INFN What next: a view from LNGS

- INFN What Next: meaning and aims
- Achievements at mid-term (Apr 2014- Apr 2015)
- Initiatives at LNGS: the long term future of astroparticle physics and the **opportunities for its major underground lab**
- Double beta decay and direct dark matter detection: focus on **common challenges and shared facilities**
- **Non conventional approaches**: INFN What Next as a think tank
- Conclusions

F. Terranova (Univ. of Milano-Bicocca and INFN) on behalf of the INFN WN Conveners for **Dark Matter [**M. Battaglieri, N. Fornengo, A. Ianni, N. Mazziotta, G. Polesello, P. Ullio] and **Neutrinos** [C. Brofferio, C. Giunti, E. Lisi, M. Spurio, FT]

INFN What next

A very peculiar initiative fostered by INFN and addressed to all physicists involved (or willing to be involved) in INFN projects . Its aims are to:

- Investigate **new directions** and approaches to address the main mission of INFN (*)

The classical distinction between "HEP activities" (Gruppo 1) "astroparticle (GR 2) and "nuclear physics" (GR 3) is not suited to address interdisciplinary challenges as "the origin of the dark matter" or the "matching of the ΛCDM cosmological paradigm with the Standard Model"

- Encourage **technology developments** (GR 5) that are not in the standard expertise of particle physicists to develop innovative approaches

It is a well established trend, especially in astroparticle physics (cryogenic detectors, laser physics, quantum devices etc.)

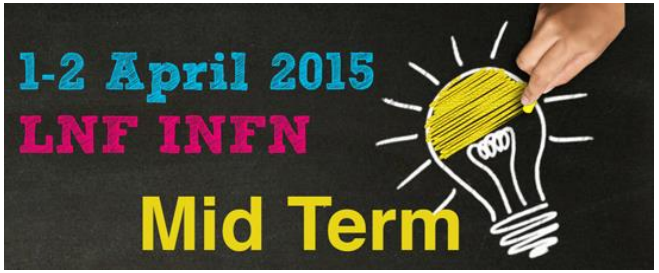
- Promote **synergy among INFN laboratories**, infrastructures and other funding agencies

The particle physics of the '80 created GR1, GR2 and GR3 and "their" laboratories (LNF, LNGS, LNS). But physics has changed a lot since then…

(*) "The National Institute for Nuclear Physics (INFN) is the Italian research agency dedicated to the study of the fundamental constituents of matter and the laws that govern them."

from kick-off…

to mid-term



The vast majority of the italian particle physics community has heard about this initiative and joined the kick-off (750 partecipants) and the many satellite meetings.

Of special relevance for the LNGS community:

Satellite meetings: Nuclear Measurements for Neutrinoless Double beta decay matrix elements (27 Mar 2014), Relic and Mossbauer Neutrinos (2 Apr 2014), Dark Matter Direct Detection (18 March and 10 July 2014) , Indirect detection (20 March 2014), searches at accelerators (21 March 2014), Neutrino Oscillation Workshop (1-2 Dec 2014, Padova)

A dedicated workshop (80 partecipants) at LNGS 15-16 October 2014

What Next LNGS: prospettive per il ruolo scientifico dei LNGS

https://agenda.infn.it/conferenceDisplay.py?confId=8474

Achievements

Proposals and discussions along the INFN What Next process have already a significant impact on the scientific life of INFN

Cosmology: LSPE (CMB polarization – balloon), EUCLID (survey)

Mass hierarchy: JUNO (reactor)

Dark Matter: QUAX (axion), SABRE (direct), SHIP (non-WIMP @ CERN-SPS), PADME (non-WIMP @ LNF)

Quantum simulation: FISH (SU(N) theories with Yb atoms)

Double beta decay: NUMEN (nuclear physics @ LNS)

These are project that have clustered interest and have been submitted to the INFN Scientific Committees (some of them, actually are already approved). **Many other proposal are under discussions** (or were discussed but dropped). Some were used to ground proposals for HORIZON 2020 (ERC, OPENFET etc.).

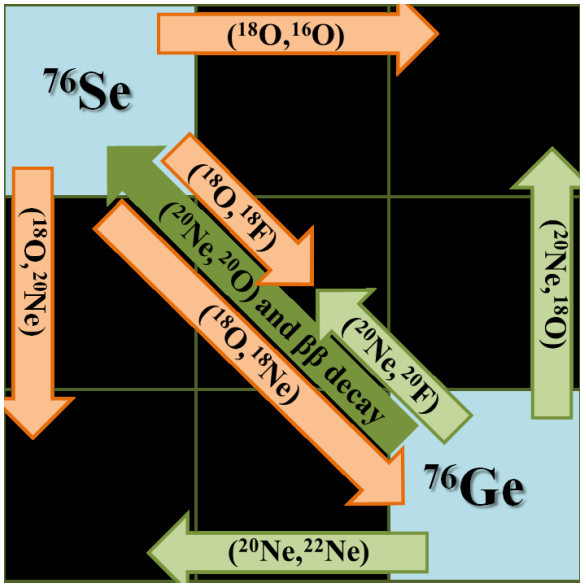
An example (of relevance for us): NUMEN

Neutrinoless double beta decay ("GR II")

Nuclear matrix element for neutrinoless double beta decay

$$1/T_{1/2}^{0\nu}(0^+ \rightarrow 0^+) = G_{01}\left|M^{\beta\beta\,0\nu}\right|^2\left|\frac{\langle m_\nu \rangle}{m_e}\right|^2$$

Heavy ion Double Charge Exchange ("GR III")



SWOT(strengths/weaknesses/opportunities/threats) analysis:
S – offers significant information to establish the link between 0νββ lifetime and absolute masses
W – does not determine uniquely the nuclear matrix elements
O – an astroparticle physics program for MAGNEX@LNS
T – requires a significant upgrade of the existing facility

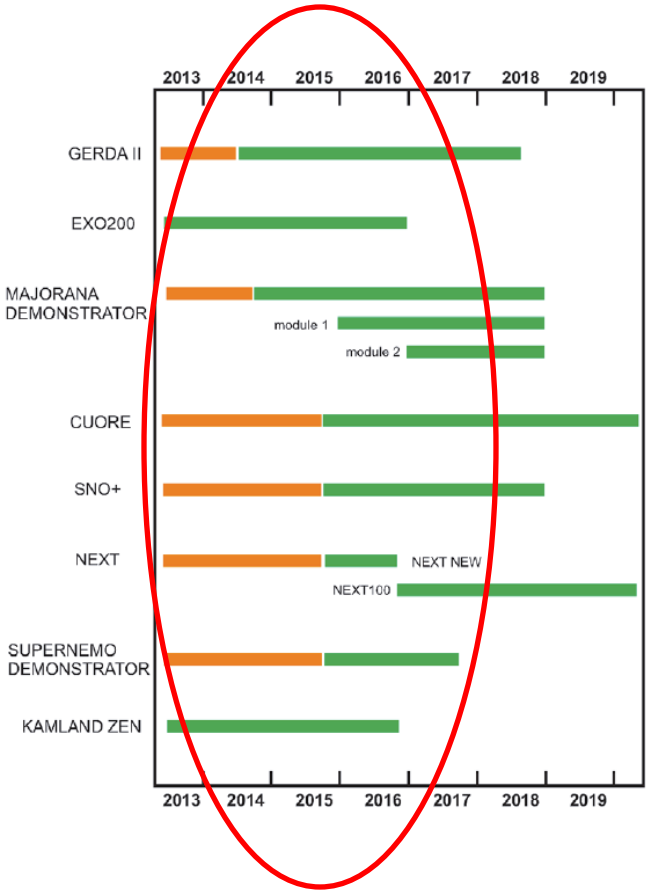
See What-Next Mid Term, LNF 1-2 April 2015

Still on double beta decay…

On a long term perspective ("LNGS beyond 2020") the trend that is already emerging will be very well established

Main aim of the experimentalists between 2001 and 2015: perform a $0\nu\beta\beta$ with a precision better than Heidelberg-Moscow; possibly, employing a technique with clear strengths and wide room for improvements

Germanium: resolution, radiopurity, enrichment
Tellurium (bolometers): resolution, radiopurity, natural abundance
Tracking (SuperNemo, Next): background rejection
Scintillators (Kamland-Zen, SNO+): mass



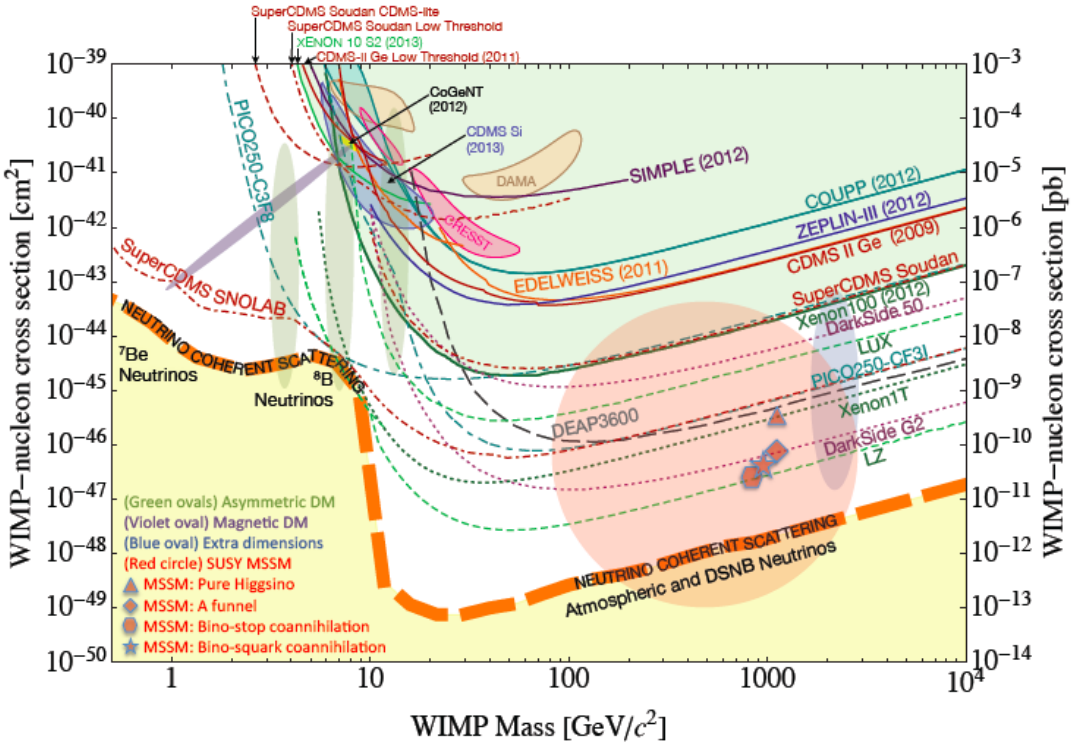
We have today GERDA-Phase I, CUORE-0, EXO e KAMLAND-ZEN **working** and **in full swing data taking**. **The aim is hence more ambitious**: carry on a measurement employing a technique that is scalable down to O(10) meV. This new goal put the emphasis on issues that were left aside during R&D…

… or on WIMP direct searches …

It comes to no surprise that the same consideration holds for direct WIMP searches

Several techniques demonstrated the capability to address theory motivated parameter regions

Experimentalists aim at establishing techniques that are scalable down to the neutrino floor



Staying "background free" down to inverted hierarchy (double beta) and to the neutrino floor (direct searches) is pivotal for any >2020 project.

Zero background

The size of the next generation Dark Matter and 0νββ requires a change of strategy in background budget reduction. **The quality of the infrastructures for material screening and test must match these new standards**

Today:

Material bulk screening (mostly gamma spectroscopy)	Surface screening (mostly alpha spectroscopy)	Construction and handling procedures drawn by past experience

Needed sensitivity for future experiments at least two order of magnitude better than current facilities
[see M. Laubenstein @ What Next LNGS]

At present we have just "proactive" (risk mitigation) techniques. The background budget is often discovered at the startup of data taking (and hitches sometime occur ☺)

This is probably the most pressing request coming from the community of underground physics during What Next

And elsewhere…

SNOWMASS CSS 2013 ON THE MISSISSIPPI
JULY 29 - AUGUST 6, 2013
ORGANIZED BY THE DIVISION OF PARTICLES AND FIELDS OF THE APS
HOSTED BY THE UNIVERSITY OF MINNESOTA

ILIAS

Low Radioactivity Techniques 2015

Zero background and opportunities for LNGS

Mid term:

Shared infrastructure (0νββ, Dark Matter, solar ν) for bulk screening

Surface screening and Radon permeation

Underground storage area of strategic material

Long Term:

Bulk and surface screening with **detectors currently used for experiments**

Test facilities with active veto

Material production and crystal growth within INFN (or EU research institute) infrastructures

[see I. Dafinei @ What Next LNGS]

Behind infrastructures we need coordinated activities: on 0νββ we are on the right track

Germanium	Bolometers	Scintillators
Gerda upscale and LSGe	Te, enrichment Cherenkov and α discr. / Scintillating bolometers	Borexino with ^{136}Xe

Combination of the GERDA and Majorana techniques and expertise

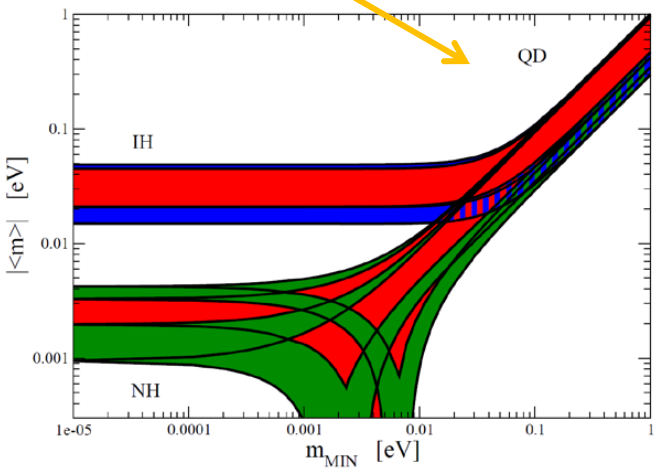
Talk at this meeting

R&D are converging toward a coherent scheme (CUPID)

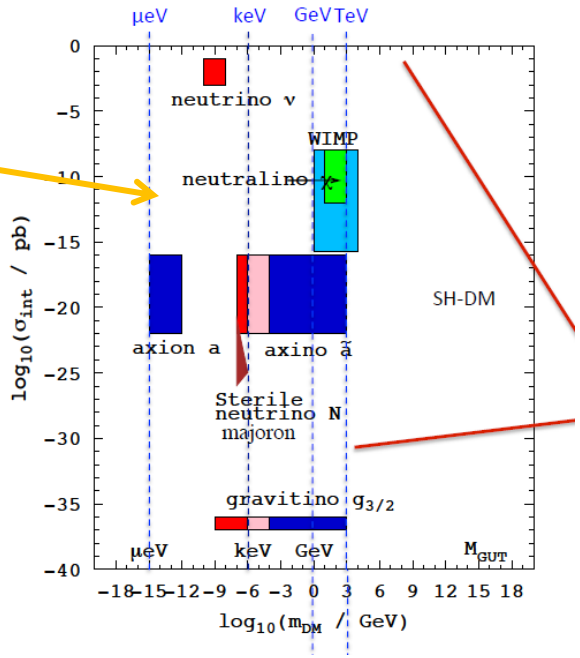
Talk at this meeting

Difficult to match with the physics plan of Borexino-SOX

But this is much easier if you are here



Instead of here

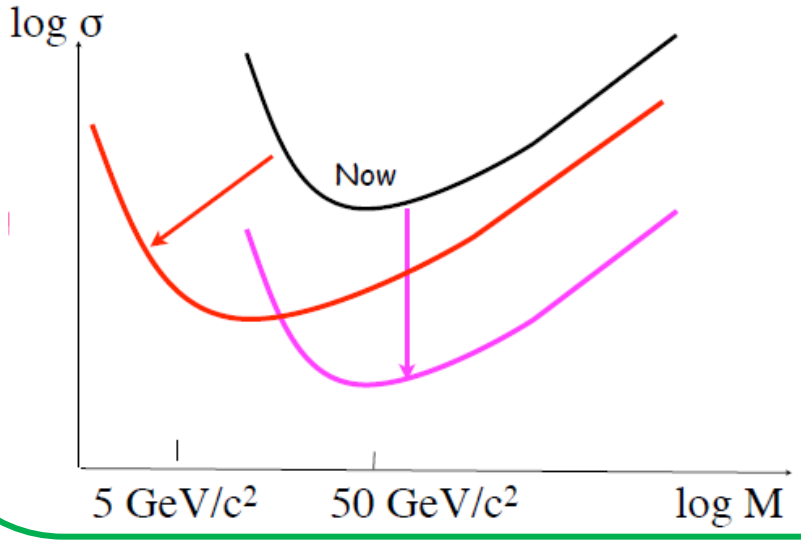


The main difference

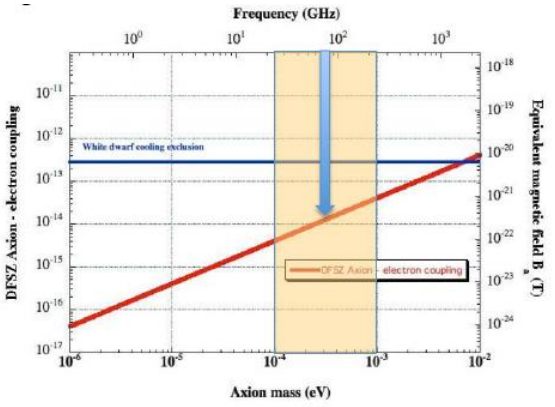
"Mass scalability in background free mode" is by far the most important parameter in 0νββ, the main thread being mostly the uncertainty on the lifetime-to-mass link (matrix element , quenching of axial coupling).

It is **definitely not the case for direct Dark Matter** detection where the WIMP≡neutralino models are perceived (after LHC-Run I…) more as benchmarks than as a solid theoretical ground. This is the reason why emphasis has been put toward:

Exploring the "open-minded" WIMP scenario: high mass ultimate sensitivity (see above), low mass (i.e. low threshold) and **model independent signatures (directionality)**



Exploring non-WIMP models at accelerators and with photon mediated processes (see N. Fornengo @ What Next Mid Term, LNF 1-2 April 2015)



Dark matter detection techniques

Developing novel techniques that reduce priors from theory models is considered with great interest worldwide. Most of the approaches discussed at What Next are also represented in this meeting

Directionality:

Anisotropic crystals	→	Talk @ this meeting
Nuclear emulsion for WIMP searches	→	Talk @ this meeting
Columnar recombination in LAR	→	Talk @ this meeting
Negative ion Time Projection Chambers		

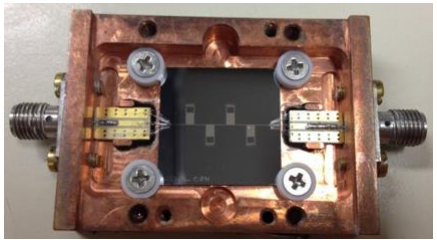
Low mass – low thresholds:

CRESST upscale	→	Talk @ this meeting
Synergy with Coherent Neutrino scattering		

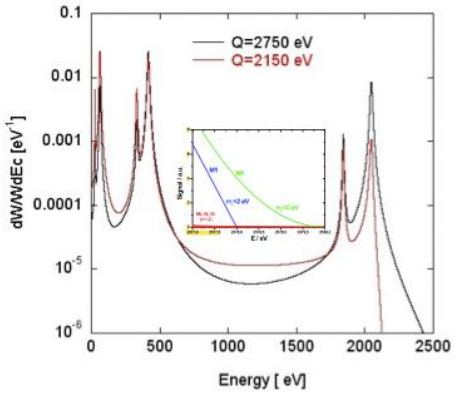
Worth mentioning: a dedicated call by GR V (INFN technology development comm.) has been put forward devoted to "Novel techniques for direct detection of Dark Matter".

Low threshold, extreme resolutions

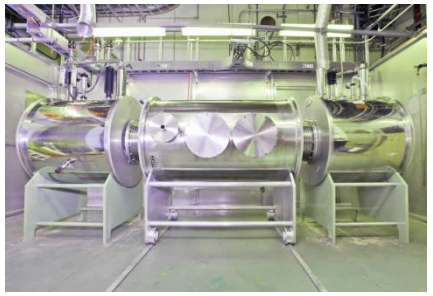
Cherenkov light in bolometers (0νββ)



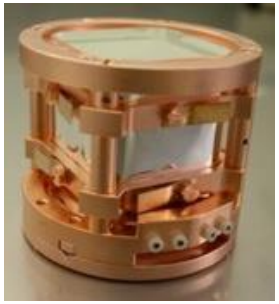
Absolute neutrino masses with calorimetric techniques



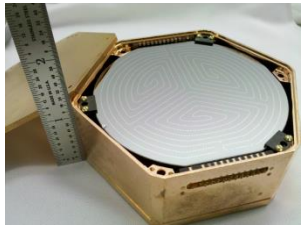
Relic neutrinos



Low threshold recoil (dark matter)



Neutrino Coherent scattering



Underway

Very challenging

Really very challenging…

Conclusions

- INFN What Next is a good opportunity to explore innovative venues and call into question the fences among “accelerator physics”, “astroparticle physics”, “fundamental physics” and “cosmology”

- LNGS and, in general, the physics of rare events has been at focus of our activities: we discussed many new proposals on double beta, dark matter, neutrino physics (absolute masses, solar, relic, Mossbauer neutrinos) of relevance for LNGS. Several of them will be discussed in this meeting, too

- INFN What Next is underway: the wrap up meeting is scheduled on February 2016 and the activities of the Neutrino, Cosmic rays (**not covered in this talk**: R. Aloisio and F. Vissani among the convenors), Dark Matter Working Groups are not over.

More information and links to WG pages in
https://agenda.infn.it/internalPage.py?pageId=3&confId=7588
Or just google “infn what next” ☺