H-NS科学目标与探测器研制

Yuxiang Zhao (yxzhao@impcas.ac.cn)

Institute of Modern Physics, Chinese Academy of Sciences

报告提纲

- H-NS物理
- H-NS探测器设计与研制
- 总结

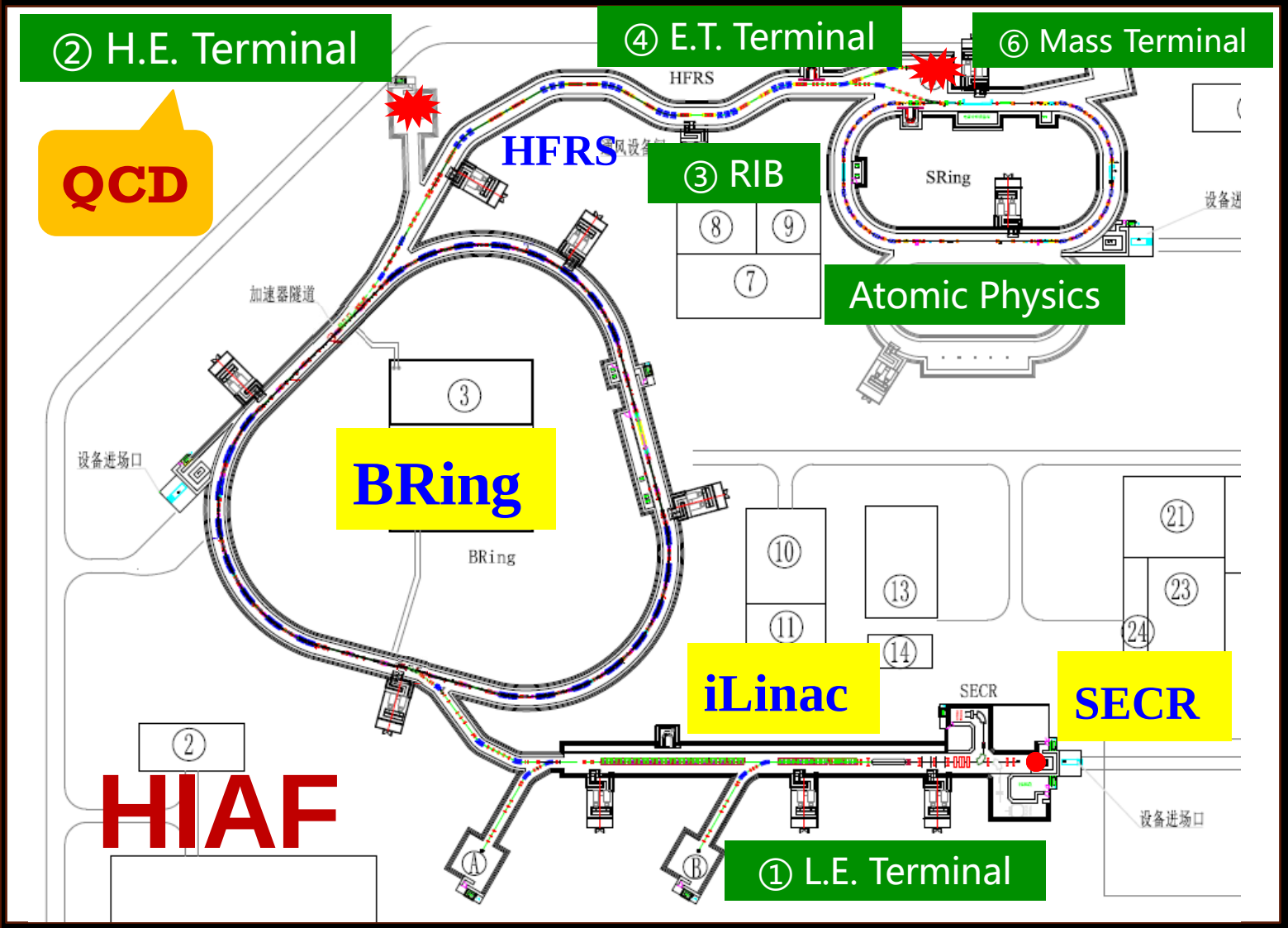
Heavy-ion accelerator fires up

An accelerator that will produce the world's most intense pulses of heavy ions generated its first beam on 28 October. When fully operational, China's High Intensity heavy-ion Accelerator Facility (HIAF), nestled among the mountains of southern Guangdong province, will send pulses of exotic, short-lived ions into fixed targets or into a storage ring to support research on the properties of atomic nuclei and how stars forge heavy elements, as well as material sciences and biomedicine. The research center, which joins the ranks of similar facilities worldwide, represents a $420 million investment by the Chinese Academy of Sciences's Institute of Modern Physics. Institute officials say HIAF will be open to foreign researchers. —Dennis Normile

Report by Science on Nov. 6th, 2025

High Intensity heavy-ion Accelerator Facility

(HIAF, Huizhou, China)



HIAF Physics：

(i) Atomic physics;
(ii) Nuclear physics;
(iii) Applied research in biology and material science etc.

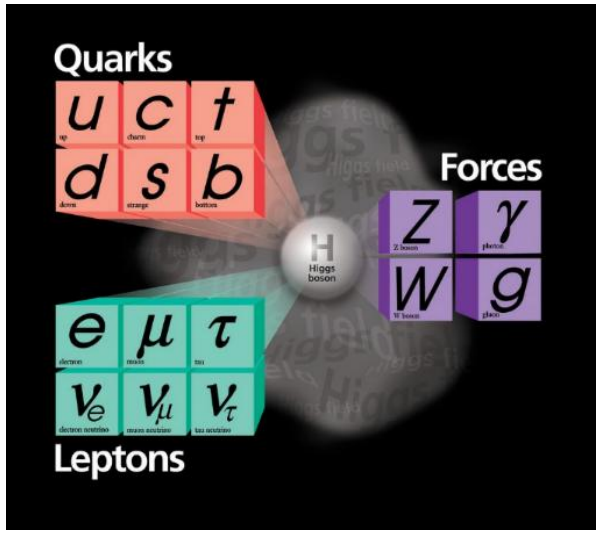
HIAF Commission started in 2025

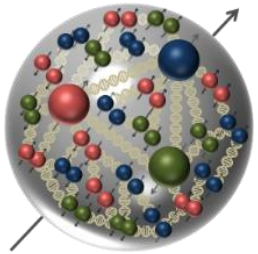
Science
Volume 390, Issue 6773
Nov 2025

HIAF beam parameters

Ion species	Kinetic Energy (GeV/u)	Beam intensity (ppp)
p	9.3	6.0×10^{12}
$^{16}O^{8+}$	4.25	6.0×10^{11}
$^{18}O^{6+}$	2.6	6.0×10^{11}
$^{78}Kr^{19+}$	1.7	3.0×10^{11}
$^{209}Bi^{31+}$	0.85	1.2×10^{11}
$^{238}U^{35+}$	0.835	1.0×10^{11}
$^{238}U^{78+}$	2.6	1.0×10^{10}

Understand Visible Matter: 核子内部结构





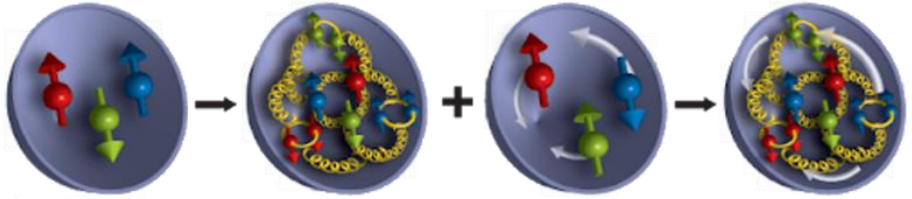
质子自旋结构?

质子质量起源?

可见物质

自旋

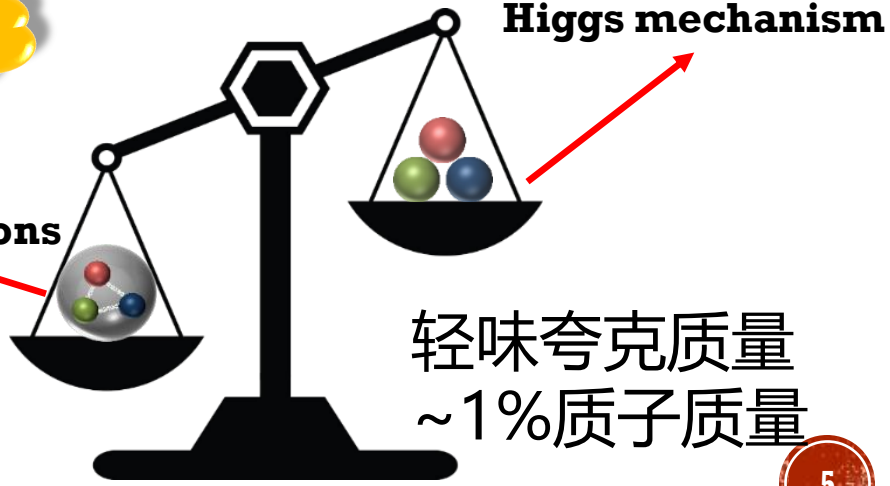
Gell-Mann
夸克模型



质量

Dynamics of gluons

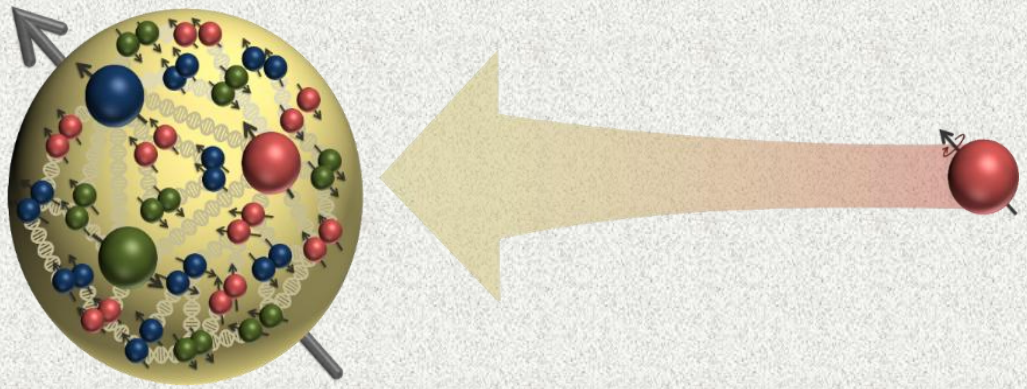
~99%
质子质量



轻味夸克质量
~1%质子质量

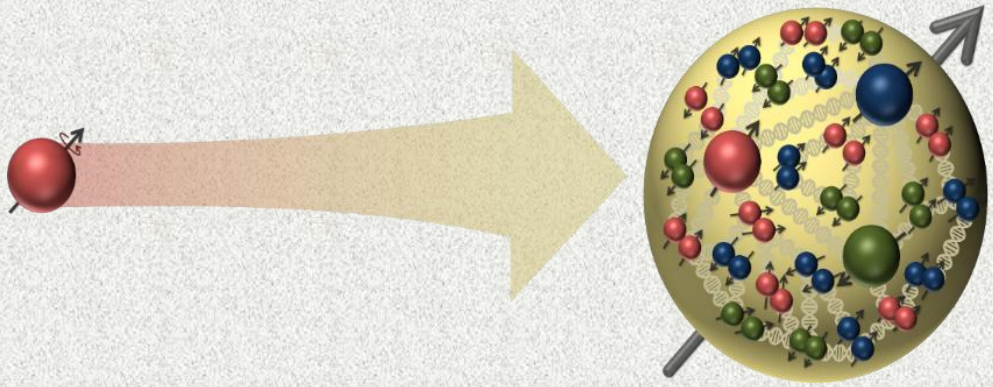
Hadron Structure with "Spin"

EIC: **Initial state** is polarized
- How do partons form polarized nucleons?



Initial state created by accelerator

HIAF: Λ polarization, final state
- How do partons form polarized Λs?



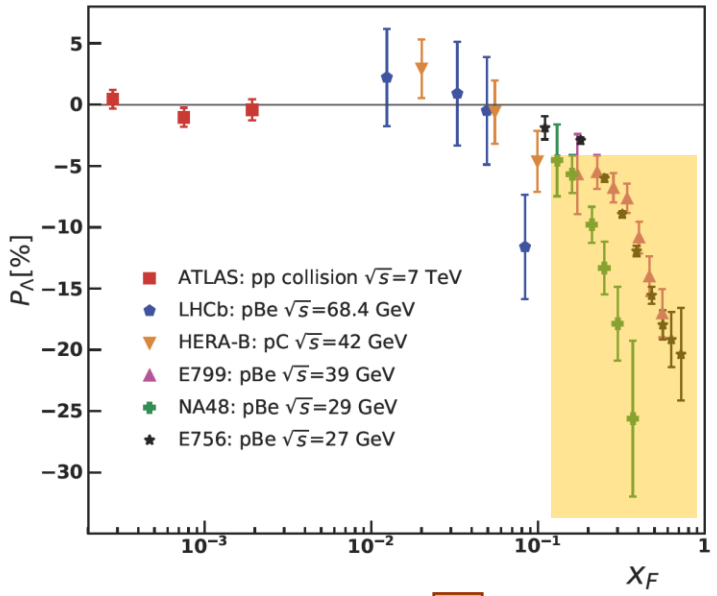
Final state

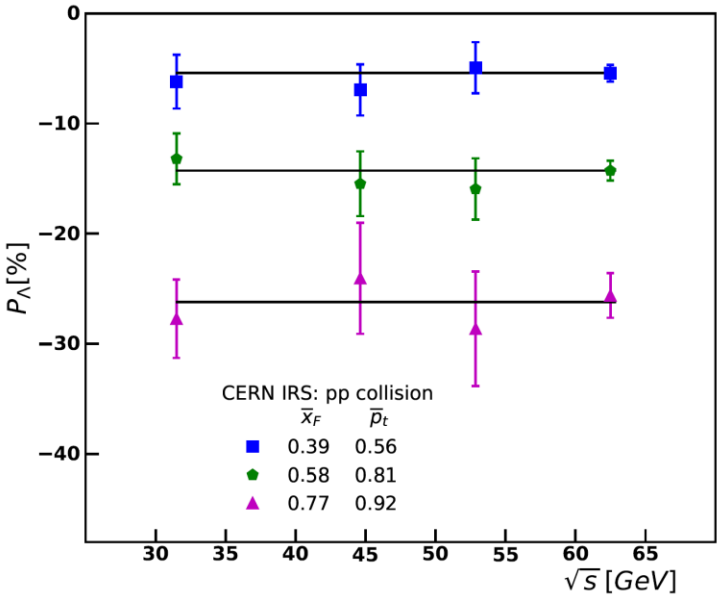
Λ serves as its own spin analyzer through the decay $\Lambda^0 \rightarrow p + \pi^-$

Origin of nucleon spin may well related to the origin of the Λ polarization

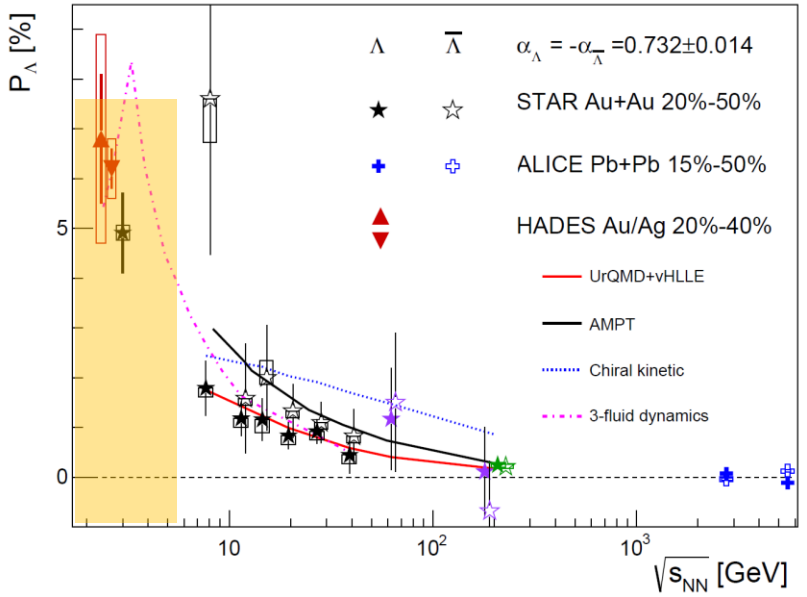
早期Λ极化实验研究

Λ production plane





Event plane

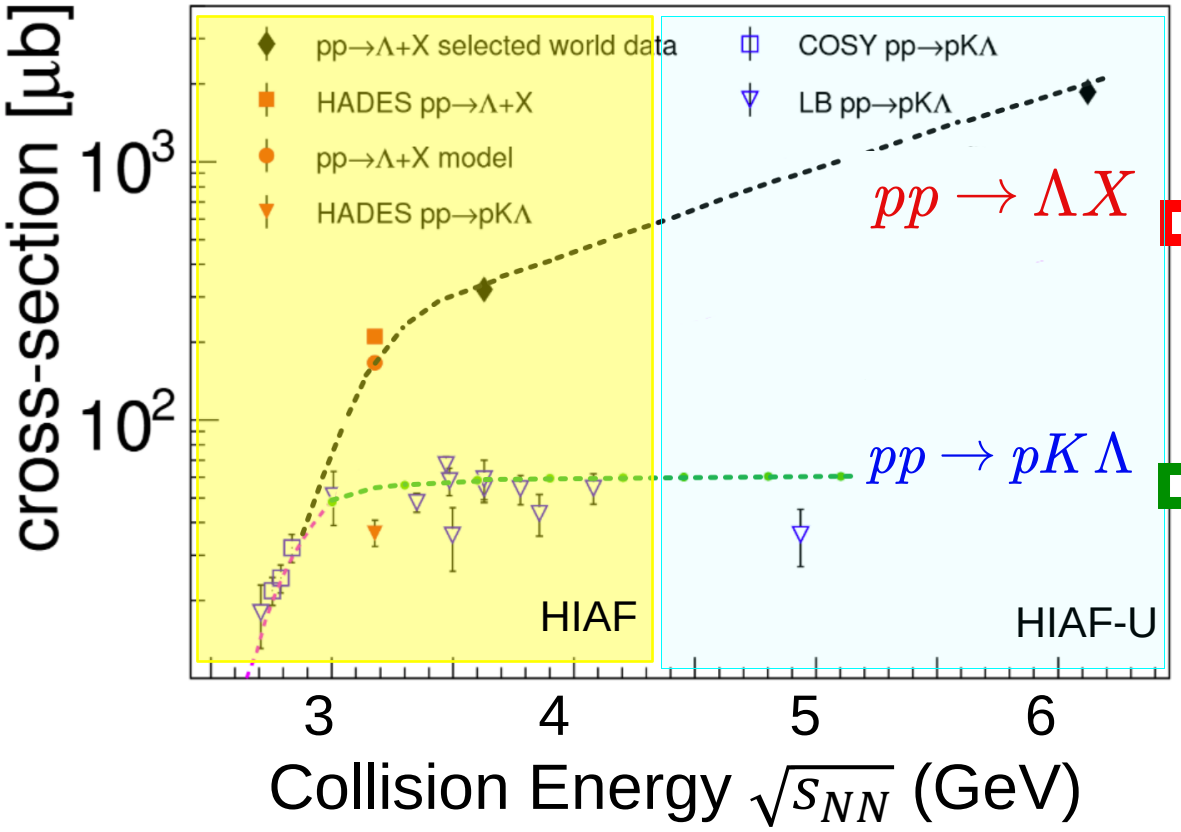


极化信号显著
是HIAF覆盖的区域

能量依赖展现出
“scaling” 现象 (?)

重离子反应中的整体极化效应
HIAF覆盖能区信号显著

Λ Production and Polarization

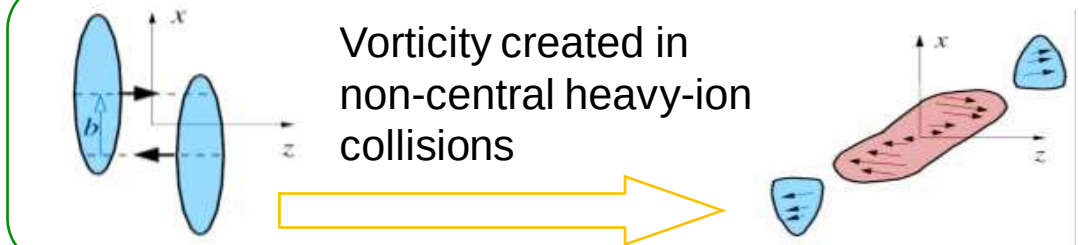


(1) p + p (A) $\rightarrow \Lambda + X$

Polarization puzzle:
ZT Liang, and C. Boros, PRL**79**, 3608 (1997); PRD**61**, 117503 (2000). H Dong and ZT Liang, PRD**70**, 014019 (2004); PRD**72**, 033006 (2005).

(2) p + p $\rightarrow \Lambda + K + p$

Exclusive Process:
R Machleidt, K Holinde and C Elster, Phys. Rept.**149**, 1 (1987). BC Liu, BS Zou, PRL**96**, 042002 (2006).



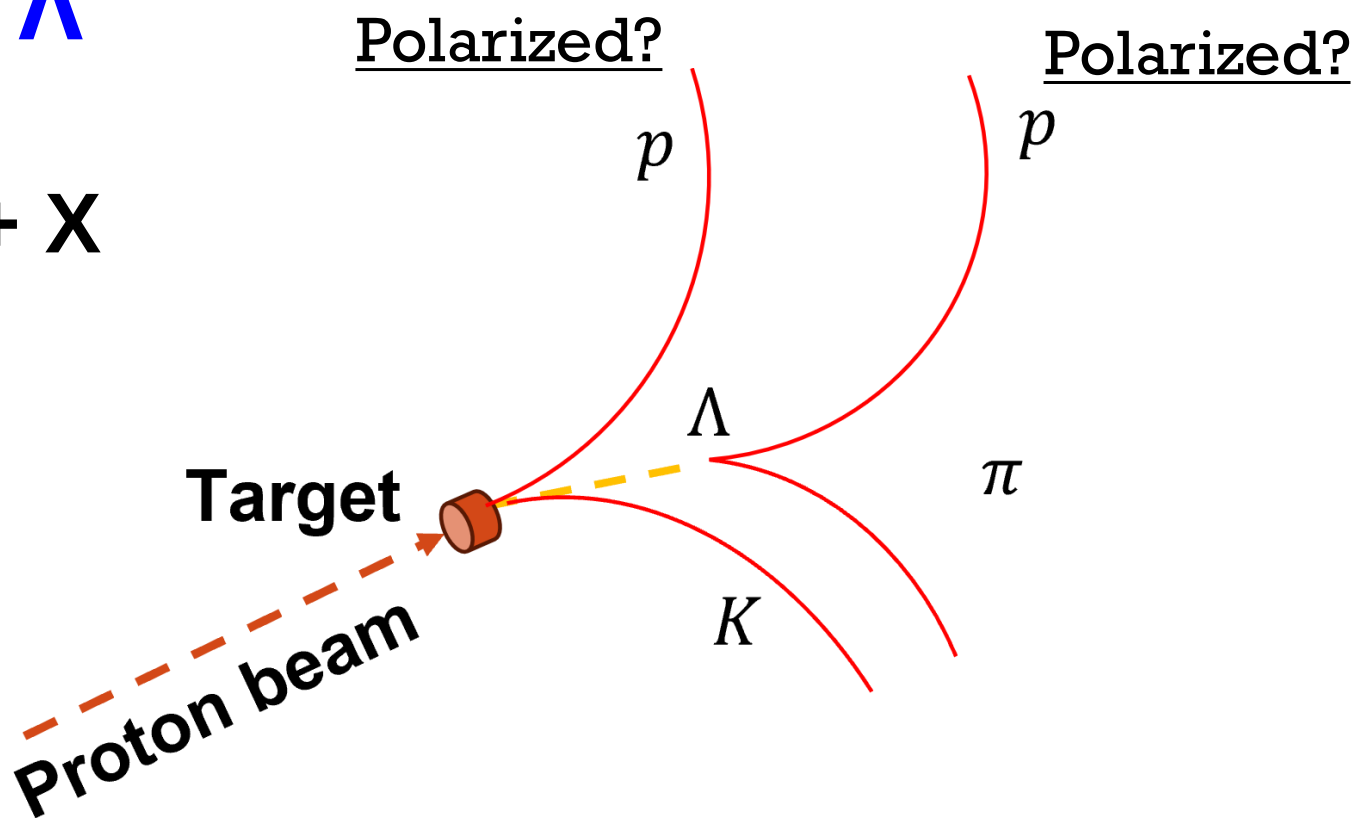
(3) A + A$\rightarrow \Lambda + X$

Global Polarization:
ZT Liang, XN Wang, PRL**94**,102301 (2005); PLB**629**, 20 (2005). JH Gao, *et al.*, PRC**77**, 044902 (2008).

Is Proton Polarized ?

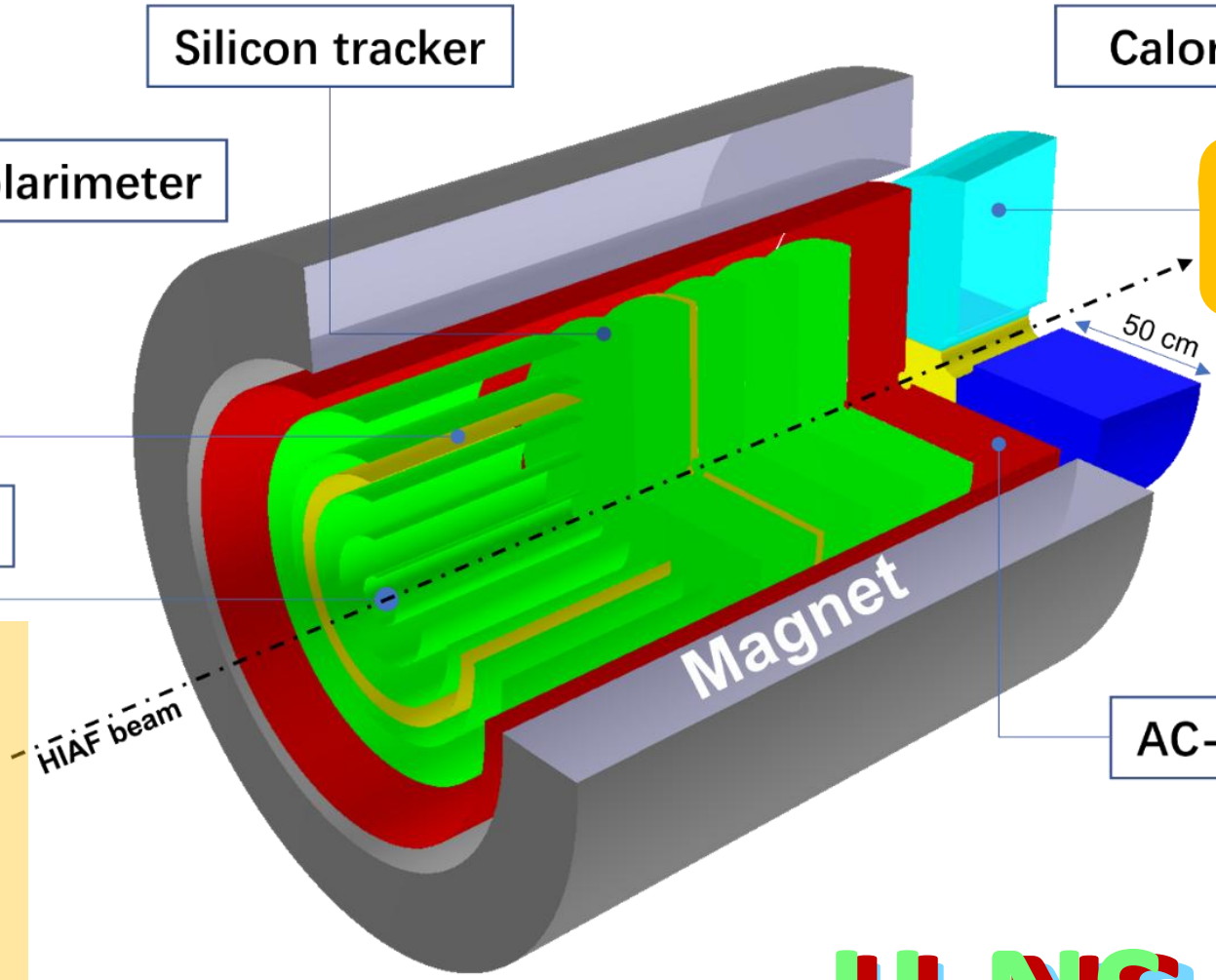
pp → p K Λ

pp → p/Λ + X



H-NS上专门设计了探测器直接测量质子极化

超子-核子谱仪 (H-NS) 概念设计

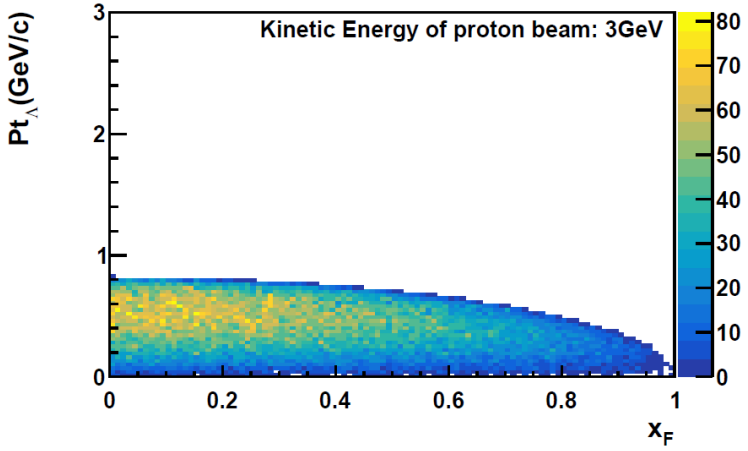


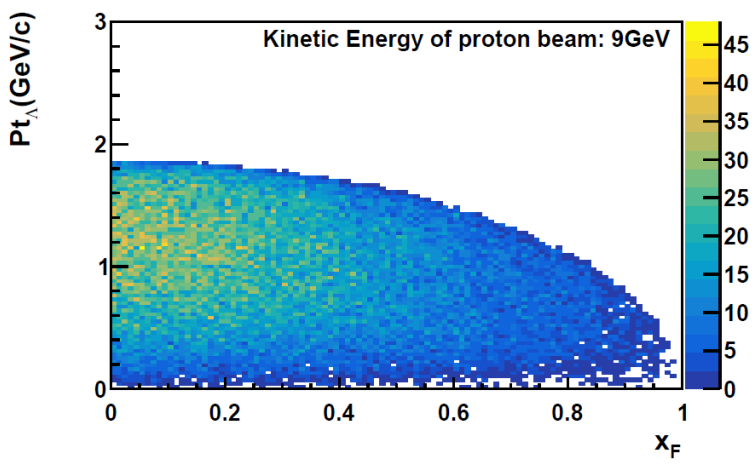
Participating Institutes: ≥ 22 (China), more are welcome!

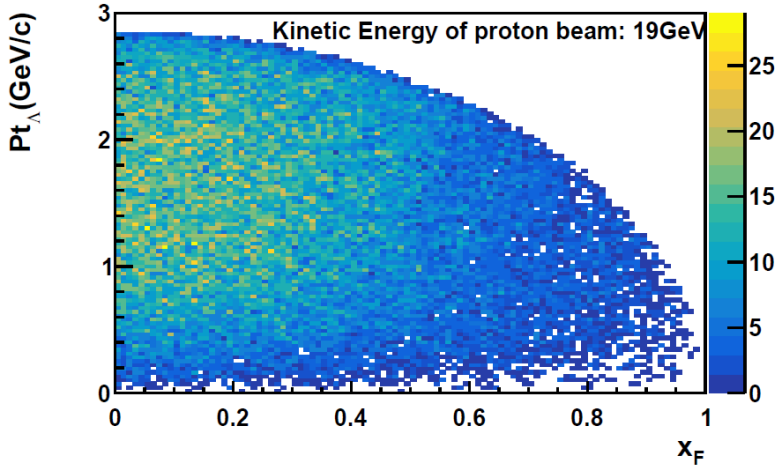
R&D Efforts: (1) Pixel tracker; (2) AC-LGAD; (3) **Baryon Polarimeter;** (4) Target systems; (5) Calorimeter; (6) FEE; (7) DAQ; (8) Magnet; (9) Beam line; (10) Mechanical structure design

H-NS

The opportunity of H-NS





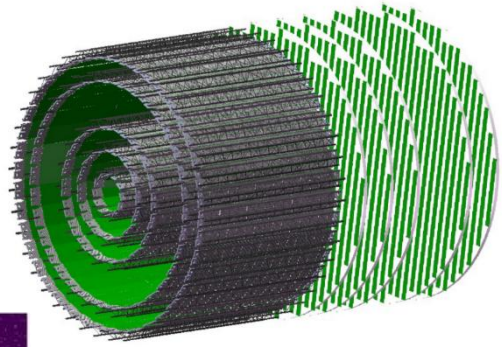


3 GeV → 9 GeV → 20 GeV → 32 GeV

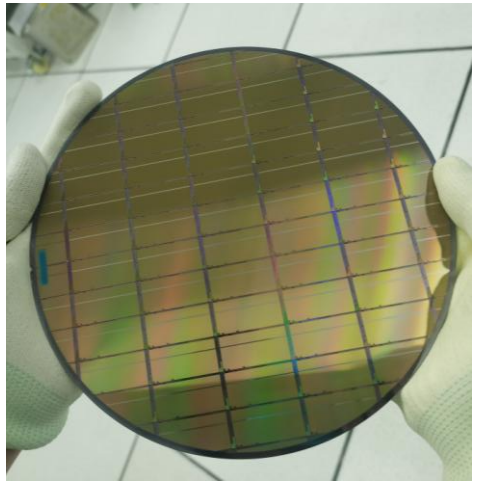
Allow for a multi-dimensional mapping of the Λ^0 polarization and production

- Beam energy scan
- p→p, p→A, A→A data taking

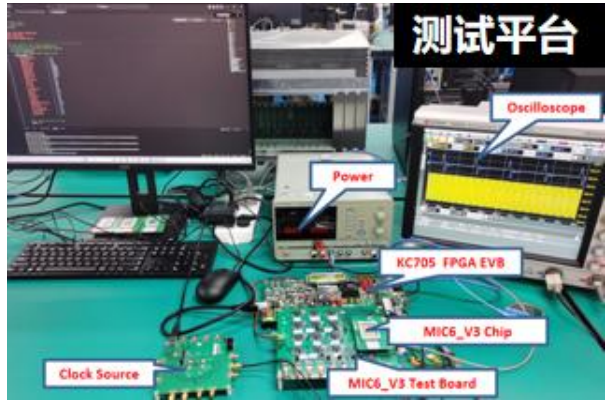
Silicon tracker at H-NS



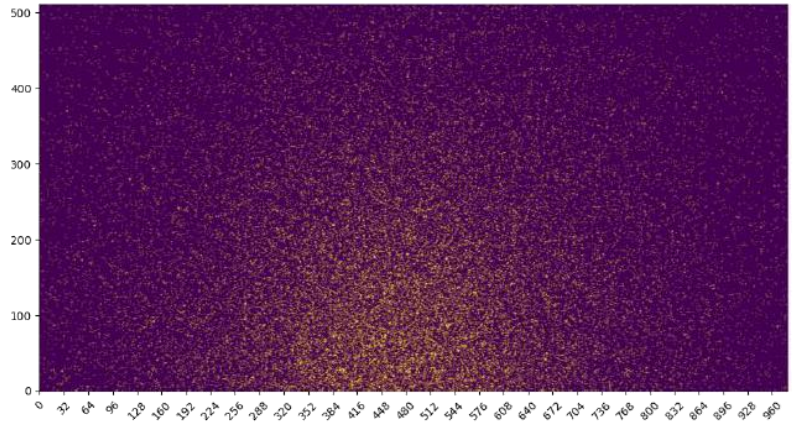
MIC6-v3晶圆



MIC6-v3 development at CCNU

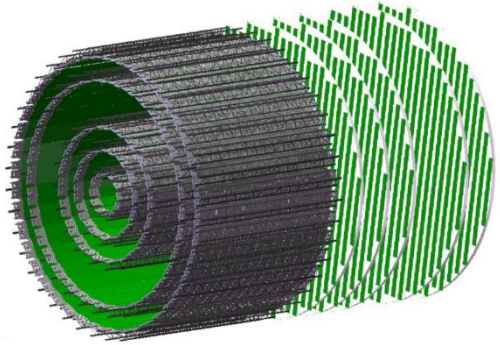


^{90}Sr 源测试



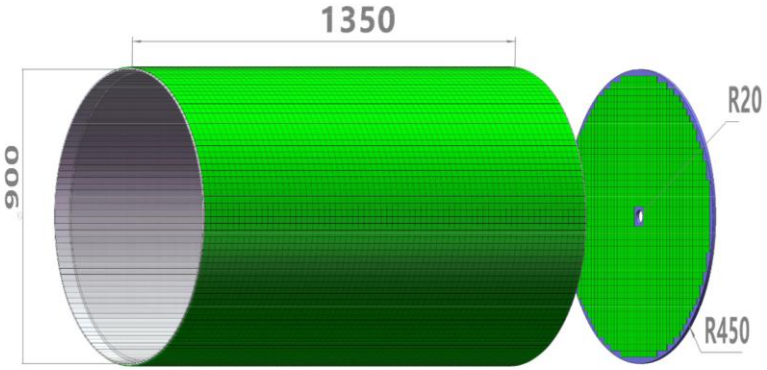
- **MIC6 MAPS pixel chip:** development and manufacture with the domestic process
- **Readout electronics** (ITS2 based design) **and DAQ** (ALICE CRU/FELIX protocol, GBTx, …)
- **Detector assembly and integration:**
  - **Vertex detector:** Stave module design (spatial resolution: ~ 5 μm with pixel size 30 μm, total material < 0.8%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 < 0.8%X/X_0 per layer)

Silicon tracker specs



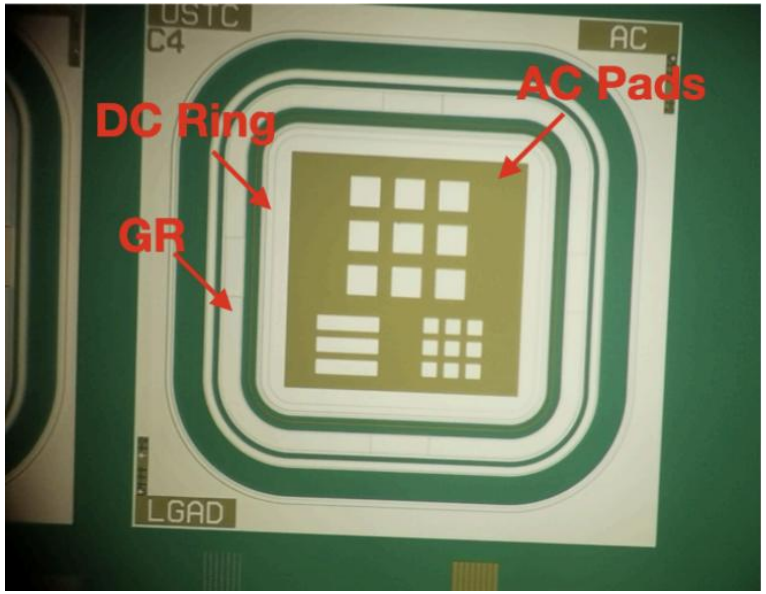
	Barrel					Forward				
	L0	L1	L2	L3	L4	D0	D1	D2	D3	D4
Radius / Z position (cm)	5	11	17	29	35	40	55	70	85	100
Active area (cm^2)	1310	3058	4368	7426	9173	4009				
Nr. staves / ladders	12	14	20	34	42	114				
Nr. MAPS chips	336	784	1120	1904	2352	1028				
Length / inner outer radius (cm)	42					2 / 38				
MAPS chip dimensions (mm^2)	15 ×30									
MAPS chip thickness (μm)	50 or 100									
Pixel size (μm^2)	30 ×27									
Nr. Pixels per chip ($r\phi \times z$)	497 ×980									
Material budget (X/X_0)	≤ 0.4%									

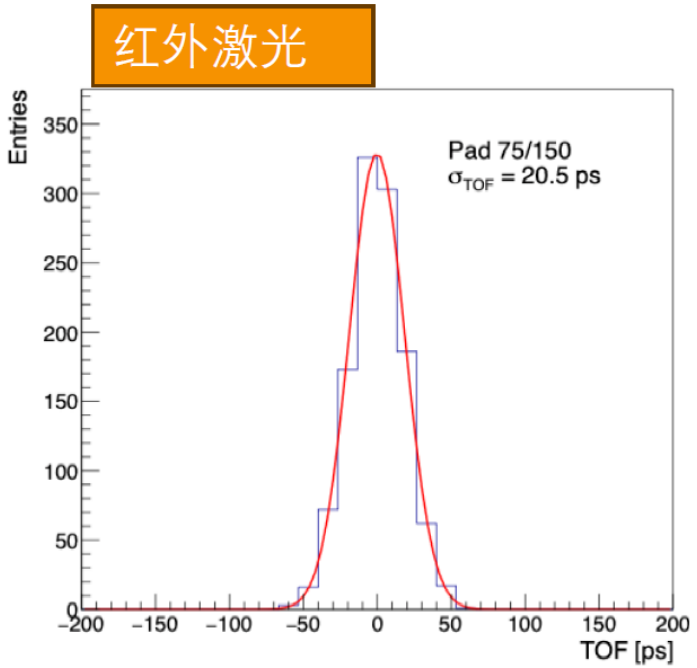
AC-LGAD at H-NS

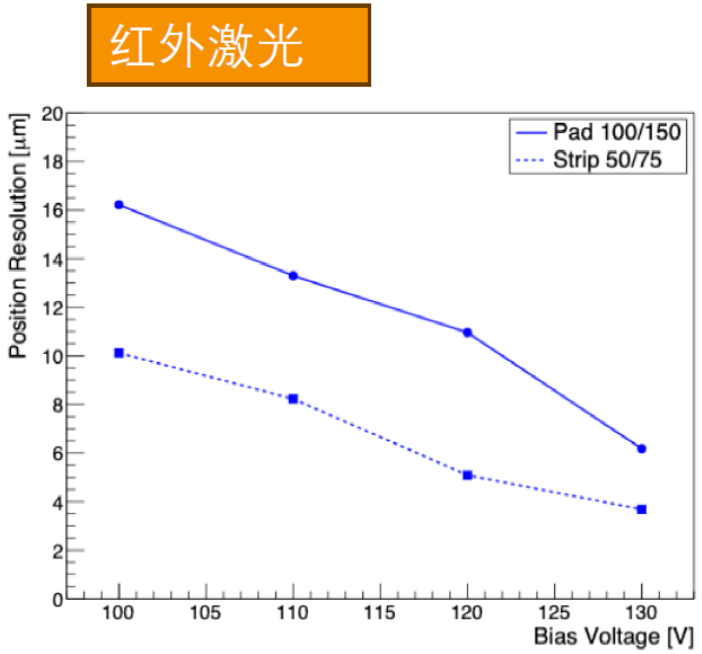


R&D is ongoing at USTC:

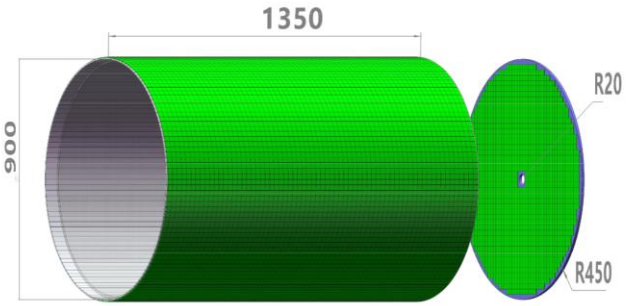
- Two wafers with different n^+ dose: W5 high n^+ dose and W6 low n^+ dose.
- Sensor size : 1300×1300×50 μm.
- Sensor with different pad-pitch size: Large pad size/pitch: 100/150 μm, Small pad (Strip) size/pitch: 50/75 μm.







AC-LGAD specs



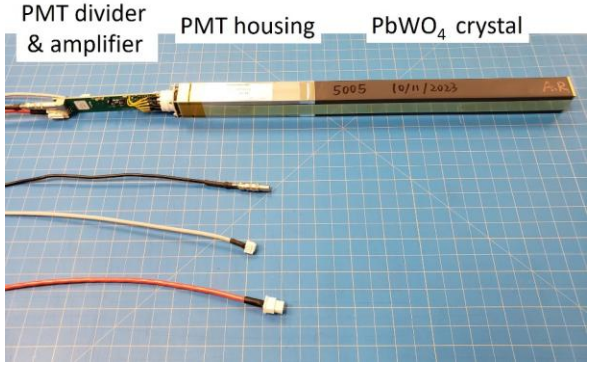
	Barrel	Forward
Radius / Z position (cm)	45	115
Active area (cm^2)	37520	5888
Nr. LGAD chips	9380	1472
Length / inner outer radius (cm)	136	2/45
LGAD chip dimensions (mm^2)	400	
LGAD chip thickness (μm)	300	
Pixel size (mm^2)	1.3×1.3	
Nr. Pixels per chip	225	
Material budget (X/X_0)	≤ 50%	

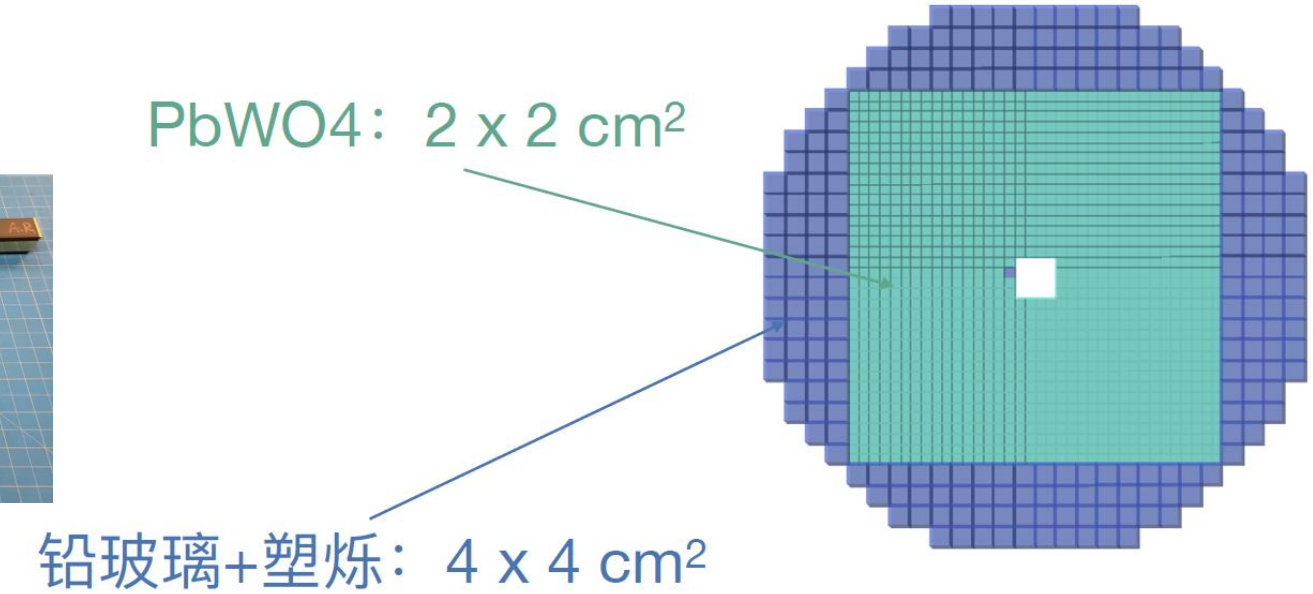
Endcap calorimeter

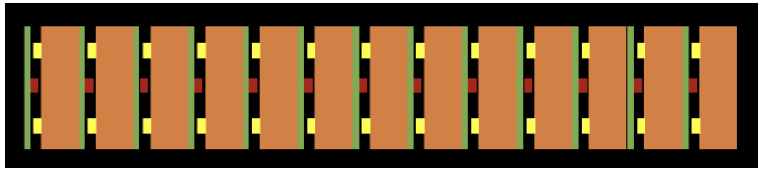
量能器系统双重功能：

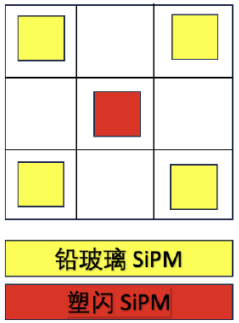
1. 重建中性粒子γ,π^0 等，服务物理研究
2. 高性能量能器R&D 平台，支撑未来实验

- PbWO4晶体：体积紧凑，能量分辨率良好
  - 能量分辨：3%/$\sqrt{E}$
  - 空间分辨：～3mm



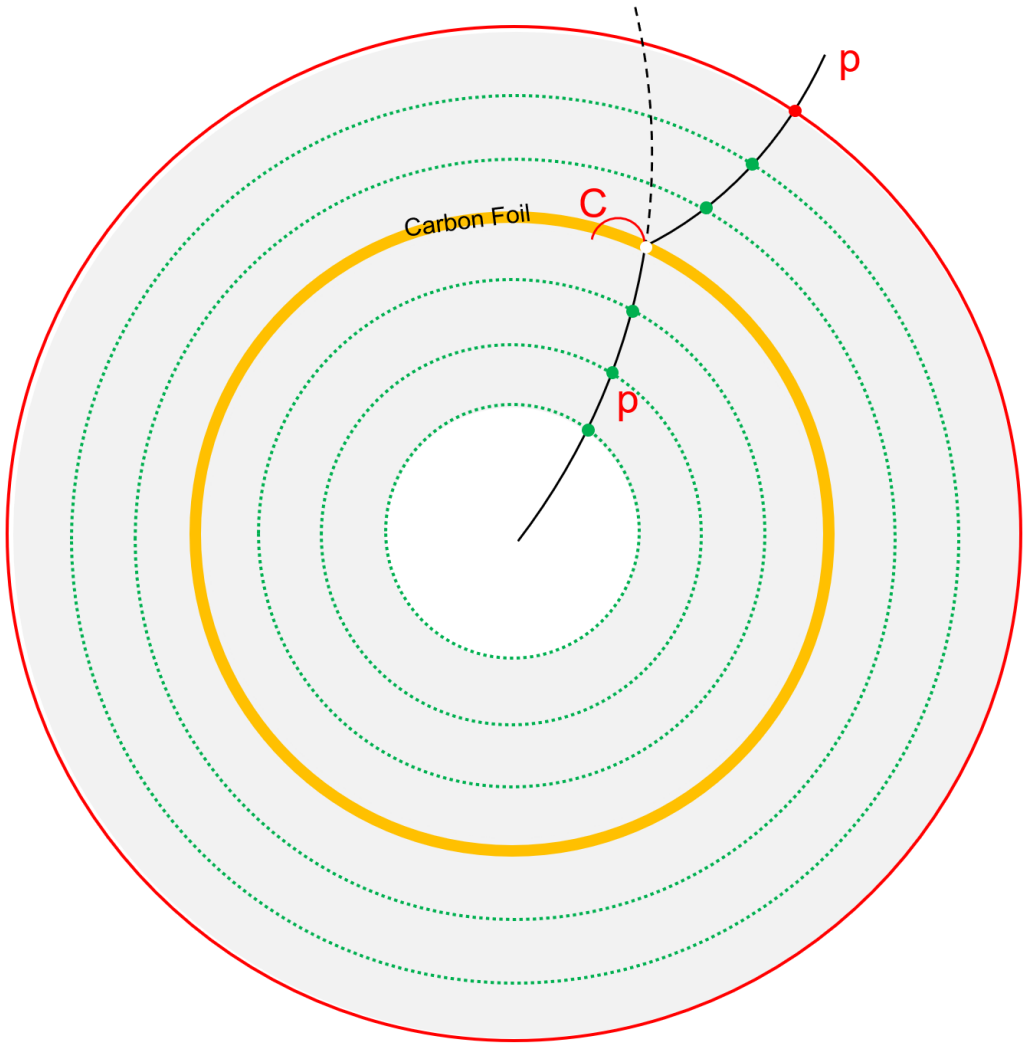




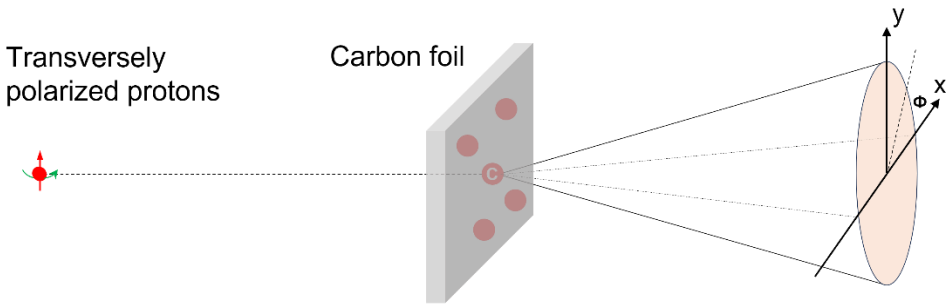


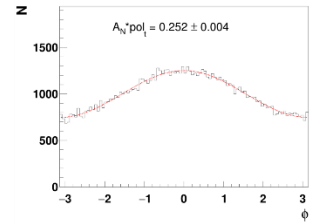
切伦科夫光和闪烁光双读出量能器预研

Baryon polarimeter: determining proton polarization via elastic scattering



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



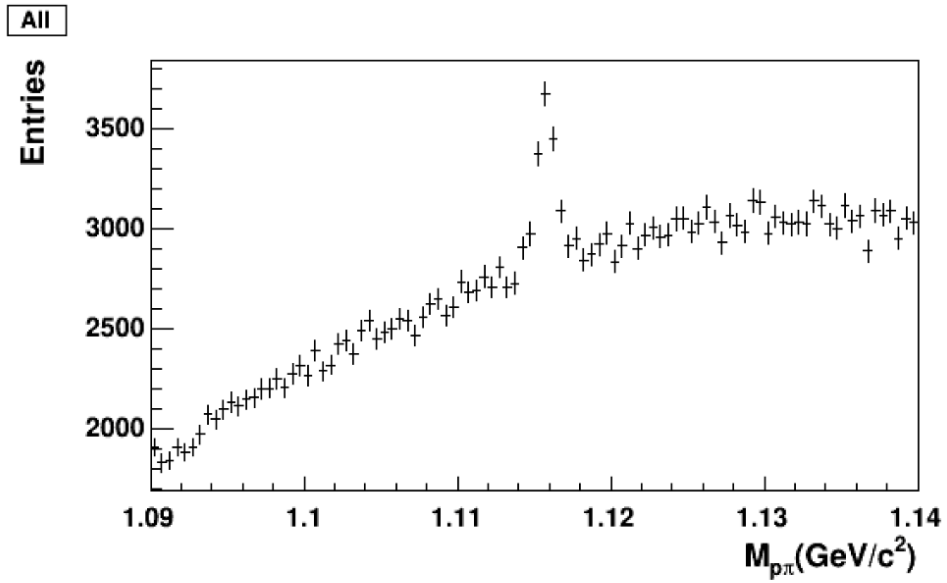


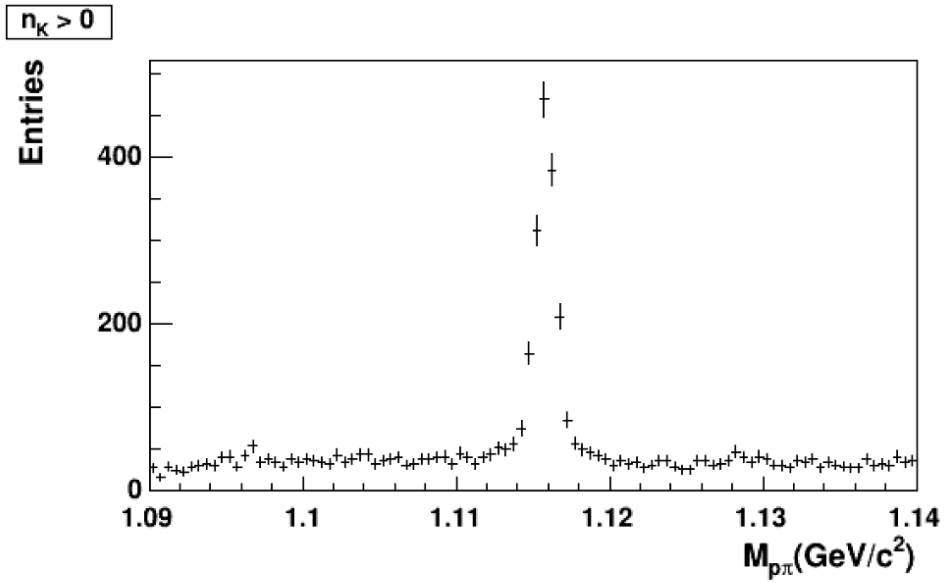
More protons to the left:
Left-right asymmetry

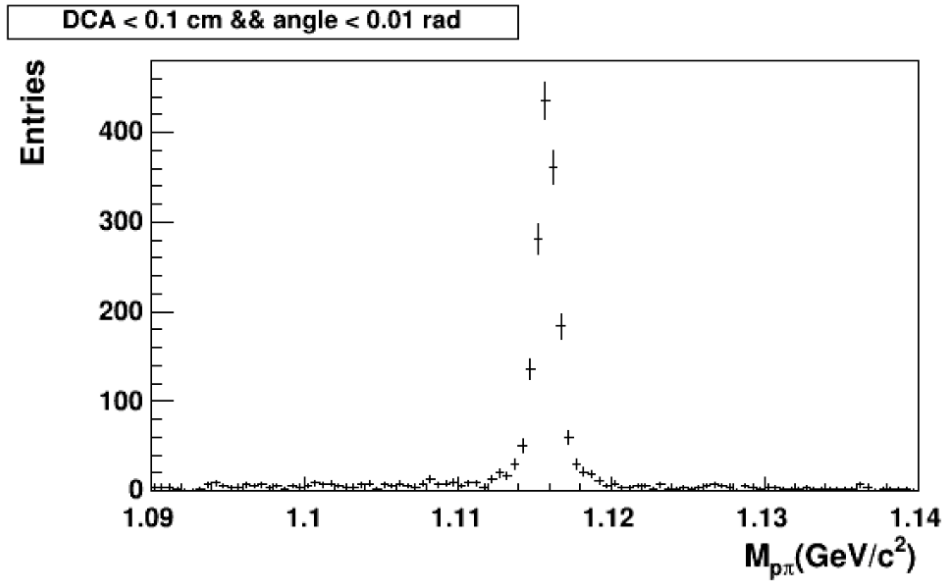
- **Carbon Foil layer**
  - **~1 mm thickness**
  - **Material budget: <1% X/X_0**
  - **Probability: pC (1E-3)**
- **Position : in-between the tracking devices**

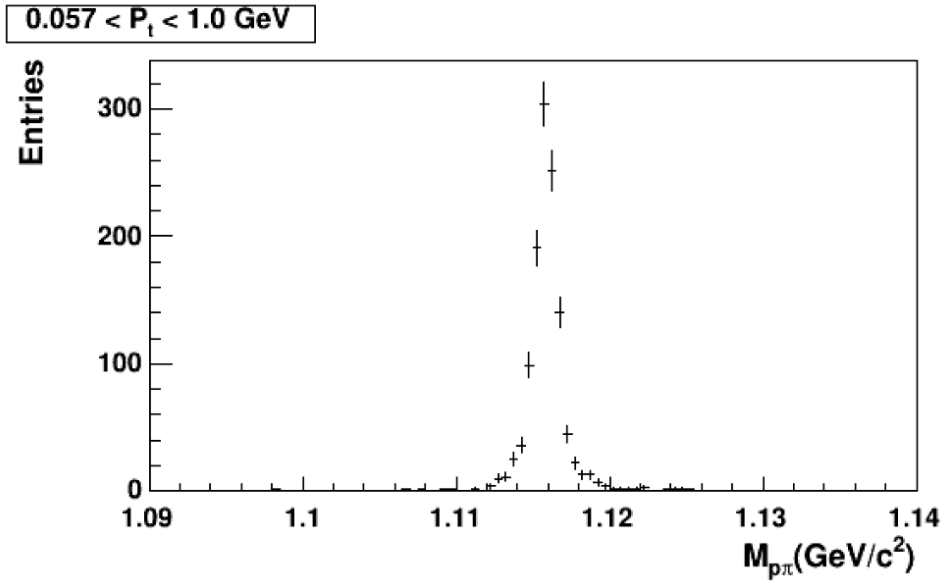
Y. T. Liang et. al. Phys. Rev. D 112, L031502 (2025), 2512.02804, 2601.21325

Almost background free reconstruction (Beam energy 3.5 GeV)

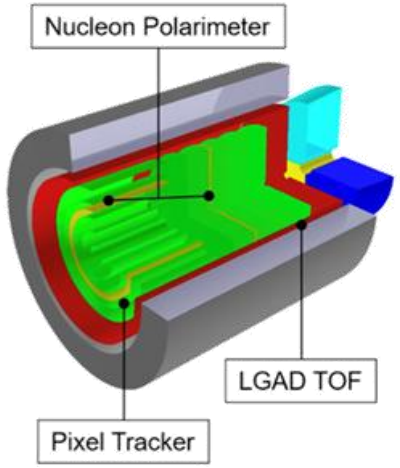








Projection of Λ and proton polarization (beam energy: 9.3 GeV)



H-NS

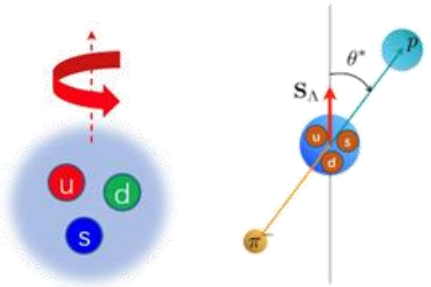
Reaction: p+p

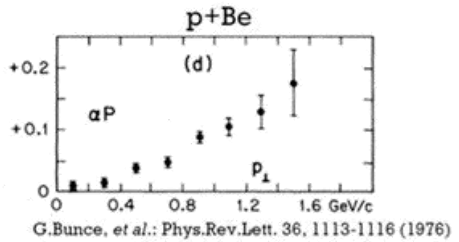
Event rate:1MHz

Time: 3 months

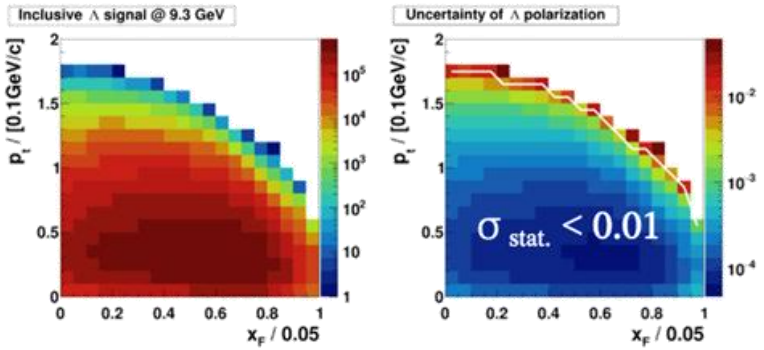
- pp → Λ+X N ~ 10^{11}
- pp → p+X N ~ 10^{13}
- pp → pKΛ N ~ 10^{10}

p p → Λ + X $\sigma_{stat.} < 0.01$ 2D:400 bins



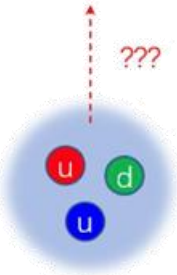


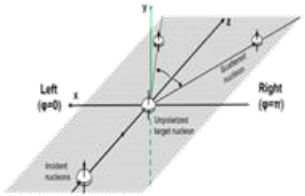
Λ polarization

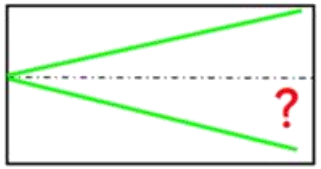


p p → p + X $\sigma_{stat.} < 0.02$ 2D:400 bins

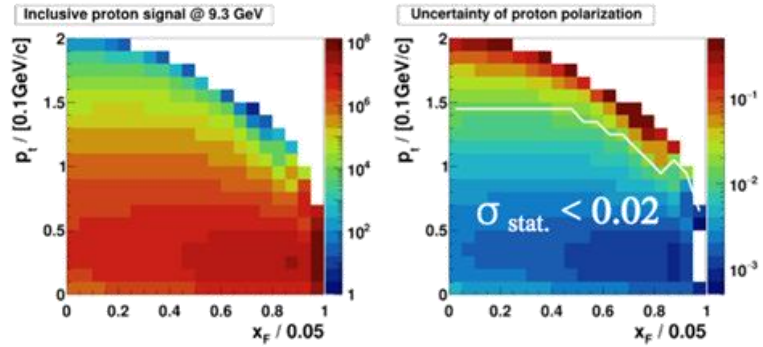
pC scattering ~ 10^{13} * $4*10^{-4}$ = $4*10^{9}$



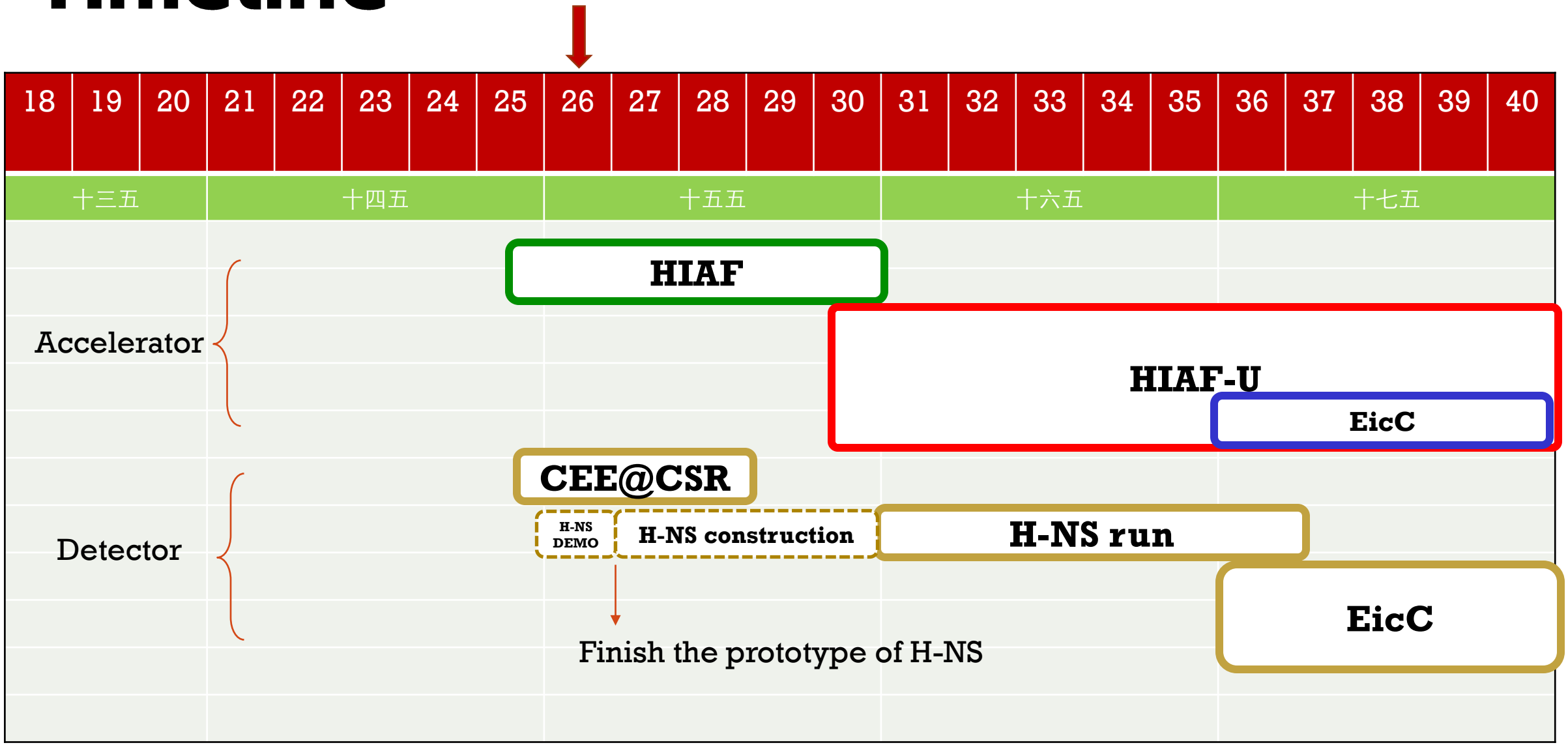




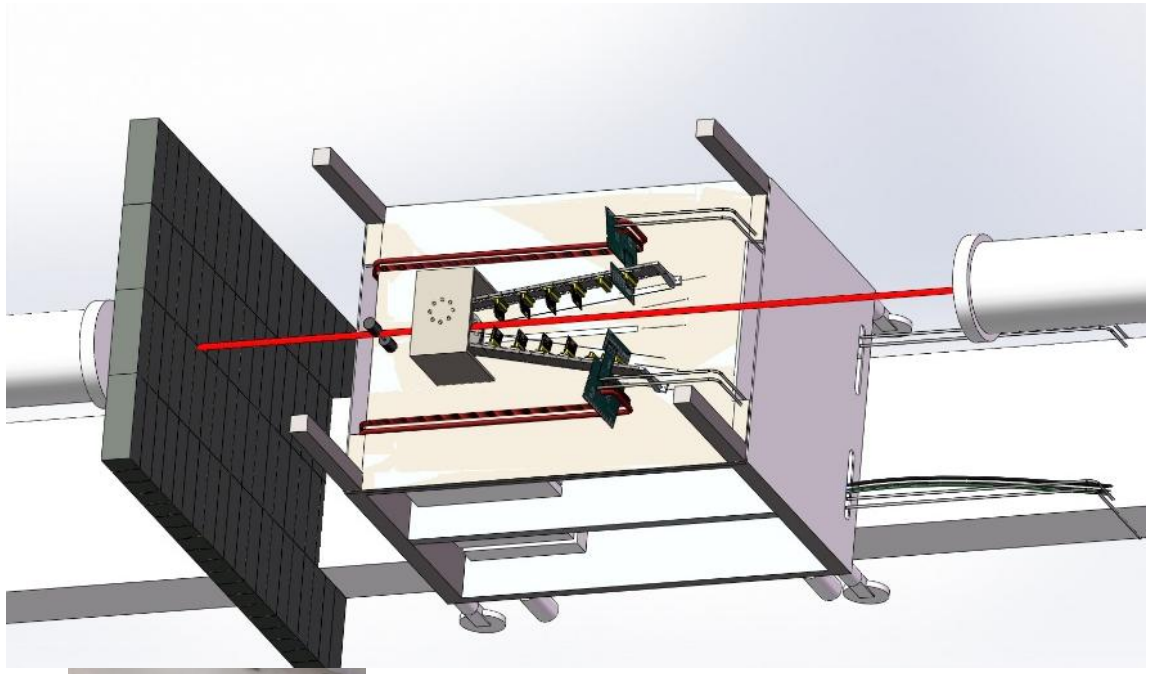
proton polarization

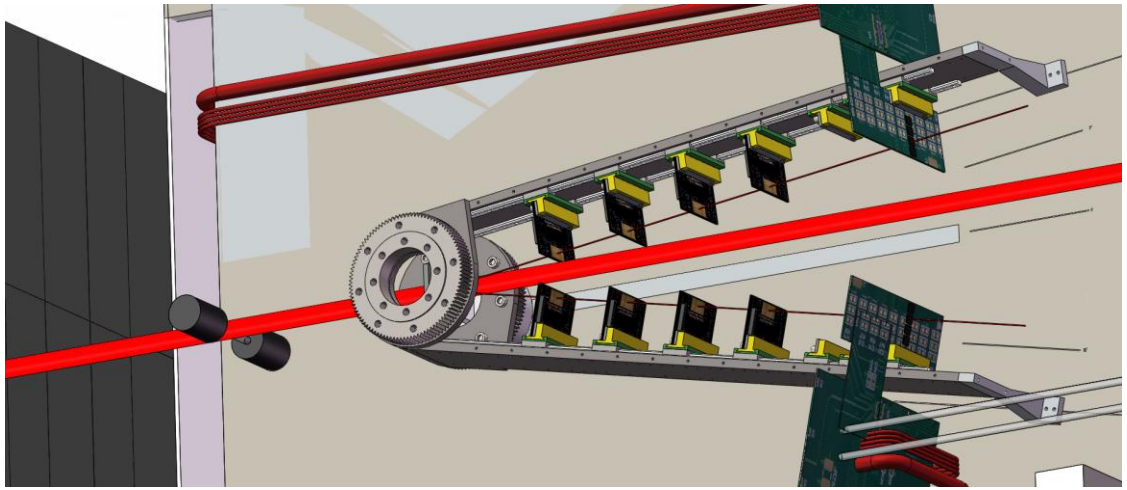


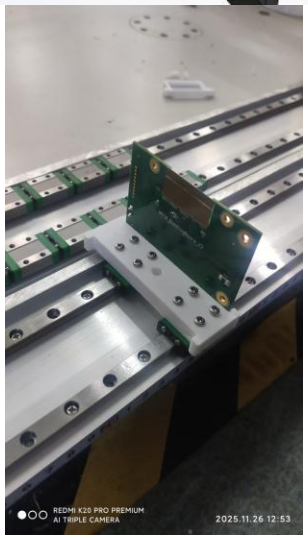
Timeline


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
Finish the prototype of H-NS

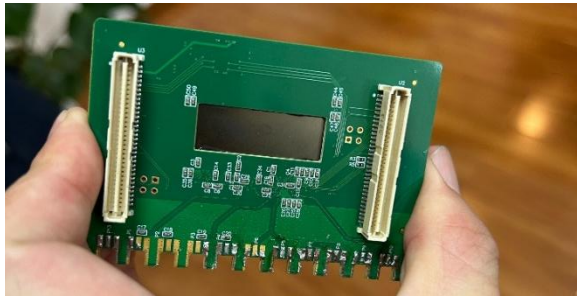
H-NS0: DEMO to demonstrate that detector+electronics+DAQ+control system works



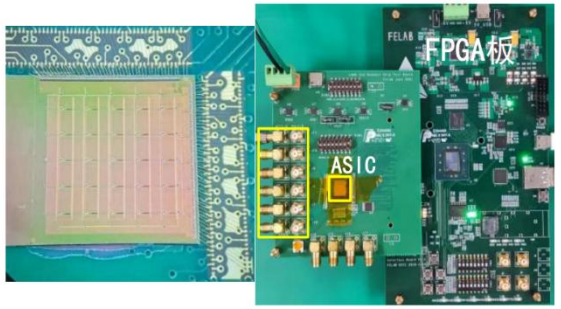




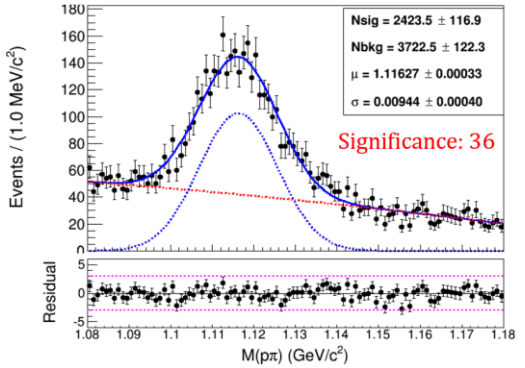
Installation is ongoing in Huizhou



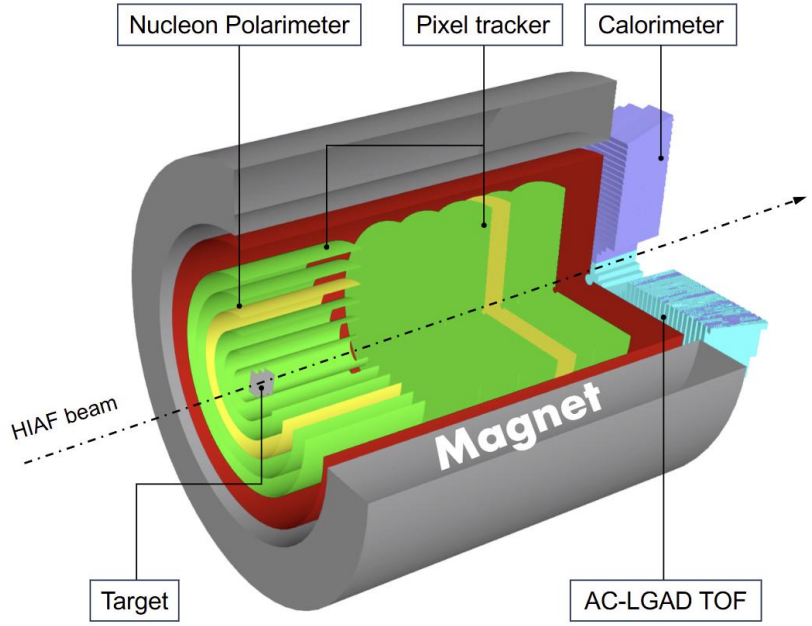
MAPS



LGAD



Hyperon-Nucleon Spectrometer



国内参与单位（目前22家单位）： 北京大学、北京航空航天大学、北京师范大学、复旦大学、高能物理研究所、国科大、河南师范大学、湖州师范学院、华东师范大学、华南师范大学、华中师范大学、近代物理研究所、理论物理所、南开大学、清华大学、山东大学、香港中文大学（深圳）、中国原子能研究院、郑州大学、中科大、中山大学...

H-NS 白皮书：
2606.06553

I. Physics：

- Λ production and polarization (*p*+*p*)
  - Medium effect (*p*+*A*)
  - Global polarization of Λ hyperon (*A*+*A*)
- Hadron physics via *p*+*p*
  - s-sbar system, complementary to BESIII
  - polarization as extra constraints

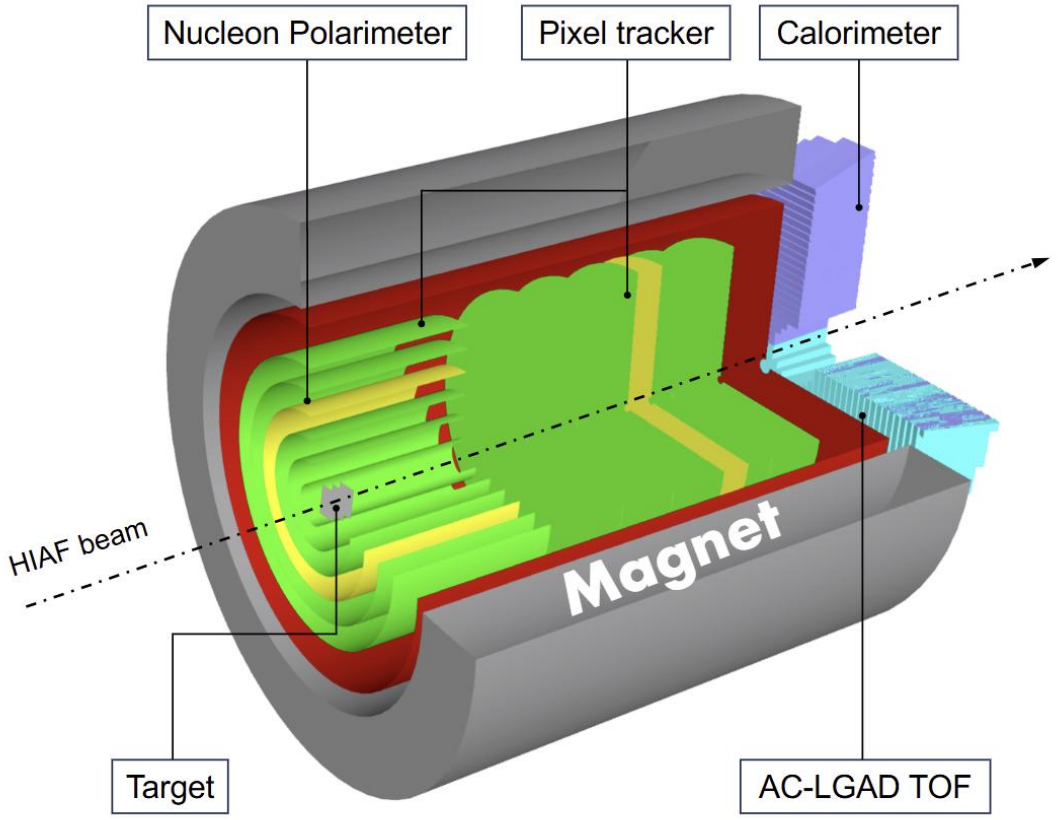
II. Community：

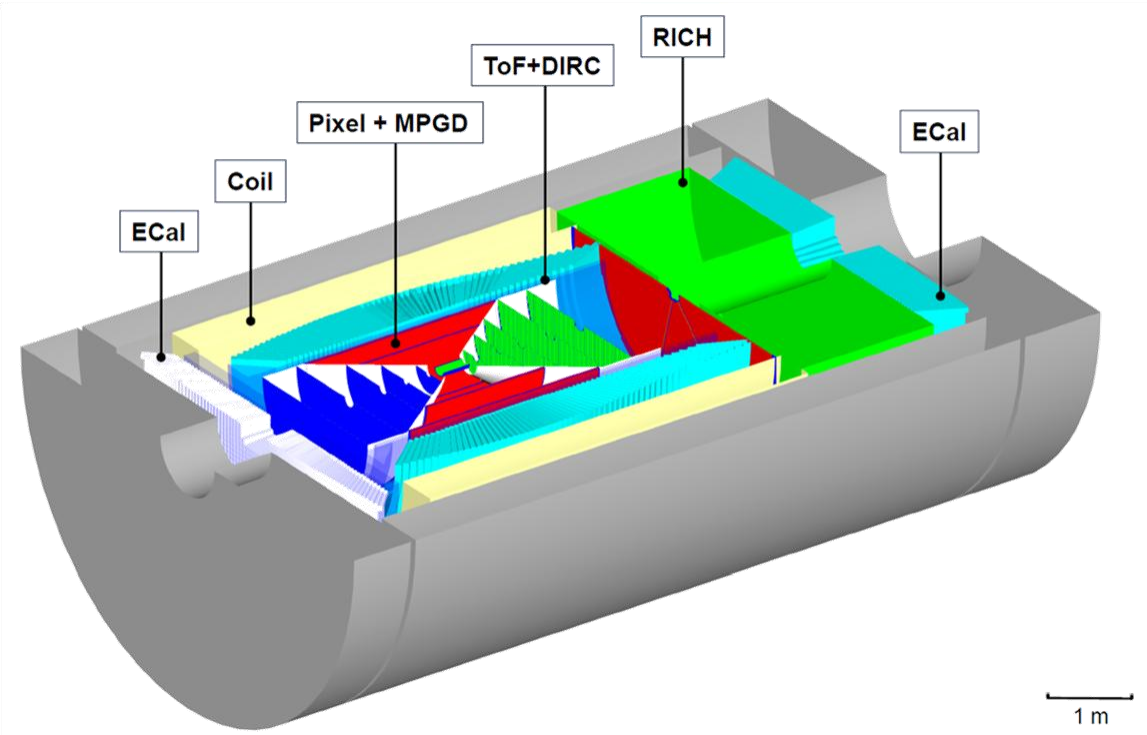
- Supports both communities of hadron structure and heavy-ion physics
- International participations (Germany, Japan)

III. Detector R&D

- Many parts are similar for CEPC, H-NS, EicC, and STCF. Save resources!
- H-NS: a detector R&D platform for EicC(½ EicC)

H-NS探测器 = ½ EicC探测器





H-NS | EicC

Thank you !