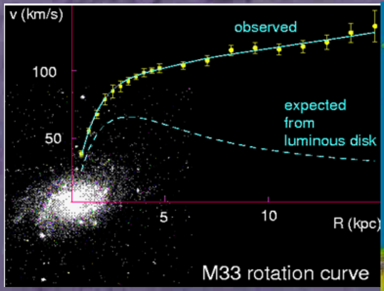
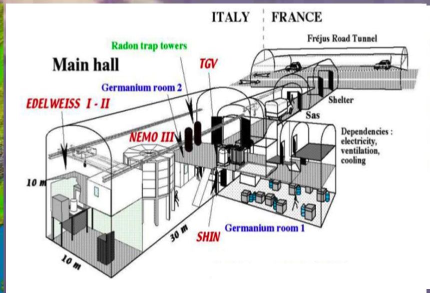
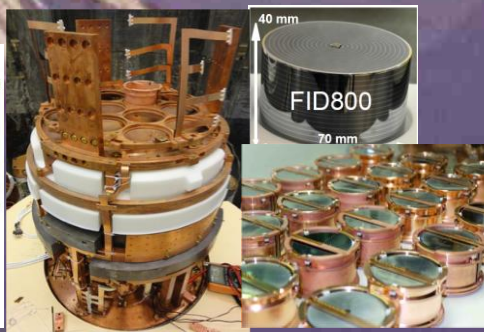
Maryvonne De Jesus
(for the Edelweiss Collaboration)

Edelweiss-III experiment: Status and First Data

AXION-WIMP 2015, 22 - 26 June 2015 University of Zaragoza, Spain

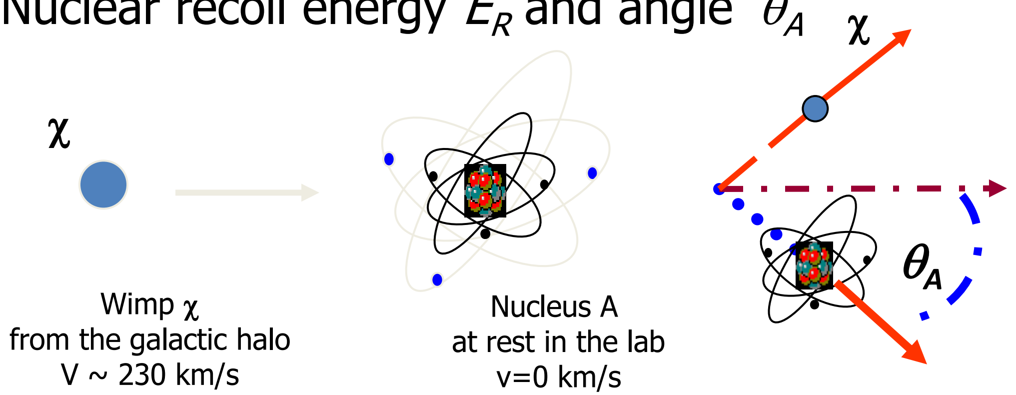






Dark Matter Direct Detection Principle

Nuclear recoil energy E_R and angle θ_A



$$E_R^{max} = E_\chi \frac{4 m_\chi m_N}{(m_\chi + m_N)^2} \cos^2 \theta_A$$

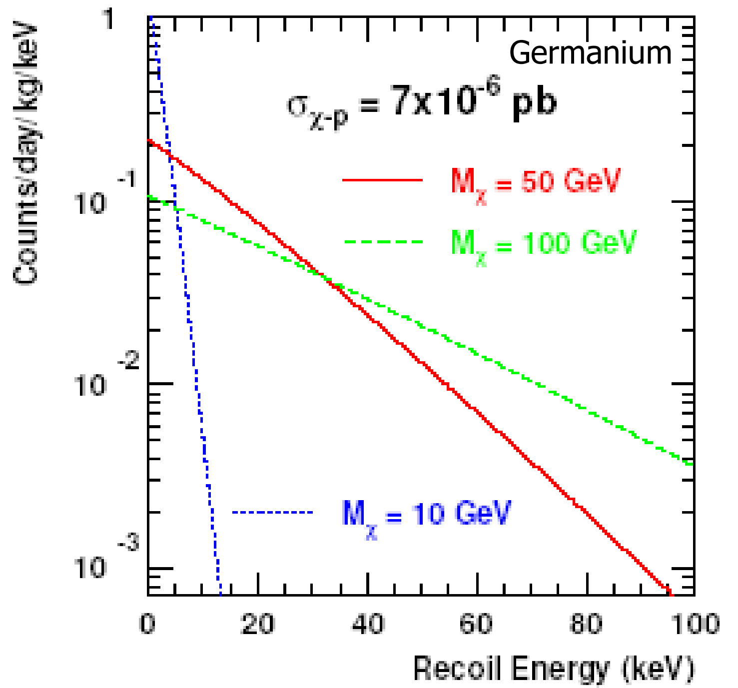
~ 1 keV < E_R < ~100 keV

$$R \propto \frac{\rho_0 \sigma}{m_\chi m_N} \langle v_\chi \rangle$$

- **Expected rate** < 1 interaction per kg per year
- **Recoil Spectrum** : exponential shape
  -> rather similar to most backgrounds

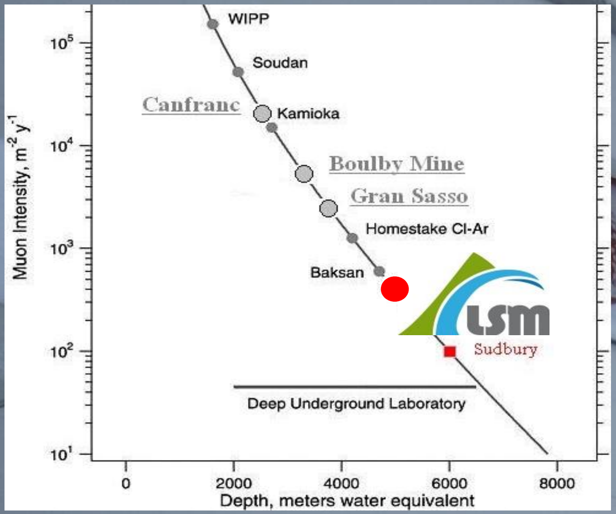
$$\frac{dR}{dE_R} = \frac{R_0}{E_0 r} e^{(-E_R / E_0 r)}$$

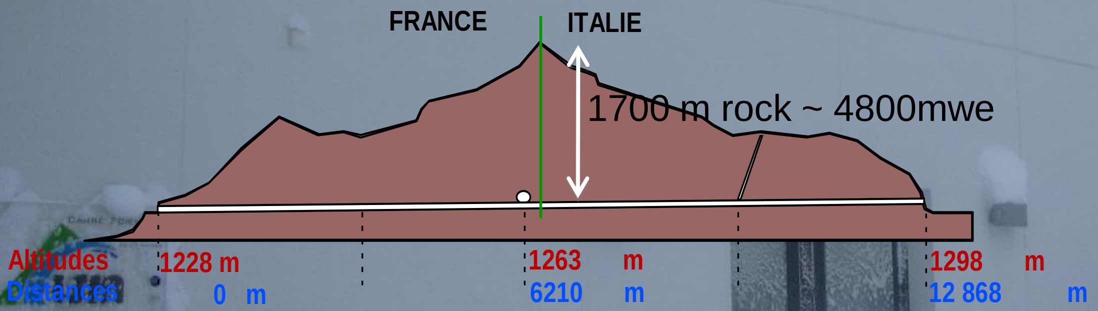
- **Radioactive background** of most materials is much higher than event rate
- **Requirements :**
  - **-> Low energy threshold**
  - **-> Shields and Material selection**
  - **-> Large detector mass**
  - **-> Underground Laboratory**

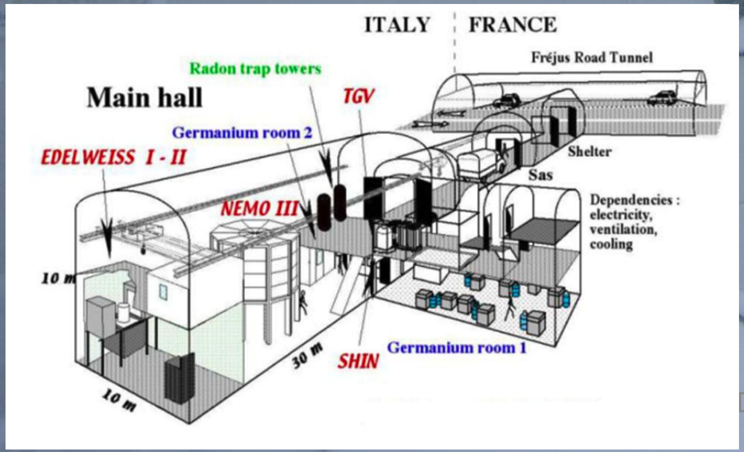


Modane Underground Laboratory

(Laboratoire Souterrain de Modane)
Deepest underground Lab in Europe
5 $\mu/m^2/day$
~10^{-6} $n/cm^2/s$ (E>1MeV)







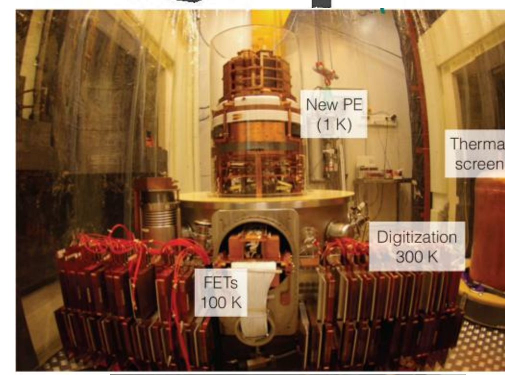
http://www-lsm.in2p3.fr/

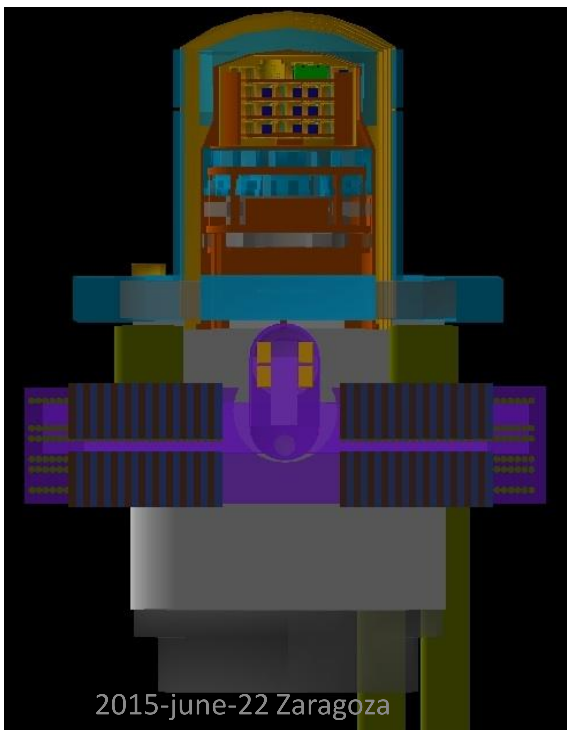
EDELWEISS III set-up

- **Clean Room** (Class A: <10000 p/m3) with deradonized air suply (from 10 Bq/m^3 → ≈ 30 mBq/m^3)
- **Active muon veto** : 97.7% geometric coverage

$N^{\mu\text{-}n} = 0.6\ ^{+0.7}_{-0.6}$ evts (90% CL, 3000kg.d)

- **External PolyEthylen Shielding** (n): 50 cm
- **Externel Lead Shielding** (β,γ) : 18 cm + 2cm Roman Lead

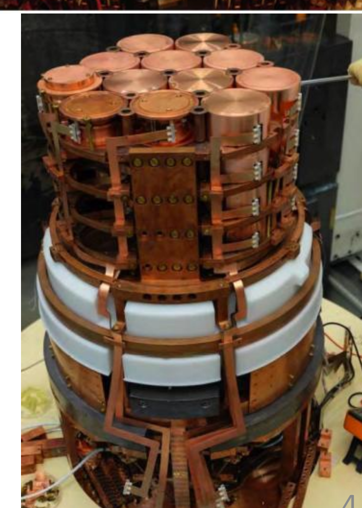




- Extra 15 cm Internal Roman Pb (1K)
- Material selection

New w/r to EDW-II

- Extra 10 cm PE shield below detectors
- NOSV Copper
- New Kapton cables and connectors:
  1K-10mK (Steel) and 10mK-10mK (Cu)
- New electronics
  (FETs 100K and Digitization 300K)
- New Cryogenics to reduce microphonics



Edelweiss Germanium detectors

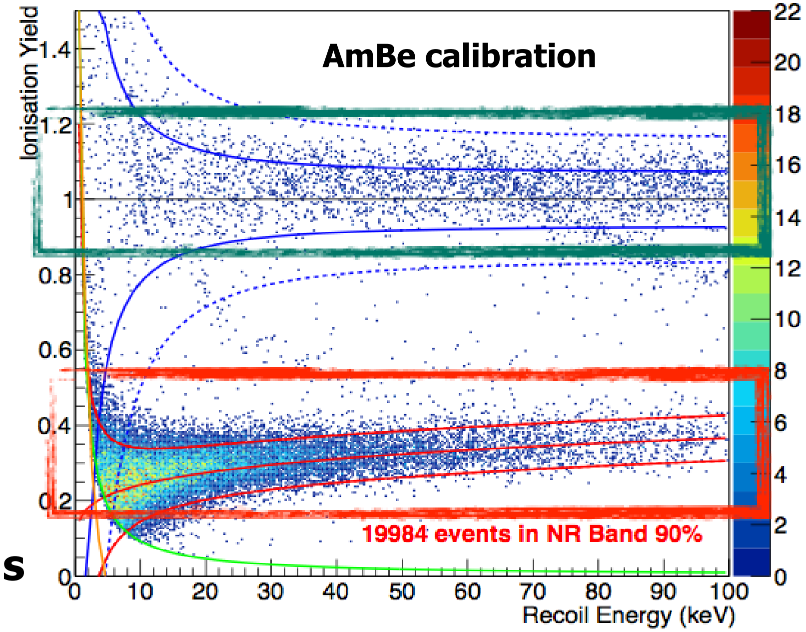
Two measuring channels

•**Heat (phonons)** with NTD thermal sensors
(Neutron Transmutation Doped sensor):
Full thermalization of the phonons within the bulk of the detector and the sensor itself

$$E_{recoil} \approx E_{heat}$$

•**Ionization yield** for particle identification,
$Q = E_{ion}/E_{recoil}$:

Q = 1 for electron recoils
$Q \approx$ 0,3 for nuclear recoils

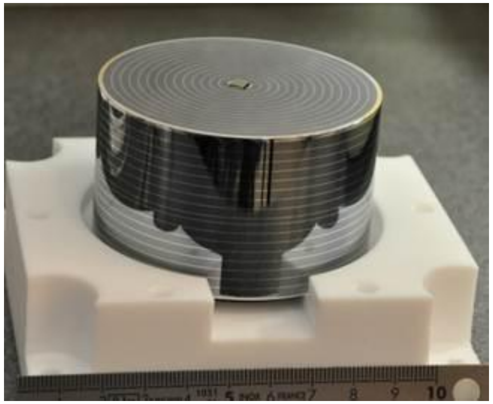


Most backgrounds (e, ©) produce electron recoils

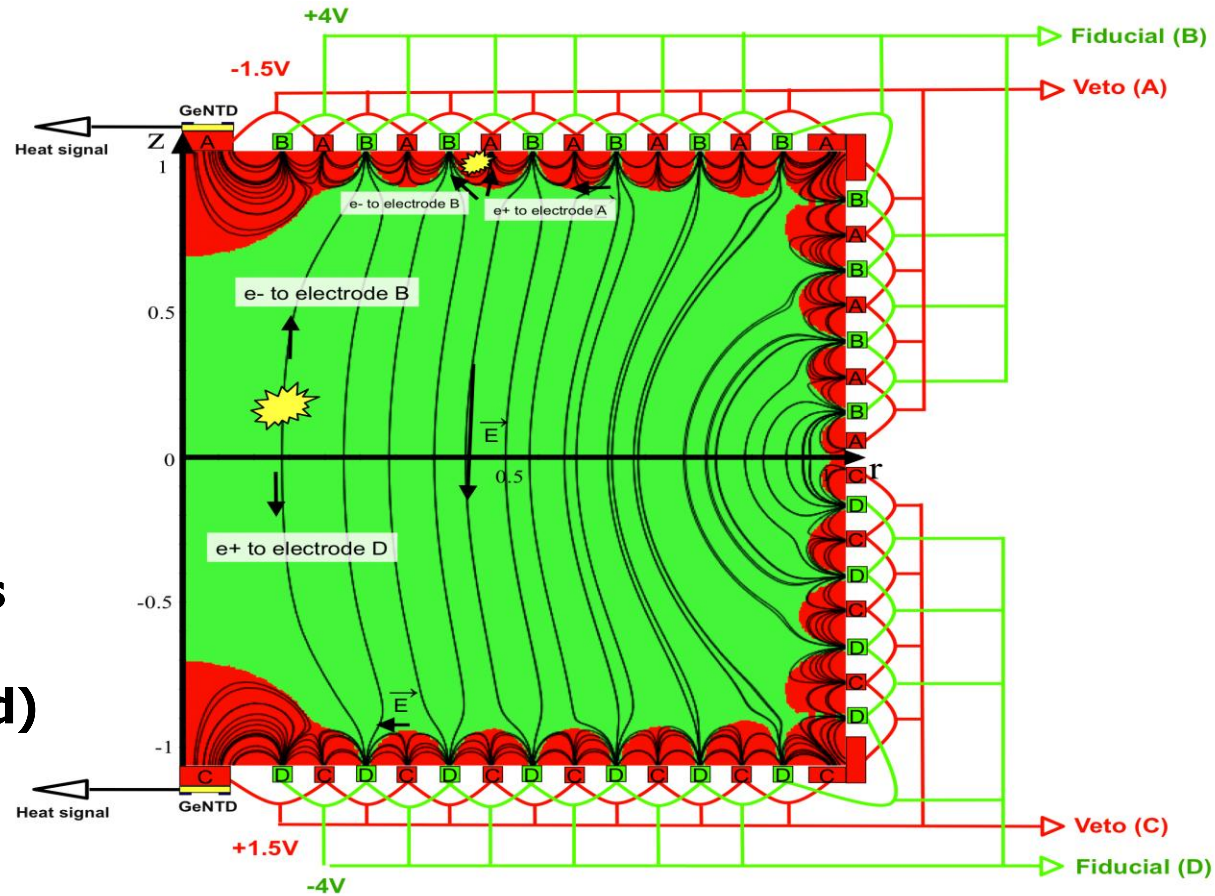
WIMPs and neutrons produce nuclear recoils

FID Ge-bolometers: Fully InterDigitized design

Height: 4 cm



Diameter: 7 cm

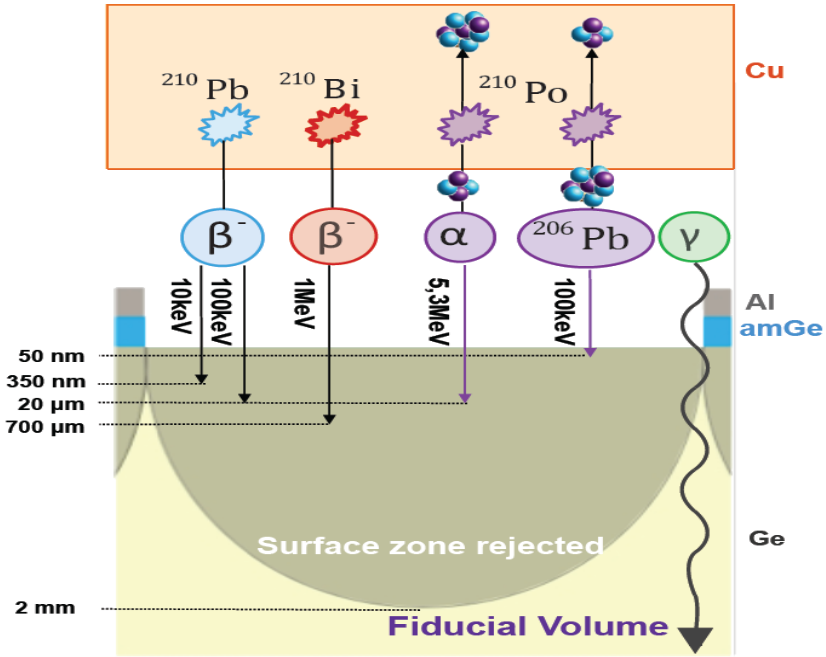


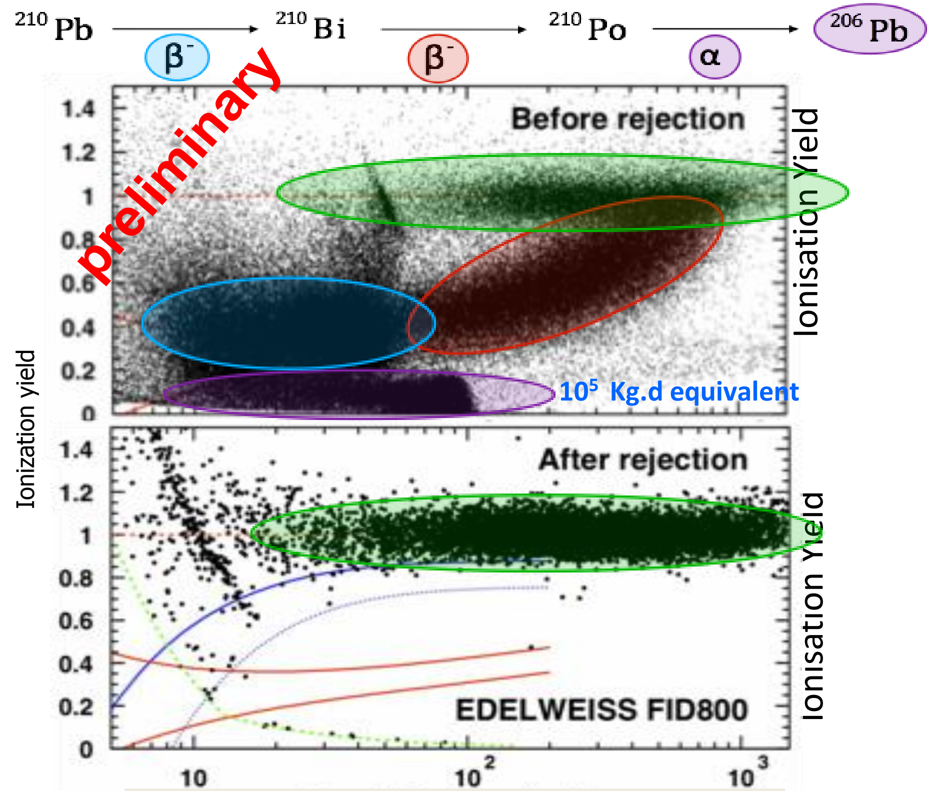
- **~ 820 g HP-Ge Crystals**
- **2 Ge NTD**
- **F(ully) I(nter)D(igitized) Aluminium electrodes**

-> **Vetoing surface events**

(~**600 g** fiducial mass)

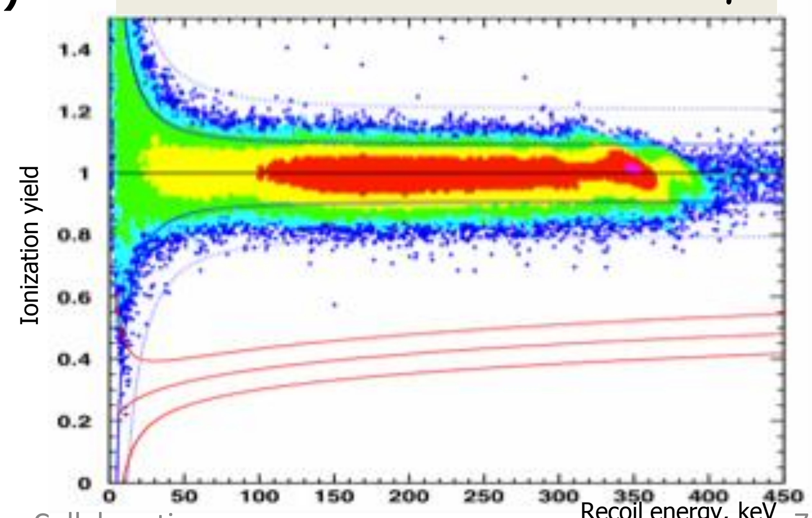
FID Surface Rejection





FID Surf rejection factor 4×10^{-5} (90% CL, >15 keV)

calibration with ^{133}Ba 411663 γ



FID Gamma Rejection

Gamma calibration with ^{133}Ba

FID Gamma Rejection factor < 5.6×10^{-6}

(EDW-II ID Rejection factor: 3+-1 x 10^{-5})

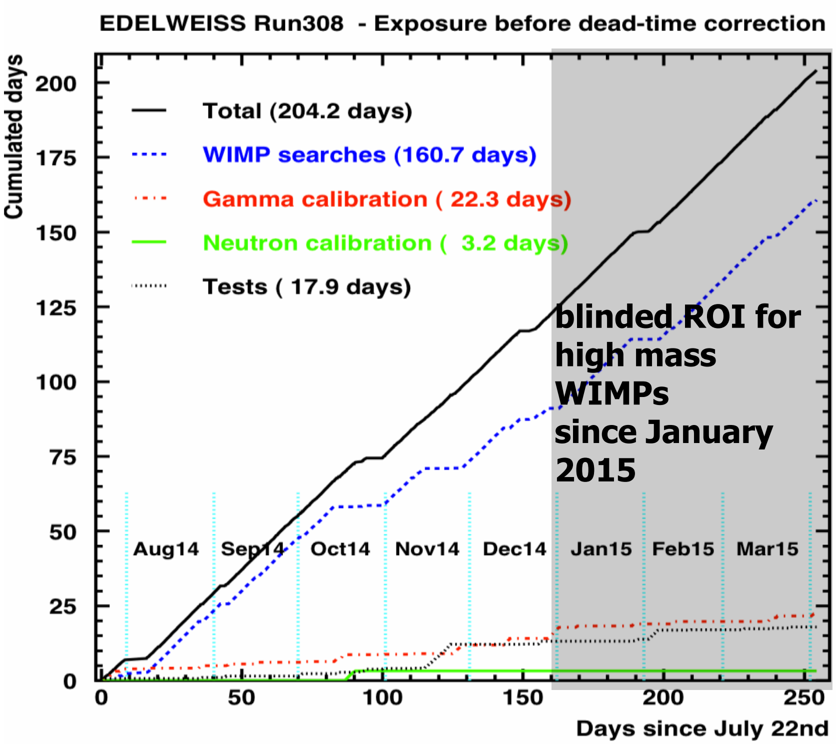
RUN308 Status

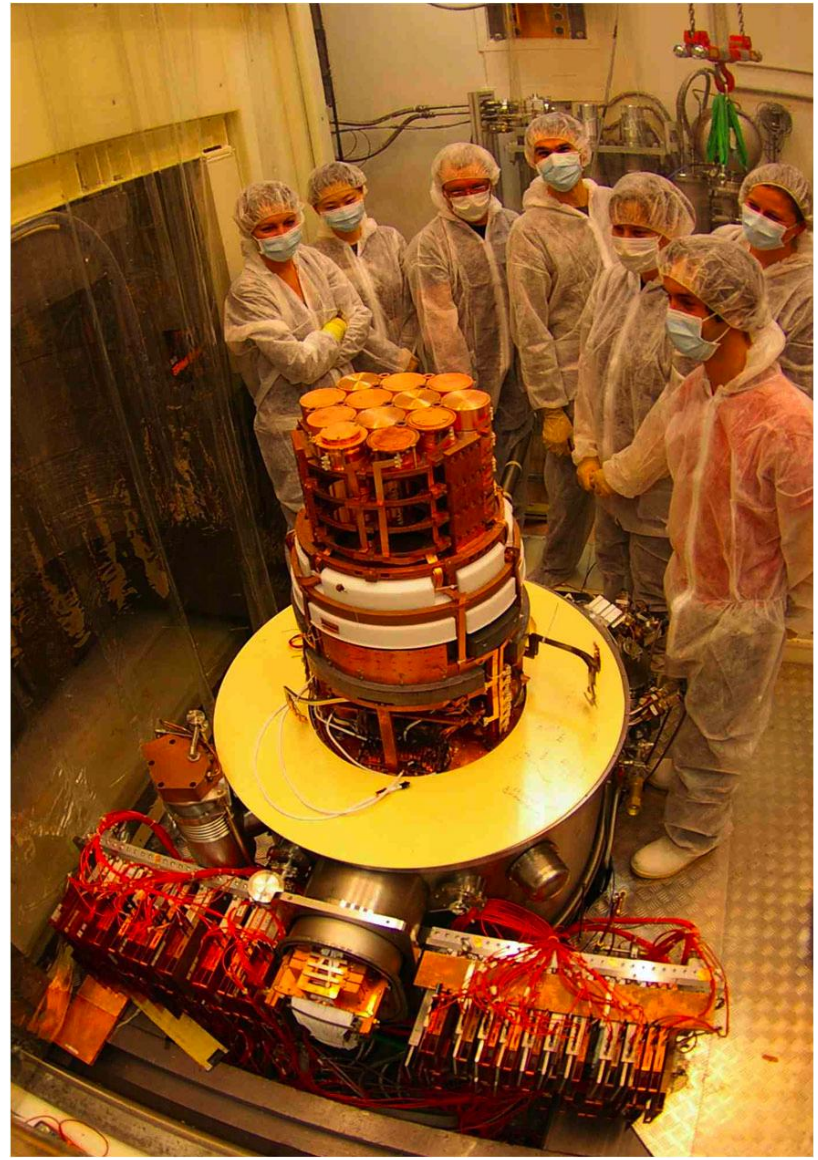
WIMP data-taking: July 2014 – April 2015

- **36 x 800 g detectors installed in cryostat**
- **24 x 800 g detectors cabled**

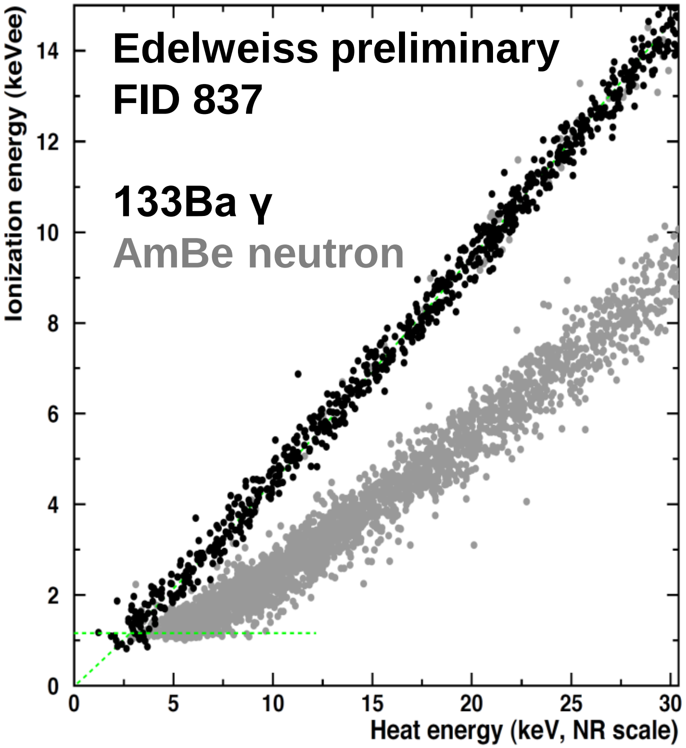
  -> more than 14 kg of fiducial mass in Ge

- **Facility able to acquire 3000 kgd per 6 months**





RUN308 Status: Performance of the selected FID800



	EDW- III subsample1 x FID800
Exposure	35 kg days
Threshold	3.6 keVnr
FWHM Ion Fiducial	0.54 keVee
FWHM Heat	0.33 keVee

After 6 months of data taking: demonstration with a first data set

Improved performances at low energies (largely due to new electronics, i.e. improved baseline resolution)

Good γ/neutron discrimination

- **1 keVee in Ionization (4 σ)**
- **3 keVnr in Heat**

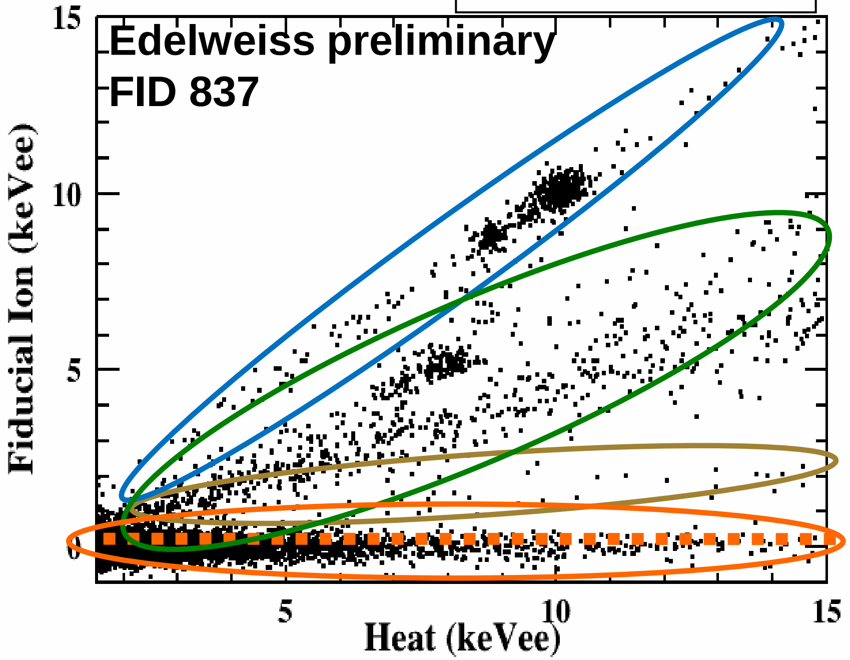
One detector with good baselines and low threshold

Expect ~7 other detectors with similar performances

→ **Low-mass WIMP analysis**

RUN308 Status: First Low Mass WIMP search with EDW-III Data

Before cuts



Fiducial gamma

Surface γ & β

Pb

Heat Only Events

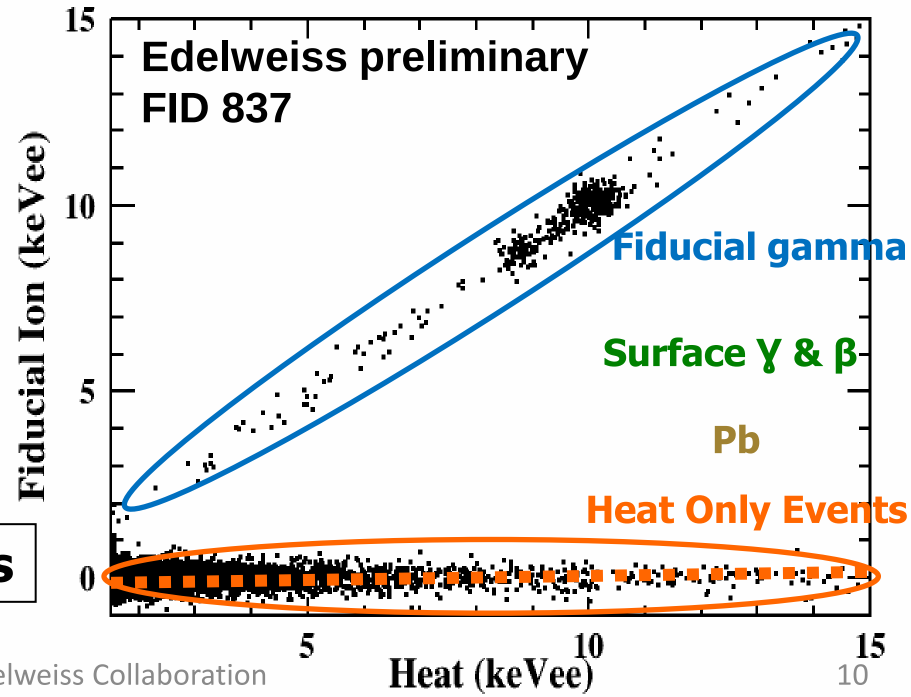
PRELIMINARY

1 FID sub-sample: 35 kg days

Define a rough region of interest

- **Singles**
- **1.5 < Eh < 15 keVee**
- **0 < Ei < 15 keVee**
- **Ev < 5 σ**

After cuts



RUN308 Status: Low mass analysis ingredients:

WIMP signal and bkg modeled within ROI

Wimp model :

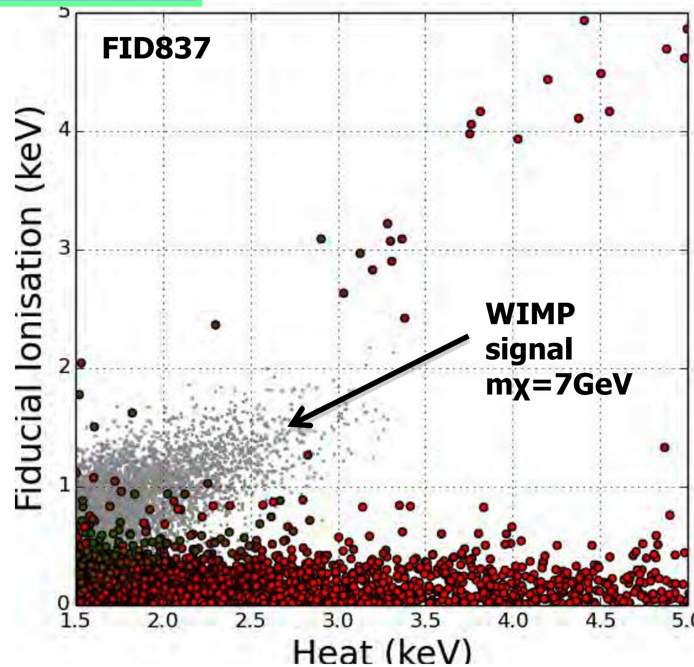
Monte-Carlo simulations -> Wimp distribution R($M_{\chi.}$, σ_{WN})

MC events converted into 6 variables (4 ionisation and 2 heat)

Background models are data driven:

- Use regions w/o signal (sideband) to build the model

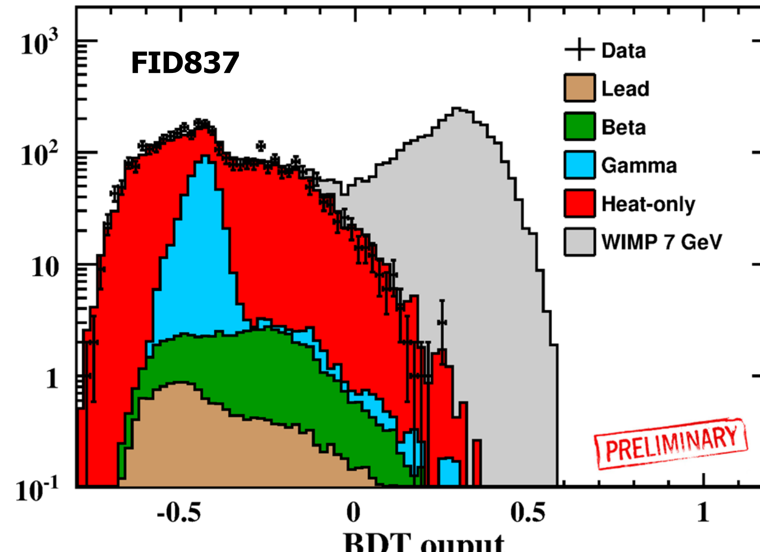
- Use calibrations (^{210}**Pb)** as crosscheck



Boosted Decision Tree (BDT) within ROI

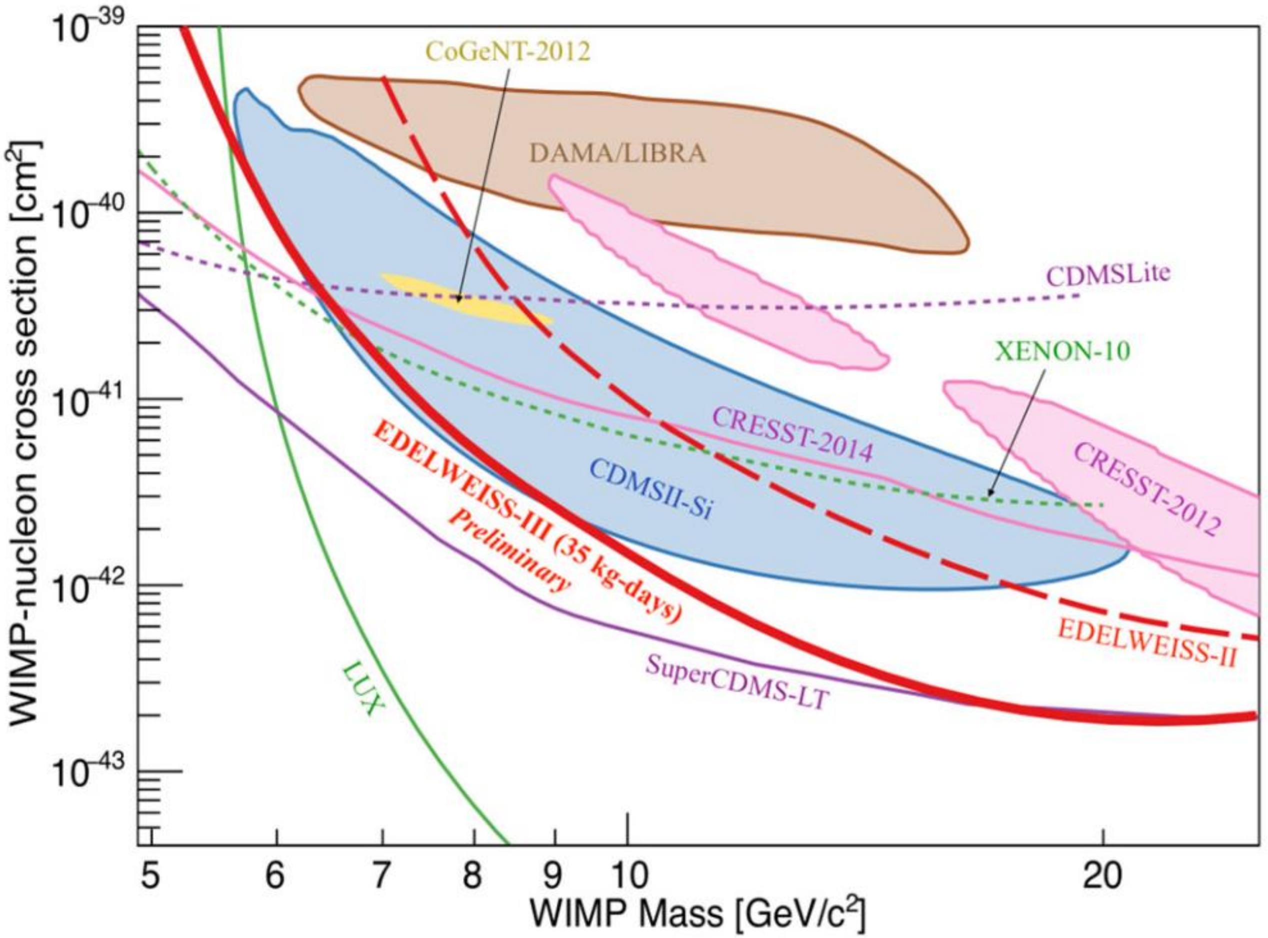
Combine the 6 variables (4 ionisation and 2 heat) for optimized Signal/Background discrimination

-> one BDT per WIMP mass
-> cut and efficiency on signal



RUN308 Status: preliminary results

-> conservative limit: w/o background subtraction



- ★ **limits in agreement with previous projections**
- ★ **already competitive results for small subset of available data**

Clearly room for progress

Summary and Outlook

- **Low energy WIMP mass analysis shows competitive results for small set of data**
- **Expect fast improvements in sensitivity:**
  - x10 more data of similar quality
  - Will decrease the analysis threshold
- **High WIMP mass analysis ongoing**

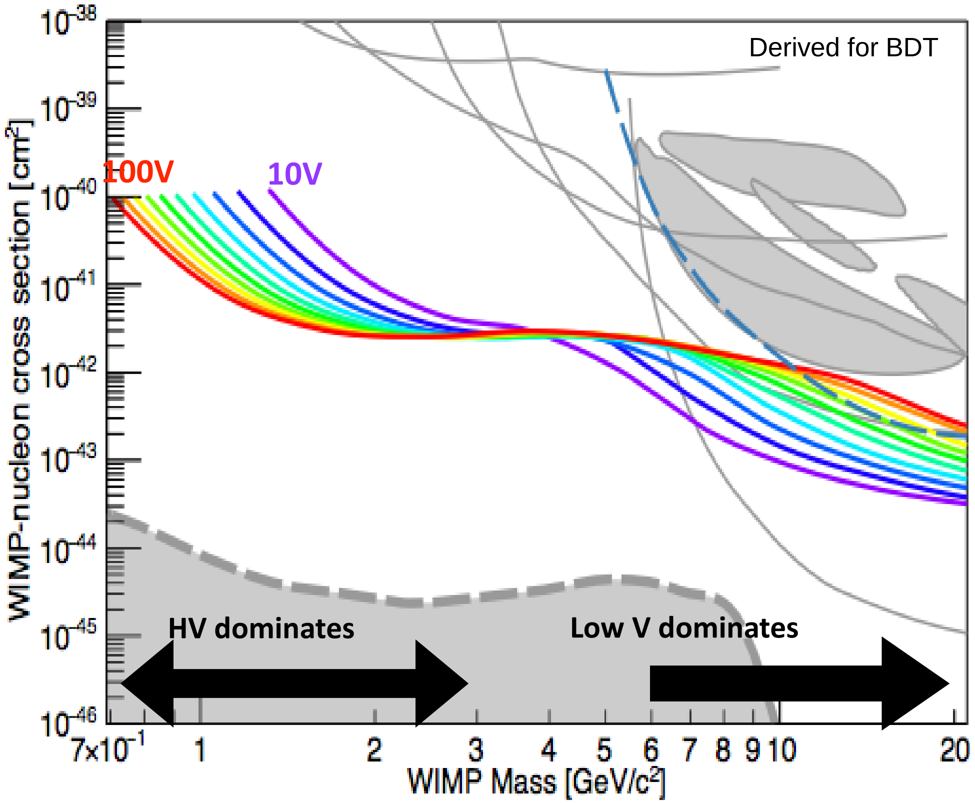
- **Since June 8th Run309 started !!**

R&D

- **HEMT** to lower ionization threshold

  (High Electron Mobility (field-effect) Transistor)

- **HV studies** (Neganov-Luke amplification)
  - reduction of Heat-Only events by x100
  - 100 eV (RMS) ion & heat
  - 350 kg-days



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

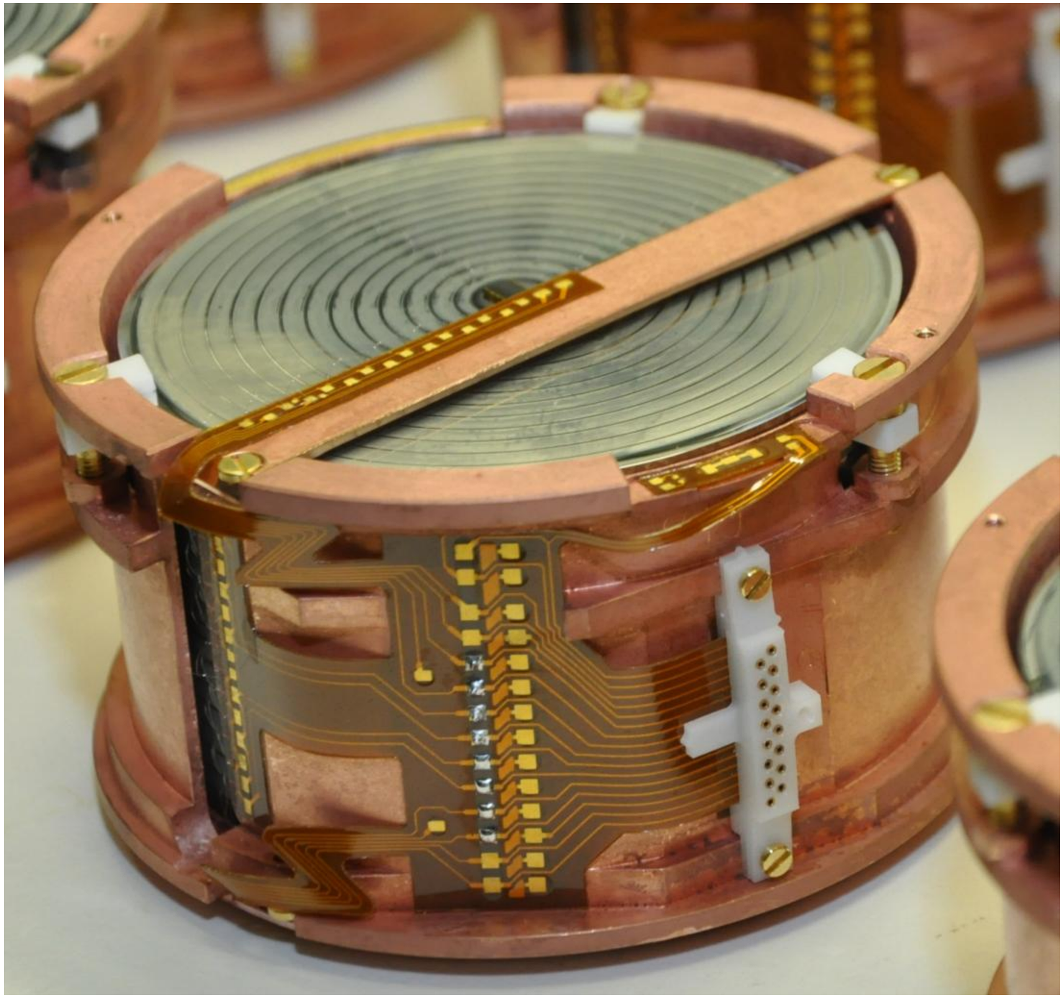
Oxford University
University of Sheffield

Thanks!

Backup Slides

Edelweiss-III: 36 new FID800 produced …

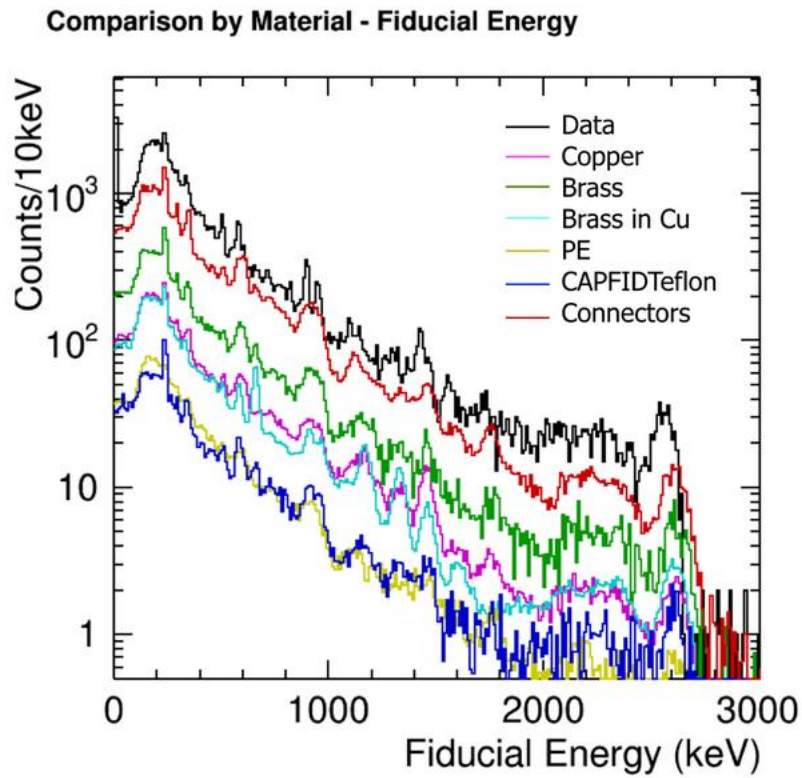
FID Ge-bolometers: Fully InterDigitized design



EDW-III background budget

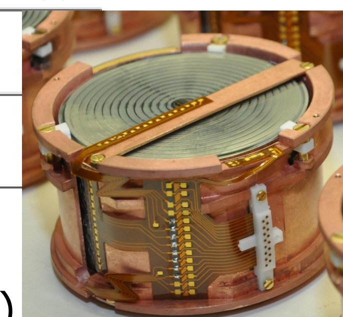
- **Gamma Background** In the fiducial volume, the gamma rate in ROI (100keV-4MeV) is 235counts/(kgd), considering a fiducial exposure of about 380kgd
- fiducial volume, the gamma rate in ROI (20-200keV) is 70counts/(kgd), considering a
  fiducial exposure of about 380kgd.

(best fit to the experimental spectrum requires additional scale factor to the contaminations assumed in simulations: 60Co(0.45) 40K(0.4) 238U(0.54) 232Th(0.9))



- **Neutron Background**
  (SOURCES4A & GEANT4)

Number of Ge detectors	kg·d	E_{th} >10 keV; Second Hit>3 keV Total	Single	E_{th} >20 keV; Second Hit>10 keV Total	Single
24	5431	4.8	1.4	3.2	1.1
36	8147	7.9	2.2	5.2	1.7



Internal radiogenic neutrons limit total exposure :

Expected <1 bkg event starting 4500kgd (2.5×10^{-9} pb) to 12000kgd (10^{-9} pb)

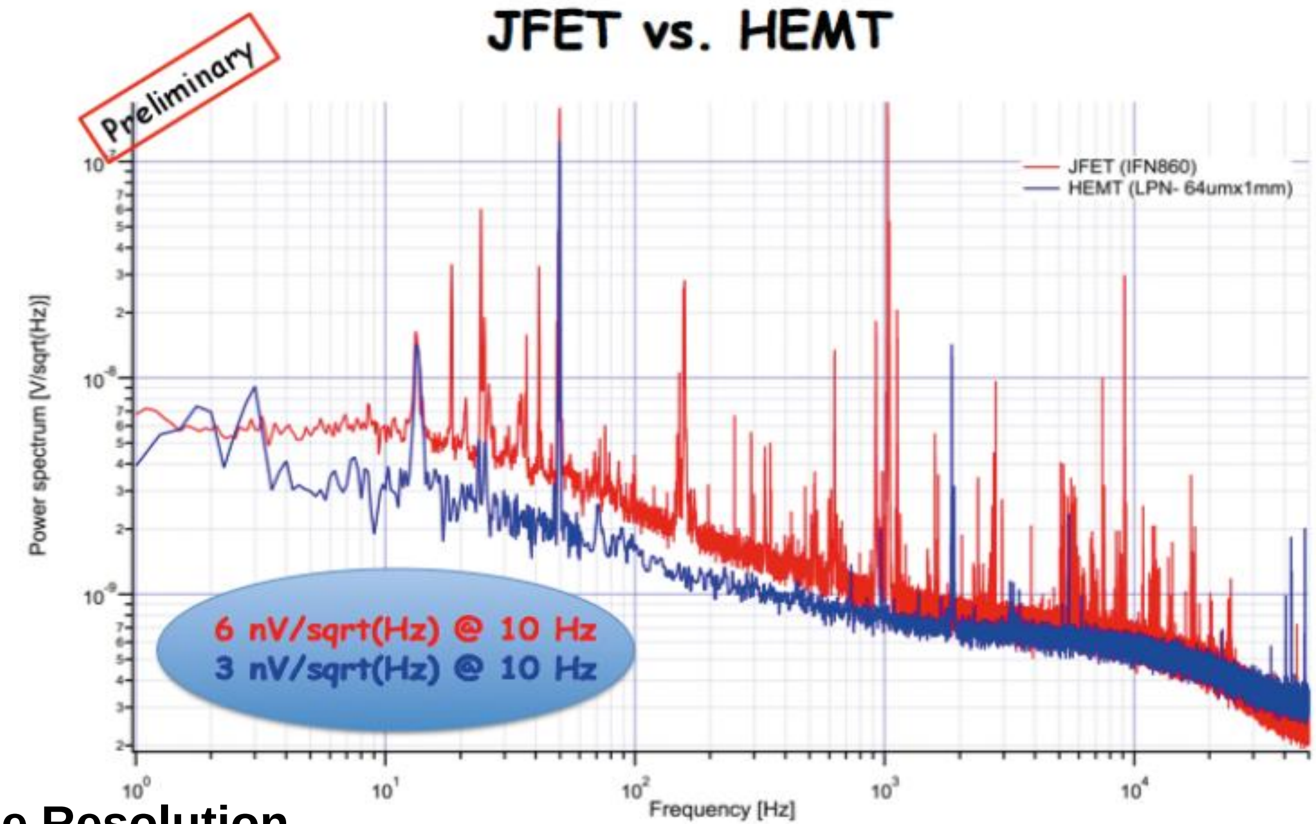
First low-mass WIMP search with a subsample of Edelweiss-III data

- after 6 months of data taking: demonstration with a first data set
- **one detector with good baselines and low threshold**
- expect ~7 other detectors with similar performance

	EDW-III subsample (1 x FID800)	EDW-II (4 x ID400)
exposure	35 kg.days	113 kg.days
threshold	3.6 keVnr	≈ 5 keVnr
FWHM ion fid	0.54 keVee	0.72 keVee*
FWHM heat	0.33 keVee	0.82 keVee*

*** *best* detector**

R&D with HEMTs (instead of FET)
- work at lower temperature
- lower noise



Baseline Resolution

FWHM	Edelweiss-II		Edelweiss-III		R&D HEMT
Ionization	900 eV	→	600 eV	→	300 eV
Heat	1.2 keV	→	1.0 keV		