China Hyperon-Nuclear Spectrometer

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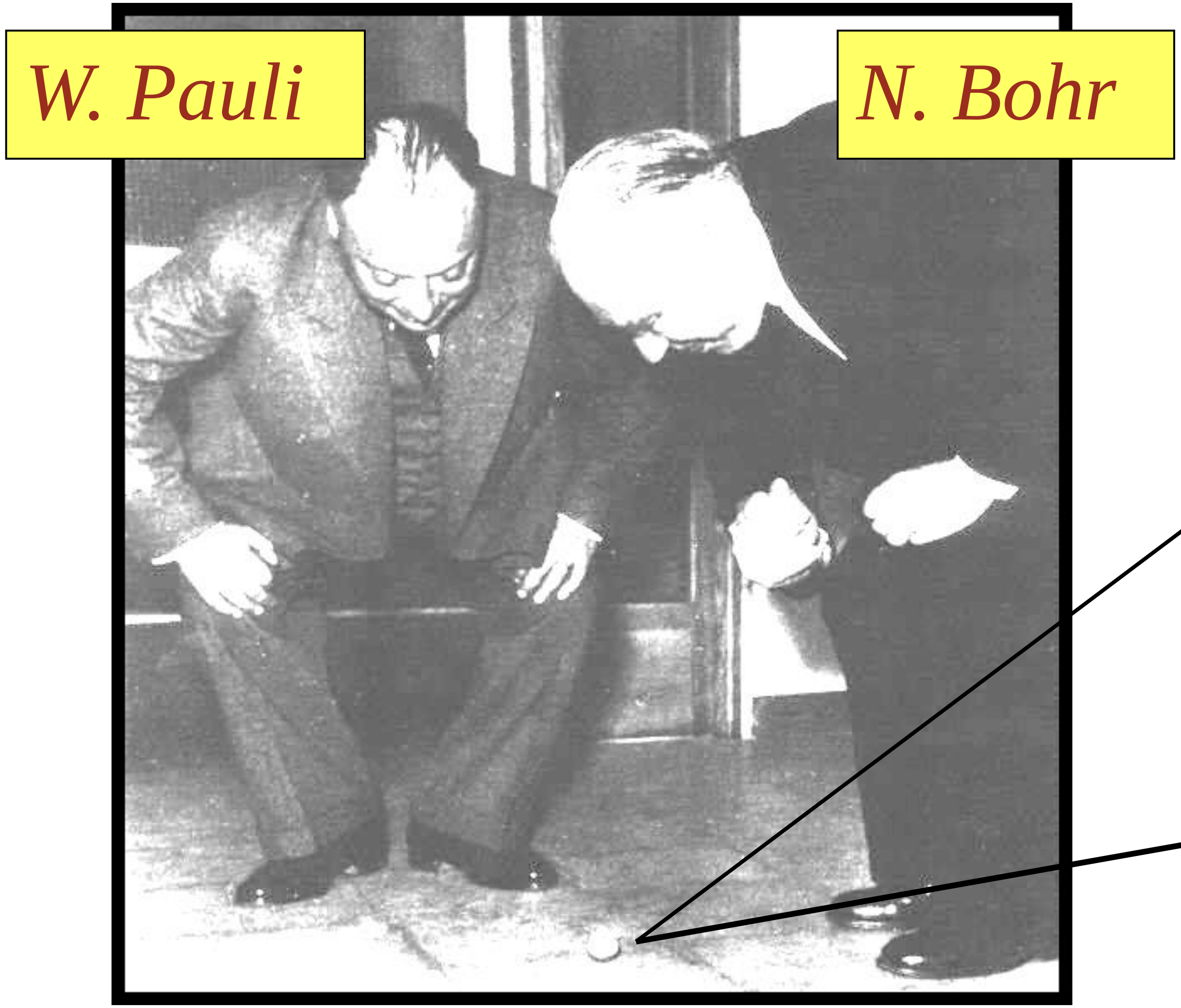
Yuxiang Zhao

Institute of Modern Physics, Chinese Academy of Sciences

Outline

- Introduction
- CHNS at HIAF
- Summary and Outlook

Putting a "spin" on physics



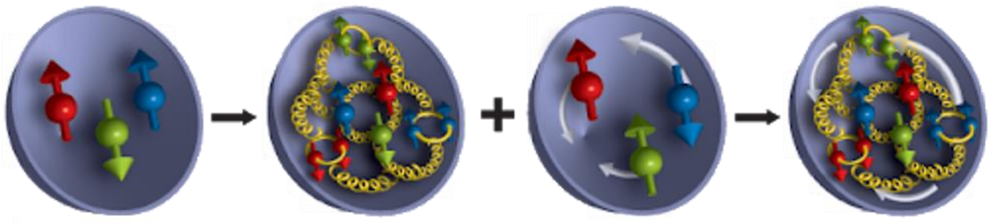
A particle's spin is one of its basic characteristics, like its mass or electric charge, and physicists have long tried to nail down the dynamics at work behind the spin of particles made of quarks.

University of Lund

1951-5-31

About nucleon spin structure

1988 EMC experiment → "Spin crisis"

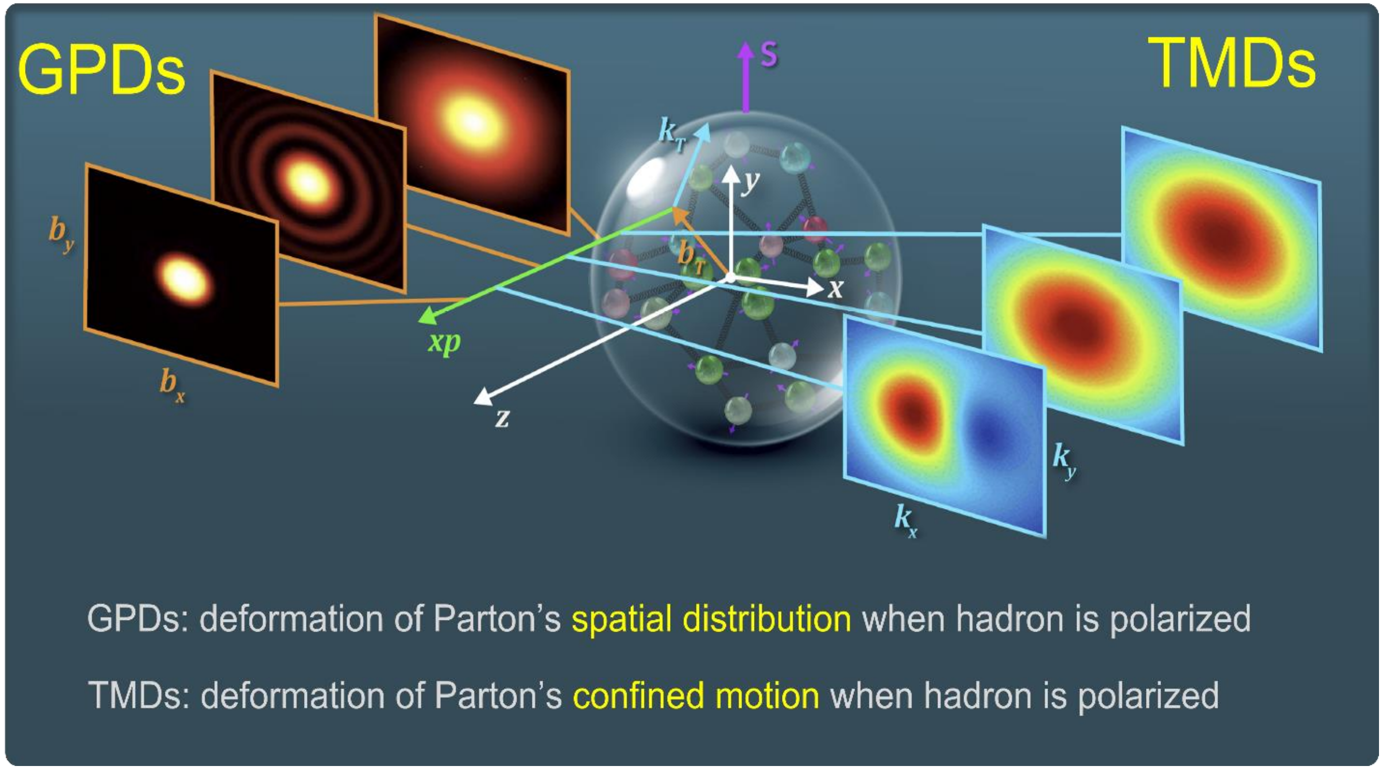


1970s 1980s/2000s Now

Spin decomposition:

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

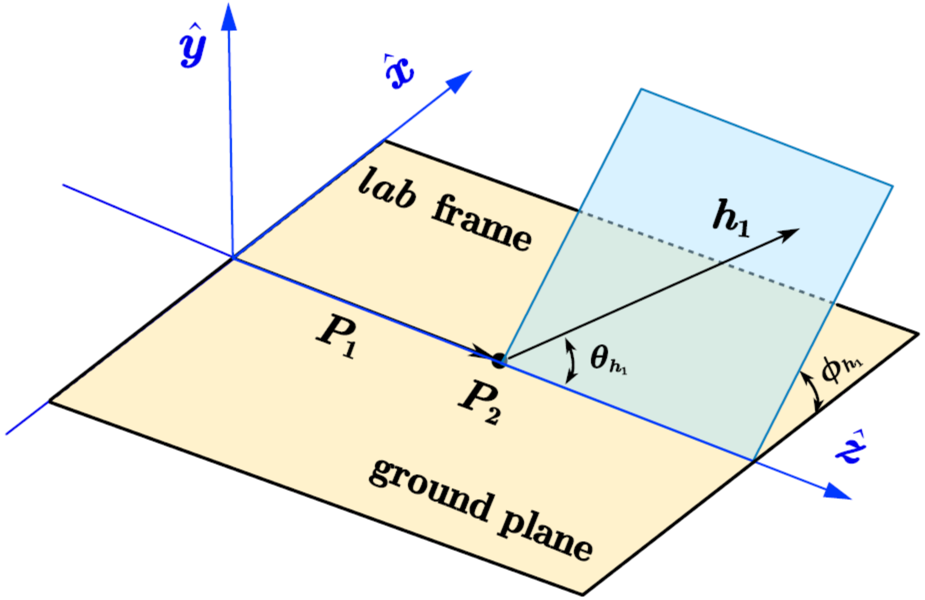
Quark spin | **Gluon Spin** | **Quark OAM** | **Gluon OAM**

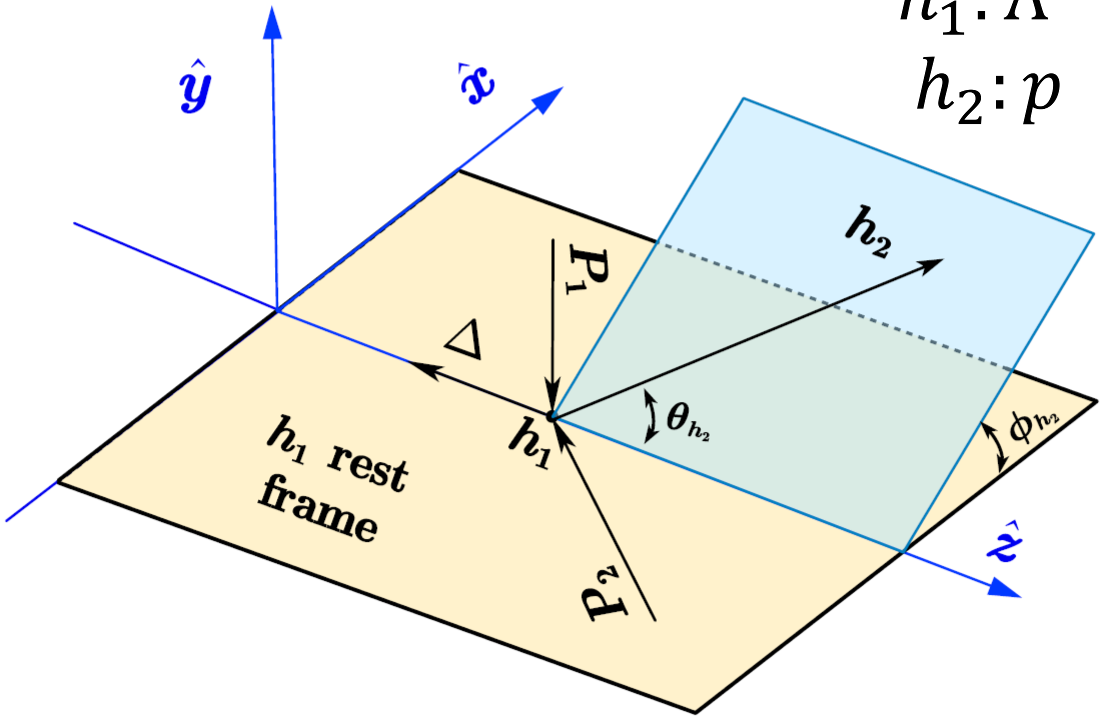


We have a framework for the understanding of the spin structure of the nucleon

A new domain: from nucleon to hyperon

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



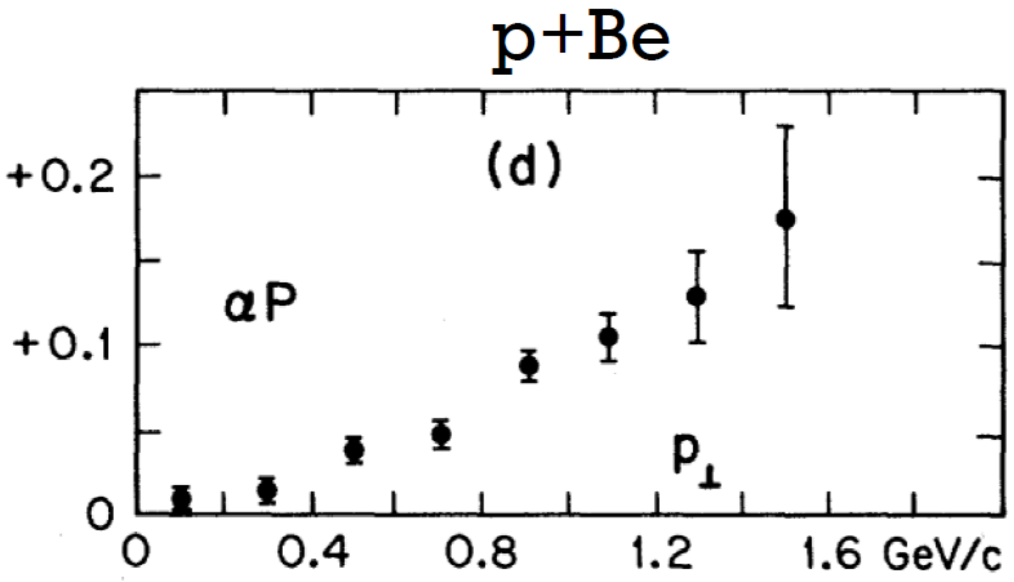


$h_1 : \Lambda^0$

$h_2 : p$

$$\text{yield} \sim (1 + \alpha P cos\theta_{h_2})/4\pi$$

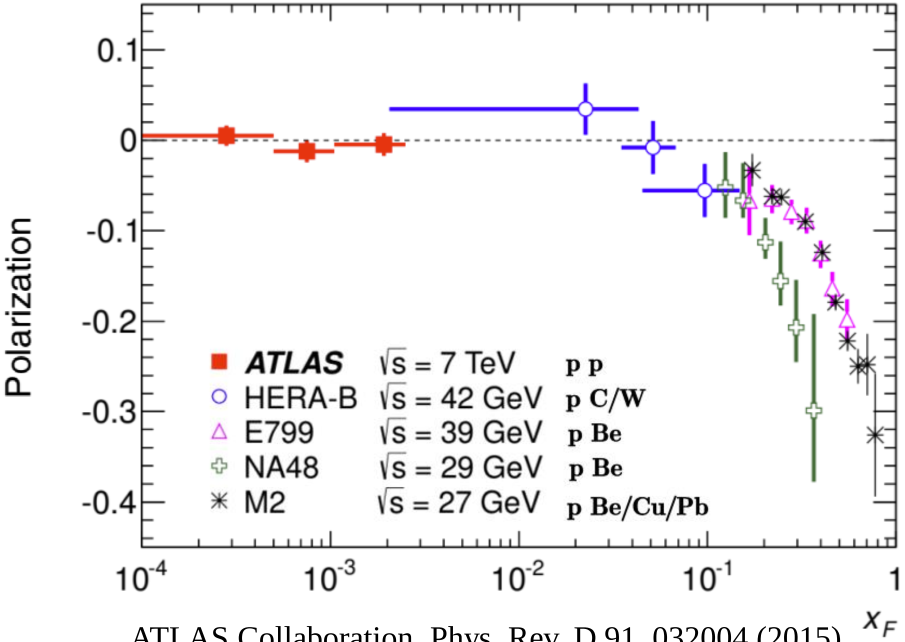
First observation of Λ^0 polarization in the 1970's



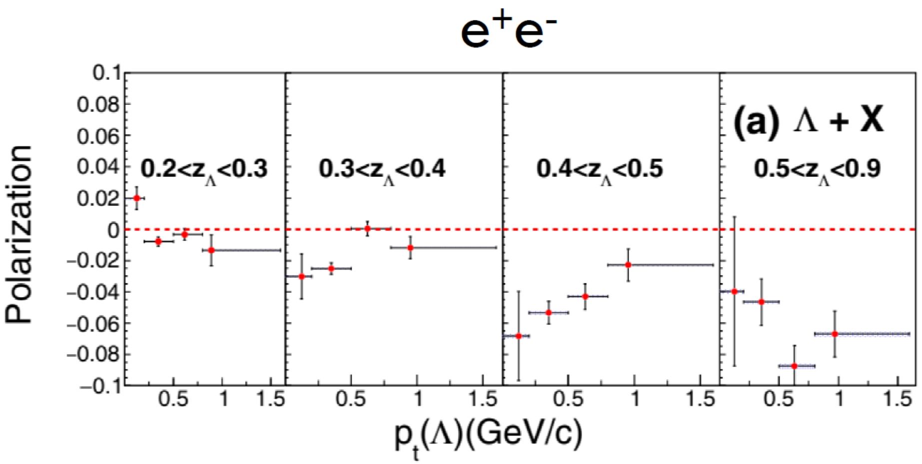
G.Bunce, *et al.*: Phys.Rev.Lett. 36, 1113-1116 (1976)

- Hyperons can be produced polarized in collisions of elementary particles
- Discovered at Fermilab in the 1970's in p + Be collisions: 300 GeV protons on Beryllium

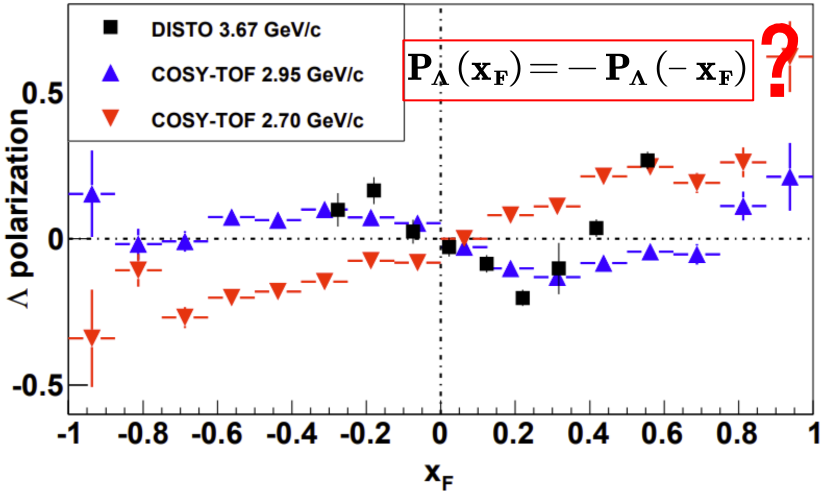
Λ^0 polarization observed in both high and low energy collisions

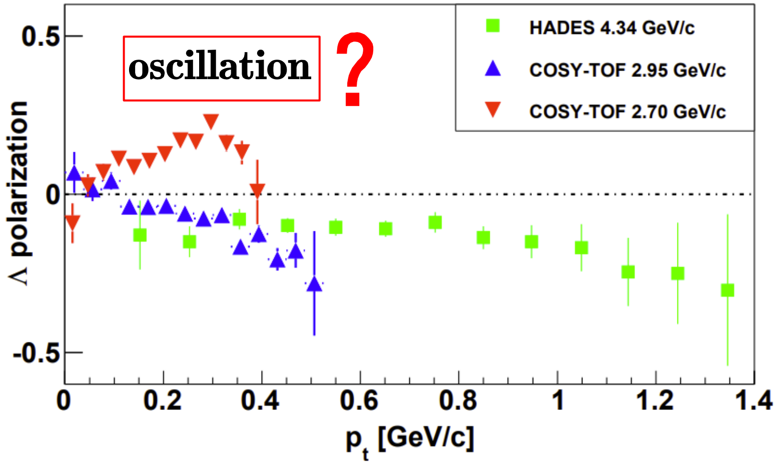


ATLAS Collaboration, Phys. Rev. D 91, 032004 (2015)



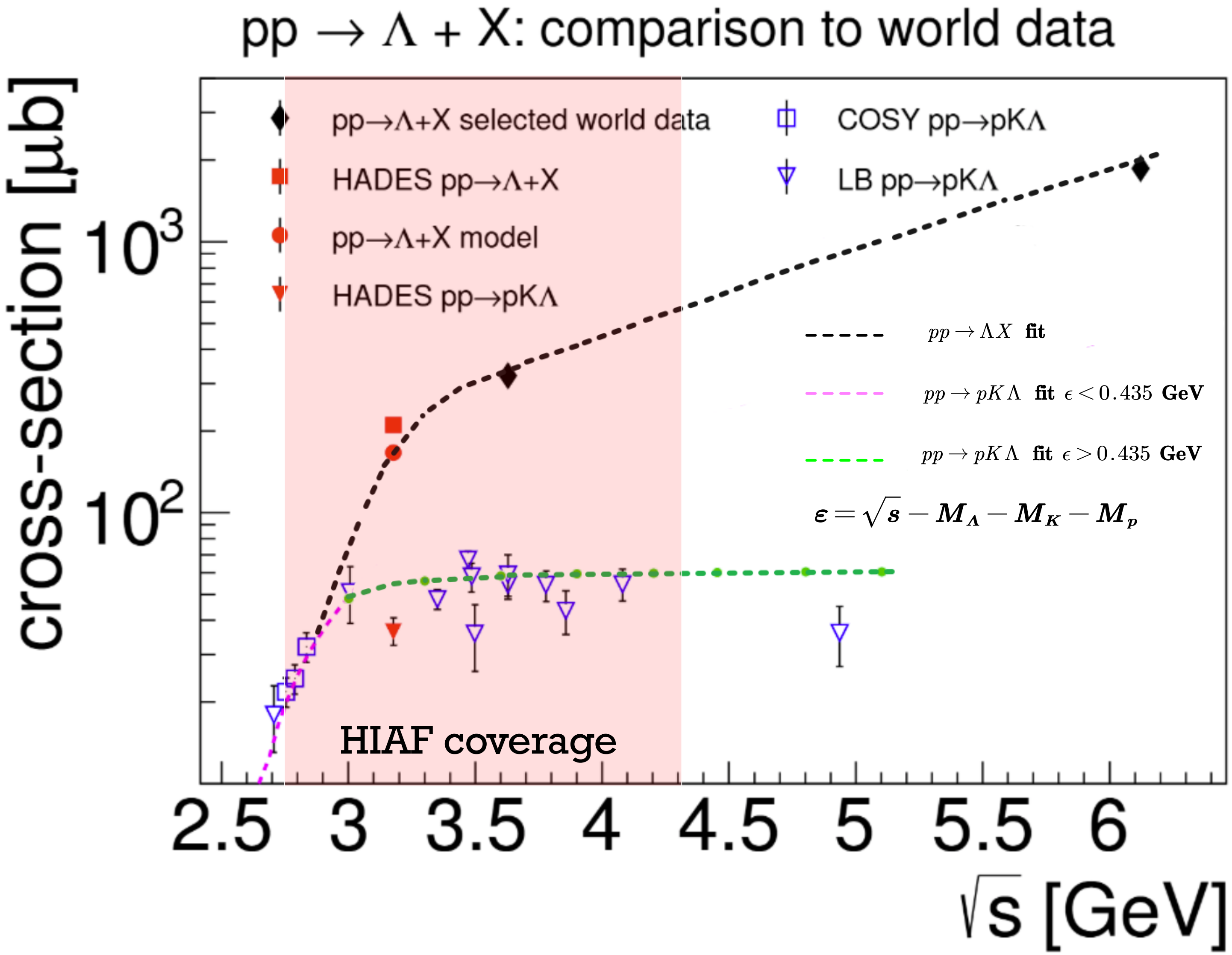
BELLE: Phys.Rev.Lett. 122, 042001 (2019)





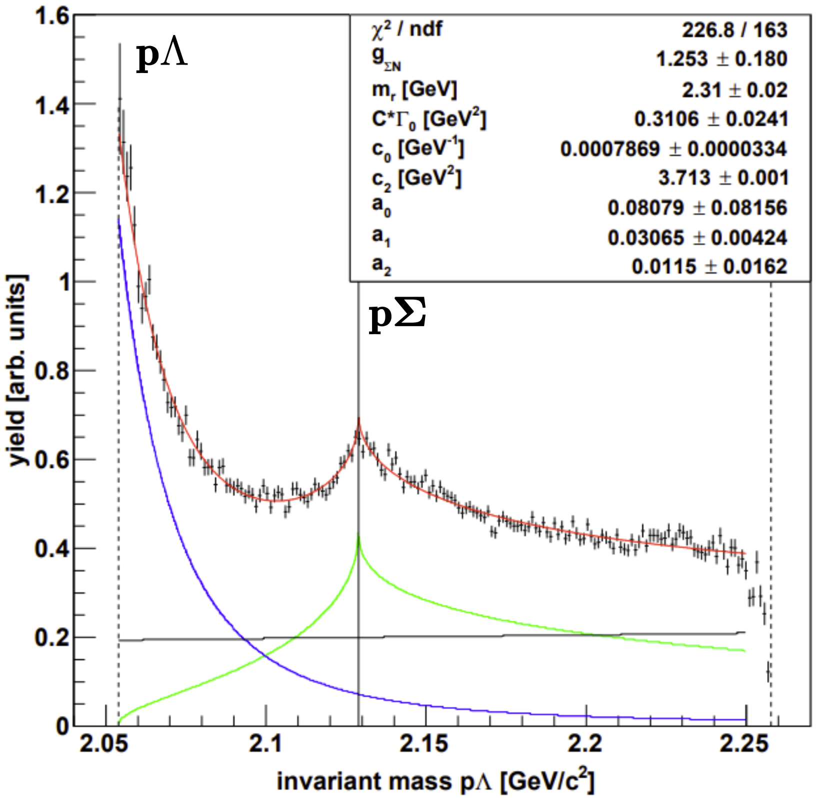
COSY-TOF Collaboration, Eur. Phys. J. A 52, 337 (2016)

Not only polarization but also production



Not only polarization but also production

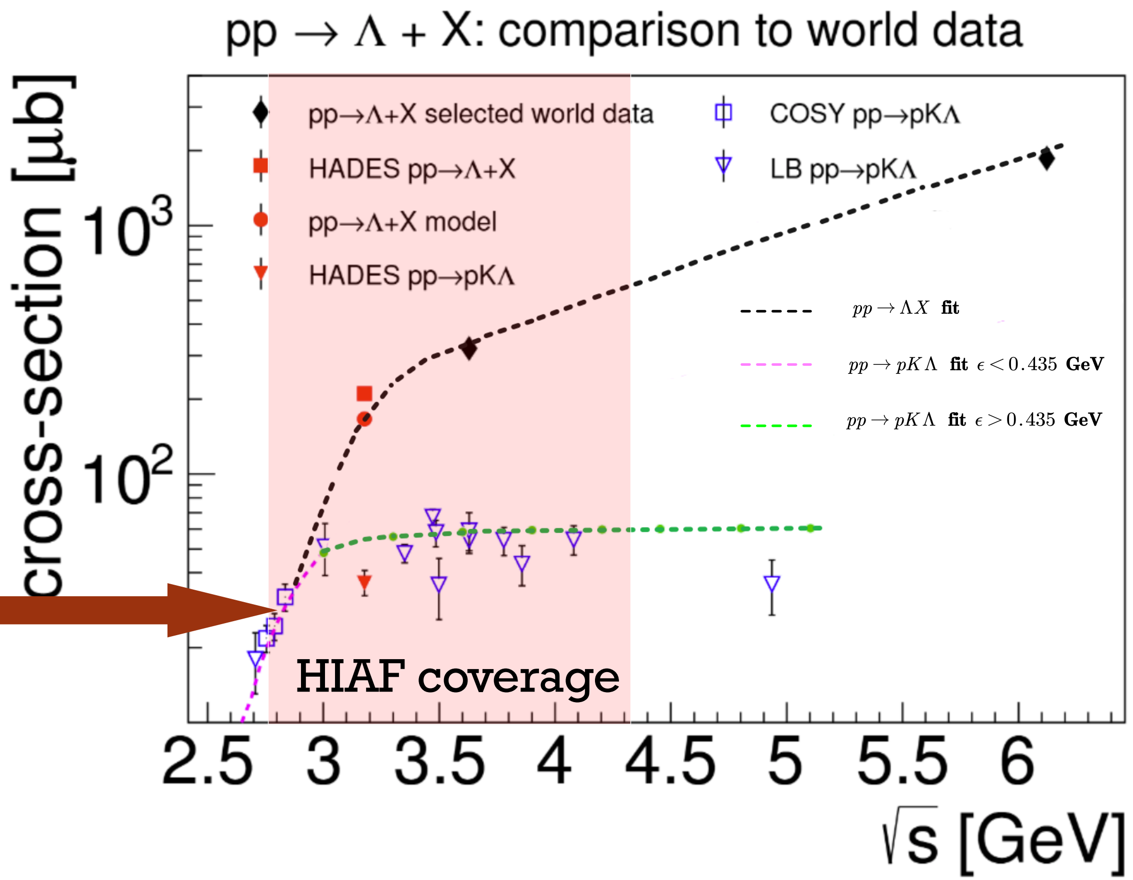
$\mathbf{p(2.95\ GeV)+p\rightarrow pK\Lambda}$



$$\frac{d\sigma^{\mathrm{meas}}}{dm_{p\Lambda}} \Big/ \frac{d\sigma^{\mathrm{MC}}}{dm_{p\Lambda}} = \mathrm{FSI}(m_{p\Lambda}) + \mathrm{TH}(m_{p\Lambda}) + \mathrm{RF}(m_{p\Lambda})$$

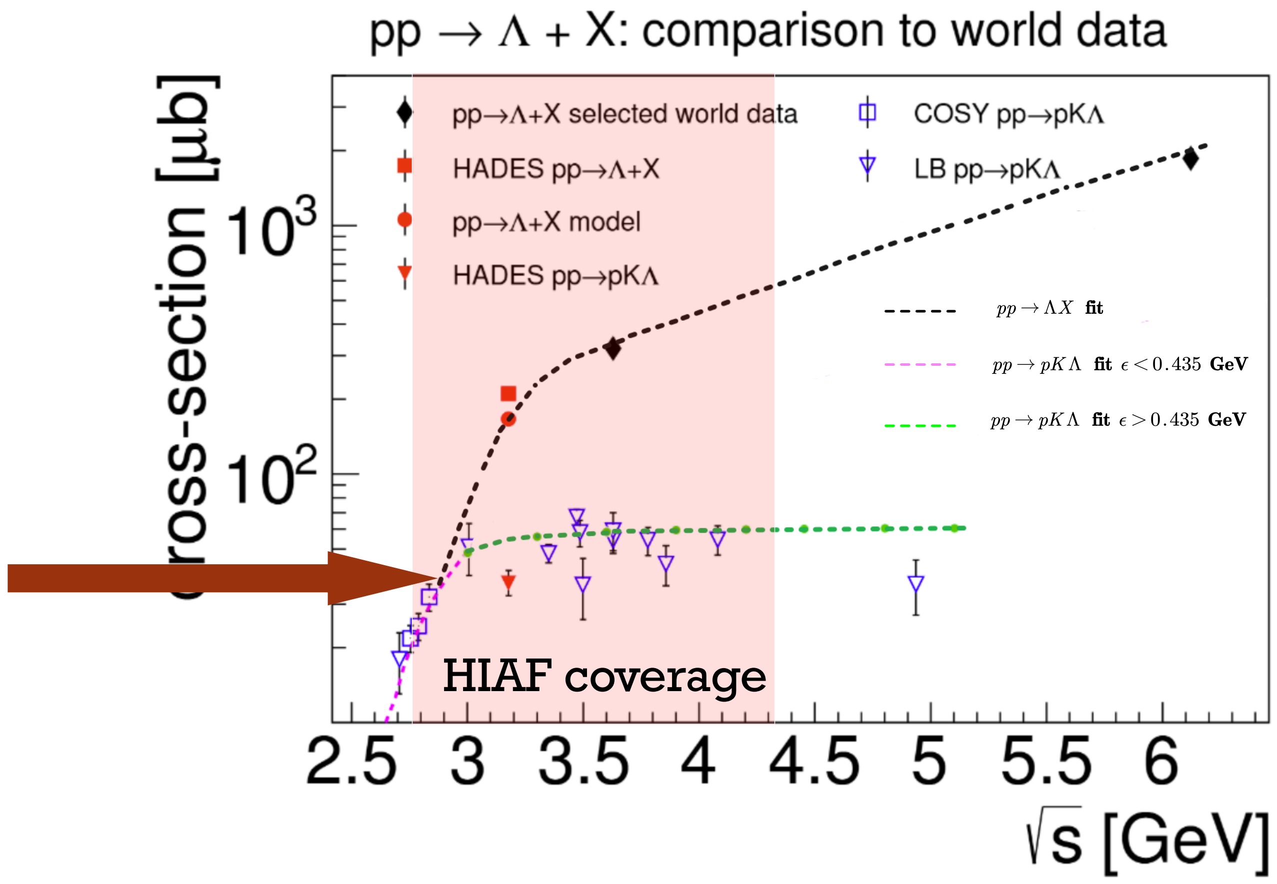
hyperon-nucleon (pΛ) interaction | **coupled channel effect of NΛ↔NΣ** | **reflections of the N* resonances**

COSY-TOF Collaboration, Eur. Phys. J. A 52 1, 7 (2016).



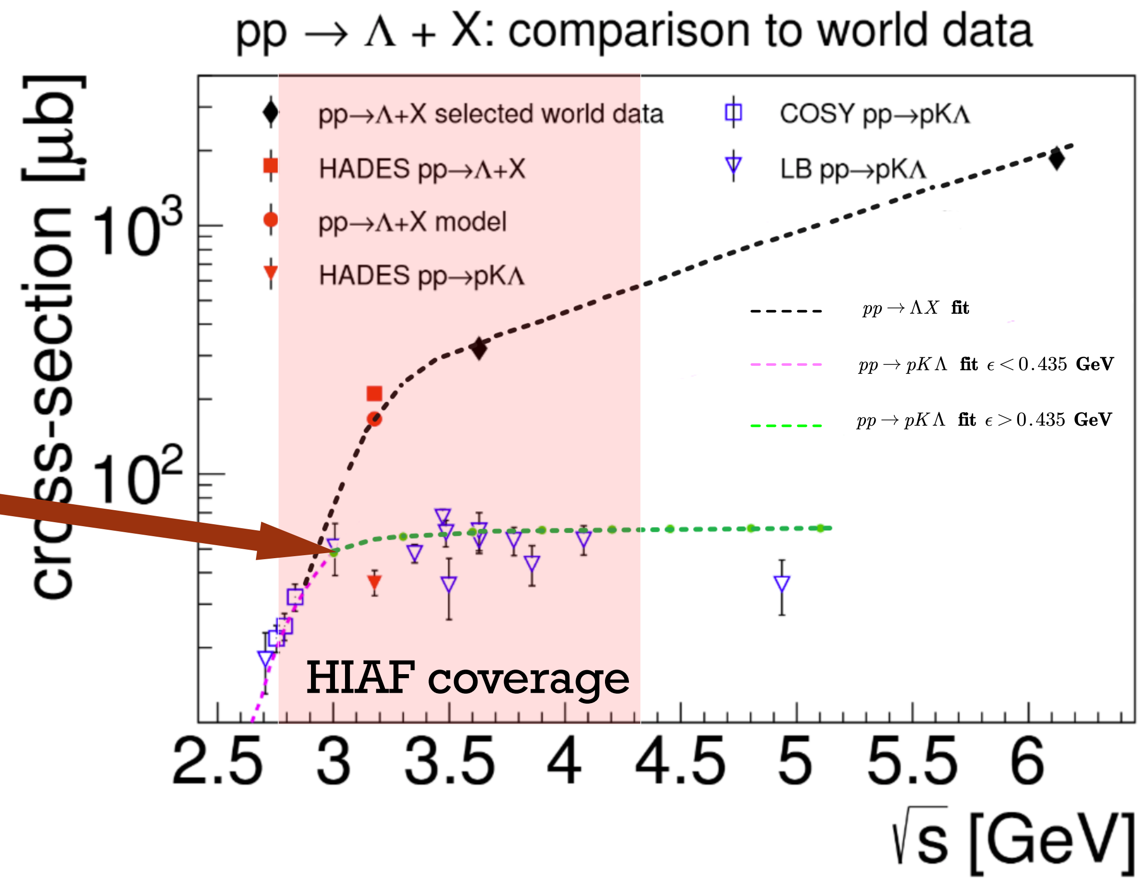
Not only polarization but also production

Inclusive production XS becomes higher compared to exclusive process



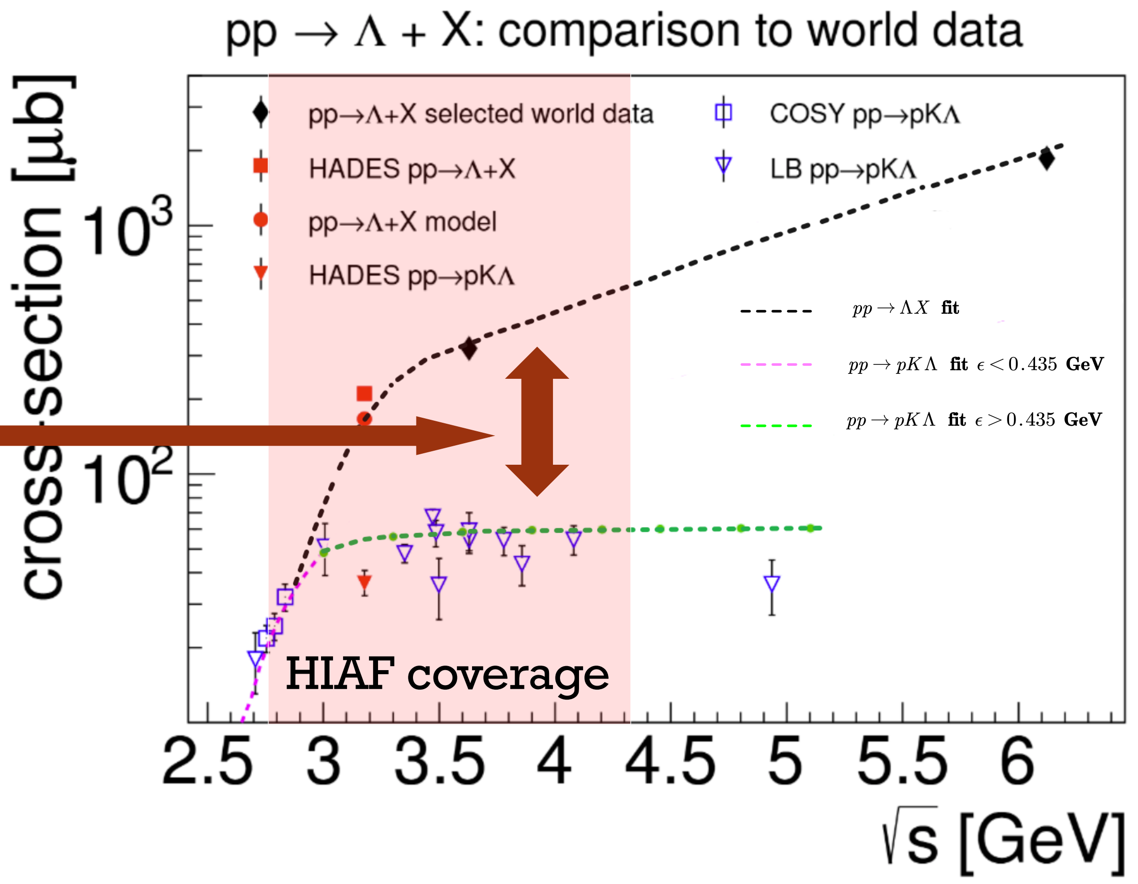
Not only polarization but also production

Exclusive process XS becomes flat

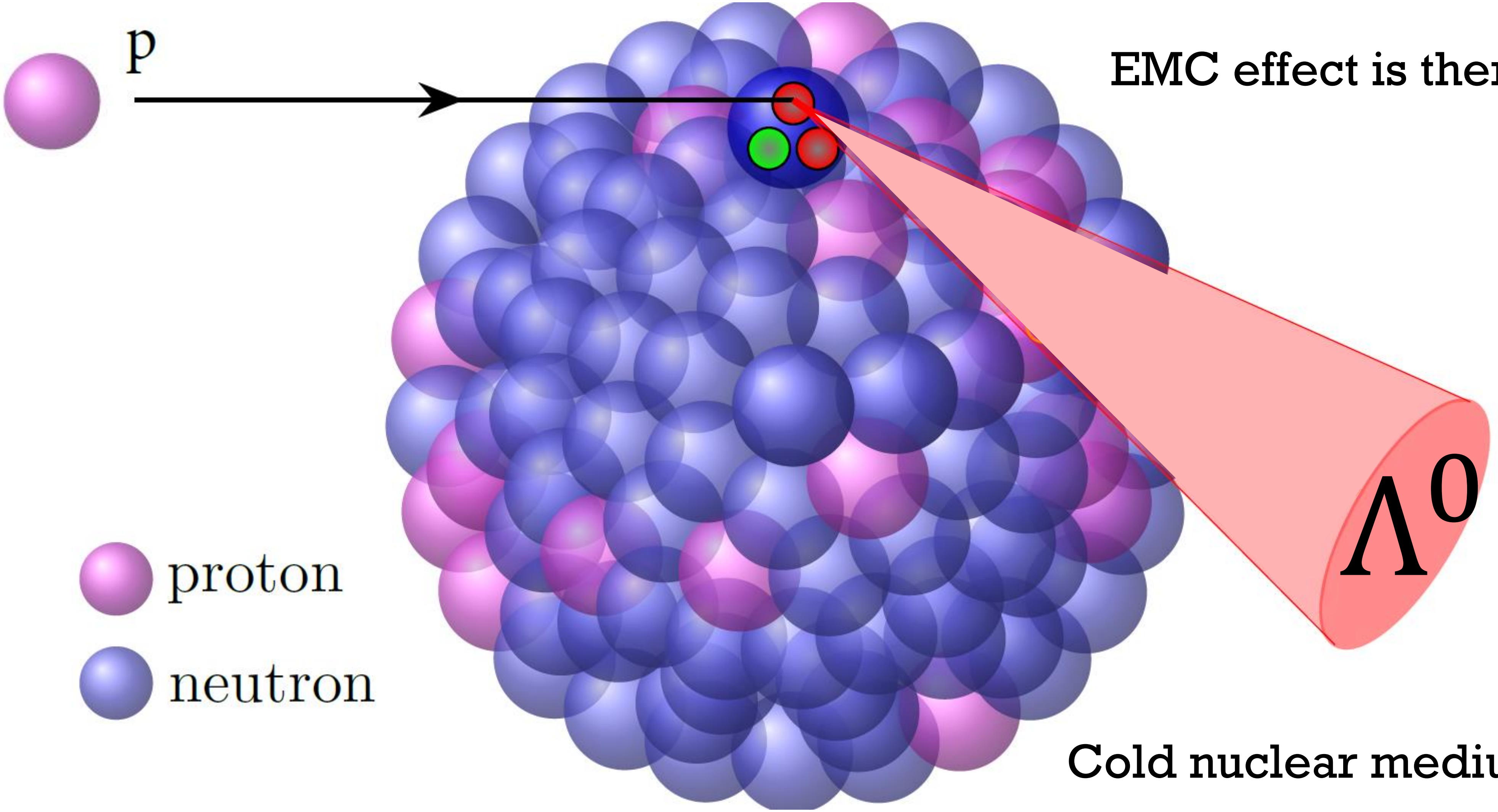


Not only polarization but also production

Resonance and fragmentation



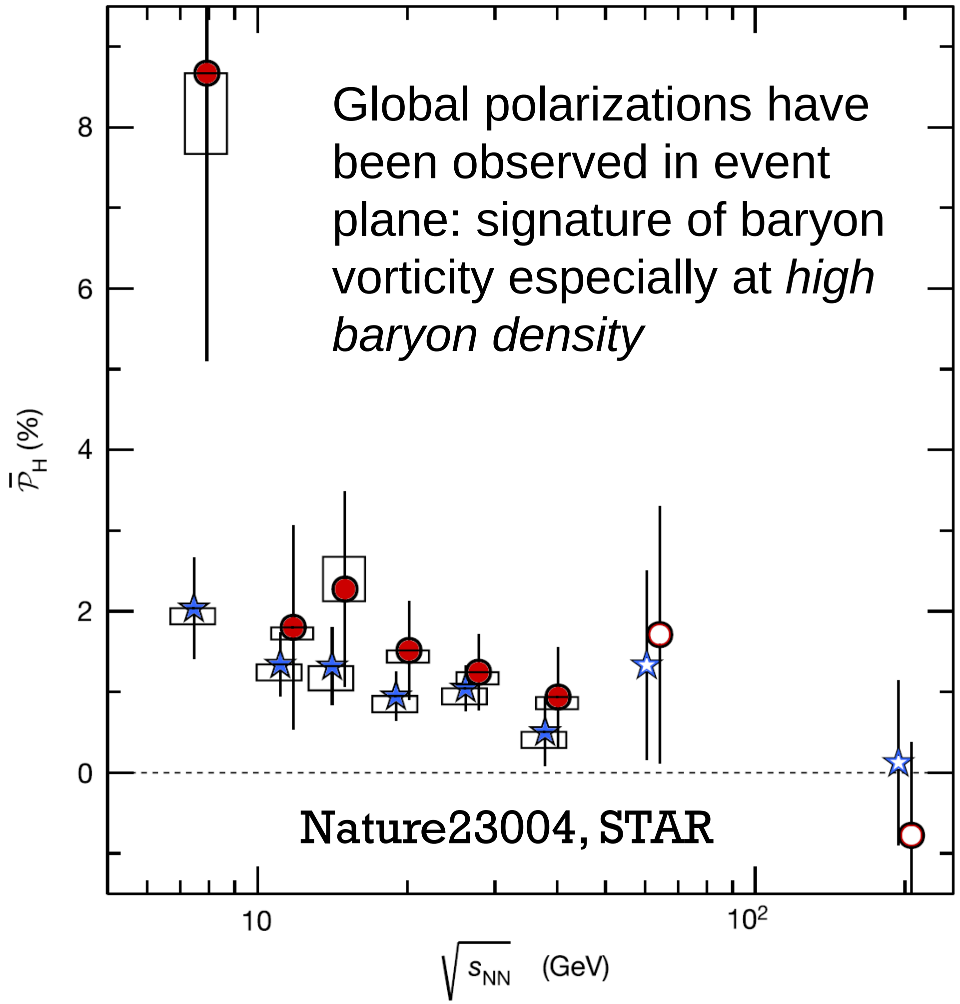
What's more?   with p-A

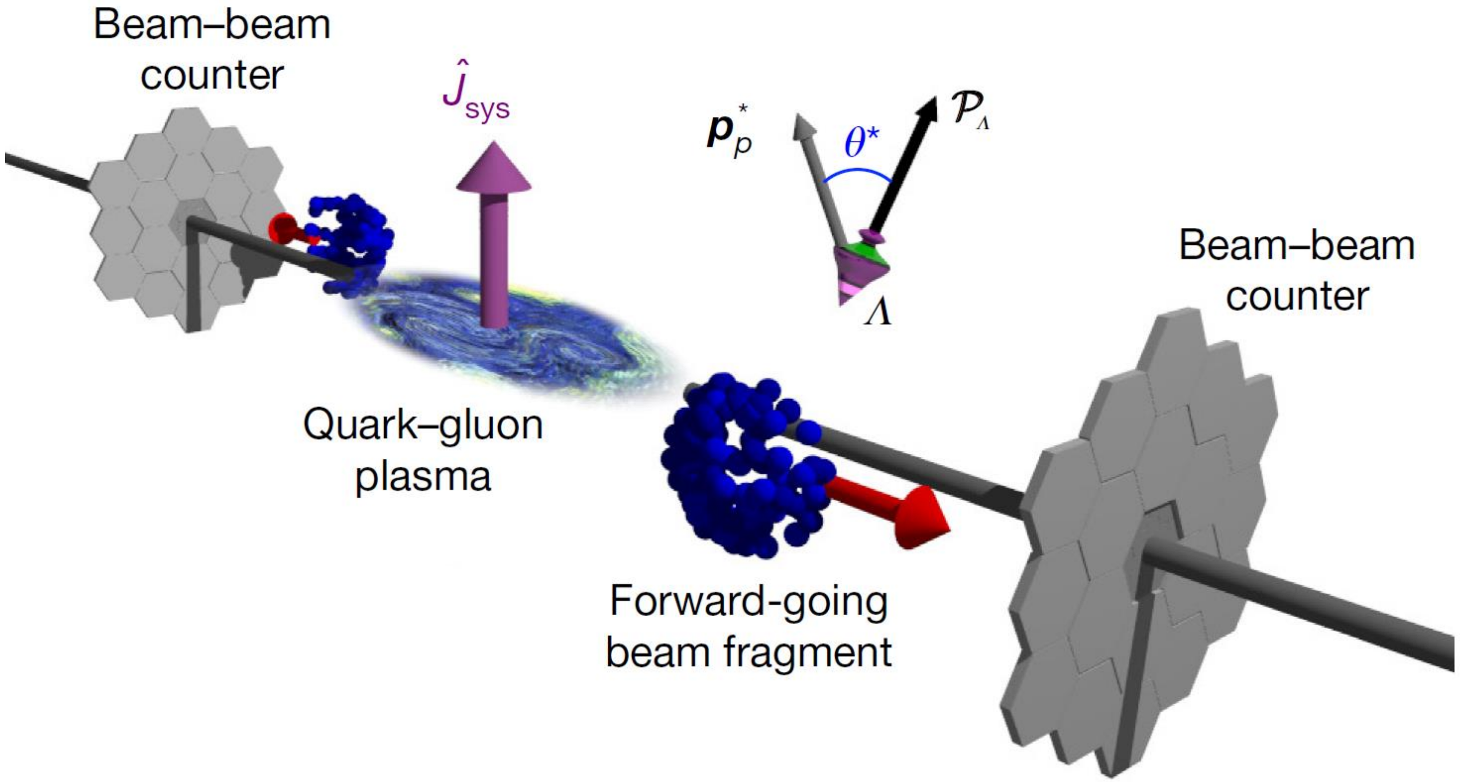


EMC effect is there for PDFs

Cold nuclear medium effect

What's more?   with A-A





Hot nuclear medium effect

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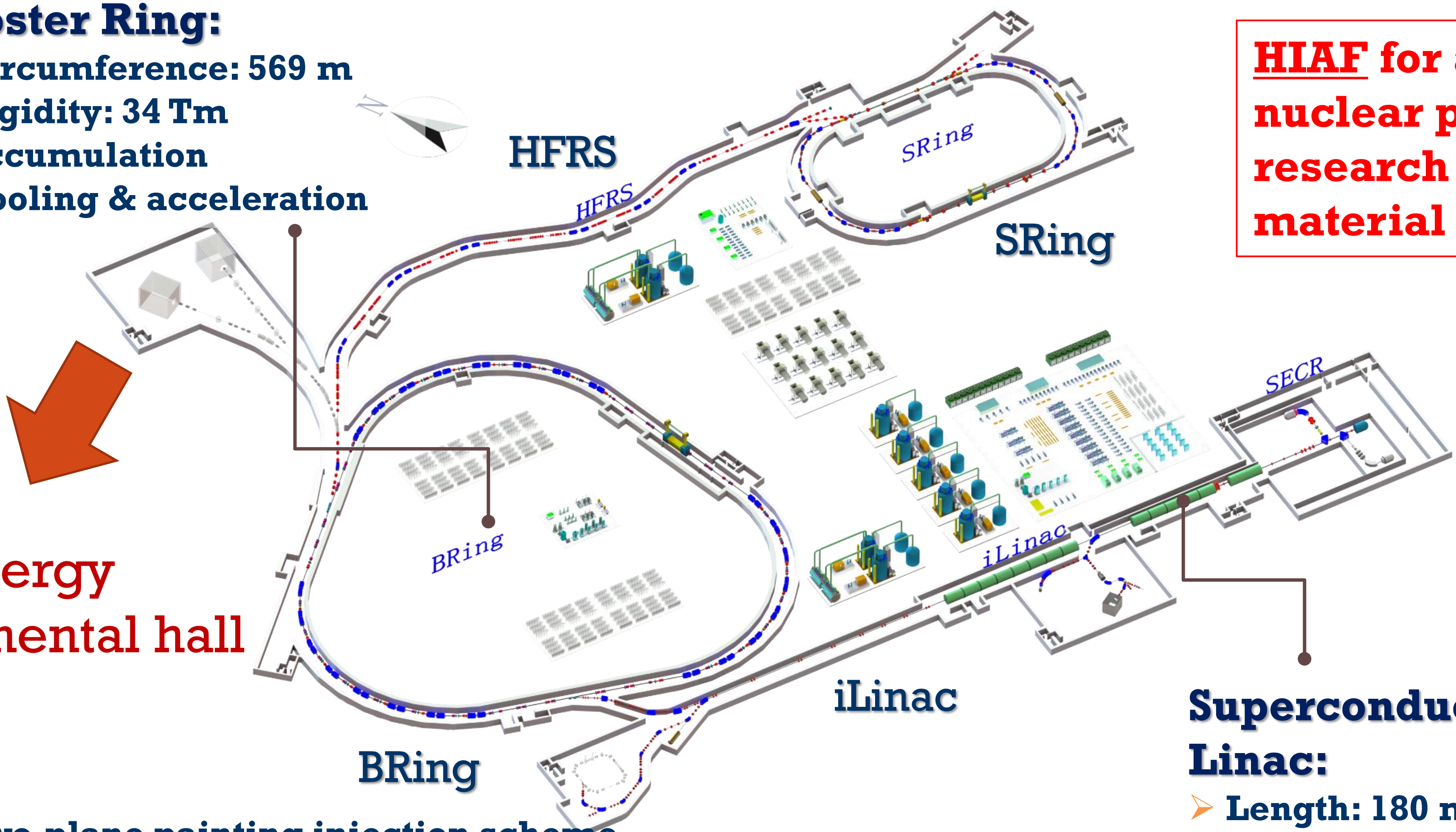
High Intensity heavy-ion Accelerator Facility (HIAF)

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

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



High energy experimental hall

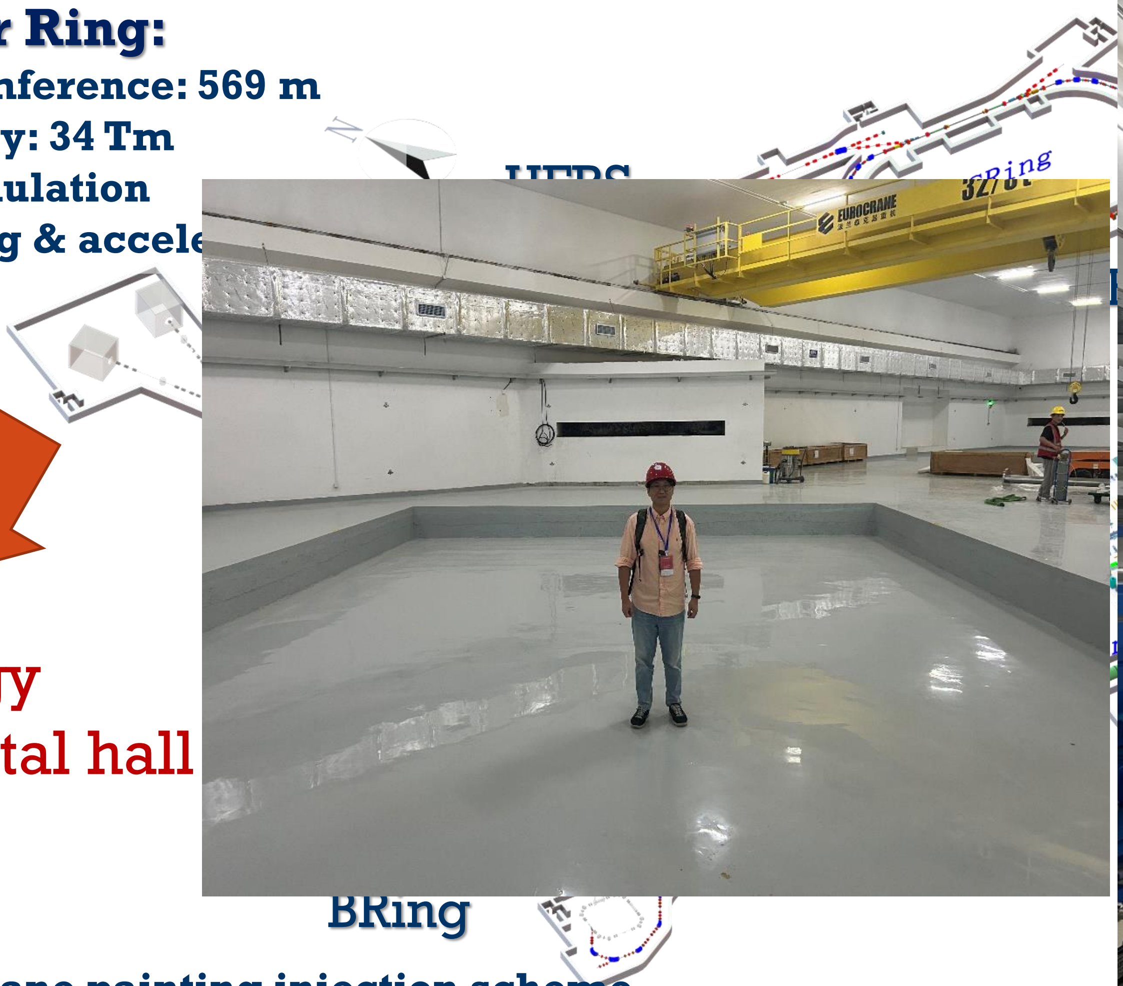
- Two-plane painting injection scheme
- Fast ramping rate operation

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

High Intensity heavy-ion Accelerator Facility (HIAF)

Booster Ring:

- **Circumference: 569 m**
- **Rigidity: 34 Tm**
- **Accumulation**
- **Cooling & accele**



High energy experimental hall

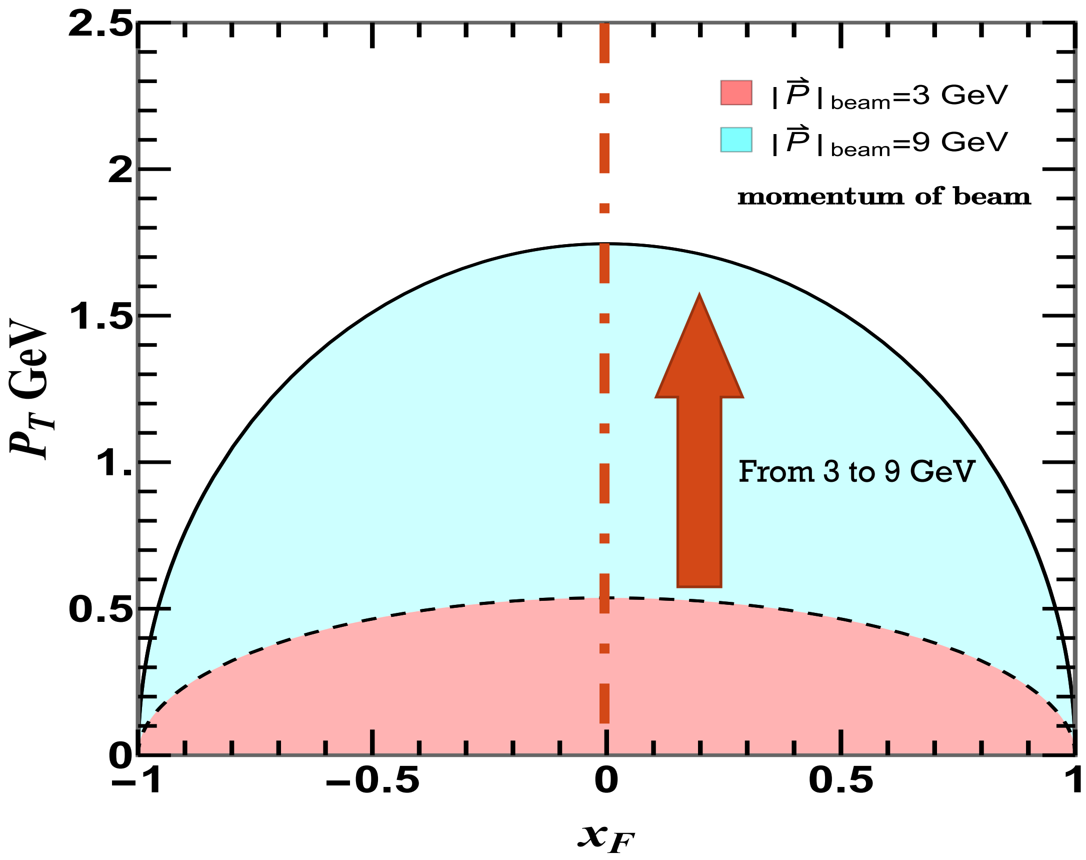
- **Two-plane painting injection scheme**
- **Fast ramping rate operation**

HIAF under construction in Huizhou

HIAF beam parameters

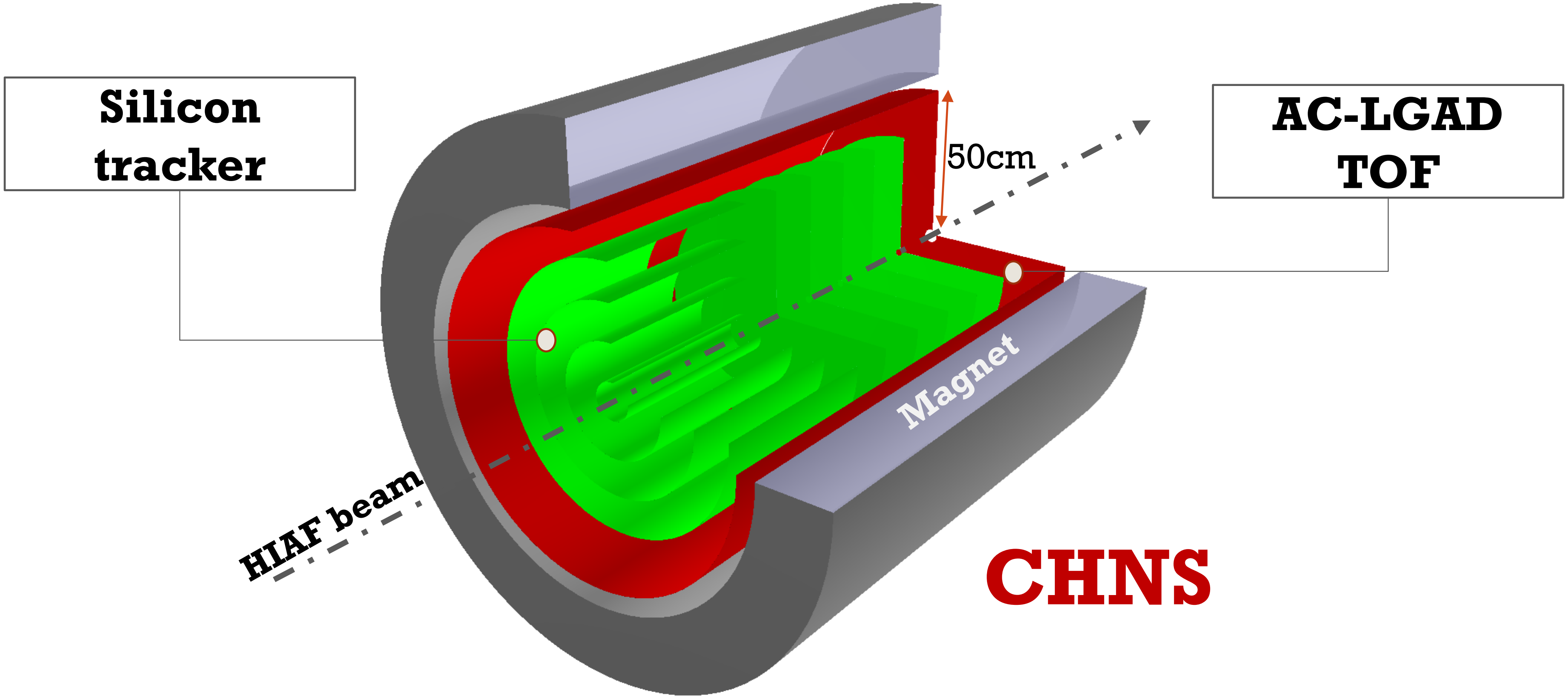
Ion	Intensity (ppp)	Energy (GeV/u)
$^{238}U^{35+}$	2.0×10^{11}	0.84
$^{238}U^{76+}$	5.0×10^{10}	2.5
$^{129}Xe^{27+}$	3.6×10^{11}	1.4
$^{78}Kr^{19+}$	5.0×10^{11}	1.7
$^{40}Ar^{12+}$	7.0×10^{11}	2.3
$^{18}O^{6+}$	8.0×10^{11}	2.6
p	5.0×10^{13}	9.3

HIAF kinematics coverage



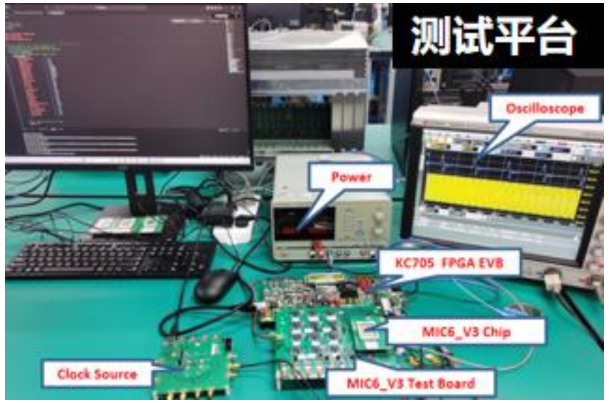
Allow for a multi-dimensional mapping of the Λ^0 polarization and production

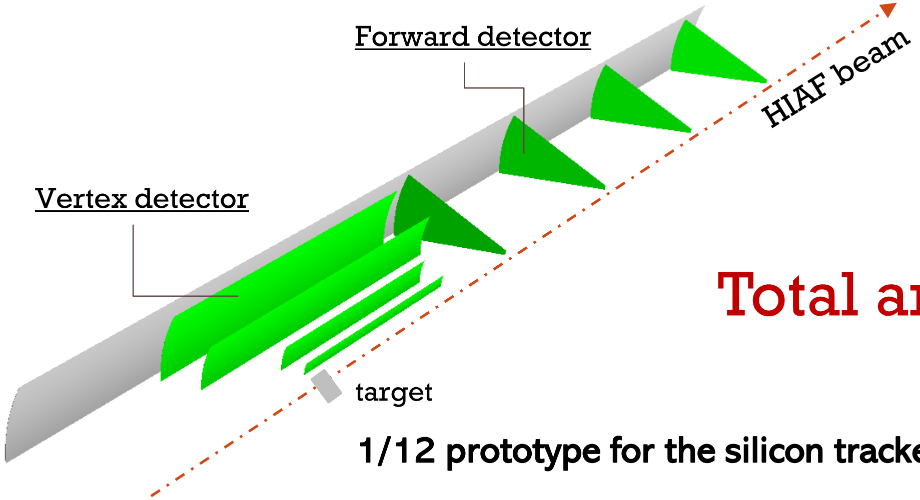
China Hyperon-Nuclear Spectrometer



Silicon tracker at CHNS

MIC6 development at CCNU





1/12 prototype for the silicon tracker

Total area of silicon tracker: ~1m^2

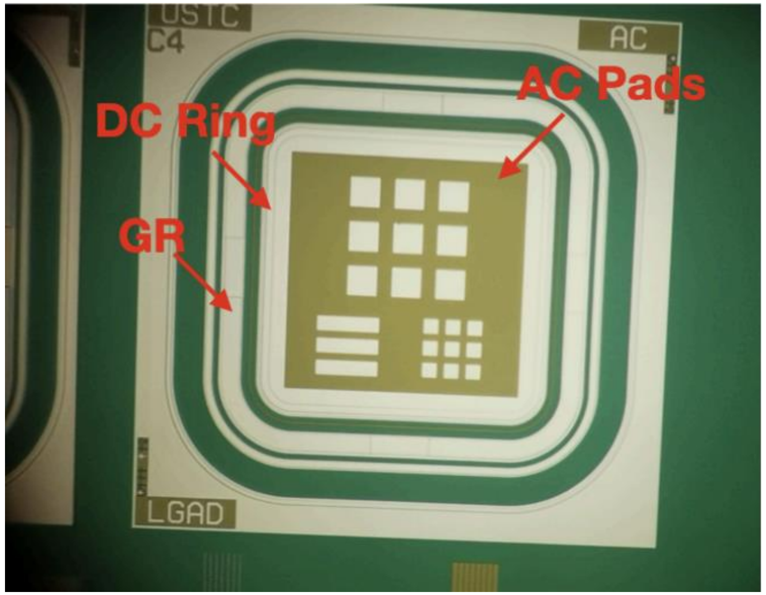
- **MIC6 MAPS pixel chip:** development and manufacture with the domestic process
- **Readout electronics** (ITS2 based design) **and DAQ** (ALICE CRU/FELIX protocol, GBTx, …)
- **Detector assembly and integration:**
  - **Vertex detector:** Stave module design (spatial resolution: ~ 5 μm with pixel 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)

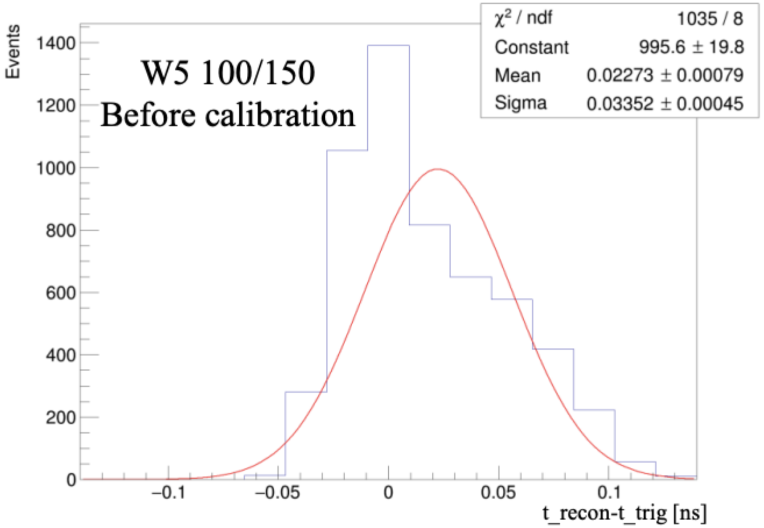
Details: See Xiangming Sun's talk

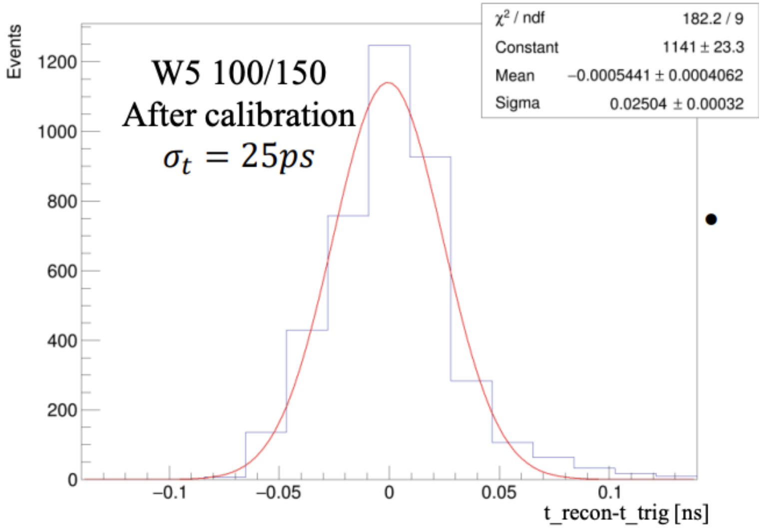
AC-LGAD at CHNS

Recent development 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.

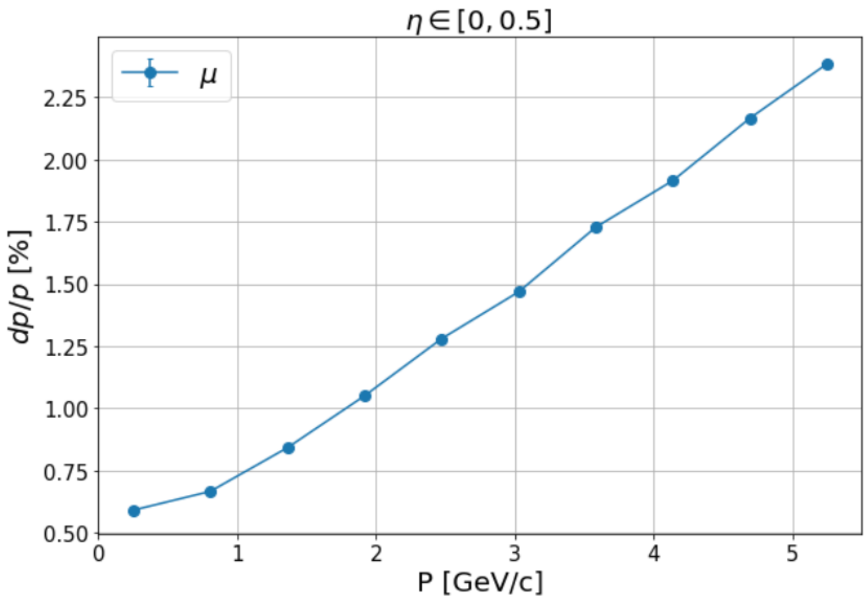


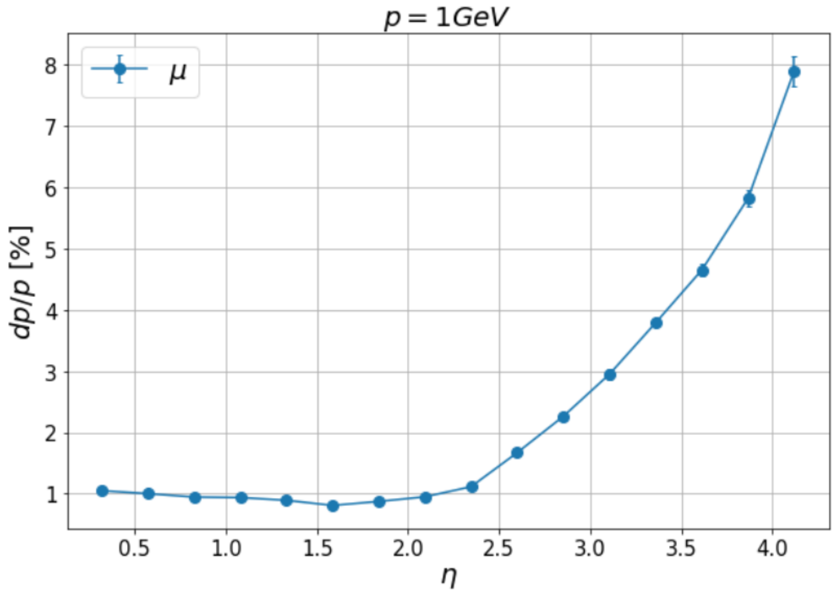


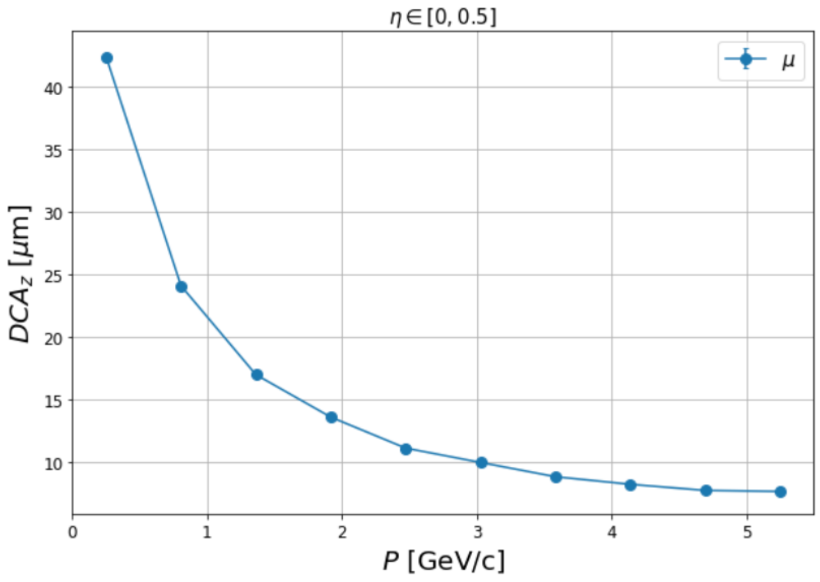


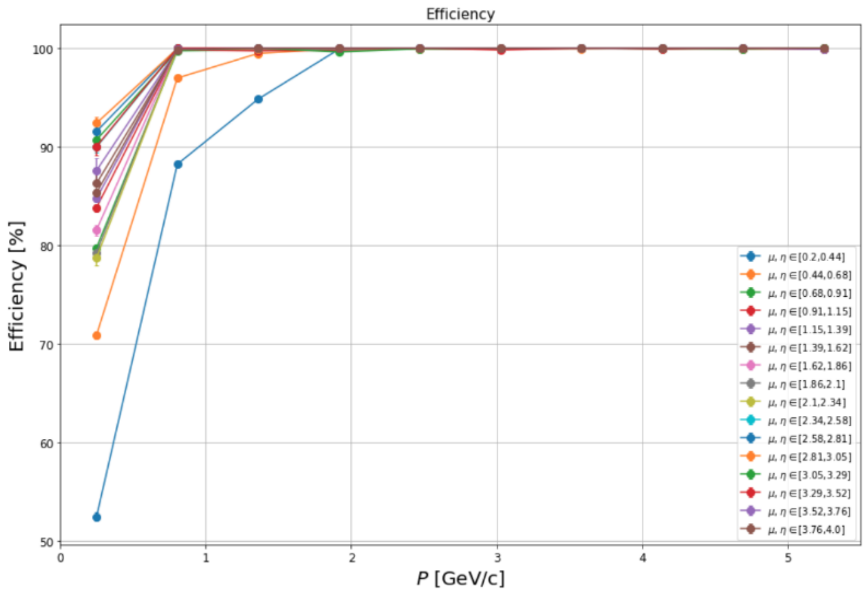
Total coverage at CHNS: ~4.5 m^2

Detector performance simulation

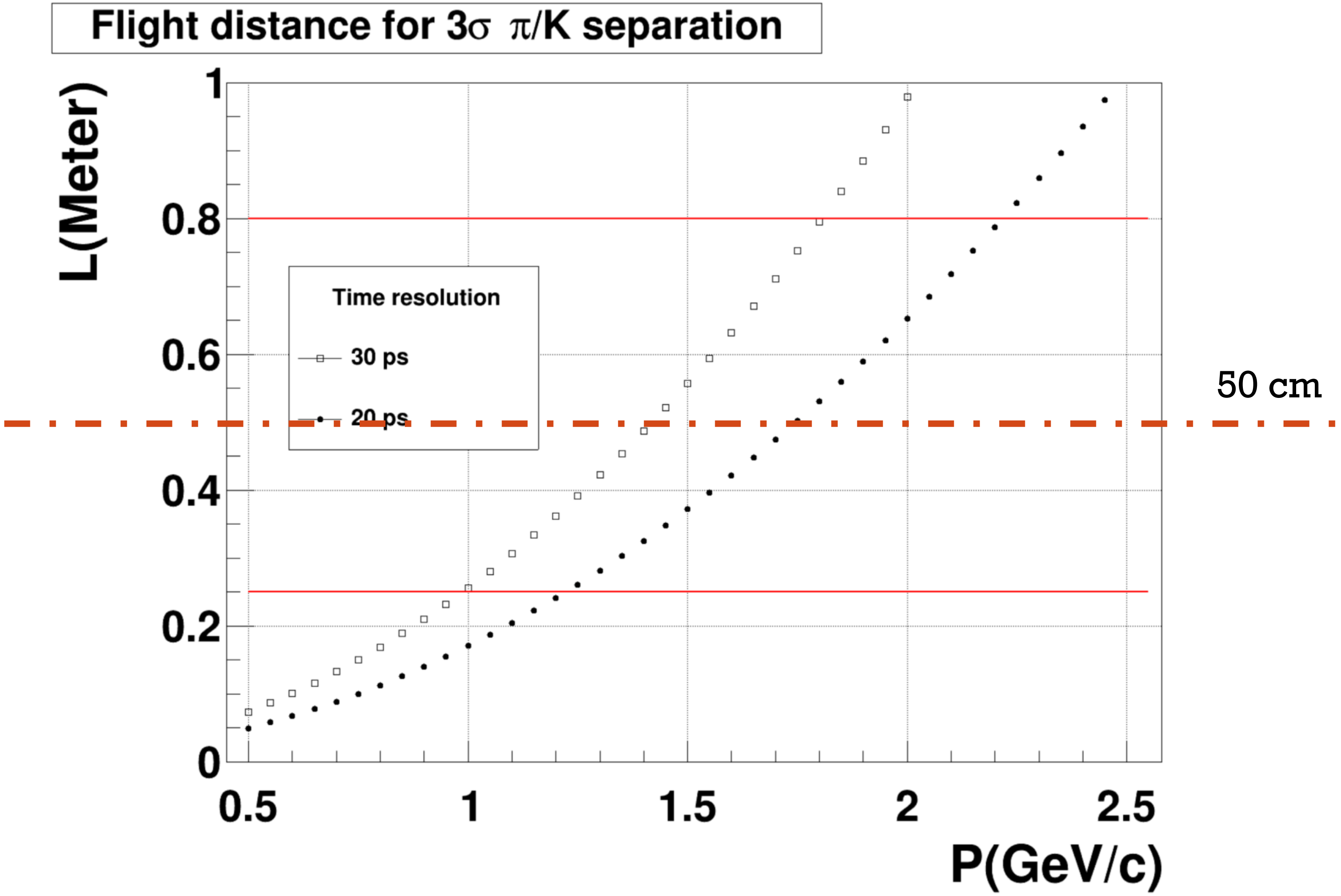




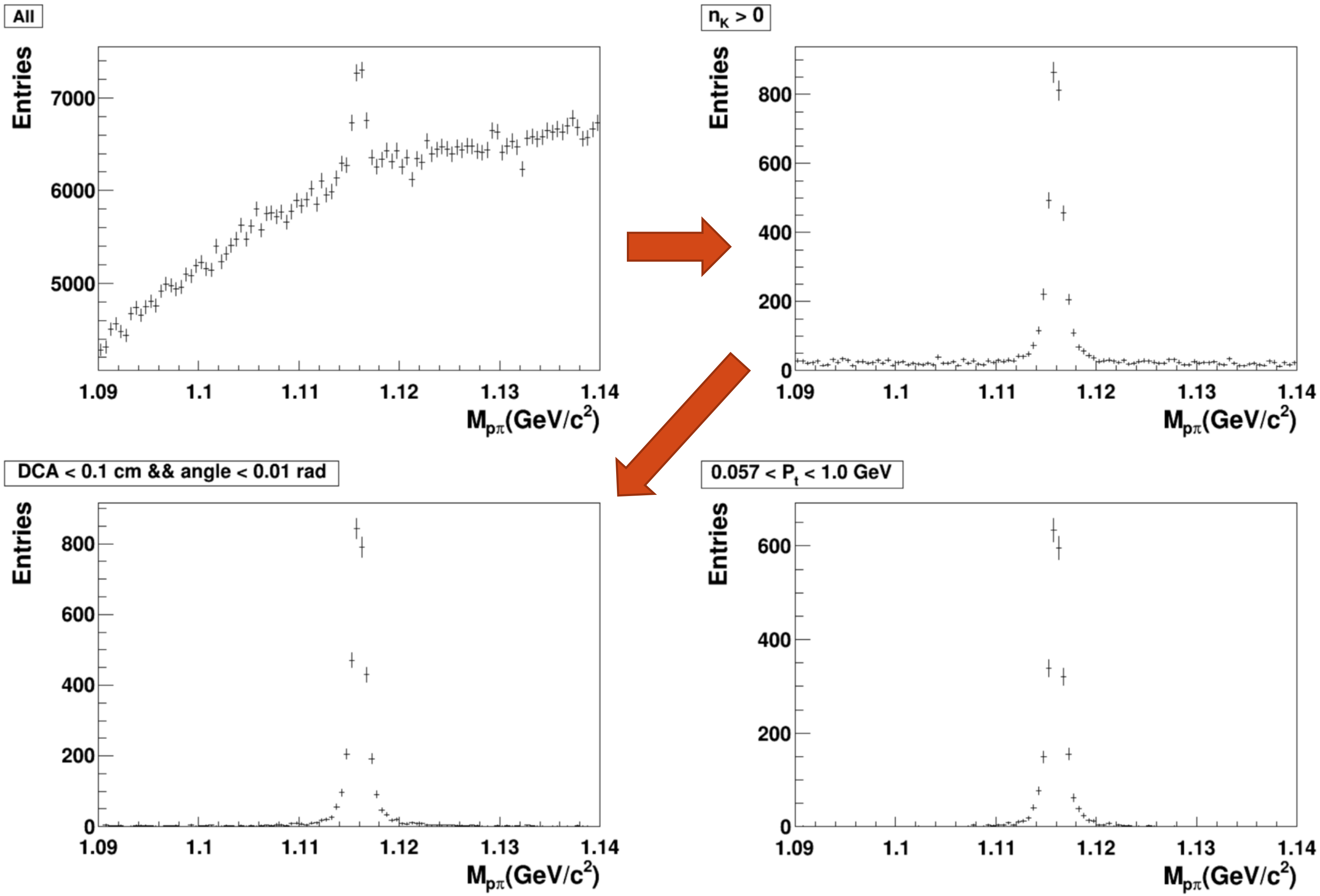


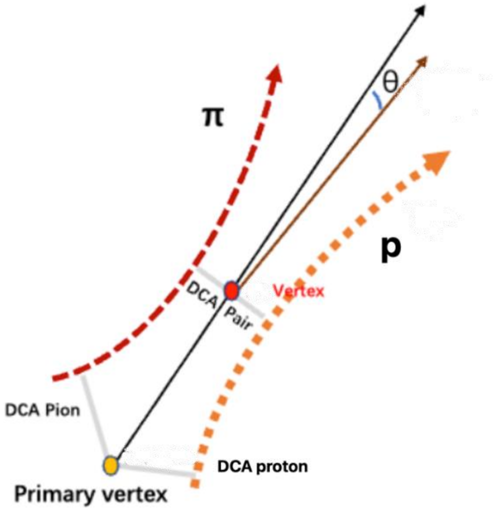


AC-LGAD as time-of-flight detector for PID



Λ^0 reconstruction with PLUTO simulation





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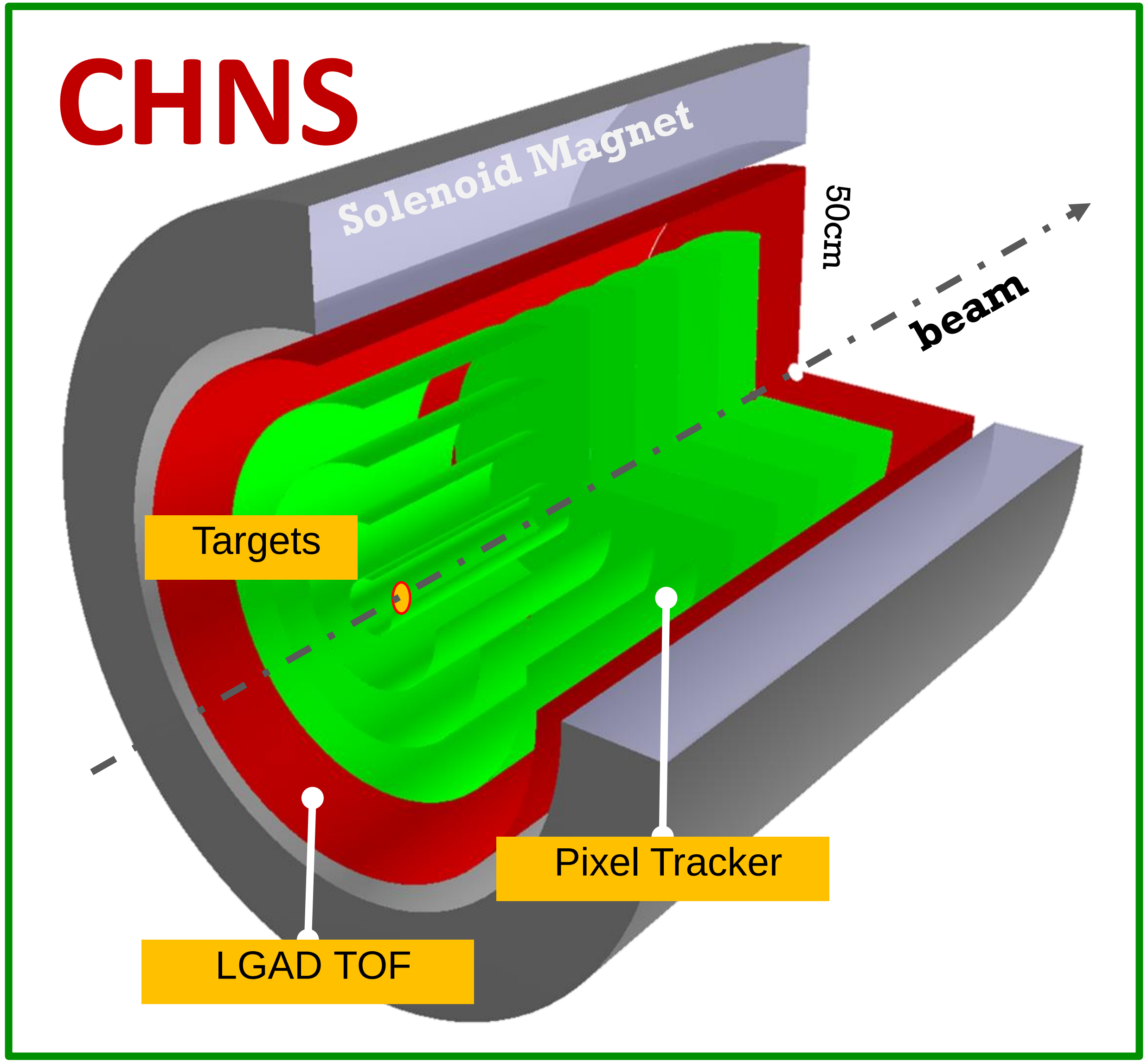


I. Physics:

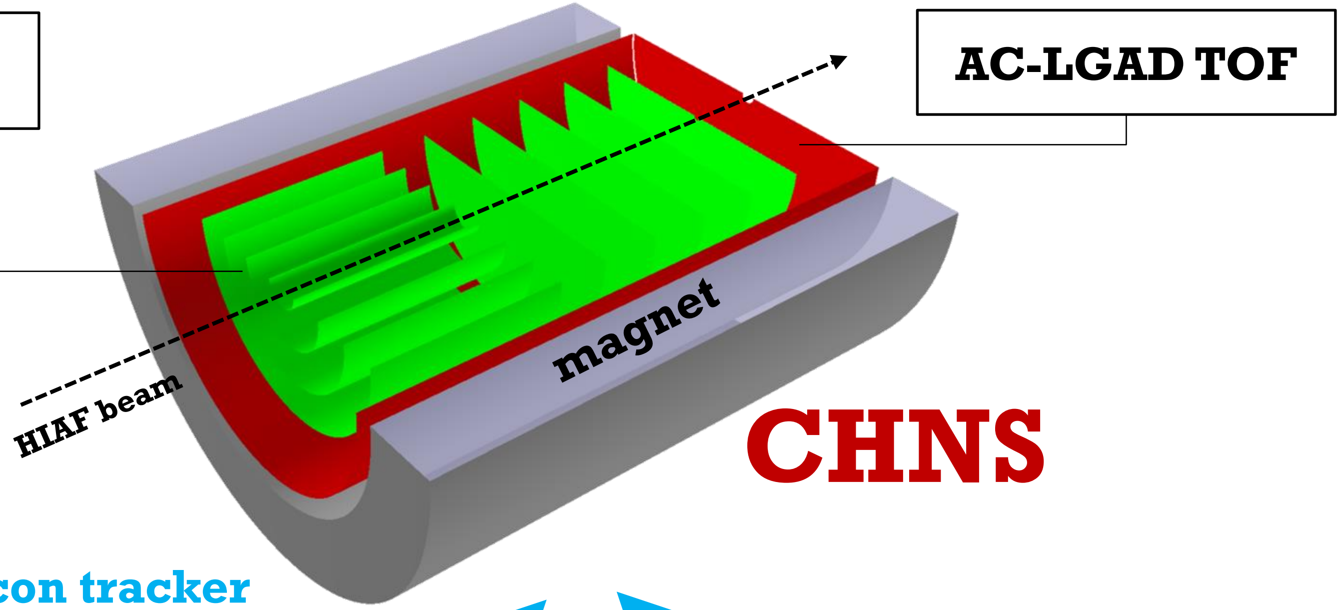
1) Λ production and polarization (*p+p*)
2) Medium effect (*p+A*)
3) Global polarization of Λ hyperon (*A+A*)

II. Community:

1) Supports both communities of hadron structure and heavy-ion physics
2) International interests are very welcome!

III. Detector R&D

1) Many parts are similar for CHNS, EicC, STCF and CEPC. Save resources.
2) CHNS: a detector R&D platform for EicC, ½ EicC



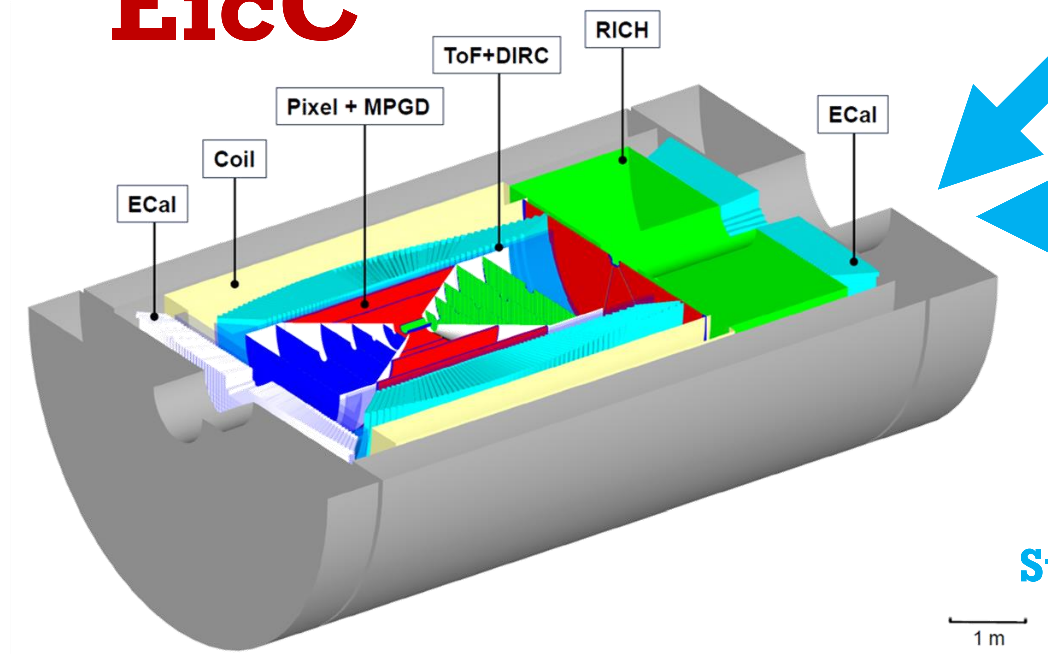
CHNS

Silicon tracker
AC-LGAD (PID)
Super-conducting Solenoid

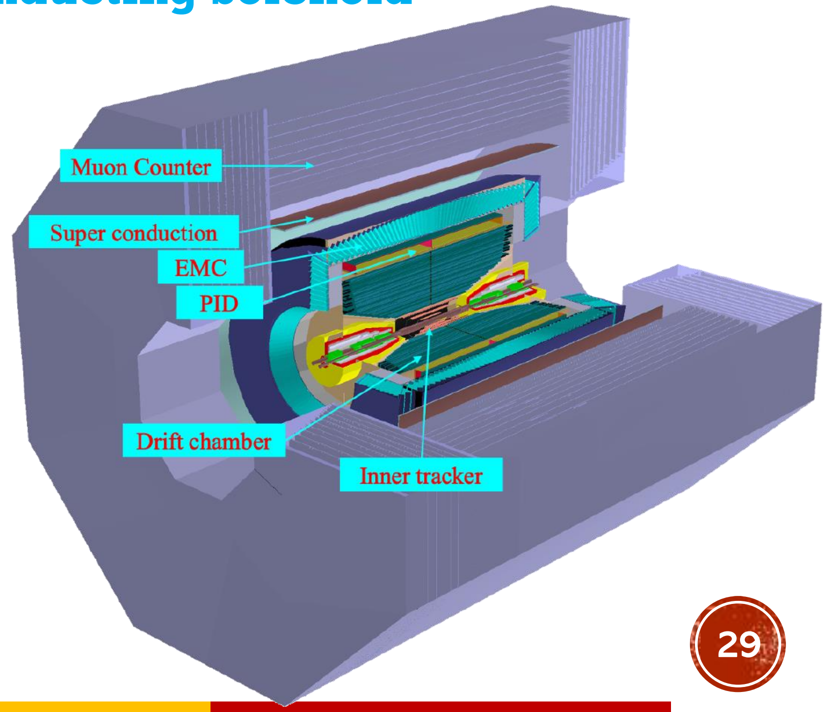
Silicon tracker
Super-conducting Solenoid

STCF

EicC



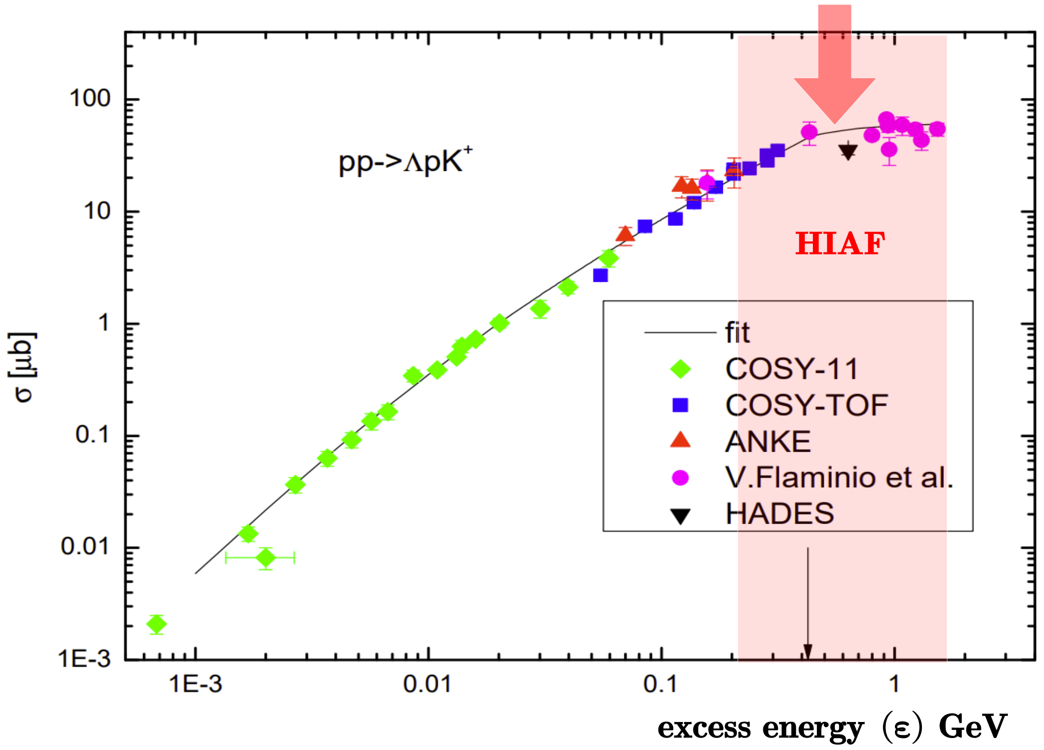
Silicon tracker
MPGD tracker
DIRC (PID)
RICH (PID)
Ecal
Super-conducting Solenoid



Thank you !

backups

Exclusive production of Lambda

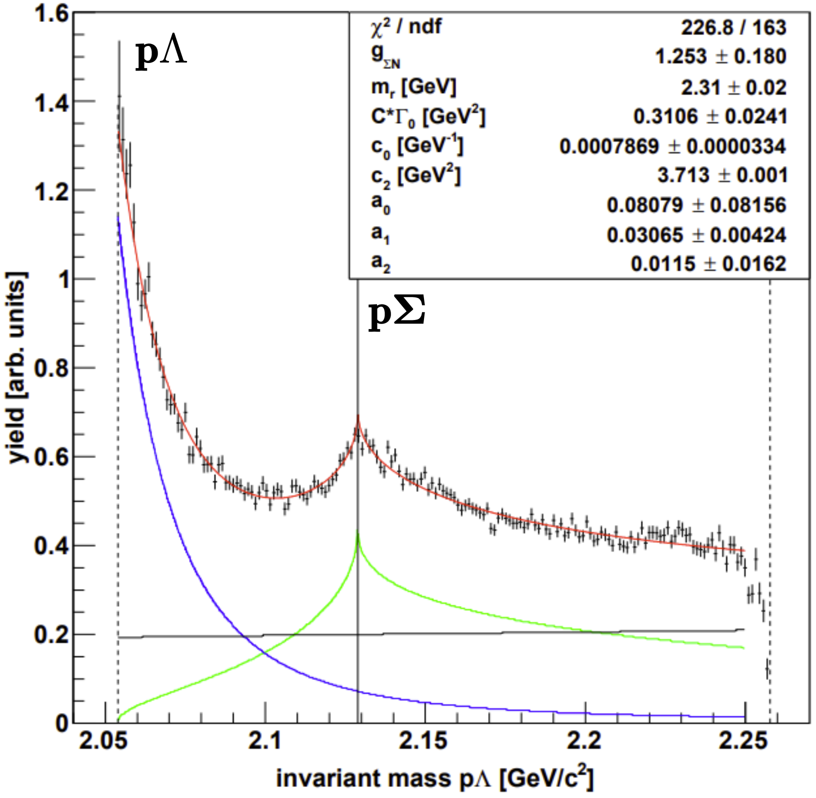


$$\varepsilon = \sqrt{s} - M_\Lambda - M_K - M_p$$

$$\sigma_{pp\to\Lambda pK^+}(\varepsilon) = \begin{cases} \dfrac{A_\Lambda\left(2\varepsilon\sqrt{s}-\varepsilon^2\right)^2}{4m_p^2 + B_\Lambda\left(2\varepsilon\sqrt{s}-\varepsilon^2\right)^2} & 0.435\ \text{GeV} < \varepsilon < 2.0\ \text{GeV}, \\ \dfrac{C_\Lambda \varepsilon^2}{\left[1+\sqrt{1+\varepsilon/D_\Lambda}\right]^2} & 0 < \varepsilon \leq 0.435\ \text{GeV}, \end{cases}$$

E. Ya Paryev, M. Hartmann, Yu T. Kiselev, Chin. Phys. C 41, 124108 (2017).

$p(2.95\ \text{GeV}) + p \rightarrow pK\Lambda$



$$\frac{d\sigma^{\text{meas}}}{dm_{p\Lambda}} \Big/ \frac{d\sigma^{\text{MC}}}{dm_{p\Lambda}} = \text{FSI}(m_{p\Lambda}) + \text{TH}(m_{p\Lambda}) + \text{RF}(m_{p\Lambda})$$

hyperon-nucleon (pΛ) interaction | **coupled channel effect of NΛ↔NΣ** | **reflections of the N* resonances**

COSY-TOF Collaboration, Eur. Phys. J. A 52 1, 7 (2016).

pp → Λ + X: comparison to world data