A Large Ion Collider Experiment

Istituto Nazionale di Fisica Nucleare

Università degli Studi di Salerno

Studies of Λ_c production in pp and p-Pb collisions with ALICE at the LHC

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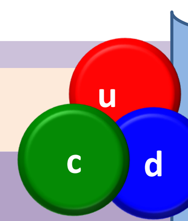


Λ_c is the lightest open charm baryon:
Mass ~ 2286.46 MeV/c^2
cτ ~ 59.9 µm

Introduction

Why study Λ_c?

- **Charm** production is a sensitive probe of the **Quark-Gluon Plasma** (QGP), produced in ultra-relativistic heavy-ion collisions. Charm quarks produced in hard parton scattering processes in the early stages of the collision, traverse the QCD medium, interact with its constituents and experience the whole evolution of the medium.
- Together with charmed mesons, the measurement of Λ_c in Pb-Pb collisions could give an insight into the hadronization mechanisms in the QGP, measuring the **baryon over meson ratio** in the heavy-quark sector [1].

Λ_c in pp collisions

- Useful test for perturbative Quantum Chromo Dynamics (pQCD)
- Evaluate the baryon contribution to the total cross section of charm production at the LHC with ALICE.
- Existing Λ_c measurements in pp collisions are in a different energy [2] or kinematic regime [3].
- Reference for Pb-Pb collisions.

Λ_c in p-Pb collisions

- Reference for Pb-Pb collisions.
- Study of cold nuclear matter effects not due to the QGP formation, such as nuclear modification of the Parton Distribution Functions (PDF), k_T broadening or energy loss.

Λ_c decay channels studied in ALICE

- **$\Lambda_c^+ \rightarrow pK^-\pi^+$ and charge conjugate (c.c.)**
  - non-resonant: B.R. = (3.8 ± 0.4)%
  - resonant: p K*(892): B.R. = (2.13 ± 0.30)%
  - Λ(1232)$^{++}$ K$^-$: B.R. = (0.86 ± 0.30)%
  - Λ(1520) π$^+$: B.R. = (2.4 ± 0.6)%
  - B.R. tot = $(6.84\ ^{+0.32}_{-0.40})$%
- **$\Lambda_c \rightarrow p\overline{K}^0$ and c.c.**
  - ↳ K^0_S (50%)
  - ↳ $\pi^+\pi^-$: B.R.= (69.20 ± 0.05)%
  - B.R. tot = (1.11±0.10)%
- **$\Lambda_c \rightarrow e^+\Lambda\nu_e$ and c. c**
  - recently started, very promising study.
  - B.R. tot = (2.9±0.5)%

ALICE detectors essential for this analysis

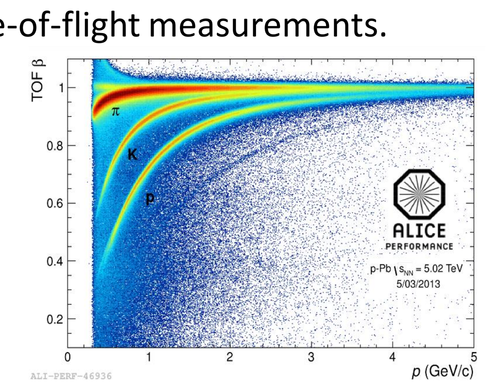
Inner Tracking System (ITS)

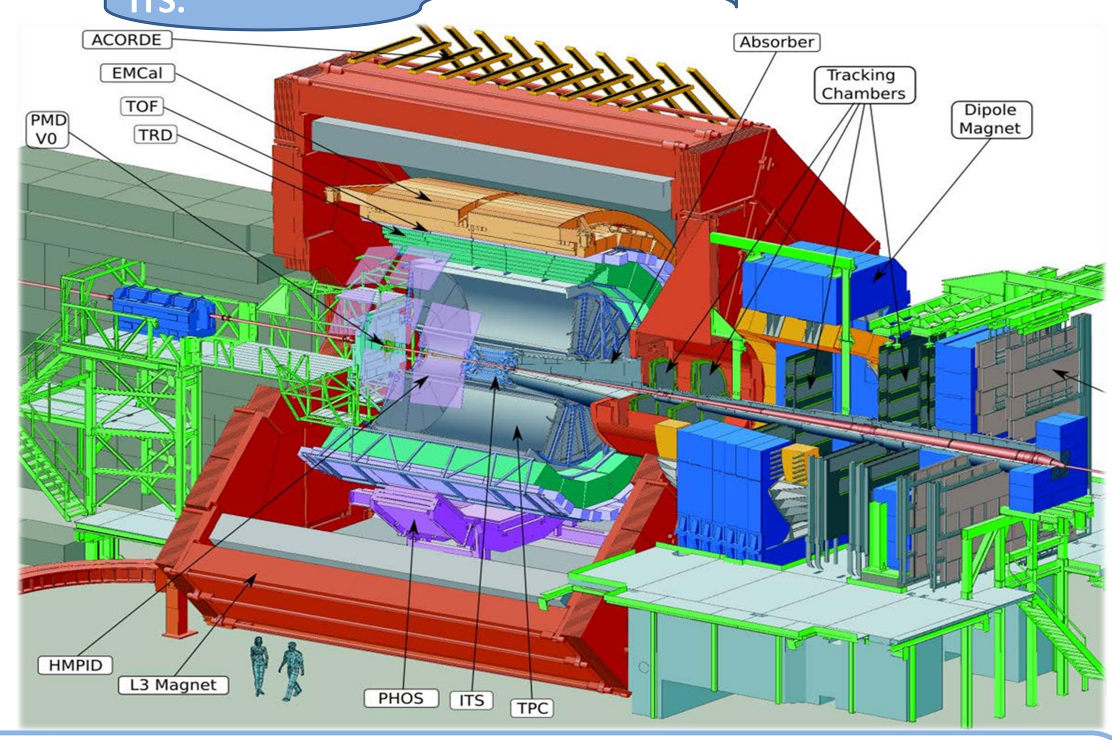
- Reconstruction of primary and secondary vertex.

Λ_c measurement in Pb-Pb collisions is challenging with the impact parameter resolution of the current ITS.

Time Of Flight (TOF)

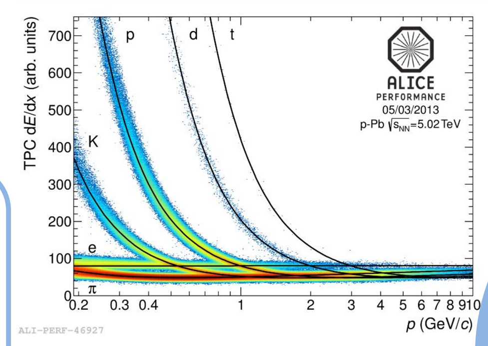
- Particle Identification (PID) of e, π, K, p with time-of-flight measurements.





Time Projection Chamber (TPC)

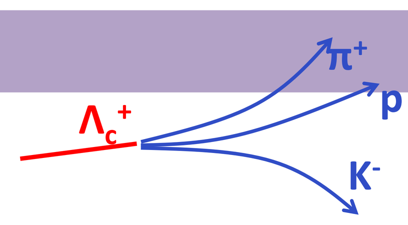
- Tracking
- Particle Identification (PID) of e, π, K and p with dE/dx measurements.



Data sample

- pp: ~ 3.0 x 10^8 minimum bias events analyzed at $\sqrt{s}$ = 7 TeV.
- p-Pb: ~ 1.0 x 108 minimum bias events analyzed at $\sqrt{s_{NN}}$ = 5.02 TeV.

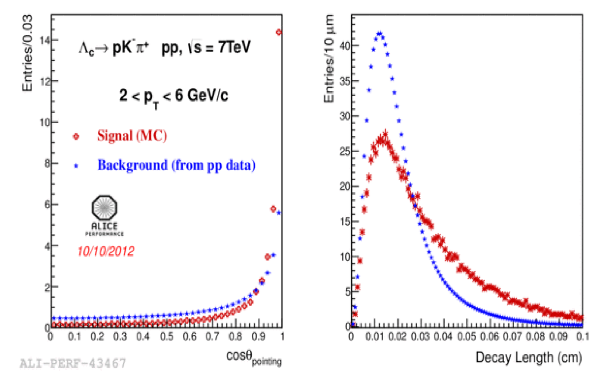
Reconstruction of $\Lambda_c \rightarrow pK\pi$



pKπ candidates building

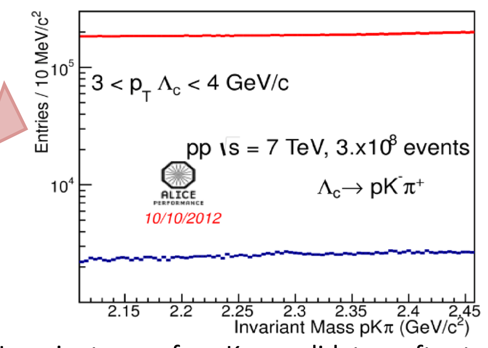
- Pairs of opposite charge tracks selected. Third track added to build a triplet and secondary vertex of the triplet estimated.

Cuts applied: high-quality single tracks cuts, cuts on daughter p_T, quality of reconstructed vertex, DCA (distance of closest approach between tracks), cosine of Λ_c pointing angle (angle between the Λ_c flight line and the momentum of the reconstructed Λ_c candidates), Particle Identification (PID).



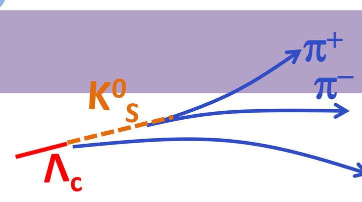
Particle Identification (PID)

- PID is essential to identify protons, kaons and pions.
- Detector used: TOF and TPC.
- Used approach: Bayesian PID (maximum probability criterion).
- Using PID the background is suppressed by a factor 100!



Invariant mass for pKπ candidates, after topological selection, with (in blue) and without (in red) Bayesian PID.

Reconstruction of $\Lambda_c \rightarrow pK^0_S$

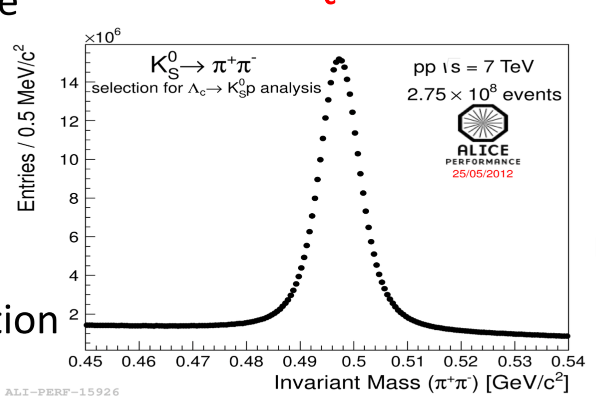


pK^0_S candidates building

- **K^0_S candidates** selected from pairs of opposite charge tracks forming a vertex displaced from the interaction vertex.

Cuts applied: high-quality single tracks cuts, DCA between tracks, radius of fiducial volume, cosine of V^0 pointing angle.

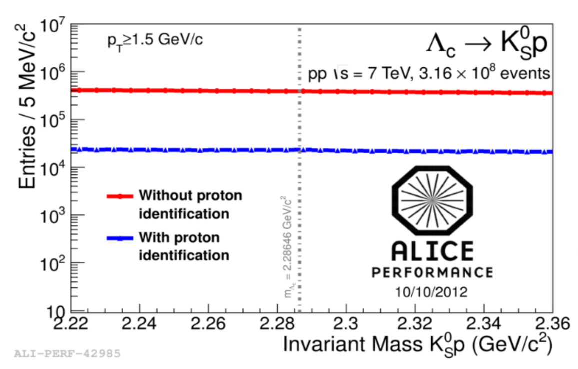
- **Proton candidates** selected according to track selection and PID, combined with selected K^0_S to build Λ_c candidates.



A clear K^0_S signal in $m_{inv}(\pi^+,\pi^-)$ limits the combinatorial background, despite the low B.R.

Particle Identification (PID)

- PID is essential to identify protons.
- Detector used: TOF and TPC.
- Used approach: number of sigma cuts and combined PID.
- Using PID, the background is suppressed by a factor 20!



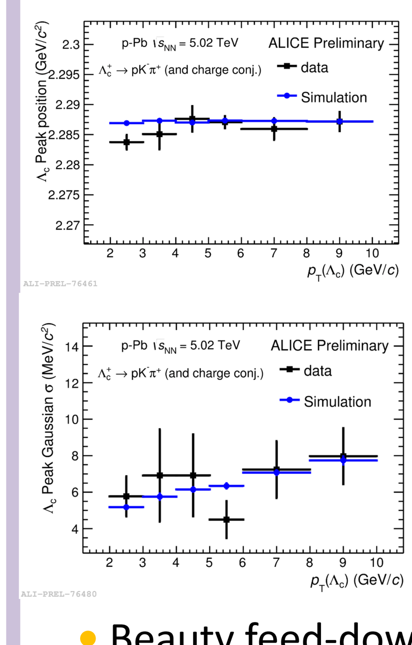
Invariant mass for pK^0_S candidates, after topological selection, with (in blue) and without (in red) PID.

In both analyses:

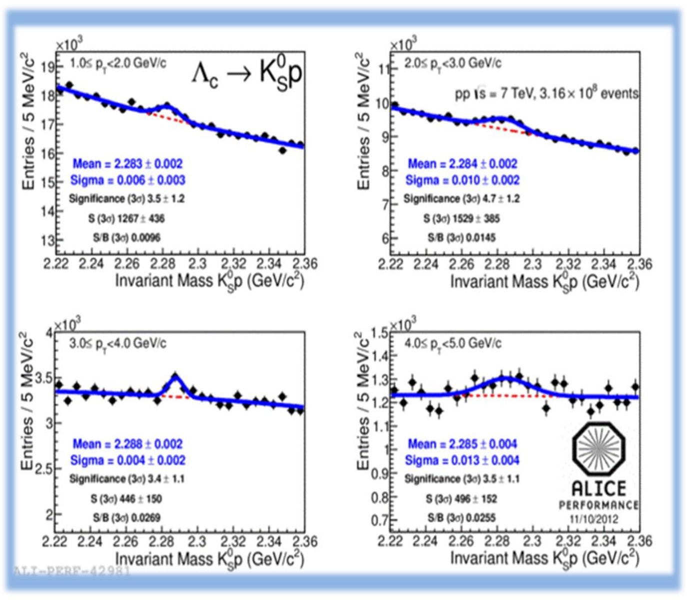
- Λ_c is reconstructed in a wide momentum range.
- A good agreement with Monte Carlo expectations is observed.

Signal extraction, after further selection:

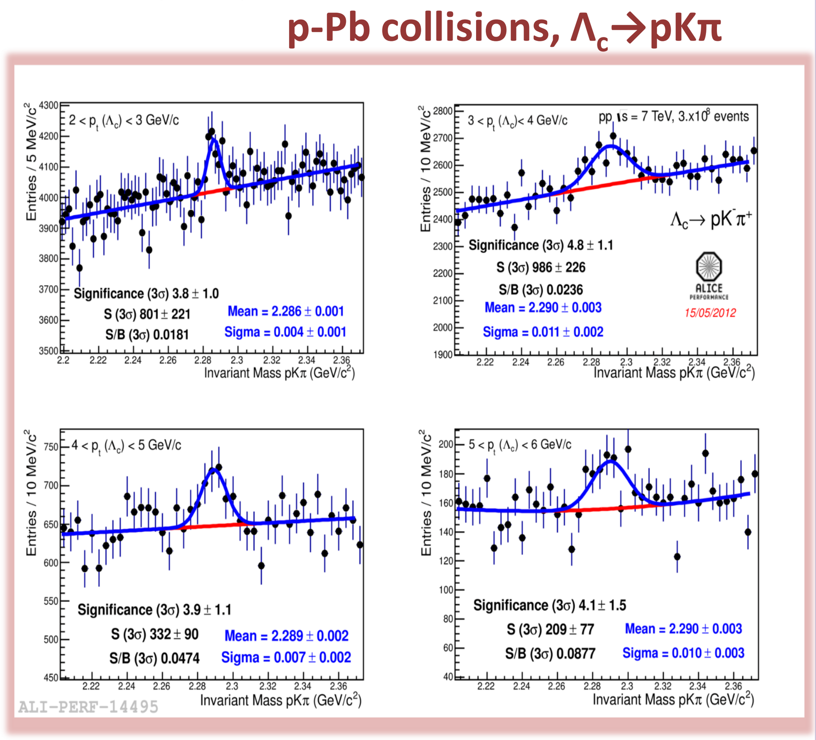
- Standard topological cuts on variables offering good S/B separation.
- Cut on multivariate discriminator (BDT) [4].



pp collisions, $\Lambda_c \rightarrow pK^0_S$



p-Pb collisions, $\Lambda_c \rightarrow pK\pi$



The analyses are ongoing:

- Beauty feed-down fraction estimated with two methods, using measured yield and expected Λ_b from theoretical calculations (FONLL predictions [5]).
- Efficiency and acceptance corrections estimated using Monte Carlo simulations.
- Systematic uncertainty determination.

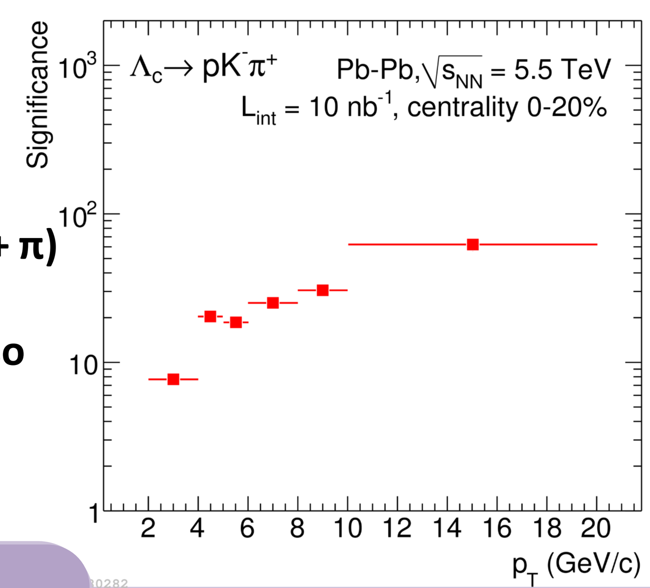
Final target: First measurement of Λ_c cross sections in pp and p-Pb collisions at mid rapidity at the LHC energies with ALICE!

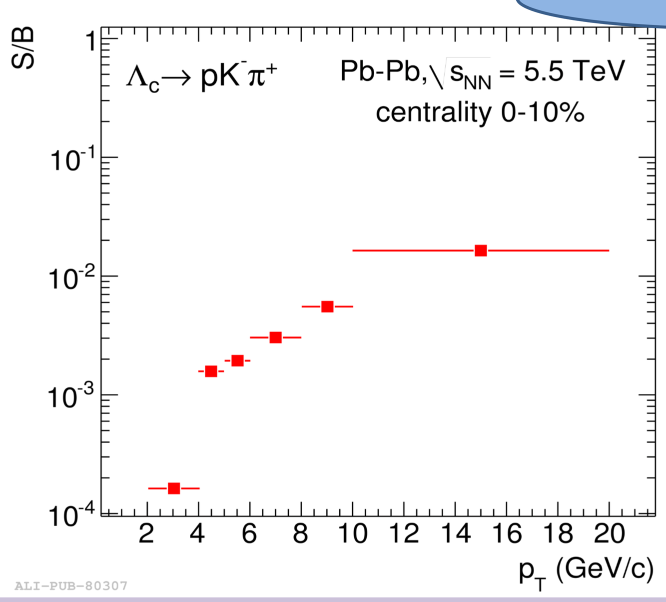
Perspectives for feature measurements

Main goals of the ALICE ITS Upgrade [6] after the second LHC long shutdown (2019-2020) :

- Improve impact parameter resolution by a factor of ~3
- Improve tracking efficiency and p_T resolution at low p_T
- Record data with higher rate

- **Charmed baryons Λ_c (as well as beauty baryons Λ_b via the decay $\Lambda_b \rightarrow \Lambda_c + \pi$) will be accessible for the first time**
- **Baryon/meson ratios (Λ_c/D), and elliptic flow of charmed baryons will also be accessible**





- **Full kinematics reconstruction**
- **Down to p_T~2 GeV/c!**
- **Statistical precision ~12%**
- **Systematics ~30% (feed-down mainly)**

References

[1] Yasui, S. et al. Indian J.Phys. 85 (2011) 1043-1046.
[2] G. Bani et al., Il Nuovo Cimento, vol. 104 A (1991).
[3] LHCb-PAPER-2012-041.
[4] A. Hoecker, P. Speckmayer, J. Stelzer, J. Therhaag, E. von Toerne, and H. Voss, TMVA - Toolkit for Multivariate Data Analysis, PoS ACAT 040 (2007), arXiv:physics/0703039.
[5] M. Cacciari et al., Journal of High Energy Physics October 2012, 2012:137.
[6] B. Abelev et al (The ALICE Collaboration), J. Phys. G41 (2014) 087002.