The EDELWEISS dark matter search : Low-mass WIMP results and prospects

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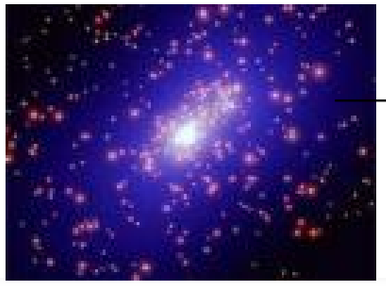
TeVPA - 29/10/2015

The EDELWEISS WIMP search experiment

- **WIMP direct detection**
  - Search for low-energy (keV-scale) nuclear recoils
- Specific **massive Germanium bolometer** technology
  - Phonon readout : <u>spectroscopic capability down to very low energy</u>
  - Ionisation signal : <u>fantastic background rejection</u>
- Low-background facility @ Laboratoire Souterrain de Modane



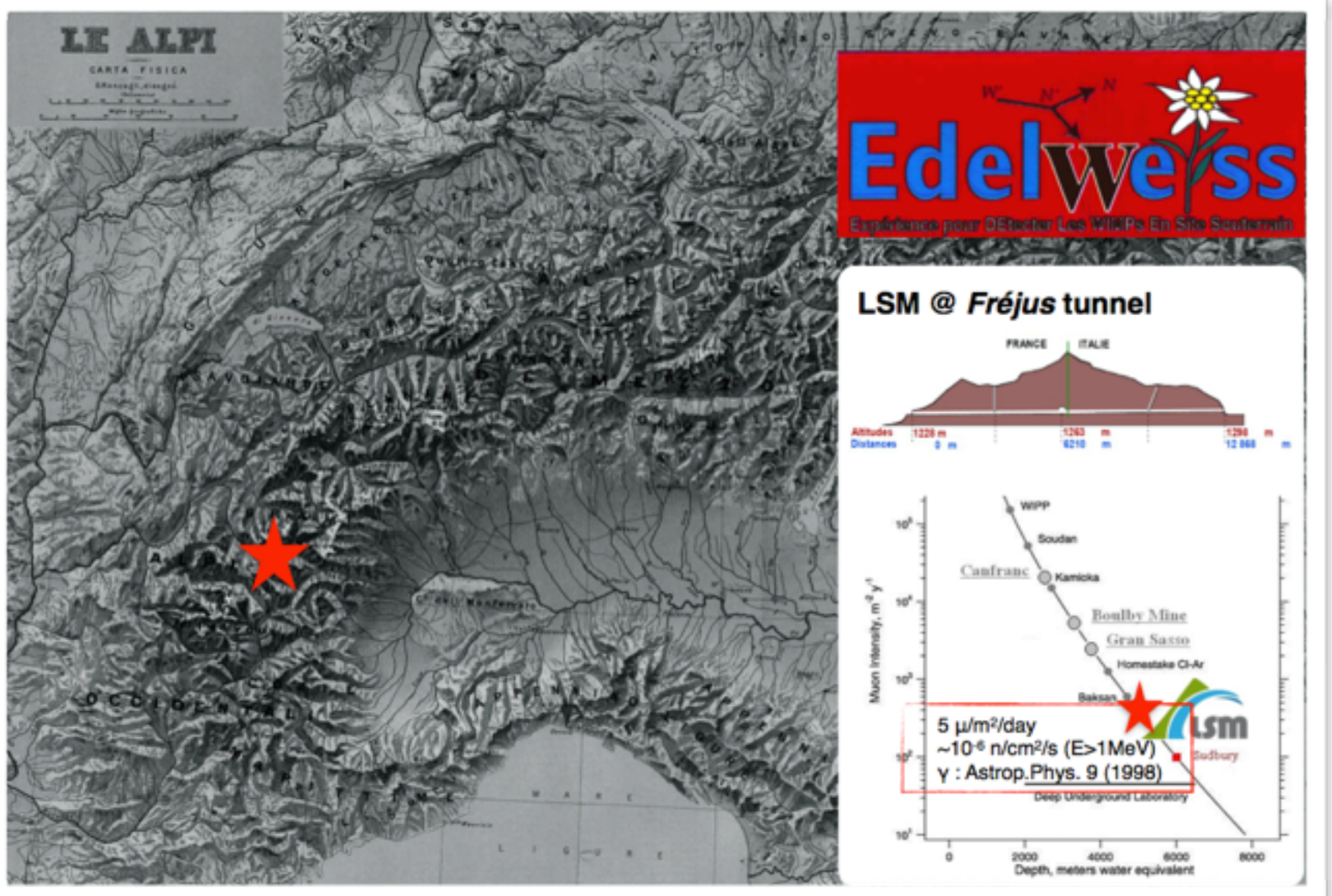
Galactic WIMP

velocity v ~ 200 km/s
local density ρ_0

Interaction in a terrestrial detector

θ_r

Energy deposition
Nuclear recoil E_r



EDELWEISS infrastructure @ LSM

- **Active muon veto**

  $N_{\mu\text{-}n} = 0.6\ ^{+0.7}_{-0.6}$ evts (90%CL, 3000 kgd)

  [Astropart. Phys. 44 (2013) 28]

- **Polyethylene shielding (neutrons)**
- **Lead shielding (β, gammas)**
- **Cryostat** :

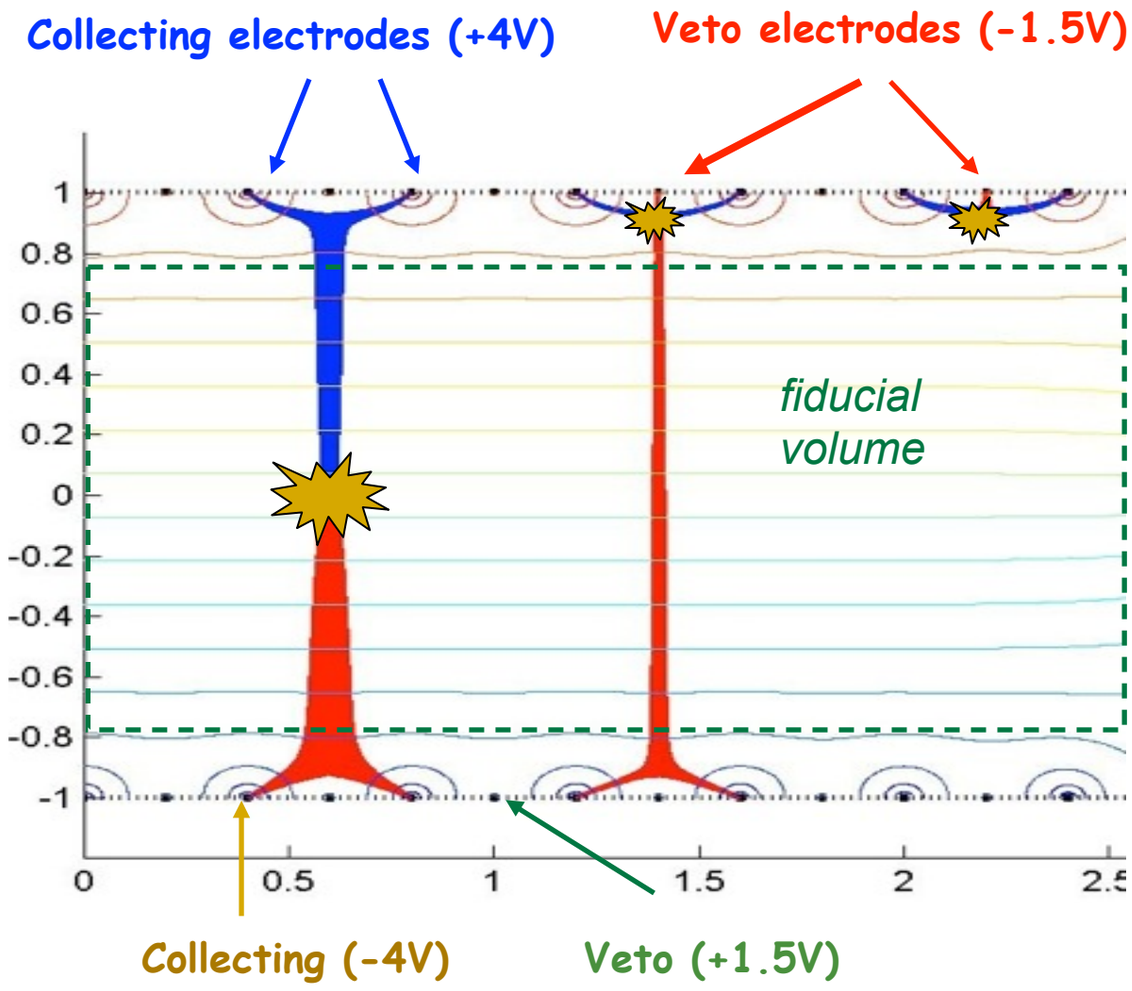
  thermal shield

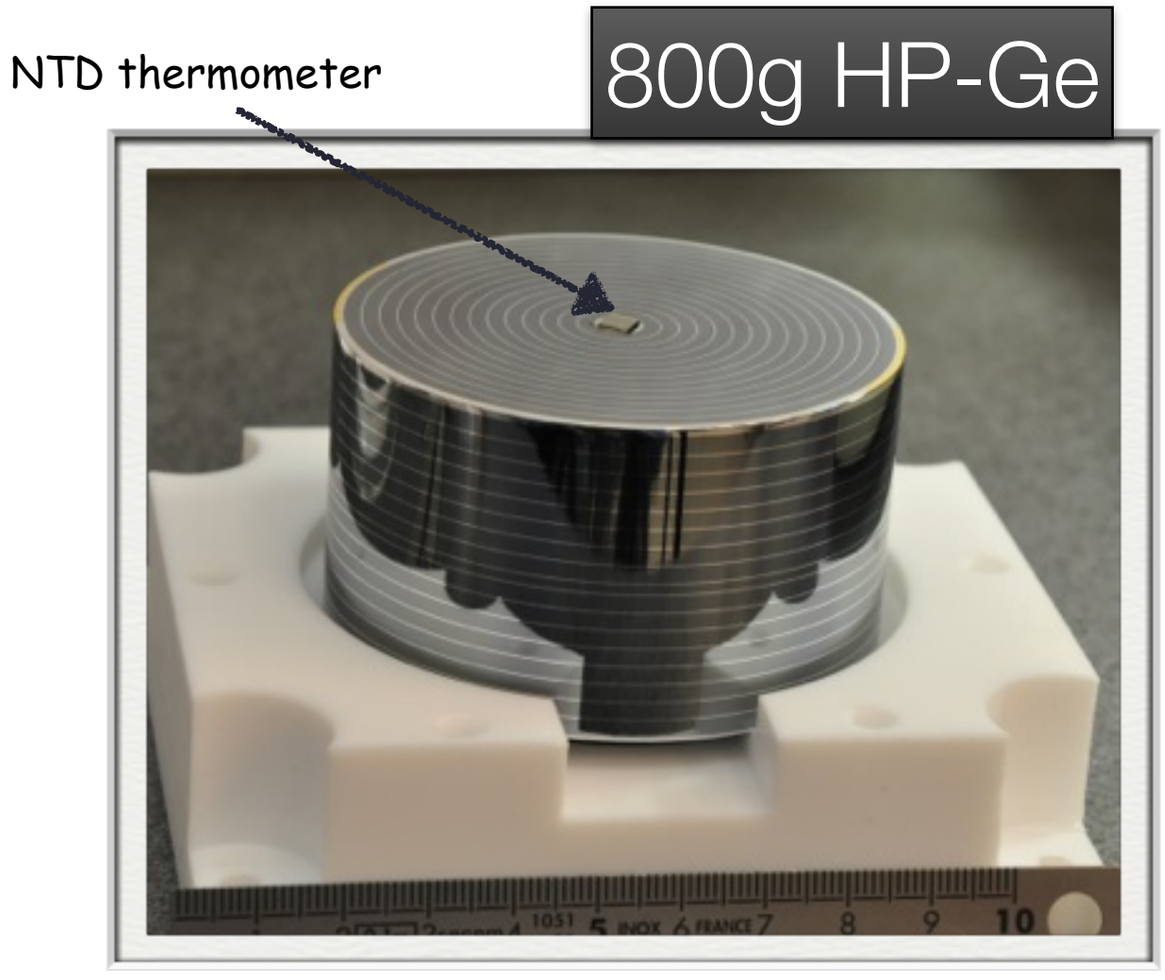
  dilution fridge, detector temperature T ~ 18 mK (40 kg mass)

  extra polyethylene and roman lead inside cryostat

  dedicated low-noise cold electronics and wirings

EDELWEISS-III « FID » detectors





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 ~ 1 for electron recoils (β, gamma, and axions)
- Yield ~ 0.3 for nuclear recoils (neutrons, and WIMPs)

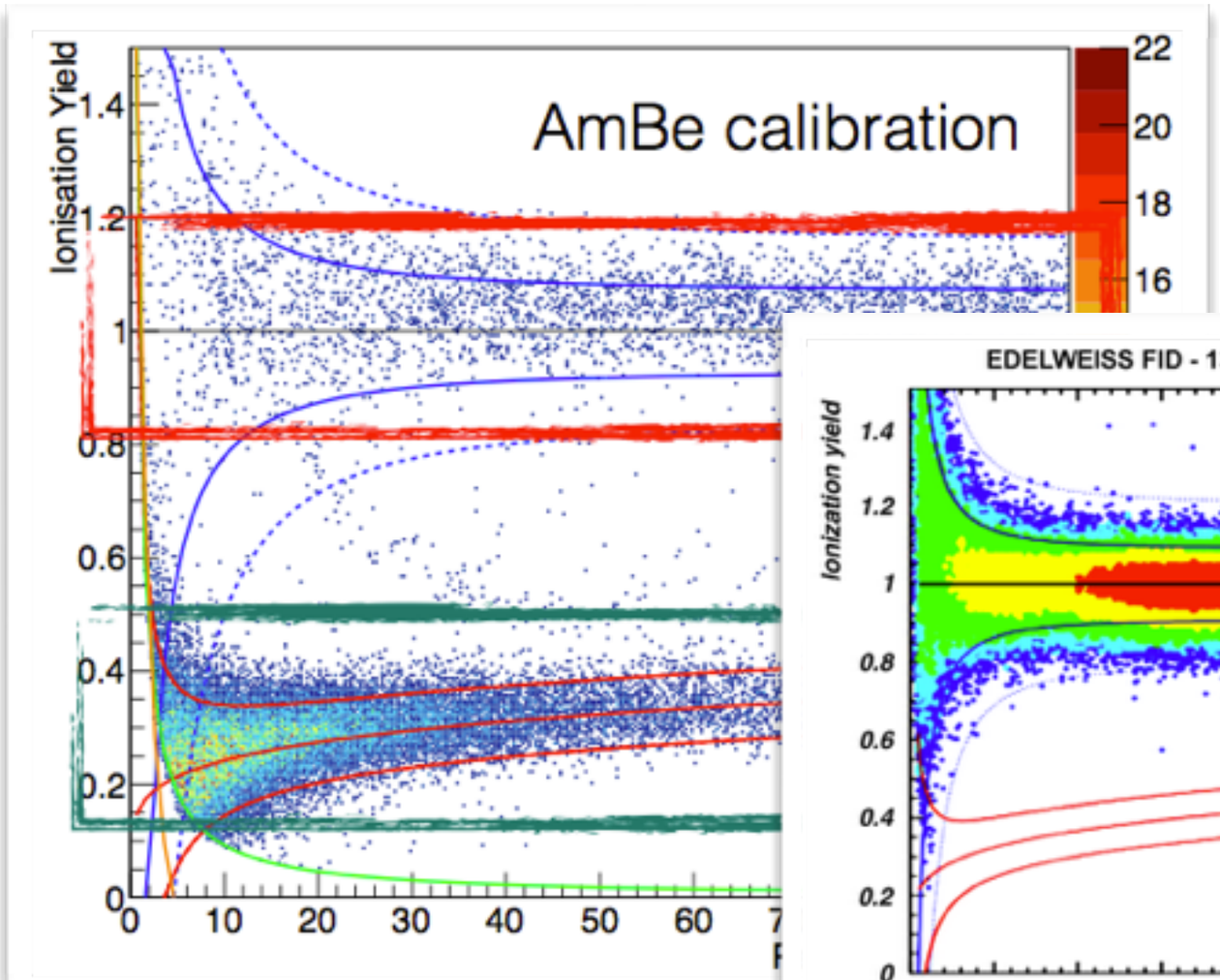
Detector performance

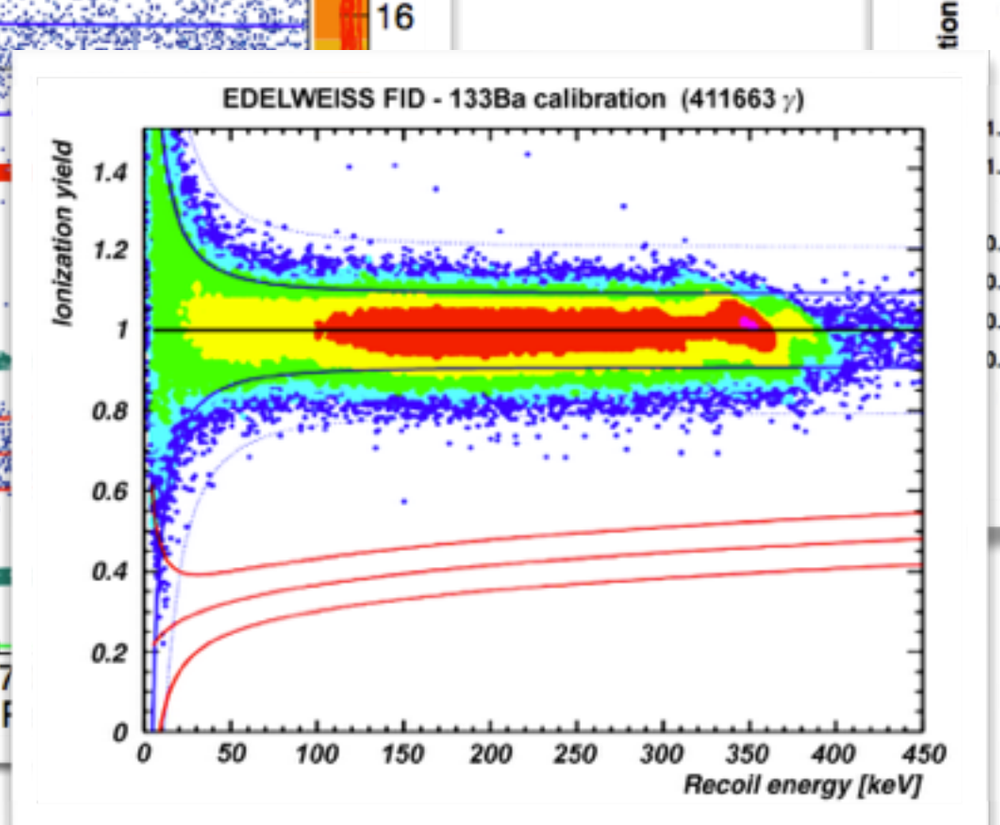
- Demonstrated fiducial gamma rejection from ^{133}Ba calibration : rejection factor < 6×10^{-6}

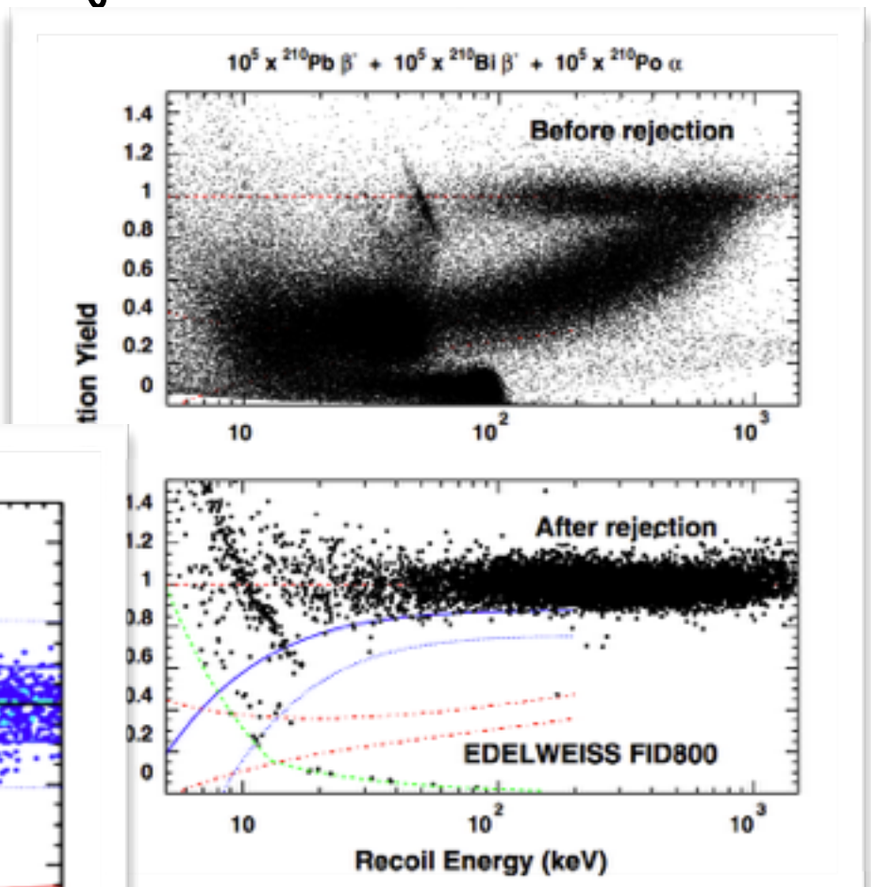
[J Low Temp Phys (2012) 167:1056-1062]

- Demonstrated surface event rejection from a ^{210}Pb source : rejection factor < 4×10^{-5}

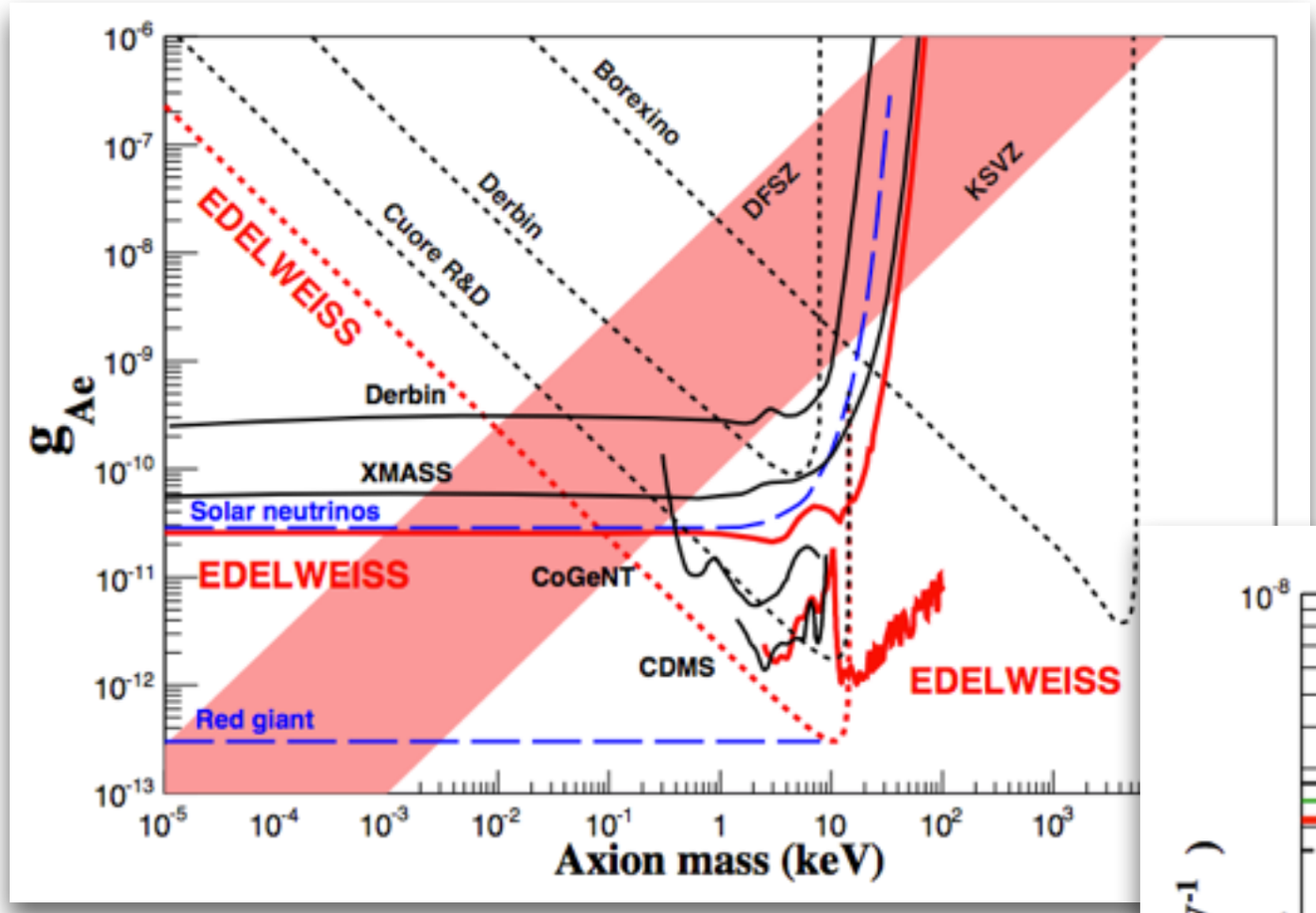
[J Low Temp Phys (2014) 176:870-875]



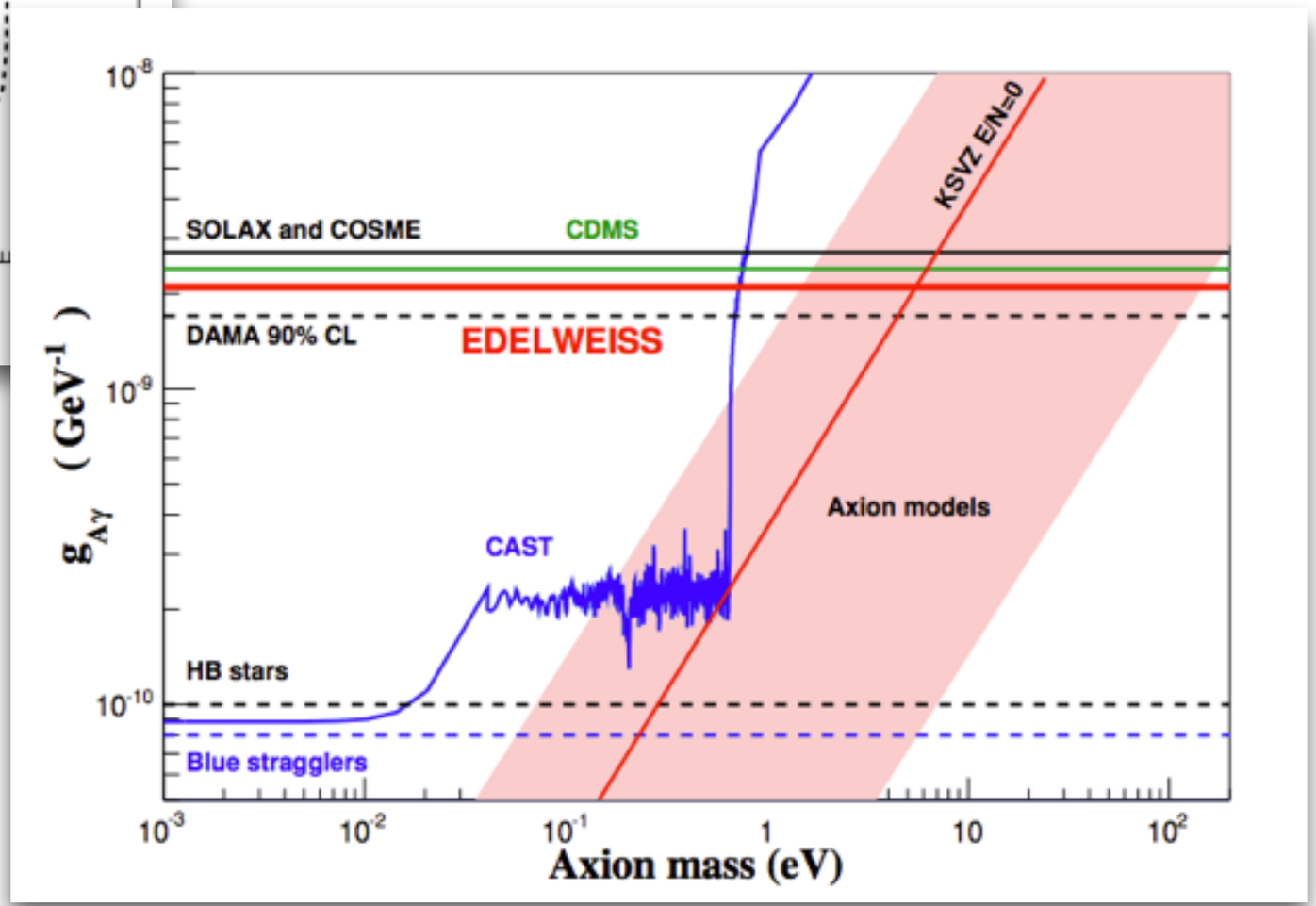




Axion results from EDELWEISS-II



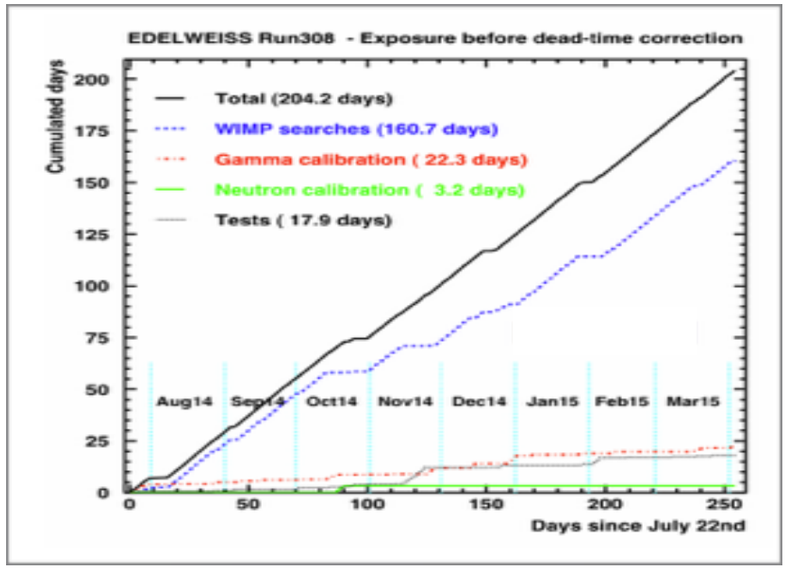
Search for **electron recoils from solar or dark matter axions** using EDELWEISS-II « ID » detectors (up to 448 kg-days fiducial)

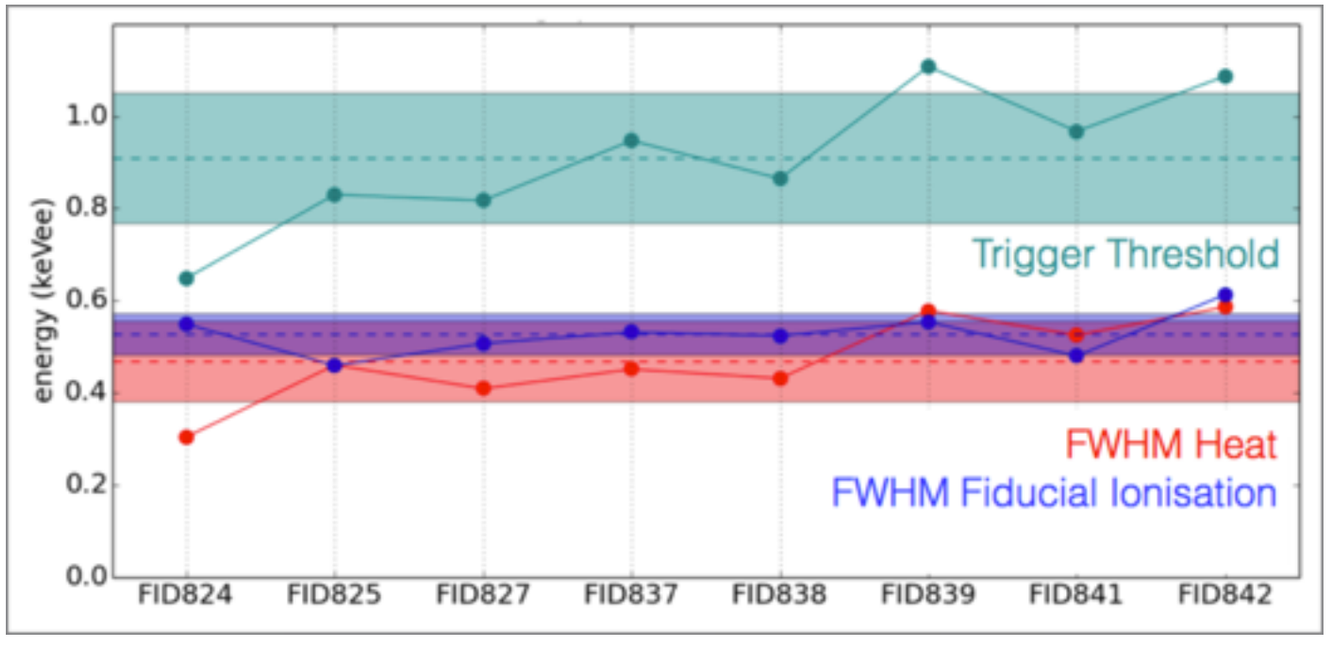


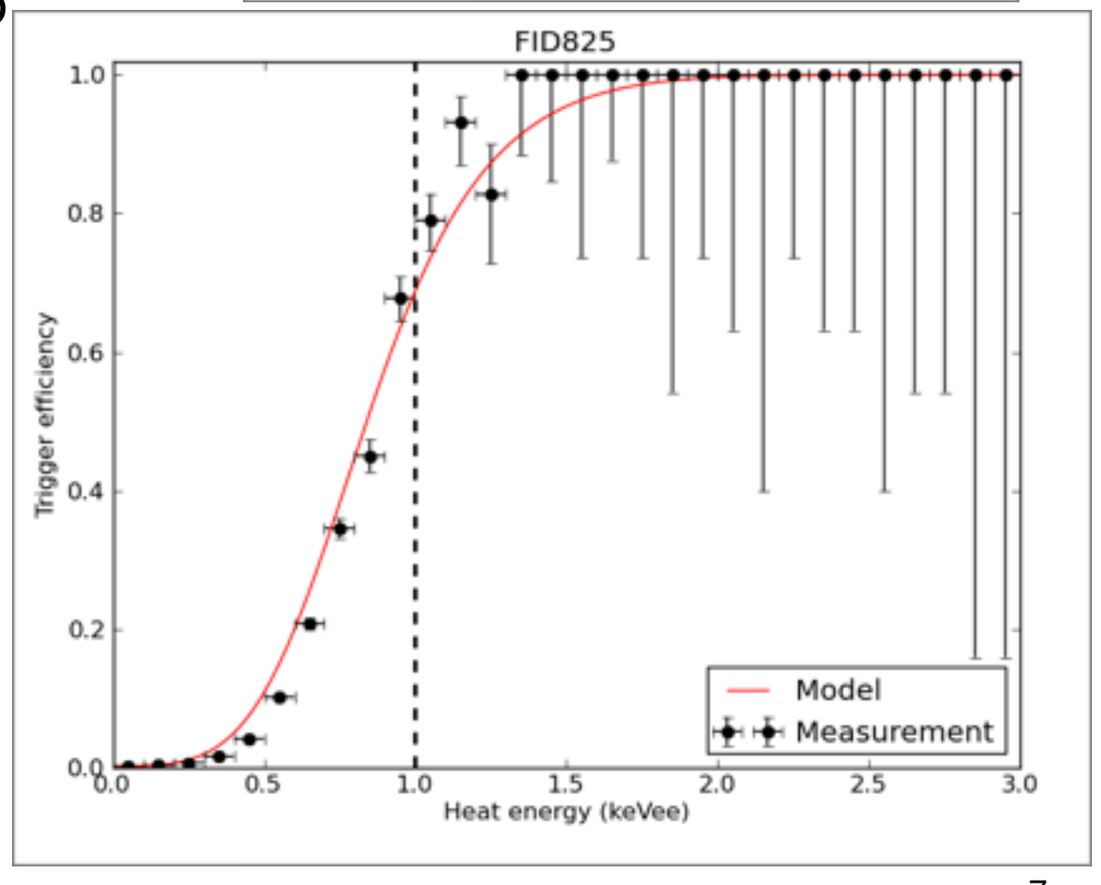
[JCAP 11 (2013) 067]

A search for low-mass WIMPs with EDELWEISS-III

- **Low mass WIMPs : M ~ 4 - 20 GeV**
  eg. asymmetric dark matter
  Low-energy (~ keV) nuclear recoils
- Dedicated « near-threshold » analysis
  8 detectors used among 24
  582 kg-days (fiducial)
- Analysis threshold 4 FID @ 1keVee, 4 FID @ 1.5 keVee (1keVee = 2.4 keVnr)







Low-mass WIMP search : backgrounds

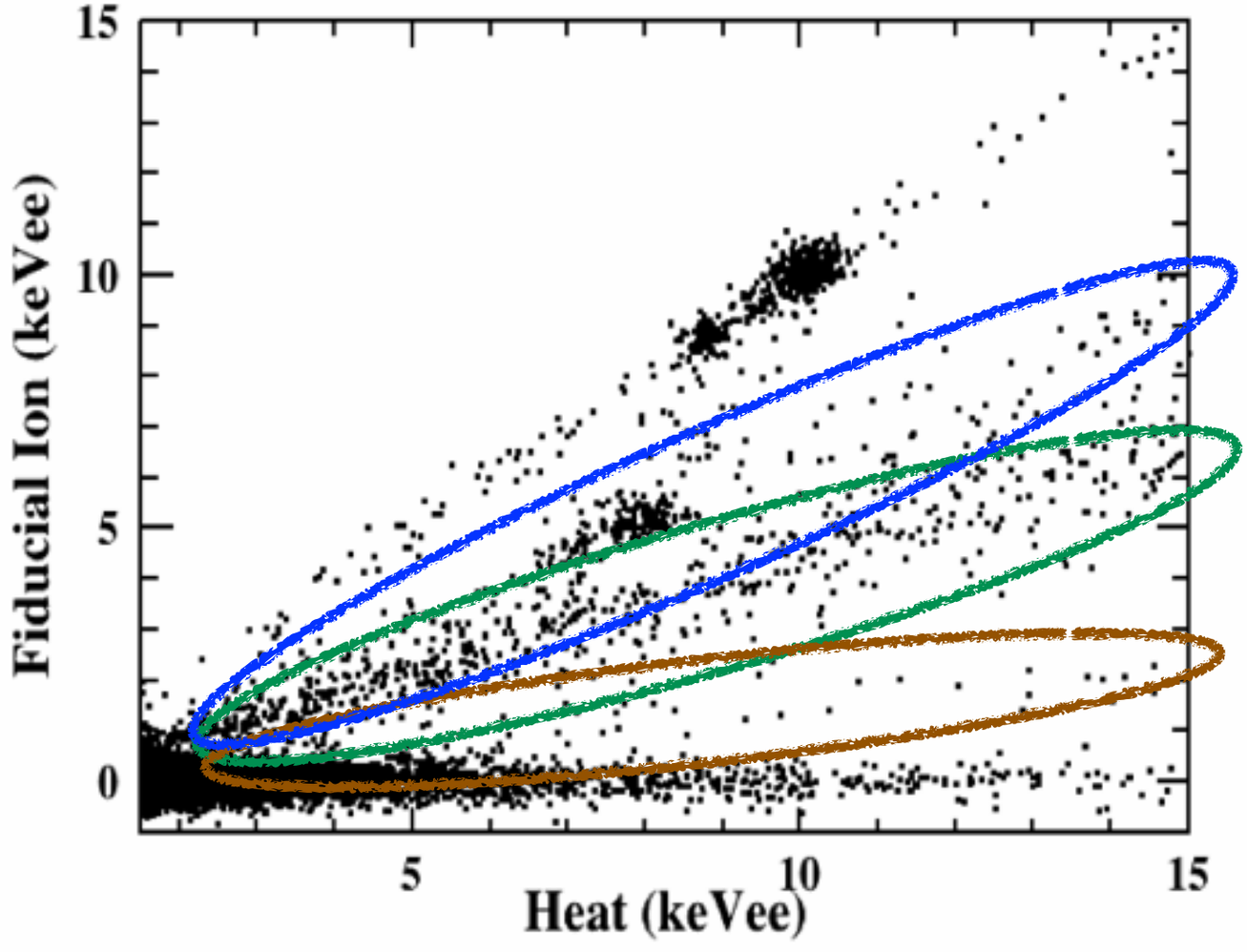
Surface events
- beta radioactivity and lead recoils
- gammas outside fiducial volume

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

Neutrons
- mostly radiogenic origin

« Heat-only » events
- dominant background @ low energy
- under investigation, probably mechanical origin

for illustration (FID837 subset)



For all backgrounds : data-driven model from sideband data

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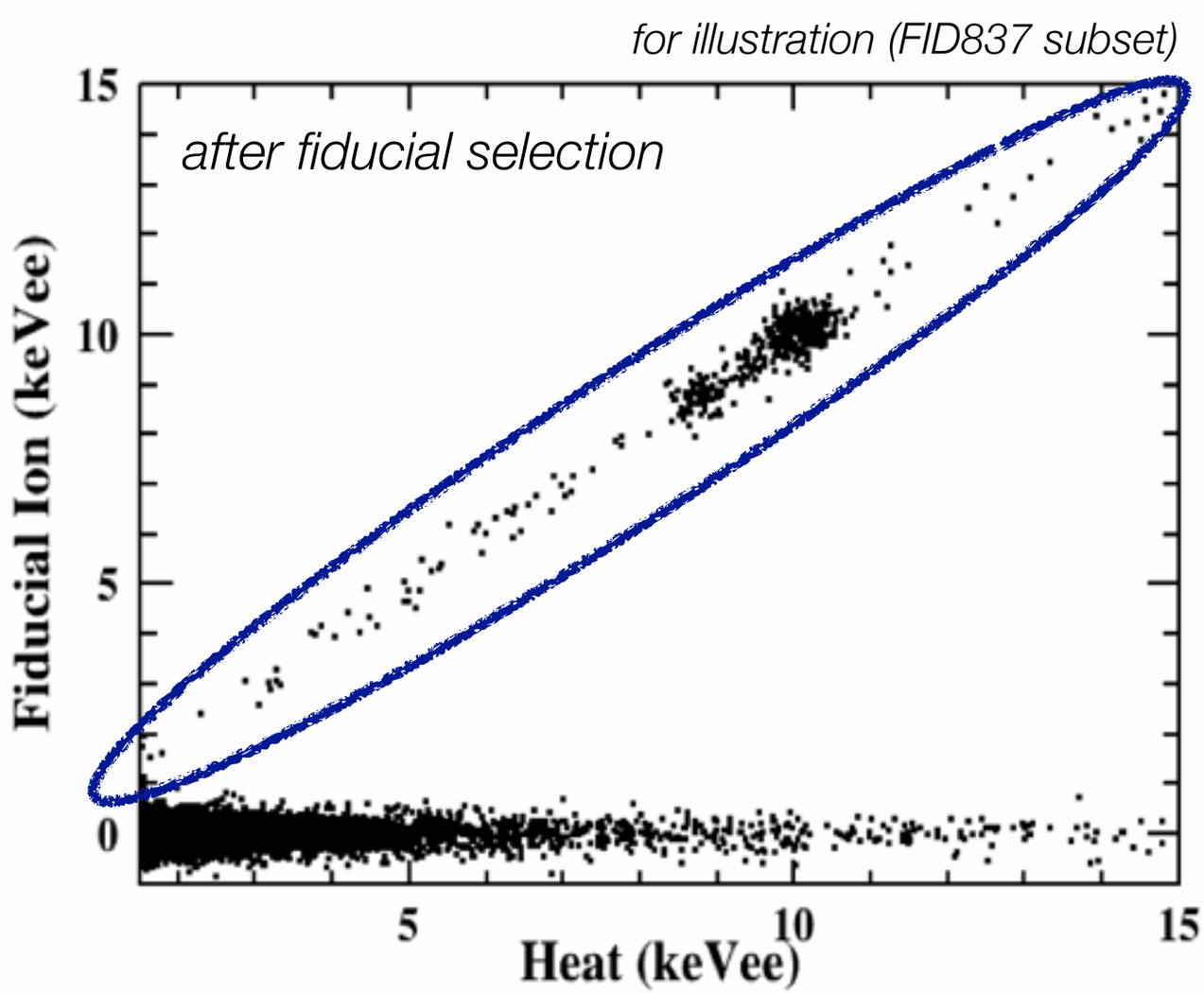

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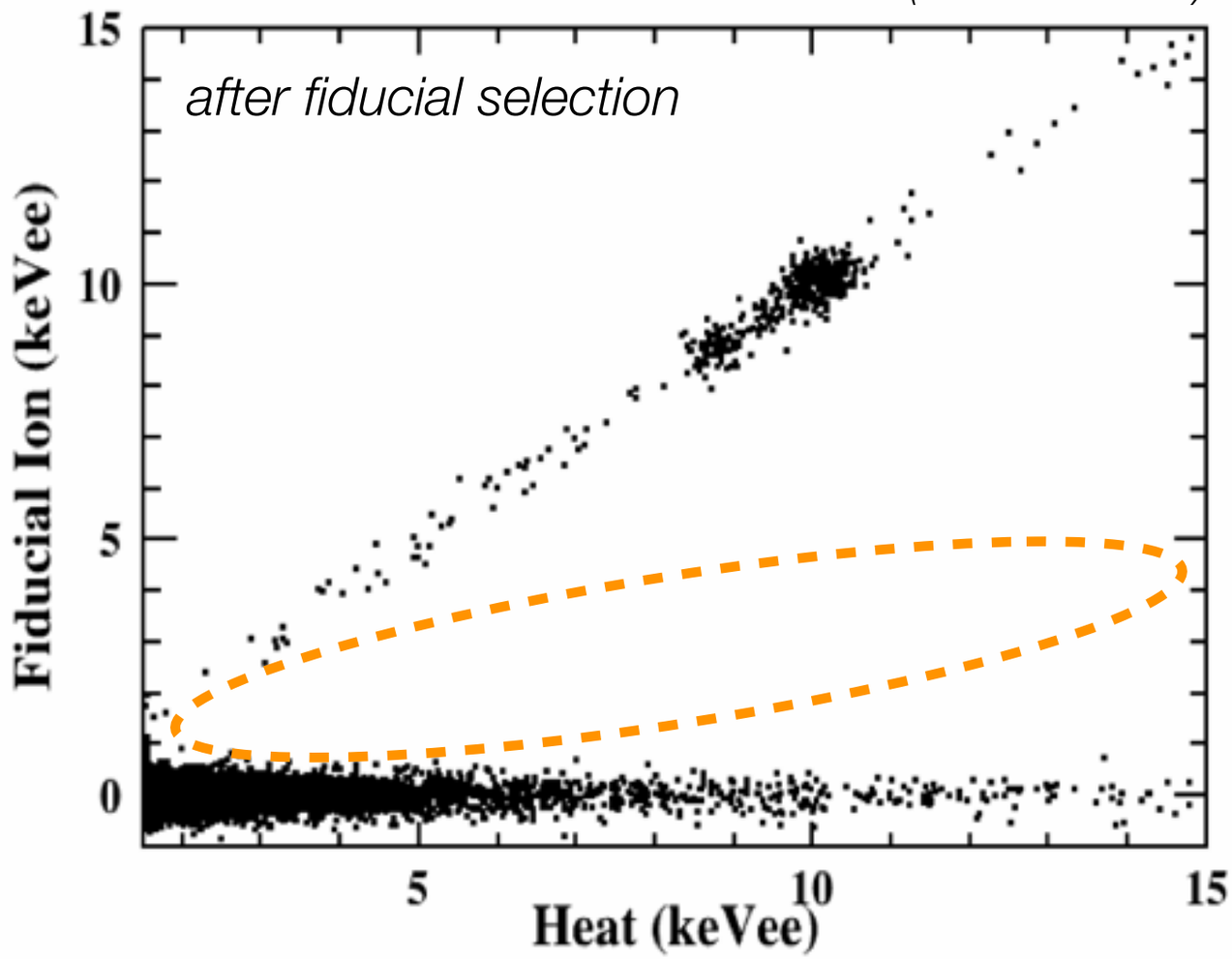

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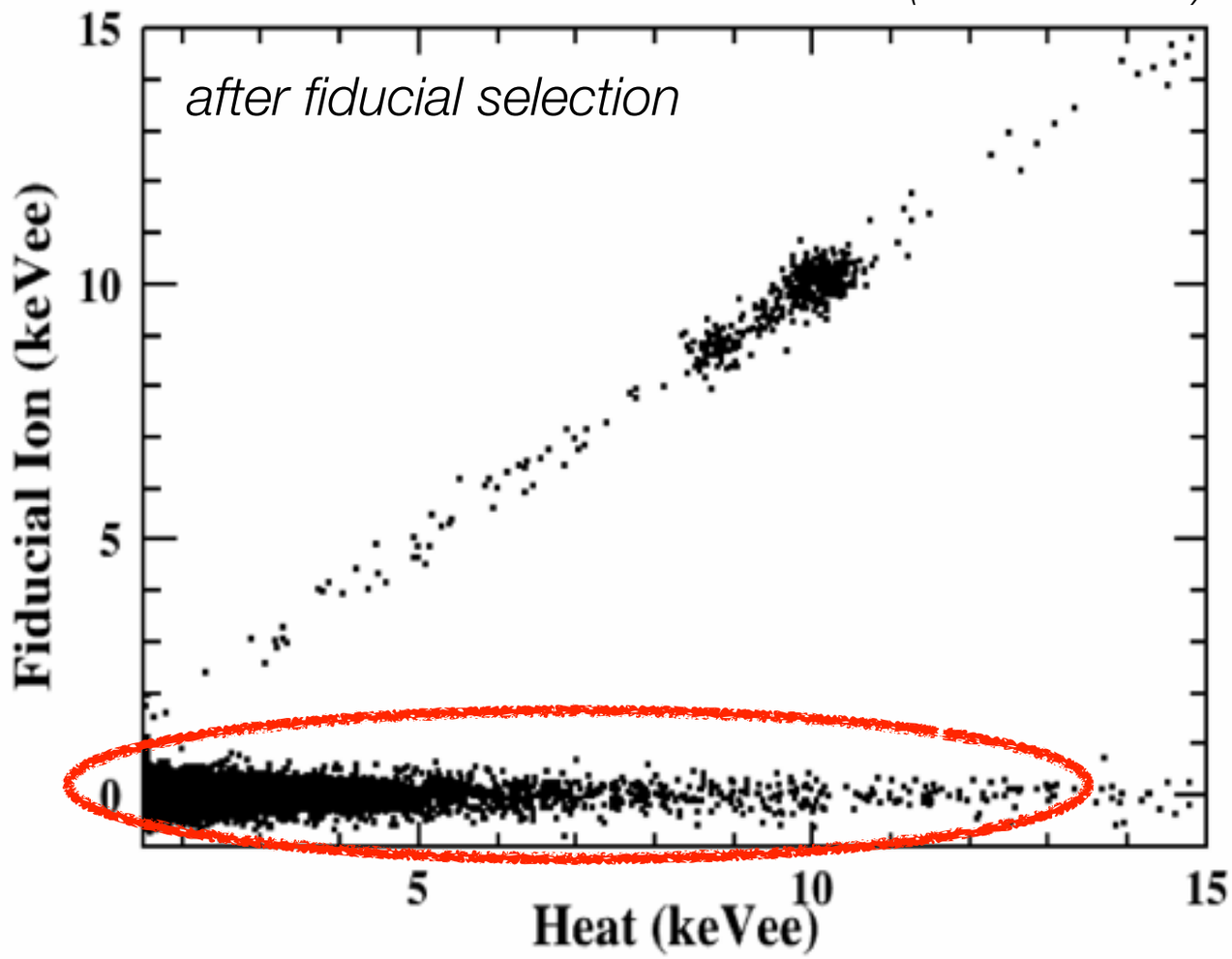

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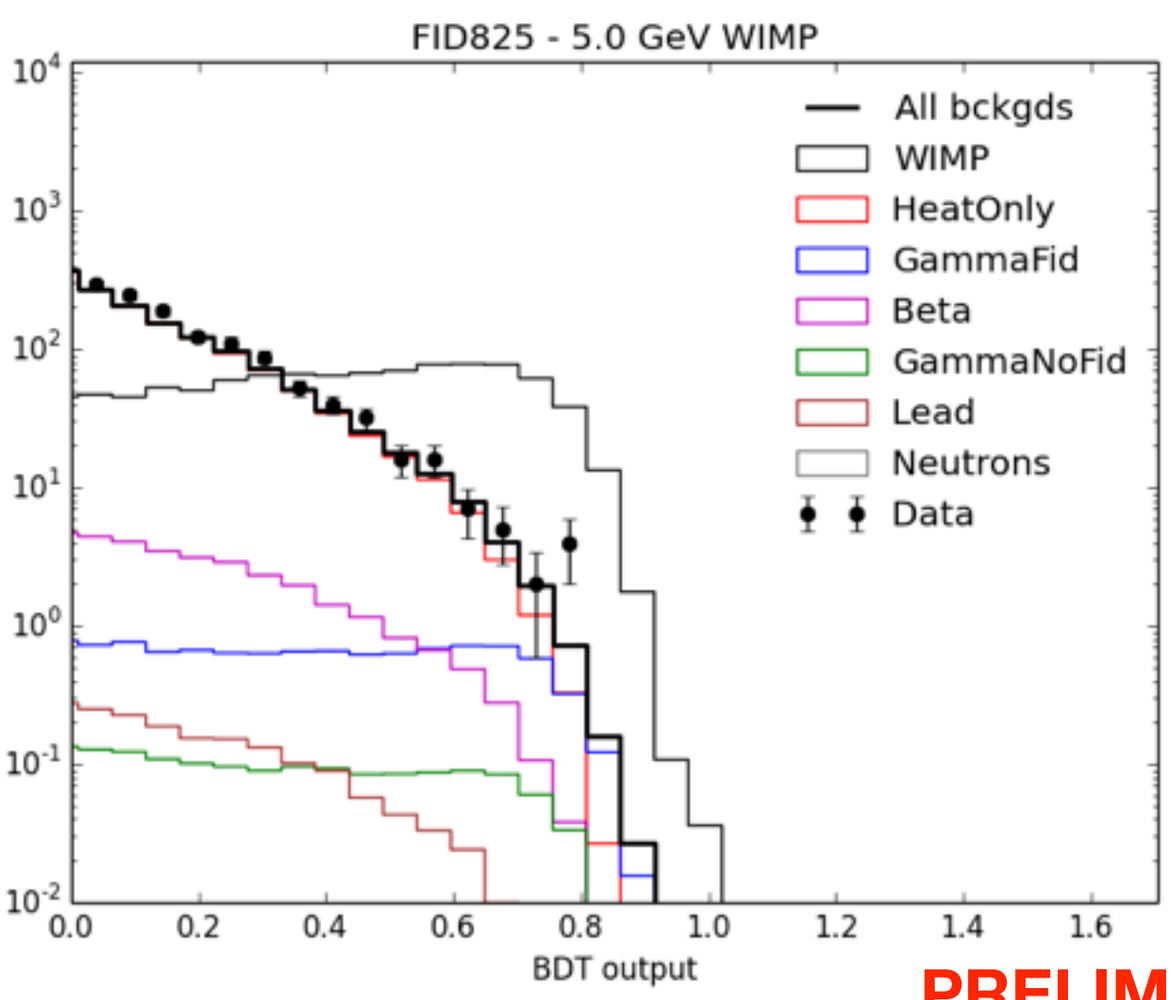
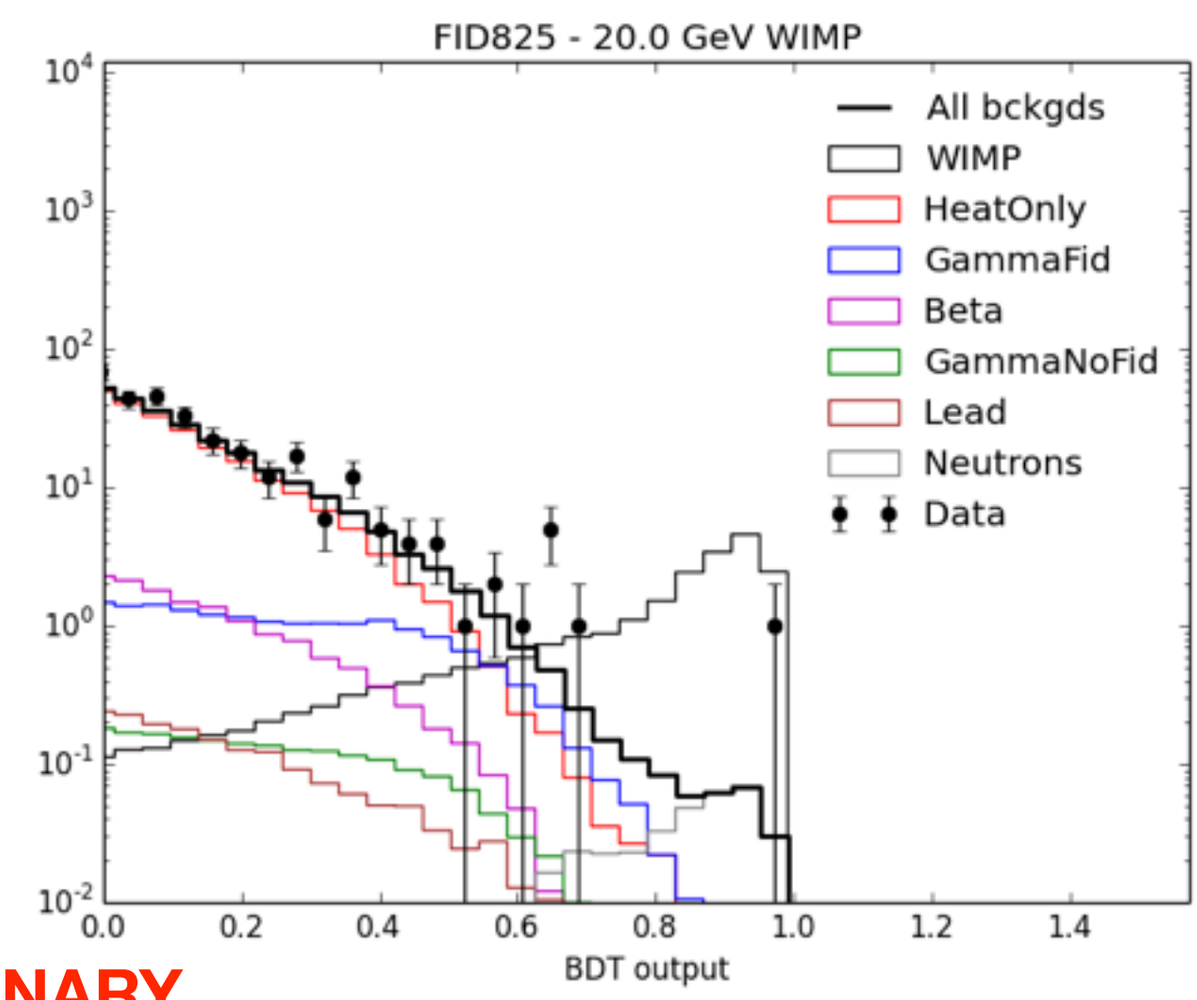
Low-mass WIMP search : BDT distributions

- **Blind « WIMP box » :** veto < 5 σ , 0 < Eion < 8 keV_{ee} , 1(1.5) < Eheat < 15 keV_{ee}
- **Combine all channels from a detector** (4 ionisations + 2 heats) **to a single BDT output optimizing signal/background**
- Train BDT using background models + expected WIMP signal + individual detector effects
- One BDT / detector and WIMP mass





PRELIMINARY

Low-mass WIMP search : results

- Poisson limit after (blind) BDT cut

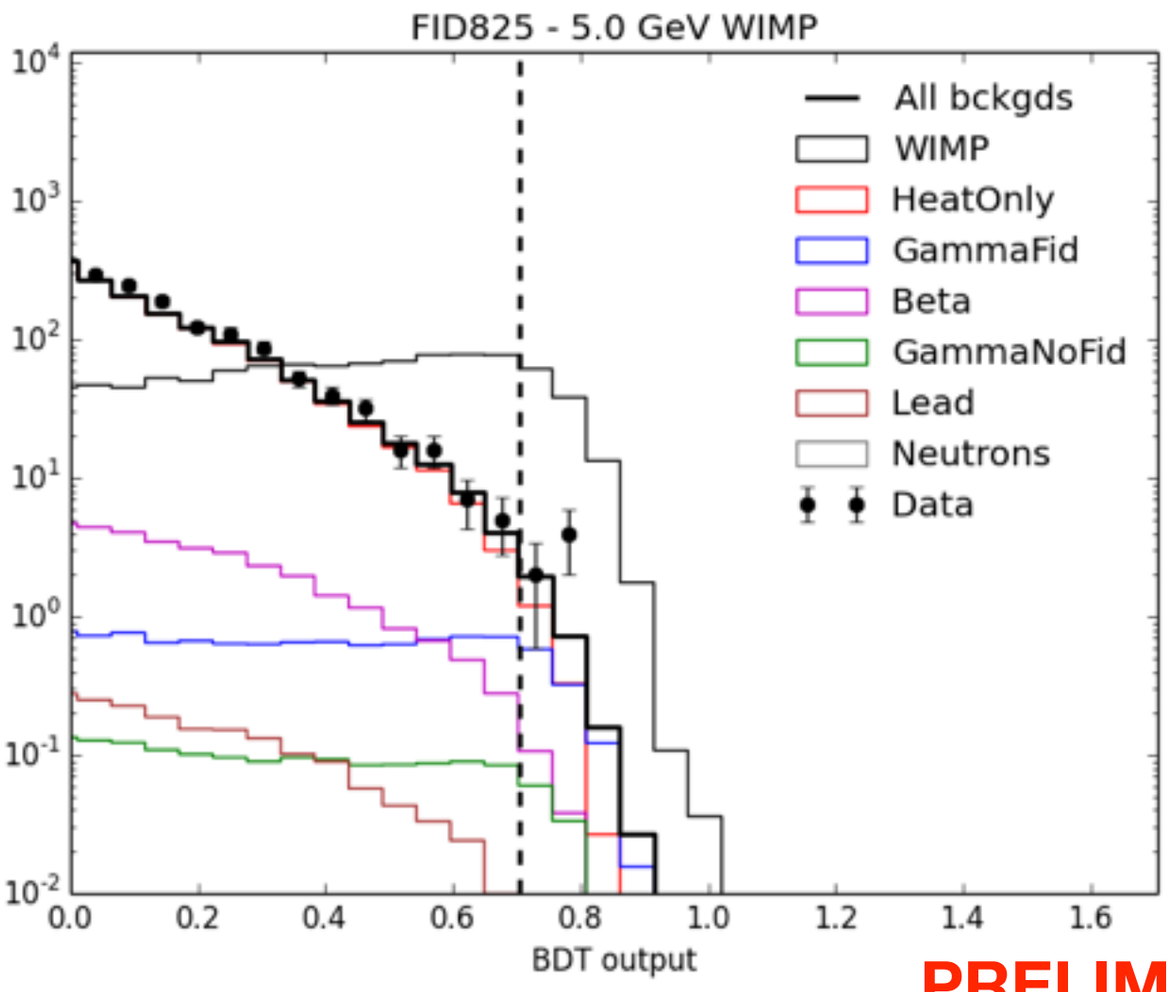
  No background subtraction

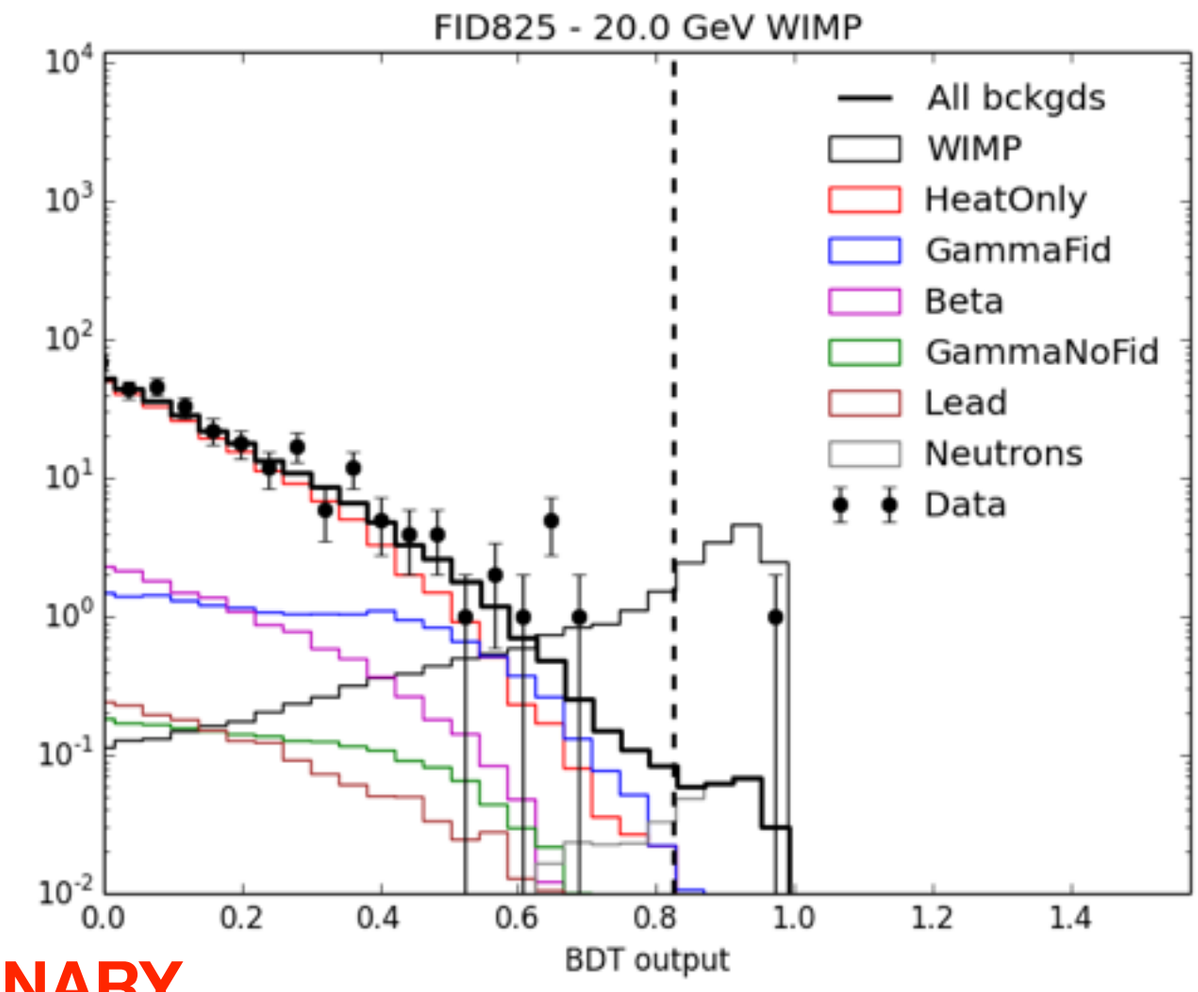
- Dominant backgrounds:

low mass (5 GeV) : heat-only events and cosmogenic gamma line

high mass (20 GeV) : radiogenic neutrons (systematics ~ 50%)

	N_bkg expected	N_bkg observed
5GeV	6.14	9
20GeV	1.35	4

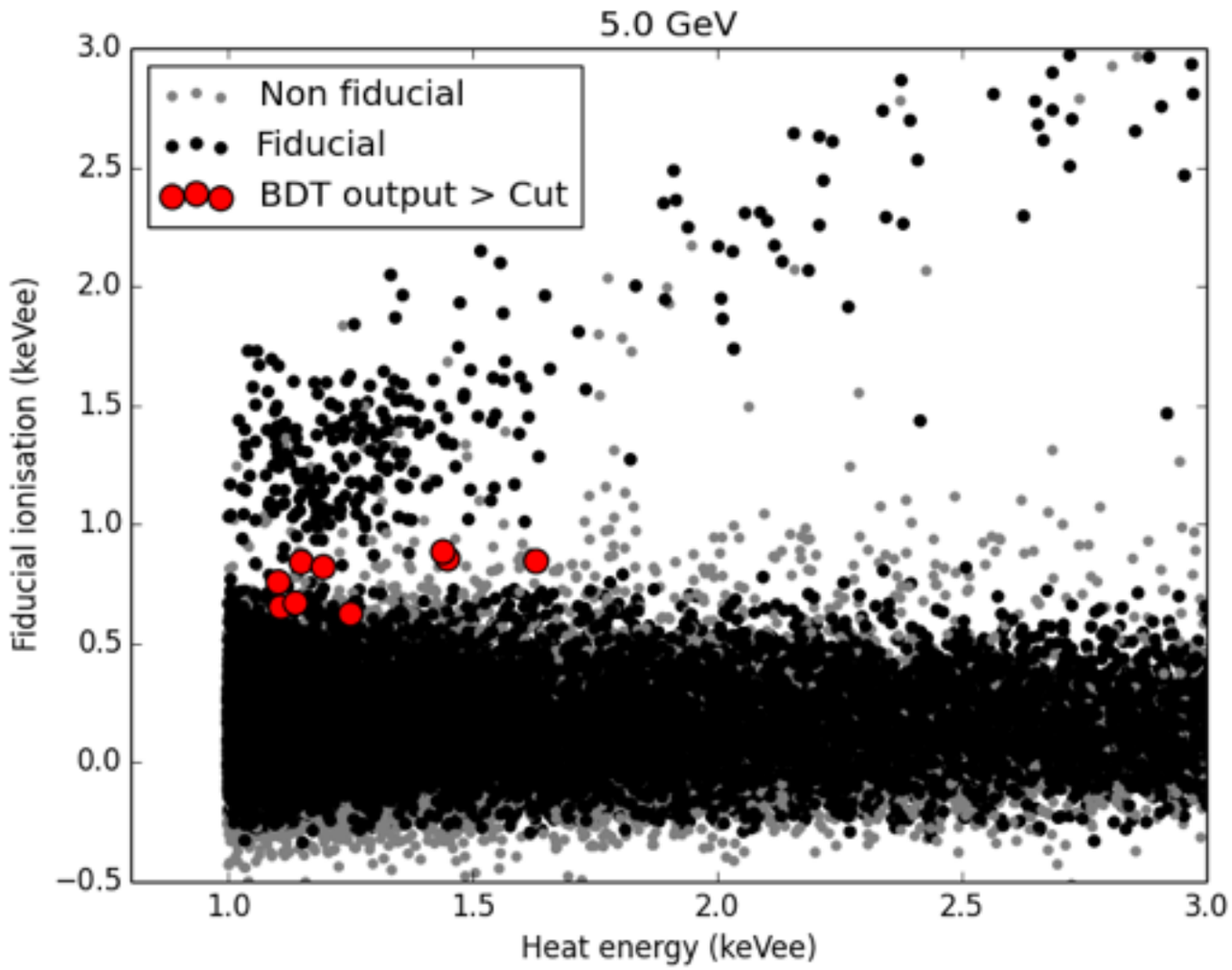


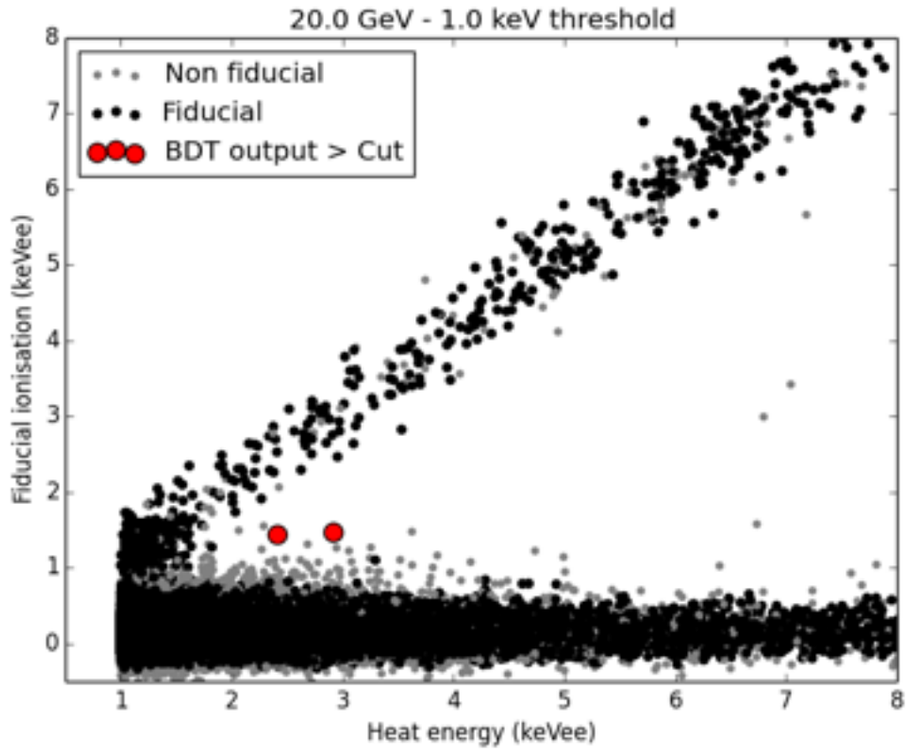


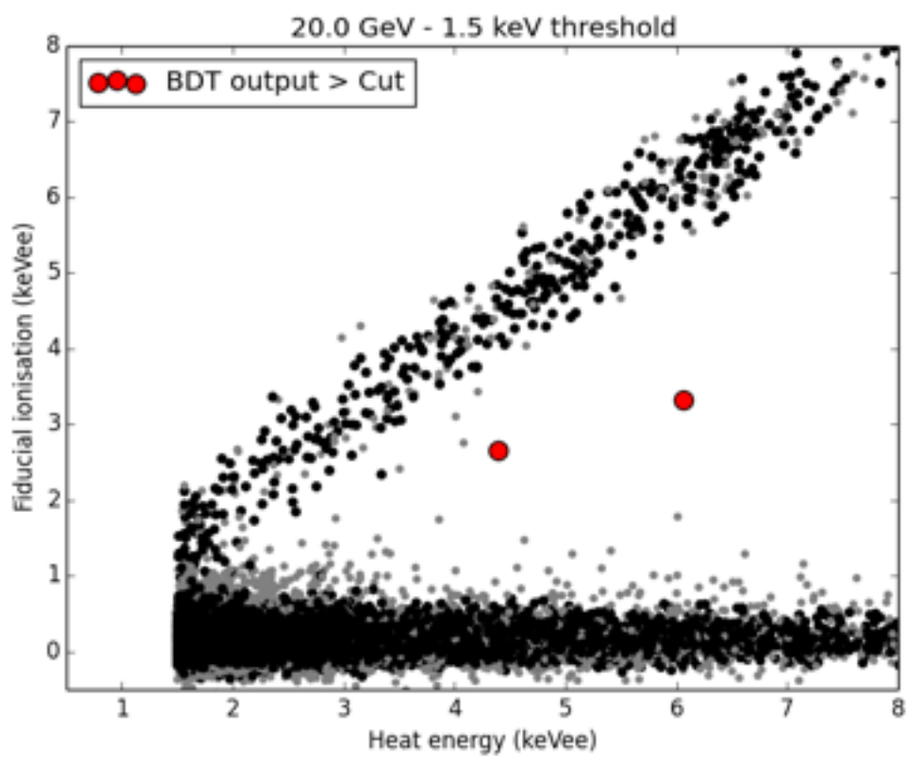
PRELIMINARY

Candidate events

M_{wimp} = 5 GeV : 4 detectors @ 1keVee heat threshold
—> 9 events
M_{wimp} = 20 GeV : 4 detectors @ 1 keVee, 4 @ 1.5 keVee
—> 4 events



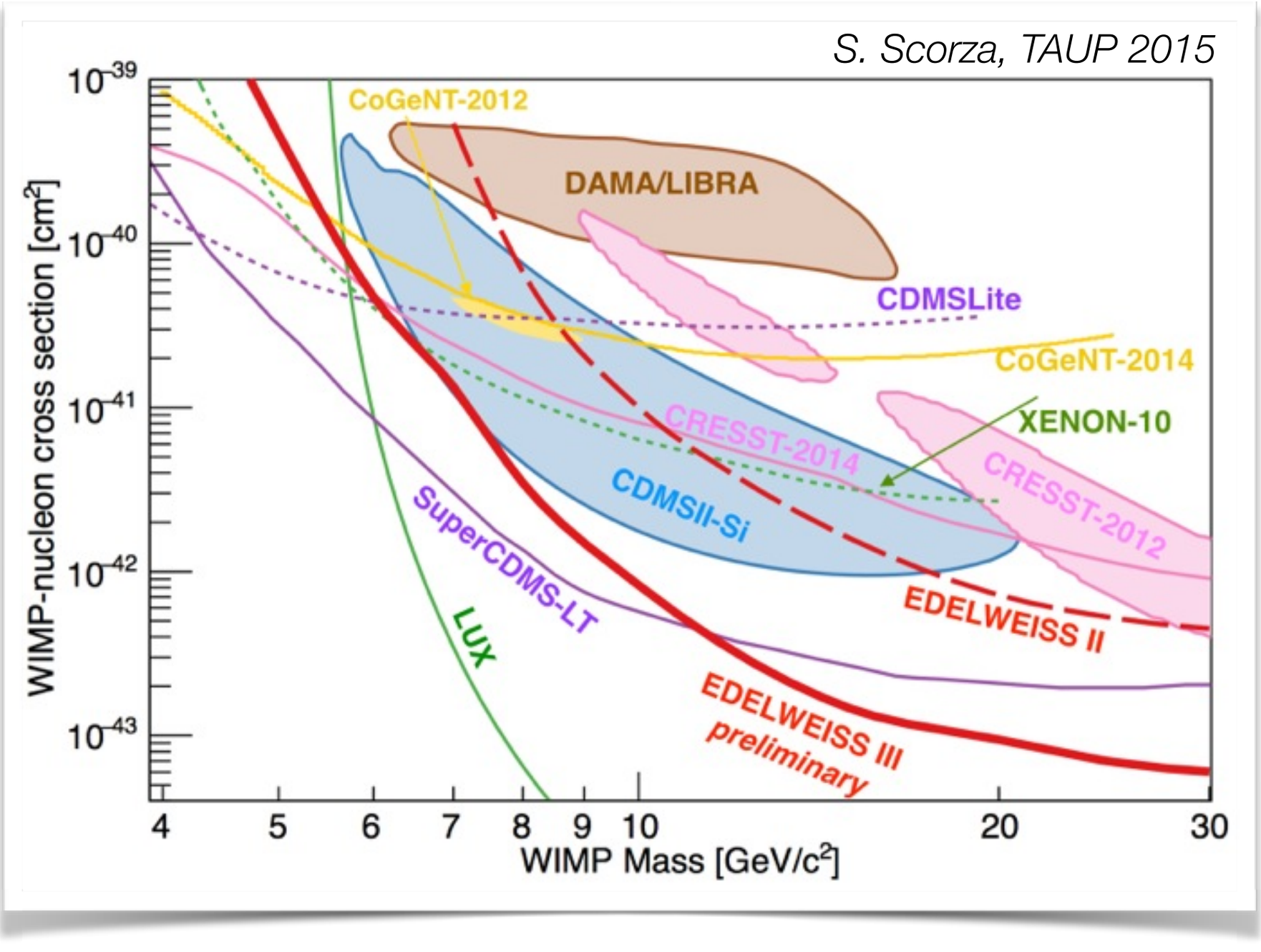




PRELIMINARY

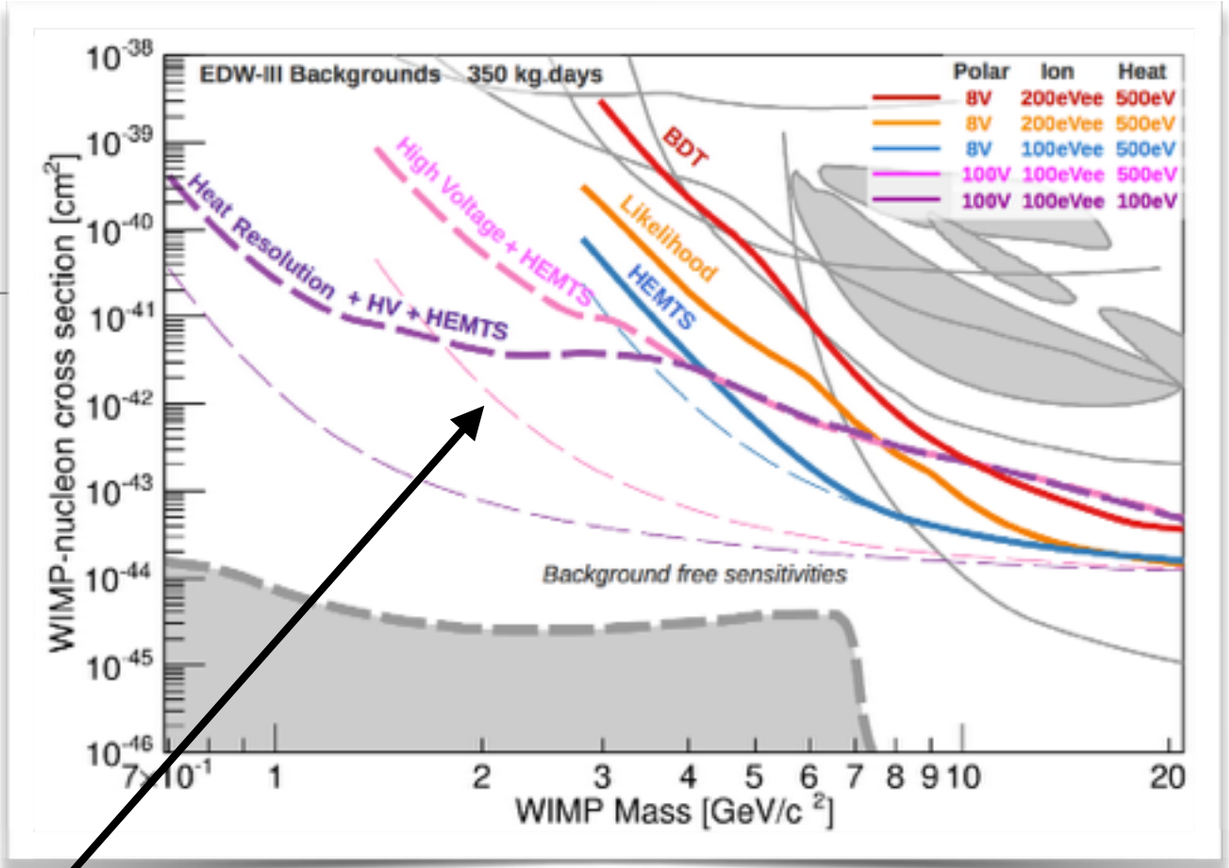
Low-mass WIMP search : results

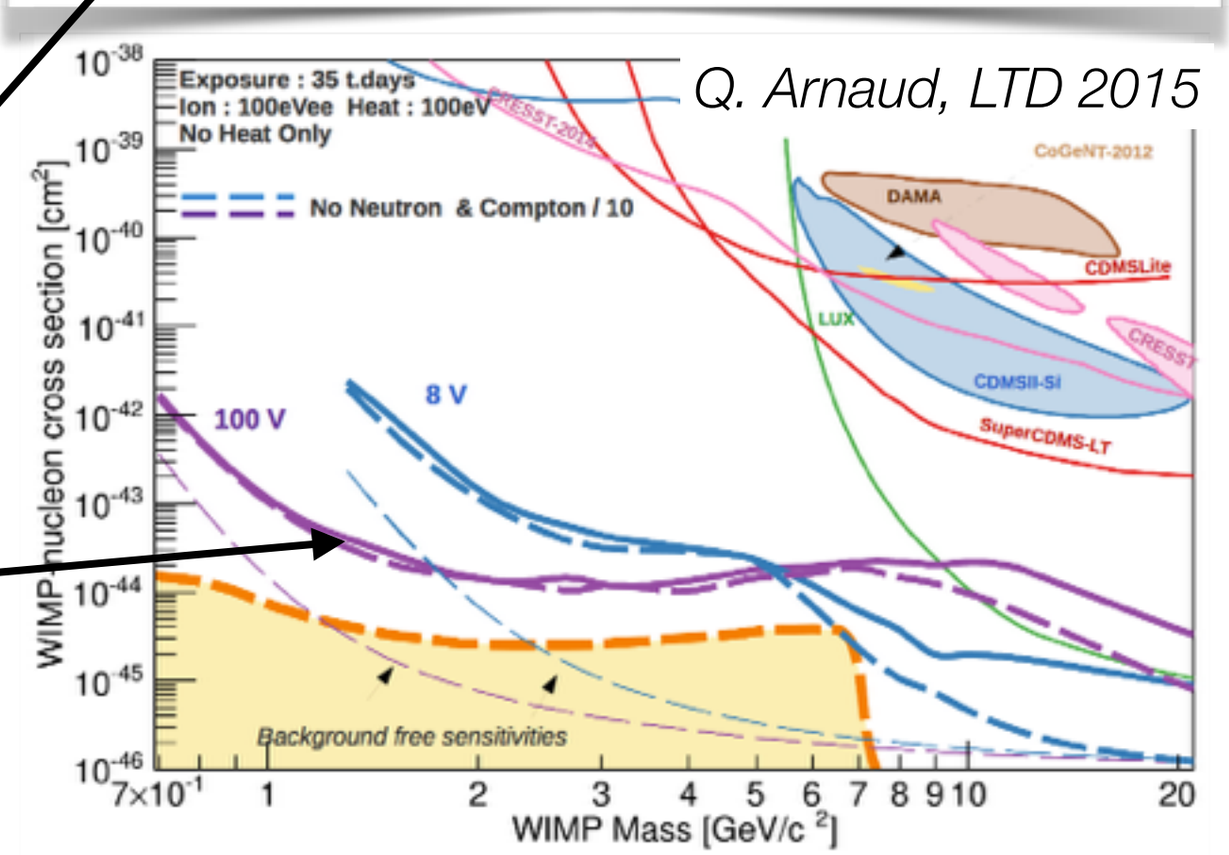
S. Scorza, TAUP 2015



Towards GeV-scale WIMPs and solar neutrinos

- **R&D developments :**
  - Reduce heat-only events
  - **Luke-Neganov heat signal amplification with « high » voltages (~100 V)**
  - Improve resolutions : heat (thermal modeling) and ionisation (HEMT amplifiers)
- **Short term :**
  - Explore WIMPs with M ~ GeV within current infrastructure
- **Long term** (new infrastructure, wider collaboration) :
  - Improve low-mass WIMP sensitivity down to ~10^{-43} cm2
  - Detect ^{8}B solar neutrinos through coherent scattering





Thanks !

CEA Saclay (IRFU & IRAMIS)
CSNSM Orsay (CNRS/IN2P3 & Paris Sud)
IPNL Lyon (CNRS/IN2P3 & Univ. Lyon 1)
Néel Grenoble (CNRS/INP)
LPN Marcoussis (CNRS)

KIT Karlsruhe (IKP, EKP, IPE)

JINR Dubna

Oxford University
University of Sheffield