

MEASUREMENT OF THE NEUTRINO VELOCITY WITH THE OPERA DETECTOR IN THE CNGS BEAM

The OPERA Collaboration

<http://arxiv.org/abs/1109.4897>

Sep 26, 2011

SPEED OF LIGHT



SPEED OF GRAN SASSO NEUTRINOS

- Friday, September 23, 2011
- OPERA experiment



speed of ν_μ :

$$v = (1.000\,024\,7 \pm 0.000\,004\,1)c$$



6 sigma deviation !

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speed of ν_μ :

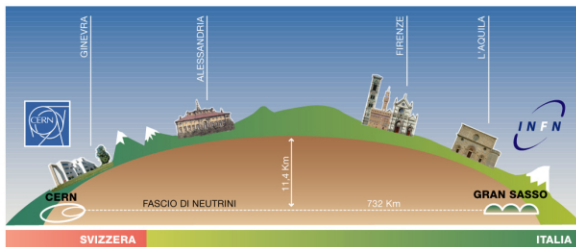
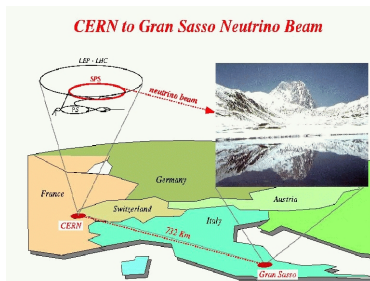
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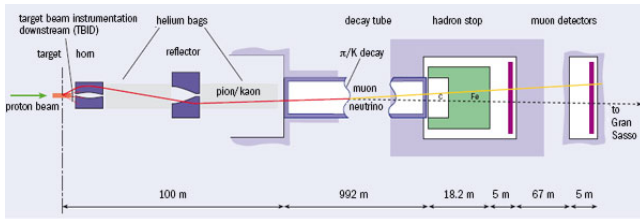
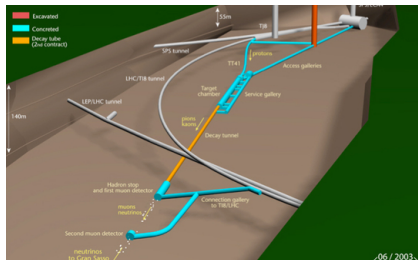
6 sigma deviation !

$$\nu_{\mu} \longrightarrow \nu_{\tau}$$

$$\langle E_{\nu} \rangle = 17 \text{ GeV}$$



CERN NEUTRINOS TO GRAN SASSO (CNGS)



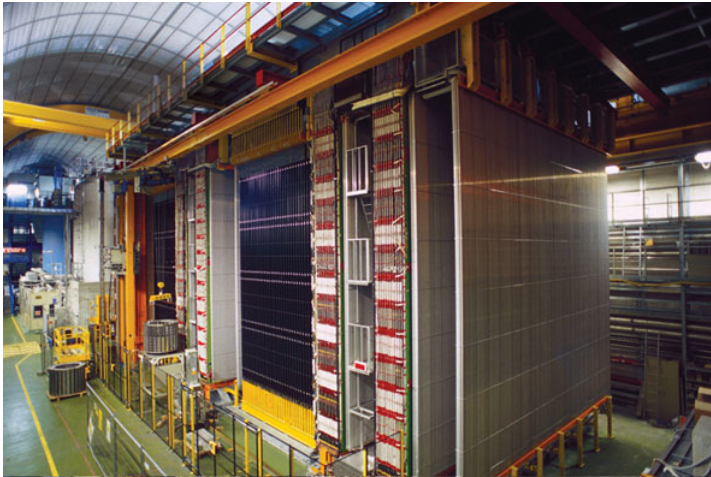
LABORATORI NAZIONALI DEL GRAN SASSO (LNGS)



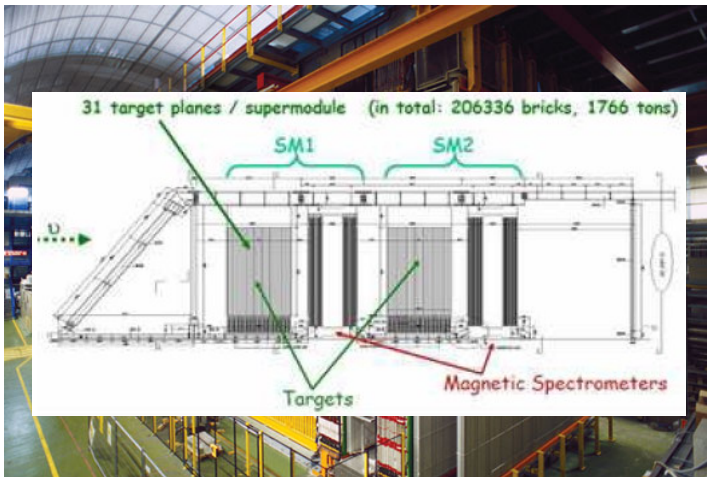
↕ ~ 1400 m of rock



OPERA DETECTOR



OPERA DETECTOR



2009 – 2011:

CERN
 10^{20} protons



OPERA
16 000 neutrinos

distance: $731\,278.0 \pm 0.2$ cm

time of flight: ~ 2.5 ms

precision: < 10 ns

$$\delta t = \text{ToF}_c - \text{ToF}_\nu = (60.7 \pm 6.9 \pm 7.4) \text{ ns}$$

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expectation due to the neutrino mass:

$$\frac{|v - c|}{c} < 10^{-19}$$

measurement:

$$\frac{v - c}{c} = 2.5 \times 10^{-5}$$

- **Fermilab, USA, 1979**

short baseline

ν_μ , $E_\nu > 30$ GeV

$$\frac{|v - c|}{c} \leq 4 \times 10^{-5}$$

- **supernova SN1987A**

168 000 l.y.

ν_e , $E_\nu \approx 10$ MeV

$$\frac{|v - c|}{c} \leq 2 \times 10^{-9}$$

- **Fermilab's MINOS, USA, 2007**

732 km

ν_μ , $E_\nu \approx 3 \text{ -- } 100$ GeV

$$\frac{v - c}{c} = (5.1 \pm 2.9) \times 10^{-5}$$

(1.8 sigma)

- **OPERA, Italy, 2011**

732 km

ν_μ , $E_\nu \approx 17$ GeV

$$\frac{v - c}{c} = (2.48 \pm 0.28 \pm 0.30) \times 10^{-5}$$

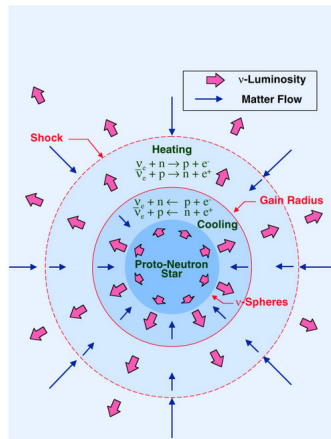
(6 sigma)

SN1987A

- Feb 24, 1987
- type II supernova
- 168 000 l.y.
- 23 neutrinos (13 s, 10 MeV)
- light 3 hours later

3 hours \Rightarrow 1.000 000 002 0 c

OPERA \Rightarrow 4 years earlier

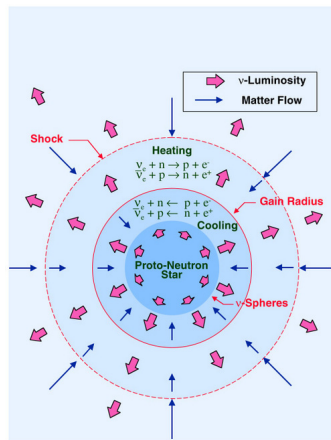


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