Considerations on more physics opportunities at KLF

Kenta Itahashi, The University of Osaka

Considerations on more physics opportunities at KLF

- ΛN scattering measurement
- Kaonic nuclei search

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ΛN scattering measurement

for study of two-body spin dependent YN interaction

Baryon-baryon interaction is important to test $SU(3)_f$ symmetry of octet baryons (N, Λ, Σ, Ξ) and to construct Y-nucleus inteaction

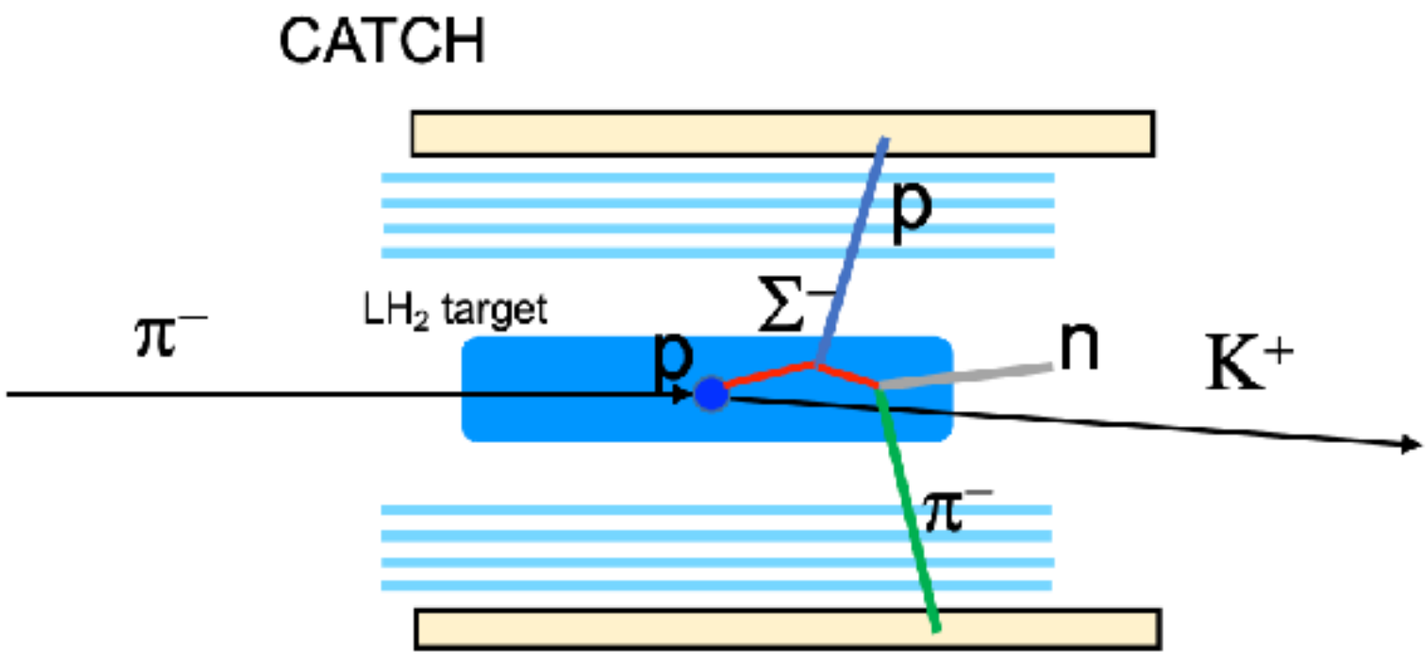
- The short-range regions of YN interaction is particularly interesting, where the roles of quark-quark interactions become visible
- Realistic 2-body YN interaction based on scattering data is important to understand the EOS of the neutron stars
- YN interaction still has large uncertainties including ΛN-ΣN conversion
- Spin dependent interaction (spin-spin, spin-orbital, tensor) can be studied using polarized H/D targets at KLF in the future

There are several experiments in J-PARC to study ΣN scattering…

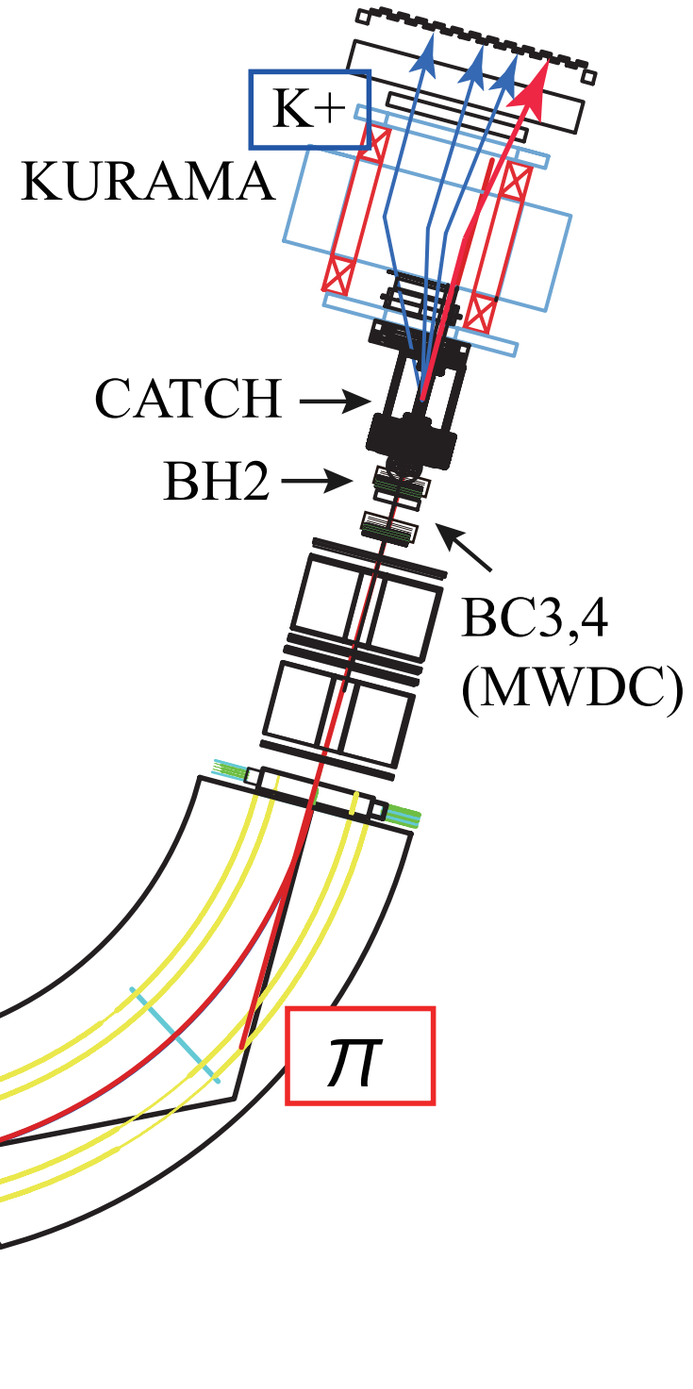
J-PARC E40 measured Σp scattering cross section

H(π⁻, K)Σ

Σ rescattering with H



J-PARC K1.8 beamline



1.4 GeV/c π+ beam

1.32 GeV/c π- beam

19 M π beam /spill(=5.2s)

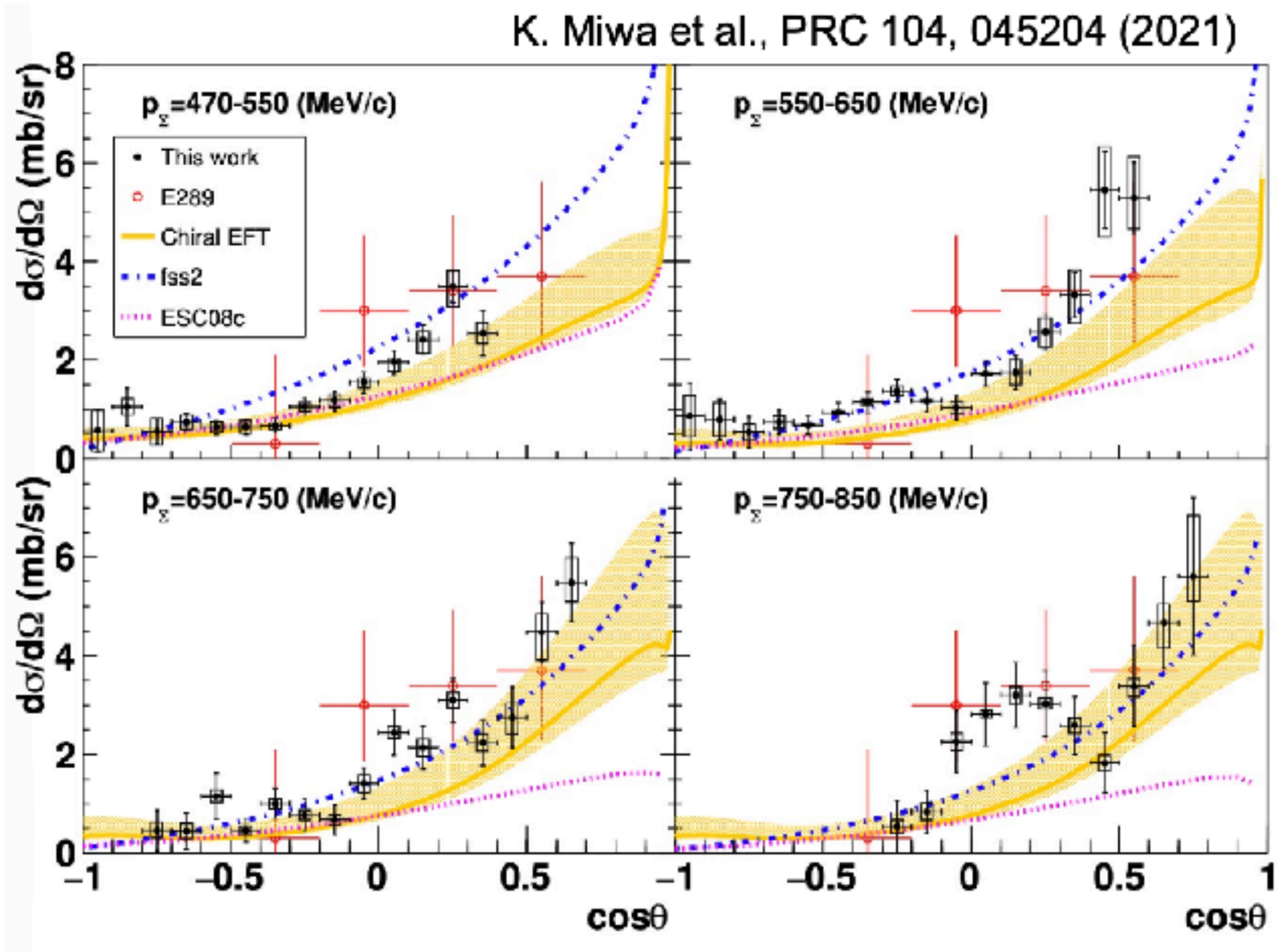
EMMI Miwa's talk

J-PARC E40 measured Σp scattering cross section

$H(\pi^-, K^+)\Sigma^-$

Produced Σ rescattering with H

Σ^-p



・fss2, Chiral EFT : reasonable angular dependence.

・ Nijmegen ESC models underestimate for the forward angle.

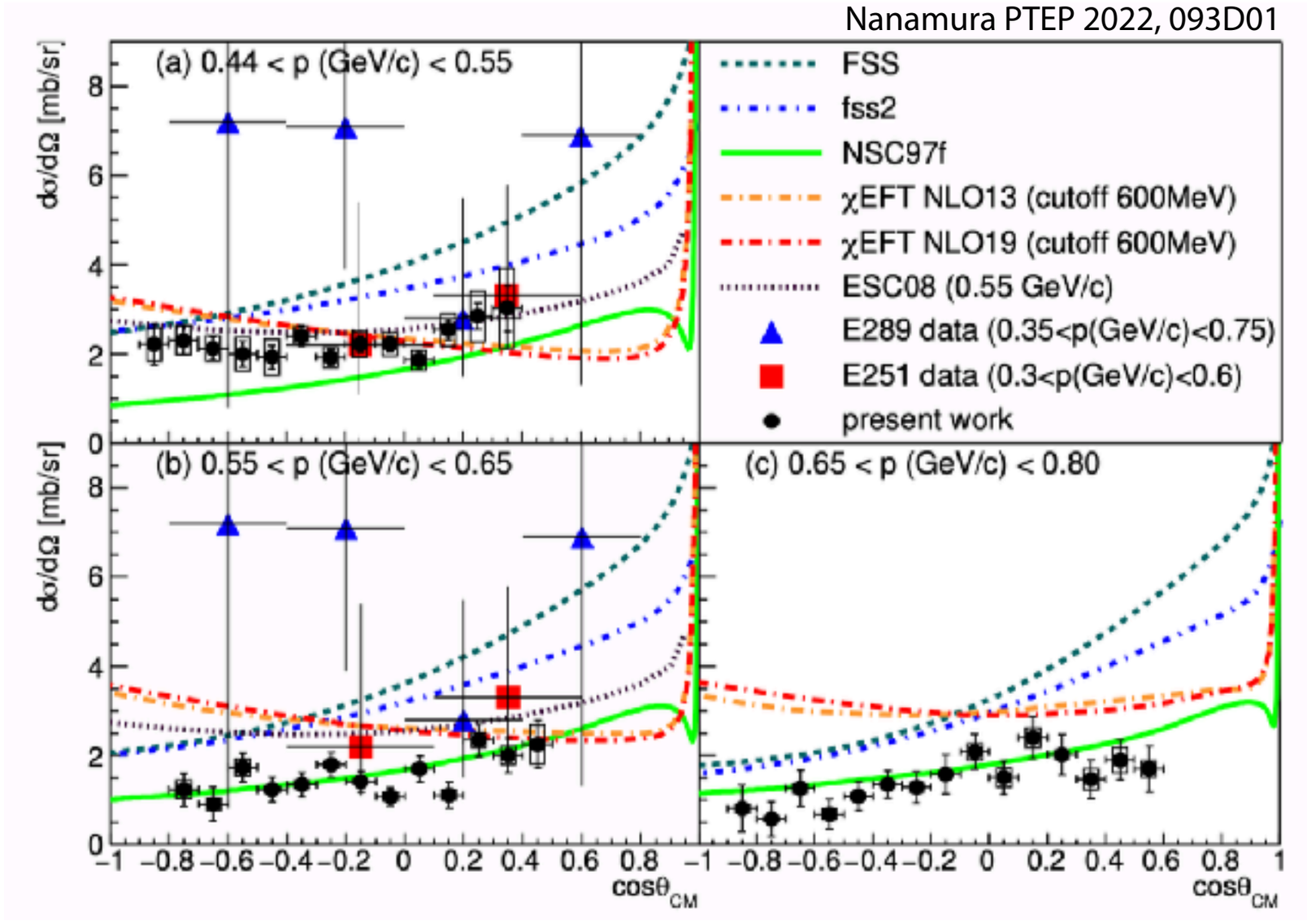
J-PARC E40 measured Σp scattering cross section

$H(\pi^-, K^-)\Sigma^+$

Produced Σ rescattering with H

Σ^+p

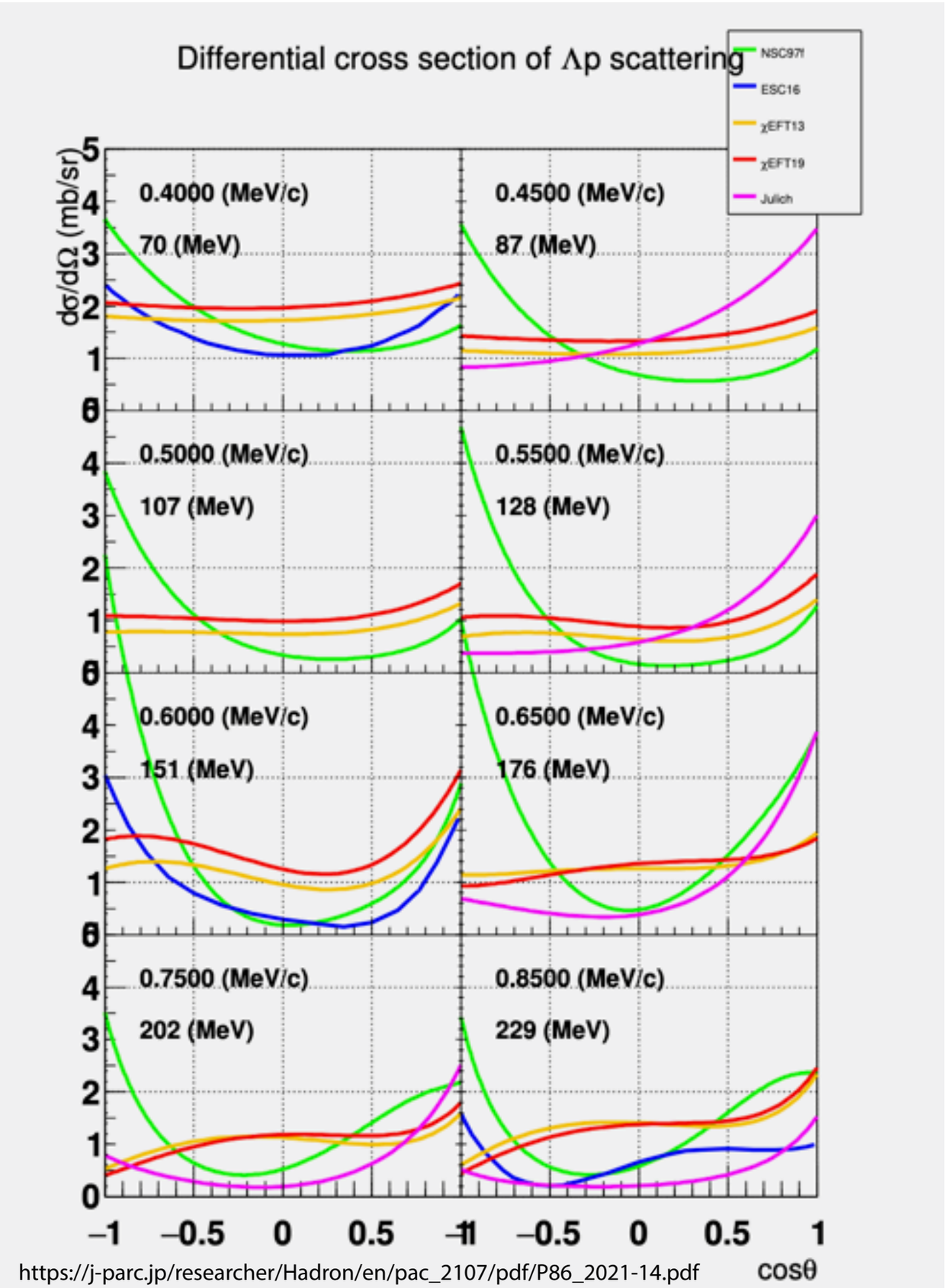
Nanamura PTEP 2022, 093D01



- fss2, FSS (quark model) are too large compared to data
- Chiral EFT's momentum dependence does not match with data
- Nijmegen (ESC) models are rather consistent.

Nanamura HIN25

Λp scattering differential cross section



https://j-parc.jp/researcher/Hadron/en/pac_2107/pdf/P86_2021-14.pdf

Cross section has still large uncertainty.
Theories predict different angular dep.

10% stat. error is a good goal.

Since interaction is spin-dependent, scattering measurement with polarized beam/target is important in later stages.

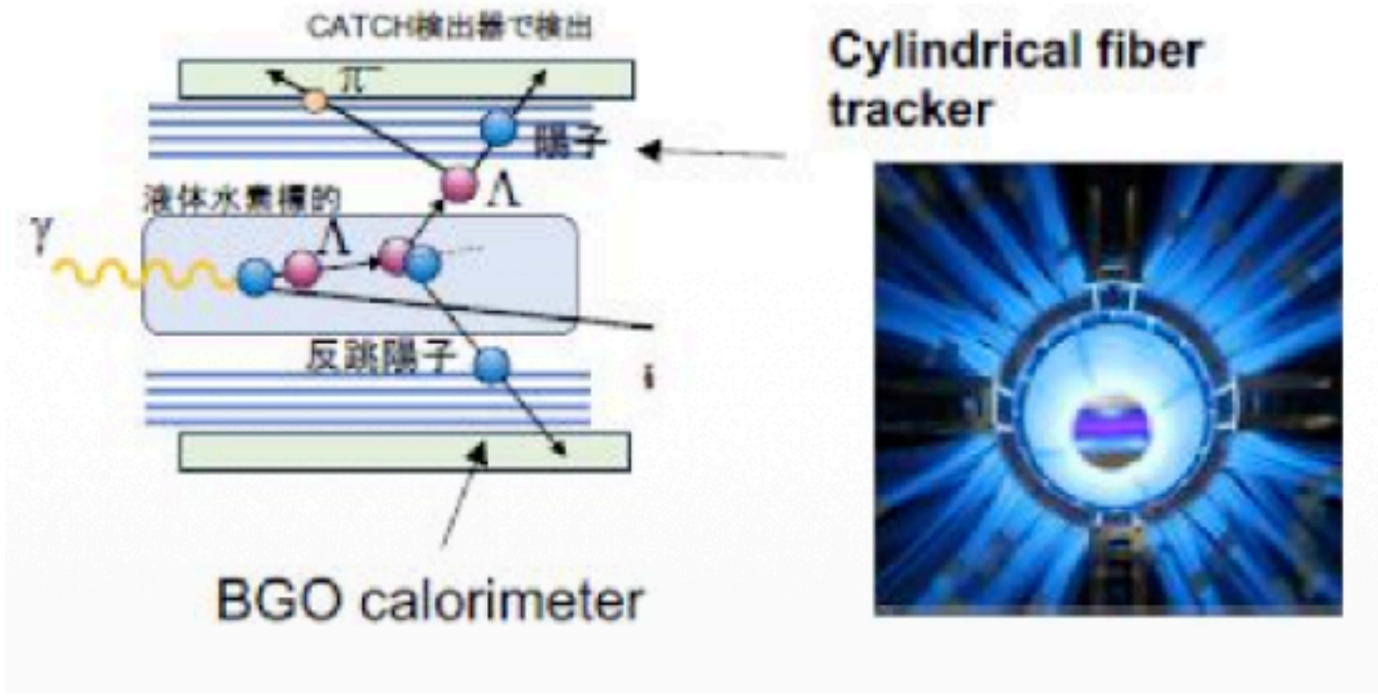
An experiment ongoing in SPring-8 to study ΛN scattering…

SPring-8 LEPS for Λp scattering measurement

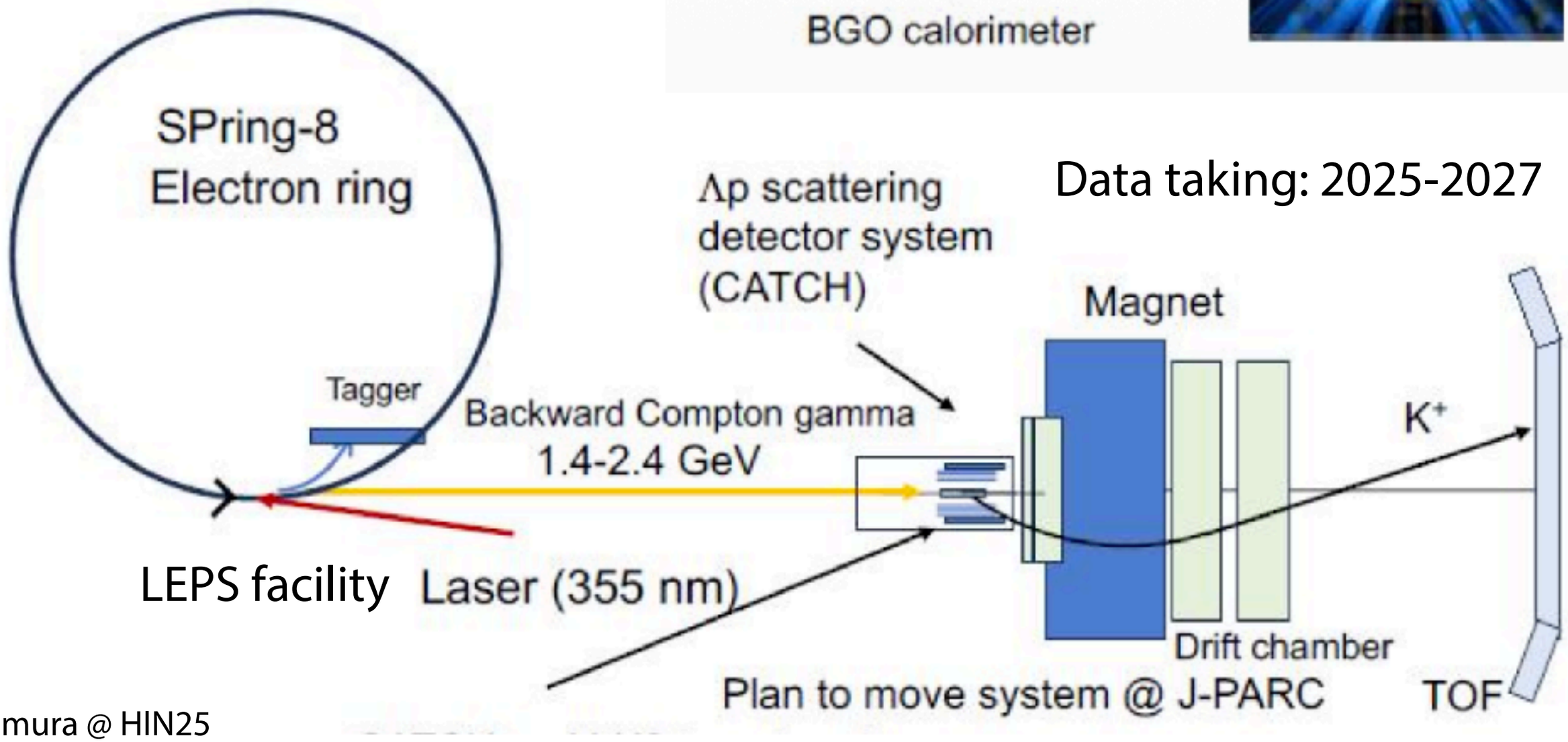
H(γ,K⁺)Λ
and Λ rescattering with H

10^7 tagged incident Λ / 2.5 yr

Λ 0.3-0.6 GeV/*c*



Data taking: 2025-2027



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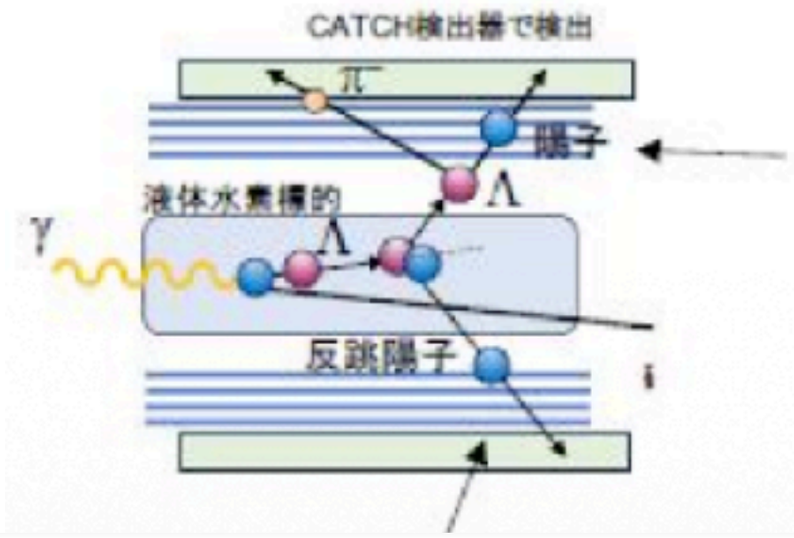
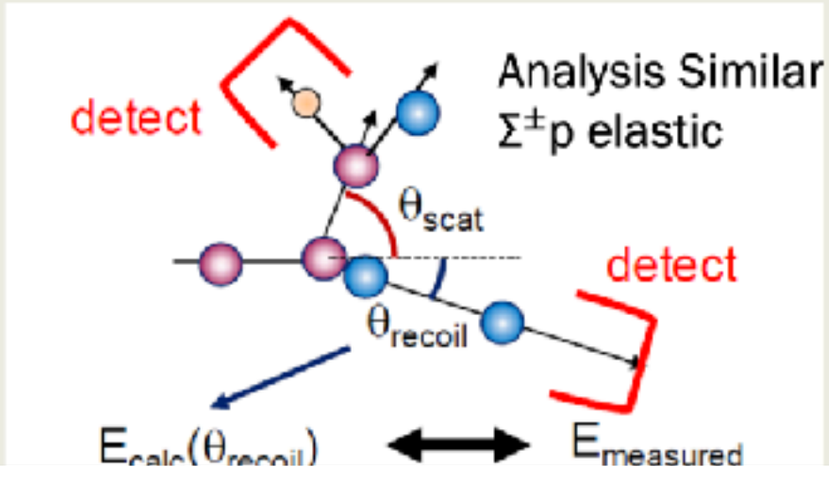
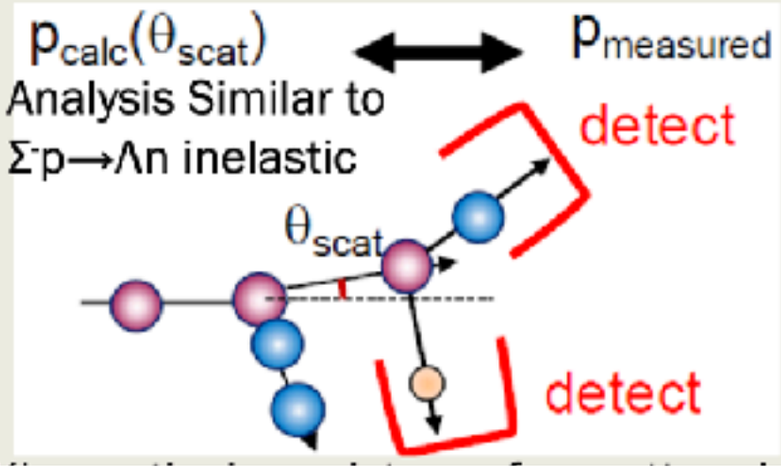


Cylindrical fiber tracker

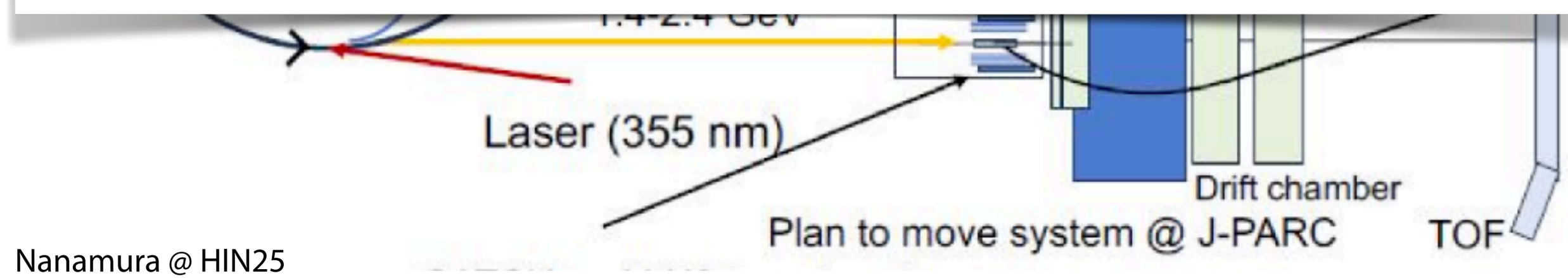
- Detection of at least 1 proton and 1 pion from the Λp→ppπ⁻ final states is required
  - *Kinematical consistency check for recoil proton or scattered Λ is possible*





Measured

Λ momentum
proton momentum
$\pi^{\pm}$ direction

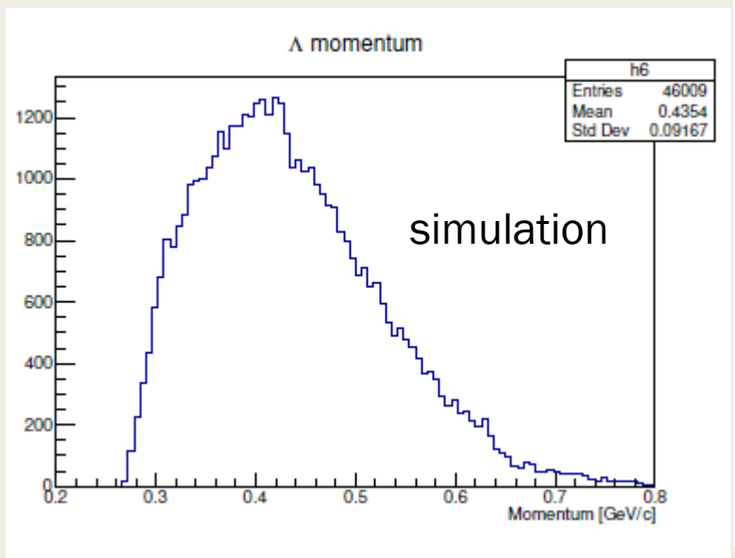


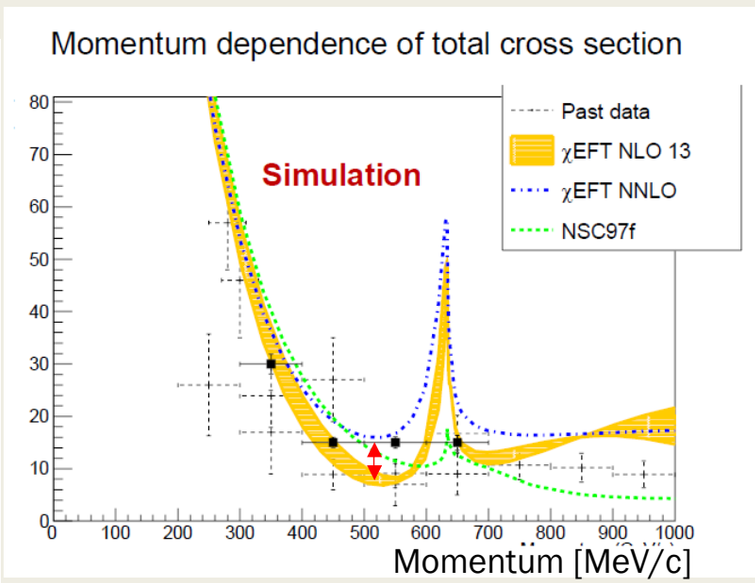
SPring-8 LEPS for Λp scattering measurement

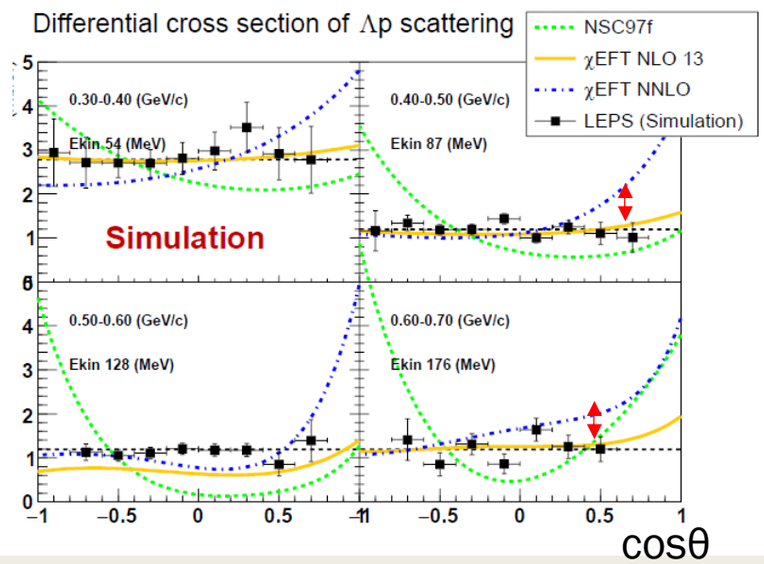
H(γ,K⁺)Λ
and Λ rescattering with H

Λp scattering Experiment @ SPring-8

- Λ momentum range
  - *0.3-0.6 GeV/c*
    - Corresponding to (nucleon) fermi momentum in nuclei and neutron star
    - Constraints on theoretical models
      - *Both total cross section and angular dependence are important.*

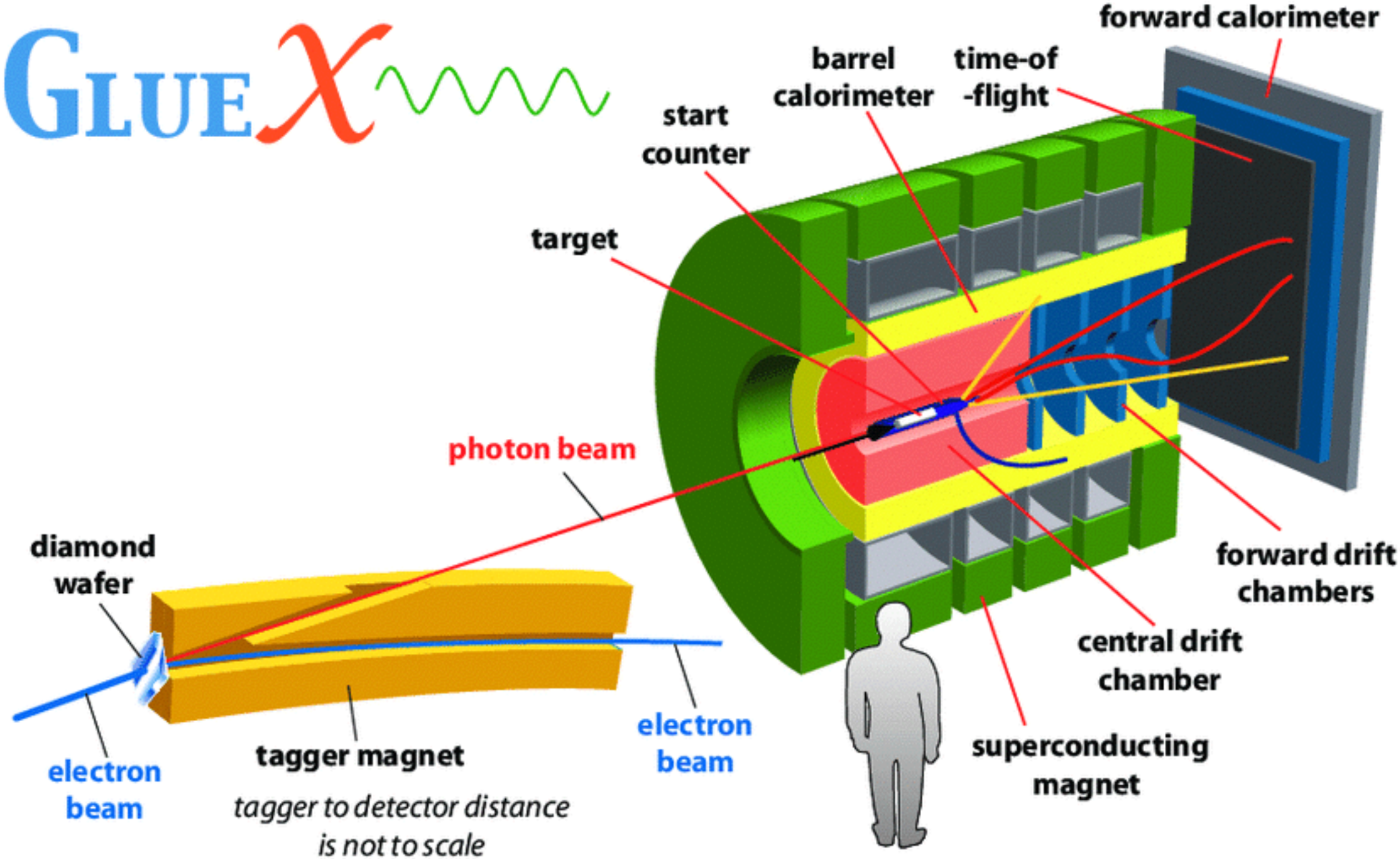






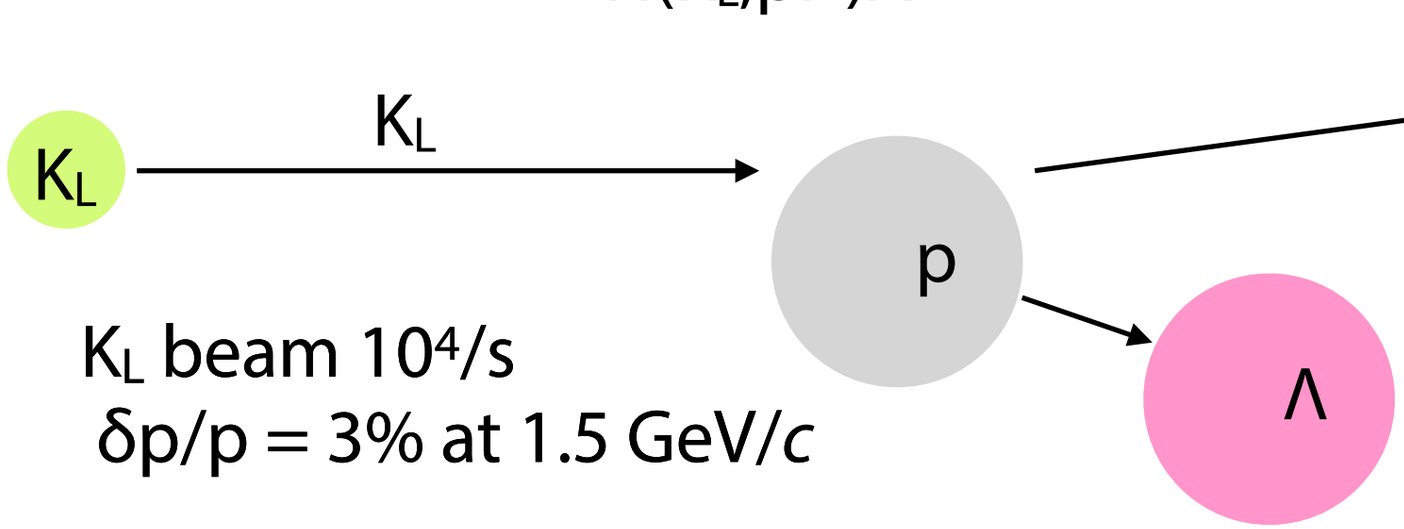
KLF for Λp scattering measurement

H(K_L,pi^+)Λ and Λ rescattering with H



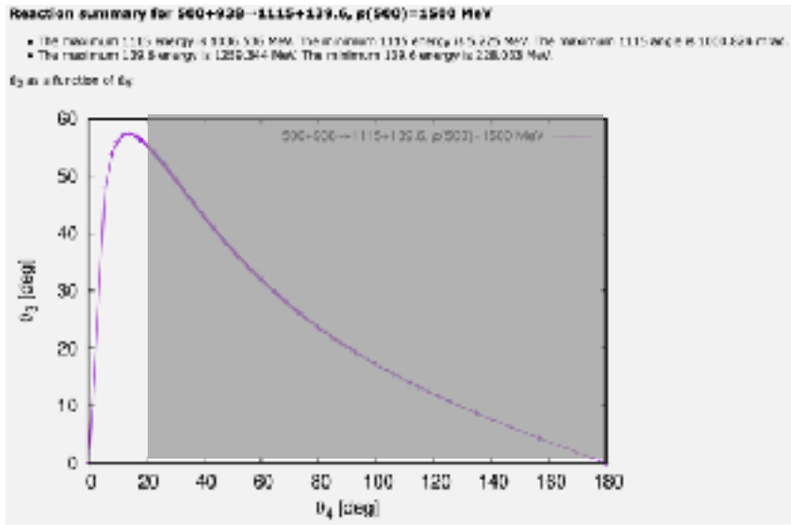
Experimental Concepts

$H(K_L,pi^+)\Lambda$



Missing mass of Λ

p_Λ measurement



K_L beam 10^4/s

$\delta p/p = 3\%$ at 1.5 GeV/*c*

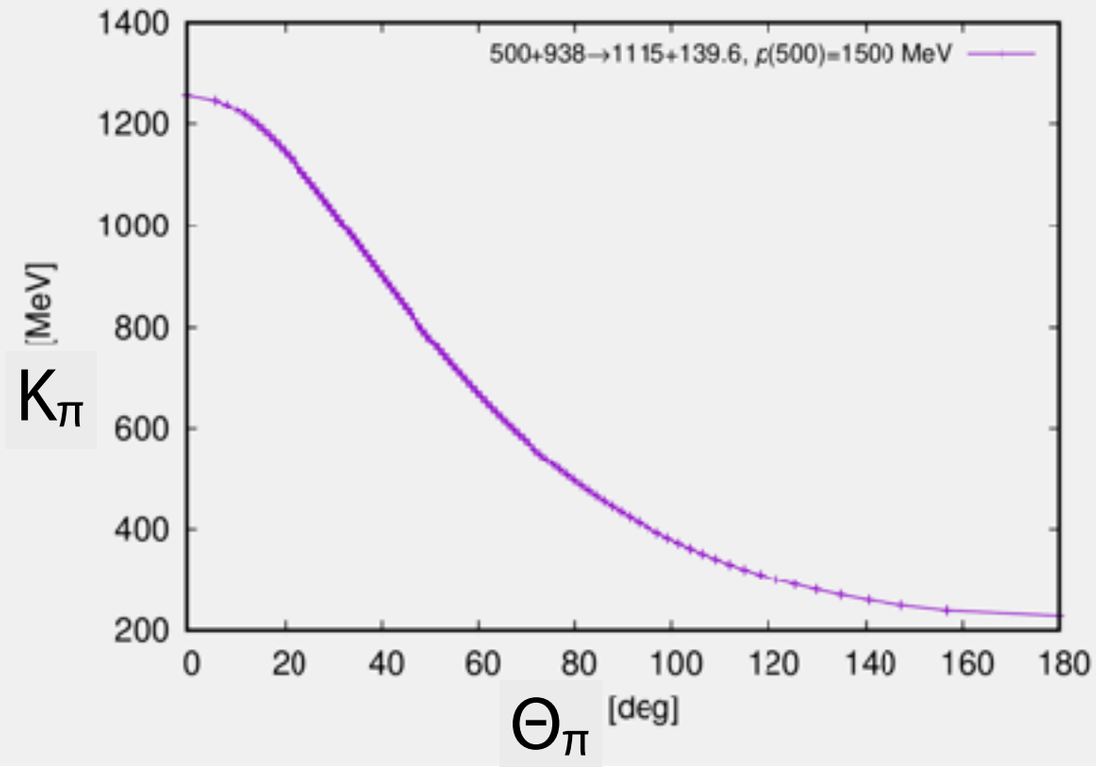
$K_\Lambda < 150$ MeV

$\Theta_\Lambda < 55$ deg.

Reaction summary for 500+938→1115+139.6, *p*(500)=1500 MeV

- The maximum 1115 energy is 1036.536 MeV. The minimum 1115 energy is 5.225 MeV. The maximum 1115 a
- The maximum 139.6 energy is 1259.344 MeV. The minimum 139.6 energy is 228.033 MeV.

KE_4 as a functior of θ_4:



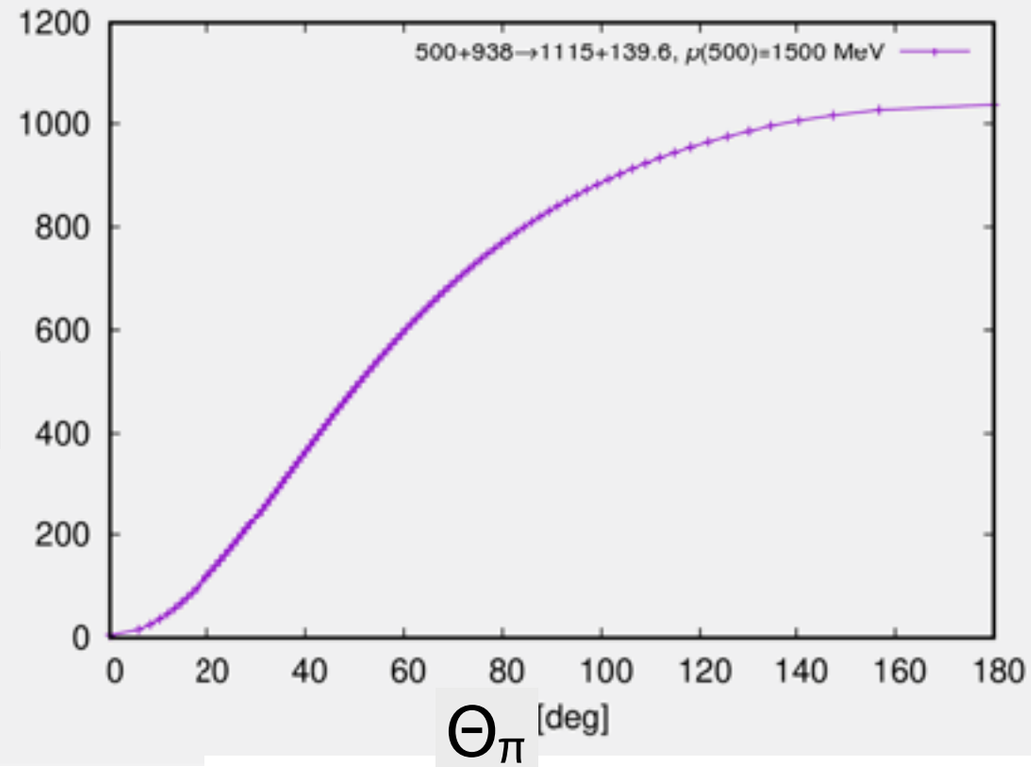
K_π

Θ_π

Reaction summary for 500+938→1115+139.6, *p*(500)=1500 MeV

- The maximum 1115 energy is 1036.536 MeV. The minimum 1115 energy is 5.225 MeV. The maximum 1115 angle is 1000.824 mrad.
- The maximum 139.6 energy is 1259.344 MeV. The minimum 139.6 energy is 228.033 MeV.

KE_3 as a function of θ_4:

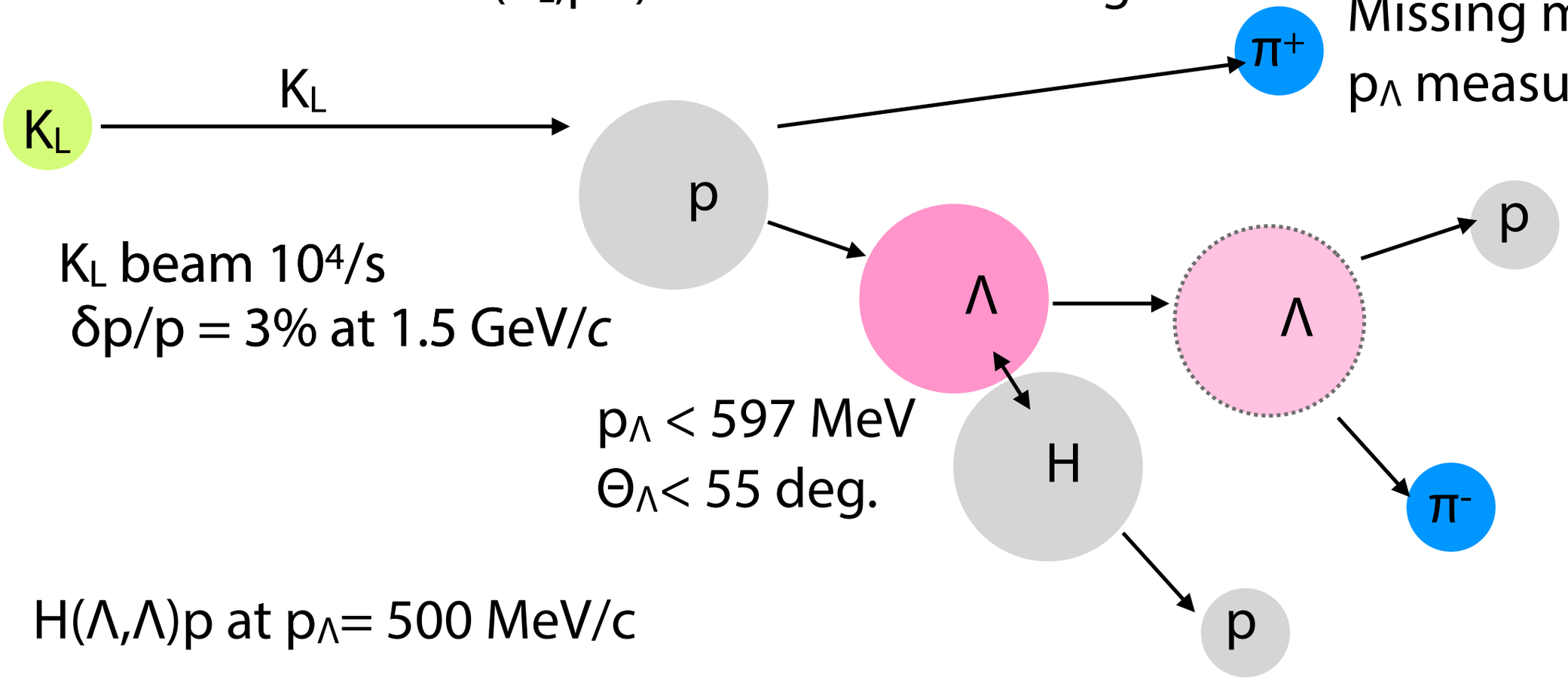


K_Λ

Θ_π

Experimental Concepts

H(K_L,pi$^+$)Λ and Λ rescattering with H



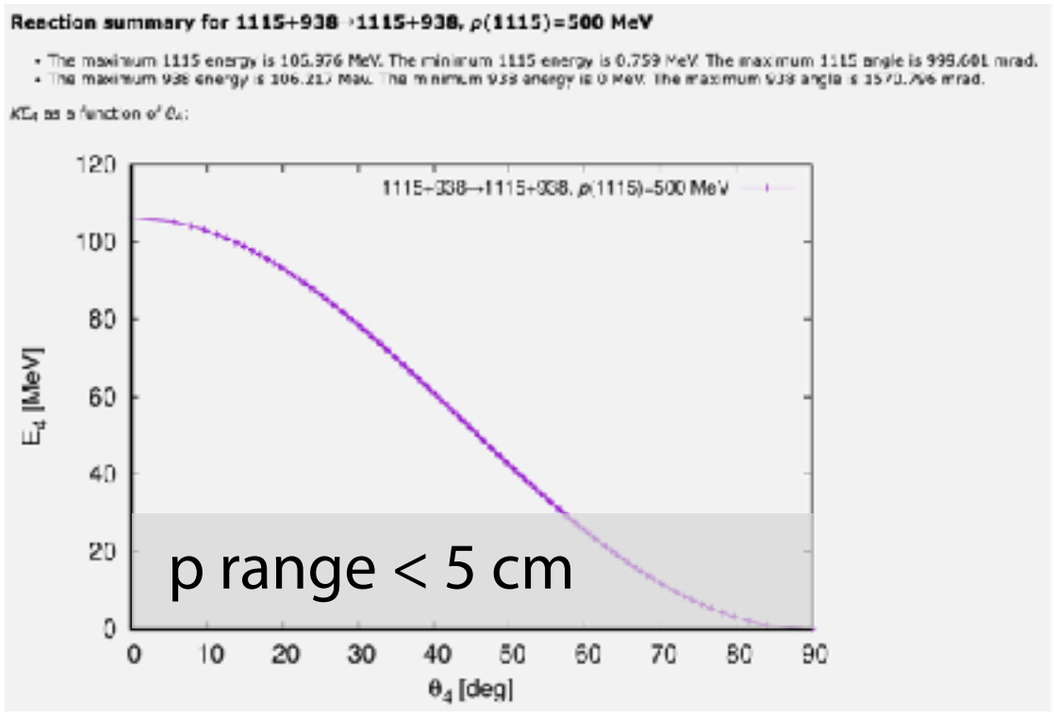
K_L beam 10^4/s

δp/p = 3% at 1.5 GeV/*c*

p_Λ < 597 MeV

Θ_Λ< 55 deg.

H(Λ,Λ)p at p_Λ= 500 MeV/c



Assume 10 kilo Λ in p_Λ= [450,550] MeV/c,

dΩ = 0.032 sr

target 15 cm LH_2, and 1 mb/sr cross sec.

→ ~100 counts/bin with ~20 bins

Kinematically complete measurement

(Missing one particle is accepted)

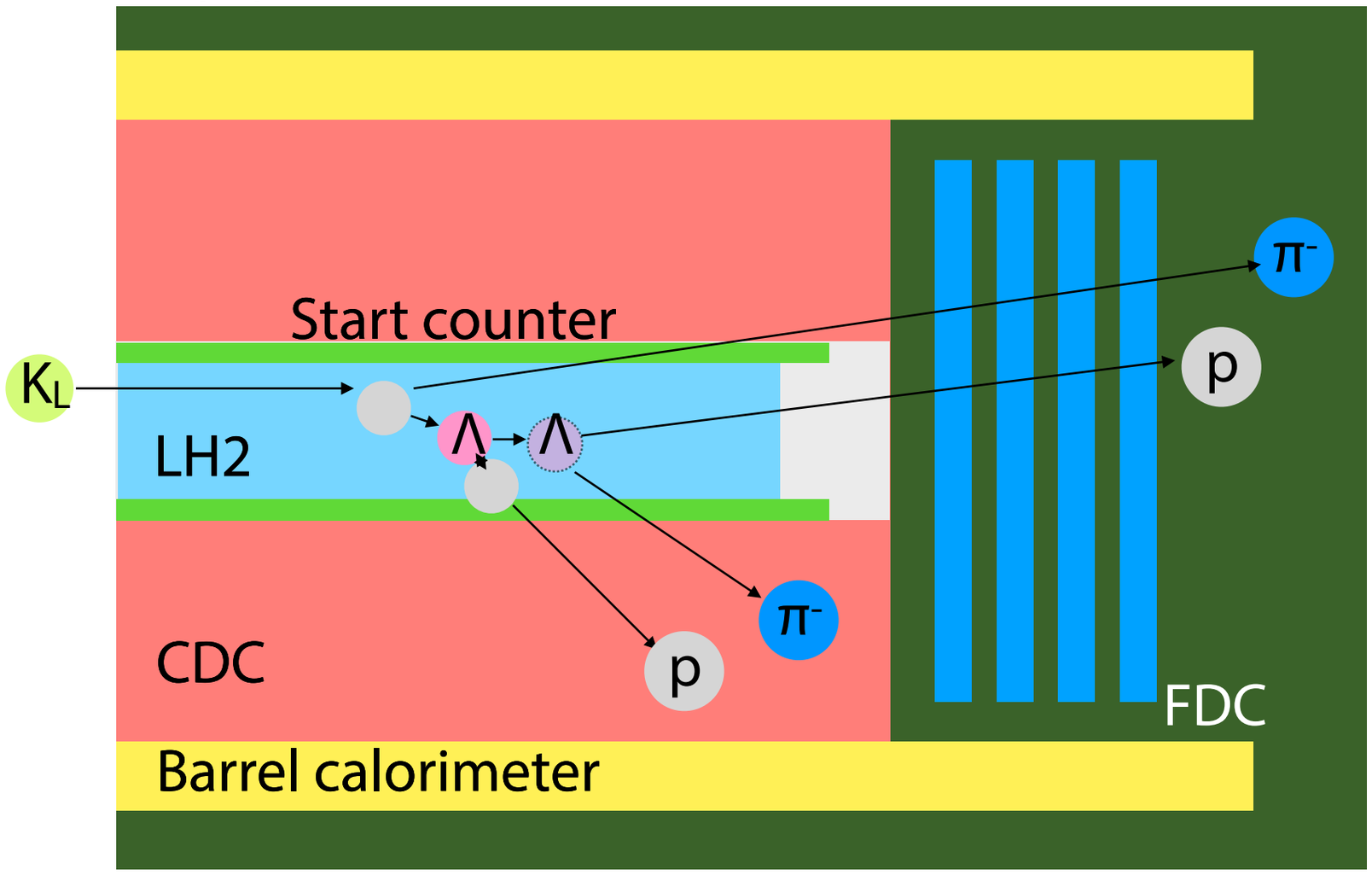
Experimental Concepts

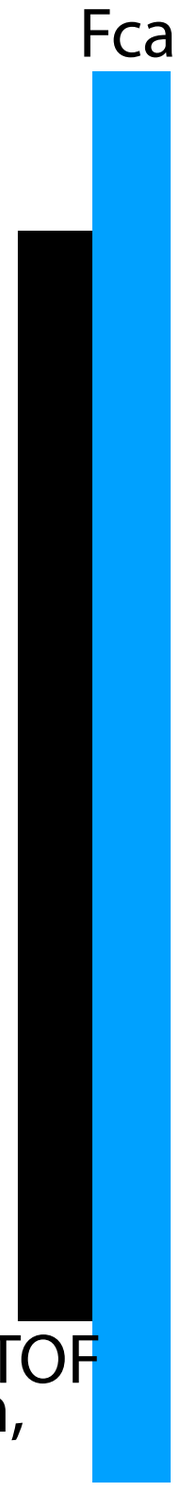
$H(K_L,pi^+)\Lambda$

$H(\Lambda,\Lambda)p$

K_L beam 10^4/s

$\delta p/p$ = 3% at 1.5 GeV/*c*



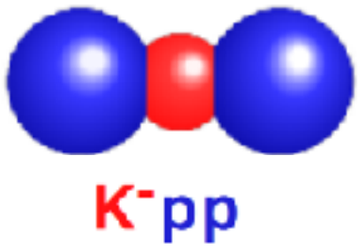


M.C. wanted for PID, energy resolution, angular resolution, acceptance including range, and background estimate

Start counter performance is a key and R&D ongoing in Osaka + RIKEN

Polarized H in future

- ΛN scattering measurement
- Kaonic nuclei search



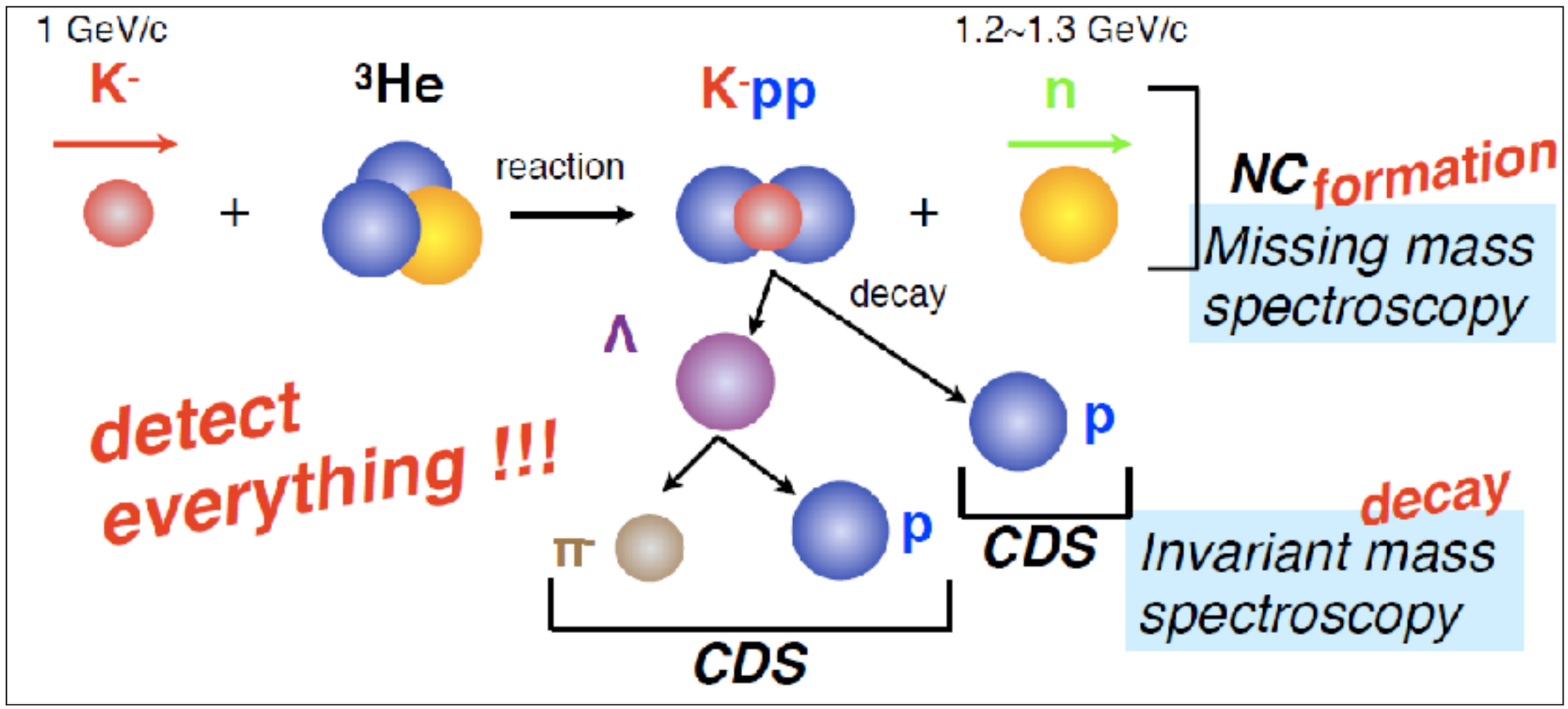
"K-pp" Spectroscopy @ J-PARC E15

- **Kaonic nuclei = anti-kaon – nucleus bound states**

  Possible high-ρ objects close to neutron stars

  Predicted from attractive $\bar{K}N$ interaction in I=0 channel and recently discovered in J-PARC E15

^{3}He(K-,n)K-pp, K-pp → Λp

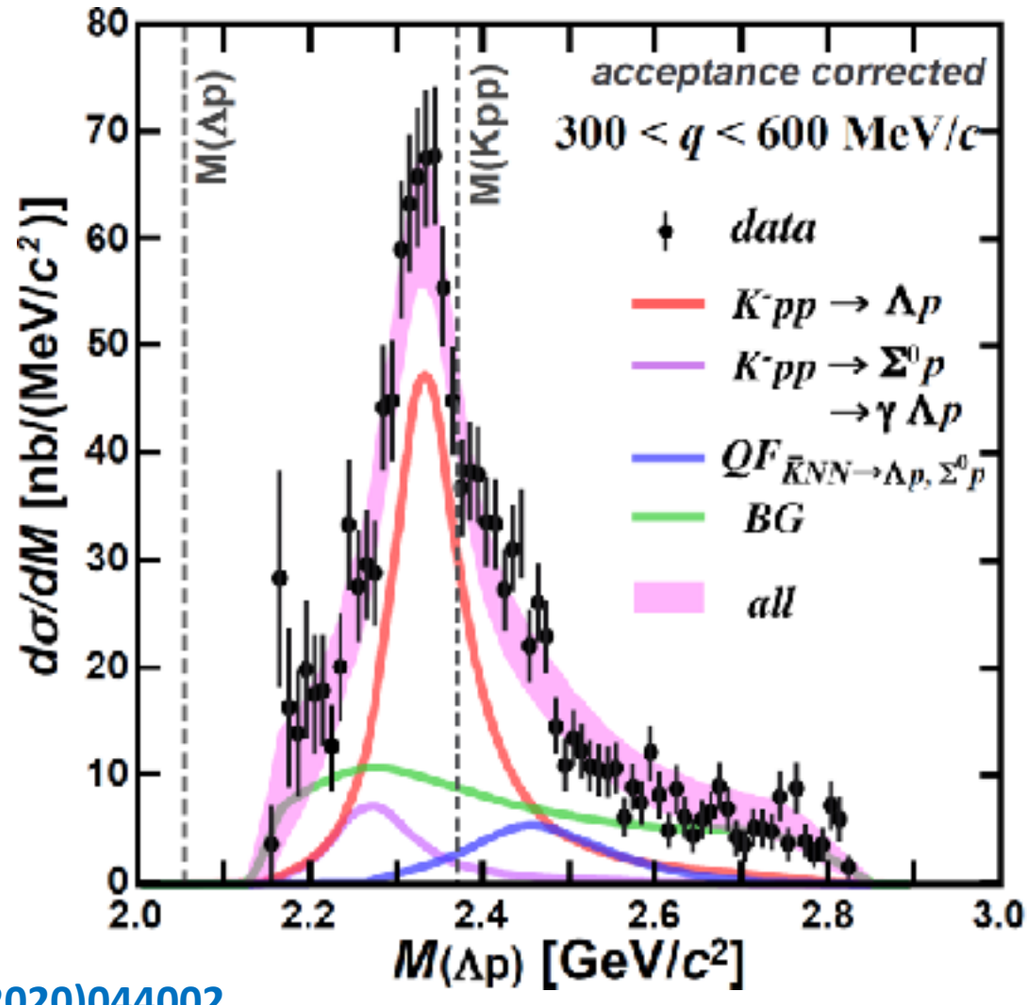


I=0 K-p attractive interaction contributes largely to form K-pp

“K⁻pp” Spectroscopy @ J-PARC E15

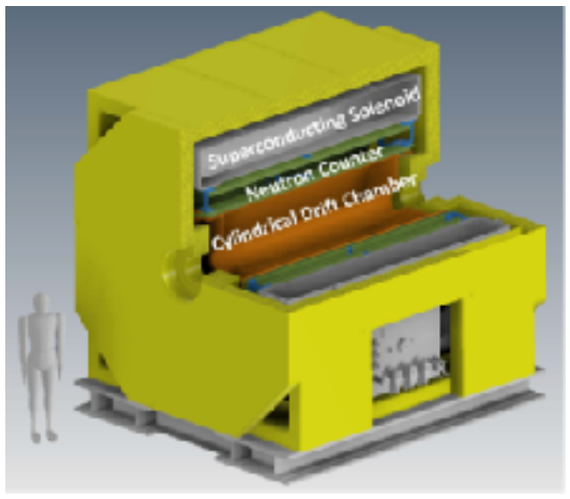
- **Kaonic nuclei = anti-kaon – nucleus bound states**

✓ Predicted from attractive $\bar{K}N$ interaction in I=0 channel



PRC102(2020)044002.

B_{Kpp} ~ 40 MeV, Γ_{Kpp}~ 100 MeV



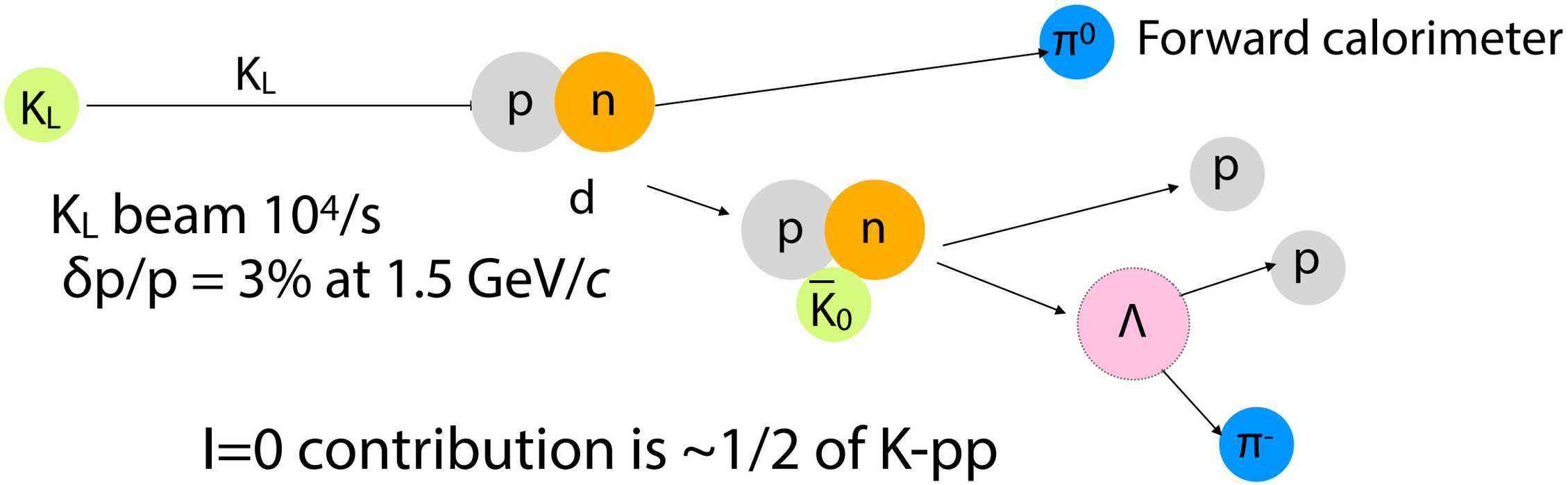
New system in construction
for spin parity determination + …

I=0 K⁻p attractive interaction contributes largely to form K-pp

KNN at KLF

— Kaonic nuclei —

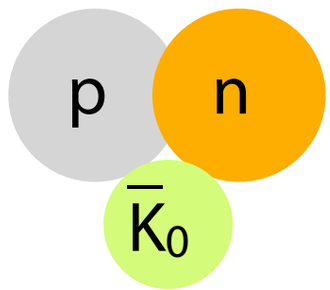
$D(K_L,pi^0)\bar{K}_0pn$



K_L beam 10^4/s

$\delta p/p = 3\%$ at 1.5 GeV/*c*

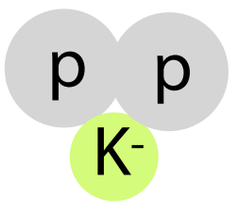
I=0 contribution is ~1/2 of K-pp



weak binding?

J-PARC E15

$^3He(K^-,n)K^-pp$



We need feasibility study
incl. background, Xsec, Resol….

How about this?

$D(K_L,pi^+pi^-)\bar{K}pn$

Ishikawa…

Summary

- ΛN scattering measurement is important for setting constraints in the YN 2-body interaction
- Theories predict different scattering angle dependence of cross section
- KLF provides opportunity for high quality scattering data
- Further opportunity of studying spin-dependent interaction is important using polarized targets
- Using D(K_L,π^0)(K^0bar pn) reaction, we have a chance to search for KbarNN bound states. Though binding energy seems to be smaller than K-pp (in J-PARC E15), it may worth studying the feasibility
- SC performance is a key to set constraints on the initial beam energy and kinematical conditions