Recent status
of the Dark Matter search with EDELWEISS

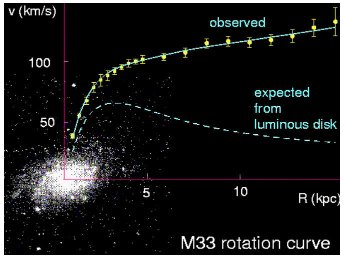
Valentin Kozlov for the EDELWEISS collaboration

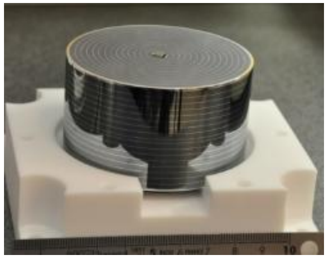
Institute for Nuclear Physics, Karlsruhe Institute of Technology

8th Patras Workshop on Axions, WIMPs and WISPs

Chicago and Fermilab

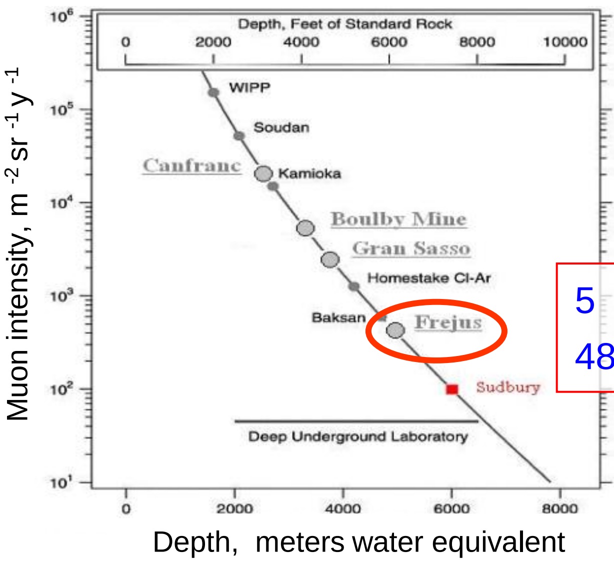
18-22 July 2012



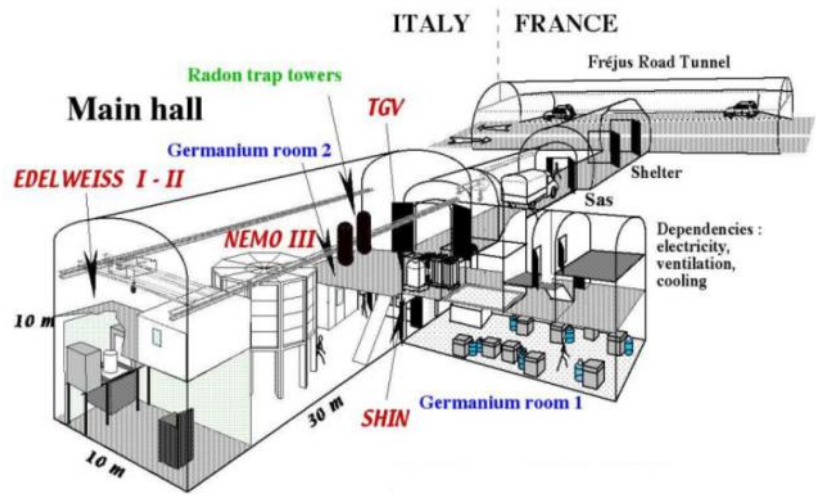


Edelweiss: search for WIMPs @ LSM (France)

LSM

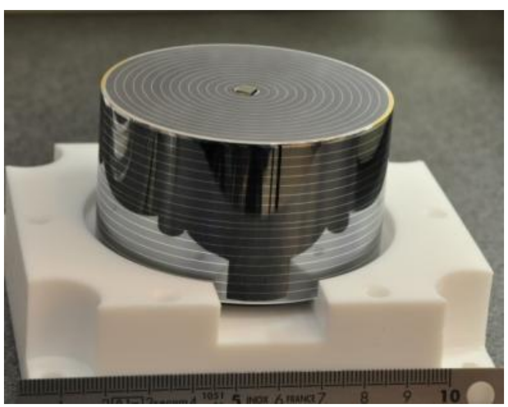


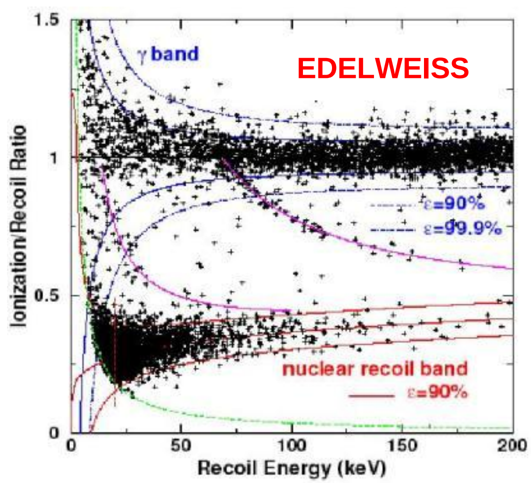
5 μ/m²/day
4800 mwe



Ge-bolometers

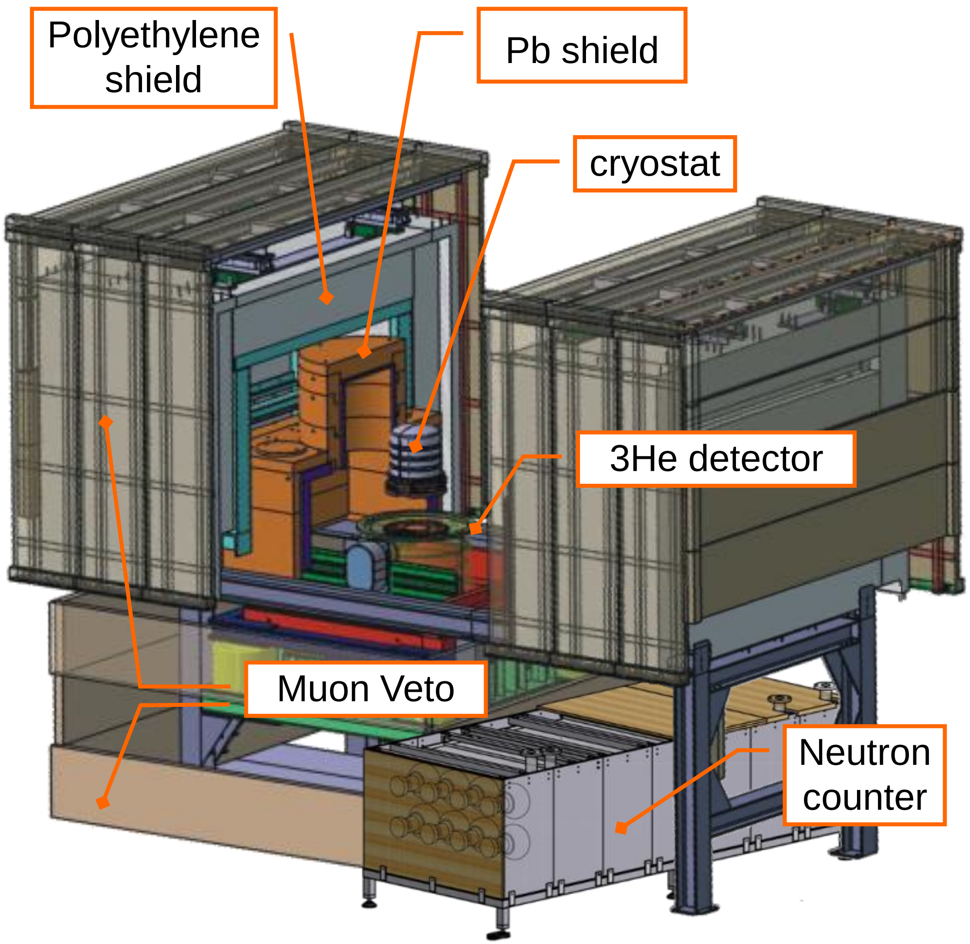
Ge-bolometers of (F)ID-type





- **Simultaneous measurement**
  - **Heat @ 18 mK** with Ge/NTD thermometer
  - **Ionization @ few V/cm**
- **Evt by evt identification** of the recoil by ratio $Q=E_{ionization}/E_{recoil}$
  - **Q=1 for electron recoil**
  - **Q≈0.3 for nuclear recoil**

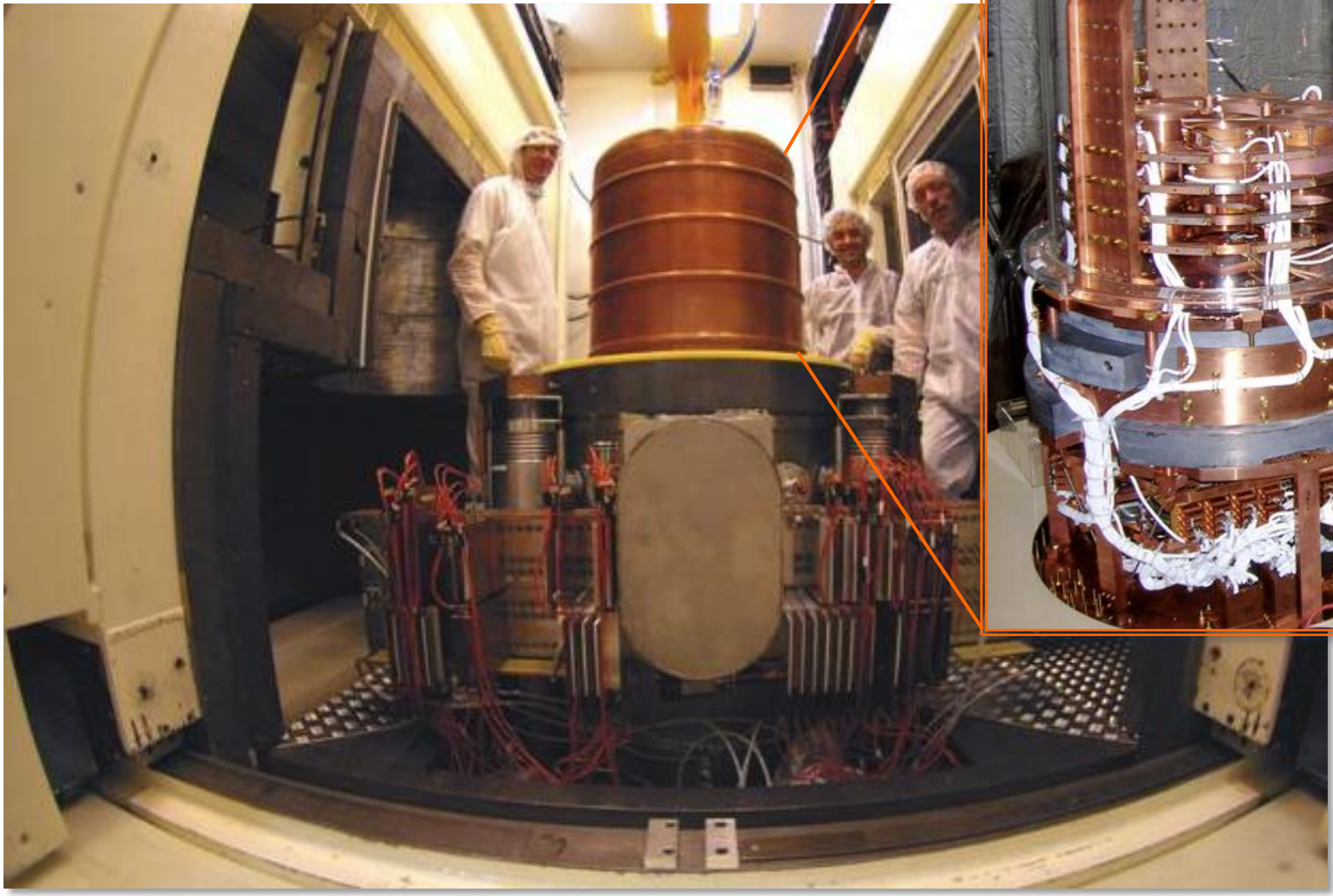
Edelweiss-2 (3) experimental set-up



- **Edelweiss-3 goal $\sigma_{\chi\text{-}n}$ = a few·10^{-9} pb**
- Cryogenic installation (18 mK) :
  - Reversed geometry cryostat
  - **Can host up to 40 kg of detectors**
- Shieldings :
  - Clean room + deradonized air
  - Active muon veto (>98% coverage)
  - **PE** shield **50 cm** (EDW-3: +internal PE)
  - **Lead** shield **20 cm**
- (Many) others :
  - Remotely controlled sources for calibrations + regenerations
  - Radon detector down to few mBq/m^3
  - thermal neutron monitoring (He^3 det.)
  - study of muon induced neutrons (liquid scintillator 1 m^3 neutron counter)
- 18 cool-downs operated since 2006

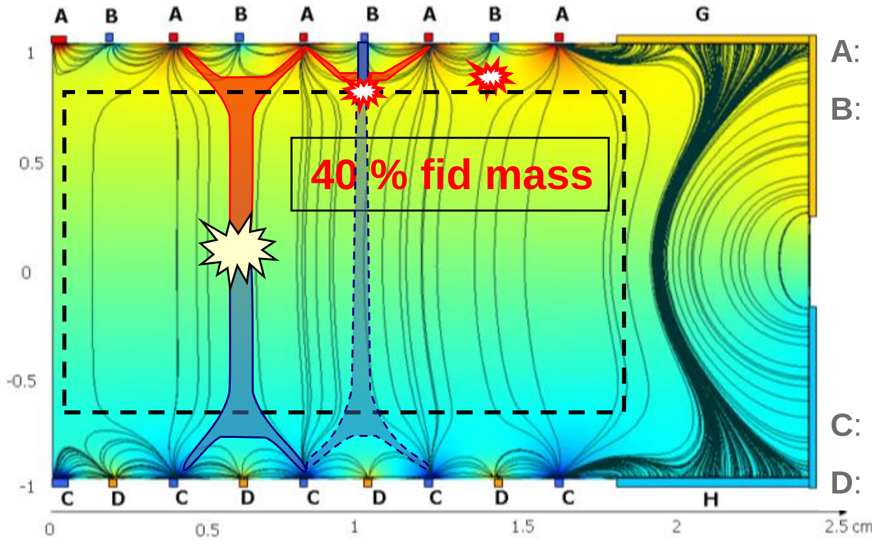
Edelweiss-2 setup: View from ‚inside‘

Edelweiss-2 setup: View from ‚inside'



Cryostat: inside

InterDigitized (ID) design: surface evt rejection

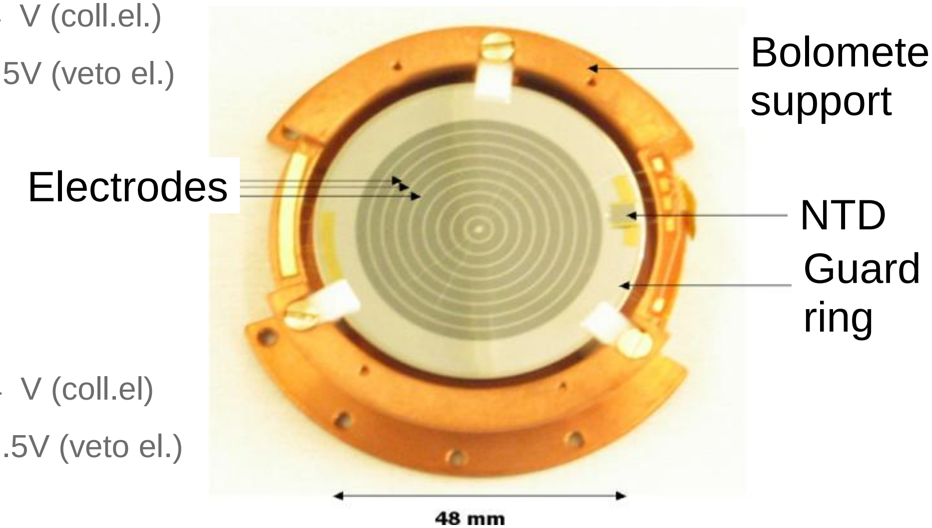


A: +4 V (coll.el.)

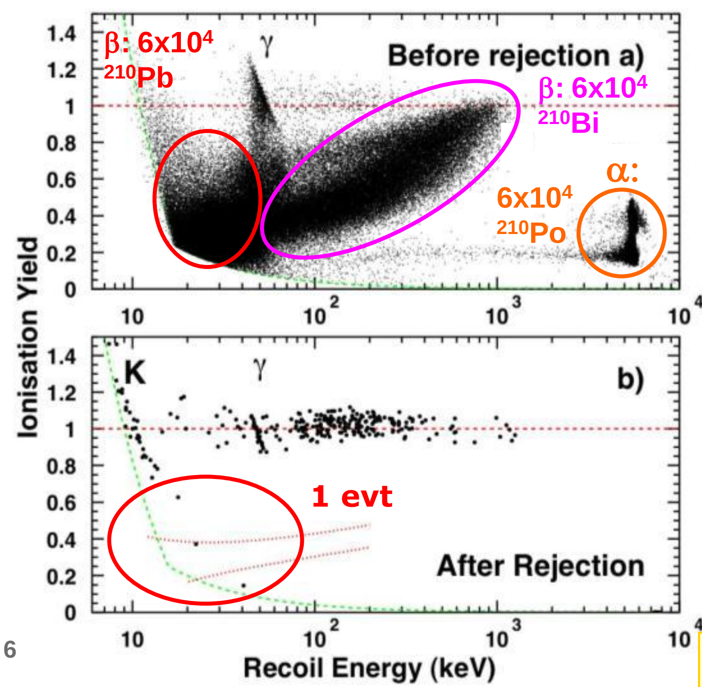
B: -1.5V (veto el.)

C: -4 V (coll.el)

D: +1.5V (veto el.)



Surface events



Surface events rejection:

intentional ^{210}Pb source: 6×10^4 events total

requiring no signal on veto electrodes: 1 event left

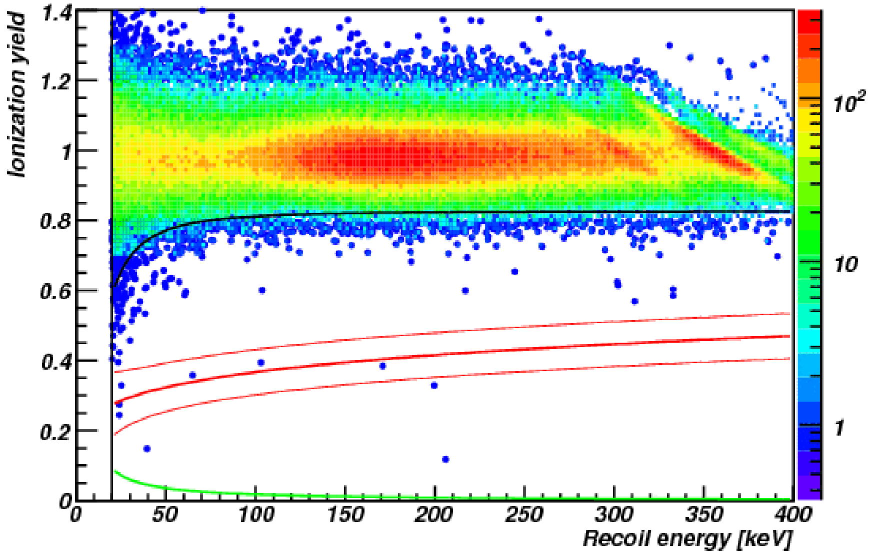
→ rejection factor for surface events of 6×10^{-5} (90% CL)

→ In case of *no other background*:
$\sigma_{SI} \sim 4 \times 10^{-10}$ pb (90% CL, $M\chi = 70$ GeV/c^2)

Broniatowski et al. Phys Lett B 681 (2009) 305; arXiv:0905.0753

ID-detectors: γ rejection & fiducial volume

Gamma rejection



Gamma rejection

^{133}Ba calibration data: fiducial only evts

1.82×10^5 events with 20 < E < 200 keV
(3.5×10^5 in total)

6 events ("anomalous")

→ γ–rejection factor of 3×10^{-5} NR / γ

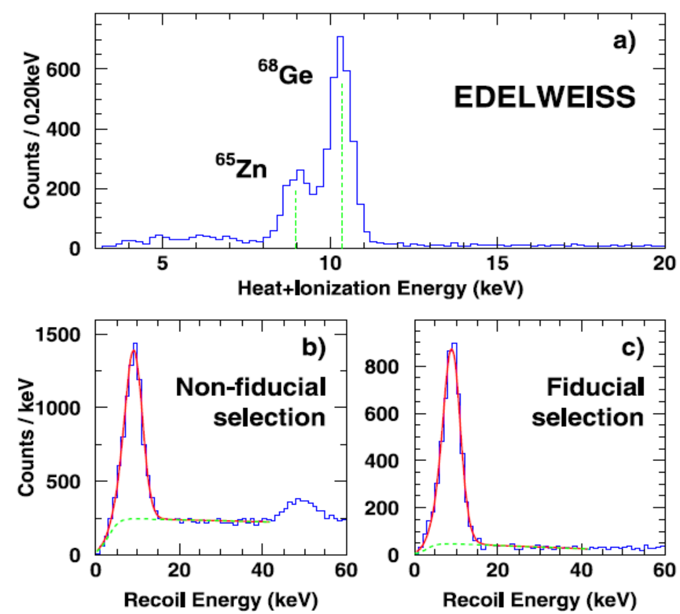
Fiducial volume

Fiducial volume (ID400): 166 ± 6 g => 160 g :
primarily limited by the guard region

→ Measurement with cosmogenic lines: ^{68}Ge + ^{65}Zn

→ Consistent with neutron calibration data

→ Consistent with electrostatic model estimation

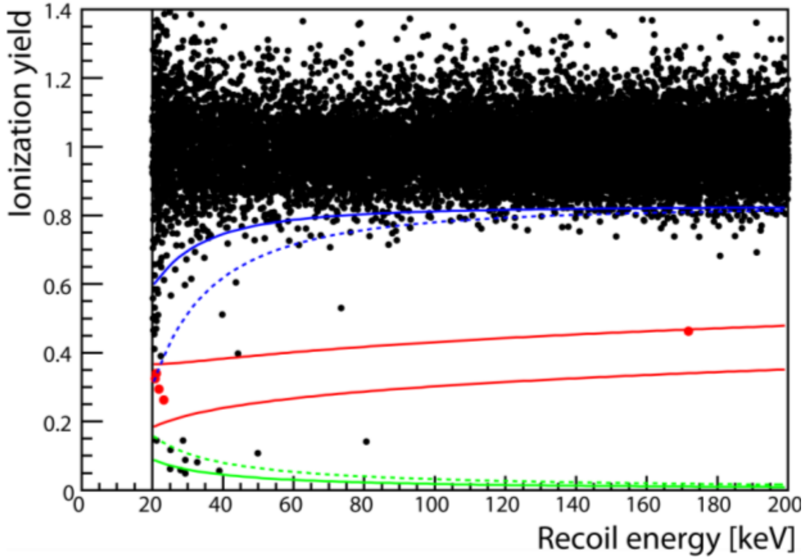


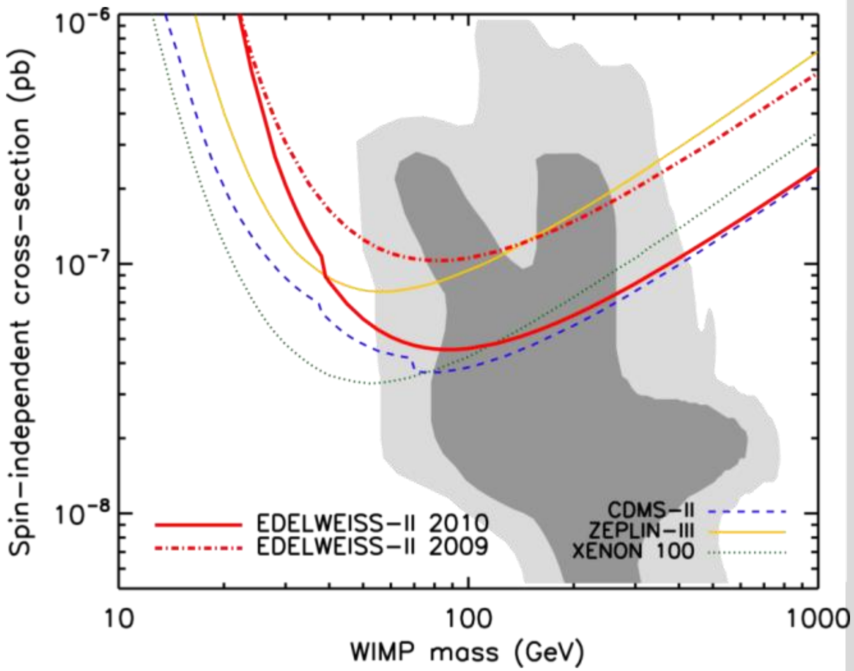
WIMP search : E_R>20keV (2008+2009+2010)

- 10 ID 400-g detectors
- Total exposure : **427 kg.d**
- in 90% NR band, i.e. WIMP RoI : **384 kg.d**
- **5 events observed:** 4 with E < 22.5 keV
  1 with E = 172 keV
- Expected background **< 3** (90% CL)

WIMP Halo:
local density of 0.3 GeV/c^2
Maxwellian velocity distribution
v_{rms} = 270 km/s
v_{Earth} = 235 km/s
v_{escape} = 544 km/s

$\sigma_{SI} < 4.4 \times 10^{-8}$ pb (90% CL), $M\chi$ = 85 GeV





Phys Lett B 702 (2011) 329; (arXiv: 1103.4070)

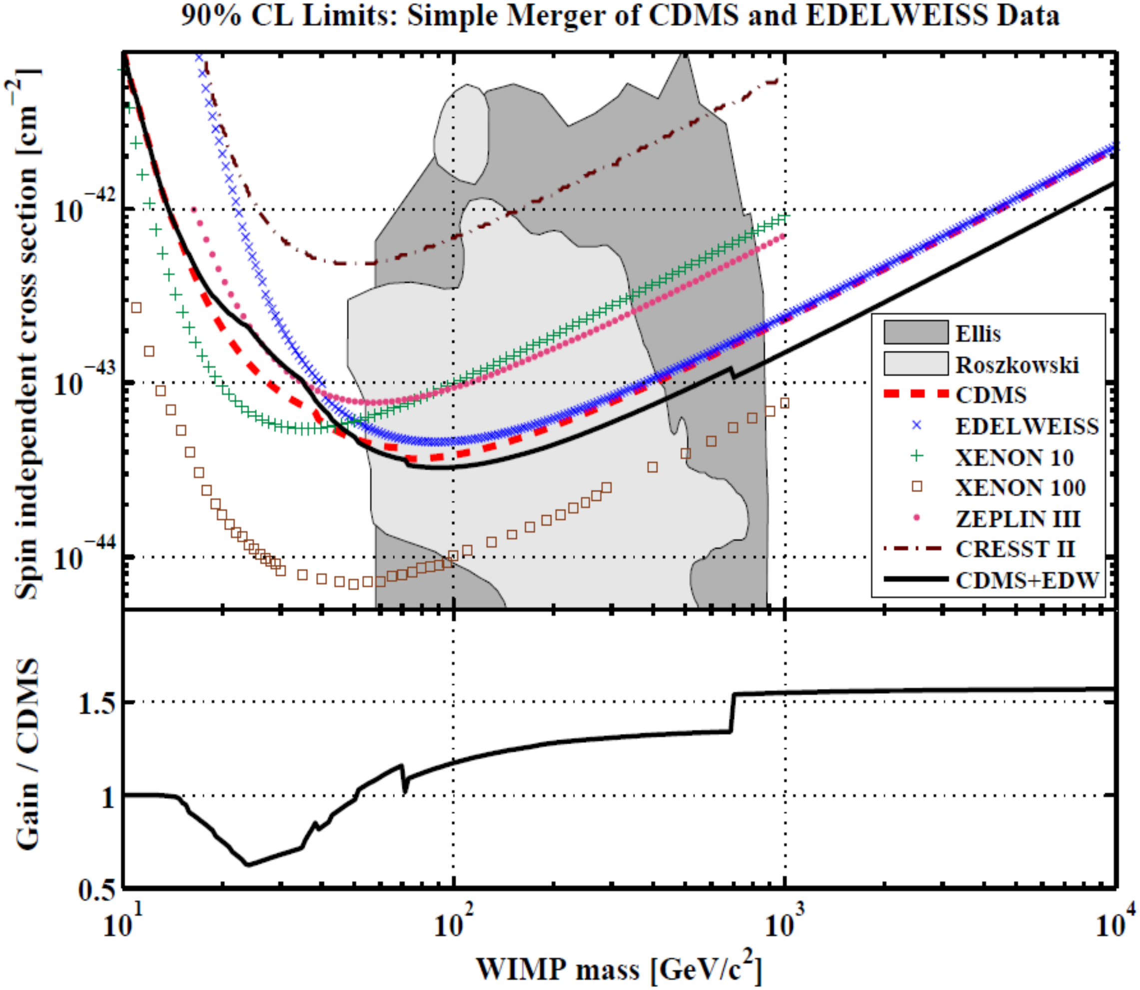
EDELWEISS + CDMS combined limits

- The use of the same target material allows simple combination of data.
- Simple merger of data sets was chosen prior to any analysis.

EDW: 384 kg.d, [20, 200keV], 5 evts
CDMS: ~379 kg.d, [~10, 100keV], 4 evts

- Other methods have also been tested (see paper).

~50% gain at high WIMP masses.



Phys. Rev. D 84, 011102 (2011); arXiv: 1105.3377

WIMP search: Low mass (1)

arXiv:1207.1815v1

- New independent analysis $E_R < 20$ keV
- Select ID detectors sensitive to nuclear recoils down to 5 keV
- General strategy to select the data set :
  - Keep 4 detectors with sub-keV ionisation and heat baseline resolutions
  - Remove noisy periods
  - χ^2 based cut
  - Exclude coincidences (muon veto, other bolometers)
  - Fiducial cut based on ionisation signal – energy independent
- Best energy estimator to search for nuclear recoils near the threshold:

$$E_{heat} = \frac{E_{rec}}{1+V/3}\left(1+\frac{V}{3}Q_n(E_{rec})\right), \quad Q_n(E_{rec}) = 0.16\, E_{rec}^{0.18}$$

O.Marteneau et al. NIM A530 (2004) 426

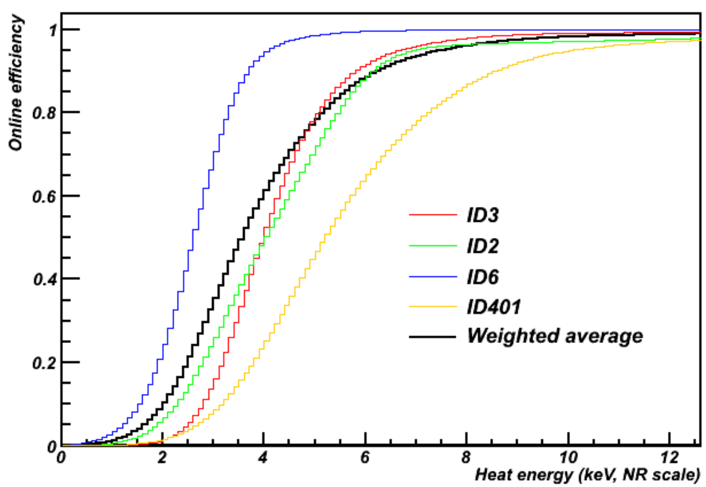
- Efficiency loss due to the online trigger (f(noise)):

$$\varepsilon_{online} = 0.5\left(1+Erf\left(\left(E_{rec}-E_{thresh}\right)/\sigma\sqrt{2}\right)\right)$$

(tested with gamma calibration on Compton plateau)

→ Good trigger efficiency @ low energy :

78 % @ 5 keVnr, 90 % @ 6.3 keVnr



WIMP search: Low mass (2)

arXiv:1207.1815v1

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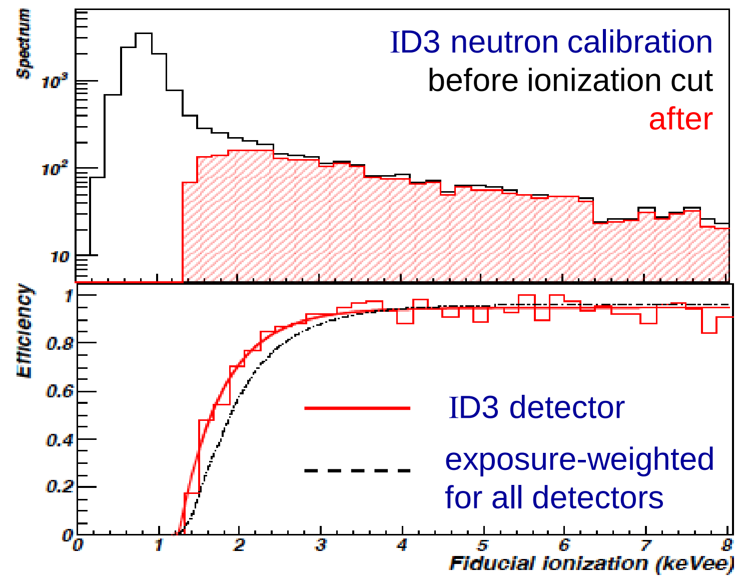
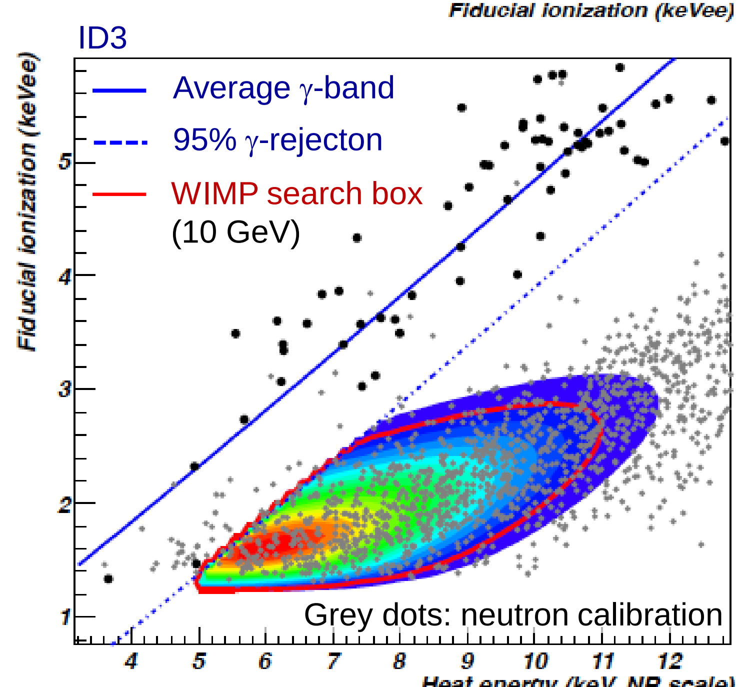
Use *Ionization signal* for:

- Fiducial selection
  - – No signal on veto and guard electrodes
  - – No difference between fiducial electrodes
- Ionization cut (rejection of ionizationless events):
  - – Δt < 30 μs for pulses on fiducial electrodes
  - – E_{ion} > 1.4 .. 1.9 keV (2 x FWHM)
- Construct (E_{heat},E_{ion}) plane :
  - – residual fiducial gamma background along:

$$E_{ion} = E_{rec}\left(1+Q_n\left(E_{rec}\right)V/3\right)/\left(1+V/3\right)$$

  - – width is defined by σ_{ion}, σ_{heat} (independent)
- Define "WIMP search box" in the (E_{heat},E_{ion}) plane for each WIMP mass and detector based on:
  - – 90% of WIMP signal density, $\rho\left(E_{rec}, E_{ion}\right)$
  - – below 95% gamma rejection cut



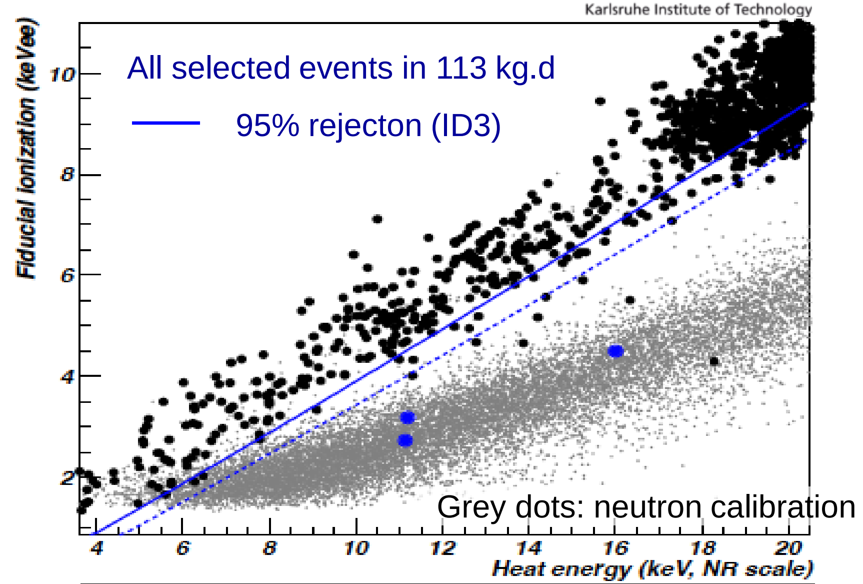


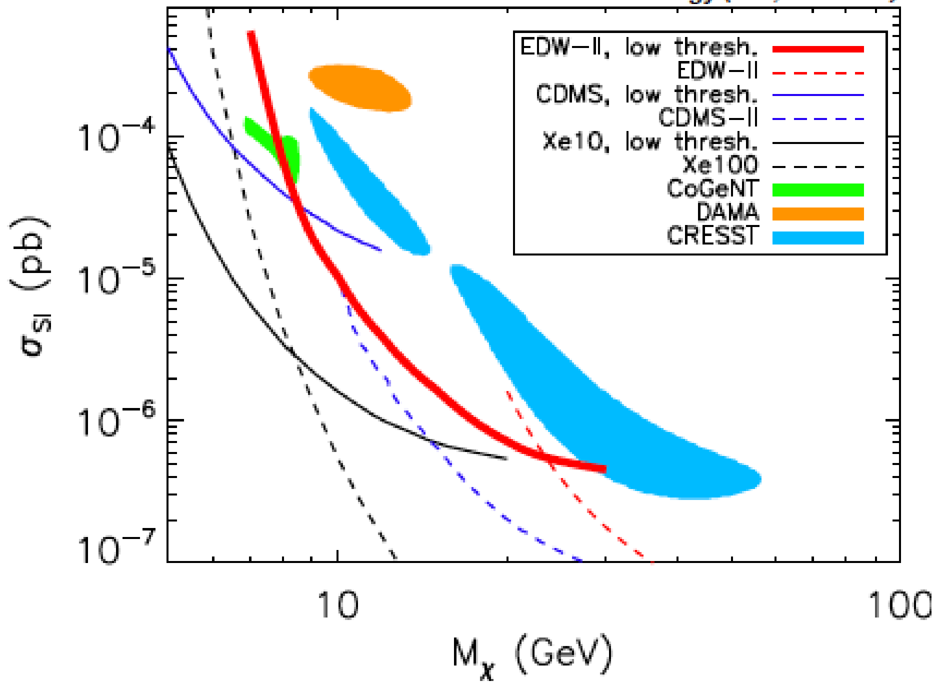
WIMP induced NR spectrum: C. Savage, Phys.Rev. D74 (2006) 043531

WIMP search: Low mass, results

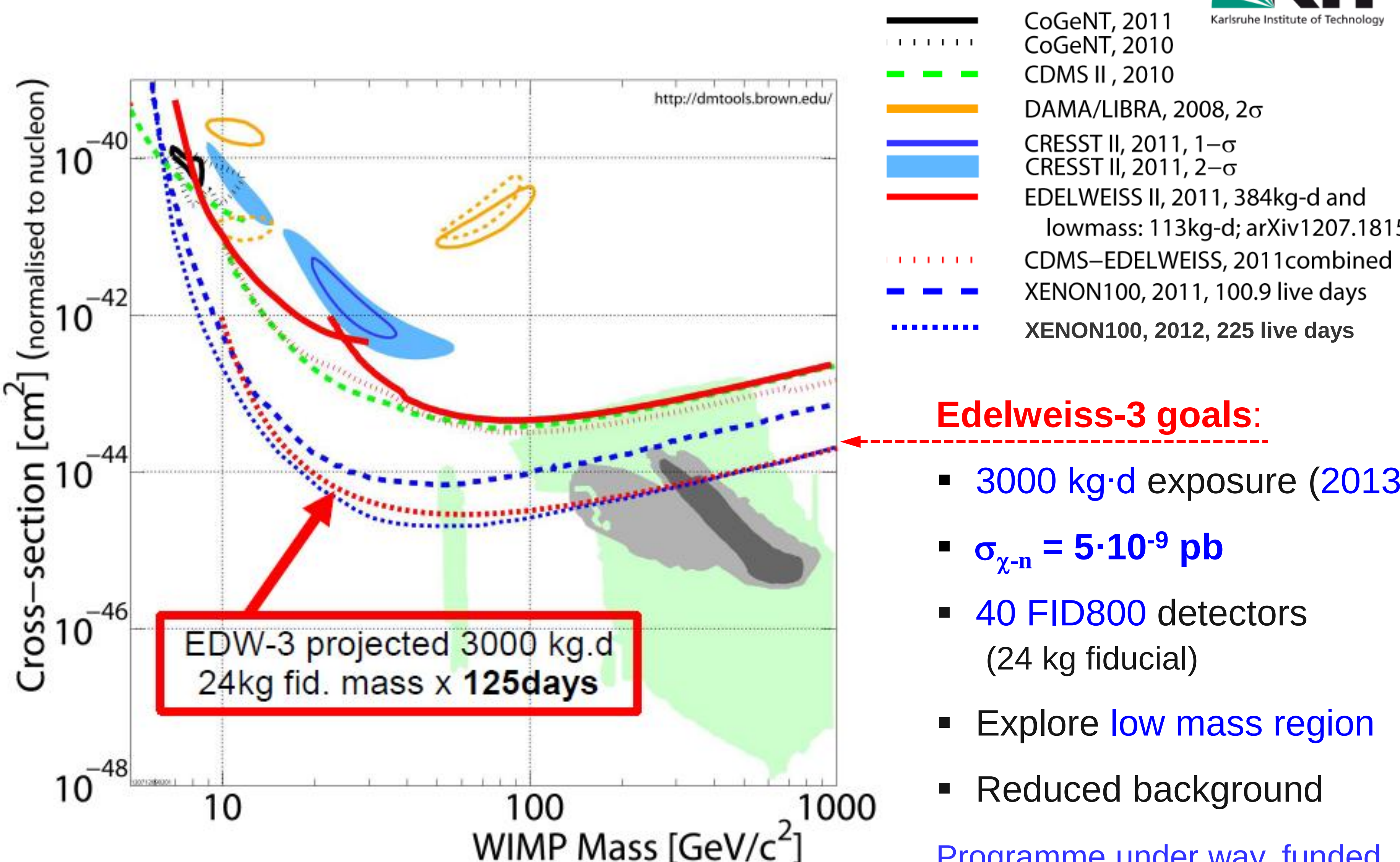
arXiv:1207.1815v1

- Total fiducial exposure : 113 kg.d
- 3 evts observed in the WIMP box
  (one event for $M\chi$ = 10 GeV)
- Estimated background (5-20 keV):
  - Neutron < 1.7 evt, most probable 1.0 evt
    (based on Monte-Carlo + activity meas.)
  - Gamma < 1.2 evt
- Limits on σ_{SI} derived from Poisson statistics
- Significantly extends EDW limits
  for $M\chi$ = 7-30 GeV
- Good rejection of surface events!





Towards EDELWEISS-3 (goals 2013)



Edelweiss-3 goals:

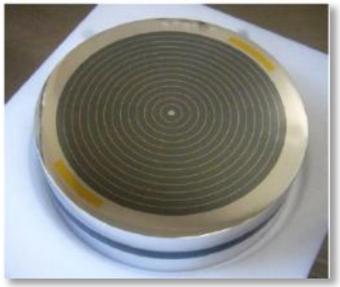
- 3000 kg·d exposure (2013)
- $\sigma_{\chi\text{-}n} = 5 \cdot 10^{-9}$ pb
- 40 FID800 detectors
  (24 kg fiducial)
- Explore low mass region
- Reduced background

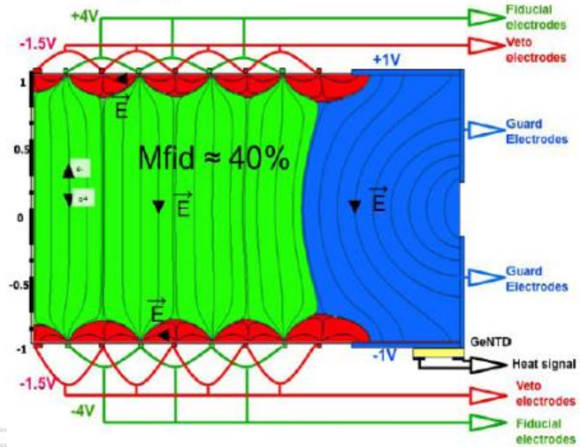
Programme under way, funded.

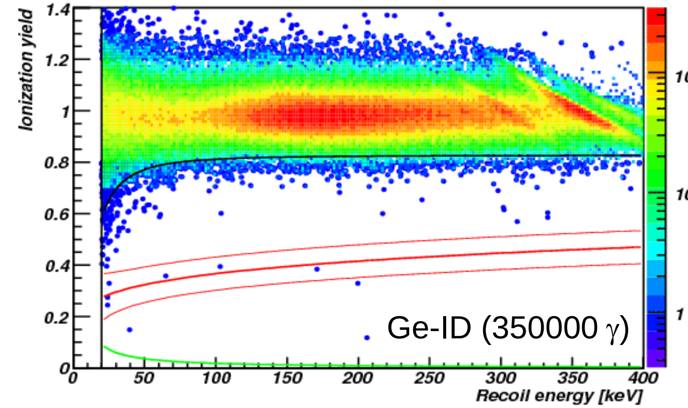
EDELWEISS-3 : new FID800

- ID400 (fid. 160g) => FID400 (300g) => FID800 (600g)

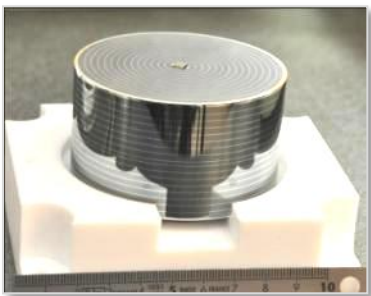
ID400

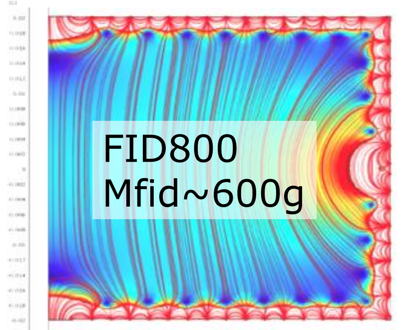


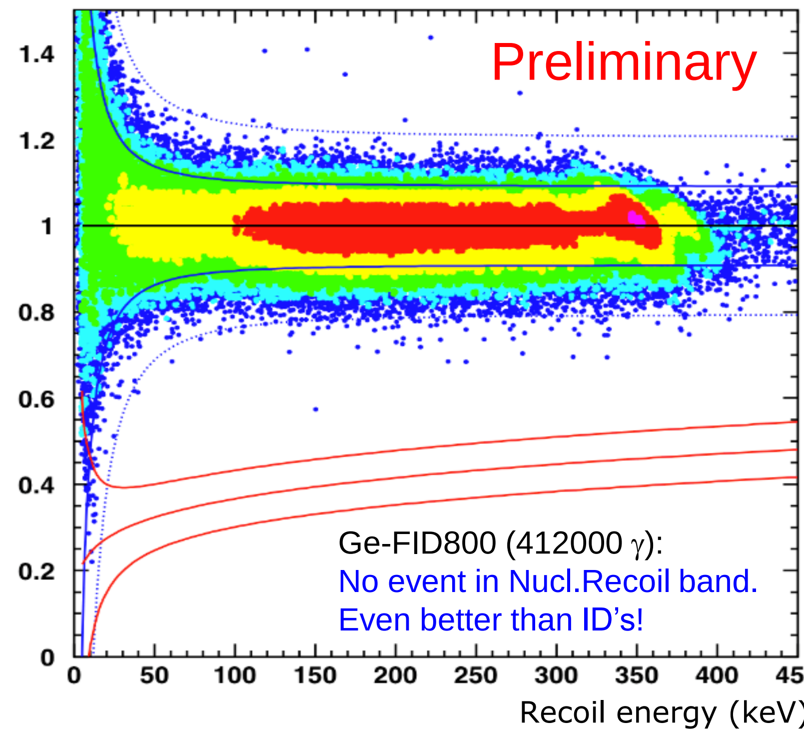




FID800

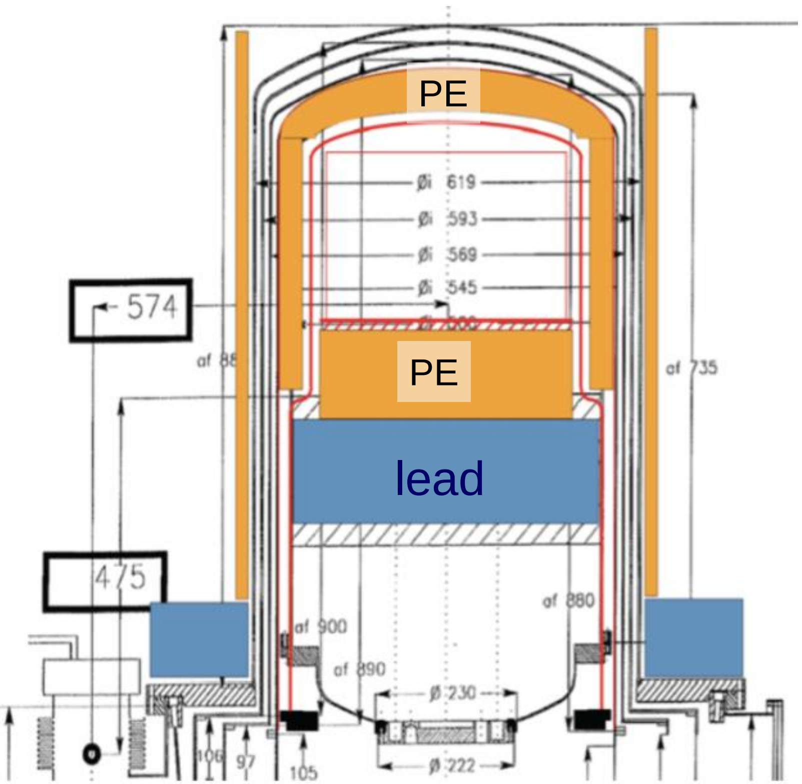


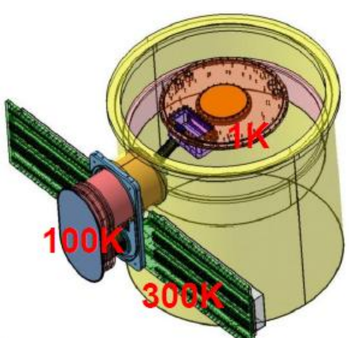




- 2 NTD heat sensors (better heat ch), 4 ionization channels, instead of 6.
- Larger Fiducial volume (75% vs. 40%)
- No event in NR (^{133}Ba: $4 \cdot 10^5$ γ's)
- Fabrication up to 1 FID800 / week (mandatory leakage-current tests)

Infrastructure improvements





Within the Edelweiss-2 setup:

- upgrades of muon veto, cryogenics, cabling, shielding
- Improved material selection
- Extra internal PE shield.

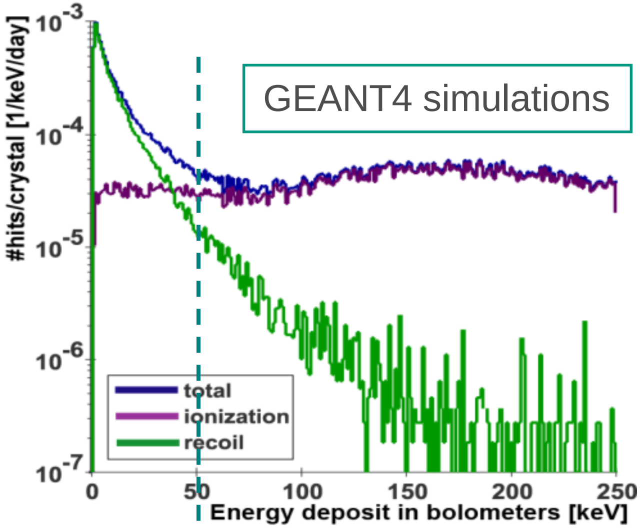
Background (20 – 200 keV)	**EDW-2 (evt / kg.d)**	**EDW-3 (evt / kg.d)**
Gamma rate	82	14 – 44
Ambient neutrons	$(2.6 - 8.1)\cdot 10^{-3}$ mainly due to cables and connectors	$(0.8 – 1.9)\cdot 10^{-4}$
Muon-induced neutrons	$< 1\cdot 10^{-3}$	$< 2\cdot 10^{-4}$

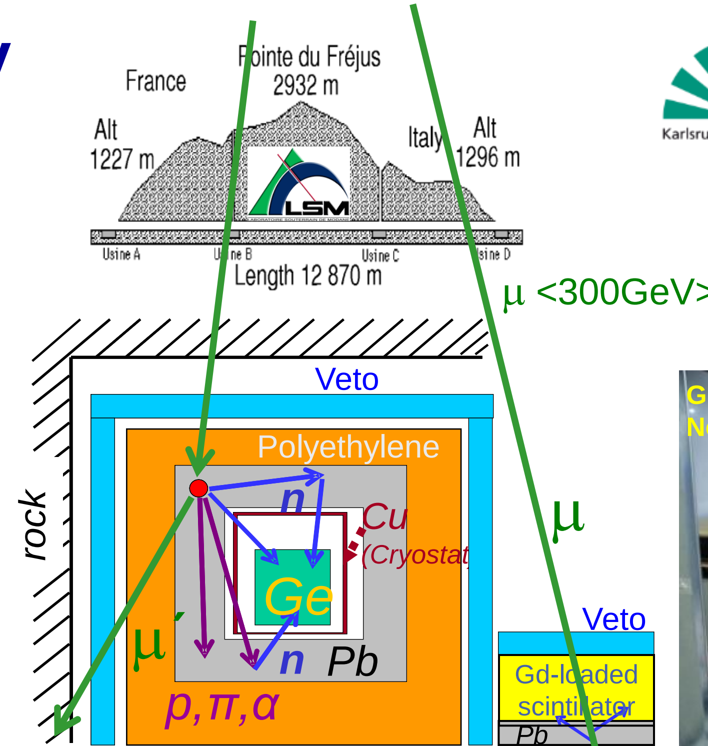
- Modify electronics and DAQ (scalability): 240 channels + auxiliary detectors
- New event-based readout
- More analysis tools
  Kdata: ROOT-based, multi-tier, db, …

NIM A 684,(2012) 63–72

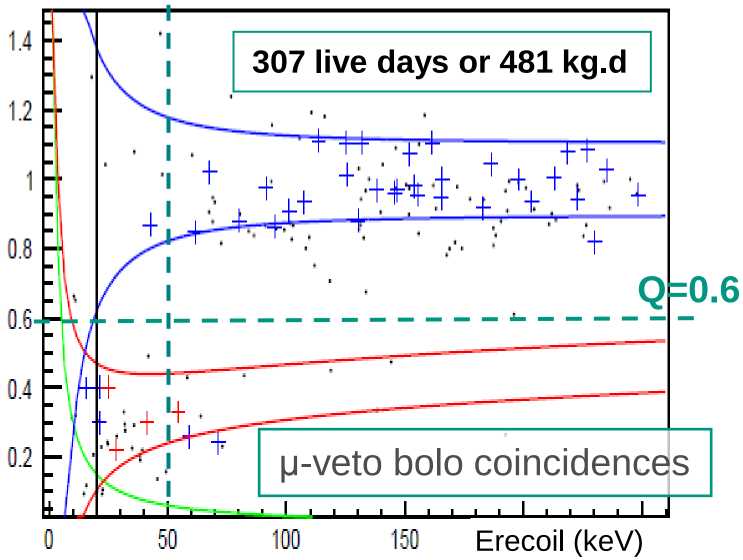
μ-induced background study

1.

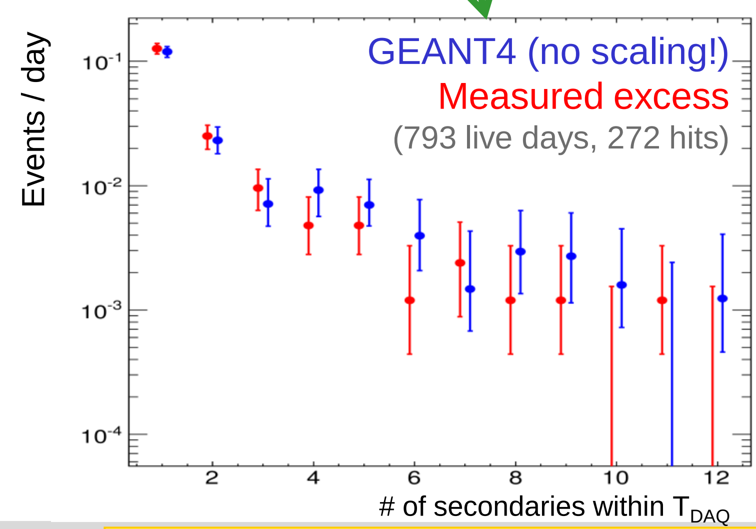




2.

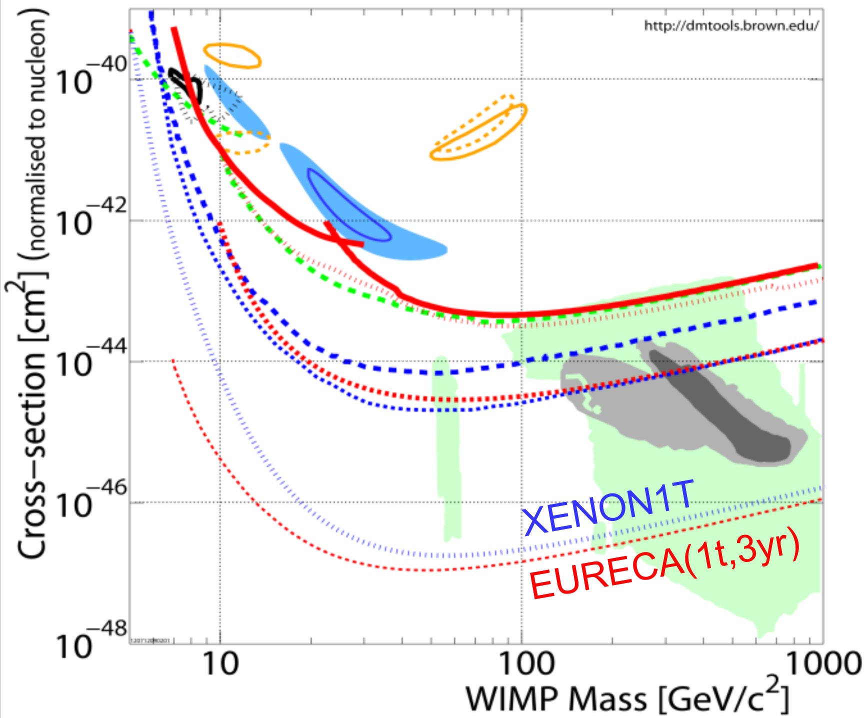


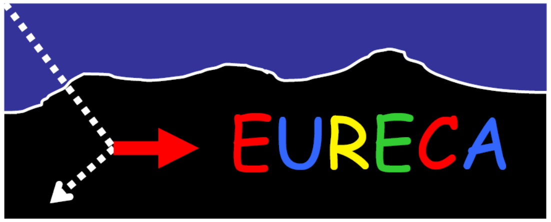
3.



Astro Part 34 (2010) 97; arXiv:1006.3098

EURECA, LSM extension





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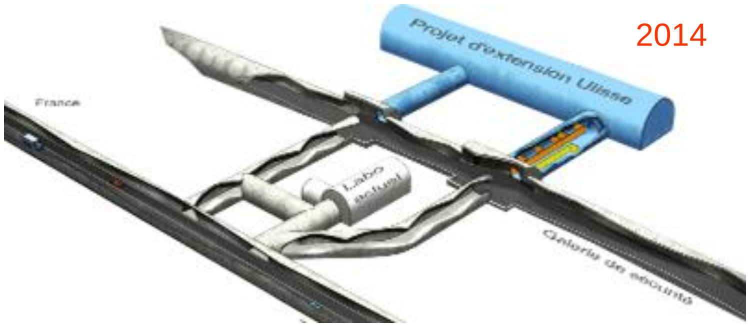
- # To probe **$10^{-10} \div 10^{-11}$** pb
- # Background **10^{-3}** evt/kg/yr
- # 150 kg → 1 ton Cryo detector; 2015 (150kg) 2018 (1 ton)
- # Multi-target (Ge, $CaWO_4$)
- # CRESST + EDELWEISS + ROSEBUD + ... ;

ASPERA

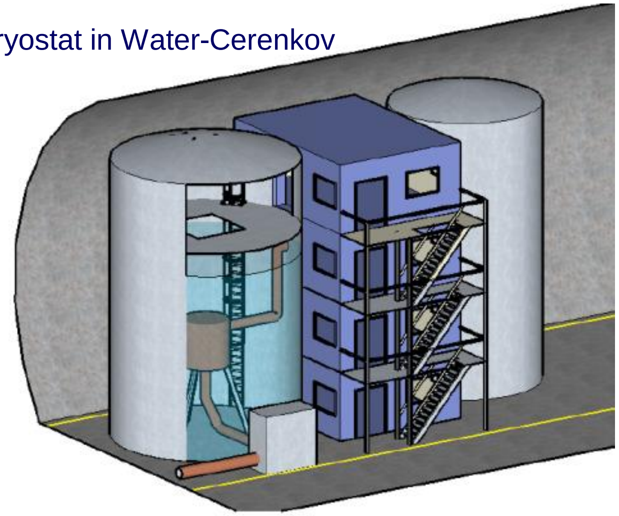
2 experiments (**different nuclei, different techniques**), e.g. **1 bolometric**, 1 noble liquid;

Fréjus road safety tunnel: excavation started **!**

→ unique option for LSM extention !



Cryostat in Water-Cerenkov



Summary & Outlook

- ✓ EDELWEISS-2 final analysis of one year (2009-2010): $4.4 \cdot 10^{-8}$ pb, eff. exposure: 384 kg.d

Phys Lett B 702 (2011) 329

- ✓ EDELWEISS-2 data are combined with CDMS

Phys. Rev. D 84, 011102 (2011)

- ✓ Low WIMP mass analysis: $1.0 \cdot 10^{-5}$ pb for $M\chi$=10 GeV, eff.exposure: 113 kg.d

arXiv:1207.1815v1

- ✓ EDELWEISS-3 scientific goal is a few 10^{-9} pb e.g. $5 \cdot 10^{-9}$ pb, eff. exposure of 3000 kg.d (125 live days in 2013);
- ✓ New Ge-FID800 (600g fiducial), improved background rejection
- ✓ Upgrades of the set-up and DAQ
- ✓ Various background studies

→ Road to 1 ton experiment, **EURECA**

Science & Technology Facilities Council

ANR

bmb+f - Förderschwerpunkt Astroteilchenphysik Großgeräte der physikalischen Grundlagenforschung

HELMHOLTZ ASSOCIATION

Alliance for Astroparticle Physics

The EDELWEISS Collaboration

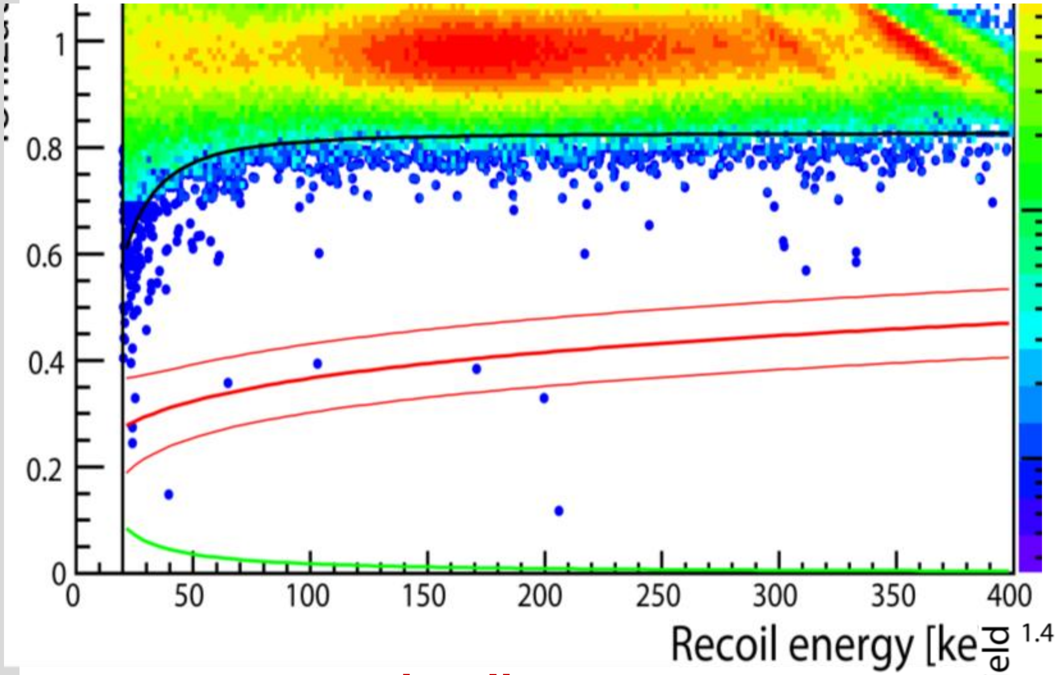
≈ **50 persons (30 FTE);**
11 PhD students;
5 post-docs;
4 countries

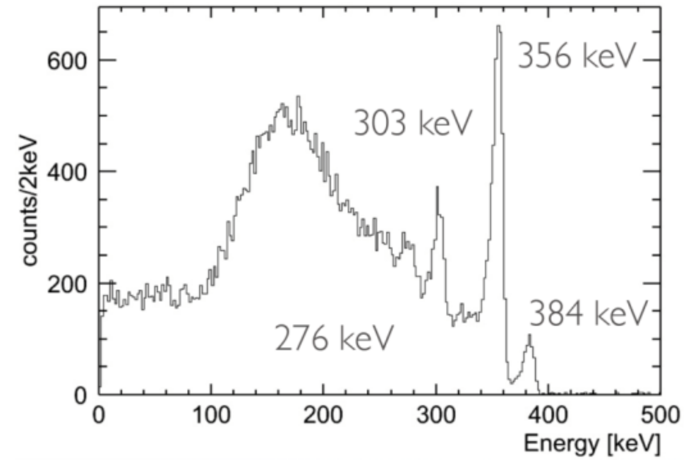
• CEA Saclay (IRFU & IRAMIS)	• Detectors, electronics, aquistion, data handling, analysis
• CSNSM Orsay	• Detectors, cabling, cryogenics
• IPN Lyon	• Electronics, cabling, low radioactivity, analysis, detectors, cryo
• Institût Néel Grenoble	• Cryogenics, electronics
• KIT Karlsruhe (IKP, IEKP, IPE)	• Vetos, neutron detector, background, analysis, electronics
• JINR Dubna	• Background, neutron, radon monitors
• Oxford University	• Detectors, cabling, cryogenics, analysis
• Sheffield University	• MC simulations

BACKUP SLIDES

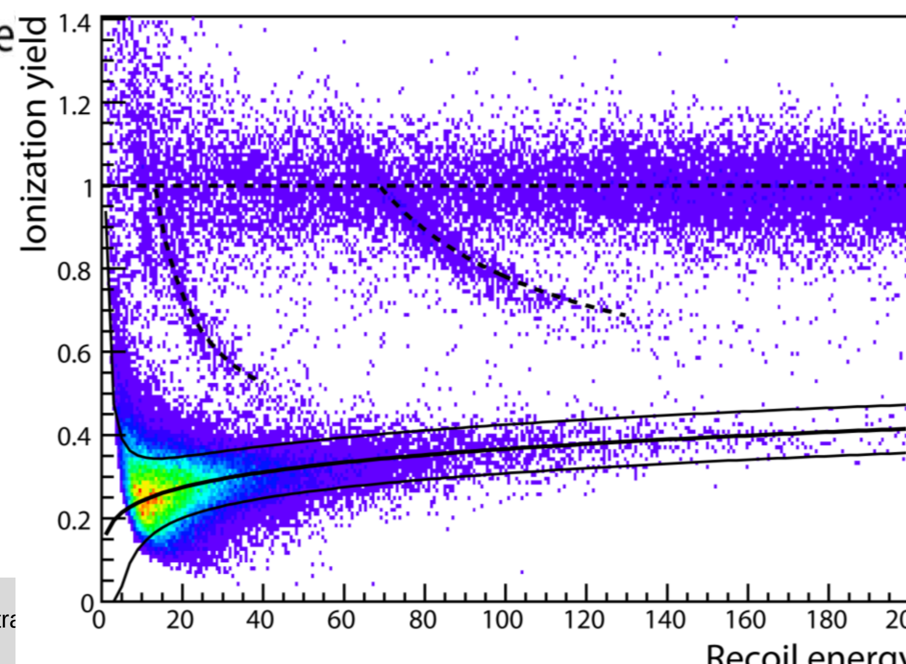
ID Calibration

γ calibrations with ^{133}Ba

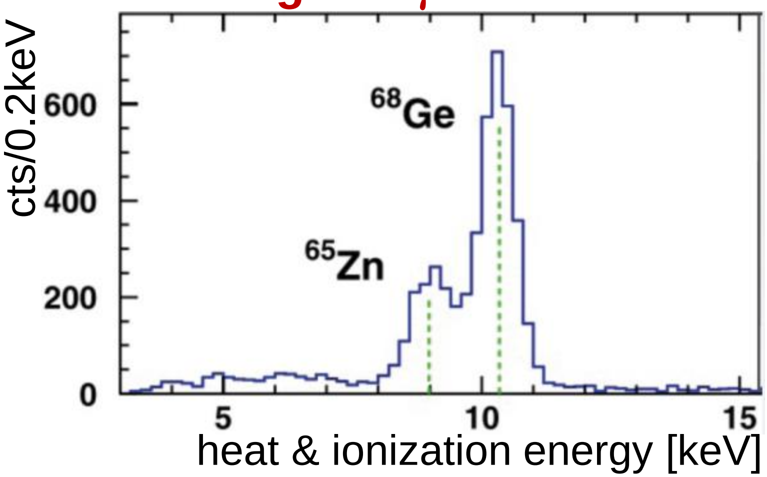




n calibrations with AmBe



cosmogenic γ lines



EDW-2 background: neutrons from rock & materials

Source	Material	Neutron events (384 kg×days)
Hall walls	Rock	<0.01
Hall walls	Concrete	<0.1
Shielding	Polyethylene	<0.01
Shielding	Lead	<0.08
Support	Stainless steel	<0.01
Support	Mild steel	<0.04
Warm electronics	PCB	1.0±0.5
1K connectors	Aluminium	0.5±0.2
Thermal screens, crystal supports	Copper	<0.1
Coaxial cables	PTFE	<0.5
Crystal holders	PTFE	<0.01
Electrodes	Aluminium	<0.01
Total		<3.1