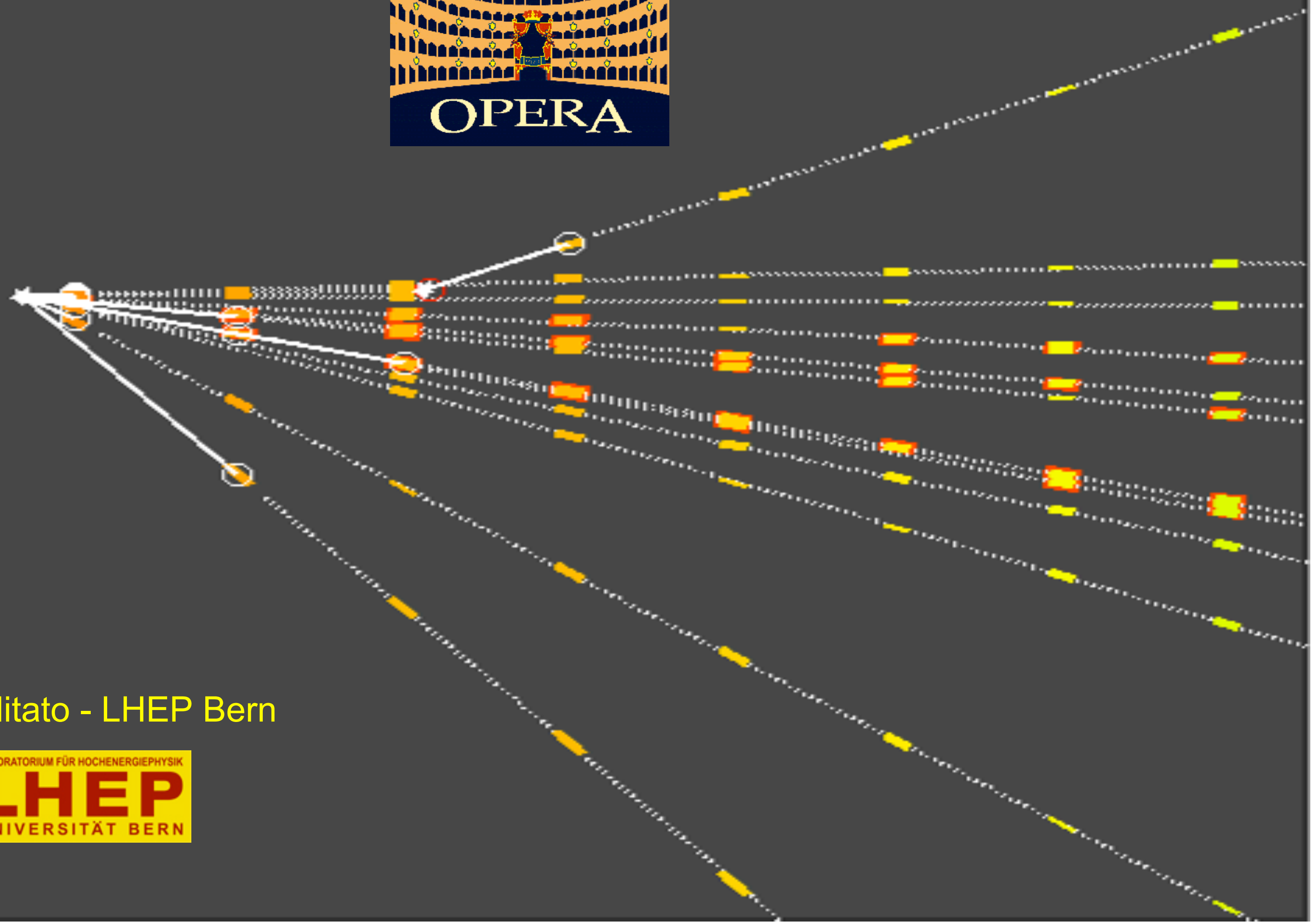
Status and perspectives of the OPERA experiment



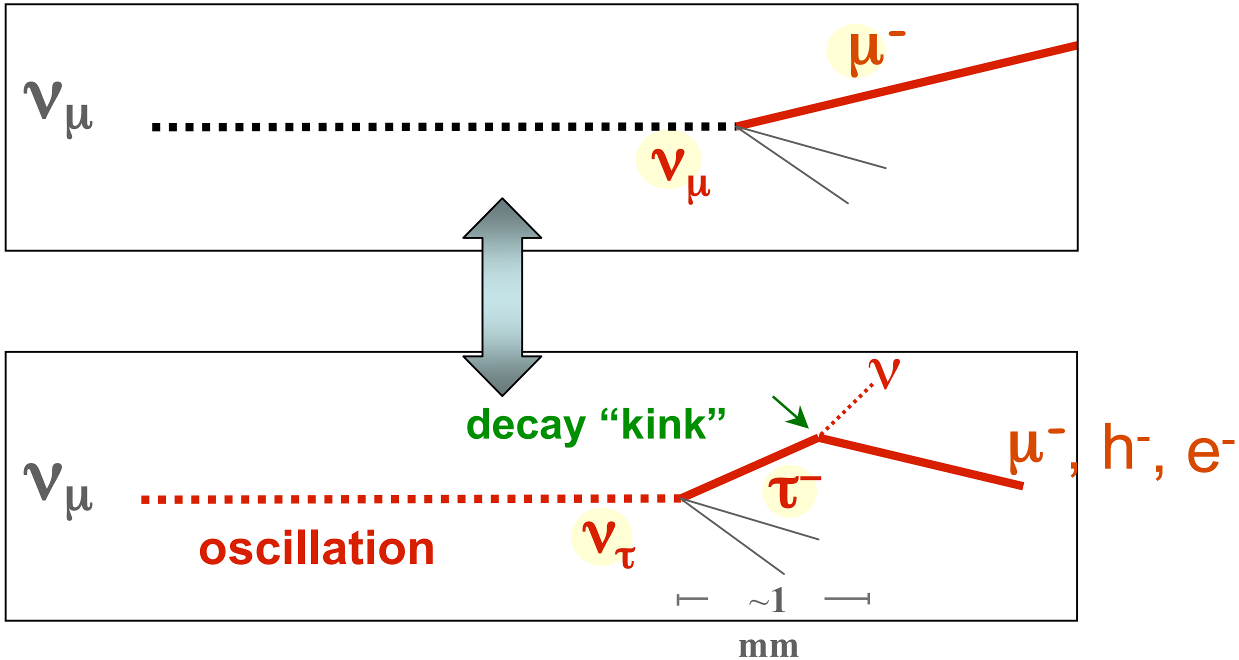
A. Ereditato - LHEP Bern

First direct detection of neutrino oscillations in appearance mode, following the SK discovery of oscillations with atmospheric neutrinos. One missing tile in the oscillation picture

$$P(\nu_\mu \rightarrow \nu_t) \sim \sin^2 2\theta_{23} \cos^4\theta_{13} \sin^2(\Delta m^2_{23} L/4E)$$

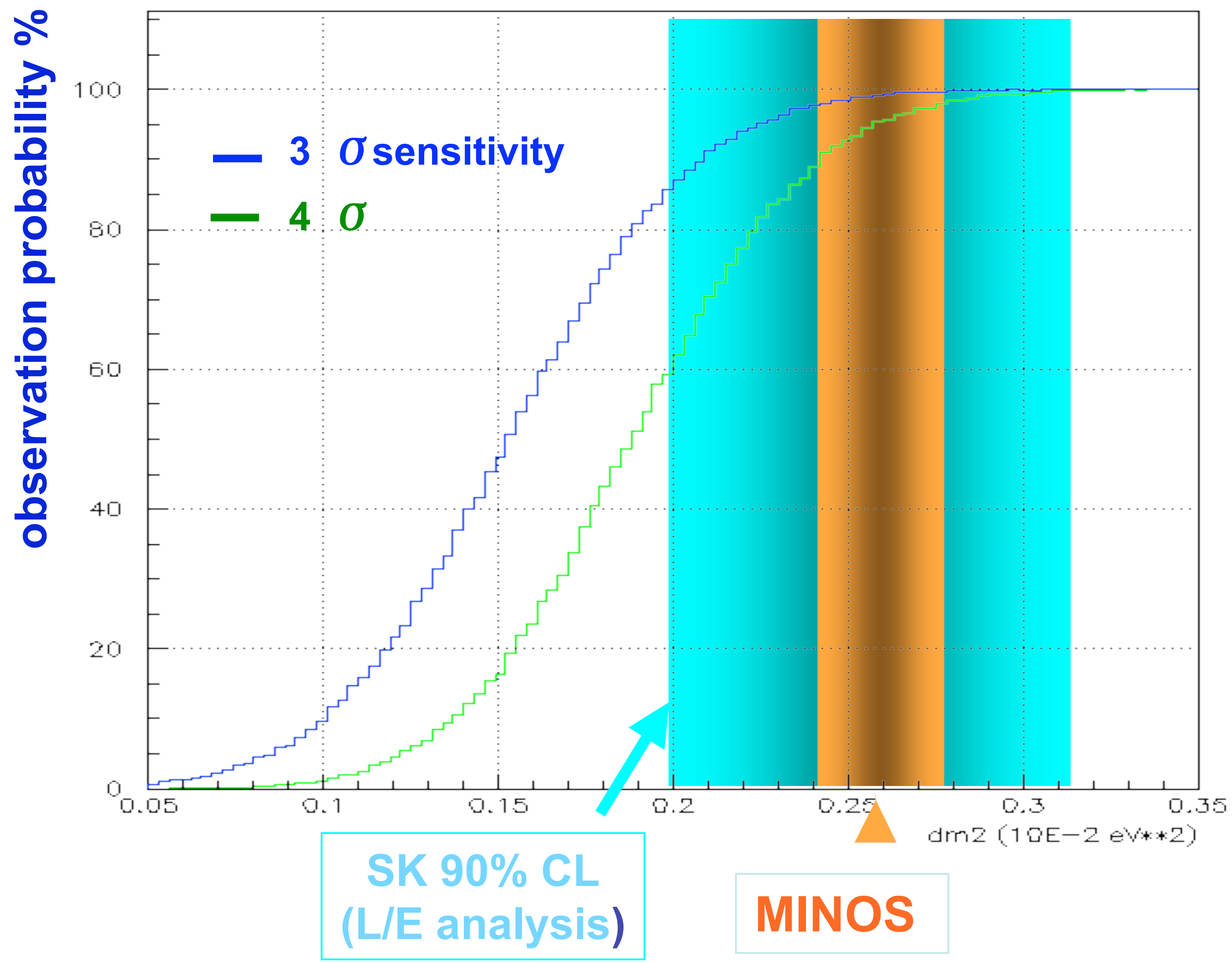
Requirements:

1) long baseline, 2) high neutrino energy, 3) high beam intensity, 4) detect short lived τ's

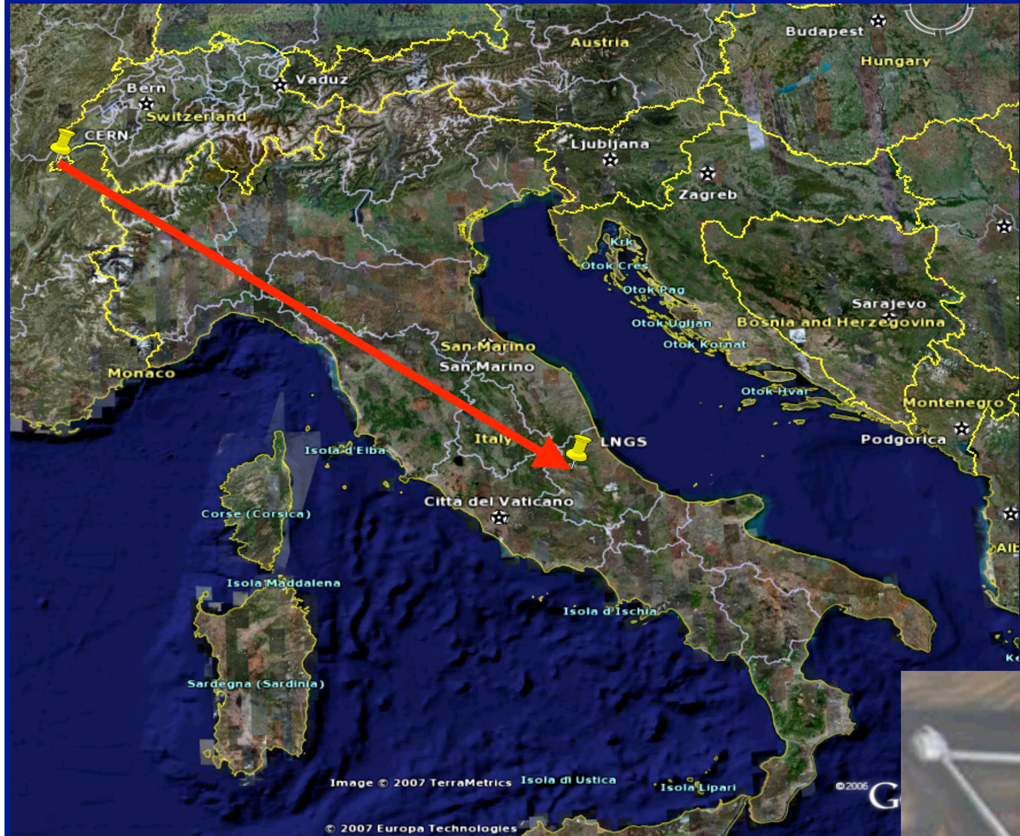


OPERA ν_τ appearance observation probability

Assume 22.5x10^{19} pot, 10-15 signal events, < 1 BG



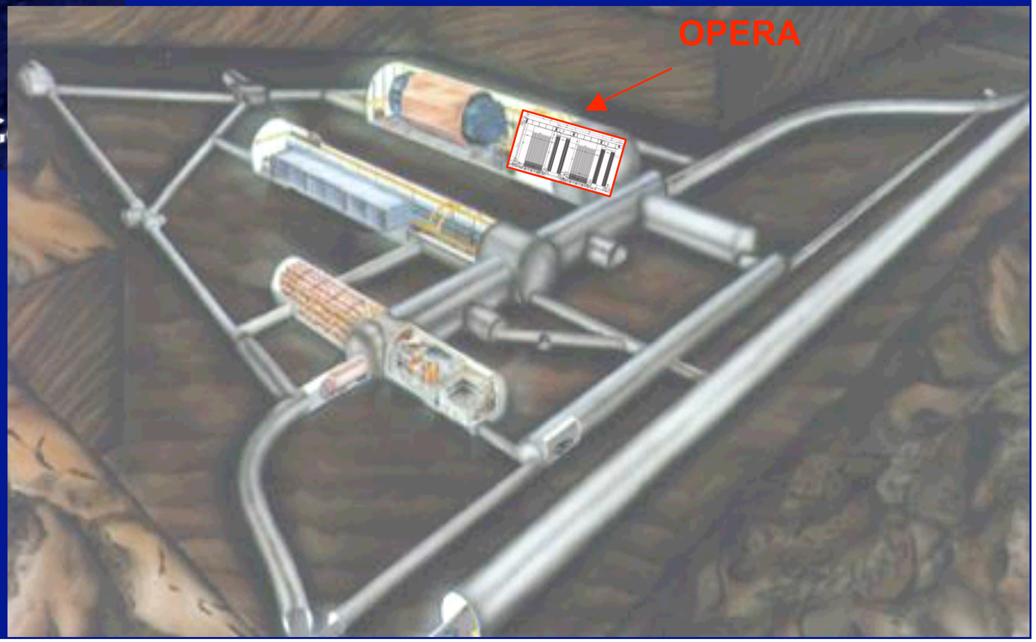
CNGS beam: tuned for τ-appearance at LNGS (730 km away from CERN)



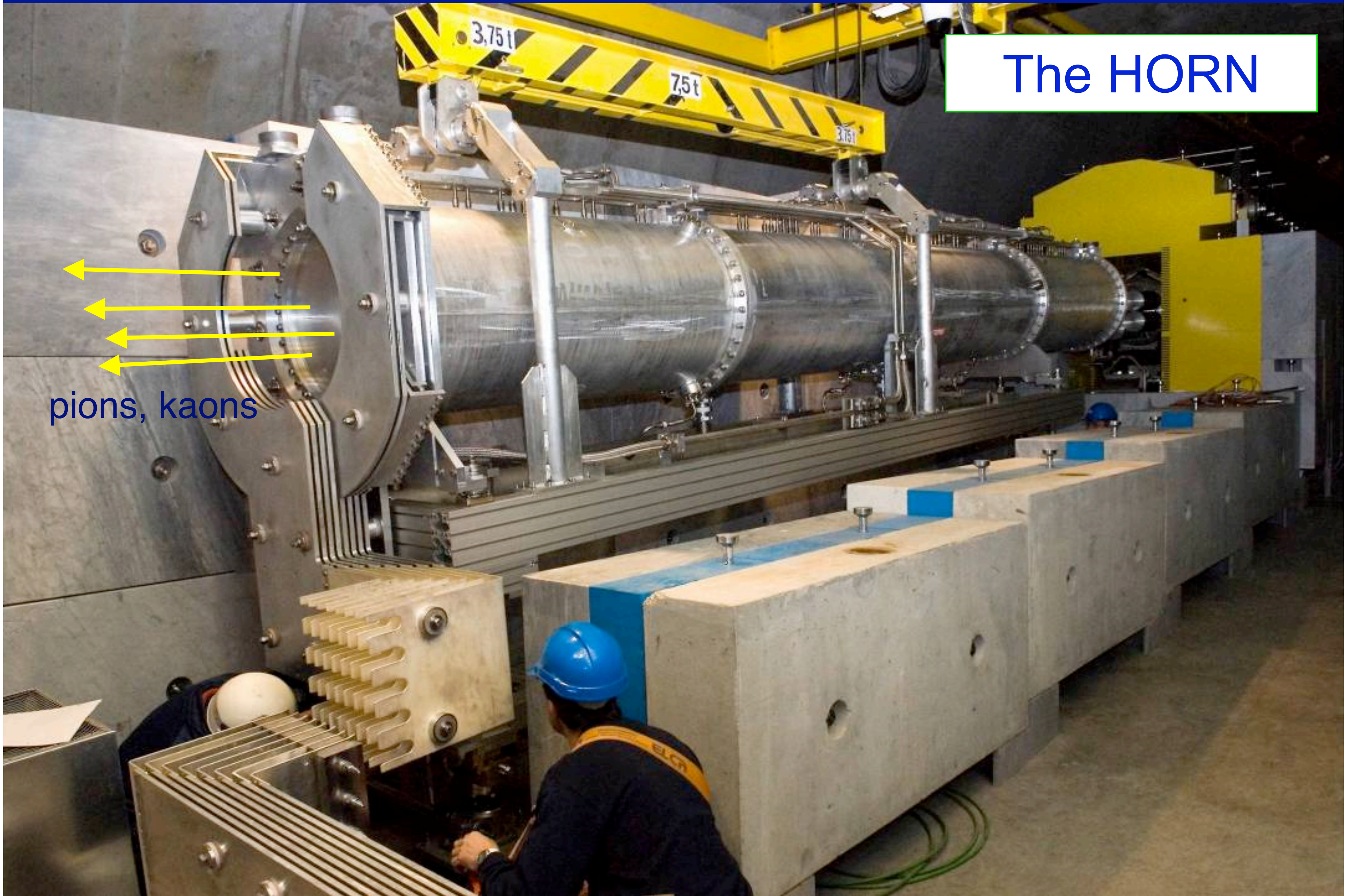
Mean ν_μ energy 17 GeV

Requested to deliver: 22.5 x 10^{19} pot

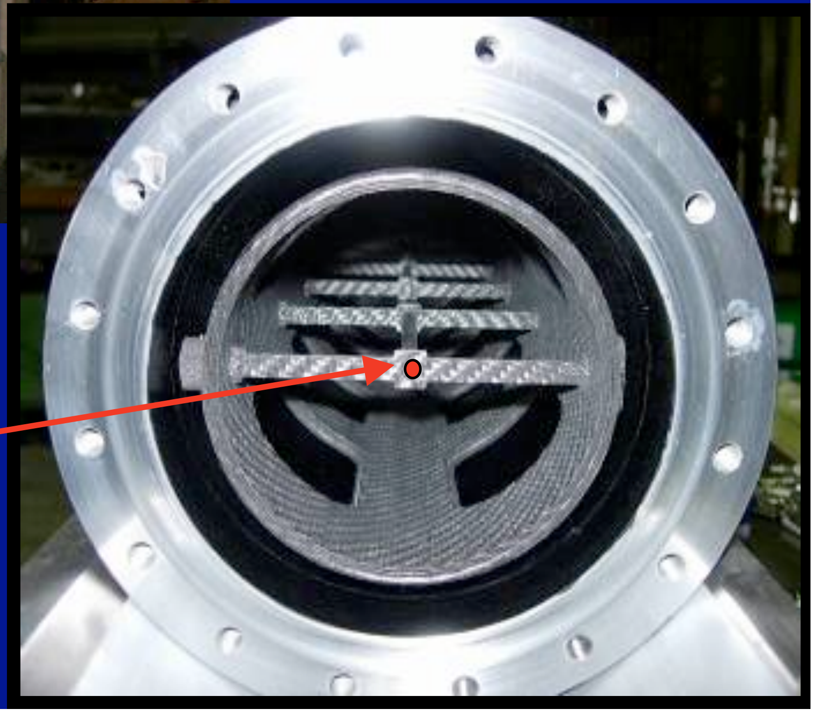
LNGS: the largest underground laboratory in the world



The HORN



CNGS target



5 mm diameter rods

OPERA detector concept

Conflicting requirements:

Large mass (low cross-section)

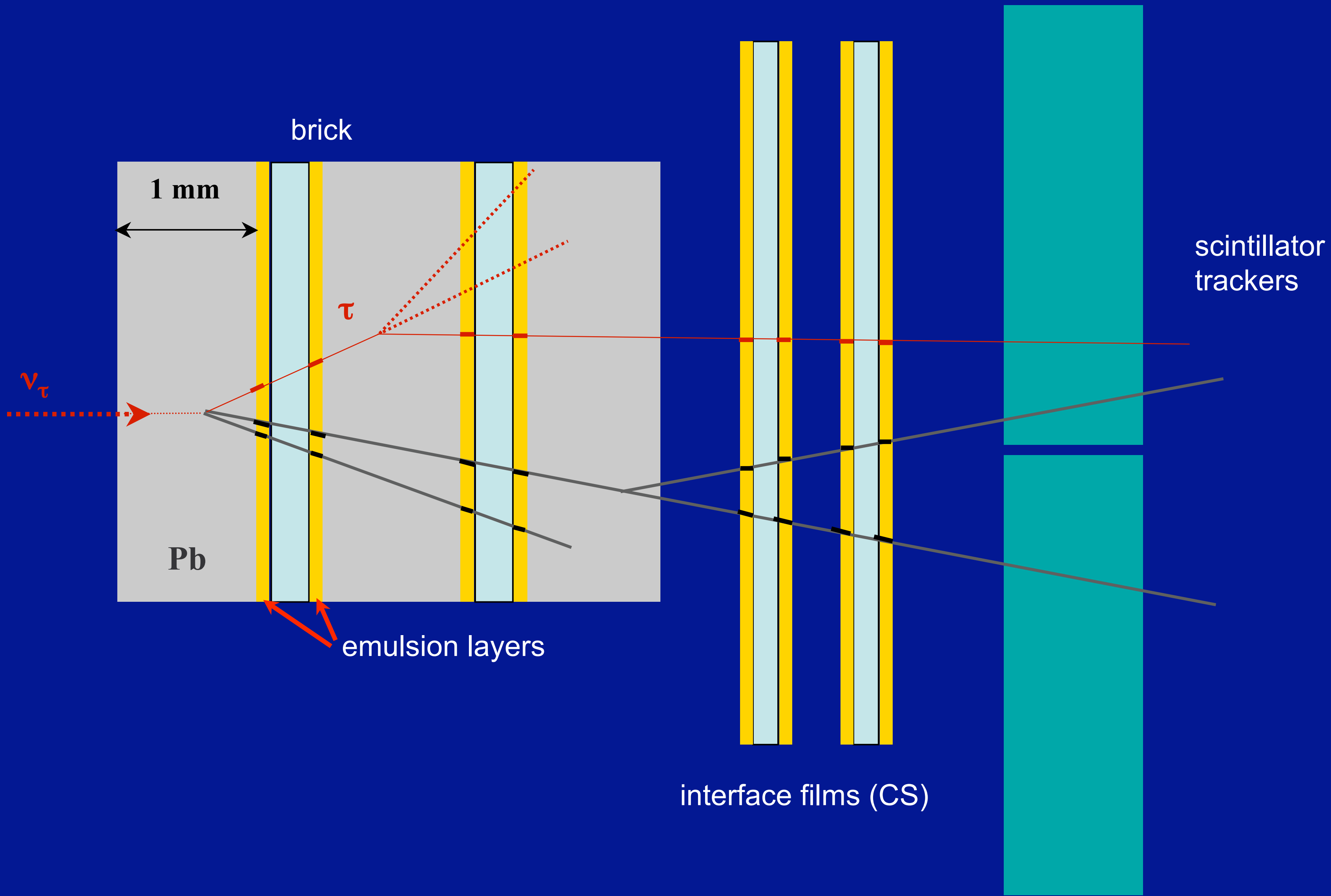
High granularity (signal selection and background rejection)

- Detection method: novel nuclear emulsion film technique (Nagoya/Fuji film) coupled to modern automatic scanning devices (Japan, Europe). Unprecedented large scale
- Very successful for medium scale past experiments: E531, CHORUS, DONUT
- OPERA: sandwich arrangement of emulsion films and lead plates (ECC technique)
- Complement with electronic detectors (hybrid apparatus) to provide time resolution to the emulsions and contribute to the kinematical event analysis

Target: 1300 tons

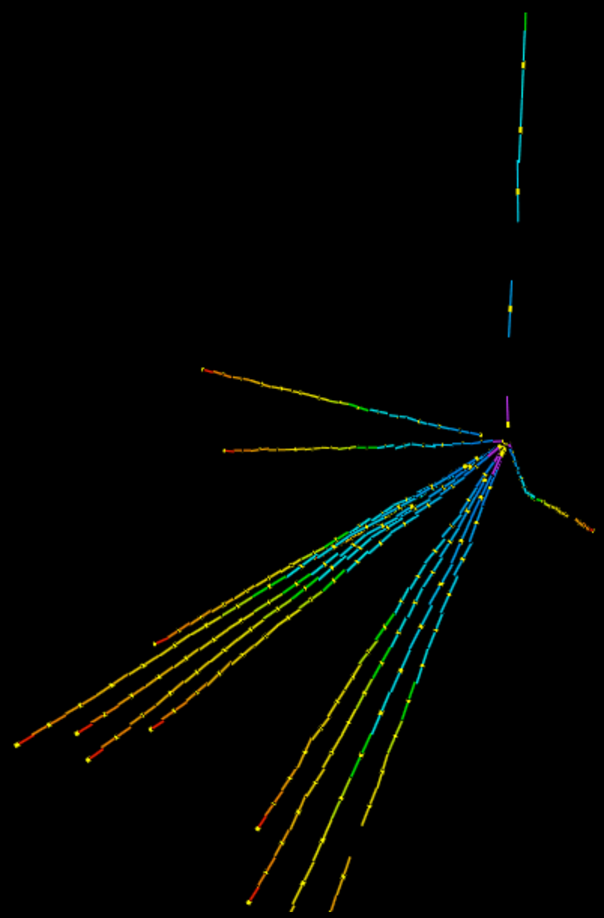
~25,000	neutrino interactions
~120	ν_τ interactions
~10	ν_τ identified
~ 0.5	BG events

OPERA detector concept in a snapshot

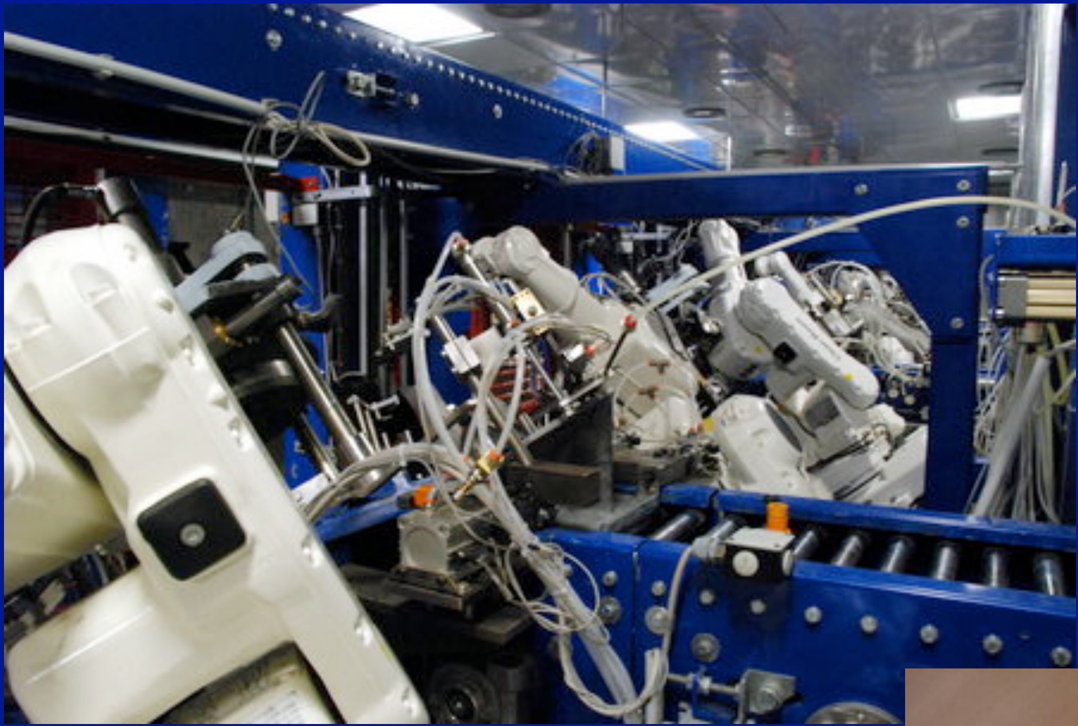


ECC technique: 2000 discovery of ν_τ's with the DONUT experiment

by K. Niwa and coworkers

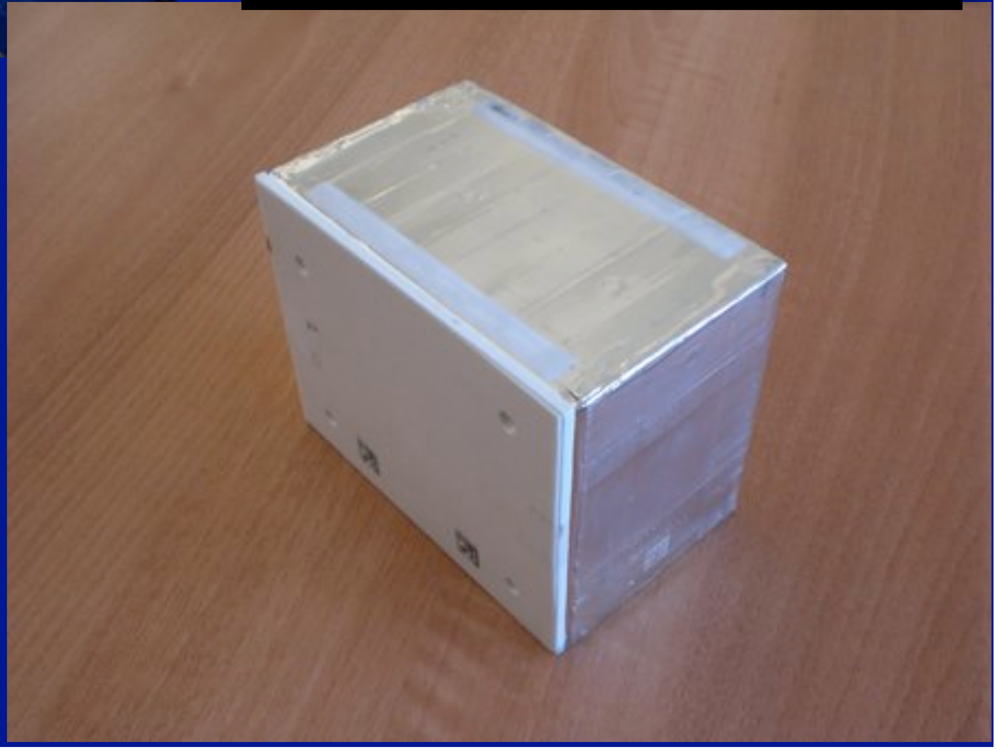


OPERA detector and related facilities



Robots of the
brick assembly machine

Assembled brick with interface emulsions

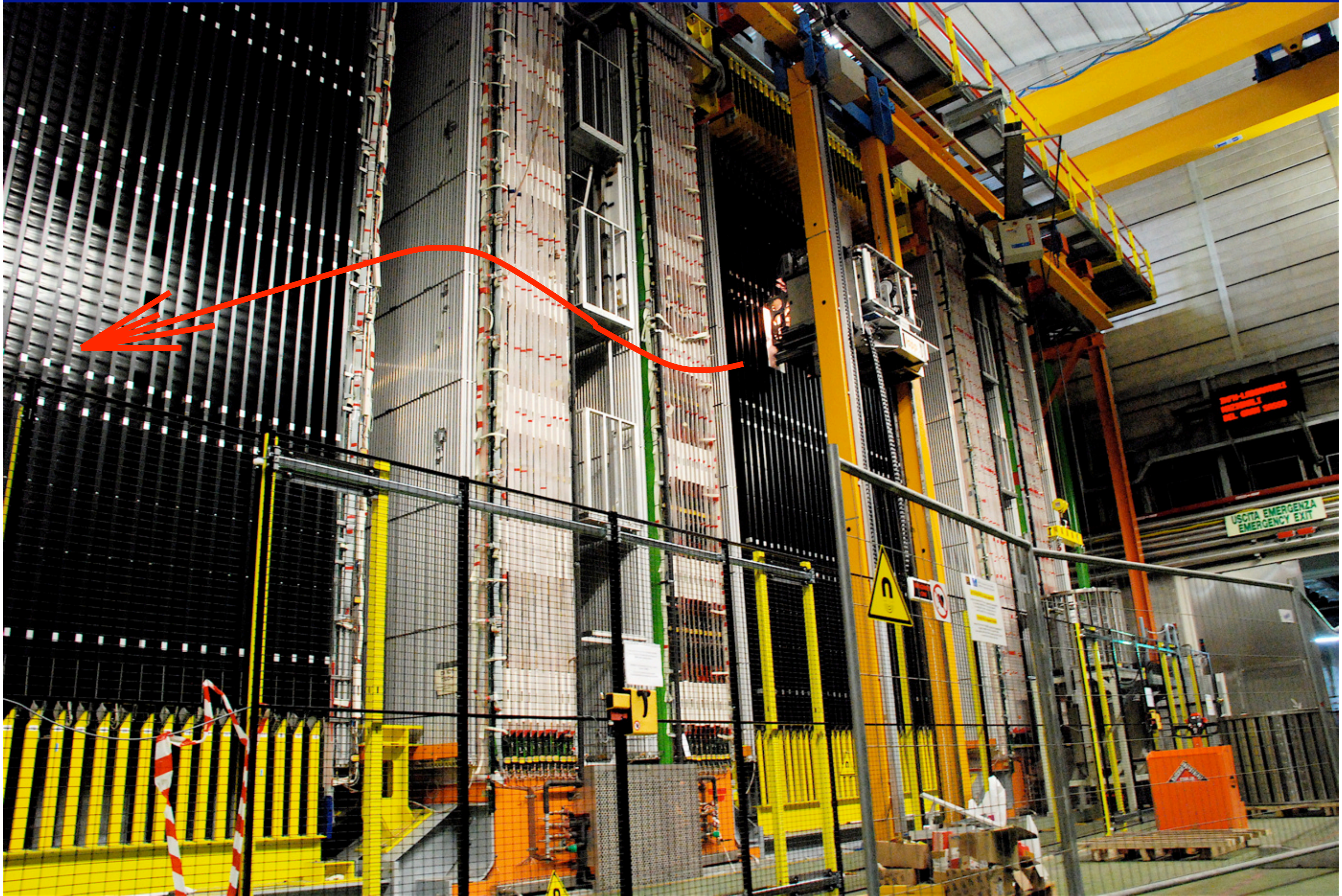


~150,000 bricks produced and installed:

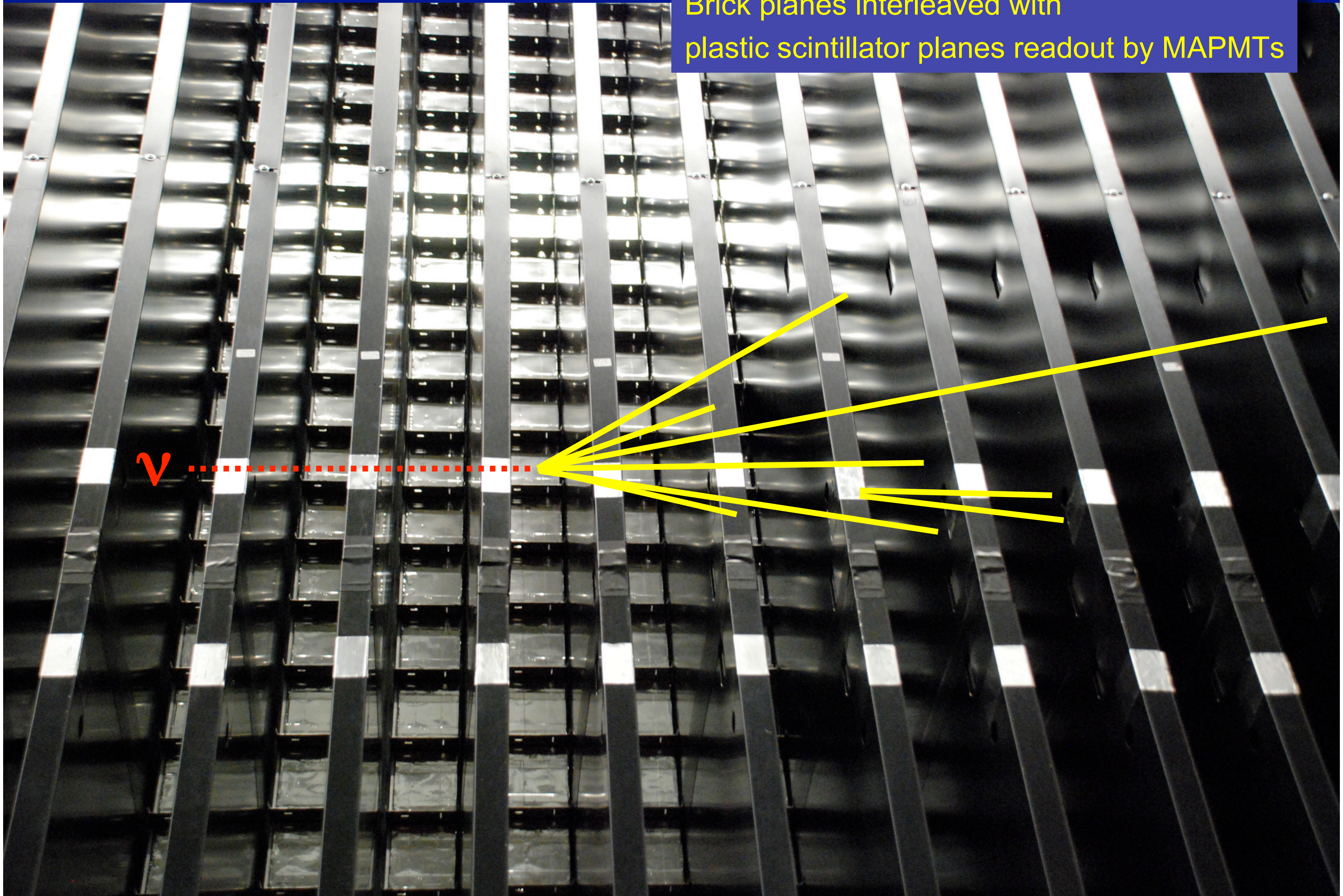
8.3 kg and 10 X_0 each

57 +2 emulsion films and 57 1mm lead plates per brick (12.5 cm x 10 cm)

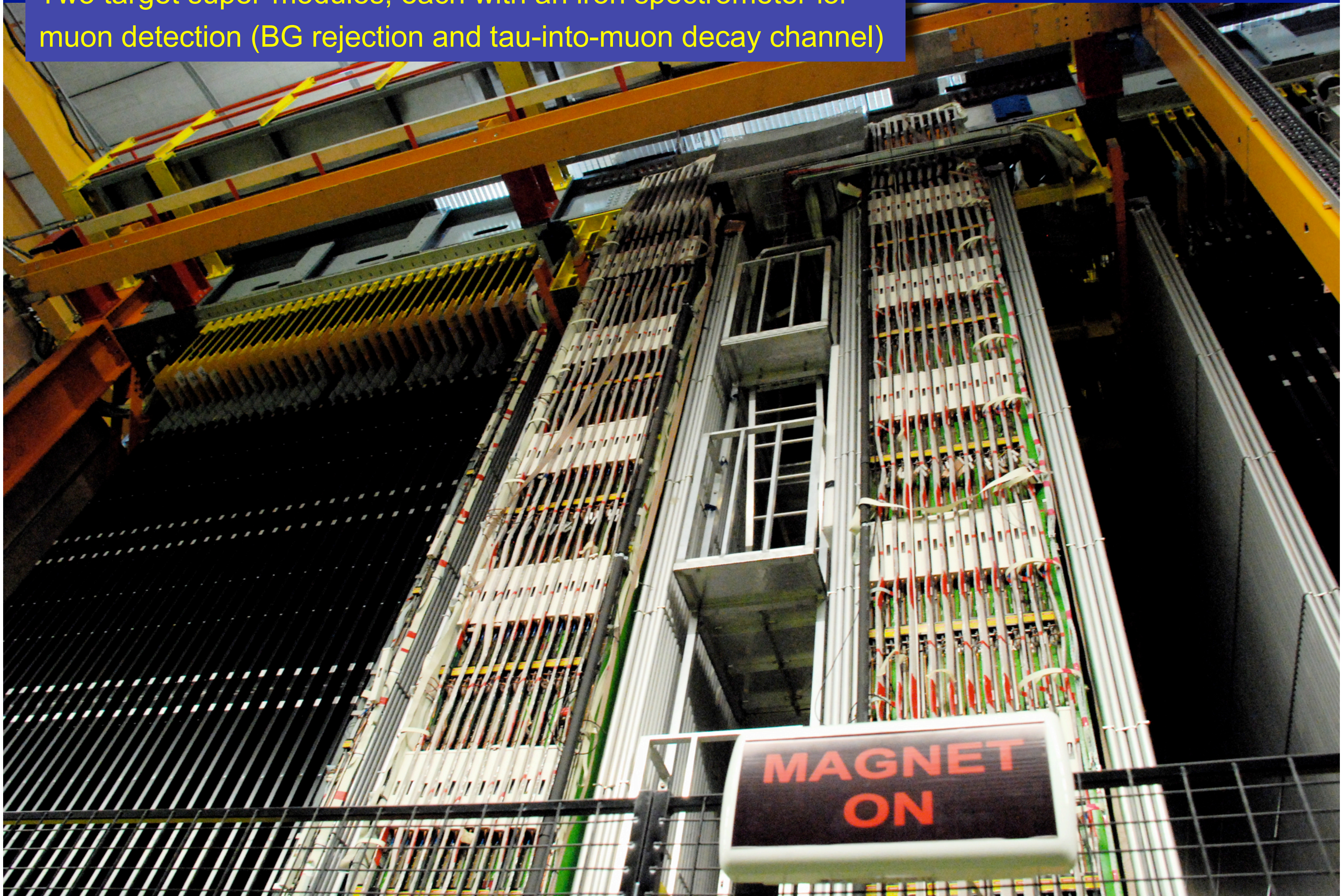
For a total of 105,000 m^2 of lead surface and 111,000 m^2 of film surface (~ 8.9 million films)


USCITA EMERGENZA
EMERGENCY EXIT

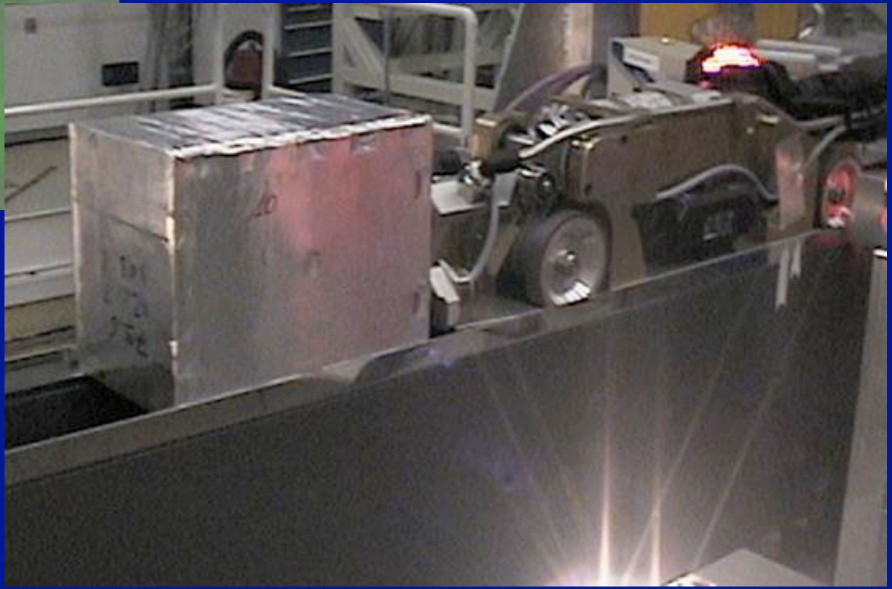
Brick planes interleaved with
plastic scintillator planes readout by MAPMTs



Two target super-modules, each with an iron spectrometer for muon detection (BG rejection and tau-into-muon decay channel)



Automatic brick manipulation machine



Large facilities for brick handling after extraction:

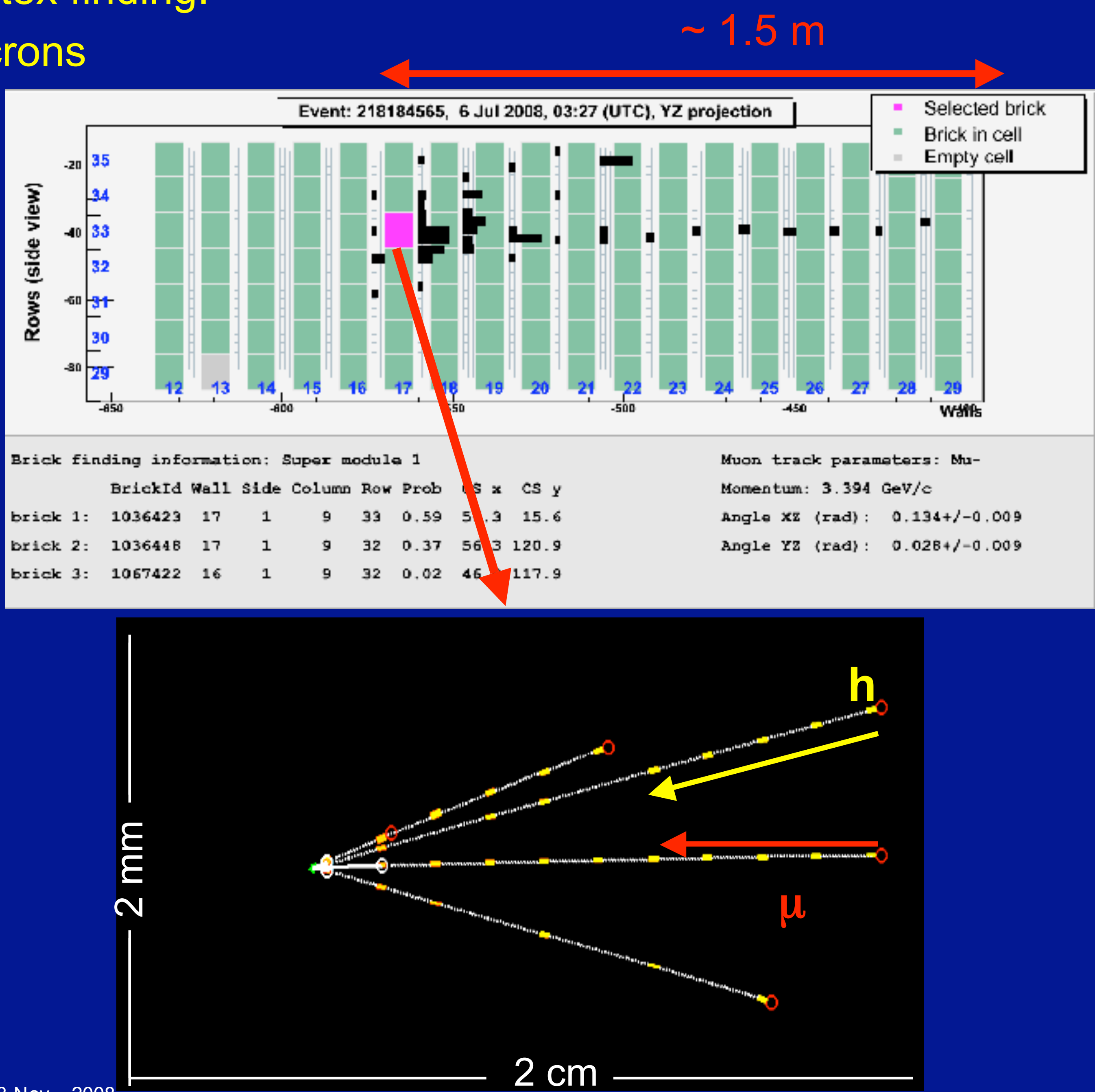
- X-ray marking
- Cosmic-ray alignment
- Industrial emulsion processing

Automatic high-speed microscopes (~40 in the collaborations)

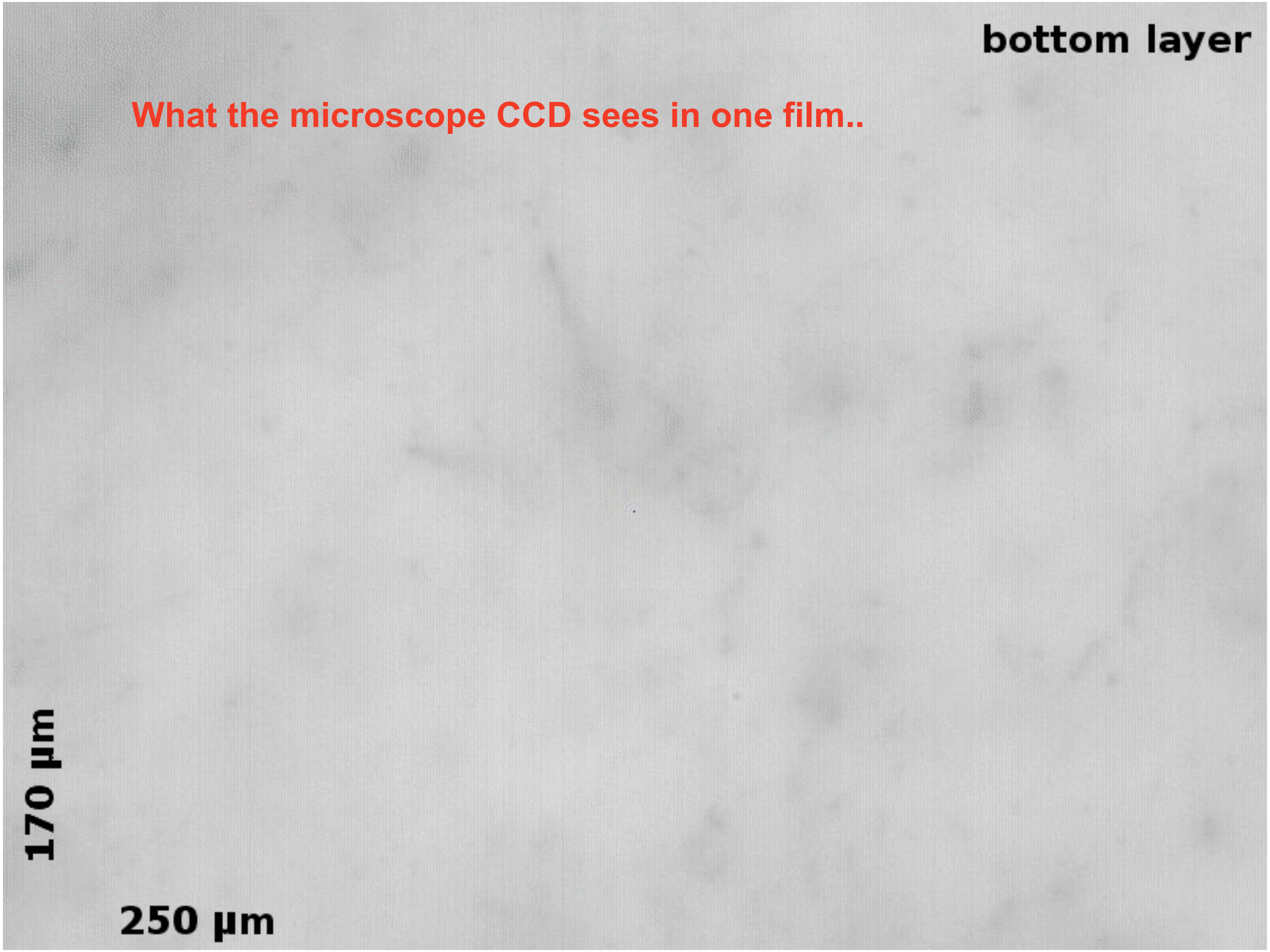
LHEP Bern: Swiss Scanning Station with 5 microscopes. ~10 physicist from Bern and ETHZ involved. Largest european laboratory

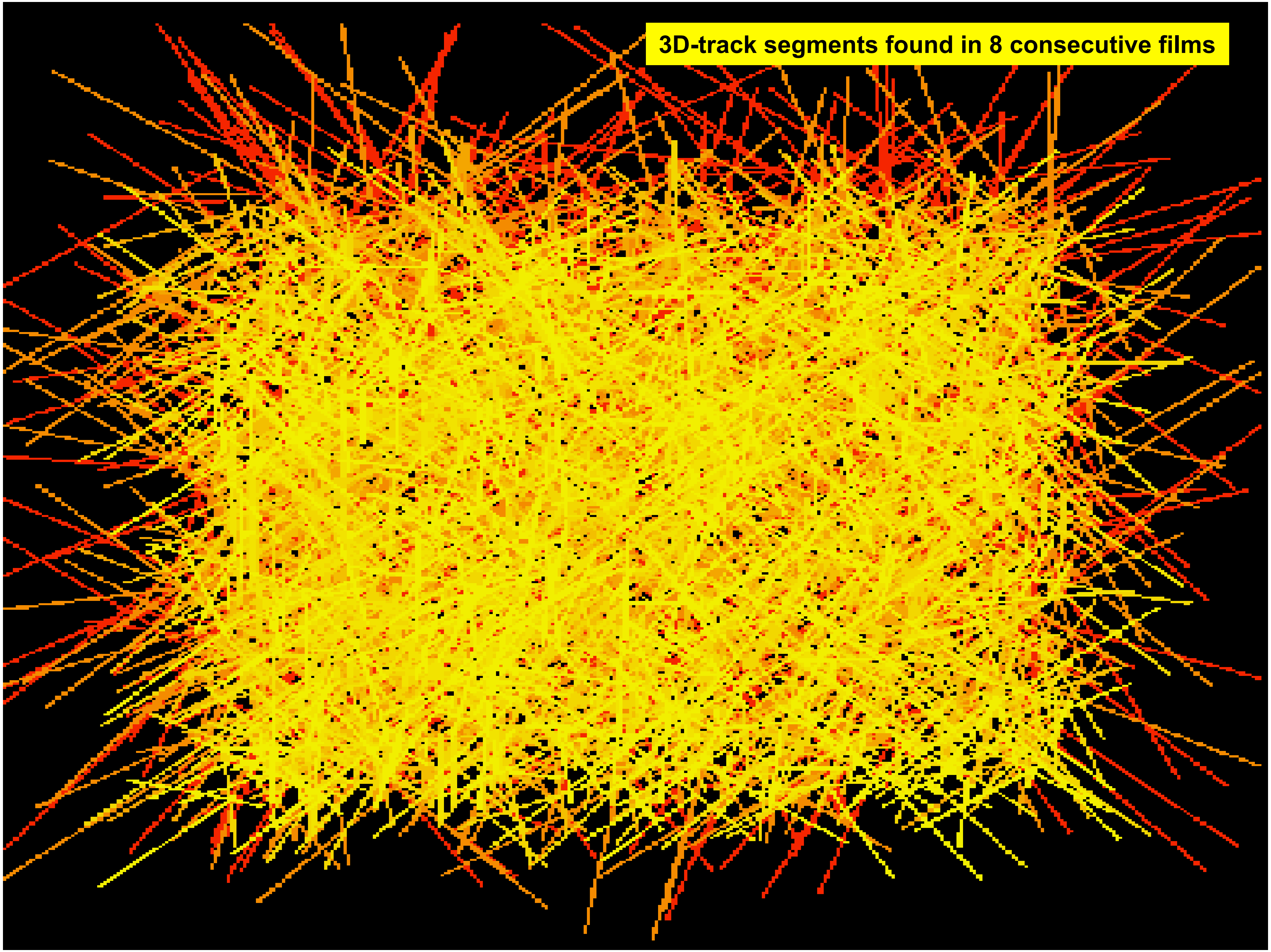
Goal: analyze ~ 20% of the total OPERA brick statistics (up to1000 brick/year).

From trigger to vertex finding: from meters to microns

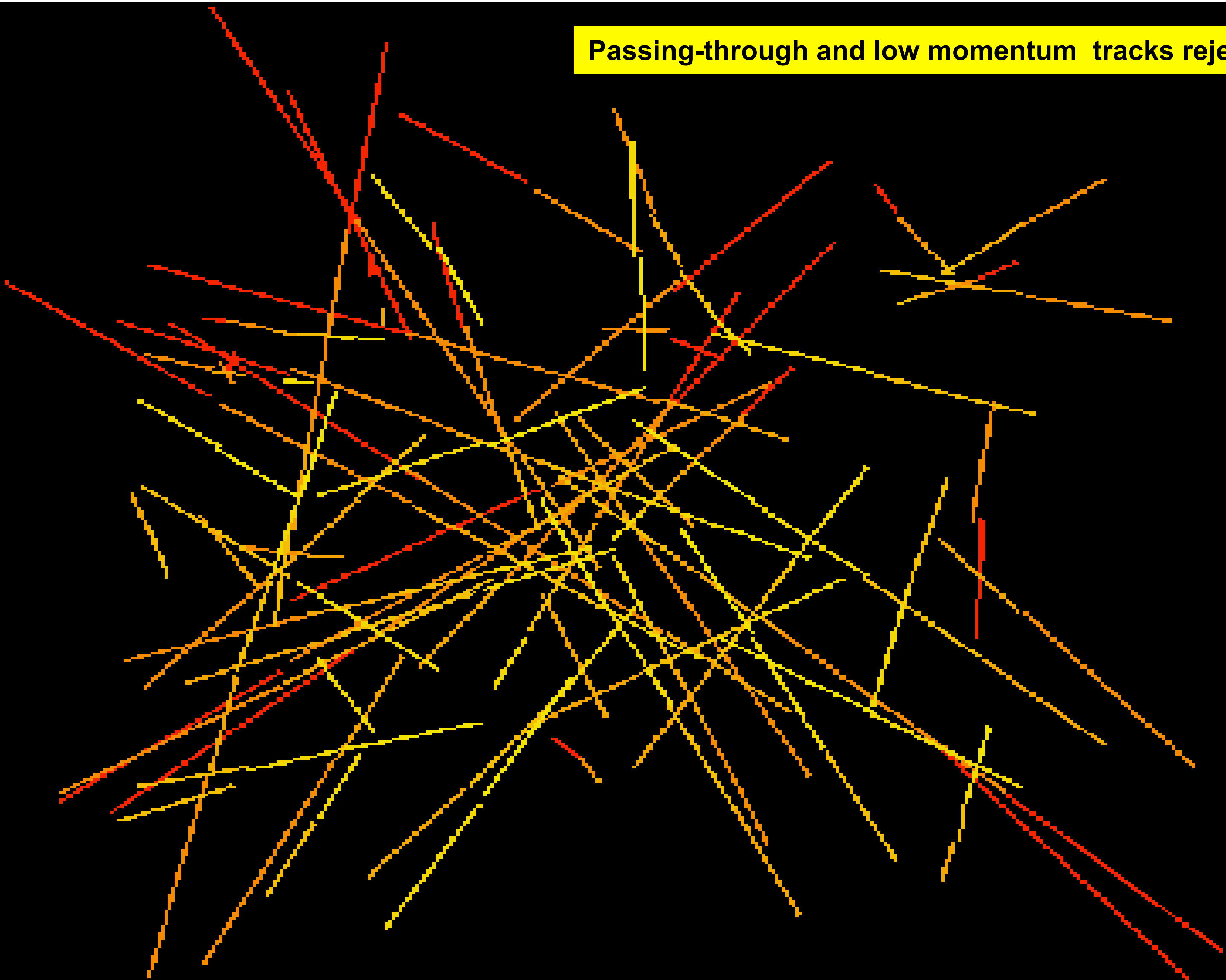


What the microscope CCD sees in one film..

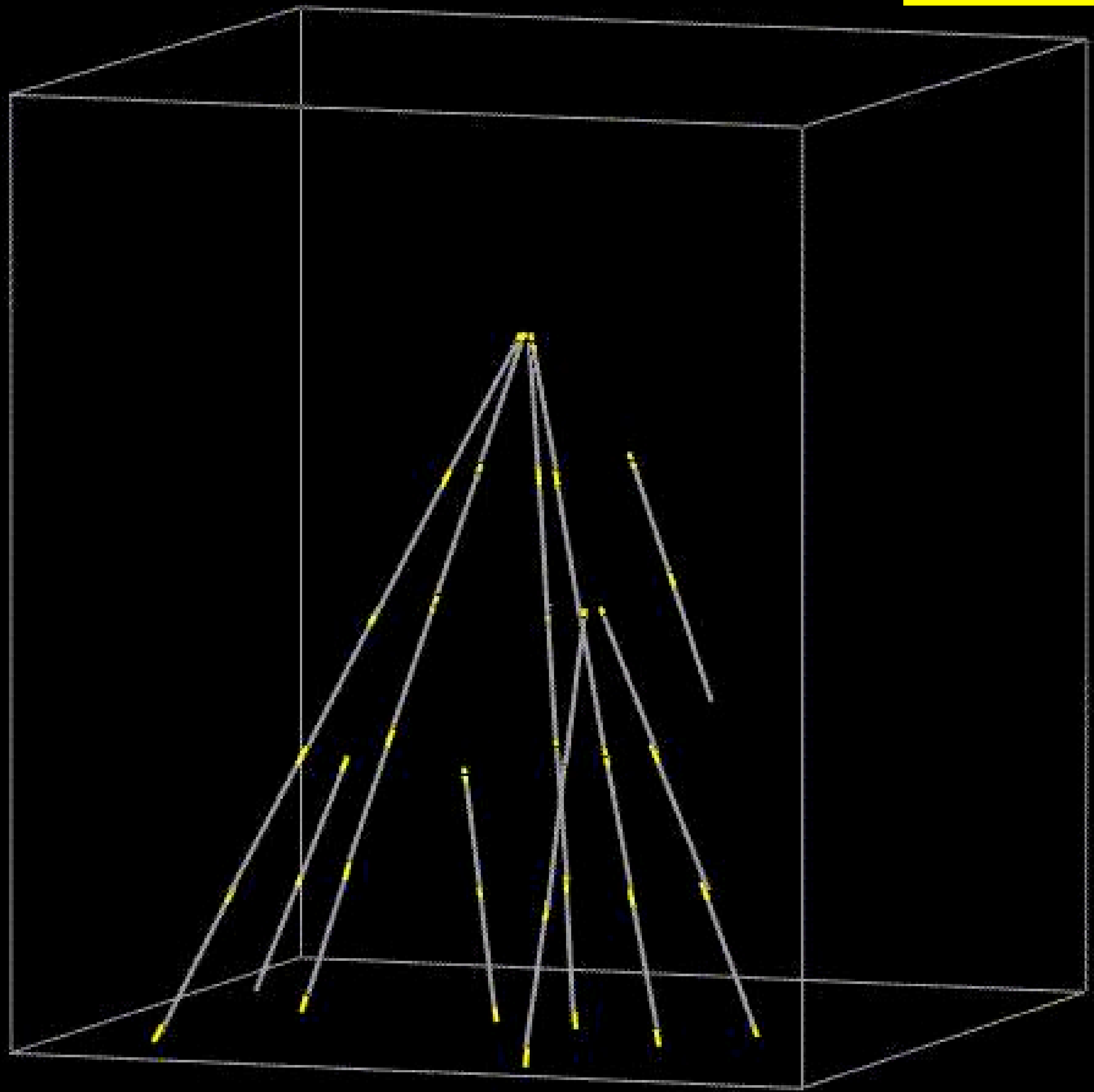



3D-track segments found in 8 consecutive films

Passing-through and low momentum tracks rejection



Vertex reconstruction



OPERA recent history

May 2006: electronic detector commissioning

Aug 2006: technical run, **0.76×10^{18} pot** collected

319 interactions in the rock, mechanical structure and iron of the spectrometer

Oct 2006: start of brick production

Oct 2007: pilot physics run (~40% target) **0.82×10^{18} pot**

first 38 neutrino events in the lead/emulsion target

Jun 2008: OPERA detector filled and fully commissioned (~150,000 bricks)

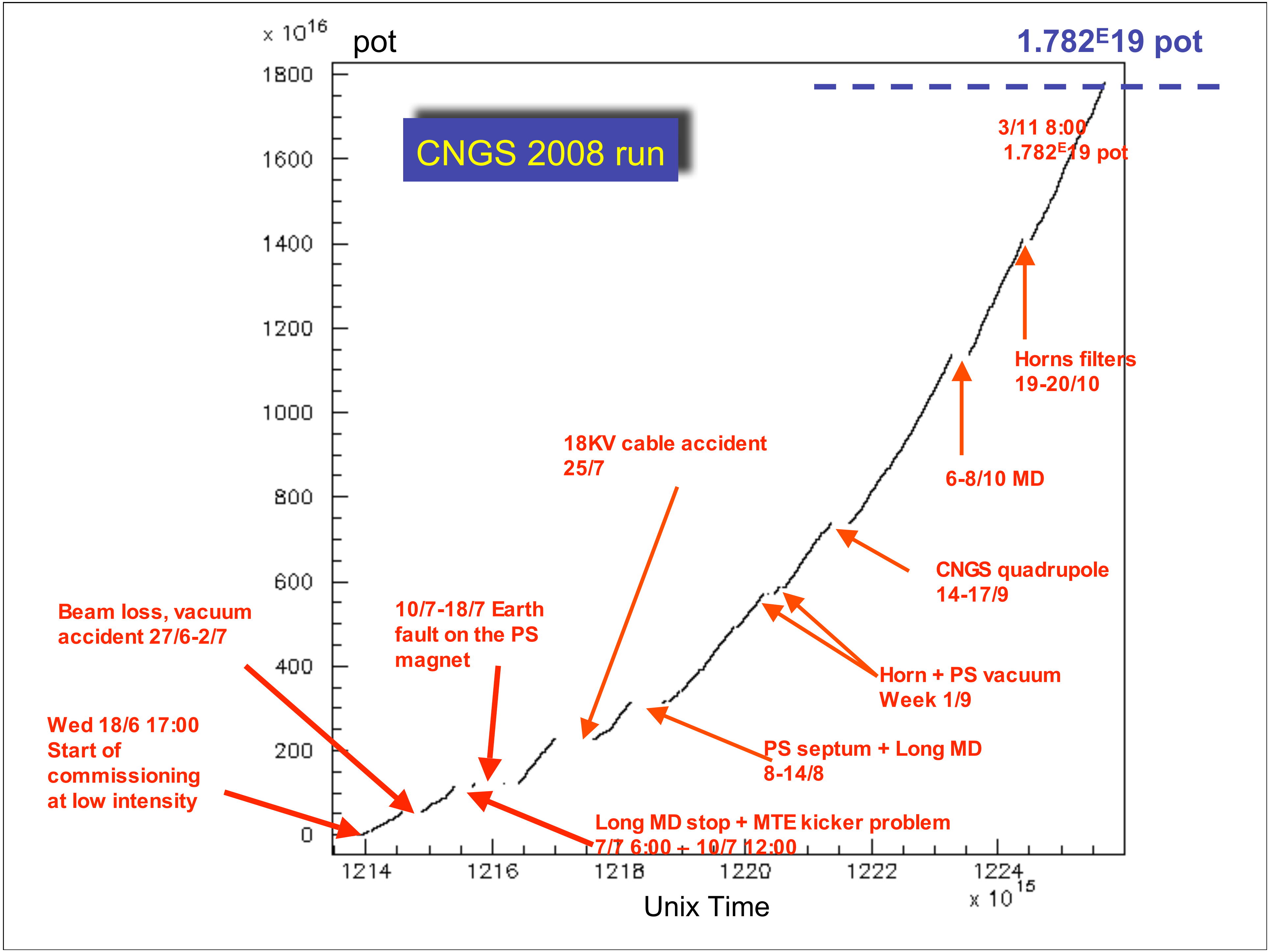
Jun 2008: Start first OPERA production run

Nov 2008: **18×10^{18} pot** and ~1700 neutrino events in the target:

54 charm events, …0.6 τ

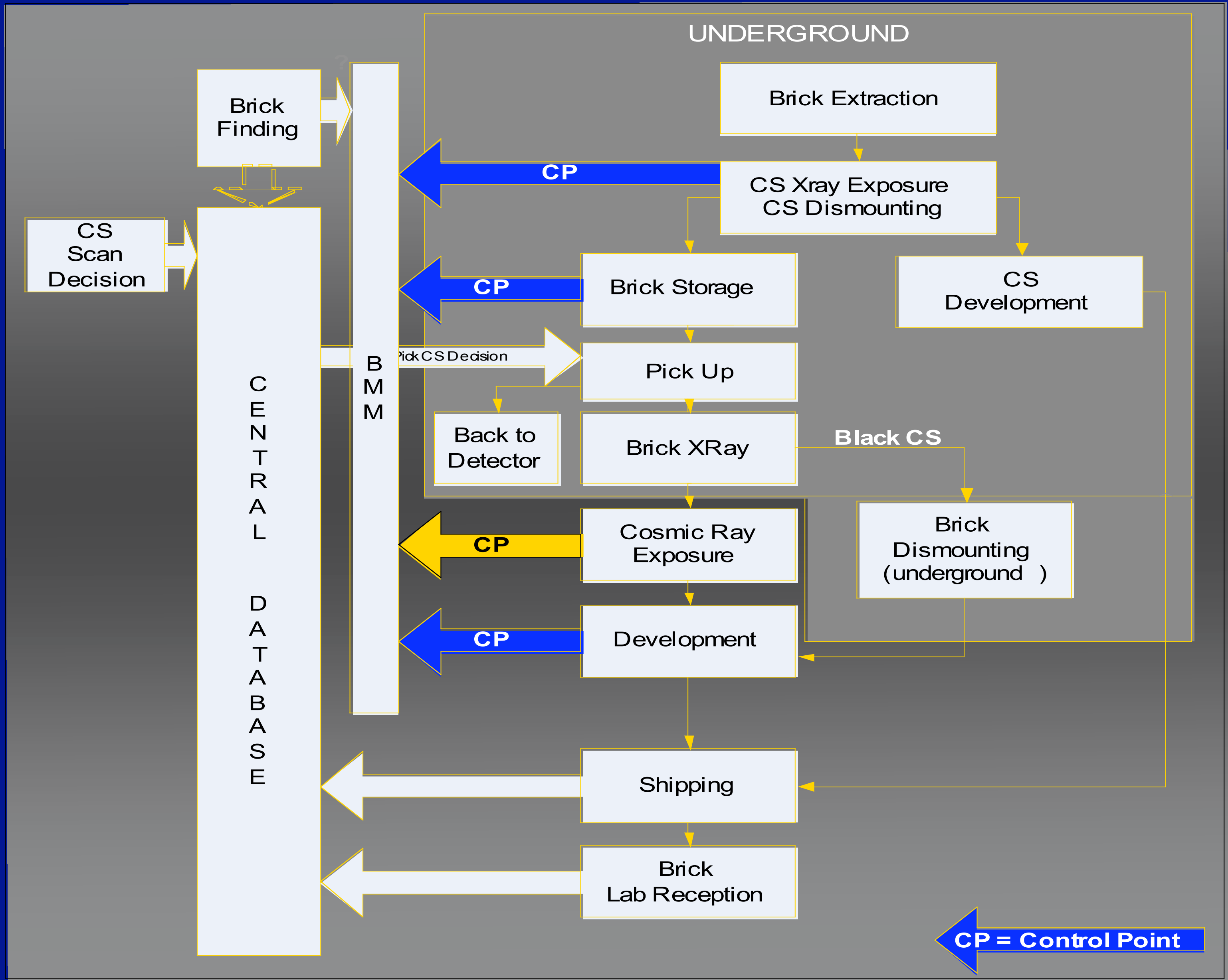
Goal of the 2008 CNGS/OPERA run

- First “production” run: very successful operation of CNGS and OPERA
- Proof that the complex event analysis machinery works according to specs
- Use collected statistics to experimentally estimate detection efficiencies and backgrounds
- Start to be sensitive to interesting decay topology events

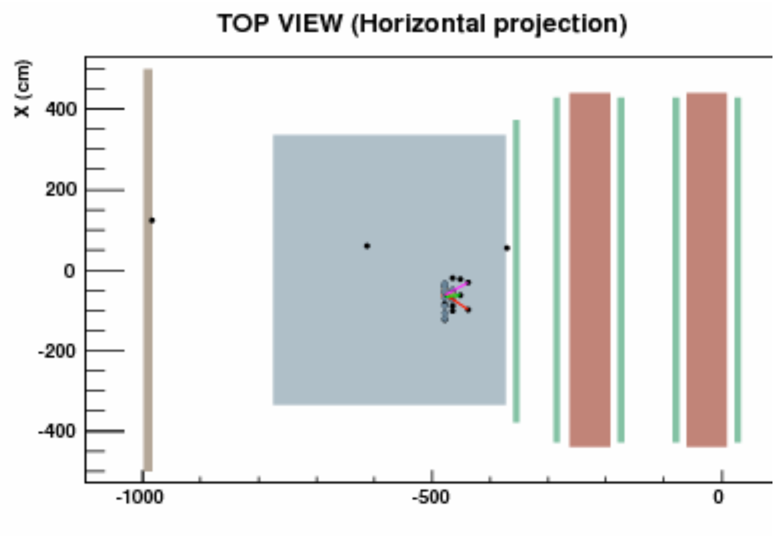


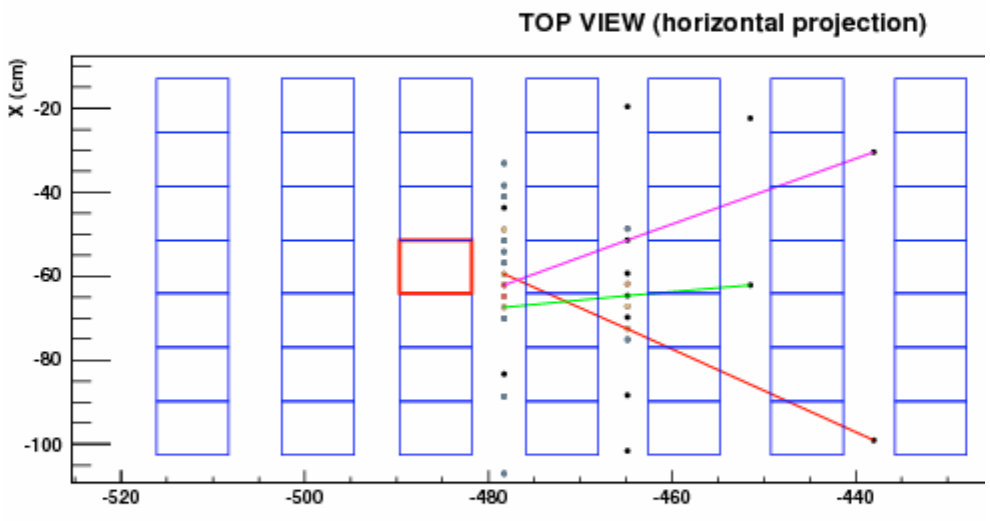
CNGS 2008 run
x 10^16 pot
1.782^E19 pot
1800
1600
1400
1200
1000
800
600
400
200
0
1214
1216
1218
1220
1222
1224
x 10^15
Unix Time
3/11 8:00
1.782^E19 pot
Horns filters
19-20/10
6-8/10 MD
18KV cable accident
25/7
CNGS quadrupole
14-17/9
Horn + PS vacuum
Week 1/9
PS septum + Long MD
8-14/8
Long MD stop + MTE kicker problem
7/7 6:00 – 10/7 12:00
10/7-18/7 Earth
fault on the PS
magnet
Beam loss, vacuum
accident 27/6-2/7
Wed 18/6 17:00
Start of
commissioning
at low intensity

Schematics of the analysis chain



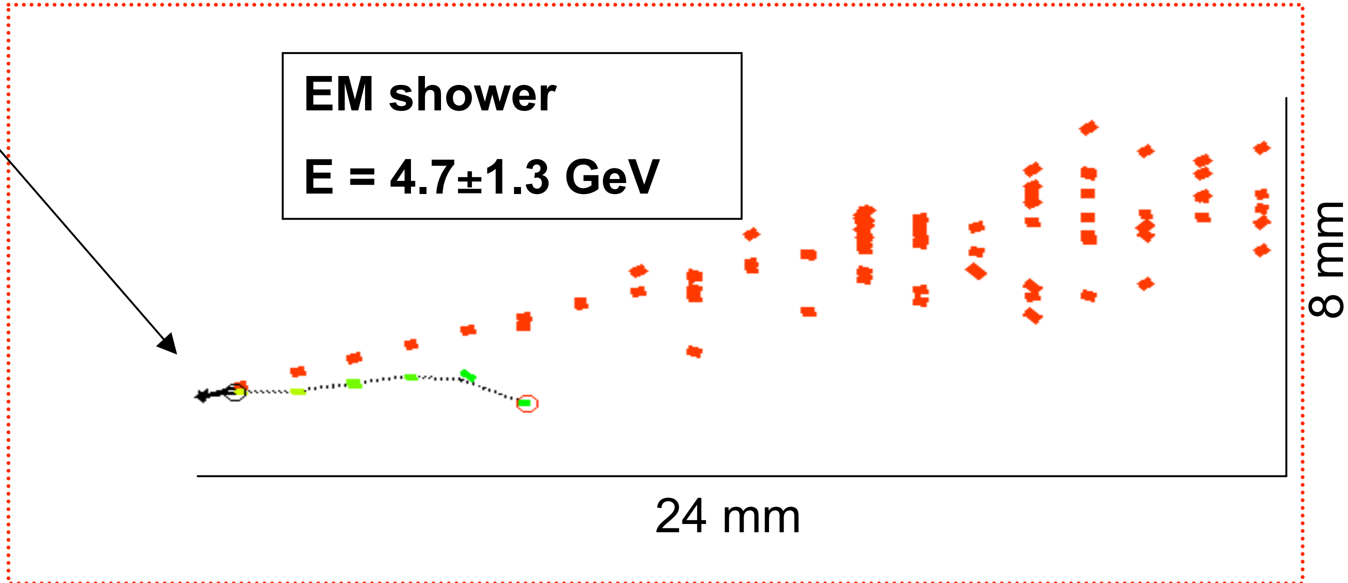
Event 183545620 located in Bern – first ν_e candidate



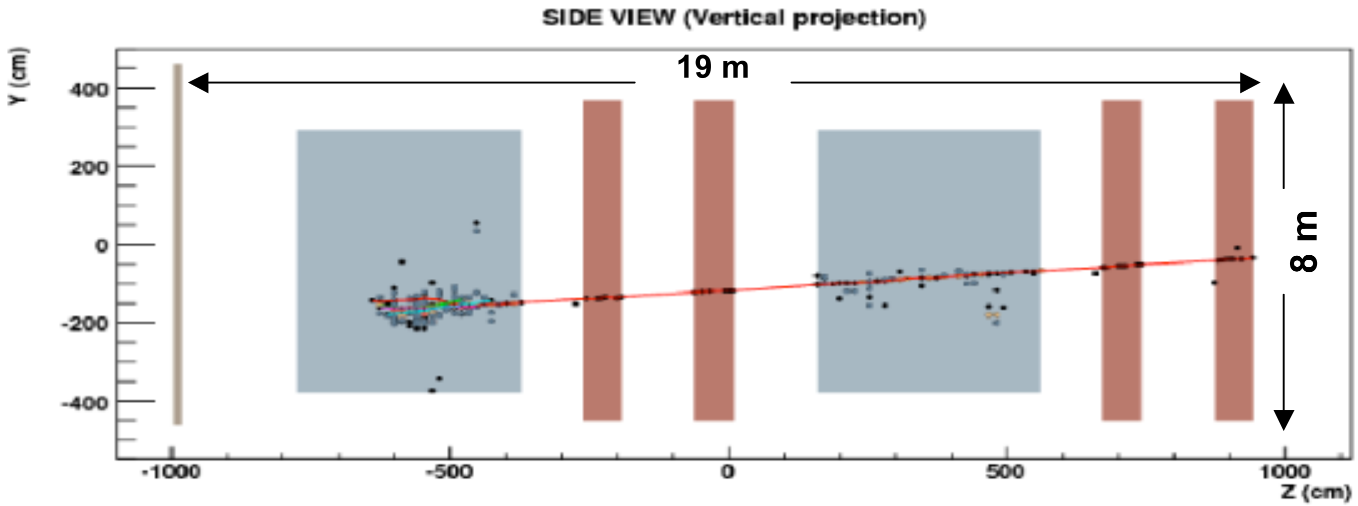


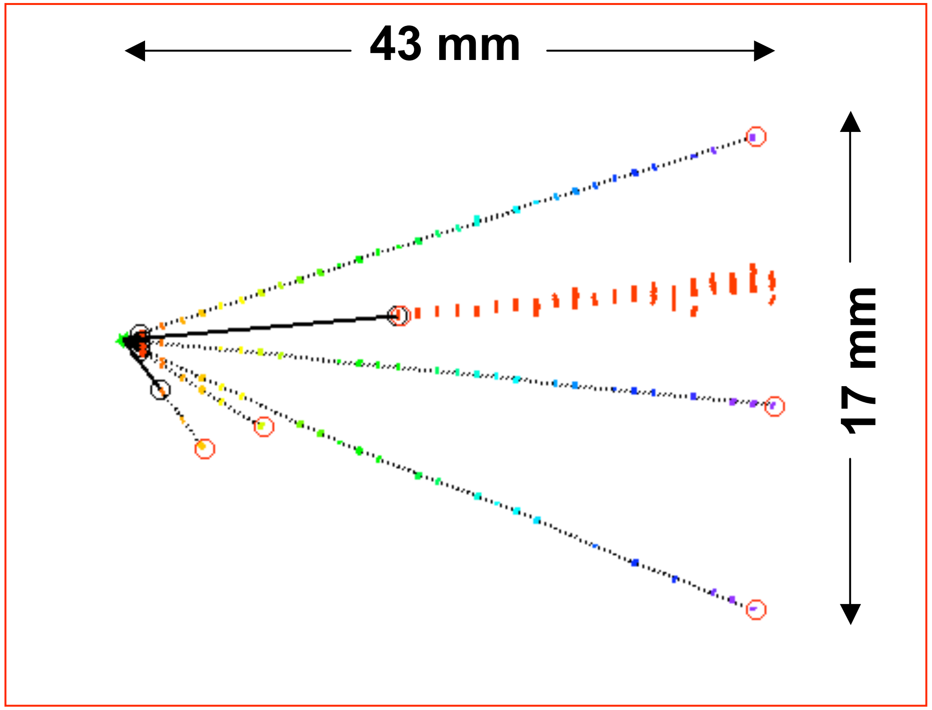
Neutrino vertex

IP = ~3μm



Event 178969961: ν_μCC interaction

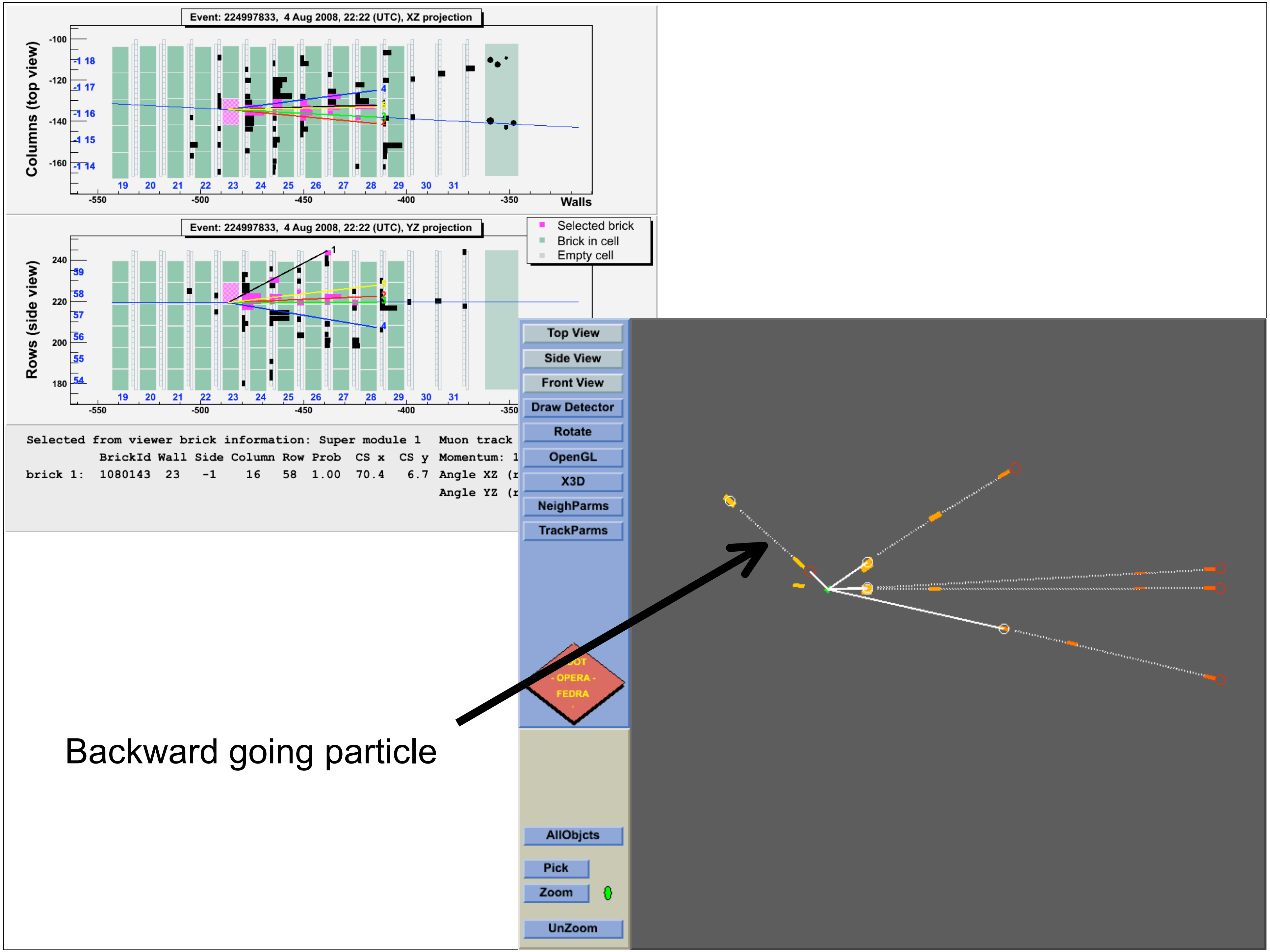




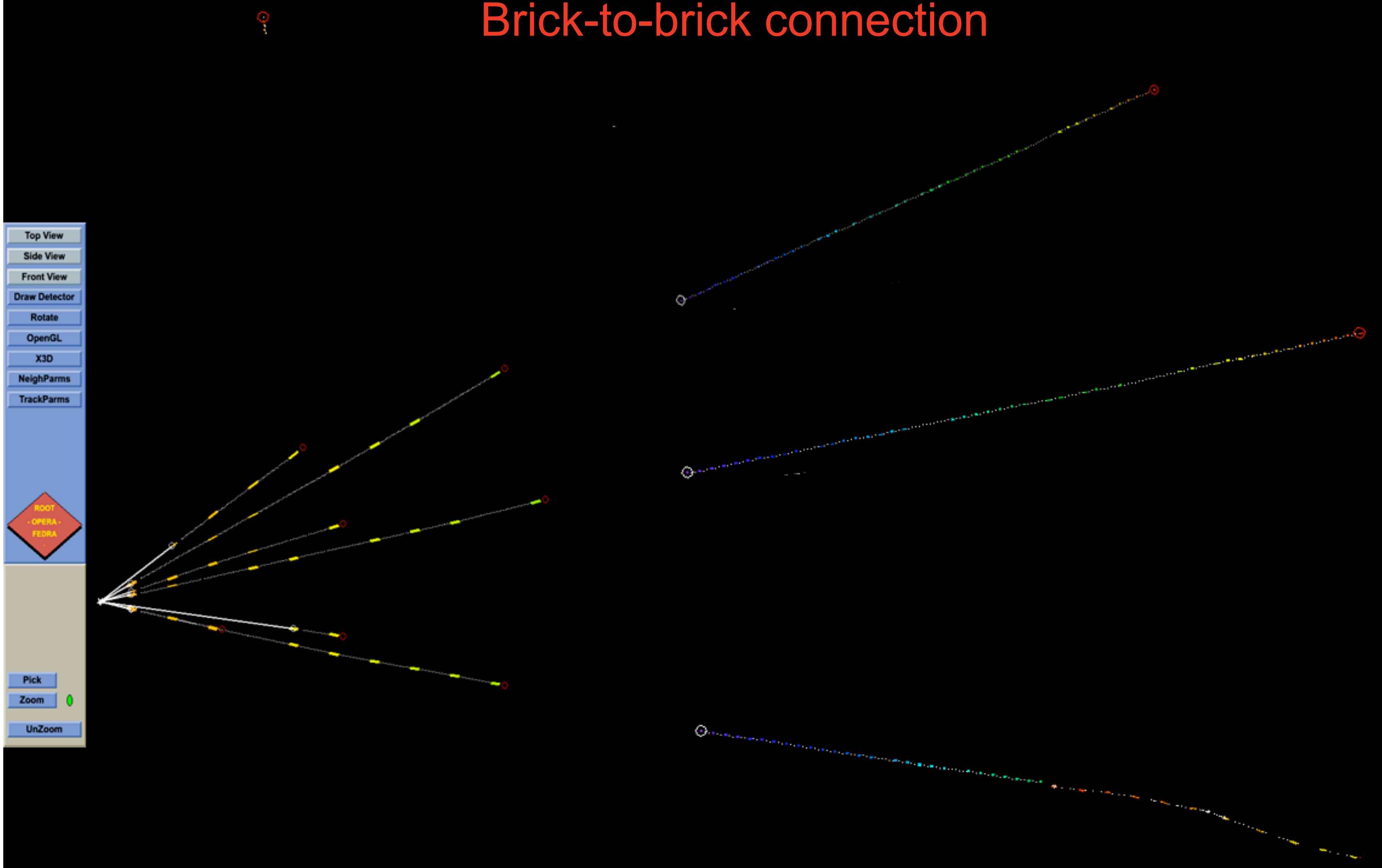
5 prongs

<IP> = 9 mm

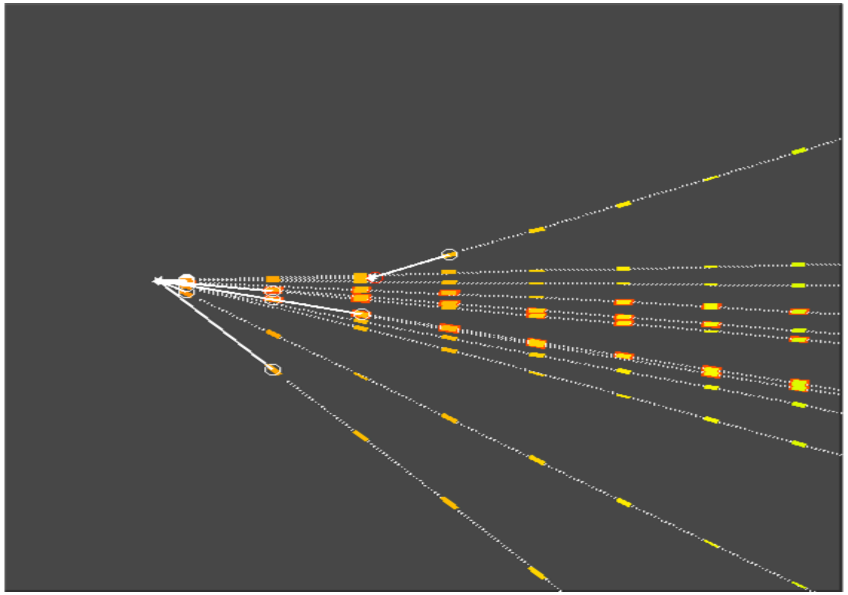
EM shower pointing to the vertex (γ conversion)

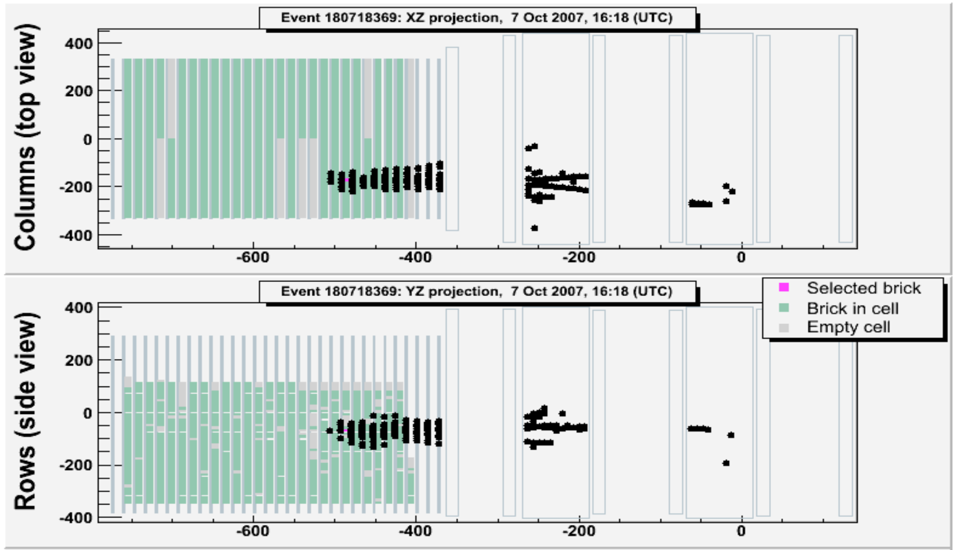

Event: 224997833, 4 Aug 2008, 22:22 (UTC), XZ projection
Columns (top view)
Walls
Event: 224997833, 4 Aug 2008, 22:22 (UTC), YZ projection
Rows (side view)
Selected brick
Brick in cell
Empty cell
Selected from viewer brick information: Super module 1
BrickId Wall Side Column Row Prob CS x CS y
brick 1: 1080143 23 -1 16 58 1.00 70.4 6.7
Muon track
Momentum: 1
Angle XZ (r
Angle YZ (r
Top View
Side View
Front View
Draw Detector
Rotate
OpenGL
X3D
NeighParms
TrackParms
OPERA
FEDRA
AllObjcts
Pick
Zoom
UnZoom
Backward going particle

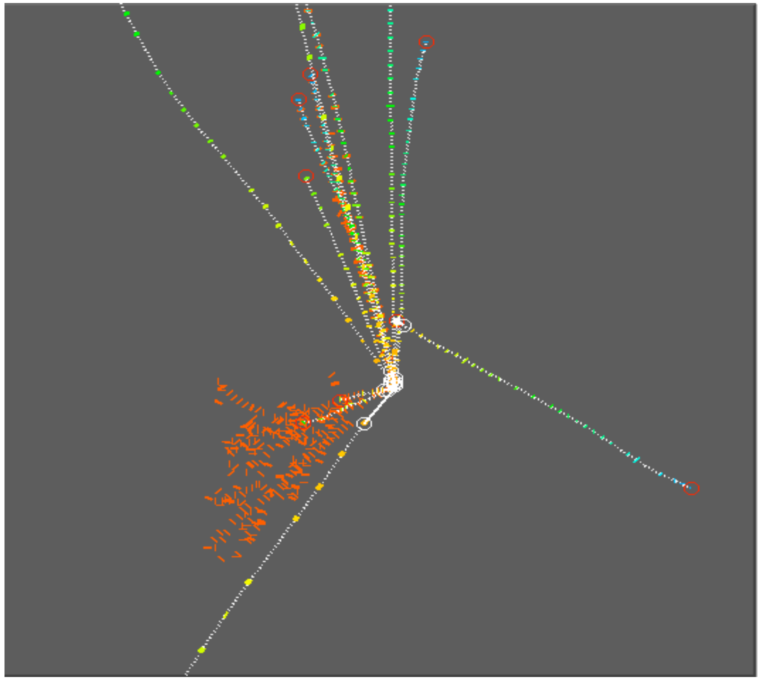
Brick-to-brick connection



2 charm decay candidates so far: the first one…







Clear kink topology
Two EM showers pointing to the vertex

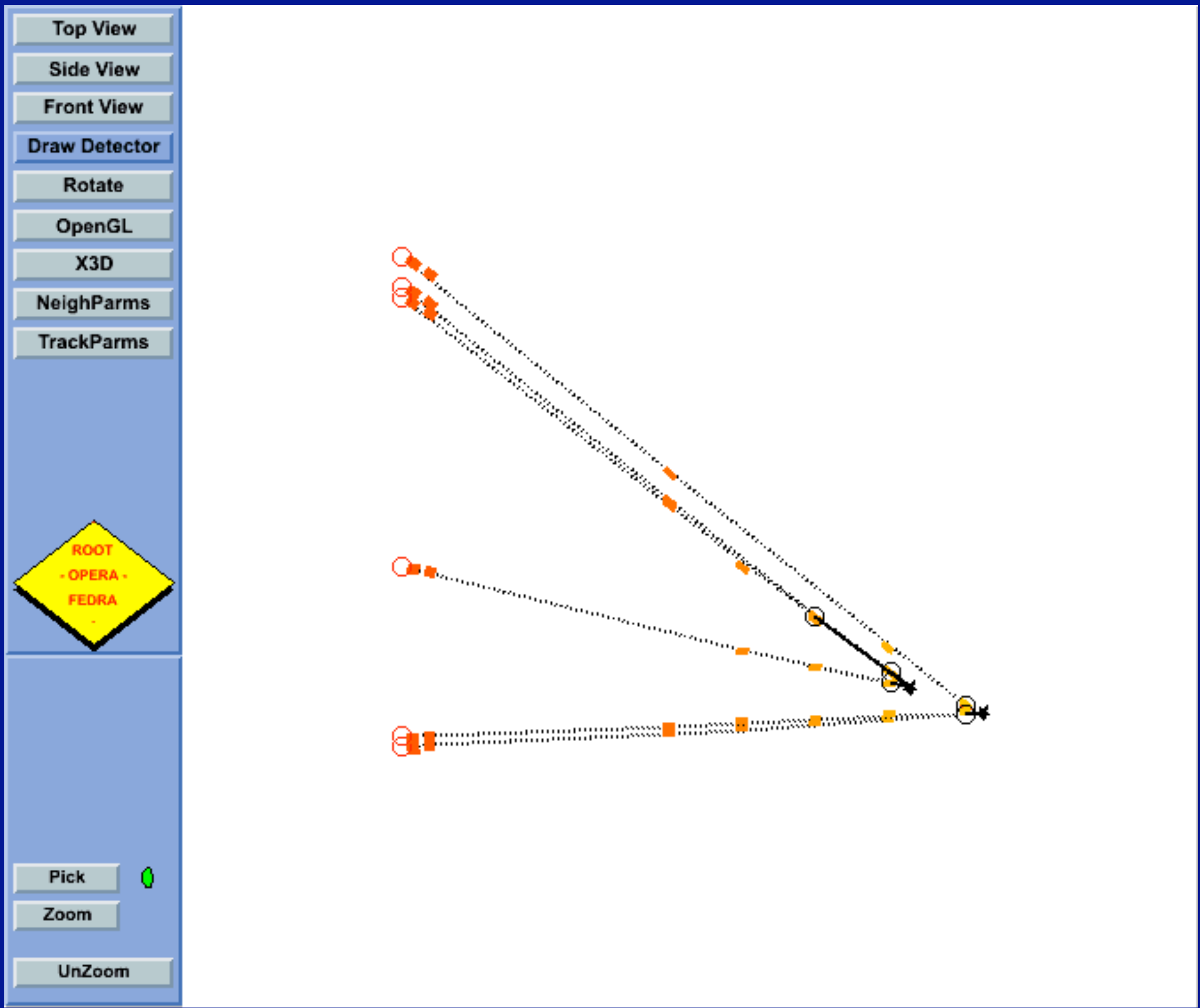
Flight length	3247.2 μm
θ_{kink}	0.204 rad
$P_{daughter}$	3.9 (+1.7 -0.9) GeV
P_T	796 MeV

4×10^{-4} probability for a hadron re-interaction to have a P_T > 600 MeV

…the second charm candidate…

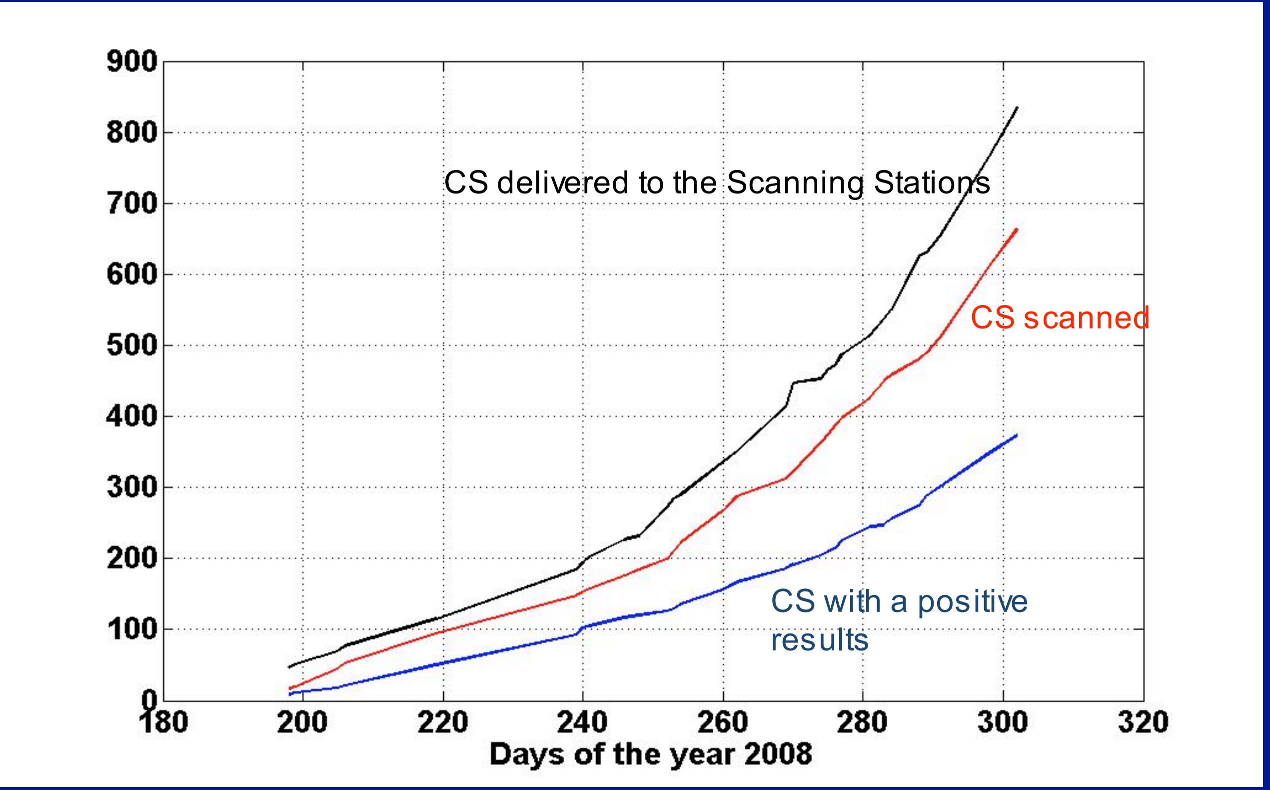
three charged prongs decay

Kaon decay probability 10^{-4} , hadron re-interaction probability $1x10^{-5}$



Measure detection efficiencies with real data.

Some examples: preliminary low statistics analyses



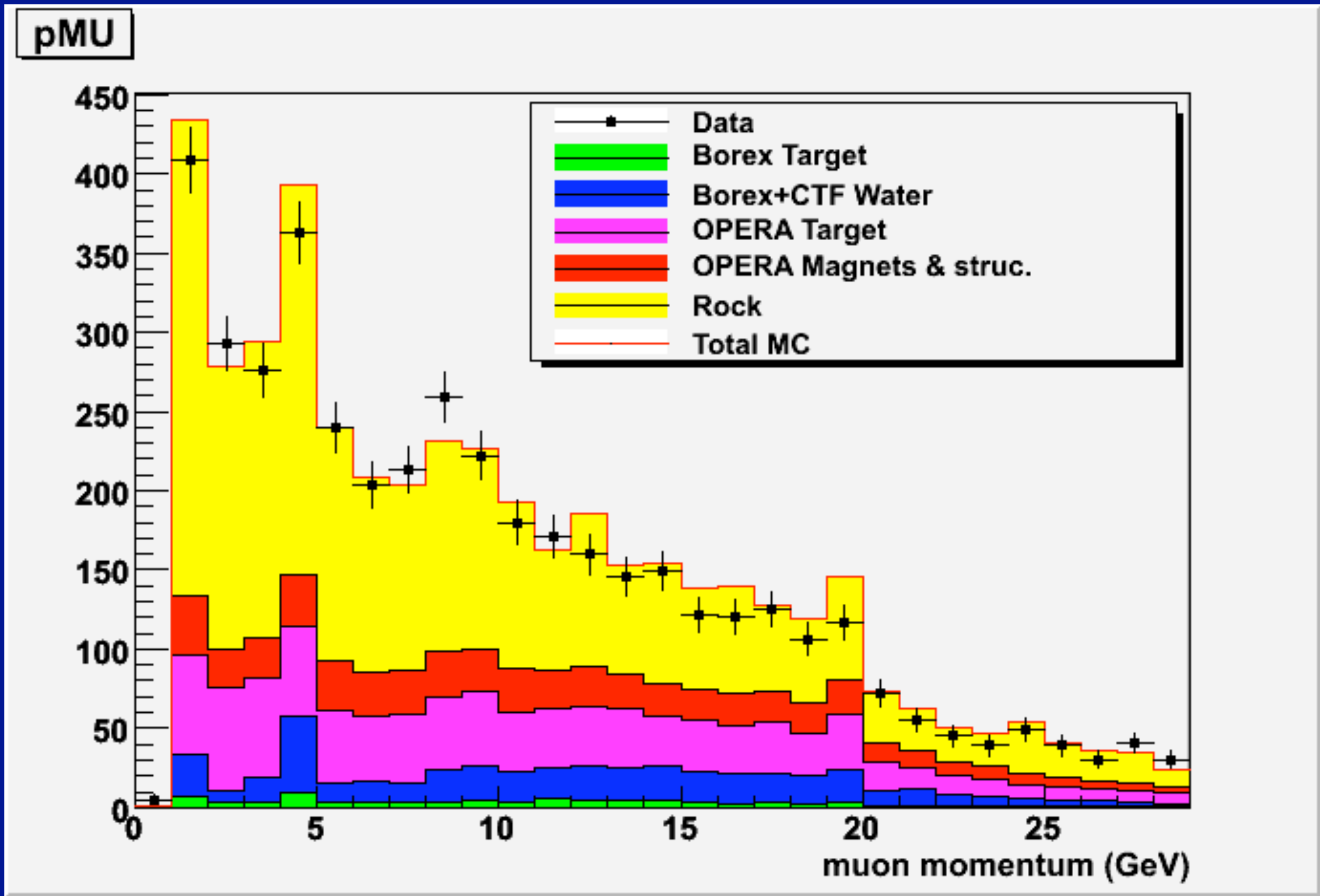
Brick finding efficiency: from CS measurement (only one brick extracted): 67±5 (stat)% (MC predicts 72%). Rise to >80% by extracting a second brick if required

CS finding efficiency: 74 ± 6% (~80% expected by MC) measured with a first set of real data. More precise estimates with increasing statistics. New method being tested: better efficiency ~89±3%

Vertex finding efficiency: for CC ranges from 86 to 96 % (93% from MC)
for NC ranges from 74 to 89 (81% from MC)

Example of analysis and event reconstruction capabilities:

momentum reconstruction for CNGS related muon tracks



Swiss researchers in OPERA

OPERA: 35 institutions, 200 people

LHEP Bern (including the former Neuchatel group):

A. Ariga, T. Ariga, A. Ereditato, F. Juget , J. Knüsel, I. Kreslo, G. Lutter, F. Meisel,
M. Messina, U. Moser, C. Pistillo, K. Pretzl, J.L. Vuilleumier

ETHZ:

A. Badertscher, C. Lazzaro, A. Rubbia, T. Strauss

Past and current activities: conceptual design, proposal, CNGS design, Target Tracker, lead production monitoring, microscopes and emulsion film robot, test beams, emulsion scanning and physics analysis

Management & coordination duties:

A. E. (Spokesperson)
U. Moser (Member of the Editorial Board)
F. Juget (Member of the Analysis Steering Board)

Theses in progress:

J. Knüsel (LHEP):	Low momentum muon identification
C. Lazzaro (ETHZ):	Determination of the CNGS neutrino energy spectrum from CC events reconstructed with the electronic detectors
F. Meisel (LHEP):	Measurement of the ν_e contamination of the CNGS beam
T. Strauss (ETHZ):	Neutrino induced charmed particle decays

The OPERA experiment has started full data taking in the CNGS beam:

- 2008 run: ~$1.8x10^{19}$ pot, ~1700 interactions in the bricks
- ~45 charm decays and ~0.6 τ events expected

Detector and ancillary facilities performed extremely well

The event analysis chain successfully proceeds “quasi-on-line”

Detection efficiencies and BGs are being computed with real data

Interesting events have already been analyzed

Forecast for 2009:

- 170 days of running: ~$3.5x10^{19}$ pot (requested $4.5x10^{19}$)
- Sufficient integrated statistics for candidate events (~2 events)
- Precise evaluation of efficiencies, BG and sensitivity

The collaboration and the CERN beam teams are very motivated and committed: required ingredients for the full success of the project. Key Swiss contribution