New Phase of the EDELWEISS Dark Matter Search Experiment

- Scientific goal
- Status and results of the EDELWEISS experiment
- EDELWEISS-III
- Conclusion and outlook

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NUCLEUS-2014 Minsk, July 2nd, 2014

Motivation

Astrophysical data clearly shows existence of an unidentified form of matter

Edelweiss

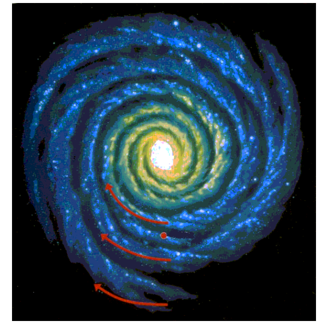
Expérience pour DEtecter Les WIMPs En Site Souterrain

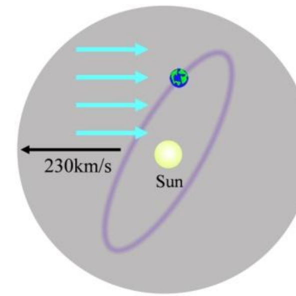
The EDELWEISS experiment search Non Baryonic Cold Dark Matter in form of WIMPs with Cryogenic HPGe Detectors

About 50 scientists from

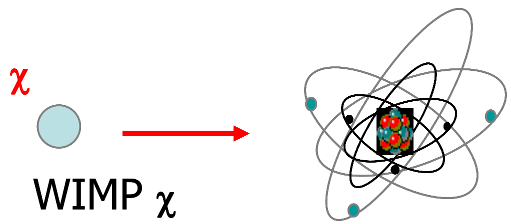
- CRTBT, SPM-CNRS, Grenoble, France
- CSNSM, IN2P3-CNRS, Universite Paris XI, Orsay, France
- CEA, (IRFU / IRAMIS) Saclay, France
- Department of Physics and Astronomy, University of Sheffield, UK
- **DzLNP, Joint Institute for Nuclear Research, Dubna**
- IPNL, Lyon, IN2P3-CNRS, France
- **KIT (IK / EKP/ IPE), Karlsruhe, Germany**
- Laboratoire Souterrain de Modane, CEA-CNRS, Modane, France
- University of Oxford, Department of Physics, Oxford, UK.

A Search for Cold Dark Matter with Cryogenic Detectors at Frejus Underground Laboratory



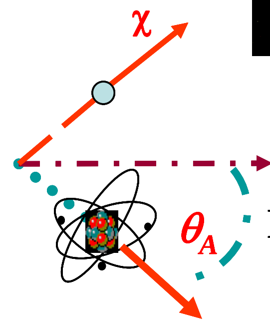


EDELWEISS experiment
search for rear events of
WIMP-nucleon scattering



WIMP χ
from the galactic halo
V ~ 230 km/s

Nucleus A
at rest in the lab

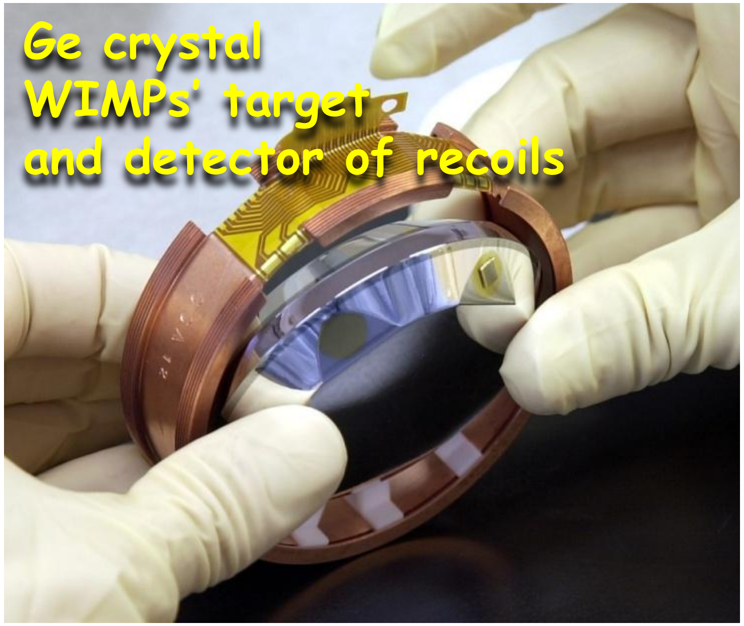


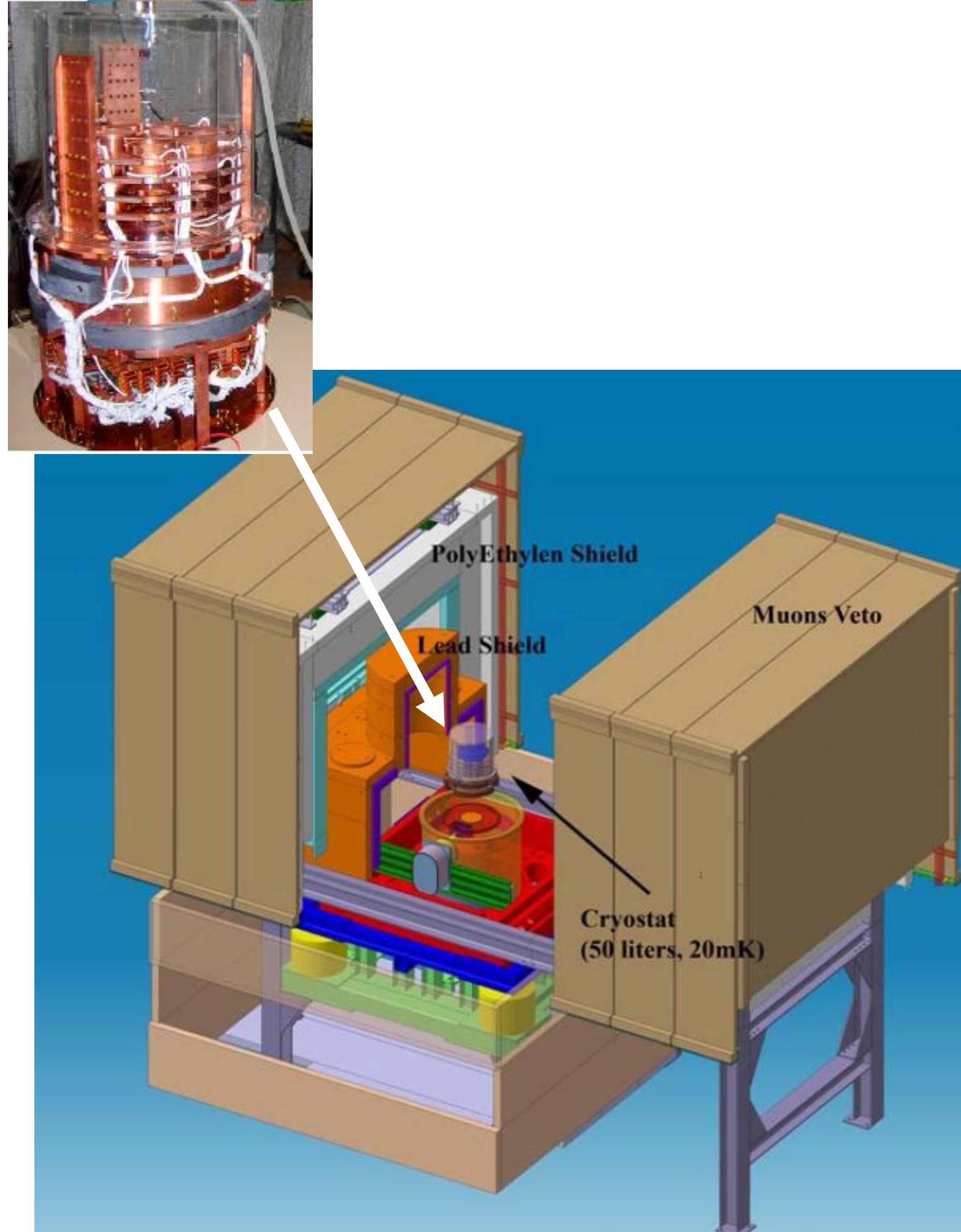
$$E_R = E_\chi \frac{4 M_A M_\chi}{(M_A + M_\chi)^2} \cos^2\theta_A$$

Main experimental challenges are:
event rate is ultra small (below of 1 per 100 kg of matter per day);
energy deposition is tiny (below of 100 keV)

Thus main tasks for any Dark Matter search experiment are:
detector mass + long stable data taking
detectors' performance (low threshold, good resolution)
background reduction

The EDELWEISS experiment





Solutions of the background problem:

1. Traditional

2. Special

Solutions of the background problem:

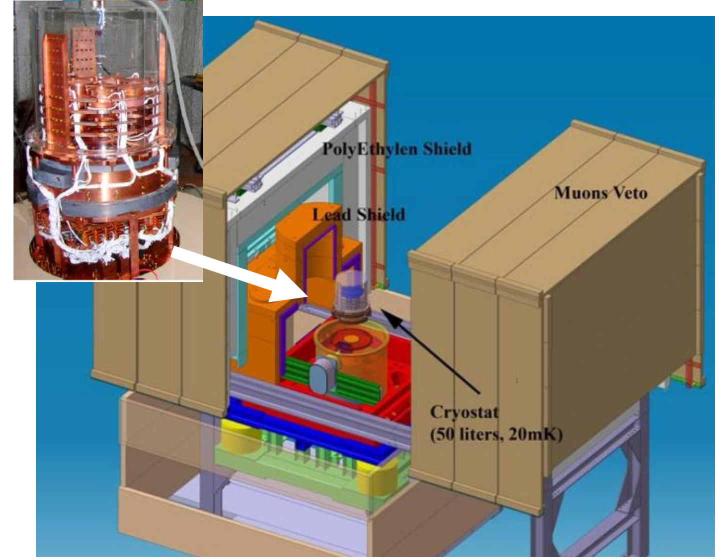
1. Traditional

Experiment is located in one of the deepest underground laboratory – LSM – with muon flux only 4 $\mu/m^2/day$

Using of multi layer shielding + active veto system

Material selection

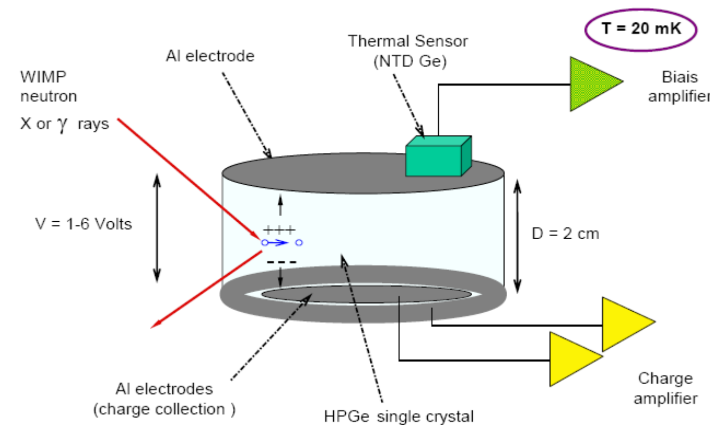
Continuous control of radon and neutron background



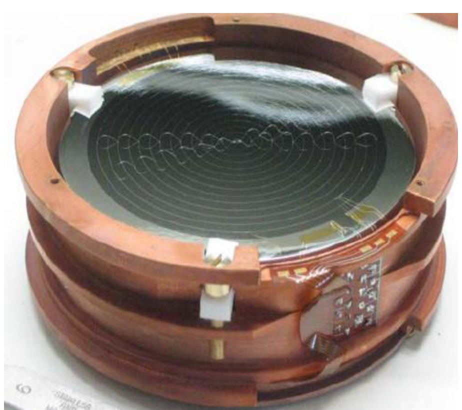
2. Special

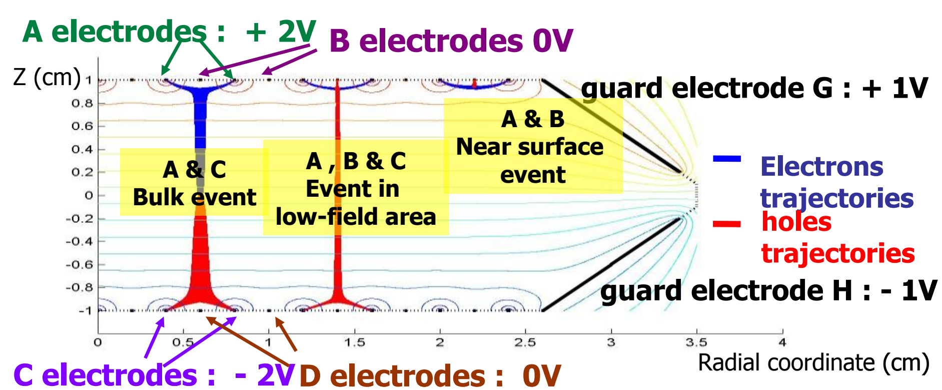
Using of *Heat* and *Ionization* HPGe detectors, running in ^3He-^4He dilution cryostat (<20 mK)

> Ratio $E_{ionization}/E_{recoil}$ is
> =1 for electronic recoil
> ≈0.3 for nuclear recoil
> ⇒Event by event identification of the recoil
> ⇒<u>Discrimination γ/n > 99.99%</u>

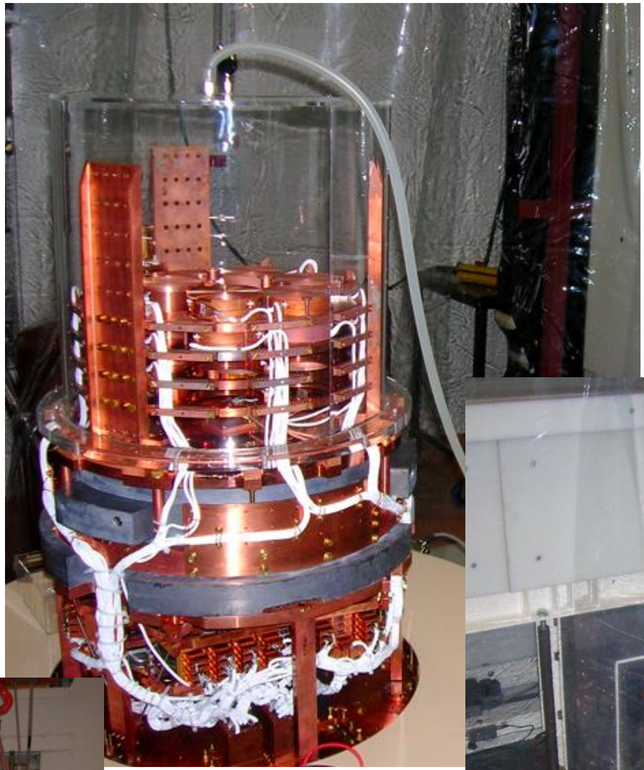


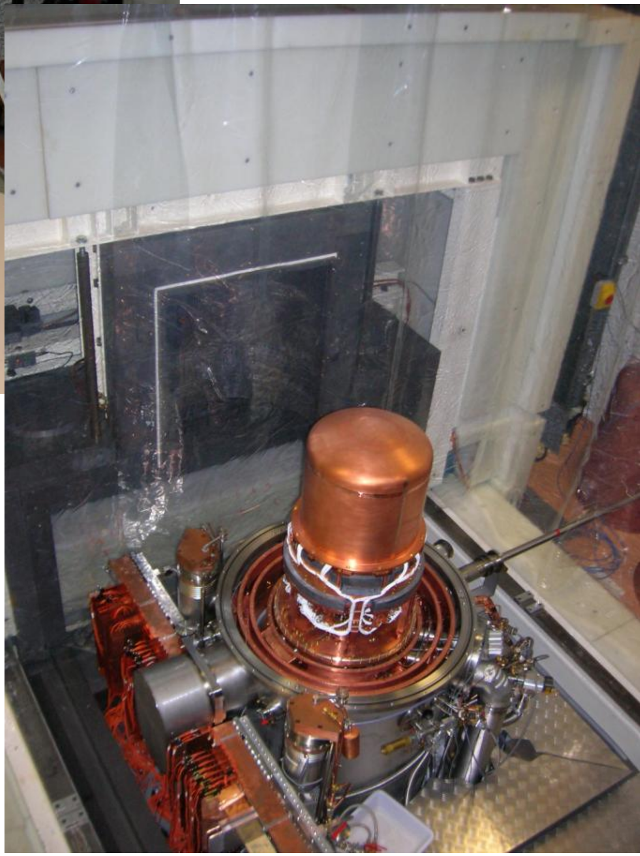
Detectors with special concentric planar electrodes for active rejection of surface events (miss-collected charge)



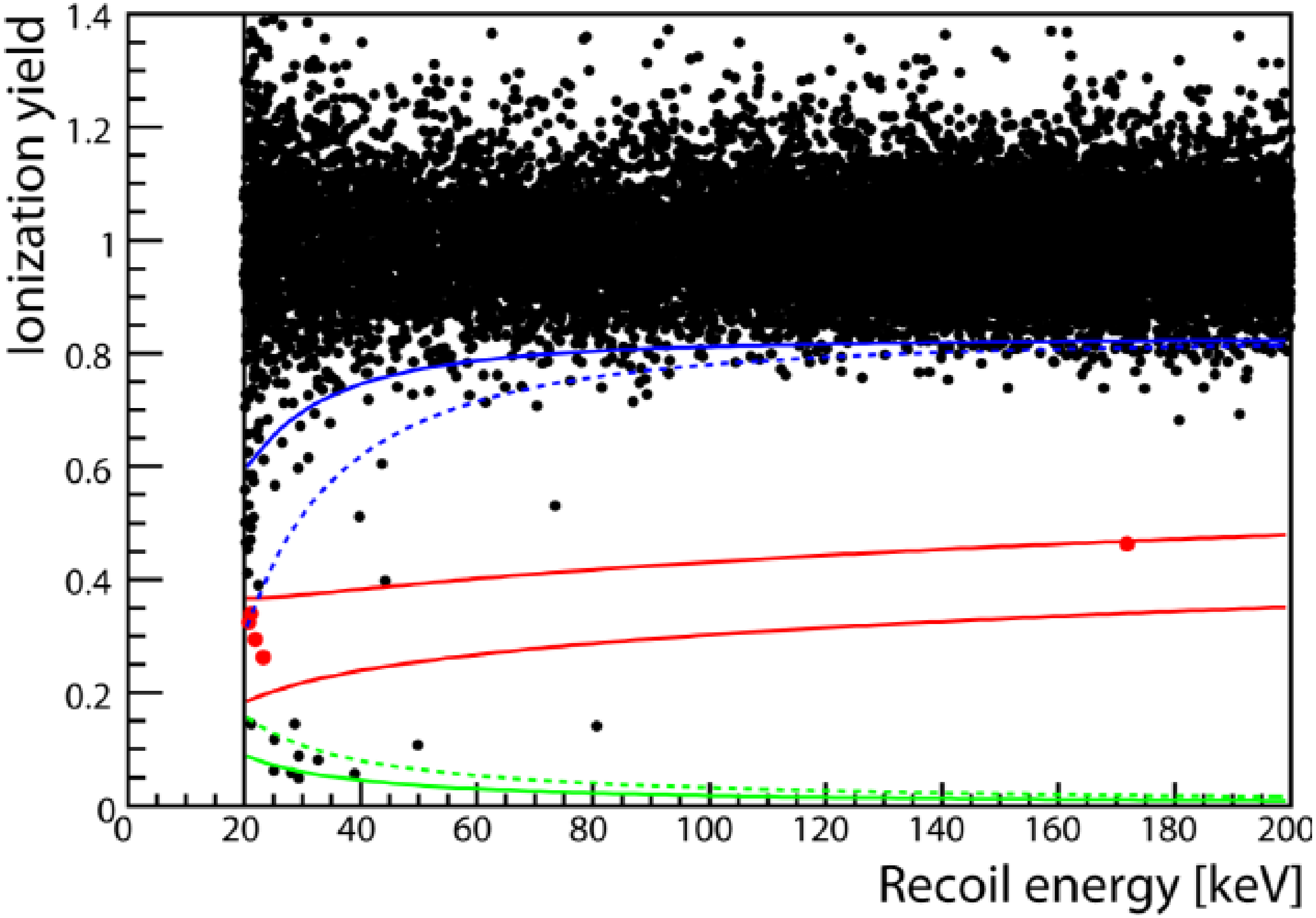


The EDELWEISS-II





Main result of the EDELWEISS-II phase of the experiment
10 ID ~400 g HPGe detectors (fiducial mass 1.6 kg)



total exposure of 427kg.d → 384kg.d in 90% NR band (WIMP RoI) fiducial mass 1.6kg

5 events observed (4 with E<22.5keV; 1 with E=172keV)

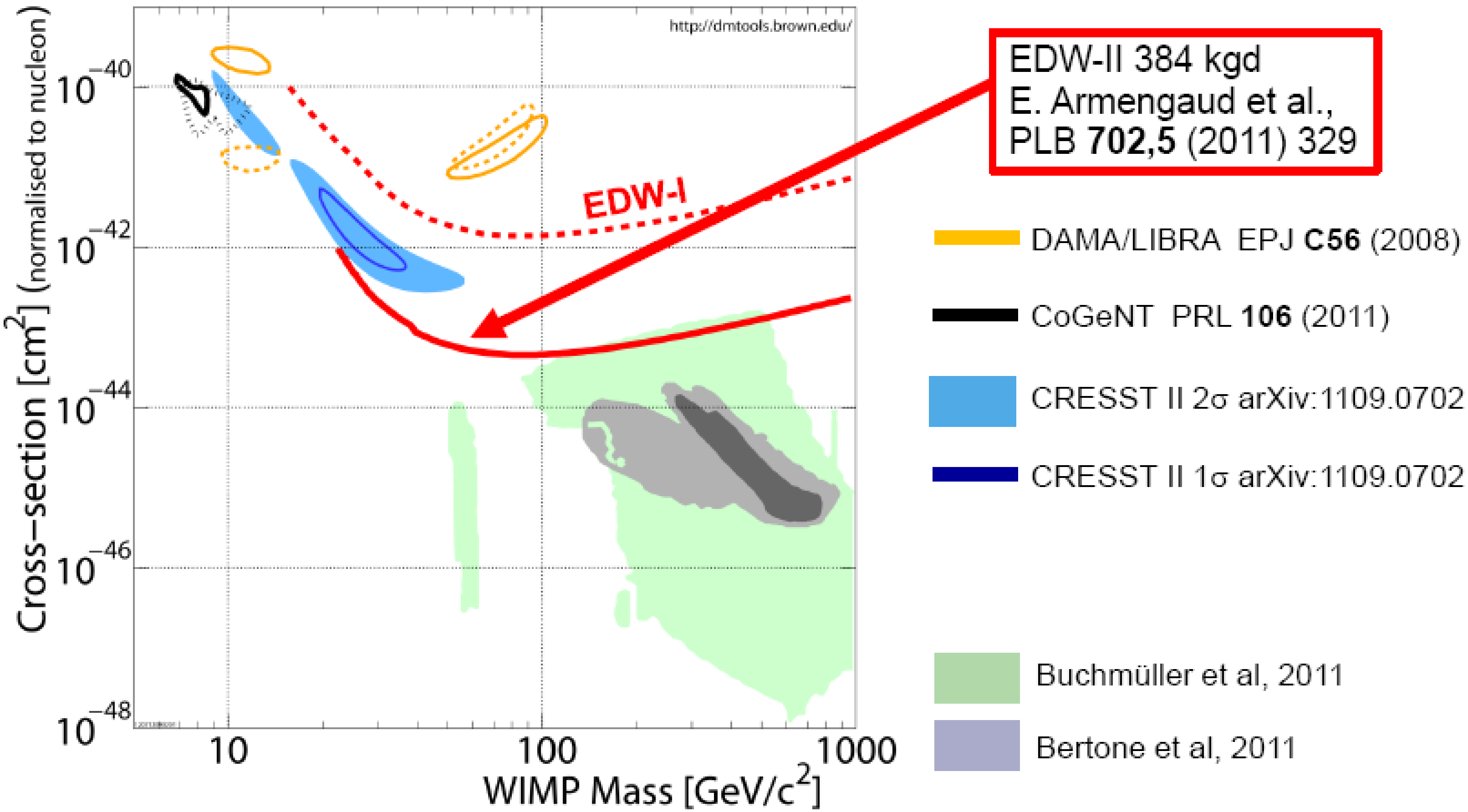
3 evts bg expected 20<E<100 keV

→ no indication for a WIMP signal **PLB702,5 (2011) 329**

standard halo → $\sigma_{SI} < 4.4 \times 10^{-8}$ pb at 90%C.L. for $M_{WIMP} = 85$ GeV/c^2

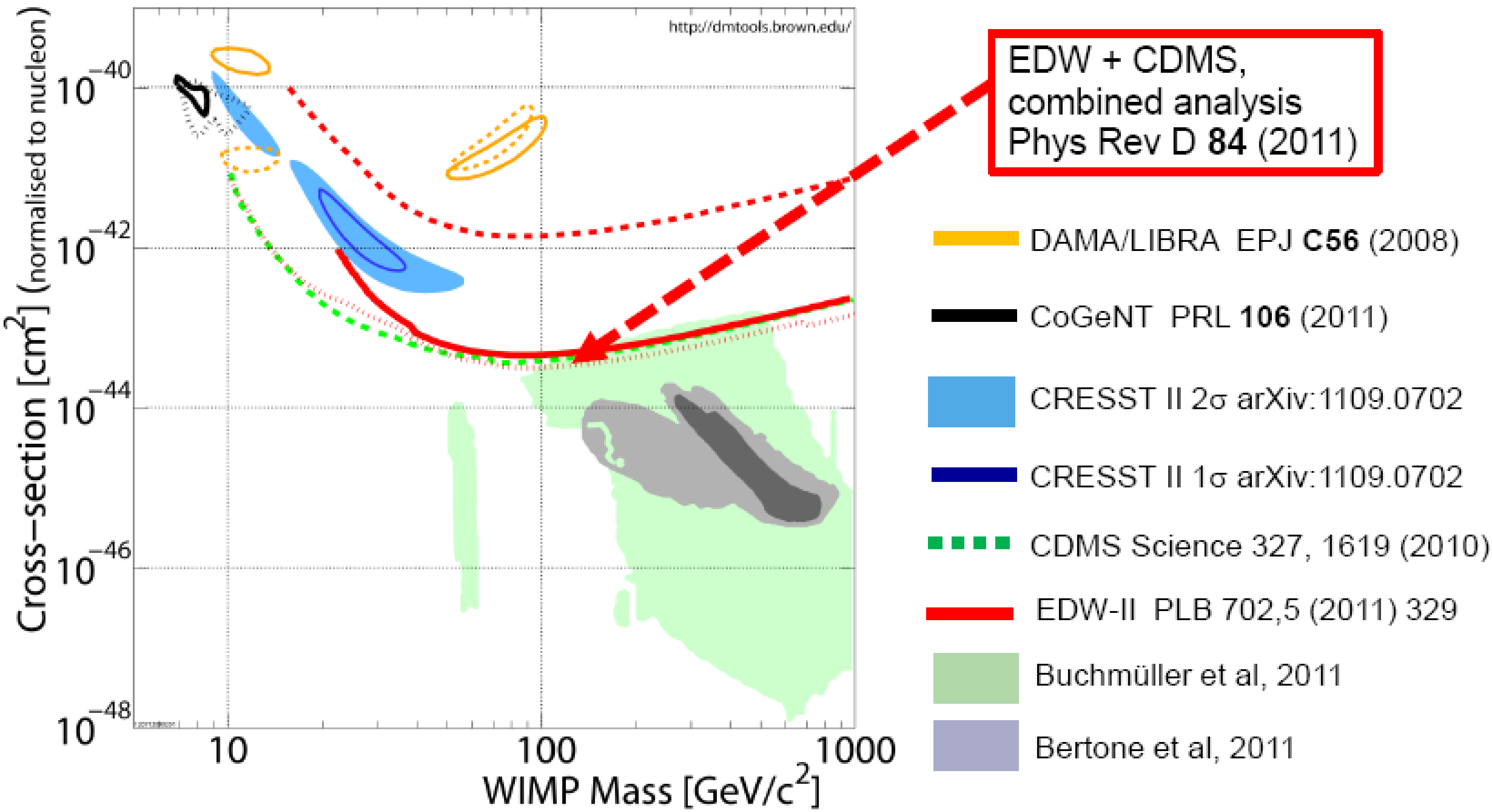
The EDELWEISS results

EDW (384kgd; [20-200keV], 5evts → $\sigma_{SI} < 4.4 \times 10^{-8}$ pb; $M_{WIMP} = 85$ GeV/c^2)
EDW-I → EDW-II **x20 improvement**



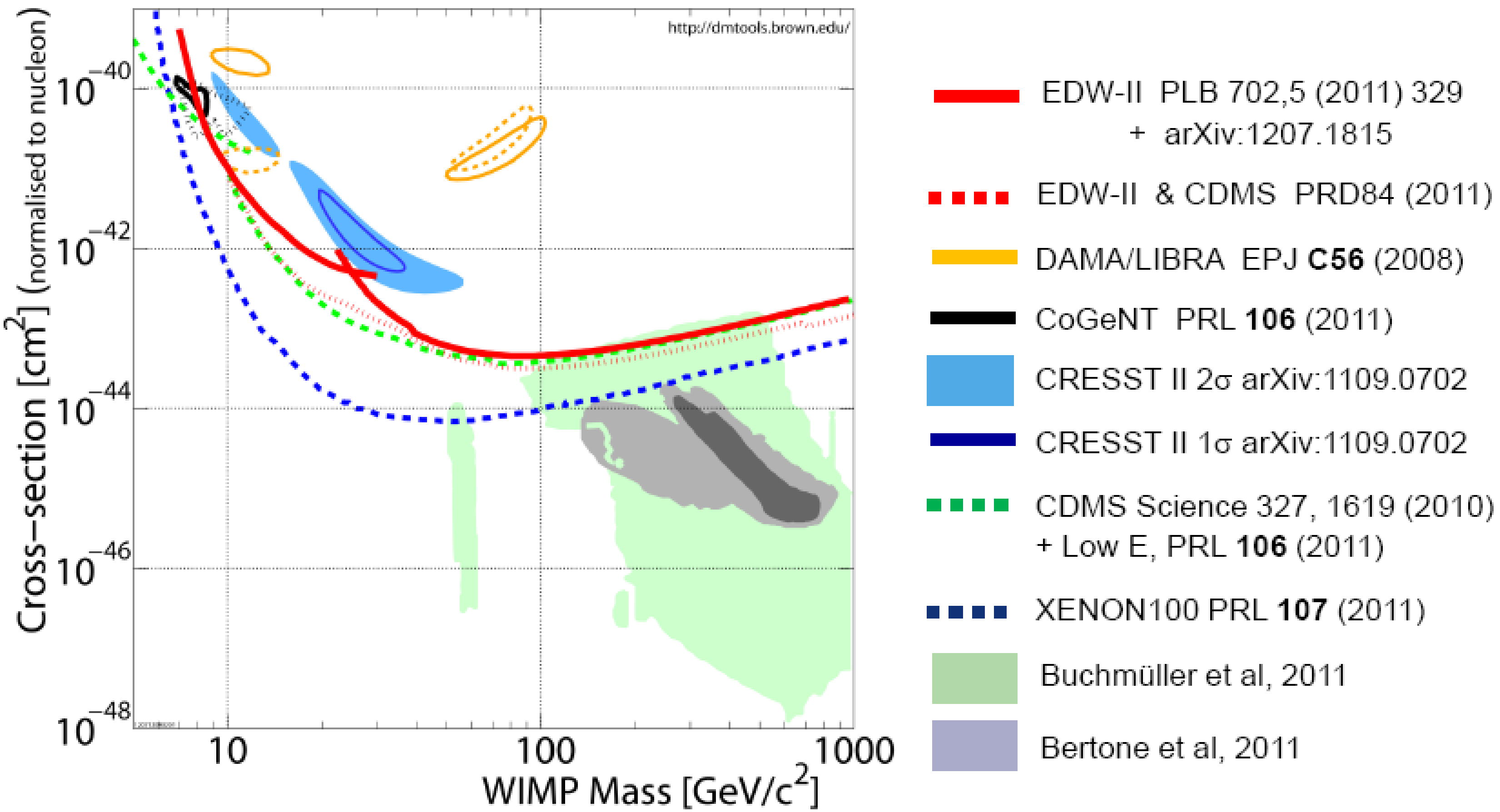
EDELWEISS + CDMS

EDW (384kgd; [20-200keV], 5evts → σ_{SI} < 4.4 x 10^{-8} pb; M_{WIMP} = 85 GeV/c^2)
CDMS (~379kgd; [~10-100keV], 4 evts; σ_{SI} <3.8 x 10^{-8} pb; M_{WIMP} = 70 GeV/c^2)



EDELWEISS results for low mass region

EDW (384kgd; [20-200keV], 5evts → $\sigma_{SI} < 4.4 \times 10^{-8}$ pb; $M_{WIMP} = 85$ GeV/c^2)
113 kgd; [5-20keV], 1-3 evts → $\sigma_{SI} < 1.0 \times 10^{-5}$ pb; $M_{WIMP} = 10$ GeV/c^2)

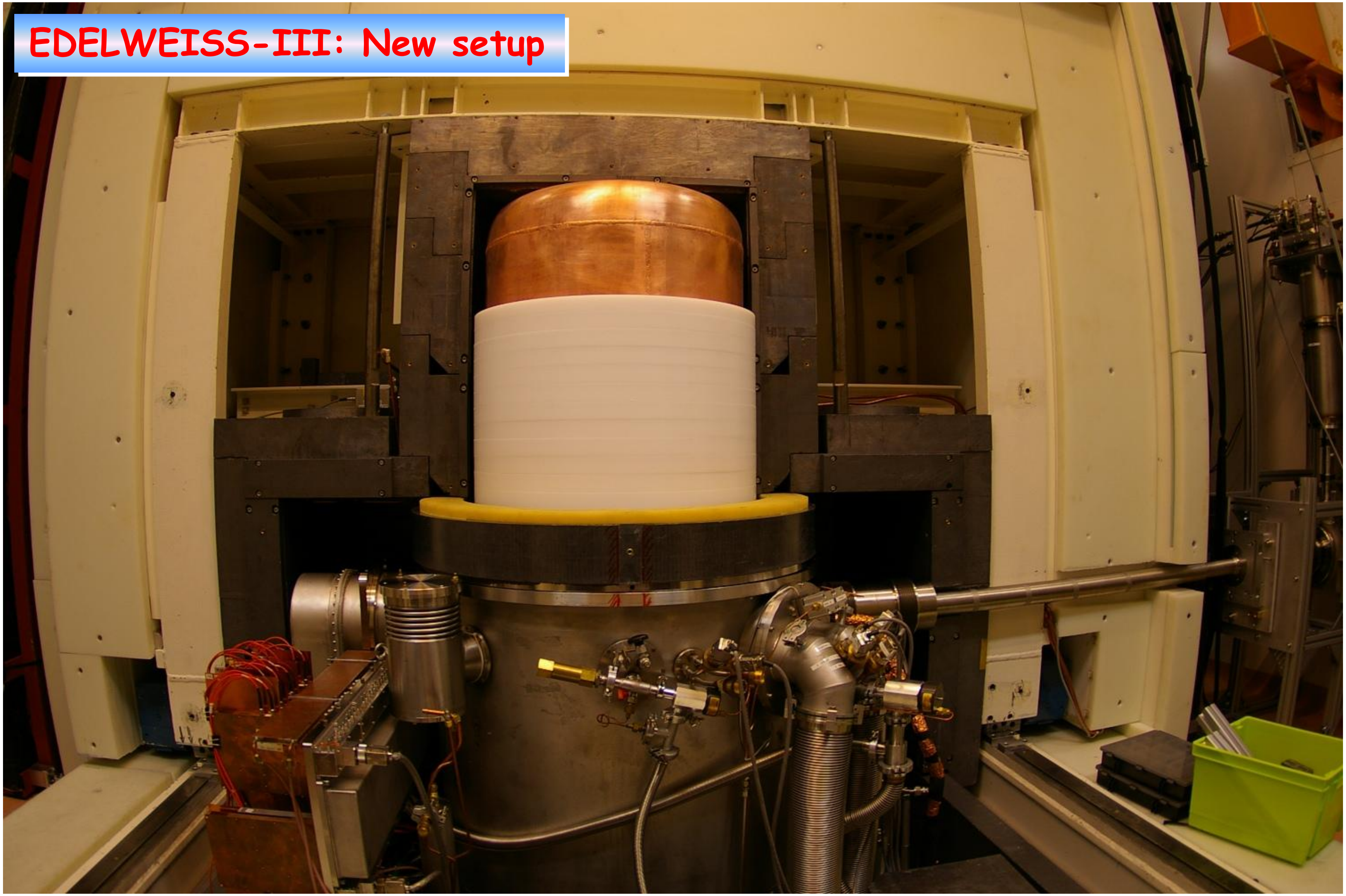


Excellent results but where are WIMPs?

↓

EDELWEISS-III

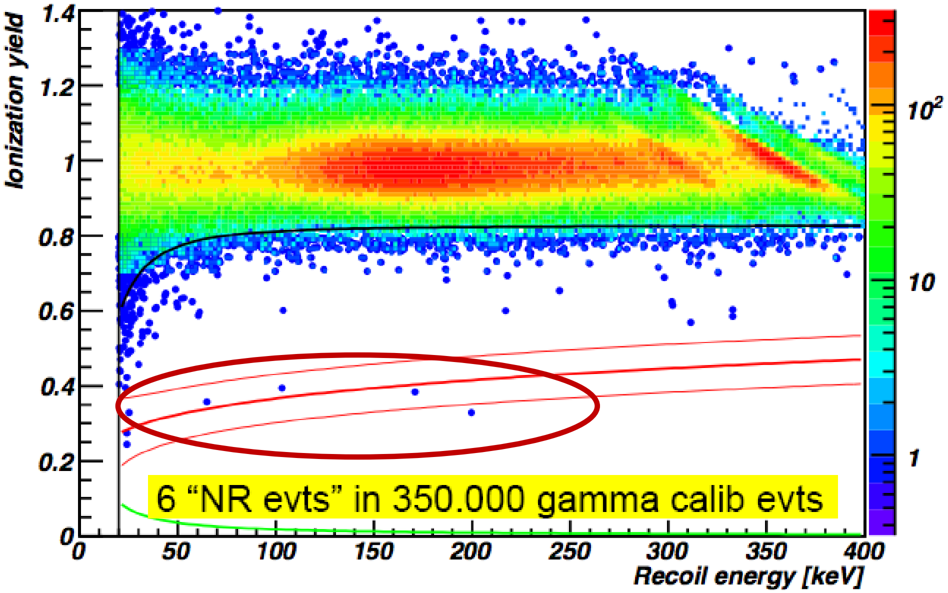
Excellent results but where are WIMPs?



Main upgrade from EDELWEISS-II to EDELWEISS-III

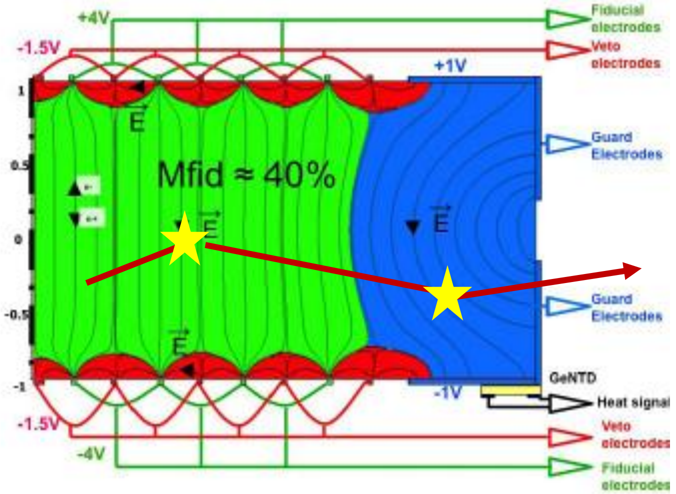
- Nature of the background
- Detector's mass

Both aims are targeted with new FID800 detectors + improved experimental setup



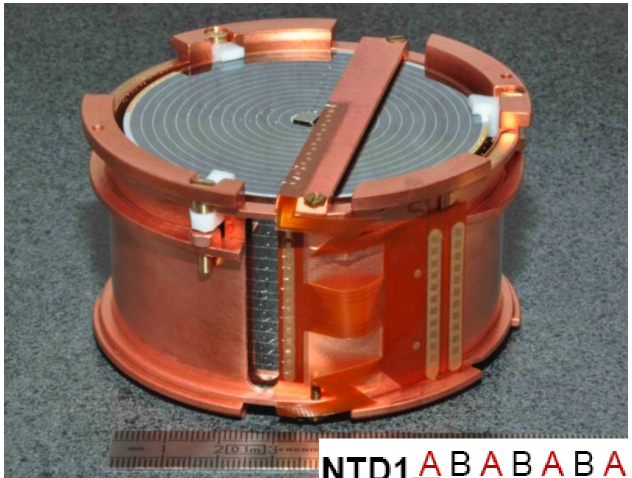
γ (^{133}Ba) calibration of ID400 detectors (EDELWEISS-II).

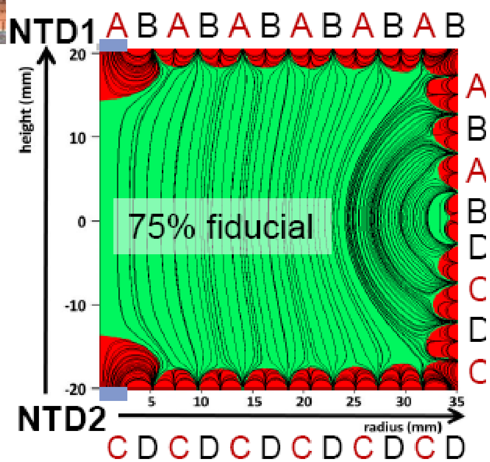
Excess of events in the intermediate region, events in the WIMP search region



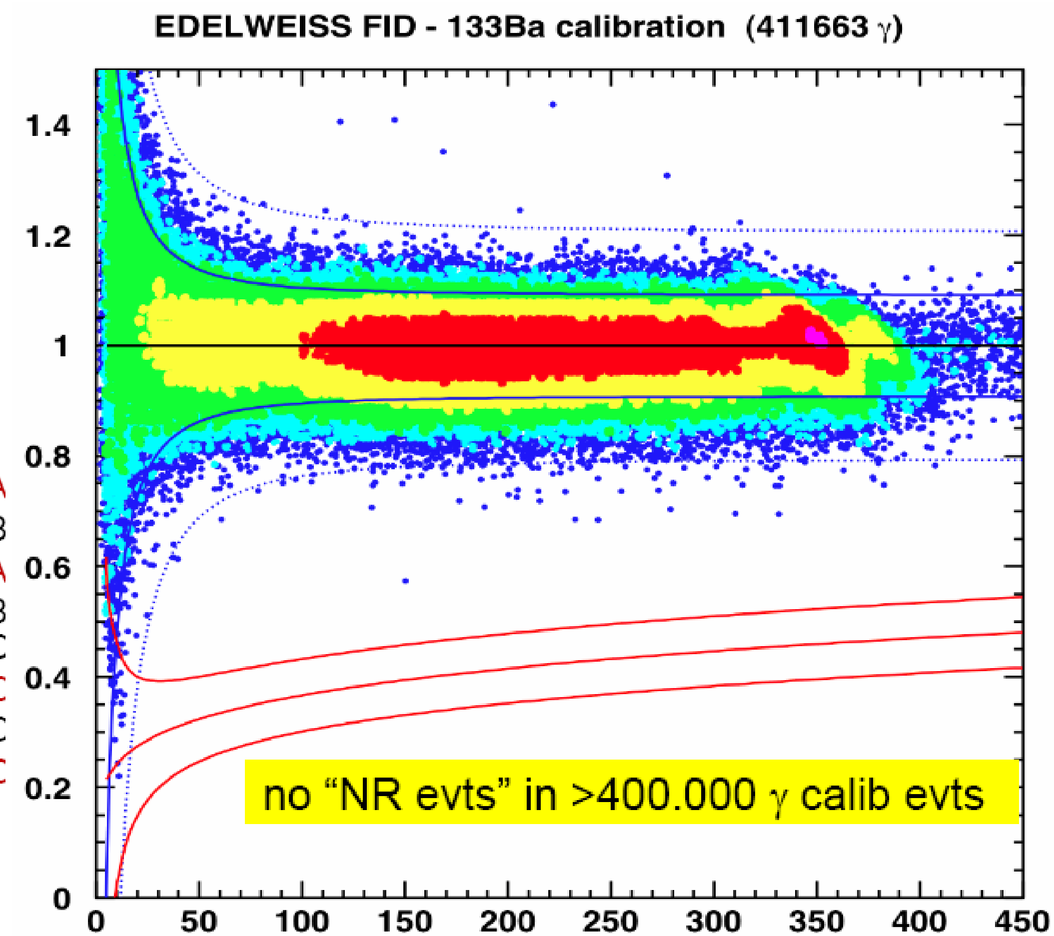
How to improve

FID800 detectors





- FID800: 800-850 g / detector
- Two NTD termistors
- All surfaces have special electrodes scheme, fiducial volume ~ 75%



No events in the WIMP search region, less events in the intermediate region

EDELWEISS-III: improved neutron shielding

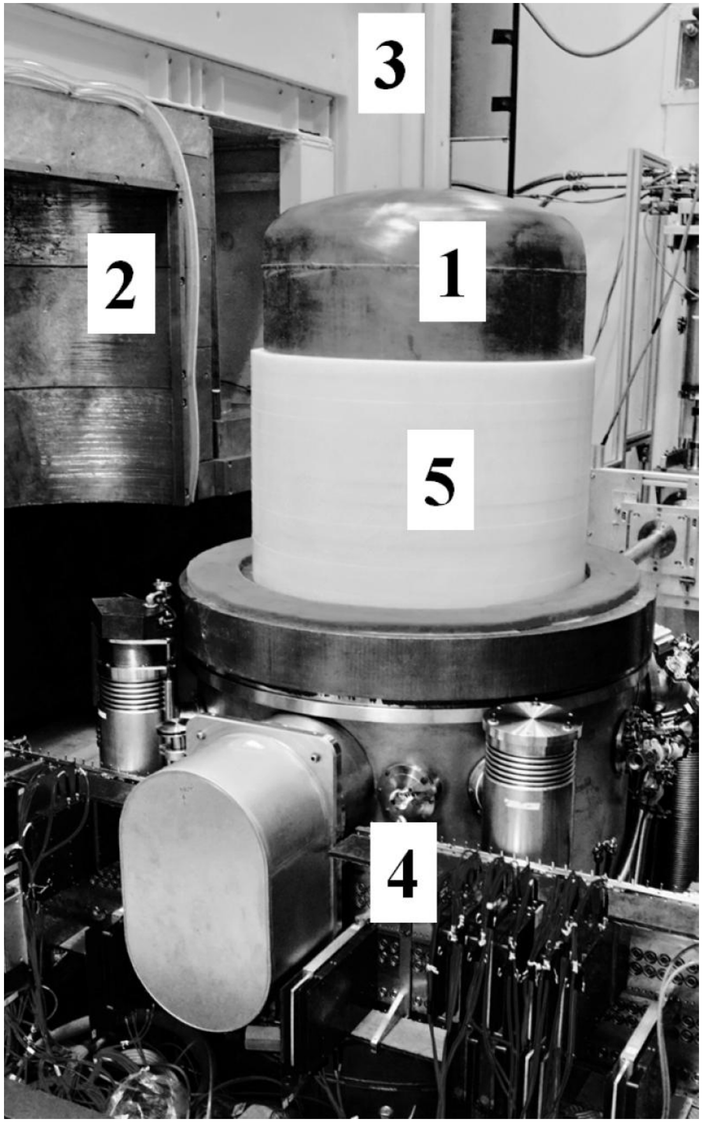
Neutron background reduction by 10 + times

~10 cm of polyethylene below detectors.

~6 cm of PE on the sides and top.

Low-radioactive cables and connectors.

New copper screens (cryostat), plates and bars.

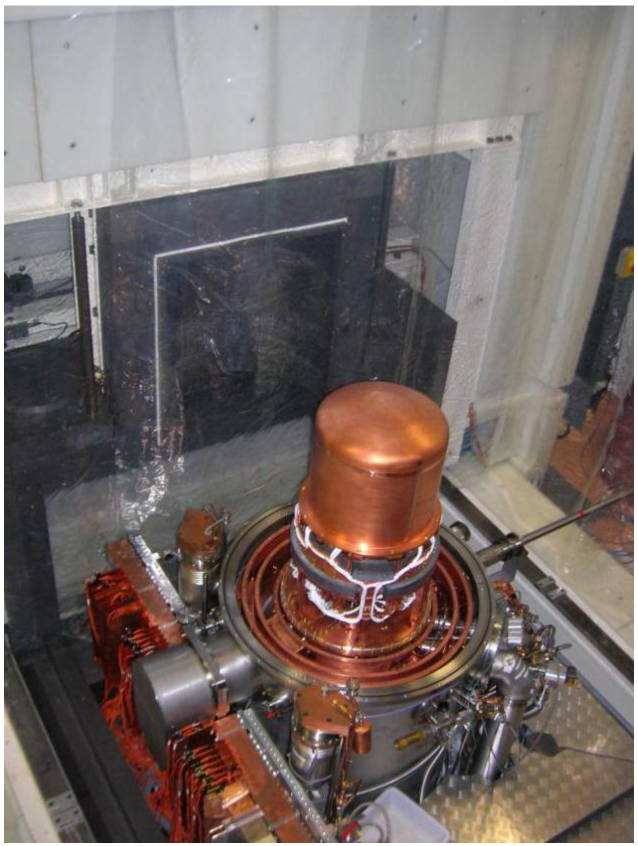


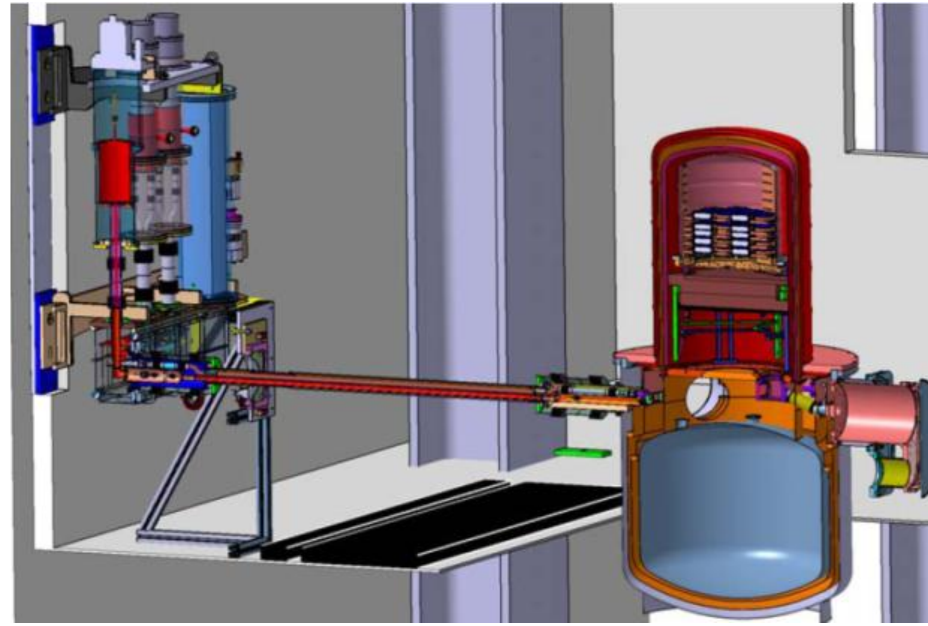
1: external cupper screen of the cryostat; 2: lead shielding; 3: main polyethylene shielding (EDELWEISS-2 and 3); 4: electronics in the main polyethylene shielding; 5: part of the new polyethylene shielding (EDELWEISS-3).

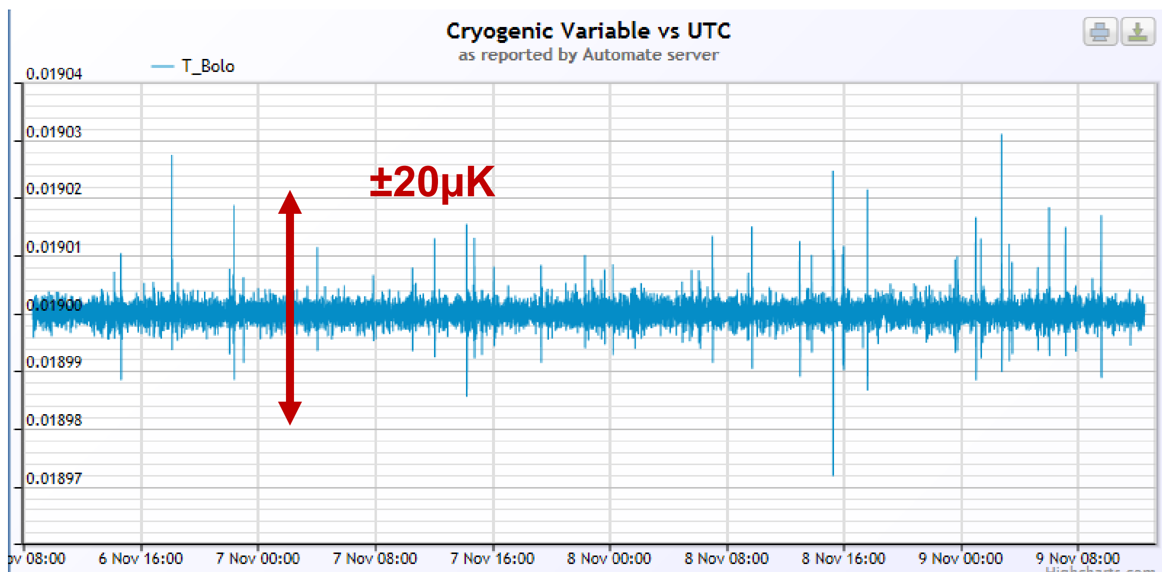
EDELWEISS-III

- Less microphonics.

Resolution improvement by 30%.

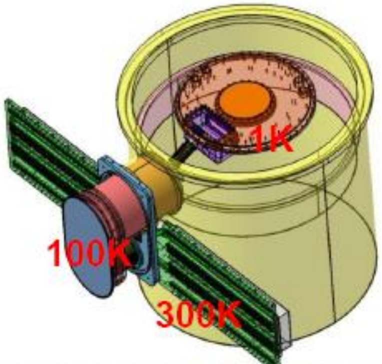




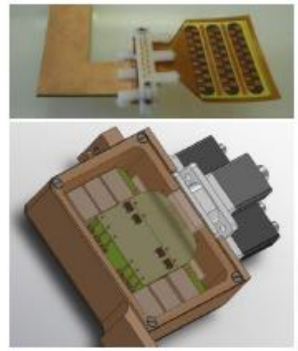


EDELWEISS-III, new fast electronics

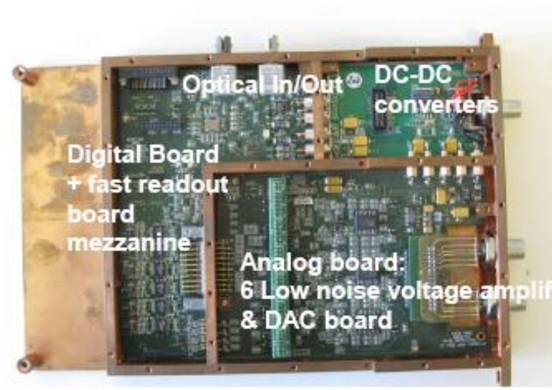
upgrade of electronics & cabling



new cables 300K-100K-1K-10mK



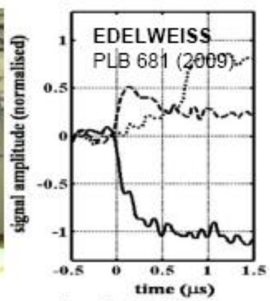
FET boxes

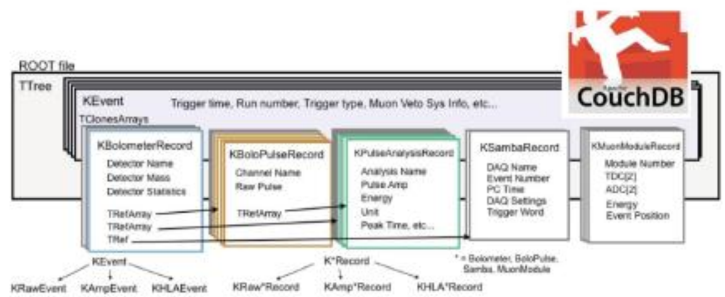


AD boxes w/ 100kHz/40MHz sampling

→ new front-end electronics <1 keV FWHM baseline resolution

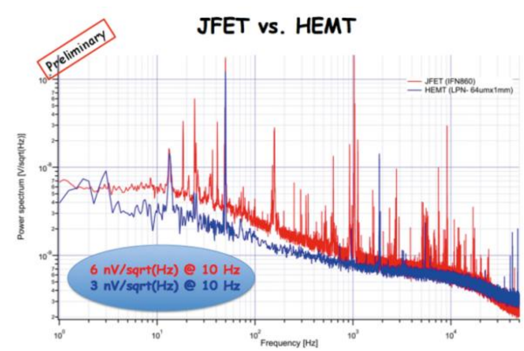
upgrade of DAQ & data structure





>240 ch´s in 1 crate; fast trigger for ionisaton

A. Cox et al., NIM A684 (2012)



FE electronics

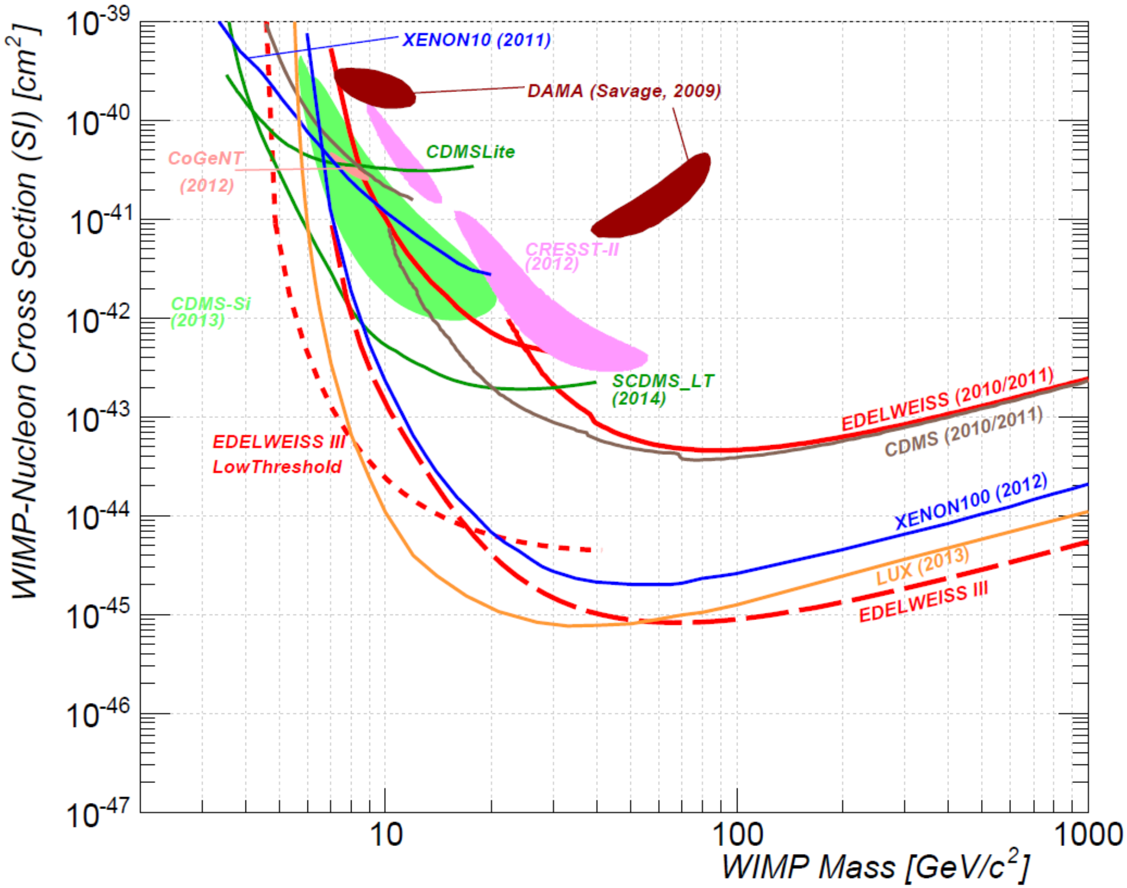
– low power high resol. HEMT@4K

EDELWEISS-III, 36 new FID800 detectors produced and installed in the cryostat
Significant increase of the fiducial mass (from 1.6 kg to ~22 kg)

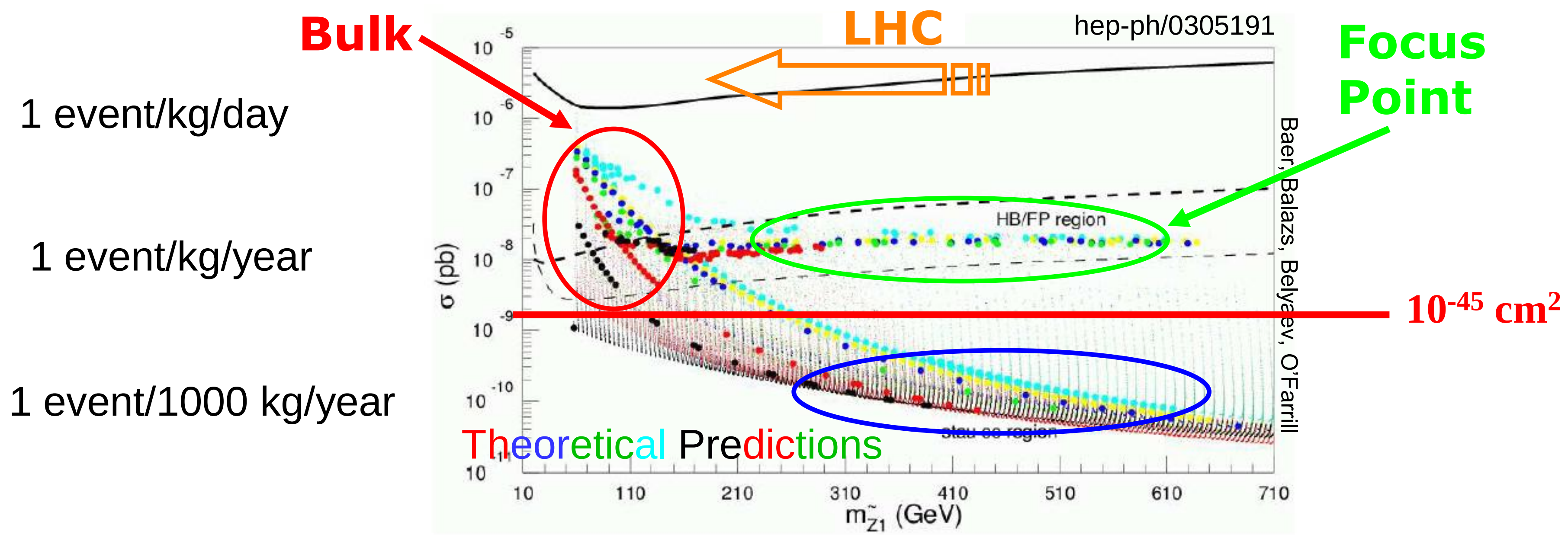
EDELWEISS-III timeline and aims

- Now, July 2014
  - fully equipped cryostat with 36 FID800 detectors
- end 2014
  - reach 3.500 kg.d (125 days of data taking)

  sensitivity to WIMP-nucleon SI cross-section of better of the $4x10^{-45}$ cm^2 for a M_{WIMP} ~100 GeV/c^2
- early 2016
  - reach 12.000 kg.d (500 days of data taking)



The target



We hope to see WIMP’s signals soon

Conclusion and outlook

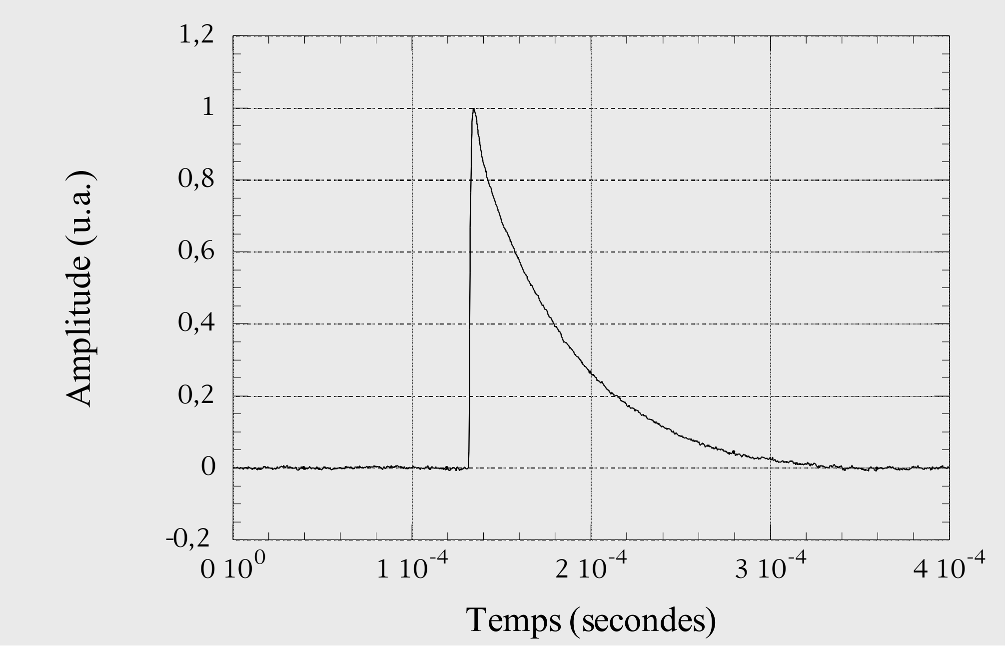
• Dark Matter problem is important for both particle physics and astrophysics;

•EDELWEISS experiment located at Modane Undeground Laboratory (France). The experiment aimed for direct WIMP observation in terrestrial laboratory with HPGe cryogenic detectors working in heat-ionization mode;

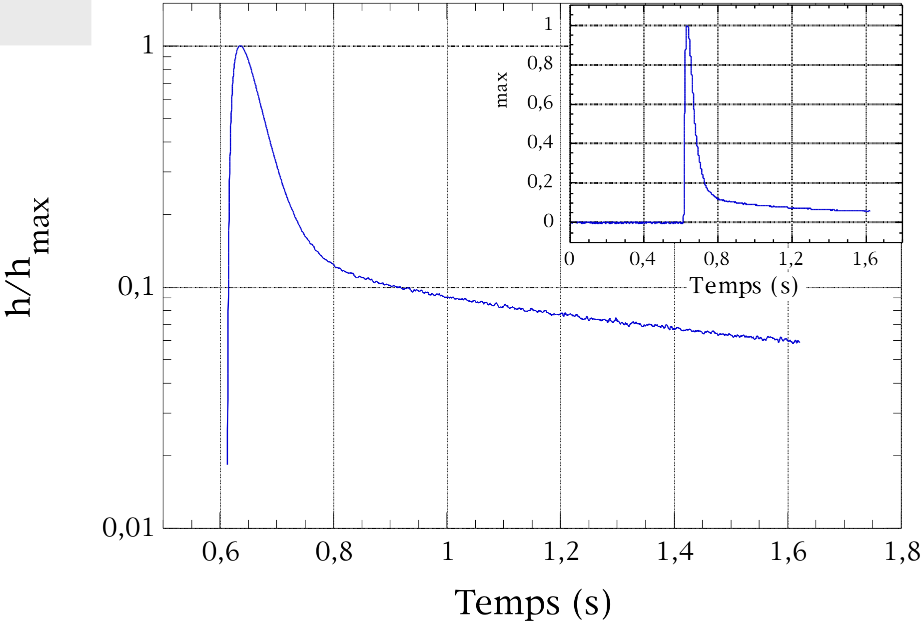
• EDELWEISS has a potential for exploring 10^{-45} cm^2 level in next few years (region of interest of SUSY models – discovery of WIMPs);

BACKUP SLIDES

IONISATION SIGNAL

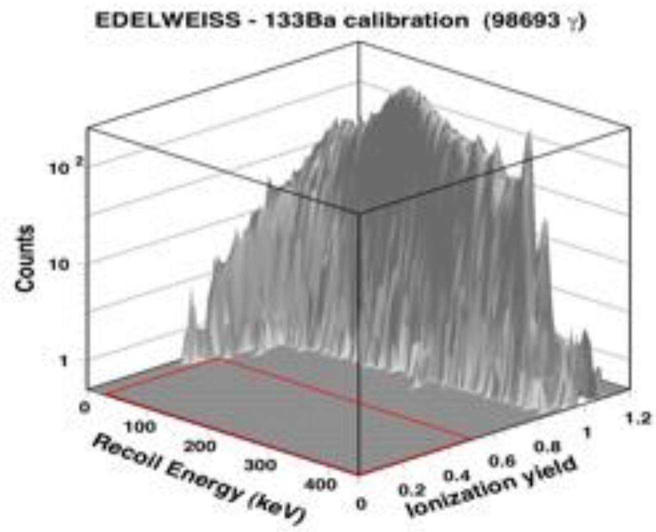


HEAT SIGNAL



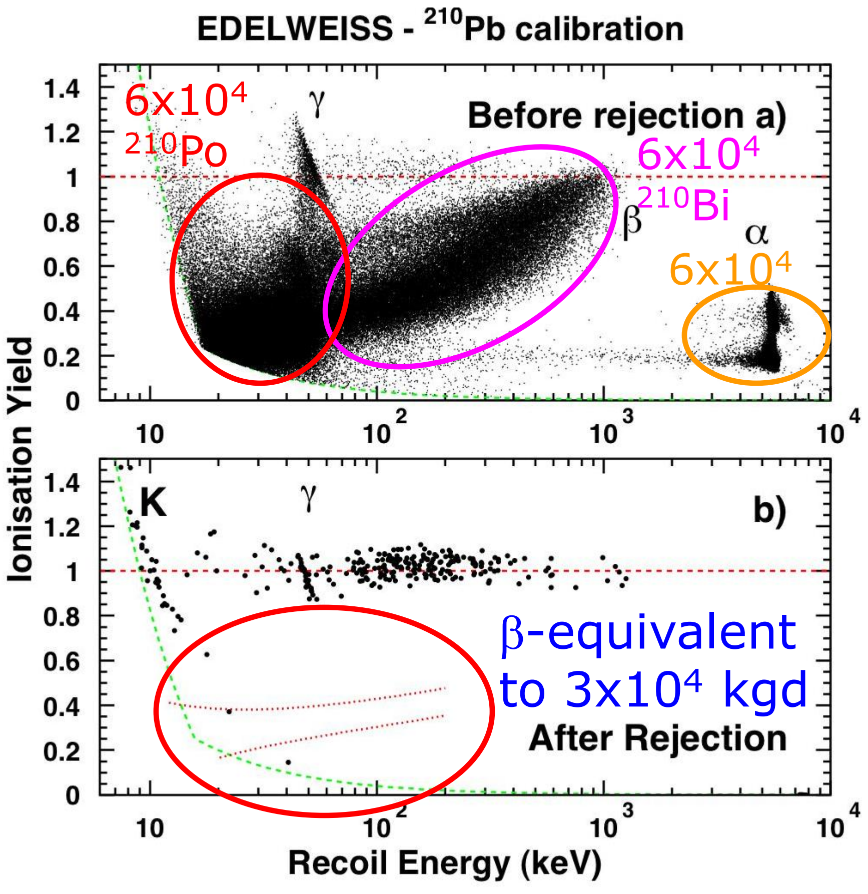
ID detectors and results

- ^{210}**Pb source calibration at LSM**
- **Rejection ~ 1 in 2 10^4 !**
- Equivalent to exposure of 4000- 40 000 kgd !

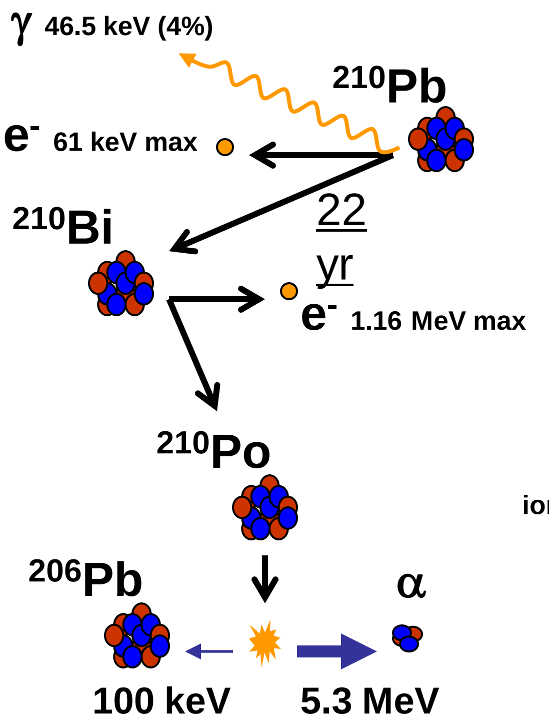


- Gamma rejection better than 1 in 10^5
- Expected background ~0.1 per 3000 kg.d

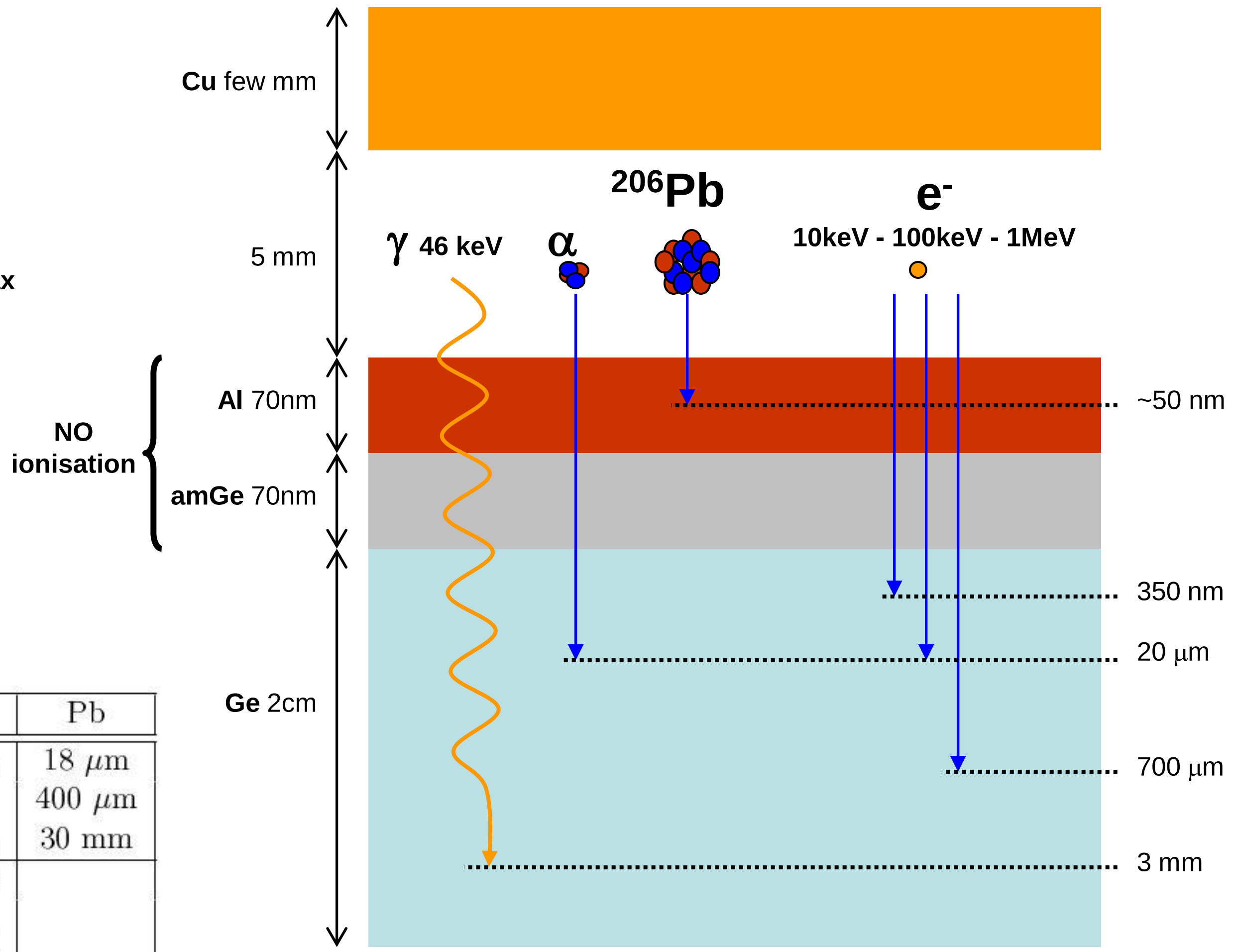
^{210}Pb β rejection of 200g

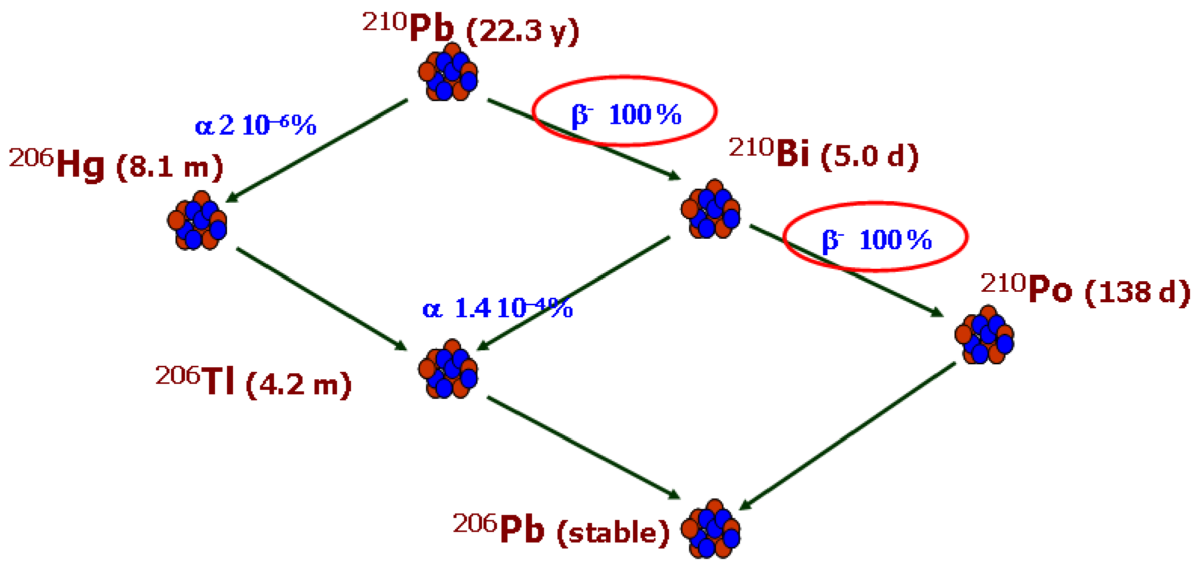


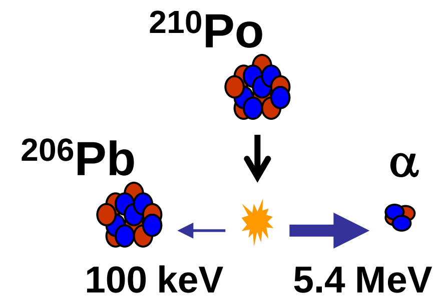
Scheme of background surface events

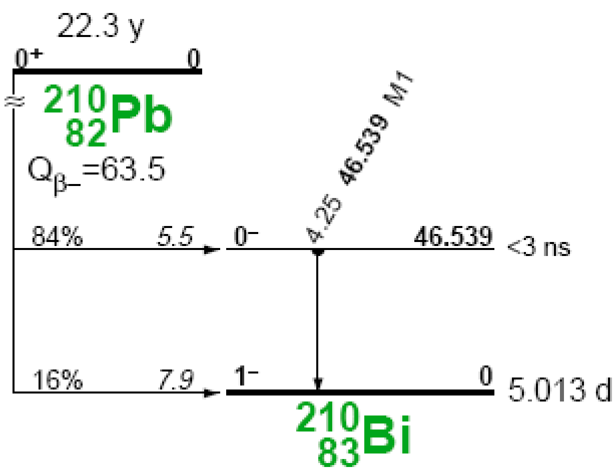


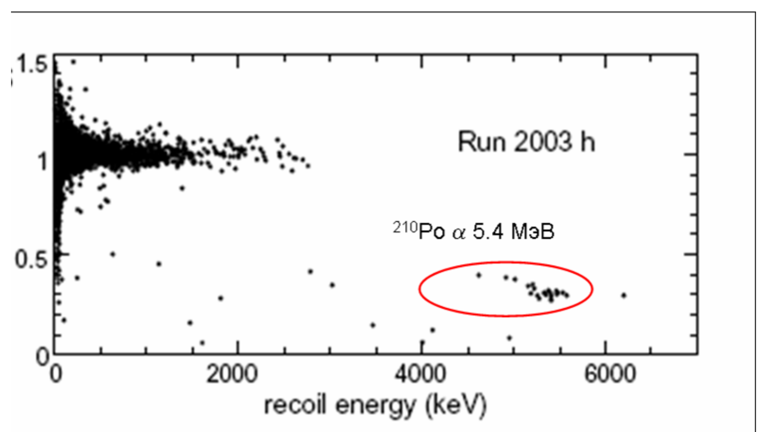
Particule	Energie	Cu	Ge	Pb
Gamma	10 keV	9 μm	170 μm	18 μm
	100 keV	6 mm	8 mm	400 μm
	1 MeV	40 mm	80 mm	30 mm
Electron	10 keV	200 nm	350 nm	
	100 keV	11 μm	20 μm	
	1 MeV	340 μm	700 μm	
Alpha	5.3 MeV	11 μm	19 μm	15 μm
Polonium	100 keV	40 nm	68 nm	





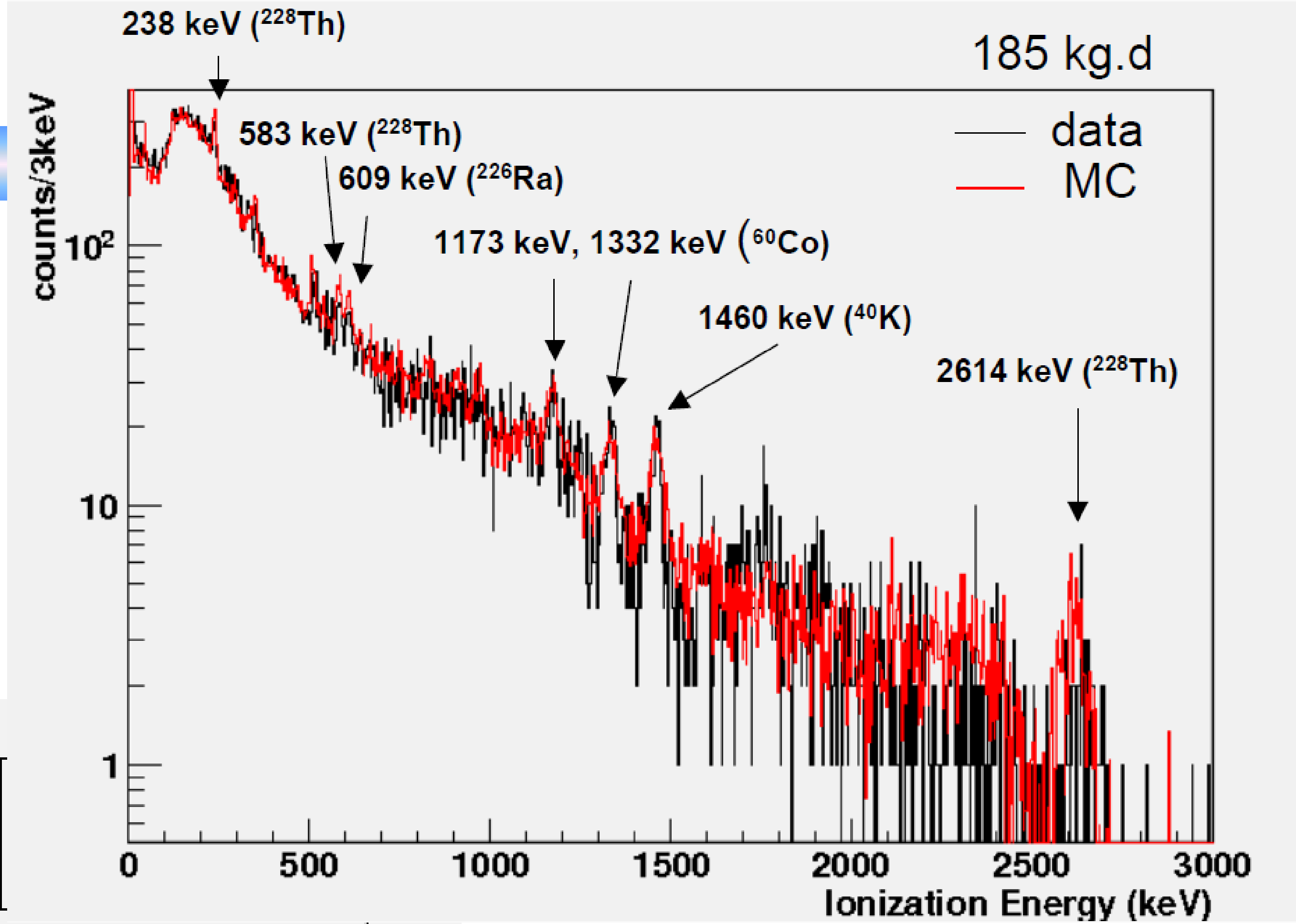


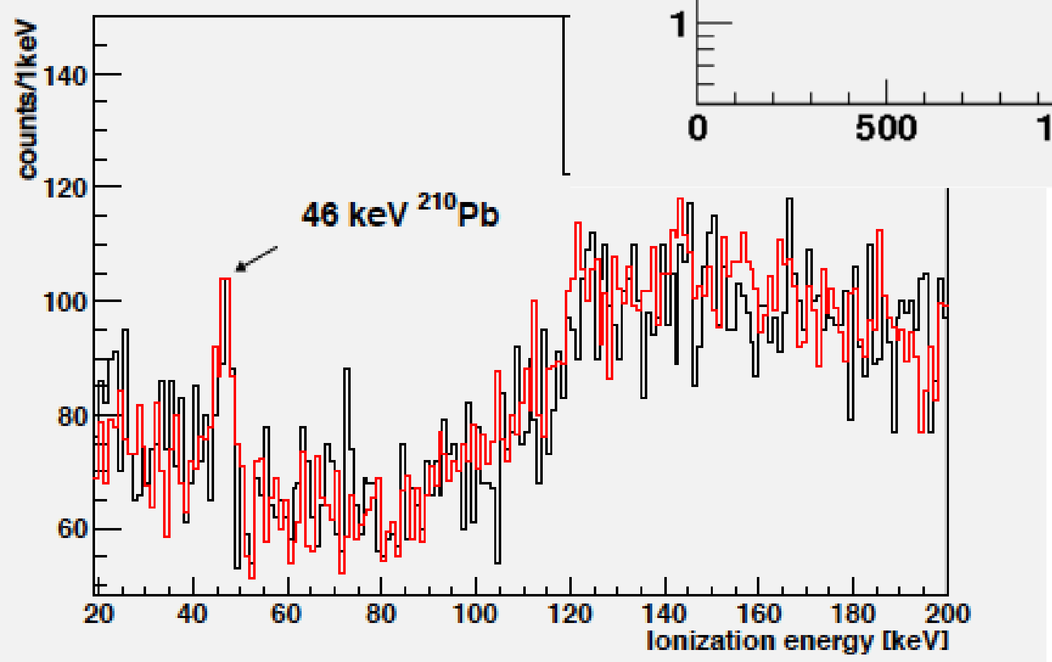




Level of contamination is very low: < 0.5 alphas / detector / day
(few tenth atoms of ^{210}Pb per cm^2)
Anyway need a confirmation that background is due surface events -> MC + experimental test

γ-induced background





Background budget of Edelweiss-II, final

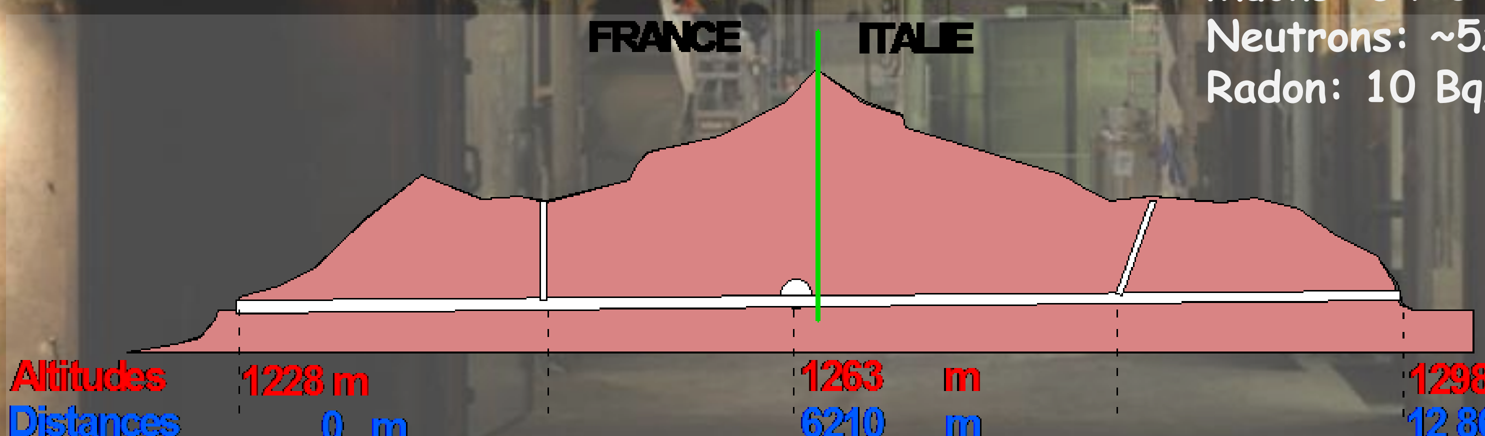
Background in RoI (20-200 keV)		Rate 90%CL (event / 384 kg.d)
γ-background	$1.8 \cdot 10^4$ events	
133Ba calibration:	$\times\ 3 \cdot 10^{-5}$ leakage into RoI	< 0.9
Surface events	5000	
210Pb source:	$\times\ 6 \cdot 10^{-5}$	< 0.3
Neutrons from all components		
Geant4 x measured radiopurity		< 3.1
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**

Modane Underground Laboratory (LSM)

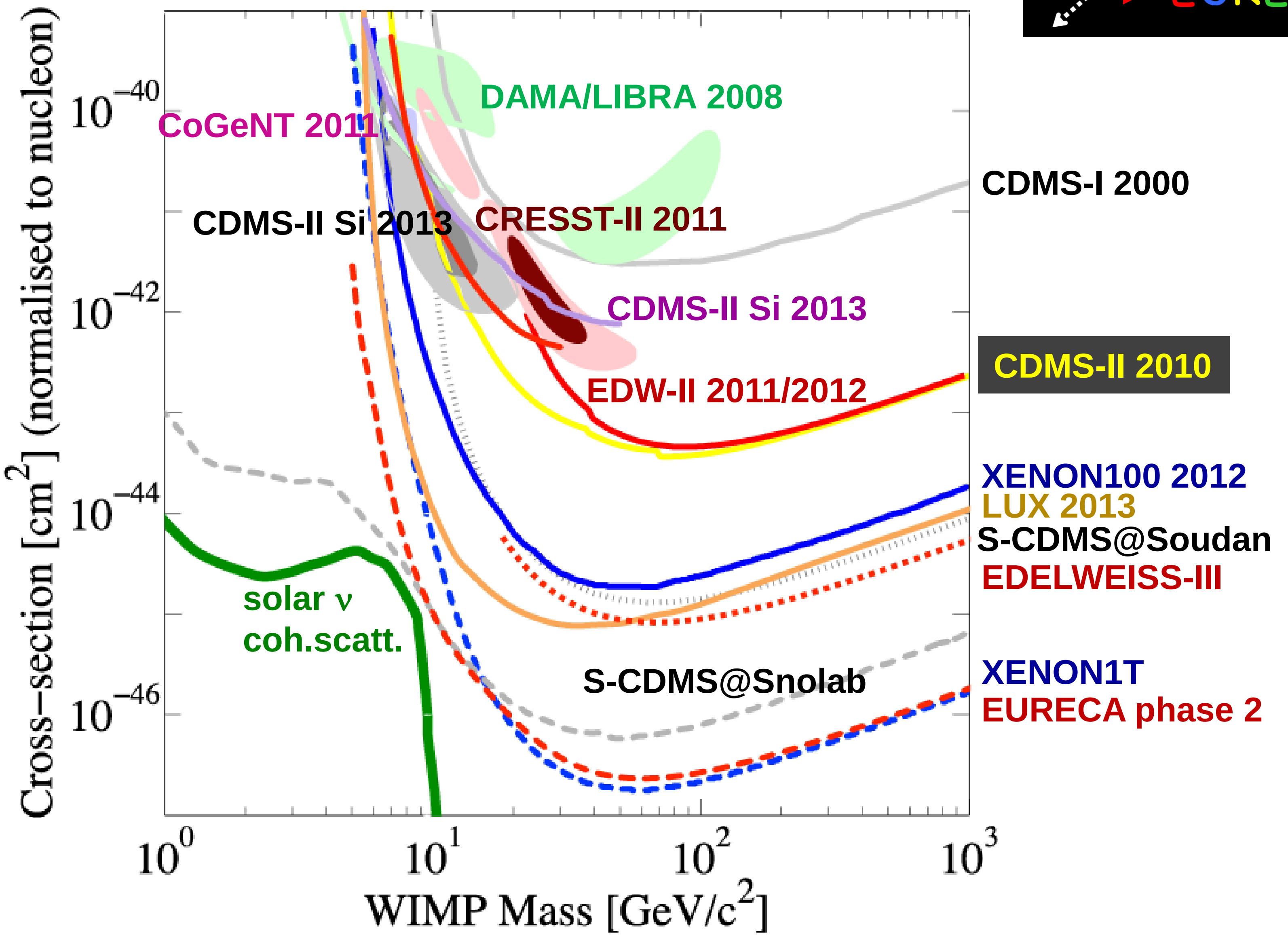
Go deep underground to search for probably most interesting part of the Universe

Depth: 4800 m.w.e
Surface: 400 m^2
Volume: 3500 m^3
Access: horizontal

Muons: $5 \times 10^{-5}\ \mu.m^{-2}.s^{-1}$
Neutrons: $\sim 5 \times 10^{-2}\ n.m^{-2}.s^{-1}$
Radon: 10 Bq/m^3



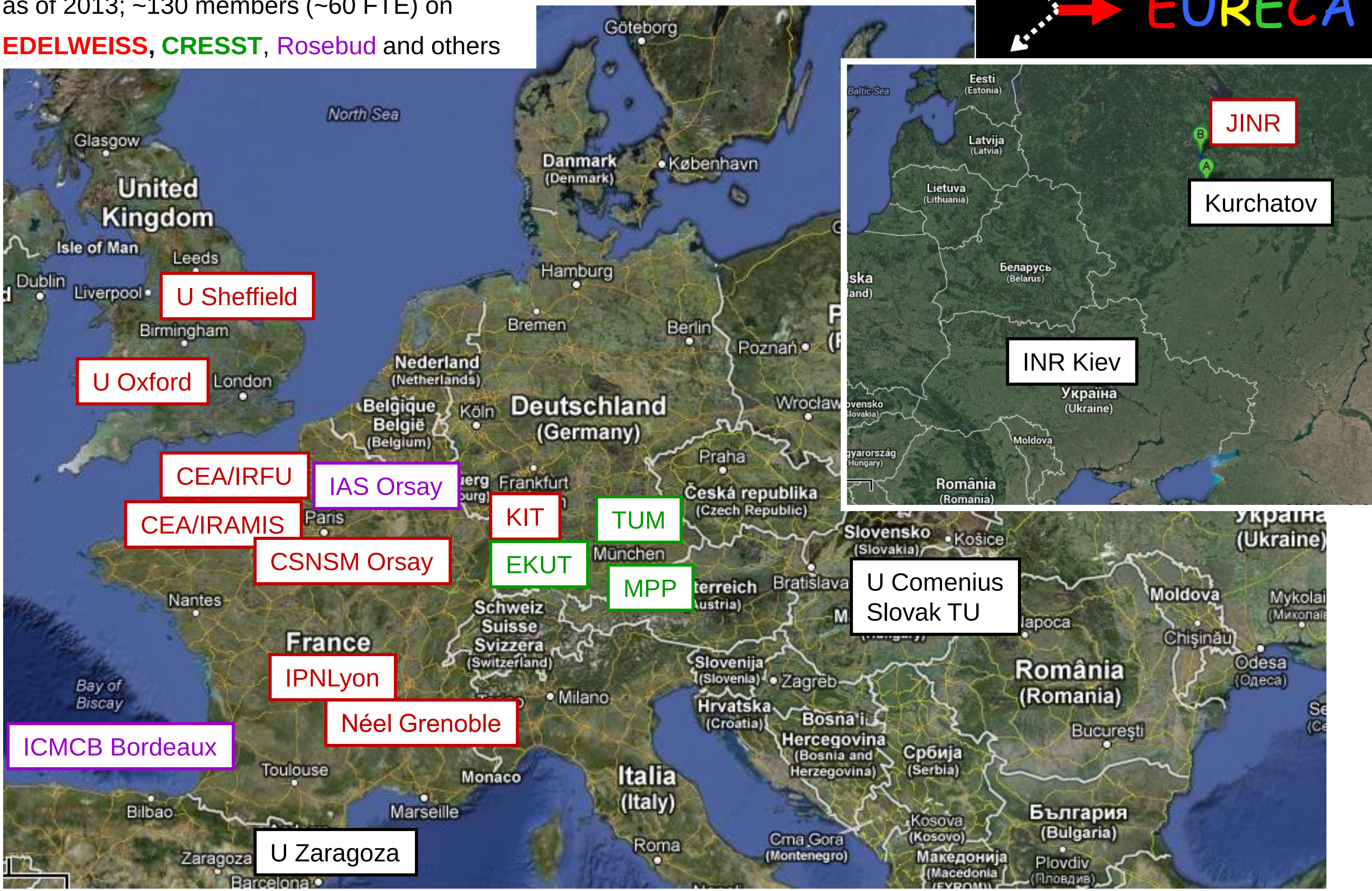
Beyond EDELWEISS-III → EUREKA



EURECA collaboration

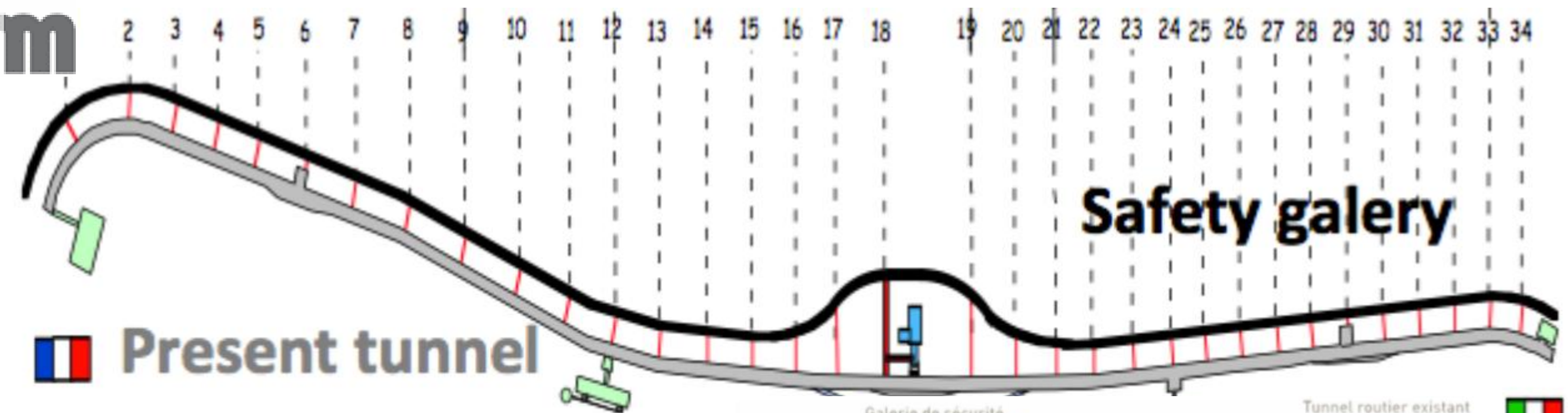
as of 2013; ~130 members (~60 FTE) on

EDELWEISS, **CRESST**, Rosebud and others

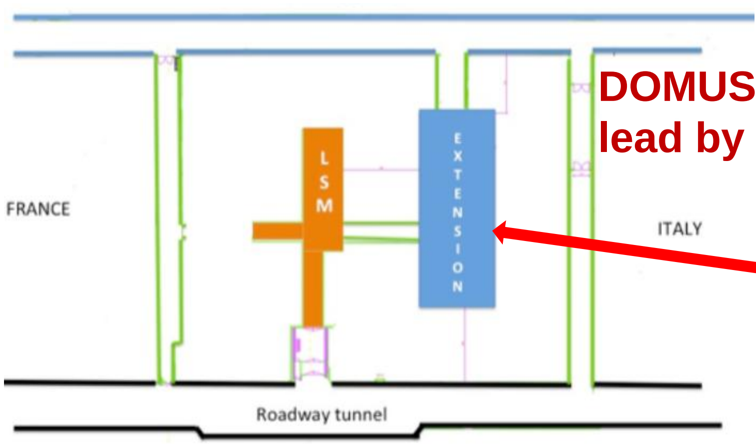


EURECA "baseline" site: DOMUS@LSM

Fréjus tunnel: 12870m; safety gallery decided in 2006



funded extension scheme



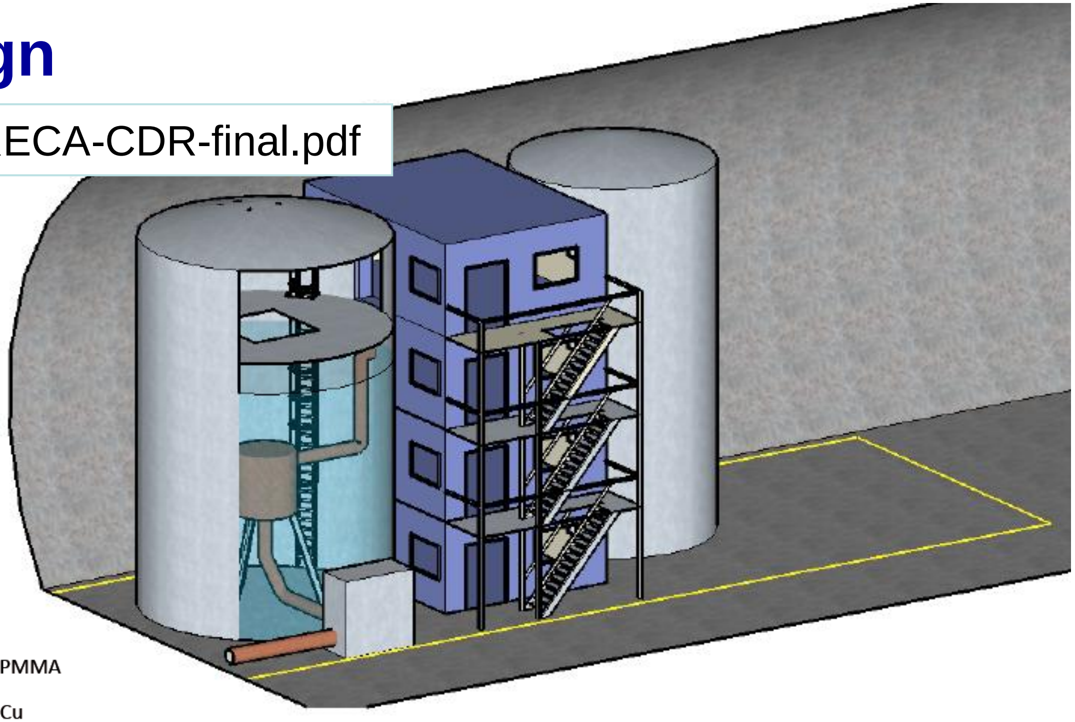
DOMUS project lead by CNRS

length: 40m
width: 19m
height: 16m
volume: 12.000 m^3

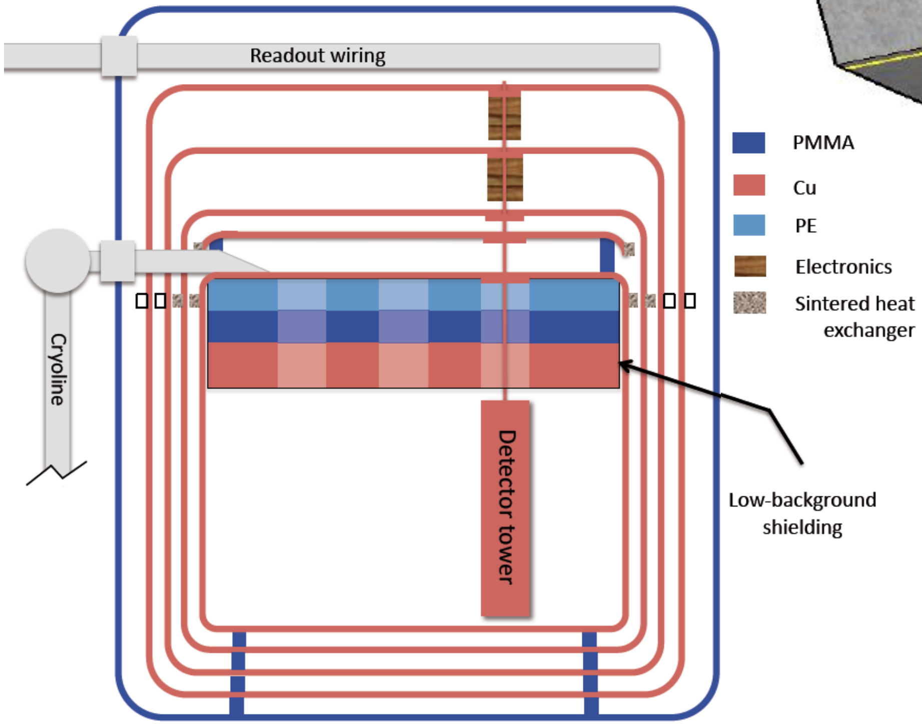
digging early 14 or end 15
6m excavation
10m outfitting
ready by 2016/2017
(F. Piquemal, TAUP13)

EURECA baseline design

https://dl.dropbox.com/u/58745013/EURECA-CDR-final.pdf

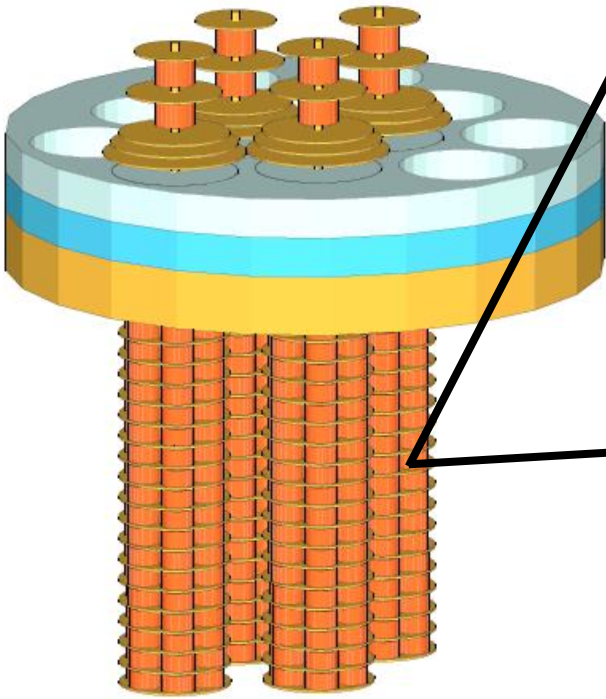


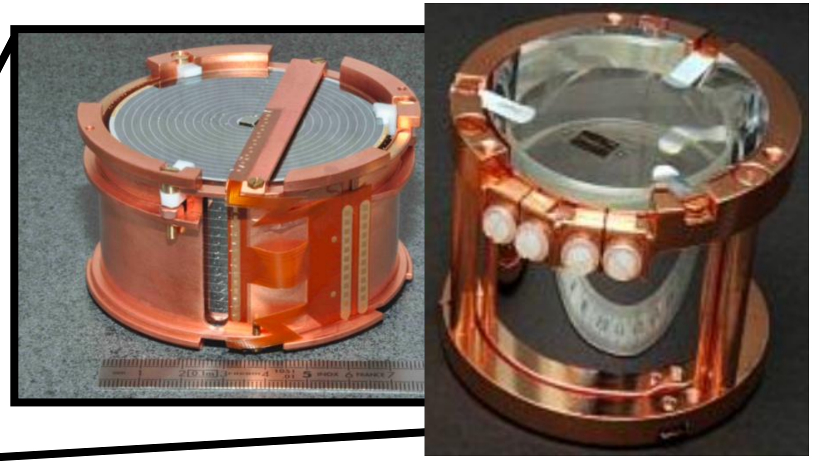
- mass(Cu) ~ 2035 kg
- mass (PMMA) ~ 1650 kg
- mass (detectors) ~ 1000 kg



Infrastructure	Baseline option
	Space
EURECA volume	10×24-m footprint × 12-m height
Cryostat	2-m diameter × 2-m height
Water shield tank	8-m diameter × 12-m height
Water buffer	6.5-m diameter × 12-m height
Man tower	6×8-m footprint × 12-m height
Cleanroom suite	48-m^2 footprint × 3-m height
Cryogenics	6×5-m footprint × 3-m height

EURECA detector towers



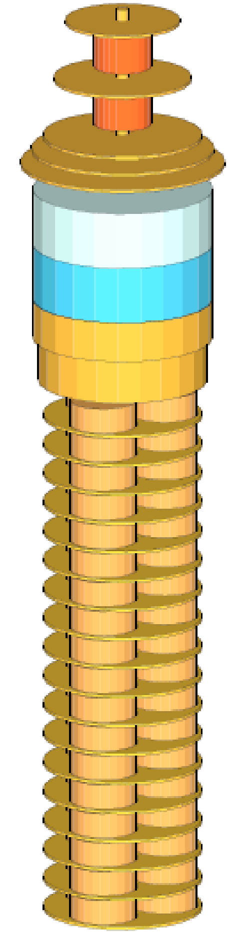


12 towers with Ø=280mm tray
tower spacing: d=360mm

tower of 18x6 casings with
Ø=86mm; h=48mm
→1296 detectors **800g-Ge**

(or 2160 detectors **300g-$CaWO_4$**)

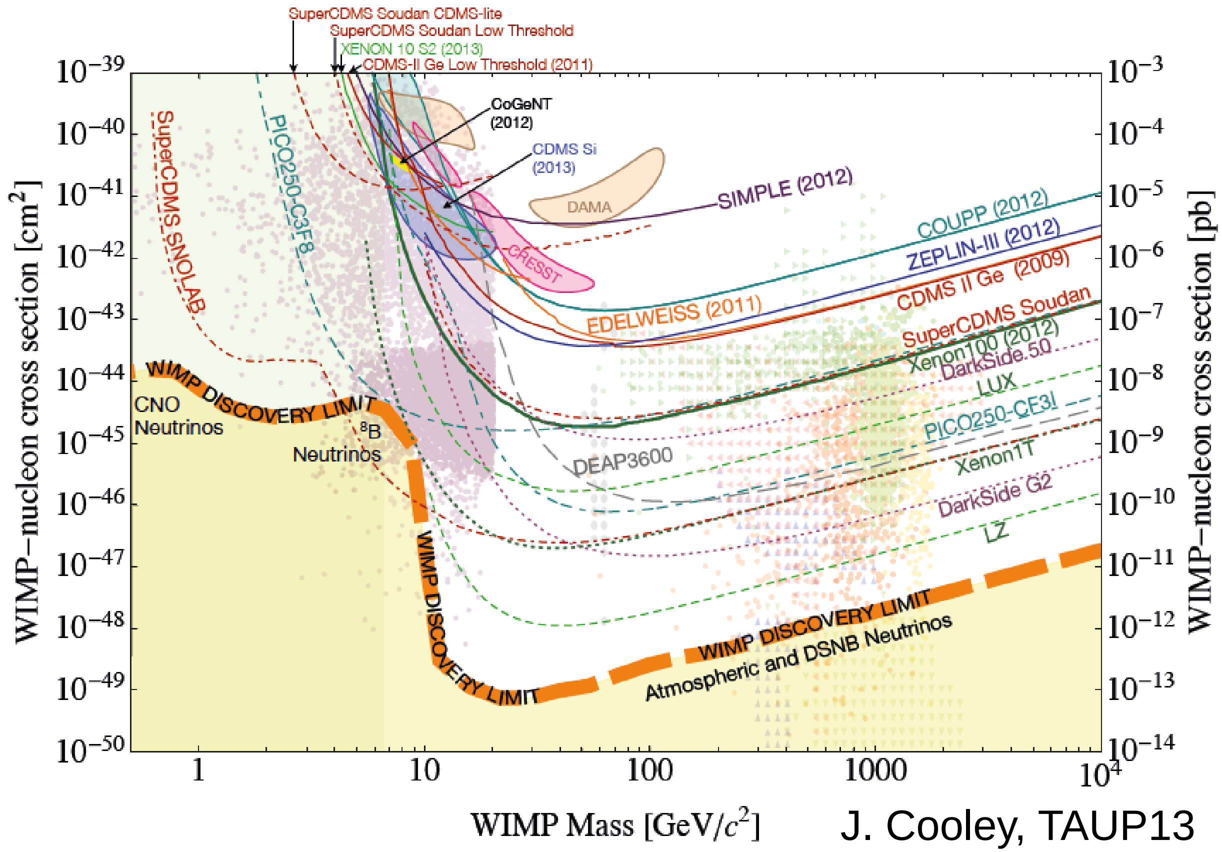
alternative:
tower of
18x3 casings
Ø=110mm; h=48mm
→648 detectors **1600g-Ge**



2013 ongoing study:
a) technical design of a tower
b) cabling & frontend electr.
c) thermal conductance tests

SNOWMASS 2013

Where Are We Going?



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