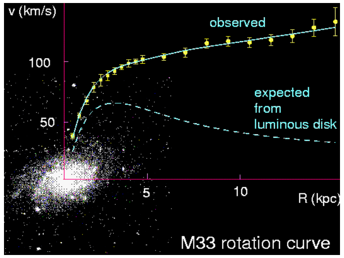
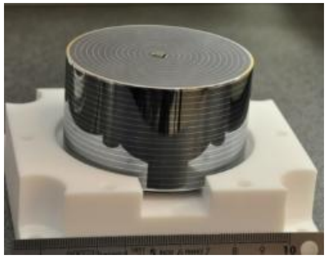
The EDELWEISS Dark Matter search program

Valentin Kozlov for the EDELWEISS collaboration

Institute for Nuclear Physics, Karlsruhe Institute of Technology

9th Patras Workshop on Axions, WIMPs and WISPs
Mainz / Schloß Waldthausen, Germany
24 - 28 June 2013





Outline

- Edelweiss-2 summary
  - Bolometers and the setup
  - Main results for DM search:
    - WIMPs: ‘standard’ (100 GeV) and low-mass (10 GeV)
    - (Axion search (10^{-5}-10^{2} keV): C.Nones talk on Thursday)
  - Background budget
- Edelweiss-3 program
  - Decreased background
  - Improvements of the setup
  - Bigger and better bolometers
  - Expected sensitivity
- EURECA prospects
- Summary and Outlook

Edelweiss: search for DM @ LSM (France)

Karlsruhe Institute of Technology

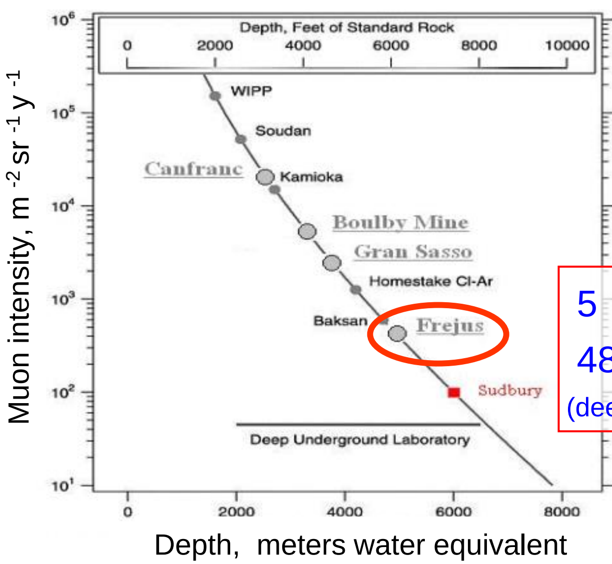
Collaboration

Collaboration meeting 3/2013 @Karlsruhe

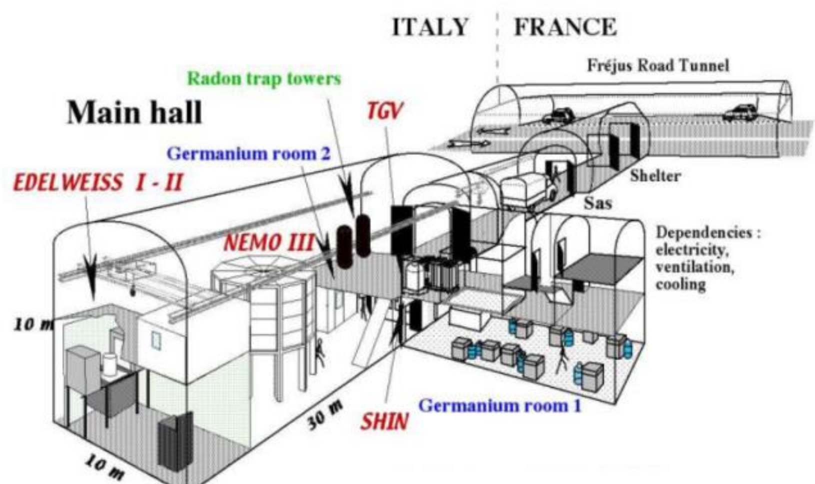
≈ **50 persons (30 FTE);**
10 PhD students;
4 post-docs;
4 countries

France	Germany	Russia	UK
Grenoble Lyon Orsay Saclay	Karlsruhe	Dubna	Oxford Sheffeld

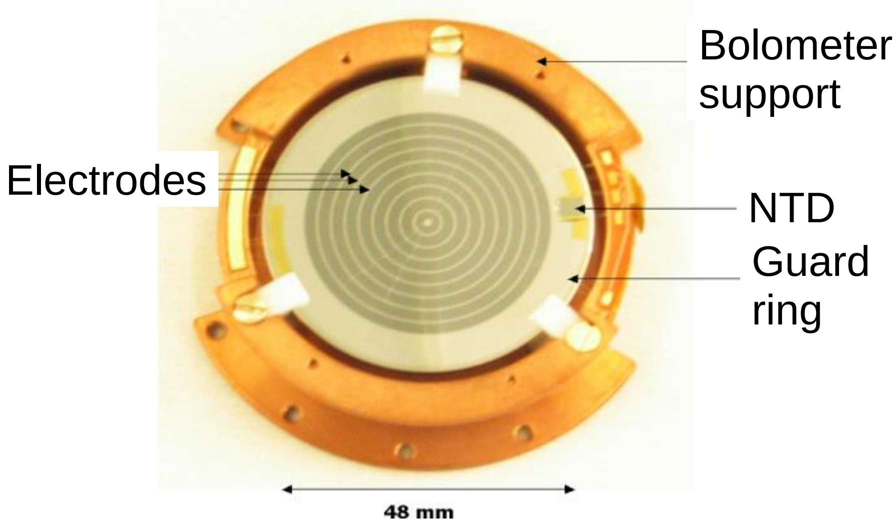
LSM



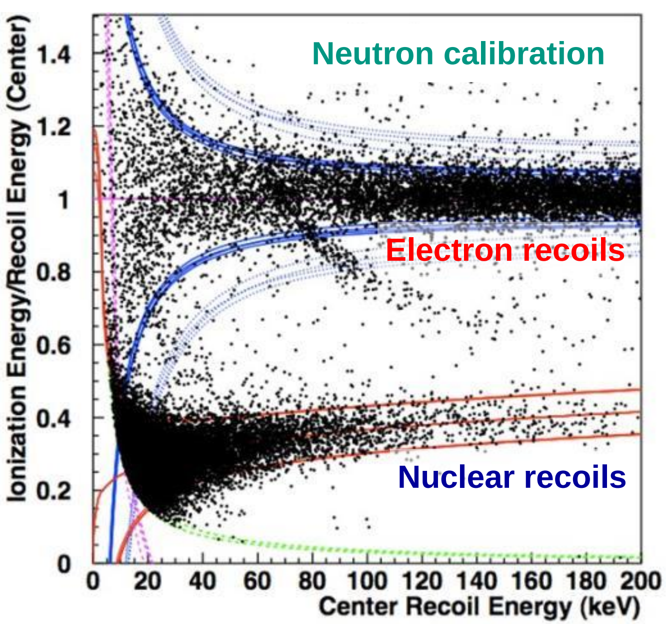
5 μ/m^2/day
4800 mwe
(deepest in Europe)

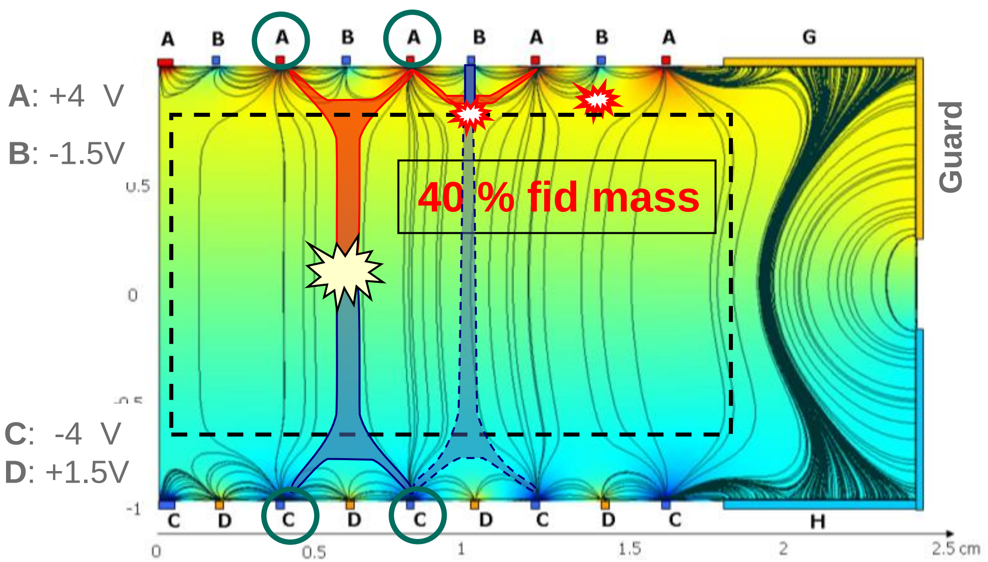


(F)ID Ge-bolometers: (Fully) InterDigitized design



- **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**
- **Vetoing surface events (ID electrodes)**





Broniatowski et al. Phys Lett B 681 (2009) 305

ID Ge-bolometers: surface event rejection

Measurement:

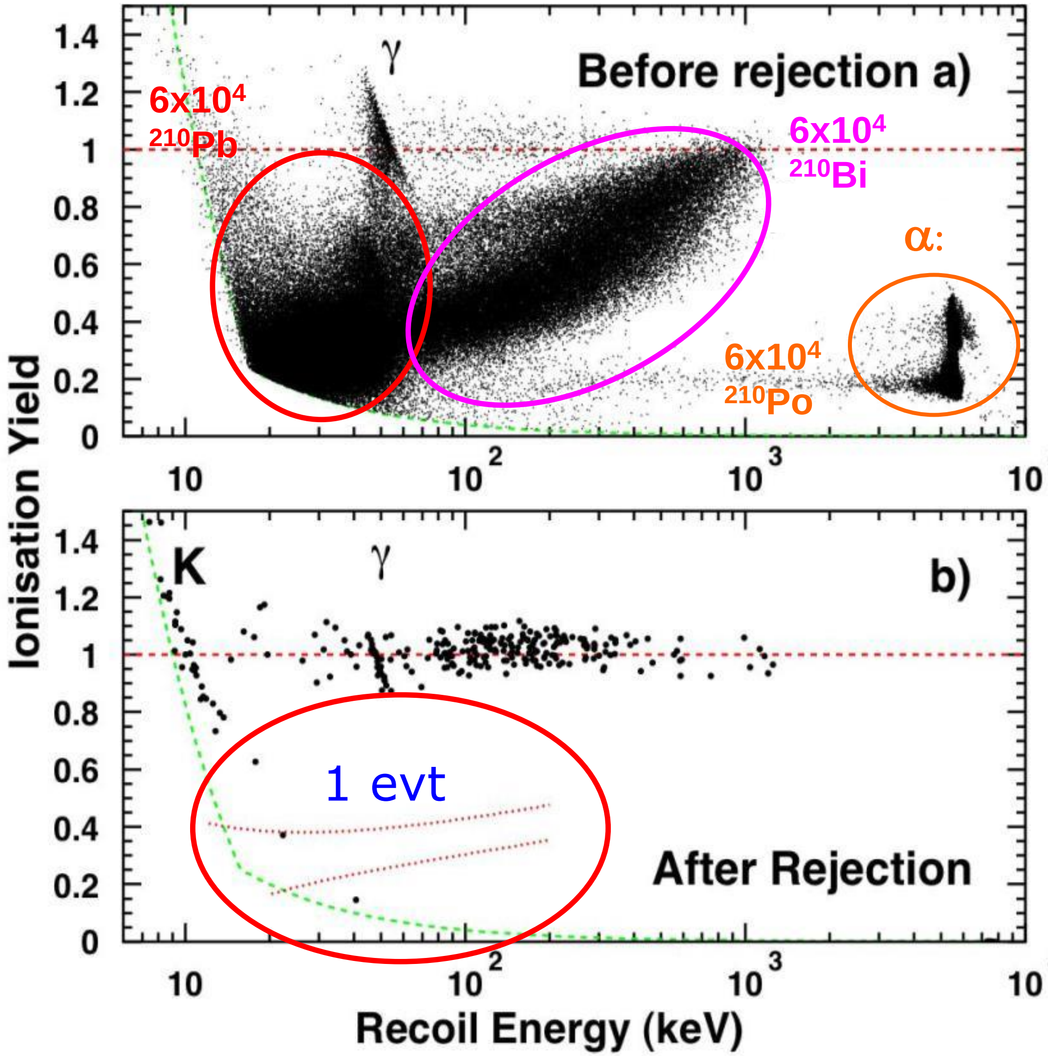
intentional ^{210}Pb source:
6 x 10^4 events total

requiring no signal on veto electrodes:
1 event left

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

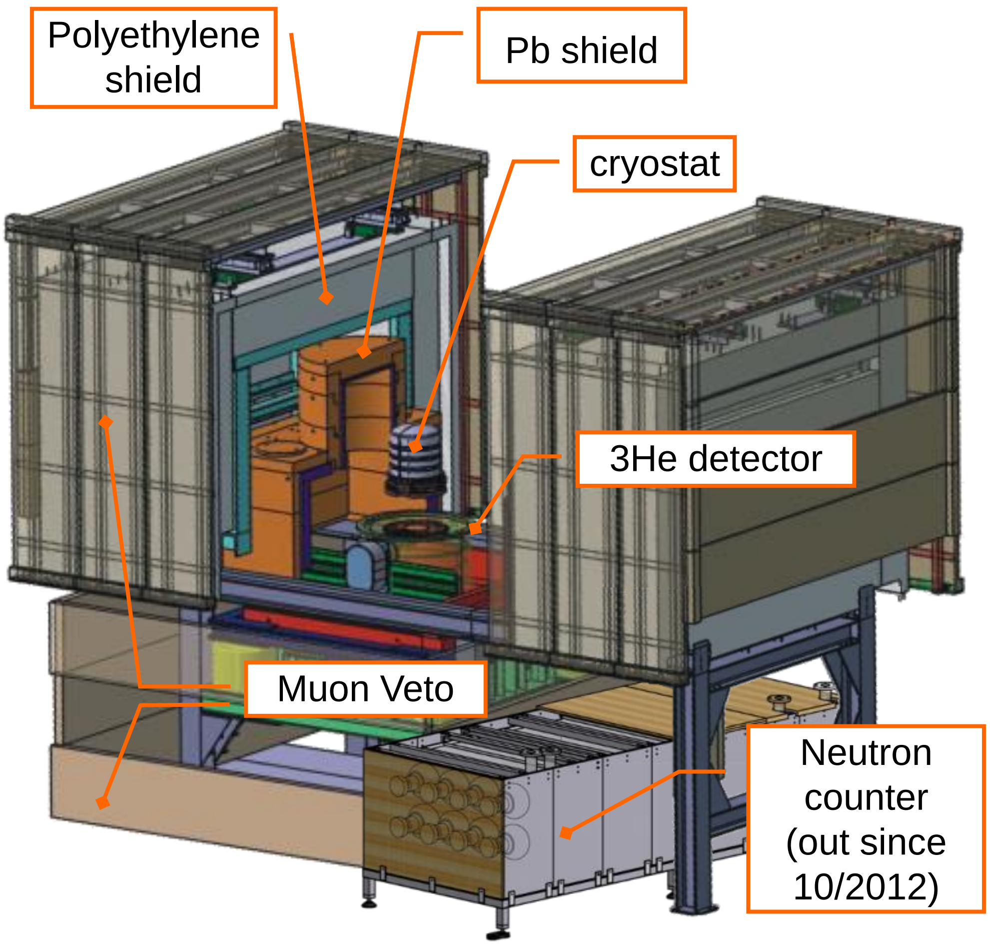
→ In case of *no other background*:
$\sigma_{SI} \sim 4 \times 10^{-46}$ cm^2
(90% CL, $M\chi$ = 70 GeV/c^2)

NB : CDMS decided on an ID-inspired design for their new detectors.



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

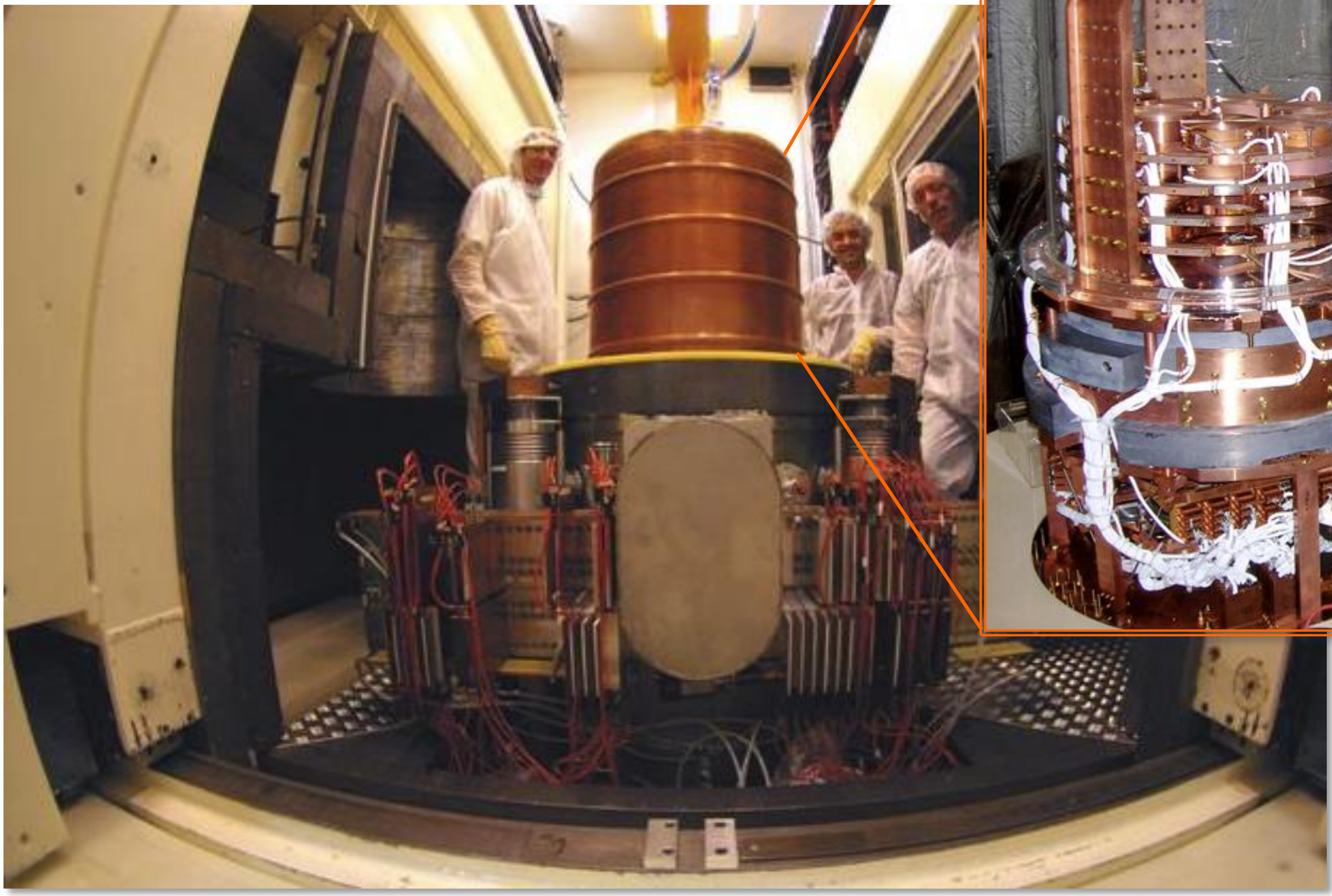
Edelweiss-2 (3) experimental set-up

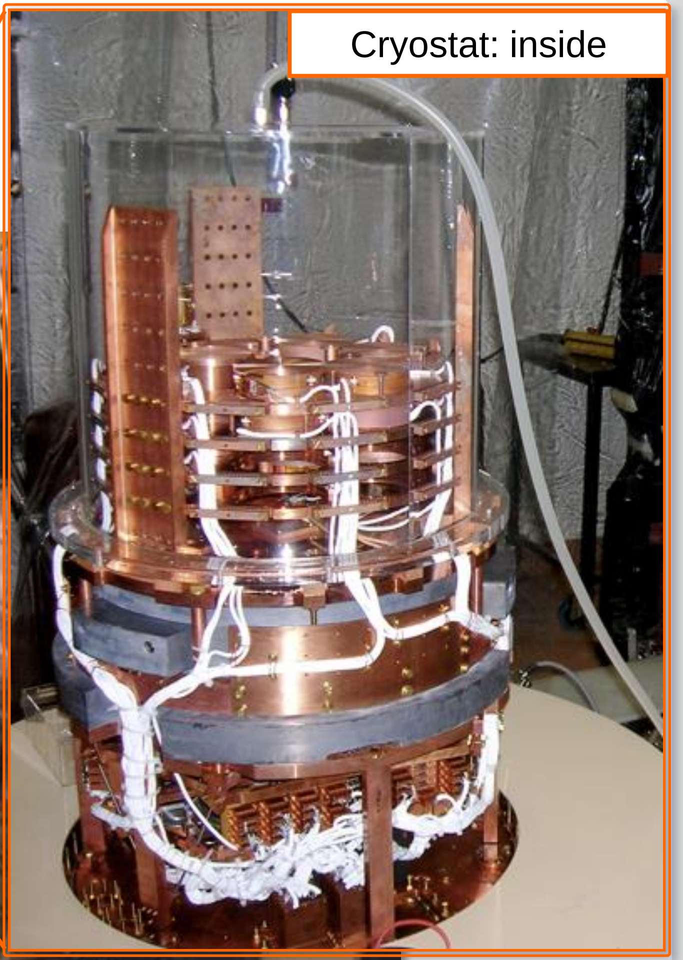


- **Edelweiss-3 goal $\sigma_{\chi\text{-}n} = 10^{-45}$ cm^2**
- Cryogenic installation (18 mK) :
  - Reversed geometry cryostat
  - **Can host up to 40 kg of detectors**
- Shieldings :
  - Clean room + deradonized air
  - Active muon veto (>98% coverage)
  - **PE** shield **50 cm** (EDW-3: +internal PE)
  - **Lead** shield **20 cm**
- (Many) others :
  - Remotely controlled sources for calibrations + regenerations
  - Radon detector down to few mBq/m^3
  - thermal neutron monitoring (3He det.)
  - study of muon induced neutrons (liquid scintillator 1 m^3 neutron counter)
- 20 cool-downs operated since 2006

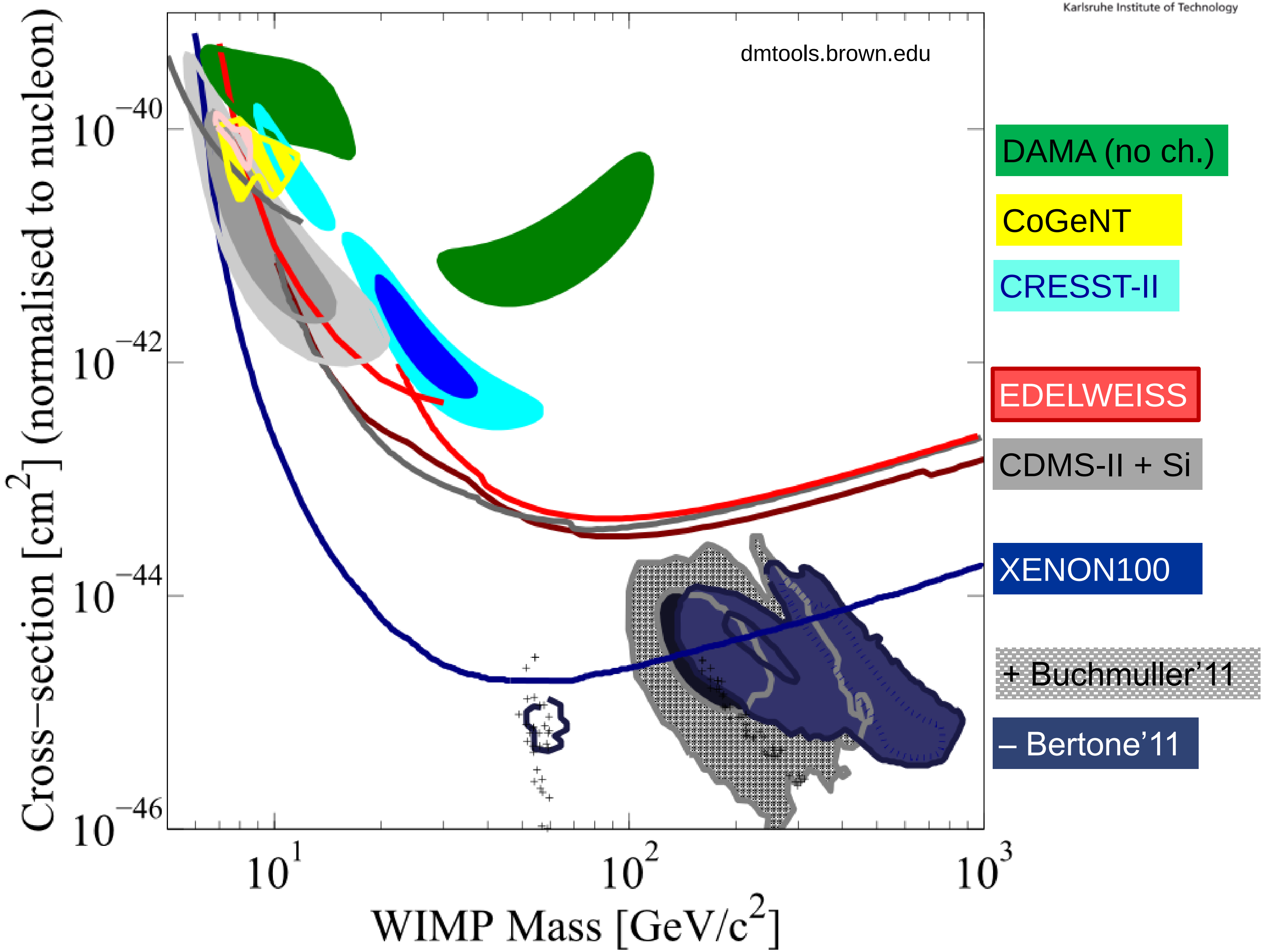
Edelweiss-2 setup: View from ‚inside'

Edelweiss-2 setup: View from ‚inside'

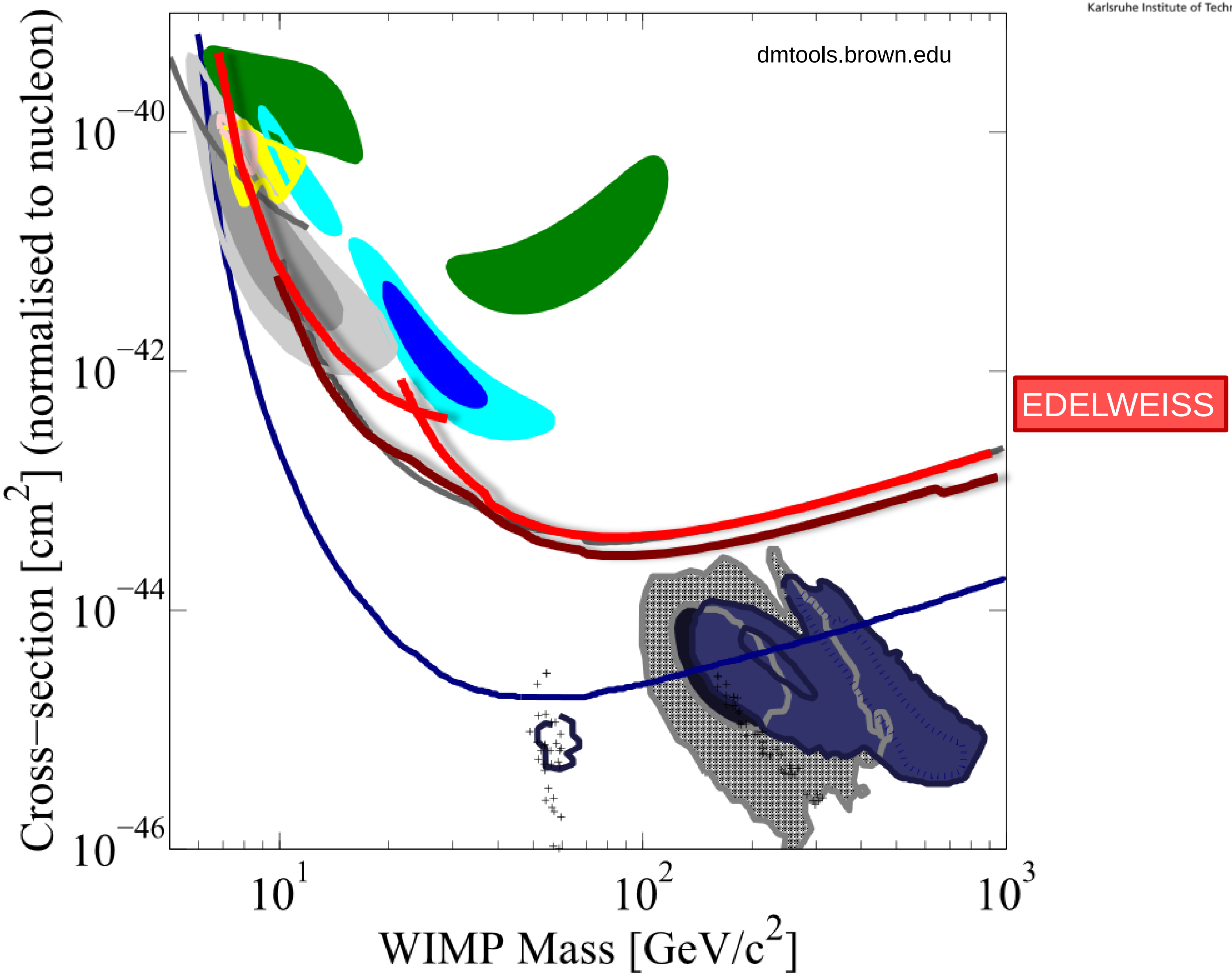




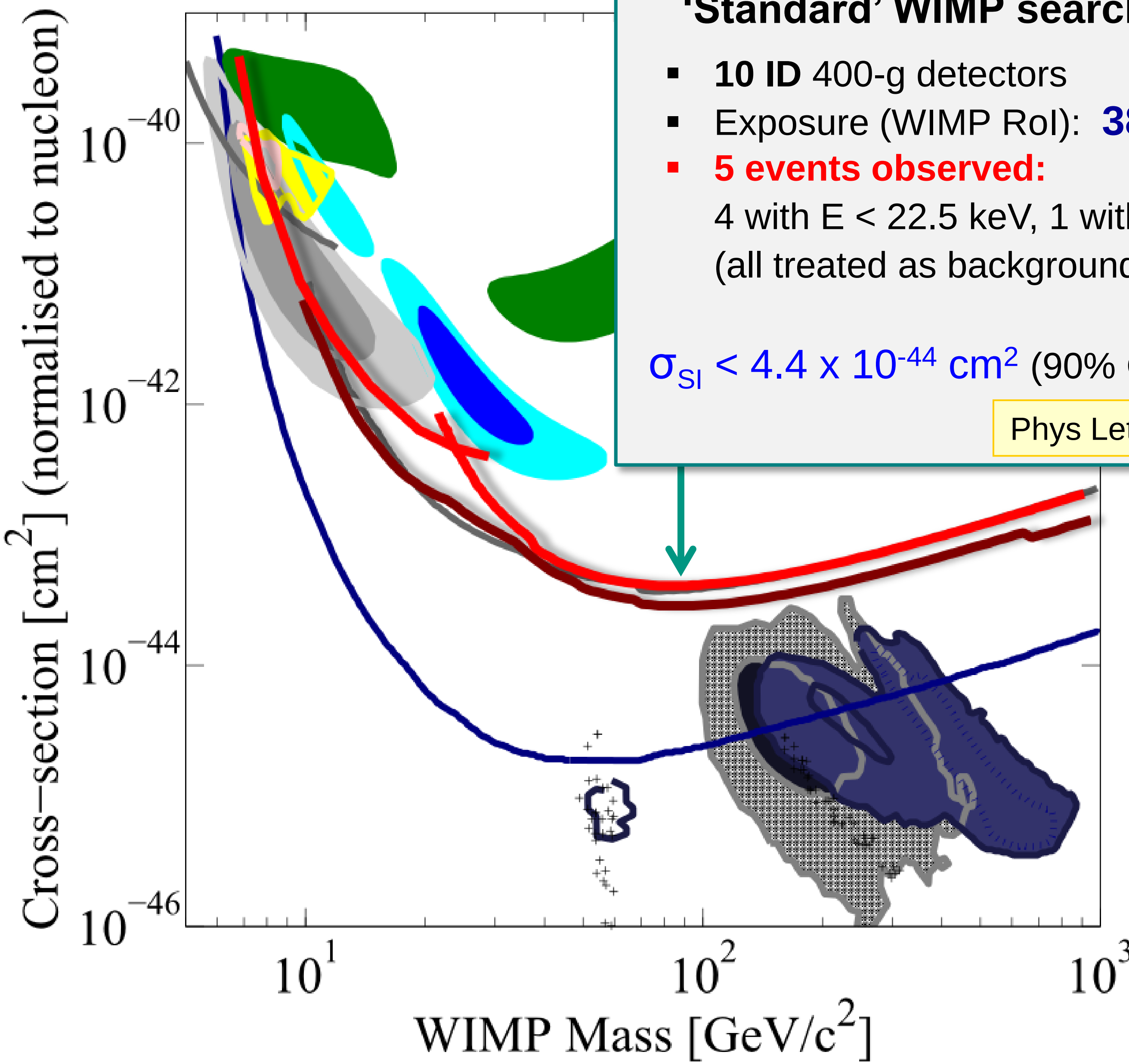
Edelweiss-2 WIMP search : 2008+2009+2010



Edelweiss-2 WIMP search : 2008+2009+2010



Edelweiss-2 WIMP search : 2008+2009+2010



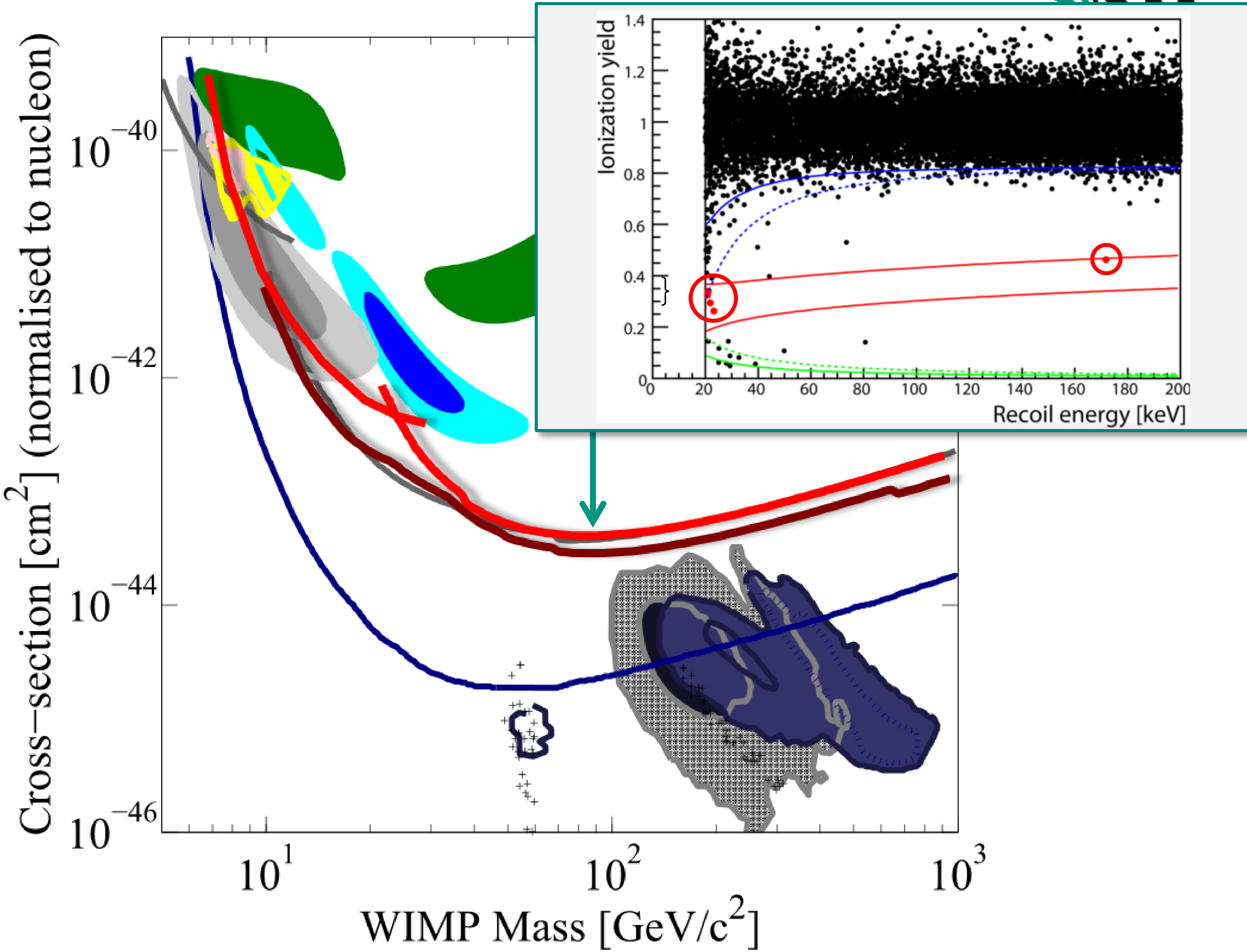
'Standard' WIMP search

- **10 ID** 400-g detectors
- Exposure (WIMP RoI): **384 kg.d**
- **5 events observed:**
  4 with E < 22.5 keV, 1 with E = 172 keV
  (all treated as background)

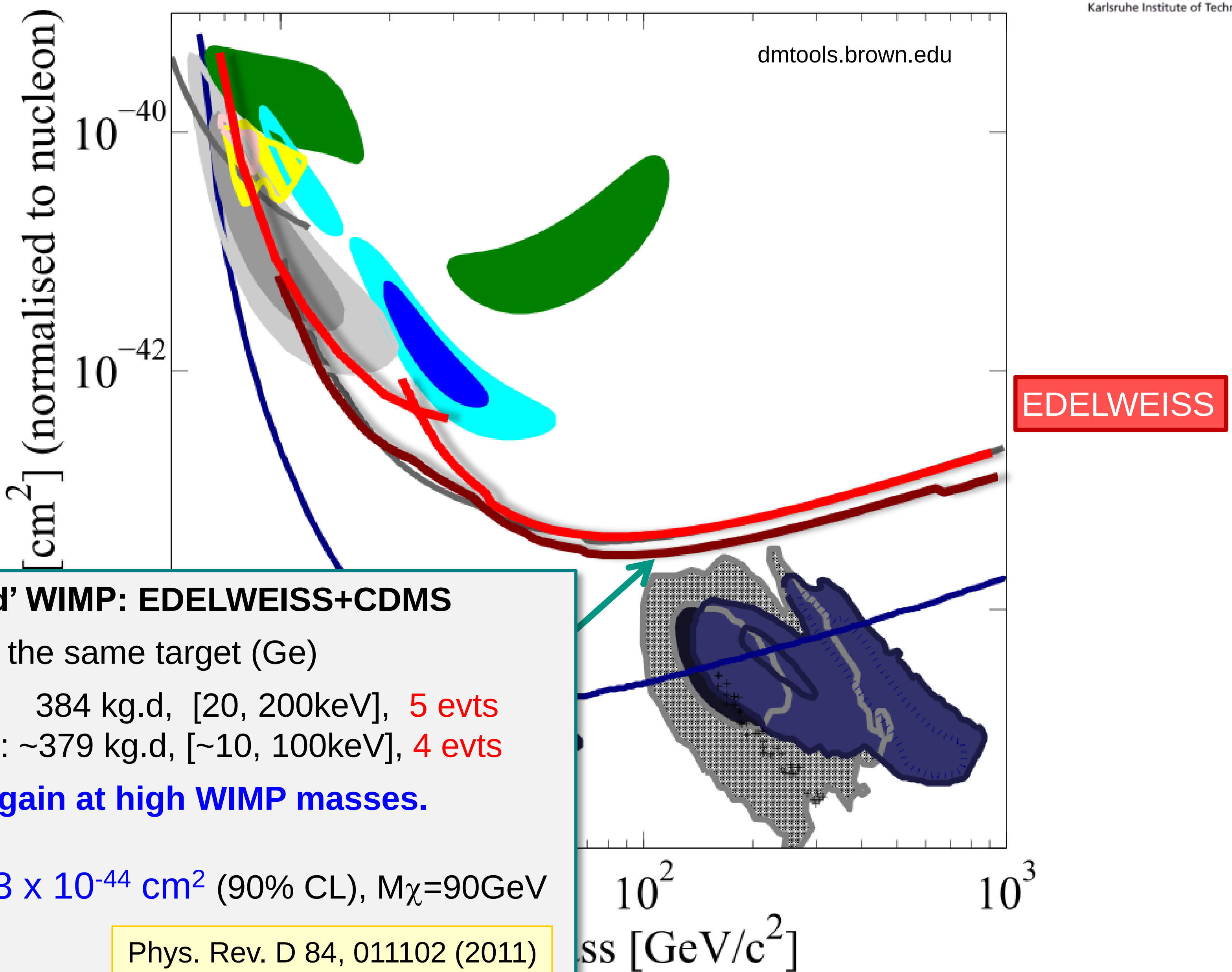
$\sigma_{SI} < 4.4 \times 10^{-44}$ cm^2 (90% CL), M_χ=85GeV

Phys Lett B 702 (2011) 329

Edelweiss-2 WIMP search : 2008+2009+2010



Edelweiss-2 WIMP search : 2008+2009+2010



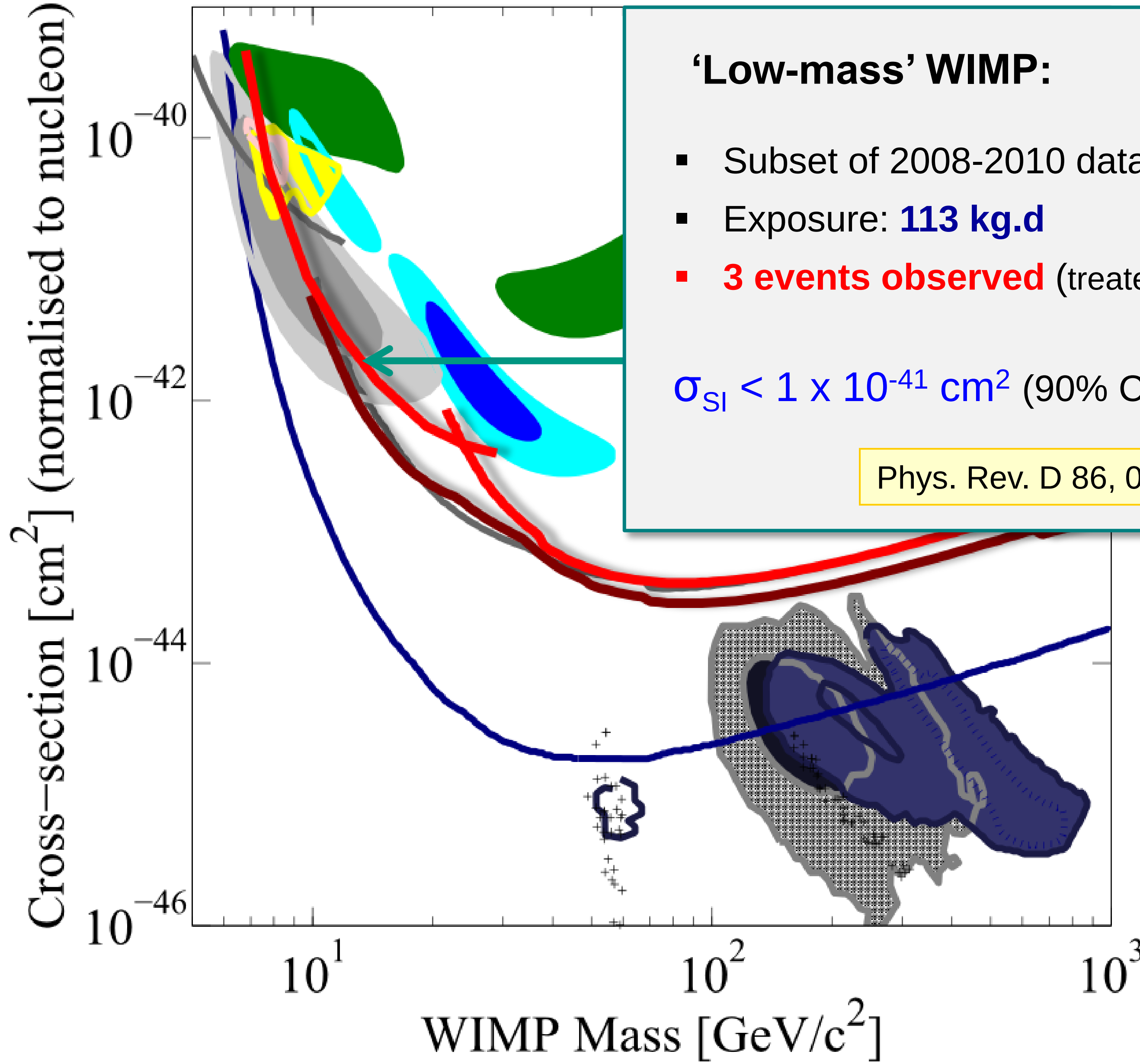
'Standard' WIMP: EDELWEISS+CDMS

- Use of the same target (Ge)
- EDW: 384 kg.d, [20, 200keV], 5 evts
  CDMS: ~379 kg.d, [~10, 100keV], 4 evts
- **~50% gain at high WIMP masses.**

$\sigma_{SI} < 3.3 \times 10^{-44}$ cm^2 (90% CL), Mχ=90GeV

Phys. Rev. D 84, 011102 (2011)

Edelweiss-2 WIMP search : 2008+2009+2010



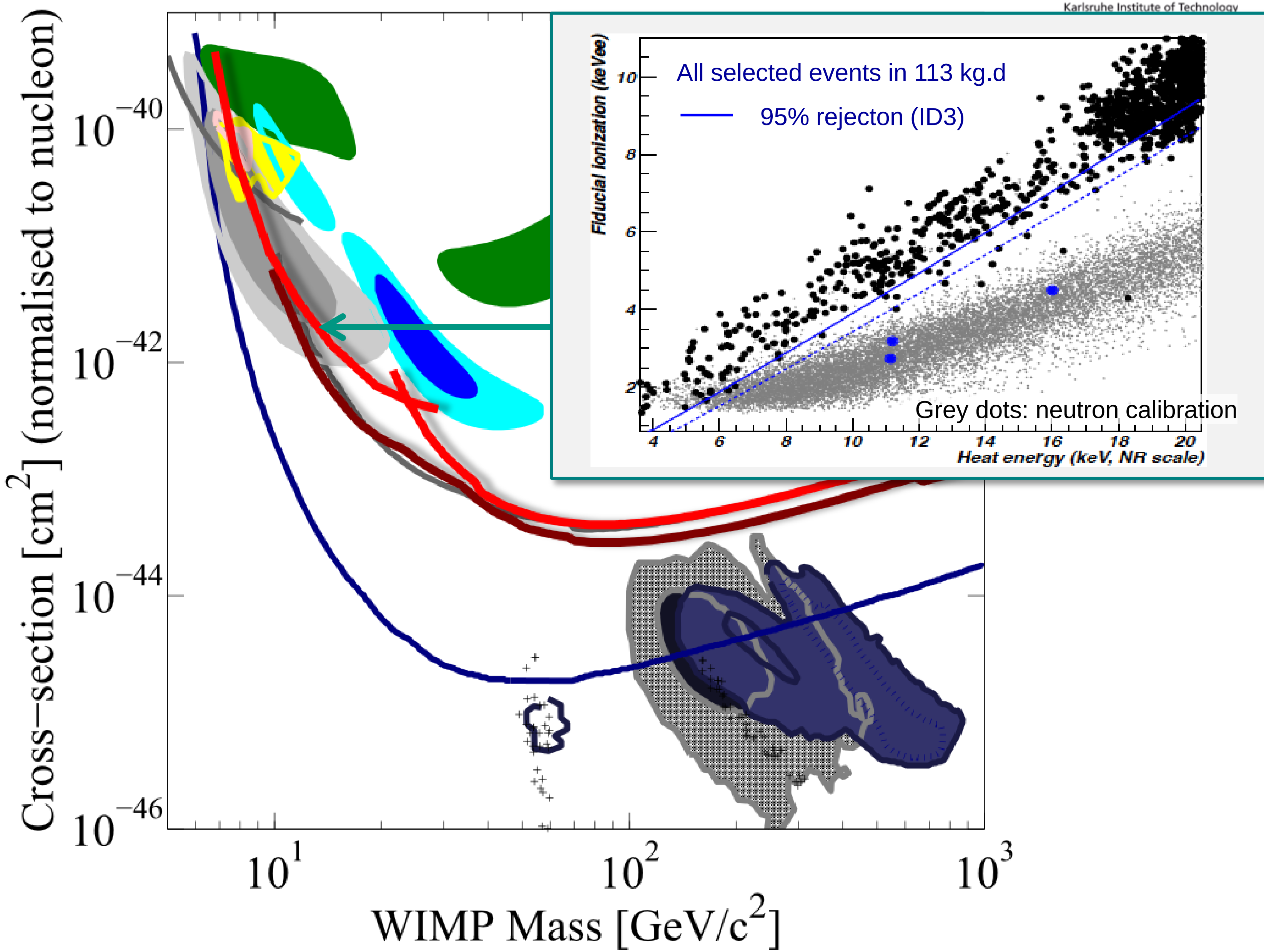
'Low-mass' WIMP:

- Subset of 2008-2010 data
- Exposure: **113 kg.d**
- **3 events observed** (treated as background)

σ_{SI} < 1 x 10^{-41} cm^2 (90% CL), $M\chi$=10GeV

Phys. Rev. D 86, 051701(R) (2012)

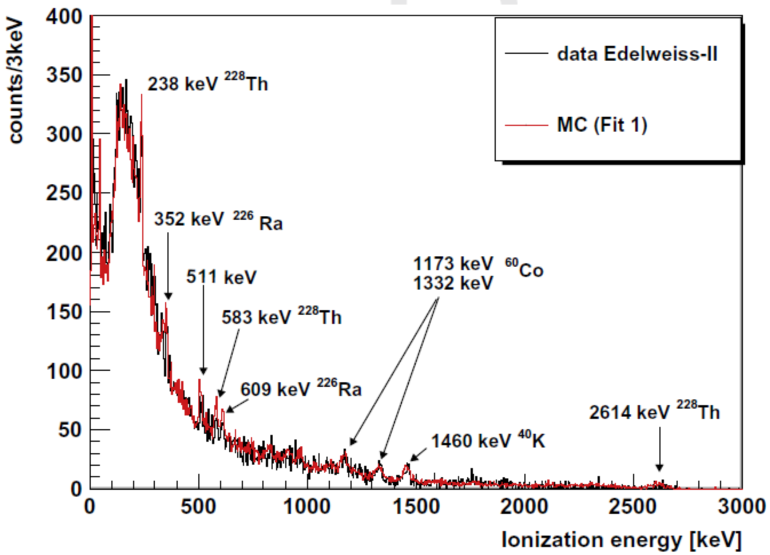
Edelweiss-2 WIMP search : 2008+2009+2010



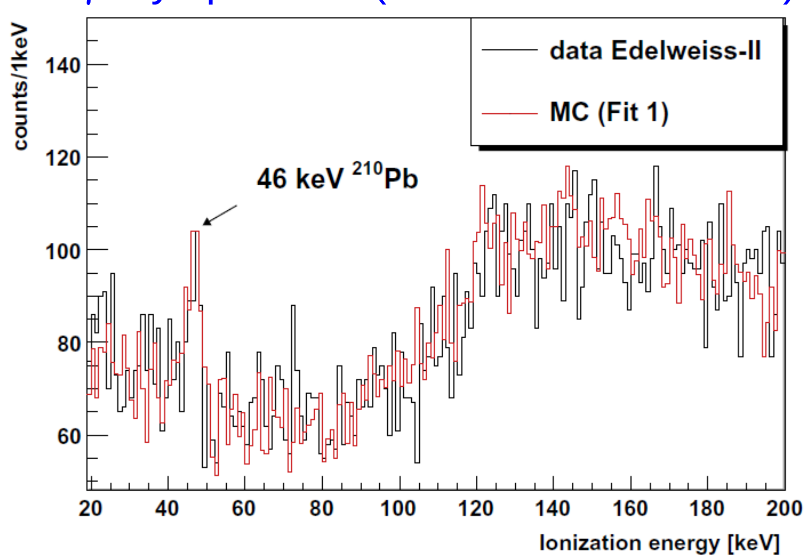
Background budget of Edelweiss-2

1. Geant4 simulations of the complete setup (γ-, n-, μ-induced n-background);
2. Ambient γ-, n- rates are normalized on measured material radiopurity, by means of γ-ray spectrometry, neutron activation (PE), mass-spectrometry (steel, Pb);
3. μ-induced neutron rate is deduced from the muon-veto data and simulations;
4. ID-detector γ-rejection from 133Ba calibrations;
5. ID-detector surface event rejection from the measured one with 210Pb source.

γ-ray spectrum



γ-ray spectrum (zoom below 200 keV)



Astropart. phys. accepted; arXiv:1305.3628

Background budget of Edelweiss-2, final

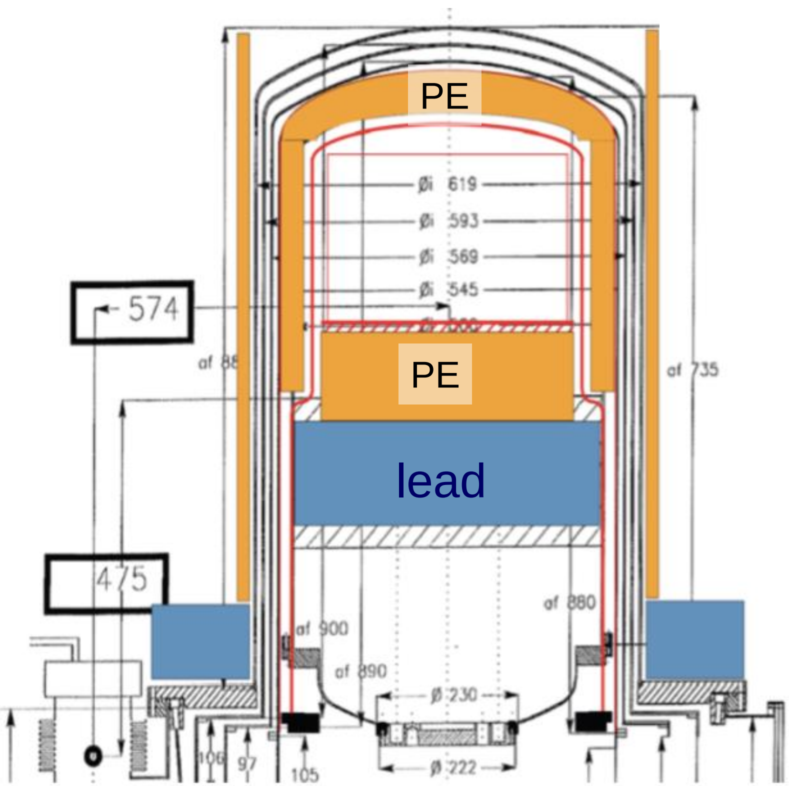
Background in RoI (20-200 keV)		Rate 90%CL (event / 384 kg.d)
γ-background	$1.8\cdot10^4$ events	
133Ba calibration:	$\times\ 3\cdot10^{-5}$ leakage into RoI	< 0.9
Surface events	5000	
210Pb source:	$\times\ 6\cdot10^{-5}$	< 0.3
Neutrons from all components		
Geant4 x measured radiopurity		< 3.1
μ-induced events	$\Gamma^{\mu-n} = 0.008^{+0.005}_{-0.004}$ (events/kg.d)	
veto efficiency (conservative):	>93.5%	< 0.72
Total		**< 5.02**

Result:

- Measured signal is interpreted as background
- Need better material purity (e.g. contribution from Cu parts @10mK and thermal screens)
- Need an additional neutron shield (neutrons from cables, connectors and electronics)

Edelweiss-3: Goals and improvements

Karlsruhe Institute of Technology



Within the Edelweiss-2 setup:

- Goal: 10^{-45} cm^2 with 40 FID800 (24 kg fiducial)
- Improved material selection
- Extra internal PE shield:
  - ca.10 cm below bolometers
  - ca. 5 cm on a side and top
- upgrades of muon veto, cryogenics, cabling, thermal screens
- Modify electronics and DAQ (scalability): 240 channels + auxiliary detectors
- New event-based readout
- More analysis tools: Kdata: ROOT-based, multi-tier, db, …

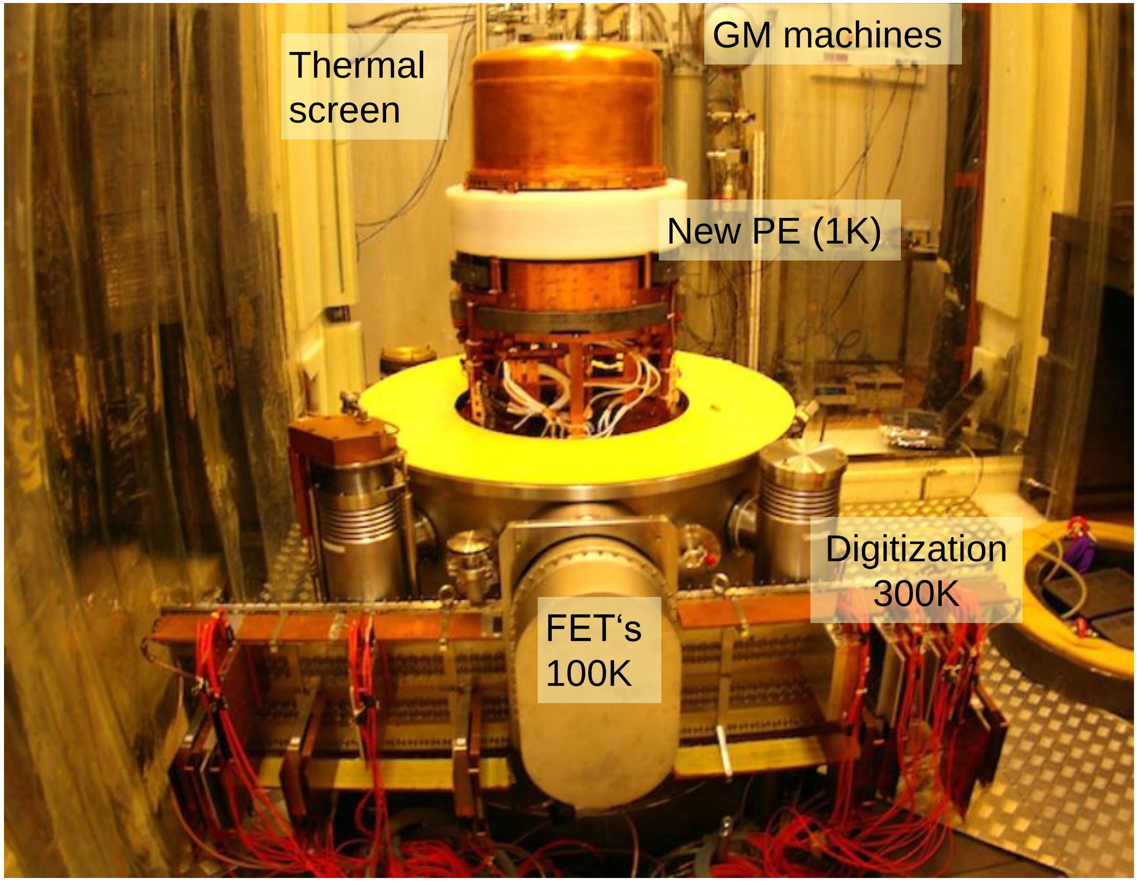
NIM A 684 (2012) 63

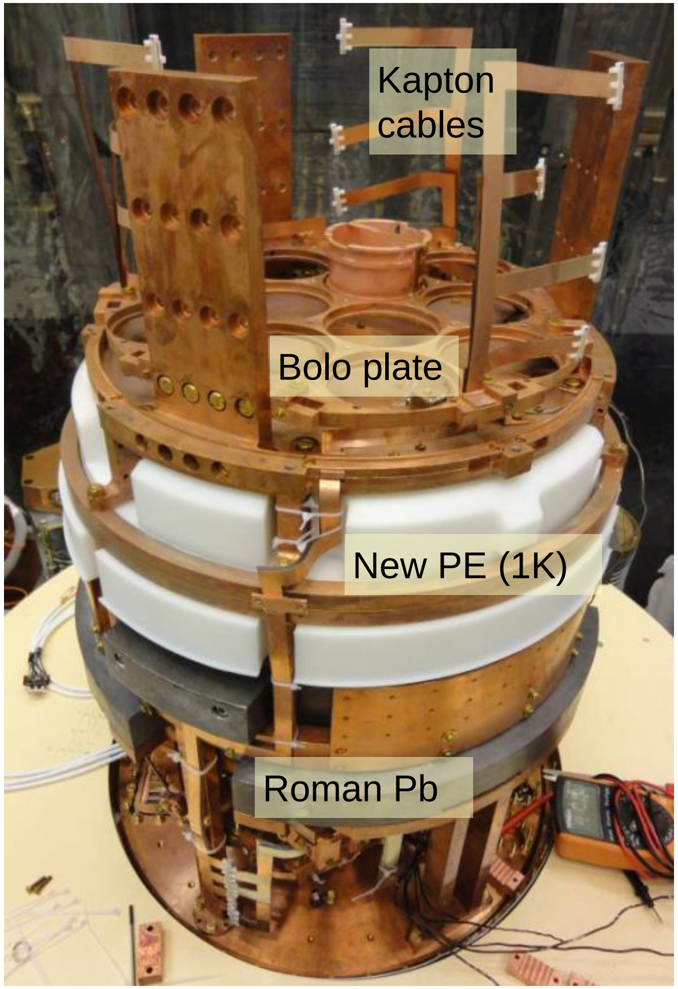
Background (20 – 200 keV)	EDW-2 (evt / kg.d)	EDW-3 (evt / kg.d)	Improvement
Gamma rate	82	14 – 44	up to 6
Ambient neutrons	$< 8.1\cdot10^{-3}$	$(0.8 – 1.9)\cdot10^{-4}$	up to 100
Muon-induced neutrons	$< 2\cdot10^{-3}$	$< 2\cdot10^{-4}$	up to 10

Astropart. phys. accepted; arXiv:1305.3628

Astropart. phys. 44 (2013) 28

Edelweiss-3: new PE shield and screens





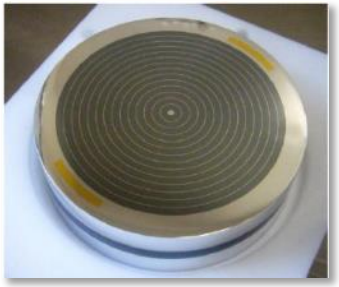
- ✓ Additional PE shield, new Cu thermal screens
- ✓ Kapton cables and connectors between 1K-10mK (Steel) and 10mK-10mK (Cu)
- ✓ ALL cold electronics at 100K : relay instead of resistances for FeedBack and detectors biases

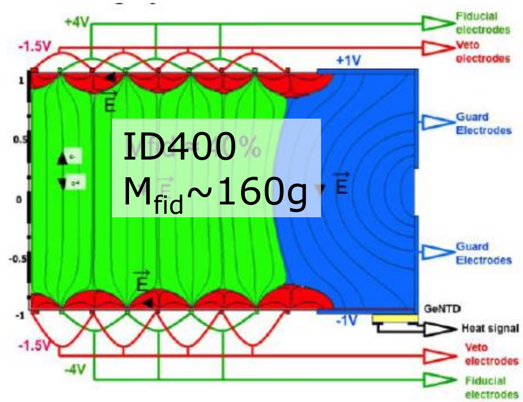
J Low Temp Phys 167 (2012) 645

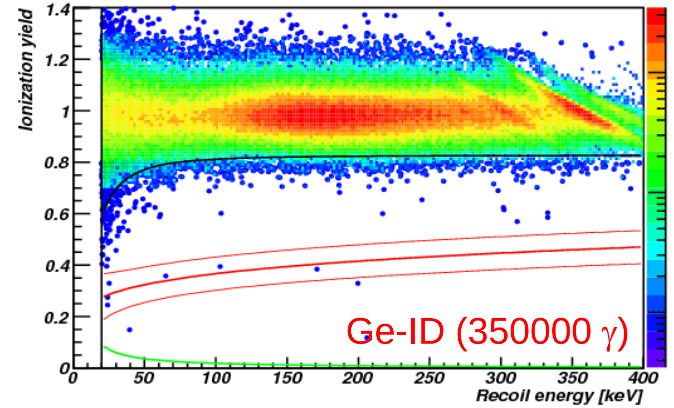
Edelweiss-3: new FID800, γ-rejection

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

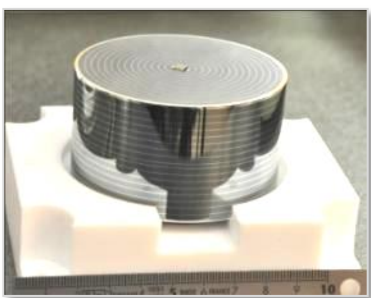
ID400

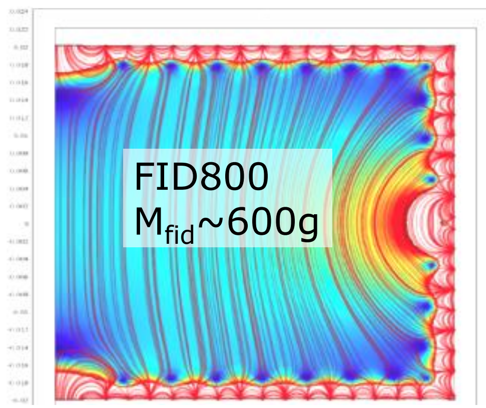


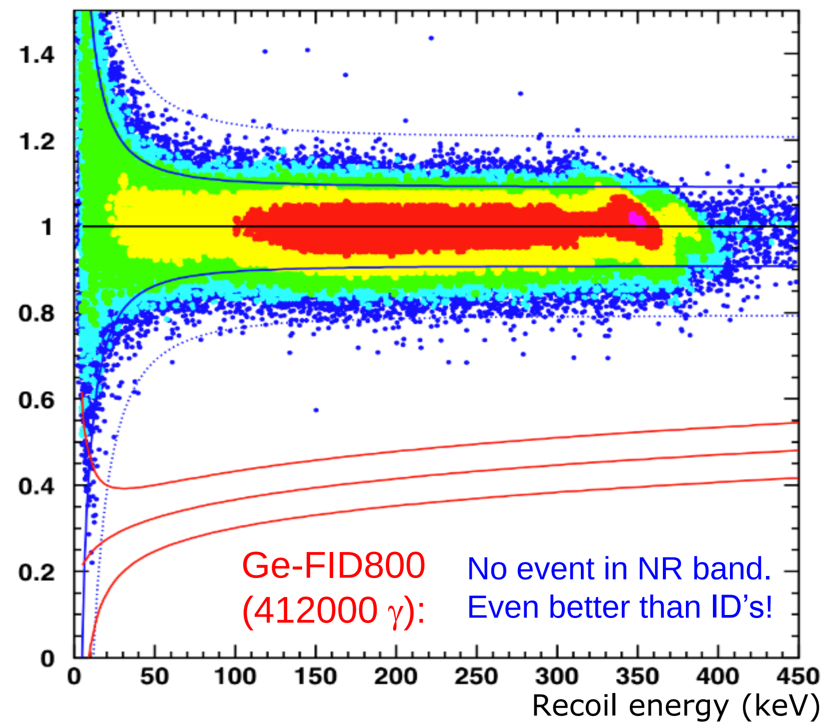




FID800

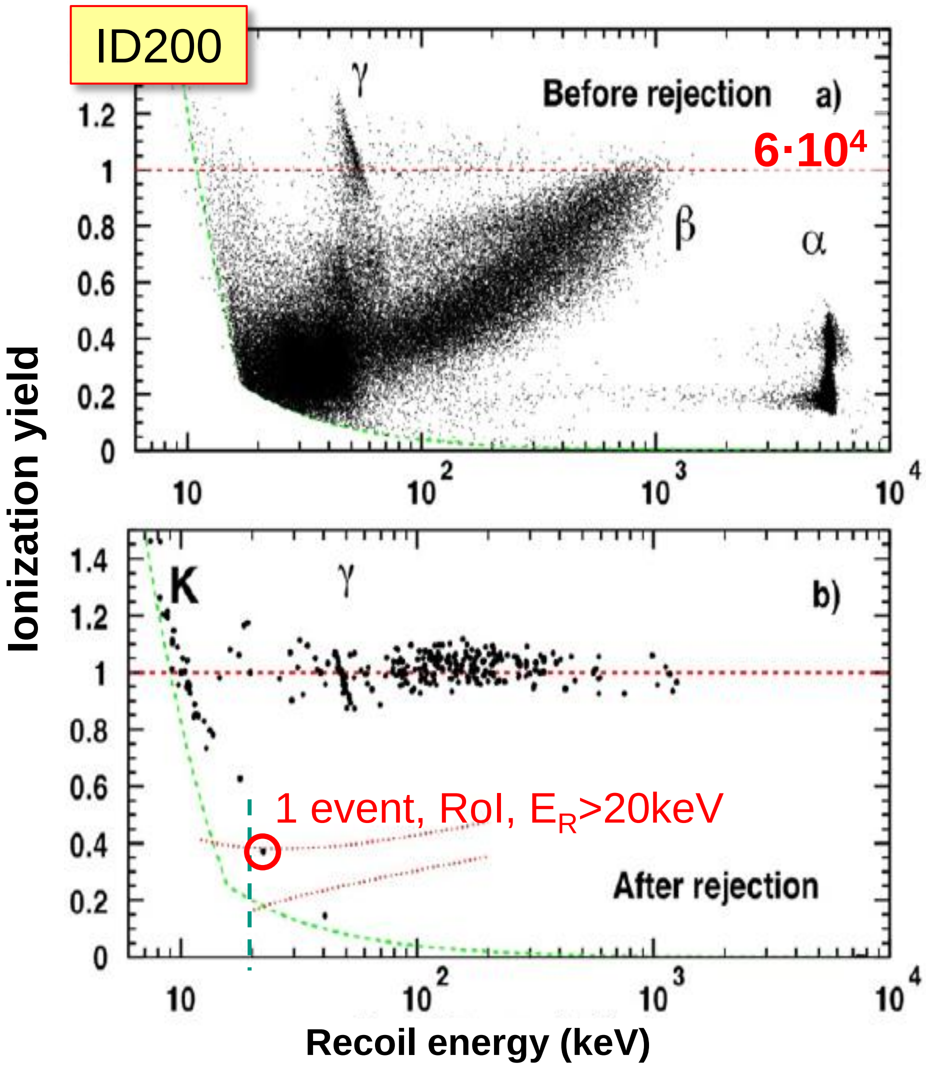


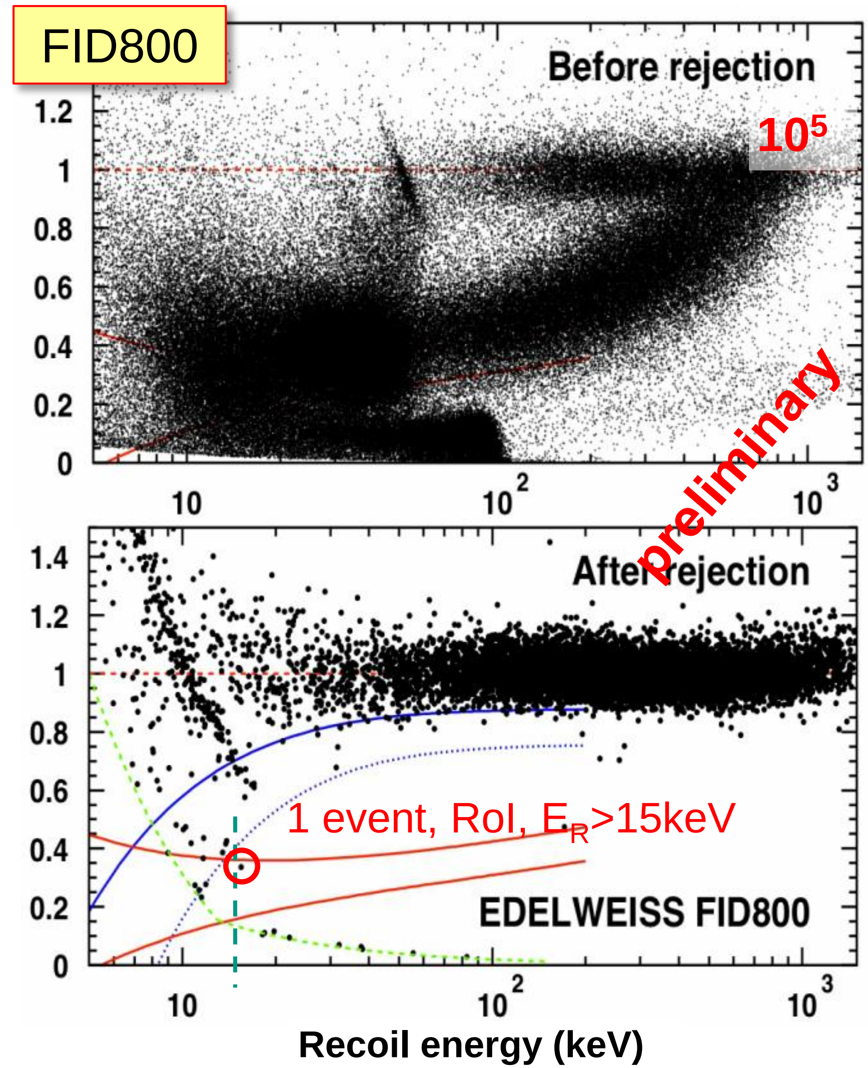




- 2 NTD heat sensors (better heat ch), 4 ionization channels
- Larger Fiducial volume (75% vs. 40%)
- No event in NR (^{133}Ba: $4{\cdot}10^5$ γ's)
- Fabrication up to 1 FID800 / week (mandatory leakage-current tests)

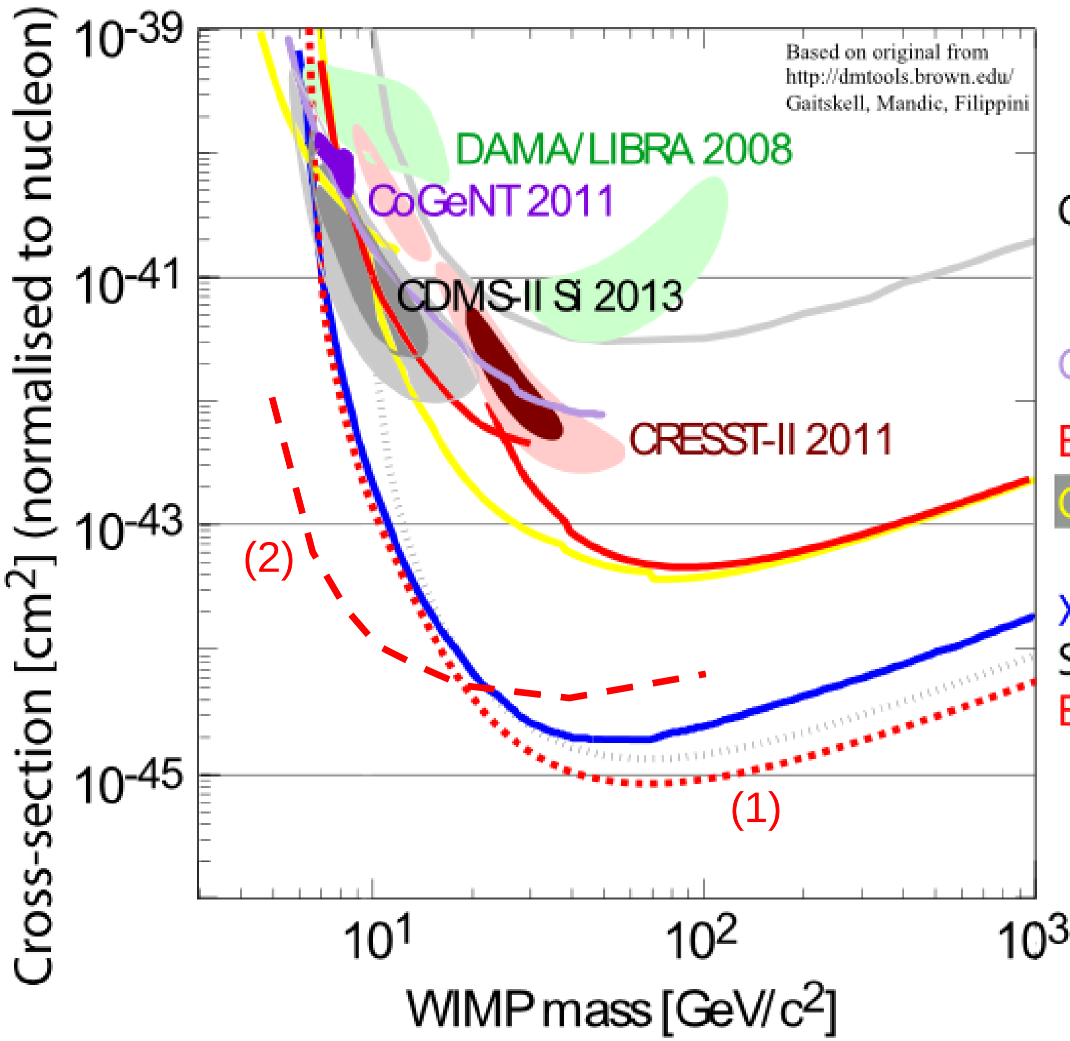
Edelweiss-3: new FID800, surface-rejection





Surf. event rejection: ID200: $6\cdot10^{-5}$ (90% CL, >20 keV) → FID800: $4\cdot10^{-5}$ (90% CL, >15 keV)

Edelweiss-3: Sensitivity goals



CDMS-I 2000

CDMS-II Si 2013

EDW-II 2011/2012

CDMS-II 2010

XENON100 2012

S-CDMS@SOUDAN

EDW-III (2014-2015):

(1) ‚Standard' WIMP: 12000 kgd, E_R>15keV, no event

(2) Low-mass WIMP: 1200 kgd (4 FID800)
HEMT R&D: 300eV FWHM, E_R>3keV (4K)

High Electron Mobility Transistor (HEMT):
works at low temperature, low noise, low power, …

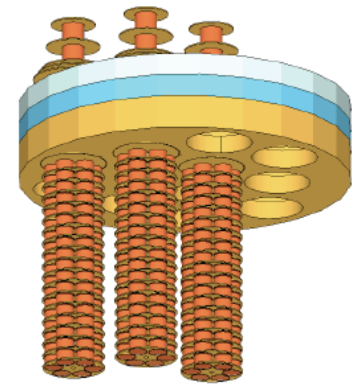
EURECA, LSM extension

\# EDELWEISS + CRESST + ROSEBUD + ... ;

\# **CDR** is written (the collaboration is really active!)

\# To probe **$10^{-46} \div 10^{-47}$** cm^2

\# Two phase: 150 kg → 1 ton of Cryo detectors; Multi-target (Ge, $CaWO_4$)

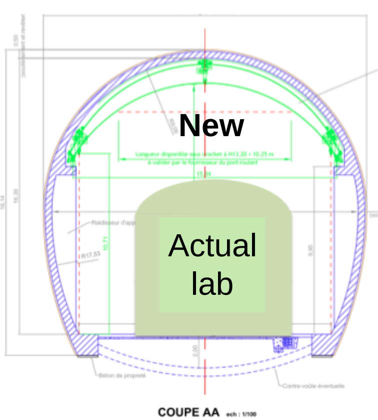


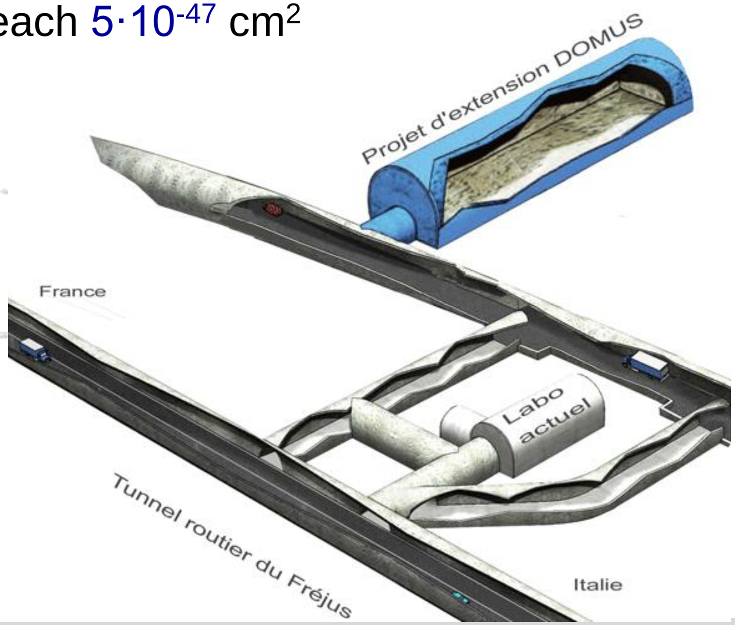
\# Basic features:

- Large water tank as active shielding
- Favorite site: new extension of LSM (approved! Expected 2016)
- 7 mK base temperature, „adjustable“
- Flexible design, one tower : fully integrated, 7mK-300K

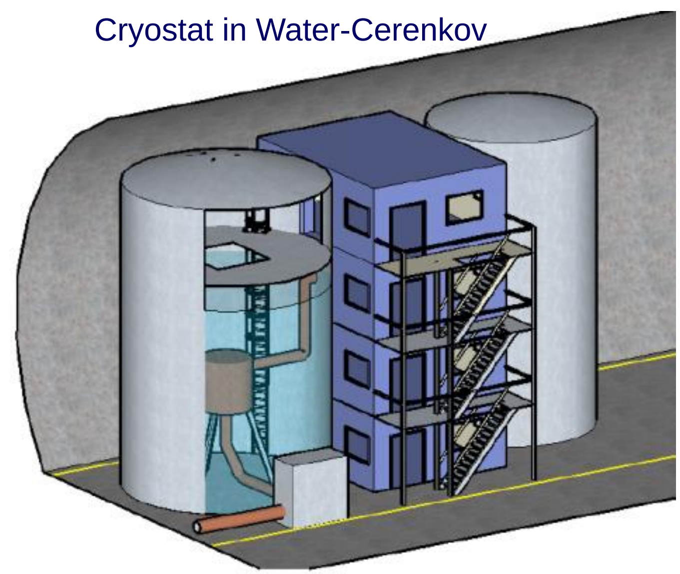
\# Potential collaboration with SuperCDMS:

- 200 kg Ge-bolometers
- plans to reach $5 \cdot 10^{-47}$ cm^2





Cryostat in Water-Cerenkov



Summary & Outlook

Edelweiss-2:

✓ ‚Standard' WIMPs:

Phys Lett B 702 (2011) 329

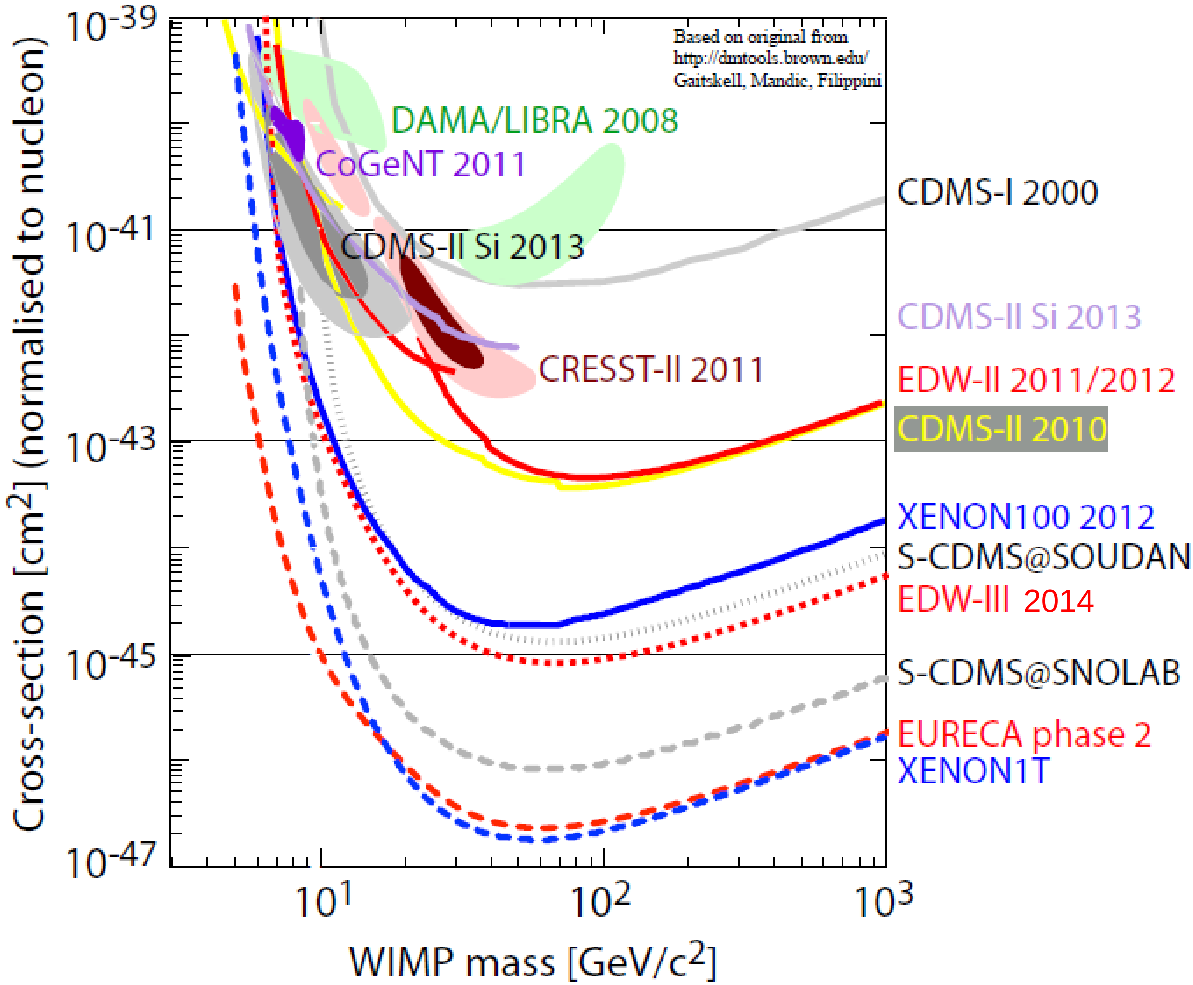
Phys. Rev. D 84, 011102 (2011)

✓ Low-mass WIMPs:

Phys. Rev. D 86, 051701(R) (2012)

✓ Axion search:

C.Nones, Thursday talk



Edelweiss-3:

✓ Improved γ-, n-backgrounds: materials, shields, cables, electronics, cryogenics

✓ New Ge-FID800 (600g fiducial), improved background rejection

✓ EDELWEISS-3 scientific goal is 10^{-45} cm² (e.g. $5\cdot10^{-45}$ cm² in 125 live days in 2014)

ANR
bmb+f - Förderschwerpunkt Astroteilchenphysik Großgeräte der physikalischen Grundlagenforschung
HELMHOLTZ ASSOCIATION Alliance for Astroparticle Physics
Science & Technology Facilities Council

Backup slides

BACKUP SLIDES

WIMP search: Low mass

Phys. Rev. D 86, 051701(R) (2012)

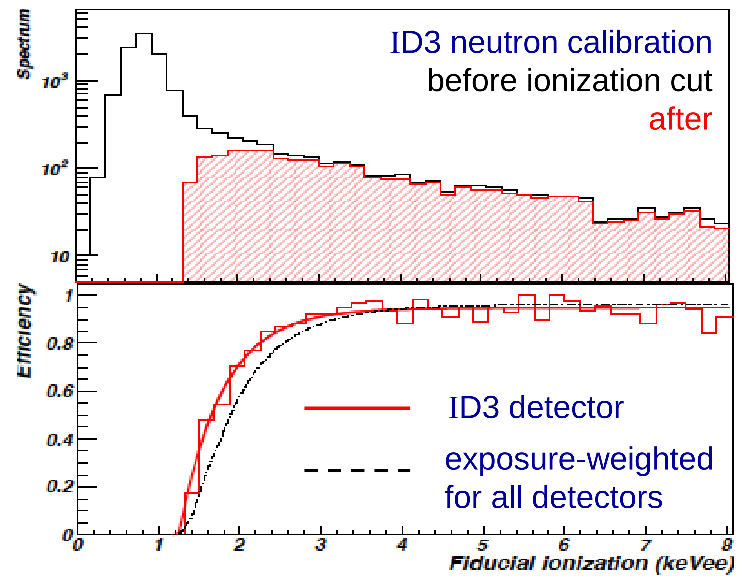
- Select ID detectors sensitive to nuclear recoils down to 5 keV

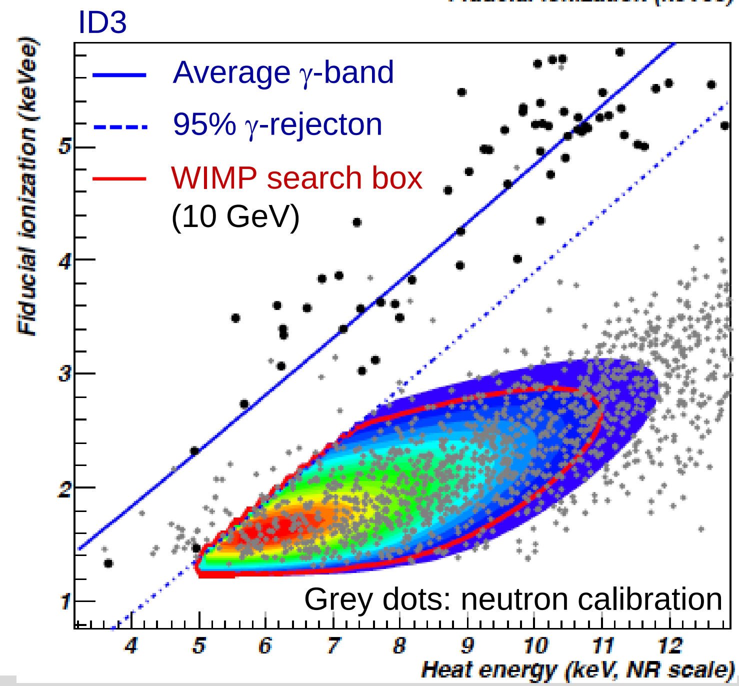
Use *Ionization signal* for:

- Fiducial selection
- 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

Radioactive contaminations, EDELWEISS-2

Component/Material	Mass (kg)	Radioactivity in materials (mBq/kg or mBq/unit☆)				Other radionuclides
		^{226}Ra	^{228}Th	^{60}Co	^{40}K	
Detector holders/PTFE	0.02	<7	<5	<20	<100	^{210}Pb<80
Electrodes/Al	$<3\cdot10^{-5}$	0.27 ± 0.19	1.4 ± 0.2	-	$1.1\ \pm^{0.2}_{0.1}$	^{26}Al: $0.38\pm^{0.19}_{0.14}$
Detector casings/ CuC2 copper[a]	3	0.025 ±0.015	0.033 ±0.016	0.038 ±0.010	<0.39	^{238}U< 1.4, ^{235}U< 0.9 ^{54}Mn: 0.024 ± 0.010[b]
Disks, bars, 10 mK chamber/ CuC1 copper	90	<1	<0.7	<1	<110	^{210}Pb:180 ± 140
Screens 7–11/copper	320	<3	<2	<2	<25	
Dilution unit☆	≈1	<20	<20	<20	<100	^{108}Ag:331 ± 32
1 K connectors	0.32	644 ± 65	1353 ± 138	<25	1181 ± 197	^{238}U:1994 ± 204
Coaxial cables	1.4	10 ± 7	<6	<8	120 ± 60	^{210}Pb<110
Bolometer boxes☆ (warm electronics)	50 units	331 ± 17	235 ± 13	-	340 ± 40	^{238}U:$134\ \pm^{65}_{15}$ ^{210}Pb:1019 ± 56
Roman lead shield	≈120	<0.3	<0.3	-	<1.3	^{210}Pb<120
Modern lead shield	30,000	<3	<1	-	-	^{210}Pb: $(24\pm1)\times10^{3}$ ^{238}U< 0.01 ppb
Polyethylene shield	40,000	5 ± 1	<2	<3	16 ± 2	^{238}U:1 ppb, ^{232}Th:0.1 ppb
Mild steel support	8600	-	-	-	-	^{238}U< 0.01 ppb ^{232}Th< 0.01 ppb

[a] CuC2 copper has been measured at LNGS with the GeMPI detector [8].
[b] The activities of short-lived cosmogenic isotopes in CuC2 copper correspond to (10 ± 2) days of exposure.

Astropart. phys. accepted; arXiv:1305.3628

Radioactive contaminations, EDELWEISS-3

Component	Material	Mass (kg)	Radioactivity in materials (mBq/kg)					Gammas $(kg \times days)^{-1}$	Neutrons Events/year
			^{226}Ra	^{228}Th	^{210}Pb	^{40}K	^{60}Co		
Cables	Apical, Cu	0.2	26 ± 15	<50	346 ± 110	167 ± 126	<25	5–11	0.03–0.07
Connectors	Delrin, brass	0.056	32 ± 20	<53	$11{,}000 \pm 1000$	680 ± 220	<36	1–8	0.02–0.06
Screws	Brass	0.1	4.9 ± 1.3	<3	<100	<40	<3	<1	<0.003
Screens, support	Cu	~500	<0.016	<0.012	–	<0.11	<0.018	<7	<0.01
Shielding	CH_2	~90	0.65 ± 0.08	0.30 ± 0.07	<3	<1	<0.06	7–14	0.03–0.06
Connectors	Al, resin	1.6	80 ± 9	158 ± 6	743 ± 48	129 ± 33	<4	0.2–0.3	0.3–0.5
Cables	PTFE	~1	<35	<28	190 ± 40	440 ± 110	<19	<1	<0.1
Cold electronics	PCB	0.23	7800 ± 500	12600 ± 1200	4500 ± 400	6500 ± 1200	<120	1–2	0.04–0.06
Warm electronics	PCB	-	$26{,}500 \pm 1500$[a]	$19{,}300 \pm 1100$	$82{,}000 \pm 5000$	$27{,}000 \pm 3000$	-	<1	0.3–0.5
Total								14–44	0.7–1.4

[a] Decay rates for warm electronics are given for the whole set (not in mBq/kg).

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