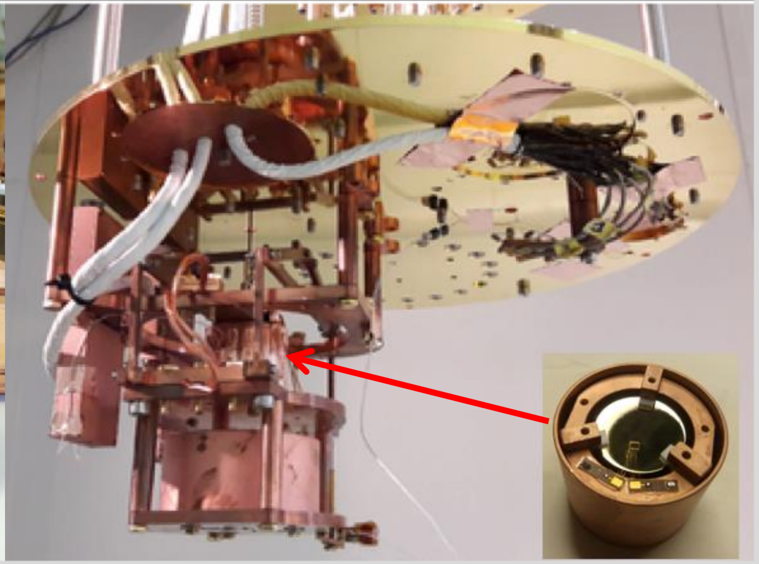
The EDELWEISS Dark Matter Search

Astroparticle Physics in Germany, Mainz 17-19.09.2018

Bernhard Siebenborn on behalf of the EDELWEISS collaboration

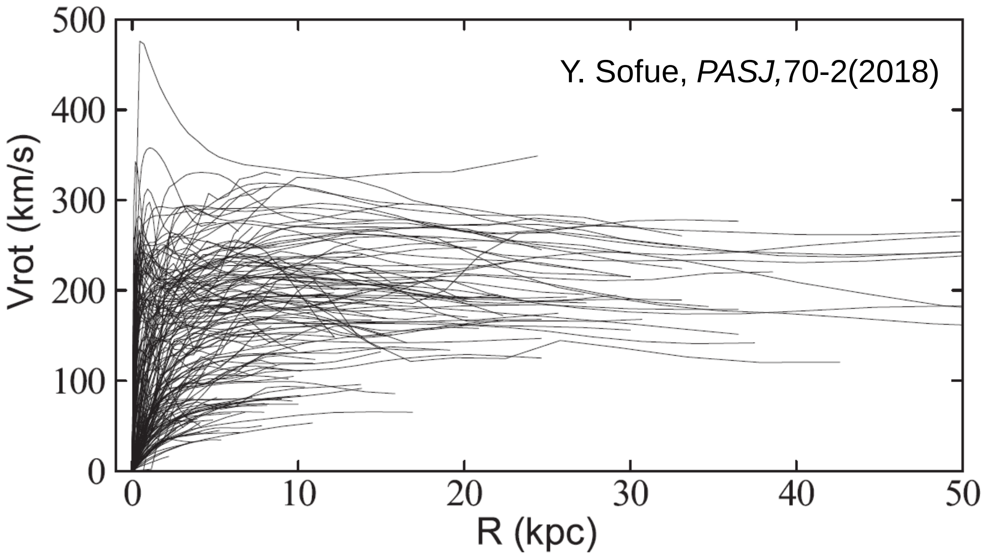


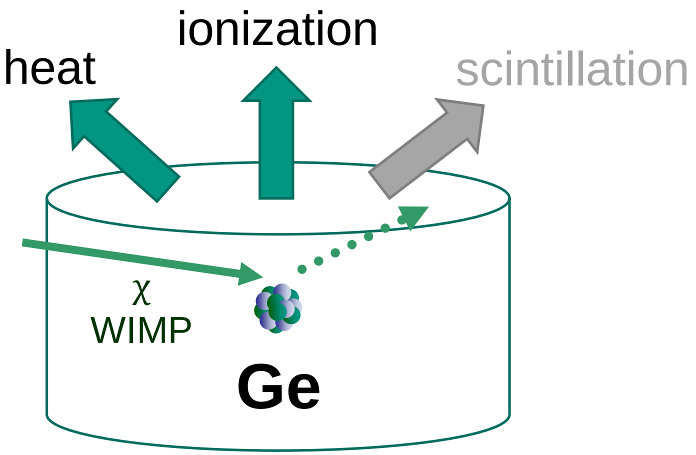


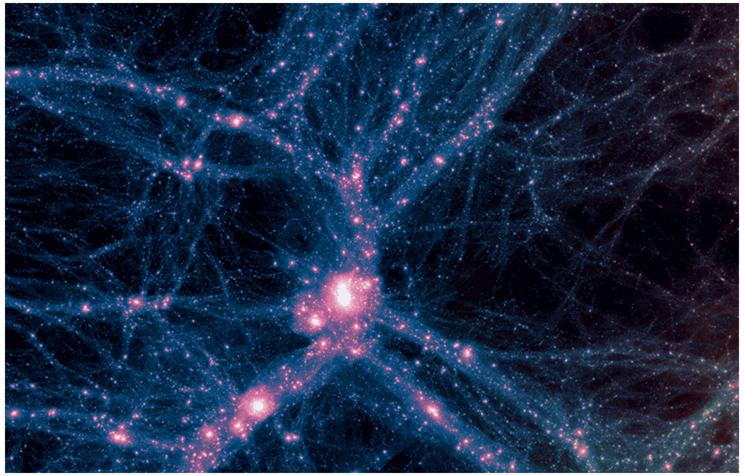
WIMPs as Dark Matter

- Rotation curves of galaxies → DM halo
- Assume DM particle candidate: WIMP
  - gravitation
  - additional “weak” interactions
- WIMP-nucleus scattering in detector
- Kinematics → keV-scale recoils
- Potential for WIMP discovery in a detector via combination of
  - heat
  - Ionization
  - scintillation

- Unknown parameters:
  - cross section
  - WIMP mass

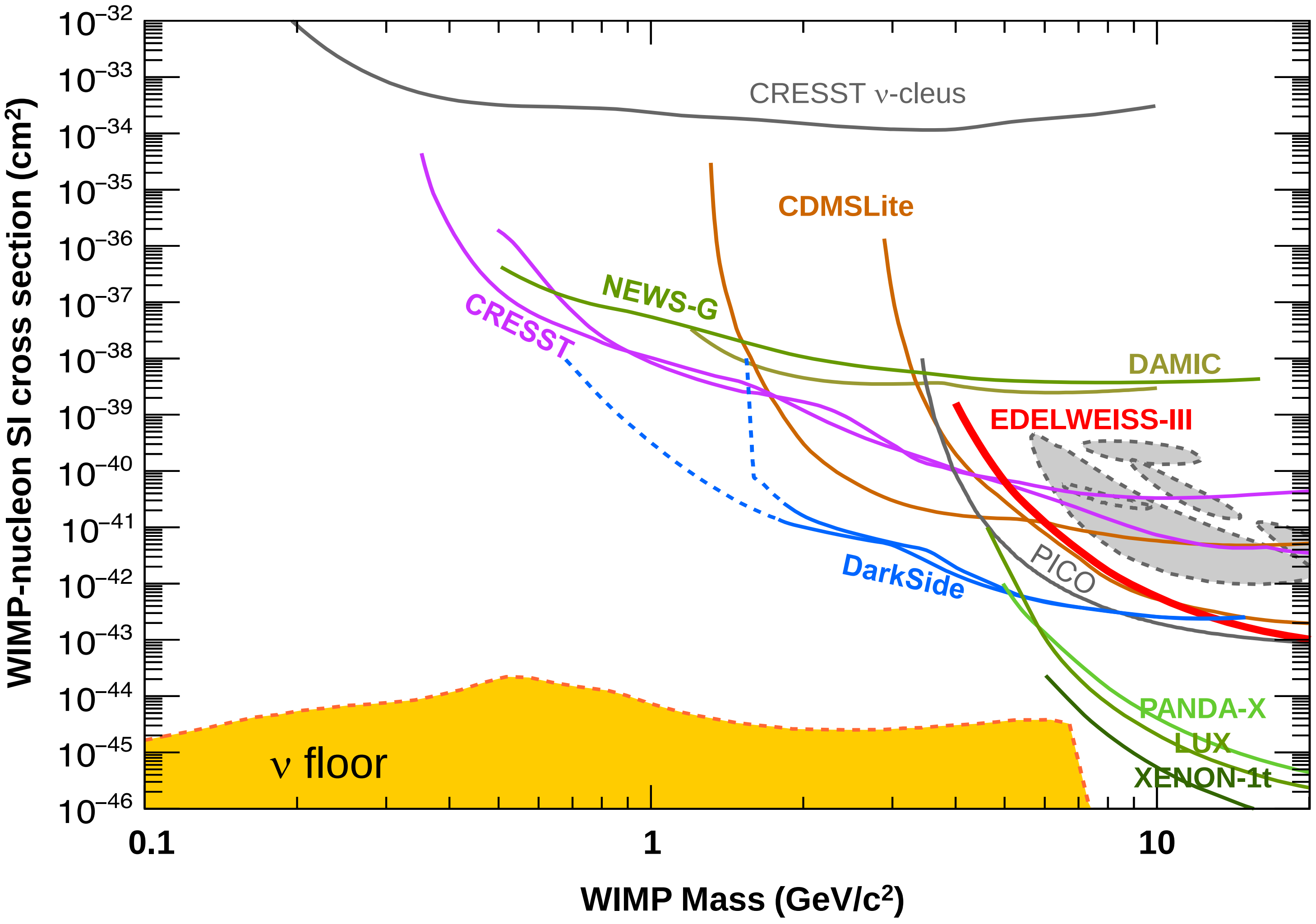




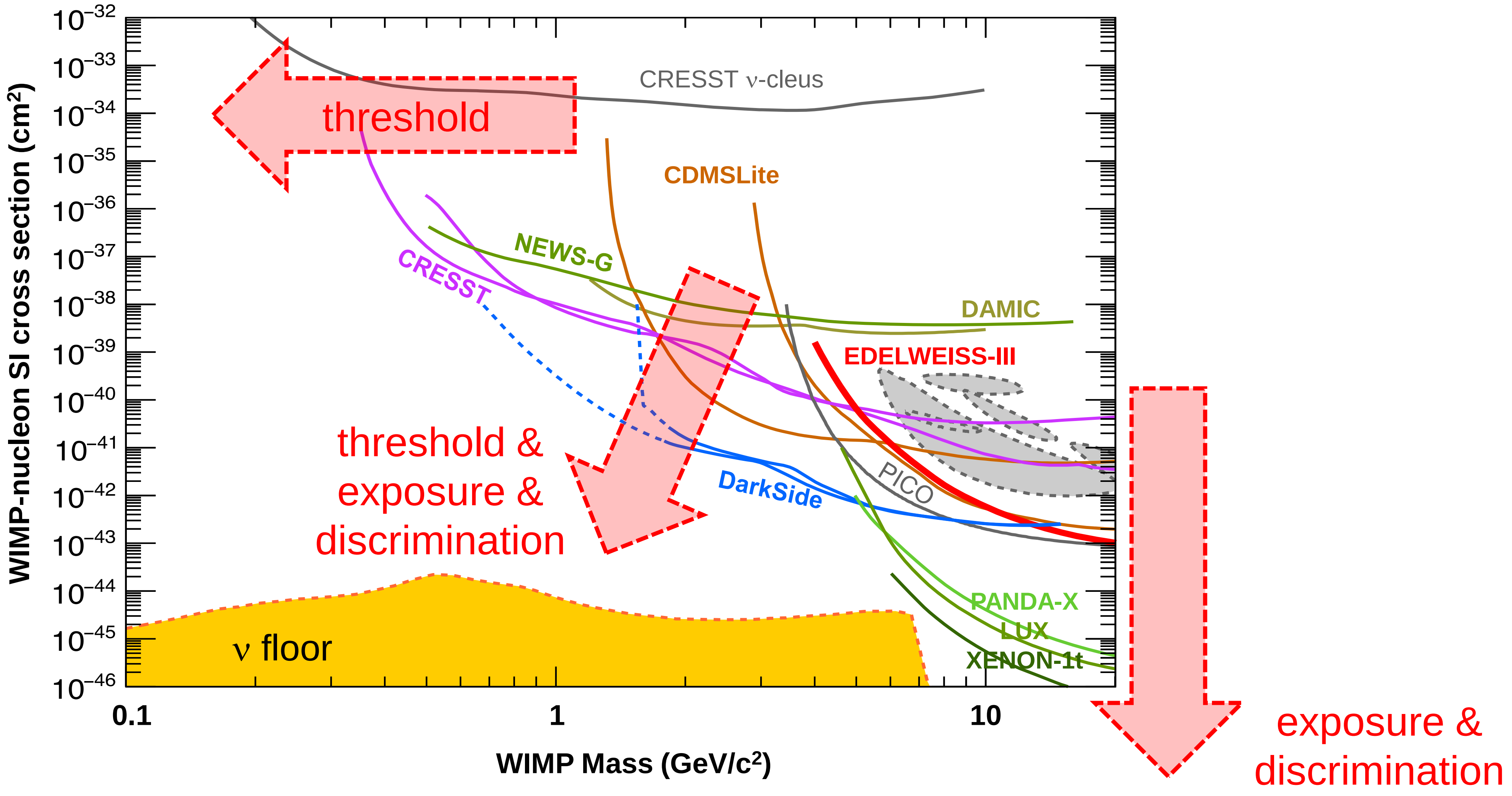


credit to Illustris Collaboration

(low mass) WIMP searches



(low mass) WIMP searches



EDELWEISS low mass WIMP searches

EDELWEISS-III

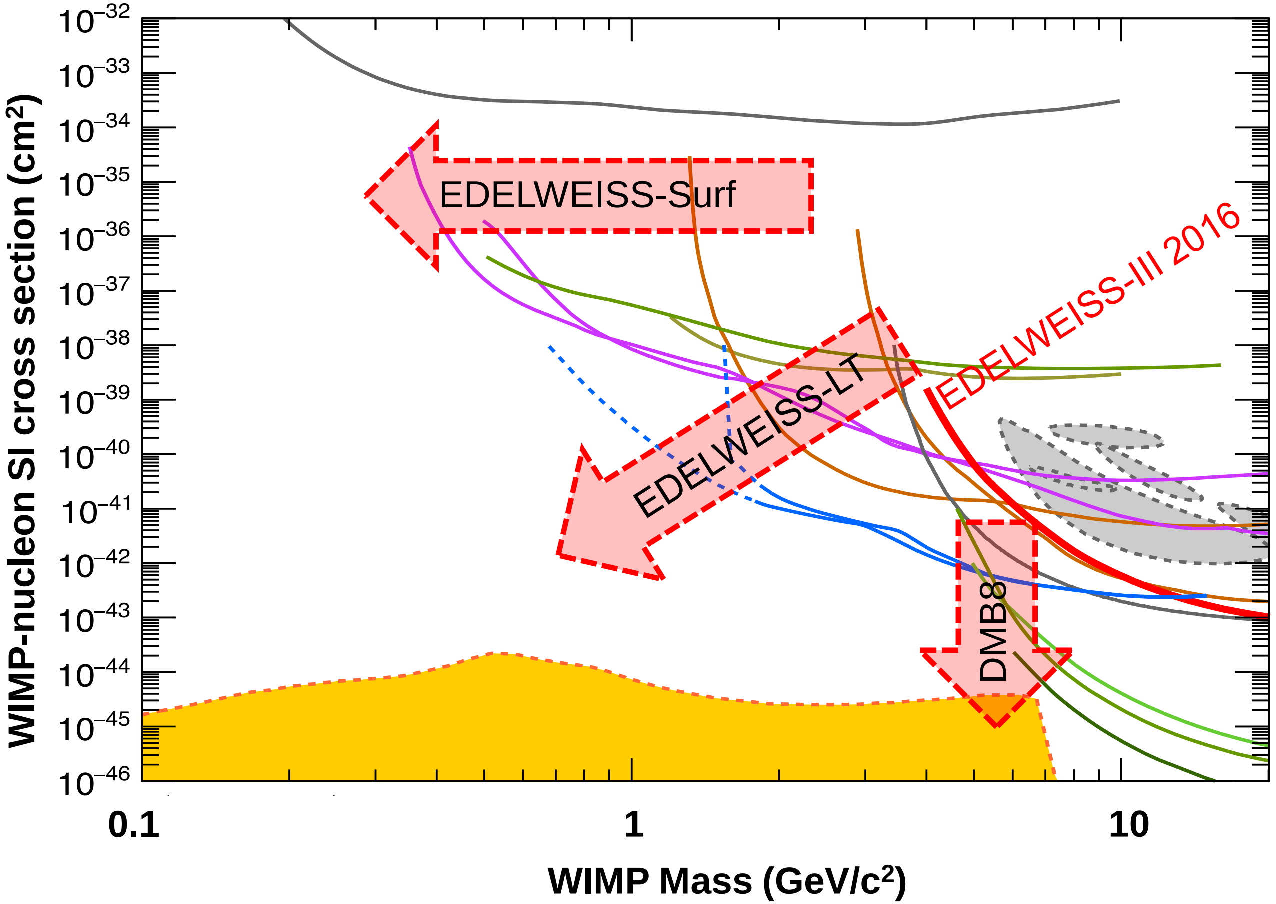
- Exploitation of results with 20 kg array
  → EPJC 76 (2016) 548

Ionization channel R&D

- Improving discrimination to explore the ^{8}B region with resolution (DMB8)
- Exploring non-WIMP DM with smaller array

Heat channel R&D

- Improving the heat channel resolution to reach lower WIMP masses
- Above-ground R&D (Surf) and deployment at LSM (LT)

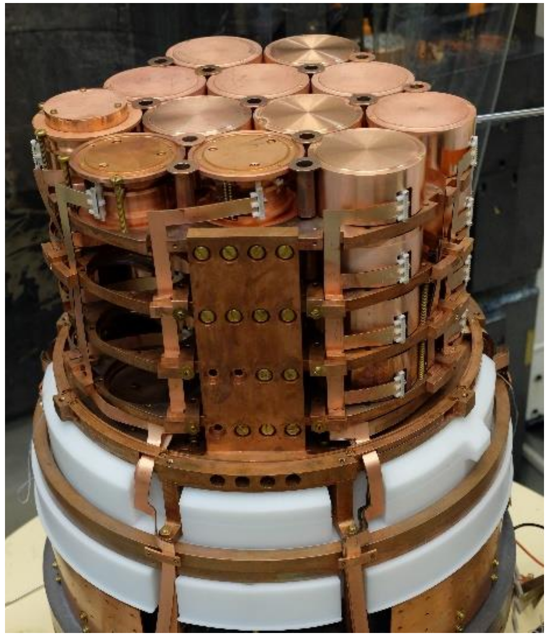


EDELWEISS collaboration

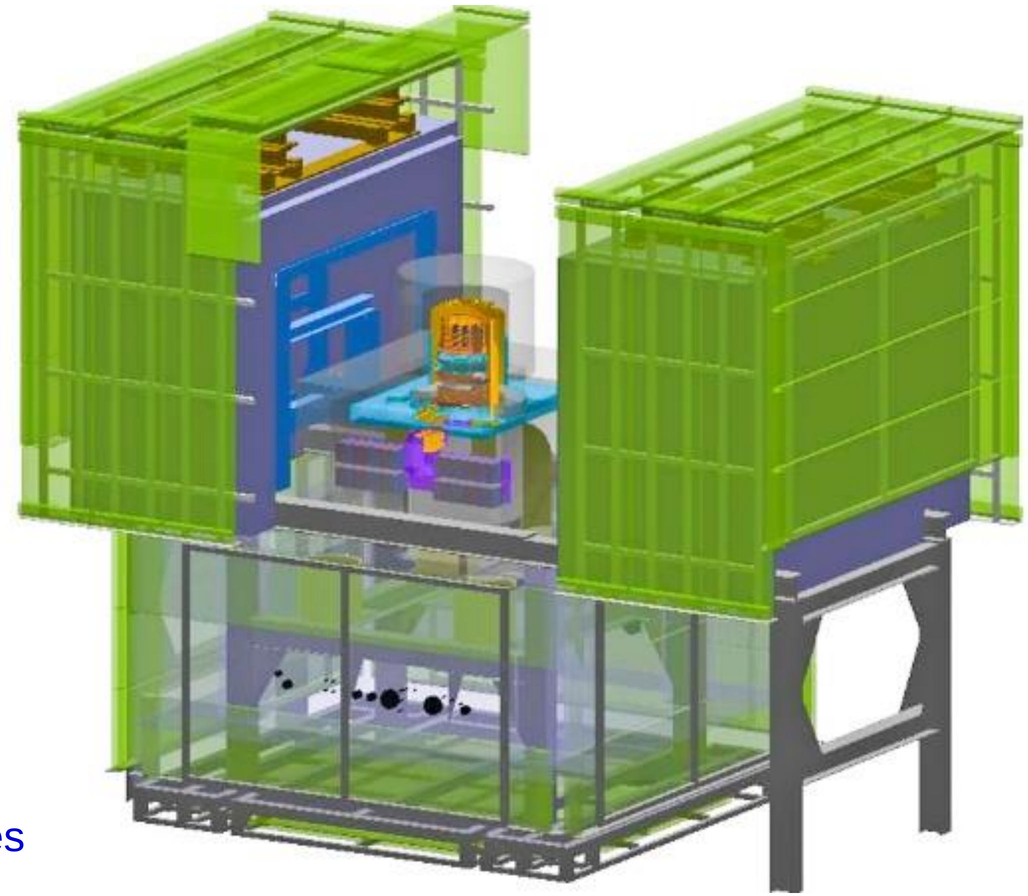
France	CEA Irfu/Iramis (Saclay) CSNSM (Orsay) Institut Néel (Grenoble) IPNL (Lyon) LPN (Marcoussis)
Germany	KIT (Karlsruhe)
Russia	JINR (Dubna)
GB	University of Oxford University of Sheffield

EDELWEISS-III setup

- Laboratory: LSM, ~4800m.w.e. rock overburden (deepest in Europe) → 5 µ/m²/d
- Active muon veto + PE + Pb shield
- Clean room, de-radonised air → 10-20 mBq/m³
- Cryostat hosting up to 40kg of detectors at 18mK
- Selection of radio pure material

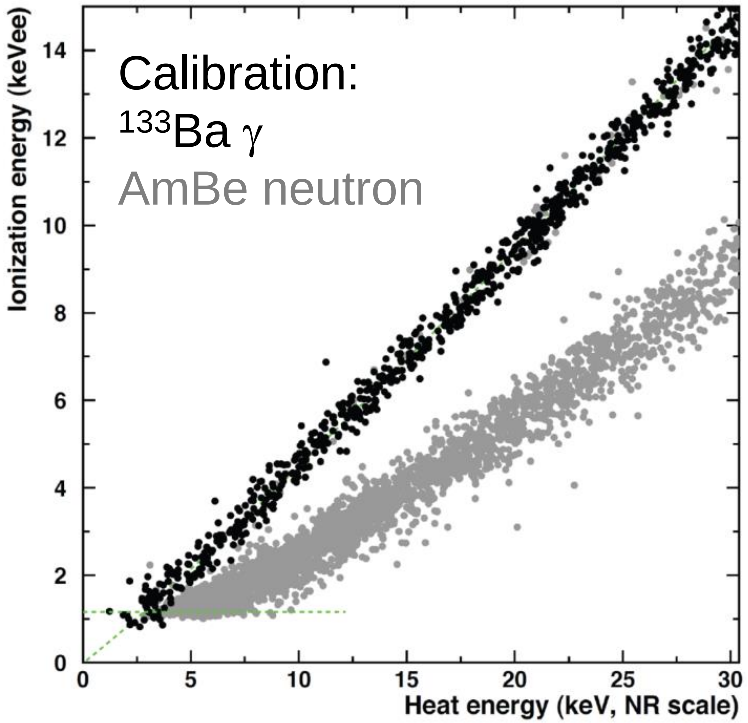


Performance of the EDELWEISS-III experiment for direct dark matter searches
JINST 12 (2017) P08010

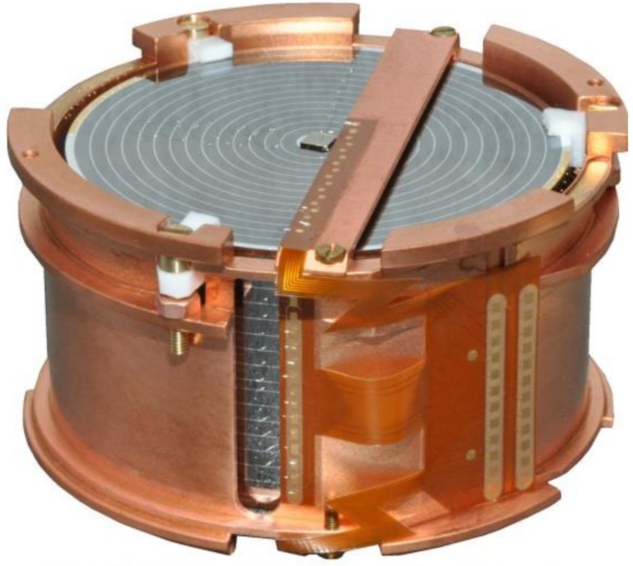


EDELWEISS-III detectors

- ~870g mono-crystal high purity Ge detectors
- 2 heat sensors per detector (GeNTDs)
- Electrodes: Al rings covering all faces

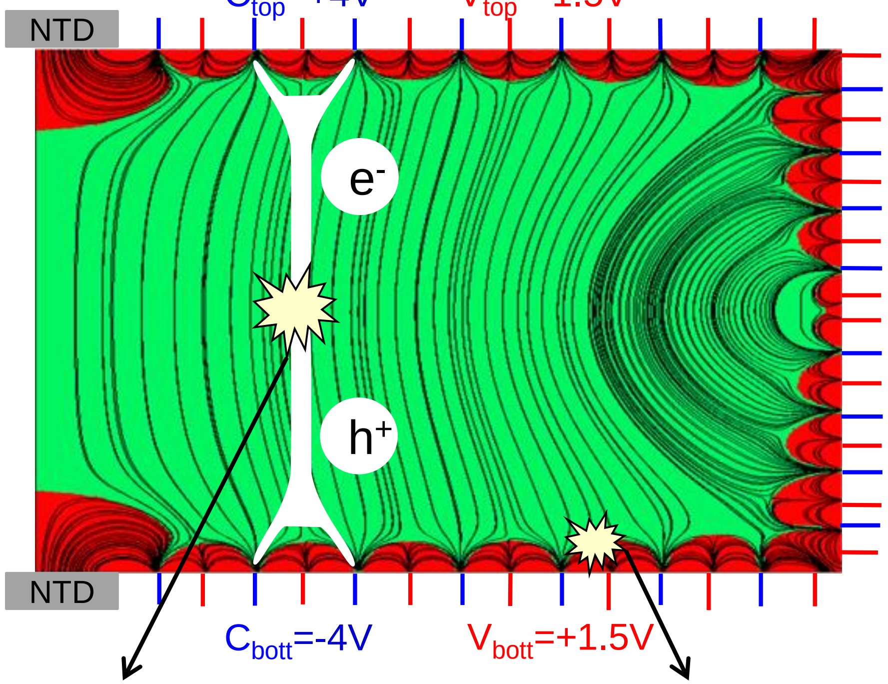


T_{op} = 18 mK



- Clear **event-by-event** separation down to ~ keV energy (nuclear recoils)

surface event rejection ~10^{-5}
PLB 681 (2009) 305–309



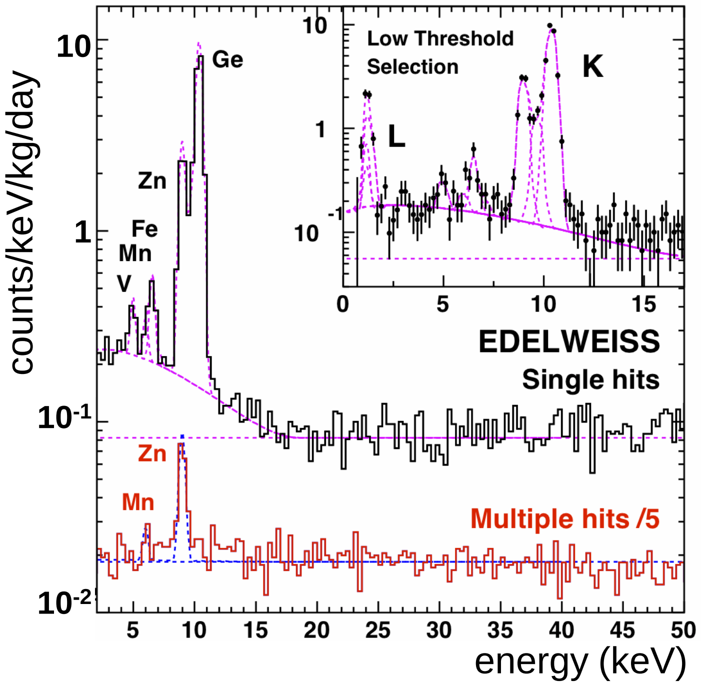
Bulk/Fiducial event: Signal on C_{top}&C_{bott}

Surface event: Signal on C_{bott}&V_{bott}

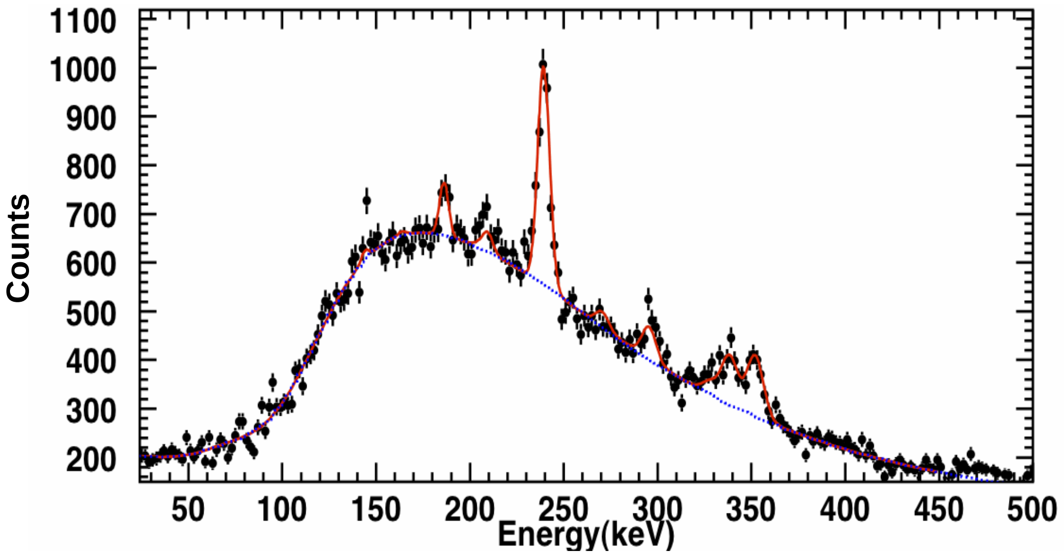
Axion-like particle searches (e^- recoils)

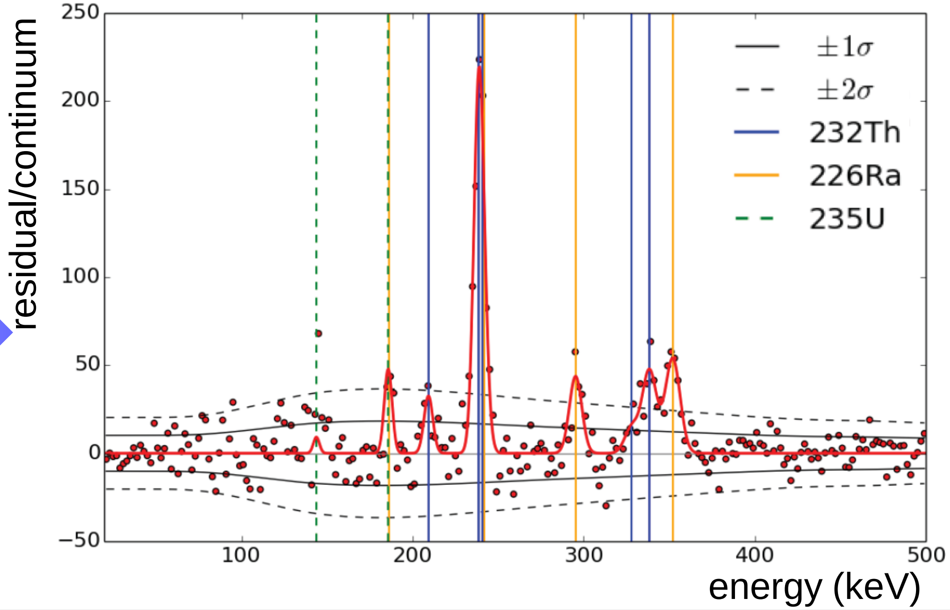
- Starting point: study of **electron recoil spectrum** of cosm. activ.
  - Threshold: 0.8 keV_{ee} to 2 keV_{ee}
- Analysis extended to higher energy for line search up to 500 keV_{ee}
- Intensities of observed peaks consistent with known Th/U lines
- Baseline resolution: 193 eV_{ee}

Astropart. Phys. 91 (2017) 51



arXiv:1808.02340





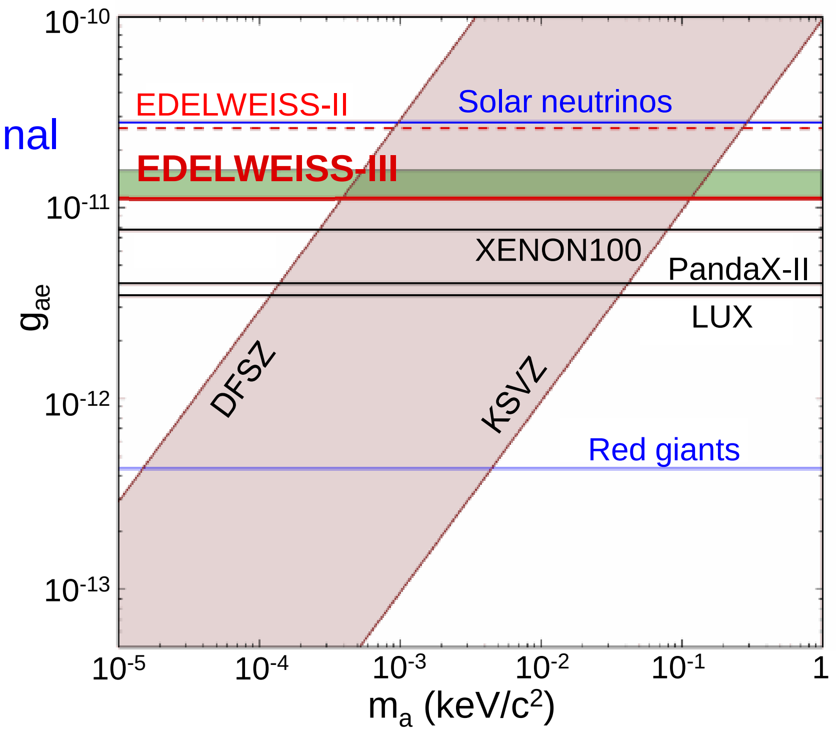
ALP and dark photon results (e^- recoils)

Emission of Axion/ALPs from the sun

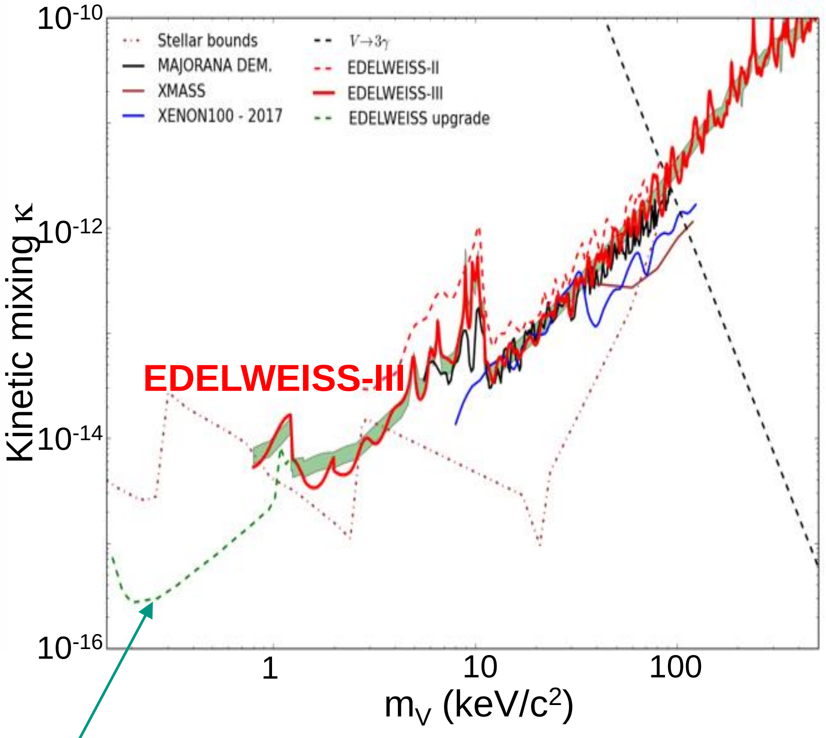
keV-scale Bosonic DM

Compton-
Bremsstrahlung-
Recombination-
De-excitation-like signal

CBRD signal



Kinetic coupling κ of dark photon



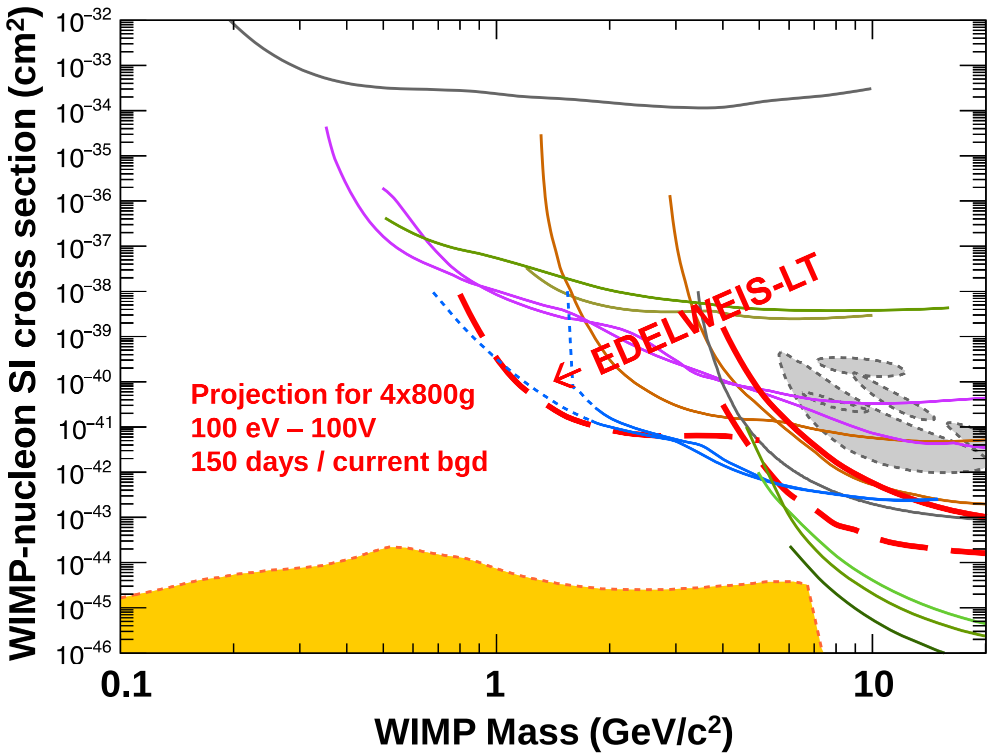
expected sensitivity with improved ionization channel

- Best Ge-based limits <6 keV (thanks to surface rejection)
- Start to explore <1 keV

arXiv:1808.02340

prospects for GeV-range masses

Complete study based on present measured backgrounds and resolutions *vs* possible improvements:
PRD 97 (2018) 022003



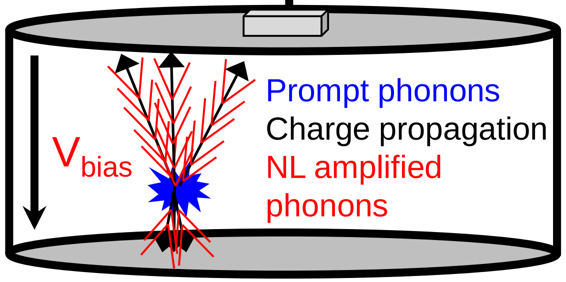
Lower thresholds

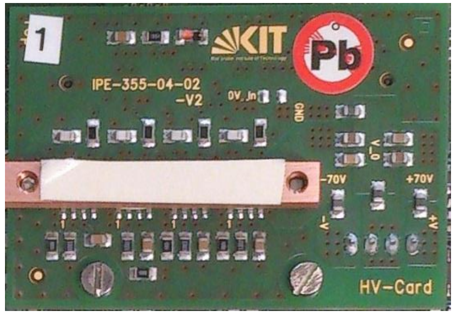
1. Use of Neganov-Luke boost to lower thresholds (increased detector voltage 8 V → **100 V**)

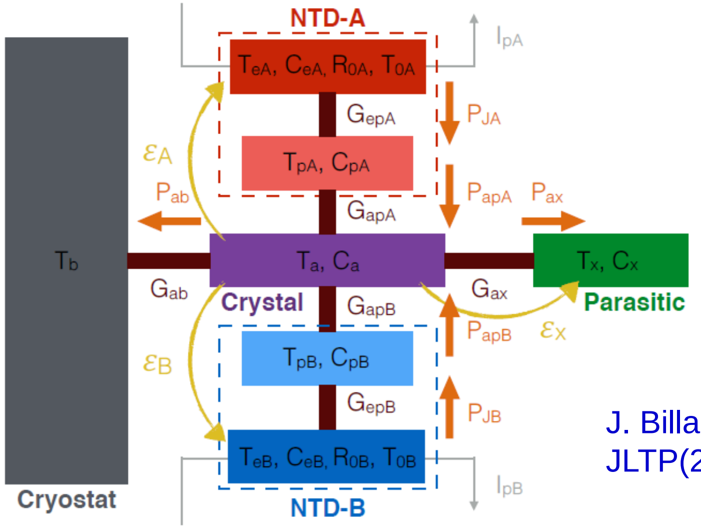
2. Improve heat resolution, objective of 800g detectors: σ_{phonon} = 500 eV → **100 eV** *(50 eV resolution already achieved on 200 g detector)*

EDELWEISS-LT: NL-boost & improved heat

$$E_{NL} = \frac{E_{ion}}{\varepsilon} \cdot V_{bias}$$



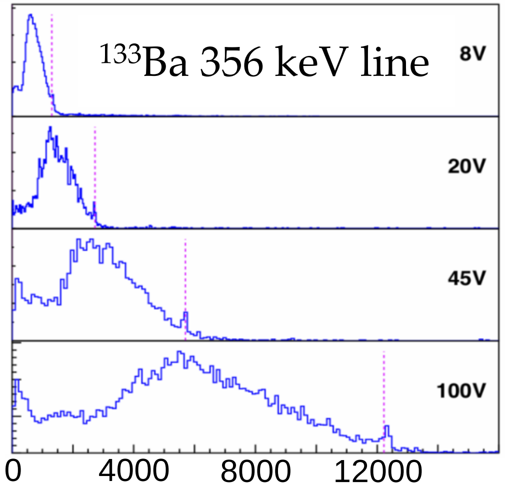


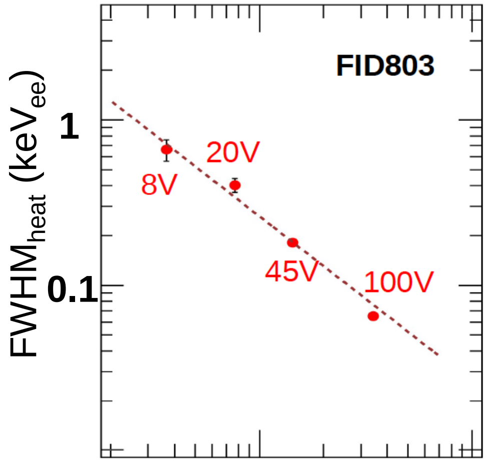


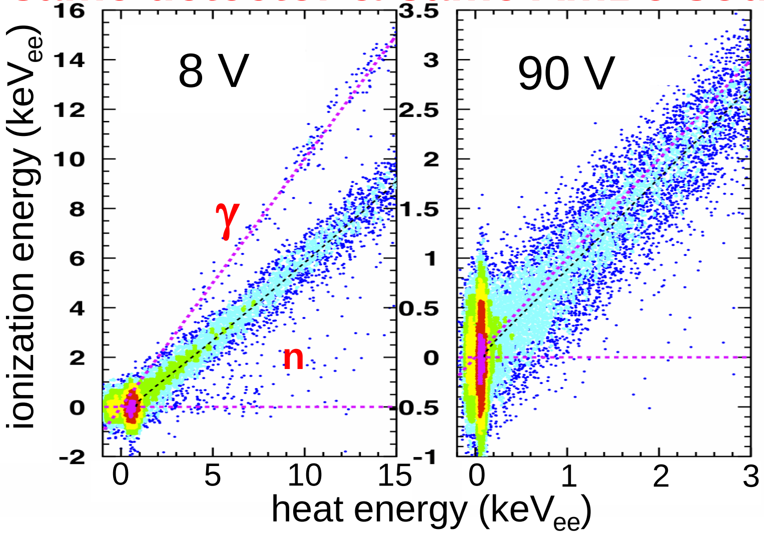
J. Billard et al., JLTP(2016)184:299

- ✓ **100V bias already achieved**
- ✓ **Observe nucl. recoils down to ~0.1 keV_{ee}**
- ✓ **Full ion.+heat readout possible at any V**

same detector & same AmBe source

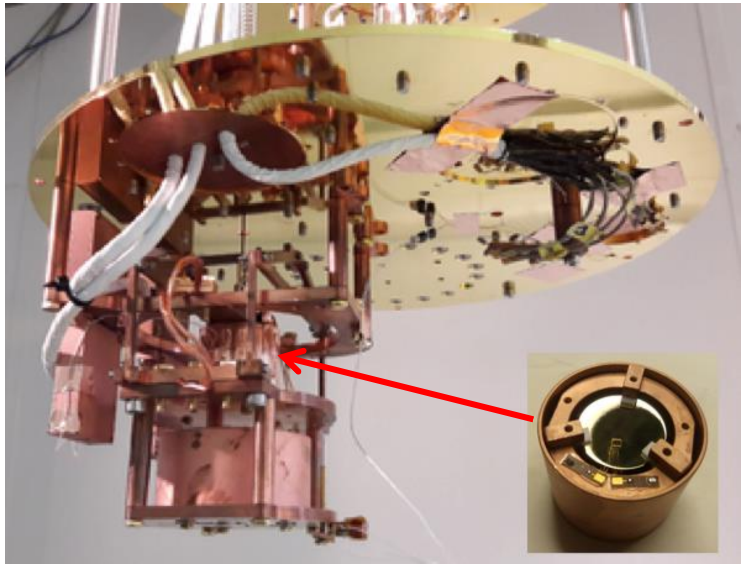




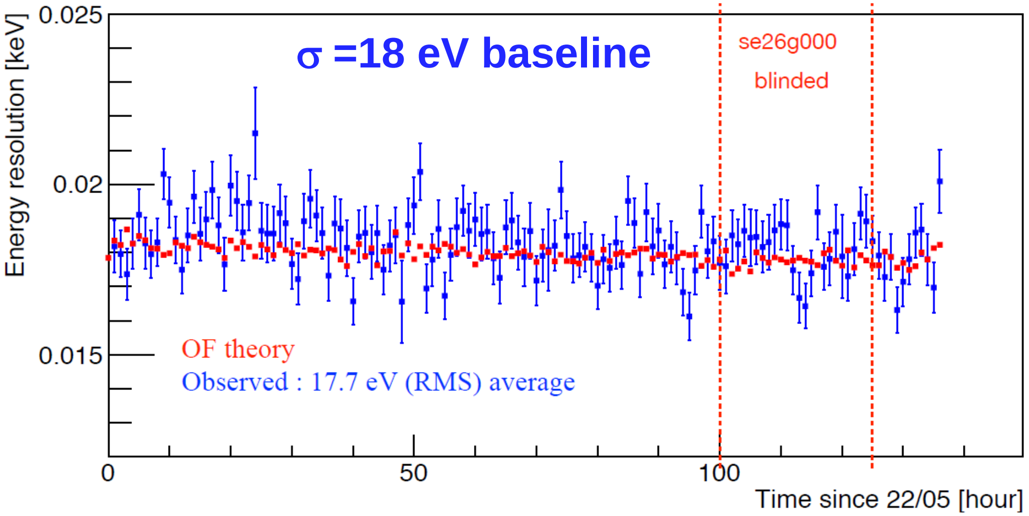


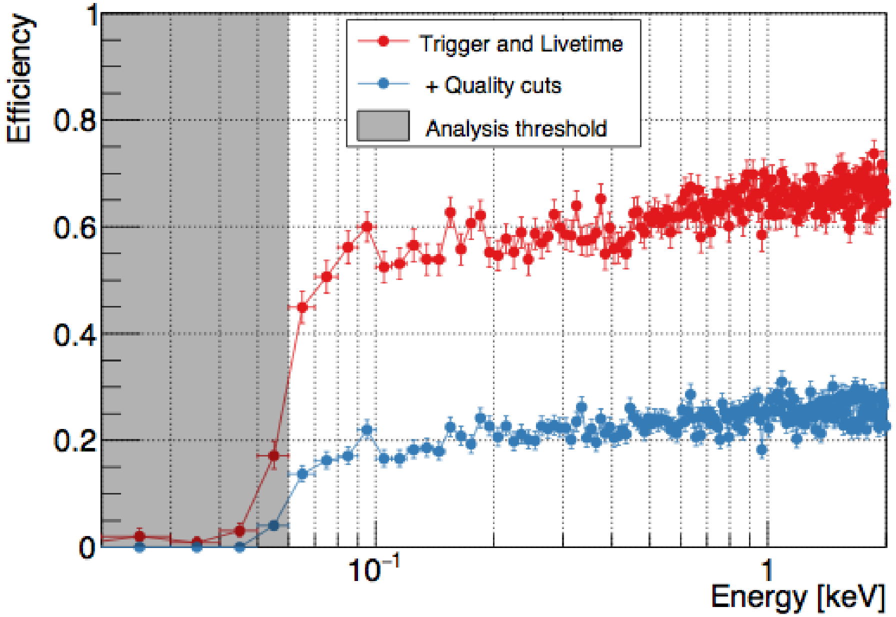
resolution improvements on a 32g HPGe

Karlsruhe Institute of Technology



- R&D with 32g HPGe combined with the objective of testing the above-ground sensitivity to sub-GeV WIMPs
- *optimized* NTD heat sensor on a 32g crystal, no electrodes (i.e. 1keV = 1keV$_{NR}$)
- kept at 17 mK in IPNL low-vibration dilution fridge [arXiv:1803.03463]
- one day blinded for WIMP search in [0-2] keV region
- 60eV analysis threshold

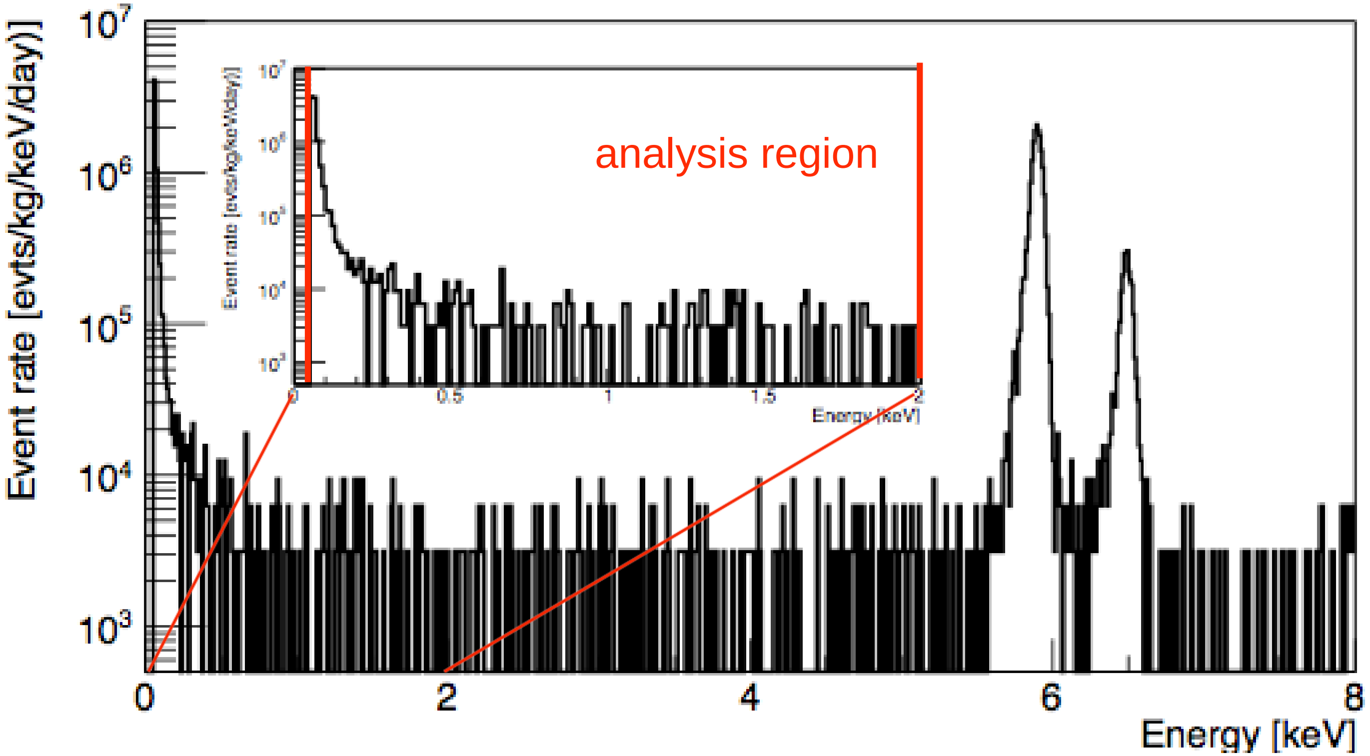




unblinding the data

- No surprise:

  blinded day = carbon copy of preceding + following days



8000 dru 0.6-2.0 keV

4000 dru > 7 keV

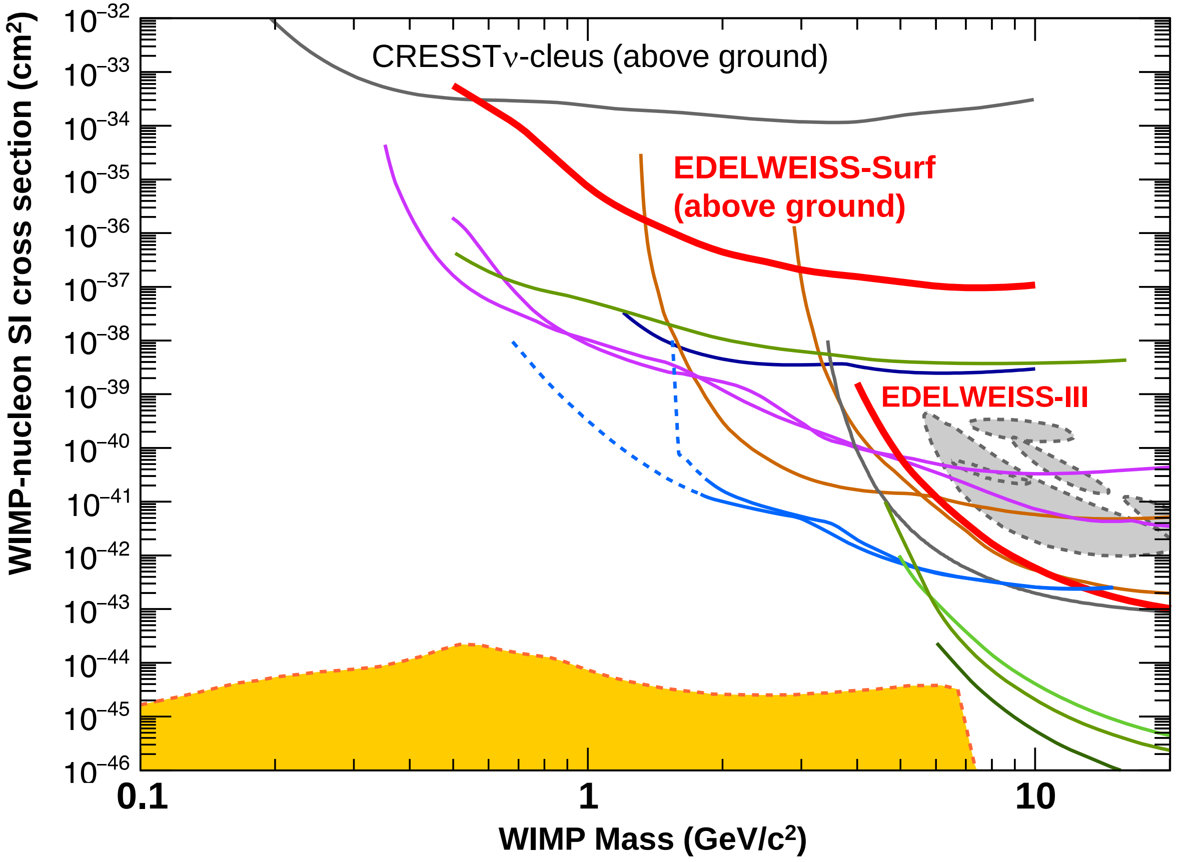
- Find maximal WIMP rate compatible with total number of counts observed in the pre-defined windows
  → 90% CL on WIMP signals as function of WIMP mass

EDELWEISS surface limit

- Best above-ground limit down to 600 MeV/c^2: SIMP
- First sub-GeV limit with Ge, down to 500 MeV/c^2

- Achieved resolution on a smaller detector exceeds by x5 the original LT goal with 800 g detectors

- Small detectors with lower thresholds to be combined with expertise acquired on HV: threshold reduction by factor (1+V_{bias}/3) in keV_{ee}



Conclusions & outlook

- EDELWEISS-III : large detectors with excellent rejection
  - Exploitation of FID to get best ALP limits, enter the sub-keV range

- EDELWEISS-MELODI: develop large detectors with EDELWEISS design
  - Exploring non-WIMP DM with prototype: ALPs in the 0.1-1 keV range
  - Building block for larger search experiment (DMB8), addressing specifically region where DM signal has to be spectrally separated from solar ^{8}B neutrinos

- Prospects in the sub-GeV-WIMP range: beyond EDELWEISS-LT
  - Going beyond original [PRD] goal: 100 eV → 18 eV (~500 eV EDW-III)
  - Best surface limit for WIMPs above 0.6 GeV/c^2
  - Combining excellent energy resolution with NL-boost
    → 2019/2020: intensive R&D in surface labs
  - KIT + U Heidelberg: NL-boosted Ge detectors with MMC phonon sensors
    → DELight