

# Status of Dark Matter searches with EDELWEISS

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# The EDELWEISS WIMP search experiment

## WIMP direct detection

- Search for low-energy (keV-scale) nuclear recoils

Others : eg axion searches



Galactic WIMP

velocity  $v \sim 200$  km/s  
local density  $\rho_0$

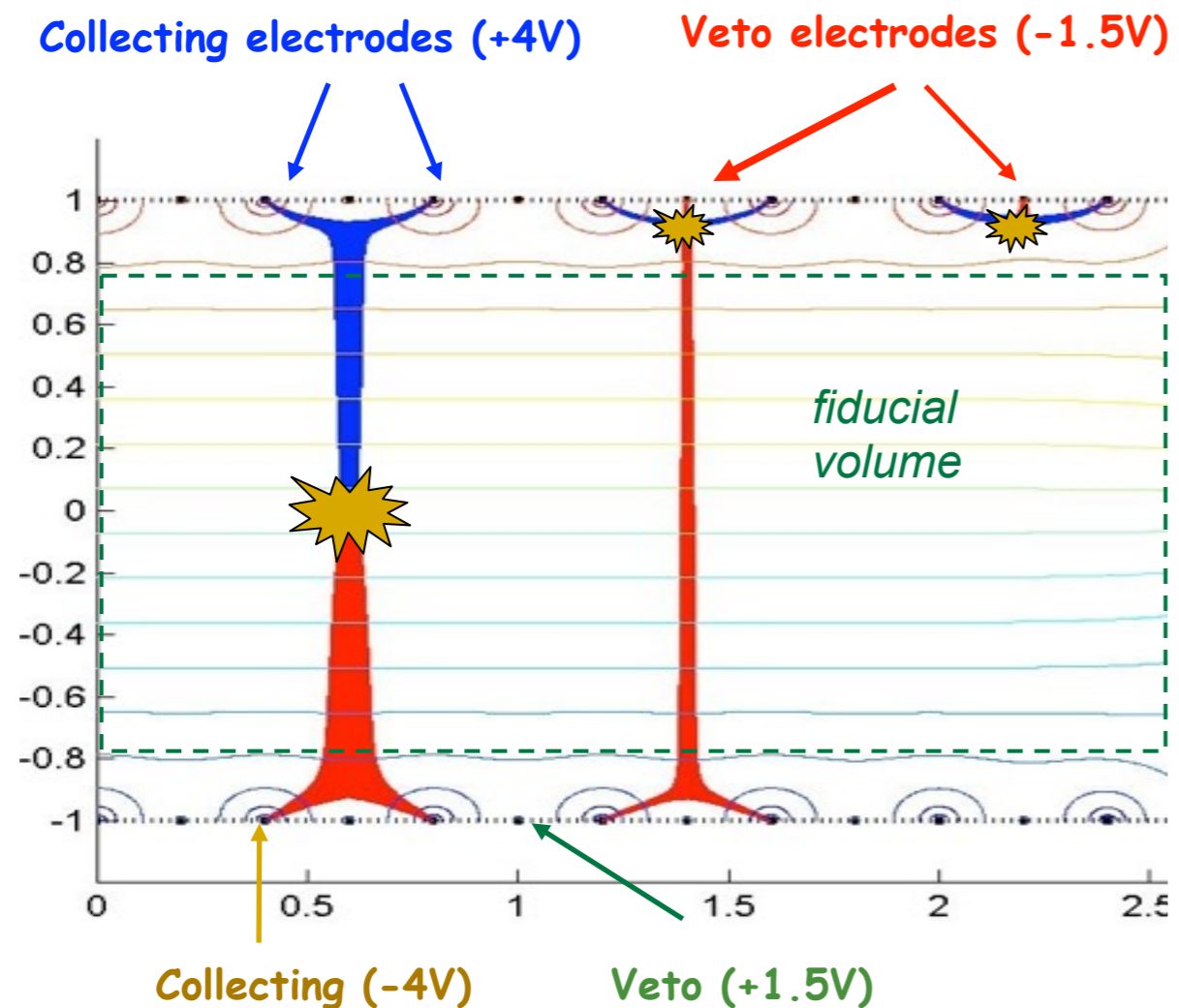
Interaction in a  
terrestrial detector

$\theta_r$   
Energy deposition  
Nuclear recoil  $E_r$

- Specific massive Germanium bolometer technology
- Low-background facility @ Laboratoire Souterrain de Modane :
  - Active muon veto [ *Astropart. Phys.* 44 (2013) 28 ]
  - Polyethylene shielding (neutrons)
  - Lead shielding ( $\beta$ , gammas)
  - Cryostat : dilution fridge, detector temperature  $T \sim 18$  mK (40 kg mass)
  - Extra polyethylene and roman lead inside cryostat
  - Dedicated low-noise cold electronics and wirings

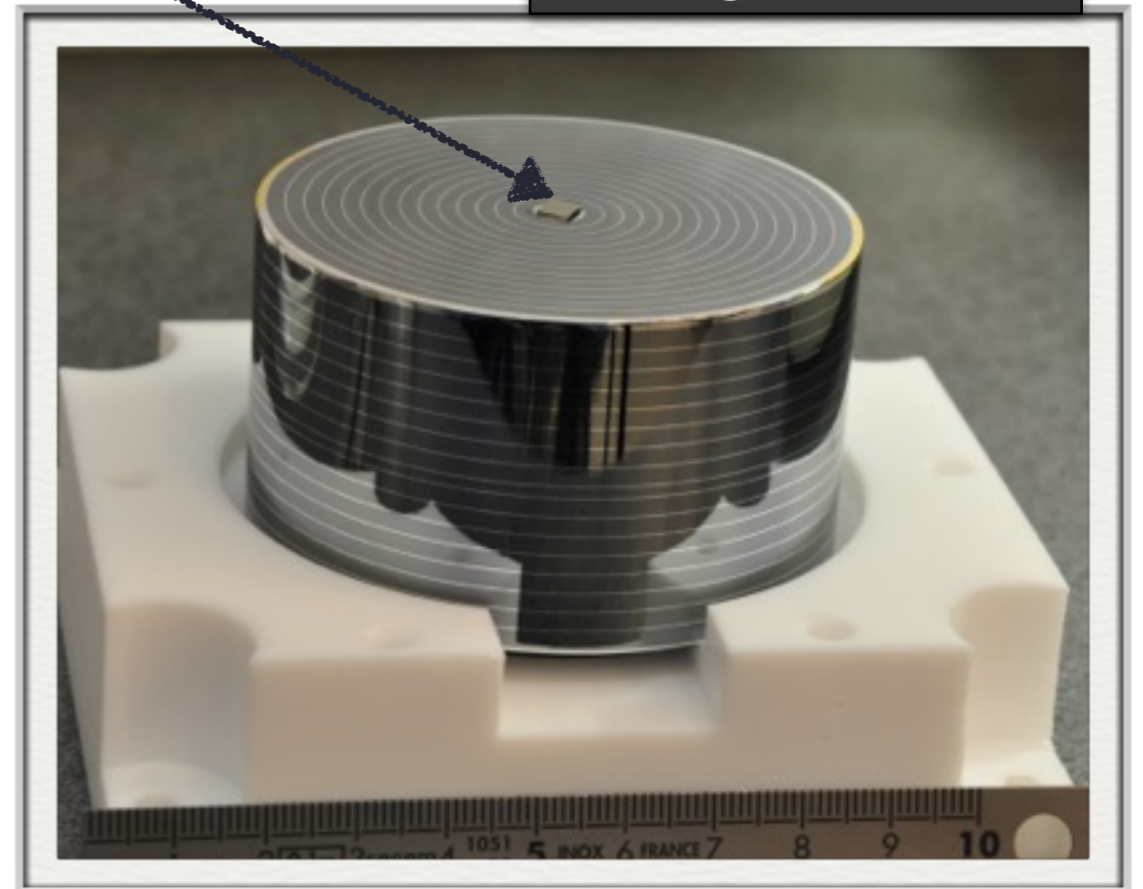


# EDELWEISS-III « FID » detectors



NTD thermometer

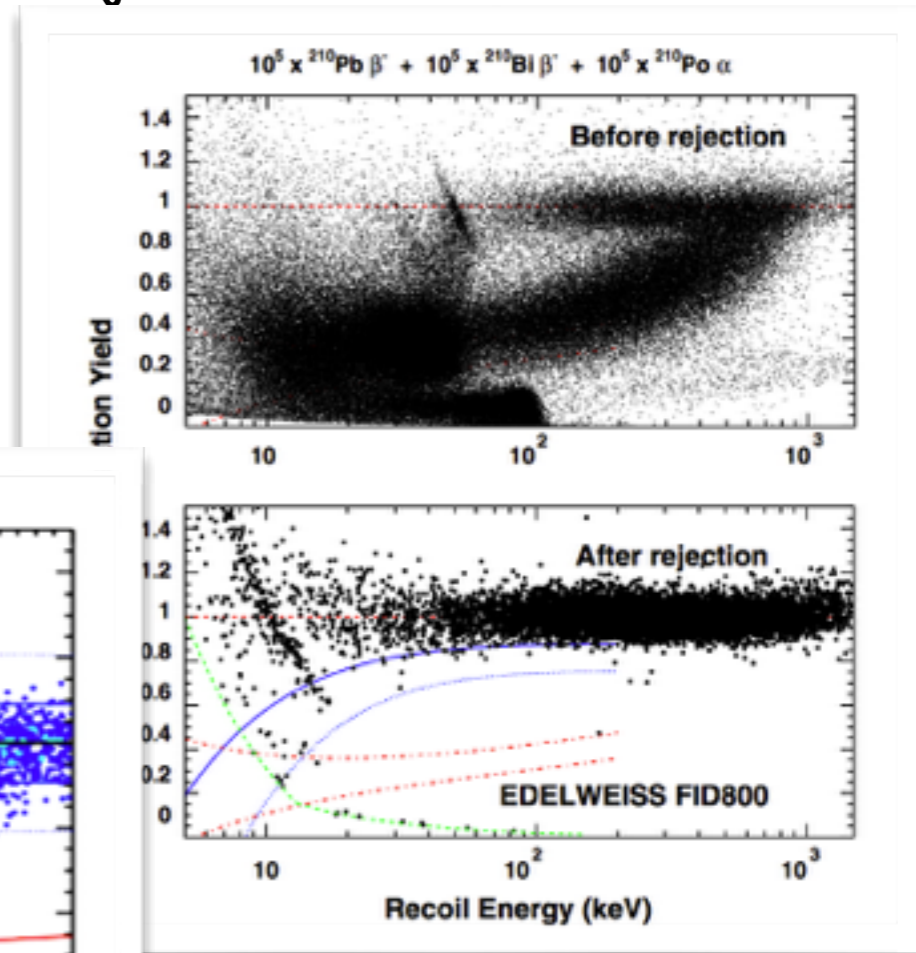
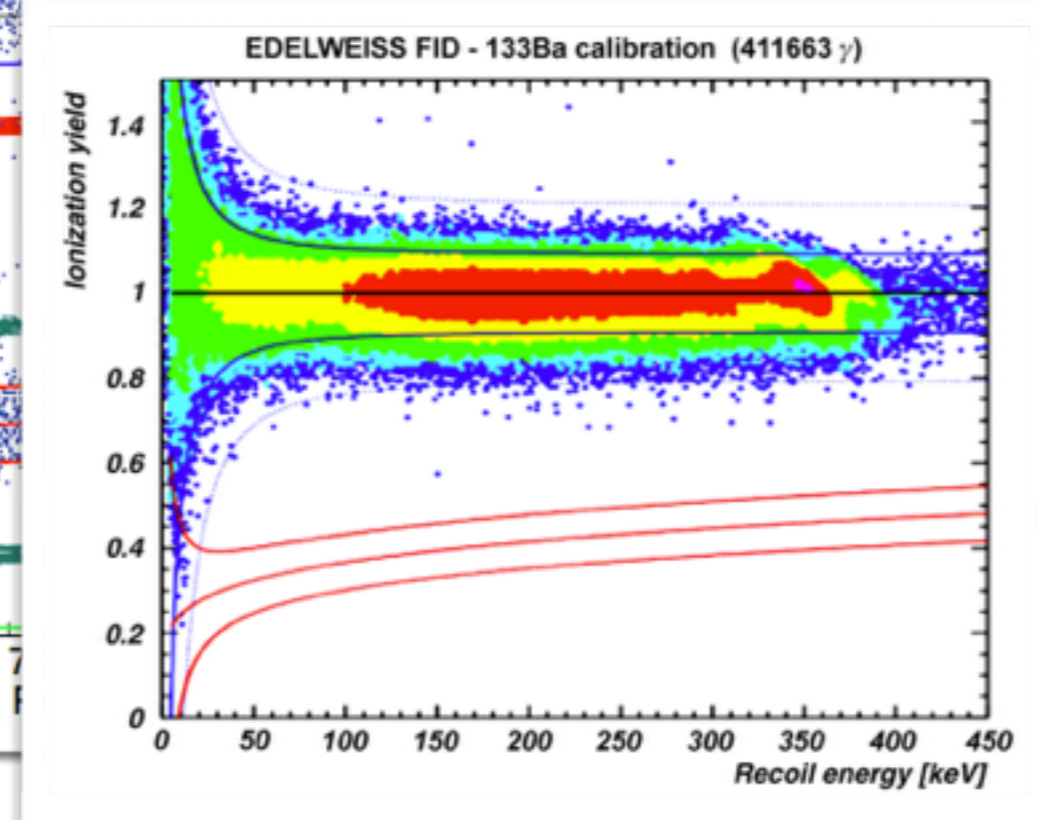
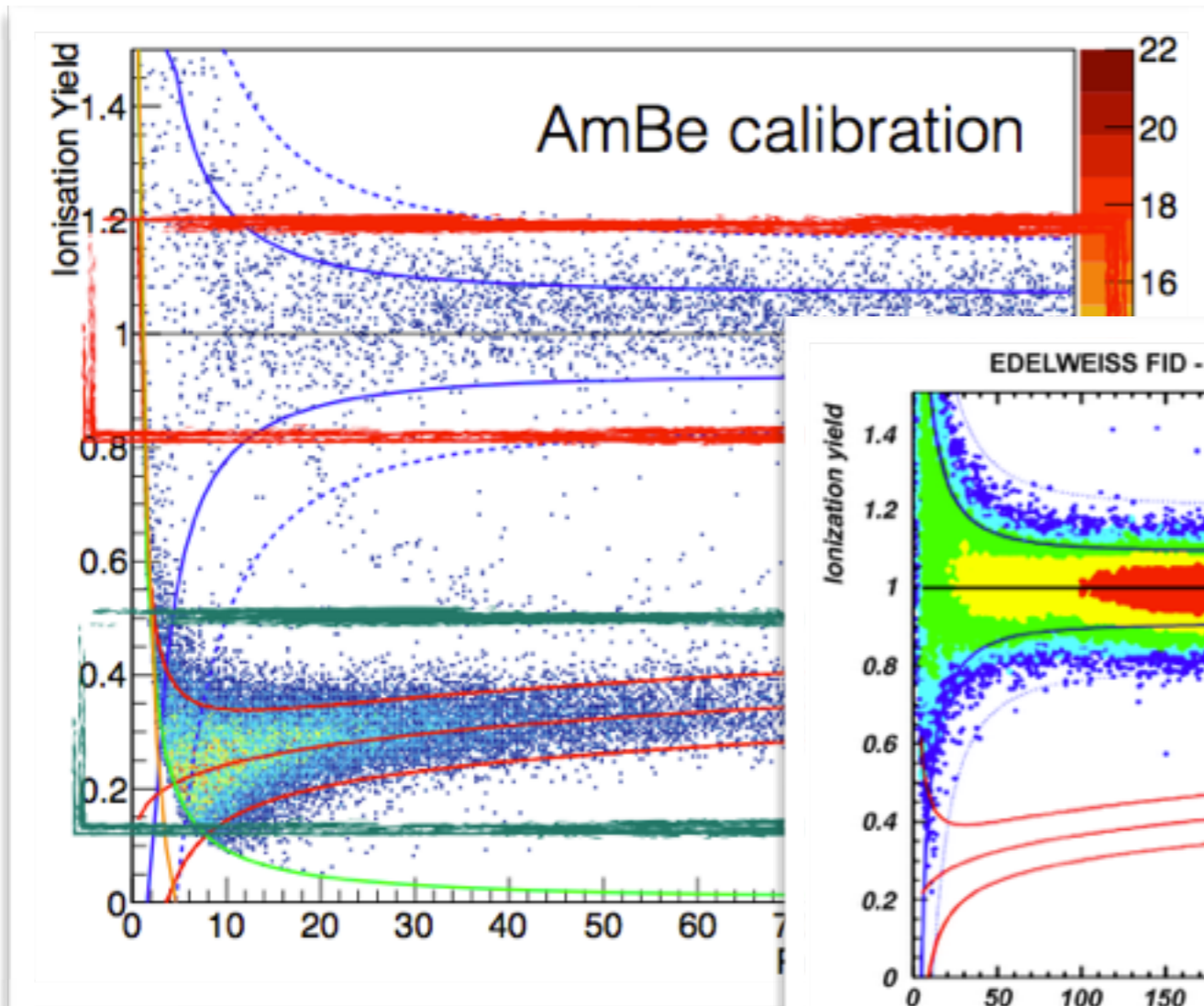
800g HP-Ge



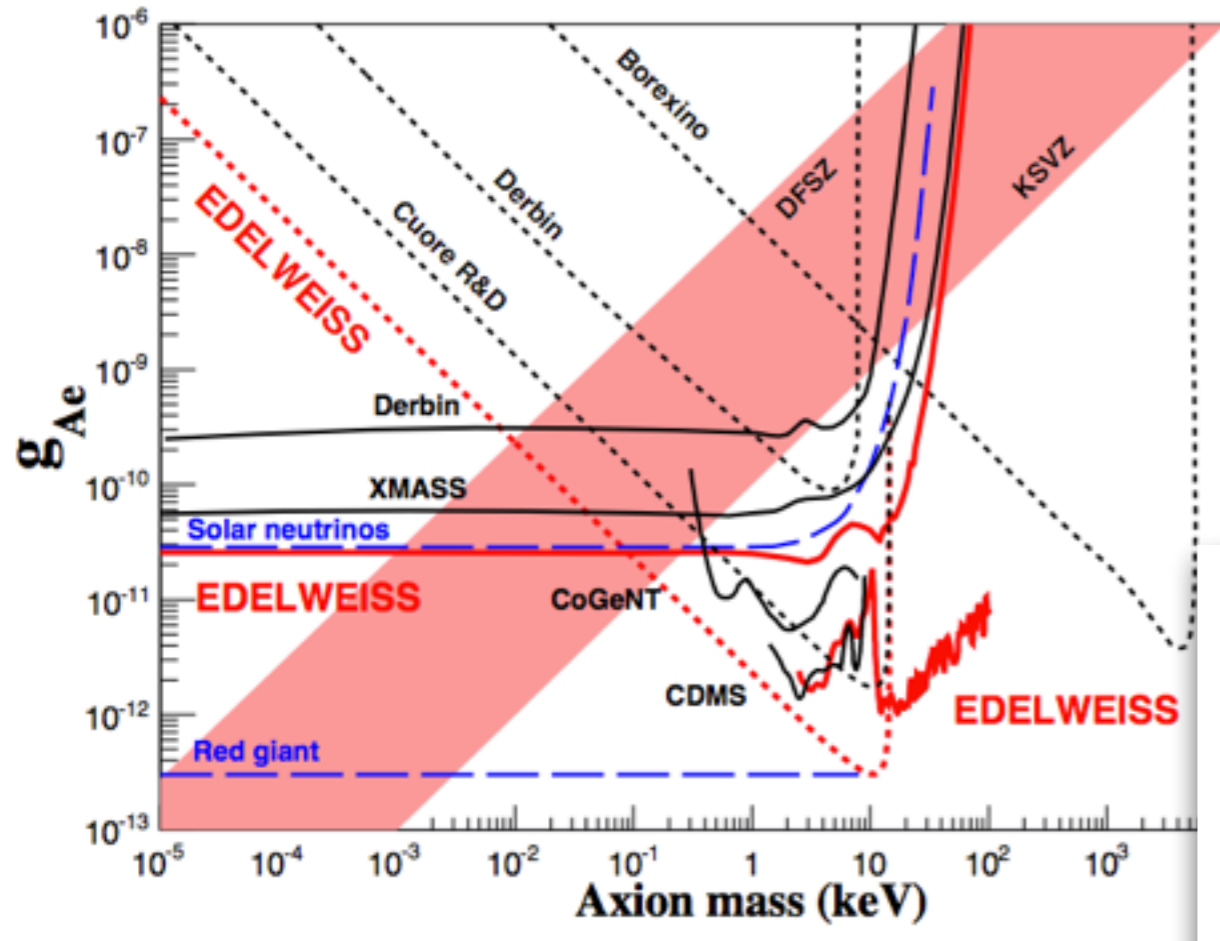
- 1) Select fiducial interactions from the topology of ionisation signals  
[ Phys Lett B 681 (2009) 305-309 ]
- 2) Measure the ionisation yield = ionisation / recoil energy :
  - Yield  $\sim 1$  for electron recoils (  $\beta$ , gamma, neutrinos and axions )
  - Yield  $\sim 0.3$  for nuclear recoils ( neutrons, neutrinos and WIMPs )

# Detector performance

- Demonstrated fiducial gamma rejection from  $^{133}\text{Ba}$  calibration : rejection factor  $< 6 \times 10^{-6}$   
[J Low Temp Phys (2012) 167:1056-1062]
- Demonstrated surface event rejection from a  $^{210}\text{Pb}$  source : rejection factor  $< 4 \times 10^{-5}$   
[J Low Temp Phys (2014) 176:870-875]

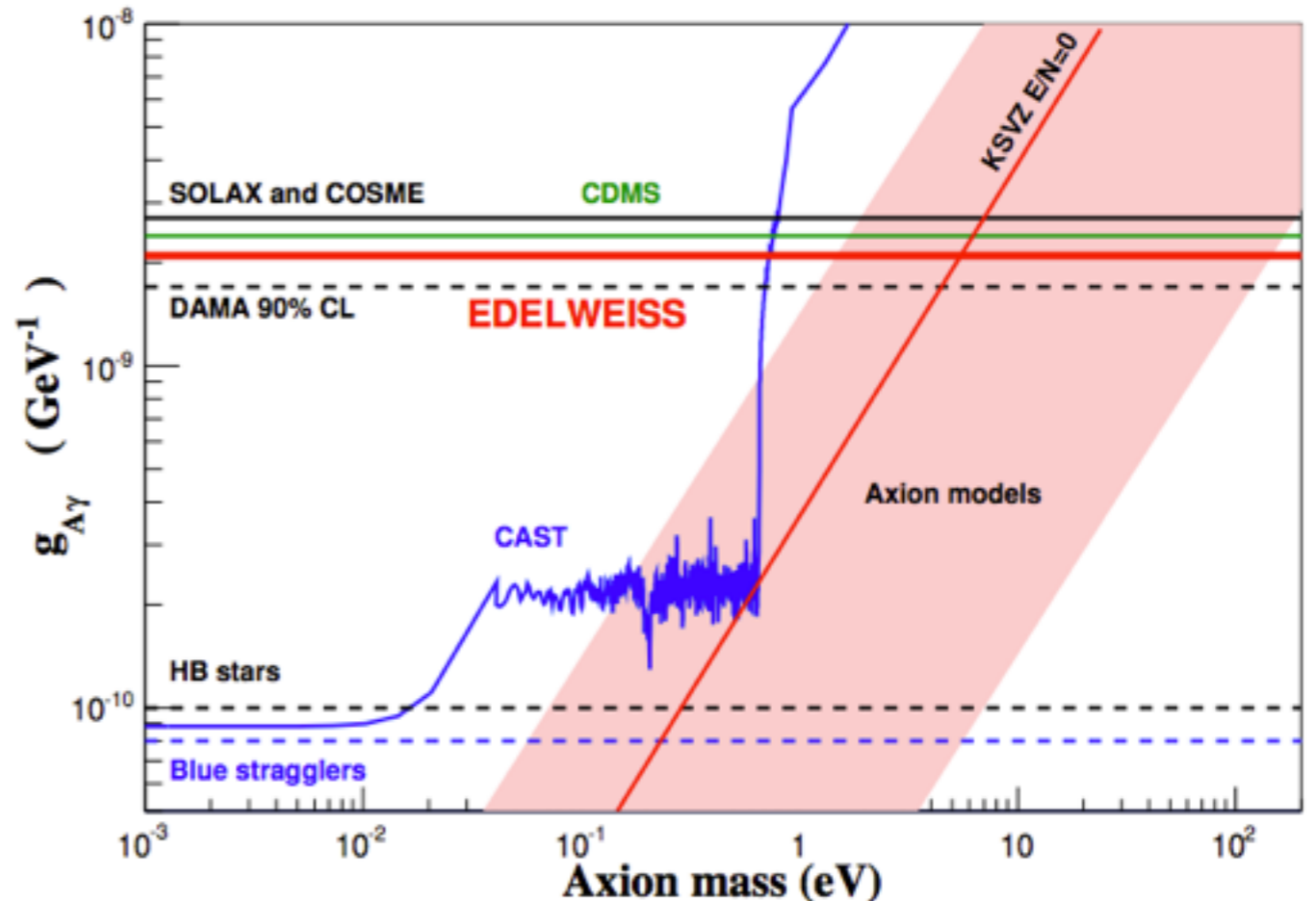


# Axion results from EDELWEISS-II



Data ~ 2009-2010

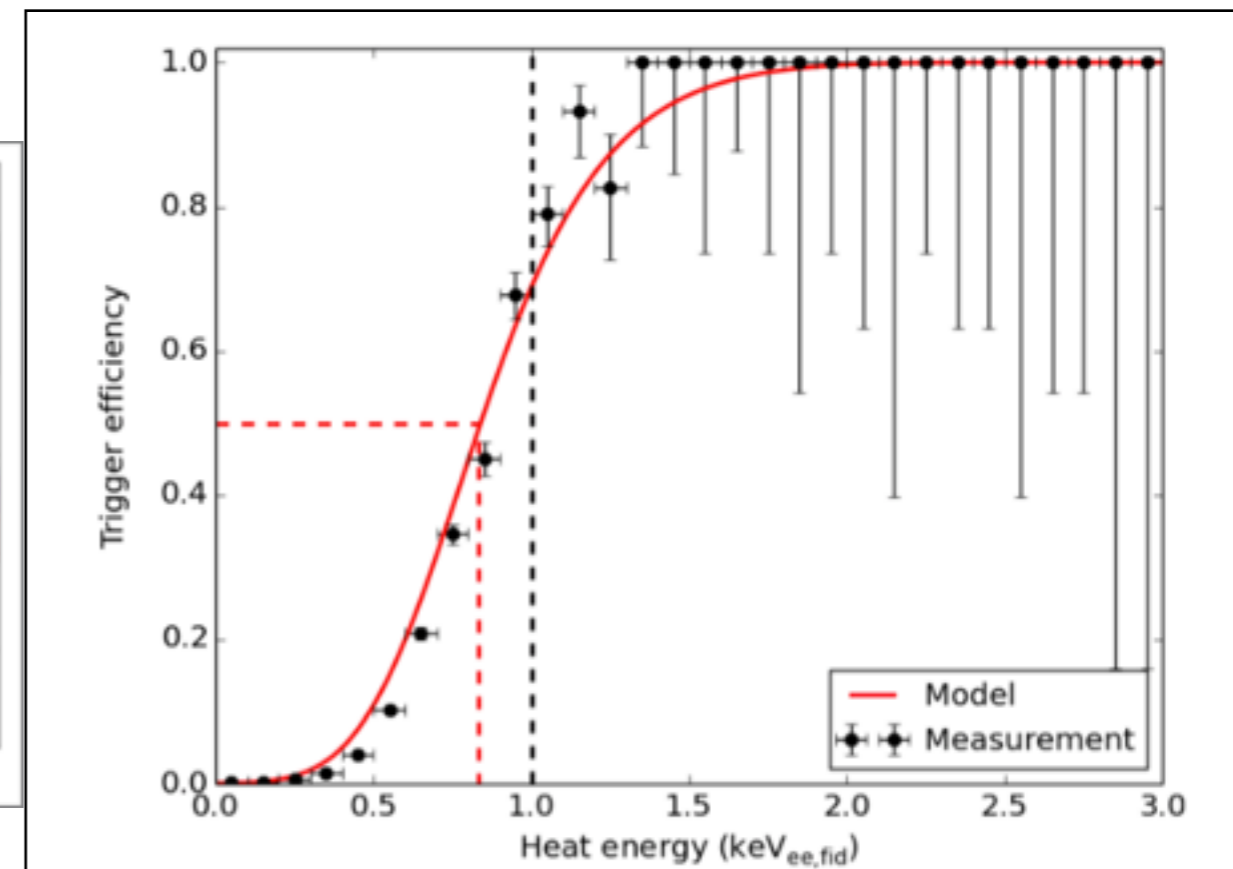
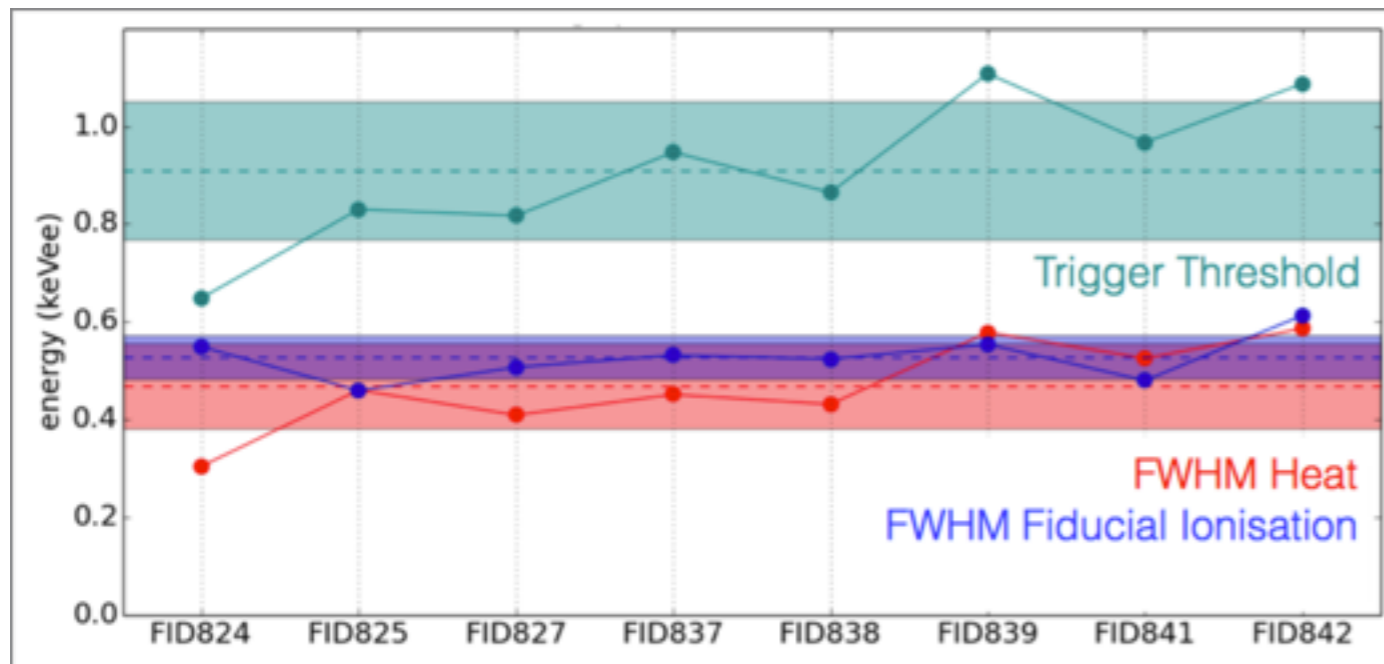
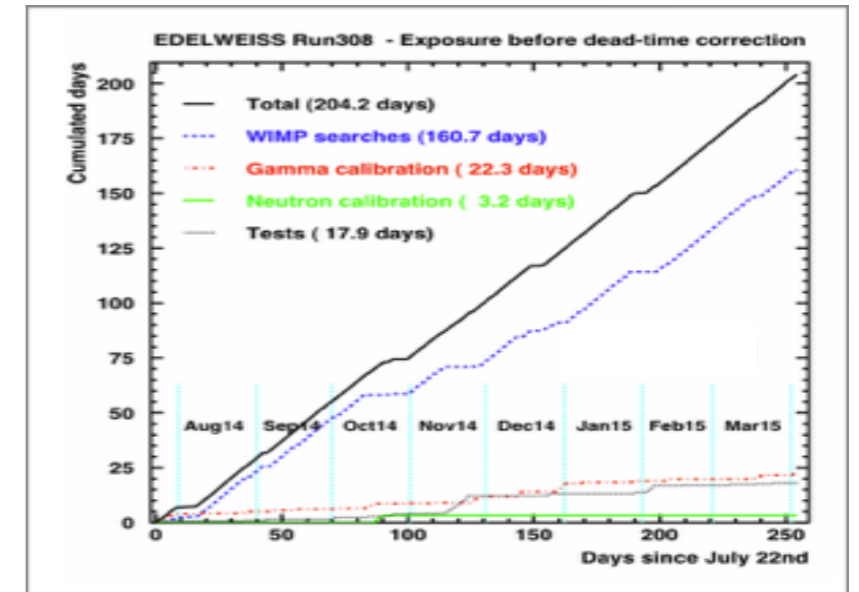
Search for electron recoils from solar or dark matter axions using EDELWEISS-II « ID » detectors (up to 448 kg-days fiducial)



[ JCAP 11 (2013) 067 ]

# Search for low-mass WIMPs with EDELWEISS-III

- **Low mass WIMPs :  $M \sim 4 - 20 \text{ GeV}$**   
eg. asymmetric dark matter  
Low-energy ( $\sim \text{keV}$ ) nuclear recoils
- **582 kg-days** (fiducial) from 8 detectors (2014-2015)
- Analysis threshold @ 1 - 1.5 keV<sub>ee</sub> (1keV<sub>ee</sub> = 2.4 keV<sub>nr</sub>)



# Low-mass WIMP search : backgrounds

## Surface events

beta radioactivity and lead recoils  
gammas outside fiducial volume

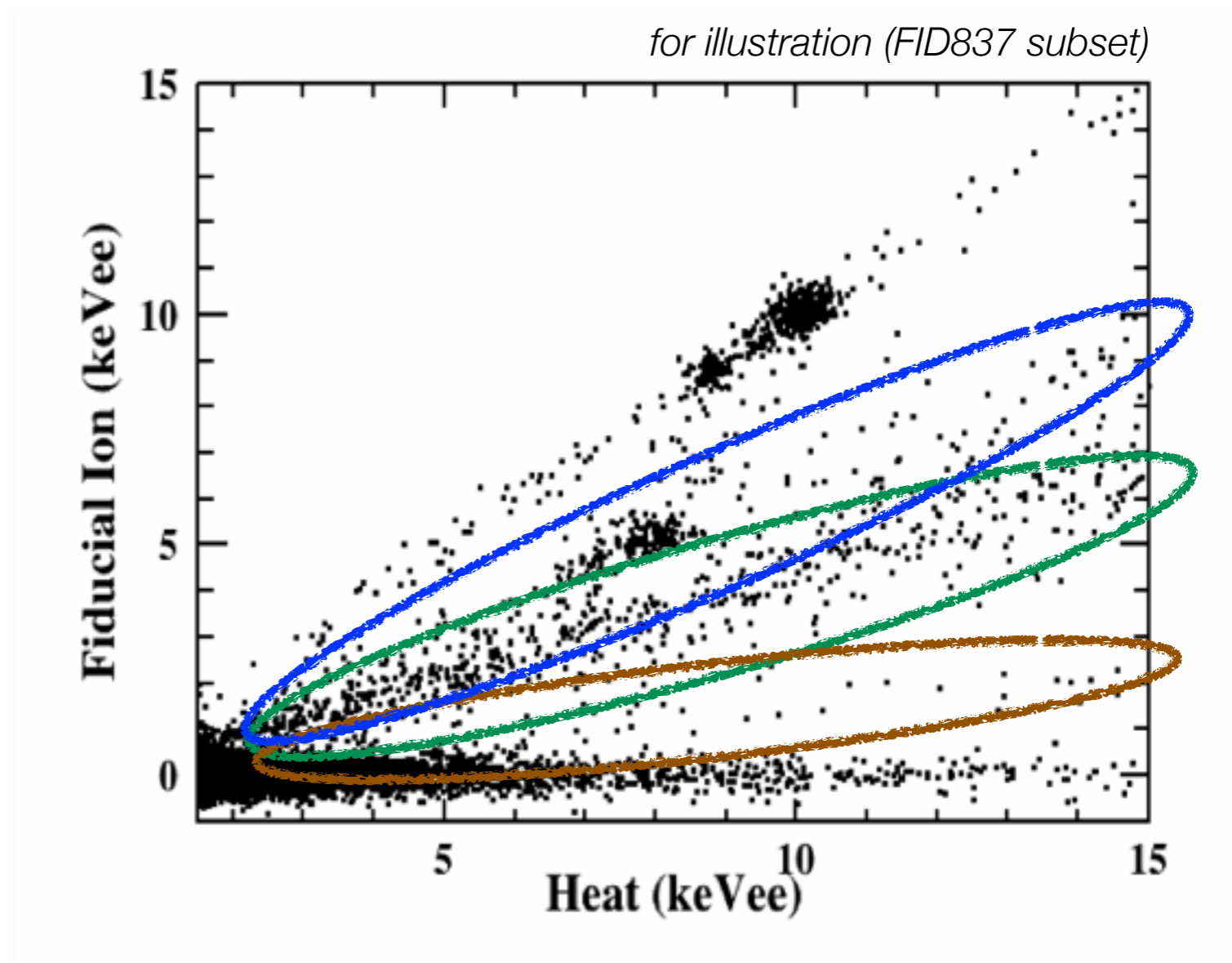
Electron recoils in fiducial volume  
cosmogenic lines (K and L shells)  
smooth component

## Neutrons

mostly radiogenic origin

## « Heat-only » events

dominant background @ low energy  
under investigation, probably  
mechanical origin



For all backgrounds : data-driven  
model from sideband data

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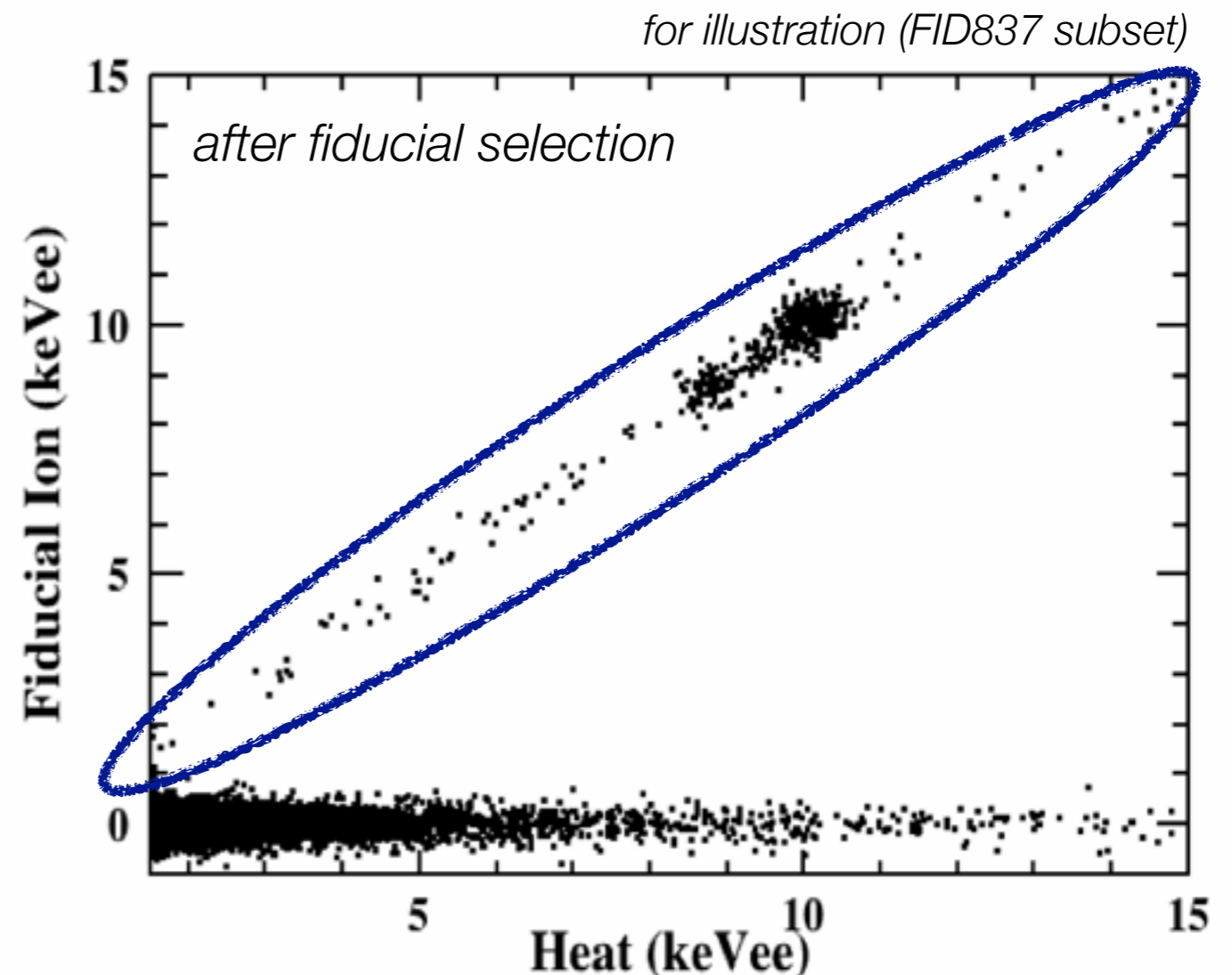
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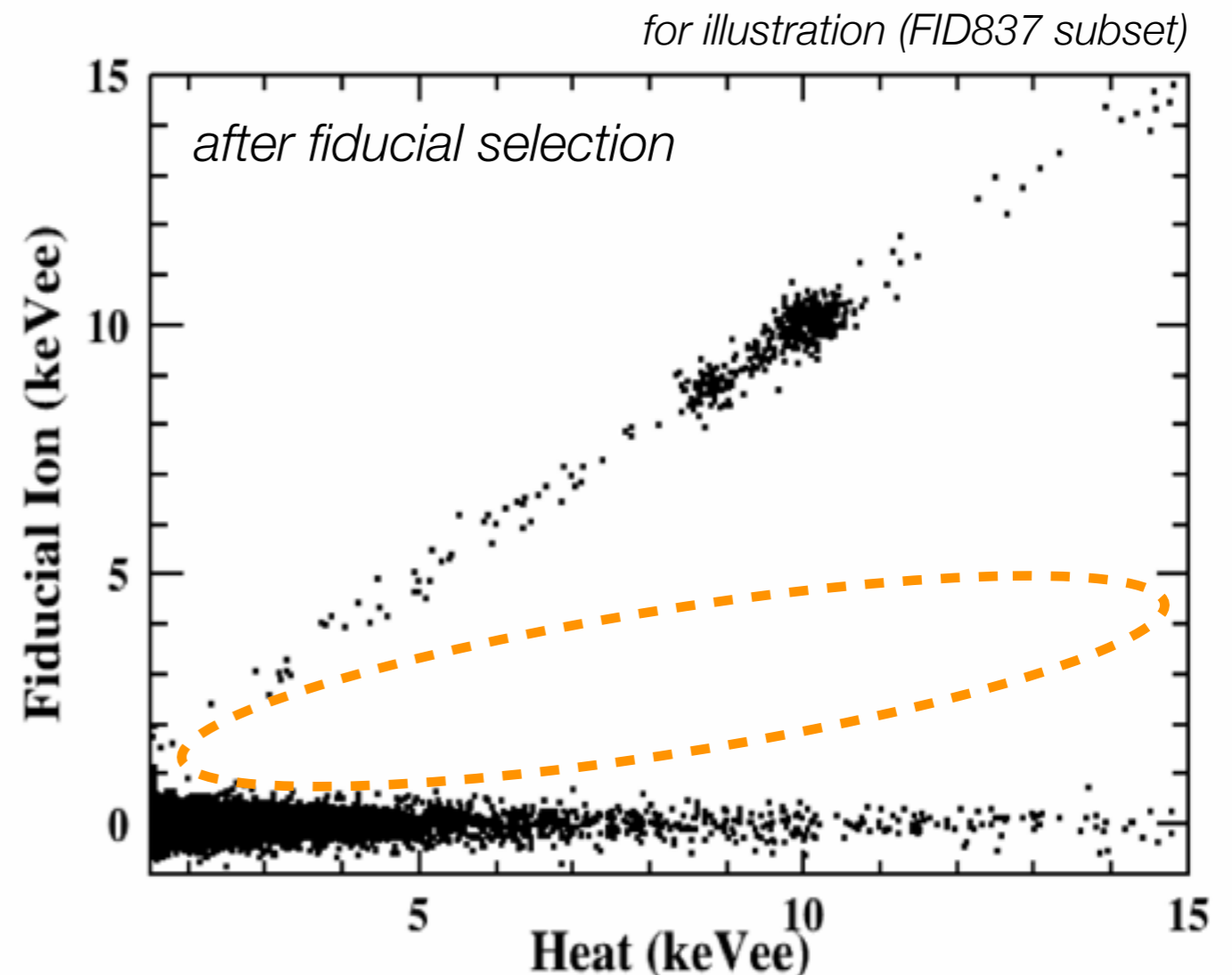
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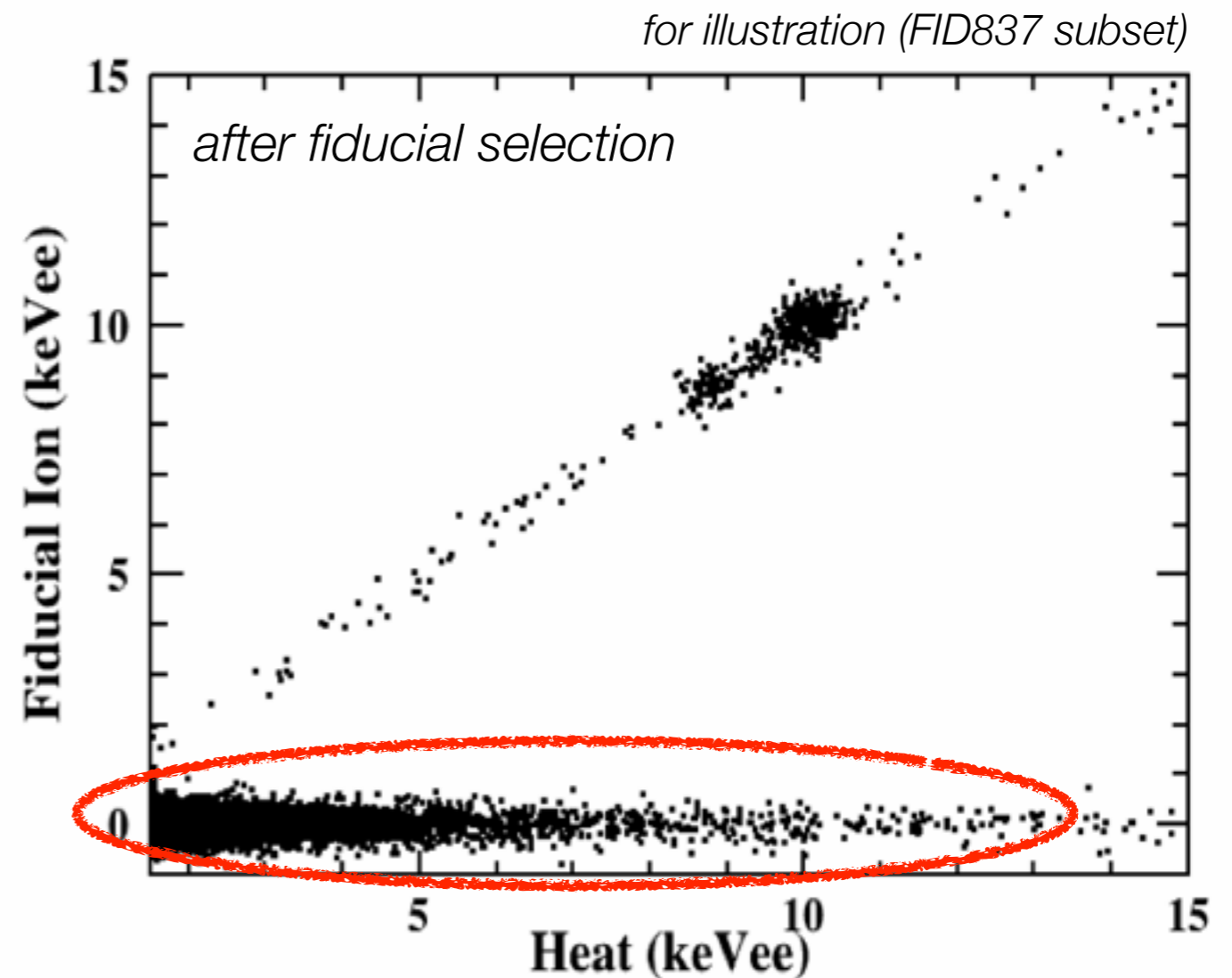
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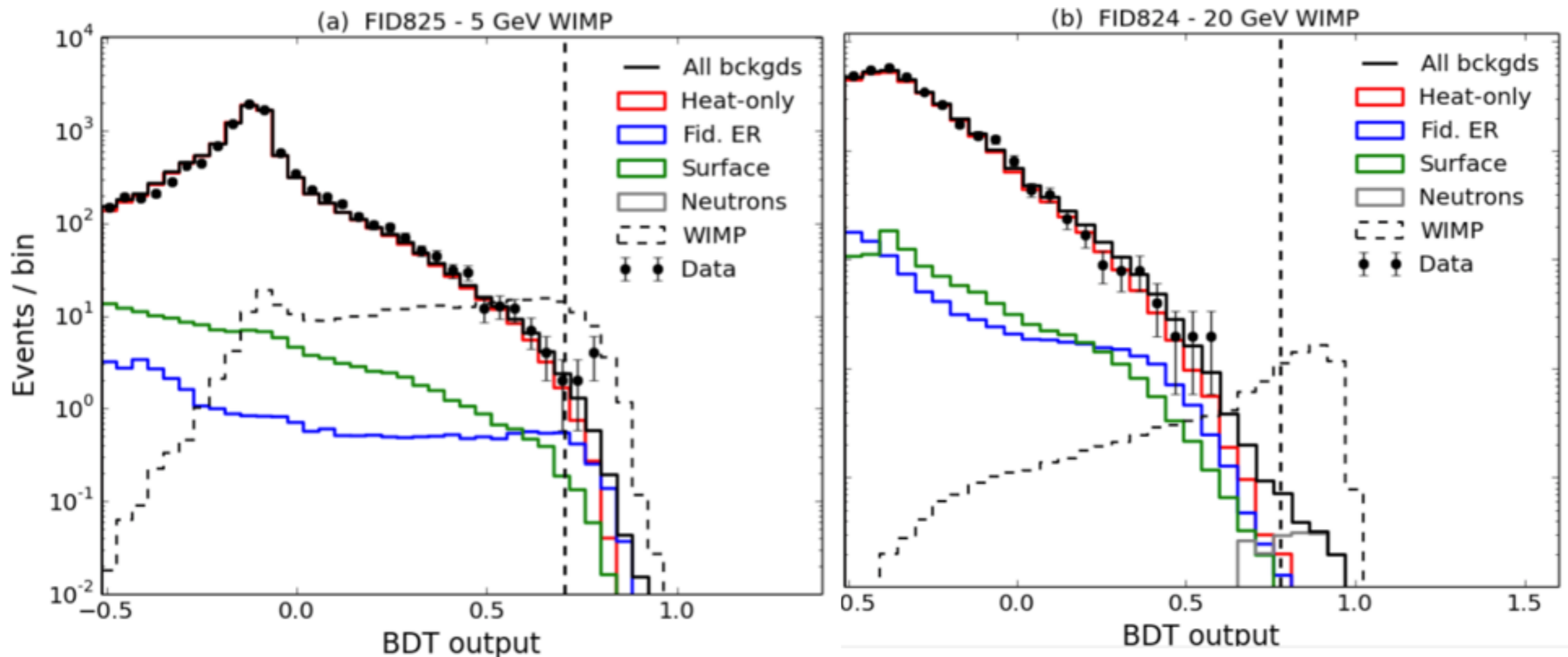
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For all backgrounds : data-driven  
model from sideband data

# Low-mass WIMP search : BDT + cut

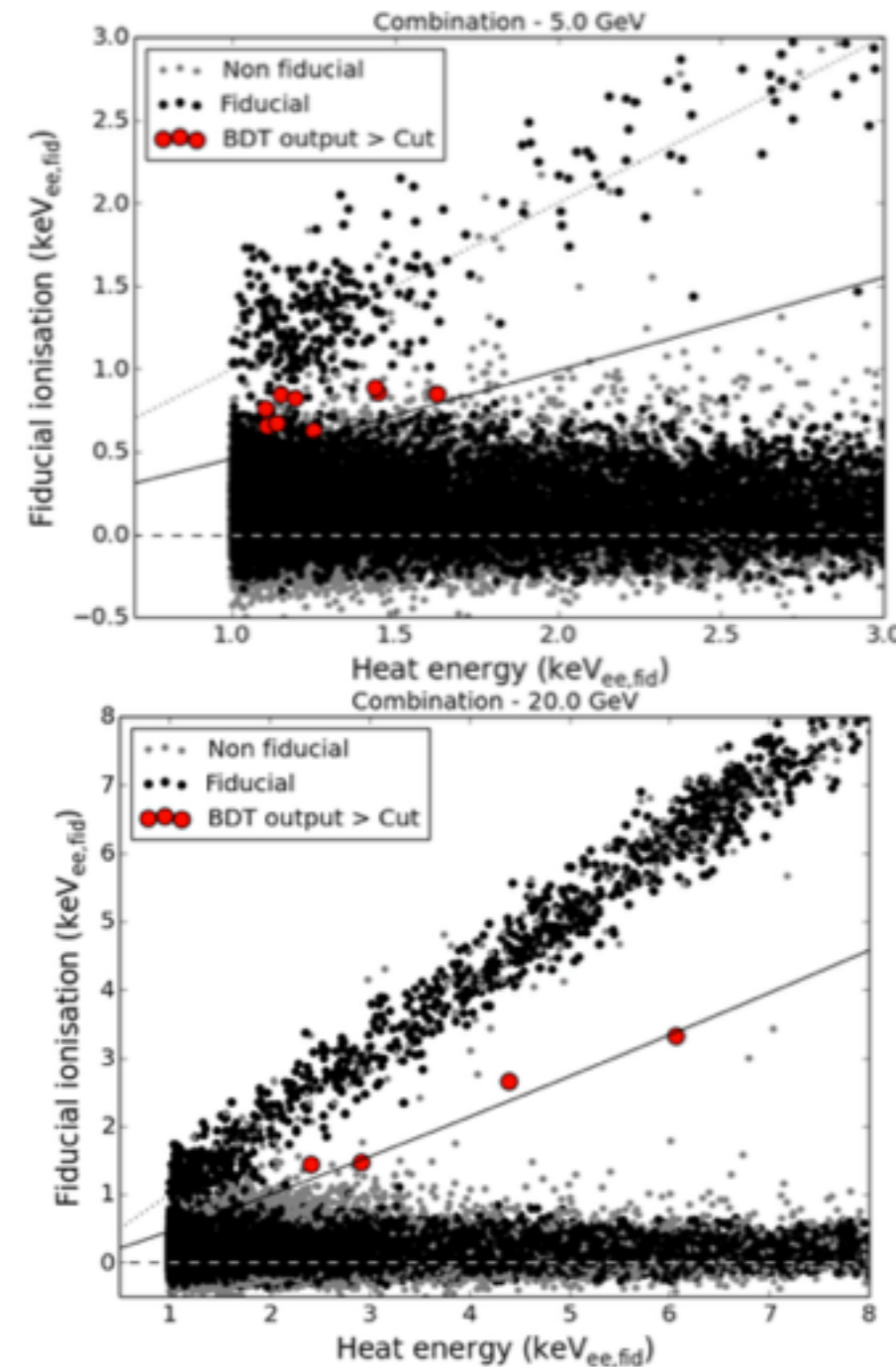
- **Blind « WIMP box »** :  $\text{veto} < 5 \sigma$  ,  $0 < E_{\text{ion}} < 8 \text{ keV}_{ee}$  ,  $1(1.5) < E_{\text{heat}} < 15 \text{ keV}_{ee}$
- **Combine all channels from each detector (4 ionisations + 2 heats) to a single BDT output optimizing signal/background**
- **Train BDT using background models + expected WIMP signal + individual detector effects**



# Low-mass WIMP search : results

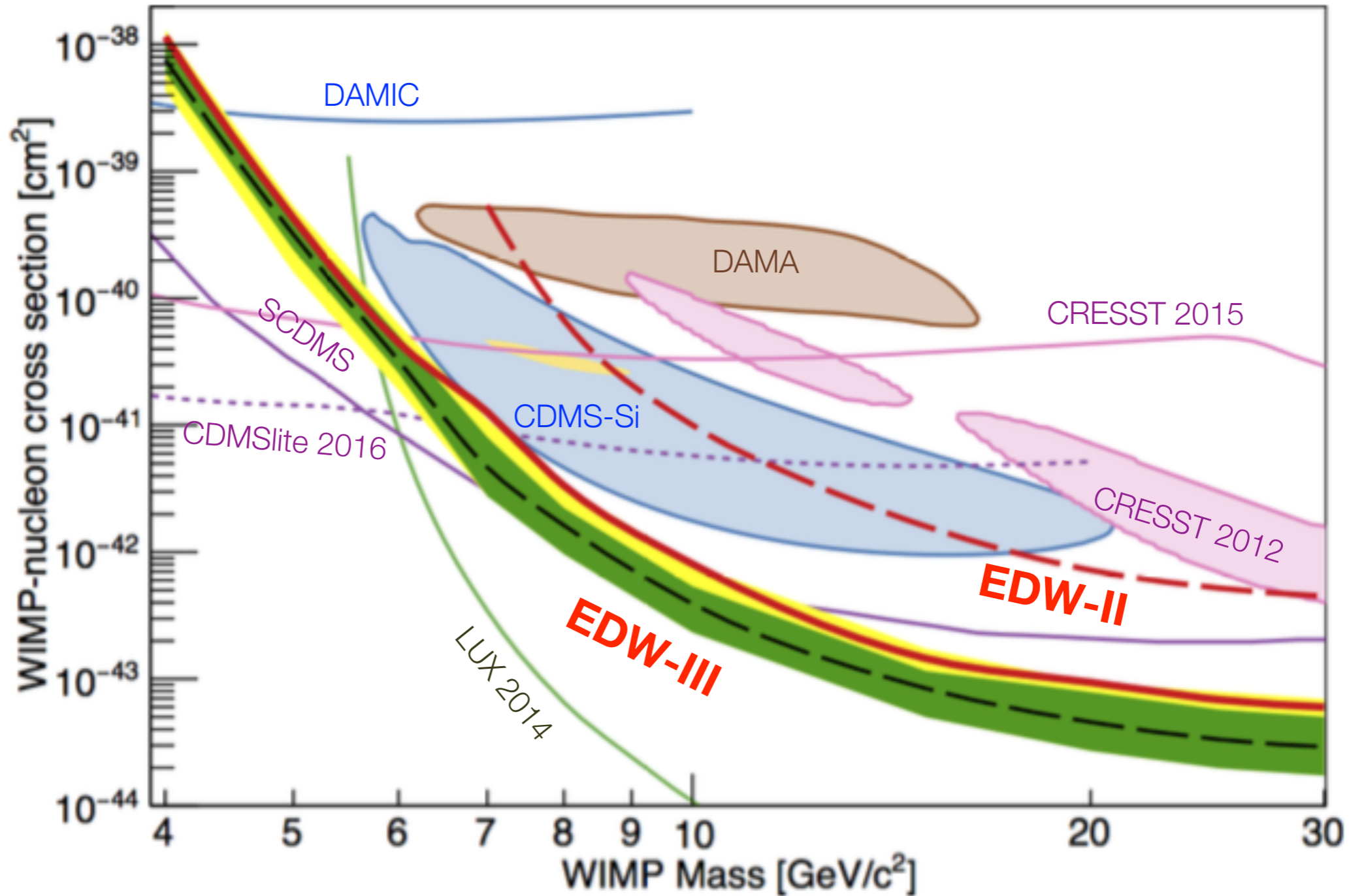
- Poisson limit after (blind) BDT cut  
No background subtraction
- Dominant backgrounds:  
low mass (5 GeV) : **heat-only events** and cosmogenic gamma line  
high mass (20 GeV) : **radiogenic neutrons** (systematics ~ 50%)
- No statistically significant excess observed  
minimum p-value 1.1%

WIMP mass	5 GeV/c <sup>2</sup>	7 GeV/c <sup>2</sup>	10 GeV/c <sup>2</sup>	20 GeV/c <sup>2</sup>
Fiducial neutrons	0.02 ± 0.01	0.15 ± 0.07	0.36 ± 0.16	1.05 ± 0.47
Fiducial ER	2.71 ± 0.43	1.02 ± 0.16	0.43 ± 0.07	0.12 ± 0.02
Heat-only events	2.87 <sup>+0.49</sup> <sub>-0.03</sub>	0.43 <sup>+0.07</sup> <sub>-0.00</sub>	0.20 <sup>+0.03</sup> <sub>-0.00</sub>	0.11 <sup>+0.02</sup> <sub>-0.00</sub>
Others	0.55 ± 0.16	0.12 ± 0.04	0.09 ± 0.03	0.07 ± 0.02
Total background	6.14 <sup>+0.67</sup> <sub>-0.46</sub>	1.71 <sup>+0.19</sup> <sub>-0.18</sub>	1.07 ± 0.18	1.35 ± 0.47
Events observed	9	6	4	4
p-value	22%	1.1%	2.8%	6.3%



# Low-mass WIMP search : results

[ JCAP 05 (2016) 019 ]



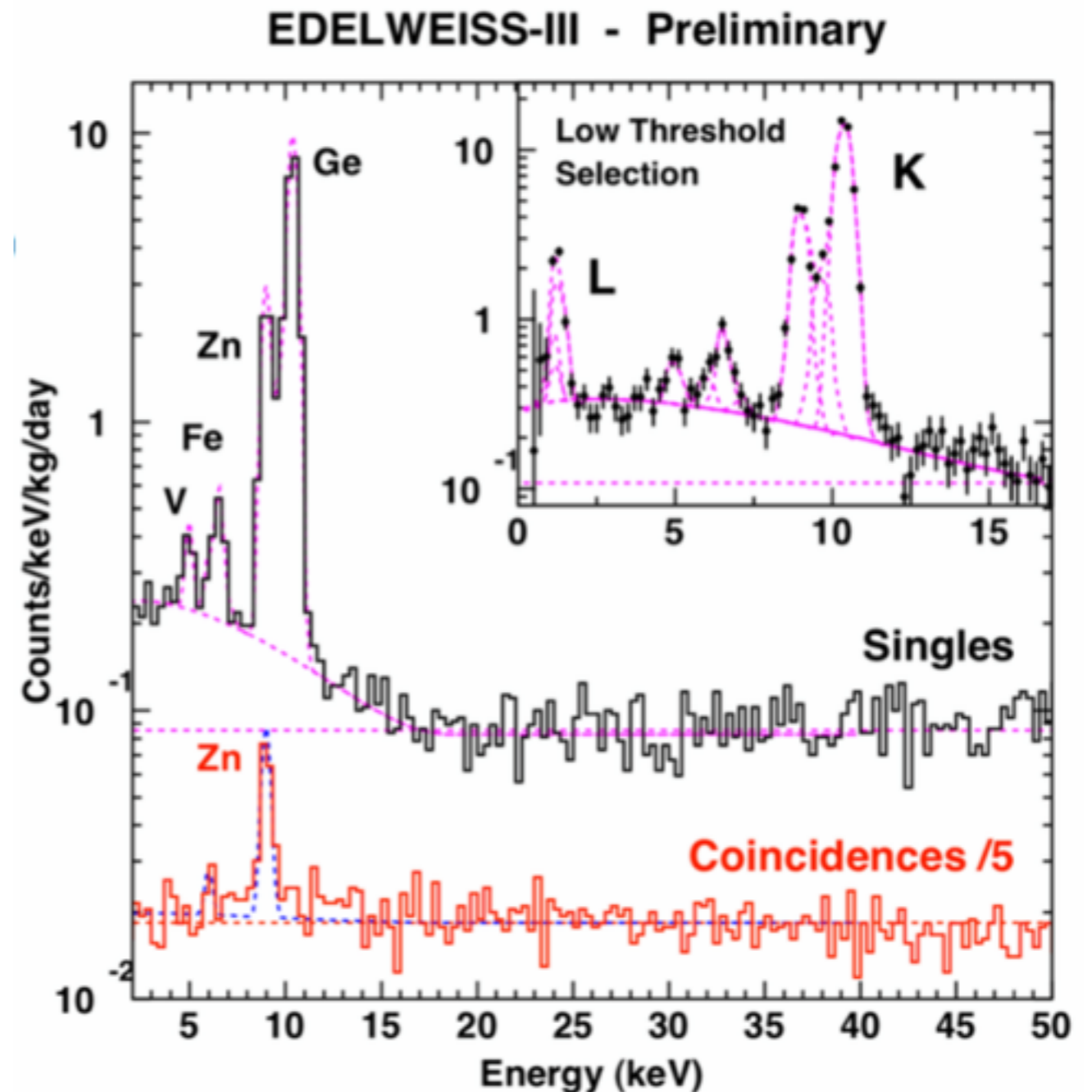
# EDELWEISS-3 : Intrinsic tritium beta background

Same data, but let's take a look at electron recoils ...

Low gamma background  $< 0.1$  dru

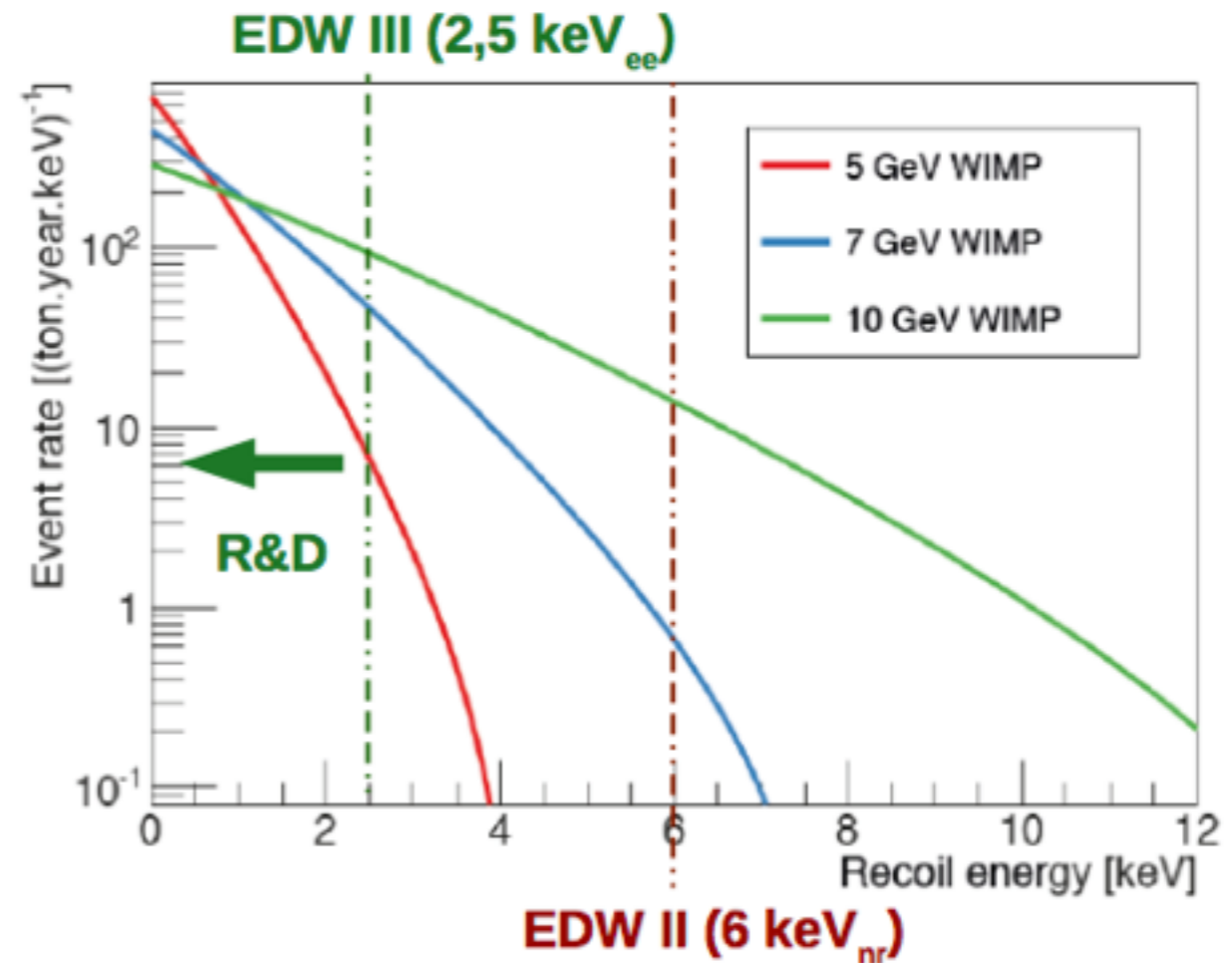
$\Rightarrow$  first Ge experiment to observe the intrinsic tritium beta spectrum convincingly.

- One of the major background components for next generation Ge experiments
- First measurement of cosmogenic tritium production rate : paper to come



# Ongoing R&D for low-mass WIMPs

Goal : sensitivity to  
lower mass WIMPs  
( $\sim 1$  GeV)



- Suppression of heat-only background
- **Optimisation of phonon sensors (improved threshold)**
- Improved ionisation resolutions with HEMT devices
- **« High-voltage » operation**

# R&D : High-voltage

$$\text{Heat signal} = E_{\text{rec}} + (\text{charge}) \times (\text{Voltage})$$

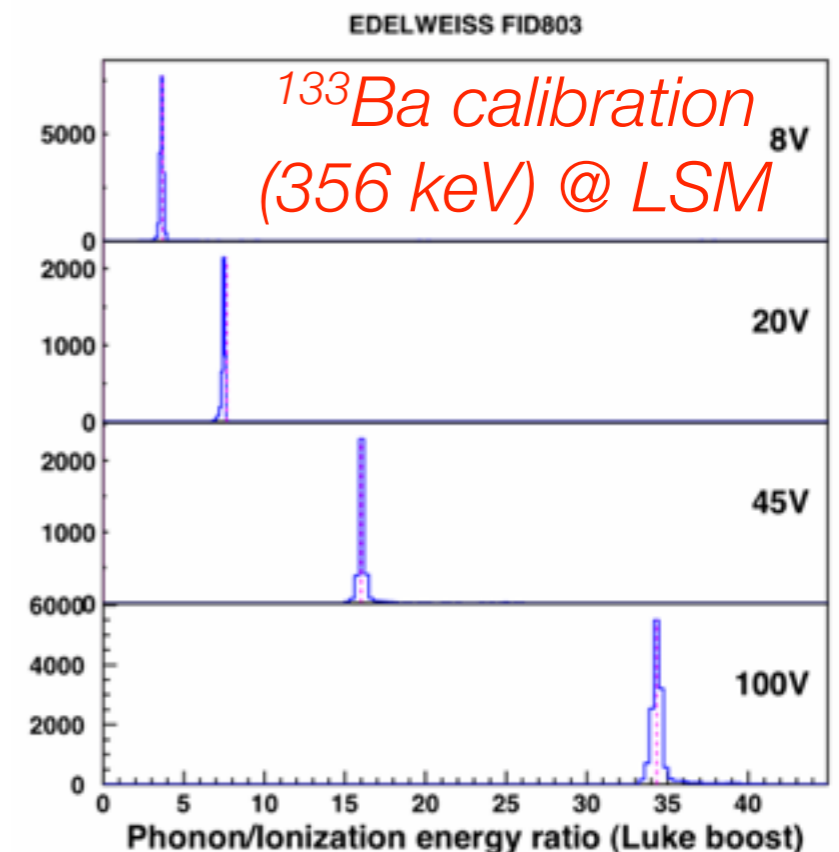
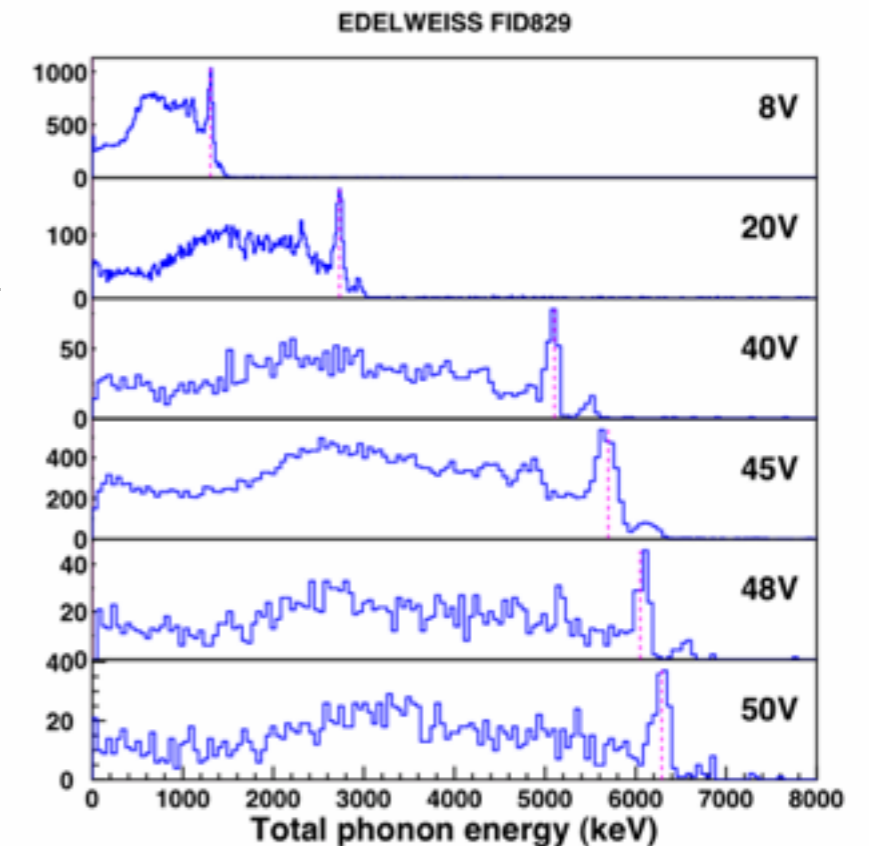
« Boost » the heat signal : lower threshold, at the price of background rejection

Up to 100 V working :

- Neganov-Luke boost  $\sim 35$

- Threshold  $\sim 60 \text{ eV}_{ee}$

First calibrations and physics runs @ LSM ...





# Conclusion and outlook

