Measurement of Λ_c^+ baryon production in p-Pb collisions with ALICE at the LHC

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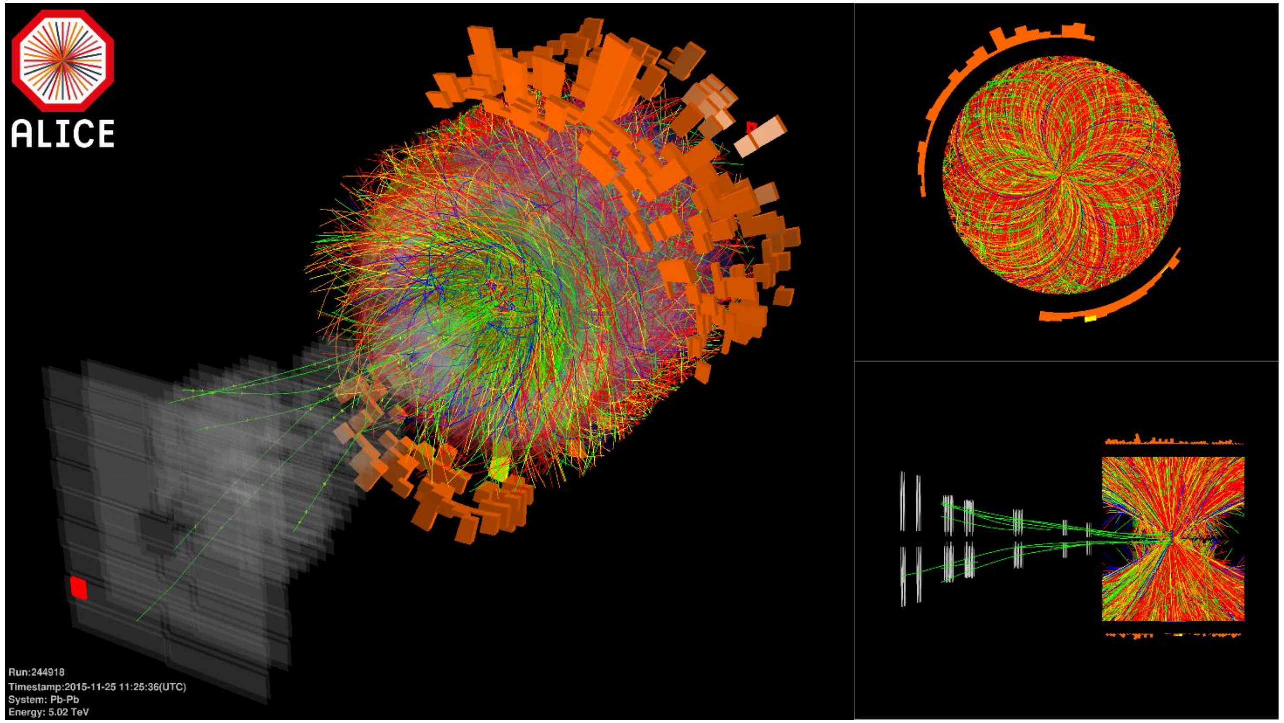
Physics Motivation

- ALICE is optimised to detect products of heavy-ion collisions at ultra-relativistic energies.
- These collisions provide the best experimental conditions to produce the Quark-Gluon Plasma (QGP).
- By observing the particle distribution/production QGP properties can be probed.

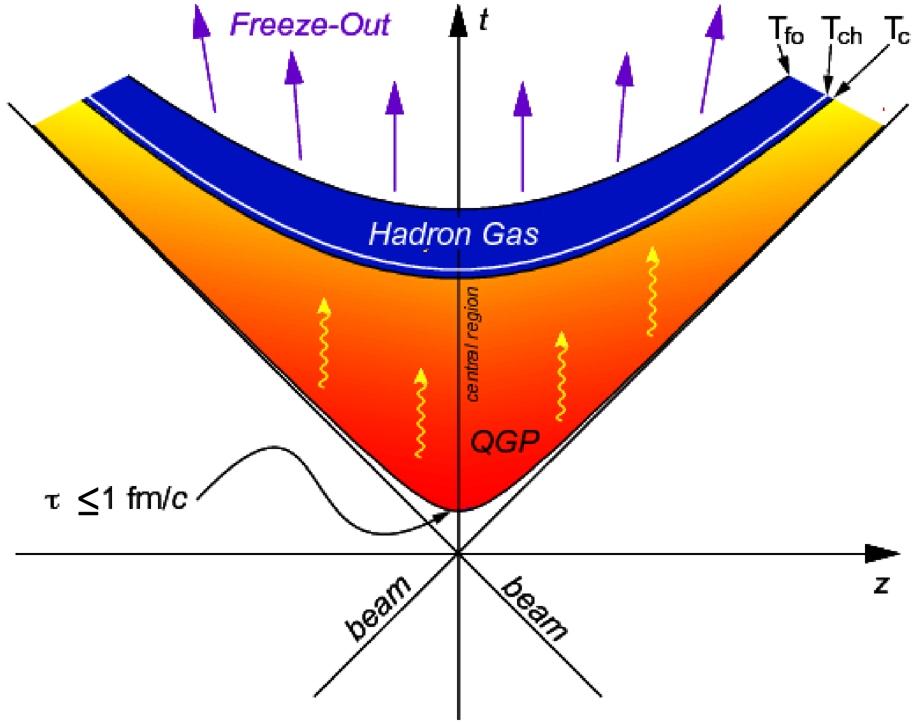


Event display for a 5.02TeV Pb-Pb collision from 2015

Physics Motivation

Why look at heavy-flavour particles in these heavy-ion collisions?

- Heavy quarks (c,b) are produced primarily in hard scatterings at the early stages of the collisions and experience the entire evolution of the QGP.
- Heavy quarks are unlikely to be produced thermally by the QGP.
- Propagation of these quarks through the medium can provide quantitative information on energy loss, transport and hadronisation processes.



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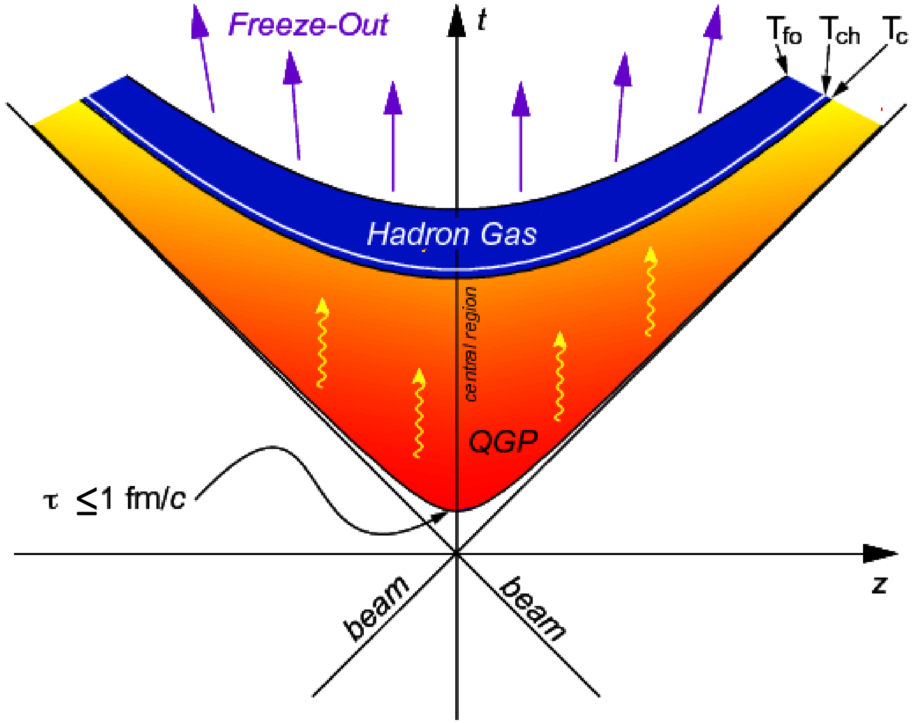

What about smaller systems?

- p-Pb
- pp

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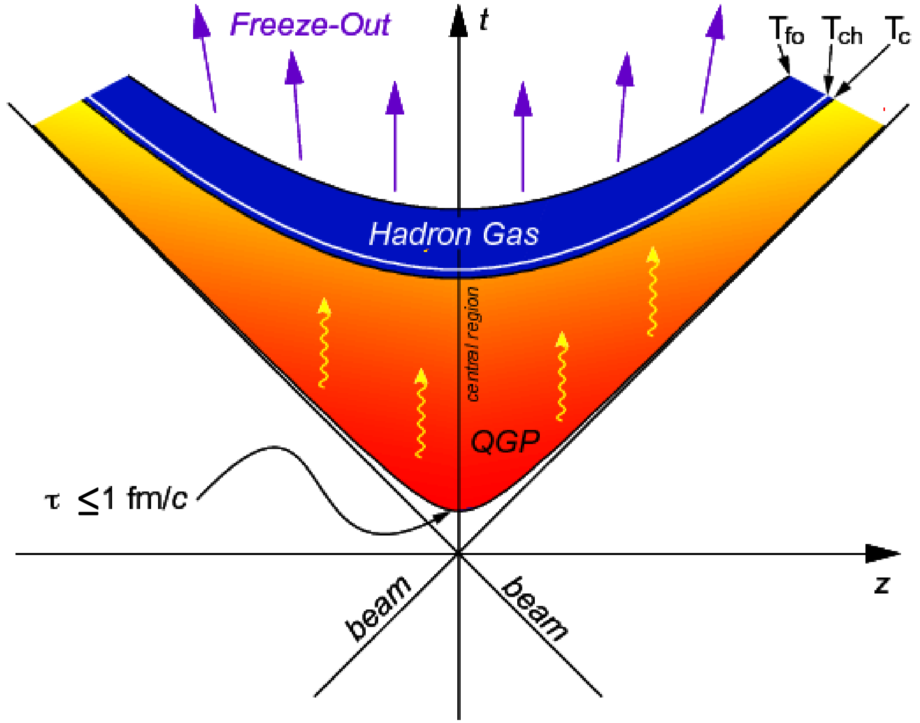

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p-Pb collisions

- Traditionally used to disentangle ‘hot’ and ‘cold’ effects.
- Collective effects in small systems?

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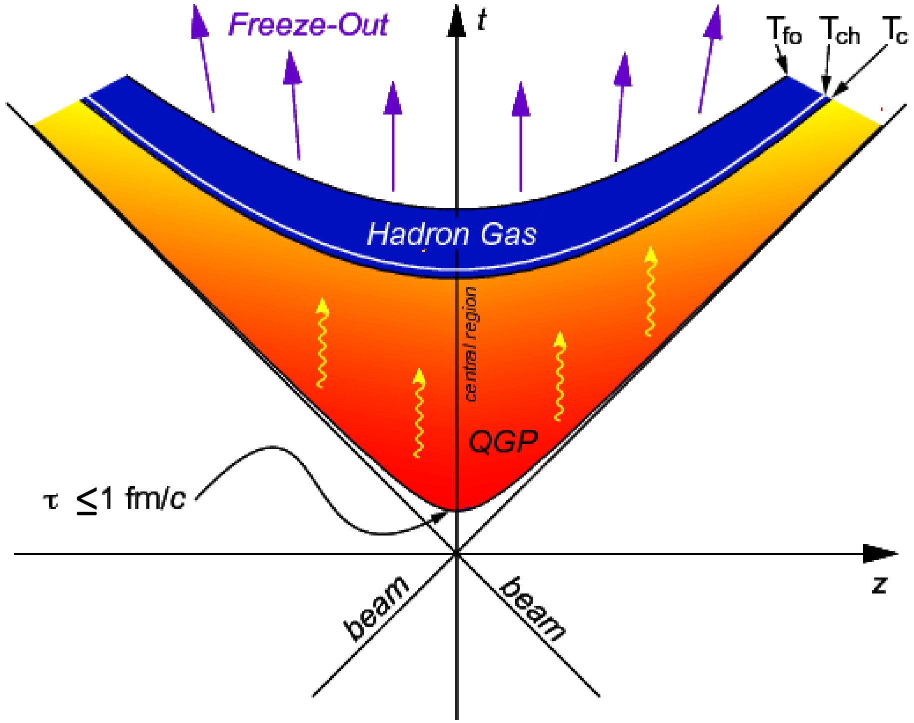

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pp collisions

- Test pQCD predictions
- Reference to larger systems

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- Not many measurements available for charmed baryons (Λ_c^+) especially at LHC energies.
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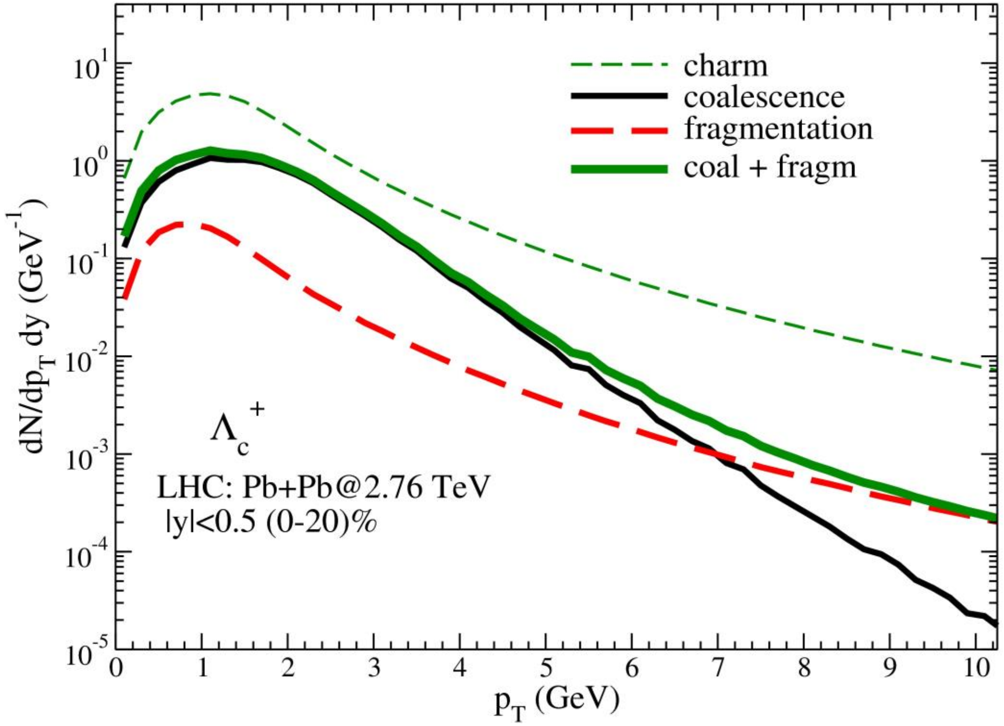

Plumari et al.: Eur. Phys. J. C (2018) 78: 348.

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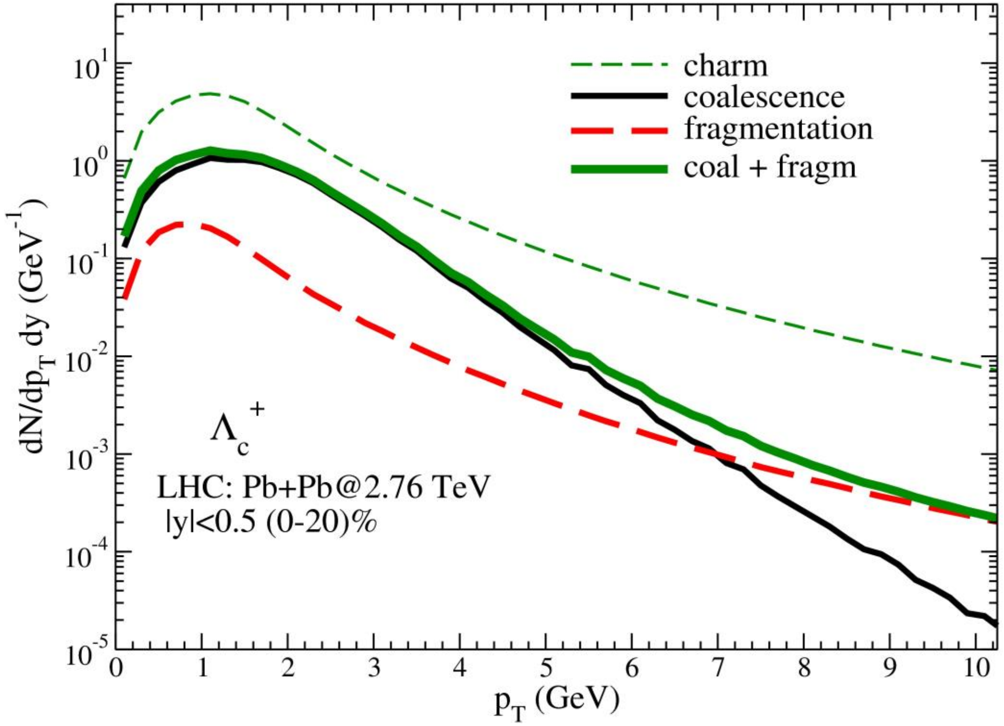
2. Recombination [2]



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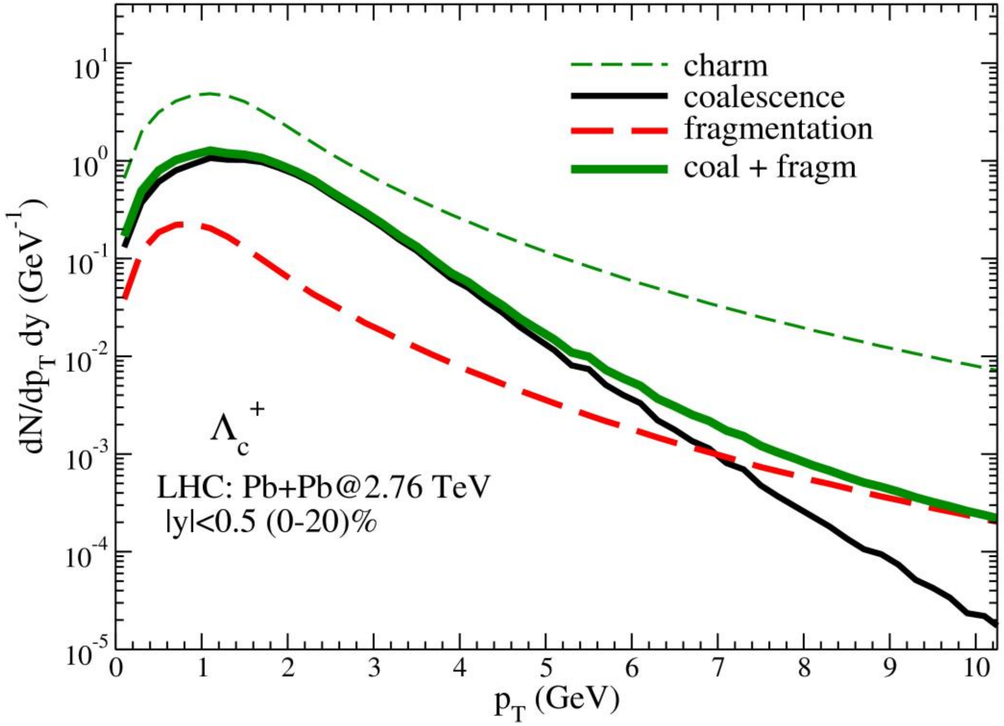

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- Quarks created from the QCD vacuum.
- Indicated by a low b/m ratio.

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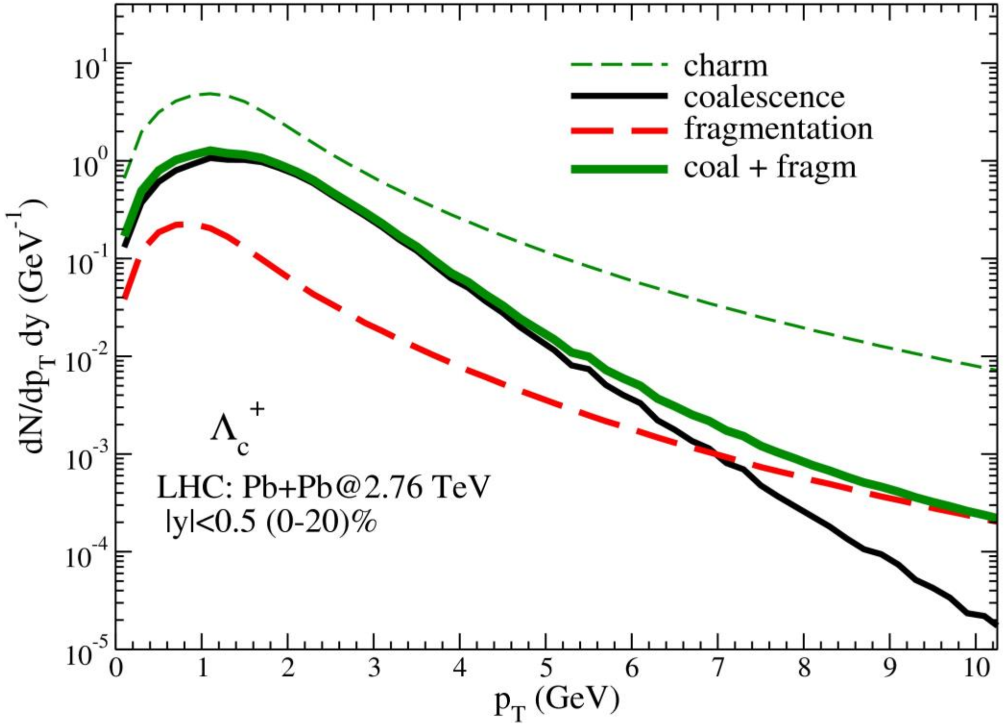

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Fragmentation:

- Quarks created from the QCD vacuum.
- Indicated by a low b/m ratio.

Recombination:

- Quarks in similar phase space combine into a hadron
- Indicated by a high b/m ratio
- Further enhancement with diquarks.

References:
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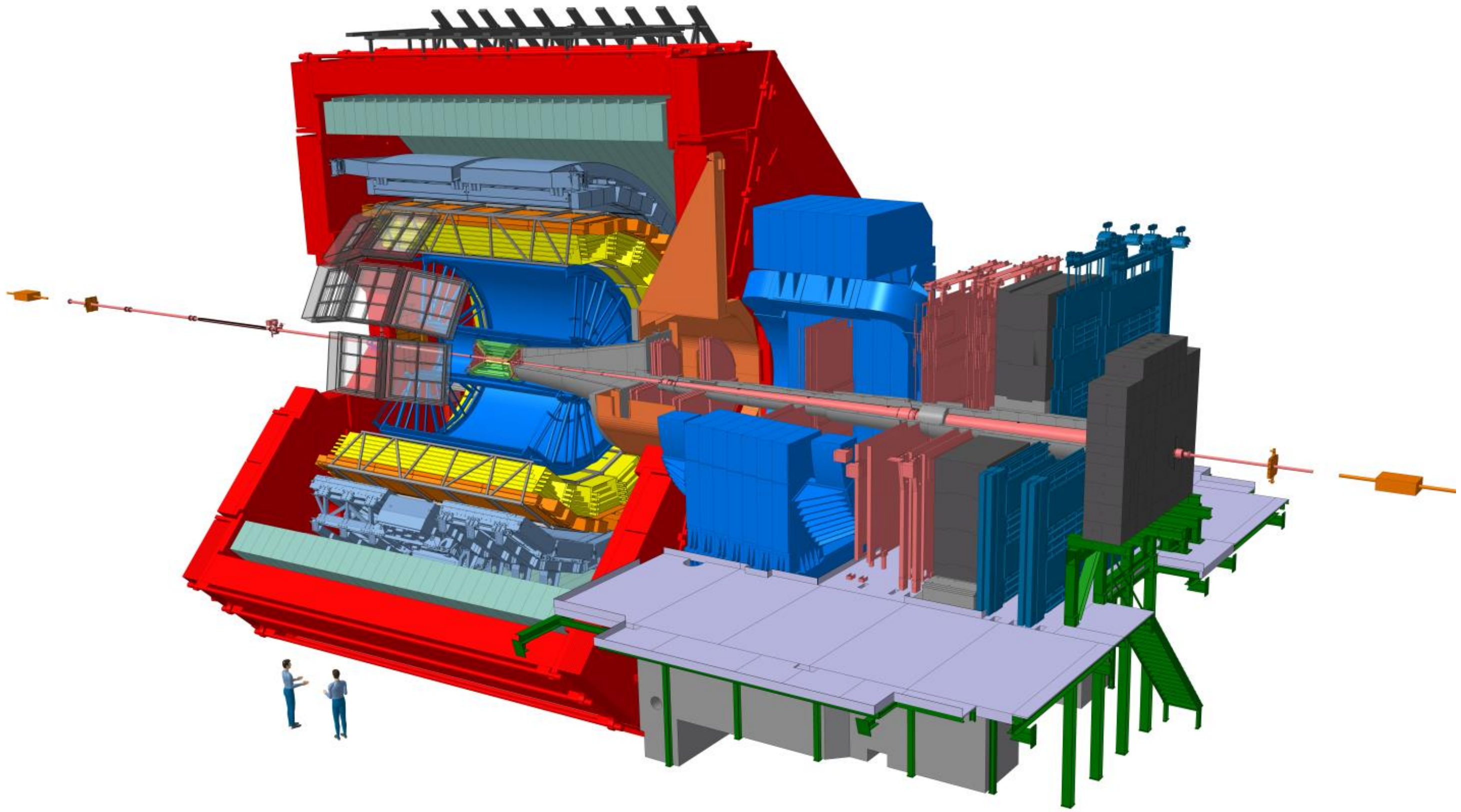
Measurement of Λ_c^+ baryon in p-Pb

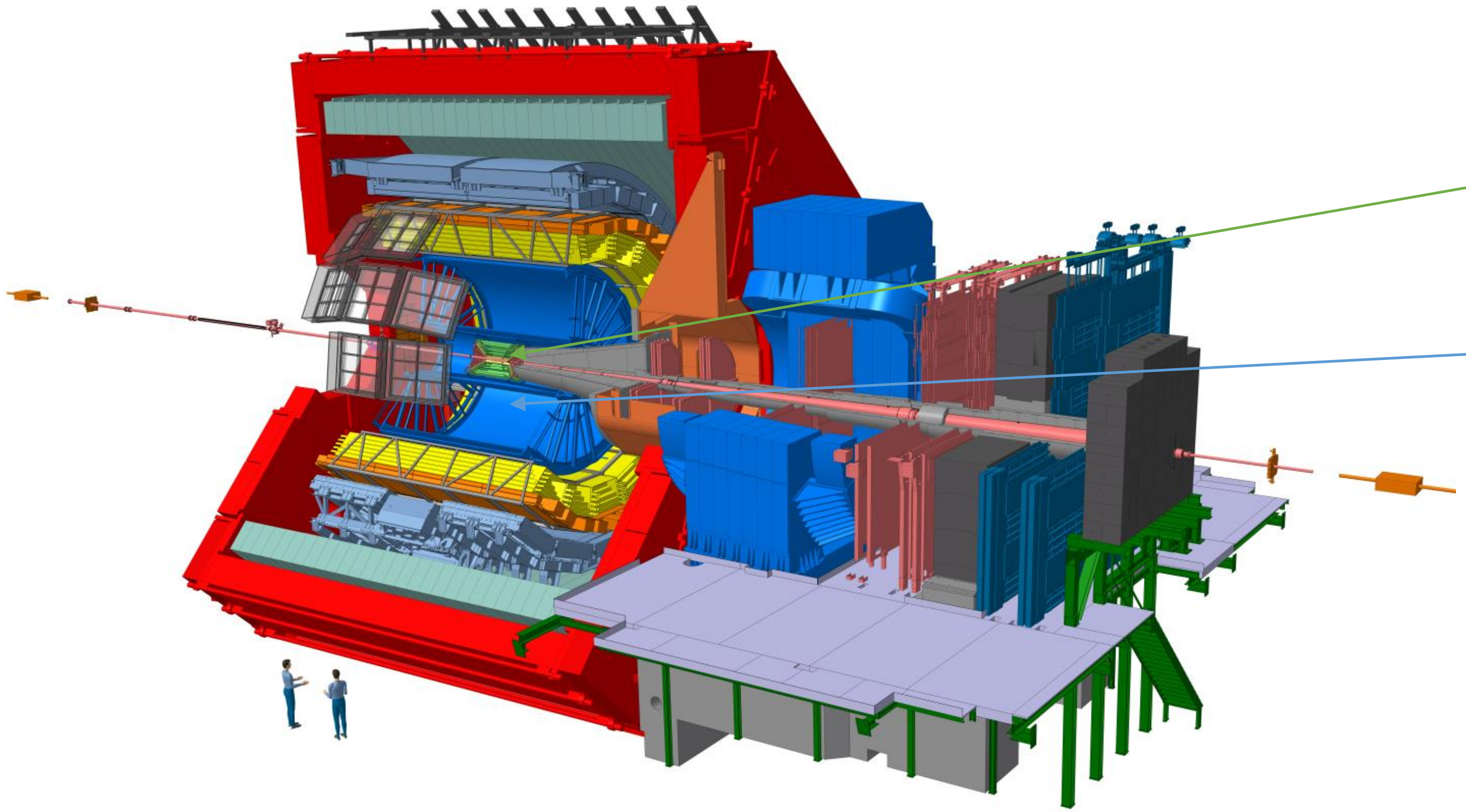


- Here we will look primarily at the Run 2 analysis for the $\Lambda_C^+ \rightarrow pK^-\pi^+$ decay channel with standard cuts.

- This was combined with the $\Lambda_C^+ \rightarrow pK^0_s$ channel performed with standard cuts and MVA.

- Six times the statistics of Run 1, the aim is to extend the p_T range covered and cross-check the measurements from Run1.

Reconstructing the Λ_c



Track reconstruction is provided by Inner Tracking System (ITS) and Time Projection Chamber (TPC).

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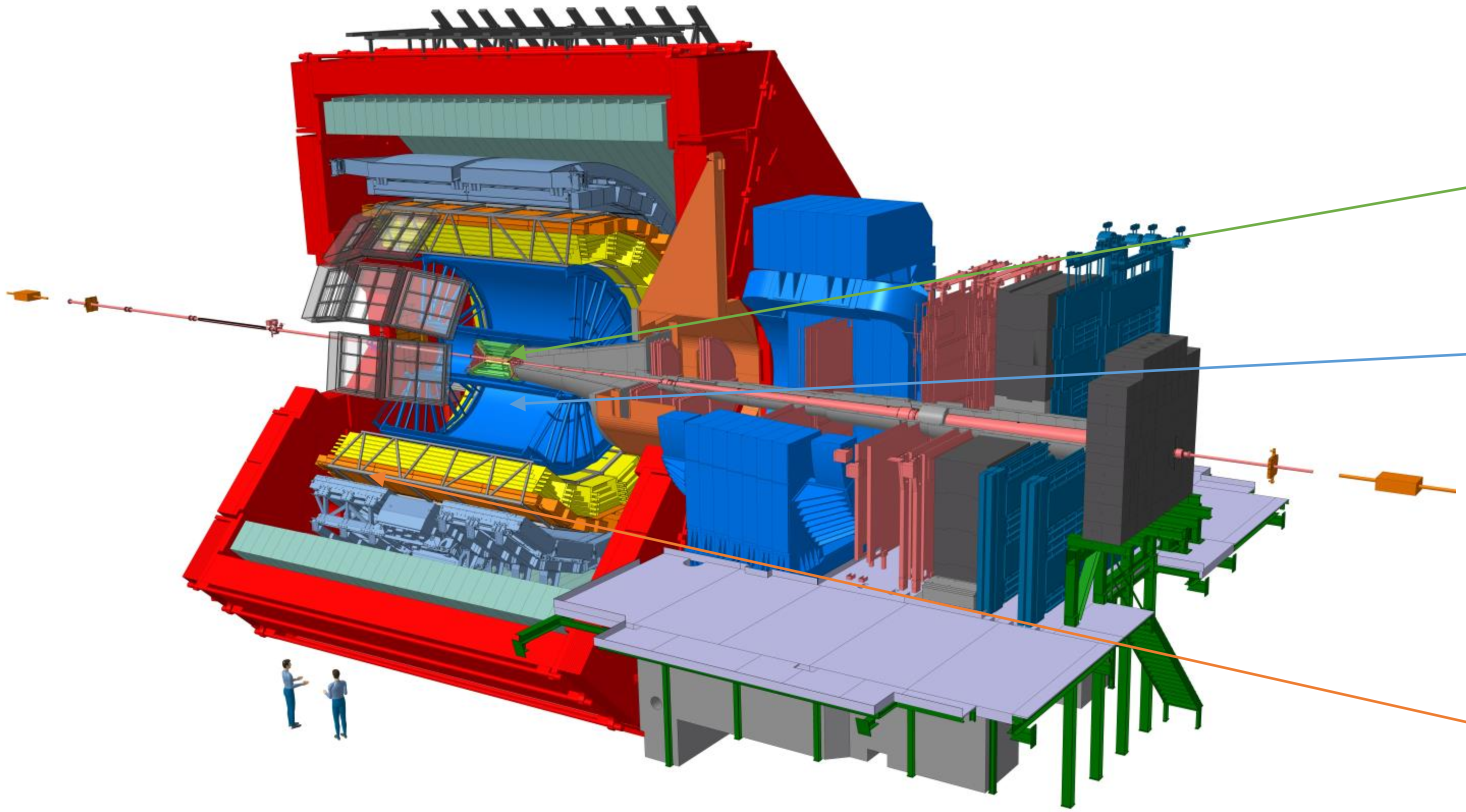
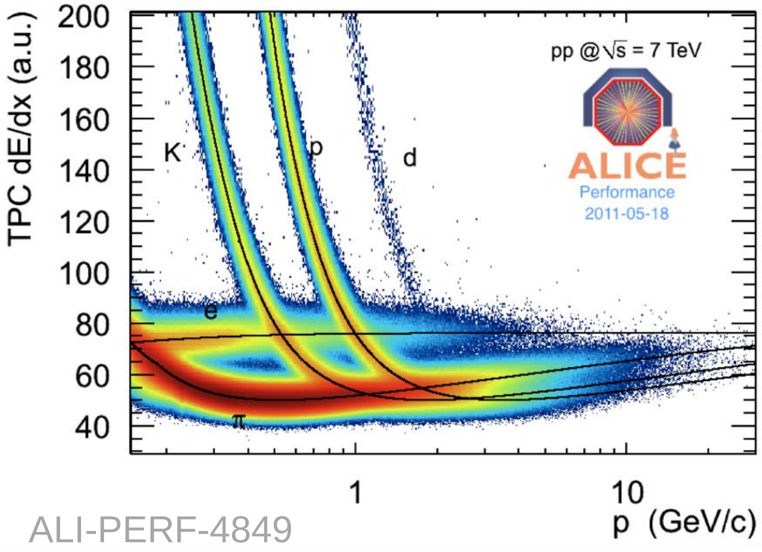


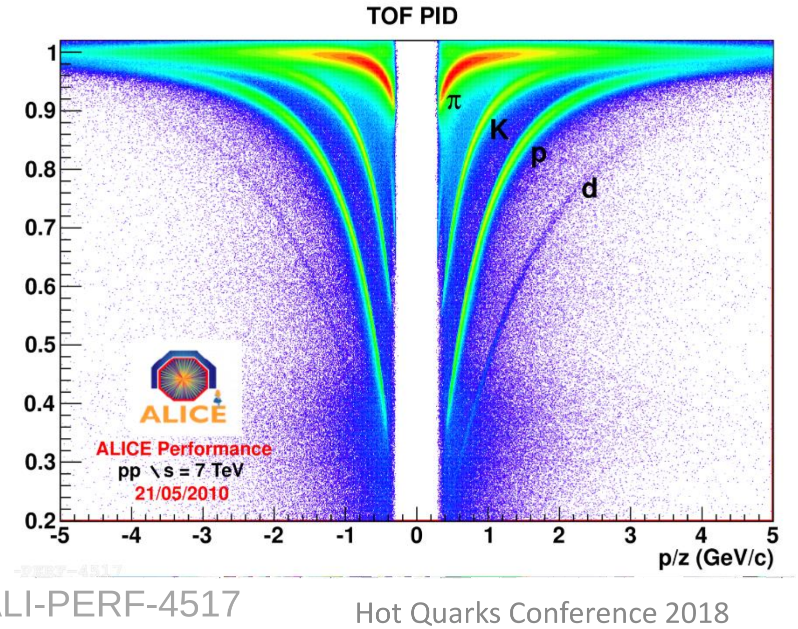
Track reconstruction is provided by Inner Tracking System (ITS) and Time Projection Chamber (TPC).

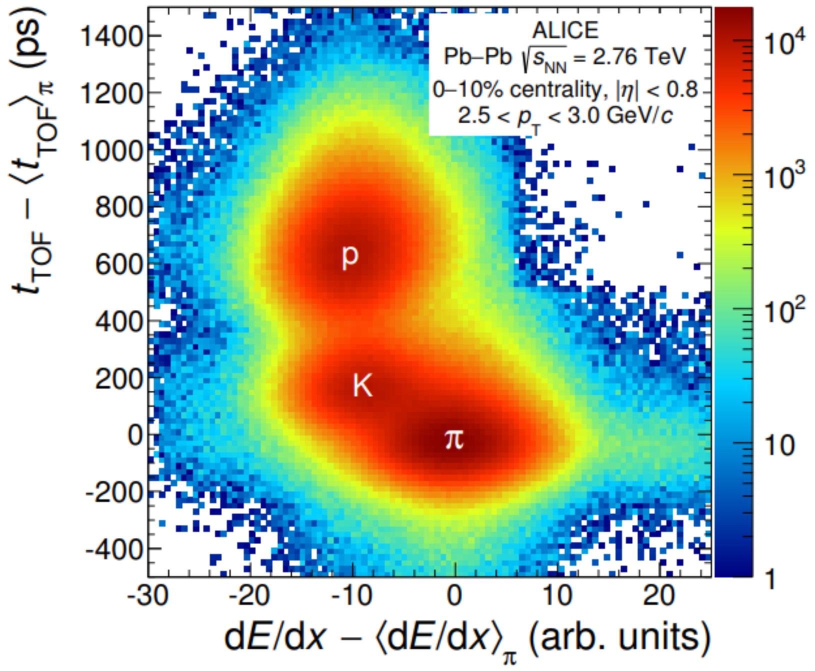
PID provided by d*E*/dx measurements by the TPC and time of flight measurements by the Time-of-Flight (TOF) detector.

Particle Identification



Background is reduced by use of Bayesian Particle Identification with maximum probability criteria.





Eur. Phys. J. Plus 131 (2016) 168

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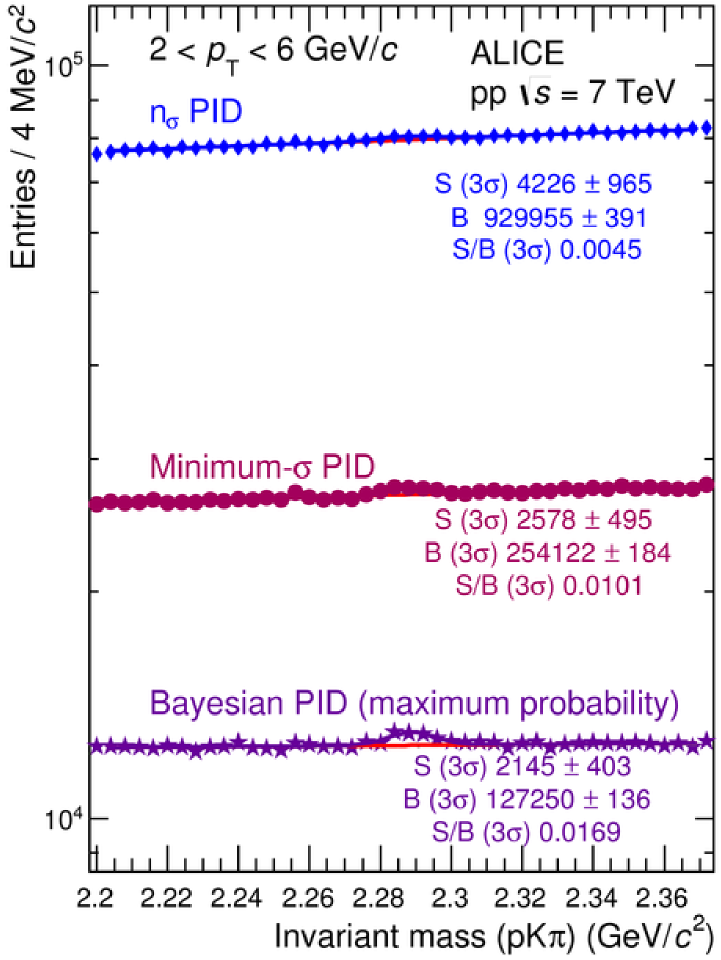

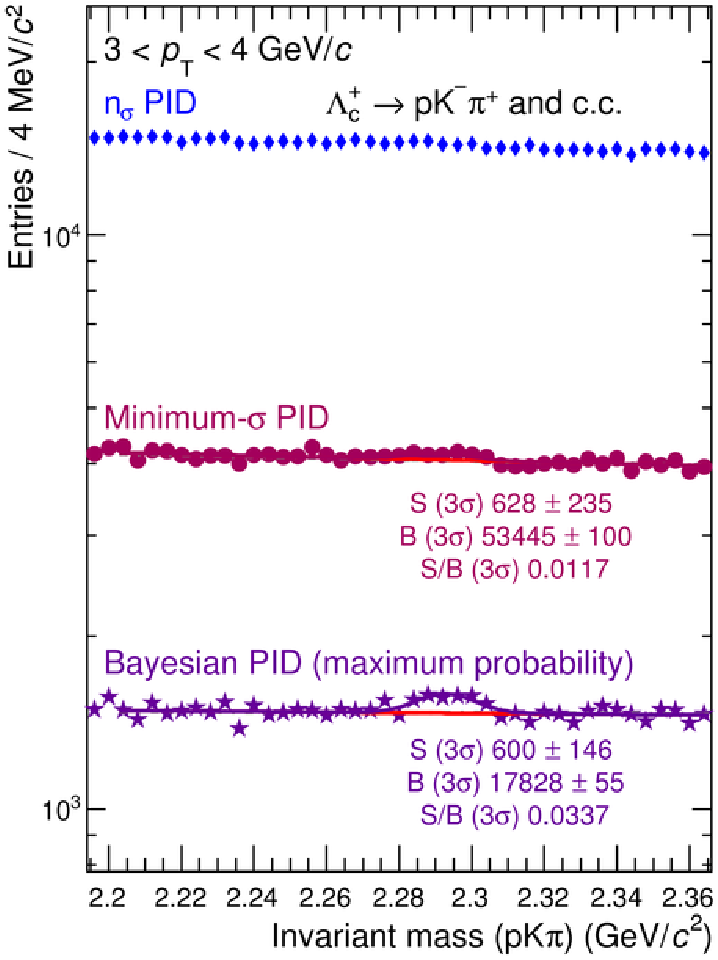

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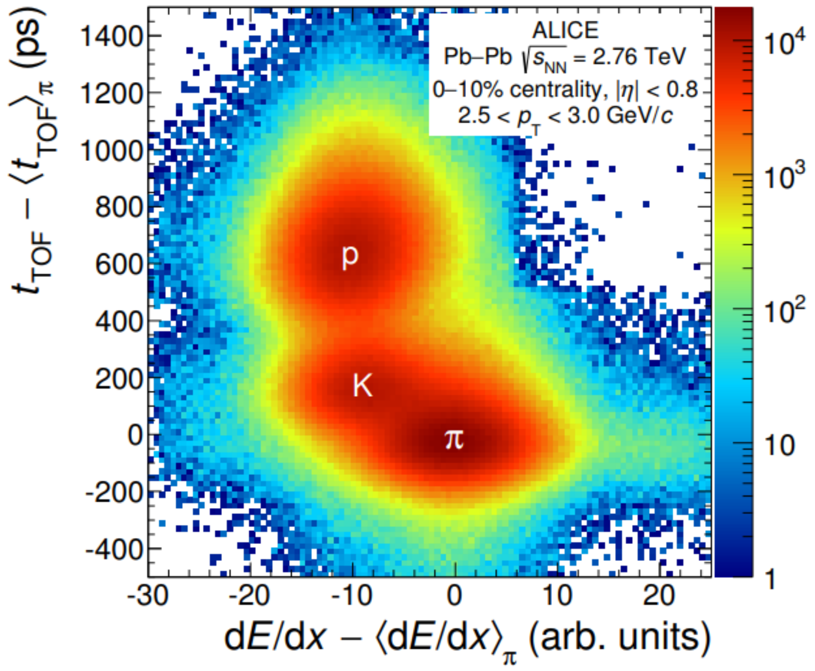
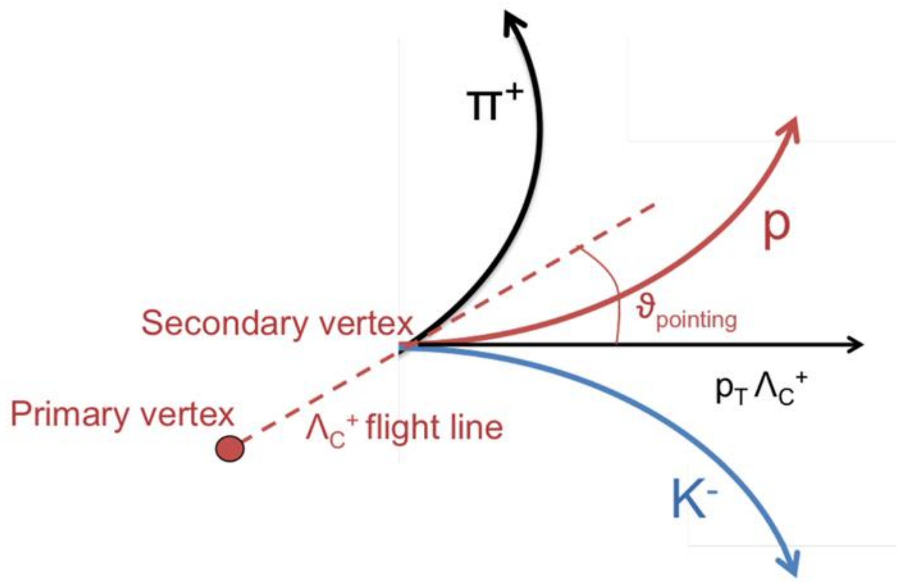


Plots from Eur. Phys. J. Plus 131 (2016) 168

Topological cuts

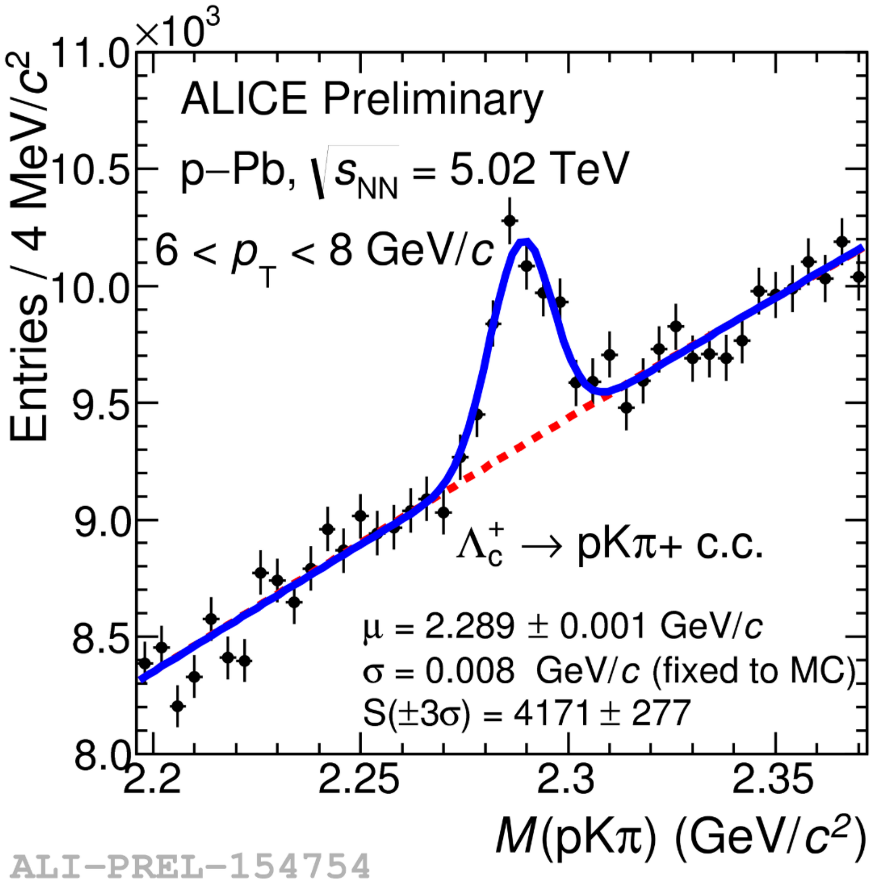
Features of the decay topology are used to further reduce background. Such as:

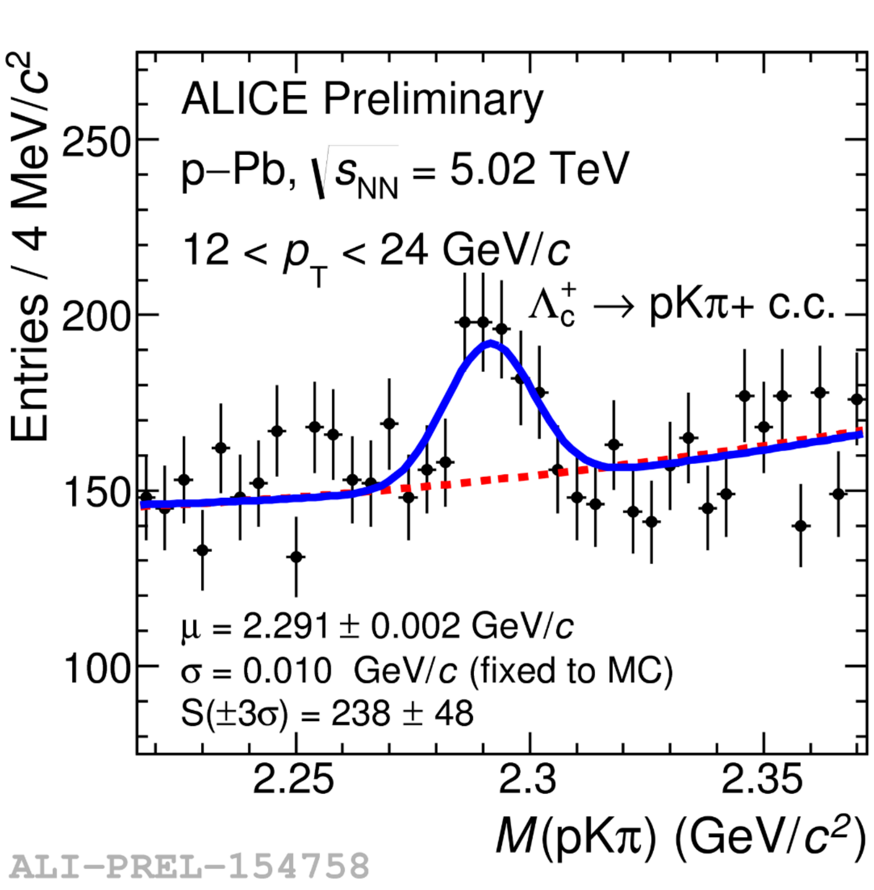
- Decay Length
- Cos$\theta_{pointing}$
- Decay product transverse momenta



Cuts are optimised using simulated background and signal events from Monte Carlo.

Signal extraction





Raw Yield is extracted by p_T binned Inv. Mass plots

p_T range extended for Run2 with 12-24 GeV/c

Cross section

The fraction of Λ_c from charm quarks

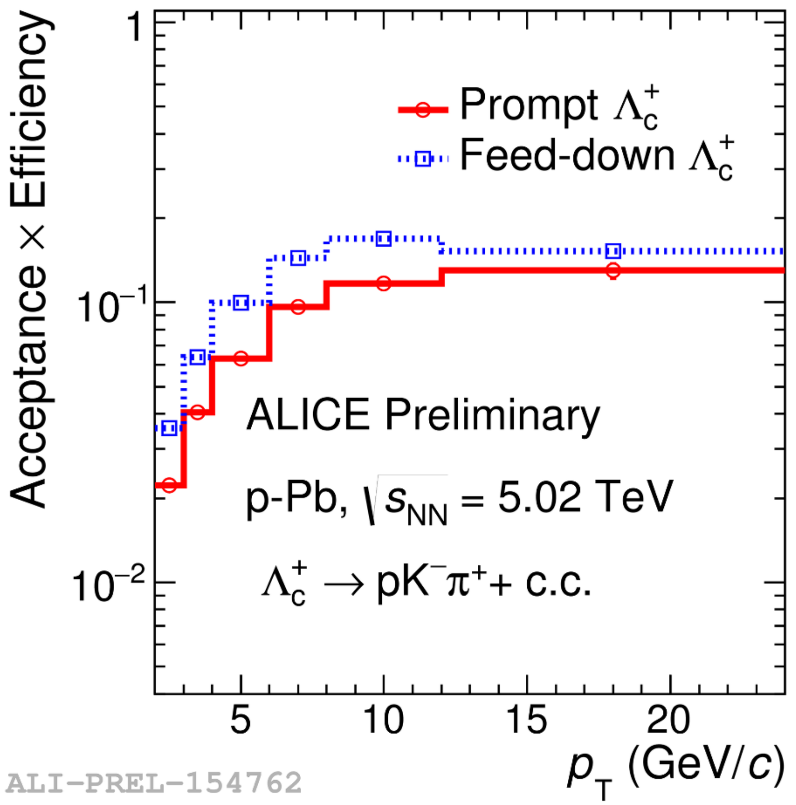
The measured yield extracted from the invariant mass plots

$$\frac{d\sigma^{\Lambda_c^+}}{dp_T}\Big|_{y_{lab}<0.5} = \frac{1}{2}\frac{1}{\Delta p_T}\frac{f_{prompt}(p_T)\cdot N_{raw}^{\Lambda_c^\pm}(p_T)\big|_{y_{lab}<y_{fid}(p_T)}}{\alpha_y (Acc x \varepsilon)_{prompt}(p_T)\cdot BR\cdot \mathscr{L}_{int}}$$

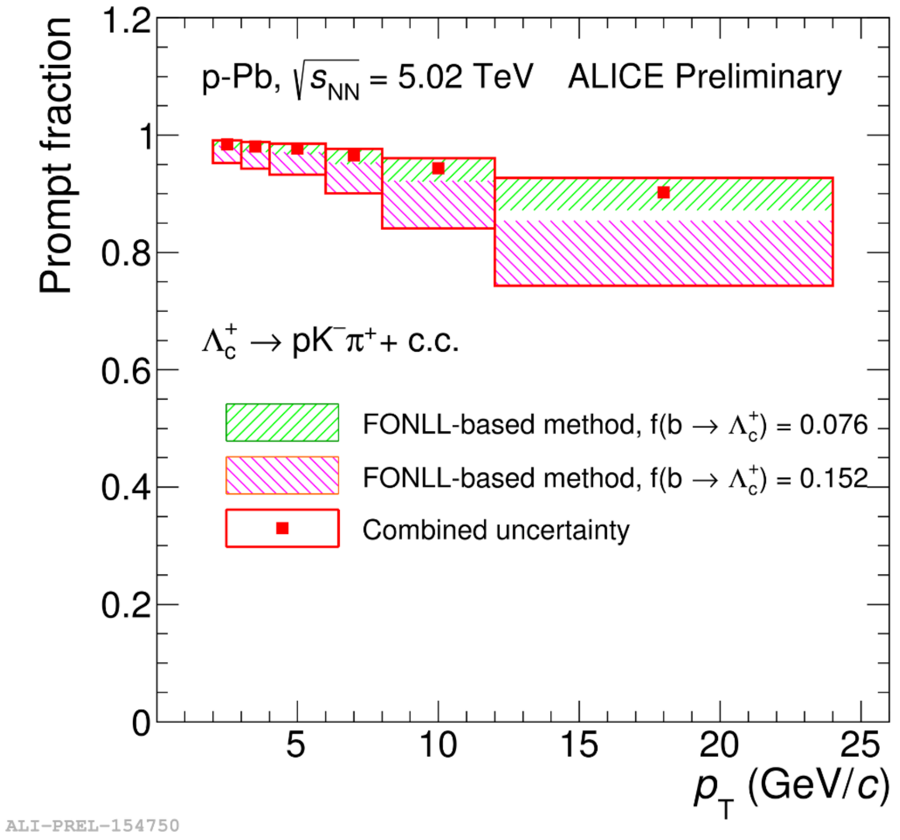
Efficiency and Acceptance factors

Corrections

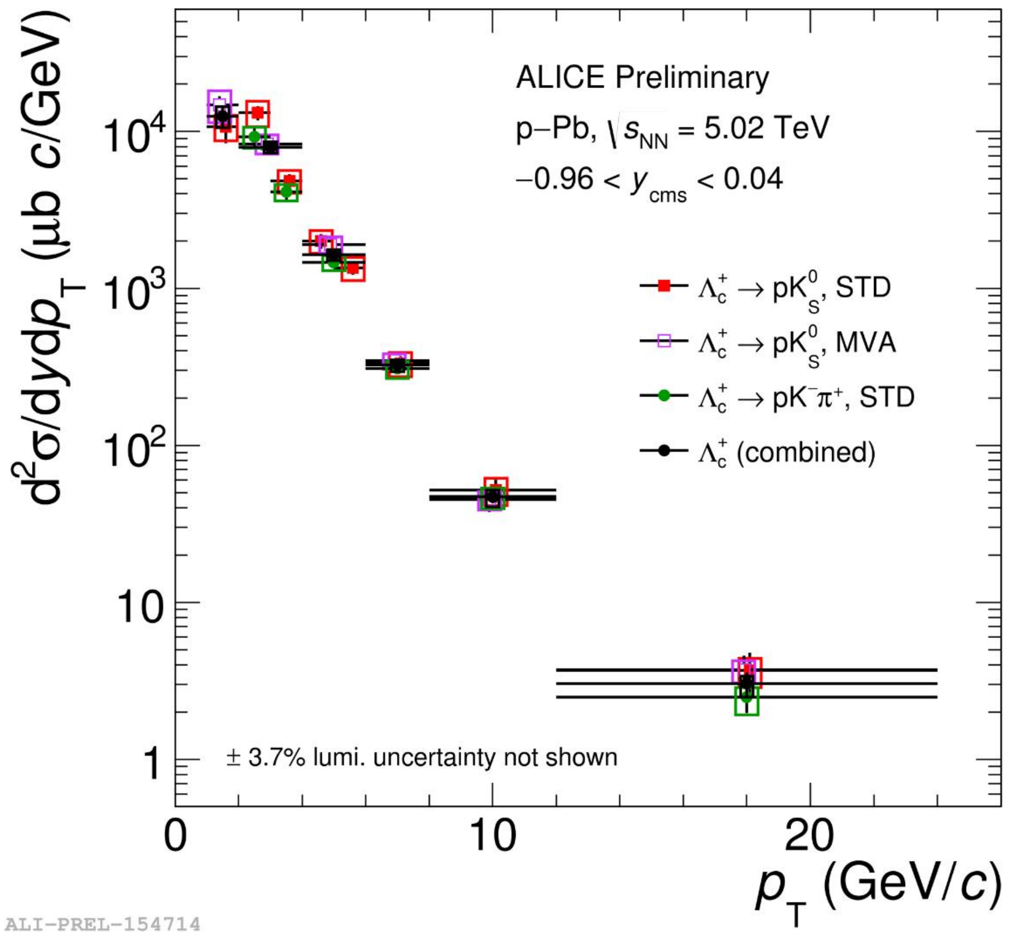
- The measured Λ_c^+ yield must be corrected to take into account both the efficiency and acceptance of the detector.
- This is done with the use of a Monte Carlo after applying reconstruction, PID and topological selections

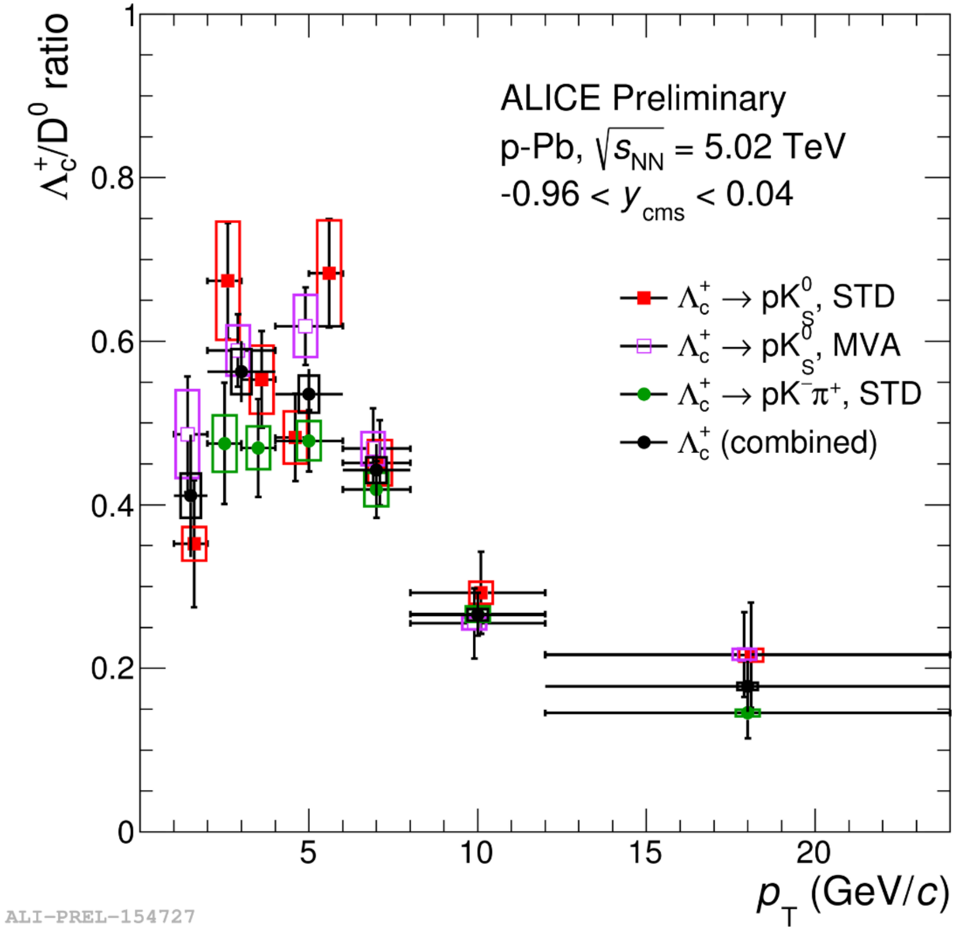


- Contribution by Λ_c^+ from decays of heavier beauty hadrons is also subtracted.
- This is estimated by calculations made in perturbative QCD



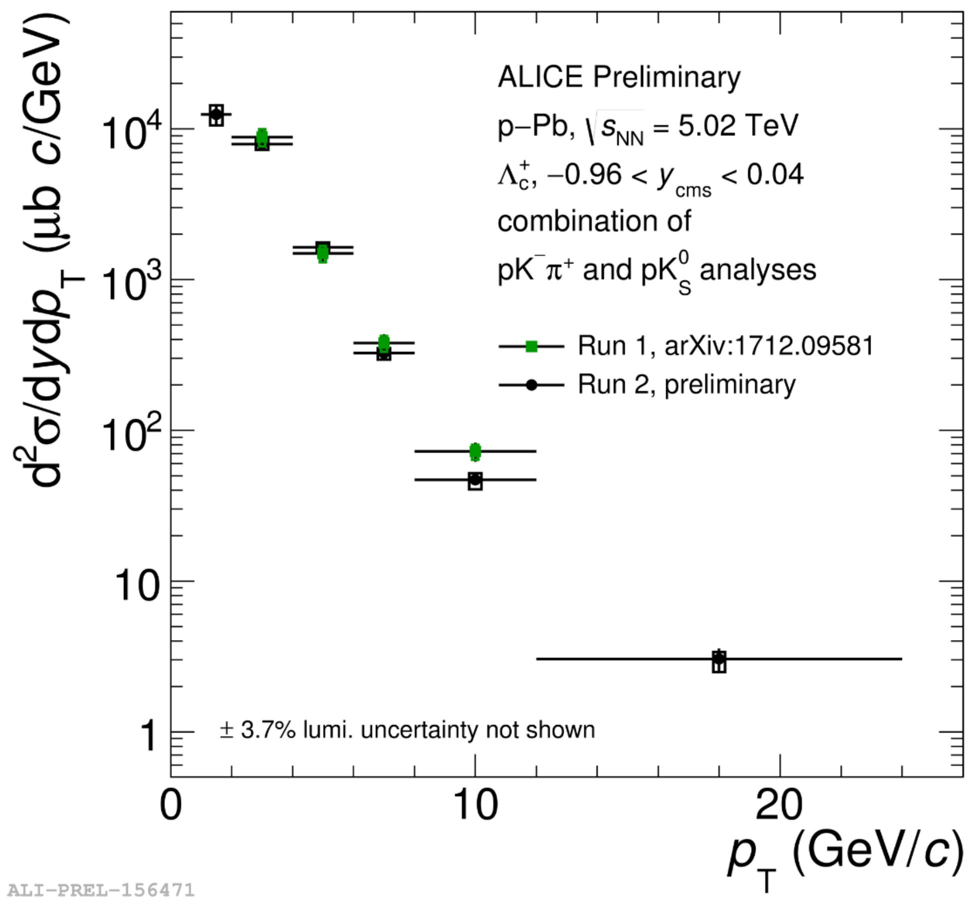
Results

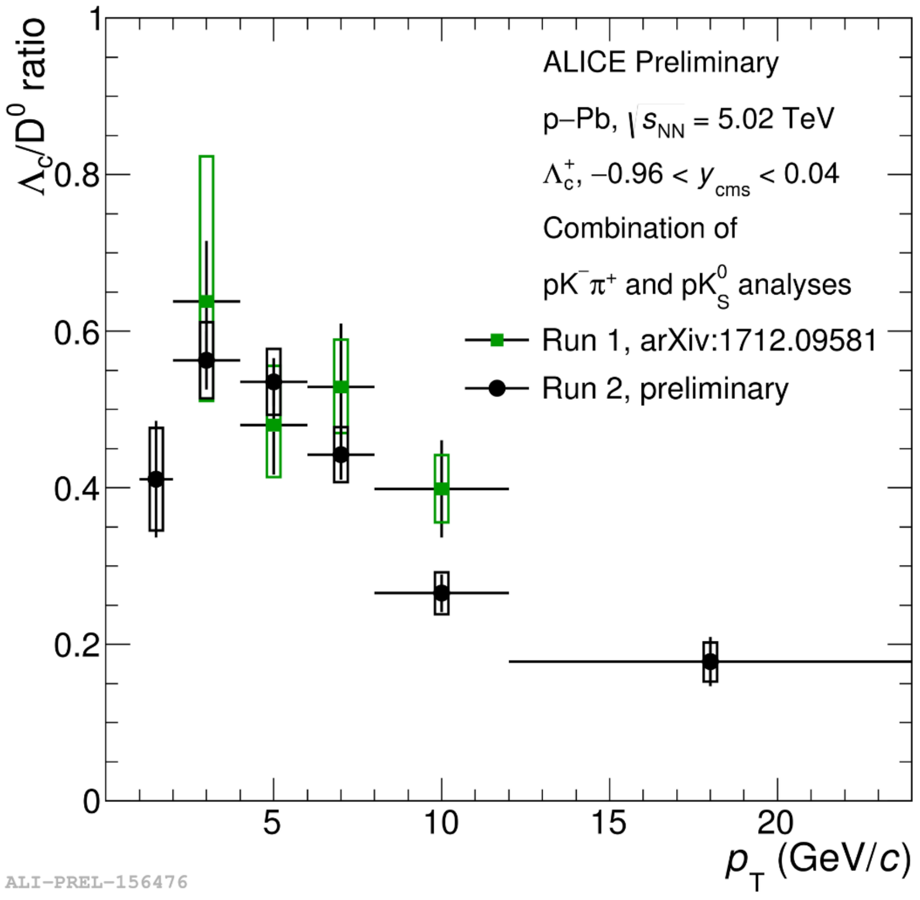




- The measured cross-sections are compatible within statistical and systematic uncertainties.

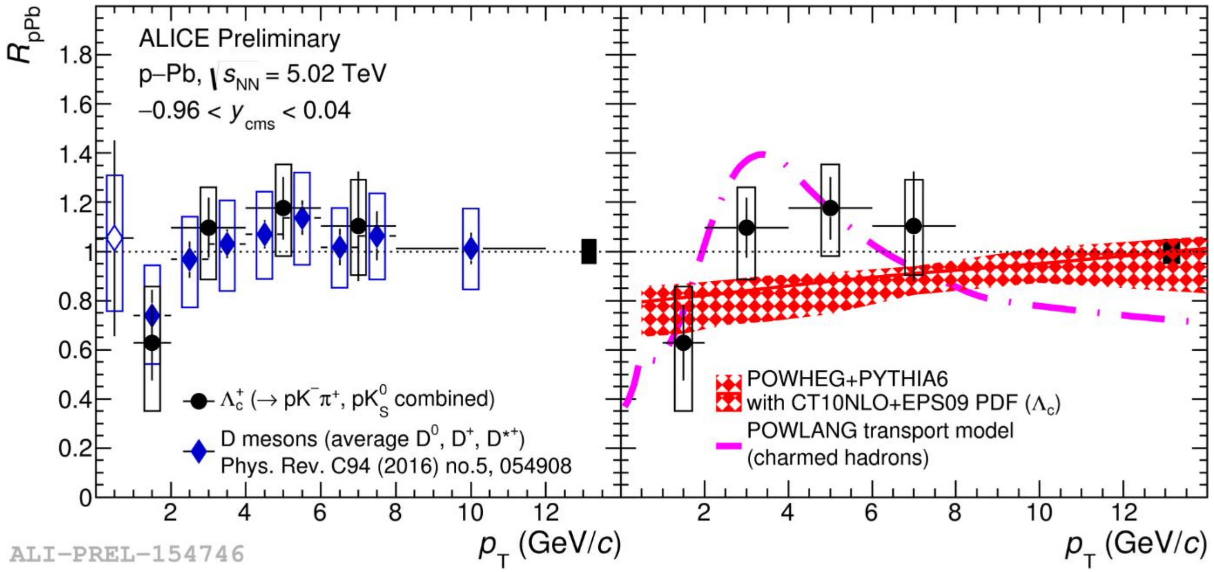
Comparison to Run 1





- Large improvement in uncertainties from run-2 data compared to run-1

R_{pPb} & comparison to light flavours



- Results consistent between charmed baryons and mesons, no significant CNM effects.
- Λ_c R_{pPb} described reasonably well by PYTHIA/POWLANG models within uncertainties.

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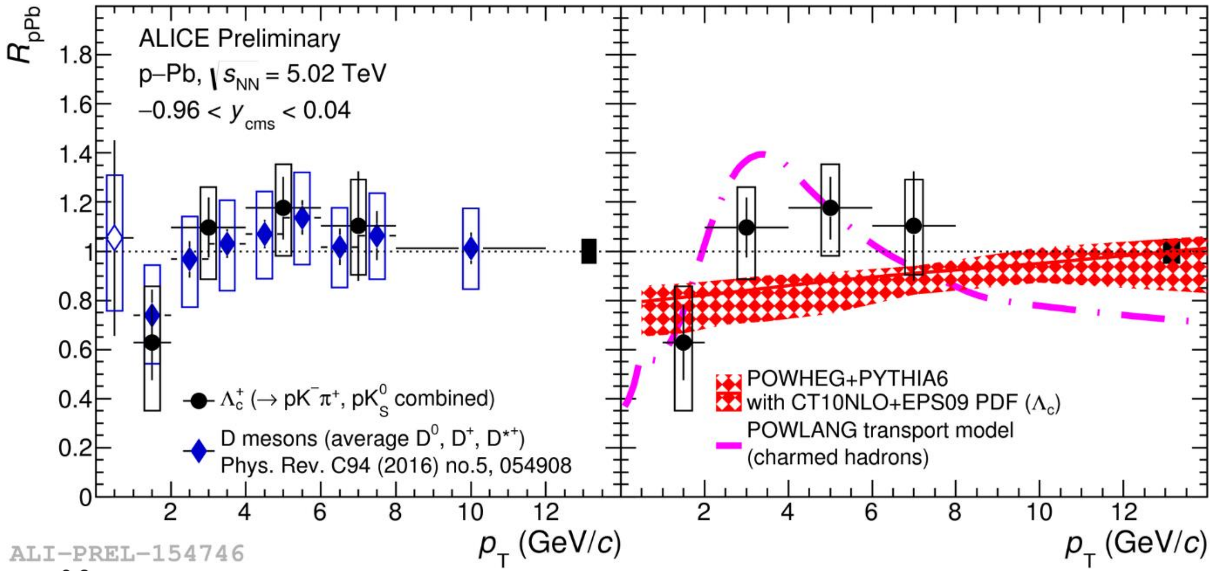

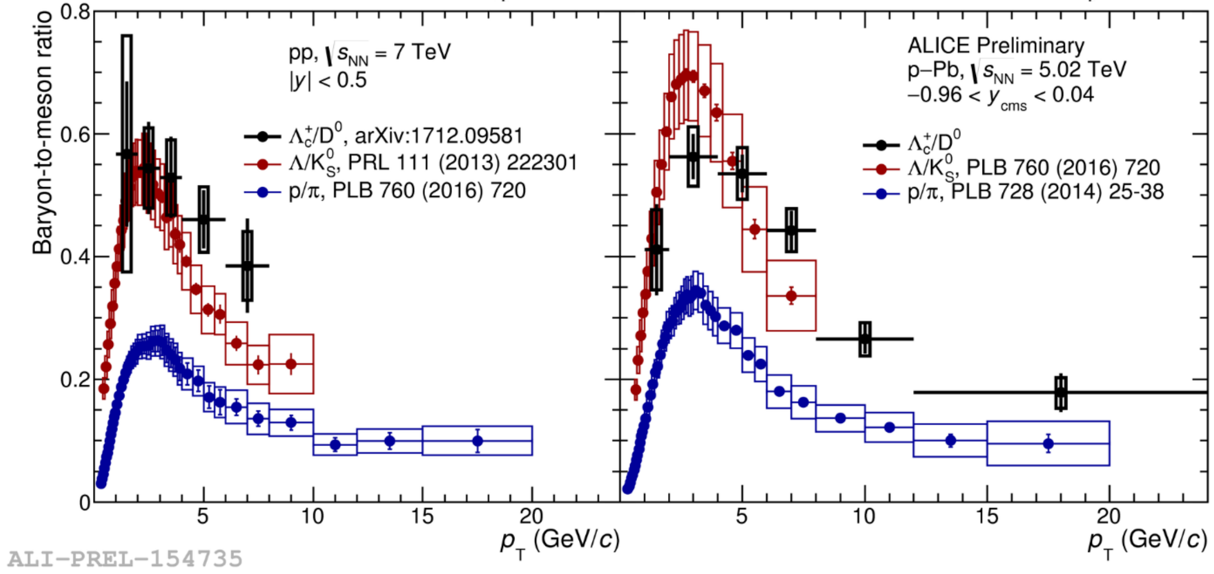

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- Λ_c R_{pPb} described reasonably well by PYTHIA/POWLANG models within uncertainties.

- Striking similarity between Λ_c /D_0 and Λ/K^0_S for both collision systems; p_T shape similar to p/π ratio

What’s next?

Potential future analyses:

- Cross section measurement with MVA method.
- Multiplicity dependent measurement?
- Look at pp collision systems

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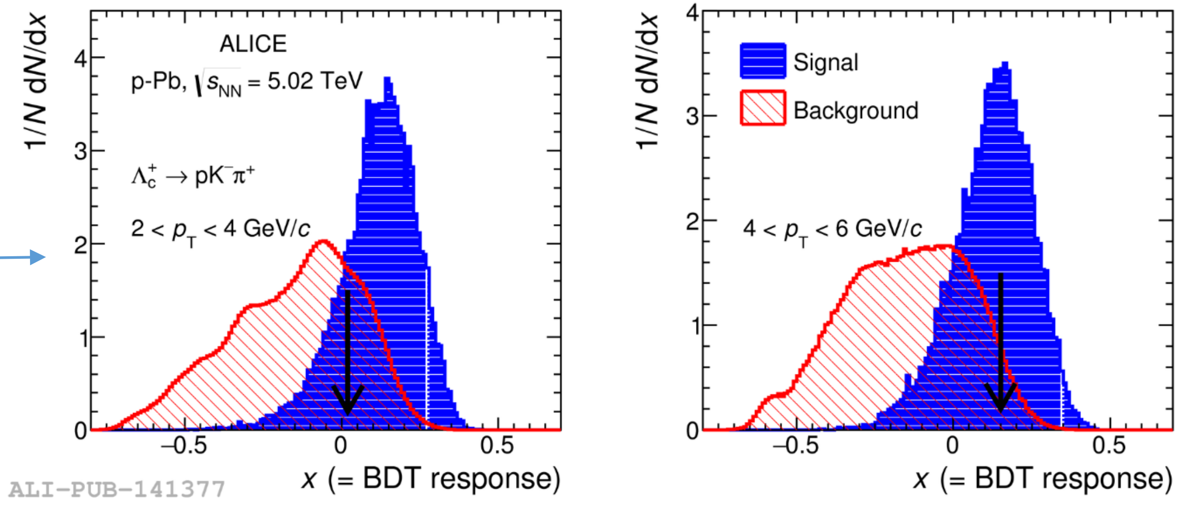
improved signal extraction

improved systematics



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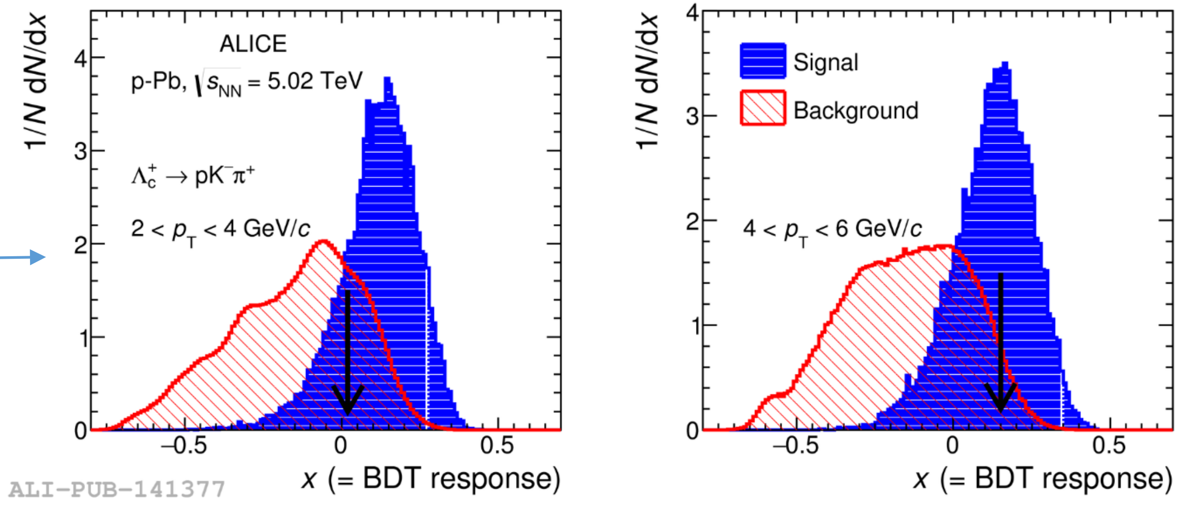
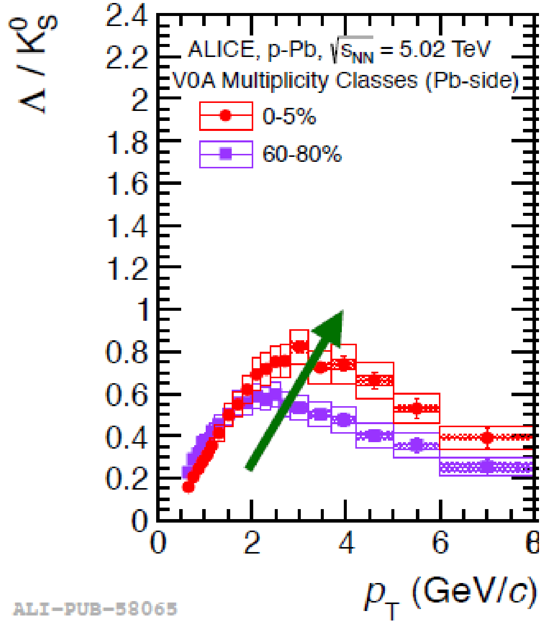


Strange baryon/meson ratio rises with multiplicity

Does this hold for charm?



Summary

- Heavy-Flavour quarks are good probes of the QGP, experiencing the full evolution of the medium
- Measurement of charmed baryon production (from the corresponding b/m ratio) gives sensitivity to hadronisation processes
- Run 2 results have greater precision and an extended p_T range compared to Run1
- Striking similarity in p_T shape between the b/m ratios from both light and heavy-flavour
- Plenty of possible extensions to these measurements available!

Thank you for listening!

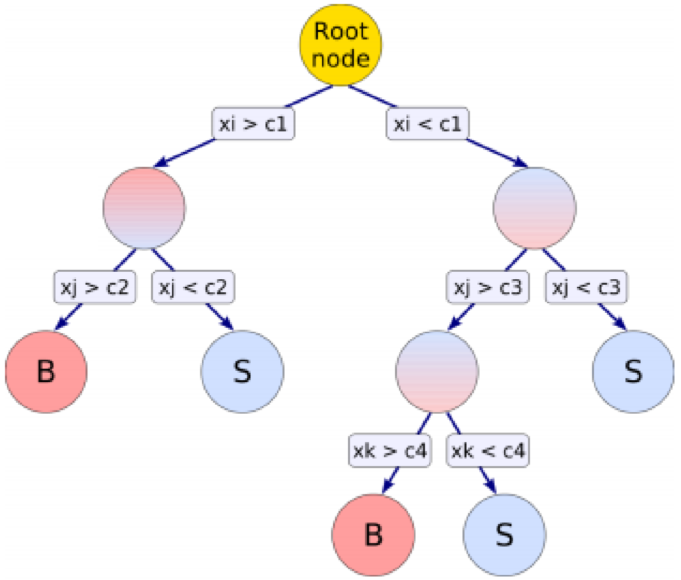
And thanks to:
A. De Caro, E. Meninno, J. Norman and J. Wilkinson

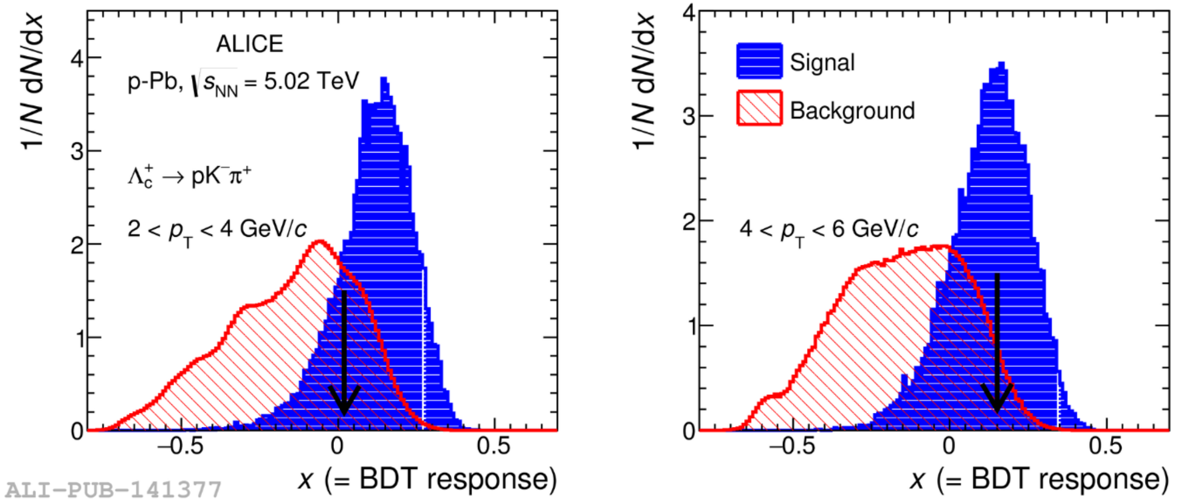
Back up

Boosted Decision Tree analysis

- One way to improve signal extraction is to employ a multivariate technique. One method (already used in Run1 and for the pK^0_s channel for Run2) are BDTs.

- A decision tree aims to make successive cuts to separate signal and background.
- Decision trees can be combined into ensembles that classify using a majority vote.

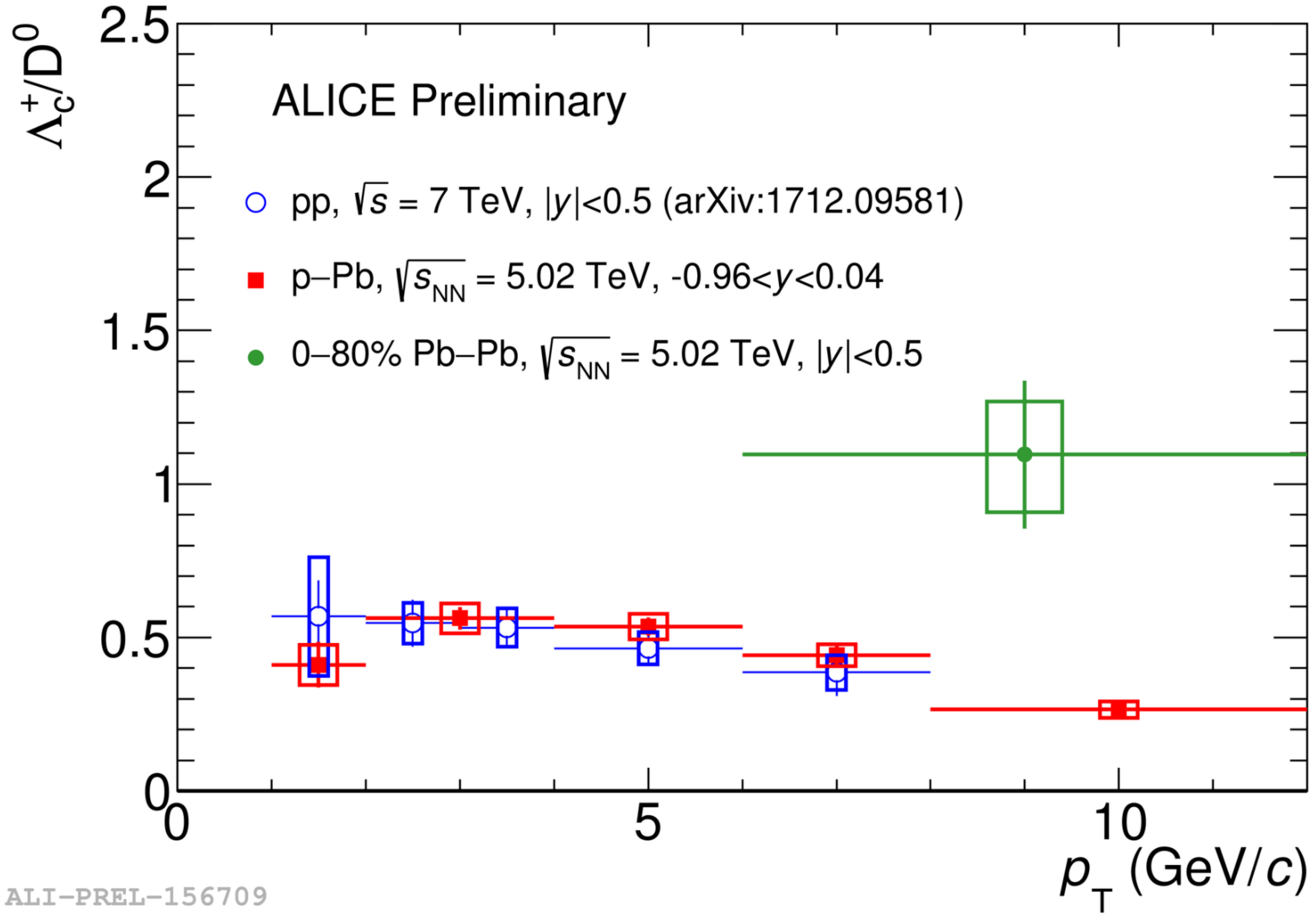




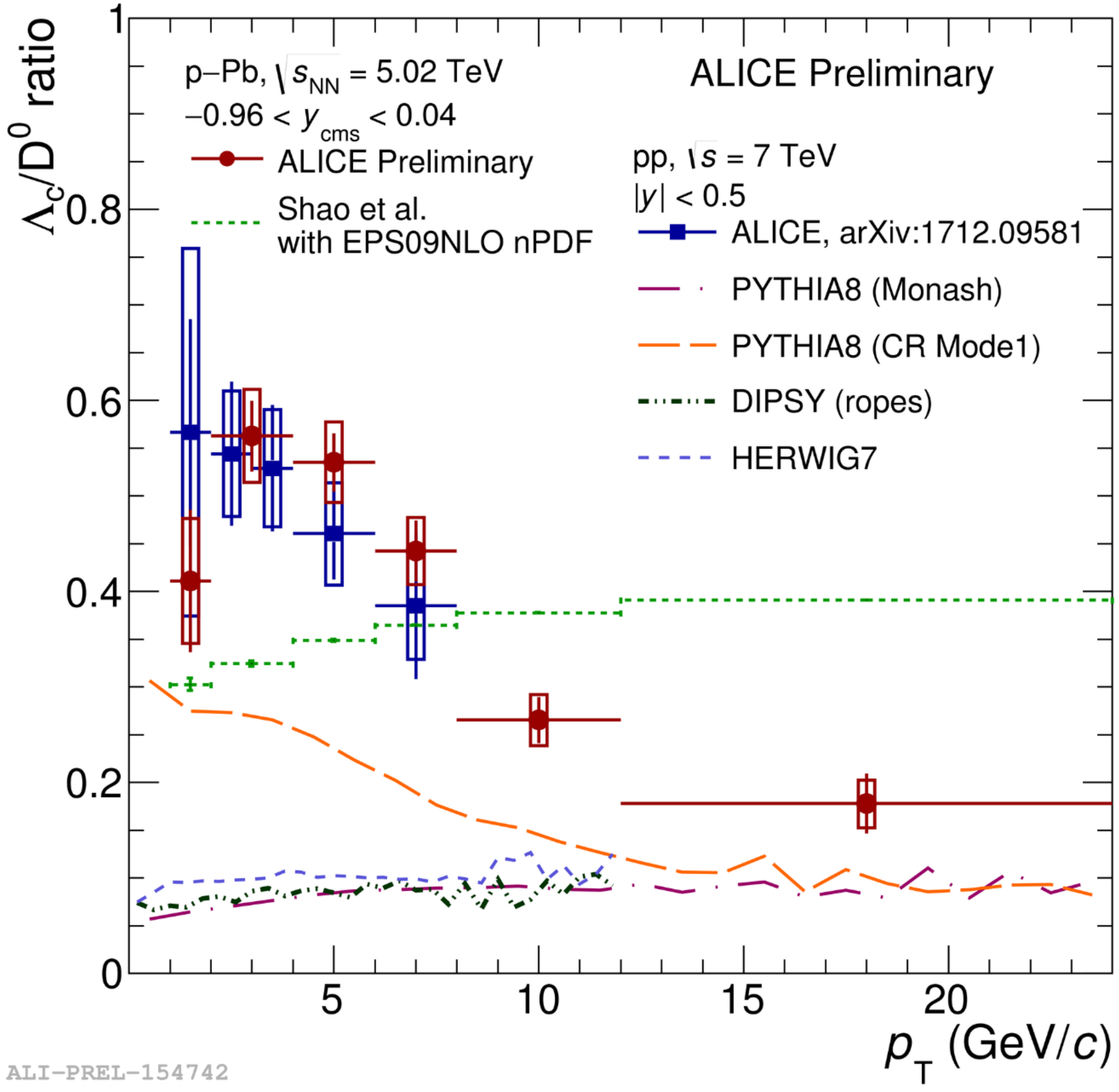
- After training and testing trees on simulation. They can then be applied to data.

- The BDT will give a response between 0 and 1 indicating background-like and signal-like candidates, respectively.

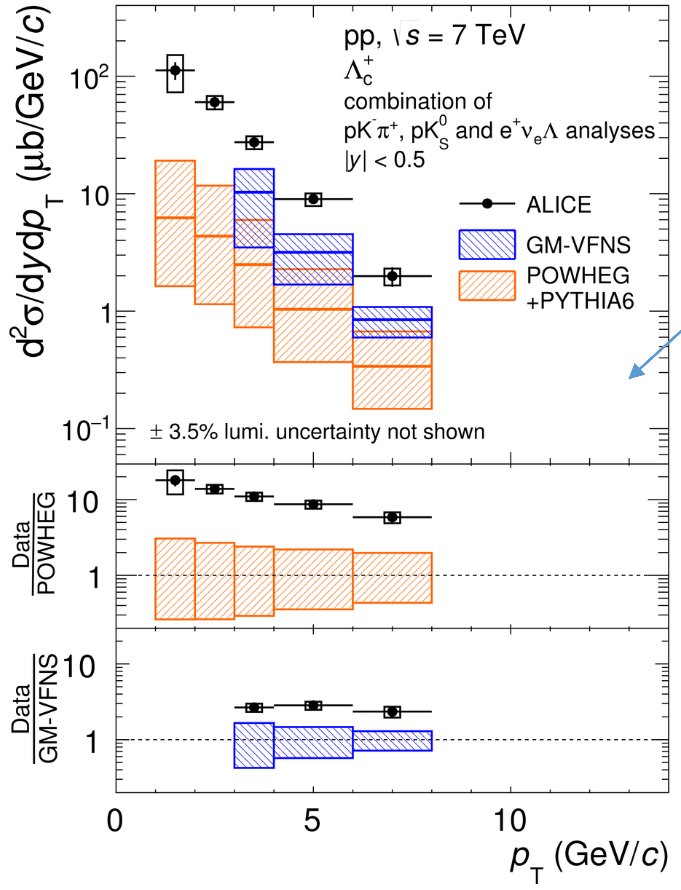
Lc/D: all systems



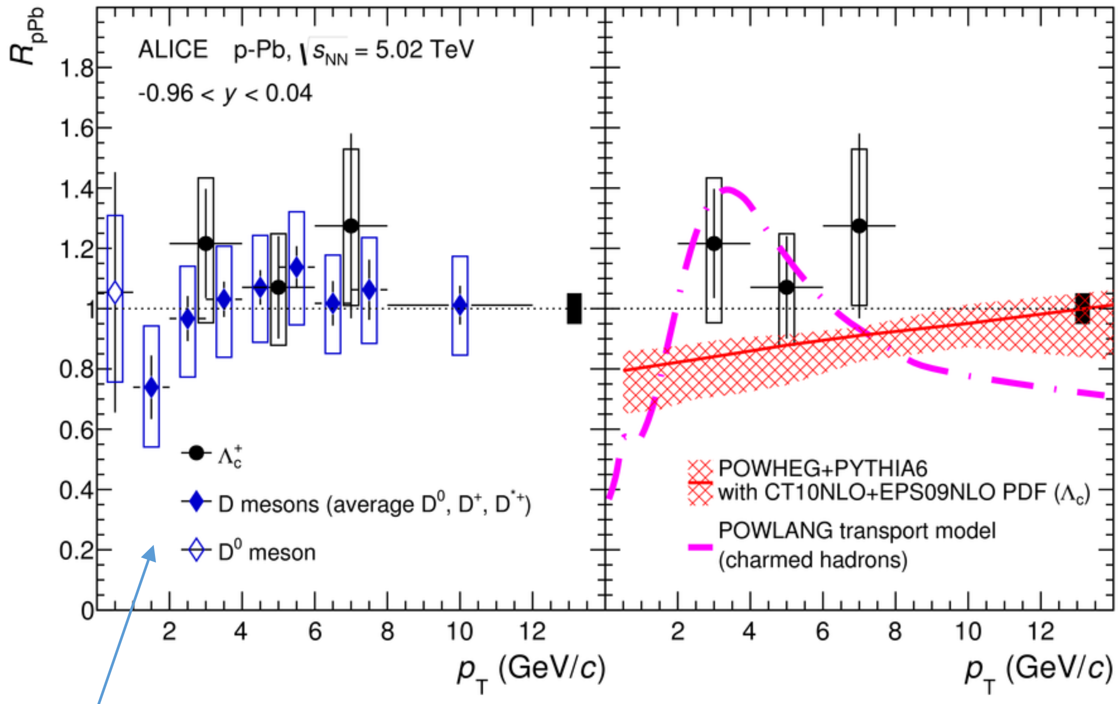
Lc/D vs Models



Highlights from Run 1



- Cross section is consistently underestimated by theoretical models

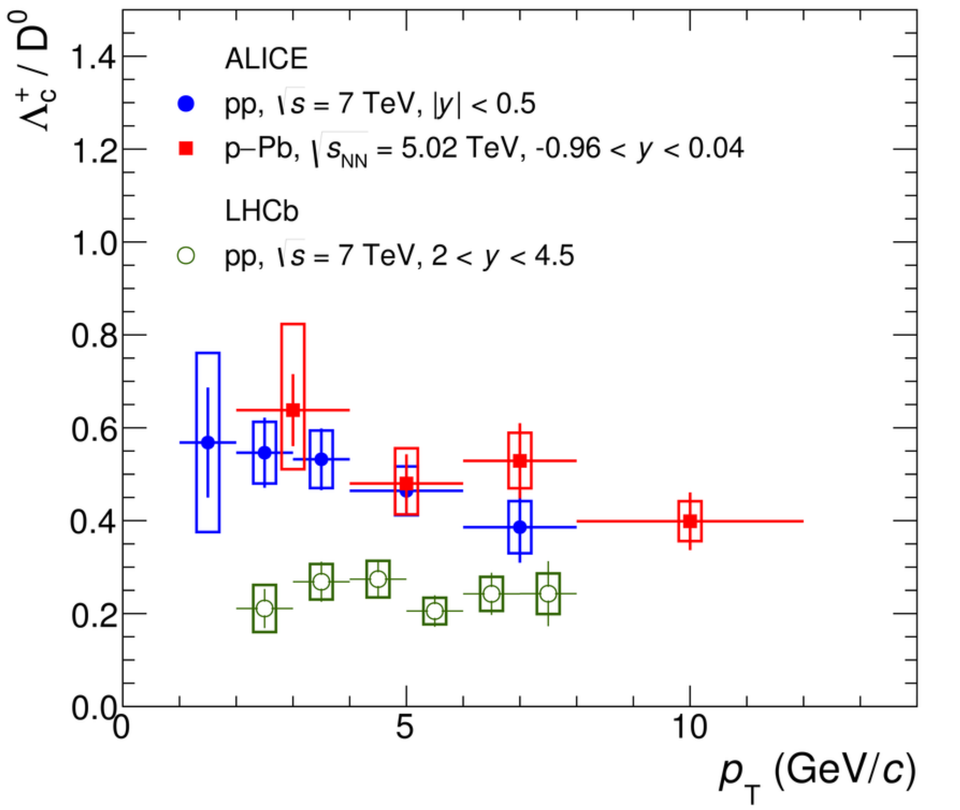


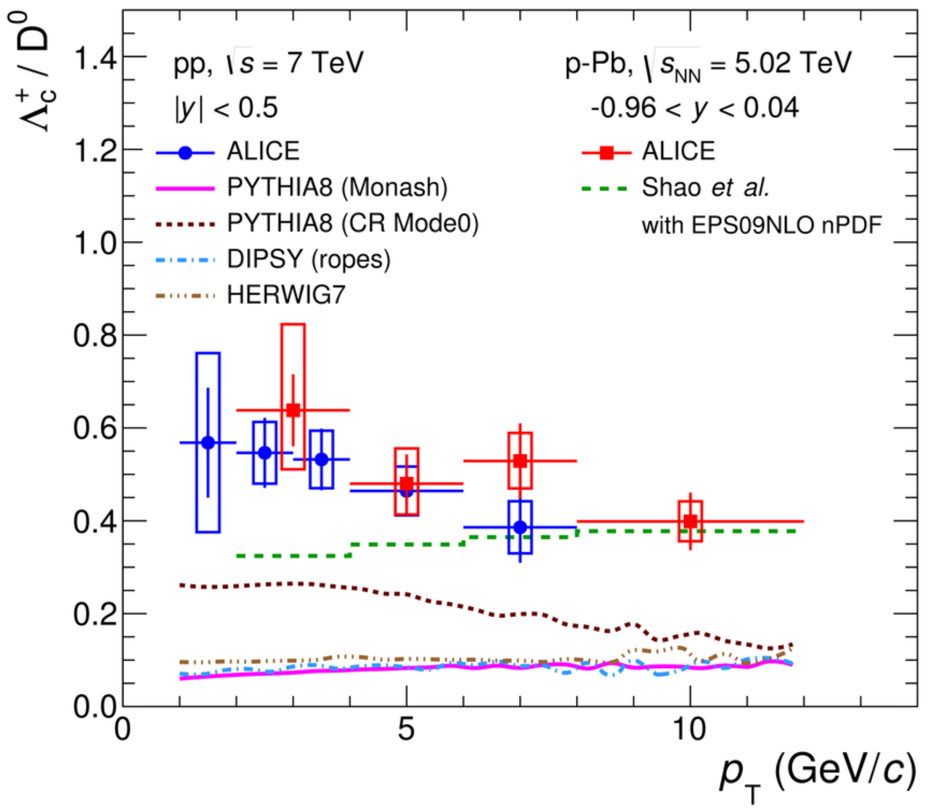
- Nuclear modification factor, RpPb is consistent with both unity and D meson measurement

$$R_{pPb}(p_T) = \frac{1}{A}\frac{d\sigma_{pPb}/dp_T}{d\sigma_{pp}/dp_T}$$

R_{pPb} < 1 = suppression
R_{pPb} > 1 = enhancement

Highlights from Run 1





- Λ_c^+/D ratios in pp and p-Pb are compatible
- ALICE measurement systematically higher than LHCb

- Λ_c^+/D ratio is higher than MC
- model with colour reconnection closer to data
- model tuned to LHCb pp data is even closer

Bayesian PID

Probability of getting signal S given it is from particle of species i

Prior probability of finding a particle of species i

$$P(H_i|\vec{S}) = \frac{P(\vec{S}|H_i)C(H_i)}{\sum_{k=e,\mu,\pi,\ldots} P(\vec{S}|H_k)C(H_k)}.$$

Probability of track belonging to particle species i given signal S

Coalescence vs Fragmentation