What Next “Mid Term”: neutrini e oscillazioni

M. Spurio
per il gruppo «neutrini»
C. Brofferio, C. Giunti, E. Lisi, F. Terranova

SWOT analysis (Strengths, Weaknesses, **Opportunities**, Threats)

- ~~Oscillazioni dei neutrino~~ → **balistico**
- ~~LNBX: (CP, MH)$_{west}$~~ → **strategia politica ente**
- ~~HK/T2K/T2HK : (CP, MH)$_{est}$~~ → **come sopra**
- ~~SB, neutrino sterile~~ → **Alta politica CERN/FNAL**
- ~~Astrofisica dei Neutrini~~ → **c. r.**
- ~~Liquid Argon per rivelatori~~ → **C.R.**
- Doppio beta, masse → **Sì**

- DBD, masse assolute → prossimo talk di Francesco Terranova

Grazie per l'attenzione

- Dopo il Meeting dell'Angelicum, situazione cambiata
- Meeting a Padova 1-2 Dicembre su

https://agenda.infn.it/conferenceDisplay.py?confId=8736

BUT……

F. Ferroni, La Thuile 2014

- The neutrino community does not express a coherent view
- in general there is nothing wrong with this
- except in a few special cases
- and a global project is one of those cases

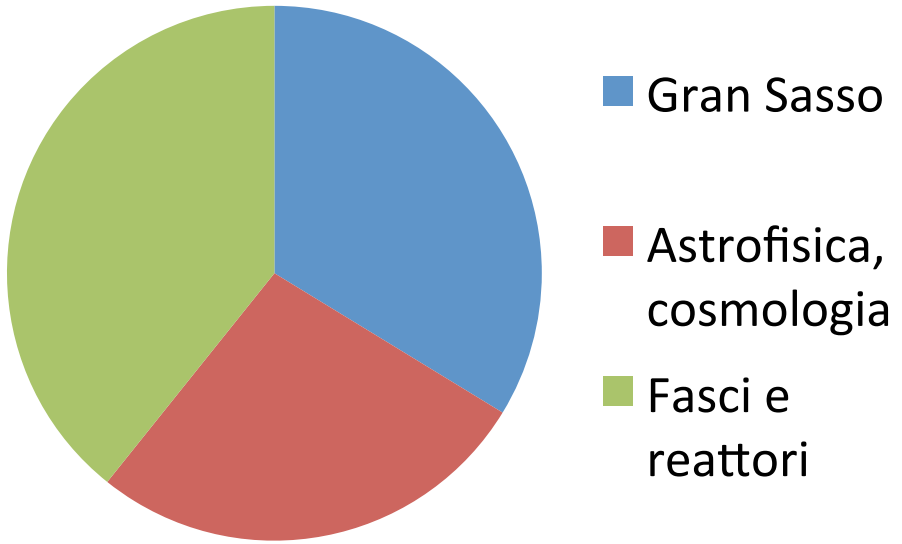
La comunità «neutrini» INFN

SIGLA	FTE
Borex	12,8
Cosmo_WN	1,0
Cuore	31,2
Gerda	10,3
Icarus	19,0
Juno	5,5
KM3	39,0
LVD	3,5
Nessie	4,8
OPERA	25,6
T2K	8,3
TOTALE	**161**

FTE Commissione 2 = 593
Commissione 1 = 703
Commissione 3 = 430

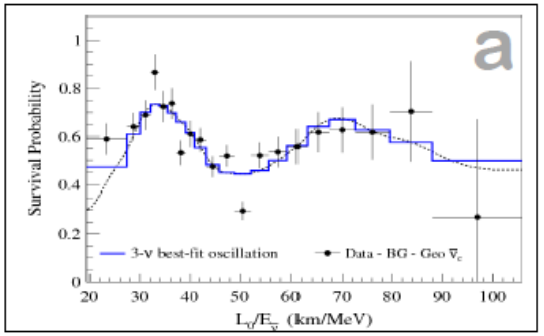
La fisica del neutrino coinvolge:

- ~ **27%** della CN2
- ~ **9%** dei fisici sperimentali INFN

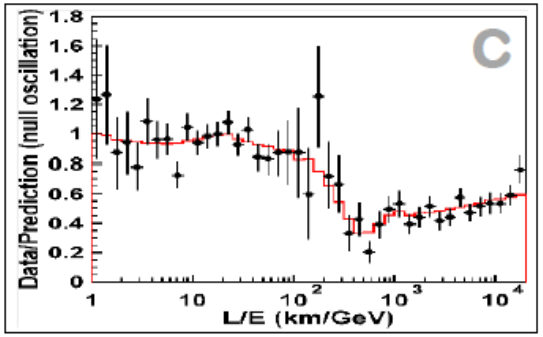


Recent discoveries: α → β oscillations in vacuum and matter

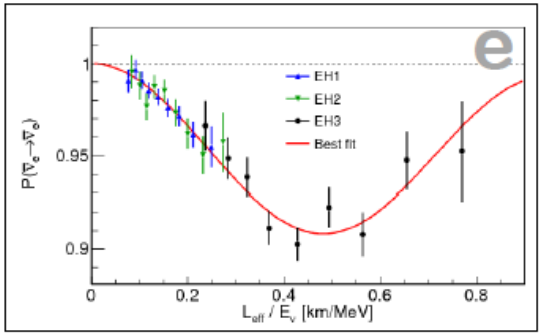
e→e



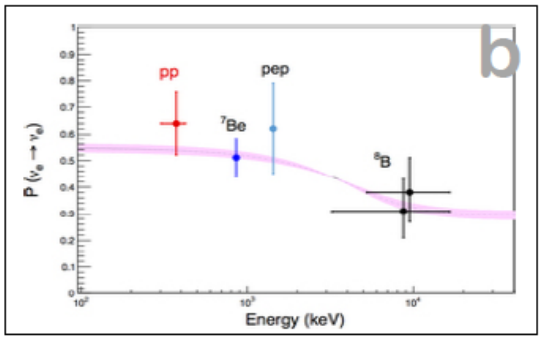
μ→μ



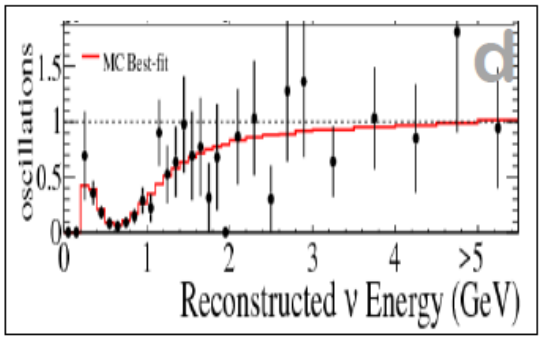
e→e



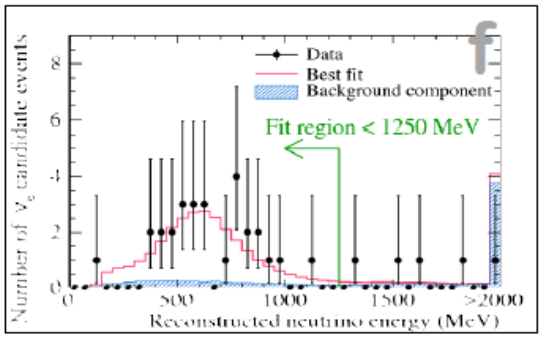
e→e



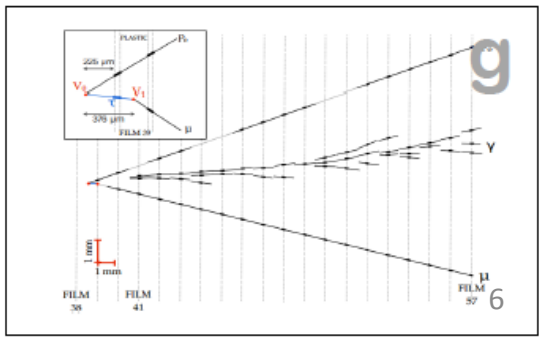
μ→μ



μ→e



μ→τ



Data from various types of neutrino experiments: (a) solar, (b) long-baseline reactor, (c) atmospheric, (d) long-baseline accelerator, (e) short-baseline reactor, (f,g) long baseline accelerator (and, in part, atmospheric).

(a) KamLAND [plot]; (b) Borexino [plot], Homestake, Super-K, SAGE, GALLEX/GNO, SNO; (c) Super-K atmosph. [plot], MACRO, MINOS etc.; (d) T2K (plot), MINOS, K2K; (e) Daya Bay [plot], RENO, Double Chooz; (f) T2K [plot], MINOS; (g) OPERA [plot], Super-K atmospheric.

Pontecorvo-Maki-Nakagawa-Sakata (PMNS) matrix

$$U_{\alpha i} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{bmatrix} \begin{bmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{bmatrix} \begin{bmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha/2} & 0 \\ 0 & 0 & e^{i\beta/2} \end{bmatrix}$$

Terra Cognita

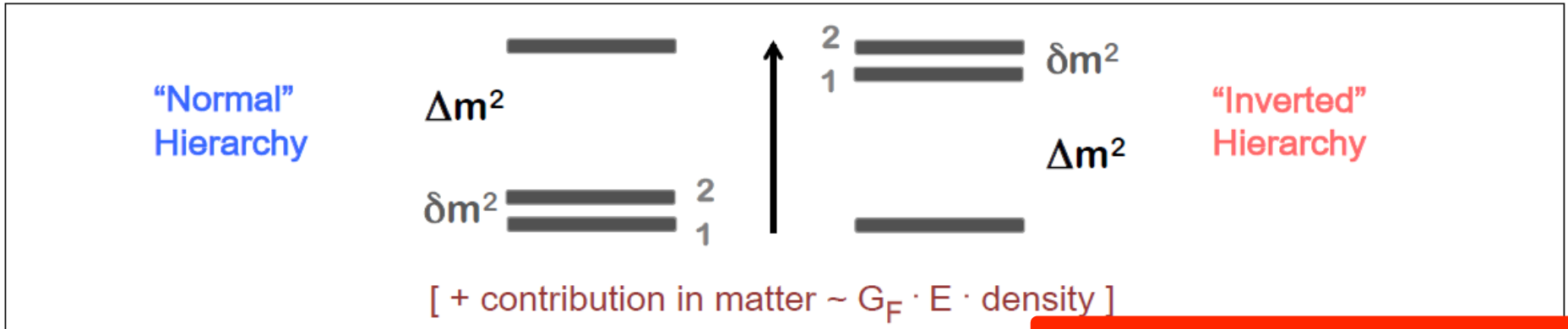
Mixing angles θ_{23}, θ_{13}, θ_{12} : known ✔

[only if Majorana]

Terra Incognita I

CP-violat. phase(s) δ (α, β) : unknown ✗

Mass-squared spectrum (up to absolute scale)



Terra Cognita

δm^2, Δm^2: known ✔ Matter effects (solar ν): ✔

Terra Incognita I

Hierarchy : unknown ✗

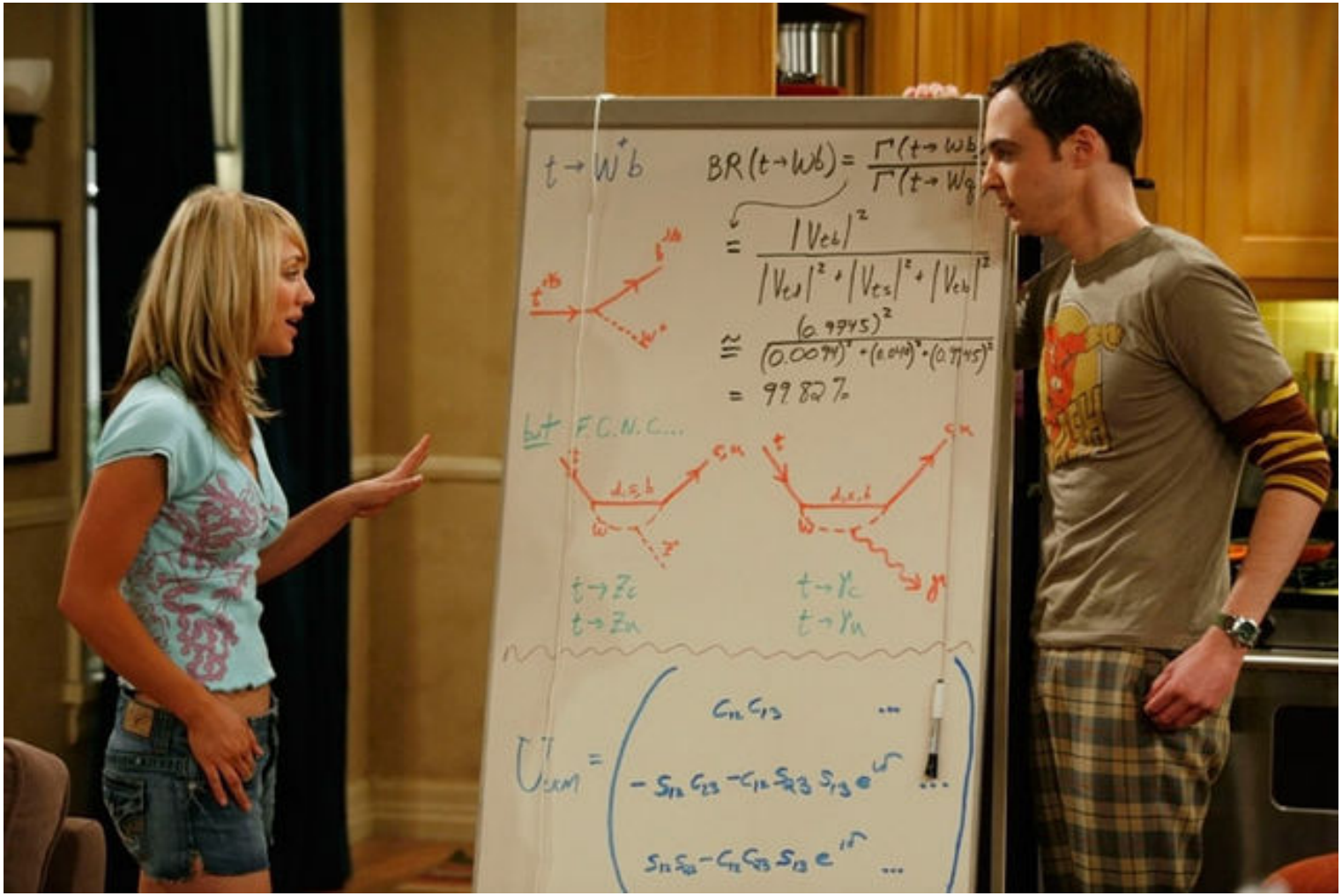
E. Lisi (C2- 11/2014)

Un problema dell'INFN

- La fisica del neutrino è stata ed **è sentita** come «fisica di Gruppo 2»
- Chiusura troppo ermetica verso gli aspetti sperimentali del settore leptonico, lasciati come esclusiva al Gruppo II
- (… la «Terra Cognita» di Lisi)

Weaknesses

…ma non è solo un problema INFN



Current 3ν picture in just one slide (with 1-digit accuracy)

Flavors = e μ τ

Abs.scale Normal hierarchy... or... Inverted hierarchy mass^2 split

Terra Incognita I

Occorrerà comunque stabilire una strategia (priorità, investimenti, …) per massimizzare la visibilità dell'ente. Non è possibile con 1/3 del 10% degli FTE

Diamole per note

Terra Cognita:

$\delta m^2 \sim 8 \times 10^{-5}$ eV^2
$\Delta m^2 \sim 2 \times 10^{-3}$ eV^2
$\sin^2\theta_{12} \sim 0.3$
$\sin^2\theta_{23} \sim 0.5$
$\sin^2\theta_{13} \sim 0.02$

Terra Incognita:

δ (CP)
sign(Δm^2)
octant(θ_{23})
absolute mass scale
Dirac/Majorana nature

The JUNO detector concept

Requirements:
Large detector: **20 kt LS**
Energy resolution:
3%/√E → 1200 p.e./MeV

	KamLAND	JUNO
LS Mass	~1 kt	20 kt
Energy Resolution	6%/√E	3%/√E
Light Yield	250 p.e./MeV	1200 p.e./MeV

Top muon detector
Water cherenkov detector
Buffer container or PMT support
~15000 20" PMTs, coverage:~80%
Buffer
LS container
20 kton LS
~1500 20" veto PMTs

AG (PD) JUNO 2 Dicembre 2014 5 / 20

JUNO ! Fisica scomoda e di altissima qualità

The CERN Neutrino Platform

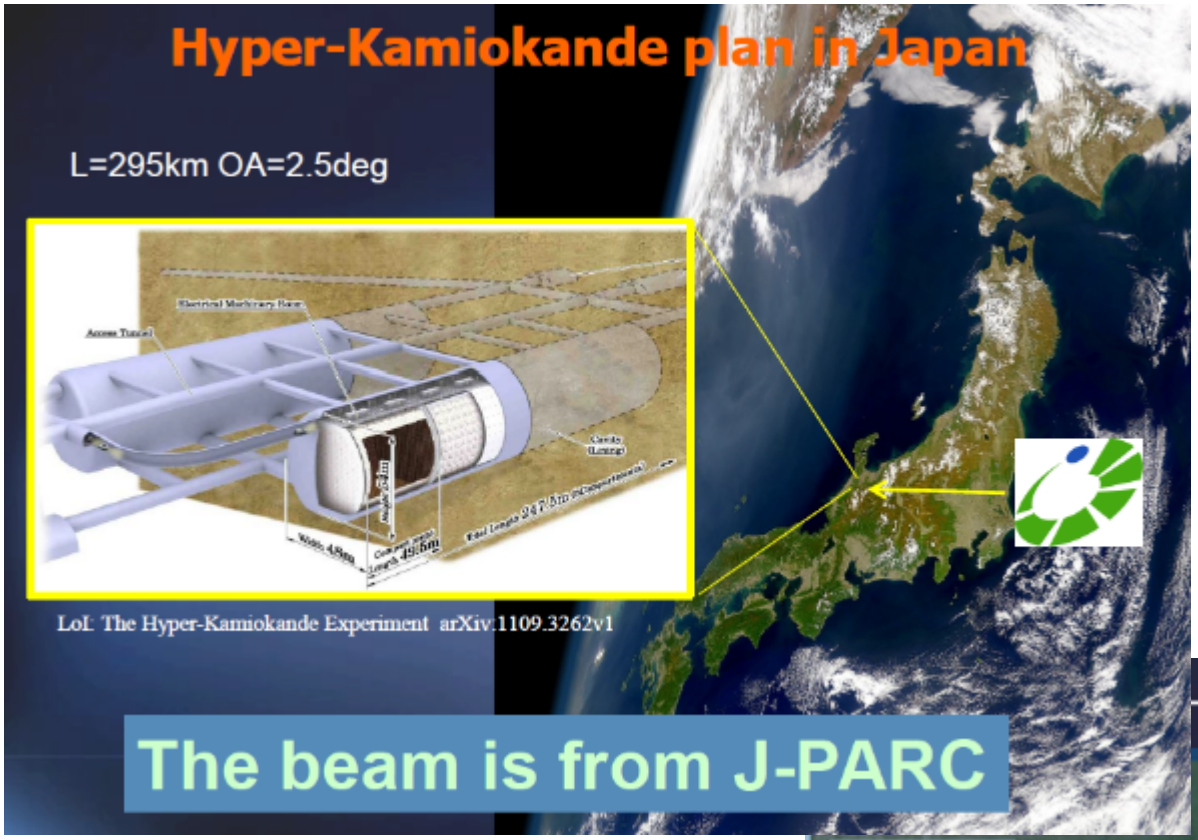
Marzio Nessi, CERN & University of Geneva

The future possible landscape for new Neutrino Accelerator Infrastructure (as far we understand today!)

- ✓ *no beams at CERN!*
- ✓ *US and/or Japan ?*

Follow up: Misura sezioni d'urto

- arXiv:1412.5987
- R&D per la Neutrino Platform



- EST: Piccolo gruppo INFN interessato

- WEST: Sinora, nessun segnale di interesse

Terra Incognita II (absolute mass observables)

(m_β, $m_{\beta\beta}$, Σ)

In the 3ν framework:

β **decay**, sensitive to the "effective electron neutrino mass":

$$m_\beta = \left[c_{13}^2 c_{12}^2 m_1^2 + c_{13}^2 s_{12}^2 m_2^2 + s_{13}^2 m_3^2\right]^{\frac{1}{2}}$$

0νββ decay: only if Majorana. "Effective Majorana mass":

$$m_{\beta\beta} = \left|c_{13}^2 c_{12}^2 m_1 + c_{13}^2 s_{12}^2 m_2 e^{i\phi_2} + s_{13}^2 m_3 e^{i\phi_3}\right|$$

Cosmology: Dominantly sensitive to sum of neutrino masses:

$$\Sigma = m_1 + m_2 + m_3$$

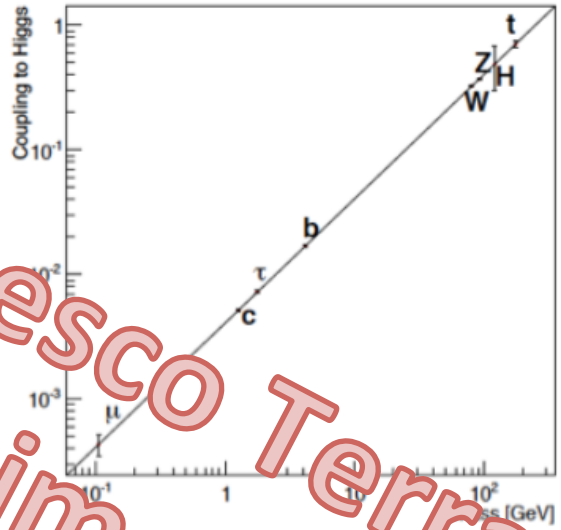
Note 1: These observables may provide handles to distinguish NH/IH.
Note 2: Majorana case gives a new source of CPV (unconstrained)
Note 2: The three observables are correlated by oscillation data→

E. Lisi (C2- 11/2014)

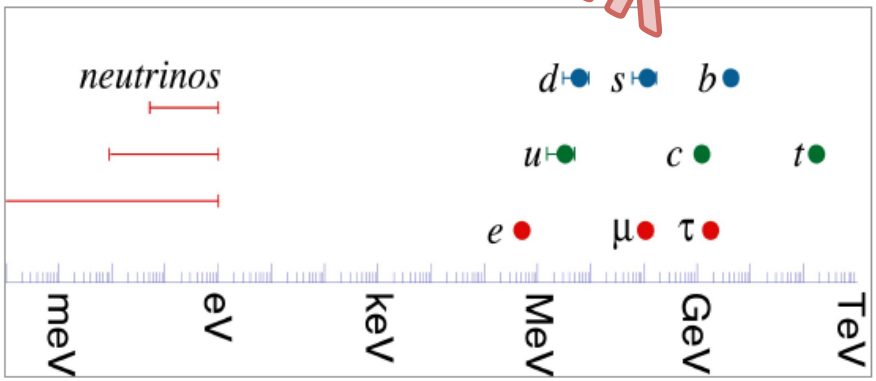
Linking two fundamental research expeditions:

Ref: Francesco Terranova, Prossimo talk

1. Test Higgs sector

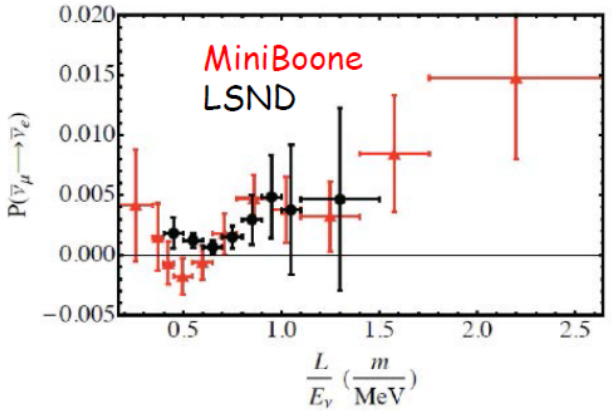


2. Find ν masses



…Terra incognita III

Light states: conflicting sightings of ν_s with (sub)eV mass from various sailors in the last 20 years… new land or mirage?



Available data: intriguing, but not conclusive or convergent.

The question raised by the LSND claim is still with us:
Is there $\nu_\mu \to \nu_e$ appearance at a scale $\sqrt{\Delta M^2} \sim O(0.1\text{-}1)$ eV ?

In recent years, further interest in light sterile ν raised by:

1) Possible associated $\nu_e \to \nu_e$ disappearance signals
2) Possible associated extra radiation in cosmology

ν_μ Disappearance

Janet Conrad, MIT
WINP2015, 2/5/15

The long-term future of particle physics in the US is largely neutrino-based.

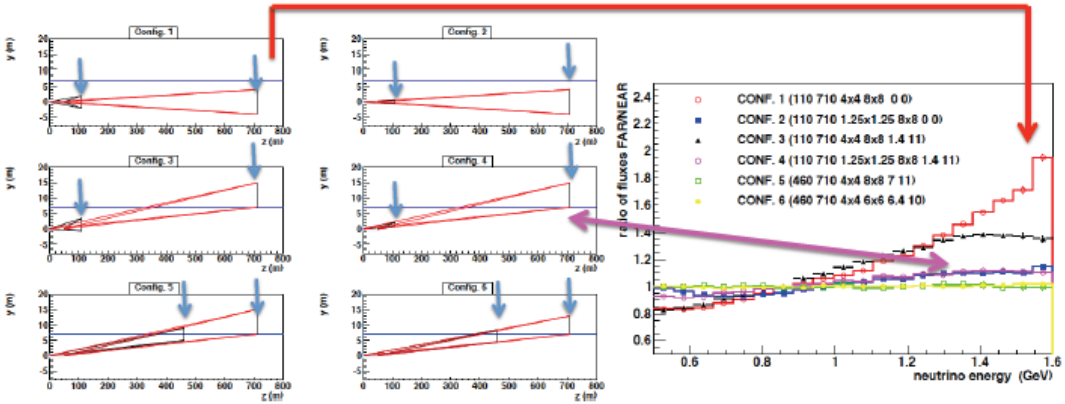
...You get to the long-term future via the intermediate-term future!

An intermediate neutrino program that is <u>scientifically decisive</u>
is the best path to long-term-future success
for DOE and NSF.

A study of configurations for the BNB (FNAL) beam by the NESSiE Collaboration

hep-ex/1404.2521

Flux ratios can show big differences
Between near and far detectors!



4 m x 4 m near

1.25 m x 1.25 m near

(Both designs have an 8 m x 8m far detector)

Choice is config. 4

Need to understand the shape to ~1% level!

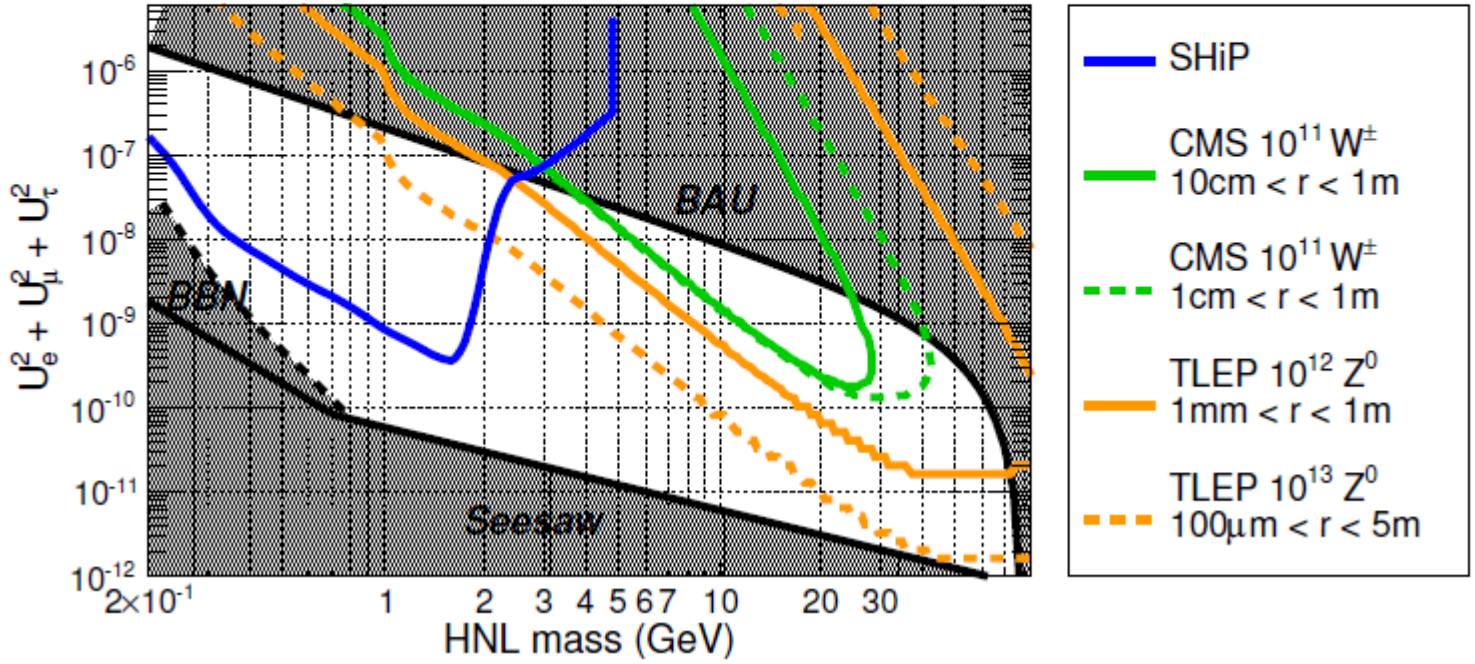
Terre ancor più incognite

SHiP
Search for Hidden Particles

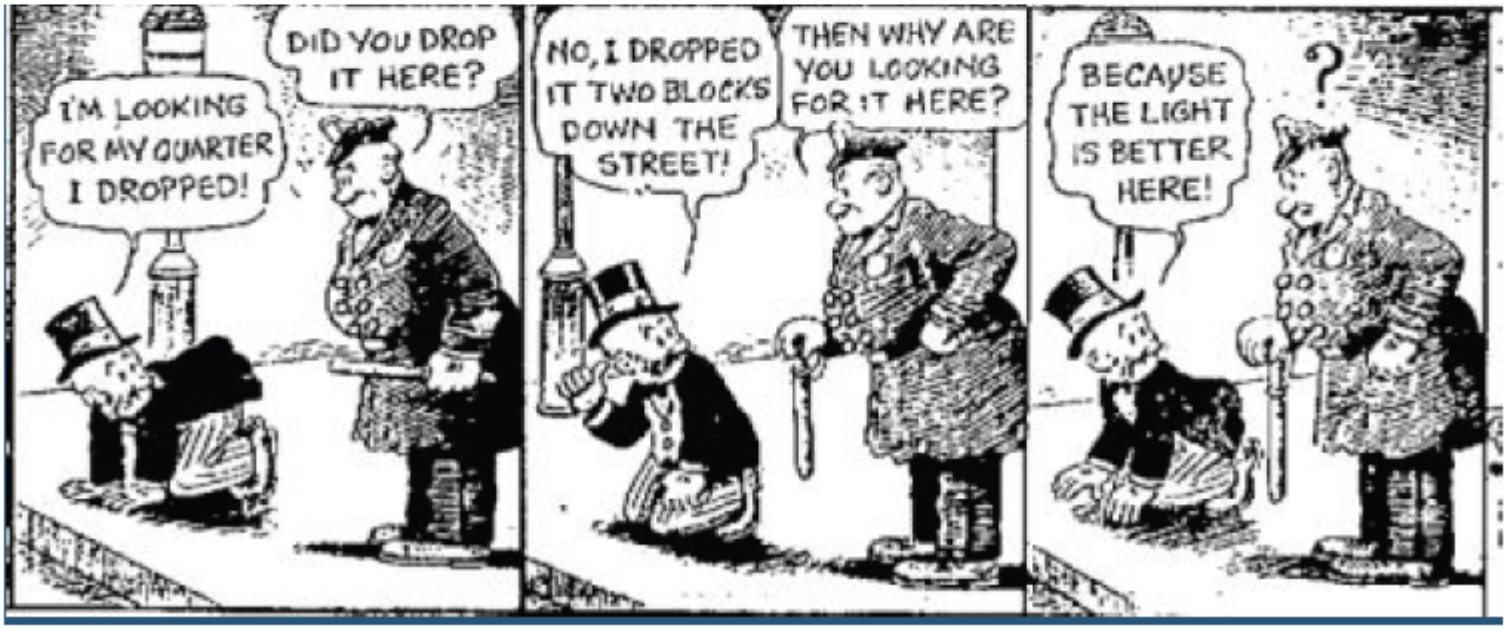
SHiP

SEARCH FOR HIDDEN PARTICLES

A new experiment proposal



- Searches for new physics beyond SM: explore the high intensity frontier
- SM guaranteed physics program: $\bar{\nu}_\tau$ discovery, ν_τ cross-section studies and more
- Technical proposal in preparation (Spring 2015)



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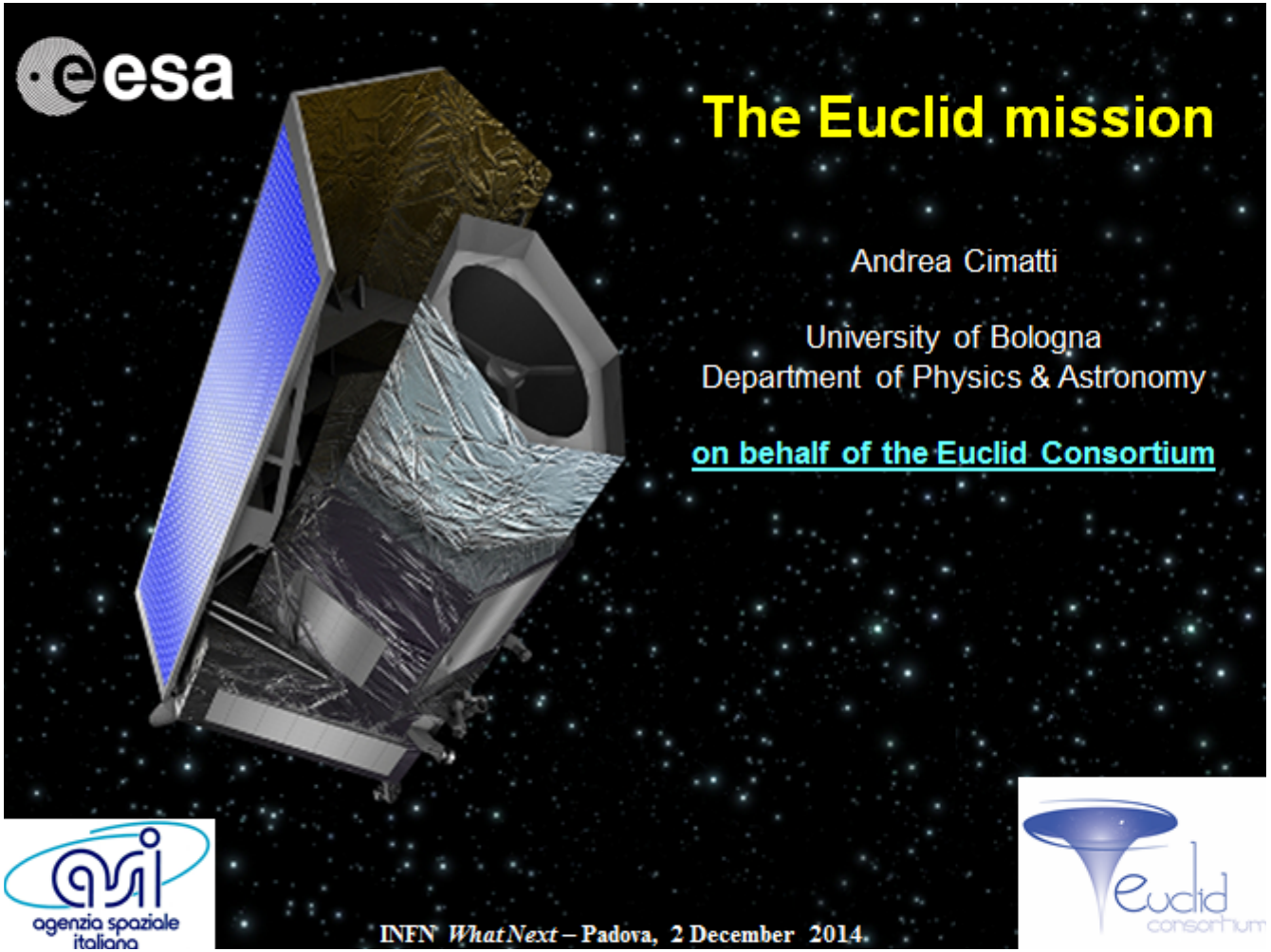
- Attenzione «effetto lampione»: non dobbiamo condizionare le scelte di fisica dalla presenza di infrastrutture che dobbiamo utilizzare (siano anche il CERN, o i LNGS)

Un effetto quantistico: interferenza Neutrini - Raggi Cosmici

- Astrofisica dei neutrini giunta ad un punto critico con la scoperta di IceCube
- ANTARES e KM3NeT (fase 1, finanziata PON) hanno la possibilità di contribuire alla comprensione dell' origine dei nu cosmici. Astrofisica → fase 2, «ARCA»
- KM3NeT in Francia, in cerca di €, «ORCA» ha la possibilità di anticipare la misura di MH
- Le risorse (umane, finanziarie) necessarie per le due imprese forse esulano dalle disponibilità INFN
- Dovremo (ahimè!) decidere strategia/priorità

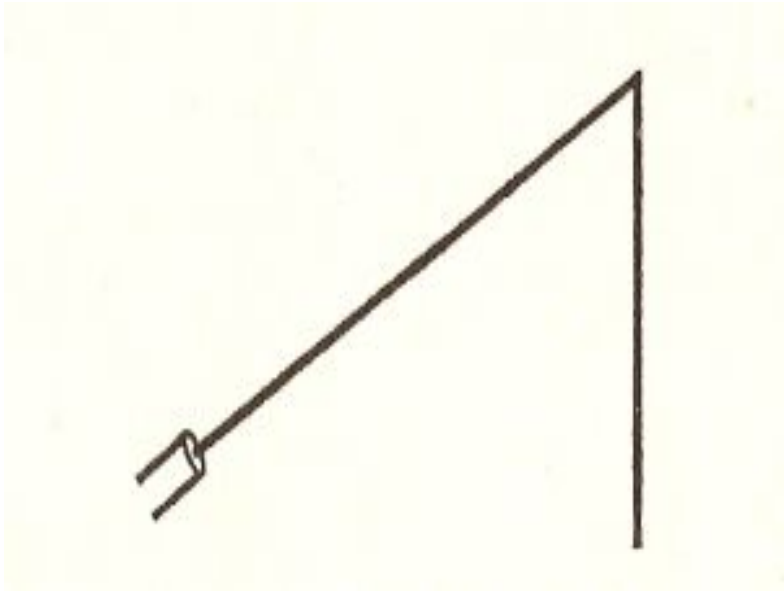
Neutrino trigger
interferenza particelle - cosmologia

- «Rivoluzione» copernicana in ambito INFN
- Un reale trionfo di WN

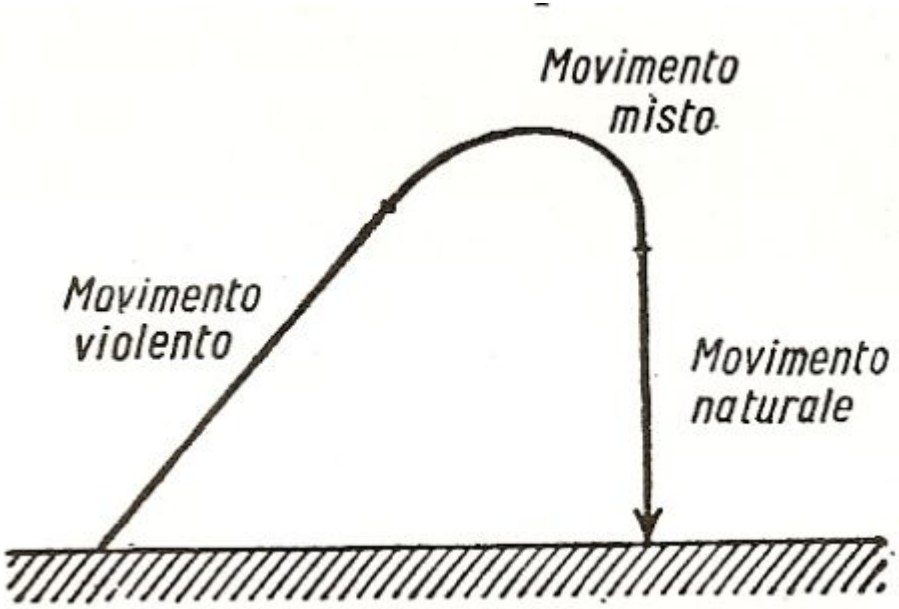


Fisica del neutrino e del settore debole:

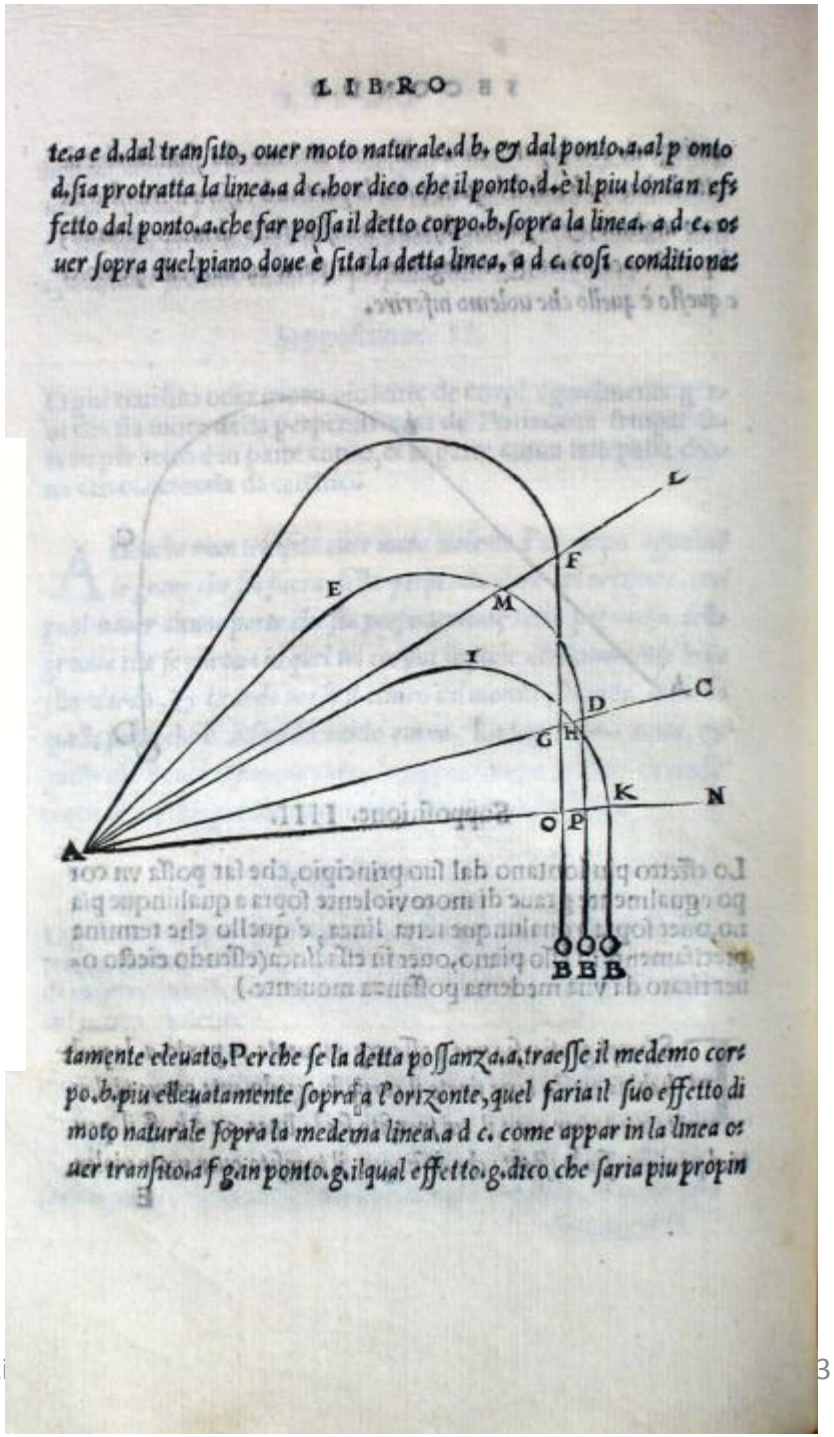
- Forse ancora balistica: conoscenze sperimentali



… sviluppi teorici



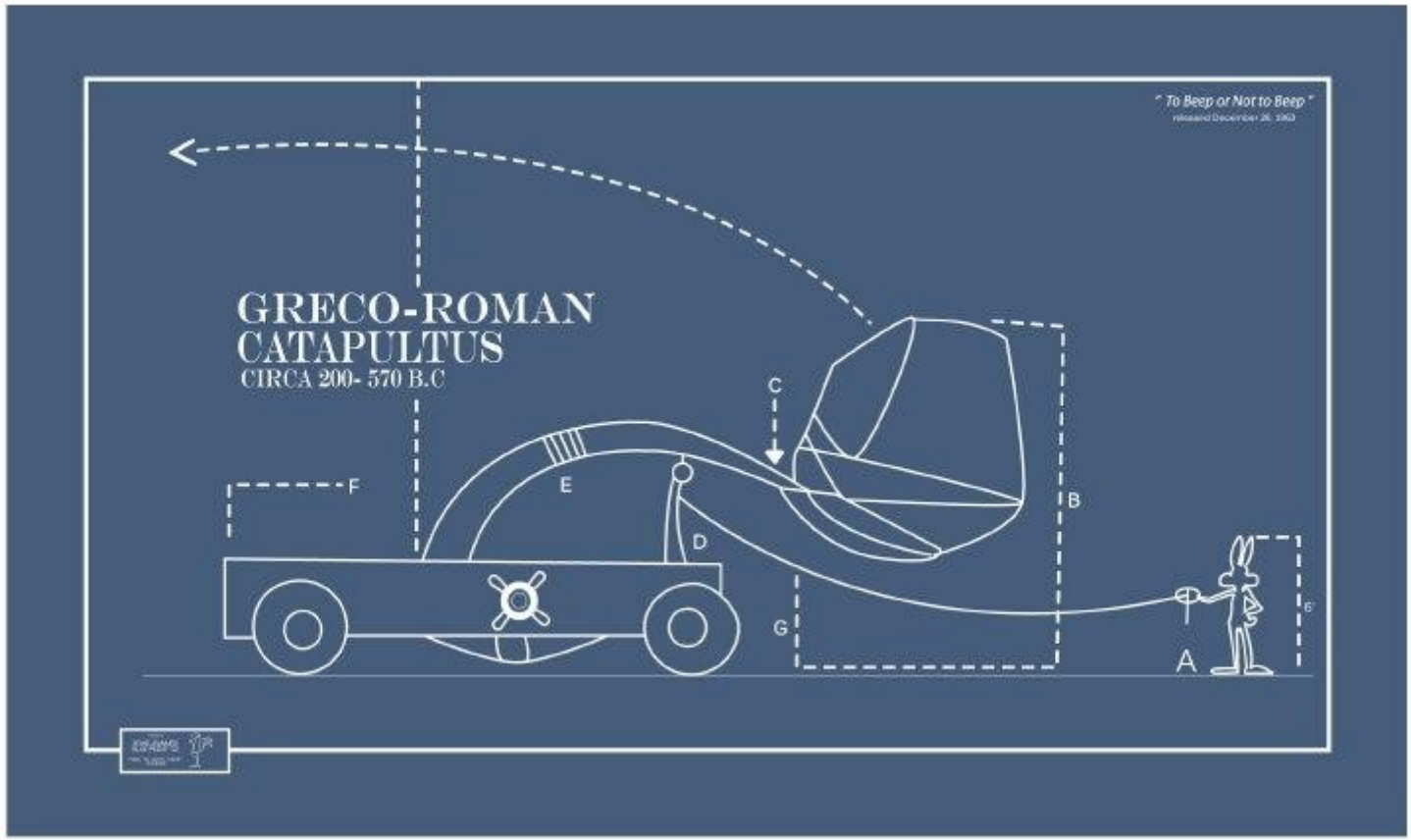
Curva Balistica di Tartaglia:
Delli quesiti et inventioni diverse, 1546


LIBRO

te.a e d.dal transito, ouer moto naturale.d b. & dal ponto.a.al p onto d.sia protratta la linea.a d c.hor dico che il ponto.d.è il piu lontan effetto dal ponto.a.che far possa il detto corpo.b.sopra la linea. a d c. ouer sopra quel piano doue è sita la detta linea. a d c. cosi conditionat

tamente eleuato. Perche se la detta possanza.a.traesse il medemo corpo.b.piu elleuatamente sopra a l'orizonte, quel faria il suo effetto di moto naturale sopra la medema linea.a d c. come appar in la linea ouer transito.a f g.in ponto.g.ilqual effetto.g.dico che saria piu propin

… ma dove andremo a finire dipende dalle **condizioni iniziali**



Conclusioni

- What Next? Per i «neutrini» è lavoro **qui** e **ora**
- Troppo sbilanciata la disponibilità di risorse per lo studio del settore adronico (CKM) rispetto a quello leptonico (PMNS)
- Parametri fondamentali da misurare che richiedono un significativo sforzo INFN **«now»** (terra incognita I)
- Natura, massa del neutrino (terra incognita II)

→ Francesco

- Problema dello sterile tuttora da risolvere (ma si vuole affrontare?)
- Ma questa fisica non si fa al CERN

FOLLOWING CERN STRATEGY

F. Ferroni, La Thuile 2014

- find a place somewhere in the world where to execute the right experiment with the spirit of a 'global project'
- just to be clear as the LHC upgrade or the ILC adventure
- the place looks like FermiLab + Homestake
- not perfect (limited by the fact that you can't move either object !) but possibly sufficient with and additional bonus.....

FERMILAB BONUS

F. Ferroni, La Thuile 2014

- The lab has already a working (actually two) neutrino beam
- it can host SBL experiment(s) that would serve at cleaning up the field (or send somebody to Stockholm), to expose new R&D detectors to a real neutrino beam and , more important of all, to gather around real experiments and million of events a community that shall form the core of the future LB(NE) collaboration
- I assume that the technology is LAr

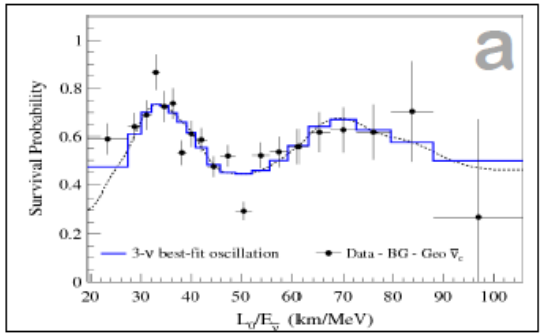
JUST AN INFN POINT OF VIEW

F. Ferroni, La Thuile 2014

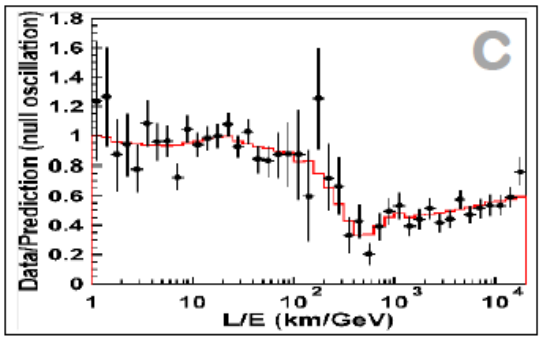
- We know what LAr is
- We have run for a couple of years a 600 Ton detector at LNGS exposed to CNGS
- We have presented a proposal for a SBL experiment at FNAL
- An italian group is already committed to LB(NE)
- (when I say we, I mean Carlo Rubbia group fully supported by INFN)

Can be charted in a simple 3ν theoretical framework

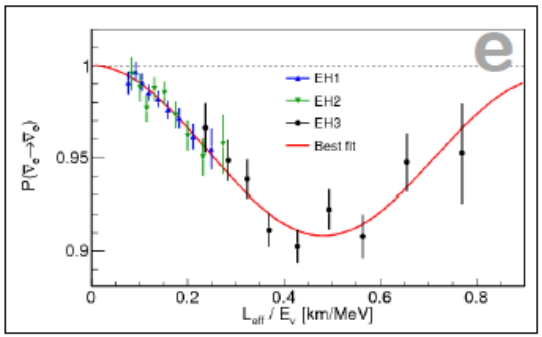
e→e (δm^2 , θ_{12})



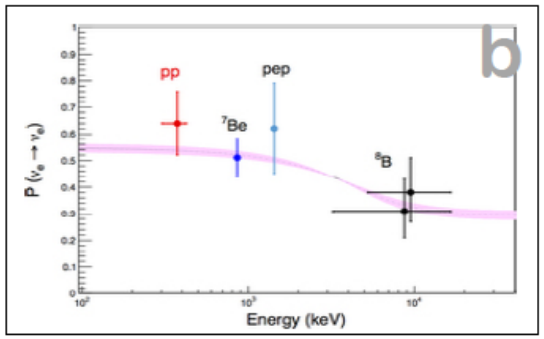
μ→μ (Δm^2 , θ_{23})



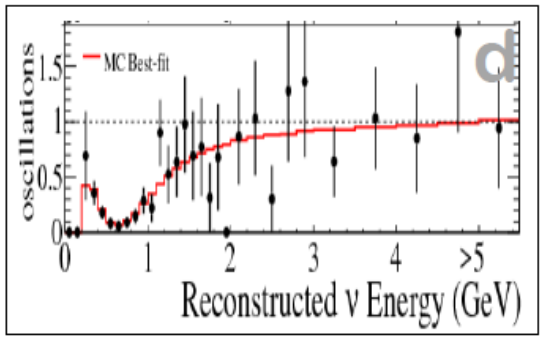
e→e (Δm^2 , θ_{13})



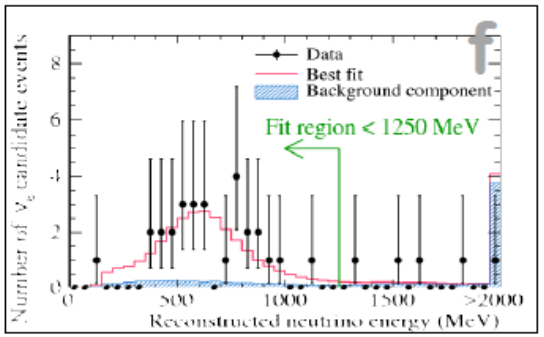
e→e (δm^2 , θ_{12})



μ→μ (Δm^2 , θ_{23})



μ→e (Δm^2 , θ_{13} , θ_{23})

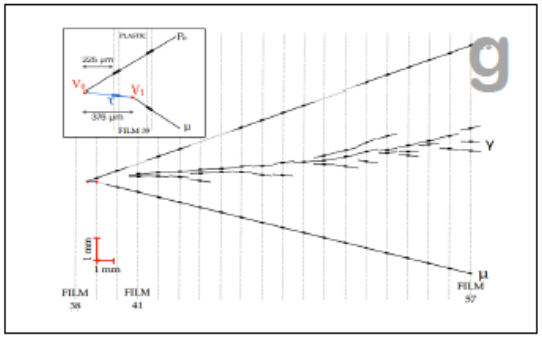


Terra cognita:

δm^2 $|\Delta m^2|$

θ_{12} θ_{23} θ_{13}

μ→τ (Δm^2 , θ_{23})



E. Lisi (C2- 11/2014)