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ALICE Collaboration



TECHNISCHE
UNIVERSITÄT
DARMSTADT

QGP France Meeting - Etretat

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Study of strange particles production
in proton-proton collisions with the
ALICE detector

Outlines

Which role for the strangeness in pp at LHC ?

pp collisions are the baseline for heavy ions collisions but they are also interesting in themselves, especially at the very high LHC energy.

- 1-
 - Characterize and describe the nature of the medium created through statistical models:
 - Measurement of production yields & ratio

- 2 -
 - Better understand the hadronisation mechanisms: fragmentation/coalescence;
 - Study the underlying event description, the importance of multiple interactions:
 - Dynamics at intermediate p_t & ratio Λ/K_S^0

ALICE experiment

Strange particles analysis requires mainly two detectors in the central barrel:

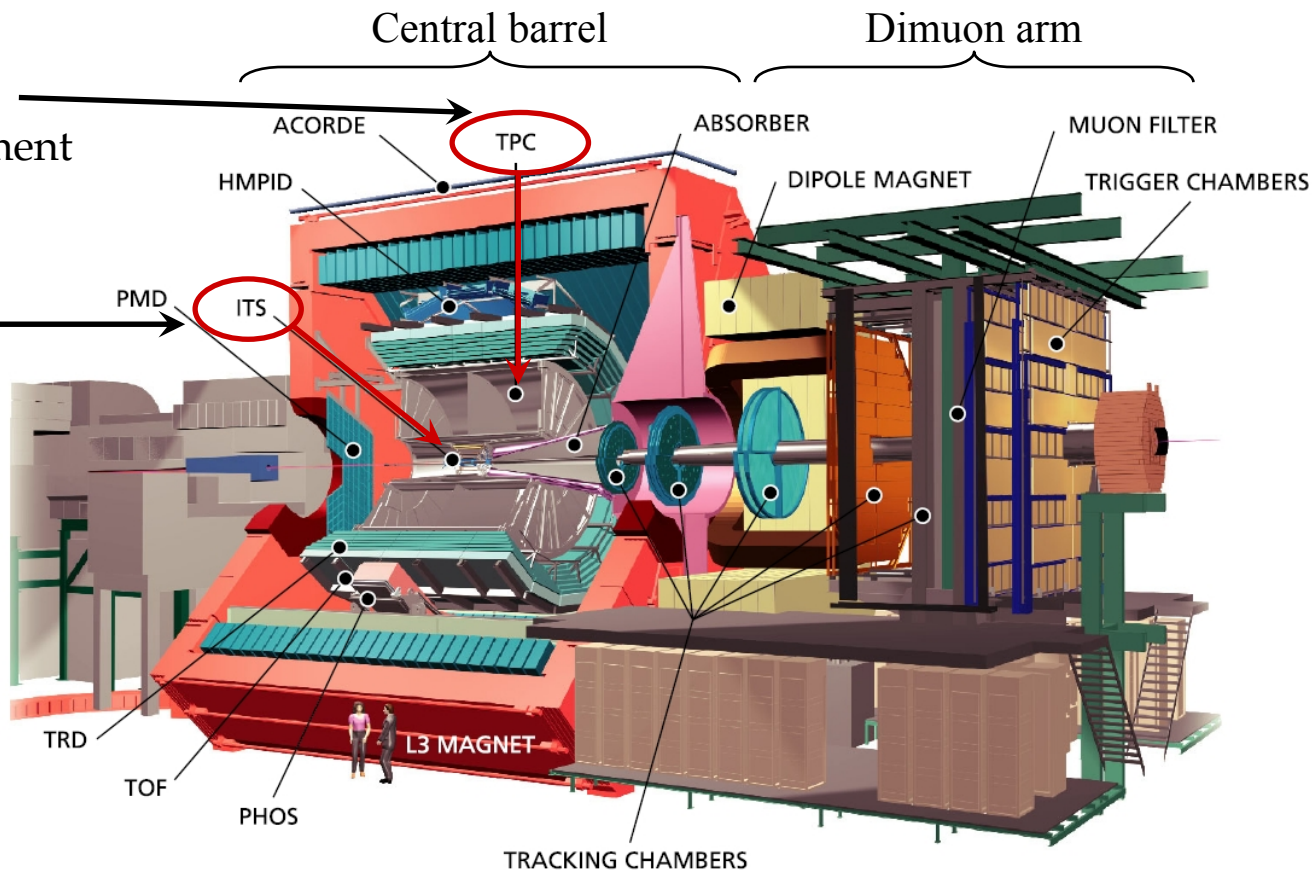
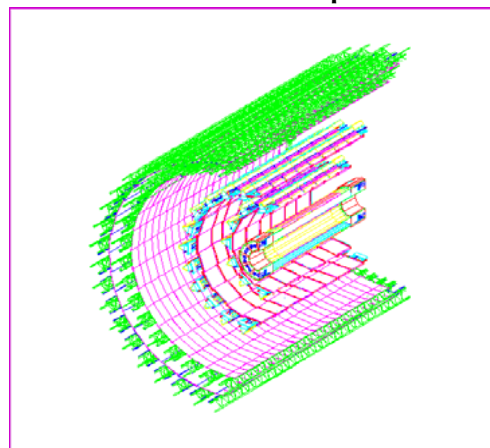
- Time Projection Chamber:

Tracking + dE/dx measurement

$$-0.9 < \eta < 0.9$$

- Inner Tracking System:

$$-0.9 < \eta < 0.9$$



Play an important role for the secondary vertex reconstruction;
Give complementary information: make the p_t resolution better for particles reconstructed in the TPC & allow reconstruction of very low p_t particles that are invisible in the TPC

Statistical description & strange particles ratio in pp

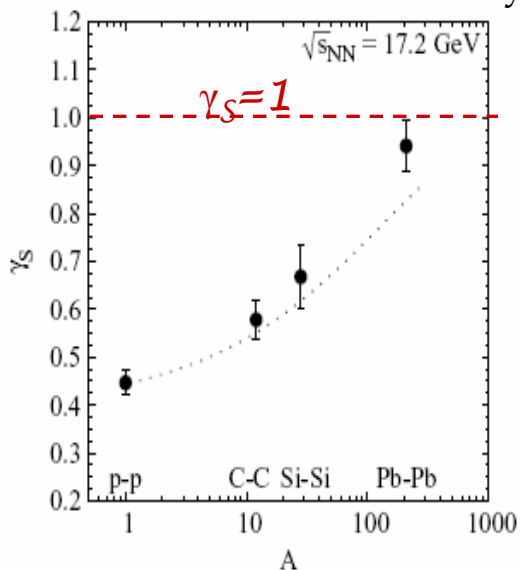
Particle production calculated within the *statistical model* is quantified by a set of thermal parameters:

- Temperature;
- Volume;
- A set of chemical potentials related to charge conservation.

Conservation of electric charge and baryon number is formulated in the Grand-Canonical ensemble whereas **strangeness conservation is treated canonically in pp collisions.**

SPS data showed an stronger suppression of strange particles yields than expected in the canonical model.

(Phys.Rev.C73(2006)044905)



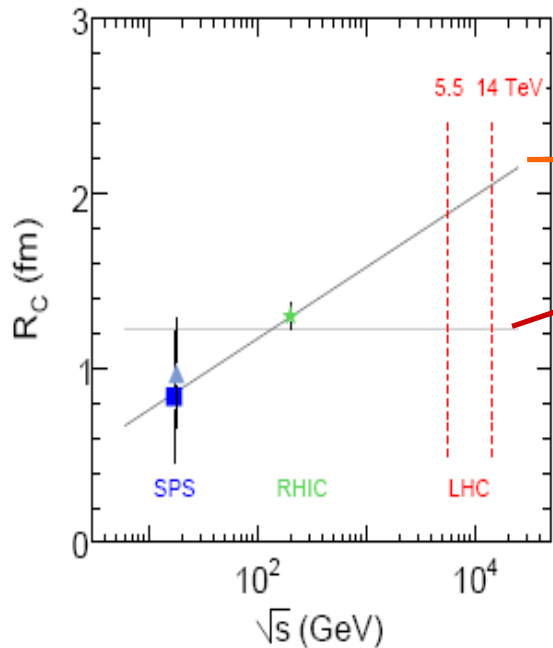
An additional suppression effect had to be included:

- R_C : radius of the sub-volume within which the strangeness is conserved exactly;
- Or γ_S factor to account for deviations from experimental data

What to expect at LHC ?

Extrapolation of the parameters from SPS to LHC:

- Temperature: no variation expected between SPS, RHIC and LHC;
- Strong decrease of μ_B from SPS to RHIC, all chemical potentials should be very small at LHC;
- *But R_C value at LHC remains largely uncertain !*



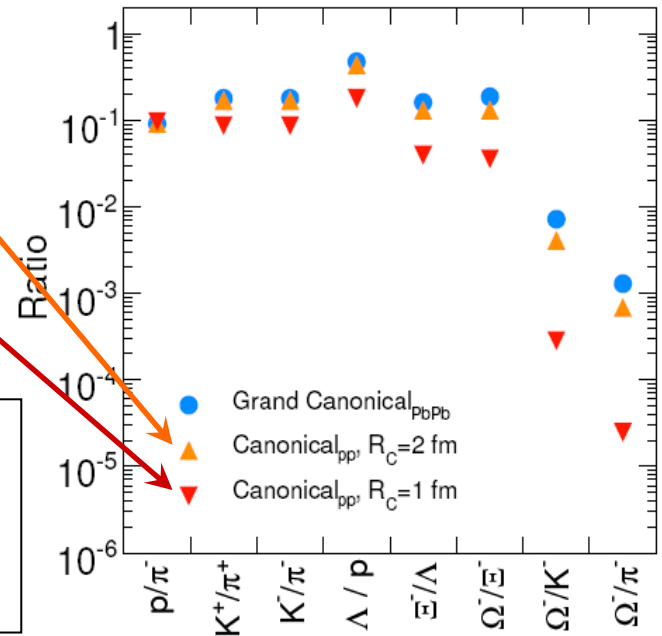
Two limiting case:

-Increase till $R_C \approx 2$ fm at LHC;

Saturation at $R_C \approx 1$ fm;

Strange particle and above all multi-strange particle ratios are very sensitive to the value of R_C .

I.Kraus Phys.Rev.C79(2009) 014901



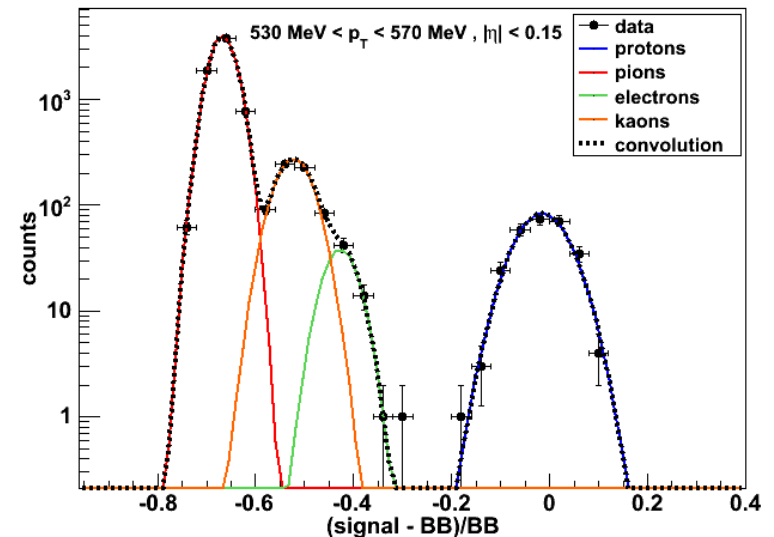
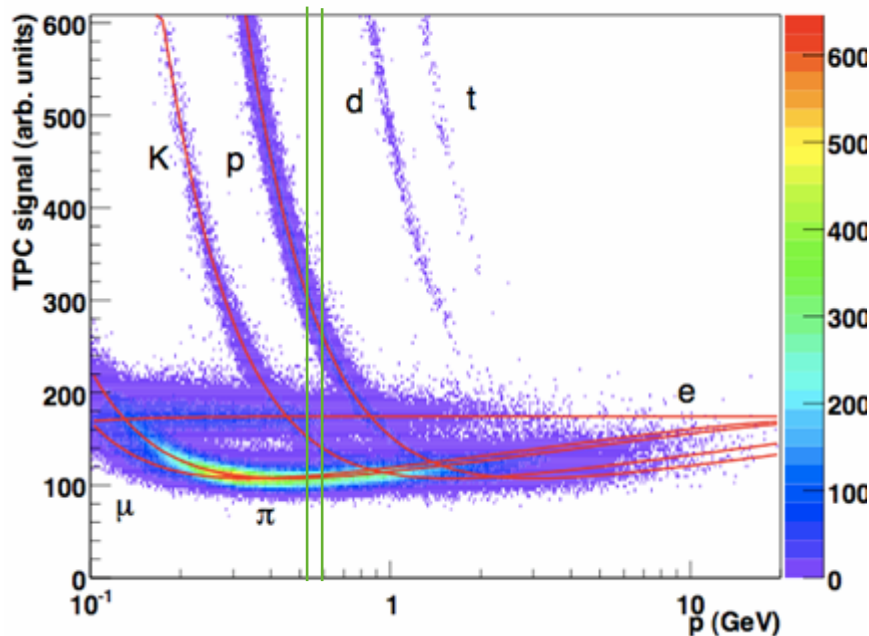
Phys.Rev.C79(2009) 014901

For large values of R_C , the particle ratios are very close to the Grand canonical description.
The strange particle ratio are a good observable to test the canonical description in pp at LHC

Charged kaons identification

Alexander Kalweit, TU Darmstadt

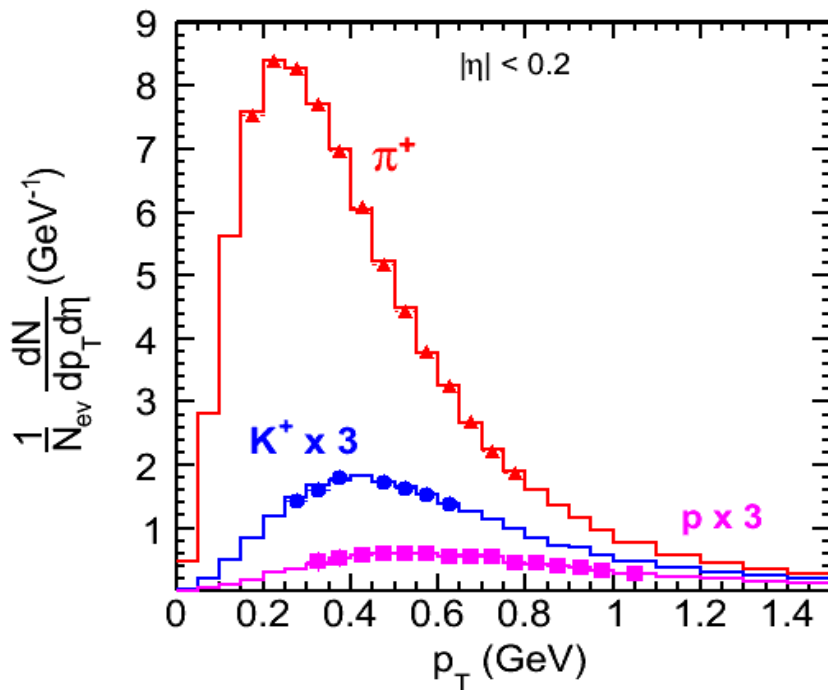
The ALICE TPC provides excellent particle identification in the low p_t region.
Extraction of K^+ and K^- yields by deconvolution of several gaussians.



Charged kaons production analysis

Alexander Kalweit, TU Darmstadt

- Spectra of charged kaons (+ protons and pions) in the low- p_t region:
 $p_t < 1.5$ GeV/c
- Spectra at higher p_t will be obtained with the help of the TOF and PID in the relativist rise with the TPC;



- ratios: K^+/π^+ , K^+/K^- , p/π^+ etc., as a function of p_t and multiplicity



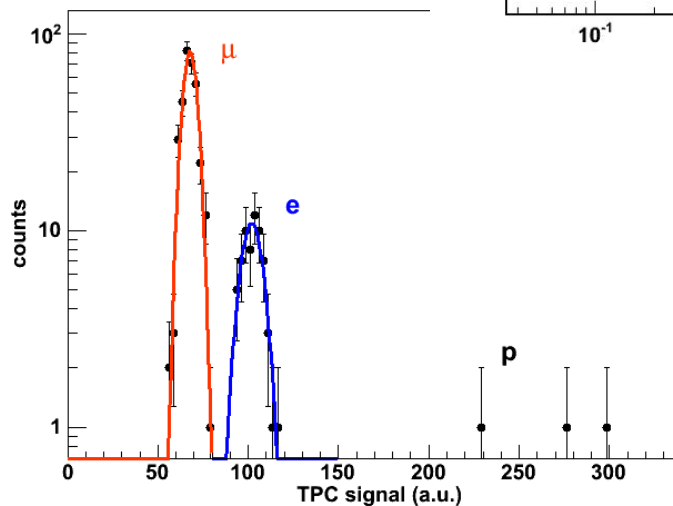
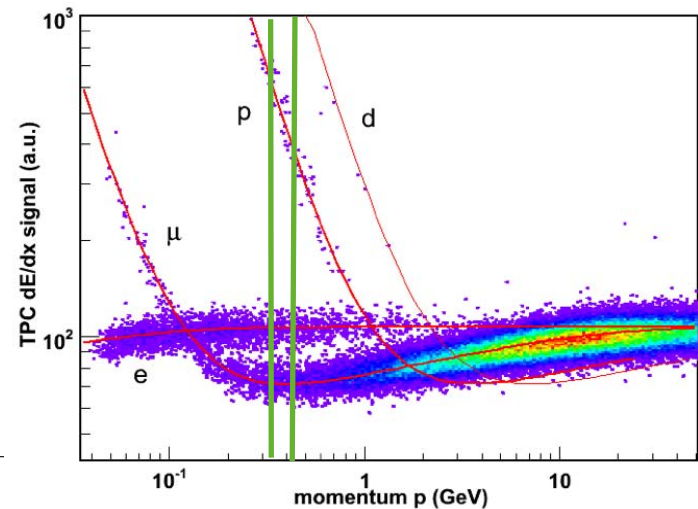
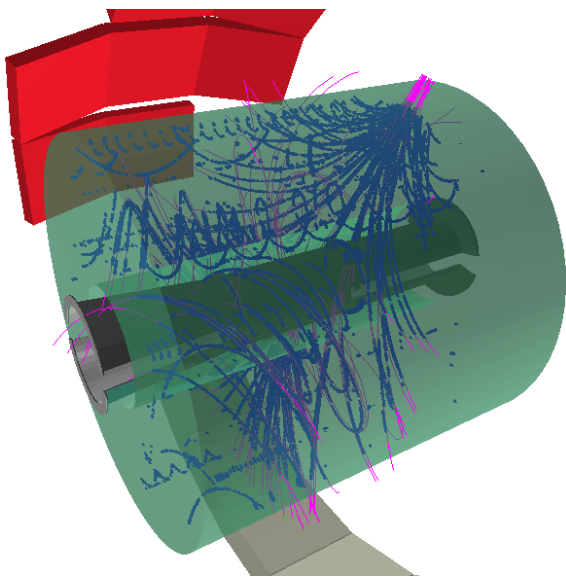
Ratio important to understand the statistical description of the collision;

p_t spectra to be fitted to extract parameters to describe the collision.

Some Results obtained with cosmics data

Commissioning of the TPC particle identification is well progressing;
Resolutions are sufficient for physics ($\approx 5.7\%$)

Alexander Kalweit, TU Darmstadt



Lambda and K_S^0 reconstruction

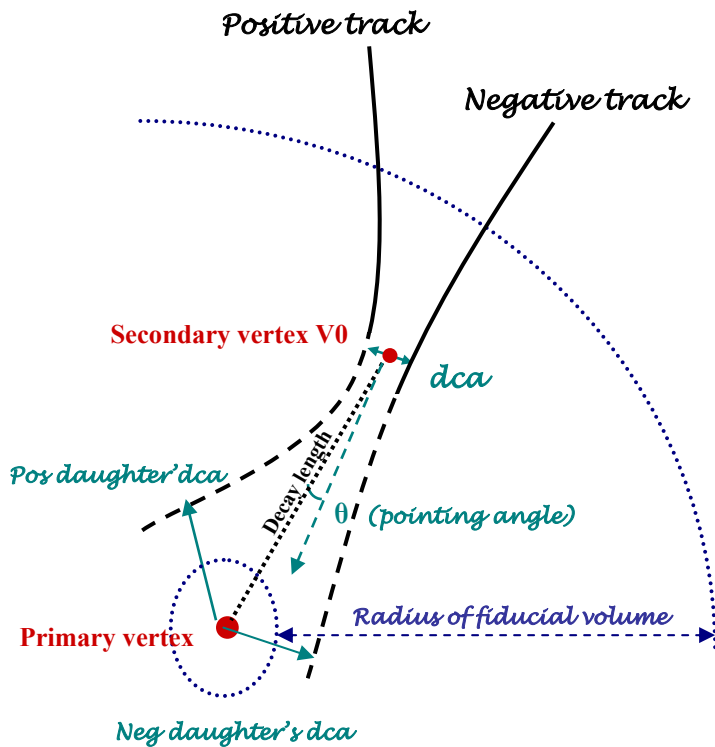
Two tracking strategies for V0 reconstruction have been developed:

On-the-fly V0 finder: During tracking

- Check the likelihood of having a V0 while adding clusters to the tracks.

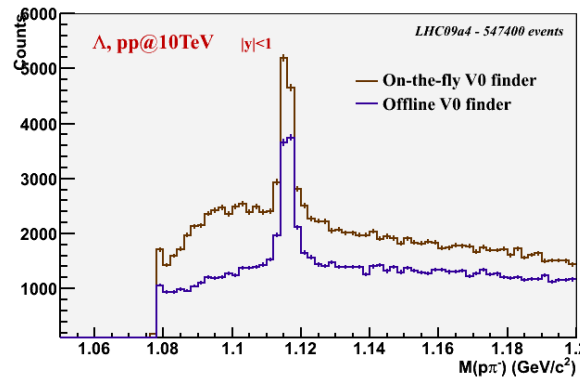
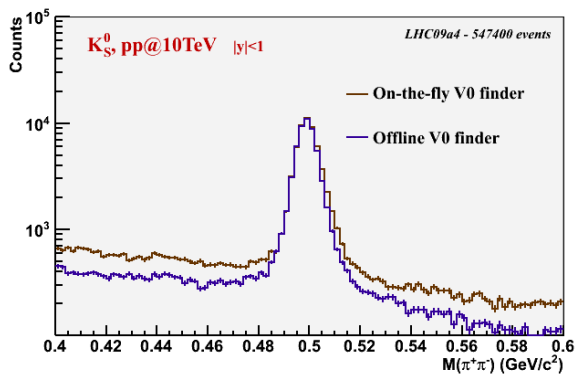
Offline V0 finder: After full tracking

- Selection of secondary tracks depending on their dca to primary vertex;
- Association of two opposite charged secondary tracks + topological cuts.



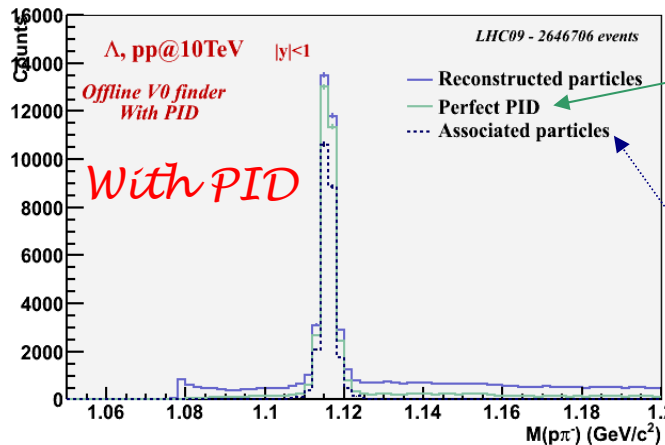
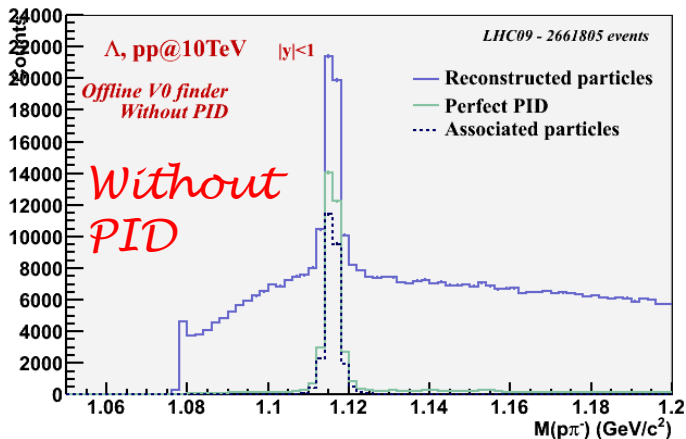
Lambda and K_S^0 reconstruction

- Straightforward signal extraction without further selection optimization



ALICE simulations $pp@10\text{TeV}$ -
Pythia 6.214 - 500K events

- Help of PID with the TPC. Improvements for the Λ identification mainly



Perfect PID:

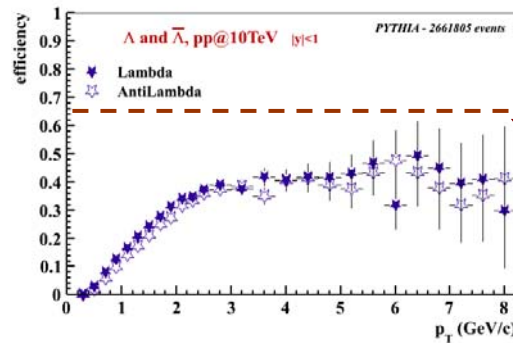
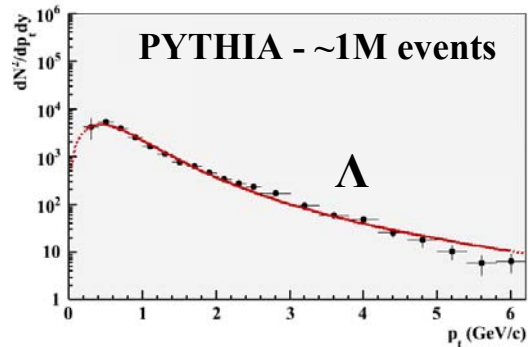
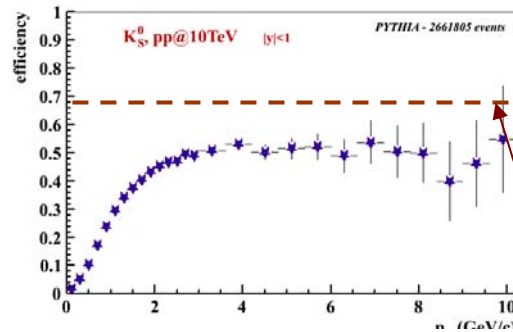
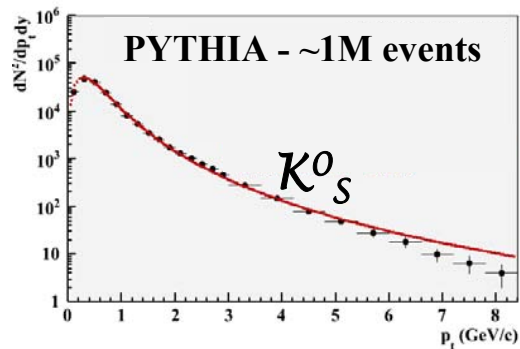
Nature of the daughters checked via Monte-Carlo information.

Associated particles:

Particles reconstructed having as Monte-Carlo partner: signal only !

Lambda et K_S^0 reconstruction

K_S^0 and Λ reconstruction extremely inefficient at very low p_t :



Λ reconstructed for $p_t > 0.4$ GeV/c
 K_S^0 reconstructed for $p_t > 0.2$ GeV/c

→ Extracting the yield requires to fit the spectra to be able to extrapolate at low p_t (Exponential fit)

Branching ratio

Expected LHC running conditions for 2009:

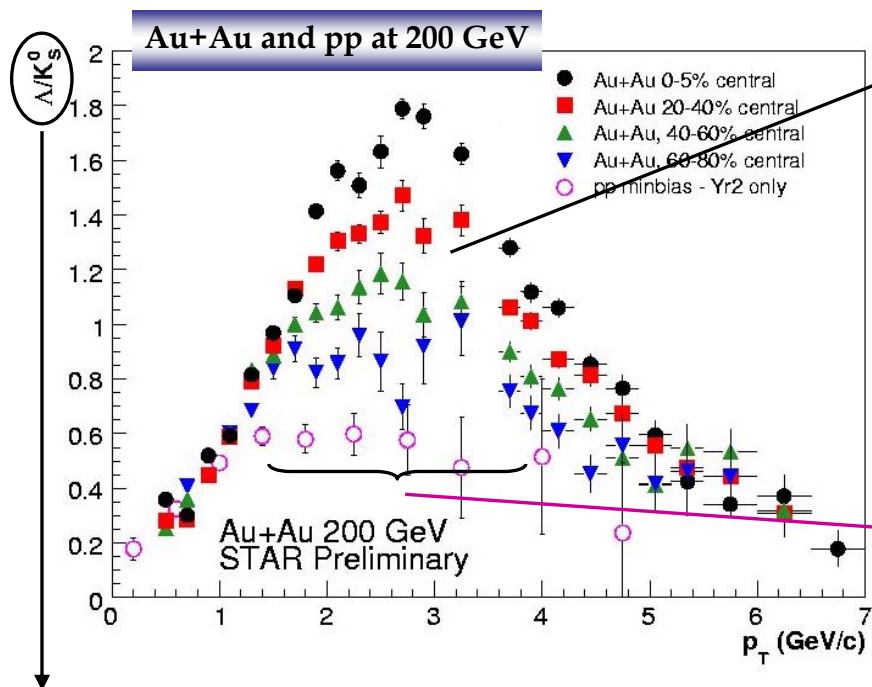
Proton-proton collisions at 900 GeV;
 Luminosity: $2.9 \cdot 10^{27} \text{ cm}^{-2} \cdot \text{s}^{-1}$
 Minimum-Bias event rate: 150 s^{-1}

At 900 GeV, we estimate that around 3 M events will be enough to reach a reasonably good statistic up to $p_t=8$ GeV/c for K_S^0 and up to $p_t=6$ GeV/c for Λ .

↻ 5 or 6 hours of data taking !

Strange particles to investigate the intermediate p_t region

Hadronisation mechanisms and dynamics at intermediate p_t via the study of Λ/K^0_s



STAR data have shown an increase of **baryon/meson ratio:**

- over a limited p_t range:

$$1,5 \text{ GeV/c} < p_t < 4-5 \text{ GeV/c.}$$

- in heavy ions collisions;

The more central is the collision, the stronger is the increase of the baryon/meson.

This phenomena is not observed in proton-proton collisions.

Phenomena observed for all the baryons and mesons (see p/π in PHENIX experiment) but strange particles are interesting because of their reconstruction techniques → large p_t range

→ Overlap of hard phenomena at high p_t and soft phenomena at low p_t ;

→ Coalescence models as a possible explanation of the baryon production in heavy ions collisions.

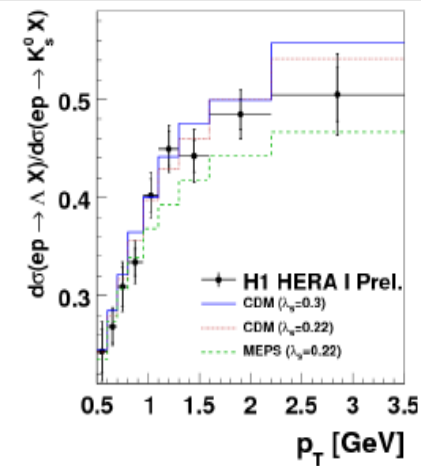
Baryon and meson production in pp collisions

Collisions at HERA: $e+p$ ($E_e = 27.6$ GeV, $E_p = 920$ GeV \rightarrow 319 GeV) \rightarrow

$e+p$: elementary collisions, only hadronisation by fragmentation !

The Λ/K_S^0 ratio in such collisions indicates the value that can be reached by the fragmentation process.

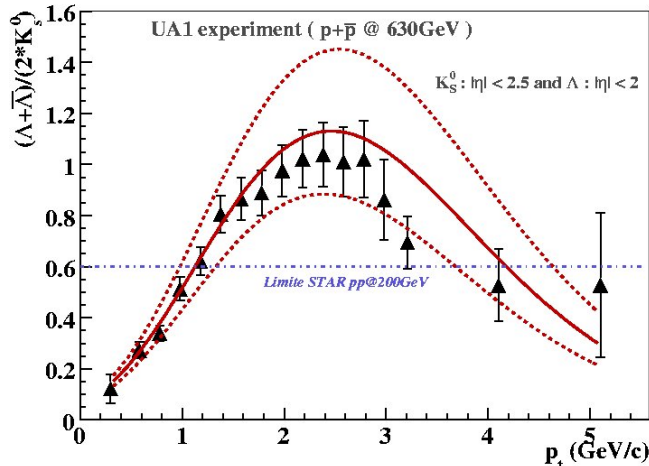
\hookrightarrow coherent with the amplitude of the Λ/K_S^0 ratio in $pp@200$ GeV at RHIC (hadronisation by fragmentation)



DIS 2008
A.Falkiewicz

In pp collisions at $\sqrt{s}=200$ GeV, the Λ/K_S^0 ratio was well below unity.

What is happening when the collision energy increases ?



At $\sqrt{s}=630$ GeV, the ratio is surprisingly high. However one cannot a priori invoke coalescence to explain this amplitude.

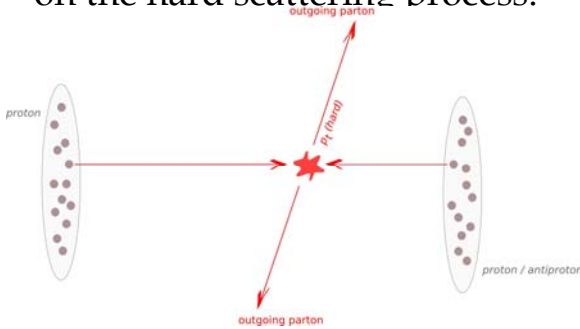
Which are the production mechanisms that take place in these pp collisions ?

What can we expect at LHC energies ?

Baryon/meson ratio: PYTHIA predictions at LHC energies

Pythia, a model based on the Lund fragmentation

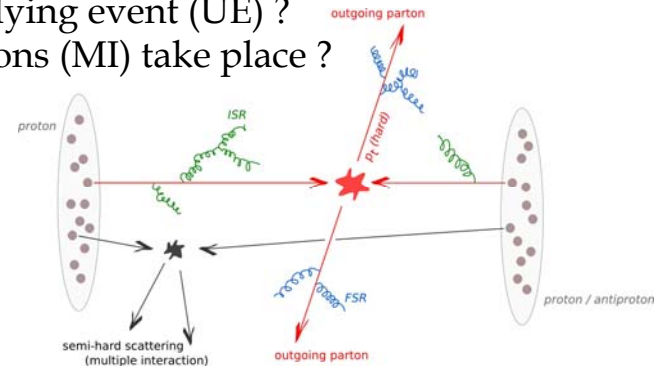
In pp collisions, we mainly focus on the hard scattering process:



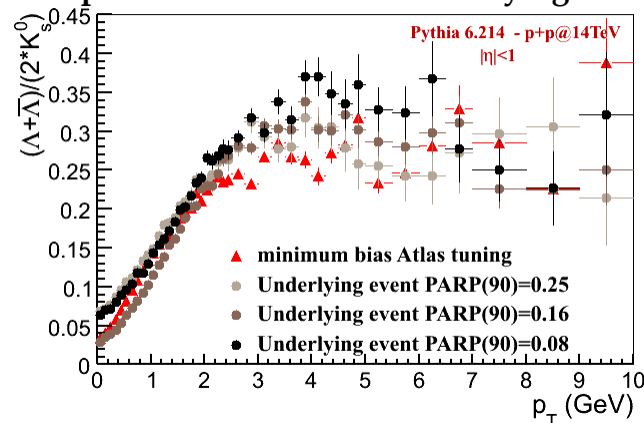
But is it enough to understand pp collisions at high energy ?

What about the underlying event (UE) ?

Can multiple interactions (MI) take place ?



Comparison Min-Bias and underlying event descriptions:

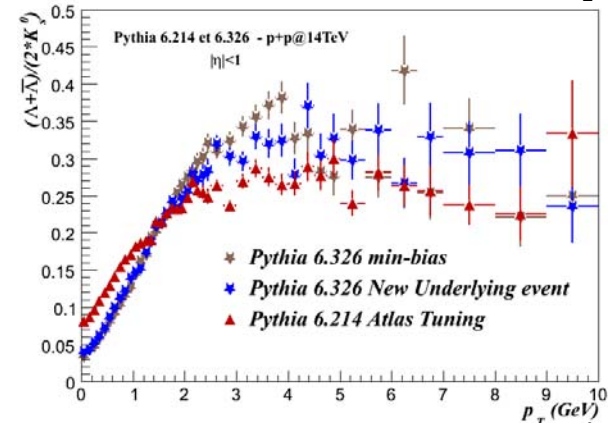


PARP(90): parameter that controls the rate of MI:

PARP(90) \uparrow = MI \downarrow

Values of PARP(90) chosen according to PYTHIA authors' suggestion.

Comparison PYTHIA 6.2 and 6.3 Min-Bias descriptions:



PYTHIA 6.2 \rightarrow 6.3: new treatment of UE (MI and ISR, FSR)

PYTHIA 6.2 with ATLAS tune: standard extrapolation for LHC, tuning used by the ALICE collaboration.

\rightarrow Λ/K_s^0 ratio far from the value already reached in UA1...

\rightarrow **Increasing the multiple interaction rate in the underlying event helps increase a bit the ratio**

But still Λ/K_s^0 ratio very low in PYTHIA, Missing a factor 2 at least...

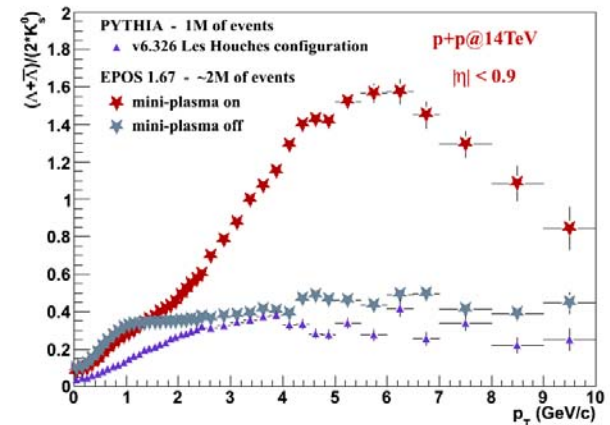
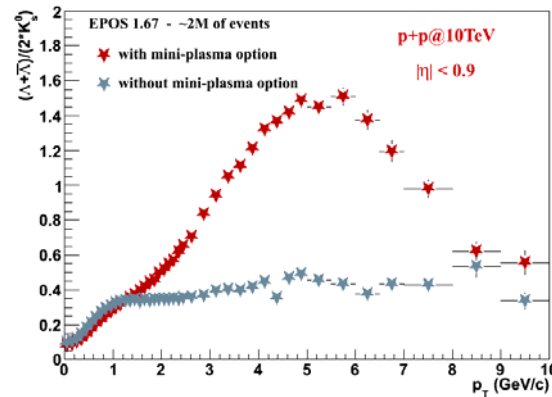
Baryon/meson ratio: EPOS predictions at LHC energies

EPOS: a multiple interaction model based on Pomeron exchanges

EPOS considers the possibility that collective phenomena take place in pp collisions (mini-plasma).

The effect of this collective phenomena over the ratio Λ/K_S^0 are dramatic:

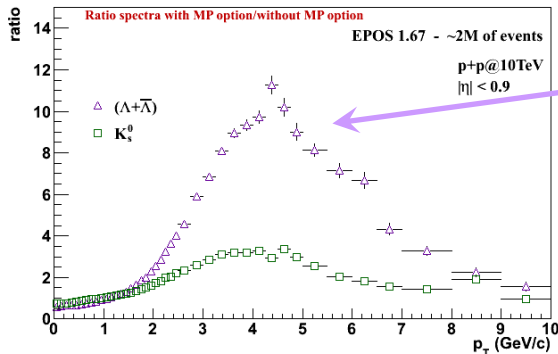
→ very strong increase of the ratio at intermediate p_t in pp at 14 TeV but also 10 TeV



The increase of the Λ/K_S^0 ratio is due to a very strong increase of the baryon production for $2 \text{ GeV}/c < p_t < 7 \text{ GeV}/c$.

If the data will show such an increase of baryon production, then according to EPOS that could be interpreted as the manifestation of collective phenomena:

- Are p-p collisions elementary ? Baseline for heavy ion collisions ...??
- Perspective of a new physics in p-p !



Baryon/meson ratio: EPOS predictions at LHC energy

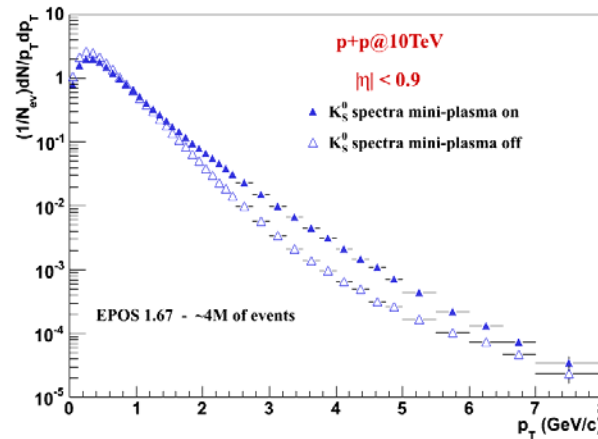
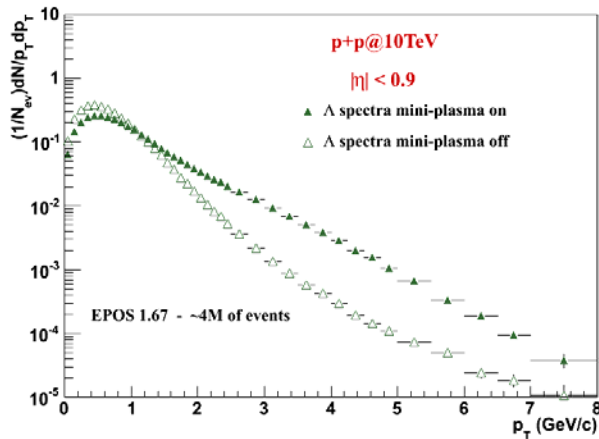
To understand a bit better the increase of the baryon/meson ratio in EPOS:

The total yield increases when mini-plasma is switched on

+

The shape of the p_t spectra changes: shift to higher p_t

	Mini plasma off	Mini plasma on
Yield Λ (per event)	0.25	0.31
Yield K_S^0 (per event)	0.98	1.0



Strangeness: an important role to play in LHC pp collisions

Strange particles are an interesting tool to investigate the nature of the system created in pp.

At LHC, strange particles analysis might lead us to renew our view of proton-proton collision:

➤ The strange particles ratio could be close to one obtained within a Grand-canonical description...

➤ Can collective phenomena take place in LHC pp collisions ?

The ratio Λ/K_S^0 is an efficient tool to analyse the hadronisation mechanisms and eventually the presence of collective phenomena. Possible variations of the ratio with multiplicity influence will be interesting to study.

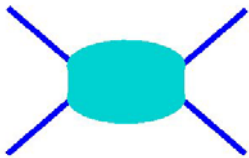
ALICE detector has the capabilities to reconstruct the strange particles with a good statistic and up to a quite high p_t .

Back-up

EPOS: a multiple interaction model

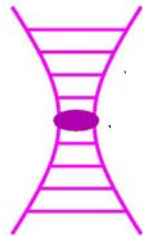
Interaction between partons are described by *Pomeron* exchange.
Multiple interaction phenomena are treated as elementary scatterings happening in parallel.

Soft pomeron:



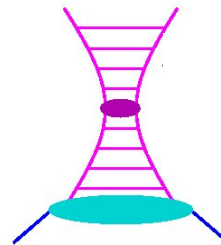
Pure non perturbative contributions to the process where all virtual partons appearing in the internal structure of the diagram have a virtuality $Q^2 < Q_0^2$.

Hard pomeron:

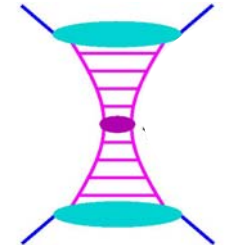
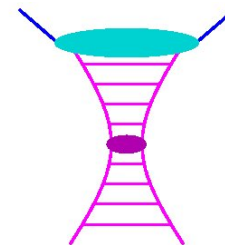


Interaction between two valence quarks

Semi-hard pomerons:



Interactions valence quark - sea quark



Interaction between two sea quarks

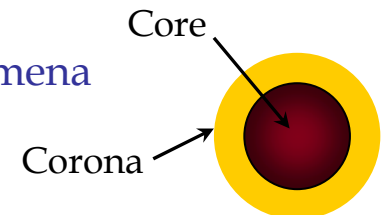
Pomeron hadronisation:

→ Within a string model

Mini-Plasma option:

Interaction zone divided in two parts:

- the core:
high density - collective phenomena
- the corona



pp interaction representation

