522 Wilhelm and Else Heraues-Seminar "Exploring the Neutrino Sky and Fundamental Particle Physics on the Megaton Scale", 21-23 January 2013, Physikzentrum Bad Honnef, Germany

Search for $\nu_\mu \rightarrow \nu_\tau$ oscillations in the OPERA experiment.

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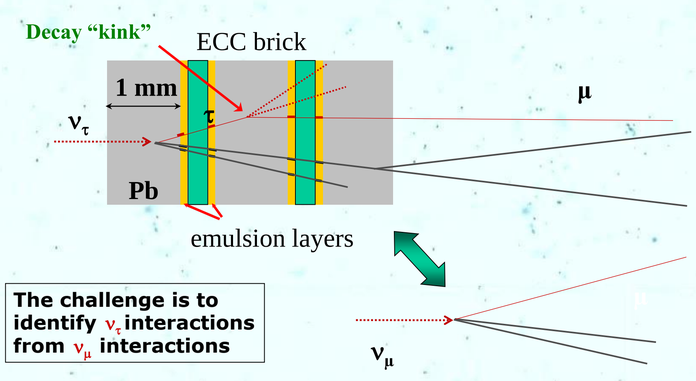
OPERA experiment

The OPERA experiment is designed for direct observation of ν_τ appearance in a pure ν_μ beam as a result of $\nu_\mu \rightarrow \nu_\tau$ oscillation.

$$P(\nu_\mu \rightarrow \nu_\tau) \approx \cos^4\theta_{13}\sin^2 2\theta_{23}\sin^2\left(1.27\frac{\Delta m^2_{23}[eV^2]L[km]}{E[GeV]}\right)$$

Detection of the ν_τ appearance signal



The challenge is to identify ν_τ interactions from ν_μ interactions

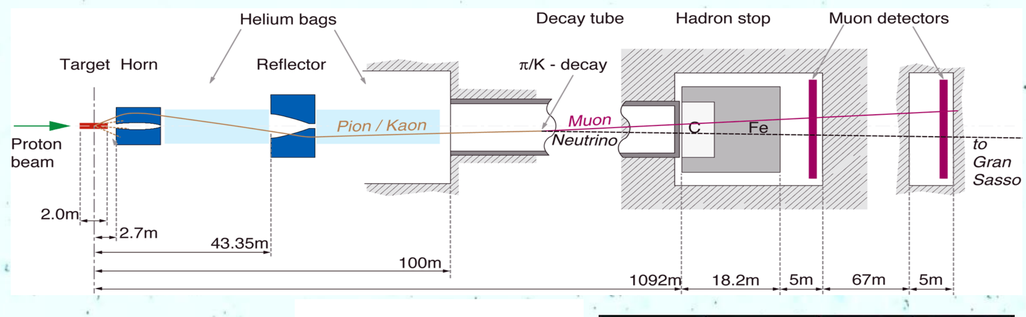
Two conflicting requirements:
- Large mass ⟺ low Xsection
- High granularity
  - ⟹ signal selection
  - ⟹ background rejection

Target: ~1250 tons
$18.6E^{19}$ pot during 5 years run

- **>17 000 neutrino interactions**
- **~100 ν_τ interactions**
- **~10 ν_τ identified**
- **< 1 background event**

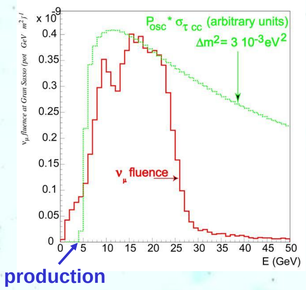
CNGS neutrino beam

OPERA uses the long baseline CNGS neutrino beam from CERN to Gran Sasso underground physics laboratory. The beam is optimized to have the maximal number of ν_τ CC interactions in the detector.

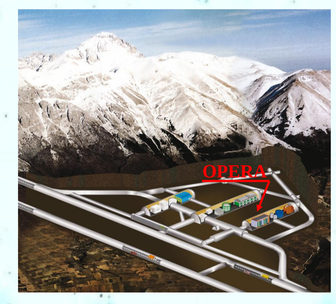


Beam energy and contamination

$<E\nu_\mu>$	17 GeV
$(\nu_e+\bar{\nu}_e)/\nu_\mu$	0.87%
$\bar{\nu}_\mu / \nu_\mu$	2.1%
ν_τ prompt	negligible

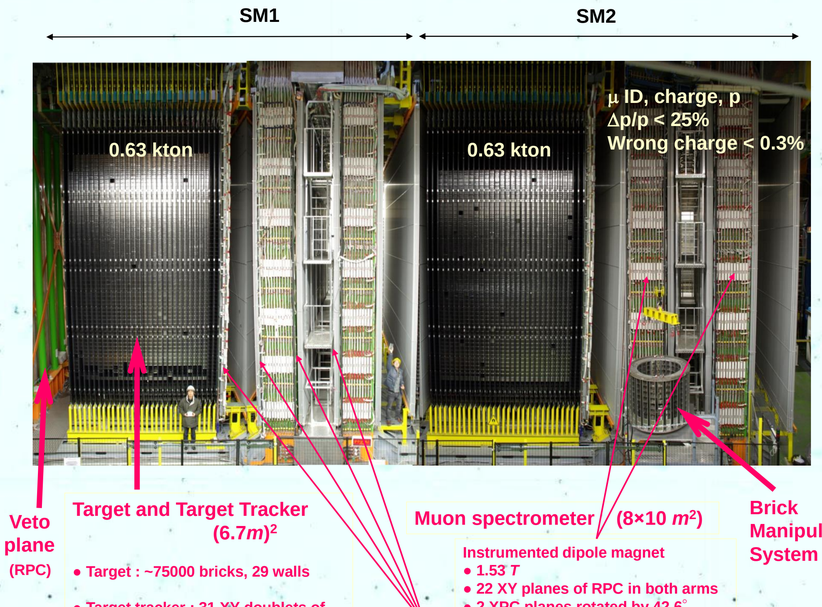


Year	POT/Year	Neutrino Int. In the target	Integrated POT / Proposed value
2008	$1.78x10^{19}$	1698	7.9%
2009	$3.52x10^{19}$	3557	23.6%
2010	$4.04x10^{19}$	3912	41.5%
2011	$4.84x10^{19}$	4210	63.0%
2012	(~$4.7x10^{19}$)	(~4050)	(~84%)



OPERA hybrid detector

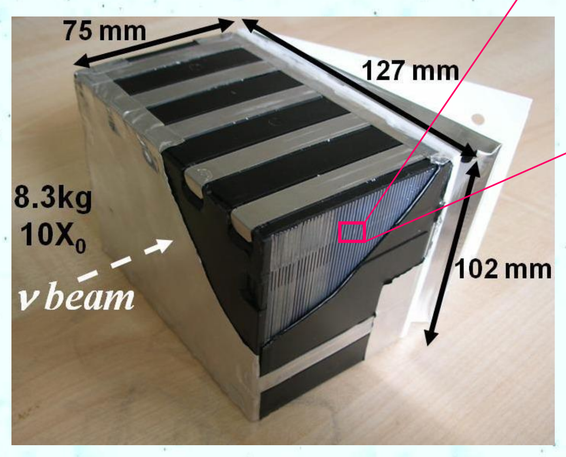
2 identical super-modules (target, TT, Spectrometer) + veto system

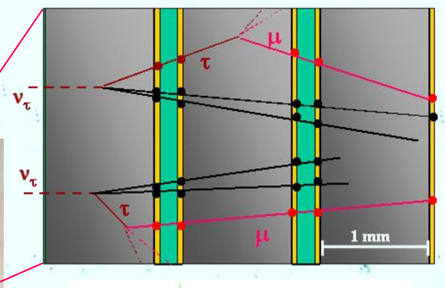


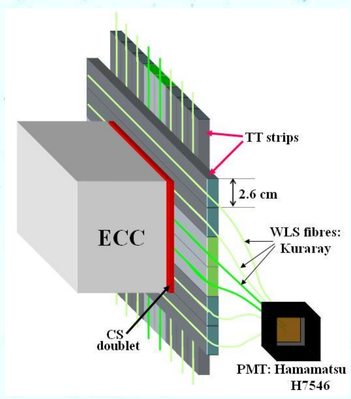
OPERA ECC brick

OPERA exploits Emulsion Cloud Chamber (ECC) technique for the direct detection of tau leptons produced in the charge current interaction of the ν_τ with matter of the detector.

Basic unit of OPERA detector is a ECC brick: 56 lead plates interlieved with nuclear emulsion films which are very high resolution tracking devices.







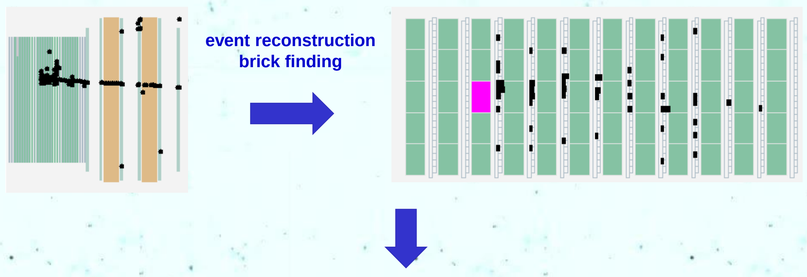
Signal/background for $\nu_\mu \rightarrow \nu_\tau$ oscillation channel ($22.5 * 10^{-19}$ p.o.t.):

τ decay channel	B.R. (%)	Signal $\Delta m^2 = 2.5*10^{-3}\ eV^2$	Background
$\tau \rightarrow \mu$	17.4	1.51	0.08
$\tau \rightarrow e$	17.8	2.05	0.15
$\tau \rightarrow h$	~48	1.68	0.18
$\tau \rightarrow 3h$	~14	0.56	0.14
Total		5.79	0.55

Main background sources:

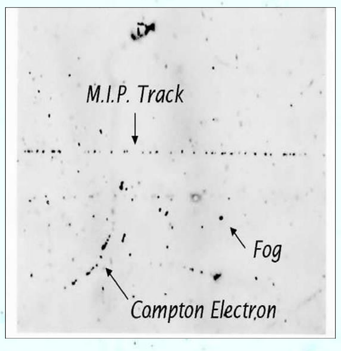
- **Production and decay of charmed particles;**
- **Hadron reinteractions;**
- **Large angle muon scattering.**

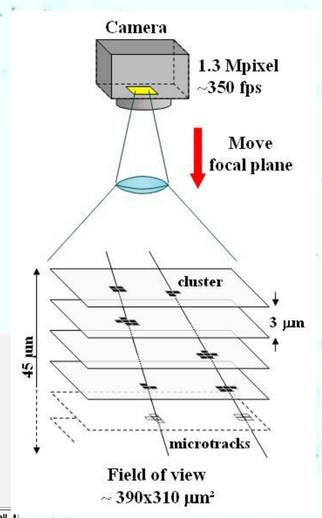
Scheme of event analysis



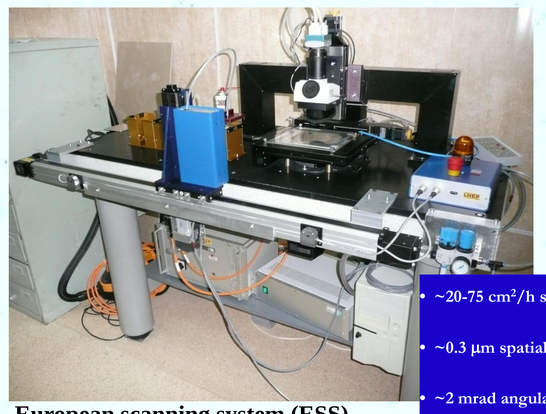
- **Brick extraction**
- **Changeable Sheet development**
- **Changeable Sheet tracks search**
- **Brick development**
- **Brick scanning and analysis**

Analysis of nuclear emulsions





Fully automated microscope scanning systems

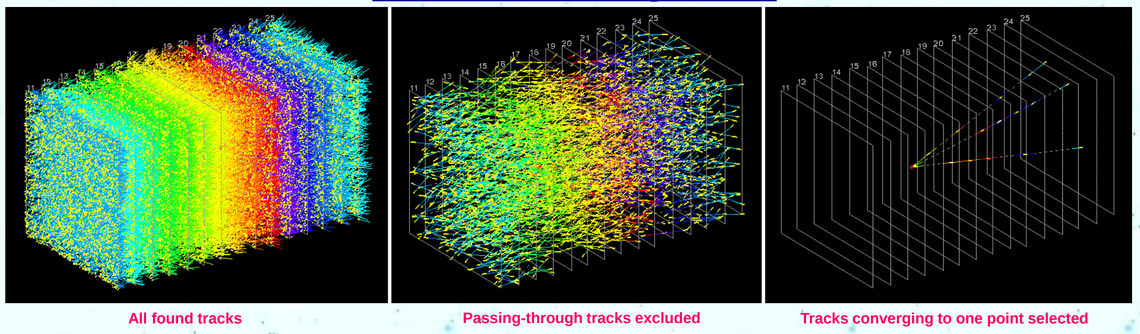


European scanning system (ESS)

S-UTS (Japan)

- ~20-75 cm^2/h scanning speed
- ~0.3 μm spatial resolution
- ~2 mrad angular resolution
- ~90% base track detection efficiency

Vertex reconstruction procedure



All found tracks — Passing-through tracks excluded — Tracks converging to one point selected

OPERA ν_τ candidate events