The status of the OPERA experiment

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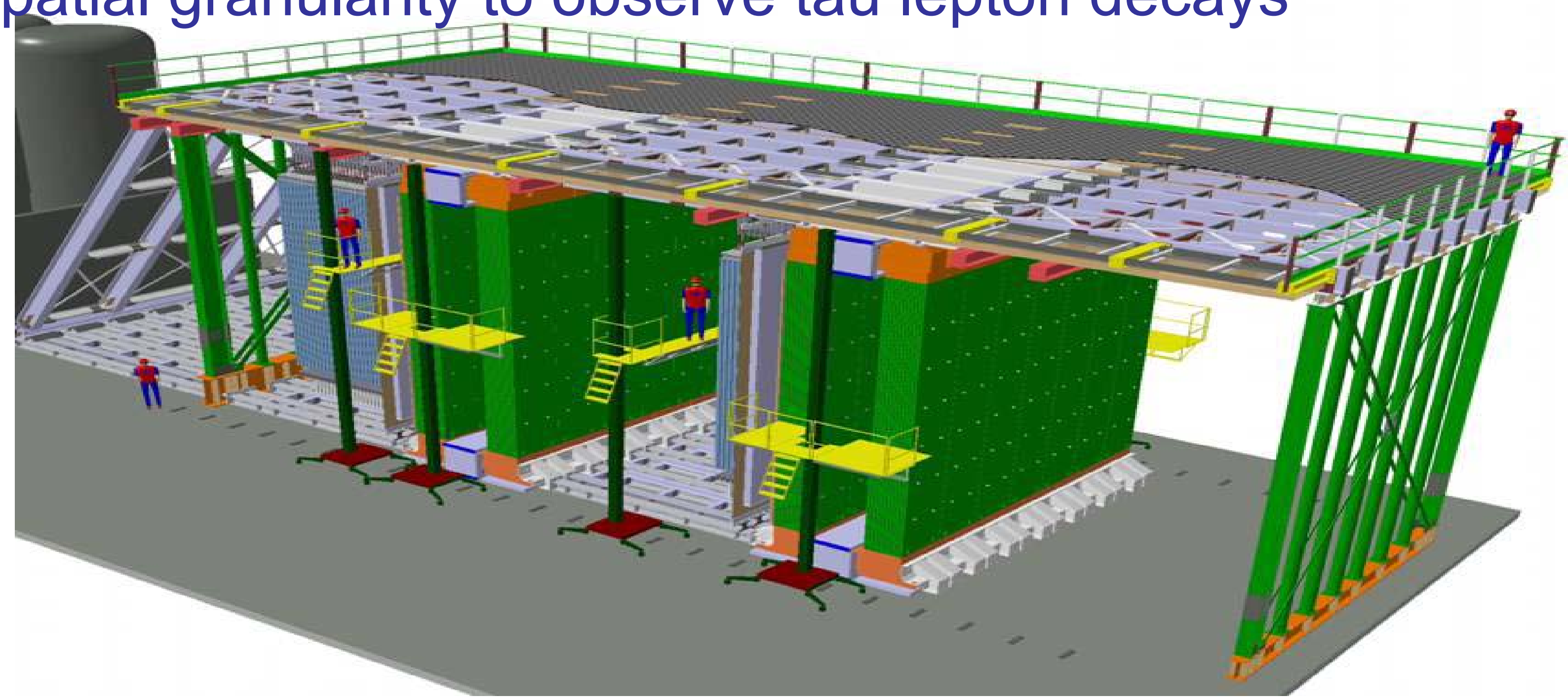
Conceptual design

Construction status (started in 2003)

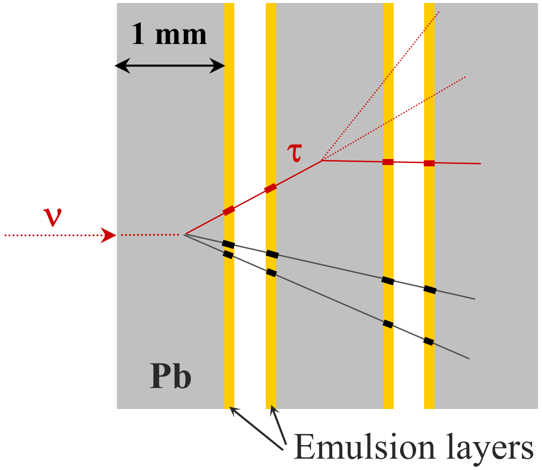
Physics performances

Physics motivation and conceptual design

- Provide unambiguous evidence for $\nu_\mu \rightarrow \nu_\tau$ oscillations in the atmospheric neutrino region through the appearance of ν_τ in a pure ν_μ beam
- Search for the sub-leading $\nu_\mu \rightarrow \nu_e$ oscillations (θ_{13})
- ν_μ beam produced at CERN and sent to Gran Sasso (730 km far away)
- Beam flux reduction and weak neutrino interactions → Kton
- High spatial granularity to observe tau lepton decays

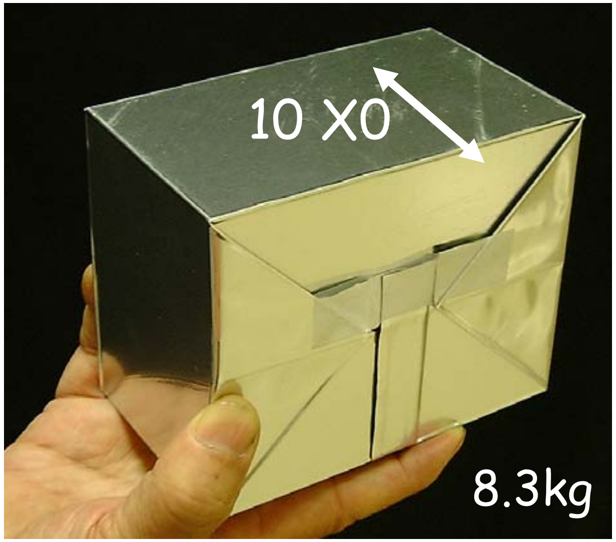


Experimental design



- Target based on the Emulsion Cloud Chamber (ECC) concept
- 56 1mm Pb sheets and 57 300 μm emulsion films
- At the same time capable of large mass (1.8 kton) and high spatial resolution (<1μm) in a modular structure

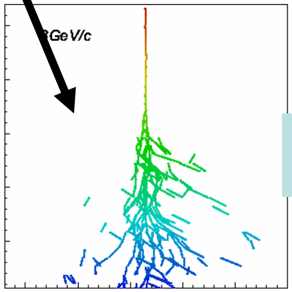
The basic unit : the « brick »



10.2 x 12.7 x 7.5 cm

ECC topological and kinematical measurements

- Neutrino interaction vertex and decay topology reconstruction
- Measurement of hadron momenta by Multiple scattering
- dE/dx pion/muon separation at the end of range
- Electron identification and energy measurement
- Visual inspection at microscope replaced by kinematical measurements in emulsion



8 GeV

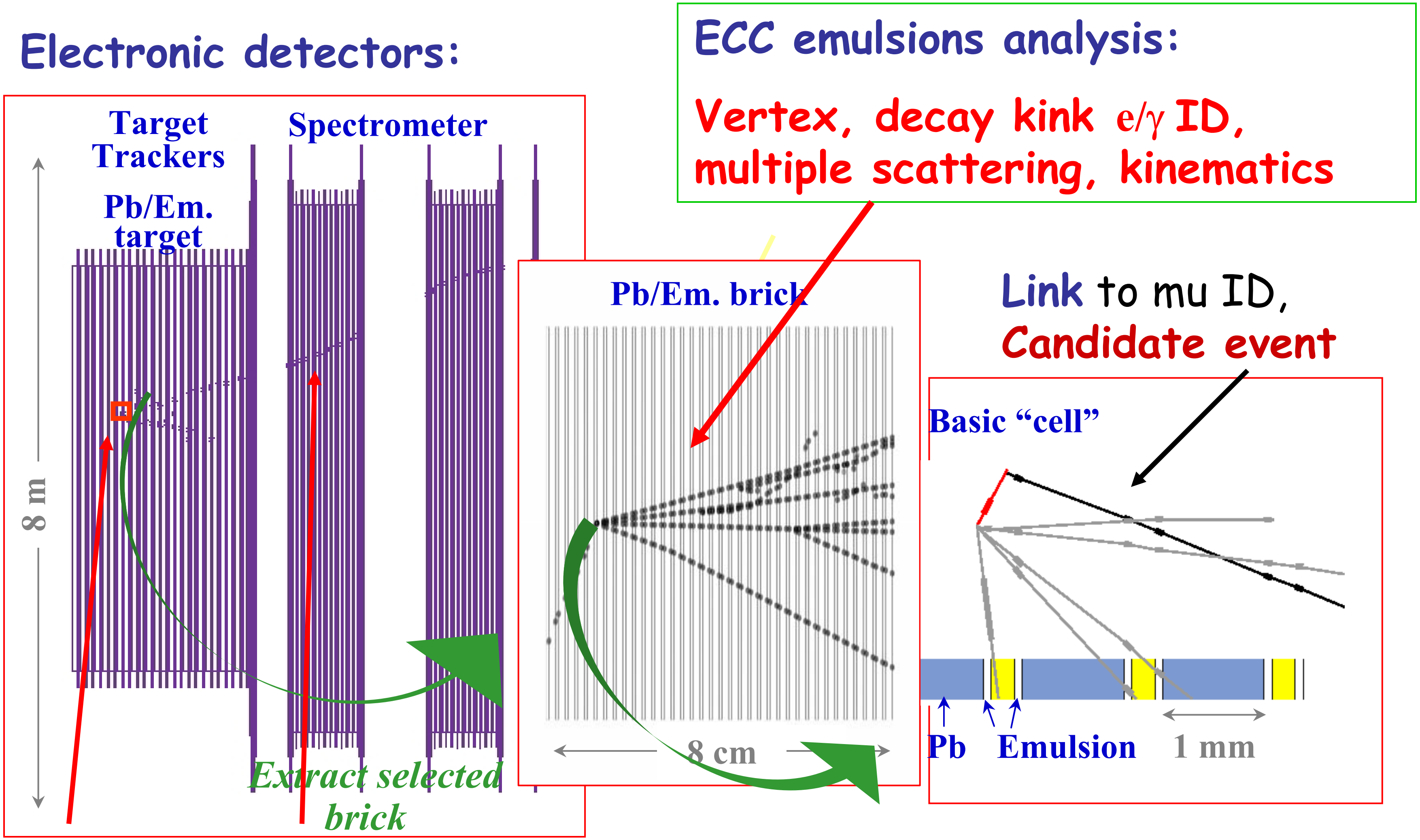
ECC technique successfully used by DONUT for the ντ direct observation

Electronic detector task

- **trigger** and **localization** of neutrino interactions
- **muon** identification and momentum/charge measurement

→ need for a **hybrid** detector

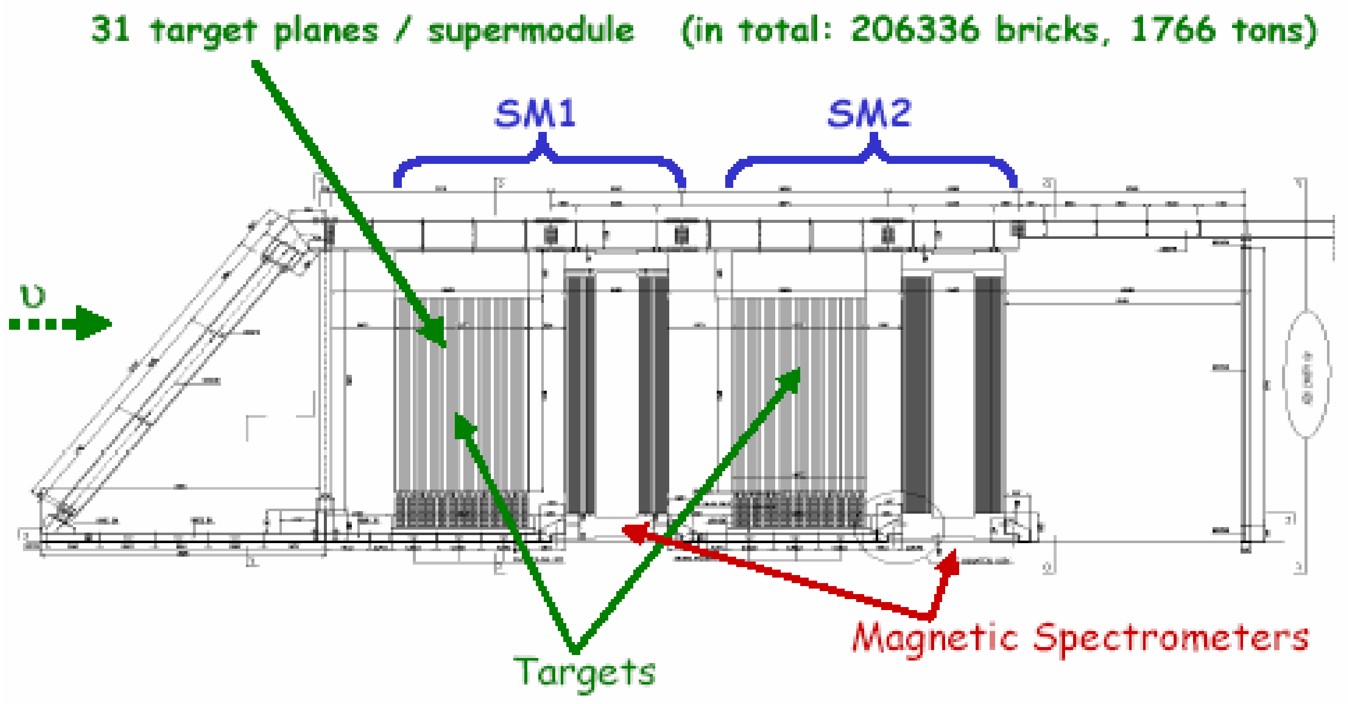
Electronic detectors:



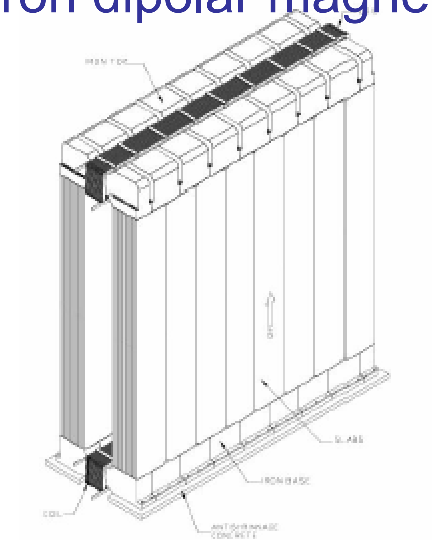
Brick finding, muon ID, charge and p

$\Delta p/p \sim 21\%$

Apparatus layout



iron dipolar magnet

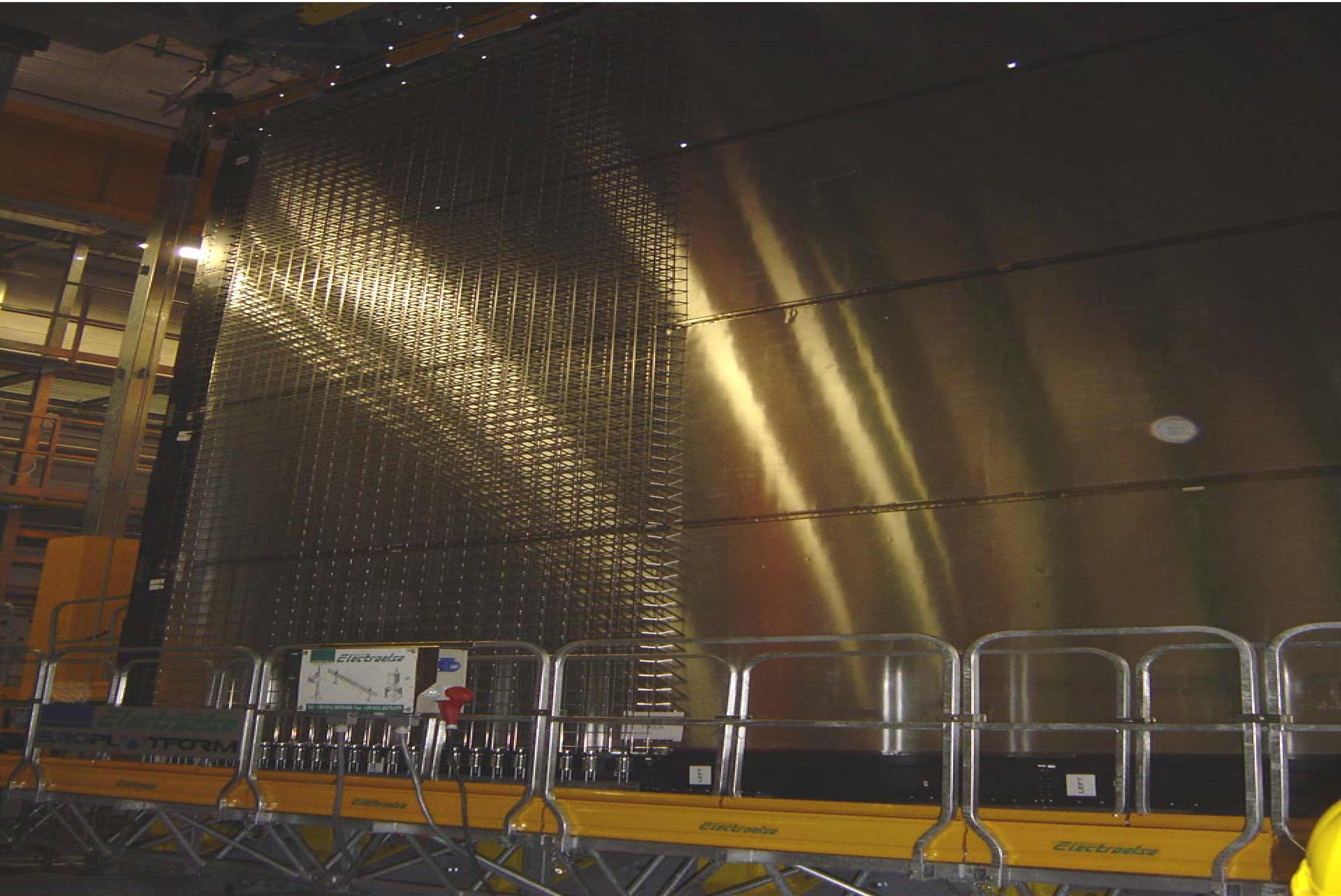


- First magnet completed
- Second magnet under construction → May 05
- Target tracker (scintillator) planes being assembled → Apr 05 (SM1)
- Target walls under installation (SM1 → Sep 05, SM2 → Feb 06)

Target Tracker plane assembly @ LNGS

Target tracker plane insertion

First two semi-walls installed (01/12)

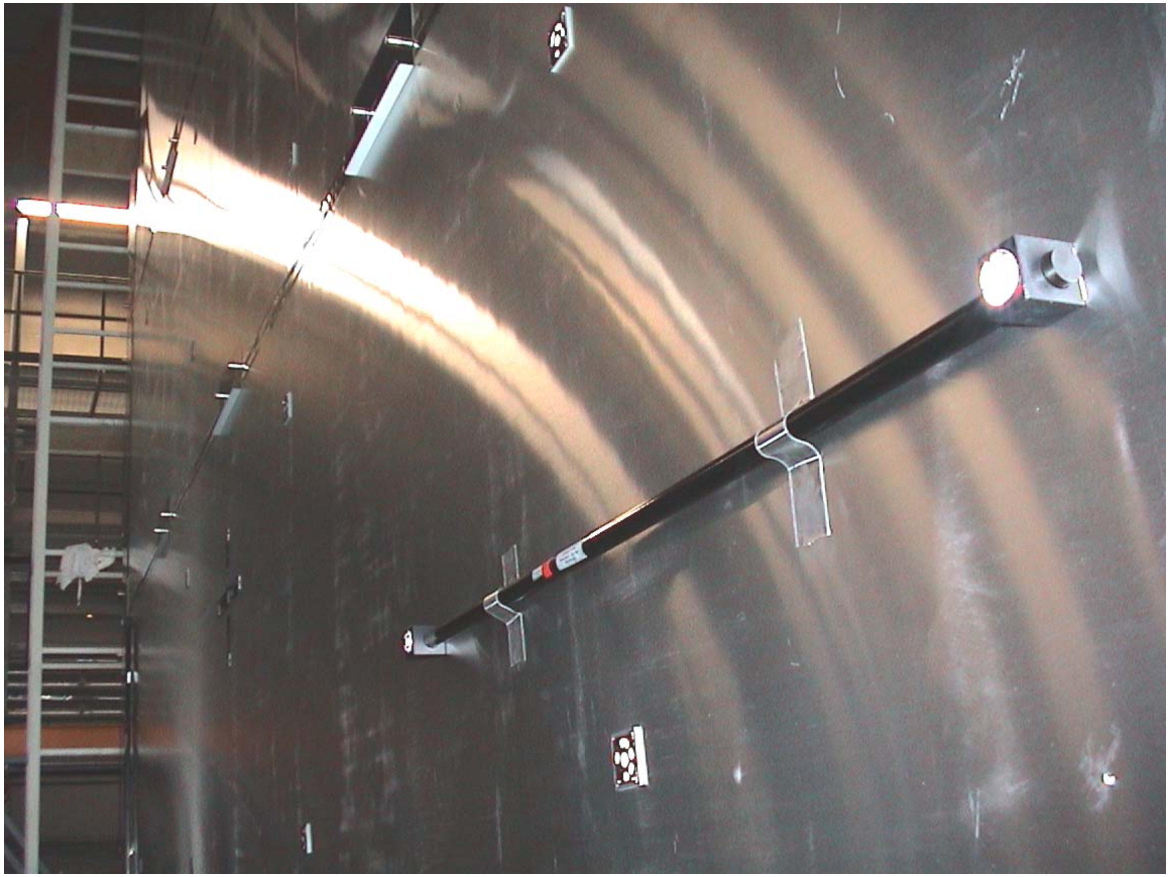


Photogrammetry available at LNGS

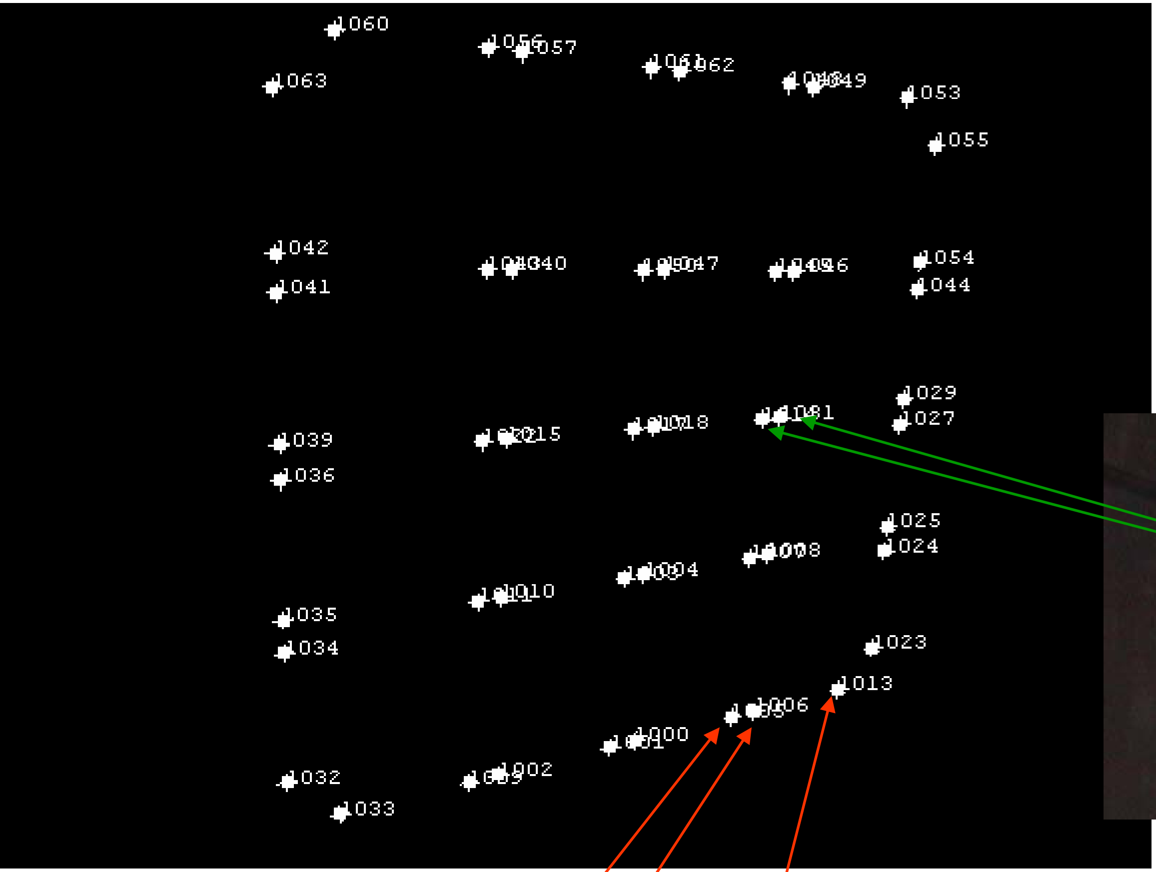
First photogrammetric survey (13/9/04)

• LNGS staff trained by CERN experts

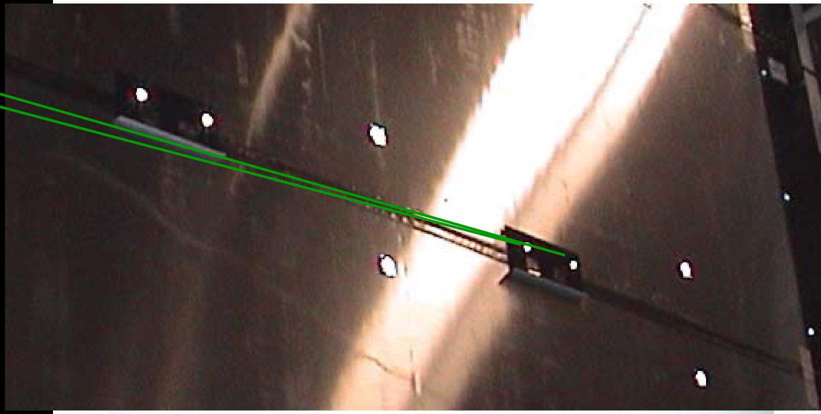
• LNGS equipment

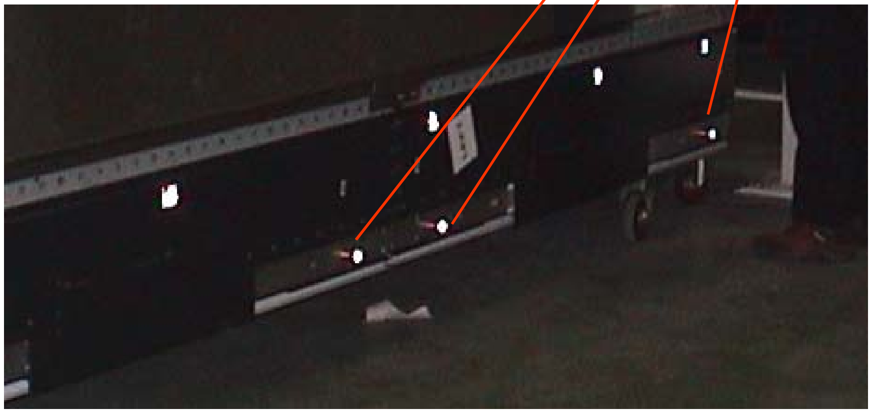


3D representation of the reference points



Reference points
on the bars
2 points/bar
18 points in total





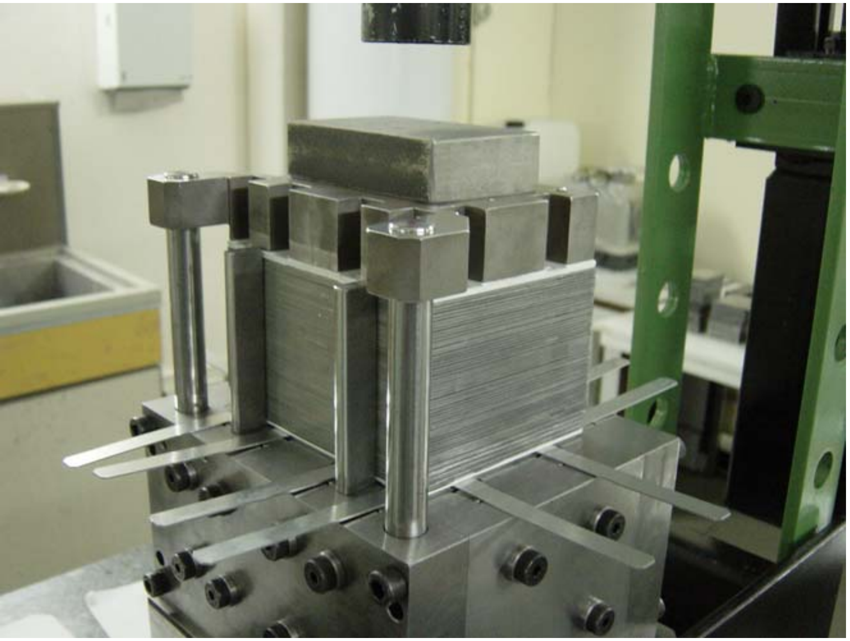
Reference points
on the
End-caps
2 points/End-cap
32 points in total

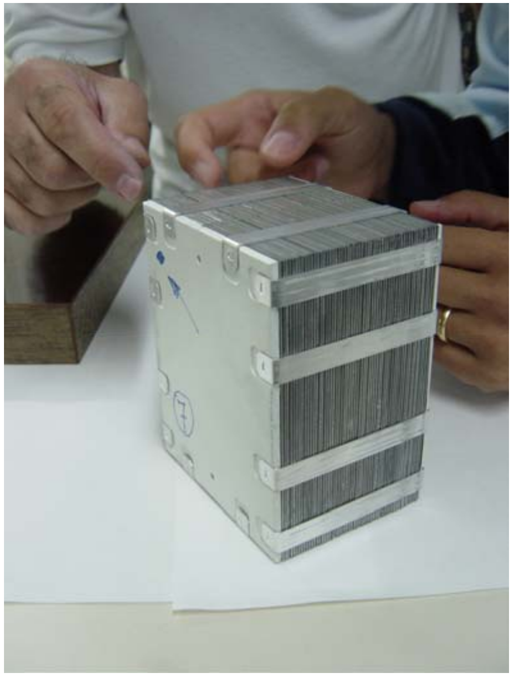
The precious element: nuclear emulsions from belts to bricks

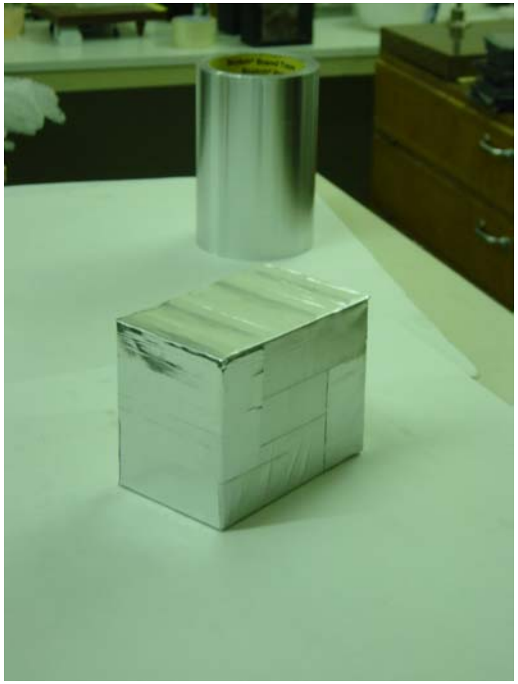
- Emulsions produced by Fuji (Japan)
- Stored at the Tono mine (Japan) and treated to reduce the background (refreshing procedure)
- Delivery at Gran Sasso after treatment
- 1.5 million films (~13%) being sent from Nagoya Port to Gioia Tauro on 14/12 and arriving at Gioia Tauro on 06/01 and hence delivered at Gran Sasso
- Brick assembling machine commissioning: Feb 05
- Brick filling will start on Oct 05

Packaging studies

- final bricks have been successfully used in test beam
- mechanical properties measured and within specs
- optimisation in progress for automation
- Firm selection done in Jan 04





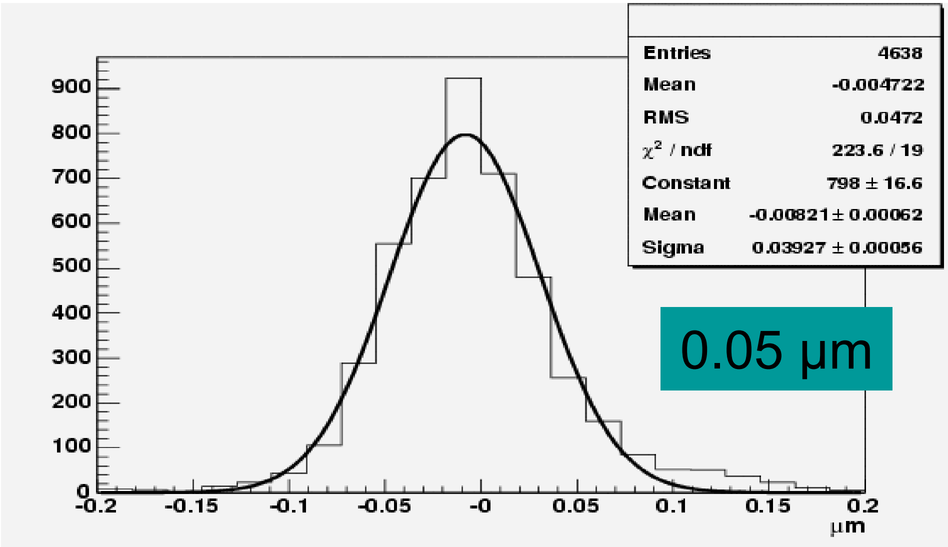


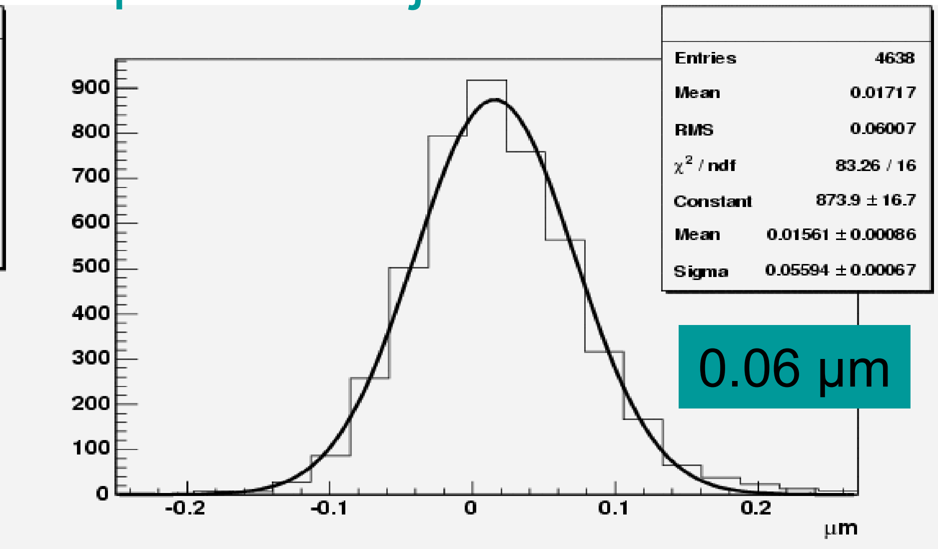
Emulsion scanning

- Real time analysis: several tens of bricks extracted/day
- About 1500 cm^2 to be scanned/day
- High speed (20 cm^2/h) fully automatic scanning systems (one order of magnitude faster than previous generation)
- R&D started independently in Europe and Japan based on different approaches
- First prototype developed and tuned in Europe
- Successfully running since Summer 04 with high efficiency (>90%), high purity (2/ cm^2 /angle) and design speed
- 2 mrad accuracy at small incident angles

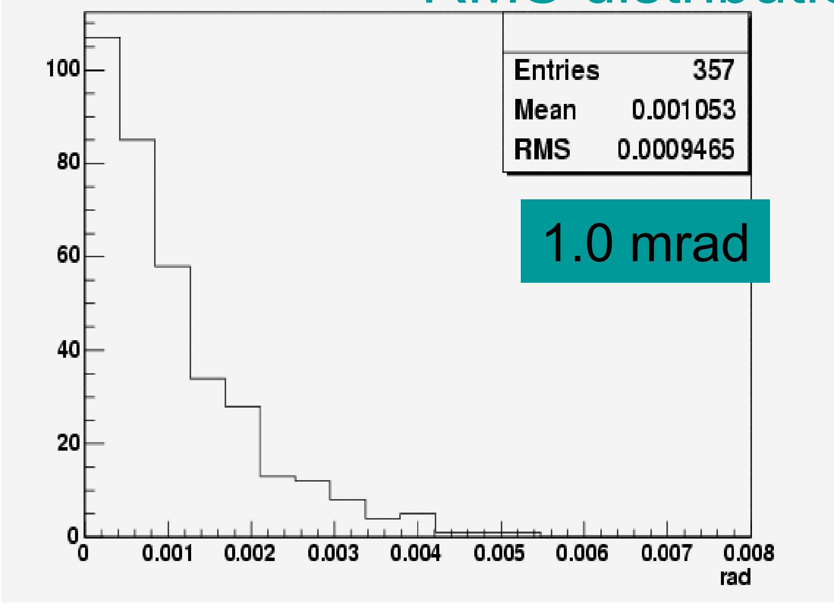
Precision position and angular measurements

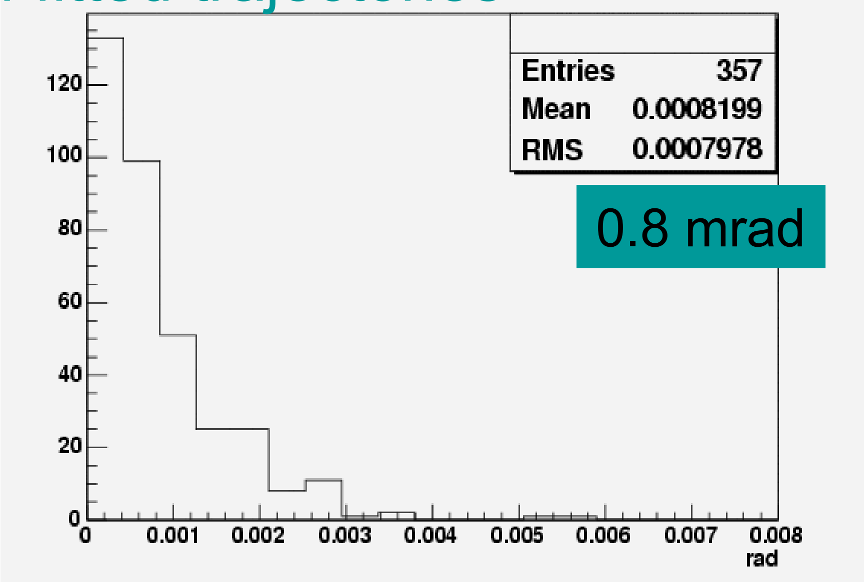
Position measurement of particle trajectories





RMS distribution of fitted trajectories

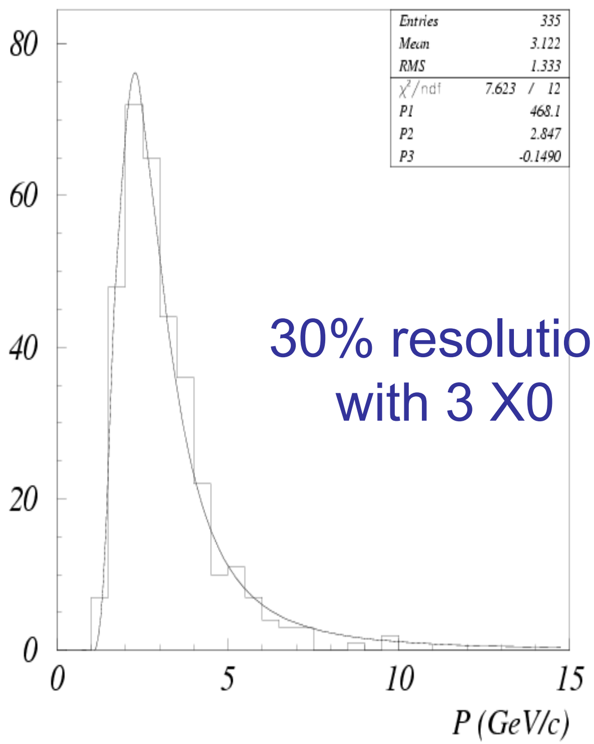




Momentum measurement by Multiple Scattering

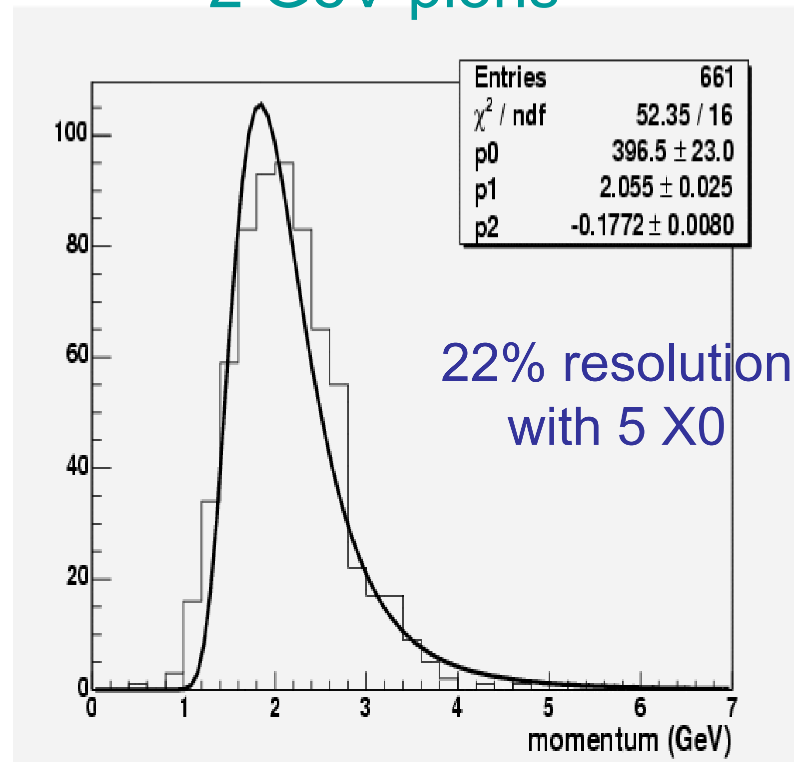
Routinely scanning performed

3 GeV pions



30% resolution with 3 X0

2 GeV pions



22% resolution with 5 X0

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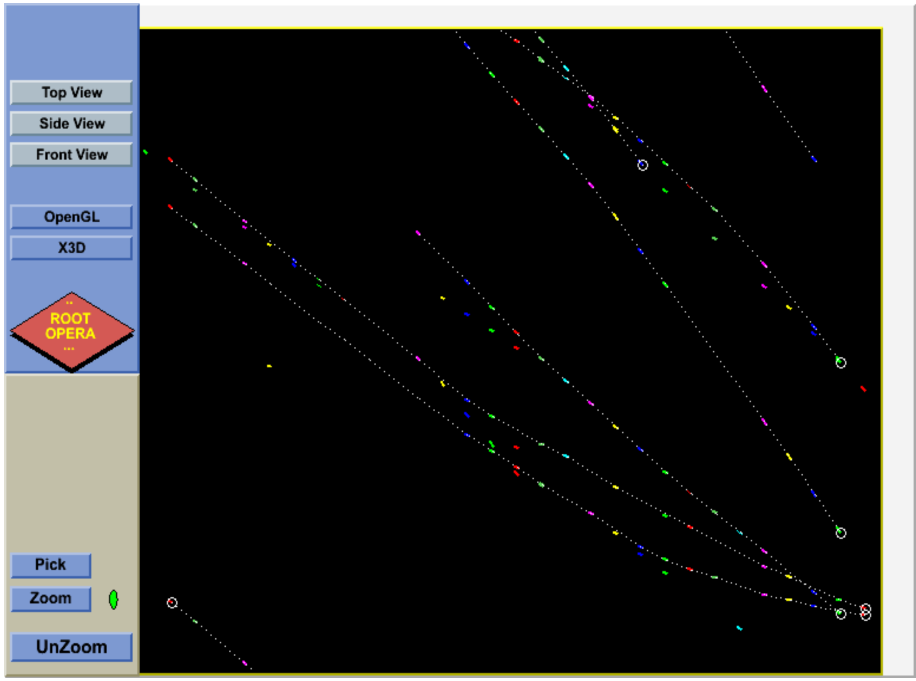
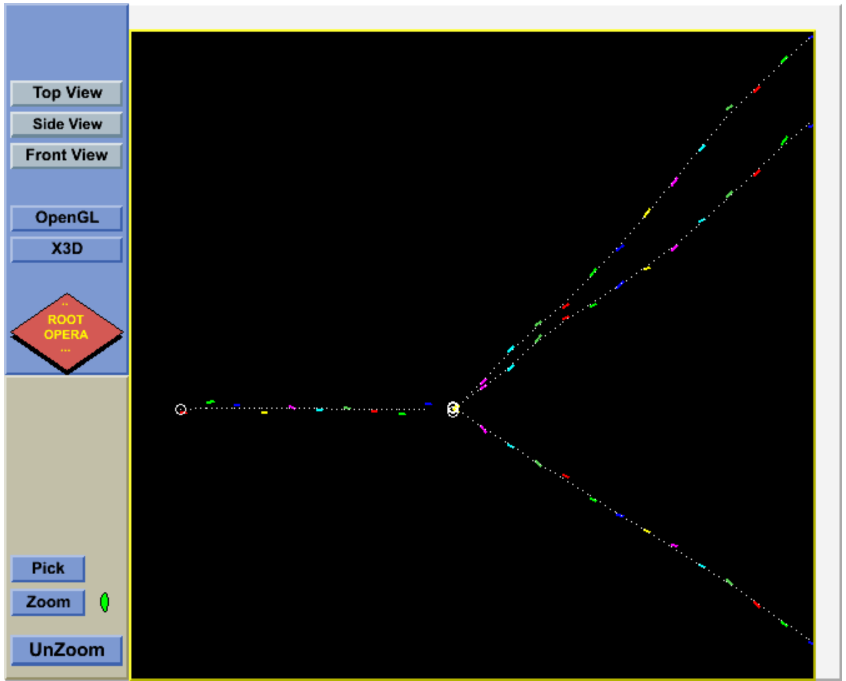
Vertex finding studies

- Test exposure of brick to pion beams at CERN
- Check the vertex finding efficiency
- Track following and fitting with Kalman filter (progressive track fitting)
- Vertex reconstruction

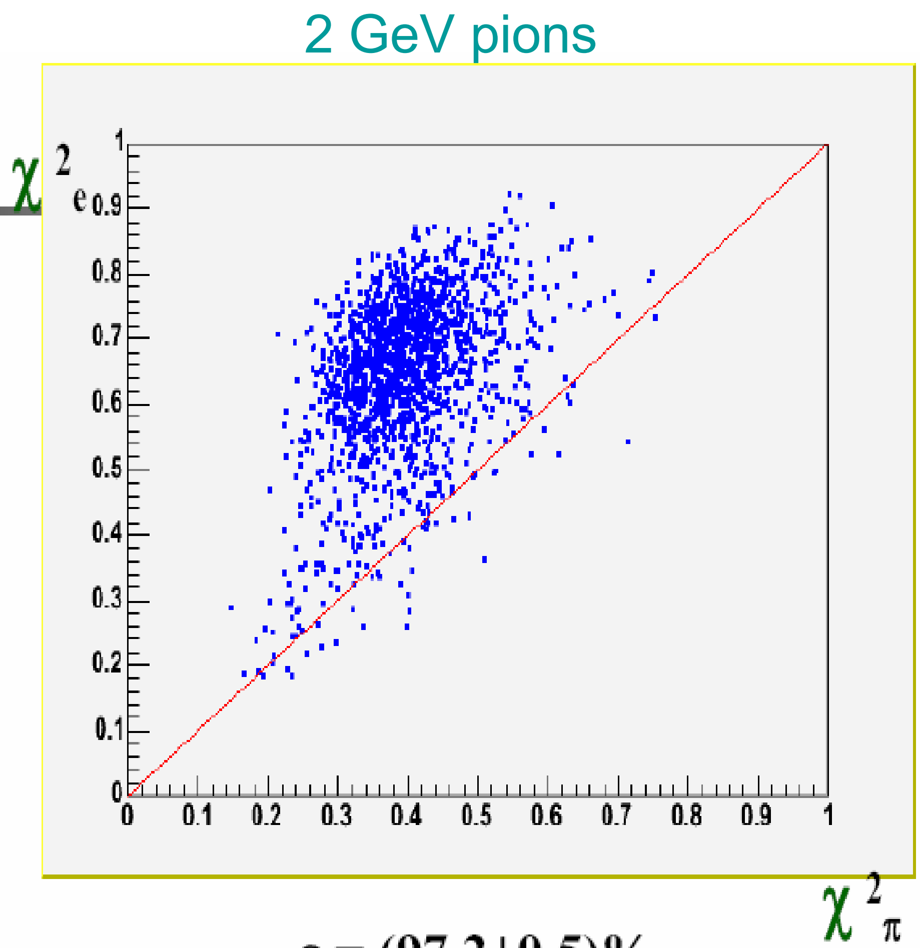


4 GeV pion track following

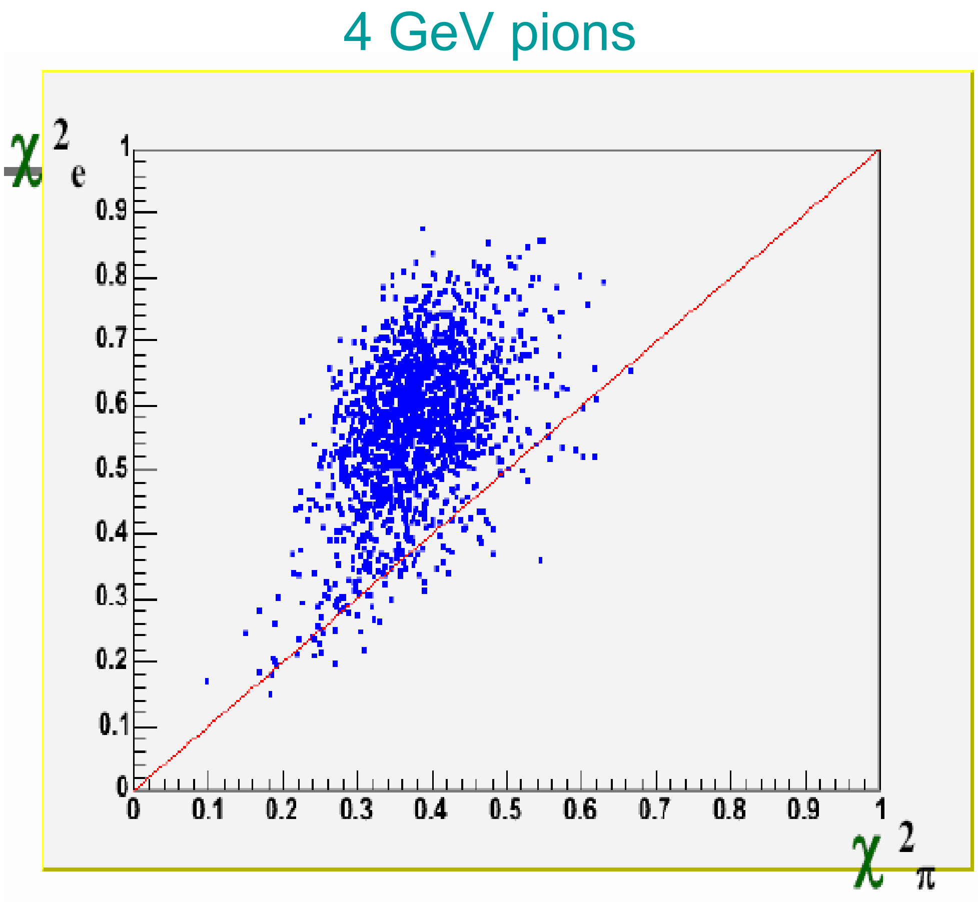


Pion interaction vertex (preliminary)

Pion/electron separation study



$\varepsilon = (97.2 \pm 0.5)\%$



$\varepsilon = (95.8 \pm 0.5)\%$

χ^2 analysis based on multiple scattering
preliminary results

How to check the decay finding efficiency

Neutrino induced charm production is a good reference sample

CHORUS

- About 2000 neutrino induced events with an identified charmed particle in the final state have been detected in the emulsions of the CHORUS experiment
- The total charm cross-section and, separately the neutral and the charged ones, may be predicted to the OPERA case with an accuracy equal or better than 10%
- The error on the total charm production cross-section is expected to be dominated by systematics which at present are 10%

OPERA

- We assume 5000 DIS events per year

  (shared mode, standard operation, no pot increase considered)
- 5% total charm cross-section
  - 250 charm events expected
  - About 100÷150 maybe detected (assuming 50% eff.)

Comments on efficiency check

All decay topologies (kink, multi-prong) can be analysed separately

- Already after 1 year data taking
  (i.e. precision measurements for about 100-150 charm candidates)
  the efficiency can be estimated with an accuracy better than 20%
- After 3 years of such a dedicated study
  the precision will be limited to ~10%
  by the error on the predicted number of charm events
  (i.e. systematic error on the CHORUS cross-section)

How to check the reliability of kinematical cuts

- The Monte Carlo used in OPERA has been carefully validated with data by the NOMAD Collaboration

  Kinematics and dynamics of neutrino interactions well modeled

- NOMAD had C target (light material) while in OPERA we have Pb (heavy material), but the used model does not depend on the nucleus
- We plan to precisely scan a minimum bias sample of about 1000 located neutrino interactions :

  (~750 CC (~4% stat $\Delta\varepsilon$), ~250 NC (~6% stat $\Delta\varepsilon$))

  to fine tune the intranuclear interaction model in describing the interactions on lead

Expected number of background events

(5 years run, nominal intensity)

(in red : possible improvements)	$\tau \rightarrow e$		$\tau \rightarrow \mu$		$\tau \rightarrow h$		total	
Charm background	.210	.117	.010	.007	.162	.160	.382	.284
Large angle μ scattering			.116	.023			.116	.023
Hadronic background			.093	.093	.116	.116	.209	.209
Total per channel	.210	.117	.219	.123	.278	.276	.707	.516

30% possible background reduction

1. Charm background :
   - Being revaluated using new CHORUS data
   - πμ id by dE/dx would reduce this background by 40%
     ⇒ being tested in July 2004 at PSI (pure beam of π or μ stop)
2. Large angle μ scattering :
   - Upper limit from past measurements used so far
   - Calculations including nuclear form factors give a factor 5 less
     ⇒ tested in Oct 2004 at CERN X5 beam with Si detectors
3. Hadronic background :
   - Estimates based on Fluka standalone : 50% uncertainty
   - Extensive comparison of FLUKA with CHORUS data and GEANT4 would reduce this uncertainty to ~15%

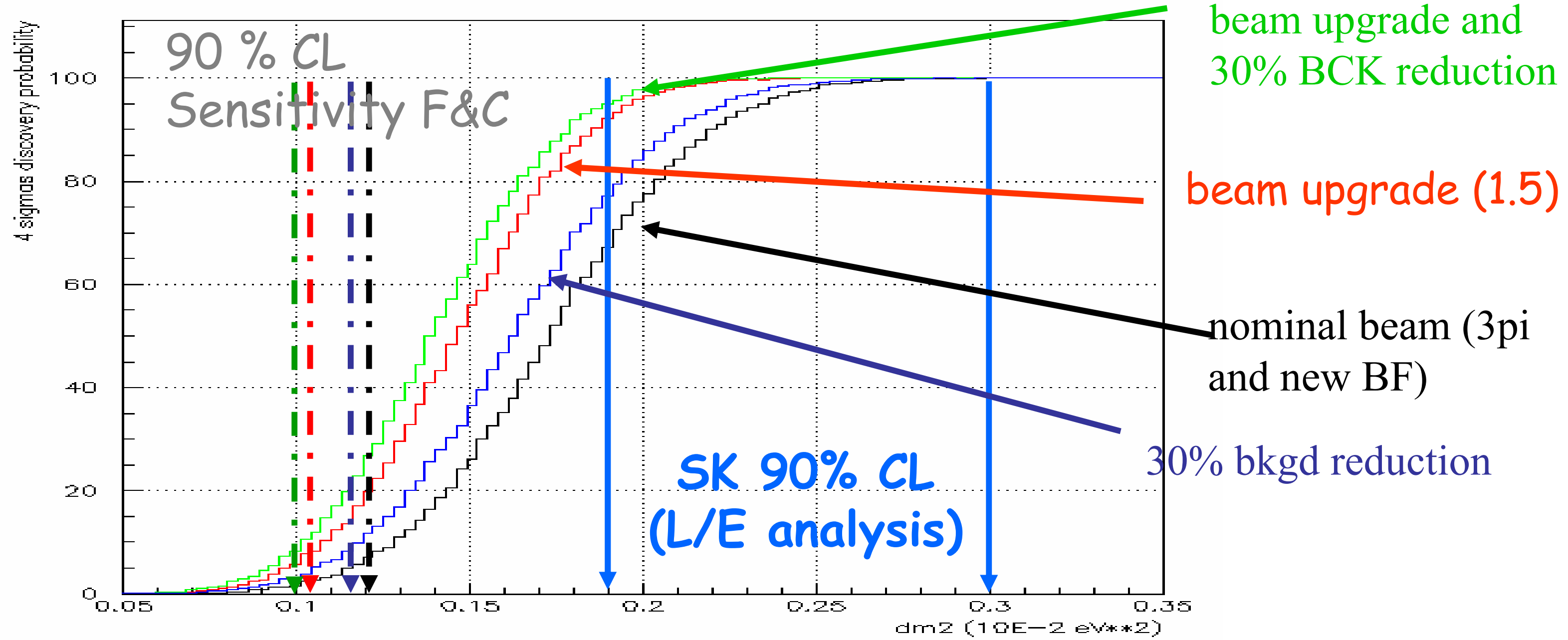
ν_τ expected events

full mixing, 5 years run @ 4.5 x10^{19} pot / year

(…) with CNGS beam upgrade (x 1.5)

	signal (Δm^2 = 1.9 x 10^{-3} eV^2)	signal (Δm^2 = 2.4 x 10^{-3} eV^2)	signal (Δm^2 = 3.0x 10^{-3} eV^2)	BKGD
Nominal	6.6(10)	10.5(15.8)	16.4(24.6)	0.7(1.1)
+ brick finding + 3 prong decay	8.0(12.1)	12.8(19.2)	19.9(29.9)	1.0(1.5)

4 σ discovery potential vs beam intensity



Conclusions

- The installation of the OPERA experiment is on schedule
- Completion of the first Super-Module foreseen in Sep 05 and filled in Feb 06
- The second SM completed in Feb 06 and filled in Sep 06
- Data taking will start in May 2006 and run in parallel with the filling of the detector
- Efficiency and background are based on robust numbers from previous experiments and tests
- Updated document on physics performances will be published soon
- Test to achieve and/or improve the design performances are under way

OPERA sensitivity to θ_{13}