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

Emeline Queguiner for the EDELWEISS collaboration

GDR Terascale, May 25 2016

cnrs dépasser les frontières IN2P3 Les deux infinis

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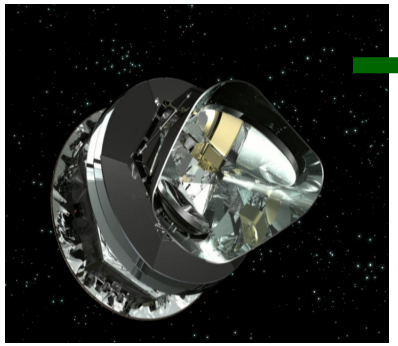
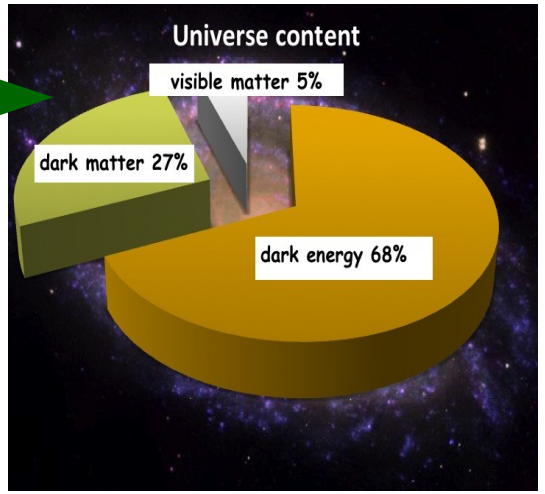
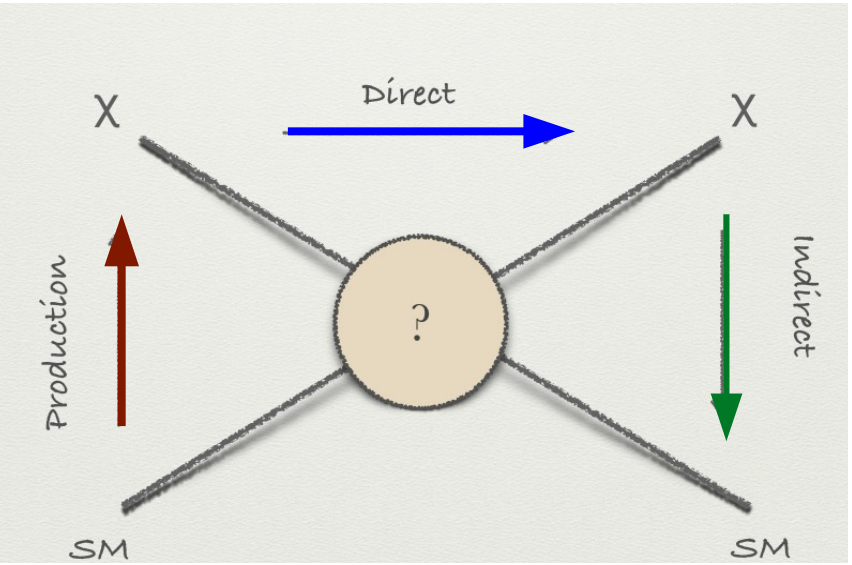
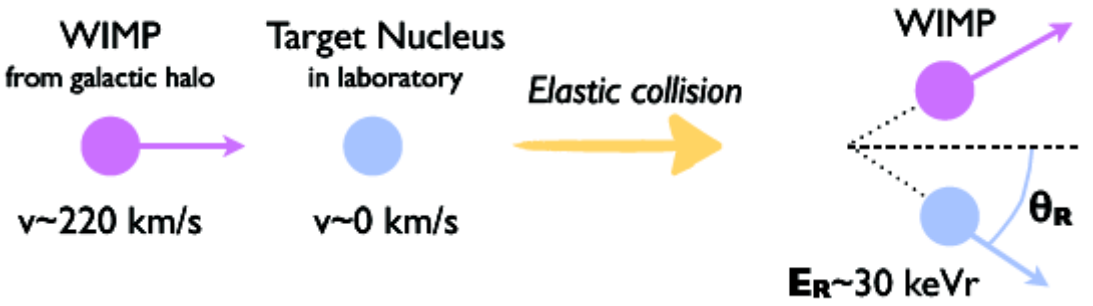
Detection of the dark matter



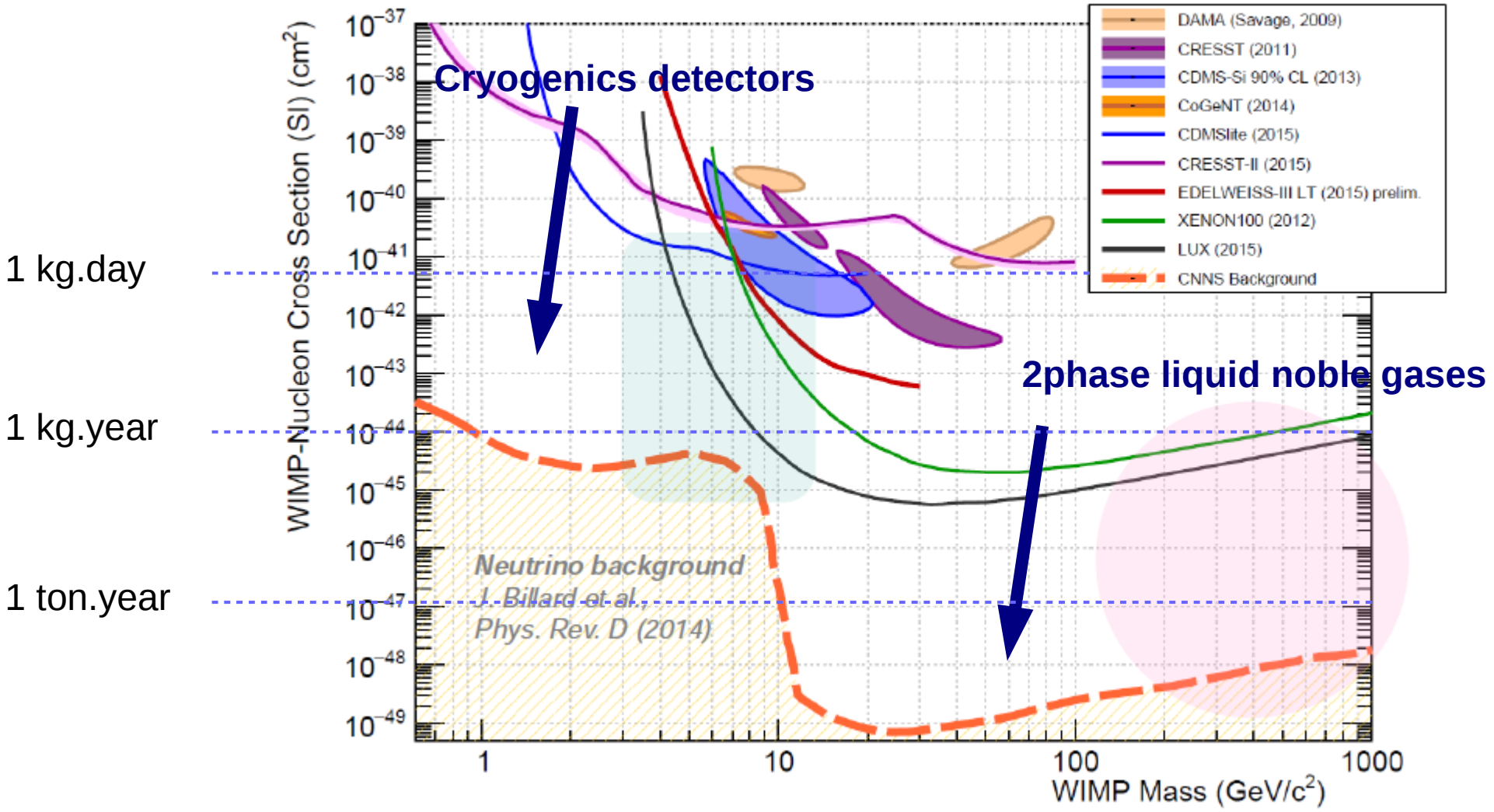




→ **Collider detection** : production of dark matter with the LHC
→ **Indirect detection** : detection of annihilation product in cosmic rays
→ **Direct detection** : elastic scattering on target nuclei

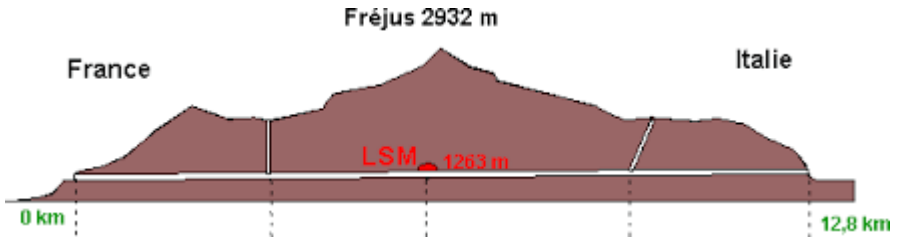


State of the art



Rate < 1 event/kg/year

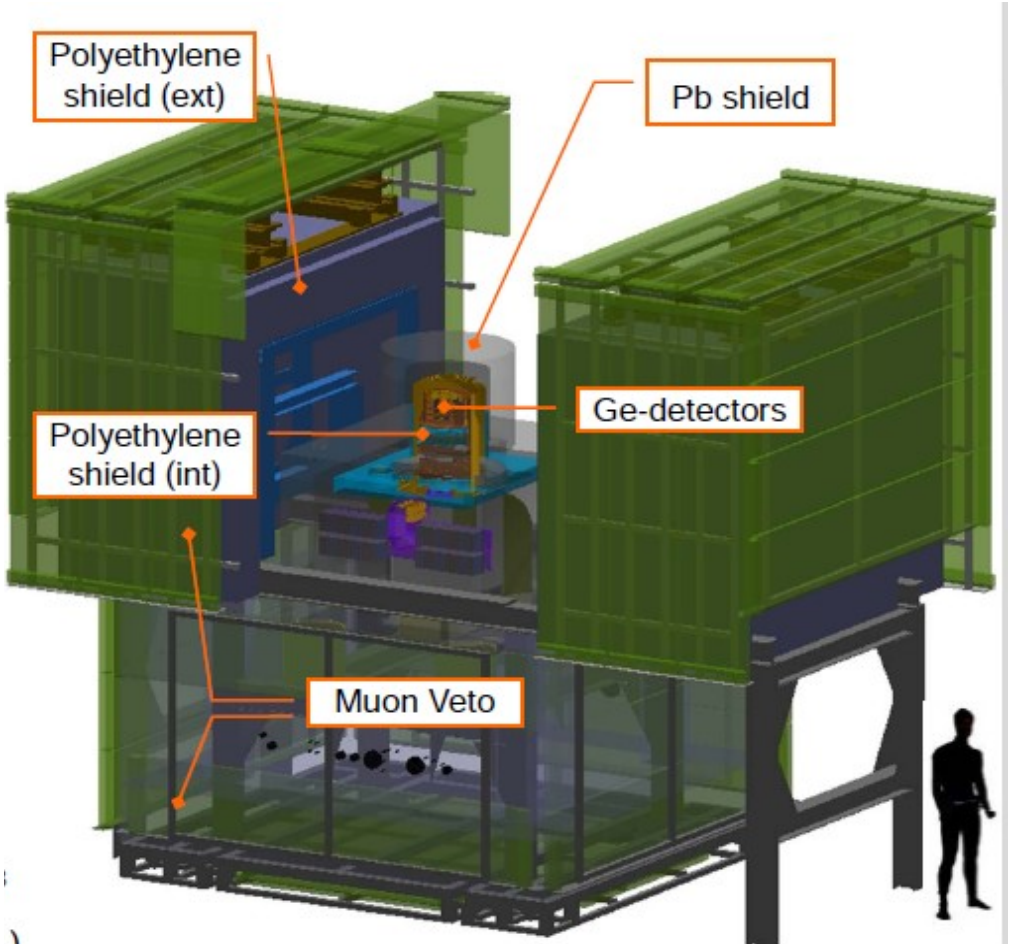
The EDELWEISS experiment



LSM at Modane

Shielding :
- Clean room
- Active muon veto
- Internal and external PE shield
- Lead shield
- Deradonized air

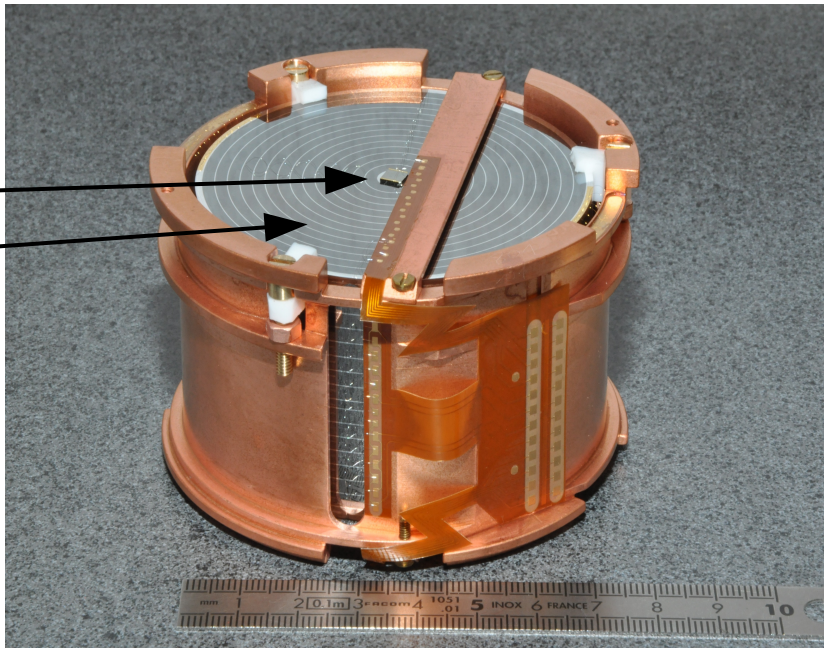
Cryogenic installation (18mK)



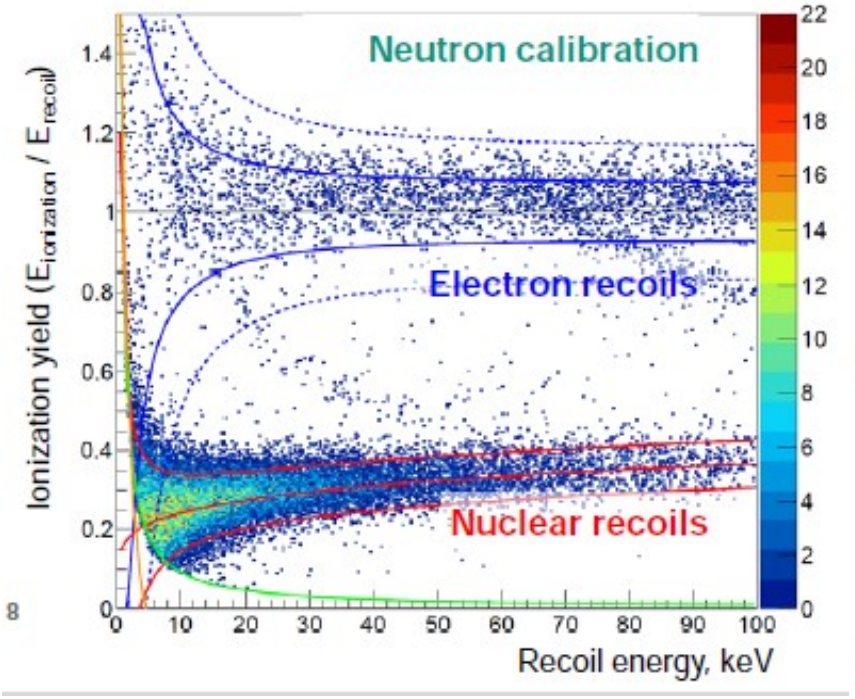
FID 800 : Germanium detectors

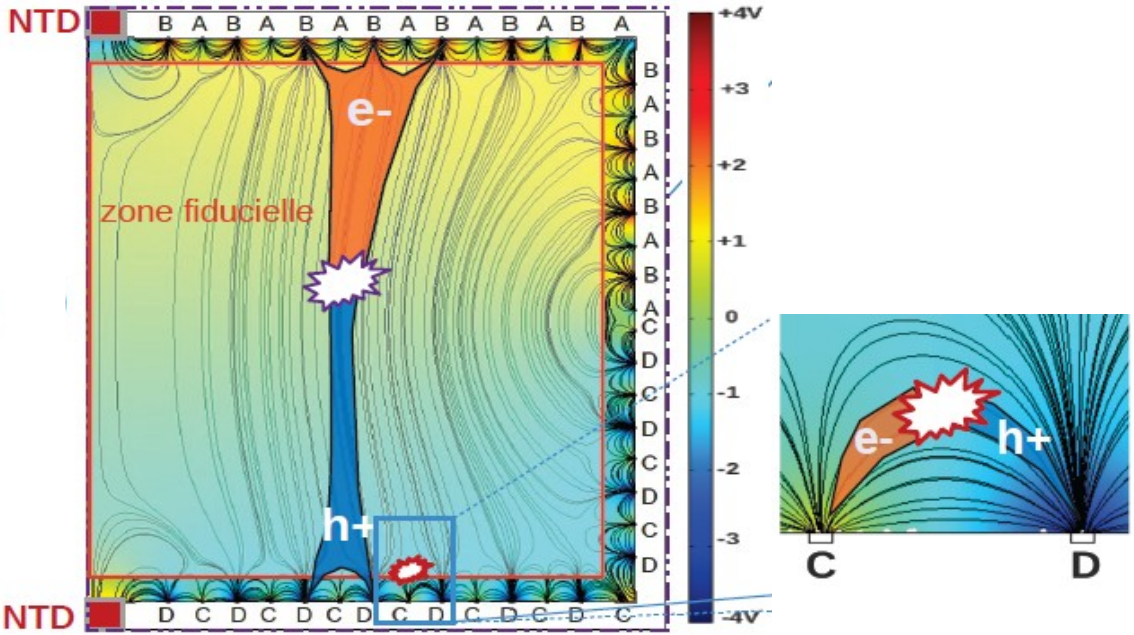
Surface event rejection with electrodes

Simultaneous measurement :
- Heat (thermal sensors)
- Ionization (interdigitized electrodes)



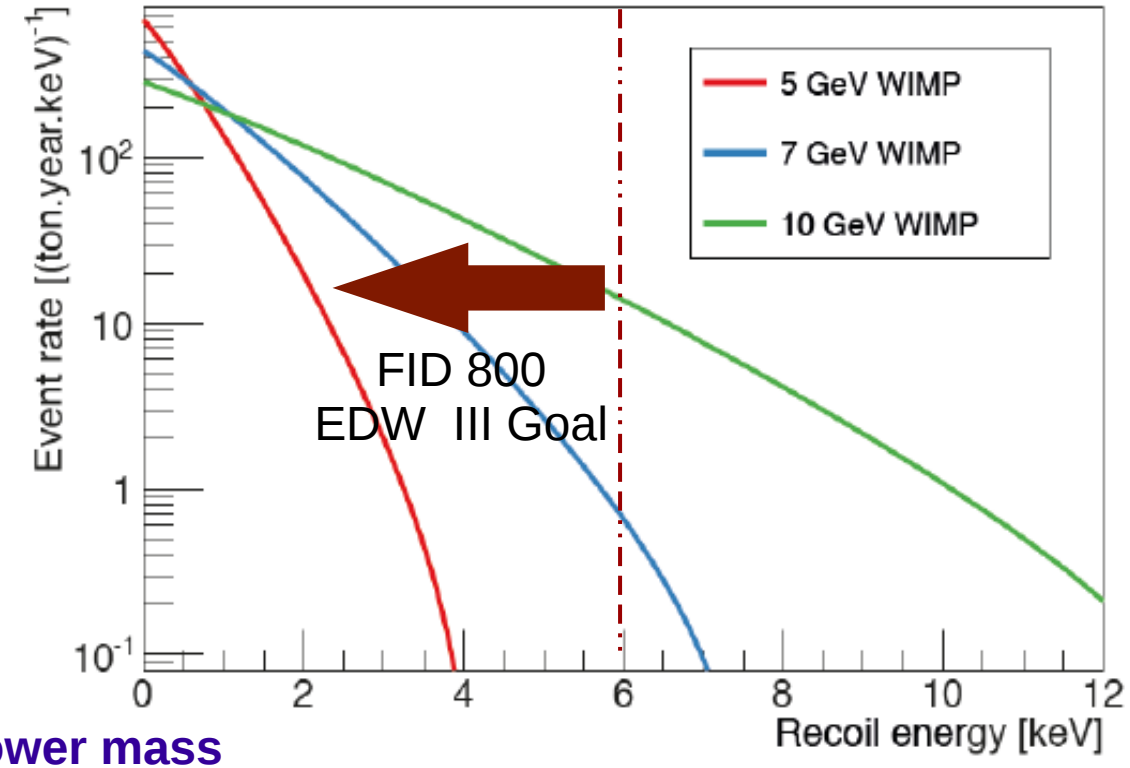
Event identification with Quenching factor (Q = Eion/Erecoil):
- Electron recoil → Q = 1
- Nuclear recoil → Q ~ 0.3





Strategy for low mass WIMP search

Threshold = 6 keV$_{nr}$
(EDW II)



- Goal : Reach lower mass

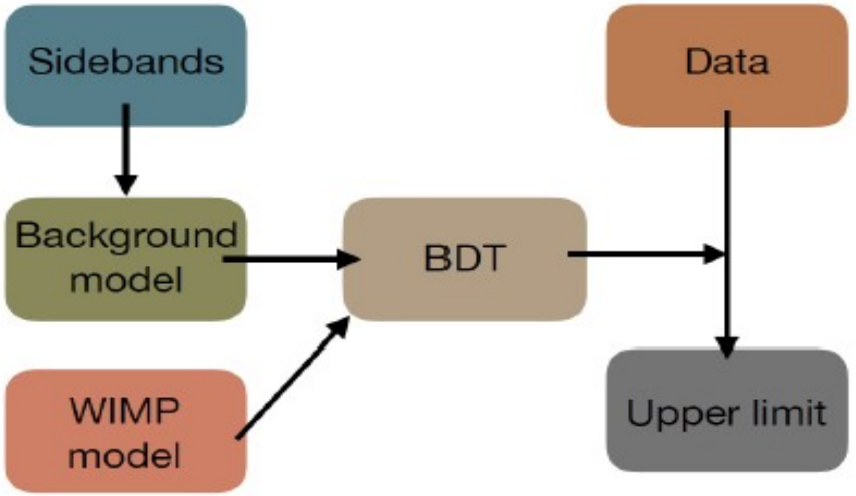
→ **Now : Low threshold analysis (background model + exposure)**

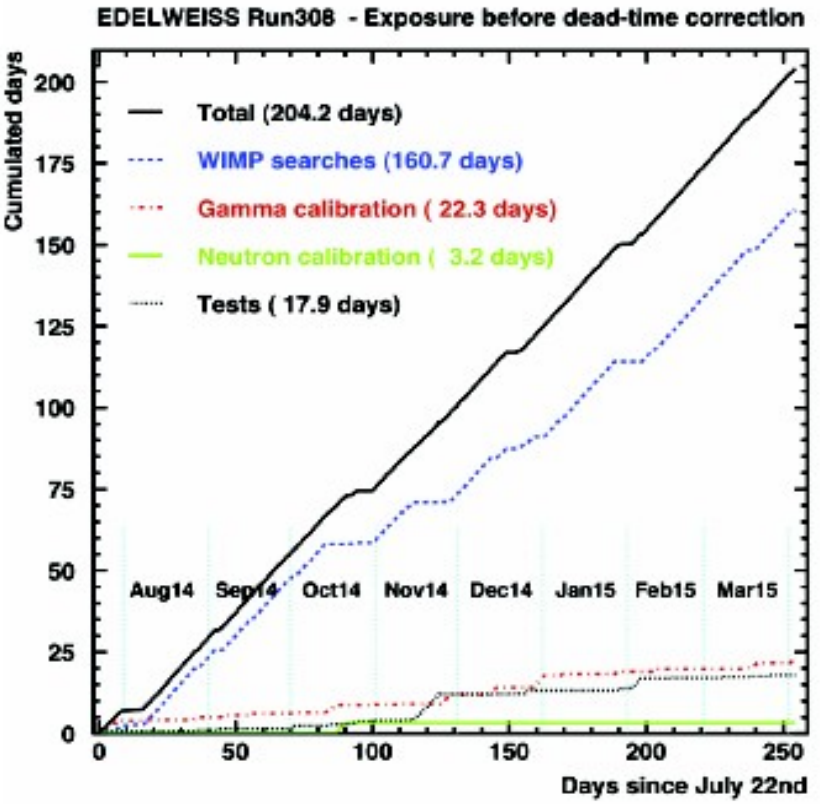
Low threshold analysis

- Use 8 detectors with lowest trigger threshold (initially, 24 detectors in the cryostat) : 4 at 2.4keV$_{nr}$ and 4 at 3.6keV$_{nr.}$

- 582 Kg.days of fiducial exposure (August 2014-March 2015)

- Blind analysis optimized for exclusion





Define WIMP box (ROI) :

- $1 < E_{heat} < 12\ keV_{ee}$
- $0 < E_{ionization} < 8\ keV_{ee}$
- 5 sigma surface veto electrode
- single (not coincidence)

Background models

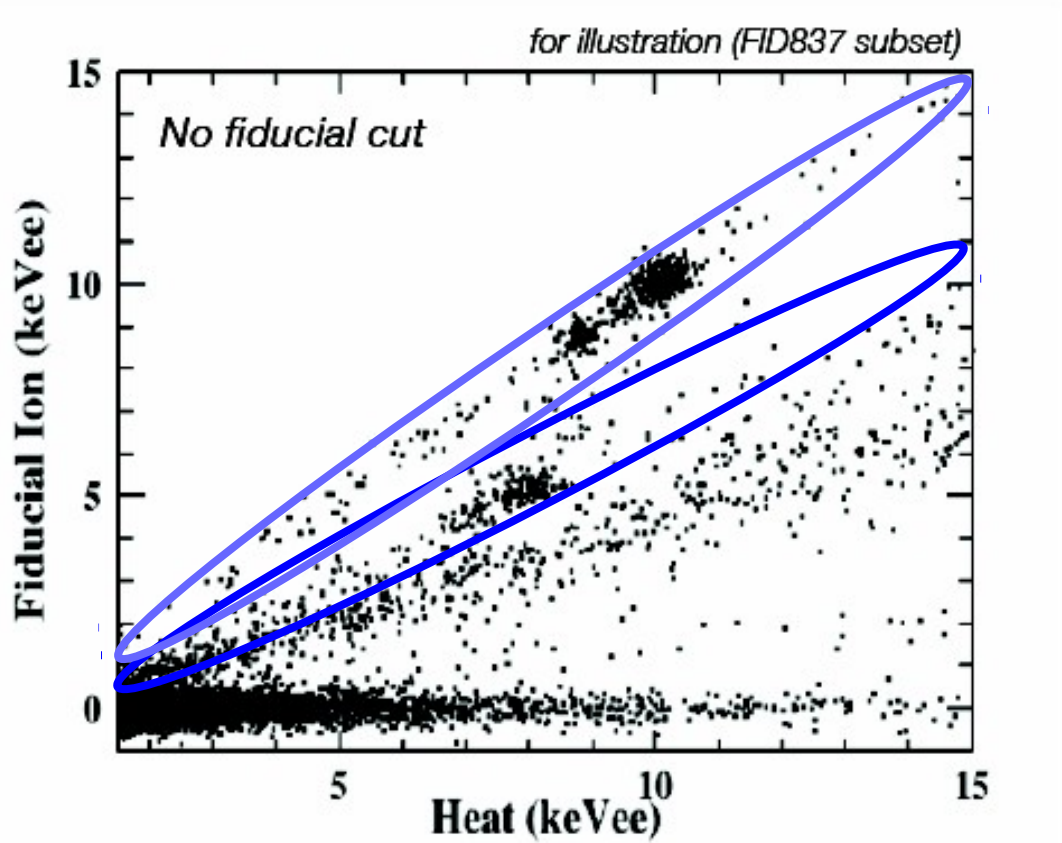
Use data driven

Use region where no signal is expected depending on the type of background

EDW III backgrounds :

- Fiducial gamma
- Surface gamma

→ Internal radioactivity and cosmogenic activation lines



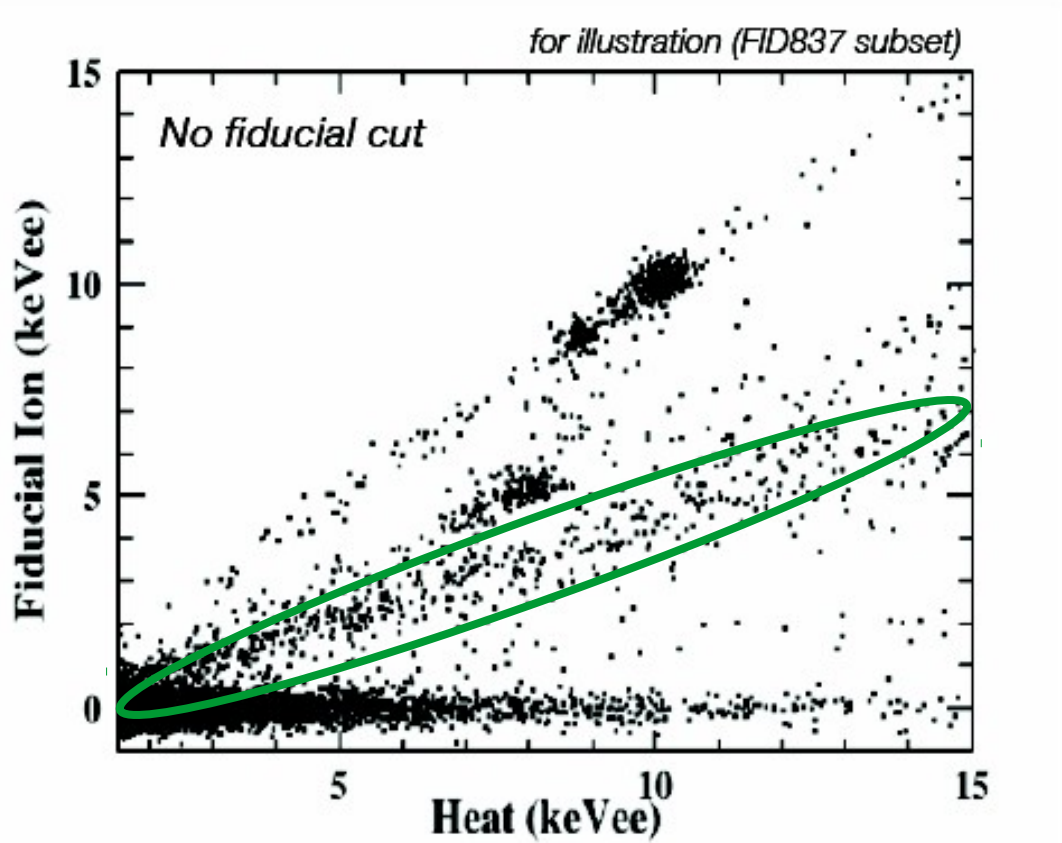
Background models

Use data driven

Use region where no signal is expected depending on the type of background

EDW III backgrounds :

- Fiducial gamma
- Surface gamma
- Surface beta → ^{210}Pb surface events



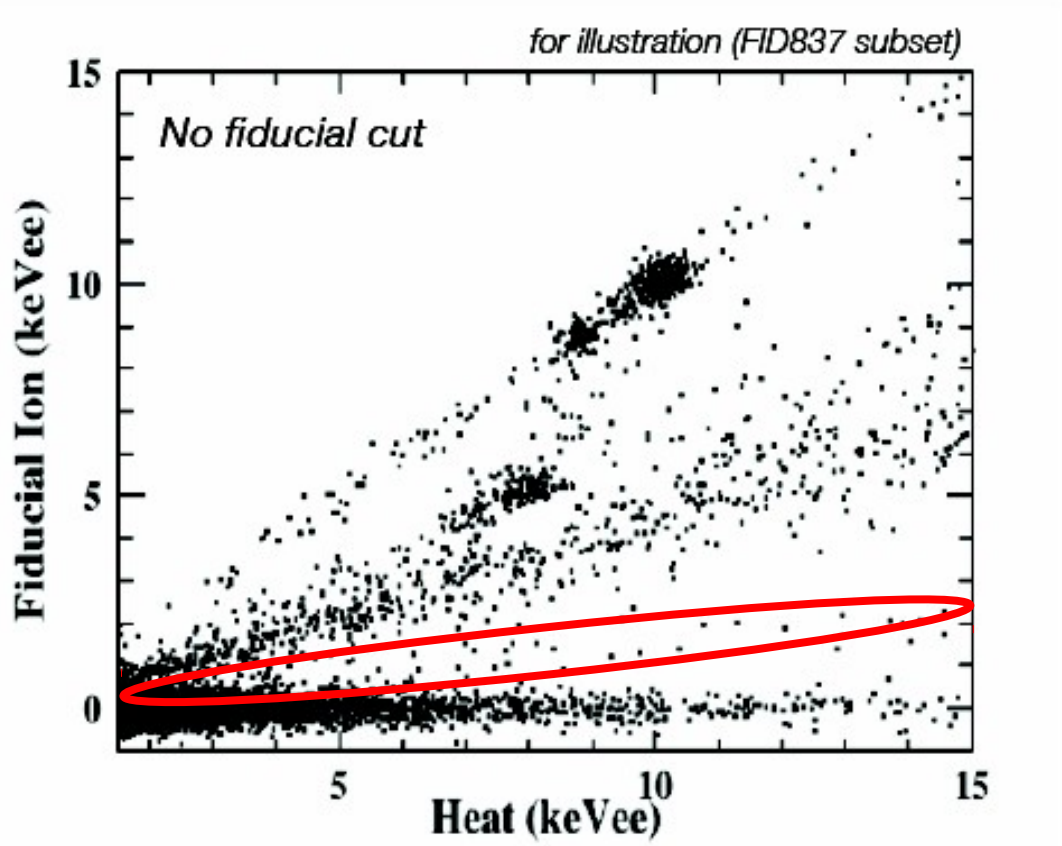
Background models

Use data driven

Use region where no signal is expected depending on the type of background

EDW III backgrounds :

- Fiducial gamma
- Surface gamma
- Surface beta
- Neutron → Radiogenic origin



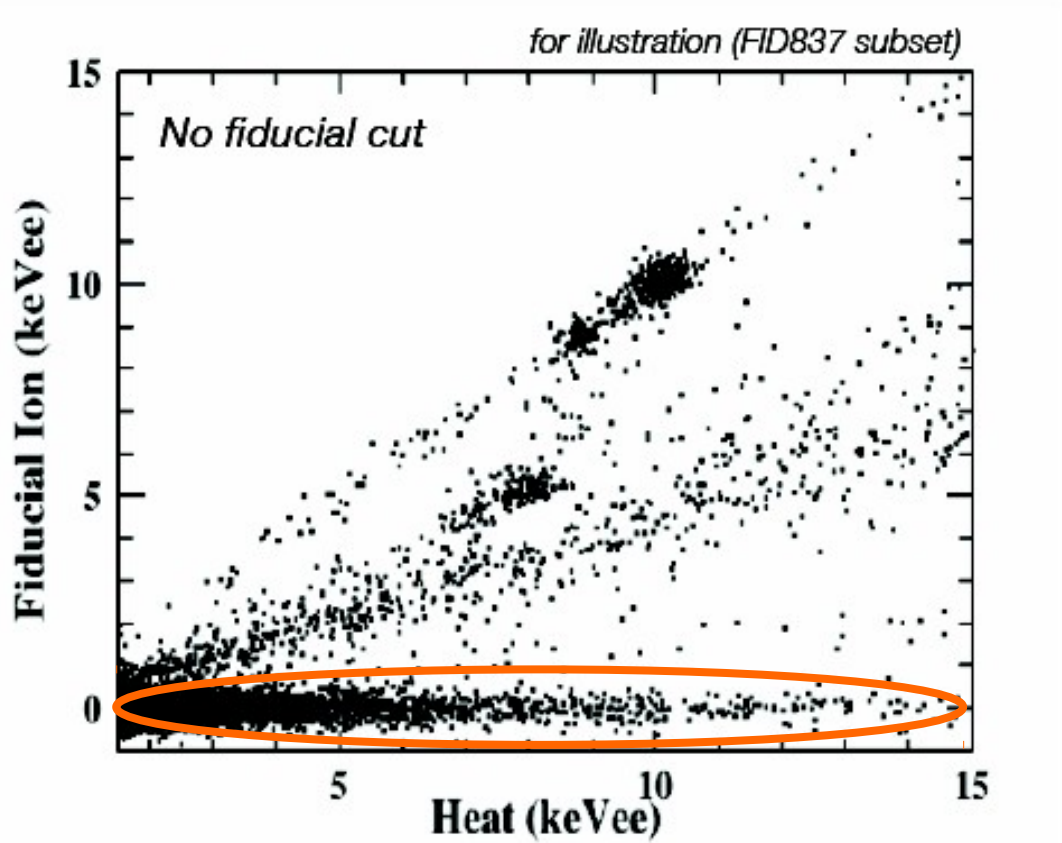
Background models

Use data driven

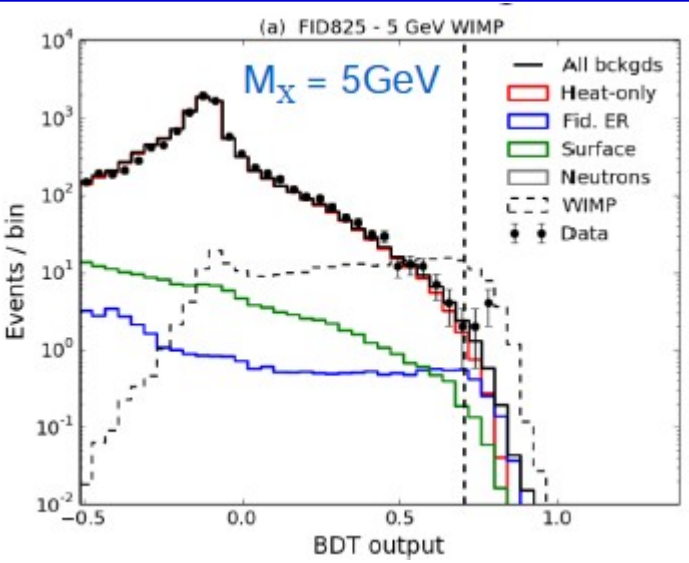
Use region where no signal is expected depending on the type of background

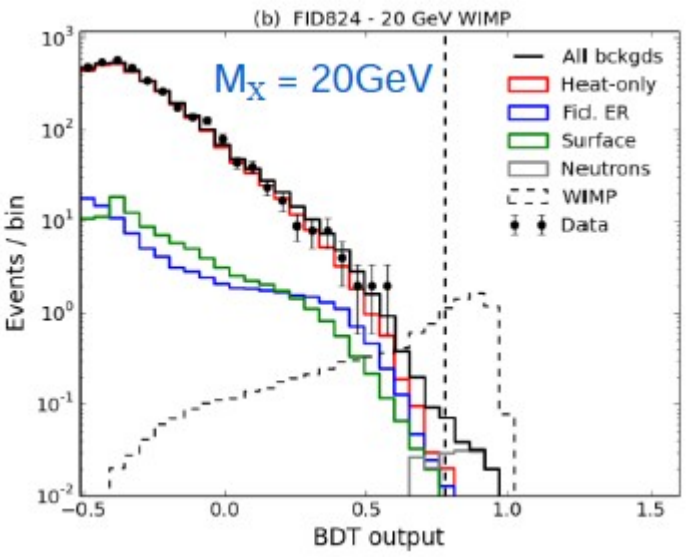
EDW III backgrounds :

- Fiducial gamma
- Surface gamma
- Surface beta
- Neutron
- Heat only → Origin under investigation

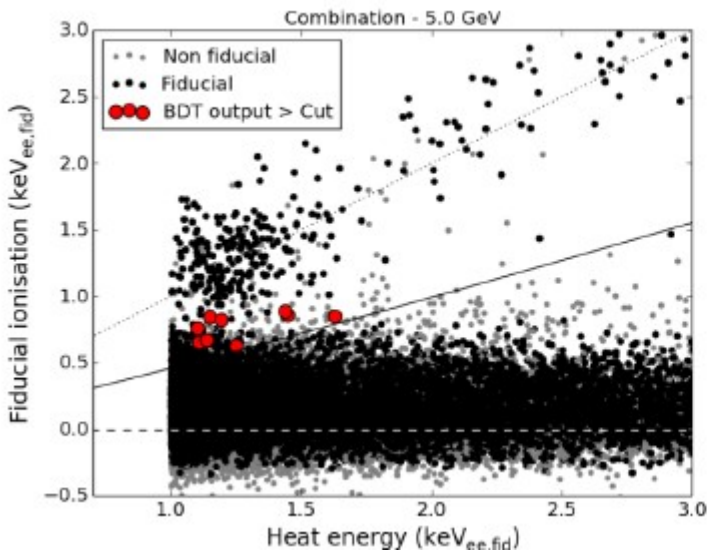


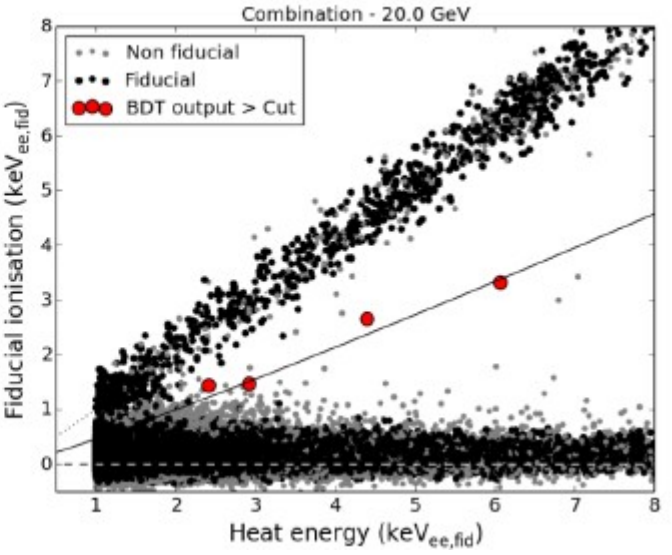
BDT





Dominant background at 5 GeV is Heat only and at 20 GeV it's neutrons.





Low threshold analysis results

WIMP mass	$5\,\mathrm{GeV}/c^2$	$7\,\mathrm{GeV}/c^2$	$10\,\mathrm{GeV}/c^2$	$20\,\mathrm{GeV}/c^2$
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	$2.87^{+0.49}_{-0.03}$	$0.43^{+0.07}_{-0.00}$	$0.20^{+0.03}_{-0.00}$	$0.11^{+0.02}_{-0.00}$
Others	0.55 ± 0.16	0.12 ± 0.04	0.09 ± 0.03	0.07 ± 0.02
Total background	$6.14^{+0.67}_{-0.46}$	$1.71^{+0.19}_{-0.18}$	1.07 ± 0.18	1.35 ± 0.47
Events observed	9	6	4	4
p-value	22%	1.1%	2.8%	6.3%

- Slight excesses of events for all WIMP mass

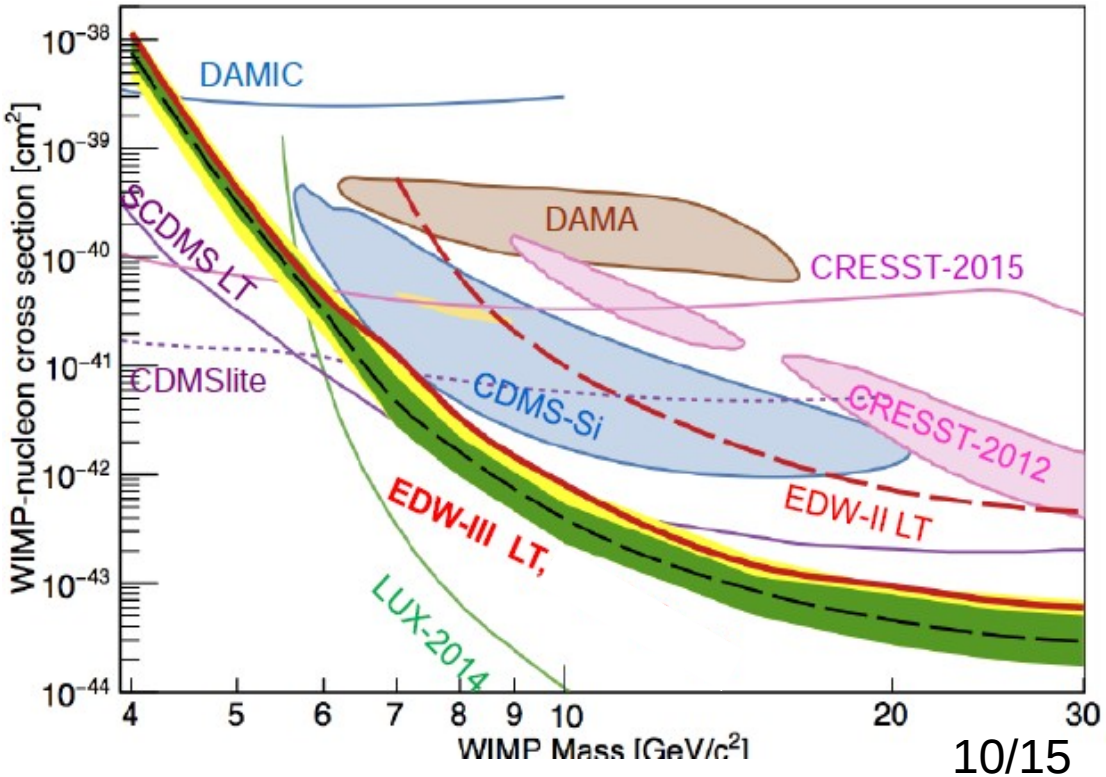
- Strongest excess at 7 GeV

=> limit on the mass and the cross-section done :

- dashed line in red : EDW II

- New result EDW III : red line

- dashed line in black : expected limit from background model



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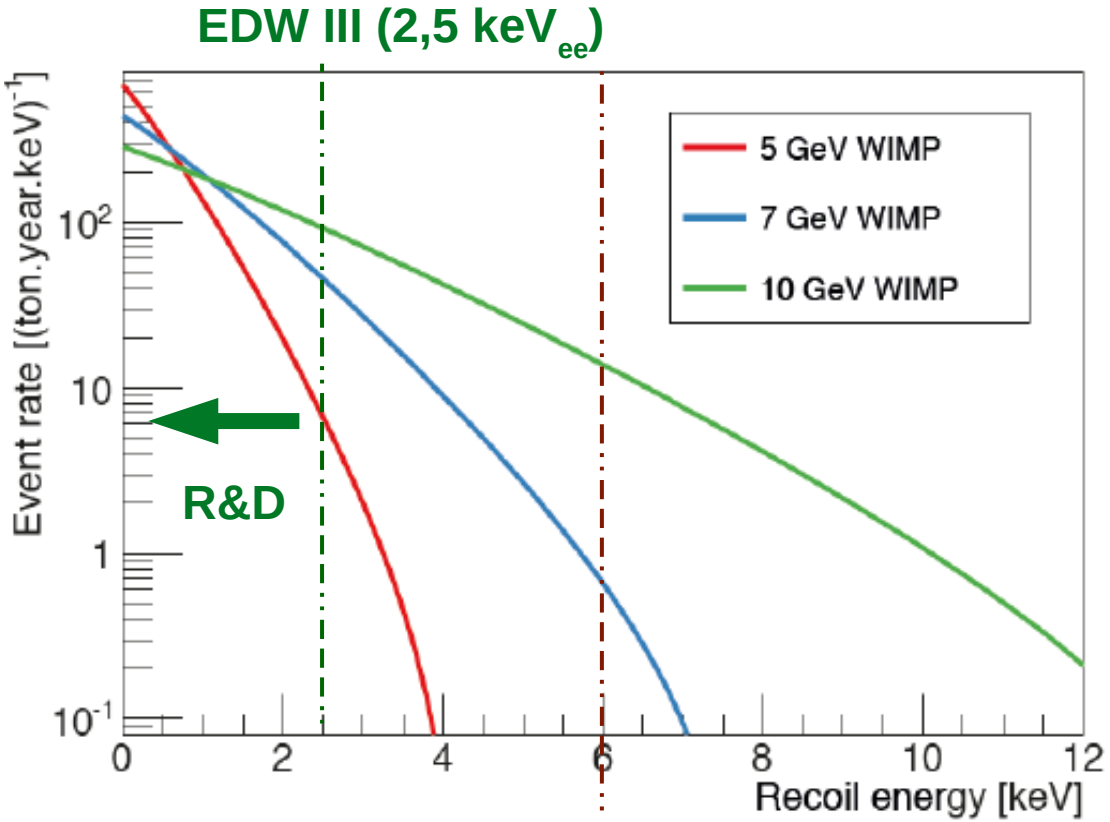


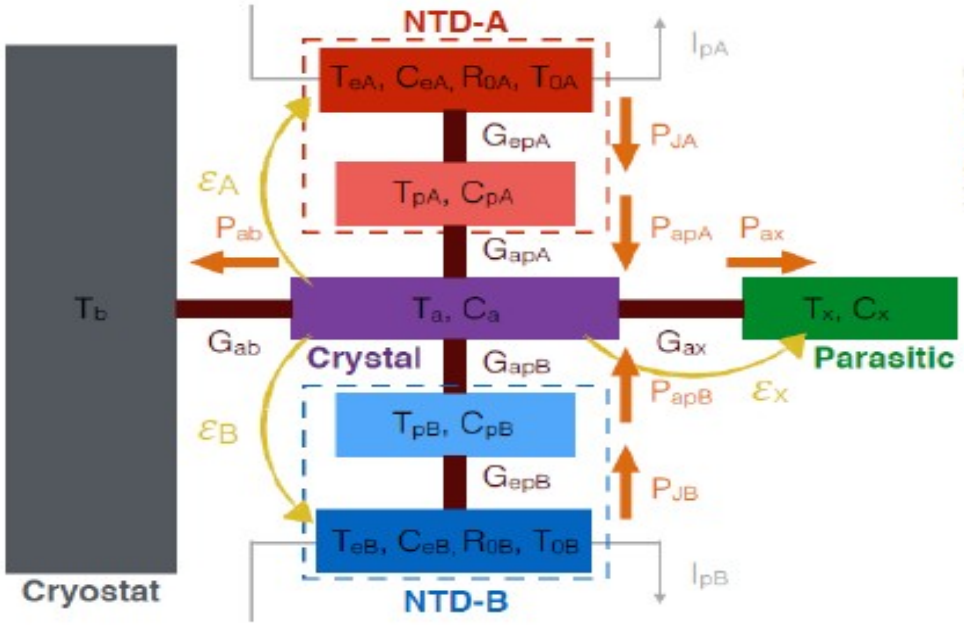
- Goal : Reach lower mass

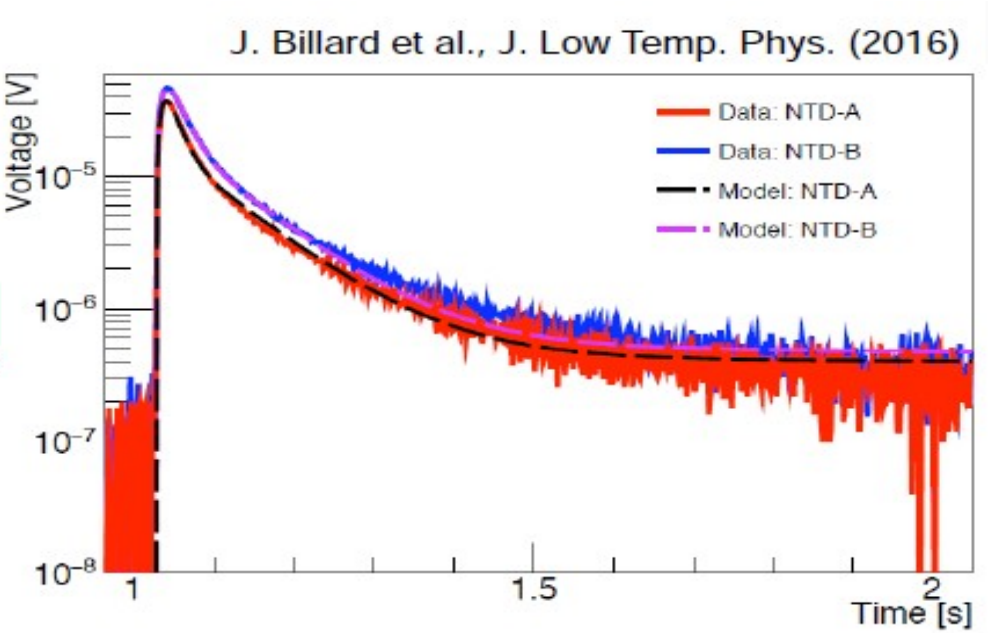
→ Low threshold analysis (background model + exposure)

→ **In progress : Sensors optimization**

→ **In progress : HV (8 V → 100 V)**

R&D : Improved sensors



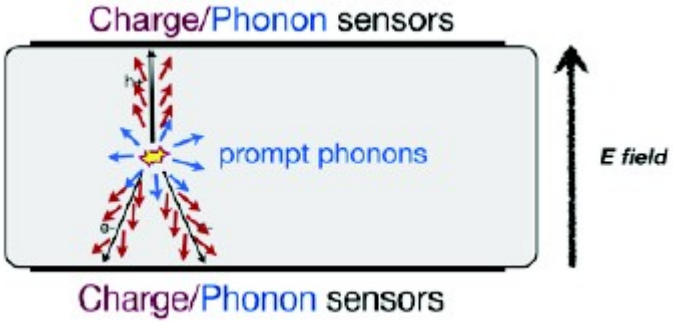


Detailled thermal model of heat signals that fits very well observed pulses :
- presence of parasitic heat capacity
- Sensitivity to ballistic phonons
- New sensors should reach 100 eV baseline resolution (to be tested this year)

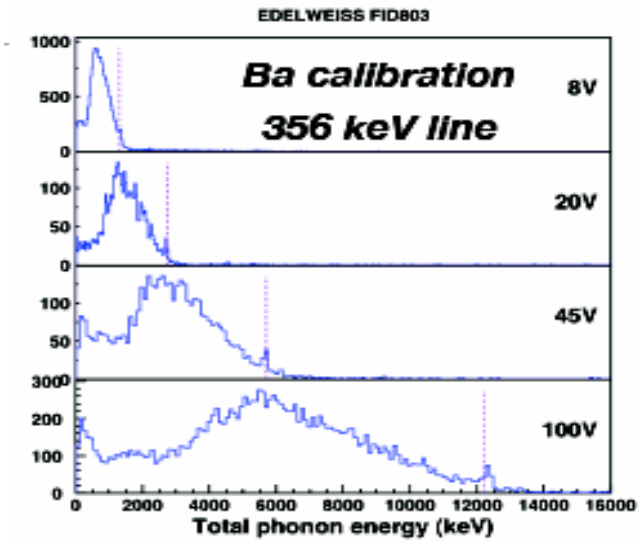
HEMT (High Electron Mobility Transistor) R&D for ionization signal ongoing in collaboration with SuperCDMS → Reach 100 eV_{ee} baseline resolution too.

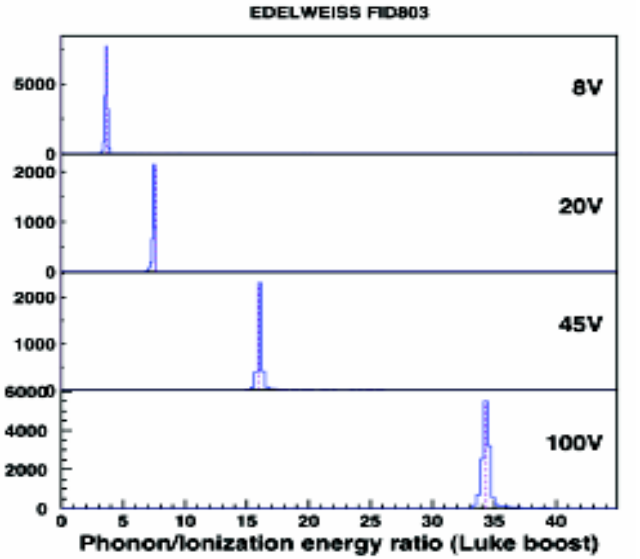
High voltage R&D

Neganov-Luke's effect amplification :



$$E_t = E_r + \frac{1}{3\,eV} E_Q \Delta V$$





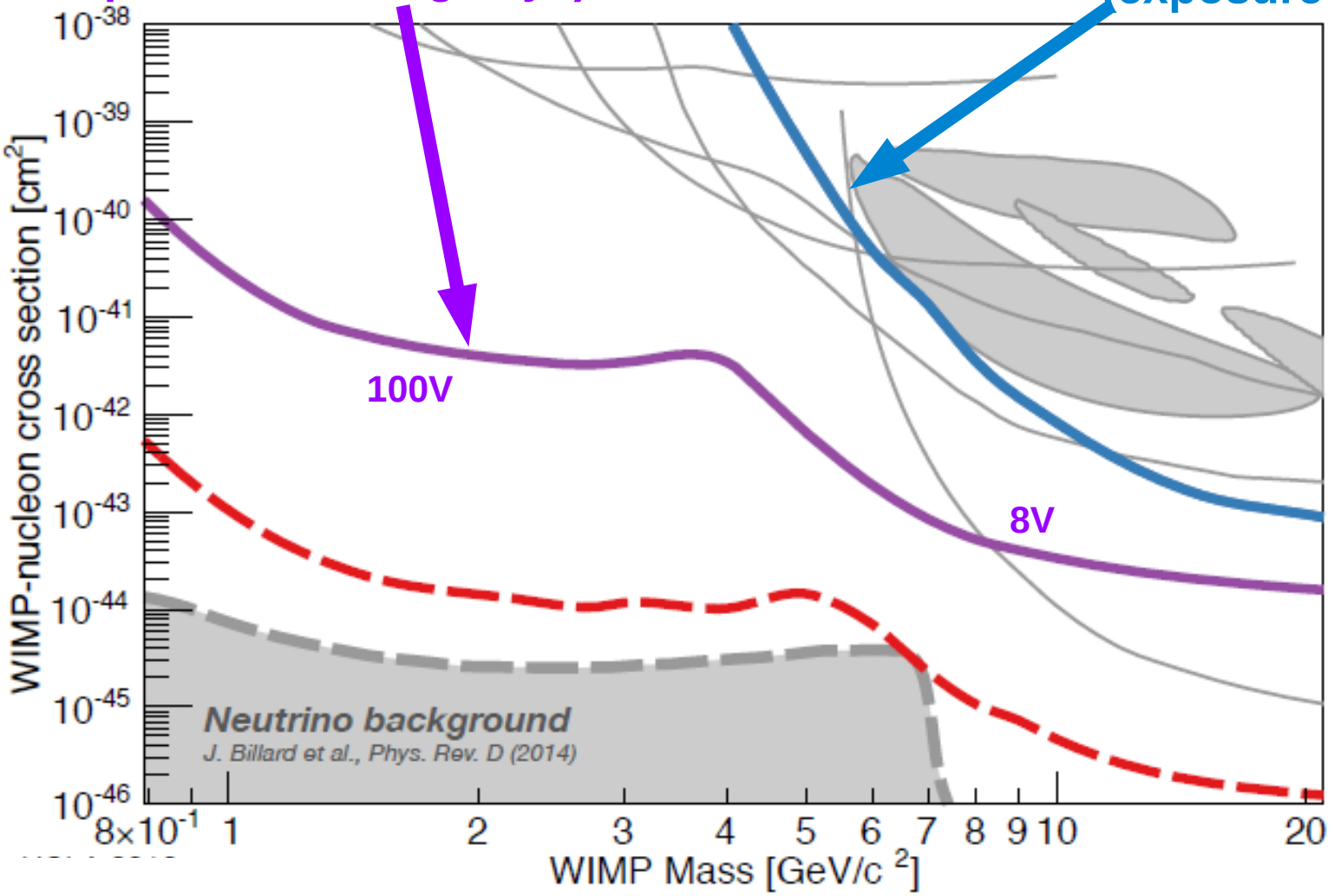
- First Dark Matter run with HV detectors
- Working to level up to 100V for a boosting factor of ~35
- First data with Ba calibration : ~60 eV_{ee} threshold
- Readout both ionization and heat signal still possible

- Problem : discrimination between ionization and heat signal difficult at lower energy

Conclusion and Prospects

Goals for 2017 (R&D ongoing , exposure = 350 kg.days)

EDW III LT analysis (exposure = 582 kg.days)



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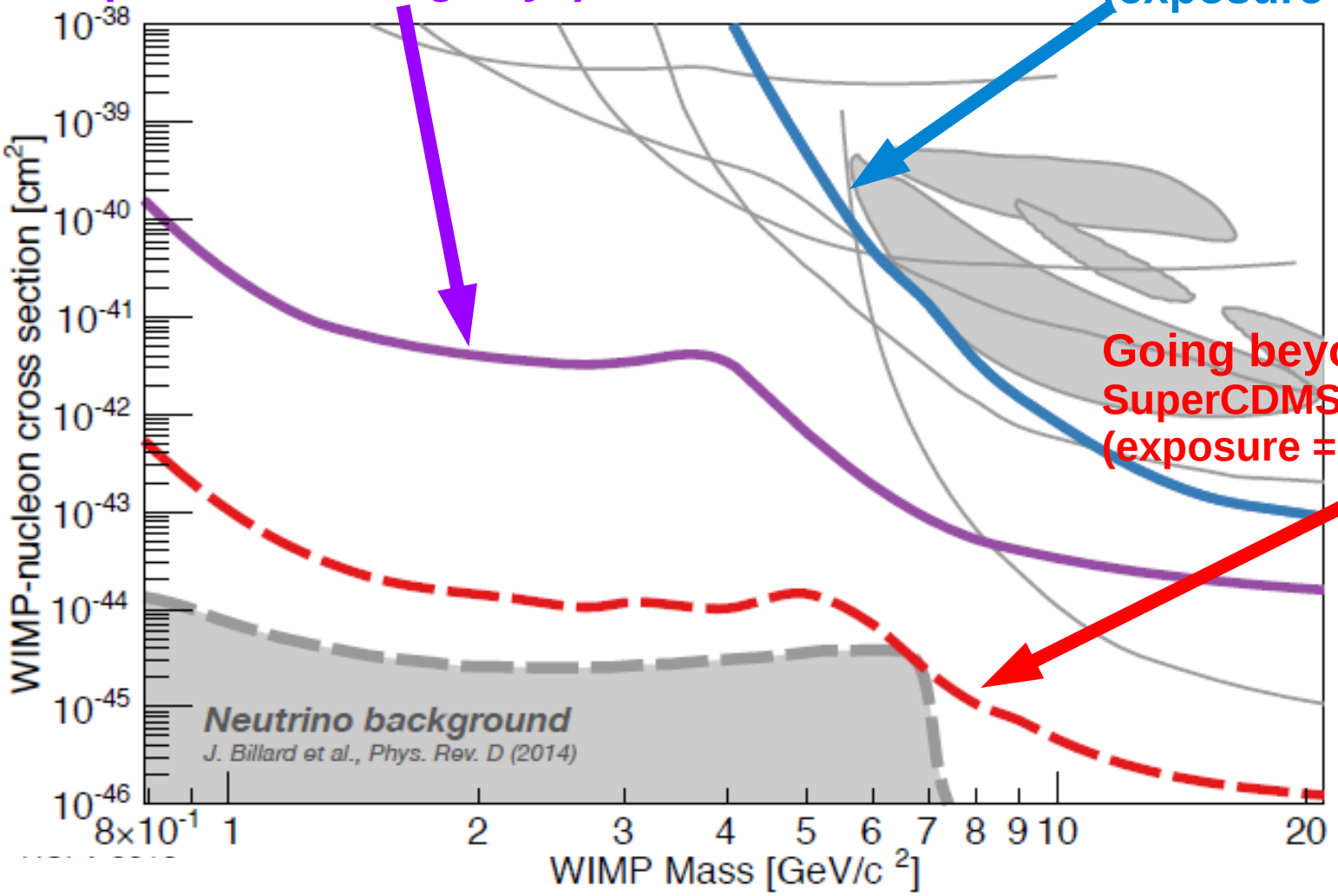

Going beyond (ton-scale)
SuperCDMS + EURECA + EDW
(exposure = 35000 kg.days)

The EDELWEISS Collaboration

CSNSM CNRS/IN2P3
IPNL CNRS/IN2P3
NÉEL CNRS/INP
CNRS
Irfu CEA/IRFU
IRAMIS CEA/IRAMIS
KIT IKP EKP IPE
Karlsruher Institut für Technologie
JINR DUBNA
Univ. OXFORD
The University Of Sheffield. Univ. SHEFFIELD

Thanks for your attention