Ongoing activities in CHORUS

1.	Final paper on oscillations	O. Sato, L. Scotto Lavina
2.	Charm production in ν and ν-bar interactions	G. De Rosa, U. Dore
3.	D0 topological Branching Fractions	G. De Lellis, B. Saitta
4.	c-cbar production in NC and CC interactions	G. De Lellis, M. Guler
5.	D*-->D0 decays	T. Kawamura, B. Saitta
6.	Trimuons	ITEP group
7.	Dimuons	A. Cocco
8.	Rare decays of charged and neutral D's	N. Bruski, D. Frekers
9.	Muonic decays of charm	S. Kalinin, P. Vilain
10.	Multiplicities	U.Kose, M.Guler, G. De Rosa, P.Migliozzi
11.	X-distribution of charm	A. Artamonov, G. De Rosa
12.	Charm fragmentation	A. Kayis,J. Panman, T. Ferraro
13.	Total charm cross-section	G. De Rosa, F. Di Capua
14.	Charmed fractions	F. Di Capua, F. Spada
15.	Structure functions	M.Serin-Zeyrek,S.Kama,R.Oldeman,A.Cocco
16.	Lambda_c->Sigma	T. Furukawa, K. Niwa
17.	Comprehensive charm paper	G.De Lellis,M.Komatsu,P.Migliozzi,O.Sato

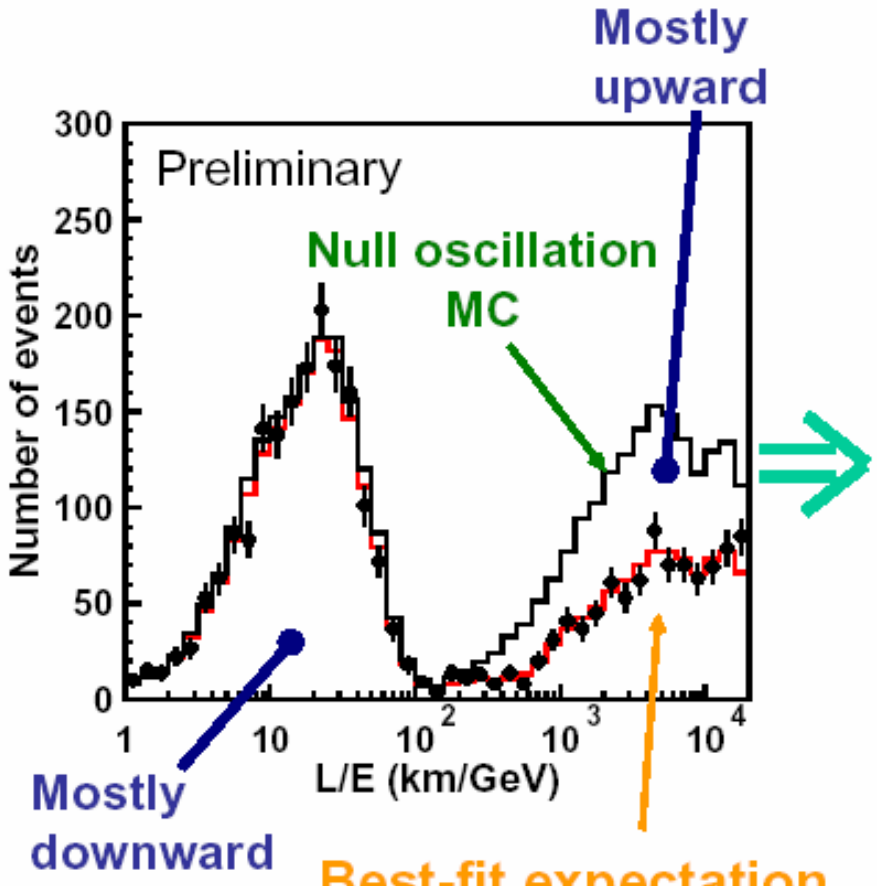
OPERA Physics

(Physics Coordinators: M. Komatsu, P. Migliozzi)

- Confront emerging picture with precision data
  - demonstrate $\nu_\mu \rightarrow \nu_\tau$ is dominant mode:

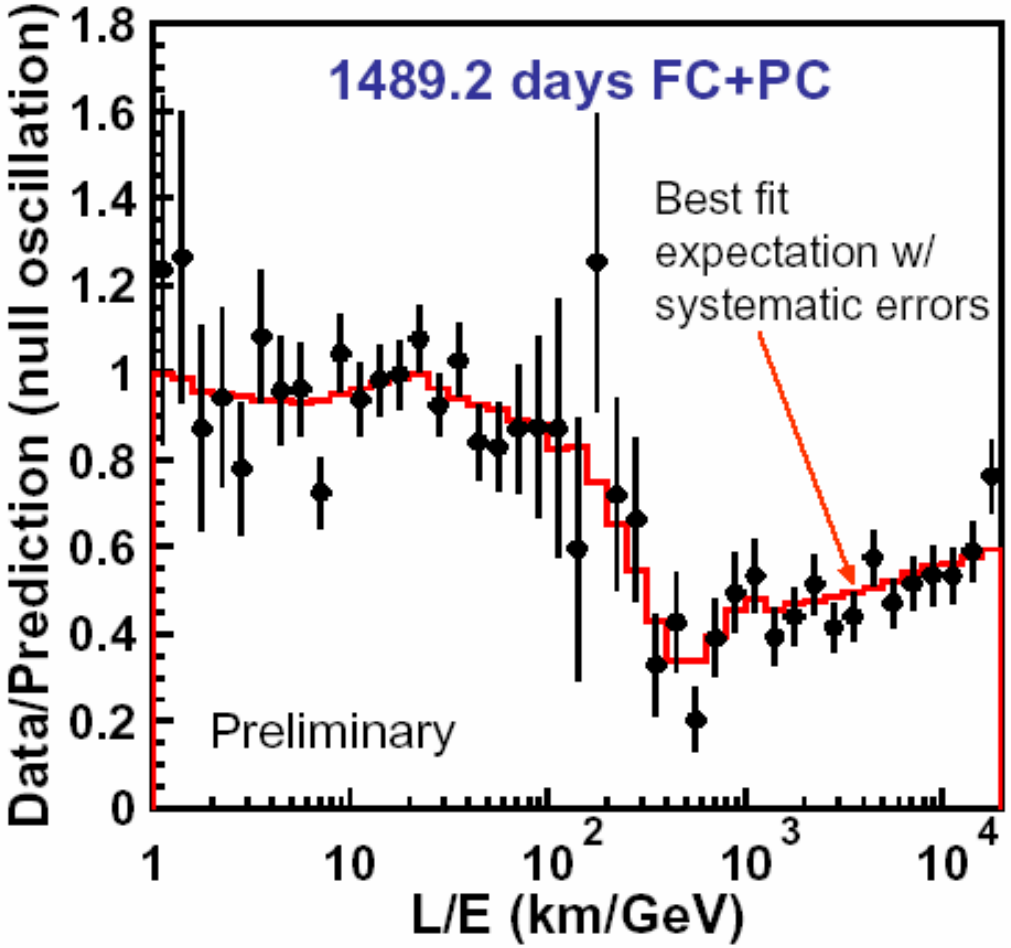
    Tau appearance !
- Look for new phenomena
  - evidence for non-zero $\theta_{13} \rightarrow$ detection of ν_e appearance
  - ...

Latest news from SK (I)



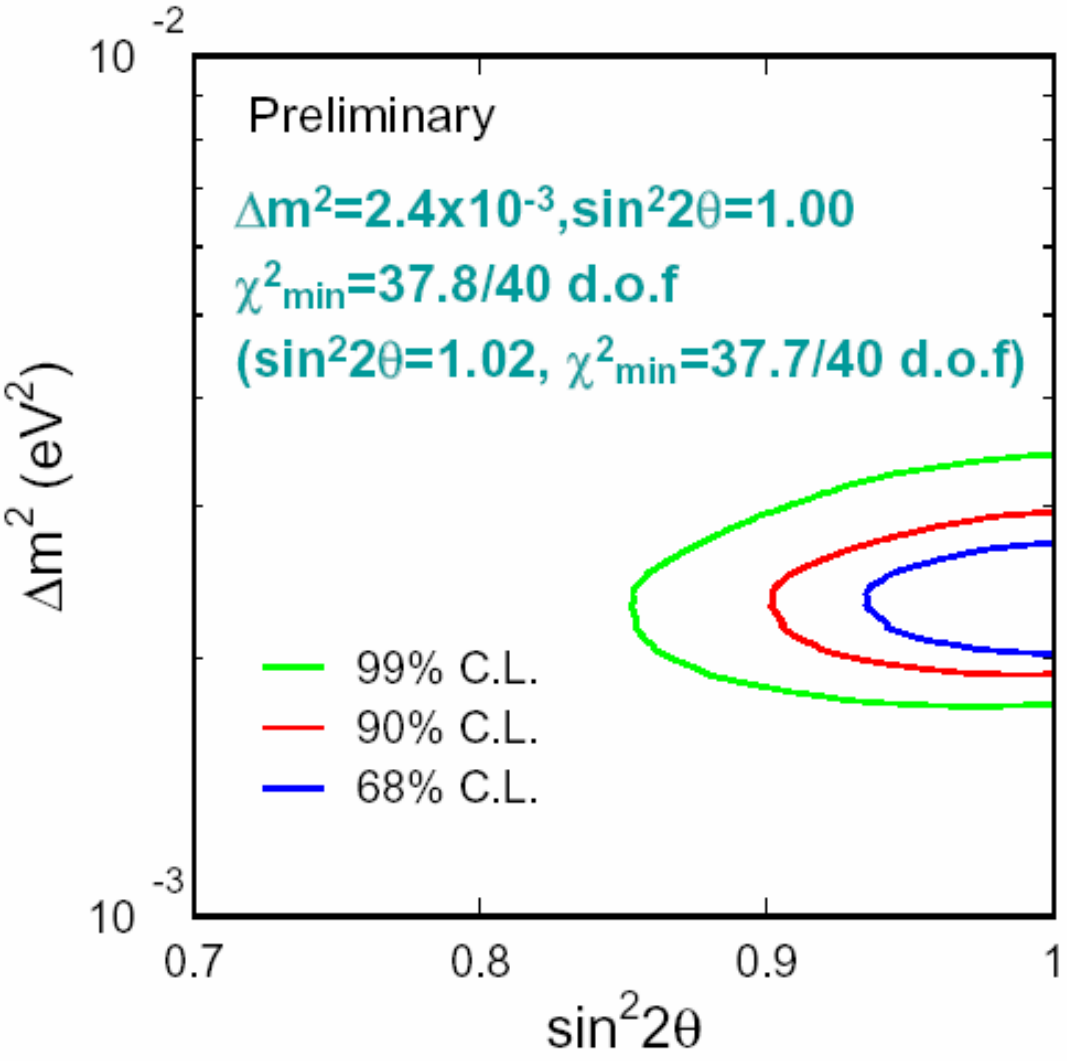
$\Delta m^2=2.4\times10^{-3}, \sin^2 2\theta=1.00$

$\chi^2_{min}=37.8/40$ d.o.f



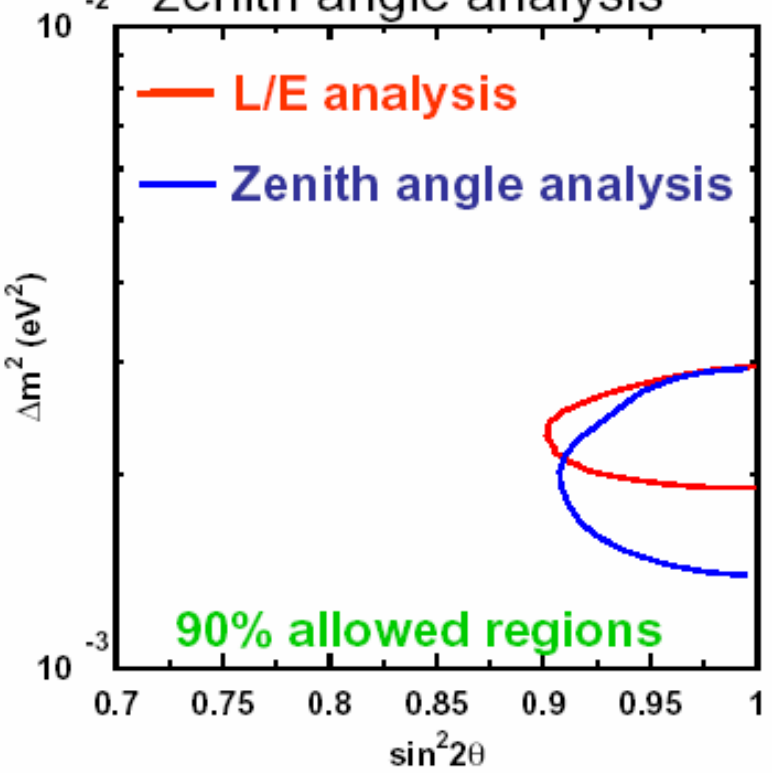
First dip is observed as expected from neutrino oscillation

Latest news from SK (II)



1.9x10^{-3} < Δm^2 < 3.0x10^{-3} eV^2
0.90 < sin^{2}2θ at 90% C.L.

Consistent with standard zenith angle analysis



Expected number of background events

(5 years run with 1.8 kton average target mass)

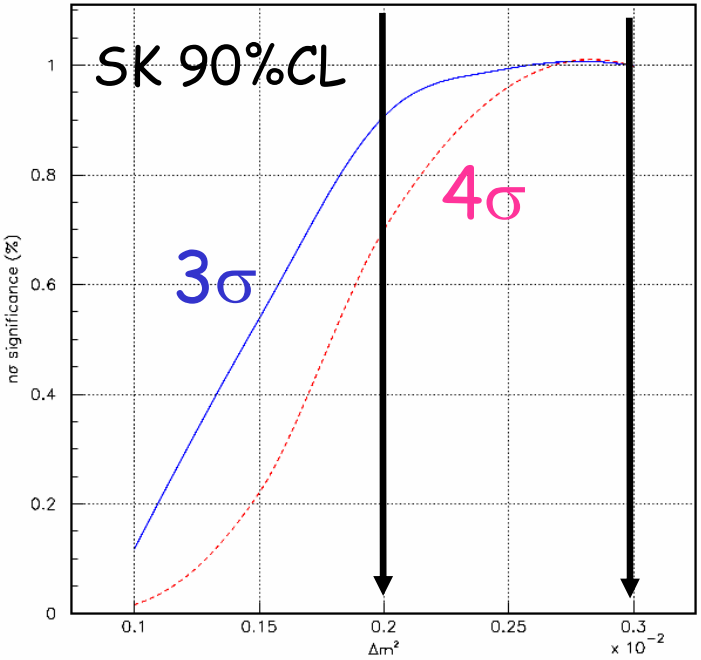
	$\tau \to e$	$\tau \to \mu$	$\tau \to h$	total
Charm background	.313	.017	.243	.573
Large angle μ scattering		.174		.174
Hadronic background		.139	.174	.313
Total per channel	.313	.330	.417	1.060

1. Charm background :
   - Being revaluated using new CHORUS data: cross section increased by 40%
   - $\pi\mu$ id by dE/dx would reduce this background by 40%
     $\Rightarrow$ being tested at KEK and at PSI (pure beam of π or μ stop)
2. Large angle μ scattering :
   - Upper limit from test @ CERN
   - Calculations including nuclear form factors give a factor 5 less
     $\Rightarrow$ 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%

Expected number of events

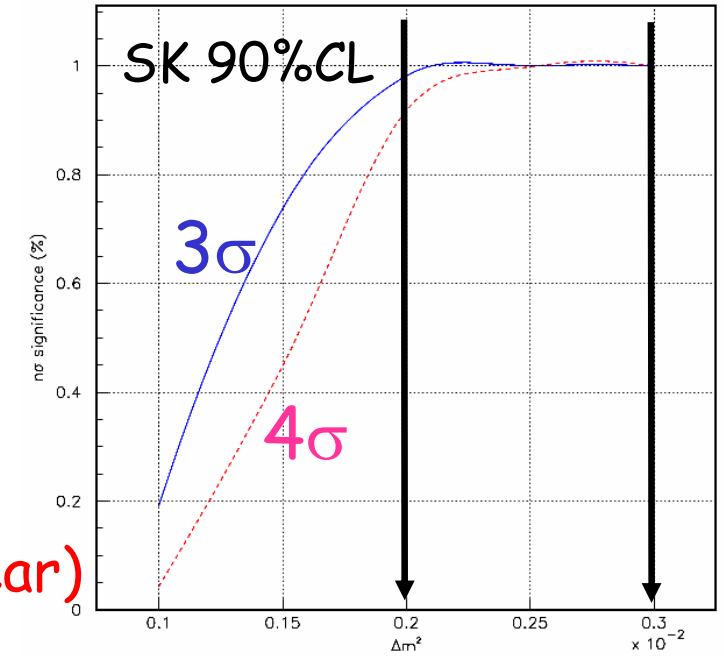
#τ expected in OPERA after 5 years
(in parenthesis a beam 1.5 more intense is considered)

Δm^2	signal 2.0×10^{-3} eV^2	signal 2.5×10^{-3} eV^2	Signal 3.0×10^{-3} eV^2	Back
Evts	7.3(11.0)	11.4(17.2)	16.4(24.6)	0.71(1.06)



5 YEARS
(4.5×10^{19} pot/year)

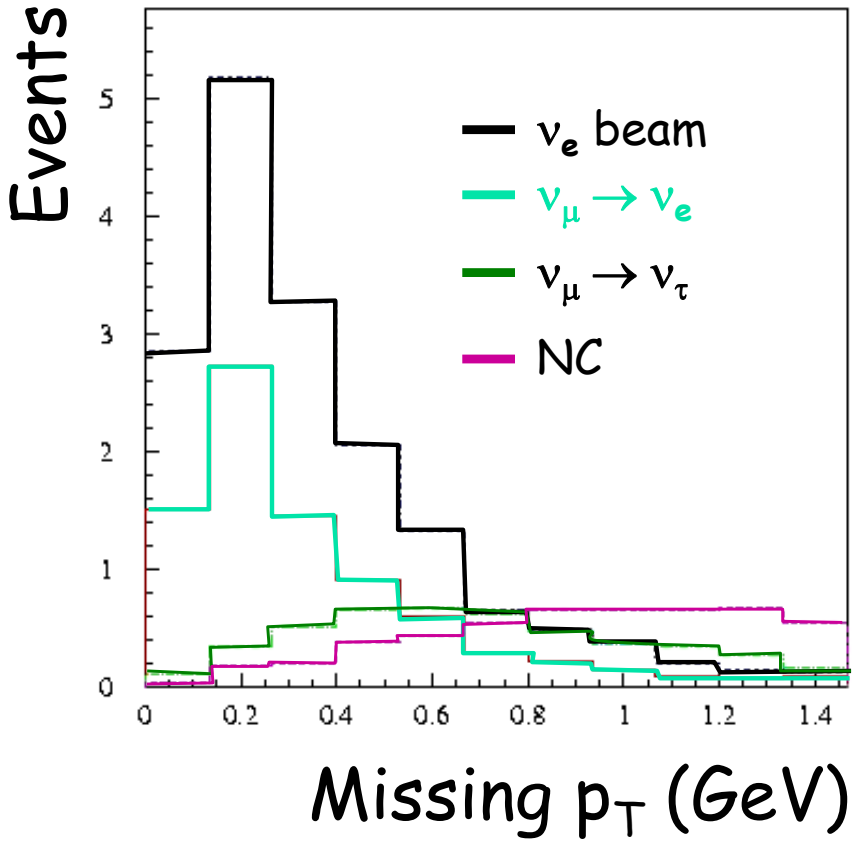
5 YEARS x 1.5
(6.8×10^{19} pot/year)

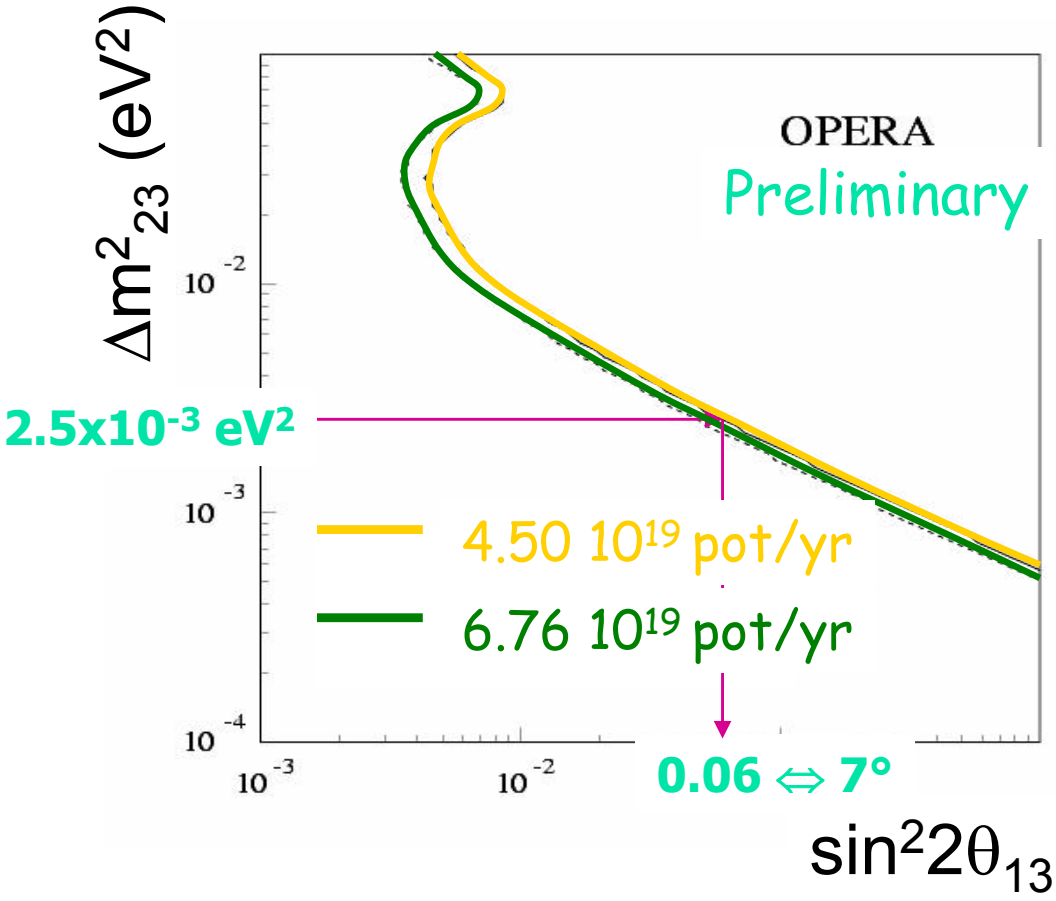


OPERA sensitivity to θ_{13}

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%

Ongoing activities in OPERA

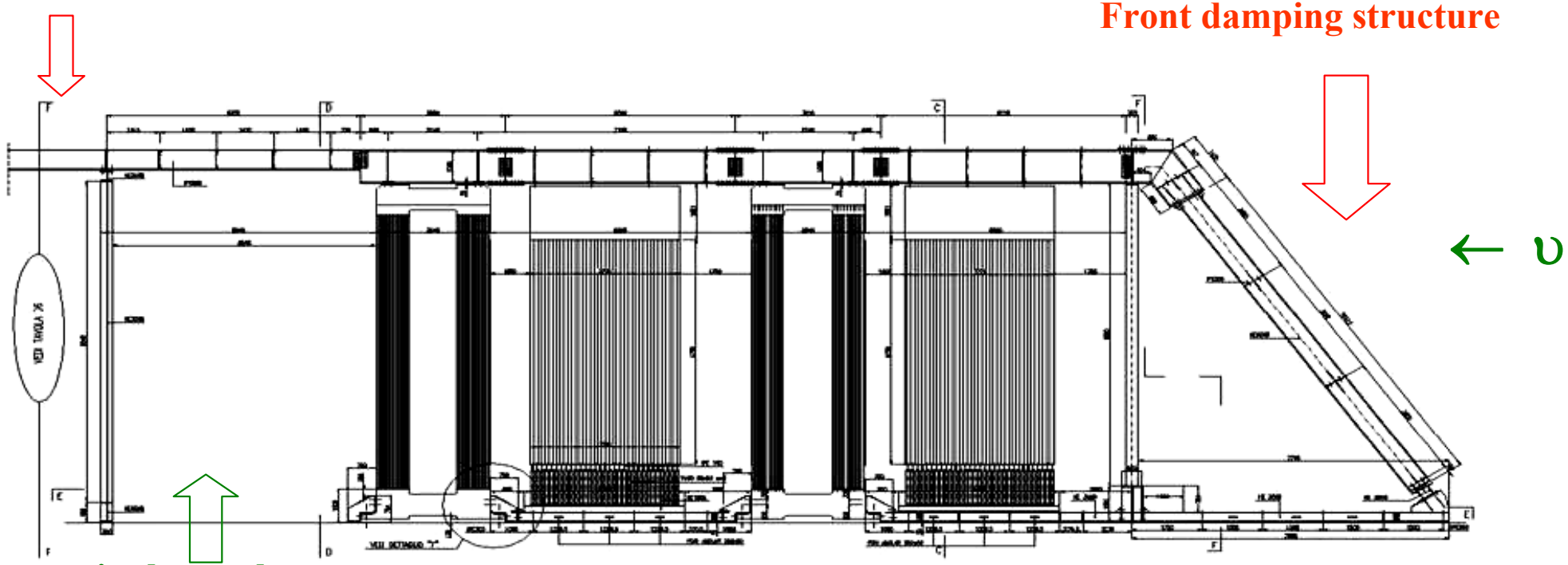
1. Installazione	Technical Coordinators : S. Buontempo, M. Spinetti; staff tecnico da INFN Napoli
2. Brick walls	E. Vanzanella, Gruppo di Frascati
3. Spettrometro (elettronica RPC, trigger)	SER, R. Acquafredda, M. Ambrosio, G. Sorrentino, gruppi di Frascati e Padova
4. Brick Assembly Machine (BAM)	Project leader: S. Buontempo, gruppo di Frascati, tecnici del CERN
5. Sistemi di scanning	
1. Hardware	Responsabile N. D'Ambrosio; F. Formisano, C. Pistillo, G. Sorrentino,SER
2. Ottimizzazione del sistema (eff., purezza, etc.)	G. De Lellis, C. Pistillo
3. Misure di precisione	S. Blokhin, D. Coppola, G. De Lellis
6. OPERA Physics	Physics Coordinators: M. Komatsu, P. Migliozzi
1. Software di ricostruzione emulsioni	Responsabile V. Tioukov; G. De Rosa, F. Di Capua, A. Marotta, Y. Petukov, L. Scotto, altri gruppi europei
2. Sviluppo MonteCarlo generale	A. Marotta, altri gruppi europei
3. Studi sensitività	Tutte le persone del gruppo
7. Attività di testbeam	Tutte le persone del gruppo

Final design of general structure

Rear damping structure

31 target planes / spectrometer (206336 bricks, 1766 tons)

Front damping structure



Electronics barrack

- LNGS approved antisismic structure
- Tender concluded
- Under construction, installed by June 04 for SM1 and by June 05 for SM2

OPERA in Hall C in september 2003 ....

(Technical coordinators: S. Buontempo, M. Spinetti)

Coil and Bar M36 Pos.

First Magnet Block

Low Basements Magnet

Frame

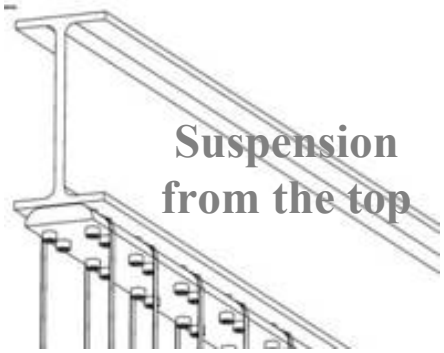
Anti-Seismic Structure

Technical support from INFN Napoli is contributing to the installation of the experiment

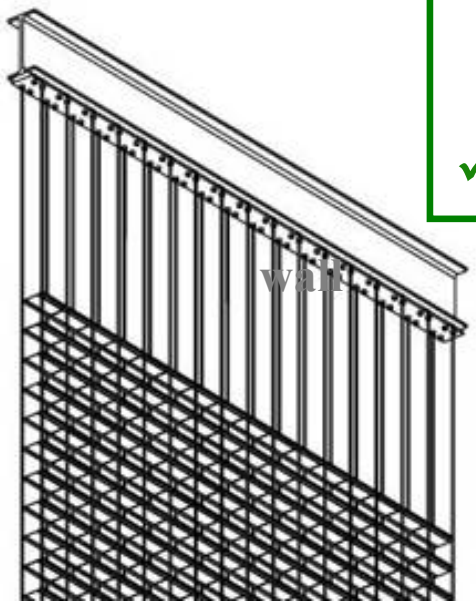
.... in March 04

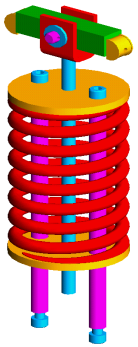
Up to today 14 planes installed

Brick Walls



- ✓Full size prototype: transported to GS
- ✓Tender: ended, approved by INFN Nov 03
- ✓Deliveries:
  - First wall : Sept 2004 (on schedule)
  - Last wall : Dec 2005
- ✓Tensioning systems: ready for SM1, being assembled for SM2



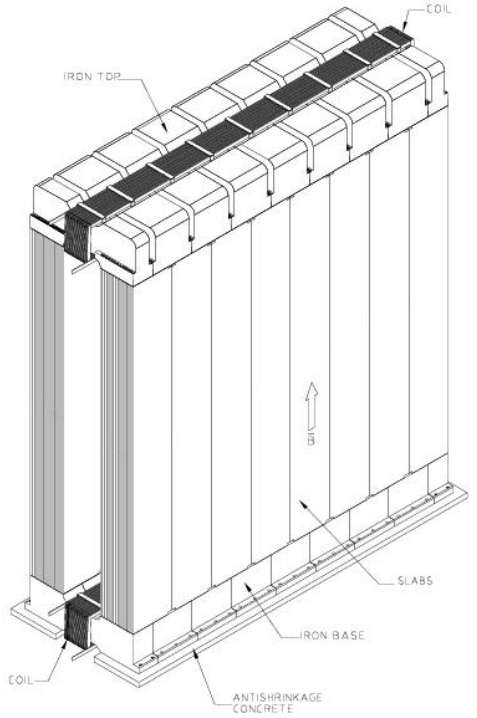


Important contribution from E. Vanzanella in the design of the brick wall

Brick loading test

Impegni di Napoli per lo spettrometro

(SER, R. Acquafredda, M. Ambrosio, G. Sorrentino)



- **Controller Board (CB)**
- **Trigger Board (TB)**
- **Collegamento tra CB e Front End Board (Backplane)**
- **Montaggio e installazione telescopio RPC per i test**
- **Test completi sulla catena elettronica di acquisizione**

Trigger board

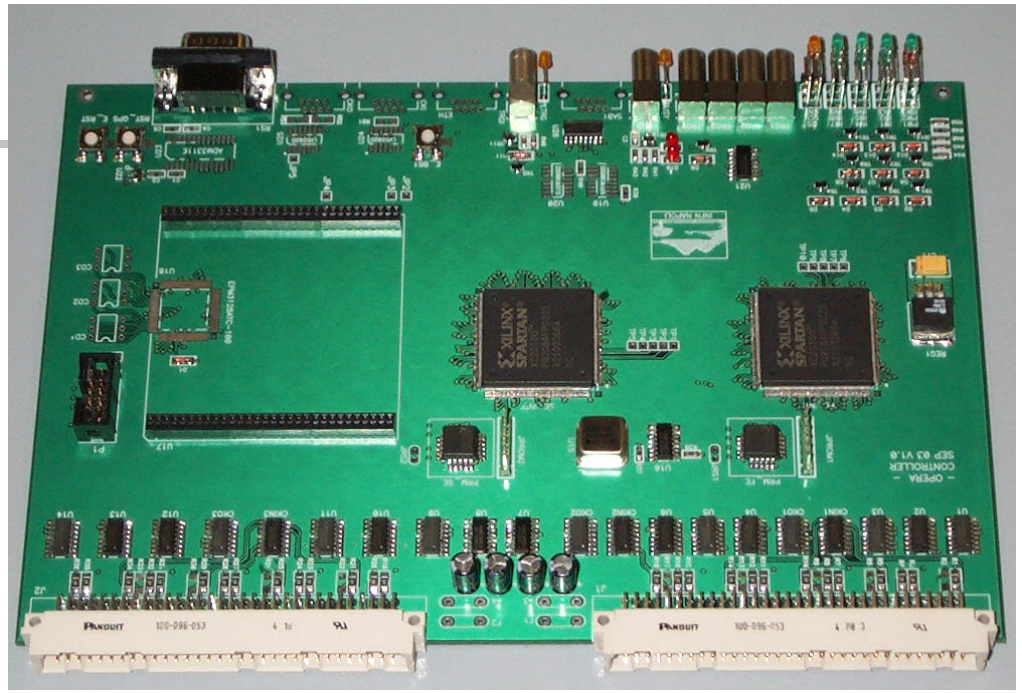
già fatto:

- **Progettazione Trigger Board**
- **Simulazione del trigger**

da fare:

- **Realizzazione prototipo scheda di trigger**
- **Test sul prototipo**
- **Produzione schede (4 + 2)**

Stazione di test per l'elettronica



- Allestimento del telescopio di RPC attrezzato per collegarvi l'elettronica.
- I test finali sull'elettronica dello spettrometro saranno effettuati a Napoli.

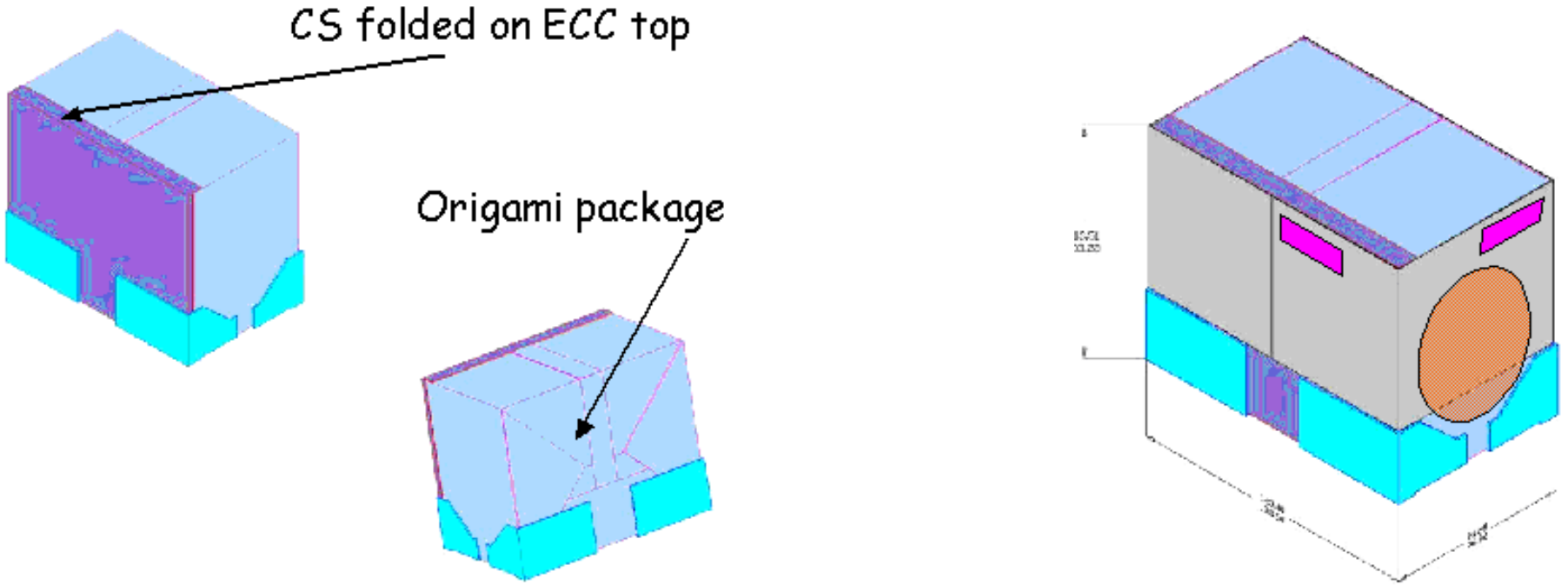
- Terminare i test su controller
- Produzione schede controller (44 + 6)
- Produzione schede collegamento tra CB e Backplane (44 + 6)

The Brick Assembly Machine (BAM)

(Project leader S. Buontempo)

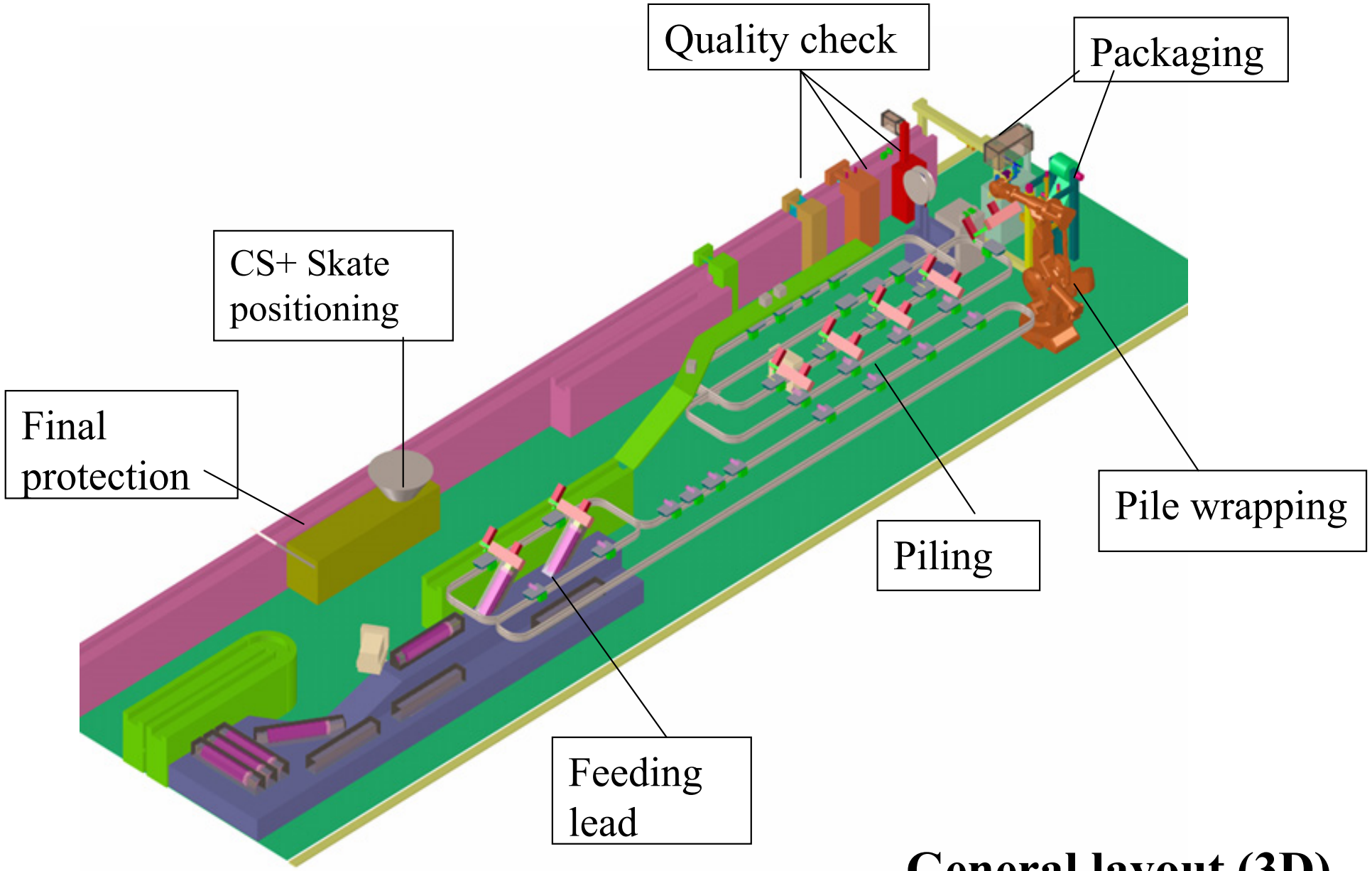
~ 23 million lead plates + emulsion sheets

~ 206,000 bricks at a rate of ~ 2 bricks/minute



- **SPECS document completed end 2002**
- **10 companies have been working for the pre-selection round in May 03**
- **4 companies have been selected and invited to the tender**
- **Tender completed in Nov 03**
- **Tecno-Cut (Swiss-Italian) consortium got the BAM contract in Jan 04**

The Brick Assembly Machine (BAM)

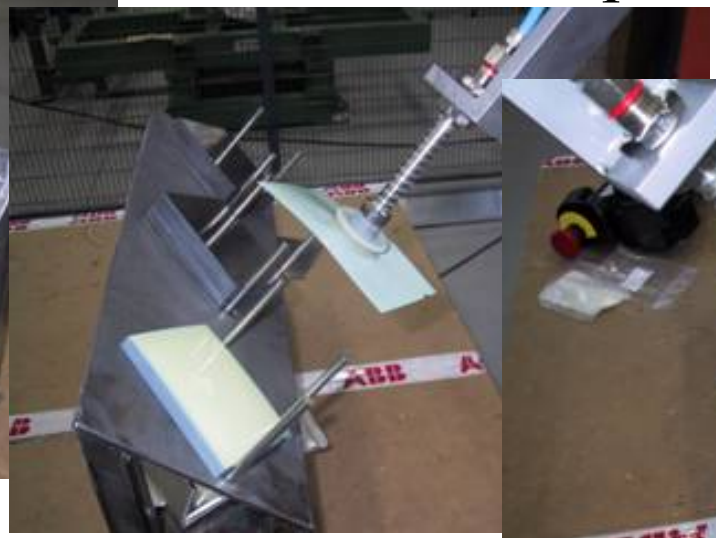


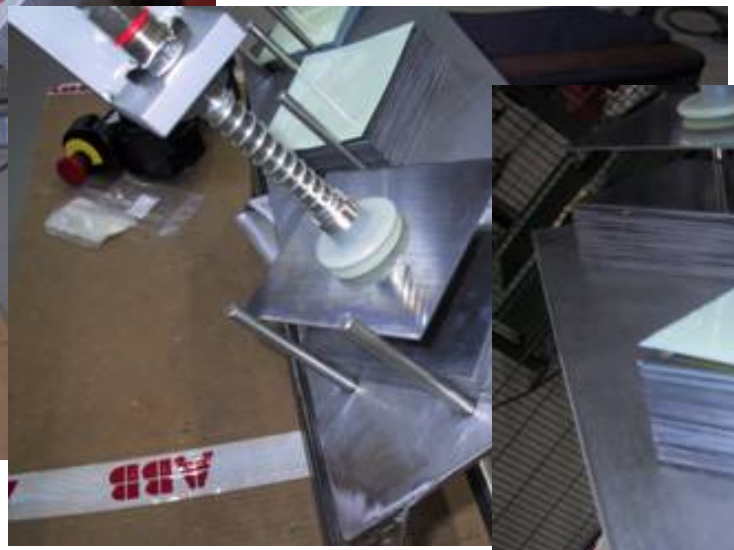
General layout (3D)

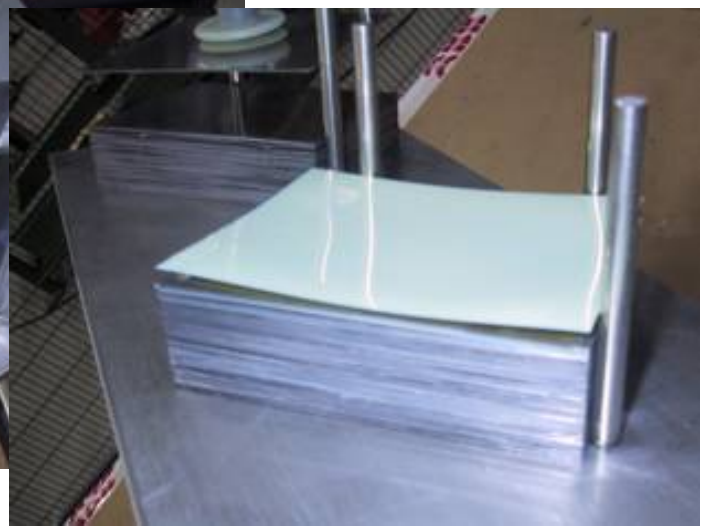
The piling station of the BAM

First mechanical tests of lead and emulsion manipulation with anthropomorphic ABB robot have started to check the precision in the piling operation

Further studies are needed on:
- vacuum sucking device
- photographic effects







Status of European Scanning System

(Bari, Bern, Bologna, Lyon, Napoli, Roma, Salerno)

- The final version is ready and working up to 20 cm^2/h, with DAQ software under tuning to improve efficiencies and purities

- New CMOS camera up to 500 fps

- New Image processor Matrox Odyssey and more powerful PCI-X workstation

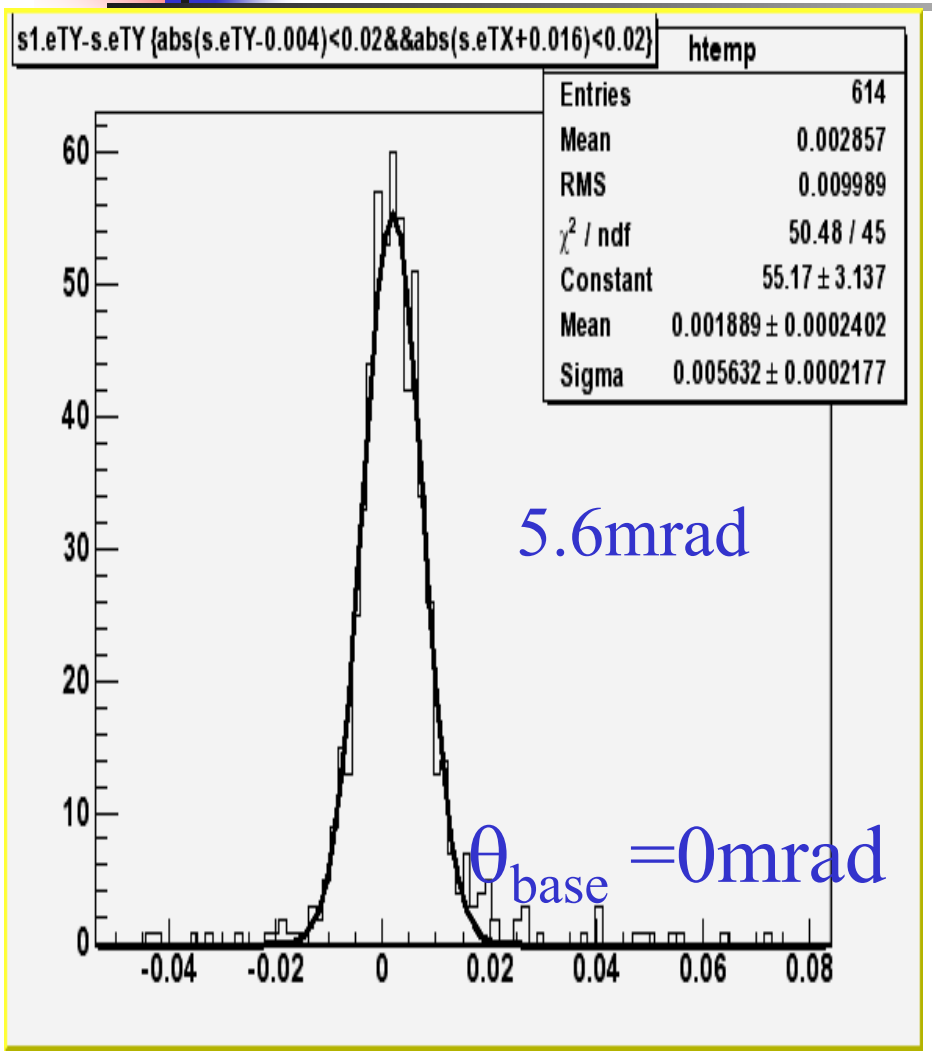
- Same Optics (Nikon) and Mechanics (Micos), now as industrial productions

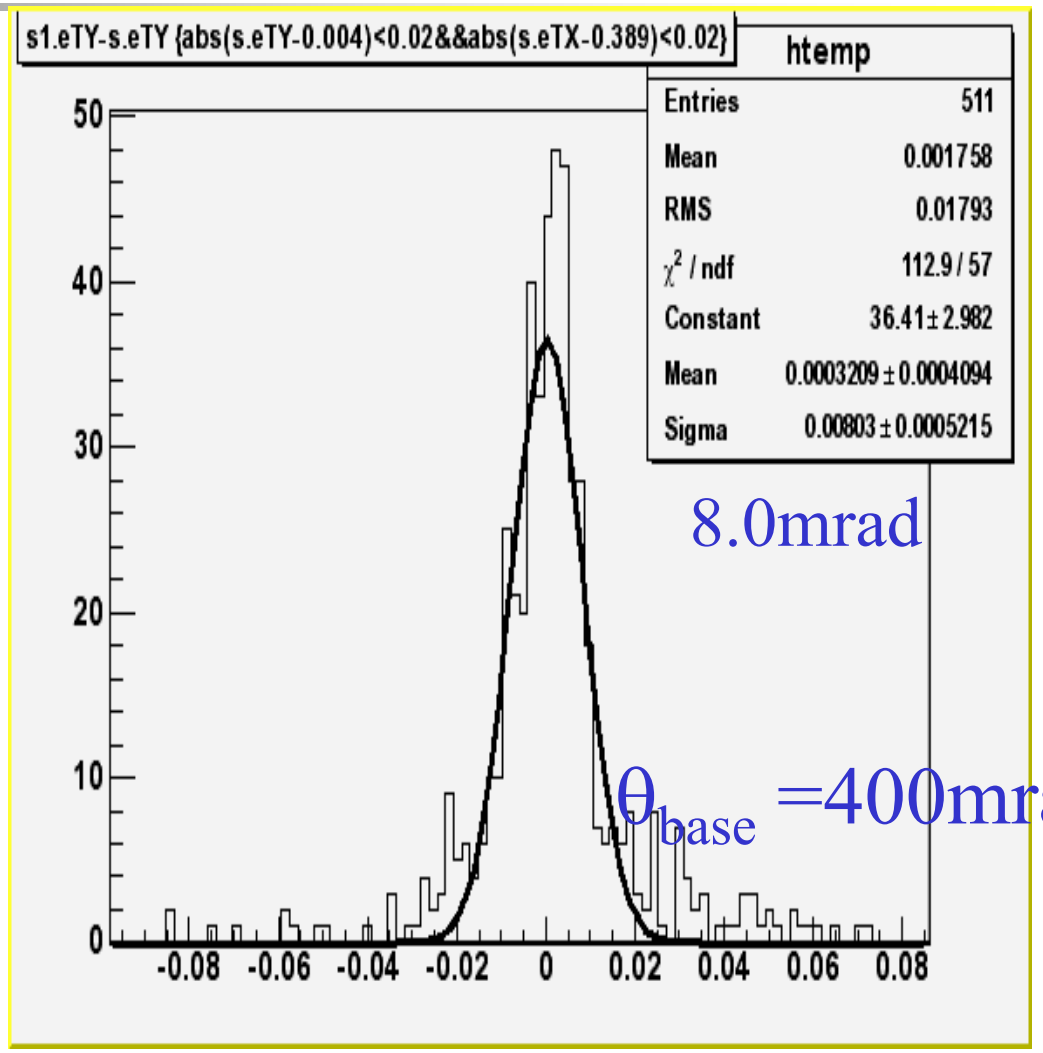
- New DAQ software continuously improving

- New System under tuning or installation in European Scanning Labs

(15 microscopes, 7 in running mode)

Base track definition: θ_{base} - $\theta_{emulsion}$

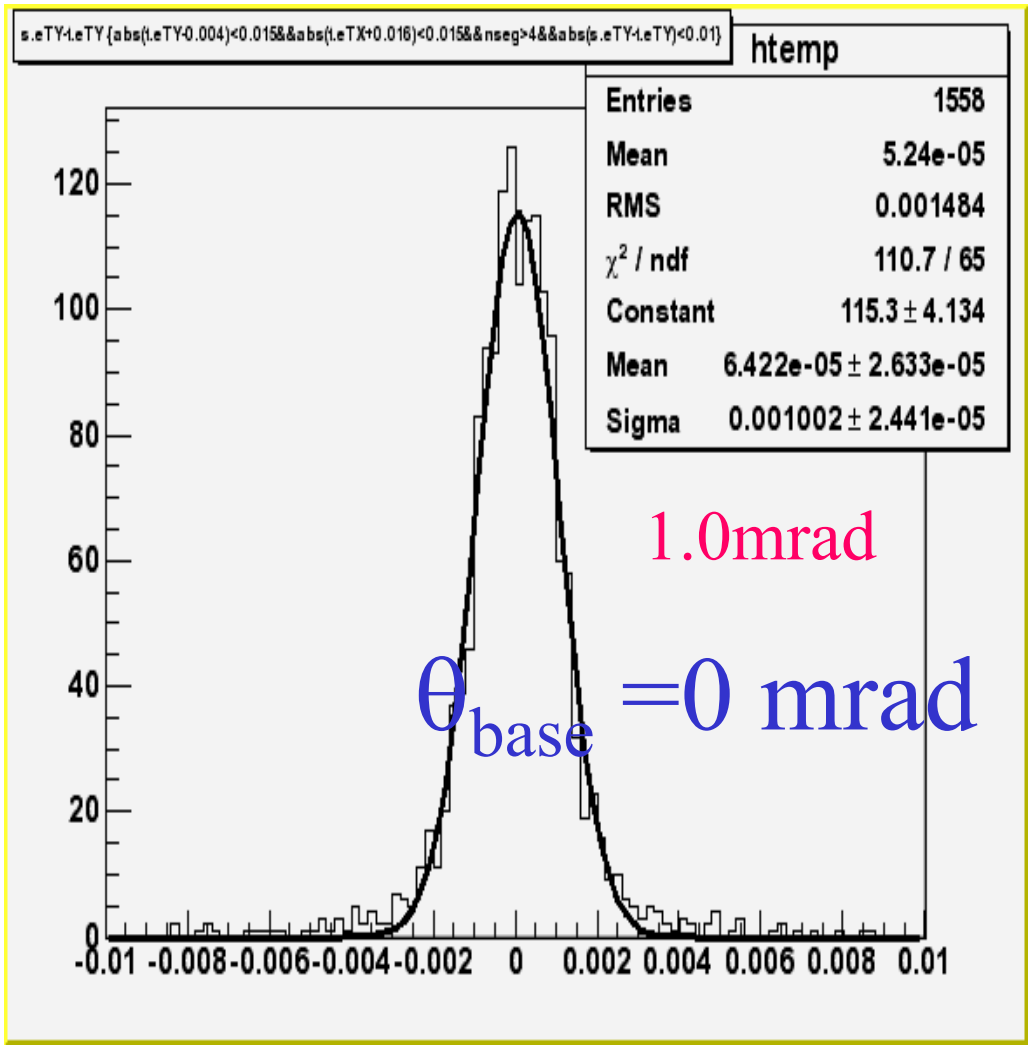


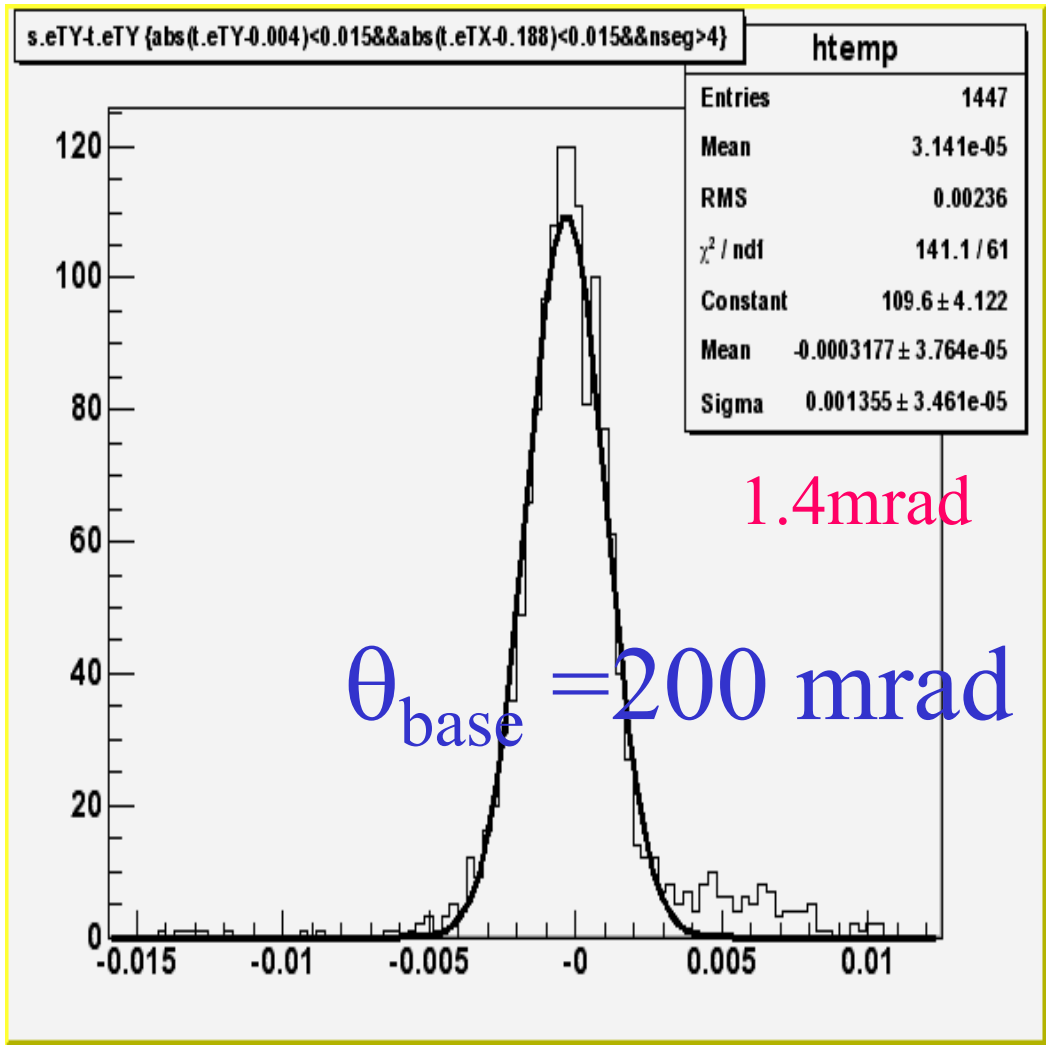


Expected angular dependence

Track following: angular residuals

$\chi^2 > \chi_0^2 = 6.25$ participate to the track following algorithm





Angular residuals: θ(fitted track) -θ(base track)

Average efficiency
(G. De Lellis, C. Pistillo)

	N4/N3	N5/N4	N6/N5	N7/N6
0 mrad	**83.4**	**88.8**	**89.0**	**89.3**
100 mrad	**83.1**	**87.0**	**86.6**	**86.8**
200 mrad	**83.0**	**86.6**	**87.0**	**88.1**
300 mrad	**80.3**	**83.1**	**83.4**	**83.2**
400 mrad	**79.8**	**82.6**	**83.0**	**83.7**

Future tests and scanning power

Development are in progress on software to improve tracking efficiency and reduce the background

Tests with final quality emulsions are foreseen in 2004 at LNGS (for background & cosmics exposure), DESY (e^-) and CERN (tracking & vertex location)

"Old" scanning systems working up to 10 cm^2/h (presently measuring 2003 test beam to improve off line analysis) will be upgraded as soon as the new system will be frozen

A total of 15 microscopes will be available for the OPERA brick scanning, among the various European Labs

Motivazioni fisiche delle misure di precisione in emulsione

Decadimento "lungo" → **τ rivelato misurando l'angolo di kink**

Decadimento "corto" → **τ rivelato mediante parametro di impatto**

Elevata risoluzione angolare ⇒ **Maggiore sensibilità dell'esperimento**

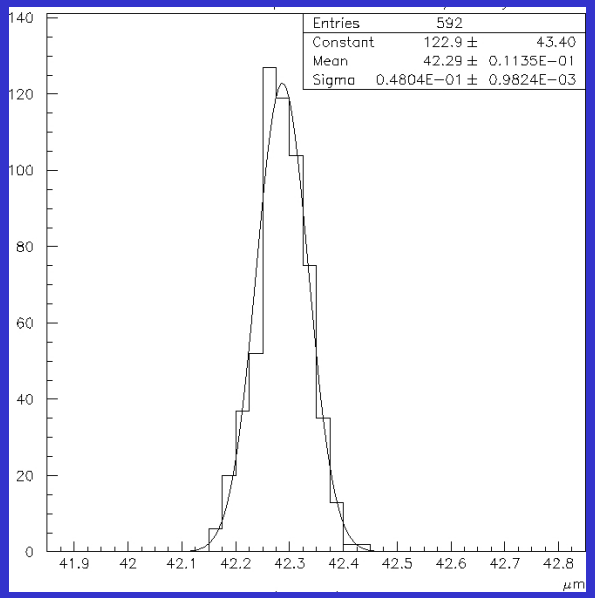
Ricostruzione cinematica degli eventi → **Rigetto eventi che simulano il decadimento del τ**

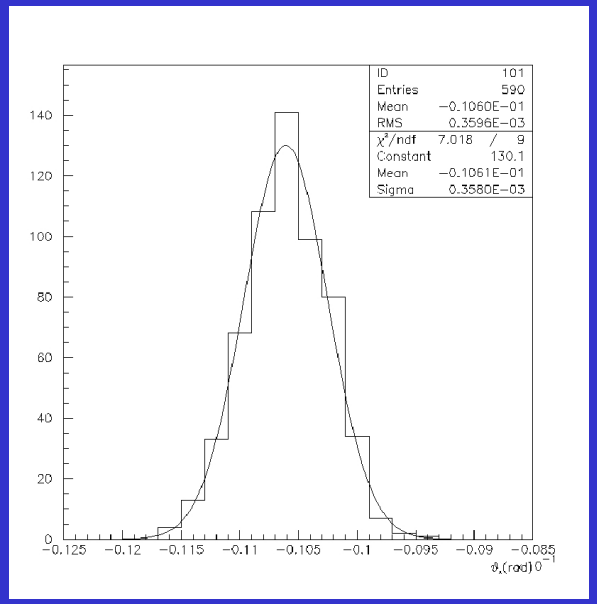
→ **misura di impulso mediante multiplo scattering nel brick: $p \sim (\theta_{diff})^{-1}$**

Elevata risoluzione angolare ⇒ **Migliore separazione segnale/fondo**
Maggiore efficienza

Principi della metodologia sviluppata e risultati
(S. Blokhin, D. Coppola, G. De Lellis)

- Acquisizione ripetuta di tracce lungo diverse lastre d'emulsione all'interno del bersaglio
- Definizione di finestre di analisi attorno ai grani di traccia
- Proprietà dei grani di traccia (baricentro) mediante filtraggio, binarizzazione e *clusterizzazione*
- Posizione dei grani di traccia e risoluzione spaziale
- Calcolo dell'angolo alla base e risoluzione angolare





Risoluzione spaziale: ~ 0.06 μm

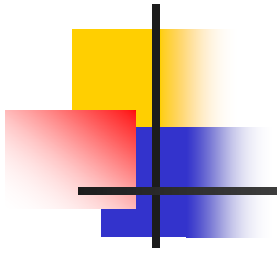
Risoluzione angolare: ~ 0.4 mrad

OPERA Offline

- OPERA software packages
  - The whole chain of C++ packages is now working
  - Choice of ROOT and standard ROOT-based tools for data persistency, simulation, event display easy switch from Geant3 to Geant4 and FLUKA
  - Geometry description common to ALL programs
- A new MC production is under way (A. Marotta one of the responsibles)
  - The aim is to recompute the OPERA sensitivity
  - The Napoli group is involved in all analyses and has the responsability (L. Scotto Lavina) to evaluate the sensitivity by using the Feldman and Cousins approach
- A reconstruction program for the emulsion data (FEDRA) based on ROOT is being developed in Napoli (V. Tioukov)

http://ntslab01.na.infn.it/fedra

Review of FEDRA modules and functionality



- Storage part (Edb) - OK
- Image&Grains processing and analysis - OK
- Microtracks->basetracks linking - OK
- Patterns alignment - OK
- Tracks finding & fitting - OK
- Vertex analysis (under development)
- Display - OK

Emulsion data flow

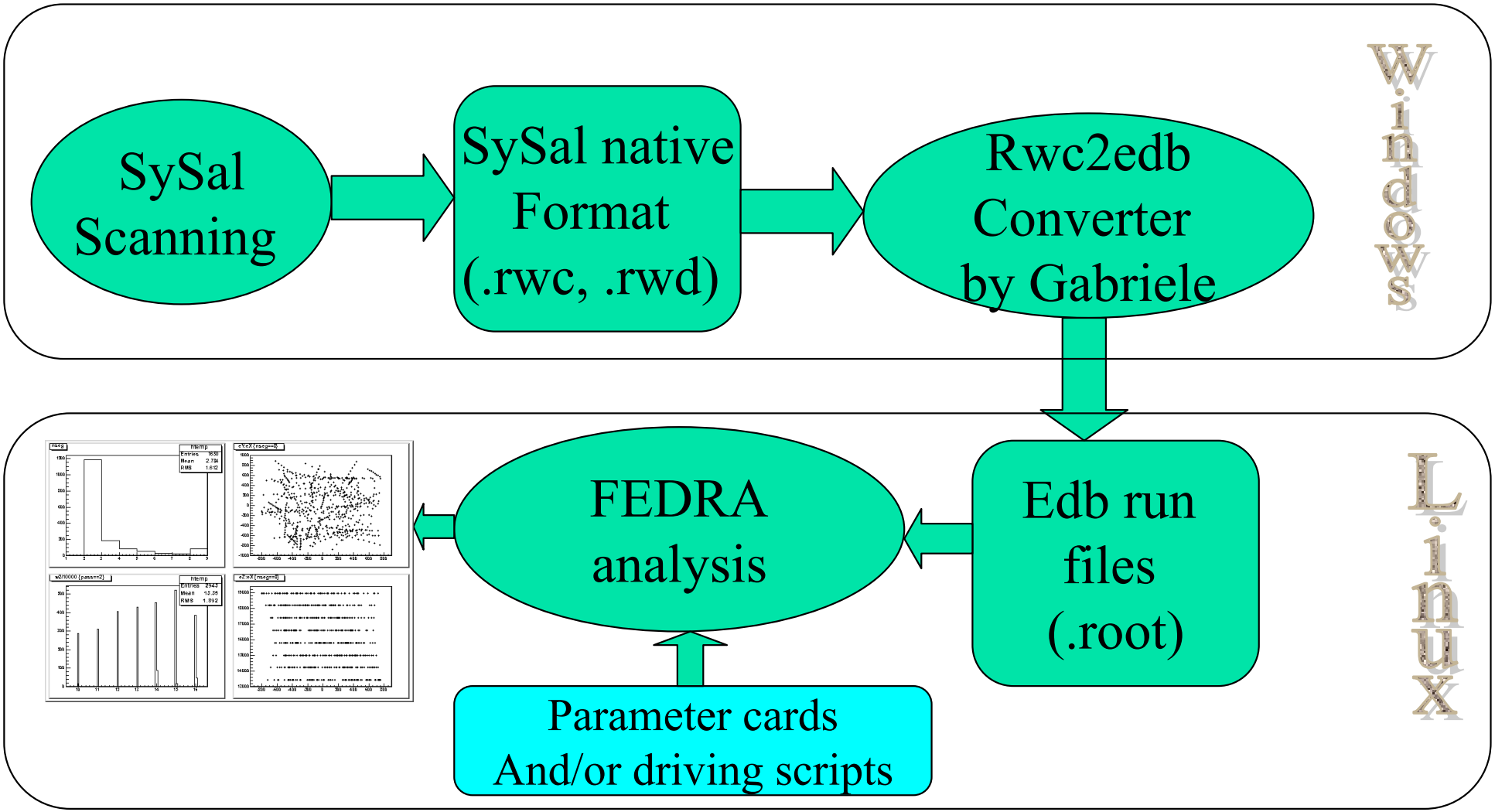
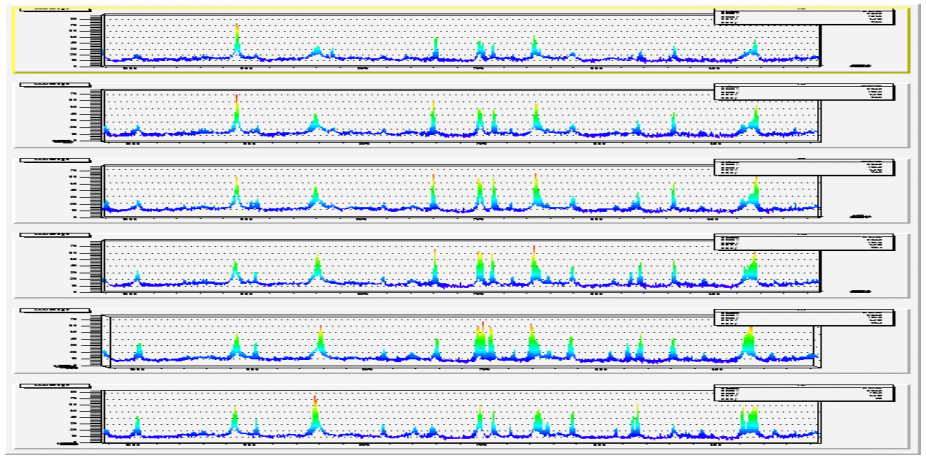
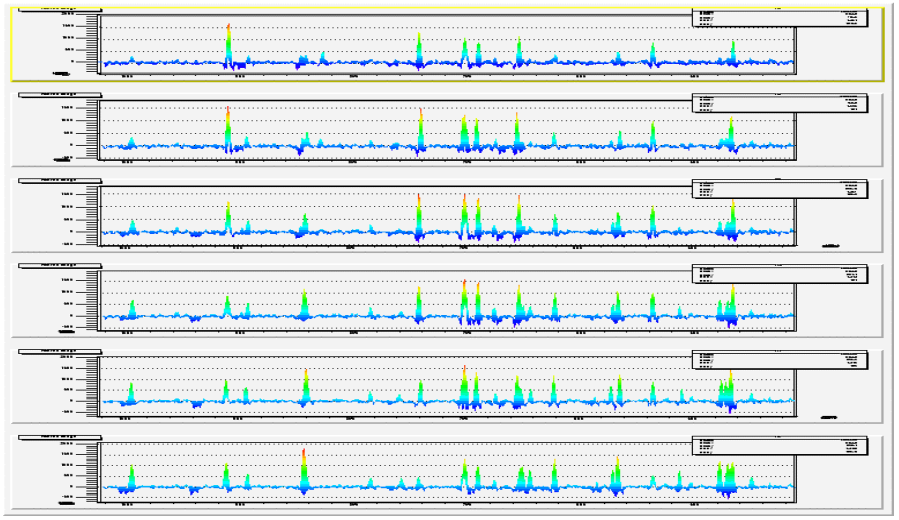


Image processing

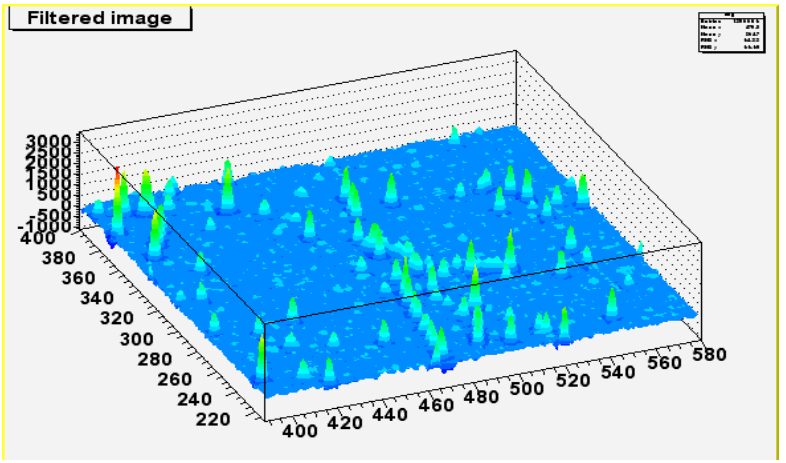
Slice of the raw image



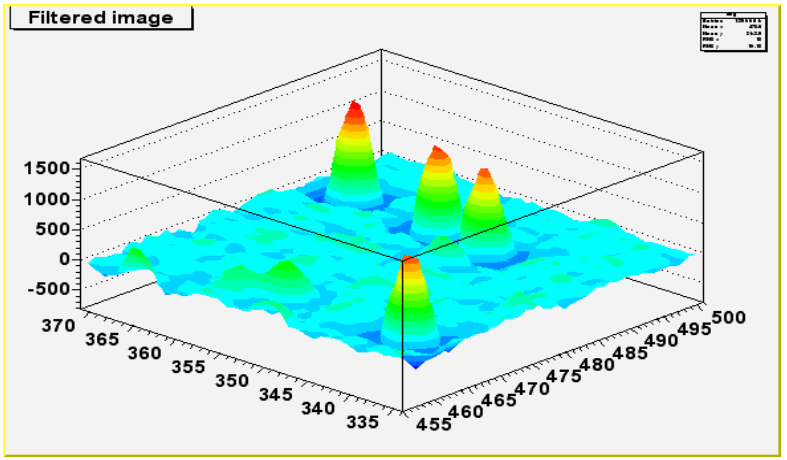
Slice of the filtered image (6x6A)

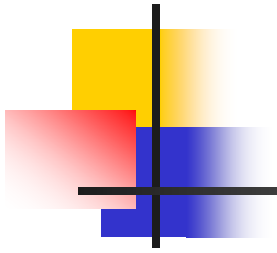


Deep inside view - image



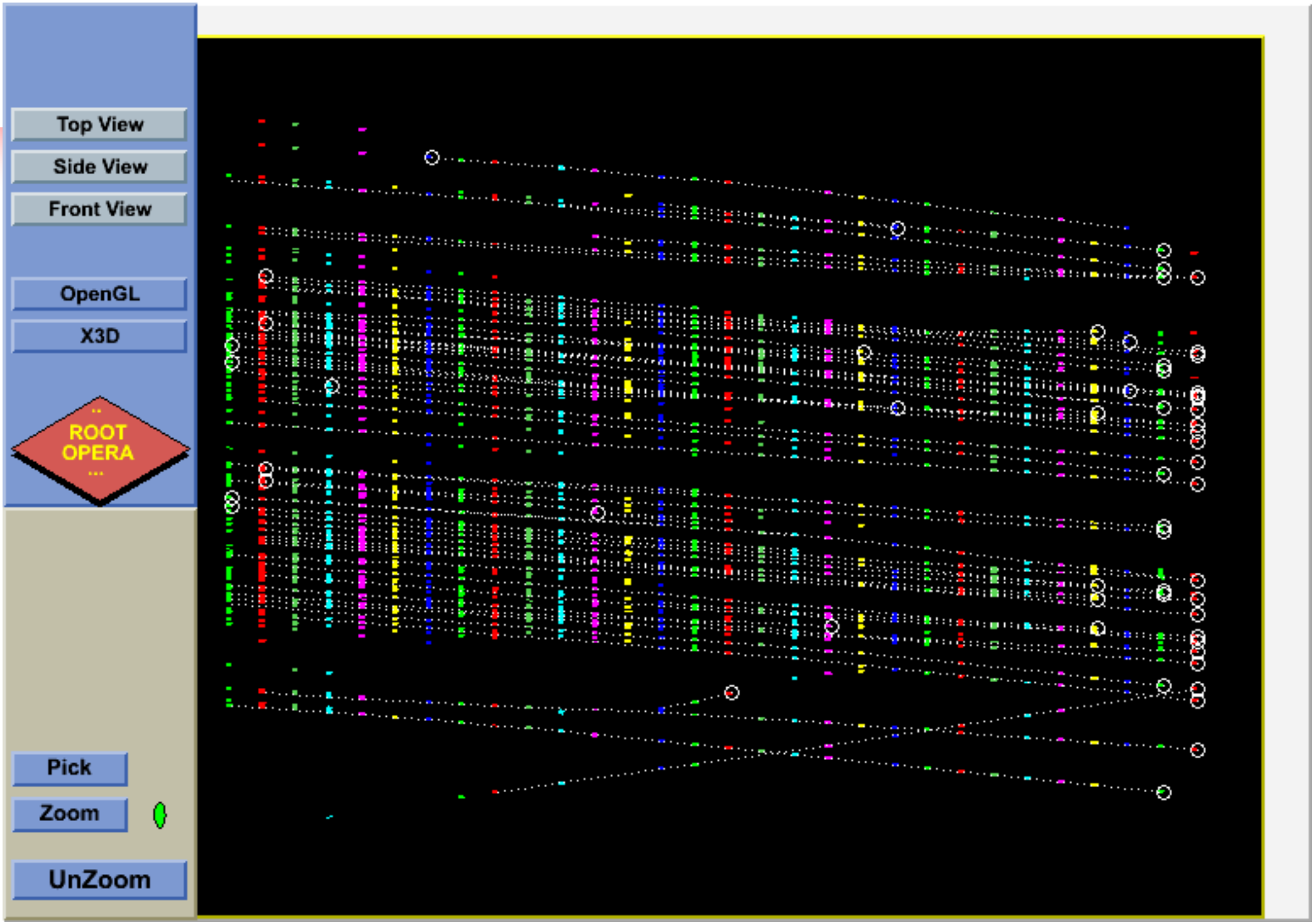
Deep inside view - image

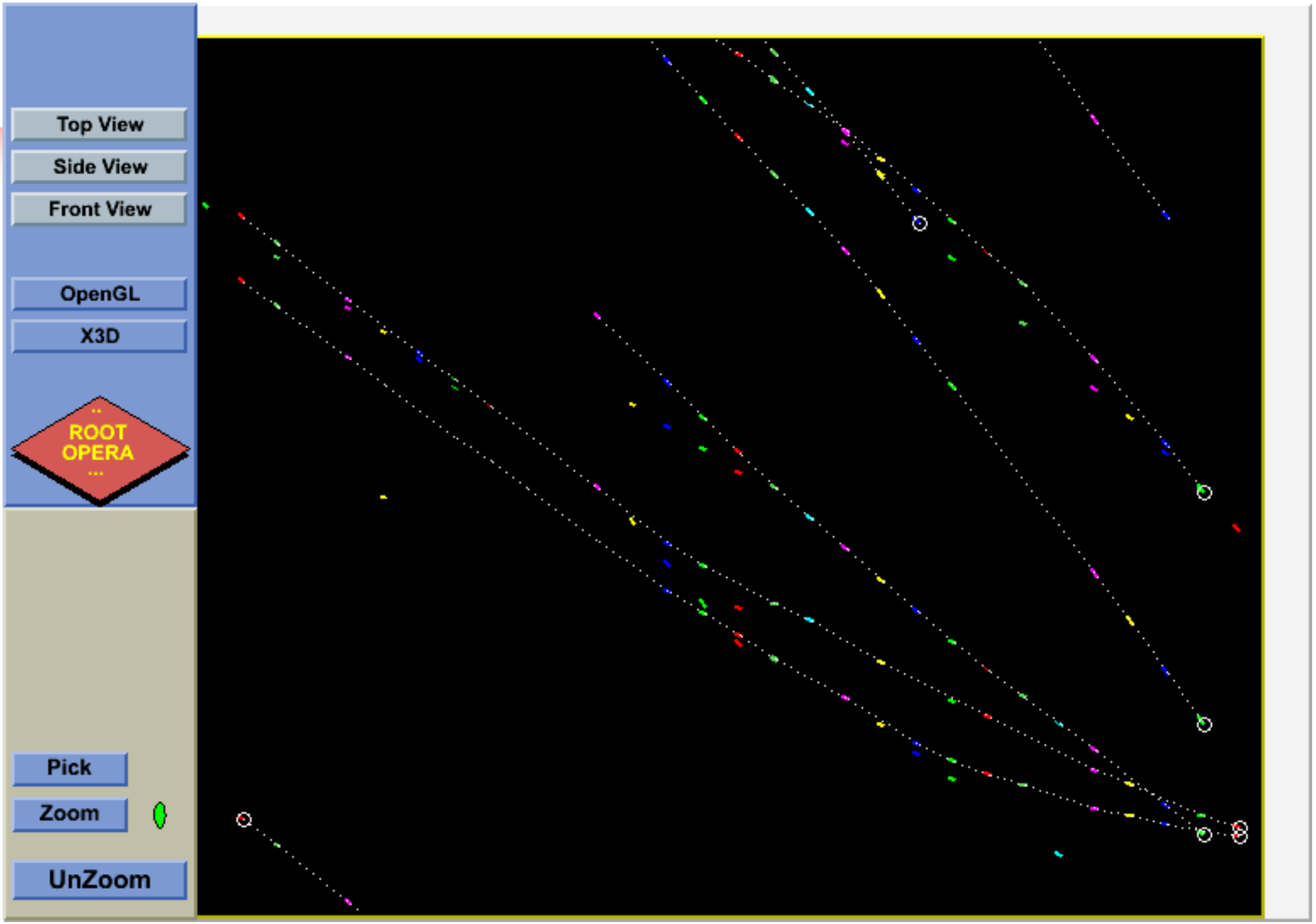




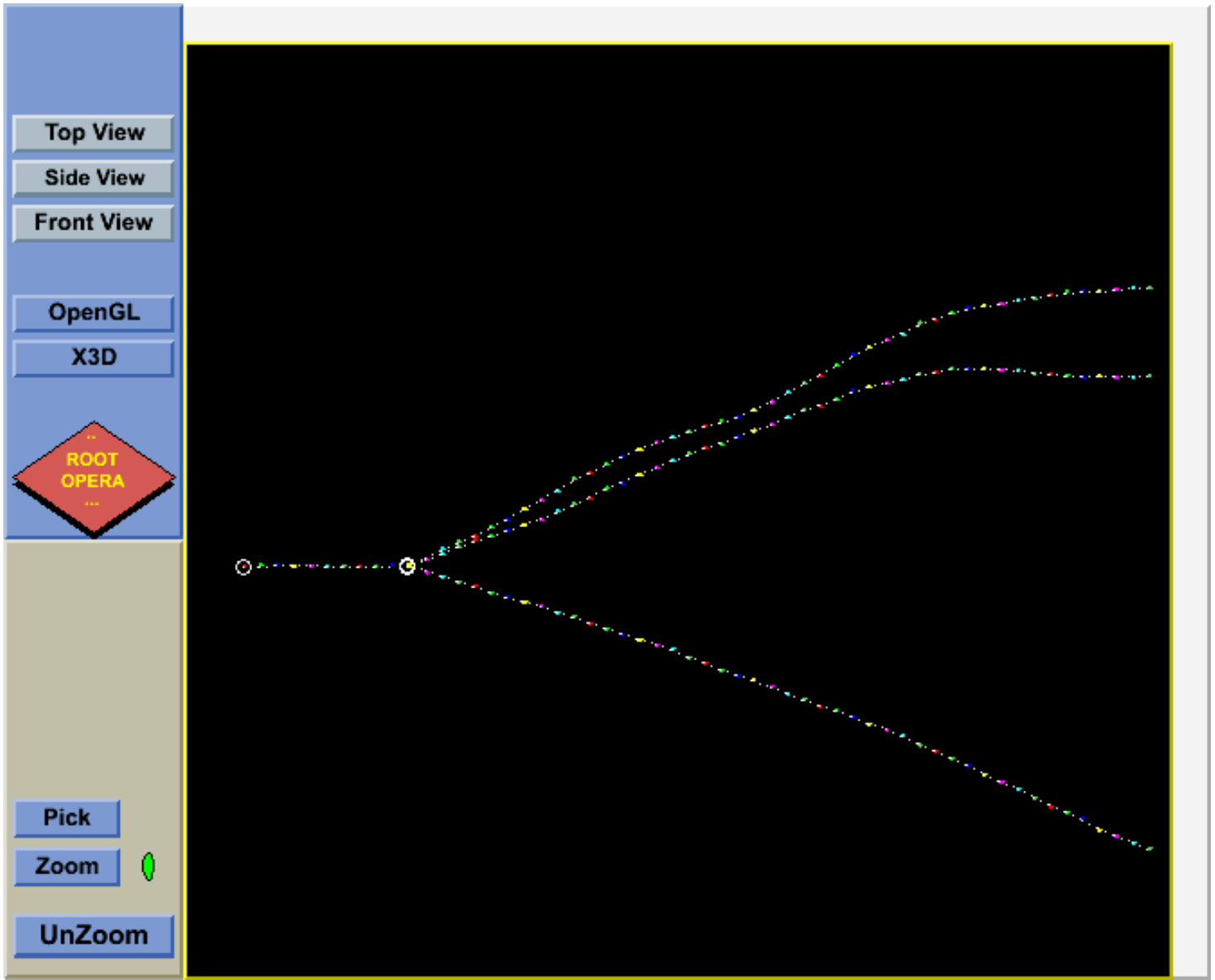
Intermediate data

- Raw data(microtracks) -> couples (basetracks) - per each plate
  - Shrinkage correction
  - Data quality check
  - alignment
- Basetracks -> linked_tracks – per dataset(brick)
  - Fine alignment
  - Track following&fitting with Kalman filter applied (progressive track fit)

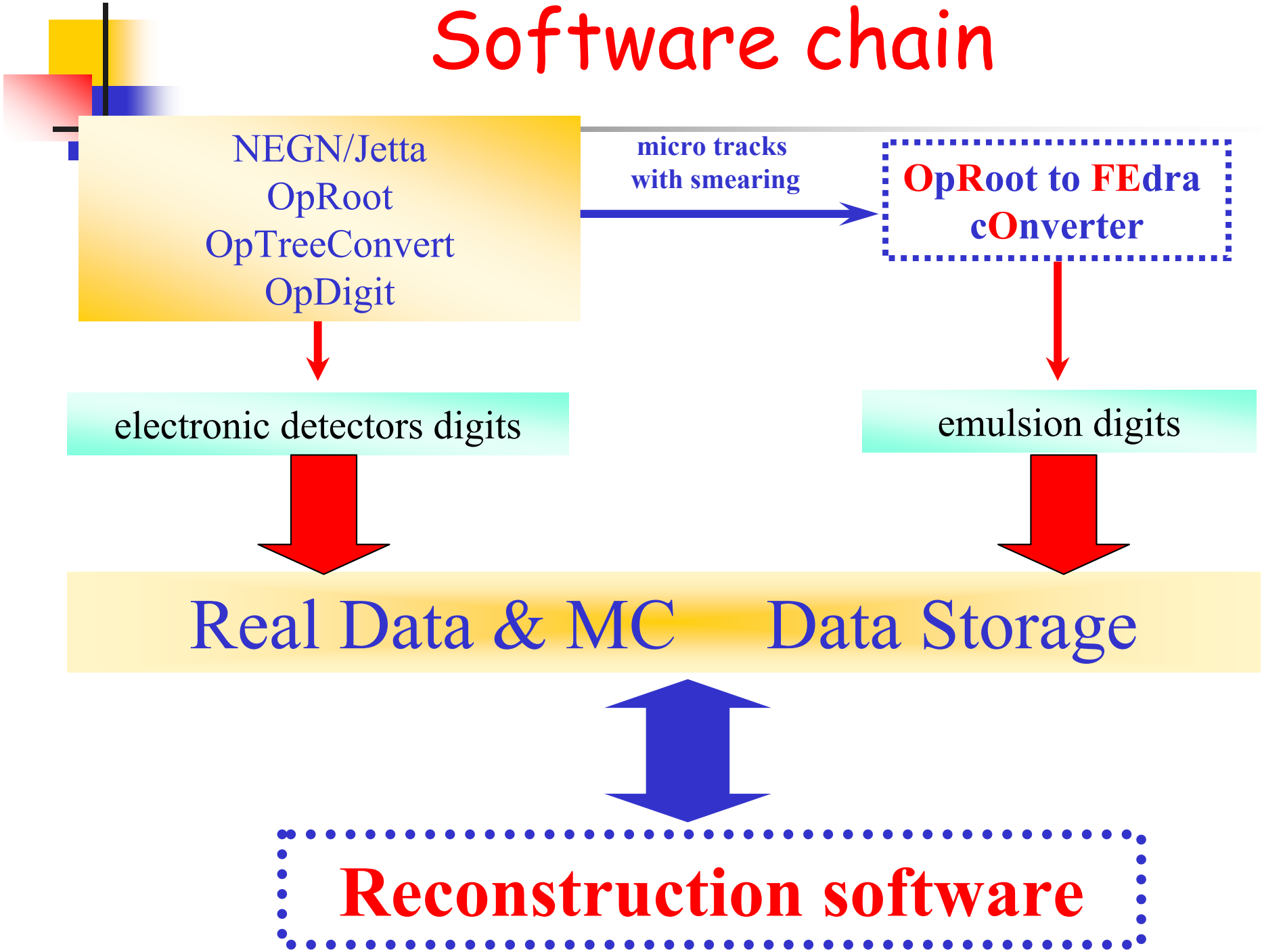

Top View
Side View
Front View
OpenGL
X3D
ROOT
OPERA
Pick
Zoom
UnZoom


Top View
Side View
Front View
OpenGL
X3D
ROOT
OPERA
Pick
Zoom
UnZoom

K->3π decay simulation to test vertex fitting quality (Y. Petukhov)



Software chain



from the microtracks to the FEDRA input

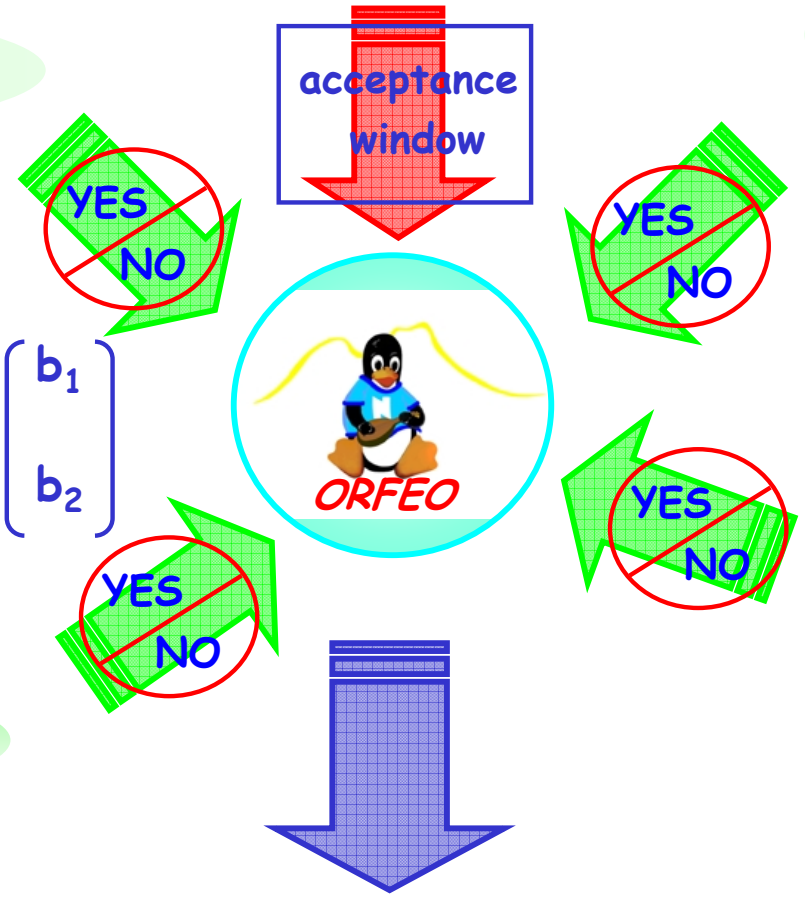
(A. Marotta)

microtracks

affine transf.

- a_{11}, a_{22} gaussian: m=1., σ =0.01;
- a_{12}, a_{21} gaussian: m=0., σ =0.01;
- b_1, b_2 gaussian: m=0., σ =1000.;

$$\begin{pmatrix} x^1 \\ y^1 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \bullet \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}$$



pulse height

1. Gaussian pulse height
2. Poissonian pulse height
3. Data parametrization

smearing

- x, y gaussian smearing:
  - mean=0. μm
  - sigma=0.5 μm
- Tx, Ty gaussian smearing:
  - mean=0. Rad
  - sigma=0.013 rad

efficiencies

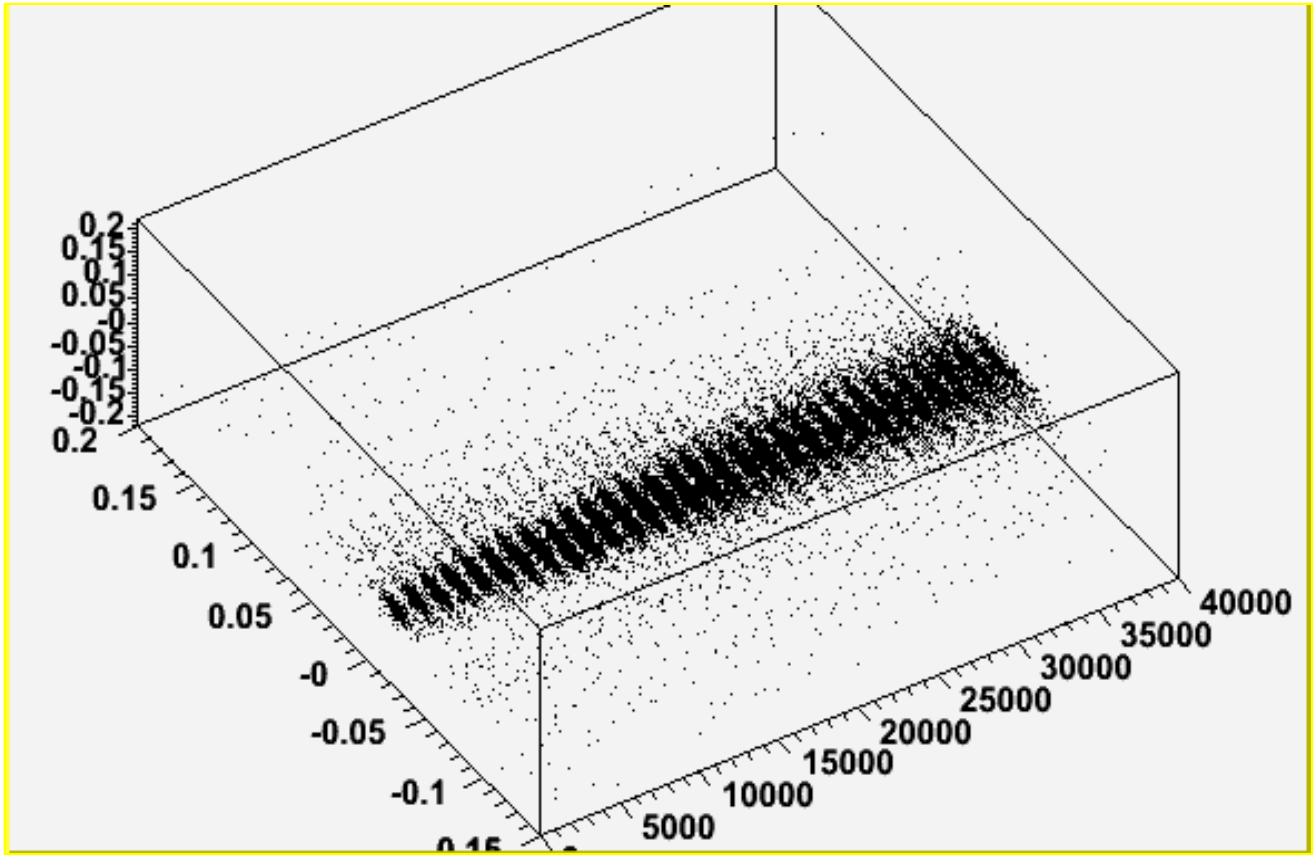
micro track rejection based on data efficiencies parametrization

FEDRA

Scanning of data (G. De Lellis, G. De Rosa, F. Di Capua, L. Scotto, V. Tioukov)

- so far 2 bricks analyzed with the ESS
- 30 plates scanned for each brick (scanning surface: 2x2 cm^2)
- Hardware configuration (old prototype)

2 GeV Pions



Off-line analysis:

FEDRA software

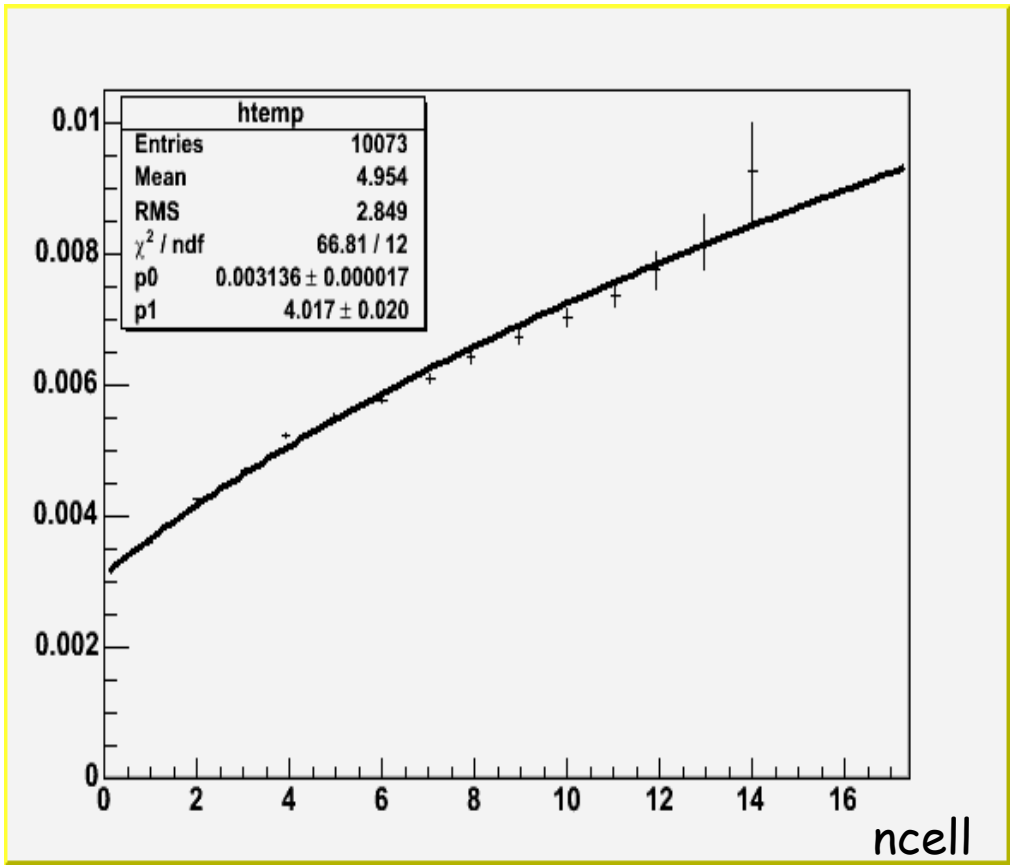
Data are available on www.ntslab01.na.infn.it/public/tb_july2003

Momentum measurement by MCS

$$\theta^{RMS}(mrad) = \frac{0.0136}{\beta P(GeV/c)}\sqrt{\frac{x}{X_0}} \oplus \sigma$$

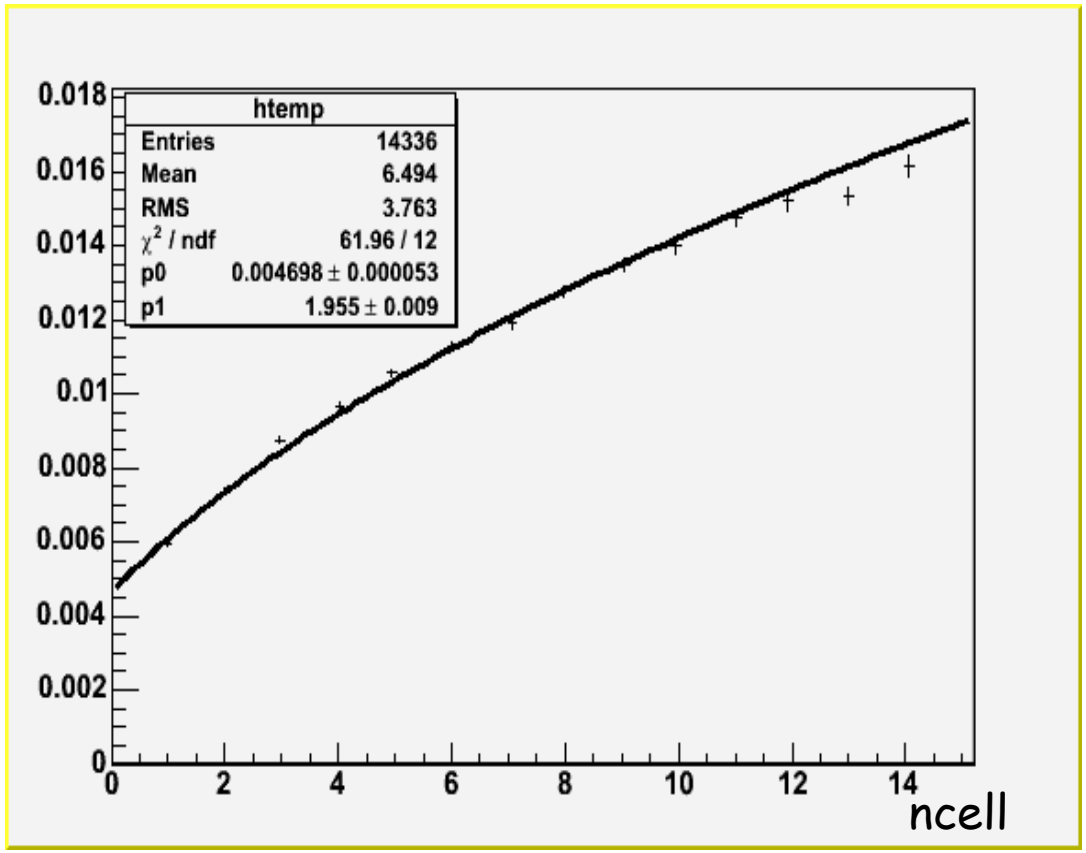
average beam momentum measurement

Brick 1 (4 GeV)



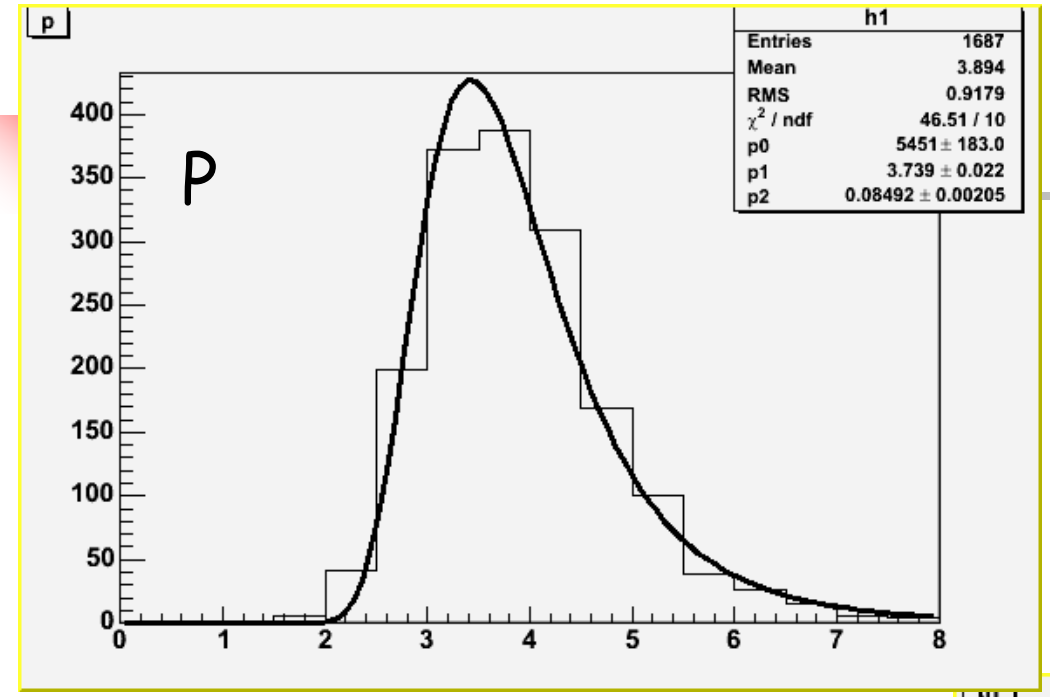
$<P_{beam}>=4.01\pm0.02$

Brick 2 (2 GeV)

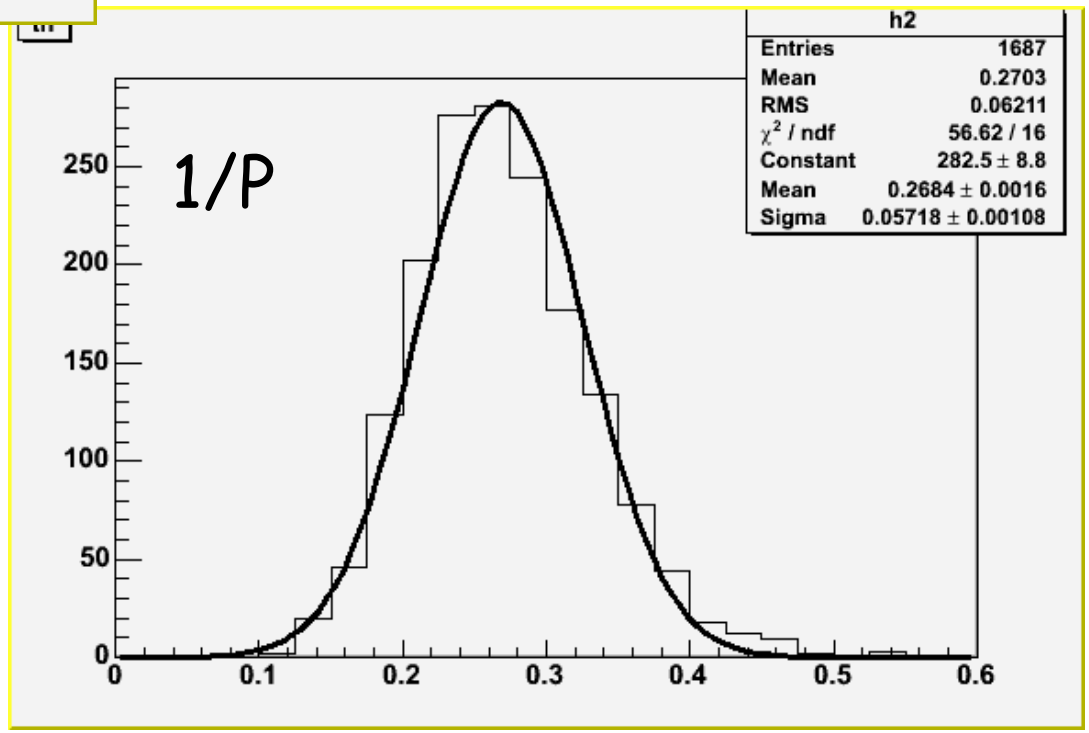


$<P_{beam}>=1.96\pm0.01$

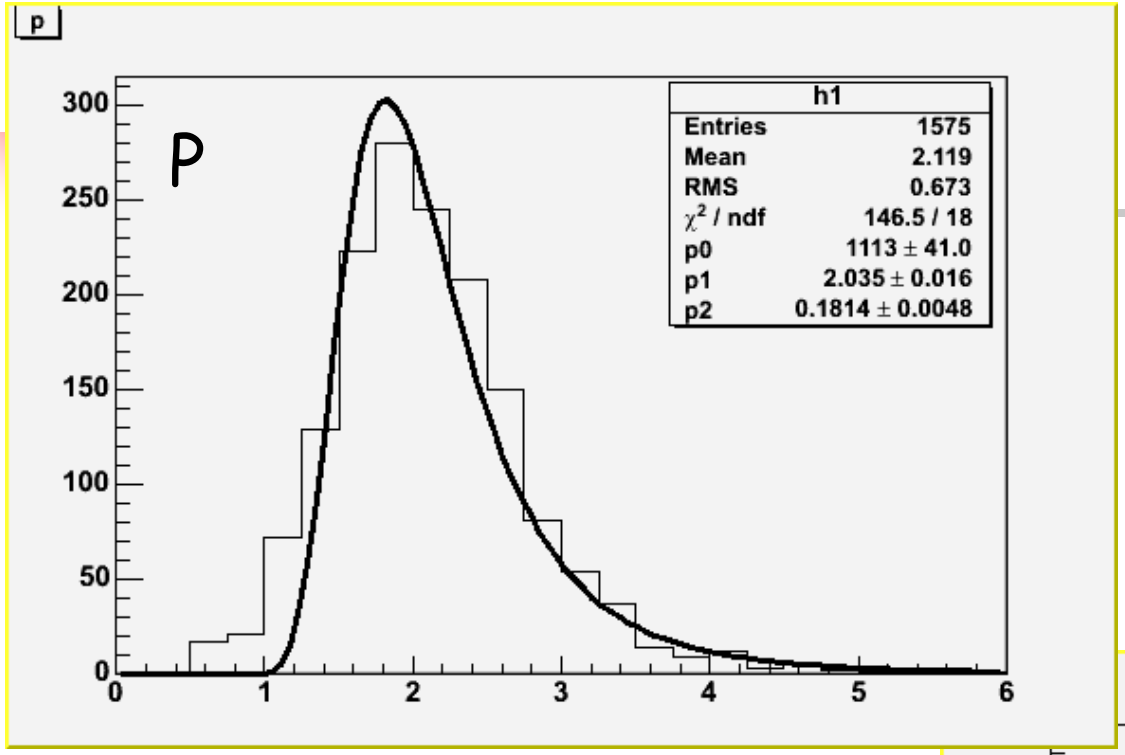
Momentum measurement track by track



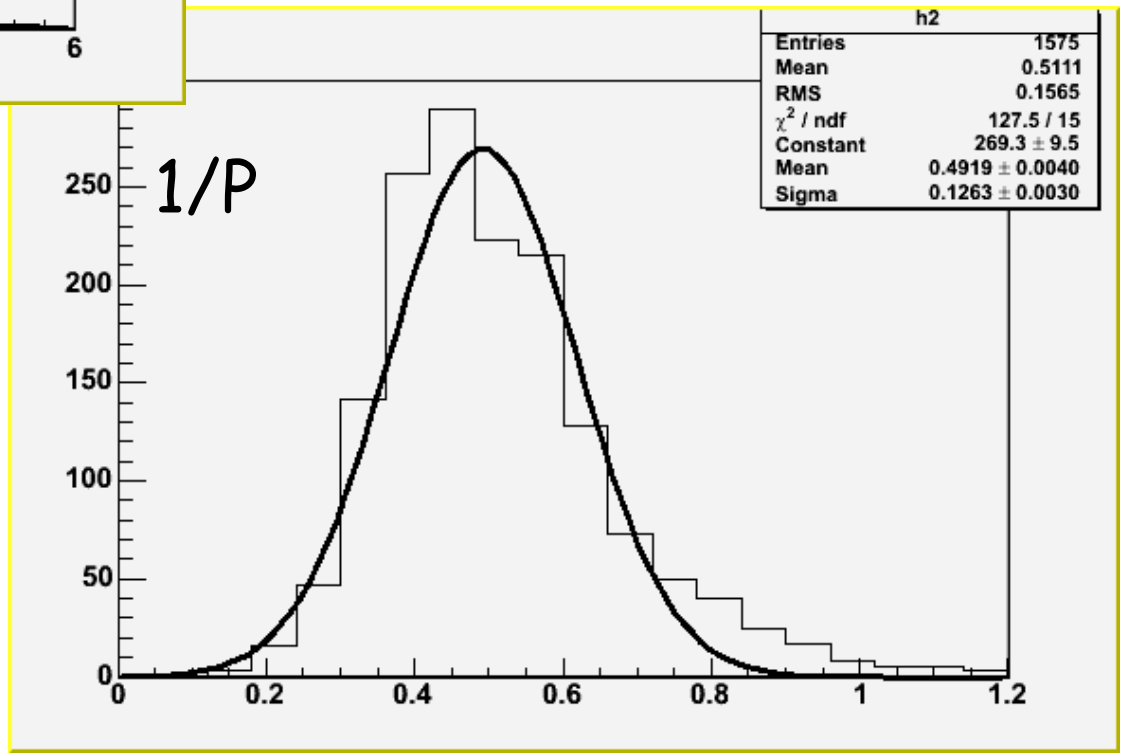
Brick 1 (4 GeV)



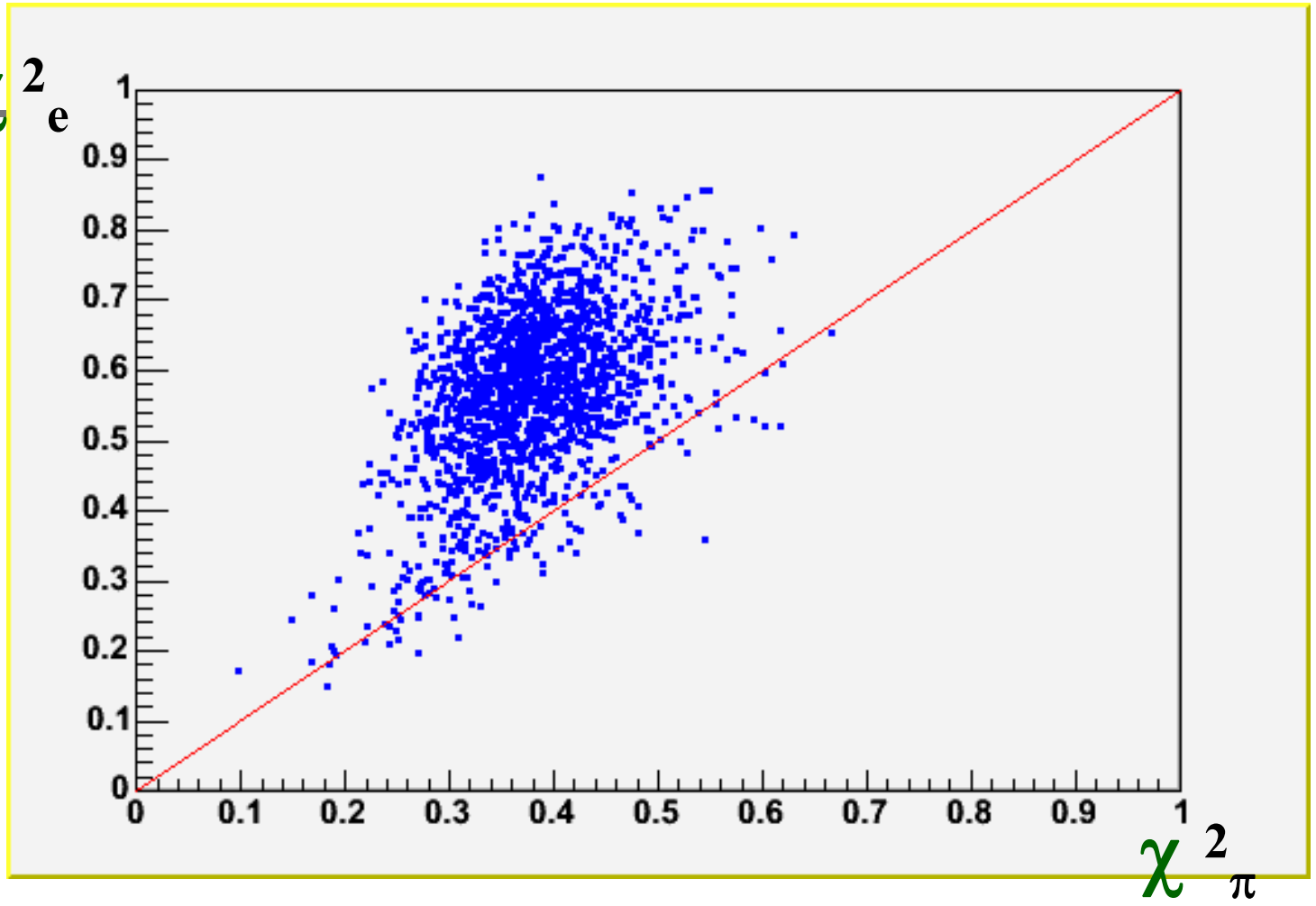
Momentum measurement track by track



Brick 2 (2 GeV)



χ^2 analysis – preliminary results (4 GeV)

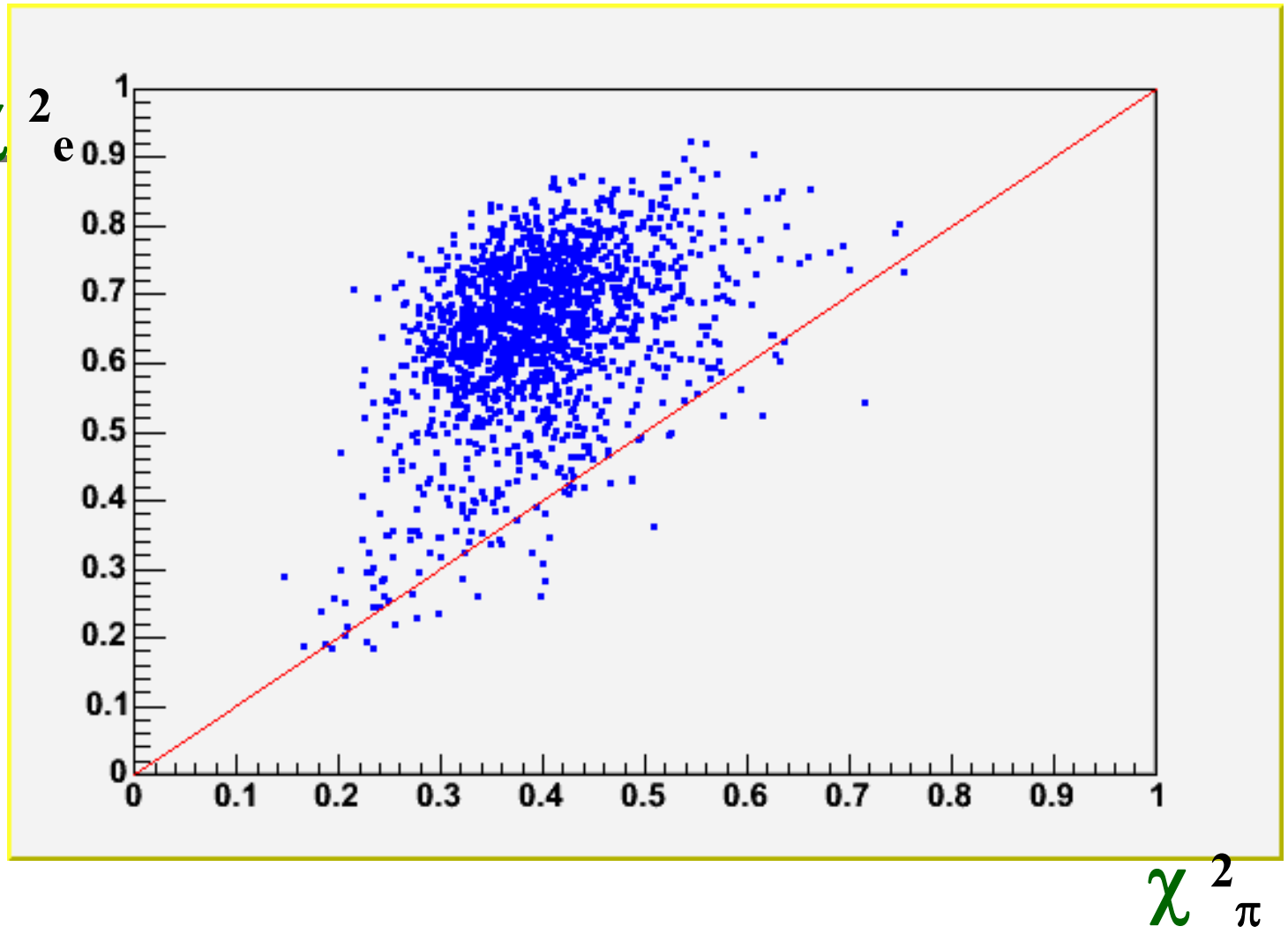


$\varepsilon = (95.8 \pm 0.5)\%$

Taking into account for muon contamination (ε_μ =100%)

$\varepsilon = \varepsilon_\pi \times 0.7 + \varepsilon_\mu \times 0.3$ ⇒ $\varepsilon_\pi = (94.0 \pm 0.5)\%$

χ^2 analysis – preliminary results (2 GeV)



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

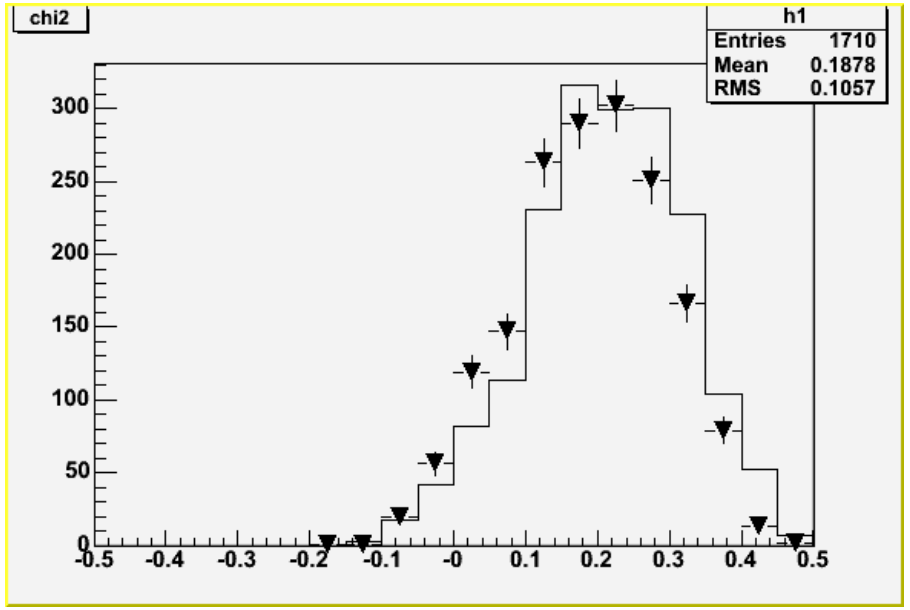
Taking into account for muon contamination (ε_μ =100%)

$\varepsilon = \varepsilon_\pi \times 0.7 + \varepsilon_\mu \times 0.3$ ⇒ $\varepsilon_\pi = (96.0 \pm 0.5)\%$

First MC studies (very preliminary)

$\Delta\chi^2$ MC / data comparison

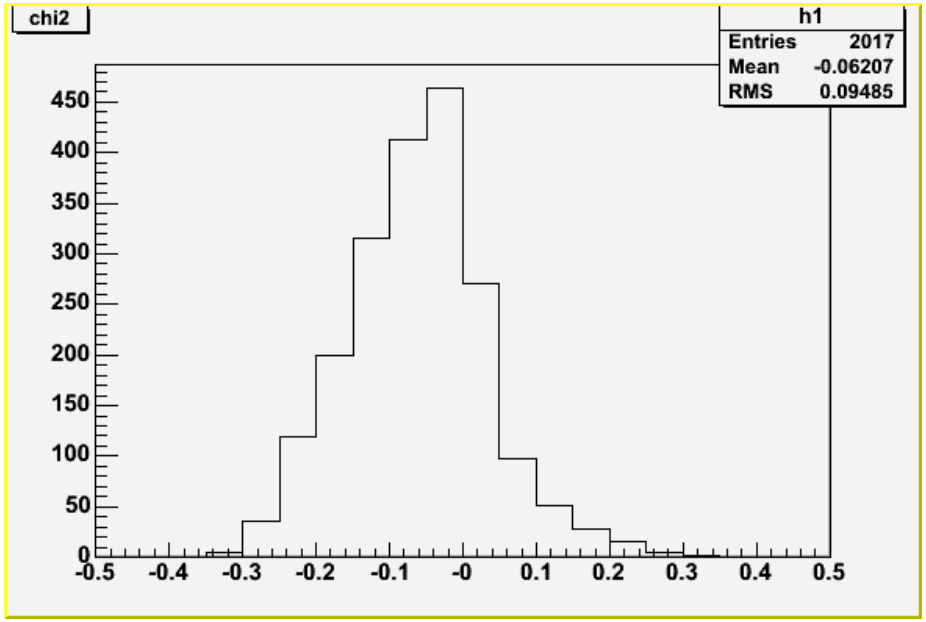
(4 GeV pions)



χ^2 analysis result on MC events:

	ε(%)
4 GeV π	94.7
2 GeV π	95.4
4 GeV **e**	76.8

$\Delta\chi^2$



Testbeam activities

- Foreseen tests in 2004
  - Technical tests at Gran Sasso laboratory
  - 3 x 2 weeks at CERN (eff./purity, vtx location, πID, MCS,…)
  - CS exposure to 1-2 MeV electron beam at CERN
  - 2 weeks at DESY for electron identification
  - Exposure at the low energy π/μ beam at PSI for dE/dx technique
- Tests in 2005
  - MiniOPERA at the Fermilab neutrino beam

Ongoing activities in OPERA

1. Installazione	Technical Coordinators : S. Buontempo, M. Spinetti; staff tecnico da INFN Napoli
2. Brick walls	E. Vanzanella, Gruppo di Frascati
3. Spettrometro (elettronica RPC, trigger)	SER, R. Acquafredda, M. Ambrosio, G. Sorrentino, gruppi di Frascati e Padova
4. Brick Assembly Machine (BAM)	Project leader: S. Buontempo, gruppo di Frascati, tecnici del CERN
5. Sistemi di scanning	
1. Hardware	Responsabile N. D'Ambrosio; F. Formisano, C. Pistillo, G. Sorrentino,SER
2. Ottimizzazione del sistema (eff., purezza, etc.)	G. De Lellis, C. Pistillo
3. Misure di precisione	S. Blokhin, D. Coppola, G. De Lellis
6. OPERA Physics	Physics Coordinators: M. Komatsu, P. Migliozzi
1. Software di ricostruzione emulsioni	Responsabile V. Tioukov; G. De Rosa, F. Di Capua, A. Marotta, Y. Petukov, L. Scotto, altri gruppi europei
2. Sviluppo MonteCarlo generale	A. Marotta, altri gruppi europei
3. Studi sensitività	Tutte le persone del gruppo
7. Attività di testbeam	Tutte le persone del gruppo