Some possible measurements using Λ0 from pp to ion-ion collisions

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March 12, 2009

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- Pt spectra
- Baryon stopping
- Polarization
- CP violation

Λ properties

Mass = 1115.683 ± 0.006 MeV/c^2

Lifetime τ = $2.632 \cdot 10^{-10}$ s $\rightarrow$ $c\tau$ = 7.89 cm

Studied decay mode:

- $p\,\pi^-$ 63.9 %

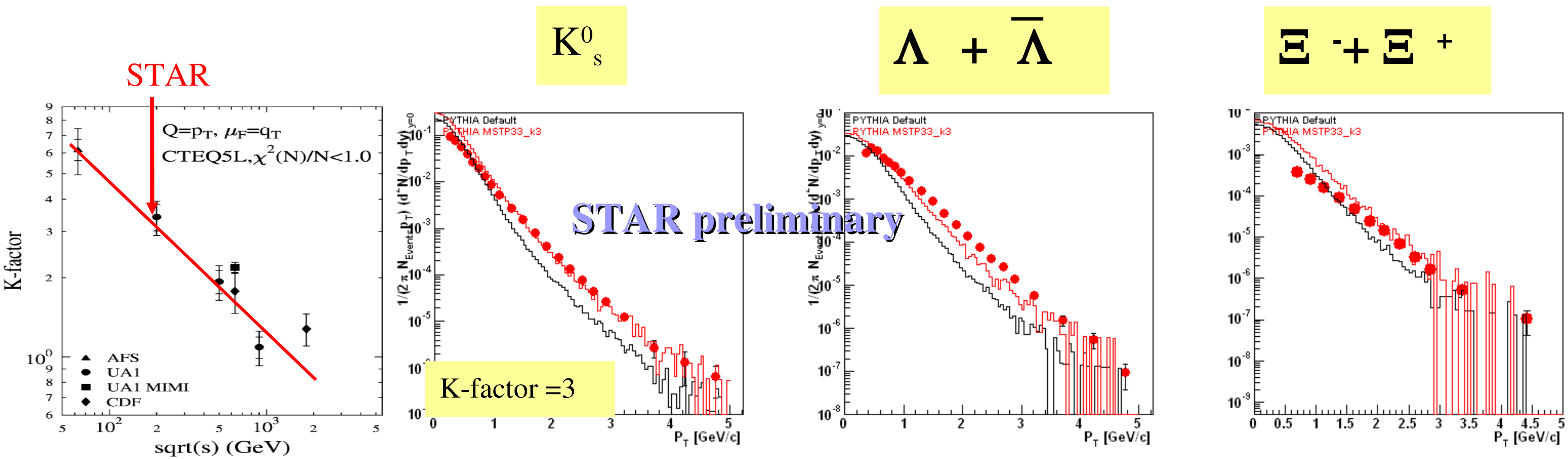
α = asymmetry coefficient

Decay asymmetry
$$\frac{dN}{d\Omega} \propto \left(1 + P_\Lambda \alpha \cos\vartheta ¿\right)$$

α = 0.642

Comparison of to LO pQCD (PYTHIA)

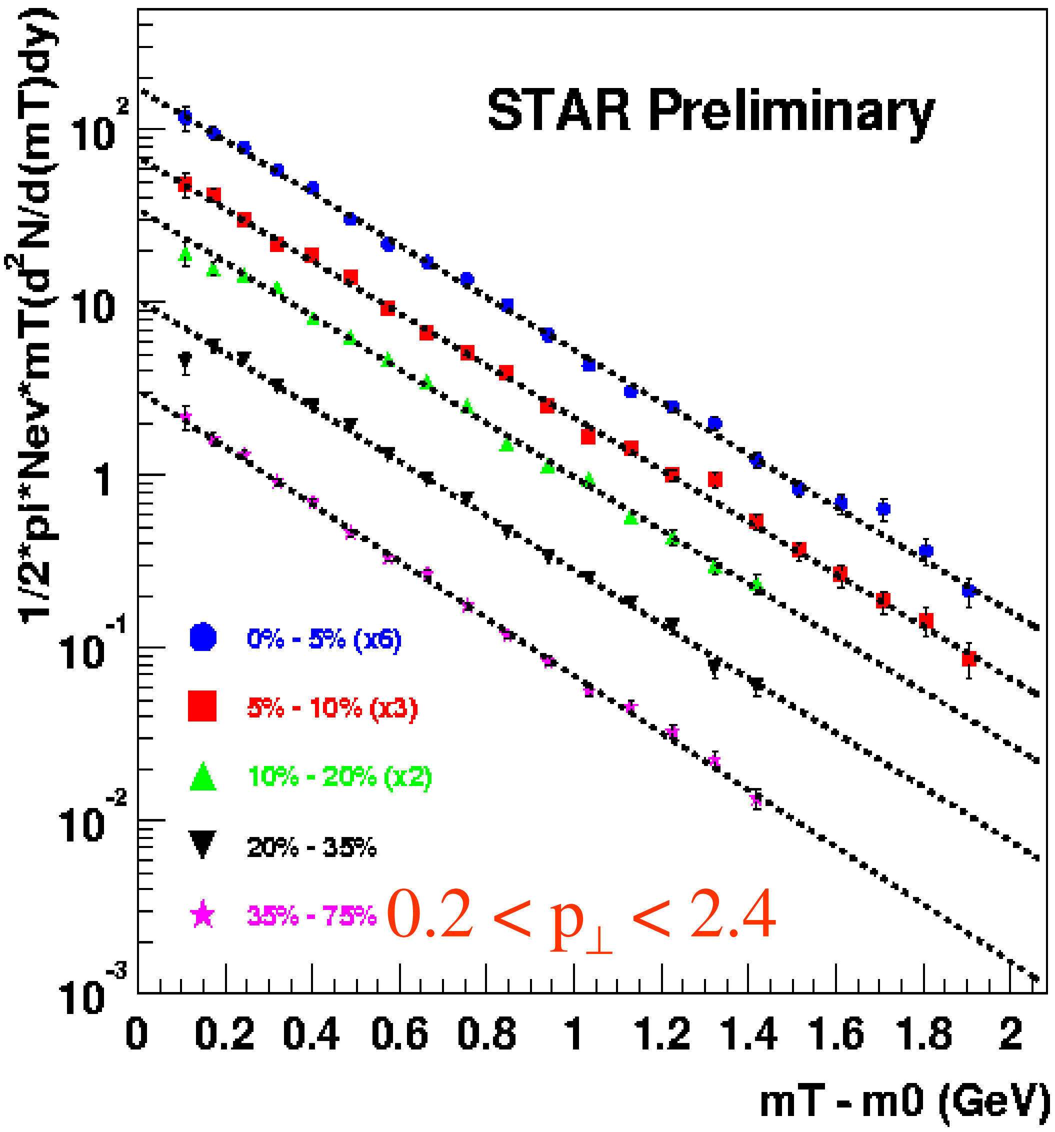
- **Starting point: PYTHIA v6.22 (MSEL1 – inelastic)**
- **First Tuning attempts:**
  - K-factor (to account for higher order processes)
  - Intrinsic k_T of partons (to account for initial state gluon radiation)



- Default PYTHIA does not describe STAR data well
- Tuned PYTHIA (K-factor=3) does a much better job for the kaons but still has problems with the strange baryons (Mark Heinz Moriod 05)

K^0_s $m_\perp$ Spectra

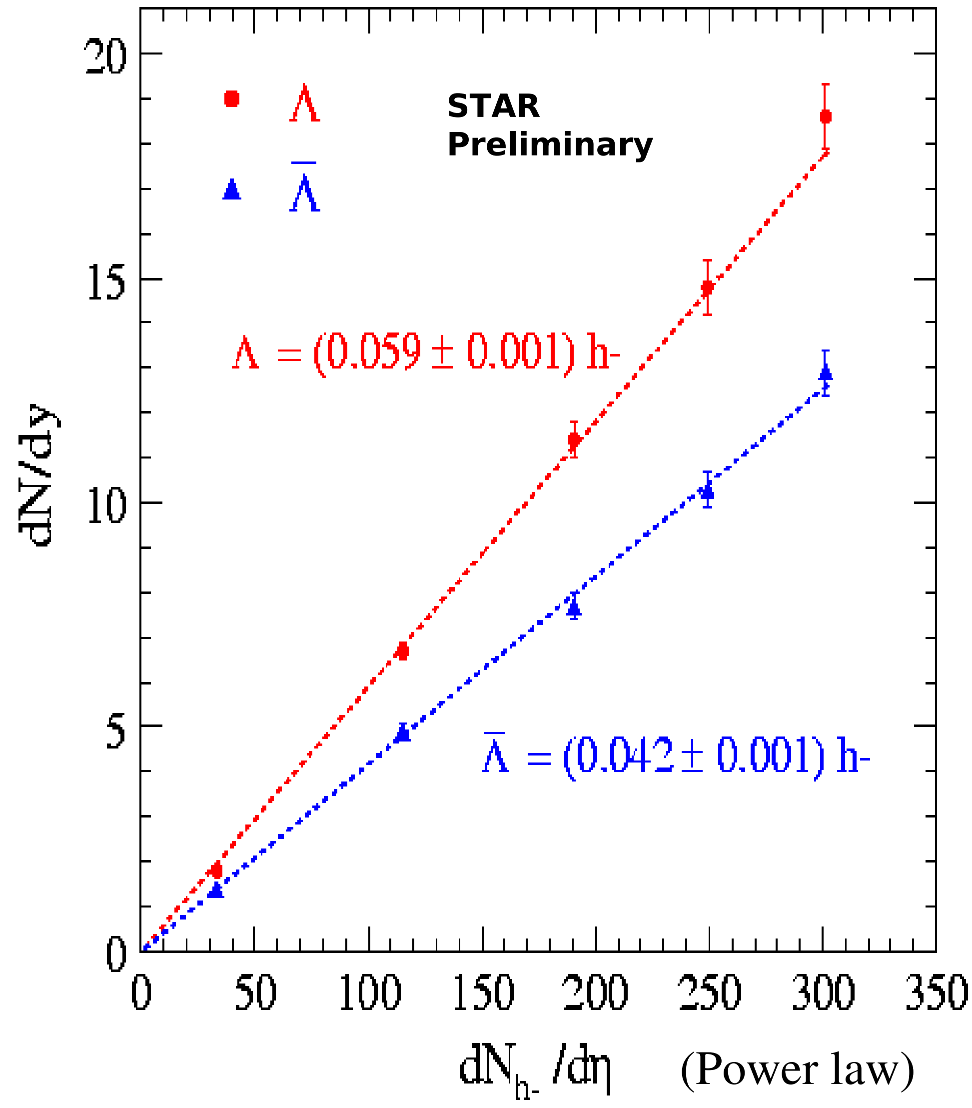
- K^0_s $m_\perp$ spectra versus centrality
- K^0_s spectra described well by a single exponential fit (shown).



Λ and $\bar{\Lambda}$ vs h^-

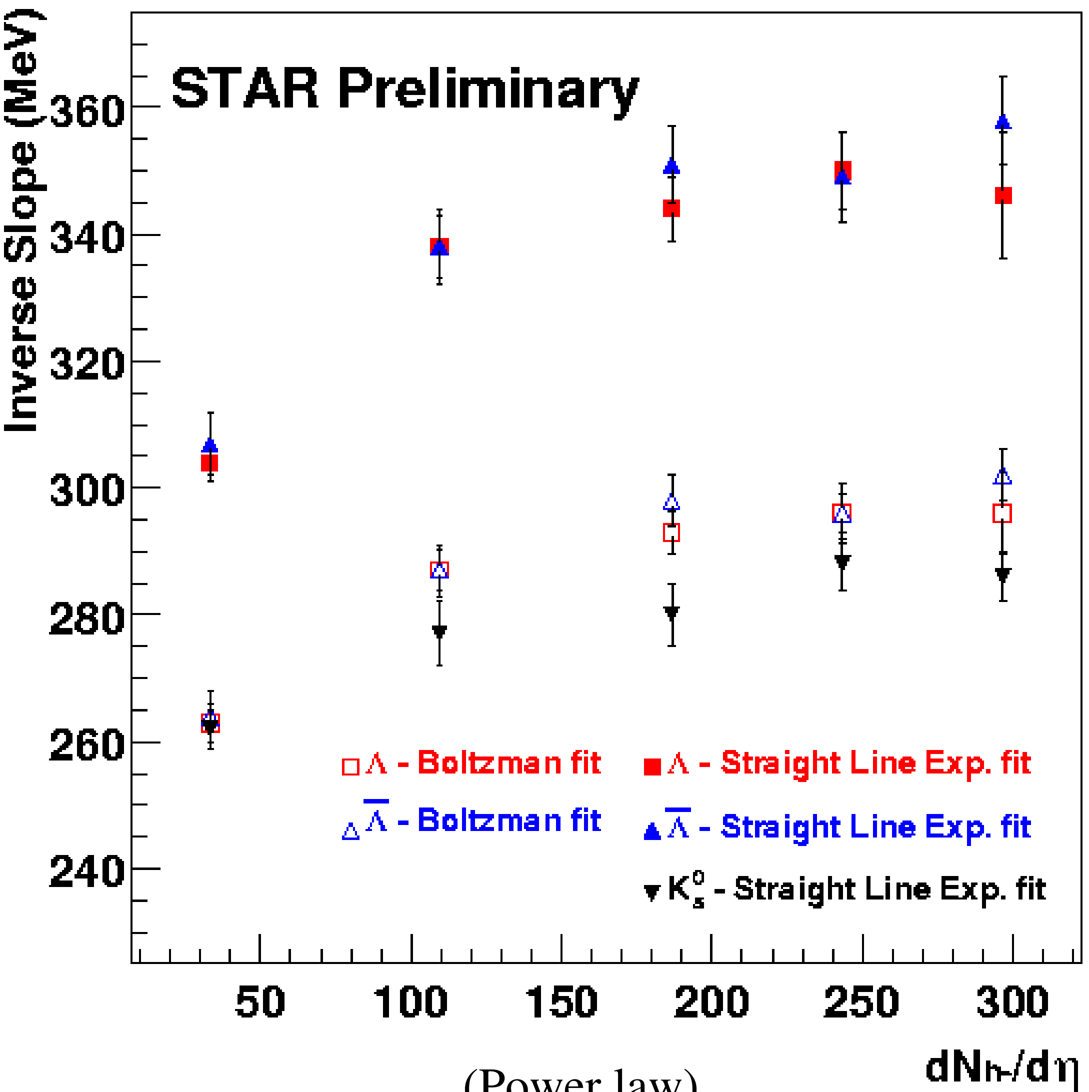
- As with the K^0_s, both Λ and $\bar{\Lambda}$ yields increase linearly with h^- as a function of centrality.

- Leads to an indication that strangeness production is saturated, even in the more peripheral collisions.



Λ , $\bar{\Lambda}$ and K^0_s Inverse Slopes

- Inverse slopes for $\bar{\Lambda}$ and Λ from both fits are consistent with each other.
- K^0_s slopes from a straight line exponential fit.
- Lower slopes in less central collisions - could indicate a smaller radial flow component.



(Power law)

Summary

- STAR is able to identify particle with high momentum (up 5GeV)
- Energy loss indicate motion in nuclear medium
- The Λ /Λ ratio of ~ 0.75 and p/p of ~ 0.65 means that there is little baryon stopping in the collision.
- The corrected Λ , Λ and K^0_s yields, relative to h^- production, indicate that strangeness production is saturated for all centralities, as was seen at the SPS.

Baryon Stopping

Baryon Stopping

Baryon production not well understood

Probing the stopping mechanism, measuring the asymmetry
(Predictions by B. Kopeliovitch et al. Z. Phys. C43,241 (1989).PLB446, 321 (1999) :

$$A_p \equiv 2 \times \frac{p-\overline{p}}{p+\overline{p}} \sim 5\%\, at\ LHC$$

$$A_{\Lambda} \equiv 2\ X\ \frac{\Lambda-\overline{\Lambda}}{\Lambda+\overline{\Lambda}}\ \text{٣٠}\ \%\ \text{at}\ LHC$$

Measurement of Λ : **study of the baryon production far from the fragmentation of initial baryons feed-down correction for proton investigation of mass dependence**

Measurement of Ξ, Ω : **feed-down correction for lambda mass dependence**

Strange particle production will be a drastic test for QCD inspired models

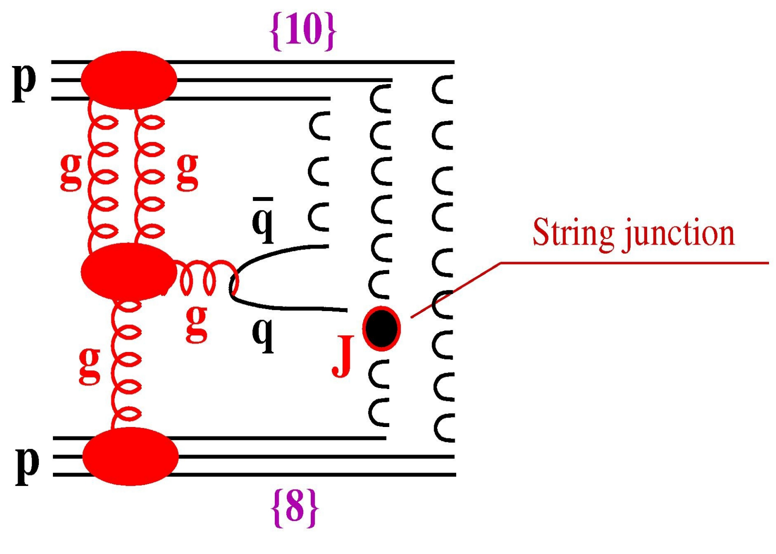
Who carry baryon number

- Standard point of view
  - quarks have baryon charge 1/3
  - gluons have zero baryon charge
- Baryon number is carried by quarks, not by gluons

It is not obvious

(B.Kopeliovich **et al. Z. Phys. C43,241 (1989).PLB446, 321 (1999)**)

- baryon number can be transferred by specific configuration of gluon field

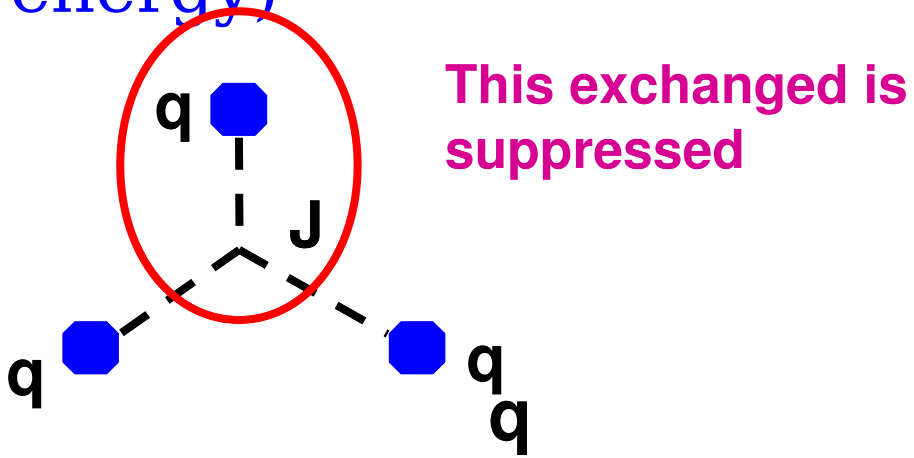


Exchange in t-channel

- Exchange of spin 1/2 (quark)

  $\propto \exp(-1/2\ \Delta y) \quad (\sim s^{-1/2})$

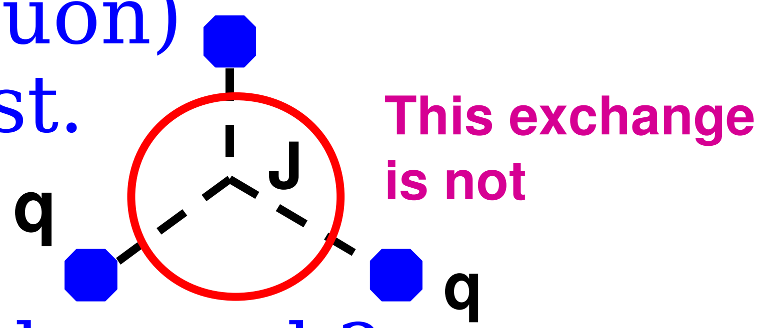
  - strong damping with rapidity interval (i.e. for annihilation with energy)



- Exchange of spin 1 (gluon)

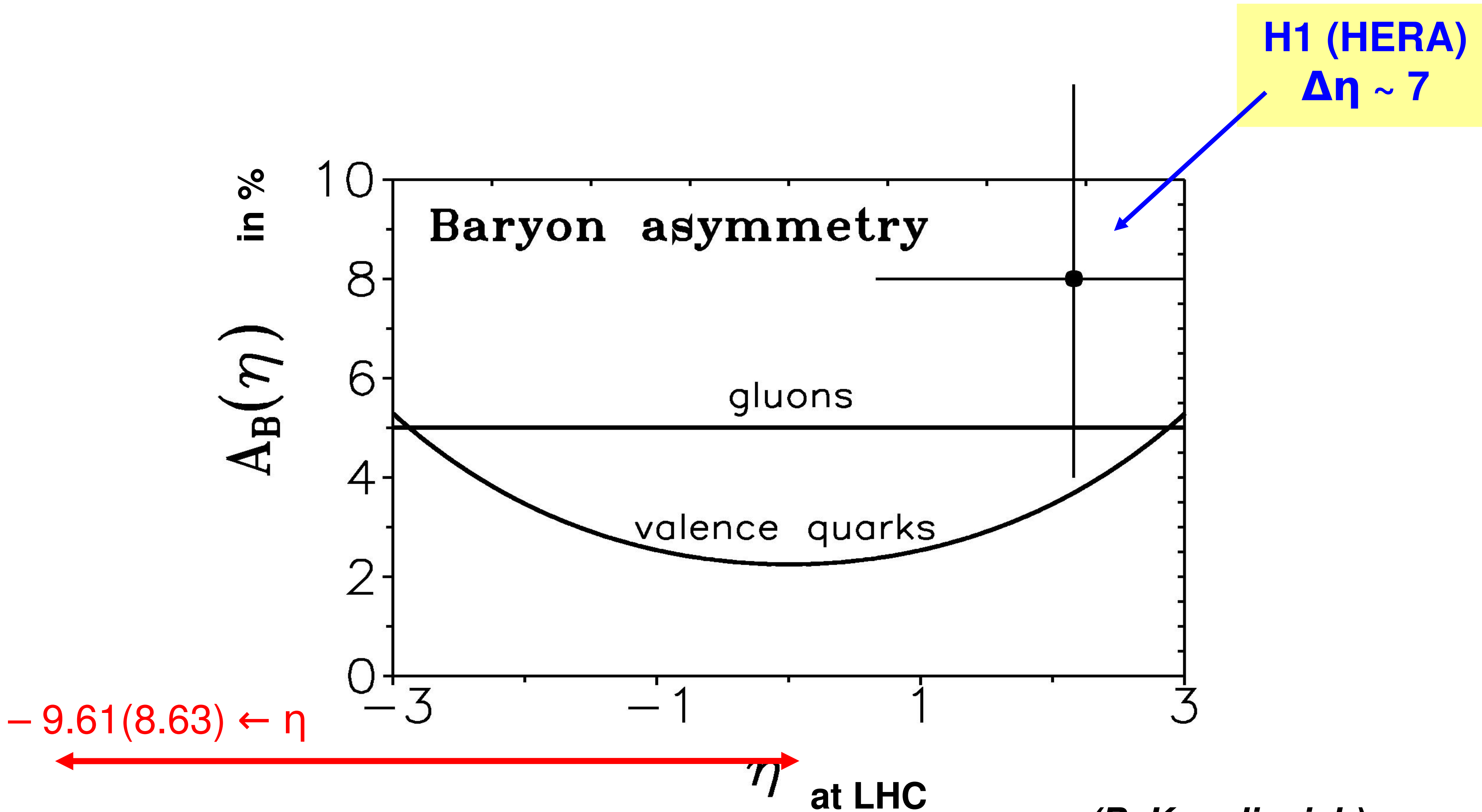
  $\propto$ const.

  - no damping at all



- Q: what is actually exchanged ?

Asymmetry A_B = 2 * (B – anti-B) / (B + anti-B)



(B. Kopeliovich)

Λ^0 Polarization

Introduction

One of the first proposed signatures to the production of a QGP
In relativistic Nucleus-Nucleus collisions was to study the change
in the polarization properties of Λ^0 hyperons as compared to that
Observe in pp collisions

The polarization effect was first observed in 1976 at FNAL in
300 Gev/c proton on Beryllium collisions.

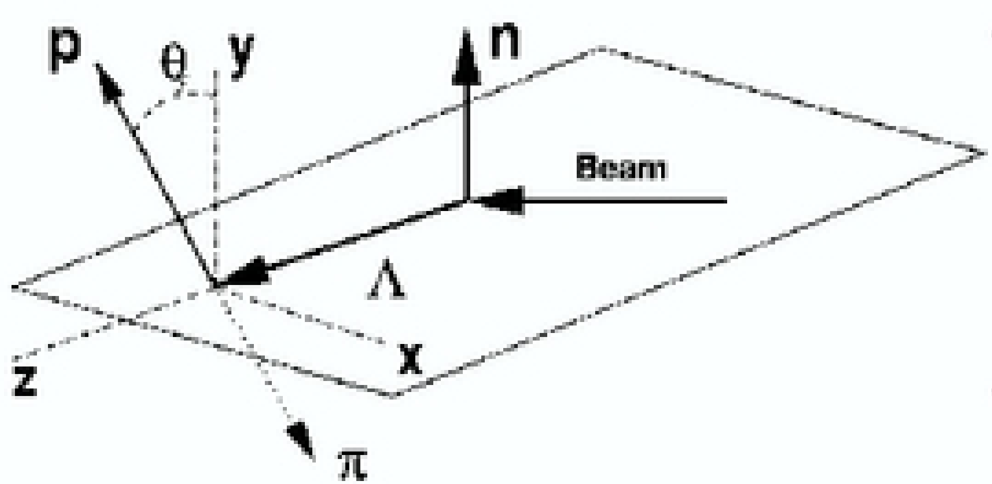
We study the polarization effect of lambda hyperon produced in
Au-Au collision by comparing the polarization in P-P collision.

Based on a recombination model of Lambda production
mechanism in Au-Au collision, a vanishing polarization of the
Lambda has been proposed as a possible signature of QGP

In the case of relativistic nucleus-nucleus collisions, the expectation
is that, Λ^0 coming from the zone where the critical density for QGP
Formation has been achieved. These plasma created Λ^0 should show
zero polarization.

$$P = \frac{|A_{\uparrow}|^{٢} - |A_{\downarrow}|^{٢}}{|A_{\uparrow}|^{2} + |A_{\downarrow}|^{2}}$$

The polarization es the difference in the Probability of producing Λ^0 with their spin pointing up or down respect to the production plane.



- Λ is produced with preferred spin direction perpendicular to reaction plane
- Angular distribution of proton in rest frame Λ is asymmetric:

$$\frac{dN}{d\cos\theta_y} = A(\cos\theta_y)(1 + \alpha P_y \cos\theta_y)$$

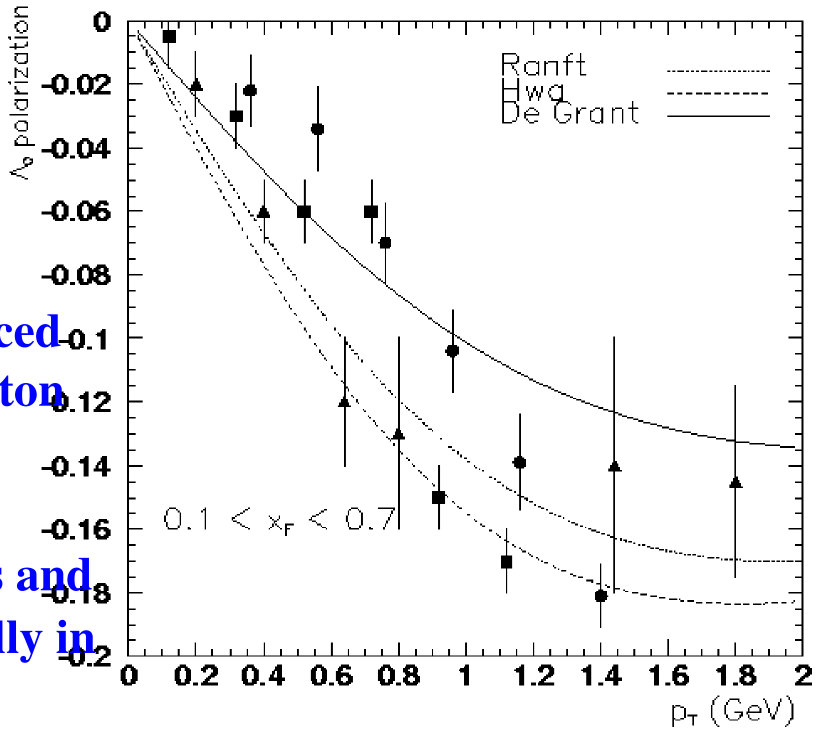
- with
  - α = Λ decay asymmetry parameter (=0.642)
  - $A(\cos\theta_y)$= detector acceptance
  - P_y = Transverse Polarization

Lambda Polarization in pp collisions

- **The Transverse Lambda polarization is known to be dependent on P_T (longitudinal momentum) and X_F (Feynman variable = $X_F = 2*P_L/Sqrt(s)$)**

- **In pp interactions, it is believed that Λo's are produced through the recombination of a sea s-quark and a proton valence diquark.**

- **Models of recombination of quarks to form baryons and mesons at low pT have been implemented successfully in the context of the parton model**

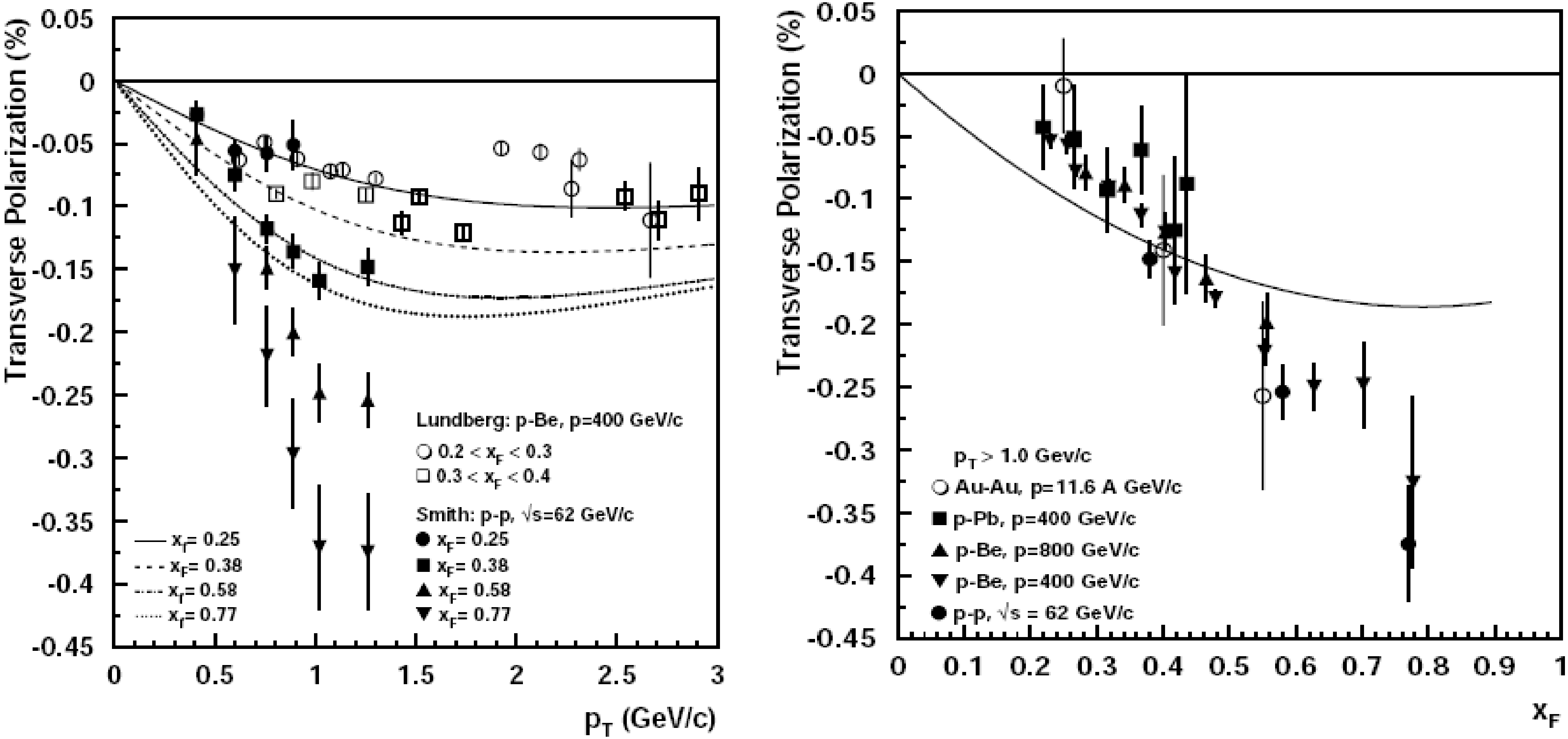


- **Recently there are studies on polarization as function of P_t Mx and E_Lambda in the reaction pp->p L0K+ (J. Félix, et al, E690 Experiment)**

Reaction pp ->pN* and N*-> Λ^o K+ Λ^0 polarization vector is proportional to N* polarization vector. (V.M. Castillo-VAllejo, J. Félix, V. Gupta, NPB 167, 118 (2007))

Characteristics

- **Polarization negatively**
- **Independent of the Energy**
- **At low pt increase with pt**

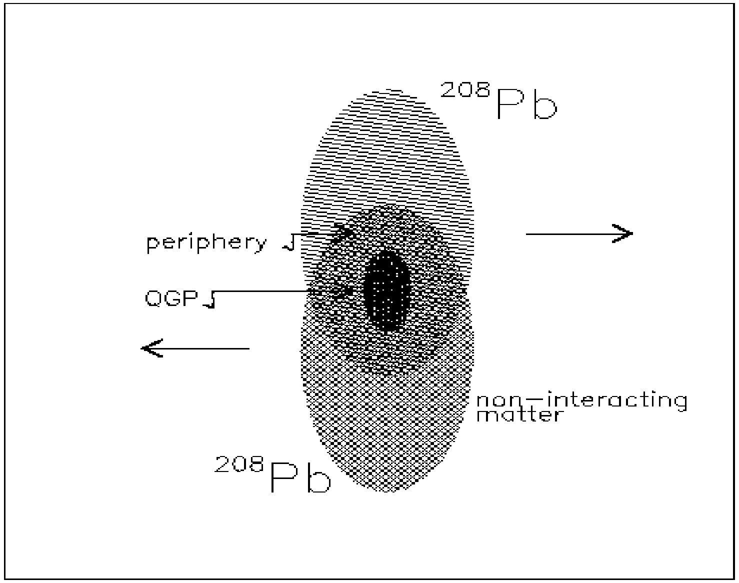


Dependence of the polarization on P_T (left) and X_F for P_T > 1 GeV/c (right). The predictions drawn are from the Thomas Precession model. With respect to the P_T -dependence the predictions are given for the four X_F values corresponding with the data. For the X_F dependence the model is calculated at P_T = 1 GeV/c.

Λ^0 Polarization in heavy-ions collisions

In a heavy-ion reaction, Λ_0's can be produced either by the coalescence of free quarks or by recombination-like processes (as in the case of p+p collisions) depending on whether or not the critical density for the production of a QGP is reached in the collision, respectively.

One can assume that Λ_0's are the sole products of the s-quark subsequent fragmentation. The important point to bear in mind is that these Λ_0's are expected to be produced unpolarized, as is the case of anti-Λ_0's produced in pp reactions.



Recombination

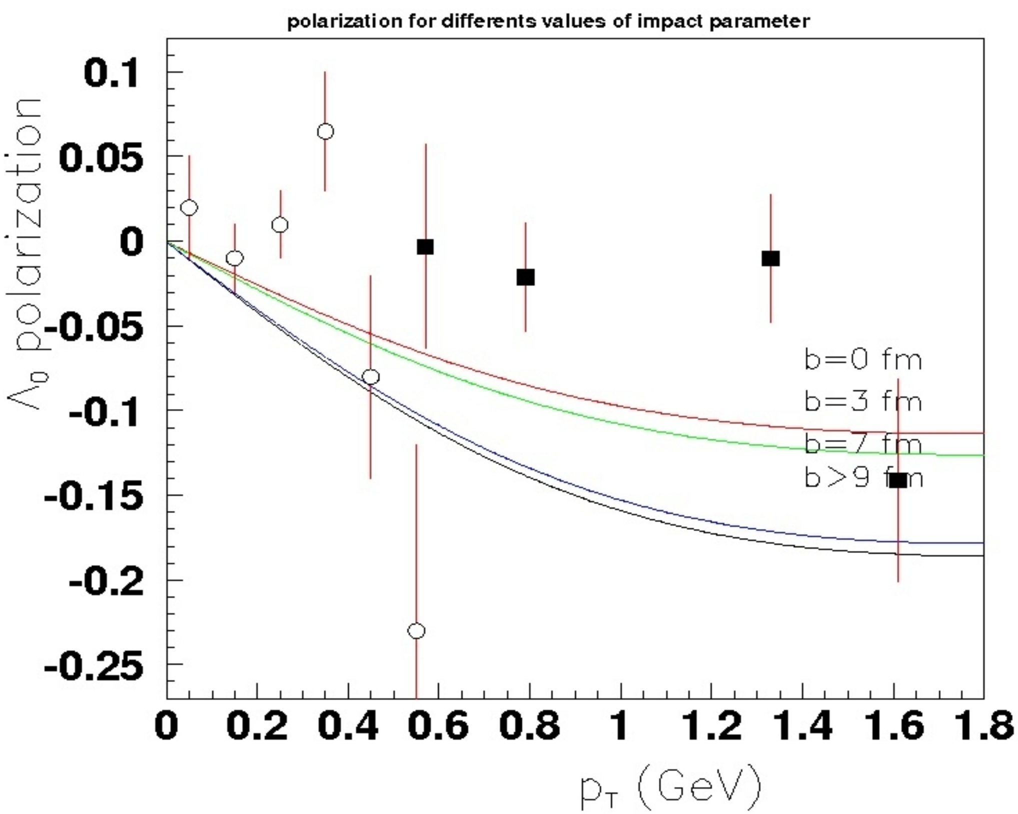
Recombination competes of ud diquarks provided by the interacting nucleons and s-quarks from the sea in the region where the critical density for QGP production is not reached. The combination of both effects produce a diminishing in the Λo polarization, as compared to p+p reactions given by:

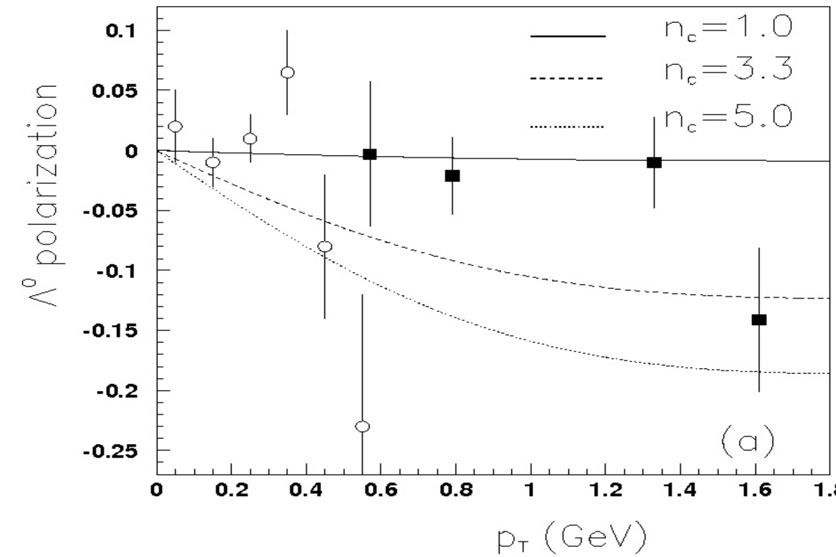
$$P = \frac{P_{rec}}{\left[\text{١} + f(b)\right]}$$

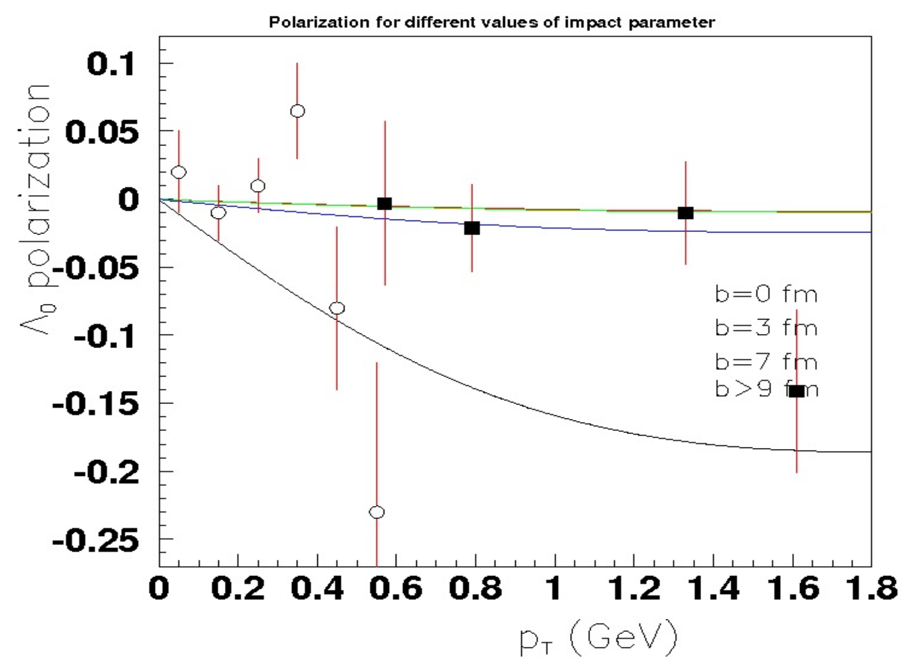
Where the function *f(b)*

$$f(b) = \left[\frac{d^{\text{٢}}\sigma_{\Lambda_0}^{QGP}}{d^2 b}\right] / \left[\frac{d^2\sigma_{\Lambda_0}^{REC}}{d^2 b}\right]$$

is the ratio between the Λo production cross sections in a QGP and recombination processes, as a function of the impact parameter *b* of the collision.


polarization for differents values of impact parameter
Λ_0 polarization
p_T (GeV)
b=0 fm
b=3 fm
b=7 fm
b>9 fm
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8

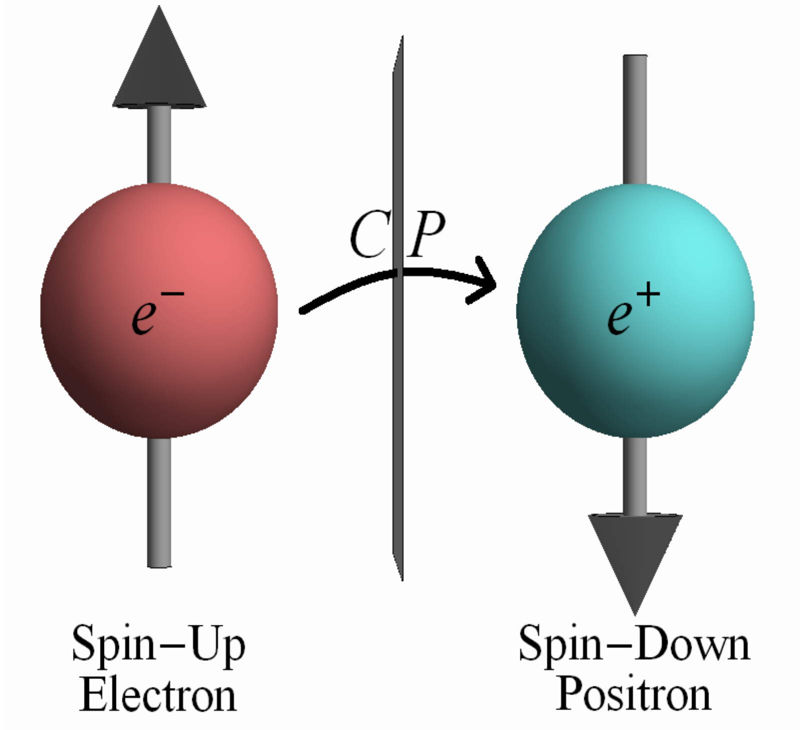

n_c=1.0
n_c=3.3
n_c=5.0
Λ^0 polarization
p_T (GeV)
(a)
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8


Polarization for different values of impact parameter
Λ_0 polarization
p_T (GeV)
b=0 fm
b=3 fm
b=7 fm
b>9 fm
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8

CP VIOLATION

Is a violation of the combination of C and Paraty. CP symmetry states that the laws of physics should be the same if a particle is interchanged with its antiparticle The discovery of CP violation in 1964 in the decays of neutral kaons resulted in the Nobel Prize in Physics in 1980 for its discoverers James Cronin and Val Fitch. It plays an important role in both in the attempts of cosmology to explain the dominance of matter over antimatter in the present Universe, and in the study of weak interactions in particle physics.

Why does the universe have so much more matter than antimatter?



The operator CP reverses the spatial axes and takes particles to antiparticles. Here a spin-up electron becomes a spin-down positron.

CP violation

Accessible signature for CP violation in spin ½ hyperons is the comparision of the angular decay distribution of the daughter baryon with that of the conjugate antibaryon in their two body noleptonic weak decay.

Decay asymmetry

$$\frac{dN}{d\Omega} = A\left(1 + P_{\Lambda}\,\alpha \cos\vartheta\right)$$

$$\alpha = 2\mathrm{Re}\frac{(S * P)}{S^{2} + P^{2}}$$

S and P the usual momentum angular Amplitudes.

$$\bar{\alpha} = -\alpha$$

$$A = \frac{\bar{\alpha} + \alpha}{\alpha - \bar{\alpha}}$$

CP symetry is violated if there are difference in the magnitude of the of this α's

Some Conclusions

- Statistical models describe anti-baryon over baryon ratios, which yields constraints on the thermal freeze-out temperature and the baryon-chemical potential. This also allows us to determine an expansion velocity in a dynamical picture .

- They also do well for Kaon and Λ ratios which dominate strangeness production and seem to indicate strangeness saturation. These singly strange particles carry remnant quarks and/or valence di-quarks and are thus dependent on the baryon-chemical potential.

- The multistrange ratios still seem to indicate strangeness enhancement and are not described by the statistical models. This indicates an additional production mechanism which should be even stronger for the Omegas.