ALICE experiment

Strange particles analyses in p+p collisions

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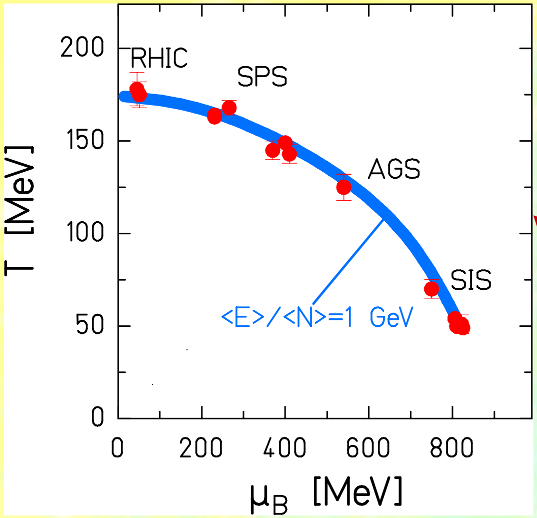
Strangeness in QGP: Statistical models for heavy ions collisions

Measurements of particles ratio and especially strange particles ratio are a clue to understand the QGP and its thermalisation through statistical models.

Statistical hadron resonance gaz model at equilibrium



Phys.Rev.Lett.81:5284-5286,1998

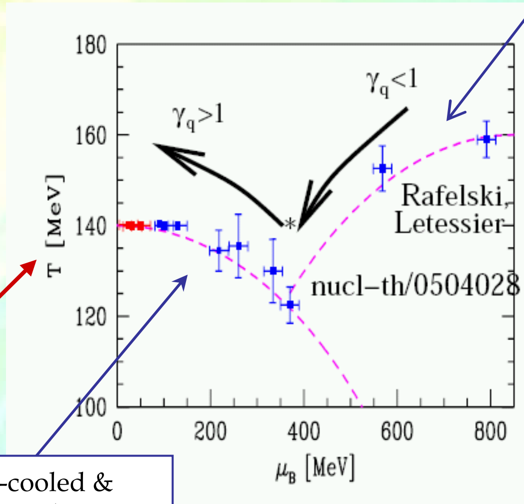
T, γ_s and μ_B are extracted from fits of particles ratio for each experiment.

$\gamma_S^{hadron} \leq 1$

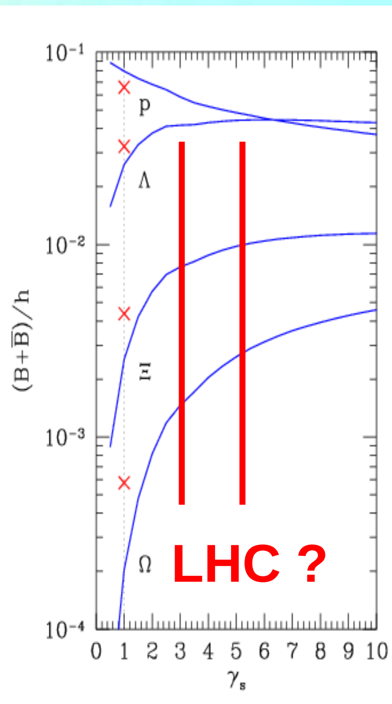
$\gamma_S^{hadron} > 1$ allowed

Non-equilibrium model (SHARE)

Hot & undersaturated system



Super-cooled & oversaturated system with high entropy



Predictions for LHC: T ~ 170 MeV
$\mu_B \sim 1$ MeV

Assumes an equilibrium of strange quarks in QGP that can lead to an over-saturation in the final state.

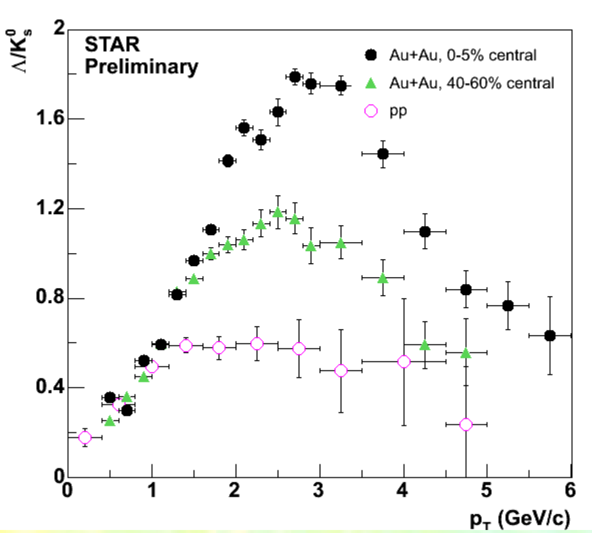
Predictions for LHC: 125 < T < 135 MeV
$3 < \gamma_S < 5$

Both models can fit the data from SIS to RHIC, it is likely LHC will distinguish between them.

And many others open questions like correlation volume…

Strangeness in QGP: *intermediate Pt*

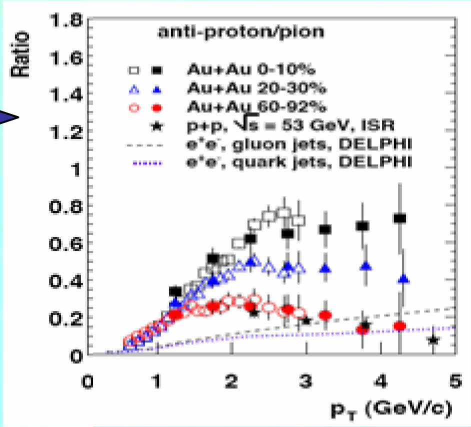
Baryon excess production at intermediate Pt has been observed in heavy ions collisions by previous experiments like STAR :



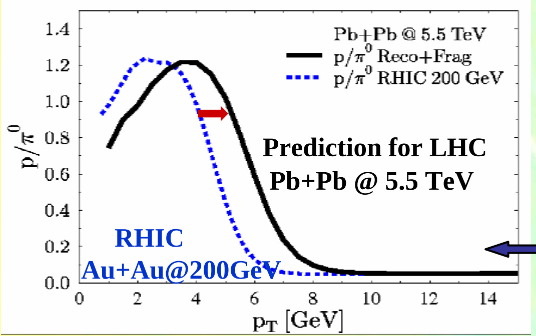
J.Phys.G:Nucl.Part.Phys.30(2004)S963

Models of **coalescence**, that assume the quark and gluon plasma formation, have been proposed as a possible hadronisation mechanism at intermediate Pt (**region between hadronisation by fragmentation at high Pt and soft domain at low Pt**).

The phenomena hasn't been observed only for strange particles:



But **strange particles give access to a wider Pt range** since strange particles identification doesn't necessarily require the use of dE/dx information.



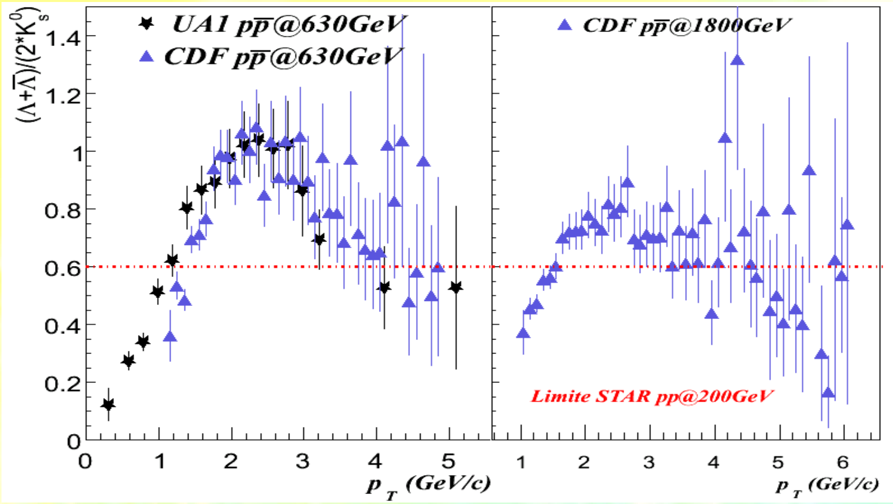
Eur.J.Phys.C34 (2004) S279

The ratio baryon/meson helps to probe the kinematical regions where hard processes dominate. Predictions of models using recombination and pQCD at LHC show that beginning of pure pQCD domain could be pushed to a higher Pt.

- need to identify particles at the highest Pt as possible
- important to check the ratio in p+p to check coalescence validity

Strangeness in QGP: intermediate Pt in pp collisions

Mixed ratio in p+p in STAR at 200 GeV was flat in Pt, but if the energy of the collision increases, the ratio reaches a quite high value and behaves similarly than in heavy ions collisions.

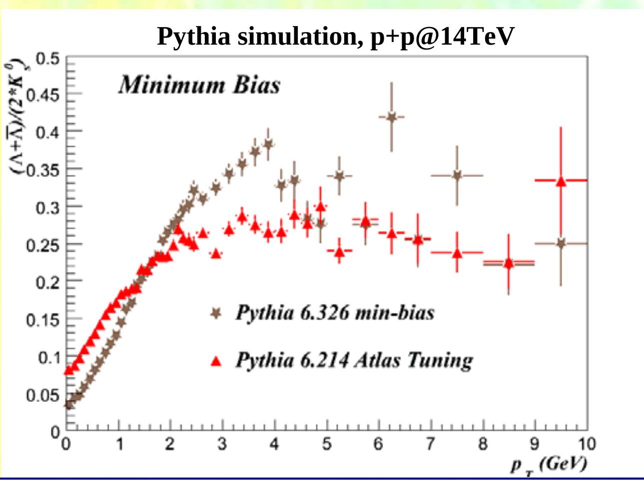


ratio computed from Phys.Lett B366(1996)441 and Phys.Rev.D(2005)052001

ratio computed from Phys.Rev.D(2005)052001

So we expect this ratio to go beyond 1 at LHC energy as well.

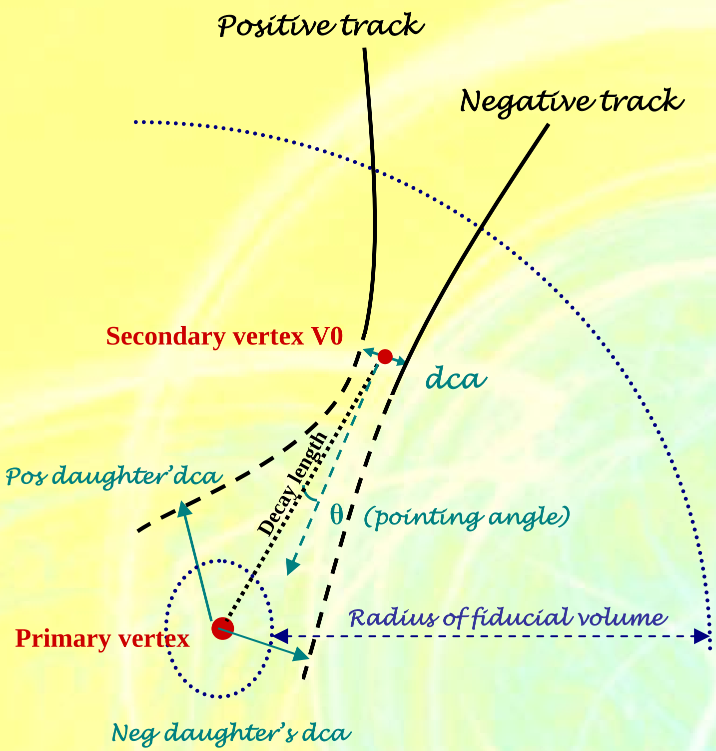
- Validity of the coalescence model…??
- Mechanisms of baryons and mesons production in p+p…??



Pythia, for different tunings, doesn't reproduce the increase of the mixed ratio observed in CDF and UA1.

The mechanism of strangeness production is still not well understood in p+p at such energy….

How to reconstruct a V0 ?



V0 secondary vertex = weak decay of a neutral particle into 2 charged daughters.

(High branching ratio in this decay mode)

↳ **K^0_S, Λ and $\overline{\Lambda}$**

particle	Decay products	Branching ratio	cτ (cm)
Λ	$p + \pi^-$	63.9 %	7.89
$\overline{\Lambda}$	$\overline{p} + \pi^+$	63.9 %	7.89
K^0_s	$\pi^- + \pi^+$	68.6 %	2.68

- **Association of two opposite charge tracks**
- **Topological cuts**:

- Distance of closest approach between the two daughters
- Distance of closest approach between extrapolation of daughter tracks and primary vertex
- Radius of fiducial volume in which the V0 is allowed to decay
- Cos(θ) to constrain the V0 momentum to point back to the primary vertex.

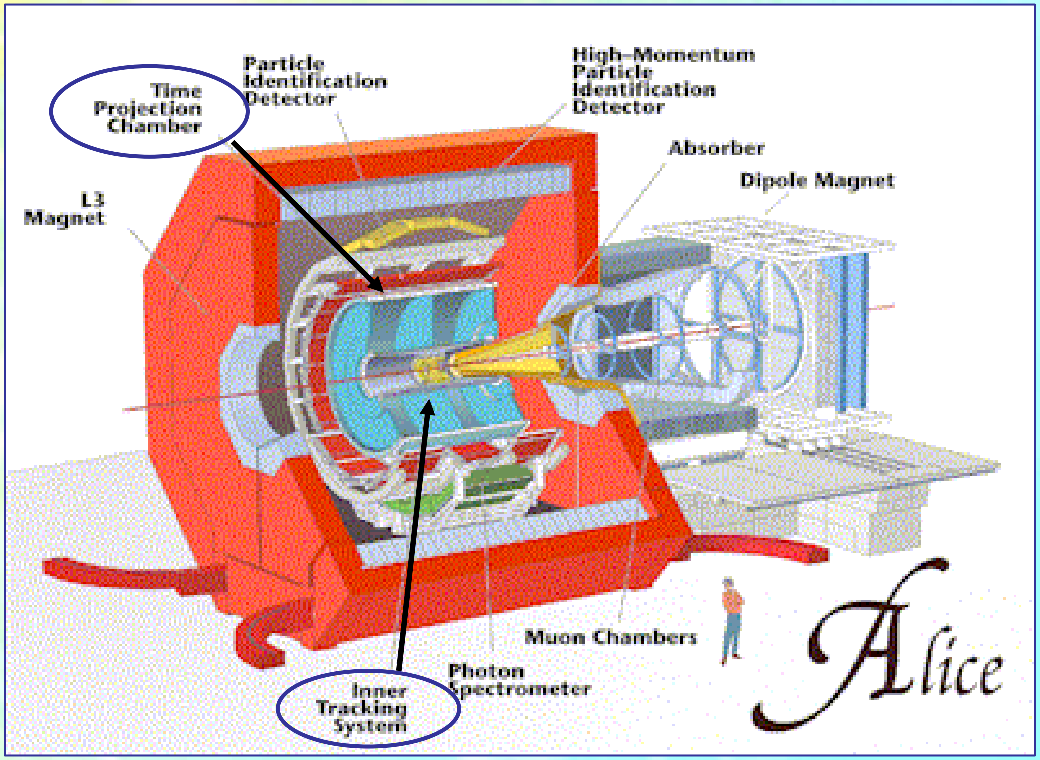
V0 reconstruction: what do we need ?

V0 reconstruction can be done with only the two main tracking detectors:

- the TPC
(time Projection Chamber)

- the ITS
(Inner Tracking System)

It plays an important role in the secondary vertex reconstruction such as the hyperons,
gives complementary information about spatial position of particle energy loss.

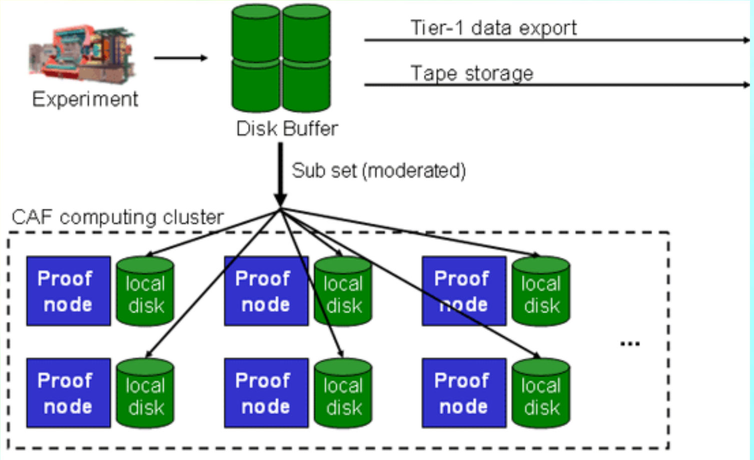


But K^0_S and Λ can even be identified without dE/dx information → doesn't require dE/dx calibration of TPC and ITS.

Our V0 analyses…

Analysis of simulated data (PDC06 events) performed with Proof on CAF

2 sets of data are available:
~200K of p+p @ 900GeV events
~2.2M of p+p @ 14 TeV events



The CERN Analysis Facility (CAF)

- Cluster at CERN running PROOF (Parallel ROOt Facility) that allows interactive parallel analysis on a local cluster.
- Design goal: 500 CPUs, 100 TB of selected data locally available.
  Since may 2006, CAF test sytem: 40 machines, 2 CPUs each, 200 GB.
- Aim of CAF: conceptionnally different from analysis on the Grid.
  Analysis of all data taken by ALICE will not be possible because of limited capacity.
  But it allows very fast development cycles: possible to run an analysis and see quickly the results.

Invariant mass distribution

How to do we calculate the invariant mass ?

- A V0 is reconstructed following the method previously explained;
- We make an assumption on the nature of the daughter particles and thus we compute the V0 invariant mass (and its momentum as well).

$$M = \sqrt{p_1 + p_2} = \sqrt{m_1^2 + m_2^2 + 2(E_1 E_2 - \vec{p}_1 \vec{p}_2)}$$

What is called "perfect PID" ?

We simulate a perfect particle identification of the detectors (TPC+ITS) done with the dE/dx of the daughters tracks.

What is an associated particle ?

A reconstructed particle with a Monte Carlo partner.

With accessing **Monte Carlo information** in the simulated data, we can check:

✓ - that the two daughters are not primary particles;

✓ - the PDG code of positive and negative daughters;

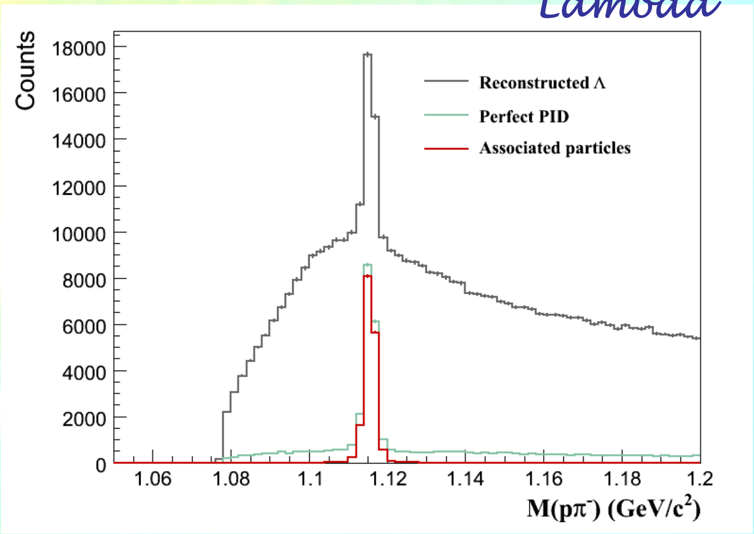
✓ - the PDG code of the parent of the two daughters.

Invariant mass distribution

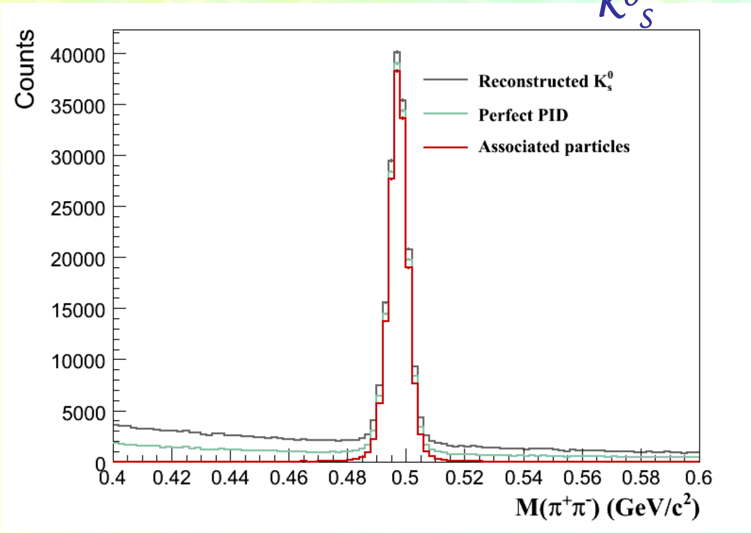
The V0 have been reconstructed without PID information from the ITS nor from the TPC (and with very loose geometrical and kinematical selection)

→ good reconstruction of K^0_S
→ reconstruction of Λ and $\overline{\Lambda}$ less straightforward because of background.

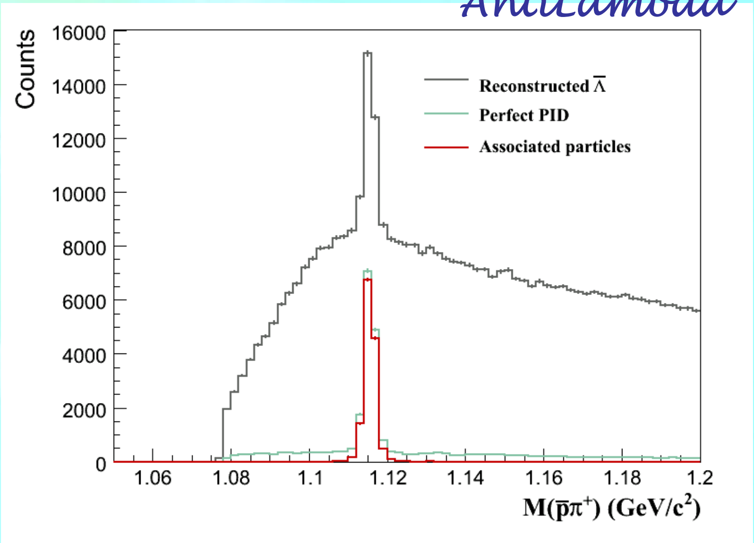
Lambda



K^0_S



AntiLambda

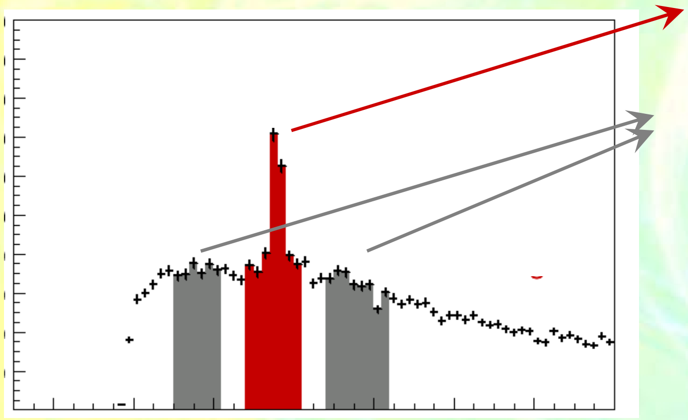


V0 analysis: signal extraction

Bin counting methods:

- Invariant mass binned into Pt bins;
- For each Pt bin, the signal is counted as follow:

- Definition of three regions in the invariant mass distribution:



- one region in the (signal+background) interval around the peak

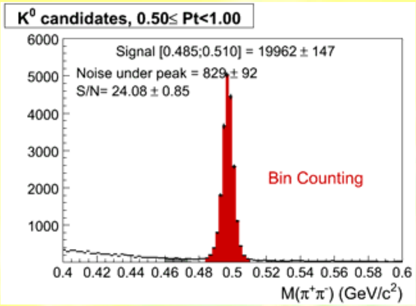
- two regions (1) and (2) in the pure background interval at the right and left of the peak

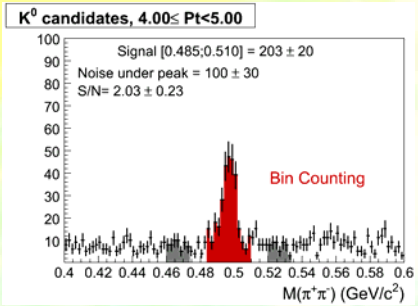
Estimation of the background under peak with a linear extrapolation between region (1) and (2).

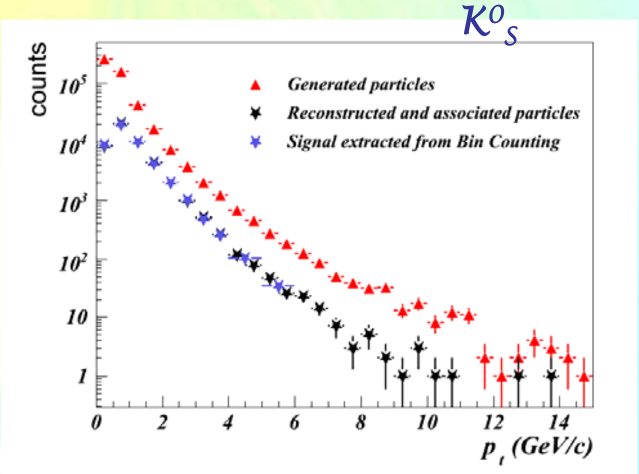
usable when the background is almost linear.

V0 analysis: signal extraction

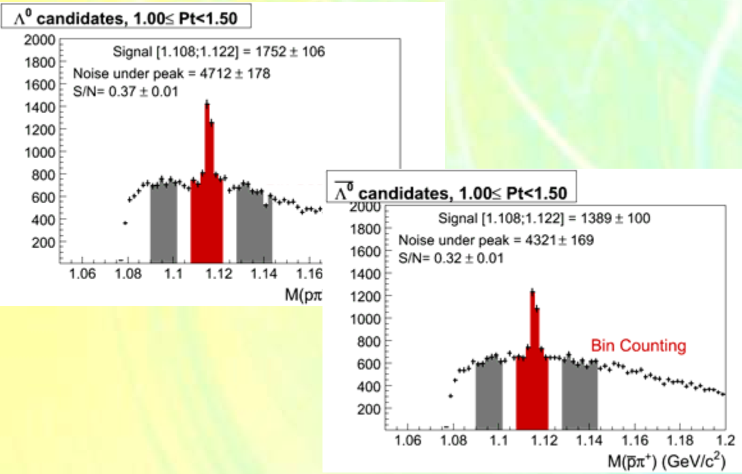
➢ K^0_S: Bin Counting works at almost all Pt.

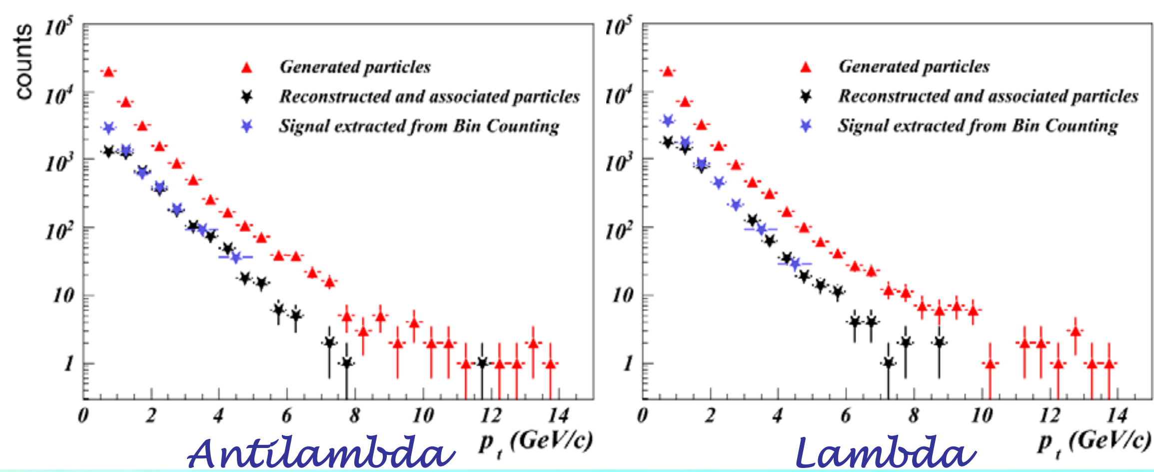






➢ But for Λ, without PID and with loose cuts, extracting the signal with the bin counting is still difficult at low Pt due to the background. Bin counting overestimates the yield at low Pt. It can be used below 1GeV/c, but with reduced background.





V0 global efficiency

Global efficiency:

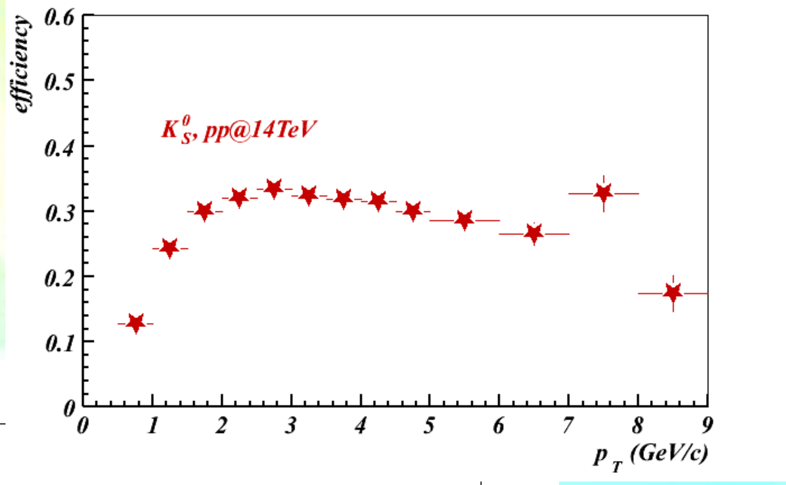
$$\varepsilon(P_t) = \frac{\text{Number of associated particles}(P_t)}{\text{Number of generated particles }(P_t)}$$

Branching ratio not taken into account, so the maximum of the efficiency is:

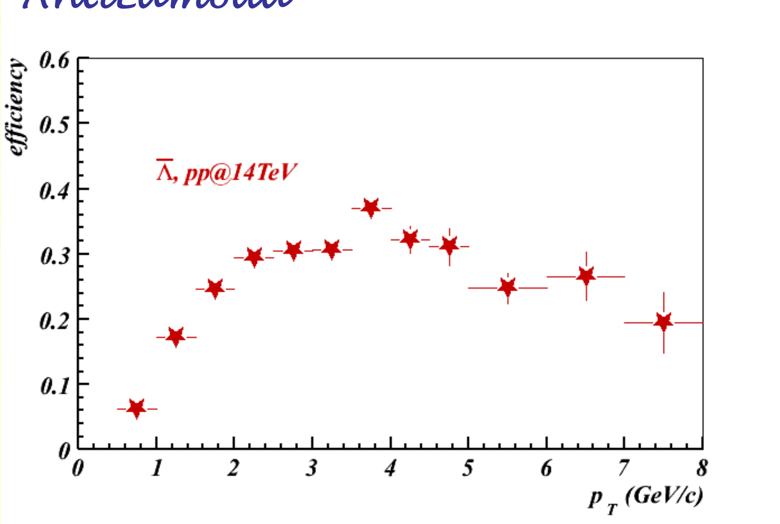
~ 0.68 for K^0_S

~ 0.64 for Λ and $\overline{\Lambda}$

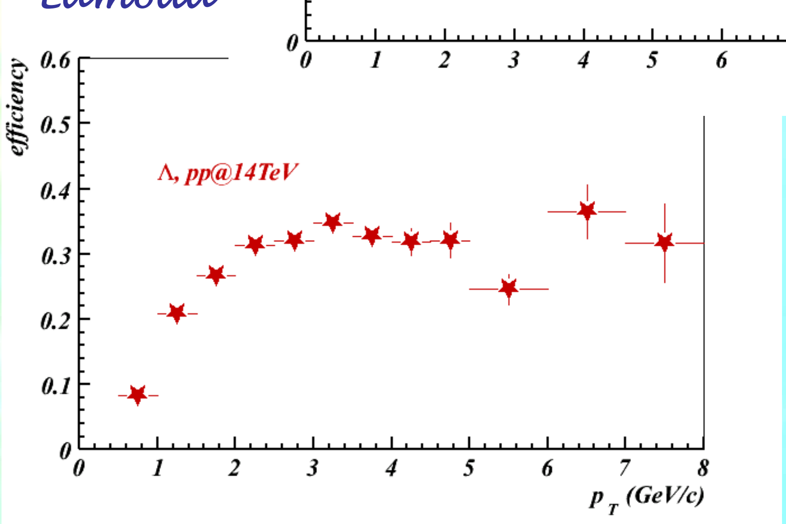
K^0_S



AntiLambda



Lambda



All particles are at mid-rapidity: |y| <1

Decrease of the efficiency at high Pt (> 4 GeV/c) → Quite unexpected behaviour Has to be investigated…

Global efficiency: why such a behaviour ?

- kITSrefit condition 's fault ? -

The explanation could be an implicit fiducial radius cut implied by a ITS refit condition:

The kITS condition requires at least 3 hits in the ITS for each daughter track of the V0.

↓

The maximum decay radius corresponds to the 2nd layer of the SDD.

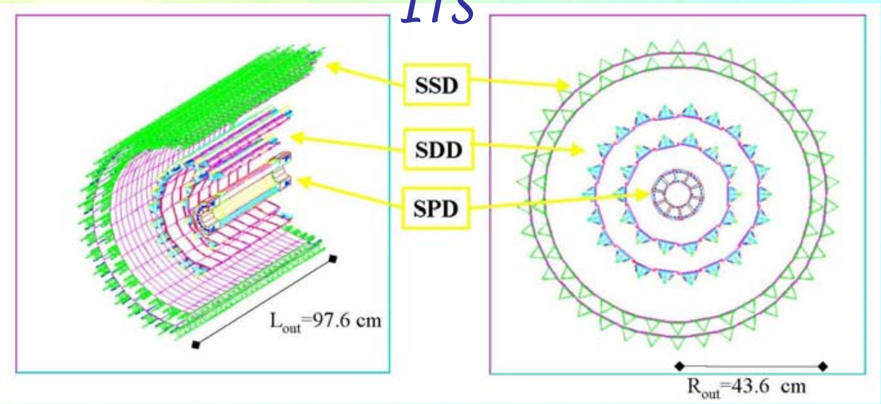
↓

But V0s with high Pt fly farther and it is unlikely they will decay before the 4th layer.

↓

The reconstruction code misses out quite a lot of high Pt V0s.

ITS

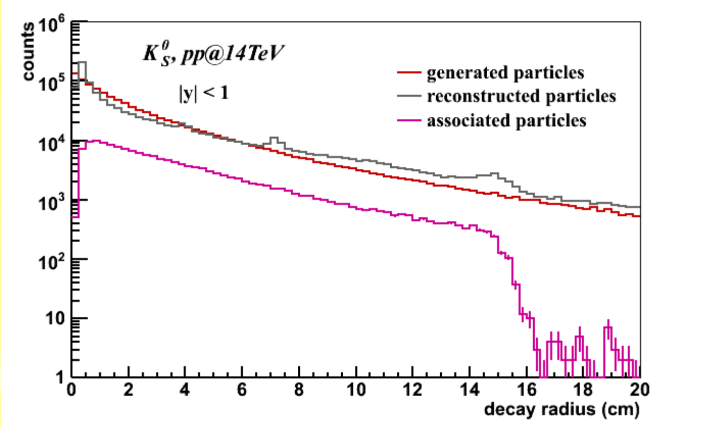


1st layer:	3.9 cm	*Silicon Pixel Detector*
2nd layer:	7.6 cm	
3rd layer:	15 cm	*Silicon Drift Detector*
4th layer:	23.9 cm	
5th layer:	37.8 cm	*Silicon Strip Detector*
6th layer:	42.8 cm	

↪ Hence the decrease of the efficiency at high Pt

Decay radius influence

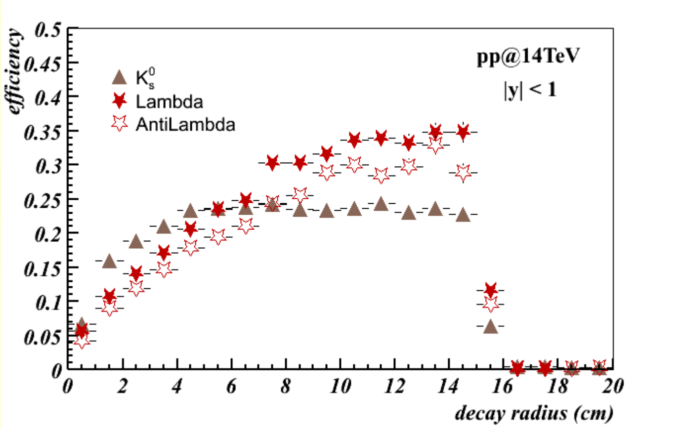
Reconstruction Rate



The number of **associated V0 vanishes quickly after the 3rd ITS layer (located a 15 cm)** due to the kITSrefit requirement

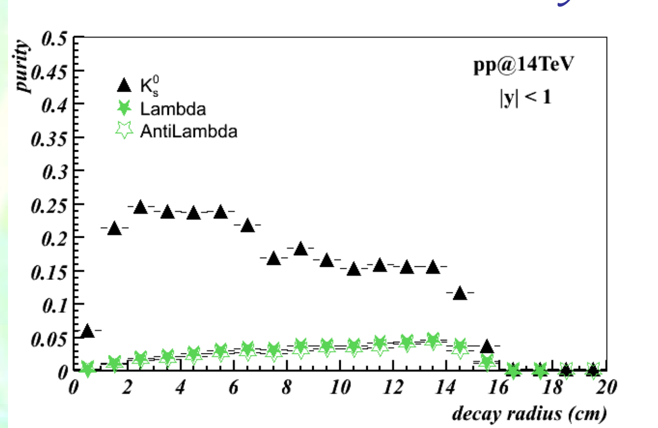
In the reconstructed particles distribution, we clearly see some peaks at the ITS layer positions corresponding to the V0s that come from γ conversion (γ→e++e-).

Efficiency



Obviously, both efficiency and purity go down to 0 for decay length > 15 cm

Purity



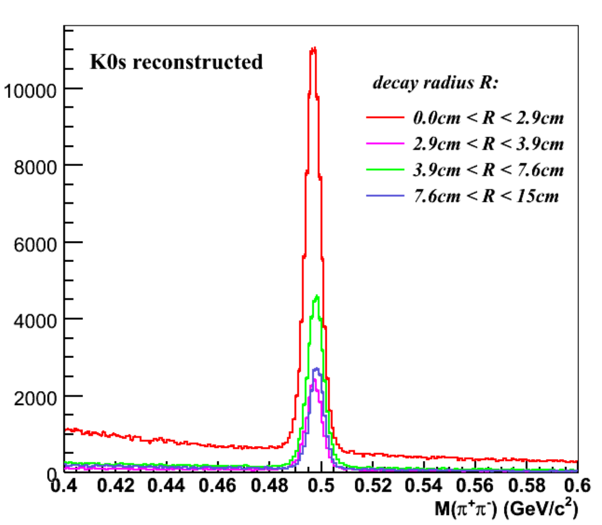
$$\text{Purity} = \frac{\text{Associated particles}}{\text{Reconstructed particles}}$$

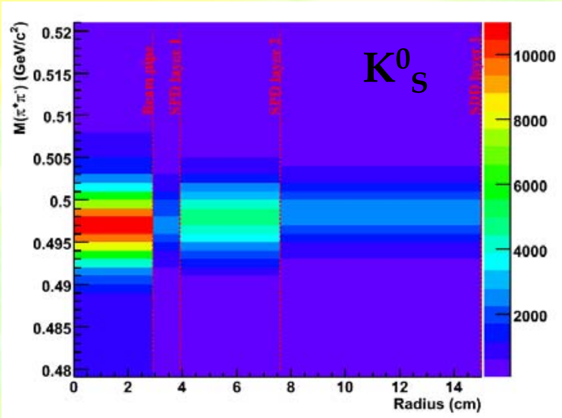
$$\text{Global efficiency} = \frac{\text{Associated particles}}{\text{Monte Carlo particles}}$$

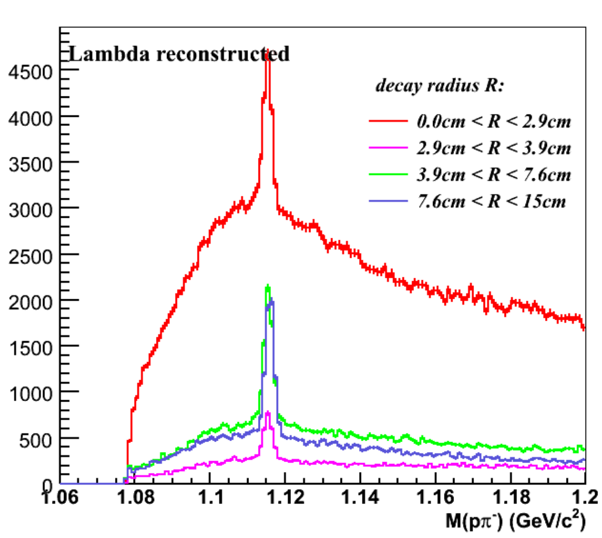
- Clear difference between K^0_S and Λ purity
  K^0_S signal corresponds to Λ background, and since K^0_S production is much more important than the Λ one → weak Λ purity.
- Decrease of purity at the ITS layers due to gamma conversion.

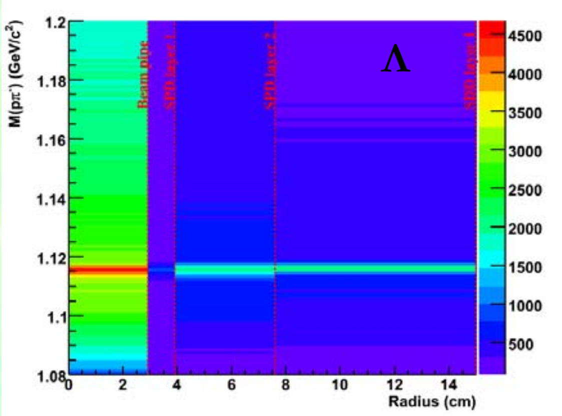
Invariant mass versus decay radius

- Reconstructed particles -









Most of the background is before R = 2.9 cm (beam pipe)

But it is also the region where the signal is the highest and where the V0 are best reconstructed.

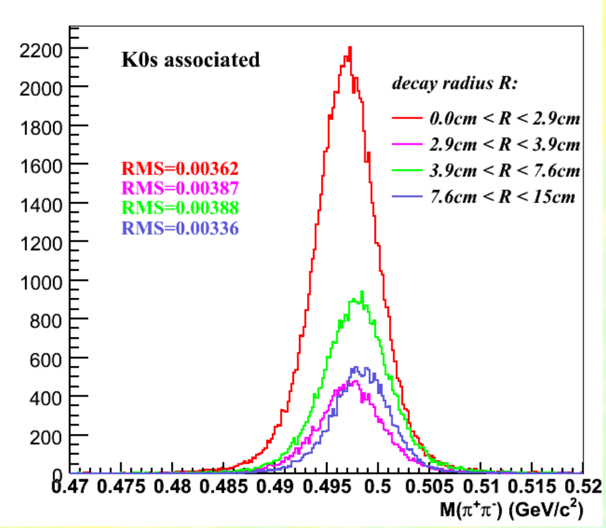
cut on decay length…?

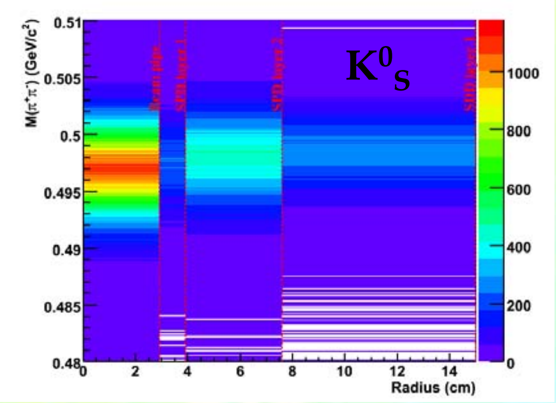
- will remove quite a lot of the statistic at low Pt…
- but will remove lots of background for Lambda.
- will lead to a decrease of efficiency but will improve purity

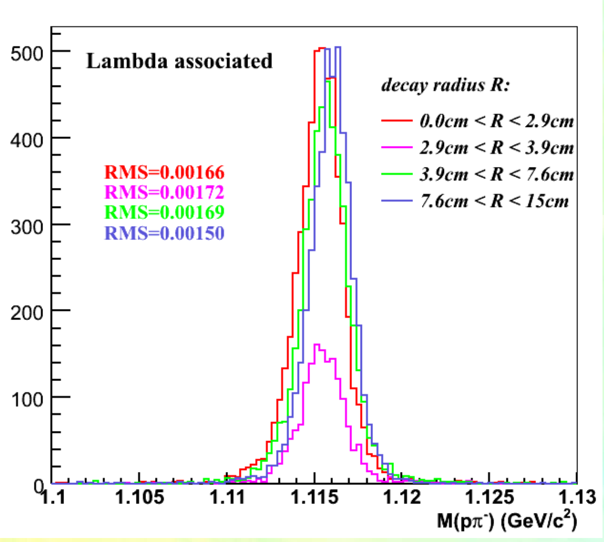
No cut on decay length is applied at the reconstruction level.
It has to be applied at the analysis level only depending on needs.

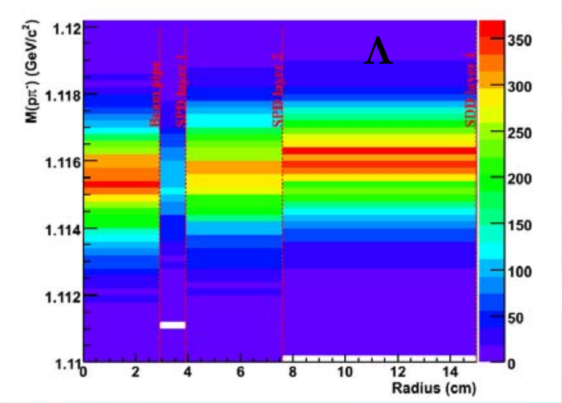
Invariant mass versus decay radius

- Associated particles -









➢ the width of the peak increases with the decay radius due to the dE/dx of the daughters tracks.

$c\tau$ (K^0_S) = 2.6 cm ➡ **Effect bigger on K^0_S**

$c\tau$ (Λ) = 7.89 cm

+daughter (proton) more energetic

➢ V0 invariant mass is shifted to a higher value when the decay radius increases.

Needs to be corrected:

if the computed invariant mass is wrong, it means the computed momentum is wrong as well…..

Conclusion

Why is strangeness interesting in QGP physics at LHC ?

- Could be used at LHC to distinguish between statistical models at or out equilibrium and thus to understand the global characteristics of QGP in heavy ions collisions.

- Could help to distinguish between hadronisation mechanisms, allows access to a wide range in Pt.

But it is mandatory to study p+p collisions first !!

Baseline for heavy ions studies, data of p+p at LHC will help to check the coalescence validity,…

Strangeness analysis of simulated p+p collisions at 14 TeV

Raw data $\xrightarrow{\text{ready}}$ ESD $\xrightarrow{\text{almost ready}}$ AOD

The V0 finder in ALICE still needs some improvements,

but full PDC06 available on CAF have been analysed and the V0 analyse codes are now ready.

We are waiting for the real data…!