Spin Physics:
Polarization, Spin Alignment, spin correlations

E. Cuautle Flores

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Hyperons polarization

• The hyperosn polarization is an old problem attributed to production mechanism. It has been propose as probe of QGP creation.

• It provide information related to angular momentum distribution and how it is transported in a collision, providing better understanding of hadronization mechanisms.

Models to explain the polarization

Lund: The Polarization comes from production mechanism. In the case of Λ°, which is formed when a string fragment, producing a $s\bar{s}$ pairs. The s quark momentum allowing combination with ud diquark, producing Λ° with $p_T \neq 0$. (Anderson, et al. PLB85 (1979)417)

DeGrand and Miettinen: assume that hyperon is formed from valence diquark ud coming from beam protons and s quark from the sea. The polarization is due to Thomas precession during the recombination of s and ud quarks.

Measurements of the polarization

The polarization depends on the kinematic variables: x_F, p_T and the mass system in which it is created. Polarization can be longitudinal and transversal.

- Polarization of Λ° as funciton of M_x

$$pp \to p\Lambda^0 K^+ (\pi^+\pi^-)^N; N = 1,2,3,4,5$$

- Polarization is defined as:

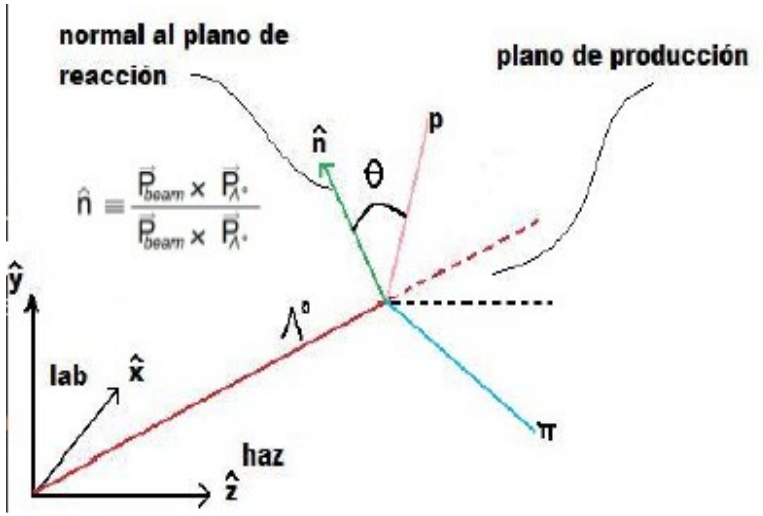
$$P = \frac{|A_\uparrow|^2 - |A_\downarrow|^2}{|A_\uparrow|^2 + |A_\downarrow|^2}$$

It measure through angular distribution of decay daughter respect to the reaction plane:

$$\frac{dN}{d\Omega} = N_0(1 + \alpha P \cos\theta)$$

α – asymmetry decay parameter (for Λ° = 0.642) where P is polarization

CP violation can be studied through measurements of the asymmetry parameter for Λ° and $\overline{\Lambda}$°

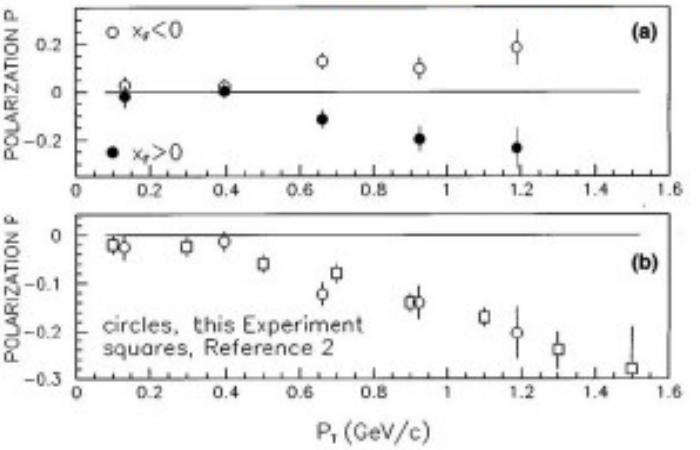


Experimental results on pp collisions: some characteristics

Phys. Rev. Lett 76, 22-25 (1996)

– Increase linearly as Pt below 1GeV/c.
Reaching a constant values after 1GeV/c.
Increase as function of x_F, No dependence is observed with the beam energy.

– The antiparticles Λ° y Ξ° does not present polarization
– Σ+ y Σ- have polarization of the same order but opposite sing
And for Σ+
decrease as functon of X_F.
– Ξ- y Ξ° have polarization different from cero and does not present dependence with XF.



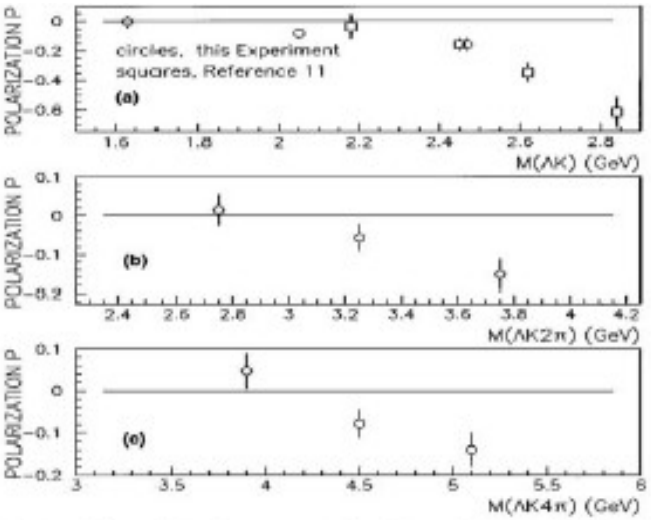


FIG. 3. Λ^0 polarization as a function of (a) $M(\Lambda K)$, (b) $M(\Lambda K\pi^+\pi^-)$, (c) $M(\Lambda K\pi^+\pi^-\pi^+\pi^-)$.

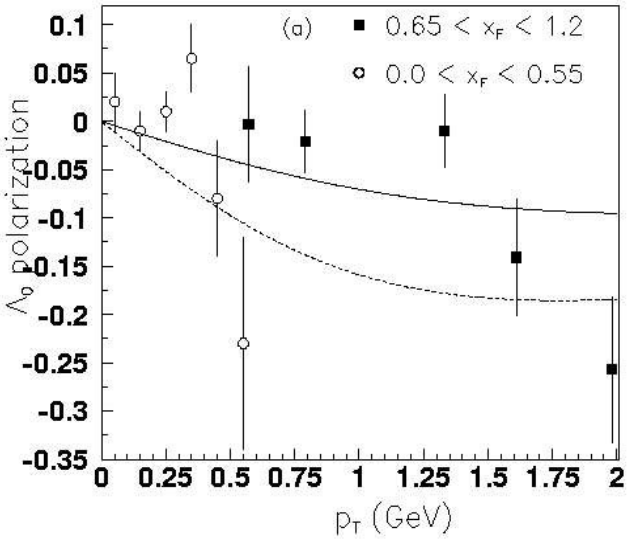
Λ_0 Polarization in heavyions collisions

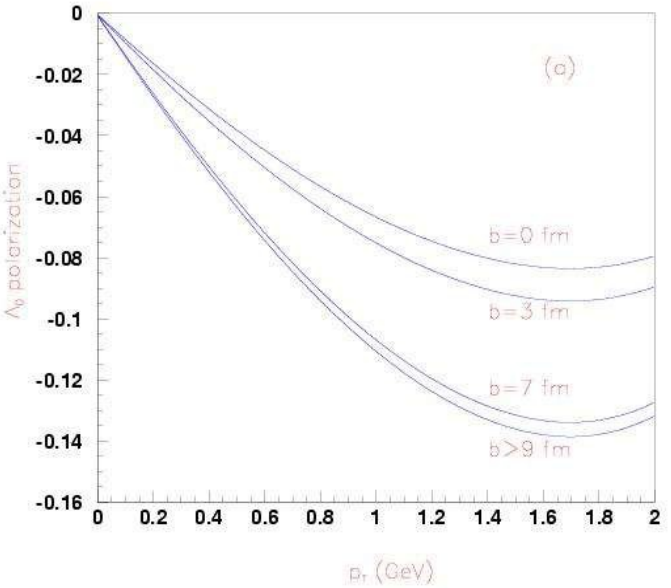
In a heavyion reaction, Λo's can be produced either by the coalescence of free quarks or by recombinationlike processes (as in the case of p+p collisions) depending on whether or not the critical density for the production of a QGP is reached in the collision, respectively.

One can assume that Λo's are the sole products of the squark
Subsequent fragmentation. The important point to bear in mind is that these Λo's are expected to be produced unpolarized, as is the case of antiΛo's produced in pp reactions

Polarization and QGP. Comparison of the polarization in Pb+Pb respect to pp collision has been proposed as probe of desconfined matter

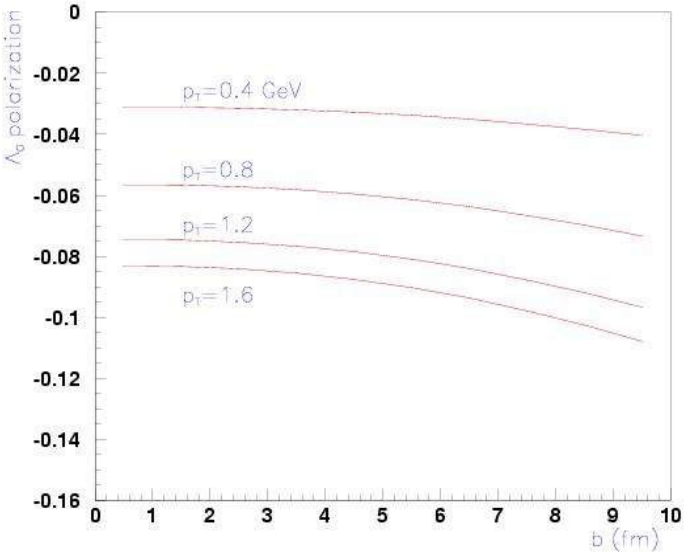
- Λ° without polarization in central collisions
- should be polarized in peripheral collisions





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

Right picture shows the polarization (in the QGP zone) as expected in ALICE.
Phys. Rev. C 65 (2002) 024902 ,
RMF 48 (2002)49



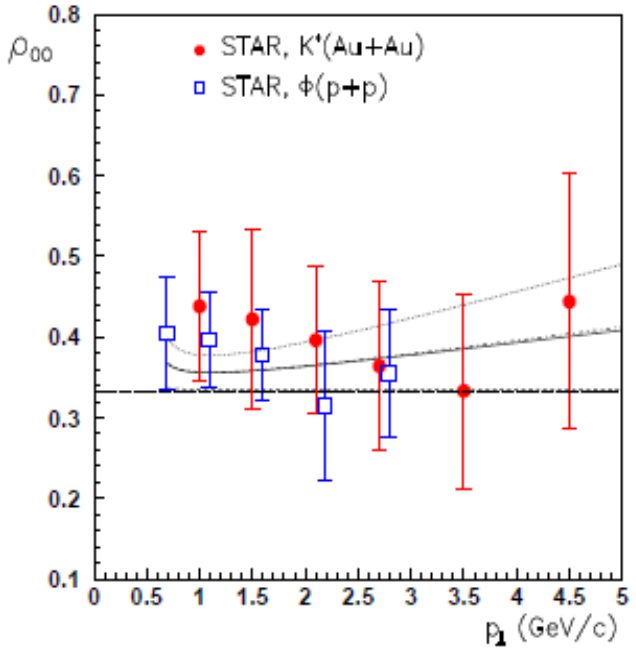
SPIN ALIGNMENT:

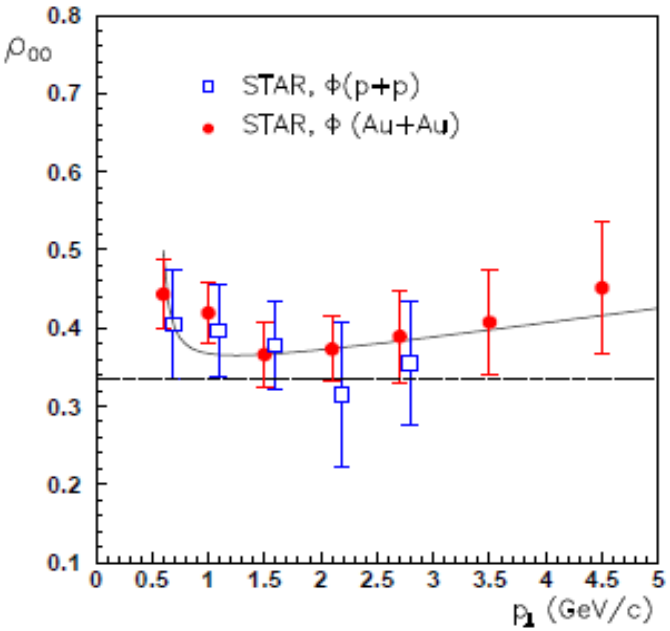
The spin alignment matrix element ρ_{00} for the vector mesons K0 and $\phi(1020)$ has been measured in RHIC at central rapidities. These measurements are consistent with the absence of polarization with respect to the reaction plane in mid-central Au + Au collisions whereas, when measured with
respect to the production plane in the same reactions and in p + p collisions, a non-vanishing an pt-dependent ρ_{00} is found. We show that this behavior can be understood in a simple model of vector meson production where the spin of their constituent quarks is oriented during hadronization
as the result of Thomas precession.

Phys. Lett. B 682 (2010) 408

$$\mathcal{P}^{s,f} = \mp \frac{\omega_T^{s,f}}{\Delta E},$$

$$\rho_{00} = \frac{1 - \mathcal{P}^s \mathcal{P}^f}{3 + \mathcal{P}^s \mathcal{P}^f}.$$





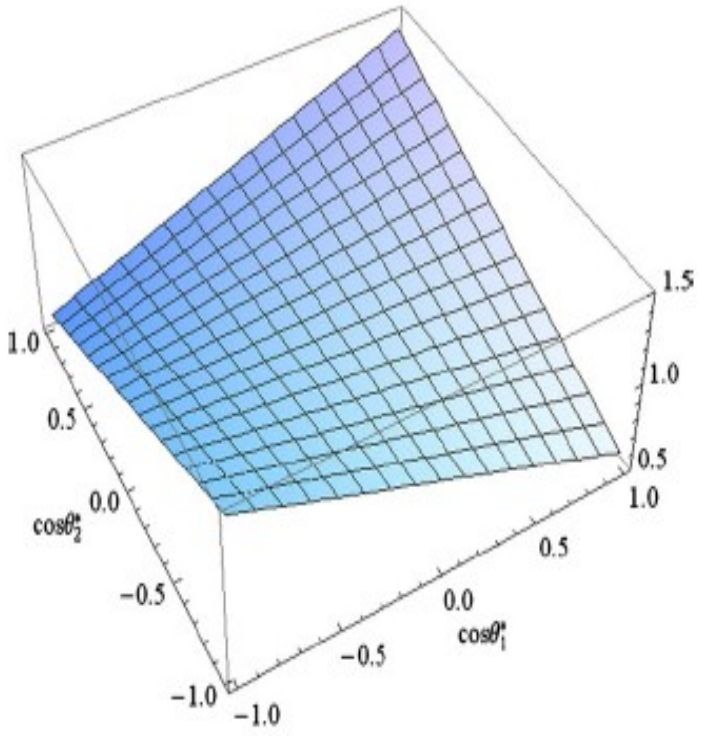
Spin Correlations of Lambda anti-Lambda Pairs as a Probe of Quark-Antiquark Pair Production

Abstract The polarizations of Λ and $\overline{\Lambda}$ are thought to retain memories of the spins of their parent s quarks and $\overline{s}$ antiquarks, and are readily measurable via the angular distributions of their daughter protons and antiprotons. Correlations between the spins of Λ and $\overline{\Lambda}$ produced at low relative momenta may therefore be used to probe the spin states of $s\,\overline{s}$ pairs produced during hadronization. We consider the possibilities that they are produced in a $^3P_0$ state, as might result from fluctuations in the magnitude of $\overline{s}s$, a $^1S_0$ state, as might result from chiral fluctuations, or a $^3S_1$ or other spin state, as might result from production by a quark–antiquark or gluon pair. We provide templates for the $p\,\overline{p}$ angular correlations that would be expected in each of these cases, and discuss how they might be used to distinguish $s\,\overline{s}$ production mechanisms in pp and heavy-ion collisions.

Eur. Phys. J. C72, 1877 (2012)

Production via a vector coupling

A couple of perturbative production mechanisms, namely the process $\bar{q}q \rightarrow \bar{s}s$, that is mediated by gluon exchange and hence via a vector coupling, or the process $gg \rightarrow \bar{s}s$ to which several perturvative diagrams contribute leading to a more complicated spin structure.



$$\frac{1}{2}\left[\left(1+a\cos\theta_1^*\right)\left(1+a\cos\theta_2^*\right)\right.$$
$$\left.+\left(1-a\cos\theta_1^*\right)\left(1-a\cos\theta_2^*\right)\right]$$
$$=\left(1+a^2\cos\theta_1^*\cos\theta_2^*\right),$$

..., but we emphasize that the $\bar{s}s$ production mechanisms might be quite different in different kinematic regimes. For example, $\bar{s}s$ pairs produced in high-pT jets might have a more 'perturbative' origin, whereas those produced in minimum-bias or heavy-ion collisions might have a more 'non-perturbative' origin. It would therefore be interesting to compare and contrast any $\Lambda\bar{\Lambda}$ spin correlations measured in these different conditions.

Superficial consideration of the LHC experiments suggests that ALICE may be best suited for measurements of $\Lambda\bar{\Lambda}$ spin correlations in minimum bias and low-pT heavy-ion collisions, whereas ATLAS and CMS may be better suited for measurements at higher pT . We emphasize that the $\Lambda\bar{\Lambda}$ pairs of interest are those with the lowest possible invariant mass, which are most likely to originate from the same 'parent' $s\bar{s}$ pair. Pairs with larger relative momenta are not expected to exhibit any significant spin

Spin physics

CP violation:
En hiperones con espín ½, una prueba de violación es comparando la distribución angular del decaimiento del barión con la del antibarión conjugado en el decaimiento debil no leptónico a 2 cuerpos.

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

Asimetría de decaimiento

$\alpha = 2Re\left(\frac{S*P}{S^2+P^2}\right)$ S y P, amplitudes de momento angular

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

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

Si α de Λ° difiere de $\overline{\alpha}$ de $\overline{\Lambda}$°, la simetría CP es violada como se ha reportado en la colaboración HyperCP