OPERA with the CNGS ν_μ beam: an experiment for $\nu_\mu \rightarrow \nu_\tau$ and…

- News from the detector
- Update of the performances for $\nu_\mu \rightarrow \nu_\tau$
- Sensitivity to θ_{13} with $\nu_\mu \rightarrow \nu_e$

- Opera-Like detector for future (θ_{13},δ)

Jean-Éric Campagne LAL-Orsay
on behalf of the Opera Collaboration

Aachen-HEP2003

OPERA

COLLABORATION
Asia-Europe

36 groups
~ 165 physicists

Belgium
IIHE(ULB-VUB) Brussels

Bulgaria
Sofia University

China
IHEP Beijing, Shandong

Croatia
Zagreb University

France
LAPP Annecy, IPNL Lyon, LAL Orsay, IRES Strasbourg

Germany
Berlin, Hagen, Hamburg, Münster, Rostock

Israel
Technion Haifa

Italy
Bari, Bologna, LNF Frascati, L'Aquila, LNGS, Naples, Padova, Rome, Salerno

Japan
Aichi, Toho, Kobe, Nagoya, Utsunomiya

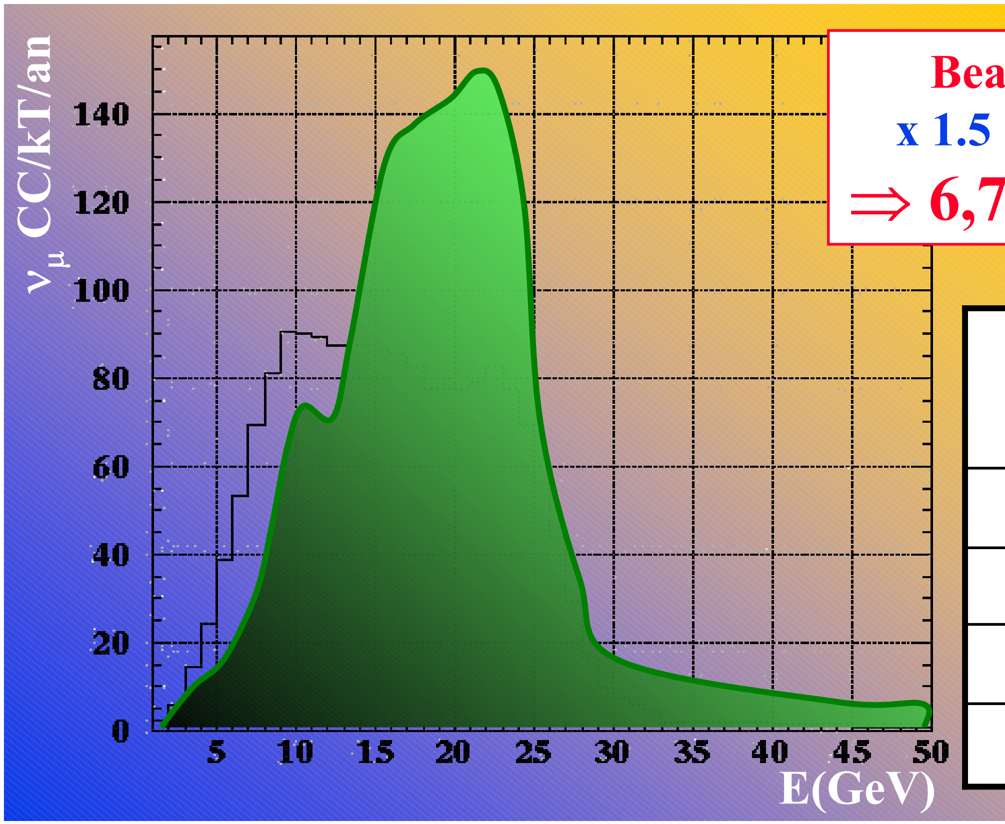
Russia
INR Moscow, ITEP Moscow, JINR Dubna, Obninsk

Switzerland
Bern, Neuchâtel

Turkey
METU Ankara

Event Rate

CNGS beam optimised for ν_τ search



Beam intensity increase granted
x 1.5 expected from original design
$\Rightarrow$ 6,76 10^{19} pot/yr, 50Evts/day

Evts/day	Shared mode 6,76 10^{19} pot/year
NC	10.96
CC DIS	31.42
CC QE+RES	4.07
Total	46.45

mass~1.7kT

ν_e + anti-ν_e beam contamination ~ 0.87%
Limiting factor for θ_{13}

1year = 200days

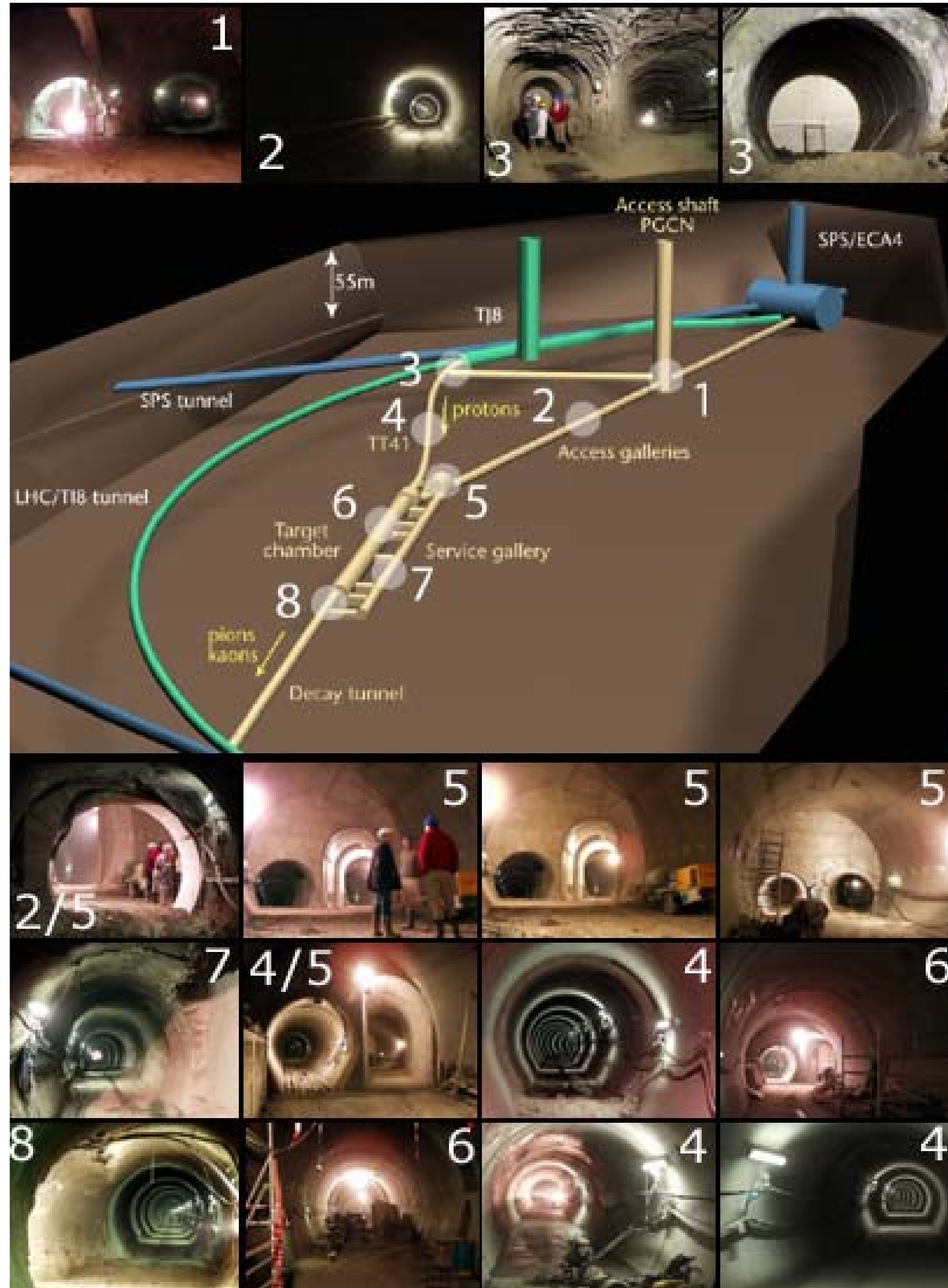
Beam Line
(April 03)

Inner Conductor of the Horn

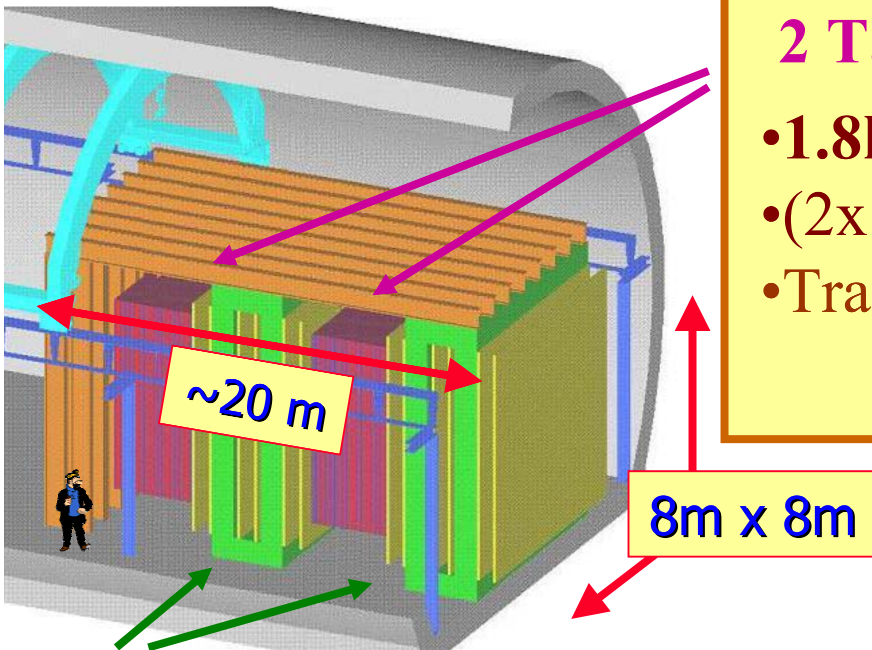
Horn June 2003 at LAL

Assembled with the Outer Conductor by end 2003 at LAL

The beam will start on spring 2006



Experiment layout at Gran Sasso



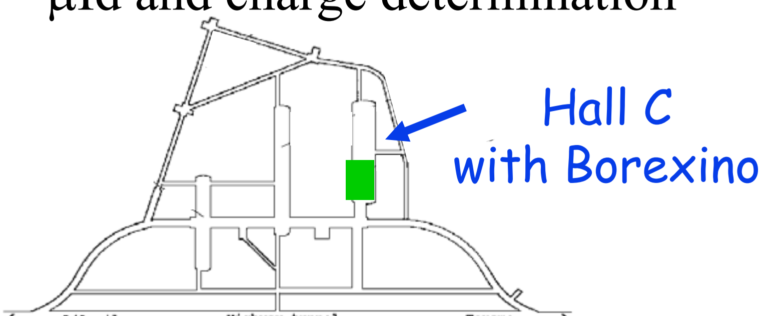
2 Targets:

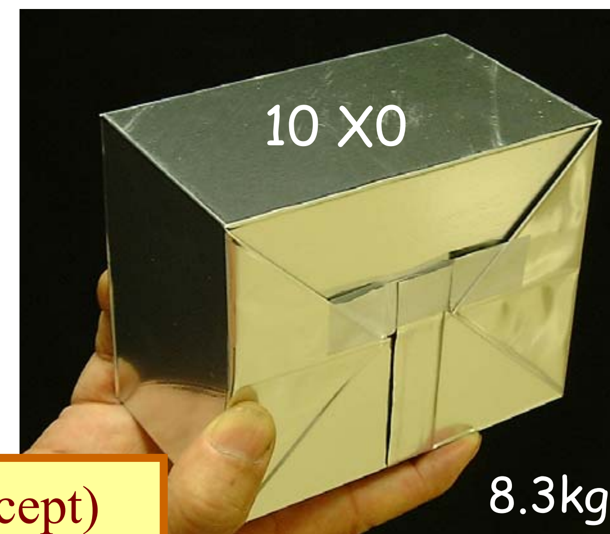
- **1.8kT** of **206 000 bricks**
- (2x 31 walls)
- Tracker in Plastic Scintillators

Trigger + Brick location + μId

2 Spectrometers: Dipole 1,6T
+RPC & Precision Trackers

μId and charge determination



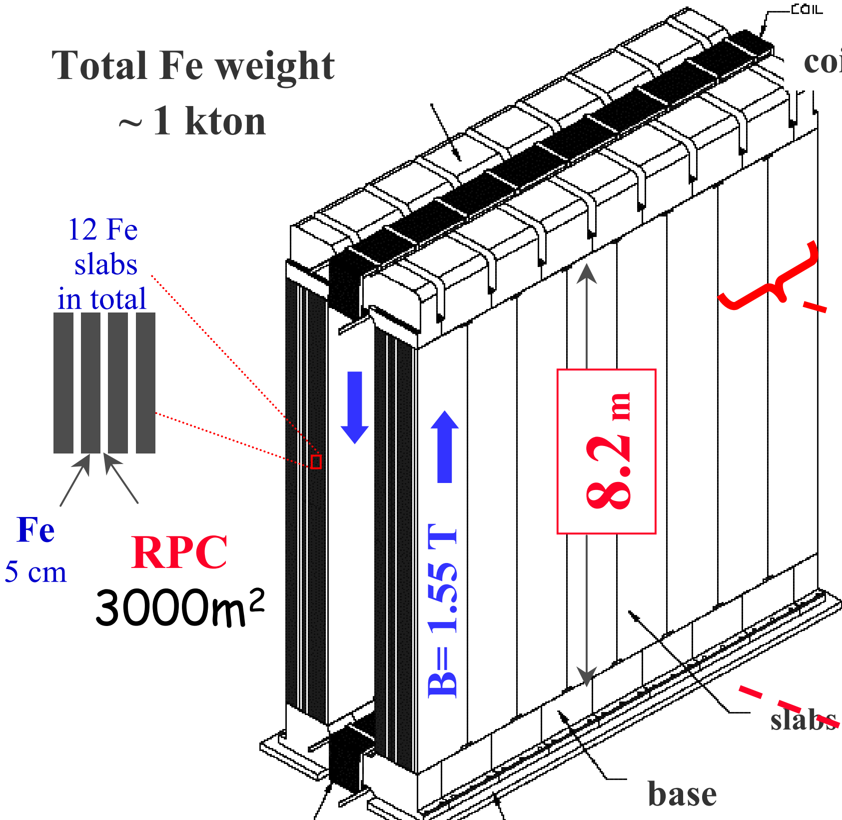


A brick (ECC concept)
56 Pb sheets 1mm
57 Fuji emulsion films
+1 Changeable Sheet

Dipolar magnet

{ *RPCs inside gaps: __muon identification__ , shower energy*
Drift Tubes: muon momentum

Total Fe weight ~ 1 kton



Full scale prototype magnet
Constructed and tested at **Frascati**

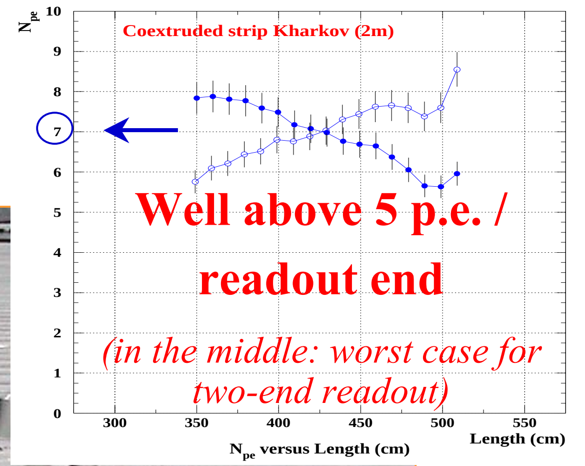
MDT prototype at Hamburg

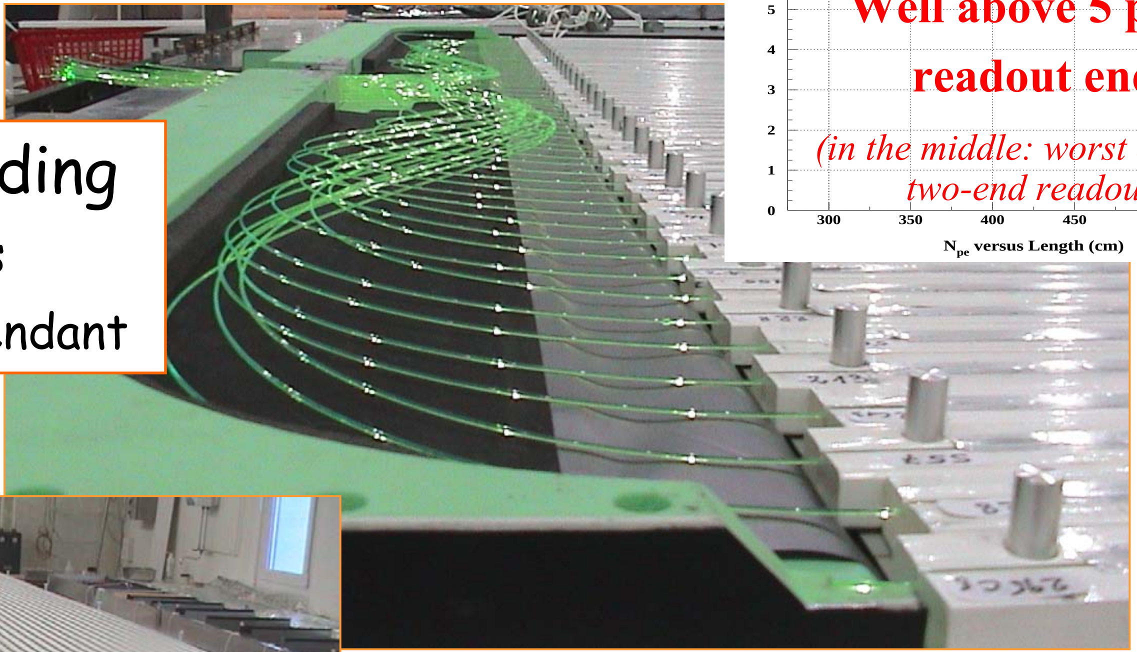
$$\varepsilon_{charge}^{miss} \approx (0.1 \div 0.3)\%$$

µId > 95% (with Target Tracker)

Hall C Gran Sasso May 03

Target Tracker
(assembly at Strasbourg)

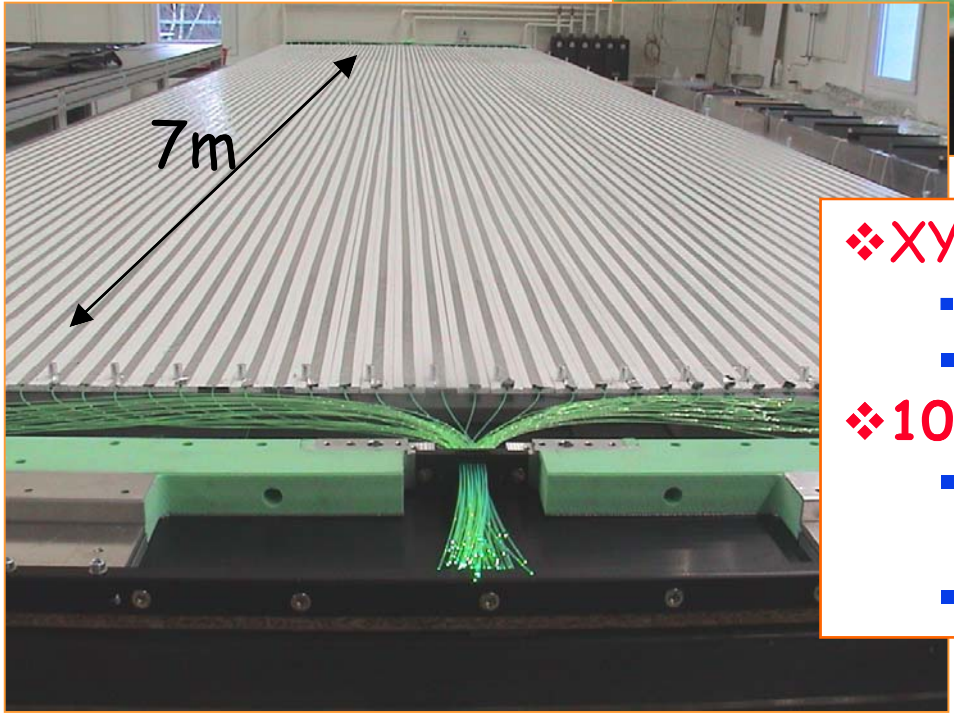




Trigger + Brick Finding

$\varepsilon_{trig} > 99\ \%$ all channels

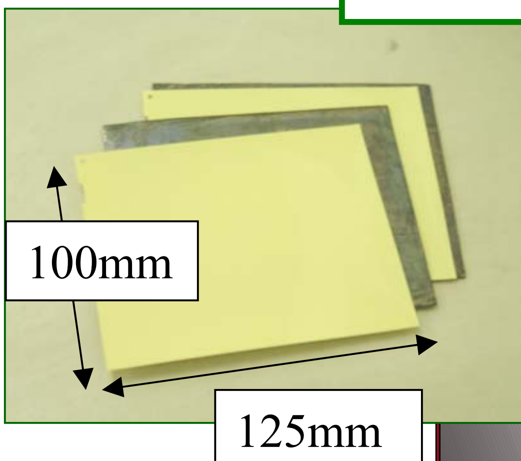
$\varepsilon_{BF} \sim 70\%$ channel dependant

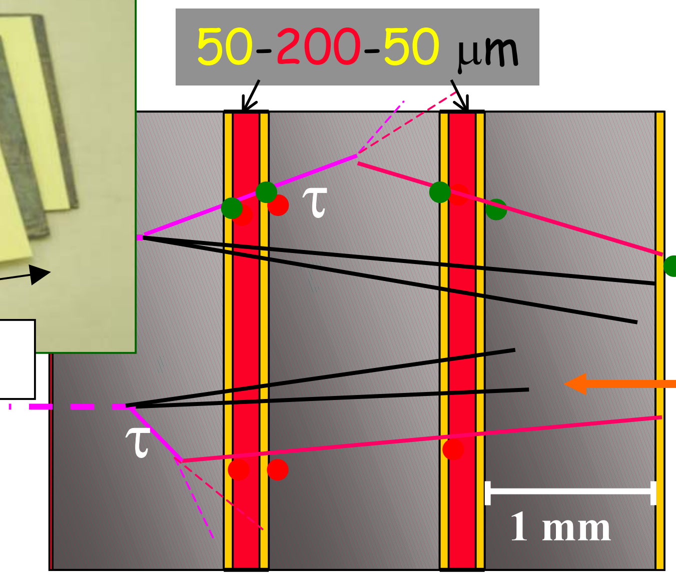


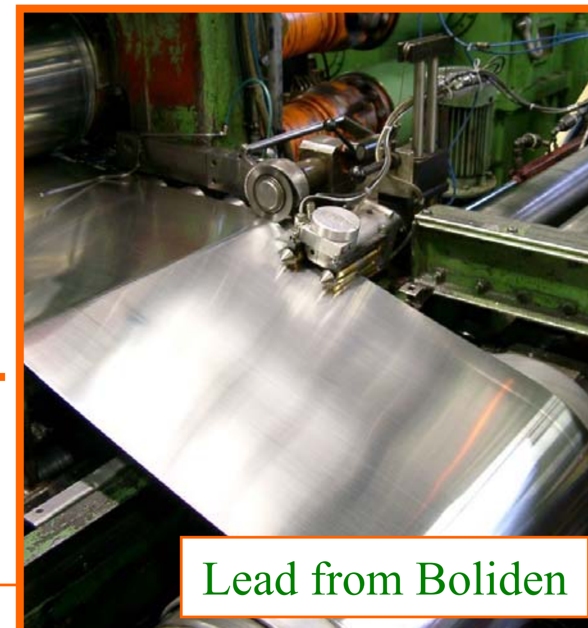
- XY planes, 7000m^2 in total
  - 32256 Scintillator strips 7m x 2.5cm x1cm
  - AMCRYS-H (Kharkov) + Kuraray WLS
- **1000 MaPMT Hamamatsu 64channels**
  - Dedicated Front End electronics for gain correction
  - Autotriggerable and threshold @ 1/5 p.e

Fuji Emulsion & Lead Production

Mass production starts April 2003 (~150 000 m²)
Refreshing done in the Tono Mine in Japan : 2 years duration
One batch sent to LNGS every 2 months starting august 2003
→ emulsion storage ready @ LNGS (Hall B) june 2003





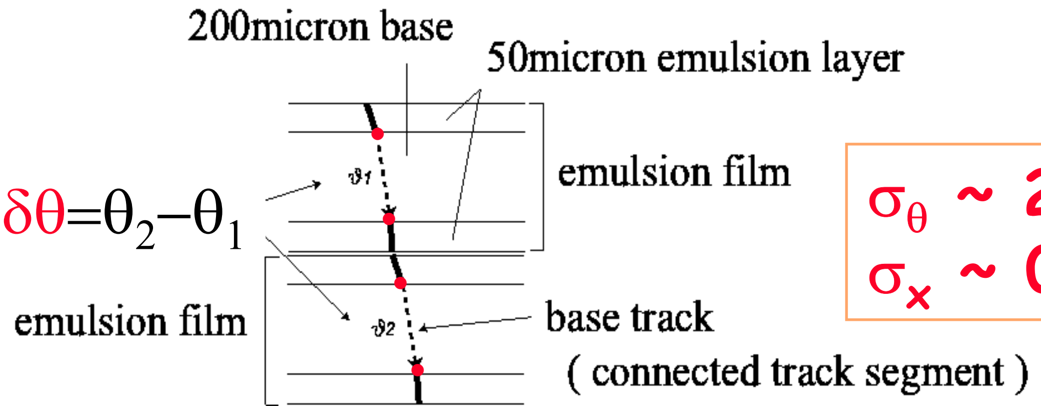


Pb +0.7 % Ca (1mm thick @ 10μm)
ready for prototype mass production in Goslar (Germany)

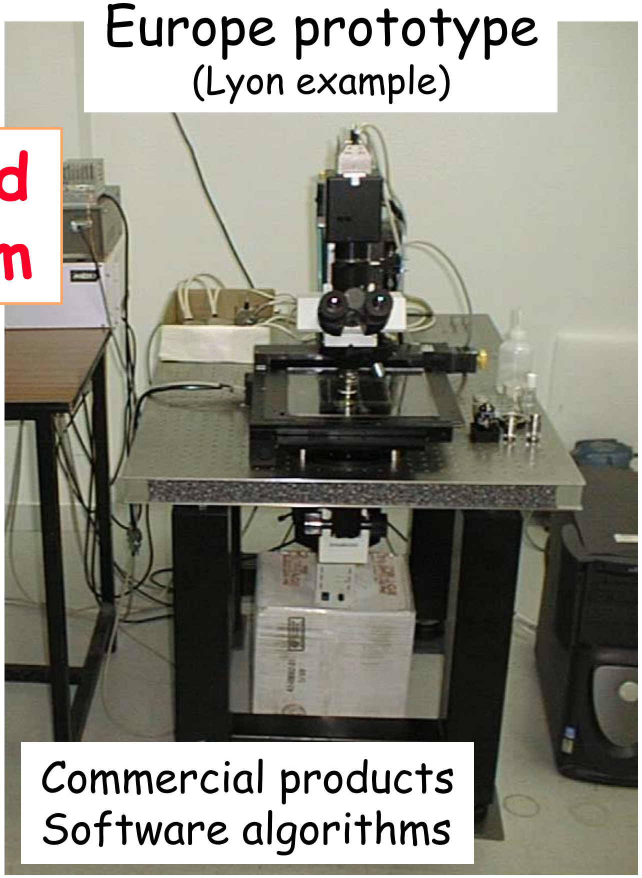
(~10⁷ plates to be produced at the end)

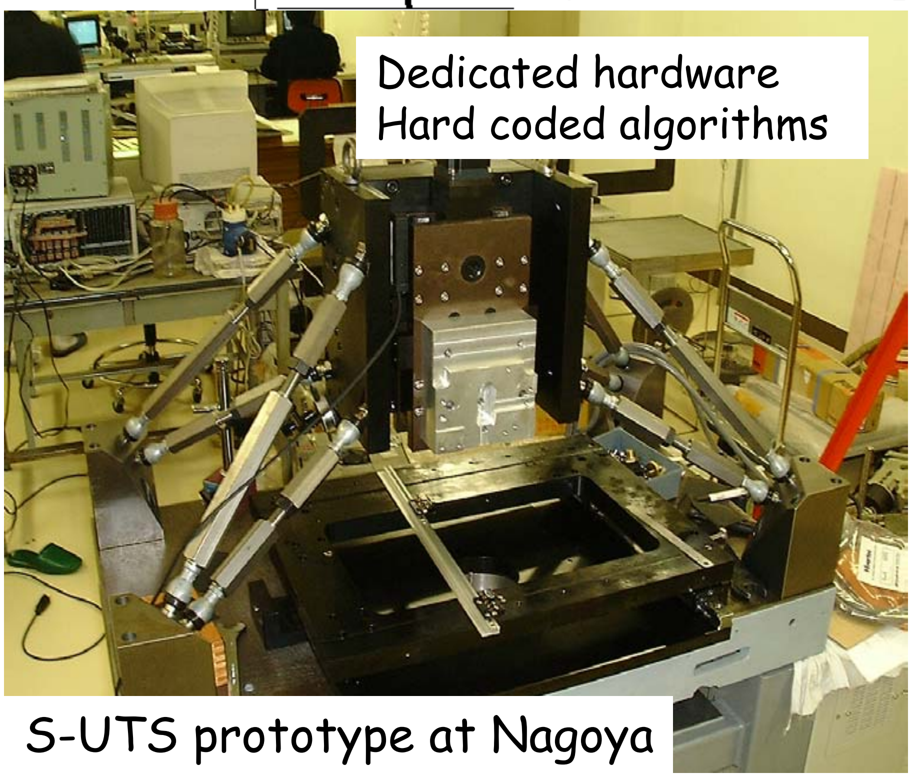
Automatic Scanning
Nagoya and Europe R&D efforts

Bari, Bern, Bologna, Lyon, Münster, Napoli, Roma, Salerno



σ_θ ~ 2mrad
σ_x ~ 0.3μm





Routine ≥ 1cm^2/hr
Near future ≥ 20cm^2/hr

ν_μ->ν_τ search

Expected number of ν_τ events $\tau \to e$, $\tau \to \mu$ and $\tau \to h$

- full mixing
- 5 years run at 6.76×10^{19} pot / year

Δm^2 ($\times 10^{-3} eV^2$)	signal 1.8	signal 2.5	signal 4.0	Back
Final Design	9.0	17.2	43.8	1.06*
With possible improvements**	10.3	19.8	50.4	0.67

Aim at the evidence of ν_τ appearance after a few years of data taking

* : 40% from charm

**: Changeable Sheet (+15% eff.), dE/dx (charm reduction by 40%)

Probability of ≥ nσ significance for different Δm^2

$\Delta m^2 (eV^2)$	3 years* (20.3×10^{19} pot)		5 years* (33.8×10^{19} pot)	
	$P_{3\sigma}$(%)	$P_{4\sigma}$	$P_{3\sigma}$(%)	$P_{4\sigma}$
1.8×10^{-3}	77.2(91.1)	46.8(68.2)	97.2(99.5)	87.4(96.2)
2.2×10^{-3}	94.9(98.9)	80.5(93.0)	99.9(100)	99.0(99.9)
2.5×10^{-3}	98.9(99.9)	93.9(98.6)	100(100)	99.9(100)
3.0×10^{-3}	100	99.6(100)	100	100
4.0×10^{-3}	100	100	100	100

The number in parenthesis are obtained assuming possible improvements

*: x 1.5 from original design ⇒ $6.76 \; 10^{19}$ pot/yr

ν_μ->ν_e search

Electron identification and Energy measurement

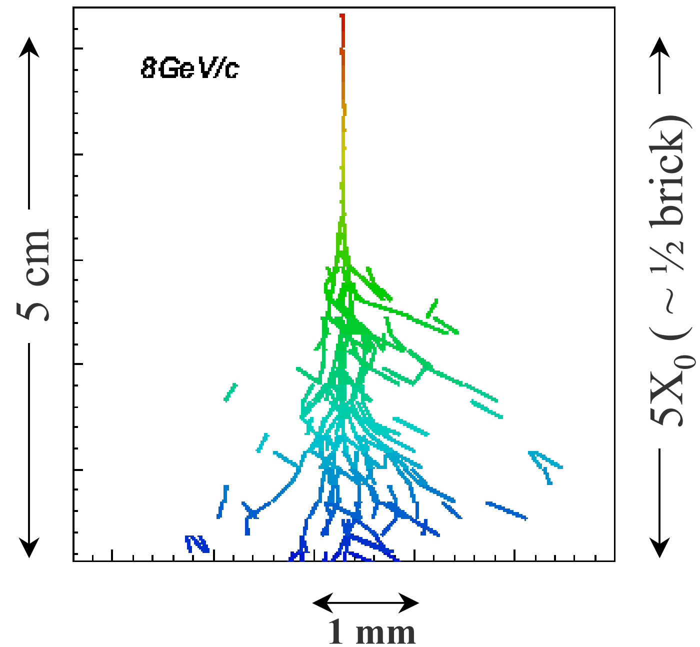
Identification

Method based on shower identification and on Multiple Coulomb Scattering of the track before showering

e/π ratio is measured with Cerenkov and ECC **(test beam)**

- ECC 1.42±0.17 Cerenkov 1.46±0.11 at 2GeV
- ECC 0.41±0.05 Cerenkov 0.32±0.03 at 4GeV

$\varepsilon \sim 90\%$, $P(\pi \rightarrow e) \sim 5\%$ (high track density)



Energy

Measured by counting the number of track segments into a cone along the electron track

Multiple Coulomb Scattering before showering

$$\frac{\Delta E}{E} \sim \frac{0.4}{\sqrt{E(GeV)}}$$

@ a few GeV **(test beam)**

Expected signal and background for the $\nu_\mu \rightarrow \nu_e$ search

$\Delta^2 m_{23} = 2.5\ 10^{-3}\ eV^2$, $\theta_{23} = 45°$

Θ_{13}	signal	$\tau \rightarrow e$	$\nu_\mu CC$	$\nu_\mu NC$	$\nu_e CC$ beam
9°	9.3	4.5	1.0	5.2	18
7°	5.8	4.6	1.0	5.2	18
3°	1.2	4.7	1.0	5.2	18
ε	0.31	0.032	$0.34\ 10^{-4}$	$7.0\ 10^{-4}$	0.082

1.65kT mean mass/5yrs @ $4.5\ 10^{19}$ pot/yr

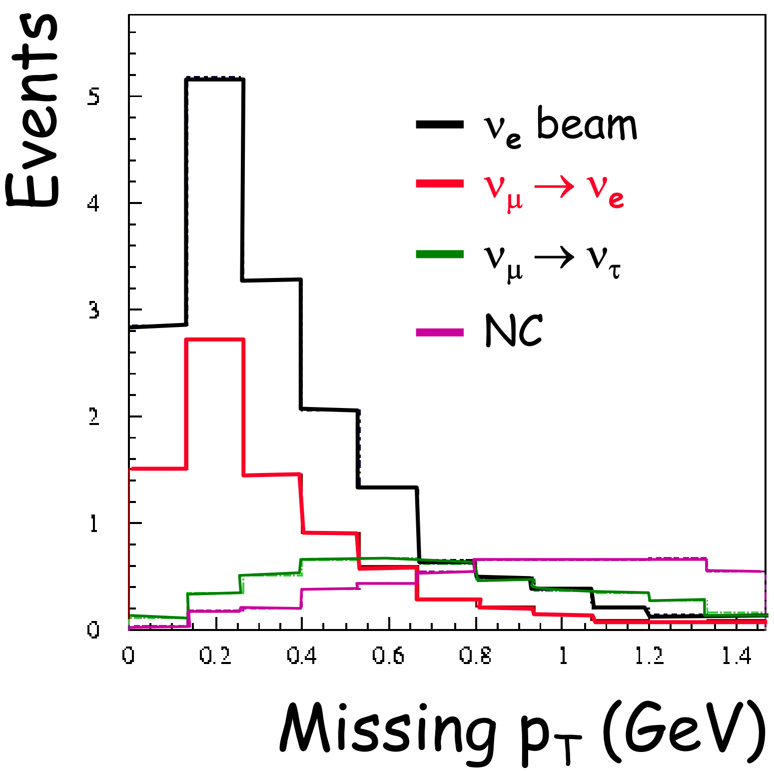
$P(\pi \rightarrow e)$~few ‰ (MC + NN analysis) thanks to low track density in OPERA

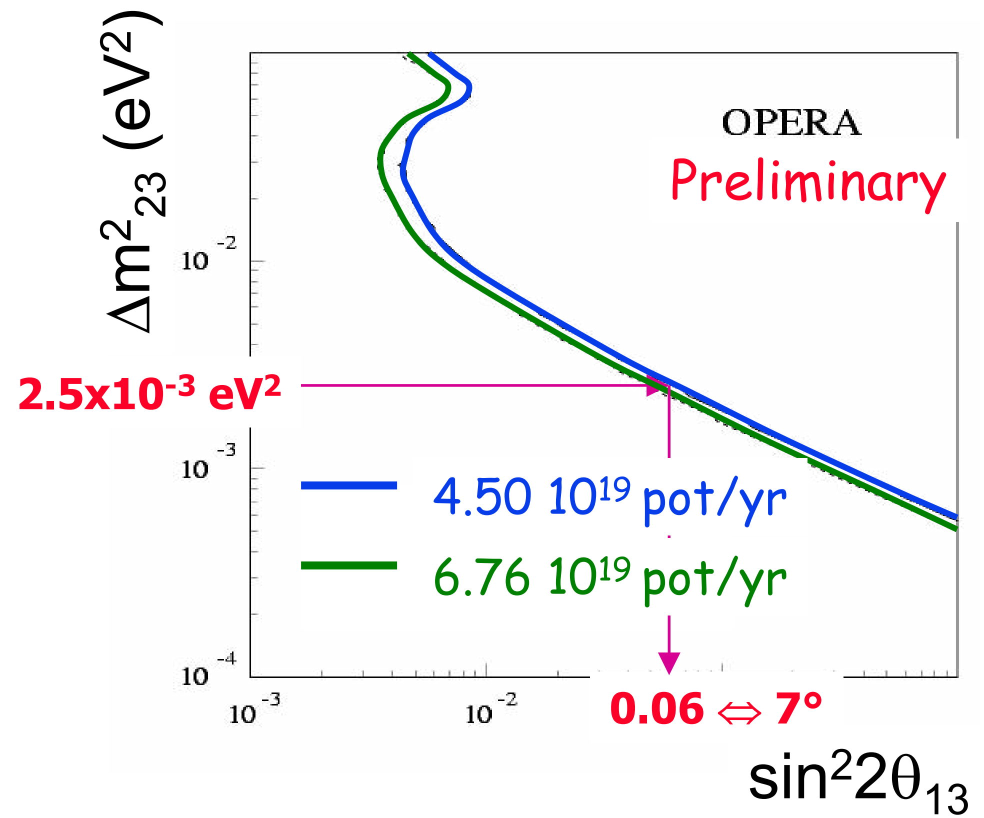
Sensitivity limited by the statistics on $\nu_e CC$

OPERA sensitivity to θ_{13} (5 yrs)

By fitting simultaneously the E_e, missing p_T and E_{vis} distributions we got the sensitivity at 90%

Only 15% increase scanning because the event location is already performed for ν_τ search.

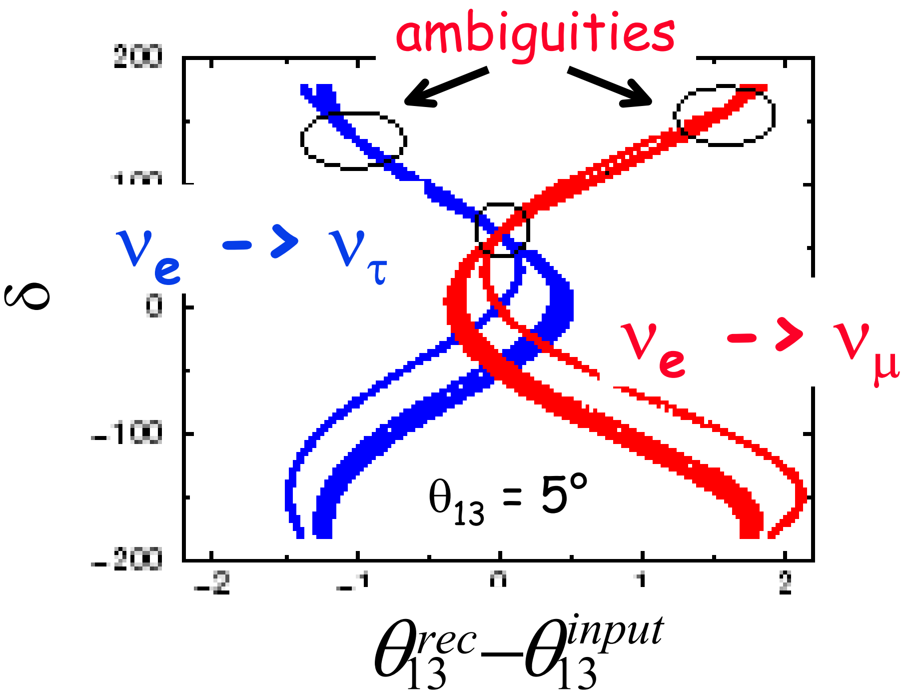


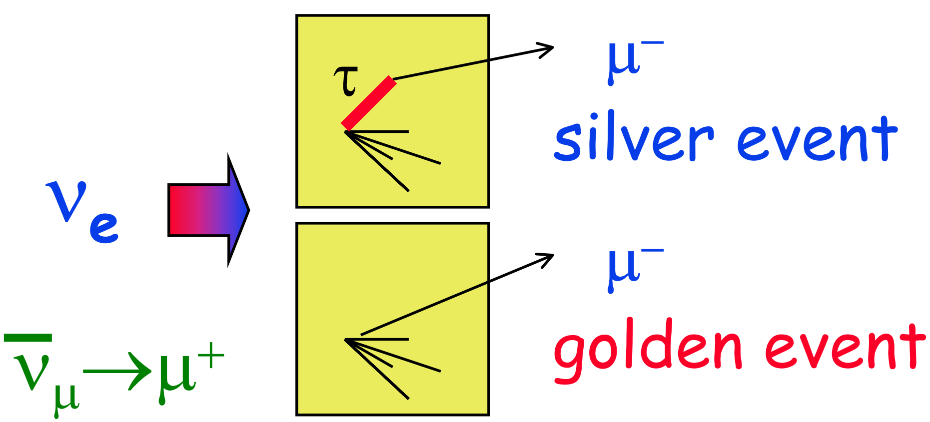


syst. on the ν_e contamination up to 10%

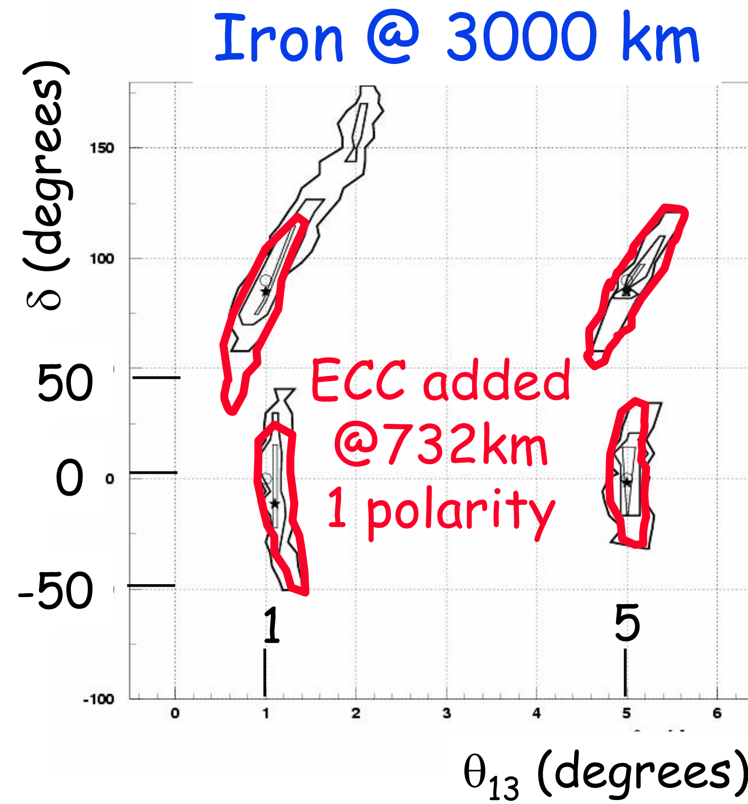
$\nu_e \rightarrow \nu_\tau$ search for future…

Combining ECC 5kT @ 732km and Iron 40kT @ 3000km





P. Migliozzi @ NuFact 03
D. Autiero et al. hep-ph/0305185



No clone regions for θ_{13}>1°

Summary about the OPERA physics program

- ν_τ appearance still an important missing piece of the neutrino oscillation puzzle for the atmospheric sector: OPERA is designed to answer.

- the CNGS program will provide significant data on θ_{13} before dedicated experiments (even if optimised for ν_τ appearance)

- $\nu_e \to \nu_\tau$ oscillations searches may alleviate ambiguities of golden event analysis for future (θ_{13}, δ) determination

We are ready in 2006
Waiting for the beam