

# R&D of emulsion technology to study fragment interaction to improve ion therapy

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The background of the slide features several faint, concentric circular patterns in a lighter shade of blue, resembling ripples in water or a target pattern, scattered across the lower half of the slide.

# Japanese-French collaboration on fragmentation study

More than 3000 patients have been treated with carbon ion therapy at NIRS in Japan since 1994.

France is joining the club of countries with hadron therapy machines “étoile” project to be realized in Lyon.

Fragmentation study is crucial to limit the damage of safe tissue

The energy range of such machines is of few 100 MeV/n

NIRS-HIMAC facility provides 100-400 MeV/n energy ions beam

GANIL facility provides few to 100 MeV/n energy ions beam

**Tools to study the fragmentation are available in both countries. They are complementary.**

# Japanese-French collaboration on fragmentation study

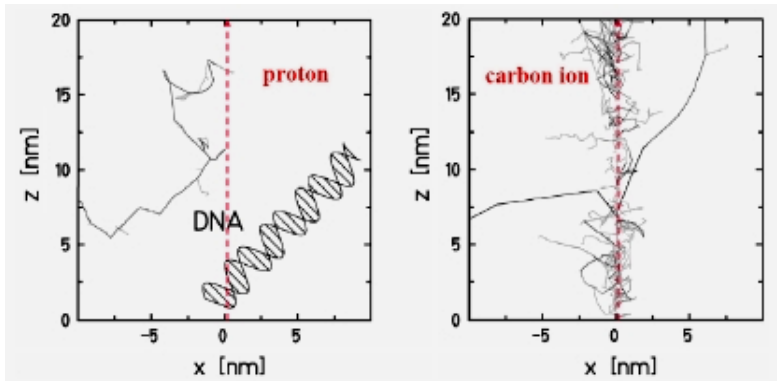
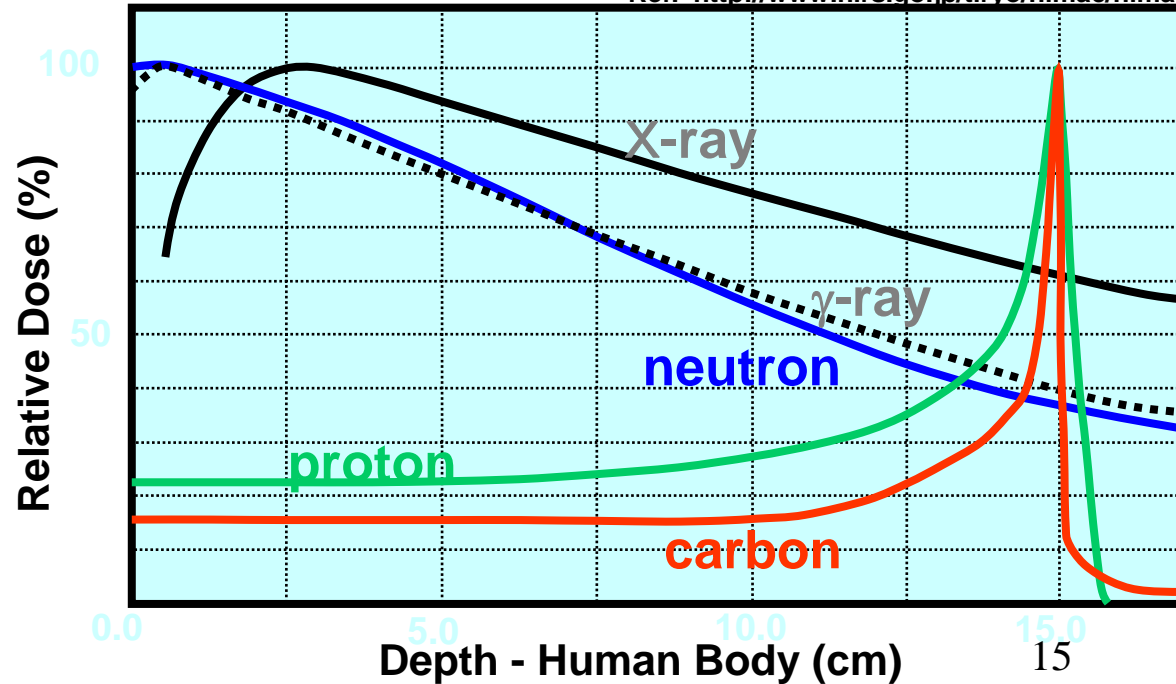
**The project we submit will help to finance**

- **French-Japanese meetings to discuss the improvement of the detection techniques.**
- **PhD students stays for short periods in France and Japan.**

# Heavy ion therapy

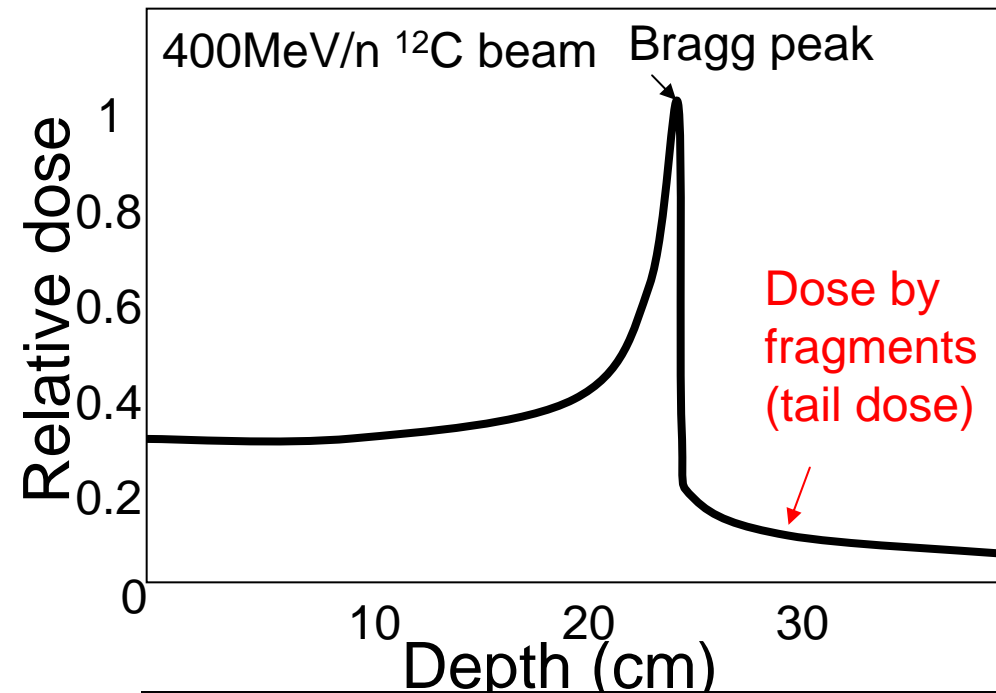
a few 100MeV/n  $^{12}\text{C}$  beam

Ref. <http://www.nirs.go.jp/tiryo/himac/himac2.htm>

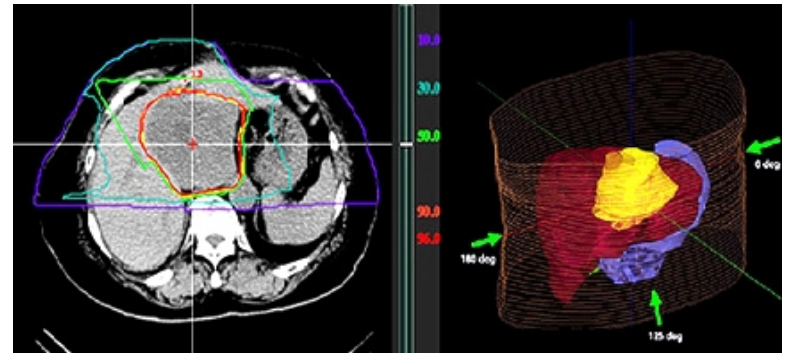


Amaldi and Kraft  
Rep.Prog.Phys.68 1861 (2005)

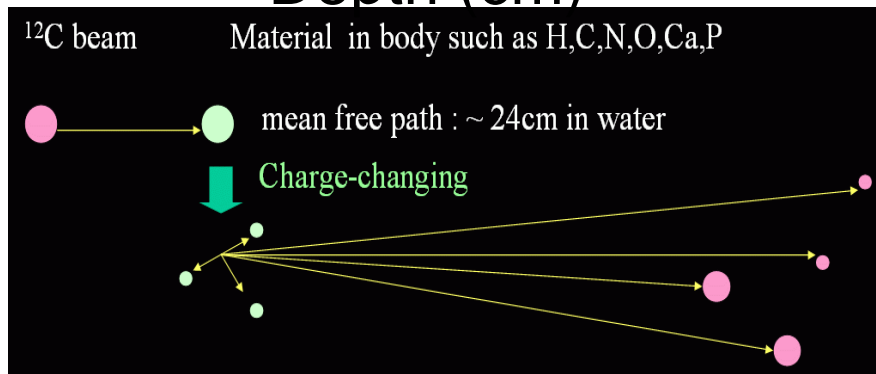
# Carbon ion therapy



Dose in body



[http://www.nirs.go.jp/hospital/conform/conform\\_04h.shtml](http://www.nirs.go.jp/hospital/conform/conform_04h.shtml)

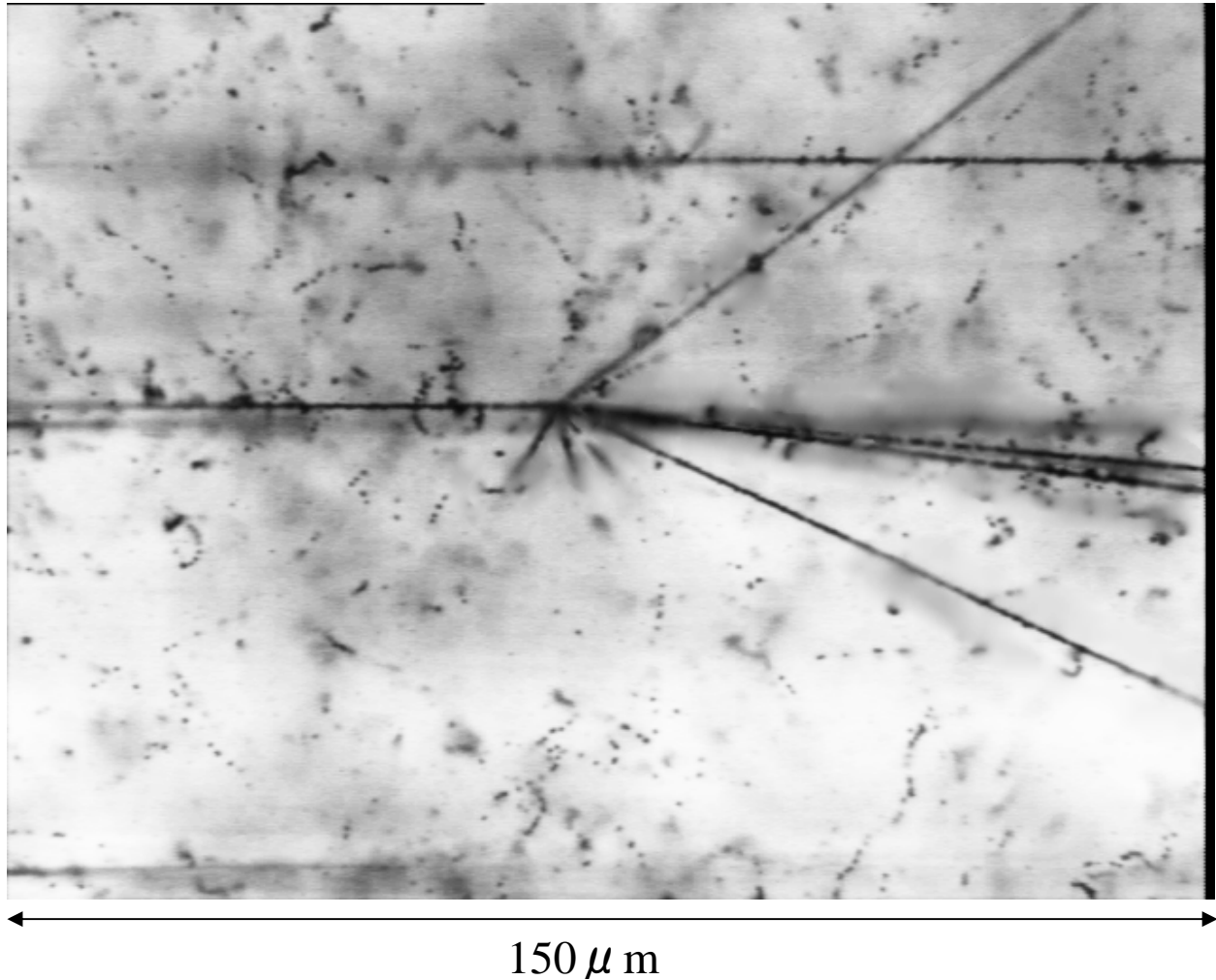


Understanding of fragmentation reactions is very important for dose calculation.

But measurement of cross sections are scarce.

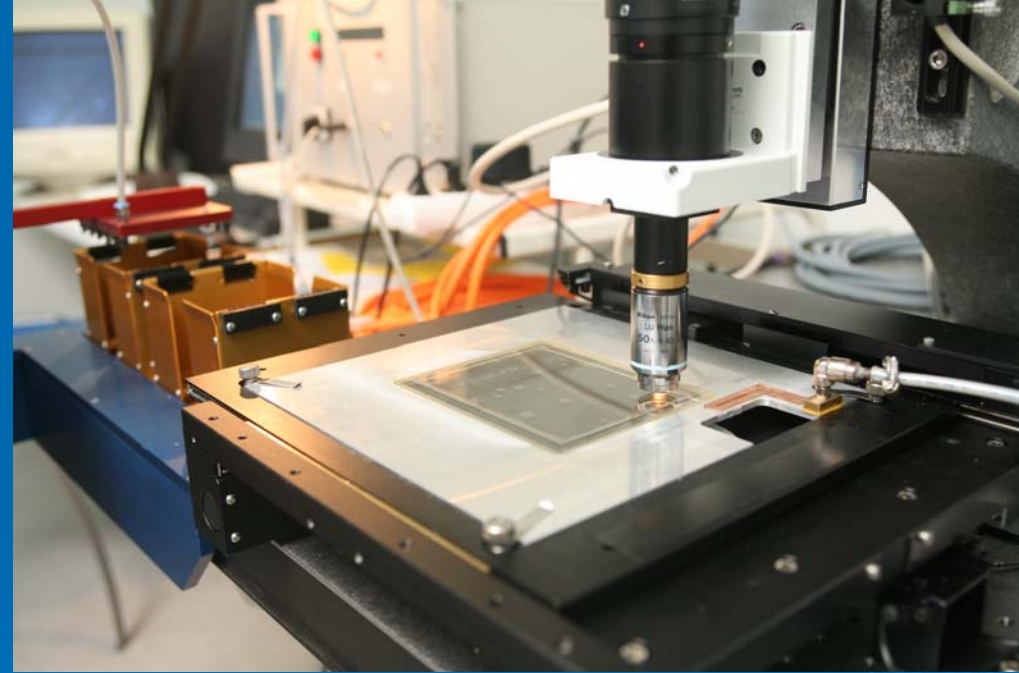
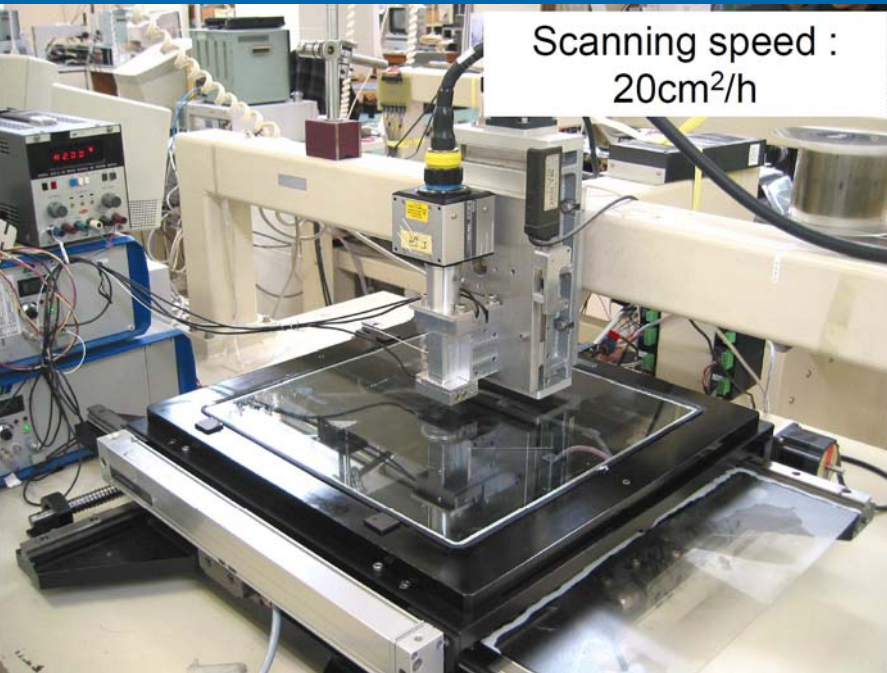
# Carbon fragmentation in nuclear emulsion

$^{12}\text{C}$   
 $180\text{MeV/u}$   
→



$4\pi$  tracking device with 3D resolution of  $\sim 1\ \mu\text{m}$   
Possible to detect and identify all charged secondary particles  
Capable of event by event analysis

# Emulsion Scanning Facility in Nagoya in Lyon



OPERA



An Emulsion-Counter  
Hybrid experiment for  
**Tau neutrino  
Appearance  
Detection.**

Collaboration :  
13countries 37 Institutes

**First Neutrino  
to Gran Sasso  
at 2006 August**

# Goal of project

- To collect data of heavy ion interactions with tissue equivalent material such as water and other materials which constitute human body such as C, N, Ca, P in the energy region from  $\sim 10$  to  $400 \text{ MeV/n}$

Beam: He, Li, Be, B, C, N, O, Ne

- To provide reaction database and validate physics models



# Activity in Japan

## NIRS-HIMAC (Chiba in Japan) P152 experiment

### Organization:

- 12 institutes from HEP, medical and space domains

#### Emulsion

- Nagoya Univ.
- Toho Univ.
- Aichi Univ. of Education
- Kobe Univ.

#### Geant4

- High Energy Accelerator Research Organization (KEK)
- Ritsumeikan Univ.
- Naruto Univ. of Education
- SLAC

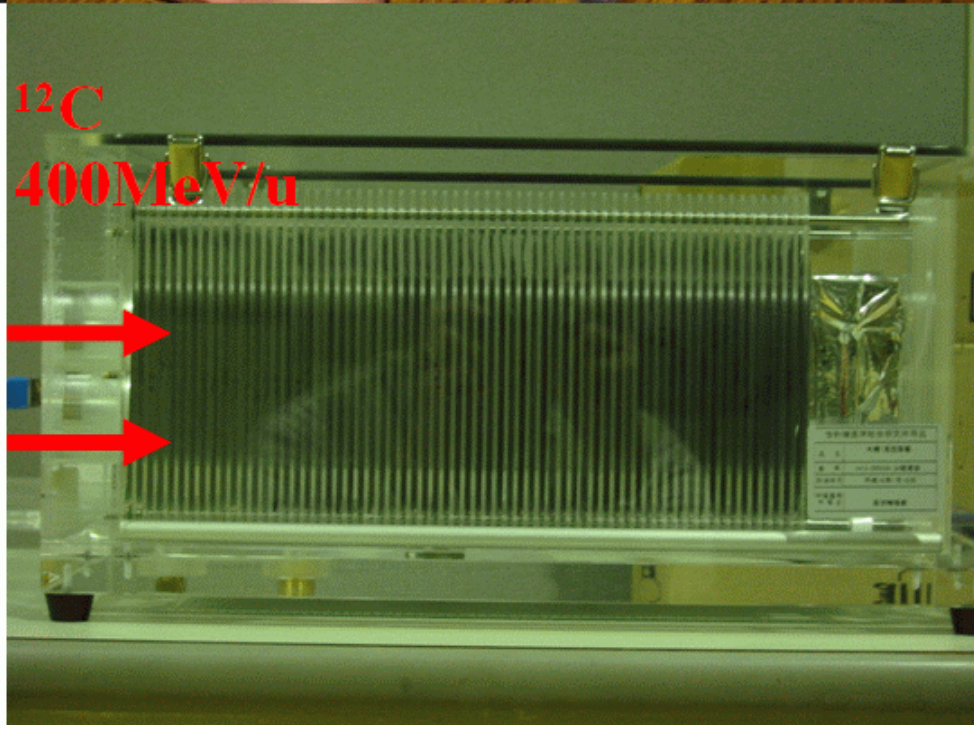
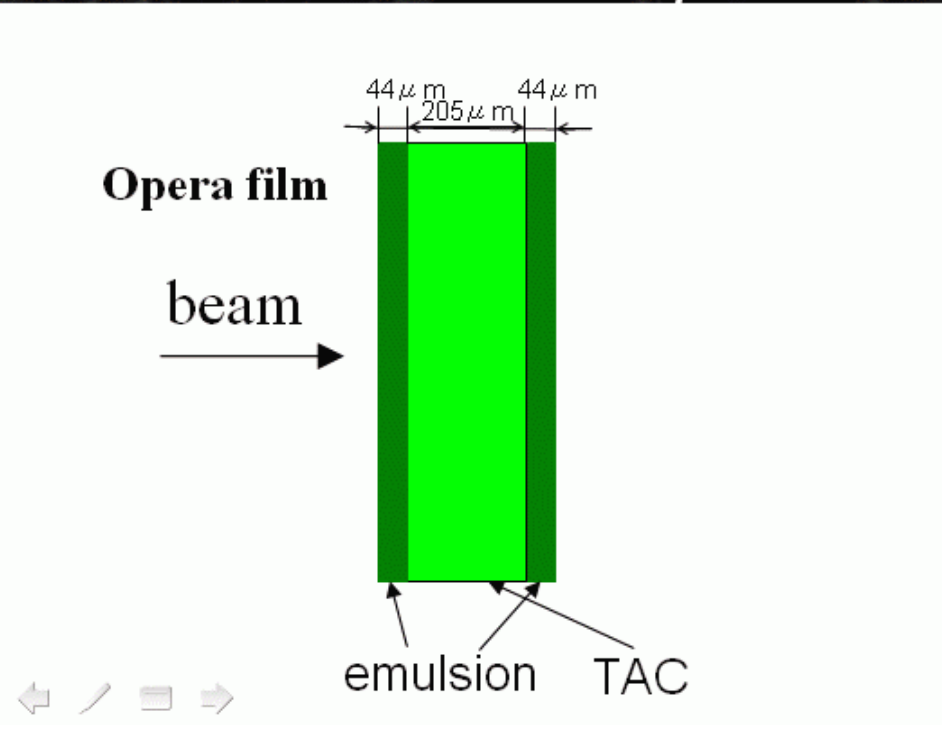
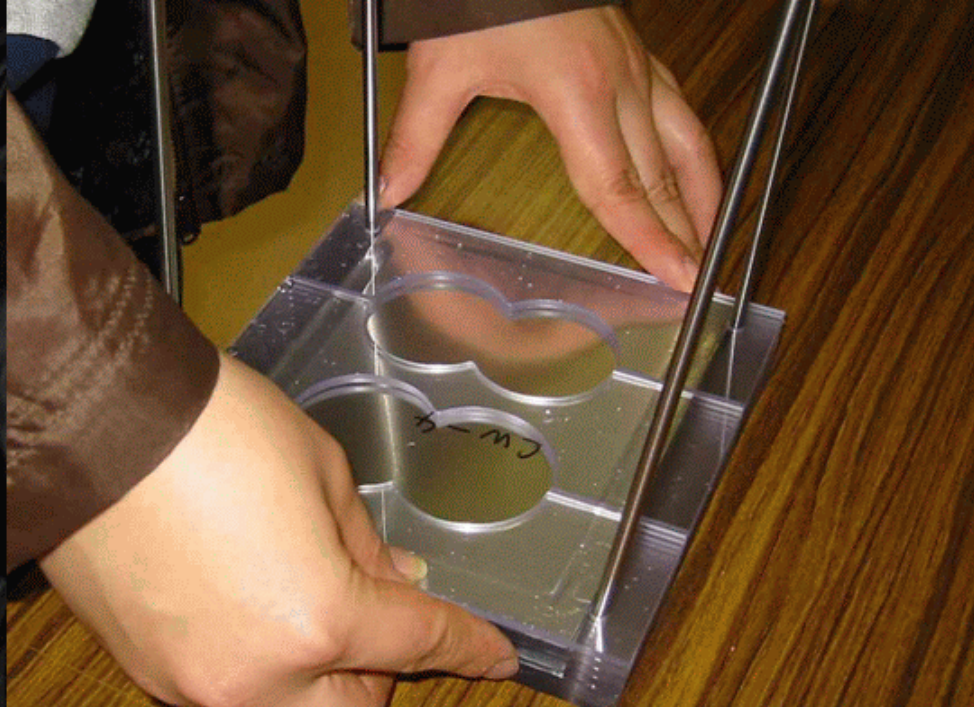
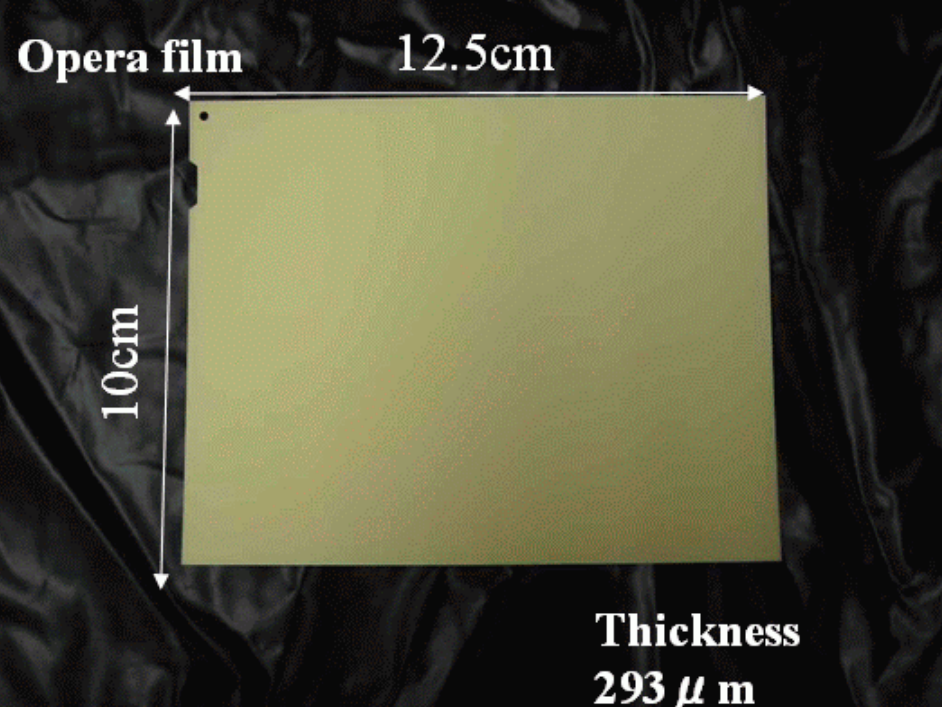
#### Medical

- National Institute of Radiological Science (NIRS)
- Gunma Univ., Faculty of Medicine

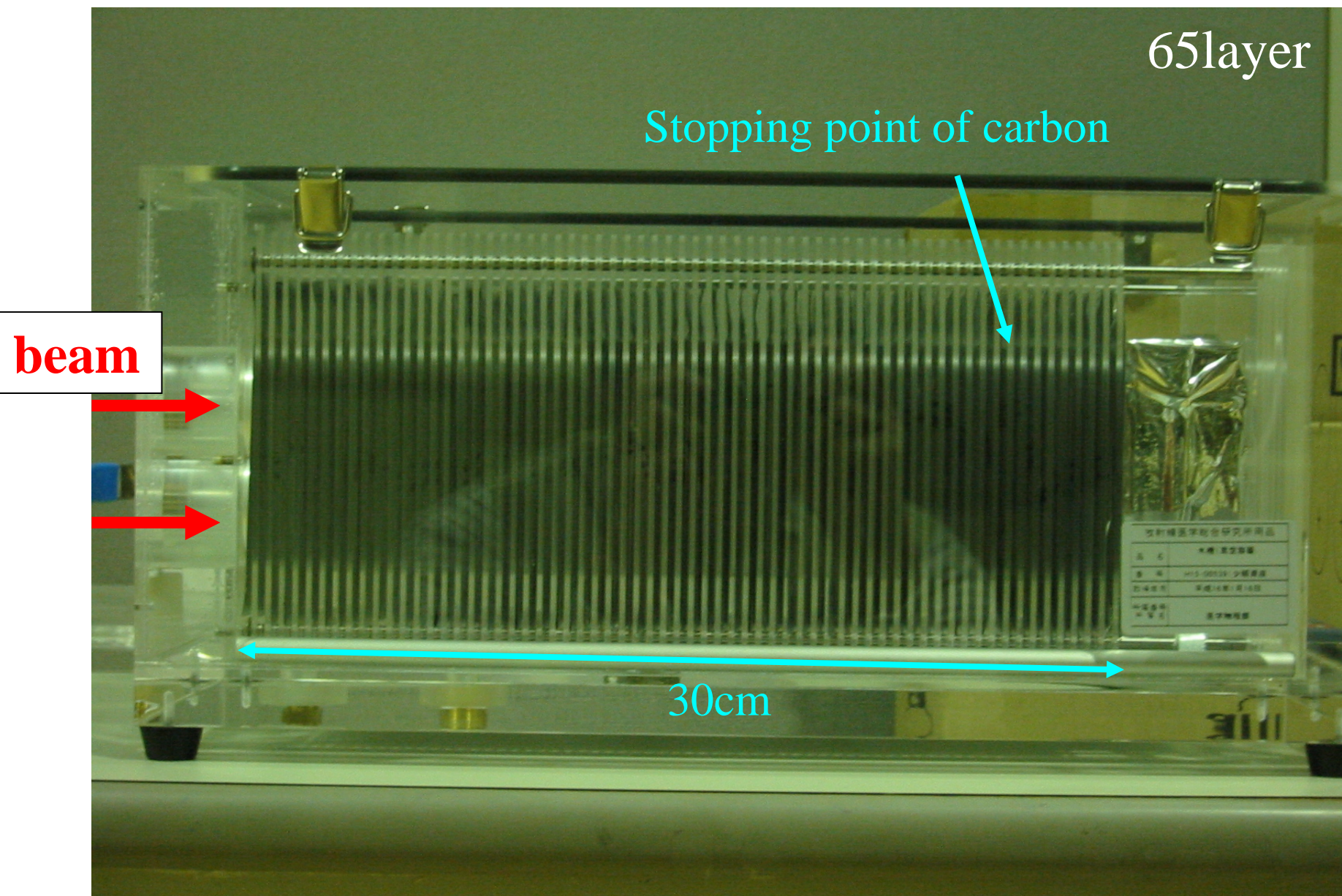
#### Space

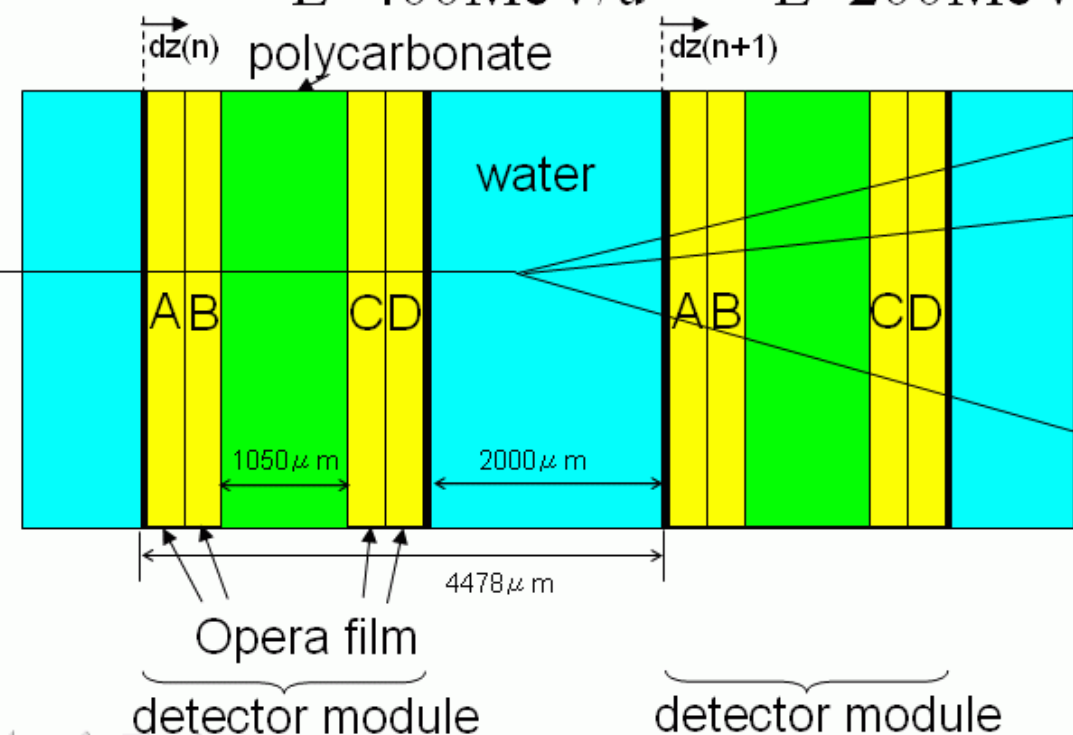
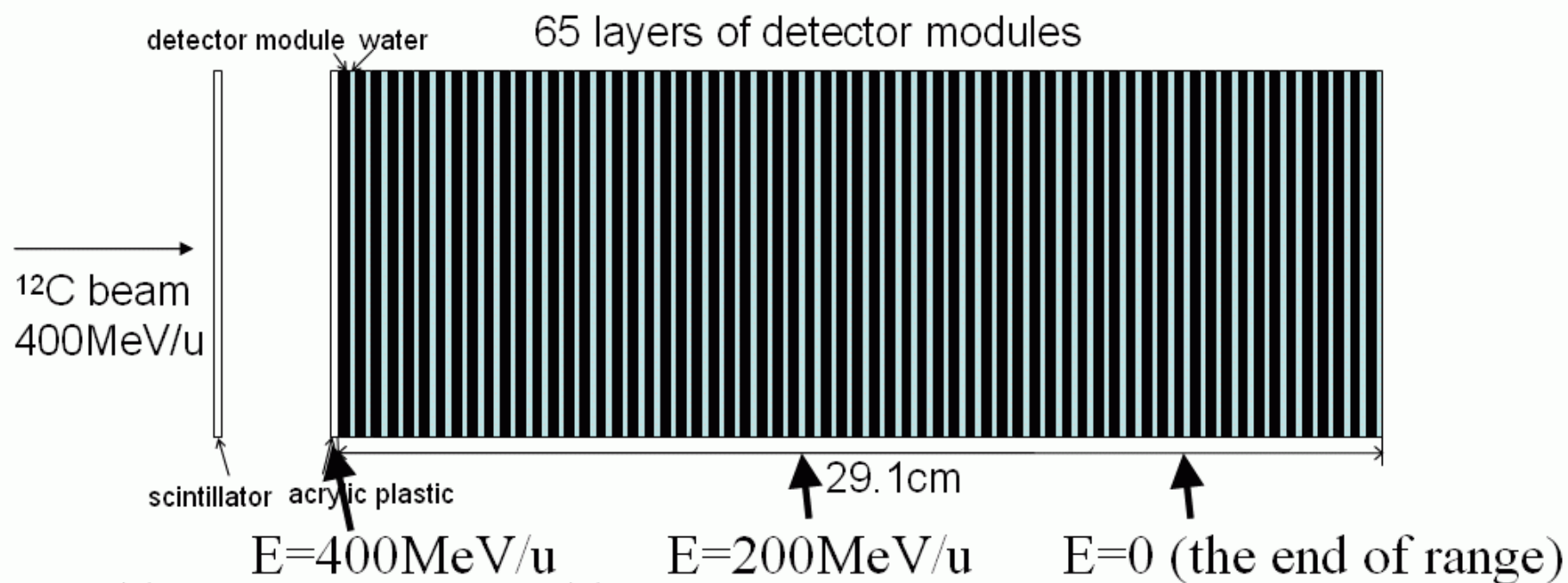
- Japan Aerospace Exploration Agency (JAXA)
- Univ. of Tokyo

- Projected started in 2003



# Physics run with 400 MeV/n $^{12}\text{C}$ and water target @ NIRS-HIMAC



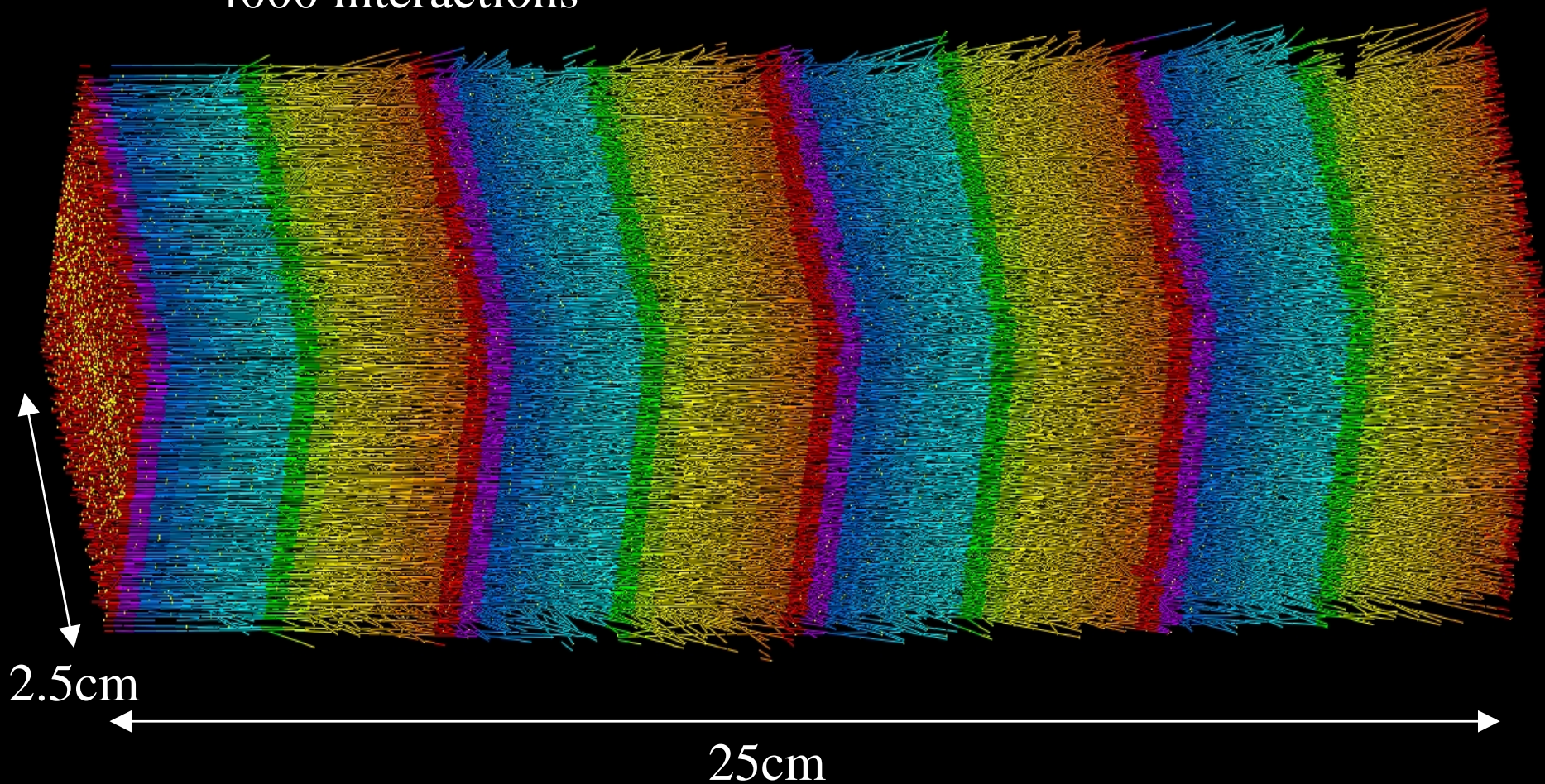


A,C: sensitive to M.I.P  
 B,D: desensitized for charge ID  
 by forced fading in high  
 temperature & high humidity  
 condition  
 erase latent image  
 “refreshing” method  
 NIM A 556 482(2006)

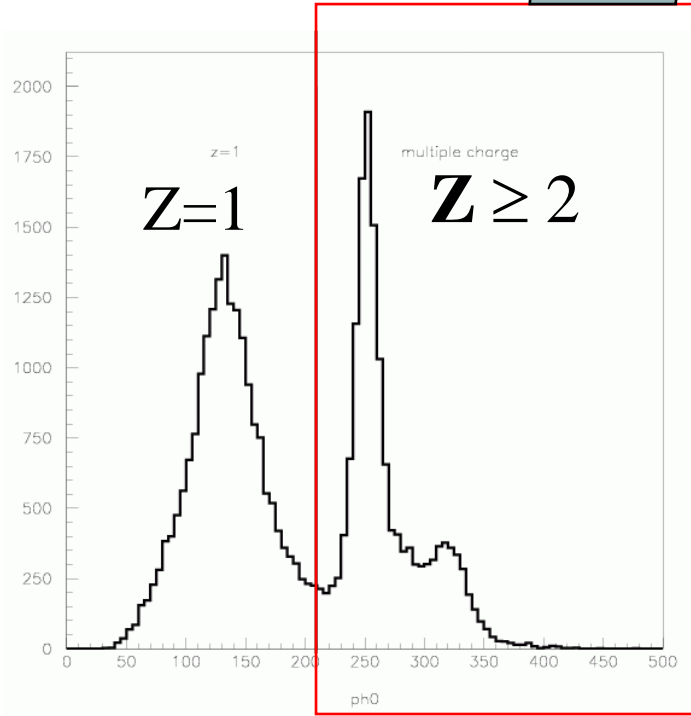
# Track and vertex reconstruction after emulsion read-out: NETSCAN

$^{12}\text{C}$  Beam  $\sim 10000$  particles  
 $\sim 4000$  interactions

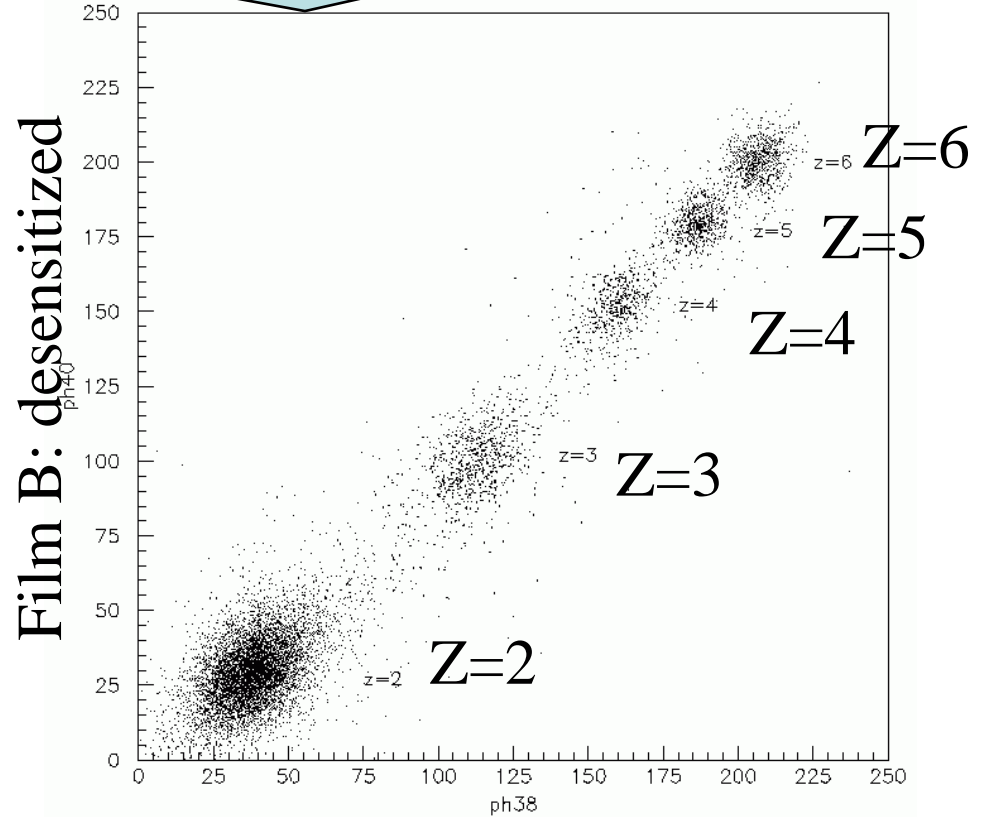
3 month to take this data by UTS



# Pulse heights



Film A: sensitive for M.I.P.



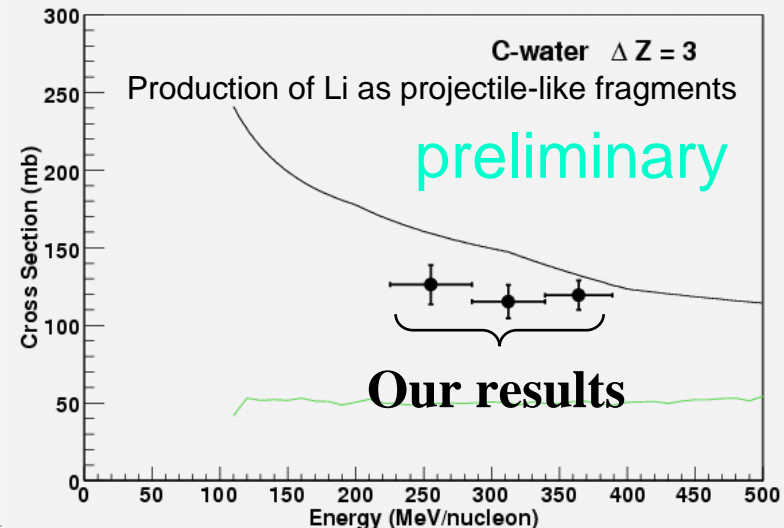
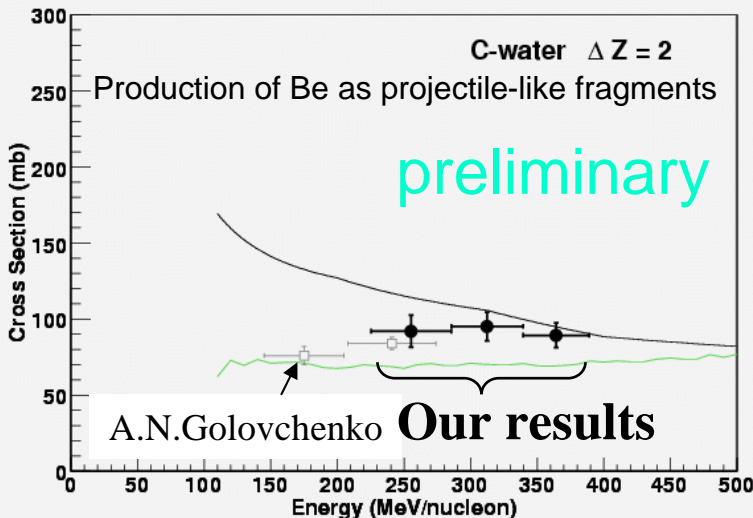
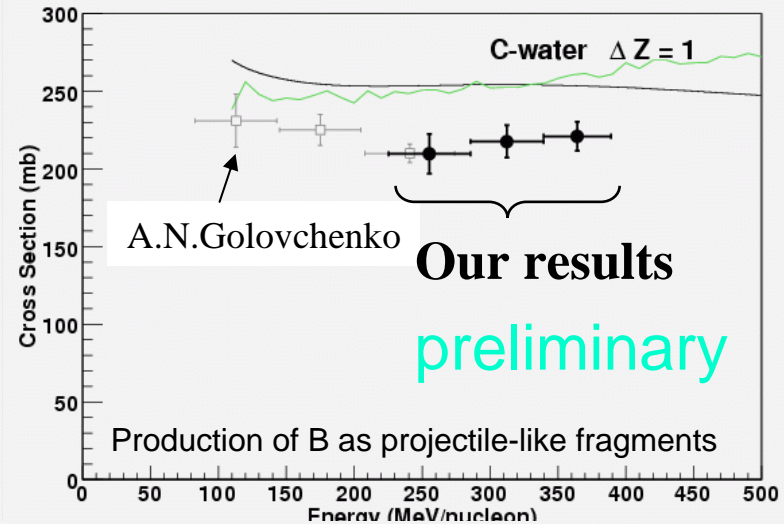
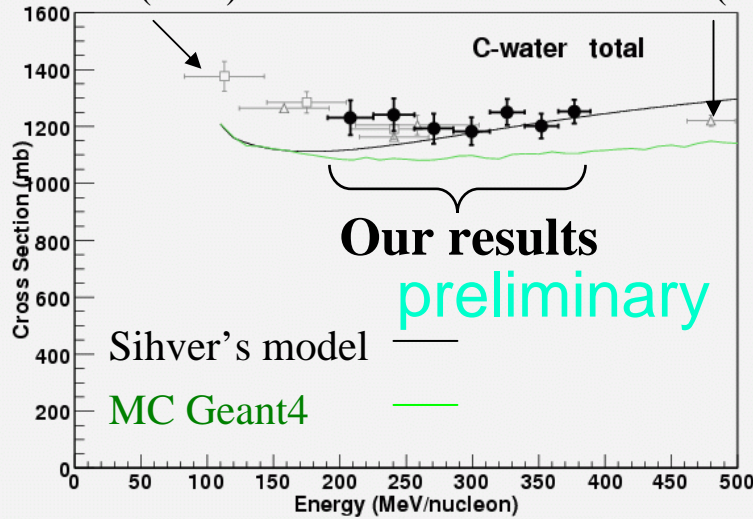
Film D: desensitized

# Carbon-Water charge-changing cross sections

Important to calculate tail dose

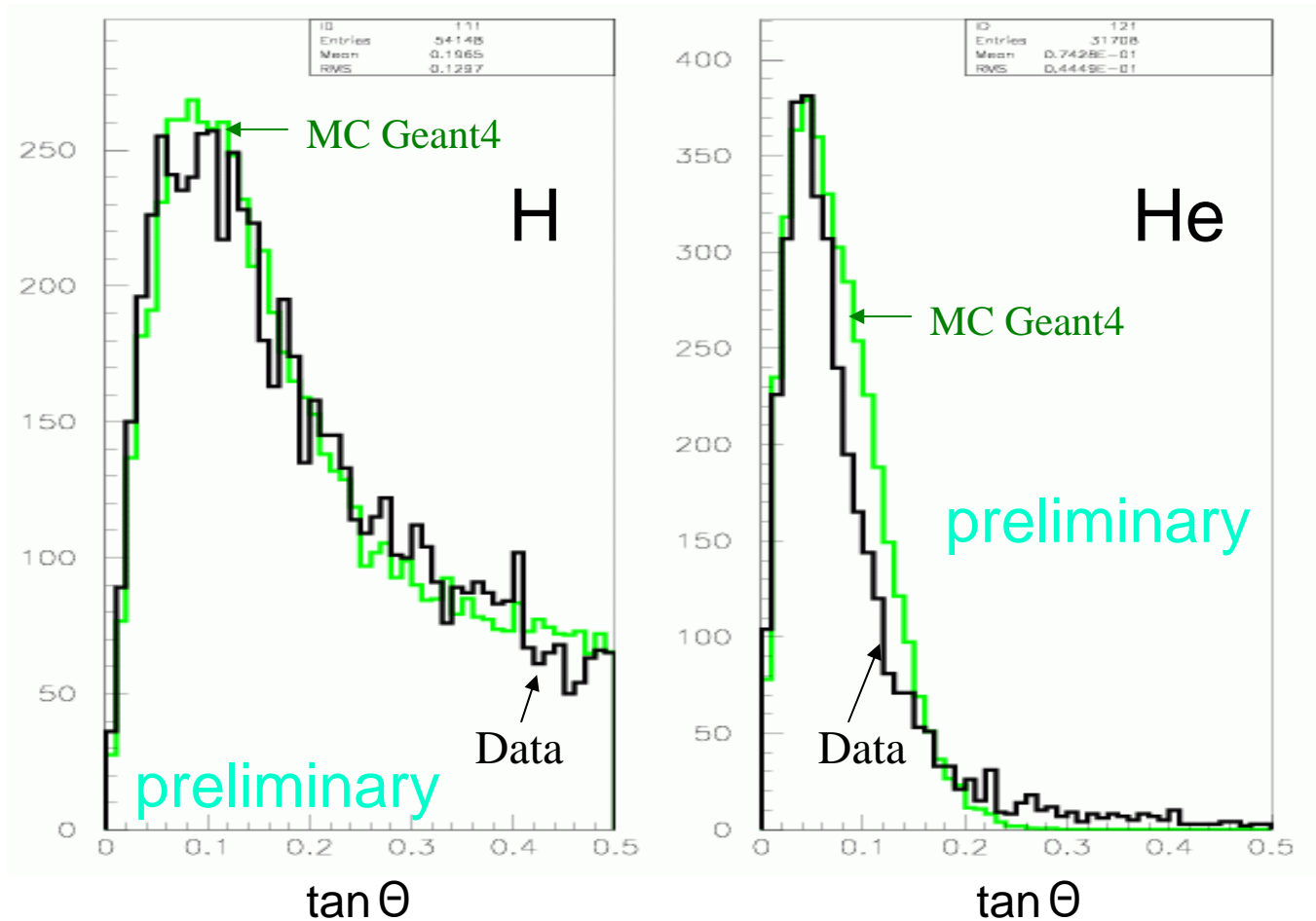
A.N.Golovchenko et al.,  
PRC 66 014609(2002)

I.Schall et al.,  
NIM B 117 221(1996)



# Angular distributions of H and He fragments

Important to calculate tail and lateral dose

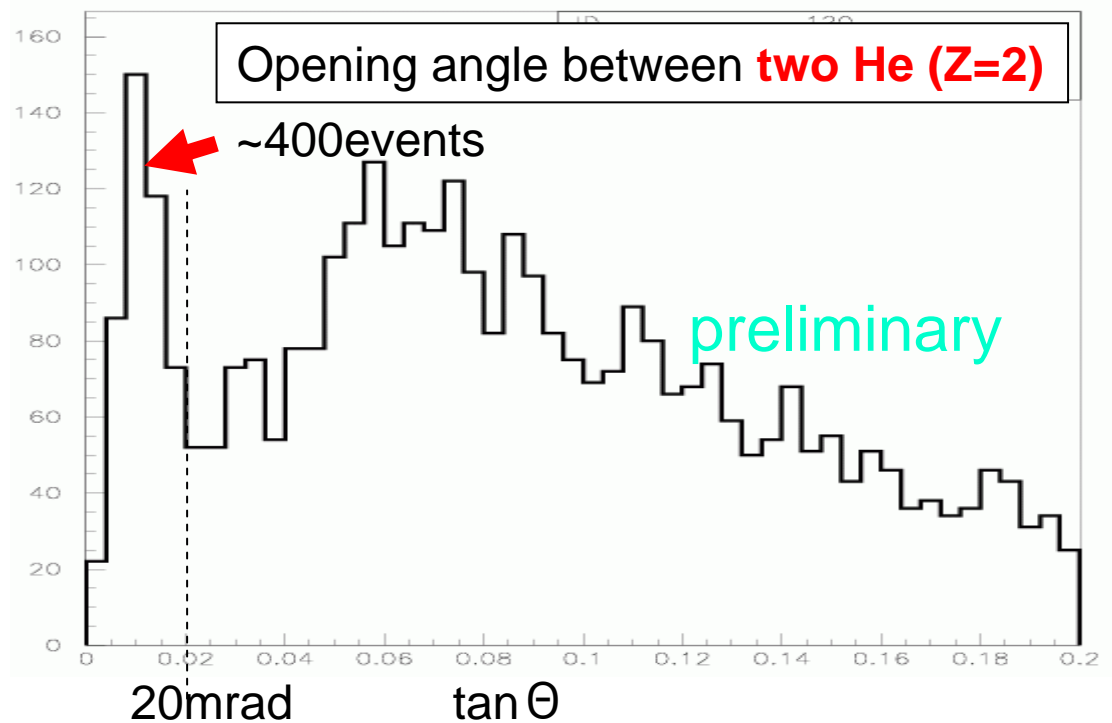
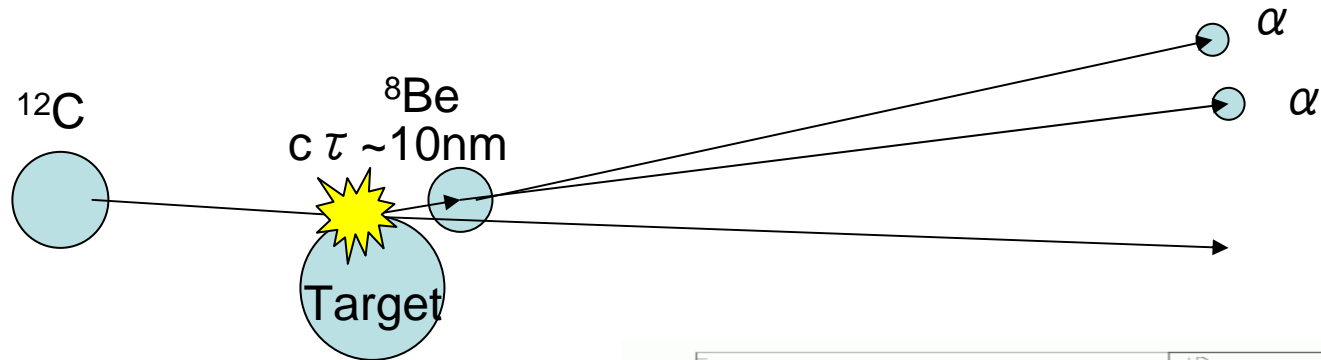




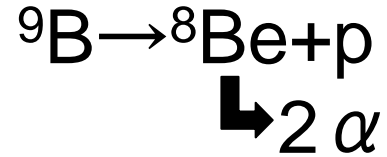
# Detection of ${}^8\text{Be}$

Small Q-value :  $\sim 90\text{keV}$

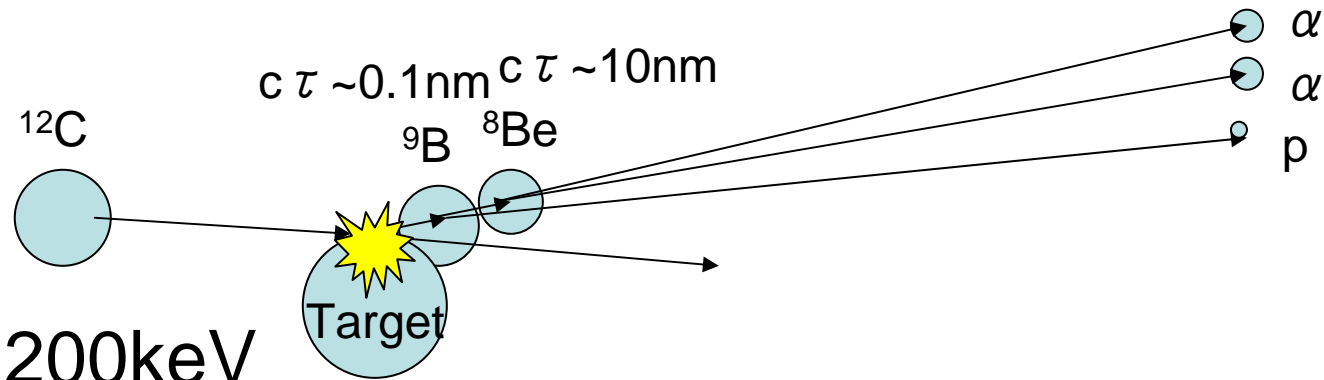
Opening angle between two  $\alpha < 20\text{mrad}$



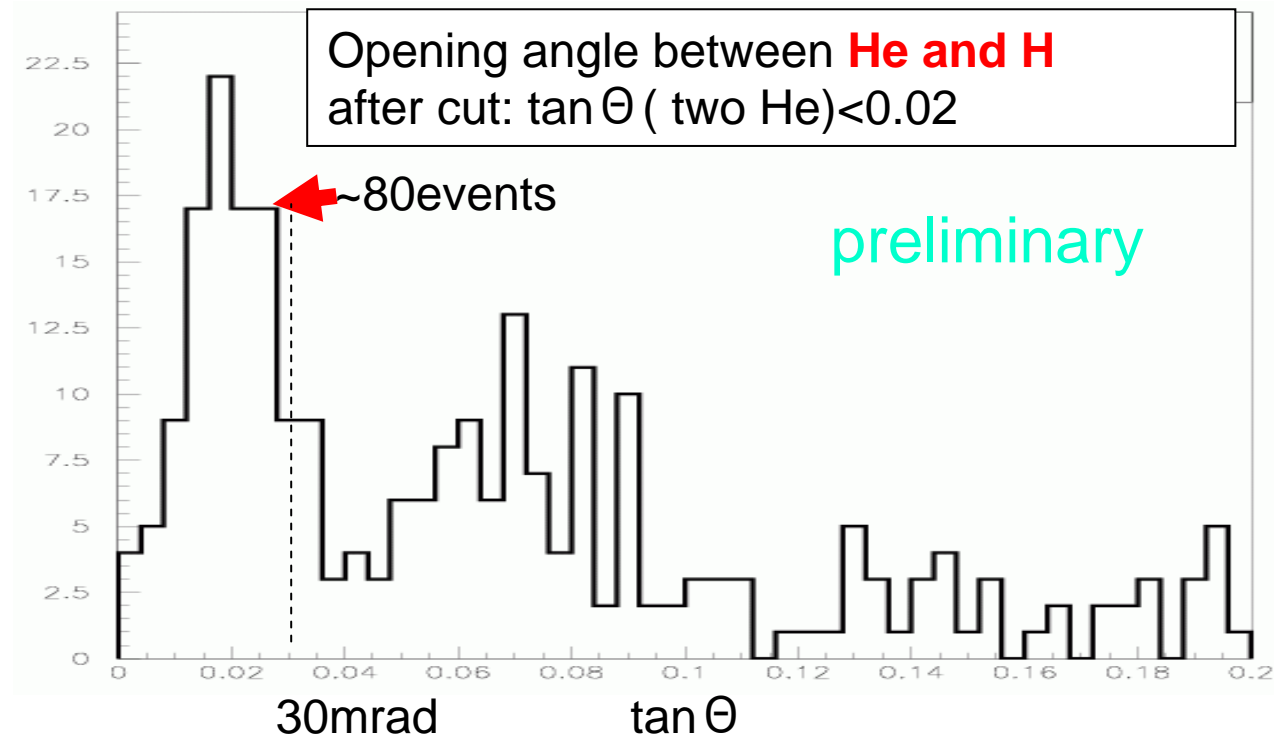
# Detection of ${}^9\text{B}$



Small Q-value :  $\sim 200\text{keV}$

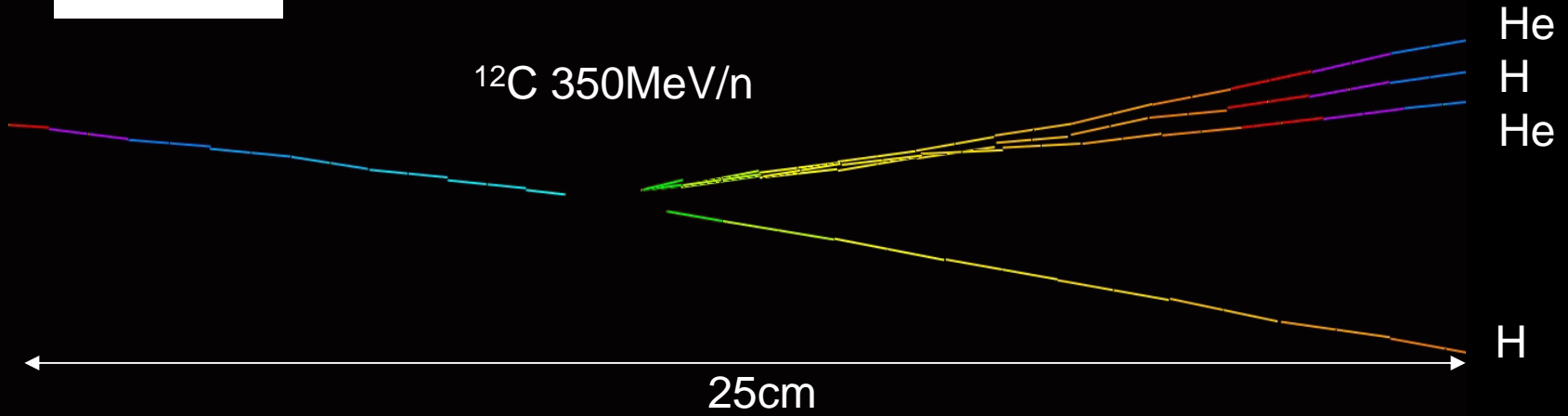


Opening angle between  $\alpha$  and  $p < 30\text{mrad}$

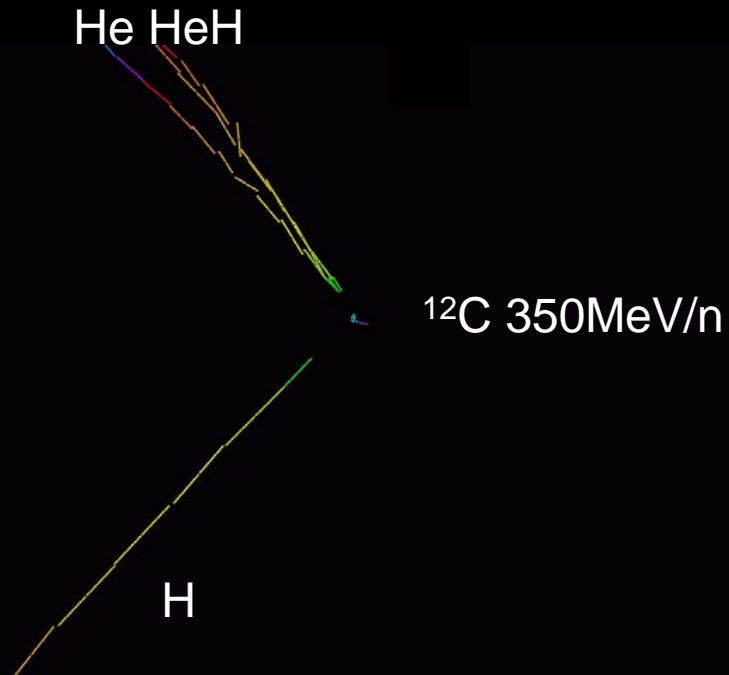


# ${}^9\text{B}$ candidate

Side-view



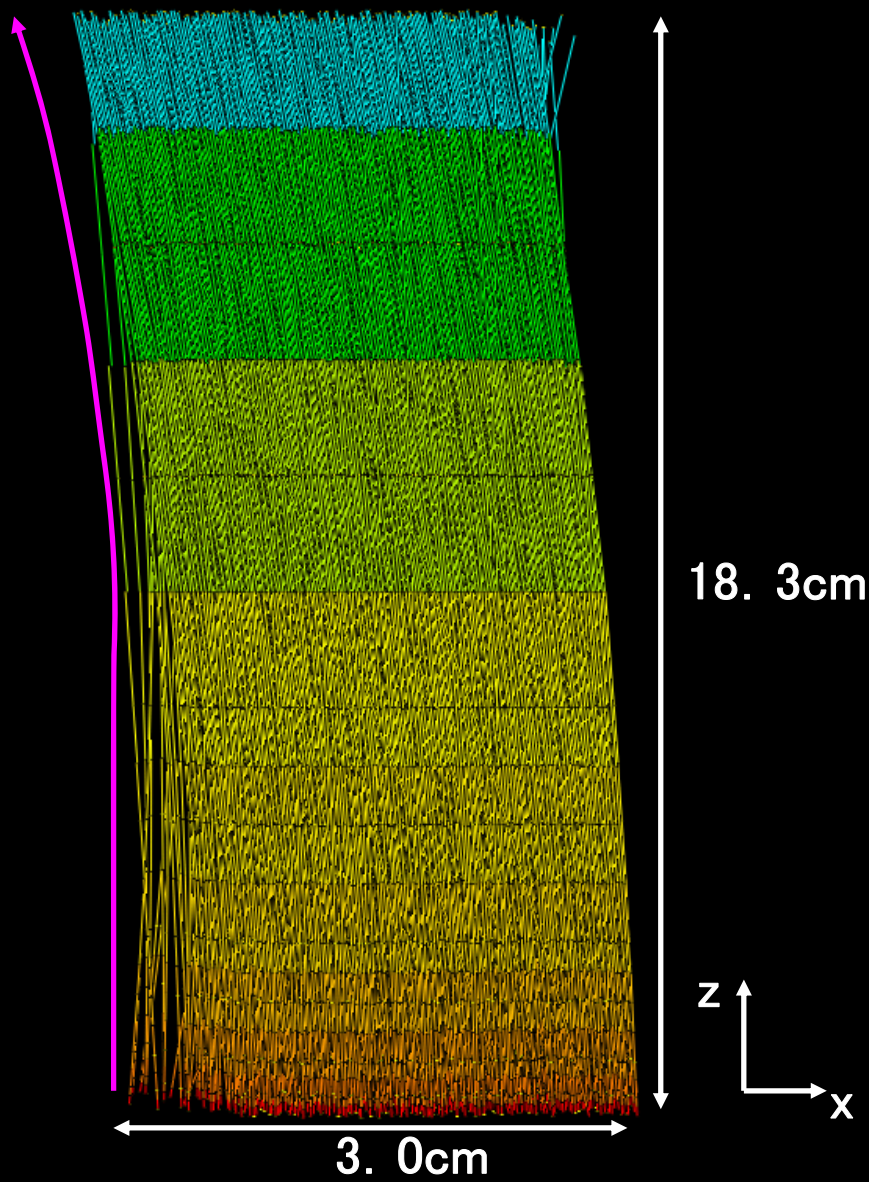
Top-view



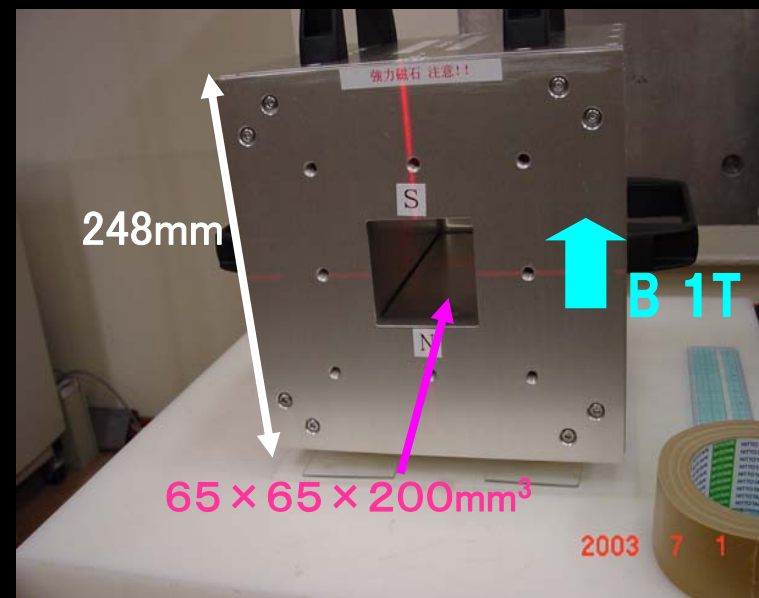
# R&D in Japan in the near future

- Data taking for various targets (C, Ca, P etc.)
- measurement of neutron flux
- isotope (mass) identification by magnetic field

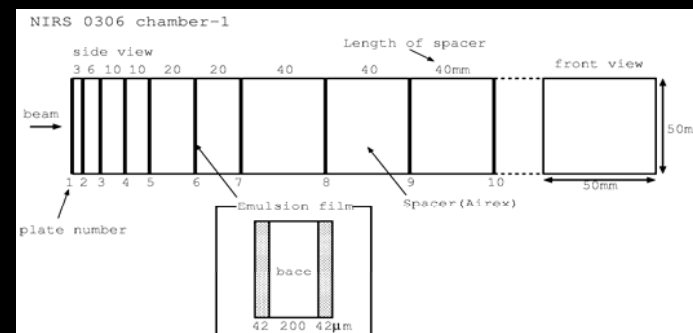
# Tracking test in magnetic field



180MeV/n  $^{12}\text{C}$  ~1000 tracks



Toho university



This technique can be applied to identify mass of fragments.

# French Scanning Facility in Lyon

4 scanning systems developed for OPERA

- Automatic
- High speed
- Sub micrometric precision

1 system is dedicated to R&D and  
biomedical application

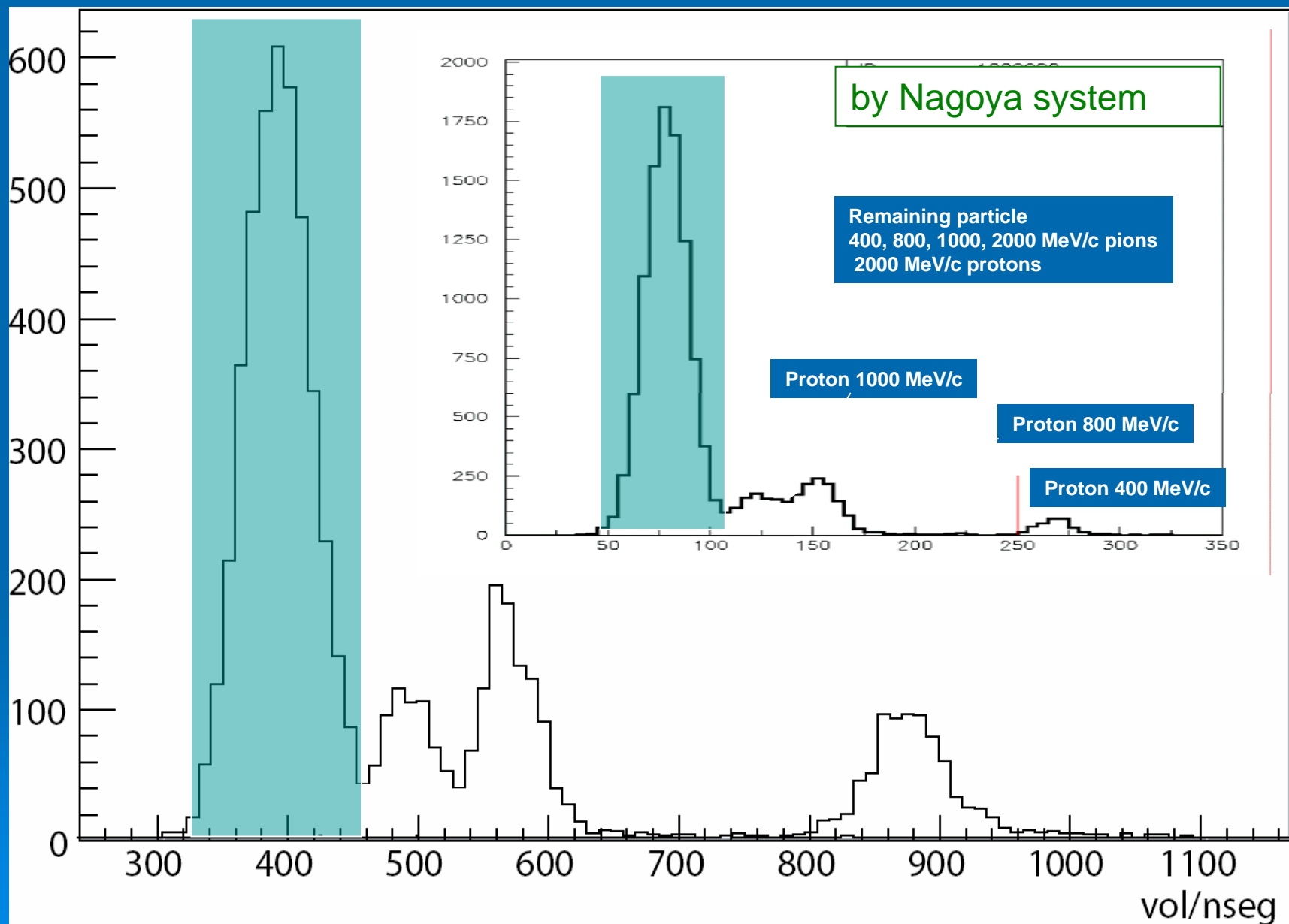
# Activities

Particle identification with nuclear emulsion using  $dE/dX$  :

High sampling technique, complementary to the technique used in Nagoya scanning systems and can be used to identify fragmentation products



# $\pi/p$ separation (data taken by Lyon system)





# Activities


CR39 scanning for

- dosage uniformity
- ions identification

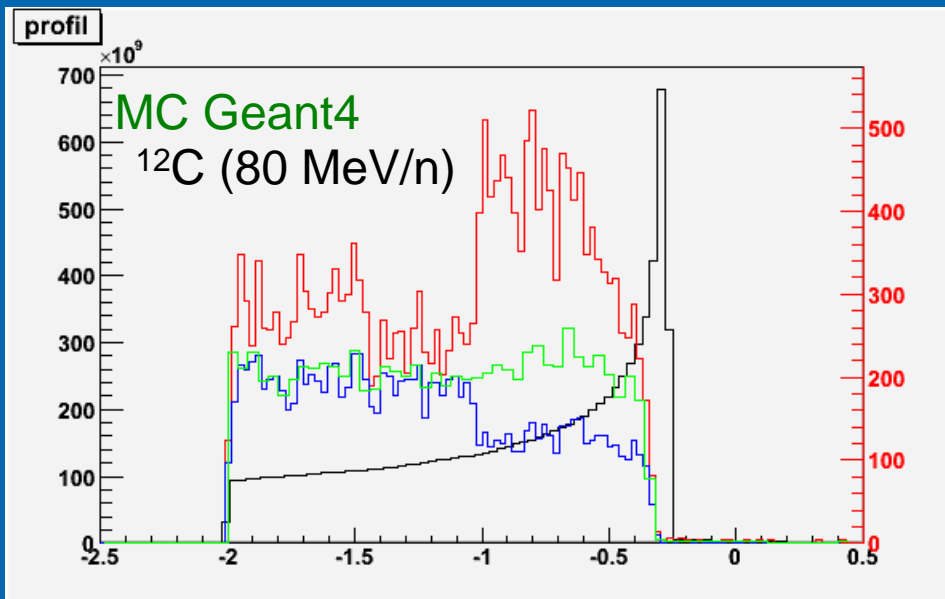
CR39 can be complementary to the nuclear emulsion and can play the role of biological tissue

**Hybrid detectors combining emulsion and CR39 can be considered in the near future to improve particle identification.**

# Activities

- Geant4 simulation of the fragmentation process
  - Ions beam exposure to biological tissues using GANIL facility
  - fragments identification using different techniques
  - Model validation
- 

# Dose profile

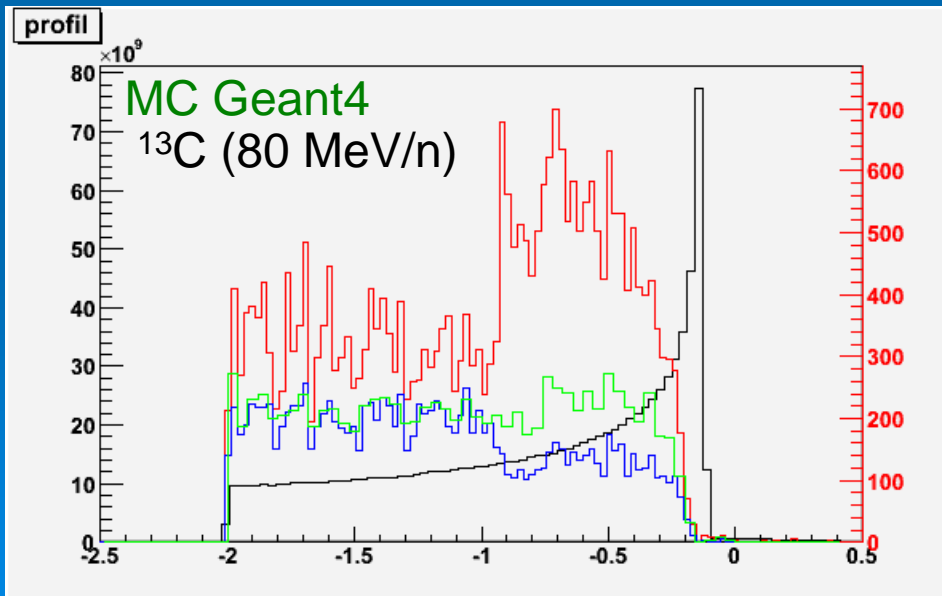


Depth (cm)

neutrons

nuclear  
reactions

gammas



~1/10 of the ions  
fragment

# Summary

- R&D of emulsion technology and physics data taking in high energy region ( $>100\text{MeV/n}$ ) has been performed using NIRS-HIMAC in Japan since 2003.
- R&D in low energy region ( $<100\text{MeV/n}$ ) was started using GANIL in France in 2006.
- Wider energy range can be obtained by using the different beams available in both countries (GANIL, NIRS) to study a variety of targets.
- We will provide heavy ion reaction database to improve heavy ion therapy.

# Nuclear Emulsion Workshop 7–9 Dec 2006

at Noyori Conference Hall Nagoya University

**Organizing committee** :: Kimio Niwa(Chair man ,Nagoya)  
Antonio Ereditato(Bern)  
Maria-Teresa Muciaccia(Bari)  
Luca Stanco (Padova)  
Yves Declais(IPNL(Lyon))

**Secretary**:: Osamu Sato

**Last Update**:: 2006/Dec/13 13:00

## -- Other emulsion application study --

- : Study of compact emulsion spectrometer for identification of neutrino/anti-neutrino [PPT PDF](#) (20') C.Fukushima
- : Volcano Mt.Asama study by emulsions [PDF](#) (20') S.Takahashi
- : Gamma Telescope [PPT PDF](#) (20') S.Aoki
- : WIMP search by NIT status report [PPT PDF](#) (20') M.Natsume,T.Naka
- : Ultracold neutrons [PPT PDF](#) (20') I.Laktineh
- : Medical Application [PPT PDF](#) (20') G.De Lellis
- : Fragmentation reaction of carbon in water [PDF](#) (20') T.Toshito

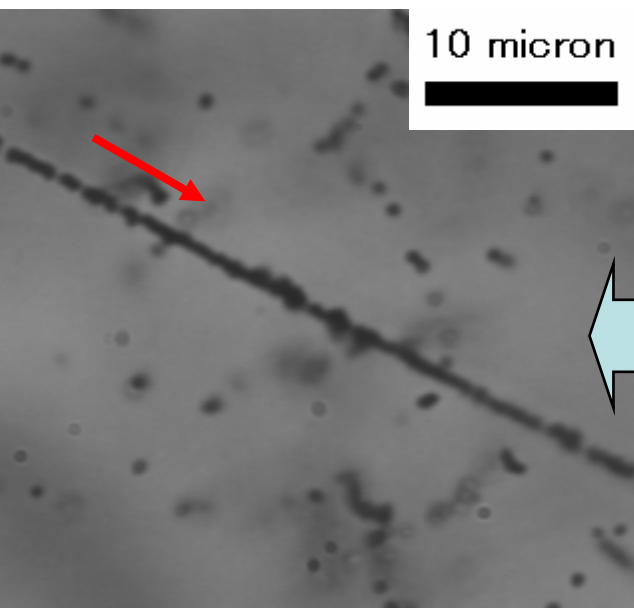
# “Etoile” project

- This is a heavy ions therapy machine project approved this year (13 Feb 2007).
- The center will be built in the Lyon region (Rhone-Alpes).
- It intends to treat 1000 patients by year.
- The first patients should be treated > 2010.

# Gold deposition development for charge identification in lower energy region $<200\text{MeV/n}$

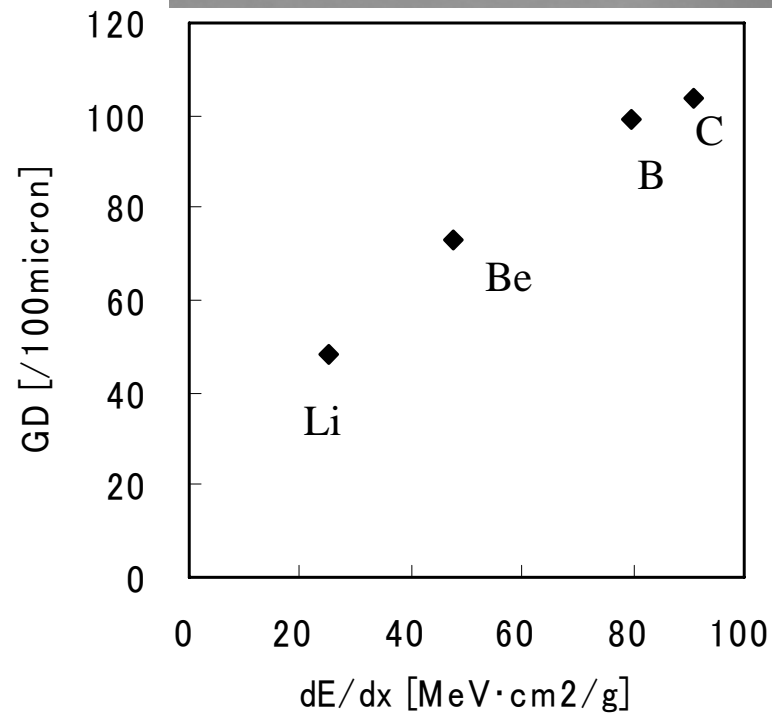
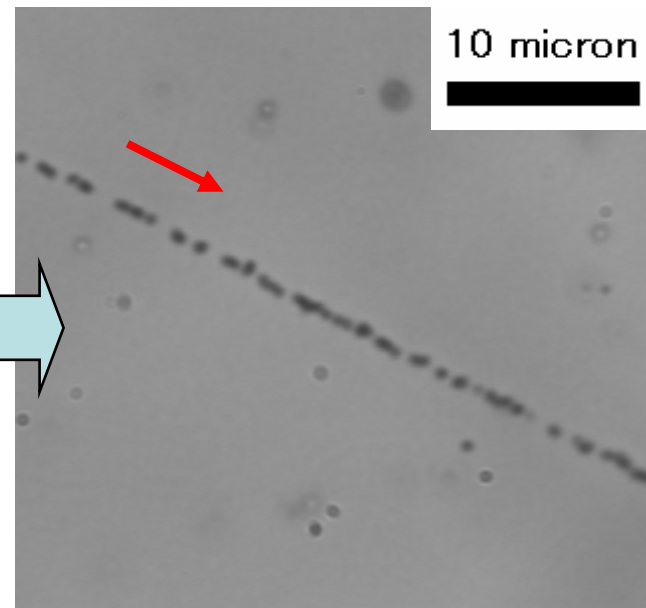
R&D by H. Kubota (Nagoya)

# XAA dev.



Carbon track  
203[MeV/u]  
M.I.P. × 50

# Gold deposition dev.

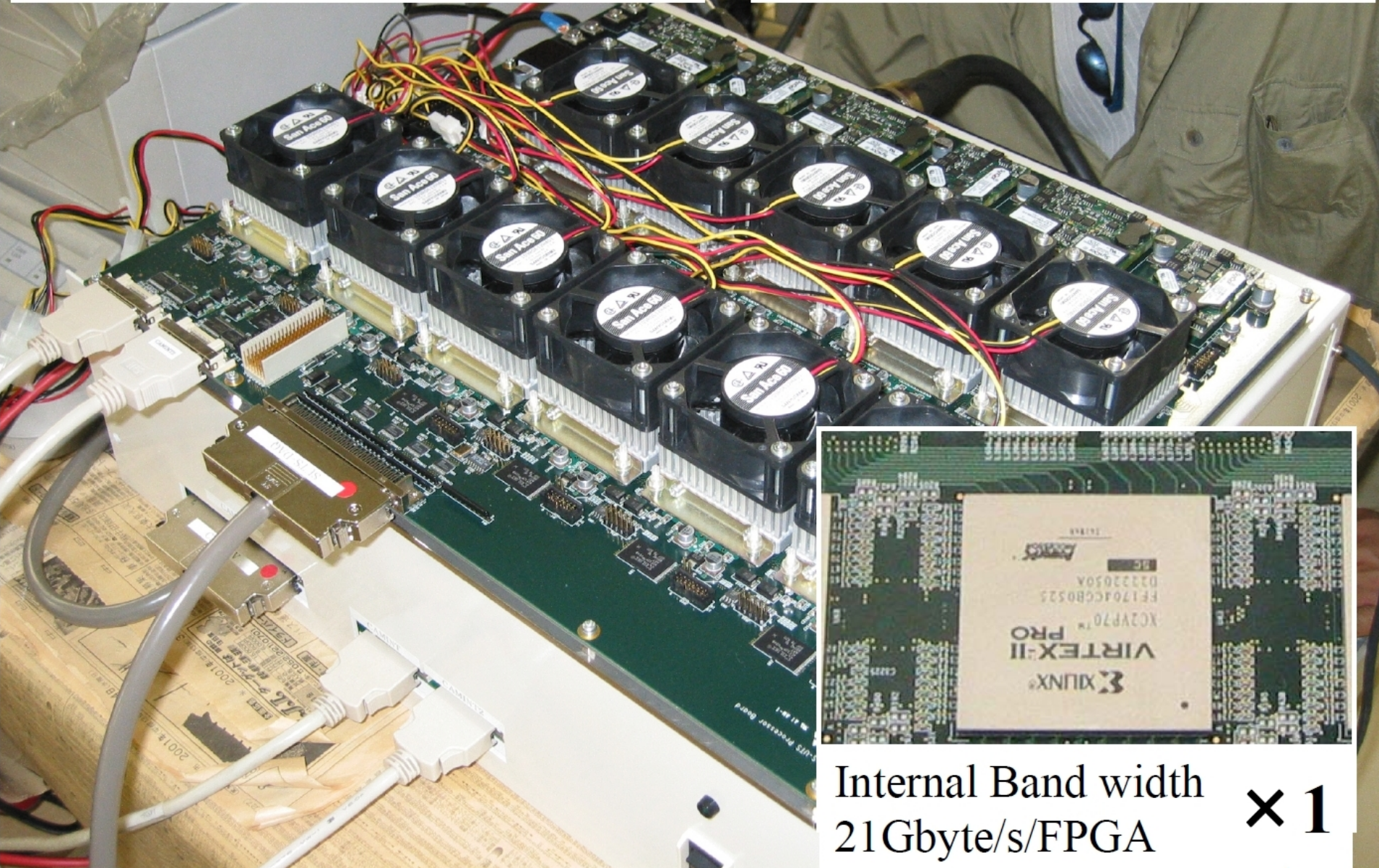




# SUTS

## Track recognition board

Processing speed :  
Up to 40cm<sup>2</sup>/h/board

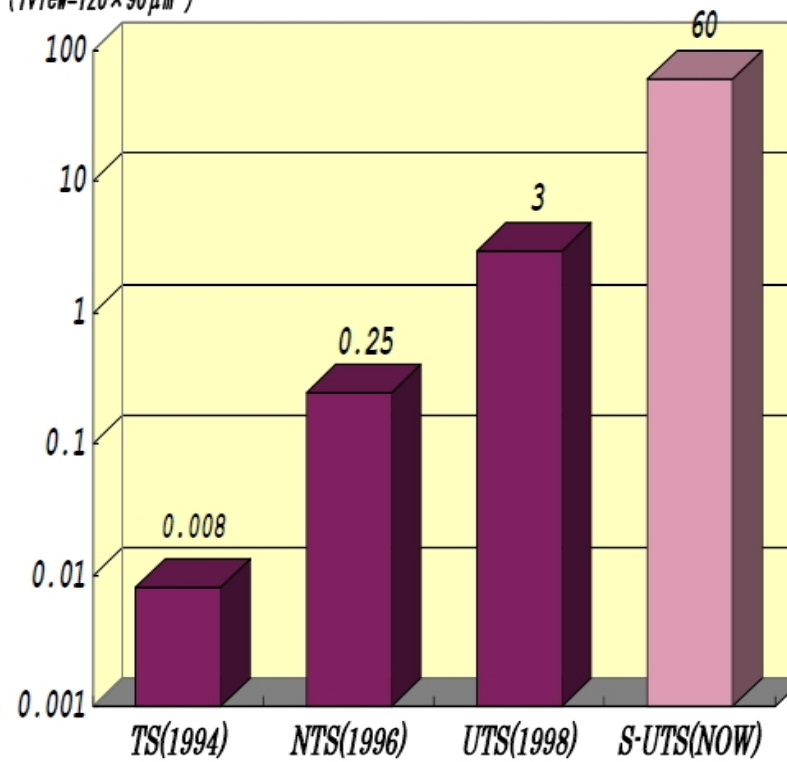


Internal Band width  
21Gbyte/s/FPGA × 1

# Scanning Power Roadmap

views/sec

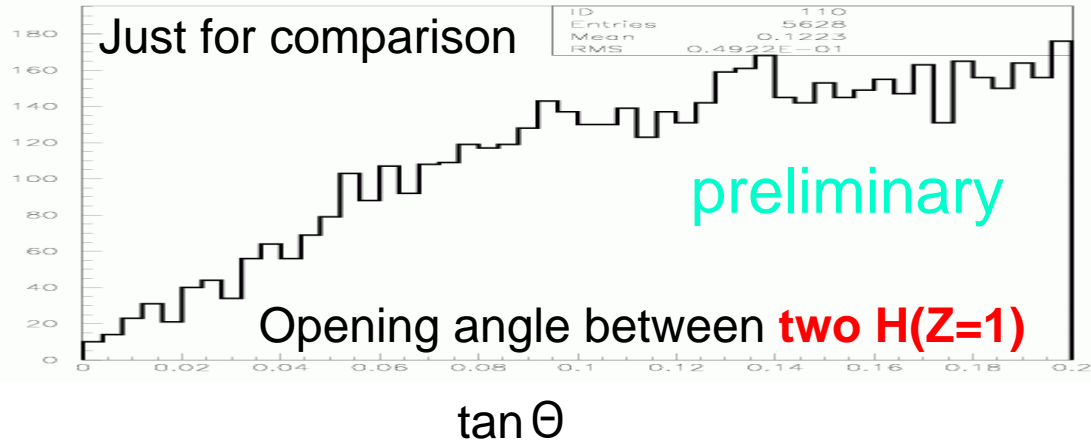
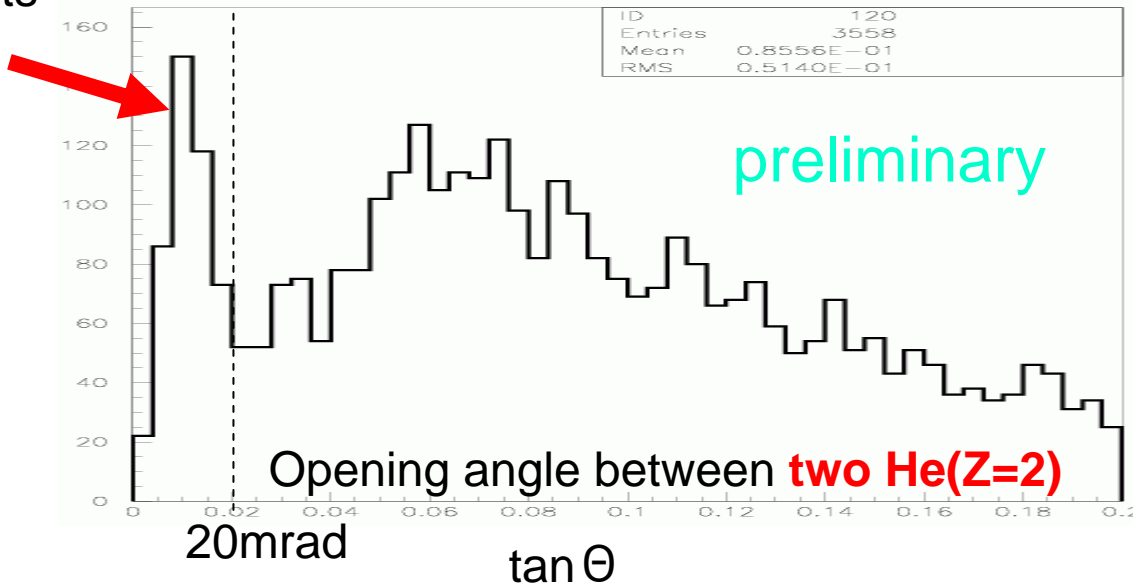
(1view=120x90 $\mu\text{m}^2$ )



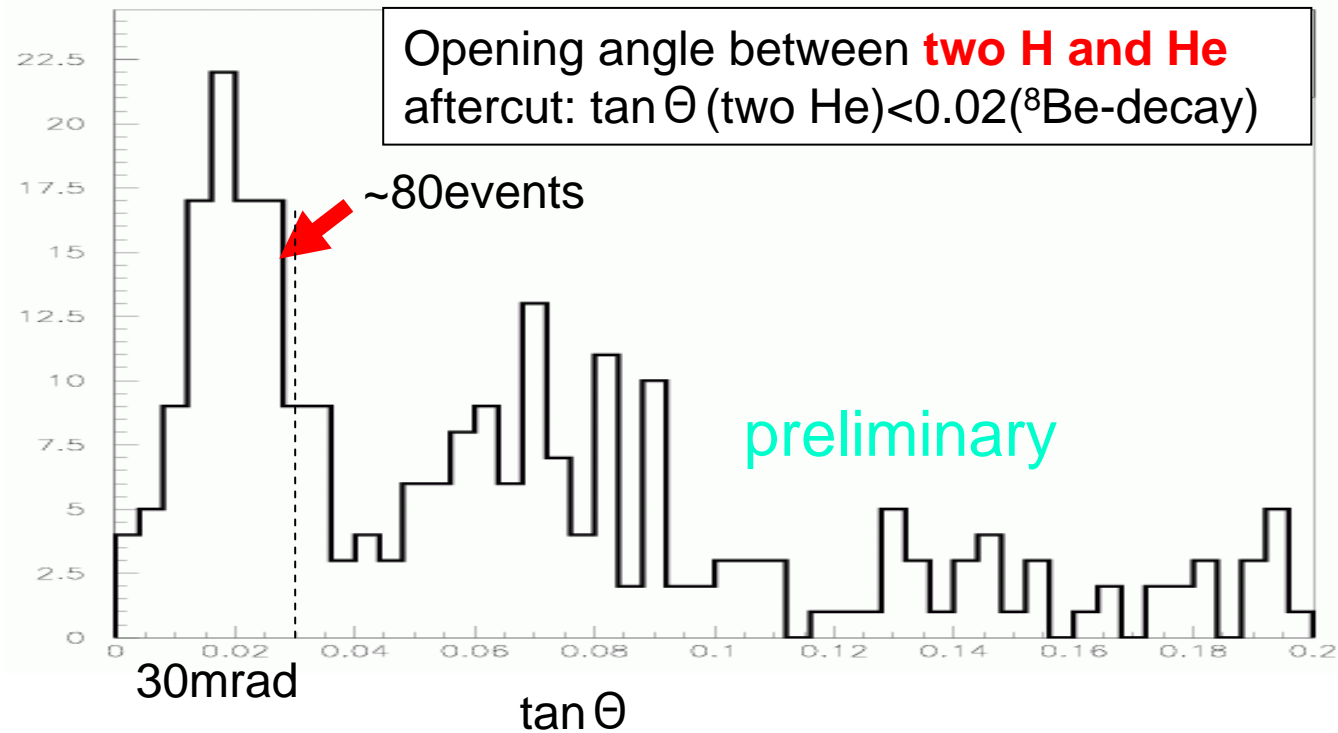
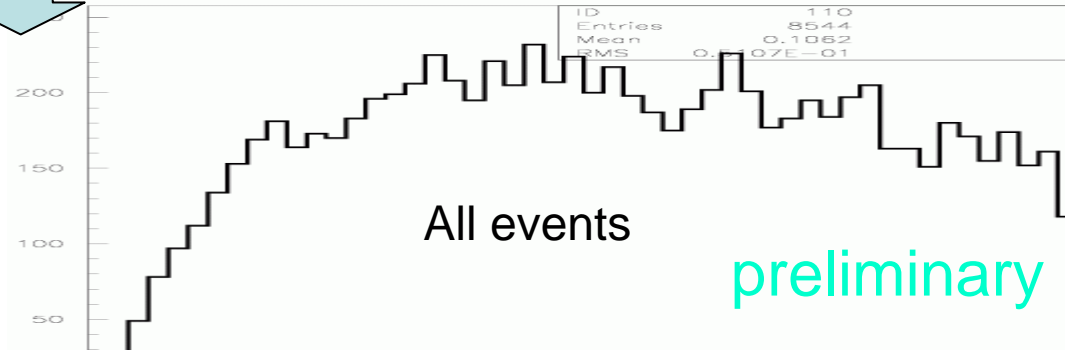
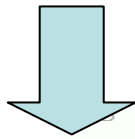
C-Water  
event by event analysis  
in 200-400MeV/n  
-Observation of  ${}^8\text{Be}$  and  ${}^9\text{B}$

# Opening angle between two He(Z=2)

~400 events observed



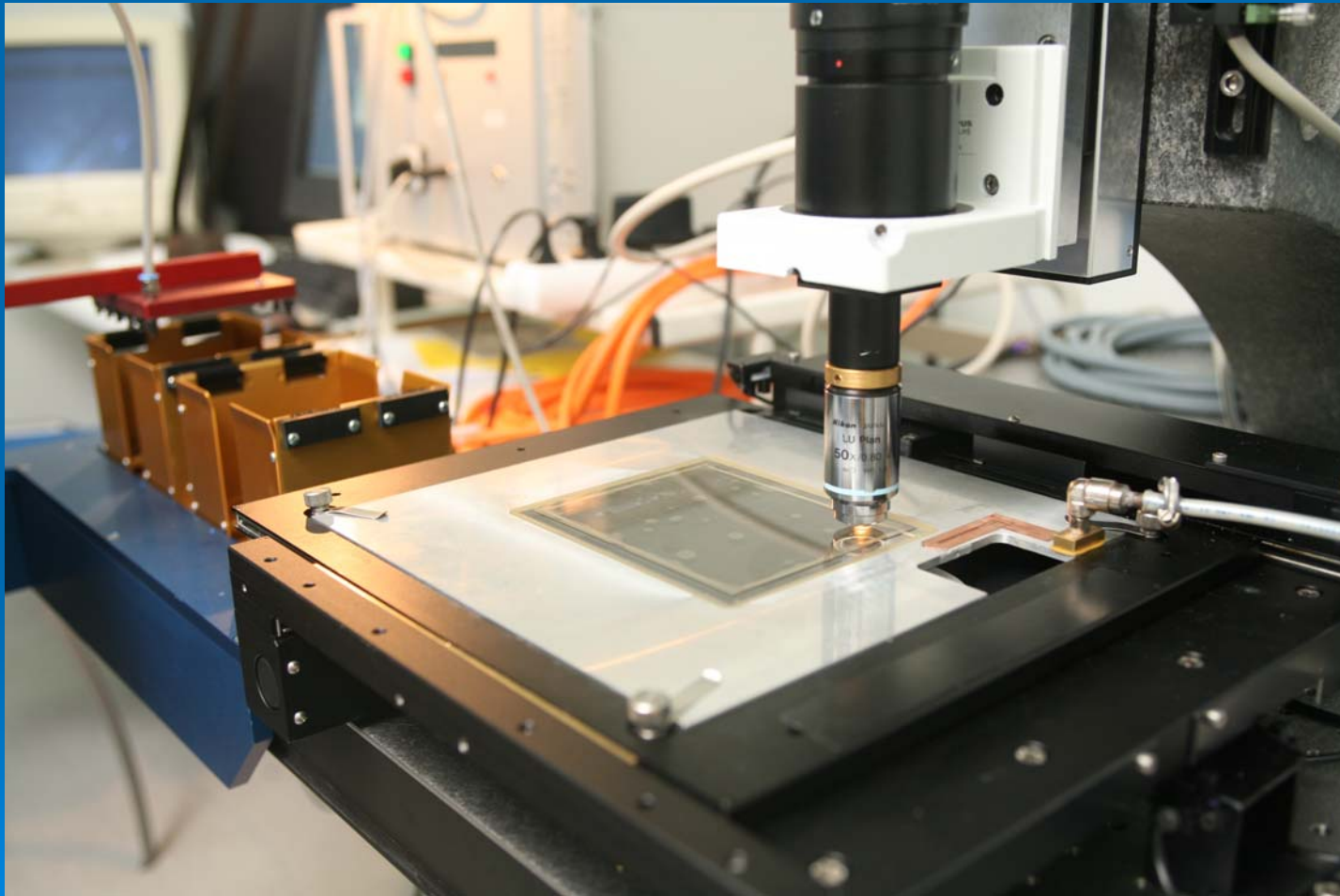
# Opening angle between He and H

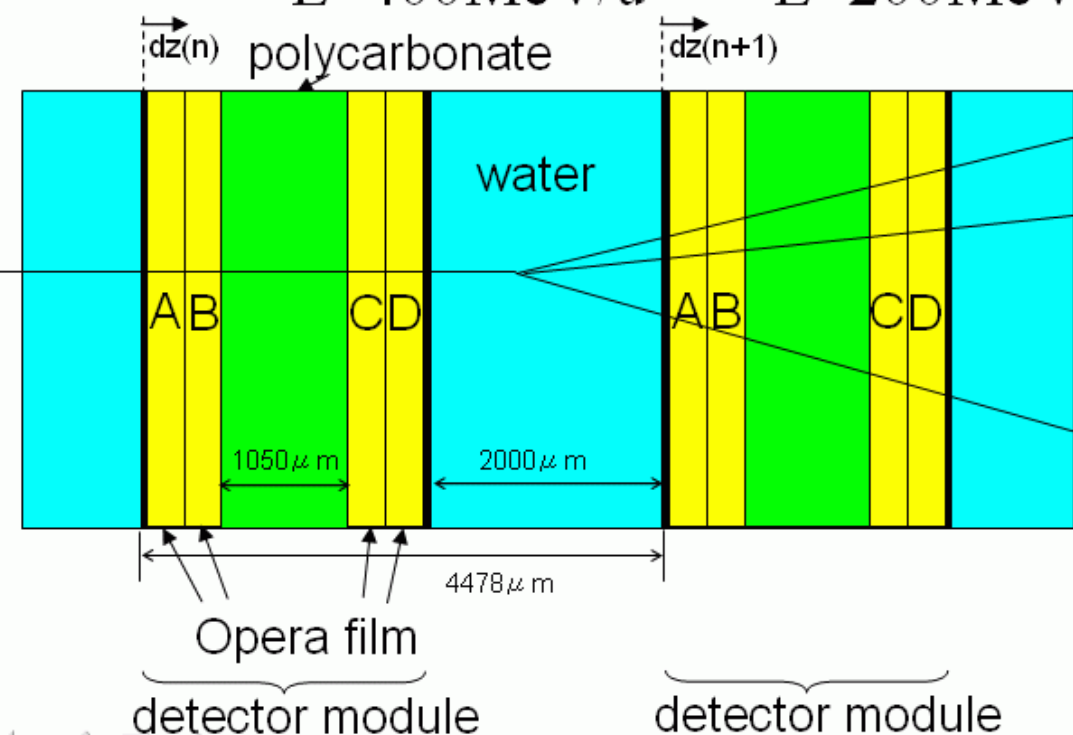
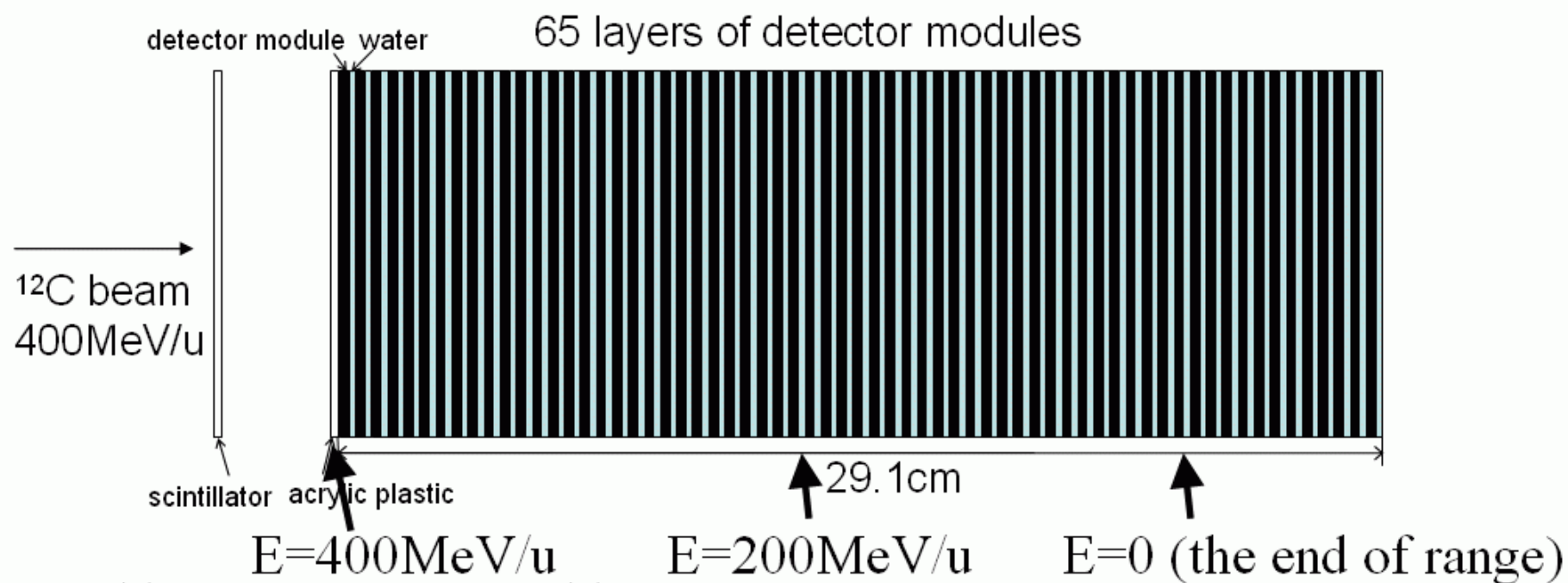


Scanning speed :  
20cm<sup>2</sup>/h



# French Scanning Facility in Lyon

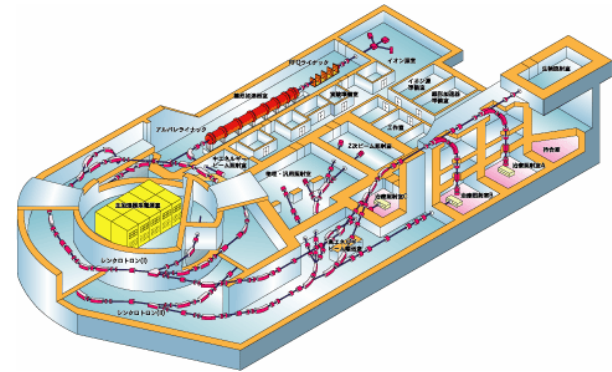




A,C: sensitive to M.I.P  
 B,D: desensitized for charge ID  
 by forced fading in high  
 temperature & high humidity  
 condition  
 erase latent image  
 “refreshing” method  
 NIM A 556 482(2006)



# Heavy ion therapy in the world



LBL, Barkeley in US in the beginning of 1970s -> stopped

HIMAC at National Institute of Radiological Sciences (NIRS) in Japan  
More than 3000 patients have been treated since 1994

GSI in German from 1997  
Number of facility is increasing in Europe and Japan.

# ${}^8\text{Be}$ candidate

${}^{12}\text{C}$  300MeV/n

He  
He

He

