First measurements of strangeness production in pp collisions with the ALICE experiment at LHC

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The status of strange baryon and anti-baryon analysis in pp collisions at LHC is reported. It is based on ALICE pp data collected at $\sqrt{s} = 900$ GeV and 7 TeV. The performance of K^0_S, Λ ($\bar{\Lambda}$), Ξ ($\bar{\Xi}$) and Ω ($\bar{\Omega}$) reconstruction via their weak decay topology is described. Transverse momentum spectra extracted at central rapidity are presented.

1. INTRODUCTION

Strange particle transverse momentum (p_t) distributions are essential observables to characterize the thermodynamical properties and the space-time evolution of the medium created in heavy-ion collisions. With the LHC commissioning in Nov. 2009 and the pp data-taking campaigns that started since then, we have the opportunity to measure them in such a small system, and thus gain access to the necessary reference for heavy-ion data taking and analyses that will start in the late 2010. Besides, particle production study in pp is of major importance in itself: while high momentum particle production is rather well understood in the framework of perturbative QCD and fragmentation functions, the soft component (underlying event) still remains a very complex issue that only phenomenological approaches manage to reproduce. In this context, thanks to their measurement technique, strange particles give the possibility to probe both the soft and hard regimes of hadron production. In addition, the s-quark brings an interesting additional component, in particular for statistical and recombination models.

In this article, we report the latest results concerning p_t spectra of K^0_S, Λ, Ξ and Ω (and their respective anti-particles) in pp collisions at LHC with the ALICE experiment, at the energies $\sqrt{s}$ = 900 GeV and 7 TeV.

2. STRANGENESS MEASUREMENT IN ALICE

The description of the ALICE experiment can be found in reference [1]. ALICE is a powerful device to identify strange decays, thanks to its low magnetic field (0.5 T), low material budget (13% of radiation length) and excellent PID capabilities that make it especially performant at low transverse momenta (p_t). To identify strange secondary vertices, we use the two main tracking devices of ALICE, both covering the full azimuth: the Inner Tracking System (ITS) that consists of six silicon layers close to the diamond, and the Time Projection Chamber (TPC). Strange particles decay by weak interaction and have got $c\tau$'s of a few centimeters. Their displaced decay vertex can, therefore, be reconstructed by topological algorithms that associate secondary tracks, getting rid of most of the background coming from primary tracks. V^0's (namely K^0_S and Λ) and cascades (Ξ and Ω) are identified in such a way, making use of several topological selections, as described in reference [2]. A summary of strange particle characteristics can be found in Table 1.

The analyses presented here were performed on minimum bias events, applying a maximum primary vertex displacement selection of 10 cm along the beam axis. The tracks accepted for analysis were required in the reconstruction procedure to be used for the inward and outward propagations, and finally refitted to the primary vertex.

For more detail, see reference [2]. Reconstructed tracks were also required to contain at least 80 (out of 160) associated clusters in the TPC, with a χ^2 lower than 4, and $p_t > 0.16$ GeV/c.

Single particle identification selections were also used for the decay daughters. In the case of the (anti-)Λ, the (anti-)proton daughter is required to leave an energy deposit in the TPC compatible with the proton dE/dX band within 5 (3) standard deviations (σ) if its momentum at the inner TPC wall is below (above) 0.7 GeV/c. In the case of the cascades, a 4-σ cut is applied on each daughter, regardless of its momentum. Both V^0's and cascades are constrained to be reconstructed inside a 'fiducial' zone in the transverse plane, extending radially from 0.2 to 100 cm around the beam axis. After the topological method is applied on strange particles, the resulting secondary vertex rapidity was imposed to be within some rapidity window (see Table 1). The resulting final efficiencies (including acceptance and branching ratios) for V^0's and Ξ are shown on Figure 1.

3. ANALYSIS RESULTS

3.1. Analysis of pp data at $\sqrt{s} = 900$ GeV

The data at $\sqrt{s} = 900$ GeV was taken in Nov.-Dec. 2009 with circulating beams of low intensity providing ~300k minimum bias events (requiring both triggers from ALICE VZERO and SPD detectors). In such conditions, 'pile-up' effects are negligible and not corrected for.

Strange particle raw yields were calculated by analysing their invariant mass spectra in various bins of p_t in the ranges [0.2-3.0] for the K^0_S, [0.6-3.5] for the Λ and $\bar{\Lambda}$, and [0.6-3.0] for the Ξ and $\bar{\Xi}$. As illustrated in Figure 2 (lower plot), the signal is calculated in the following way: the invariant mass peak is fitted by a gaussian lying on a polynomial background, which provides an estimate of the mean m_0 (measured mass) and its resolution σ_0. The quantity $S + B$ is computed by bin counting in the 'signal region' $m_0 \pm 4\sigma_0$. The background B is also estimated by bin counting, in a region away from the 'signal region' chosen according to the particle and the p_t region considered (the grey bands on the figure). The raw yields finally come from the subtraction $(S + B) - B$.

Efficiency corrections are evaluated by means of simulations. Particle are produced by the generator PYTHIA (tune D6T) [3], and propagated to the detectors by means of the transport model GEANT3 [4].

In the case of the Λ and $\bar{\Lambda}$ reconstruction, an additional correction has to be brought to the final correction factor, taking care of the contamination from the cascade decays. The feed-down correction factor relative to the Ξ ($\bar{\Xi}$) is about 13% (12%). The ones relative to the Ω and $\bar{\Omega}$ are found to be negligible, because of both the Ω production rate and its branching ratio that are (much) lower than the Ξ ones. The feed-down contribution is found to be independent of p_t, therefore a global correction is applied on the whole Λ and $\bar{\Lambda}$ p_t spectra.

The corrected differential spectra as a function of p_t ($\mathrm{d}^2N/\mathrm{d}p_t\mathrm{d}y$) integrated in the central rapidity region for K^0_S, Λ (feed-down corrected) and $\Xi + \bar{\Xi}$ are shown in Figure 3.

They are compared to various models: PYTHIA, for which three different parametrizations are presented, and PHOJET. All the considered models underestimate strange baryon production by a factor 3 in the whole range of p_t.

Different sources of systematic uncertainties have been studied for V^0 decays. First, signal extraction from the invariant mass spectra depends both on the method used, and on the mass range chosen for $(S + B)$ and B calculations. Second, the distributions of the topological selection variables differ between the observed data and the simulation; therefore the choice of these selections directly affects the final corrected spectra. These effects were taken into account, and an estimate of the error they induce was estimated to be lower than 6%. Finally, the influence of the detectors material budget has been studied by comparison with the transport model GEANT4 [5]; the antiproton absorption cross section used brought a significant effect. The systematic errors on the V^0 p_t spectra appear to be below 2% for the K^0_S, and below 7% for the Λ and $\bar{\Lambda}$. These systematic uncertainties must be added to the statistical errors of Figure 3.

Table 1
Strange particles characteristics (only charged decay modes are considered) and rapidity windows used for analysis (last column).

Particle	Decay channel	B.R. (%)	$c\tau$ (cm)	Mass (MeV/c^2)	$\lvert y\rvert$
K^0_S	$\pi^+\pi^-$	69.2	2.7	497.6	< 0.75
Λ	$p\pi^-$	63.9	7.9	115.7	< 0.75
Ξ^-	$\Lambda\pi^-$	99.9	4.9	1321.7	< 0.8
Ω^-	ΛK^-	67.8	2.5	1672.5	< 0.8

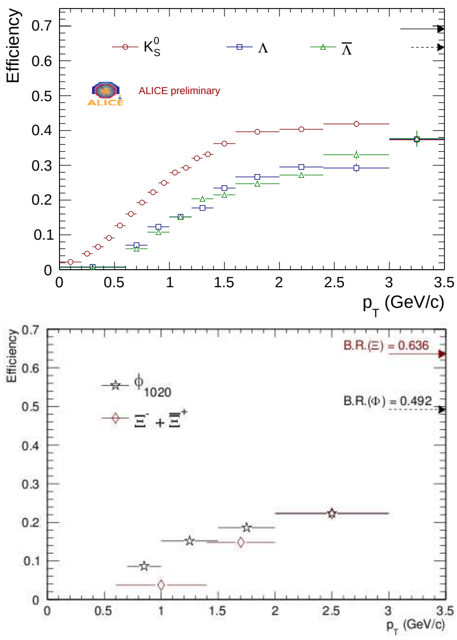

Figure 1. V^0, Ξ and ϕ reconstruction total efficiency as function of p_t.

3.2. Analysis of pp data at $\sqrt{s} = 7$ TeV

Since March 2010, the LHC has collected more than 100M minimum bias events and, at the time being, data taking and strange particle production studies are still ongoing. Figure 2 shows the reconstructed invariant mass spectrum of the $\bar{\Lambda}$ in 7 TeV pp collisions for a sample of about 8.5M events. It shows the wealth of V^0 candidates that are available for analysis, with a high signal purity. Even for the single $\bar{\Omega}^+$, the statistics of candidates reached is very promising (see Figure 2), and better than the one obtained in 900 GeV data in which both Ξ and $\bar{\Xi}$ spectra had to be merged in order to extract significant physics results.

4. CONCLUSIONS

We have presented the measured corrected p_t spectra in ALICE central rapidity of strange secondary vertices K^0_S, Λ, and Ξ from the first LHC pp data at $\sqrt{s} = 900$ GeV, which corresponds to about 300k minimum bias events. The systematic errors associated to this measurement have been discussed. Preliminary performance results obtained in the 7 TeV data have been shown from a small fraction of the total available data, and the statistics of strange particles reconstructed looks promising. This will give the possibility to investigate p_t spectra in a much wider range than what was possible at 900 GeV. These results will provide a robust baseline for heavy-ion studies that will start at the end of the year.

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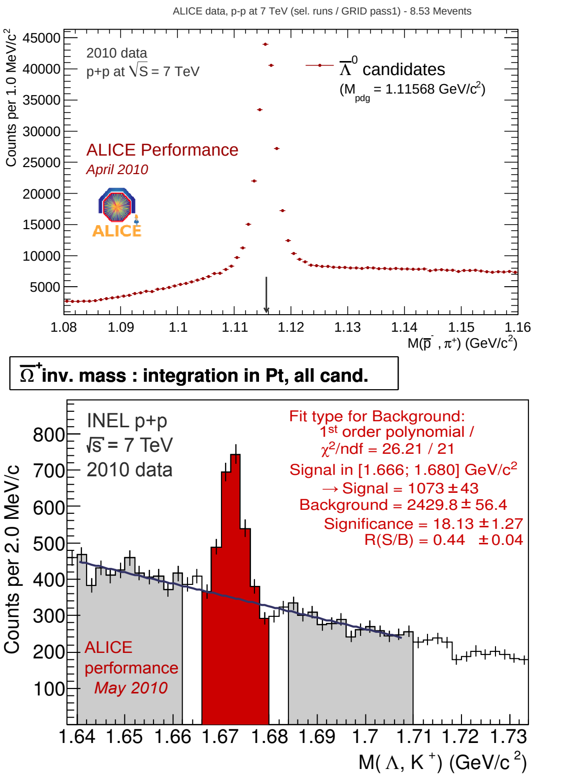

Figure 2. $\bar{\Lambda}$ and $\bar{\Omega}$ invariant mass spectra obtained for respectively 8.5M and 23.9M events in pp at $\sqrt{s}$ = 7 TeV.

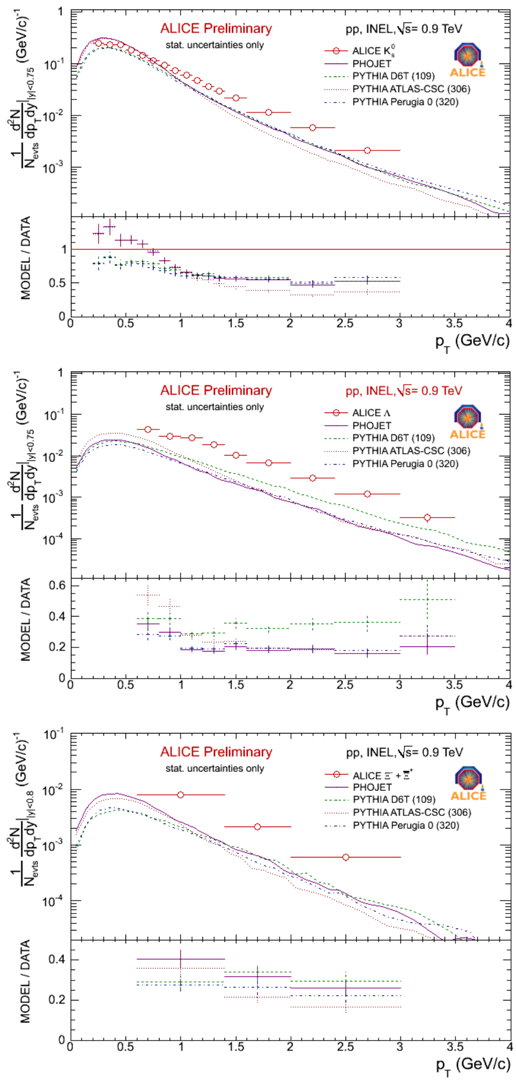

Figure 3. Comparison of K^0_S, Λ and $\Xi + \bar{\Xi}$ corrected p_t spectra with different models in pp at $\sqrt{s}$ = 900 GeV.