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An example of first physics results with ALICE at the LHC: Identified hadron spectra and ϕ resonance production

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Summary. — This work presents a study of the ALICE-TOF capability to get physics results in the first *pp* collisions at the LHC. Through a Monte Carlo simulation of the full detector response in *pp* collisions at 10 TeV it is shown how the ALICE Time Of Flight will be ready to reconstruct the hadron spectra for $p_T < 3\,\text{GeV}$ and to identify the ϕ resonances with a limited statistics, corresponding to some days of data acquisition, and with the current 130 ps TOF time resolution, calibrated with cosmic rays.

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Introduction

In this paper we briefly present the performance of the ALICE Time-Of-Flight (TOF) in identifying hadrons and resonances with the current time resolution, $\sigma_{\mathrm{TOF}} = 130\,\mathrm{ps}$.

The ALICE experiment is designed for the nucleus-nucleus collisions and therefore optimized for high multiplicity events with a high capability to reconstruct signals at "low" p_T (a few GeV/c).

Ultrarelativistic nucleus-nucleus physics concerns the possible formation of a deconfined phase: the so-called Quark Gluon Plasma (QGP) and for such a kind of study hadron spectra and short-living resonances are very important to characterize the properties of the matter produced in the collisions. In particular the resonance case is interesting because of the strong correlation between their lifetime and the QGP one.

In sect. **1** the current status of the TOF commissioning is presented focusing on the most important features for these studies.

In sect. **2** the expected capability, with the current time resolution, in reconstructing hadron spectra is presented for pions, kaons and protons.

Section **3** regards the study of a short-living resonance, the ϕ particle.

1. – TOF current status

The ALICE TOF detector is dedicated to Particle IDentification (PID) in the central barrel ($|\eta| < 0.9$) for a wide range of momenta. It was designed in order to provide the particle time-of-flight with a resolution lower than 80 ps (including all the possible error sources). In order to reach such a resolution it should be calibrated with the first pp collisions.

However, detailed studies with cosmic rays during the end of the 2008 and the beginning of 2009 have shown that a preliminary TOF calibration can produce a time resolution of 130 ps before the start of the LHC (foreseen in 2009) [1]. This very important result will allow to include the TOF in the first physics program of the experiment.

2. – Hadron spectra

Starting from the performance of the previous section it is possible to estimate the PID capability of the TOF in realistic scenarios using a large sample of Monte Carlo simulations implemented on the GRID environment with the Collaboration software AliRoot [2]. In order to extract the PID efficiency for several species of particles we have analyzed 1.8M pp events generated with PYTHIA6 MC [3]. The results for pions, kaons and protons are shown in fig. 1 in terms of efficiency and contamination.

PID efficiency is defined for each given species i as the ratio between the number of correctly identified particles i and the total number of particles i associated with a signal on the TOF; while the contamination is defined as the ratio between the number of particles misidentified as species i over the total number of particles identified as species i. For more details refer also to [4].

As expected from the current time resolution, the K/π separation is good (contamination lower than 10%) till 2.0 GeV/c, while the K/p separation for p_T lower than 3.5 GeV/c. Therefore the identified hadron spectra can be measured at the startup of the LHC with good accuracy up to 2–3 GeV/c as can be seen in fig. 2 (p_T is taken from TPC reconstruction).

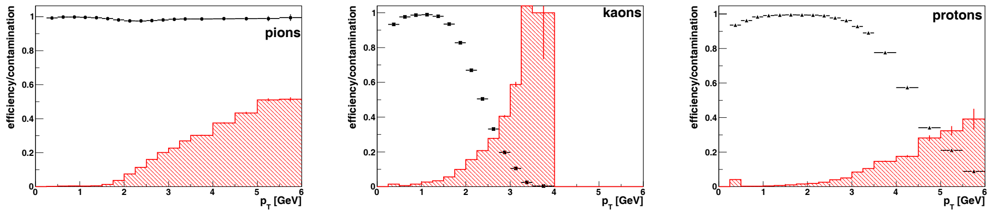

Fig. 1. – TOF ($\sigma_{\mathrm{TOF}} = 130\,\mathrm{ps}$) Particle Identification efficiency (empty histo) and contamination (filled histo) as a function of p_T reconstructed from the TPC, for pions, kaons and protons, respectively.

The true spectra (dotted lines) are compared with the reconstructed ones (big markers) corrected for the overall PID efficiency. Overall PID efficiency includes all the possible contributions to the loss of information, including track reconstruction efficiency, interaction with materials, decays, track-TOF hit matching efficiency.

As can be noted the kaon spectrum starts to be affected by contamination for $p_T > 2\,\mathrm{GeV}/c$ as expected from the PID performance.

3. – ϕ mesons reconstruction

As mentioned before short-living resonances play an important role in the identification of QGP properties. The PID information given by the TOF can be very useful for many of them like in the ϕ meson case. The K^+K^- decay channel is a natural candidate for analysis with TOF because of its separation power of the kaons from the other hadron species. A good separation means the possibility to keep the combinatorial background low, as it will be shown in the next plots.

Figure 3 (1st column) shows the K^+K^- invariant mass distribution for 1.8M pp PYTHIA6 events. The combinatorial background is directly estimated in the fit together with the signal. The fit function used to get the signal is the sum of a Breit-Wigner and a polynomial function. The S/B ratio and the significance were calculated for the different p_T bins and are very promising also with the given statistics. The significance is greater than 5 up to $p_T < 4\,\mathrm{GeV}/c$ indeed, fig. 3 (1st column) bottom. Notice that

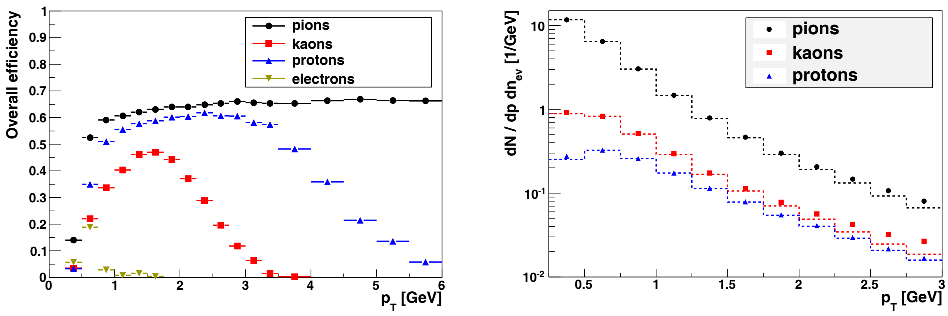

Fig. 2. – Overall PID efficiency with $\sigma_{\mathrm{TOF}} = 130\,\mathrm{ps}$, on the left. Hadron spectra reconstructed with the TOF current resolution, on the right.

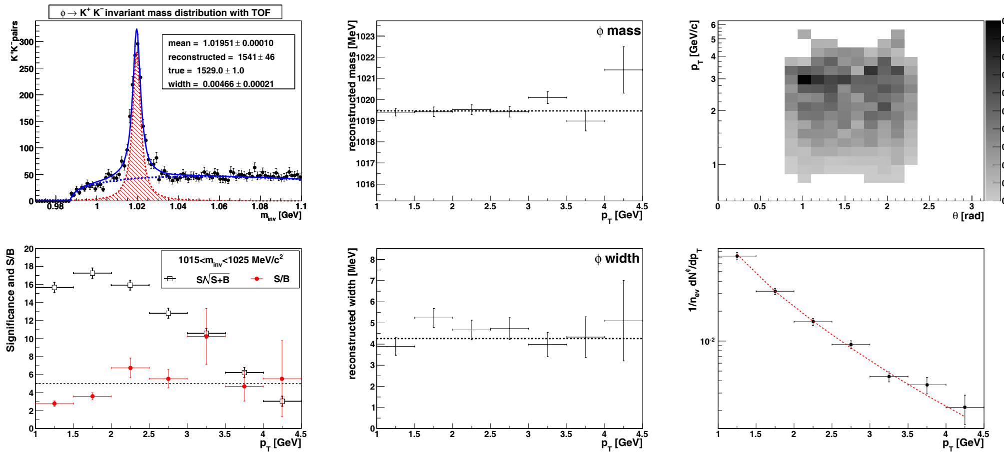

Fig. 3. – 1st column: on the top the ϕ reconstructed invariant mass is shown for 1.8 M pp events generated with PYTHIA6. On the bottom the significance in the ϕ detection is reported also for different p_T-bins. 2nd column: ϕ reconstructed parameters (mass, width) for different p_T-bins. 3rd column: ϕ (θ, p_T)-efficiency (top) and reconstructed p_T-spectrum in the central barrel (bottom) after efficiency correction.

a p_T of $4\,\text{GeV}/c$ for the ϕ is covered very well from the TOF PID because it corresponds on average to a couple of kaons with $\sim 2\,\text{GeV}/c$ momenta.

The same approach for different p_T bins was applied to the same sample of events. The resonance parameters (mass and width) were extracted from the fit and plotted in fig. 3 (2nd column) as a function of p_T.

Finally, fig. 3 (3rd column) shows the ϕ reconstructed p_T spectrum (bottom plot) after the efficiency correction (top plot) was applied.

Conclusions

In this work we present an example of the possible contributions of the ALICE TOF detector to the first physics program of the Collaboration. We emphasize the fact that the understanding of the detector performance is quite good and this will allow to measure hadron spectra and the ϕ resonance few days after the start of pp collisions at the LHC.

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