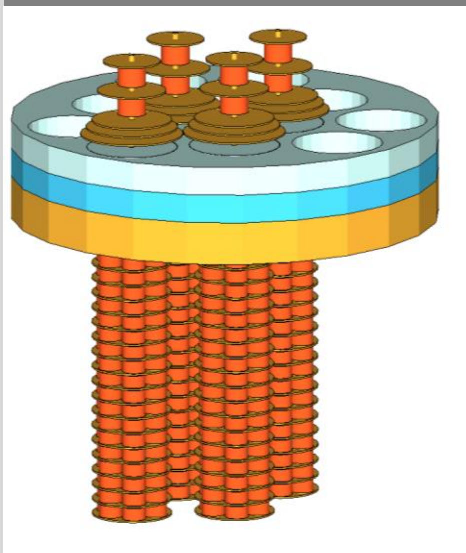
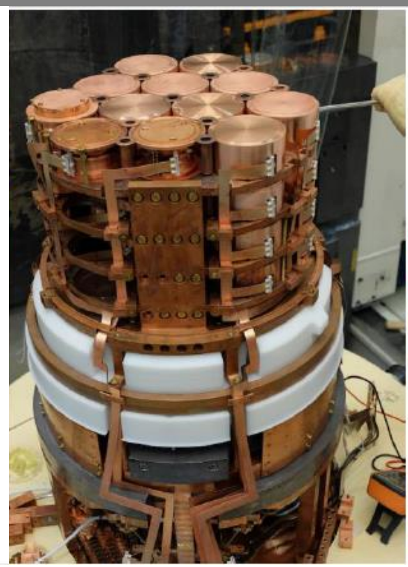
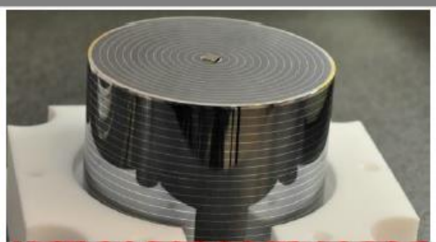
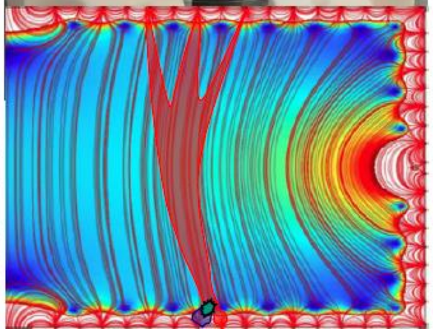
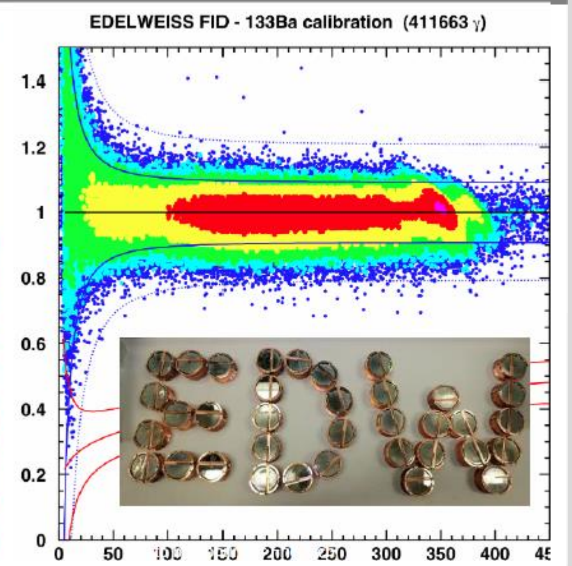
EDELWEISS-III dark matter search: first results and future

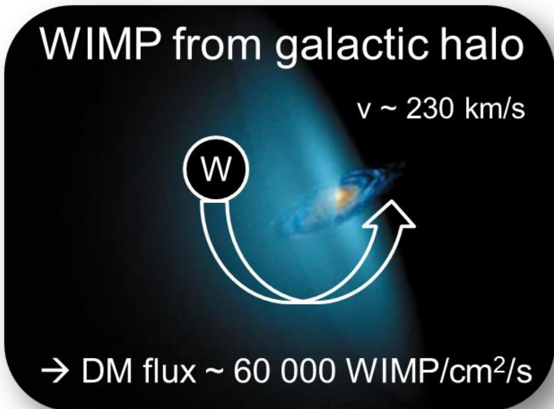
WIN 2015 – Astroparticle Session 4

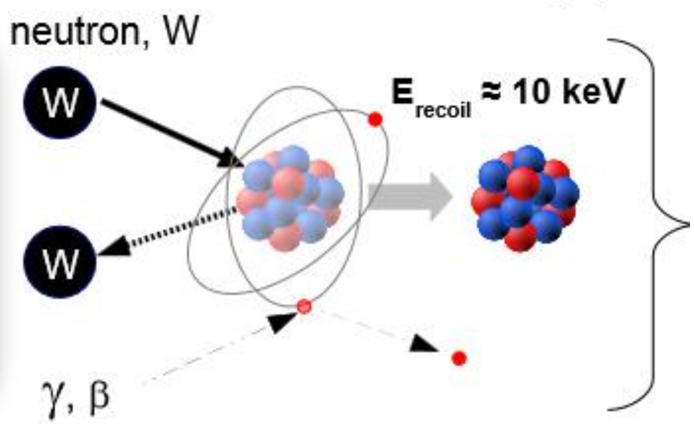
Geertje Heuermann, EKP, Karlsruher Institut für Technologie

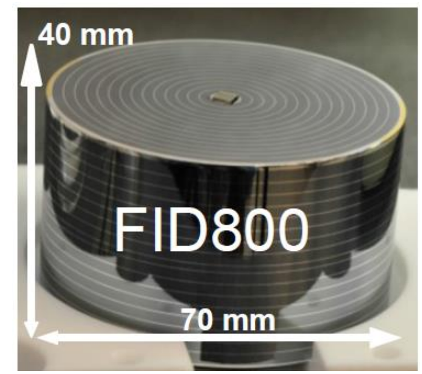
Direct Dark Matter Detection
With Heat and Ionisation Ge-Detectors

Rare event search < 1 evt/kg/year

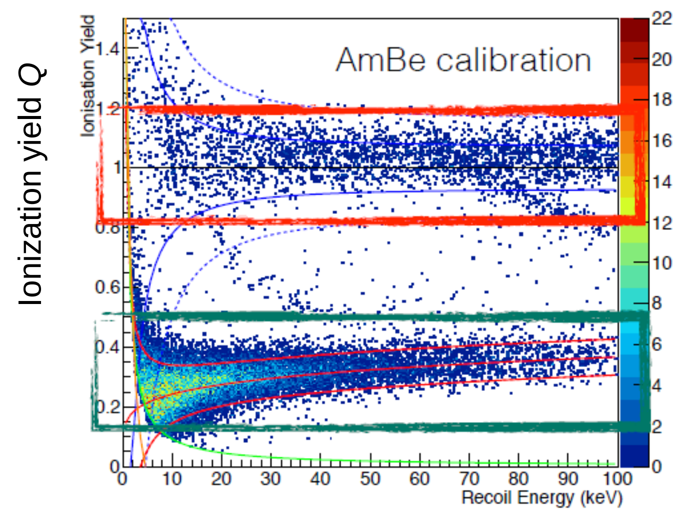




T=18mK → ΔT≈0.1 μK/keV



FID800 Fiducial Events



Two measuring channels

1. Heat (phonons) with NTD (Neutron Transmutation Doped sensor):

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

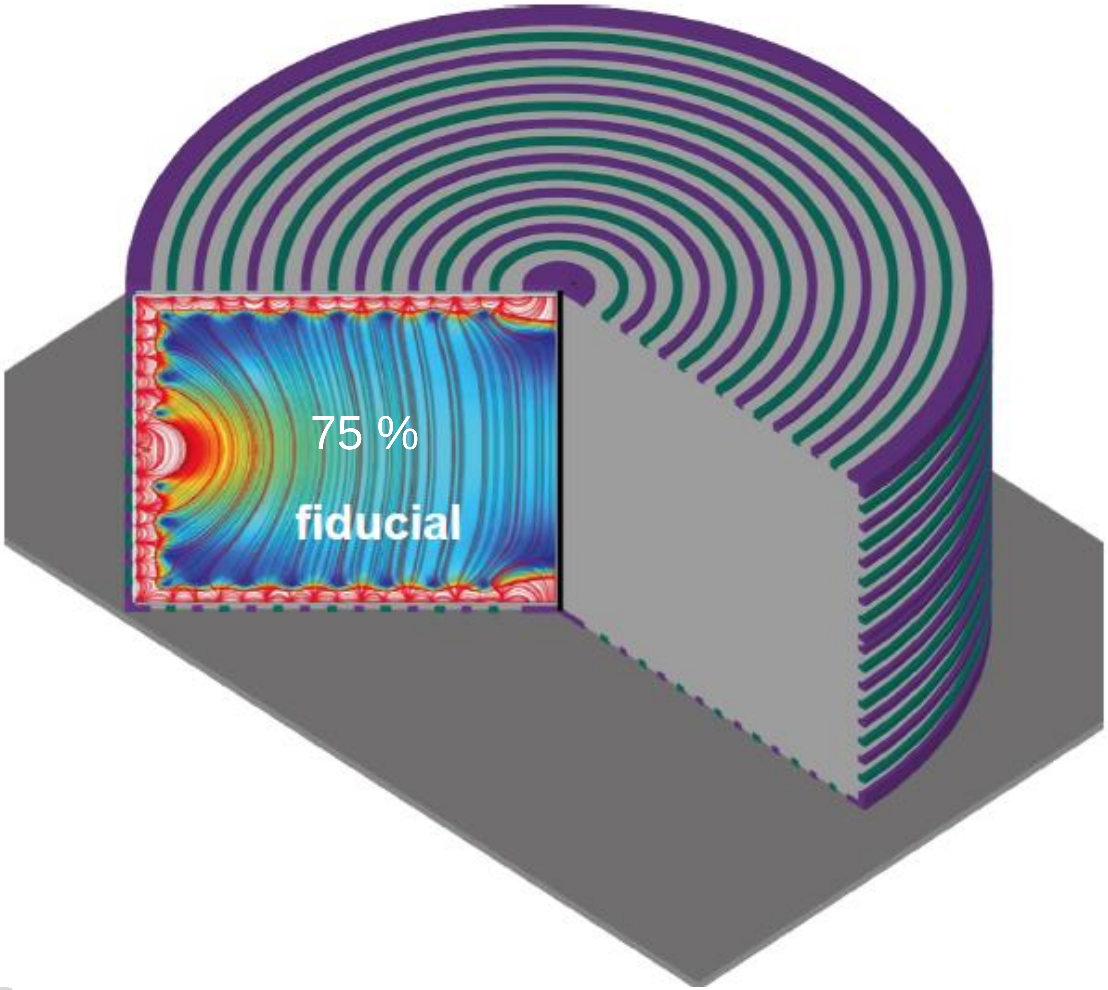
2. Ionization yield for particle identification, $Q = E_{ion}/E_{recoil}$:

   Q = 1 for electron recoils

   Q ≈ 0,3 for nuclear recoils

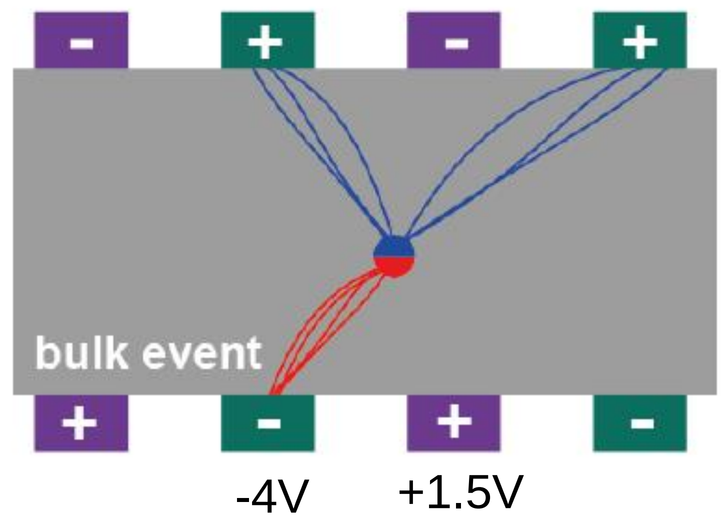
EDELWEISS Heat and Ionisation Ge-Detectors
Full Inter-Digitized 800 g HP-Ge Detector

Interleaved structure of collecting and veto Al-electrode ~ 100 nm thick



- allows identification of surface events
- reduces background

Collecting electrodes
Veto electrodes



EDELWEISS Heat and Ionisation Ge-Detectors
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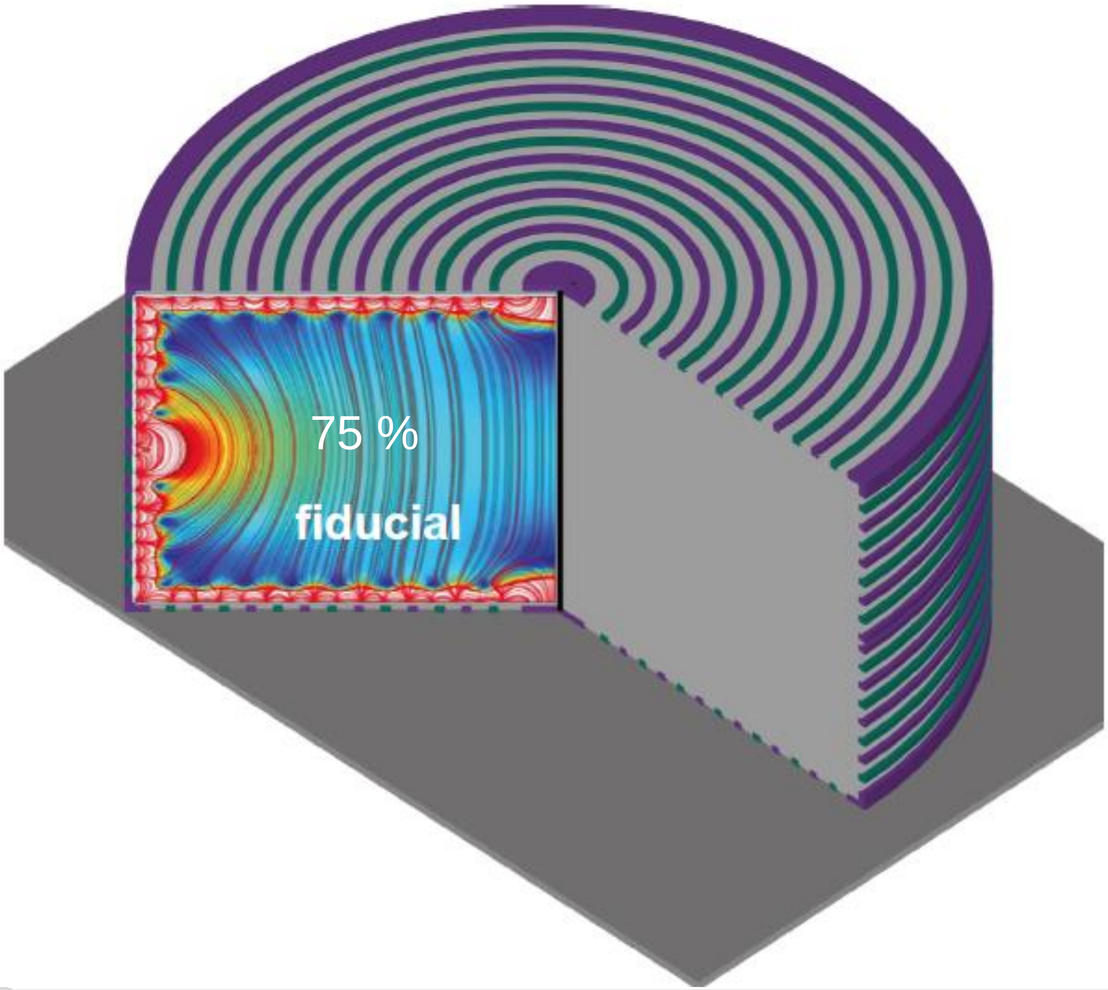

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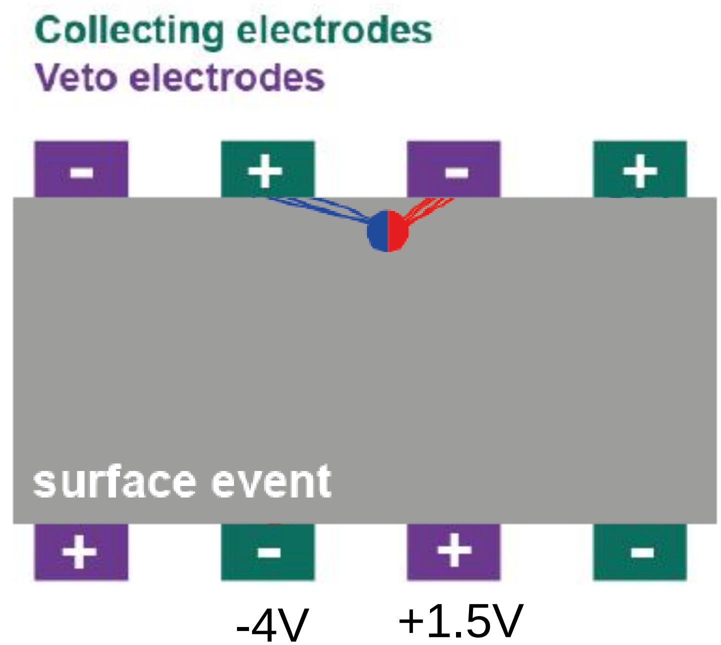
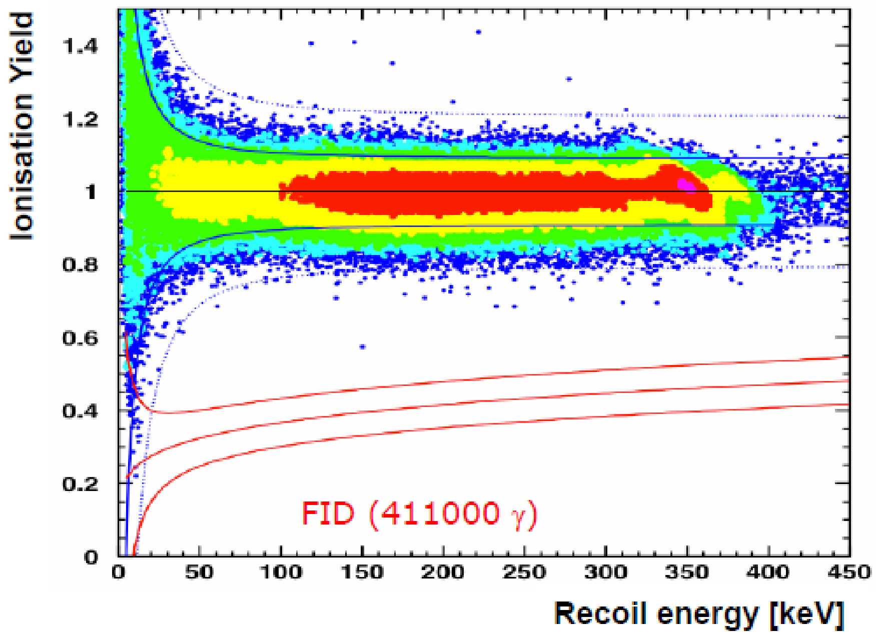


Background Rejection

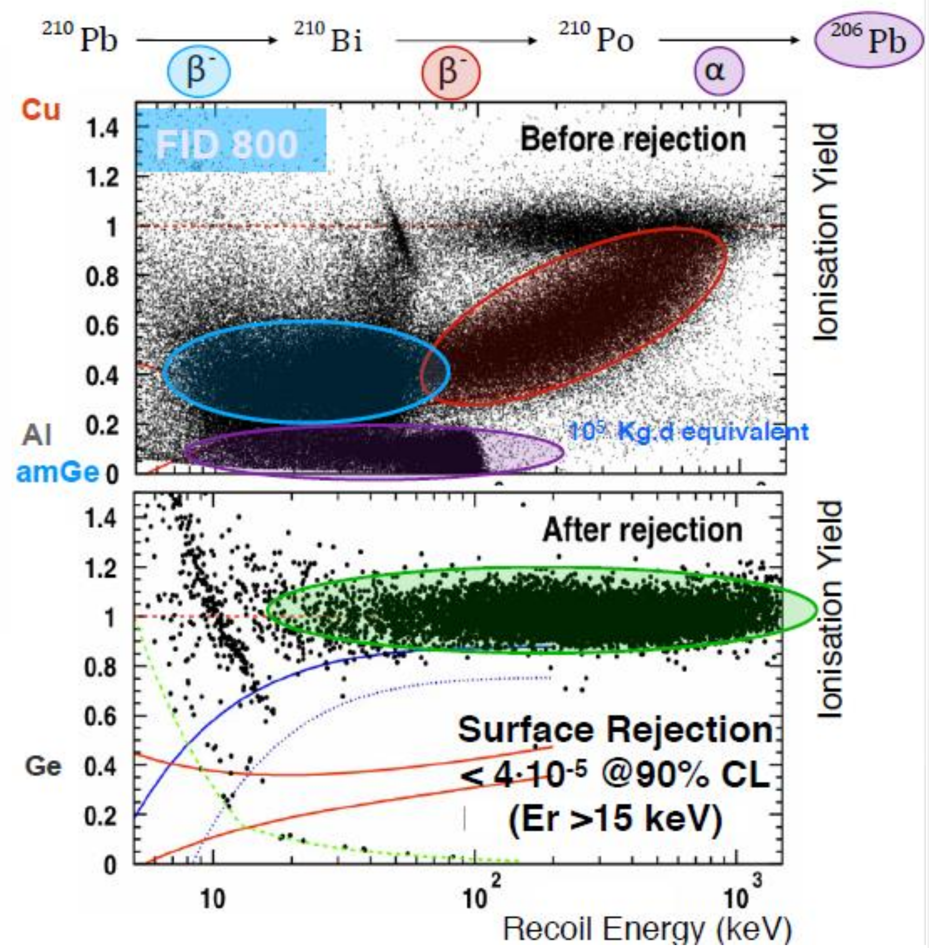
Gamma rejection

γ calibrations with ^{133}Ba

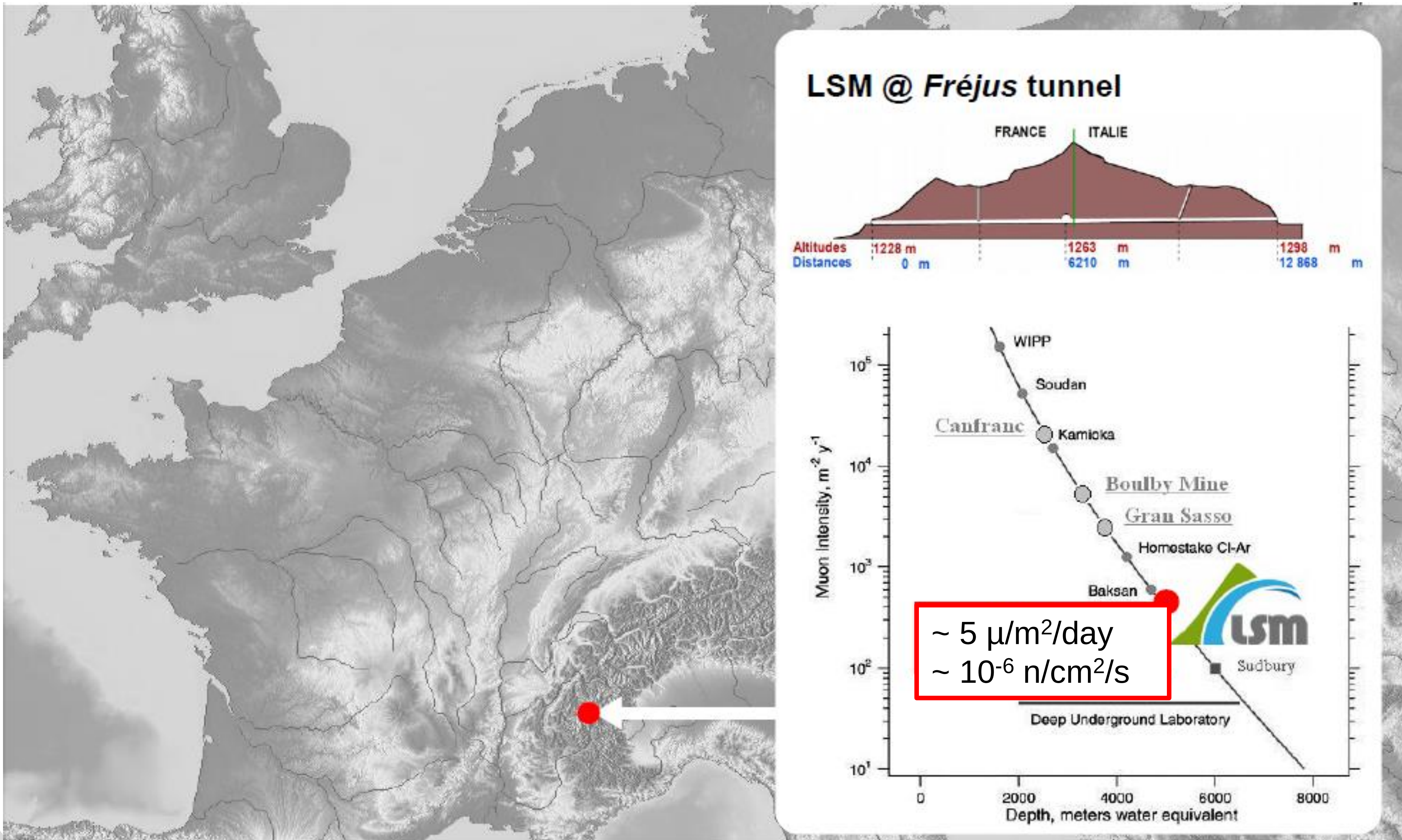


More than 400.000 γ's
γ suppression factor < 6 x 10^{-6}
< 1 „NR“ for every 100k (15-200keV)

Surface rejection



EDELWEISS-III Setup



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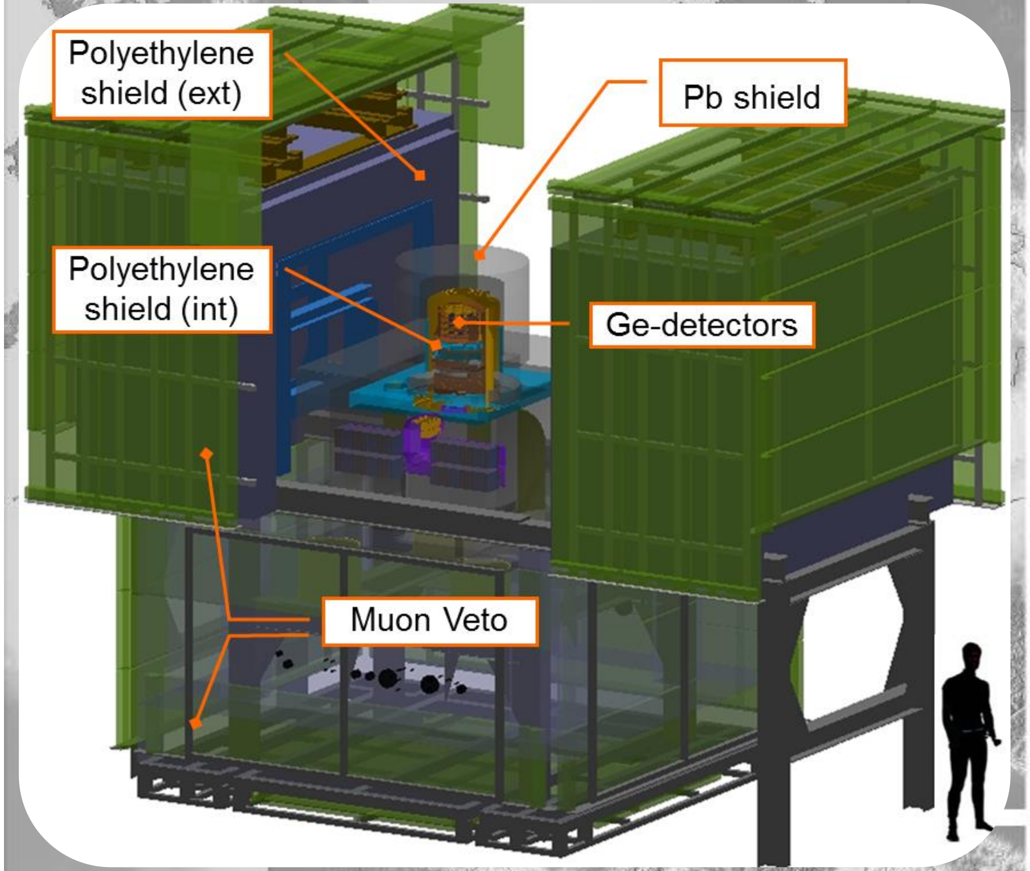

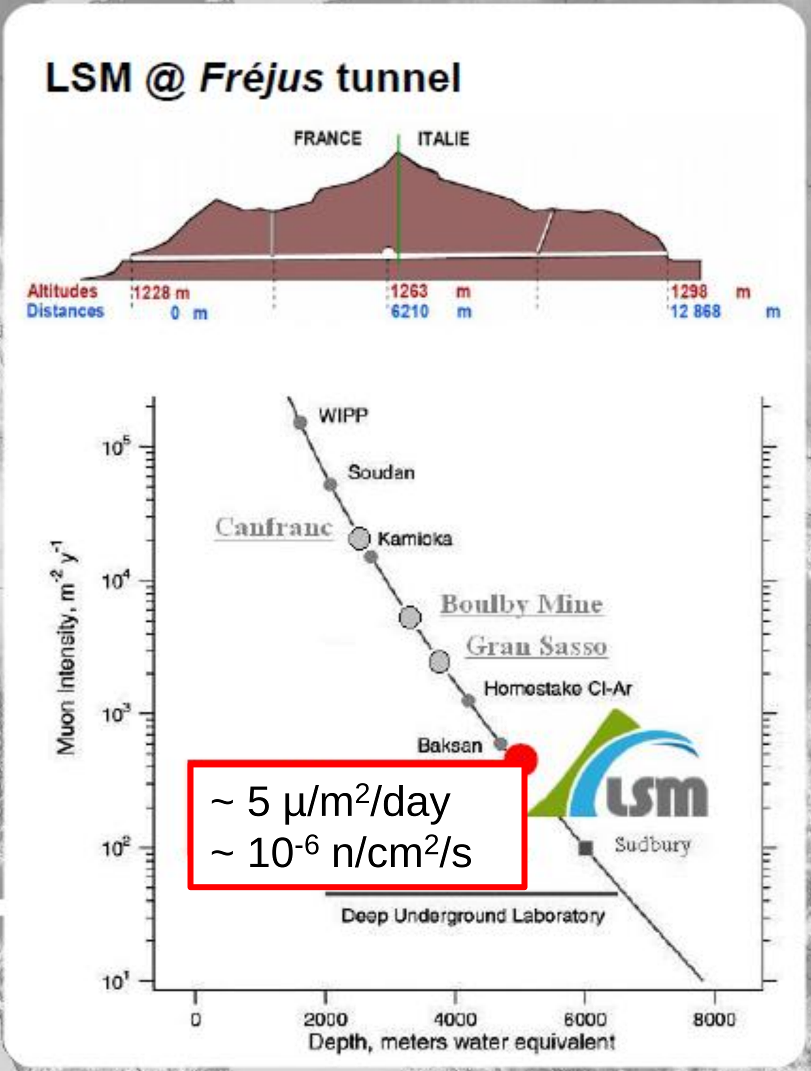

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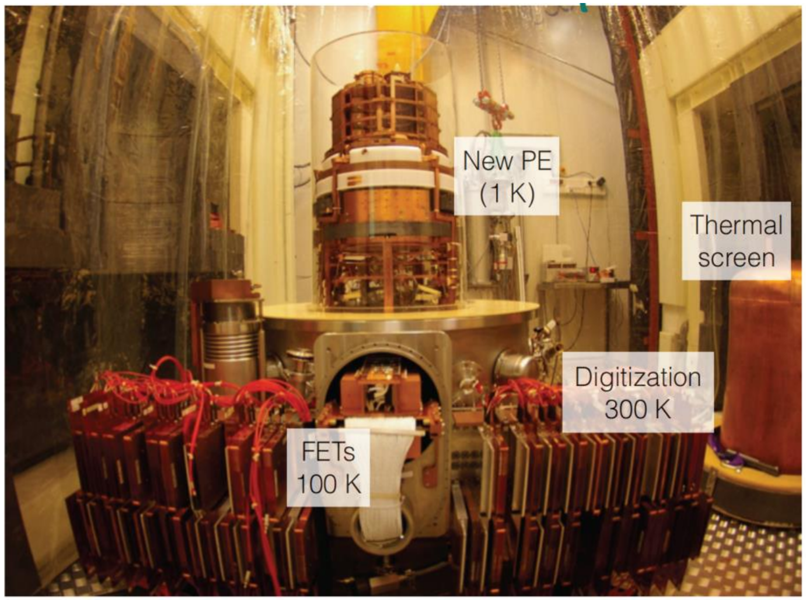

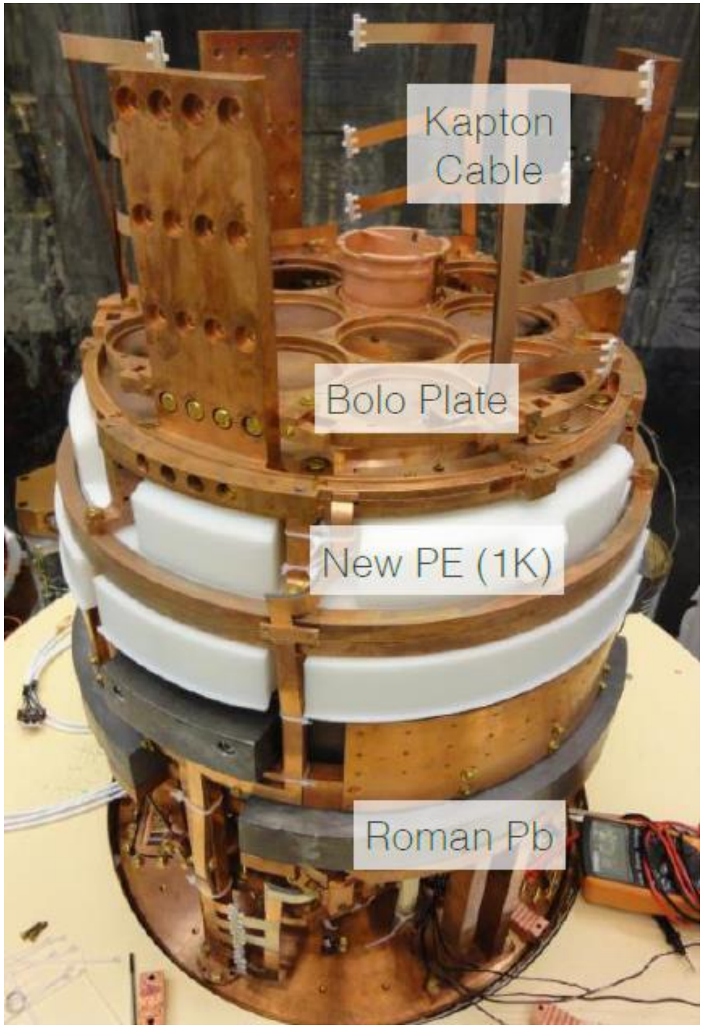

Current status of EDW-III data taking

- First physics data taking:
  - July 2014 – April 2015
  - 36 FID 800 g detectors are installed
  - 24 FID 800 g detectors are read out

Standard WIMP search detectors:

Average resolution	Baseline (keV)	356 keV (keV)
FWHM Ion	<0.6	<10
FWHM Heat	<1.0	<15

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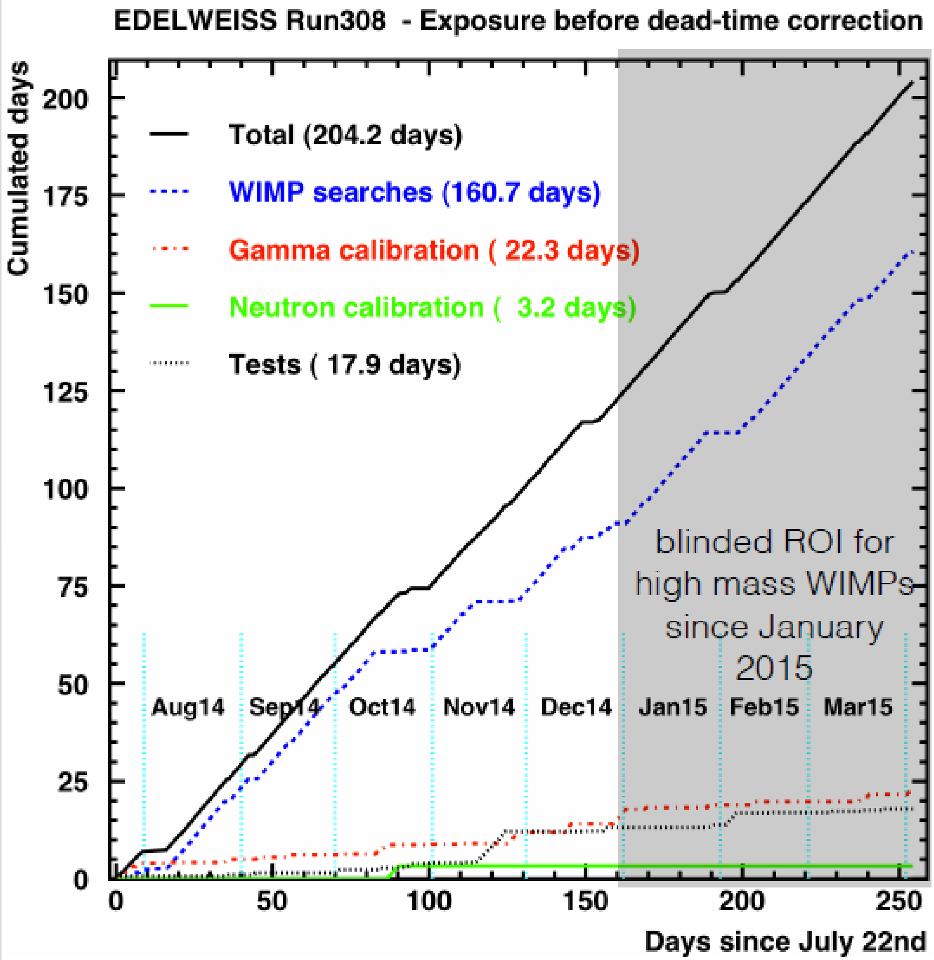

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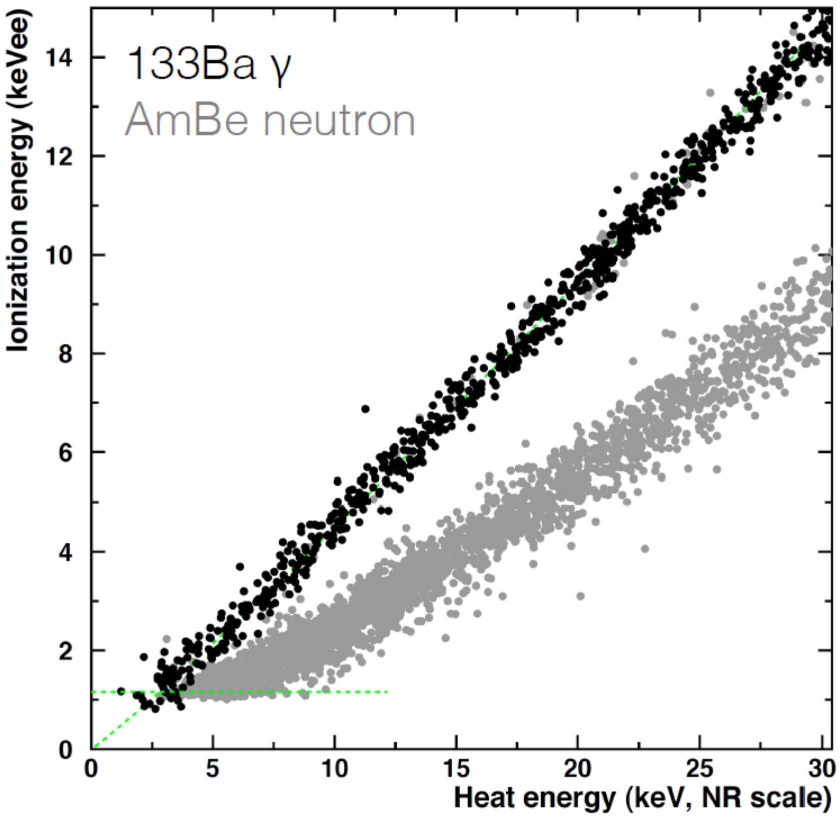
Improved performance at low energies with FID800 detectors

EDELWEISS-III: (1x) FID800 detector



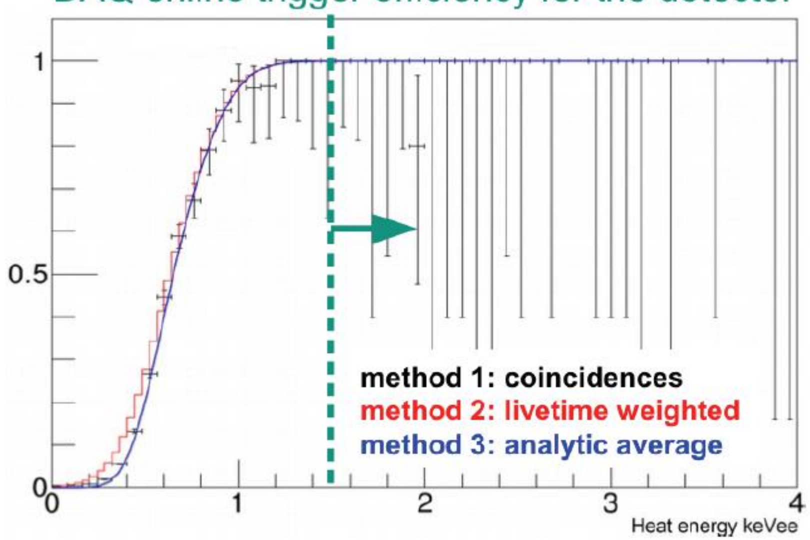
Good performance at low energies

low mass WIMP analysis

	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*

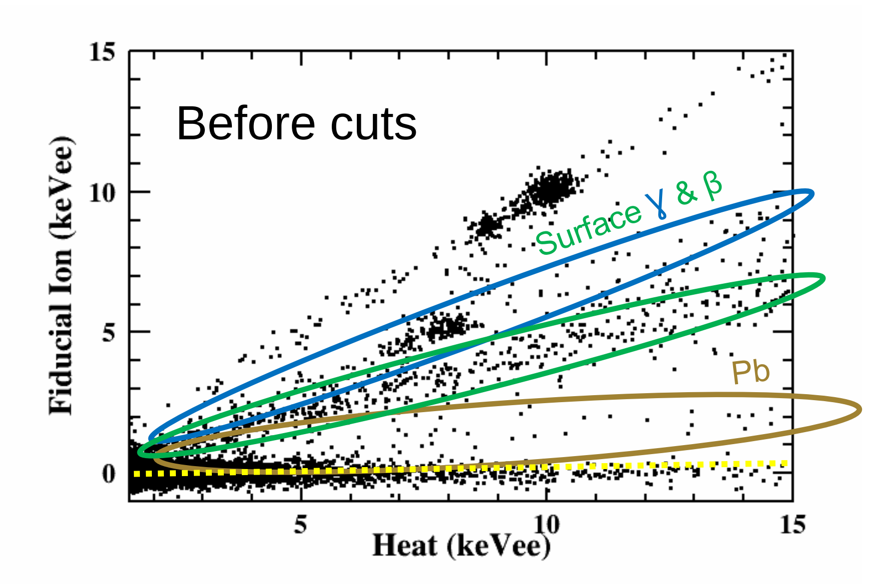
* ***best*** **detector**

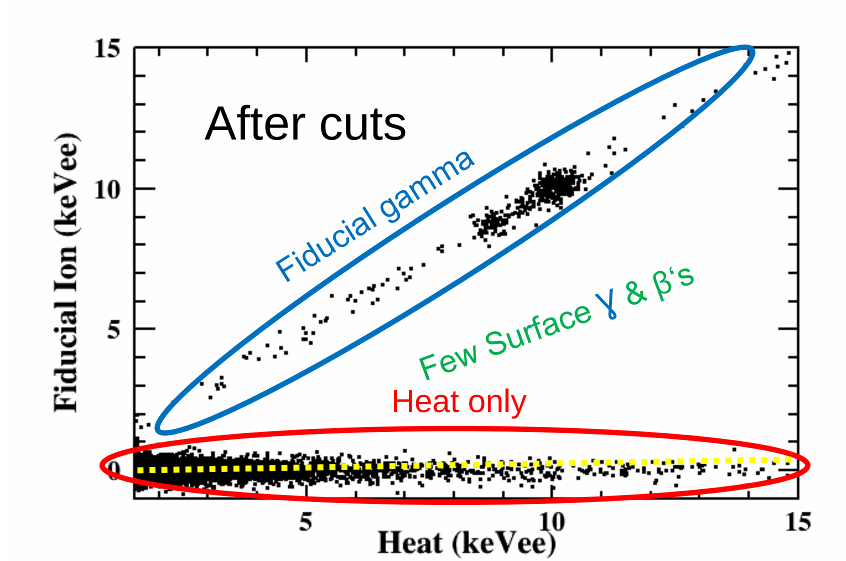
DAQ online trigger efficiency for the detector



Expect ~7 detectors with similar performance

First Low Mass WIMP search with EDW-III Data
1 FID sub-sample: 35 kg days





Loose region of interest (ROI):

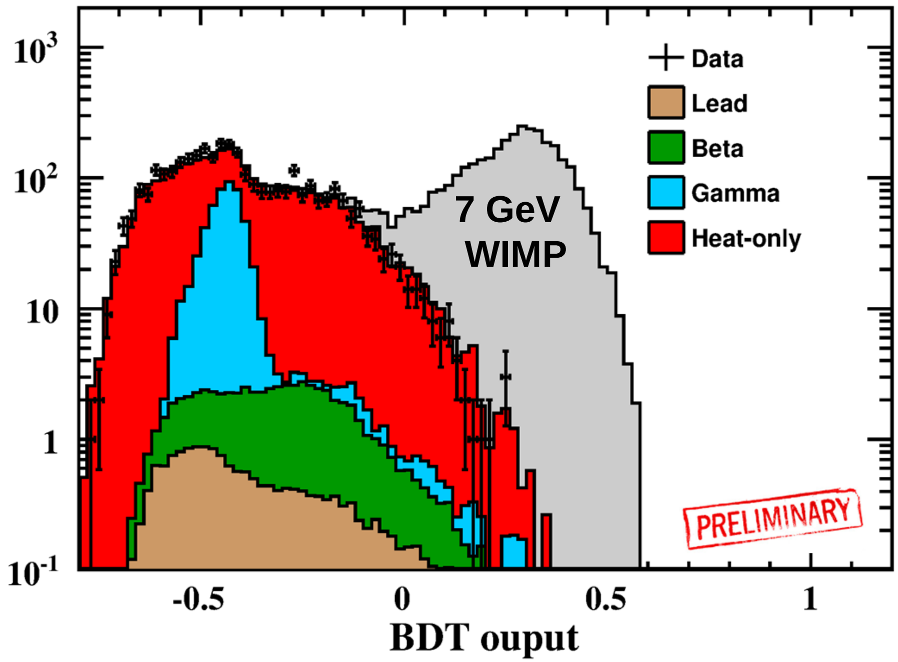
- Single NR only
- $1.5 < E_{heat} < 15$ keVee
- $0 < E_{ion} < 15$ keVee
- $E_{veto} < 5\sigma$ (fiducial cut)

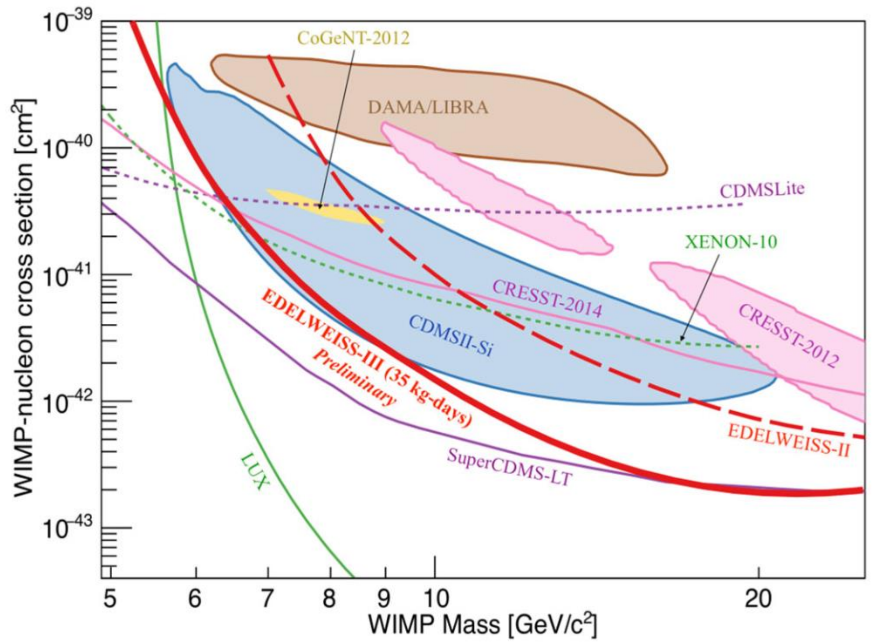
Low mass analysis ingredients:

- Boosted decision tree within ROI
- 4 ionization and 2 heat variables for Signal/Background discrimination
- data driven background models

First Low Mass WIMP search with EDW-III Data

1 FID sub-sample: 35 kg days





- one *boosted decision tree* (BDT) per WIMP mass

- conservative limit:

w/o background subtraction

- limits in agreement with previous projections
- already competitive results for

small subset of available data

⟶ **clear room for progress**

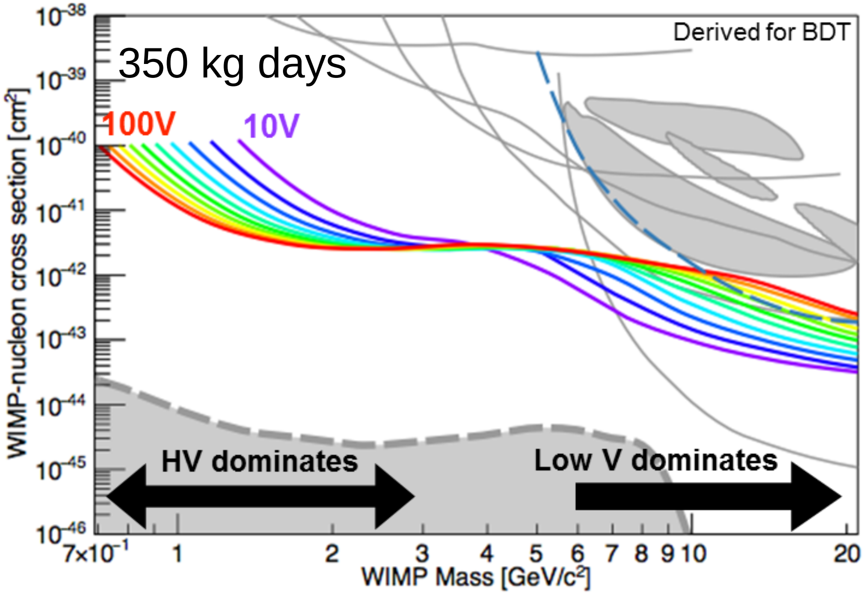
Geertje Heuermann

Outlook on EDW-III

- Standard WIMP mass analysis ongoing
- Data taking will resume in June 2015

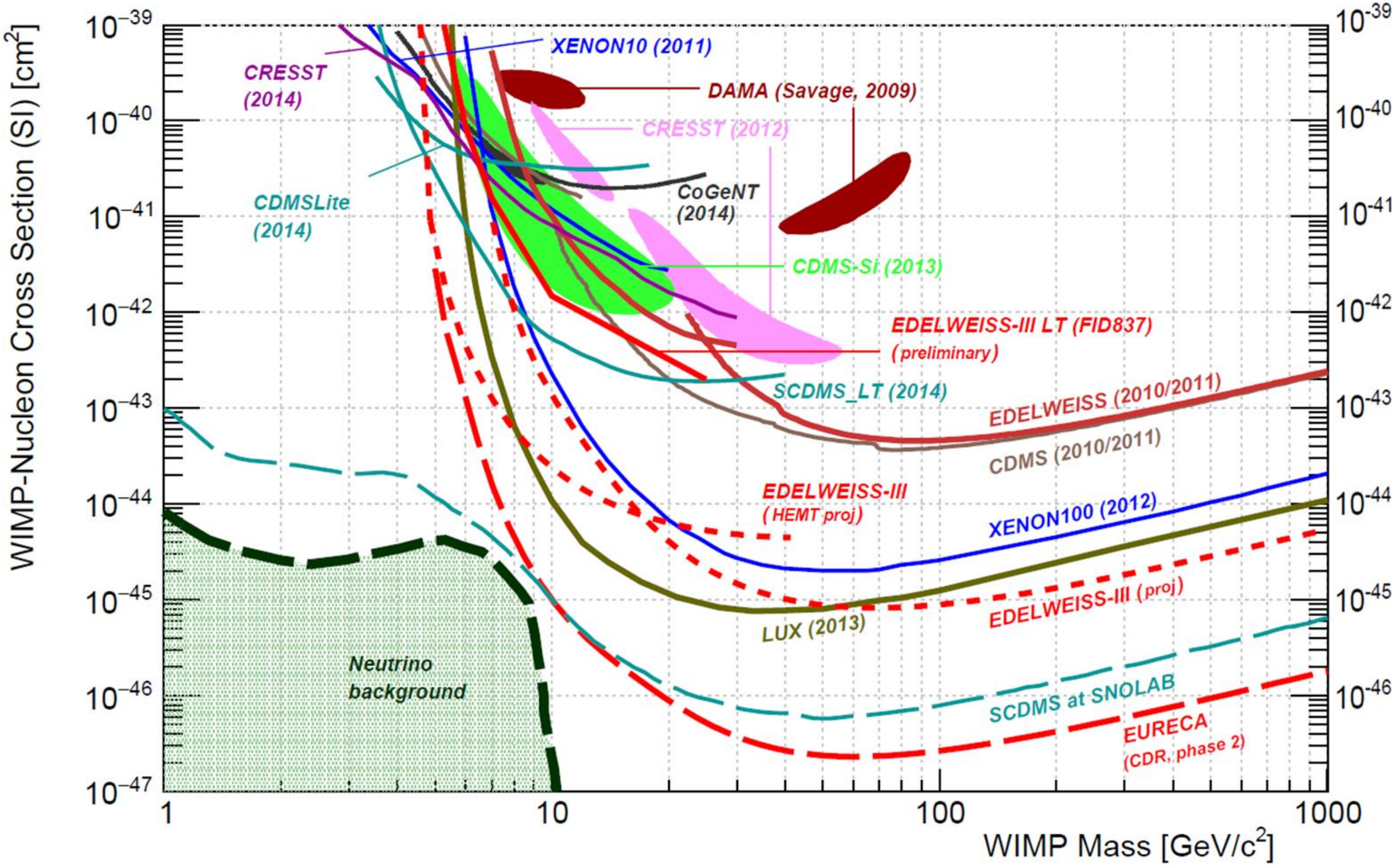
Lower threshold for low mass WIMP search:

- HEMT R&D
- High voltage studies



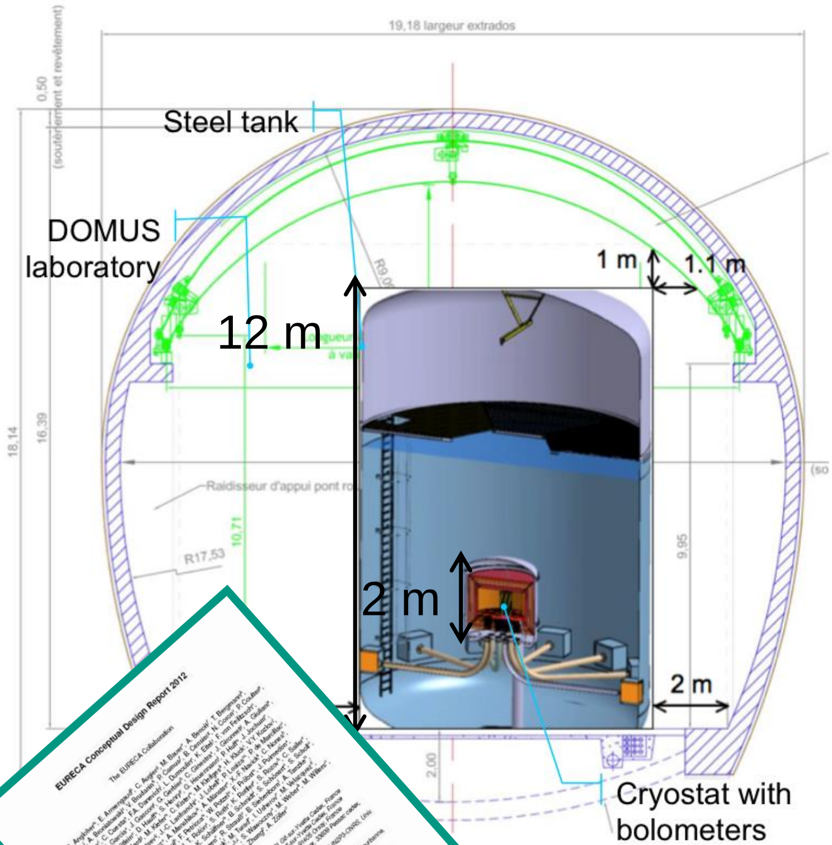
- reduction of heat only by x 100
- 100 eV (RMS) ion & heat

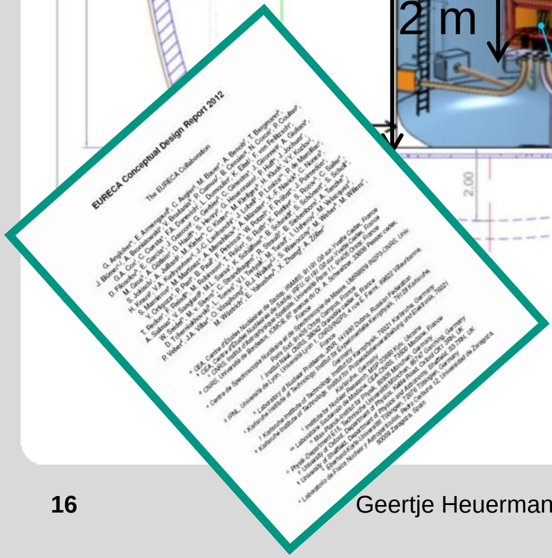
Beyond EDELWEISS-III: EURECA/SuperCDMS

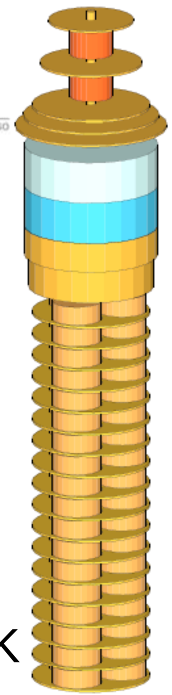


EURECA **E**uropean **U**nderground **R**are **E**vent **C**alorimeter **A**rray **E**xperiment

Proposed as 1 tonne cryogenic detector array for the search of WIMPs [CDR]



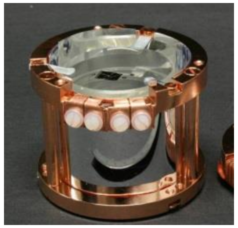


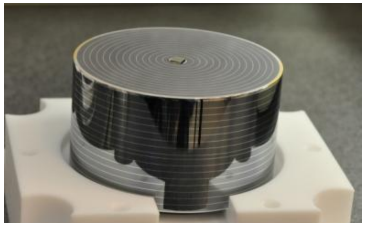


Cryogenic multi target low-mass WIMP search (< 15 GeV/c²)

- Low threshold detectors (1-2 keV_{NR})
- Detector mass ~ 50 kg
- Ge: Neganov-Luke amplified & low thresh with discrimination

- Cryogenic phonon scintillation detectors (CaWO4) as used by CRESST





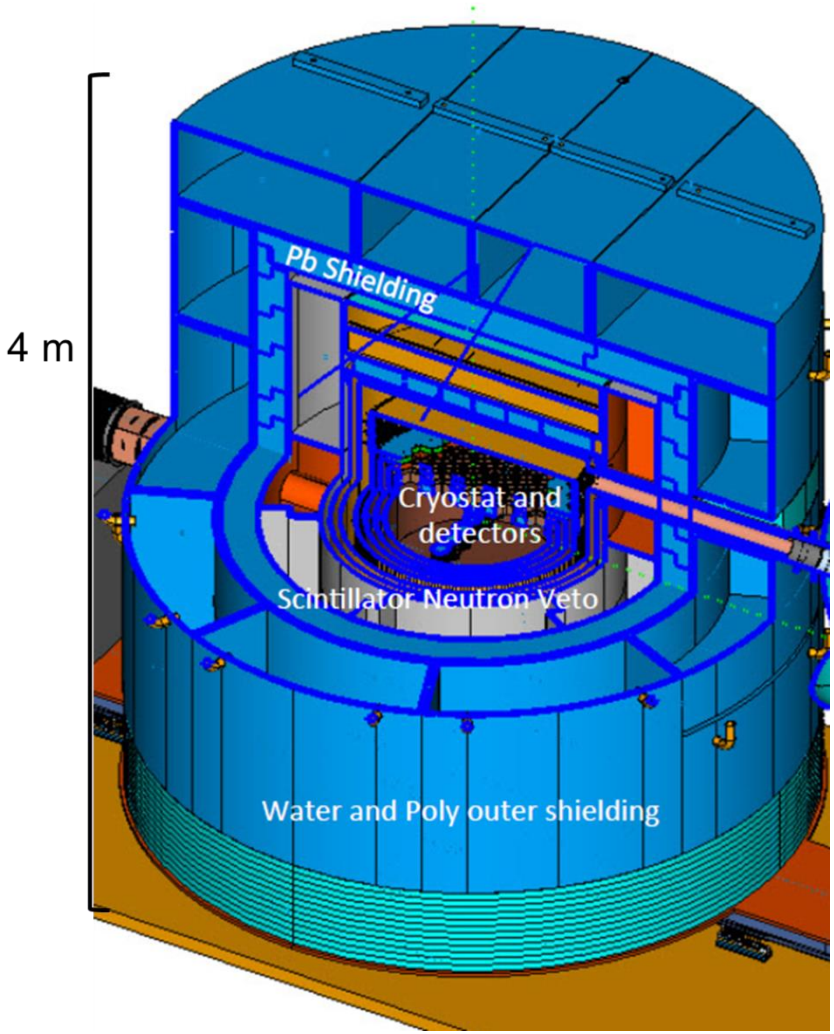
- Cryogenic phonon ioniziation detectors (Ge crystals) as used by EDELWEISS

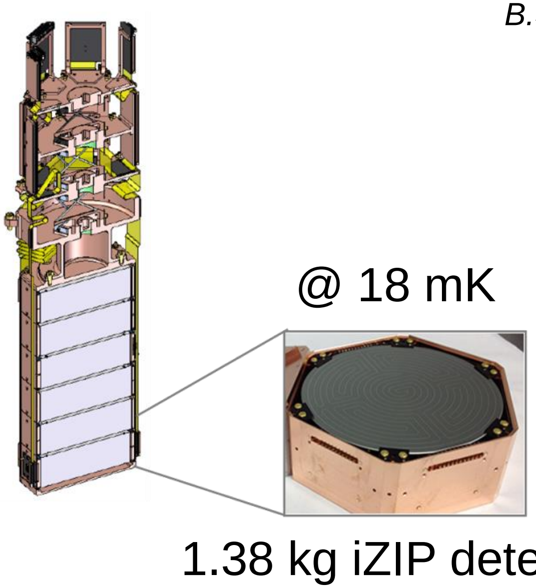
The SuperCDMS SNOLAB Experiment

Cryogenic multi target low-mass WIMP search (< 10 GeV/c²)

- Low threshold detectors
- 50 kg of Ge- iZIP detectors for $5 < M_{wimp} < 10$ GeV search
- Ge- and Si-detectors, CDMS HV for $M_{wimp} \sim 0.3 - 5$ GeV

B.Sadoulet HEPAP 140930





EURECA and SuperCDMS cooperation

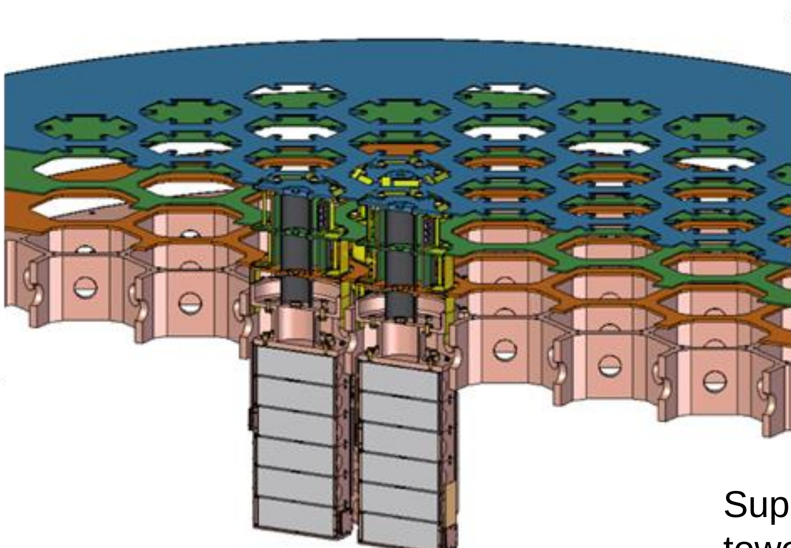
merge into a common next phase bolometer experiment with 2 x 50 kg

Perspective:

- Joined cryogenics, tower structure, warm electronics and DAQ
- Separate detector modules and cold front end electronics

Ongoing studies:

- Design & construction of a compatible towers
- Screening and background simulations



Capacity to hold 400 kg

SuperCDMS detector tower design for SNOlab

EURECA compatible detector tower design for SNOlab

Summary

EDW-III …

- Low energy WIMP mass analysis shows competitive results for small set of data
- Expect fast improvements in sensitivity:
  - We already have x10 more data of similar quality
  - Will decrease the analysis threshold
- High energy WIMP mass analysis ongoing
- Data taking will resume in June 2015

… and beyond

- EURECA/SCDMS will explore low mass WIMP space with multi-target approach
- R&D to lower threshold ongoing
- R&D to merge into common cryostat at SNOlab ongoing
- 2018 installation of first towers @ SNOlab

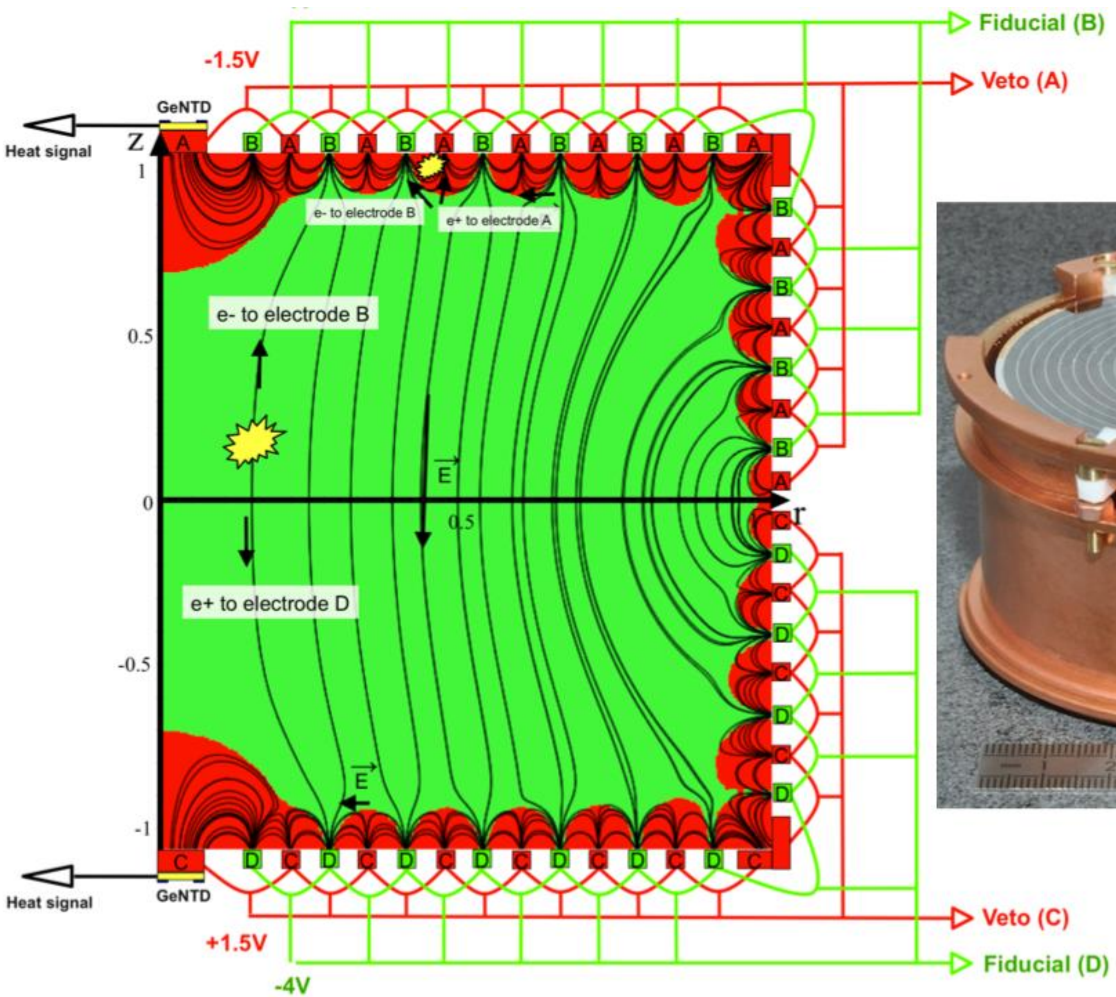
CEA Saclay (IRFU & IRAMIS)
CSNSM Orsay (CNRS/IN2P3 & Paris Sud)
IPNL Lyon (CNRS/IN2P3 & Univ. Lyon 1)
Néel Grenoble (CNRS/INP)
LPN Marcoussis (CNRS)

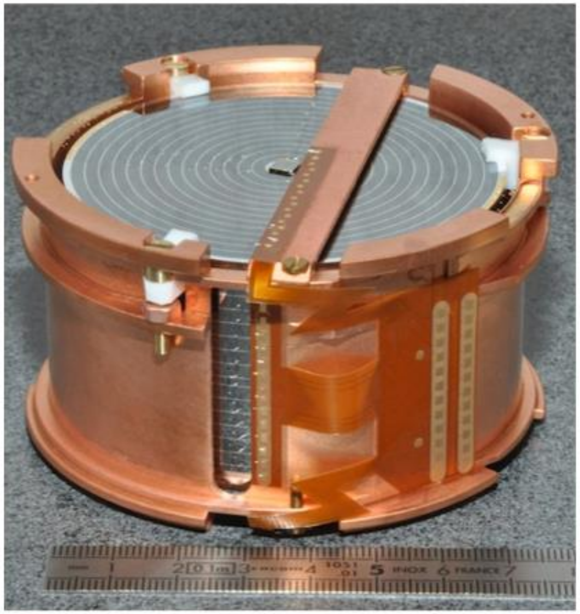
KIT Karlsruhe (IKP, EKP, IPE)
JINR Dubna
Oxford University
University of Sheffield

KIT Karlsruhe Institute of Technology

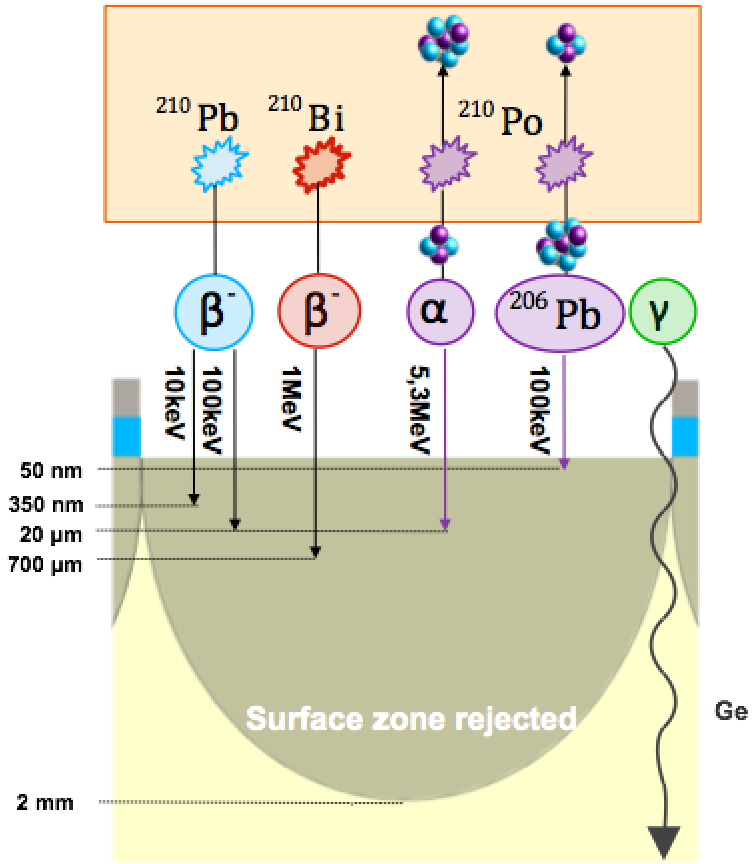
BACKUP SLIDES

FID Detector Scheme





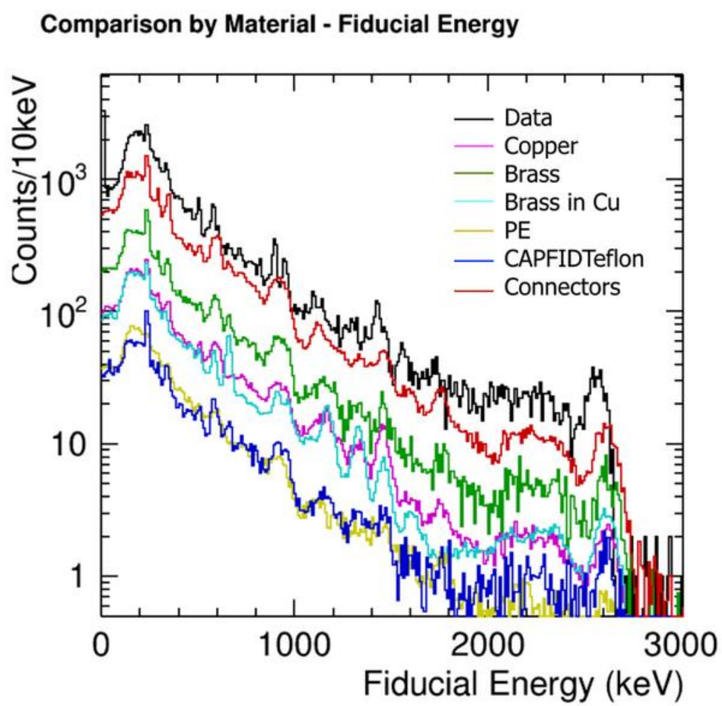
FID Surface Rejection



EDW-III background budget

Gamma Background

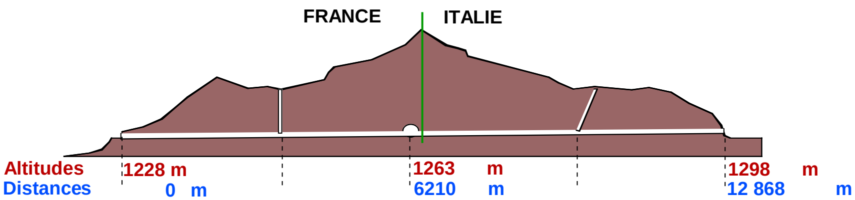
- In the fiducial volume, the gamma rate in ROI (100keV-4MeV) is 235counts/(kgd), considering a fiducial exposure of about 380kgd
- fiducial volume, the gamma rate in ROI (20-200keV) is 70 counts/(kgd), considering a fiducial exposure of about 380kgd

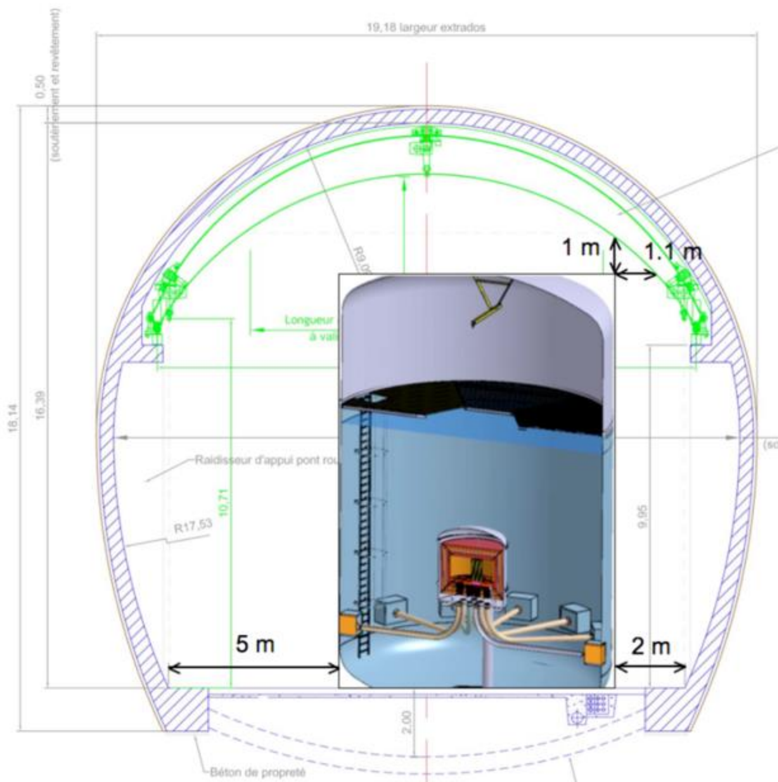


- **Neutron Background** (SOURCES & GEANT4)

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

Provision of Low Background Environment





Passive shielding: α, β, γ, n

- Internal: 15 cm of Cu/C_nH_{2n}
- External: 3m of water

Requirements on **radiopurity**:

- U/Th in Cu of the cryostat < 0.02mBq/kg
- U/Th in inner shielding < 10 mBq/kg

Active shielding: μ-induced neutrons

- Muon Veto: water Cerenkov detector

Expected Background in 550 kg of Ge-Detectors [CDR]

Source	Material	Mass kg	Contaminations U/Th, ppb	Gamma-rays events/kg/year	Neutrons events/year
Screens, Cu parts	Cu	3000	<0.002	<330	<0.07
Support rods	Cu-Ni alloy	100	0.01	20	0.05
Cables, 10 mK	Cu, Kapton	3	0.5	30	0.04
Holders	Kapton	0.2	1	50	0.01
Holders	Acrylic	0.5	0.01	2	0.0002
Screws	Cu, Zn	10	0.2	330	0.03
Electrodes	Al	0.0001	200	13	0.05
Connectors	Cu, Delrin	1	1	<5	0.01
Cables	Cu, Kapton	2	0.5	<5	0.01
Neutron shielding	Acrylic	200	0.01	<5	0.04
Neutron shielding	CH_2	300	0.1	<30	0.03
Electronics	FR4	1	2000	6	0.03
Water shielding	Water	0.4 kt	0.001	60	0.003
Muon-induced	All	–	–	–	<0.15
Total				<900	<0.53

Provision of Low Background in SCDMS