LNGS

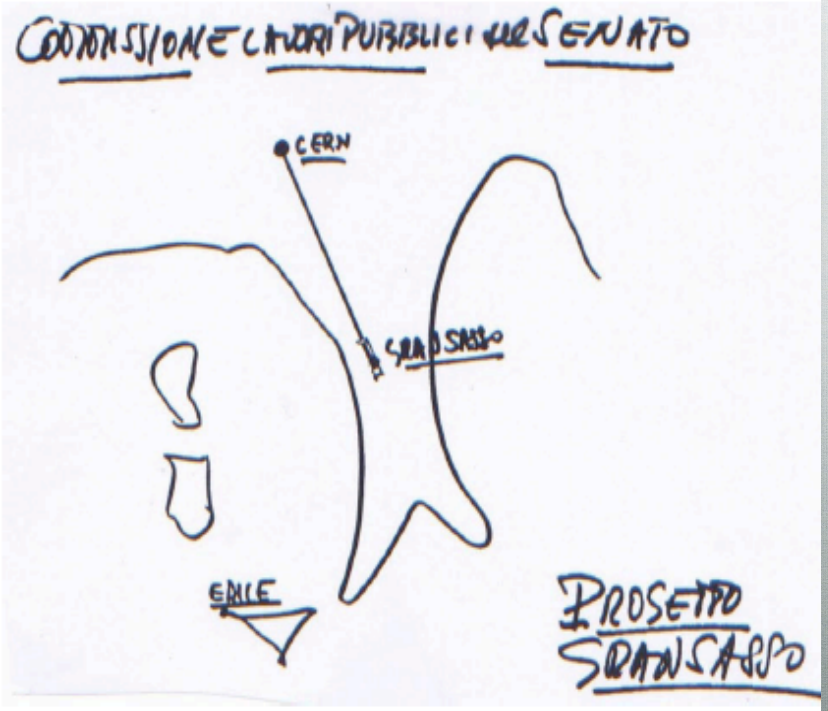
CoEPP-CAASTRO 2014

Stefano Ragazzi – LNGS Director

Laboratori Naztionali del Gran Sasso

INTRODUCTION

The birth

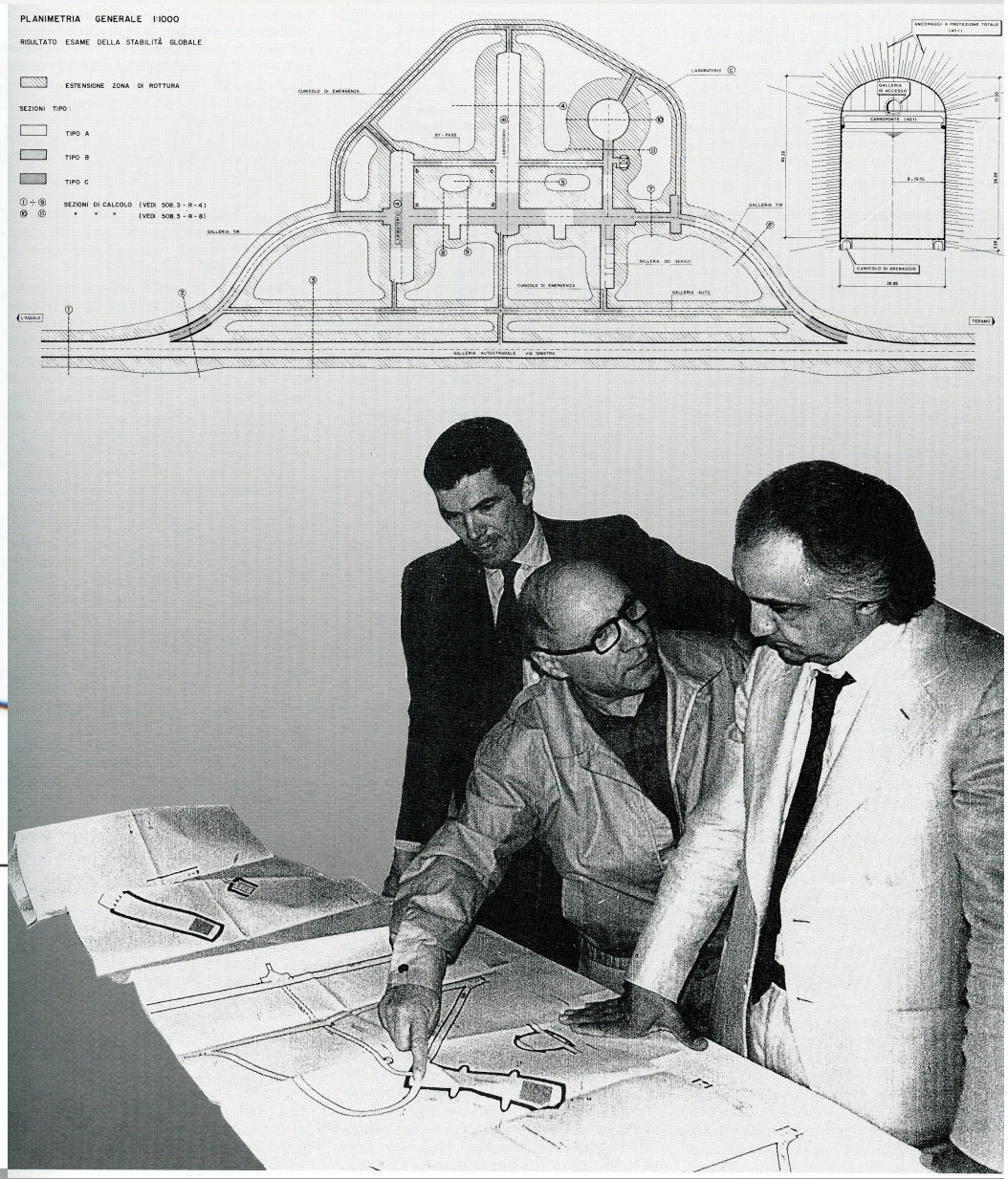


Note manoscritte di A. Zichichi presentate nella Seduta della Commissione Lavori Pubblici del Senato convocata con urgenza dal Presidente del Senato per discutere la proposta del Progetto Gran Sasso (1979).

To summarize, the scientific aims of the "Gran Sasso" laboratory are the study of:

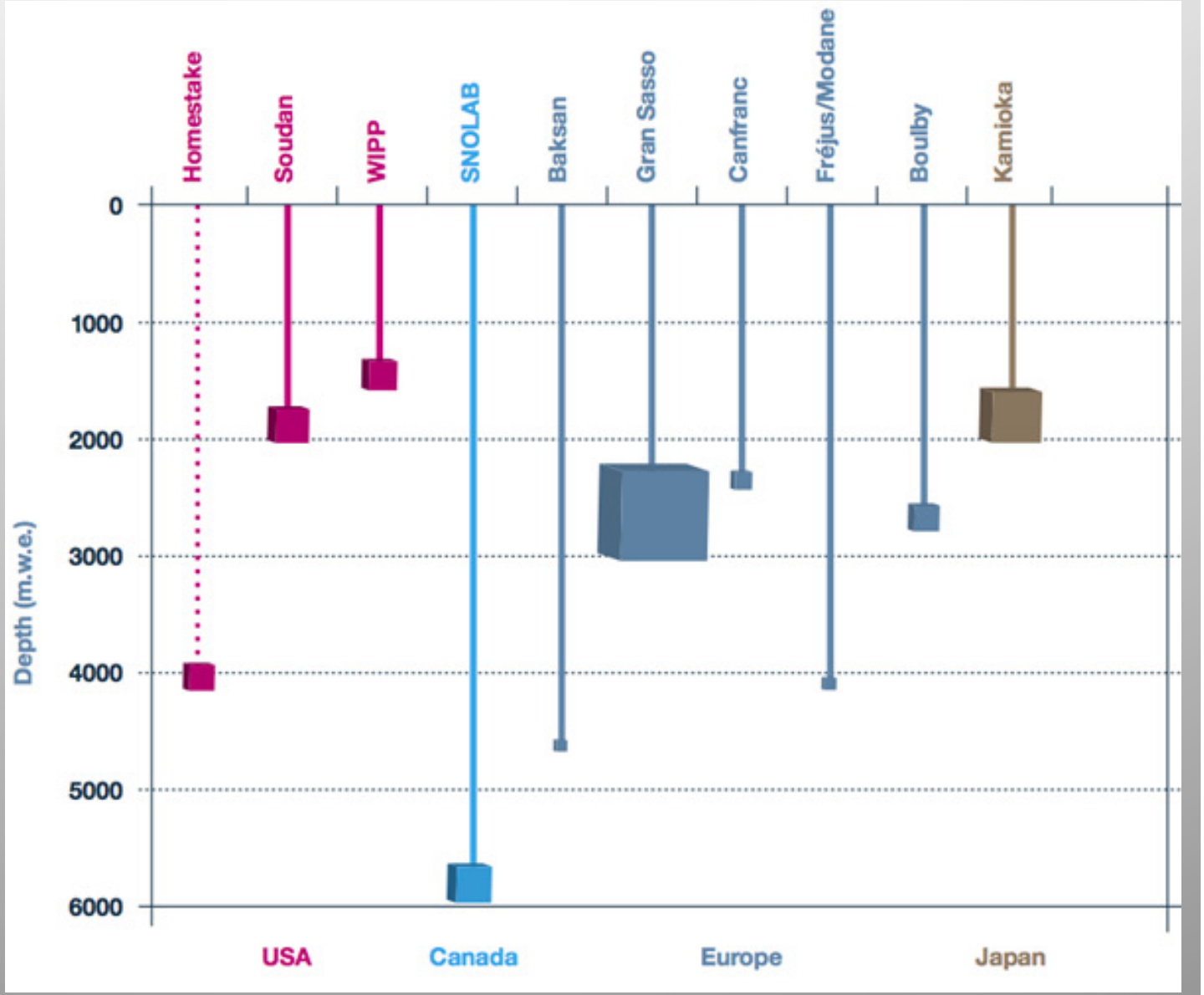
1) nuclear stability;
2) neutrino astrophysics;
3) new cosmic phenomenology;
4) neutrino oscillations;
5) biologically active matter;
6) ground stability.

NOT only $T_p \neq \infty$



Underground Science Laboratories

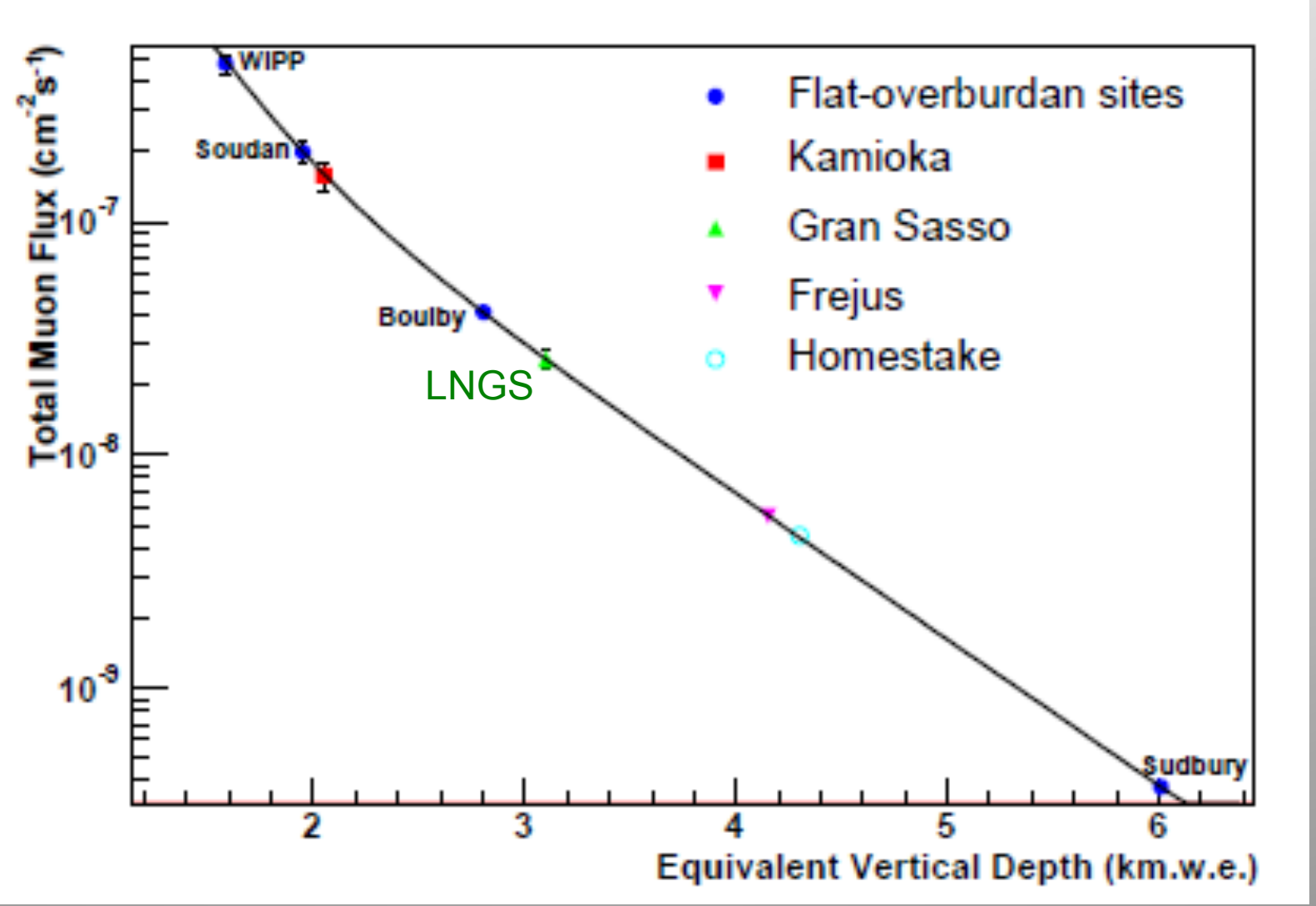
- **LNGS**
  - Largest



Plot adapted from http://www.deepscience.org/contents/facilities.shtml

Muon Flux versus depth

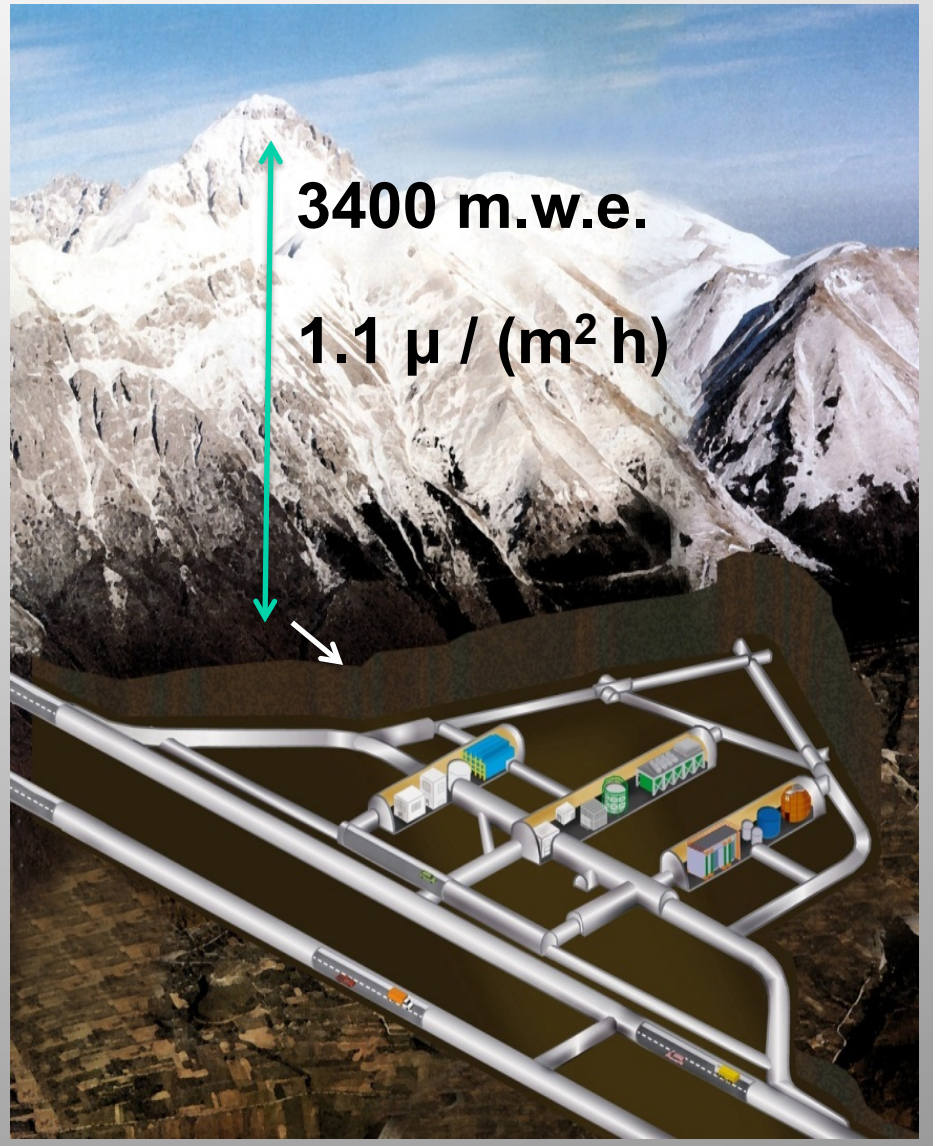
LNGS: 10^{-6} wrt surface



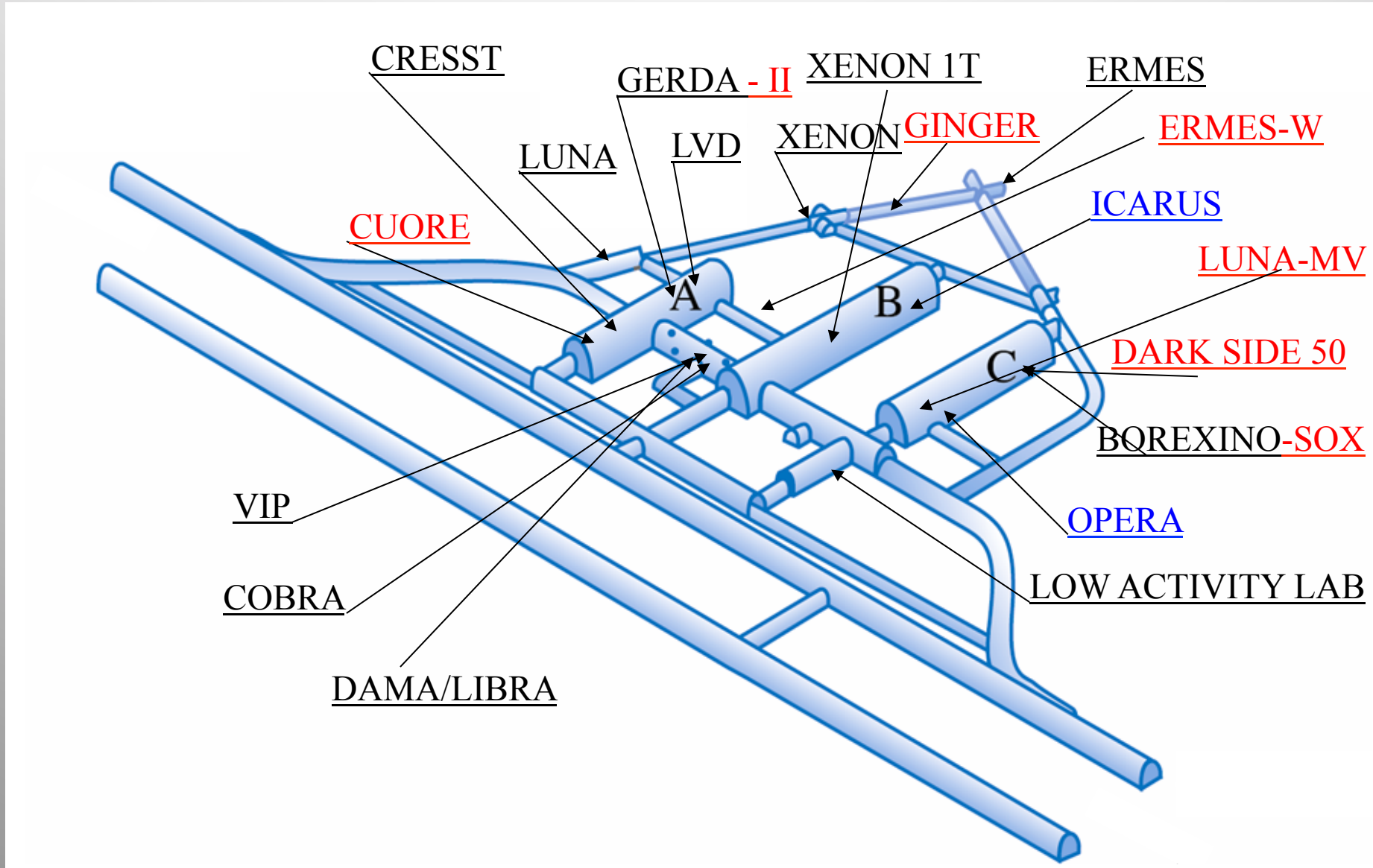
Hime and Mei, Phys.Rev. D73 (2006) 053004

The LNGS Laboratory

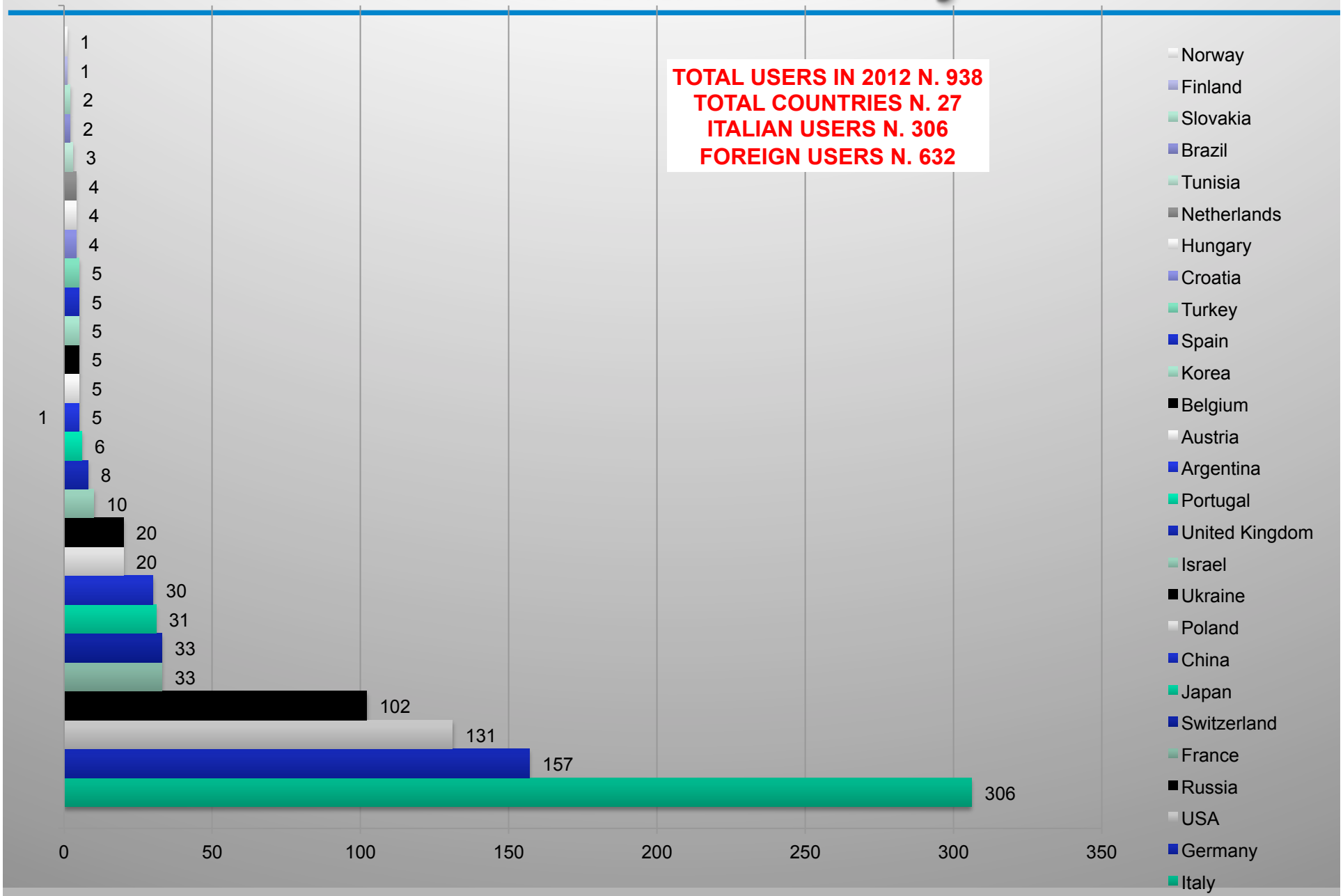
- Muon flux: 3.0 10^{-4} $m^{-2}s^{-1}$
- Neutron flux:
  - 2.92 10^{-6} $cm^{-2}s^{-1}$ (0-1 keV)
  - 0.86 10^{-6} $cm^{-2}s^{-1}$ (> 1 keV)
- Rn in air: 20-80 Bq m^{-3}
- Surface: 17 800 m^2
- Volume: 180 000 m^3
- Ventilation: 1 vol / 3 hours



A busy laboratory



LNGS: international laboratory



LNGS

Surface Lab:

- conference rooms
- offices
- canteen
- stores
- mech. workshop
- electronics lab
- chemistry lab
- mounting halls

- ~ 100 staff
- Annual operating costs: 13 M€ including personnel
  (~ 1/20th of INFN annual budget)

Main research topics at LNGS

- High energy neutrinos
- Cosmogenic and solar neutrinos
- Neutrino properties
- Nuclear astrophysics
- **Dark matter searches**

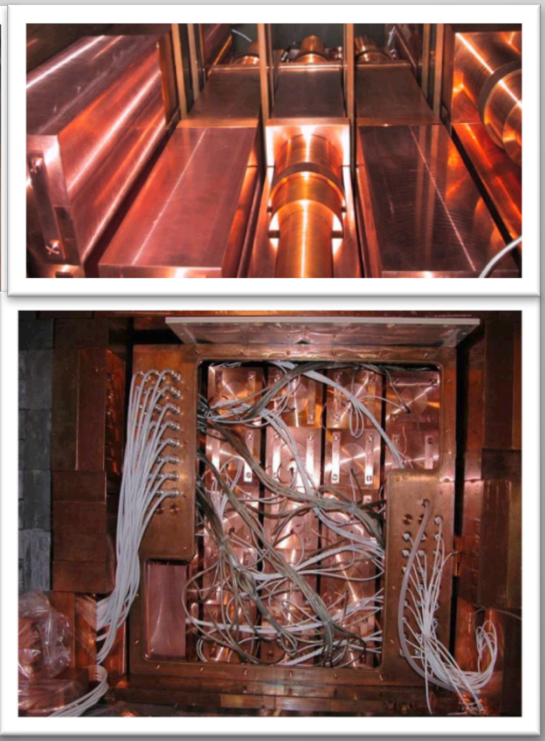
DARK MATTER SEARCHES

Dark Matter @ LNGS

- **DAMA/LIBRA**
- **XENON family**
- **CRESST**
- **DarkSide**
  - See Davide D'Angelo's talk
- **future NaI**
  - See Davide D'Angelo's talk

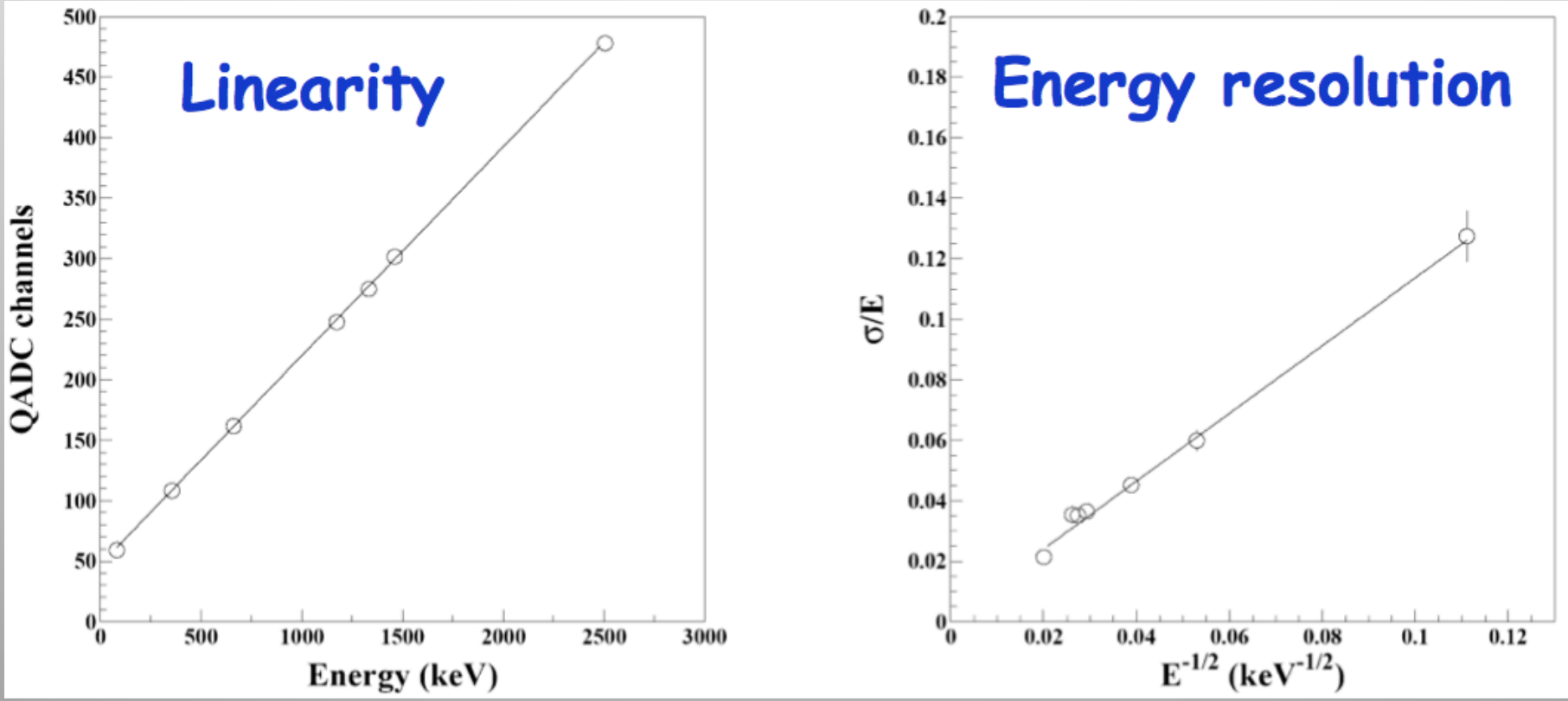
DAMA/LIBRA

- **Ultrapure Na(TI)**
  - **Residual contamination**
    - **^{232}Th, ^{238}U and ^{40}K at level of 10^{-12} g/g**



DAMA/LIBRA

accurate linearity and energy resolution measurements and stability checks



no modulation of energy scale, energy resolution, efficiency

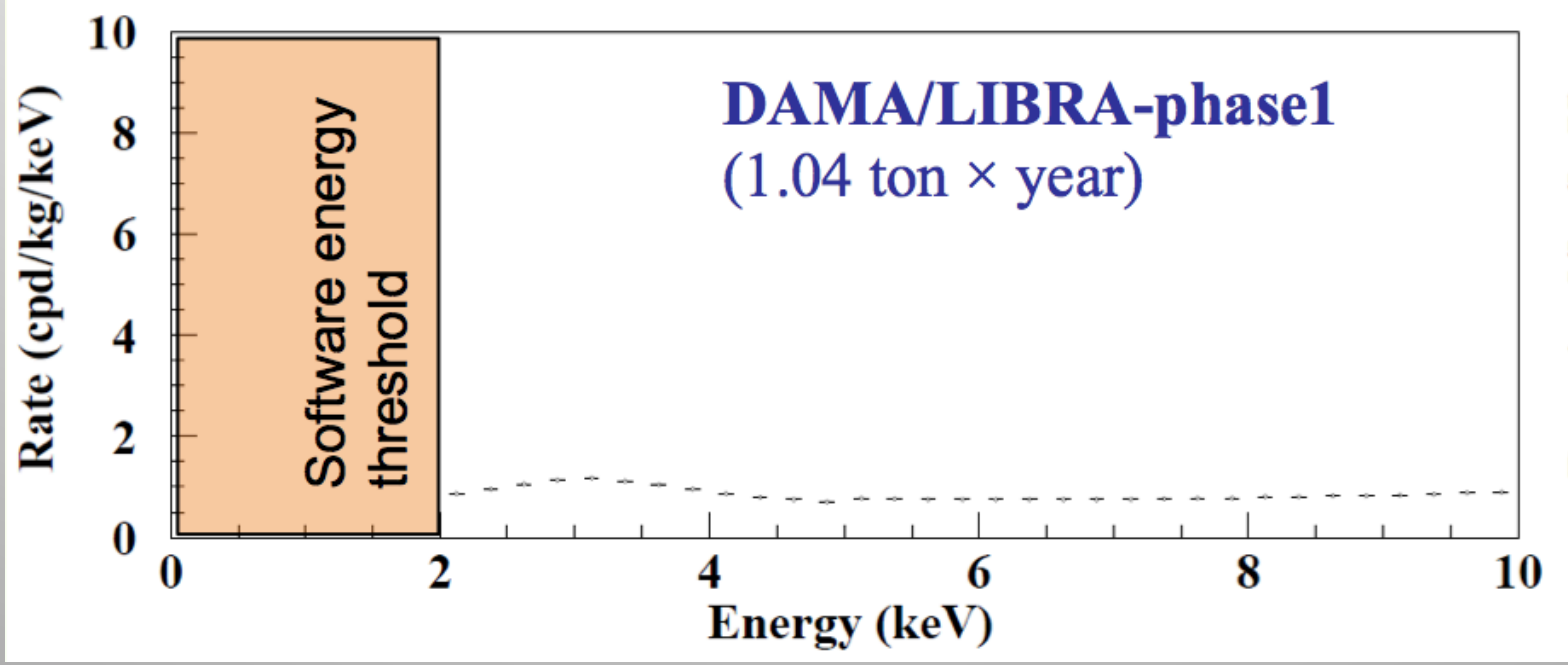
DAMA/LIBRA

- **1 ton x year experiment**

	Period	Mass (kg)	Exposure (kg×day)	$(\alpha - \beta^2)$
DAMA/LIBRA-1	Sept. 9, 2003 - July 21, 2004	232.8	51405	0.562
DAMA/LIBRA-2	July 21, 2004 - Oct. 28, 2005	232.8	52597	0.467
DAMA/LIBRA-3	Oct. 28, 2005 - July 18, 2006	232.8	39445	0.591
DAMA/LIBRA-4	July 19, 2006 - July 17, 2007	232.8	49377	0.541
DAMA/LIBRA-5	July 17, 2007 - Aug. 29, 2008	232.8	66105	0.468
DAMA/LIBRA-6	Nov. 12, 2008 - Sept. 1, 2009	242.5	58768	0.519
DAMA/LIBRA-7	Sep. 1, 2009 - Sept. 8, 2010	242.5	62098	0.515
DAMA/LIBRA–phase1	Sept. 9, 2003 - Sept. 8, 2010		379795 $\simeq$ 1.04 ton×yr	0.518
DAMA/NaI + DAMA/LIBRA–phase1:			1.33 ton×yr	

DAMA/LIBRA

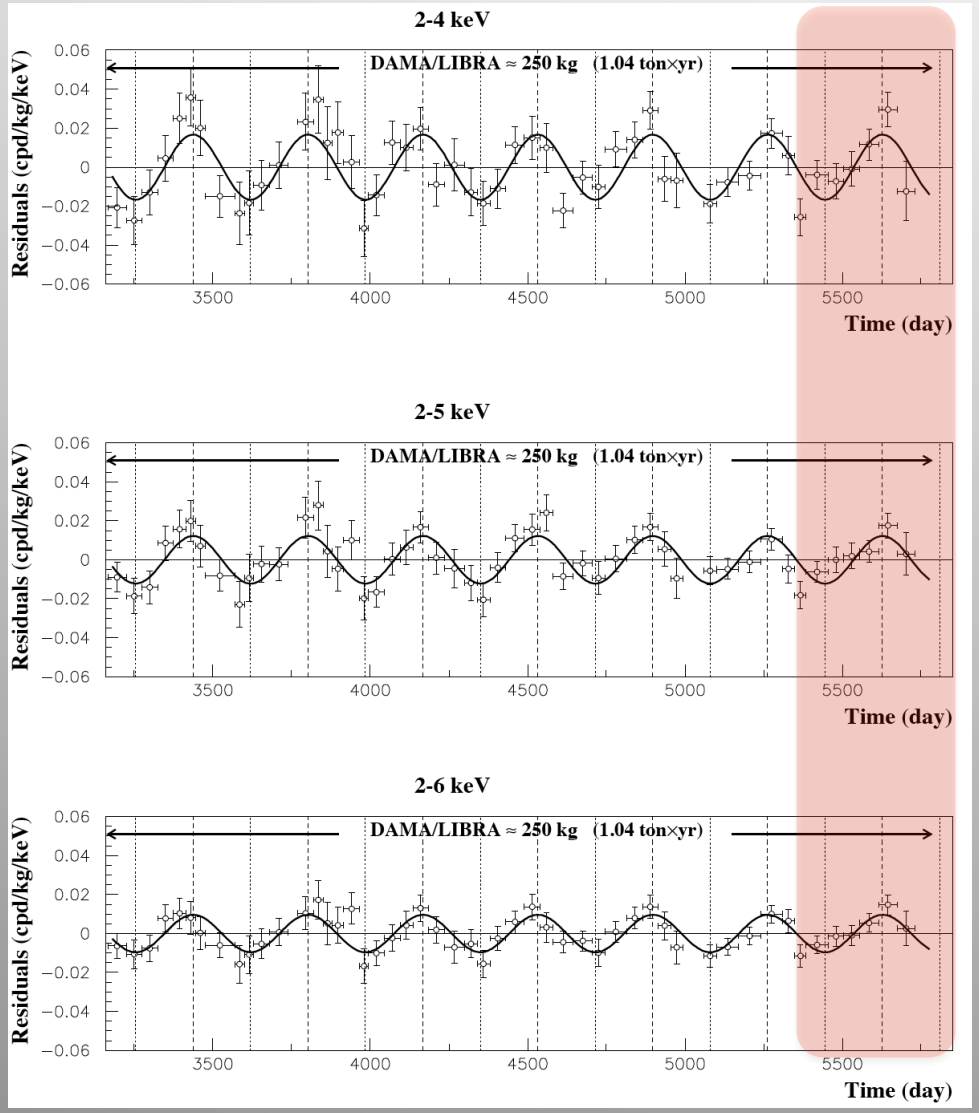
single-hit events: each detector has all the rest in anticoincidence



New run with improved PMs and threshold reduced to 1 keV is under way.
Wait for 6 years of data taking before releasing new analysis

DAMA/LIBRA

Analysis of residuals of single-hit events



A: modulation amplitude

2-4 keV

A=(0.0167±0.0022) cpd/kg/keV

χ^2/dof = 52.3/49 **7.6 σ C.L.**

Absence of modulation? No

χ^2/dof=111.2/50 ⇒ P(A=0) = 1.5×10^{-6}

2-5 keV

A=(0.0122±0.0016) cpd/kg/keV

χ^2/dof = 41.4/49 **7.6 σ C.L.**

Absence of modulation? No

χ^2/dof=98.5/50⇒ P(A=0) = 5.2×10^{-5}

2-6 keV

A=(0.0096±0.0013) cpd/kg/keV

χ^2/dof = 29.3/49 **7.4 σ C.L.**

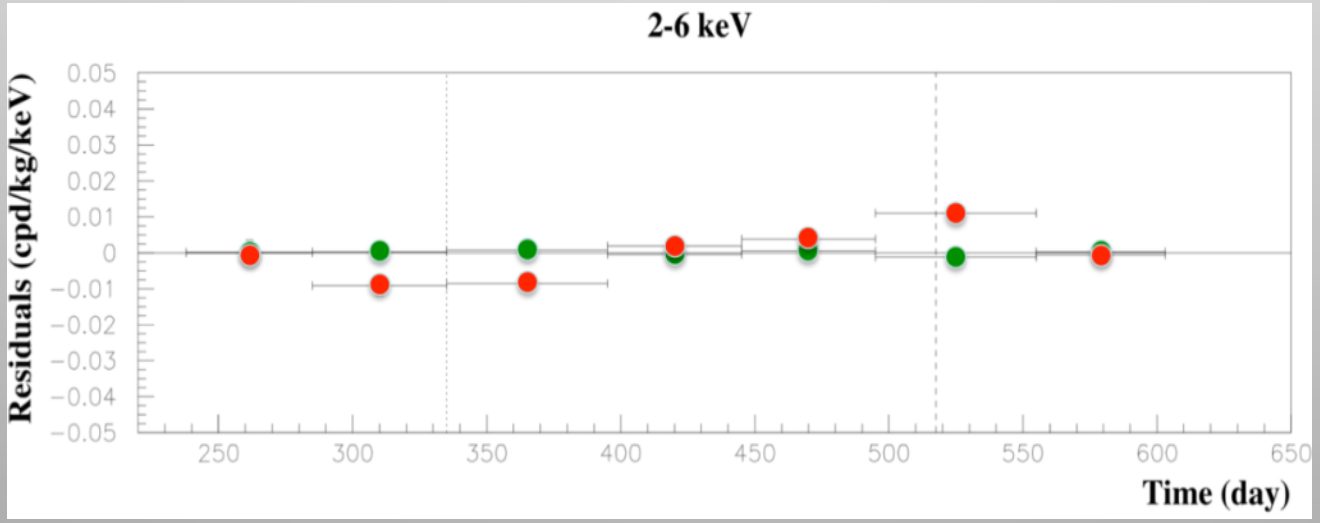
Absence of modulation? No

χ^2/dof=83.1/50 ⇒ P(A=0) = 2.2×10^{-3}

DAMA/LIBRA – annual modulation

Comparison between **single hit residual rate (red points)** and
multiple hit residual rate (green points);
A=-(0.0006±0.0004) cpd/kg/keV

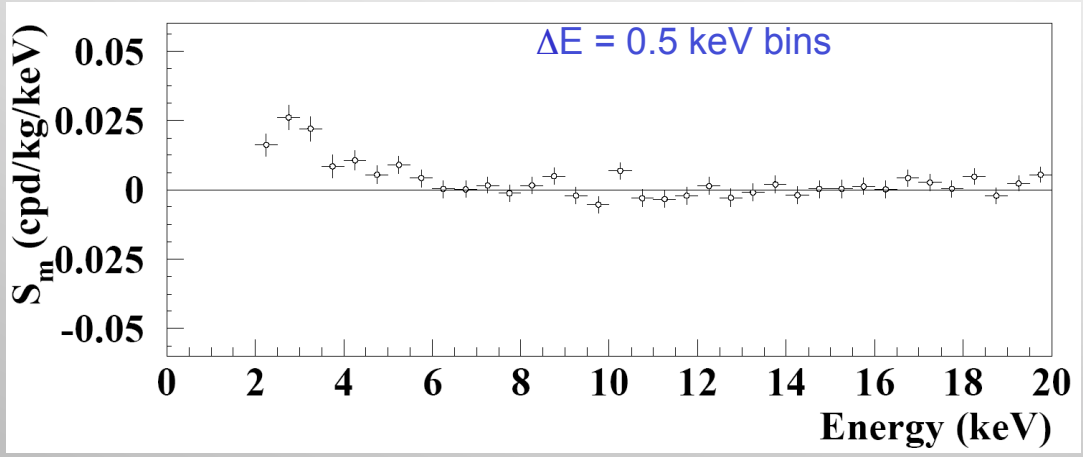
Multiple hits events = Dark Matter particle "switched off"

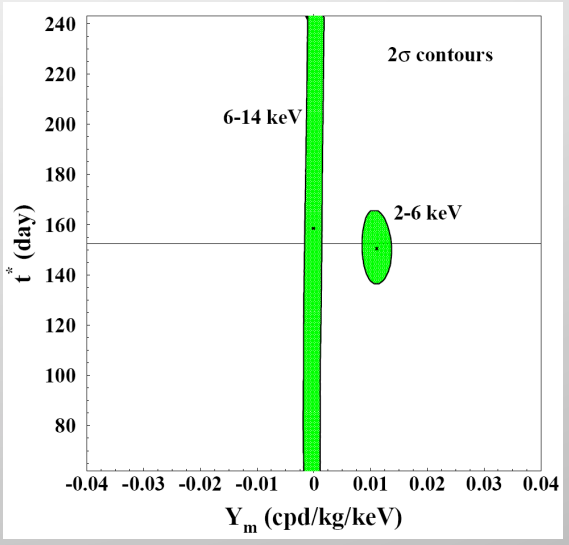


DAMA: Model Independent Annual Modulation

$$R(t) = S_0 + S_m \cos\left[\omega\left(t - t_0\right)\right]$$ *T=2π/ω=1 yr and t_0= 152.5 day*

$$R(t) = S_0 + Y_m \cos\left[\omega\left(t - t^*\right)\right]$$





- **No modulation above 6 keV**
- **No modulation in the whole energy spectrum**
- **No modulation in the 2-6 keV multiple-hit events**

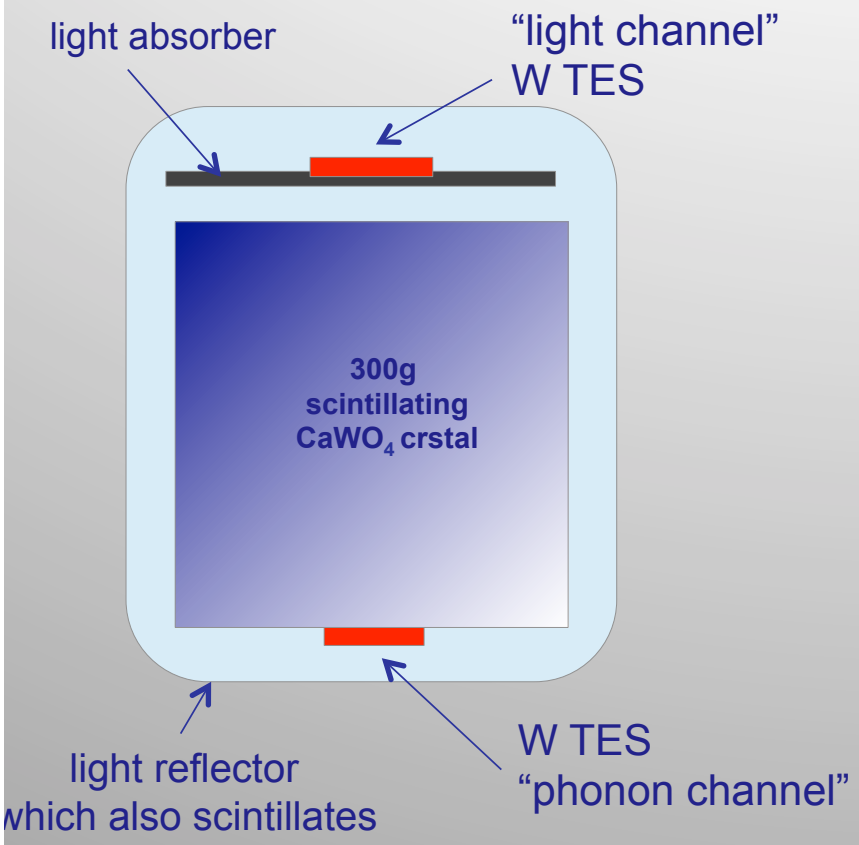
Systematics or other processes do not explain quantitatively the measured modulation amplitude and simultaneously satisfy the signal characteristics.

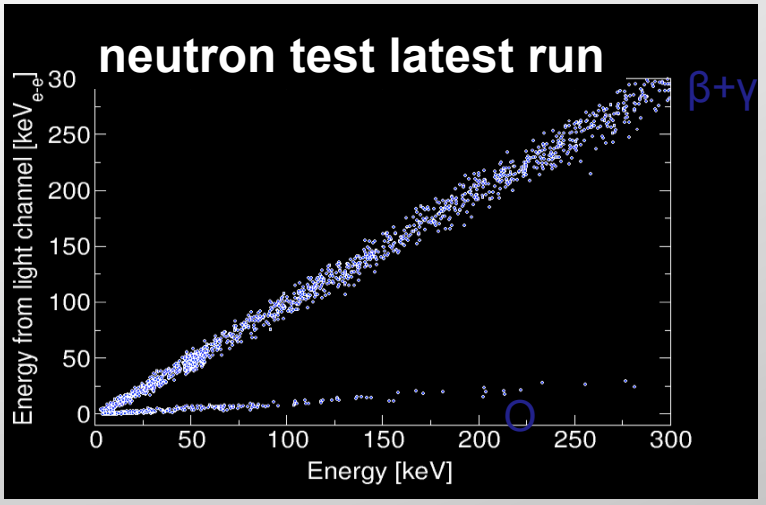
- **DAMA/LIBRA - phase 1 concluded:**
  the data of the last annual cycle will be released soon
- **New investigations on other rare processes in progress**

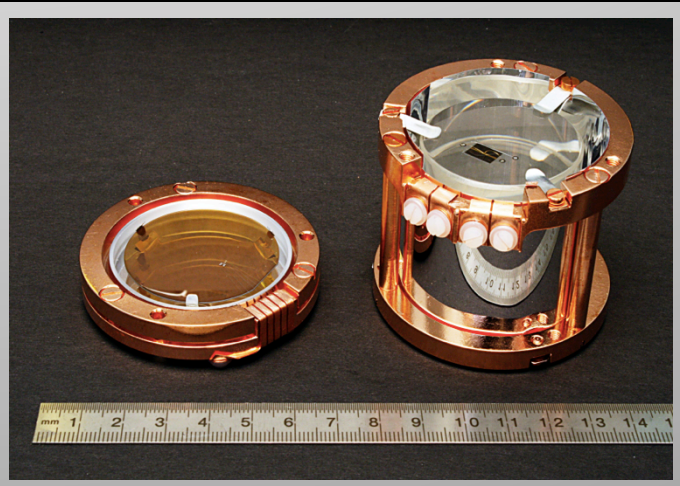
DAMA/NaI (7 years) + DAMA/LIBRA (6 years) Total exposure: 425428 kg×day = 1.17 ton×yr

EPJC 56(2008)333, EPJC 67(2010)39

CRESST-II







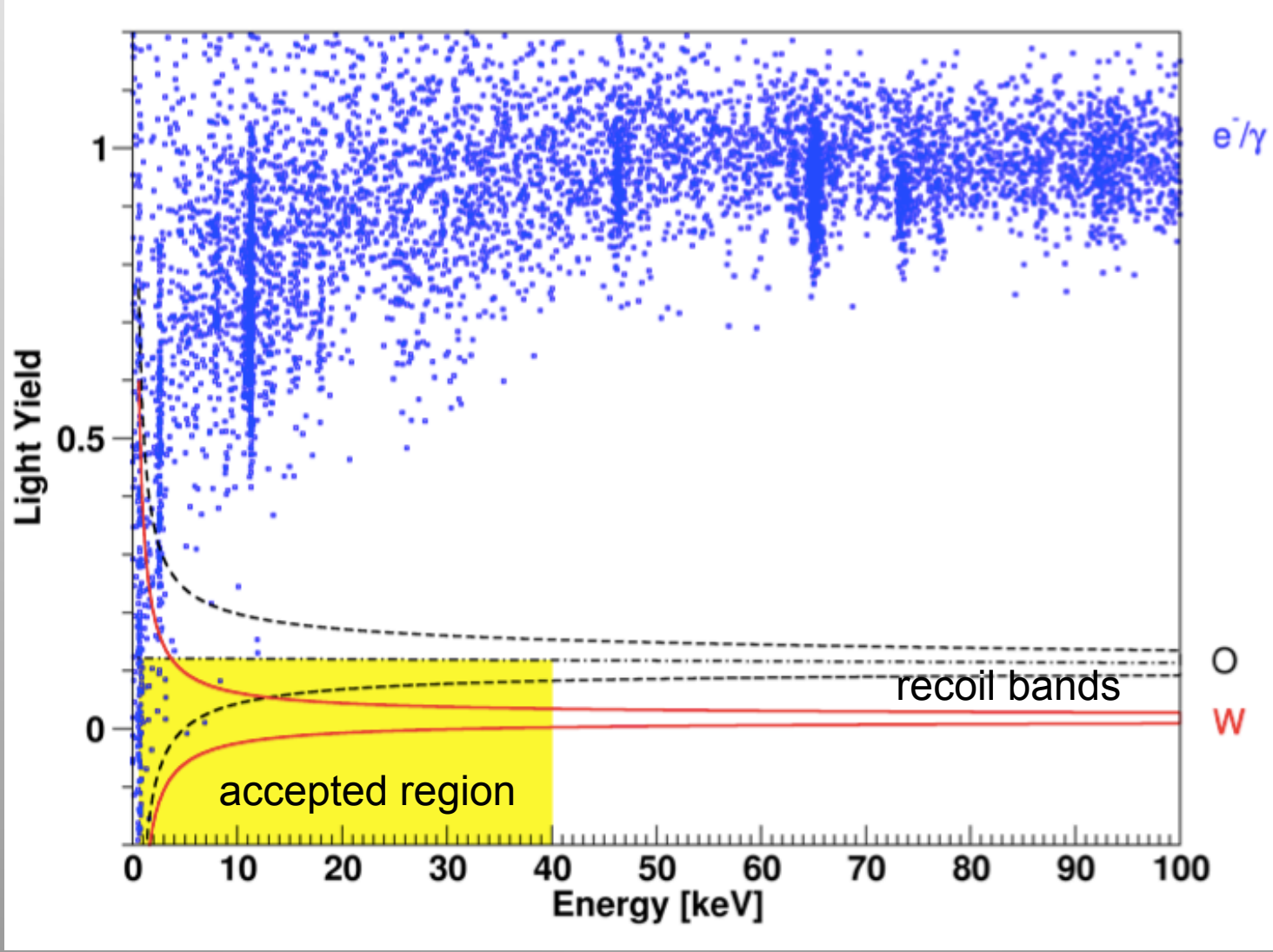
→ phonon channel provides precise measurement of deposited energy

→ Light channel distinguishes types of interaction

→ Types of recoiling nuclei distinguished by different slopes in light energy plane

CRESST-II

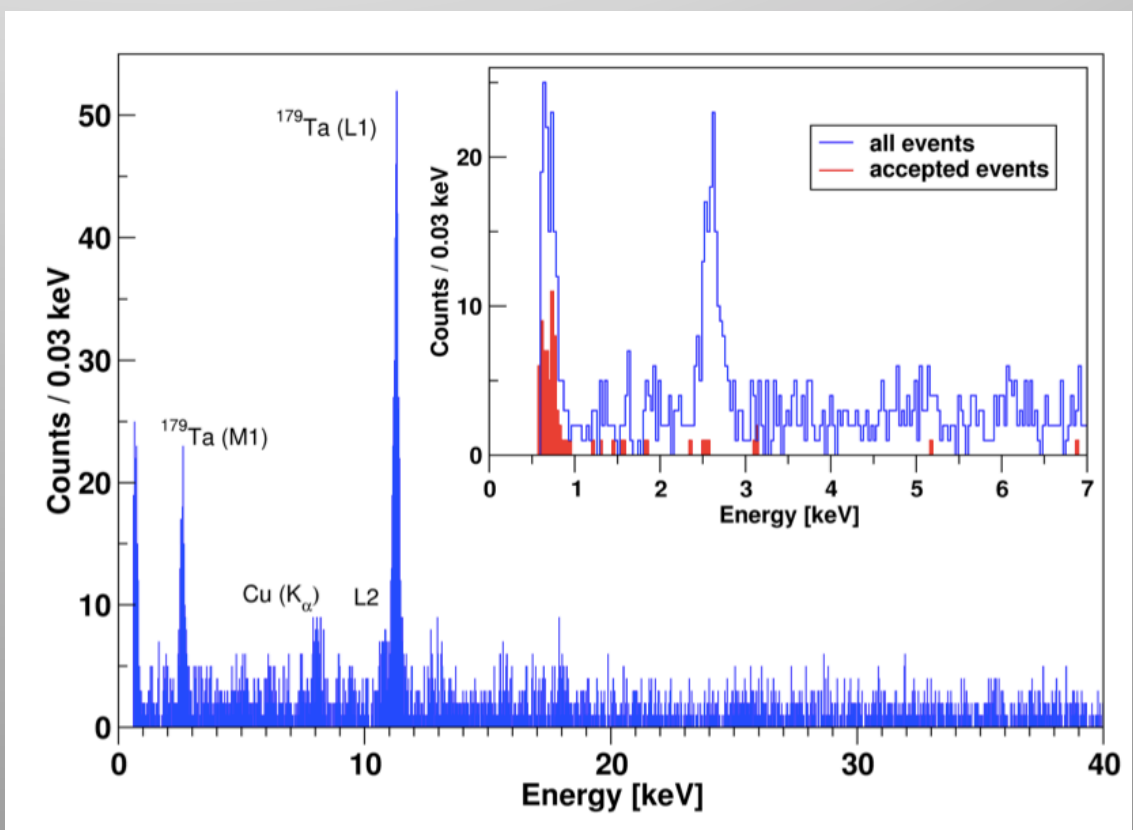
energy/LY discrimination



CRESST - II

- single upgraded detector module: new fully scintillating design (metal holding clamps replaced by $CaWO_4$ sticks)
- fully-efficient active discrimination of Pb recoils
- low-theshold analysis

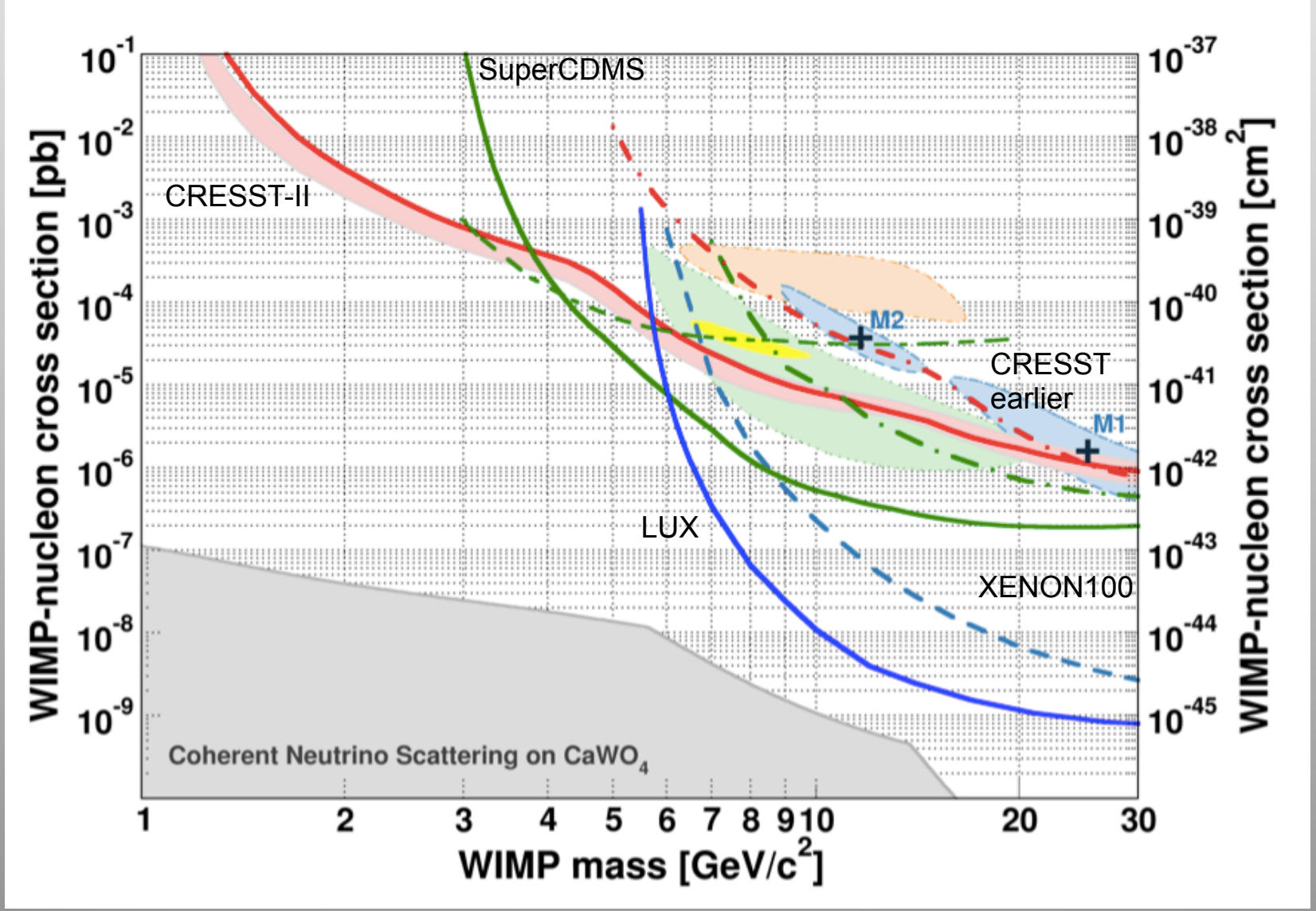
29.35 kg day live in 2013



- Blue: all events
- Red: accepted region events

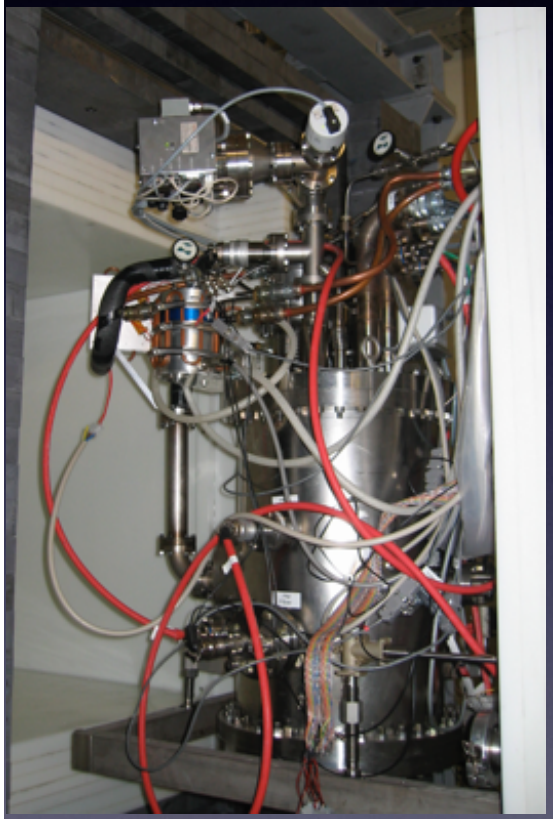
CRESST-II result

spin independent (~A^2) WIMP-nucleon scattering



The XENON DM program

2005 - 2007



XENON10

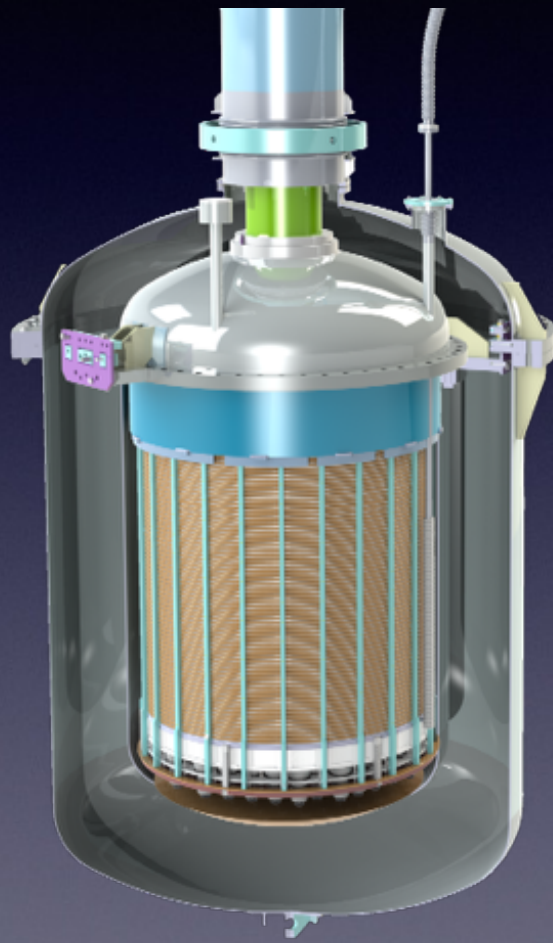
15 cm drift TPC - 25 kg

2008-2015

XENON100

30 cm drift TPC - 161 kg

2012- 2017

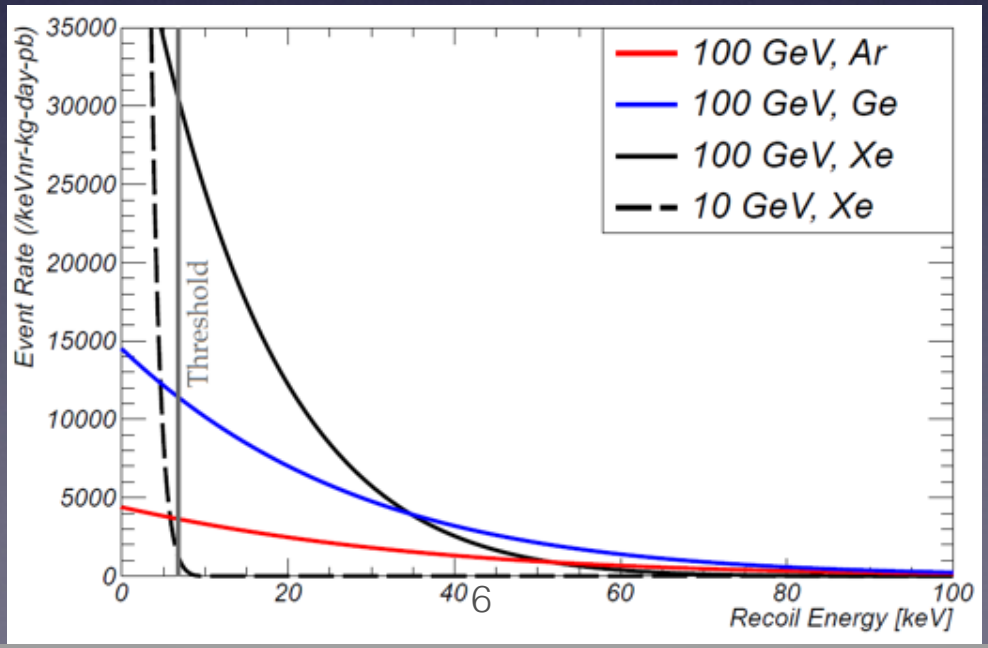


XENON1T

100 cm drift TPC - 3300 kg

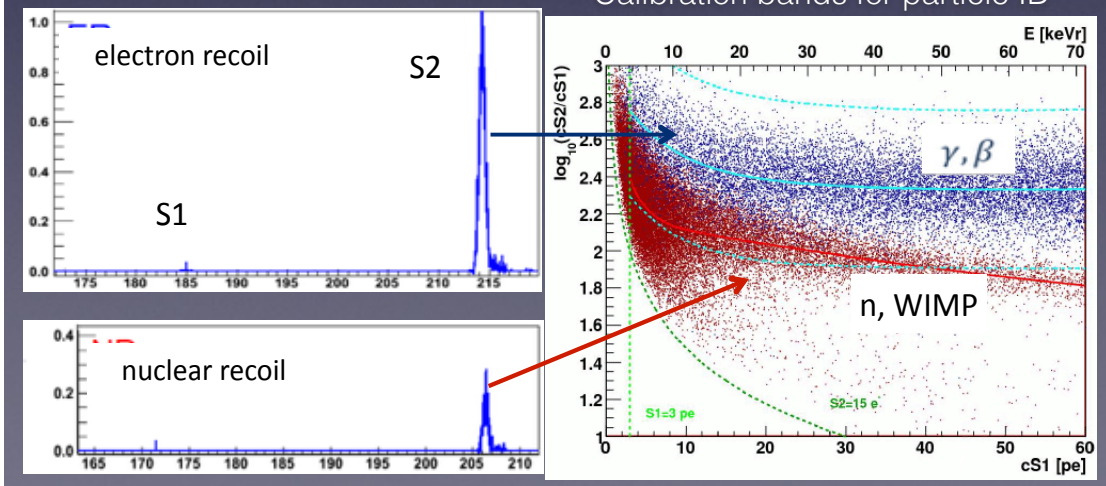
Liquid Xenon as WIMP detector

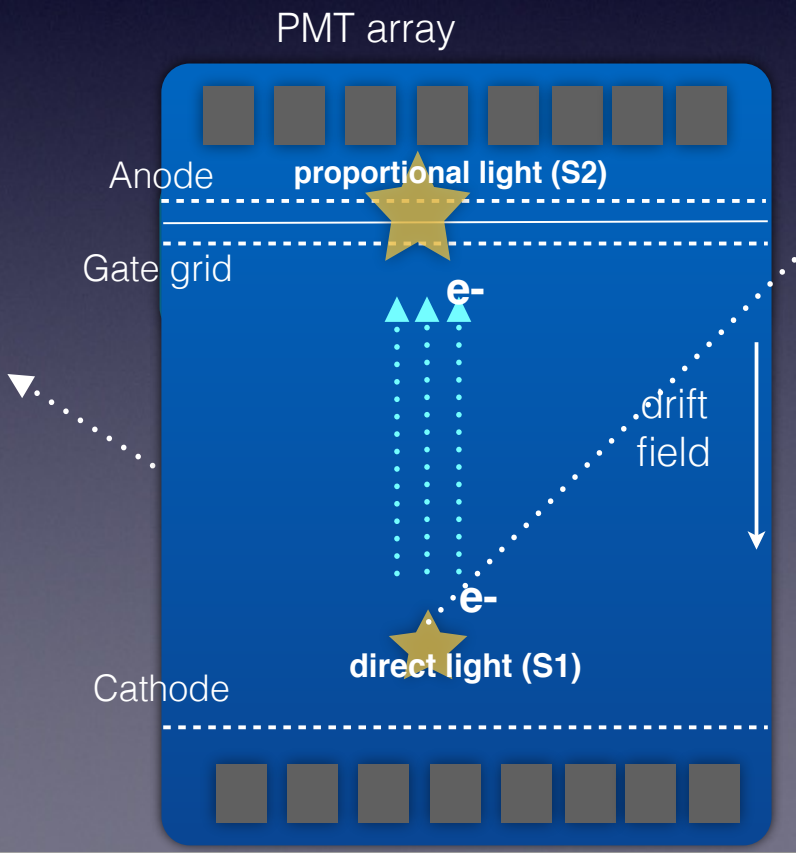
- Good target for both SI (A~131) and SD WIMP-N interactions (^{129}Xe & ^{131}Xe)
- Highest event rate for massive WIMPs
- Unique ability to measure single e^- with a two-phase TPC:
  - allows detection of light WIMPs through charge-channel only
- Enables large mass, homogeneous, self-shielded, easily scalable detector.
- Highest ionization and scintillation yield among all noble liquids
- Simultaneous charge and light detection enables ER/NR discrimination
- 3D event localization, double-scatter rejection and self-shielding provide powerful background rejection
- Excellent dielectric, inert, no long-lived radioactive isotopes.



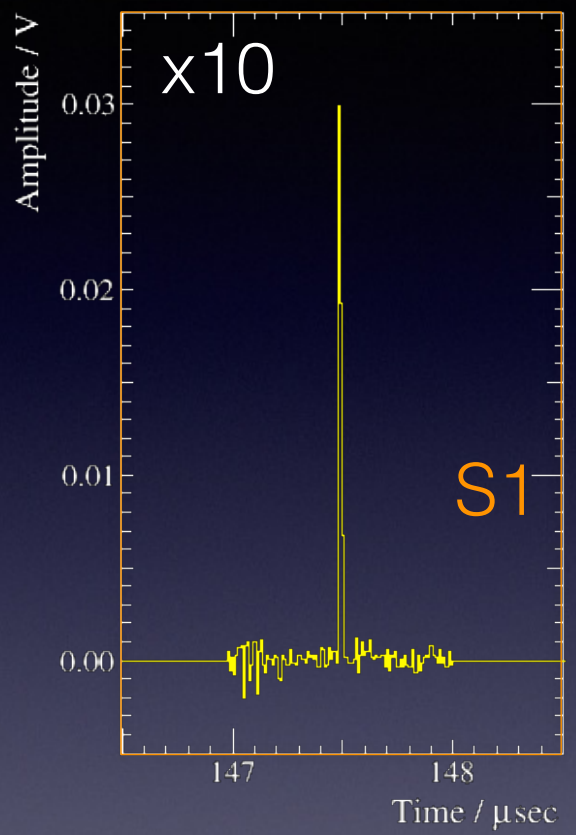
Double phase Xenon TPC

- Particle interaction in the active volume produces prompt scintillation (S1) and ionization electrons
- Electrons which reach the liquid/gas interface are extracted, accelerated in the gas gap and detected as proportional light (S2)
- PMTs in liquid and gas detect S1 and S2
- Charge/light depends on dE/dx: $(S2/S1)_{WIMP} << (S2/S1)_{gamma}$
- 3D-position sensitive detector with particle ID

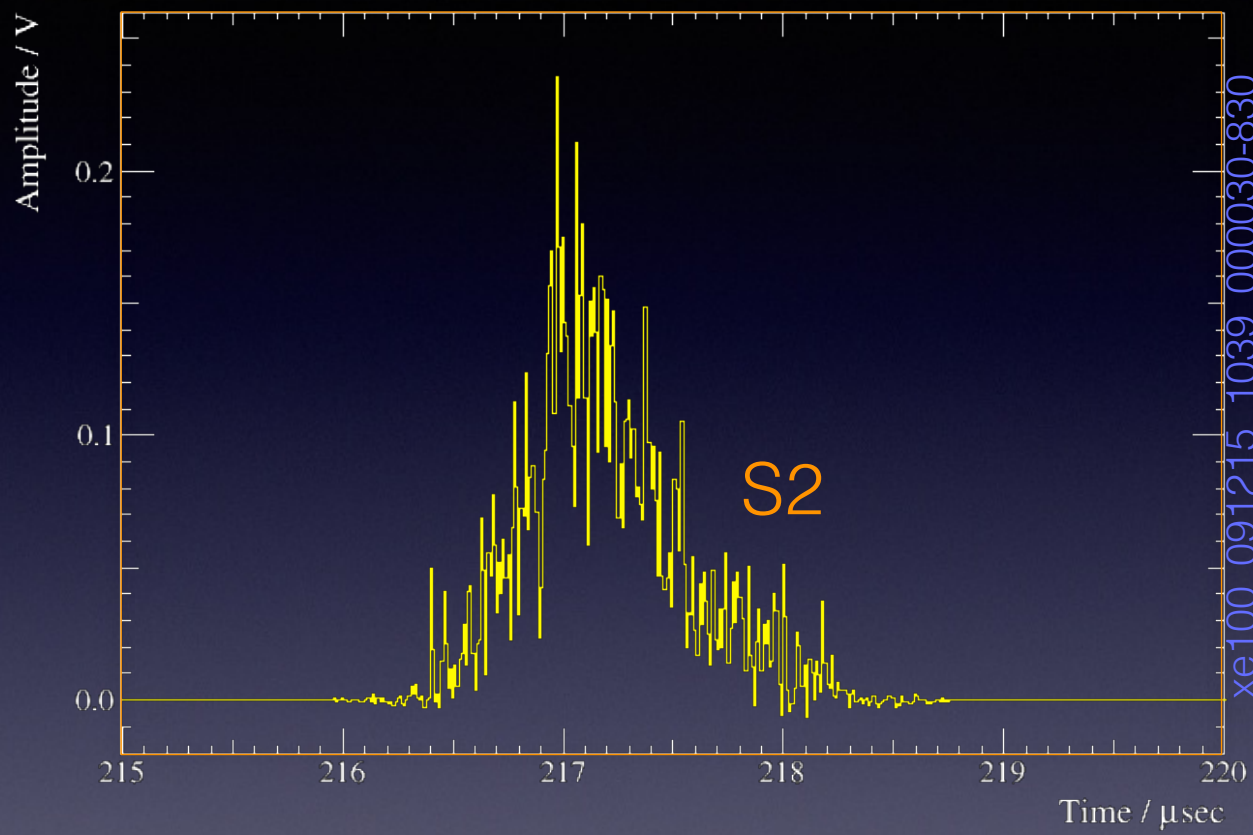




WIMP-like in XENON100



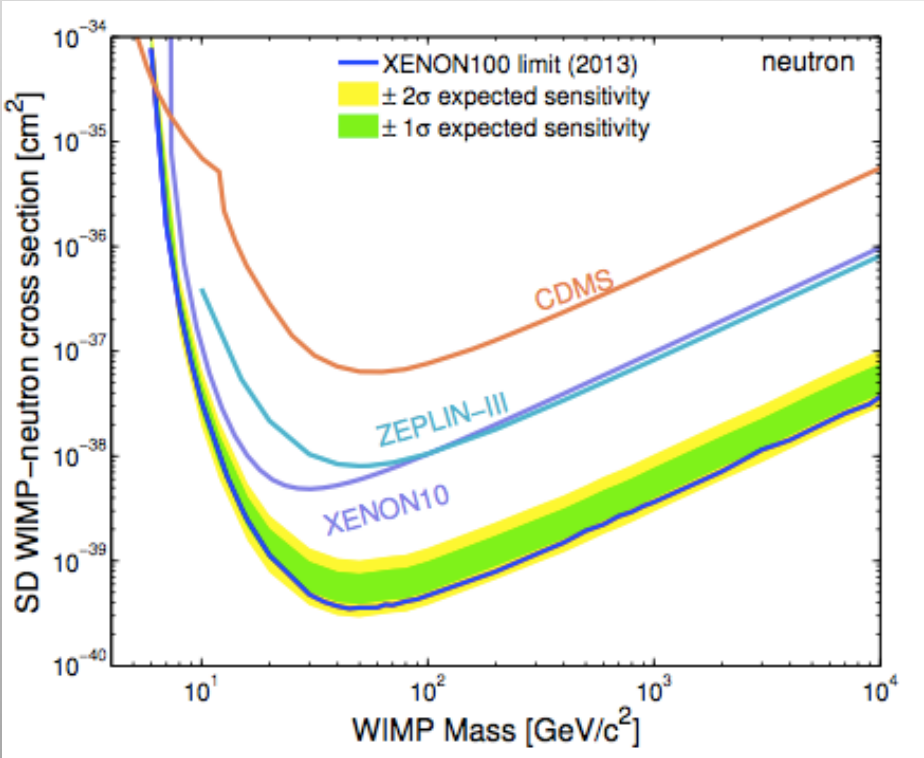
3.6 PE detected
(from ~100 S1 photons)

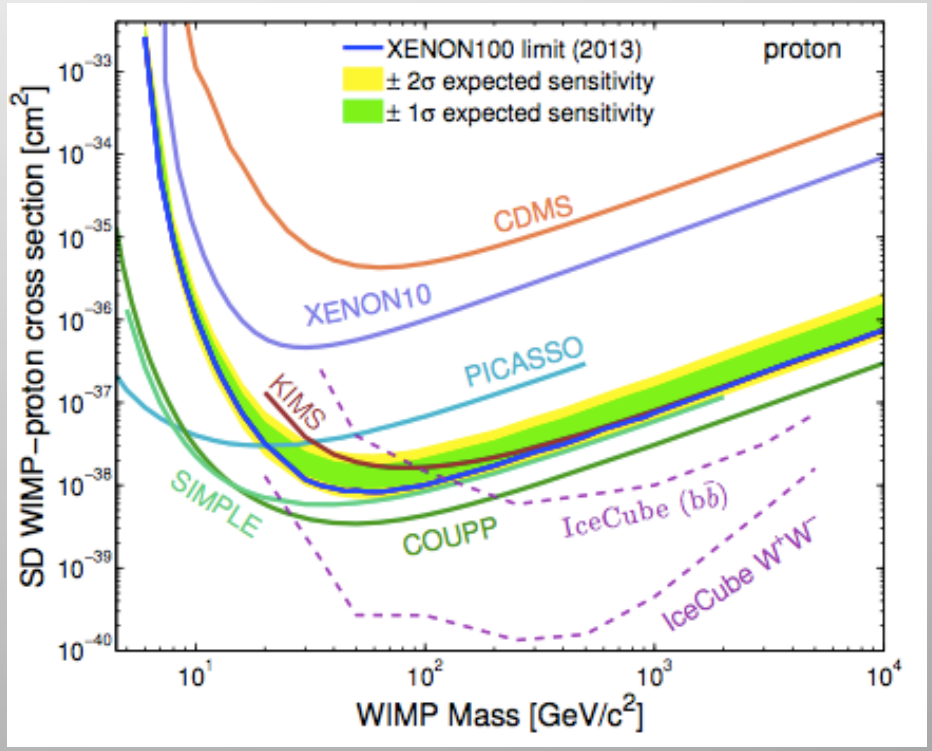


645 PE detected
(from 32 ionization electrons which generated ~3000 S2 photons)

XENON100 SD results

Bkg 5.3×10^{-3} $kg^{-1}d^{-1}$ before S1/S2 disceimination



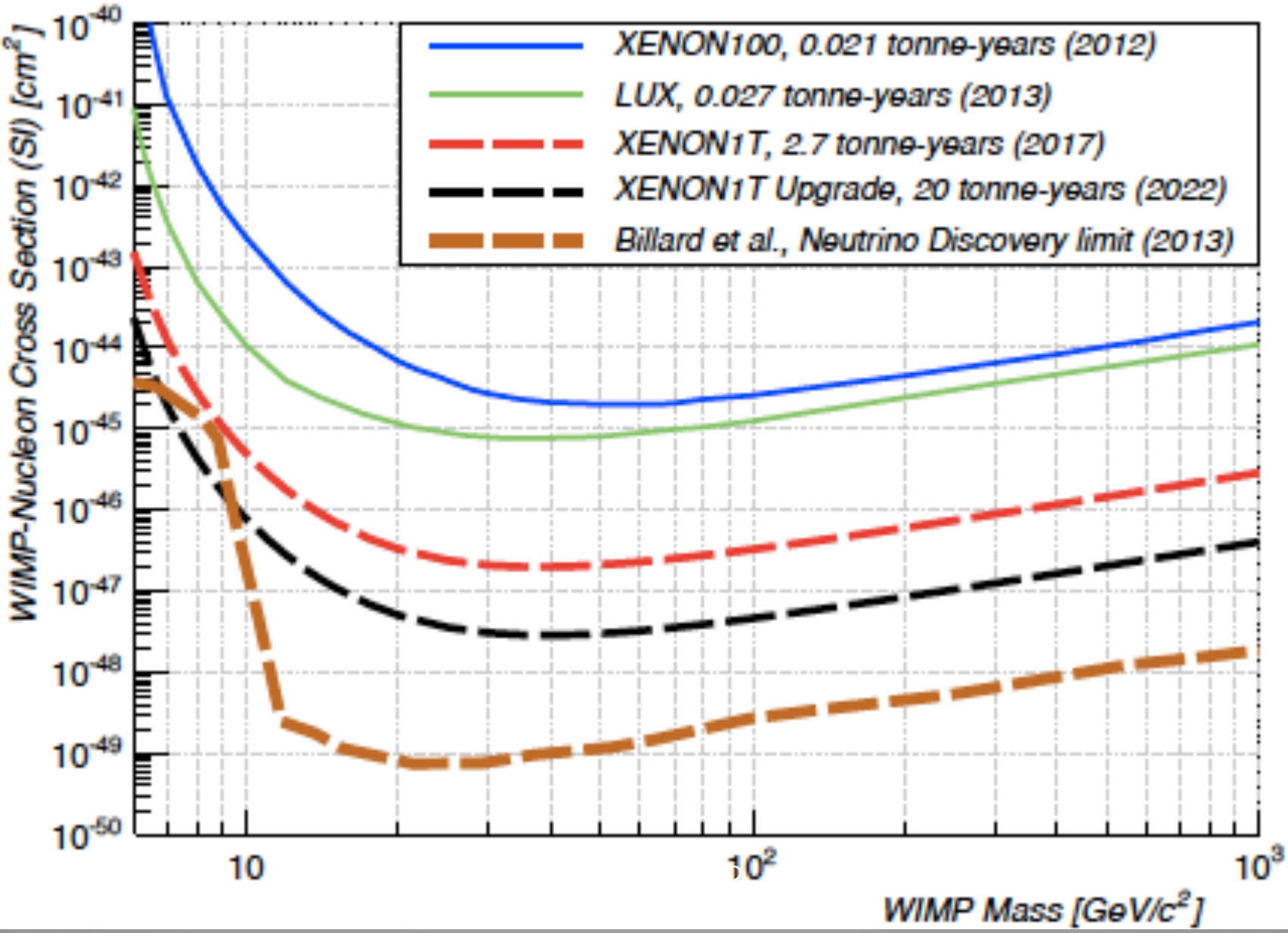


SI < 2×10^{-45} cm^2 for M=55 GeV

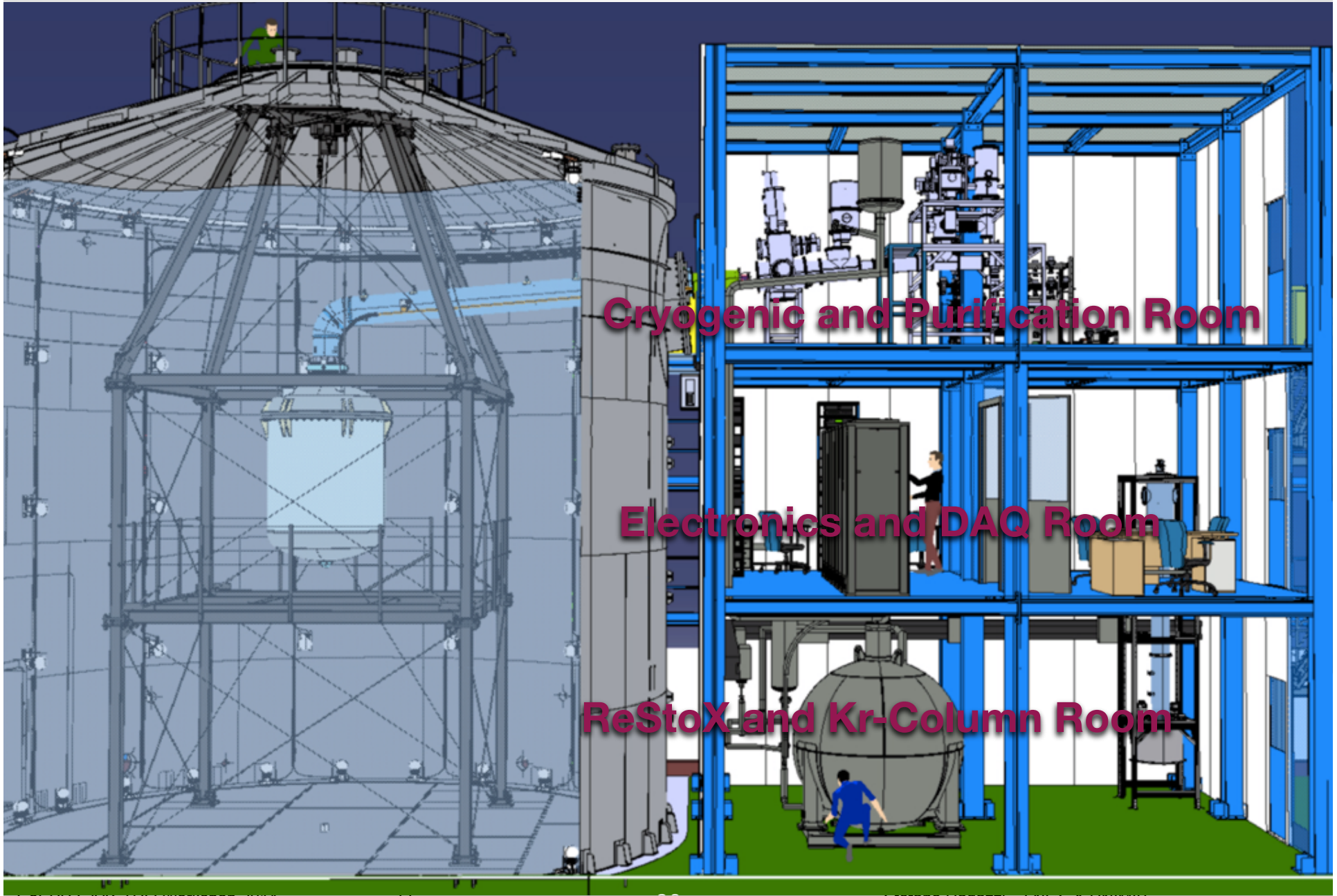
XENON1T

- Two-phase TPC with 1 meter drift and ~1 m diameter electrodes exploiting ~3.3 tonnes of Xe
- Experiment designed to enable a fast upgrade to a larger diameter TPC exploiting ~7 tonnes of Xe
- Schedule: under construction at LNGS started fall 2013
- Science Goal: 2×10^{-47} cm^2 with 2 ton-years of data or by 2017
- Funded with 50% of capital cost covered by NSF and the rest from Europe and Israel.

XENON1T sensitivity goal



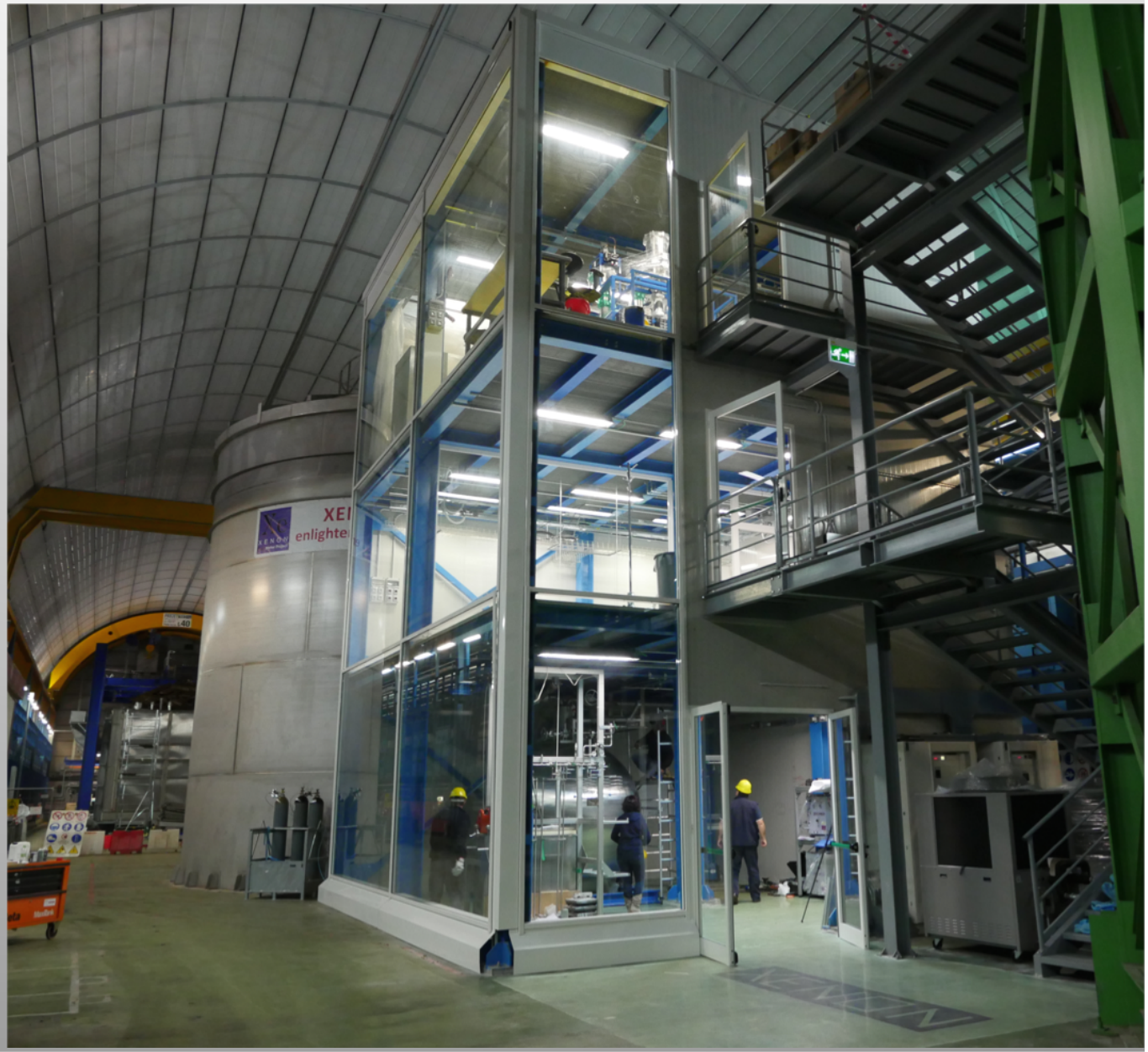
XENON1T Systems



XENON1T

HALL-B
Sep. 2014

Data in summer
2015



Outreach

OPEN DAY @ LNGS:1.500-2.000 visitors/year

Visits to underground lab:
8000 visitors/year

Labs for young students: 500-1000 students/years

Competitions for schools: ~1700 students/year

Summer Schools for students and teachers

ITIS GALILEO : theatre performance in the underground lab; was seen by 2.5 million people on a national TV channel.