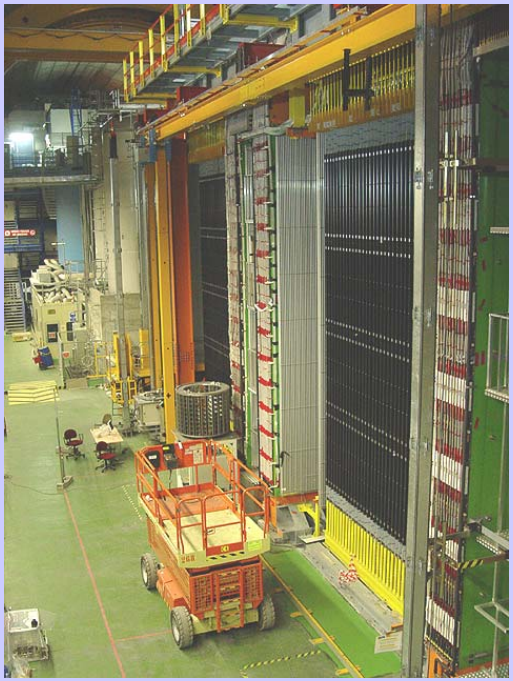


First results and status of the OPERA experiment

Focussed on the electronic detector, especially the presicion tracker (PT)

bmb+f - Förderschwerpunkt
OPERA
Großgeräte der physikalischen Grundlagenforschung

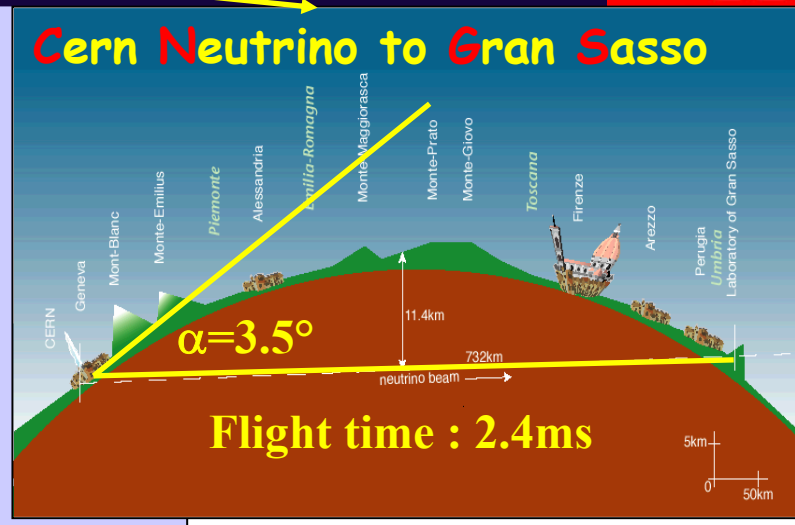
Overview

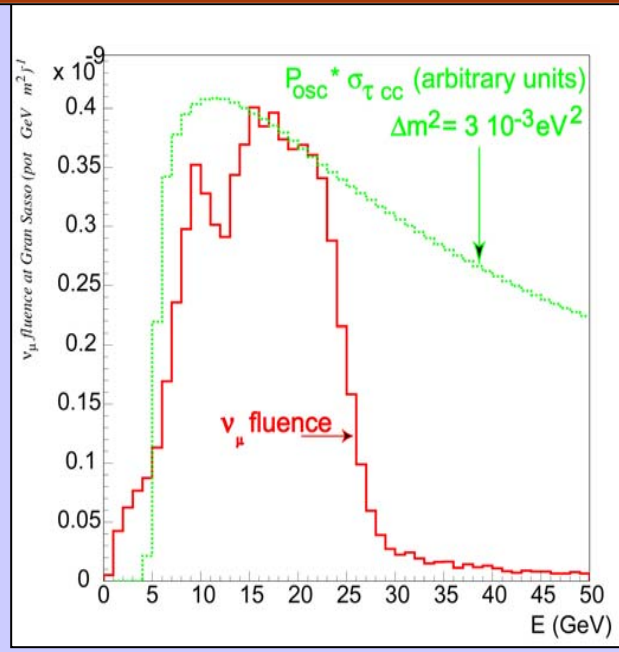
- Detector
- Runs August/Oktober 2006
- Future Runs
- Conclusion

The CNGS Beam

Beam main features:

L	732 km
<Eν>	17GeV
L/<Eν>	43km/GeV
$(\nu_e+\overline{\nu_e}) / \nu_\mu$	0.87%
$\overline{\nu_\mu} / \nu_\mu$	2.1%
ν_τ prompt	negligible





- **Event rate :**

(~1.7 Kton, $4.5 \cdot 10^{19}$ pot/year, 200 days/year)

- ~ 6200 events/year (CC+NC)
- ~ 30 events/day (CC+NC)
- ~ 25 ν_τ CC events/year for $\Delta m^2=2.4*10^{-3}eV^2$

Detector Concept

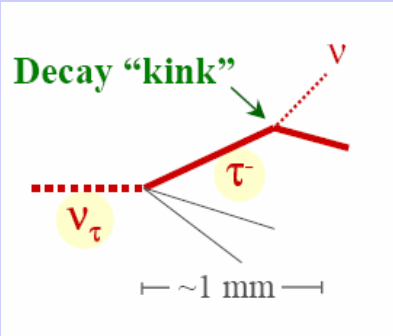
ν_μ ..... $\nu_\tau \rightarrow \tau^- + X$

oscillation

CC interaction

$\mu^- \nu_\tau \bar{\nu}_\mu$	BR 17.7 %
$h^- \nu_\tau$ neutrals	48.6 %
$e^- \nu_\tau \bar{\nu}_e$	17.8 %
$h^+h^-h^- \nu_\tau$ neutrals	15.2 %

OPERA: observation of the τ decay topology



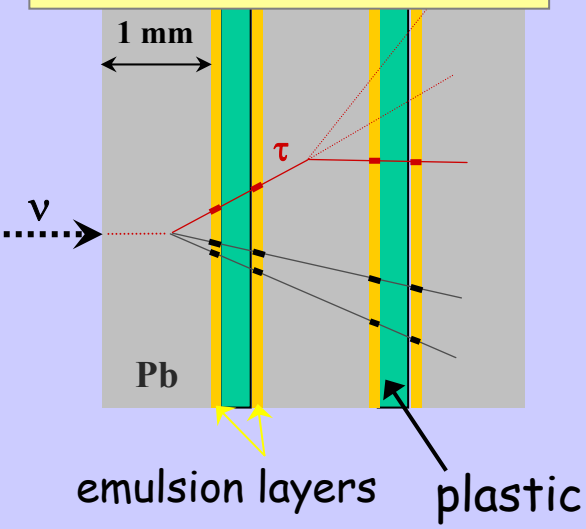
- high spatial resolution (micrometric scale)

- nuclear photographic emulsion
- lead target

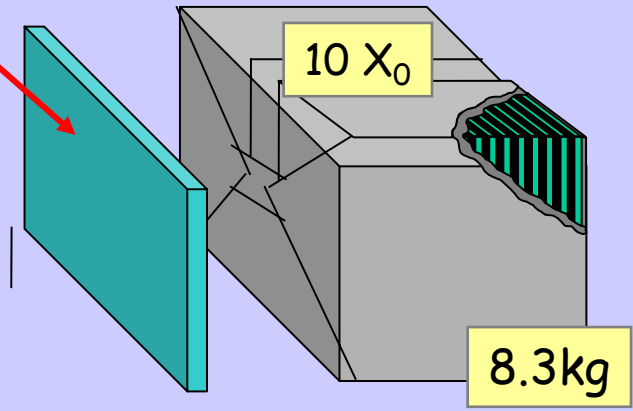
} combined to ECC (emulsion cloud chamber)

The Detector

basic unit: brick



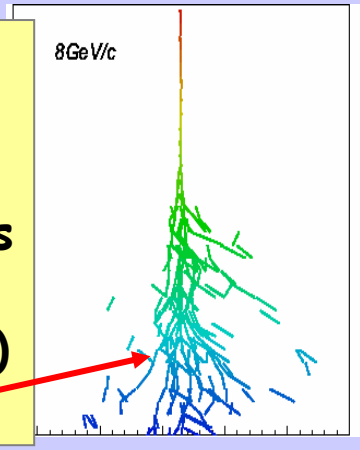
- Based on the concept of the Emulsion Cloud Chamber (ECC)
- Sandwich of 56 Pb sheets 1mm + emulsion layers
- large mass for neutrino interactions
- high spatial resolution ($\delta x \approx 1\mu m$, $\delta\theta \approx 1$mrad)
- changeable sheets(CS) with emulsion doublett in front for first checks



10.2 x 12.7 x 7.5 cm^3

ECC = stand-alone detector:

- neutrino interaction vertex
- kink topology reconstruction
- momentum measurements for hadrons (multiple scattering)
- π/μ separation at low energy (dE/dx)
- energy measurements for e,γ

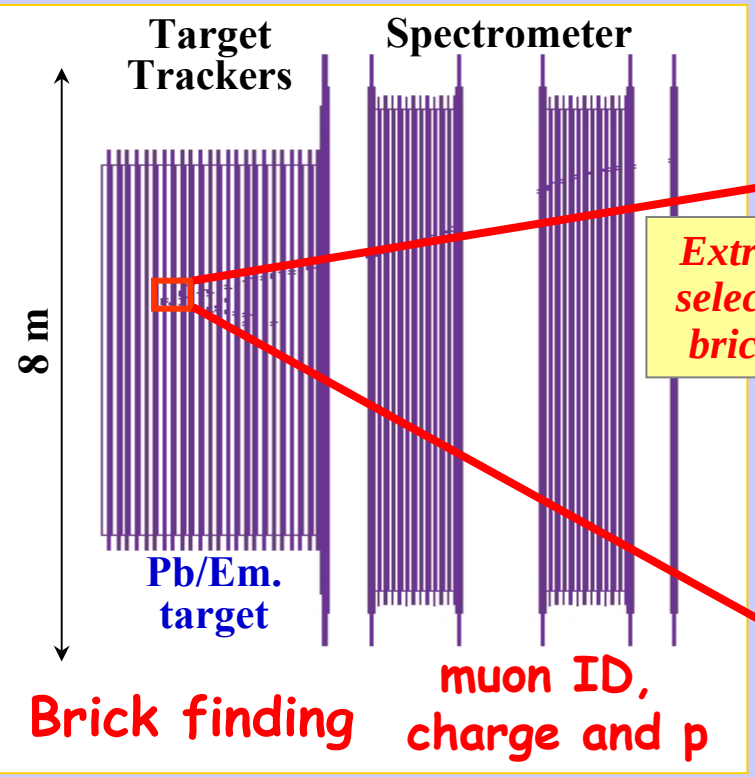


Detector Concept

ECC cannot do:
- trigger for neutrino interaction
- μ identification and momentum + charge measurement

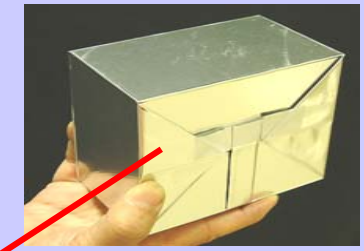
→ Hybrid detector

Electronic detectors:

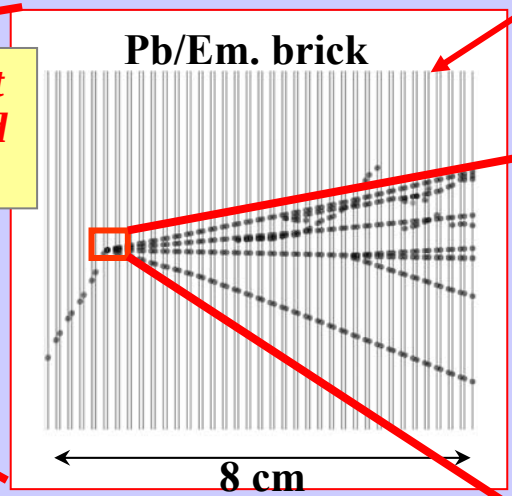


Emulsion analysis:

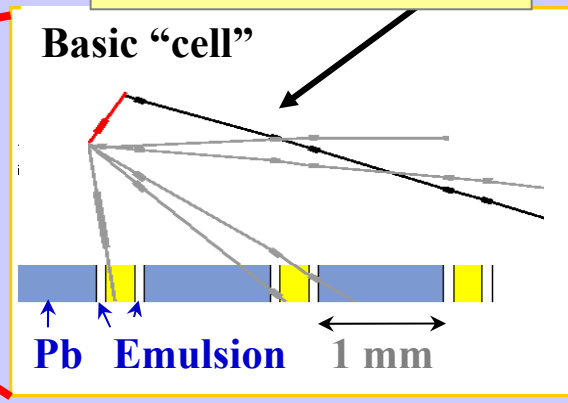
Vertex, decay kink e/γ ID, mult. scat., kinematics



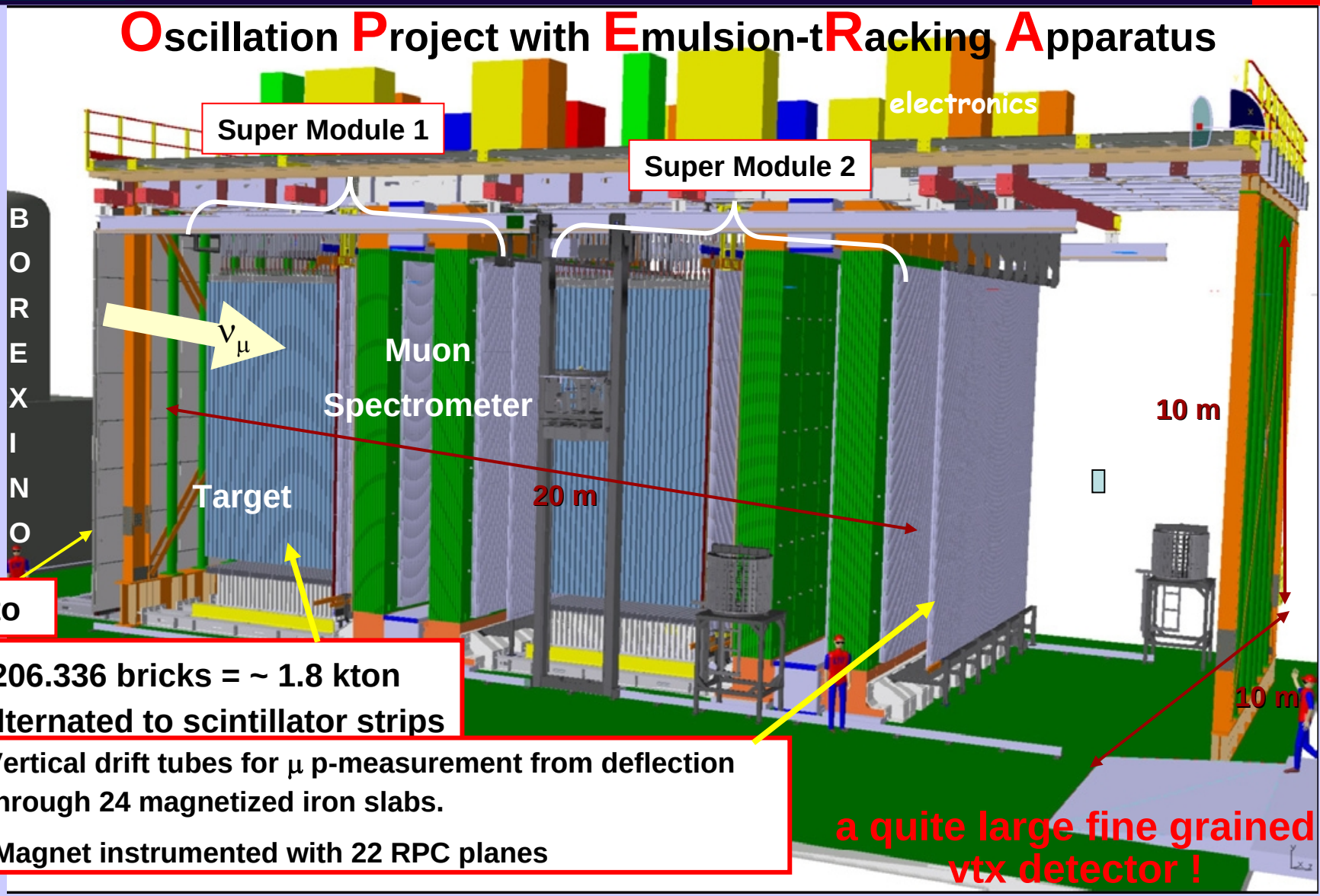
Extract selected brick



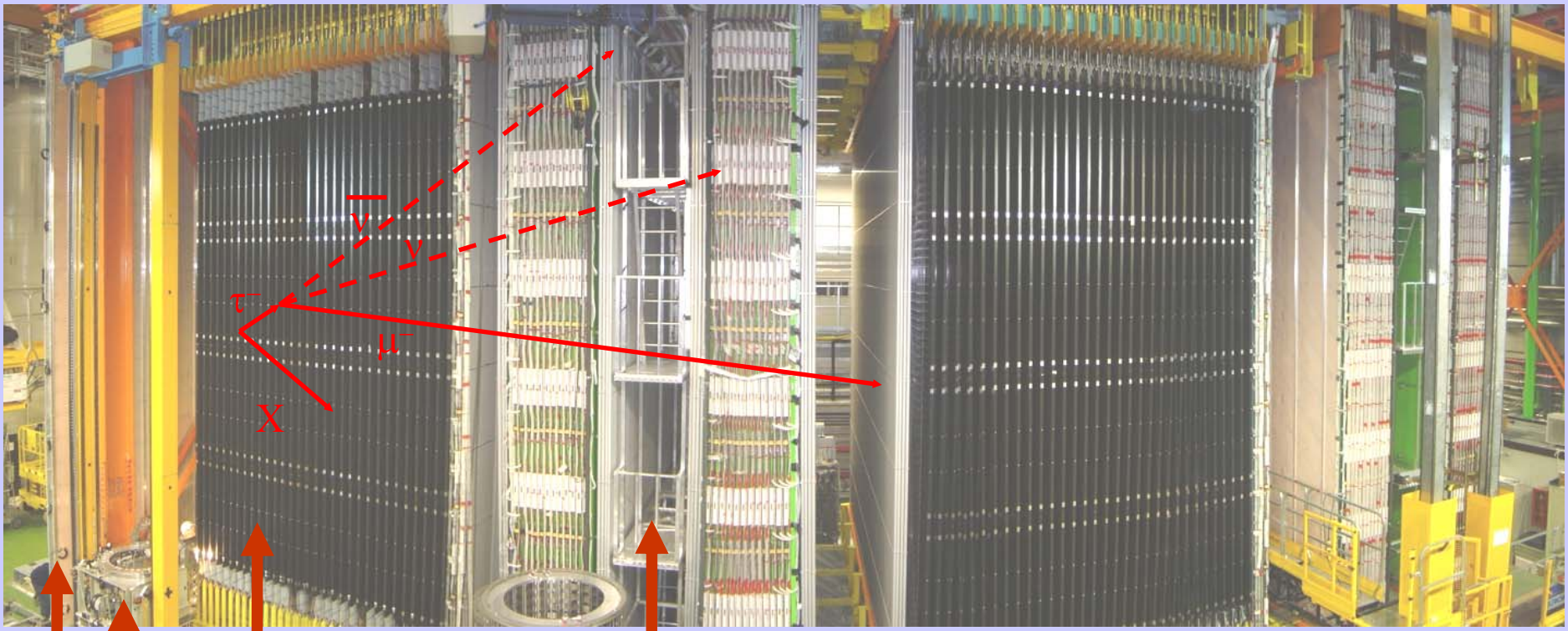
Link to mu ID, Candidate event



The OPERA detector



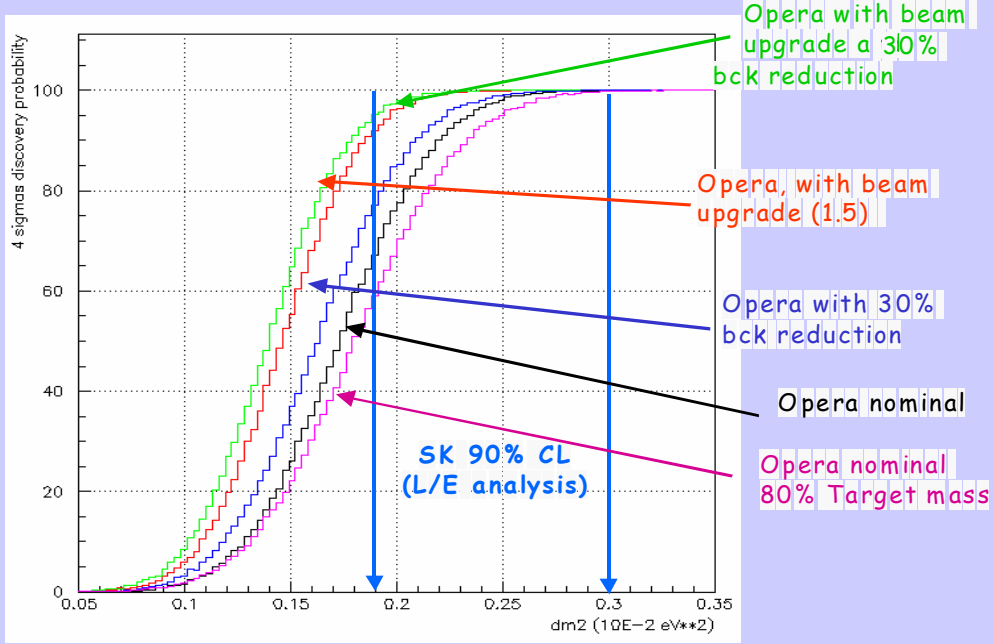
The OPERA detector



All installed and running except:
- VETO commissioning in March 07
- HPT/SM2 : first half of 2007
- brick filling is in progress

Physics potential

τ decay channel	Signal		Background
	2.4 ·10^{-3} eV^2	3.0 ·10^{-3} eV^2	
τ → μ	3.6	5.6	0.23
τ → e	4.3	6.7	0.23
τ → h	3.8	5.9	0.32
τ → 3h	1.1	1.7	0.22
ALL	12.8	19.9	1.0



Main background sources:

- charm production and decays
- hadron re-interactions in lead
- large-angle muon scattering in lead

full mixing, 5 years run @ 4.5x10^{19} p.o.t. / year

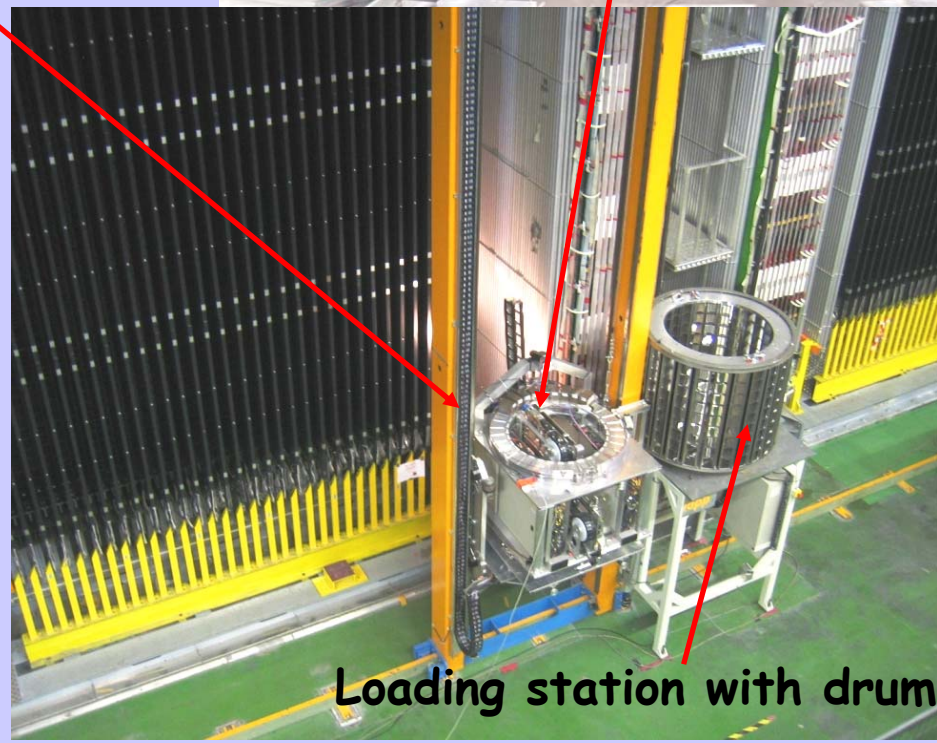
Brick Assembly Maschine (BAM)

Robotized parallel stations for automatic stacking and packaging of ~200.000 bricks

(dark room) operations start in the underground labs at LNGS (Hall B) in 2006

Brick Manipulation System (BMS)

- Robotic system
  - fill detector
  - extract candidate bricks
- 1 systems on each detector side
- Drums with 246 bricks delivered from BAM
- Identifies brick by barcode
- Positions saved in database



Brick filling started !

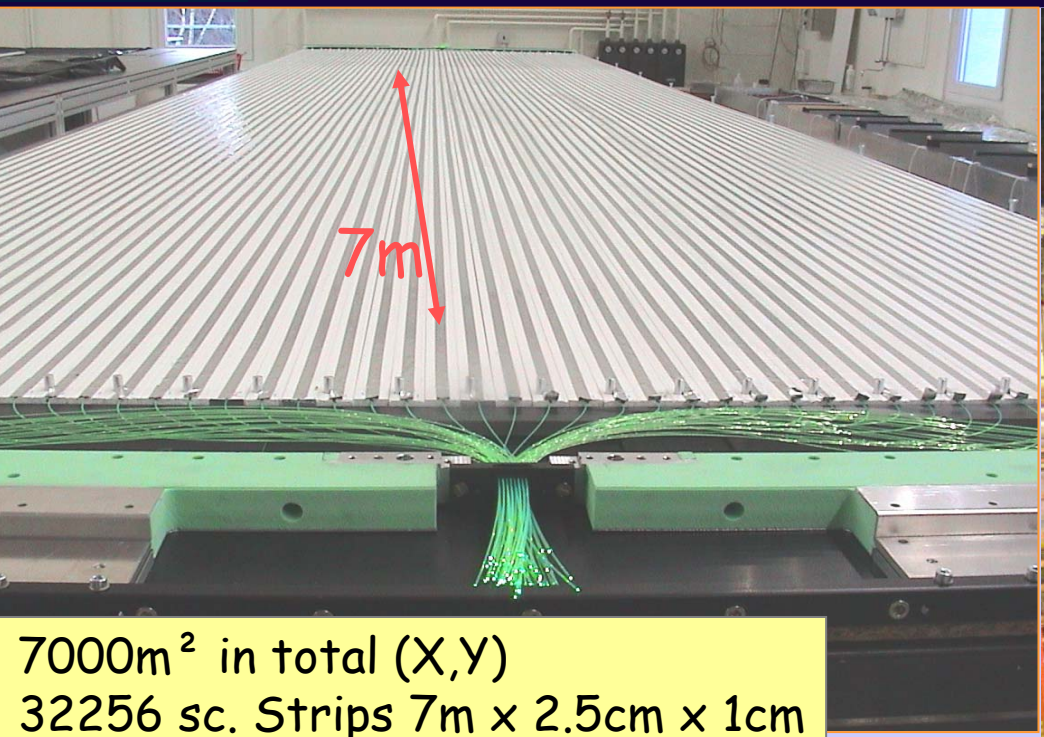
~ 2000 bricks already in the detector

schedule:

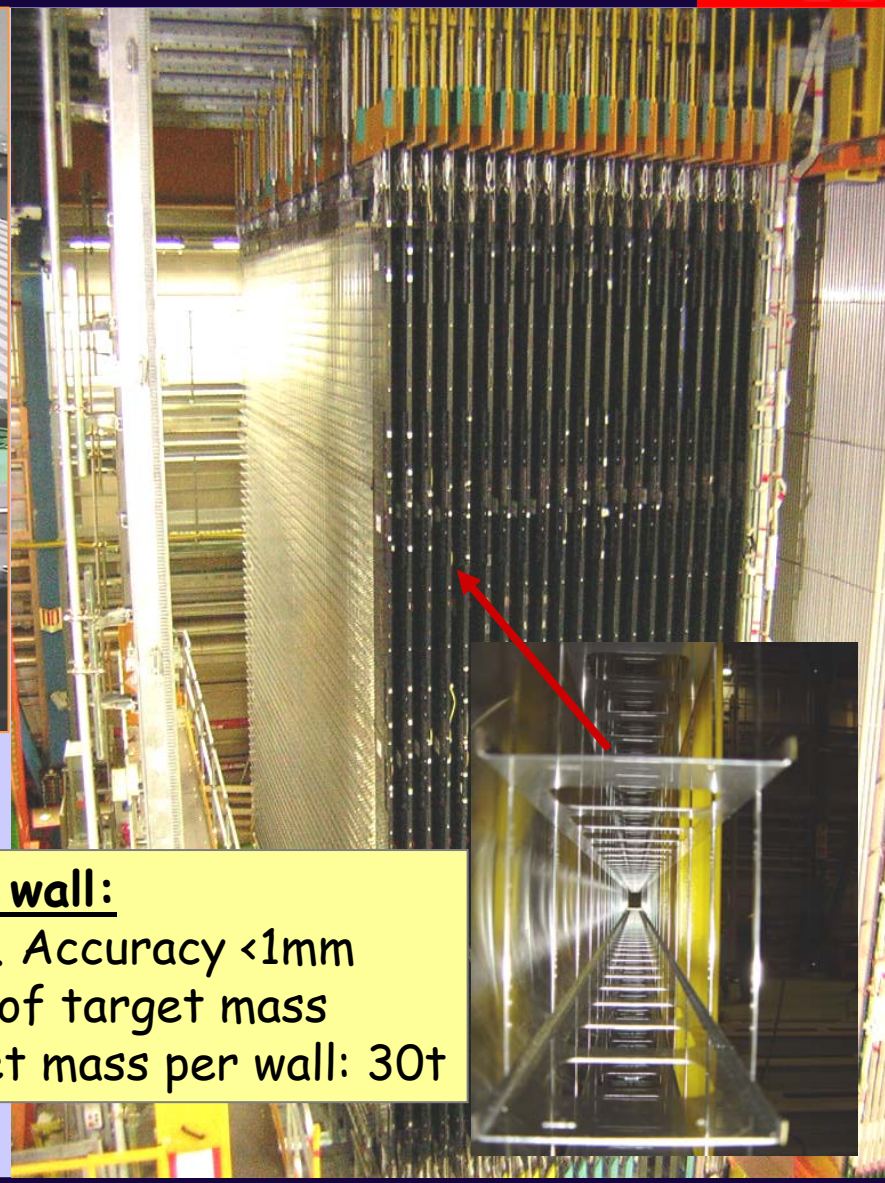
week 05-09: 05 drums/week
week 10-13: 10 drums/week
week 14 : 15 drums/week

Expected completion:
end of march 2008

Target Tracker



7000m² in total (X,Y)
32256 sc. Strips 7m x 2.5cm x 1cm
496 modules (4X+4Y per plane)
1000 MaPMT (Hamamatsu 64ch.)



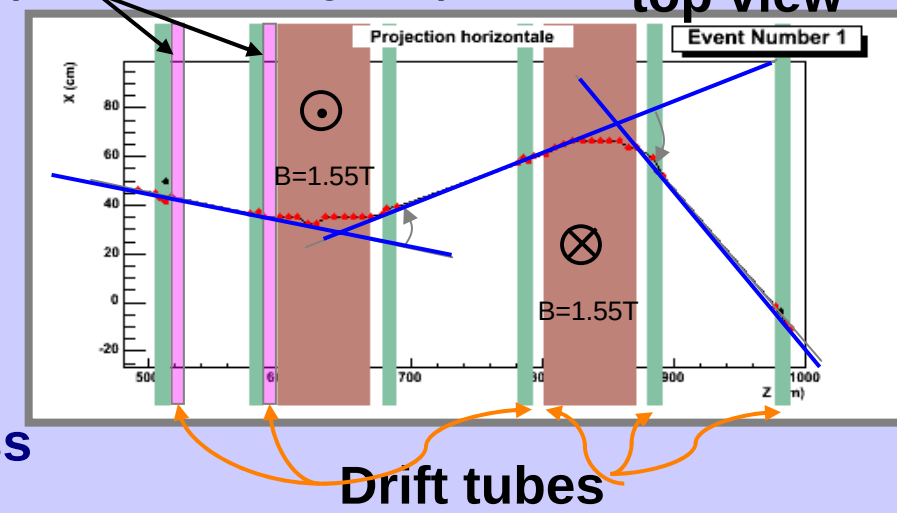
Brick wall:
Mech. Accuracy <1mm
0.6% of target mass
Target mass per wall: 30t

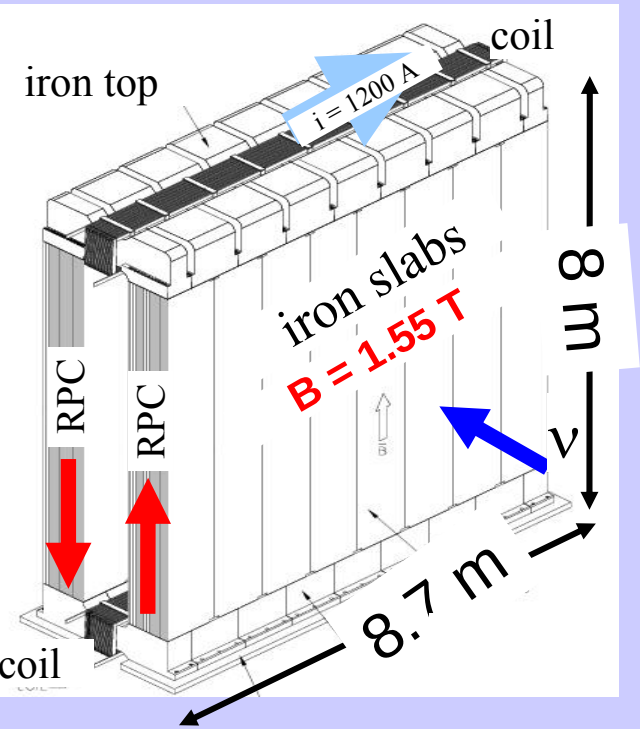
Spectrometer

- μ id together with TT
- μ momentum resolution with PT
- Δp/p = 25% (p < 25 GeV/c)
- μ charge misid ≈0.1 – 0.3%
- shower energy

RPC with inclined strips
(to solve PR ambiguities)

top view



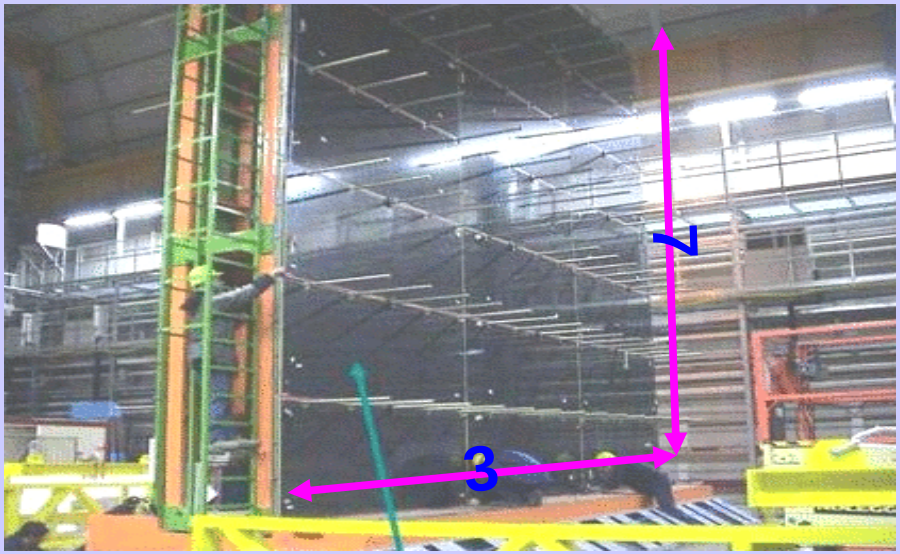


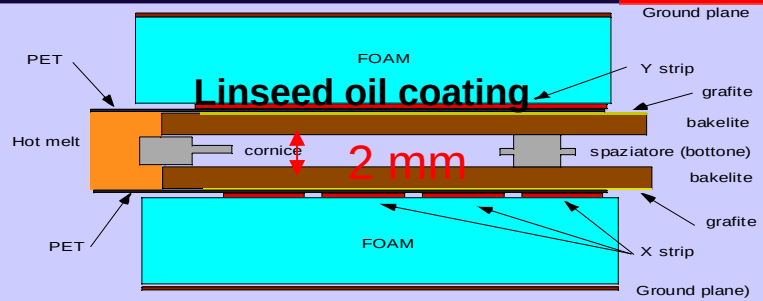
Total iron mass
1.3 Kton

- Dipolar magnet (B=1.55 T)
- 24 iron slabs, 5 cm thick + 2 cm gap
- Gaps instrumented with RPCs with horizontal and vertical strips with digital readout (inner trackers)
- 6 vertical Drift Tubes stations with 0.3 mm resolution (precision trackers)

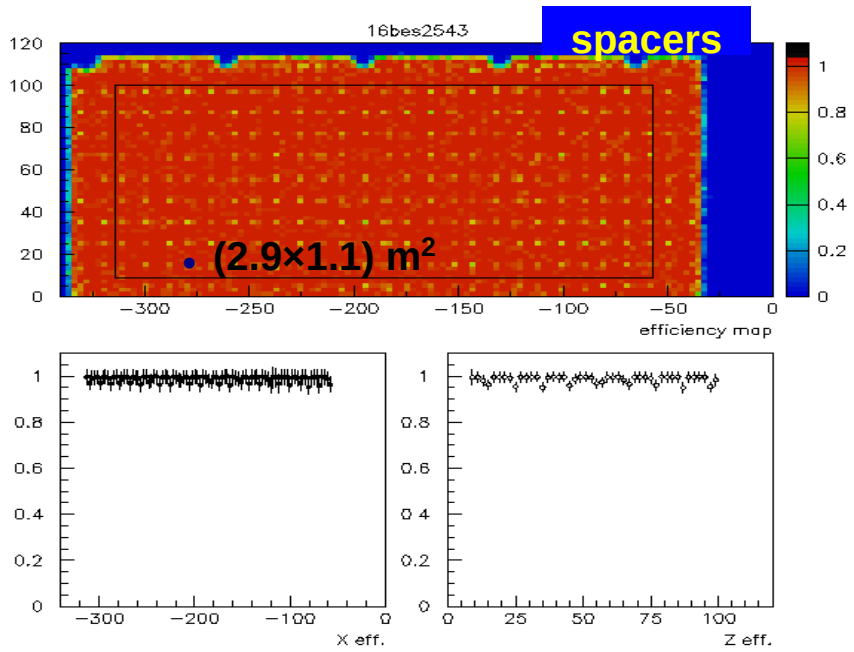
Inner Tracker (RPC/XPC)

Resistive plate chambers(RPC)





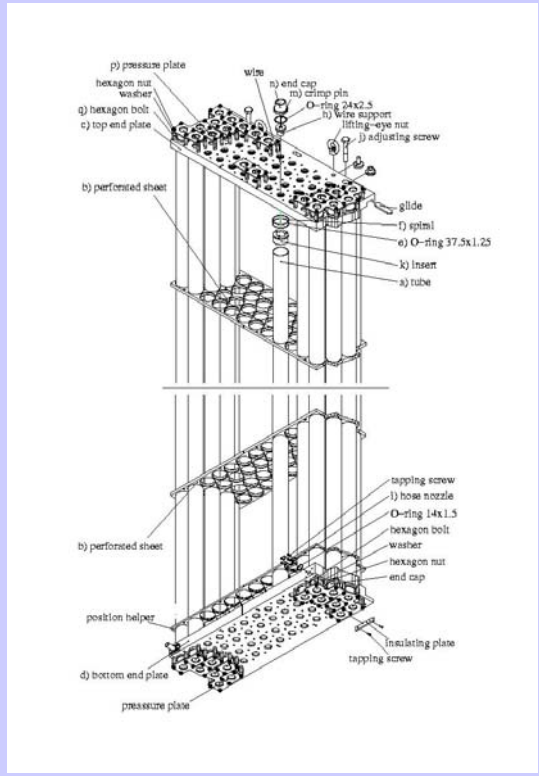
cosmic ray efficiency map for 1 chamber (at surface!)



- 462 (bakelite RPC) + 42 (XPC) x 2 ~ 1000
- tot. surface: 3326 m^2
- digital channels: ~ 27000
- strip pitches: 2.6, 3.5 cm (Vert, Hor)
- Front-End Boards: 468
- Controller Boards: 52
- Gas: 76%Ar+20%TFE+4%Iso+0.6%SF_6
- 8 kV/2mm

Precision Tracker (PT)

- Momentum measurement dp/p ~25%
- determine charge of muon
- ~10000 drifttube
- 8m long without wire support
- 80% Argon + 20% CO_2
- In 6 planes per SM with 4 layers each
- Single tube spatial resolution 350μm

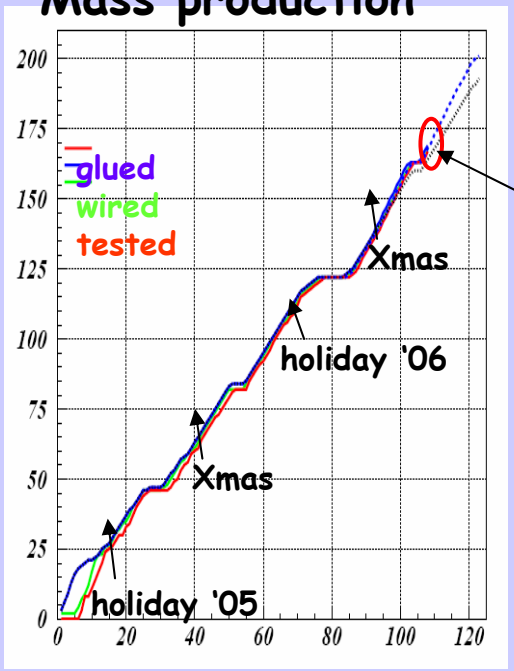


For details on gassystem and slow control see other talks in this session by Torben Ferber and Christoph Göllnitz

bmb+f - Förderschwerpunkt
OPERA
Großgeräte der physikalischen Grundlagenforschung

Status PT

Mass production

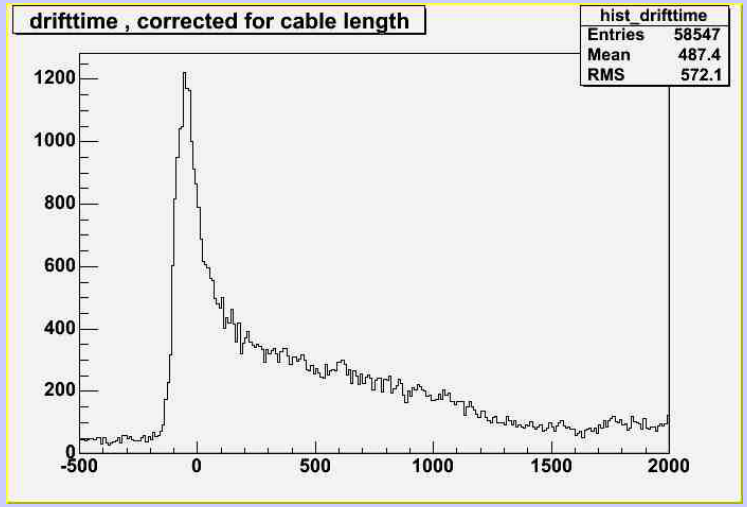


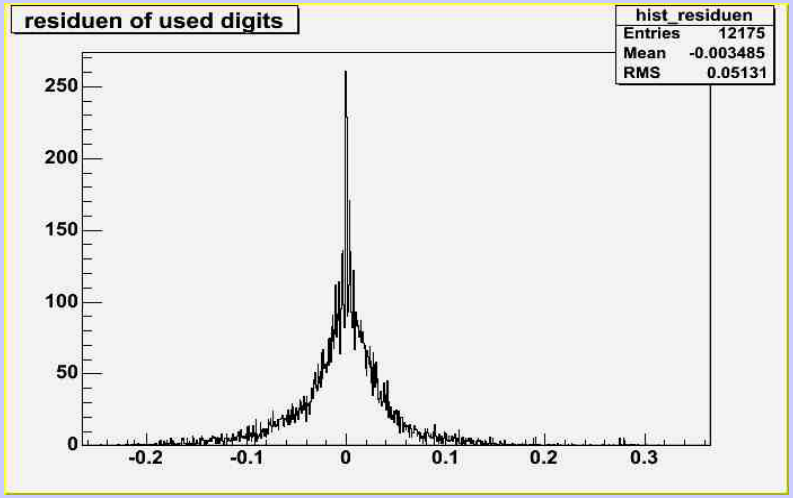
- 200 modules needed
- 180 ready by now
- SM1 ready and commisioned
- One third of SM2 installed
- Production finishes in may
- Completion of SM2 by the end of may

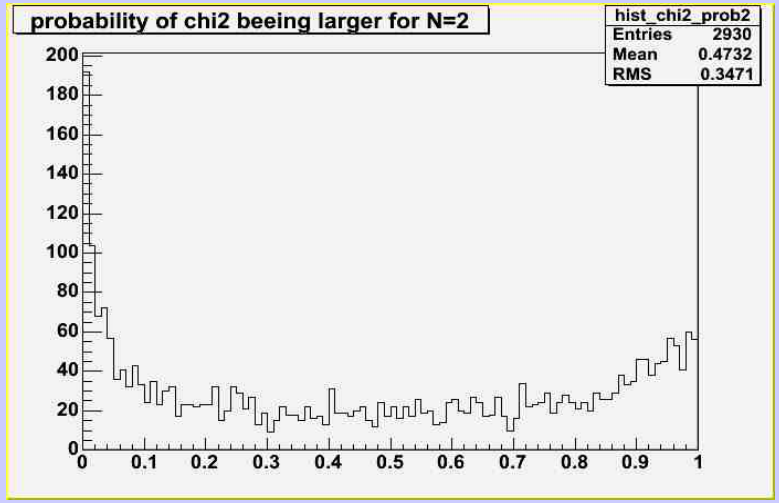
Mass production Hamburg done by technicians from ITEP(coordination Yuri Zaitsev)

PT performance

- More than 99% of the tubes in SM1 are working
  - 0.45% noisy
  - 0.28% dead
- Reconstruction running stable for MC and real data
- Single plane resolution ~ 500μm

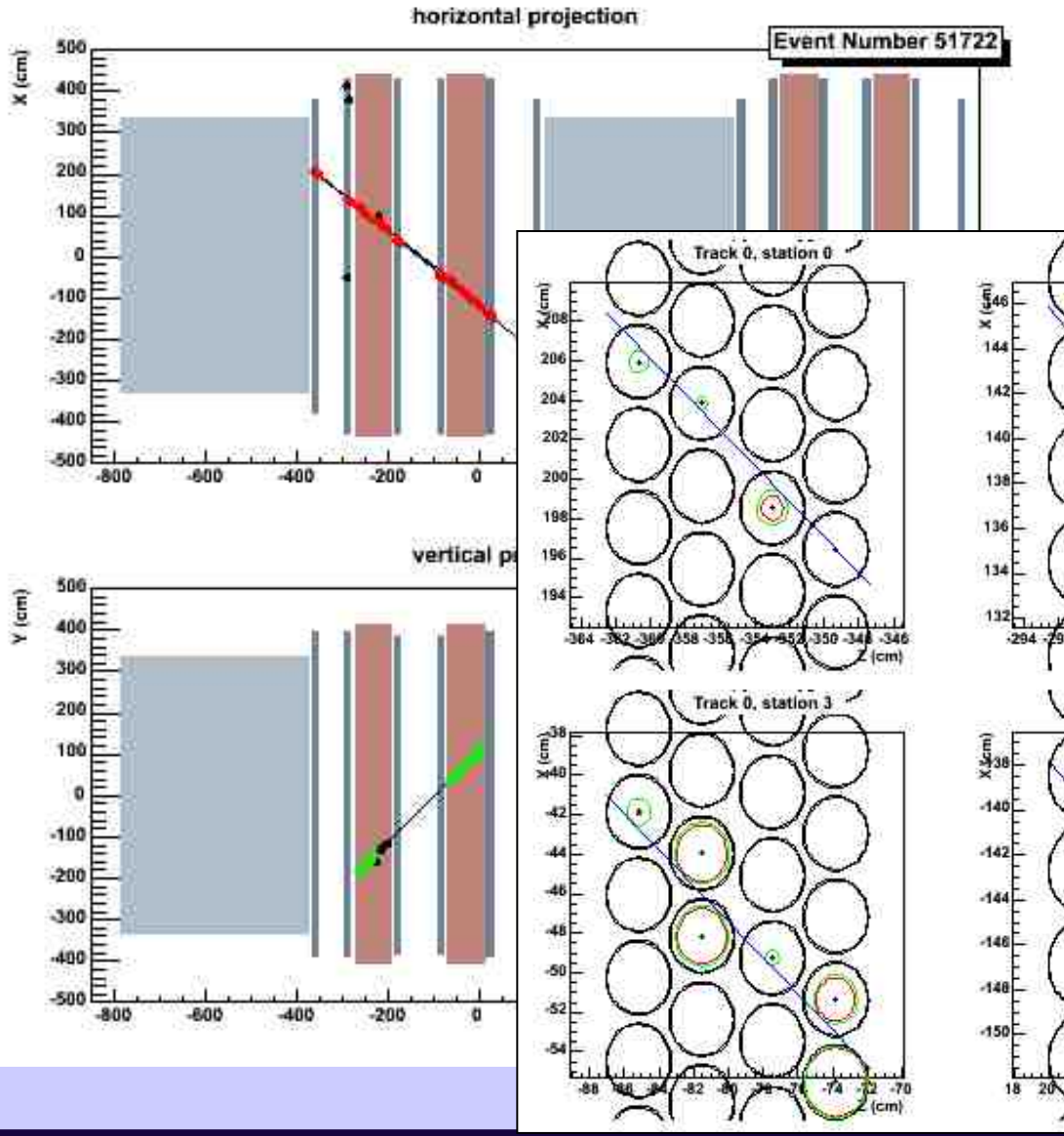






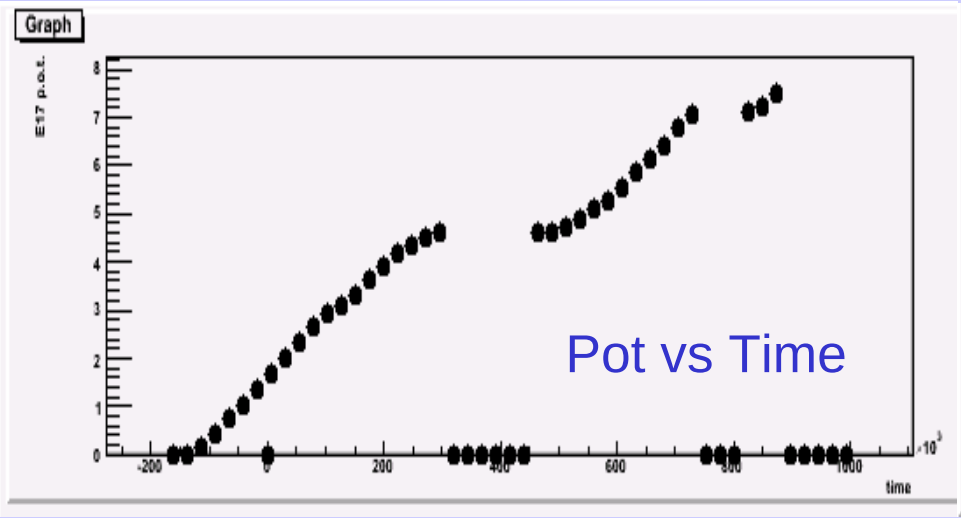
preliminary

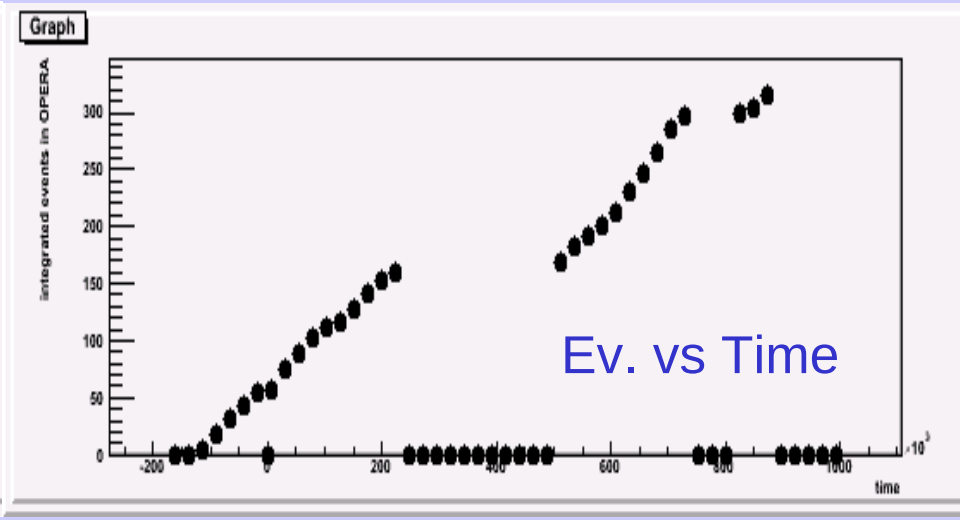
Event in HPT


horizontal projection
Event Number 51722
X (cm)
vertical p
Y (cm)
Track 0, station 0
Track 0, station 1
Track 0, station 2
Track 0, station 3
Track 0, station 4
Track 0, station 5
Z (cm)

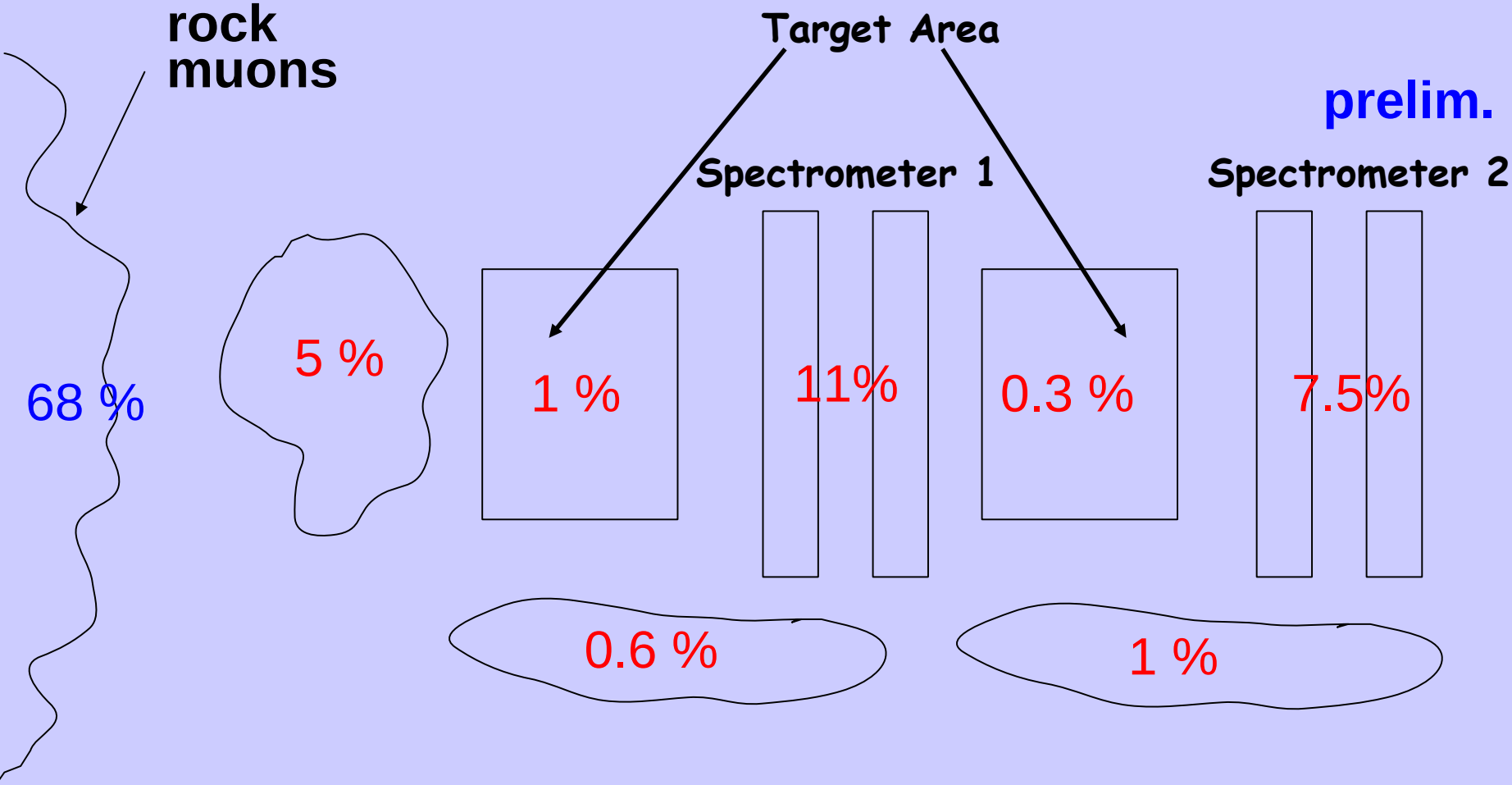
Summary of August Data

- In august run CNGS deliver $7.6 \cdot 10^{17}$ pot
- beam verified and electronic detectors comissioned
- The life time of the DAQ + detectors > 95%.
- 319 events in time with the beam (trigger + >20 hit):
- On average $(42 \pm 2) \cdot 10^{-17}$ ev/pot
  - These number are not corrected for GPS and DAQ failures which affect the first half of the run.
- only dummy bricks in detector



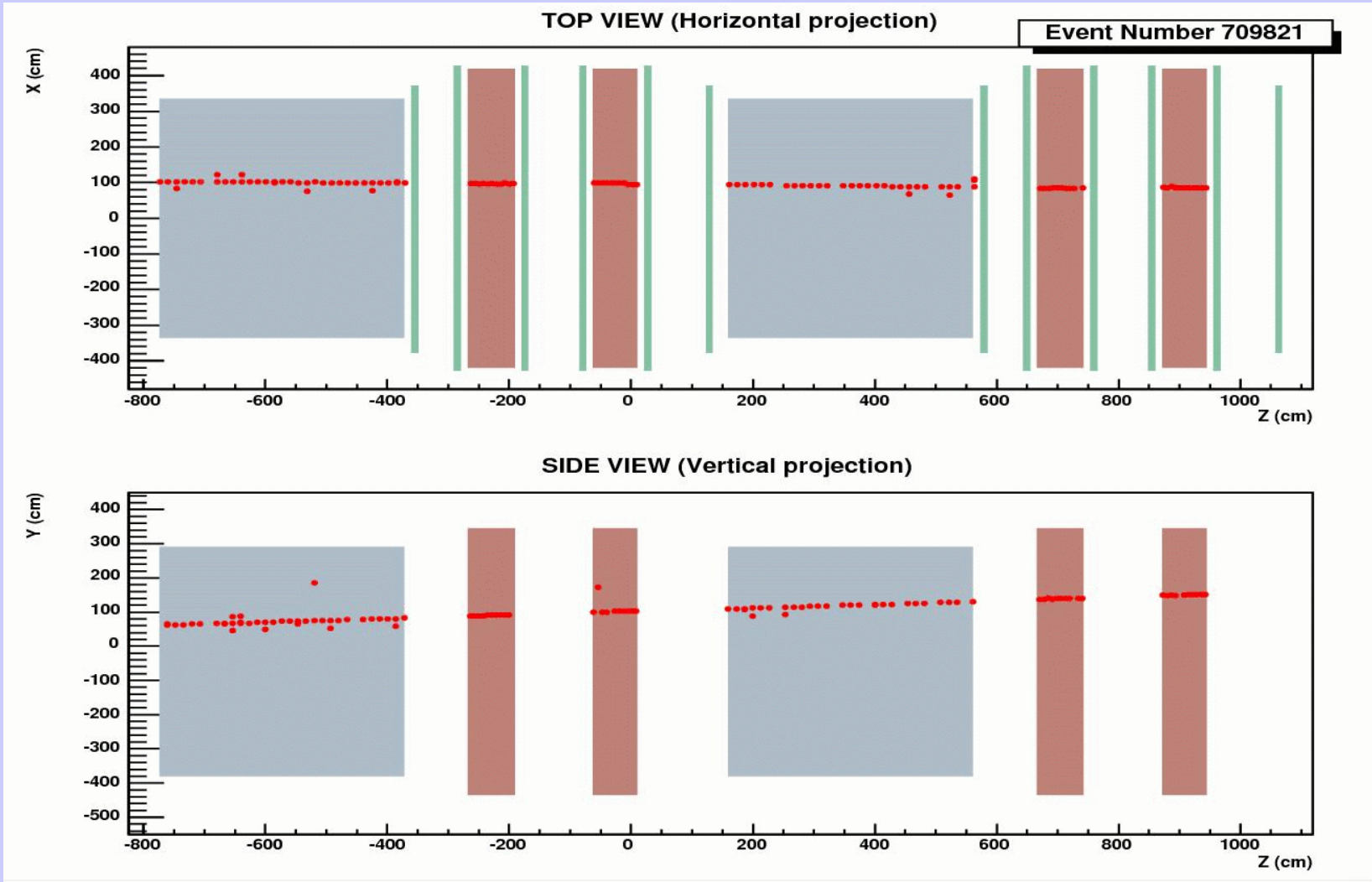


Origin of beam events

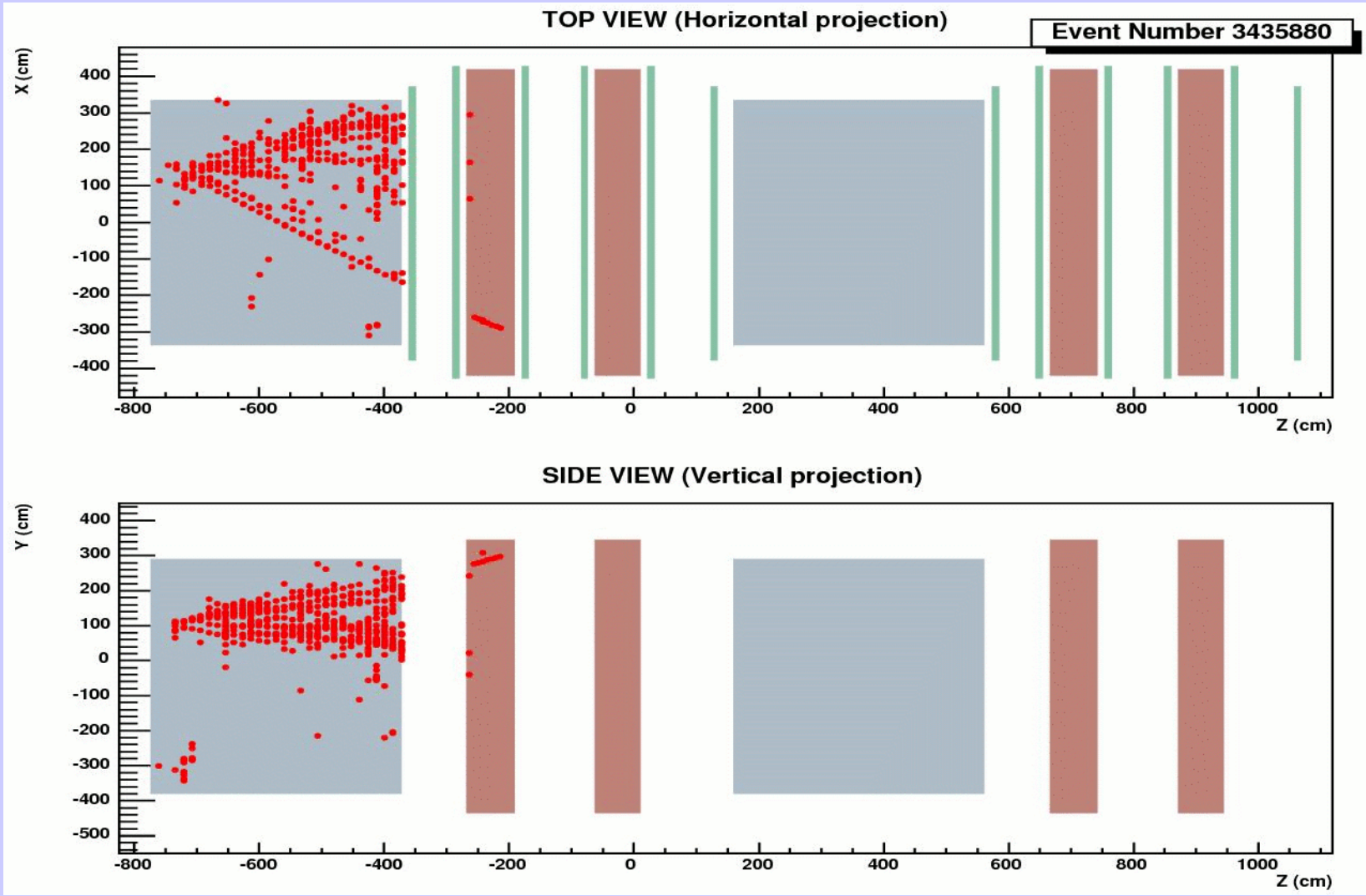


uncertain : 8.5 %

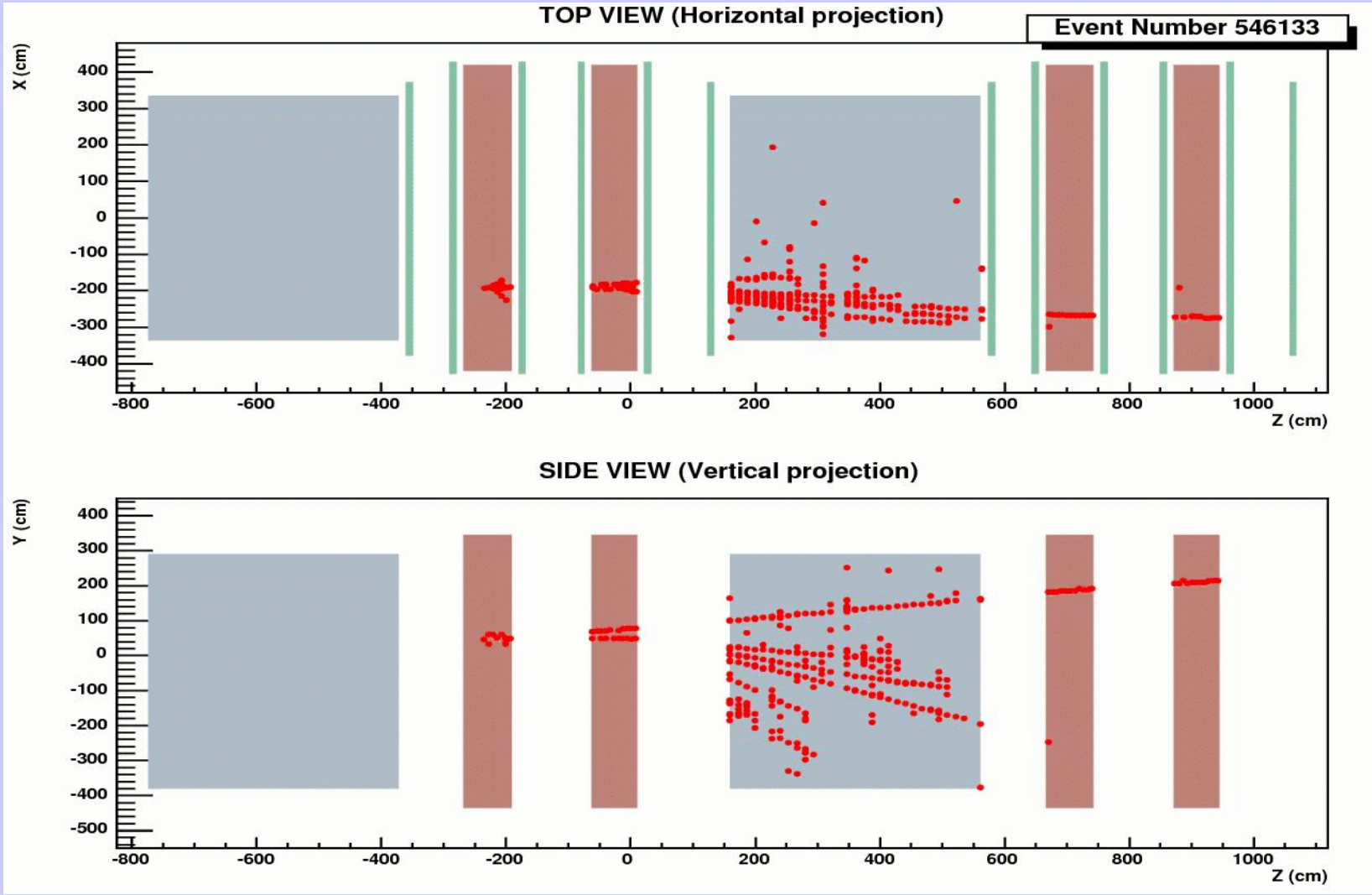
ν_{CC} in rock (rock muon)



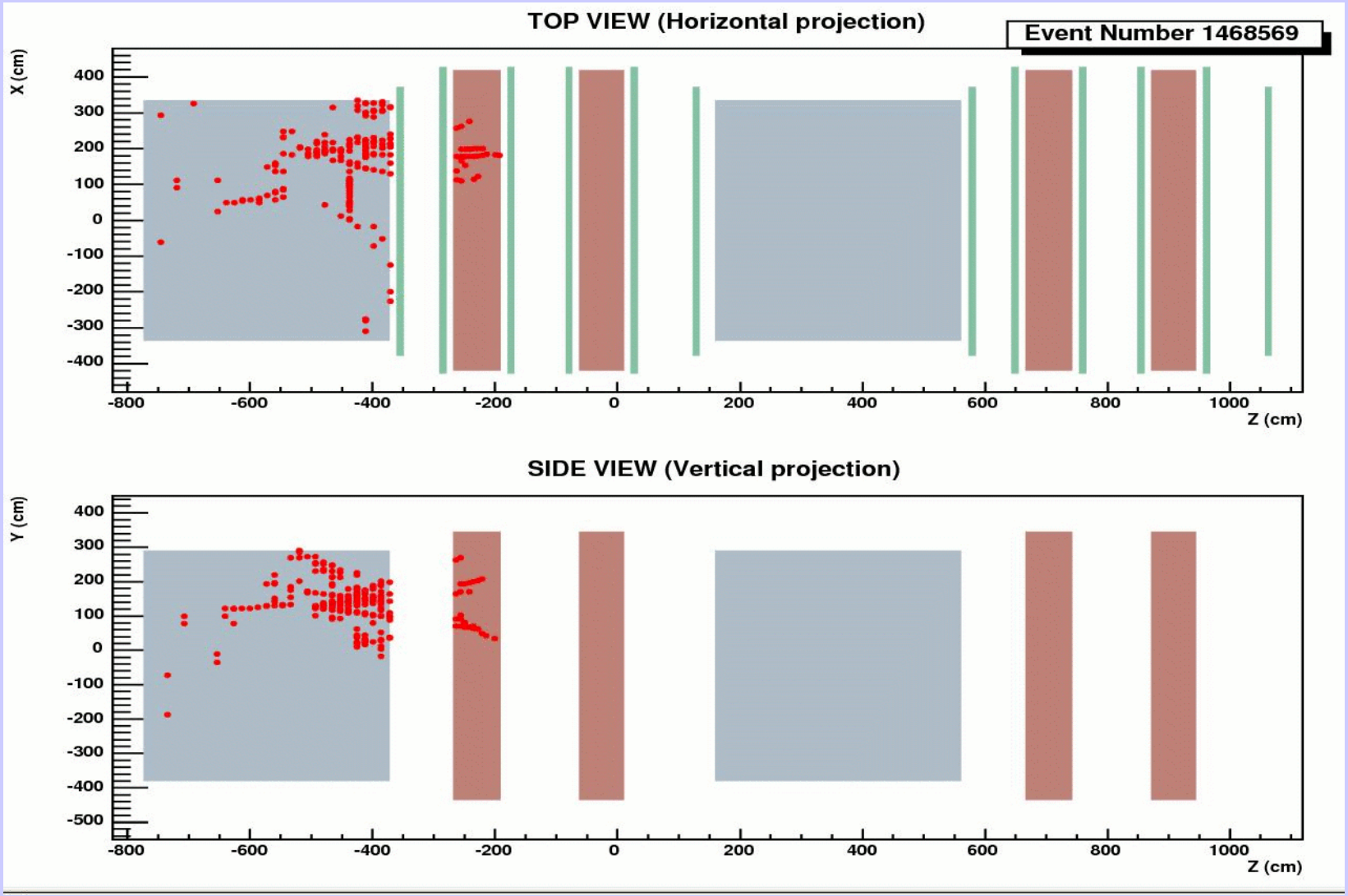
ν_{CC} in Target Tracker



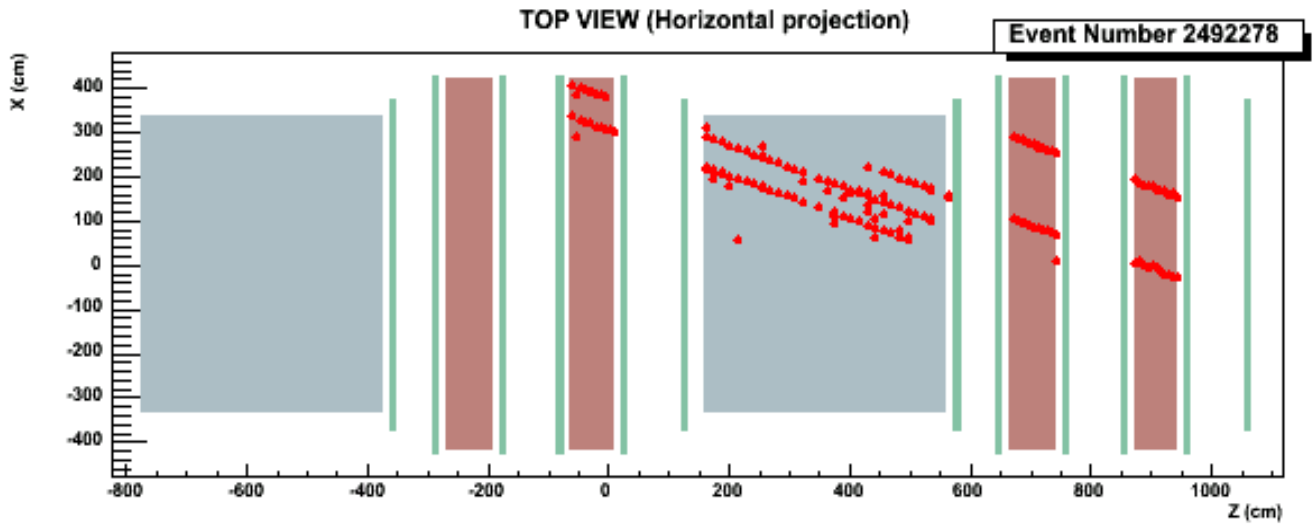
ν_{CC} in Magnet



ν_{NC} Canditate in Target

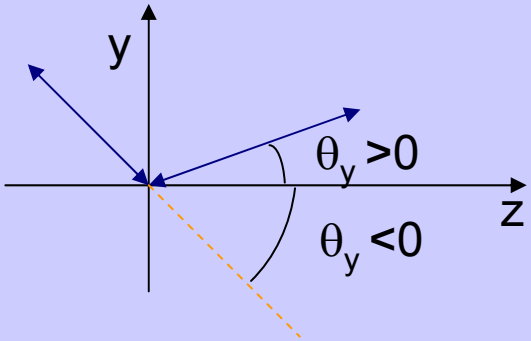


μ bundle (cosmics)

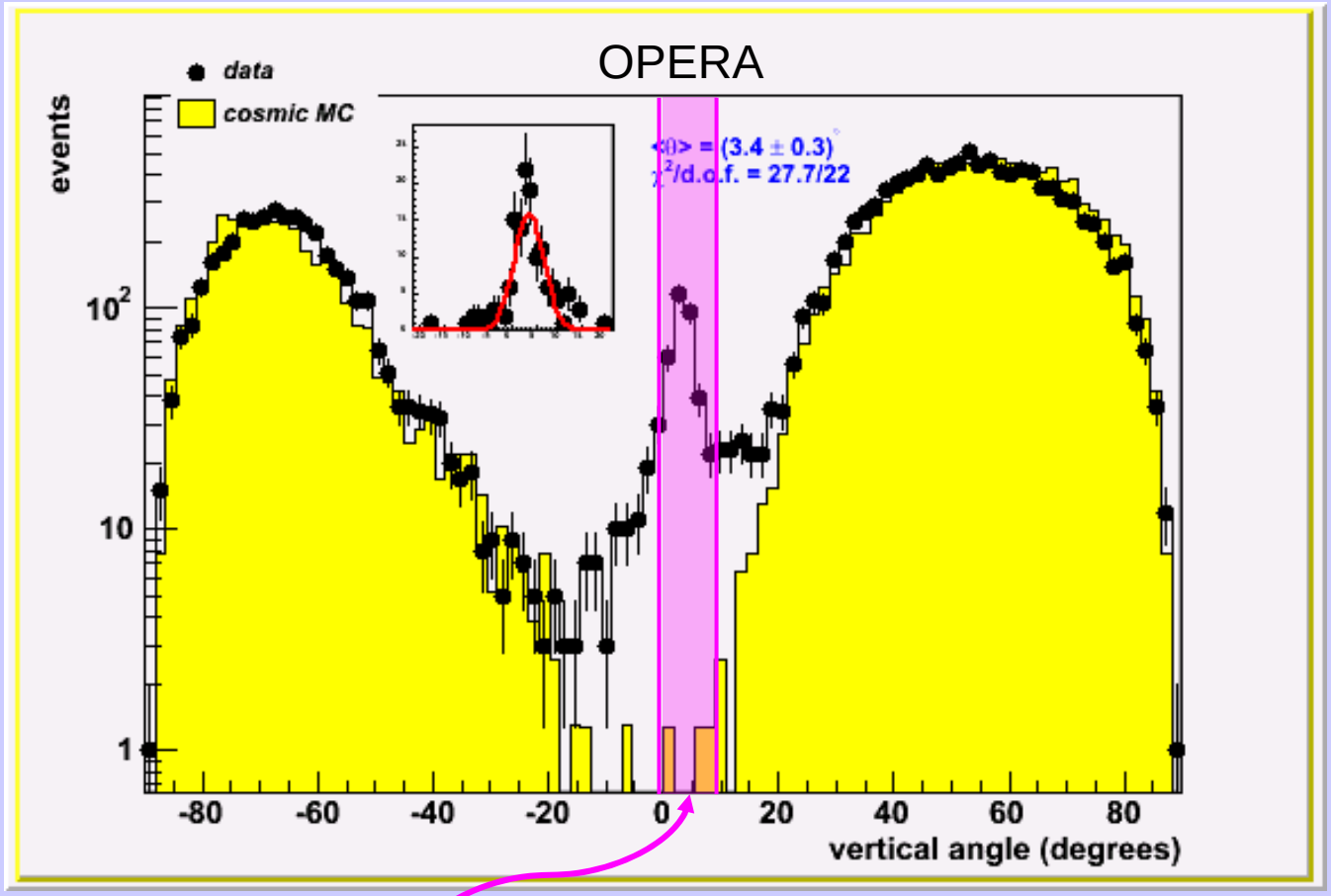


Beam Direction: August run

Zenith angle of muon track



August Run result:
$<\theta>=3.4\pm0.3$

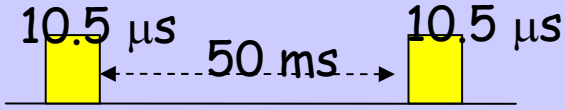


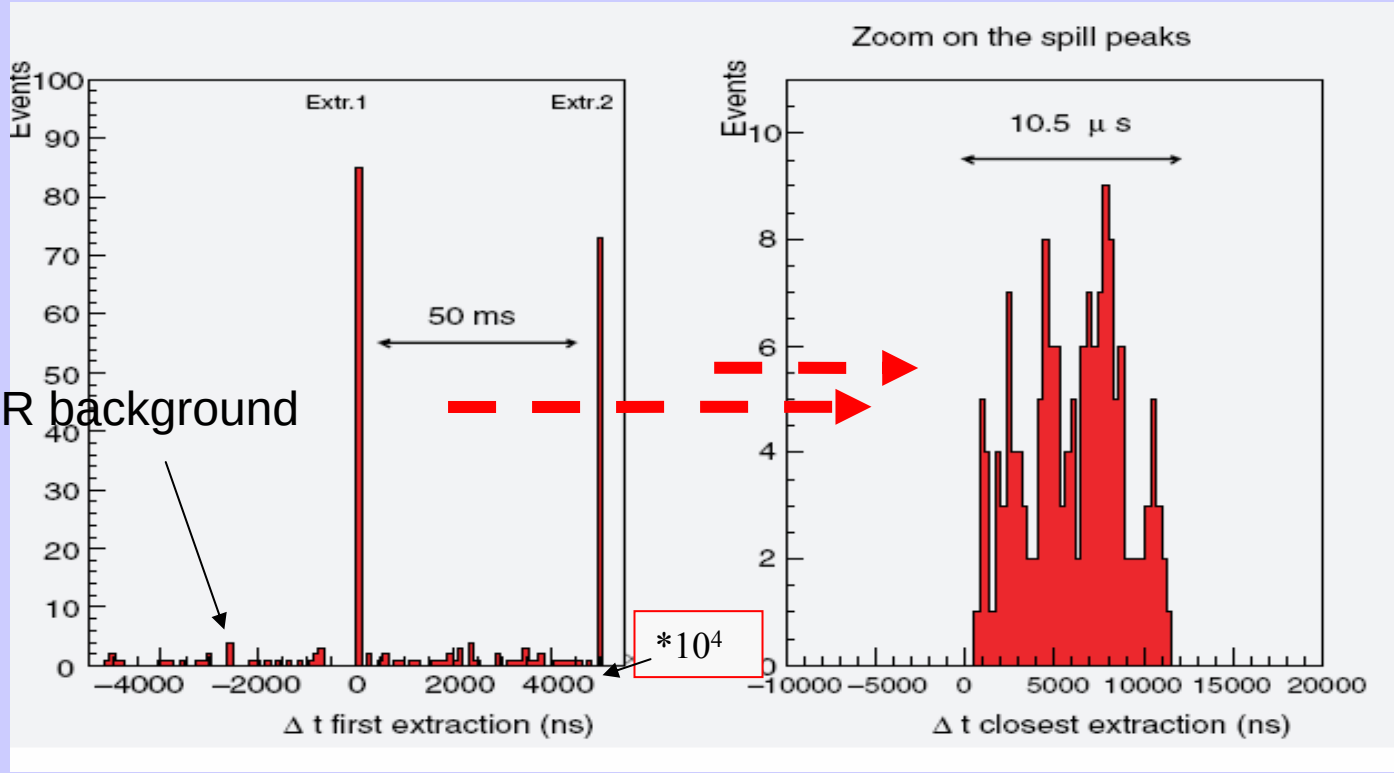
Select events around beam ($0 < \theta < 0.15$ rad) direction and check if there are on time

Time synchronsation

Event selection by using GPS timing informations

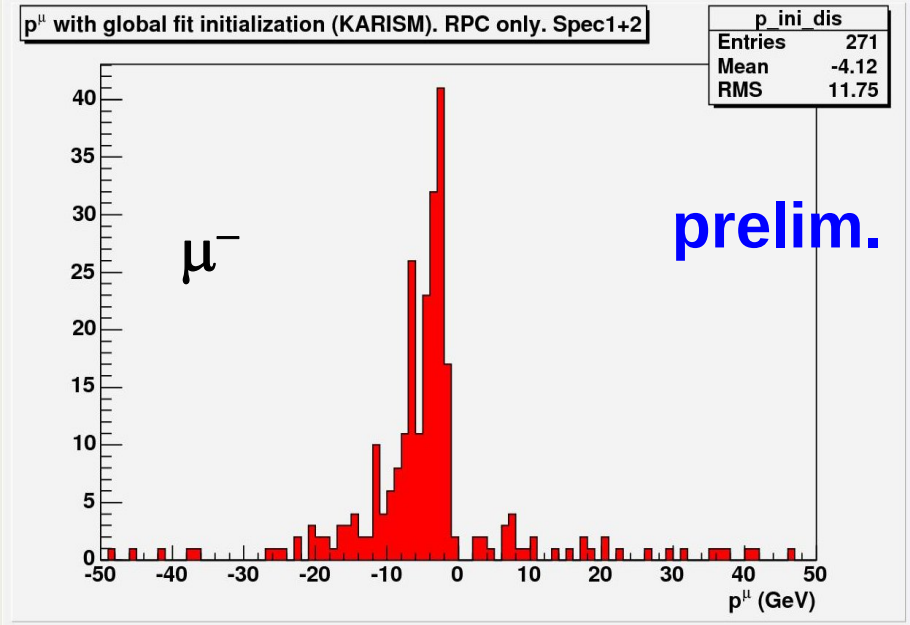
Searching events in O(ms) windows just yields a narrow peak of the order of the spill width (10.5 us) with practically no background O(10^E-4)

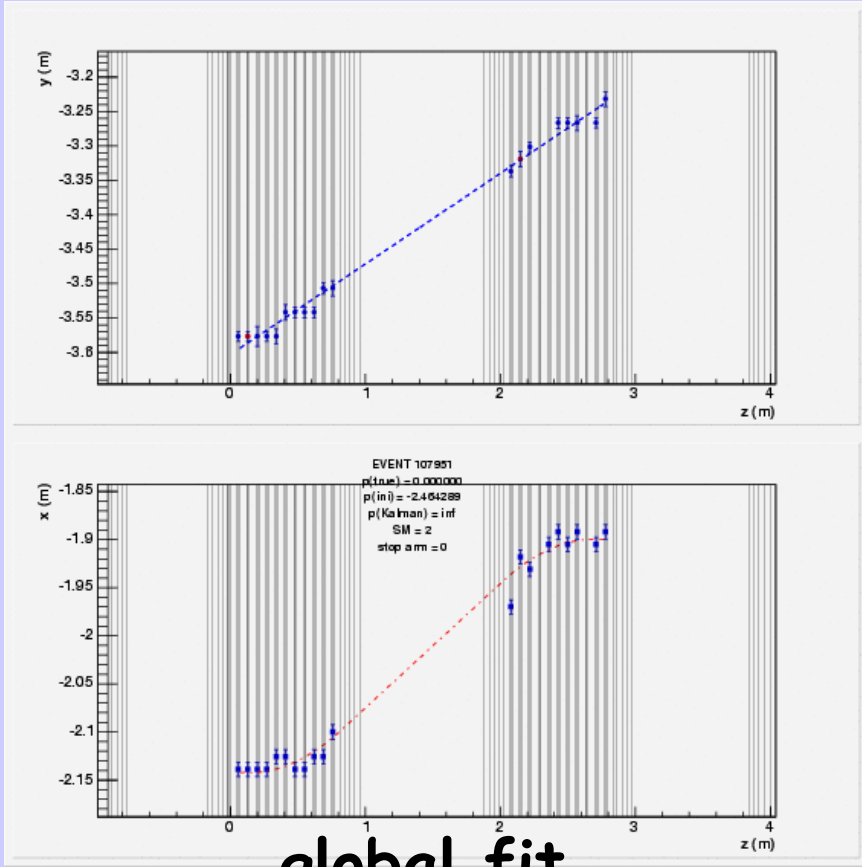




Momentum

Measured with RPC only



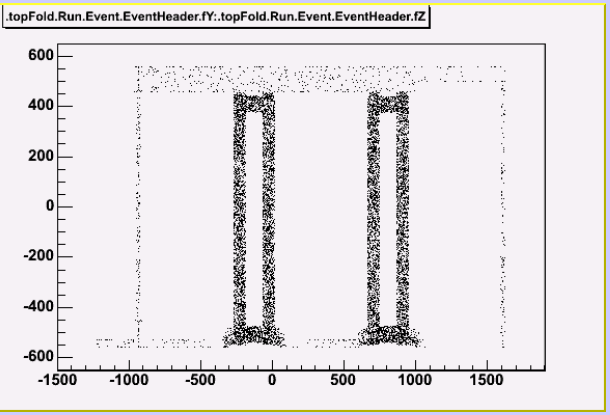


Chargeidentification will be much better with the presision tracker (PT)
⟶ misidentification 0.1-0.3%

global fit

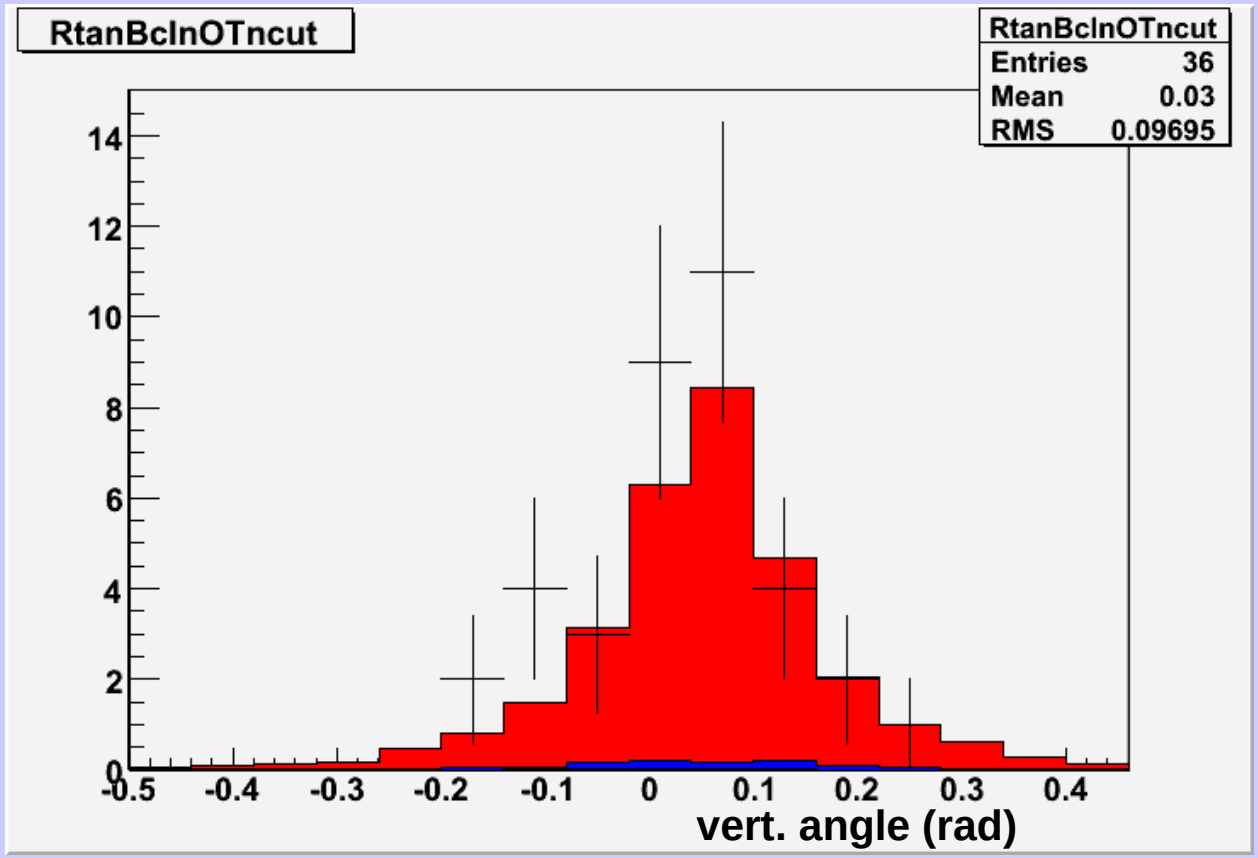
Normalization check: $\nu_{\mu CC}$ in the magnets

- Trigger + On Time + mu Id (> 10 RPC plane) + vertex in magnet OR first 2 TT2 + fiducial volume cut
- no χ^2 cut on muon trk



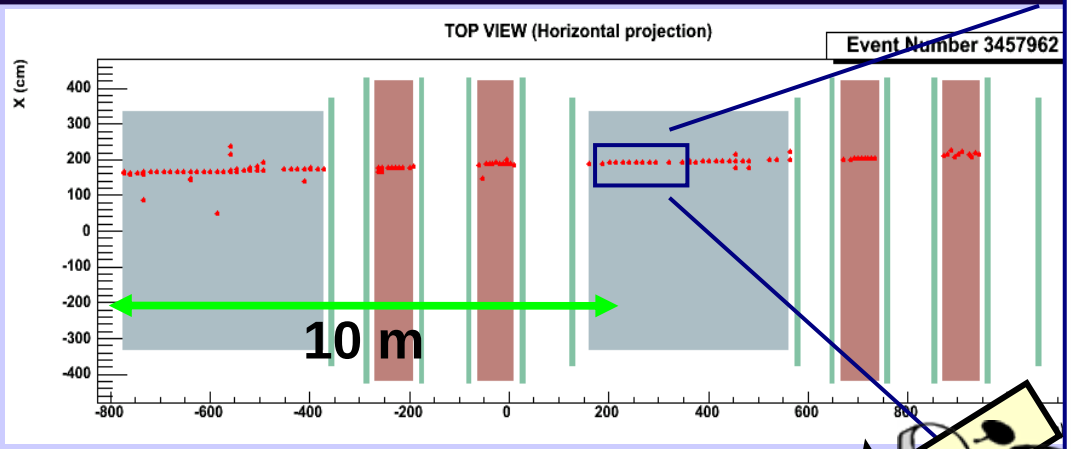
August + October
Data = 36 ± 6 evt.
MC = 29.9 evt.

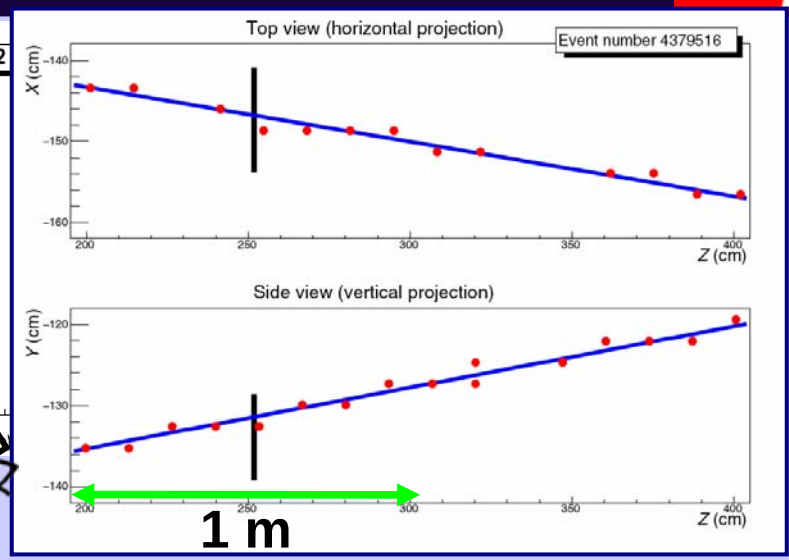
October only:
Data = 1
MC = 2.2

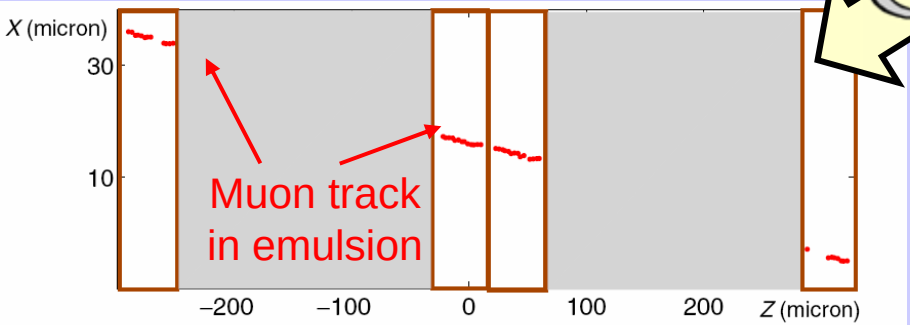


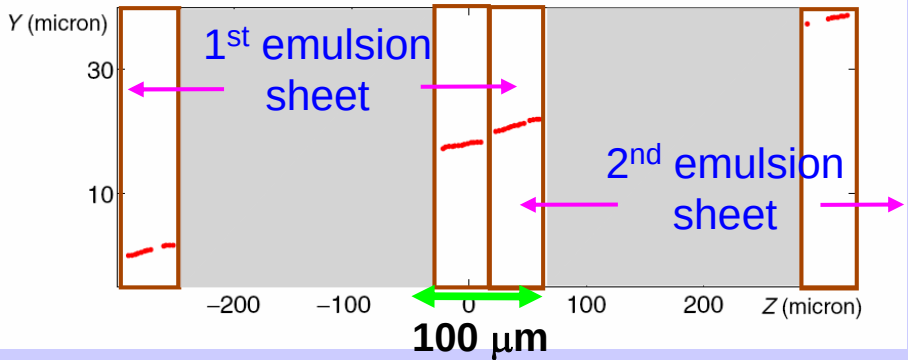
- ν_{CC} in magnets selection efficiency 52%
- very pure sample, NC contamination 4% (1,1 event)

Target Tracker - CS connection





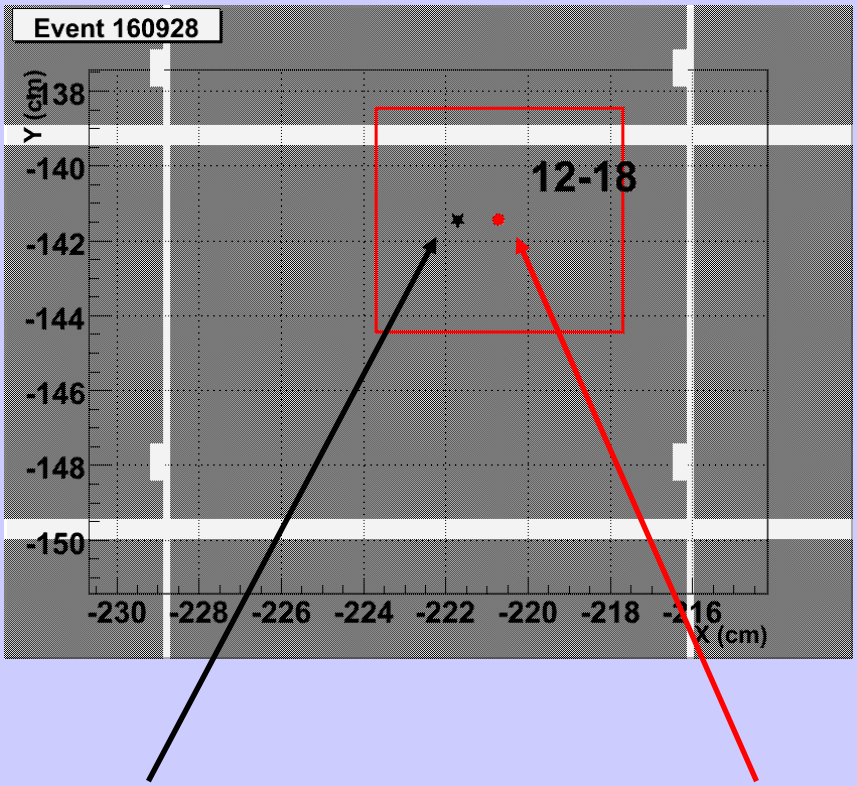


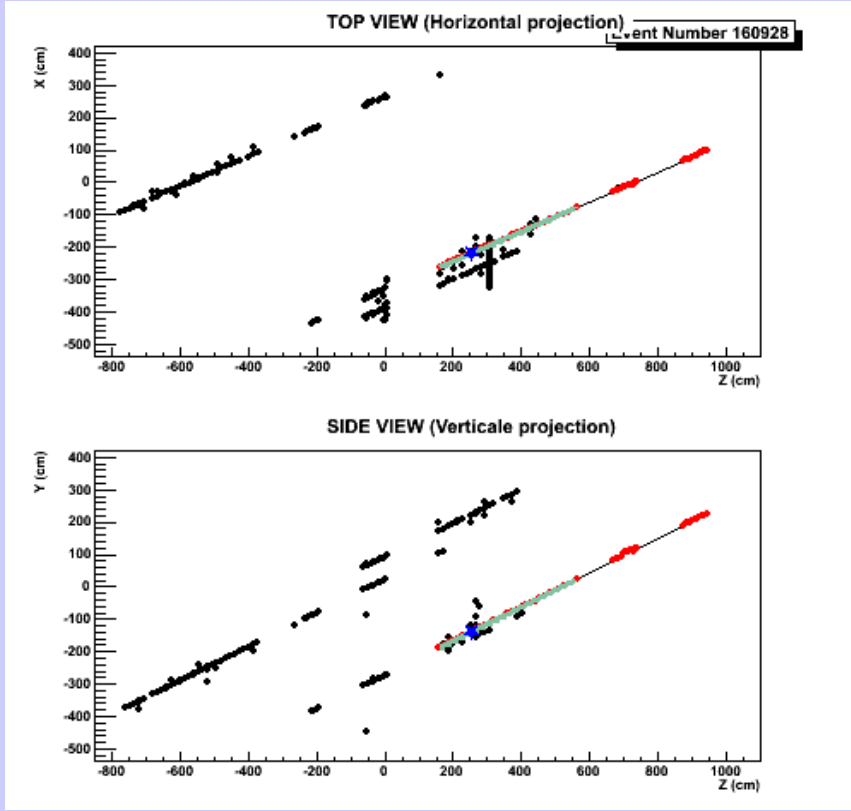


- One target wall partially instrumented with dummy bricks with real Changeable Sheet (CS) doublet to test the Target Tracker to Brick connection
- Muon tracks predicted by target tracker found in the CS doublets.
- Angular difference between prediction and found track <10 mrad, dominated by electronic detector resolution

Target Tracker - CS connection

Changeable sheet (CS)





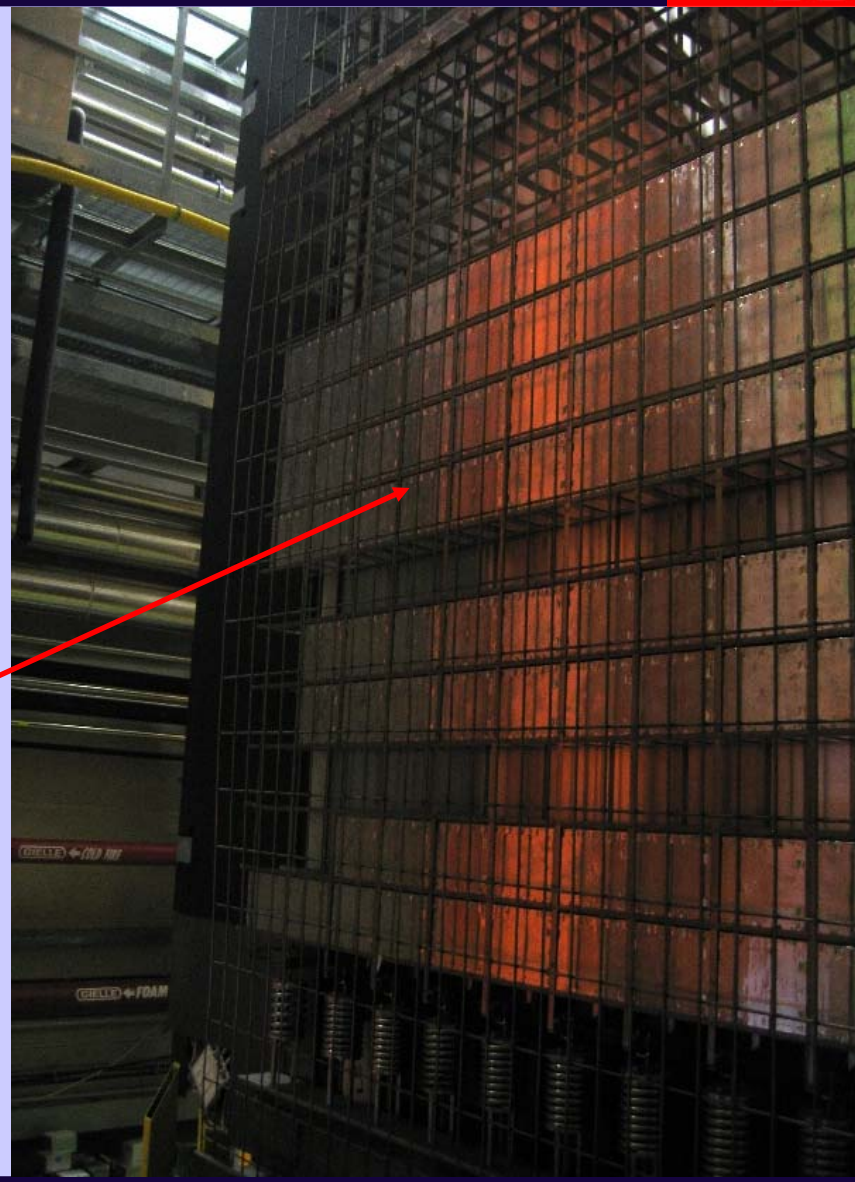
Confirmed track position

Predicted track position + search area

October run

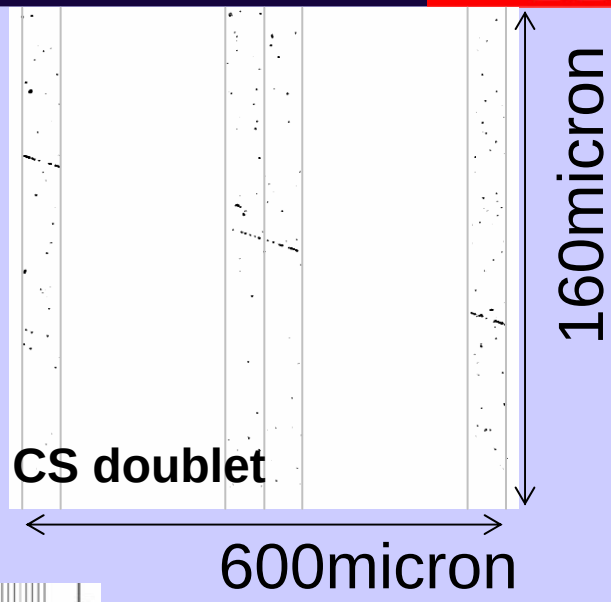
- Oct. 26th at 8.00 <-> Oct 27th at 11.00
  - due to a water leak in the reflector
- 1.2 10^{13} pot/extraction (1.7 in Aug.)
- total 0.6 10^{17} pot (7.6 in Aug.)
- 1 event with OPERA + Borexino coincidence

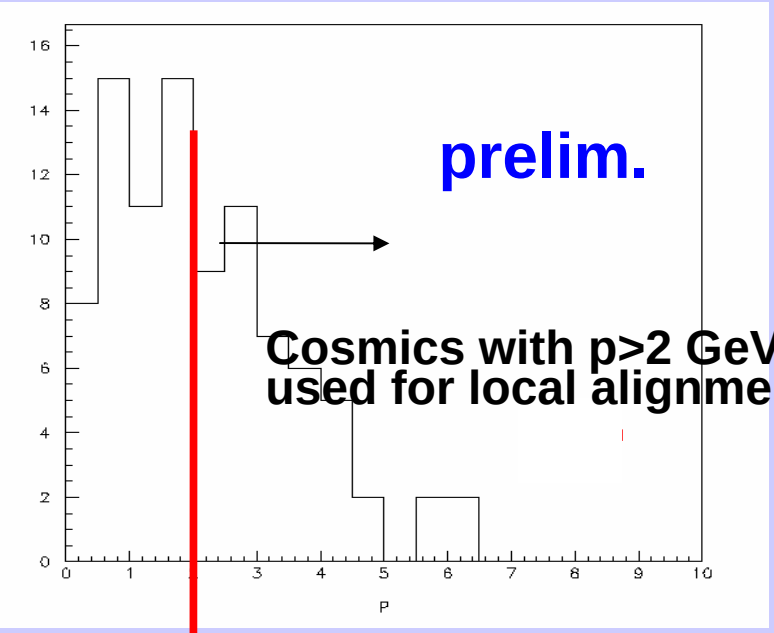
- First bricks within Detector

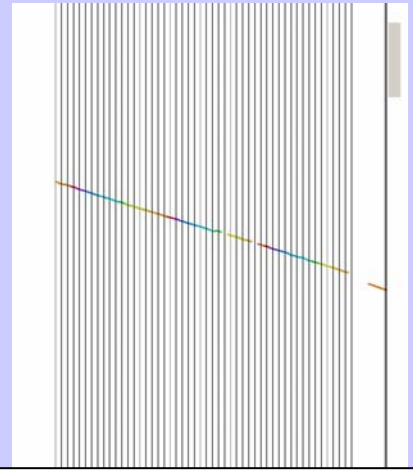


Momentum in the emulsions (Oct 06)

- Track found in CS
- Brick exposed to cosmics
- Cosmics with p>2Gev/c used for Alignment
- Momentum for track and spectrum of cosmics measured in emulsions by multiple scattering (angular method)







p = (6.4 +1.2 -0.9) GeV/c

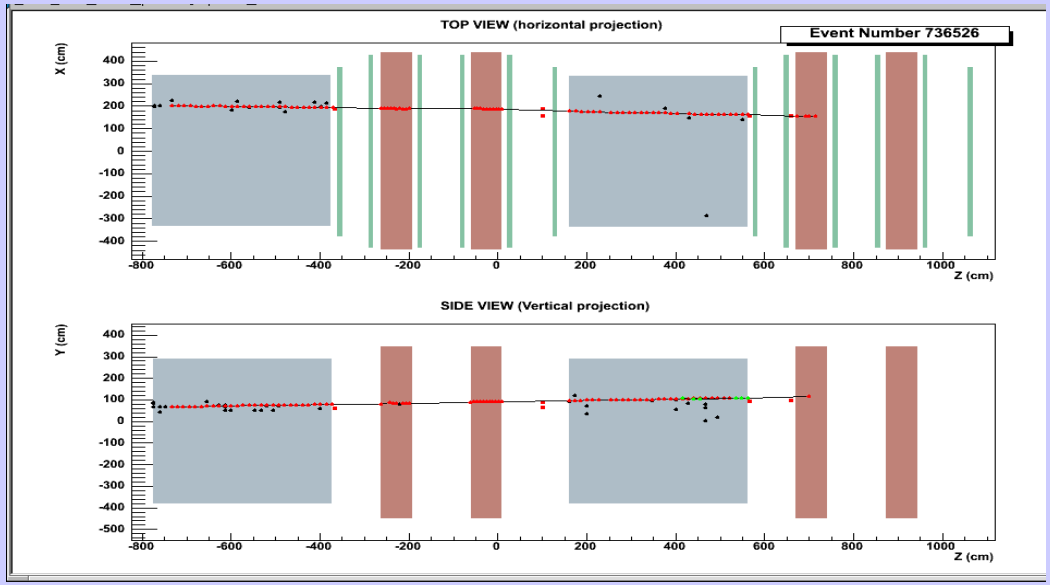
Borexino coincidence

One event in common with Borexino during the October run:

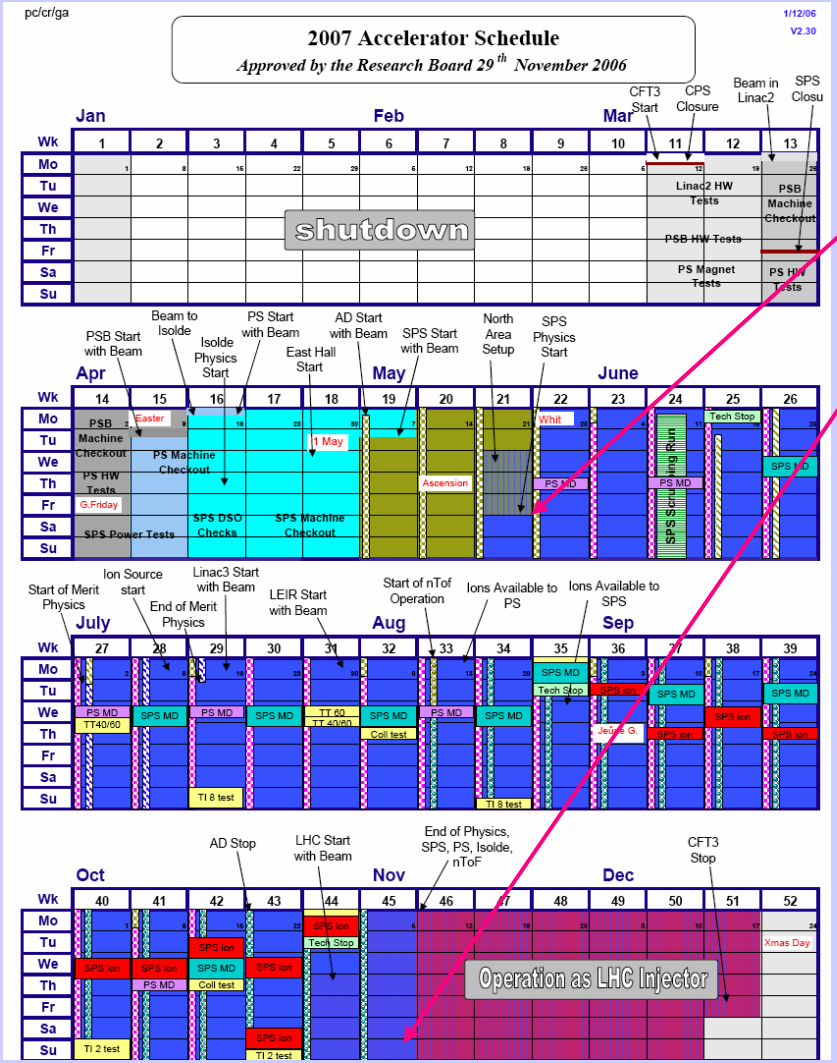
1 2909 11300 122 1161868864342099968.000 2407.000

Evt 736526 1161868864344498530 332 49997802 4074

Horizontal muon, 4074 ns after start of second extraction
Considering the TOP of 2440079 ns
The event should be at 2440 + 4.07 = 2447.07 μs
Found in Borexino at 2407 μs , 40 μs missing



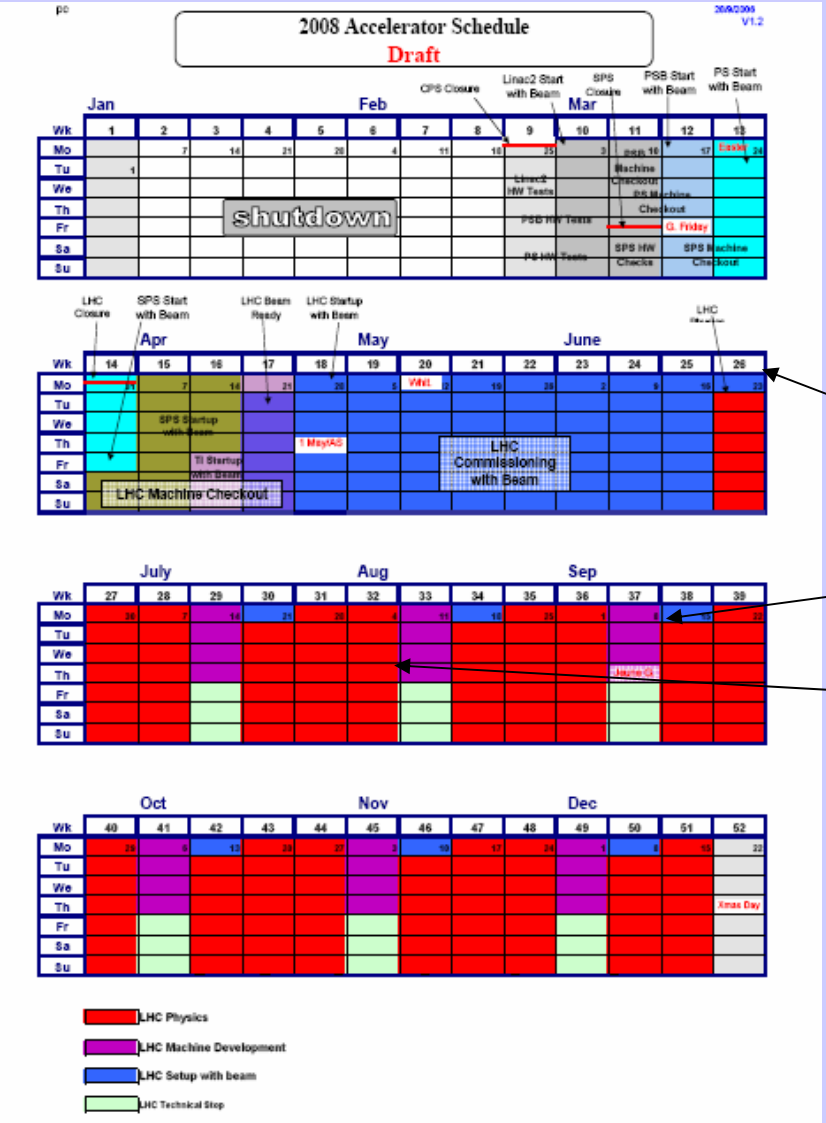
2007 CNGS run: Draft



SPS physics run:
Start: 26/5/2007
End: 7/11/2007

- **141 days of physics runs, excluding machine development.**
- **restoring of CNGS beam at the beginning of the physics run**
- **This year OPERA will get something between $1.6 \cdot 10^{19}$ p.o.t. and $2.1 \cdot 10^{19}$ p.o.t.**

Plans for 2008



Beam: 28 Apr-21 Dec
238 days (196 for CNGS)

4.4E13 p.o.t. extractions
80% machines efficiency

Supercycles:

- LHC filling (15%)
  0 CNGS
- LHC setup (35%)
  2 CNGS 22.8s 1.83E19 pot
- FT (50%)
  3 CNGS 39.6 s 2.26E19 pot

TOT. 4.09E19 p.o.t.

It will be a long run !!

Conclusion Opera

- The main aim of the OPERA experiment is to unambiguously confirm/disproof the $\nu_\mu \leftrightarrow \nu_\tau$ atmospheric oscillation channel
- The low intensity CNGS run operated smoothly for both beam and detector with good quality and stability
- The electronic detectors of OPERA took data almost continuously (95% live time) and with the expected tracking performances
- More than 300 in-spill events have been recorded with a clear time distribution
- The incoming angle of the neutrino beam has been measured and found in agreement with the expectation
- Electronic detector to changeable sheet connection tested with success
- The detector is ready for the next phase: observing neutrino interactions inside ECC bricks

Conclusion HPT

- SM1 installed and commissioned
- More than 99% of channels running smoothly
- First reconstruction results in good agreement with expectations

- Alignment needed to improve resolution
- First Momentum measurement next month

- SM2 will be installed and ready at the end of May