B01 REPORT
(ANALYSIS STATUS OF ΣP SCATTERING EXPERIMENT)

Koji Miwa (Tohoku Univ.)

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- Σp scattering experiment at J-PARC
  - *Physics motivation*
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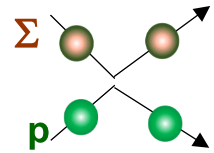
- Summary

Goals of B01: Hierarchy of matter investigated via strange hadron clusters

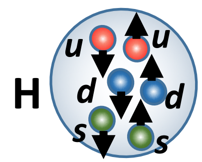
Answer the following questions at J-PARC using strange quarks

(a) Can we understand the nuclear force (B-B forces) from the quark hierarchy?

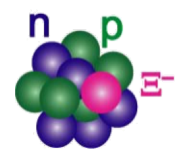
- $\Sigma^{\pm}$-p scattering experiment (E40)

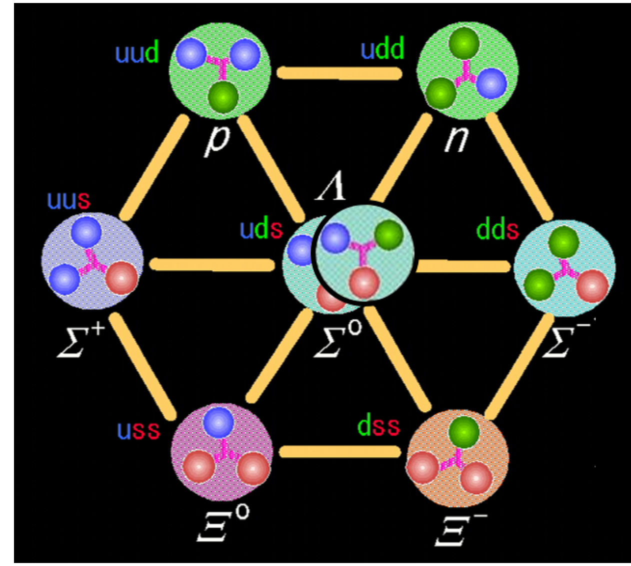


- H-dibaryon search (E42)



- Ξ-hypernuclei via $^{12}C(K^-,K^+)$ (E70)



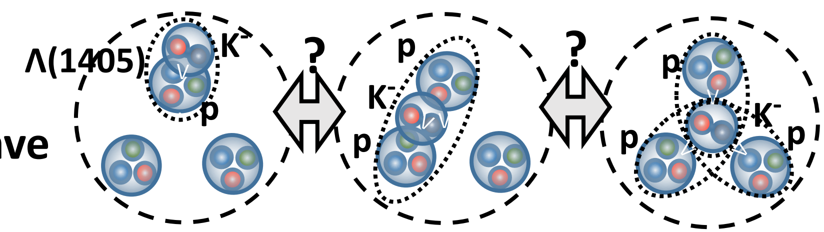


(b) Why are the nucleon hierarchy / the nuclear hierarchy well separated?

- "K^-pp" and "K^-ppp" to explore the meson-baryon sub-hierarchy

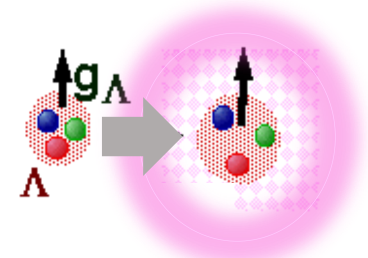
Structure of "K^-ppp"

How does K^- behave in a nucleus?

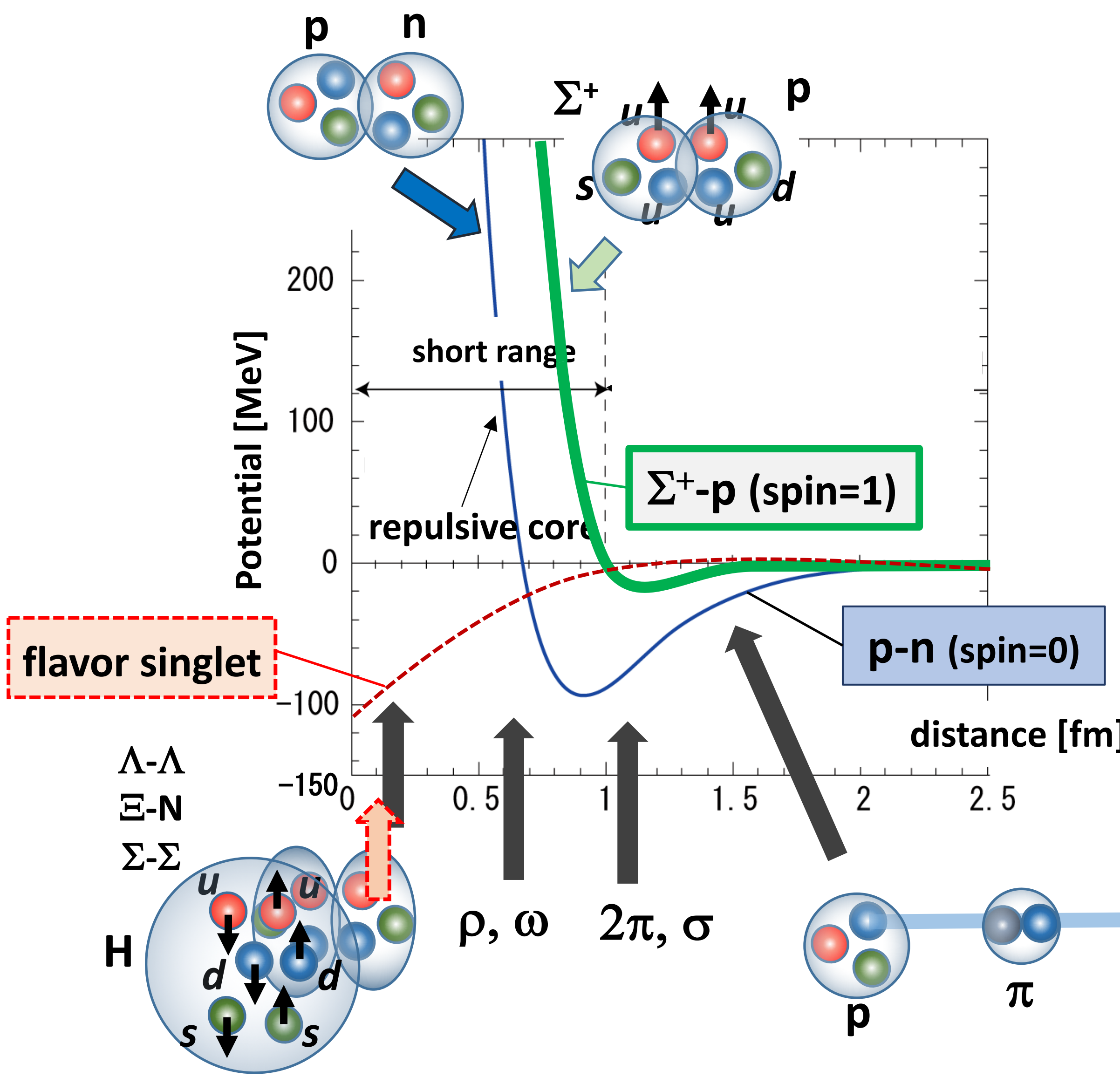


- Measure the Λ's magnetic moment in a nucleus (E63)

Does baryons change their structure in a nucleus?



Baryon-Baryon interactions with strangeness

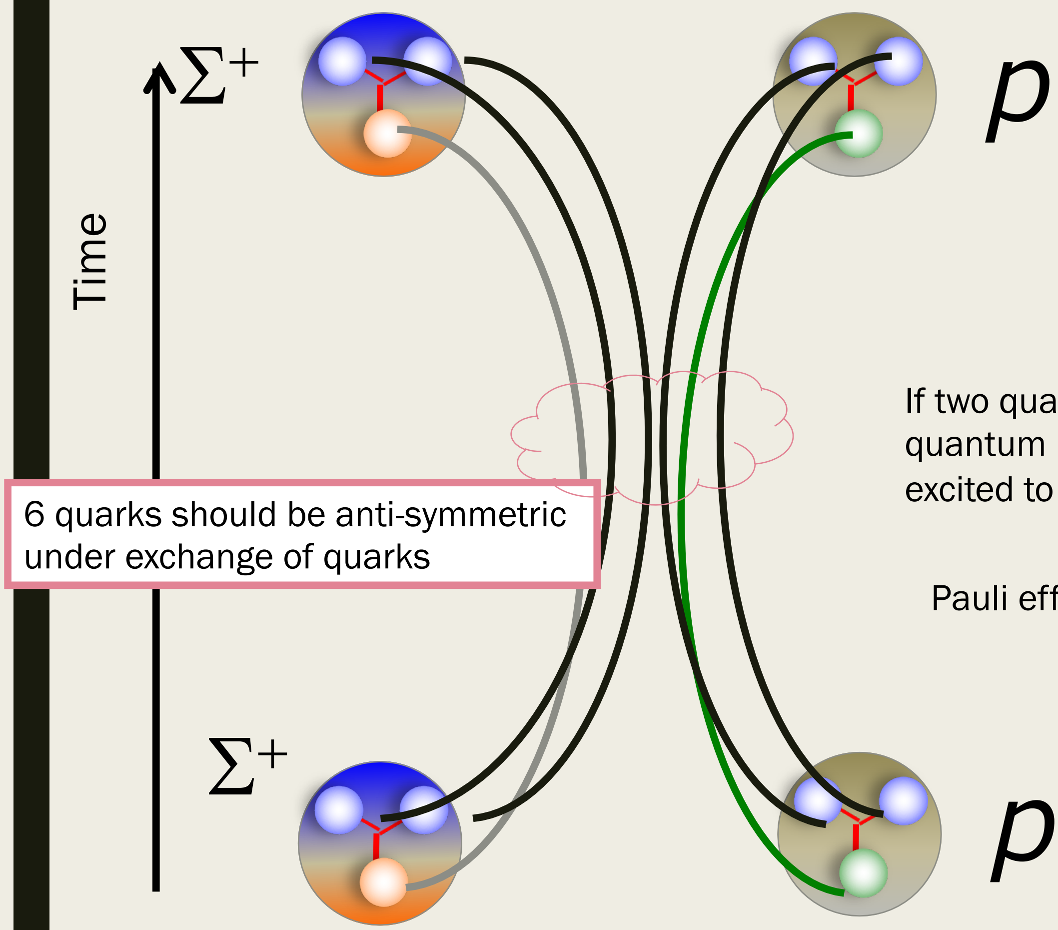


ANALYSIS STATUS OF ΣP SCATTERING EXPERIMENT

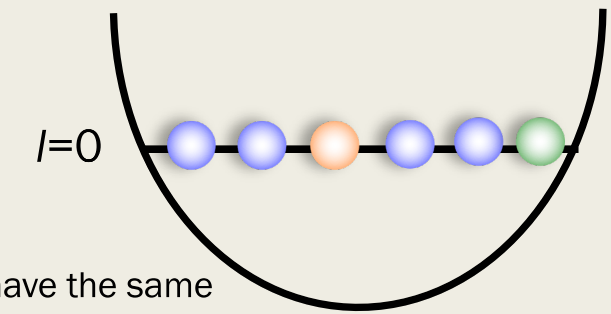
Koji Miwa (Tohoku Univ.)
for the J-PARC E40 collaboration

Quark-cluster picture in Baryon-Baryon interaction

Degree of freedom in quark
Flavor(3)•Spin(2)•Color(3)



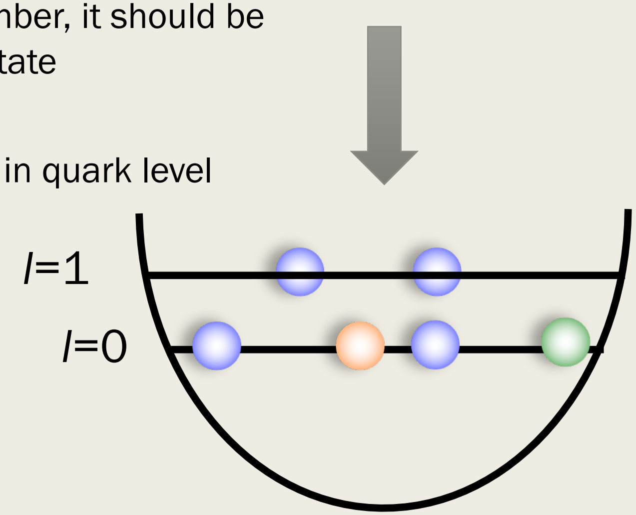
6 quarks can stay in s state in normal case



If two quarks have the same quantum number, it should be excited to p state

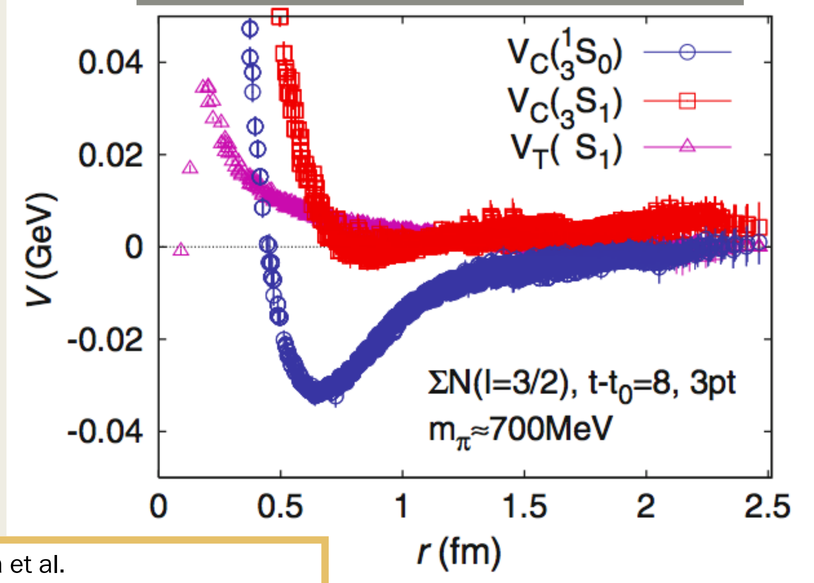
⬇

Pauli effect in quark level



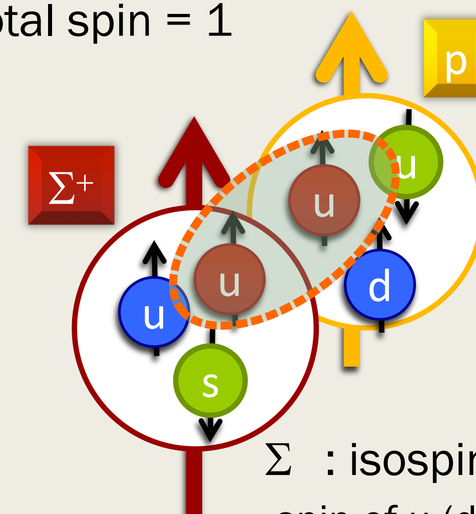
Quark Pauli effect in ΣN channel

Σ^+p potential by Lattice QCD



H. Nemura et al.
Few-Body Syst (2013) 54:1223-1226

Total spin = 1

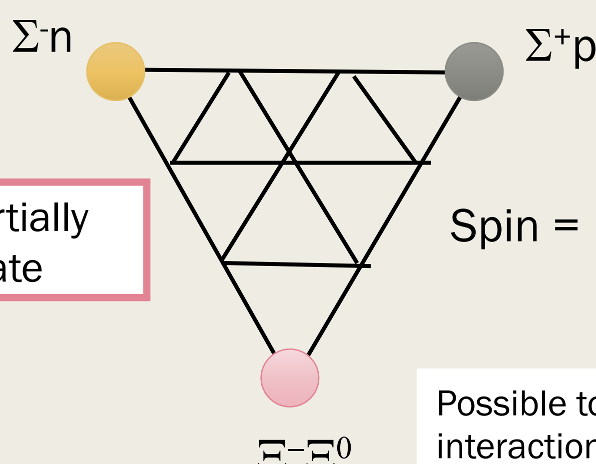


Σ : isospin 1

spin of u (d) quark is same

$$\Sigma^+ : \; uus \cdot \frac{1}{\sqrt{6}}(\uparrow\downarrow\uparrow + \downarrow\uparrow\uparrow - 2\uparrow\uparrow\downarrow)$$

$$p : \; uud \cdot \frac{1}{\sqrt{6}}(\uparrow\downarrow\uparrow + \downarrow\uparrow\uparrow - 2\uparrow\uparrow\downarrow)$$



Spin = 1

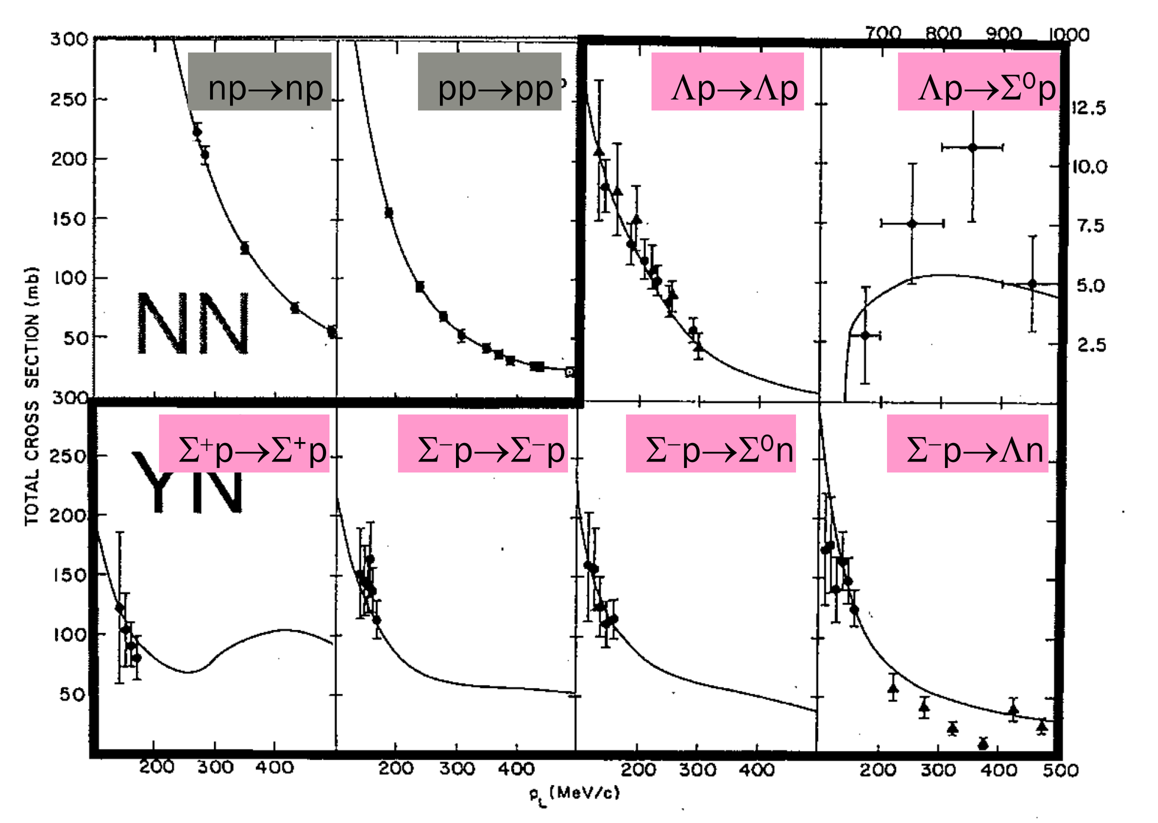
Multiplet (10) : partially Pauli forbidden state

Possible to investigate $\Xi^-\Xi^0$ interaction in heavy ion collision ?

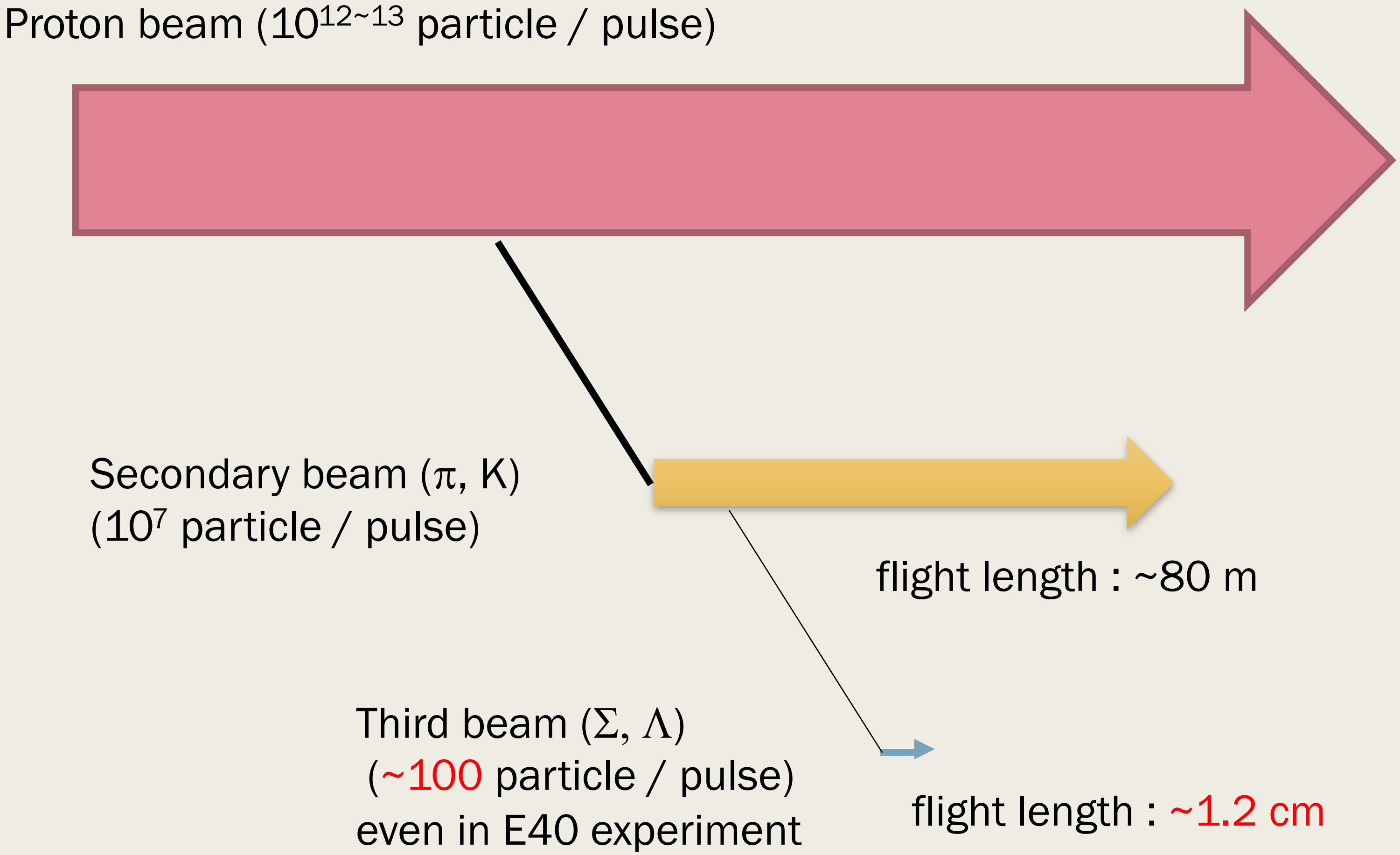
Current status of YN scattering experiment

- NN scattering data : quite accurate
- YN scattering data : very poor statistics

Y. Kondo Doctor thesis



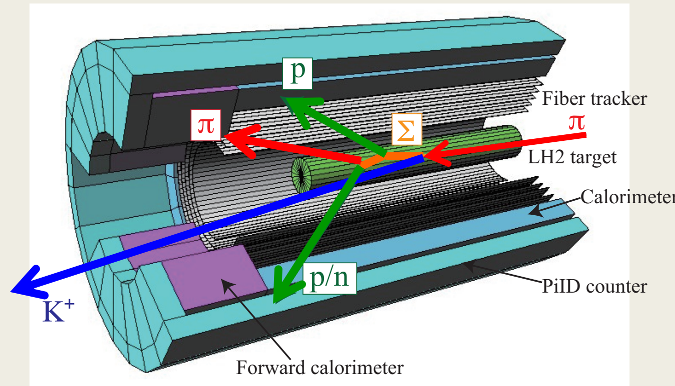
Comparison of Beam



J-PARC E40 : Measurement of $d\sigma/d\Omega$ of Σp scatterings

- Physics motivations
  - *Verification of repulsive force due to quark Pauli effect in the $\Sigma^+ p$ channel*
  - *Systematic study of the ΣN interaction by separating isospin channel*

- Measurement of $d\sigma/d\Omega$
  - *Aim to detect 10,000 events*
  - *$\Sigma^+ p$ elastic scattering*
  - *$\Sigma^- p$ elastic scattering*
  - *$\Sigma^- p \rightarrow \Lambda n$ inelastic scattering*



Kinematical identification of Σp scattering
Using LH_2 target and surrounding detector

Experimental key issues
- Usage of high intensity π beam : 2×10^7 / spill (spill = 2 sec)
- Large acceptance detector for scattered proton

J-PARC E40 Collaborators

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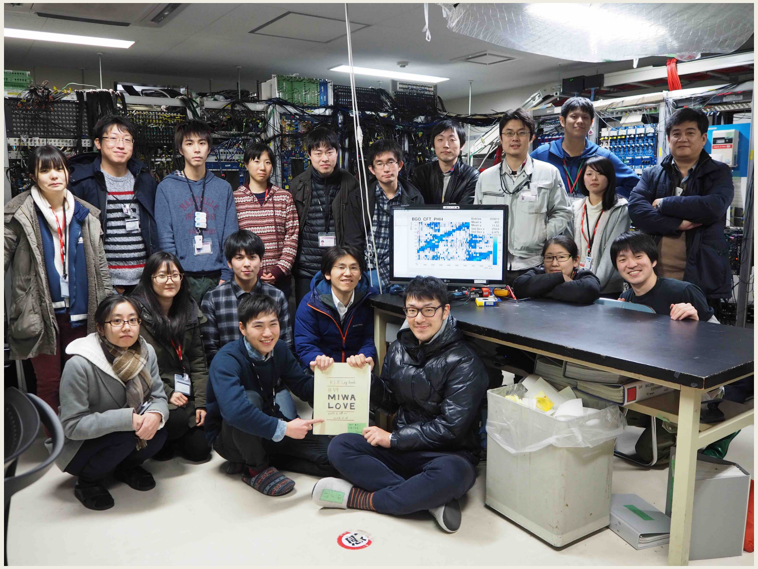

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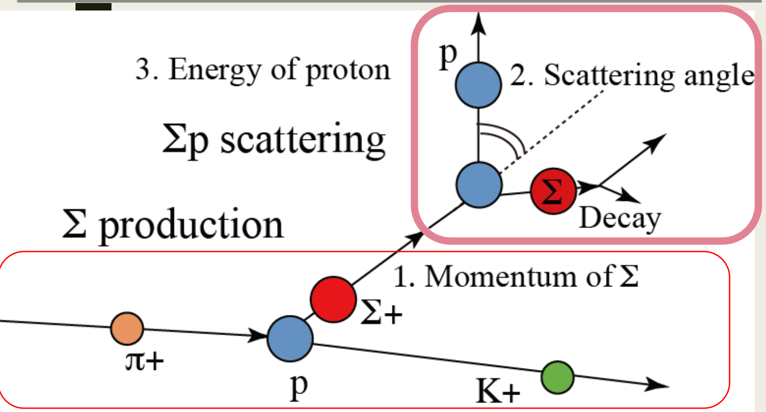
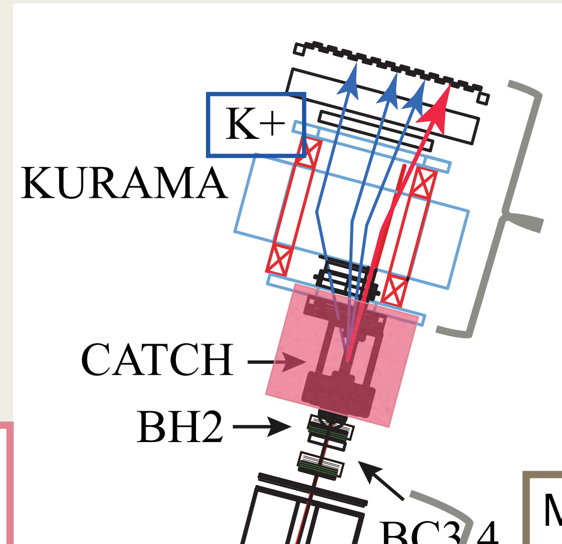
E40 detector setup concept

Two successive two-body reactions



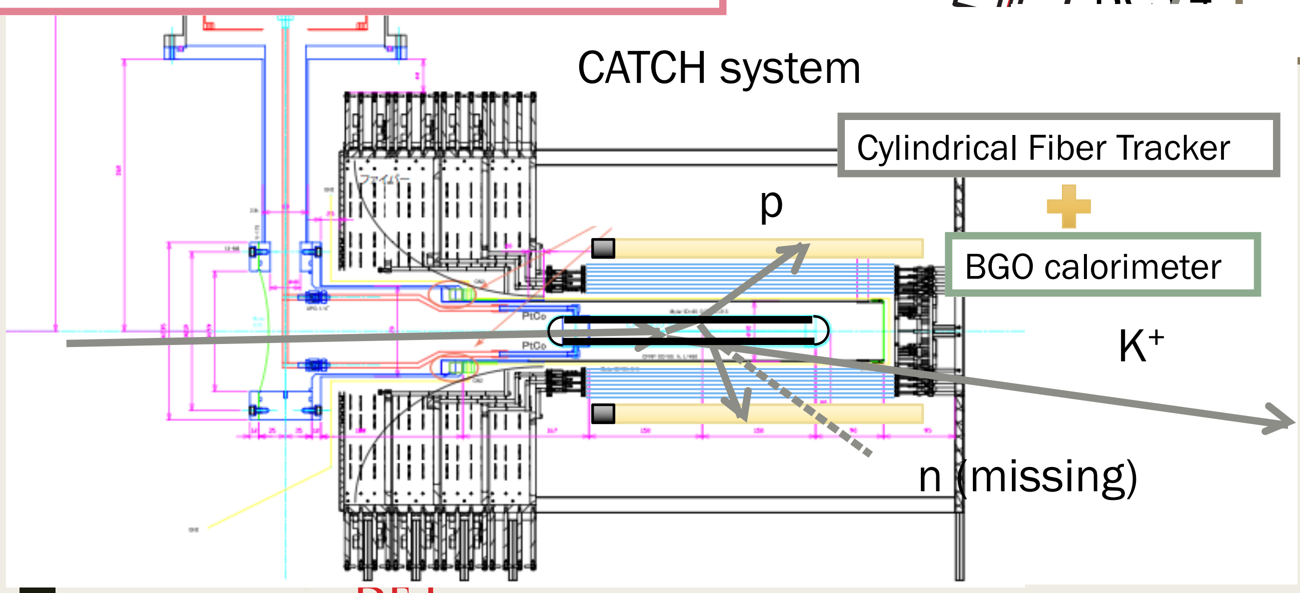
J-PARC K1.8 beamline



KURAMA spectrometer

- Identification of K^+
- Momentum analysis

Detection of Σp scattering event by CATCH detector



Momentum reconstruction
Σ beam

Beamline spectrometer

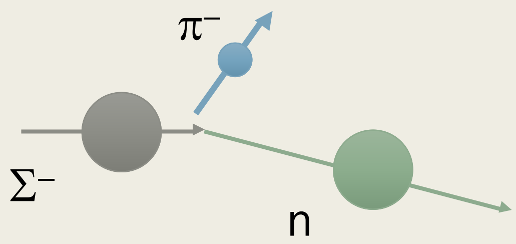
- Momentum analysis of π beam

Experiments at J-PARC

2018

1st production run

$\Sigma^{-}p$ scattering in June 2018 (~2 days)



Σ^{-} : Longer life time

No major decay channel to proton

Easier to check experimental feasibility

2019

report analysis results

2nd production run

$\Sigma^{-}p$ scattering production run in 2019 Feb. – March (~20 days)

17.5 M Σ^{-}

$\Sigma^{+}p$ scattering production run in 2019 April (~13 days)

40 M Σ^{+}

Due to accelerator trouble, half of beam time was postponed.

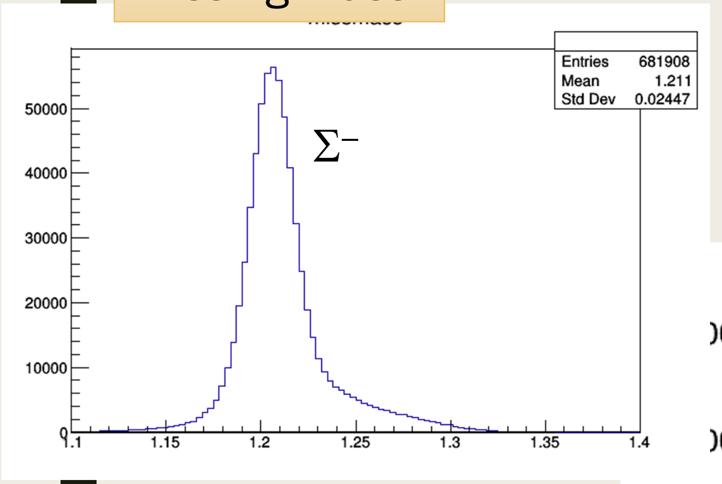
2020

3rd production run

$\Sigma^{+}p$ scattering production run in 2020 March (~14 days)

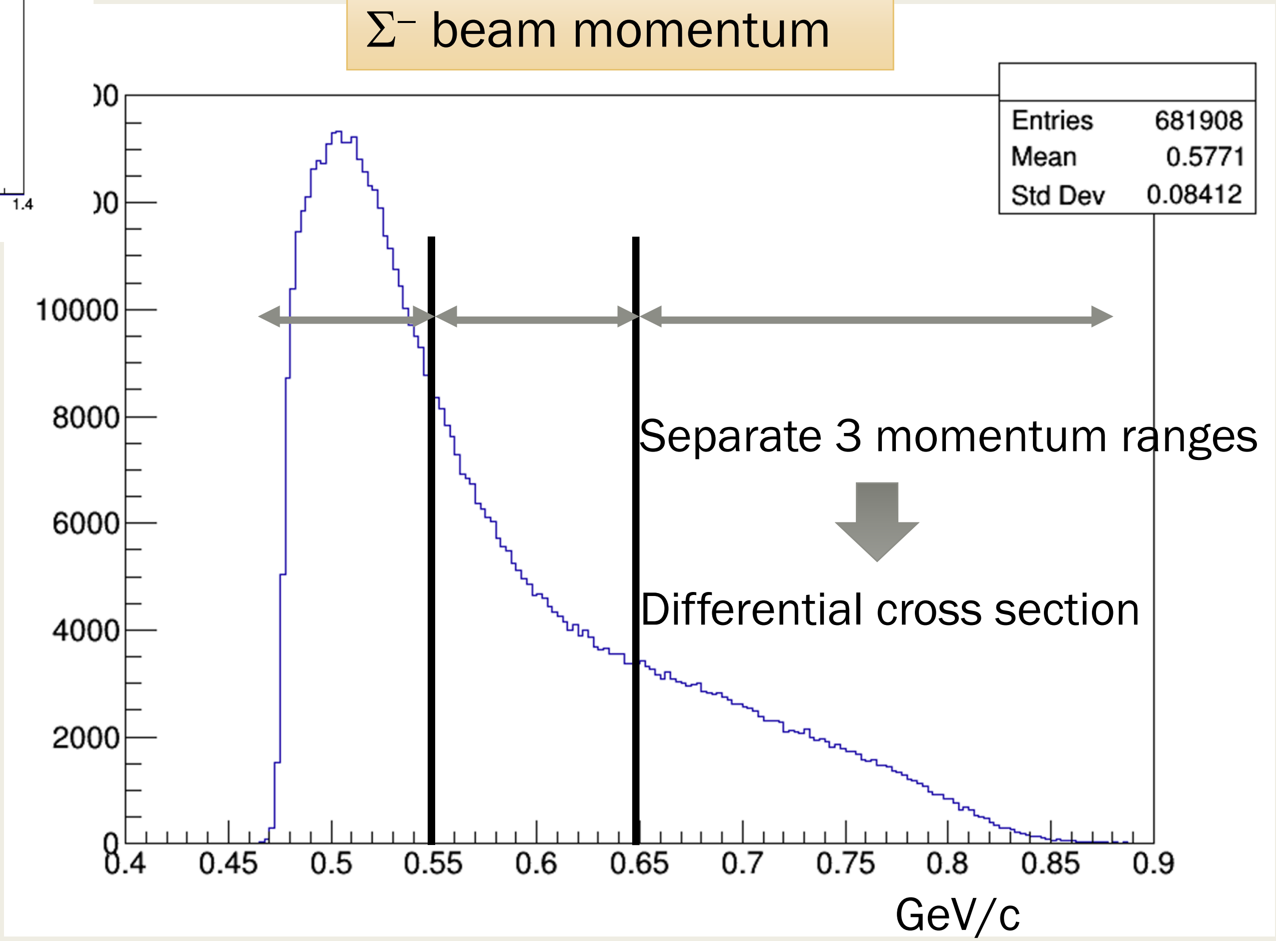
Σ^- beam momentum distribution

Missing mass

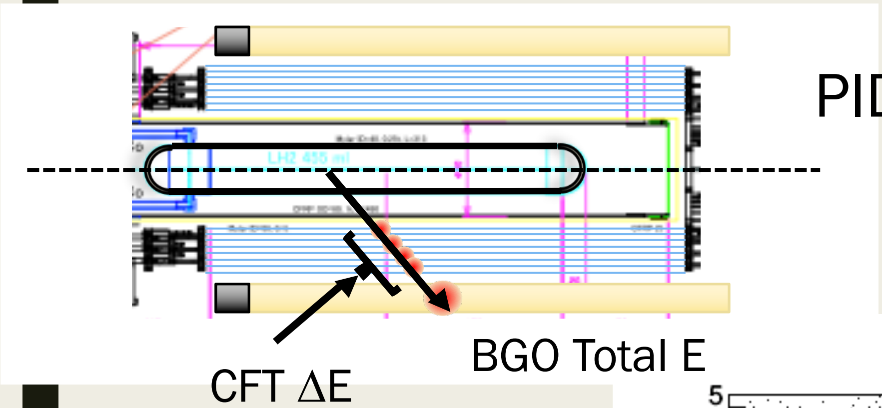


Missing mass (GeV/c^2)

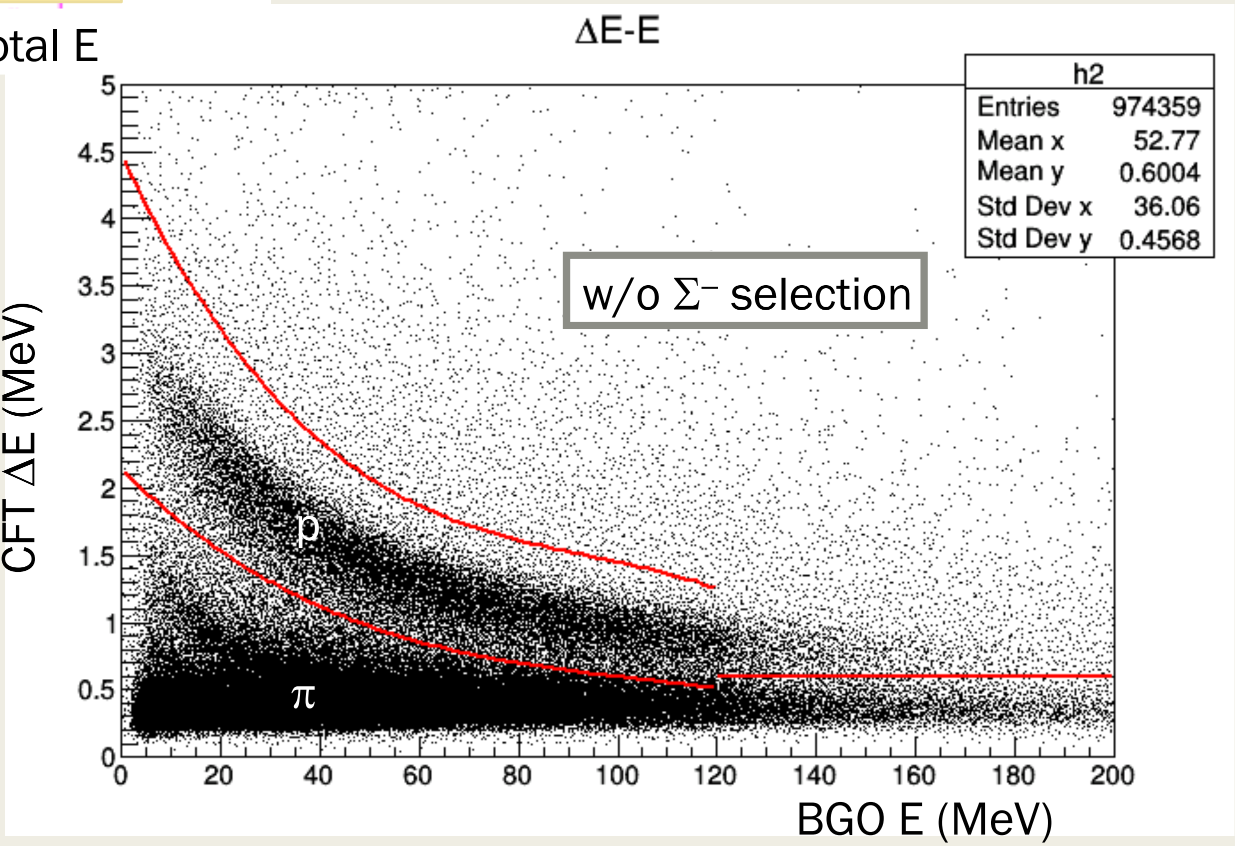
Σ^- beam momentum



CATCH analysis : Particle ID

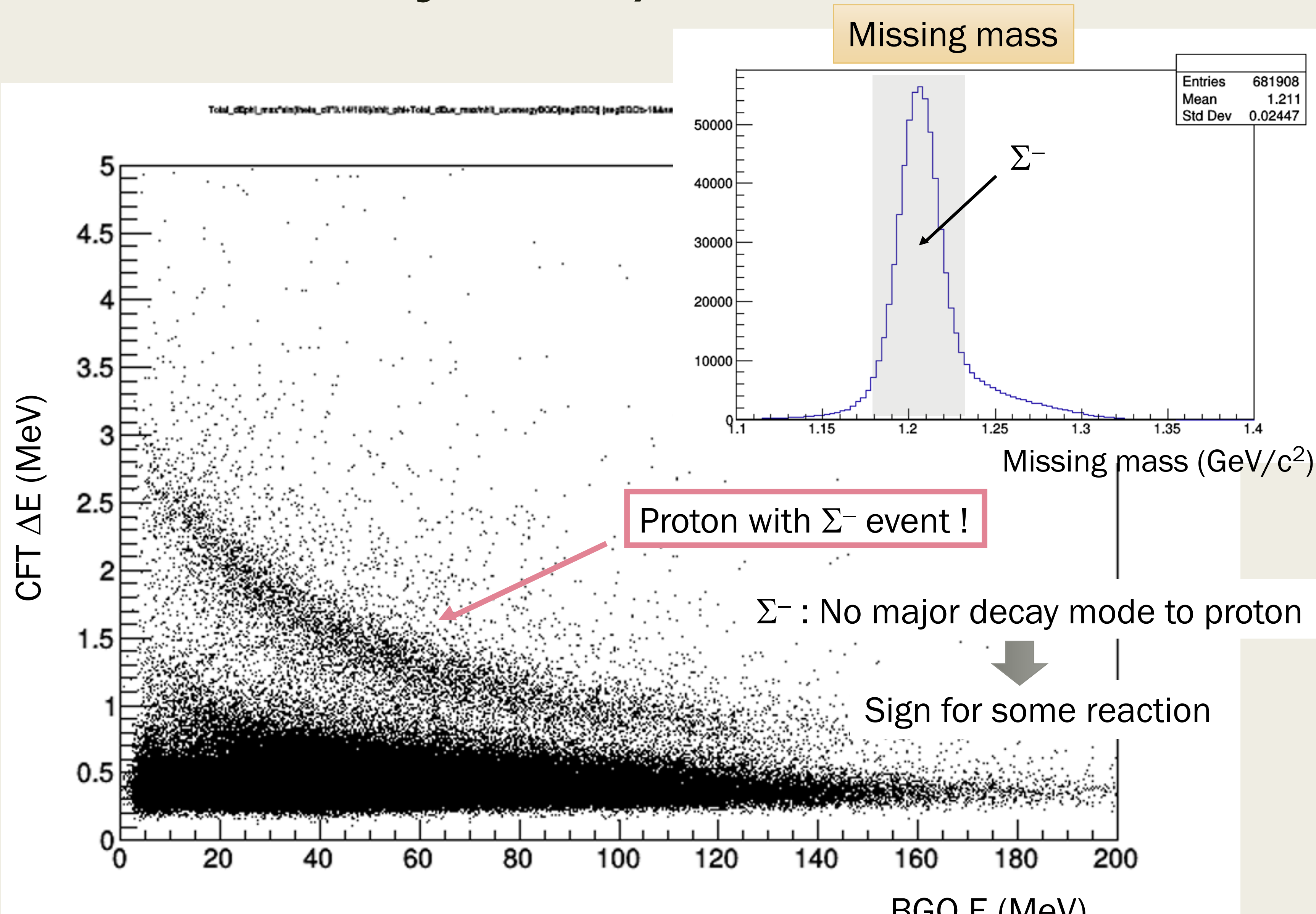


PID in CATCH was performed by ΔE-E method



π^- penetrates BGO.
For π^-, only direction can be measured.

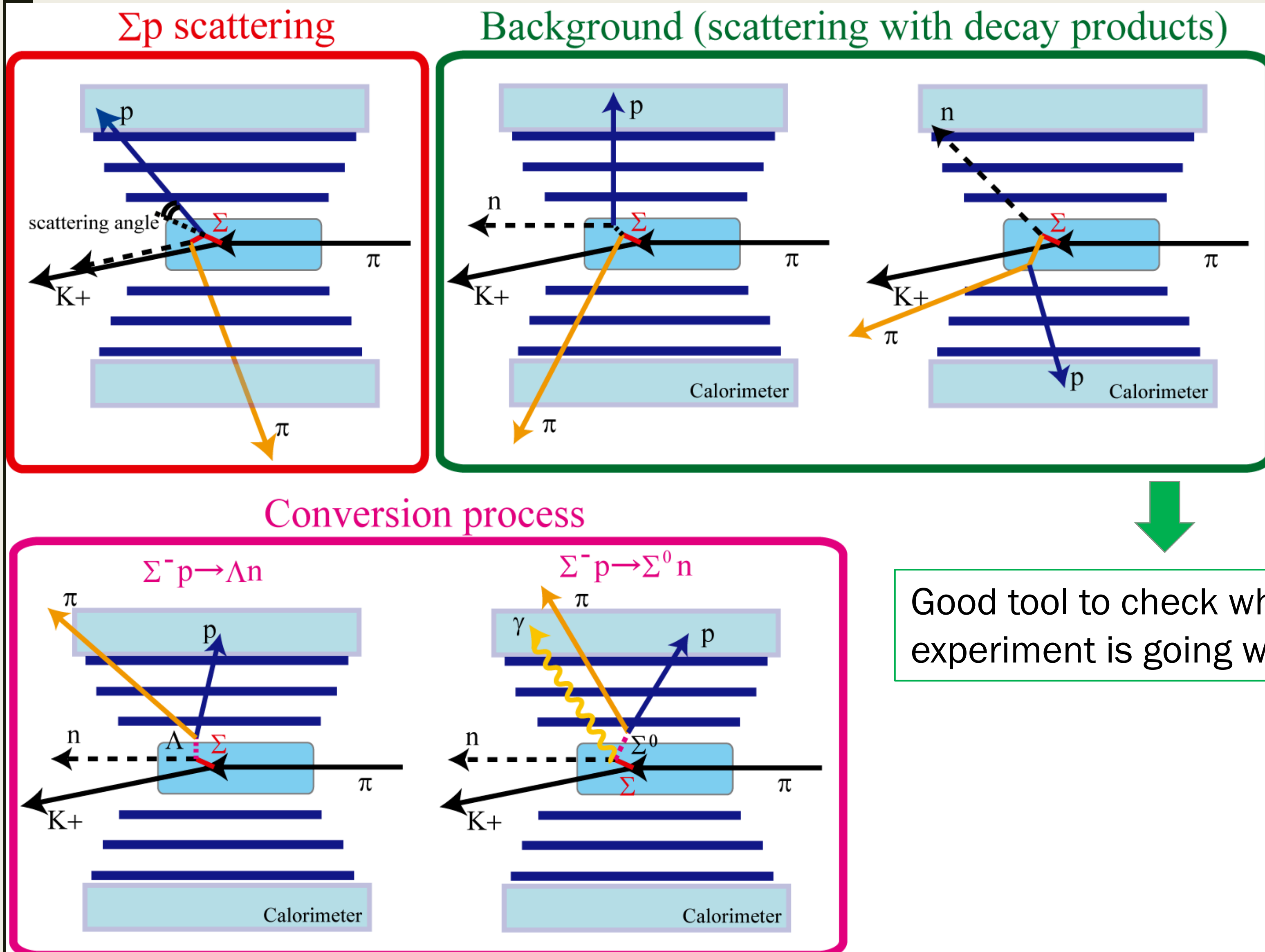
CATCH analysis w/ Σ^- event



Σ^- : No major decay mode to proton

Sign for some reaction

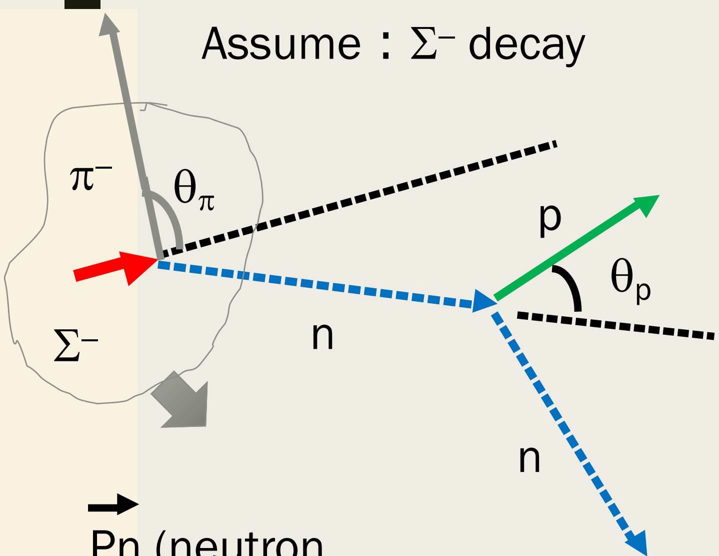
Proton event in Σ^- production



Good tool to check whether our experiment is going well or not.

np scattering

Assume : Σ^- decay



$\vec{P}n$ (neutron momentum)

Assume np scattering kinematics

Ecalc (θp)

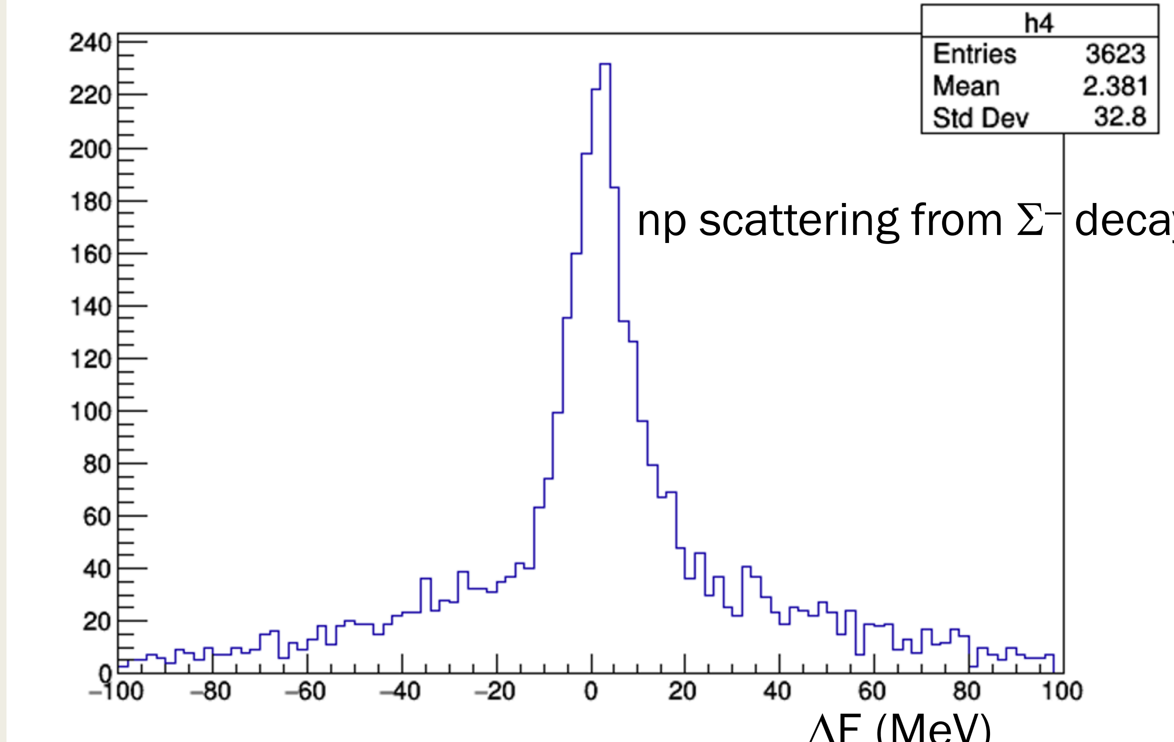
↕

Emeasure

compare

$\Delta E(np) = E_{calc} - E_{measure}$

ΔE (np) distribution



Identification with two successive reaction was possible

- Σ^- production
- Rescattering of Σ^- decay product

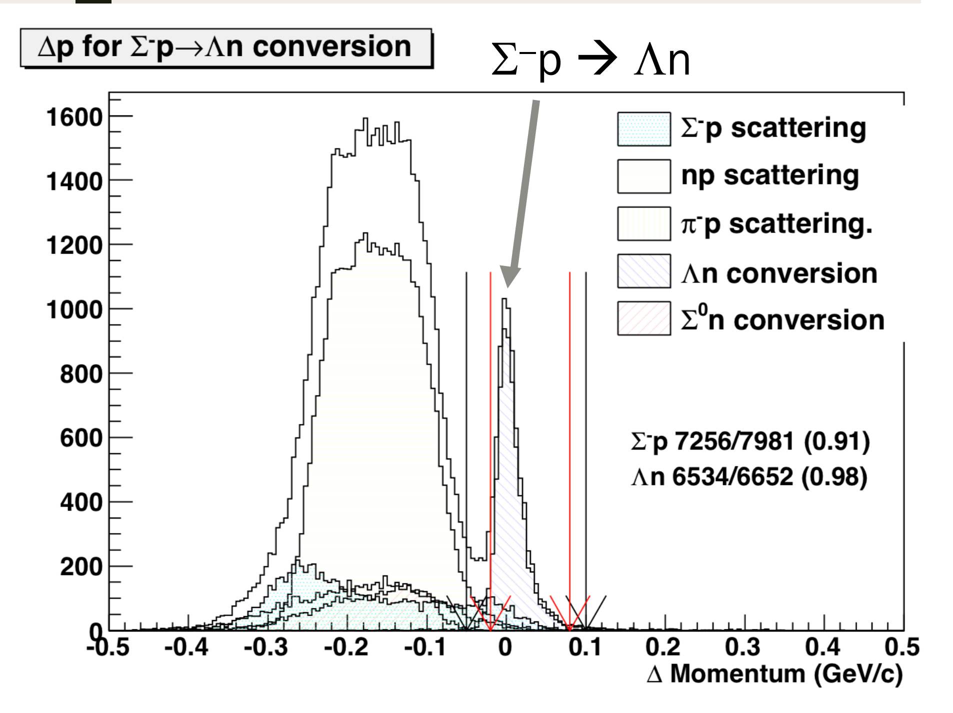
$\Sigma^- p \rightarrow \Lambda n$ conversion

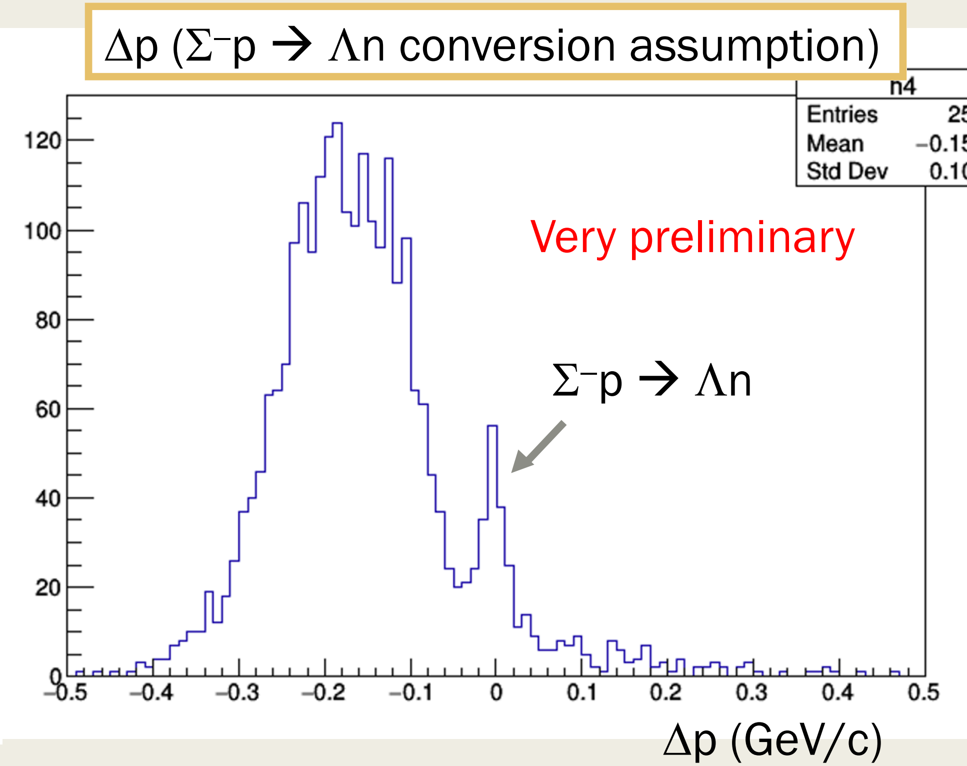
Simulation

2.5 mb/sr

Isotropic angular distribution

Λn conversion events are kinematically separated from other background

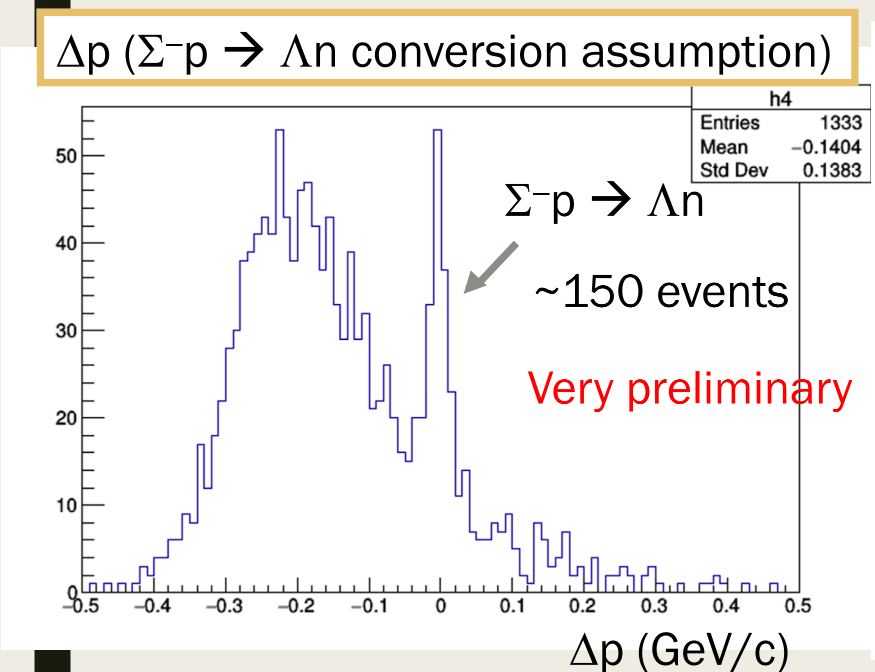


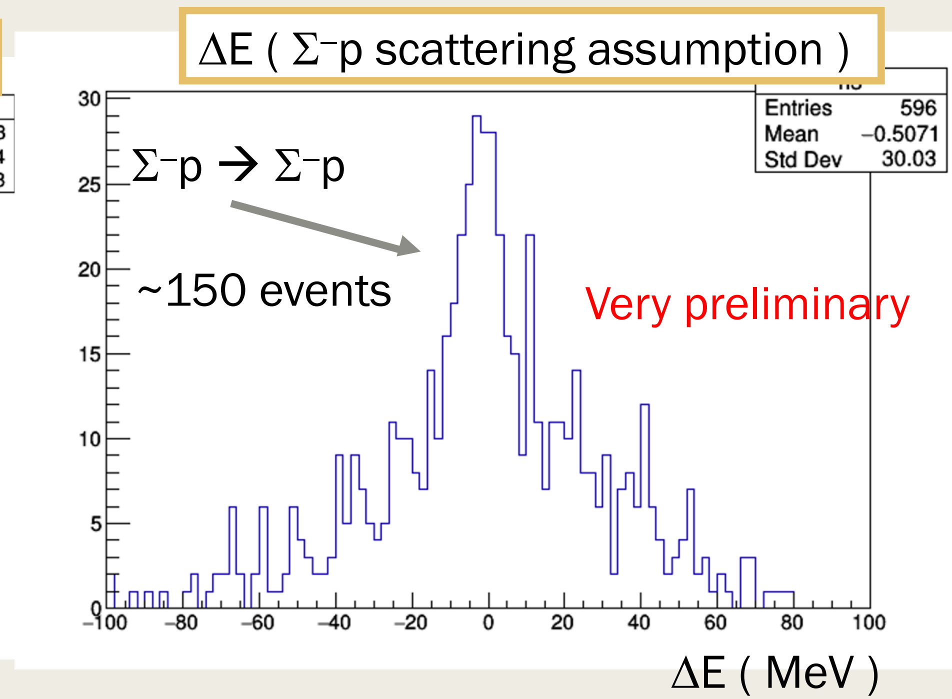


1. $\Sigma^- p \rightarrow \Lambda n$ conversion events can be clearly identified !
2. Background spectrum is almost consistent with our estimation.

Identification of Σ⁻p reactions

We checked kinematical consistency for each reaction.
The peak at Δp (ΔE) =0 satisfies the kinematical consistency for each reaction.





We could detect ~150 scattering events for both reactions from ~700 k Σ⁻ beam.
In the 2nd production run, ~18 M Σ⁻ beam was accumulated.
→ ~ 4000 scattering events are expected. (~100 times larger statistics than past experiment)

Expected physics outputs

- Σp scattering observables
  - *Σ^-p → Λn conversion*
    - proton up-down asymmetry
    - cross section
  - *Σ^-p elastic*
    - cross section
  - *Σ^+p elastic*
    - proton up-down asymmetry
    - proton left-light asymmetry (should be carefully corrected by CATCH acceptance)
    - cross section for two decay modes (systematics check)
- π^-p → $K^0\Lambda$ reaction for Λp scattering
  - *Important reaction to tag Λ beam with proton target*

Summary

- B01 : Hierarchy of matter investigated via strange hadron clusters
- ΣN interaction from Σp scattering
  - *Quark Pauli effect in $\Sigma^+ p$ channel*
  - *Systematic study of ΣN inteaction*
- $\Sigma^- p$ scattering experiment at J-PARC (1st run)
  - *$\Sigma^- p$ scattering physics run was partially carried out with high intensity (20 M/spill) π^- beam*
  - *$\Sigma^- p$ elastic scattering and $\Sigma^- p \rightarrow \Lambda n$ conversion were clearly identified.*
  - *We could realize "modern" Yp scattering experiment.*
- E40 2nd run from 2019 February
  - *~18 M Σ^- beam was accumulated.*
    - ~4, 000 $\Sigma^- p$, $\Sigma^- p \rightarrow \Lambda n$ events are expected.
  - *~40 M Σ^+ beam was accumulated*
  - *Analysis is on going. We are going to derive differential cross sections as soon as possible.*