Status of EDELWEISS

EDELWEISS-III

New result: ALP limits

Prospects for discrimination at low energy

EDELWEISS-LT program

New result: Sub-GeV WIMP limit @surface

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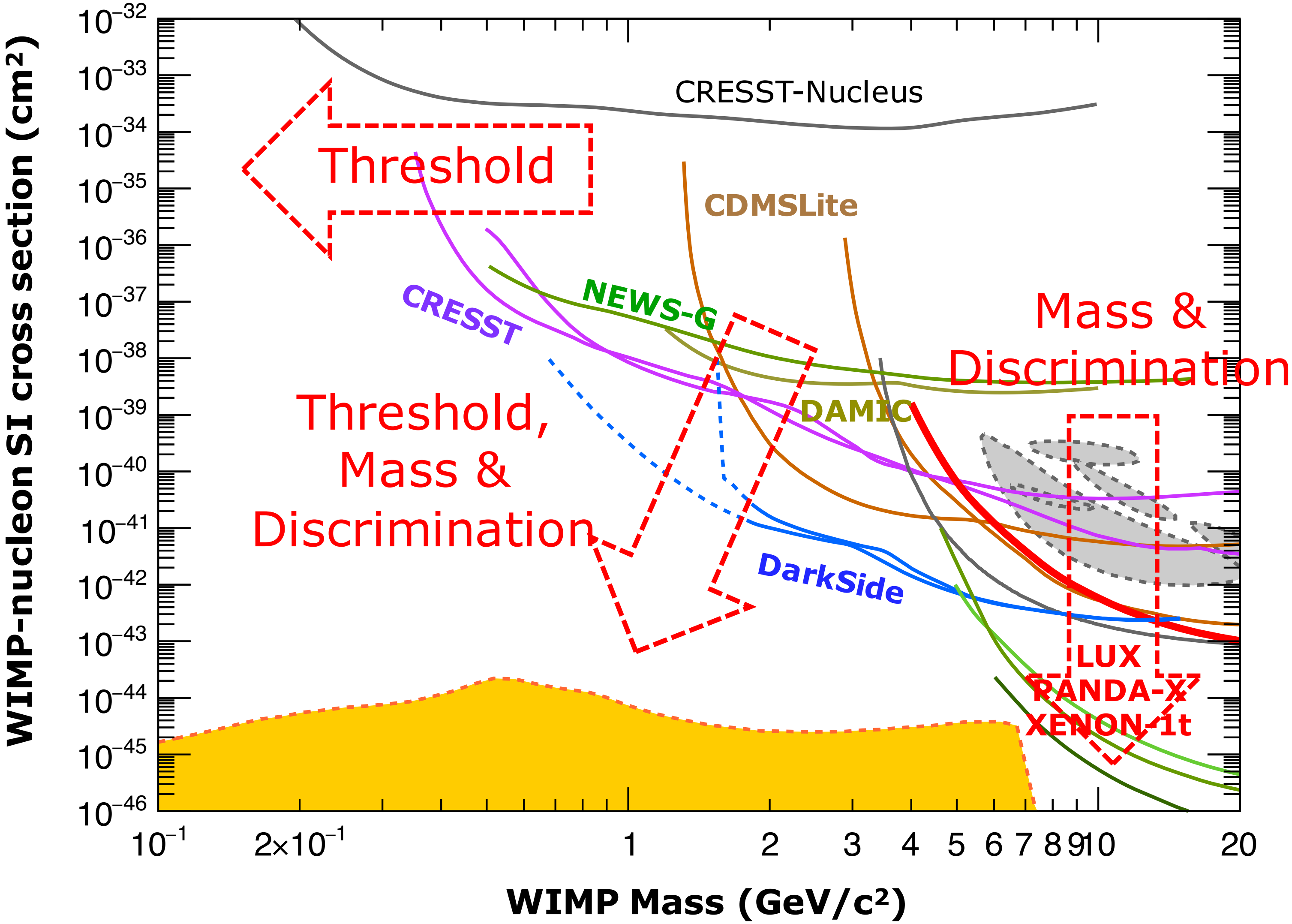
Low-mass WIMP searches



EDELWEISS Low-mass WIMP searches

EDELWEISS-III

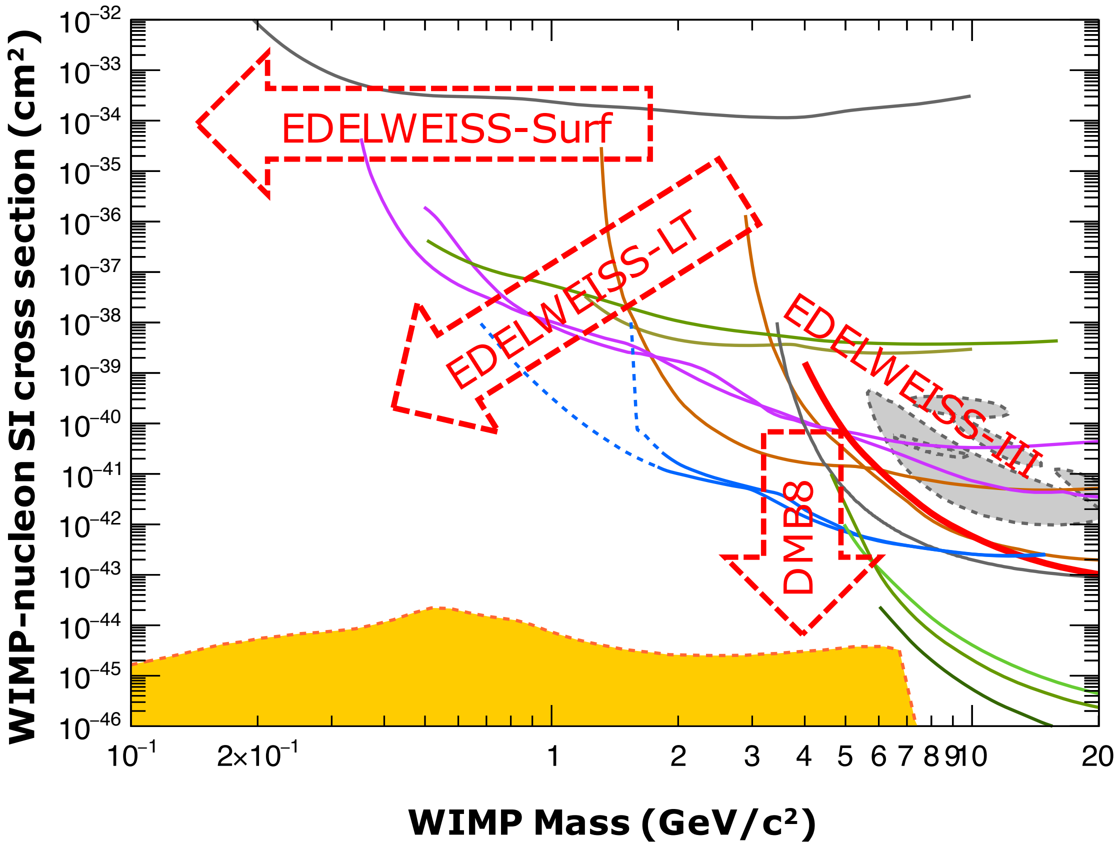
- Exploitation of results with 20 kg array

Ionization R&D

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

Heat channel R&D

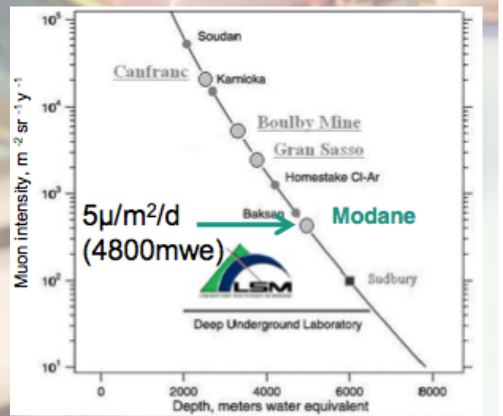
- Improving the heat channel resolution to reach lower WIMP masses
- Above-ground R&D (Surf) and deployment at LSM (LT)



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/c² WIMPs and ~3000 kgd**
  - **Extended down to 5 GeV/c² given achieved resolutions**

- **Laboratoire Souterrain de Modane**
  - **Deepest in Europe : 5 μ/m²/day**

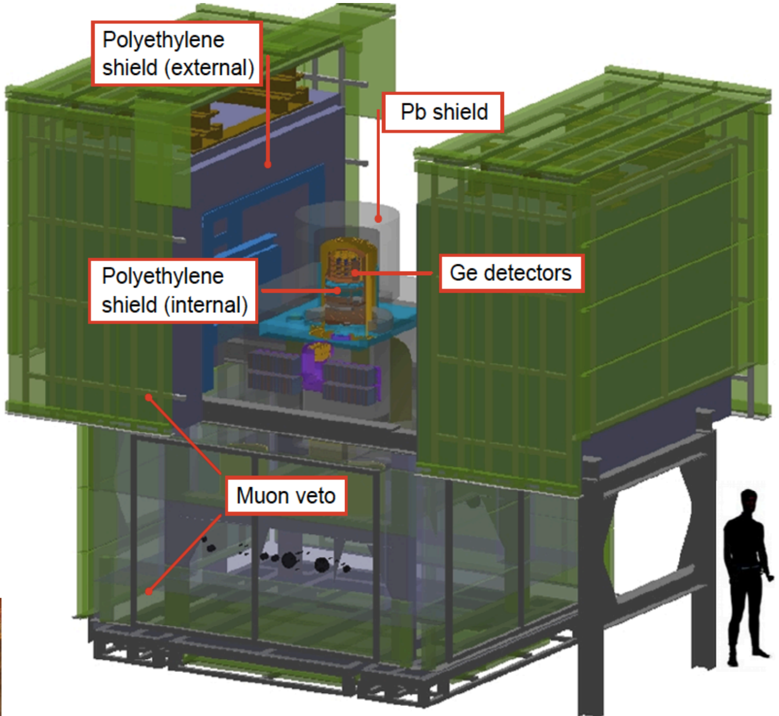


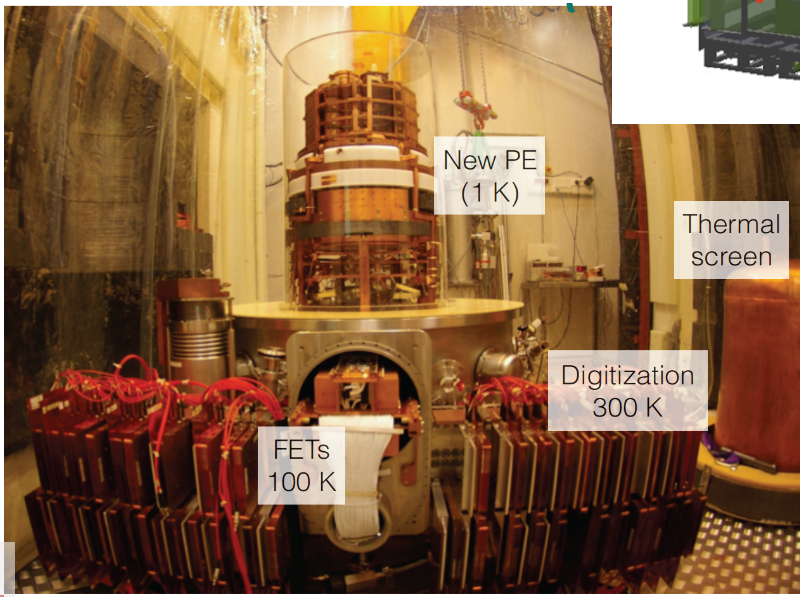
EDELWEISS Setup

- 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



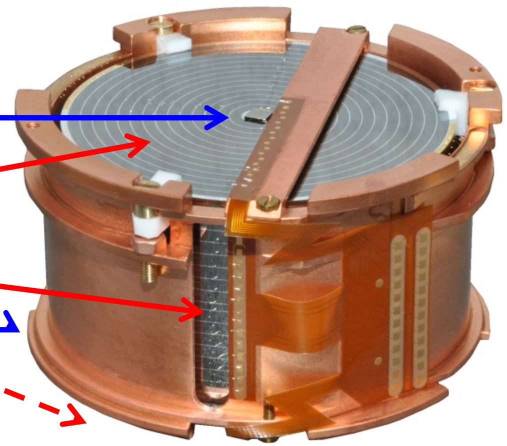


Performance of the EDELWEISS-III experiment for direct dark matter searches

[JINST 12 (2017) P08010]

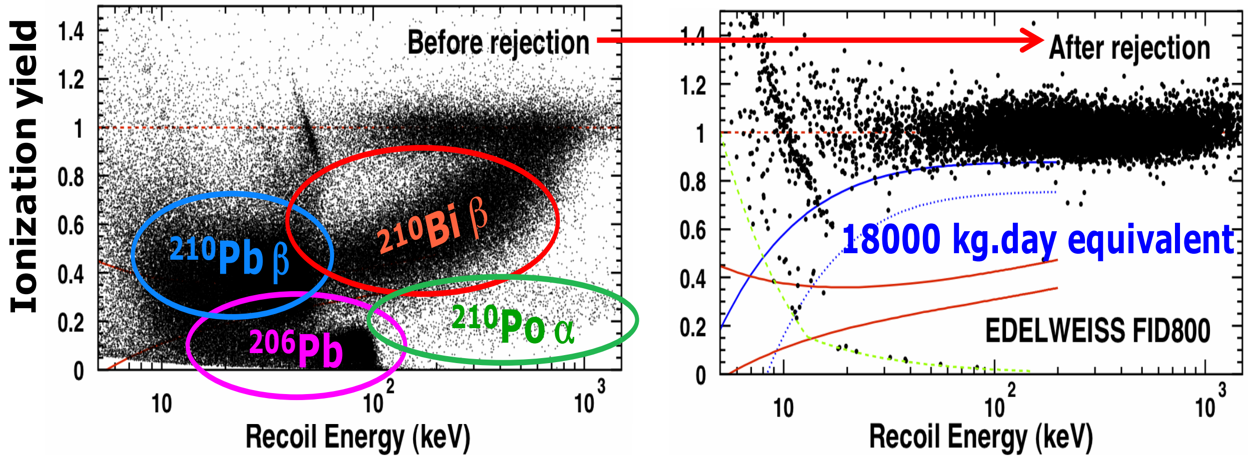
Fully InterDigitized electrode design

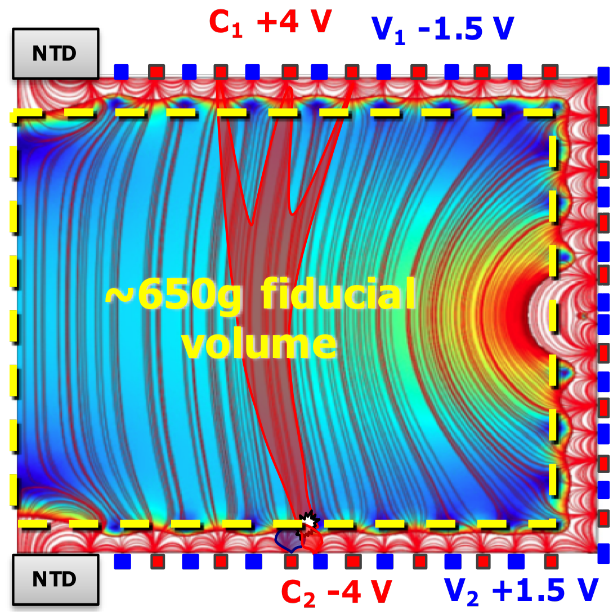
- ~870g detectors (ϕ=70 h=40 mm)
- 2 GeNTDs heat sensor per detector
- Electrodes: concentric Al rings (2 mm spacing) covering all faces
- XeF_2 surface treatment → low leakage current (<1 fA) between adjacent electrodes
  J Low Temp Phys (2014) 176: 182-187



Surface event rejection. *PLB 681 (2009) 305–309*

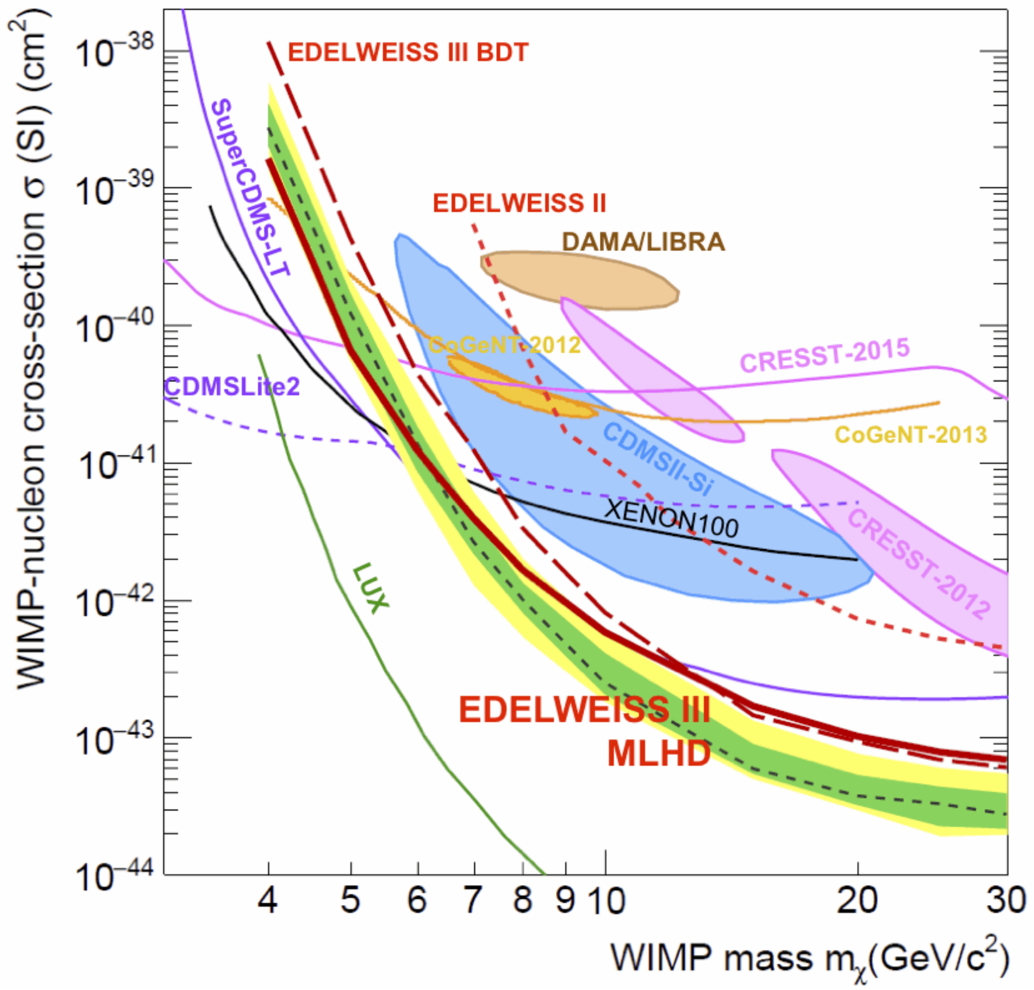
- Bulk: collection by C_1+C_2; V_1+V_2 act as veto
- Surface: charges collected by C_1+V_1 or C_2+V_2





Low-Mass reach of EDELWEISS-III

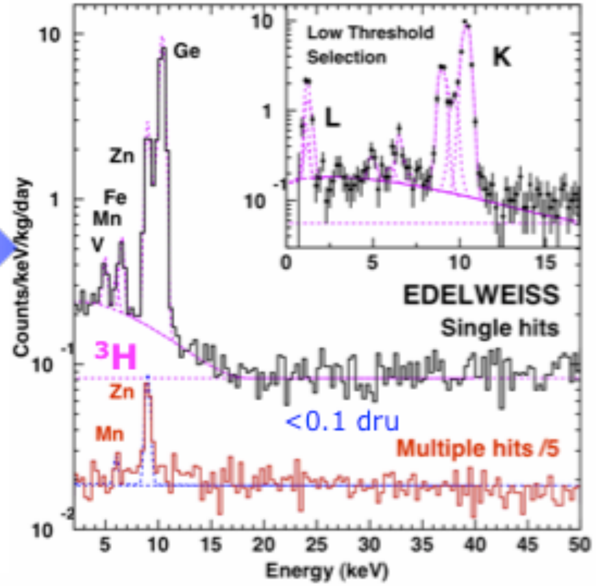
- Analysis with Boosted Decision Tree *[JCAP05 (2016) 019]*
- Analysis with Profile Likelihood *[EPJC 76 (2016) 548]*



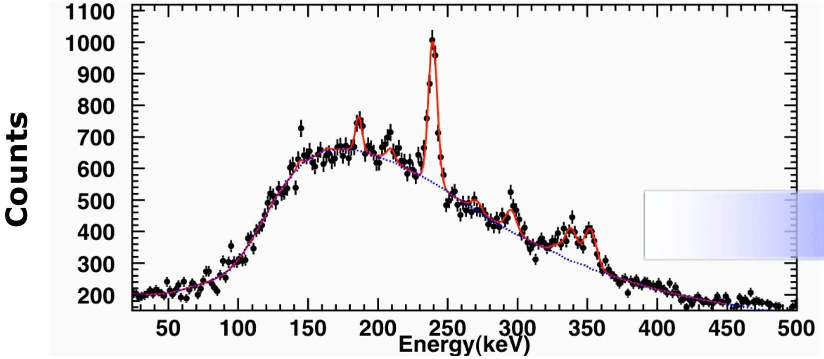
- Improvement by x20 to x150 between 7 and 10 GeV wrt EDELWEISS-II
- Limited by heat-only background: *identification and rejection using the σ=230 eV resolution on ionization*
- Ionization resolution is key for rejection
- Heat resolution is key for low thresholds

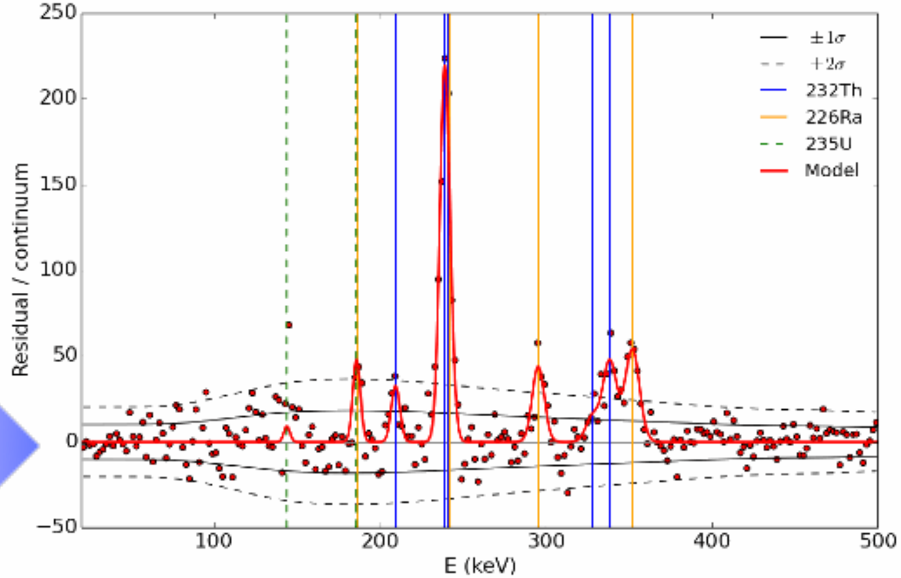
Axion-Like Particle searches

- Starting point: study of electron recoil spectrum of tritium paper [Astropart. 91 (2017) 51]
  - 1149 kgd with 2 keV_{ee} threshold
  - 287 kgd with 0.8 keV_{ee} thresholds



- Analysis extended to higher energy for line search up to 500 keV_{ee}
- Intensities of observed peaks consistent with known Th/U lines
- Resolution:
  - Baseline 0.19 keV_{ee}
  - Proportional term = 1.2%





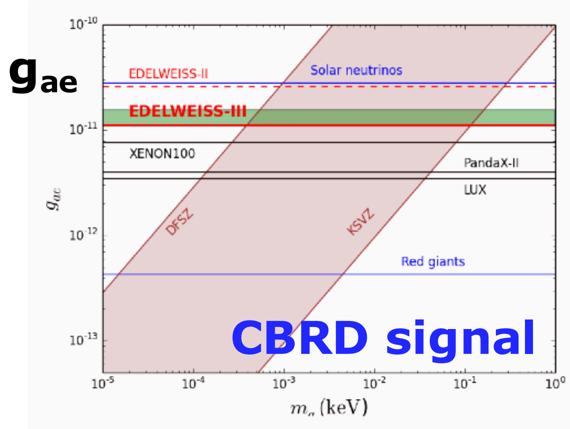
ALP & dark photons results

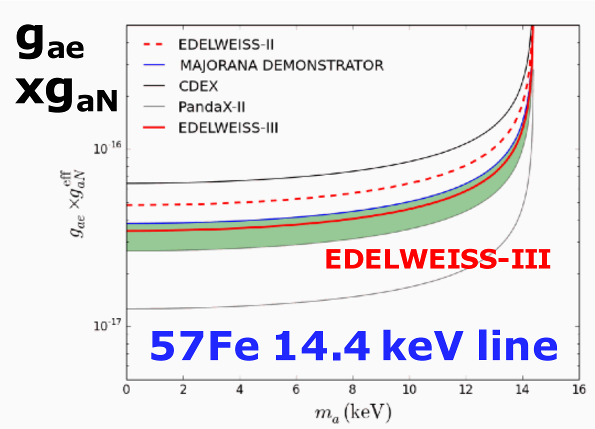
- Emission of axion/ALPs from the sun

keV-scale Bosonic DM:

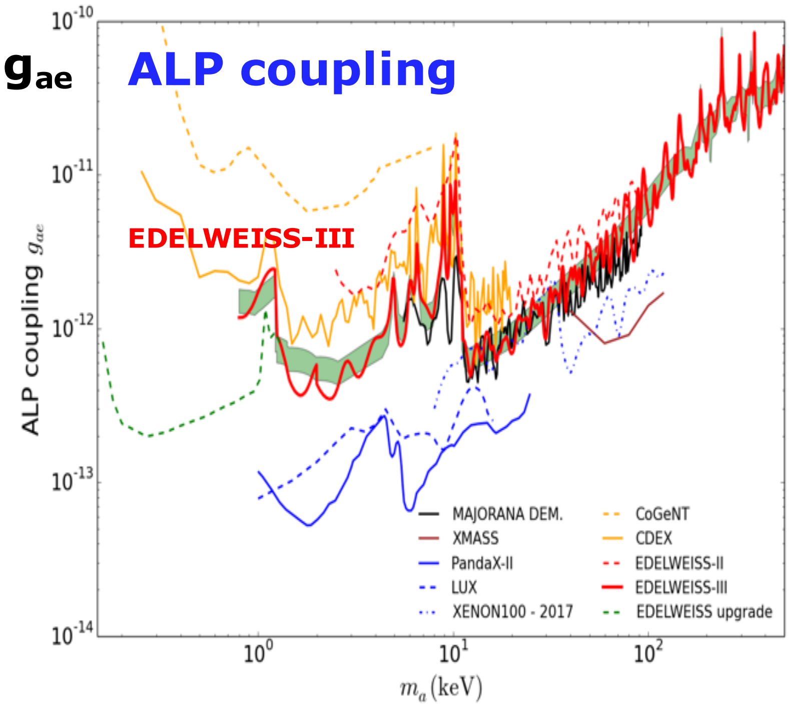
- Best Ge-based limits <6 keV (thanks to surface rejection)
- Start to explore <1 keV

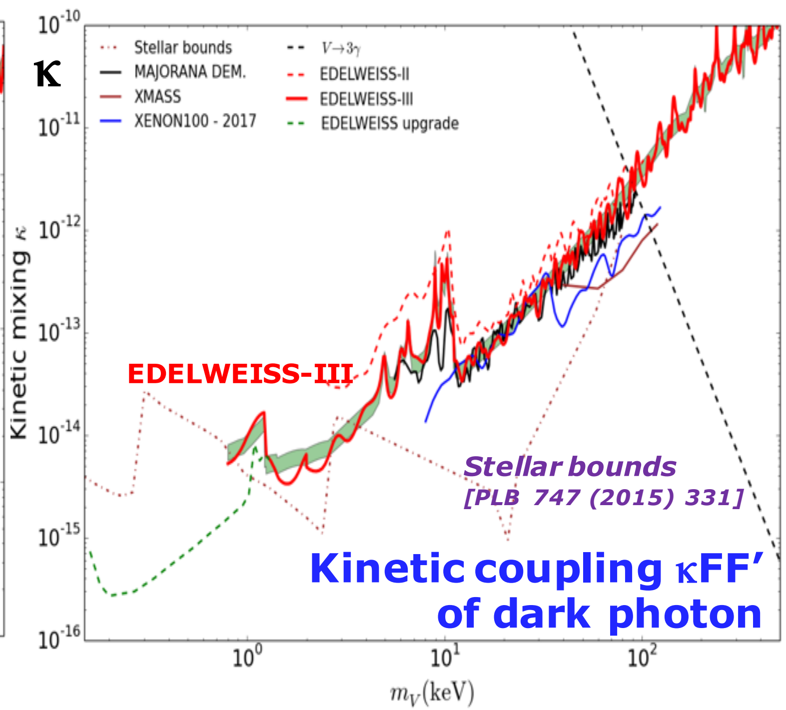
Emission of axions from the sun





Bosonic DM

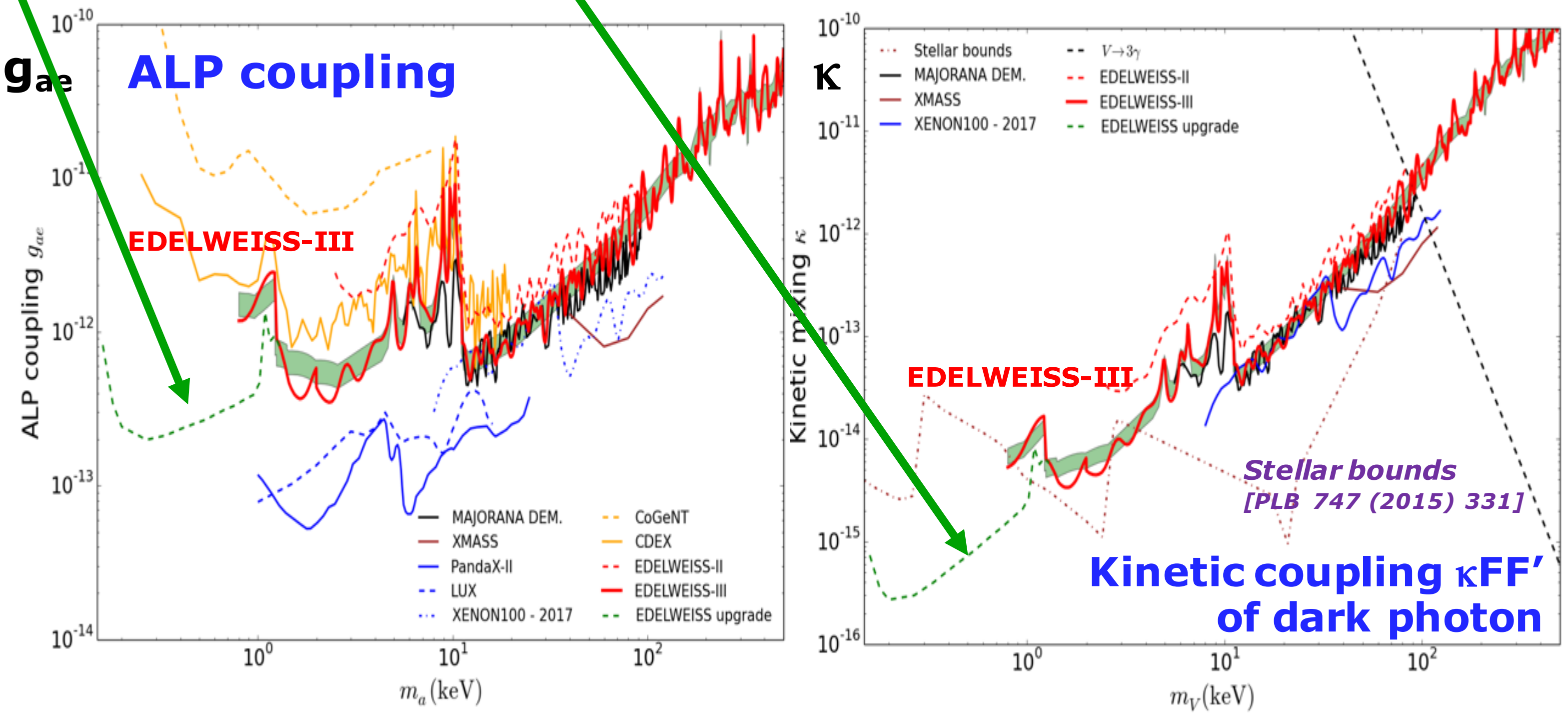




Prospective with improved ionization

- Improvements foreseen in the 100 eV – 1 keV region with improved ionization

Bosonic DM



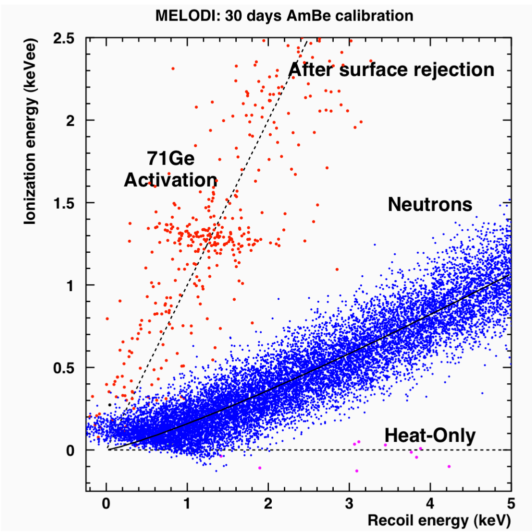
How to do it

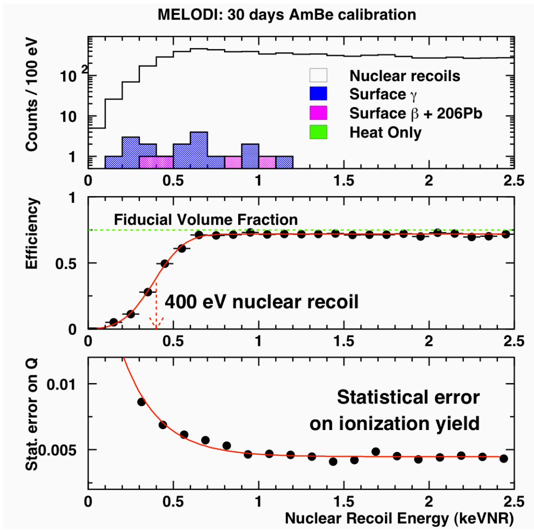
- Cold front-end: replace JFET @100K with HEMT (High Electron Mobility Transistor) @4K
- Can be operated at 4K: shorter cabling -> reduced capacitance -> better signal/noise
- Successful HEMT amplifier with sub-100 eV resolution operated on a CDMS-II detector *[A. Phipps et al., arXiv:1611.09712]*
-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

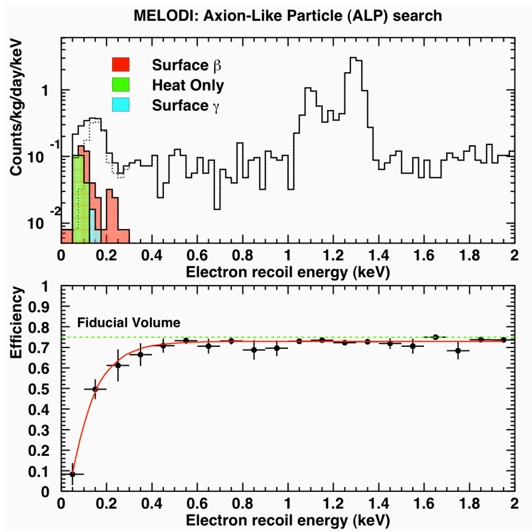
2 mm spacing → 4 mm spacing

First applications with prototype detector: MELODI

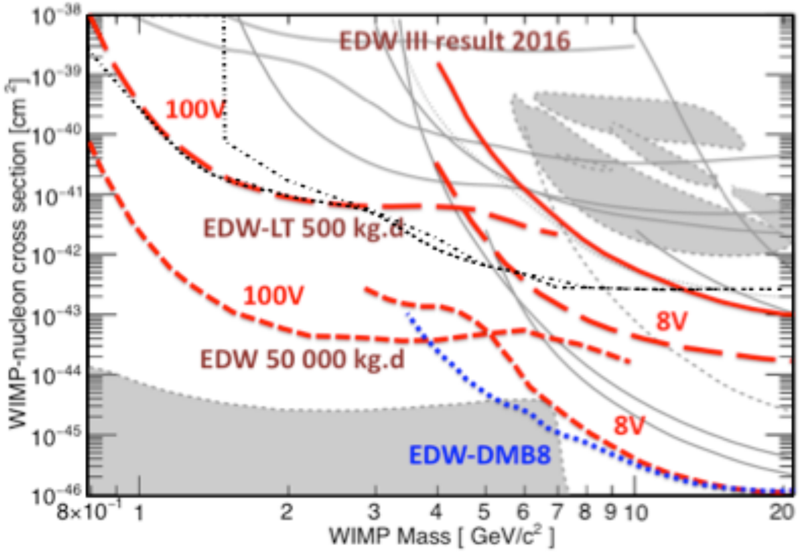
- FID detector with <40 pF + <50 eV_{ee} ion. resolution
- **Precision nuclear recoil ionization yield measurement**
- **Axion-Like Particle Dark Matter searches with 100 eV - 1 keV masses**







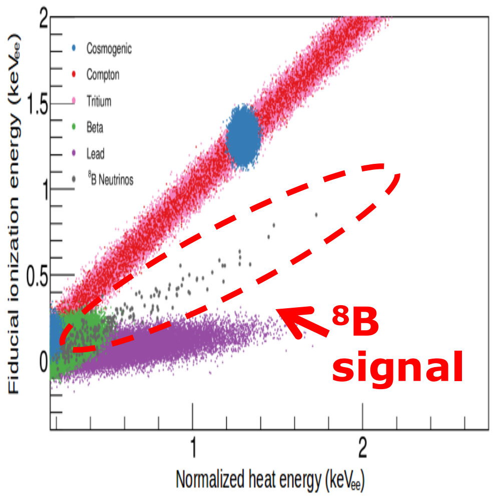
Ionization improvements: EDELWEISS-DMB8



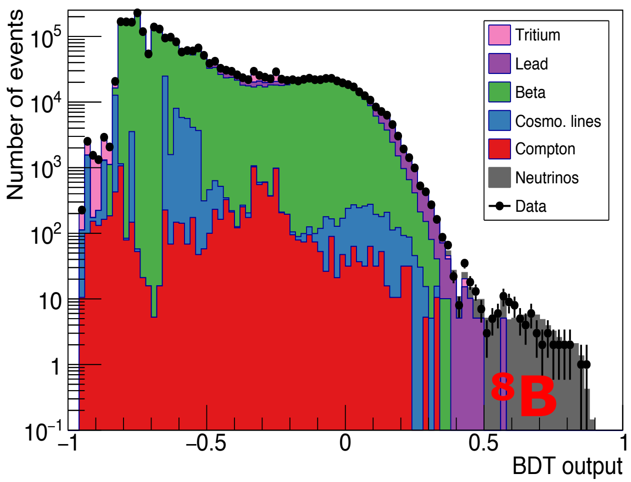
Coherent nuclear scattering from solar ^{8}B neutrinos mimic a ~6 GeV WIMP with $\sigma \sim 4.4 \times 10^{-45}$ cm^{2}

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

[PRD 97 (2018) 022003]



1 000 kg.y



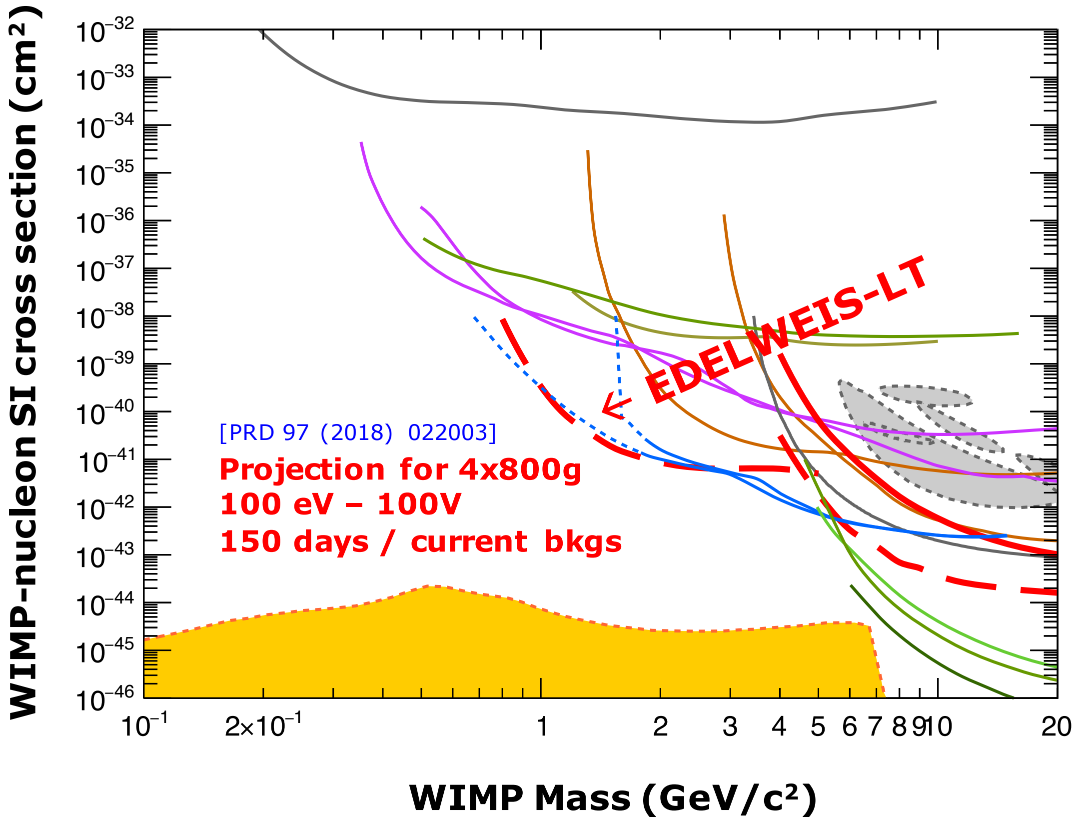
EDELWEISS-DMB8:
Operation of a 200 kg array @8V (with nuclear recoil discrimination + <10% energy resolution) in the improved background environment of SuperCDMS @ SNOLAB

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

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 Luke-Neganov boost to lower thresholds (up to 100V bias)
2. Improve heat resolution, objective of 800g detectors: σ_{phonon} = 500 eV → **100 eV**
   (50 eV resolution already achieved on 200 g detector)
3. Reduction x100 of heat-only background

EDELWEISS-LT: Luke-Neganov boost

Heat thresholds can be improved by applying larger bias voltages

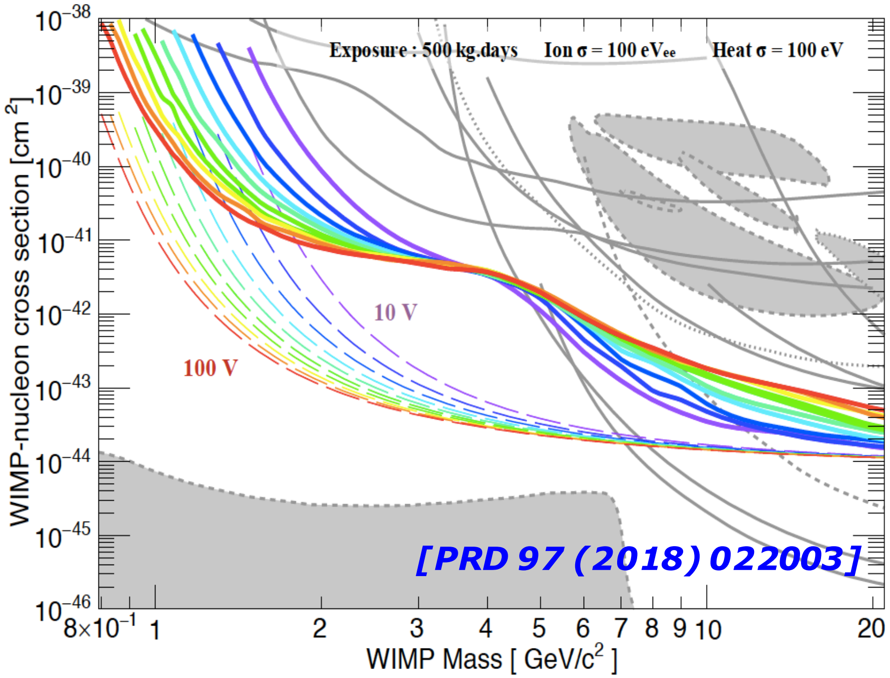
- Heat signal boosted by Neganov-Luke effect (~Joule heating, factor $[1+V_{bias}/3]$)
- Loss of ionization-based bkg discrimination: method benefits low-mass searches only
  → *10^{-41} cm^2 with 500 kgd and current bkgs*

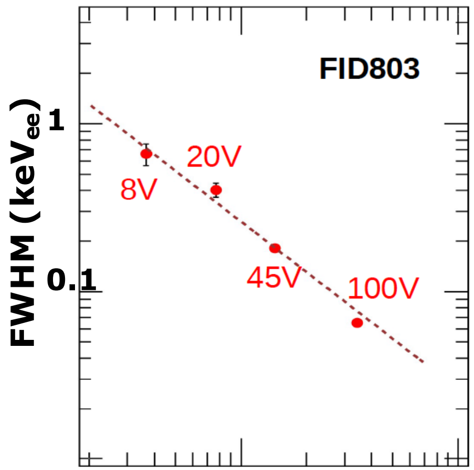
✔ **100V bias already achieved**

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

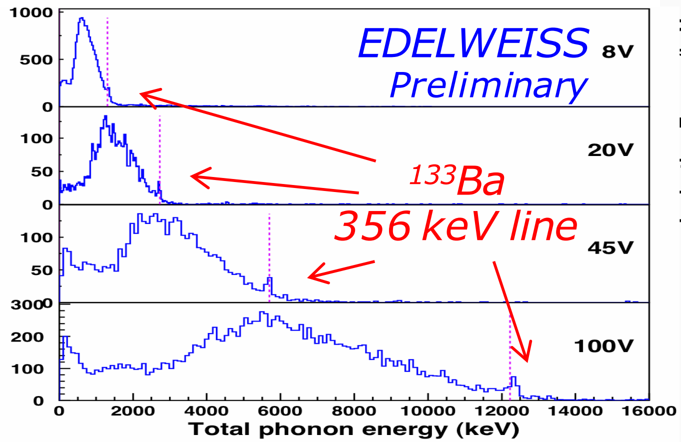
✔ **Full ion.+heat readout possible at any V**

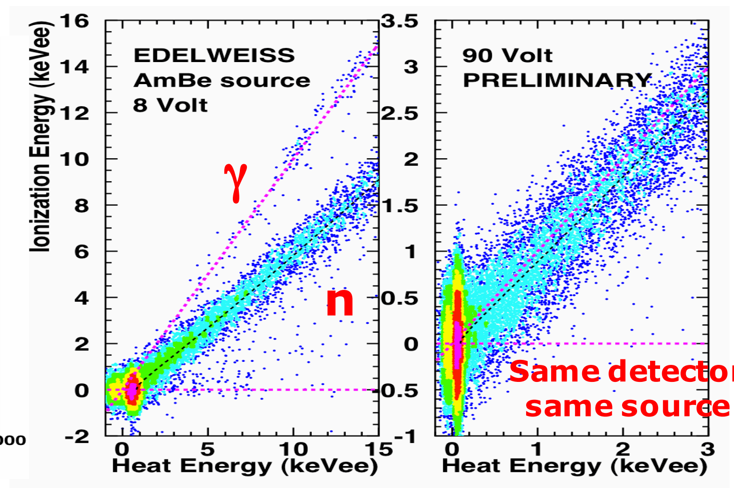
✔ ***First WIMP Data@100V analysis underway***





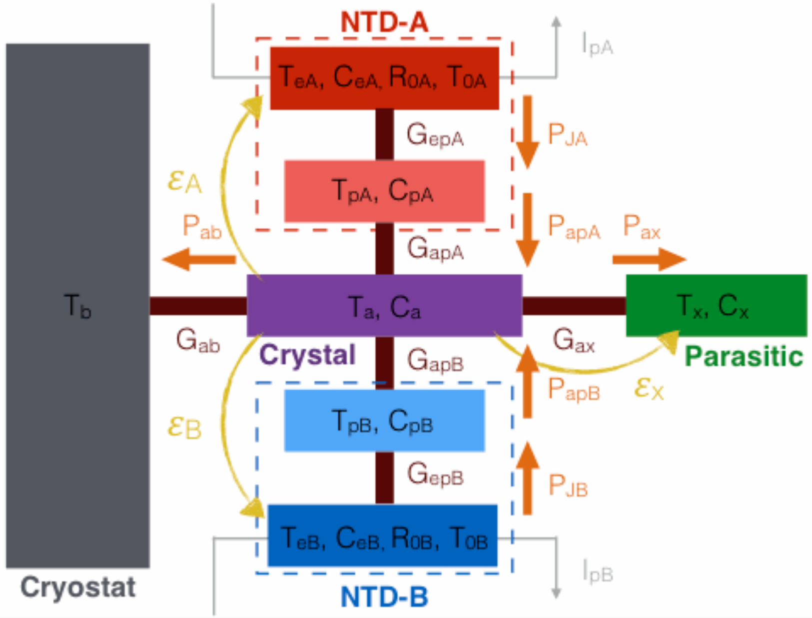
Luke boost = 1 + V/3



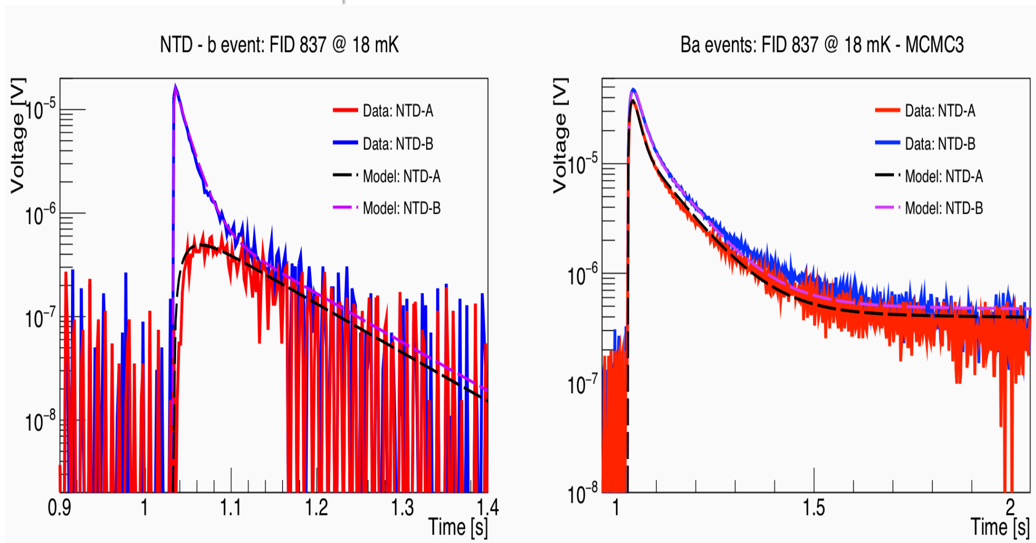


EDELWEISS-LT: heat sensor improvement

- Goal: σ_{phonon} = 100 eV baseline resolution on phonon signal
- Best achieved so far on 800g: σ_{phonon} = 300 eV
- Thermal modeling of signal, verified with dedicated measurements:
  - Identification of sensitivity to ballistic phonons
  - Identification of parasitic heat capacity
- ***Also: Explore performance of high-impedance NbSi TES sensitive to athermal phonons***

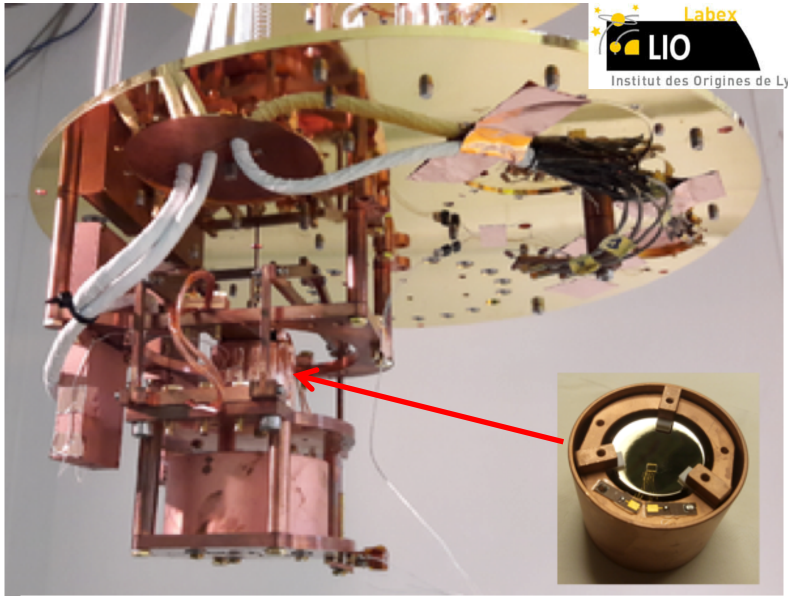


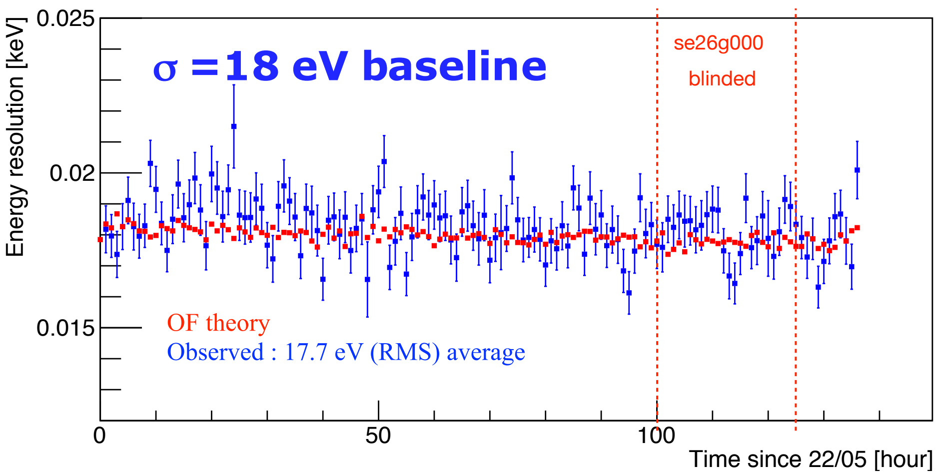
J. Billard et al., JLTP(2016)184:299

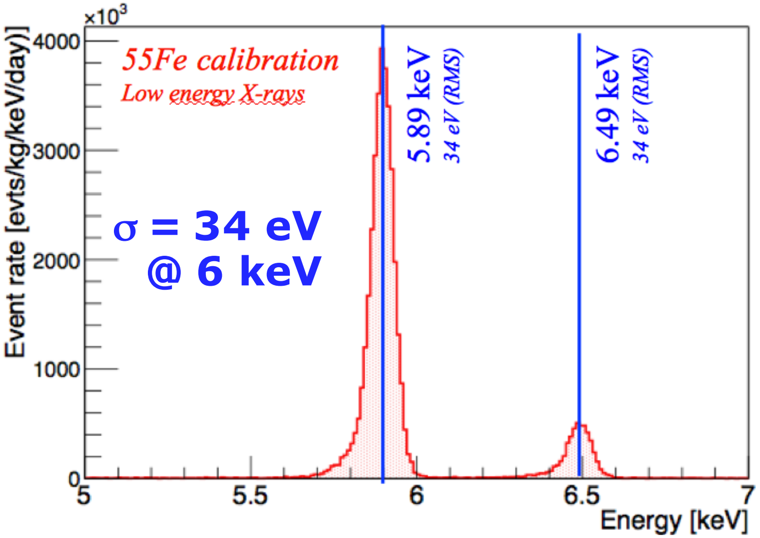


Resolution improvements on a 32g detector

- R&D with 32 g 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. 1 keV = 1 keV_{NR})
- Kept at 17 mK in IPNL low-vibration dilution fridge [ArXiv:1803.03463]
- Stable σ = 18 eV baseline resolution
- One day blinded for WIMP search in [0-2] keV region



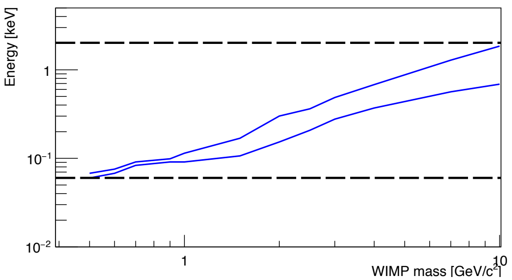




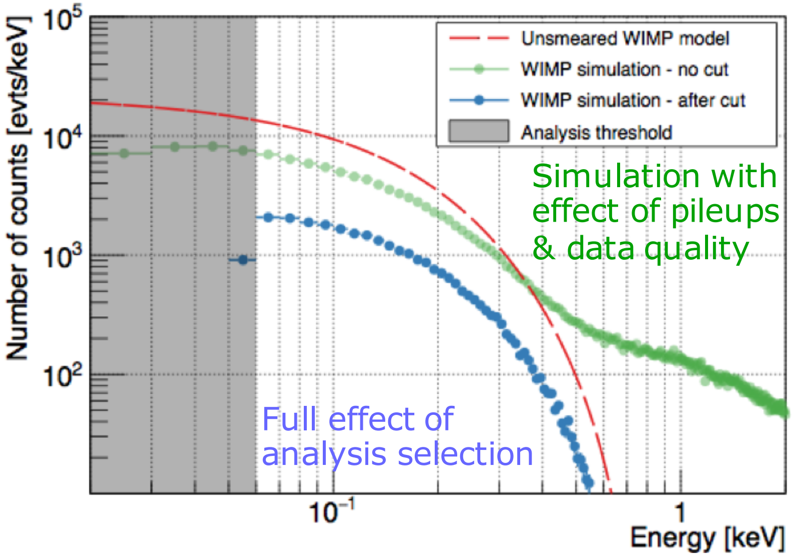
Data analysis

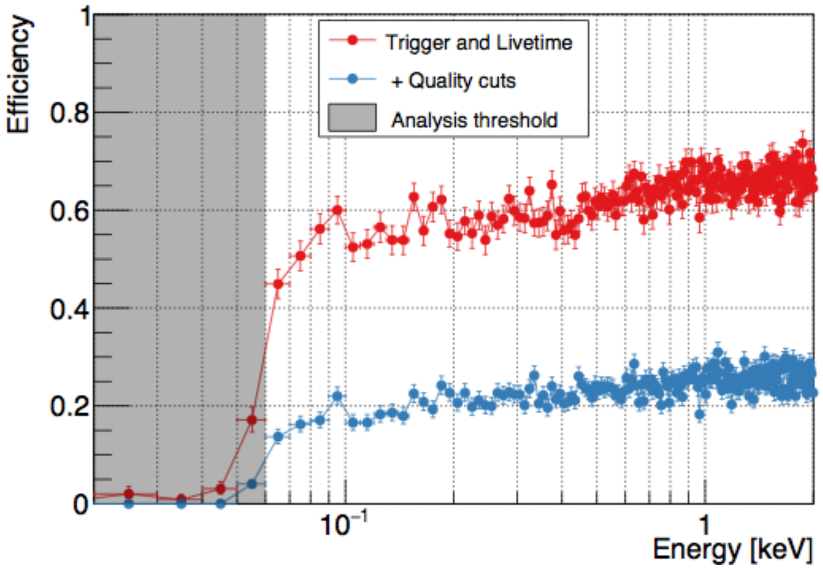
- Continuous streaming of 400 Hz data
- Optimal filtering
- Energy-dependent efficiency *and dead-time* studied by adding fake WIMP pulses to the recorded streams

  → 60 eV analysis threshold
- Background model based on the 4.7 day of unblinded data
- Poisson limit with no background subtraction: all events within range counted as WIMP candidates
- Mass-dependent range optimized using simulations of bkg + WIMP



Pre-defined search range vs WIMP mass

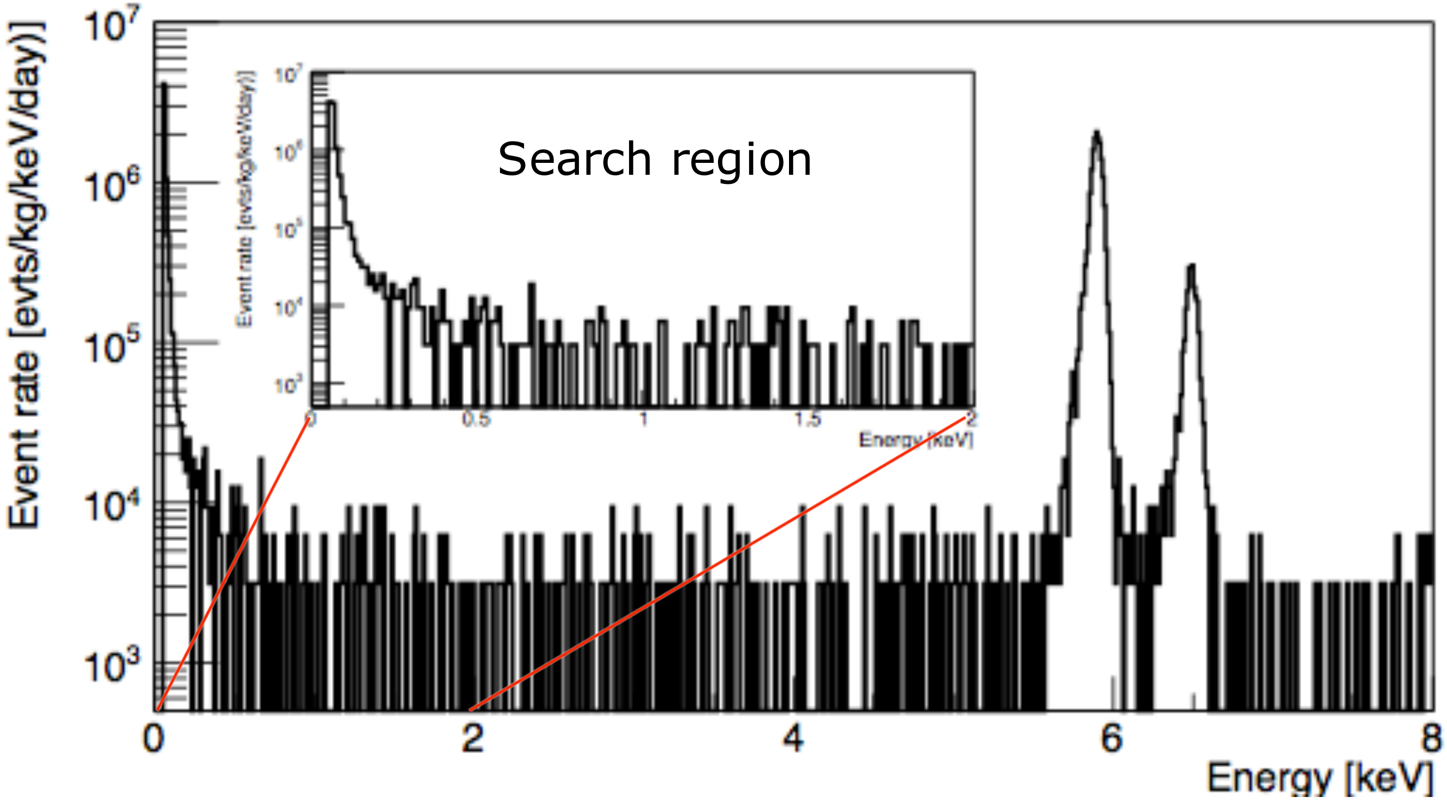




Unblinding the data

- No surprise:

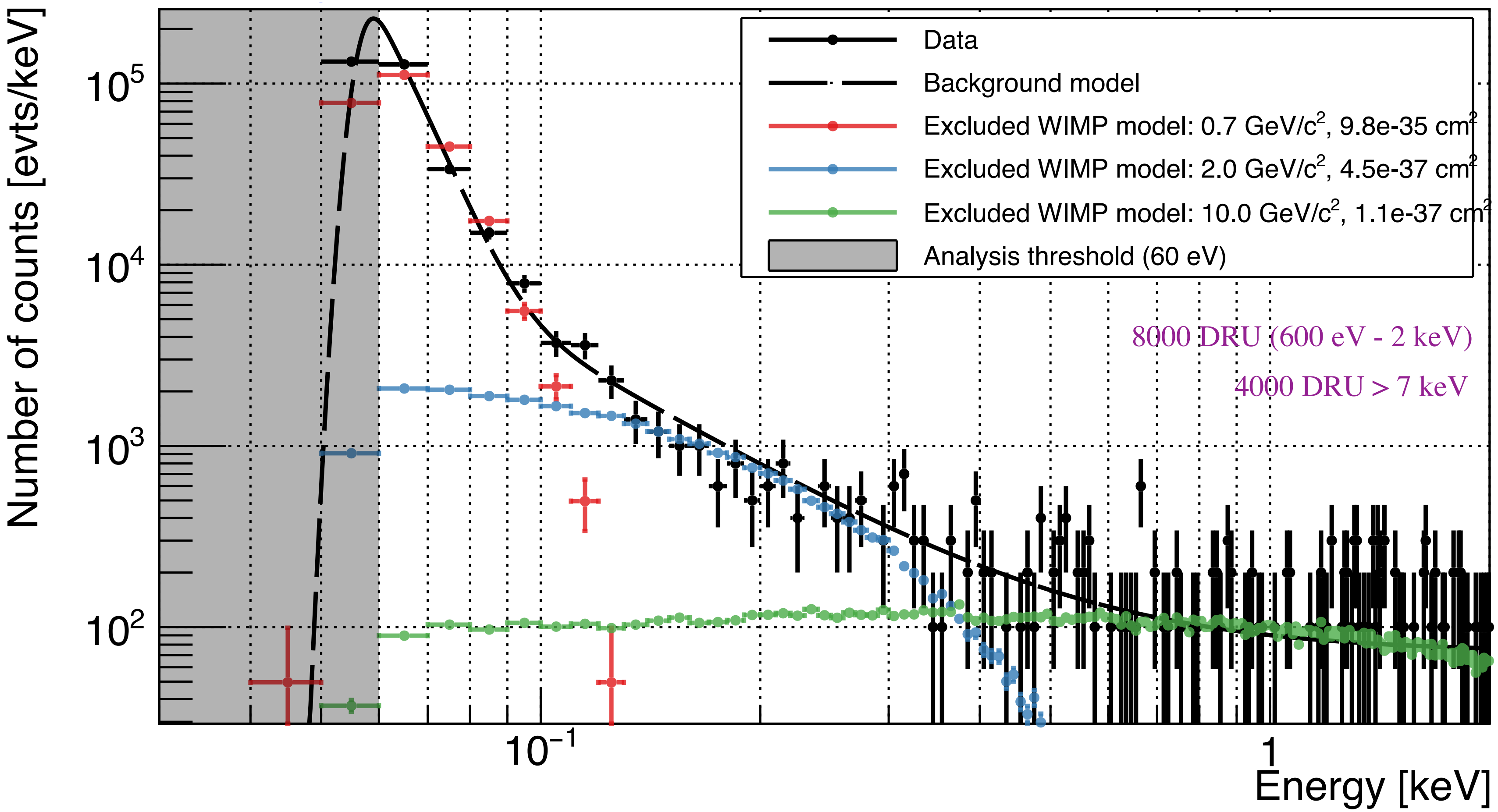
  blinded day = carbon copy of preceding + following days



8000 DRUs 0.6-2.0 keV 4000 DRUs > 7 keV

90%CL limit on WIMP signals

- Find maximal WIMP rate compatible with total number of counts observed in the pre-defined windows

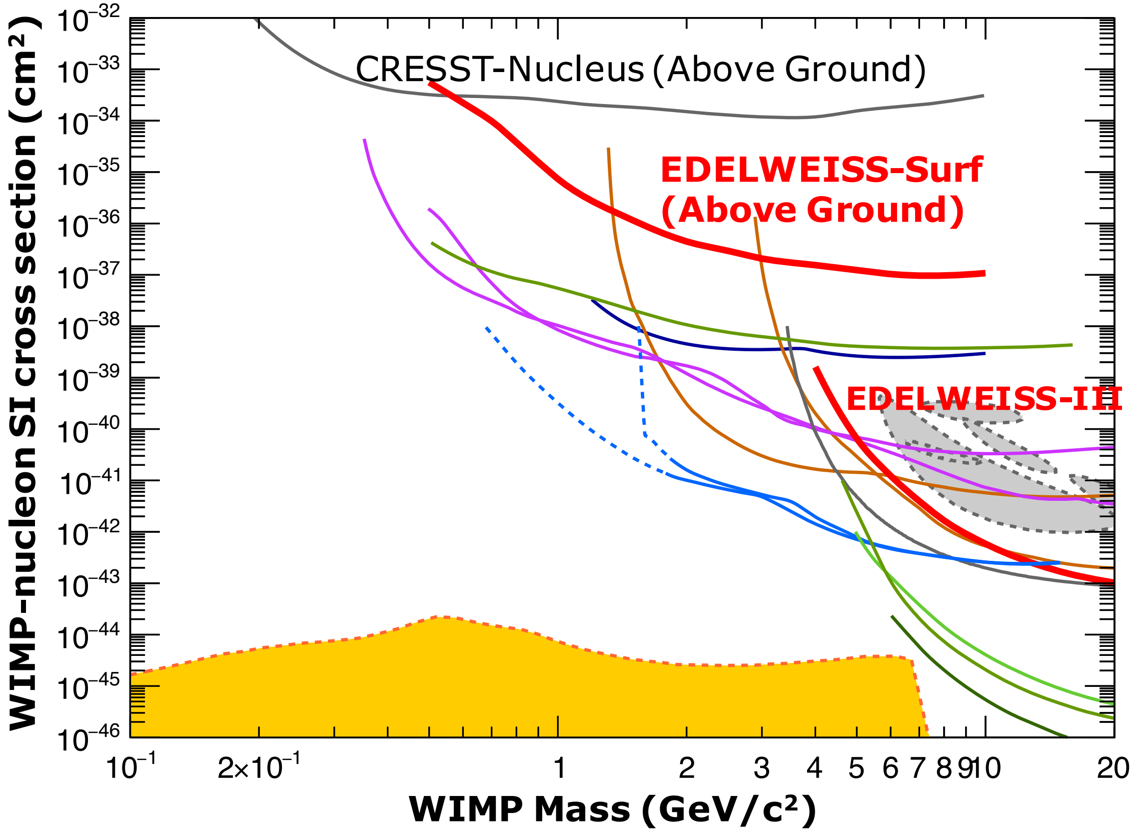


Surface limit

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

- Best above-ground limit down to 600 MeV/c²: SIMP
- First sub-GeV limit with Ge, down to 500 MeV/c²
- Opens the way for the 0.1 – 1 GeV/c² range

- 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

- EDELWEISS-III : large detectors with rejection
  - Excellent rejection performance, but not competitive with large Ar/Xe detectors above 6 GeV
  - Exploitation of excellent surface event rejections from FID to get best Ge ALPs limits, and enter the sub-keV range
- EDELWEISS-MELODI : develop large detector with FID design
  - Exploring non-WIMP DM with prototype: ALPs in the 0.1-1 keV range, and direct sensitivity to quenching at ~0.4 keV_{NR}
  - Building block for a much larger search experiment (DMB8, suited for future SNOLAB program) addressing specifically the region where the DM signal needs to be spectrally resolved from a solar ^{8}B neutrino signal
- Prospects in the sub-GeV-WIMP range: beyond EDELWEISS-LT
  - **Going beyond original [PRD] goal: 100 eV → 18 eV (wrt ~500 eV edw3)**
  - **Best surface limit for WIMPs above 0.6 GeV/c^2**
  - **Resolutions achieved on 32g detectors + expertise acquired in HV runs open the way for the 0.1-1 GeV range**

EDELWEISS-III collaboration

CSNSM CNRS/IN2P3

IPNL CNRS/IN2P3

NÉEL institut CNRS/INP

Laboratoire de Photonique et de Nanostructures CNRS

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