Λ^0 Polarization and spin alignment of vector meson(K^{*0}) in p-p and ion-ion collisions

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OUTLINE

- **Λ^0 Polarization**
  - *Production in pp collisions*
  - *Production in AA collisions*
- **Spin alignment of vector meson (K^{*0})**
  - *Theory*
  - *Experiment*
  - *Our model*
- Conclusions

Motivation

Polarization measurements could become an important tool to identify the production of Quark-Gluon Plasma (QGP). Λ^0 *Polarization found at RHIC (nucl-ex/07051691 star collaboration)*

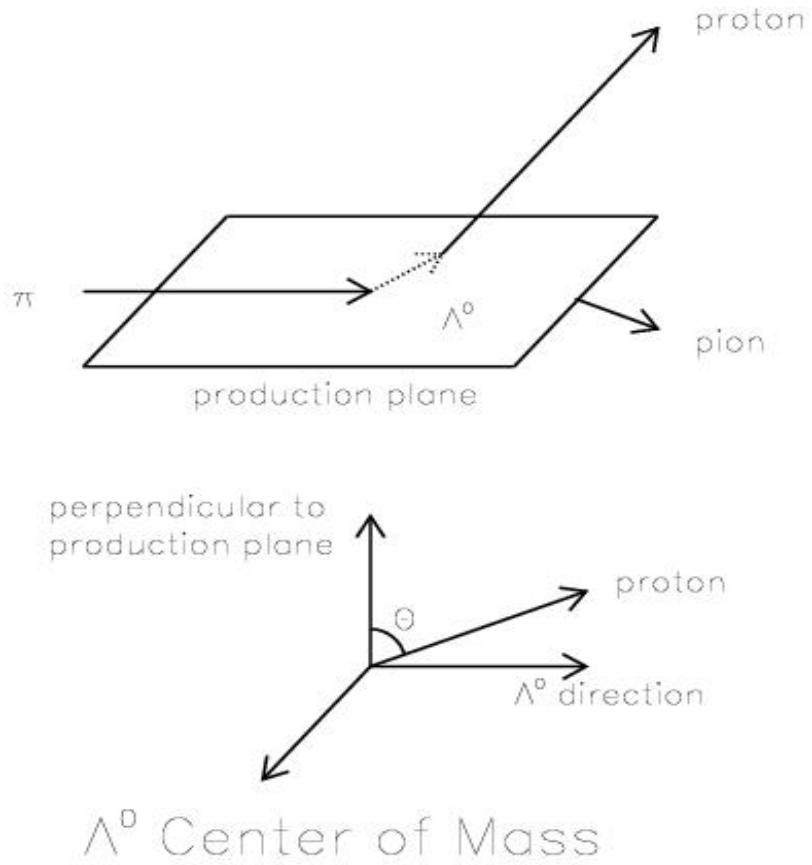
A change in polarization as a function of the centrality of the collision, compared to that observed in pp interactions, can be associated in a change in this hyperon's production mechanisms, from ordinary recombination-like processes to quark coalescence. *Same production processes, produce spin alignment of vector mesons like* K^{*0} ***Φ RHIC.***

Λ^0 Production

It is known that the spin of Λ^0 is carried by the s quark. Its preferred decay mode, Λ^0 -> рл- (64% branching ratio), is mediated by the weak interaction.

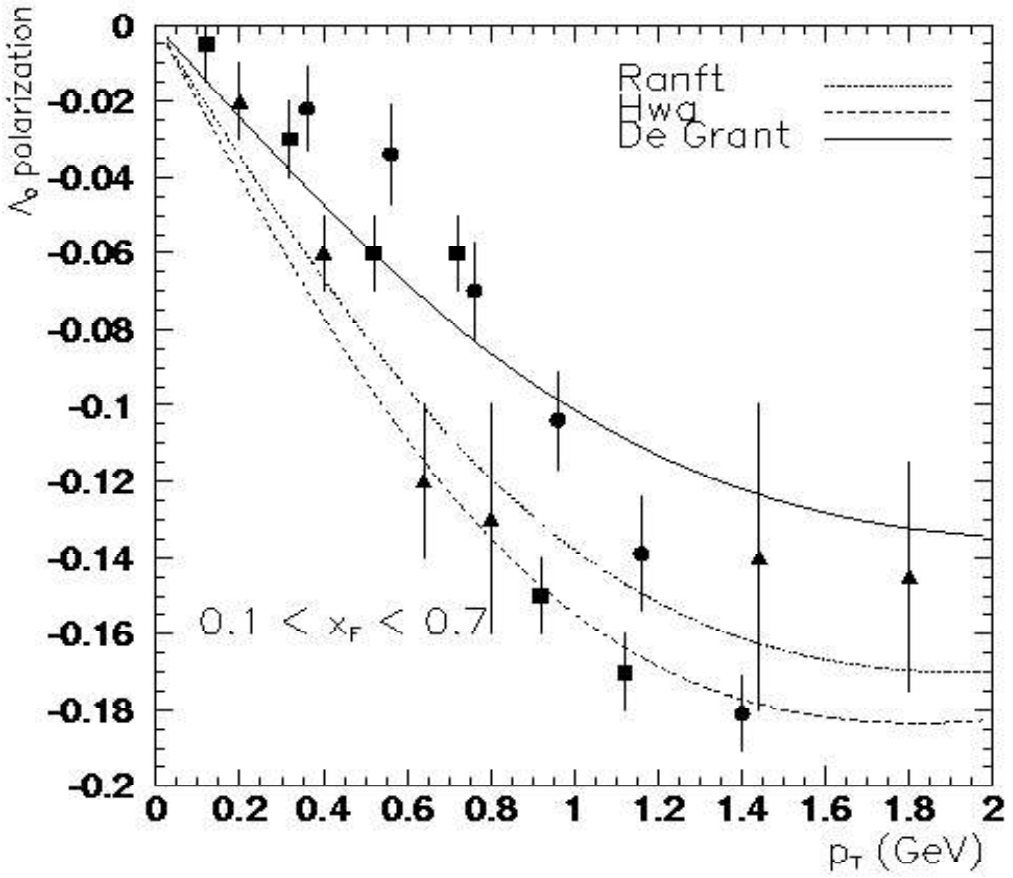
The polarization is the difference in the probabilities of producing Λ^0's with their spin pointing up or down with respect to the production plane,

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

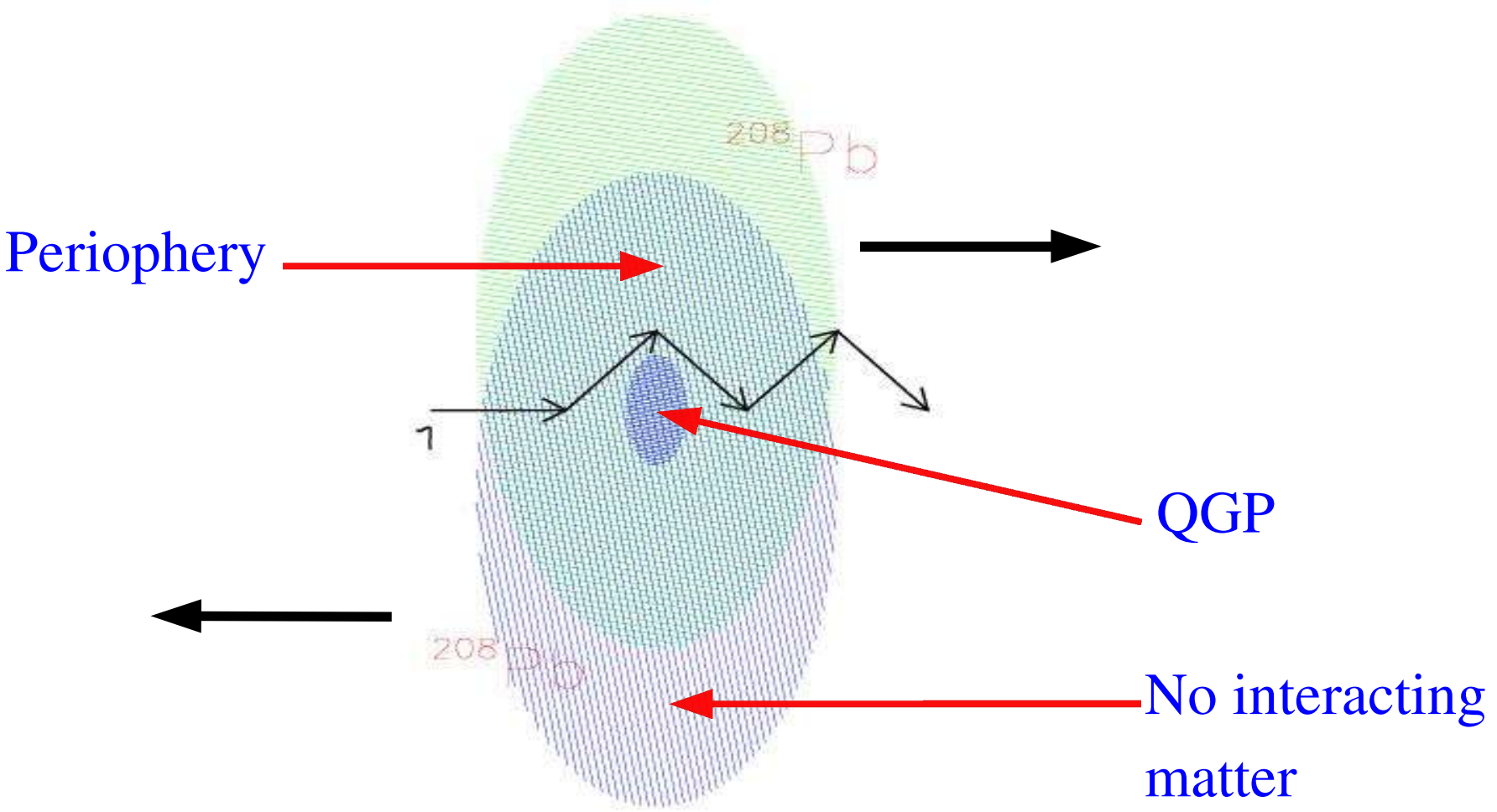


Λ^{o} Polarization in pp collisions

In pp interactions, it is believed that Λ^{o}'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 p_T have been implemented successfully in the context of the parton model



Polarization in Heavy Ion Interactions



Λ^{o} Polarization in heavy-ions collisions

In a heavy-ion reaction, Λ^{o}'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^{o}'s are the sole products of the s-quark subsequent fragmentation. The important point to bear in mind is that these Λ^{o}'s are expected to be produced unpolarized, as is the case of anti-Λ^{o}'s produced in pp reactions.

Polarization

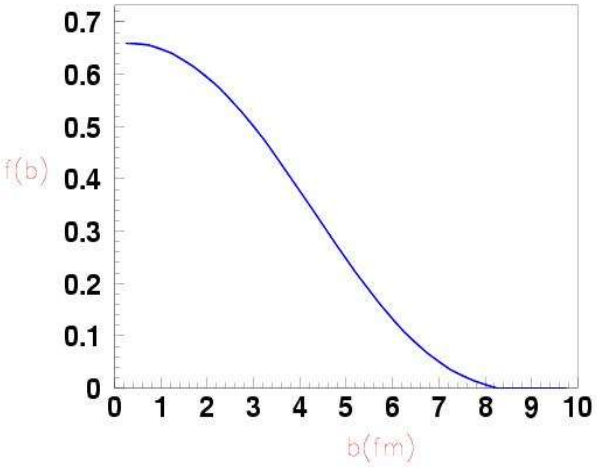
Recombination competes of ud diquarks provided by the interacting nucleons and s-quarks from the sea in the region where the critical density for QGP production is not reached.

The combination of both effects produce a diminishing in the Λ^0 polarization, as compared to p+p reactions given by:

$$P = \frac{P_{rec}}{\left[1 + f(b)\right]}$$

From recombination

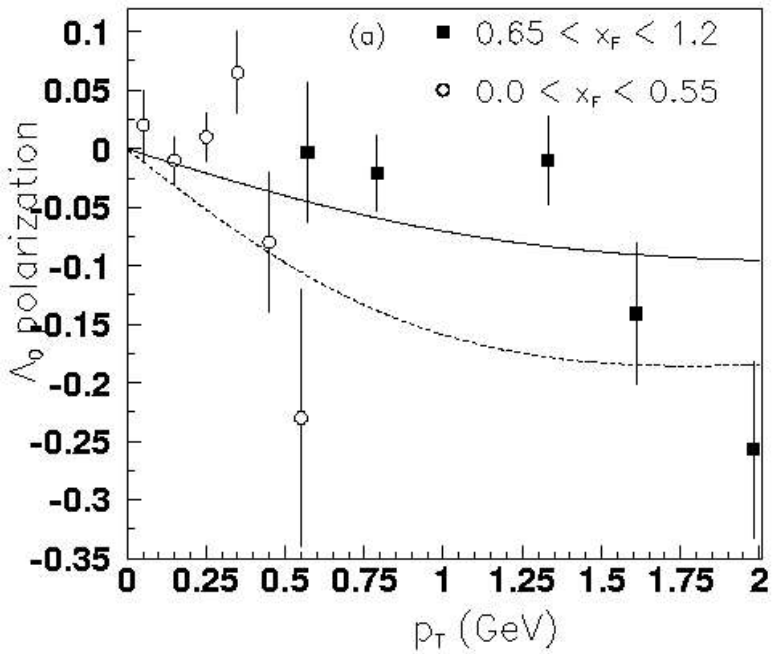
Fron QGP

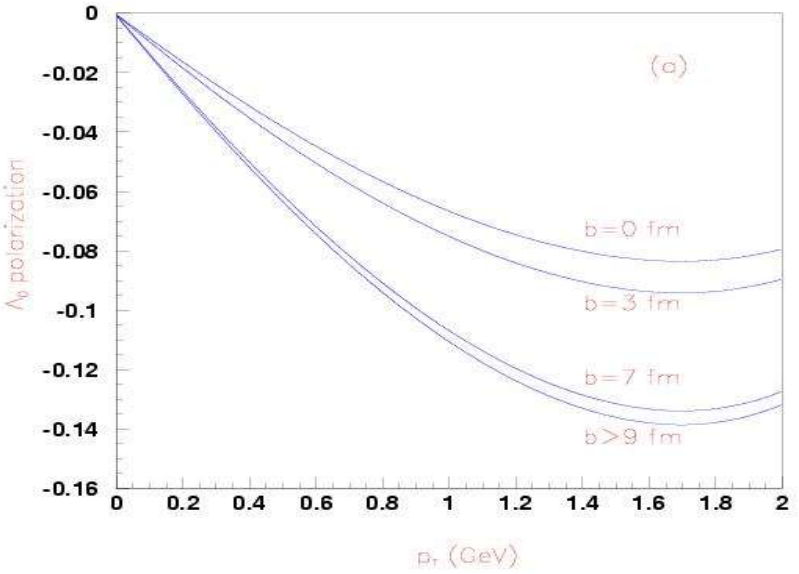


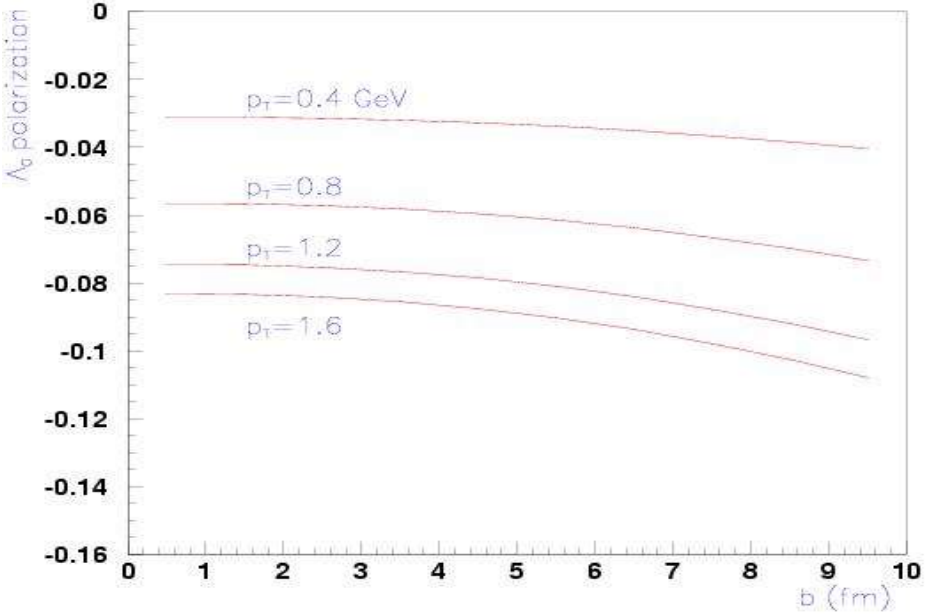
Where the function $f(b)$

$$f(b) = \left[\frac{d^2\,\sigma^{QGP}_{\Lambda^0}}{d^2 b}\right] / \left[\frac{d^2\,\sigma^{REC}_{\Lambda^0}}{d^2 b}\right]$$

is the ratio between the Λ^0 production cross sections in a QGP and recombination processes, as a function of the impact parameter b of the collision.







Polarization in Pb-Pb collisions for an impact parameter b=0, at low center of mass energy for two ranges in x_F: continuous line for $0.0 < x_F < 0.50$ and dashed line for $0.5 < x_F < 1.0$. Experimental data are from E896 colaboration.

Right picture shows the polarization (in the QGP zone) as expected in ALICE.

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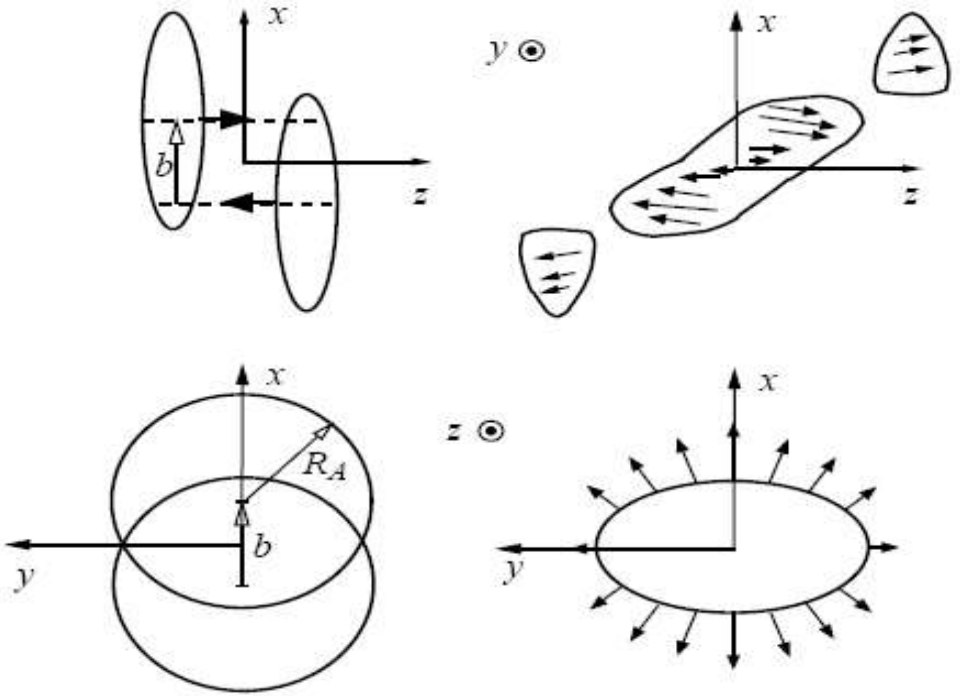
Spin alignment of vector meson (K^{*0}) in Heavy-Ion Collisions

- Theory
- Experiment ρ_{00} with respect to reaction plane

Introduction

- Spin alignment of vector mesons is a unique probe of particle production and dynamics[1,2]

1. Orbital angular momentum → spin?
2. Coalescence/Fragmentation of polarized quarks?
3. Contributions to the significant collective flow observed at RHIC?



1. Z.T. Liang and X.N. Wang, PRL 94 102301 (05), PRL 96 039901 (06), PLB 629 (05) 20-26;
2. S.A. Voloshin nucl-th/0410089.

Introduction

- Spin alignment of vector mesons is described by the spin density matrix:

$$\rho_{11} + \rho_{00} + \rho_{-1-1} = 1$$

$$\rho^{V} = \begin{vmatrix} \rho_{11} & \rho_{10} & \rho_{1-1} \\ \rho_{01} & \rho_{00} & \rho_{0-1} \\ \rho_{-11} & \rho_{-10} & \rho_{-1-1} \end{vmatrix}$$

→ **Any deviation of ρ_{00} from 1/3 manifests the spin alignment of the vector mesons**

- We measure ρ_{00} through decayed products angular distribution in the rest frame of vector mesons:

$$\frac{dN}{d\cos\theta} = Norm \times \frac{3}{4} \times \left[(1 - \rho_{00}) + (3\rho_{00} - 1)\cos^2\theta \right]$$

No need to determine the direction of the reaction plane

SPIN ALIGNMENT: Three different hadronization scenario :

1) recombine polarized quark and polarized anti-quark;

$$\rho_{00}^{\rho(rec)} = \frac{1-P_q^2}{3+P_q^2} \quad \text{and} \quad \rho_{00}^{K^*(rec)} = \frac{1-P_q P_s}{3+P_q P_s} < 1/3$$

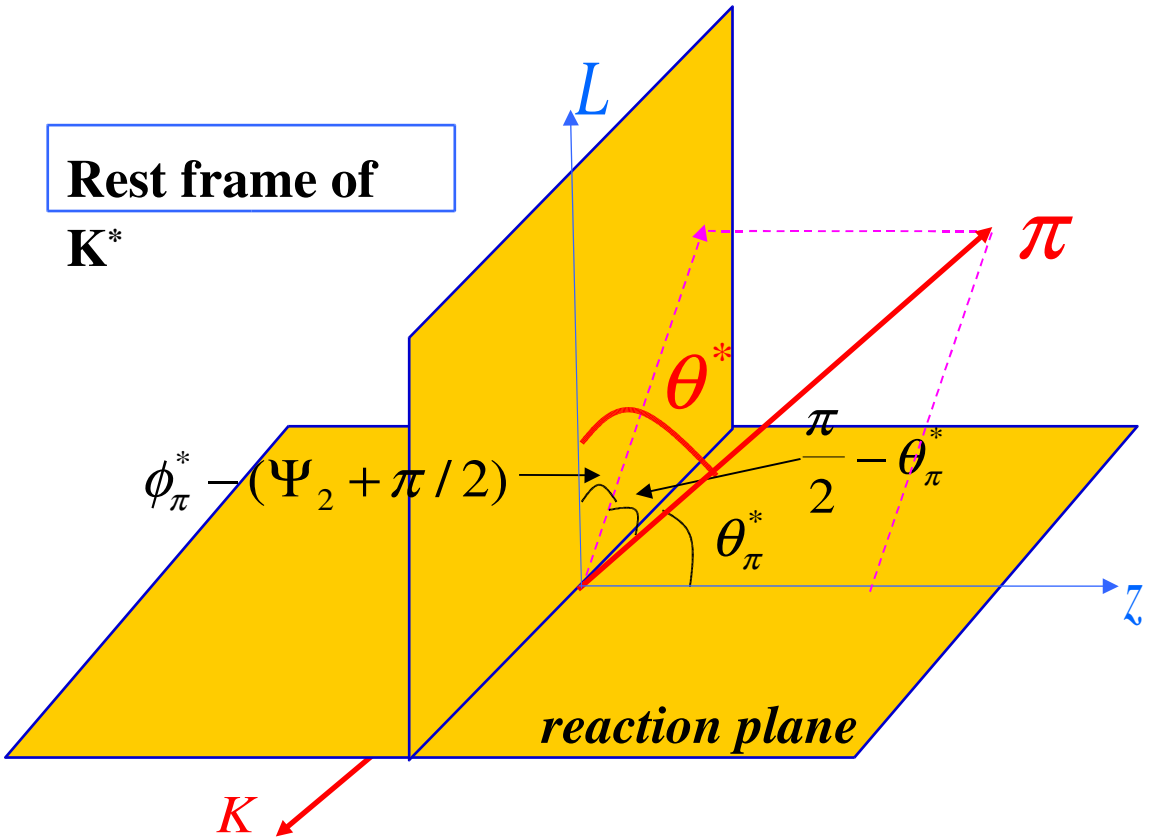
2) recombine polarized q/q with unpolarized q/q;

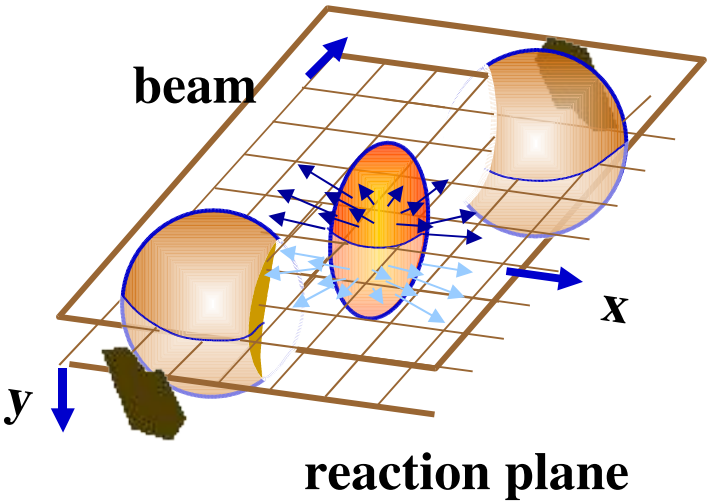
$$P_q = 0 \text{ or } P_{\bar{q}} = 0, \text{ so } \rho_{00} = 1/3$$

3) fragmentation of a fast polarized quark/anti-quark.

$$\rho_{00}^{\rho(frag)} = \frac{1+\beta P_q^2}{3-\beta P_q^2}, \rho_{00}^{K^*(frag)} = \frac{f_s}{n_s+f_s}\frac{1+\beta P_q^2}{3-\beta P_q^2} + \frac{n_s}{n_s+f_s}\frac{1+\beta P_s^2}{3-\beta P_s^2} > 1/3$$

Angle definition

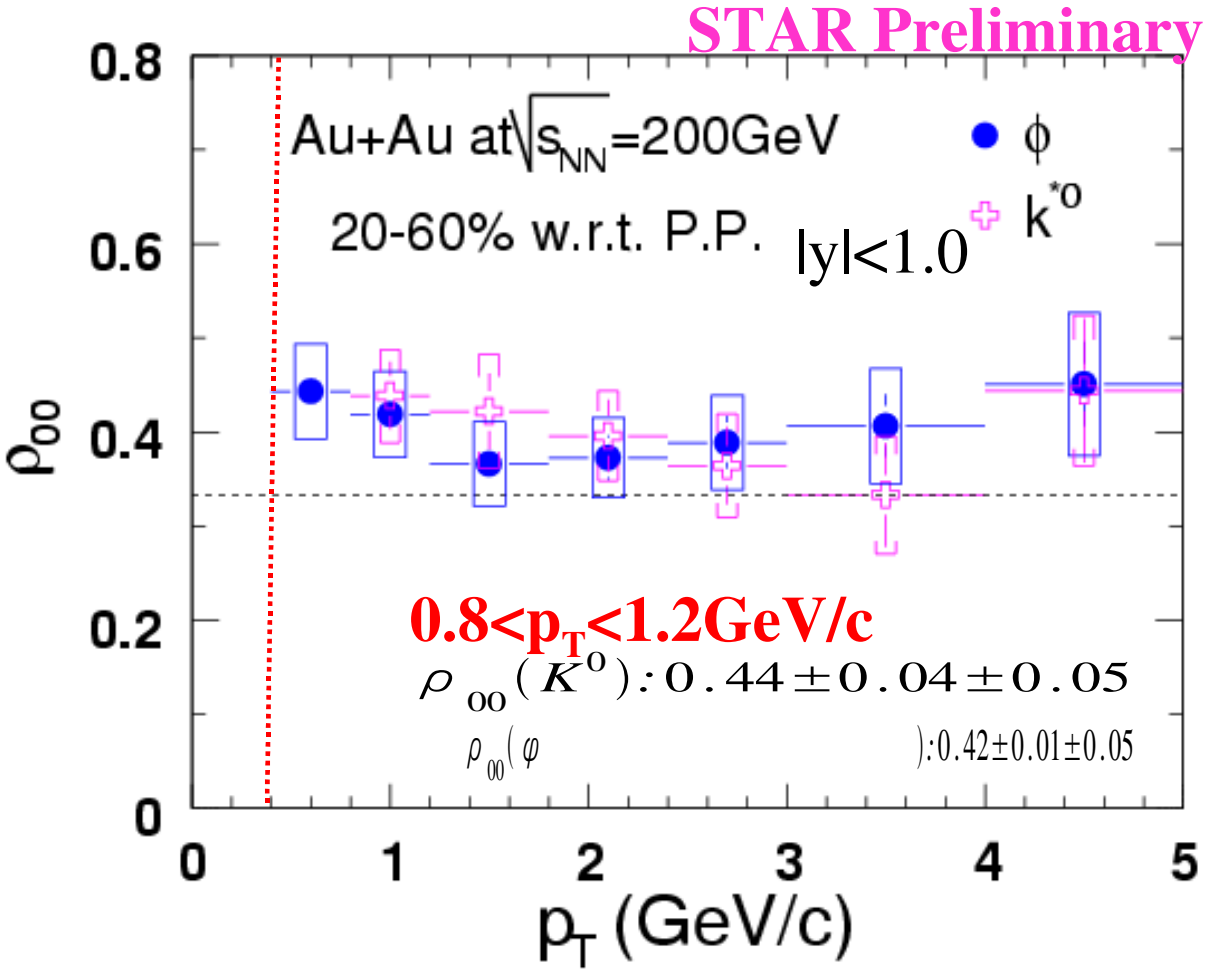




$$\cos\left(\theta^*\right) = \sin\left(\theta_\pi^*\right)\sin(\phi_\pi^* - \Psi_2)$$

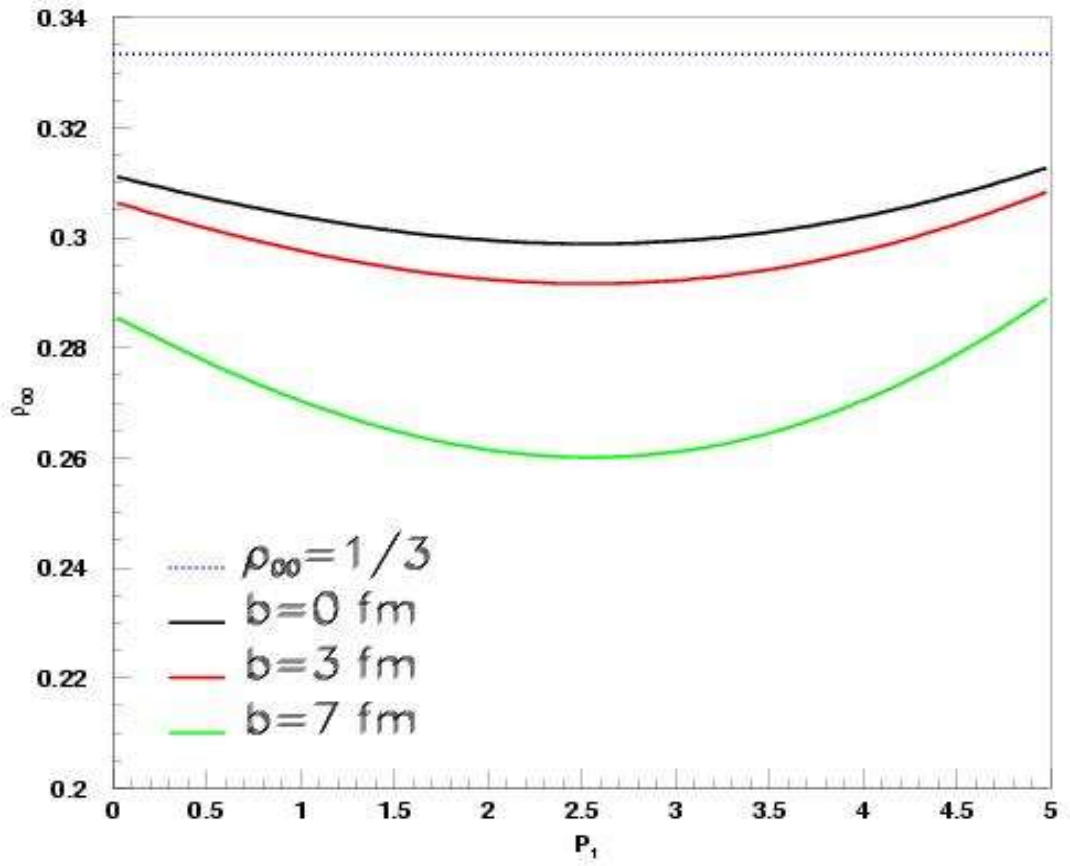
$$W\left(\theta\right) = \frac{3}{4}\left[\left(1-\rho_{00}\right) + (3\rho_{00} - 1)\cos^2\theta^*\right]$$

ρ_{00} vs p_T



K^{*0} and ϕ spin may be slightly aligned at low p_T w.r.t. production plane.

Our model of spin alignment



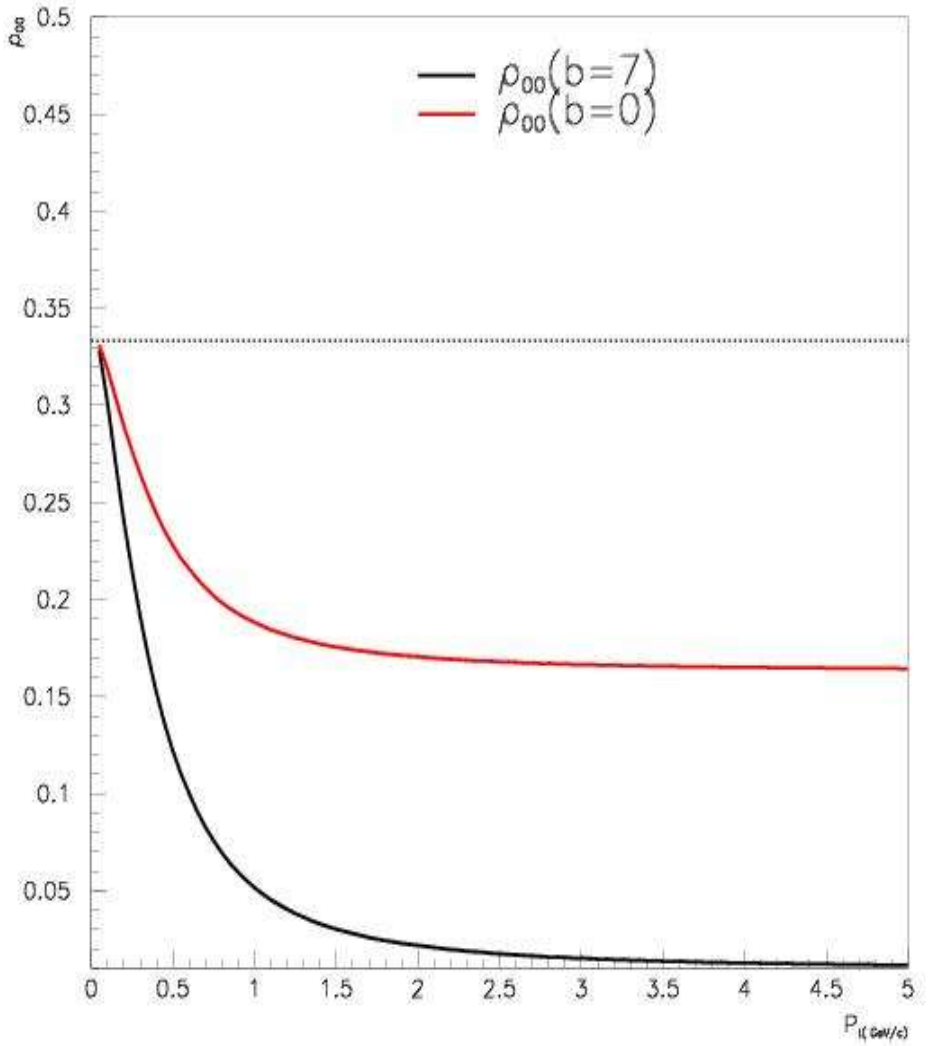
Assuming a recombination model to produce K^{*0}.

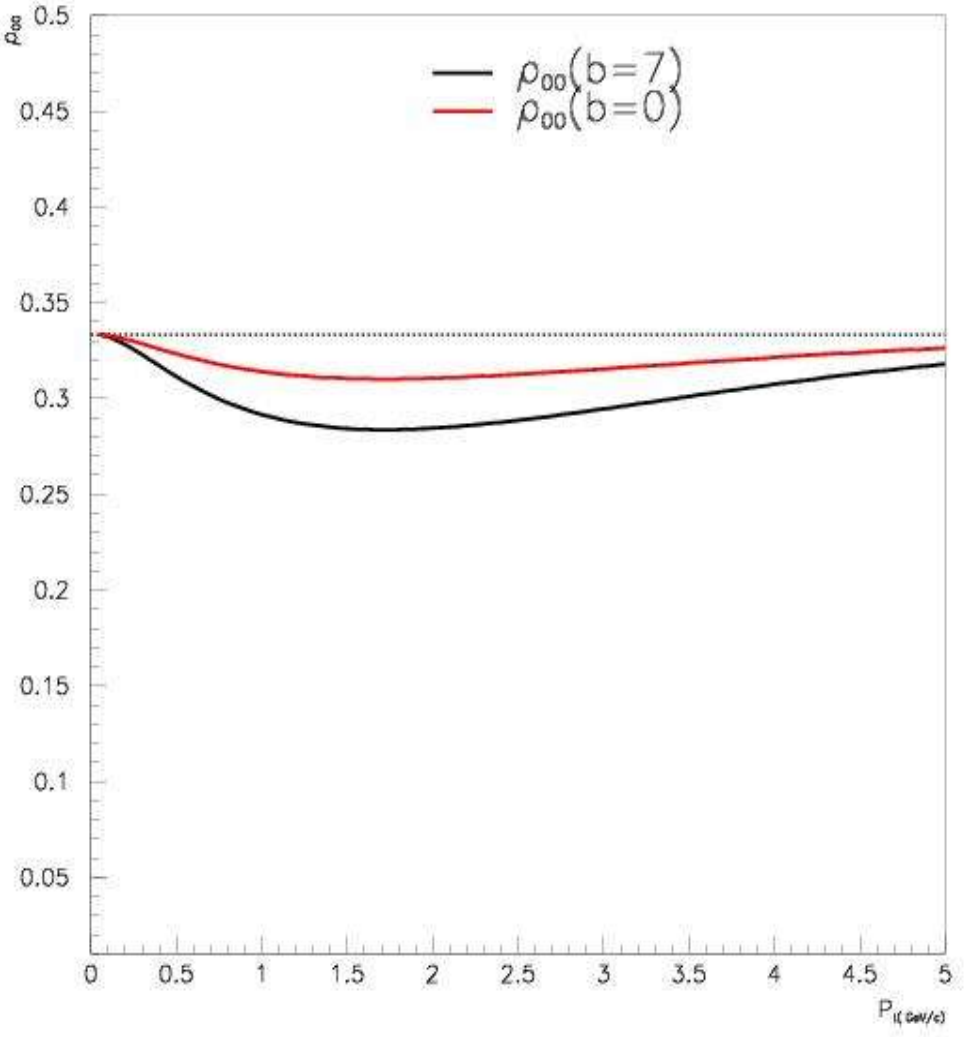
$$\rho_{00}^{\rho(rec)} = \frac{1-P_q^2}{3+P_q^2} \quad \text{and} \quad \rho_{00}^{K^*(rec)} = \frac{1-P_q P_s}{3+P_q P_s} < 1/3$$

Our model of spin alignment for K^{*0}

Taking p_t distribution as Lund model for s quark:

variable exponential





Conclusions