The Abdus Salam
International Centre
for Theoretical Physics

Bragg Curve Counter at intermediate energy

Toshiya SANAMI

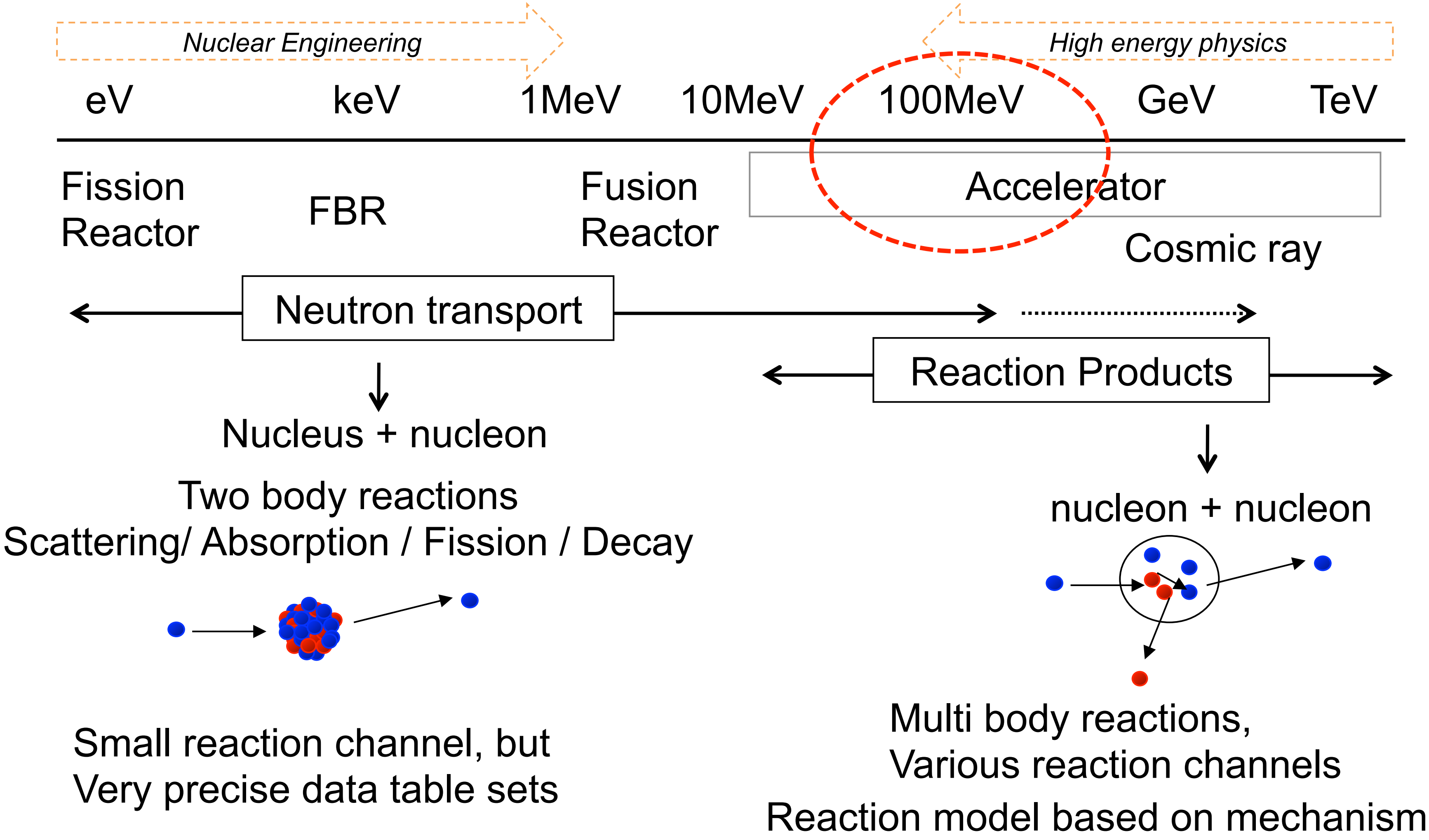
Radiation science center, Applied research laboratory,
High energy accelerator research organization (KEK)

School of high energy accelerator science,
The graduate university for advanced studies (SOKENDAI)

Scope of this talk

- DDX measurement for fragment production reaction using Bragg curve counter
  - Why do we need charged particle production reaction at hundred to tens of MeV projectiles.
  - How to measure the charged particles
  - Proton incident
    - Bragg curve counter
    - Electronics
    - Results
  - Neutron incident
    - Counter telescope
    - Bragg Curve Counter

Introduction

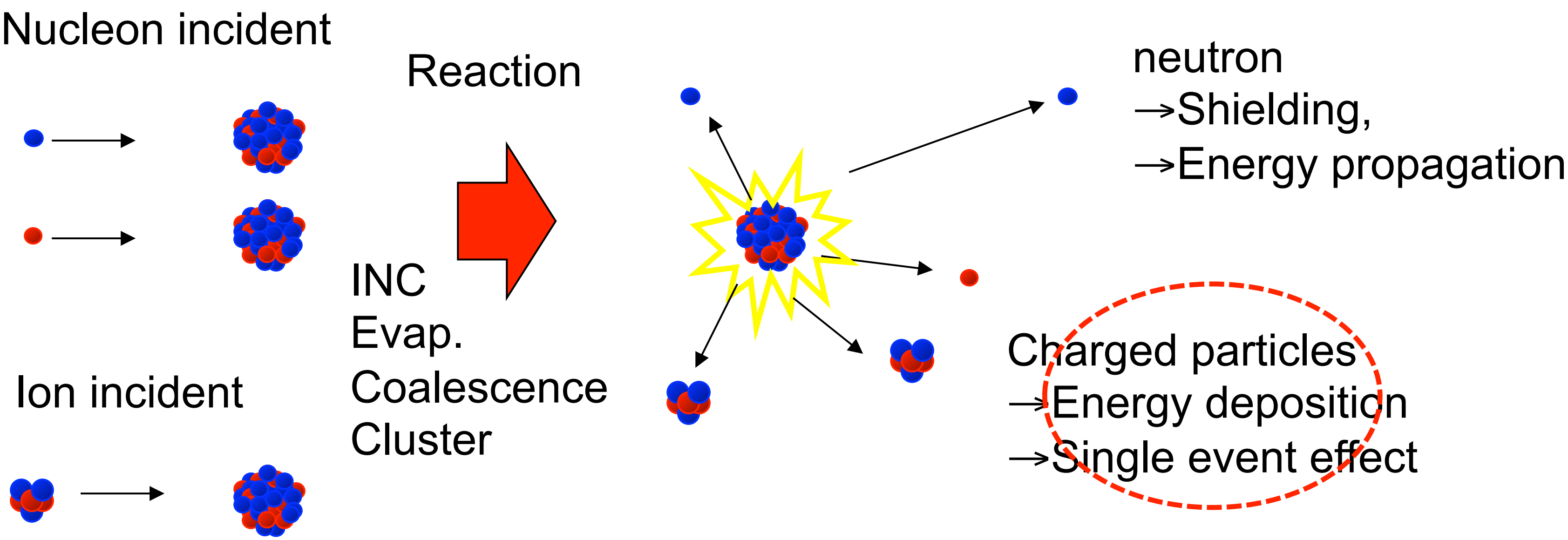


What should come out between two hierarchies ?

Nuclear reaction in intermediate energy

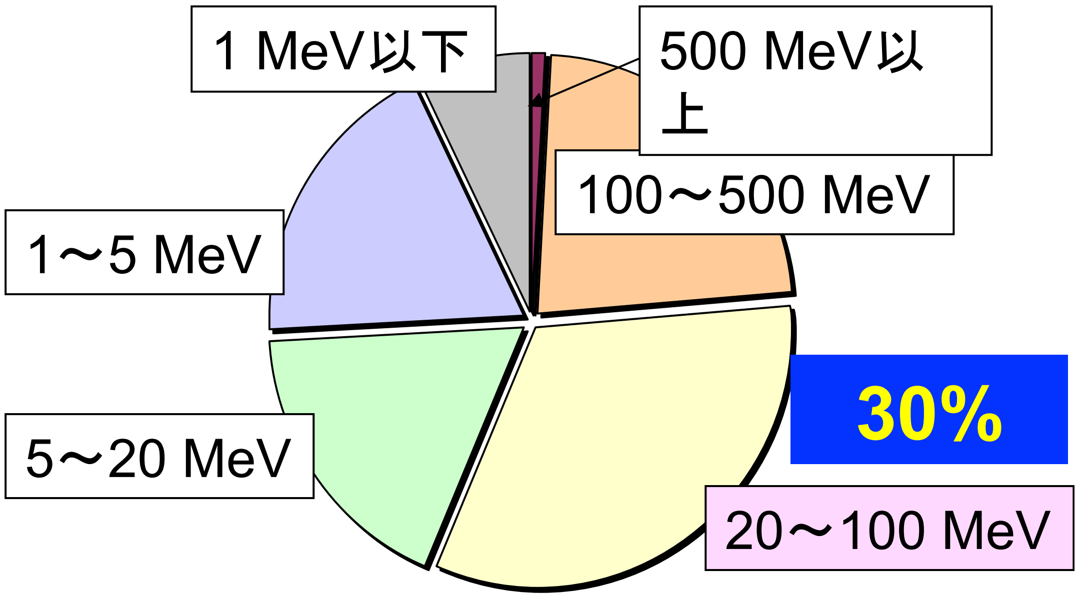
Reaction data on Intermediate energy

Application
Tumor therapy, Single event effect, Nucleosysnthsys,
Accelerator Driven system, Radiation Safety design for accelerators

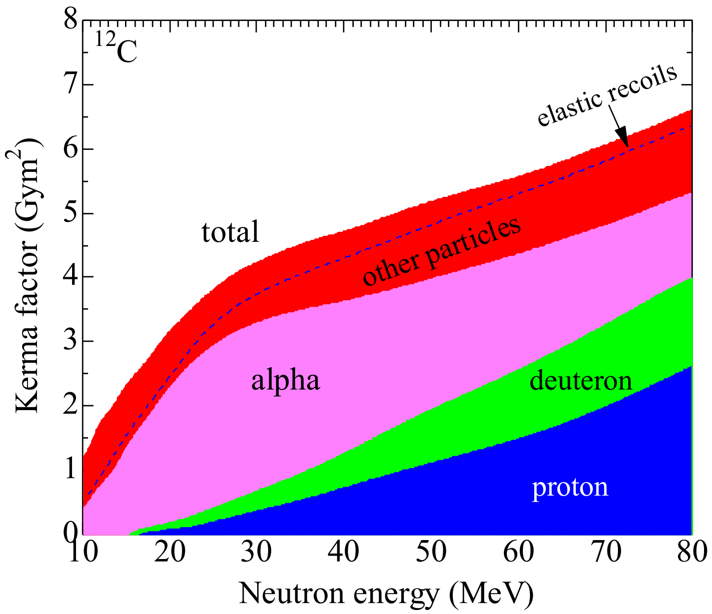


Experimental data are required to show what channels and models should be considered for each application

Neutrons above 20 MeV



Neutron effective dose at outside of 3 GeV proton accelerator housing



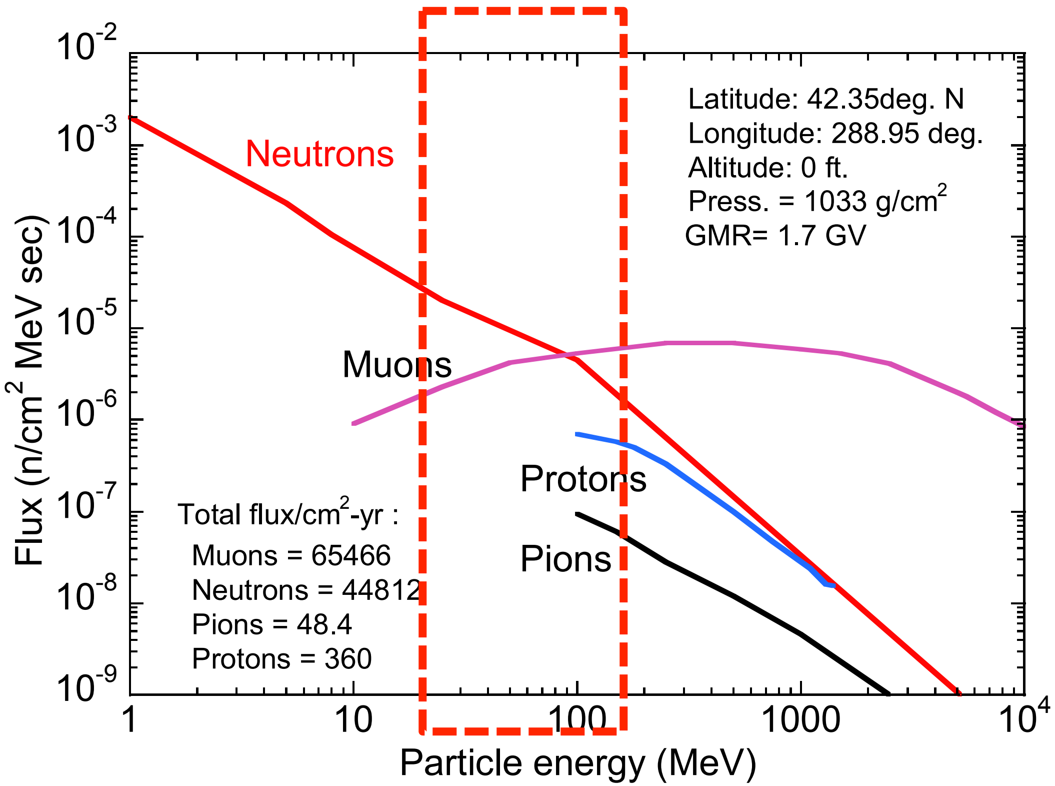
Contribution to KERMA factor (from LA150)

<u>DDX data of fragment production</u>

Single event upset

Single event upset (SEU)

→ Focus to fragment production



DDX data of fragment production

High density device

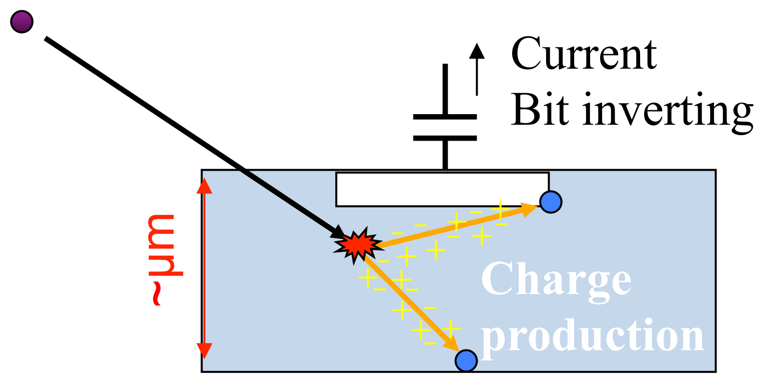
→ reduce critical charge

Fragment form nuclear reaction

→ production of electrons in a small region

Critical charge < charge production

→ Bit inverting



Experimental data

Incident	～20 MeV	20 to 1000 MeV	Above 1000 MeV
Neutron	**p,d,t,α** Data available **Li,Be,B,,,,** No production	**p,d,t,α** Data available **Li,Be,B,,,,** Few data	**p,d,t,α** No data **Li,Be,B,,,,** No data
Proton	**p,d,t,α** Data available **Li,Be,B,,,,** No production	**p,d,t,α** Data available **Li,Be,B,,,,** Few data	**p,d,t,α** Few data **Li,Be,B,,,,** Few data

Uppsala, Leuven
Tohoku

Beam should be provided by

Tohoku AVF
NIRS AVF
TIARA AVF

RCNP Ring
RIKEN

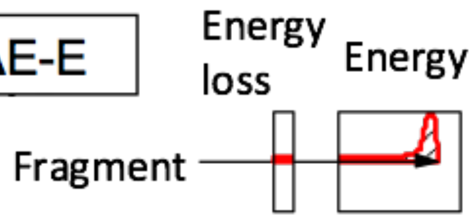
Neutron vs Proton

- Neutron - Produced as a secondary particle
  - Relatively low intensity
  - Impossible to focus
  - Difficult to count precisely
  - Background
  - Quasi-mono energetic
- Proton - Directory accelerated
  - High intensity
  - Easy to focus
  - Precise counting using counter or Faraday cup
  - No background
  - Mono energetic

- Measure cross section using proton to evaluate reaction model, then apply it to neutron

Methodology to measure of fragment

ΔE-E



Z id., high E res., high E_{thres}

Green, Machner, Budzanowski

E-TOF

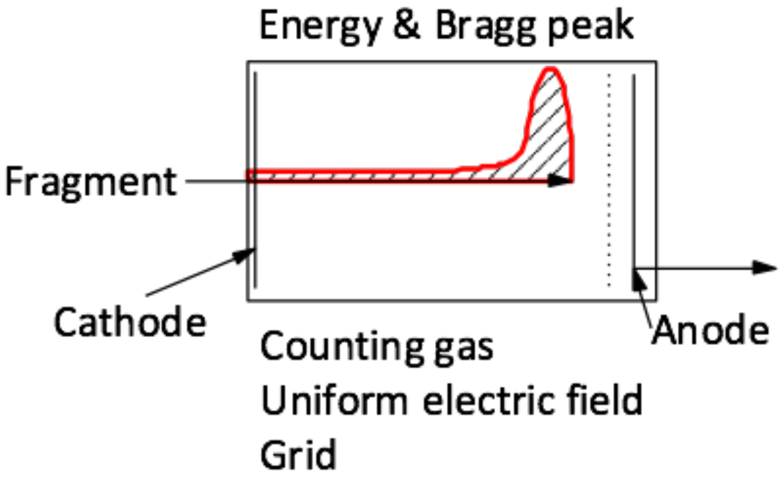
m id., low E_{thres}, low detection eff.

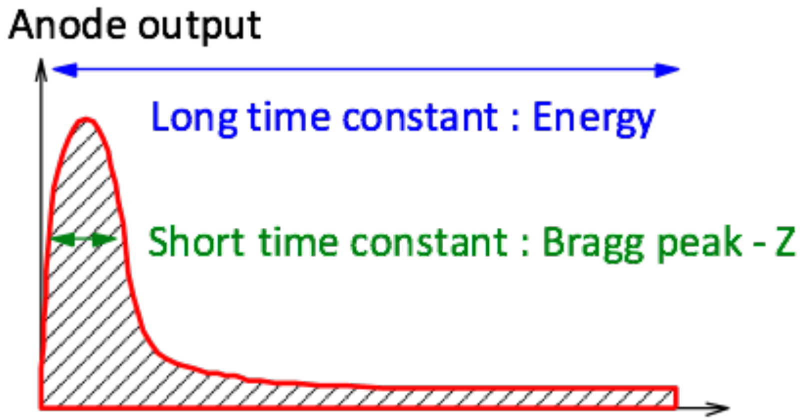
Katitokovski

Bragg Curve Counter

Z id., low E_{thres}, high detection eff.

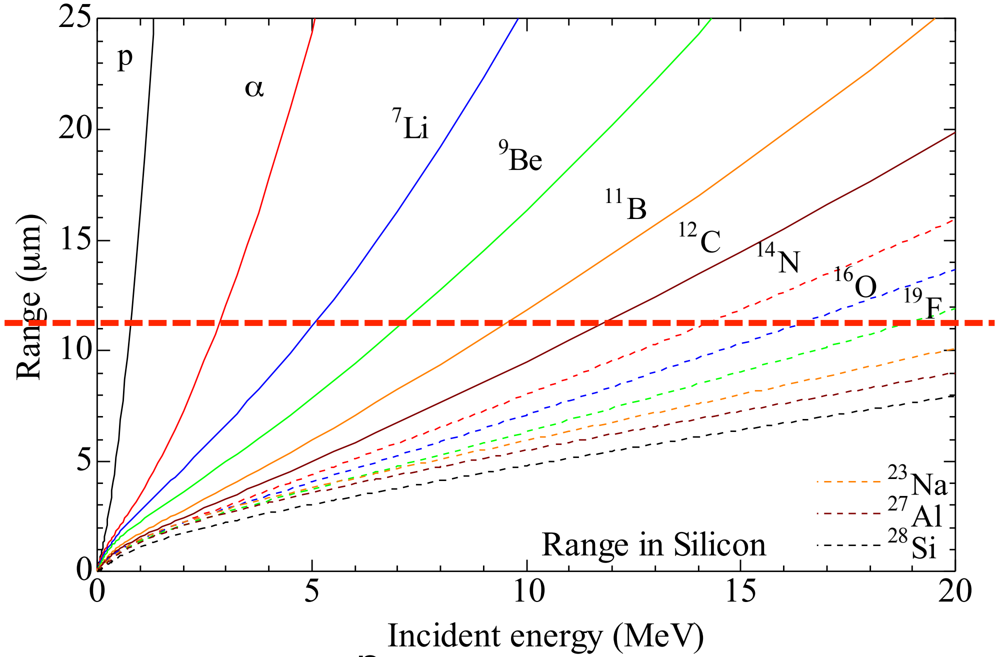
Present

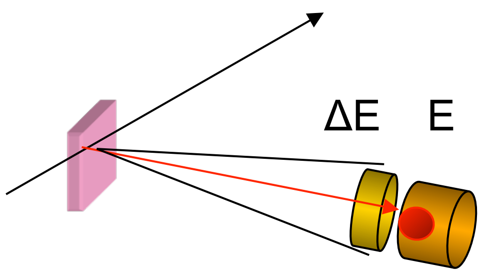




Energy loss for fragments

How to measure fragments



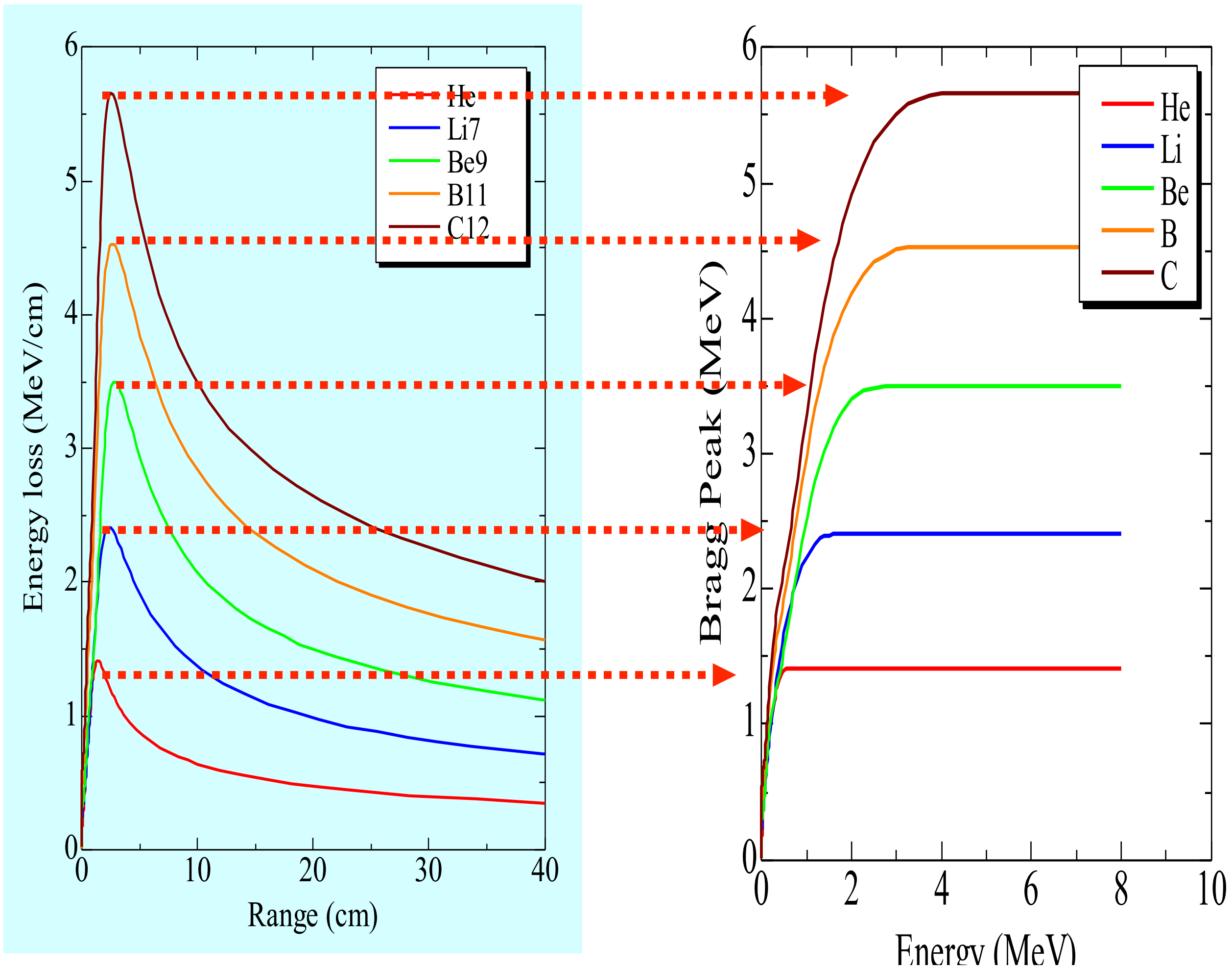


Large energy loss
→ Thin
Low production rate
→ Large area
Overlap light charged particle
→ Thin
→ Particle Identification

Thin large area SSD is not available
→ Develop detector

Bragg Curve Counter

Bragg peak height

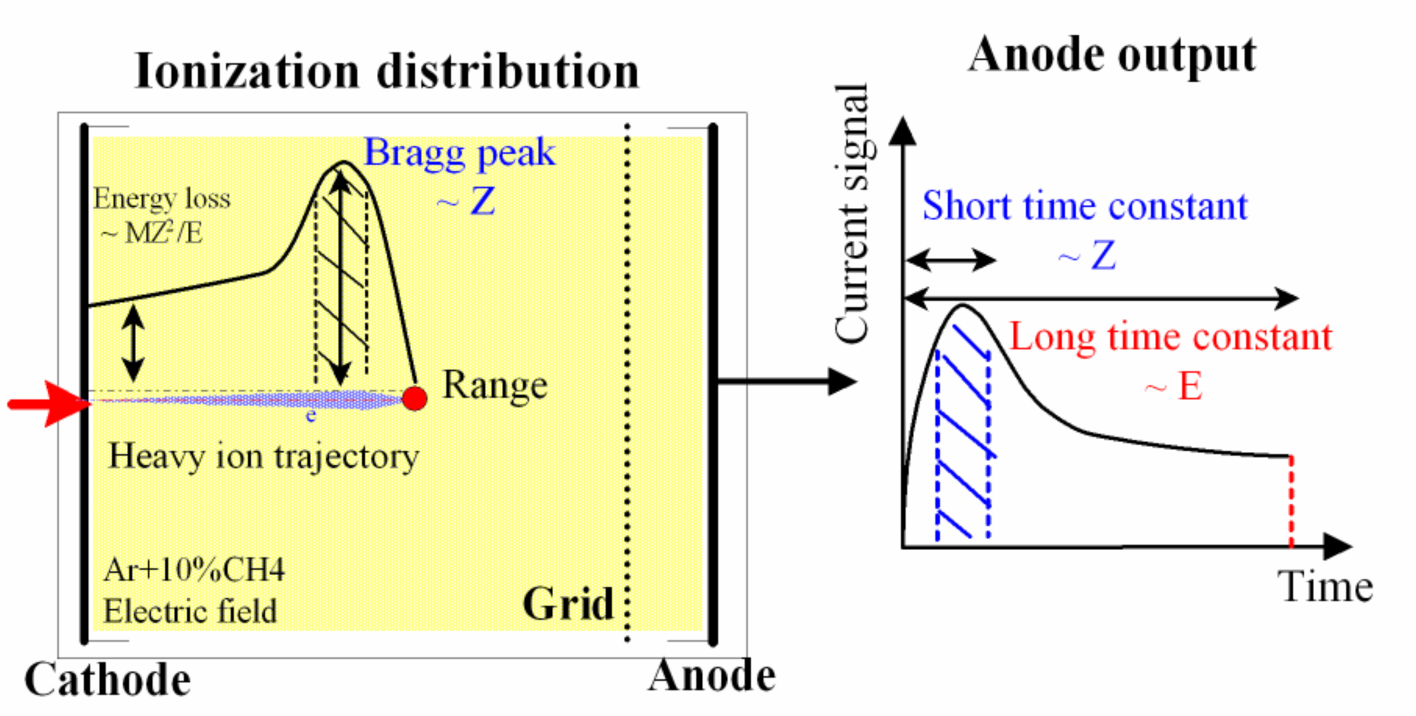


Different Bragg peak height → Distinguish Z number

Signal from Bragg Curve Counter

- Detector → Grid ionization chamber
  - Easy to become larger
  - Various thickness

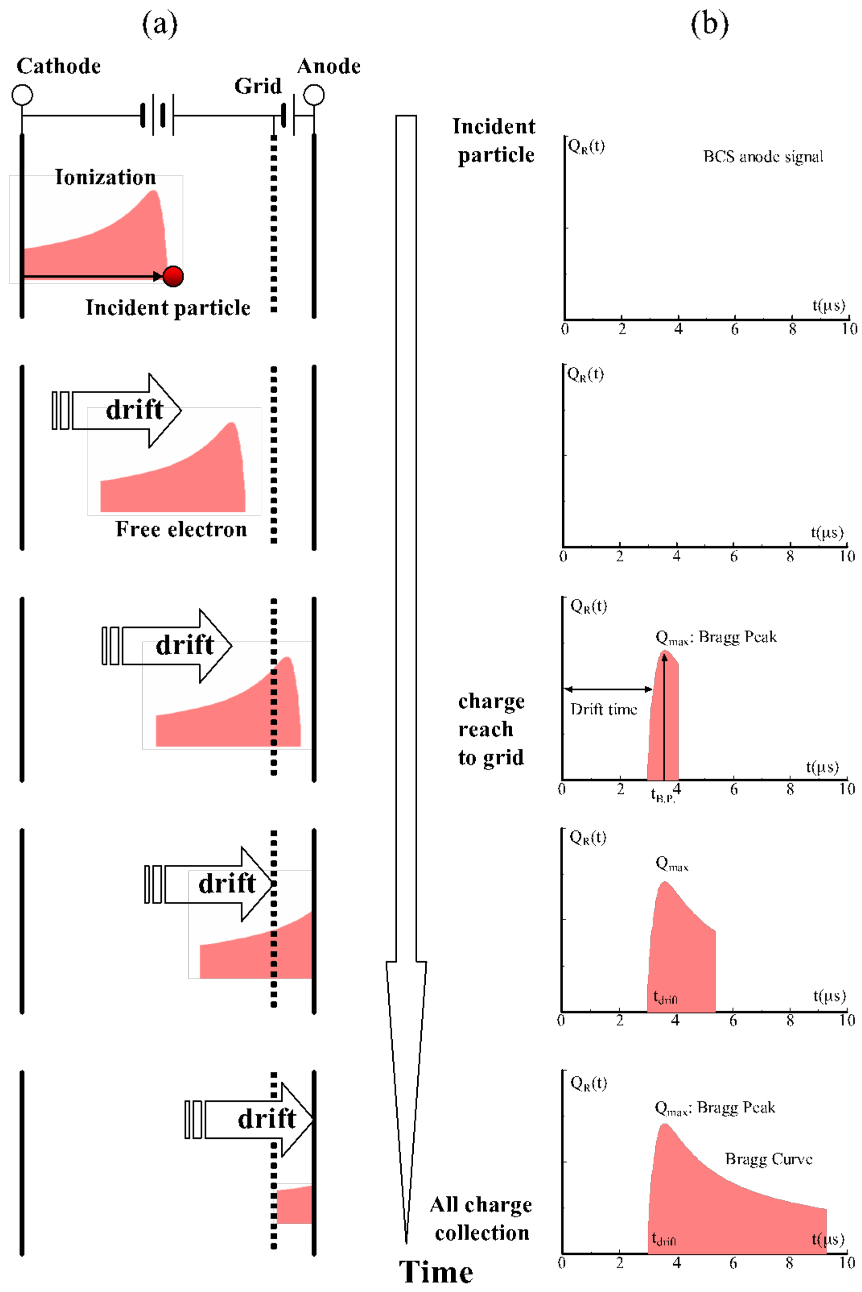
Total charge・・・Energy
Bragg peak・・・Particle identification



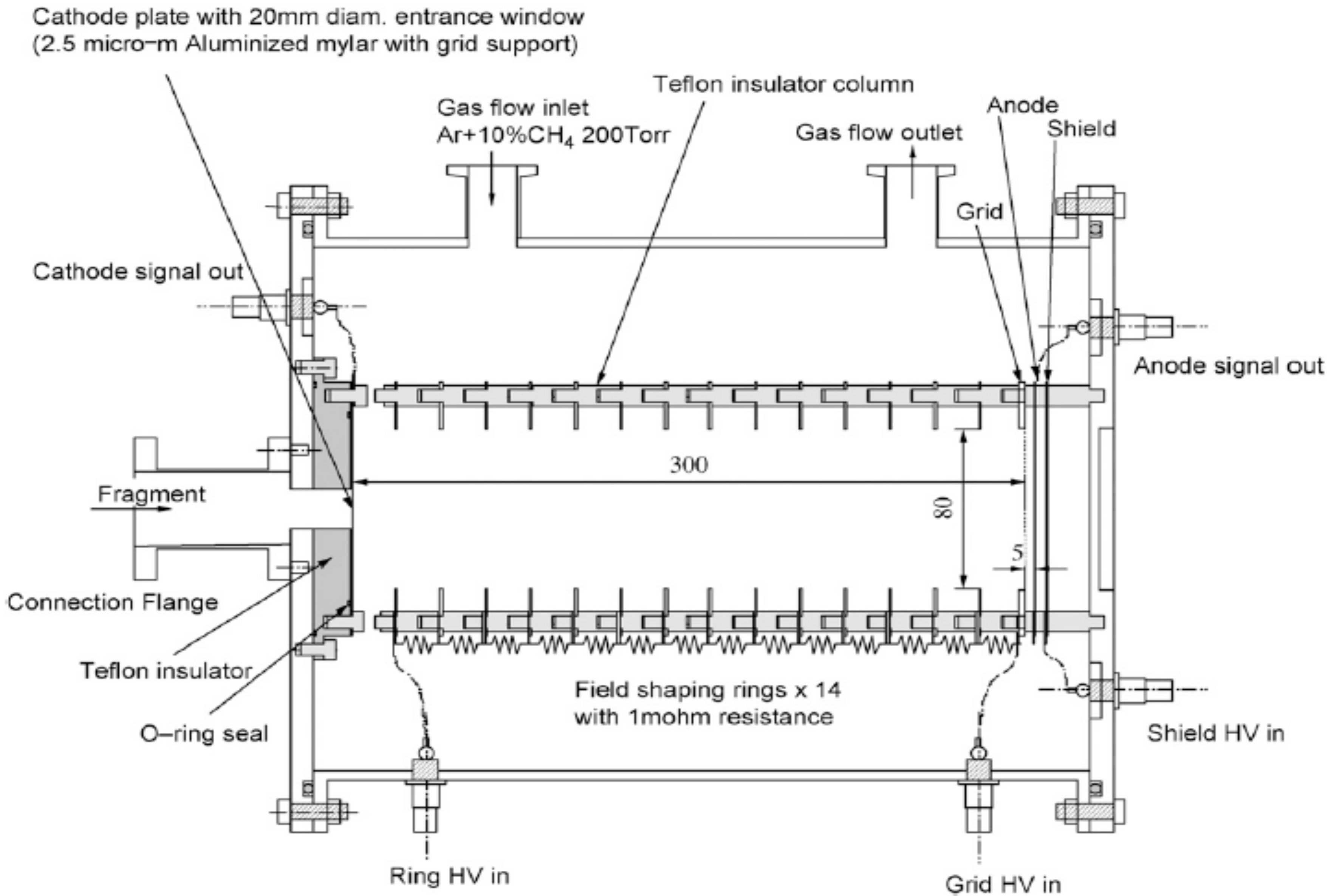
Charge and Energy of particle are obtained only one detector

→ Suitable for heavy ion measurement

Output from BCC



Actual setup of Bragg Curve Counter



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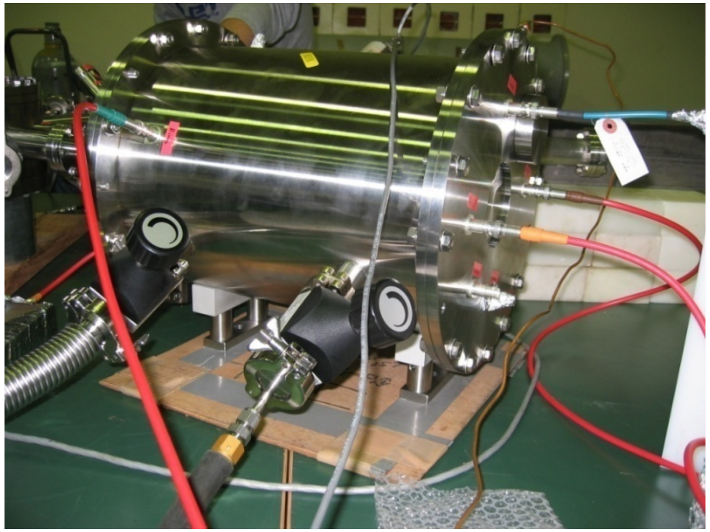
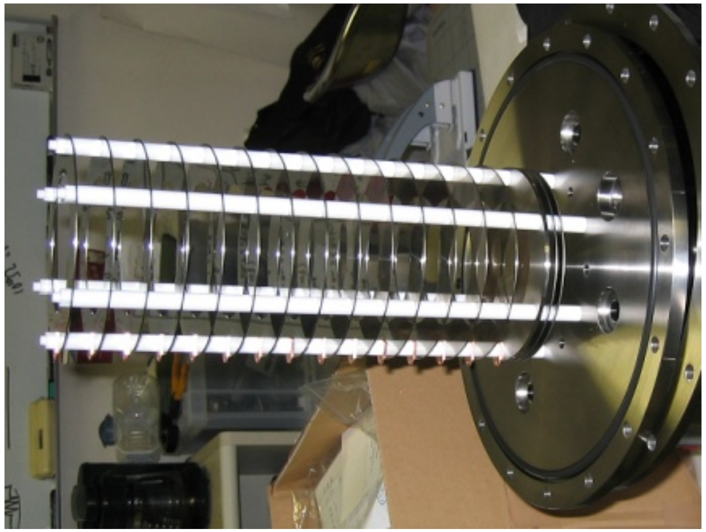
Picture of BCC

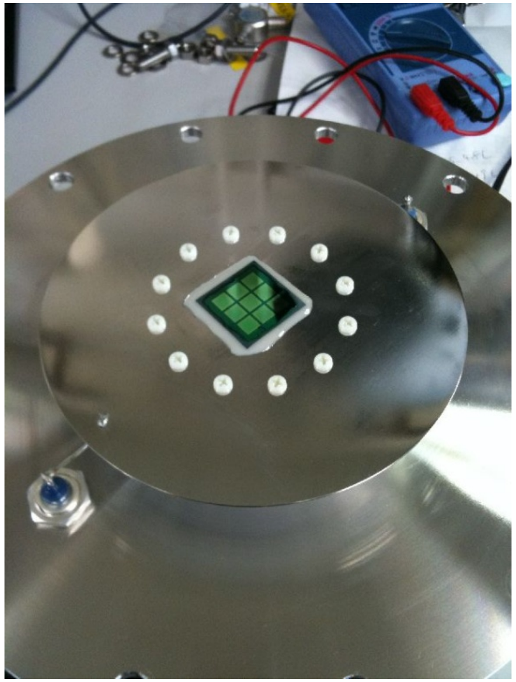


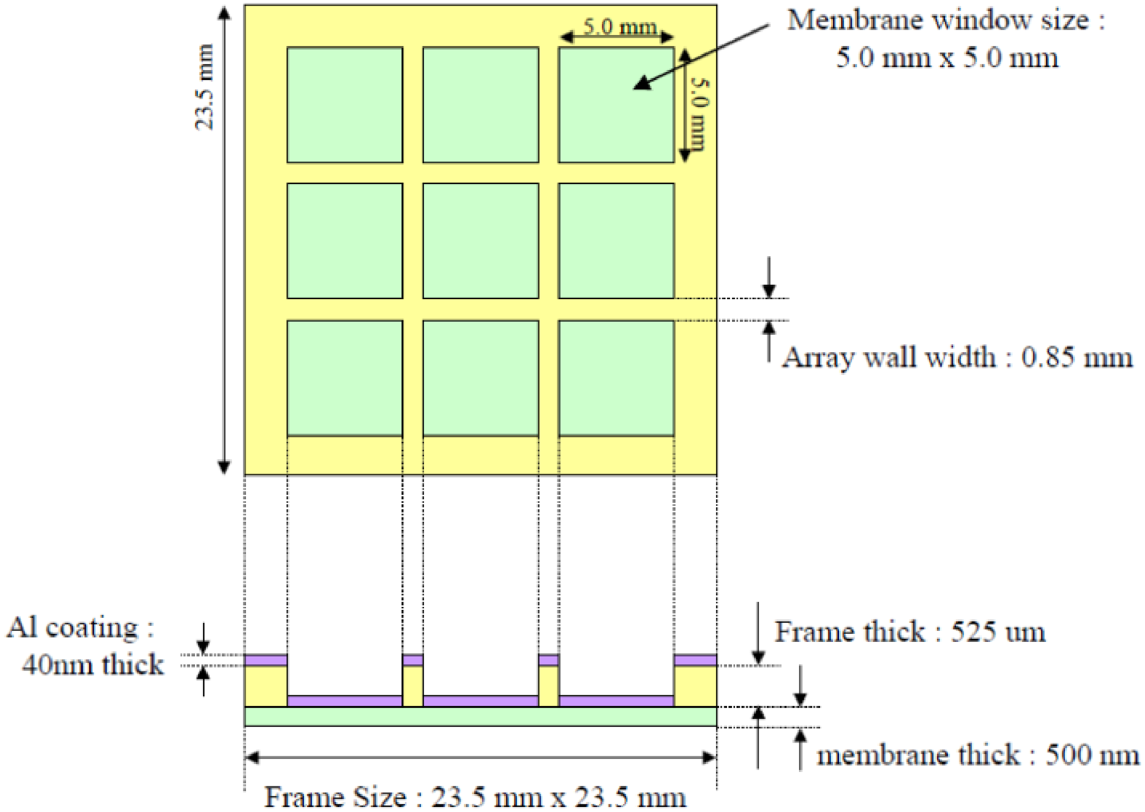
The BCC is a cylindrical chamber having a thin entrance window, cathode, grid and anode electrodes.



Field shaping rings are inserted between the cathode and the grid to maintain electric field.

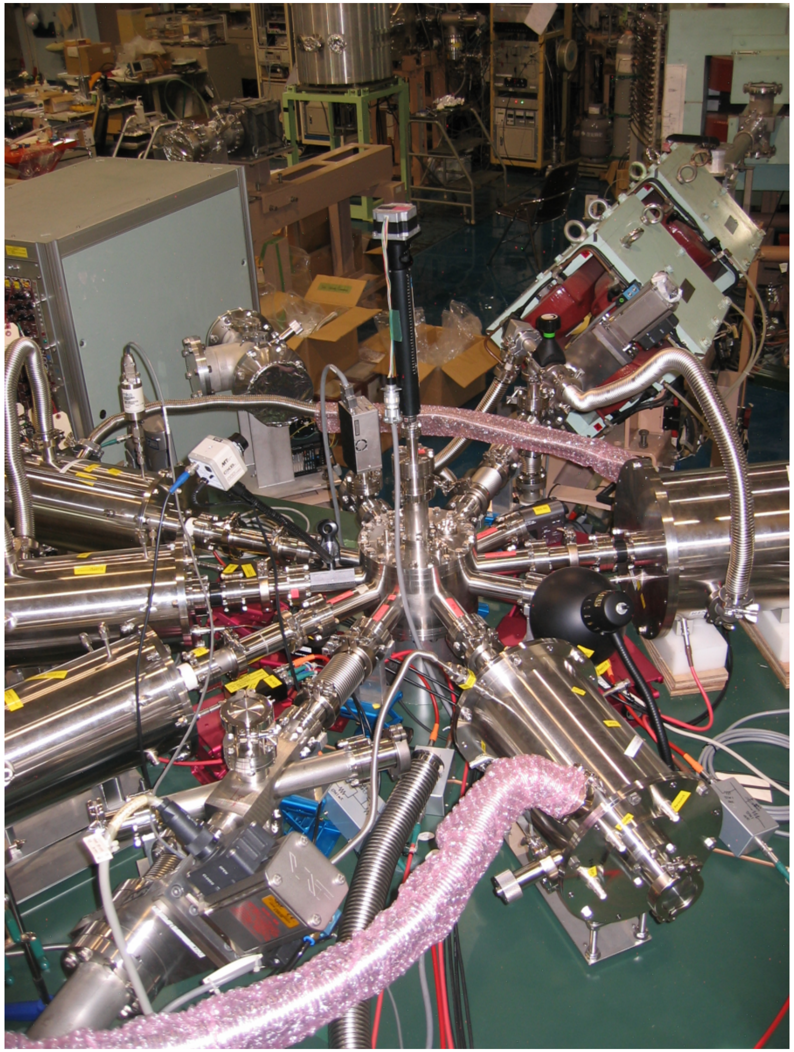
Incident window of BCC





- SiN 0.5 μm or Wire supported 2.5 μm or Aluminized Mylar

Experiment



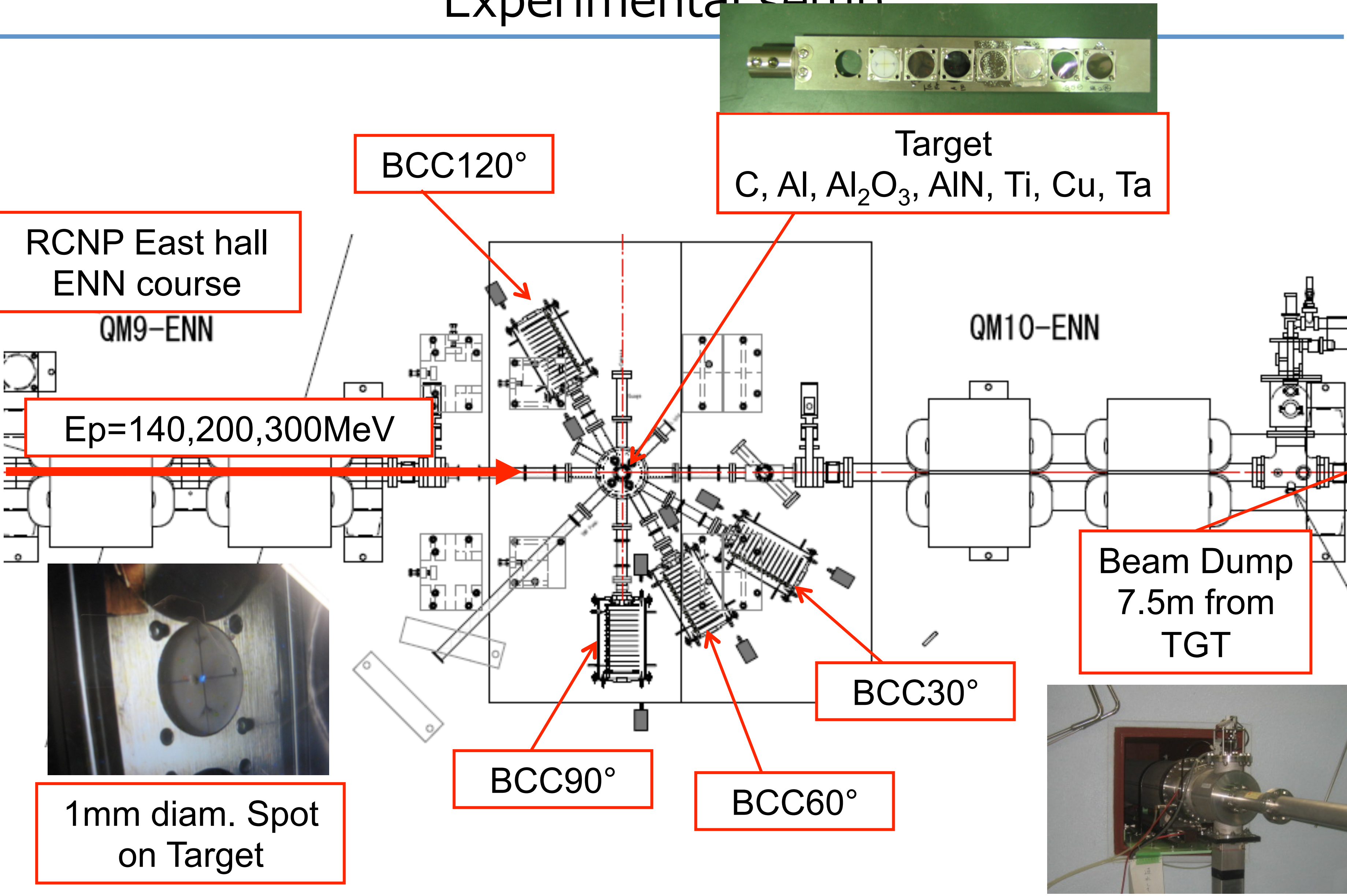
Data taking

Cyclotron facility, National institute of radiological sciences(NIRS), Japan, for 40, 50, 70 and 80 MeV protons.

Ring cyclotron facility, Research Center for Nuclear Physics(RCNP), Osaka University, Japan, for 140,200,300 MeV.

One hour run for each sample was performed with up to 10-50 nA proton beam.

Experimental setup

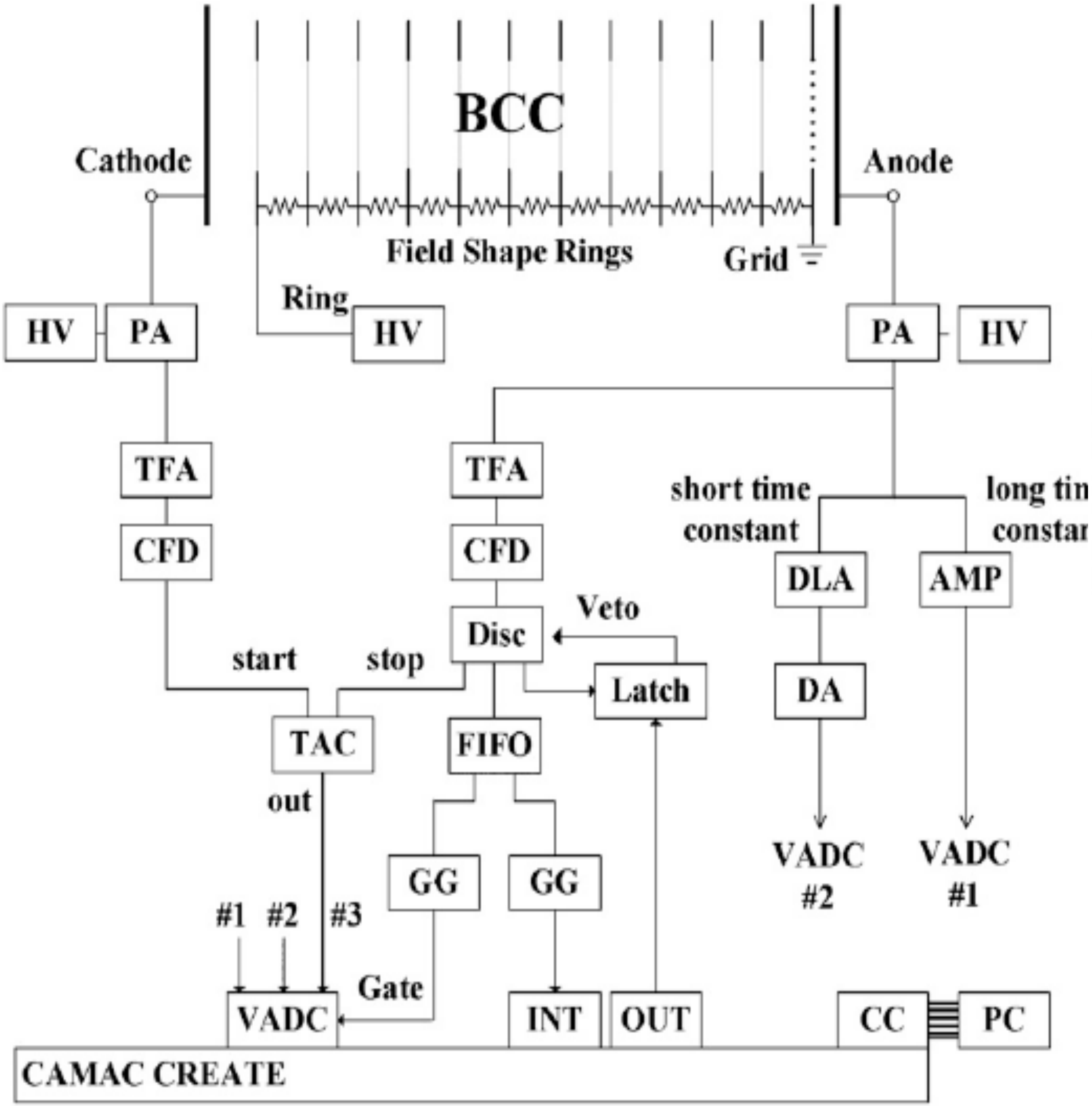


Targets

	Thickness	Style
Graphite	206 μg/cm^2	Self support
Al	0.8 μm	Self support
Al_2O_3	1.05 μm	Sputtering on Ta 10 μm
AlN	0.91 μm	Sputtering on Ta 10 μm
Ta	10 μm	Self support
Ti	1 μm	Self support
Cu	1 μm	Self support

Data for nitrogen and oxygen were obtained from AlN and Al_2O_3 data by subtracting aluminium and tantalum data taken separately.

Electronics



HV : High Voltage Power supply
TFA: Timing Filter Amplifier
Disc: Discriminator
FIFO: Fan-in/Fan-out
DLA: Delay Line Amplifier
DA: Delay Amplifier
INT: Interrupt register
CC: Create Controller

PA: Pre Amplifier
CFD: Constant Fraction Discriminator
TAC: Time-to-Amplitude Convertor
GG: Gate Generator
AMP: Amplifier
VADC: Voltage ADC
OUT: Output register
PC: Personal Computer

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Anode-Bragg peak scatter plot

Low energy fragments
↓
Time difference between anode and cathode
↓
Particle identification from range-energy relationship

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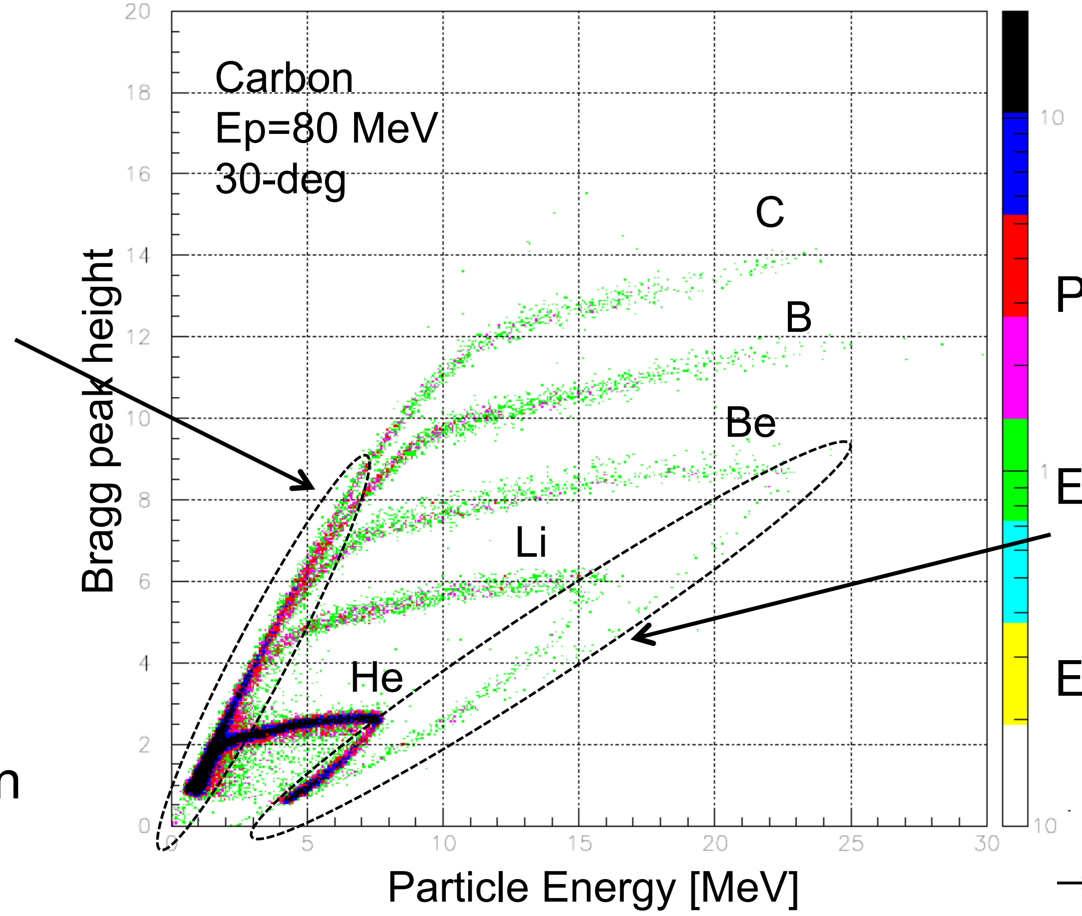

Punch out fragments
↓
Energy loss and energy
↓
Estimate on original energy

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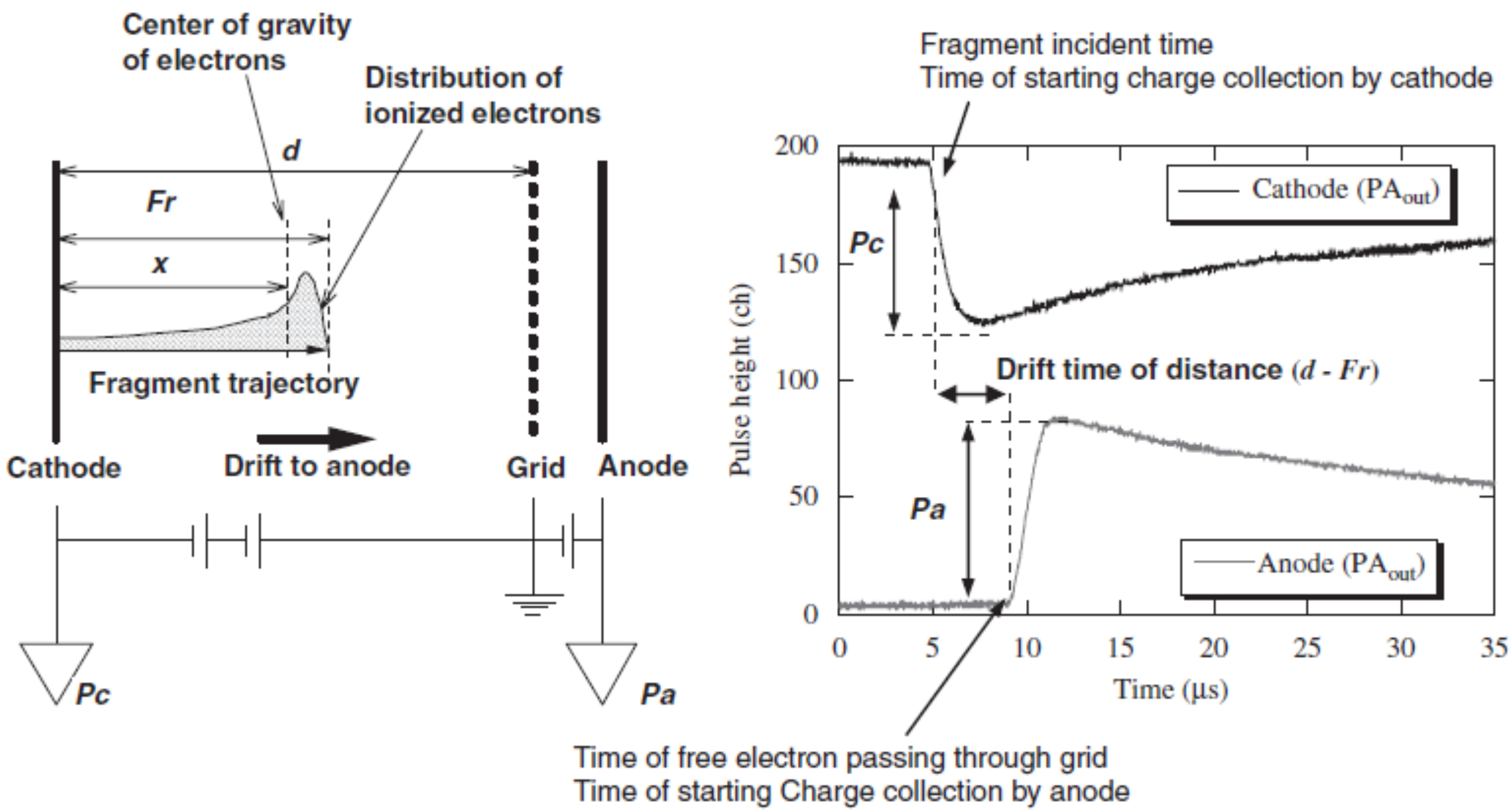
Drift time and range



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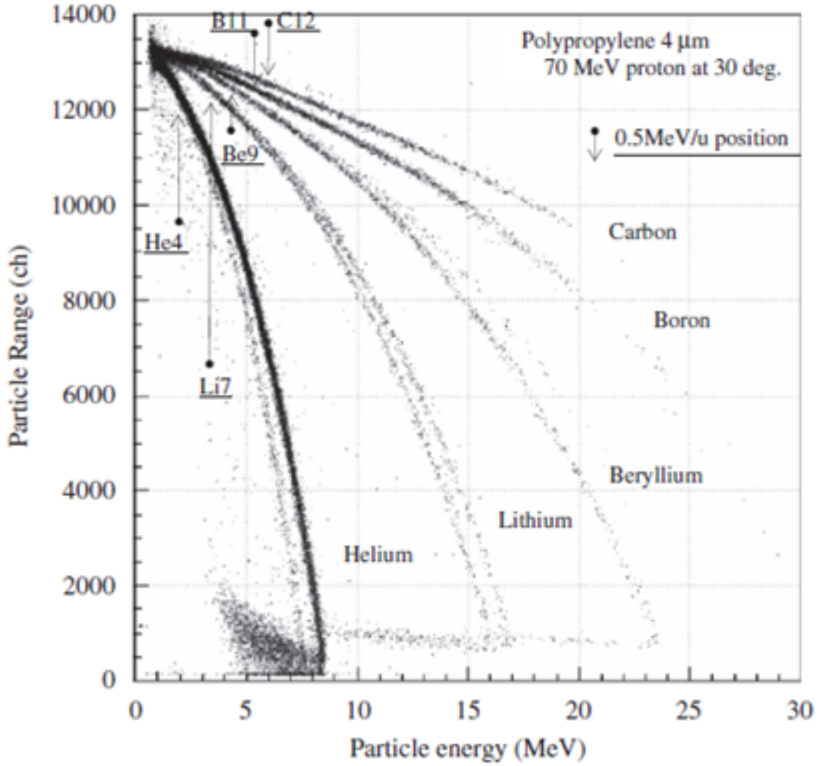
Low and high energy end improvement



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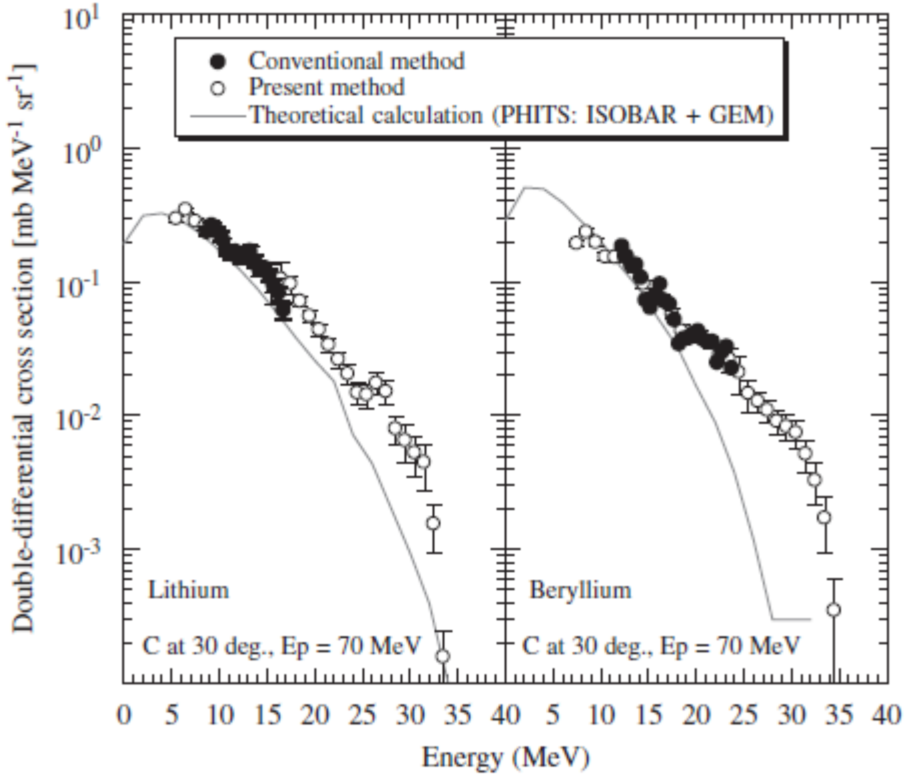

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Low energy side : Particle identification by energy vs range

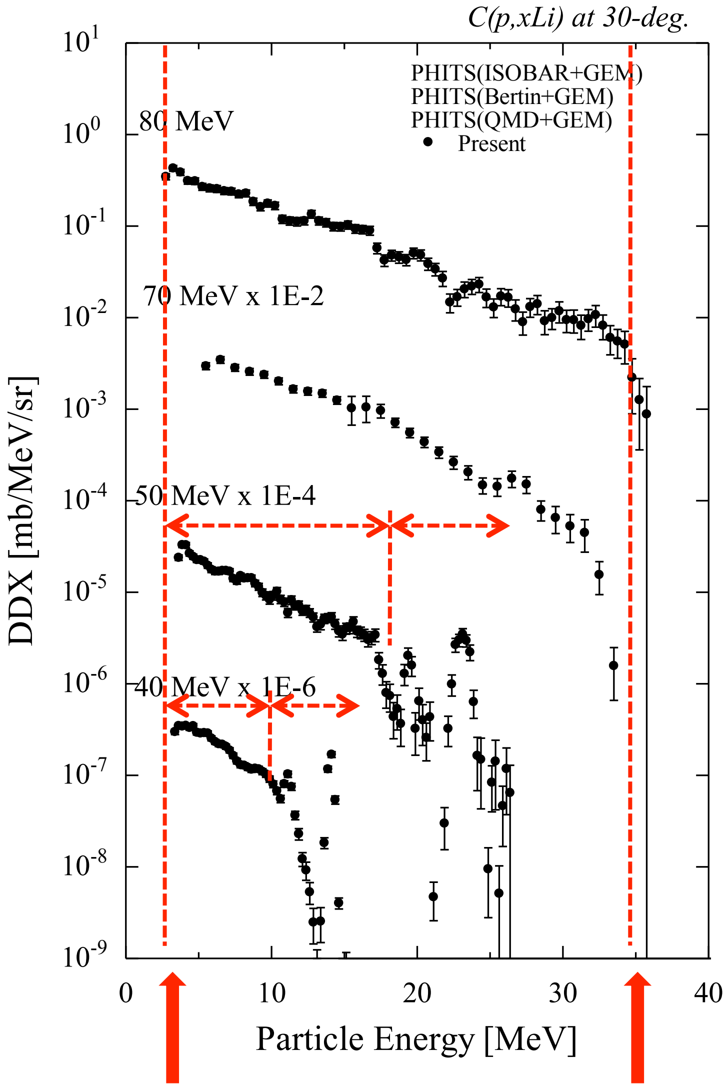
High energy side : Energy compensation analysis

Data analysis

$$\frac{d^2\sigma}{dEd\Omega}(E,\theta) = \frac{Y(E,\theta)}{\phi_p N \Delta E \Delta \Omega}$$

- Proton beam fluence : Beam current measured by Faraday cup
- Number of atoms in target : Determined from thickness
- Energy calibration: Am-α check source, punch-through particles and gas pressure, Research pulser
- Energy loss in target and window : Compensate using energy loss data
- Solid angle : Analytical equation, Am-α check source at target position

Double differential cross section



Cover energy of experimental data

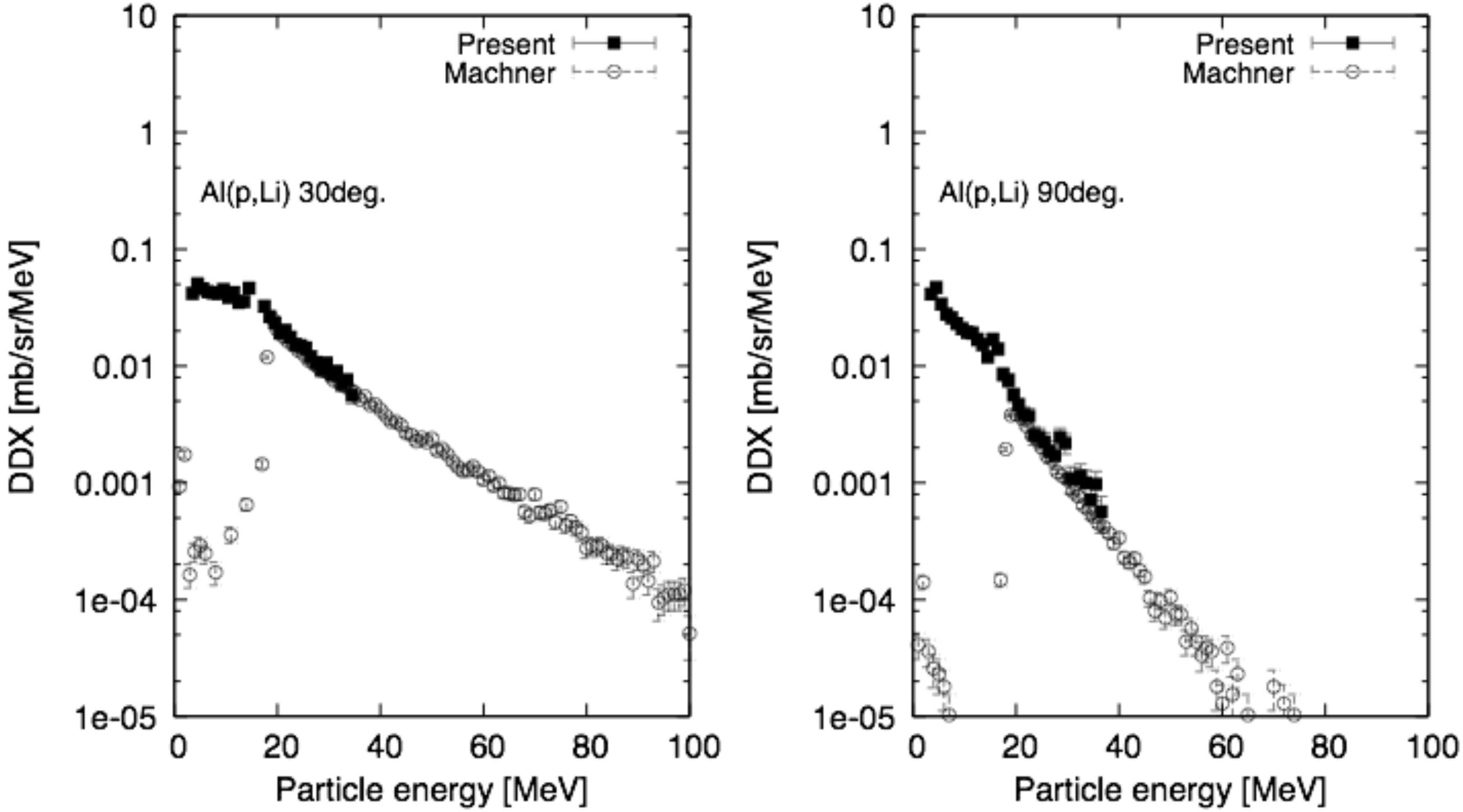
- Energy compensation analysis for punch through fragments
- Particle identification by range-energy
- Thin entrance window

Li : 4-40 MeV, Be : 5-45 MeV
B : 5-60 MeV, C : 6-60 MeV

The experimental data consist of two parts,

- high energy peak structure, and
- low energy continuous part.

Al(p,Li), Ep=200MeV



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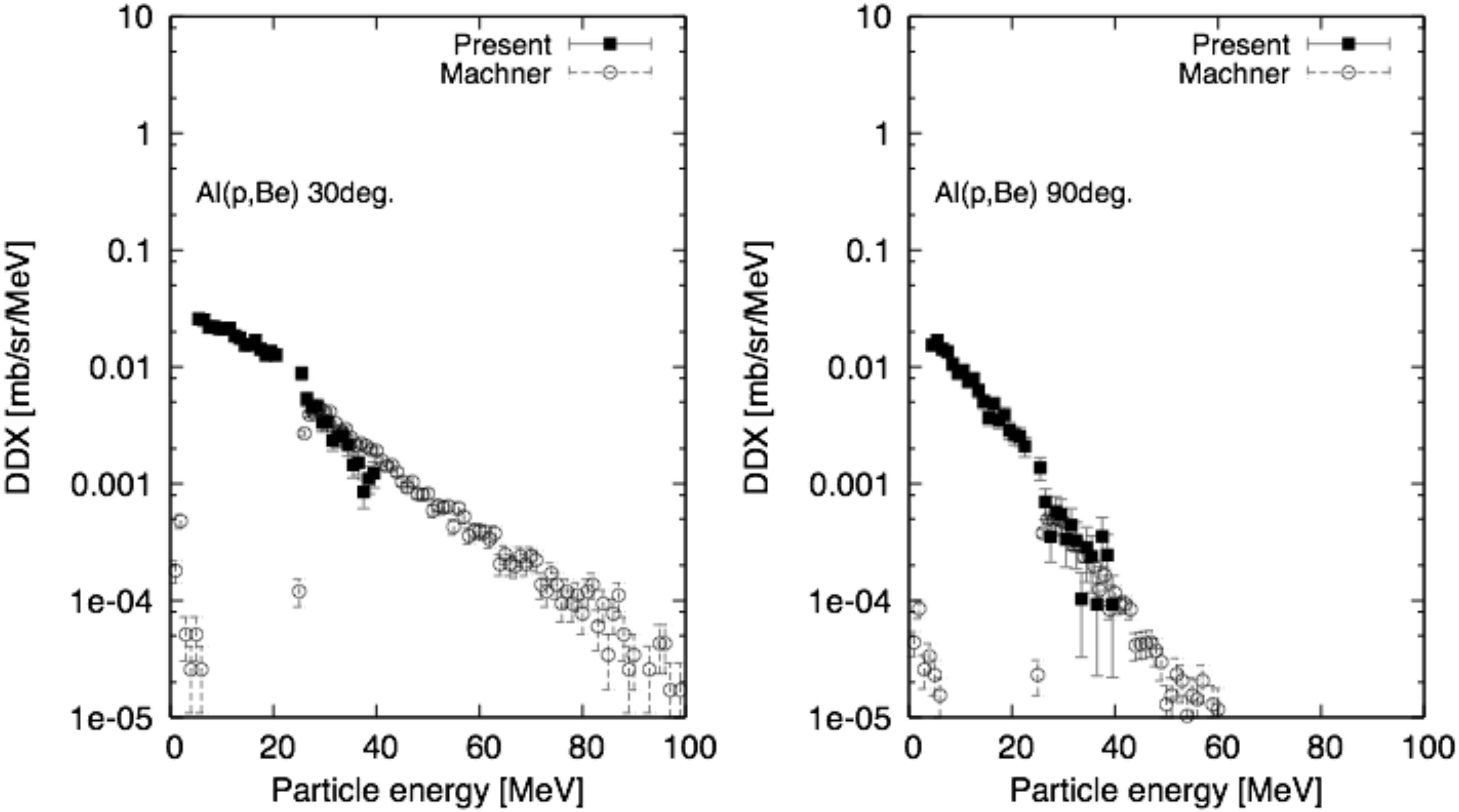
Al(p,Be), Ep=200 MeV



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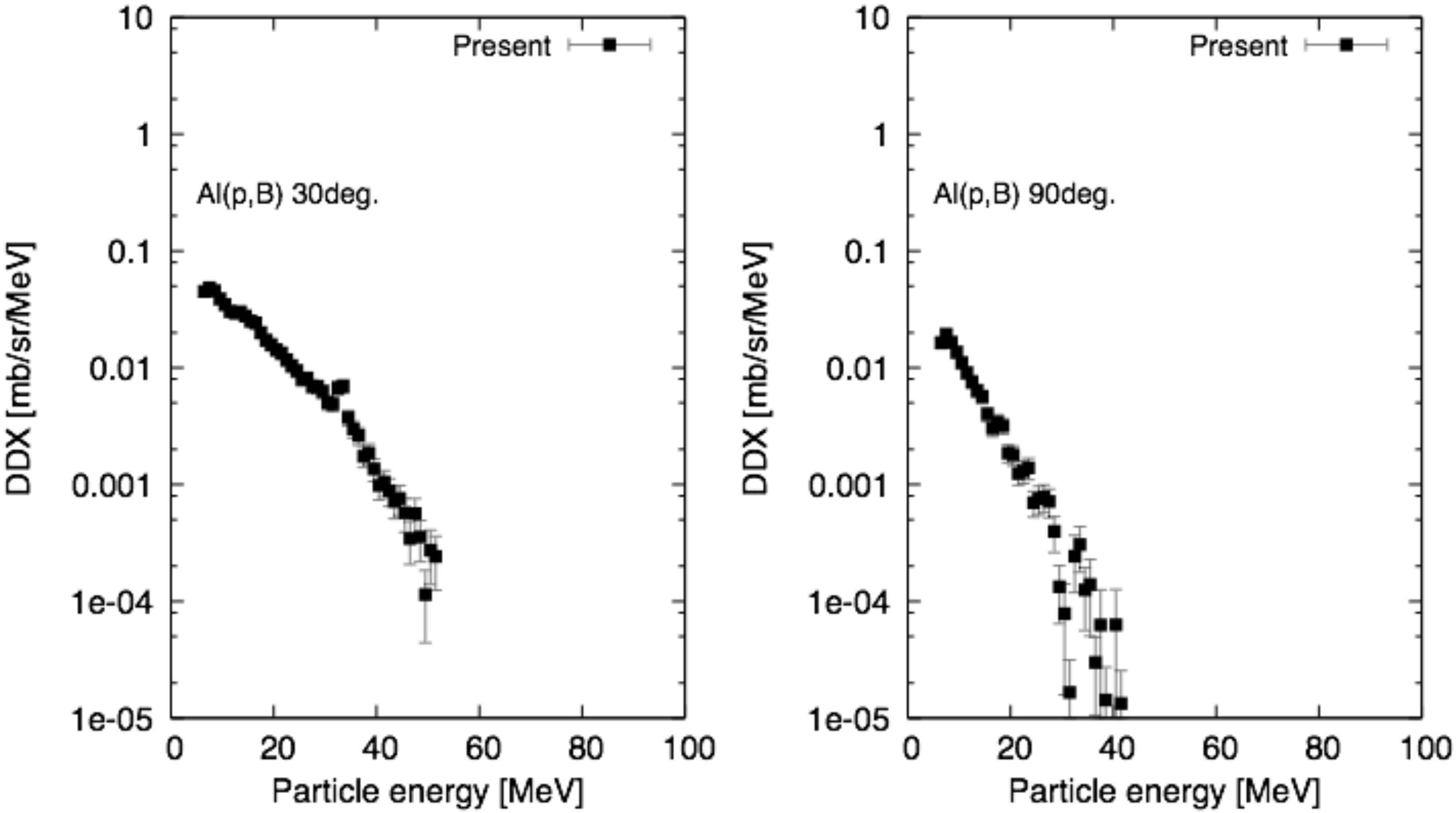
Al(p,B), Ep=200 MeV



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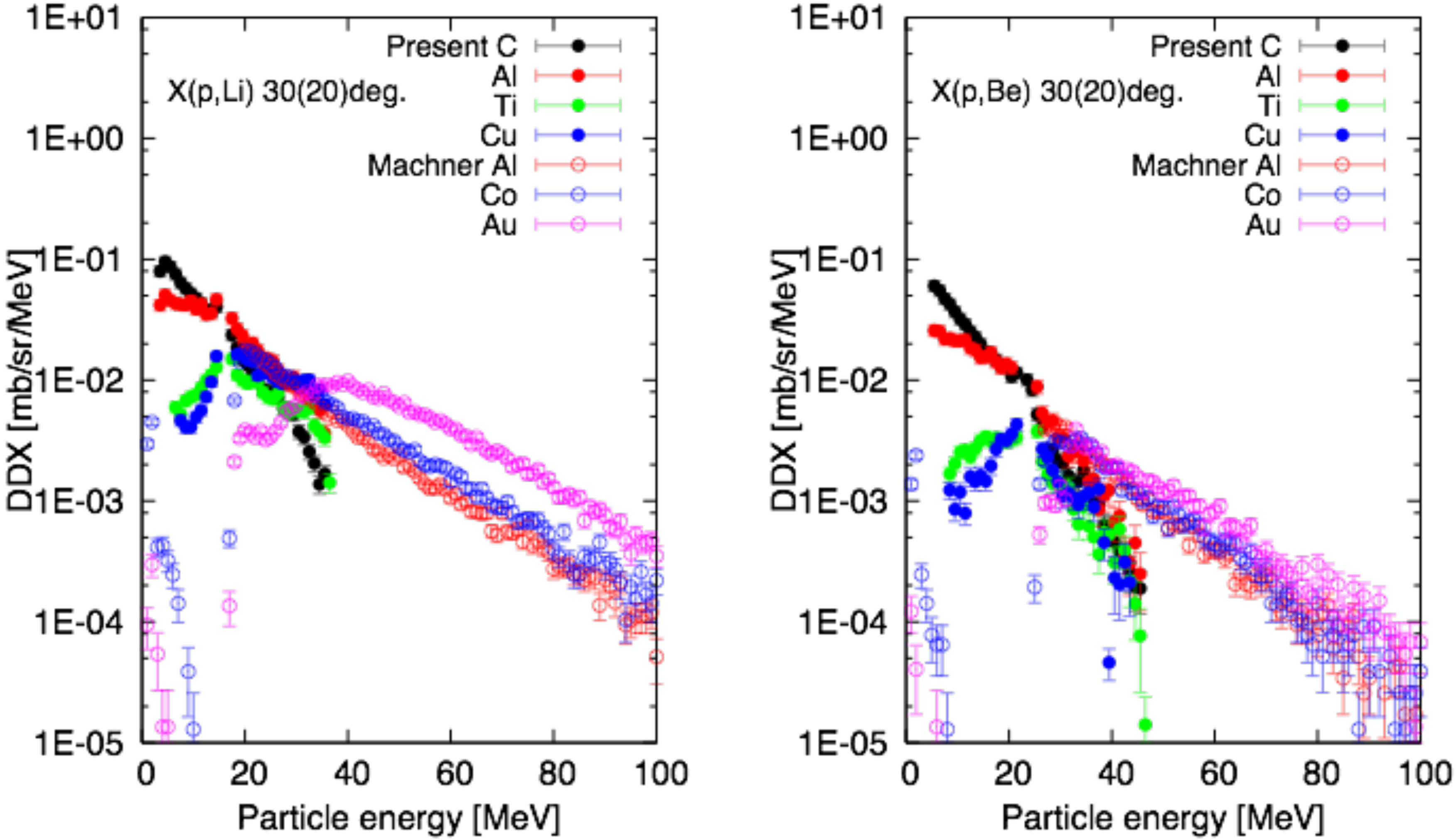
Target dependency for Li and Be emission



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Fitting equation

$$f(x) = h(x) \cdot g(x)$$

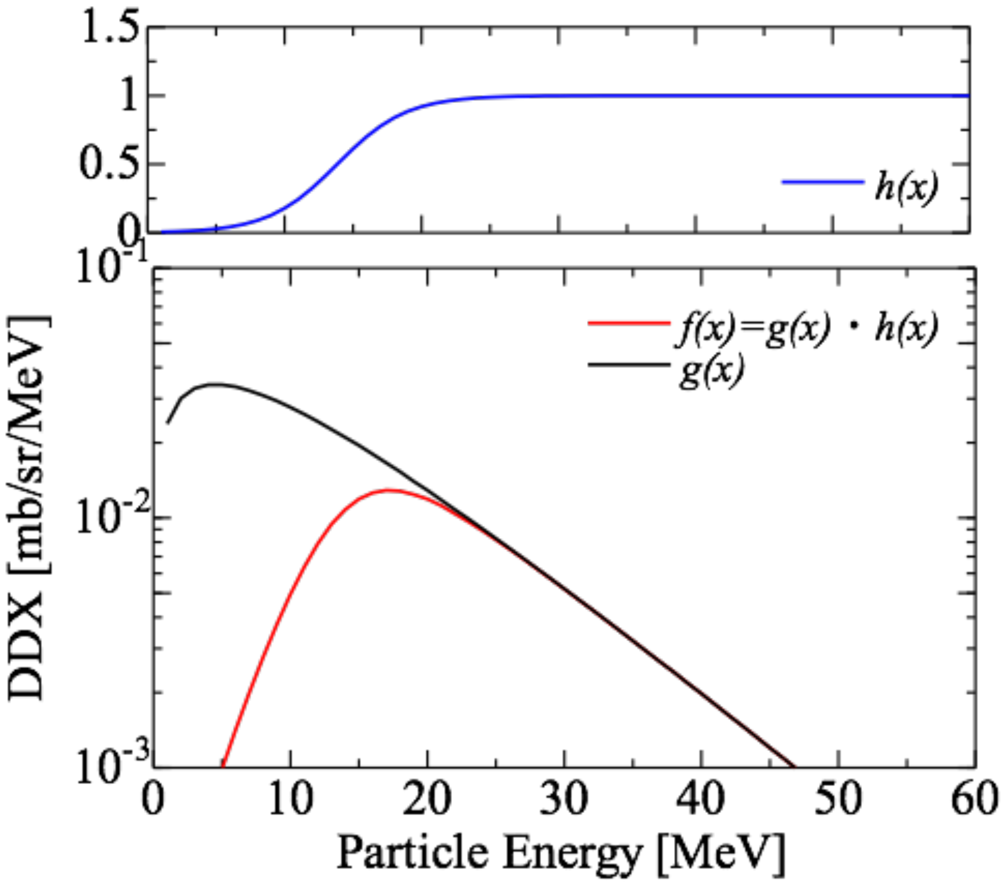
Maxwellian distribution

$$g(E) = \frac{s}{2(\pi T)^{3/2}} \sqrt{E} \cdot exp(-\frac{E}{T})$$

Coulomb barrier cut off

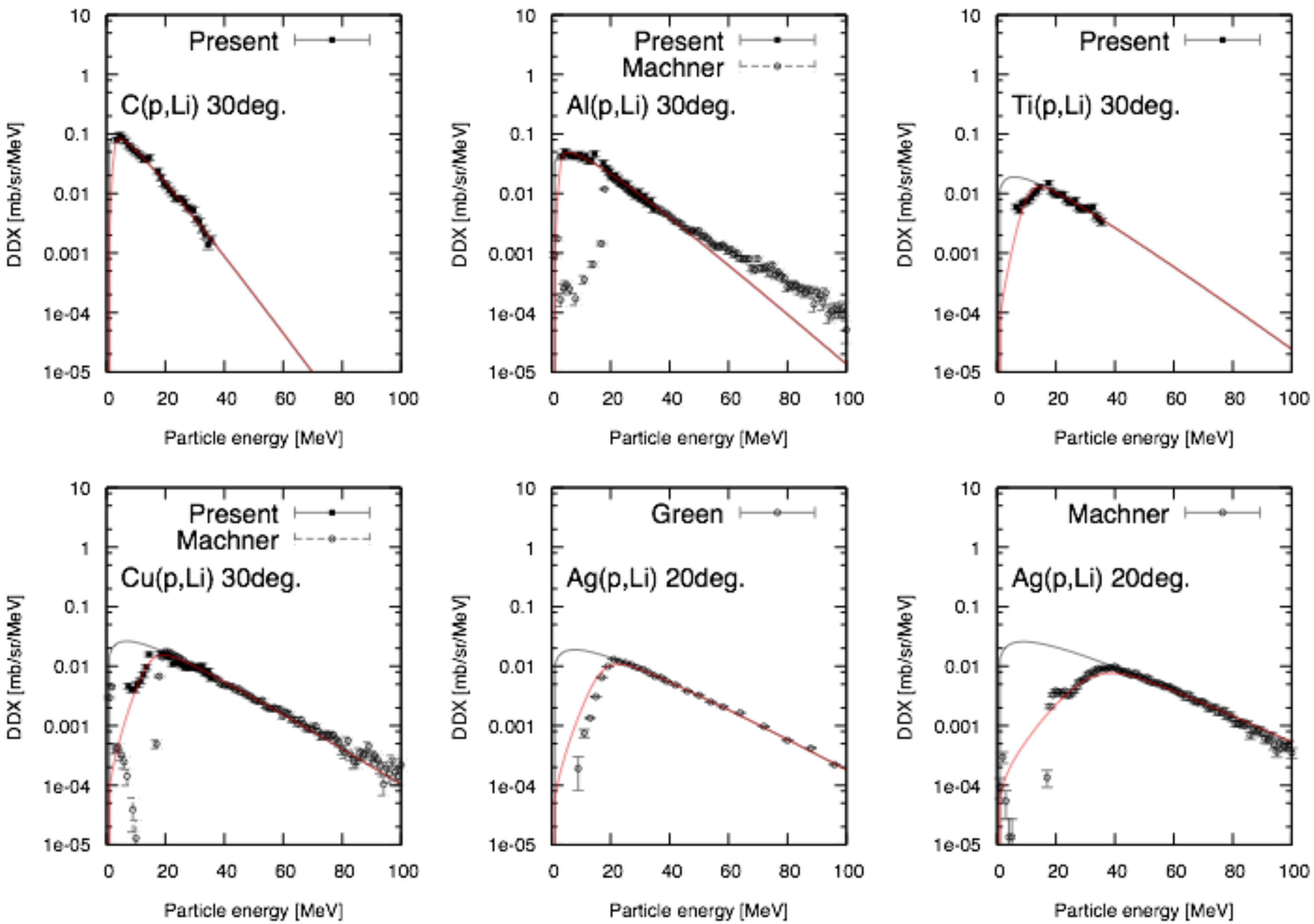
$$h(E) = \frac{1}{1 + exp(-\frac{E-kB}{d})}$$

$$B = \frac{Z_f(Z_s - Z_f)e^2}{1.44({A_f}^{1/3} + (A_s - A_f)^{1/3})}$$



- s, T, k are fitting parameter

Fitting results



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– Neutron induced reaction measurement

Neutron production target

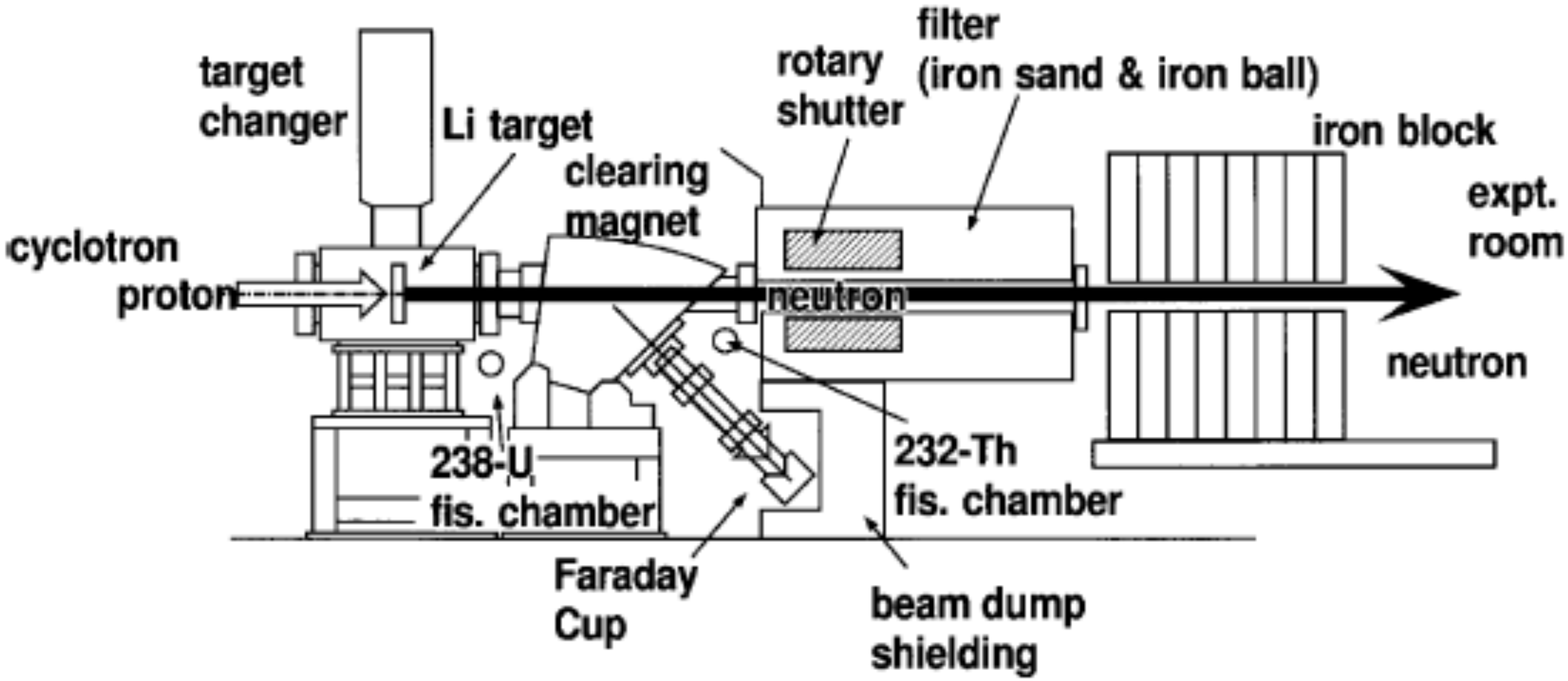
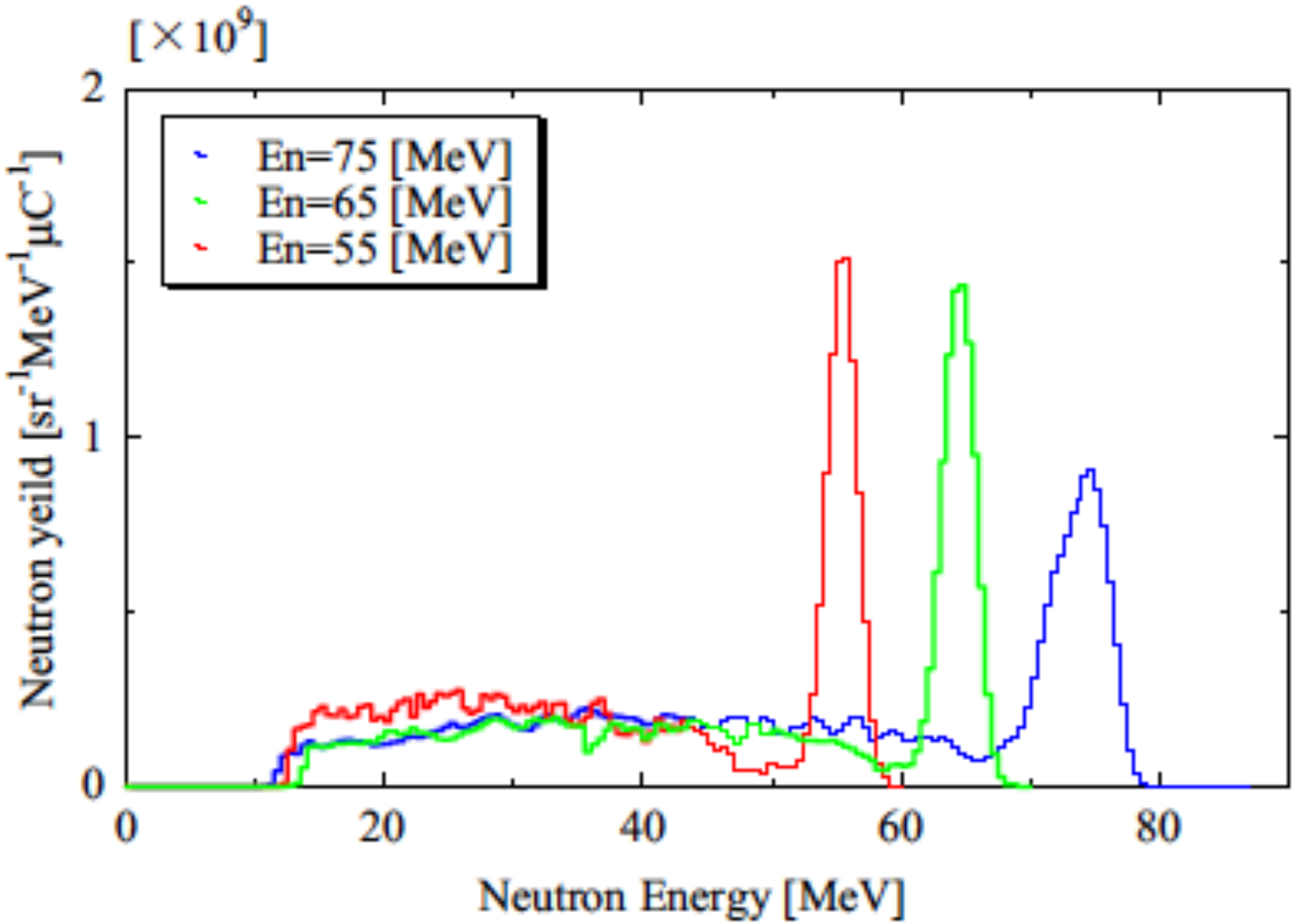
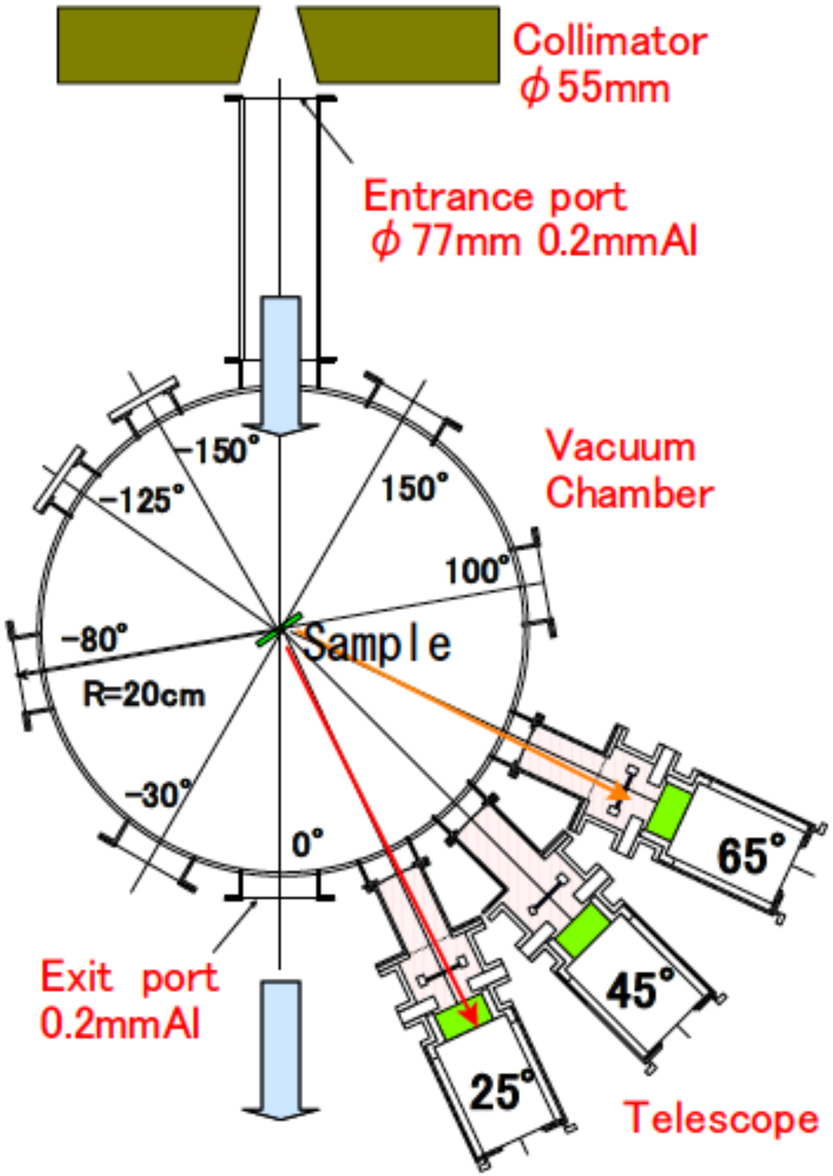


Fig. 1. Schematic view of JAERI TIARA $^{7}Li(p,n)$ monoenergetic neutron source facility.

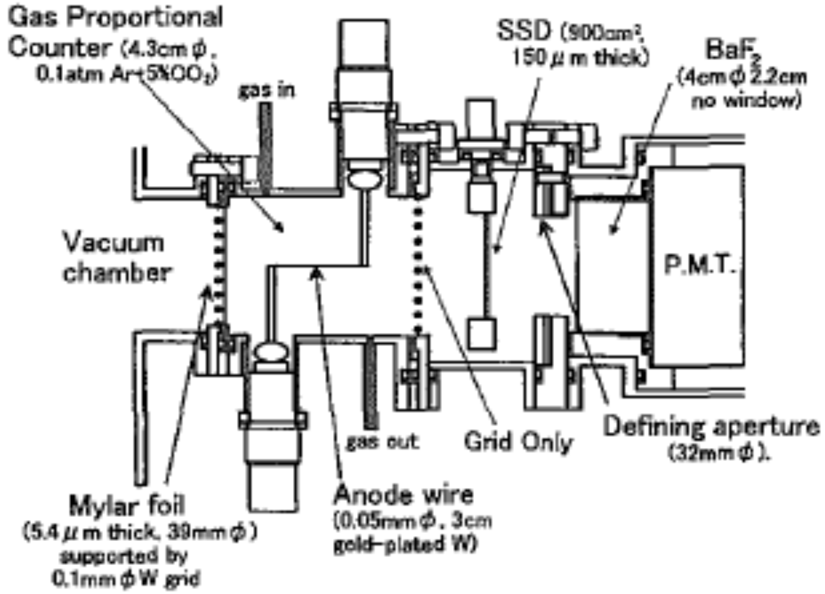
Neutron spectrum



Counter telescople

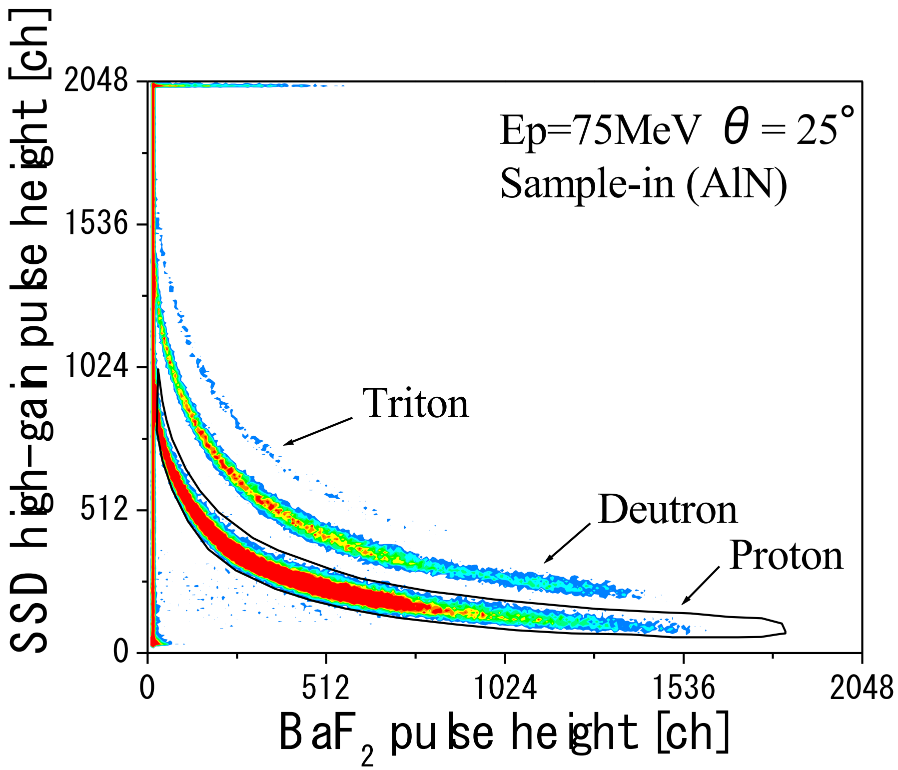


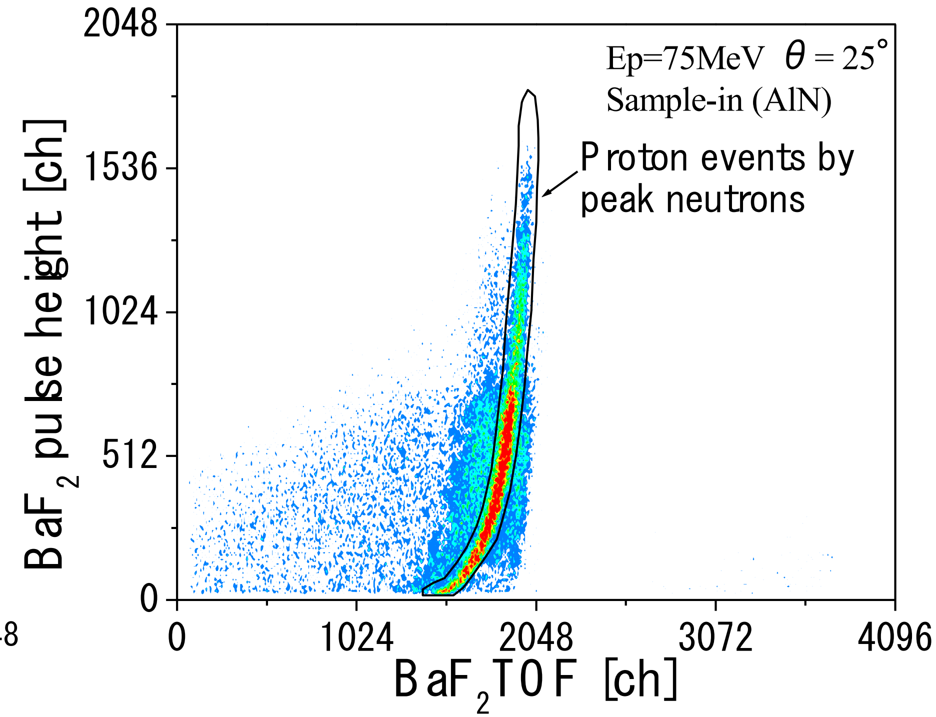
JNST sup2, p421-424 (2002)



JNST sup2, p421-424 (2002)

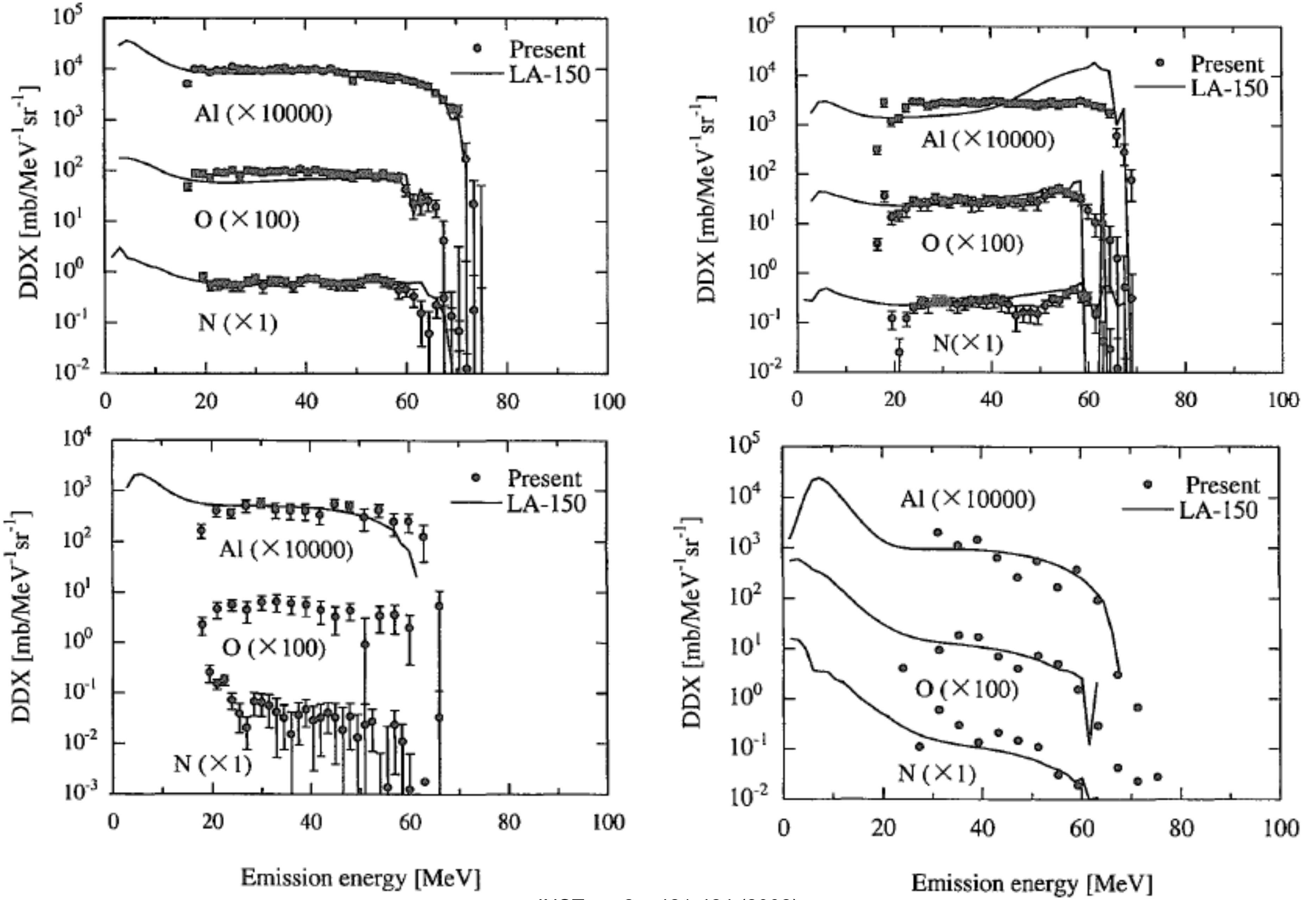
Spectrum





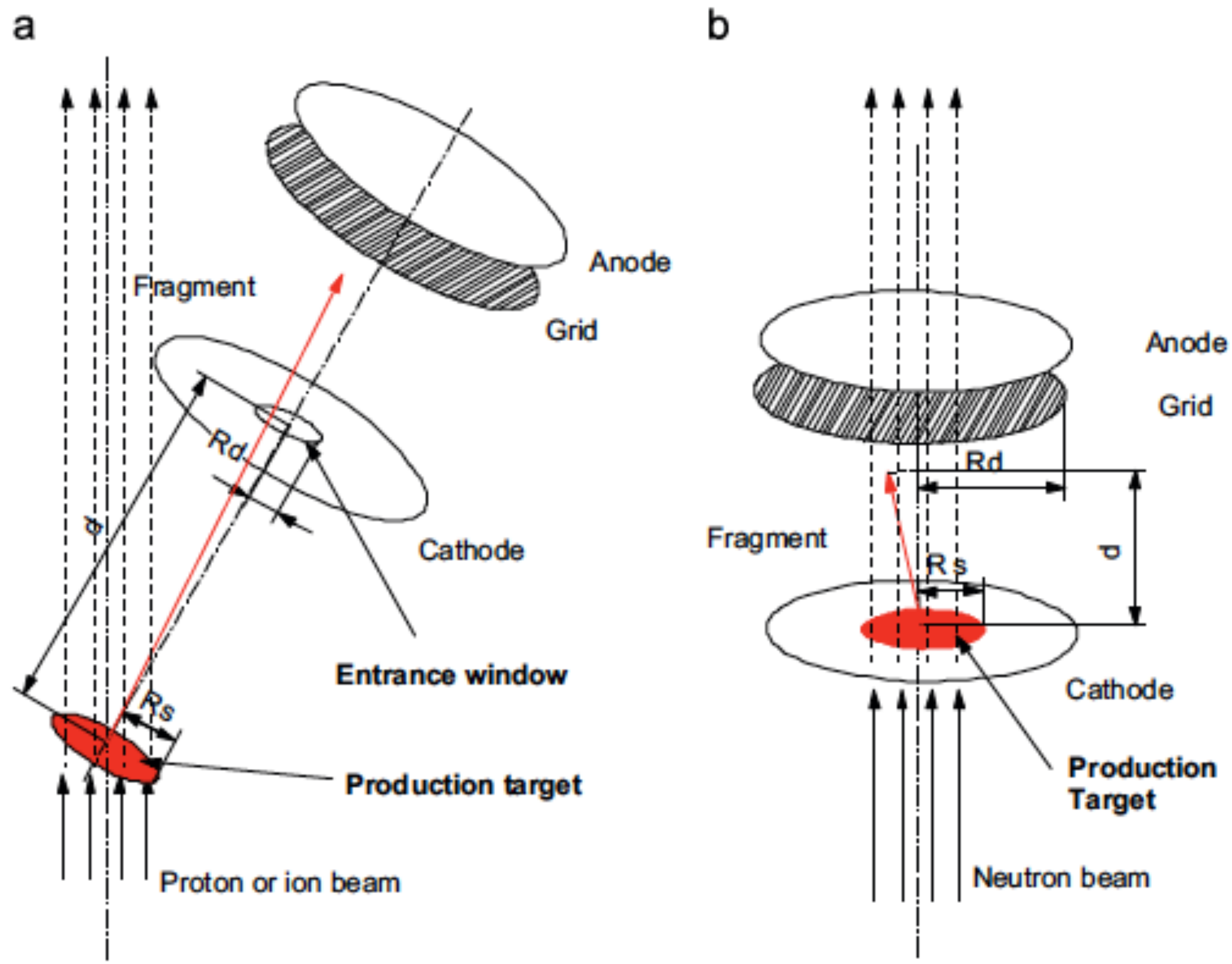
JNST sup2, p421-424 (2002)

Results



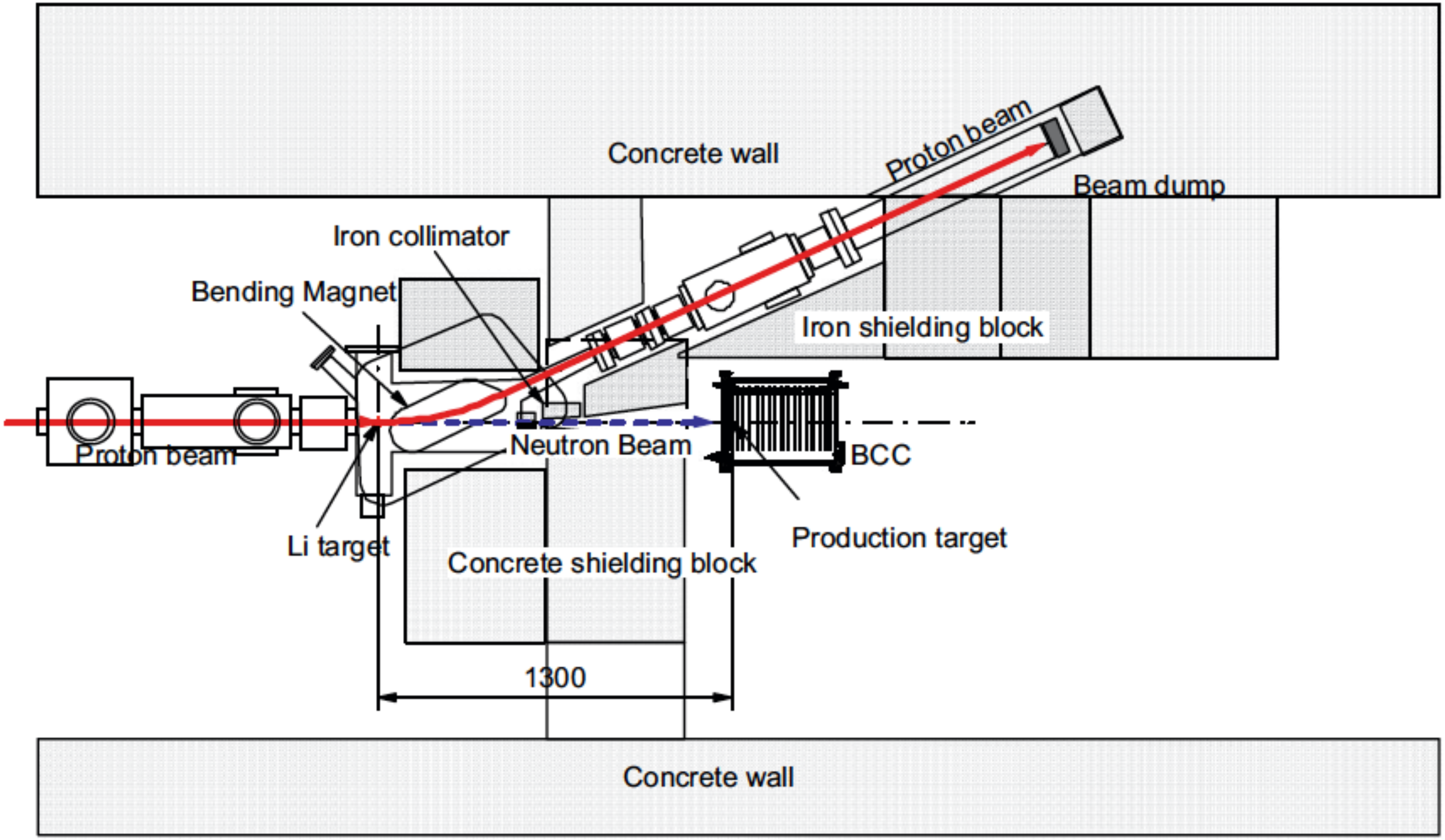
JNST sup2, p421-424 (2002)

Fragment for neutron

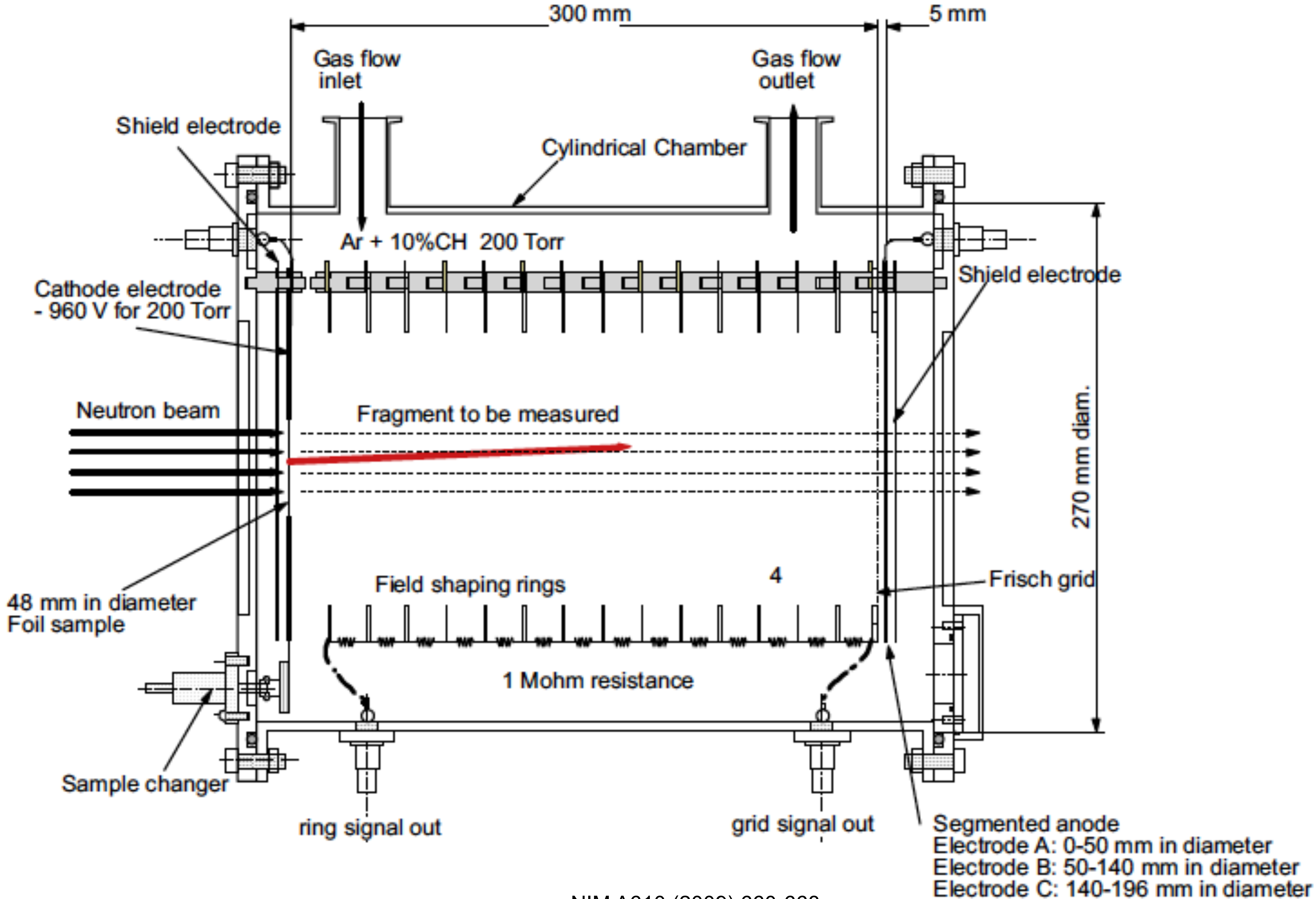


NIM A610 (2009) 660-668

Experimental setup



NIM A610 (2009) 660-668



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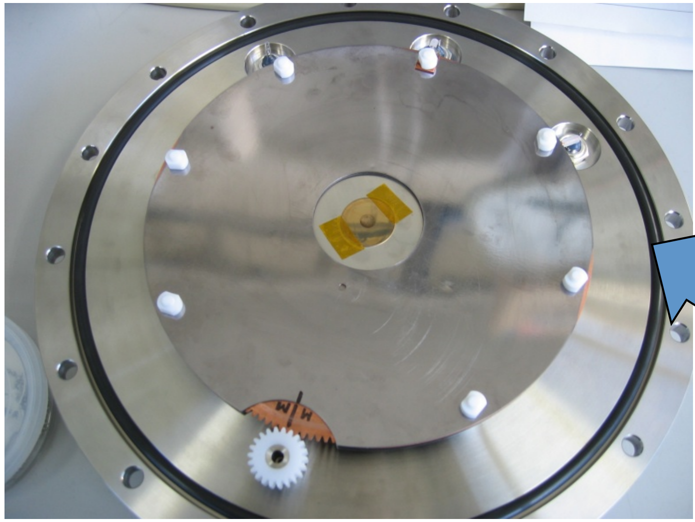

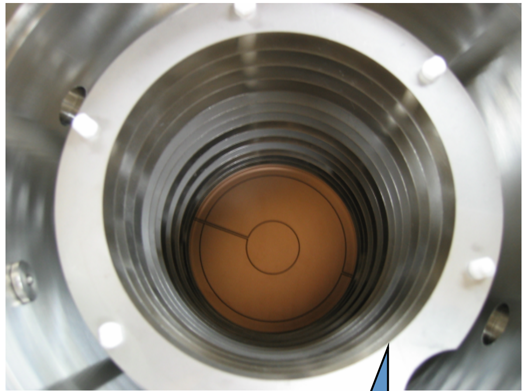

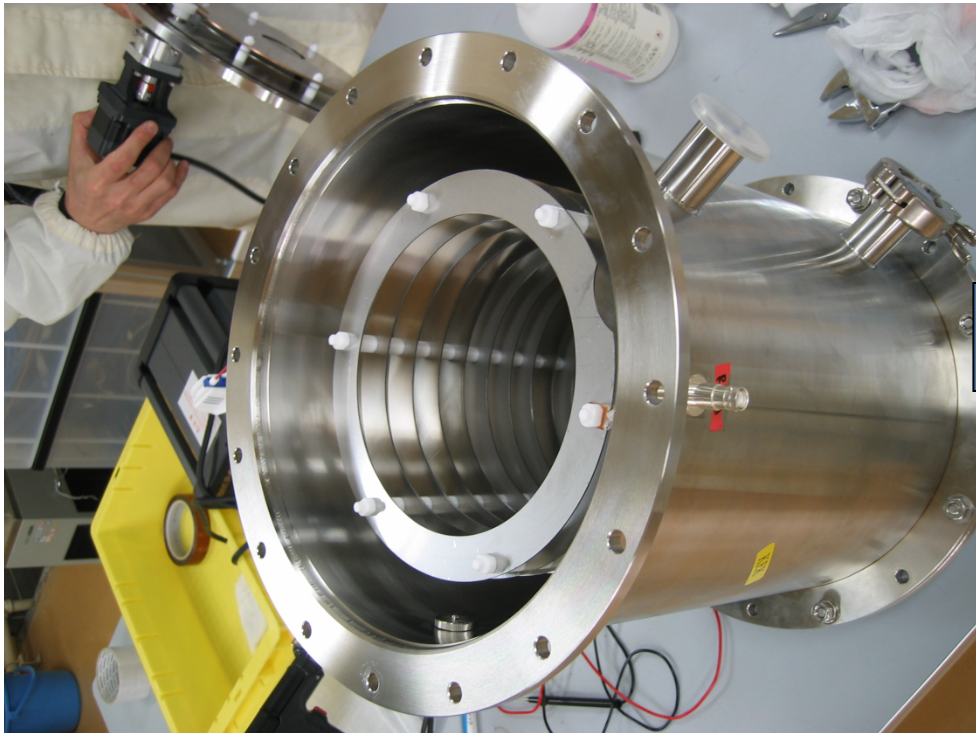

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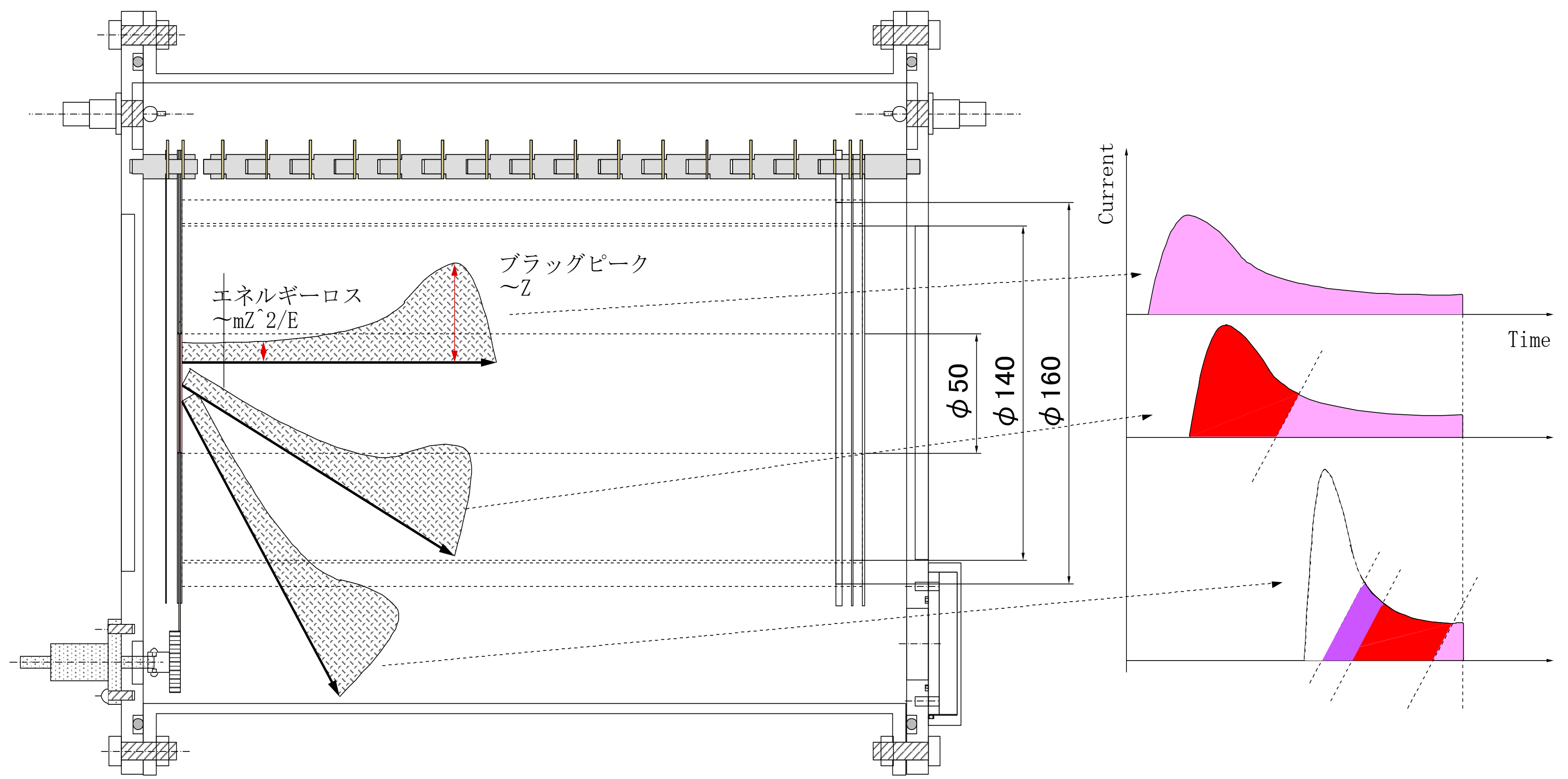
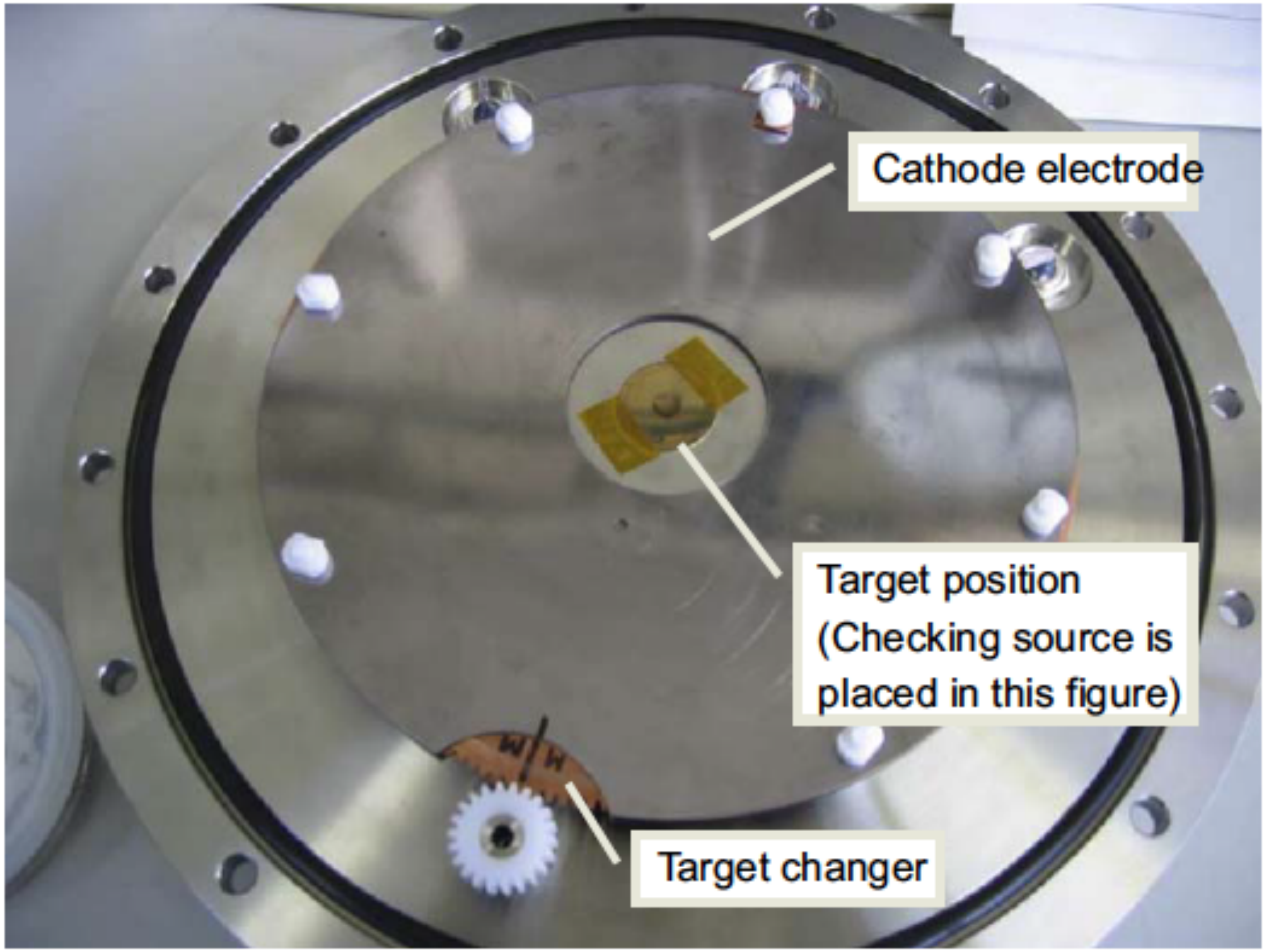
- Bragg peak height observed by BCC varies due to its angle
  - Reject angled particle using segmented anode
  - Determine detection efficiency as a function of range





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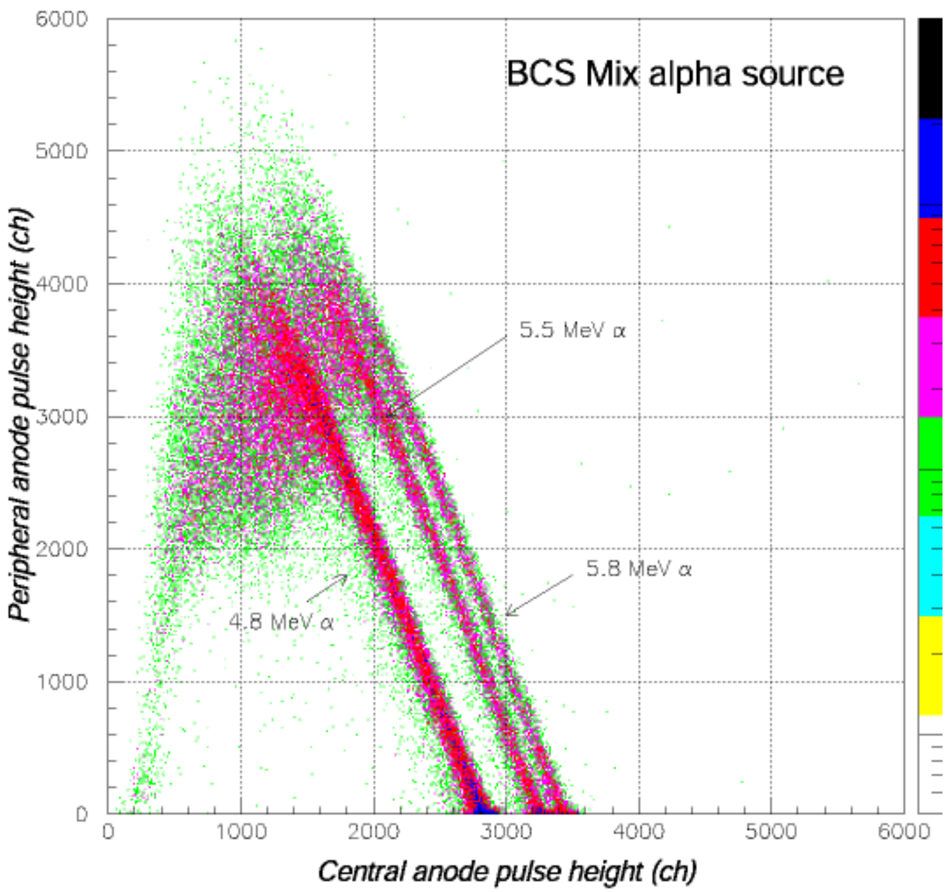

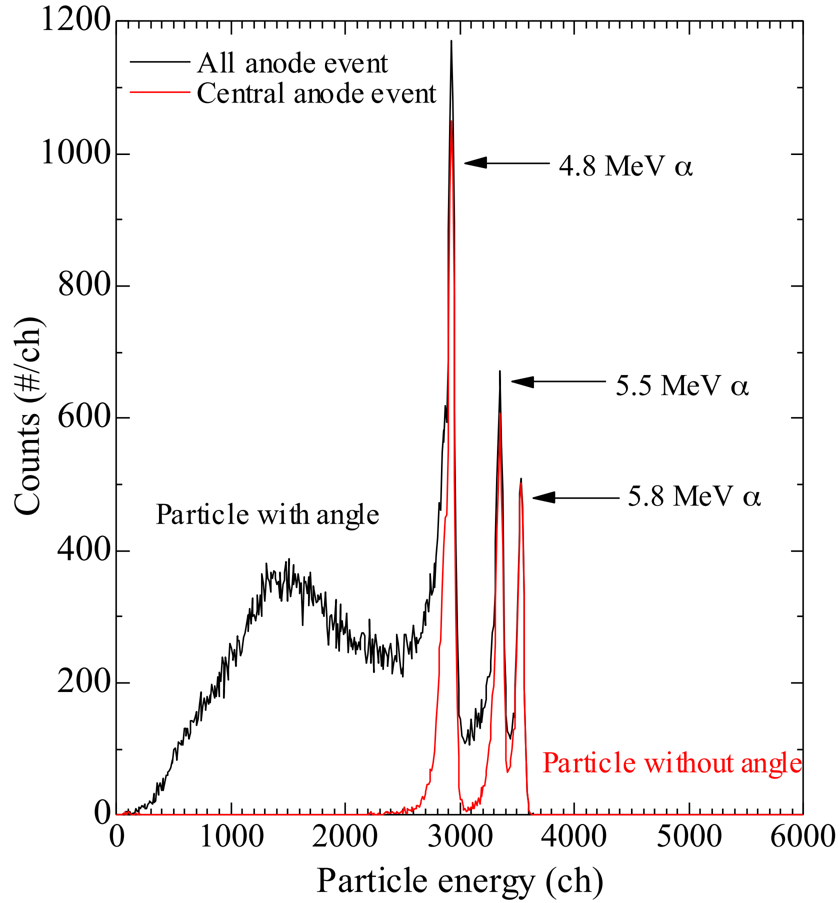

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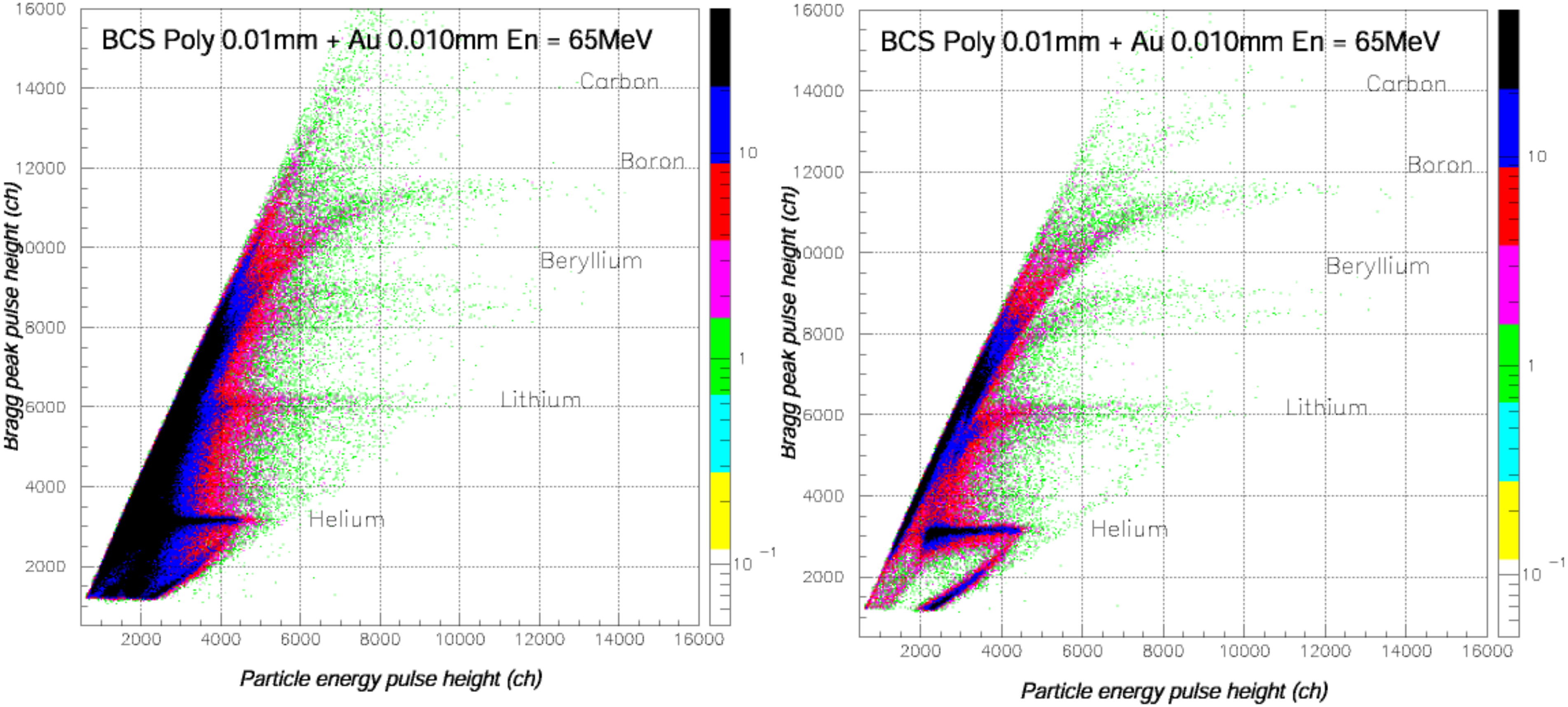

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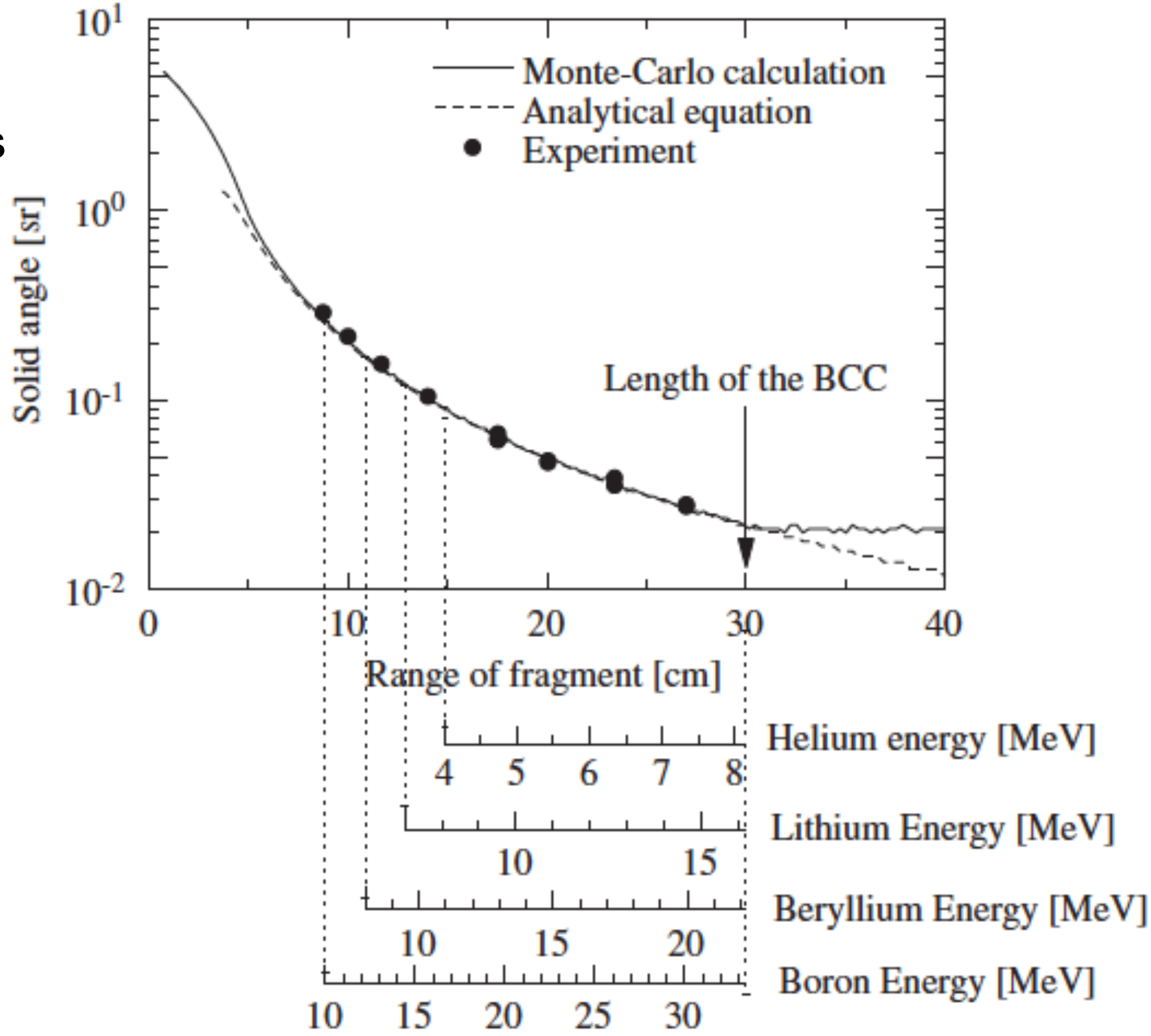
Detection efficiency as a function of range

Known α source

Artificially change its range by changing gas pressure



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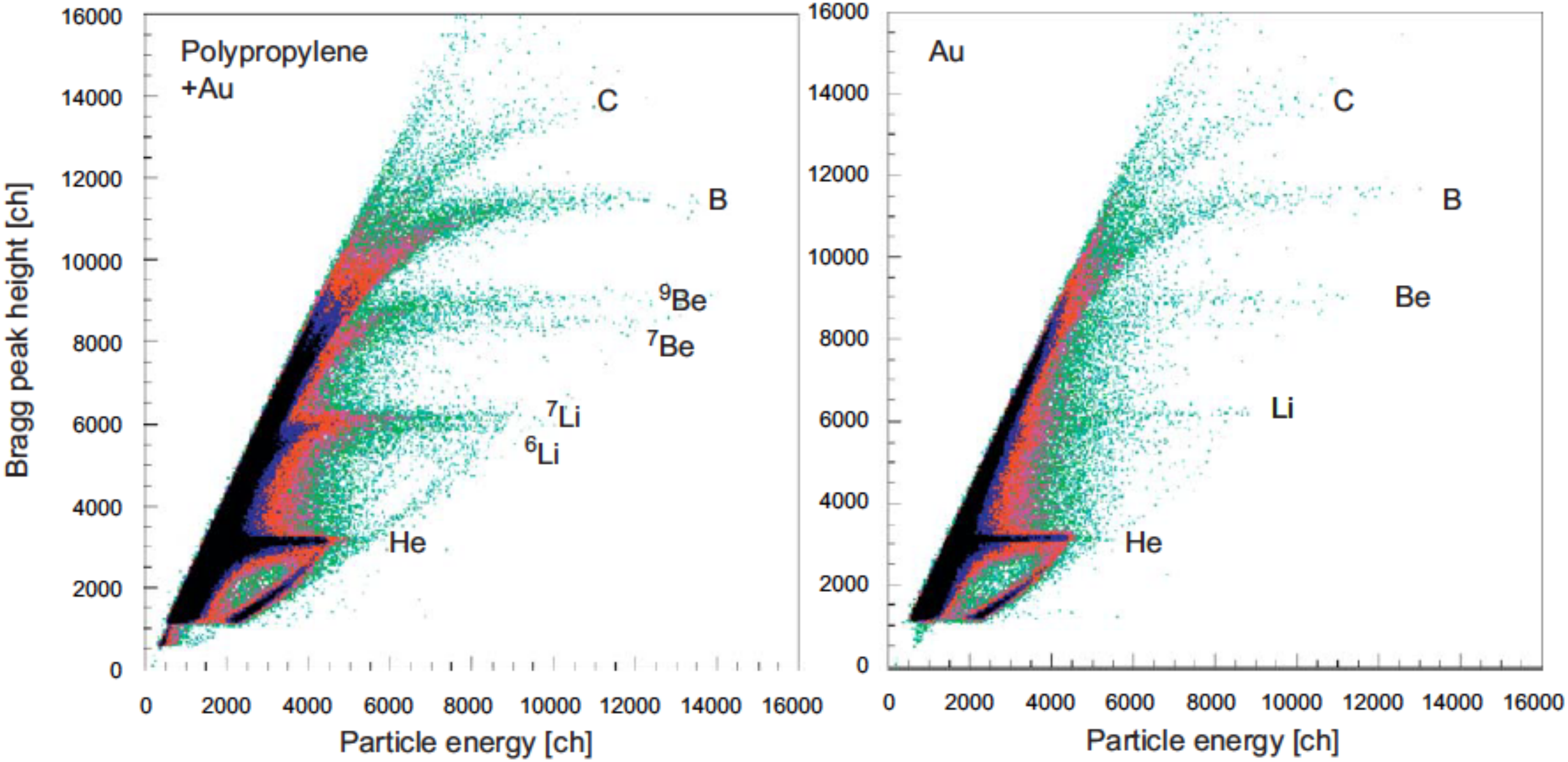
Fragment production for carbon



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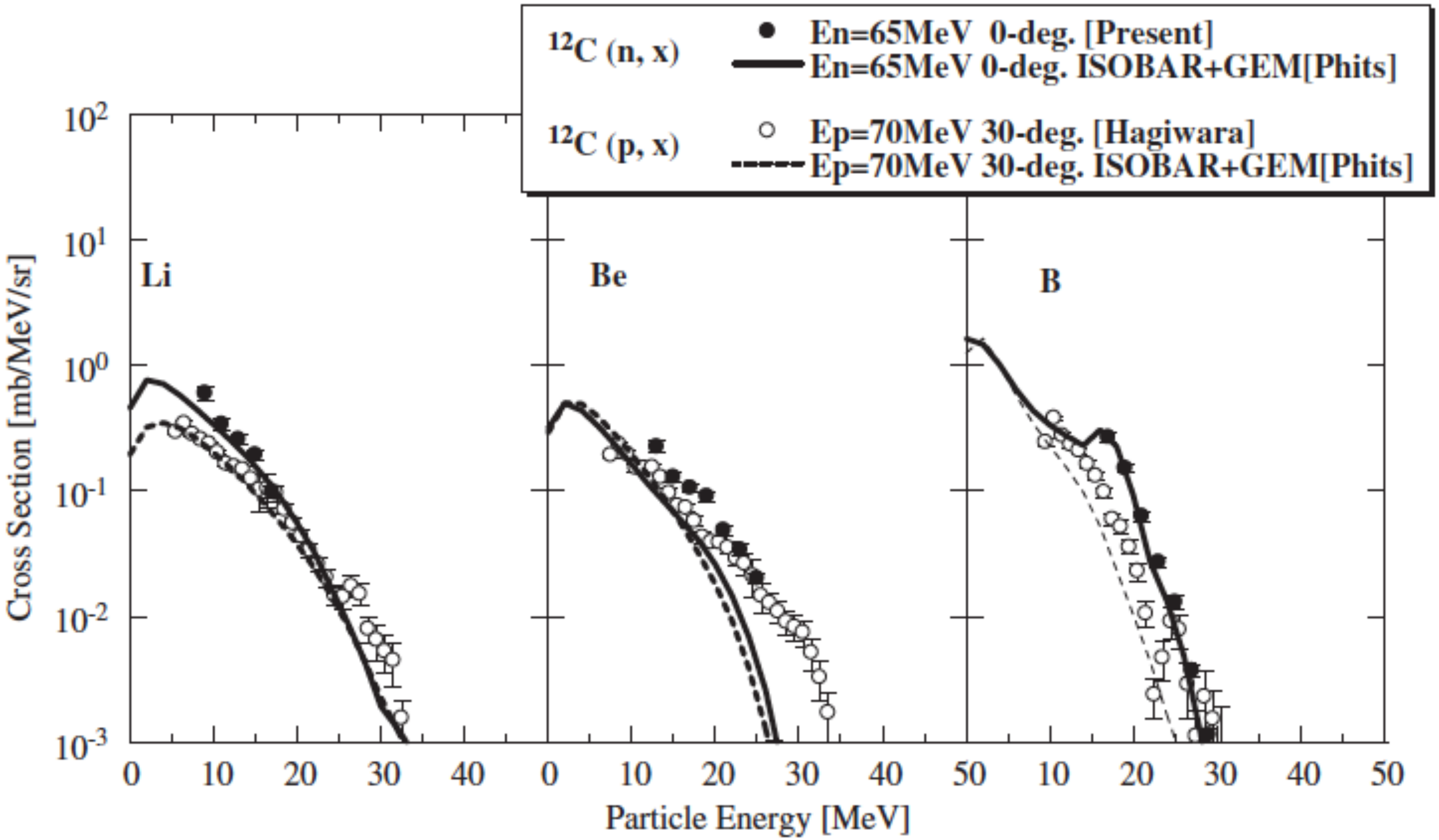
Comparison of neutron and proton induced



NIM A610 (2009) 660-668

Summary

- DDX measurement for fragment production reaction using Bragg curve counter

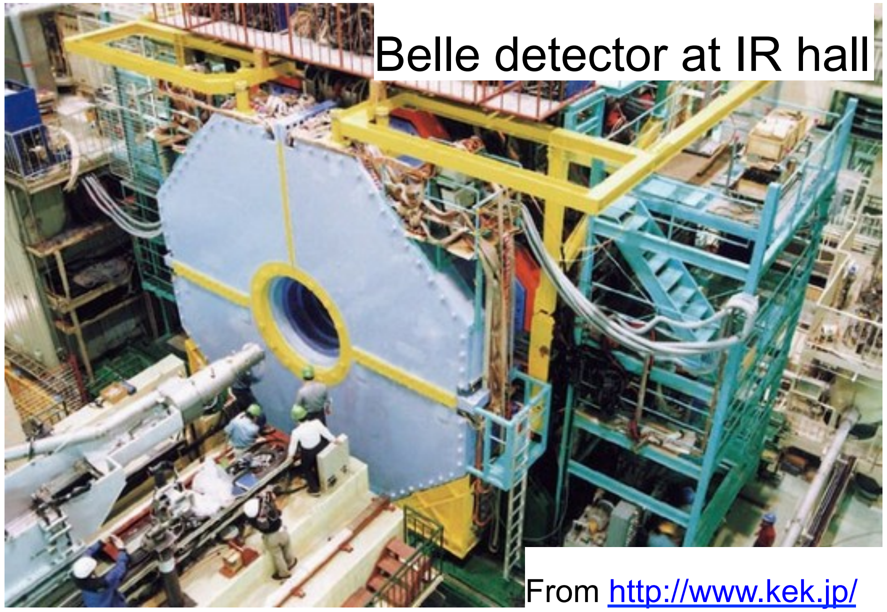
  - Why do we need charged particle production reaction at hundred to tens of MeV projectiles.
  - How to measure the charged particles

  - Proton incident
    - Bragg curve counter
    - Electronics
    - Results

  - Neutron incident
    - Counter telescope
    - Bragg Curve Counter

KEK,Japan

- Take a look KEK accelerators :
  - Visiting program of accelerator facility, contact to Public relation office in KEK (Email:kengaku@kek.jp)
  - Several courses are available for under graduate and graduate students, see our web page http://www.kek.jp for more information
- Study accelerator science and related technologies:
  - Sokendai-web http://accl.kek.jp/sokendai/e_index.html



Belle detector at IR hall

From http://www.kek.jp/

Magnets of KEKB tunnel arc section

From http://www.kek.jp/