UZH Node Activities in Astroparticle Physics

Invisibles Meeting

Madrid, March, 2012

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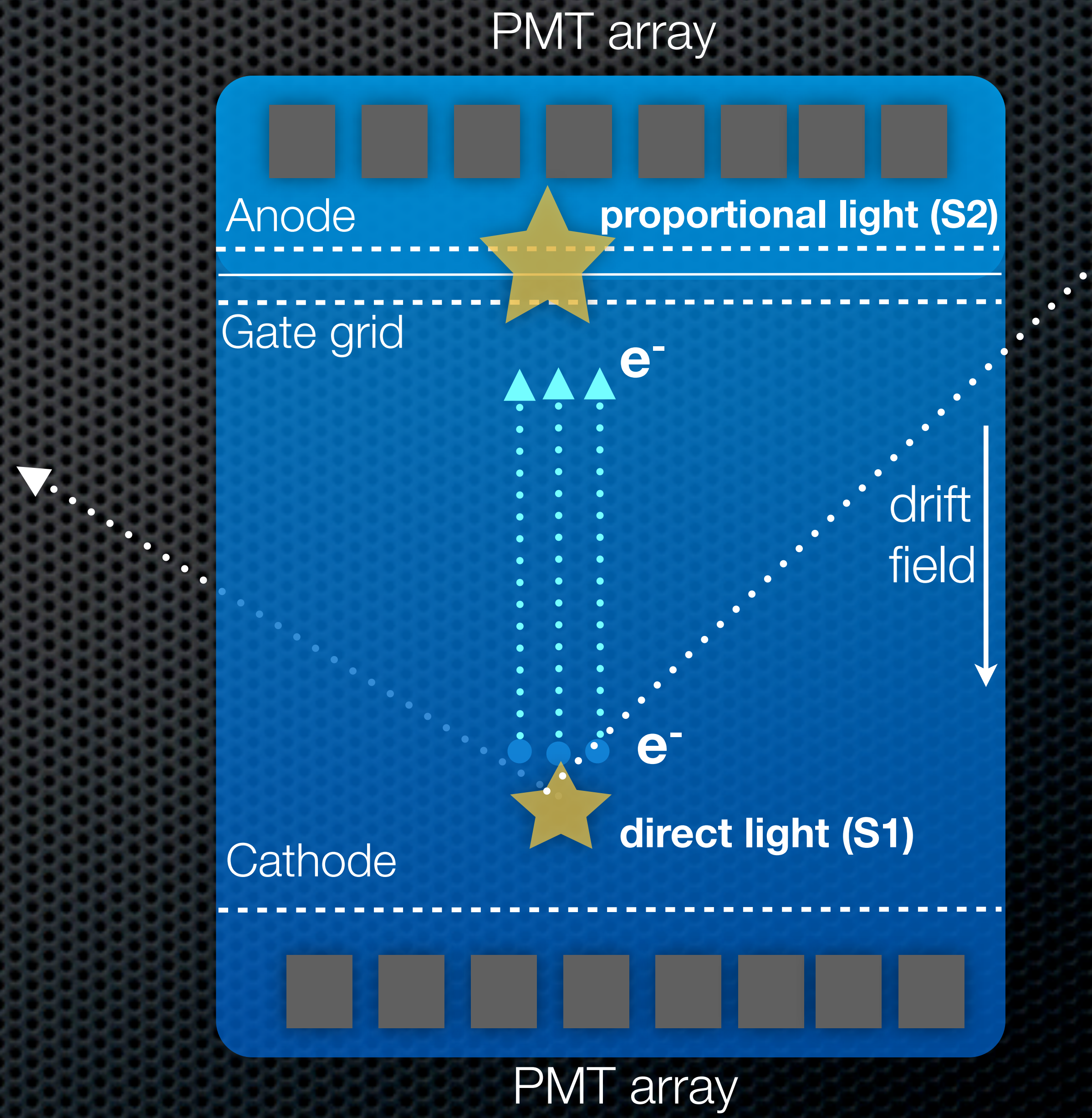
Dark matter search with noble Liquids TPCs

- Large, scalable, homogeneous and self-shielding detectors
- *Prompt (S1)* light signal after interaction in the active volume
- Charge is drifted, extracted into the gas phase and detected as *proportional light (S2)*

- charge/light depends on dE/dx
- good 3D position resolution

=> particle identification
=> fiducial volume cuts
+ self-shielding

Ar (A = 40); λ = 128 nm
Xe (A=131); λ = 178 nm



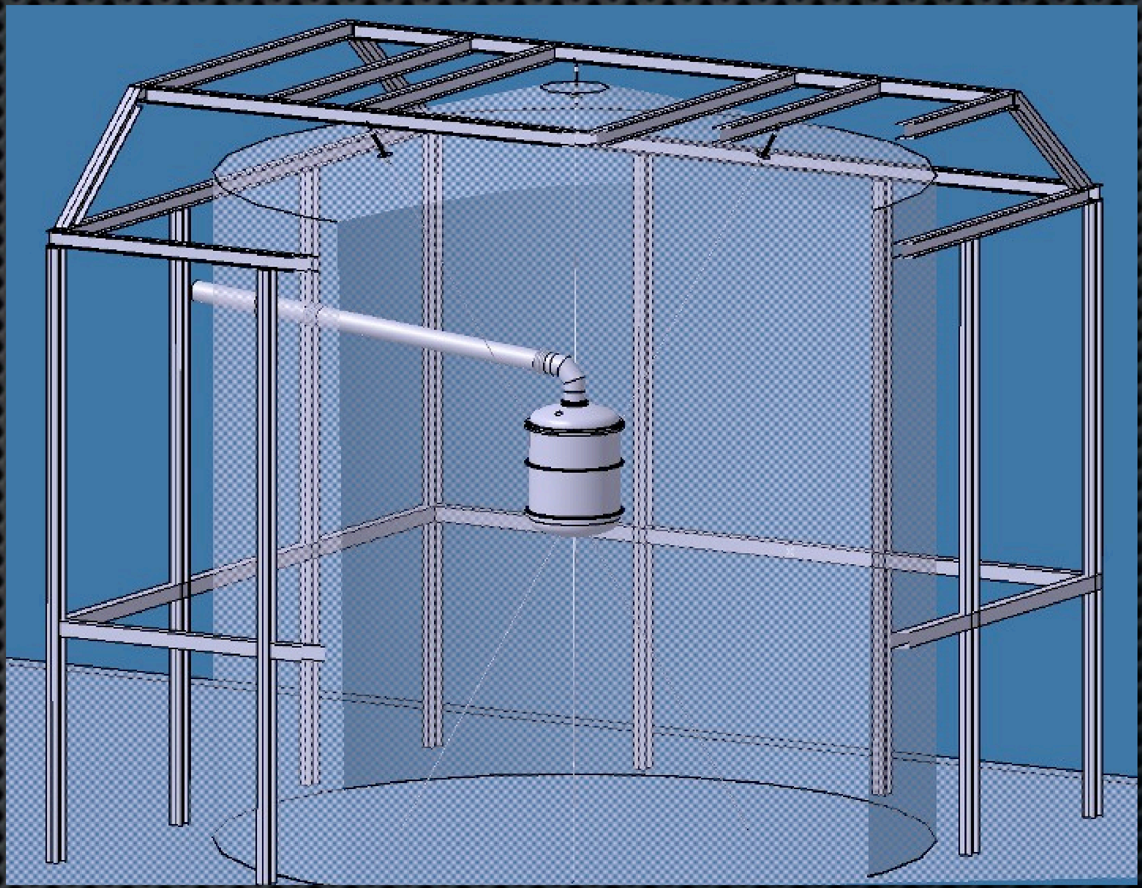
The XENON Experiment

XENON100

1 m

In conventional shield at LNGS
2008 - 2012; taking science data

XENON1T

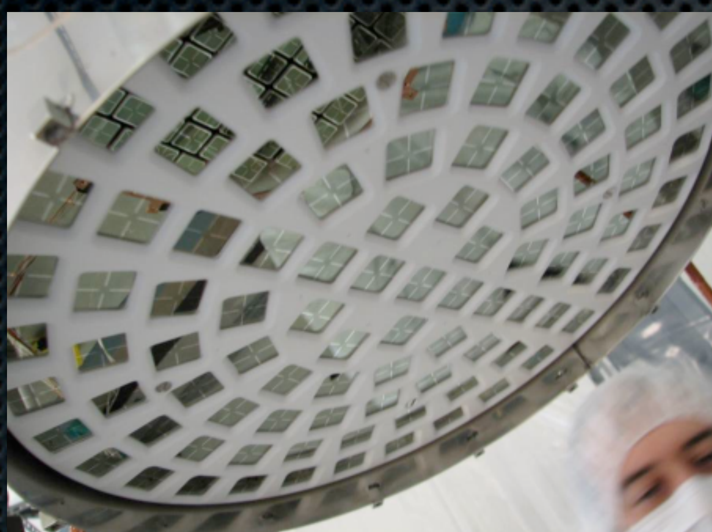


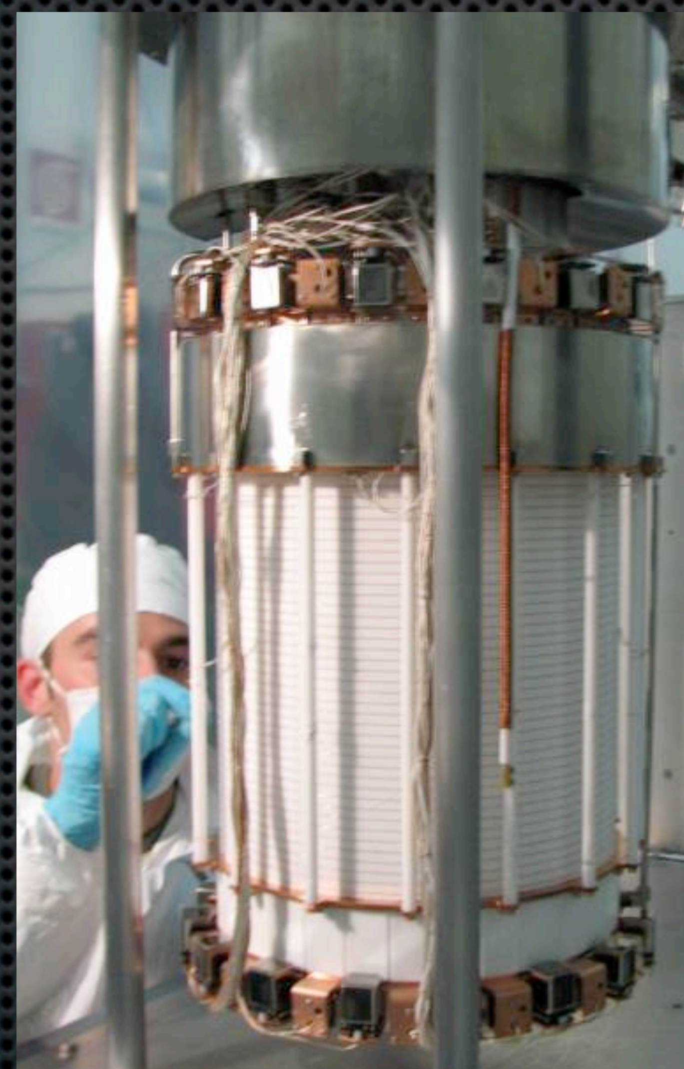
10 m

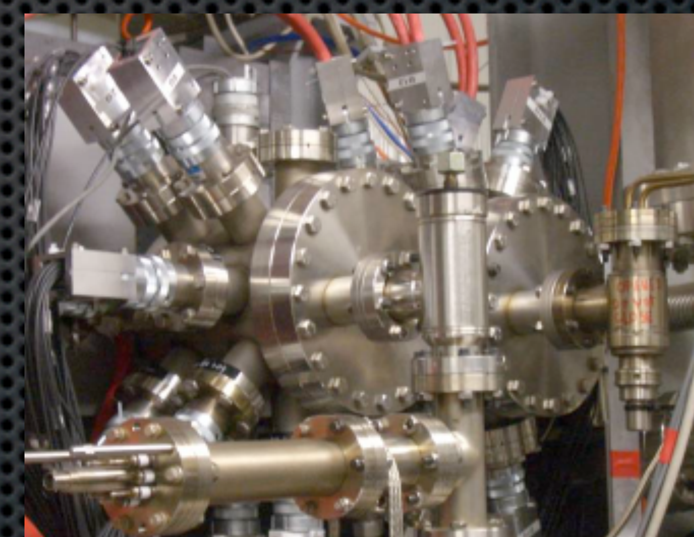
In water Cerenkov shield at LNGS
2011- 2015; construction to start in
second half of 2012

The XENON100 Detector

- 161 kg of ultra-pure liquid xenon (LXe), 62 kg in the active target volume
- 30 cm drift gap TPC with two PMT arrays (242 PMTs) to detect the prompt and proportional scintillation signals







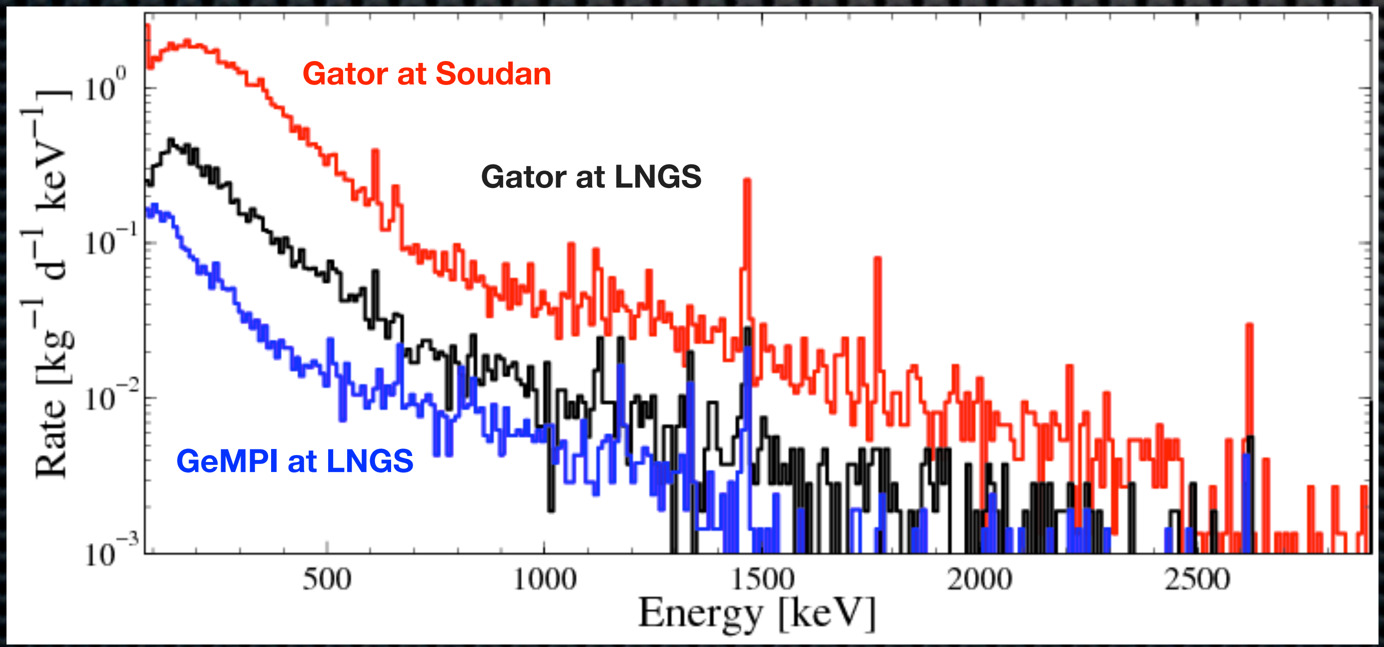
UZH XENON Activities

- Detector calibration (leading the calibration WG)
- Background studies (MC simulations and background predictions)
- Data acquisition system, trigger, electronics
- Analysis (co-leading the analysis effort, together with Columbia)
- Material screening (leading the screening WG)
- For XENON1T: TPC design/construction (with Columbia/Rice/UCLA), photosensor testing (with UCLA/Columbia) and calibration, screening (with MPIK) and DAQ (with Nikhef), light collection efficiency Monte Carlos
- In our UZH laboratory: tests of a ^{83m}Kr calibration source (with the Xürich detector), measurement of the light yield of low-energy electronics and nuclear recoils (Xürich), R&D for XENON1T and DARWIN (with MarmotX)

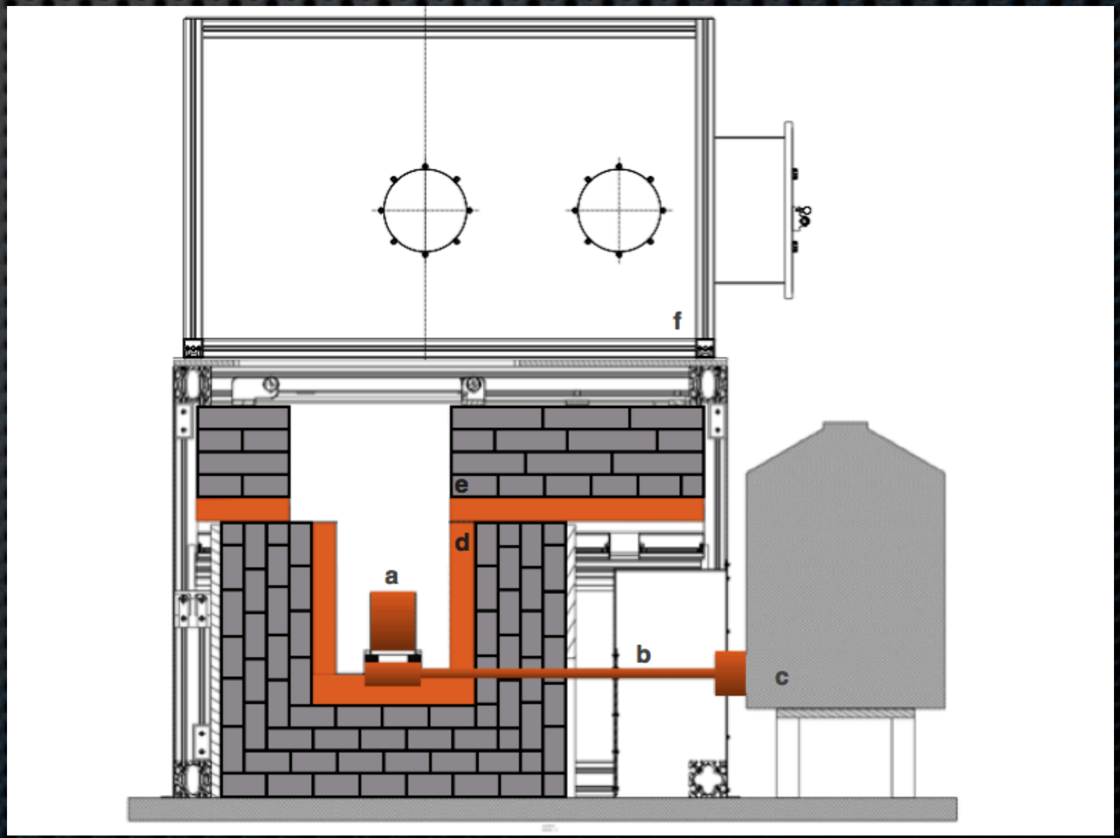
XENON100 Materials

- All detector and shield materials were screened with dedicated, ultra-low background HPGe facilities at LNGS and selected according to their radio-purity
- More than 60 components screened
- Results available (Astropart. Phys. 35:43-49, 2011 arXiv:1103.5831)

Gator's background spectrum



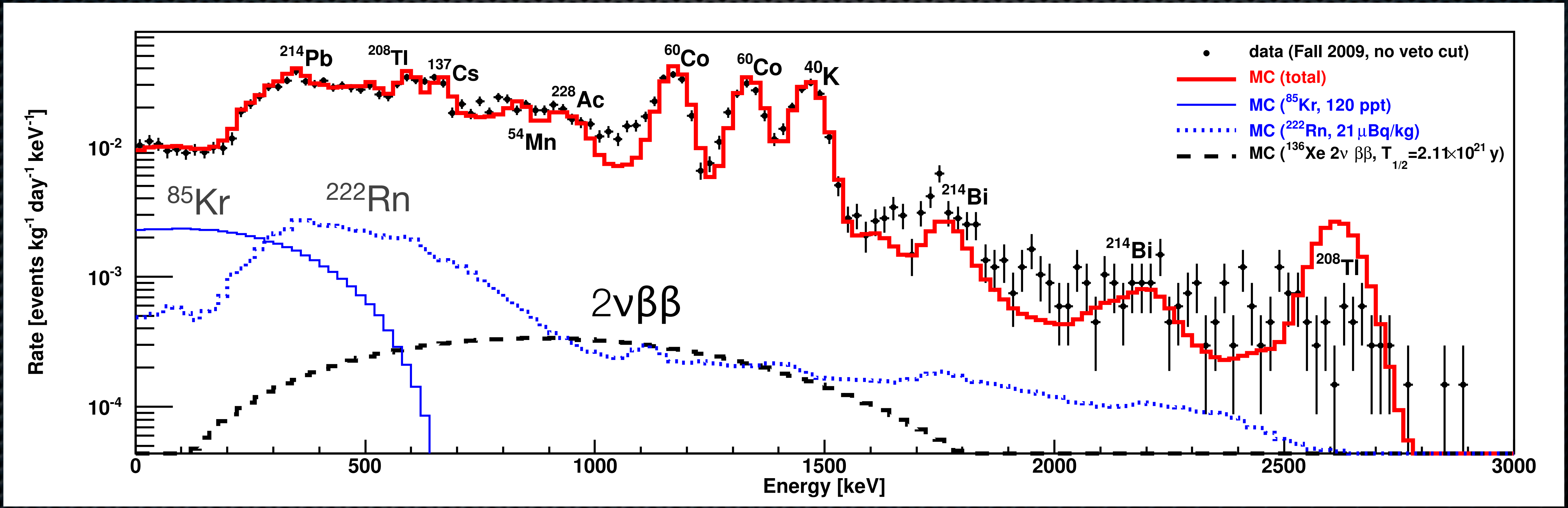
The Gator HPGe facility at LNGS



L. Baudis et al., JINST 6 P08010, 2011

XENON100 Backgrounds: Data and Predictions (UZH PhD thesis, A. Kish)

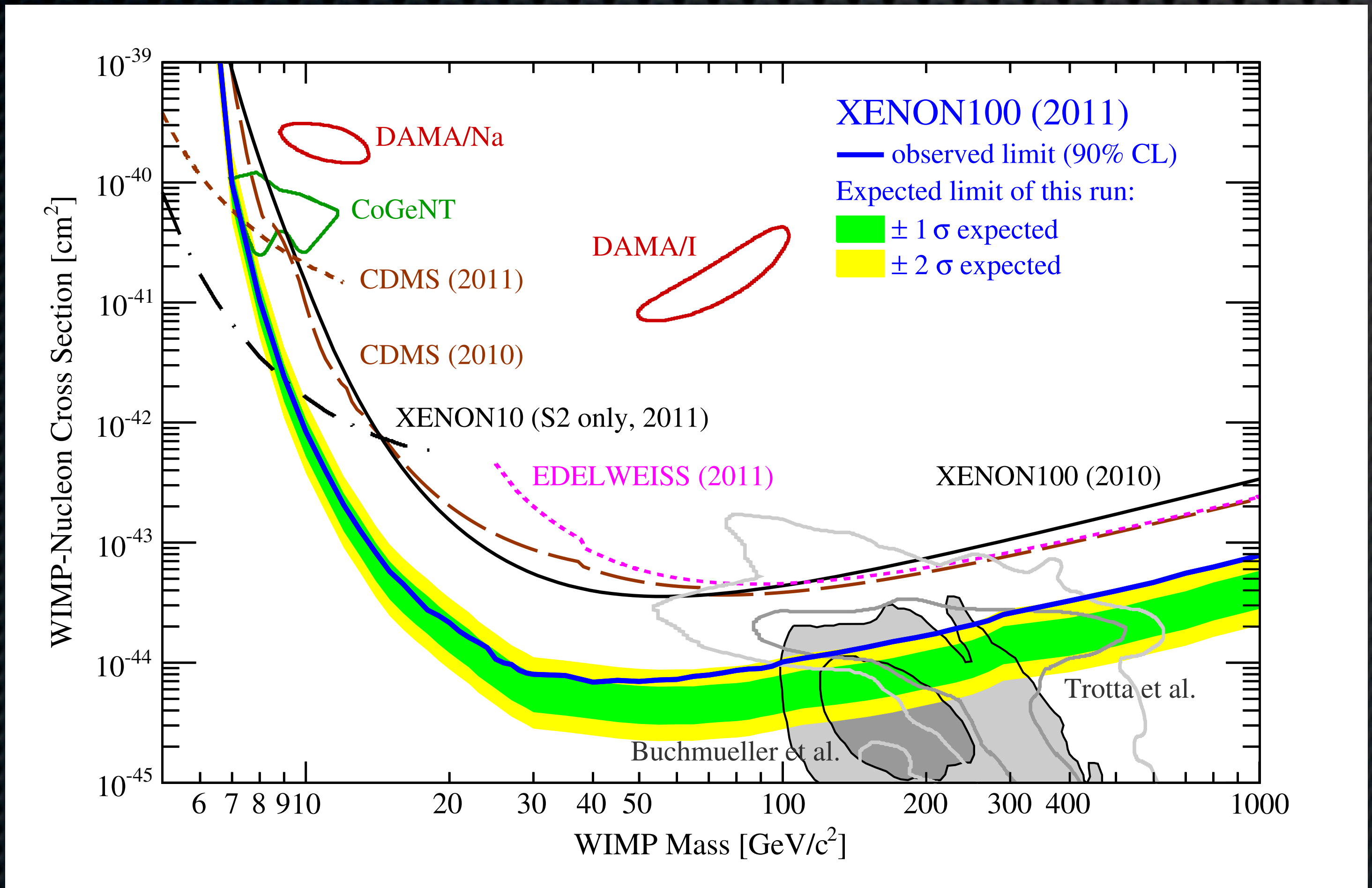
- Data versus Monte Carlo simulations (no MC tuning, input from screening values for U/Th/K/Co/Cs etc of all detector components); no active liquid xenon veto cut
- Background is 100 times lower than in XENON10 (the previous XENON phase)



XENON100 collaboration, arXiv:1101.3866, PRD 83, 082001 (2011)

XENON100: Recent Results

Phys. Rev. Lett. 107, 131302 (2011)



Green/yellow bands:

1- and 2-σ expectation, based on zero signal

Limit (dark blue):

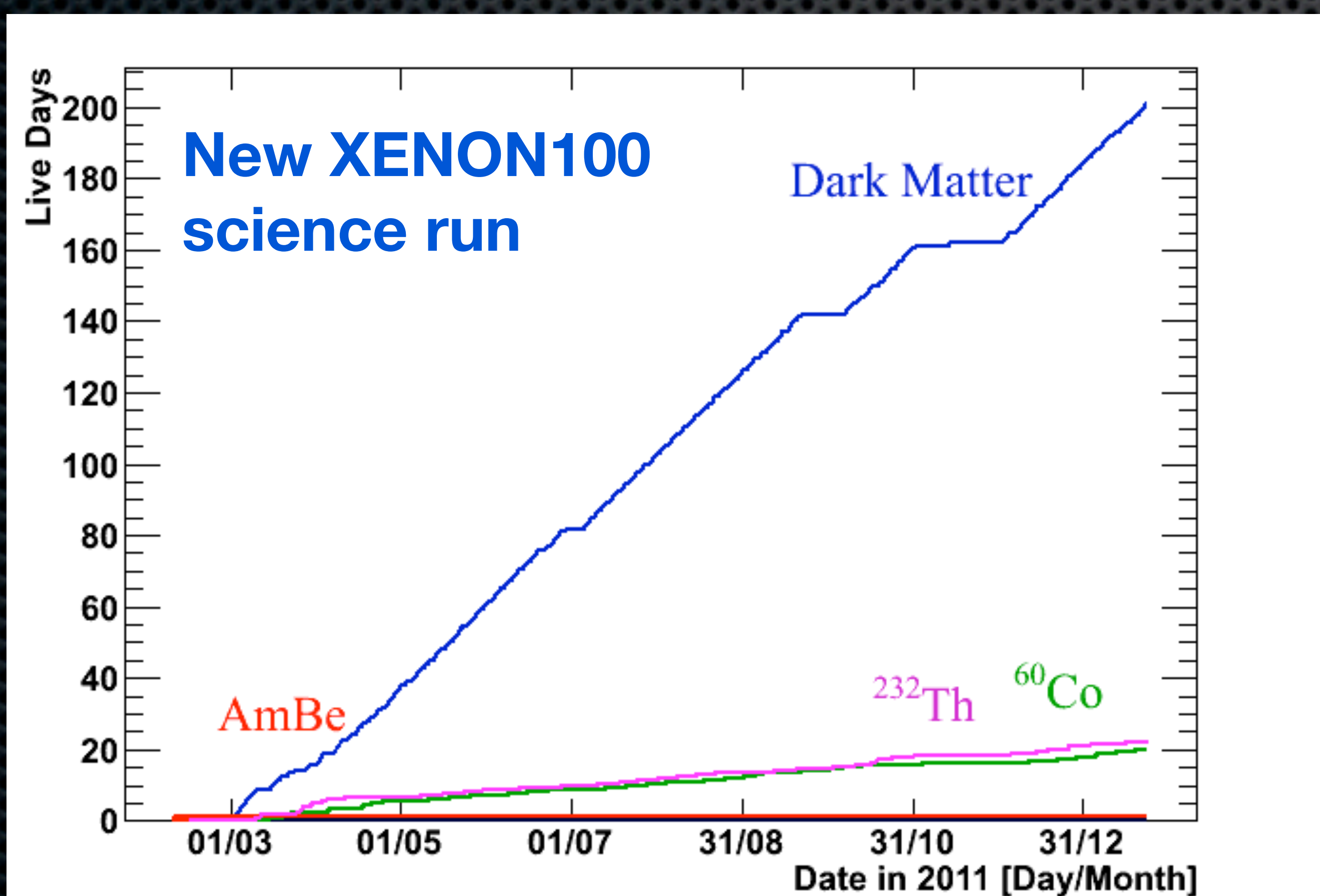
1.5 - 2 σ worse, given 2 events at high S1

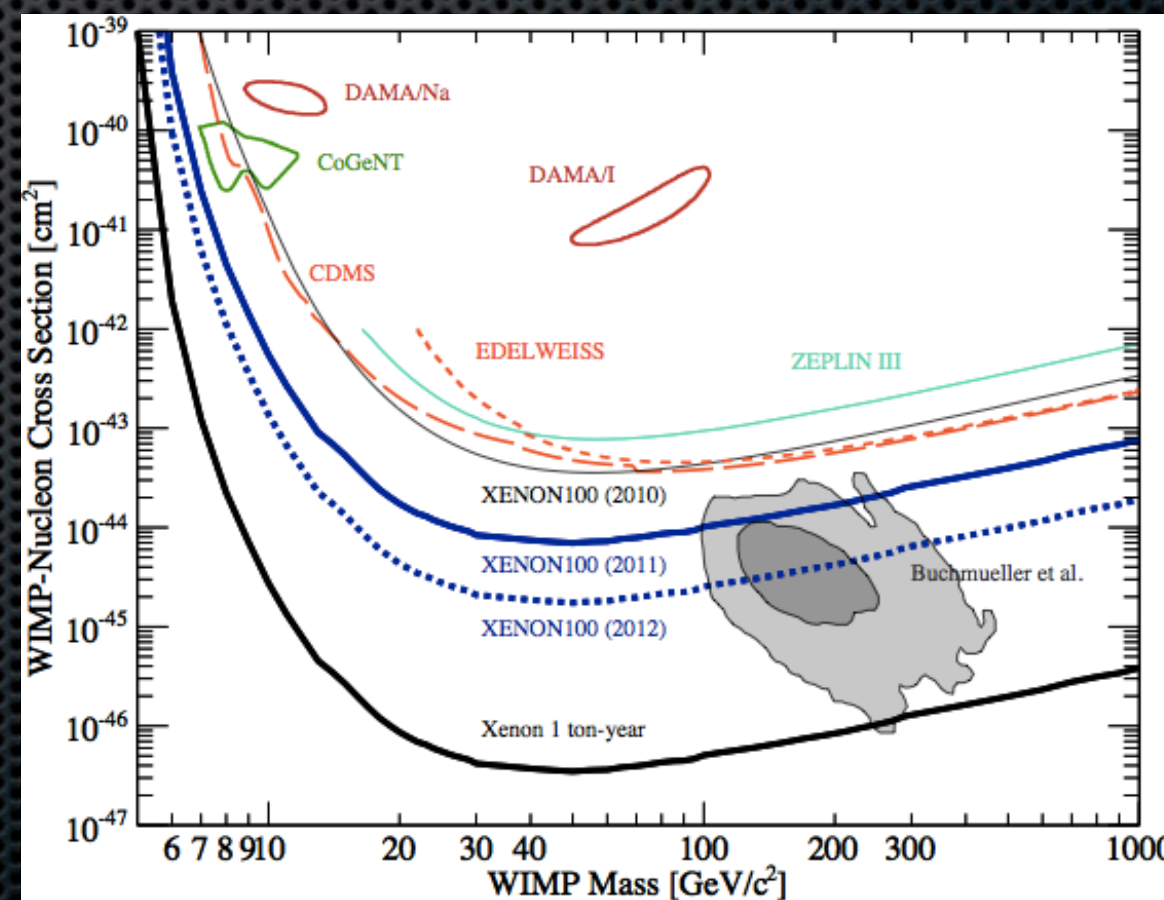
Limit at M_W = 50 GeV:

7 x 10^{-45} cm^2 (90% C.L.)

XENON: status and sensitivity

- New dark matter run started in March 2011 (~ 203 live days of data)
- Concentration of ^{85}Kr: lower by a factor of 5
- Improved LXe purity and lower trigger threshold
- Analysis in progress; release of results beginning of April
- In parallel: construction of XENON1T @ LNGS

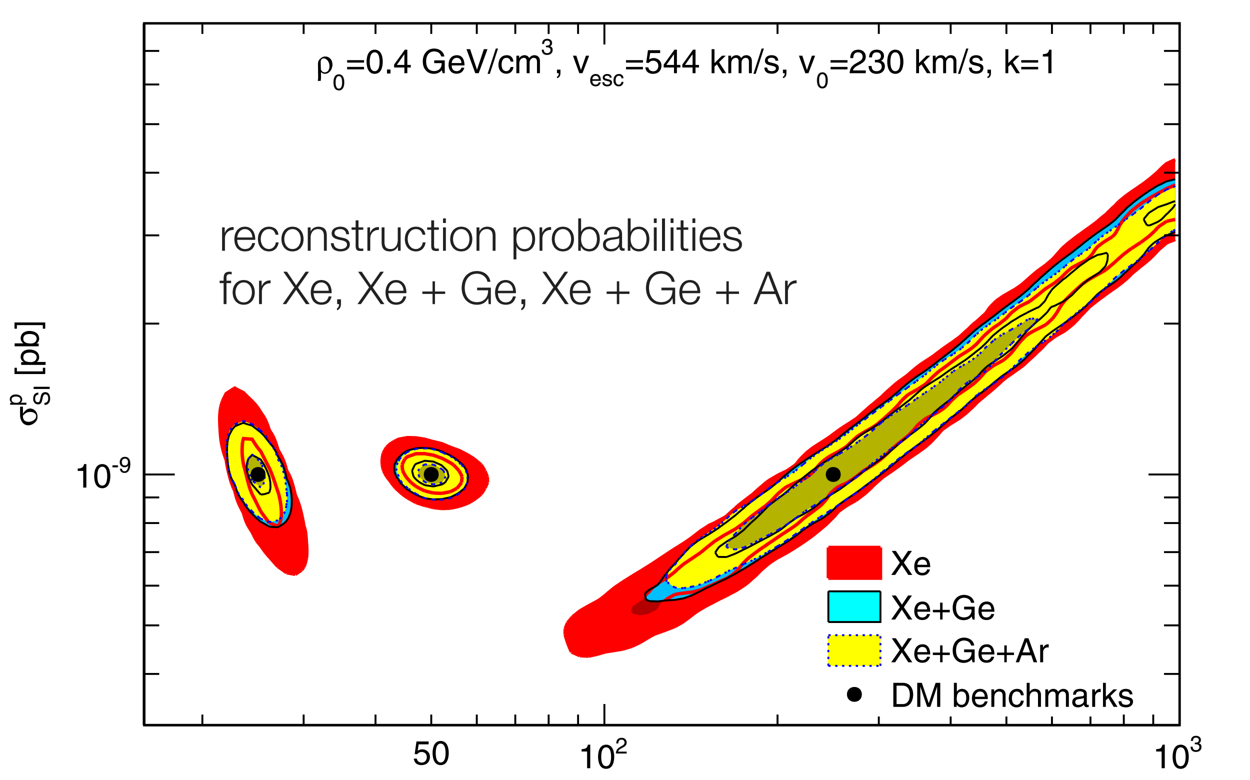




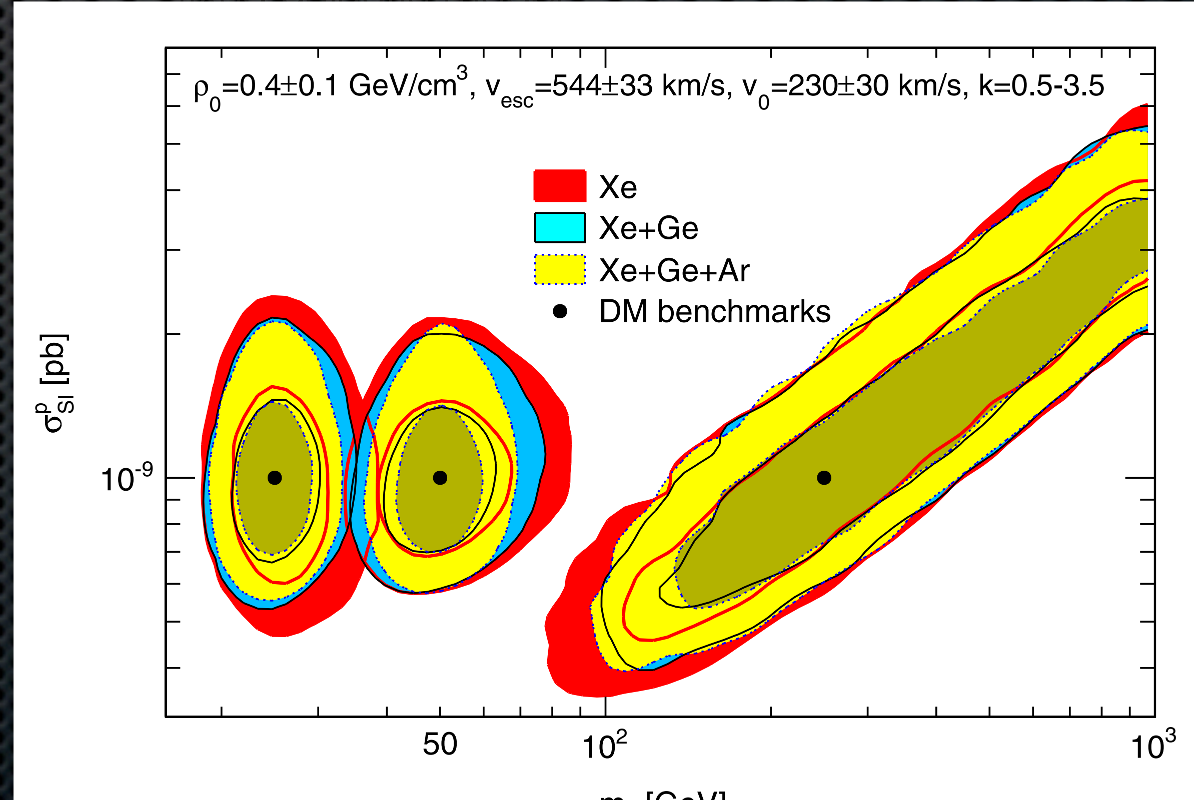
Collaboration with theorists, example

- To reconstruct WIMP properties, *larger detectors are needed*
- Different targets are sensitive to different directions in the m_χ- σ_{SI} plane

target	ϵ [ton×yr]	η_{cut}	A_{NR}	ϵ_{eff} [ton×yr]	E_{thr} [keV]	$\sigma(E)$ [keV]	background events/ϵ_{eff}
Xe	5.0	0.8	0.5	2.00	10	Eq. (7)	< 1
Ge	3.0	0.8	0.9	2.16	10	Eq. (6)	< 1
Ar	10.0	0.8	0.8	6.40	30	Eq. (8)	< 1



fixed galactic model



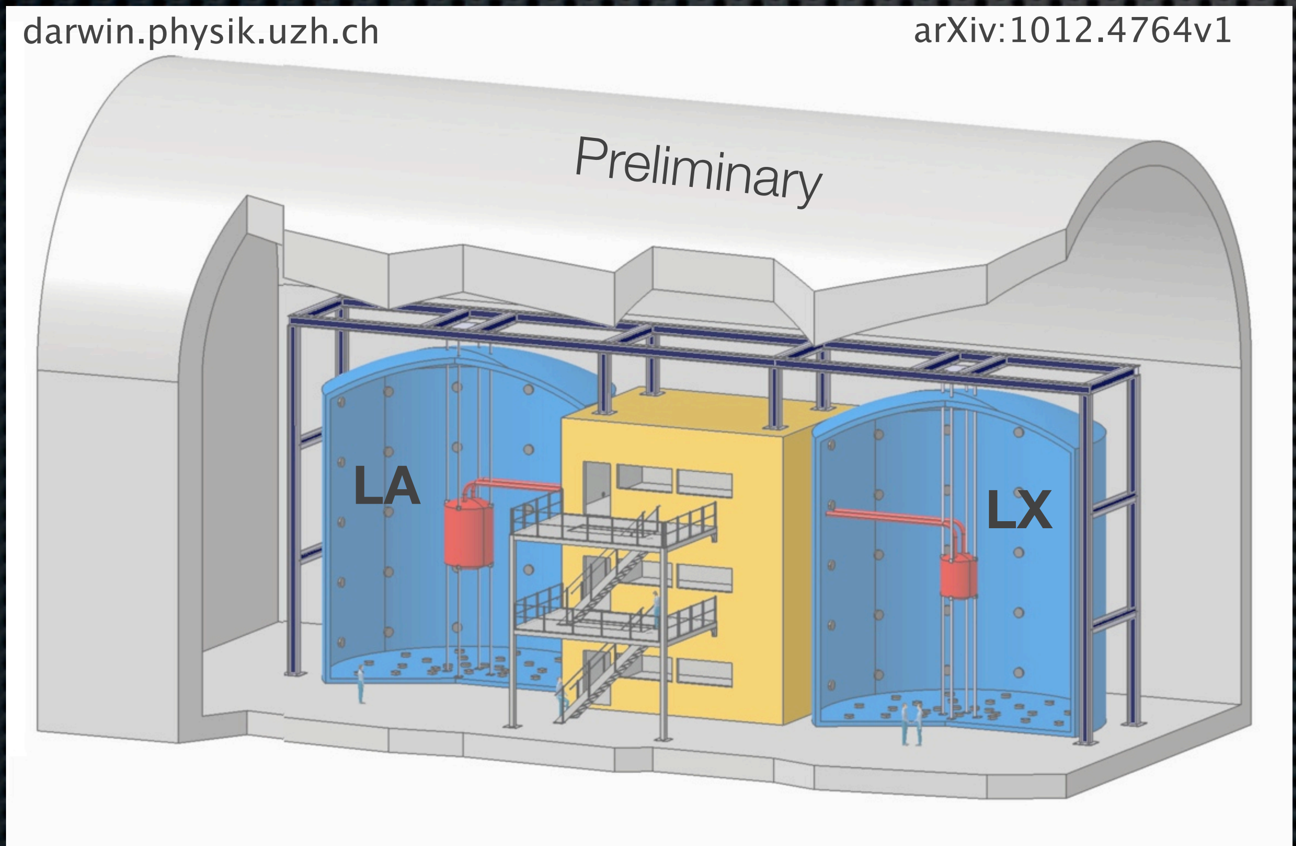
including galactic uncertainties

Miguel Pato, Laura Baudis, Gianfranco Bertone, Roberto Ruiz de Austri, Louis E. Strigari and Roberto Trotta   Phys. Rev. D 83, 083505 (2011)

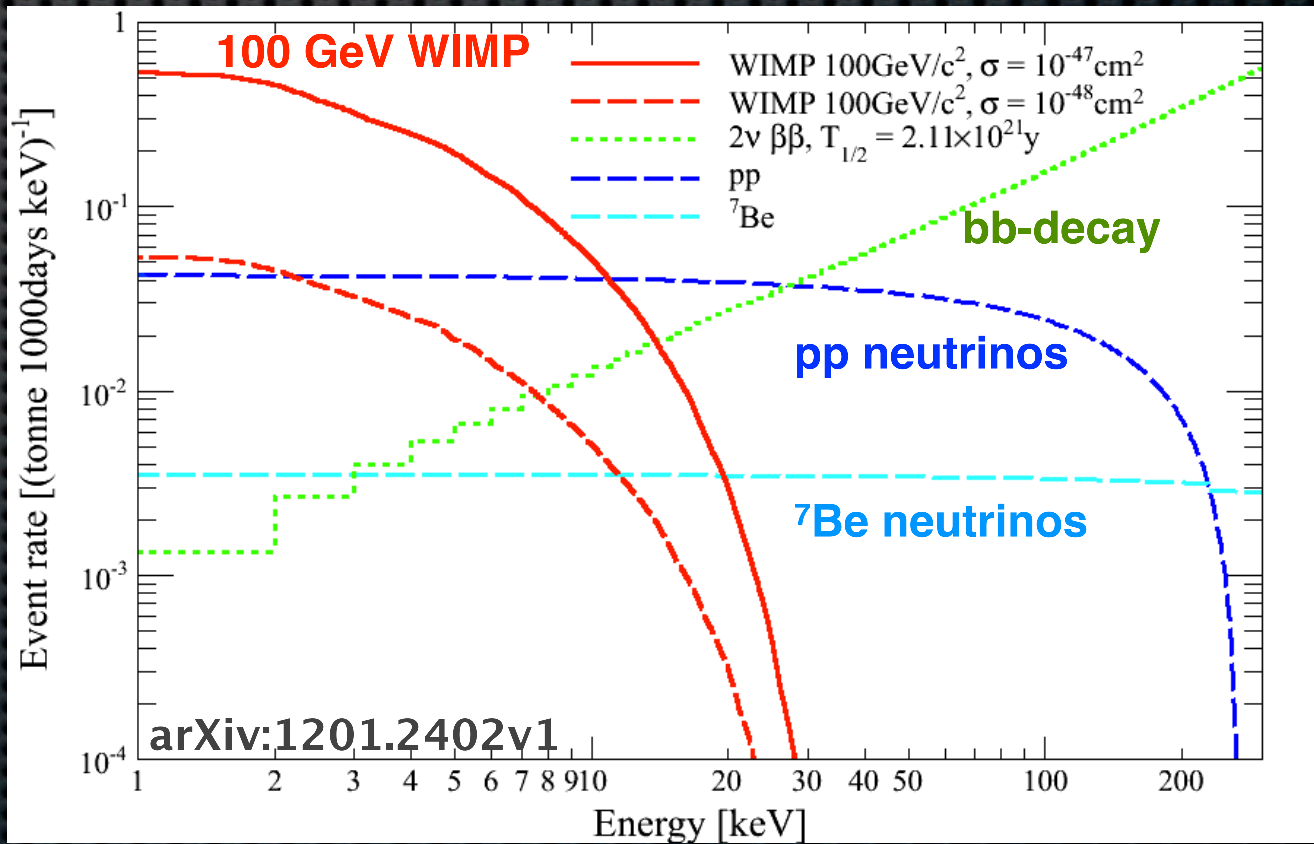
DARWIN

DARk matter WImp search with Noble liquids

- R&D and design study for next-generation noble liquid detector
- Physics goal: build the "ultimate WIMP detector", before the possibly irreducible neutrino background takes over



Sketch of possible layout for LAr and LXe cryostats in large water Cherenkov shields



2vbb: EXO measurement of ^{136}Xe $T_{1/2}$
Assumptions: 50% NR acceptance, 99.5% ER discrimination
Contribution of 2vbb background can be reduced by depletion

DARWIN

The WIMP Landscape

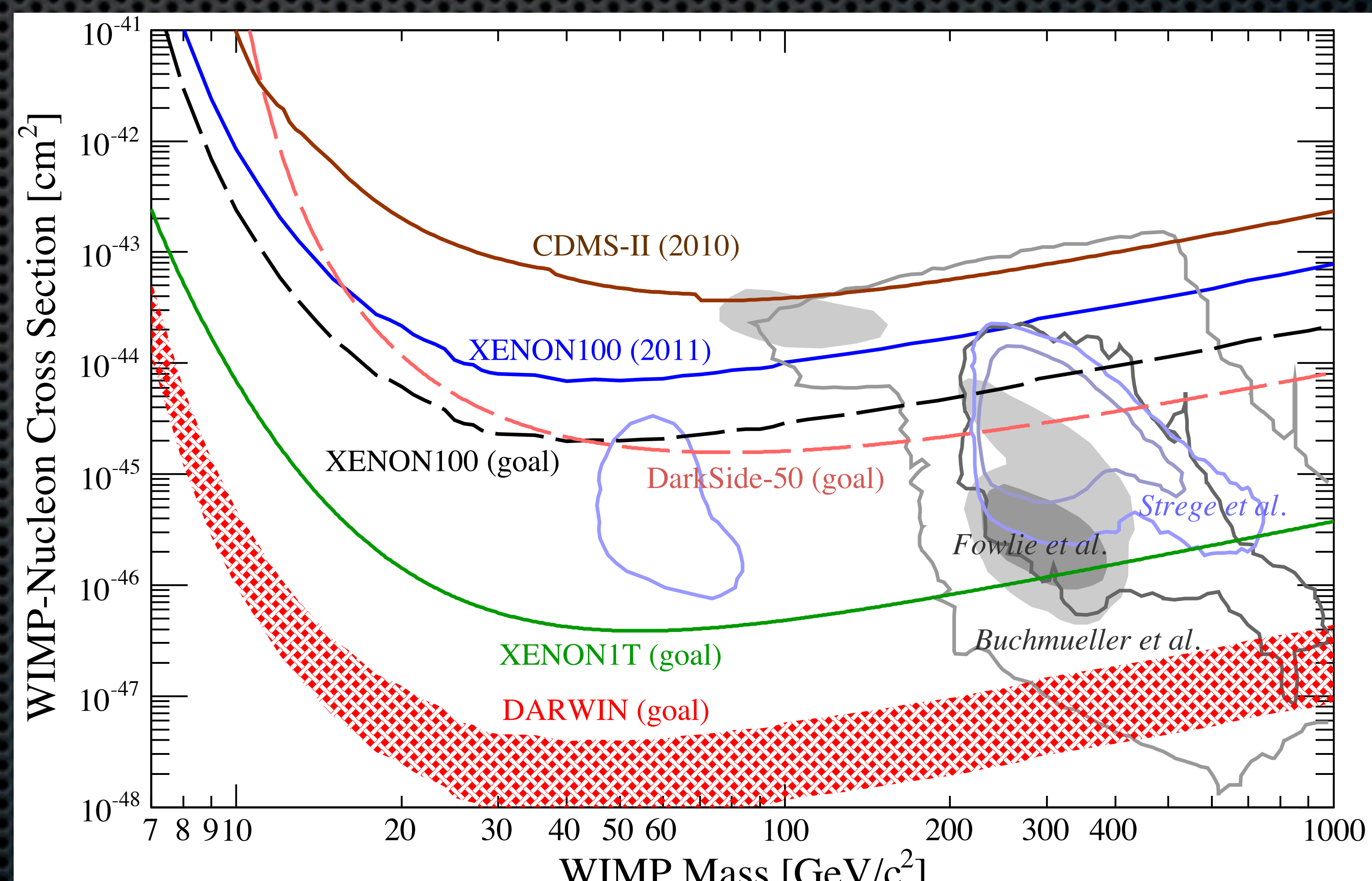
- However, goal is not exclusion limits, but WIMP detection!
- Either way, *a discovery!*

~ 1 event kg^{-1} year^{-1}

~ 1 event (10 kg)$^{-1}$ year^{-1}

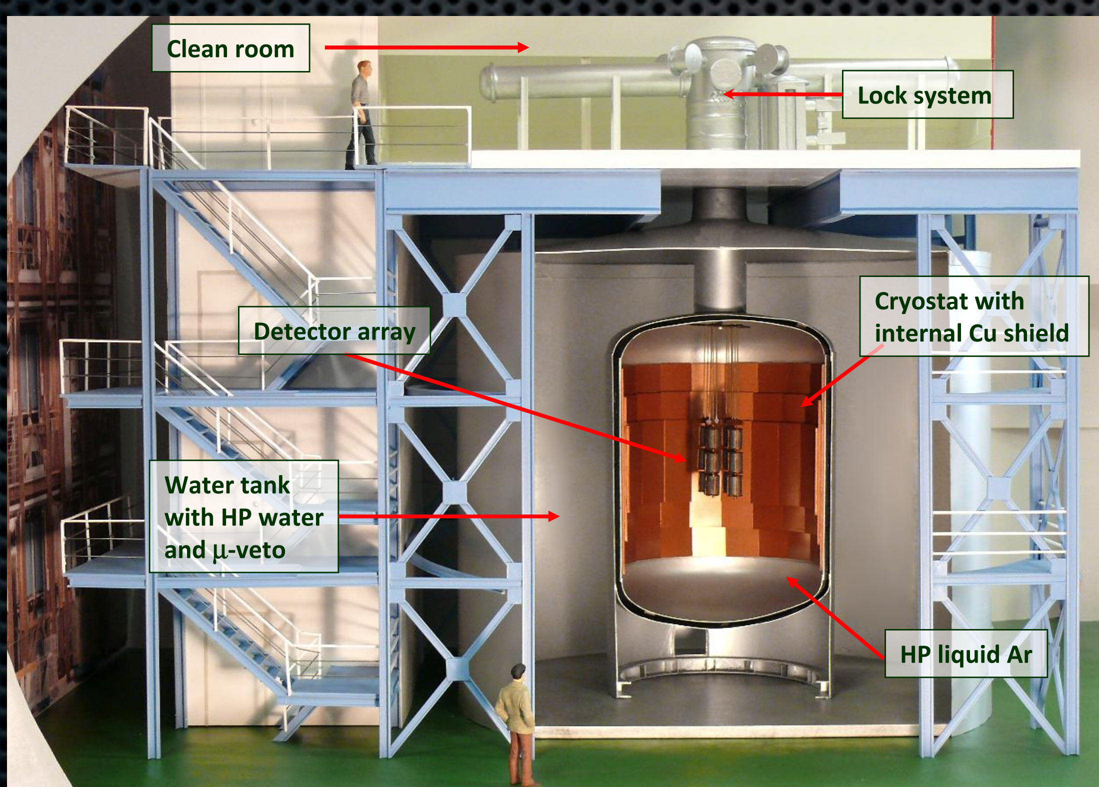
~ 1 event (100 kg)$^{-1}$ year^{-1}

~ 1 event ton^{-1} year^{-1}



GERDA

- Search for the neutrinoless double beta decay in 76Ge detectors operated in liquid argon
- Inauguration at Gran Sasso in Nov 2010
- Commissioning run until late 2011
- Physics run with all enriched detectors started in early 2012



GERDA Phase I

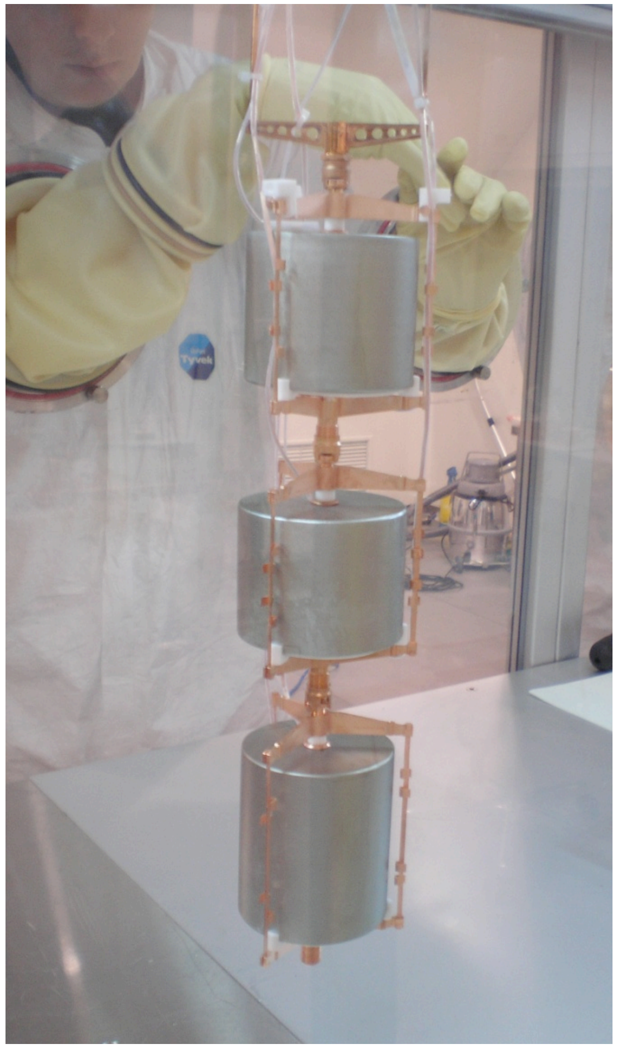
The Detectors

- Closed-ended coaxial detectors
- 8 diodes from HdM and IGEX enriched in ^{76}Ge
- 6 diodes from Genius test facility, natural Ge
- $\sim$ 15 kg of ^{76}Ge

The Goals

Test Klapdor's Claim

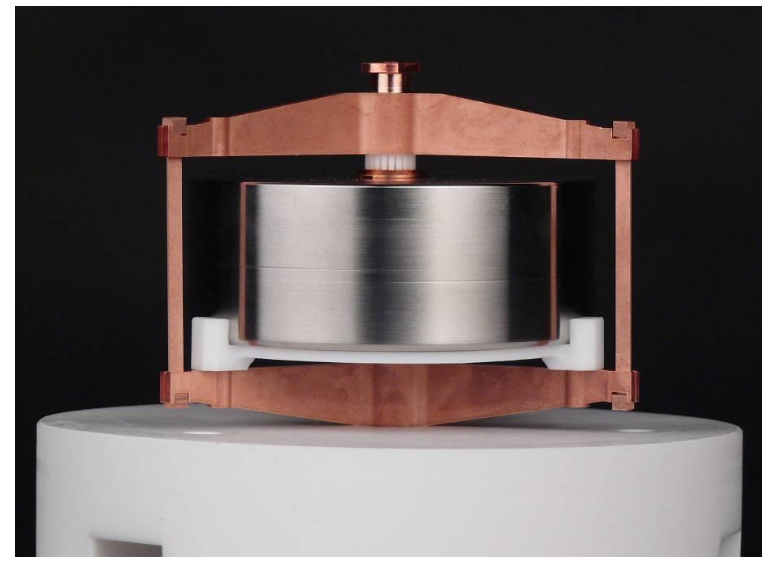
Exposure	15 kg y
Background	10^{-2} cts/(keV kg y)
Half-life	$T_{1/2} > 2.2 \times 10^{25}$ y
Majorana mass	$m_{ee} < 0.27$ eV



GERDA Phase II

The Detectors

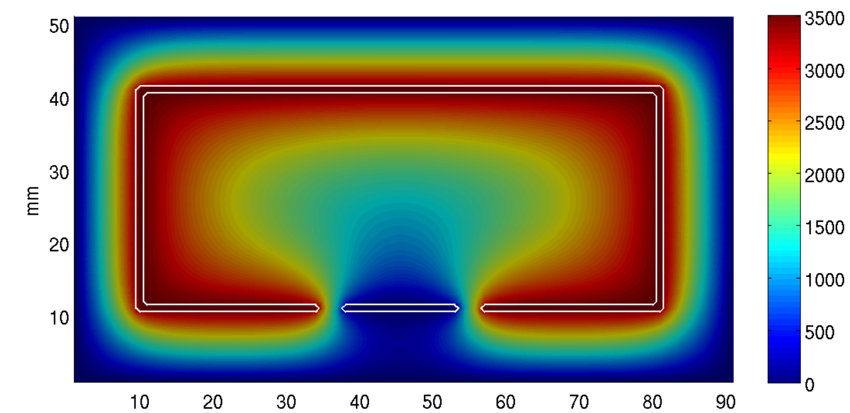
- All Phase I detectors
- Broad-Energy Germanium (BEGe) detectors enriched in ^{76}Ge
- A total of ~ 40 kg of ^{76}Ge



The Goals

Exposure	100 kg y
Background	10^{-3} cts/(keV kg y)
Half-life	$T_{1/2} > 15 \times 10^{25}$ y
Majorana mass	$m_{ee} < 0.11$ eV

Electric potential [V]



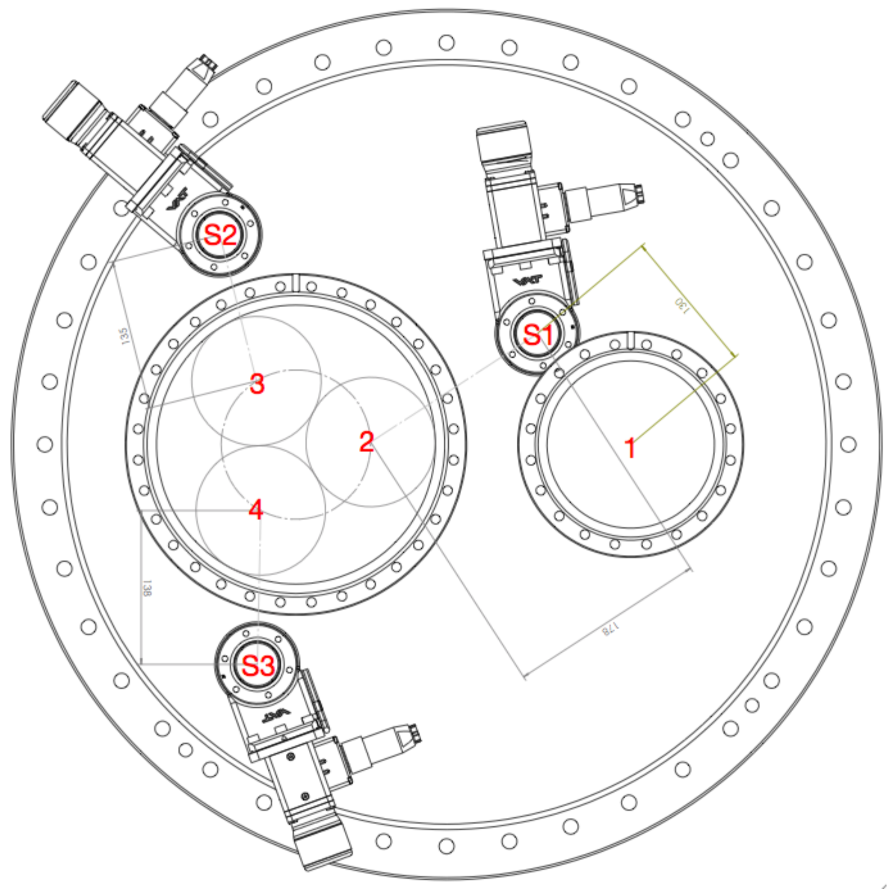
UZH GERDA activities

- Custom, low-neutron emission calibration sources (with PSI)
- Construction, installation, operation of calibration system
- Calibration (weekly) data analysis and data base
- Production/testing of phase-II BEGe (broad energy germanium) detectors(together with Munich, Heidelberg, Tübingen, INFN and Canberra)
- R&D for the liquid argon instrumentation and light read out in phase II

GERDA Calibrations

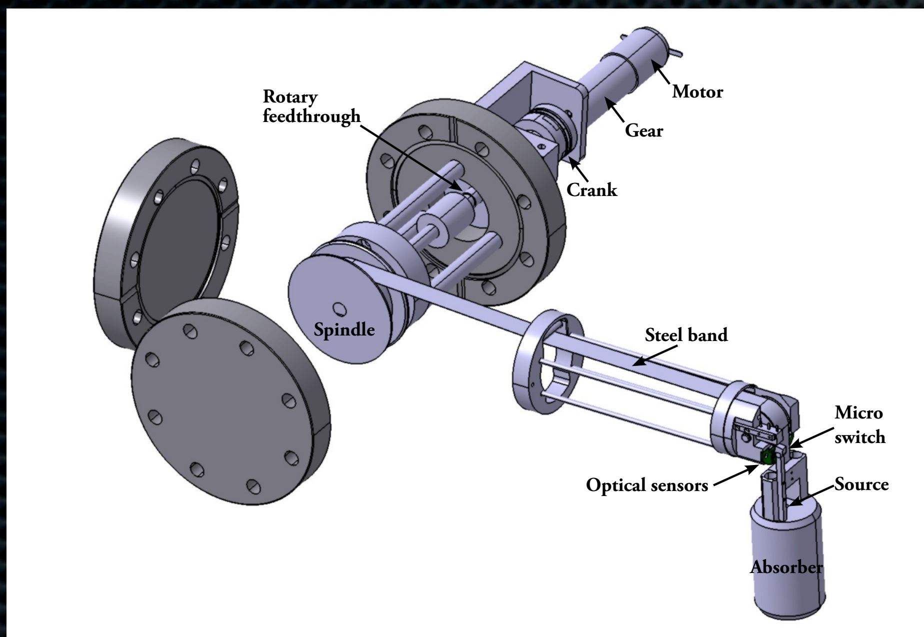
Overview

- 4 strings with 3 detectors each
- 3 ^{228}Th sources with $A = 10 - 15$ kBq
- Park position in the lock of the experiment
- Sources shielded by 6 cm of Ta
- 1 Calibration run per week:
  - 2 different z positions
  - ~ 30 min run time per position



The Calibration System (UZH)

Hardware



Positioning

Absolute Encoder

- Measures rotation of spindle
- Correctly calibrated, it gives the absolute position even in case of a power shut down
- Accuracy depends on reproducibility of winding of steel band

Incremental Encoder

- Two optical sensors (reflection light barriers) count holes in perforated steel band
- Chronology of impulses of sensors define forward and backward direction
- Accuracy depends on distance of holes and sensors and accuracy of perforation

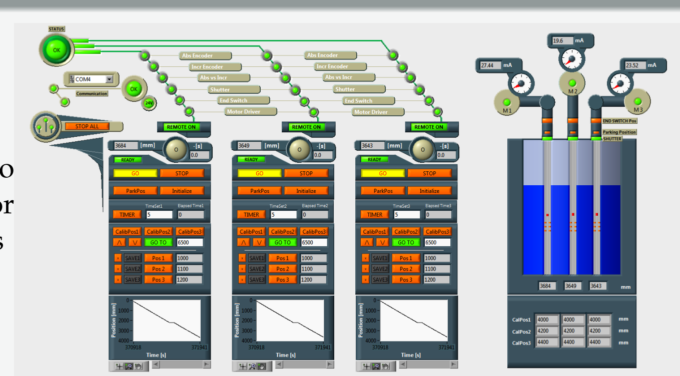
Controlling

System Control Unit

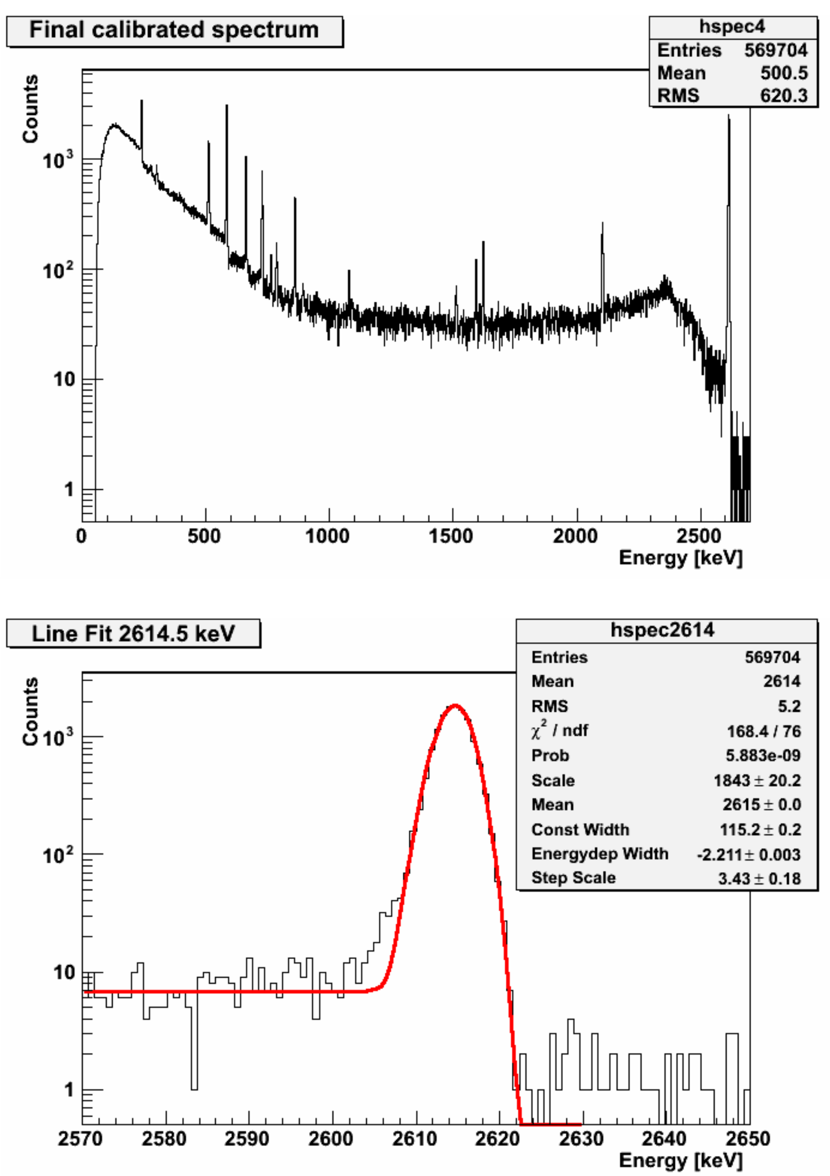
Firmware with 3 functional blocks per lowering system:
Motor, positioning and error control

Remote Control

LabView Program to operate and monitor all 3 lowering systems

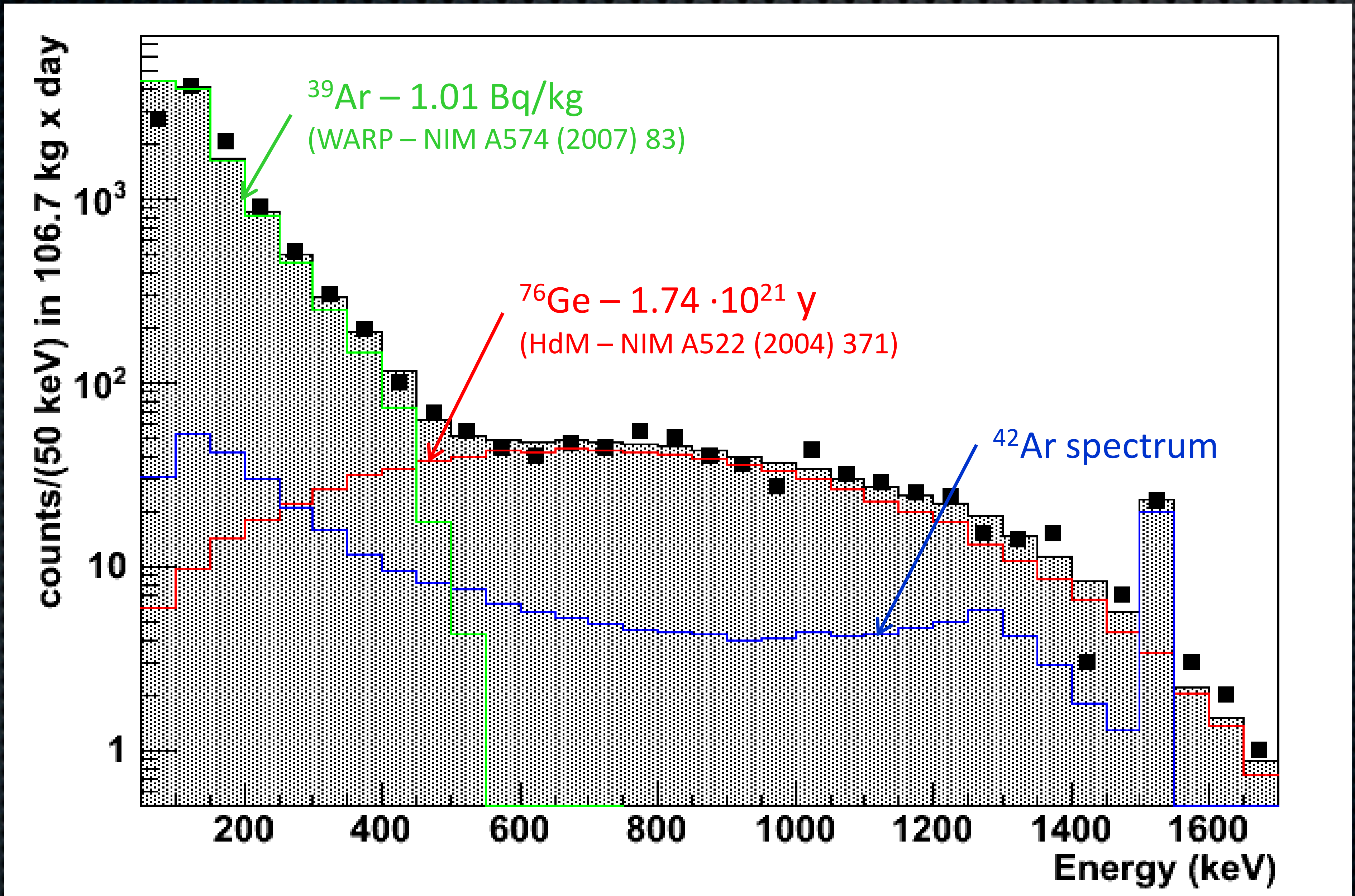


Example of calibration spectrum



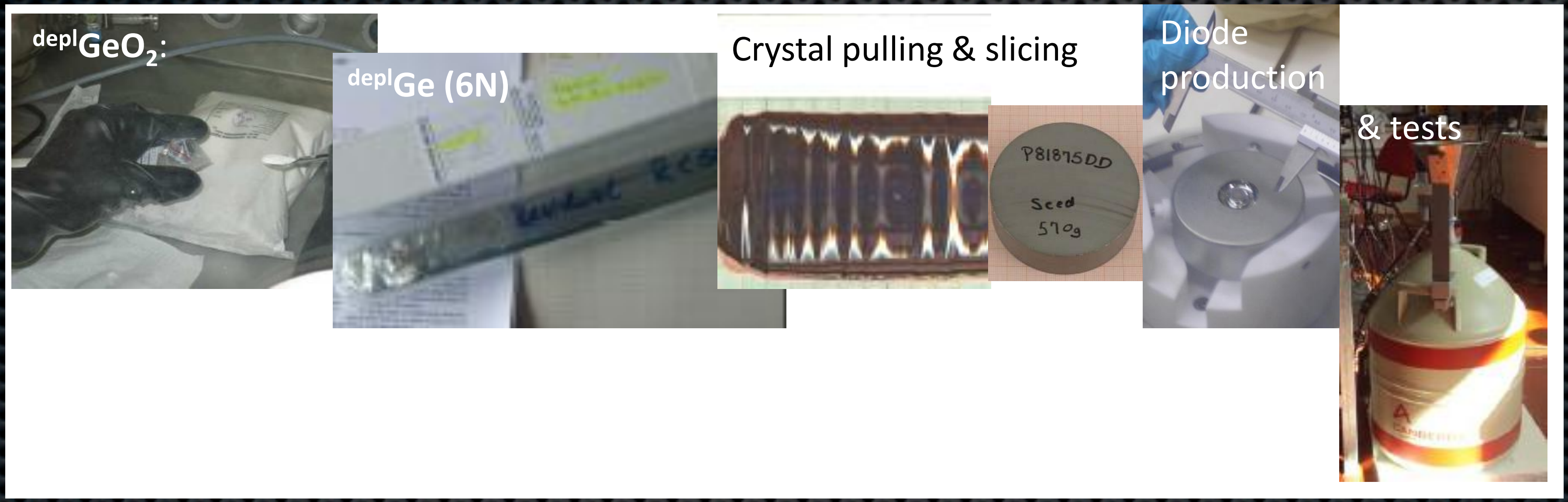
- Phase I: Closed-ended coaxial Ge diodes, p-type
- First string with three natural Ge detectors deployed in June 2010
- First string with enriched detectors deployed in June 2011
- Energy resolution (FWHM@2.6 MeV): 3.6 keV to $\sim$ 5 keV

First 2-neutrino spectrum in GERDA



GERDA Phase II detectors

- Full production chain tested with depleted germanium



- 37.5 kg of 86% enr-Ge (in form of GeO2) purified to 35.4 kg (94%)
- Canberra grows enr-Ge crystals & produces BEGe diodes; collaboration is testing these and provides feedback to production
- All phase II detectors planned to be produced and tested by summer 2013