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The 3rd Korea-Japan on Nuclear and Hadron Physics at J-PARC

"Development of a detector system to detect scattered protons for the Σp scattering experiment"

Tohoku University

Yuya Akazawa

for the J-PARC E40 collaboration

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  - BGO calorimeter
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  - Performance evaluation (CFT + BGO)
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Σp scattering experiment (J-PARC E40)

By measuring $d\sigma/d\Omega$ of Σp scattering,

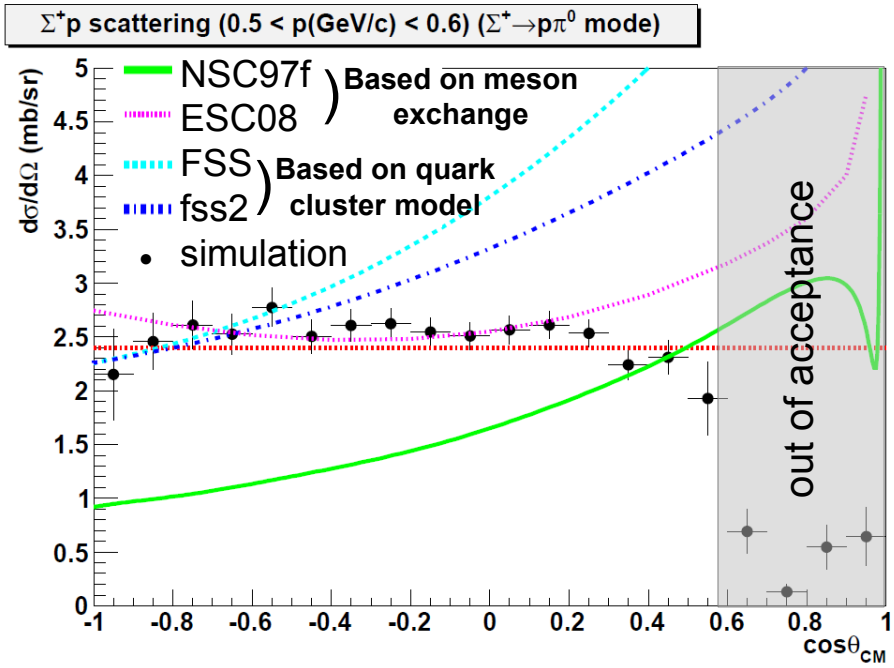
- derive **phase shift** and **the size of repulsive core** for $\Sigma^+ p$ channel

  ⇒ confirm **the quark Pauli effect**

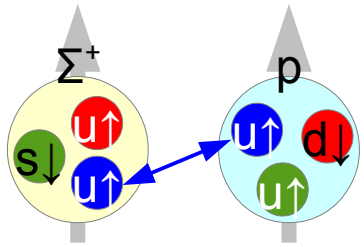
- for $\Sigma^+ p$, $\Sigma^- p$, $\Sigma^- p \rightarrow \Lambda n$

  ⇒ provide essential information to study ΣN interaction

Expected dσ/dΩ



an example of spin・flavor・color combination for Σp ($I=3/2\ {}^3S_1$)



need to measure **dσ/dΩ with sufficient precision**.

⇒⇒ detect ~**10,000** scattering events to decrease statistic error

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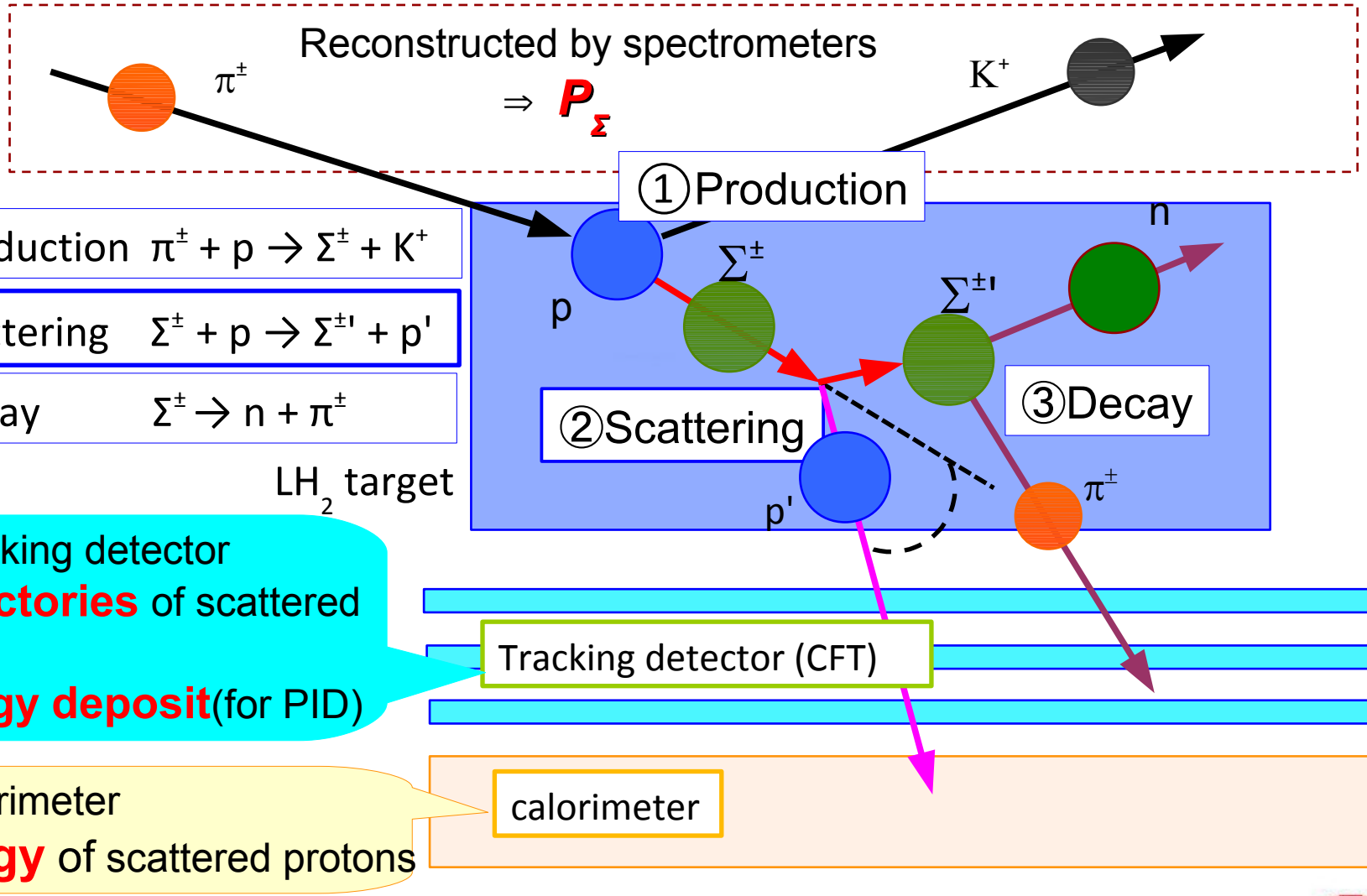
Reaction in the Σp scattering experiment



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Identification method of scattering event

- Event identification
  - $E(p')_{calc}$ ・・・scattering angle(←P_Σ & p' trajectory)

    & Assumption kinematics
  - $E(p')_{measure}$ ・・・measured by calorimeter

$$\Delta E = E(p')_{calc} - E(p')_{measure}$$

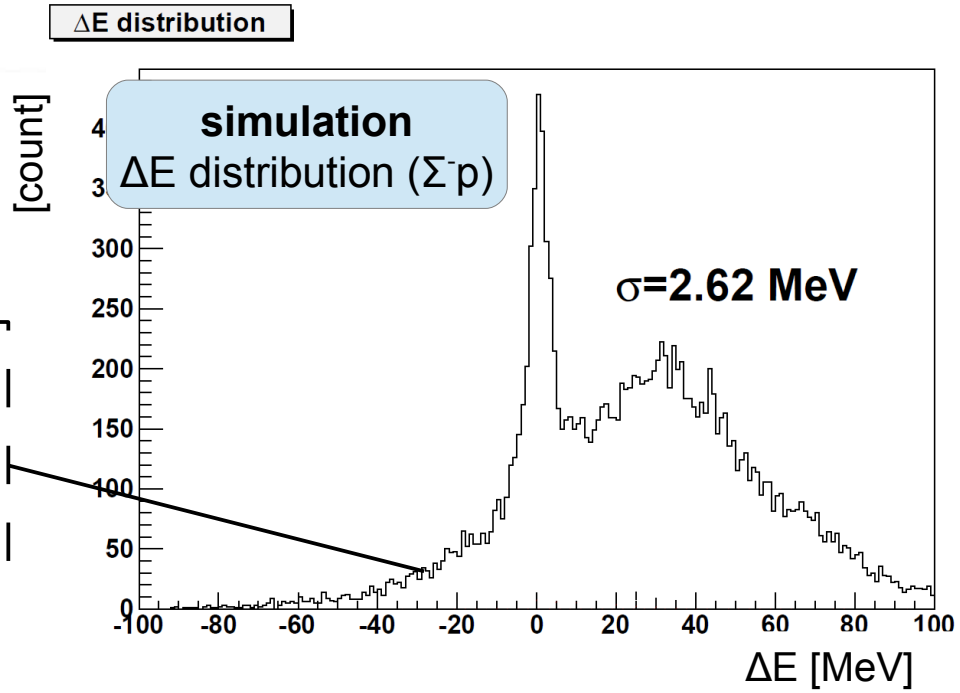
ΔE should be 0 for Σp event

Back ground

Scattered by Σ decay products

・・・$\Sigma^- \rightarrow \pi^- n$, $np \rightarrow n'p'$

$\pi^- p \rightarrow \pi^{-\prime} p'$ etc



Evaluate ΔE to identify scattering event

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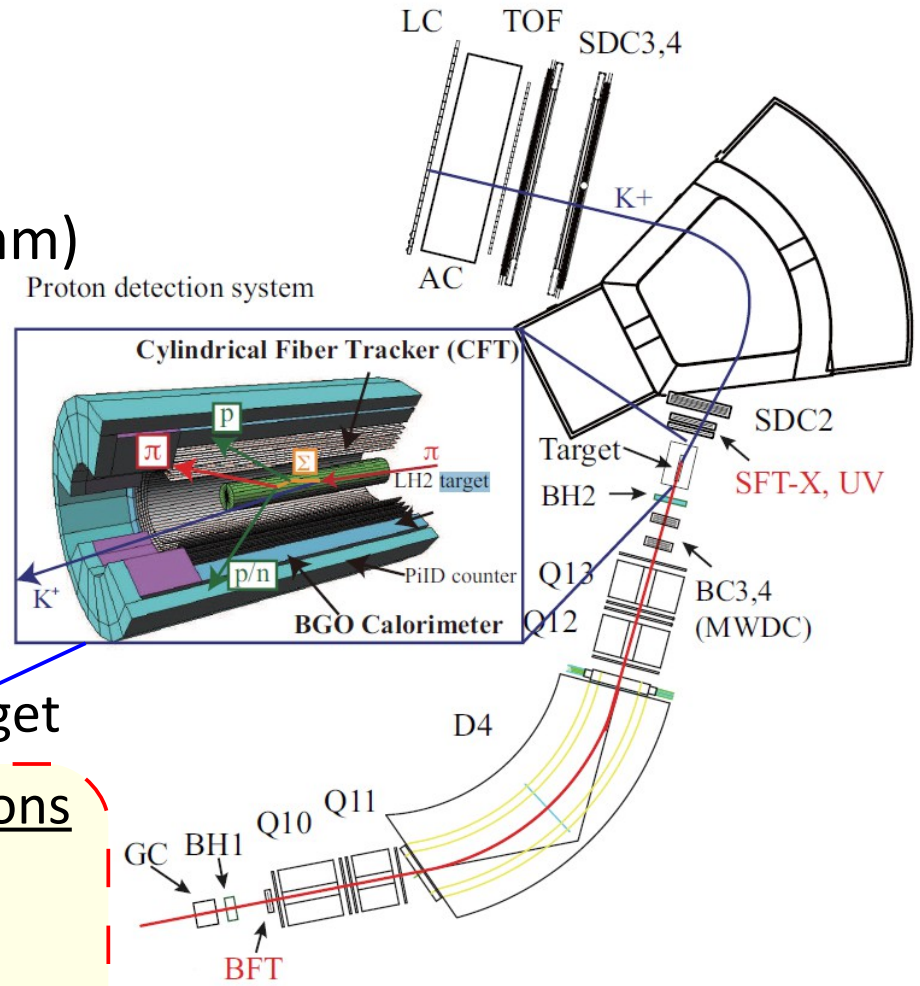
Setup for J-PARC E40

Setup

J-PARC K1.8 beam line

- Σ production & scattering
  - ・・・LH_2 target (thickness; 300mm)
- Beam
  - π beam 20M[/spill] (spill≅2s)
  - π^-:1.32[GeV/c],π^+:1.42[GeV/c]
- Spectrometer
  - upstream & downstream of target
- Detector system for scattered protons
  - Around the target
  - Cylindrical Fiber Tracker (CFT)
  - BGO Calorimeters



developing

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BGO calorimeter

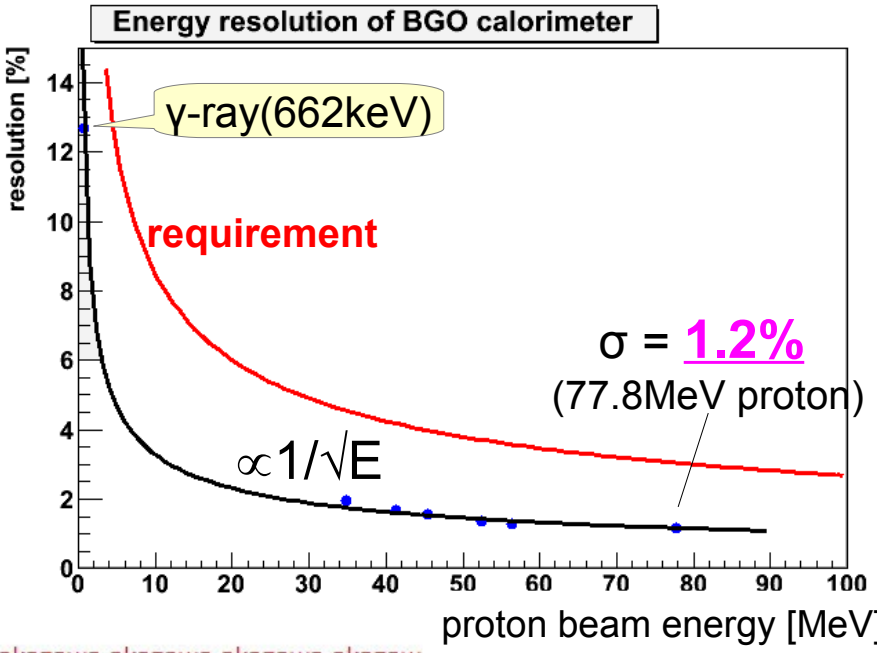
- requirements
  - Energy resolution
    - $\sigma \cong 3\%$ for 80 MeV
  - Enough **thickness**

    to stop protons (**～150 MeV**)
  - **Large size** to cover target and CFT(400 mm)

→→ **BGO crystal ($Bi_4Ge_3O_{12}$)**

$32(w) \times 25(t) \times 400(l)\ mm^3$

Energy measurement
using proton beam
at CYRIC (Tohoku Univ.)



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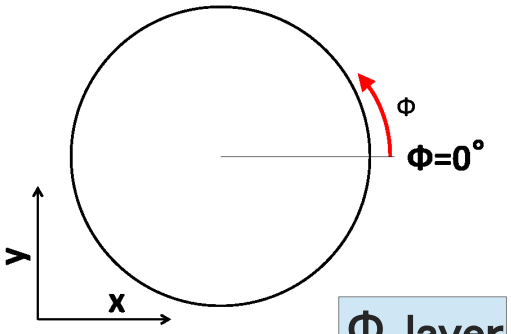
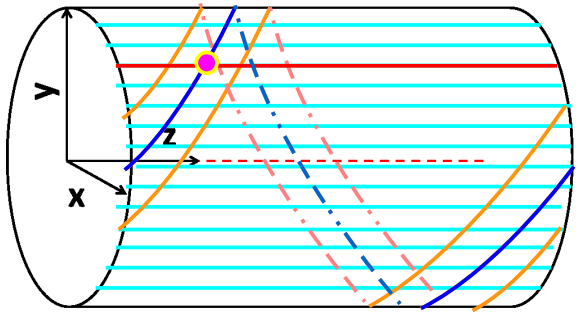
Cylindrical Fiber Tracker (CFT)

Is it possible to make such a special fiber configuration ?

- Compact size
  - Acceptance of downstream spectrometer
- Active region ・・・ **400mm** (beam direction)
- Track finding 3 dimensionally
  - 4 Φ layers (straight layer)
  - 4 UV layers (helical layer)





Φ layer measure "Φ"

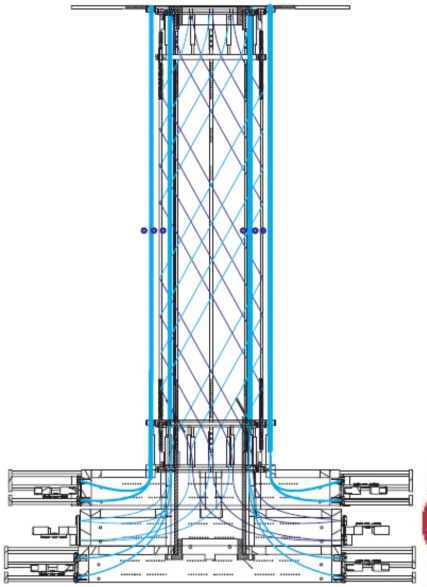
U・V layer get **z** position using "Φ"

Prototype

★3 layers
- •2 Φ layers
- •1 U layer

★Same size with actual

★Fiber diameter：0.75mm
(Kuraray SCSF-M78NN)



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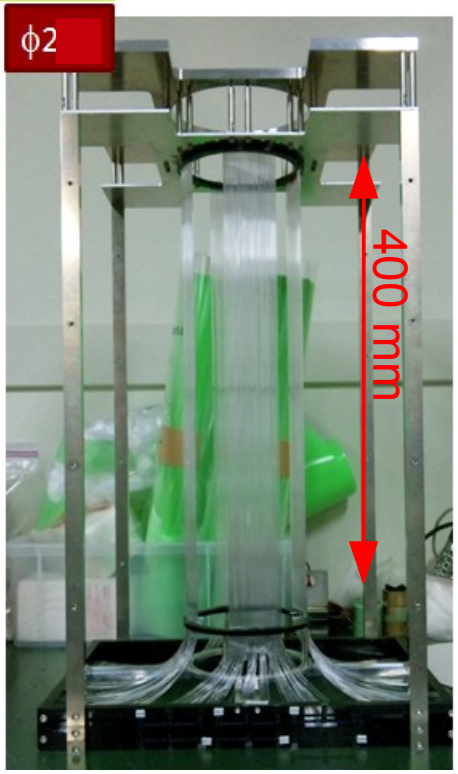
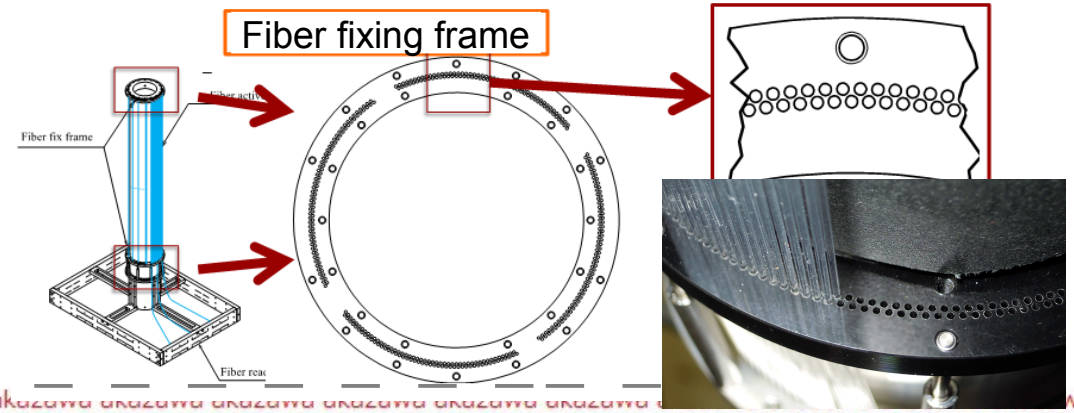
CFT : Development of a prototype

Fiber fixing frame and support bar
→ realize such fiber configuration

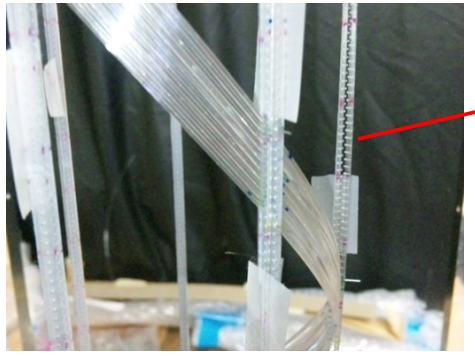
Straight layer

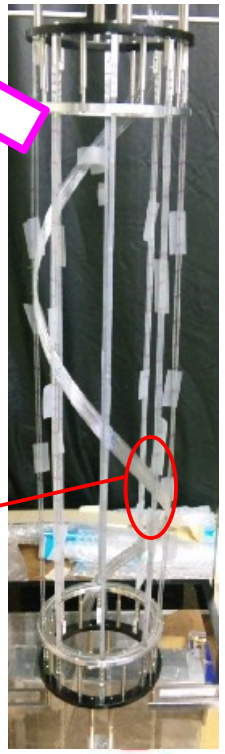


Fiber fixing frame



Helical layer





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CFT : Development of a prototype

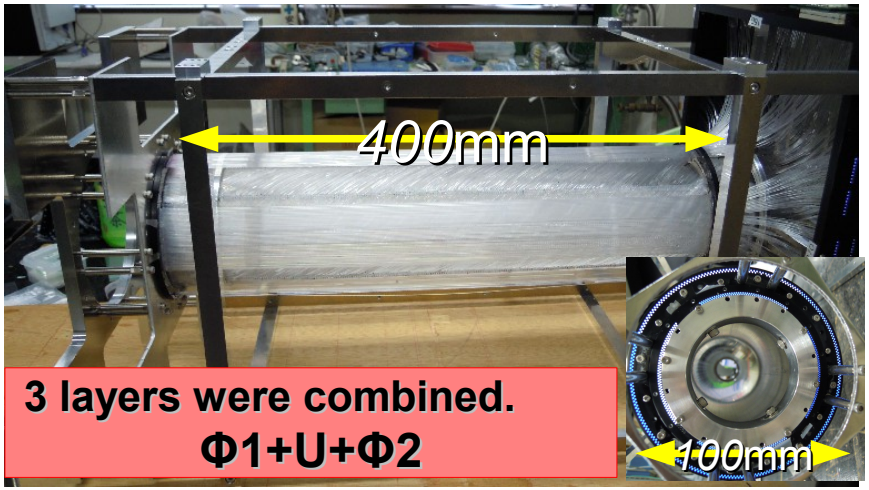
Fiber fixing frame and support bar
→ realize such fiber configuration

Straight layer

ϕ2

U

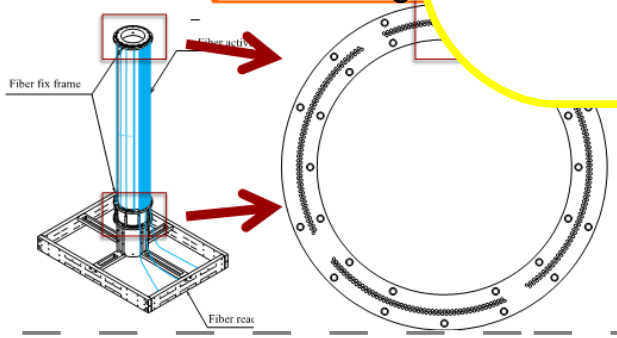
Helical layer

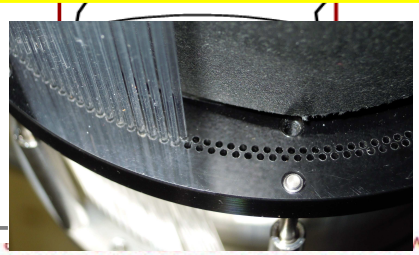


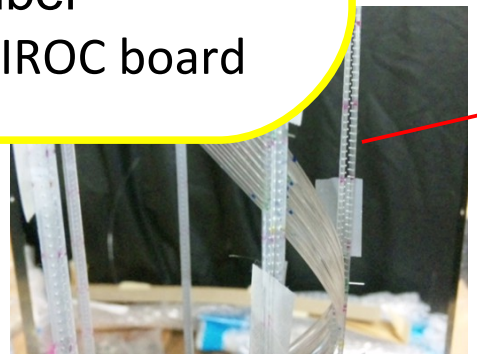
3 layers were combined.
Φ1+U+Φ2

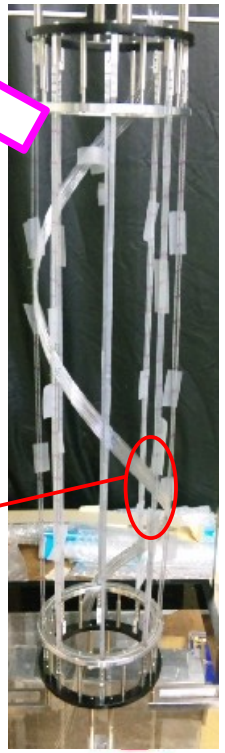
- about 1100 fibers
- Readout : MPPC fiber by fiber
  ↑ handled by EASIROC board

Fiber fixing









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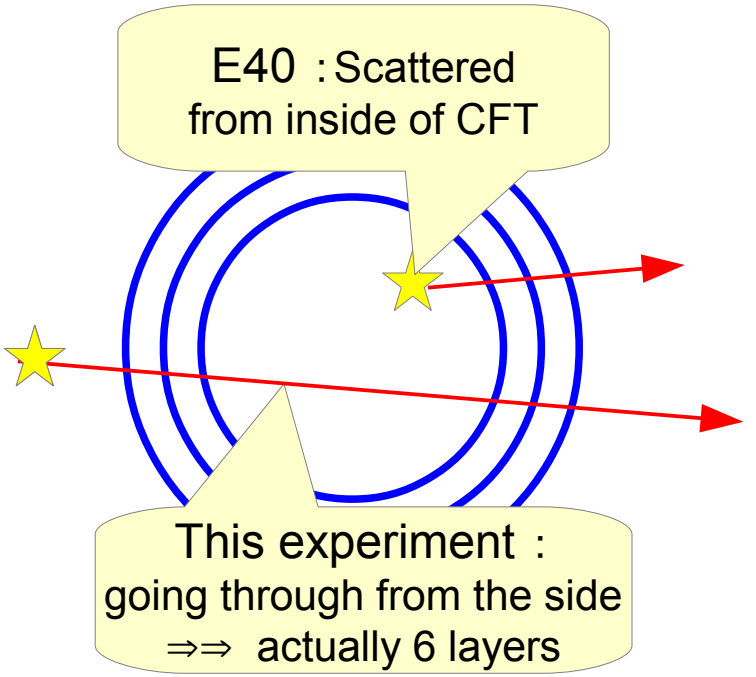
performance evaluation of (BGO + CFT)

pp,*p*C scattering experiment
@ CYRIC (Tohoku Univ.) 2013/7/23~25

purpose

- scattering event identification test

Because prototype CFT does not have enough layers



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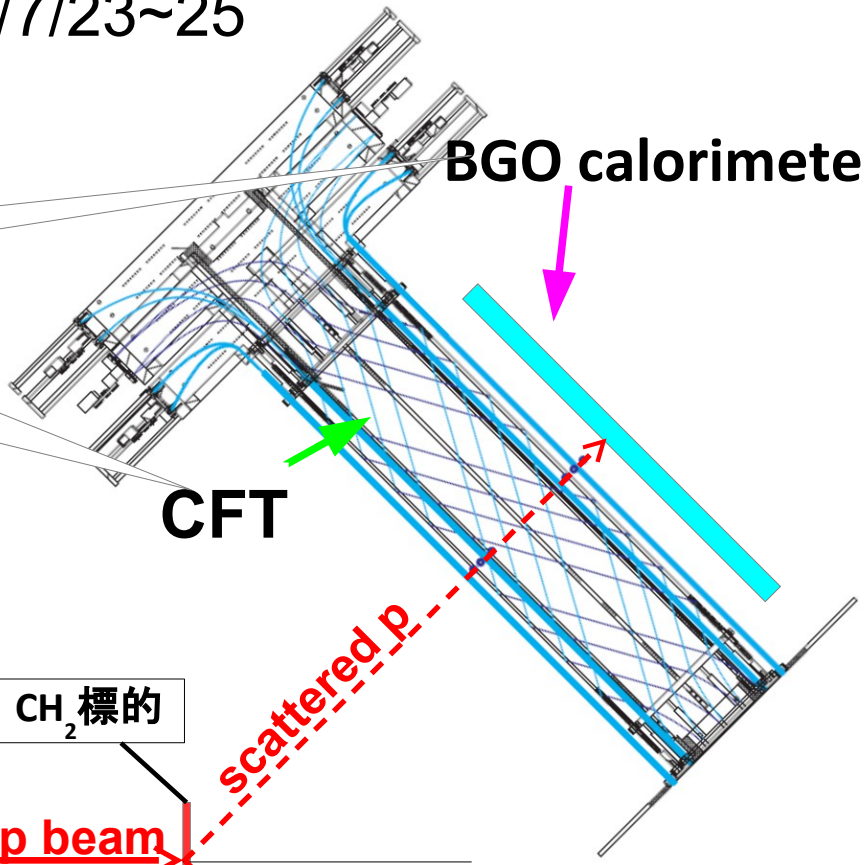
performance evaluation of (BGO + CFT)

pp,*p*C scattering experiment
@ CYRIC (Tohoku Univ.) 2013/7/23~25

purpose
- scattering event identification test

kinetic energy: ***E***

scattering angle: ***θ***
energy deposit: ***dE***



① angular resolution of CFT

② resolution of $\Delta E = E_{p'calc} - E_{p'measure}$

③ dE(CFT) & E(BGO)→ PID π/p

compare with cosmic ray

④ cross section

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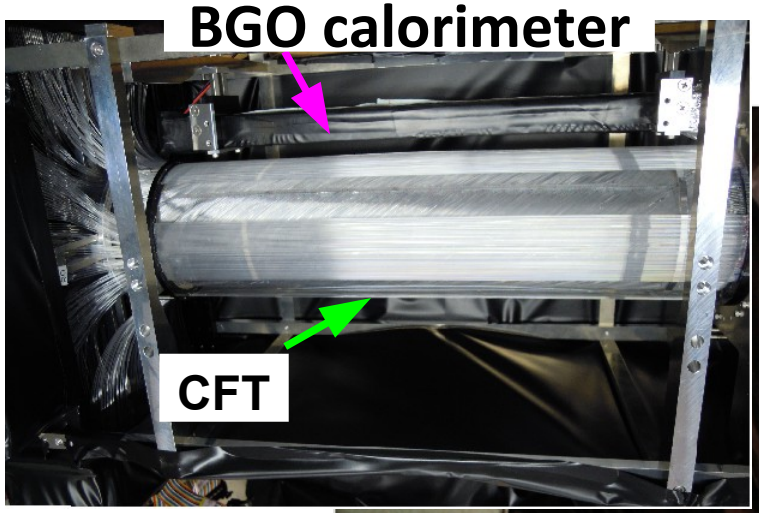
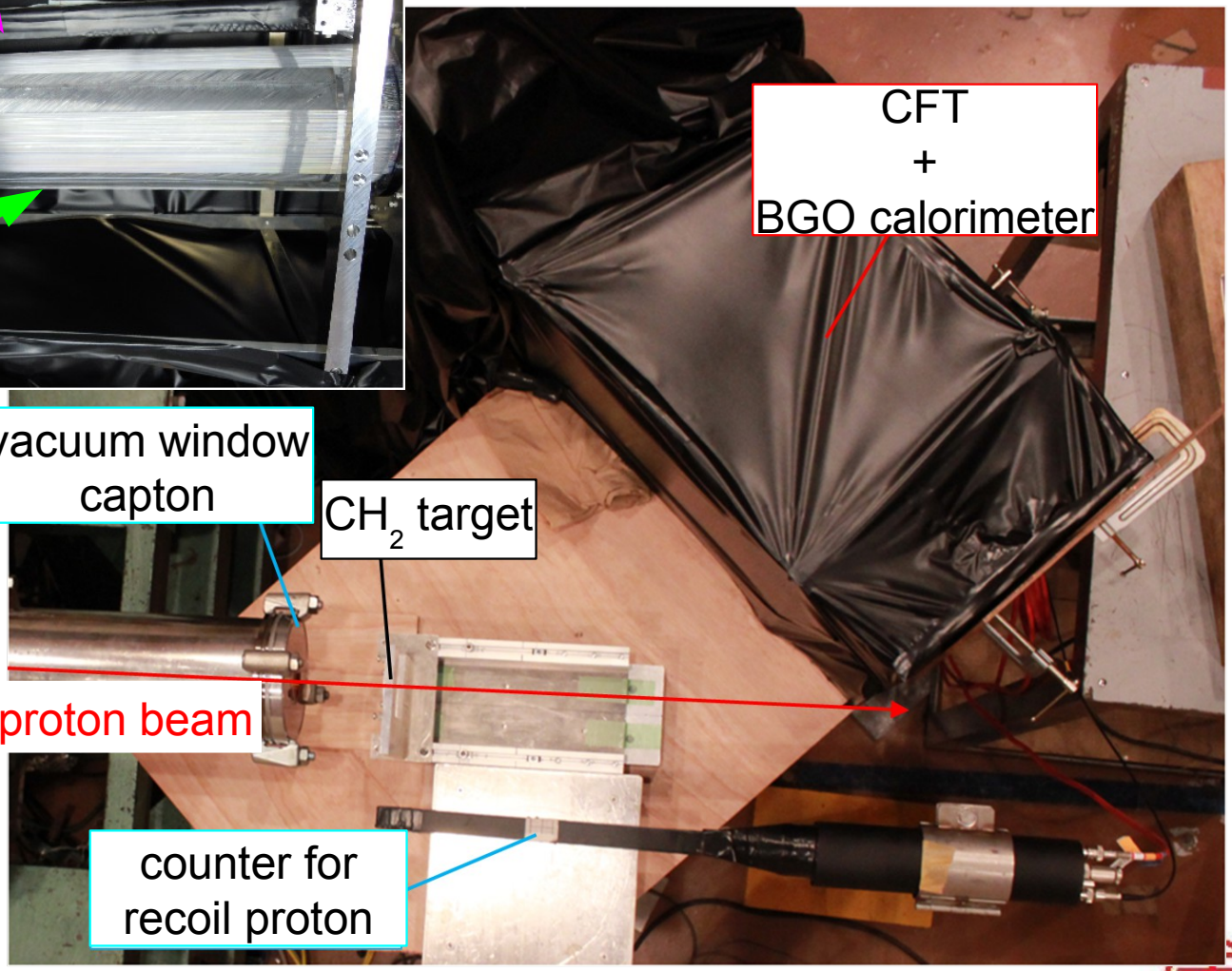
pp,*p*C scattering experiment : setup





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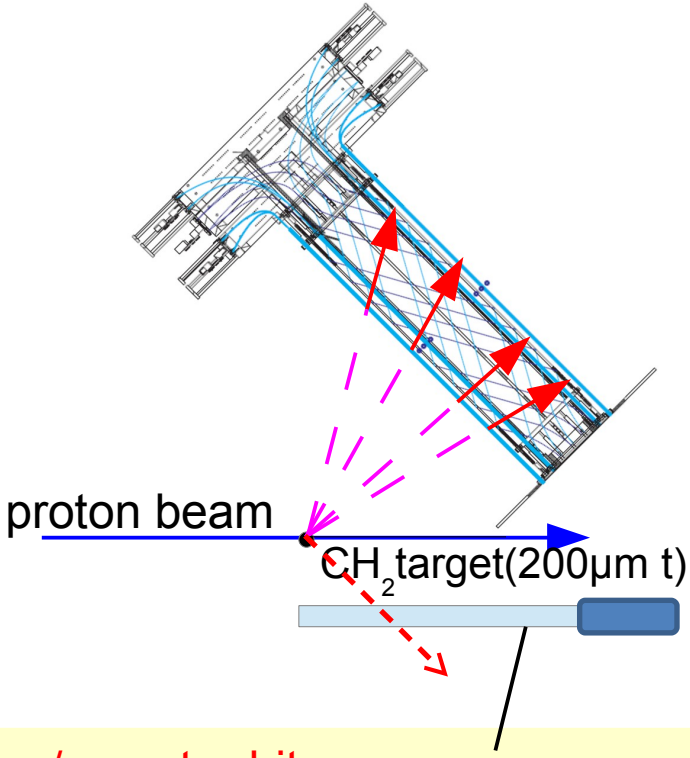
① angular resolution of CFT

Track finding using CFT

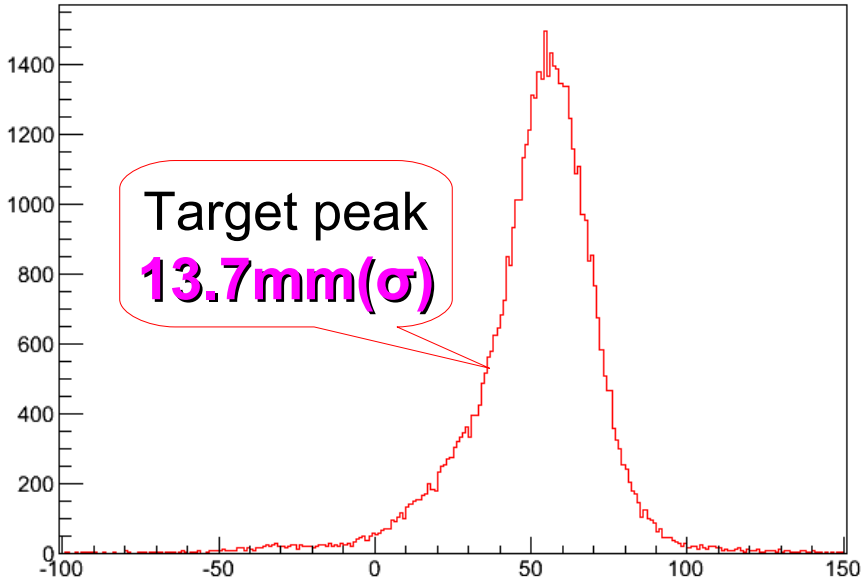
----> vertex (beam line × trajectory)



w/ counter hit :

pp scattering with H target in CH_2

vertex **w/** counter hit



・estimated from σ_{vertex}=13.7mm

$\sigma_{\Delta\theta}$=1.0°

・Ideal resolution (Geant4)

$\sigma_{\Delta\theta}$=0.77° , σ_{vertex}=9.4mm

⇒ miss-aliment of some fibers caused this deterioration

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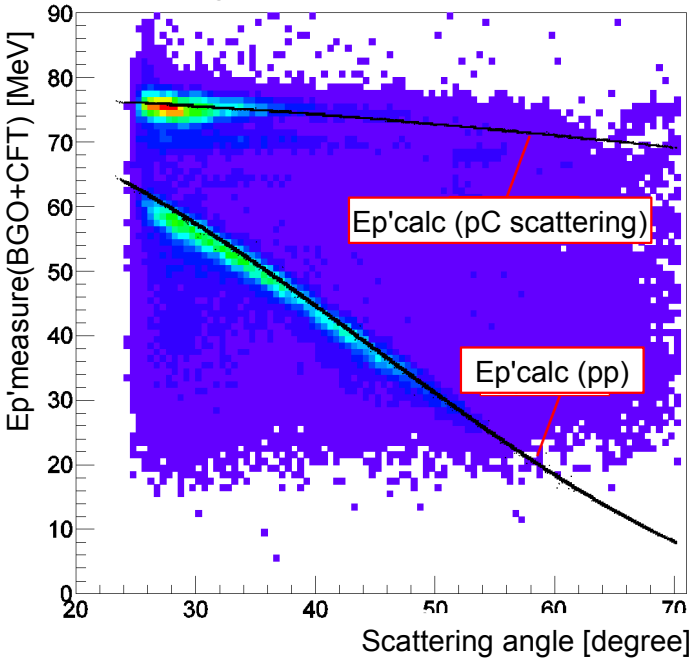
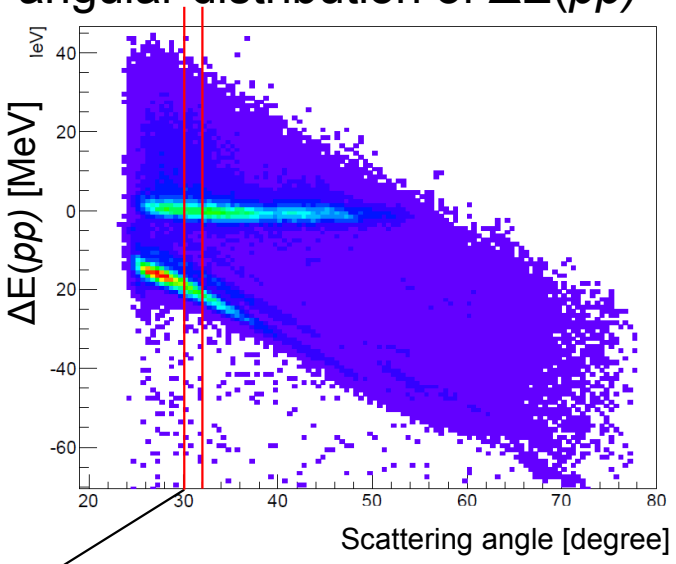
② ΔE resolution

Angular distribution of Ep'

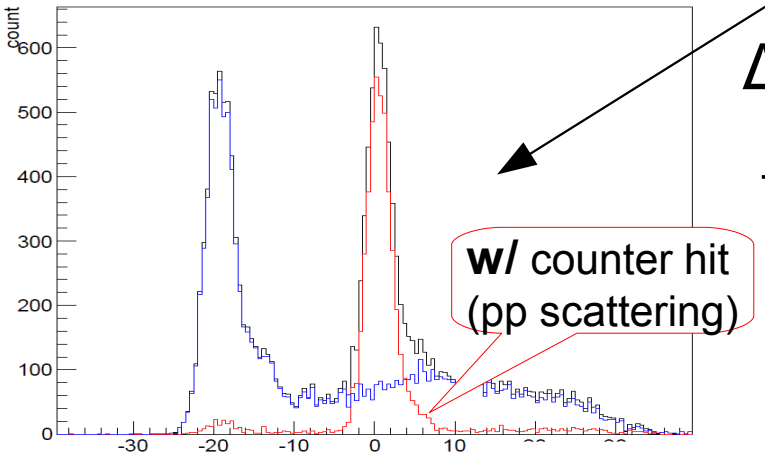


- ΔE(*pp*) = Ep'calc(pp scattering) - Ep'measure
- θ : scattering angle

angular distribution of ΔE(*pp*)



deltaE_pp 30~32degree



ΔE(pp) resolution

1.8MeV(σ) for whole θ region

⇔ ideal ; 1.5 MeV(σ)

detector system was **able to identify** scattering event.

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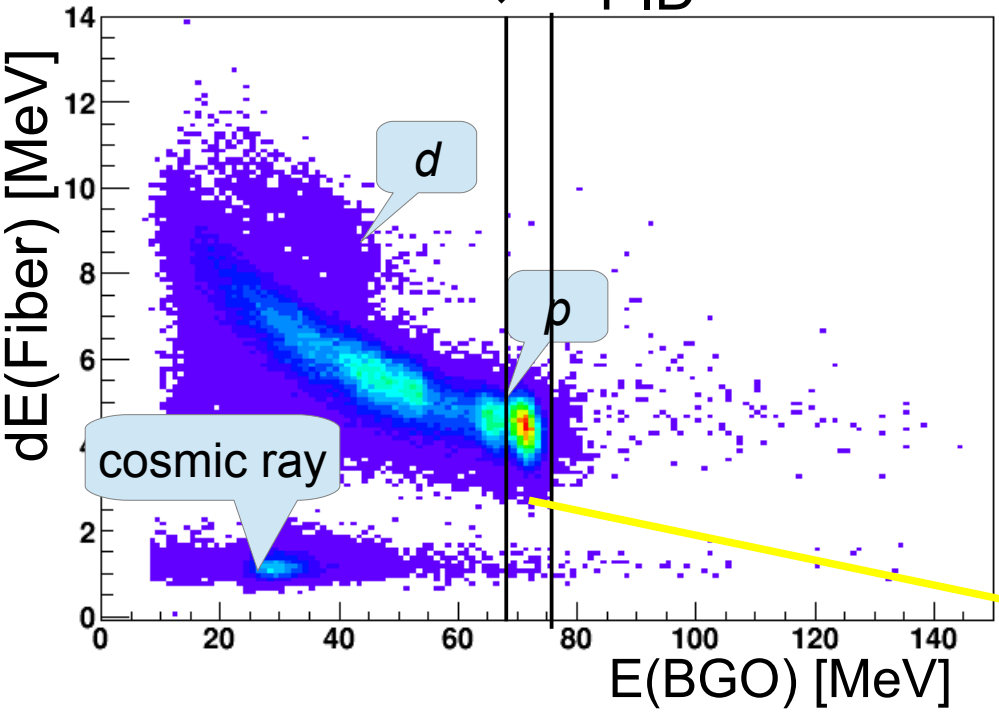
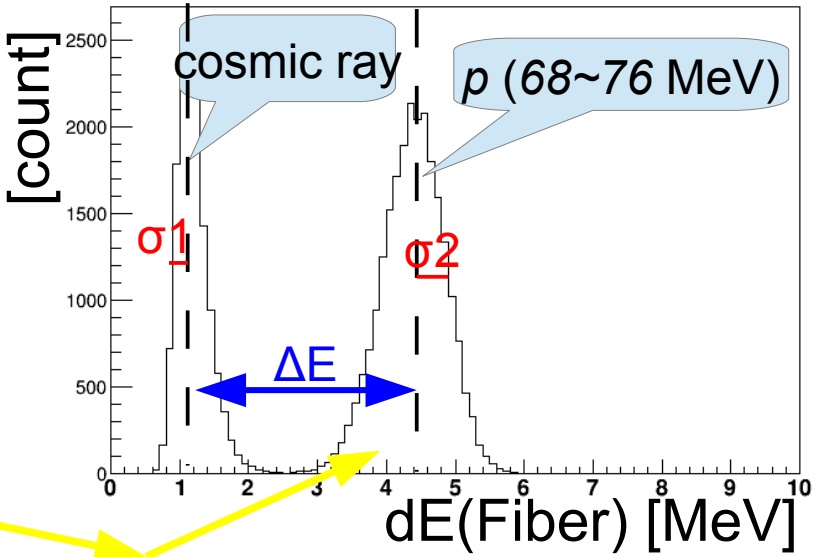
③ Particle Identification

correlation between dE(CFT) and E(BGO)

⇒ PID





resolving power
(≃ *70* MeV proton and cosmic-ray)

$\Delta E/(\sigma 1+\sigma 2) \simeq 5\sigma$

possible to resolve

Energy resolution of CFT

10 % **(dE ≃ *4～6* MeV)**

↖proton(*30~80* MeV)

16 % **(dE ≃ *1* MeV)** ←cosmic ray

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④ cross section : *p*C scattering

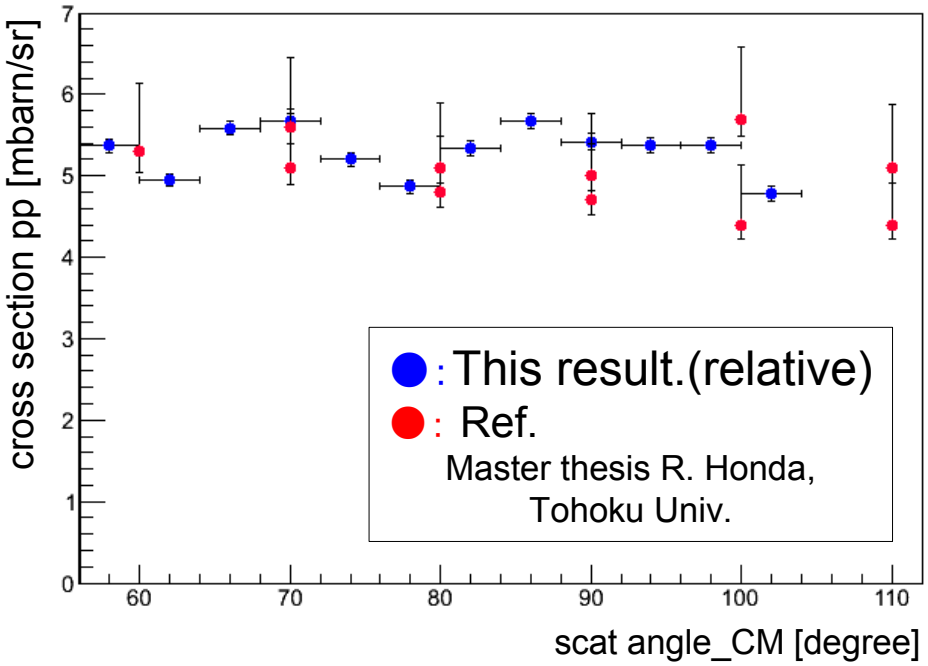
differential cross section

→→ check the identification performance again

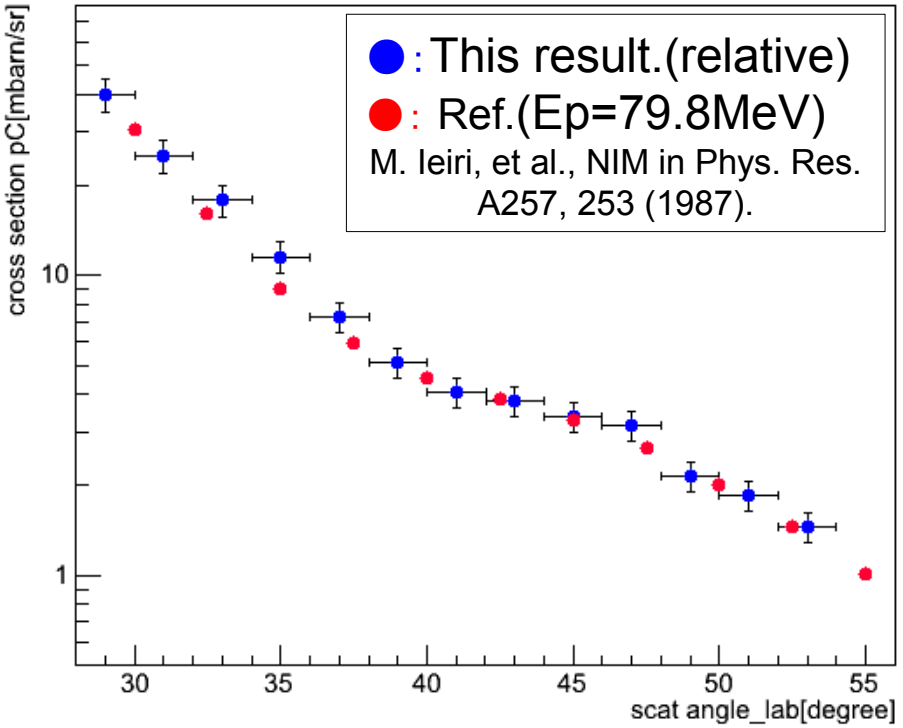
※undecided value
- beam flux (instrument)
- target select (air influence)

⇒ **angular distribution** of dσ/dΩ
(not absolute value)

cross section (*pp*)



cross section (pC)



consistent with the past experiment

→→ **Track finding by CFT** and **event identification** are successful !

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summary

- We plan to perform Σp scattering experiment at J-PARC(E40)
  - ・to confirm the quark Pauli effect
  - ・to provide essential information to study ΣN interaction
- Developing detectors
  - ✓ BGO calorimeter
    - Energy resolution **σ = 1.2 %**(*77.8* MeV p), ∝ **1/√E** relation
  - ✓ CFT
    - Established the construction method
    - **succeeded to find track**
    - angular resolution σ_θ **= 1.0[degree]** ⇔ ideal value; σ = 0.77[degree]

      need to improve
  - ✓ Detector system (BGO + CFT)
    - ΔEpp resolution=**1.8MeV(σ)**
    - Resolving power ≃***5σ*** for ***p* and *cosmic-ray***
      - CFT energy resolution; ***10 %***(*80* MeV proton) , ***16 %***(cosmic-ray)
    - pC scattering dσ/dΩ ・・・ consistent with the past experiments

      ----> **track finding by CFT** and **identification of scattering event** are successful

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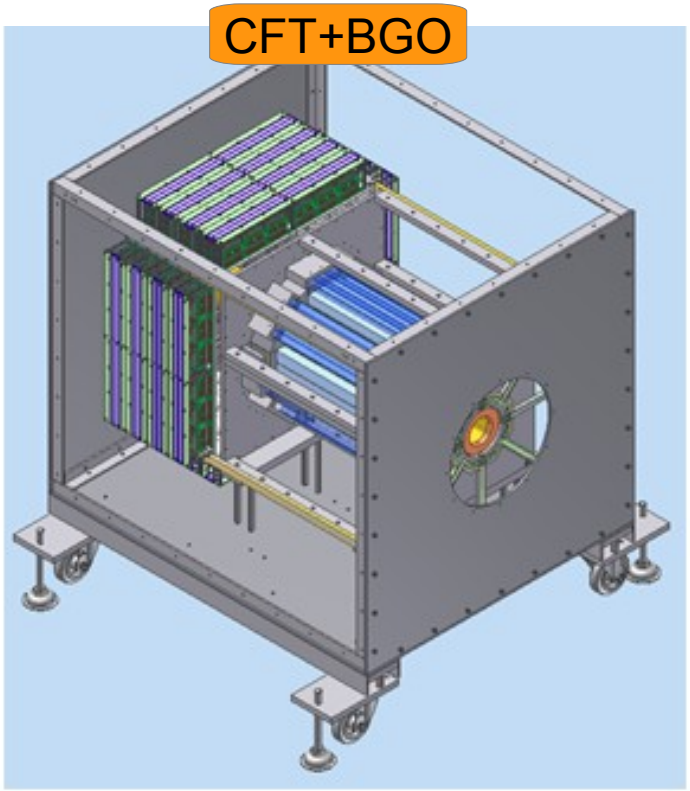
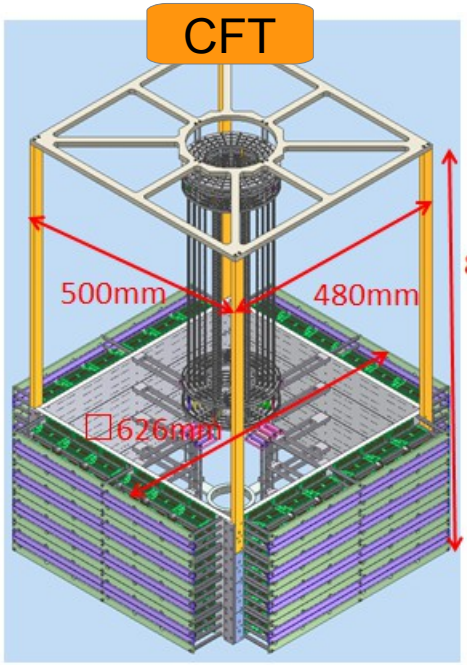
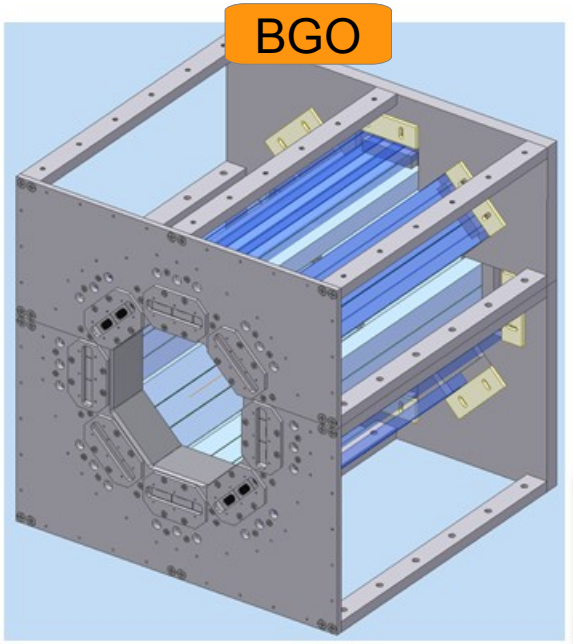
To do

Actual detectors

- Design have almost finished
- To be made







・CFT ・・・

4 Φ layers,4 U・V layers

~5,000 fibers

・BGO calorimeter ・・・

24 BGO($30\times25\times400mm^3$)

will be placed cylindrically

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