# OPERA Experiment status

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*GDR Neutrino, 29th October 2009*

# OPERA experiment

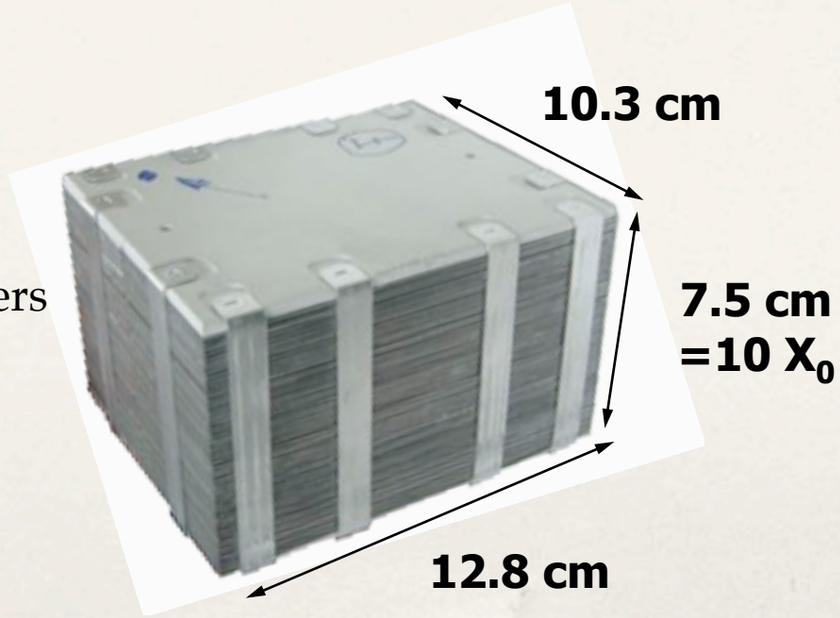
- The OPERA experiment is designed to provide an unambiguous evidence for $\nu_\mu \rightarrow \nu_\tau$ oscillation in the region of atmospheric neutrinos by looking at $\nu_\tau$ appearance in a $\nu_\mu$ beam.
- CNGS beam is designed to maximise $\nu_\tau$ CC interactions at the LNGS.
- The separation of the $\nu_\tau$CC from the dominant $\nu_\mu$ interactions is based on the identification, event by event, of the peculiar decay topology of the $\tau$: its decay length is around 280 μm, and the technic of photographic emulsion is used to measure it.

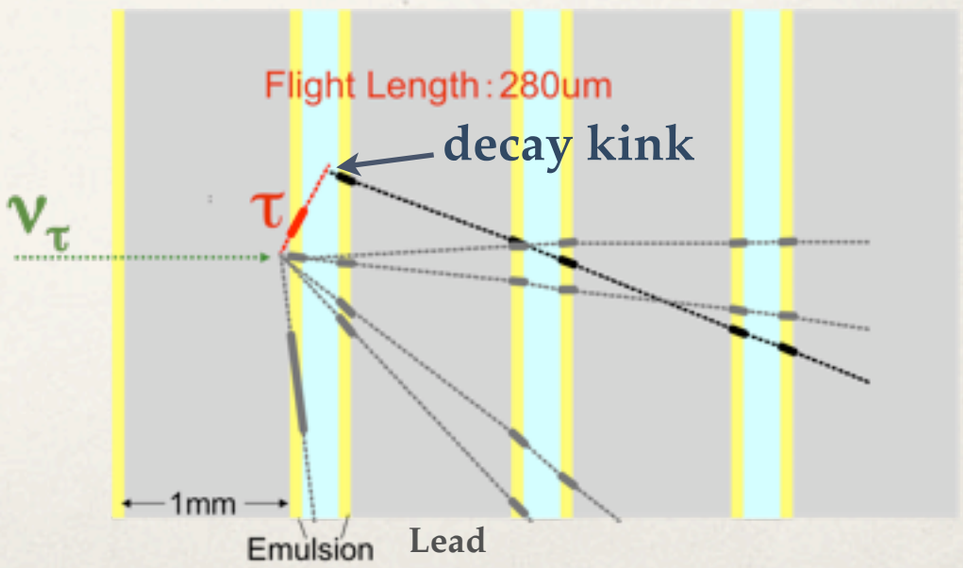
**Target Mass: 1.25 kton**
**Design goal: $4.5\times10^{19}$ pot/year**
**Long baseline: 730 km**

| | |
|---|---|
| $<E\nu_\mu>$ | 17 GeV |
| $\nu_\mu$(CC+NC)/ year | ~ 4700 |
| $\nu_\tau$ CC/year | ~20 |

**⇒Detector based on bricks:**
Sandwich of 56 (1mm) Pb sheets
+ 57 FUJI emulsion layers
+ 1 Changeable Sheet

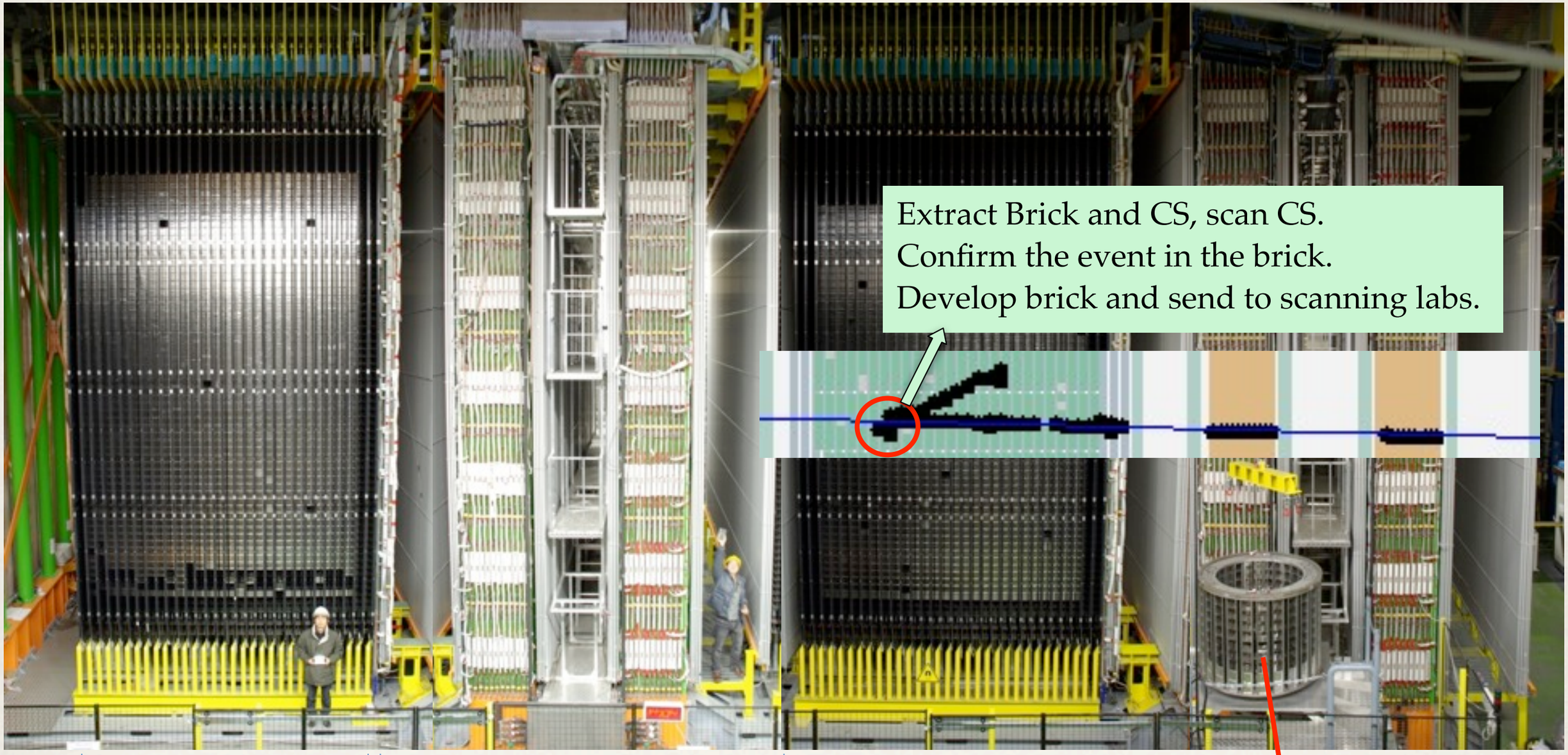
**Brick weight: 8.3 kg**



# OPERA detector

**SM1** **SM2**




**Target area**

**(ECC + CS + TT)**

**2850 bricks/wall, 53 walls**

**Muon spectrometer**
**(Magnet+RPC+PT)**

**Brick Manipulator System**

# OPERA efficiencies

- Estimated detector efficiencies ($\nu_\mu$ CC and NC events):

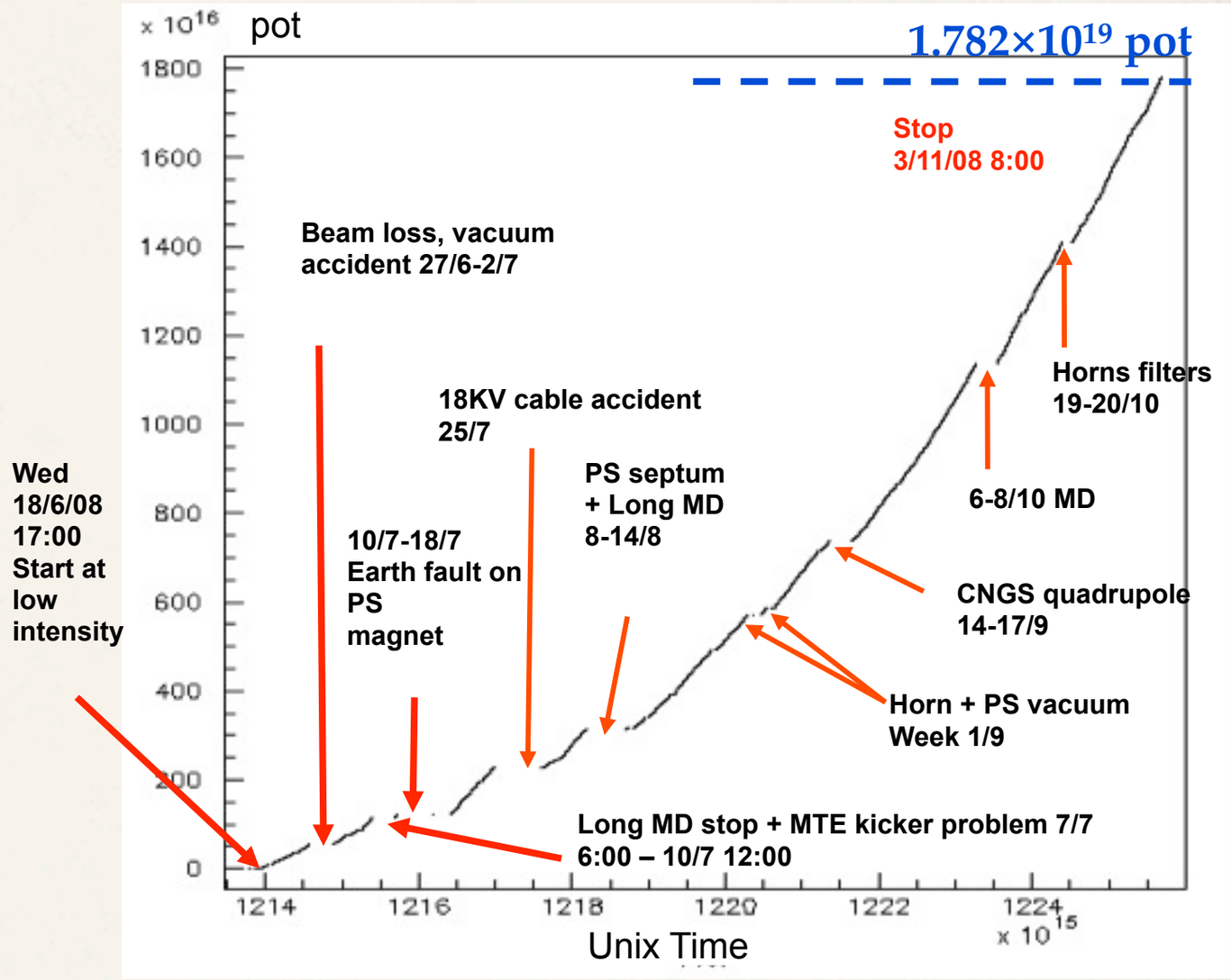
| | CC+NC |
|---|---|
| **Trigger** | **99 %** |
| **Brick-Finding** | **80 %** |
| **Changeable-Sheet** | **90 %** |
| **Geometry (edge effect)** | **94 %** |
| **Vertex localisation** | **85-90%** |
| **Total** | **60 %** |

- Estimated $\nu_\tau$ CC efficiencies and number of signal and background events for **5 years run, $4.5\times10^{19}$ pot/year:**

| **$\tau$ decay channels** | **$\varepsilon$(%)** | **BR(%)** | **Signal** | | **Background** |
|---|---|---|---|---|---|
| | | | **$\Delta m^2 = 2.5\times10^{-3}$ eV$^2$** | **$\Delta m^2 = 3.0\times10^{-3}$ eV$^2$** | |
| **$\tau \rightarrow \mu$** | **17.5** | **17.7** | **2.9** | **4.2** | **0.17** |
| **$\tau \rightarrow e$** | **20.8** | **17.8** | **3.5** | **5.0** | **0.17** |
| **$\tau \rightarrow h$** | **5.8** | **50** | **3.1** | **4.4** | **0.24** |
| **$\tau \rightarrow 3h$** | **6.3** | **15** | **0.9** | **1.3** | **0.17** |
| **ALL** | **$\varepsilon\times$BR=10.6%** | | **10.4** | **15.0** | **0.76** |

# 2008 run: CNGS performance

- In 2008 the detector was fully working.
- The number of protons on target we had is $1.78 \times 10^{19}$.
- This means that in 2008 data we expect:




| Type of events | Raw | Corrected by efficiencies |
|---|---|---|
| $\nu_\mu$(CC+NC) | 1860 | 1100 |
| $\nu_\tau$ CC | 8 | 0.8 |
| Charm | 57 | 26 |

# 2008 run: Status of event location

- Contained events in the electronic detectors: 1301 with muon, 503 without muon.

| | with muon | without muon | Total |
|---|---|---|---|
| **Events extracted** | 1242 | 356 | **1598** |
| **Bricks developed** | 993 | 249 | **1242** |
| **Vertices located in ECC** | 738 | 135 | **873** |
| **Vertices located in the dead material** | 16 | 6 | 22 |

- **Deduced efficiencies:**

| | with muon | without muon | Total |
|---|---|---|---|
| **Brick-Finding+CS efficiency** | 80 % | 70 % | **78 %** |
| **Vertex localisation efficiency** | 76 % | 56 % | **72 %** |
| **Total efficiency** | 61 % | 34 % | **56 %** |

**proposal: 60%**

- Observed Charm events so far: 15.

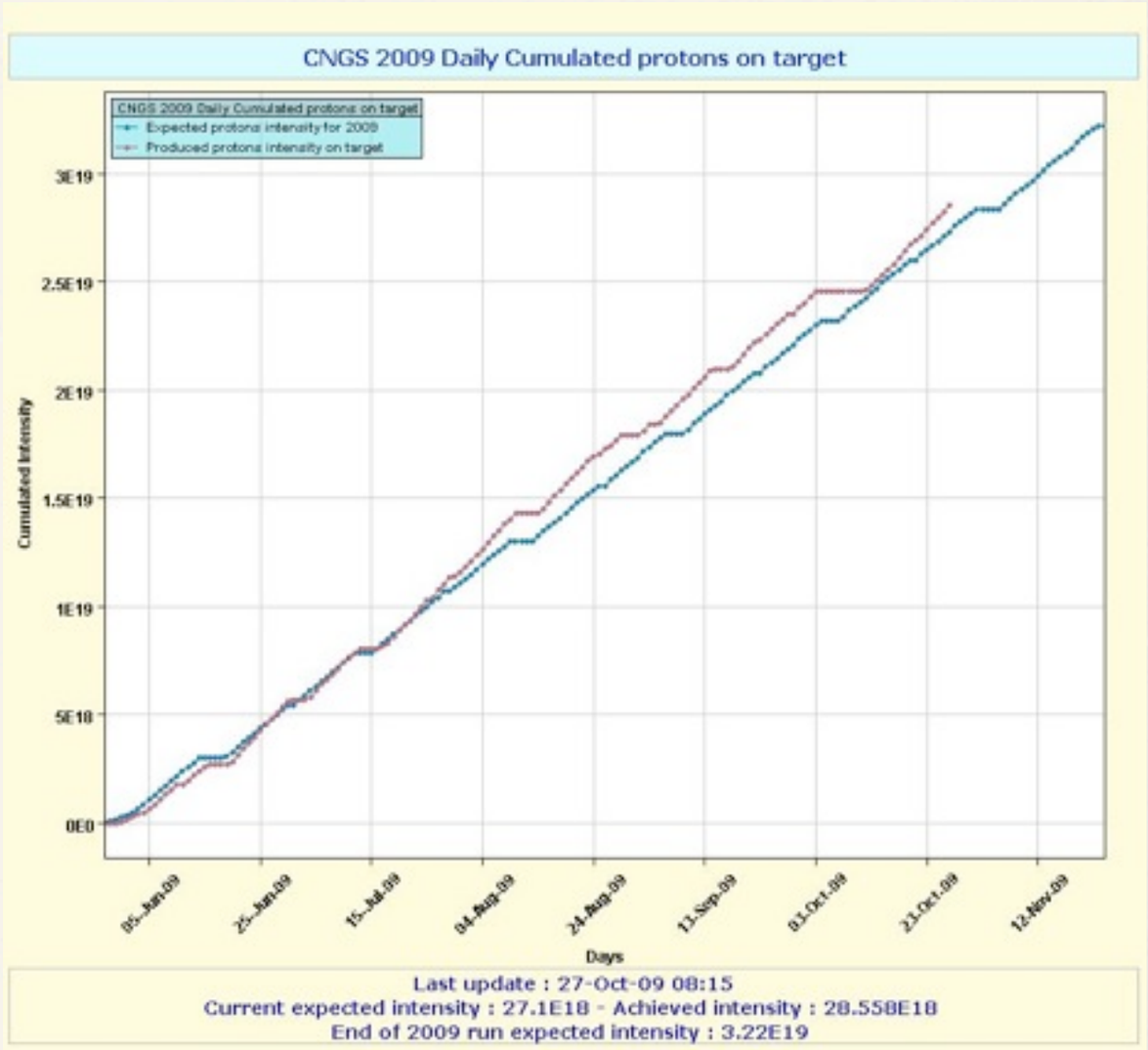
- Expected Charm events for the checked events (procedure of decay search has been applied): 17.

# 2009 run: CNGS performance

- 2955 candidate interactions in the target ($2.846\times10^{19}$ pot).

- present extrapolation for the end of the run (end of november): $3.2\times10^{19}$ pot (~ 70% of a nominal year).

- If the extrapolation is correct, we expect:

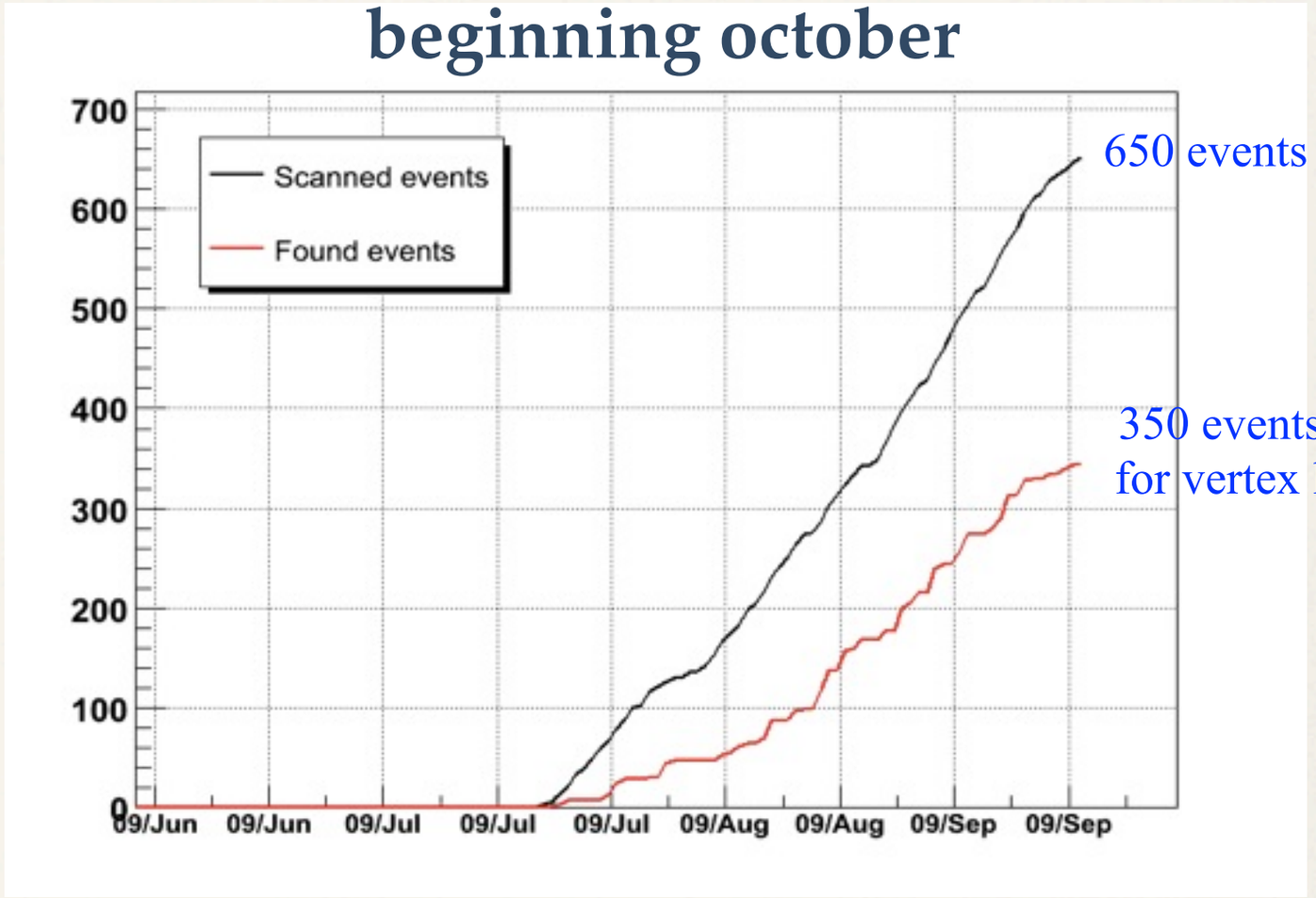



| Type of events | Raw | Corrected by efficiencies |
|---|---|---|
| $\nu_\tau$ CC | **14** | **1,4** |

- With the 2008 data, we expect 2 $\nu_\tau$ events.

# 2009 run: Status of event location

- Analysis of 2009 events is on-going while finishing the 2008 queue.
- Contained events in the ED: 2133 with muon, 822 without muon
- 1131 CS scanned, and 631 events tagged for events location.




| | without muon | with muon | Total |
|---|---|---|---|
| Brick scanning started | 21 | 113 | 134 |
| Vertices located in ECC | 13 | 76 | 89 |
| Interactions in the upstream brick | 0 | 7 | 7 |
| Vertices in the dead material | 0 | 1 | 1 |

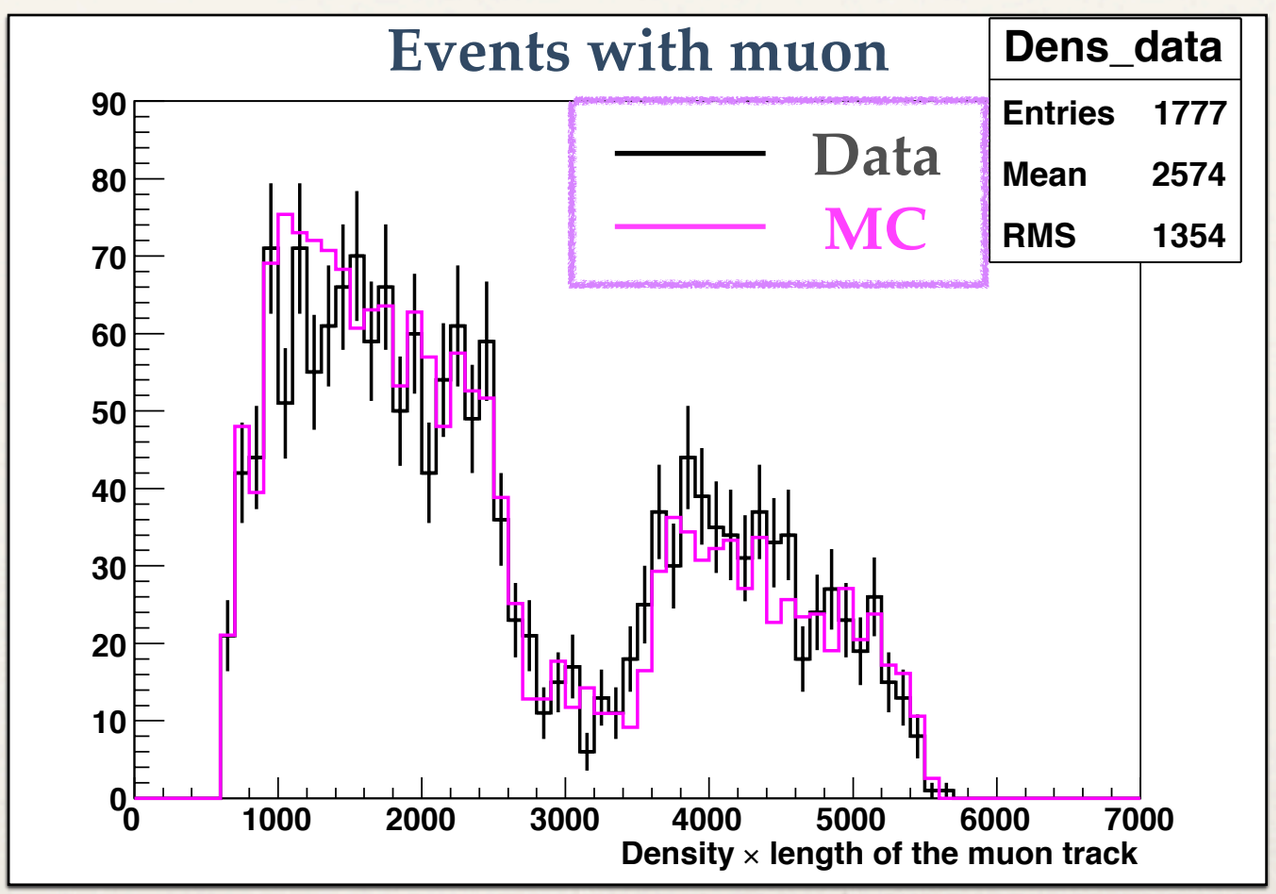
# Analysis in progress: kinematics studies

- Studies on 2008 and 2009 data using only electronic detectors, a fiducial cut is done in order to consider only contained events, and we separate the events in two categories: with and without muons.

- Studies of kinematical variables using electronic detector
  - muon identification.
  - muon momentum (range+bending in magnetic field).
  - deposited energy.
  - shower profile.
  - ratio NC/CC.

# Muon identification

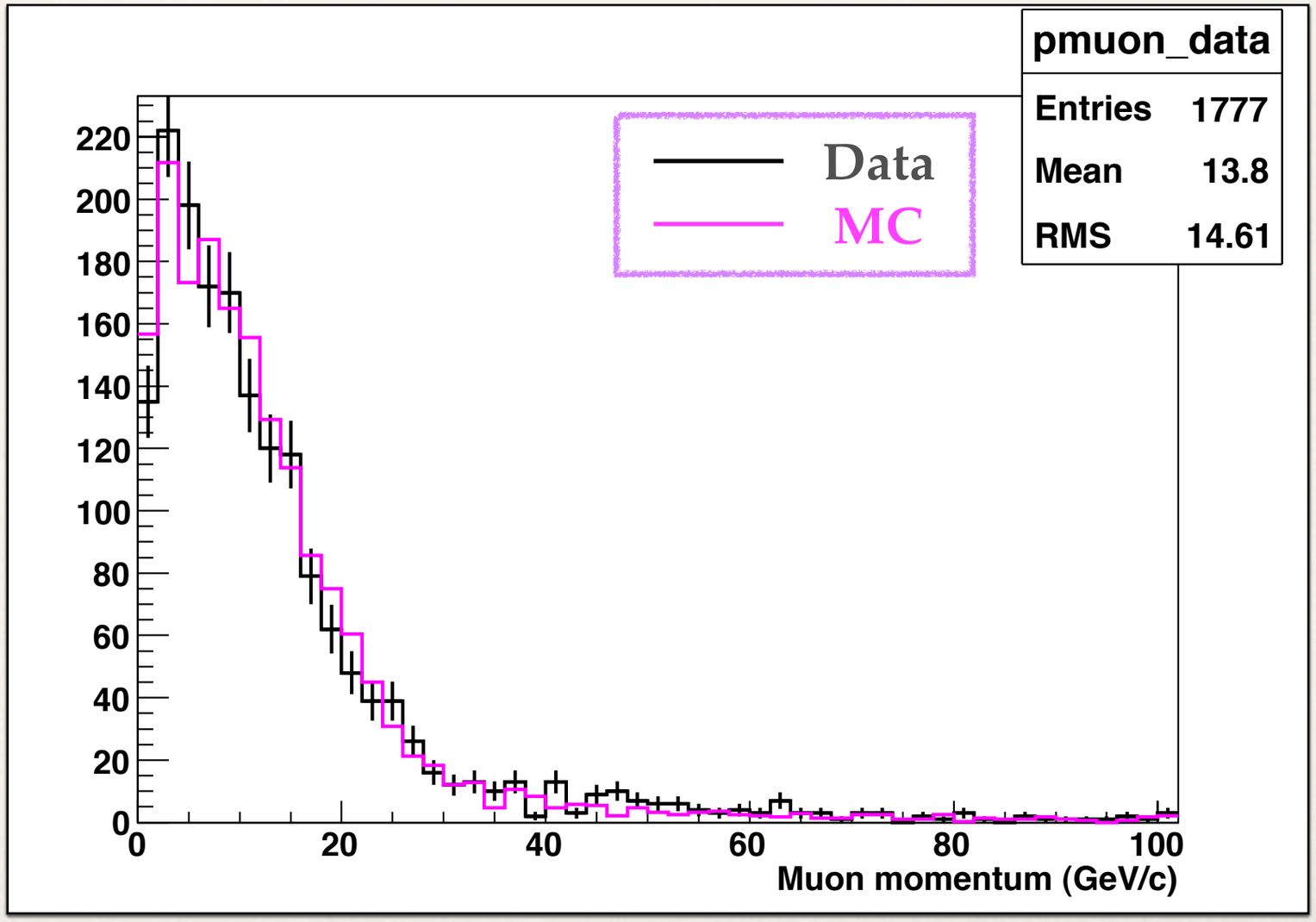
- The muon identification is of fundamental importance for the improvement of the efficiency in the $\tau \rightarrow \mu$ channels and for the reduction of charm background in all $\tau$ decay channels.
- It is done before the scanning using the electronic detectors and according to the result the brick-finding algorithm will be applied (NC and CC are different).
- The variable used is: (track length ×density of the crossed materials) and a cut of 660 $g \times cm^{-2}$ is put on this variable.




- Very good agreement between data and MC for the muon track.

# Muon momentum

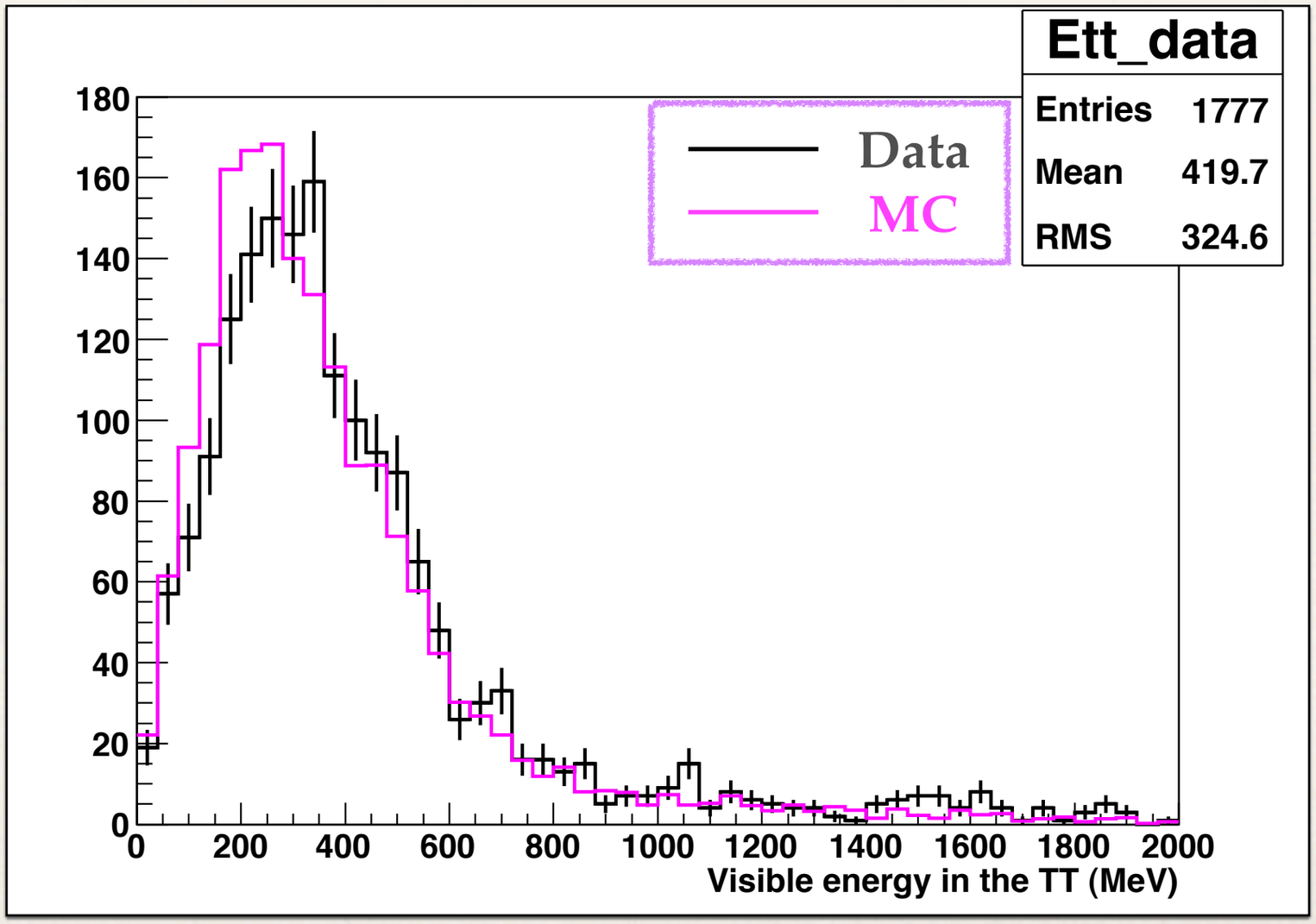
- The muon momentum is calculated using a Kalman filter (range and bending in magnetic field).
- We find a good agreement between MC and data.



# Deposited energy

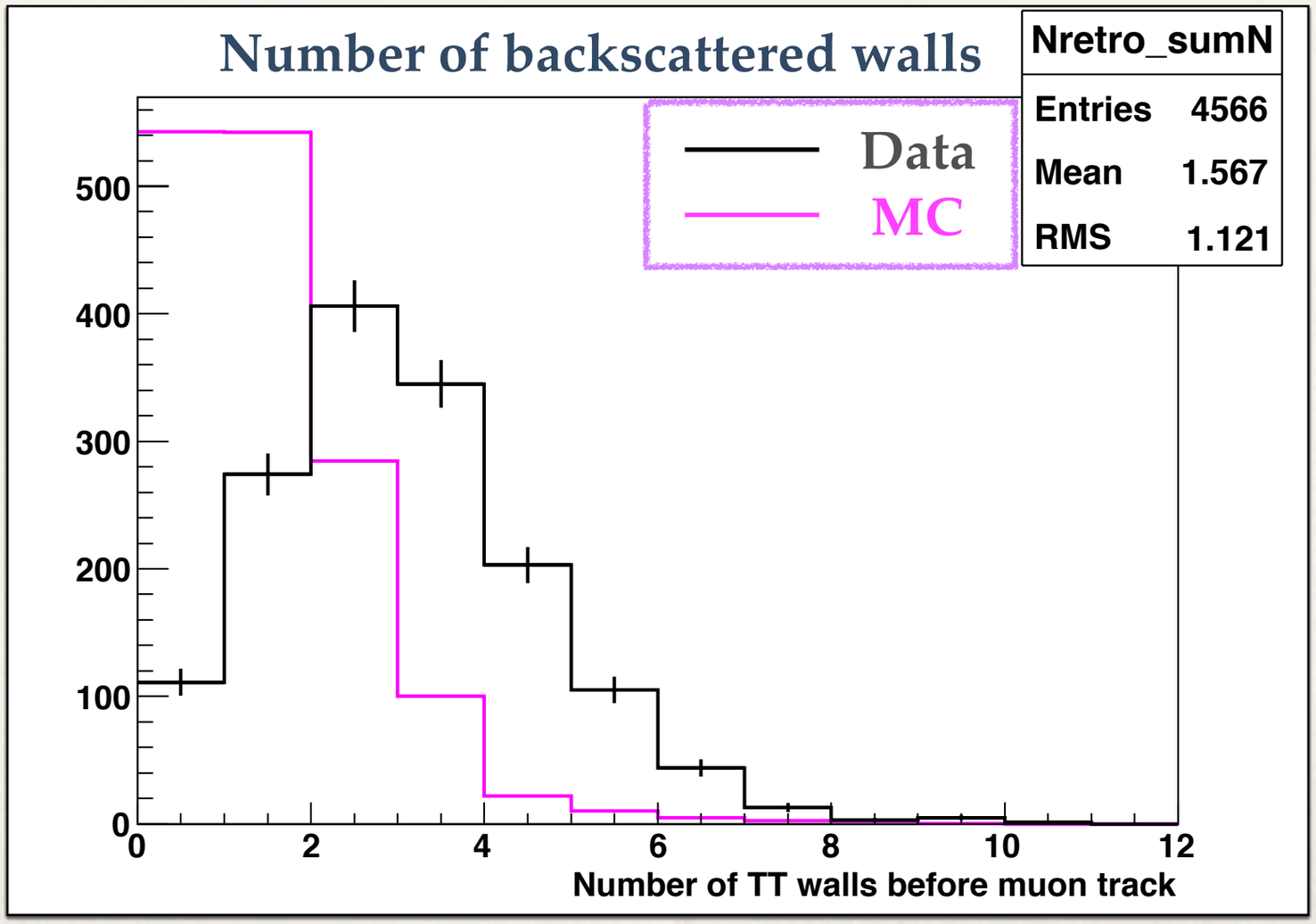
- The deposited energy in the Target-Tracker is calculated using a precise calibration (gain measurements done regularly with LED, and mip calibration using real cosmic tracks).

- We find a good agreement, but on average it seems that more energy is deposited in real data.



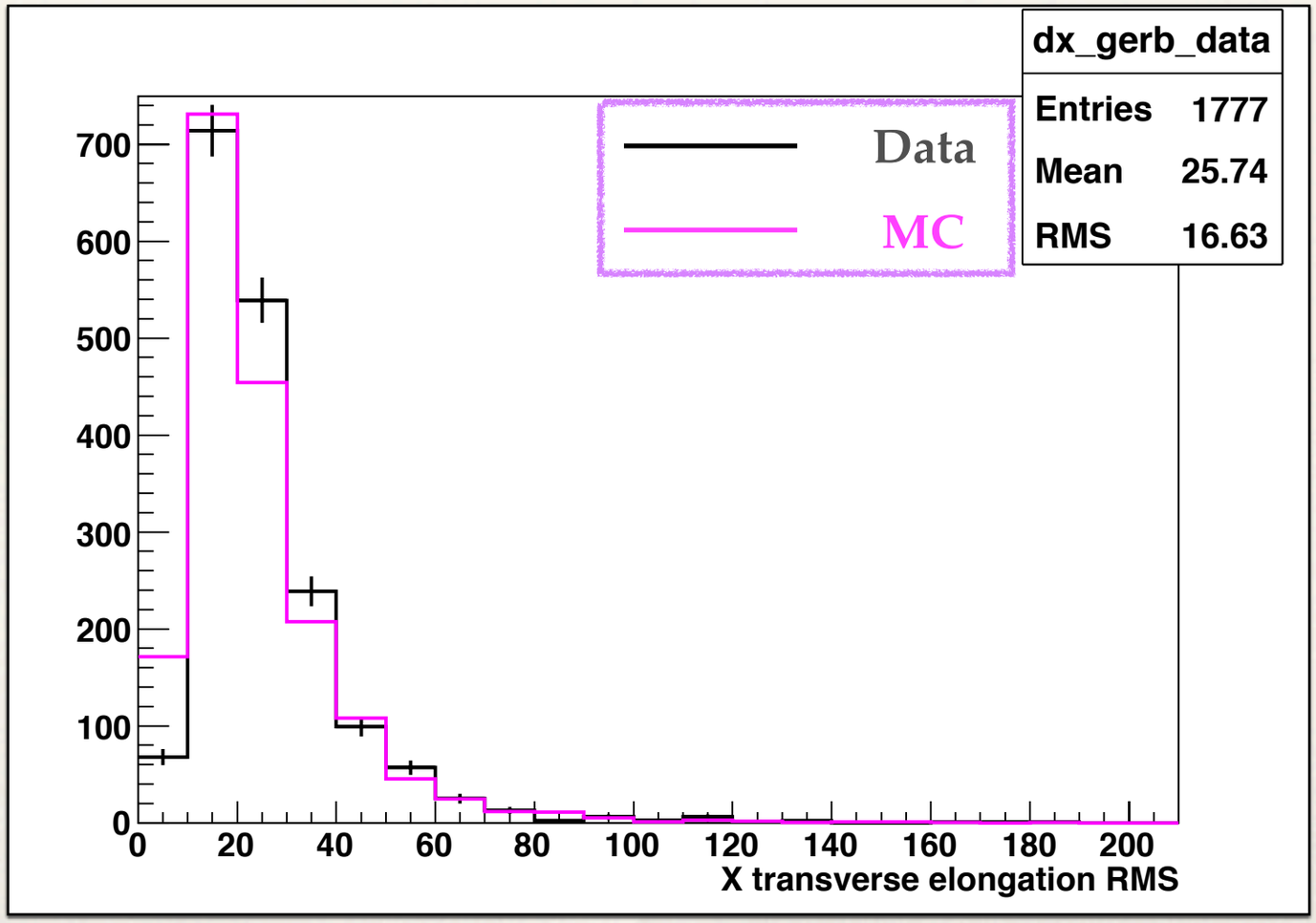
# Backscattering

- The backscattering is a result of the wall-finding algorithm (based on a Neural-Network).
- We find an important difference between data and MC: backscattering is higher in data than in MC.
- For the MC and $\nu_\mu$ CC events, we find a good efficiency of the Wall-Finding (for 84% of the cases the wall is the correct one, and for 14% it is the following one).



# Shower transverse profile

- We calculate the RMS of the transverse distribution of the shower in the X and Y projections where the Target-Tracker hit position are weighted by the number of p.e.
- The real events seem to have a larger transverse profile.
- It seems that the «hadronic activity» is higher in the real data.



# NC/CC ratio

To be independent of the tracking efficiency, an event is identified as CC if the number of touched planes is more than 14.

**MC**

| CC identified | CC misidentified | NC identified | NC misidentified |
|---|---|---|---|
| 96.1% | 3.9% | 69.0% | 31.0% |

**MC**

| OpCarac (fiducial volume) efficiency CC | OpCarac (fiducial volume) efficiency NC |
|---|---|
| 96.9% | 88.2% |

**Data**

| CC identified | NC identified |
|---|---|
| (1928) 78.0% | (545) 22.0% |

OpCarac efficiency for CC — CC identified efficiency — True number of CC — OpCarac efficiency for NC — NC misidentified efficiency — True ratio NC/CC = 0.29

$$CC_{measured} = \epsilon_{OpCarCC} \times eff_{CC} \times n_{CC} + \epsilon_{OpCarNC} \times ineff_{NC} \times \epsilon_{NC/CC} \times n_{CC}$$

$$NC_{measured} = \epsilon_{OpCarCC} \times ineff_{CC} \times n_{CC} + \epsilon_{OpCarNC} \times eff_{NC} \times \epsilon_{NC/CC} \times n_{CC}$$

**MC** NC/CC = 21.2%

**Data** NC/CC = 28.3%

We find more NC events in the data, which are due to interacting neutrons coming from a neutrino interaction in the rock or materials in front of the detector. Characterisation of this «noise» under study!

# Conclusions

- CNGS performances improved: (2008+2009) runs are expected to be as 1 nominal year ; 2010 is expected as a nominal year.
- 15 charm candidates found: systematic decay search started with an uniform selection on all the data sample.
- Analysis of 2009 progressing while completing the queue of 2008 run.
- First τ(s) expected soon in the analysis of 2008/2009.
- We find a good agreement between data and MC for the muon: reconstruction, identification, momentum measurement.
- The hadronic energy and the transverse profile seem slightly overestimated in the data with respect to simulation (based on Gfluka).
- The fraction of backscattering seems larger in the data (which affect the wall-finding). We will do new simulations using full Fluka transport.