Low-mass WIMP searches with EDELWEISS

EDELWEISS-III:

Performance, results, background model

EDELWEISS-LT:

Prospects for ~GeV scale masses, first calibrations

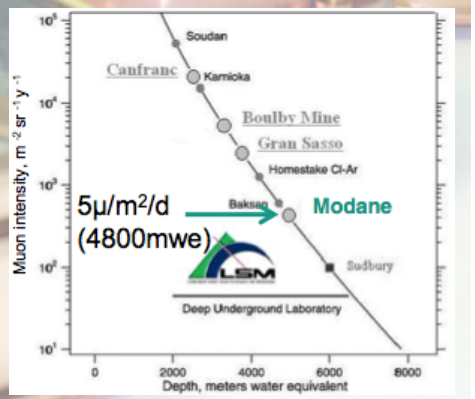
EDELWEISS-DMB8:

Prospects for the ^{8}B region

Jules Gascon
(IPNLyon, Université Lyon 1 + CNRS/IN2P3)

The EDELWEISS-III Experiment

- **Direct detection of WIMPs, germanium target**
- **20 kg Ge total, 870g units**
- **Ionization + Heat**
- **Simple & robust design**
  - **Important for scalability to large arrays**
  - **Initially designed for >20 GeV WIMPs and ~3000 kgd**
  - **Extended down to 5 GeV given achieved resolutions**
- **Laboratoire Souterrain de Modane**
  - **Deepest in Europe : 5 μ/m²/day**

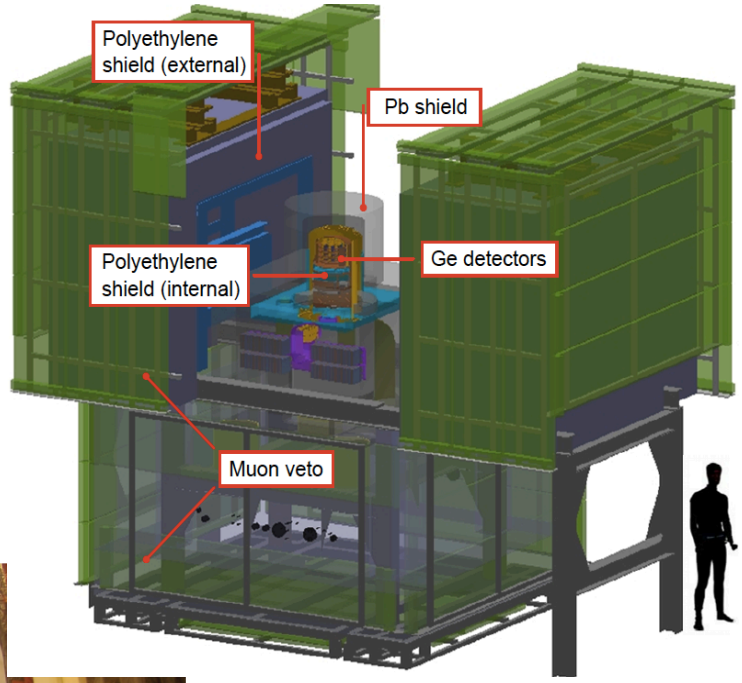


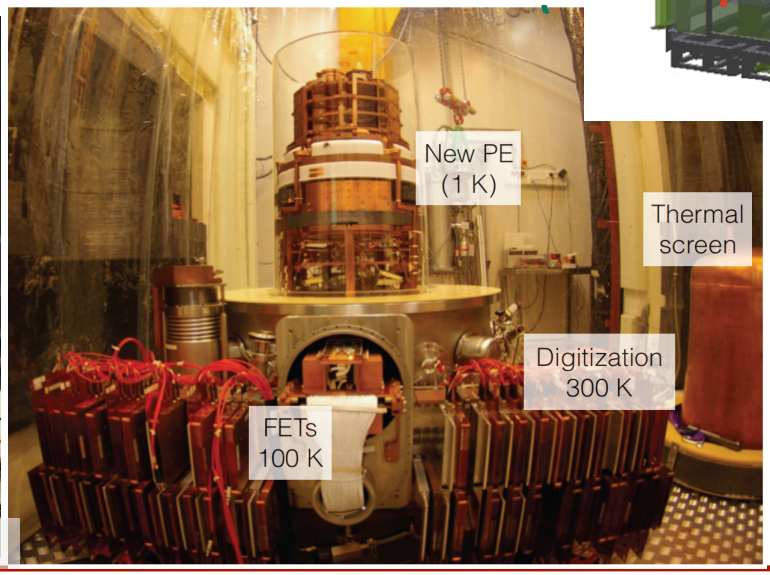
EDELWEISS Setup

- Clean room + deradonized air

  Rn monitoring down to few mBq/m³
- Active muon veto (>98% coverage)
- External (50 cm) + internal polyethylene shielding

  Thermal neutron monitoring with ³He detector
- Lead shielding (20 cm, incl. 2 cm Roman lead)
- Selection of radiopure material
- Cryostat can host up to 40 kg detector, at 18 mK



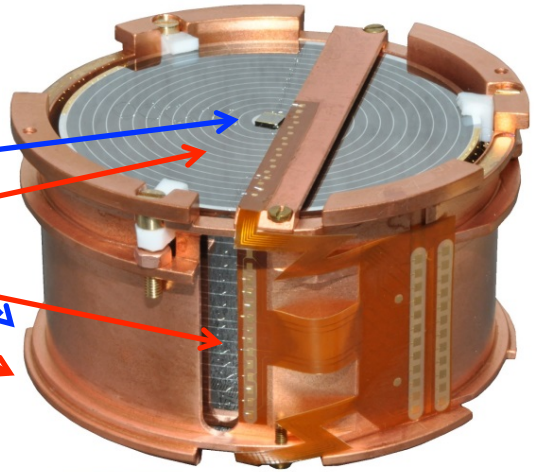


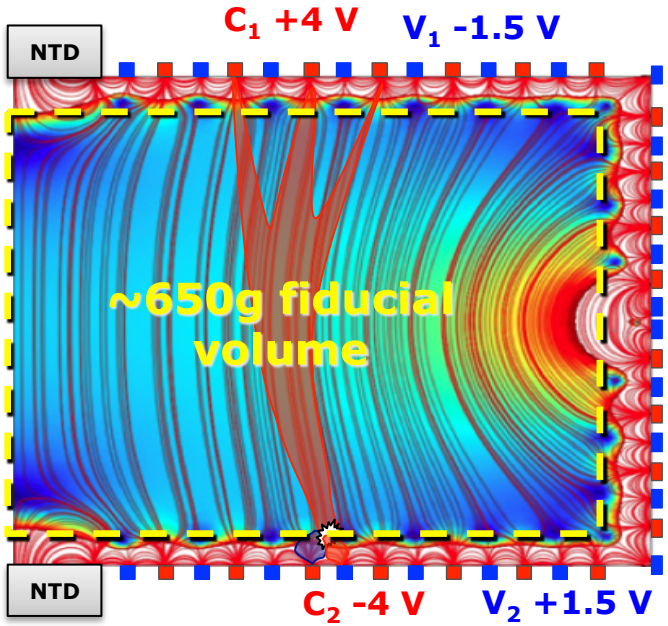
Performance of the EDELWEISS-III experiment for direct dark matter searches (arXiv: 1706.01070)

Fully InterDigitized electrode design

- ~870g detectors (ϕ=70 h=40 mm)
- 2 GeNTDs heat sensor per detector
- Electrodes: concentric Al rings (2 mm spacing) covering all faces
- XeF_2 surface treatment to ensure low leakage current (<1 fA) between adjacent electrodes

J Low Temp Phys (2014) 176: 182-187



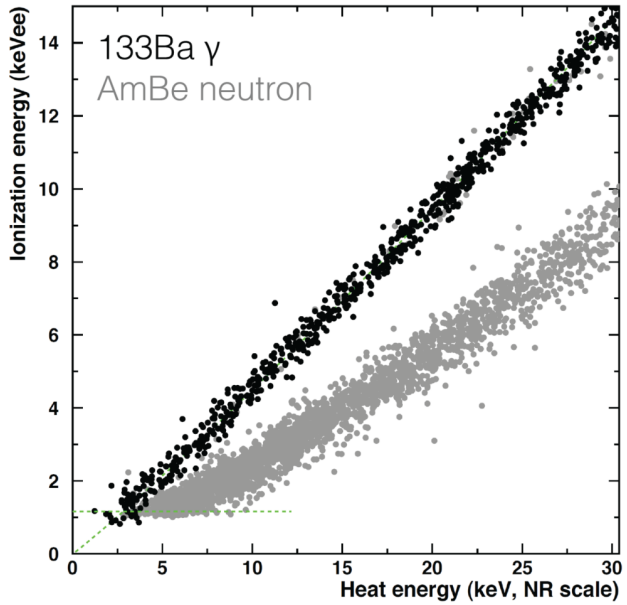


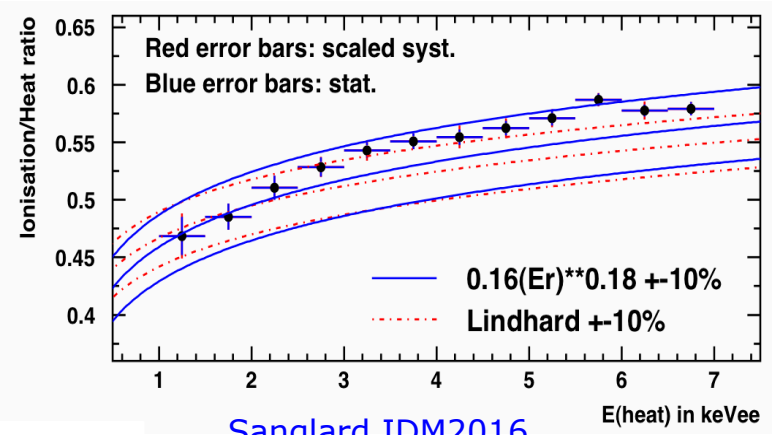
Surface event rejection

Phys Lett B 681 (2009) 305–309

- Bulk event: charges collected by C_1 and C_2: V_1 and V_2 act as veto
- Surface events: charges collected by either C_1V_1 or C_2V_2

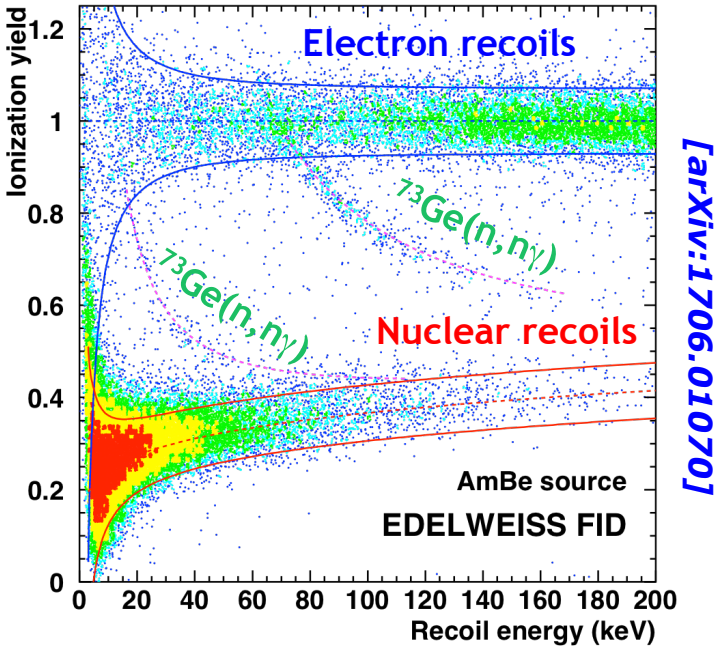
Nuclear recoil calibration + discrimination





Sanglard IDM2016

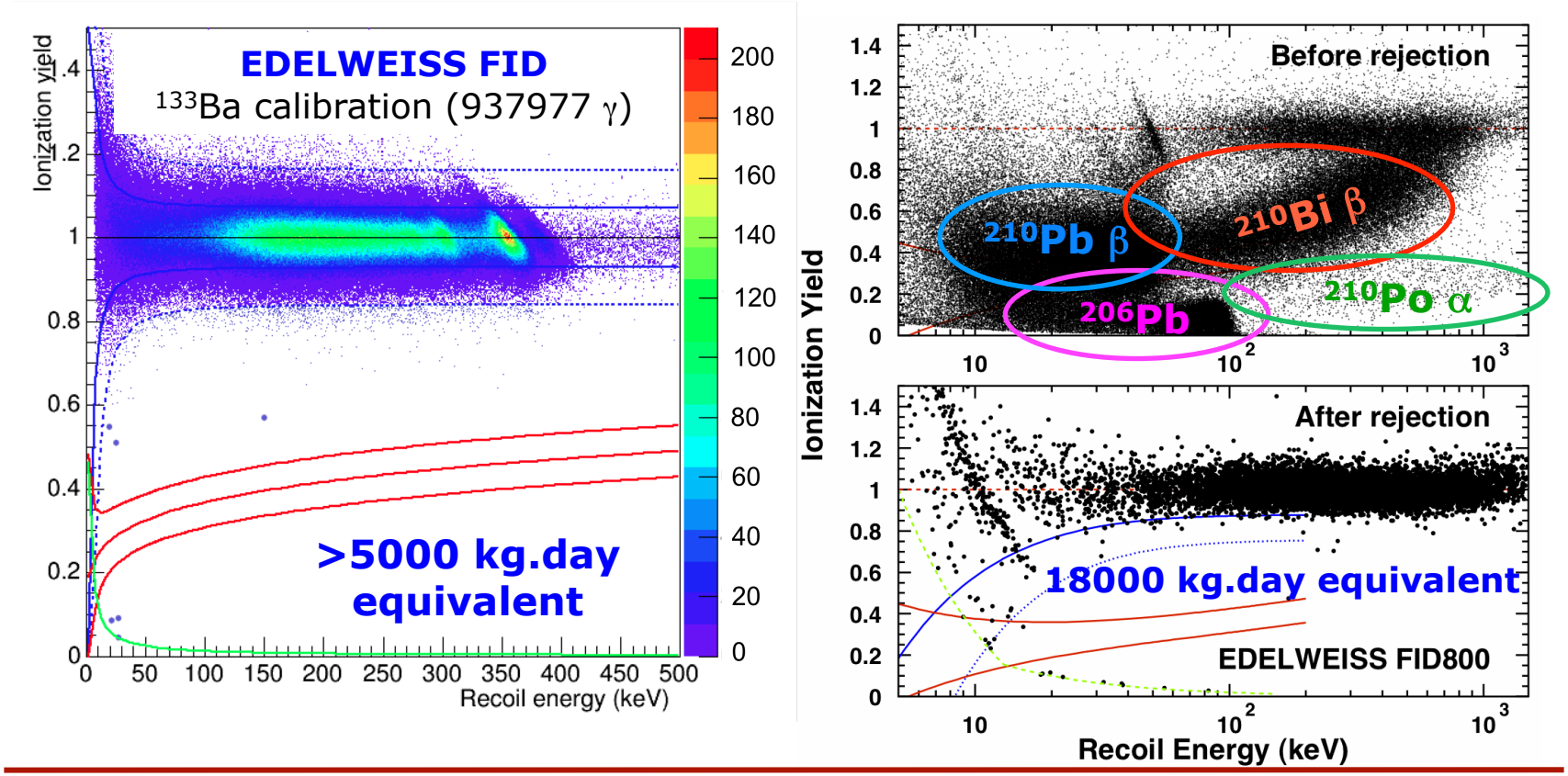
- Clear event-by-event separation down to 5 keV energy recoils
- Response to nuclear recoils calibrated down to the analysis threshold for low-mass WIMP searches
  (1 keV_{ee} heat = 2.5 keV nuclear recoil)



[arXiv:1706.01070]

Gamma rejection & Surface rejection

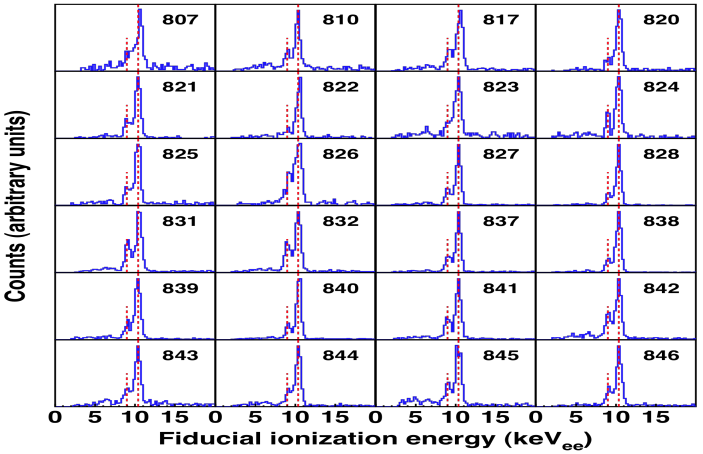
- Rejection tested with >5000 kgd equivalent samples *[arXiv:1706.01070]*
- γ rejection factor: < 2.5 x 10^{-6}
- Surface evts rejection (^{210}Pb+^{210}Bi β, ^{210}Po α, ^{206}Pb recoils): < 4 x 10^{-5}



EDELWEISS-III 3000 kgd data set

- 161 days of physics data with 24 FIDs (2014-2015)

- 24 FID with good resolutions and threshold < 5 keV_{ee} (performance studies, coincidences)

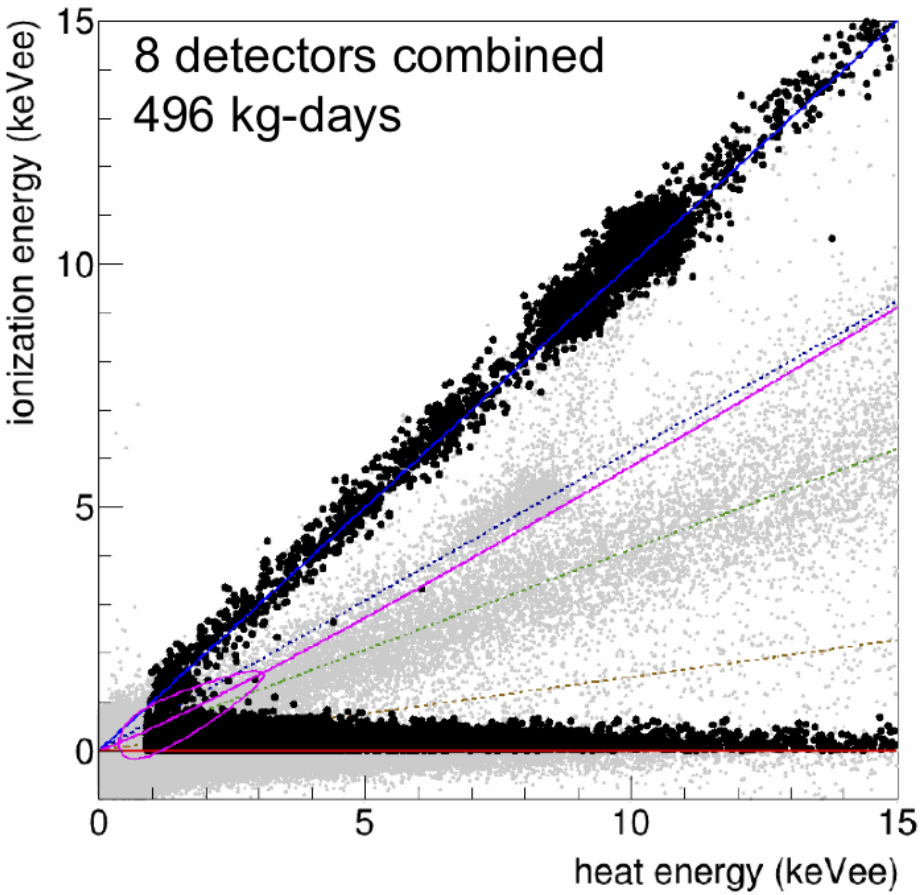


Clear 10 keV peak on all FIDs

- 19 FID with < 2 keV_{ee} (used for study of cosmogenics + ^{3}H, etc.)
- 8 lowest threshold FIDs used for low-mass WIMP search

Low-Mass analysis & background model

- Analysis with Boosted Decision Tree [JCAP05 (2016) 019]
- Analysis with Profile Likelihood [EPJC 76 (2016) 548]



Data-driven background models based on sidebands

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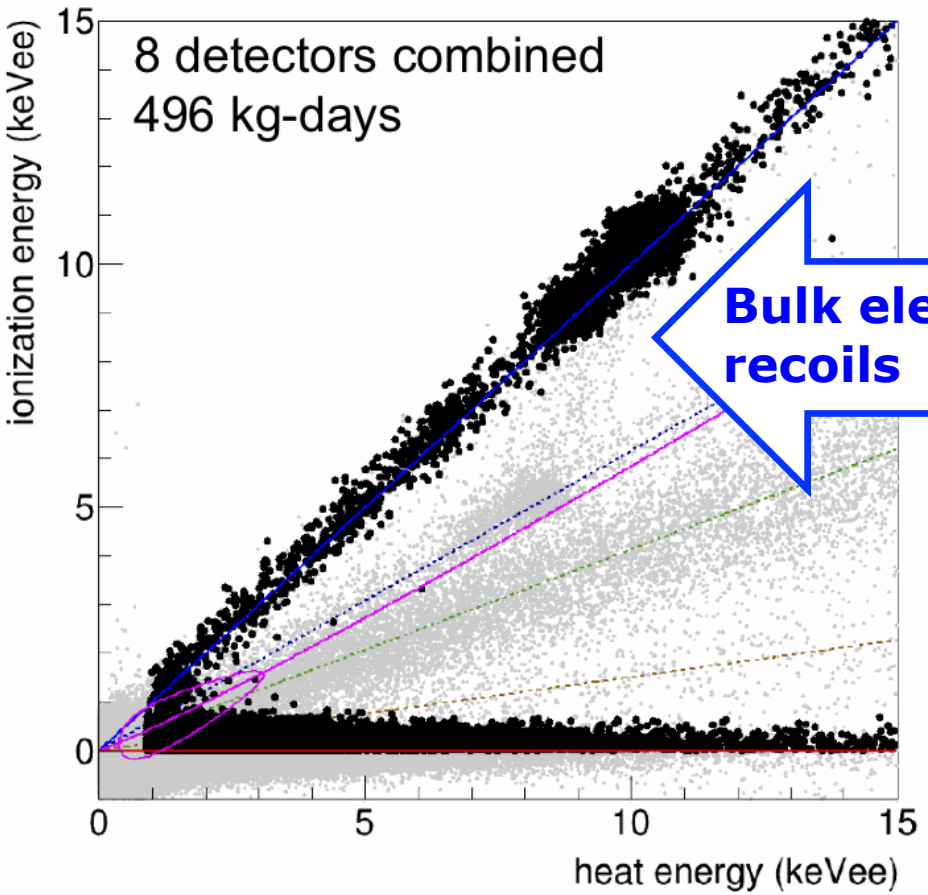

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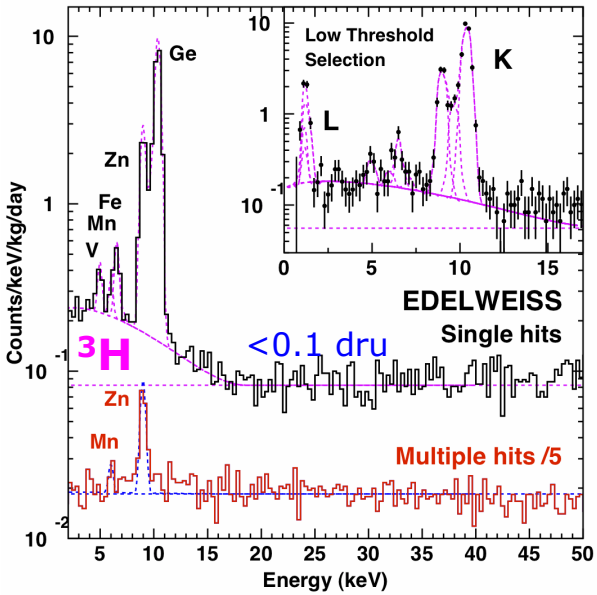

First measurement of cosmogenic production of ^{3}H in Ge [AstroPart. 91 (2017) 51] + S. Scorza talk on Wednesday

Low-Mass analysis & background model

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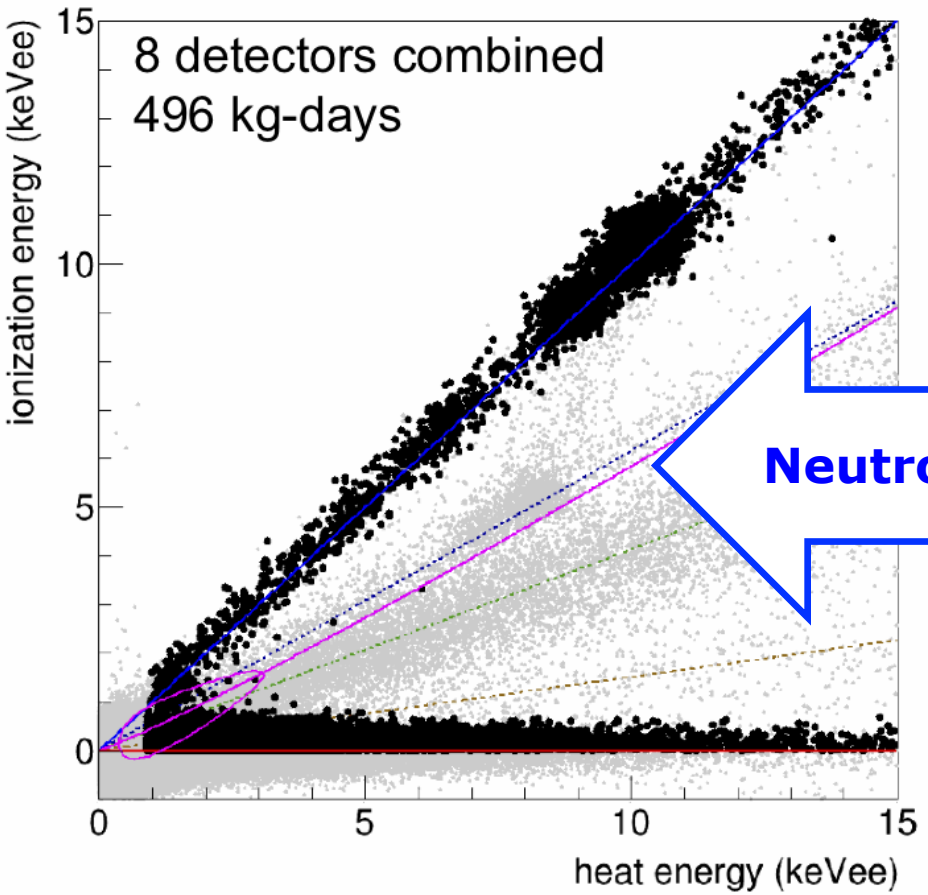

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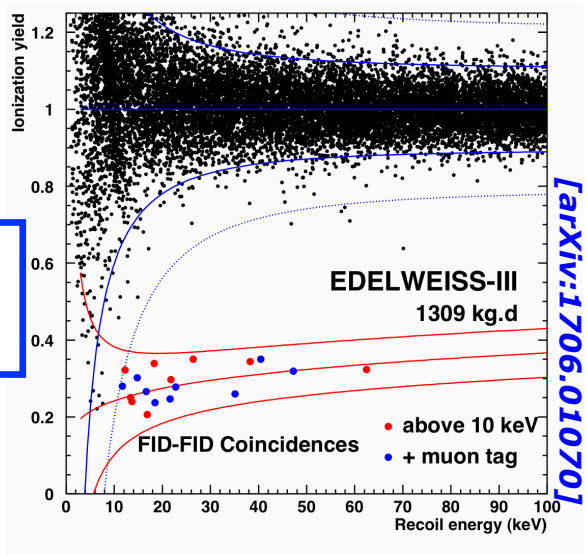

Multiple-detector events : fast neutron flux measurement

Low-Mass analysis & background model

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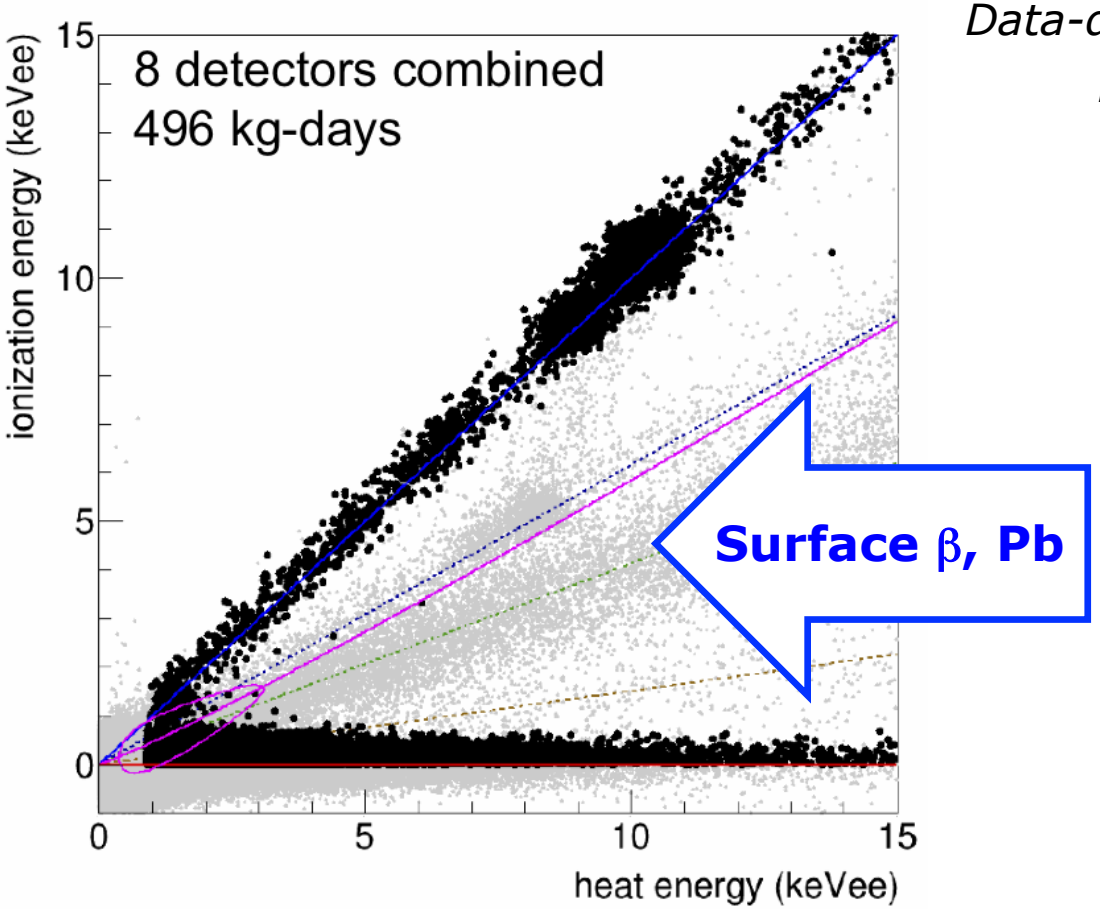
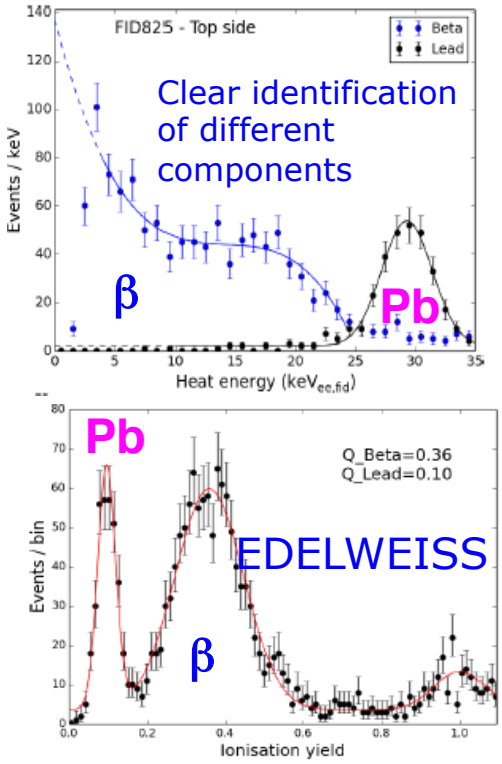


Data-driven background models based on sidebands



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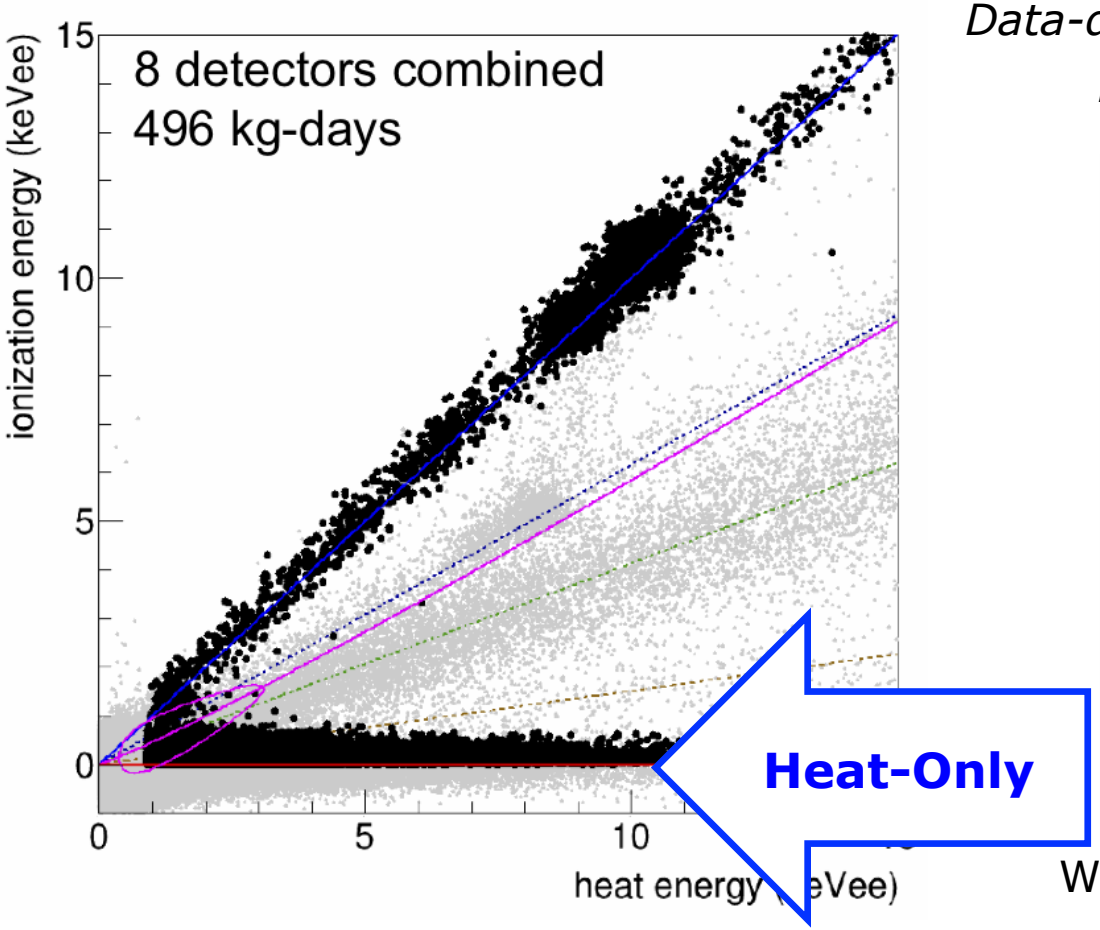
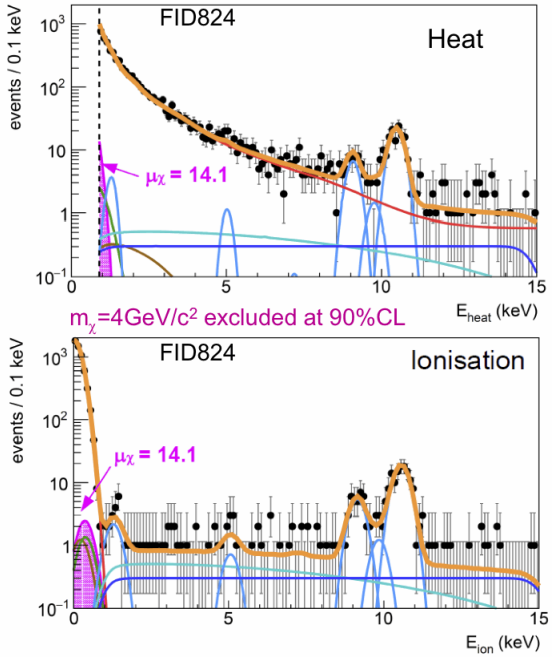


Data-driven background models based on sidebands

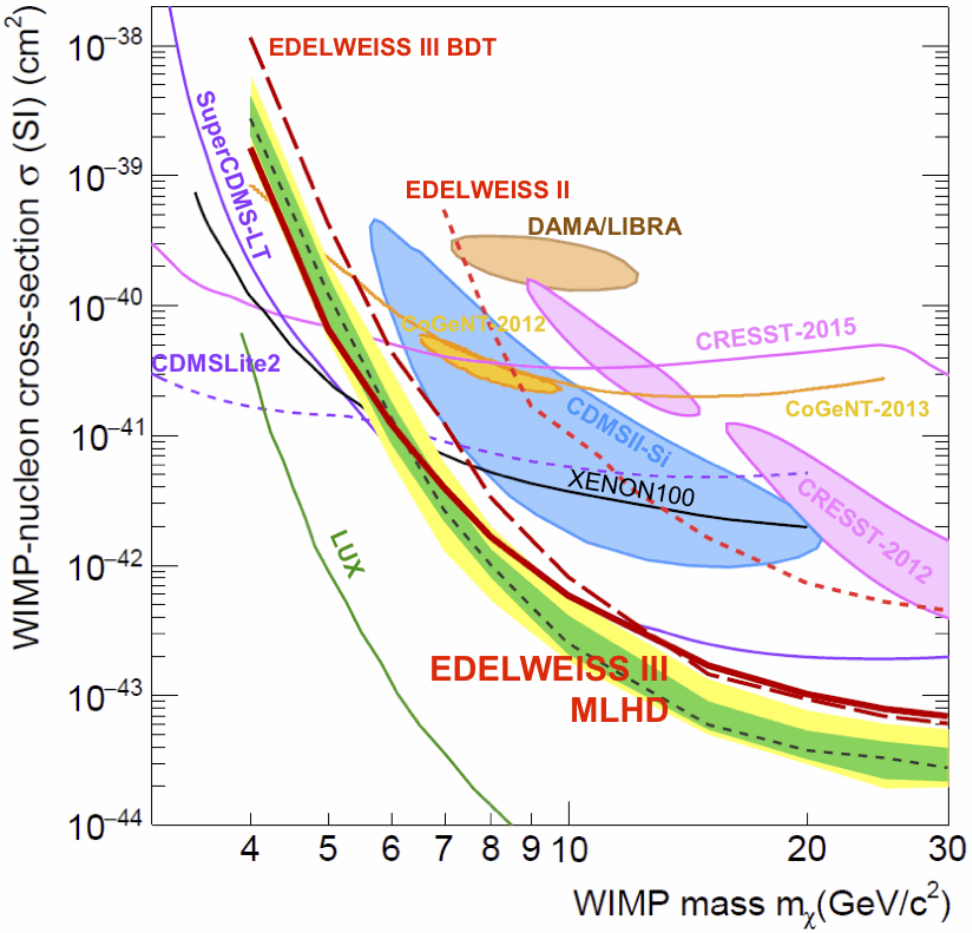
Origin under investigation



Well reproducible over >years

Low-Mass analysis

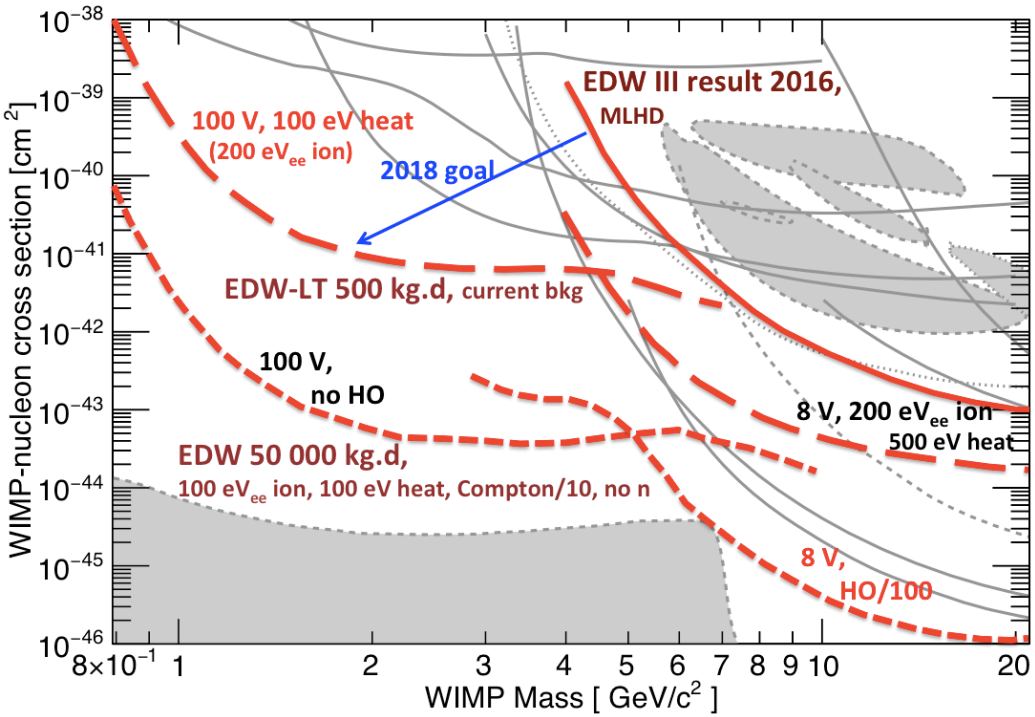
- Analysis with Boosted Decision Tree *[JCAP05 (2016) 019]*
- Analysis with Profile Likelihood *[EPJC 76 (2016) 548]*



- Improvement by x20 to x150 between 7 and 10 GeV wrt EDELWEISS-II
- Limited by heat-only background: *identification and rejection using the σ=230 eV resolution on ionization*
- Ionization resolution is key for rejection
- Heat resolution is key for low thresholds

Prospects for GeV-range masses

- [ArXiv:1707.04308]: Complete study based on present measured backgrounds and resolutions *vs* possible improvements



Lower thresholds

1. Use of Luke-Neganov boost to lower thresholds (up to 100V bias)
2. Improve heat resolution
   σ_{heat} = 500 eV → **100 eV**
   (x5 gain in sensitivity already achieved on 200 g detectors)
3. Reduction x100 of heat-only background
4. Improve ionization resolution
   σ_{ion} = 200 eV$_{ee}$ → **100/50 eV$_{ee}$**

Also: effect of improved neutron/ gamma background (+ increased mass) in the environment planned for SuperCDMS at SNOLAB

EDELWEISS-LT: Luke-Neganov boost

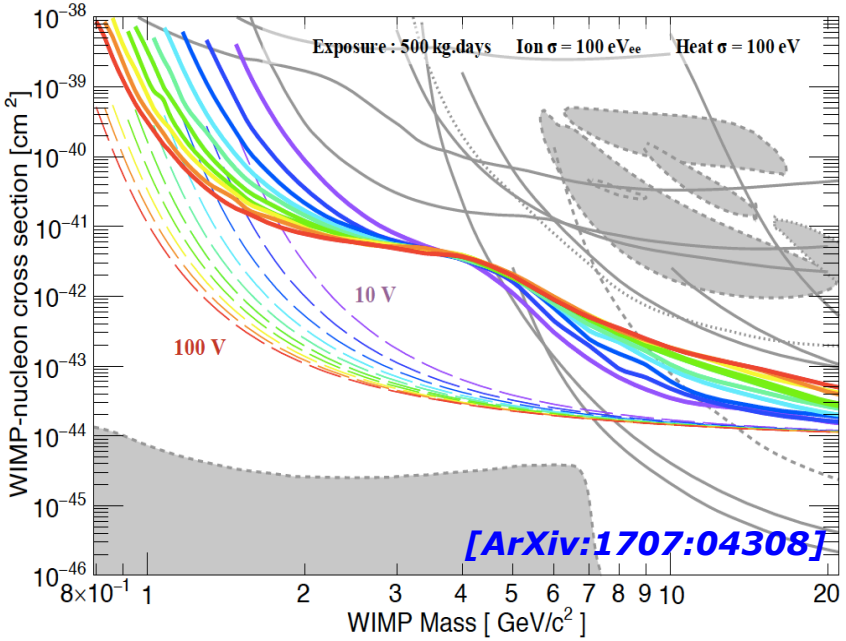
Heat thresholds can be improved by applying larger bias voltages

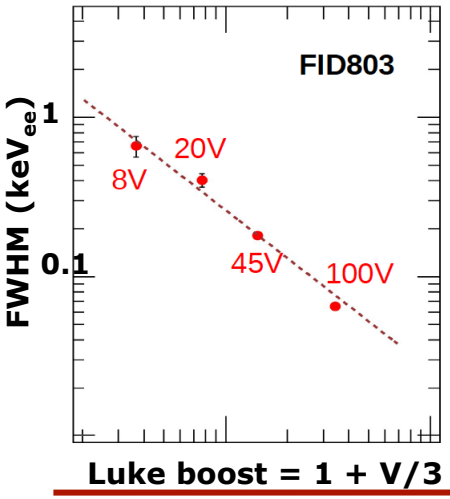
- Heat signal boosted by Neganov-Luke effect (~Joule heating, factor [1+V_{bias}/3])
- Loss of ionization-based bkg discrimination: method benefits low-mass searches only
  → *10^{-41} cm² with 500 kgd and current bkgs*

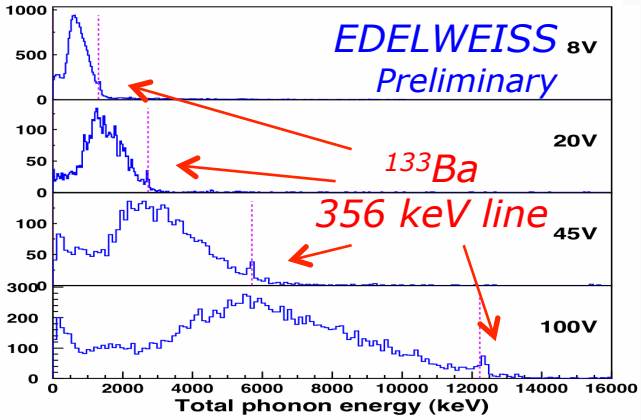
✔ **100V bias already achieved**

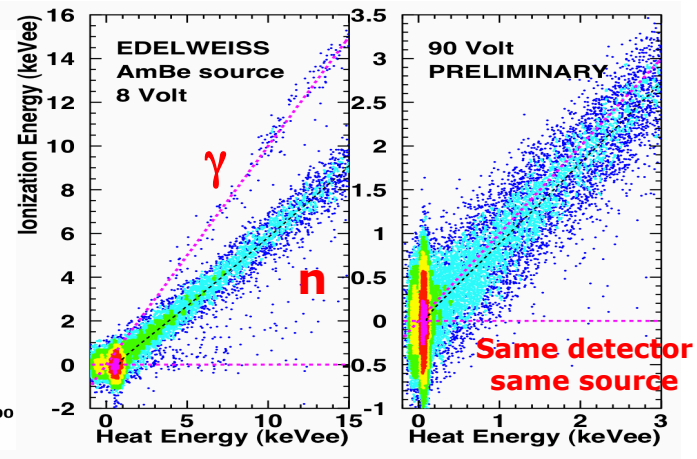
✔ **Observe nucl. recoils down to ~0.1 keV_{ee}**

✔ **First WIMP Data@100V analysis underway**



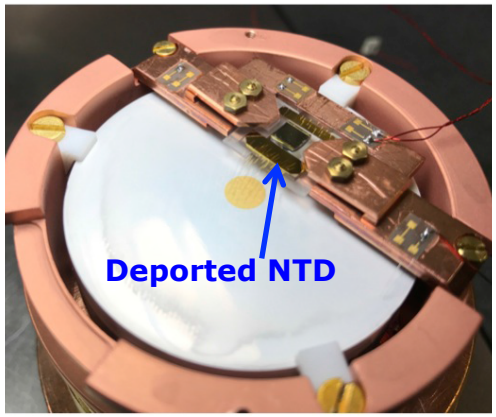


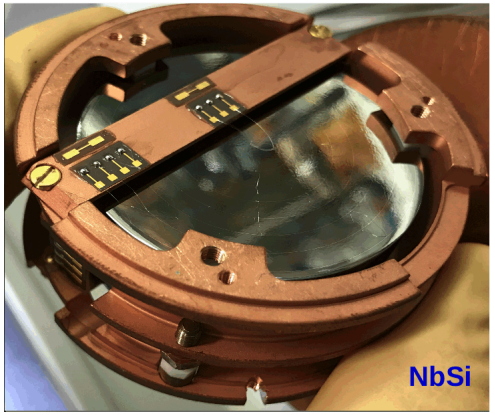


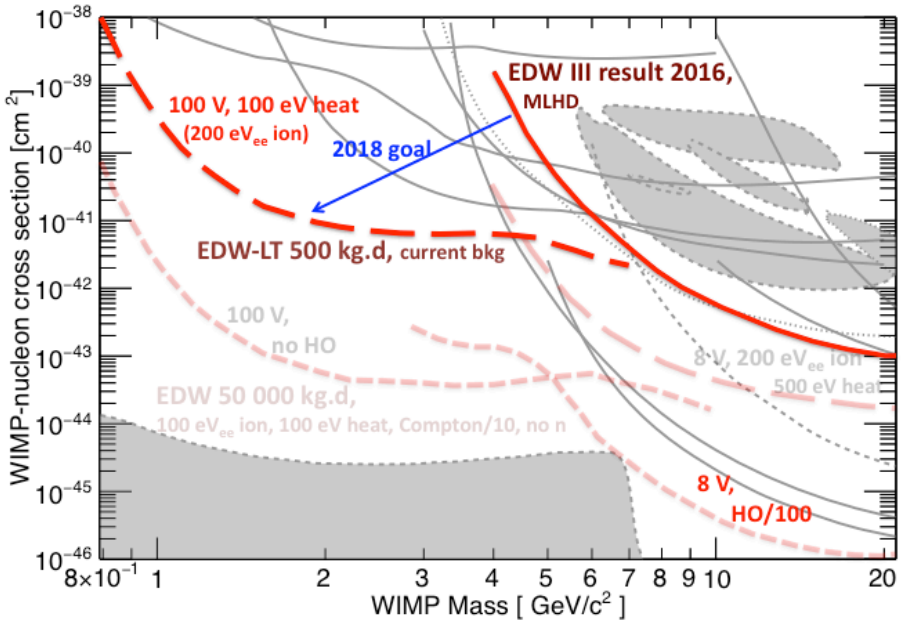


EDELWEISS-LT: Heat-only background

- Standard signals on both NTDs but none on any electrodes
- Many studied hypotheses, none conclusive so far
  - Noise, cryogenics, stress from detector suspension or from glueing, natural radioactivity…
- New detector configurations being tested to study these hypotheses
  - Deported NTD glued on separate sapphire wafer
  - Photolithographed high-impedance NbSi TES sensitive to athermal phonons
- **Dominant at low energy, but sufficiently reproducible for analysis of present 100V data**
  & for EDELWEISS-LT: operation of 4x870g at 100V for 150 days in current LSM backgrounds

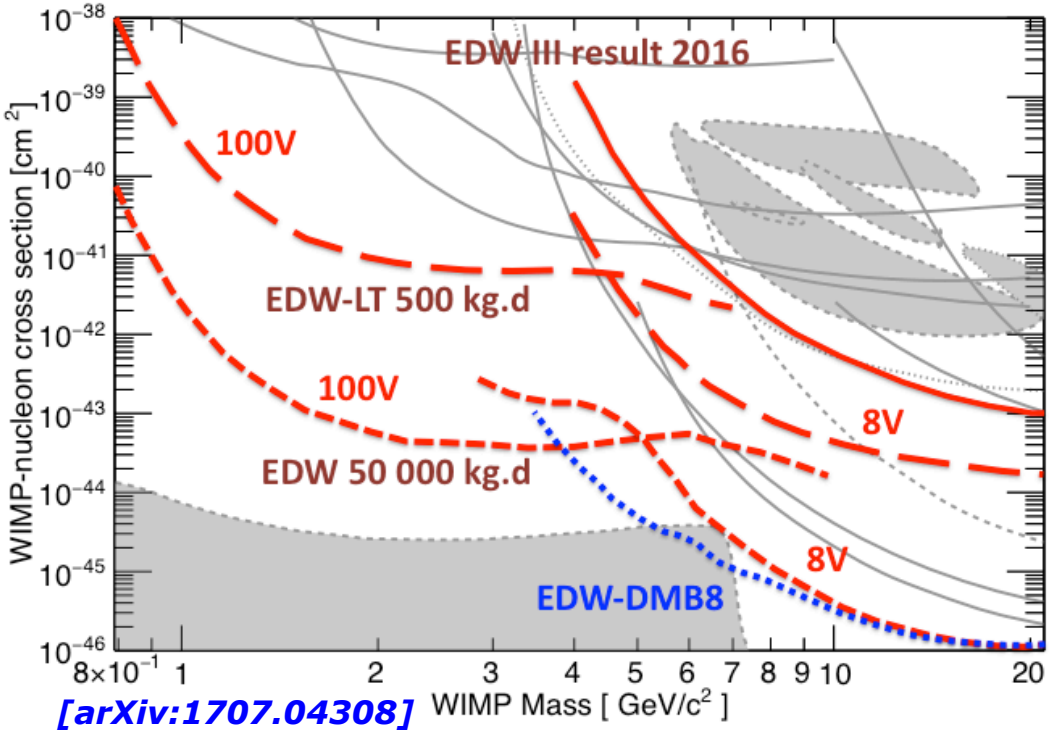






Ionization improvements

- Cold front-end: replace JFET @100K with HEMT (High Electron Mobility Transistor) @4K
- Can be operated at 4K: shorter cabling -> reduced capacitance -> better signal/noise
- Successful HEMT amplifier with sub-100 eV resolution operated on a CDMS-II detector
  [A. Phipps et al., arXiv:1611.09712]
- EDELWEISS electrode design with lower capacitance:
  2 → 4 mm spacing already achieved. Goal: reach 50 eV_{ee}.



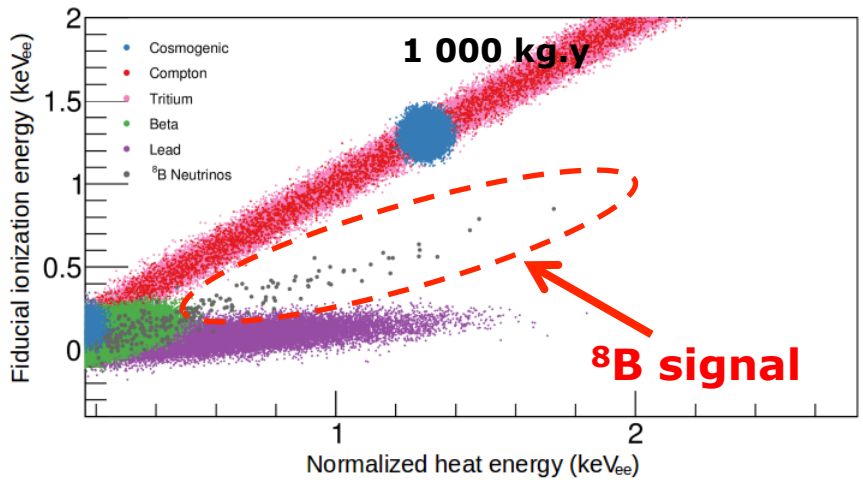
[arXiv:1707.04308]

2 mm spacing → 4 mm spacing

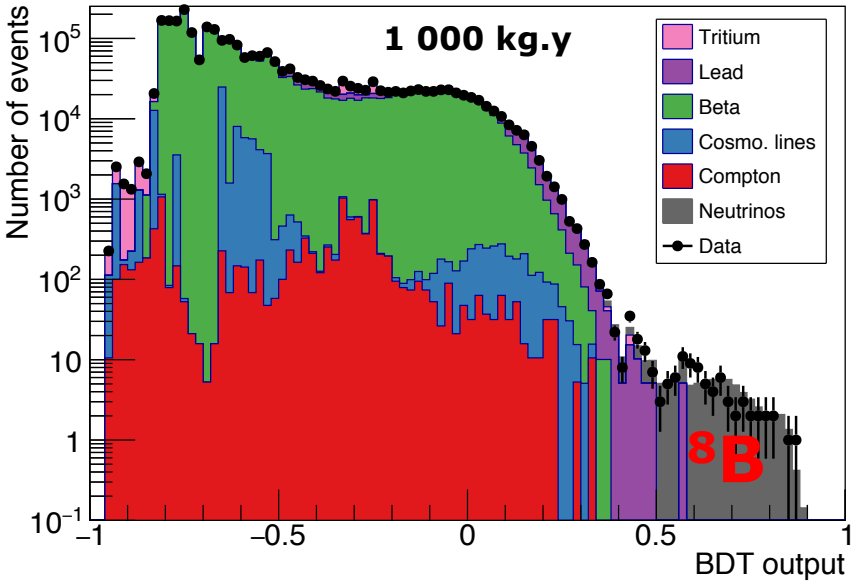
EDELWEISS-DMB8:
Operation of a 200 kg array @8V (with nuclear recoil discrimination) in the improved background environment of SuperCDMS @ SNOLAB

Probing the region of the coherent scattering of ^{8}B solar ν's with resolution and discrimination

Ionization improvements: EDELWEISS-DMB8



[arXiv:1707.04308]



[arXiv:1707.04308]

Coherent nuclear scattering from solar ^{8}B neutrinos mimic a ~6 GeV WIMP with $\sigma \sim 4.4\times10^{-45}$ cm^2

Probe with discrimination and resolution (~10%) a bkg that will soon become relevant for WIMP searches near 6 GeV/c^2.

EDELWEISS-DMB8:
Operation of a 200 kg array @8V (with nuclear recoil discrimination) in the improved background environment of SuperCDMS @ SNOLAB

Probing the region of the coherent scattering of ^{8}B solar ν's with resolution and discrimination

Conclusions

- EDELWEISS-III
  - Robust design, good reproducibility of performances *[arXiv:1706.01070] [JINST 11 (2016) P10008]*
  - Detailed description of backgrounds *[AstroPart. 91 (2017) 51]*
  - Improved ionization resolution & thresholds lead to x40 improvement of WIMP sensitivity at ~5-10 GeV wrt EDELWEISS-II. *[JCAP05 (2016) 019] [EPJC 76 (2016) 548]*

- Prospects in the GeV-WIMP range: EDELWEISS-LT *[arXiv:1707.04308]*
  - Improve thresholds x10 using boost from 8 to 100V (achieved)
  - 10^{-41} cm^2 achievable at LSM with 4 detectors with present levels of backgrounds
- Prospects for WIMPs in the ^{8}B region: EDELWEISS-DMB8
  - 50 eV ionization resolution to obtain pure nuclear recoil sample + 10% resolution on recoil energy: clear spectral identification of ^{8}B ν *[arXiv:1707.04309]*
  - Use HEMT preamplifier + reduce electrode capacitance (reduction by a factor of 2 of number of electrodes achieved)
  - ~200 kg FIDs at SNOLAB to complement nicely the SuperCDMS-SNOLAB reach

EDELWEISS collaboration

CSNSM CNRS/IN2P3

iPNL CNRS/IN2P3

NÉEL institut CNRS/INP

LABORATOIRE DE PHOTONIQUE ET DE NANOSTRUCTURES CNRS

Irfu CEA/IRFU

IRAMIS CEA/IRAMIS

KIT Karlsruher Institut für Technologie IKP EKP IPE

JINR JINR DUBNA

UNIVERSITY OF OXFORD Univ. OXFORD

The University Of Sheffield. Univ. SHEFFIELD