Proposal of a Hyperon-Nucleon Scattering Experiment using a Scifi-MPPC system

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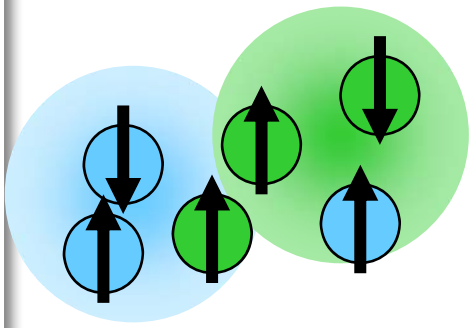
Nuclear force

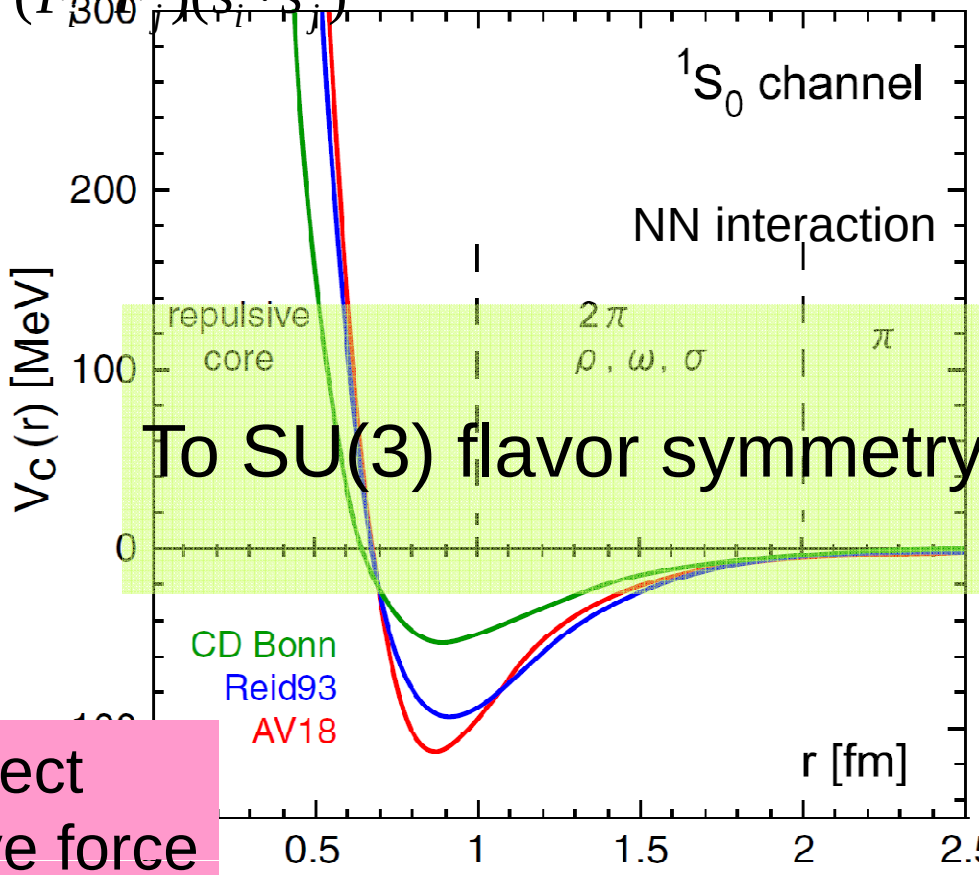
What is the origin?

Color magnetic interaction

$$H = H_0 - A\sum_{ij}\frac{\alpha_s}{m_i m_j}(F_i \cdot F_j)(s_i \cdot s_j)$$

meson exchange picture





$$V = g \cdot \frac{e^{-\frac{mc}{\hbar}r}}{r}$$

To SU(3) flavor symmetry

ΣN interaction
Isospin 3/2
Spin 1

More exchange mesons

- K
- K*, ϕ

Quark Pauli effect
Strong repulsive force

Nuclear force

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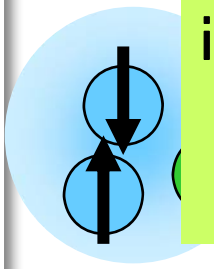
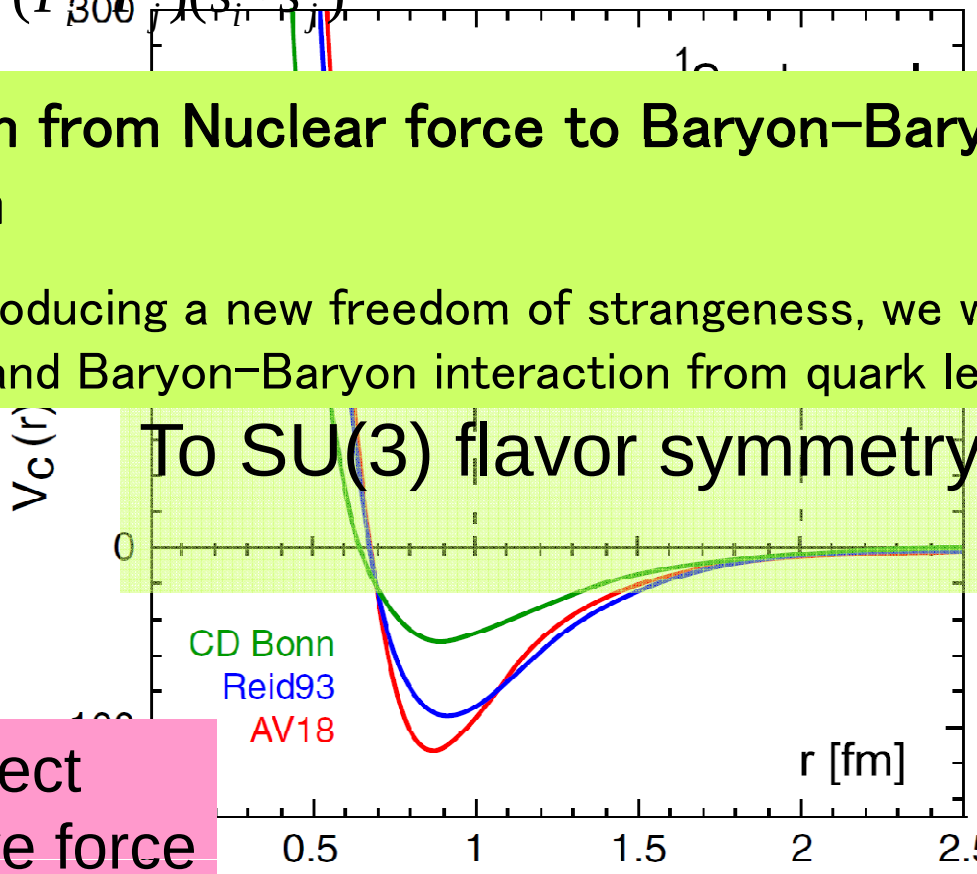


□Extension from Nuclear force to Baryon–Baryon interaction

□By introducing a new freedom of strangeness, we want to understand Baryon–Baryon interaction from quark level

To SU(3) flavor symmetry



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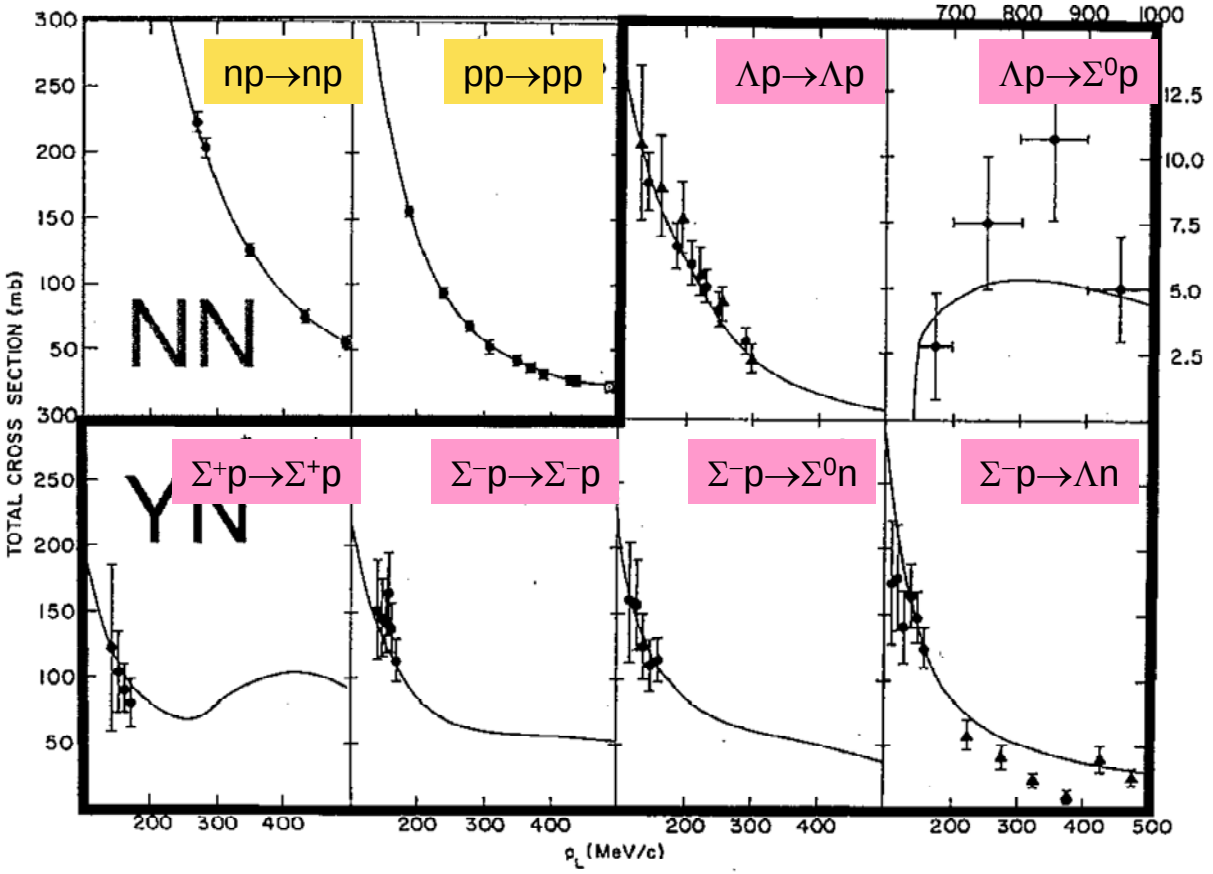
Experimental investigation of YN interaction

- Hyperon–Nucleon Scattering
  - Difficult due to short lifetime of hyperon
  - Poor data compared to NN scattering
- S
- F



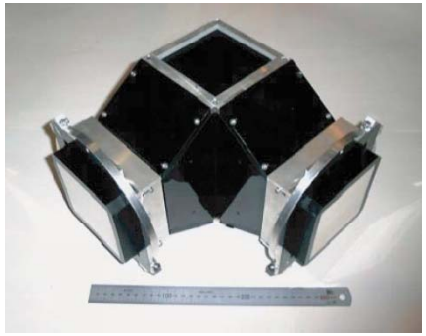
dy system

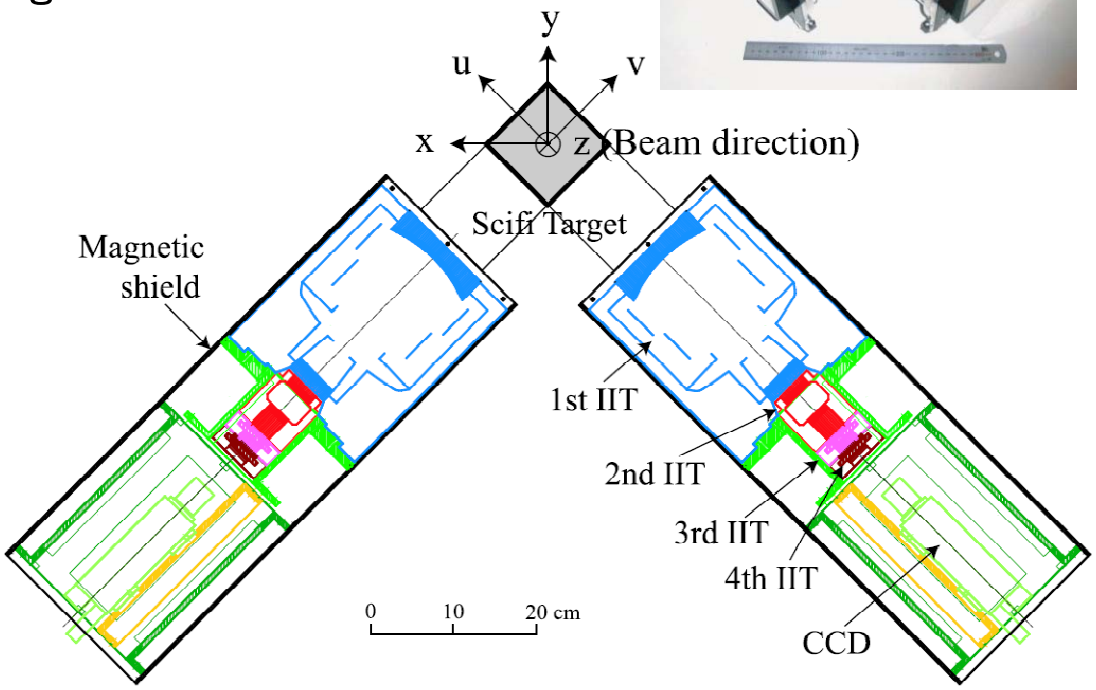
Experimental investigation of YN interaction

- **Hyperon–Nucleon Scattering**
  - Difficult due to short lifetime of hyperon
  - Poor data compared to NN scattering
- **Structure of Λ hypernuclei**
  - High resolution magnetic spectrometer
  - Gamma-ray spectroscopy using Ge detector
- **Problem**
  - Derive two body force from complex many body system
  - ΣN interaction, ΞN interaction？

Hyperon scattering experiment at KEK

- **Scintillation fiber and IIT-CCD**
  - KEK-PS E289, E452
  - Λp, $\Sigma^+ p$, $\Sigma^- p$ elastic scattering
  - Feasibility of SCIFI active target





(c) SCIFI Active Target system

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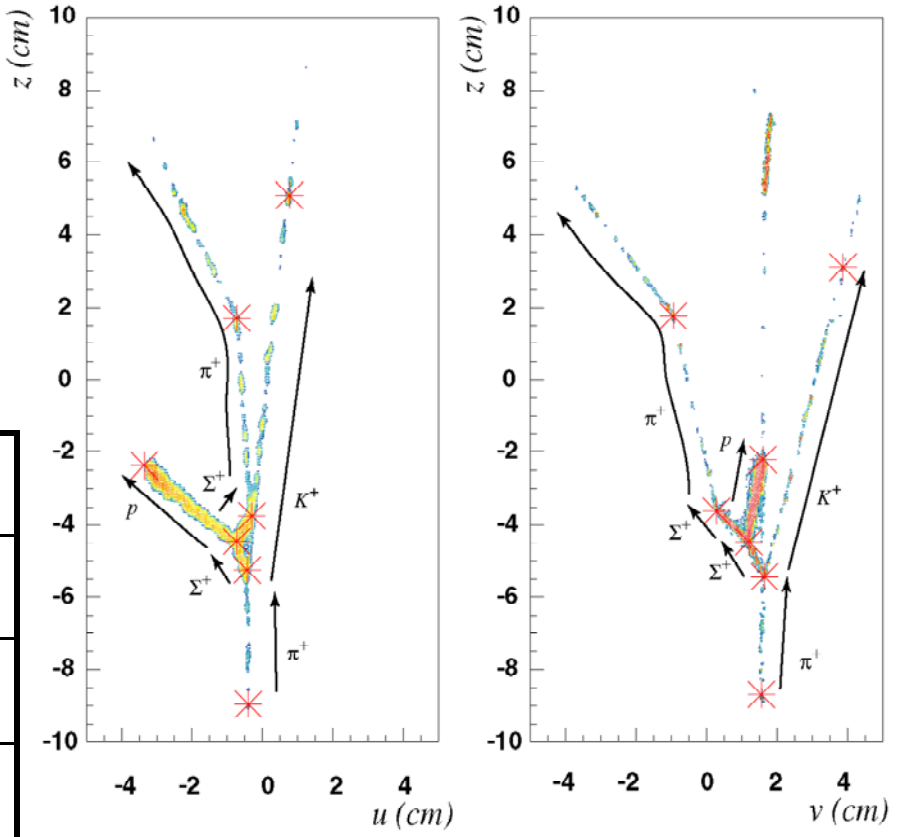

	reaction	Event number
E289	$\Sigma^+ p$	31
	$\Sigma^- p$	30
	Λp	----
E452	$\Sigma^+ p$	113

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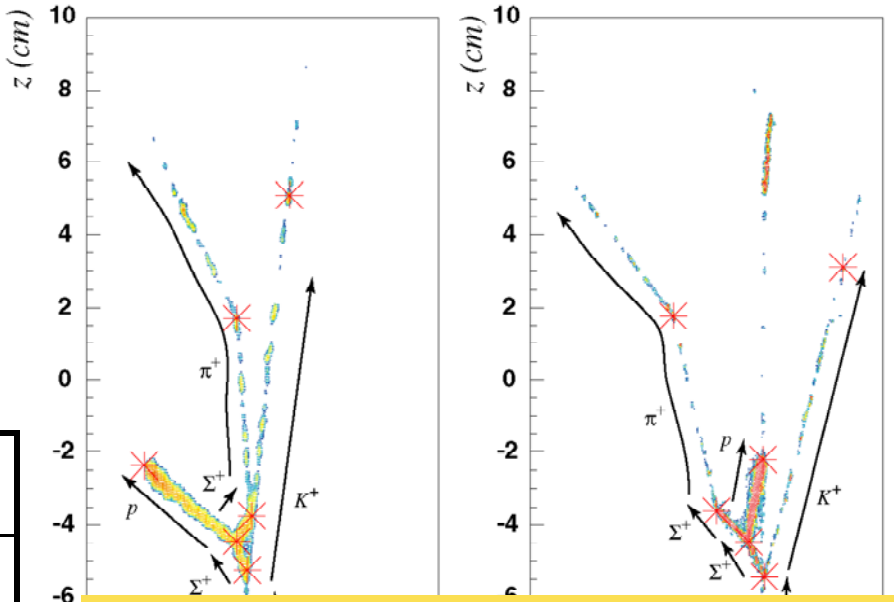
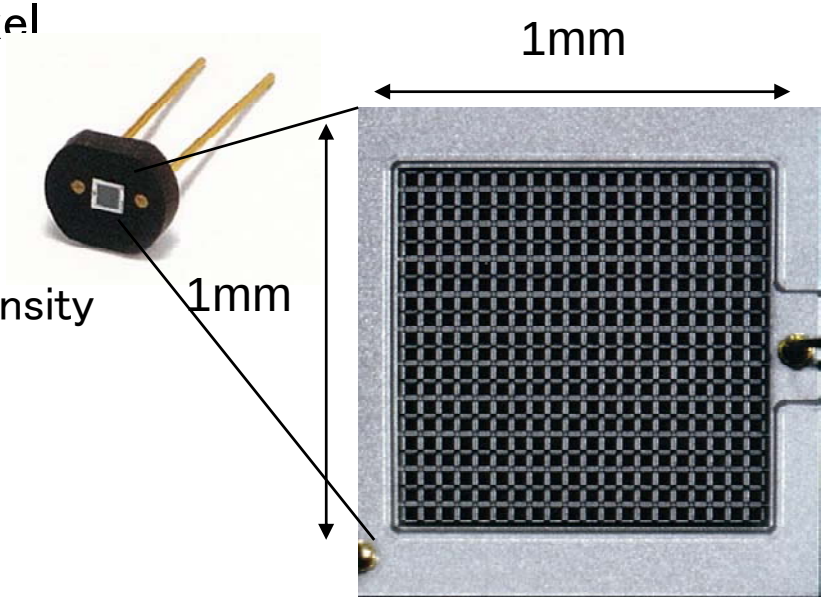


Problem
- IIT-CCD is slow
- There are overlaps of image @ beam intensity > 300kHz
- Detection of all particles in the final state is difficult

Read out system of SCIFI using MPPC's

- **Multi-Pixel Photon Counter (MPPC)**
  - New Si photo-diode consisted of multipixel of Avalanche Photo Diode (APD) operating in Geiger Mode
  - 100～1600 pixels of APD in MPPC
  - Output signal is the sum of each pixel
- **Characteristics**
  - Fast time response (< 10ns)
    - It can operate in the high beam intensity
  - Large gain (10^5~10^6)
    - Possible to detect 1 photon
  - Operation at the magnetic field
    - IIT can not work at the magnetic field



Can we use this detector for hyperon scattering experiment using a high intensity beam ?

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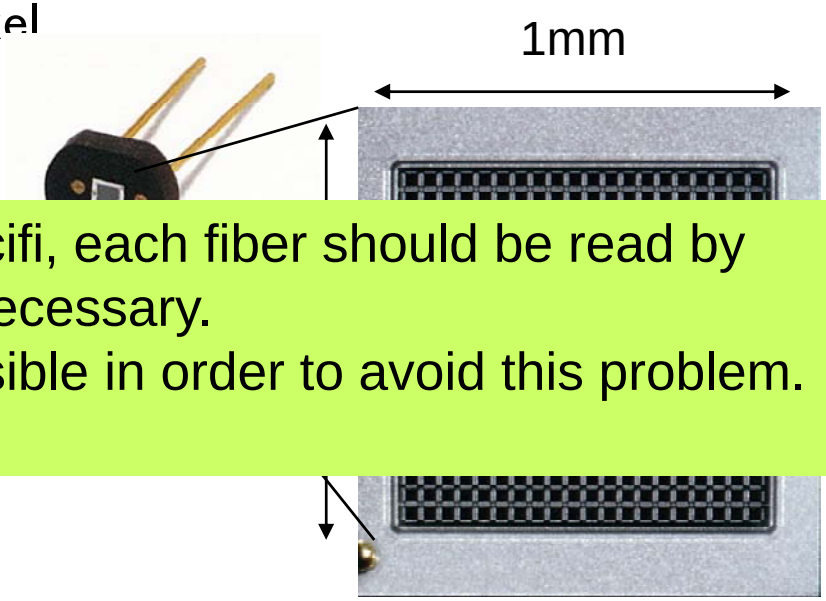


When MPPC is used for the readout of Scifi, each fiber should be read by one MPPC. Huge amount of MPPC are necessary.
The size of Scifi must be as small as possible in order to avoid this problem.

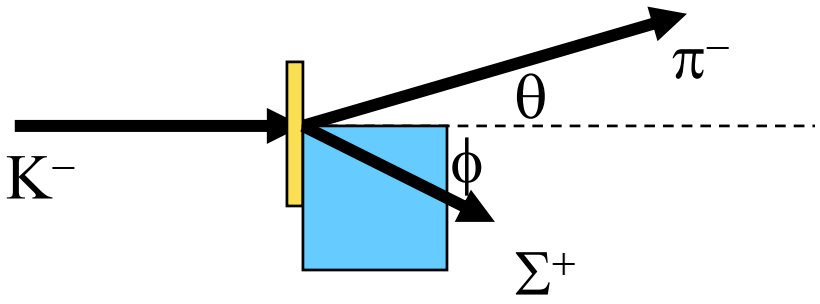
Can we use this detector for hyperon scattering experiment using a high intensity beam ?

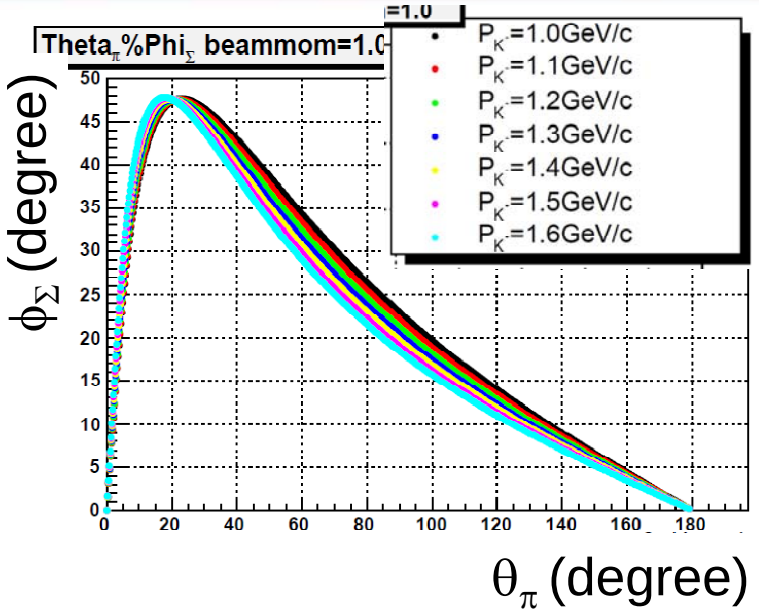
Size of SCIFI target

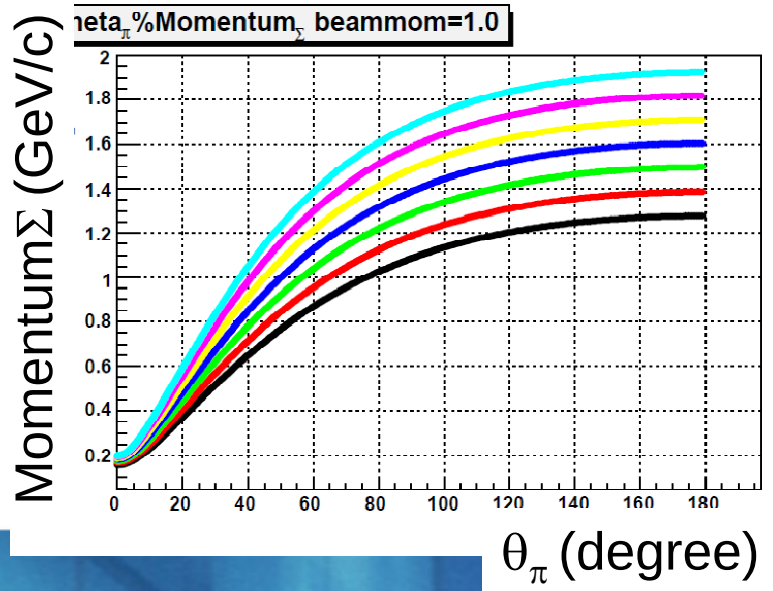
- Kinematics of Hyp. production
  - $K^-p \rightarrow \pi^-\Sigma^+$
    - Scattered angle ＜ 50 degree
- Flight length of Hyperon
  - Detection of Hyperon and proton scattering in the SCIFI.

Size is determined by the flight length of Hyperon.

3cm × 3cm × 3cm

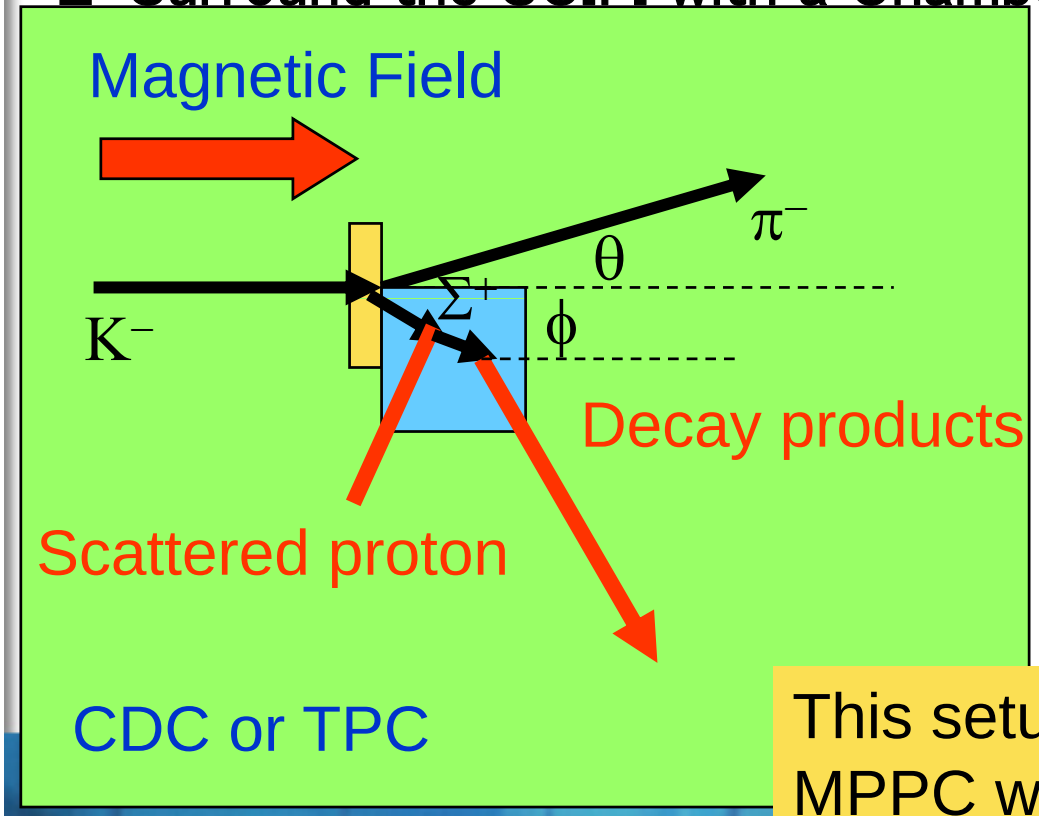




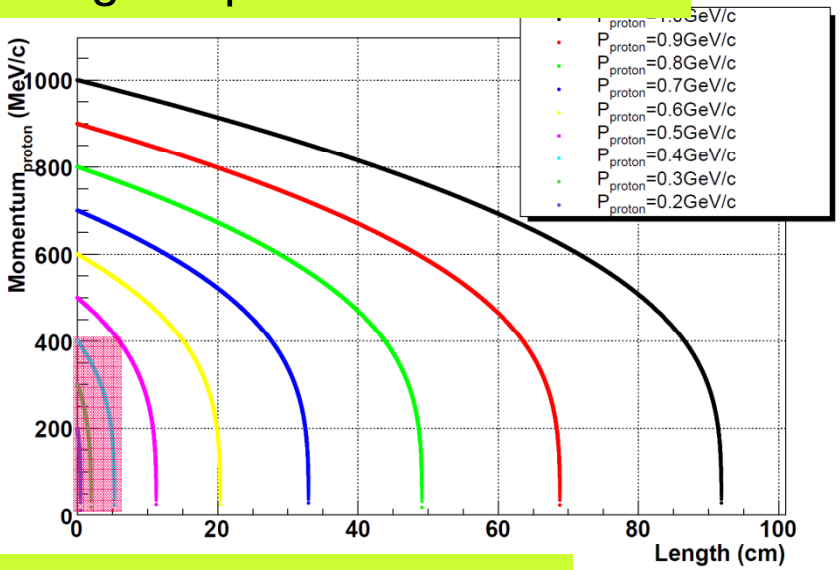


Detection of scattered particle and decay products

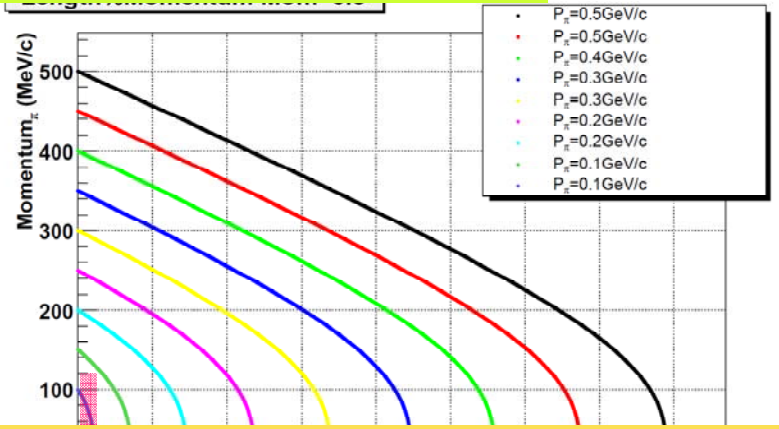
- Range in the SCIFI target
  - Proton : p <350MeV/c → stop in the target
  - Otherwise particles go to outside.
- Surround the SCIFI with a Chambe



Range of proton in the SCIFI



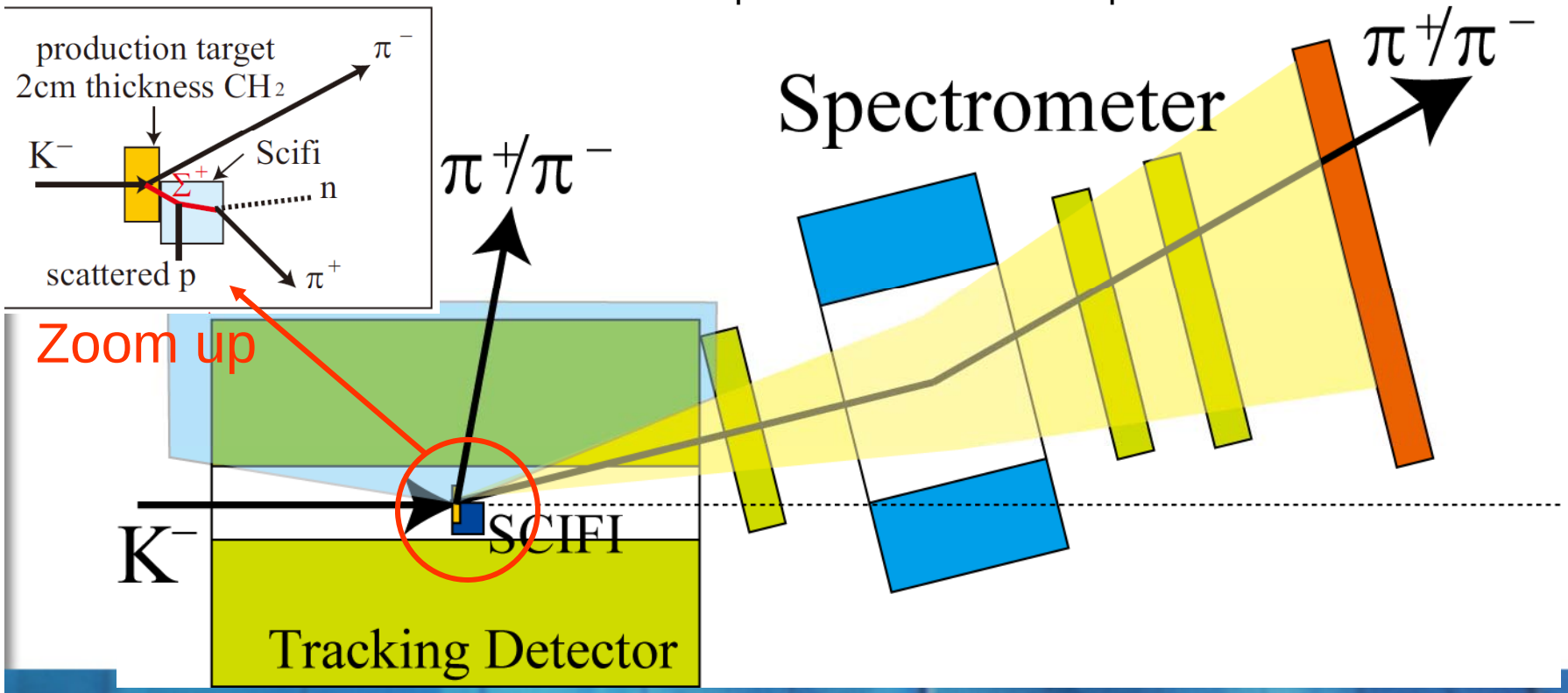
Range of π in the SCIFI



This setup is possible by using MPPC which works in a magnetic field.

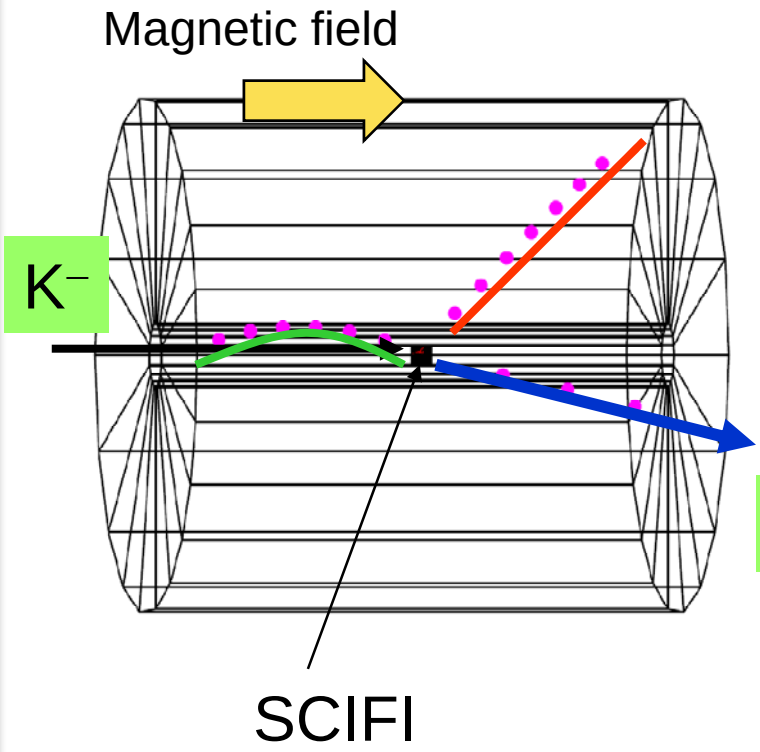
Concept of whole experimental setup

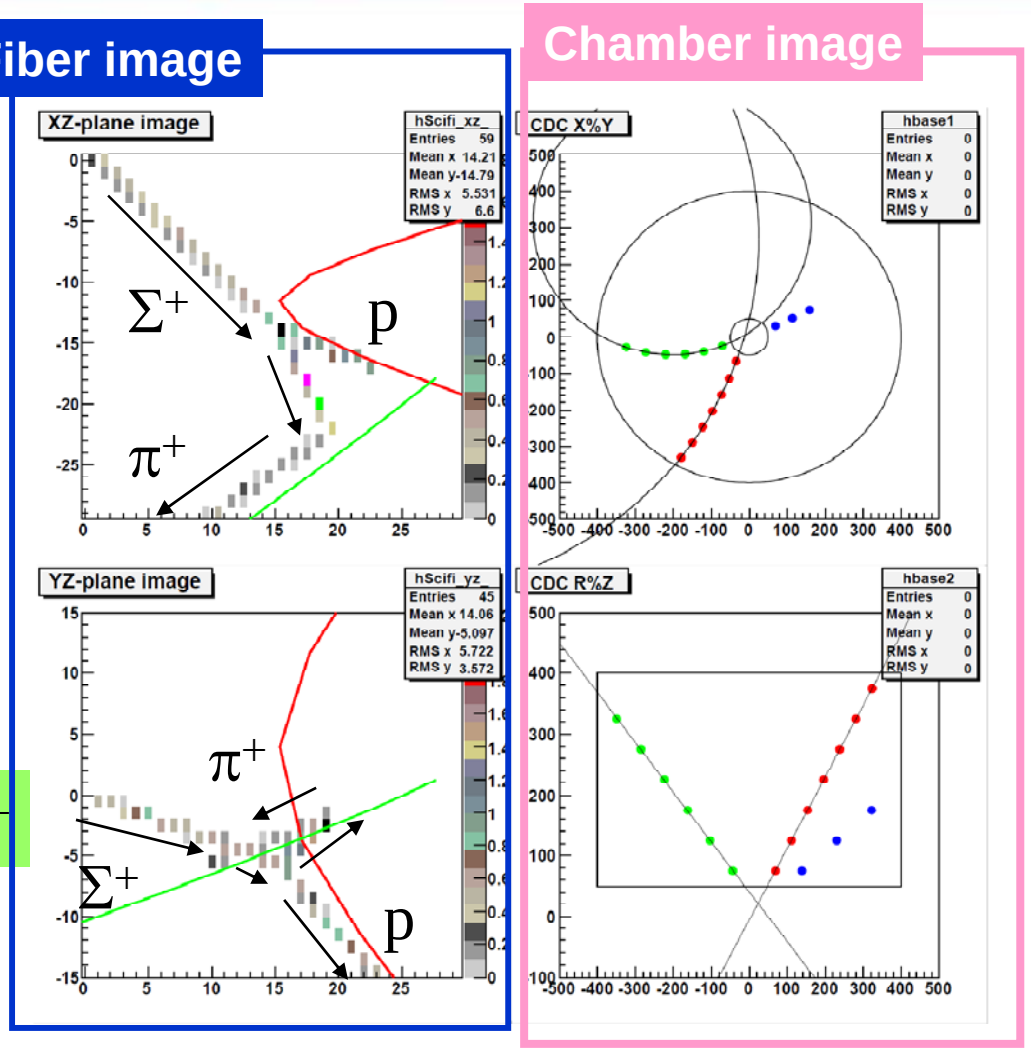
- At J-PARC
  - 1st target is Σ^+p scattering
  - Σ^+ production via (K^-, π^-) reaction using a 1.1GeV/c K^- beam
  - Forward spectrometer＋Cylindrical spectrometer
    - Improvement of acceptance for scattered particles



Typical Event Display

- We can detect all particles



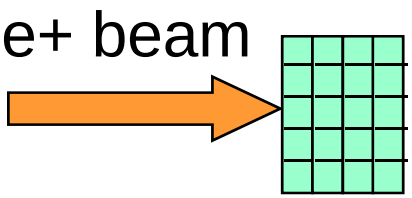


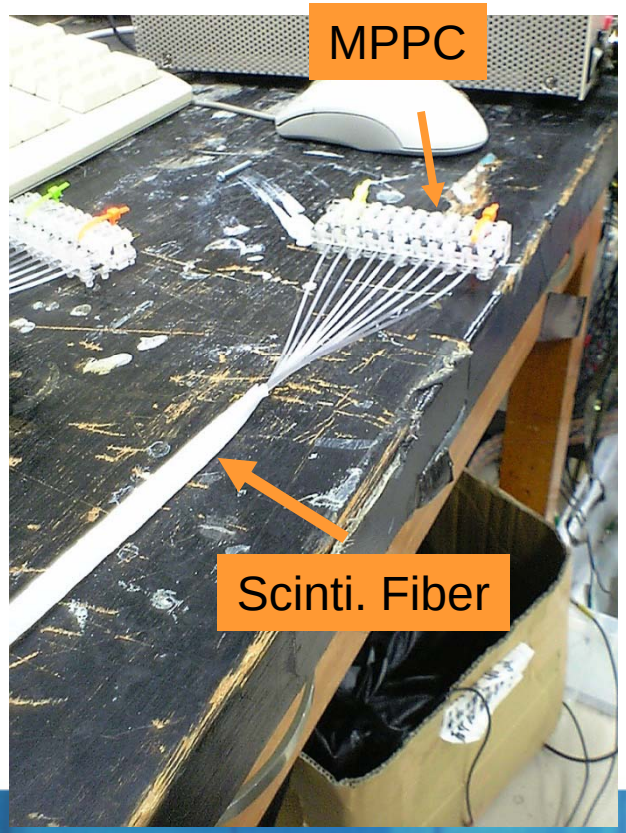
The extrapolated tracks from CDC help to understand the complex image of the Scifi

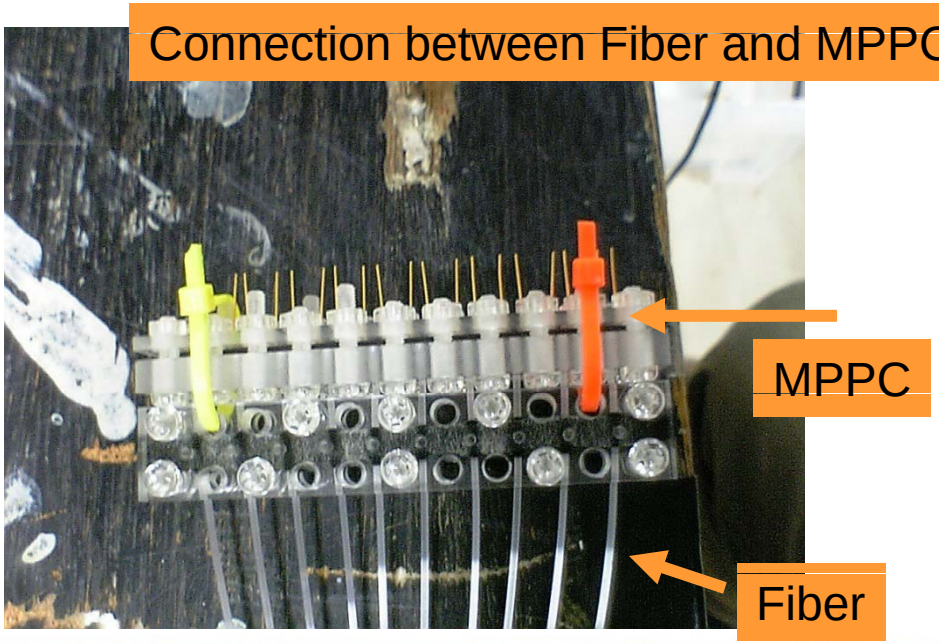
Imaging tracker inside the spectrometer

- Prototype of Scifi-MPPC system
  - Readout of 20ch MPPC

1mmx1mm Fiber 20 ch







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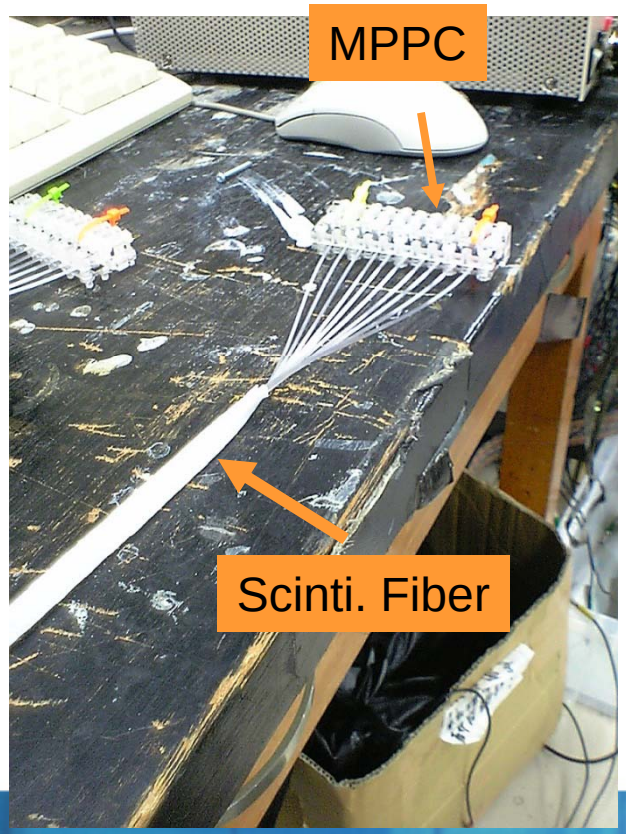
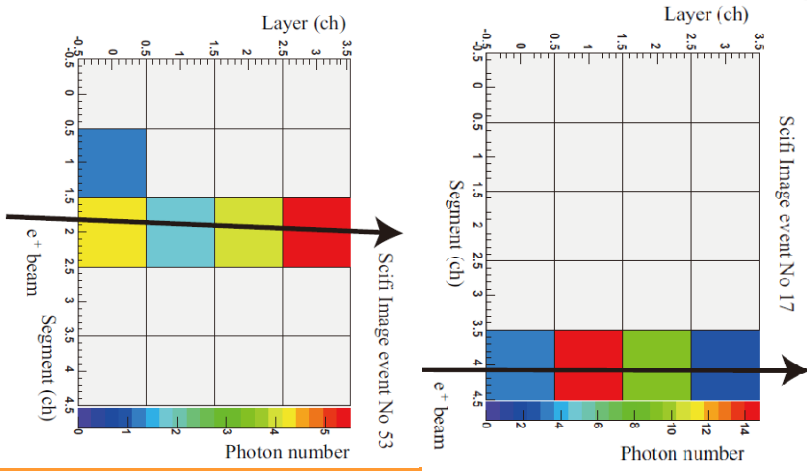
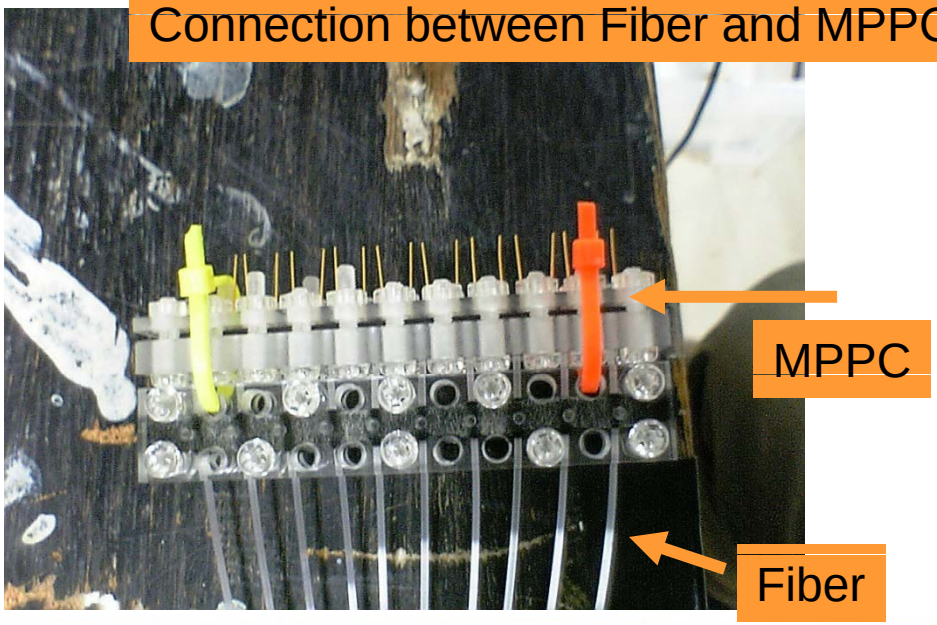


1mm

e+ beam



Connection between Fiber and MPPC



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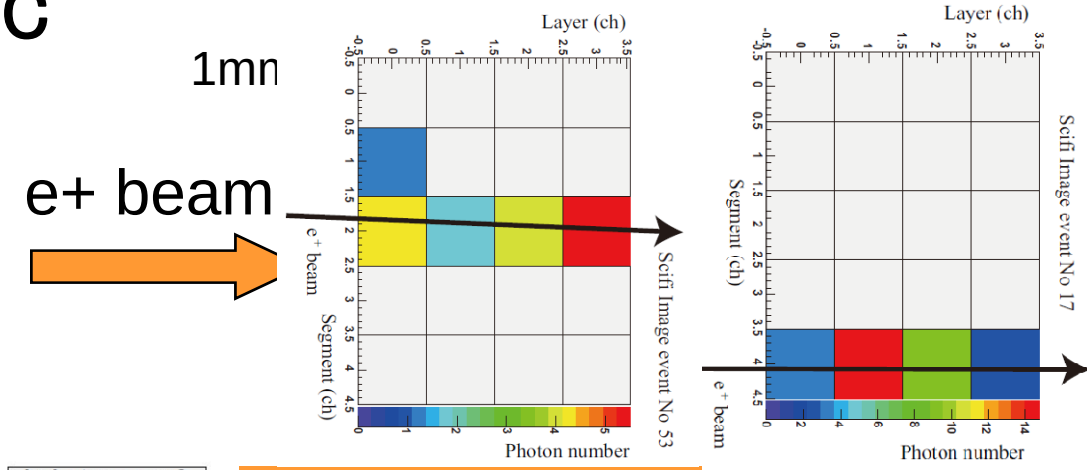
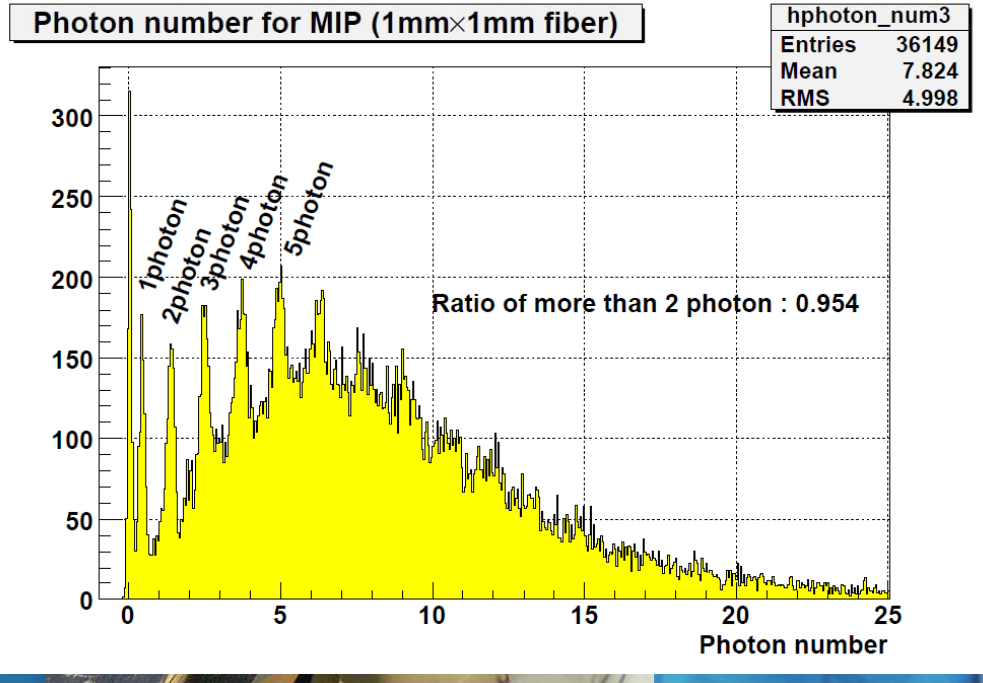
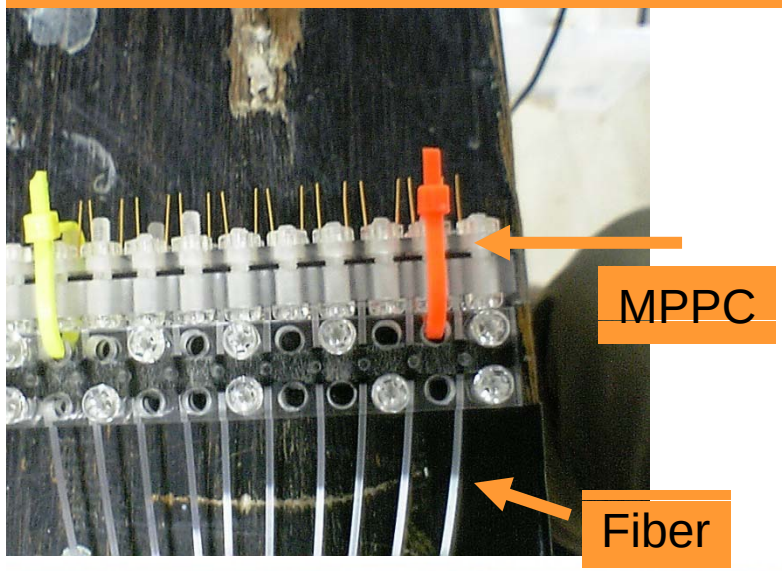
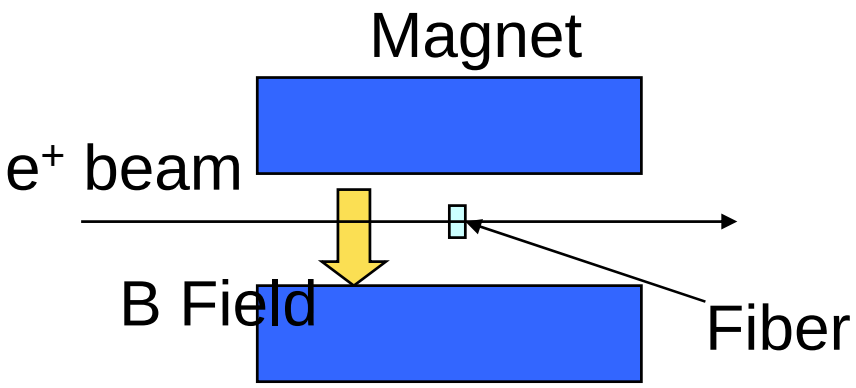


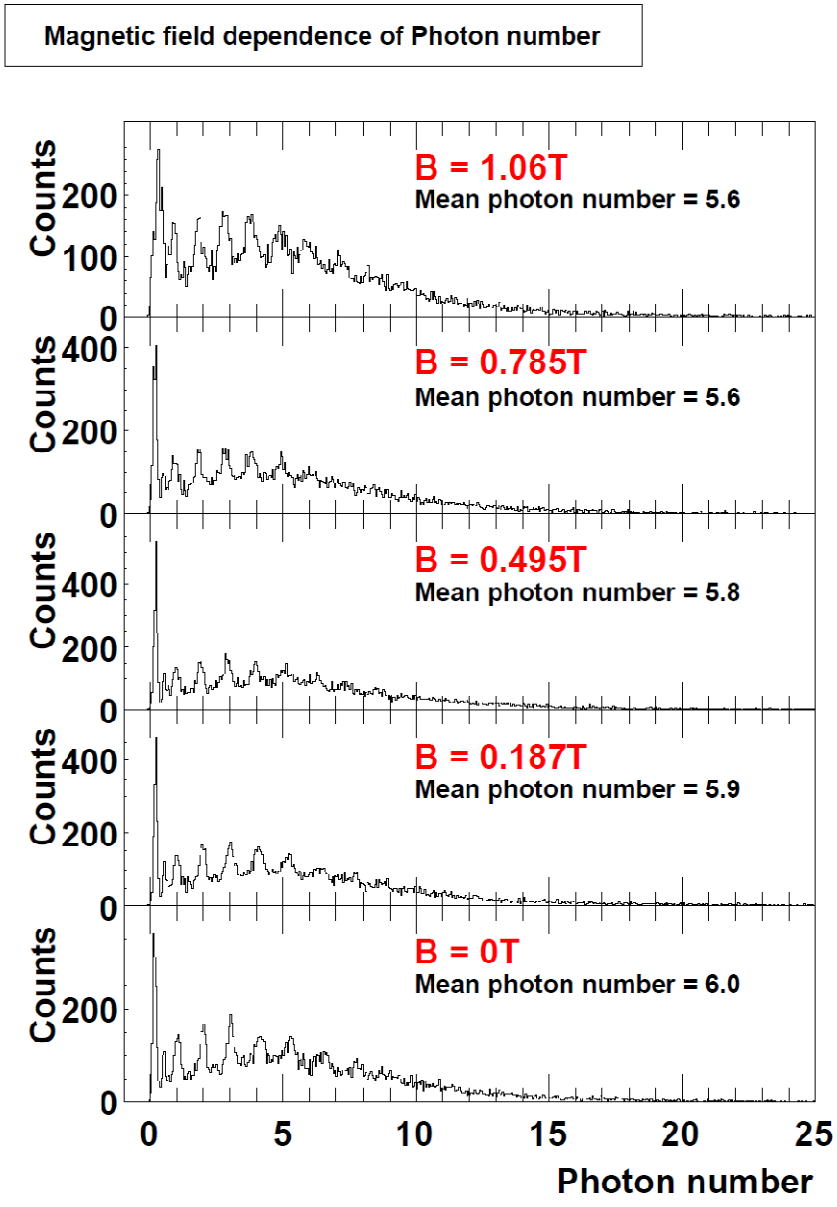




Operation in Magnetic Field



- Photon number with magnetic field
  - Photon number
  - Gain



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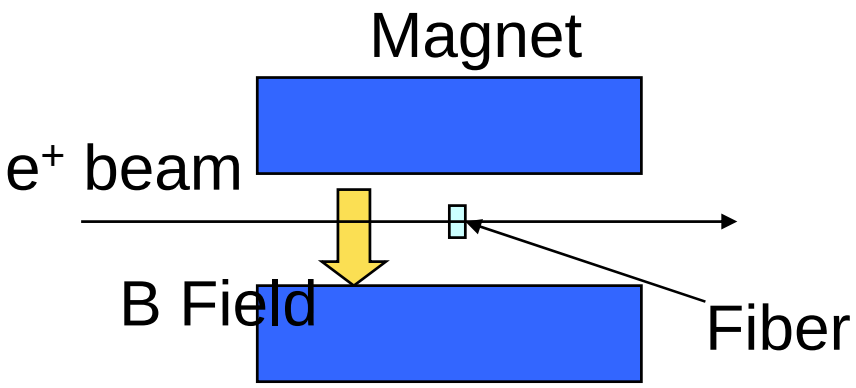
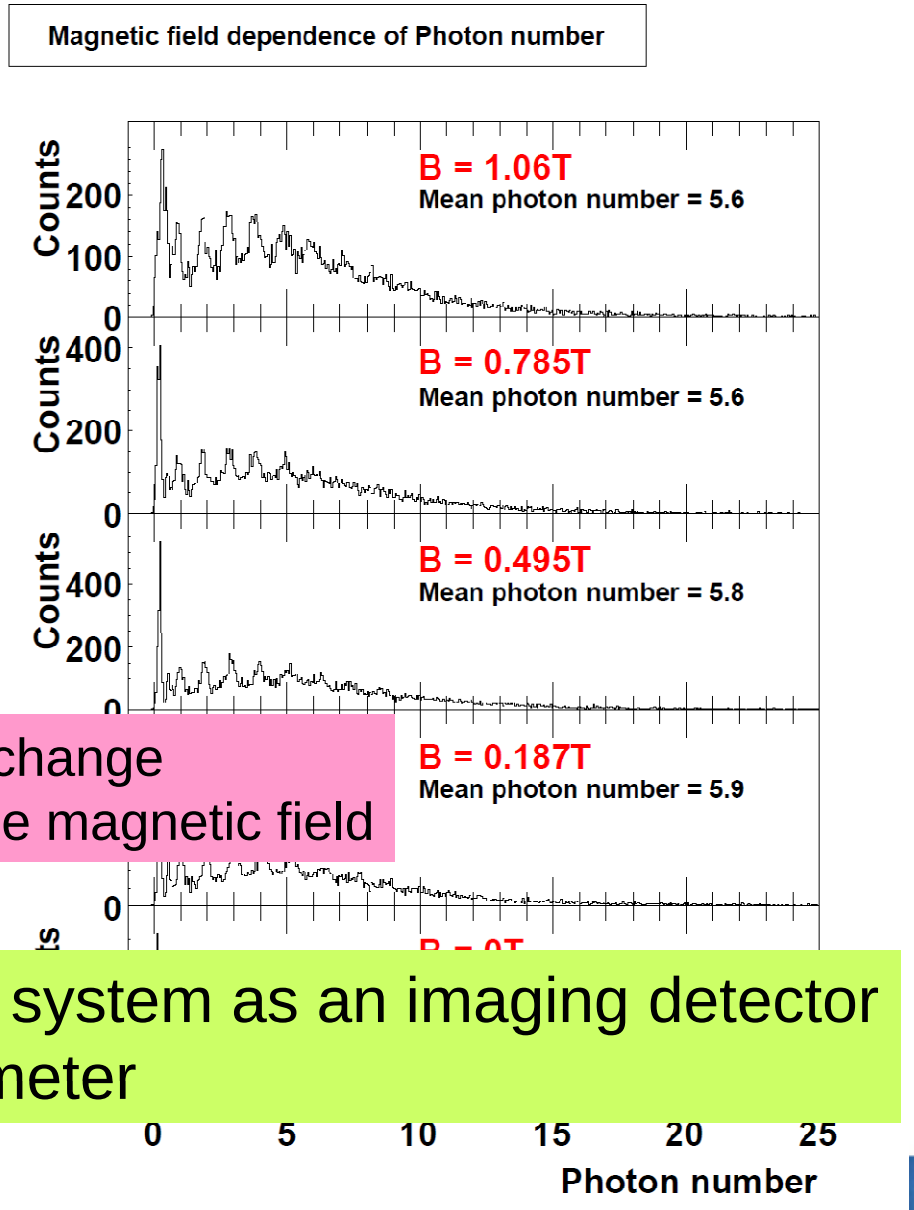


- **Photon number with magnetic field**
  - Photon number
  - Gain

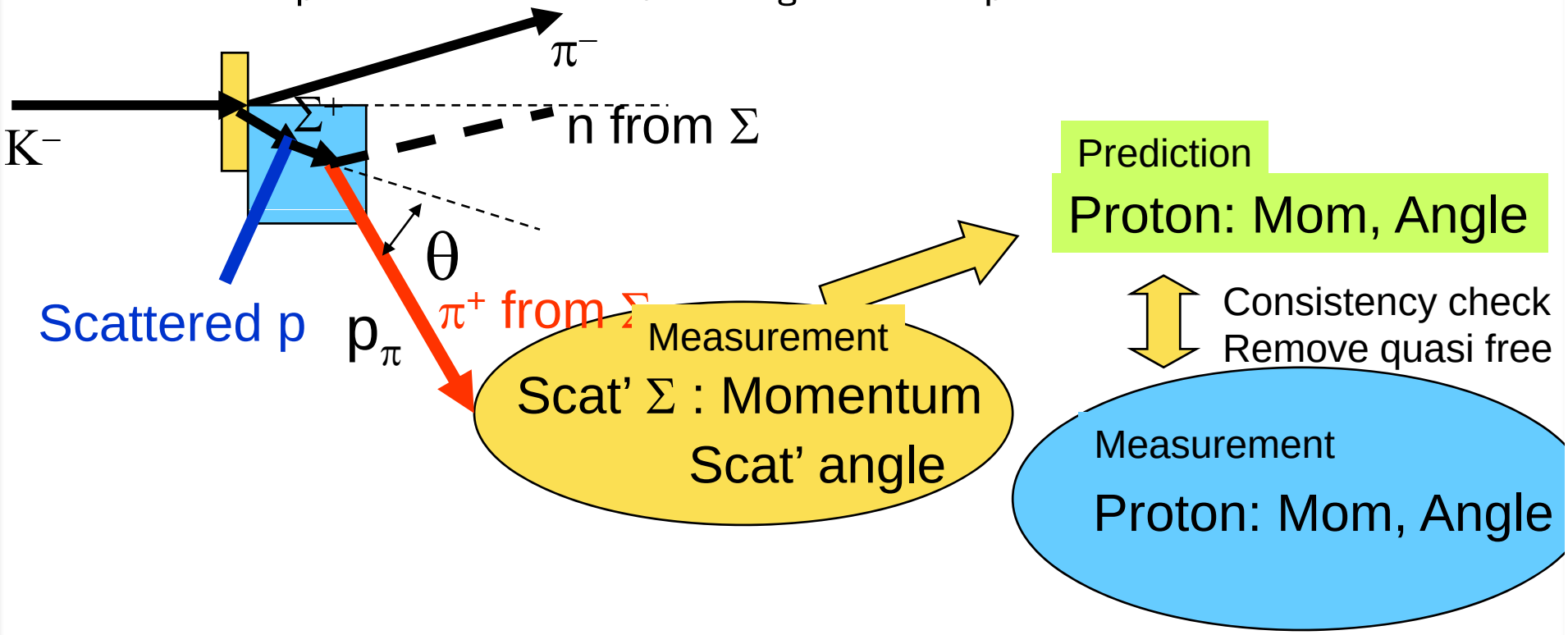
Do NOT change due to the magnetic field



We can use this Scifi-MPPC system as an imaging detector inside the magnetic spectrometer

Advantage of detecting all particles in the final state

- Remove the quasi free scattering
  - SCIFI consists of CH
  - Quasi-free scattering with proton in carbon nuclei should be separated from the scattering with free proton.



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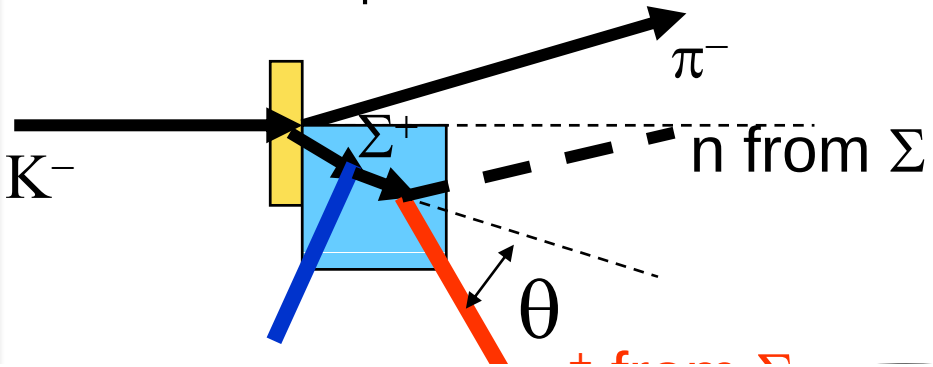


Prediction

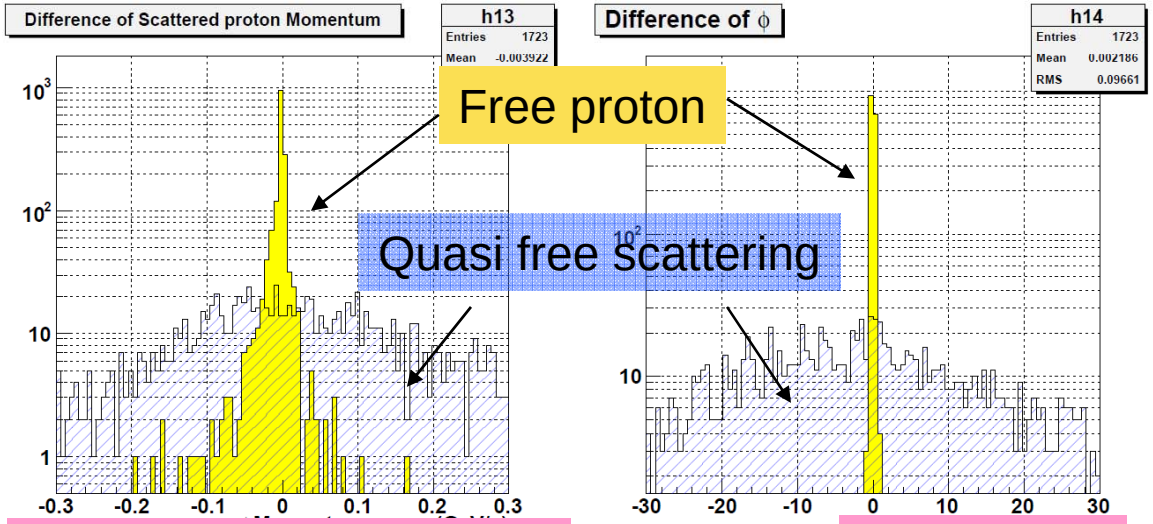
Proton: Mom, Angle

Consistency check

Remove quasi free

Measurement

Proton: Mom, Angle



$\Delta Momentum_{proton}$(GeV/c)

$\Delta\phi$ (degree)

Summary

- We want to perform Hyperon scattering experiment with high statistics at J-PARC.
- Readout system of SCIFI using MPPC
  - Fast time response → high intensity beam
  - Sufficient gain to detect one photon
  - Operation in the magnetic field→ combination of imaging tracker with magnetic spectrometer
- 1.1GeV/c K^- 10^6/spill
  - ~1000Σp scattering event in 1 month beam time
- We have submitted a LOI, please refer
  - http://j-parc.jp/NuclPart/pac_0801/pdf/LOI_Miwa_YN.pdf