

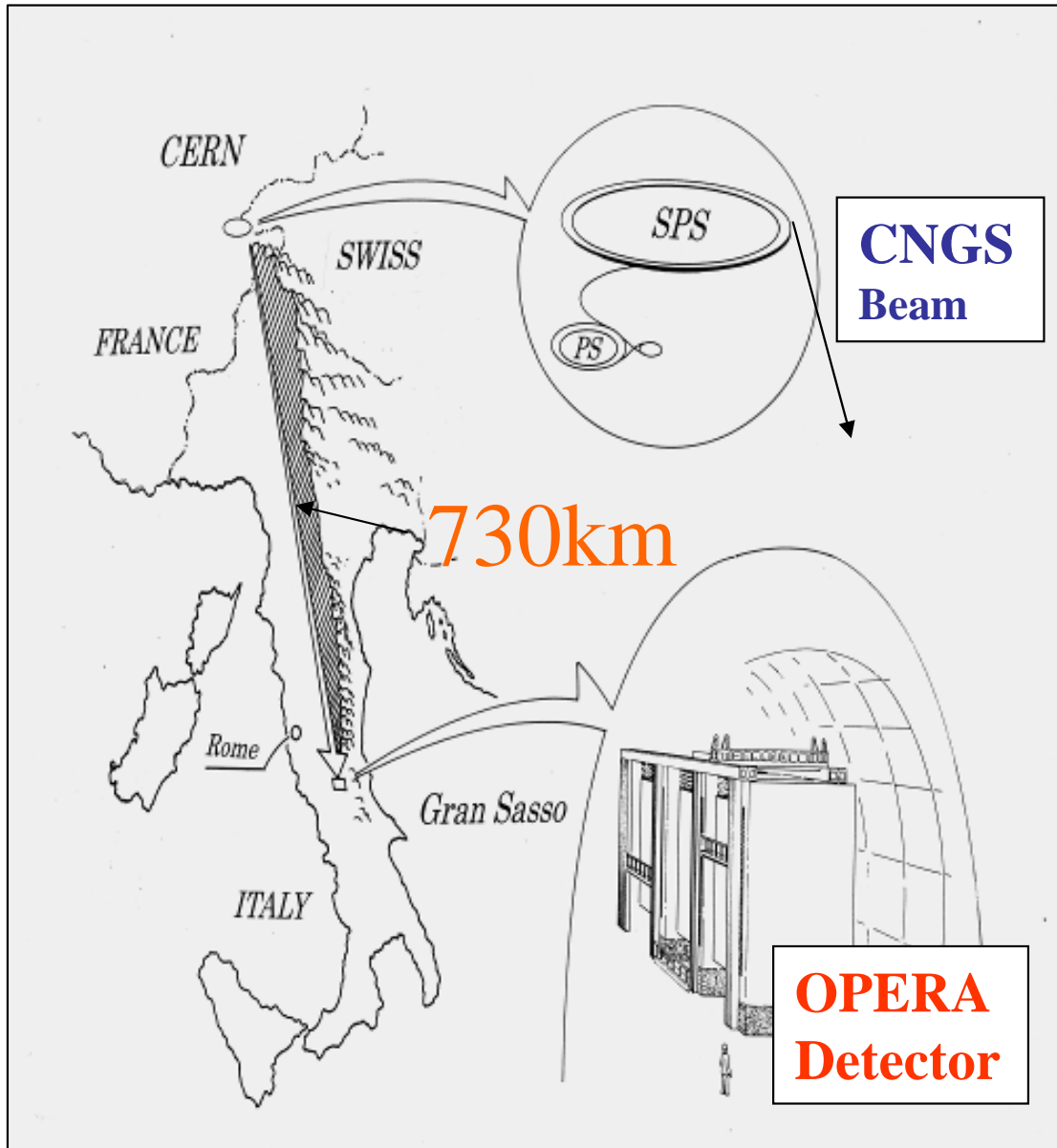
The Status of the OPERA experiment

O.Sato(Nagoya Univ.)

2007.Mar.16 フレーバー物理研究会



OPERA



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

Collaboration :

13countries 37 Institutes

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

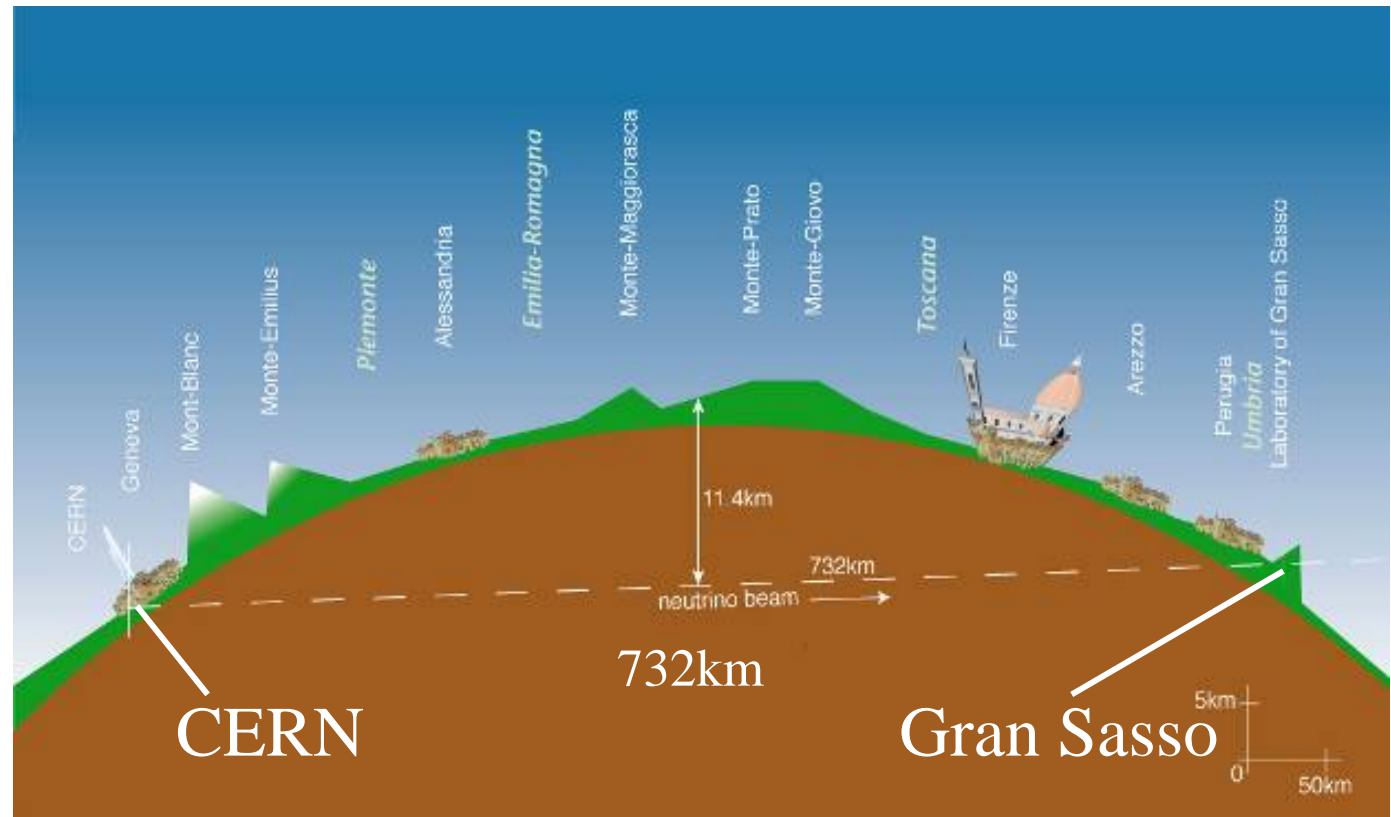
CNGS beam

Optimized to study $\nu\tau$ appearance

Nominal ν beam

ν_μ (m ⁻² / pot)	7.45x10⁻⁹
ν_μ CC / pot / kton	5.44x10⁻¹⁷
$\langle E \rangle_\nu$ (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

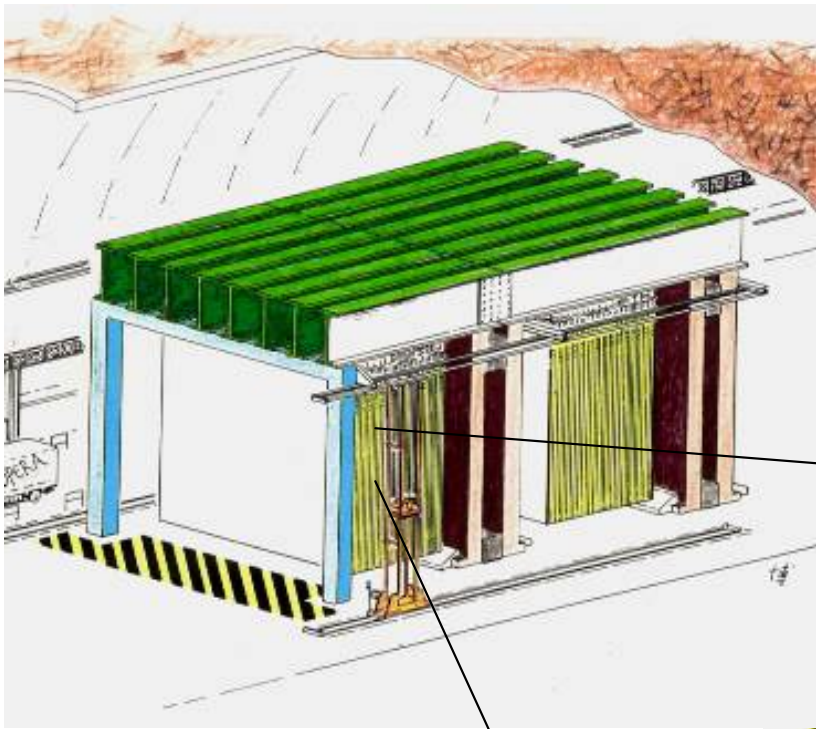


⇒ Interactions at Gran Sasso

~ 3600 ν NC+CC /kton/year
~ 16 ν_τ CC /kton/year

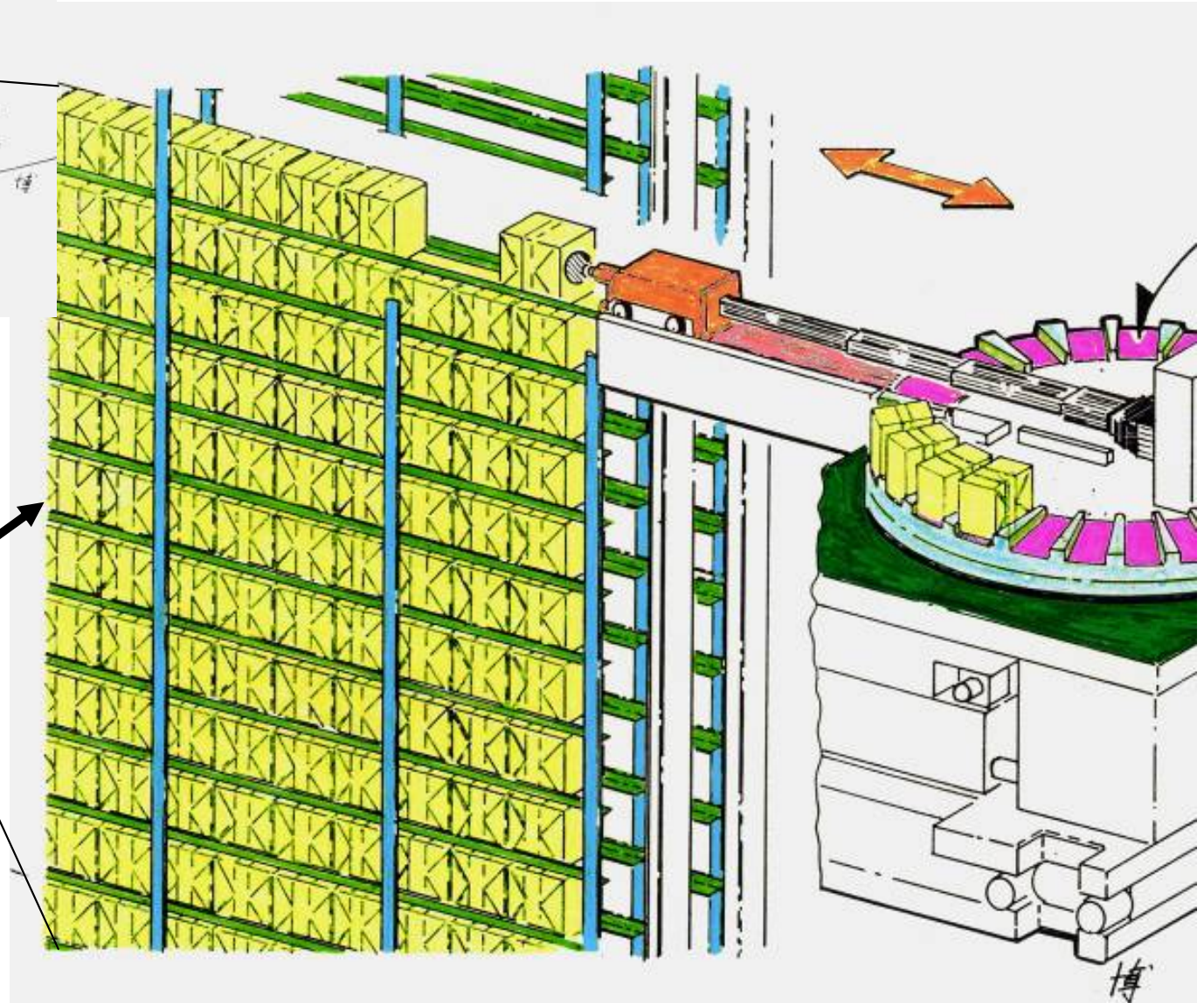
for $\sin^2 2\theta = 1$, $\Delta m^2 = 2.5 \times 10^{-3} \text{ eV}^2$

Shared SPS operation
200 days/year
4.5x10¹⁹ pot / year



~200k ECC bricks

ECC Weight ~1700ton

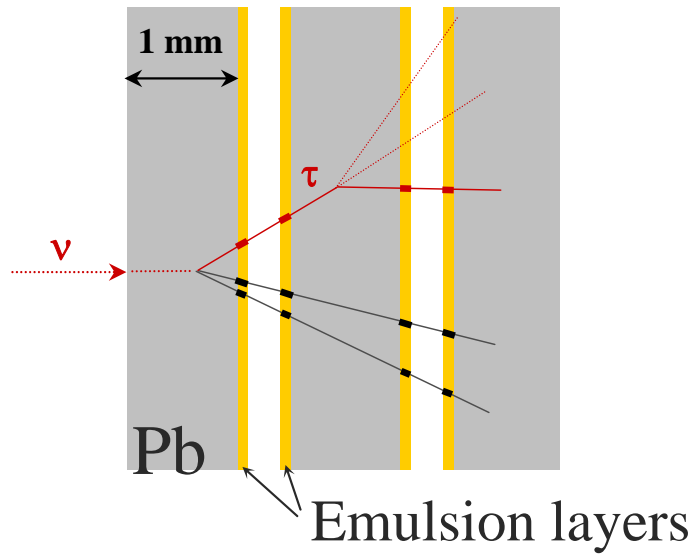


64 × 52 ECC/Wall

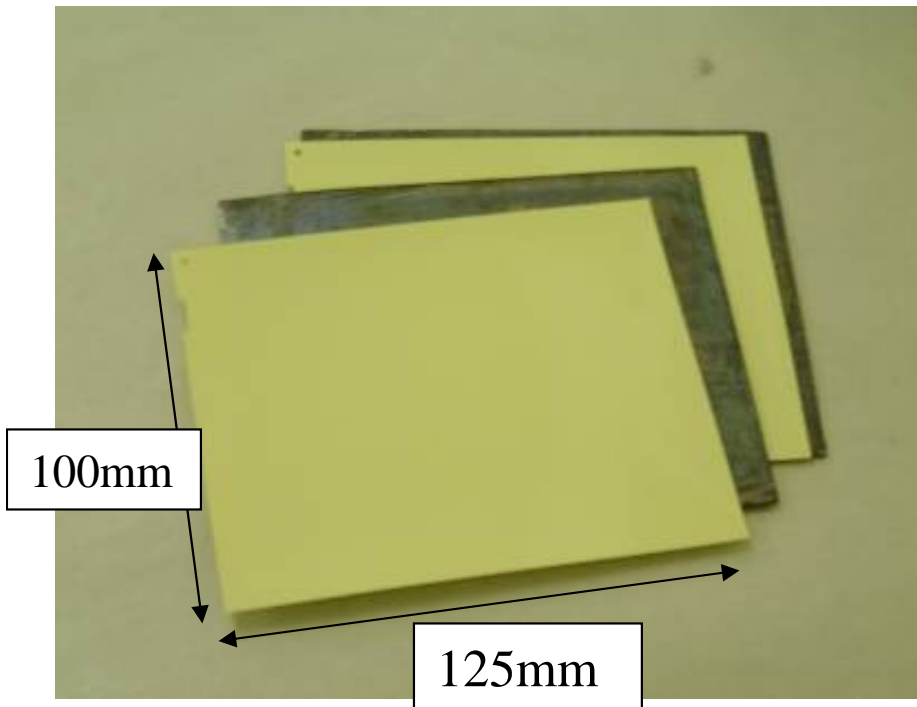
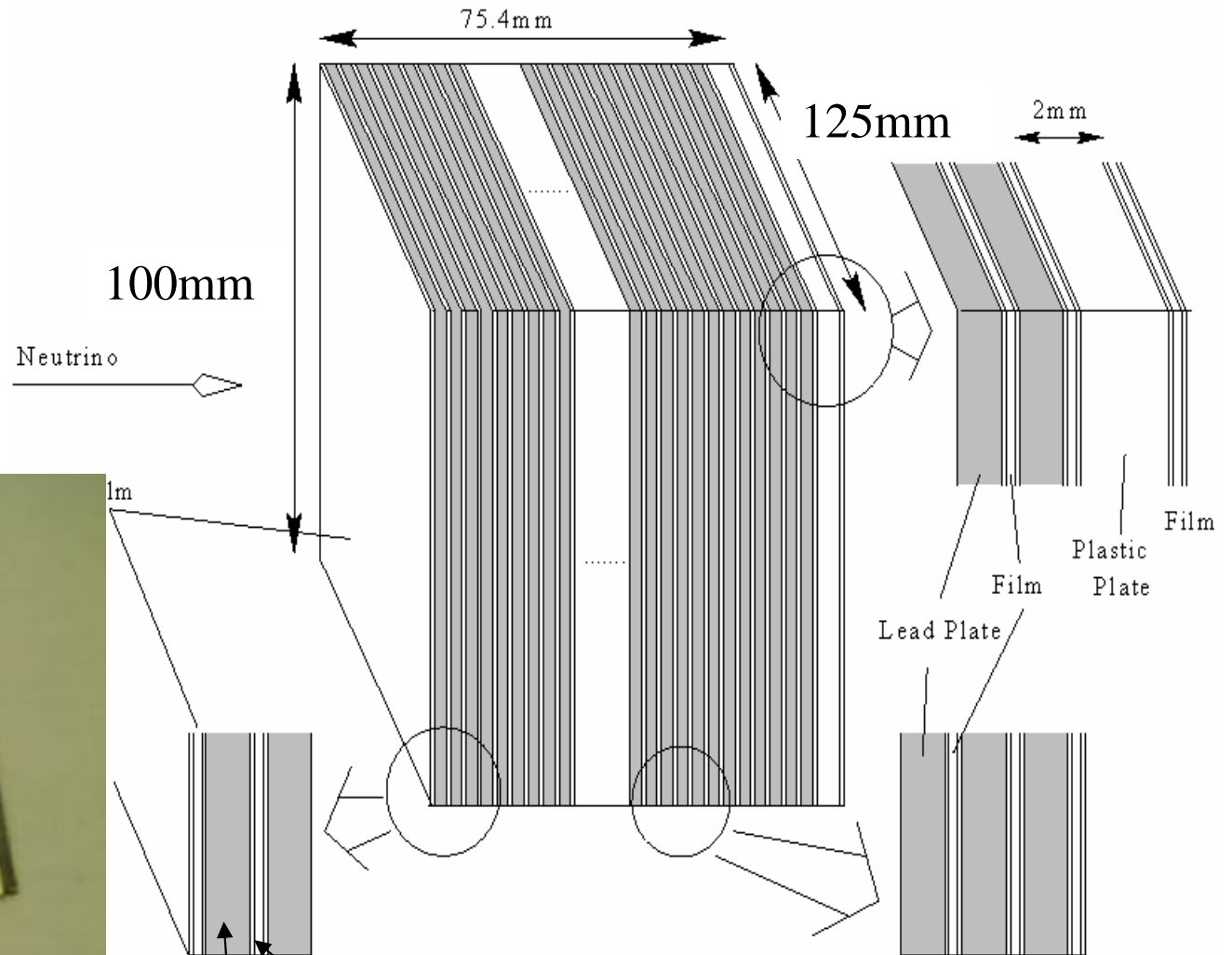
Total 62 Walls

OPERA ECC Brick

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

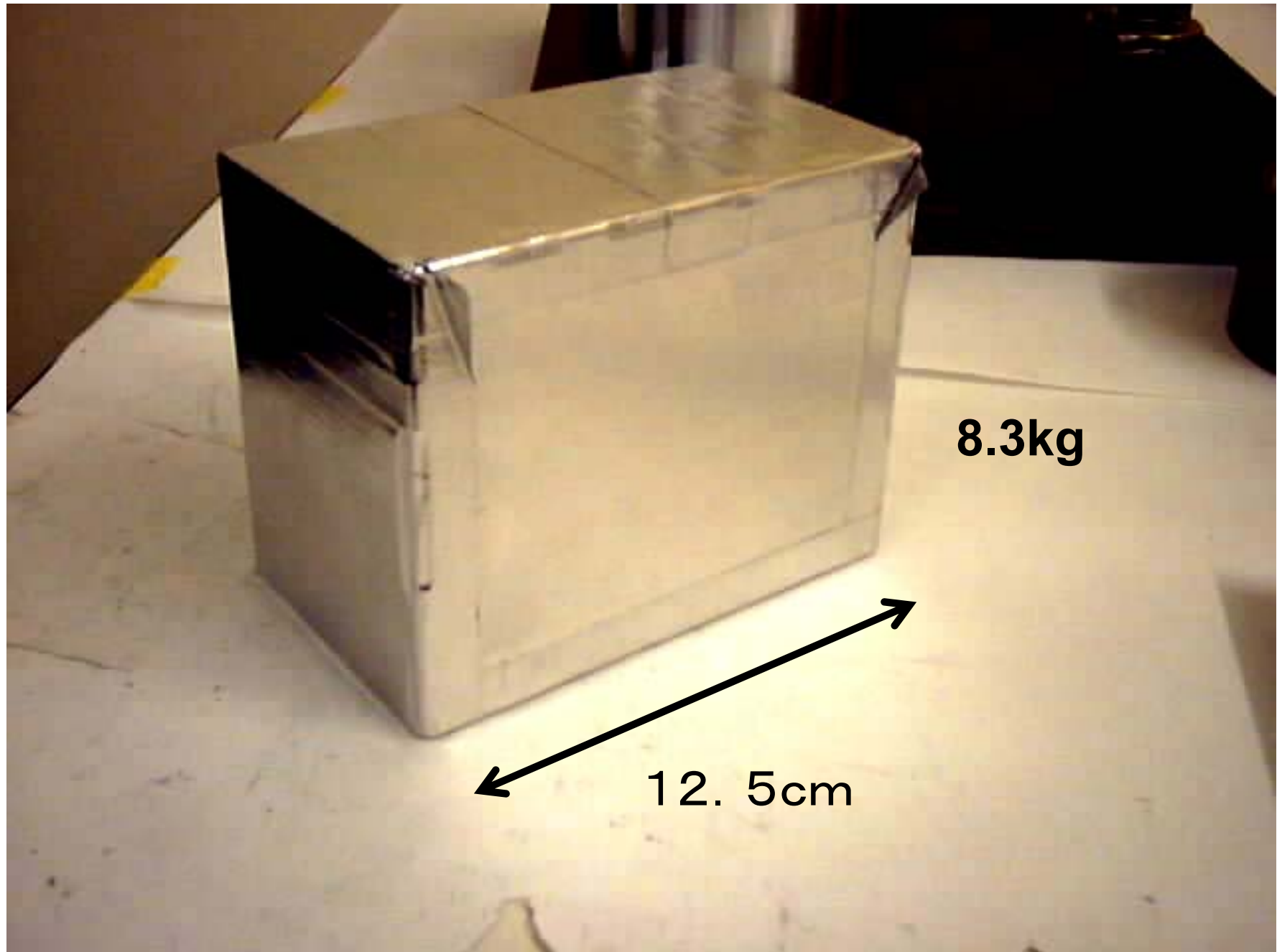


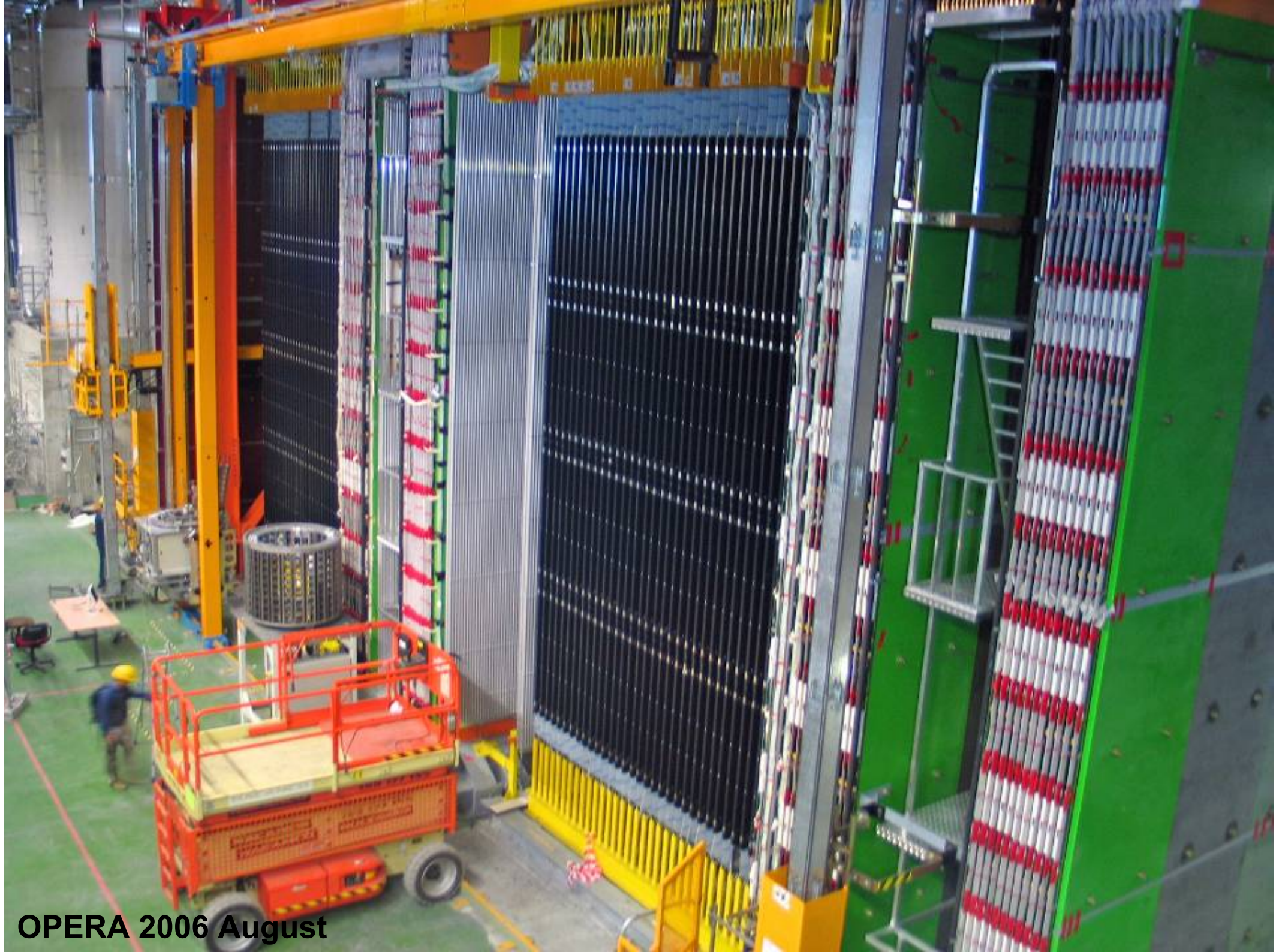
Film + 56 (Lead + Film) + Plastic plate + Film



Lead Plate Emulsion Film (OPERA Film)

ECC Brick





OPERA 2006 August

Electronic detectors installation

SM1

SM2



Veto

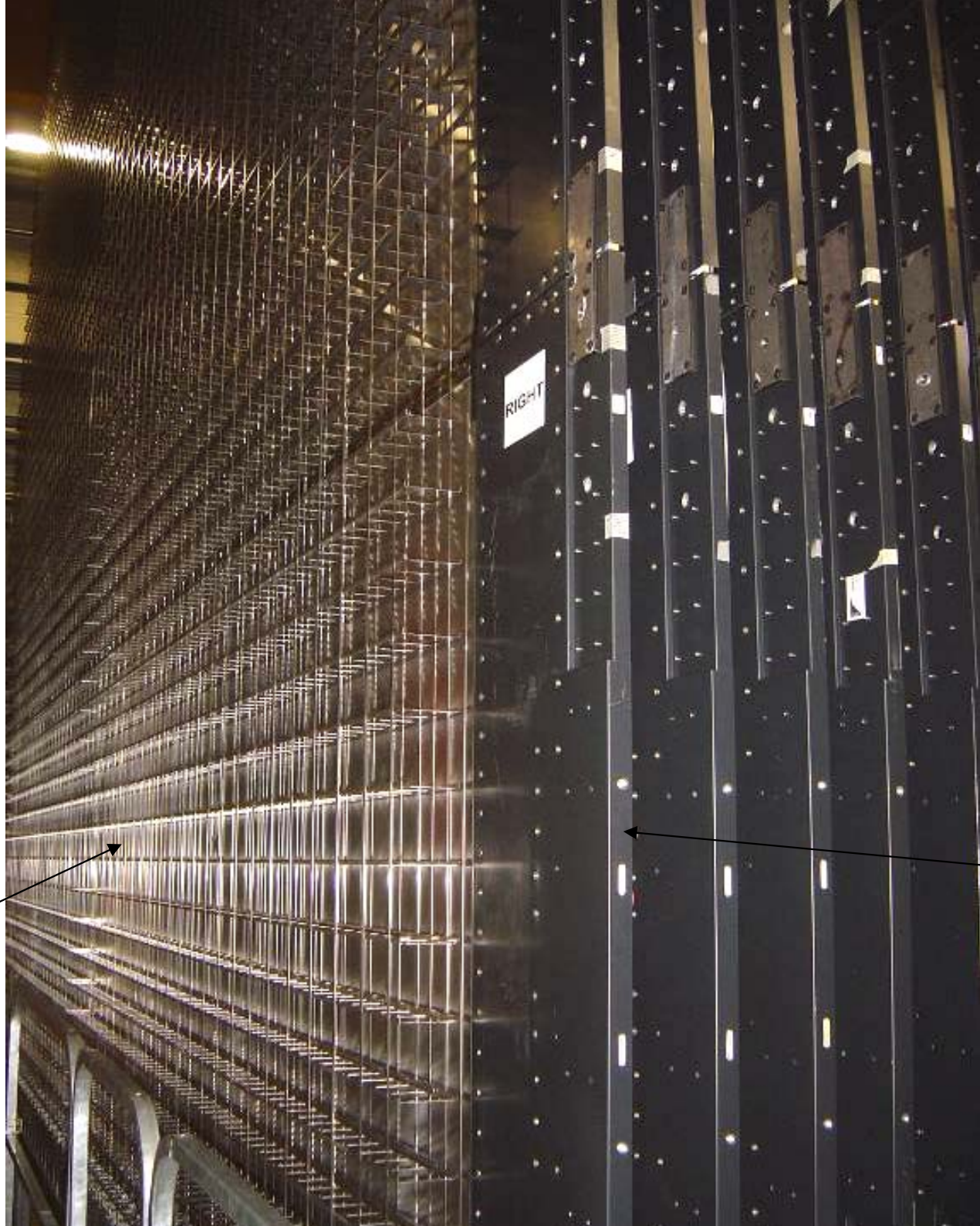
Target tracker

BMS

Spectrometer:
XPC, HPT, RPC, magnet

All installed and running except:

- VETO : commissioning start soon
- HPT/SM2 : first half of 2007



**Wall
for
ECC
bricks**

**Target
Tracker**



**Current :
1300 bricks
stored in detector**

30

29

28

27

26

25

24

23

22

21

20

19

18

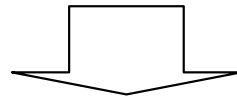
Emulsion Film

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

OPERA

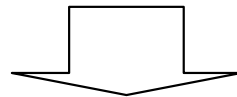
Film area required **150,000 m²**

Number of Films **1.2 × 10⁷**
(100mm × 125mm)



Mass production using commercial film
production line

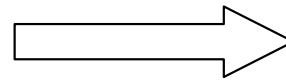
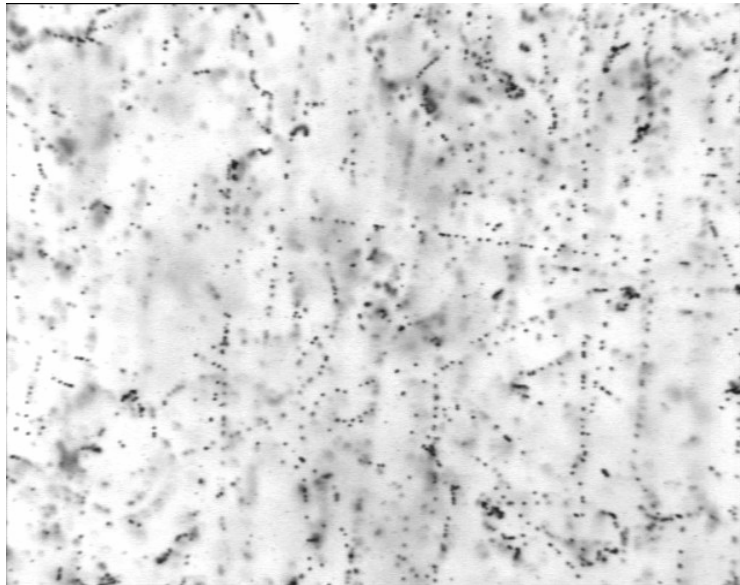
R&D Fujifilm & Nagoya ('98—'02)



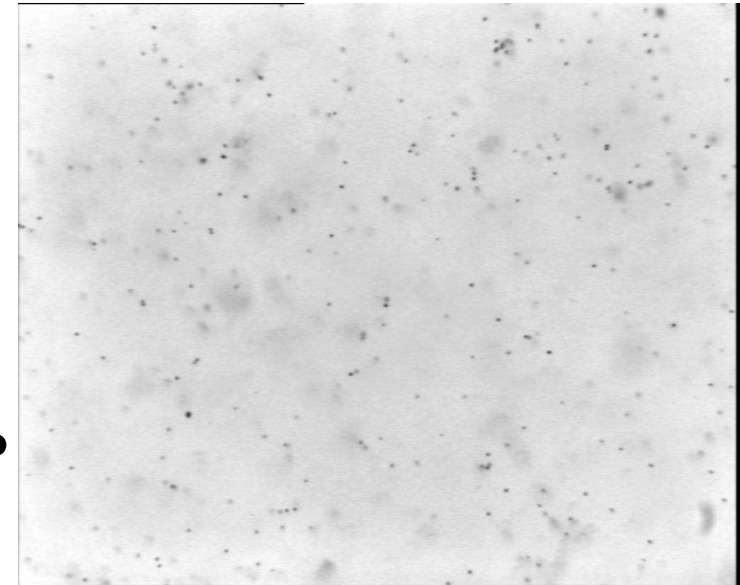
Mass production start April 2003

8,000 m²/month ~ 2 years

Refreshing



Refresh
• $T = 30^{\circ}\text{C}$
• $\text{RH} > 95\%$
3 days



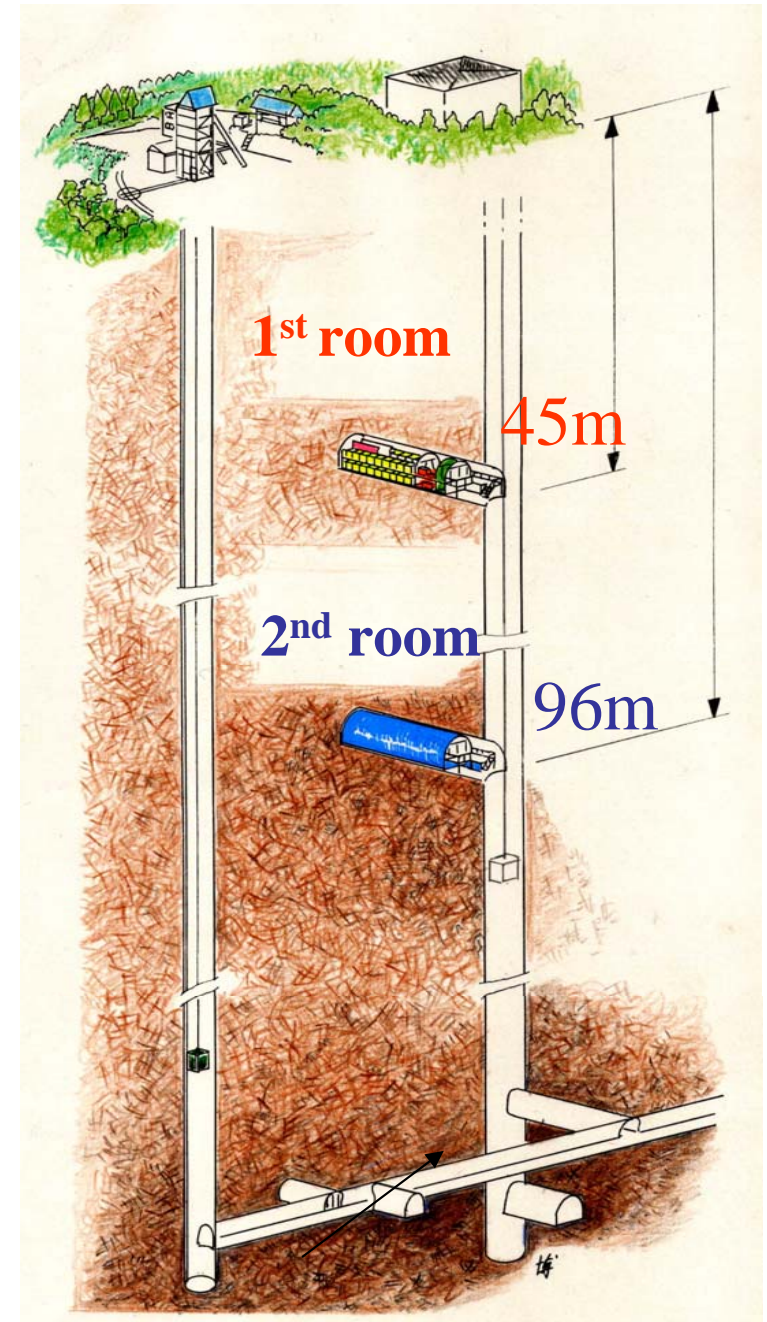
Before Refresh
B.G. > 30tracks / mm²

After Refresh
B.G. < 1tracks / mm²

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

Refresh Facility

TONO Mine underground



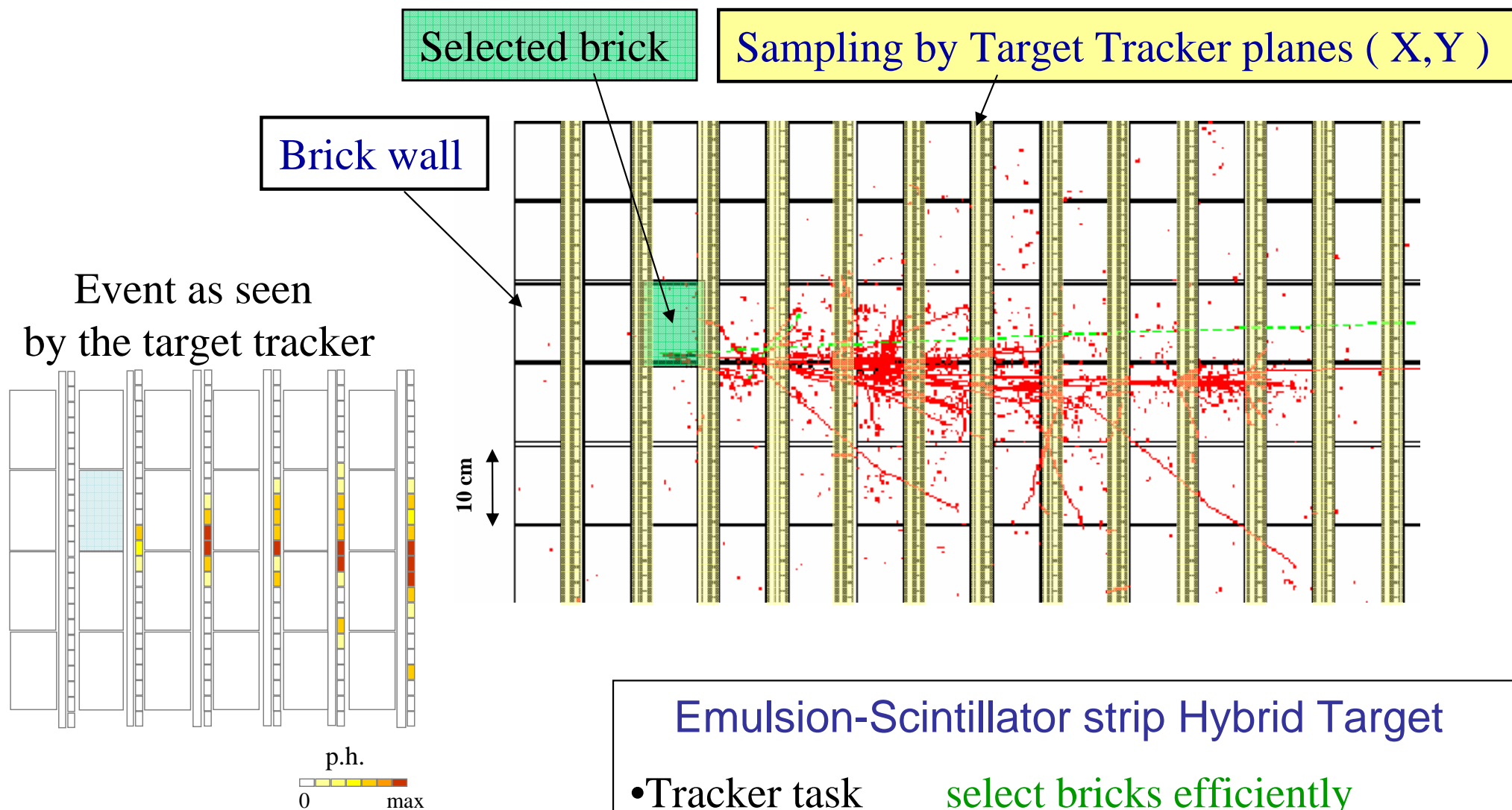
Cosmic ray flux

1st room 1/50(115m.w.e.)

2nd room 1/400(220m.w.e.)

**8M films have been refreshed
and shipped to Gran Sasso.**

Brick tagging by TT



Selected bricks extracted daily using dedicated robot

Emulsion-Scintillator strip Hybrid Target

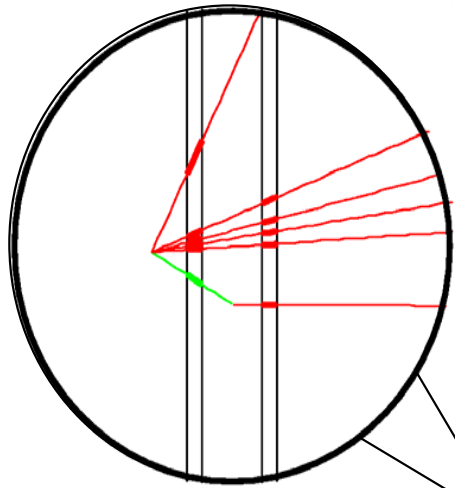
- Tracker task **select bricks efficiently**
- High scanning power + low background **allow coarse tracking**



Vertex location in OPERA ECC Bricks

(Lead Plate(1mmt)+Emulsion Film) × 56

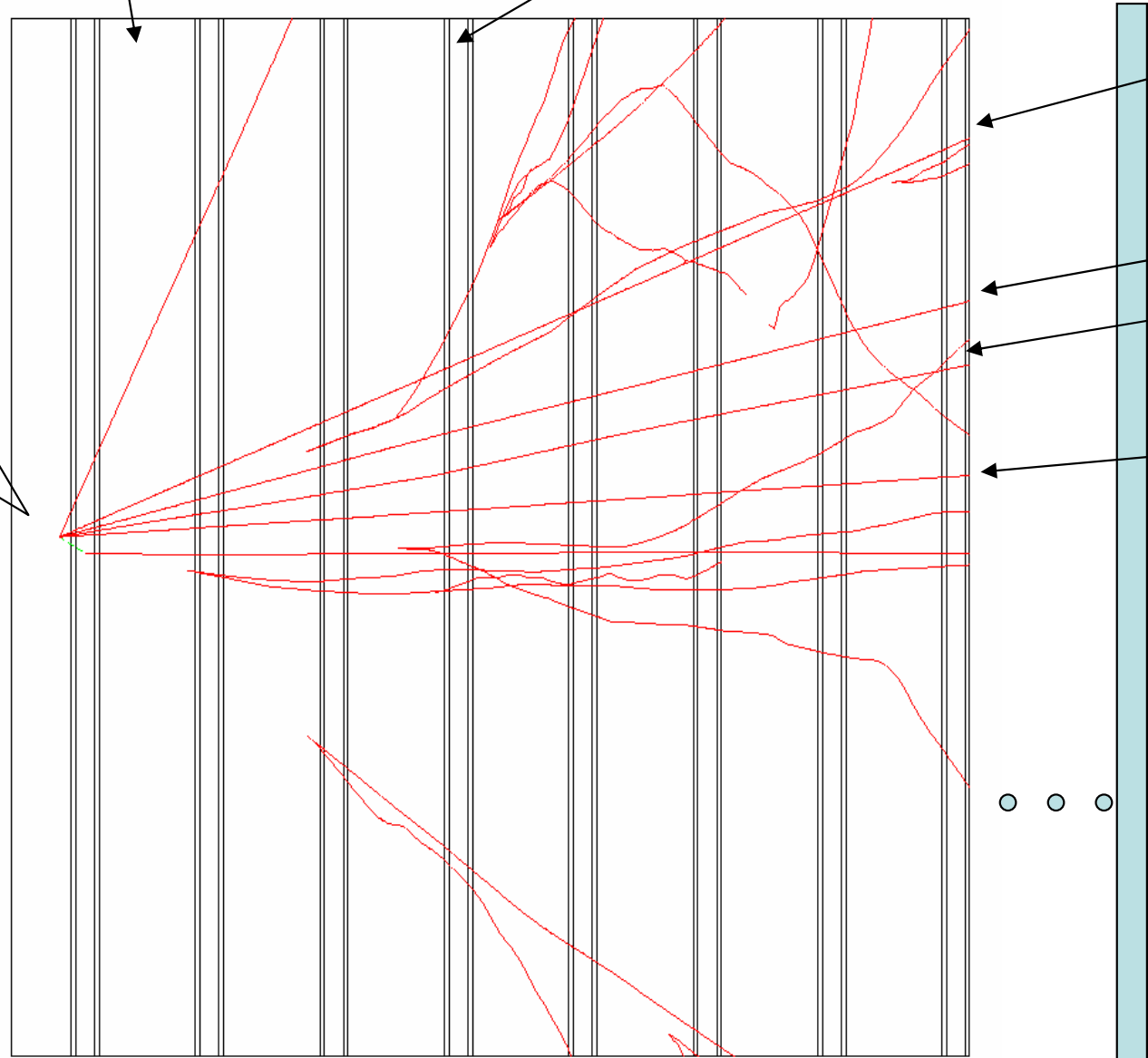
$\nu \tau$ int & τ decay



$\nu \mu \longrightarrow \nu \tau$

Lead:Target

Film:Tracking



Same sequence as E531, DONUT, CHORUS

CS

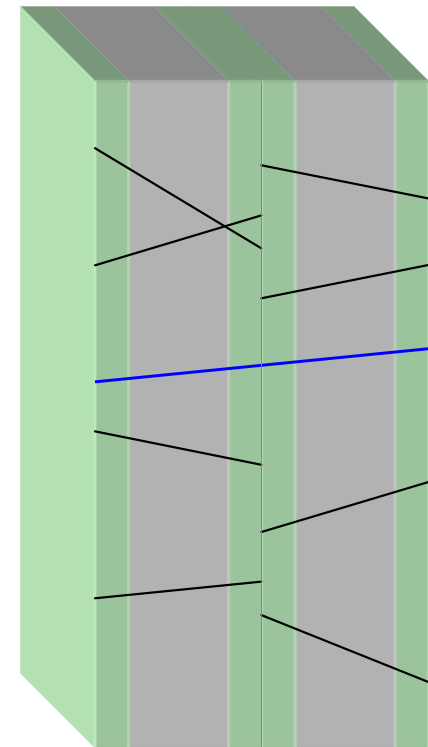
CS Design

- Required Background Level for CS For Brick Tagging

BG tracks \ll 1track/CS (10cmx12cm)

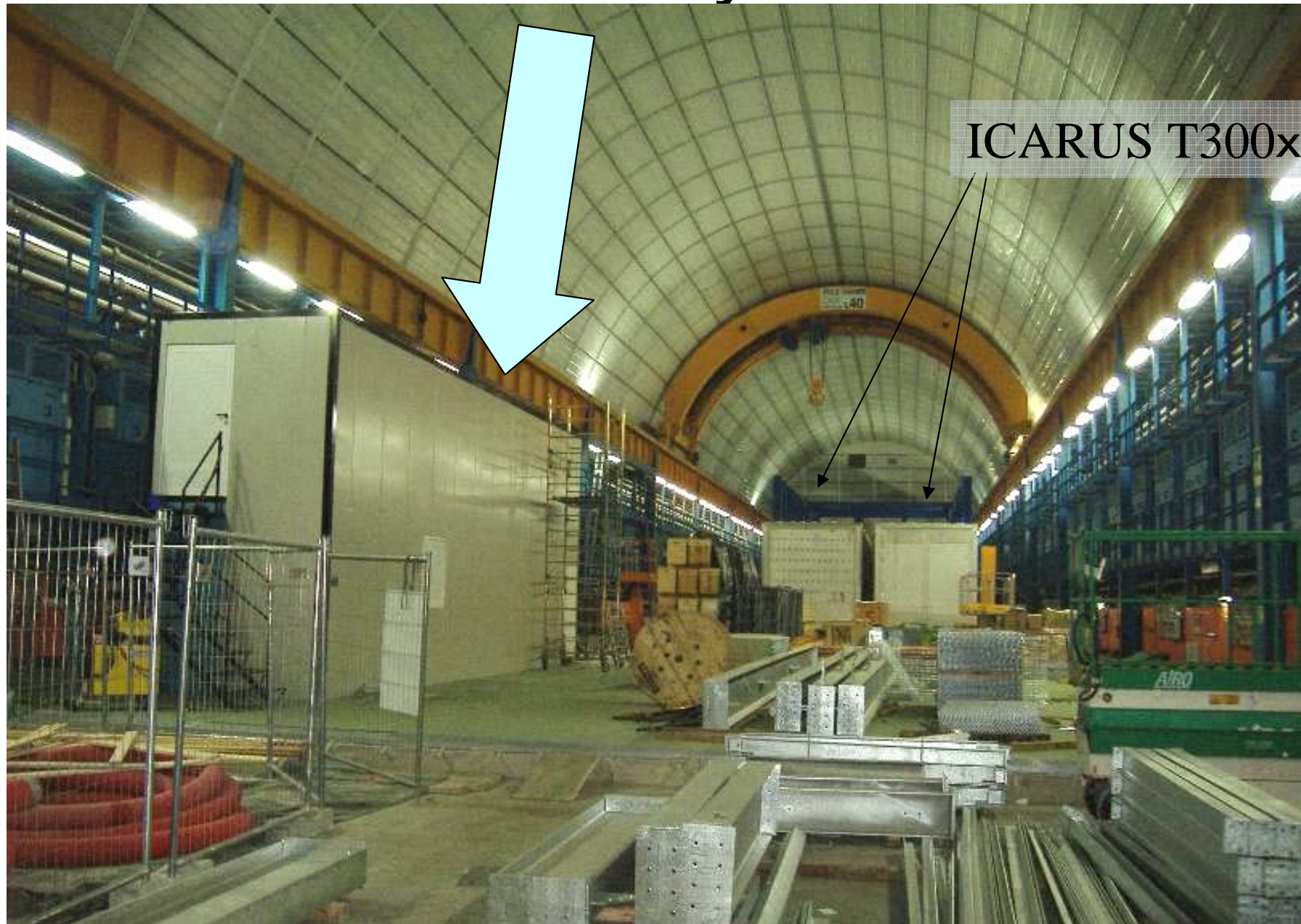
- In order to satisfy this requirement
 - Refresh in GranSasso for CS
 - Doublet Film : coincidence

CS doublet



CS type	Background after refresh (tracks/100cm ²)
Singlet	5000~10000 1 ~ 2%of Accumulated CR
Doublet	< 0.1

OPERA CS facility in GS Hall B



CS Mass production from September 2006 to June 2007

Neutrino beam exposure 2006

August run (two weeks of beam time)

TT to CS track linking test

Real CS

Track sample ::

Muons from neutrino interactions by Rock or Iron.

October run (two weeks of beam time → 24 hours)

Full chain check for location

Real CS & Brick

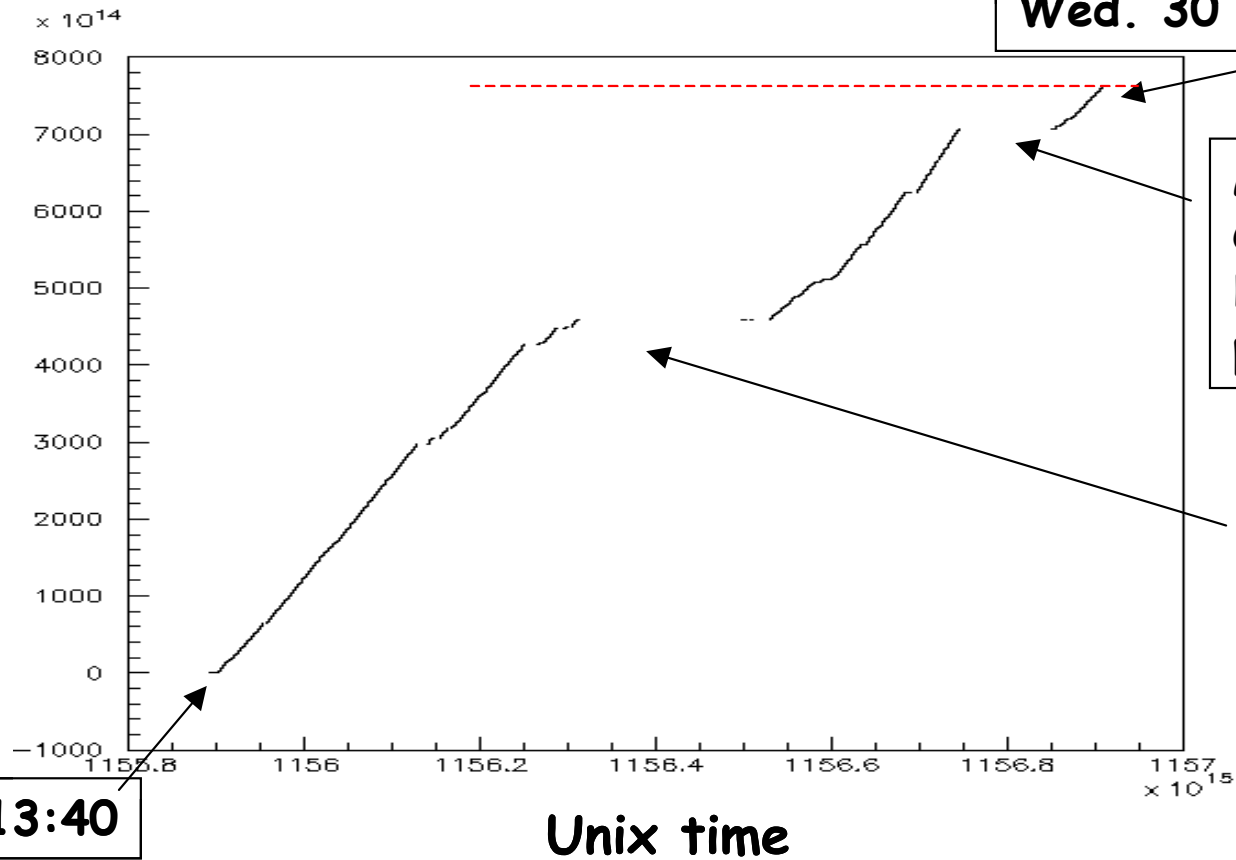
Track sample ::

Muons from neutrino interactions by Rock or Iron

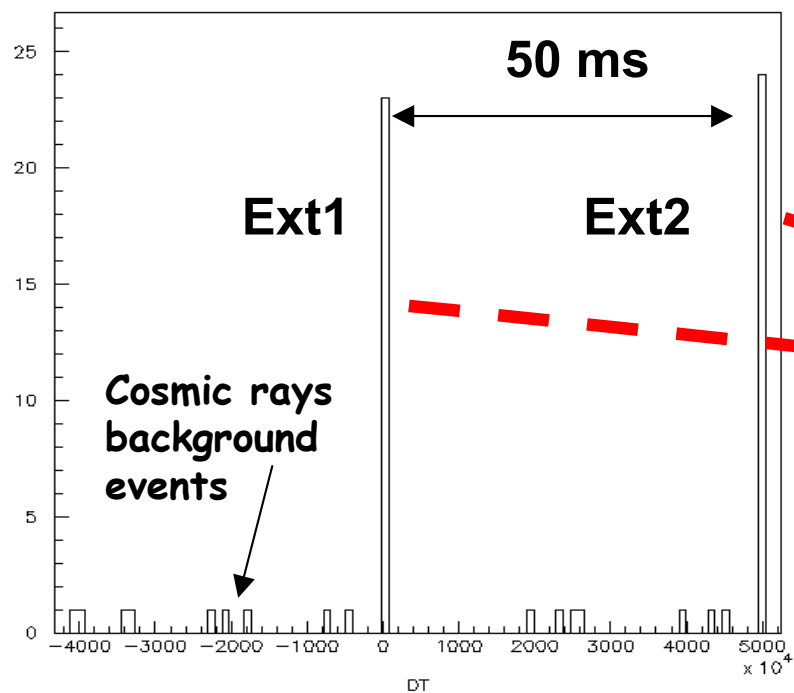
Integrated POT @ Aug '06 RUN

TOTAL:
7.6 E17 pot

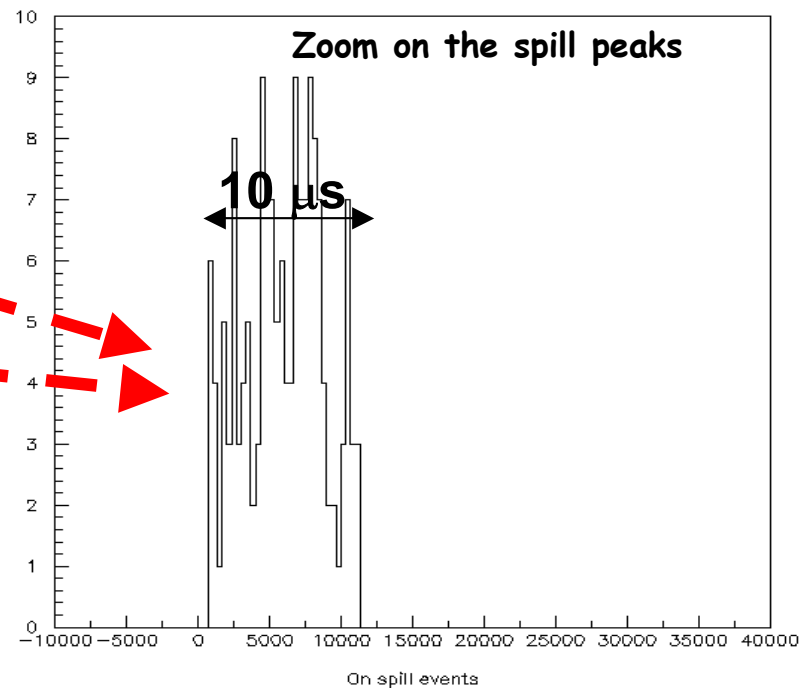
EXT1: 3.81 E17 pot
EXT2: 3.79 E17 pot



Timing : Event vs Extraction @ Aug '06 RUN

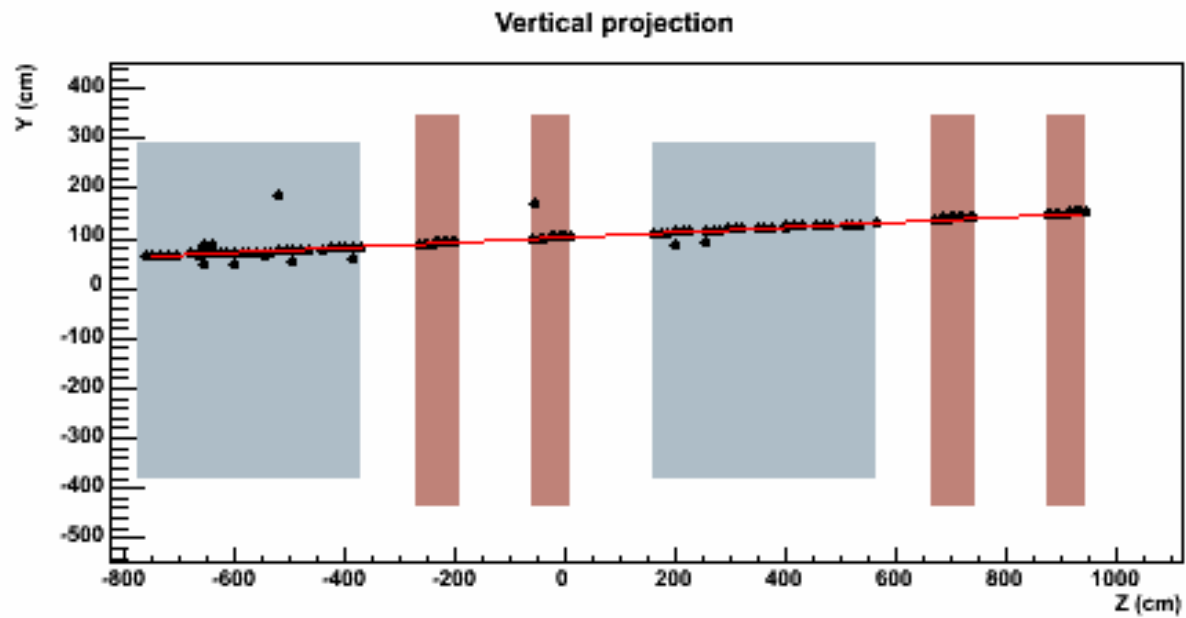
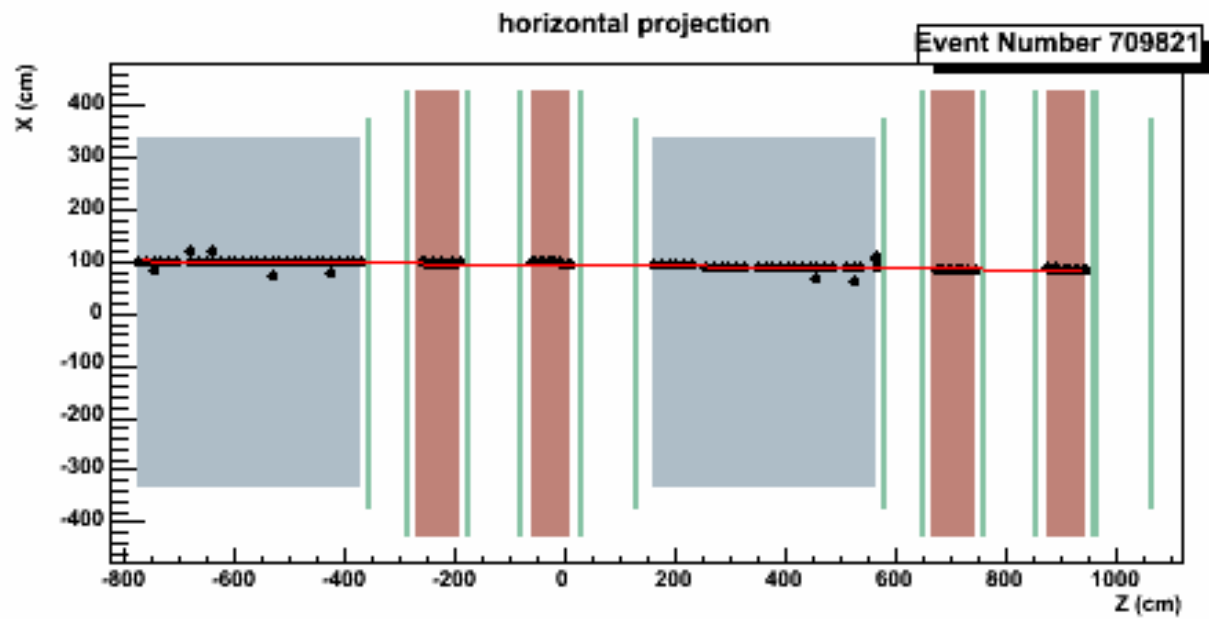


Δt first extraction (ns)

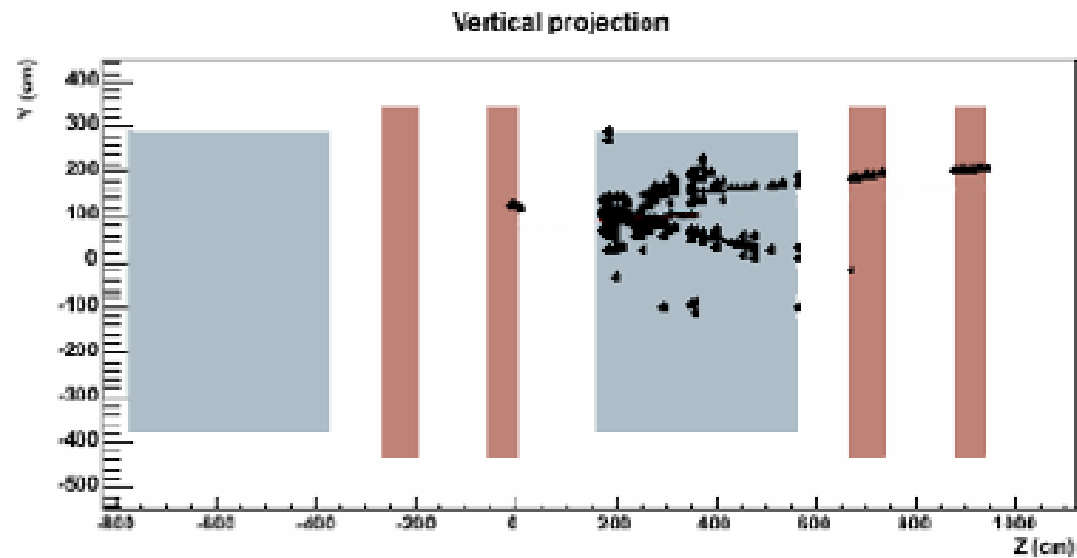
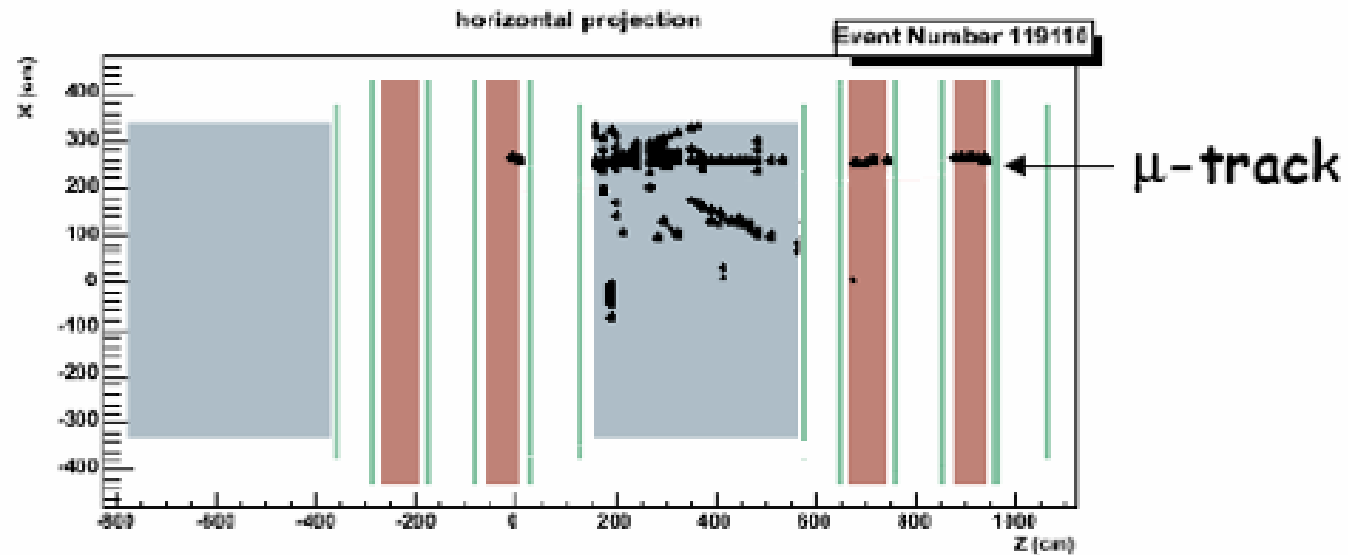


Δt closest extraction (ns)

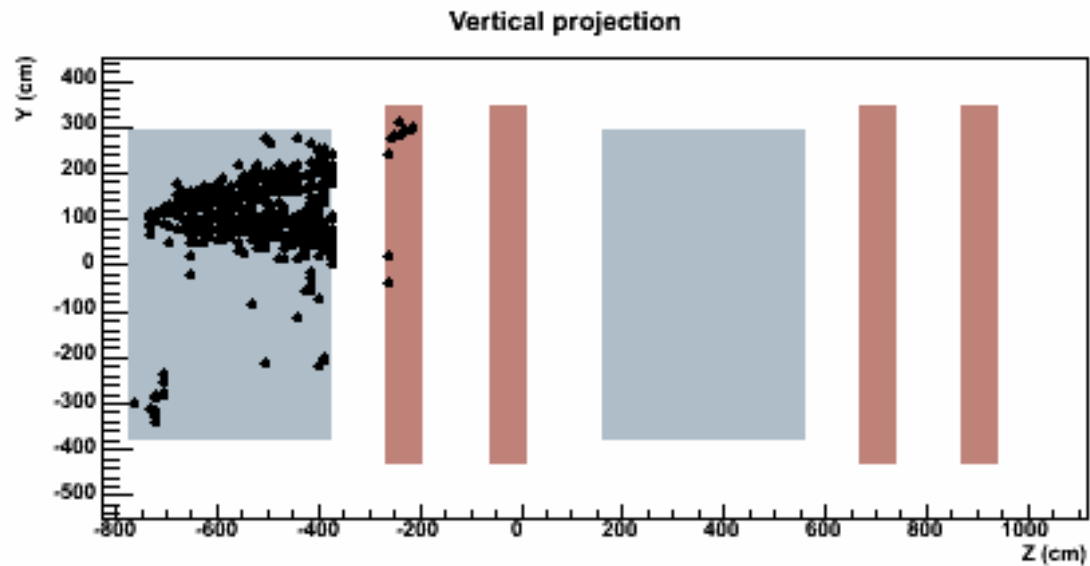
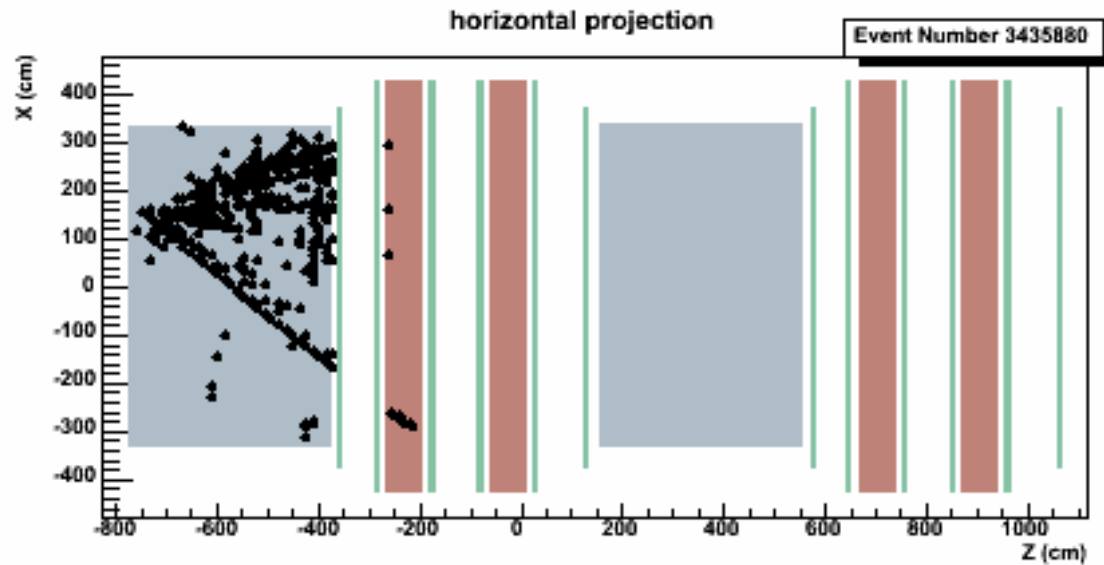
Rock muon event



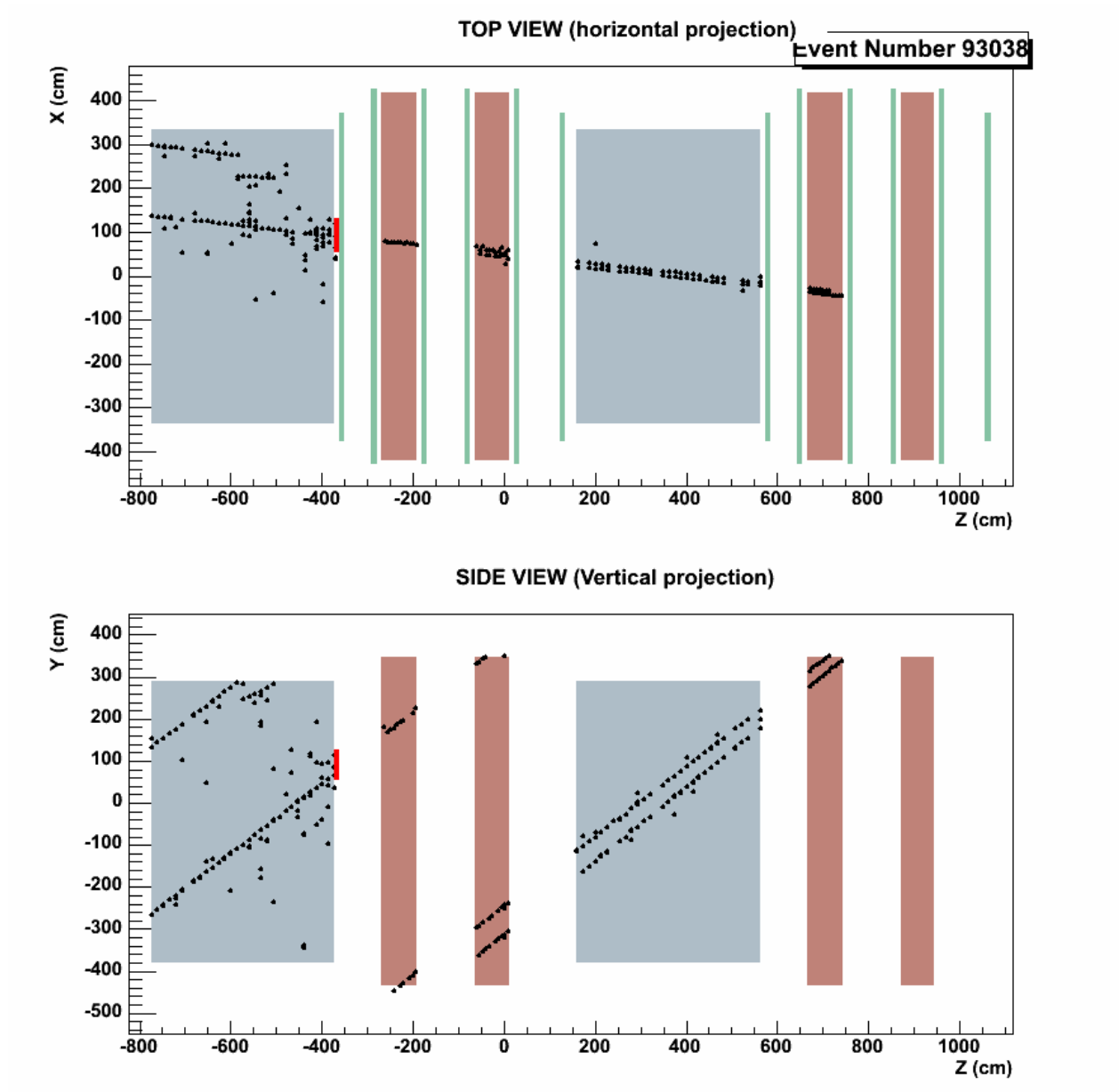
CC event in the Magnet



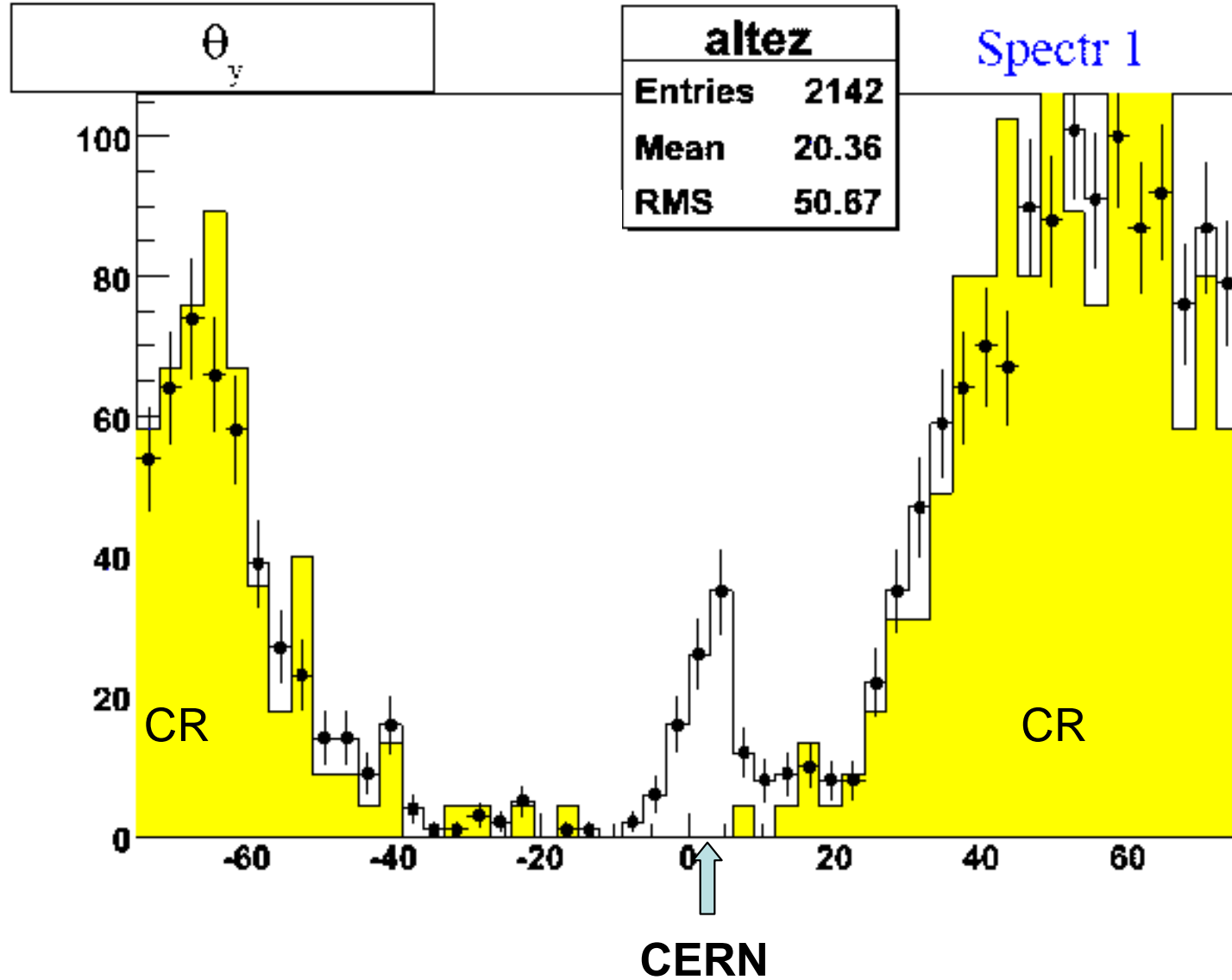
CC event in the target tracker



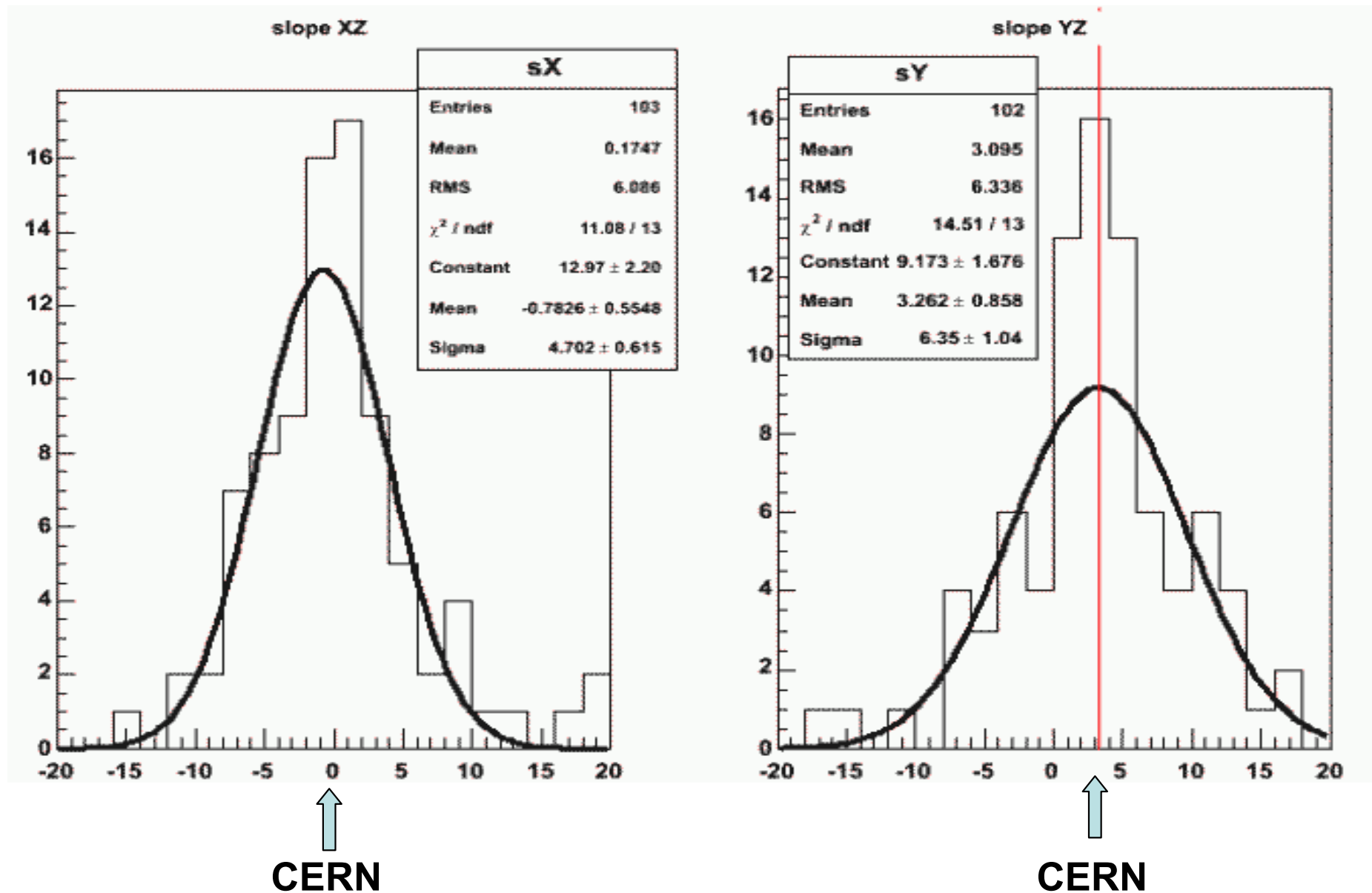
Cosmic ray event (off-timing)



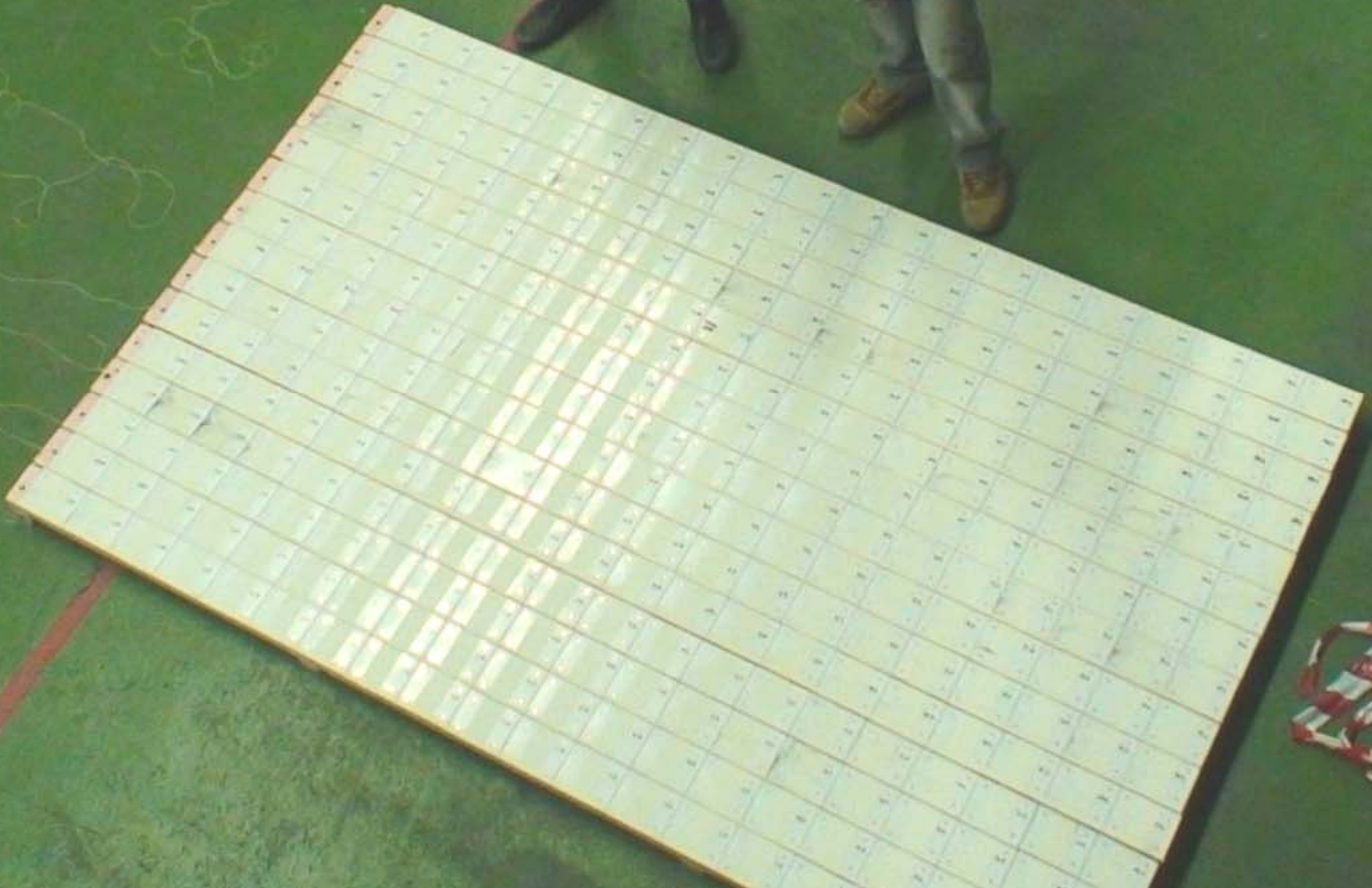
Direction: No timing cut



Rock Muon direction @Aug '06 RUN



20x15 CSD



Installation

end 18:00 Aug17th

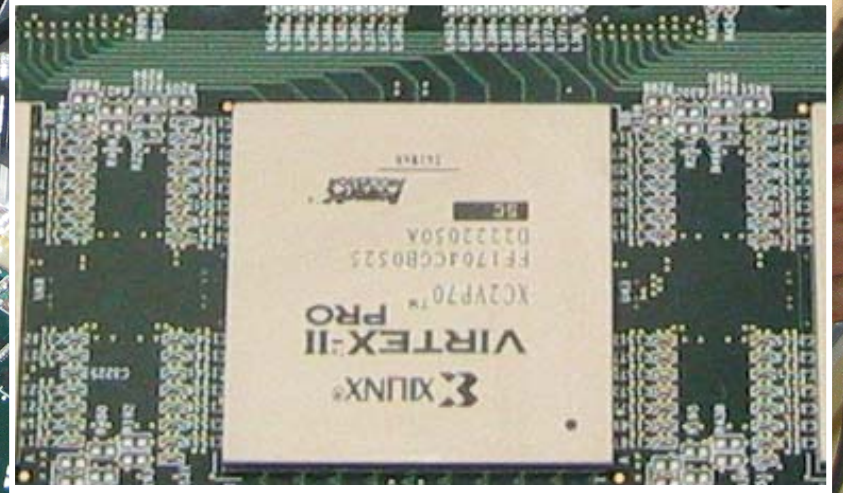
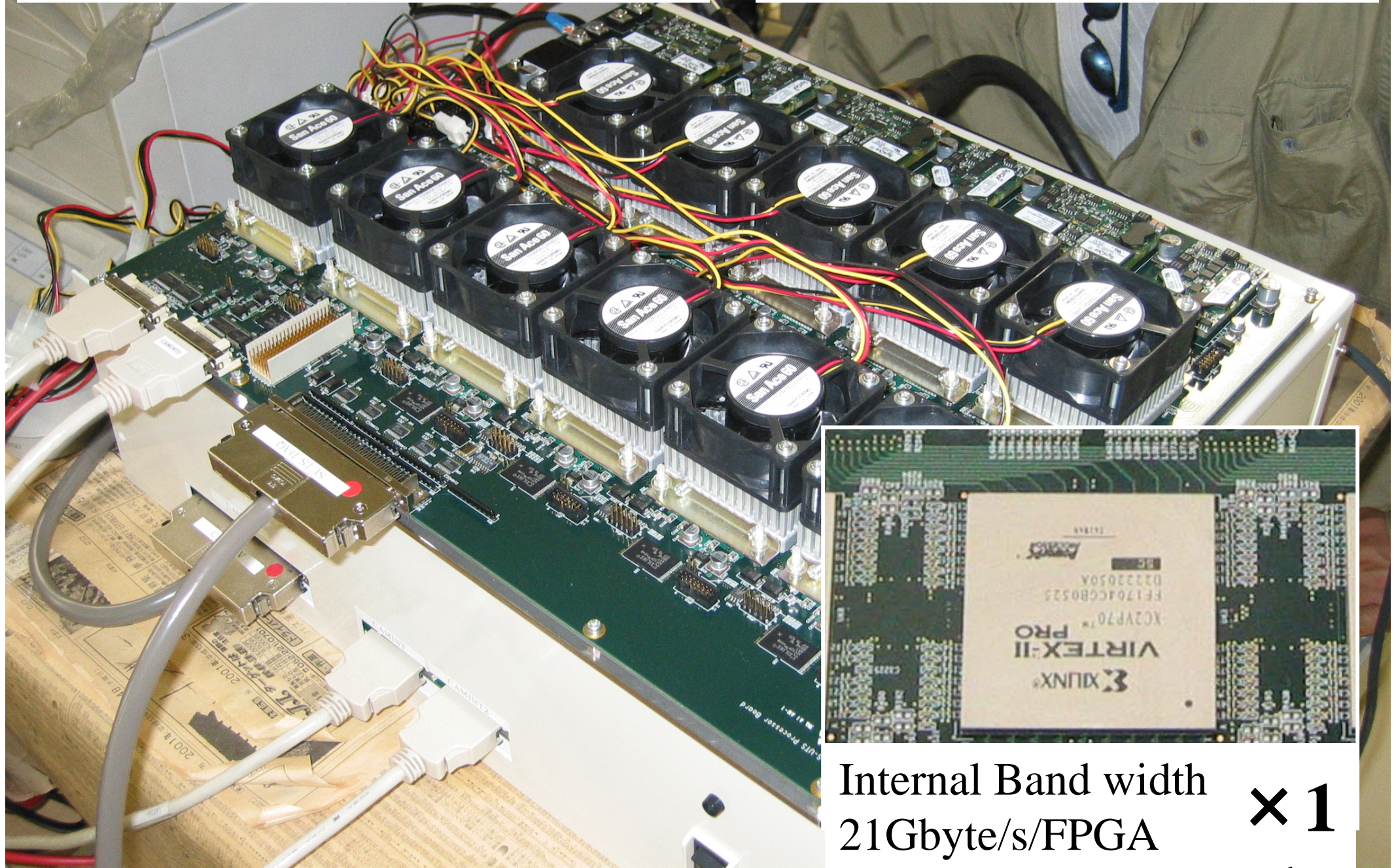


Scanning speed :
20cm²/h



SUTS Track recognition board

Processing speed :
Up to 40cm²/h/board



Internal Band width
21Gbyte/s/FPGA × 1

August run

- POT 7.6×10^{17} , Target :: 300 CS no Bricks
- About 300 on time events recorded by electric detector.
- 13 rock muon events are predicted into CS area.
- 1st Events have been located in EMULSION @Sep 2006

Several events have been found both Nagoya & LNGS.

TT prediction accuracy is about a few mm .

➔ No difficulty to locate on CC-like events in emulsion.

Back ground track density in CC is confirmed well less than 1.

Automatic selection of scanning data & Manual eye checks.

➔ Location for NC-like events .

Efficiency evaluation by these predictions is under going.

October run

- POT 0.6×10^{17} , Target :: 1000 Bricks with CS.
- Two weeks of beam exposure planned,
But stopped due to water leak at CNGS reflector.
Running time was about 24 hours and 30 events stored.

One Rock muon predicted event by TT to Brick .

Full chain of procedure have been examined.

- TT prediction (Brick tagging)
- Extraction of corresponding Brick
- Develop CS & Brick
- CS Scanning
- Track scanning into Brick

Brick & CS



CS are stuck on
Real Brick

And install into wall

Event number: 1064775

CSD ID: 3000370

Brick location: W29/RW9/COL12, rock side

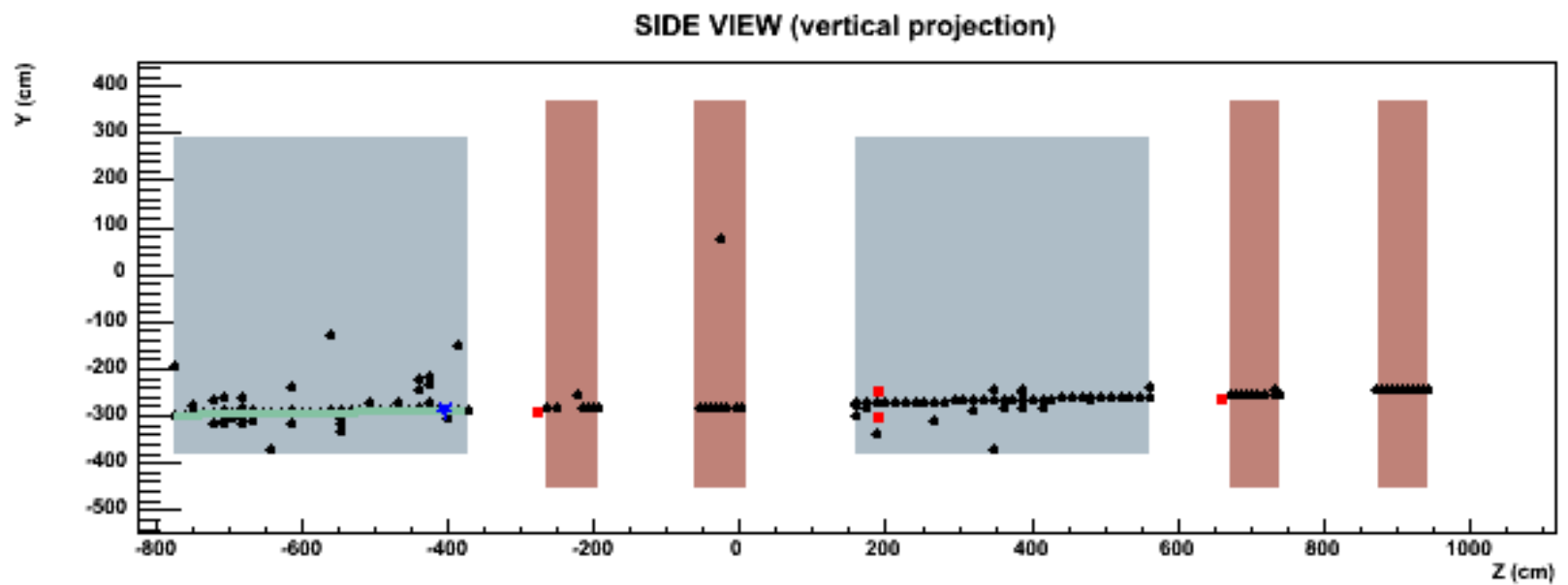
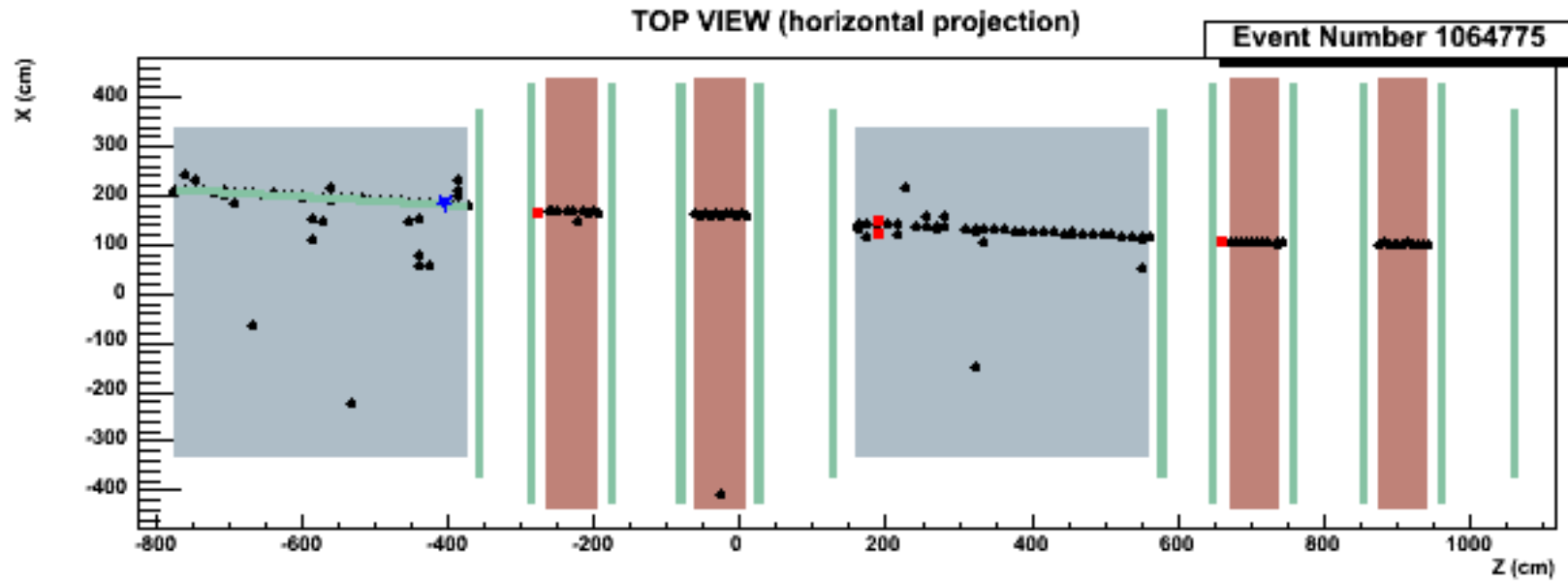
SX = -0.0839 ± 0.0013

SY = 0.0259 ± 0.0012

PX = 181.54 ± 0.27 cm

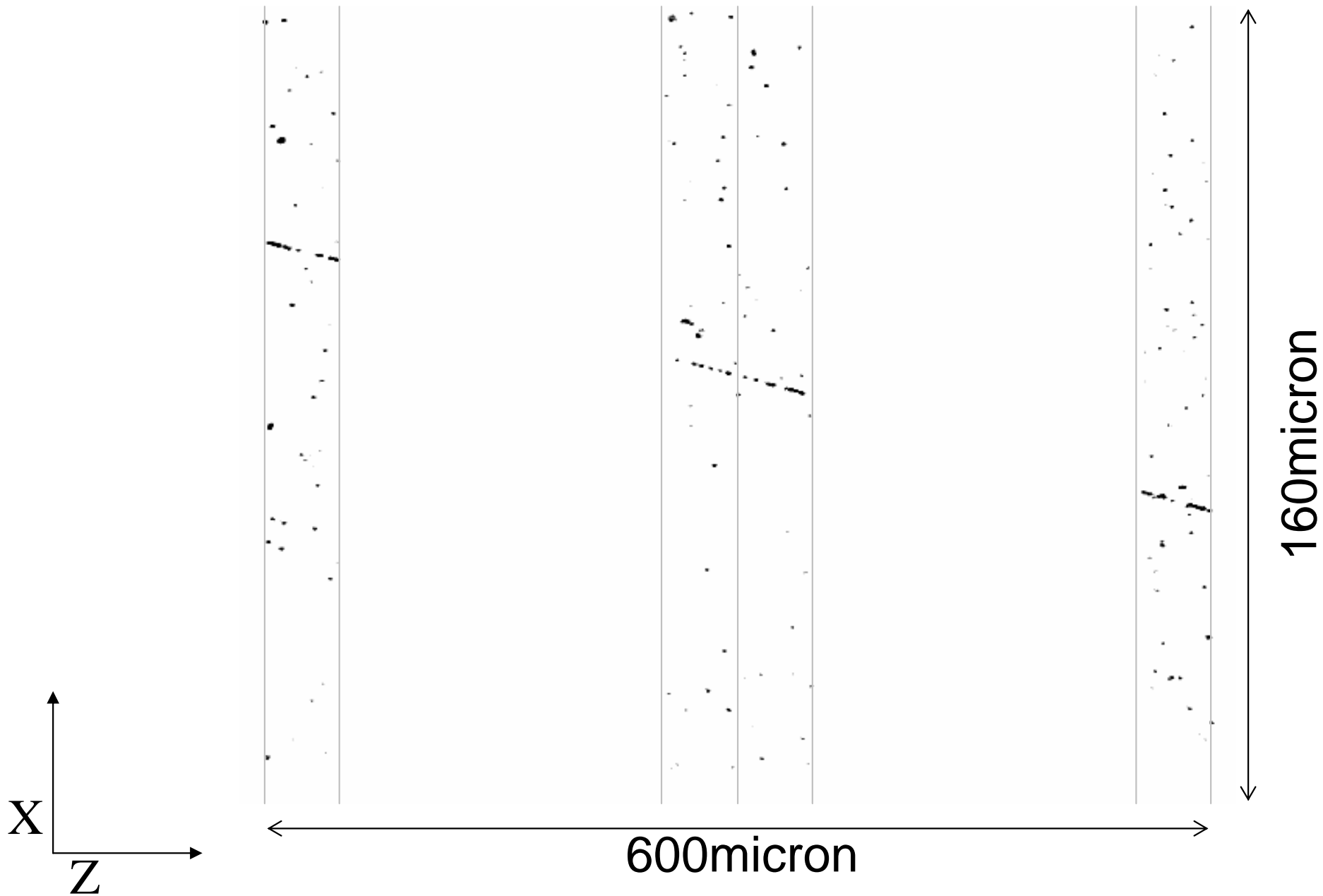
PY = -288.03 ± 0.25 cm

PZ = -401.82 cm

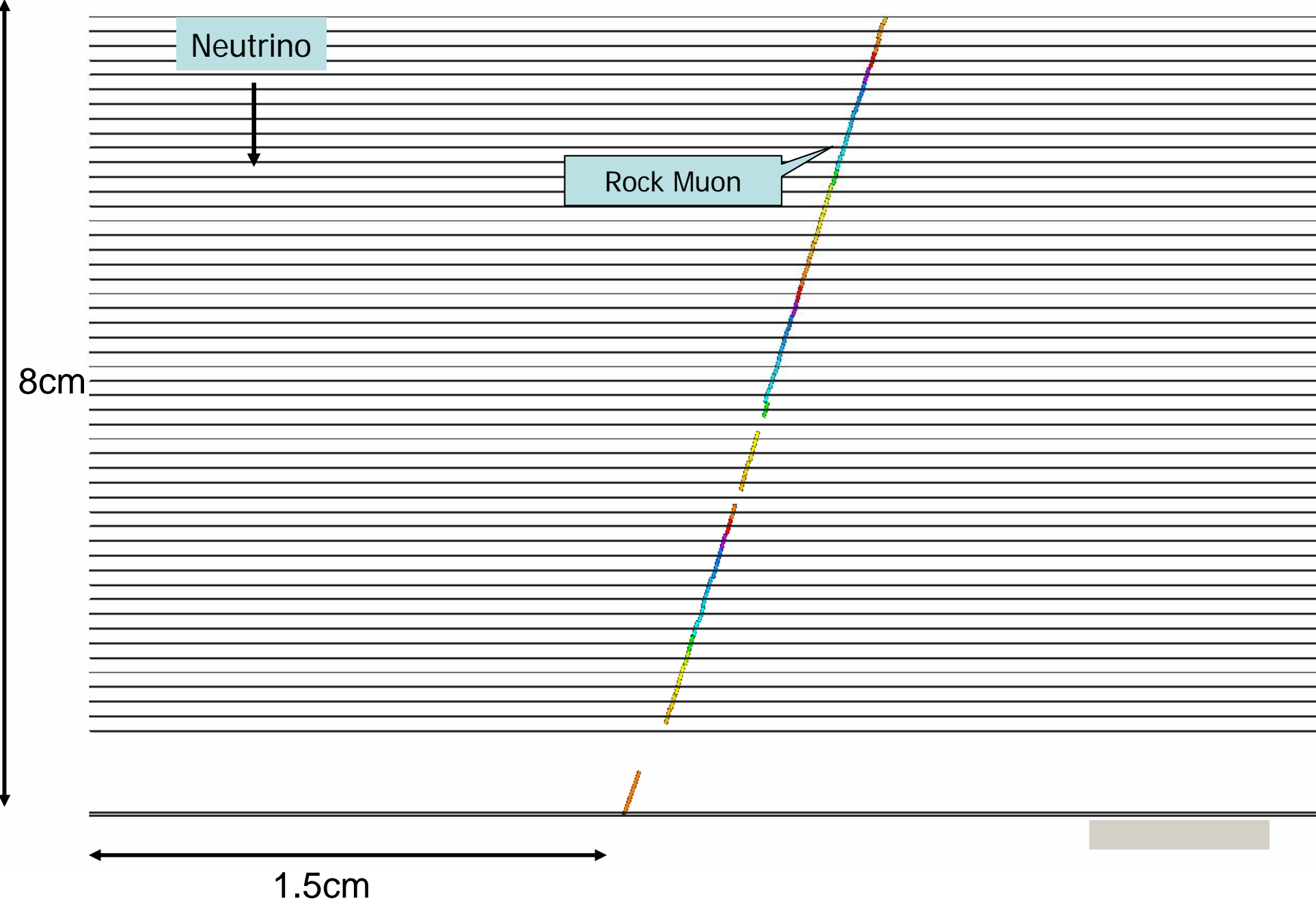


with Dario and Antoine

Found track in CSD



Connection from CSD to Brcik



Summary

- Event location by CNGS neutrino induced muons in 2006 runs done.

[1] Data taking (TT) performance well

[2] OPERA found tracks in REAL CS in August run.

[3] A full chain of REAL procedure for location was done using a rock muon event in October run.

- Brick installing started from End of Sep/2006.
About 1300 Bricks stored now.

- 2007 May REAL run will start
40,000 Bricks at the beginning of beam exposure 2007.
112,000 Bricks at the end of beam exposure 2007 .

800 to 1000 neutrino interaction will be analyzed.

Expected tau neutrino interaction# is $4.4 * 0.08 = 0.4$

Full (170,000 Bricks) installation planned till 2008 Mar.



Expected Event Yield

Target Mass :1700 ton

Full mixing, 5 years run @ 4.5×10^{19} pot / year

$\nu_{\mu} \nu_e$ Interaction

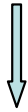
Clear ν_{τ} CC events

ν_{μ} CC	23500					
ν_{μ} NC	7075	Δm^2	1.9×10^{-3} eV ²	2.4×10^{-3} eV ²	3.0×10^{-3} eV ²	B.G.
$\bar{\nu}_{\mu}$ CC	494					
ν_e CC	188	Final Design	8.0	12.8	19.9	0.8
$\bar{\nu}_e$ CC	17					

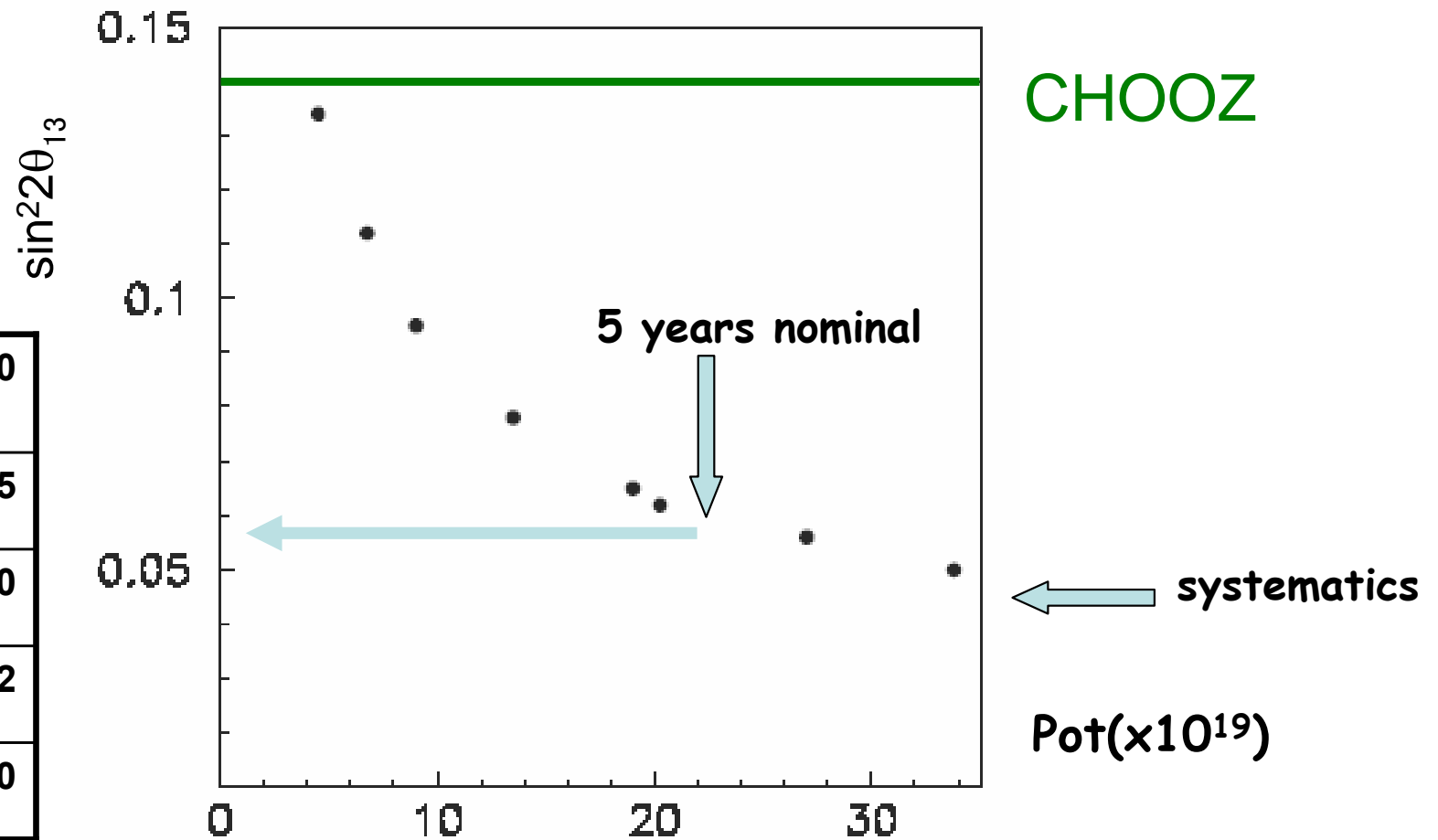
$\sin^2 2\theta_{13}$ sensitivity

Assuming : $\theta_{23}=\pi/4$, $\Delta m^2_{23} = 2.5 \times 10^{-3} \text{ eV}^2$

Nb of events
(5 years running)



Signal @ CHOOZ limit	13.0
$\tau \rightarrow e$	4.5
ν_{μ} CC	1.0
ν_{μ} NC	5.2
ν_e CC beam	18.0



The end