Group II activities at LNF

A. Paoloni

Consiglio di Laboratorio
3 Luglio 2012

CUORE

CUORE-0: motivation

Critical point in the way of CUORE experiment: uniformity of the detector array and the control of possible recontamination during the detector construction

CUORE-0:

- first tower from the CUORE assembly line
- operated as a stand alone experiment in the CUORICINO cryostat

CUORE-0 goals:

- full test and debug of the new CUORE assembly line
  - high statistics check of the improved uniformity of bolometric response
  - identify which operations are critical for the success of CUORE
  - reveal flaws and inefficiencies in the assembly procedures
- permit a thorough exercise of the analysis framework

CUORE_DTZ @LNF

Resp. A. Franceschi

Servizio Progettazione e Costruzioni Meccaniche

+

Divisione Acceleratori

Responsabilità:

Coordinamento Ingegneria

Integrazione Apparato Sperimentale

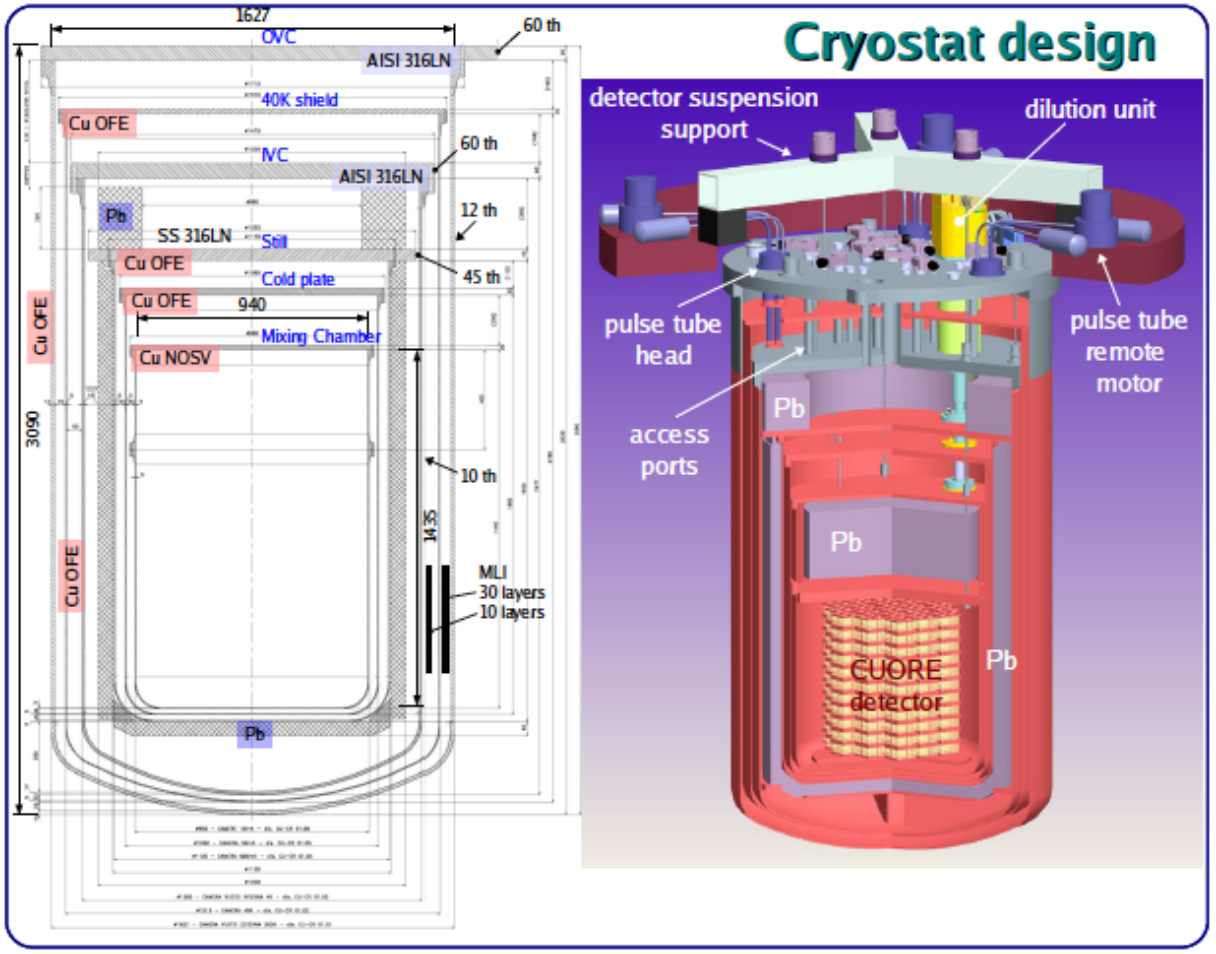
Impegno LNF 2012:

A. Franceschi 60%
C. Ligi* 40%
T. Napolitano 60%
A. Tiburzi 50%

* Div. Acceleratori

Ingegneria/Integrazione:

Torre Rivelatori
Pulizia Rame
Criostato/Criogenia
Schermature Piombo
Installaziaone Detector
Cablaggi Elettronica



Richieste CIF II semestre 2012 e 2013

SPCM
Reparto Progettazione: 9 m.u.
Reparto Metrologia: 1 m.u.
Reparto Meccanica: 1 m.u.
Reparto Carpenteria: 1 m.u.

Le richieste di Metrologia, Meccanica e Carpenteria sono motivate dall'esigenza di poter fronteggiare eventuali necessità impreviste nella fase di installazione @LNGS (da Luglio 2012) e nella quale il il gruppo CUORE_DTZ dei LNF ha dirette ed importanti responsabilità.

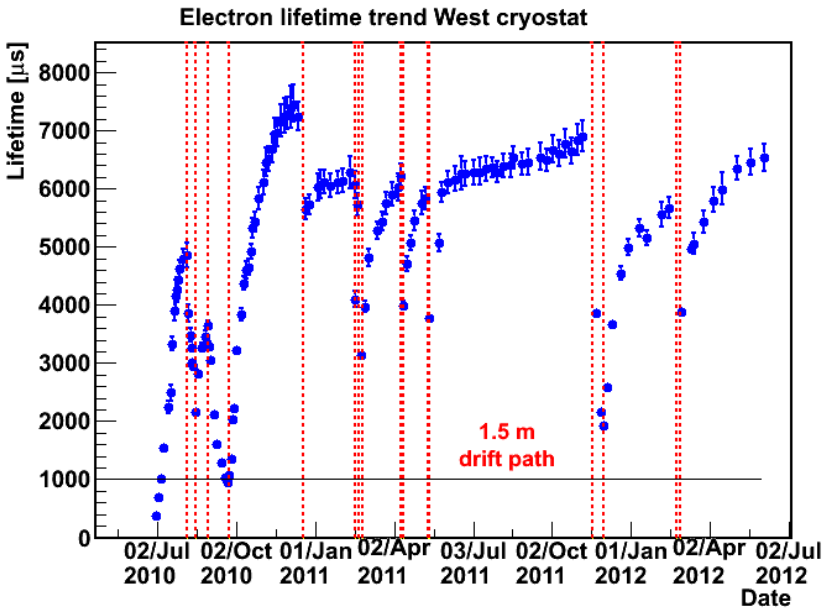
ICARUS

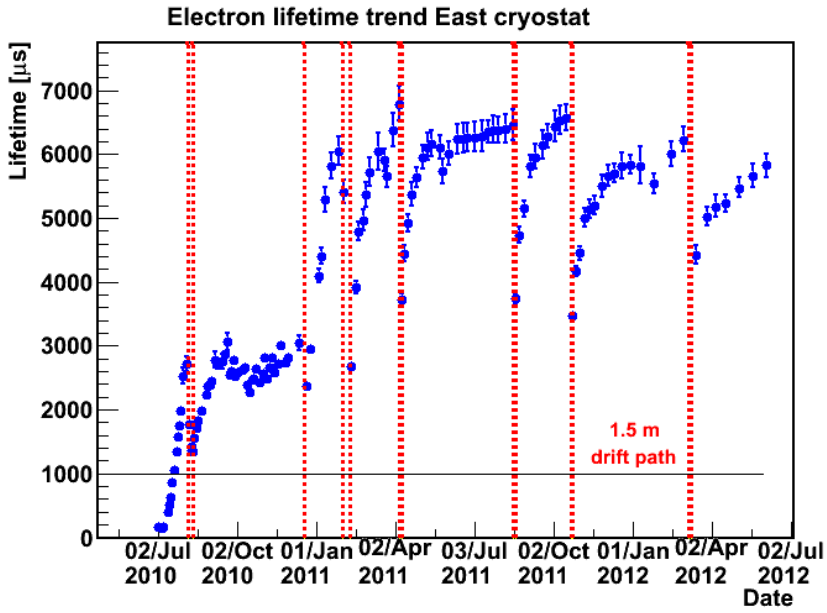
The ICARUS Collaboration

M. Antonello[a], P. Aprili[a], B. Baibussinov[b], M. Baldo Ceolin[b,†], P. Benetti[c], E. Calligarich[c], N. Canci[a], S. Centro[b], A. Cesana[f], K. Cieslik[g], D. B. Cline[h], A.G. Cocco[d], A. Dabrowska[g], D. Dequal[b], A. Dermenev[i], R. Dolfini[c], C. Farnese[b], A. Fava[b], A. Ferrari[j], G. Fiorillo[d], D. Gibin[b], A. Gigli Berzolari[c,†], S. Gninenko[i], A. Guglielmi[b], M. Haranczyk[g], J. Holeczek[l], A. Ivashkin[i], J. Kisiel[l], I. Kochanek[l], J. Lagoda[m], S. Mania[l], G. Mannocchi[n], A. Menegolli[c], G. Meng[b], C. Montanari[c], S. Otwinowski[h], L. Periale[n], A. Piazzoli[c], P. Picchi[n], F. Pietropaolo[b], P. Plonski[o], A. Rappoldi[c], G.L. Raselli[c], M. Rossella[c], C. Rubbia[a,j], P. Sala[f], E. Scantamburlo[e], A. Scaramelli[f], E. Segreto[a], F. Sergiampietri[p], D. Stefan[a], R. Sulej[m,a], M. Szarska[g], M. Terrani[f], F. Varanini[b], S. Ventura[b], C. Vignoli[a], H. Wang[h], X. Yang[h], A. Zalewska[g], K. Zaremba[o].

a Laboratori Nazionali del Gran Sasso dell'INFN, Assergi (AQ), Italy
b Dipartimento di Fisica e INFN, Università di Padova, Via Marzolo 8, I-35131 Padova, Italy
c Dipartimento di Fisica Nucleare e Teorica e INFN, Università di Pavia, Via Bassi 6, I-27100 Pavia, Italy
d Dipartimento di Scienze Fisiche, INFN e Università Federico II, Napoli, Italy
e Dipartimento di Fisica, Università di L'Aquila, via Vetoio Località Coppito, I-67100 L'Aquila, Italy
f INFN, Sezione di Milano e Politecnico, Via Celoria 16, I-20133 Milano, Italy
g Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Science, Krakow, Poland
h Department of Physics and Astronomy, University of California, Los Angeles, USA
i INR RAS, prospekt 60-letiya Oktyabrya 7a, Moscow 117312, Russia
j CERN, CH-1211 Geneve 23, Switzerland
k Institute of Theoretical Physics, Wroclaw University, Wroclaw, Poland
l Institute of Physics, University of Silesia, 4 Uniwersytecka st., 40-007 Katowice, Poland
m National Centre for Nuclear Research, A. Soltana 7, 05-400 Otwock/Swierk, Poland
n Laboratori Nazionali di Frascati (INFN), Via Fermi 40, I-00044 Frascati, Italy
o Institute of Radioelectronics, Warsaw University of Technology, Nowowiejska, 00665 Warsaw, Poland
p INFN, Sezione di Pisa. Largo B. Pontecorvo, 3, I-56127 Pisa, Italy

LAr purification





LAr continuously filtered, e^- life-time measured by charge attenuation study on cosmic μ tracks.

τ_{ele} > 5ms (~60 ppt $[O_2]_{eq}$) corresponding to a maximum charge attenuation of 17% at 1.5m

These results allow operation at larger drift distances

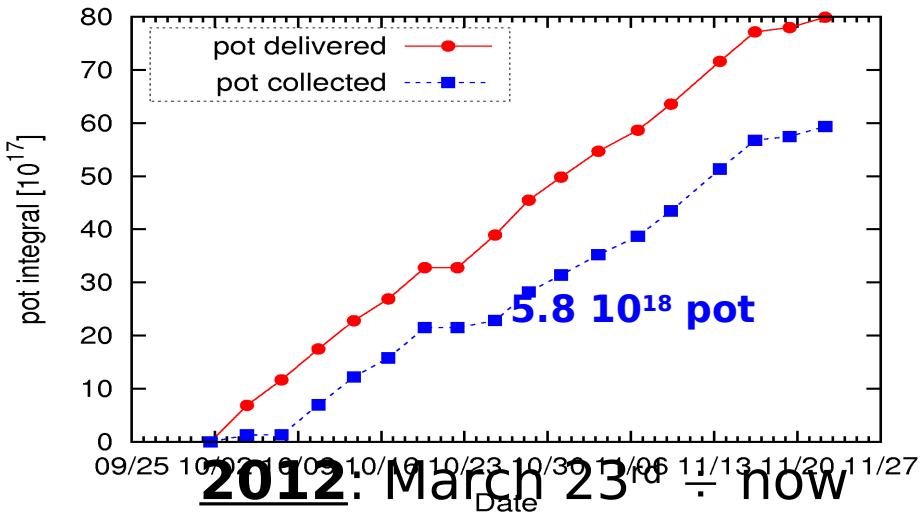
LAr recirculation system upgrade:

- 11 accidental stops up to now (LAr immersed pumps)
- New pumps with non-immersed motor already ordered – installation 2012. Similar pumps operating since 2010 on the LN2 circulation systems worked without any accidental stop.

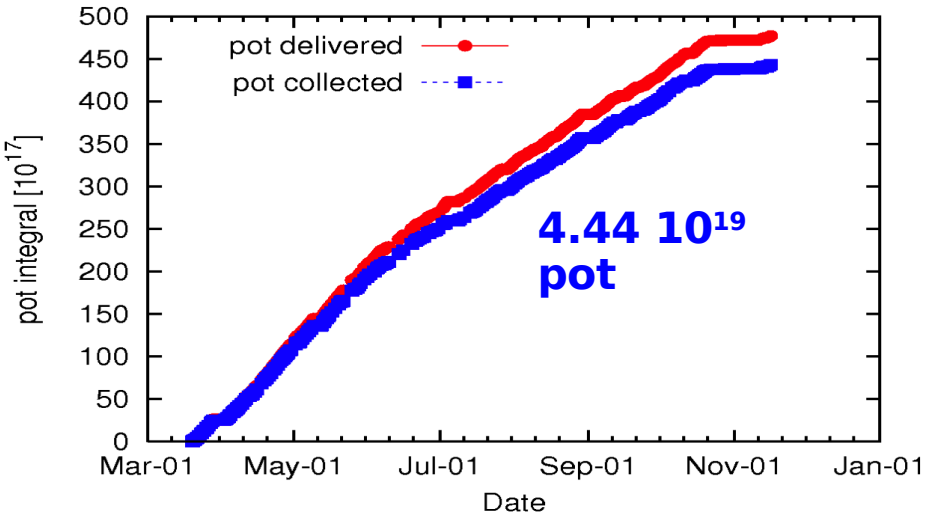
CNGS neutrino runs – summary

- **ICARUS T600 fully operational since Oct. 1st 2010**

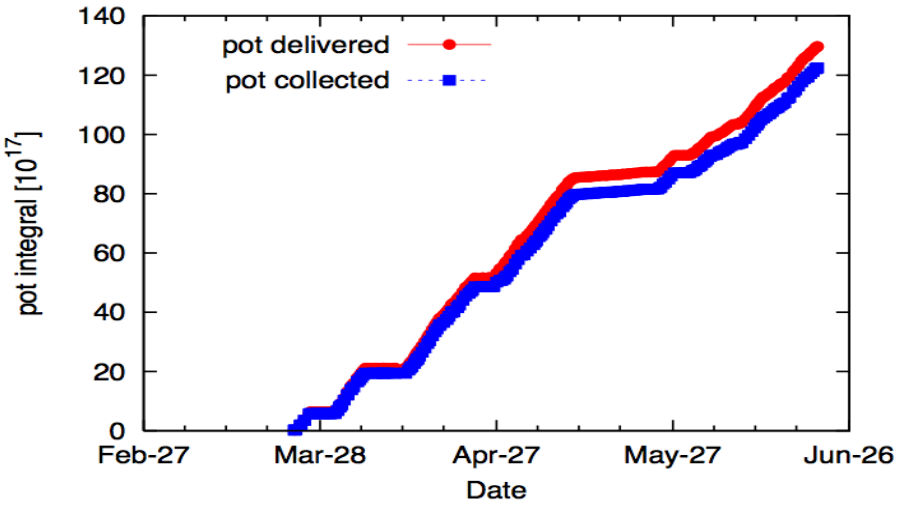
2010: Oct. 1st ÷ Nov. 22nd



2011: Mar. 19th ÷ Nov. 14th



2012: March 23rd ÷ now

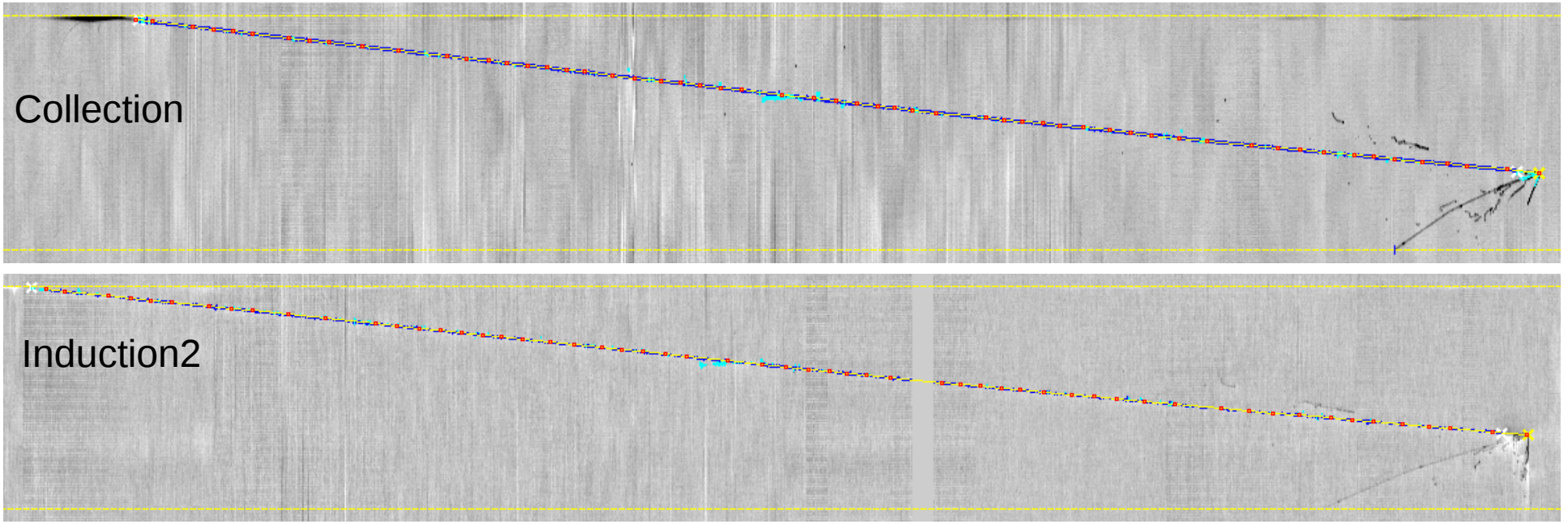


- **Detector live-time > 93%**
- November 2011 and May 2012: timing measurement with bunched beam.
- 2011 run: expected 1200 CC and 390 NC events (so far, for 2.7 10^{19} pot 925 ν interactions in 447 t fiducial volume with ~ 3% detector electronic inefficiency – DAQ crate off; 975 interactions expected from MC assuming full detector efficiency).

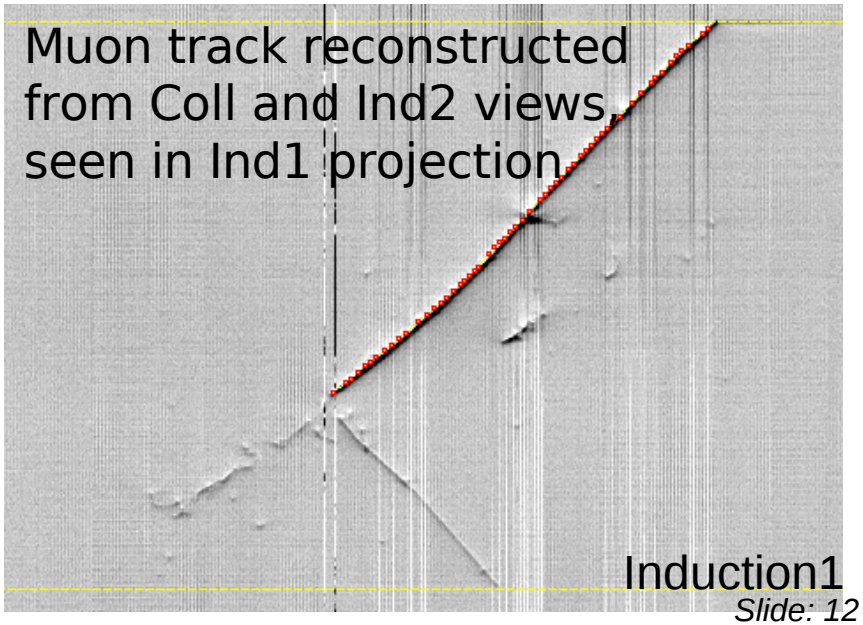
Progress on data analysis

- The analysis of CNGS neutrino events is ongoing. Results will be presented when final.
- First step on cosmic-ray analysis: automatic reconstruction of deposited energy from c-muons in agreement with expectations
- In parallel, optimization of analysis tools in term of performance, calibrations and event reconstruction:
  - Progresses in 3D reconstruction, leading to better performance especially for horizontal tracks
  - Momentum measurement by M.S. for escaping muons, under refinement
  - Progresses in the Particle Identification Algorithm
  - Progresses in automatic reconstruction: vertex finding, clustering, track finding
  - Developments on tools for calorimetric reconstruction

3D reconstruction



NEW: Single **3D** PLA-fit optimized to all available hits in the **2D** wire planes and all identified **3D** reference points (vertices, delta rays). **2D** hit-to-hit associations are not longer needed -> missing parts in a single view and horizontal tracks are now accepted.

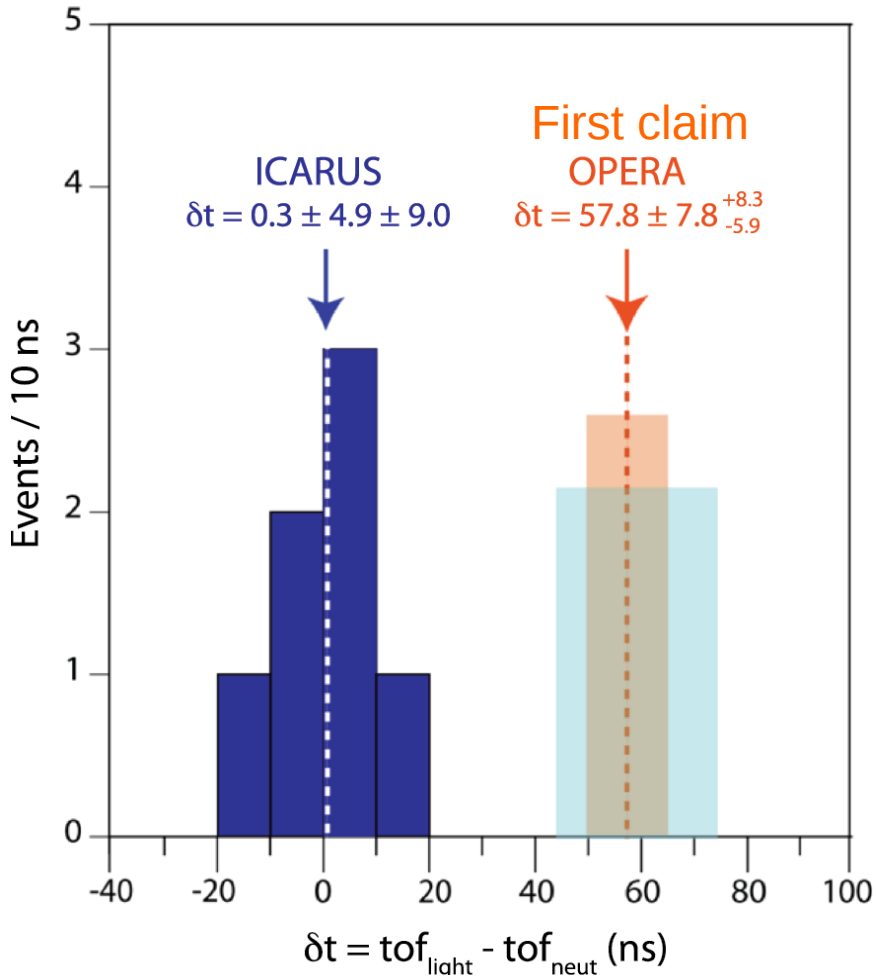


Neutrino time of flight: 2011 result

Phys. Lett. B 713 (2012) 17-22

- All fixed delays/propagation times corrected (thanks also to LNGS and CERN)
- Baseline estimation relies on existing available geodesy data (OPERA/LNGS)
- Variable corrections to GPS from OPERA/CERN recipe

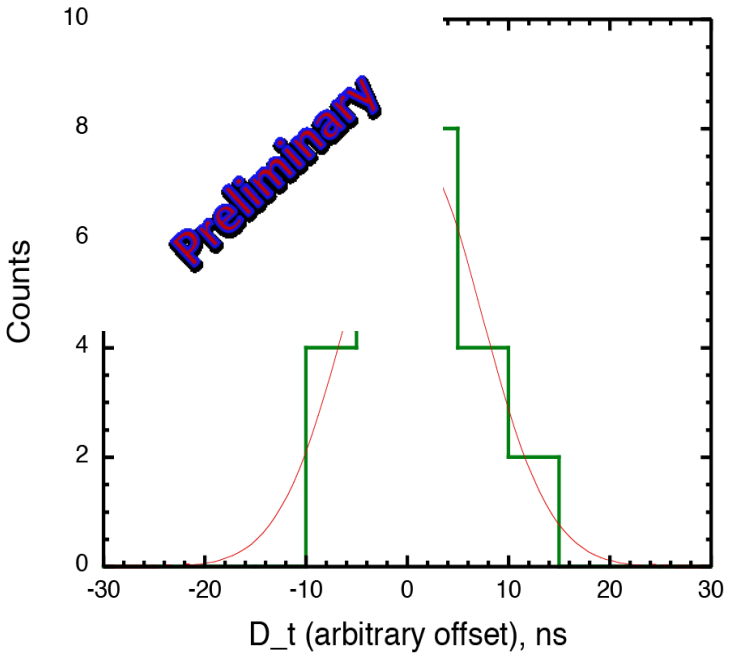
- The average $\delta t = tof_c - tof_\nu$ of the 7 events is + 0.3 ns with an r.m.s. of 10.5 ns; statistical error on the average = 4.9 ns; systematic error ~ 9 ns



Data taking/analysis with 2012 bunched CNGS

- New beam structure: 64 bunches, 3 ns width, 100 ns spacing.
- Beam related events observed in ICARUS (for ~1.8 10^{17} pot):
  - 17 crossing μ's (1 stopping) from the upstream rock;
  - 6 CC ν_μ events;
  - 2 NC ν event.

- Analysis in progress:
  - **PRELIMINARY** results compatible with 2011 value: 0. to 3. ns depending on timong synchronization path;
  - distribution r.m.s: ~ 3.7 ns (10.5 in 2011)
  - Systematics corrections and offset under final evaluation (PMT-DAQ propagation chain, topological corrections, timing delay).



Conclusion and prospects for 2013

- ICARUS T600 is the first large LAr TPC operated underground.
- The T600 is acquiring data without interruption since mid-2010 @ LNGS with CNGS beam, searching for $\nu_\mu \rightarrow \nu_\tau$ and $\nu_\mu \rightarrow \nu_e$ oscillations as well as for athmospheric ν's and proton decay.
- High detection efficiency reached for CNGS events.
- Quality of data as expected.

- Data analysis in progress, results expected on:
  - Search for $\nu_\mu \rightarrow \nu_e$ oscillations and LNSD effect
  - Search for $\nu_\mu \rightarrow \nu_\tau$ oscillations
  - 2013 dedicated to atmospheric neutrino study and proton decay search
- Contributions to the "superluminal" neutrino problem (published).

- Beyond LNGS: move ICARUS to CERN, complemented with a magnetized muon spectrometer (NESSIE), for sterile neutrino search on short base line beam submitted to CERN-SPSC:
  - Proposal, submitted to SPSC, under scientific/technical evaluation

Anagrafica gruppo LNF

Ricercatori: H. Bilokon, G. Mannocchi, P. Picchi, G. Trinchero (To). Tot FTE: 0.7

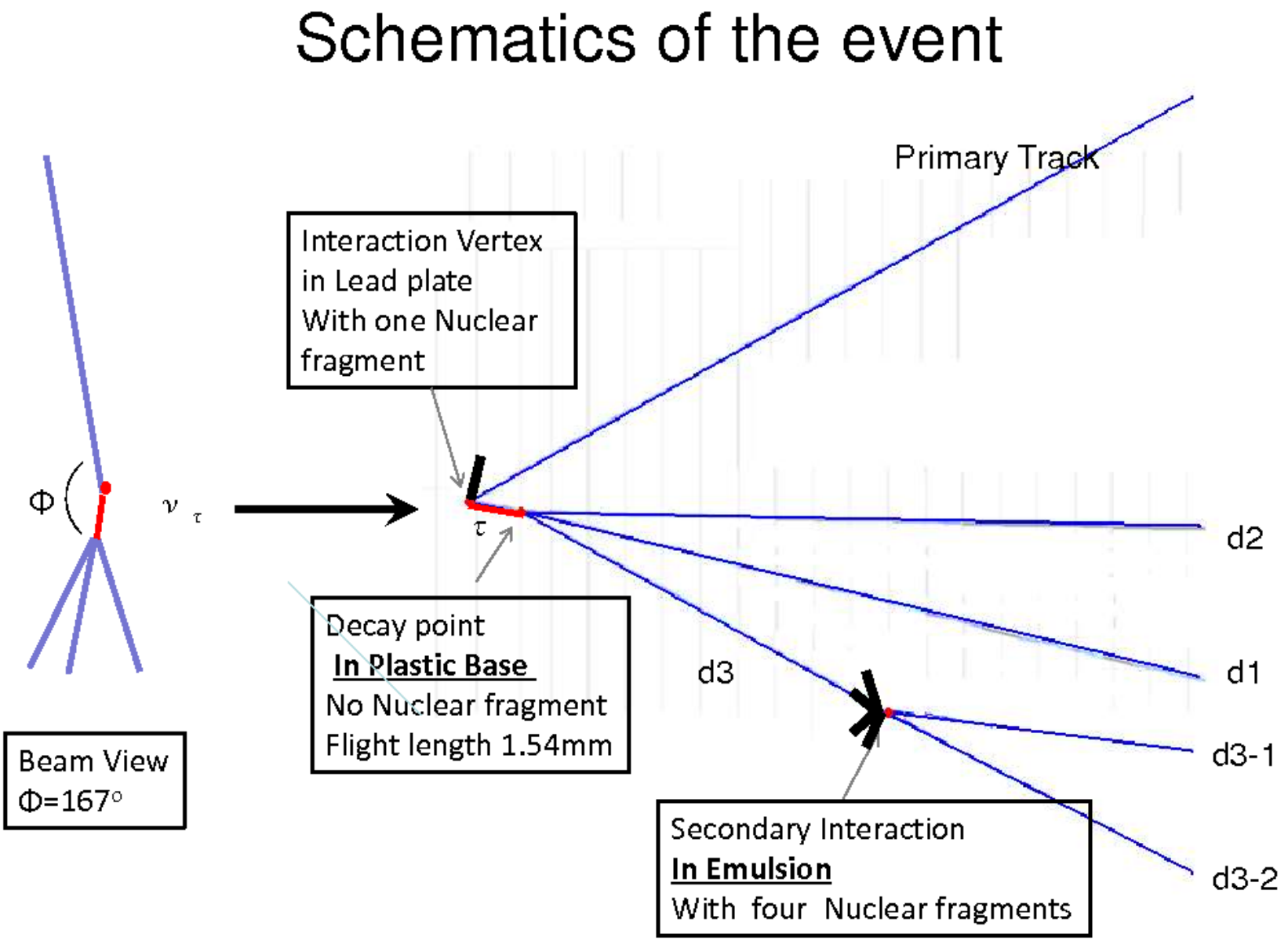
Tecnici: M. Meli (50%), G. Angelo (To, 100%)

Richieste alla CSNII minimali

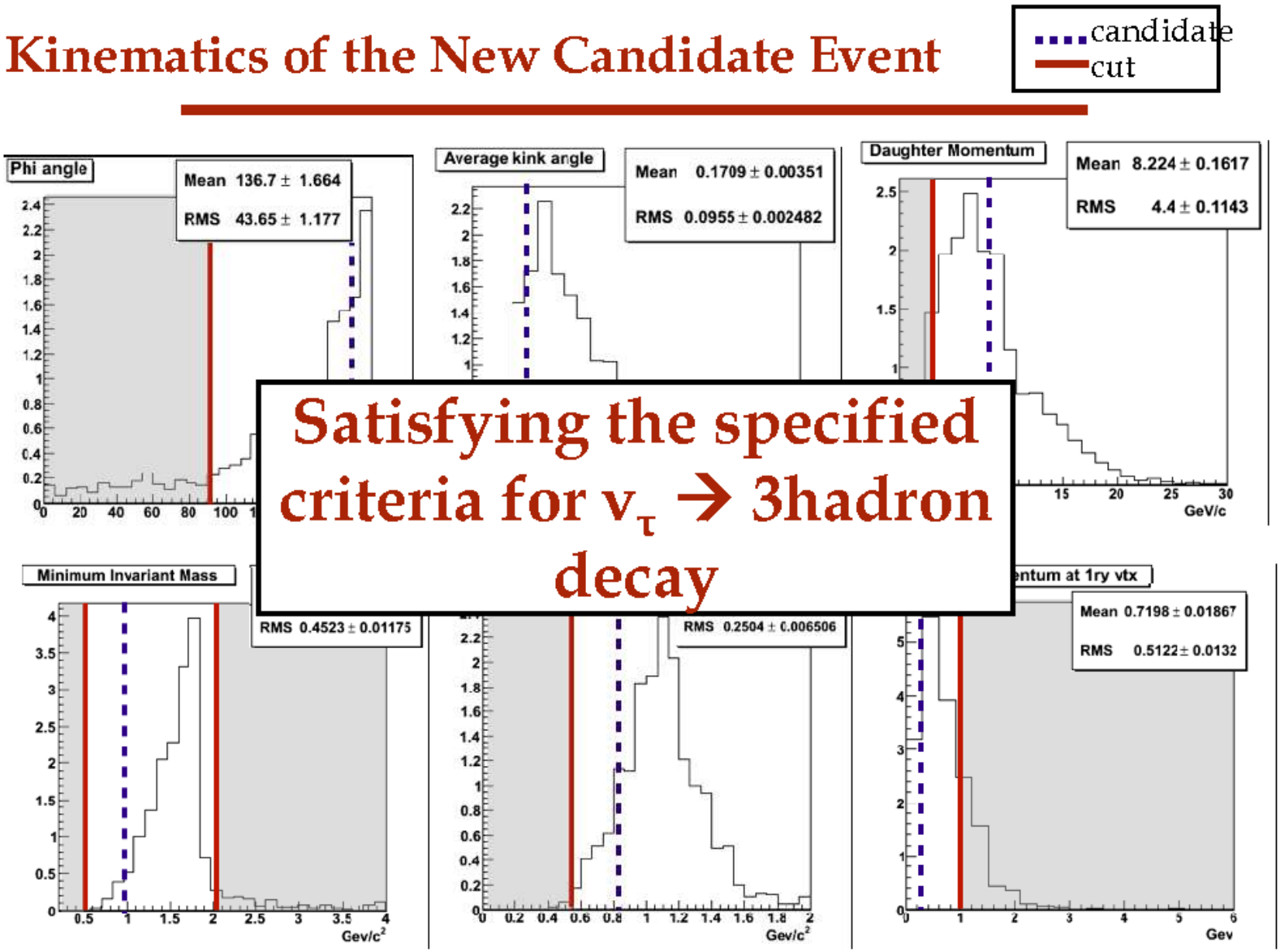
Nessuna richiesta ai servizi dei laboratori.

OPERA

Second τ candidate shown at Neutrino 2012



Kinematics of the New Candidate Event



Satisfying the specified criteria for $\nu_\tau \rightarrow$ 3hadron decay

Data analysis status

Number of pot collected up to 2011: 14.2×10^{19}
Expected number of pot after 2012 run: 18.9×10^{19} (22.5×10^{19} in the proposal)

Status of ν_τ search:

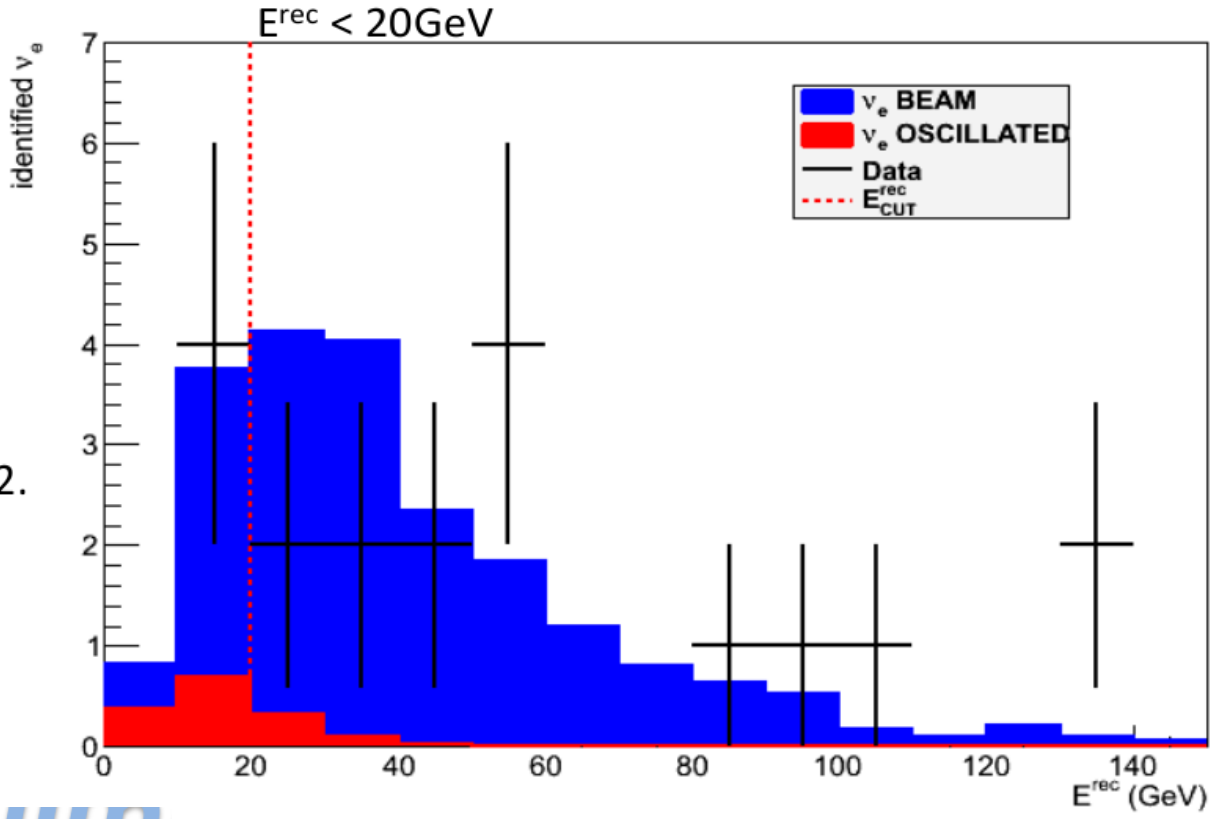
Year	Status	Events decay-searched	Expected $\nu\tau$ (preliminary)	Candidates	Expected BG (preliminary)
2008-2009	Finished	2783		1	
2010-2011	Ongoing	1343		1	
2012	Started				
Total		4126	2.1	2	0.2

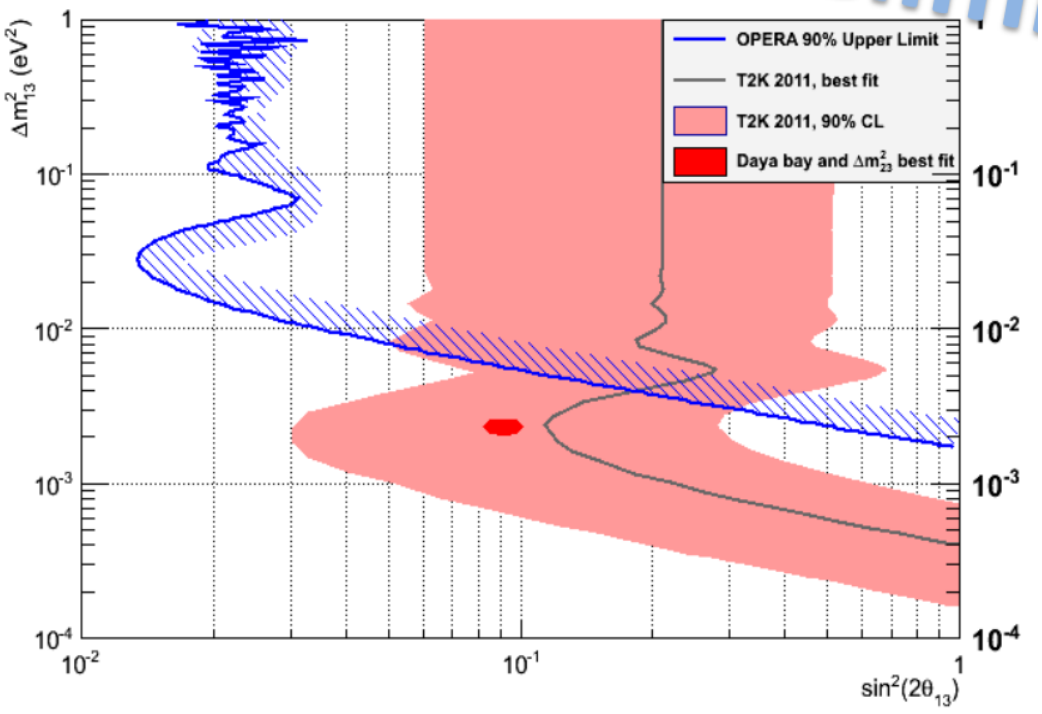
Preliminary results from $\nu_\mu \rightarrow \nu_e$ oscillation search

Data analized so far: 2008+2009

Expected events: oscillated νe 1.5, beam νe 19.2.
Observed νe : 19 events

After low-energy selection (Eν<20GeV)
Expected events: oscillated νe 1.1, beam νe 3.7
Observed νe : 4 events.

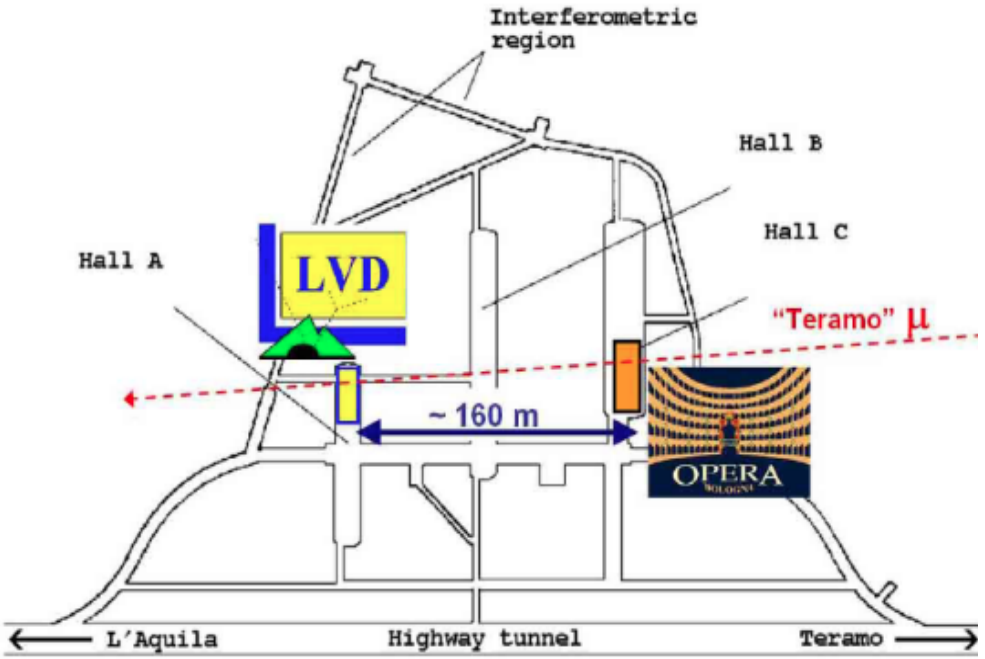


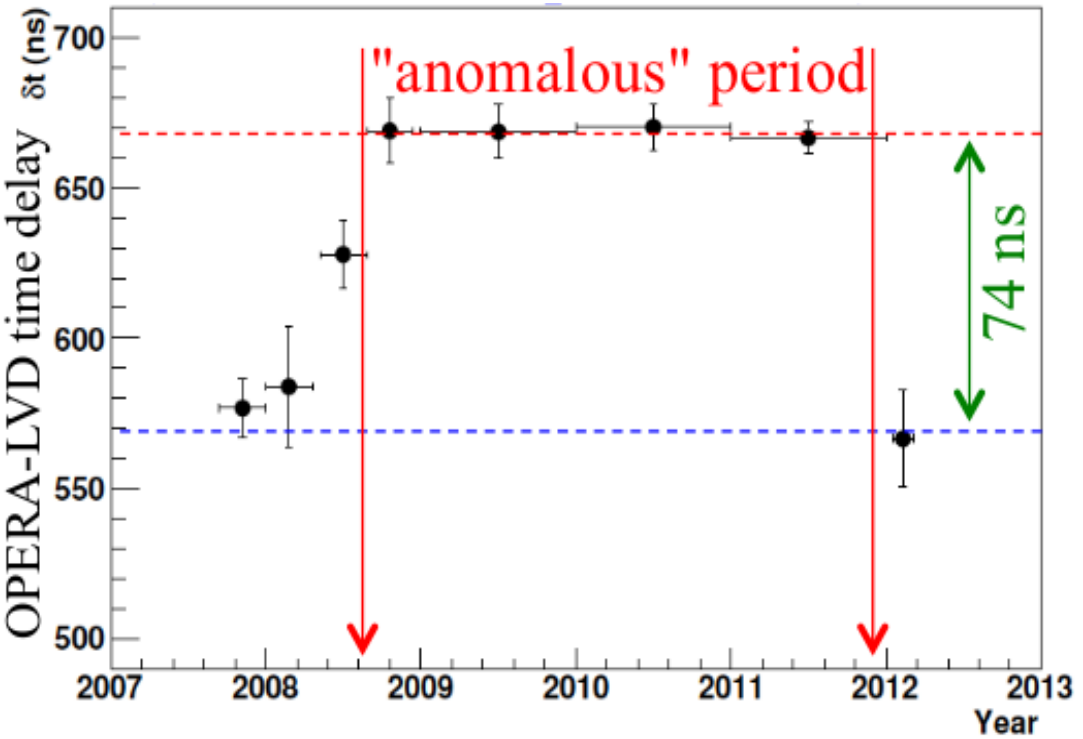


Δm_{23}=2.45E-3
$Sin^2\theta_{23}$=0.51

Neutrino velocity

During last winter two effects found affecting the super-luminal neutrino result:
1) Faulty connection of the optical fibre to the Master Clock artificially increasing the neutrino anticipation by ~74 ns.
2) Internal Master Clock frequency off by $\Delta f/f = 1.24 \times 10^{-7}$ (124 ns/s) artificially decreasing the neutrino anticipation by ~15 ns.



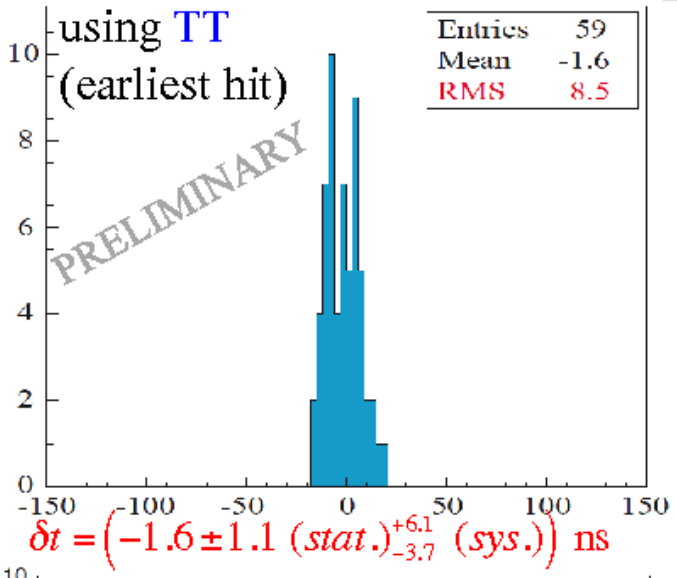


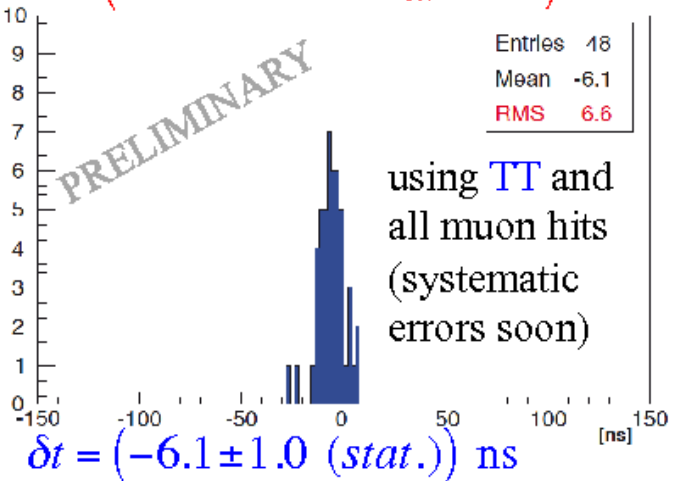
The two effects were present since 2008 (before the measurement of the neutrino velocity).
Verified by a joint OPERA-LVD analysis of cosmic muons from Teramo valley.

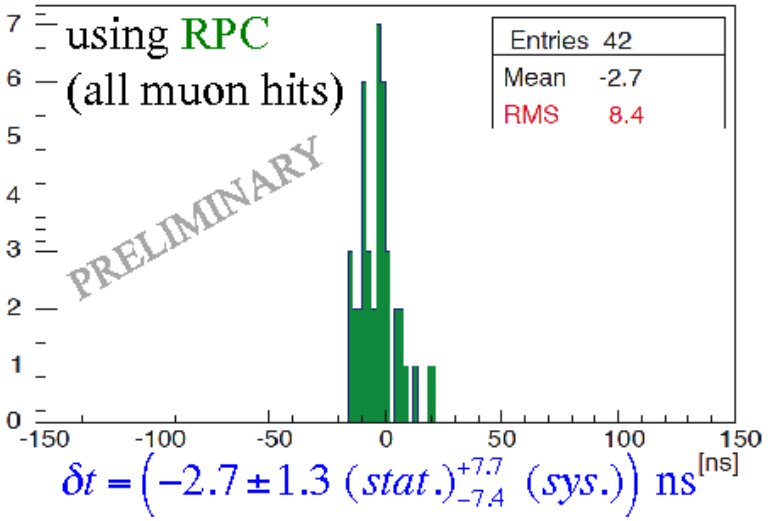
Neutrino velocity measurement on bunched beam 2012

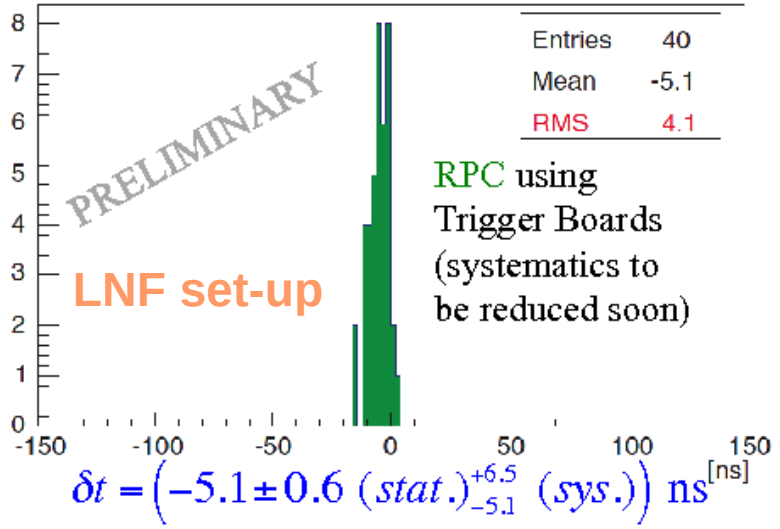
New OPERA preliminary results

(with new BCT values)









Gruppo OPERA 2013

Ricercatori: V. Chiarella, F. Grianti (Urbino), A. Longhin, N. Mauri (ass. ric.), A. Paoloni, M. Spinetti, L. Votano Tot: 4.0

Tecnici: A. Gambarara (Urbino), N. Intaglietta (30%), A. Mengucci (70%), T. Tonto (20%), M. Ventura (70%)

Attivita' del gruppo:
1) A. Paoloni technical coordinator e responsabile per il run dei detectors elettronici
2) Struttura generale dell'esperimento e mezzi di sollevamento drum BMS (SSE)
3) Magnete e sistema gas
4) Supporto al run dei detectors elettronici ed al brick handling
5) Finalizzazione dell'impianto di termalizzazione delle vasche di sviluppo
6) Rimozione dei brick incastrati nelle walls
7) Monitoraggio prestazioni degli RPC
8) Analisi dei raggi cosmici
9) Misura della velocita' del neutrino 2012
10) Scanning (1 candidato ν_e localizzato)

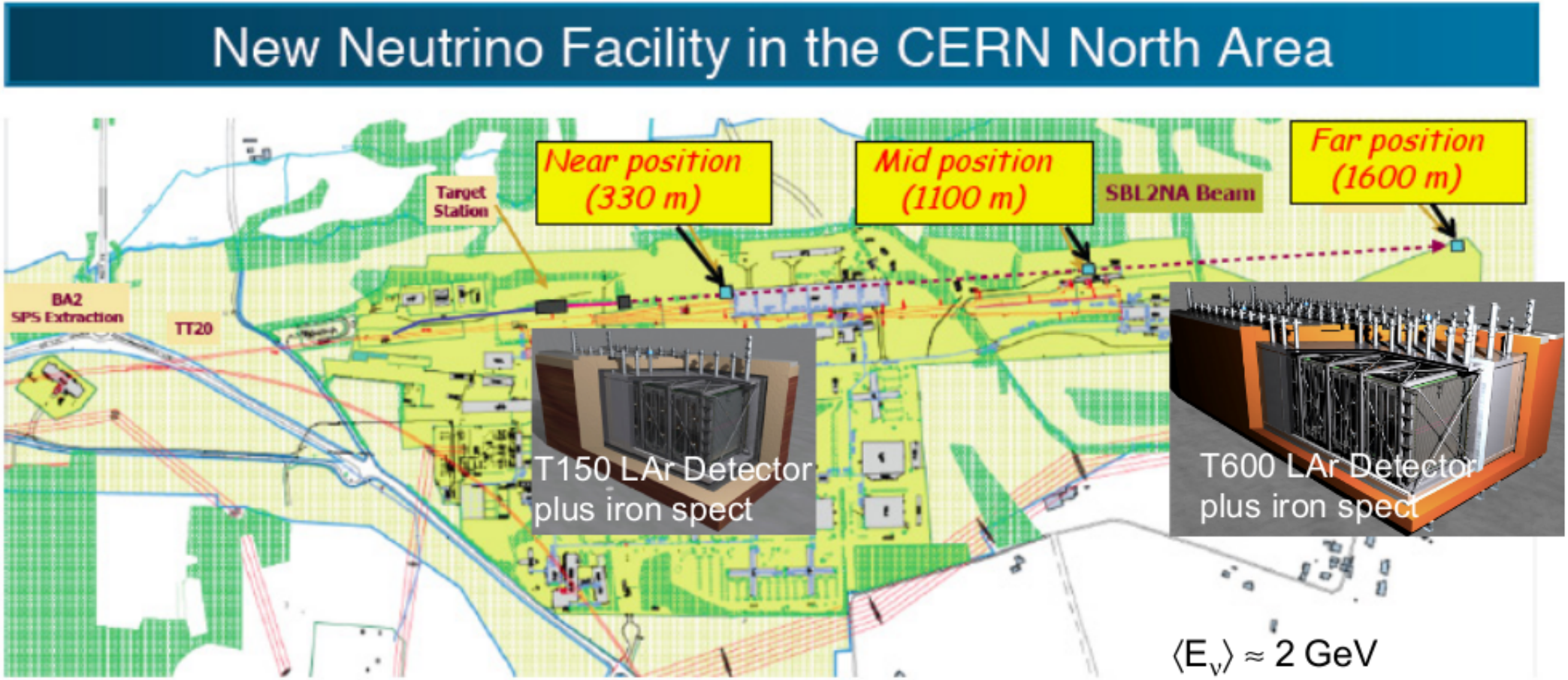
Gruppo OPERA 2013

Richieste finanziarie alla CSNII:
Missioni interne: 132 kEuro + 12 SJ (prolungamento run nel 2013 ?)
Missioni estere: 20 kEuro
Consumo: 54 kEuro + 20 SJ (prolungamento run nel 2013 ?)
Costruzione apparati: 4 kEuro

Richieste servizi LNF
SSE: vedi Nessie
SEA: 1 mu per supporto infrastrutture del laboratorio di scanning

Nessie-RD

Proposta per le studio dei neutrini sterili al CERN-SPS:
Due detectors (near and far), composti da una Lar TPC (ICARUS) complementata da uno Spettrometro per muoni (Nessie).

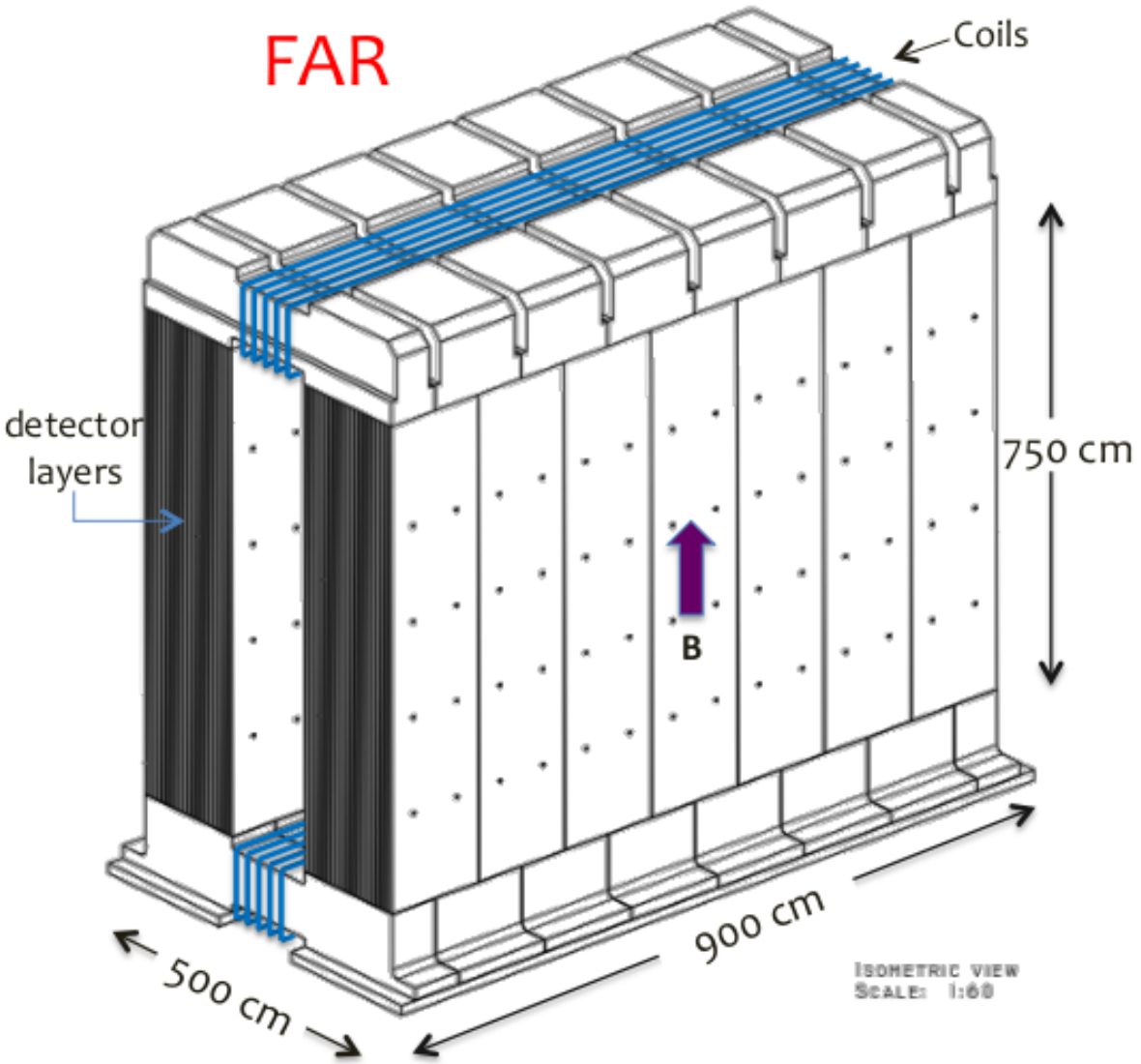


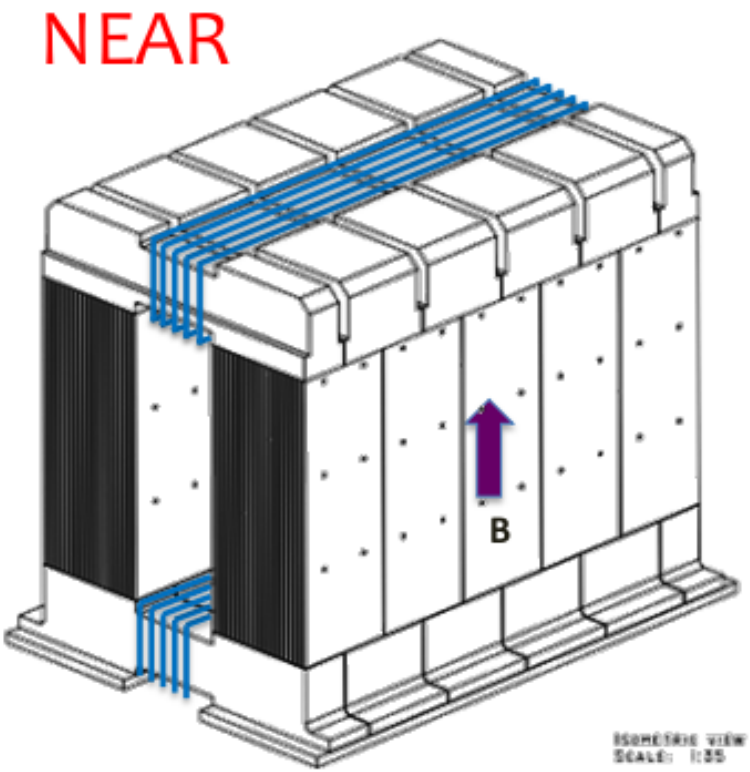
100 GeV primary beam fast extracted from SPS; target station next to TCC2; decay pipe l =100m, ø = 3m; beam dump: 15m of Fe with graphite core, followed by μ stations.

Spettrometri in Fe magnetizzato a-la-OPERA per muoni di alta energia.....

B = 1.5 T

1800 + 700 m^2 of RPC
20,000+12,000 digital channels
Precision Trackers

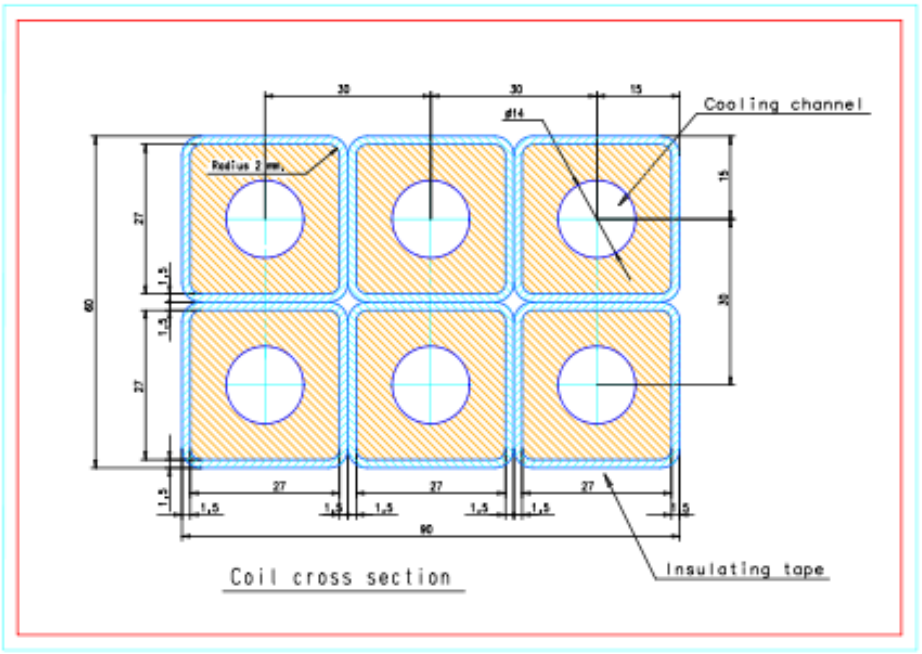


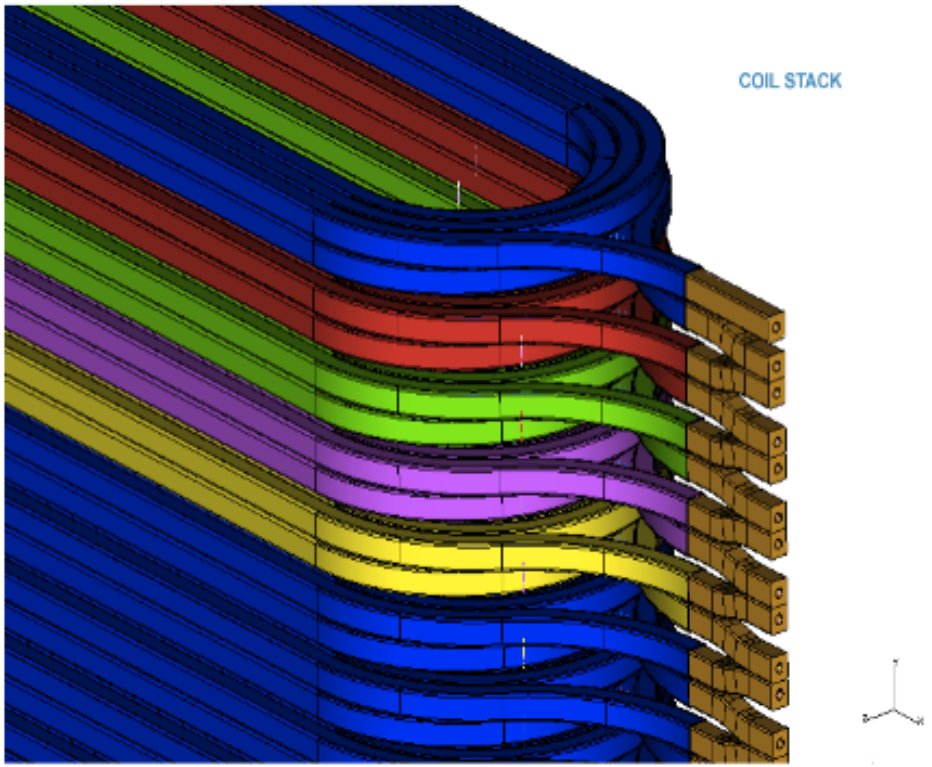


E magneti in aria tra le liquid Argon TPCs e gli spettrometri in Fe magnetizzato per i muoni di bassa energia.

Fully new concept of a 40 m^2 transverse area magnetic field in air
(**B = 0.25 T**)

The air magnet single coil structure





The air magnet coil structure
("pancake")

Gruppo NEssie-RD 2013

Ricercatori: A. Longhin, A. Paoloni Tot FTE: 0.2
Tecnici: A. Mengucci (30%), M. Ventura (30%)

Attivita' del gruppo:
1) Progettazione magneti in Ferro e struttura di supporto
2) RPC
3) Simulazione del fascio di neutrini
4) Realizzazione prototipo per studio fringe fields (verifica interferenza con Lar)
5) Test beam su prototipi di rivelatori per il magnete in aria

Richieste finanziarie alla CSNII:
Missioni interne: 30 kEuro
Missioni estere: 20 kEuro
Consumo: 45 kEuro + 225 SJ (Costruzione prototipo a LNF; disegno finale con certificazioni)

Richieste servizi LNF
SSE: 19 mu (80% A. Cecchetti e D. Orecchini)

KM3

KM3 - PORFIDO

Physical Oceanography by
RFID
Outreach

KM3

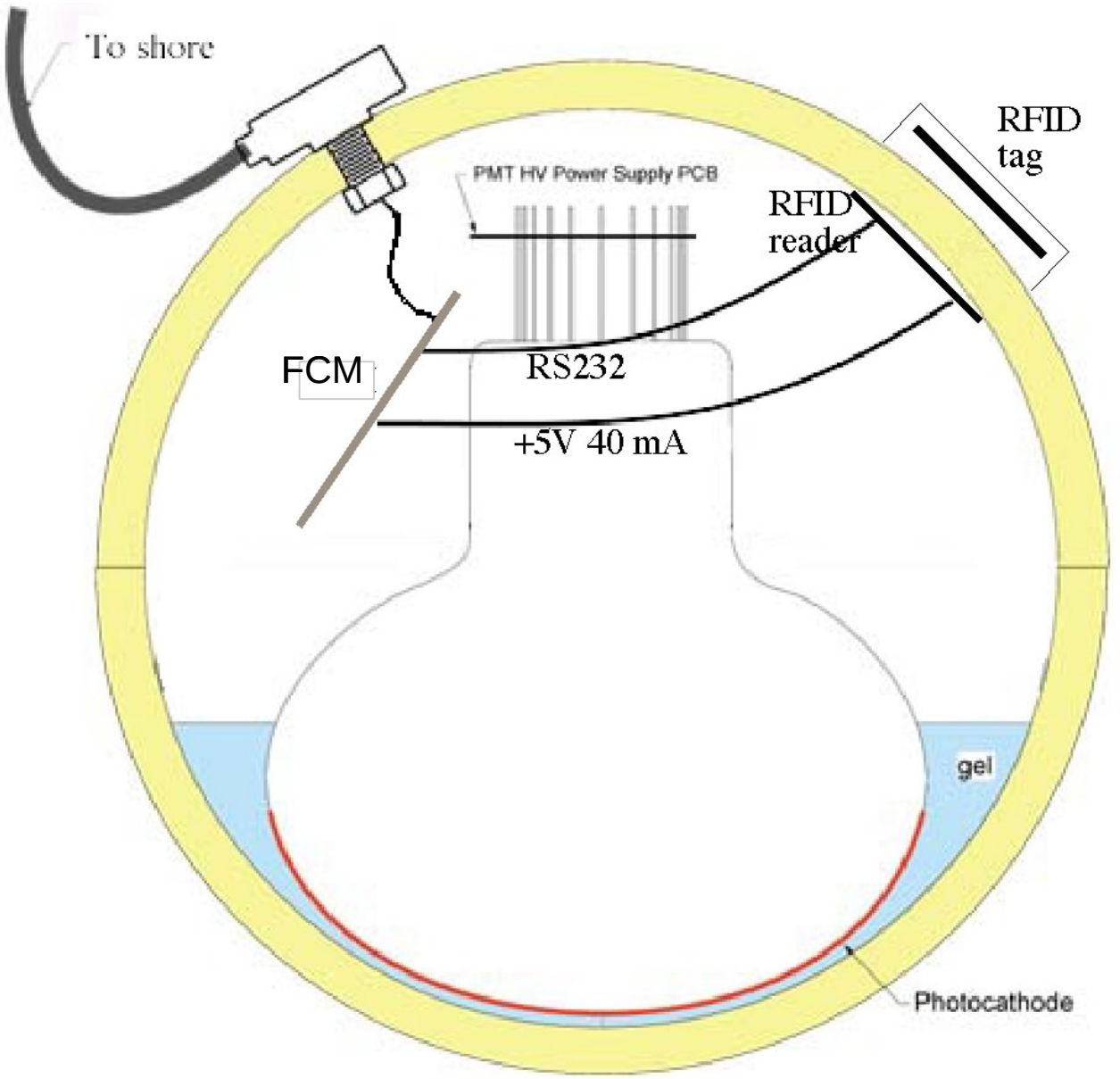
Neutrino Telescope

PON – Deploy 30 towers
at Capo Passero site

Oceanography Data

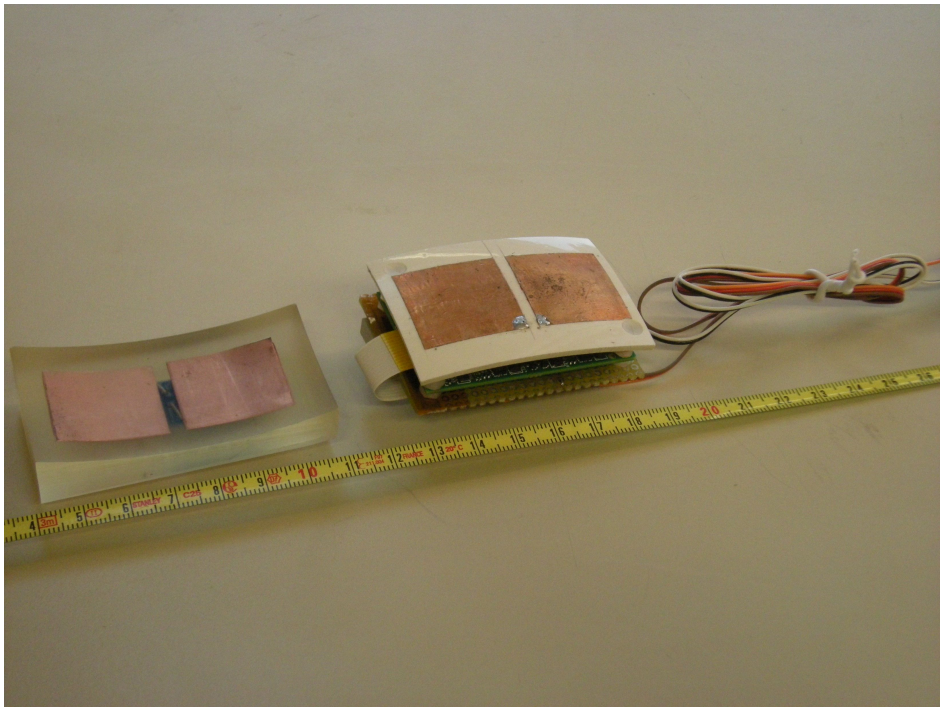
- Continuous data
- Non intrusive (reliability)
- No battery
- No connectors
- RFID

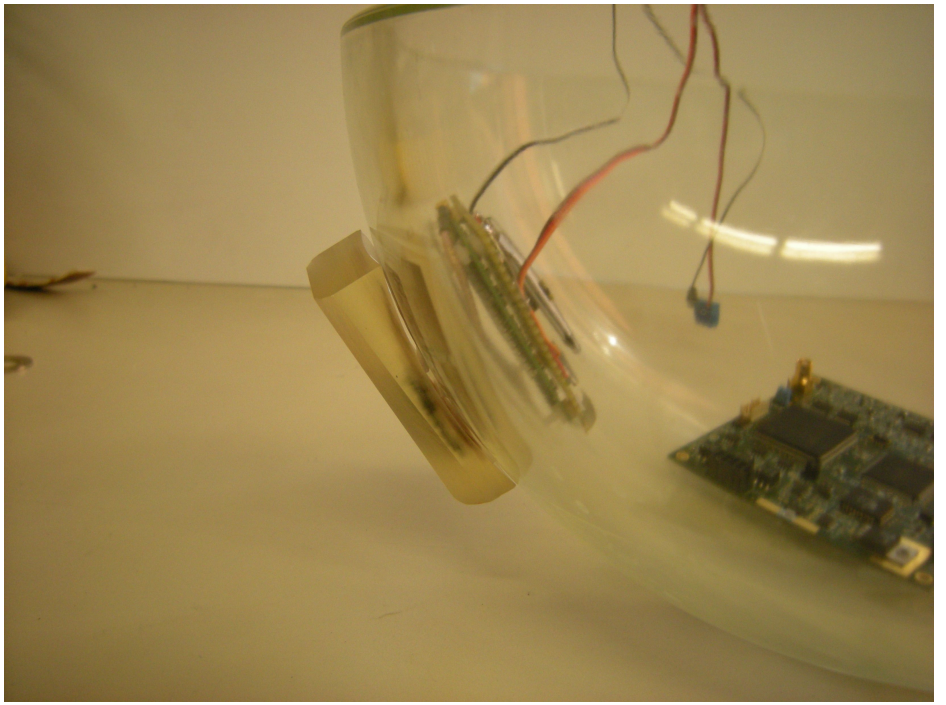
Connections



NEMO Phase 2

- 4 PORFIDOs reading temp





KM3 - PORFIDO

Sea science

High precision Temperature and salinity sensors

Water masses movement

Richieste 2013

FTE 1,7

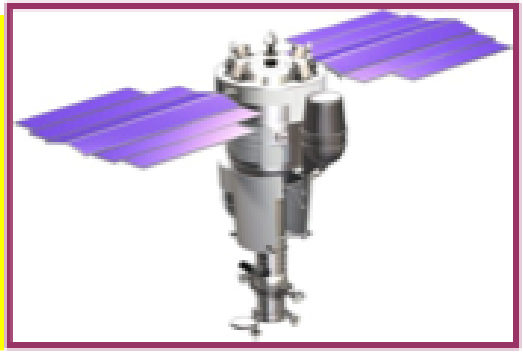
Missioni interne	28.5 K Euro
Missioni estere	7.5 K Euro
Consumo	15 K Euro

WIZARD

WIZARD/PAMELA

Ricerca di antimateria e materia oscura nella radiazione cosmica

(CSNII - Studio della radiazione cosmica nello spazio)



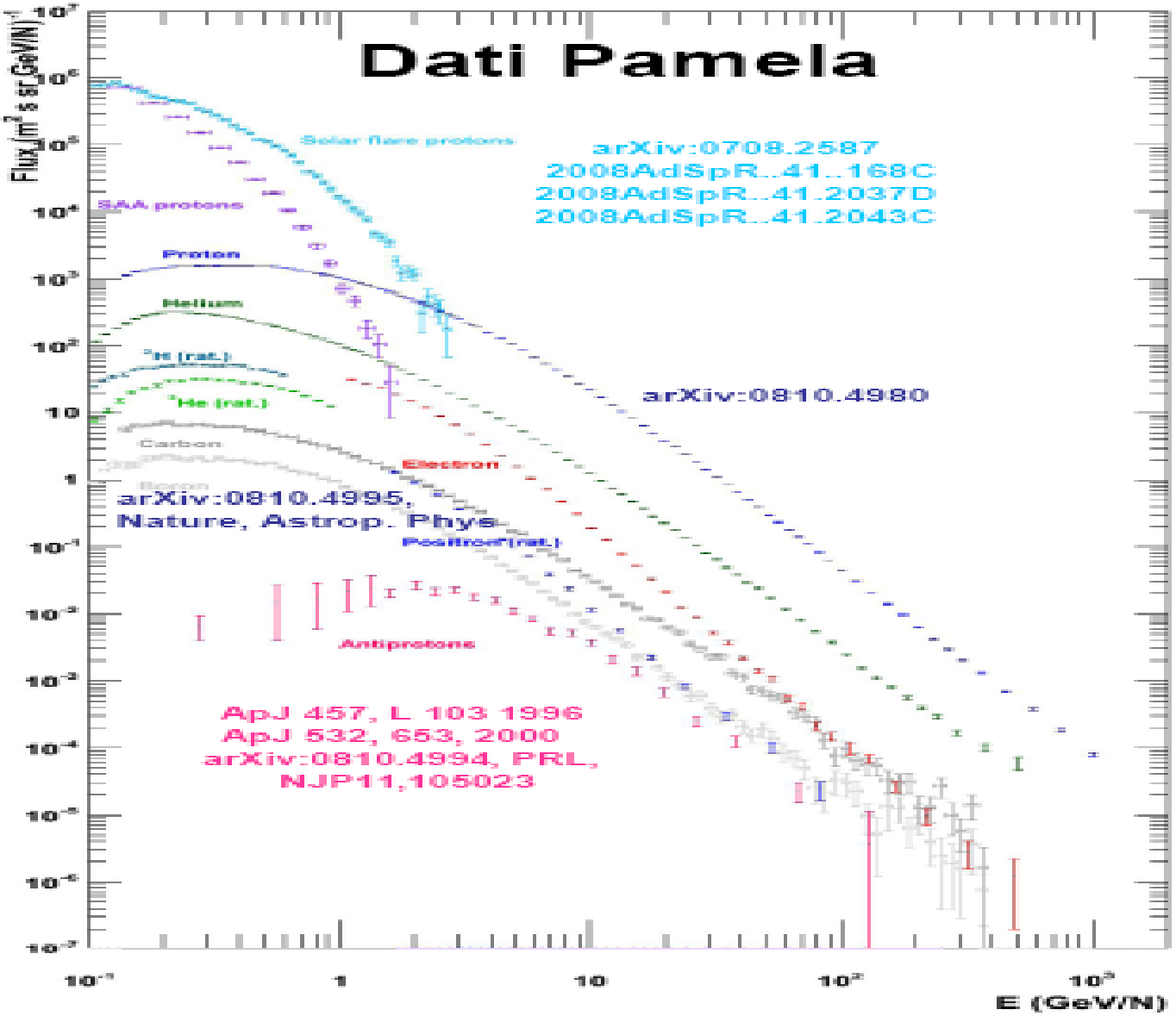
Collaborazione:

Italia: INFN Bari, Firenze, LNF, Napoli, Roma 2-Tor Vergata, Trieste
IFAC-CNR (FI), ASI, Univ.Tor Vergata (Dip.Ing.El.)
Germania: Siegen Univ.
Svezia: Stockholm KTH Univ.
Russia: Moscow(MEPhi, FIAN), IOFFE St. Petersburg, TsSKB-Progress Samara

Linea di Ricerca

- Studio di spettri, flussi e meccanismi di produzione di particelle e antiparticelle (e^-, e^+, p, antip) nei Raggi Cosmici
- Ricerca di possibili indicazioni indirette di Dark Matter
- Ricerca di antimateria cosmica (antielio)
  - Studio composizione nucleare e isotopica raggi cosmici
- Fisica solare

Summary PAMELA Results



PAMELA è in orbita e funziona regolarmente da 6 anni:

> $5x10^9$ triggers registrati e > 25 TB di dati finora trasmessi a terra.

La missione è prevista continuare nel 2013, accordi in corso ASI-INFN-Agenzia Spaziale Russa.
Nuove collaborazioni per analisi congiunte con gruppi USA, Sud Africa e Germania.

Most relevant results

- **Proton and Helium spectra** → different spectral index (unexpected result!)
- **Electron absolute flux** → Measured up to ~600GeV.
  No evident deviations from standard scenario, but not inconsistent with an additional electron component.
- **High energy positron fraction**
- **(>10 GeV)** → Increases significantly (and unexpectedly!) with energy.
  → Primary source? Dark Matter?
- **Antiproton energy spectrum** → Measured up to ~200 GeV:
  No significant deviations from secondary production expectations.
- **Solar physics**: measurement of modulated fluxes and solar-flare particle spectra
- **Physics of the magnetosphere**: first measurement of trapped antiproton flux

Studies and analyses in progress to be published

- Upgrade of positron analysis (increased statistics, higher energy)
- Primary and secondary-nuclei abundance (up to Oxygen)
- Jupiter CR proton and electron signatures
- Solar modulation (long-term flux variation and charge-dependent effects); Solar flares
- Upper limit to anti-He abundance

Gruppo WIZARD/PAMELA-LNF

Composizione 2013

G. Basini, M. Martucci (Dott.) G. Pizzella, M.Ricci

TOT 1.8 FTE

Attività svolta 2011 (II sem.) - 2012

- Controlli/gestione missione e Data taking
- Analisi dati - Conferenze (ICRC, TAUP 2011) – Pubblicazioni- Contributo originale LNF: studio e analisi possibili correlazioni nei RC con particelle da Giove (protoni ed elettroni)→ talk M. Ricci a ICRC 2011

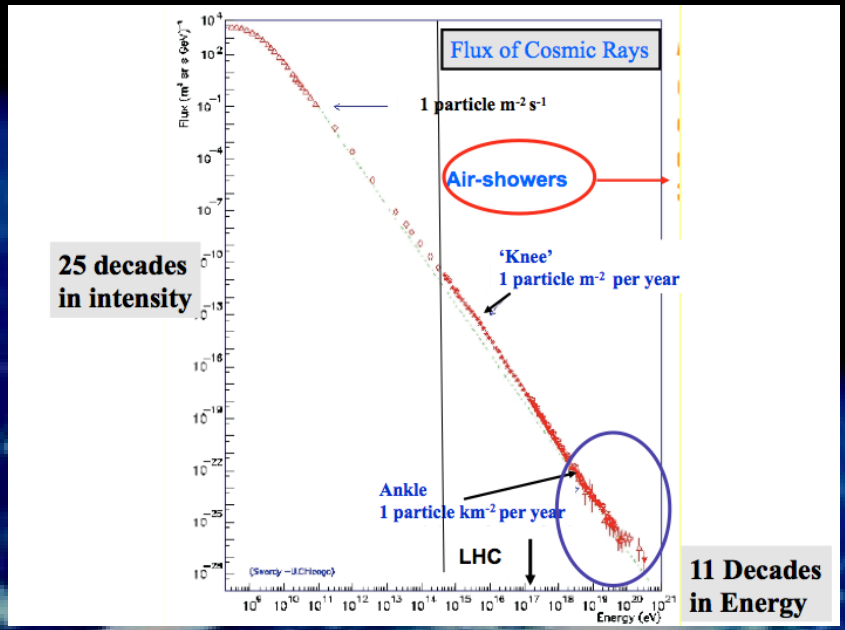
Attività prevista II sem. 2012 – 2013

- Controllo missione fino alla conclusione
- Analisi dati – Pubblicazioni – Conferenze
- Nuova collaborazione con Università USA su eventi solari (PAMELA Solar →Tesi Dottorato)

Rich. finanz. 2013
minimali per
Missioni e Consumo
(Calcolo/Storage dati)
Nessuna rich. ai Servizi
~ 30 K€

JEM-EUSO

Extreme Universe Space Observatory

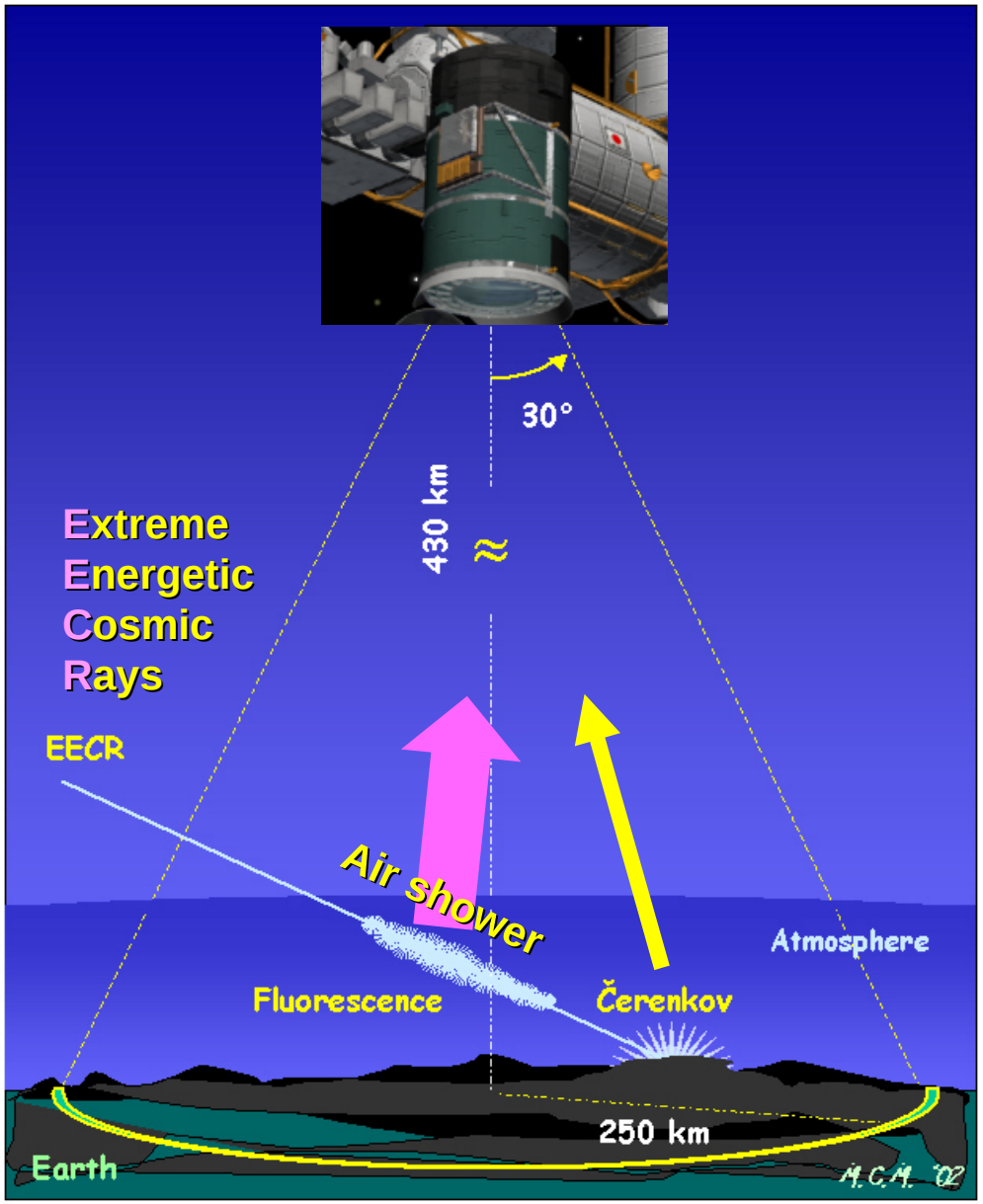


CL LNF
3 Luglio 2012

JEM-EUSO

Osservazione dei Raggi Cosmici di altissima energia (UHECR) dallo Spazio

JEM-EUSO Observational Principle



JEM-EUSO is a new type of observatory on board the International Space Station (ISS), which observes transient luminous phenomena occurring in the Earth's atmosphere.

The telescope has a super wide field-of-view (60°) and a large diameter (2.5 m).

JEM-EUSO mission will initiate particle astronomy at ~10^{20}eV.

JEM-EUSO telescope observes fluorescence and Cherenkov photons generated by air showers created by extreme energetic cosmic rays

Status of the Experiment

Road Map to JEM EUSO: 2 tests, in air and at ground

JEM-EUSO Pathfinders

1) EUSO Balloon campaign

2011/6 Approved by CNES (France)

2014 first of three launches

2) Cross-calibration tests at Telescope Array site, Utah

Collaboration with ICRR, Institute of Cosmic rays, Tokyo University, Kashiwa campus

Installation winter 2012

Il Gruppo Italiano

Italy	INFN and Univ.Bari	R. Bellotti, A. Bruno, F. Cafagna
	INFN and Univ.Catania	A.Insolia, R.Caruso, S.Riggi, M. Scuderi
	CNR-INO Firenze	A.Zuccaro Marchi
	CNR-IFAC Firenze	G. Castellini
	INFN-LNF	A.Franceschi, A.Marini, G.Modestino, M.Ricci, F.Ronga, T.Napolitano
	INFN-Naples	M.Ambrosio, C.Aramo, D.Campana, R.Carbone, L.Consiglio, G.Osteria , L.Valore
	Univ. "Federico II" di Napoli	D.D'Urso, F.Guarino, F.Isgro, M.Paolillo
	IASF-PA/INAF	O. Catalano, M.C. Maccarone, G. La Rosa, B. Sacco, A.Segreto, E. Strazzeri, A. Anzalone
	INFN & Univ. Rome "Tor Vergata"	M.Casolino, M.P.De Pascale, P.Picozza, F. Iacoangeli, G. Masciantonio
	INAF-IFSI Torino	P.Vallania
	Univ. Torino	P.Galeotti, C.Vigorito, M.Bertaina, C.Cassardo, S.Ferrarese
	Univ. Torino / ARPA Piemonte	R.Cremonini
	INAF-OATO	A.Cellino, M.Di Martino, A.Dell'Oro

48 tra Ricercatori e Tecnologi (~ 25 FTE)
INFN, INAF, CNR e Università

Contributions and Responsibilities in Italy

- **Optics**: design of the basic system of the Fresnel lens.
- **Electronics**: CPU, Data handling, Storage system, Clock, High-speed serial line.
- **Trigger System**: Definition of track recognition algorithms.
- **Mechanics**: Support structure of the Focal Surface; Mechanical Ground Support Equipment.
- **Simulations**: study and optimization of the detection efficiency and of the resolution (energy, nuclear, incident angle) of the experiment; event reconstruction.
- **Tests** of radiation hardness and qualification of components.
- **Beam tests** of detector elements and components.
- **Calibrations** with ground equipment (LIDAR, fluorescence systems, UV sources).
- **Atmosphere monitoring**: development of software and algorithms for the calibration of on-board systems (LIDAR and Infrared Camera) and for the determination of cloud coverage and height from satellite images.
- Contributions and responsibilities on **ground test at TA** and **balloon flight**

Il gruppo JEM-EUSO-LNF

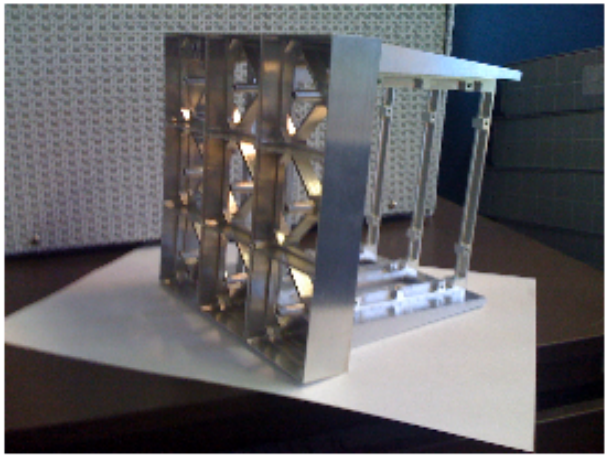
- M.Ricci (Resp.) 60%, A. Marini 50%, G. Modestino 100%,
- F. Ronga 50%, A. Franceschi 30%, T. Napolitano 30%
- **TOT FTE 3.2**

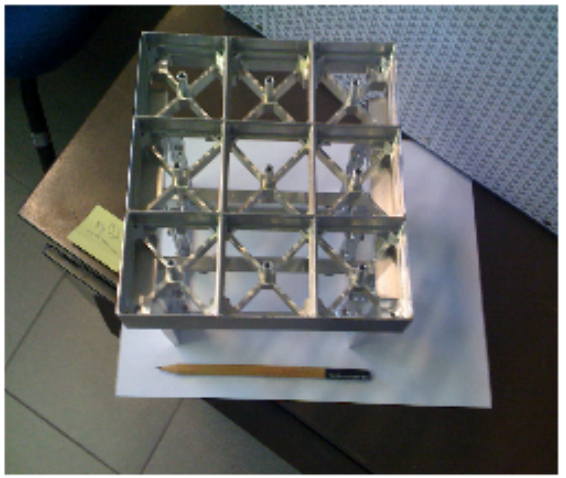
Attività svolta e in corso nei LNF

(SPCM-LNF A. Franceschi, T. Napolitano)

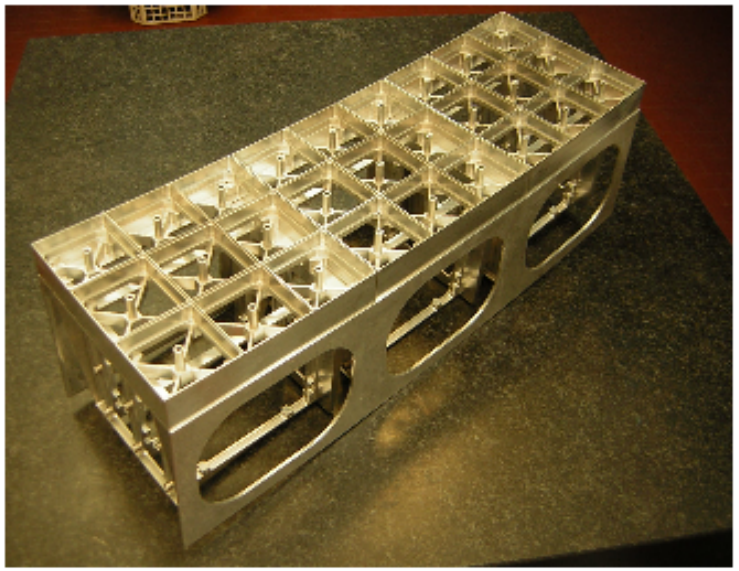
- Progetto struttura meccanica di supporto del Piano Focale (PF).
- Progetto supporti PDM (Photo Detector Module) per l'alloggiamento dei PMT e dell'elettronica associata sulla superficie del Piano Focale.
- Studi di Analisi FEM delle strutture in progetto.
- Entrambi i progetti sono stati approvati dalla Collaborazione e costituiscono la "baseline" ufficiale per la struttura del PF.
- Realizzazione supporto PDM per tests TA-EUSO e EUSO-Balloon
- Editorial board (G.Modestino) e Speaker's Bureau (Pubblicazioni e Conferenze (M. Ricci)

(SPCM-LNF)





Prototipo supporto meccanico PDM



3 moduli supporto PDM assemblati

Richieste finanziarie LNF 2013(*Preliminari*)

Miss. Interne 5.0

Miss. Estere 15.0

Consumo 15.0

Tot 35 k€

Rich. Finanziarie globali 2013 Gruppo INFN: ~ 250 k€

- Richieste ai Servizi LNF per il 2013
  - Div. Tecnica-SPCM
    - Progettazione 4 mu
    - Meccanica 4 mu
    - Metrologia 1mu

ROG

NAUTILUS

www.lnf.infn.it/esperimenti/rog

LNF : *G. Giordano (100%), A. Marini (60%), F. Ronga (60%), G. Pizzella*

Roma Tor Vergata : *M. Bassan, E. Coccia, S. D'Antonio, V. Fafone, I. Modena, A. Moleti, Y. Minenkov, A. Rocchi*

Roma Sapienza : *P. Astone, S. Frasca, G.V. Pallottino*

INAF-IFSI : *M. Visco*

Regular data exchange with Auriga
MoUs and Agreements with LIGO, VIRGO, GEO, TAMA, LVD, Beppo-SAX

Attivivita' LNF :

controllo funzionamento Nautilus e impianto recupero Elio e liquefattore,
presa dati, AFS e backups,
controllo apparato rivelazione cosmici,
data analysis

NAUTILUS
LNF - FRASCATI

Bar Al 5056 M = 2270 kg

L = 2.91 m ; Ø = 0.6 m

ν_A=935Hz; T = 0.1 K; T = 3 K

Readout: Low gap transducer + dc SQUID

Cosmic ray detector

NAUTILUS gets 4 records:

. First ultralow T massive detector: 2.3 tons at 0.09 K.

. First acoustic detector of cosmic rays.

. Best displacement sensitivity: 7 x 10^{-22} m/$Hz^{-1/2}$

. Longest continuous science run: 10 years (in

The EXPLORER/NAUTILUS SEARCH FOR SHORT GW BURSTS

1997- 2000 IGEC search *Phys. Rev. Lett. 85, 5046 (2000)*

1998 931 hours; *CQG 18, 43 (2001)*

2001 2156 hours; *CQG 19, 5449 (2002)*

2003 3677 hours; *CQG 23, S169 (2006)*

2004 5196 hours; *CQG* 25:114048 *(2008)*

1 IGEC2 search, *Phys.Rev. D76:102001 (2007)*

2006-2007 IGEC2 search, *Phys.Rev. D82:022003 (2010)*

2007-2010 > 2 years; writing paper…

Probabili richieste finanziarie 2013

- Missioni interno : 2 keuro
- Missioni estero : 3 keuro
- Inventario : 8 keuro
- Consumo : (Elio liquido e gassoso, azoto liquido, altri gas, prelievi magazzino, etc.) 80 keuro
- Manutenzioni e riparazioni : 10 keuro
- Servizi : (facchinaggi) 8 keuro