Double beta experiment using current Emulsion Technology

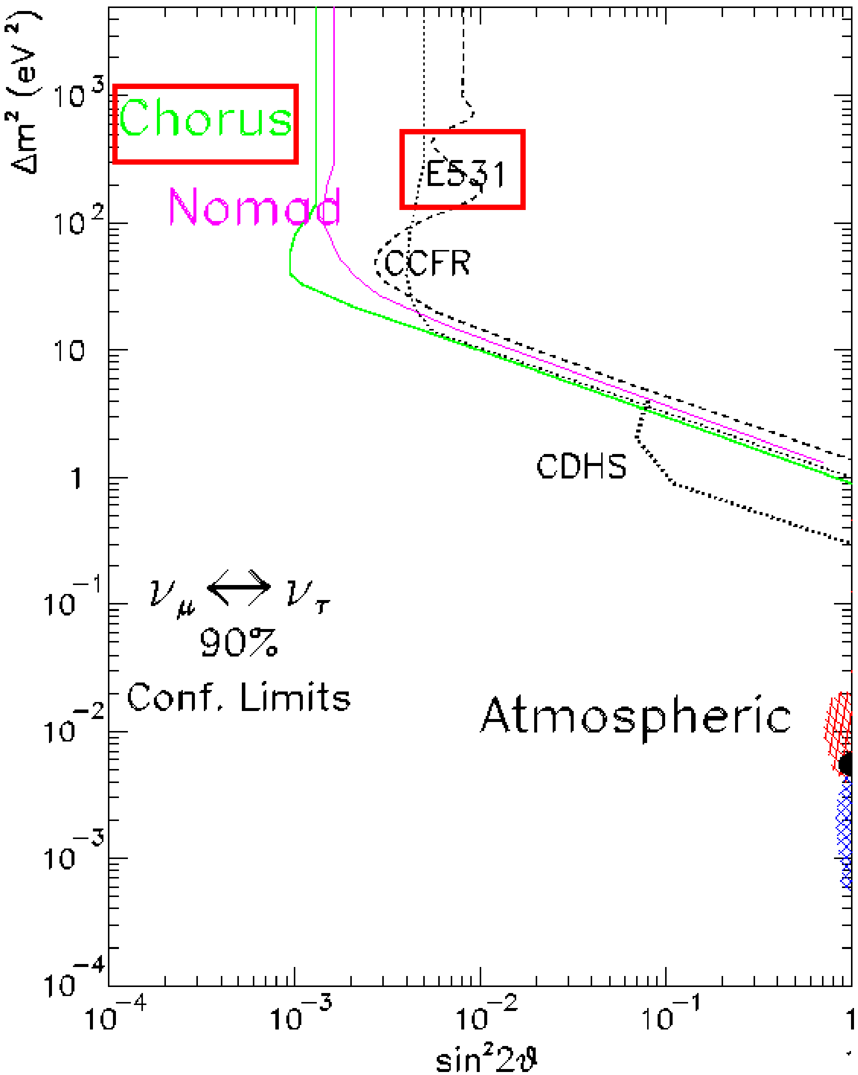
Nakamura M.

Nagoya University

2009/Oct/12

DBD09, Hawaii

Dark Matter



<u>Short base line Neutrino Oscillation experiment</u>

E531 (Fermilab),

CHORUS (CERN)

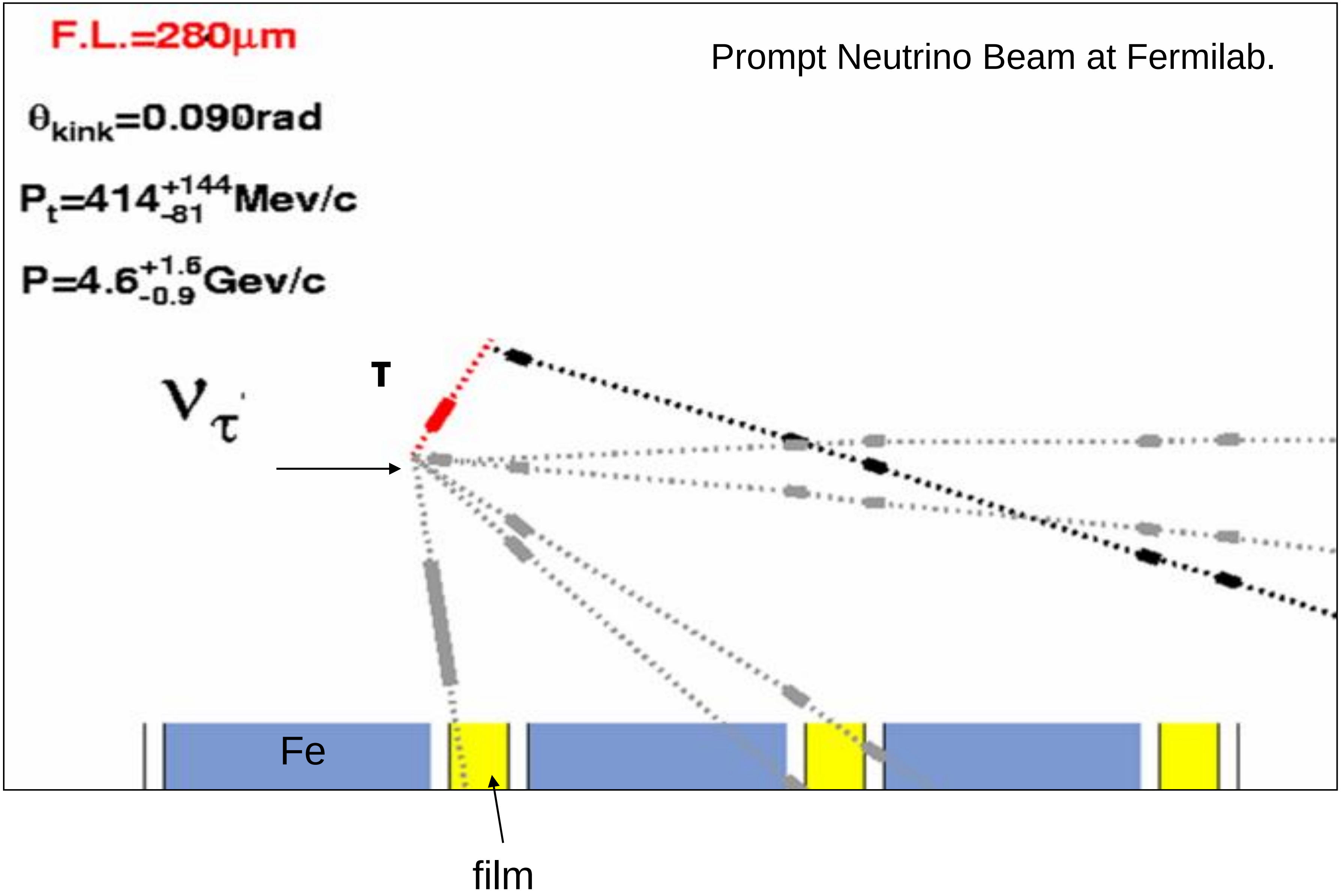
CHORUS

Emulsion Amount ~1 ton

No Tau Neutrino interaction among 350K Neutrino Interactions

$$P(\nu_\nu \rightarrow \nu_\tau) = \sin^2 2\theta \sin^2(1.27 \cdot \Delta m^2 \cdot L/E)$$

DONUT (Fermilab) 9 Tau Neutrino Interactions



OPERA

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

Collaboration :
Japan-Europe Collab.
13countries 37 Institutes

First Neutrino: 2006 August

2008 RUN : 1.78 × 10^{19} P.O.T

2009 RUN : 3.5 × 10^{19} P.O.T
(Running)

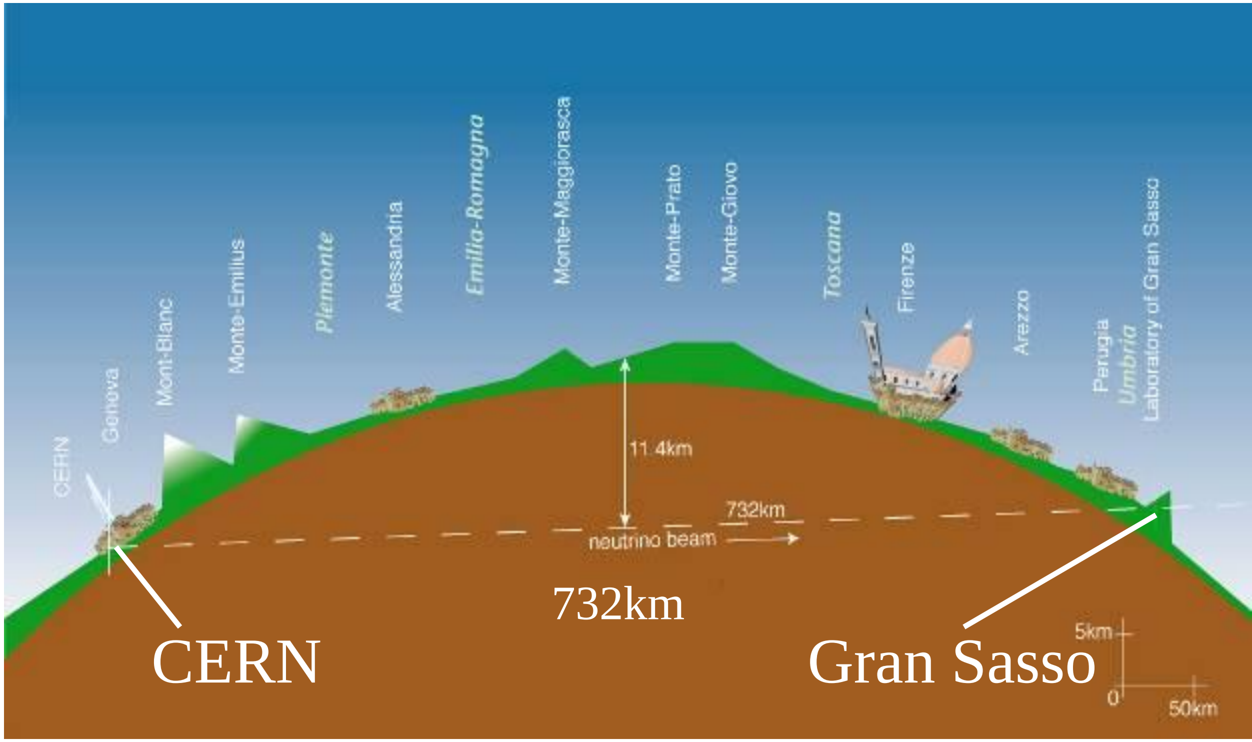
CNGS beam

Optimized to study ν_τ appearance

Nominal ν beam

ν_μ (m^{-2} / pot)	7.45×10^{-9}
ν_μ CC / pot / kton	5.44×10^{-17}
$< E >_\nu$ (GeV)	17
$(\nu_e + \bar{\nu}_e) / \nu_\mu$	0.85 %
$\bar{\nu}_\mu / \nu_\mu$	2.0 %
ν_τ prompt	negligible

400GeV protons from SPS



⇒Interactions at Gran Sasso

~ 3600 ν NC+CC /kton/year

~ 16 ν_τ CC /kton/year

for $\sin^2 2\theta = 1$, $\Delta m^2 = 2.5 \times 10^{-3}\ eV^2$

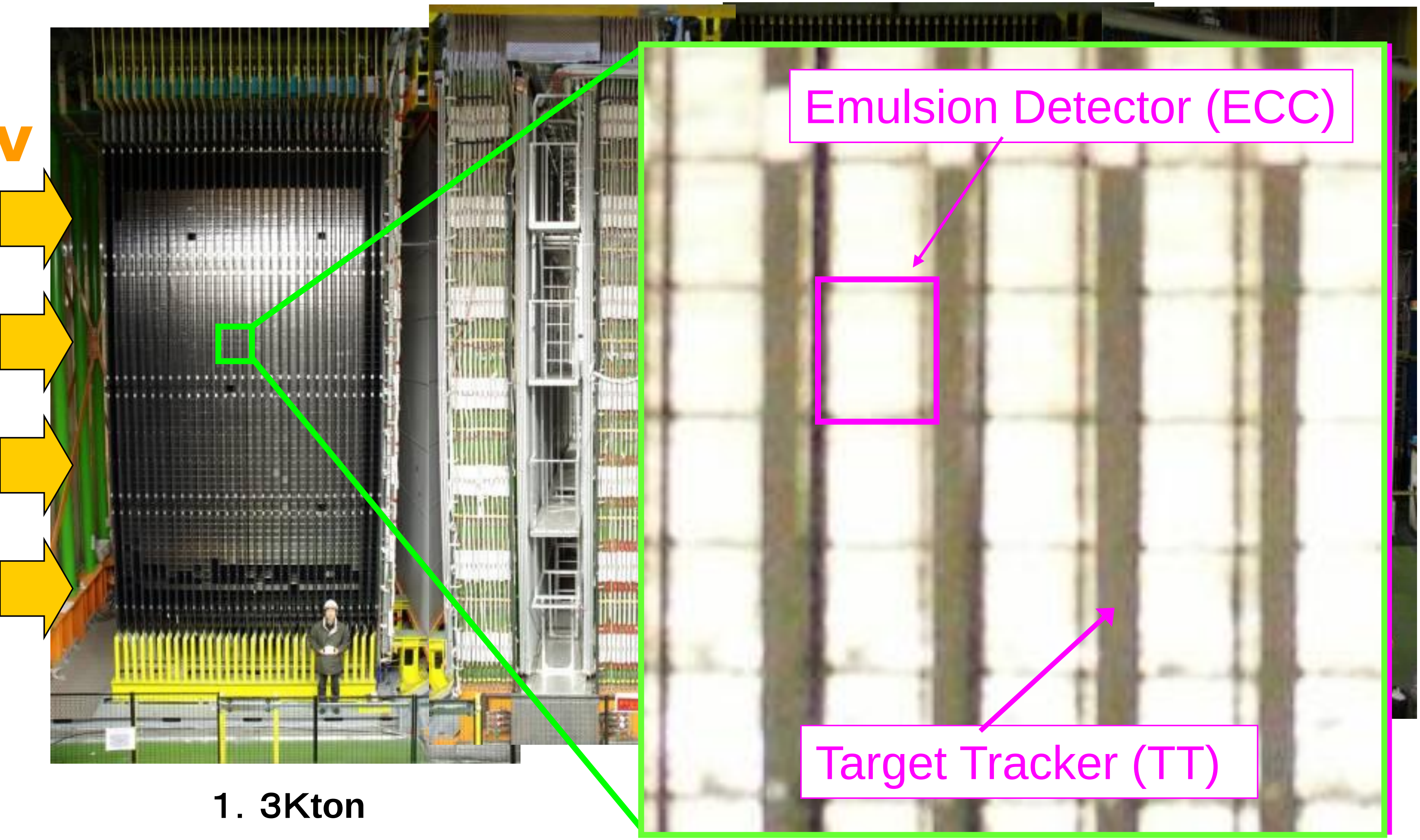
Shared SPS operation

200 days/year

4.5×10^{19} pot / year

Gran Sasso
Hall C

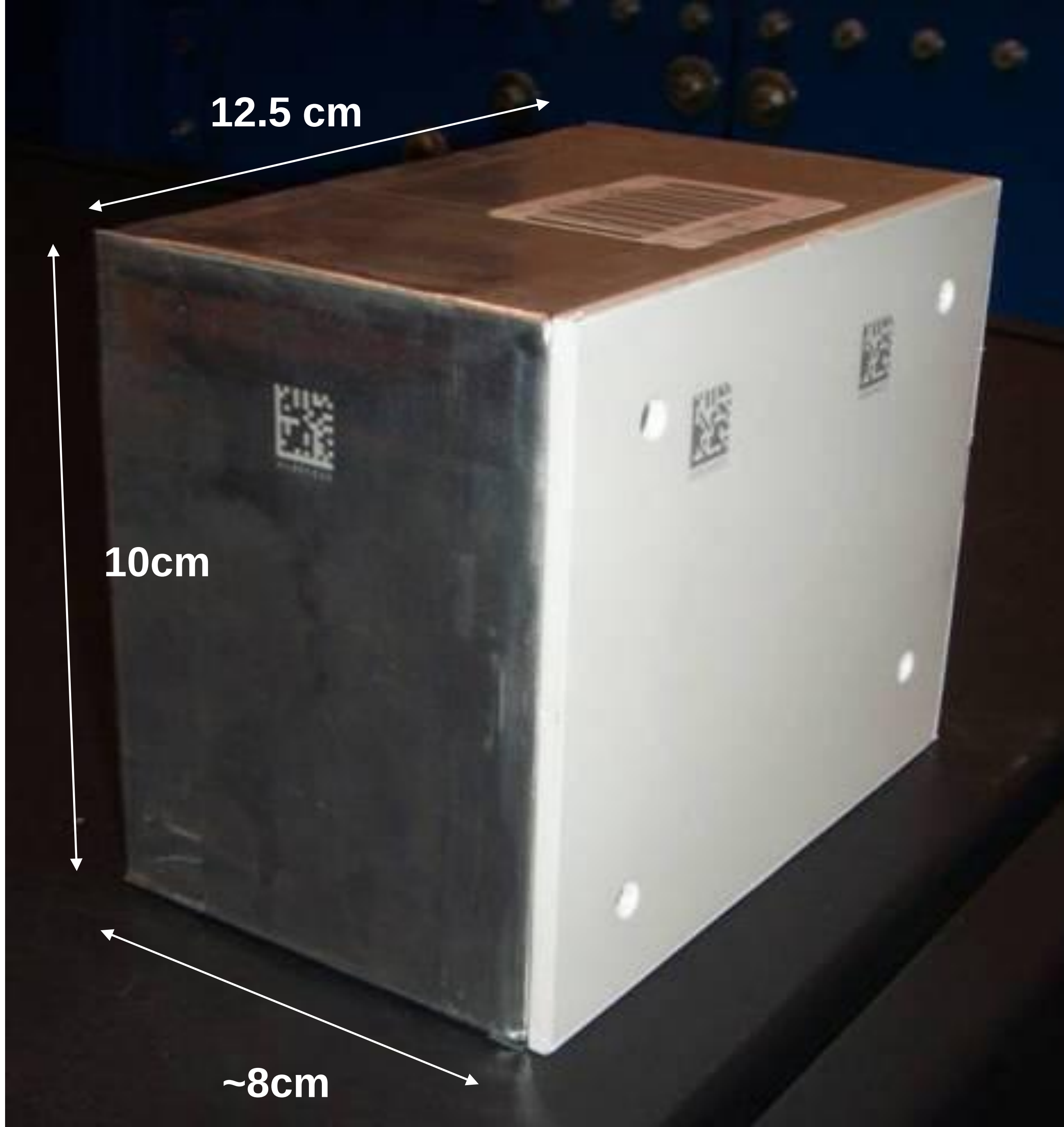
OPERA Detector



1. 3Kton

ECC

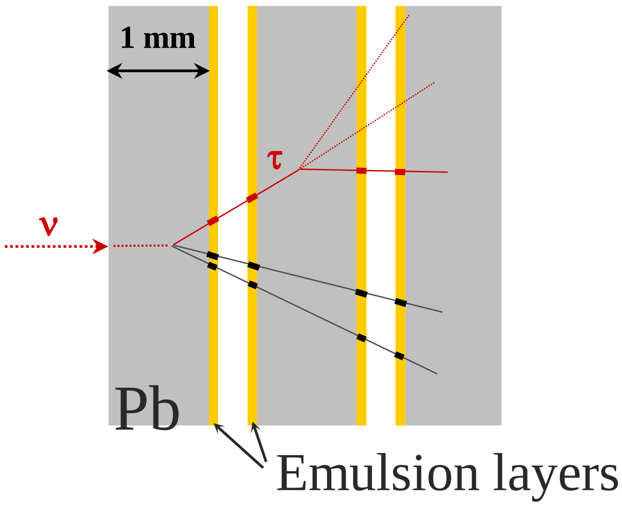
Unit of the OPERA Detector

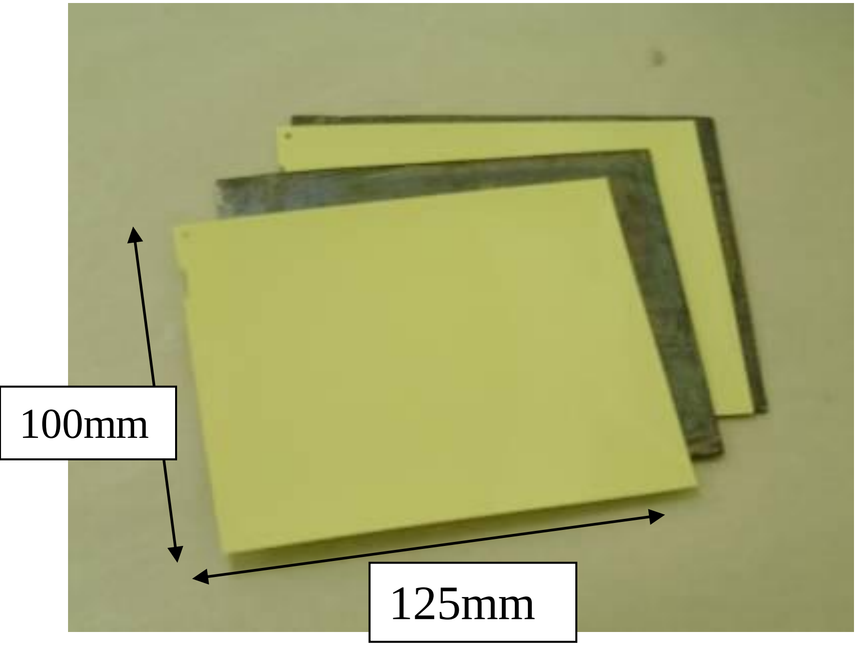


8.3kg

OPERA ECC Brick

Lead plate(1mm) / Emulsion Film (OPERA film) Sandwich





56 Lead Plates+ 57 Films

~ same structure of the DONUT ECC

Emulsion Film

Required Area : **~110,000 m^2**
Number of Films : **~10^7**
Weight of the Emulsion Gel : **~30 ton**

1998–2002 R&D (Fujifilm & Nagoya Univ.)
for the mass production using commercial film production line

2003-2005 Mass Production at Fujifilm.

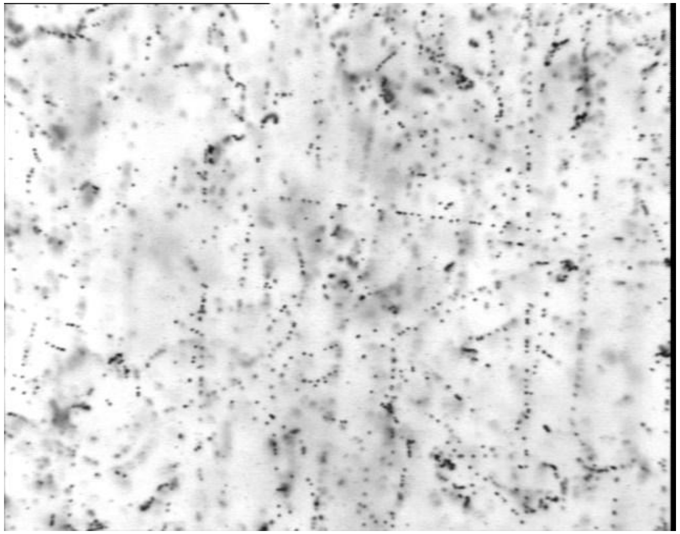
2004-2007 Refresh treatment at TONO mine.
& Shipment to GranSasso

2007-2008 ECC Brick construction and Installation.

DONE!

Taku Nakamura(Nagoya Univ.)
R&D @ Nagoya & Fujifilm

Refreshing

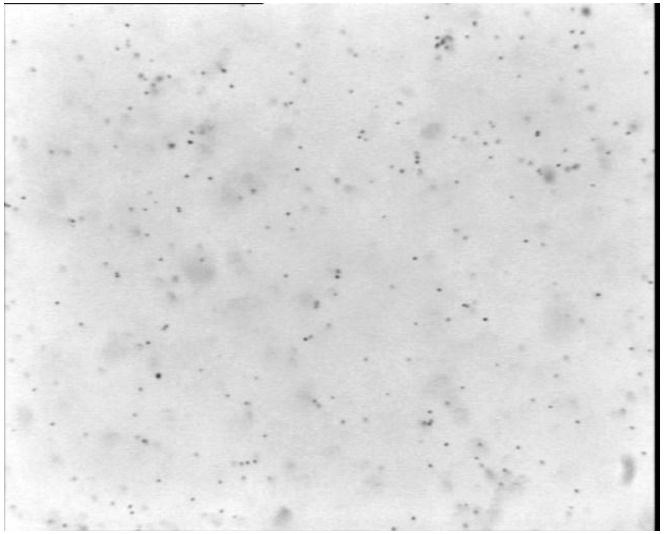


Before Refresh

B.G. > 30tracks / mm^2

Refresh
- T= 30℃
- RH ＞95%

3 days



After Refresh

B.G. < 1tracks / mm^2

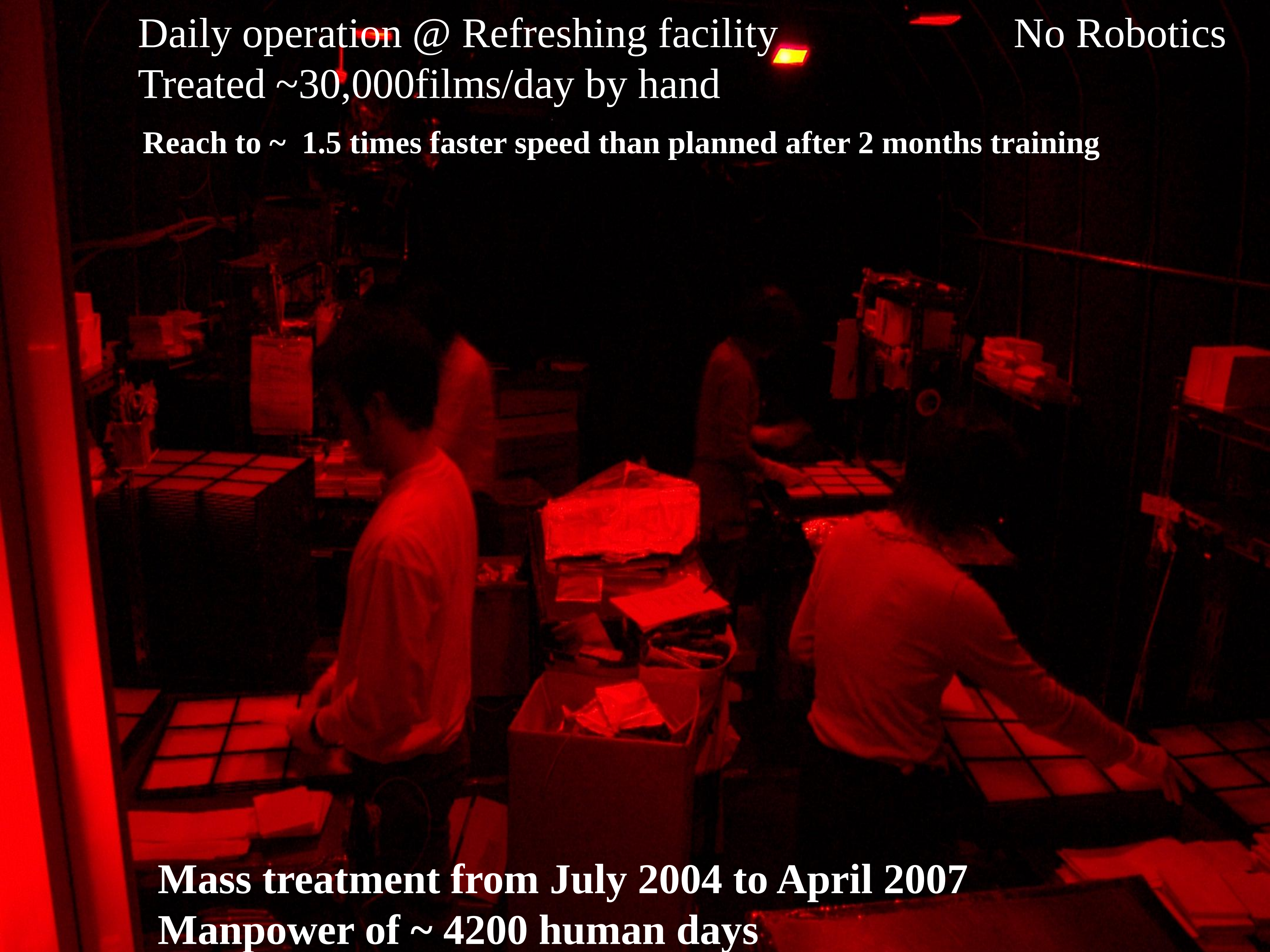
We can erase unwanted BG tracks.
~98% of the recorded tracks can be erased

Refreshing Facility @ TONO mine Gifu JAPAN

Daily operation @ Refreshing facility   No Robotics

Treated ~30,000films/day by hand

Reach to ~ 1.5 times faster speed than planned after 2 months training



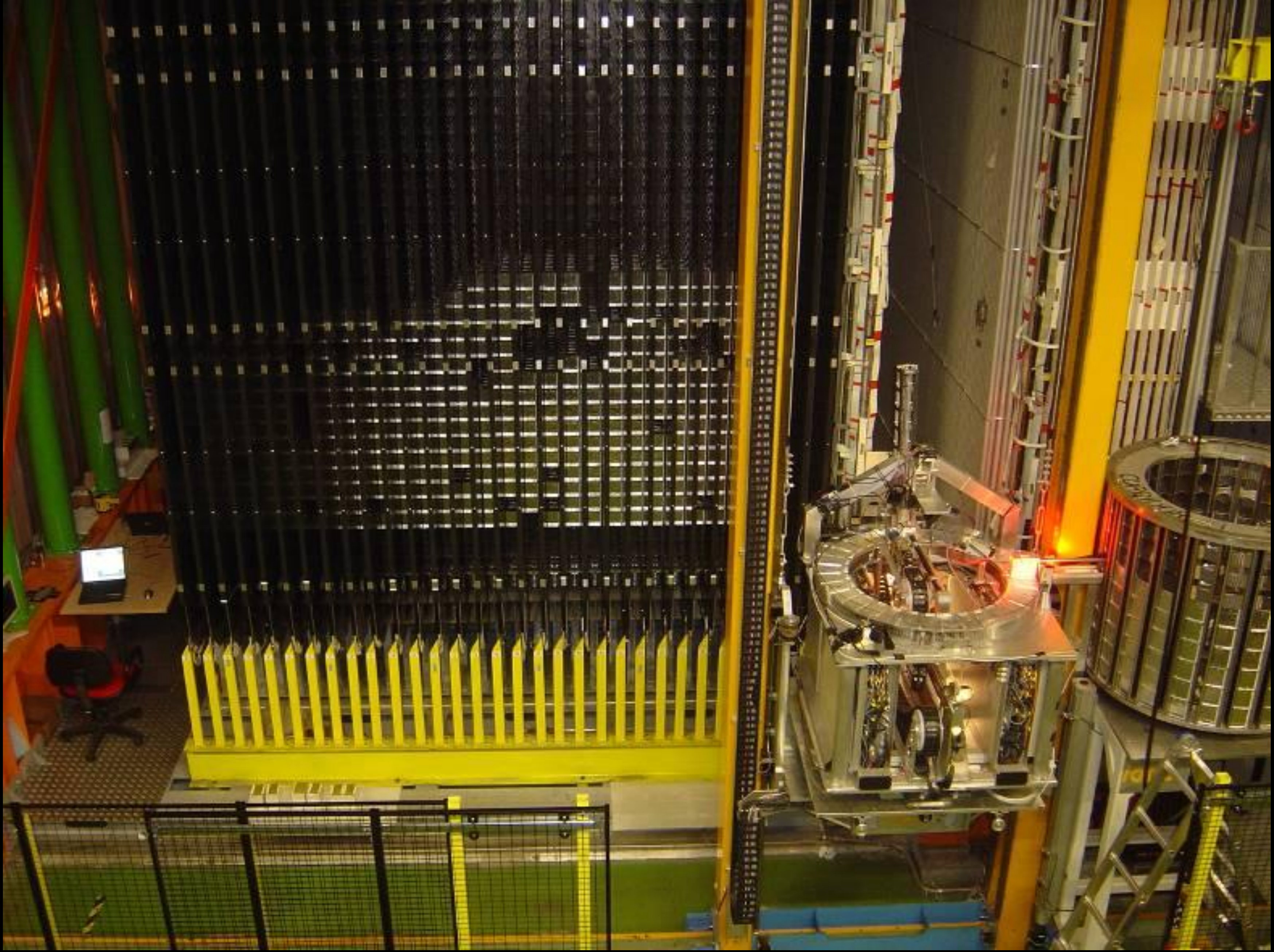
Mass treatment from July 2004 to April 2007

Manpower of ~ 4200 human days

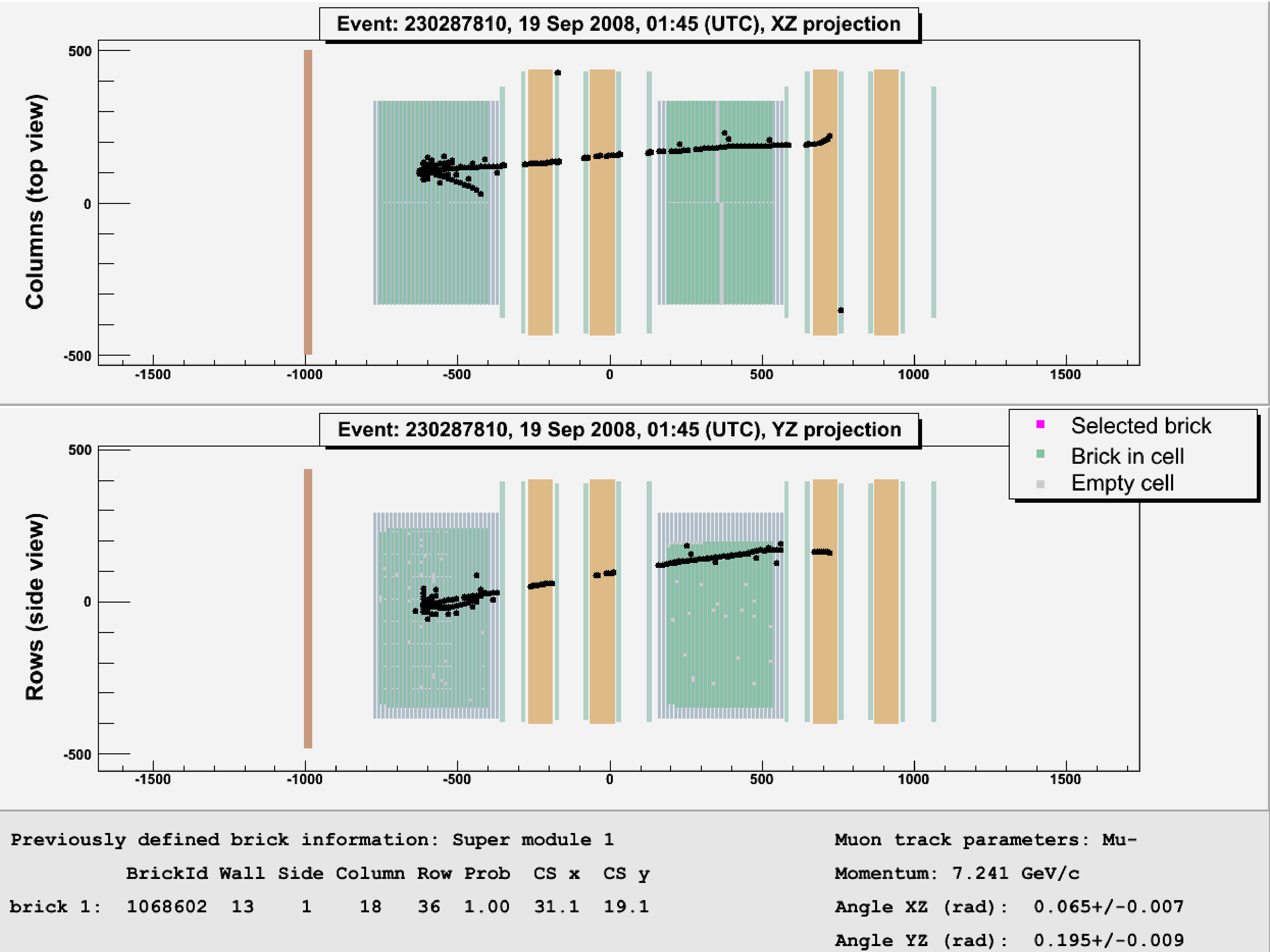
First Shipment ceremony at Gran Sasso 2005 Jan 24

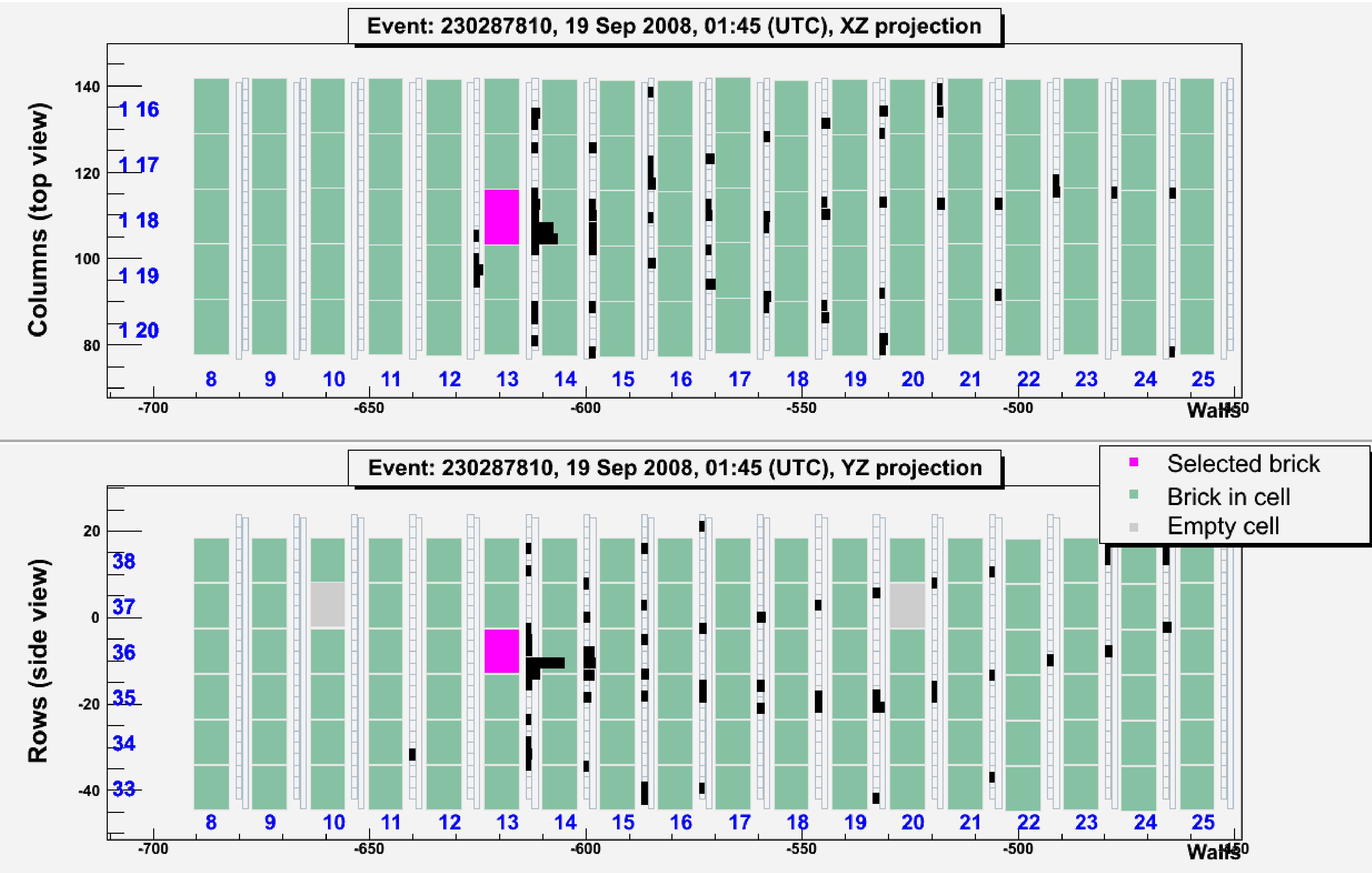
Prof. E. Coccia (Director of LNGS), Prof. K.Yamashita (Vice director of Nagoya Univ.) and Prof. K. Niwa (Nagoya University)


OPERA Emulsion facility for Special films treatment (Changeable Sheet)
Gran Sasso Hall B
ICARUS



Brick Installation by Brick Manipulating System


Event: 230287810, 19 Sep 2008, 01:45 (UTC), XZ projection
Columns (top view)
500
0
-500
-1500
-1000
-500
0
500
1000
1500
Event: 230287810, 19 Sep 2008, 01:45 (UTC), YZ projection
Rows (side view)
Selected brick
Brick in cell
Empty cell
Previously defined brick information: Super module 1
BrickId Wall Side Column Row Prob CS x CS y
brick 1: 1068602 13 1 18 36 1.00 31.1 19.1
Muon track parameters: Mu-
Momentum: 7.241 GeV/c
Angle XZ (rad): 0.065+/-0.007
Angle YZ (rad): 0.195+/-0.009



Previously defined brick information: Super module 1

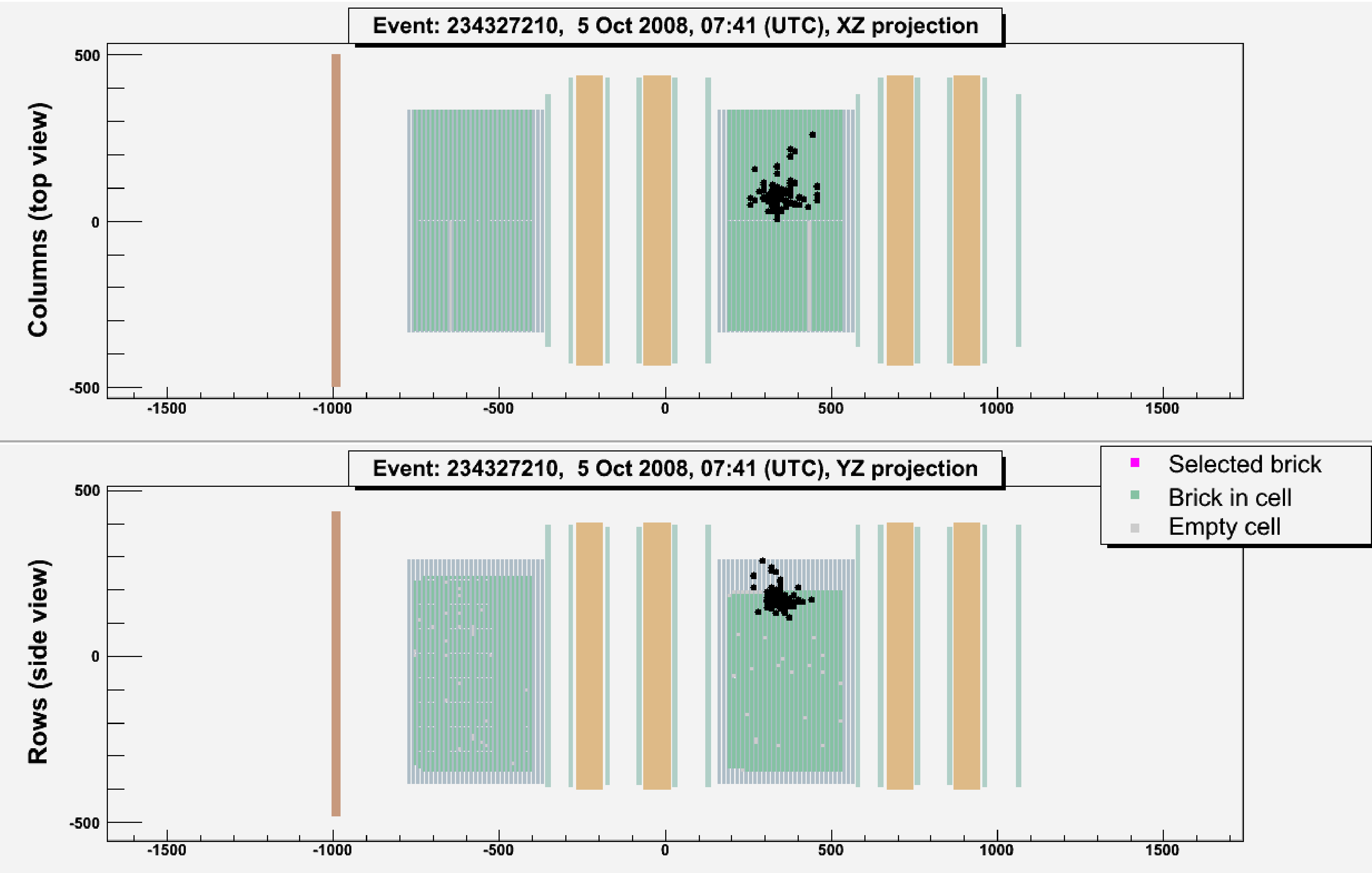
	BrickId	Wall	Side	Column	Row	Prob	CS x	CS y
brick 1:	1068602	13	1	18	36	1.00	31.1	19.1

Muon track parameters: Mu-

Momentum: 7.241 GeV/c

Angle XZ (rad): 0.065+/-0.007

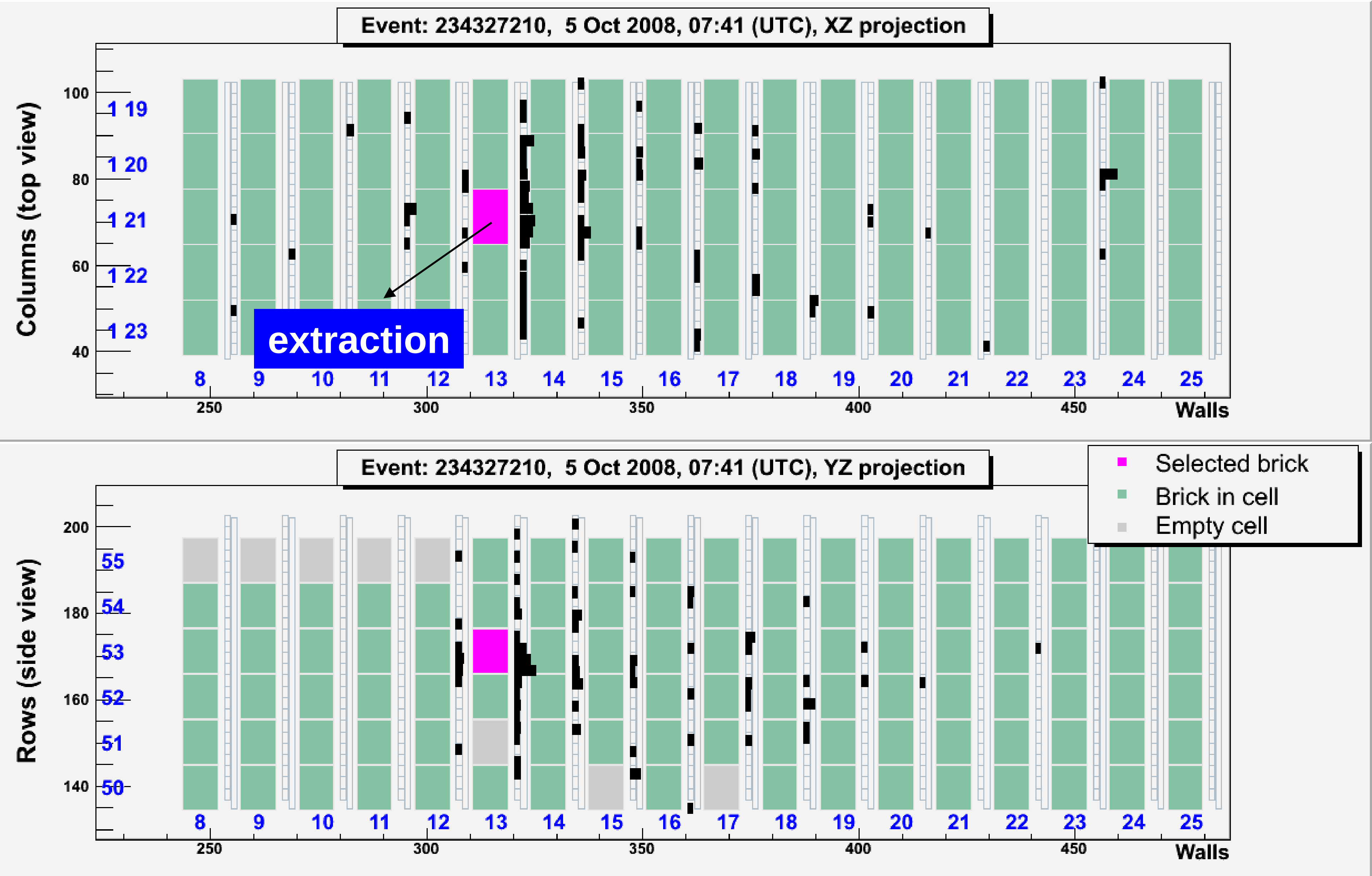
Angle YZ (rad): 0.195+/-0.009



Previously defined brick information: Super module 2

	BrickId	Wall	Side	Column	Row	Prob	CS x	CS y
brick 1:	1136584	13	1	21	53	1.00	-1.0	-1.0

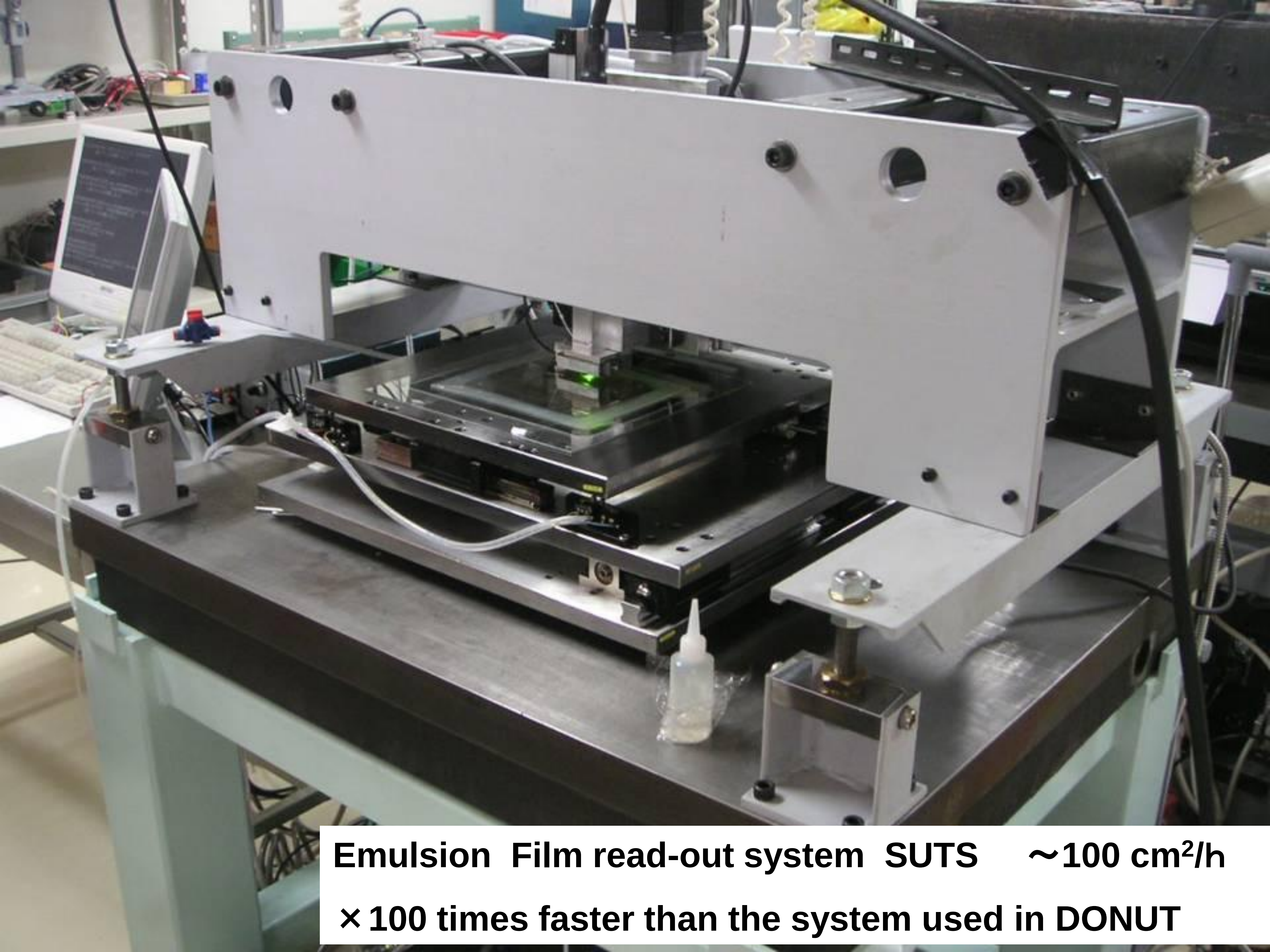
Muon track parameters: Mu-
Momentum: 0.974 GeV/c
Angle XZ (rad): N/A
Angle YZ (rad): N/A




```
Previously defined brick information: Super module 2
          BrickId Wall Side Column Row Prob  CS x  CS y
brick 1:  1136584  13    1     21   53  1.00  -1.0  -1.0
```

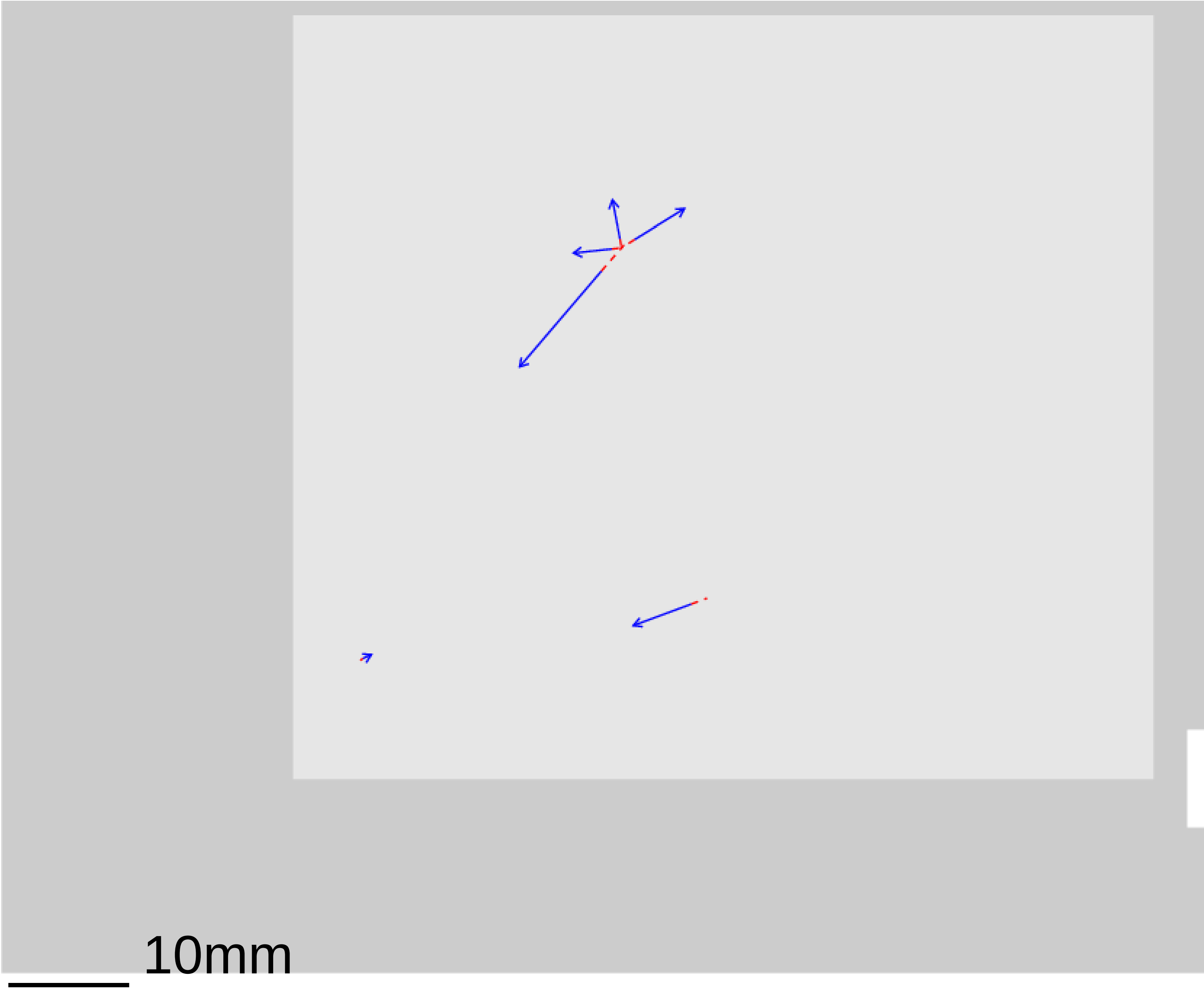
```
Muon track parameters: Mu-
Momentum: 0.974 GeV/c
Angle XZ (rad): N/A
Angle YZ (rad): N/A
```

Changeable sheet （CS）

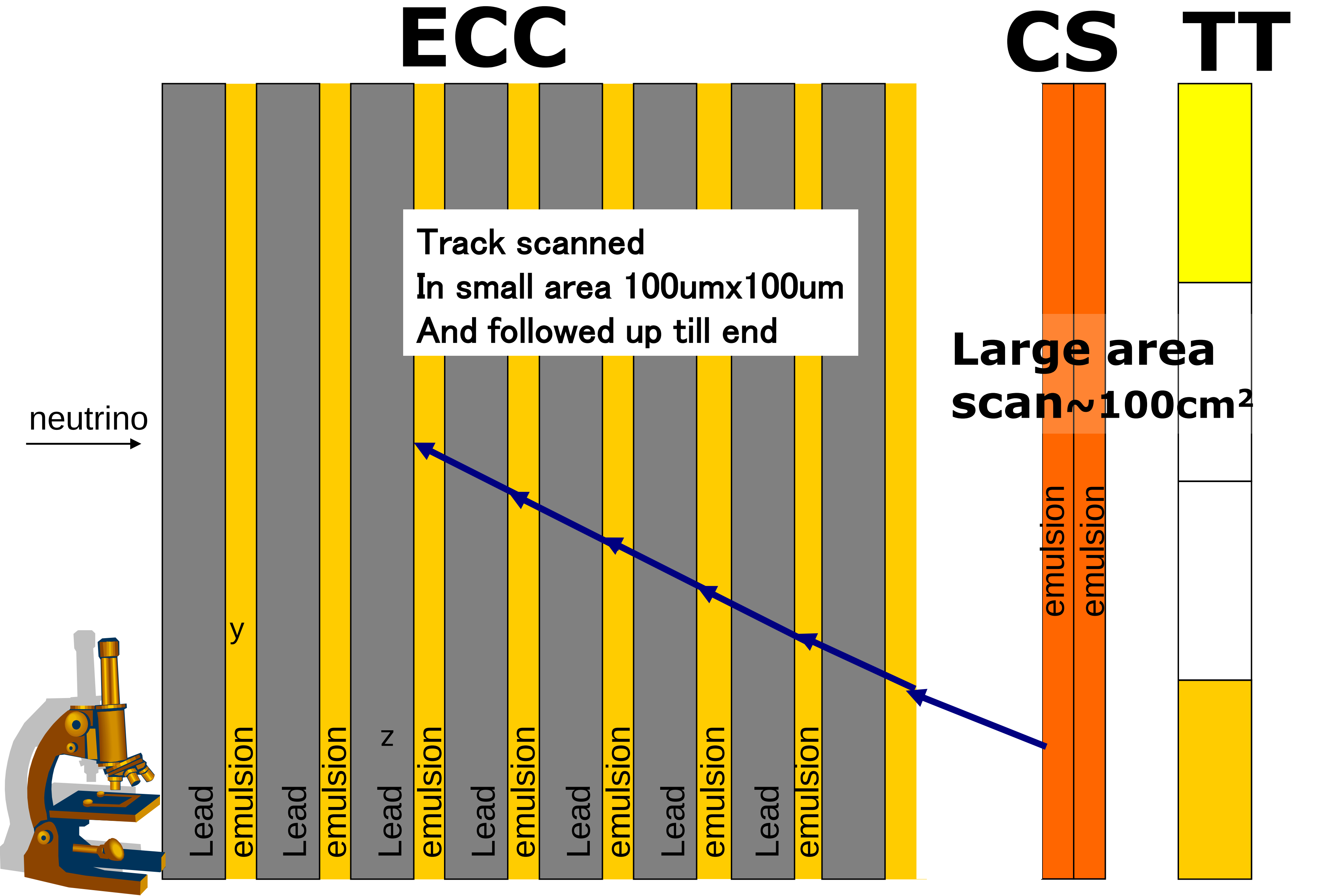


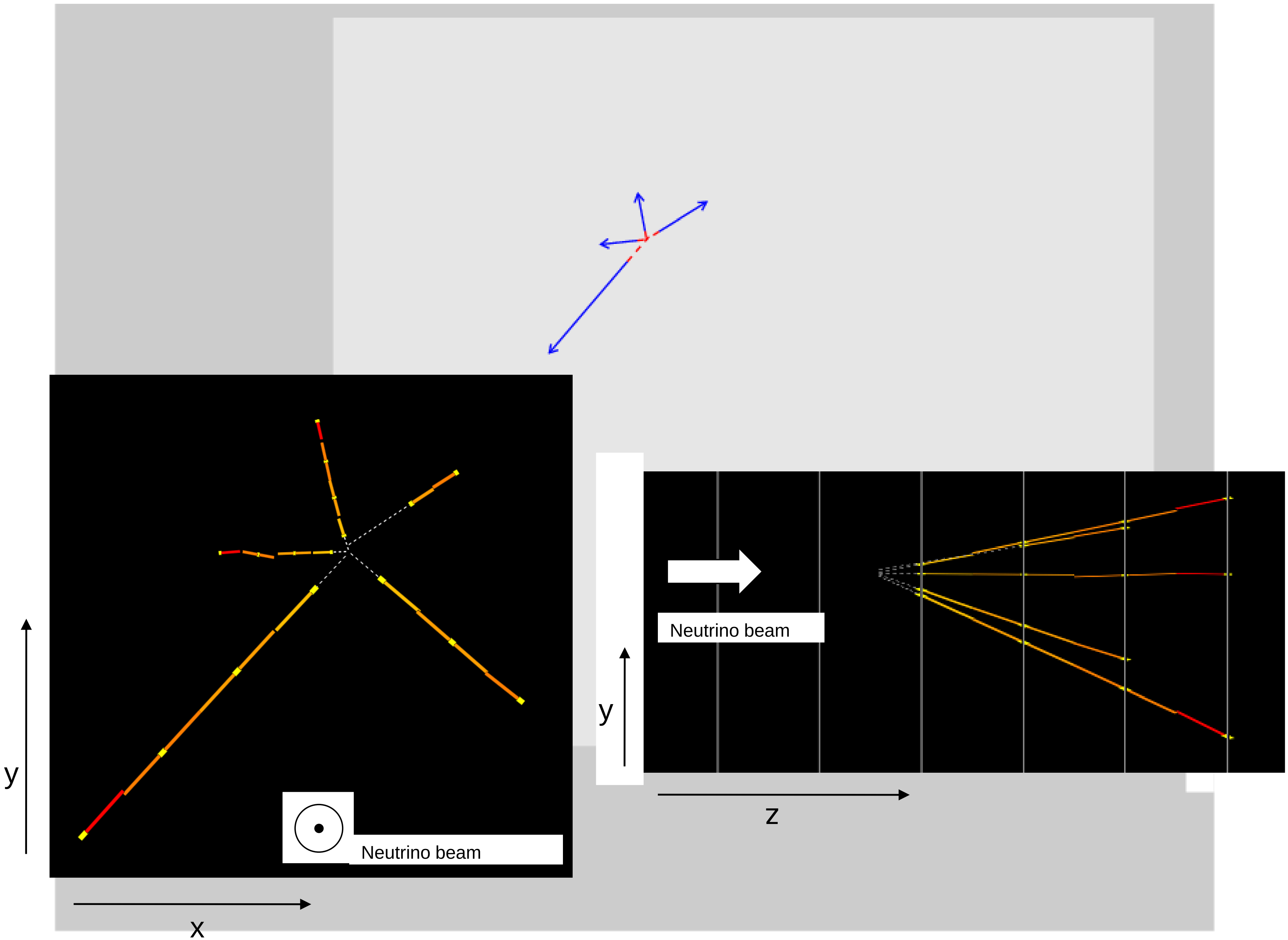
Emulsion Film read-out system SUTS ~100 cm^2/h

×100 times faster than the system used in DONUT


10mm

Vertex location procedure



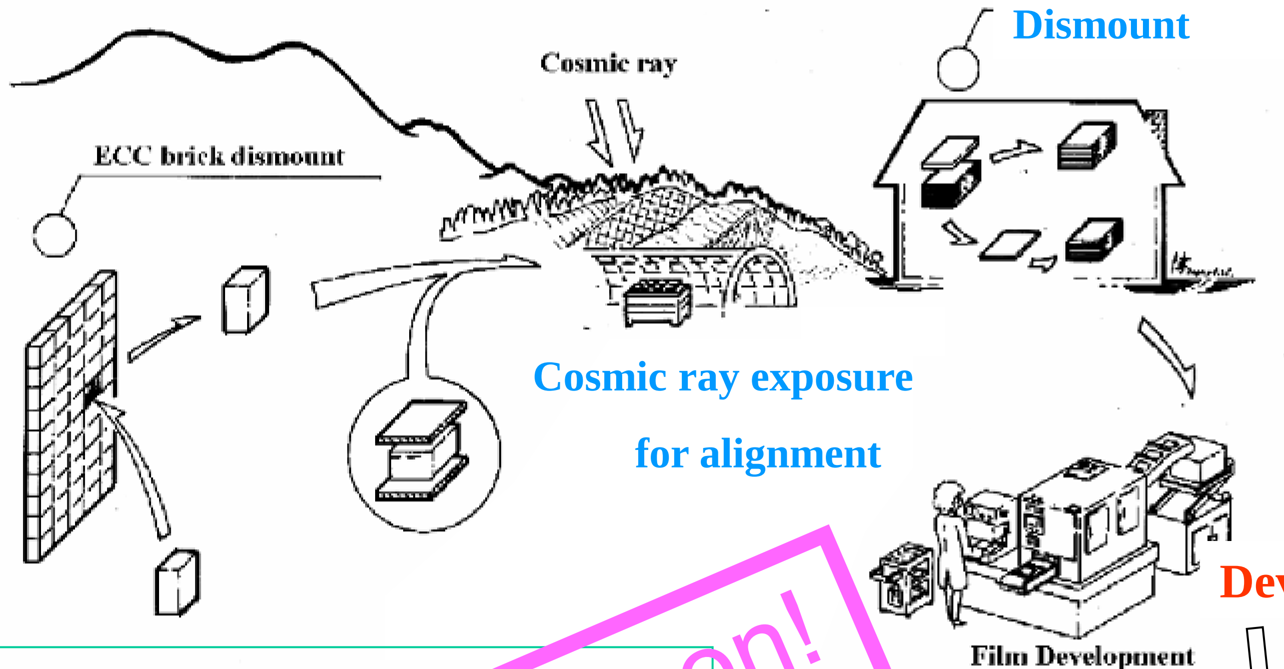


Neutrino beam
y
x
Neutrino beam
y
z

Dismount

ECC Extraction

~ 30 ECC / day



Cosmic ray exposure for alignment

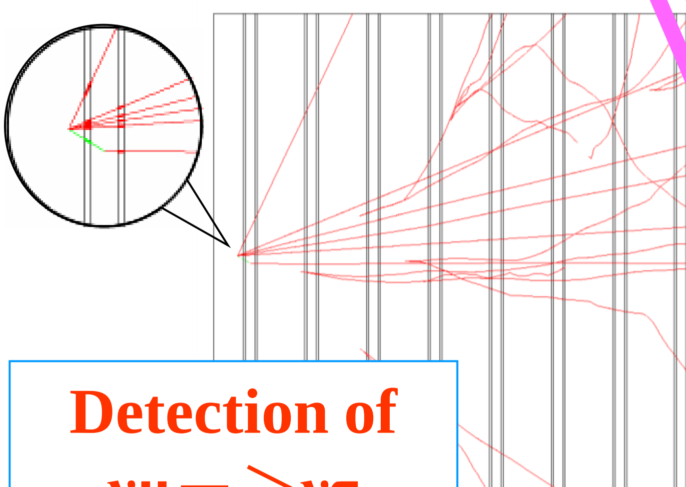
Development

Quasi-online analysis of the Events

Going on!

Film Read Out

Event analysis



Detection of $\nu_\mu \rightarrow \nu_\tau$ Oscillation

OPERA

- OPERA is accumulating Events.

 2008RUN : 1.78×10^{19} P.O.T.

 2009RUN : 3.5×10^{19} P.O.T. (Plan: Running)

> 3000 events will be located in the emulsion target (~1000 already located)

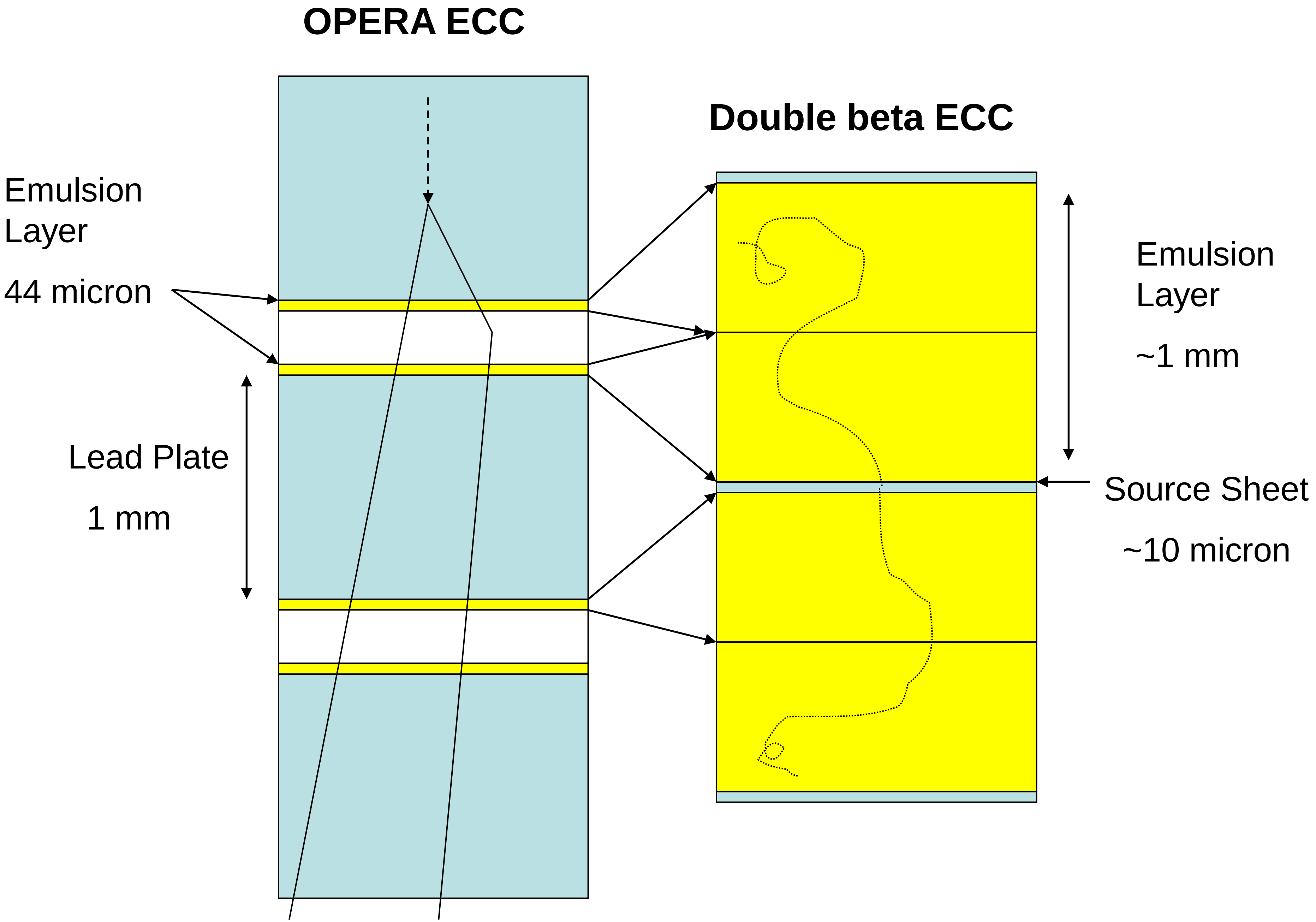
～2 good tau candidates are expected if SK is right.

Run until 2012

Emulsion for Double Beta Exp.

- Tracking calorimeter with
  1) Position resolution ～ sub micron
  2) Expected Energy resolution
     FWHM~ 8 %/√ E [MeV]
  3) No dead time / No time resolution
  4) No cryogenics, No electricity - - - - -
- Solid (Gel) state detector
  1) Compact detector : easy to shield
     ~ 2 m × 2m × 2m cubic for the source mass of ~1 ton
  2) BG isotopes (like U Th) will not move so much
     during their life. → BG rejection by position.

Detector configuration

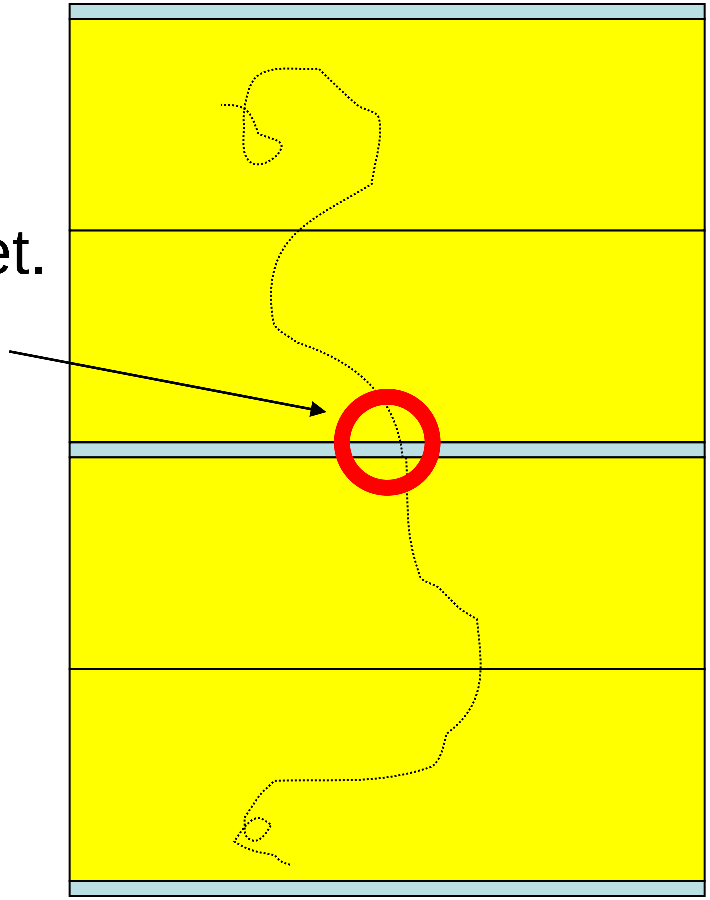


Signal detection

- Origin of the two Beta tracks should be in the source sheet.

→Tight position cut.

< ~ few micron for each direction.

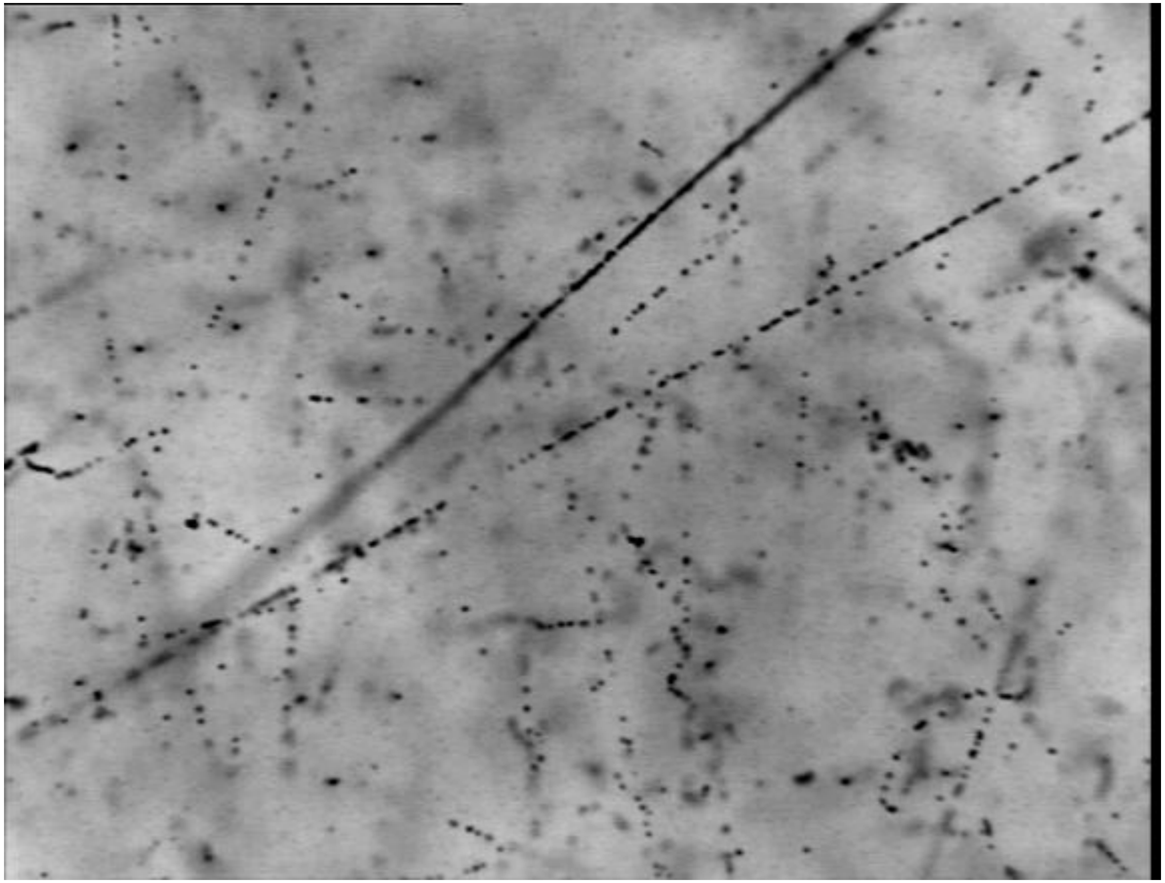


Double beta ECC

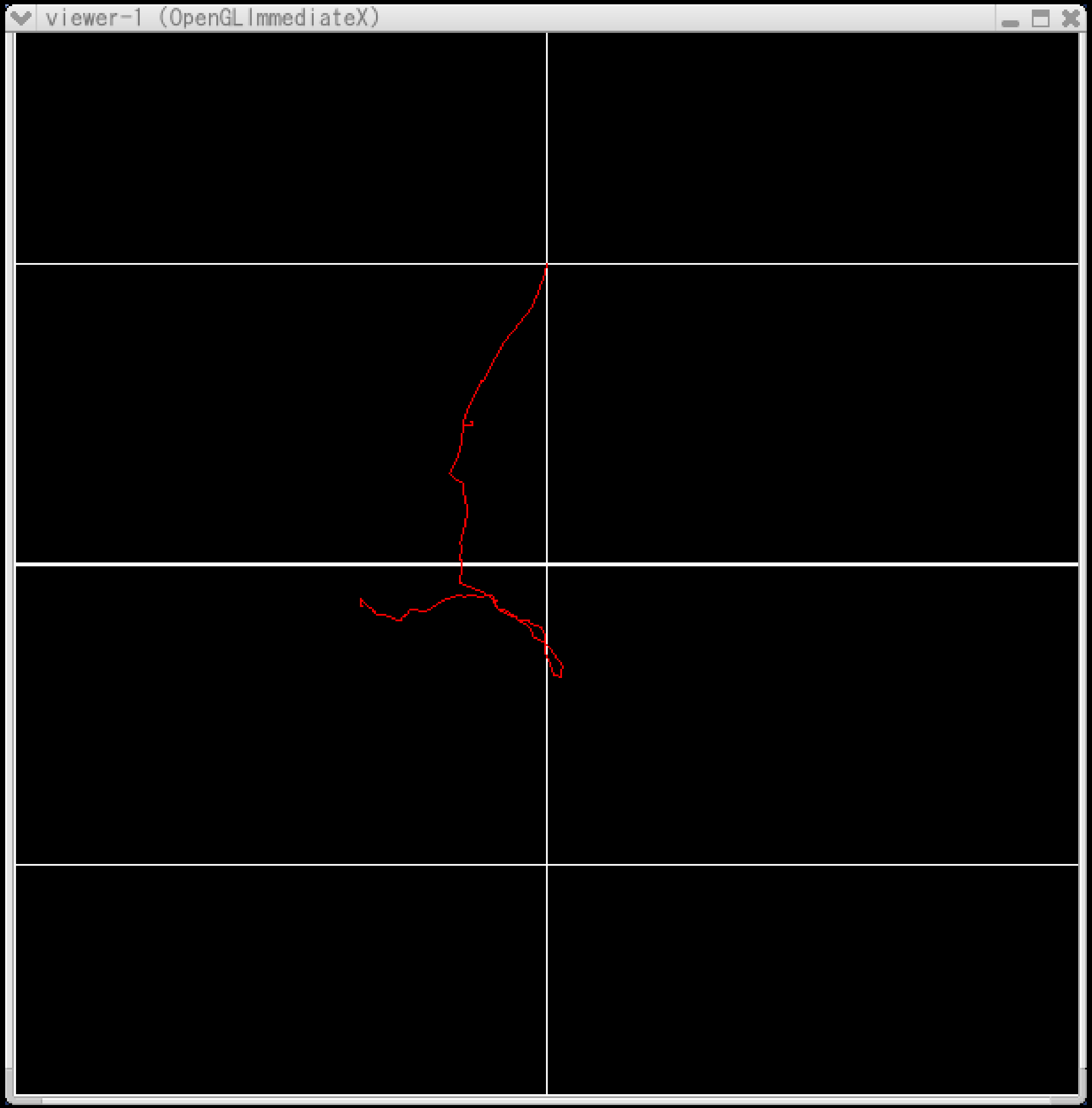
Energy Resolution

Information :Grains along the track ~1000 grains/1MeV

(~10^5 e-h pairs in AgBr micro crystals)



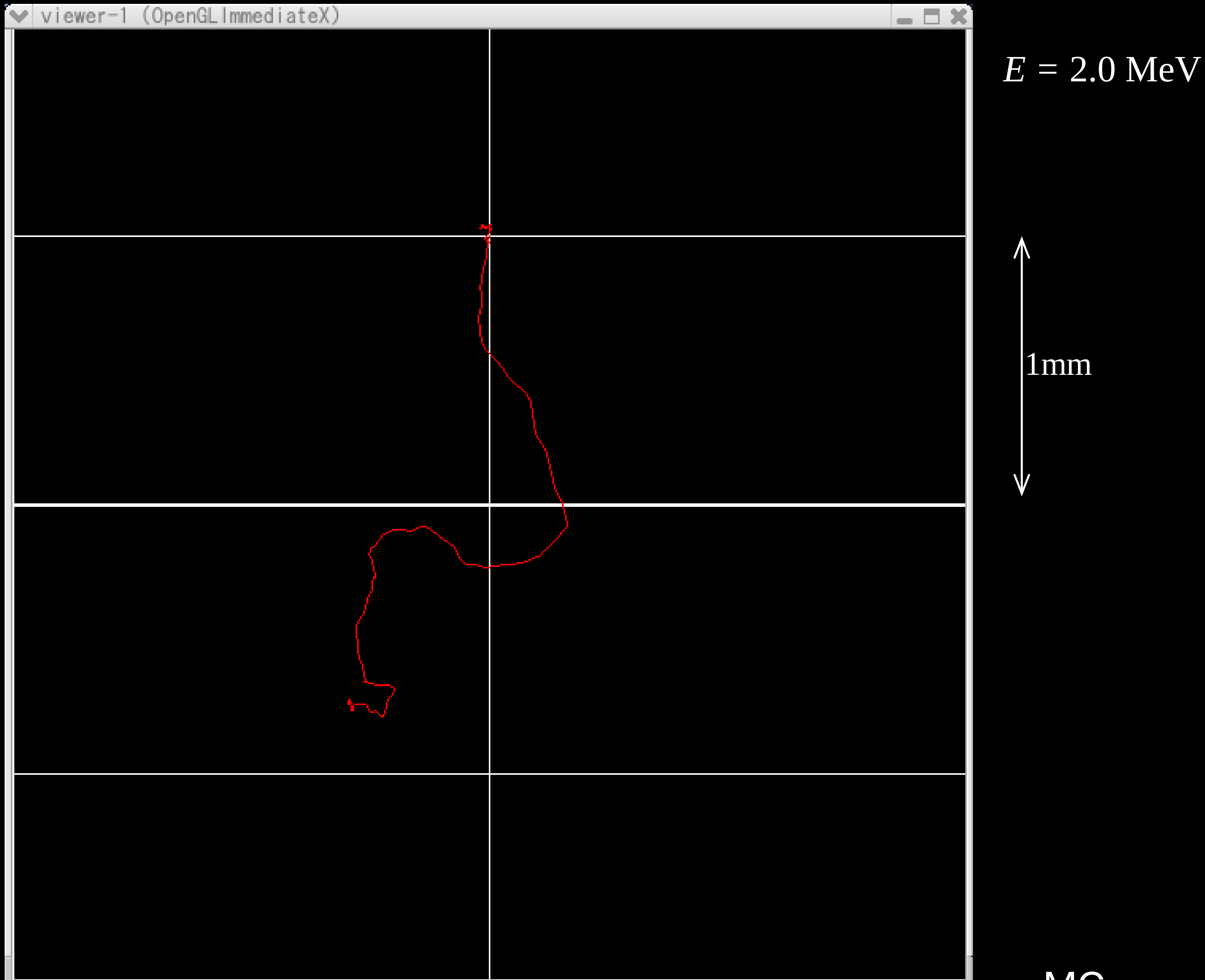
Expected Energy resolution [FWHM]~ 8 %/√ E [MeV]



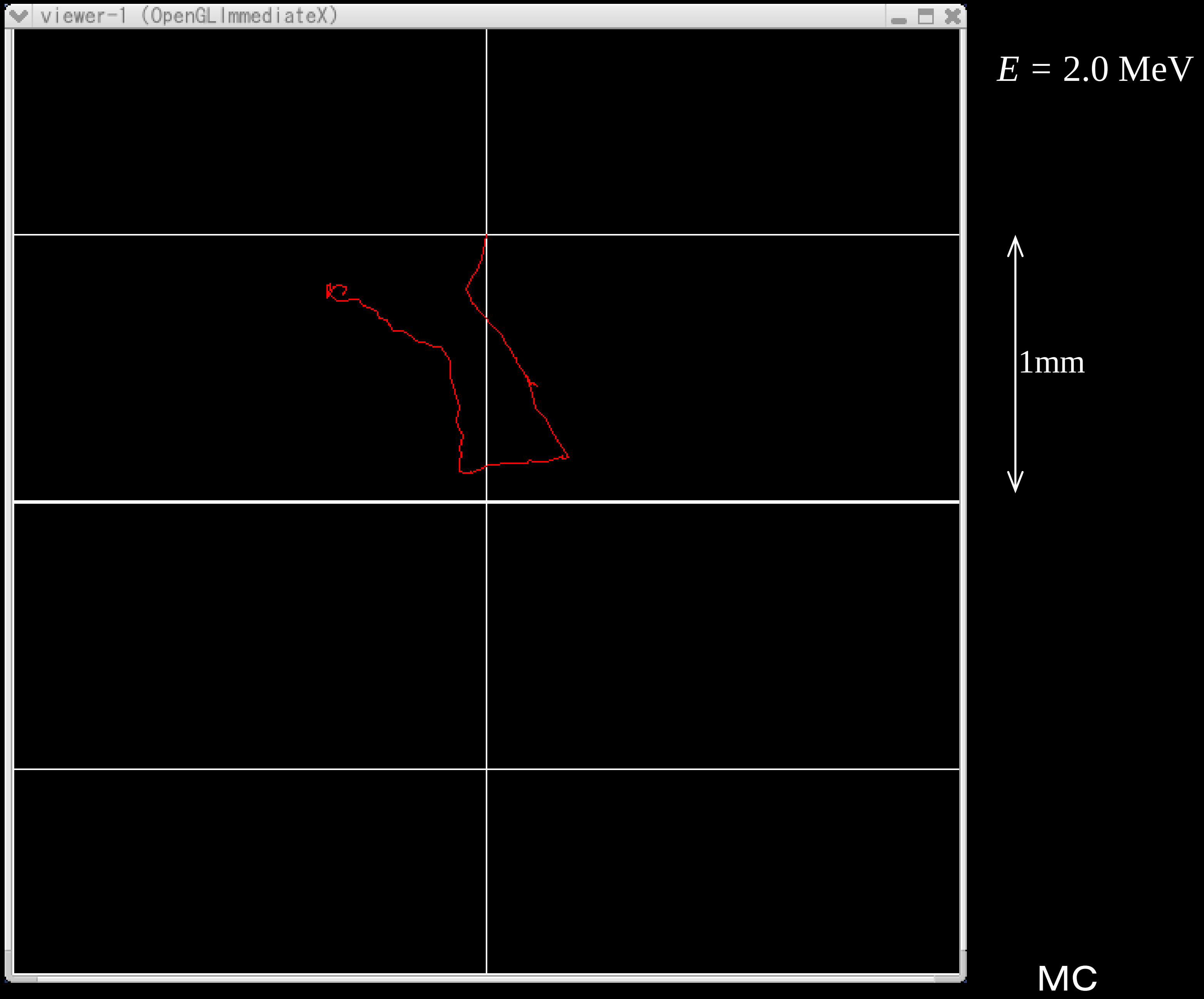
E = 2.0 MeV

1mm

MC

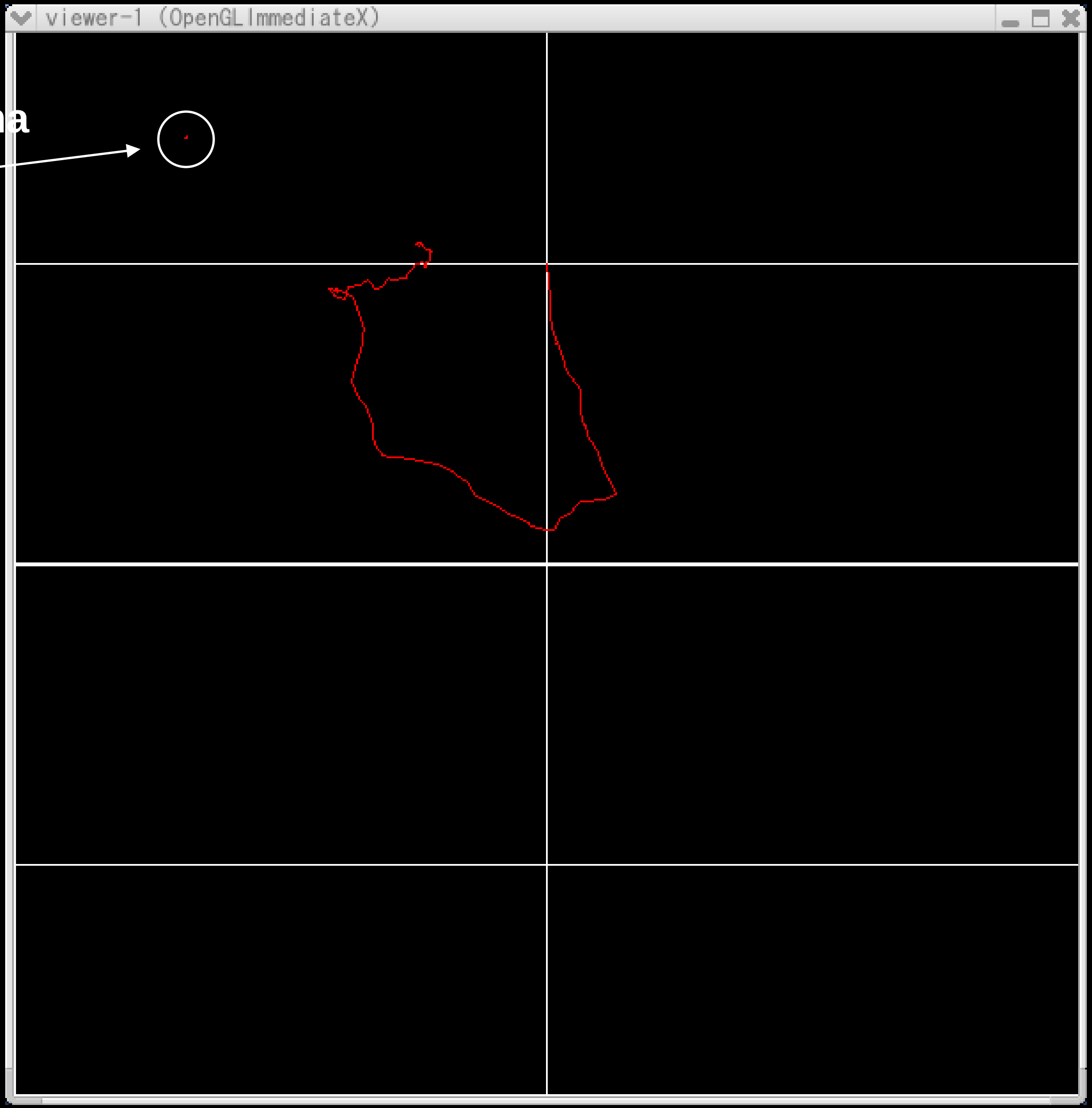


MC


viewer-1 (OpenGLImmediateX)
E = 2.0 MeV
1mm
MC

escape gamma events

→distribution tail to low energy

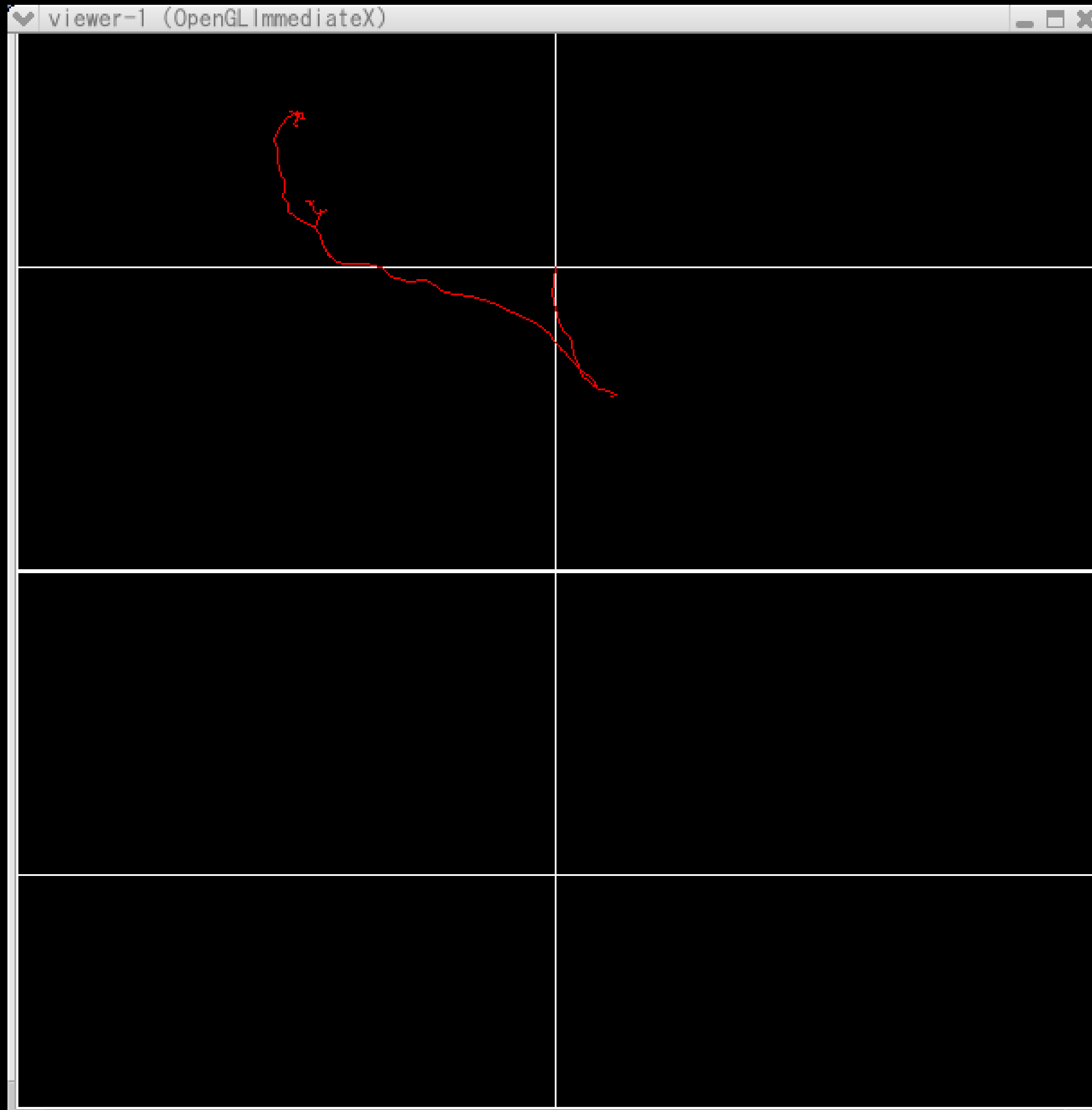


E = 2.0 MeV

1mm

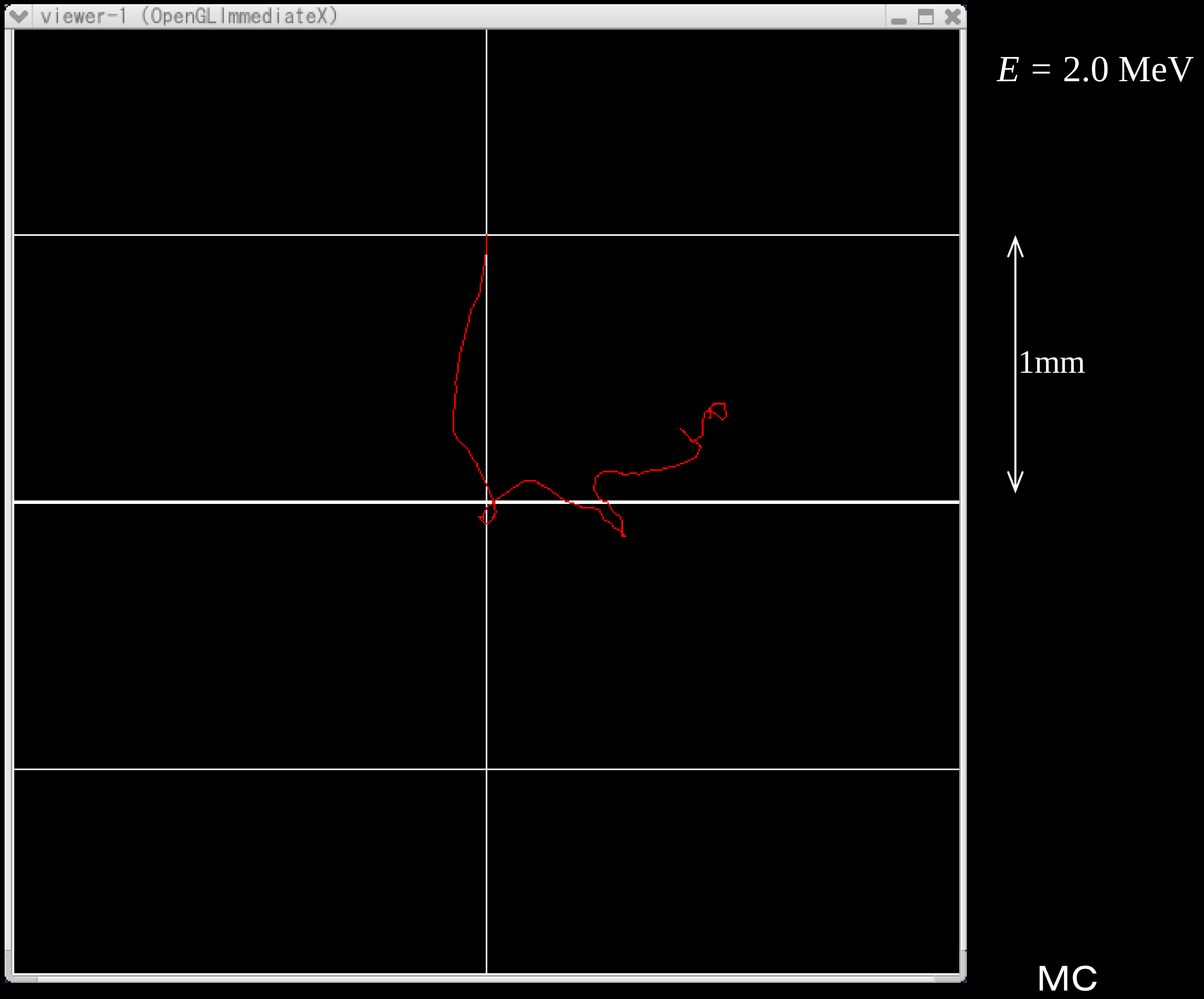
MC

E = 2.0 MeV

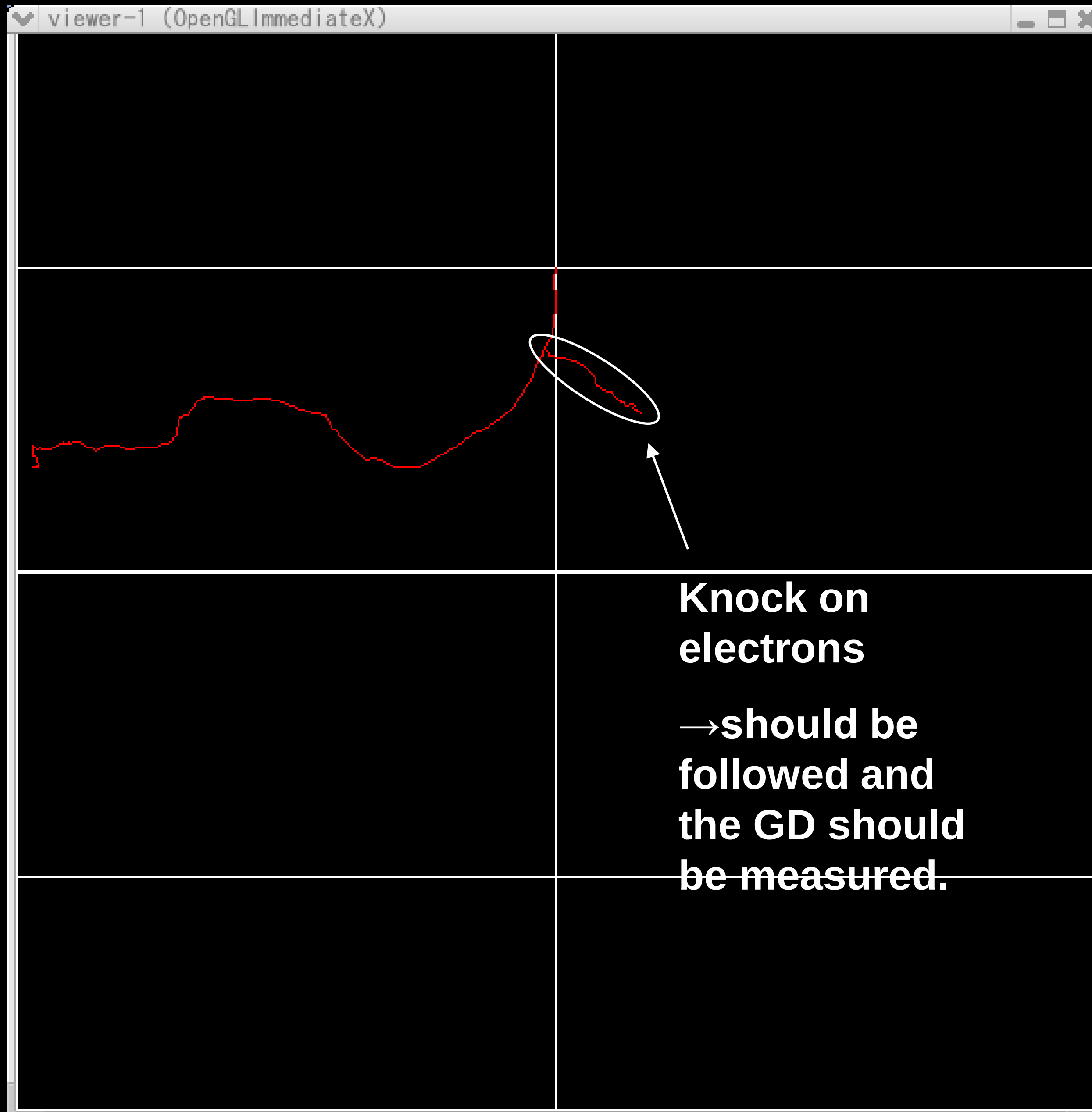


1mm

MC


viewer-1 (OpenGLImmediateX)
E = 2.0 MeV
1mm
MC

E = 2.0 MeV

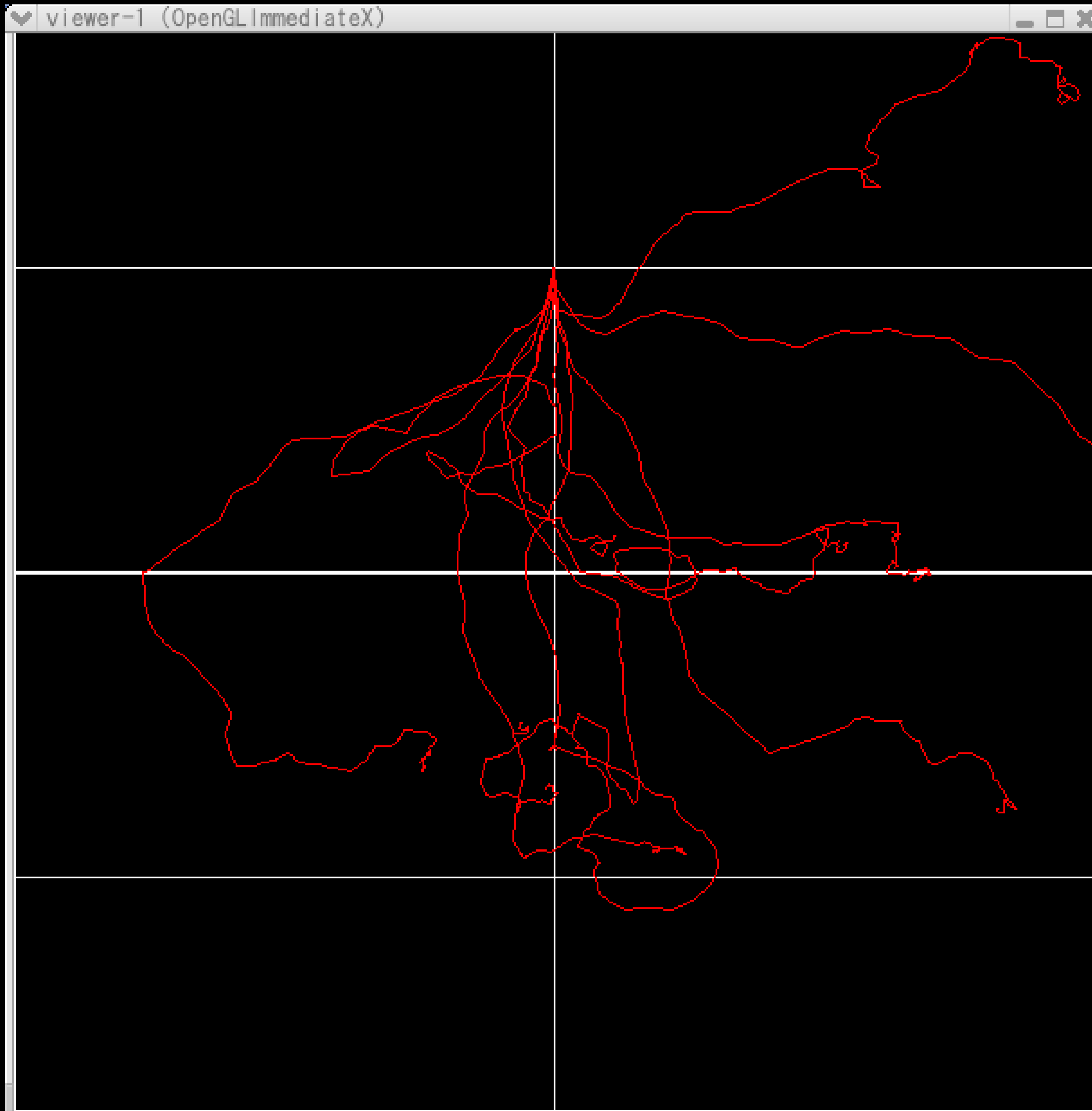


1mm

Knock on electrons

→should be followed and the GD should be measured.

MC

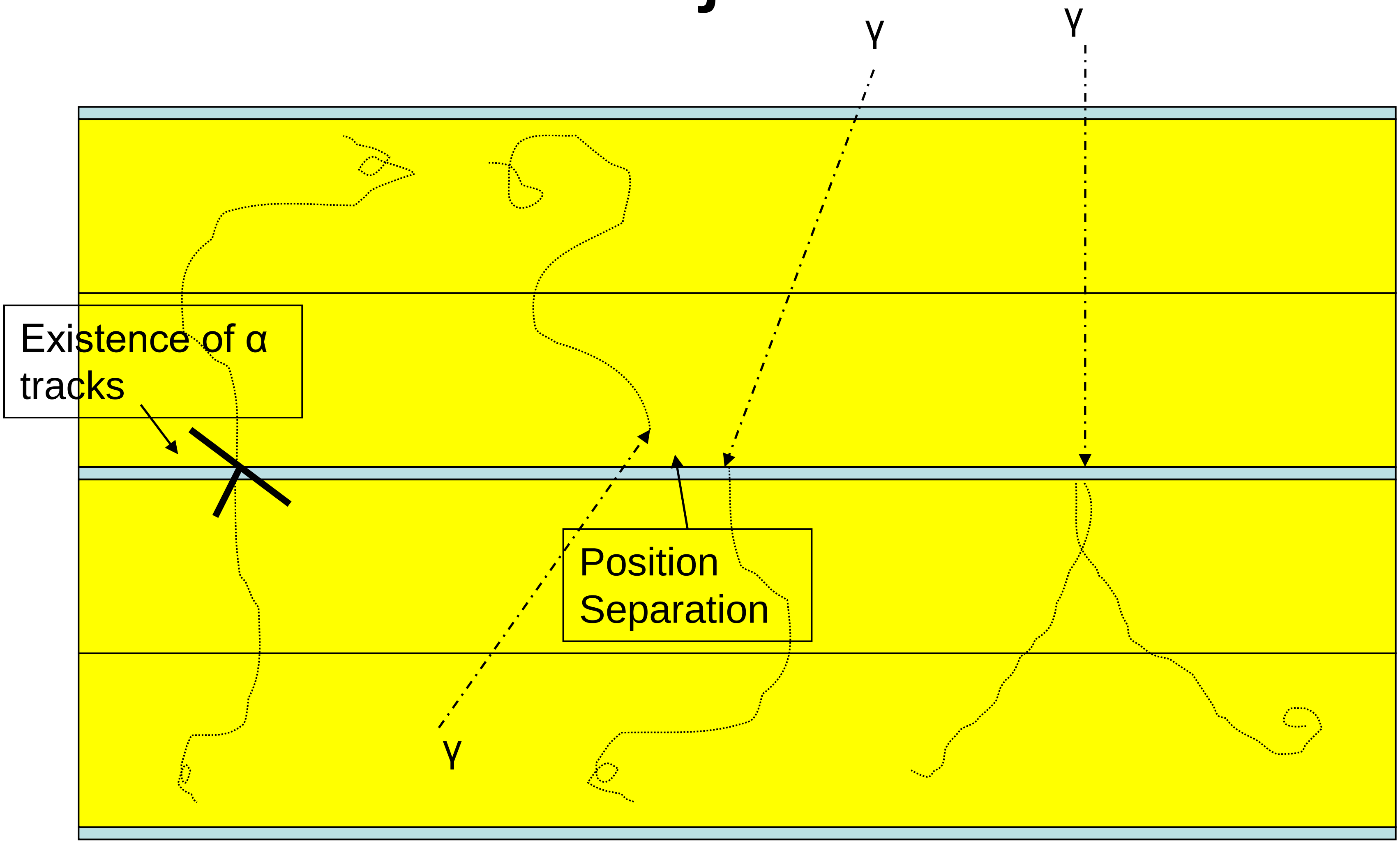


E = 2.0 MeV
10 events

1mm

MC

BG rejection



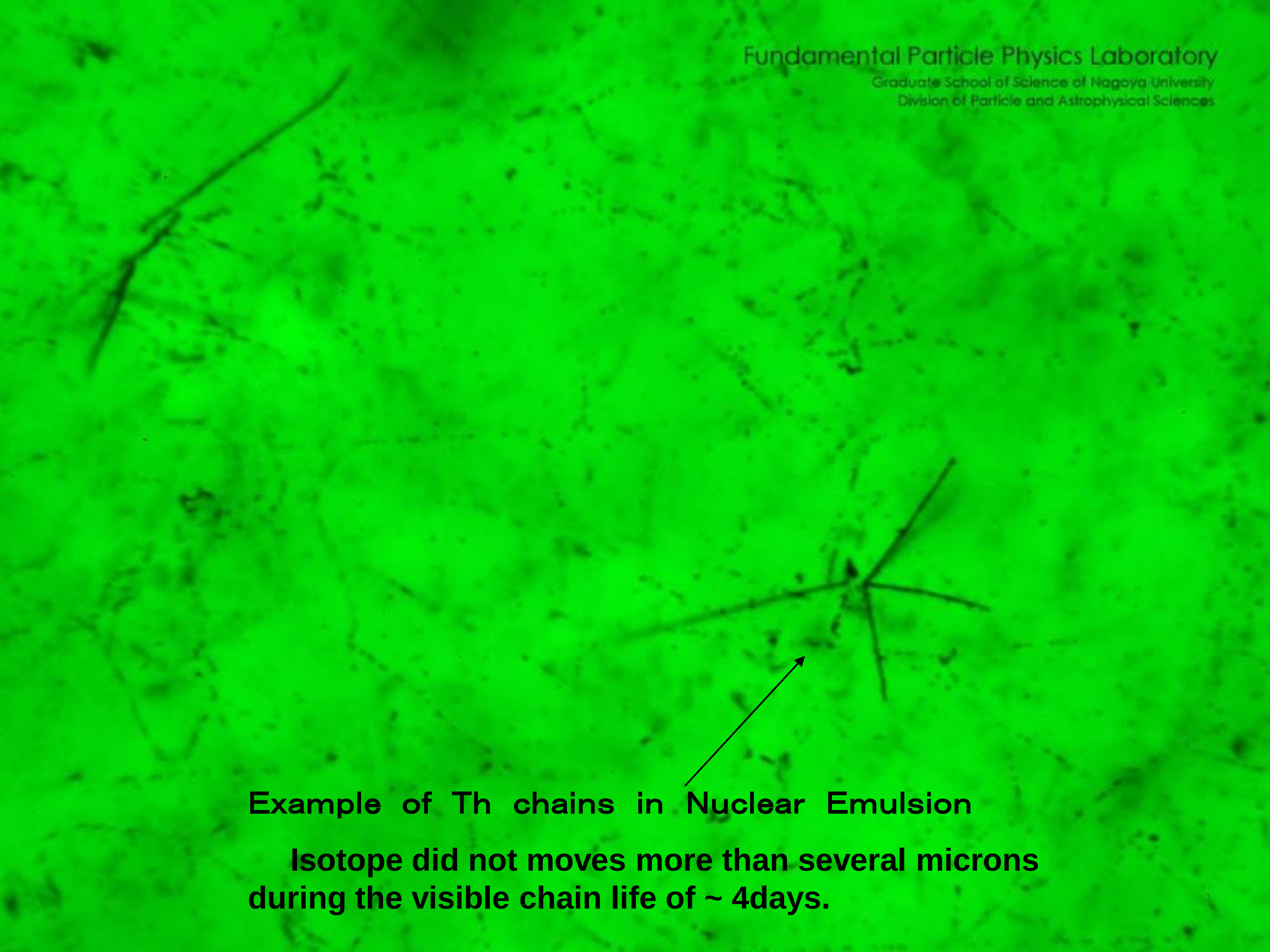
Beta from

Th U chain

Chance coincidence of Compton events or internal sources like ^{40}K

e-pair, knock-on

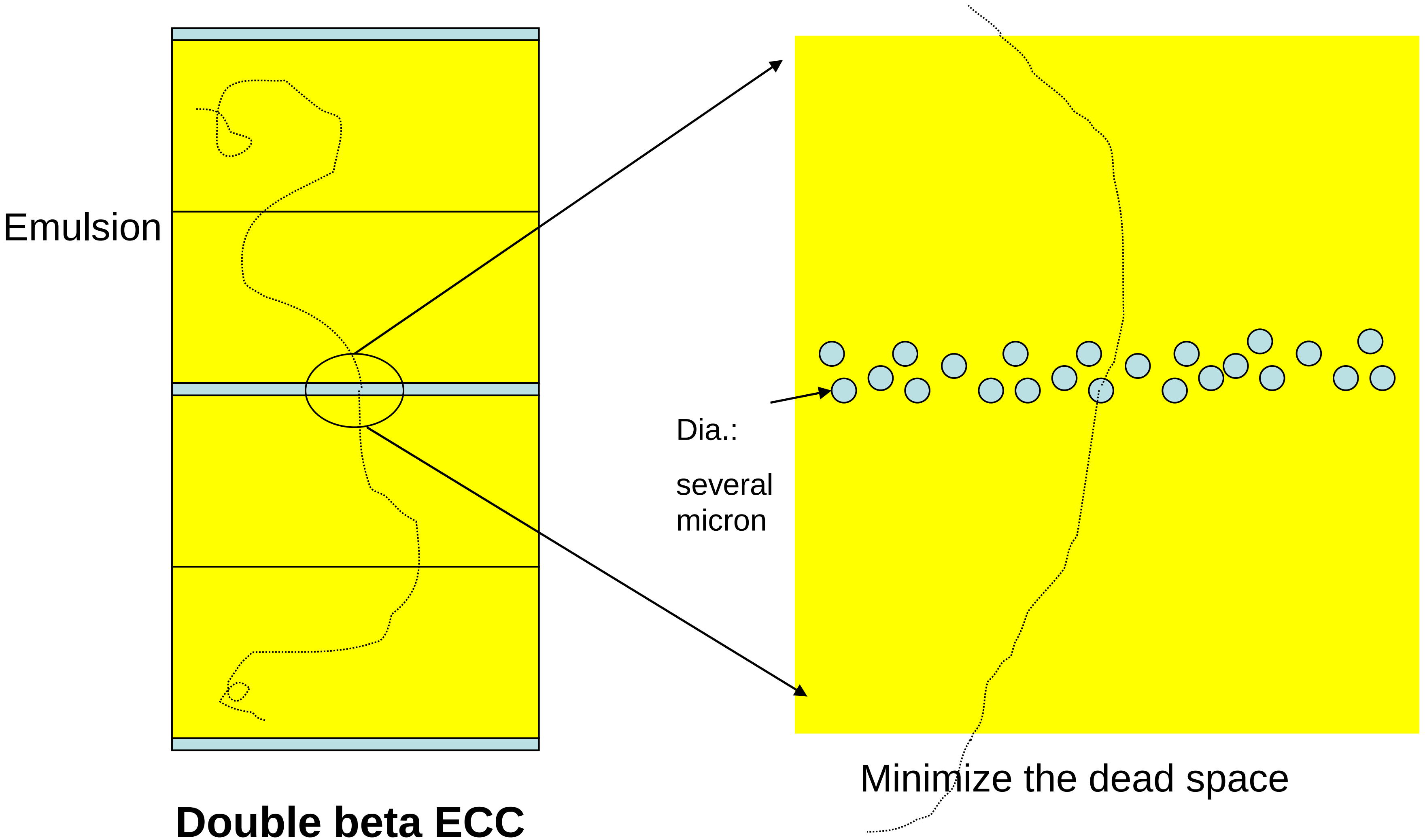
Estimate from the emulsion event.



Example of Th chains in Nuclear Emulsion

Isotope did not moves more than several microns during the visible chain life of ~ 4days.

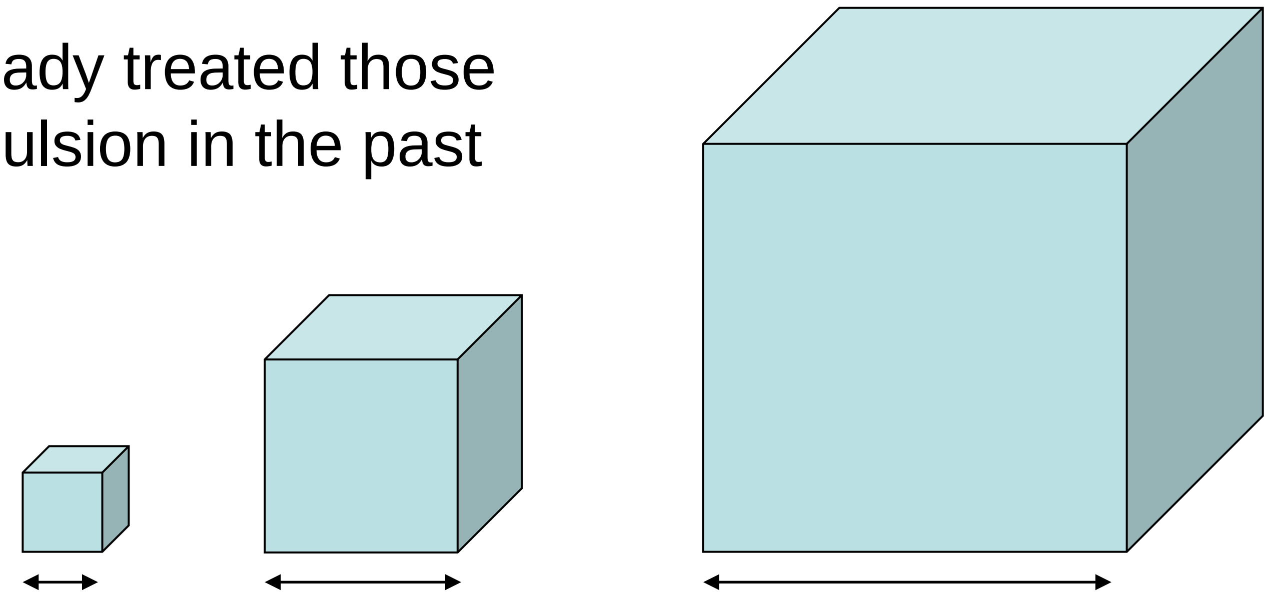
Source layer (Another idea)



Double beta ECC

Detector Size

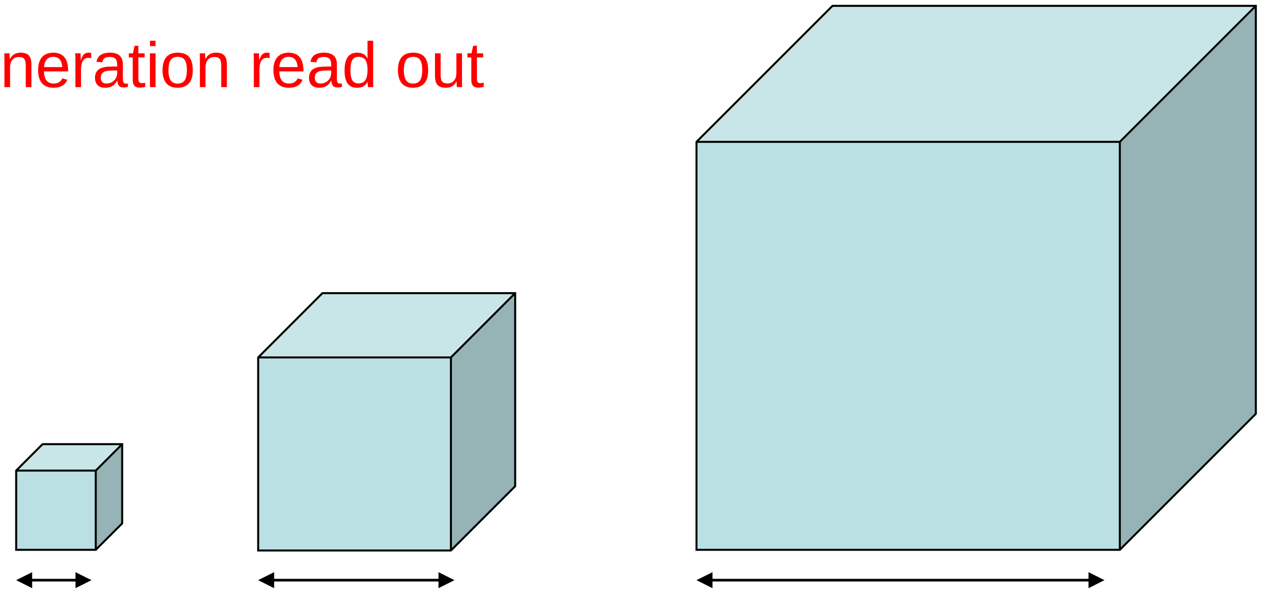
- Very Compact. Easy to Shield.
- We have already treated those amount of Emulsion in the past experiments.



	~50cm	~1m	~2 m
Source Mass	~ 10kg	~100kg	~1000kg
Emulsion mass	~100kg	~1000kg	~10000kg
Experiment Level	E531	CHORUS	OPERA

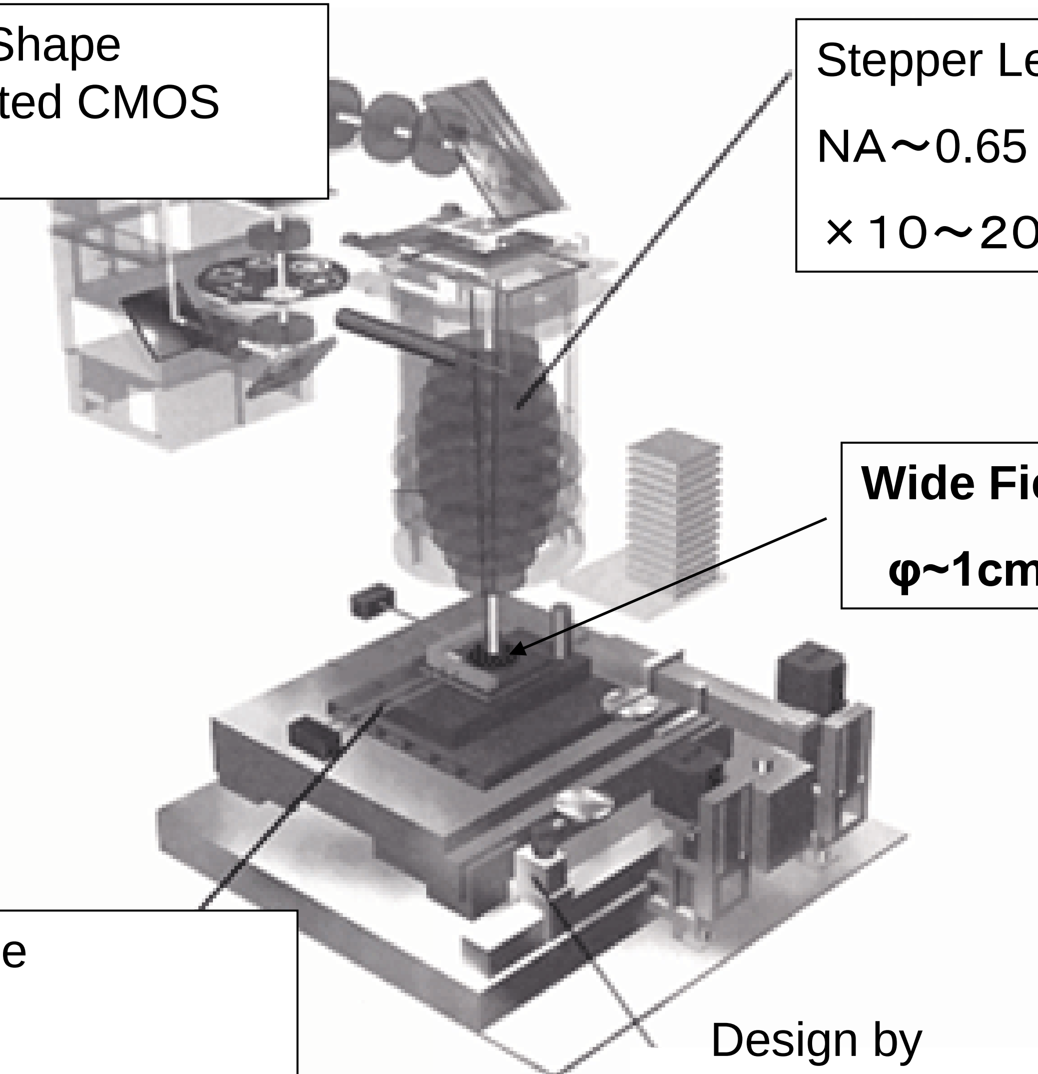
Scanning Load

- Area 1000 - 10000 m^2
- Need next generation read out system.



	~50cm	~1m	~2 m
Source Mass	~10kg	~ 100kg	~ 1000kg
Scanning Area	~100m^2	~1000m^2	~10000m^2
SUTS ×5	100days	**1000days!**	**10000days!!**

Next Generation Read out System



Mosaic Shape
Segmented CMOS
sensors

Stepper Lens

NA～0.65

×10～20

Wide Field

φ~1cm

X-Y stage

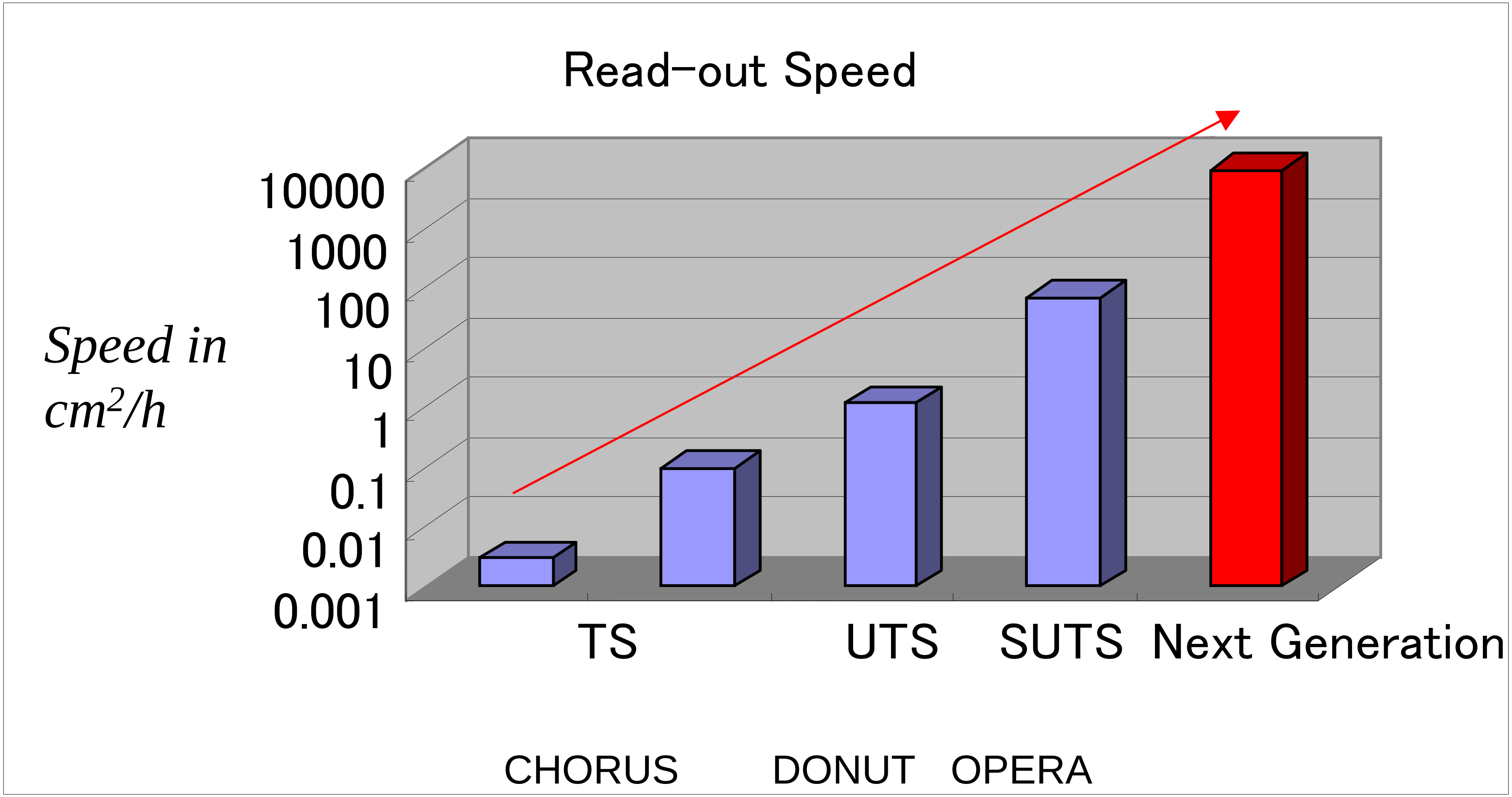
10cm/s

with anti-vibration

Design by

NAKANO Toshiyuki.

Evolution of the Scanning Power



The system ×100 faster than SUTS is under design.

R&D Subjects for Double Beta

- Reduction of ^{40}K contamination (10^{-4})

    Quite high contamination in the current Emulsion because of the production process

    $AgNO_3 + KBr \rightarrow AgBr + KNO_3$

    Replace KBr to NaBr: No difficulties: Test

- Energy Resolution Confirmation: Test & Improvement

Summary

- OPERA is running smoothly.

  → Succeed to produce and treat 110000m^2 films, corresponding to 30tons Emulsion gel.

  → Succeed to operate Fast read-out systems.

- Emulsion as a Tracking Calorimeter for Double Beta Decay.

  → Seems no large difficulties from the technical point of view.