Low mass WIMP searches with EDELWEISS III

Thibault de Boissière
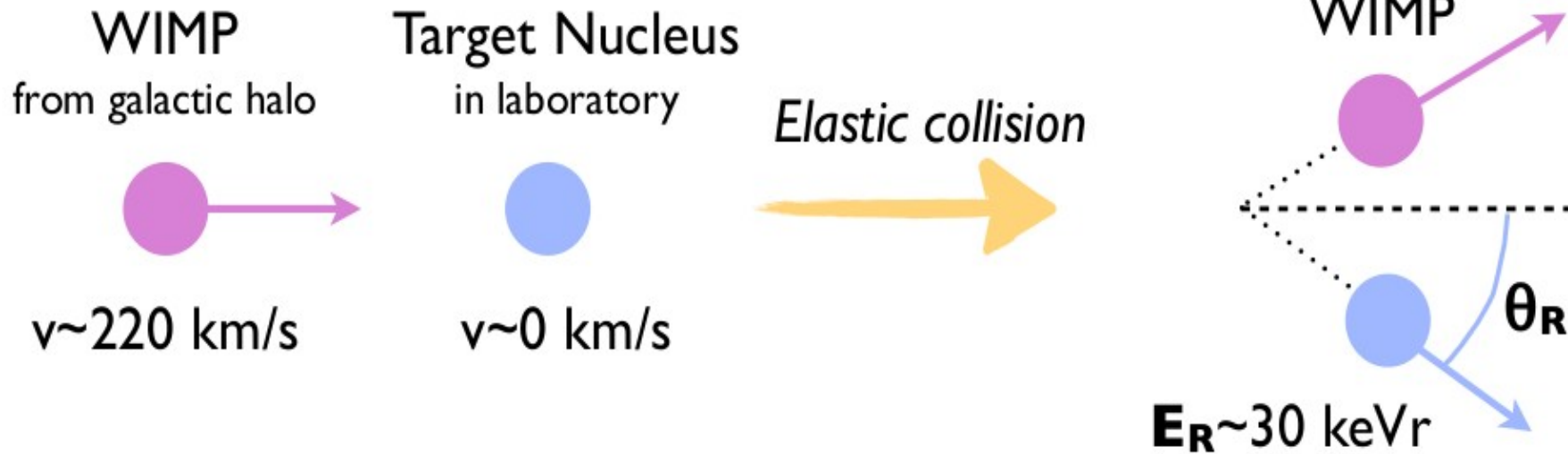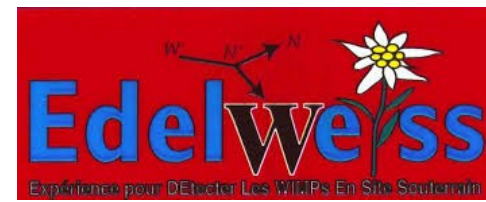
Part I
WIMP direct detection with EDELWEISS

Part I: WIMPs and EDELWEISS
What is WIMP direct detection ?

WIMP from galactic halo — $v \sim 220$ km/s

Target Nucleus in laboratory — $v \sim 0$ km/s

Elastic collision

WIMP

θ_R

$E_R \sim 30$ keVr

Typical energy:
- keV to < 100 keV

Expected WIMP event rate:
- < 1 per kg per year

Radioactive background:
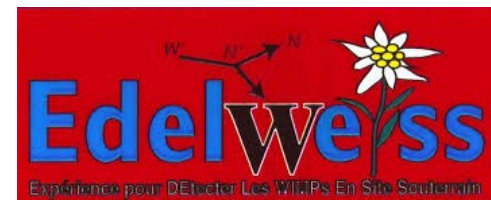- most materials give higher rate

We need :
- Low thresholds
- High exposure
- Background rejection
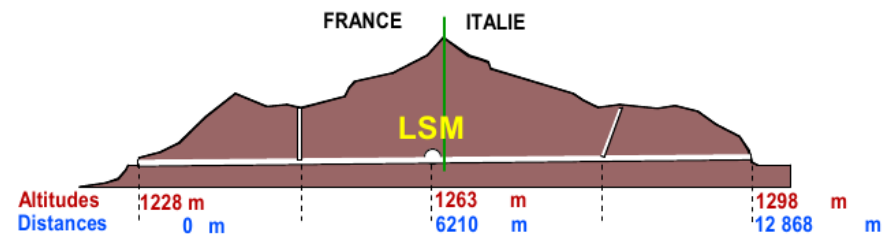
Part I: WIMPs and EDELWEISS
The EDELWEISS experiment

Detector technology:
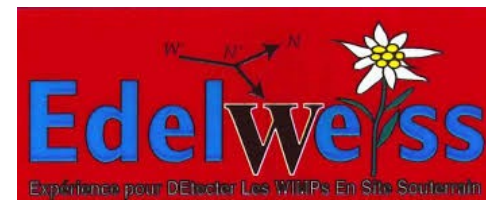- Ultra pure Ge crystals
- Cryogeny at 20 mK

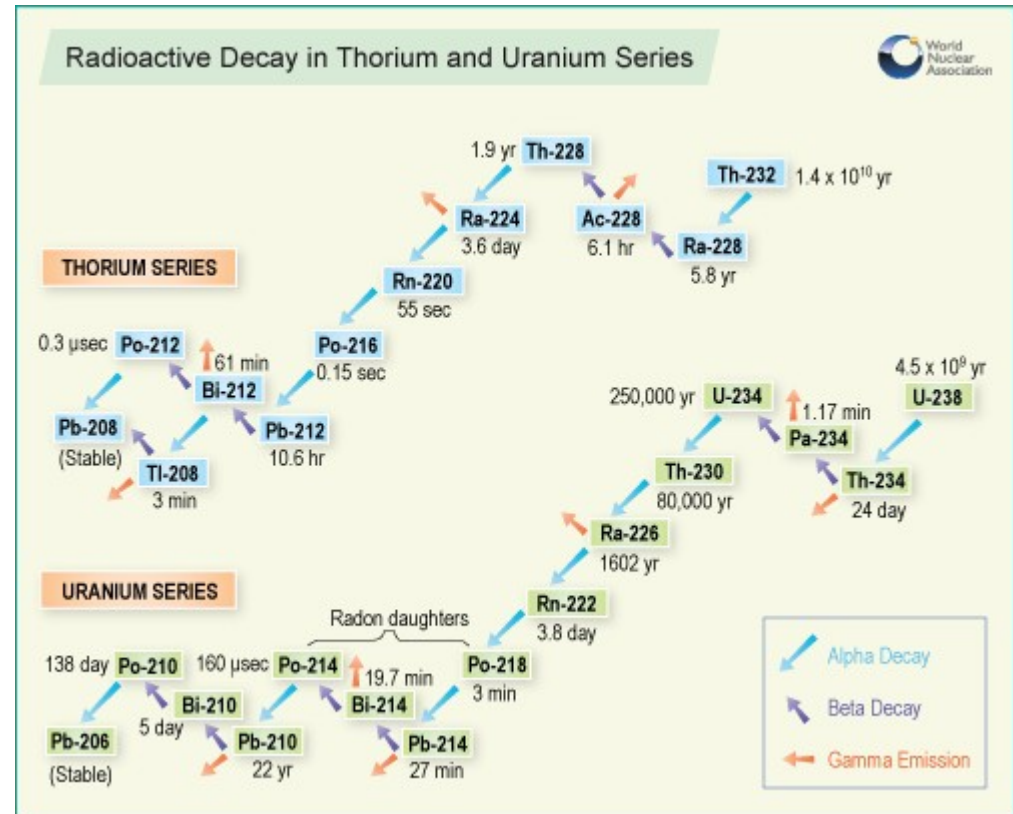**Installed underground:**
- **L**aboratoire **S**outerrain de **M**odane

FRANCE | ITALIE

LSM

| Altitudes | 1228 m | | 1263 m | | 1298 m |
| Distances | 0 m | | 6210 m | | 12 868 m |

4

Neutrons:
- Trigger **nuclear recoils**

Radioactive Decay in Thorium and Uranium Series

Part I: WIMPs and EDELWEISS
Expected backgrounds
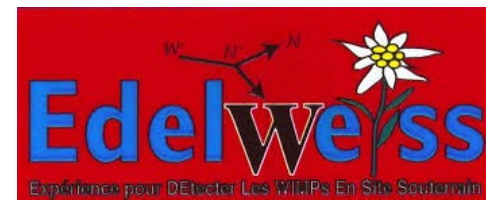
Neutrons:
- Trigger **nuclear recoils**

Gamma:
- Trigger **electronic recoils**

Element	Half life	Gamma line(s)
^{71}Ge	11 days	10.37 keV, 1.297 keV
^{68}Ge	271 days	10.37 keV, 1.2977 keV
^{68}Ga	68 min	9.66 keV, 1.1936 keV
^{65}Zn	244 days	8.98 keV, 1.0961 keV
^{55}Fe	996 days	6.54 keV
^{68}Ge	312 days	5.99 keV
^{54}Mn	330 days	4.97 keV

Part I: WIMPs and EDELWEISS
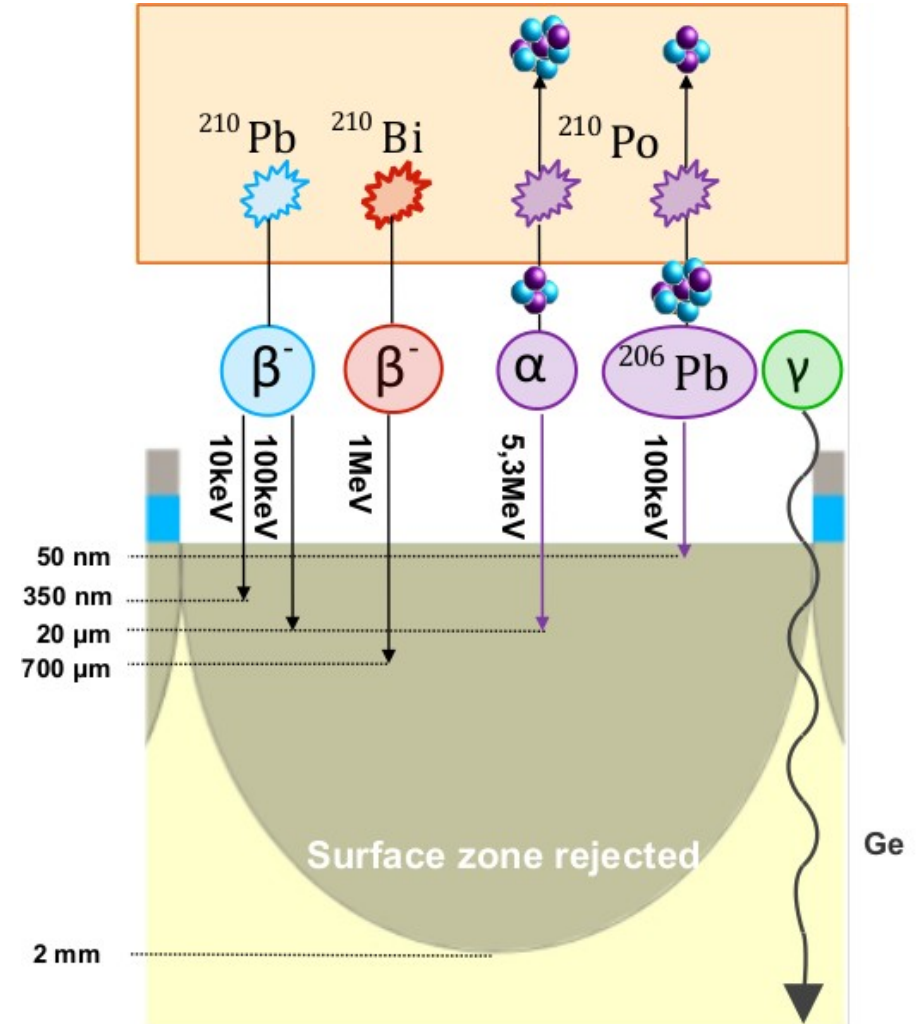## Expected backgrounds

Neutrons:
- Trigger **nuclear recoils**
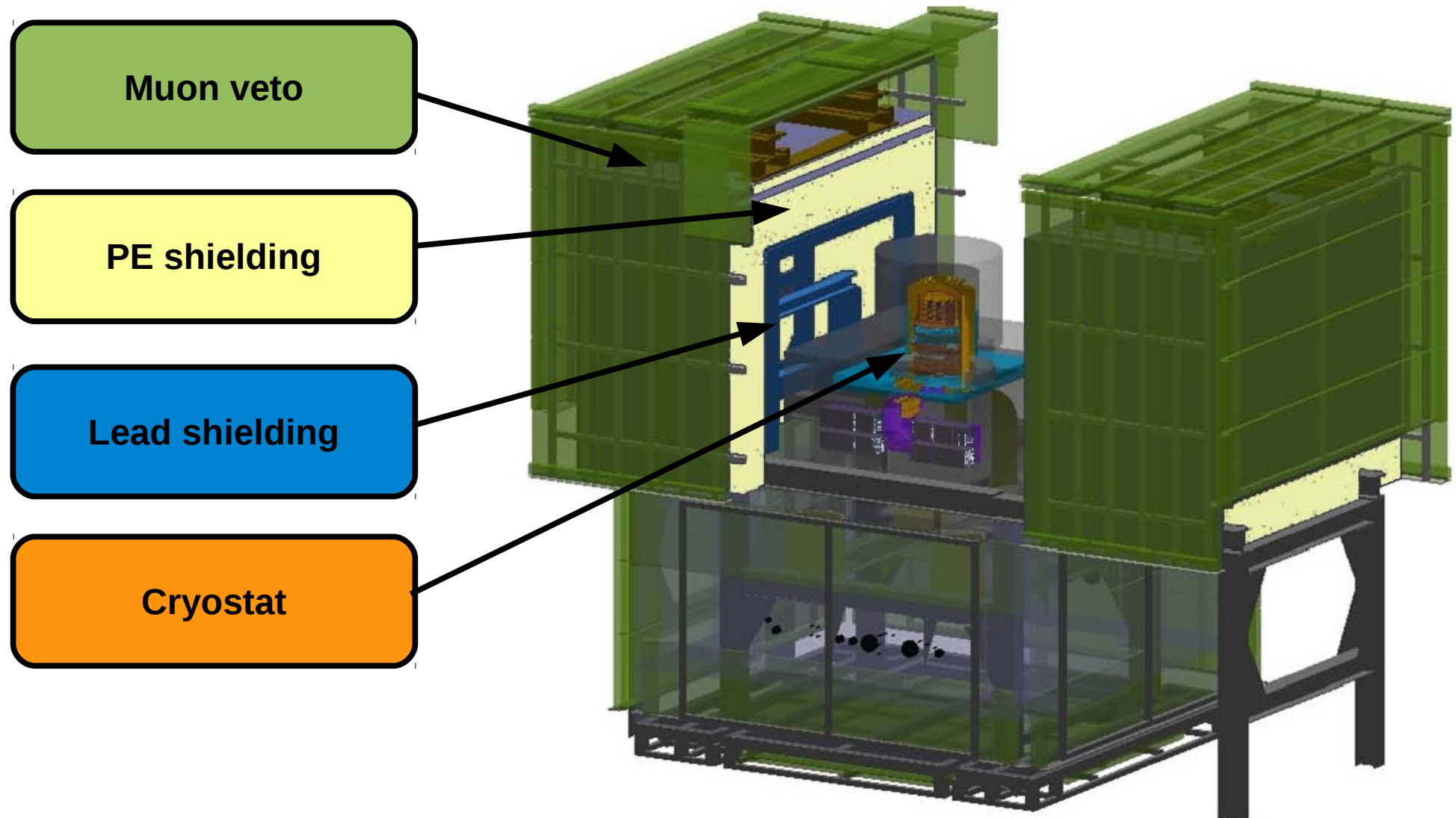
Gamma:
- Trigger **electronic recoils**

Surface radioactivity:
- γ, α, β particles and heavy nuclei
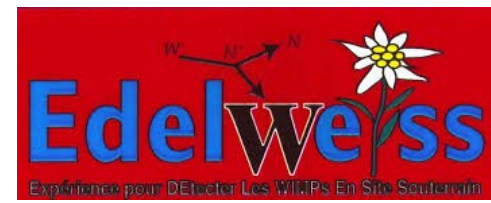- Interaction located at the surface of the detector

Part I: WIMPs and EDELWEISS
The EDELWEISS setup

Muon veto

PE shielding

Lead shielding

Cryostat

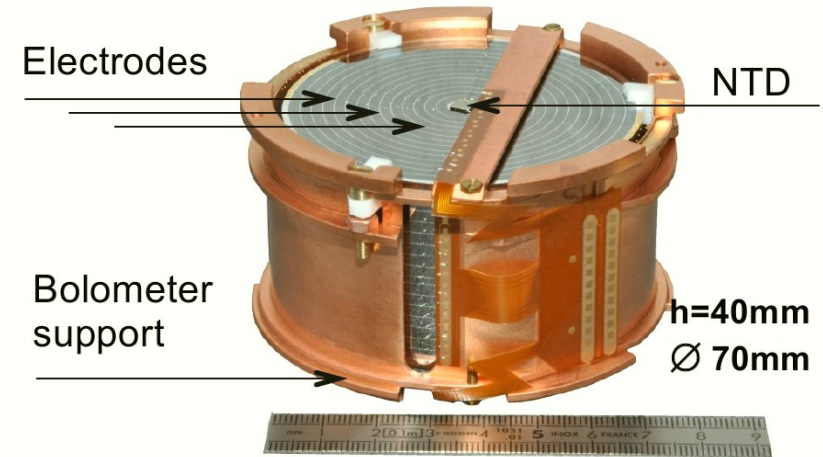## Fully InterDigit (FID) design

Double measure
- Heat signal
- Ionisation signal
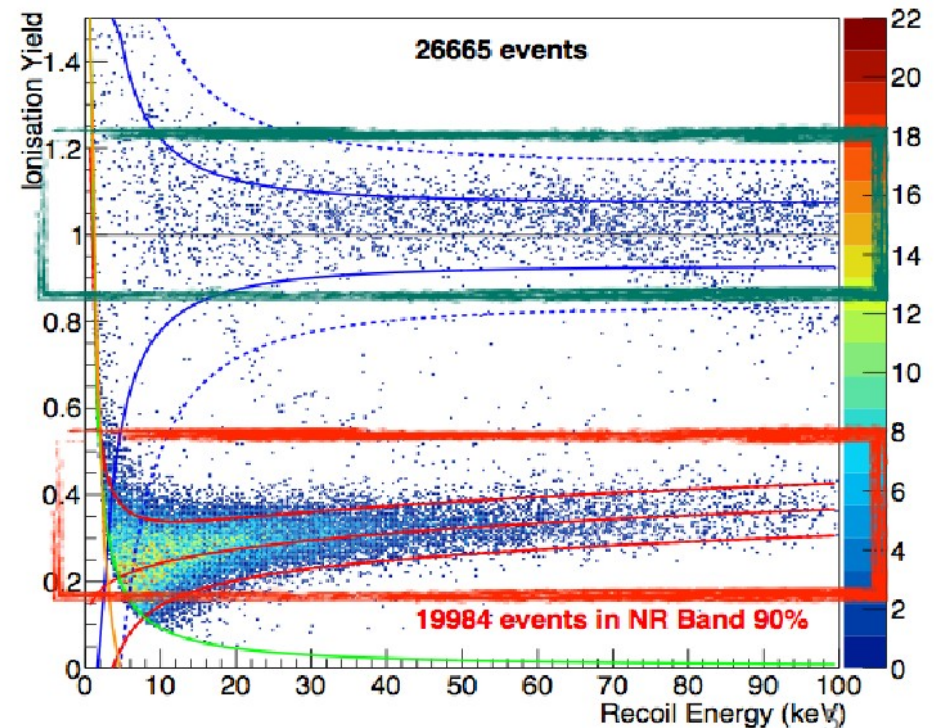
Allows to measure Q:
- $Q = EI / ER$

Q depends on the recoil type:
- $Q = 1$ (by construction) for electronic recoils
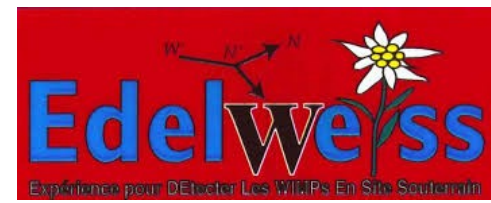- $Q \approx 0.3$ for nuclear recoils
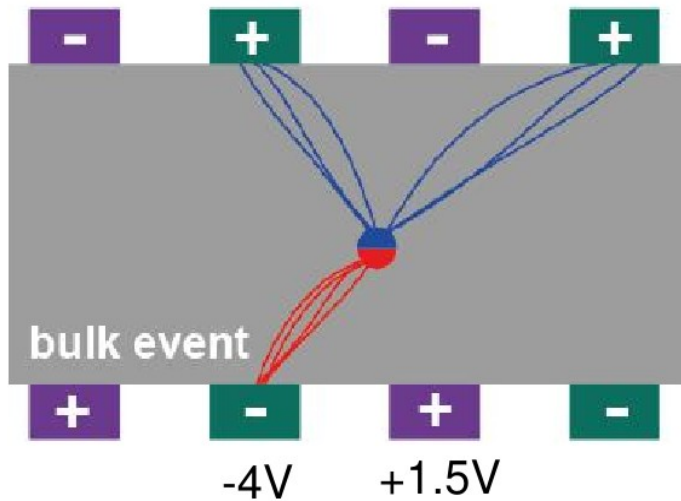
EDELWEISS III neutron calibration

Part I: WIMPs and EDELWEISS
The EDELWEISS detectors
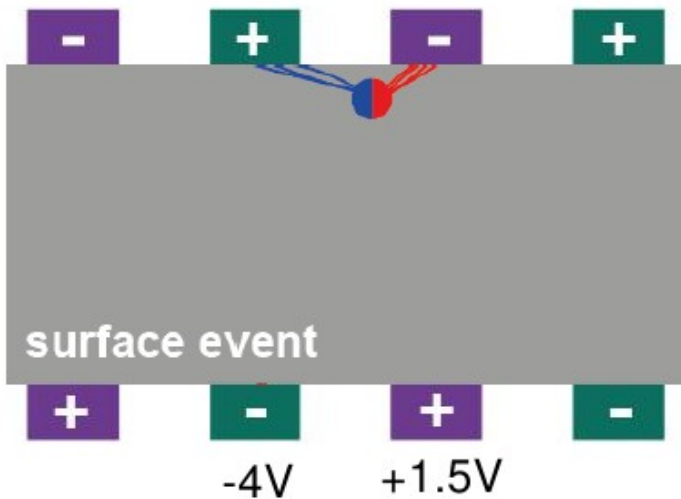
Collecting electrodes
Veto electrodes

-4V   +1.5V

Volume event
- Ionisation signal at the top and bottom
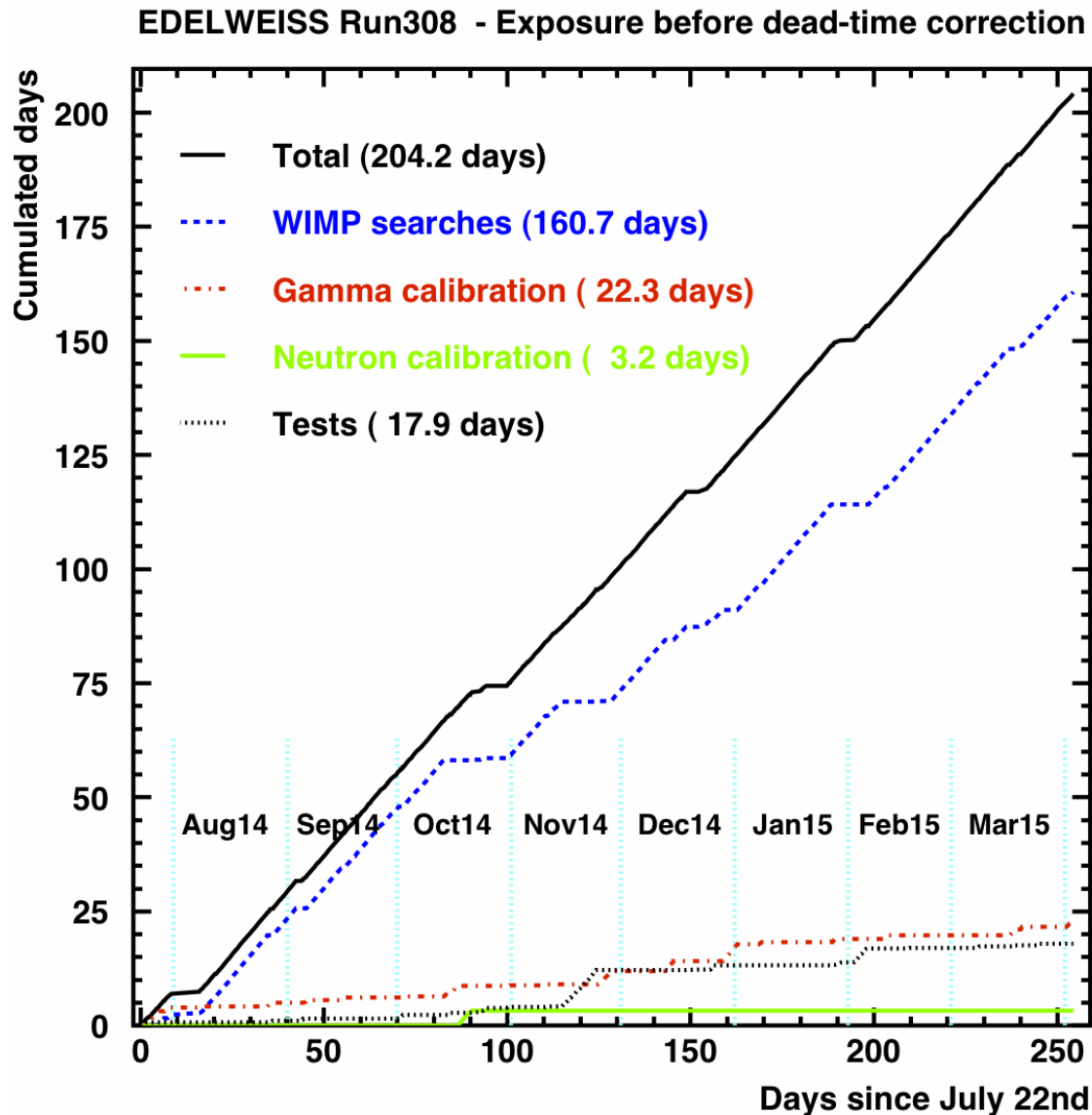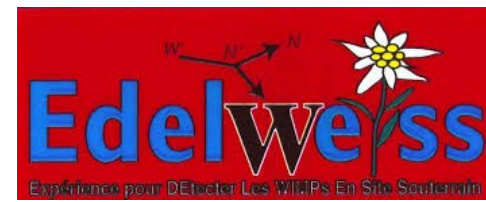- No veto **ionisation signal**

Collecting electrodes
Veto electrodes

-4V   +1.5V

Surface event
- Ionisation signal on one side
- Signal on **veto ionisation**

Part I: WIMPs and EDELWEISS
EDELWEISS-III status

EDELWEISS Run308 - Exposure before dead-time correction

WIMP data-taking : Run308
- July 2014 - April 2015

- 24 detectors read out

- 14 kg fiducial mass

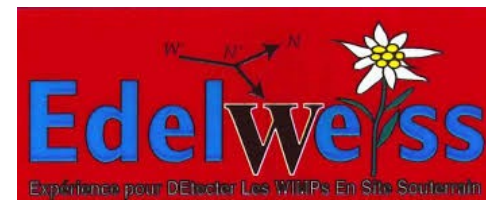- ROI blinded, except the first months of data from a single detector.

Part II
Low mass WIMP searches

Part I: WIMPs and EDELWEISS
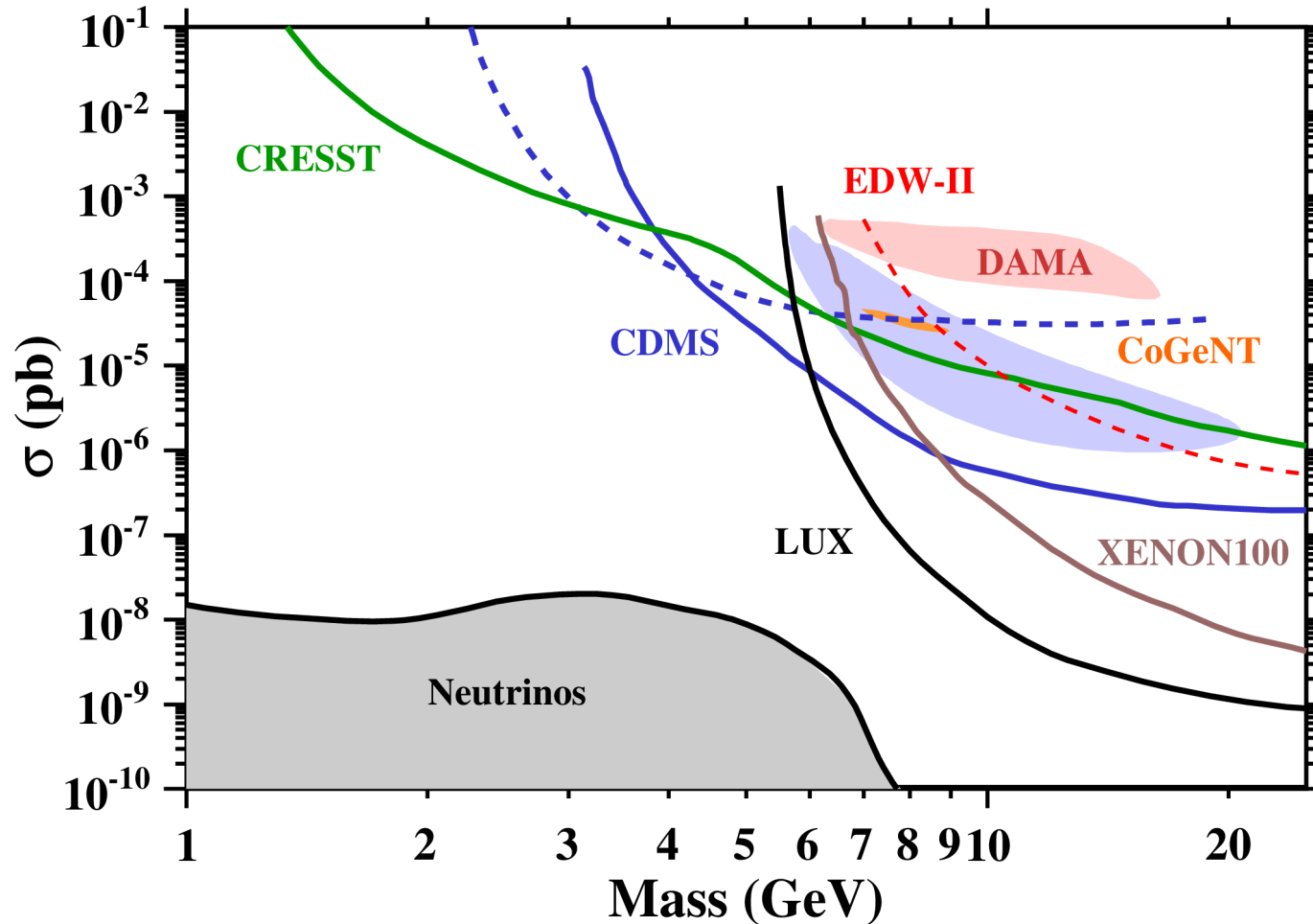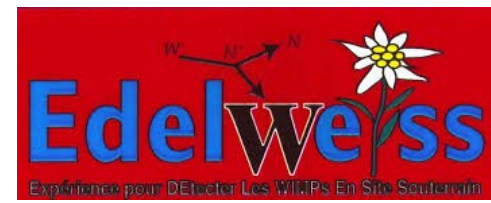## Low mass WIMPs motivations

Motivations :

- Few theoretical constraints on WIMP masses (GeV – TeV)

- Direct and indirect detection experiments have reported hints of low mass WIMPs (1 GeV – 10 GeV)

- Some theories (Asymmetric Dark Matter) naturally favour low mass WIMPs

- EDELWEISS has low thresholds and excellent discrimination which makes it competitive for low mass WIMPs.
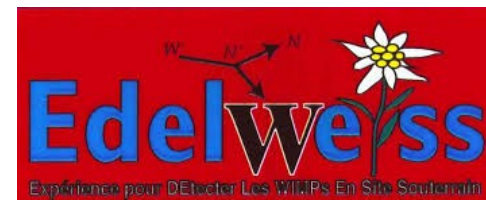
Part I: WIMPs and EDELWEISS
Low mass WIMPs searches

- Xenon-based experiments lose sensitivity for low mass WIMPs
- Further motivation : reach the neutrino floor

Part I: WIMPs and EDELWEISS
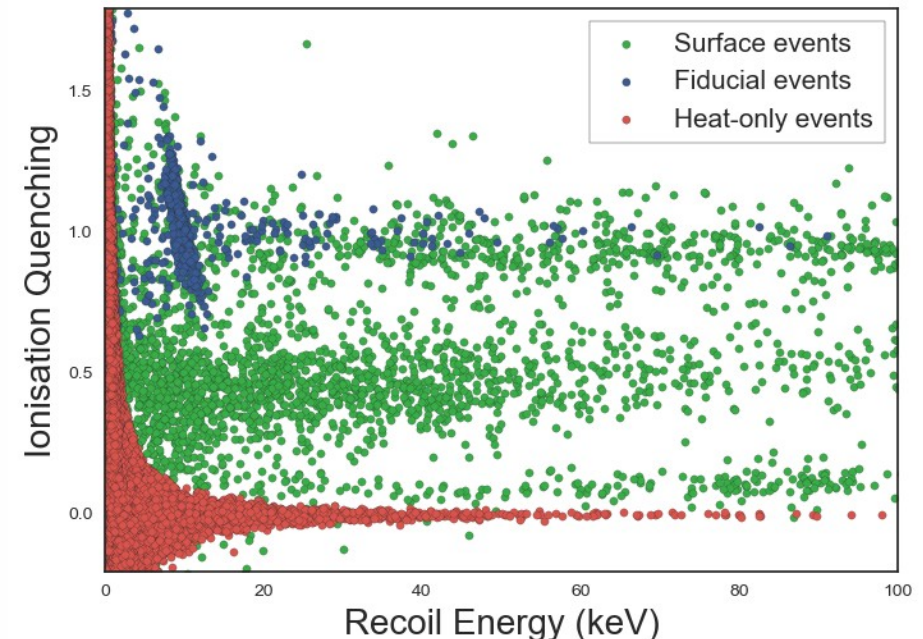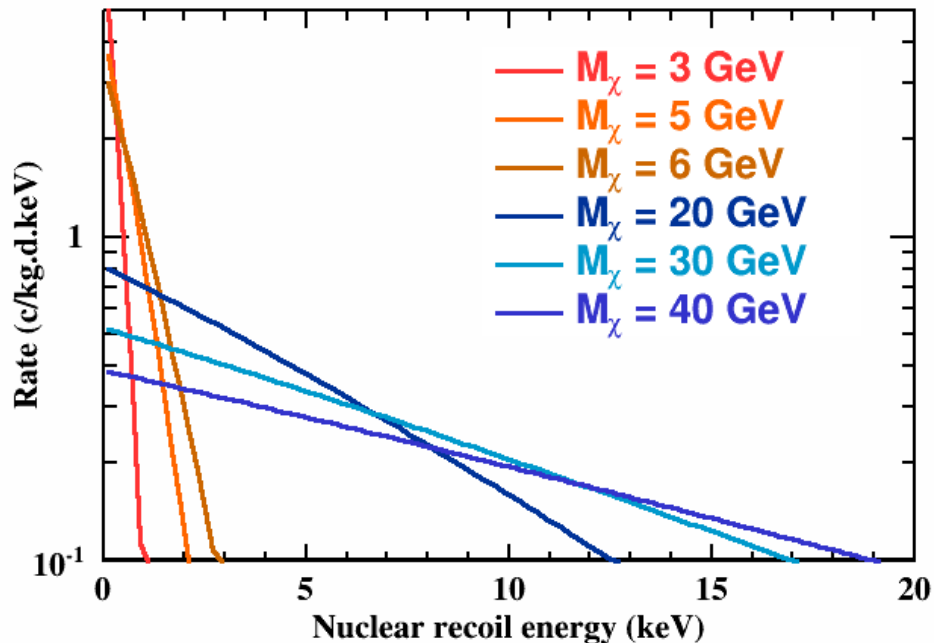## Low mass WIMPs searches : challenges

Challenges :
- Most of the signal lies near the experimental threshold
- Many background events in the signal region
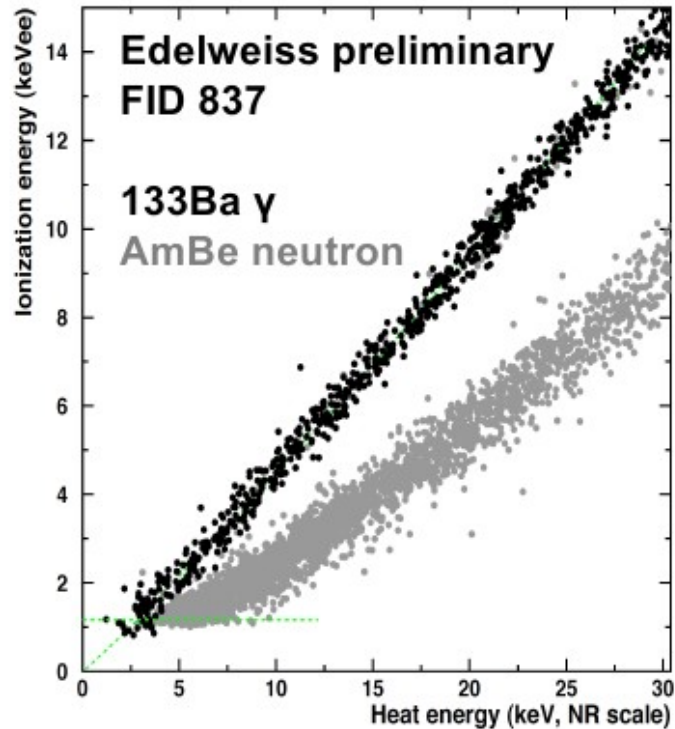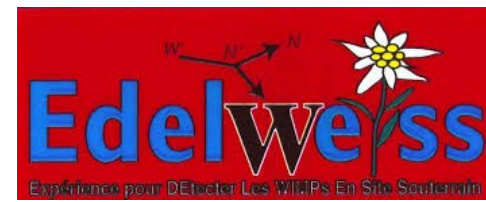- One unexpected very intense background : heat-only events, (origin unknown but not radiogenic).

Solution :
- Multivariate analysis.

Edelweiss preliminary
FID 837

133Ba γ
AmBe neutron

	EDW- III subsample FID837
Exposure	35 kg days
Threshold	3.6 keVnr
FWHM Ion Fiducial	0.54 keVee
FWHM Heat	0.33 keVee

✓ **Demonstration with a first data set** after 6 months of data taking:

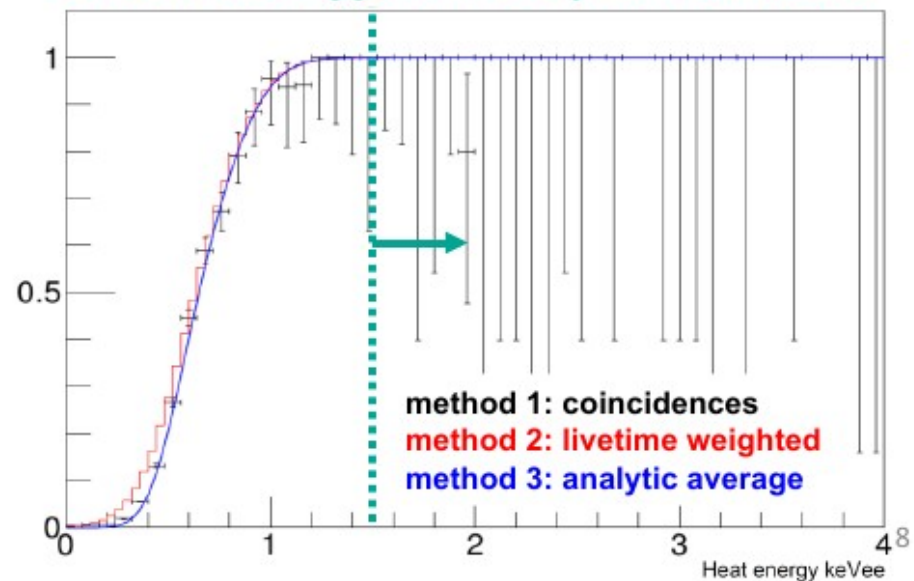- **Improved performances at low energies**
  - largely due to new electronics (*J Low Temp Phys 167 (2012) 645*)

- **Good γ/recoil discrimination**
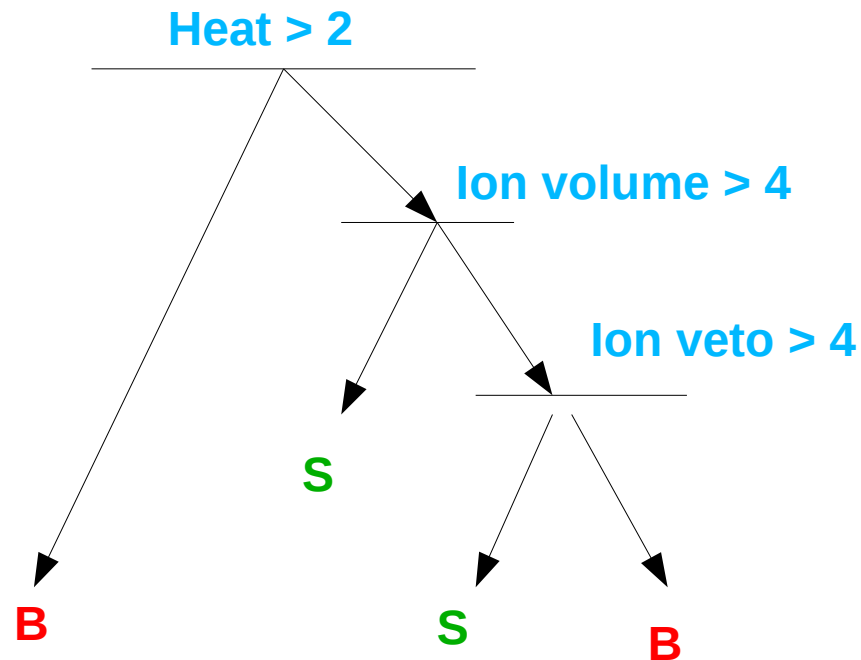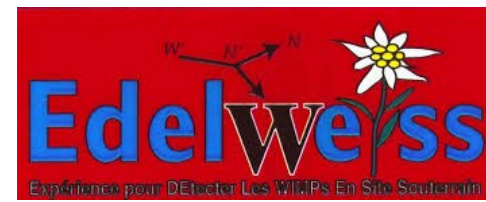 - 1 keVee in Ionization (4 σ)
  - 3 keVnr in Heat

DAQ online trigger efficiency for the detector

method 1: coincidences
method 2: livetime weighted
method 3: analytic average

Part I: WIMPs and EDELWEISS
Low mass WIMPs searches : BDTs
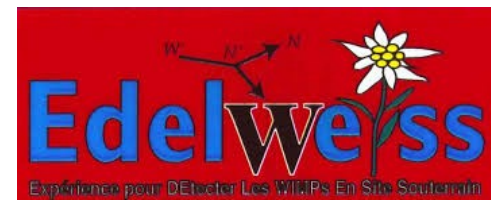

Decision trees :

- They make a series of rectangular cuts in the parameter space
- Each cut is optimised to maximise the Signal/Background separation
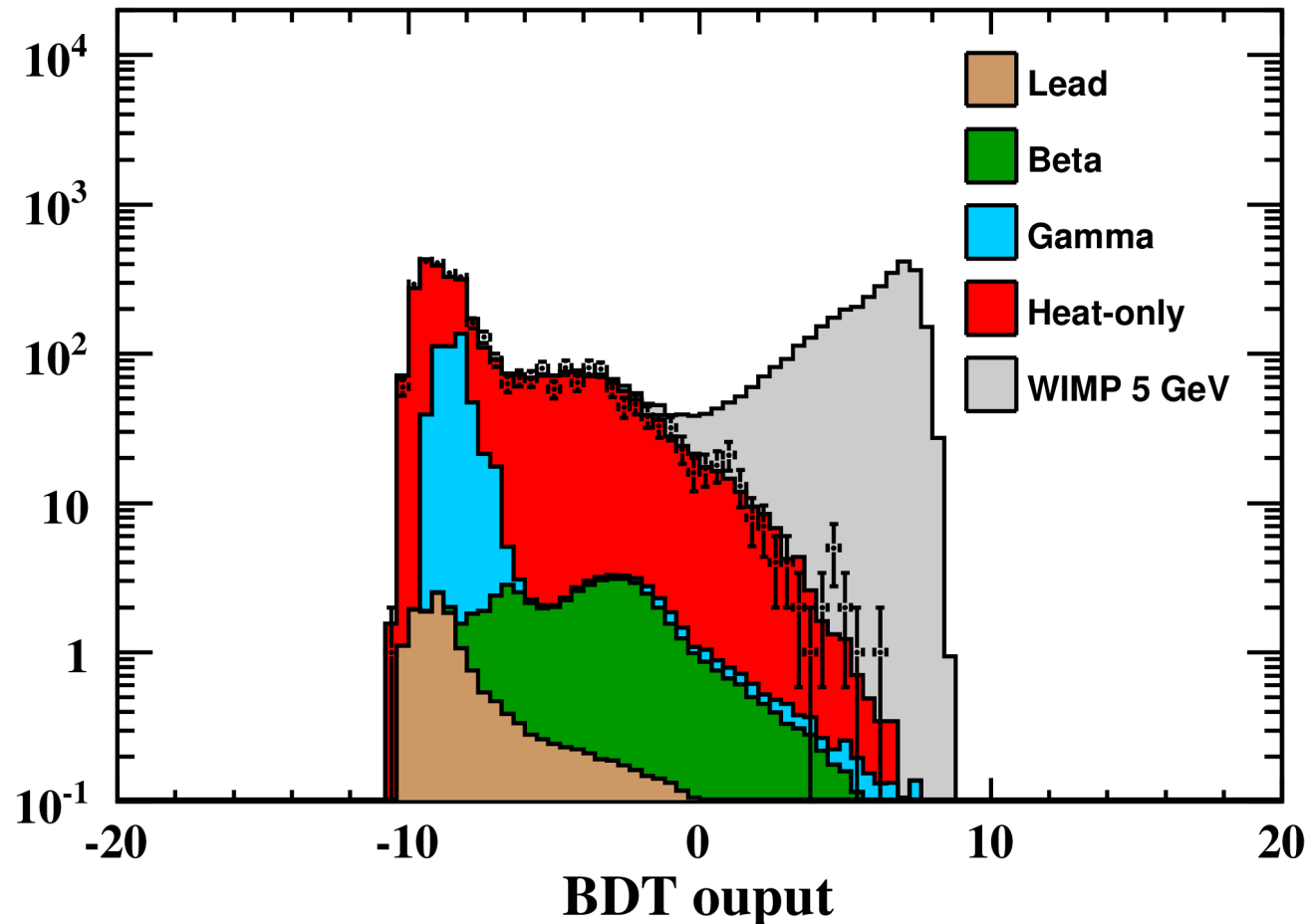
Boosted decision trees :

- Several iteration of the decision tree
- Events misclassified get more weight in the next iteration
- Final predictions are averaged

Low mass WIMPs searches : BDTs

- The BDTs are trained on simulated data
- New BDTs are trained for all masses of interest
- Final output = 1D variable to discriminate signal/background

Part I: WIMPs and EDELWEISS
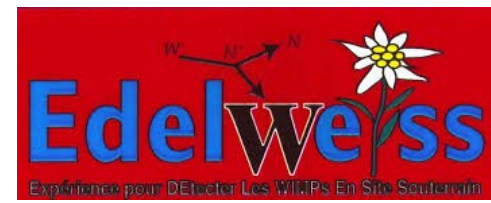## Low mass WIMPs searches : BDTs

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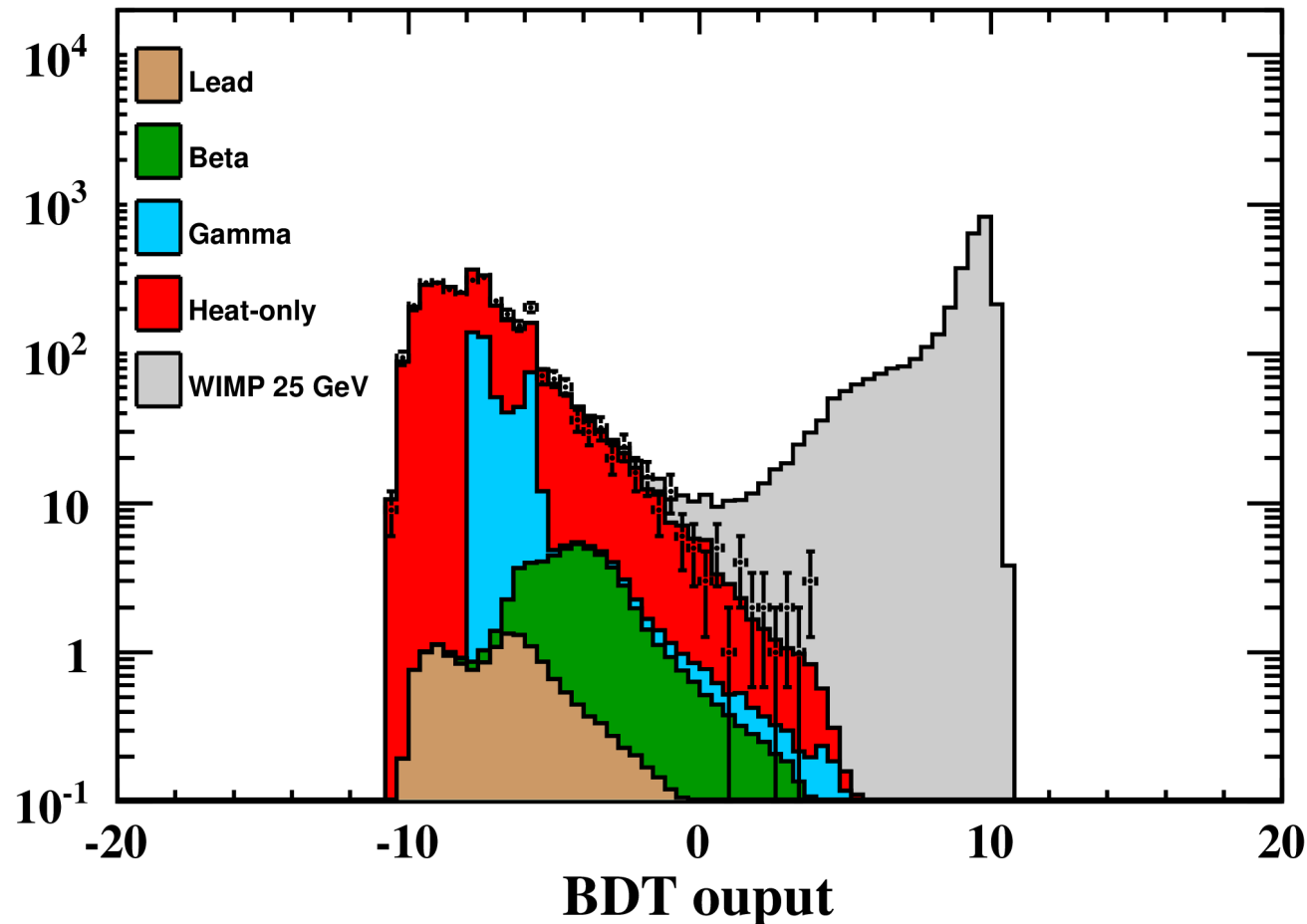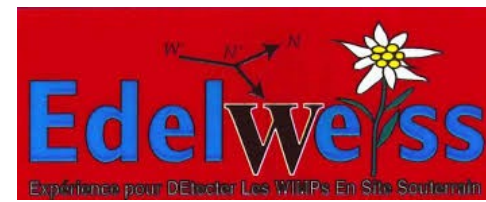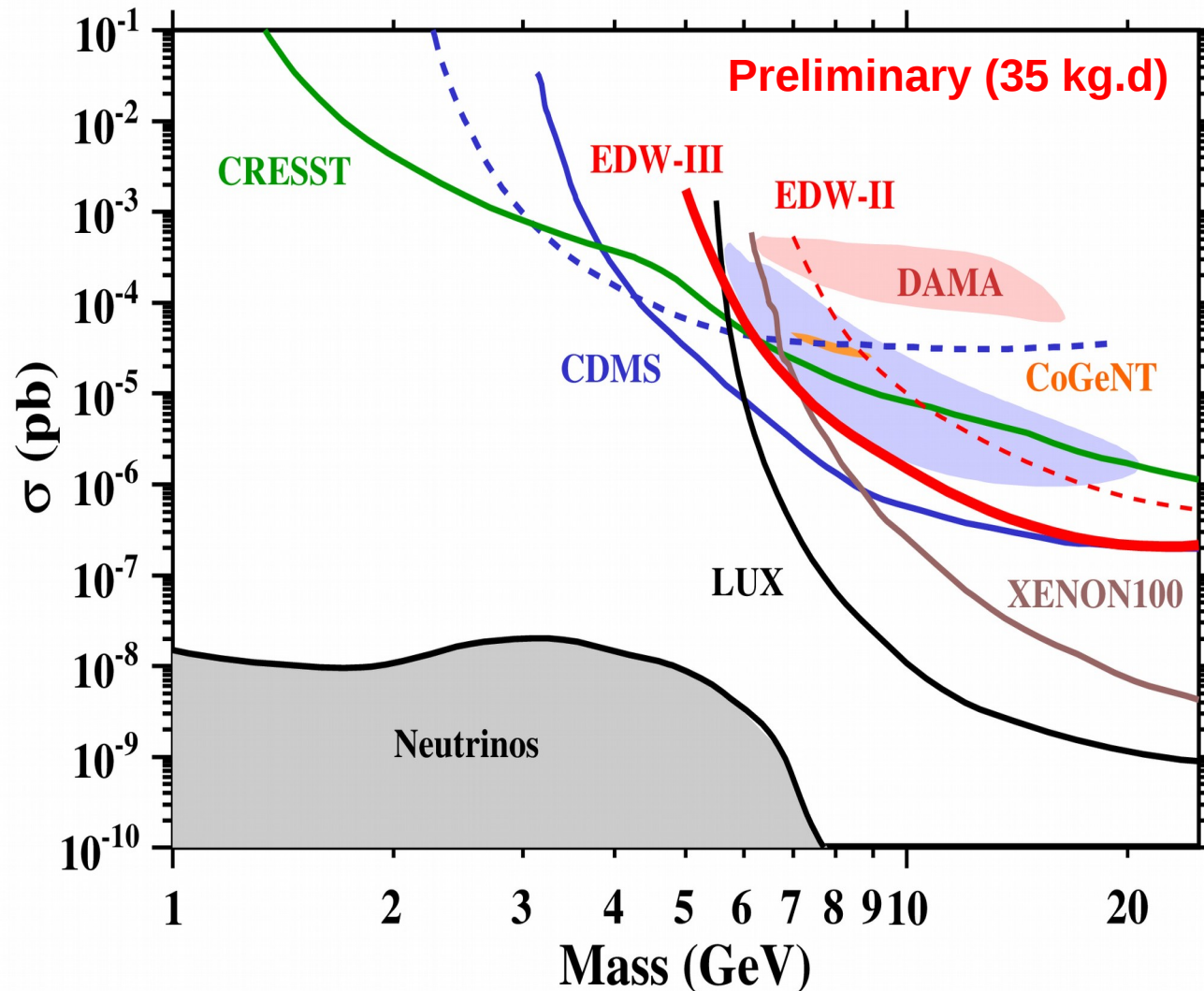- Final output = 1D variable to discriminate signal/background

Part I: WIMPs and EDELWEISS
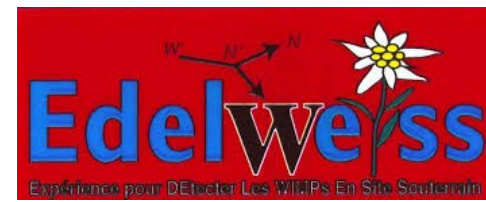## Low mass WIMPs searches : limit

- Found no evidence for a signal
- Compute upper limit after cut on BDT output

Part I: WIMPs and EDELWEISS
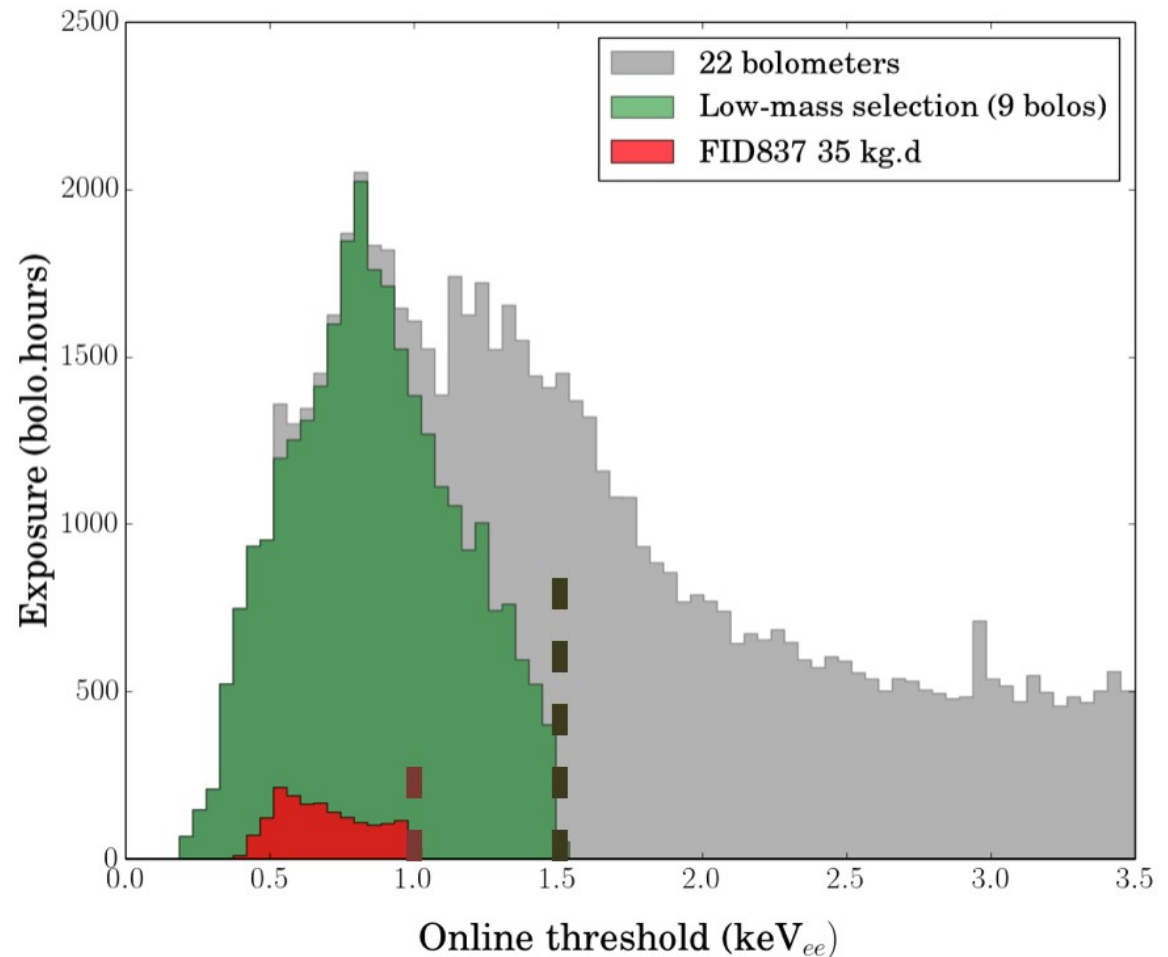## EDELWEISS-III prospects

Run308 analyses :

- **Low mass**
  - 9 bolometers selected, x10 increased exposure, lower threshold
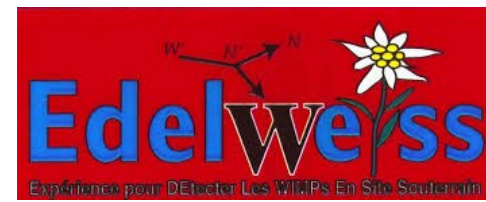 - unblinding in coming weeks

- **High mass**
  - Analysis ongoing

New Run309 :

- 12 new detectors cabled
- 1 High voltage detector
- R&D on heat-only events

Part I: WIMPs and EDELWEISS
EDELWEISS-III prospects

Heat-only events:
- Main background of the experiment
- New detector holders under study
- Main priority

Ionisation channel:
- New electronics design to reach $\sigma(\text{Ion}) < 100$ eV
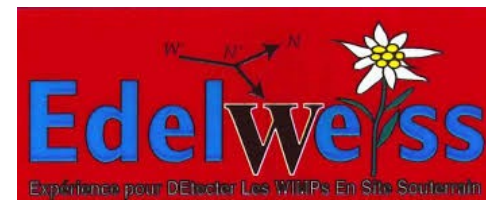- This will help discrimination at low energies

High voltage strategy:
- Increase the detector voltage
- This improves the heat threshold but the ionisation discrimination is reduced
- Currently tested at LSM

EDW-III background
350 kg.d $\sigma_E\_\text{ion} = 100$ eV$_{ee}$ $\sigma_E\_\text{heat} = 100$eV
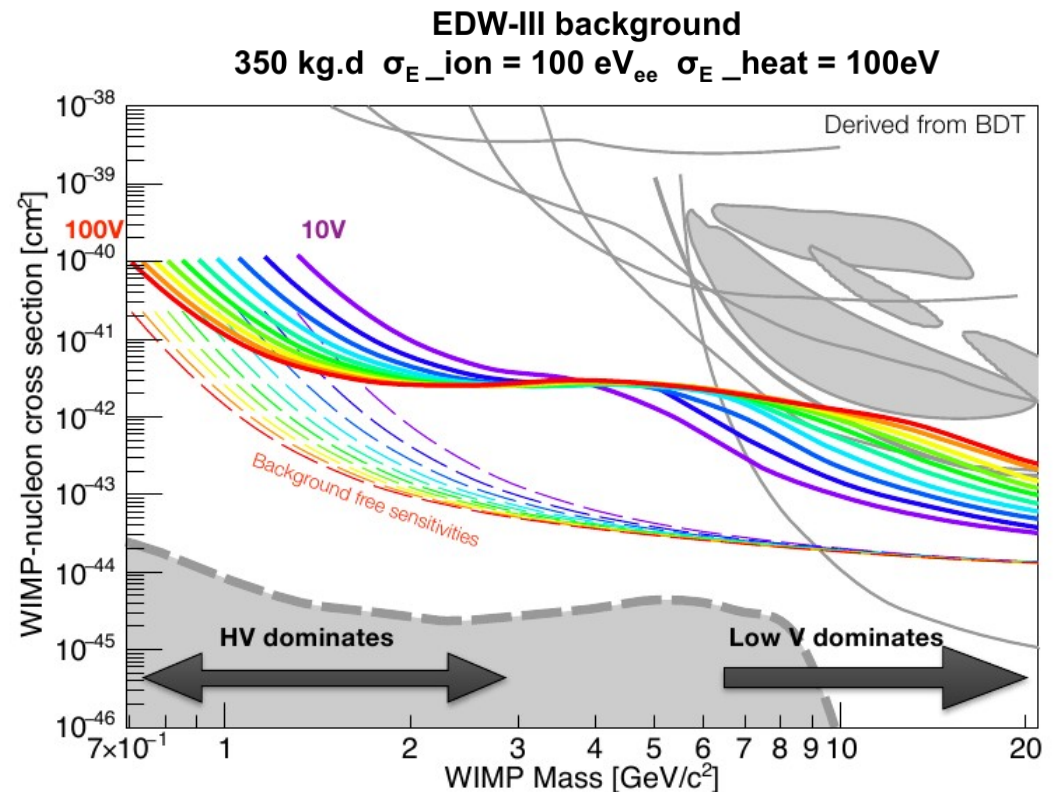
Part I: WIMPs and EDELWEISS
EDELWEISS-III conclusions

Run308:

- The analysis of a subset of the data (35 kg.d) already shows competitive results
- Final analysis ongoing, with improved threshold and > 10x exposure
- Expect **fast improvements.**

Roadmap to low mass WIMPs:

- Get rid of heat-only events, improve ionisation resolution and decrease heat threshold with high voltages.
- Projection scenario shows that the EDW-III setup at LSM is compatible with a low mass program up to few 1000 kg.d : < 2018-19