Search for low-mass WIMPs with the EDELWEISS-III experiment

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UCLA Dark Matter
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The EDELWEISS-III Experiment

CSNSM CNRS/IN2P3

IPNL CNRS/IN2P3

NÉEL institut CNRS/INP

LABORATOIRE DE PHOTONIQUE ET DE NANOSTRUCTURES CNRS

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10 institutions

The EDELWEISS-III Experiment

- Upgrade from EDELWEISS-II:
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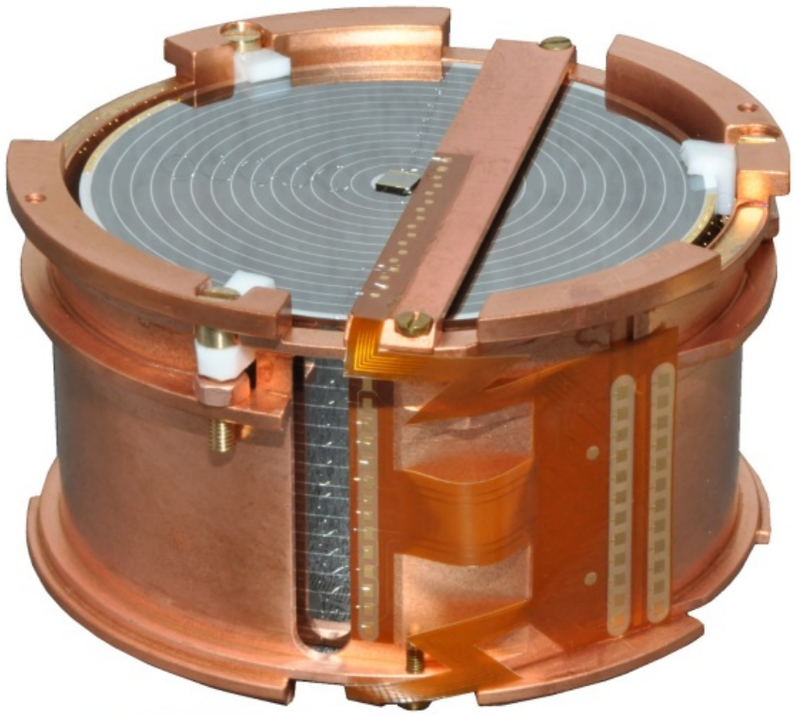

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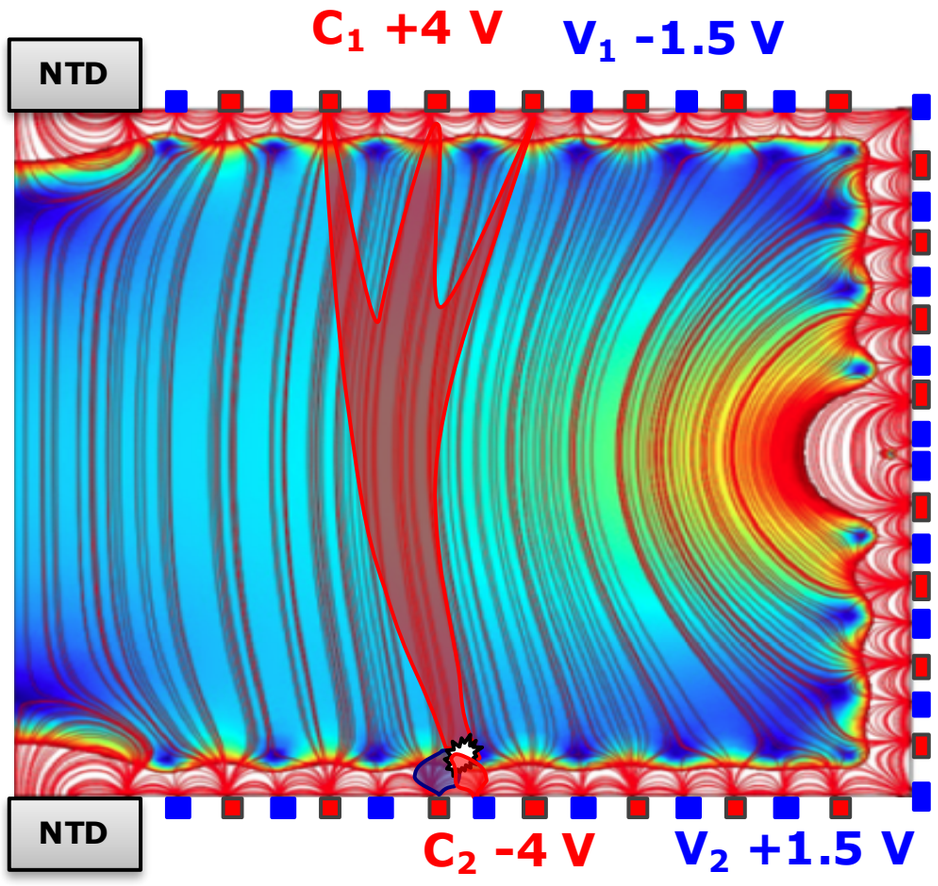

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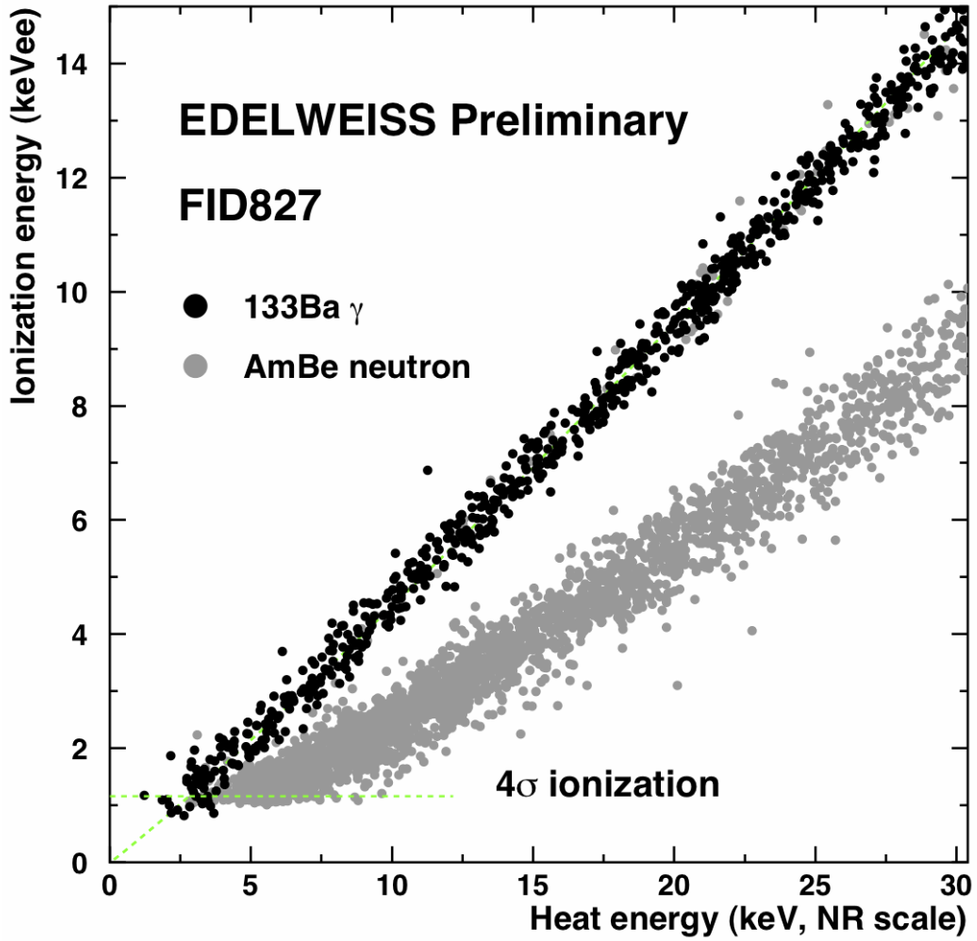

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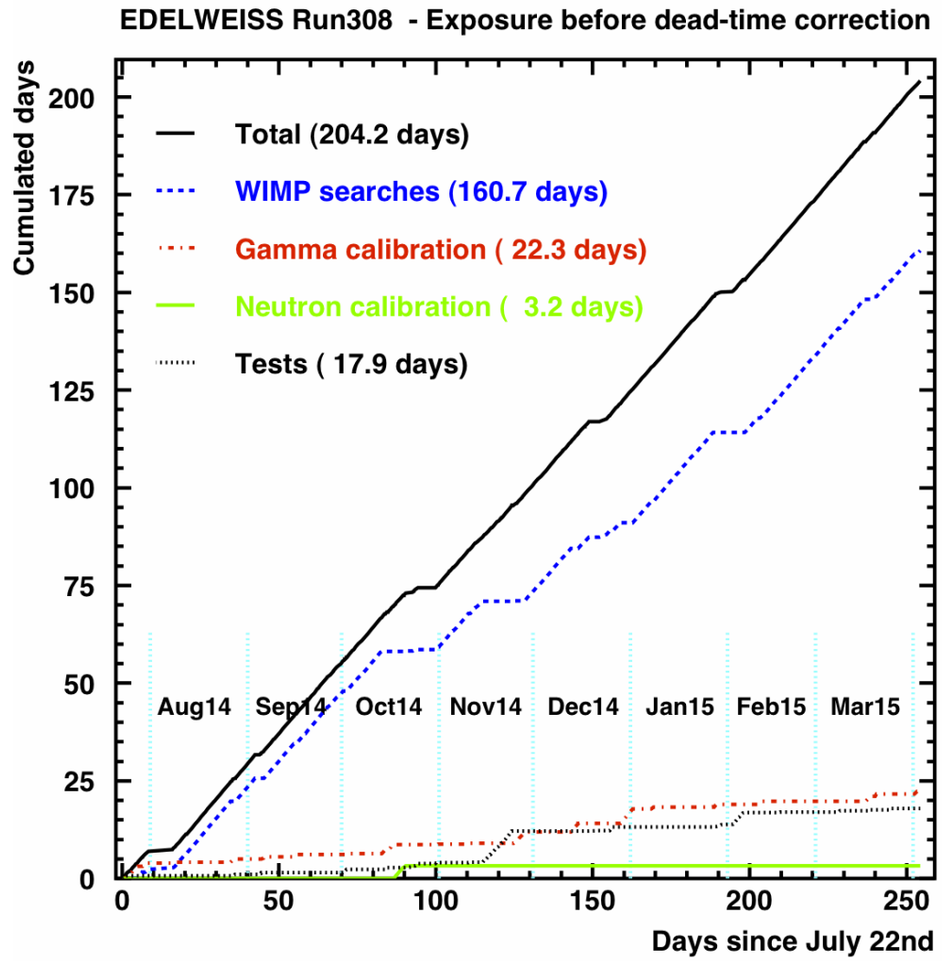
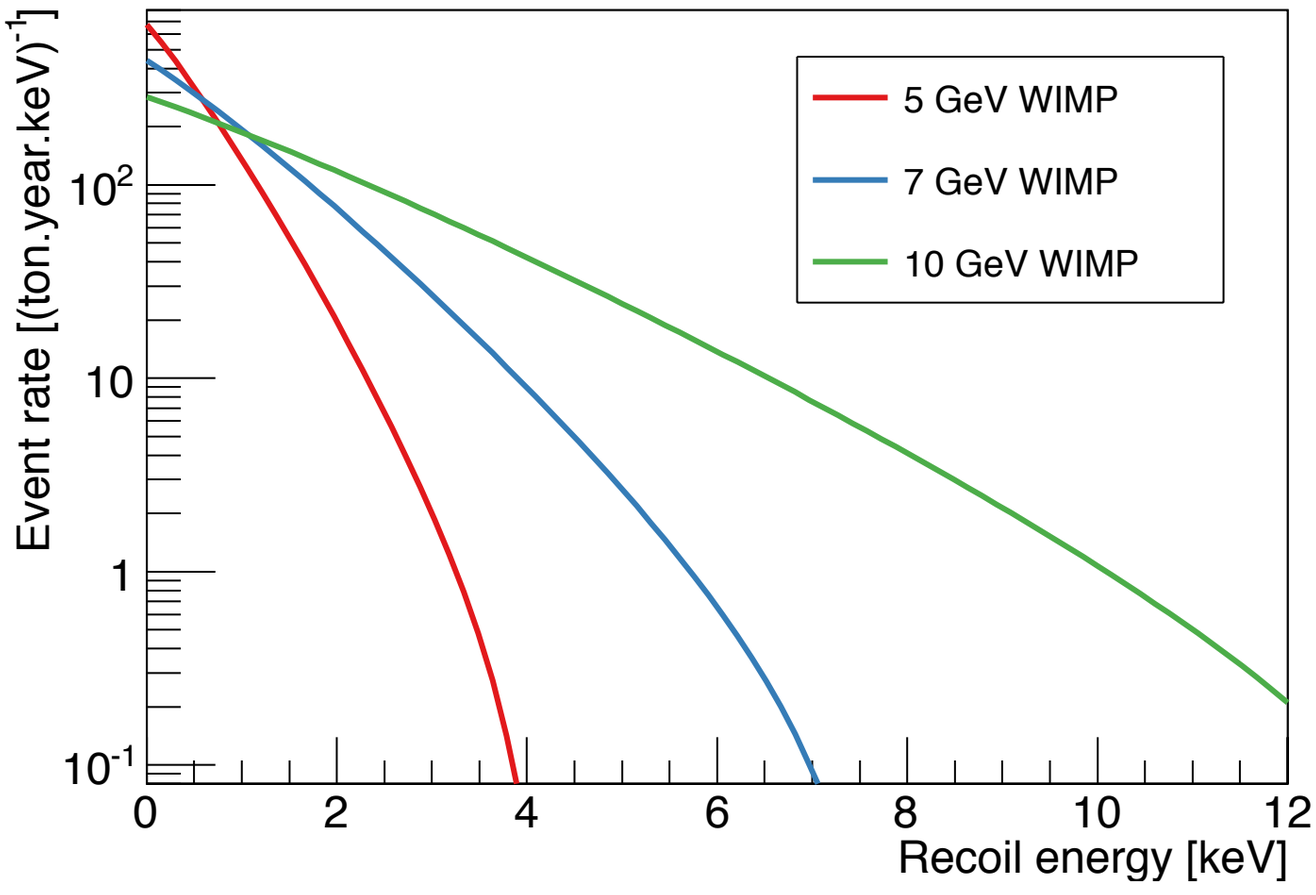
- 161 days of DM data with 20 kg of Ge target



Strategies for Light WIMP Searches

Lowering the energy threshold is the key for light WIMP searches



1. Low Threshold analysis: Improve exposure and extend background ID to low energy

2. High Voltage: Amplification of the signal to reduce the effective threshold

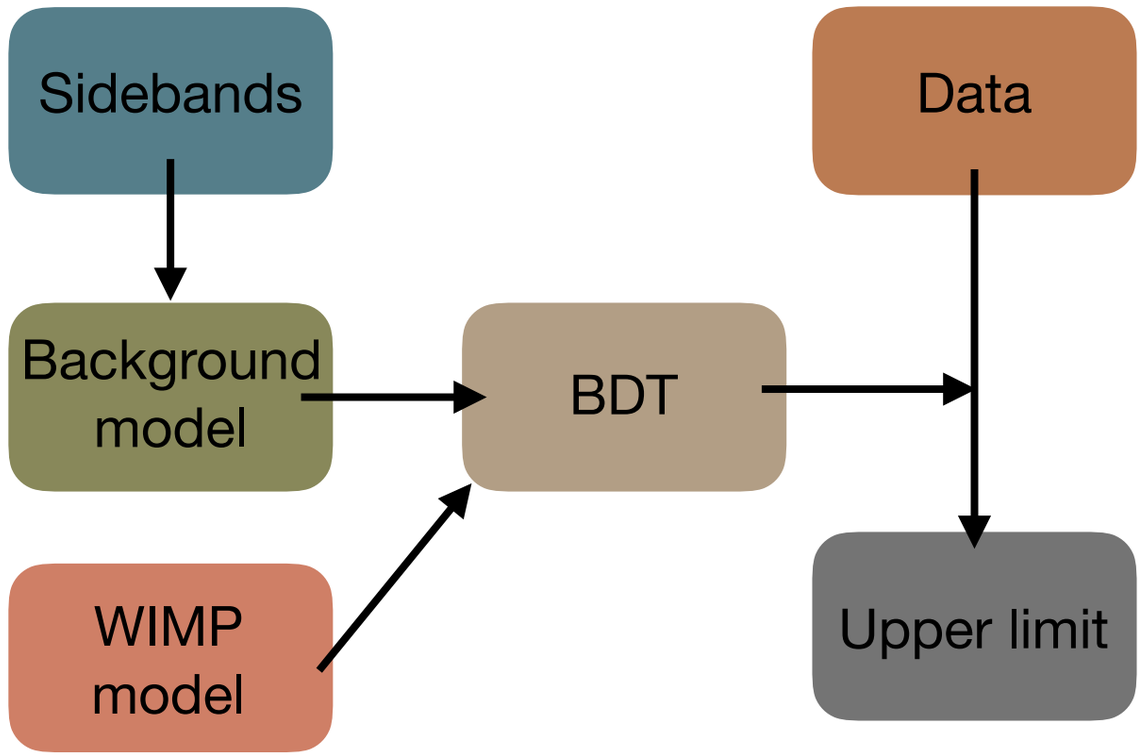
3. Optimized sensors: Improve energy resolutions to reduce thresholds

Ongoing R&D ...

Low Threshold analysis

Lowering the analysis thresholds down to the experiment's trigger thresholds

- Use 8 detectors with lowest trigger thresholds (4 @ 2.4 keVnr and 4 @ 3.6 keVnr)
- 582 kg-d of fiducial exposure (August. 2014 - March 2015)
- **Blind analysis optimized for exclusion**

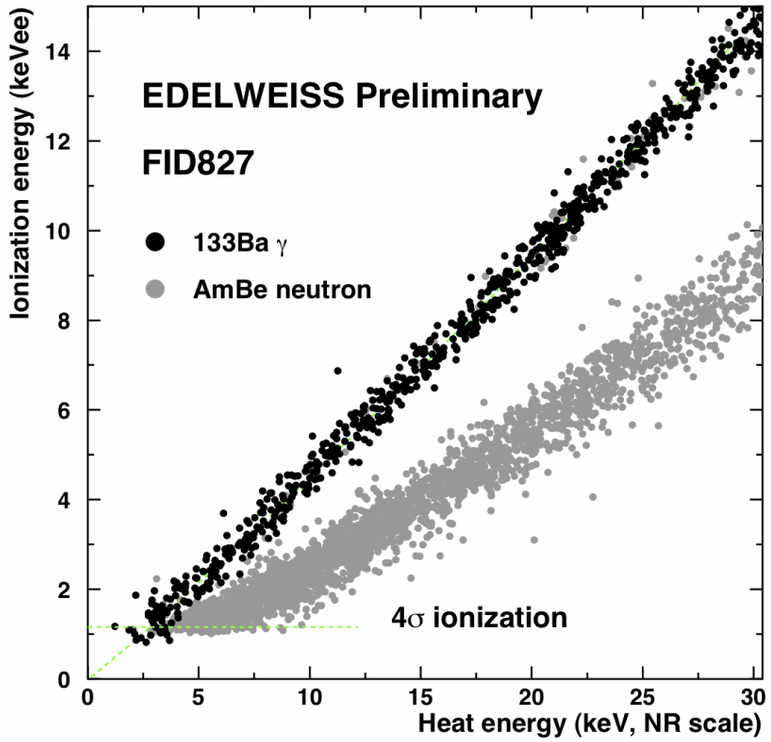


Low Threshold analysis

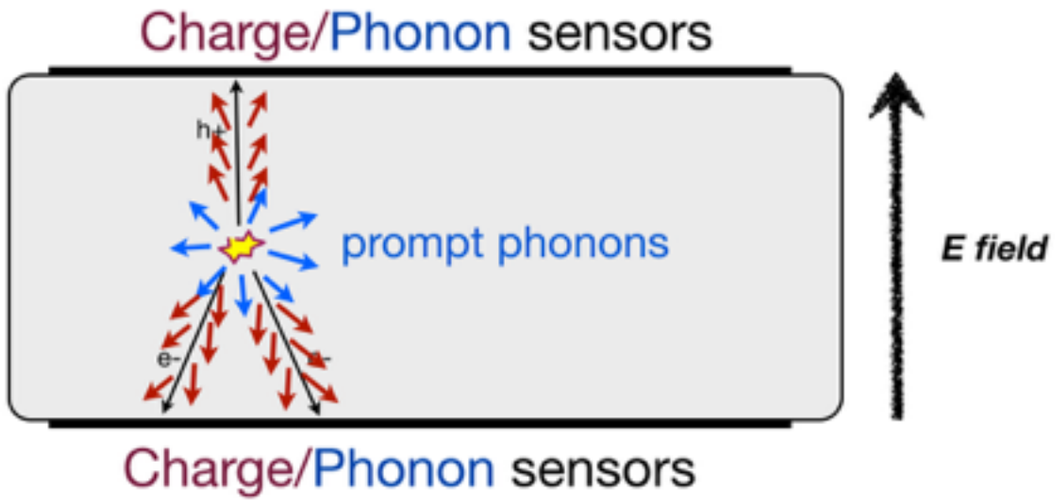
$$E_t = E_r + E_L$$

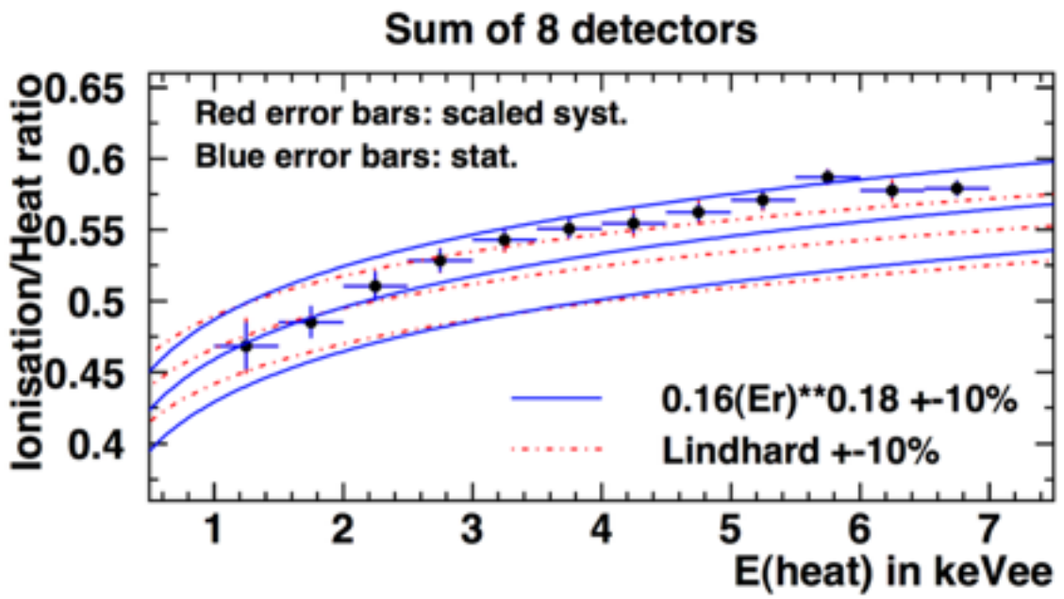
$$E_r = E_t - \frac{1}{3\,eV} E_Q(E_t)\Delta V$$

- Since signal-to-noise is poor, consider mean ionization energy for nuclear recoils
- Nuclear recoil calibration better fitted to a power law
- Consistent with Lindhard's prediction with less ionization at low energy and more at high energy



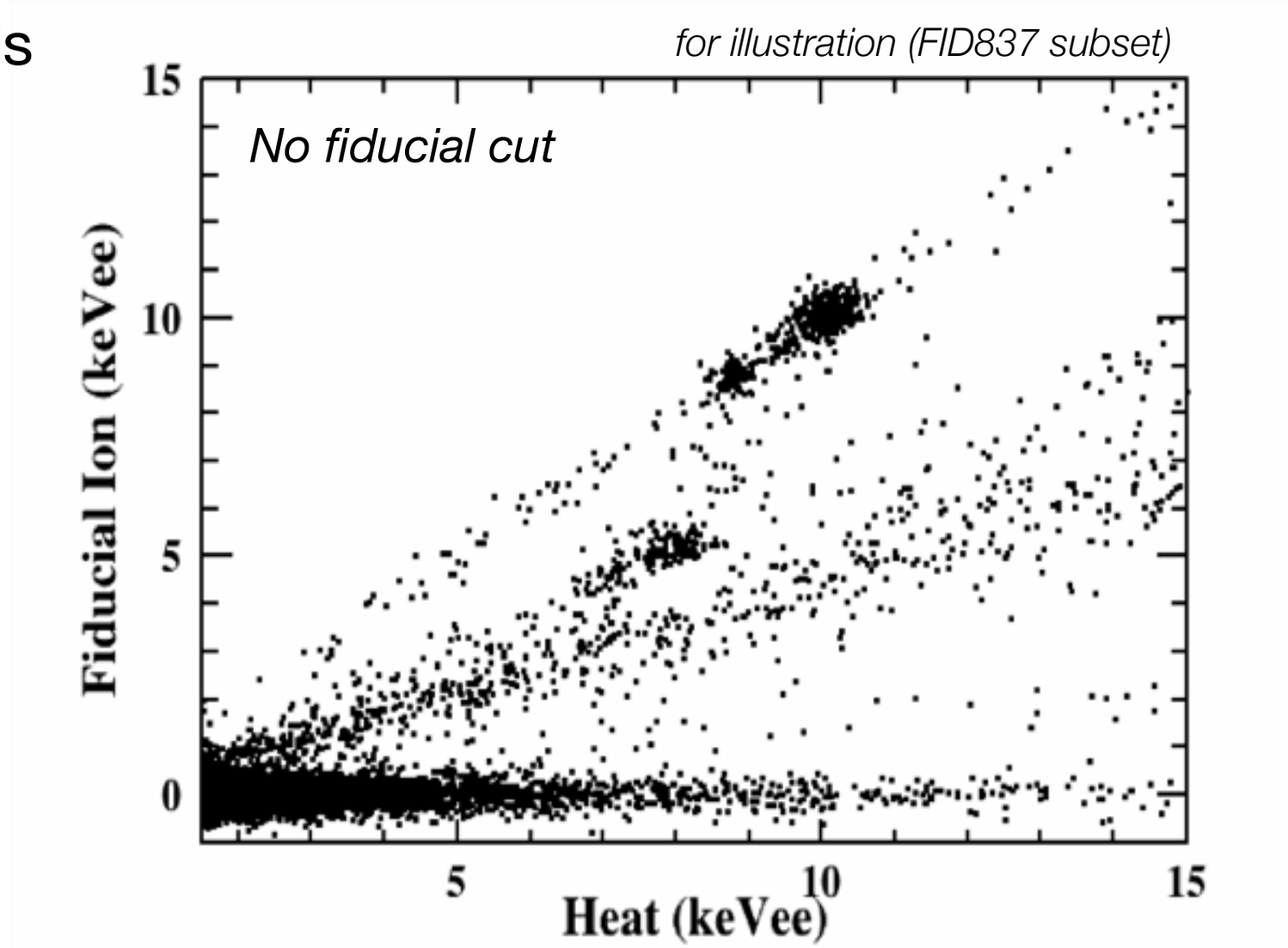
8V





Low Threshold analysis

EDELWEISS-III backgrounds

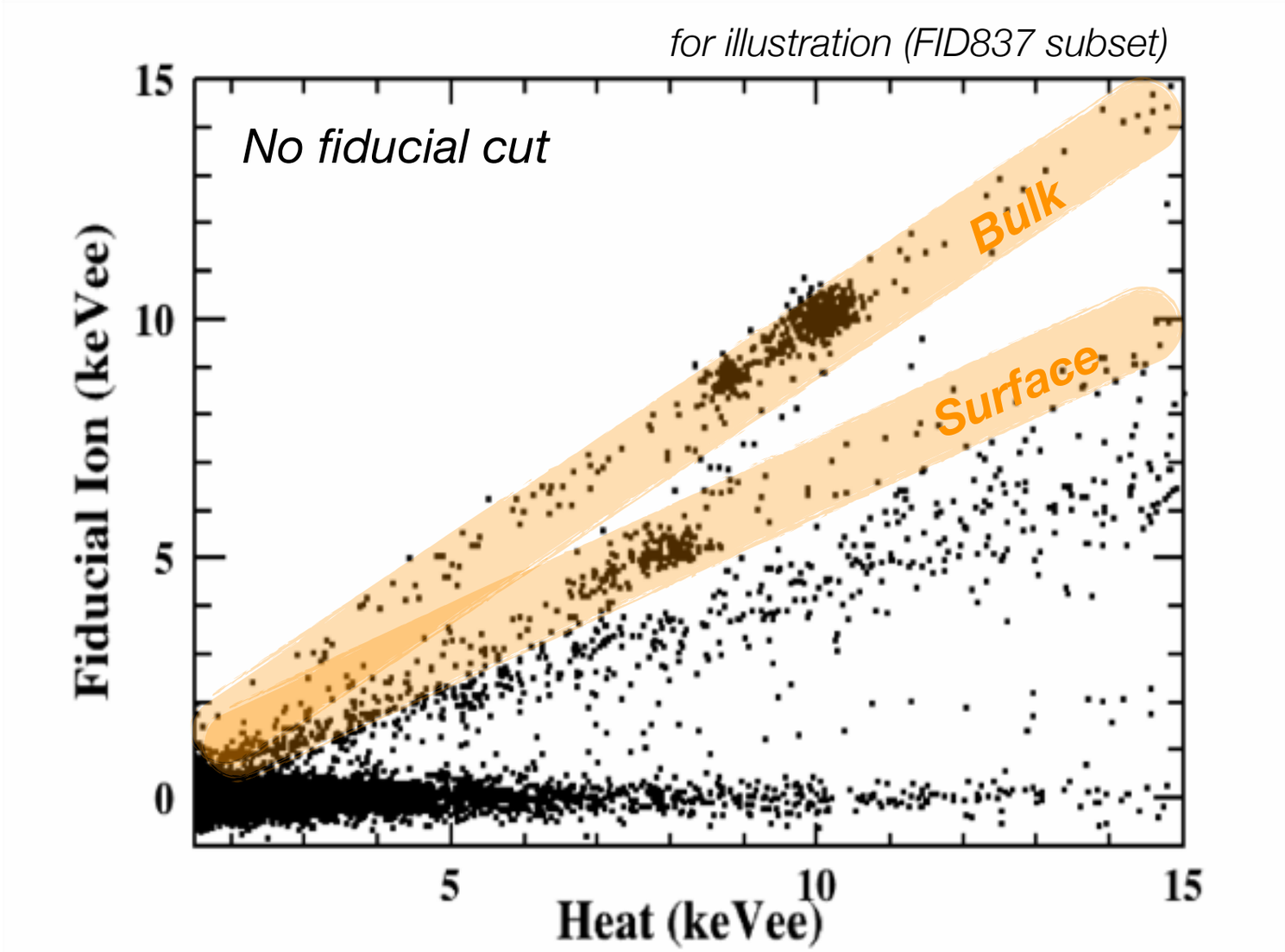


For all backgrounds : data-driven model from sideband data

Low Threshold analysis

Gamma + activation lines

- Internal radioactivity from shielding and cryostat
- Cosmogenic activation lines: K/L-shell capture from ^{68,71}Ge, ^{65}Zn, ^{68}Ga



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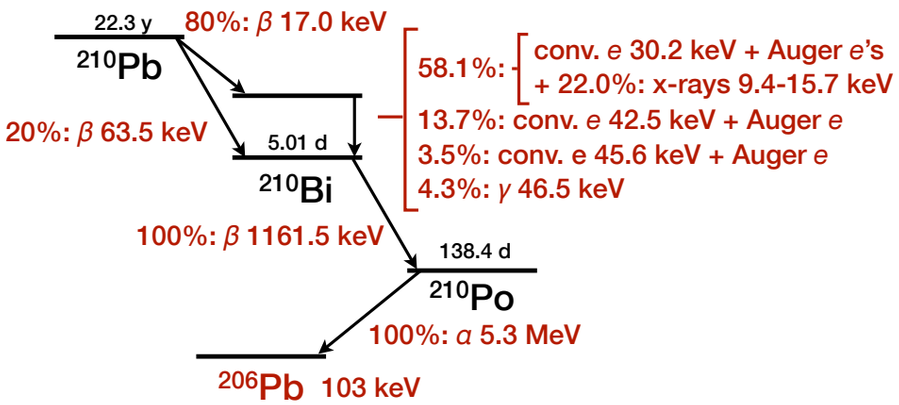
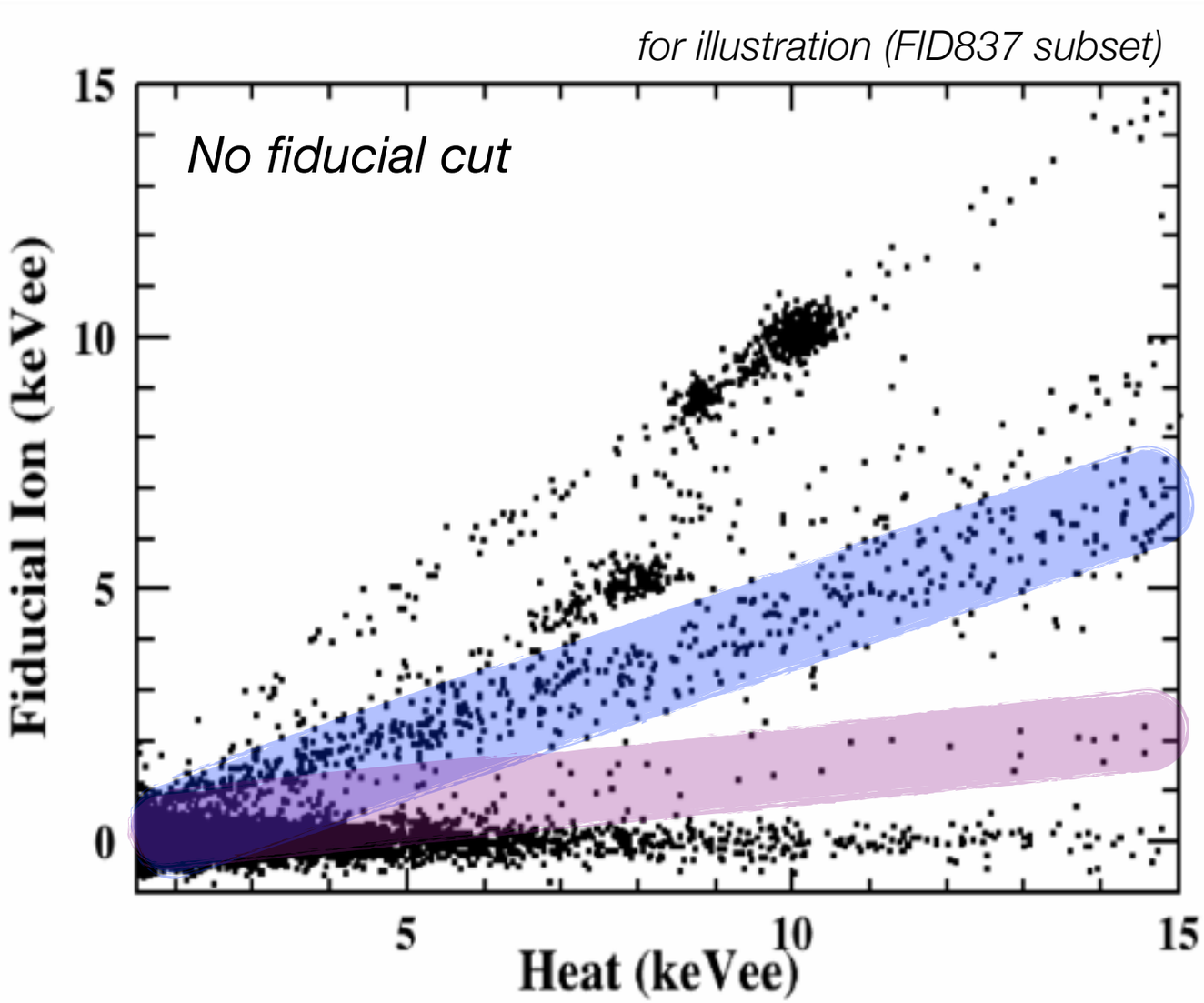
Low Threshold analysis

^{210}Pb “surface events”

- betas and ^{206}Pb nuclei from ^{210}Pb decay chain
- events are located on detector face and sidewall ***surfaces*** from ^{222}Rn contamination



for illustration (FID837 subset)



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Low Threshold analysis

Neutron

- Radiogenic origin only for the neutron background
- Estimated from coincident Nuclear Recoils scaled by the single-to-multiple ratio derived from Geant4 simulations

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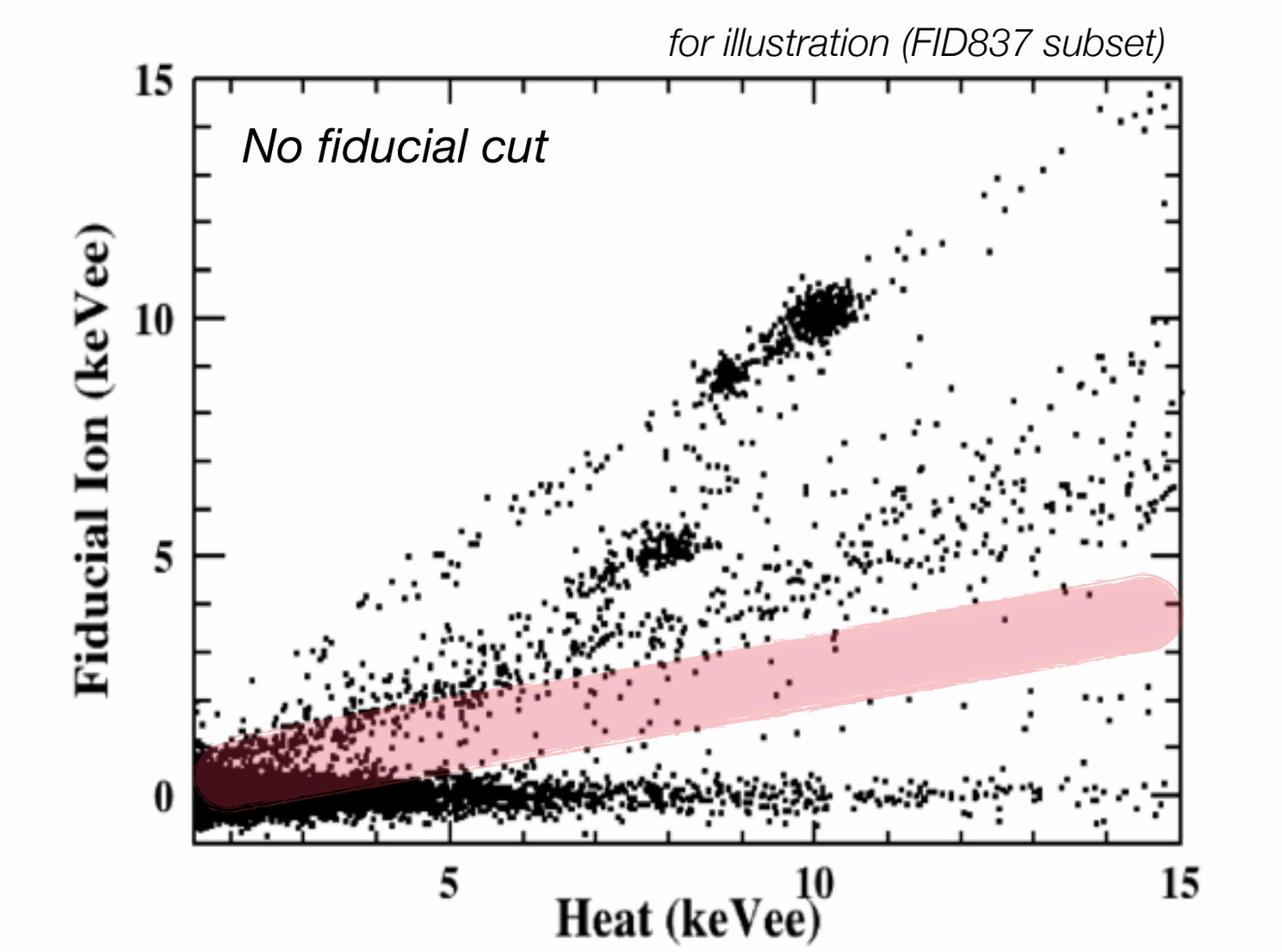

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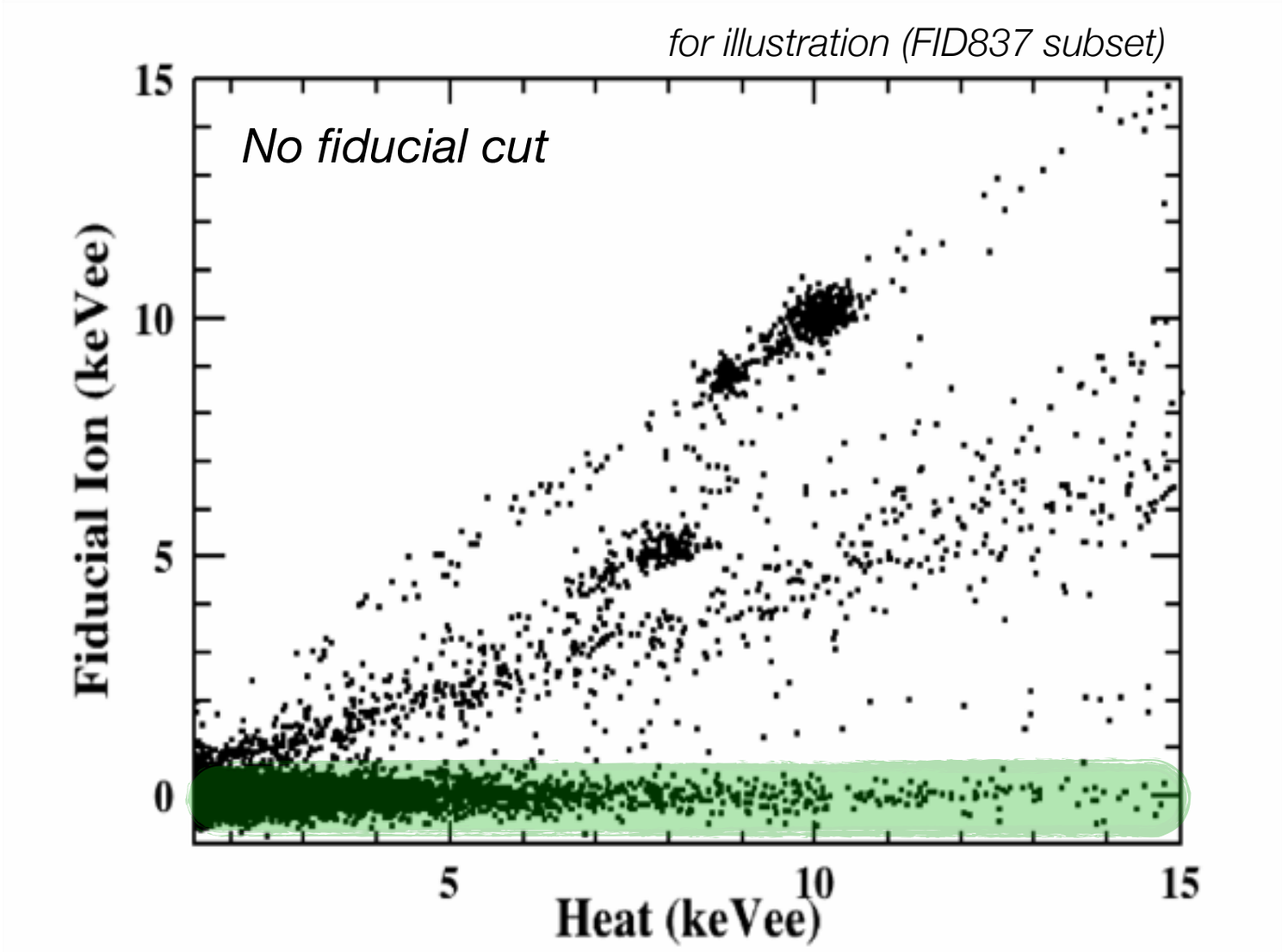
Low Threshold analysis

Heat only

- Dominating background at low-energy
- Estimated from Eion<0 sideband data (no WIMP expected)
- Origin under investigation highest priority of the EDELWEISS collaboration



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Low Threshold analysis

- Blind WIMP box:

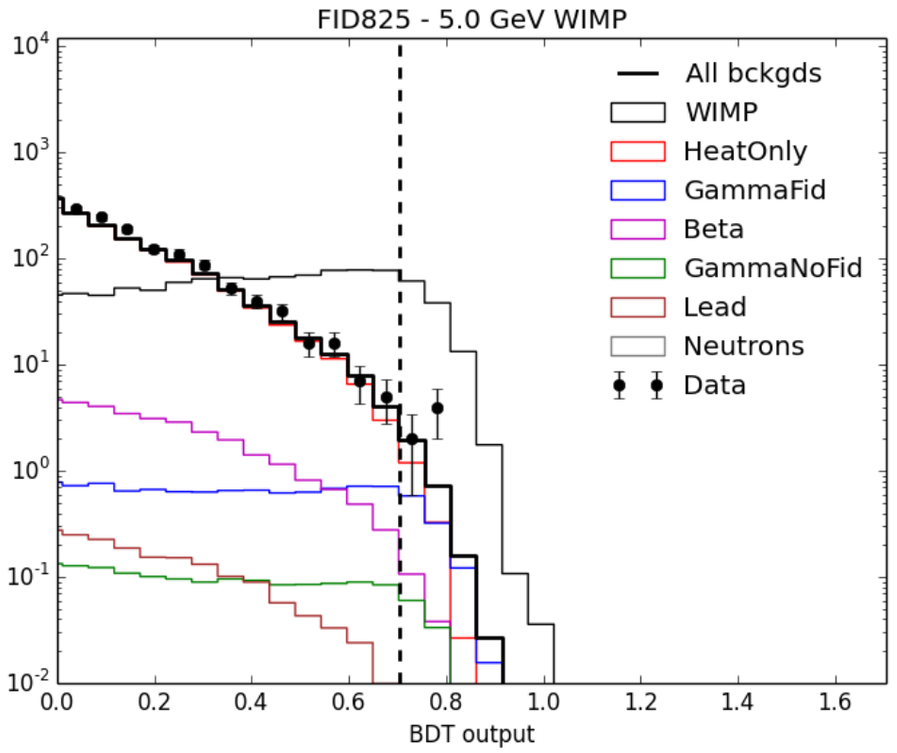
  veto < 5 σ , 0<Eion<8 keV_{ee} , 1<Eheat<15 keV_{ee}

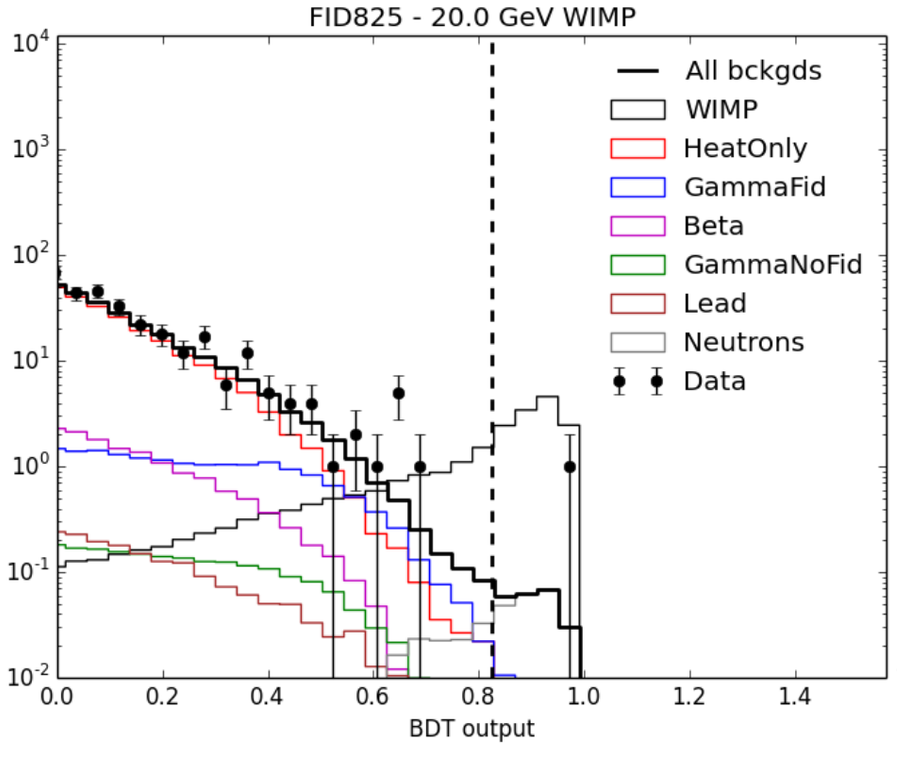
- A BDT analysis with 6 variables:

  4 ionization, 1 heat and heat only event rate

- One BDT trained per WIMP mass and per detector

- Combined detector cut optimization for 4, 5, 6, 7, 10, 15, 20 and 30 GeV WIMP masses based on model only: **blind**

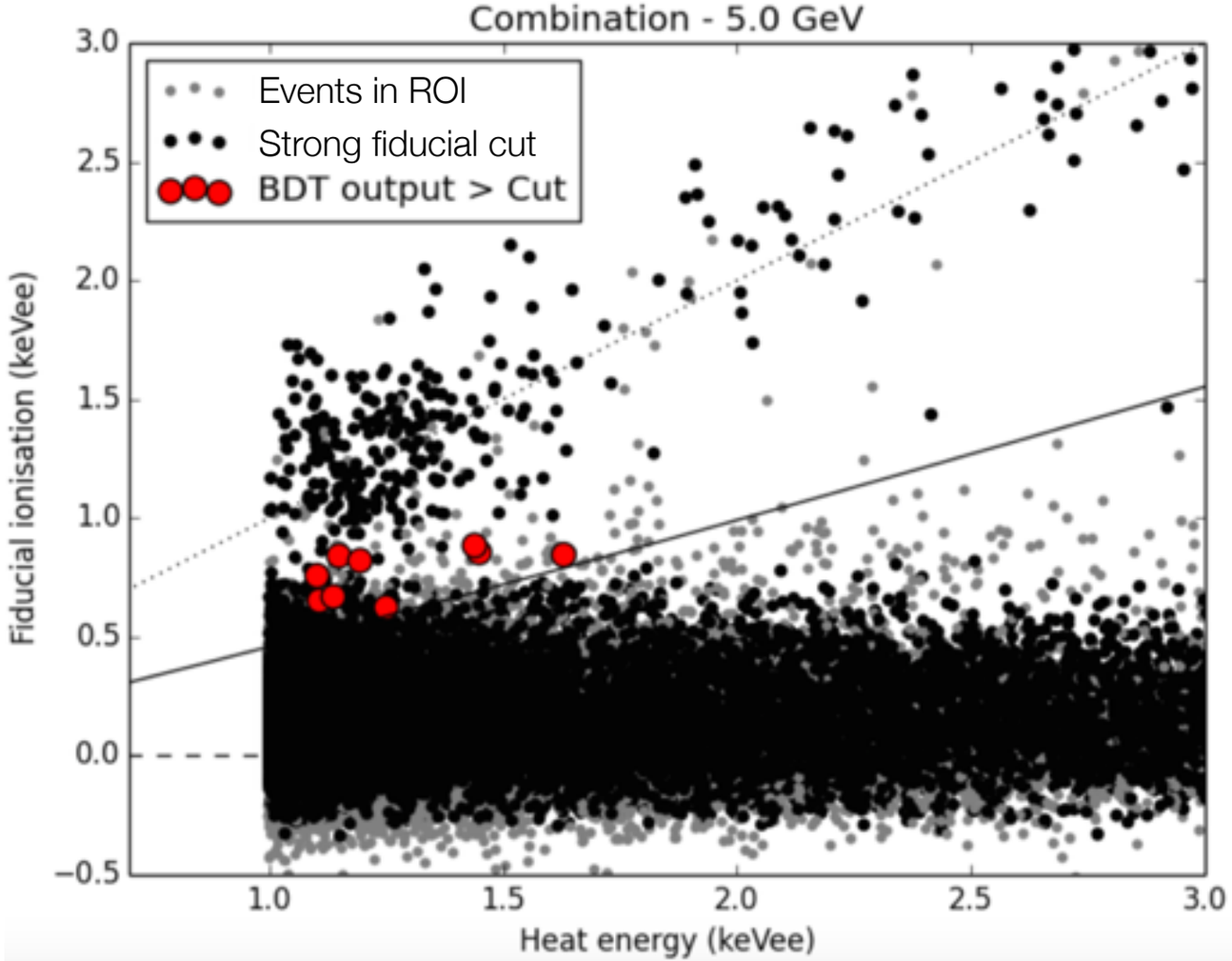


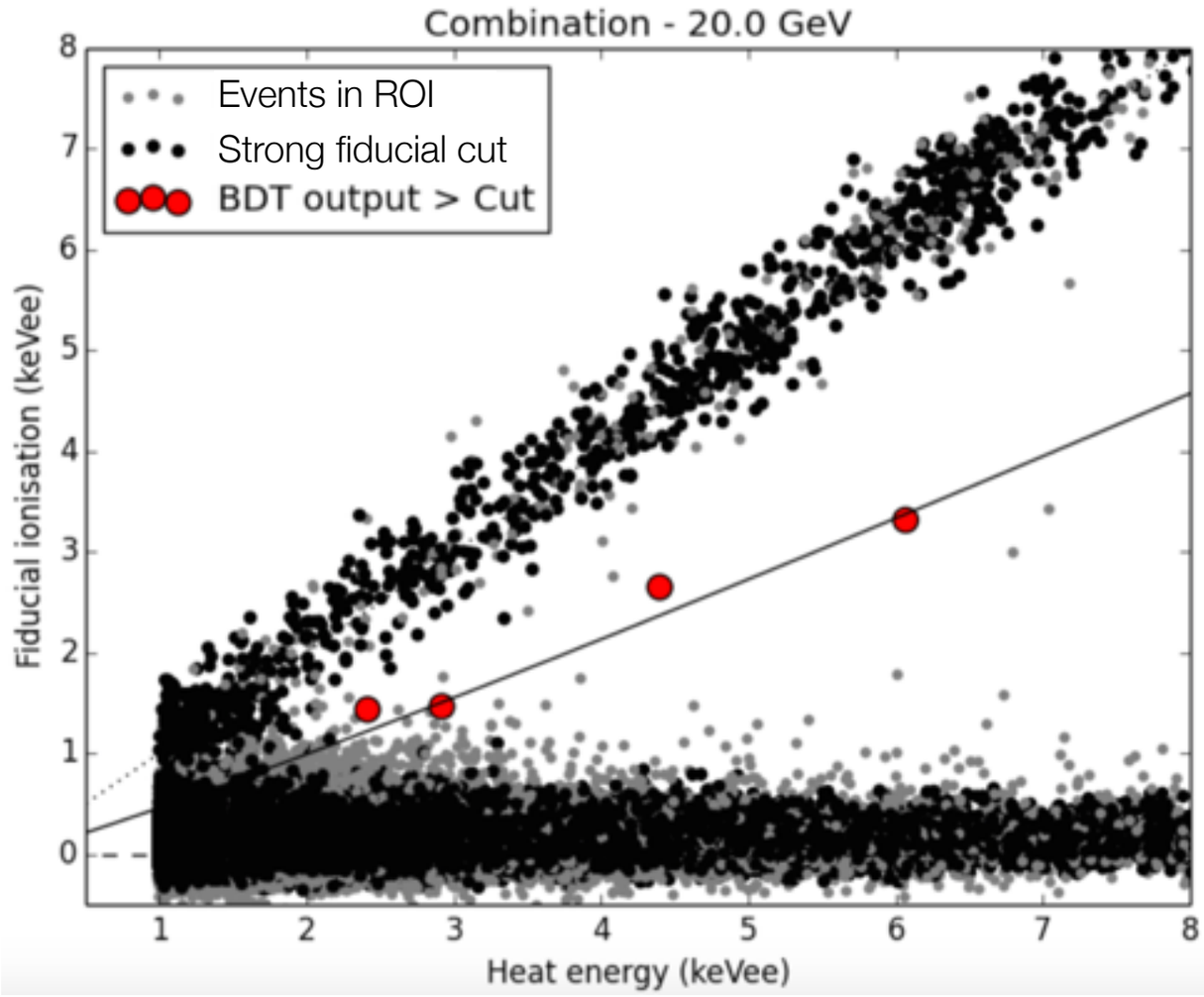


Low Threshold analysis

WIMP mass	5 GeV/c^2	7 GeV/c^2	10 GeV/c^2	20 GeV/c^2
Fiducial neutrons	0.015 ± 0.01	0.15 ± 0.07	0.4 ± 0.2	1.1 ± 0.5
Fiducial ER	2.7 ± 0.4	1.0 ± 0.2	0.4 ± 0.1	0.1 ± 0.02
Heat-only events	$2.9^{+0.5}_{-0.0}$	$0.4^{+0.07}_{-0.0}$	$0.2^{+0.03}_{-0.0}$	$0.1^{+0.02}_{-0.0}$
Others	0.5 ± 0.15	0.12 ± 0.04	0.1 ± 0.03	0.1 ± 0.03
Total background	$6.1^{+0.7}_{-0.4}$	1.7 ± 0.2	1.1 ± 0.2	1.4 ± 0.5
Events observed	9	6	4	4
p-value	22 %	1.1 %	2.8 %	6.3 %

- No statistically significant excess
- Minimum p-value is 1%
- Dominant backgrounds:
  - **5 GeV: Heat Only**
  - **20 GeV: Radiogenic neutrons**

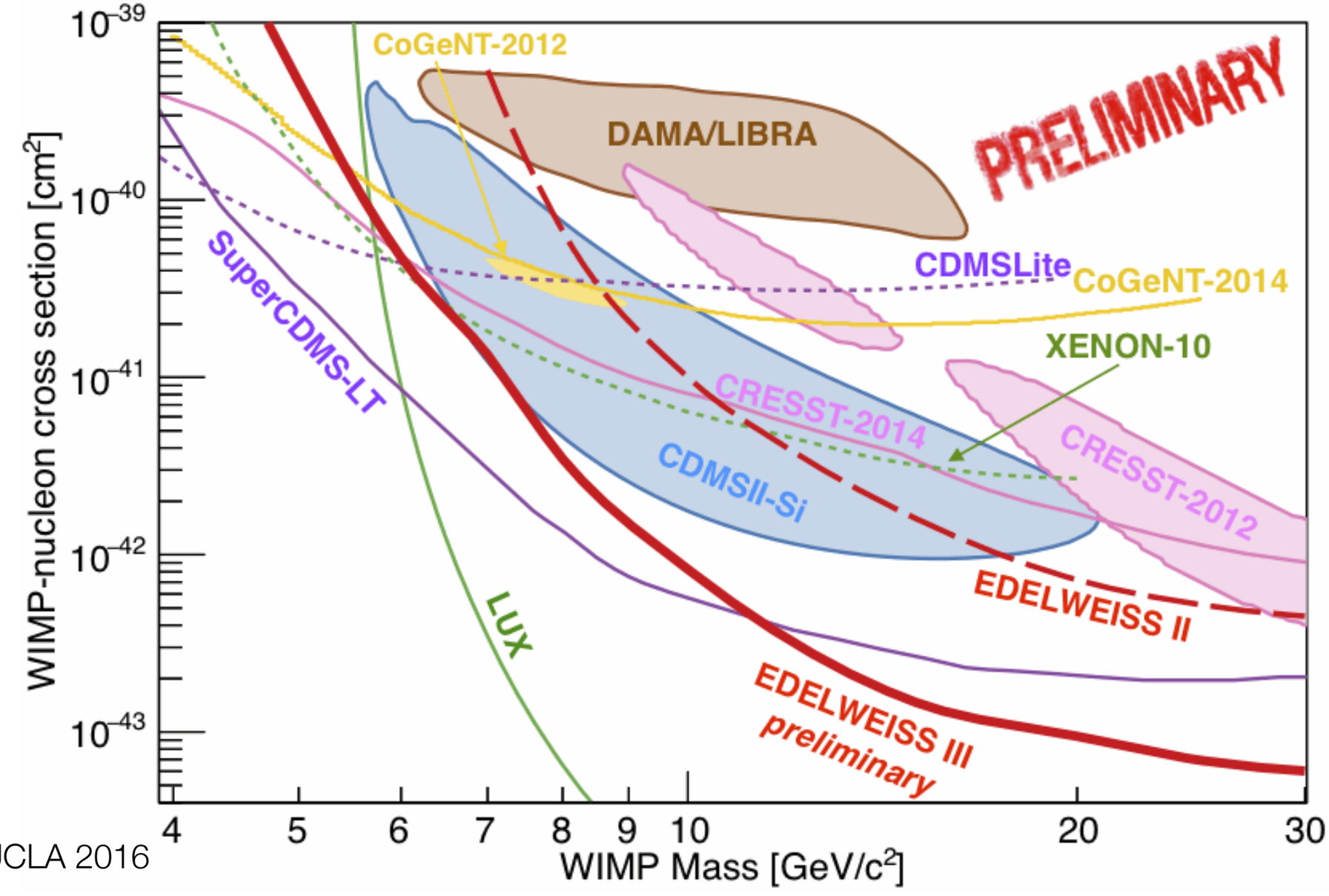




Low Threshold analysis

set 90% CL Poisson upper limit (no background subtraction)

- 4.6×10^{-40} cm^2 at 5 GeV (x40 better than EDW-II [PRD 86 (2012) 051701R])
- 6.2×10^{-44} cm^2 at 30 GeV (x8 better than EDW-II)
- Profile likelihood analysis is ongoing



Low Threshold analysis

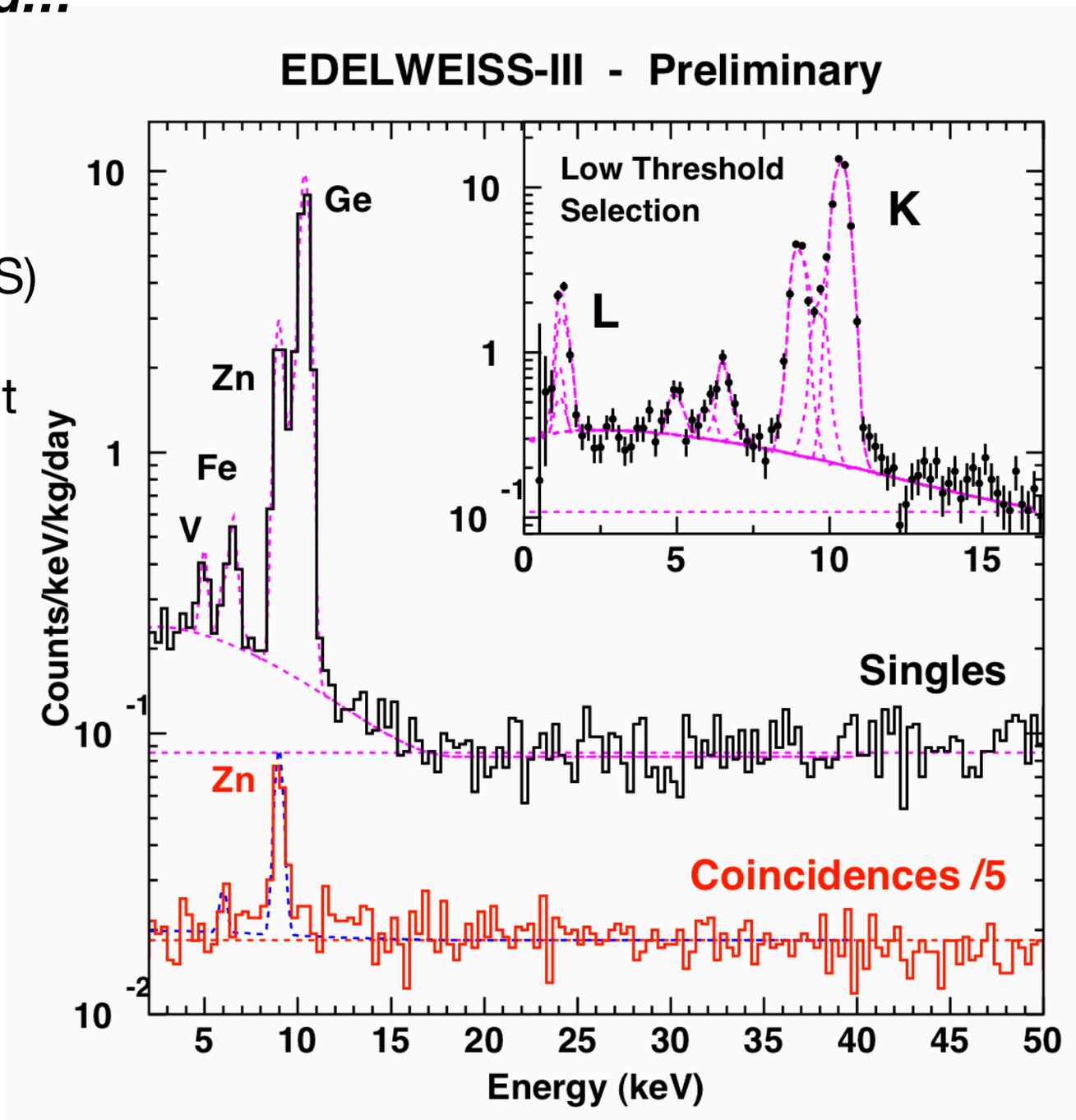
Let's take a closer look at the ER band…

- Thanks to its impressively low gamma background (<0.1 DRU) and exquisite ionization energy resolution (200 eV RMS)

- EDELWEISS-III is the first Ge experiment to observe the intrinsic tritium beta background convincingly

- Tritium beta decay is one of the major background component for next generation Ge experiments

- First measurement of the cosmogenic tritium production rate: ***paper to come***



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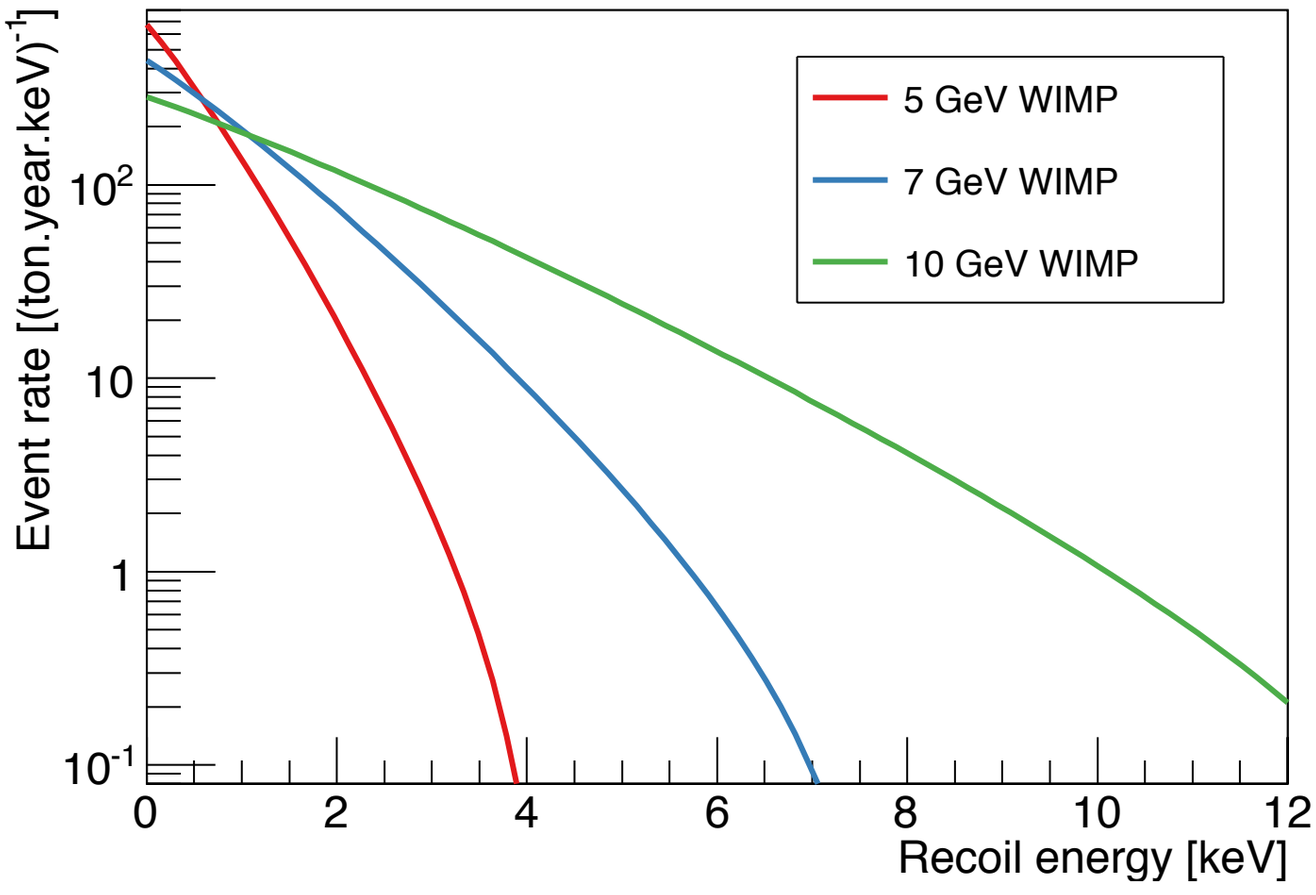

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R&D: High Voltage

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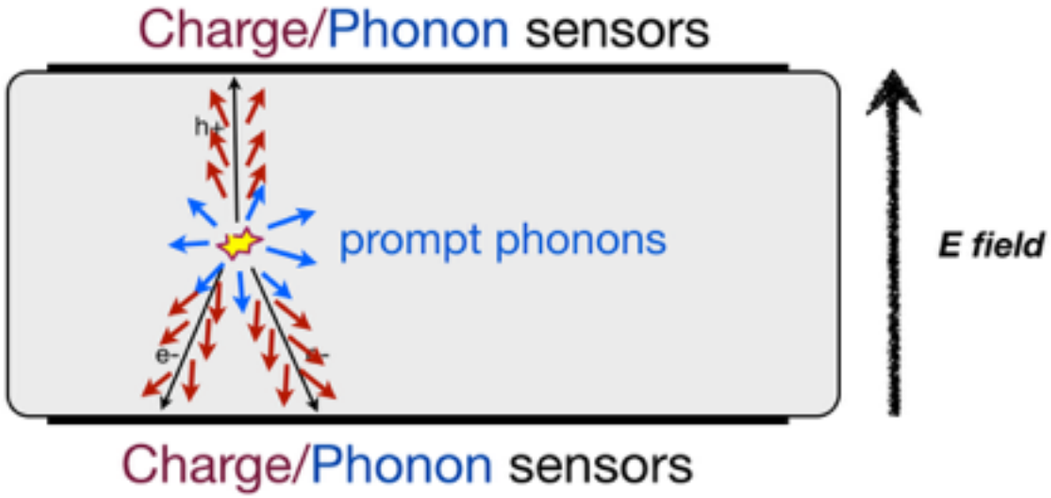
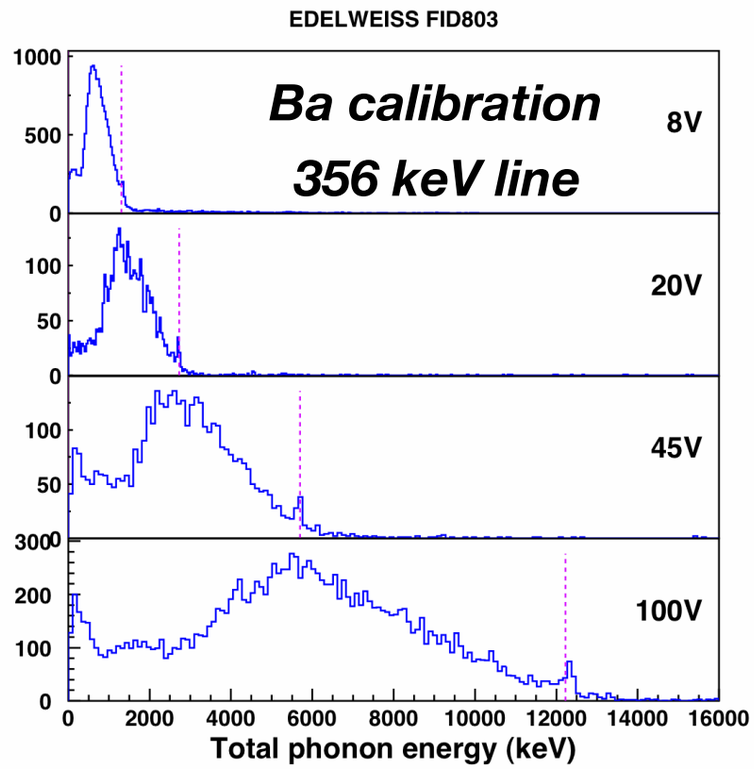
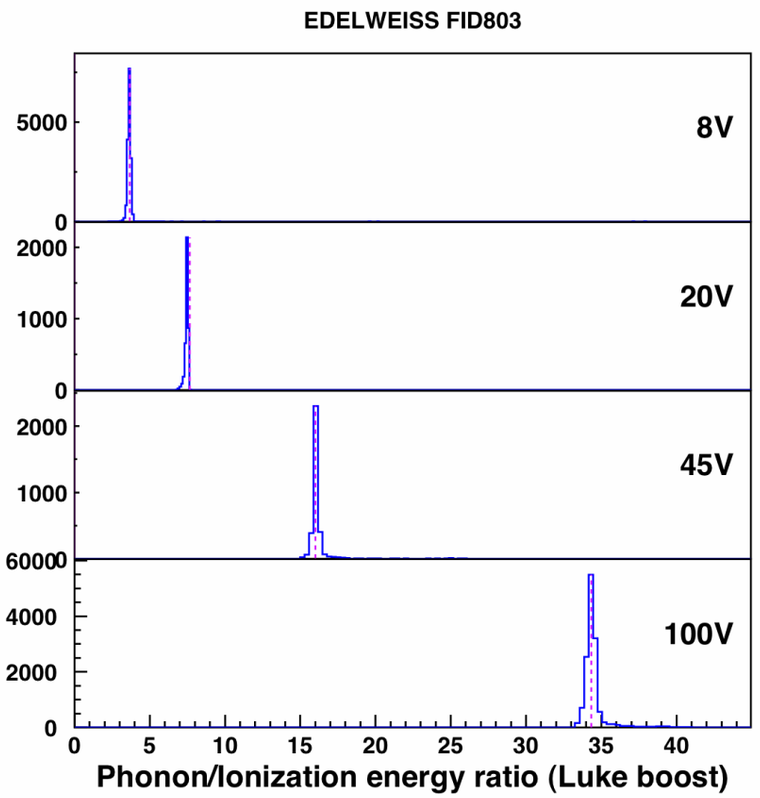
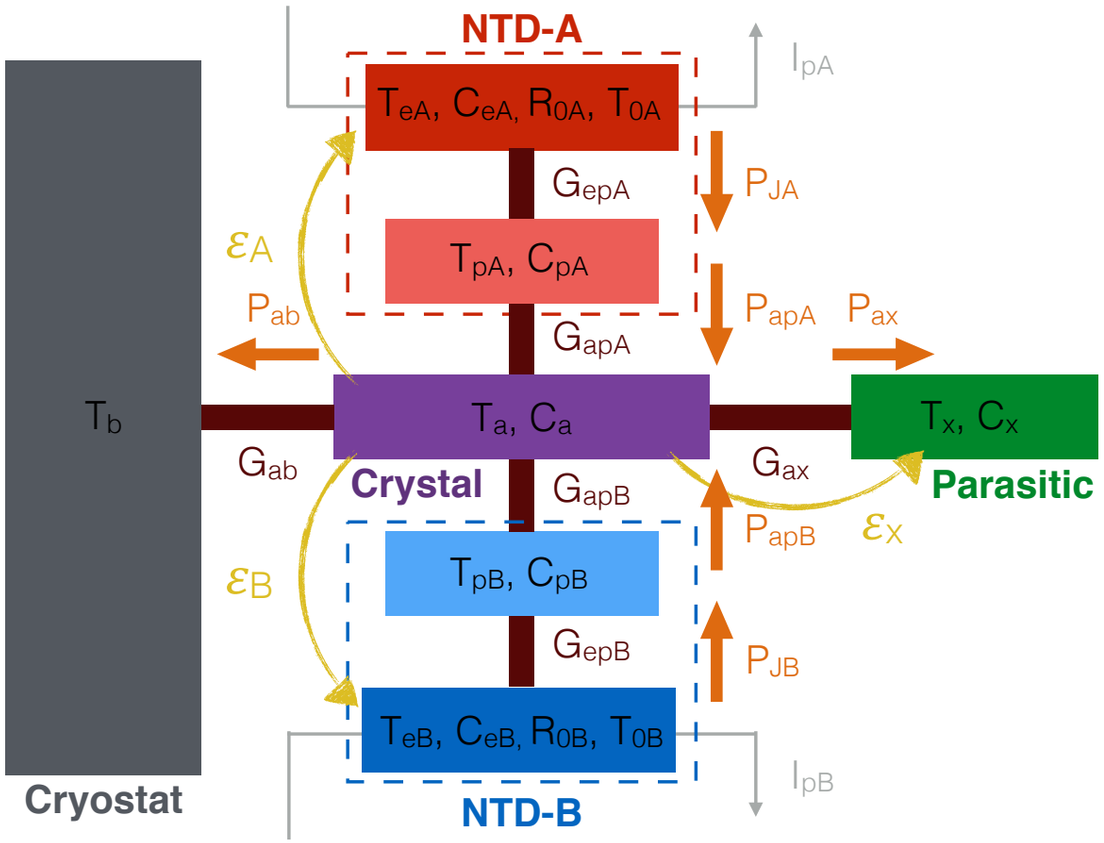


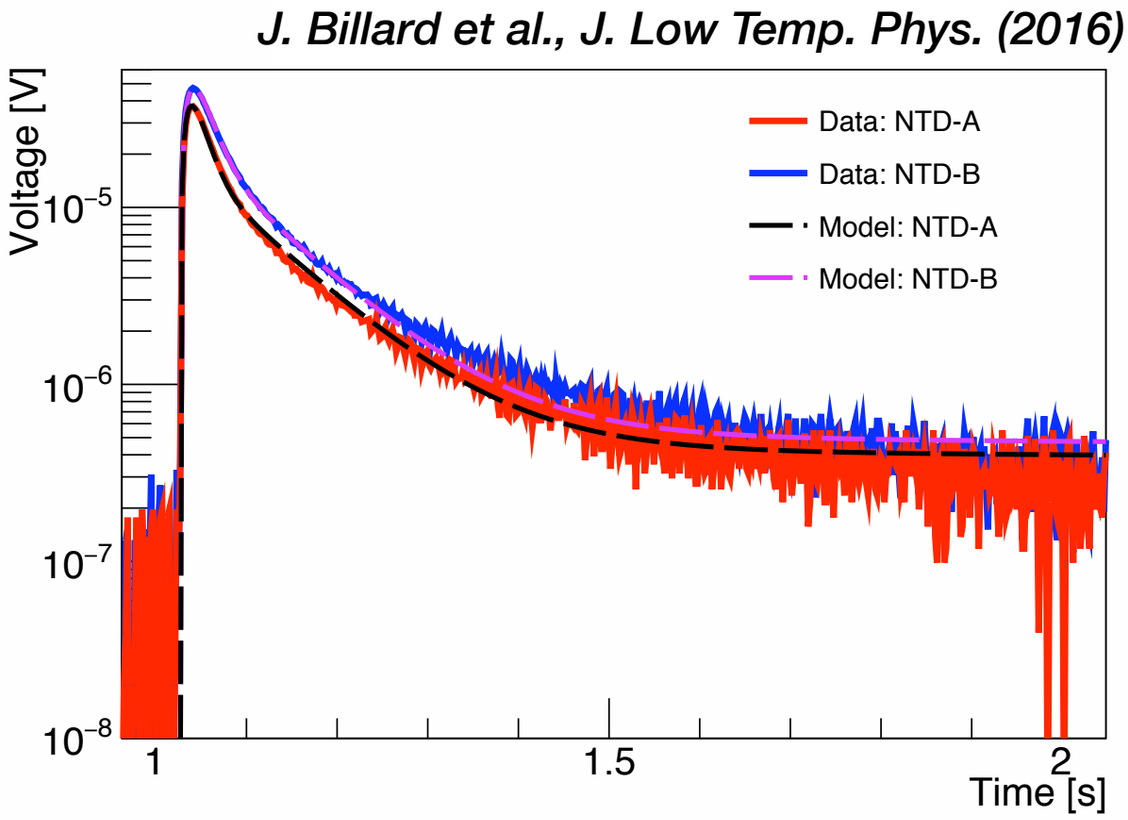




- First Dark Matter run with HV detectors ongoing
- Even in HV mode, we can still **readout both ionization and heat signals**
- Working **up to 100 V** leading to a boost factor of ~35 with Lowest threshold achieved of **60 eVee**

R&D: Improved sensors



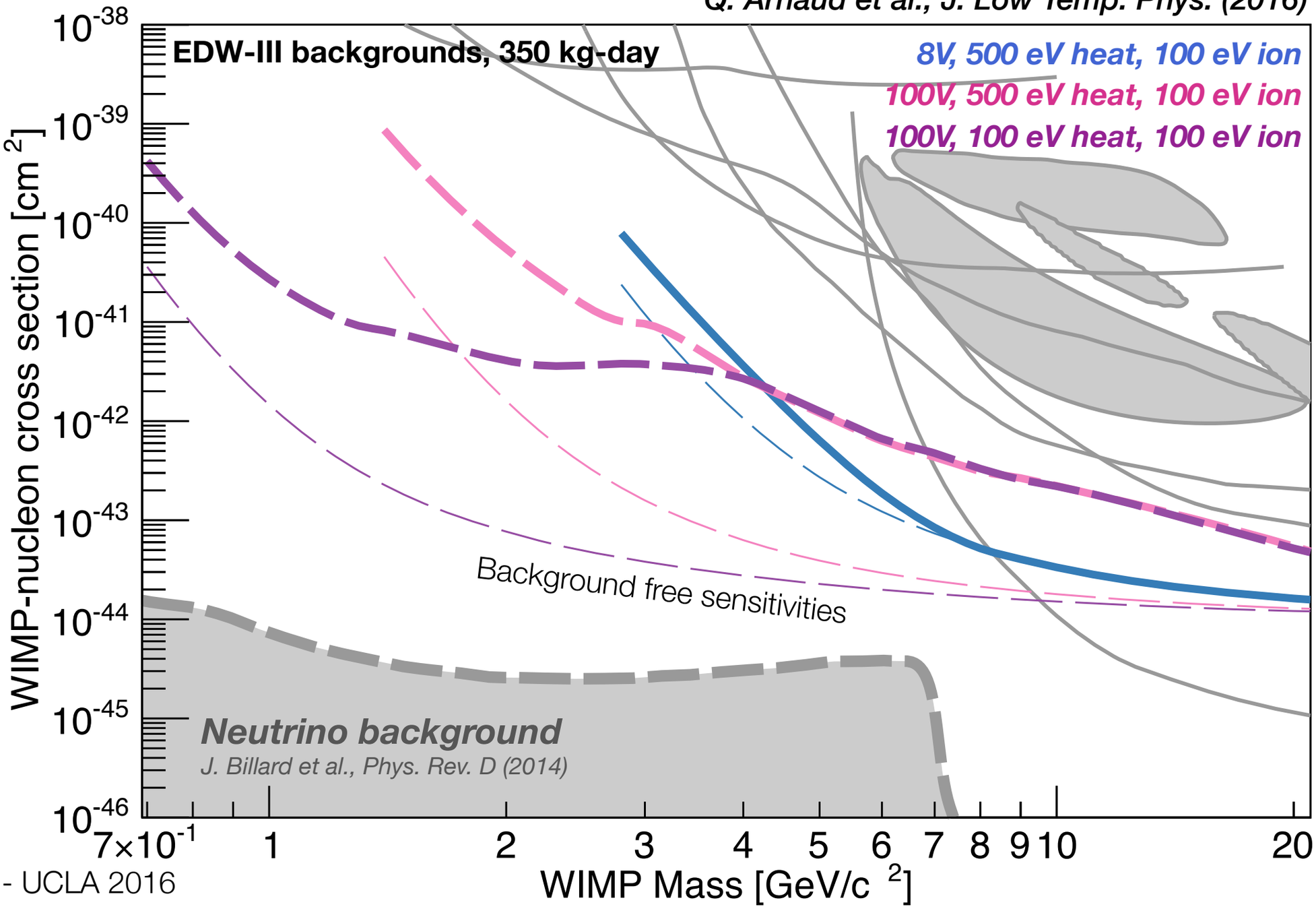


- We developed a detailed model of our heat signals that fits very well observed pulses
  - Sensitivity to ballistic phonons and presence of a parasitic heat capacity
  - Optimized sensors, to be tested this year, should reach 100 eV baseline resolution
- HEMT R&D for ionization signal also ongoing in collaboration with SuperCDMS to reach 100 eVee baseline resolution ***A. Phipps et al., J. Low Temp. Phys. (2016)***

R&D: Prospects

Goal for 2017 reachable from EDELWEISS-III setup:

Q. Arnaud et al., J. Low Temp. Phys. (2016)



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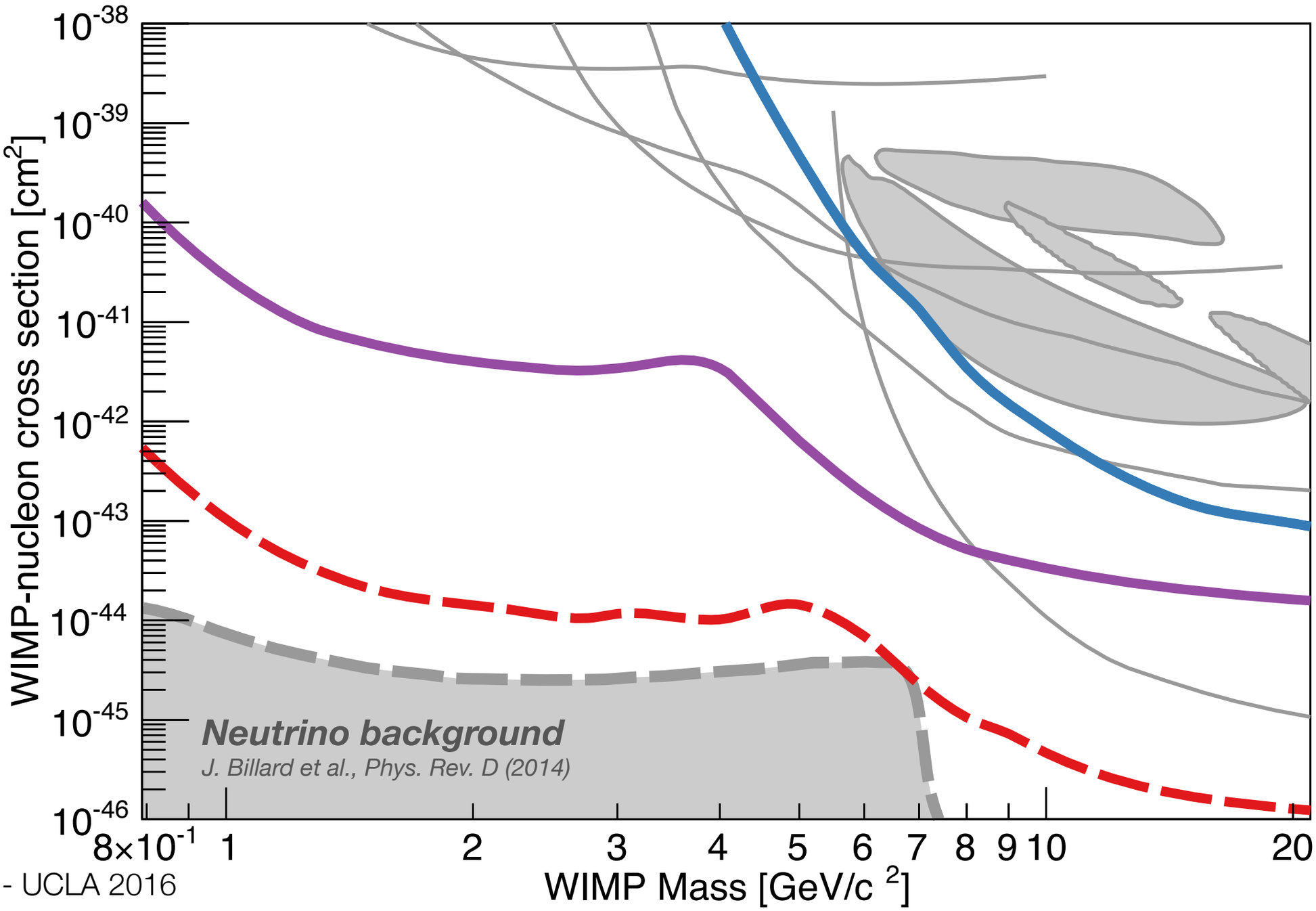

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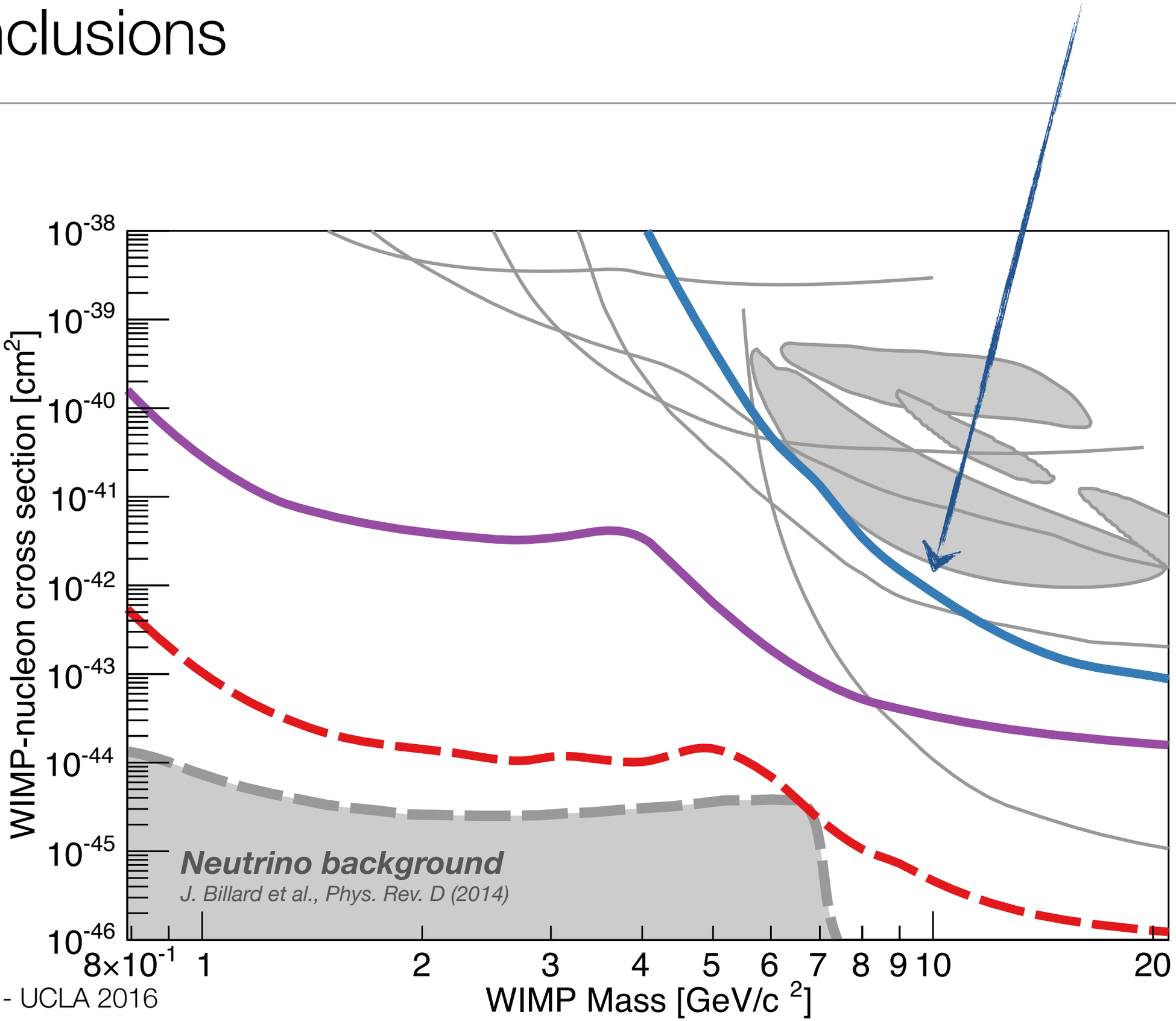


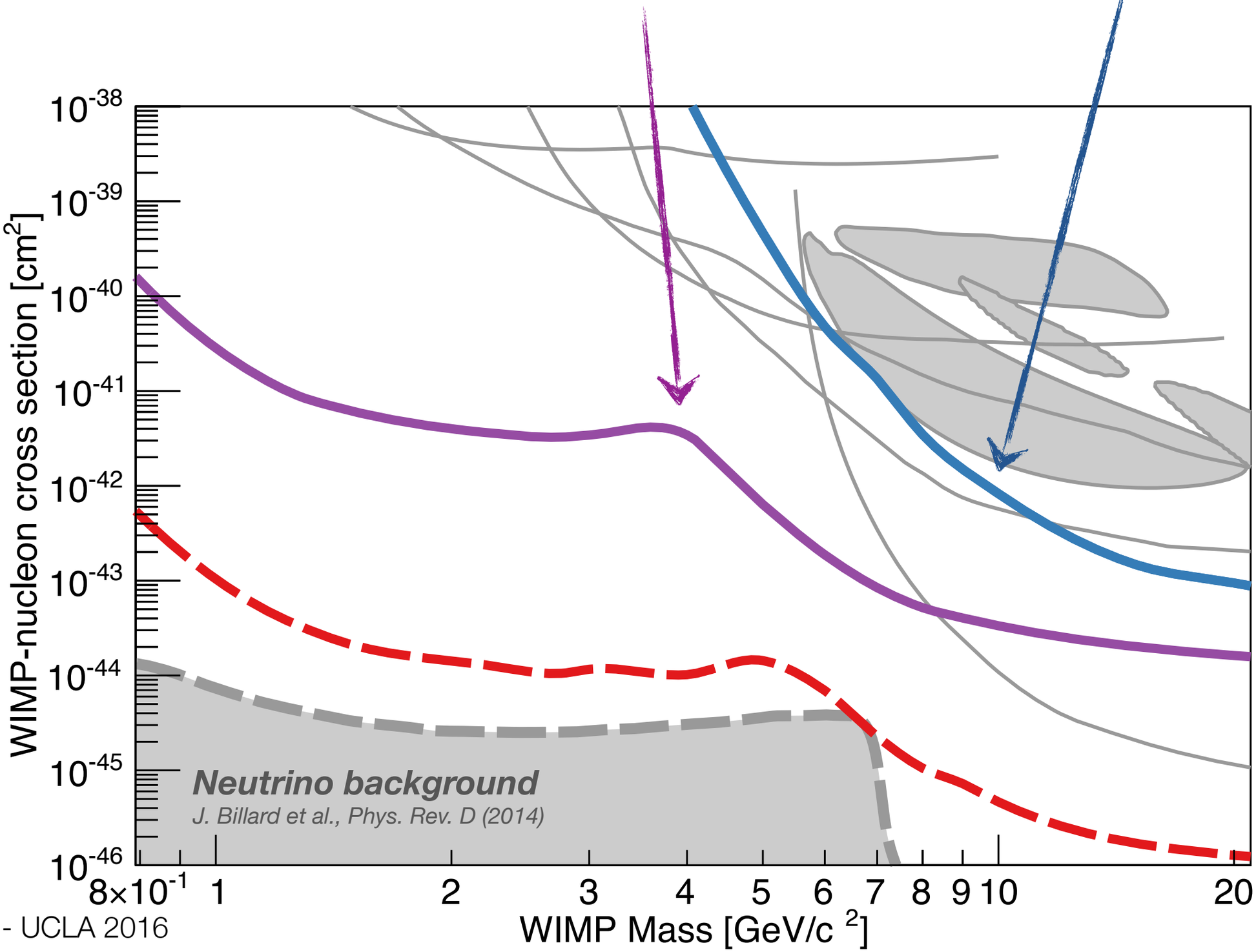
EDELWEISS-III LT analysis

to be submitted

Conclusions

EDELWEISS-III goals for 2017

intense R&D efforts ongoing



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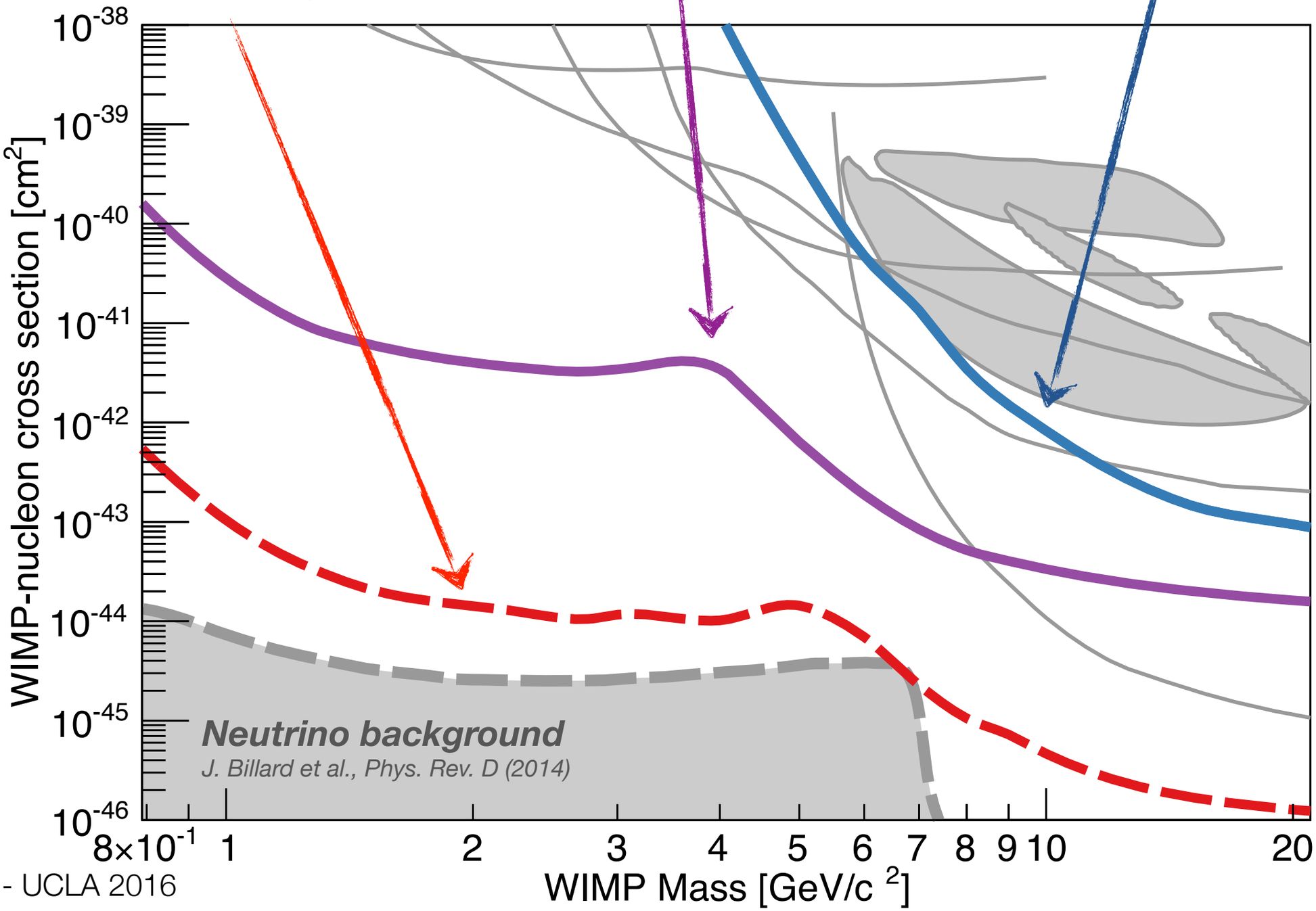
Going beyond (ton-scale)

EDELWEISS-EURECA-SuperCDMS