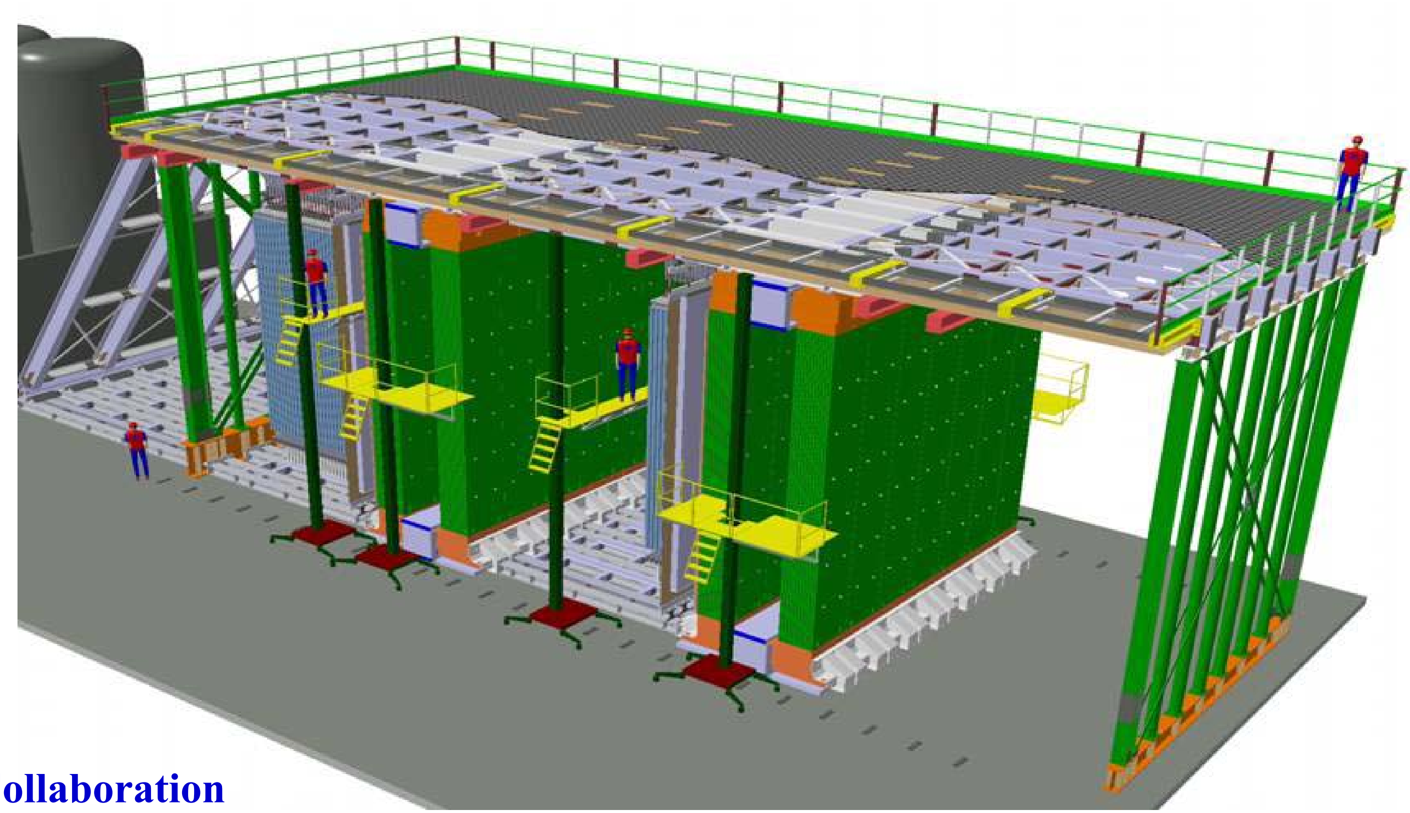
Villars Meeting
Status of OPERA/CNGS1
September 23th , 2004

1. News on experiment installation
2. Answer to SPSC worries
3. FAQ on physics performances
4. Recall of physics performances
5. Conclusions



Yves Déclais
on behalf of the OPERA Collaboration

Milestones

Achieved :

- Refreshing facility installed
- First magnet completed
- Brick packaging decision
- BAM ordering
- Scanning speed 20cm^2/h

→ **SPSC, July 04**

Next Milestones

1. Target installation commissioning: sep 04
2. Emulsion delivery @ LNGS : oct 04
3. BMS automation validation : dec 04
4. BAM commissioning @ factory : feb 05
5. Start brick filling : sep 05

→ **In progress**

→ **On schedule**
First shipment will leave Japan in october

OPERA in Hall C : end of june 04

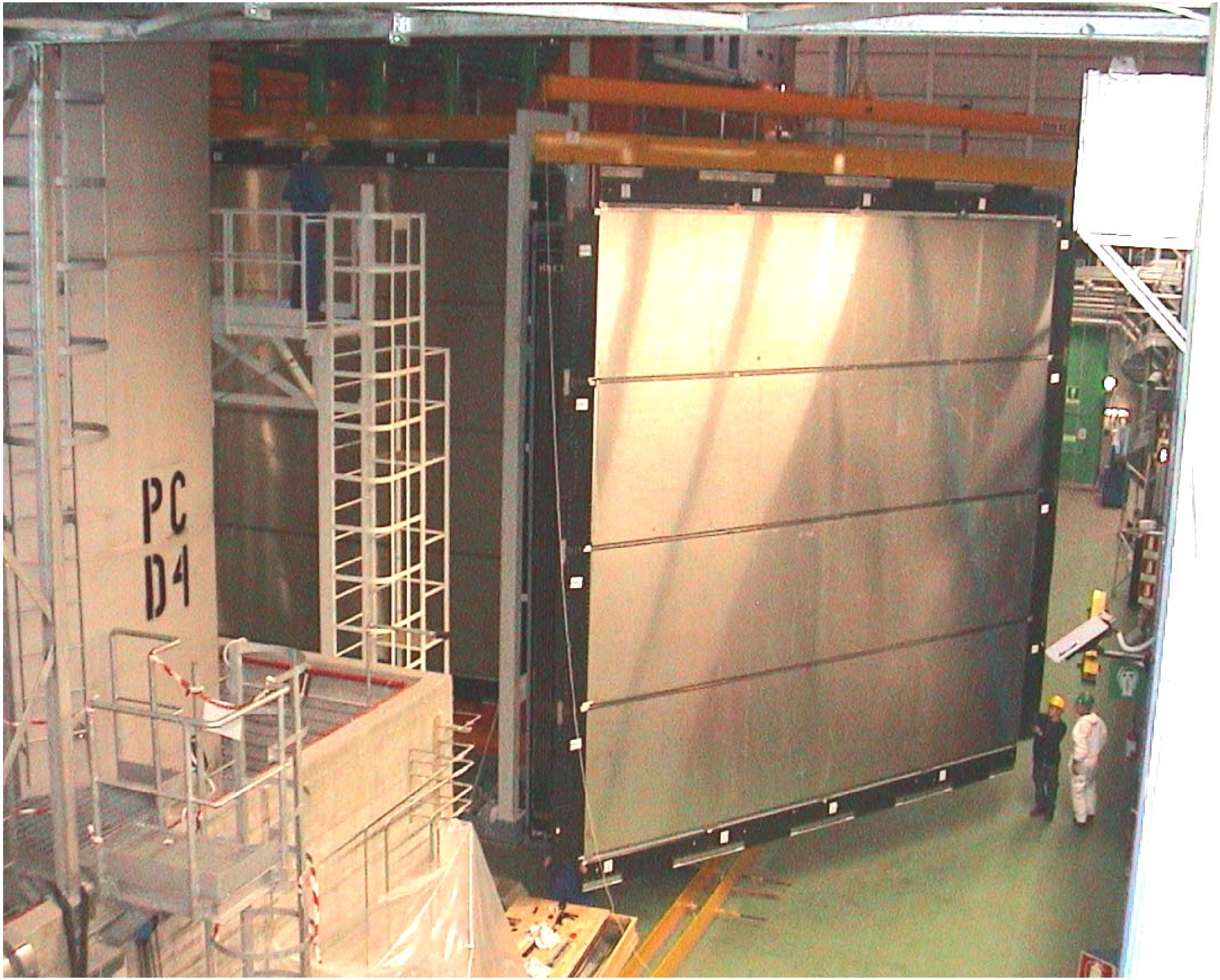
Hall C

end of august 04

- SM1 mechanical structure : july 04
- Rails alignment : august 04
- TT modules delivery : august 04
- Magnet 2 installation resumed : sept 04

Target Tracker : plane assembly @LNGS

Target Tracker : plane handling @LNGS



Target Tracker : plane storage @LNGS

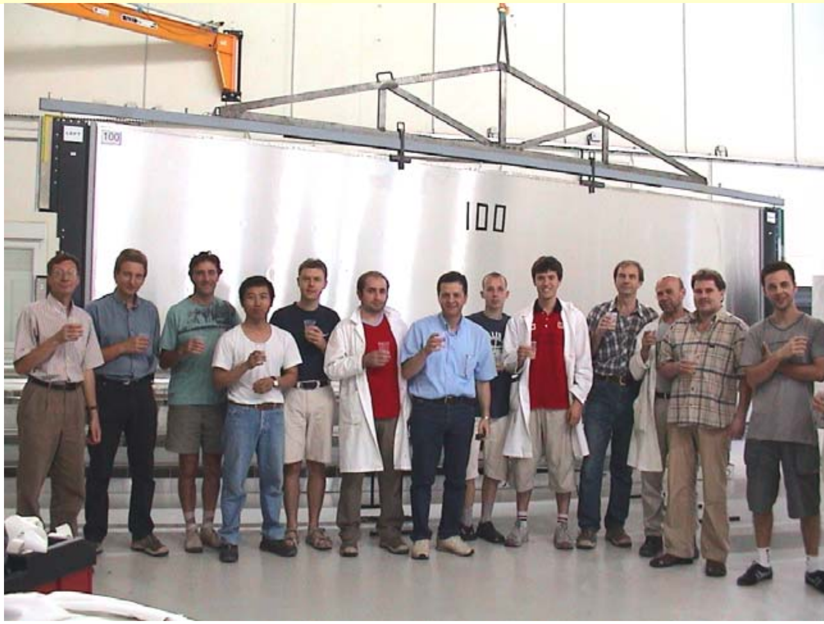
Target Tracker : plane insertion (a)

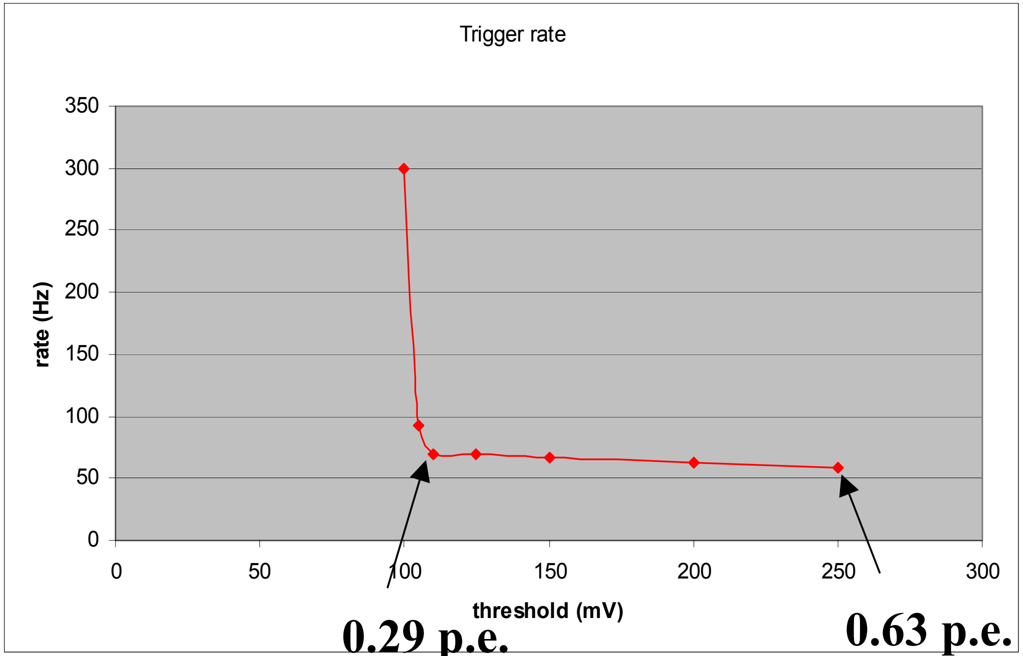
Target Tracker : plane insertion (b)

Target Tracker : plane insertion (c)

Target Tracker : summary

- **modules production on schedule :**
  > 100 produced (20%)
- **quality control being optimised**
- **commissioning of the electronics**
  and DAQ @LNGS in progress

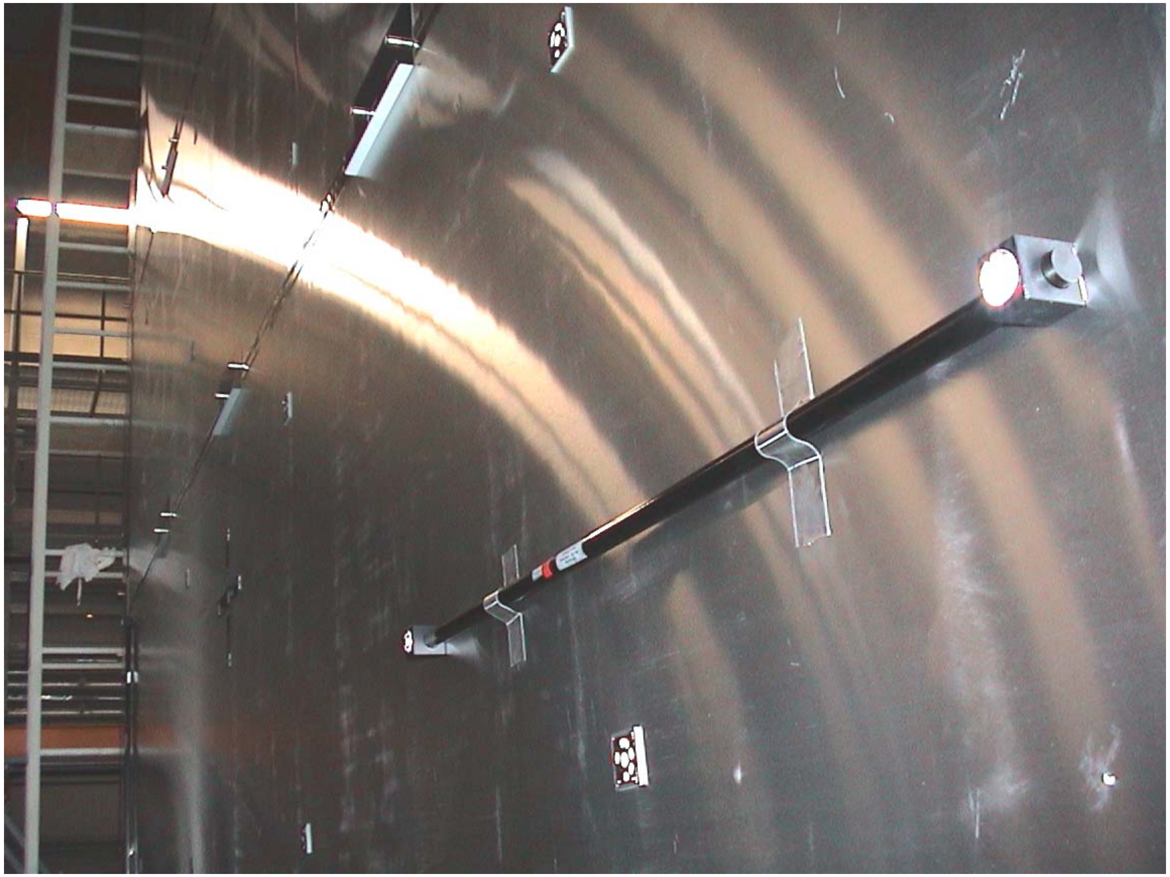




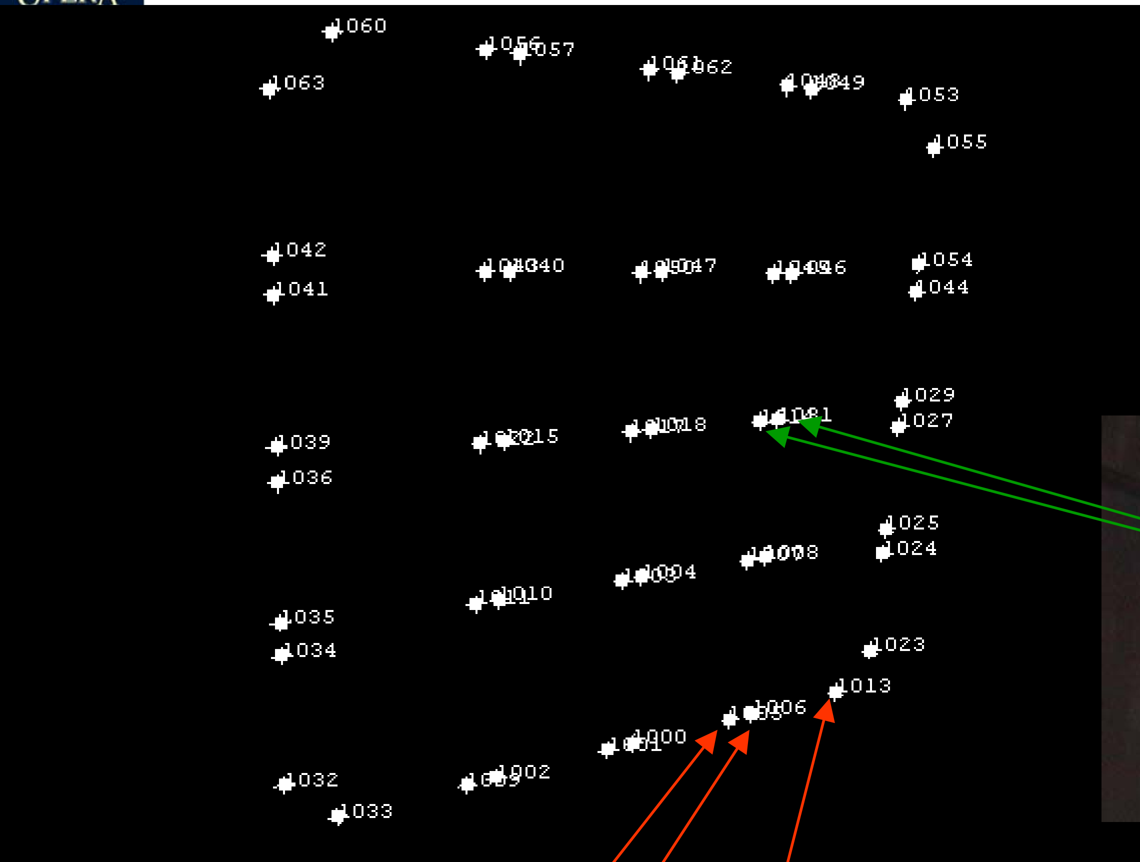
Photogrammetry available at LNGS

First photogrammetric survey (13/9/04)

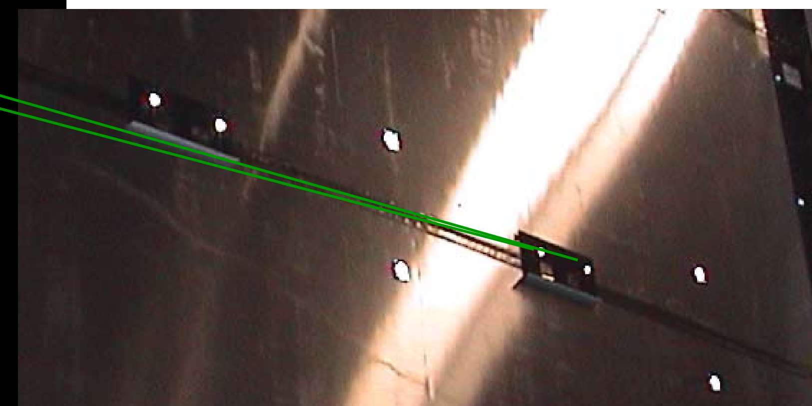
- LNGS staff trained by CERN experts
- LNGS equipment



3D representation of the reference points



Reference points
on the croisillions
2 points/croisillion
18 points in total



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

Brick wall : production machinery (a)

Brick wall : production machinery (b)

Brick Wall : production

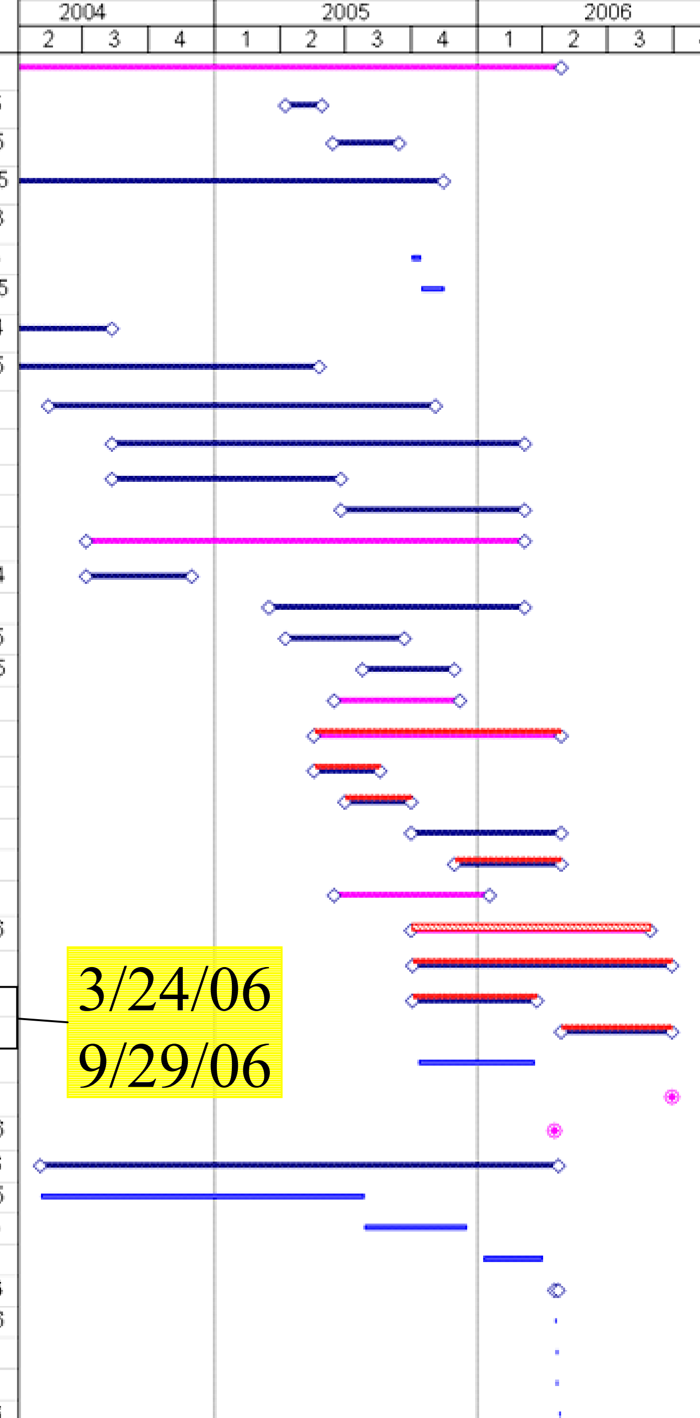
Tendering (start)	MAY 2003
Tendering (end)	OCT 2003
Production contracts signed	JAN 2004
First wall prototype built	JUL 2004
First wall delivered at LNGS	OCT 2004
Last wall delivered at LNGS	JUN → DEC 2005

Turnbuckles (commercial parts)	✓ @ LNGS
Columns, Brackets, Pins, Bottom Rails (COMIT)	✓ @ LNGS
Isertion tool (LNF)	✓ @ LNGS
Bolts (commercial parts)	✓ @ LNGS
Top Rails (CECOM, LMM)	✓ @ LNGS

Reference marks positioning (for alignment)	✓ JUNE 2004
Rails installation/alignement 1st SM	✓ AUGUST 2004
Walls installation/alignement 1st SM	OCT 04 → JUN 05
Rails installation/alignement 2nd SM	JUN/JUL 2005
Walls installation/alignement 2nd SM	JUL 05 → FEB 06

General Planning

ID	Task Name	Duration	Start	Finish
226	INSTALLATION IN GS EXPERIMENT HALL C	153.83 w	Mon 2/10/03	Thu 4/27/06
227	C R & ELECTRONIC ROOM	7 w	Fri 4/8/05	Mon 5/30/05
233	BAM	13 w	Mon 6/13/05	Wed 9/14/05
237	SPECTROMETERS (2 MAGNETS & RPC's)	134.03 w	Mon 2/10/03	Mon 11/14/05
238	Preliminary working	15 w	Mon 2/10/03	Wed 5/28/03
239	Veto plane mechanics	2 w	Fri 9/30/05	Fri 10/14/05
240	Veto plane detector	4 w	Fri 10/14/05	Mon 11/14/05
241	Magnet 1	58.35 w	Fri 5/30/03	Wed 8/11/04
274	Magnet 2	95.15 w	Fri 5/30/03	Wed 5/25/05
311	TARGET TRACKERS MOUNTING	72 w	Fri 5/14/04	Fri 11/4/05
330	TARGET WALLS	73.94 w	Wed 8/11/04	Tue 3/7/06
331	SM1	41.18 w	Wed 8/11/04	Fri 6/24/05
410	SM2	32.76 w	Fri 6/24/05	Tue 3/7/06
489	XPC's & PRECISION TRACKERS	79.34 w	Mon 7/5/04	Tue 3/7/06
490	XPC 1	20.88 w	Mon 7/5/04	Tue 11/30/04
496	Precision tracker 1	46.24 w	Wed 3/16/05	Tue 3/7/06
529	XPC 2	23.05 w	Fri 4/8/05	Wed 9/21/05
535	Precision tracker 2	18 w	Mon 7/25/05	Tue 11/29/05
568	CABLING (detector to control room)	24.35 w	Wed 6/15/05	Tue 12/6/05
571	MANIPULATORS	44.8 w	Wed 5/18/05	Thu 4/27/06
572	SM1 cavern side	13 w	Wed 5/18/05	Fri 8/19/05
578	SM1 corridor side	13 w	Thu 6/30/05	Fri 9/30/05
585	SM2 cavern side	25.8 w	Fri 9/30/05	Thu 4/27/06
589	SM2 corridor side	17.43 w	Wed 11/30/05	Thu 4/27/06
594	COMMISSIONNING WITHOUT BRICKS	27.35 w	Wed 6/15/05	Tue 1/17/06
597	ECC BRICK MANUFACTURING WITH BAM	43 w	Fri 9/30/05	Wed 8/30/06
599	WALL BRICK FILLING (2b/min 8h/day)=960 bricks)	47.2 w	Mon 10/3/05	Fri 9/29/06
600	SM1 brick filling	21.6 w	Mon 10/3/05	Fri 3/24/06
602	SM2 brick filling	21.6 w	Thu 4/27/06	Fri 9/29/06
604	COSMIC DATA TAKING WITH BRICKS	20 w	Mon 10/10/05	Tue 3/21/06
605	FULL DETECTOR COMPLETED	0 d	Fri 9/29/06	Fri 9/29/06
606	CNGS Beam delivery	0 d	Wed 4/19/06	Wed 4/19/06
607	OPERA RUNNING	94.6 w	Mon 5/3/04	Mon 4/24/06
608	OPERA LNGS external building	60 w	Mon 5/3/04	Wed 7/27/05
609	Emulsion processing laboratory	20 w	Thu 7/28/05	Fri 12/16/05
610	Processing tests	12 w	Mon 1/9/06	Fri 3/31/06
611	OPERA brick processing cycle	0.8 w	Wed 4/19/06	Mon 4/24/06
612	First brick extraction	1 d	Wed 4/19/06	Wed 4/19/06
613	Brick cosmic rays exposure	1 d	Thu 4/20/06	Thu 4/20/06
614	Emulsion development	1 d	Fri 4/21/06	Fri 4/21/06
615	Emulsion shipping to scanning labs	1 d	Mon 4/24/06	Mon 4/24/06



Summary on experiment installation

- OPERA installation is sticking to the schedule

- Work in Hall C will slow down for 3 weeks for safety work
  this time will be used for completing
  the commissioning of the target installation
  without changing the overall schedule

- Interference with BOREXINO still a big worry for OPERA
  - PC loading station operating in Hall C
  - OPERA isolation of PC leakage from BOREXINO
  - independant fire extinguishing system
  $\Rightarrow$ under study by LNGS management

SPSC worries

In view of the experiment schedule
and its importance for the future competitivness of the experiment,
the SPSC voiced concern
about the recent change of the brick design,
about the timely start of brick series production,
And about the funding of the second tracker station.

about brick packaging

- **brick packaging decision:**

The strategy followed by the collaboration has been to gather as much as possible experience and results on both solutions (vacuum and mechanical packaging) and to take the decision at the latest possible time taking into account the constraints related to the installation schedule of the experiment.
All results from long term stability tests and expertise from packaging experts was in favor of the mechanical packaging.
The use of emulsion films in OPERA is completely new with respect to previous experiments (use of industrial films, refreshing, 5 years life time, huge quantity to handle) so it was essential to study in details all aspects .

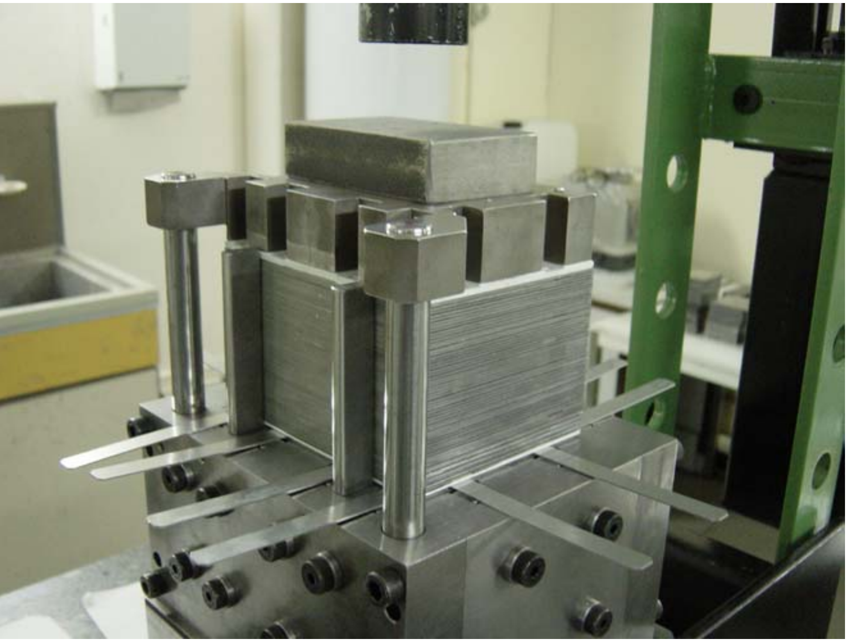
- **timely start of brick series production :**

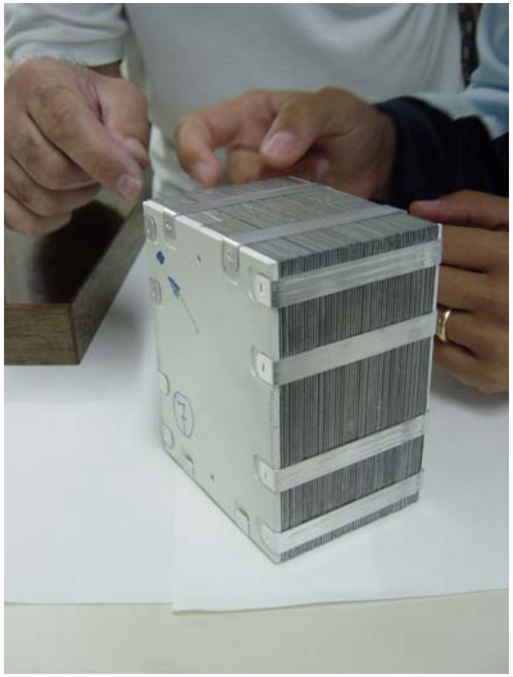
The industrial mass production of 200 000 bricks can be analysed by companies having a large experience in automatic industrial packaging, as soon as the choice of the packaging is defined and safe.
The technical specs has been studied in details with the help of specialised engineering offices and milestones defined by contract.

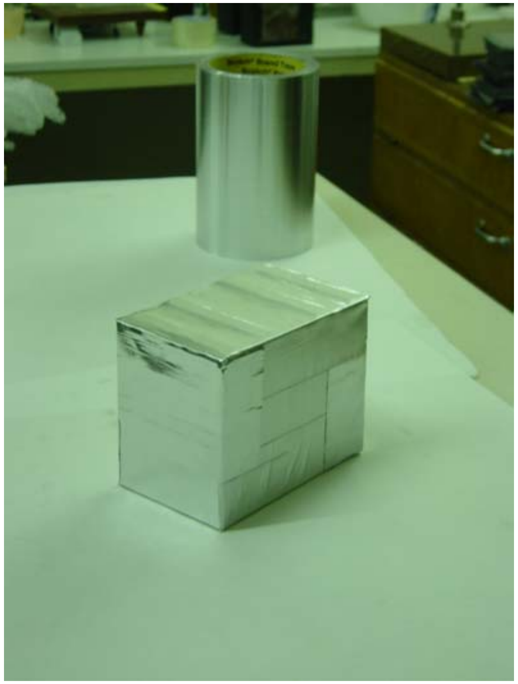
- **the BAM project is on schedule**

Packaging studies

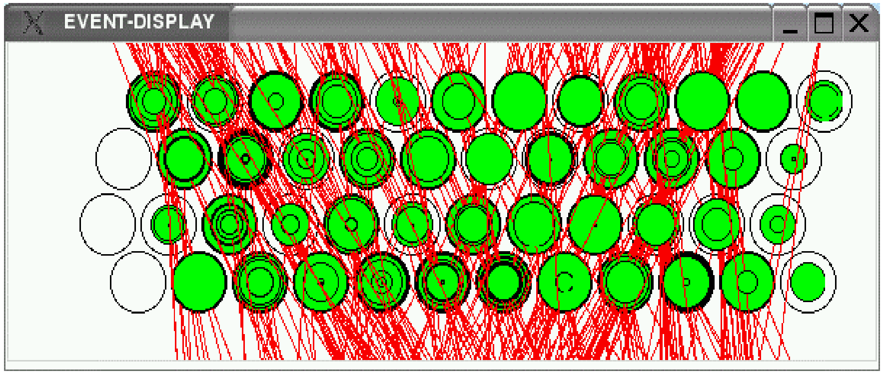
- final bricks have been successfully used in test beam
- mechanical properties measured and within specs
- optimisation in progress for automation







Precision Tracker status in Hamburg



•Strongly motivated group

Reinforced with 2 new PHD

• More support from Hamburg university

and BMBF still being negociated

- All electronics in mass production
- Test setup taking data for software validation
- Modules mass production on schedule : 20 in 2004 (96/SM)

Study in progress in order to minimise the effect of missing PT planes on the background during the first year of data taking (2006):

- **installing PT planes in the first part of the magnet**
- **using RPC**

this will provide the sign of the muon

How to check the decay detection efficiency?

Charm is a 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 the kinematical cuts? (I)

IN OPERA THE CRUCIAL TAG FOR A TAU CANDIDATE IS THE DETECTION OF A DECAY TOPOLOGY

- A minimum bias sample has to be carefully scanned in order to check the reliability of the Monte Carlo used to define the kinematical cuts in the hadronic channel
- NB The kinematical analysis in OPERA is not a crucial item, unlike in the NOMAD experiment (see Table)

	OPERA $\nu_\mu NC$	NOMAD $\nu_\mu NC$	OPERA $\tau \to h$	NOMAD $\tau \to h$
ε_{kin} @1^{ry} vtx	0.20	2.0×10^{-6}	0.65	0.021
P_t kink > 0.6 GeV/c	8.4×10^{-5}	-	0.28	-
Total	1.7×10^{-5}	2.0×10^{-6}	0.18	0.021

How to check the reliability of the kinematical cuts? (II)

- 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

Δm^2 versus YEAR

Atmospheric exps

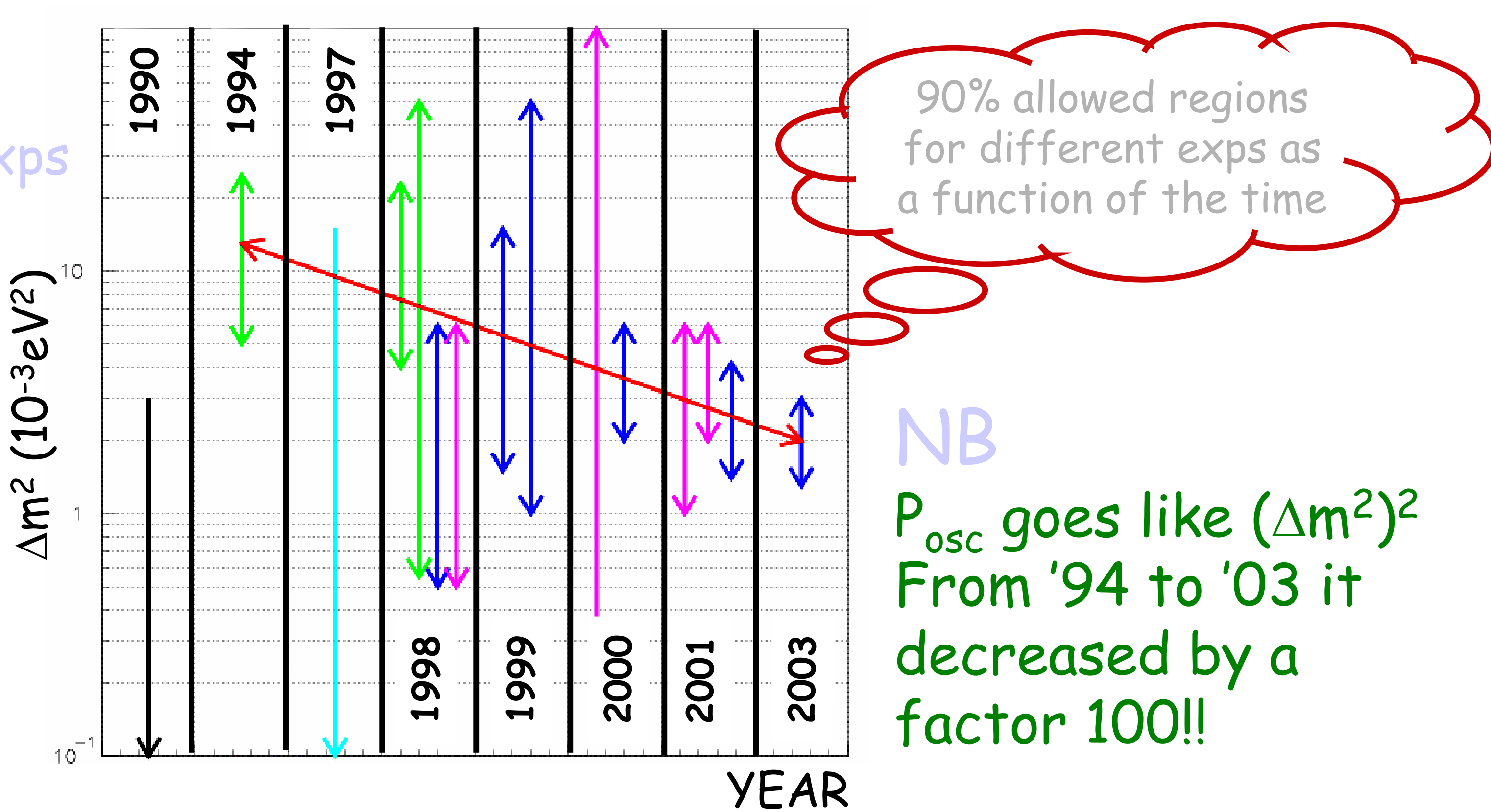
Frejus

Kamiokande

IMB

Super-K

Macro



NB

P_{osc} goes like $(\Delta m^2)^2$
From '94 to '03 it decreased by a factor 100!!

Very difficult the tuning at the atmospheric mass scale!

Impact both on $\nu_\mu \to \nu_\tau$ and $\nu_\mu \to \nu_e$ oscillation searches

τ detection efficiencies *(in % and including BR)*

Channels considered at the time of the CNGS approval in 1999 :

$\tau \rightarrow e$ (DIS+QE, long)	3.0
$\tau \rightarrow \mu$ (DIS+QE, long)	2.6
Overall efficiency	ε = 5.6

	DIS long	*QE long*	*DIS short*	*Overall**
$\tau \rightarrow e$	2.7	2.3	1.3	3.4
$\tau \rightarrow \mu$	2.4	2.5	0.7	2.8
$\tau \rightarrow h$	2.8	3.5	-	2.9
Total	8.0	8.3	1.3	9.1 % Eff * BR

* weighted sum on DIS and QE events

Improvements under study:

- use of a changeable sheet on the back side of the brick
- Brick finding strategy : +10% (does not change the signal/background ratio)
- channel $\tau \rightarrow 3$ prongs (1.0% eff, including BR 15%) : +10%

Efficiency for the: $\tau \to \mu$ channel

BR	Evt long	ε Localization	Kink+ kinematics	Id μ + ECC connection	Others
0.176	0.39	0.73	0.73	0.80	0.96 → 2.8%

6.8%

Application of the 3D chart

Additional fraction of extracted bricks

Extraction strategy:	$\tau \to \mu$	$\tau \to e$	$\tau \to h$	
Only the Highest Prob. Brick (HPB)	73.5%	75.4%	64.2%	
HPB + second most probable brick (SMPB) if P1-P2<0.1	+1.0%	+3.0%	+4.7%	→ 0.3%
HPB + SMPB if P1-P2<0.2	+2.0%	+5.0%	+6.9%	→ 0.4%
HPB + SMPB if P1-P2<0.3	+2.8%	+5.8%	+8.2%	→ 0.5%
HPB + SMPB (P2> 1%)	+8.1%	+9.7%	+12.0%	→ 1.2%
Sequential extraction of all the bricks in the list (with P>1%)	+9.6%	+12.0%	+16.1%	→ 1.9%

Net efficiency gain → +7.7% + 10.1 +14.2%

Minimal reduction of the target mass

Expected number of background events

(5 years run, nominal intensity)

(in red : possible improvements)	$\tau \to e$	$\tau \to \mu$	$\tau \to h$	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: cross section increased by 40%**
   - **πμ id by dE/dx would reduce this background by 40%**
     ⇒ being tested at KEK and this july 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**
     ⇒ will be measured in 2004 in 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%**

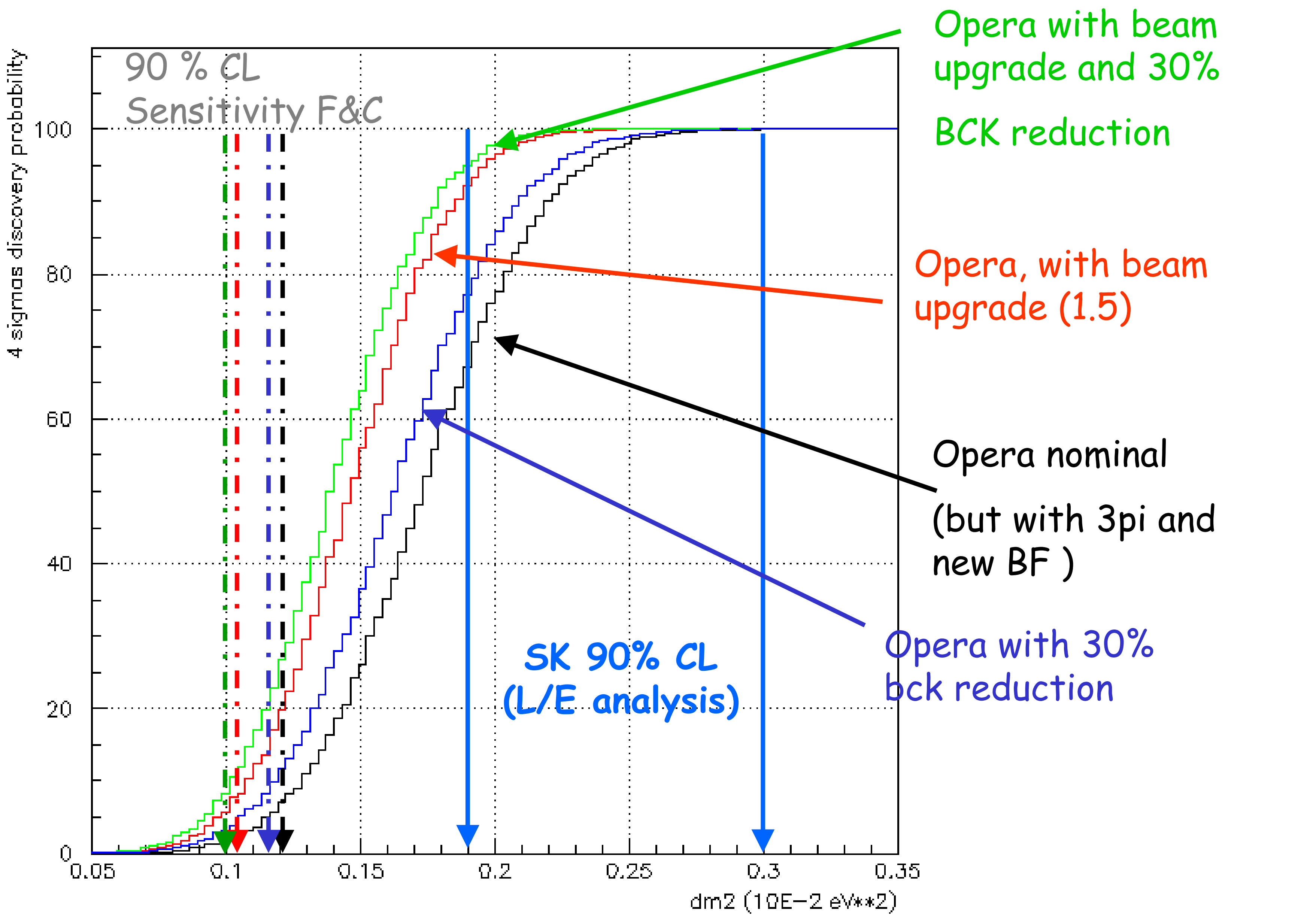
$\nu_\mu \rightarrow \nu_\tau$ sensitivity

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

	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
OPERA 1.8 kton fiducial	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)
Background reduction	8.0(12.1)	12.8(19.2)	19.9(29.9)	0.8(1.2)

(…) with CNGS beam upgrade (X 1.5)

4 σ discovery potential vs beam intensity



ν_μ->ν_e search with OPERA

Beam systematics

- We assumed a 5% error on the ν_e flux

  (see A. Guglielmi talk at NOW04 for details on the CNGS systematics)
- With the OPERA detector it is possible to (thanks to the spectrometer)
  - Measure the μ^- energy spectrum (at high-energy ν_μ from K^+ decays dominate)
  - Measure the μ^+ energy spectrum (anti- ν_μ from K^- decays dominate)
- Good samples (O(1Kevts)) to cross-check the beam simulation

- Given the small number of expected events in OPERA (see later) the sensitivity to θ_{13} is dominated by the statistical fluctuations of the background

  $\rightarrow$ more pots are needed!!!

$\nu_\mu \rightarrow \nu_e$: selection efficiencies

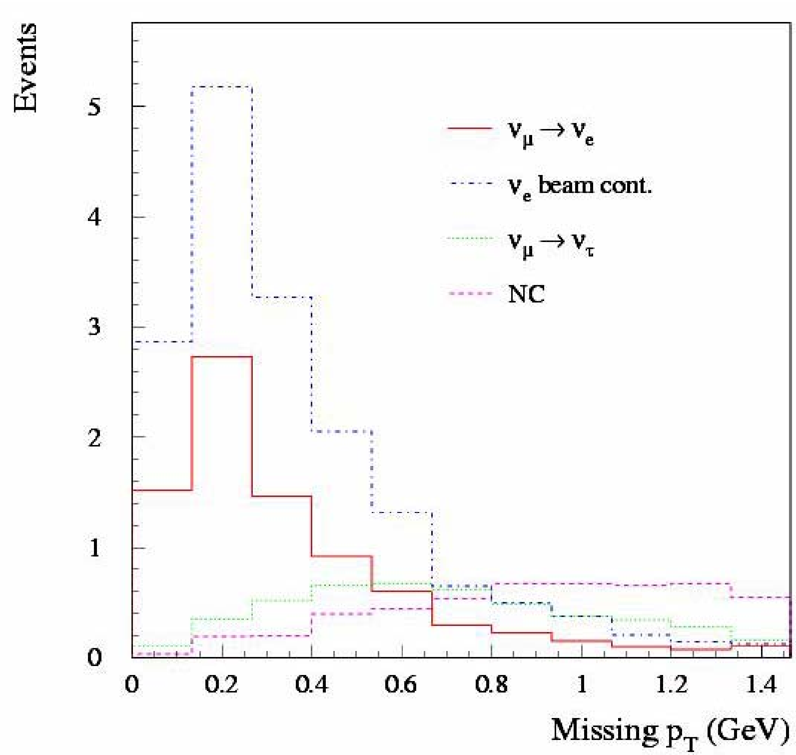
		signal	$\tau \rightarrow e$	ν_μCC	ν_μNC	ν_eCC beam
Location eff.	ξ	0.53	0.053	0.52	0.48	0.53
Total eff.	ε	0.31	0.032	0.34×10^{-4}	7.0×10^{-4}	0.082

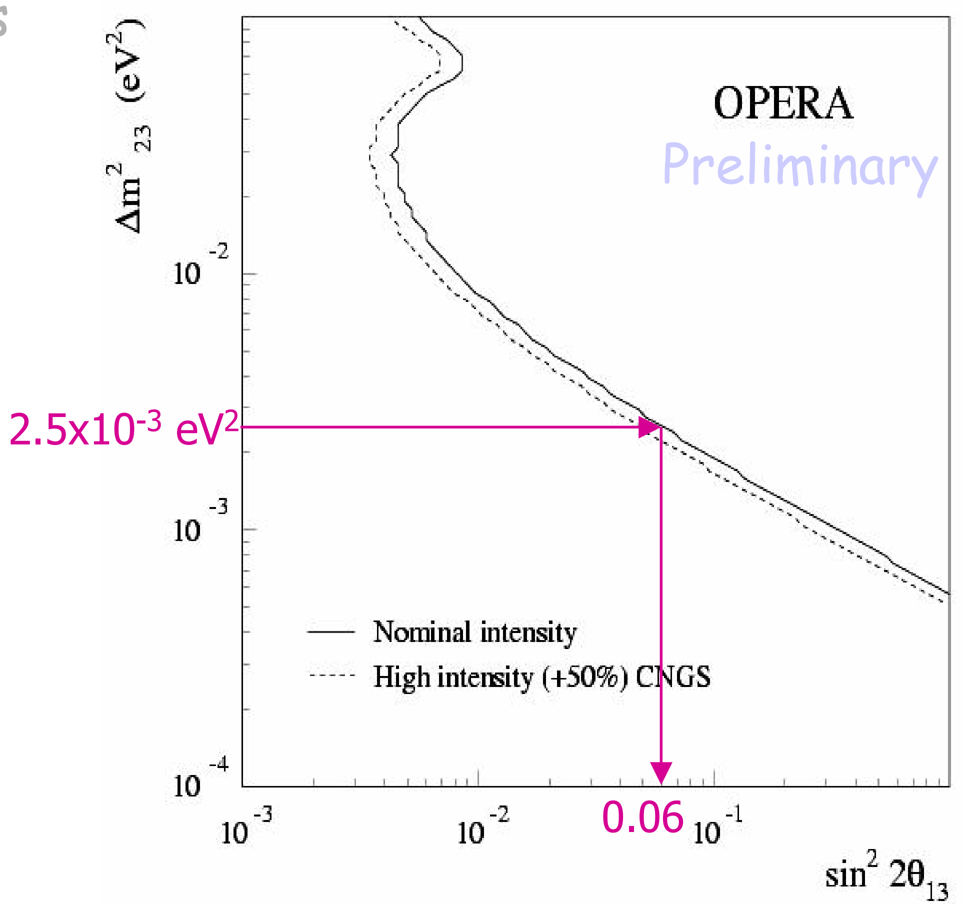
Expected signal and background assuming 5 years data taking with the nominal CNGS beam and $\Delta m^2_{23} = 2.5 \times 10^{-3}$ eV^2, $\sin^2 2\theta_{23} = 1$

θ_{13}	signal	$\tau \rightarrow e$	ν_μCC	ν_μNC	ν_eCC beam
9°	9.3	4.5	1.0	5.2	18
8°	7.4	4.5	1.0	5.2	18
7°	5.8	4.6	1.0	5.2	18
5°	3.0	4.6	1.0	5.2	18
3°	1.2	4.7	1.0	5.2	18

OPERA sensitivity to θ_{13}

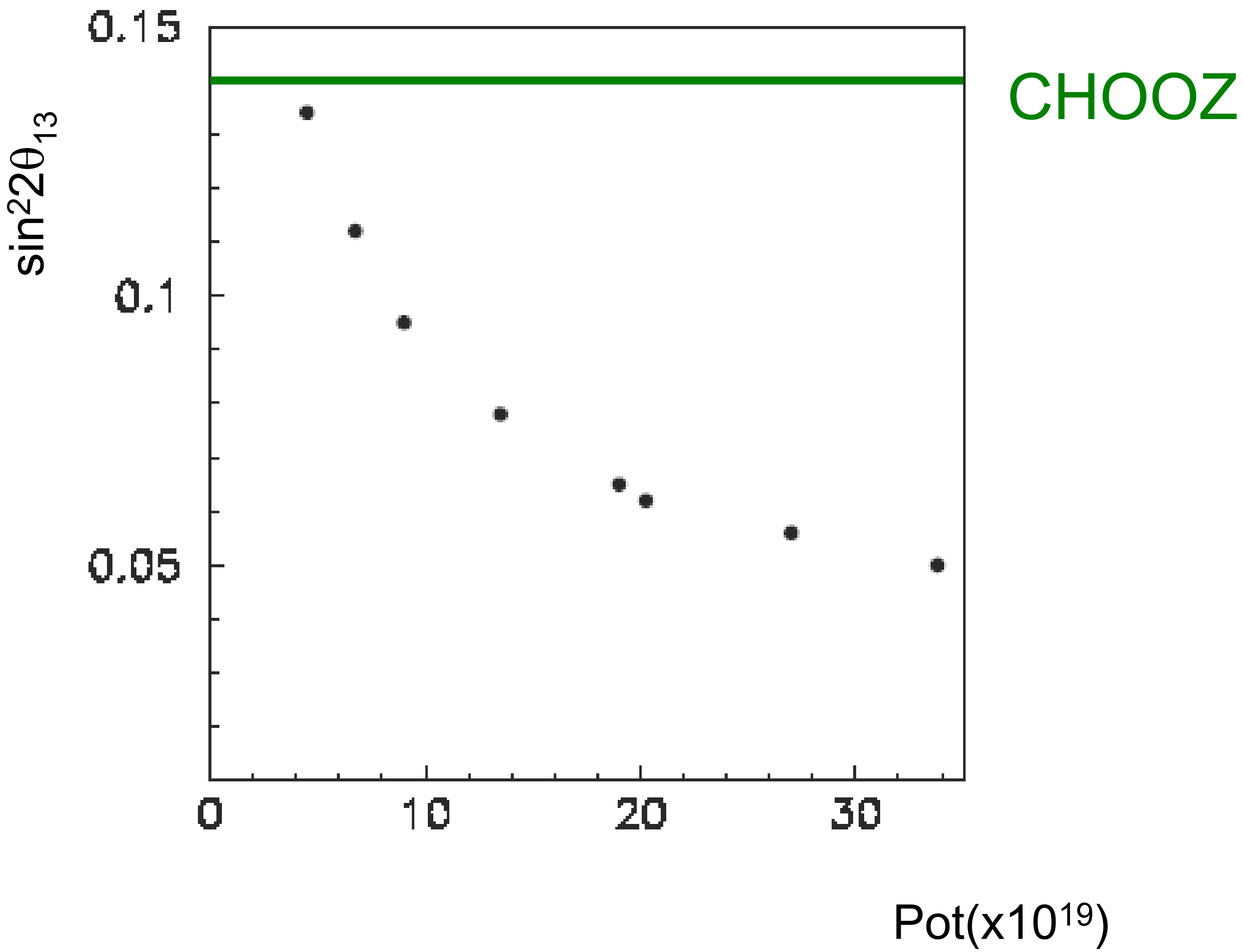
By fitting simultaneously the E_e, missing p_T and E_{vis} distributions we got the sensitivity at 90%





Pots are an important issue

OPERA $sin^2 2\theta_{13}$ as a function of the pots



Conclusions

- despite the difficulties @ LNGS
  the installation of the OPERA experiment is following the expected schedule

- the completion of the first SuperModule is foreseen in sept 05 and filled in feb 06
  the second completed in feb 06 and filled in sept 06
  → we need a physics run in 2006 to start the physics program
  (data taking will run in parallel with the filling of the detector)

- efficiency and background are based on robust numbers
  from previous experiments and tests : improvements are under study

- to cover the allowed range of Δm^2 from SuperK analysis
  → at least the nominal conditions (4.5 10^{19} pot/year)should be granted
  (improve the efficiency of the accelerator complex)
  → and even more protons onto the CNGS target are needed:
  either by increasing the number of CNGS cycles
  or (and) increasing the proton intensity in the SPS as soon as possible
  → multi-turn ejection from PS to SPS is urgently needed