Detector and physics simulation for Hyperon-Nucleon Spectrometer (H-NS)

Aiqiang Guo for Simulation Working Group

Institute of Modern Physics, Chinese Academy of Sciences

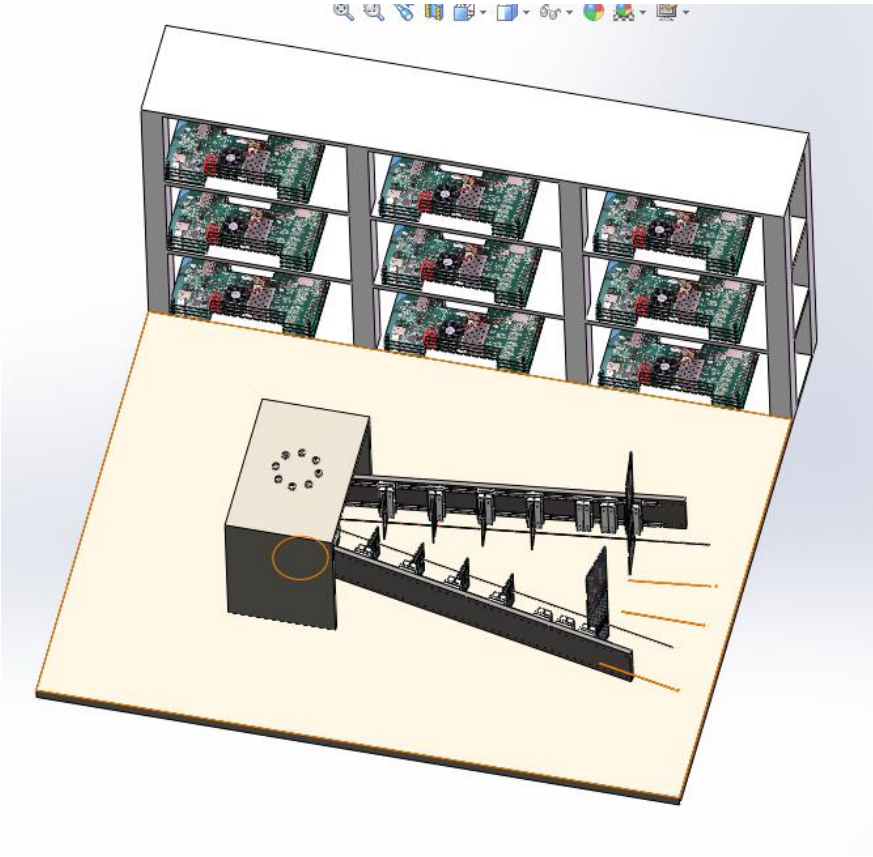
IMP-Huizhou-Aug. 1 2025

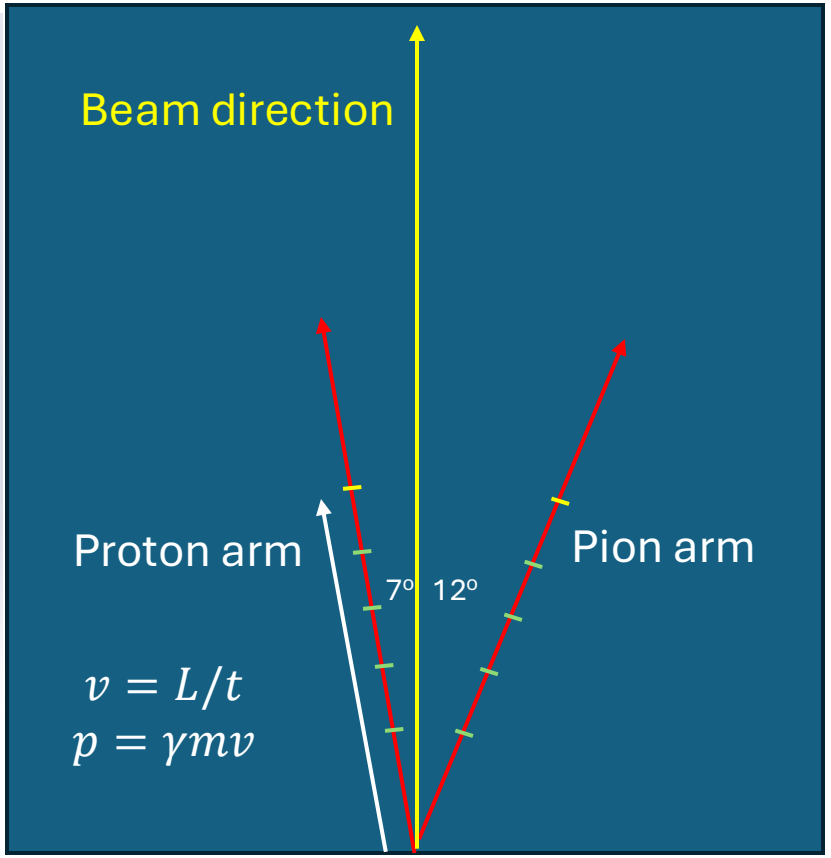
The goal of this working group

- Detector simulation
  - H-NS0(YP,JP)，TF(AQ)
  - H-NS with Dipole magnet, TF (AQ, CX)
  - H-NS with solenoid, TF (GN,LQ)
- Physics projection @ H-NS
  - Λ polarization in pp, p-A (CX)
    - P_t, X_f, energy dependent
    - Inclusive and exclusive
  - Λ production (JL)
  - Σ poloarization in pp, p-A (JL)
  - Proton polarization in pp, p-A (CX,JP)
  - Global Λ polarization(SX, XH)
  - HN production (YL)
  - H-N interaction ?
  - Hadron spectroscopy in pp ?

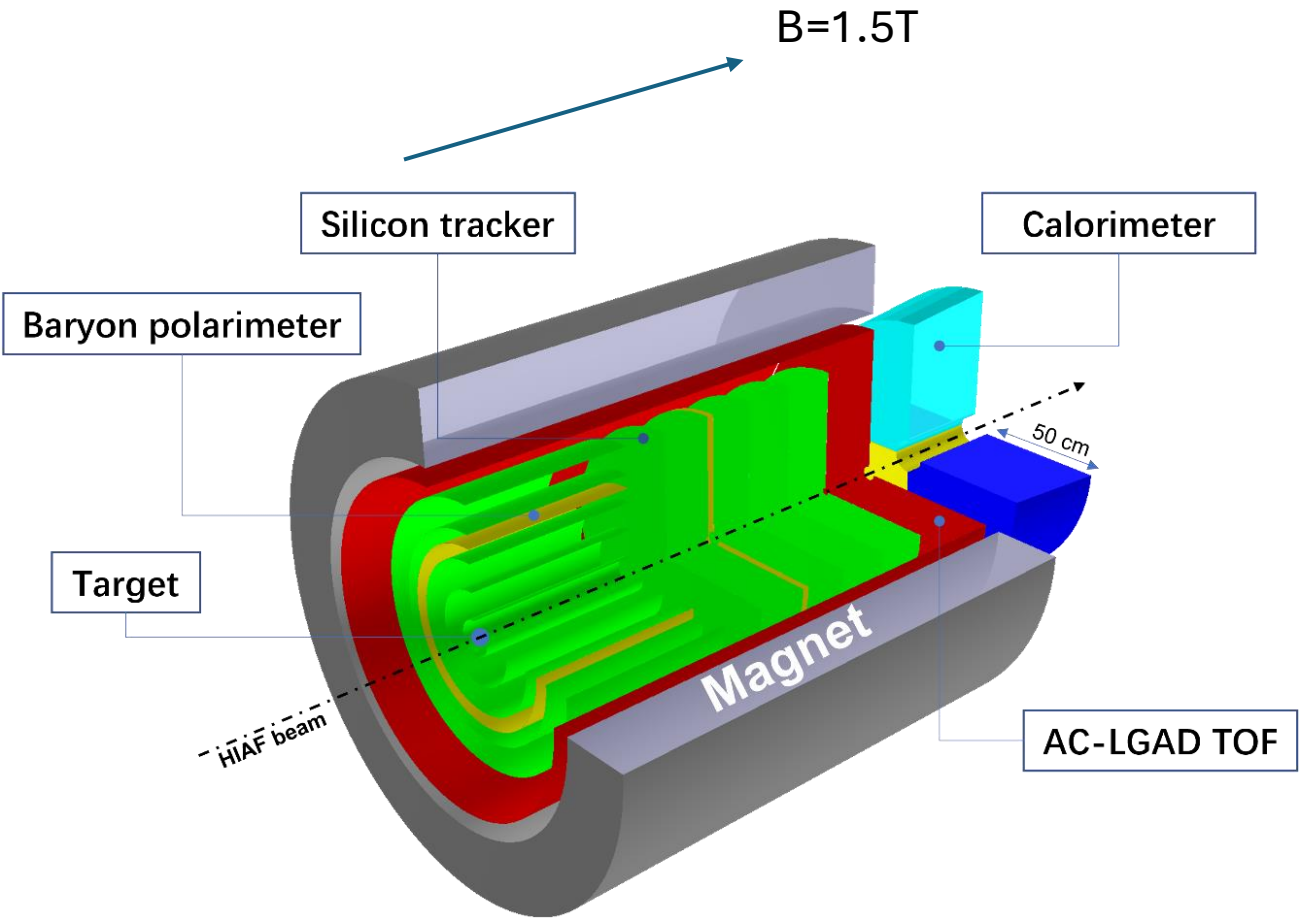
H-NS0 Simulation

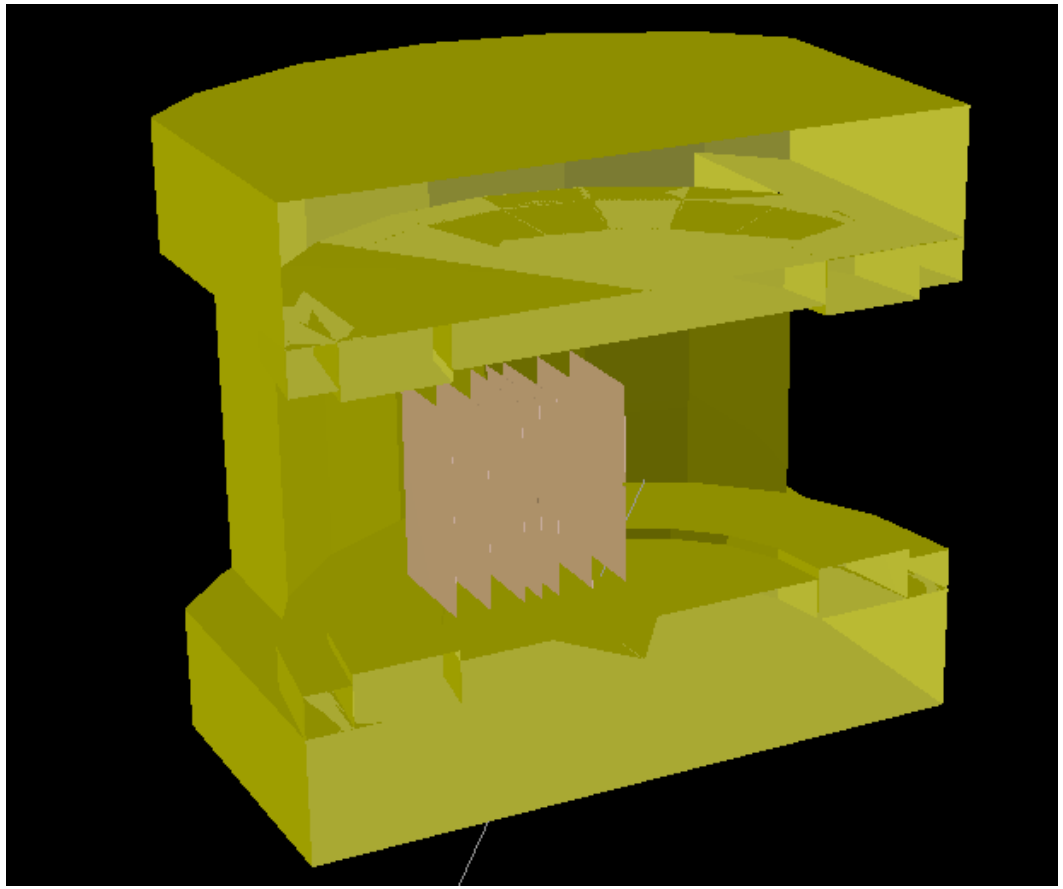
- Status:
  - Preliminary design
  - Performance study
  - Λ reconstruction method validation
- To to list:
  - Optimize the geometry, angle, layer, alignment
  - More realistic simulation:
    - Real geomtry
    - Full simulation
  - Physics projection
    - Cross section measurement





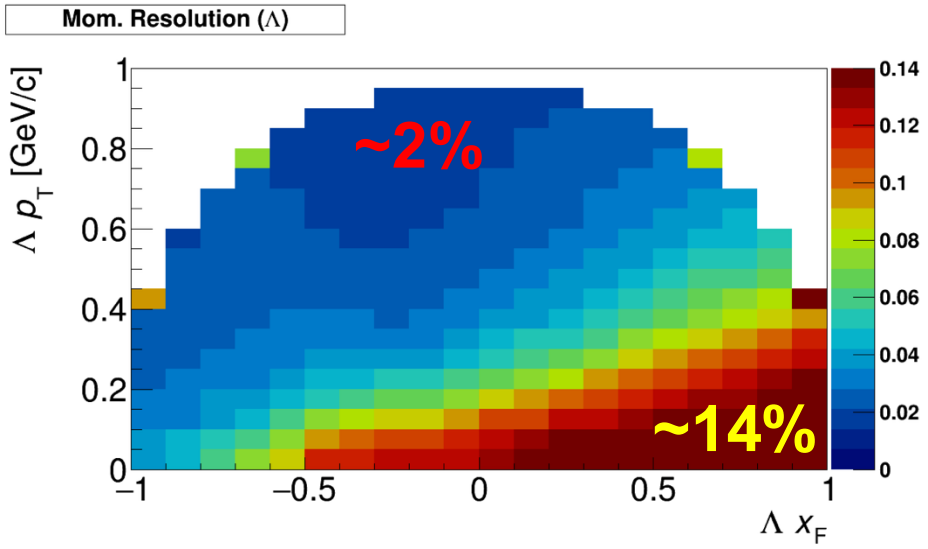
H-NS: Dipole or Solenoid, this is a question?



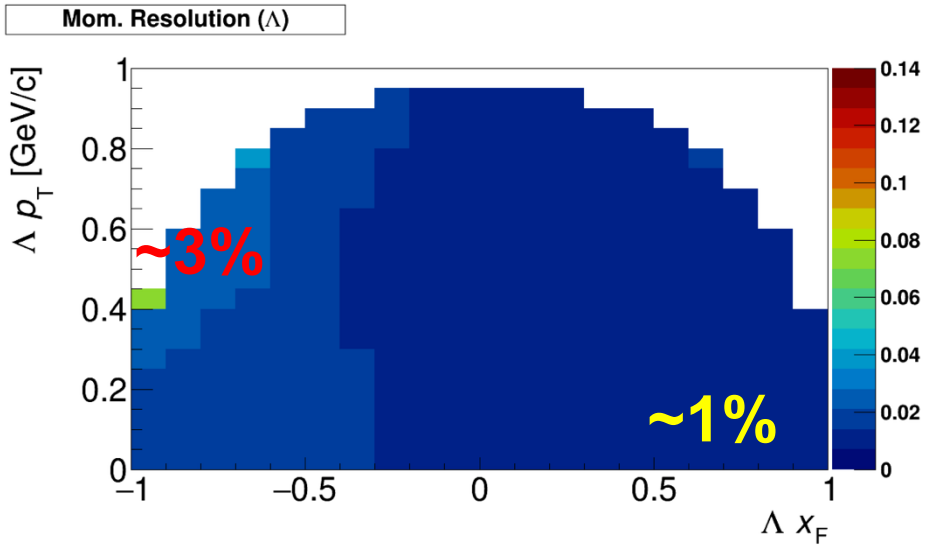


P resolution: Solenoid vs Dipole

Solenoid

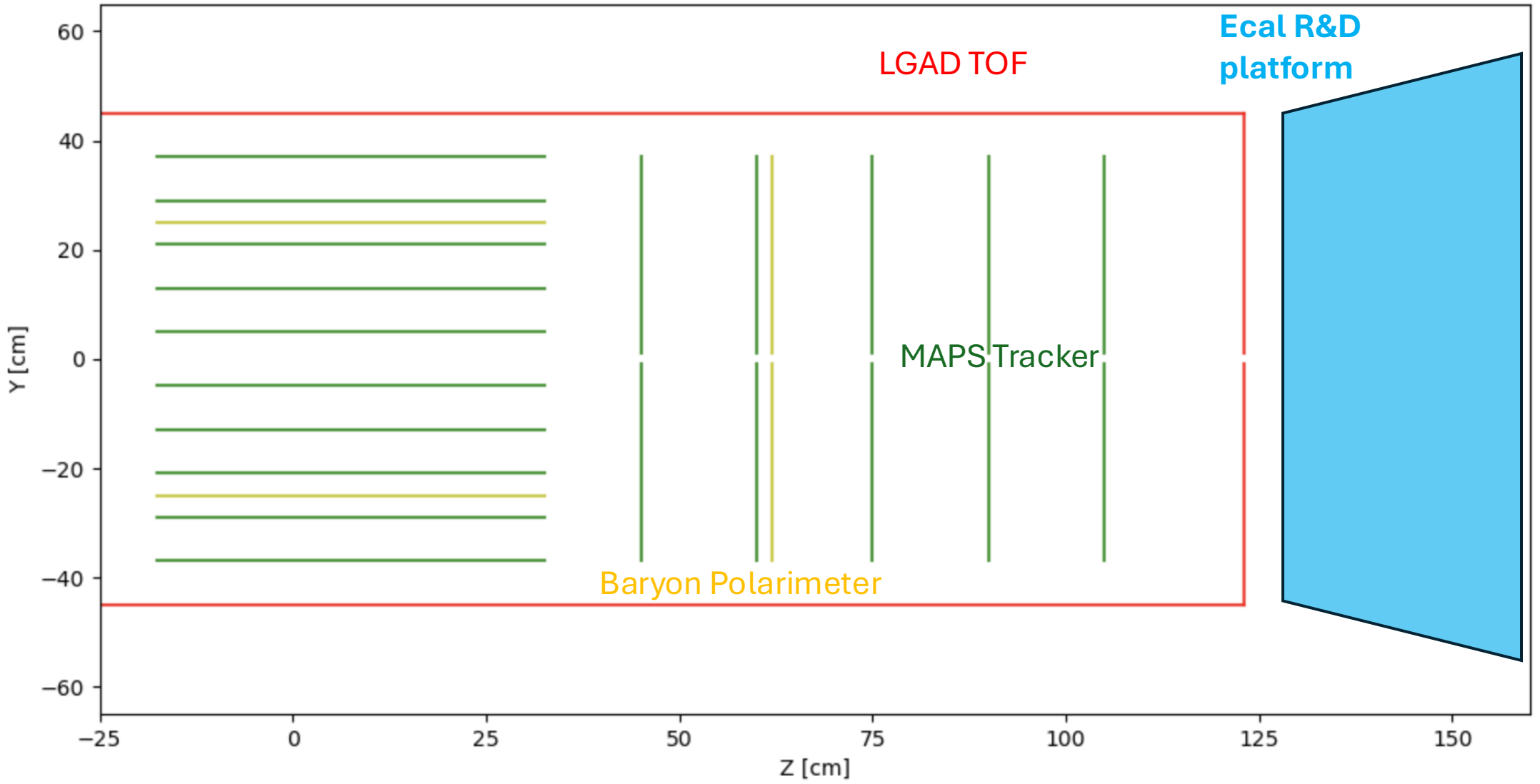


Dipole



$$\frac{\sigma_p}{p} = \frac{|p_{\text{truth}} - p_{\text{rec}}|}{p_{\text{rec}}}$$

H-NS geometry @ different B configurations ?



H-NS simulation

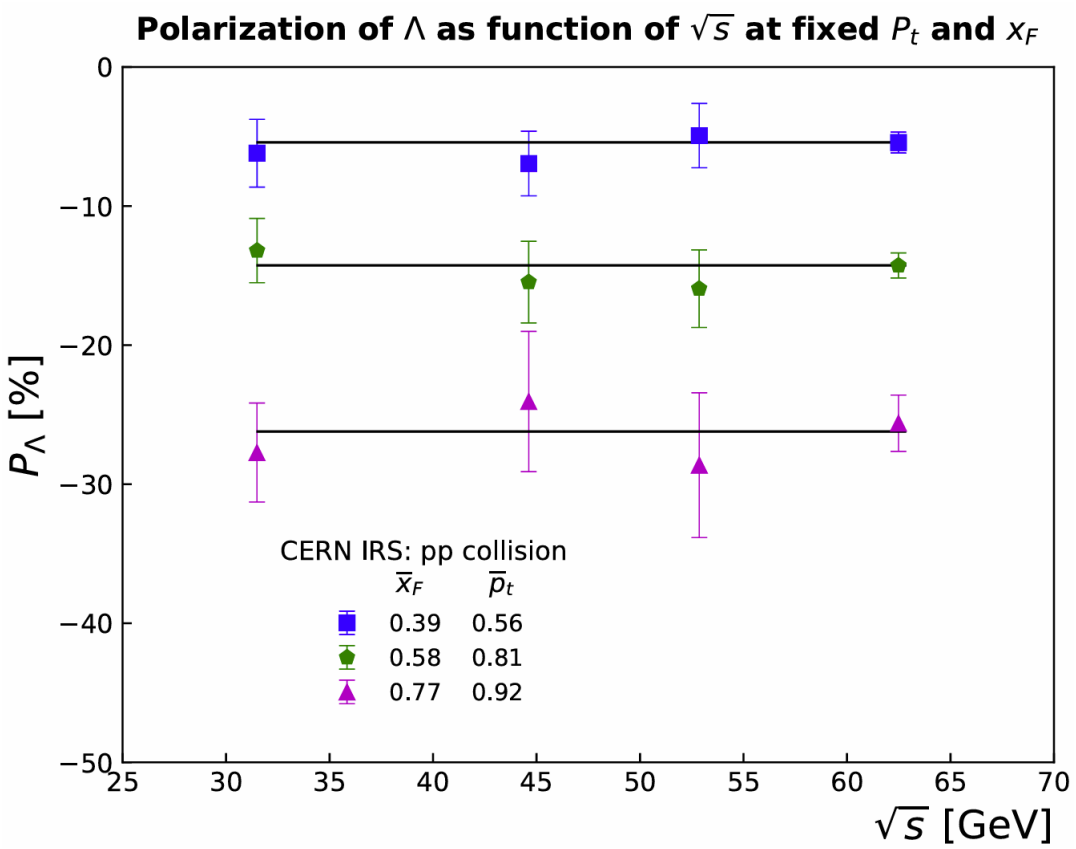
To do list: Optimize the geometry with

- Dipole
  - P, vertex resolution, efficiency
  - Impact on physics
- Solenoid
  - P, vertex resolution, efficiency
  - Impact on physics
- It will be an iterative procedure together with physics projection at H-NS

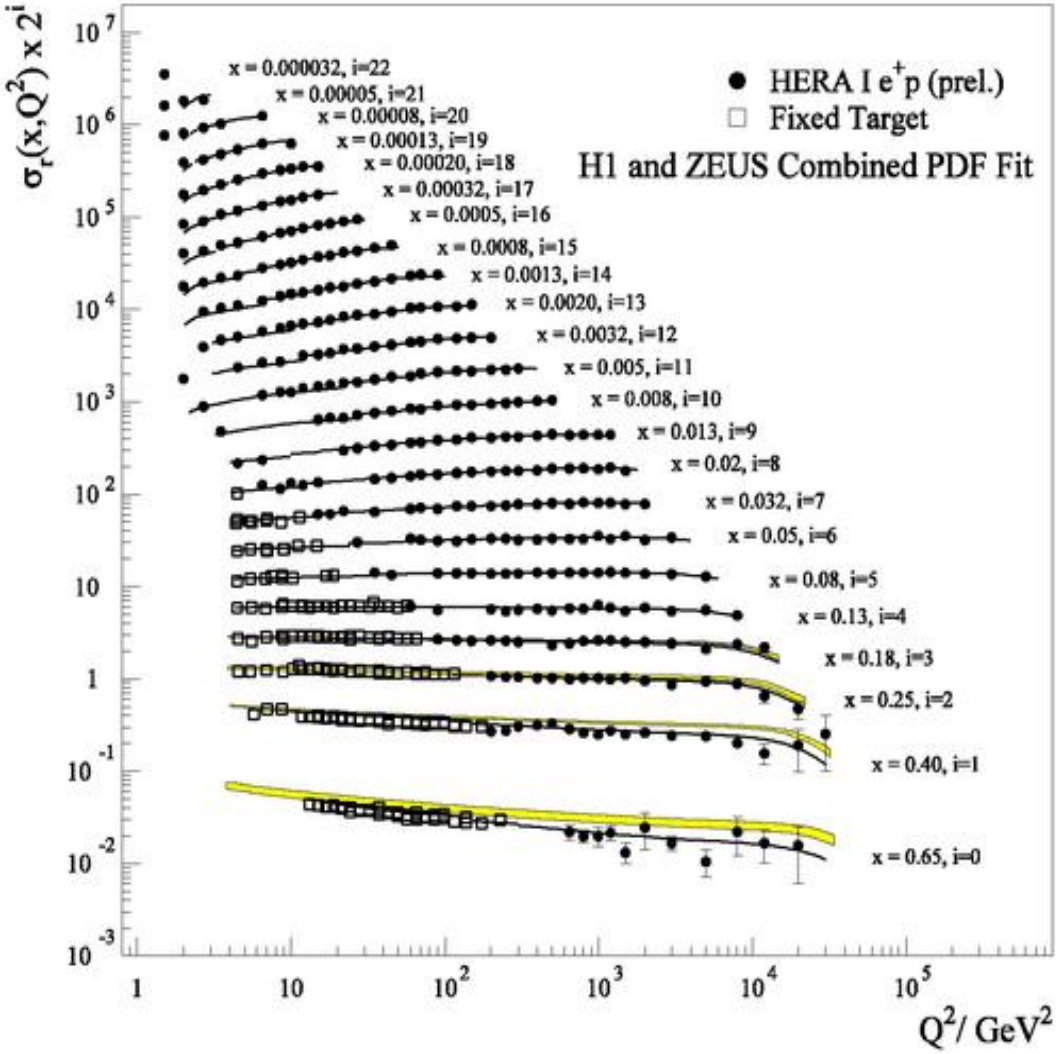
Physics @ H-NS

Hyperon polarization in inclusive Λ production

$pp \to \Lambda X$

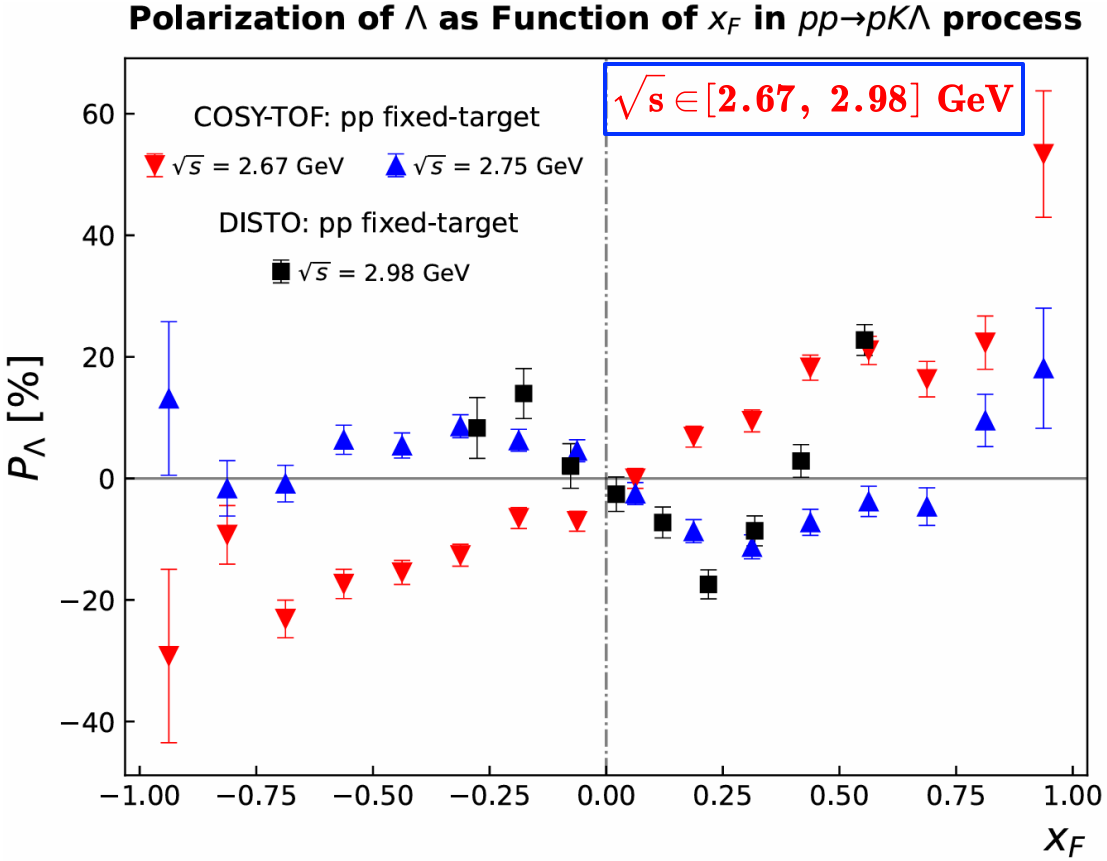


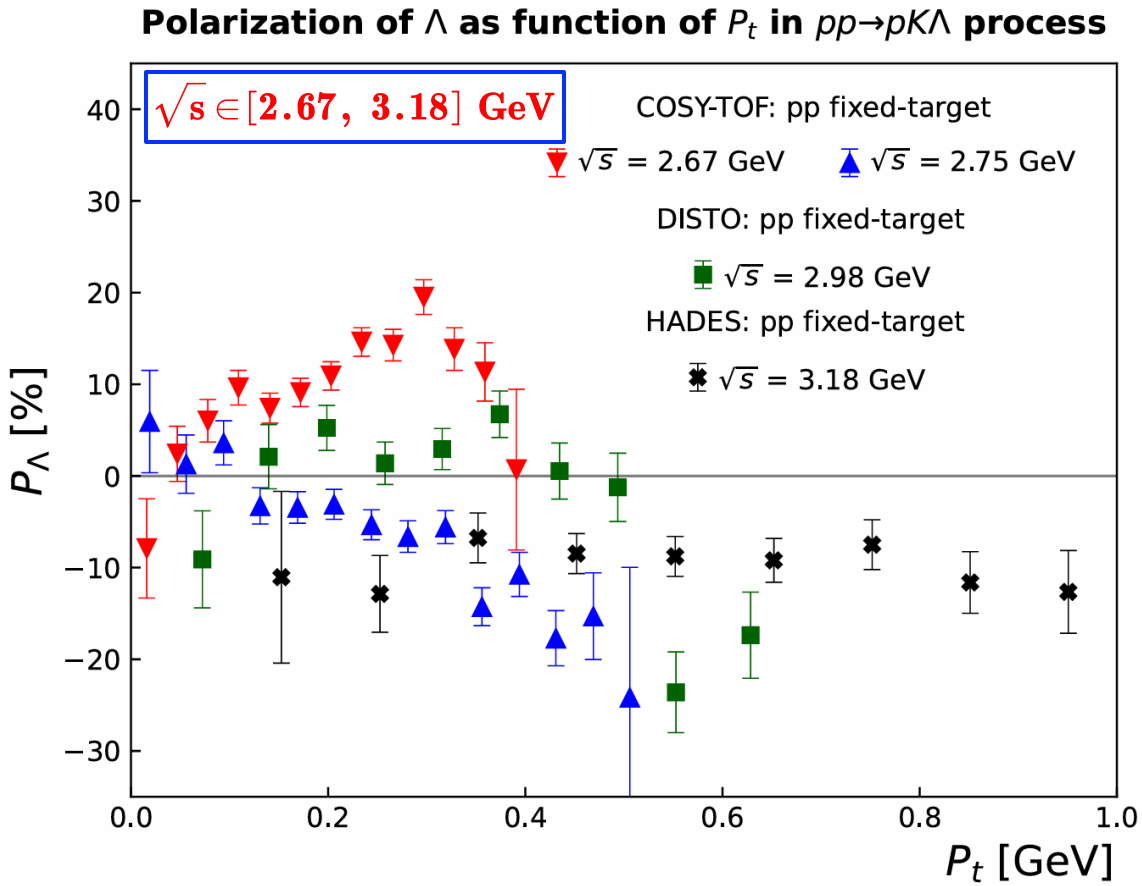
R608 Collaboration, PLB 185, 209 (1987).



"Scaling" of Λ polarization ?

Hyperon polarization in exclusive Λ production





Λ polarization exhibits multiple **reversals** in a very small energy range

Observation of hyperon production in p-p reaction

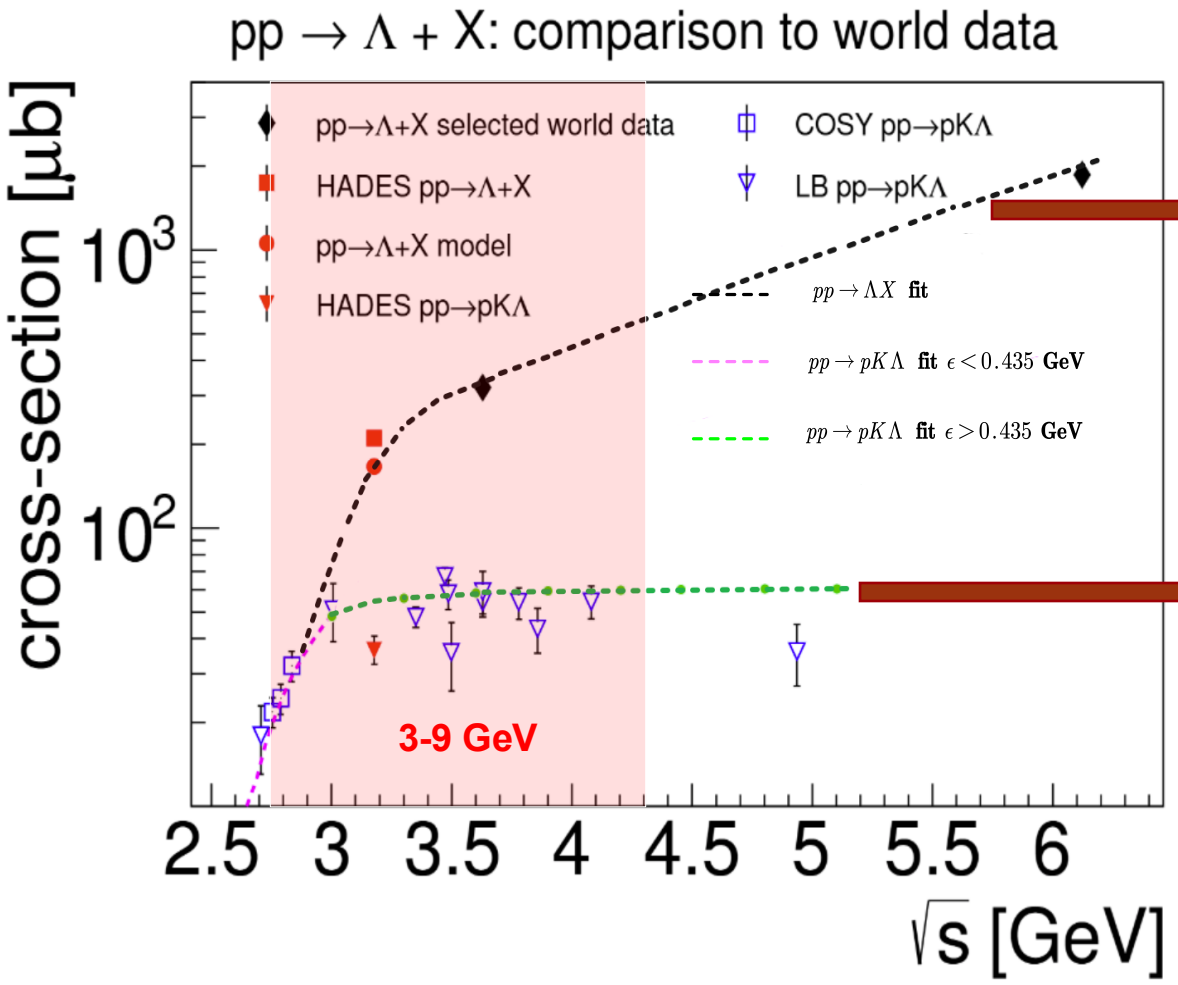
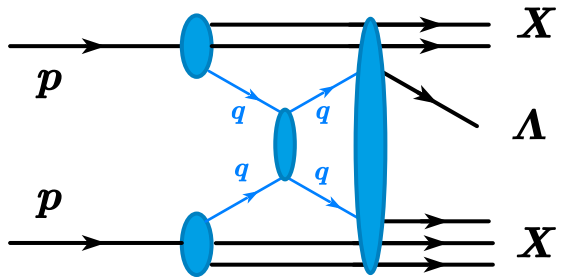


Figure frome: HADES Collaboration, Phys. Rev. C 95, 015207 (2017).

$pp \rightarrow \Lambda X$

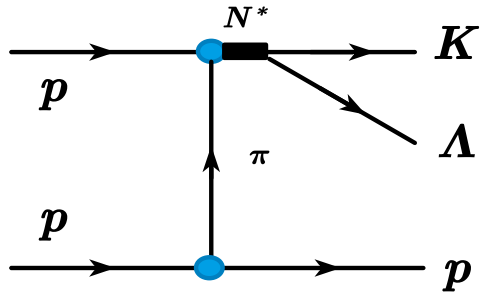
$pp \rightarrow pK^{+}\Lambda$

Fragmentation model



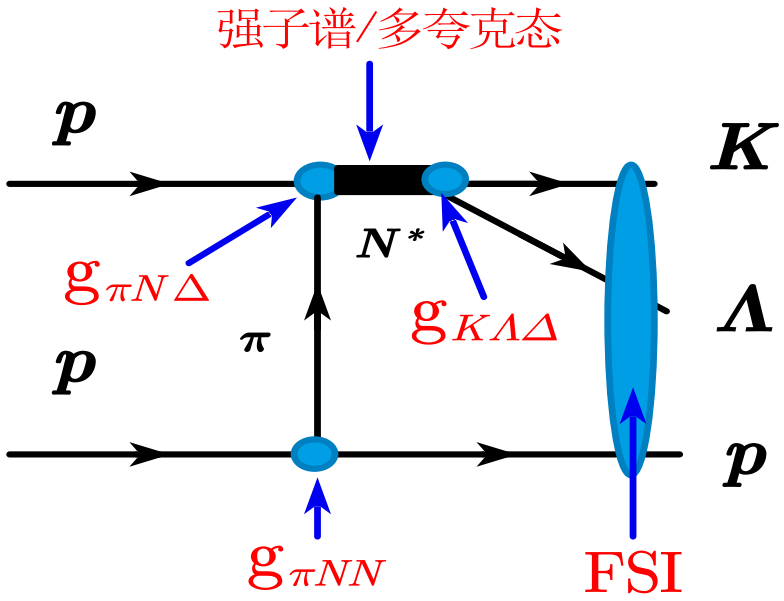
Liang Zuo-tang, and C. Boros, Phys. Rev. Lett. 79, 3608 (1997).

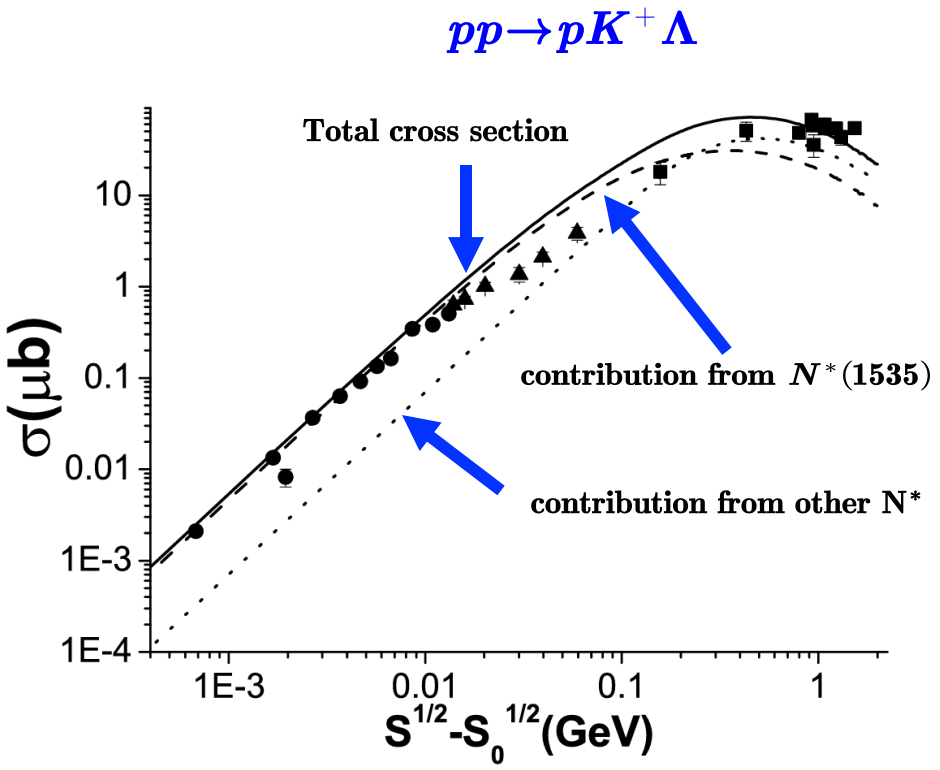
One-Boson-Exchange model



R. Machleidt, K. Holinde and C. Elster, Phys. Rept. 149, 1 (1987).

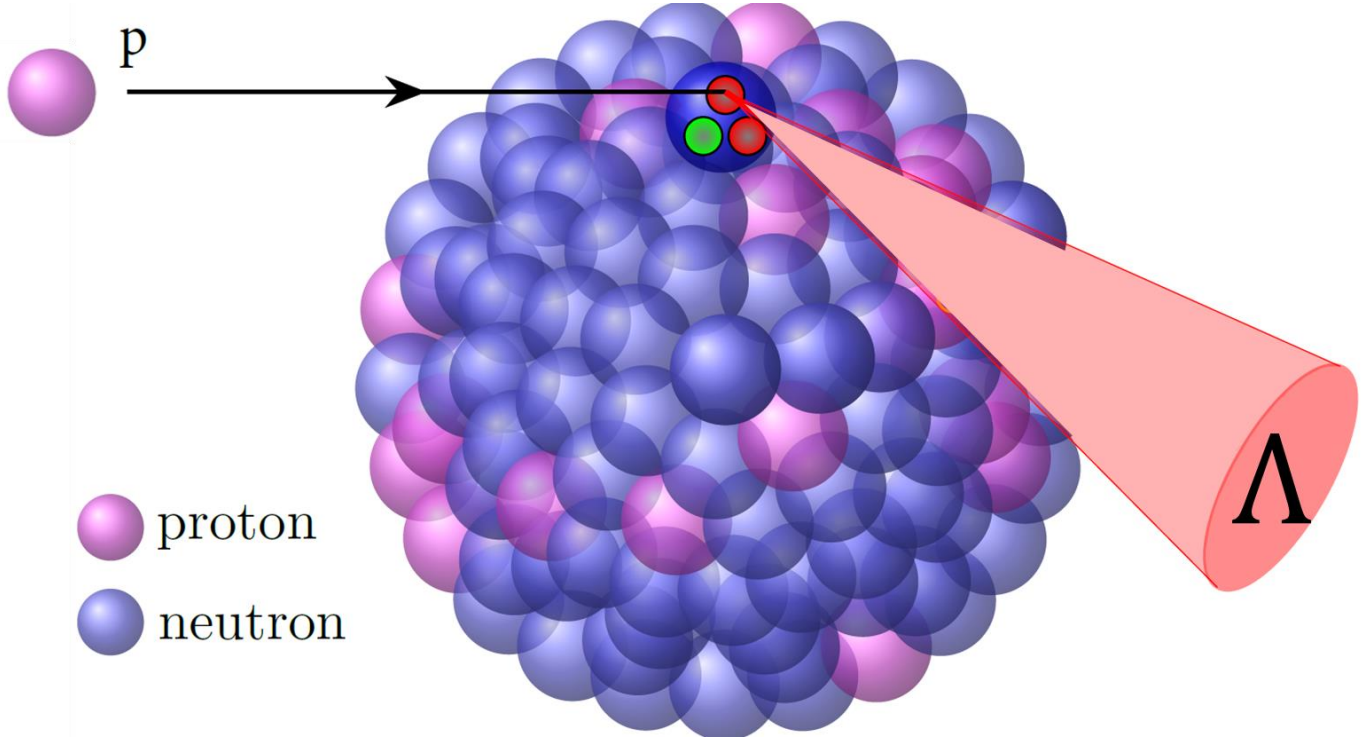
Hyperon production in $pp \to pK^+\Lambda$ process

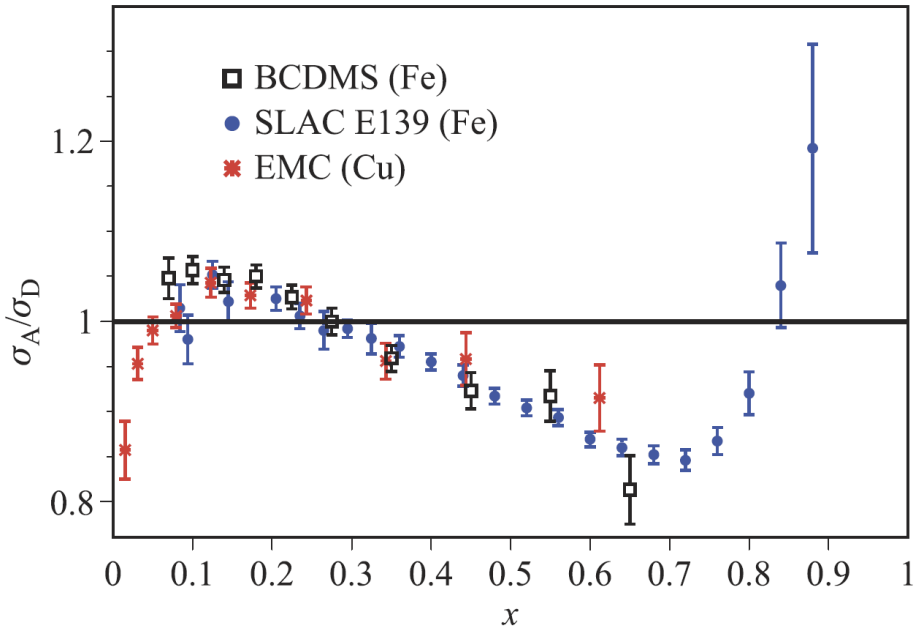




B. C. Liu, B. S. Zou, PRL 96, 042002 (2006.)

EMC effect for Λ production

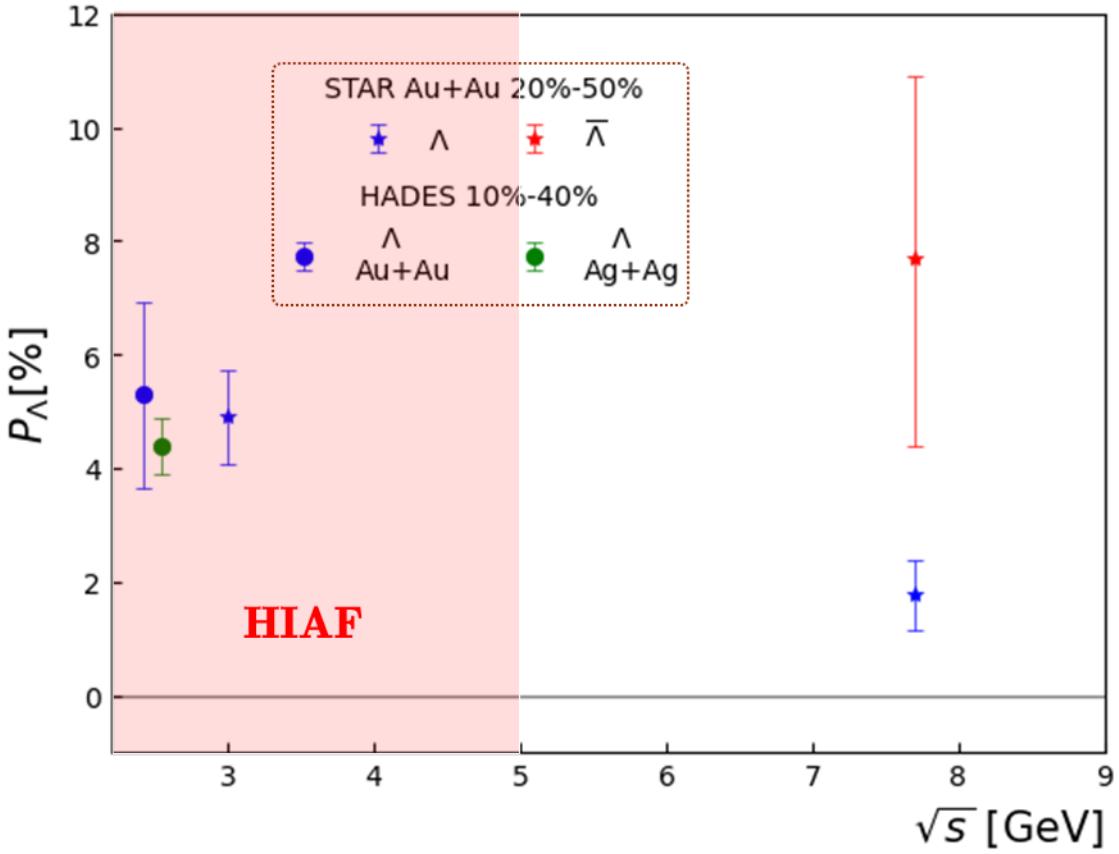


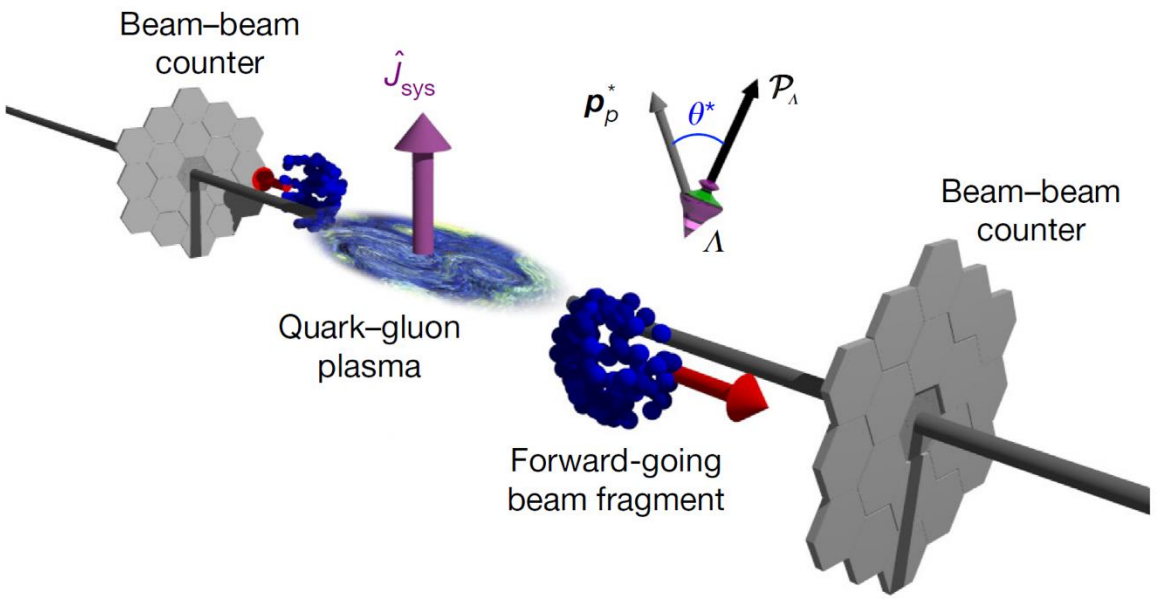


EMC effect is there for PDFs

Cold nuclear medium effect for Λ polarization

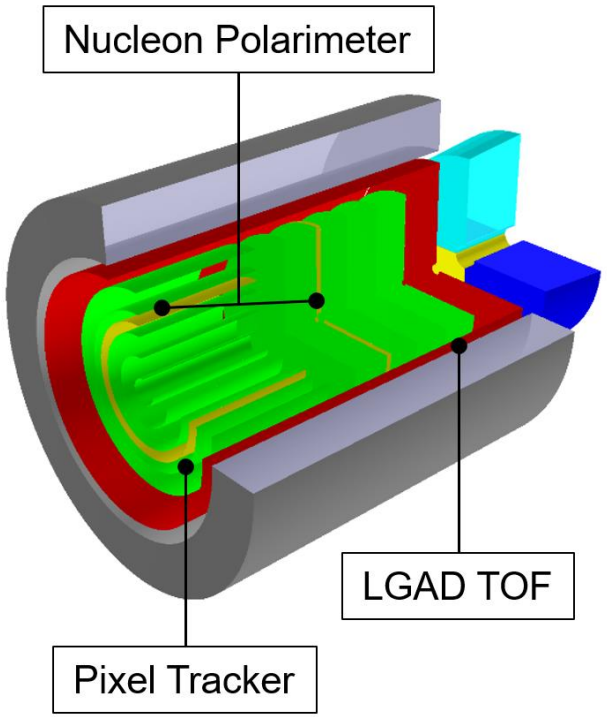
Global polarization of Λ

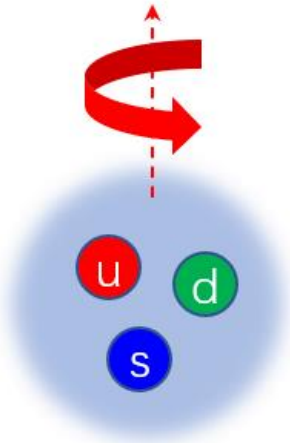


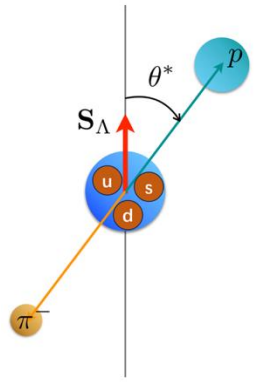


Hot nuclear medium effect

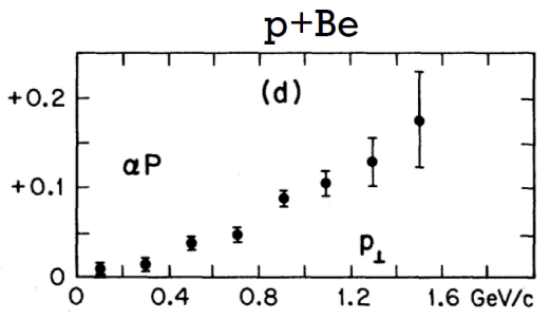
Baryon polarimeter at H-NS



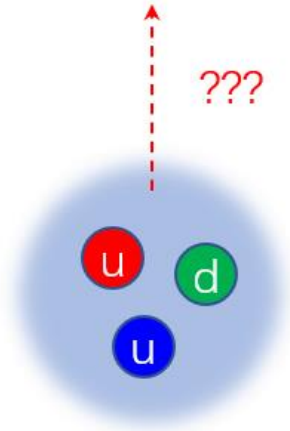


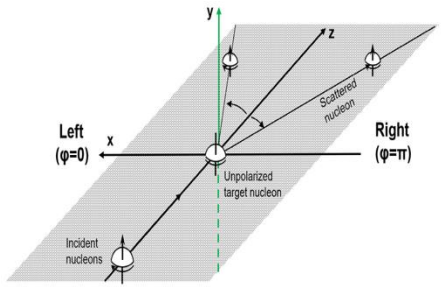


超子弱衰变角分布测量超子极化



G.Bunce, *et al.*: Phys.Rev.Lett. 36, 1113-1116 (1976)





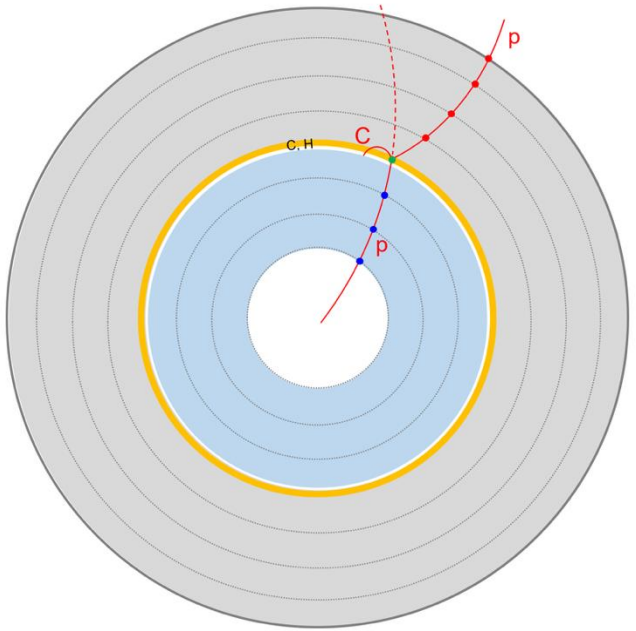
核核弹性散射测量核子极化

same stat. as Lambda

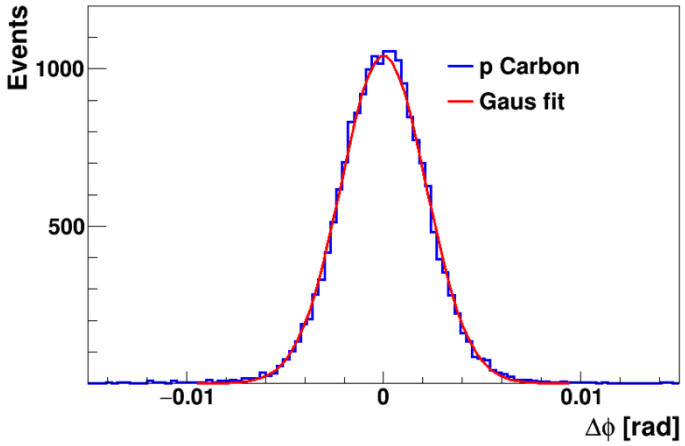
???

- 以核子极化为参考/对比，可以更好的理解超子的极化机制以及自旋起源

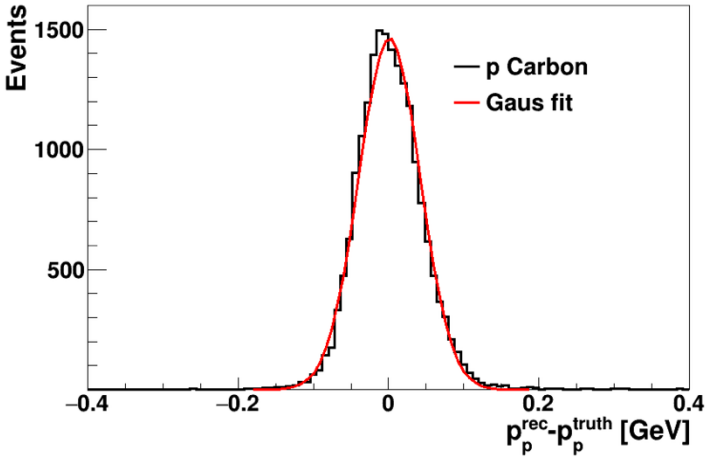
Precision measurement of proton polarization



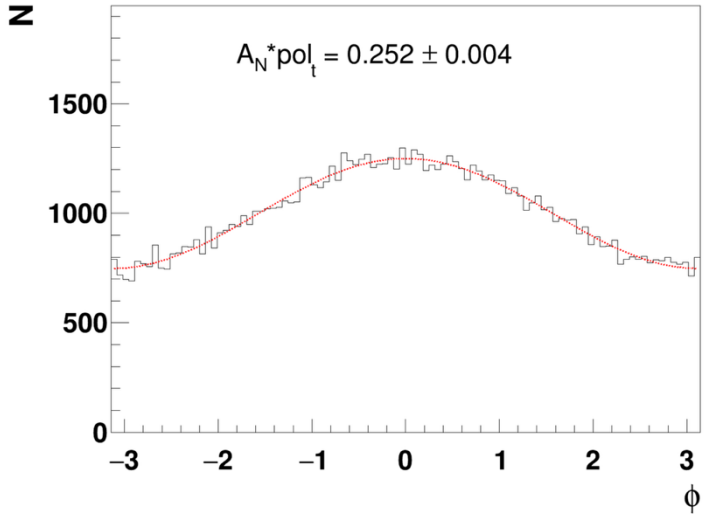
$\sigma = 2.16$ mrad



$\sigma = 0.041$ GeV



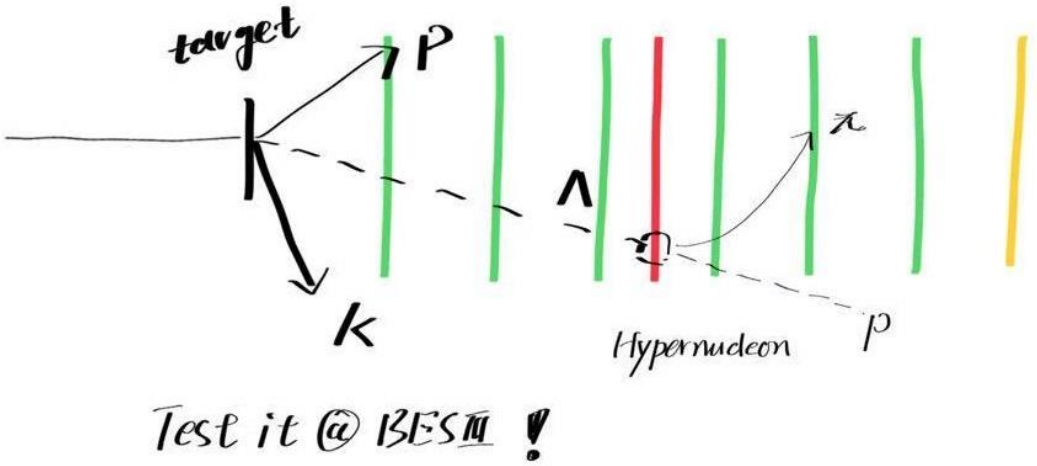
Input: 0.250



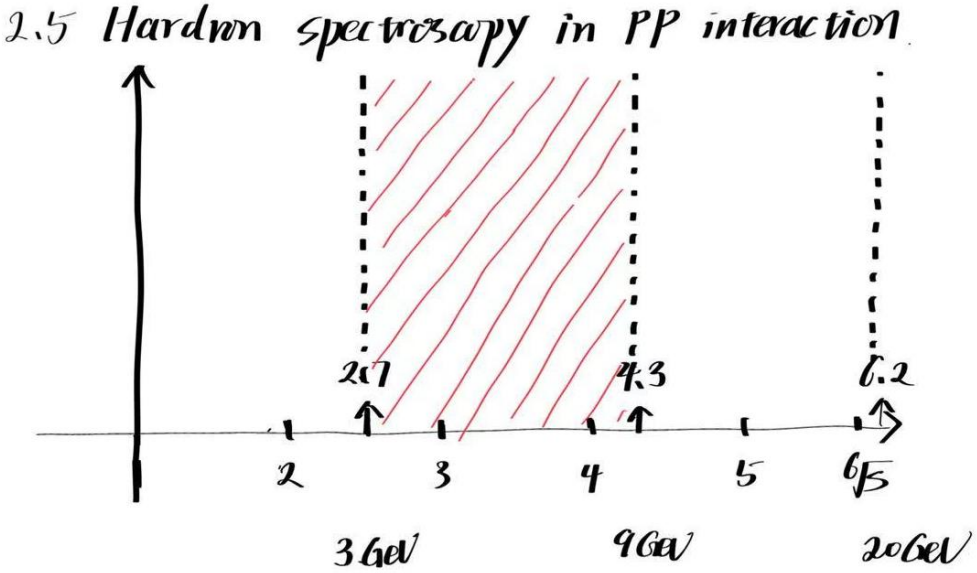
- ✓ Scattering track: > 90%
- ✓ Non-scattering track: < 1E-5
- ➢ Low background contamination!
- ➢ High precision measurement!

Other topics

- H-N interaction



- Hadron spectroscopy



Resource

- Computing resource:
  - SNSC:

cpu6248R	CPU 计算节点	浪潮 NF5280M5	2* Intel Xeon 6248R （3.0GHz，24 cores），384GB DDR4	8
cpueicc	CPU 计算节点	浪潮 NF5280M5	2* Intel Xeon 6248R （3.0GHz，24 cores），512GB DDR4	15

Simulation, filtering

  - HNS-IMP-Huizhou：
    - XEON 8358P*2， 64 core, 512 GB, 70T

Analysis

- Software framework
  - ChnsRoot @ Gitee: https://gitee.com/aiqiang-guo/chns-root
  - Managed by Git
- Webpage
  - Pingcode
  - Indico@IMP

Summary

Hopfully, we can finish the white paper at the end of this year!!

- Detector simulation
  - H-NS0(YP,JP), TF(AQ)
  - H-NS with Dipole magnet, TF (AQ, CX)
  - H-NS with solenoid, TF (GN,LQ)
- Physics projection @ H-NS
  - Λ polarization in pp, p-A (CX)
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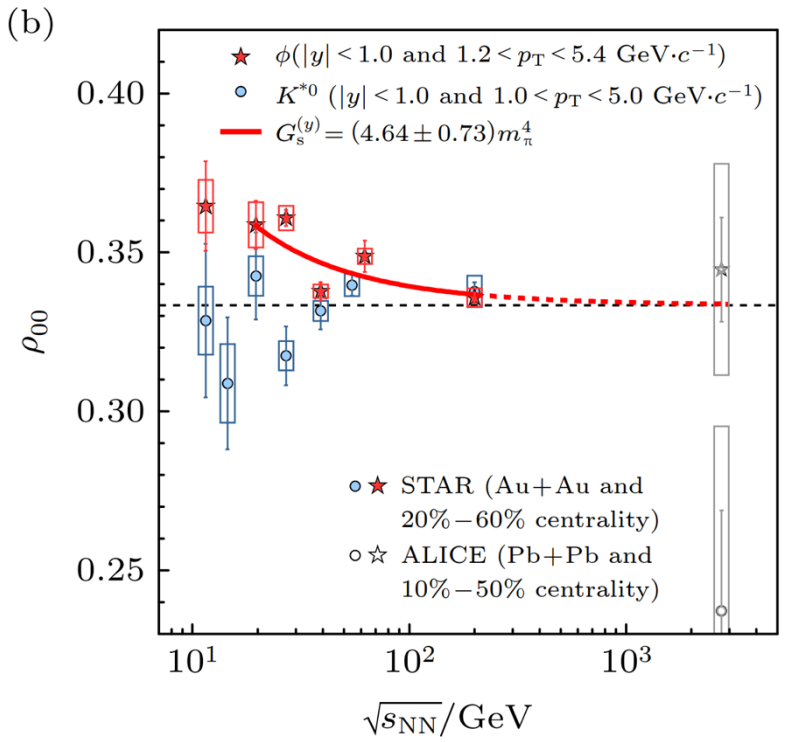
  - Global Λ polarization(SX, XH)
  - HN production (YL)
  - H-N interaction ?
  - Hadron spectroscopy in pp ?

Global polarization of vector mesons

$$\rho_{00}^{V} = \frac{1 - P_{q_1} P_{\bar{q}_2}}{3 + P_{q_1} P_{\bar{q}_2}}$$



STAR Collaboration, Nature 614 244 (2023).

No quark polarization correlations

$$\rho_{q_1 q_2 q_2} = S_\mu^{q_1} S_\nu^{q_2} S_\rho^{q_3} \Sigma_\mu^{q_1} \Sigma_\nu^{q_2} \Sigma_\rho^{q_3}$$

$P_{q_1,i}$

Two-quark polarization correlations

$$\rho_{q_1 q_2 q_2} = (S_{\mu\nu}^{q_1 q_2} S_\rho^{q_3} + S_{\mu\rho}^{q_1 q_3} S_\nu^{q_2} + S_{\nu\rho}^{q_2 q_3} S_\mu^{q_1} - 2 S_\mu^{q_1} S_\nu^{q_2} S_\rho^{q_3}) \Sigma_\mu^{q_1} \Sigma_\nu^{q_2} \Sigma_\rho^{q_3}$$

$c_{ij}^{(q_1 q_2)}$
$c_{ij}^{(q_2 q_3)}$
$c_{ij}^{(q_1 q_3)}$

Three-quark polarization correlations

$$\rho_{q_1 q_2 q_2} = S_{\mu\nu\rho}^{q_1 q_2 q_3} \Sigma_\mu^{q_1} \Sigma_\nu^{q_2} \Sigma_\rho^{q_3}$$

$c_{ijk}^{(q_1 q_2 q_3)}$

Ji-peng Lv, Zi-han Yu, ZTL, Qun Wang, and Xin-Nian Wang, PRD 109, 114003 (2024).