Status of Hyperon-Nucleon Spectrometer (H-NS)

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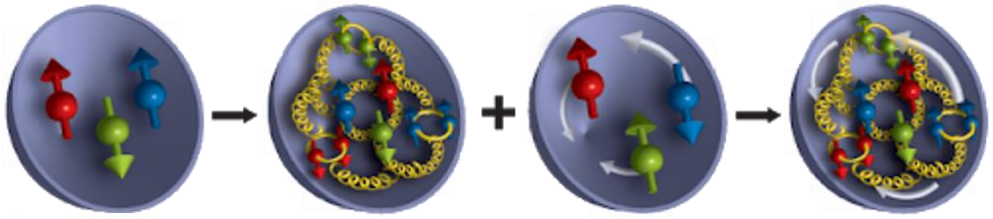
2026-7-1 西安

Nucleon Spin Structure

1988 EMC experiment → "Spin crisis"

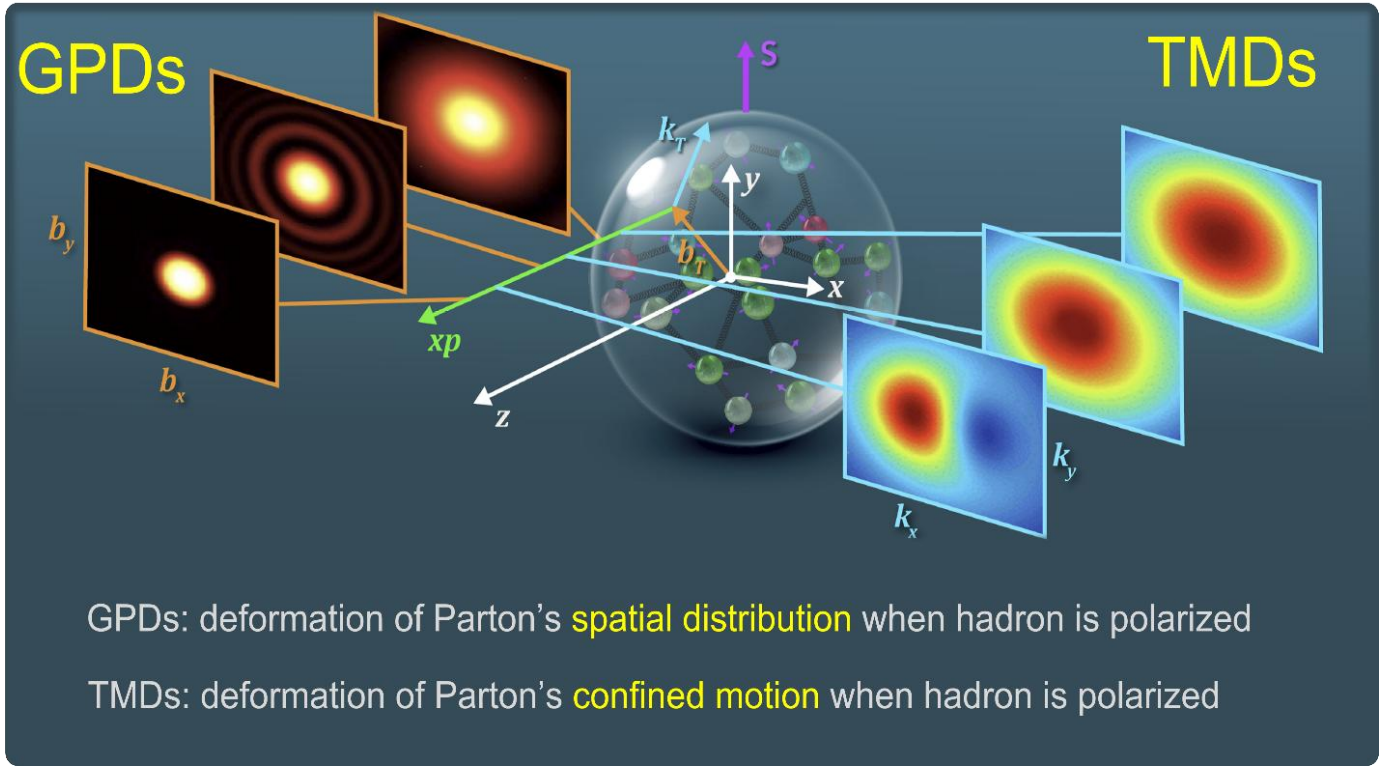


1970s 1980s/2000s Now

Spin decomposition:

$$S_{tot} = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \mathcal{L}_q + \mathcal{L}_g$$

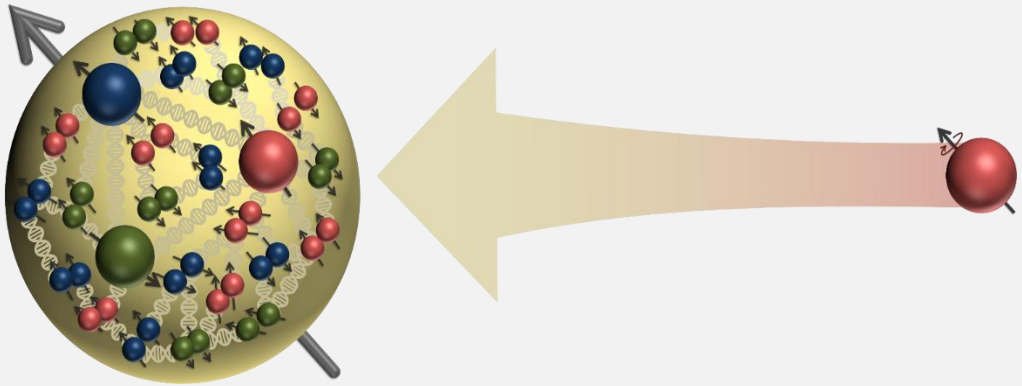
Quark spin | Gluon Spin | Quark OAM | Gluon OAM



We have a framework for the understanding of the spin structure of the nucleon

Hadron Structure with “Spin”

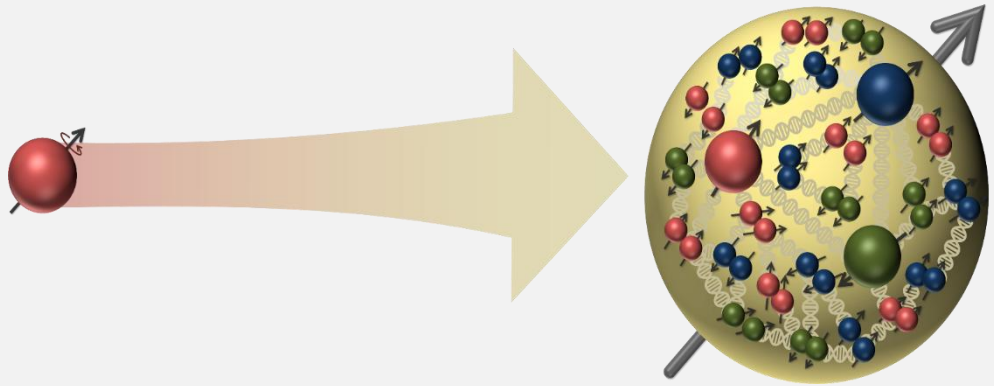
EIC: **Initial state** is polarized
-How do partons form up a polarized nucleon?



Initial state

Polarized by device

Λ polarization: **Final state** is polarized
-How do partons form up a polarized Λ / p?

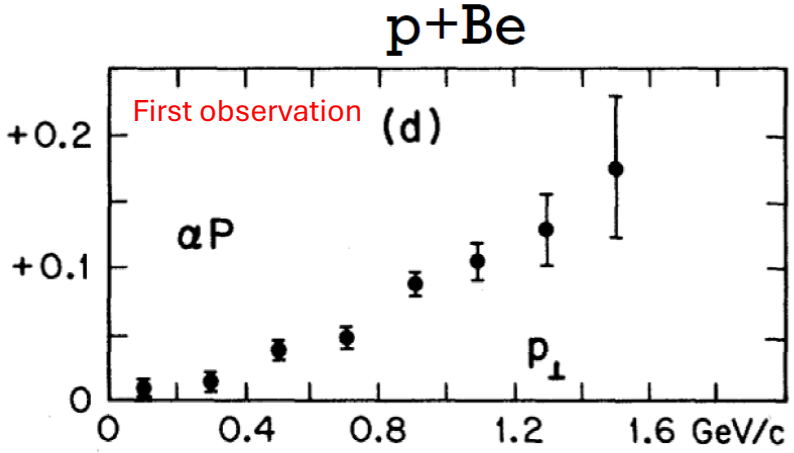


Final state

Λ serves as its own spin analyzer through the decay $\Lambda^0 \rightarrow p + \pi^-$

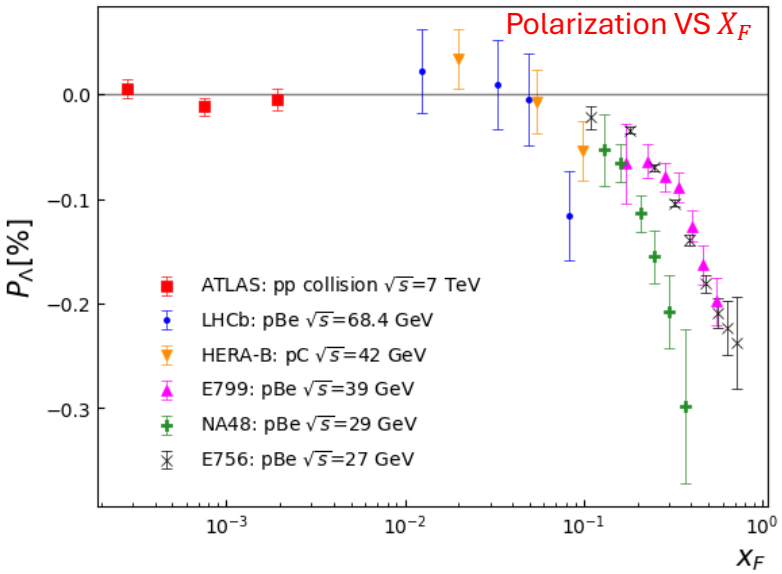
origin of nucleon spin VS origin of Λ or p polarization

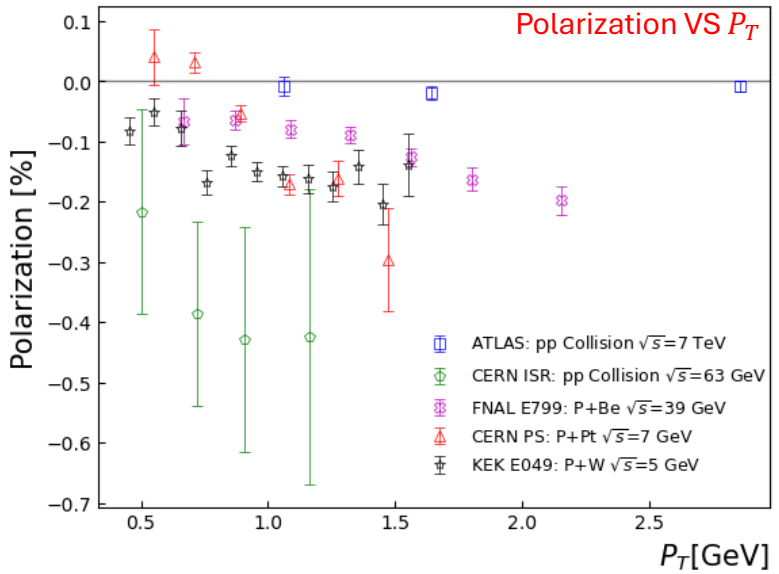
Puzzle of Λ Polarization

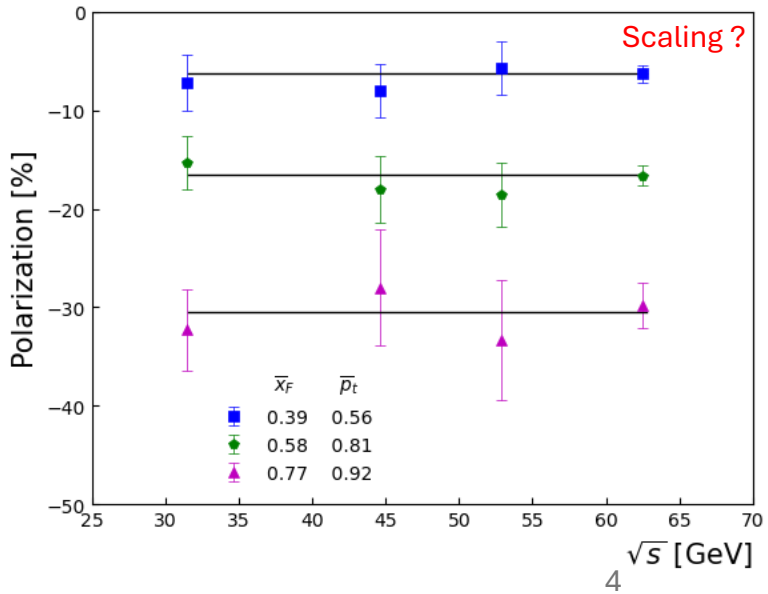


G.Bunce, *et al.*: Phys.Rev.Lett. 36, 1113-1116 (1976)

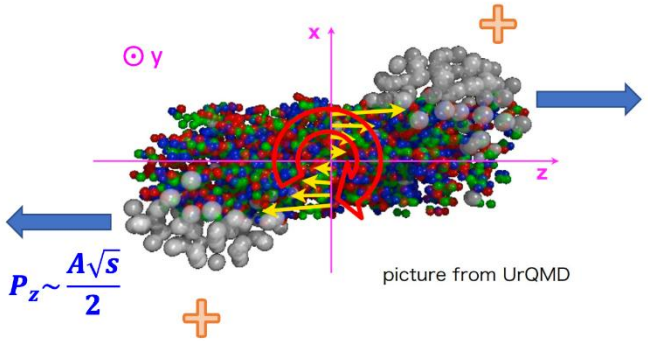
- In 1976 at Fermi-Lab, Hyperons were produced polarized in p + Be collisions: 300 GeV protons on Beryllium target
- Λ is observed to be polarized in e-e, e-p, p-p, p-A, A-A processes
- Unlike the case of "Proton spin crisis", it is lack of systematic studies both theoretically and experimentally

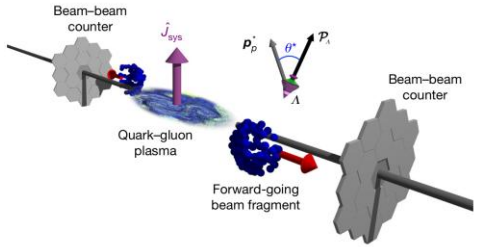


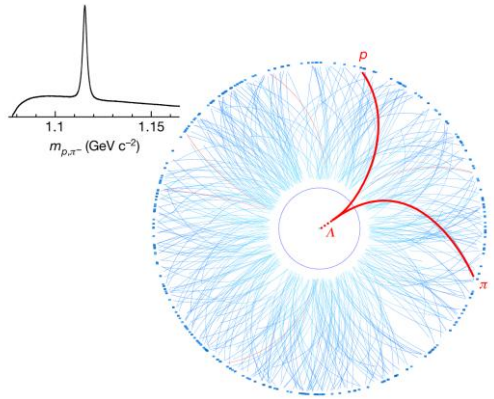




Λ Global Polarization in Heavy Ion Collision







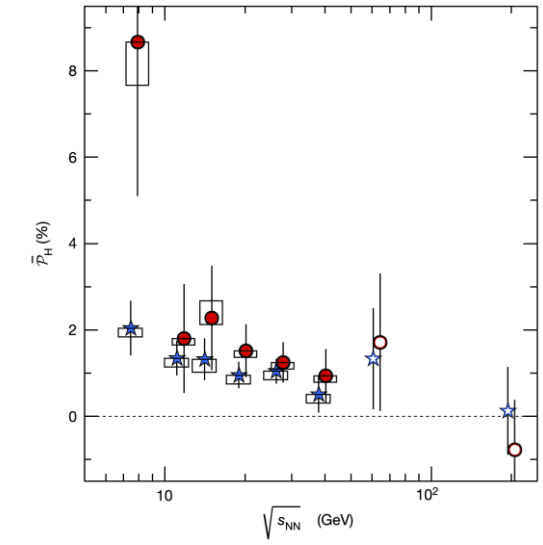
$$J_0 \sim \frac{Ab\sqrt{s}}{2} \sim 10^6 \hbar$$

Global angular momentum

$$eB \sim \gamma \alpha_{\mathrm{EM}} \frac{Z}{b^2} \sim 10^{18}\ \mathrm{G}$$

Strong magnetic field

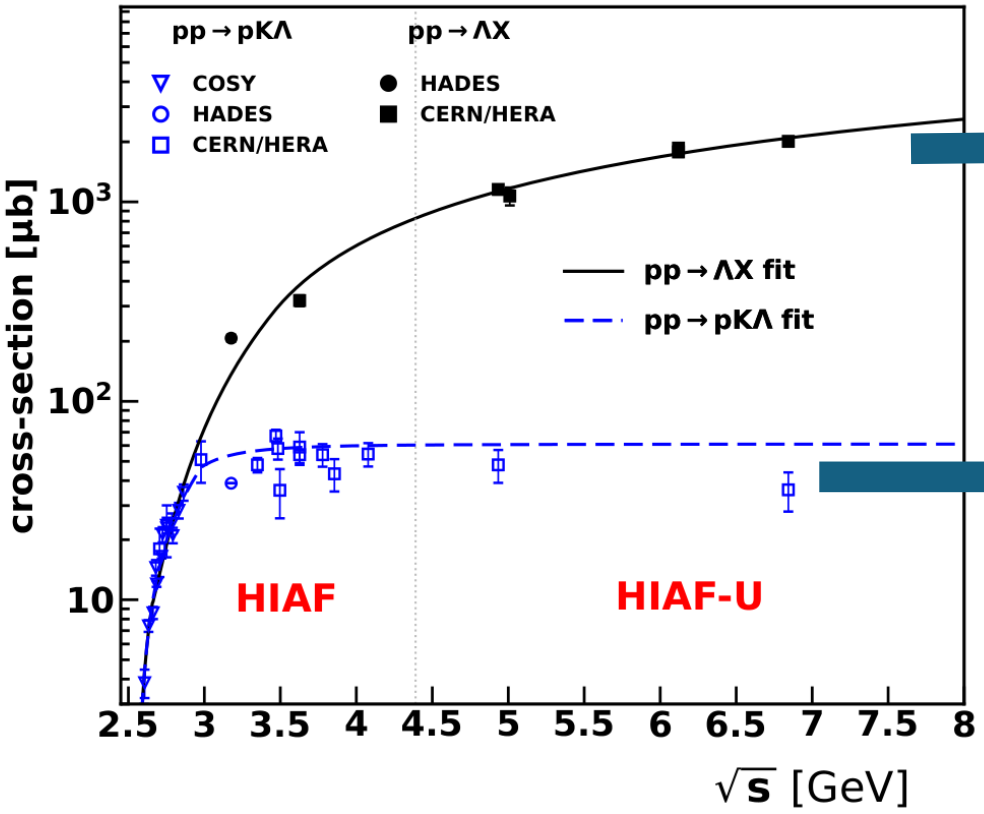
- Λ polarization studied in heavy ion collision.
- This effect can be attributed to the vorticity of the QGP, strong magnetic fields, and quantum anomalies.
  - Clear centrality dependent
  - Expect vanished at $\sqrt{s_{NN}} \sim 2m_N$



STAR, Nature 548, 62 (2017)

Z. T. Liang and X. N. Wang, Phys. Rev. Lett. 94, 102301 (2005); 96, 039901(E) (2006).

Rich Topics for Hadron and Heavy Ion Physics

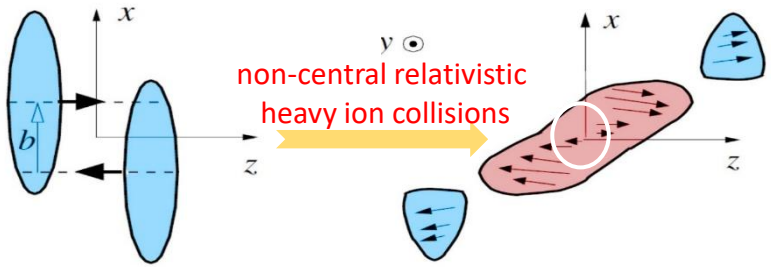


$pp(A) \rightarrow \Lambda + X$ **polarization through hadronization**

Zuo-tang Liang, and C. Boros, Phys. Rev. Lett. 79, 3608 (1997); PRD 61, 117503 (2000).
H. Dong and Zuo-tang Liang, PRD 70, 014019 (2004); PRD 72, 033006 (2005).

$pp \rightarrow \mathrm{p} + \mathrm{K} + \Lambda$ **Λ polarization in exclusive processes**

R. Machleidt, K. Holinde and C. Elster, Phys. Rept. 149, 1 (1987).
B. C. Liu, B. S. Zou, PRL 96, 042002 (2006).



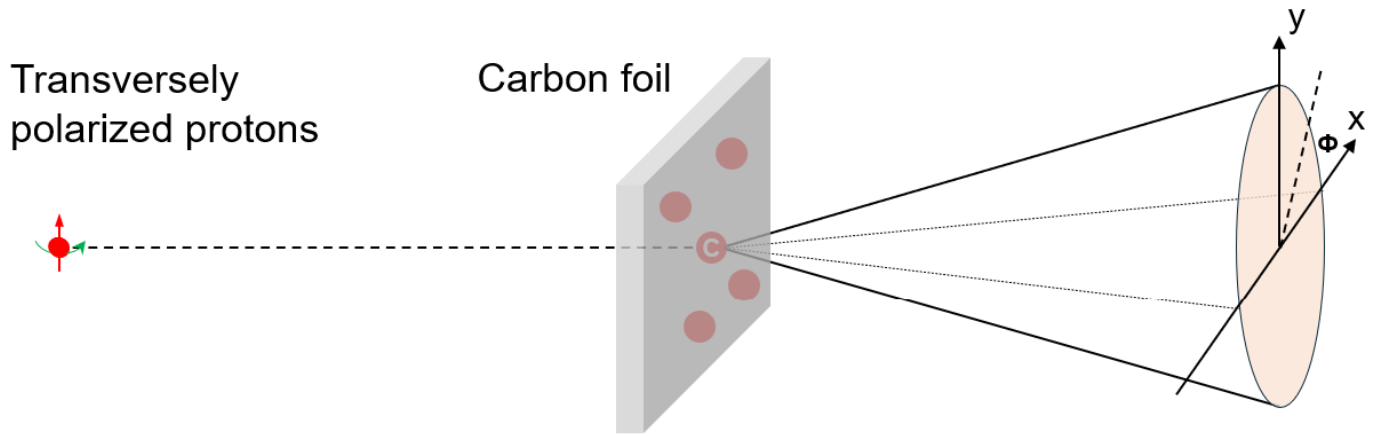
$AA \rightarrow \Lambda + \mathrm{X}$ **Global polarization**

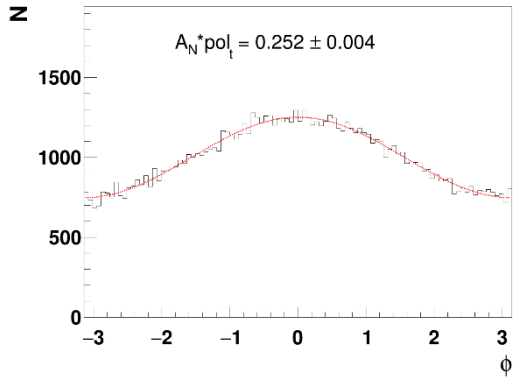
Zuo-Tang Liang, Xin-Nian Wang, PRL 94,102301 (2005); PLB 629, 20 (2005).
Jian-Hua Gao, Shou-Wan Chen, Wei-tian Deng, Zuo-Tang Liang, Qun Wang, Xin-Nian Wang, PRC 77, 044902 (2008).

Principle of Proton Polarimeter

Relation between the **spin-dependent cross-section** of p + p/C scattering and the **asymmetries**

$$\frac{d\sigma}{d\phi d\cos\theta} = \frac{1}{2\pi}\frac{d\sigma_0}{d\cos\theta}\left[1 + P_y A_N(\theta)\cos\phi\right]$$





More protons to the left:
Left-right asymmetry

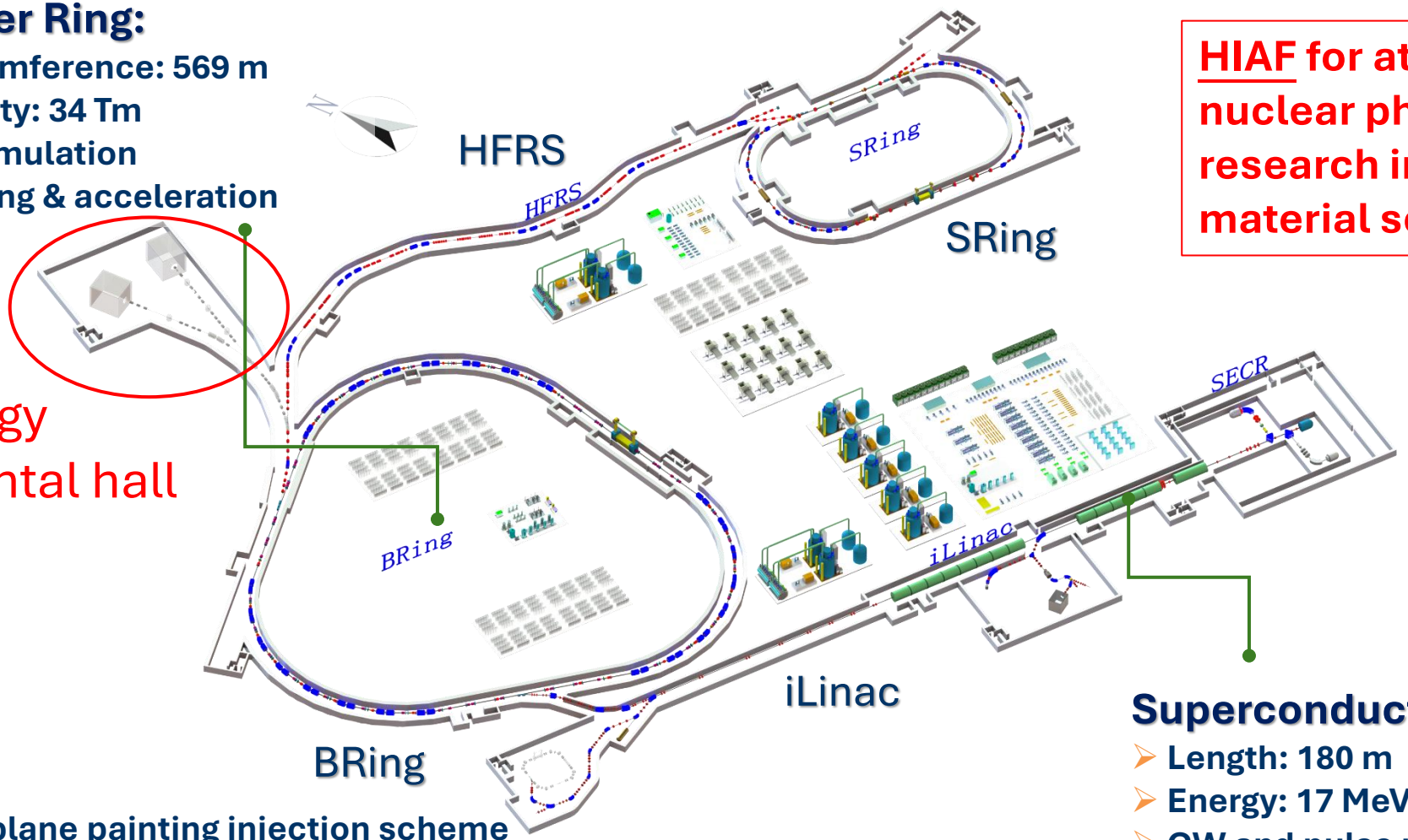
Widely used as polarimetric reaction to measure proton beam polarization (PSI, TRIMUF, LAMPF, COSY, SATURNE, ZGS, KEK-PS, AGS, RHIC …)

New detector on H-NS to directly measure proton polarization

High Intensity heavy-ion Accelerator Facility (HIAF)

Booster Ring:

- Circumference: 569 m
- Rigidity: 34 Tm
- Accumulation
- Cooling & acceleration



High energy experimental hall

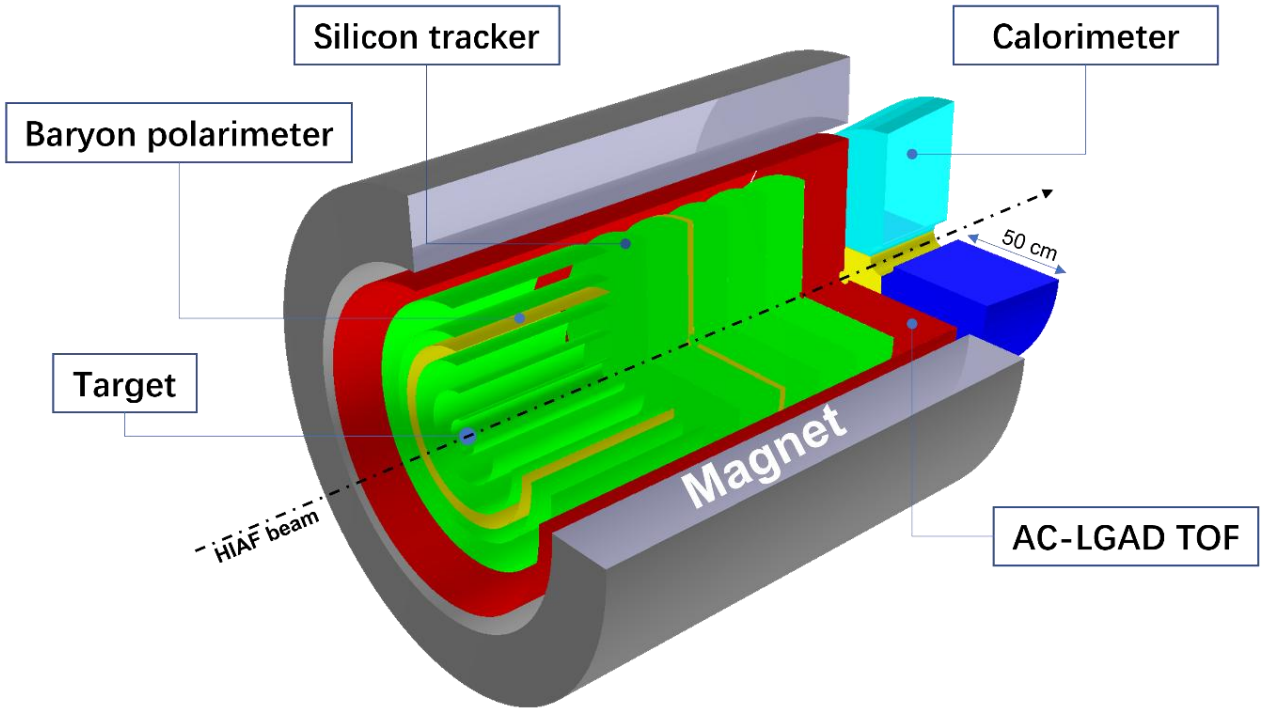
HIAF for atomic physics, nuclear physics, applied research in biology and material science etc.

Superconducting Ion Linac:

- Length: 180 m
- Energy: 17 MeV/u (U^{34+})
- CW and pulse modes

- Two-plane painting injection scheme
- Fast ramping rate operation

Hyperon-Nucleon Spectrometer (H-NS)



Mag. Field: 1.5 Tesla

Tracker: MIC6, 30X30 μm^2, 0.35%X/X_0

LGAD: σ_t ~ 30 ps , 300X300 μm^2

Calorimeter: σ_E ~ 3% @ 1GeV

Polarimeter: nucleon and photon polarization

Momentum resolution:

- ~2%@1GeV

PID:

- K, π separation (~3σ) up to 2 GeV/c .
- K, p separation (~3σ) up to 5 GeV/c

Vertex resolution:

- Excellent vertex resolution for background suppression
- Low Material budget (<10%)

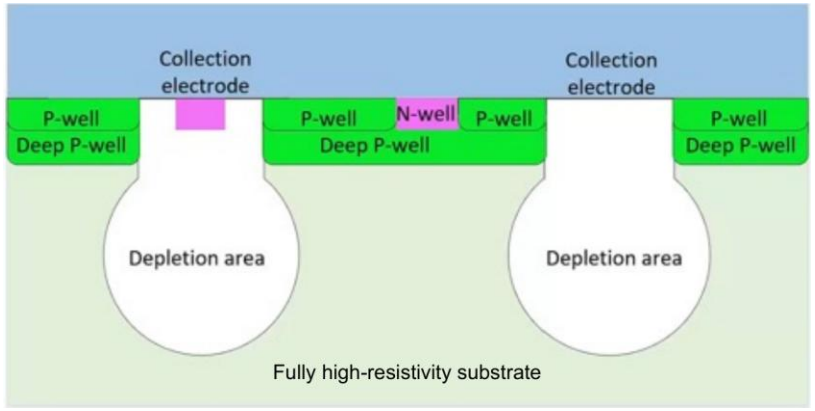
Acceptance:

- 5 to 100 degree

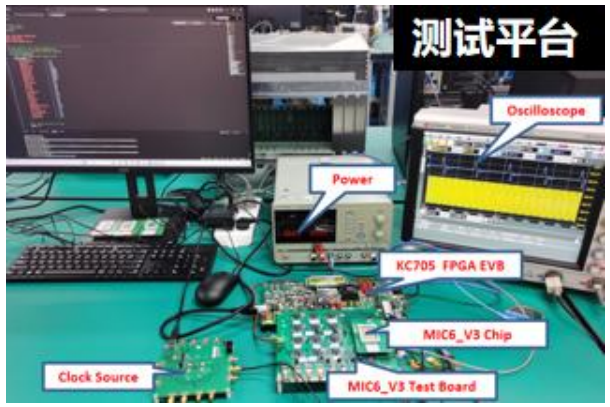
High event rate

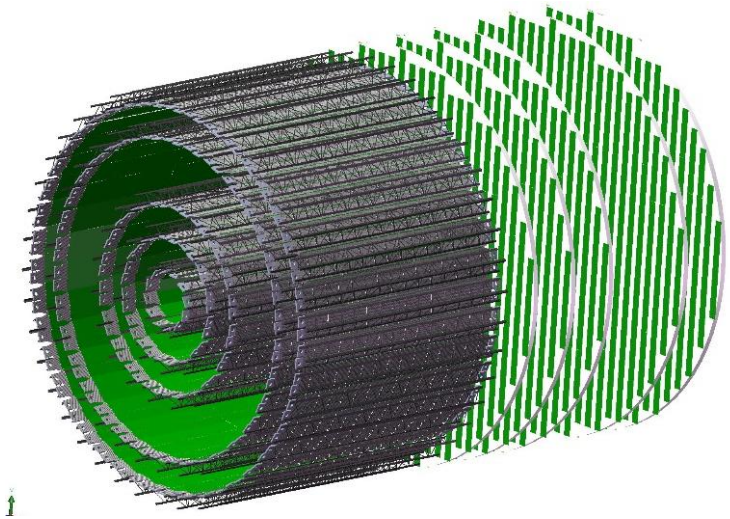
- 100MHz

Silicon tracker at H-NS

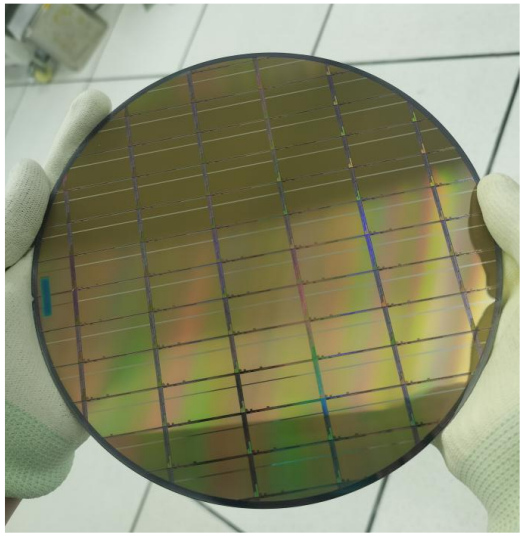


MIC6 development at CCNU



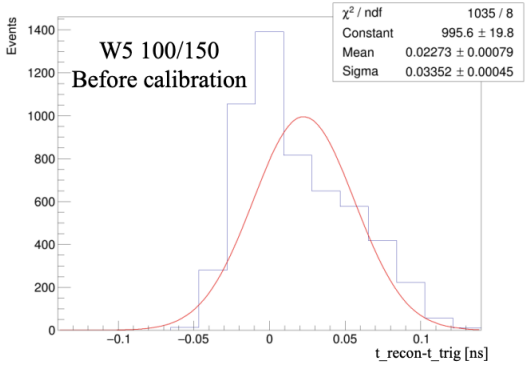


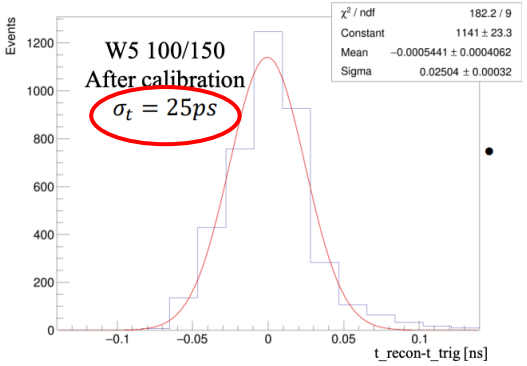
- **MIC6 MAPS pixel chip:** development and manufacture with the domestic process
- **Readout electronics** (ITS2 based design) **and DAQ** (ALICE CRU/FELIX protocol, GBTx, …)
- **Detector assembly and integration:**
  - **Vertex detector:** Stave module design (spatial resolution: ~ 5 μm with pixel size 30 μm, total material < 0.35%X/X_0 per layer)
  - **Forward tracker:** Ladder module aligned to disc super-module (spatial resolution: ~ 5 μm with pixel size 30 μm, total material < 0.45%X/X_0 per layer)

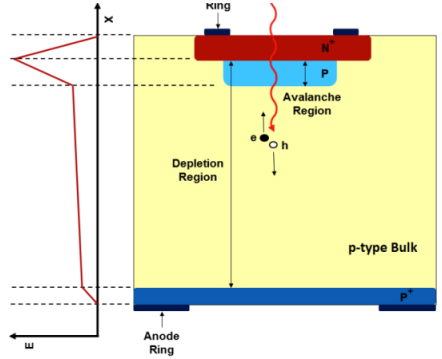


AC-LGAD at H-NS

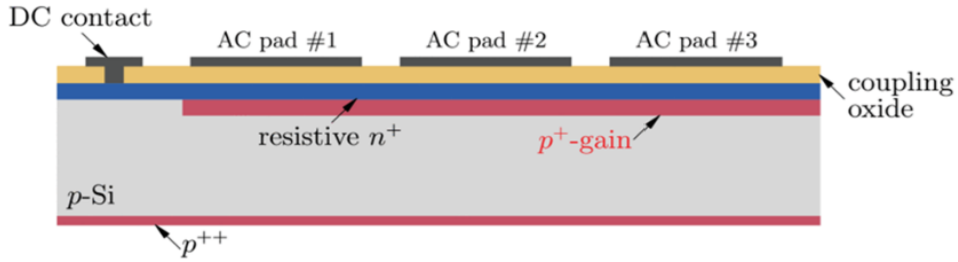
- Low Gain Avalanche Diode (LGAD):
  - A p+ doped layer (commonly called gain layer) is implanted near the PN junction
  - Low fill factor with finer granularity
- AC-LGAD:
  - The gain layer is not segmented and a dielectric layer is deposited between the gain layer and segmented electrodes
  - Simultaneously good spatial and temporal resolutions
- Recent development from USTC:
  - Two wafers with different n^+ dose: W5 high n^+ dose and W6 low n^+ dose.
  - Sensor size : 1300×1300×50 μm.
  - Sensor with different pad-pitch size: Large pad size/pitch: 100/150 μm, Small pad (Strip) size/pitch: 50/75 μm.



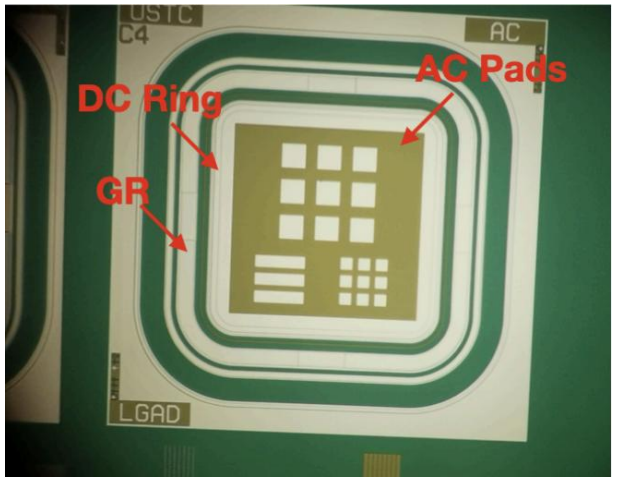




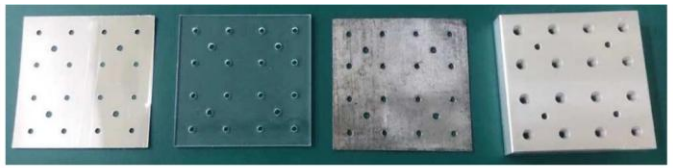
(a) LGAD

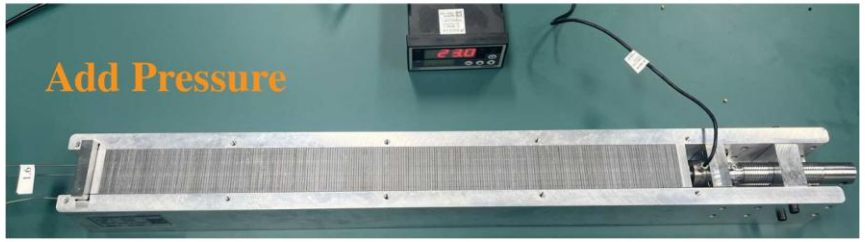


(b) AC-LGAD

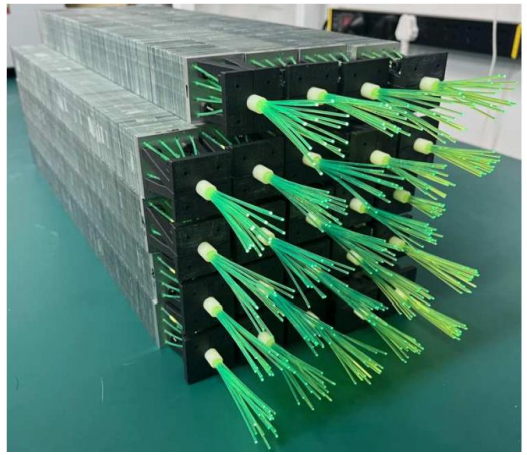


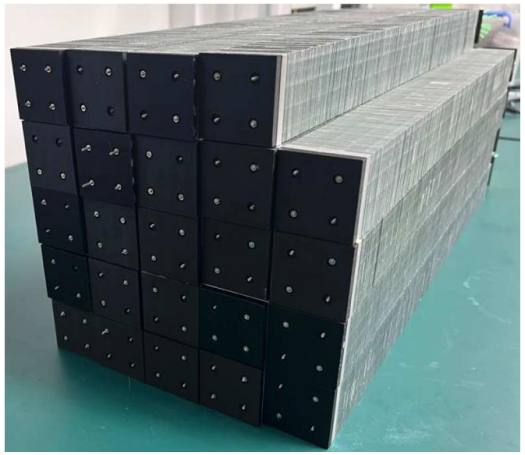
The Endcap Calorimeter at H-NS





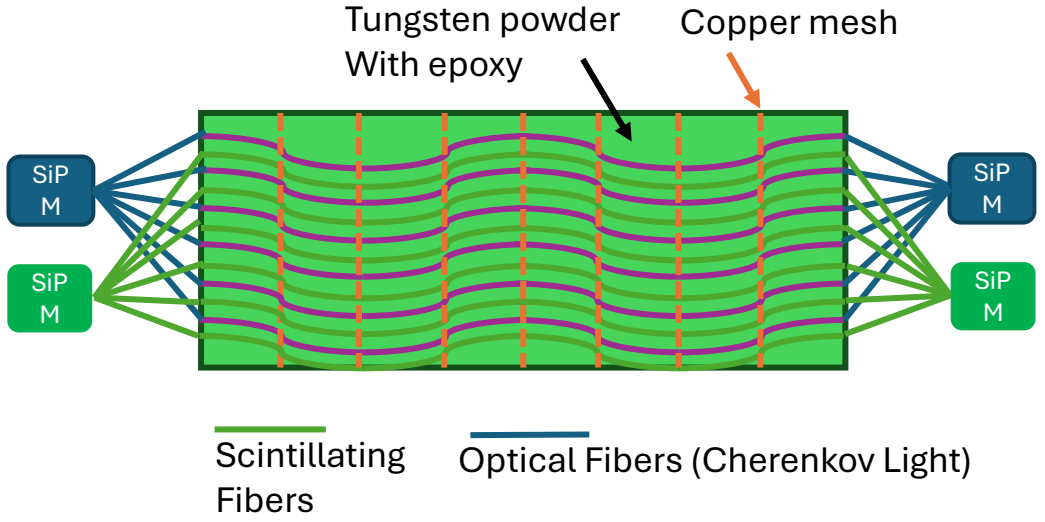
Shashlik Module





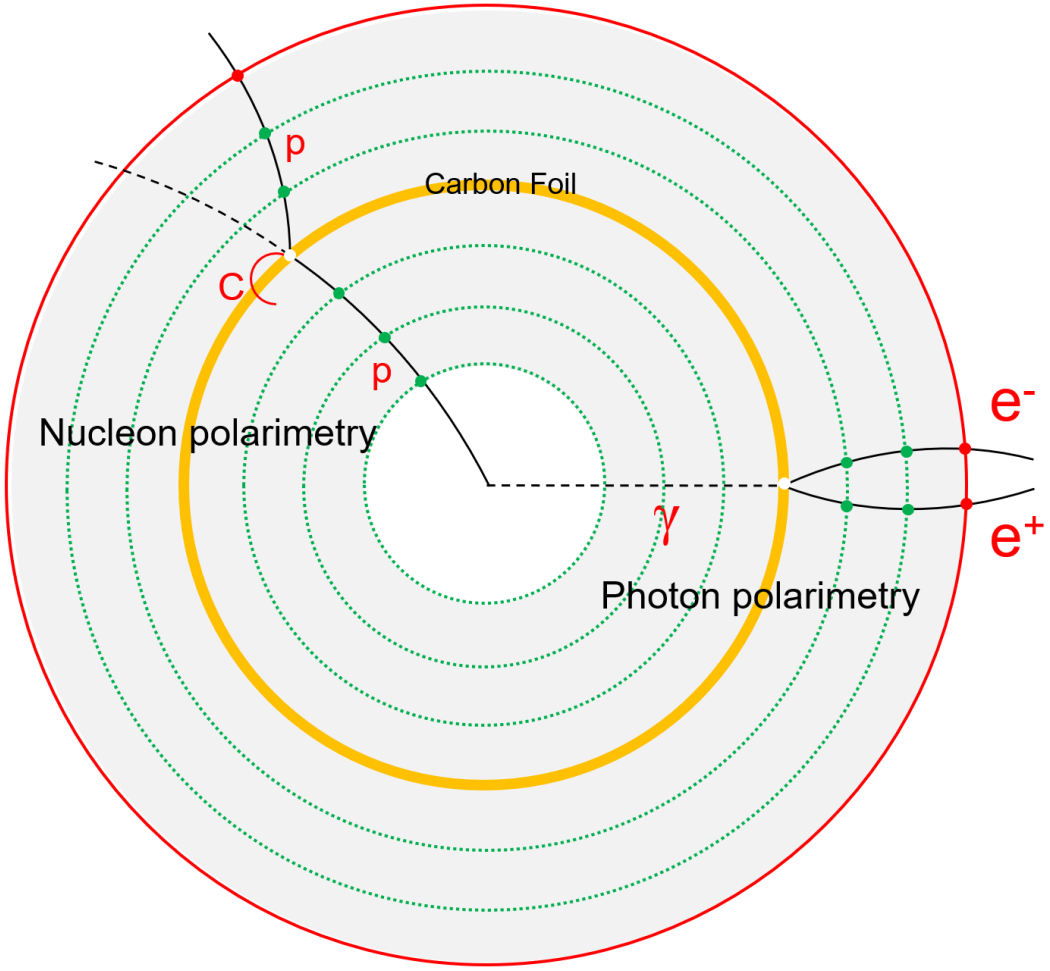
Prototype of Calorimeter

Dual read-out: better hadron shower resolution, PID capability



- R&D for calorimeter technology
- Hybrid design for the end-cap ECAL:
  - PbWO4 with high granularity for the central part,
  - Lead glass with cost-effective for the outer part

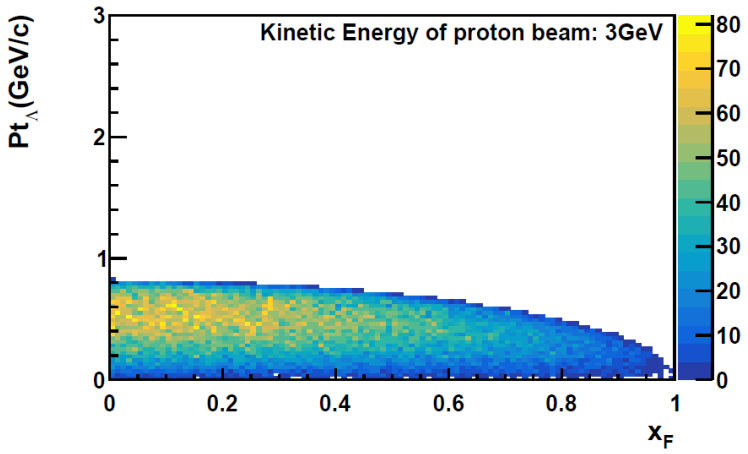
Proton Polarimeter at H-NS

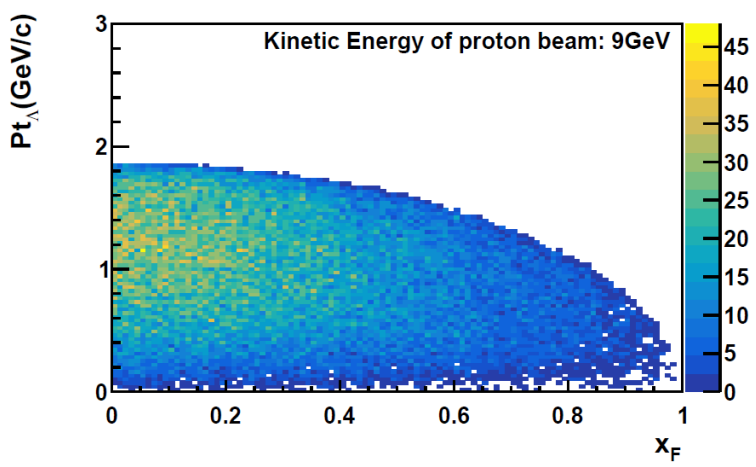


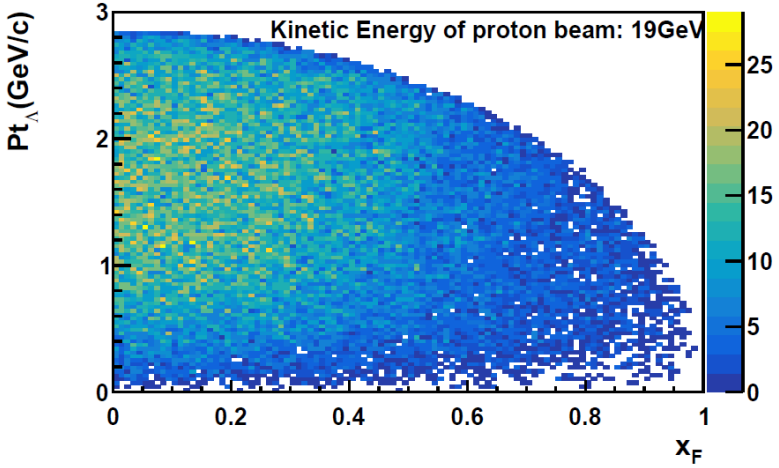
- **Carbon foil**
  - **0.5-1 mm thickness (<1% X/X_0)**
  - **R: 20-30 cm**
  - **Probability: pC / pp , γ-conversion(1E-3)**
  - **Tiny influence to conventional performance**
- **Position : in-between the tracking devices**
  - **Appliable in all reactions: ee/ep/pp/pA/AA**
  - **Appliable in high energy machines**

Yutie Liang, et. al., Phys. Rev. D 112, L031502
NST in press, arXiv: 2512.02804
NST in press, arXiv: 2601.21325

H-NS Kinematics Coverage







3 GeV → 9 GeV → 20 GeV

Allow for a multi-dimensional mapping of the Λ^0 polarization and production

1. Beam energy scan
2. p → p, p → A, A → A data taking

Uncertainty Projection of the Polarization Measurement

pp → p/Λ + X

H-NS

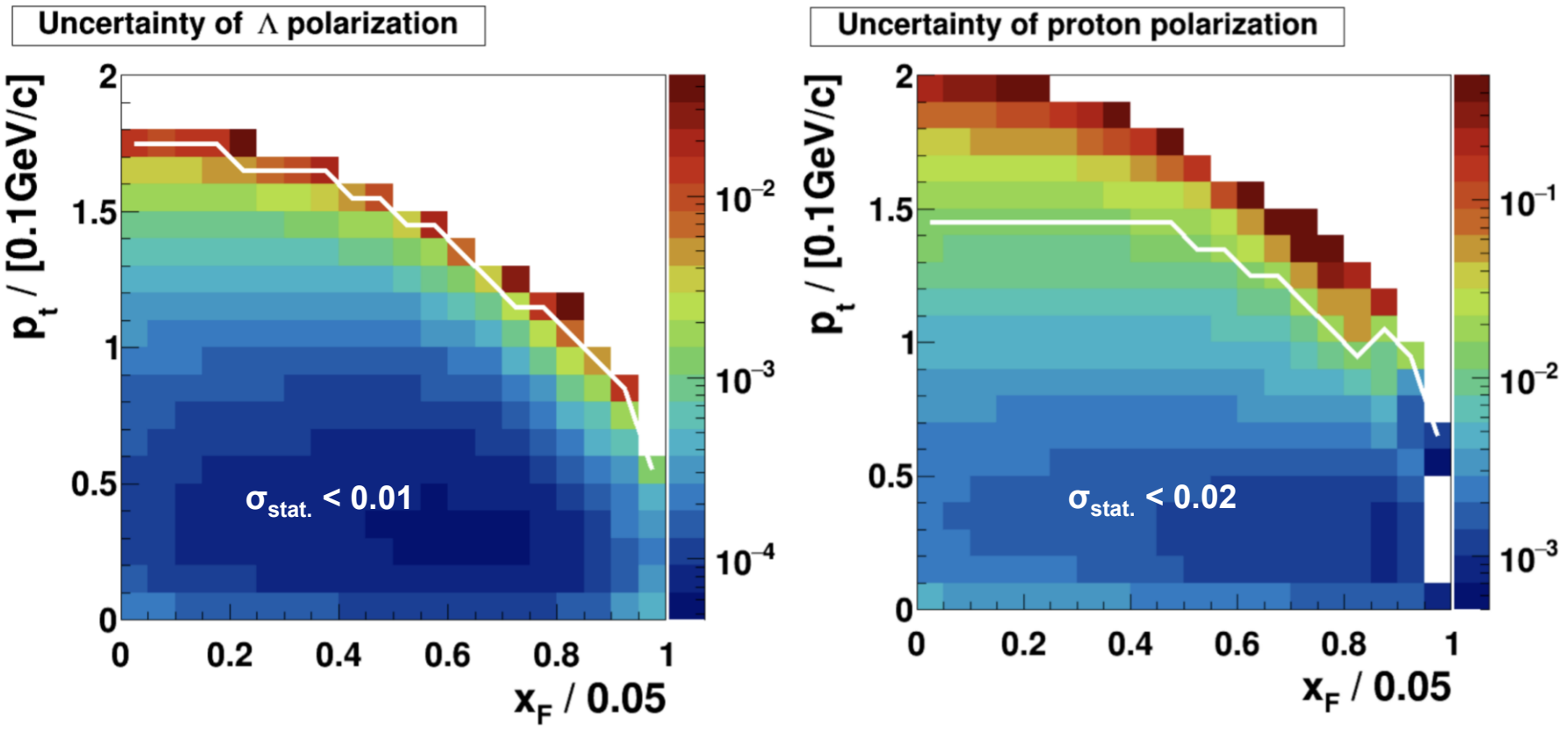
Reaction: p+p

Event rate:1MHz

Time: 3 months

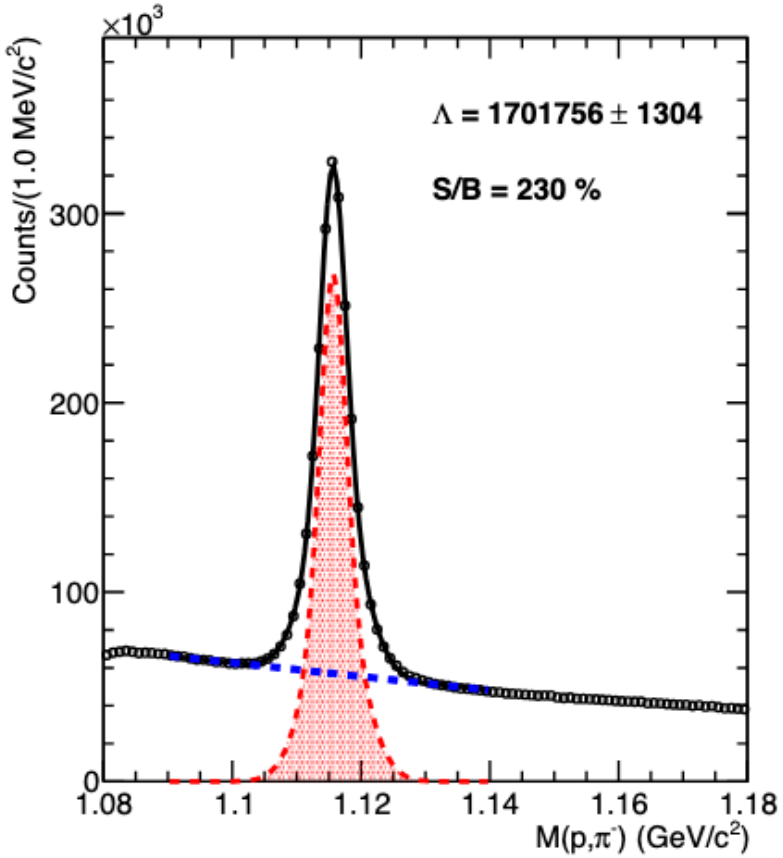
- pp →Λ+X N ~ 10^{11}
- pp → p+X N ~ 10^{13}
- pp → pKΛ N ~ 10^{10}

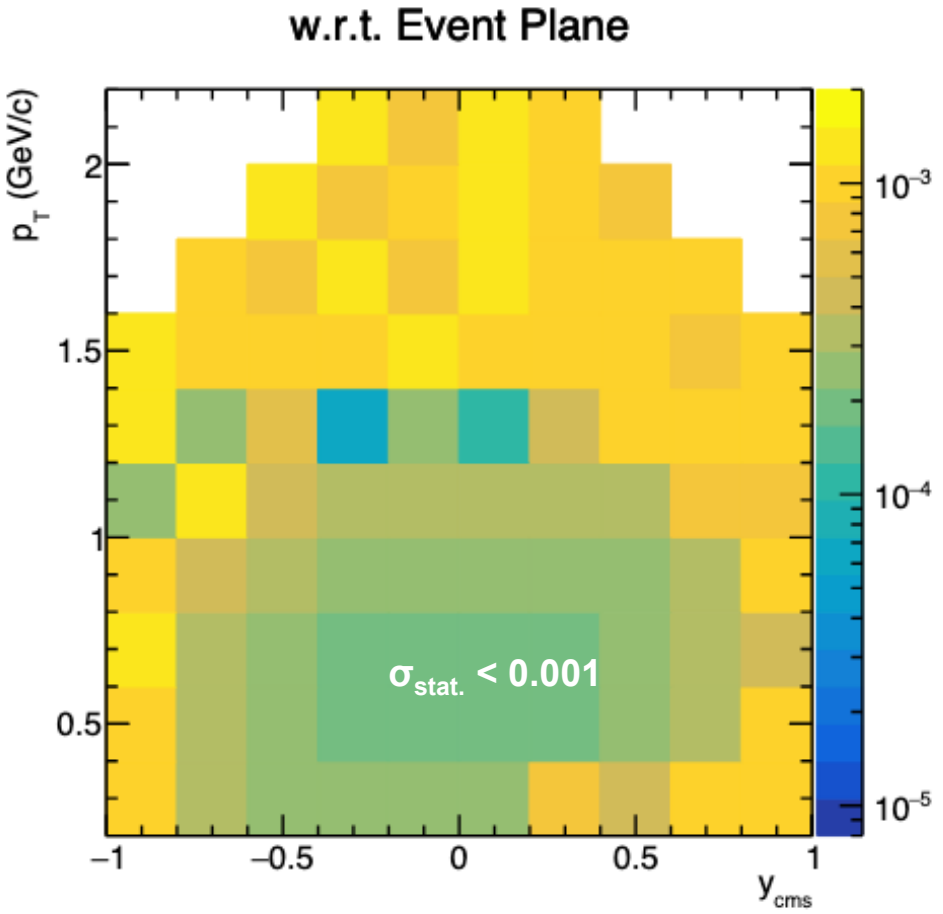
$\sigma_{stat.}$ < 0.01 for Λ 400 bins $\sigma_{stat.}$ < 0.02 for p 400 bins



Uncertainty Projection of the Global Polarization in A-A

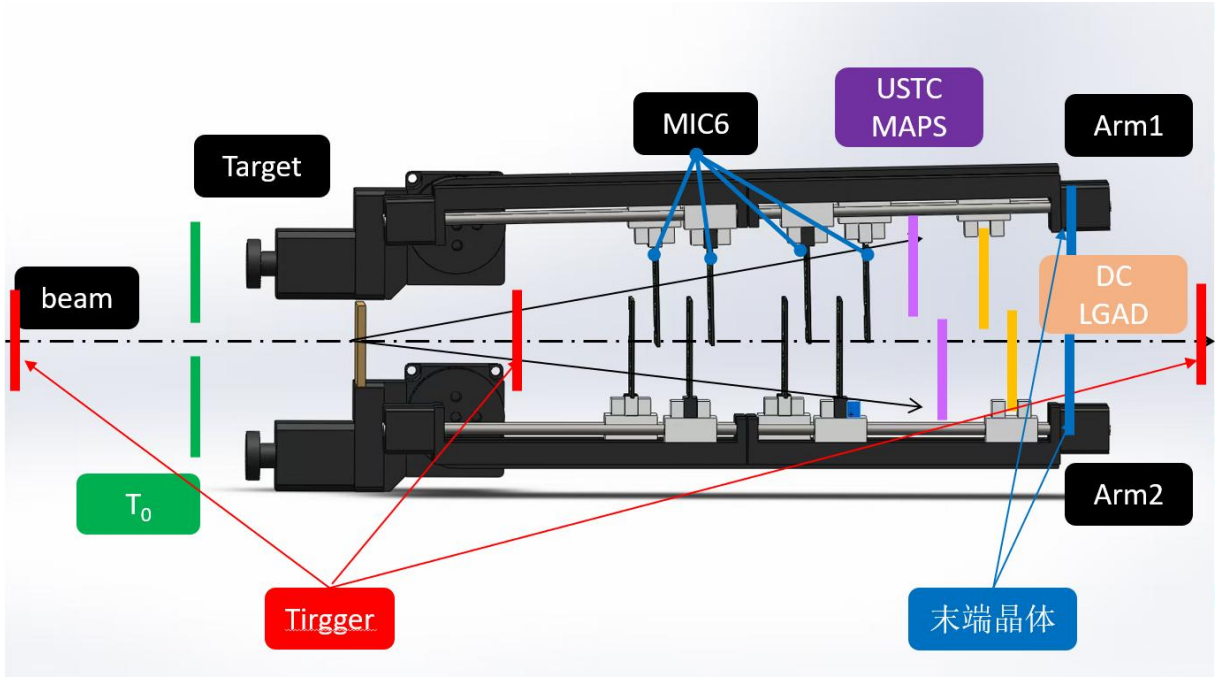
Au+Au events at beam kinetic energy of 2.8 GeV/u





2D uncertainty of Λ polarization using 10^{11} Au+Au events, few weeks data taking

H-NS0: Prototype of H-NS

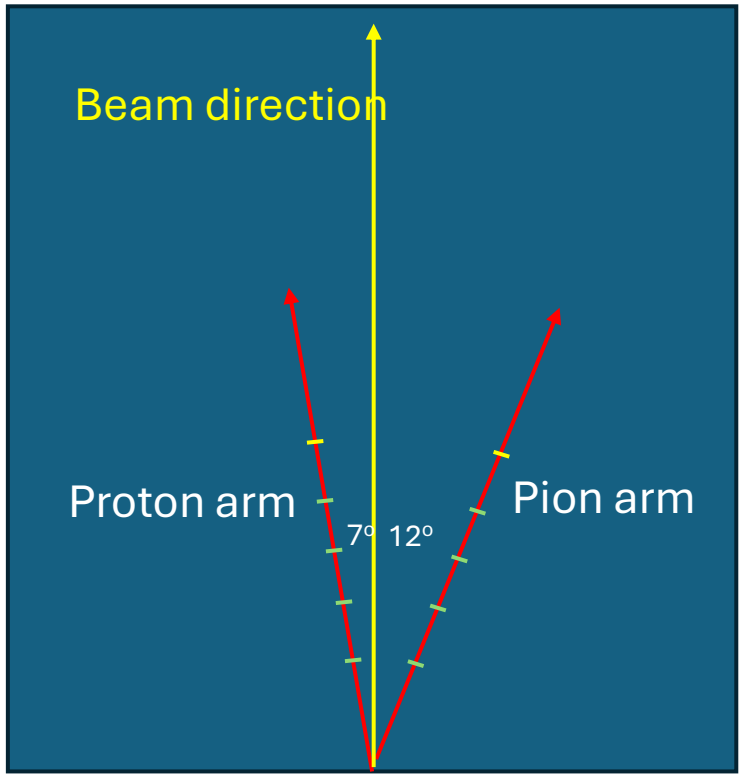


Two arms design with tracking detectors and TOF.
Use HIAF beam for testing the technologies used for H-NS.

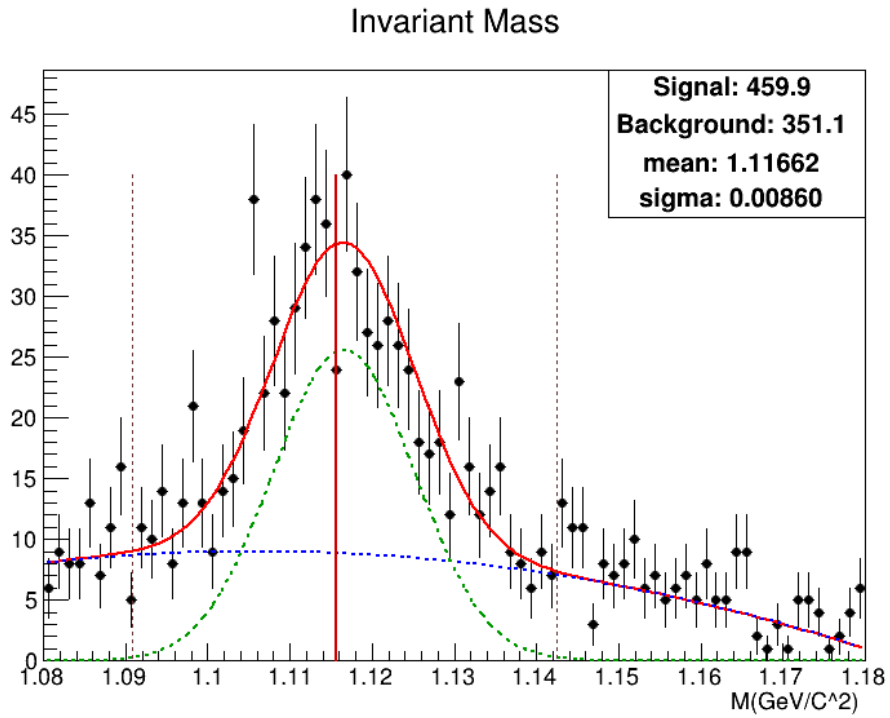
Front view

Side view

H-NS0: Simulation



Beam:	1X10^8 (pps)
Target:	1% C target
Cross section ratio σ(Λ)/σ(tot):	~ 0.1 %

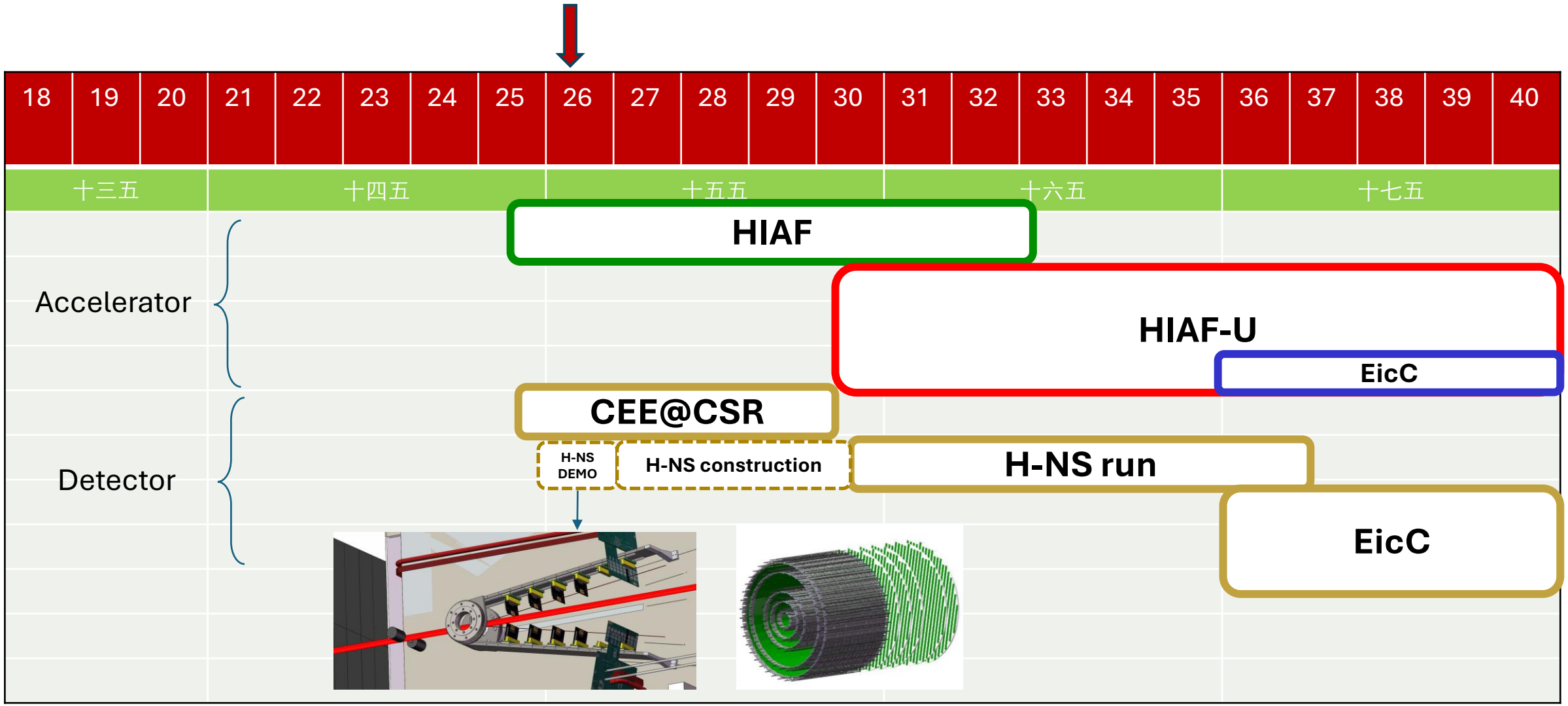


Reconstructed Λ from 820M O+C Events with 2.6 GeV/u beam

Efficiency ~ **5 * 10^{-6}**

10000 Λ needs ~23 days

Timeline


18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
十三五
十四五
十五五
十六五
十七五
Accelerator
Detector
HIAF
HIAF-U
EicC
CEE@CSR
H-NS DEMO
H-NS construction
H-NS run
EicC

White Paper

Hyperon-Nucleon Spectrometer

White Paper

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Contents

Summary

- A conceptual design of the Hyperon-Nucleon Spectrometer (H-NS) is proposed at HIAF.
- The polarization of the hyperon and proton can be studied at H-NS.
- The white paper of H-NS has finished.
- A prototype of H-NS is under construction for beam testing.