EP Newsletter of the EP department

A word from the Head of the EP department - July 2016

Editorial

*by **Manfred Krammer***

Dear Colleagues, Members of the EP Department and CERN Users,

We are in the middle of a fantastic year for CERN. After a difficult start, with some negative interference from the creatures in the Pays de Gex, the LHC is running like a Swiss clock breaking one record after another. Likewise, the LHC Experiments are keeping up and taking high quality data. When this newsletter gets online the experiments will have collected already more data than in 2015. With excitement we may look forward to see the results of this data in the various search channels but also in the precision physics channels.

The EP newsletter you are hopefully about to read covers the restart of the LHC experiments and some of the many other activities at CERN. Examples are the completion of the first stage of the HIE-ISOLDE project with the installation of the first two superconducting modules. This post-accelerator will open new physics opportunities for the ISOLDE community at CERN. The results from the CLOUD experiment have made it into the news all over the world recently. Their studies have shed light on the mechanism of cloud formation and are an important input for the climate change discussion. To reduce CERNs impact on the environment the EP-DT group is working on improving the efficiency of the gas usage in the LHC experiments and on the development of new more environmentally friendly gases for future detectors. These topics and much more can be found in this edition of our newsletter. Enjoy the reading!

Let me finally also take the opportunity to wish you and your family a nice summer season. I hope you will also enjoy your well-deserved holiday break, if you decide to take one.

With best regards,

Manfred Krammer
EP Department Head

LHC Restart 2016

by ***Panos Charitos***

The Large Hadron Collider (LHC) and its experiments are back in action, now taking physics data at 13TeV. The goal is to improve our understanding of fundamental physics which ulitmately in decades to come can drive innovation and inventions by researchers in other fields. The Higgs was the last piece of the puzzle for the Standard Model. In 2016 the ATALS and CMS collaboration of the LHC will study this boson in depth and possibly pave the way for new discoveries. Over the next three to four months there is a need to verify the measurements of the Higgs properties taken in 2015 as well as check for hints of possible deviations from the Standard Model. Following a short commissioning period, the LHC operators will now increase the intensity of the beams so that the machine produces a larger number of collisions.

We have asked from the run coordinators of the four largest LHC experiments ALICE, ATLAS, CMS and LHCb to share with us few words about the first data taking from 2016. Their broad physics programme will be complemented by the measurements of three smaller experiments (TOTEM, LHCf and MoEDAL) that focus with enhanced sensitivity on specific measurements and may hold the key to new physics.

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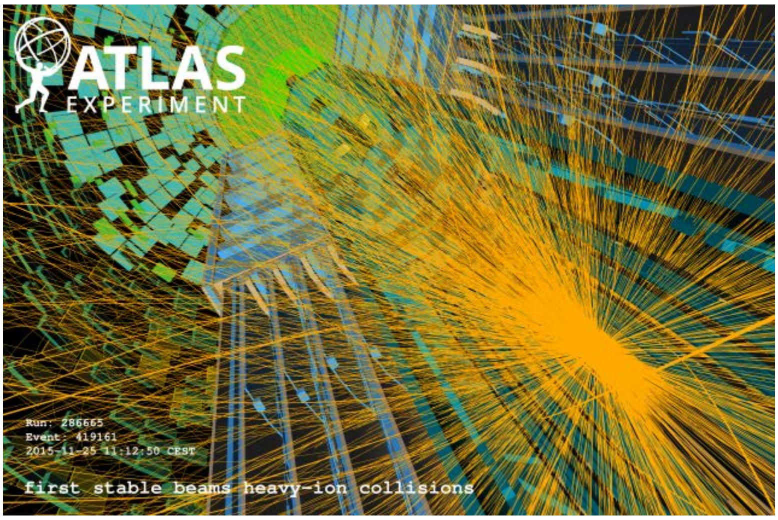
ATLAS



After a successful data taking campaign in 2015, ATLAS is back to observing LHC collisions with a performance which is expected to be the same - if not better - than that achieved last year. We have taken advantage of the yearly LHC technical stop to consolidate and improve our detector performance, and we are enthusiastically anticipating the luminosity the LHC will deliver in the coming months.

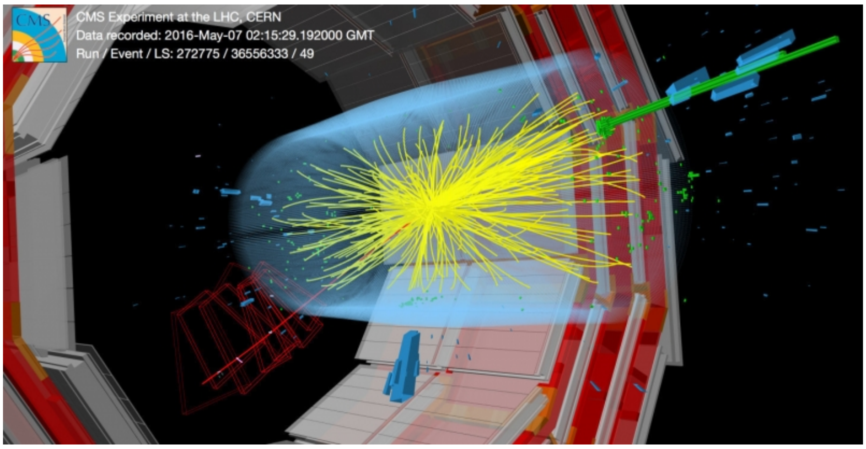
In 2015 data taking was smooth, with more than 87% of the collisions collected being deemed good simultaneously for all of our sub-detectors. In such a large system of course some headaches are always possible: in our case they came from the anomalous current absorption by the Insertable pixel B Layer sensors. These were diligently monitored and investigated by the pixel detector experts and in the end led only to the loss of "pixel good" status for two physics fills over all the data taking periods. Despite these issues, we concluded 2015 with a fraction of live channels per subdetector at the same level or - in many cases - better than what we had in Run I.

During the 2015-2016 shutdown we diligently maintained and improved our detectors. The main situation we faced was the substantial damage - observed during access - to one of the bellows at the top of the C-side forward toroid. The superconducting toroids are integral part of our muon spectrometer. The concern that a leak could develop brought us to organize and execute - with great support from the CERN technical teams - a repair campaign. This culminated with the embedding of the deformed bellow inside a larger bellow welded around it. The intervention was carried out very accurately and successfully, and our toroids were brought back in full health on time for LHC beams.

Significant upgrades were also deployed in ATLAS: we have a brand new forward proton detector (AFP) installed 220m down the tunnel from ATLAS, as well as several measures taken in order to cope with the more challenging pile-up and bandwidth requirements of 2016 LHC operations at 40 cm beta*. Small age-related issues have also been addressed throughout the ATLAS detector, and noise figures have been improved. The ATLAS Trigger and Data Acquisition system has been in part refurbished, with brand new processing units being deployed, and new exciting triggering capabilities being progressively enabled in the course of 2016.

Now physics production has begun, with the ATLAS subsystems having been re-commissioned with cosmic rays, early LHC collisions and the first "stable beams" data. Preliminary figures show a performance in terms of data taking efficiency and quality consistent with 2015. The even better news is that we see room for further improvement in several directions: while we will inevitably face harsher conditions as the LHC luminosity is being ramped up, everybody at Point 1 is working hard and relentlessly to make our data taking perform even better than last year. This is a challenge that we are all very eager to tackle from as many directions as possible, in order to maintain and even surpass the performance figures achieved in 2015.

CMS



LHC Run 2 is in full swing, the data are beginning to pour in, and the CMS collaboration is reaping the benefits of hard work!

Run-1 was a phenomenal success at CERN, with all collider experiments making physics discoveries using the highest energy hadron collisions ever created by LHC. As might be imagined, this was no cakewalk--the physics came along with challenges. As an example, already in the third year of Run 1 the instantaneous luminosity delivered to CMS was at nearly the design value, while the luminosity per bunch crossing exceeded the design by about half. With the prospects of higher luminosity, 25ns bunch spacing, and high pileup at sqrt(s)=13 TeV, Run 2 promises to set the bar even higher to extract physics signals from an even more challenging environment.

To take advantage of the increased luminosity in Run 2 and in Run 3, CMS has focused the first phase of its upgrade program to improve the ability of the detector to detect rare physics signals in a high pileup environment. To better "separate the wheat from the chaff," an additional layer of silicon tracking is being added, the granularity of the hadronic calorimeter is being refined, and the processing power of the Level-1 trigger system is being augmented.

To take advantage of the increased luminosity already in 2016, the production and installation schedule for these upgrades was designed to install the hardware during the Year-End Technical Stops both at the end of 2015 and the end of 2016. As a result, the 2016 collision run is the first with Phase-1 upgrade hardware in use at CMS, with the Hadronic Calorimeter upgrade partially in place and the Level-1 Trigger upgrade now fully functioning to collect data at point 5.

The design of the new trigger uses the increased bandwidth of optical fibers to pass high resolution information to large FPGAs. The FPGAs are mounted on electronics cards based on uTCA (micro Telecommunications Computing Architecture), with a small footprint and large processing power. The design enables higher level processing to be applied to each event, for example, to correct for pileup, improve the identification of taus, and better isolate electromagnetic objects.

Preparations to implement this technology began several years ago and a methodical approach was taken to deploy it in a systematic, staged manner. "Stage-1" of the upgrade trigger was deployed in 2015 and the full "Stage-2" of the trigger is now in place for 2016. This has guaranteed a fully operational trigger at all times with definitive improvements at each step.

The fruits of our labour are paying off now, with high quality data being collected at high rates. The data are carefully being scrutinized by collaborators, and the prospects are good that we will find whatever new physics Nature is holding for us!

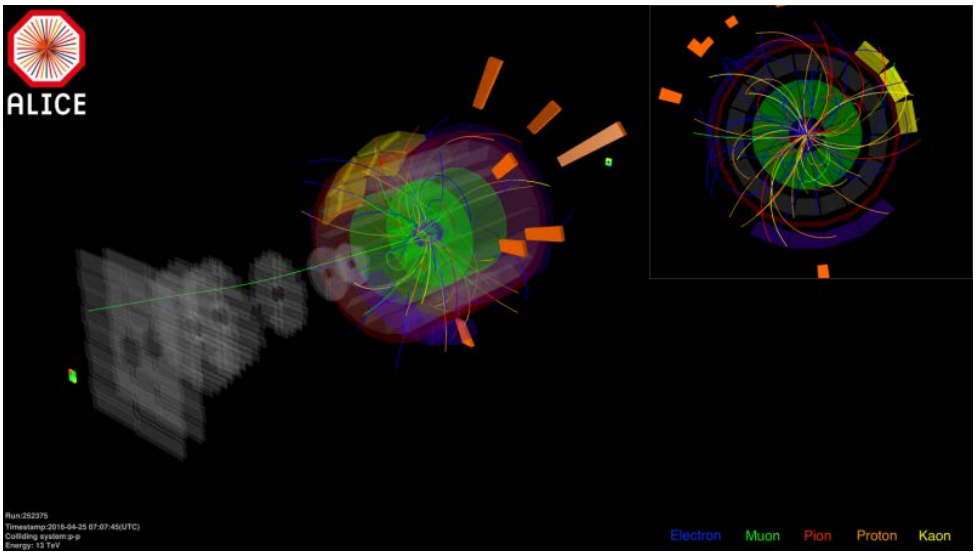
LHCb

After the winter shutdown, during which the LHCb detector was consolidated but where no major intervention took place, the experiment started the data collection campaign at the end of April when the LHC delivered the first collisions. In less than a week, enough data were collected to perform the initial calibration and alignment of the detector that is always needed after a long stop. Right after these technical activities, the accumulation of data for the physics analyses started. In the middle of May, LHCb also participated to the van der Meer scan runs in order to obtain precise luminosity calibration for the year 2016. This special run was also used to collect other types of collisions: collisions of the LHC proton beam with a Helium target injected directly in the LHCb interaction point. These data will be analyzed to perform a measurement of the production cross-section of anti-protons in proton-Helium collisions. This measurement will be an important input for the cosmological models of anti-particle productions and could be used to interpret the observations of the AMS experiment for example.

During year 2016, the LHCb experiment expects to collect about 1.5 fb^{-1} of data, which will represent a sample at least as large as the one collected during the entire Run 1. This is partly due to the increase of the beauty production cross-section, but not only. Thanks to the improvements made on the trigger software during the winter shutdown, in particular on the execution speed of the selection algorithms, the efficiency to collect interesting particle decays increased significantly. In addition, the detector is now fully calibrated and aligned online. This new important feature was developed and used already in 2015, and was ready since the first day of operation in 2016. It is also a crucial ingredient for the increase of trigger efficiencies. For the study of charm decays, the increase of statistics compared to Run 1 will be even larger.

The detector is operated since the beginning of the year from an entirely new control room, in a new building at Point 8. Thanks to the joint effort between the SMB, EN and TE CERN departments in collaboration with LHCb, this new facility provides excellent working conditions for the shift crews, composed as before of 2 persons, a shift leader and a data manager.

ALICE



In the early hours of 23 April when the Large Hadron Collider (LHC) operator team declared the first stable beams for this year and as soon as the luminosity reached the desired value at Interaction Point 2 (IP2) all participating detectors of ALICE joined in the data taking, harvesting the first proton-proton data at 13 TeV of Run 2 in 2016. After the first collisions with single pilot bunches the bunch intensity as well as the number of bunches inside the LHC was increased in an unprecedented way. Trigger selections during this period allowed for a successful and vigorous data taking campaign thus far resulting in a quarter of the planned minimum bias events as well as 15 million high multiplicity events to be collected already.

After completing its extensive commissioning which included the installation of 216 readout cards, the Time Projection Chamber (TPC) was ready to be included in the first runs. With the first data collected during stable beams the ALICE team was able to test the performance of the new readout cards of the TPC as well as to check the data quality after the replacement of the gas of the TPC. These specific runs were carried out at higher than normal collision rates during the intensity ramp up phase of the LHC allowing for maximum read out rates for the TPC which will also be encountered during the p-Pb run later in this year.

In order to collect more data for, among other, the production of low-mass particles the magnetic field of the solenoid was temporarily lowered from the nominal field of 0.5 T to 0.2 T. Almost 54 million of these minimum bias events were recorded under these conditions.

On 17 May the van der Meer scan for ALICE was performed successfully. Eight successive scans were performed over three-and-half hours. During the van der Meer scans of the other three experiments the special beam optics applicable to IP2 allowed for data taking, including also the Zero Degree Calorimeter (ZDC) detector, resulting in 15 million ultra-diffractive minimum bias events.

As the LHC is currently performing the last steps towards running at the maximum foreseen number of bunches ALICE is ready and gearing up to complete its proton-proton data taking at 13 TeV. At the same time the team is looking eagerly forward to joining the p-Pb campaign which will be carried out at 5 and 8 TeV, respectively, from mid-November to mid-December of this year.

The author would like to thank: Siegfried Förtsch (ALICE), Alex Cerri (ATLAS), Grek Rakness (CMS), Patrick Robbe (LHCb)

LHC experiments go greener: Strategies for reduction of greenhouse gas emissions in the detector systems

by ***Roberto Guida & Beatrice Mandelli***

At the LHC experiments a wide range of gas mixtures is used for the operation of different gaseous detectors. Some of these gases, such as $C_2H_2F_4$, CF_4 and SF_6, are indicated as greenhouse gases (GHG) due to their high Global Warming Potential (GWP). The control of GHG emission is an important subject for the operation of the current experiments as well as for the design of future particle detectors. Indeed the European Union is taking regulatory action to control F-gases as part of its policy to combat climate change [1]. Despite the recent EU F-gas regulation, GHGs should remain available for research

Different strategies have been adopted at CERN for reducing the GHG emissions coming from particle detectors.

A common and efficient approach is the recirculation of the gas mixture by using complex gas systems. In this case, between 85% and 99% of the gas mixture is continuously recuperated and re-injected into the system allowing an excellent reduction of emissions. Nevertheless, these gas systems require a particular care and their stability as well as the accumulation of impurities need to be attentively evaluated for good and safe long-term detector operation. Gas recirculation systems allowed reducing operational costs and emissions by 90% or more already during LHC Run 1. The remaining GHG emission came from gas systems operated in open mode, leaks in the detectors or from the fraction of gas that could not be re-injected into the gas recirculation system. During LS1 several gas recirculation systems have been upgraded or tuned to optimize their efficiency. Furthermore the ALICE MTR Resistive Plate Chamber (RPC) and LHCb GEM gas systems have been upgraded to gas recirculation. In parallel dedicated studies led to the design and commissioning of a portable gas recirculation unit, which is extensively used by several detector communities for R&D and laboratory applications. A second possible action to reduce the GHG emission is the recuperation of the fraction of gas that is sent to the exhaust in the gas recirculation system. Numerous gas separation and recuperation units have been designed and built in the past years and are now operational in the different LHC experiments.

As a long-term perspective, the use of less invasive gases has also being investigated. Nowadays the hydrofluorocarbons are being substituted in industries by the hydrofluoroolefeins (HFOs), which have a very low GWP. Refrigerant properties of HFOs are well known while the effect of ionization processes in particle detectors using these new freons is under investigation. The first searches focused on replacements of $C_2H_2F_4$, which is the main gas component for the RPC gas mixture and it contributes for about 70% of the total LHC particle detection GHG emission (RPC are extensively used in the ALICE, ATLAS and CMS experiments). A complete replacement of $C_2H_2F_4$ with the HFOs does not give satisfactory results using the current LHC detector front-end electronics and high voltage systems. Nevertheless interesting results have been obtained for avalanche and streamer operations with several eco-friendly gas mixtures (Figure 1). Considering current and future detector application, the gas substitution is not easily feasible and long R&D tests will be necessary to find a technically viable alternative.

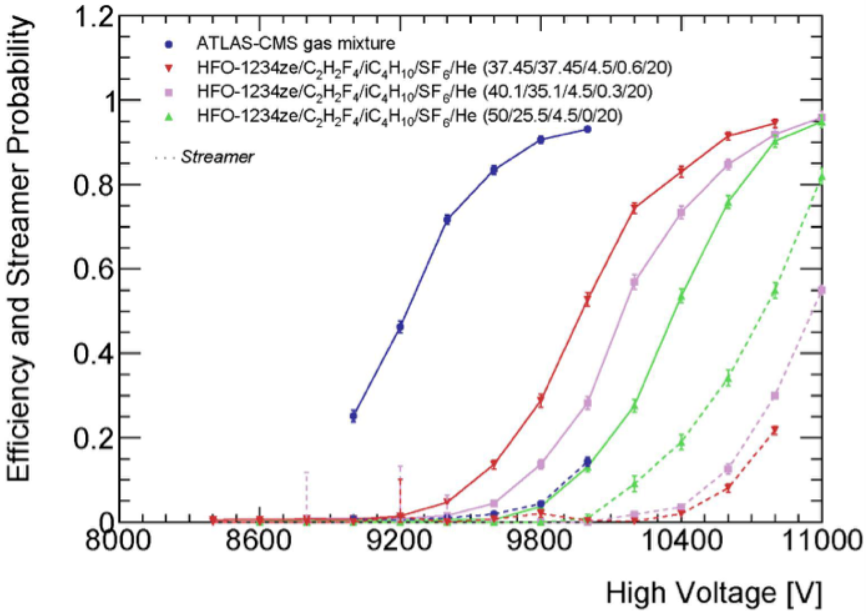


Figure 1. RPC efficiency and streamer probability for different gas mixtures containing 20% of He, 4.5% iC_4H_{10}, a small fraction of SF_6 (between 0 and 0.6% and a partition of $C_2H_2F_4$ and HFO-1234ze.

The limitation and reduction plan of the GHG emissions from the LHC experiments will continue during Run 2 and Run 3 within the two main research lines discussed above (optimization of the gas systems and possible replacement of high GWP gases). A constant effort is necessary from experiments and the DT group to pursue this purpose in the most efficient and safe way for the good operation of the LHC gaseous detectors.

References:

[1] Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.

Design study of a twin solenoid and dipoles detector magnet system for the FCC study

by **Matthias Mentink, Alexey Dudarev, Helder Filipe Pais Da Silva, Christophe Paul Berriaud, Gabriella Rolando ,Rosalinde Pots, Benoit Cure, Andrea Gaddi, Vyacheslav Klyukhin, Hubert Gerwig, Udo Wagner, Herman ten Kate**

The Future Circular Collider study for hadron-hadron collisions (FCC-hh) foresees a collision energy of 100 TeV, which is about 7 times higher than the LHC. For the detectors this means that in order to determine the properties of the particles the superconducting detector magnets have to provide stronger magnetic fields over longer distances with respect to ATLAS and CMS.

One of the conceptual detector magnet designs currently being developed for FCC-hh is the “Twin Solenoid”, which features two concentric superconducting solenoids. The inner main solenoid provides an axial magnetic field of 5 to 6 T in a free bore of 10 to 12 meters, while the outer shielding solenoid provides about 3 T in the gap between the solenoids. This outer solenoid serves two purposes: to provide a magnetic field for bending muons, and to minimize the stray field outside the twin solenoid at a minimum, so that magnetic-field-sensitive equipment may be used in close vicinity to the detector magnet. The design presented here is the 6 T version with a free bore of 12 m, which is the most challenging variant.

In terms of size, this system is unlike any detector that currently exists. The stored magnetic energy of 56 GJ and the corresponding cold mass of about 4 kt are over 20 times higher than in the CMS detector; the current record holder with a stored energy of 2.7 GJ and a cold mass of 220 tons. In addition, the system also comprises vacuum vessels, support structure, trackers, calorimeters and muon chambers for a total weight of 20-30 kt.

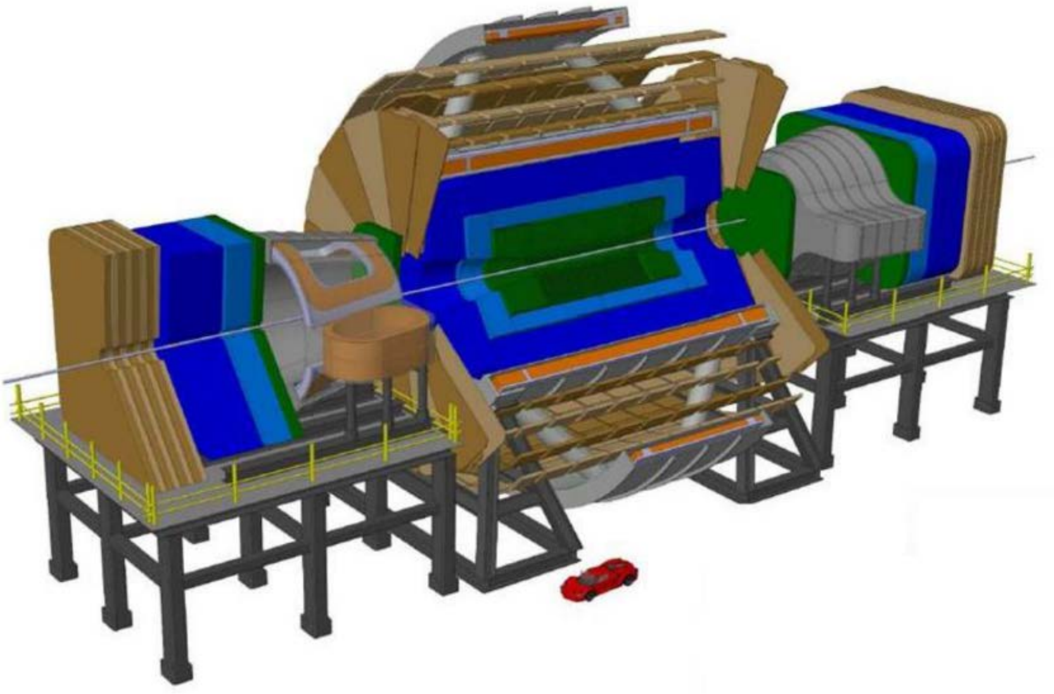
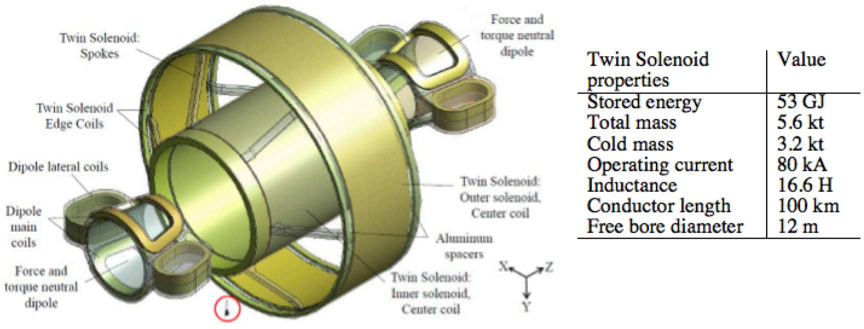


Figure 1. Overview of the detector design, showing superconducting coils (orange), vacuum vessels (light-grey), beam tube (light-grey), trackers (green), calorimeters (blue), muon chambers (brown) and support structure (dark grey). The two particle beams come from opposite directions through the beam tube and collide in the center of the twin solenoid, resulting in particle products travelling in all directions. The car is added to illustrate the scale of the system.

Detectors operate by magnetically bending the trajectory of particles and subsequently determining the basic properties of each particle from its trajectory and its ability to traverse matter. Thus, after particle beams collide in the center of the detector, the trajectory of the resulting particle products are bent when exposed to a perpendicularly oriented magnetic field, and interact with the trackers and calorimeters which prevent a fraction of them from tunneling through. The properties of muons, which do tunnel through the calorimeters and inner main solenoid, are determined by muon chambers located in between the inner main and outer shielding solenoid.

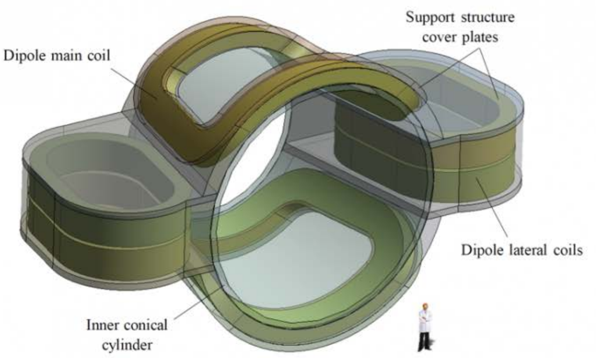
Bending particles with a solenoidal magnetic field works well for particles travelling in a direction that is perpendicular to the beam but less so for a direction almost parallel to the beam, because the solenoidal field is also oriented parallel to the beam and does not affect the trajectory of the latter. For this purpose, superconducting dipoles are positioned in the forward direction in which the field orientation is perpendicular to the beam so that even the trajectories of particles travelling in the forward direction obtain a curvature. The concept of combining solenoids with dipoles for providing curvature to particles regardless of their direction is referred to as ‘full coverage’. The twin solenoid and dipoles design provides full coverage with magnetic field integrals of 36 Tm in the free bore for particles travelling perpendicular to the beam and 10 Tm for particles travelling parallel to the beam.



Twin Solenoid properties	Value
Stored energy	53 GJ
Total mass	5.6 kt
Cold mass	3.2 kt
Operating current	80 kA
Inductance	16.6 H
Conductor length	100 km
Free bore diameter	12 m

Figure 2. Twin solenoid & dipoles design features two superconducting concentric solenoids in the center in combination with force and torque neutral superconducting dipoles. The overall length of the system is 43 m and the overall diameter is 27 m.

The combination of solenoids and dipoles in close vicinity presents a major engineering challenge. The magnetic fields exerted by a dipole and a solenoid are oriented perpendicular to each other whereas an alignment of the magnetic fields is energetically more favorable. Ordinarily this would result in a large transverse force and a very large torque on both the solenoid and the dipole. In this design however, the dipoles combine main dipole coils with lateral dipole coils where the geometry of the lateral dipole coils is optimized to not only reduce the stray field but also bring the net torque and force on the dipole to practically zero. In a similar fashion the inner and outer coils of the twin solenoid are placed in a force and torque neutral position with respect to each other and strong supports counter any forces resulting from misalignment.



Dipole properties	Value
Stored energy	1.5 GJ
Cold mass	380 tons
Operating current	20 kA
Inductance	7.5 H
Free bore diameter	~6 m

Figure 3. Force & Torque – neutral dipole. The superconducting coils are indicated in green. The lateral coils are located next to the main coils for the purposing of reducing the stray field and bringing the net force and torque on the dipole to zero.

A second challenge in conceiving the design is the presence of competing criteria. For example, reducing the overall weight of the detector magnet has several benefits, such as reducing the requirements on the crane needed for lowering the system down to the detector cavern, but it also means that the stresses in the windings will be higher. Another example is that placing the dipole further away from the twin solenoid would reduce the stresses in the cold mass of the dipole resulting from the solenoidal field, but would also increase the overall size of the system. In this preliminary design a relatively low mass is assumed where the feasibility of the stress level in the conductor is subject of ongoing research, and the dipole is placed within a few meters of the twin solenoid.

*An animation prepared by **Helder Filipe Pais Da Silva** showing the assembly of the FCC-hh detector based on the preliminary design concept.*

In summary, the twin solenoid & dipoles detector magnet assembly features a combination of very large superconducting magnets, with a total stored magnetic energy that exceeds that of current detector magnet systems by a significant margin. The unique configuration provides substantial bending power for particles travelling in all directions. The system is finely balanced in terms of the forces and torques and the overall performance of the system meets the preliminary requirements for a future FCC-hh detector.

For more details: M. Mentink et al., "Design of a 56 GJ Twin Solenoid & Dipoles Detector Magnet System for the Future Circular Collider", http://snf.ieeecsc.org/abstracts/design-56-gj-twin-solenoid-dipoles-detector-magnet-system-future-circular-collider-winner

HIE-ISOLDE: Stage 1 fully installed

*by **Maria Jose Garcia Borge***

ISOLDE is CERN's radioactive beam facility that produces low energy and post-accelerated beams. The high energy and intensity, average intensity of 2 μA, of the proton beam from the PS booster on different thick targets produces high quality intense beams of rare nuclei. The ISOLDE facility at CERN offers the largest selection of ISOL-beams worldwide with more than 1000 different isotopes of 75 chemical elements.

The High Intensity and Energy at ISOLDE, HIE-ISOLDE, project intends to improve the experimental capabilities at ISOLDE over a wide front. The impact of the increase of energy and intensity of the injectors together with improvements in several aspects of the secondary beam properties such as purity, ionisation efficiency and optical quality are addressed in the HIE-ISOLDE Design Study. Its implementation will be done gradually. A new physics domain will be accessible from the increase of energy of the post-accelerated beams. The plan is to boost the energy of the beams, going in stages from the previous energy of 3 MeV (REX-ISOLDE) via 5.5 MeV to finally 10 MeV per nucleon (MeV/u) for radioactive ion beams of A/q up to 4.5, by first extending and later replacing the 7-gap and 9-gap with superconducting quarter-wave resonator cavities. The aim is to achieve full energy variability from 0.3 MeV/u to 10 MeV/u and operational flexibility while maintaining beam quality and keeping a very compact linac design compatible with the existing ISOLDE building.

The major component to boost the energy of the post-accelerated beams is the addition of a new superconducting (SC) linear accelerator (HIE-linac) based on Quarter Wave Resonators (QWRs) with twenty high-b cavities cooled by helium and installed in four cryomodules. The HIE-linac upgrade is staged to deliver higher beam energies to the experiments as soon as possible. The first stage involves the design, construction, installation and commissioning of the first two cryomodules downstream of REX. We report here on the completion of the first stage of the HIE-ISOLDE project approved by CERN in September 2009. We expect the first radioactive beam with up to 5.5 MeV/u for A/q = 4.5 at the end of August. We plan to celebrate the completion of phase 1 at CERN the 28th of September.

Each cryo-module contains five cavities and one solenoid. Due to the limited space it has been necessary to design and build accelerating cavities with a very high voltage gradient of 6 MV / m and low heat dissipation below 10 W. The high-b cavities used at ISOLDE adopted a technology based on copper cavities sputter-coated with niobium. The technique was invented at CERN for the cavities of LEP [C. Benvenuti et al., Appl. Phys. Lett. 45 (1984) 583]. The ISOLDE cavity design follows the technique developed later at Legnaro to accelerate heavy ions at the ALPI linac [V.

Palmeri et al., PAC1991]. A stainless steel vacuum vessel contains five cavities and a solenoid surrounded by a thermal screen, which is actively cooled with helium at 50 K. In order to minimise the drift length between cavities and the overall length of the machine a common vacuum was chosen for the beam and cryogenic insulation. Although the major challenge was to produce cavities achieving the required performance, the assembly of the cryomodule also presented a challenge. Unlike the LHC cryomodules, for example, in which the internal surfaces of the cavities are isolated from the other components, all the elements of the HIE-ISOLDE cryomodule are located in the same vacuum. The cryomodule is therefore more compact, which is essential given the limited space in the ISOLDE building.

A new high-energy beam transfer line brings the post-accelerated beams to the experiments. Presently two identical beam lines at 90 degrees to the transfer line have been operative for physics since 2015. A third one will be mounted in the winter shutdown of 2017 to accommodate the ISOL Solenoidal Spectrometer, ISS, until the storage ring, TSR, will be coupled to HIE-ISOLDE.

The first cryomodule was ready at the beginning of 2015 and the first radioactive beams were accelerated to 4 MeV/u in the autumn of 2015. First studies were dedicated to explore the shell evolution in the vicinity of the spherical nucleus ^{68}Ni, by performing Coulomb excitation studies in^{74,76}Zn on heavy targets. In this region adding neutrons beyond N=40 leads to a rapid increase of collectivity, with a challenging interplay of both collective and single-particle degrees of freedom. Such rapid changes indicate underlying complex effects and make the region ideal for testing theoretical calculations. The results obtained, even if the conditions were far from ideal, demonstrate the importance of reaching higher beam energies which allowed for the population of higher spin states with sizable cross sections opening in this case the possibility of multi-step Coulomb excitation.

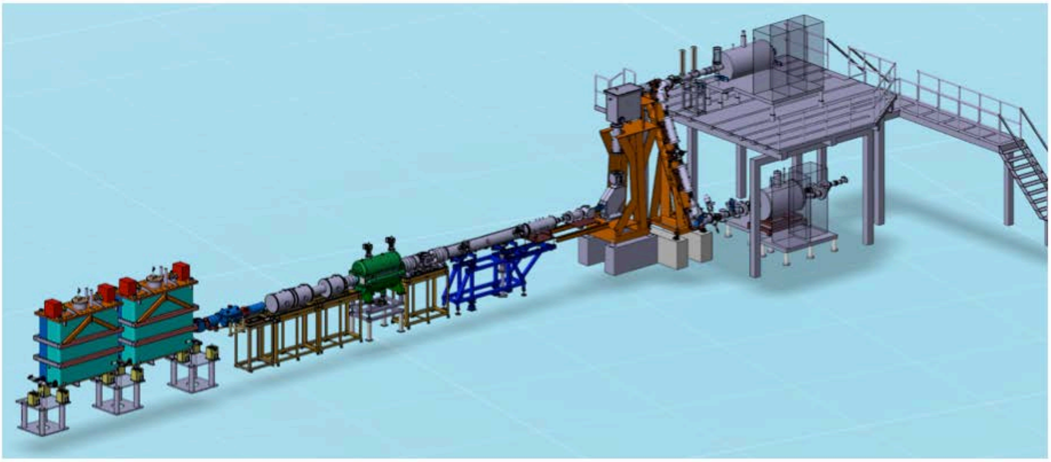


Fig. 1: 3D-view of the post-accelerator at ISOLDE as it looks in 2016. It combines the exiting REX-linac with two superconducting cryomodules with a total of 10 QWR cavities to boost the energy to 5.5 MeV/u for A/q = 4.5

During the shutdown of 2016, as part of HIE-ISOLDE stage 1, the second cryo-module has been added to the SC Linac, see photo of the descent of the cryomodule to be coupled to the HIE-linac, and fig. 2 for a photo taken at the end of April 2016 showing the two cryomodules coupled to the linac. In parallel with the commissioning of CM1 and CM2 in the ISOLDE facility, the assembly of the remaining two high–β cryomodules (CM3 and CM4) for the phase 2 of the HIE-ISOLDE energy upgrade is on-going. One cryo-module will be added in 2017 prior to the experimental campaign and the fourth one at the beginning of 2018 in order to reach the expected 10 MeV/u for A/q = 4.5 during the full year before LS2.

To prepare for the physics campaign with post-accelerated beams at 5.5 MeV/u a workshop was held (https://indico.cern.ch/event/462504/) on the 1st of February 2016 with more than 50 participants. There 75% of the approved experiments were represented expressing their interest in running this year. More importantly they demonstrated that the physics case was still relevant and of great interest. We expect to start with experiments at the end of August after the commissioning of the HIE-linac that is already quite advanced. Presently the beam time schedule has been released and seven experiments out of the thirty discussed in the February Workshop have been scheduled. The first one is the study of ^{59}Cu(p,a) cross section and its implications for nucleo-synthesis in core collapse supernovae. This experiment constitutes the first opportunity to measure this key reaction at astrophysical burning energies. This experiment will be performed in the second beam line. Then we will continue with multi Coulomb excitation studies near the double magic nuclei ^{78}Ni, ^{100}Sn and^{132}Sn in the first beam line. Transfer reaction studies at the neutron drip line will explore resonant states and the dipole resonance in the halo nuclei ^{11}Li. This experiment will be performed at the energy of 7 MeV/u available at HIE-ISOLDE stage 1 for A/q = 3, and feasible for light nuclei. The campaign will close with the study of statistical properties of warm nuclei. The enhancement of gamma strength observed at low energies in stable nuclei if confirmed in exotic nuclei will have an effect in neutron capture cross sections in astrophysical scenarios. **We are looking forward to this HIE-exciting period**

MoEDAL releases new mass limits for the production of monopoles

*by **B Acharya et al. MoEDAL Collaboration***

In April, the MoEDAL collaboration submitted its first physics-research publication on the search for magnetic monopoles utilising a 160 kg prototype MoEDAL trapping detector exposed to 0.75 fb^{-1} of 8 TeV pp collisions, which was subsequently removed and monitored by a SQUID magnetometer located at ETH Zurich. This is the first time that a dedicated scalable and reusable trapping array has been deployed at an accelerator facility.

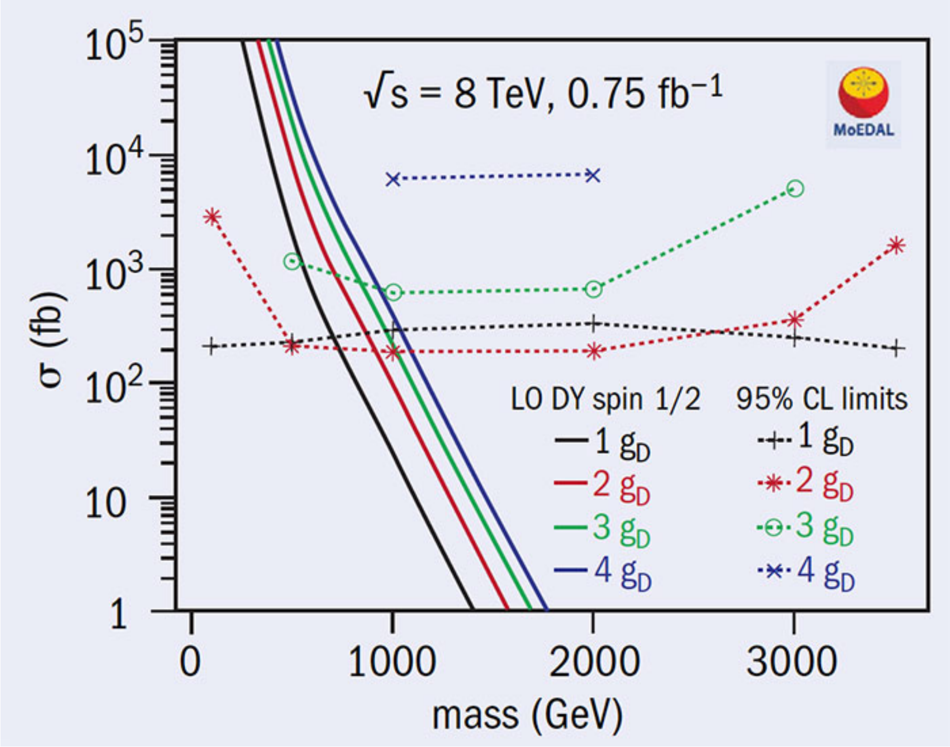


Figure 1. Cross-section upper limits at 95% confidence level for DY monopole production as a function of mass for spin-1/2. The various line styles correspond to different monopole charges. The solid lines are DY cross-section calculations at leading order. Image credit: MoEDAL Collaboration.

The innovative MoEDAL detector employs unconventional methodologies designed to search for highly ionising messengers of new physics such as magnetic monopoles or massive (pseudo-)stable electrically charged particles from a number of beyond-the-Standard-Model scenarios. The largely passive MoEDAL detector is deployed at point 8 on the LHC ring, sharing the intersection region with LHCb. It employs three separate detector systems. The first is comprised of nuclear track detectors (NTDs) sensitive only to new physics. Second, it is uniquely able to trap particle messengers of physics from beyond the Standard Model, for further study in the laboratory. Third, MoEDAL's radiation environment is monitored by a TimePix pixel-detector array.

Clearly, a unique property of the magnetic monopole is that it has magnetic charge. Imagine that a magnetic monopole traverses the superconducting wire coil of a superconducting quantum interference device (SQUID). As the monopole approaches the coil, its magnetic charge drives an electrical current within the superconducting coil. The current continues to flow in the coil after the monopole has passed because the wire is superconducting, without electrical resistance. The induced current depends only on the magnetic charge and is independent of the monopole's speed and mass.

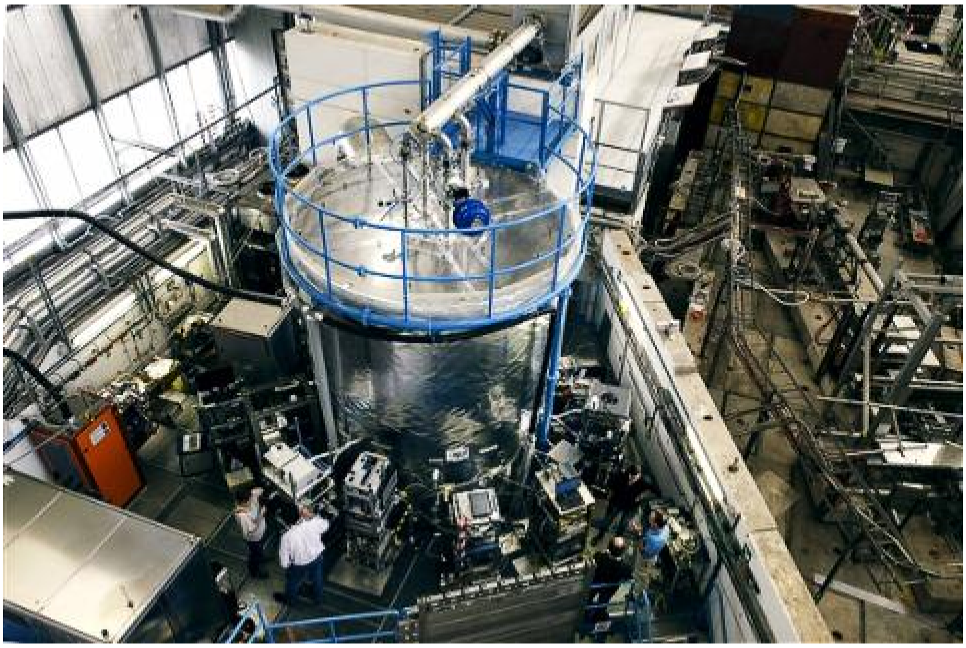
In the early 1980s, Blas Cabrera was the first to deploy a SQUID device in an experiment to directly detect magnetic monopoles from the cosmos. The MoEDAL detector can also directly detect magnetic charge using SQUID technology, but in a different way. Rather than the monopole being directly detected in the SQUID coil *à la Cabrera*, MoEDAL captures the monopoles – in this case produced in LHC collisions – in aluminium trapping volumes that are subsequently monitored by a single SQUID magnetometer.

No evidence for trapped monopoles was seen in data analysed for MoEDAL's first physics publication described here. The resulting mass limit for monopole production with a single Dirac (magnetic) charge ($1g_D$) is roughly half that of the recent ATLAS 8 TeV result. However, mass limits for the production of monopoles with the higher charges $2g_D$ and $3g_D$ are the LHC's first to date, and superior to those from previous collider experiments. Figure 1 shows the cross-section upper limits for the production of spin-1/2 monopoles by the Drell–Yan (DY) mechanism with charges up to $4g_D$. Additionally, a model-independent 95% CL upper limit was obtained for monopole charge up to $6g_D$ and mass reaching 3.5 TeV, again demonstrating MoEDAL's superior acceptance of higher charges.

Despite a relatively small solid-angle coverage and modest integrated luminosity, MoEDAL's prototype monopole trapping detector probed ranges of charge, mass and energy inaccessible to the other LHC experiments. The full detector system containing 0.8 tonnes of aluminium trapping detector volumes and around 100 m^2 of plastic NTDs was installed late in 2014 for the LHC start-up at 13 TeV in 2015. The MoEDAL collaboration is now working on the analysis of data obtained from pp and heavy-ion running in 2015, with the exciting possibility of revolutionary discoveries to come.

Recent results from the CLOUD experiment

by ***Panos Charitos & Jasper Kirkby***



The CLOUD experiment studies how new aerosol particles form or "nucleate" in the atmosphere and grow to sizes where they modify clouds and climate. Using a particle beam from the CERN Proton Synchrotron, CLOUD is also investigating whether these processes are affected by ionisation from galactic cosmic rays. Atmospheric aerosol particles cool the climate by reflecting sunlight and by forming more numerous but smaller cloud droplets, which makes clouds brighter and extends their lifetimes. Cooling due to increased aerosol particles from human activities has offset part of the warming caused by increased greenhouse gases. To determine the amount of cooling requires knowledge of the aerosol state of the pre-industrial atmosphere. Unfortunately we cannot directly measure this since there are almost no regions of today's atmosphere that are perfectly free of pollution. So the pre-industrial atmosphere must be simulated with climate models based on sound measurements of the underlying microphysical processes obtained by laboratory experiments. CLOUD brings together fundamental experiments with climate modelling in a single international collaborative effort.

CLOUD has studied the formation of new atmospheric particles in a specially designed chamber under extremely well controlled laboratory conditions of temperature, humidity and concentrations of nucleating and condensing vapours. In the present experiments we measured the formation and growth of particles purely from organic vapours emitted by trees (so-called biogenic vapours). The particular vapour studied was alpha-pinene, which gives pine forests their characteristic pleasant smell. Alpha-pinene is rapidly oxidised on exposure to ozone, creating vapours with extremely low volatilities but only tiny concentrations of around one molecule per trillion (10^{12}) air molecules.

Using CERN know-how, the CLOUD chamber has achieved much lower concentrations of contaminants than all previous experiments, allowing us to measure particle nucleation and growth from biogenic vapours in the complete absence of contaminant vapours such as sulphuric acid. The collaboration has developed state-of-the-art instruments to measure the vapours, ions and aerosol particles at ultra low concentrations in the air sampled from the CLOUD chamber. We measure how these vapours and ions form molecular clusters and which vapours control the subsequent particle growth. A special feature of CLOUD is its capability to measure nucleation enhanced by cosmic-ray ionisation generated by a CERN pion beam - or with all the effects of ionisation completely suppressed by an internal electric field.

What has CLOUD discovered? CLOUD has found that oxidised biogenic vapours produce abundant particles in the atmosphere in the absence of sulphuric acid. Previously it was thought that sulphuric acid – which largely arises from sulphur dioxide emitted by fossil fuels – was essential to initiate particle formation. We found that ions from galactic cosmic rays strongly enhance the production rate of pure biogenic particles – by a factor 10-100 compared with particles without ions, when concentrations are low. We also show that oxidised biogenic vapours dominate particle growth in unpolluted environments, starting just after the first few molecules have stuck together and continuing all the way up to sizes above 50-100 nm where the particles can seed cloud droplets. The growth rate accelerates as the particles increase in size, as progressively higher-volatility biogenic vapours are able to participate. We quantitatively explain this with a model of organic condensation.

These results are important for our understanding of climate. Ion-induced nucleation of pure biogenic particles may have important consequences for pristine climates since it provides a hitherto-unknown mechanism by which nature produces particles without pollution. And, once embryonic particles have formed, related but more abundant oxidised biogenic vapours cause the particle growth to accelerate. Rapid growth of the new particles while they are still small and highly mobile implies a larger fraction will avoid coagulation with pre-existing larger particles and eventually reach sizes where they can seed cloud droplets and influence climate. Pure biogenic nucleation and growth may raise the baseline aerosol state of the pristine pre-industrial atmosphere and so may reduce the estimated anthropogenic radiative forcing from increased aerosol-cloud albedo over the industrial period.

Ion induced pure biogenic nucleation may also shed new light on the long-standing question of a physical mechanism for solar-climate variability in the pristine pre-industrial climate.

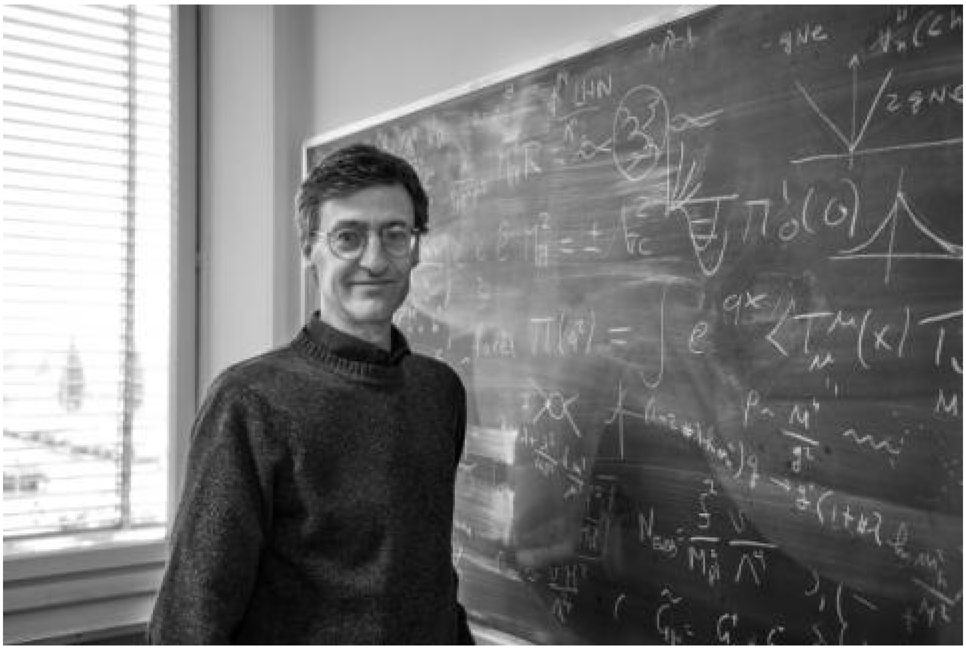
A paper published simultaneously in Science (Bianchi, F. et al. Science, doi 10.1126/science.aad5456, 2016) reports observations made at the Jungfraujoch of pure organic nucleation in the free troposphere, confirming the relevance of the CLOUD measurements to the atmosphere.

Read the two publications here:

Kirkby, J. et al. ***Ion-induced nucleation of pure biogenic particles. Nature, doi 10.1038/nature17953 (2016).***
Tröstl, J. et al. ***The role of low-volatility organic compounds in initial particle growth in the atmosphere. Nature,***
doi 10.1038/nature18271 (2016).

Interview with Gian Giudice: Head of CERN's Theory Department

by ***Panagiotis Charitos***



Gian Giudice, is the new Head of CERN's Theory Department. Following his inspiring talk durign the FCC Week 16 we discuss with him about the LHC results and the present global landscape in particle physics as well as his view on the future developments in the field.

Following the LHC discoveries, how would you describe the present situation in the field of particle physics?
Today the situation in particle physics is largely dominated by uncertainty. It is too early to draw definitive conclusions, as the LHC Run 2 has just started. However, we cannot deny that most of our pre-LHC theoretical expectations have not been confirmed by the first data. As a result, the field is dominated by a sense of uncertainty. The uncertainty of what's going to happen next and the uncertainty of what are the right directions to explore.

However, this uncertainty only adds to the excitement because the history of physics has taught us that moments of crisis are followed by scientific revolutions. We are living through a moment of challenges and opportunities.

The recent story of the 750 GeV bump is an example of how new data can completely shift the focus of the scientific community. Theorists are ready to embrace new ideas. The discovery of the Higgs boson has been a crucial chapter in our understanding of the electroweak breaking sector. But our understanding is not complete. There are still many open questions.

Do you think that future data from the LHC could help us answering these questions?
All of us are expecting from future LHC data the indications of how to proceed. Theorists need these data to get clues on how to answer open questions about electroweak symmetry breaking, the role of naturalness, and the possible existence of dark matter in the form of massive weakly-interacting particles.

But LHC data will not only affect theoretical research. The future of experimental particle physics will be shaped by what's going to happen in the next few years. During the 2016 Future Circular Collider week in Rome I was impressed to see how fast the landscape of high-energy physics is changing. The interest of countries like Japan and China is making the landscape much richer and promising, while new projects at CERN are taking shape thanks to important technological R&D efforts and advancements. Things are already moving fast, but I expect that new LHC data will accelerate this process dramatically.

I would like to take this opportunity and ask you about the foreseen HL-LHC upgrade of the LHC and how data from this phase could enrich our present understanding and possibly help us in defining the next priorities for HEP?

HL-LHC is the natural continuation of the LHC program. New physics may hide in rare processes and their exploration requires large data samples. This is why a high luminosity phase is a unique discovery tool. HL-LHC can collect in a single year the same amount of data recorded by the LHC during its entire operation period of about ten years. This leap in statistics would allow us to improve the determination of the Higgs couplings by about a factor of two or, in the case of rare processes like the decay of the Higgs into two muons, by about a factor of three. This is like using new high-resolution lenses in the microscope that scrutinizes the Higgs boson. We are looking for unexpected features in the Higgs couplings, which could be visible only when high-resolution lenses are used.

It is still premature to assess the real exploratory power of HL-LHC. If new discoveries are made at the LHC, it is likely that high statistics will be the crucial ingredient to fully comprehend the meaning of these discoveries and unravel the correct theoretical interpretation.

Looking back why do you think that there were so high expectations for new physics at the LHC?

Even before the Higgs discovery, the Standard Model of particle physics worked beautifully. However, its validity was limited in its energy domain. We knew that something must have come in at the energies explored by the LHC. Indeed, that "something" was found to be the Higgs boson. The theoretical prediction was confirmed by experiments. Our high expectations were correct and it was a triumph of the combination between theoretical and experimental physics.

Now that the Higgs boson has been discovered, the Standard Model may seem a complete theory. And yet theorists, even before the starting of the LHC, had high expectations that the Higgs could not be the full story. The reason for this belief is that a fundamental scalar particle raises a problem of naturalness. We still don't understand how this issue is resolved in nature, but it was expected that its solution involved new physics within the LHC energy domain.

During your talk you referred to the issue of naturalness and reflected on its meaning for future searches. How do you think that a concept like naturalness could inform our efforts to answer some of the open questions?

Naturalness is a central concept in particle physics today. It is related to the description of nature in terms of a stack of effective quantum field theories, in which each theory describes a specific domain of scale distances. This is a powerful tool, because it allows us to separate our description of nature into many different intervals of distances. Then, we can restrict our considerations to a limited range of scales and derive a consistent theoretical description of the relevant phenomena, without full knowledge of nature's inner workings at all possible distances. Naturalness is a reasonable logical consequence of this hierarchical structure of nature made of a stack of theories with scale separation. Of course, naturalness is not a logical necessity for a consistent universe. It could be that nature has chosen to create a universe without scale separation, in which phenomena at completely different distances are inextricably linked. If that were the case, our approach in terms of effective quantum field theories is doomed to fail.

For all we know, naturalness seems to be respected in the world of particle physics. There is only one known exception and this is the cosmological constant. Not surprisingly, we don't have a full dynamical theory for the cosmological constant.

Soon the LHC will settle the question about naturalness in the context of the Higgs mechanism. This will have momentous consequences for the way we approach new physics beyond the Standard Model. If naturalness holds for the Higgs, then new physics must show up very soon. If new physics doesn't show up, we have to reconsider our strategies about the exploration of what's behind the Higgs mechanism.

Do you think that the concept of naturalness could also help us in forming different questions?
Certainly the concept of naturalness will remain central in forming and posing our questions about the electroweak symmetry breaking sector, no matter what the LHC finds. However, it is quite possible that we will have to reformulate the concept and use new theoretical tools to address it.

It is premature to tell what the new directions will be. Some proposals have been put forward for overturning the conventional approach to naturalness in the Higgs sector. One idea is based on the multiverse, in which our universe is selected by anthropic considerations in a process similar to a Darwinian natural selection. Other ideas are based on relaxation during cosmological evolution, in which our universe is singled out by a process similar to self-organized criticality.

Do you think that designing and building future machines could lead to rethink about some of the fundamental questions in modern physics?
Physics is a natural science. No matter how fascinating theoretical speculations can be, we need data to verify ideas and guide us in our research. At the moment, pushing the high-energy frontier looks like the most promising direction to make progress in our search for the fundamental principles of nature.

How would you describe the present field in theoretical physics?
As I said previously, we are living times of uncertainty. The field in theoretical physics is becoming more fragmented and physicists are trying to pursue different directions. I expect that new data from the LHC may trigger a big change in the field of theoretical physics. It may happen already this summer, as the hint of the 750 GeV bump is really tantalizing.

Do you think that after the LHC we may stop referring to the Standard Model?
I hope so (laugh!). The Standard Model is one of the greatest achievement of human intellect. It is nearly unbelievable that all natural phenomena, in spite of their emergent complexity, are the result of a single simple mathematical principle: gauge symmetry. And it is fantastic that humans were able to discern this secret of nature and discover the principle of its inner conceptual simplicity.

But physicists are always thirsty for deeper explanations. In spite of its tremendous success, the Standard Model leaves some questions unanswered. Its structure is not unique and many of its parameters cannot be computed within its theoretical framework. There are good indications that the Standard Model is not the ultimate theory of nature, but is only another effective quantum field theory valid up to a limited scale. We don't know what the next step in nature’s construction is and not even if we will ever be able to prove that there is another step. But we cannot give up: we need to explore further and seek answers.

I really hope that after the LHC we will refer to the Standard Model as an old beautiful artefact left on display in a dusty museum of science, while physicists will be busy playing with a brand new theory whose name I cannot even imagine now.

Guido Altarelli Memorial Symposium

by ***Panagiotis Charitos***

Guido Altarelli Memorial Symposium

June 10, 2016. CERN Main Auditorium

Speakers

L. Maiani (Università la Sapienza, Roma, IT)
G. Parisi (Università la Sapienza, Roma, IT)
S. Forte (Università la Statale, Milano, IT)
G. Martinelli (Università la Sapienza, Roma, IT)
L. Di Lella (CERN, EP Department, CH)
R. K. Ellis (IPPP, Durham, UK)
R. Barbieri (ETH Zürich, CH and SNS, Pisa, IT)
G. Dissertori (ETH Zürich, CH)
I. Masina (Università di Ferrara, IT)

Link http://indico.cern.ch/e/AltarelliMemorialSymposium

Organizers L. Alvarez-Gaume, A. De Rujula, J. Ellis, E. Elsen, S. Ferrara, F. Gianotti, G. Giudice, P. Jenni, M. Mangano, M. Pepe Altarelli, G. Veneziano

The recent Guido Altarelli Memorial Symposium hosted at CERN, honoured the memory of the late Guido Altarelli, a pioneer of the unravelling of the strong interaction and the structure of hadrons, an outstanding communicator of particle physics, and a mentor and strong supporter of junior scientists. Internationally acclaimed for his pioneering research in QCD, weak interactions, precision tests of the Standard Model, neutrino physics and more, he was also universally appreciated for his close interaction with his experimental colleagues.

The event brought together many of his collaborators and friends who gathered to celebrate the life of an exceptional scientist and human.

Guido became a senior staff physicist in the theory division at CERN in 1987; he worked there until 2006, and he served as the theory division leader in 2000–04. In 1992 he joined the newly founded University of Rome 3, where he remained until formal retirement in 2011. He then divided his time between teaching in Rome and conducting research, mostly at CERN. He continued his research up to his last months. Toward the end of his career, he received three prestigious awards: the 2011 Julius Wess Award from Karlsruhe Institute of Technology, the 2012 J. J. Sakurai Prize for Theoretical Particle Physics (shared with Bryan Webber and Torbjörn Sjöstrand) from the American Physical Society, and the 2015 High Energy and Particle Physics Prize from the European Physical Society.

Among Guido's most important contributions are his papers on octet enhancement of nonleptonic weak interactions in asymptotically free gauge theories. He showed for the first time how the newly born theory of quantum chromodynamics (QCD) could contribute to solving some of the old mysteries of weak interactions—in this case, the dominance of the $DI = 1/2$ strangeness-changing processes over the much weaker $DI = 3/2$ processes. His other important contributions of that period are the first computation of the electroweak corrections to the muon magnetic-moment anomaly, the discovery of a large QCD correction to the naive parton prediction in m^+m^-production, and above all, the derivations of the Altarelli–Parisi equations. The evolution equations stemmed from an idea of Guido's to make previously obtained results on scale violations clearer and more exploitable. The paper was written while both authors were in Paris, and Guido liked to remark that it is the most cited high-energy physics French paper.

With the new millennium, Guido started working on a subject he had become fascinated with: the elegance of the tri-bimaximal neutrino mixing. Many of his papers, mostly with Ferruccio Feruglio, are dedicated to the search for the origins of that baffling symmetry.

His scientific success was inseparable from his human qualities. Guido aimed to get a deep understanding of the world, hence his great passion for history, especially that of the many countries he traveled through. His characteristic traits were his great kindness and intellectual honesty, coupled with a rather ironic view of life in general and of himself. His great inquisitiveness and the enjoyment that he derived from learning new things and putting a puzzle together allowed him to summarize subjects in ways that permitted us to take stock of the current state of a field of research and see new directions to pursue. He liked clear, precise formulations that could be understood by all.

Guido was a generous scientist who conceived many of his works in a spirit not only of discovery but also of service to the community. He relished his collaborations in the large particle-physics community. It is difficult to think what the status of the field would be without his contributions.

Giorgio Parisi one of Guido’s close collaborators and friends recalled in his obituary for Gudio:

"It is a very sad event which has brought us together today, since we are here to say a final ‘Goodbye’ to our dear Guido. Our grief is only partially eased by the sight of such a great number of friends who have joined us, some from far away.

Our time on Earth is limited, and Guido’s time was ended too soon. But what is really important is the mark we leave behind. Guido’s legacy is deeply engraved in our understanding of the laws of the Universe and in modern physics.

Guido was a great scientist, gifted with an exceptional talent for physics, as we all know. But he was not a reclusive or selfish scientist, interested only in what personal prestige might be gained from his research. Guido was also a researcher who worked with others within a large community, that of CERN, and in the high-energy particle physics community in general.
Many of Guido’s works, from the most famous to the lesser known, were conceived in a spirit not only of research, but also in a spirit of service to the community to which he belonged. Even his most celebrated work, which we published together, stemmed from one of his ideas, which was to make previously-obtained results on scale violation clearer and more exploitable.
However, those of us who are here today know very well that Guido also left a deep impact on our hearts. For some of us, such as myself, he was a brotherly friend, for others he was a teacher or close colleague, and we all owe something to him.

It’s difficult to think of Guido without remembering his easily-triggered laugh, which was never meant to mock, but was a humorous way of expressing his complicity or his surprise at a new idea. Perhaps his most characteristic traits were his great kindness and intellectual honesty, coupled with a rather ironic view of himself and life in general.

As often happens, his scientific success was inseparable from his human qualities, and did not depend only on his technical capabilities. His great inquisitiveness, the enjoyment he derived from learning new things and putting the pieces of a puzzle together, allowed him to make summaries of topical subjects, which were crucial, not only because they allowed us to take stock of the *current state of a field of research, but also because they could indicate new directions to take. He liked clear, precise formulations which could be understood by all. In my case, the collaboration I had with Guido was extremely useful. I did not possess those particular qualities, and so we were complementary.*

We saw each other for the last time last July, in Vienna, where we received a prize which we had been awarded jointly. His illness had already begun to progress, even though it was not apparent. We embraced each other, had a long talk, and had dinner twice with Monica, with whom he formed a solid and tightly-bonded couple.

He appeared to be well, and even though I hadn't seen him for several years, I did not notice anything amiss (not many people knew that he was in bad health). He was the same old Guido, calm and jovial, with whom it was a pleasure to speak. We also talked about his children, and the pride and affection he felt for them were palpable. I'll never forget his serenity at a time which was so tragic for him, and I do not know if I would be capable of doing the same.

Giorgio Parisi – 6 October 2015"

Micro-pattern gaseous detectors applications for imaging purposes, and the prospects of the actual developments

Introduction

Micro-Pattern Gaseous Detectors (MPGDs) are a family of detectors with gas as active medium. They were conceived in order to overcome the limitations of the Multi-Wire Proportional Chambers (MWPCs) [1] with respect to position resolution, their capability to cope with high particle fluxes, and long-term stability. Back in 1988, Oed invented the Micro-Strip Gas Chamber [2], which is considered the first exemplar of the MPGD family. Today, Gaseous Electron Multiplier (GEM) [3] and Micro Mesh Gaseous Structure (Micromegas) [4] are the most commonly used devices. The goal of these structures is to amplify the otherwise small amount of ionisation charge produced in the gas by the interacting particles. All MPGDs have in common production techniques, which rely on photolithographic procedures typical of the Printed Circuit Board manufacturing, and the presence of a dielectric substrate to support the electrodes. In 2008, the establishment of the CERN RD51 Collaboration [5] fostered the coherent and synergistic developments of MPGDs to prove the scalability of the concepts and the industrialisation of the production procedures. Today, MPGDs are sufficiently mature to be widely used in High Energy Physics, as exemplified at the LHC experiments: ATLAS [6], CMS [7] and ALICE [8] upgrades foresee their use.

Imaging with MPGDs

In recent years, these devices found applications beyond High Energy Physics mainly due to their imaging capabilities. Some examples that do not exhaust the list of applications are:

- The developments to obtain a radiation-hard detector based on GEMs for imaging and dosimetry applications during gamma-ray treatments [9].

- GEMs have been used for X-ray fluorescence of artworks in order to unveil underlying paintings over large surfaces [10].

- A portable and battery-driven muon telescope based on Micromegas is used for cosmic muon tomography [11], presently scanning the Egyptian Pyramids.

All these devices typically have the signals read out electronically. This means that each channel has its own amplification and digitisation chain. Despite being unavoidable in some occasions, an alternative to this approach exists: the so-called optical readout. Scintillation light produced during the amplification avalanche can be detected, making the gaseous detector a scintillating plate with extraordinary light yield. The first ideas of taking pictures of scintillating gases go back to the beginning of the ’80. For instance, Charpak and collaborators used an image intensifier camera to photograph a parallel plate avalanche detector filled with Ar/CH4/TEA [12]. The choice of the gas mixture was mainly driven by the scintillation spectrum. Unfortunately, not many gases scintillate in the visible window, for which most of the light sensors are optimised. CF4 is one of them, and the mixture of Ar/CF4 80/20 emits orange light in a broad peak around 630 nm. Modern MPGDs coupled with modern cameras are very promising tools to deliver fast and good quality images. R&D in this direction already exists [13, 14, 15], and this technique will certainly be exploited much more in the future.

Optical readout

In the Gaseous Detector Development laboratory at CERN an optically read out triple GEM detector was built. The scheme and a picture of the device are shown below.

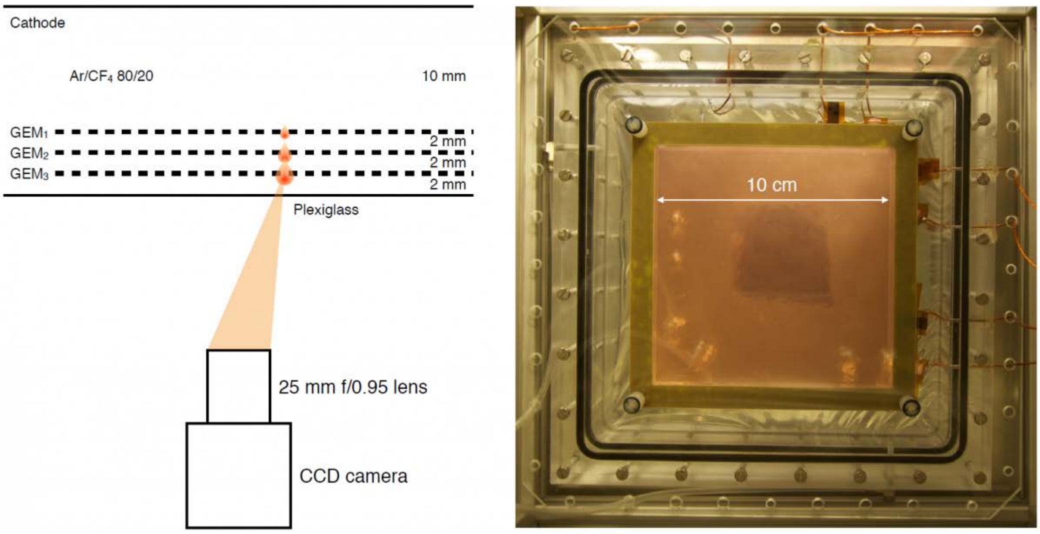


Fig. 1: Scheme of the detector and picture of the detector from the position of the camera.

The triple GEM guarantees large amplification, and therefore large amount of scintillating light. The camera, focussed on the last amplification stage, records a small fraction of the produced light due to geometrical acceptance, but still large enough to detect the signals of few primary electrons. In fact, at a charge amplification of 10^5, the light yield is of the order of 10^6 ph/keV, huge compared to 40 ph/keV typical of a very common scintillator like NaI(Tl).

Some example applications

The next figure shows two X-ray radiographies of the same dead mammal, a bat. The one on the left was taken with a triple GEM detector read out electronically, the other is actually the photograph of the scintillating GEM detector. Very similar quality is achieved with much less effort in the latter case: this image was obtained with less than a second exposure, and with no post-processing. It is displayed as it comes out from the camera.

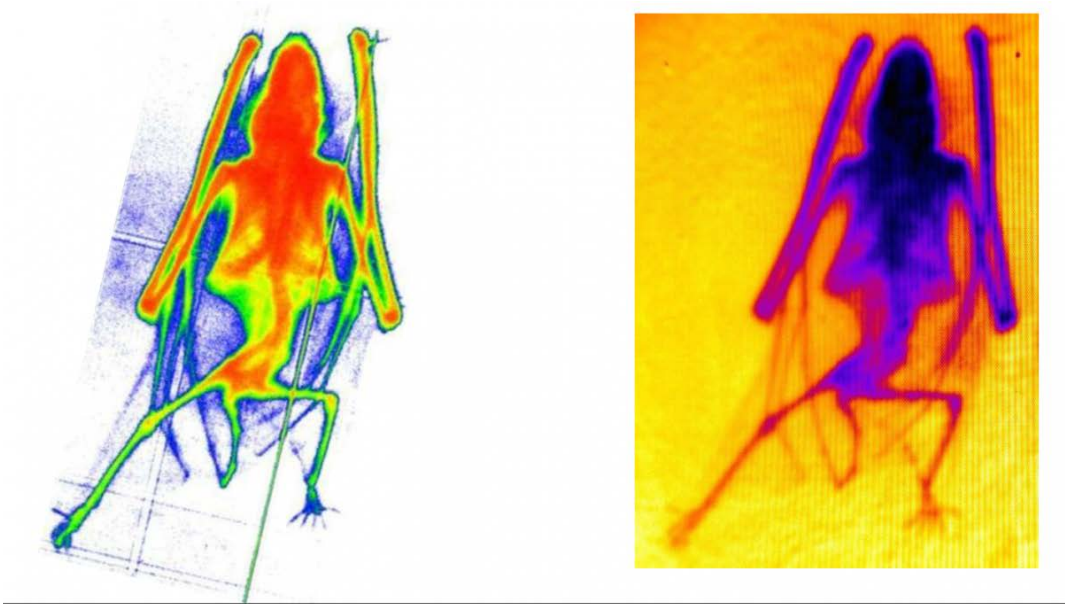


Fig 2: Radiography of the same bat with triple GEM detector electronically (left) and optically (right) read out.

A small toy quadcopter is an object more enjoyable to radiograph: it actually flies. The movie below shows the first flight of the drone in front of the detector illuminated by an X-ray beam, a technique that clinically is called fluoroscopy. This movie is not intended to show the skills of the pilot, but is the proof of the simplicity and robustness of the acquisition.

Fig. 3: fluoroscopy of a flying drone.

By taking radiographies of an object at different angles it is possible to reconstruct it three-dimensionally. The sinograms are obtained from the raw images, and the 3D model derives from applying a filtered back projection, typical of Computer Tomography. Again, the detector delivers good quality images that can be immediately used with minimal post-processing treatment.

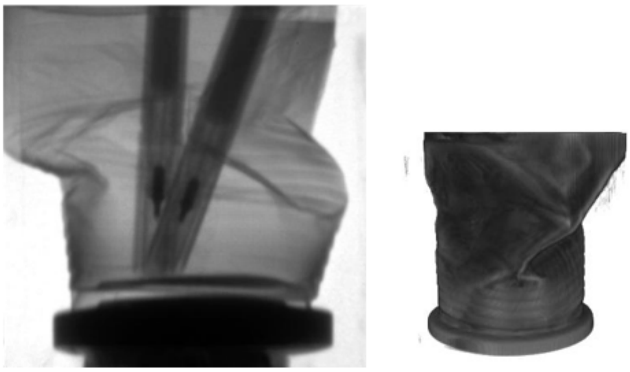


Fig. 4: Series of radiography of a squashed plastic glass containing two pens (left) used to reconstruct the object three-dimensionally (right).

Single ionising events can be detected decreasing the exposure time and increasing the gain of the GEMs. The images below display some examples:

- Two tracks from highly ionising alpha particles from the decay of 220Rn and its daughter 216Po.
- Low but localised energy released by X-rays from a 55Fe source.
- Shower development from a charged pion interacting in an iron brick just outside of the detector.
- Minimum ionising muon with a long delta ray.

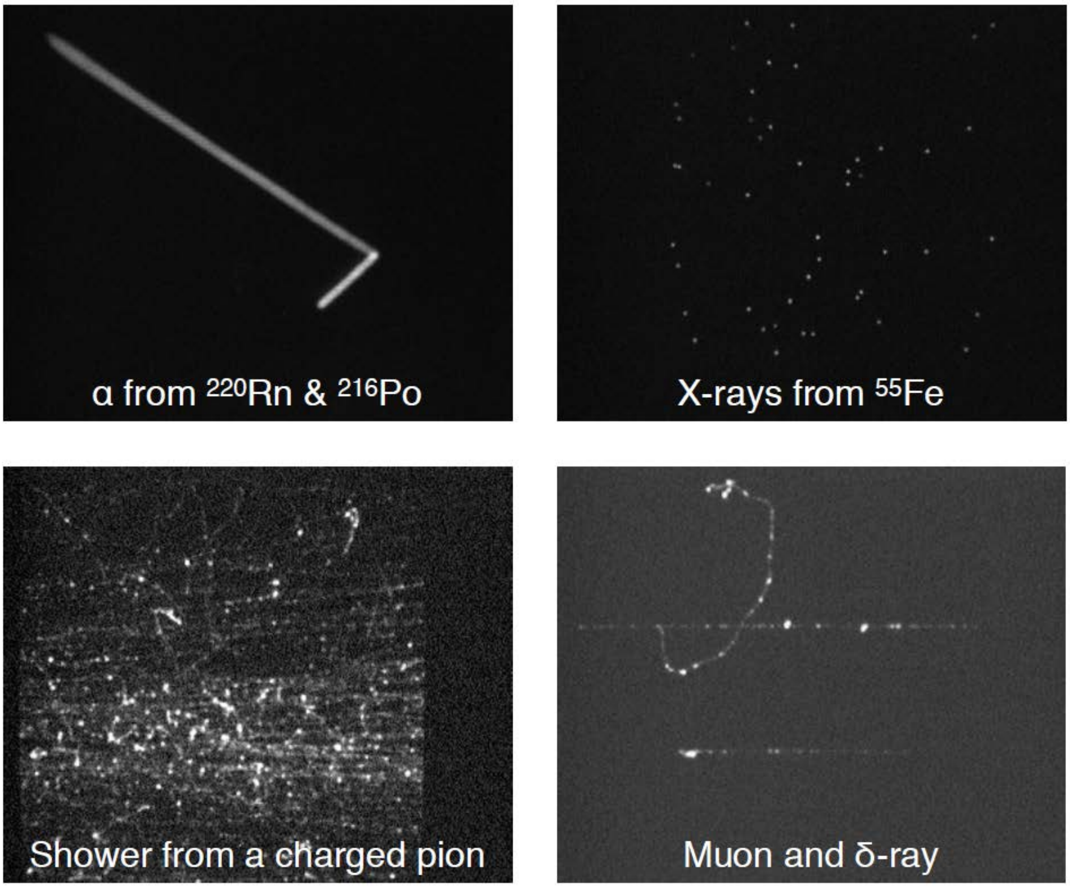


Fig. 5: Sample images of different ionising events.

The topology of these events is already very instructive. Moreover, the images contain quantitative information: the grey scale is proportional to the local energy release. As an example, the energy of the 5.9 keV X-ray from the 55Fe source can be estimated with a resolution better than 25% FWHM, as shown in this figure.

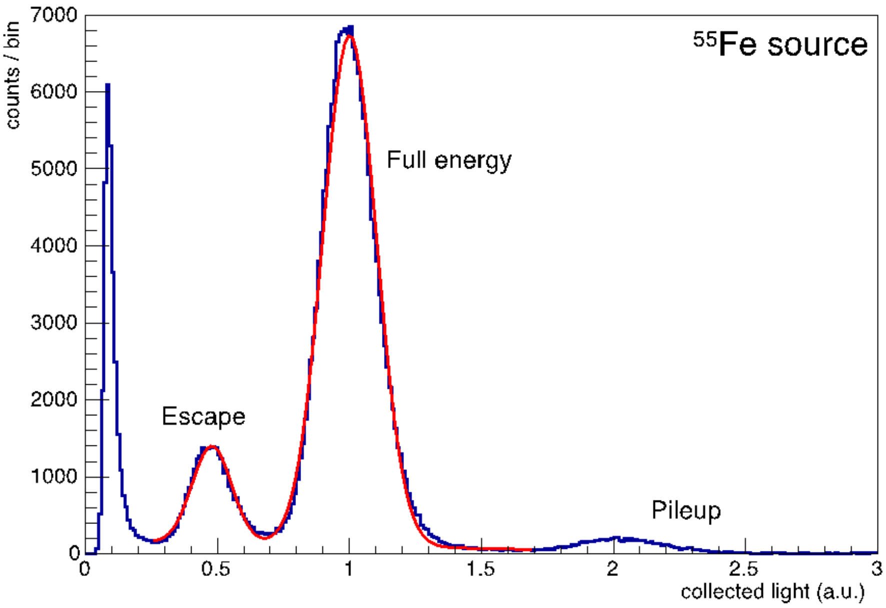


Fig. 6: Distribution of the light collected by the camera when exposing the detector to a 55Fe source.

This capability can be used to perform (in few minutes) a position and energy resolved X-ray fluorescence of an extended object. The target, illuminated with an X-ray beam, is the collection of metals shown below in the image on the left. The characteristic X-rays from each metal pass through a pin-hole before reaching the detector: the spatial information is traded with acquisition time. Energy and position are measured for each interacting X-ray. Translating the measured energy into a colour scale, the resulting fluorescence image is shown in colours.

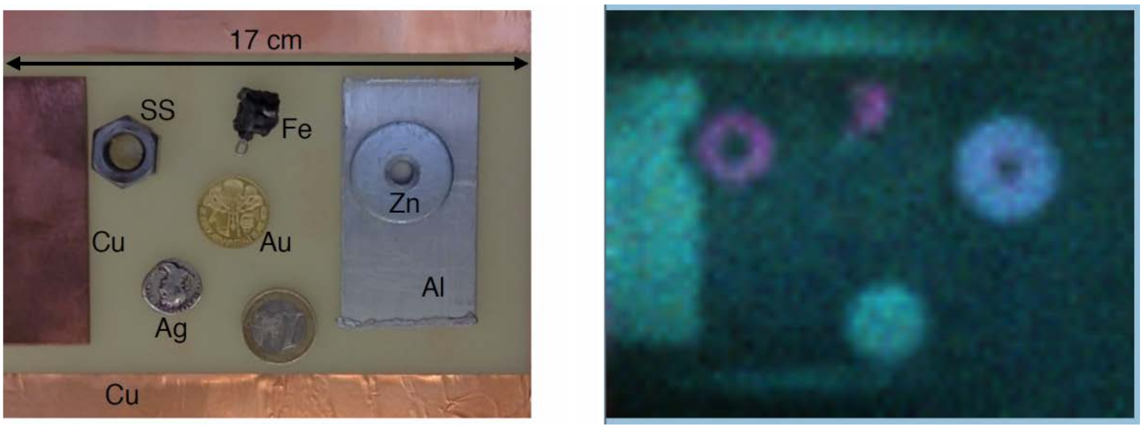


Fig. 7: Picture (left) and X-ray fluorescence image (right) of a collection of metals.

Different materials, having characteristic emission spectra, have characteristic colours: copper-rich in green, iron-rich in pink, and zinc-rich in blue. With the same colour code, the characteristic spectra are shown in the histogram below.

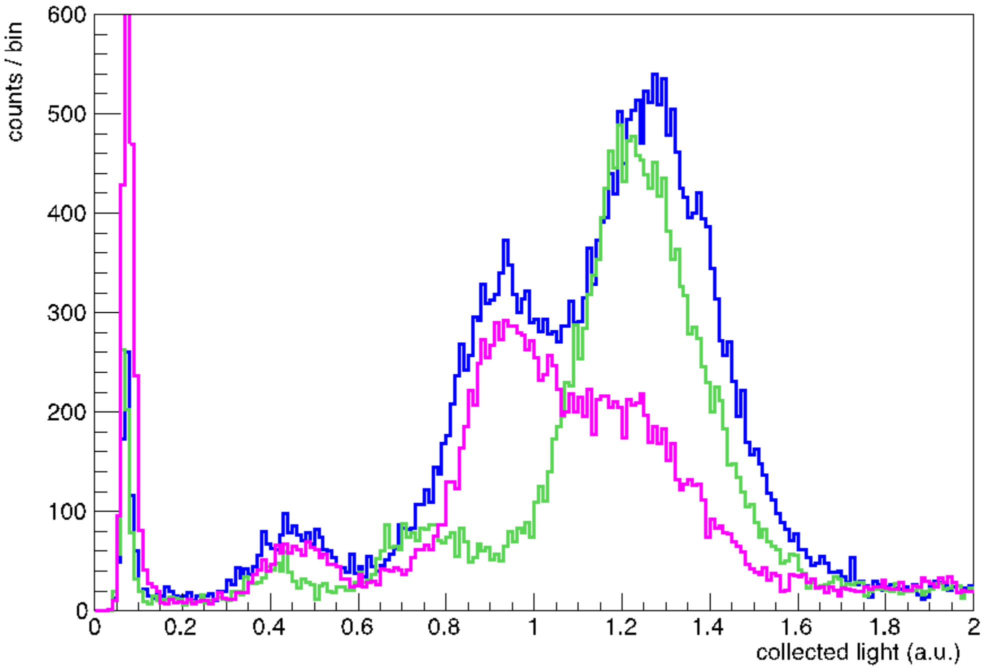


Fig. 8: Collected light spectra from the X-ray fluorescence for different materials.

Conclusions

What is highlighted in this article is a round up of possible usage of the optical readout, a versatile, intuitive and simple technique for imaging with MPGDs. More information can be found in [16, 17]. Keeping in mind that the prototype detector was not optimised for any of the measurement performed, one can imagine several other applications, ranging from X-ray crystallography over large areas, online beam monitor in hadron therapy treatments, rare events searches with Time Projection Chambers, and possibly several others.

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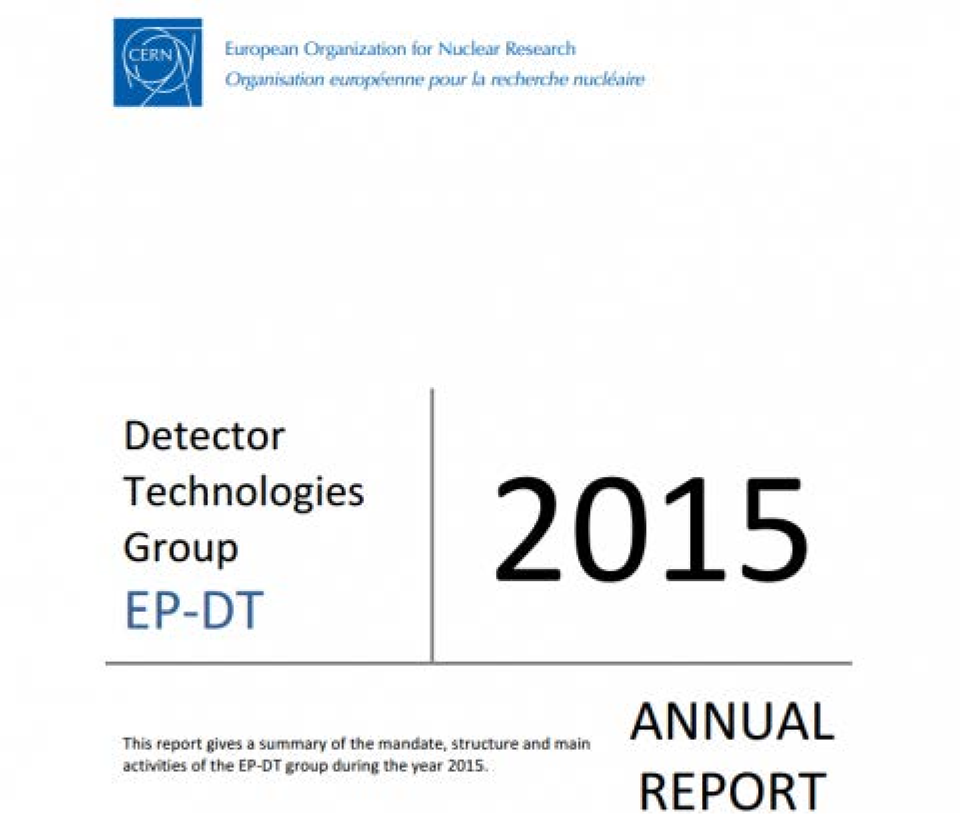
EP-DT group presents the 2015 annual report

by ***Mar Capeans and Paolo Martinengo***



European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

Detector
Technologies
Group
EP-DT

2015

This report gives a summary of the mandate, structure and main activities of the EP-DT group during the year 2015.

ANNUAL
REPORT

The EP-DT group has published its Annual Report where key activities throughout 2015 are described as well as a wider description of how the group is organized and interacts with the experimental community.

The mandate of the EP-DT group covers development, construction, operation and maintenance of particle detectors for the experiments at CERN. The group is engaged in several detector projects for LHC and non-LHC experiments. Specific partnerships for LHC Phase 1 and 2 detector upgrades have been settled with CERN teams, in particular with ALICE and LHCb, where DT supports several challenging detector upgrade projects. Agreements for engineering and detector prototyping support for the ATLAS and CMS Phase 2 detectors have started and will significantly ramp up in 2016. Mechanical and engineering support to CLOUD, AEgIS, NA62 and CAST, where DT staff plays important coordination roles, has also been an important part of the work. The group also pursues R&D on detector technologies and detector infrastructure systems for the interest of the overall HEP community.

A description of the efforts and achievements of 2015 can be found athttps://cds.cern.ch/record/2153804/files/EPDT_AnnualReport2015.pdf

CMS releases new data

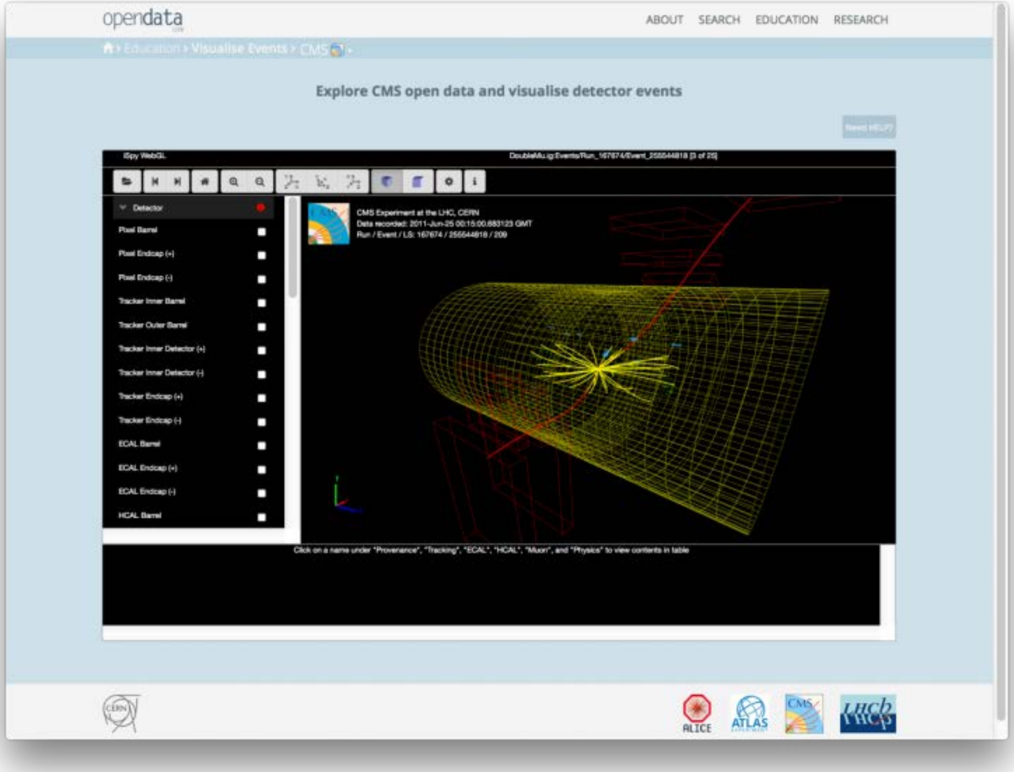
by ***Achintya Rao***

Rediscover the Standard Model of particle physics and much more with open data from the Large Hadron Collider

Today, the CMS Collaboration at CERN has released more than 300 terabytes (TB) of high-quality open data. These include over 100 TB, or 2.5 inverse femtobarns (fb^{-1}), of data from proton collisions at 7 TeV, making up half the data collected at the LHC by the CMS detector in 2011. This follows a previous release from November 2014, which made available around 27 TB of research data collected in 2010.

Available on the CERN Open Data Portal — which is built in collaboration with members of CERN's IT Department and Scientific Information Service — the collision data are released into the public domain under the CC0 waiver and come in types: The so-called "primary datasets" are in the same format used by the CMS Collaboration to perform research. The "derived datasets" on the other hand require a lot less computing power and can be readily analysed by university or high-school students, and CMS has provided a limited number of datasets in this format.

Notably, CMS is also providing the simulated data generated with the same software version that should be used to analyse the primary datasets. Simulations play a crucial role in particle-physics research and CMS is also making available the protocols for generating the simulations that are provided. The data release is accompanied by analysis tools and code examples tailored to the datasets. A virtual-machine image based on CernVM, which comes preloaded with the software environment needed to analyse the CMS data, can also be downloaded from the portal.



Explore CMS open data and visualise detector events

CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 00:15:00.883123 GMT
Run / Event / LS: 167674 / 255544818 / 209

Click on a name under "Provenance", "Tracking", "ECAL", "HCAL", "Muon", and "Physics" to view contents in table

A CMS collision event as seen in the built-in event display on the CERN Open Data Portal (Image: CERN)

These data are being made public in accordance with CMS's commitment to long-term data preservation and as part of the collaboration's open-data policy. "Members of the CMS Collaboration put in lots of effort and thousands of person-hours each of service work in order to operate the CMS detector and collect these research data for our analysis," explains Kati Lassila-Perini, a CMS physicist who leads these data-preservation efforts. "However, once we've exhausted our exploration of the data, we see no reason not to make them available publicly. The benefits are numerous, from inspiring high-school students to the training of the particle physicists of tomorrow. And personally, as CMS's data-preservation co-ordinator, this is a crucial part of ensuring the long-term availability of our research data."

The scope of open LHC data has already been demonstrated with the previous release of research data. A group of theorists at MIT wanted to study the substructure of jets — showers of hadron clusters recorded in the CMS detector. Since CMS had not performed this particular research, the theorists got in touch with the CMS scientists for advice on how to proceed. This blossomed into a fruitful collaboration between the theorists and CMS revolving around CMS open data. "As scientists, we should take the release of data from publicly funded research very seriously," says Salvatore Rappoccio, a CMS physicist who worked with the MIT theorists. "In addition to showing good stewardship of the funding we have received, it also provides a scientific benefit to our field as a whole. While it is a difficult and daunting task with much left to do, the release of CMS data is a giant step in the right direction."

Further, a CMS physicist in Germany tasked two undergraduates with validating the CMS Open Data by re-producing key plots from some highly cited CMS papers that used data collected in 2010. Using openly available documentation about CMS's analysis software and with some guidance from the physicist, the students were able to re-create plots that look nearly identical to those from CMS, showing what can be achieved with these data. "I was pleasantly surprised by how easy it was for the students to get started working with the CMS Open Data and how well the exercise worked," says Achim Geiser, the physicist behind this project. Simplified example code from one of these analyses is available on the CERN Open Data Portal and more is on its way.

Prior to the launch of the CERN Open Data Portal with the first batch of research-quality data from CMS, the Collaboration had provided certain curated datasets for use in high-school workshops. These "masterclasses", developed by QuarkNet(link is external) and conducted under the aegis of theInternational Particle Physics Outreach Group, bring particle-physics data to thousands of high-school students each year. These educational datasets are also available on the CERN Open Data Portal, along with an "event display" for visualising the particle-collision events.

"We are very pleased that we can make all these data publicly available," adds Kati. "We look forward to how they are utilised outside our collaboration, for research as well as for building educational tools."

Read more about CMS Open Data on the CERN Open Data Portal.

New staff members and fellows: April - May 2016

Stefania Bordoni

I am an experimental particle physicist and I joined the EP department as a Fellow since April 2016 to work with the Neutrino Platform. After a PhD in ATLAS I start working on neutrino oscillation in the T2K experiment. As a fellow I will be contributing to the activities related to the protoDUNE single phase detector, a Liquid Argon TPC that will be installed in the North Area and will serve as a detector prototype for the next generation of Long Baseline neutrino experiment (DUNE

Andrew Chisholm

I am an experimental particle physicist joining CERN as a research fellow having been based at the University of Birmingham as a PhD student and research fellow. I have joined the CERN ATLAS Data Processing group where I will focus on the commissioning and calibration of charm quark initiated jet tagging algorithms for use as tools in physics analyses. I am also interested in exploiting such algorithms to explore the capabilities of the ATLAS experiment to constrain the charm quark Yukawa coupling and better understand the production of charm quarks in association with electroweak bosons.

Arely Cortes Gonzalez

I'm an experimental particle physicist working in the ATLAS experiment since 2008, first as a PhD student with the University of Illinois, at Urbana Champaign, and then as a Postdoc with IFAE, Barcelona. I joined the CERN ATLAS group in April, as an applied fellow with the Tile Calorimeter. During these years I'll be collaborating in the calibration group of the calorimeter, working on the combination and intercalibration of all systems. I'll also remain involved in the TileCal operations during the collision data taking periods. In addition to my work with the detector, I'm co-convening the Jets+Dark Matter Exotics physics group in ATLAS, which follows from my participation and coordination of the “monojet” search done with 2012 and 2015 data.

Louis Helary

I'm a new research fellow who joined the ATLAS Central Trigger Processor group in April 2016. I have been a member of the ATLAS collaboration since October 2008 when I started my PhD in high energy physics at LAPP (Annecy-le-vieux), before joining Boston University as a post-doctoral researcher for four years. I'm now very happy to expand my research experience and to work on the level one trigger after having been involved in the activities of the LAr calorimeters and the Muon spectrometer. I’m particularly interested in di-boson physics, from Standard Model measurements to searches for new physics.

Jan Kieseler

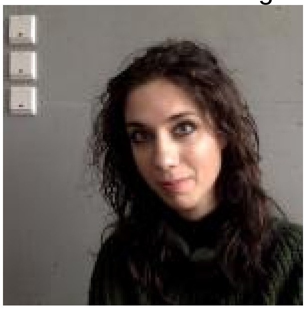
I joined the CERN CMS group as a research fellow in April. I have been working in top-quark physics since 2011 with particular focus on top-quark mass and top-quark pair cross section measurements. Within the CERN CMS group, my aim is to continue my involvement in top-quark physics, but also to broaden my knowledge in measurements of electroweak boson production and to contribute to the developments for the CMS high-granularity calorimeter upgrade.

Michael Lupberger

I joined the EP department as a Fellow in May to work on a neutron detector for the European Spallation Source. My main subject will be the firmware and front-end for the readout system of this new gaseous detector, which is developed by my group EP-DT-DD. As a particle physicist, I am interested not only in the electronics, but also complete detector systems and the physics related to them. Before I joined CERN, I finished my PhD at the University of Bonn on an ILC related project.

Andreas Maier

After finishing my PhD at Max-Planck-Institute for Physics in Munich in top quark physics and the ATLAS pixel detector refurbishment, including the construction of the ATLAS IBL detector, I joined the EP-LCD group at CERN in May 2016 as a fellow. My work will include the development, testing and construction of the CMS High Granularity Calorimeter (HGCAL) as well as physics analyses for CLIC. I am looking forward to a fruitful time at CERN!



Anna Stakia

"Early Stage Researcher" within the “Marie Sklodowska-Curie Actions” Innovative Training Network AMVA4NewPhysics, at CERN, in the Experimental Physics (EP) Department of CMS, whilst working towards my PhD. Objectives of this position: Utilisation and optimisation of Multivariate Analysis (MVA) methods and tools in the context of searches for new physics.

Saray Ugidos Seman

Joined the EP-DT-EF section as a Fellow, after one year working for a contractor Company at CERN. I have a bachelor in economics and law, a master in Management QHSE and a postgraduate in Industrial Safety. My job in this moment consists in management chemical safety. I’m working to different buildings for the specifics safety and environmental procedures.