Quantum spin correlations in $\Lambda\bar{\Lambda}$ pairs production

at NICA SPD

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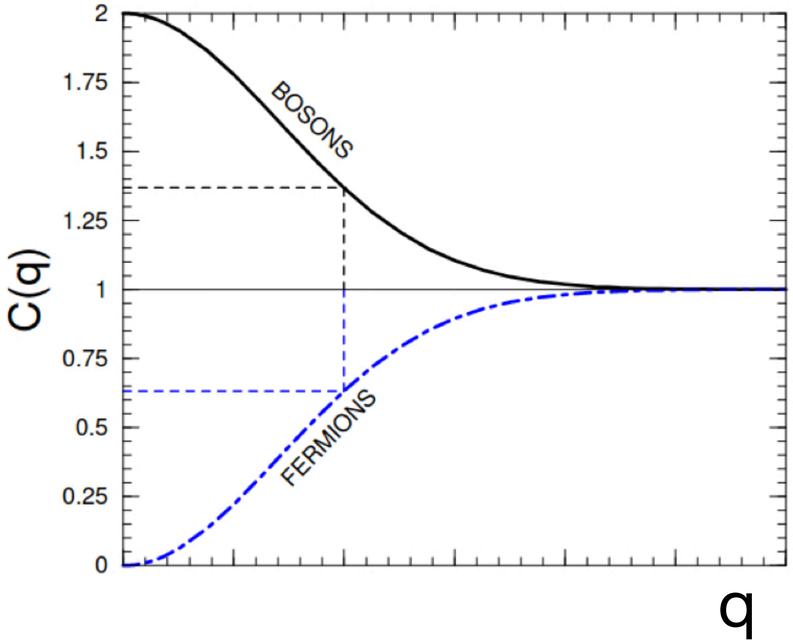
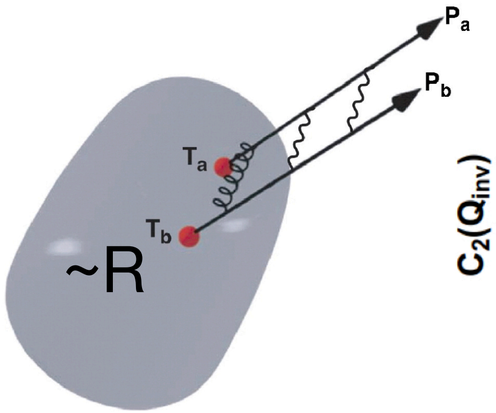
Quantum correlations in hadronic interactions

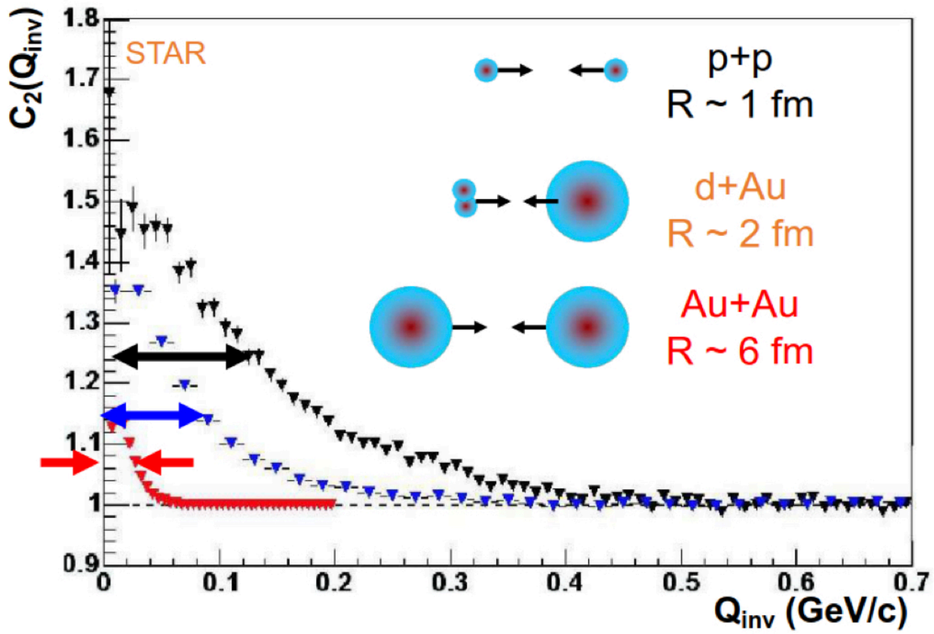
Correlation femtoscopy

$$C(\vec{p}_1,\vec{p}_2) \equiv \frac{\mathcal{P}_2(\vec{p}_1,\vec{p}_2)}{\mathcal{P}_1(\vec{p}_1)\mathcal{P}_1(\vec{p}_2)} = 1 + \frac{|\int d^3x e^{-i\vec{q}\cdot\vec{x}}\rho(\vec{x})|^2}{|\int d^3x \rho(\vec{x})|^2} = C(\vec{k},\vec{q})$$

- correlation function

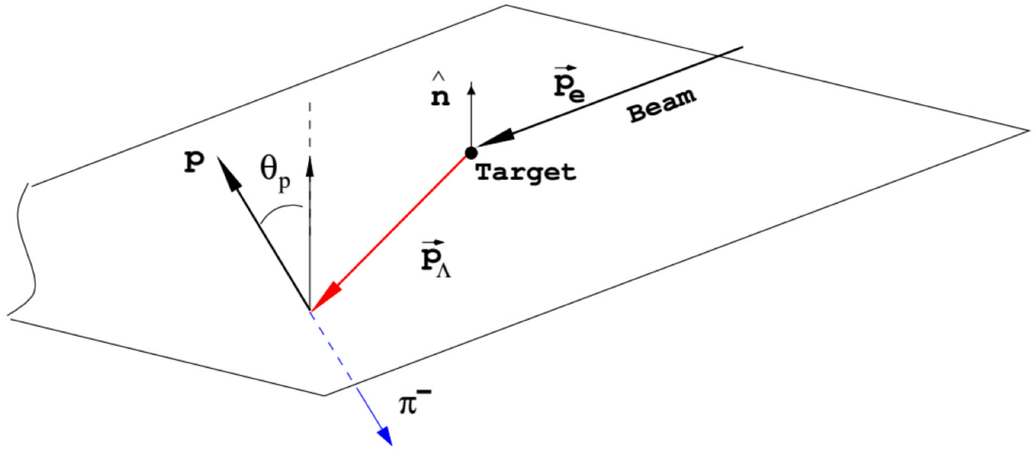




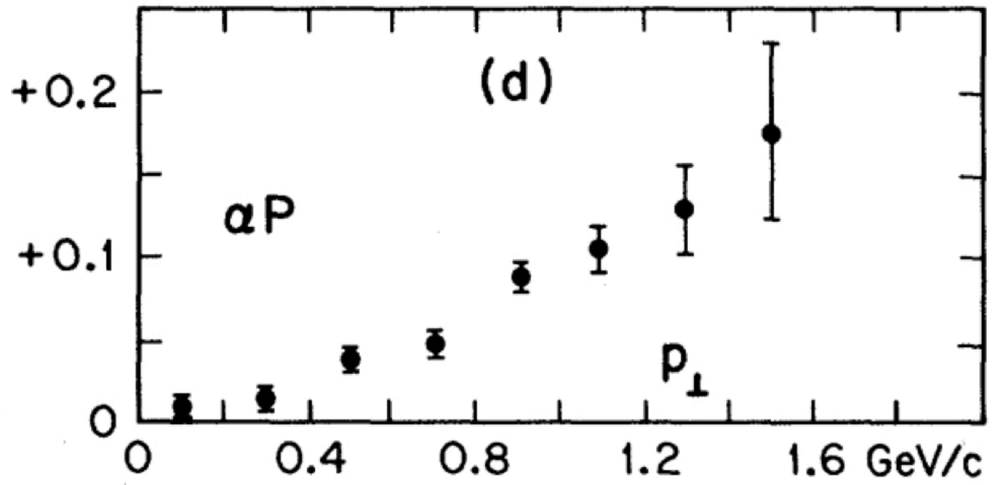


Λ polarization

If you don't know what to measure, measure Λ polarization!



$$\sigma \sim 1 + \alpha_0 P_\Lambda \cos\theta_p$$

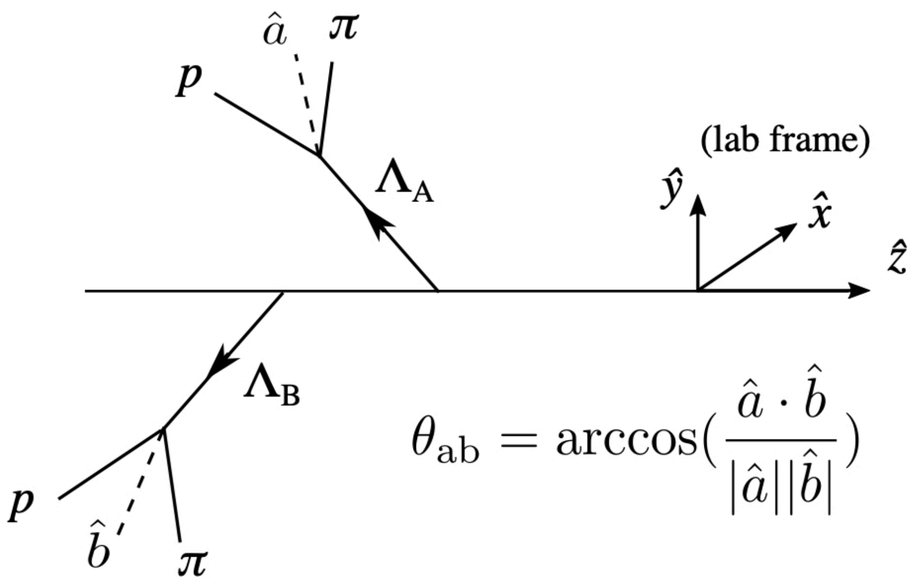


Unpolarized p-Be collisions at $\sqrt{s}$=24 GeV

$\Lambda\bar{\Lambda}$ pair production

Spin correlations

Measurement of Bell-type inequalities and quantum entanglement from Λ-hyperon spin correlations at high energy colliders
Wenjie Gong, Ganesh Parida, Zhoudunming Tu, and Raju Venugopalan *Phys.Rev.D* 106 (2022) 3, L031501
https://arxiv.org/abs/2107.13007



rotational invariance
nonlocality

$$\frac{P(\hat{\mathbf{a}},\hat{\mathbf{b}})}{P(\hat{\mathbf{a}})P(\hat{\mathbf{b}})} = 1 + (\lambda_{11} - \lambda_{44})\cos(\theta_a - \theta_b)$$

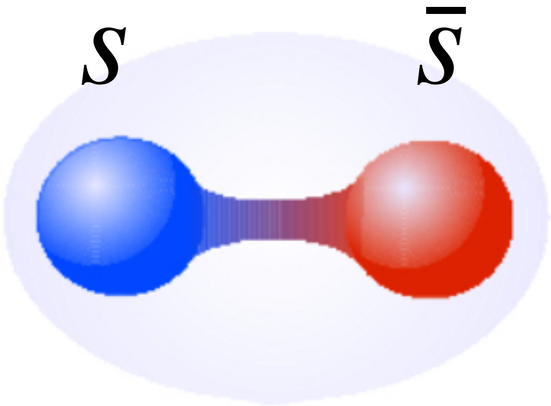
if >1/2 the $\rho(\hat{a},\hat{b})$ is entangled state

(sufficient but not necessary condition)

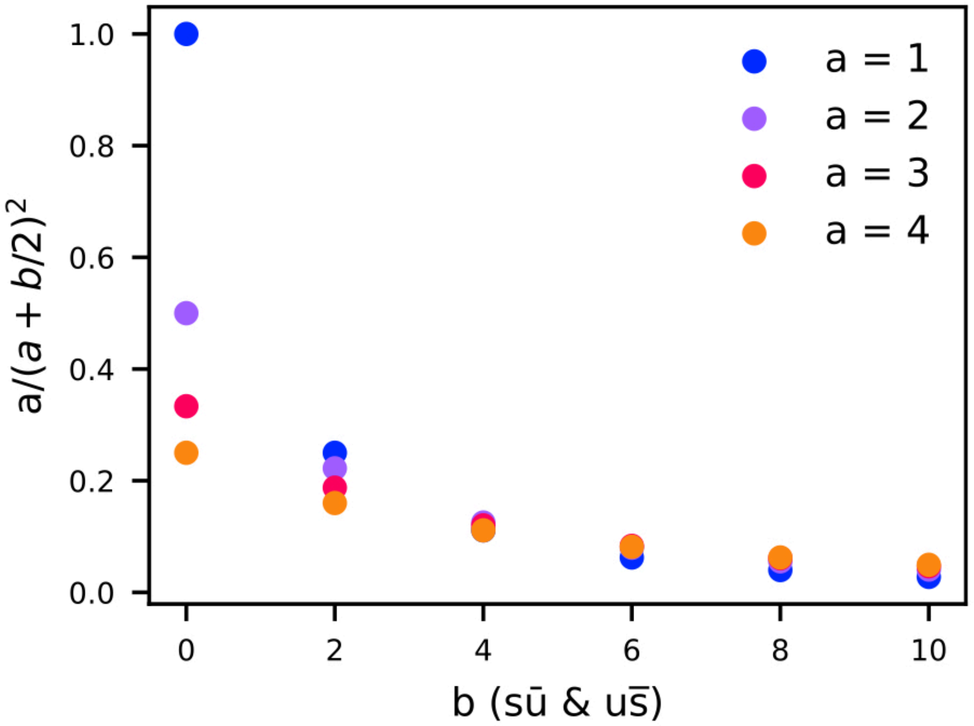
$$\sigma \sim 1 + \alpha^2 P_{\Lambda\bar{\Lambda}} \cos\theta_{ab}$$

Quantum correlations in hadronic interactions

two flavor spin chain model



String hadronization into **a** $s\bar{s}$ and **b** $s\bar{u}, u\bar{s}$ singlets



modulation:

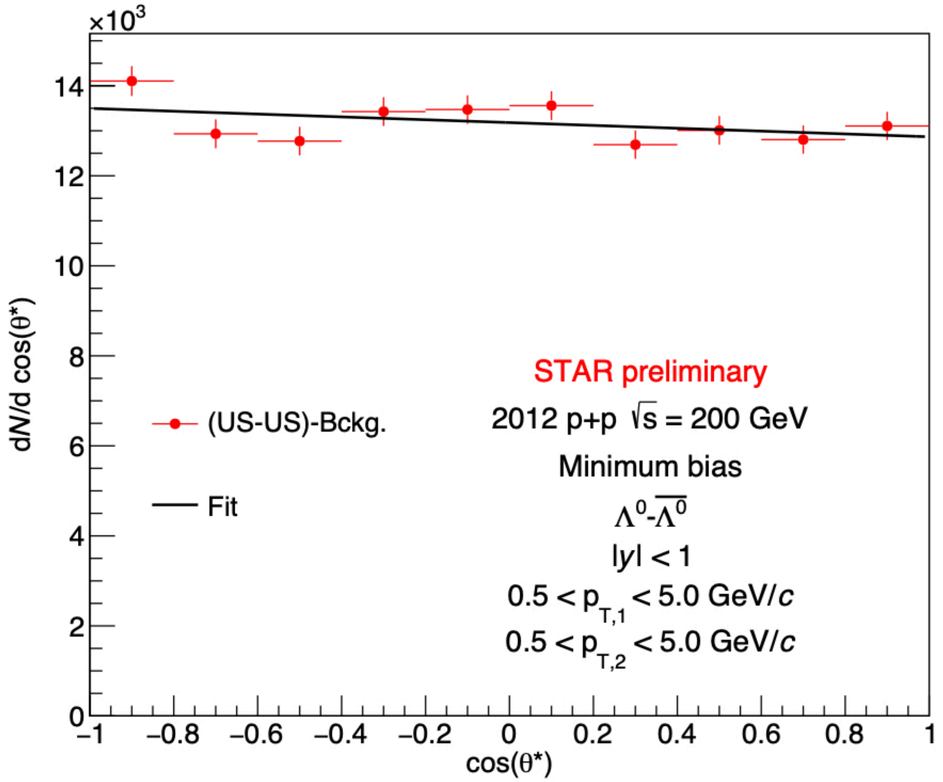
$$1 - \frac{a}{(a + b/2)^2} \cos(\theta_2 - \theta_1)$$

Higher modulation at lower multiplicity!

STAR results

very fresh (DIS 2024 proceedings)

400M of unpolarized MB pp-events at $\sqrt{s}$=200 GeV (2012)

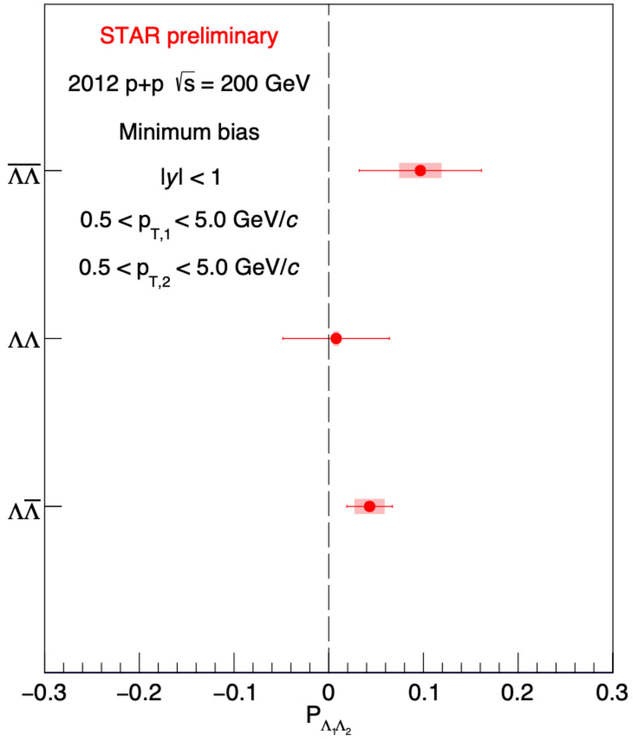


400M MB events

130k $\Lambda-$pairs

$$|y| < 1$$

$$0.5\ GeV/c < p_T < 5.0\ GeV/c$$

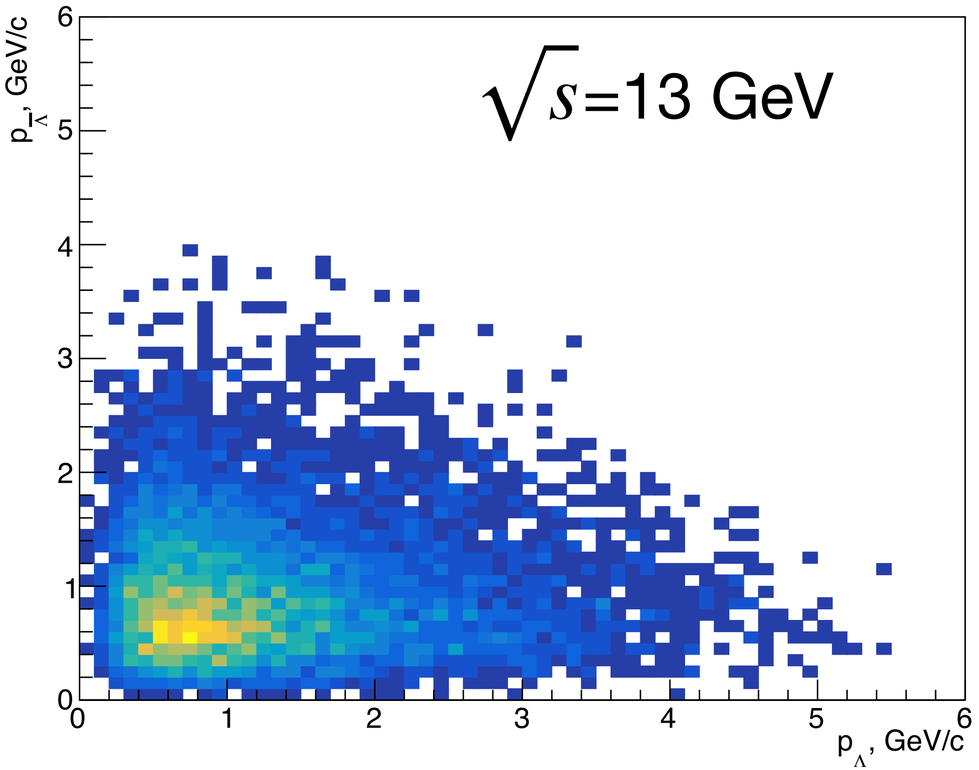


https://inspirehep.net/files/c9da0173bdf7ba5fb6e629f07b230682

$\Lambda\Lambda$-pairs at SPD

per 1 M of pp interactions	10 GeV	13 GeV	27 GeV
LaL events	5 200	8 800	20 800
LaL pairs	5 900	10 000	25 100
LL events	4 300	5 400	9 600
LL pairs	4 400	5 600	10 200
aLaL events	5	50	900
aLaL pairs	5	50	900

We reach the STAR statistics in 3 hours!



L=10^{31} cm^{-2} s^{-1} , p-p collisions

A_{Λ}=0.2

BF($\Lambda \rightarrow p\pi$) = 0.64

16 $\Lambda\bar{\Lambda}$ pairs decaying into $p\pi$ per second at 13 GeV

Summary

- What do we study? The part of hadronization mechanism related to quantum entanglement and nonlocality
- Actual almost unexplored problem
- Task in line with the main program of the SPD project
- Popular keywords: “quantum entanglement, spin correlations, nonlocality, etc”
- Possibility, even in the first phase
- Quite a simple task for the first-stage setup
- Our project is competitive in this task

Predictions for EIC