ALICE

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1 Introduction

ALICE is an experiment at CERN which involves about 1600 physicists from more than 150 Institutions from several Countries. Italy participates with 12 groups and about 200 physicists. The Frascati group has been deeply involved in the electromagnetic calorimeters (EMCal, DCal), both on the hardware and software side, while for the data analysis the group is focused on the physics of the jets from both light and heavy-flavours. The choice of these specific analyses comes from the fact that the calorimeters, in addition to the tracking, enables ALICE, like no other experiment before, to explore the physics of jet quenching, i.e. the interaction of energetic partons with the QCD hot and dense medium, over the large kinematic range provided by the LHC. EMCal and DCal provide both fast triggers (level 0 and 1) for photons, electrons, and jets, and a High Level Trigger (HLT) as well. They also measure the neutral energy component of jets, enabling full jet reconstruction in all collision systems, from proton-proton to Pb–Pb, passing through the p–Pb collisions. The combination of the EMCal+DCal calorimeters, the excellent ALICE charged tracking capabilities, and the modest ALICE magnetic field strength, is a preferred configuration for jet reconstruction in the high background environment of heavy-ion collisions, allowing detailed optimization of background rejection while preserving the crucial jet quenching signals down to very low transverse momenta.

From 2012, the majority of the INFN groups in ALICE decided to participate to the major upgrade of the spectrometer by constructing a new generation Inner Tracking System (ITS) based on Monolithic Active Pixel Sensors (MAPS), with greatly improved features in terms of: determination of the distance of closest approach (DCA) to the primary vertex, standalone tracking efficiency at low p_T , momentum resolution and readout rate capabilities. The new detector will replace the existing ITS and will be installed during the LHC Long Shutdown 2. Since the birth of the project, the Frascati group is involved both in the R&D for the detector assembly, in the electronic testing station setup and in the beam tests for the characterisation of the silicon chip prototype. During the production phase, LNF will be one of the hubs for the final assembly and test of the modules (staves) ready to be installed in the ALICE spectrometer. ALICE data open the frontiers to rare events, to flavour jet physics, and give new tools for investigating the QCD and the Quark Gluon Plasma.

2 The new Inner Tracking System

LNF will be one of the five world laboratories selected for the assembly of the new ALICE Inner Tracking System (ITS). The decision came in October 2014 and since then activities to prepare a new laboratory in a clean room fully instrumented has been intensively carried on. In the new laboratory the R&D for the assembly procedures, test and prototype characterisation are progressing and in perfect time with the scheduled work. Several dummy stave modules with dummy silicon chip modules have been assembled and verified. New procedures for gluing, soldering and stave positioning by a laser driven procedure have been developed. The precision required for the ITS construction needed the installation of a new large Coordinate Measuring Machine with the accuracy of few μm and a working area of 200 x 90 x 60 cm^3. The operators needed a specific training course for learning the programming tools and operating the movement of the probes.

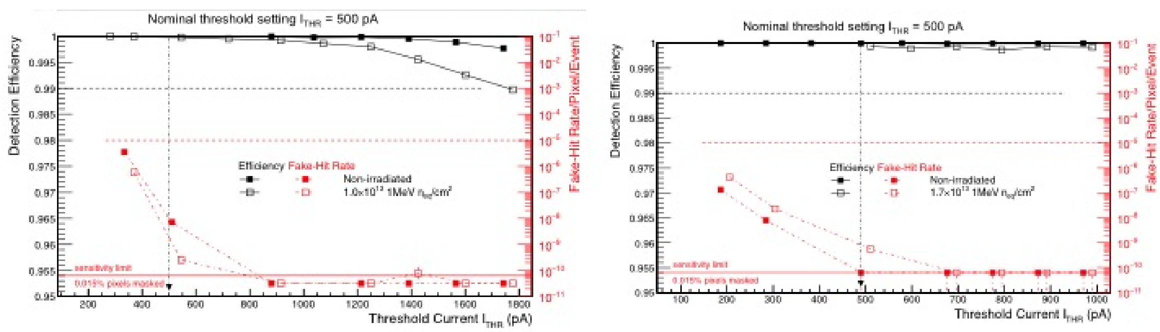

Figure 1: *ALPIDE architecture efficiency and fake-hit rates for two bias voltages: 3V (left) and 6V (right).*

This unique machine, one of the very few within INFN, also due to the experience acquired by the technicians of the ALICE group specialised in operating it, has been also used to perform precision measurements for other experiments in the laboratory. A strong contribution has been given in an intensive test campaign taken place at the LNF Beam Test Facility in order to characterise the sensors prototypes. The campaign has taken place in four different data taking periods from March to December. Both the two proposed solutions for the chip architecture were tested: the MISTRAL one proposed by the group of Strasbourg and the ALPIDE one mainly developed at CERN. Detailed presentations on the results obtained have been exposed at several internal ALICE ITS upgrade collaboration meetings, workshops and conferences. In particular, the LNF Alice group has also strongly contributed in the MISTRAL architecture testing campaign providing a specific data acquisition system and a reference tracking telescope made by two stations equipped each with two M18 analog monolithic pixel sensors with 10 μm pitch.

The measurements performed for the ALPIDE solution, that thanks to the remarkable availability and features of the BTF beam in two testing periods, allowed to collect more than one thousand different sensor parameters configurations: different pixels characteristics like diode size and distance, bias type, epitaxial layer thickness, back bias voltage values. The conclusion briefly summarised in Fig. 1 allows to take a decision on which of the eight pixel configurations present in the pALPIDE3 version prototype have to be used in the final version of the sensor. From the figure, it is clear that the measured detection efficiency is largely above the required value of 99% and, simultaneously, the fake-hit rate per pixel per event is well below the required value of 10^{-5}.

3 Calorimeters

The DCal calorimeter expands the physics capabilities of the EMCal by enabling back-to-back correlation measurements, which are impossible with the EMCal alone, and is essential to obtain a complete picture of the physics addressed by the EMCal. Together, DCal and EMCal form a two-arm electromagnetic calorimeter. The EMCal subtends 110° and the DCal subtends 60° in the azimuthal angle ϕ, with both detectors covering a pseudorapidity range $|\eta| <0.7$, thereby providing good acceptance for di-jets with radii R<0.4.

The LNF group had the responsibility of coordinating the construction and assembly of the detector in the European-Asiatic zone and provided a big part of the WLS fibers, grouped in bundles. The DCal installation has been completed at the end of 2014.

In 2015 the work on the readout of both EMCal and DCal has been carried on in order

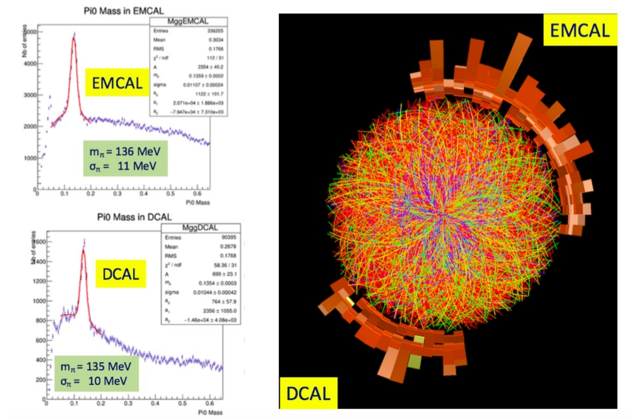

Figure 2: *Left: π^0 mass reconstructed in EMCal and DCal. Right: event display with a back-to-back jet event reconstructed in the calorimeters.*

to provide a unique and integrated system with PHOS, the other high granularity calorimeter of the ALICE spectrometer. The different geometries of the calorimeters have been taken into account as well as the gap of 33 cm between DCal and PHOS. EMCal/DCal (and PHOS) L0 and L1 trigger electronics have been replaced entirely, providing low-noise L0 single shower, L1-γ and L1-jet triggers from PHOS. Moreover, the trigger has been implemented in order to provide combined L1-γ and L1-jet triggers and centrality depended L1-jet self-contained using a median from DCal/PHOS for EMCal signals and viceversa. All the calorimeters readout electronics have been upgraded from serial (RCU) to parallel (SRU) units. At the end of the LHC shutdown, the full readout is operational at 5 kHz.

An example of the EMCal and DCal performances is shown in Fig. 2. On the left side the reconstructed π^0 mass for the two detectors is show, while on the right side is shown an event display of the online reconstruction of the ALICE central spectrometer. It is clearly shown a back-to-back jet event reconstructed in the calorimeters.

4 Post LS1 and Data Taking operations

After the LHC Long Shutdown 1 where the LNF group had the heavy and important responsibility for coordinating the consolidation work and preparation for the data taking 2015, the ALICE detector has been in data taking, with beam, since the LHC restart in May 2015. During the machine intensity ramp up ALICE has collected diffractive data while, in the following 50 and 25 ns intensity ramp up phase, ALICE have been operating at instantaneous luminosities up to 5 Hz/μb collecting 620 M of minimum bias events and integrating 4.35 /pb of di-muon triggers and 1.81 /pb of high multiplicity triggers for ridge studies in *pp* collisions. The luminosity targets for 2015 have been successfully matched.

The heavy-ion run for 2015 was characterised by a very packed schedule as it included one week of *pp* reference running at 2.51 TeV/beam, one lead source refill, one machine development shift for crystal collimation, the ALICE polarity flip which requires loss maps revalidation, vdM scans and two quench tests. Despite the difficulties of the multiple configuration changes on the machine and detector side, ALICE has successfully exploited the available time collecting 130 minimum bias events which amounts to 13% of the request formulated for RUN2 (1000M).

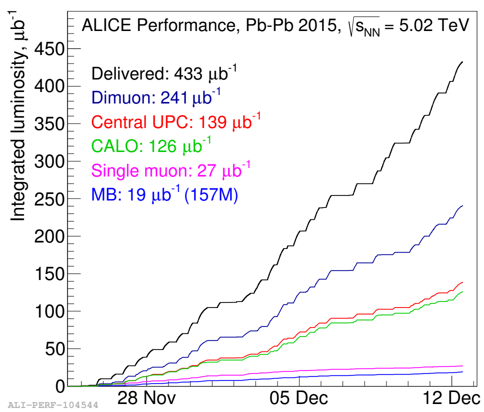

Figure 3: *Total integrated luminosity for various triggers in PbPb at 5.02 TeV taken in 2015 under the LNF run coordination.*

During the remaining 3 weeks the machine has delivered high luminosity Pb-Pb collisions and ALICE has achieved the historical milestone of running at its design luminosity of 1000 Hz/b for and average of 2.4 h at the beginning of each high intensity fill which is somewhat lower then the projected figure (3-4 h). The overall integrated lumi was 433 /μb. The average running efficiency during the 4 weeks (proton reference and lead run) was above 90%. In conclusion, ALICE has collected in 7 months of operation 7.2 PB of raw data equivalent to the whole RUN1 (2010/13) dataset.

In all these activities, the LNF group played a key role, not only having a period run coordinator, shift leaders and crew members during the data taking, but mainly because the whole run coordination was carried on by F.Ronchetti, member of the LNF group.

5 Heavy-flavour measurement via electrons

Heavy quarks, i.e. charm and beauty, are produced primarily in the initial, hard partonic scatterings of the hadron collisions and their production in *pp* interactions is well described by perturbative QCD. In ultra-relativistic heavy-ion collisions, heavy quarks propagate through and interact with the hot and dense QCD matter, therefore, measurements of heavy-flavour production provide relevant information on the early stage of the collisions and parton-medium interaction. In Pb–Pb collisions, a strong suppression of D mesons and electrons from heavy-flavour decays have been observed. In case of electrons, the strong suppression was observed up to $p_{\mathrm{T}} = 18$ GeV/c in most-central collisions. The production of electrons from heavy-flavour in pPb collisions, which is a reference for Pb–Pb due to absence of hot and dense QCD matter, shows that there is no such suppression up to 20 GeV/c. Thus it is confirmed that the suppression is mainly due to energy loss of patrons in the QCD metter. Especially at high-p_T, electrons coming from beauty decay are dominant, so there is a first qualitative indication that not only charm, but also the more massive beauty quarks lose energy. Further information about the mechanism of energy loss of heavy-flavours in the QCD matter can be obtained by measuring production of jets which originally comes from heavy flavours. In ALICE, inclusive jets production has been successfully measured at $p_{\mathrm{T}} >$20 GeV/c both in *pp* and Pb–Pb collisions. The idea of the analysis carried on at LNF is to use heavy-flavour decay electrons to find heavy-flavour jets. From a Monte Carlo simulation, heavy-flavour decay electrons are well correlated in rapidity and azimuthal direction with the original heavy quarks. By electron measurements in the pp and Pb–Pb collisions, the fraction of the heavy-flavour hadron decay electrons in measured electron samples with the ALICE detectors is about 50% at $p_{\rm T} \sim 3$ GeV/c and it becomes dominant at high-$p_{\rm T}$. Therefore, using high $p_{\rm T}$ electrons, it is possible to measure heavy-flavour jets with small background contributions. With data recorded during LHC Run1, we observed the raw spectrum up to around 60 GeV/c in most central Pb–Pb collisions. Currently, the analysis is concentrated on the determination of efficiencies and unfolding. All the analysis steps, background subtraction, efficiencies and unfolding corrections, were tested by a Monte Carlo simulations giving very positive feedback, Fig. 4. As an extension of the analysis, we are performing studies of heavy-flavour dijet following the same concepts. For this stage, such recoil jets have been observed on away-side in pp collisions at $\sqrt{s} =$ 8 TeV. In Run2, combining the EMCal and DCal calorimeter signals, already mentioned before, there will be a clear improvement of the statistics acquired.

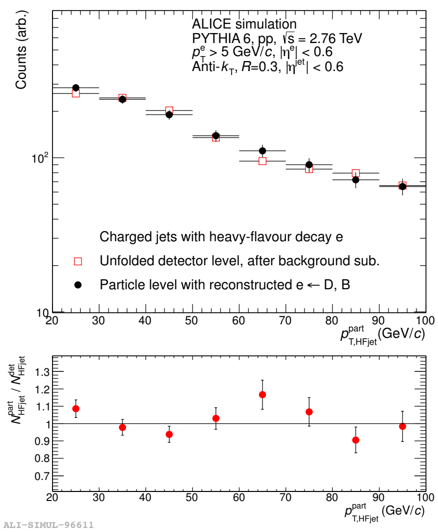

Figure 4: *Monte Carlo simulation showing the performance of heavy-flavour jet measurements via electrons.*

6 Polarization studies

Another analysis which sees the LNF group involved starts from the fact that there are still several fundamental questions related to the spin structure of the nucleon which remain unanswered, including a possibile description of the 3D structure of the Parton Distribution Functions at high energies. In particular, Λ^0 hyperon polarization is a potentially powerful way of probing polarized quark content inside the nucleon. Its decay into a proton and a pion in a parity violating weak decay opens to the determination of the Λ^0 hyperon polarization by measuring the angular distribution of its decay products. Particularly, the study of the transverse polarization of Λ^0 and $\bar{\Lambda}^0$ hyperon in ALICE would allow to access the Boer-Mulders distribution that measures the transverse spin asymmetries of quarks inside an unpolarised hadron in a kinematic regime never reached before.

After having reconstructed these particles in events at different collision energies ($\sqrt{s} = 2.76$, 7 and 8 TeV) both a multiplicity and an asymmetry distribution study have been performed. The asymmetry in Λ^0 ($\bar{\Lambda}^0$) decays, both with respect to the production plane and the thrust vector has been measured as a function of p_T and η. Promising results show an asymmetry as a function of η of less than per cent. The measured asymmetry has opposite sign for Λ^0 and $\bar{\Lambda}^0$, increases as a function of p_T and flips the sign when going from positive to negative pseudorapidity region.

Publications

The ALICE Collaboration has published 42 papers in 2015. The publications are accessible at the link: http://aliceinfo.cern.ch/ArtSubmission/publications

Talks

1. P.Di Nezza, Talk: *"Particle identified jet studies in ALICE"*, 7^{th} International Conference on Physics and Astrophysics of Quark Gluon Plasma, Feb 2015, Kolkata, India;
2. L.Calero Diaz, Seminar: "Λ^0 *polarisation at the LHC"*, University of Ferrara, May 2015, Ferrara, Italy;
3. P.Di Nezza, PhD Course: *"Quark Gluon Plasma in Heavy-Ion Collisions"*, International School Niccoló Cabeo, Jun 2015, Ferrara, Italy;
4. P.Di Nezza, Invited talk: *"Il tracciatore interno a stato solido per l'upgrade di ALICE"*, SIF National Congress, Sep 2015, Rome, Italy.