Edelweiss,past,present and future

M.P.Chapellier CSNSM/CNRS/ORSAY

for the Edelweiss collaboration

A search for neutralinos, supersymetric particles if they exist, and with density large enough in our terrestrial space inside the galaxy

Dark Matter: Jubileum or race to catch the wind?

Richland 19-21 June 2012

Plan

<> Past: from 1988, 1g of Al2O3 to 2010

3* 320g ultrapure Ge EdelweissI

10*400g ID beginning of EdelweissII

<> Present 10* 800g ultrapure Ge EdelweissII

<> Future 40* 800g ultrapure Ge EdelweissIII+ EURECA

Motivations for a low temperature physicist to do Astrophysics?

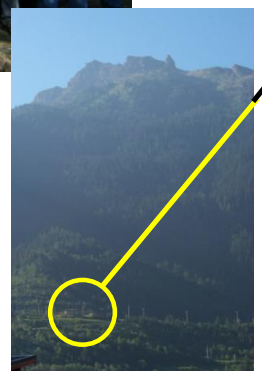
As a Scottish lord said about love:	What could be said of Astrophysics
The pleasure is momentary	idem
The position is ridiculous	the position is dangerous (scarce really new publications)
The expense is damnable	idem
(G.K.Chesterton)	(M.P. Hatter)

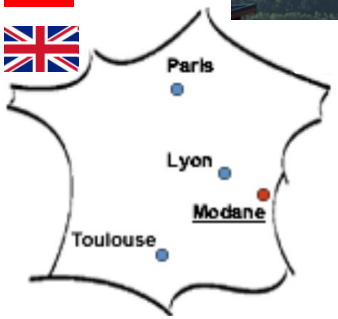
Nevertheless….. You love it!!

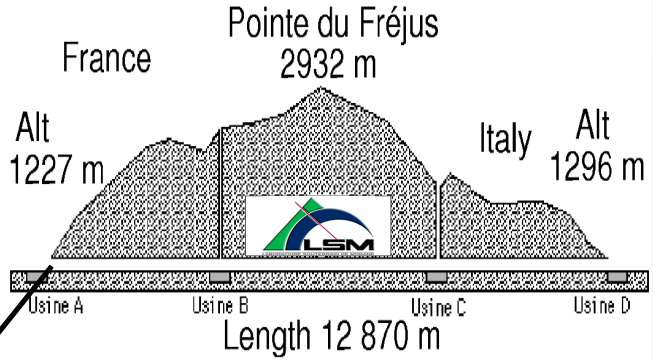
LSM office

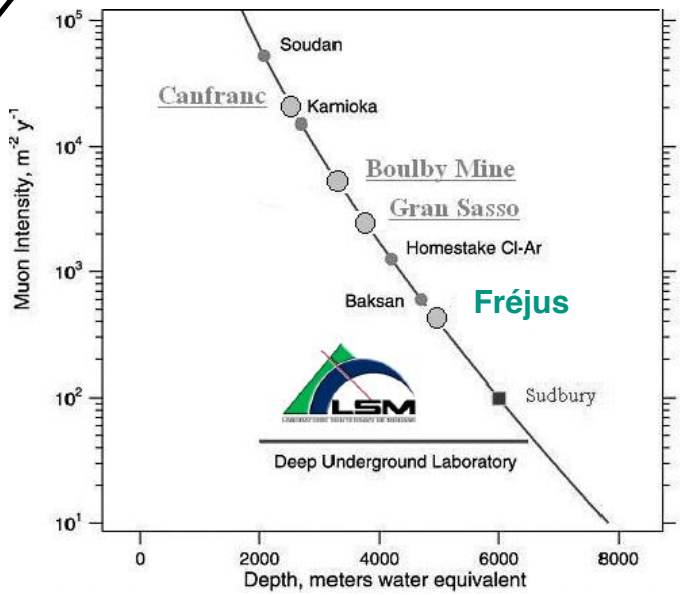
The team, the site

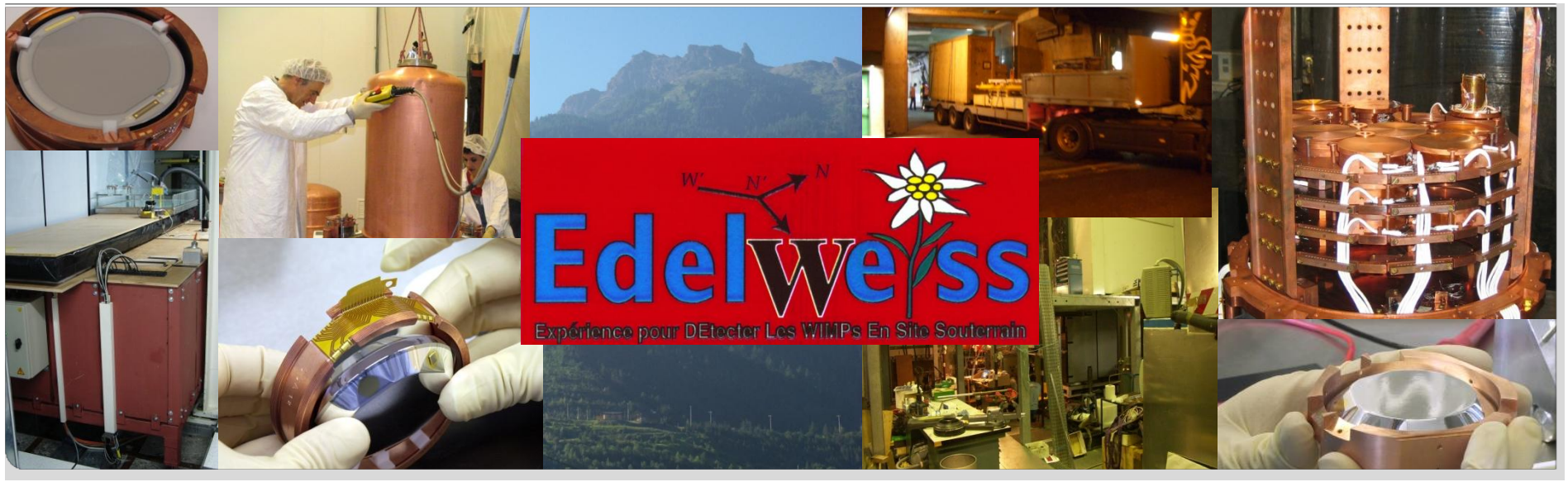
CEA Saclay (IRFU)
Paris-Orsay (CSNSM)
IPN Lyon
Inst. Néel Grenoble
KIT(IKP, EKP & IPE)
JINR Dubna
Oxford Univ.
Sheffield Univ.










W'
N'
N
Edelweiss
Expérience pour DEtecter Les WIMPs En Site Souterrain

The Past

from 1g of Al2O3 (1988) to 3* 320g ultrapure Ge (2003) Edelweiss I with a small home made low radioactivity cryostat (the blue cryostat) with a cold space of one liter

What were the problems?

*Small mass and no more space

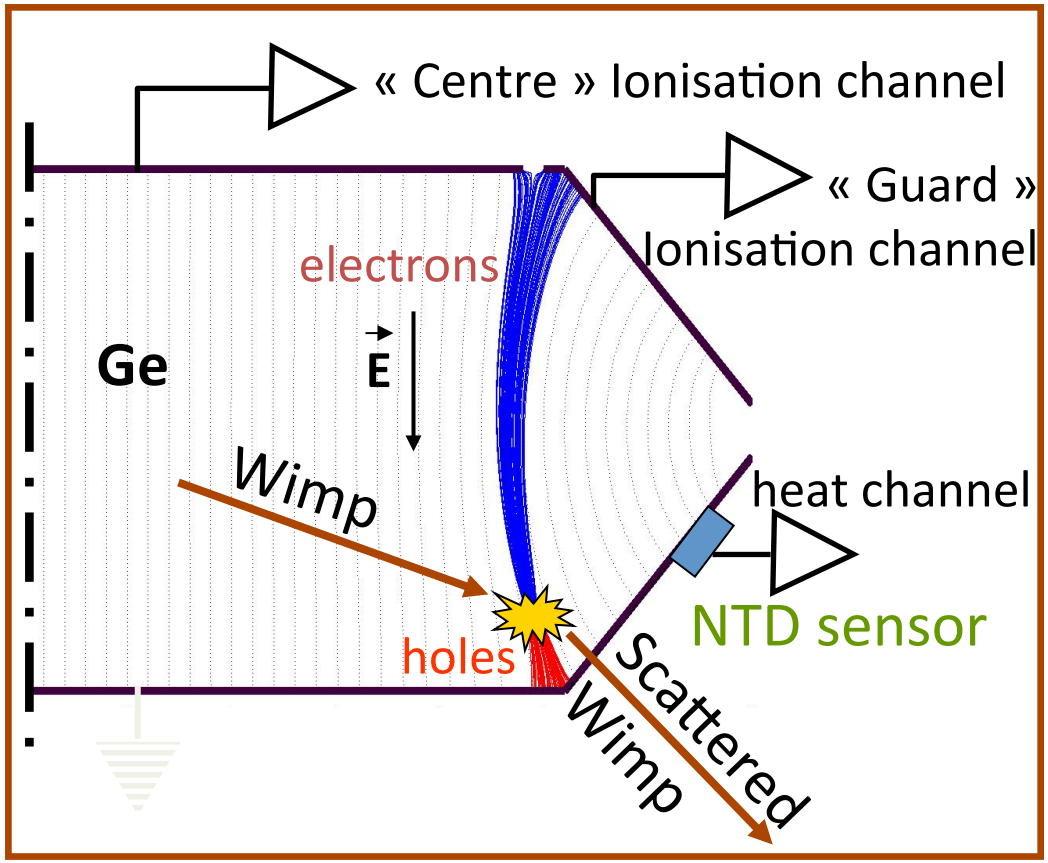
*No muon veto

*Neutron induce (one clear n-n coincidence)

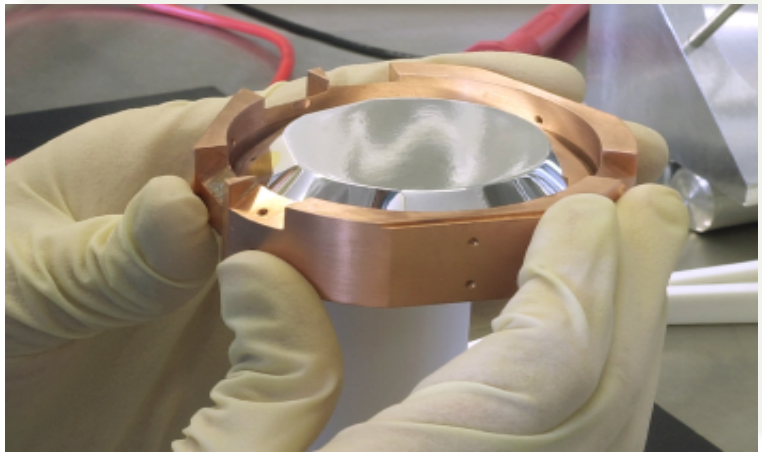
*Surface electron events

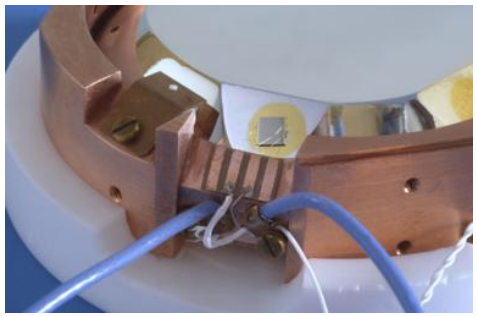
* Radon

Heat and ionisation detectors



320g high purity Ge detectors

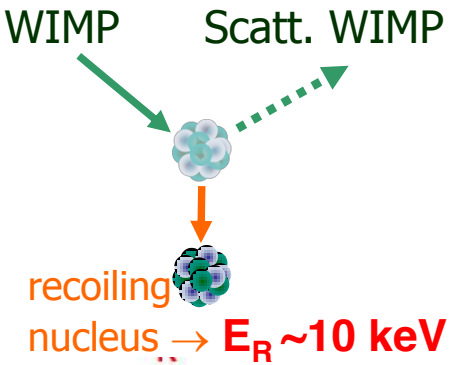




- **Ionisation**: some thousands pairs over some 100ns
- 2 Al sputtered electrodes (Centre +Guard)

- **Heat**: some µK over ms
- Neutron Transmutation Doped thermistor

The way to Edelweiss II



Count rate:

< 1 evt/kg/year!

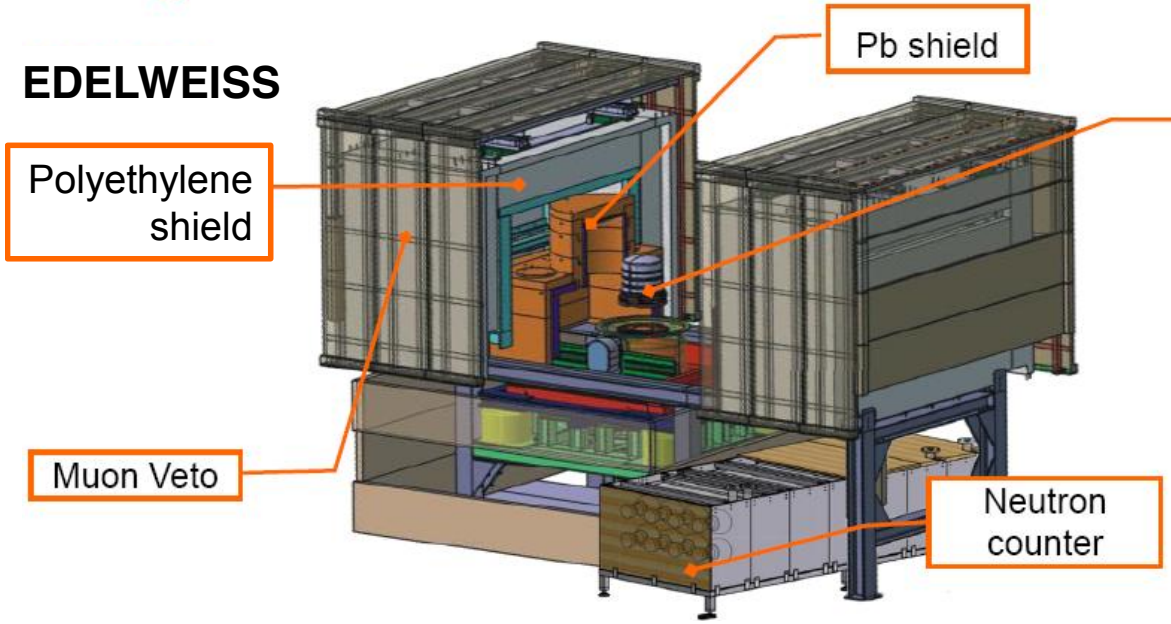
Challenges to overcome:

- α, β, γ ;
- **Neutrons;**
- **μ-induced events;**

Way to go:

- **low radioactivity;**
- **powerful rejection;**
- **background knowledge;**

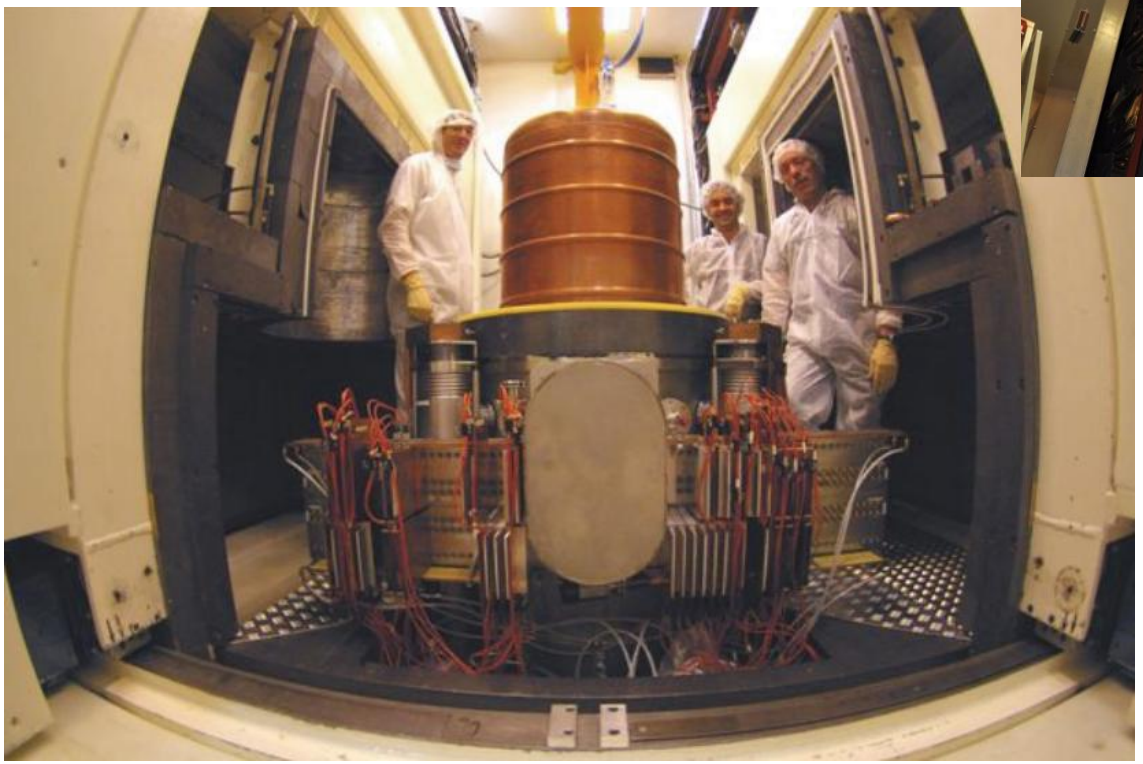
EDELWEISS



Side monitoring detectors:

- Rn detector
  down to few mBq/m3
- He3 neutron detector
  (thermal neutron monitoring inside shields)
  sensitivity ~10^{-9} n/cm^2/s
- Gd-loaded liquid scintillator neutron counter
  (study of μ-induced neutrons)

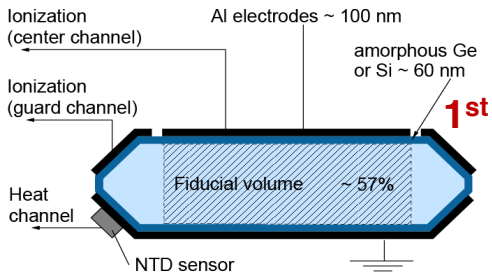
Inside the LSM, Edelweiss II



EDW II technology

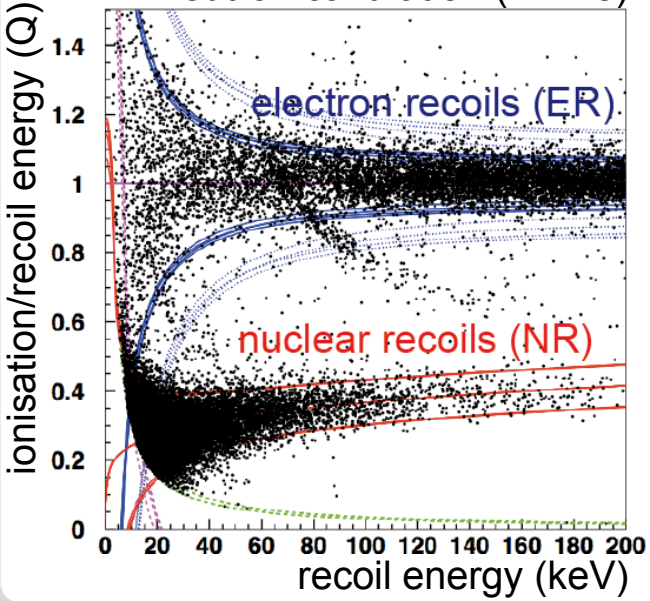
Germanium bolometers

- **Ionization measurement @ few V/cm**
- **Heat measurement (NTD sensor)**
- discriminating between ER and NR
  Q = ionization/recoil energy

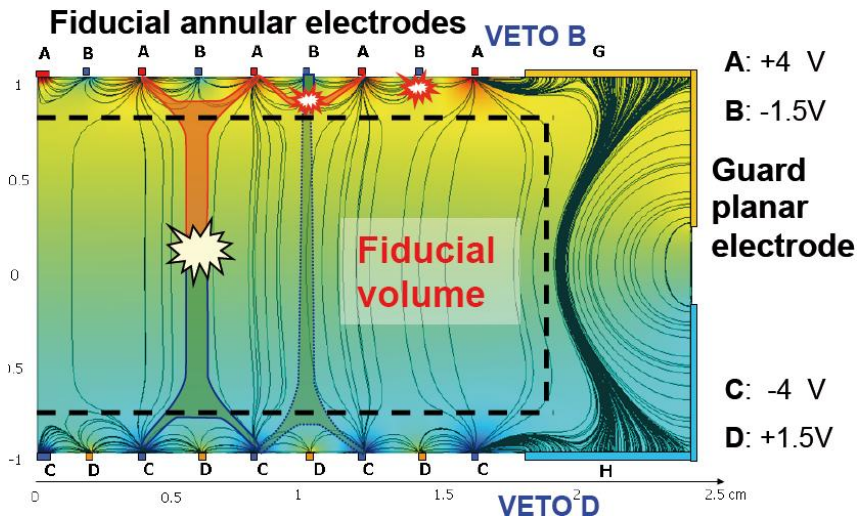


1st generation
GeNTD
320g
all planar
electrodes

neutron calibration (AmBe)



2nd generation ID400



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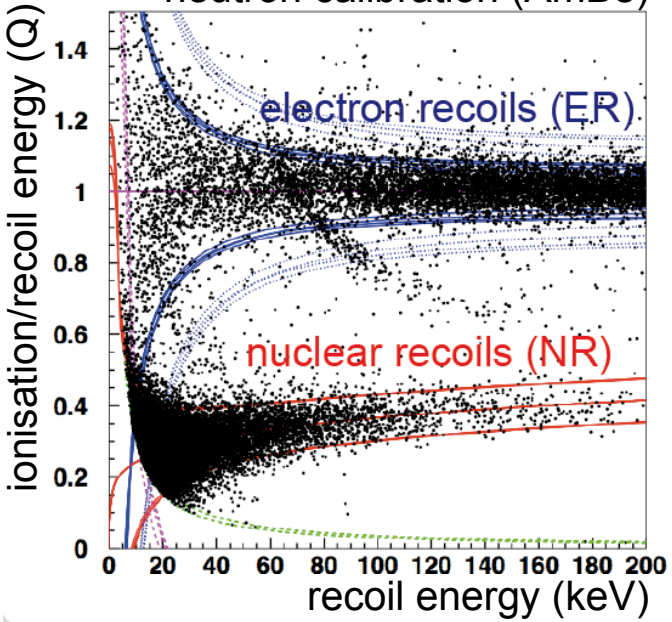
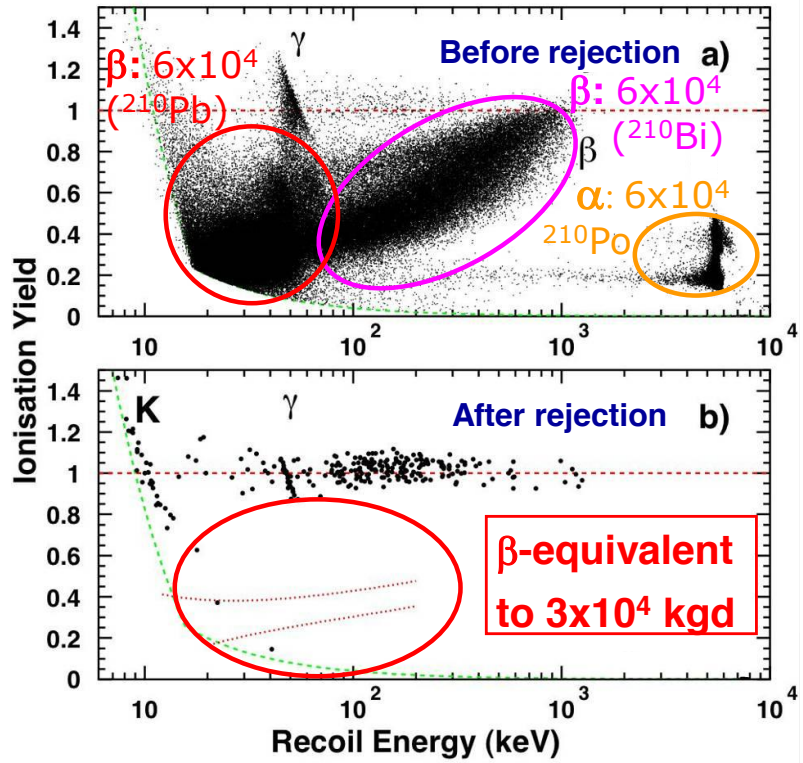
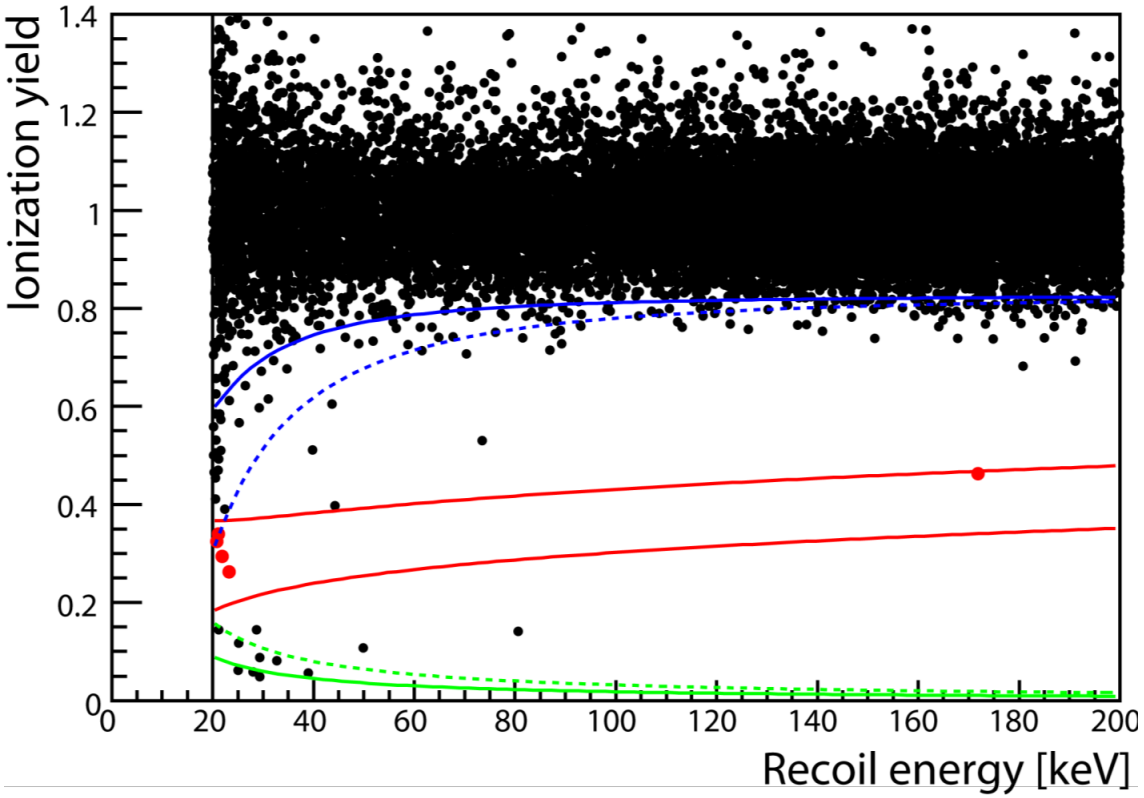


rejection of surface events
due to veto electrodes



Phys Lett B 681 (2009) 305

Edelweiss II final results



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)

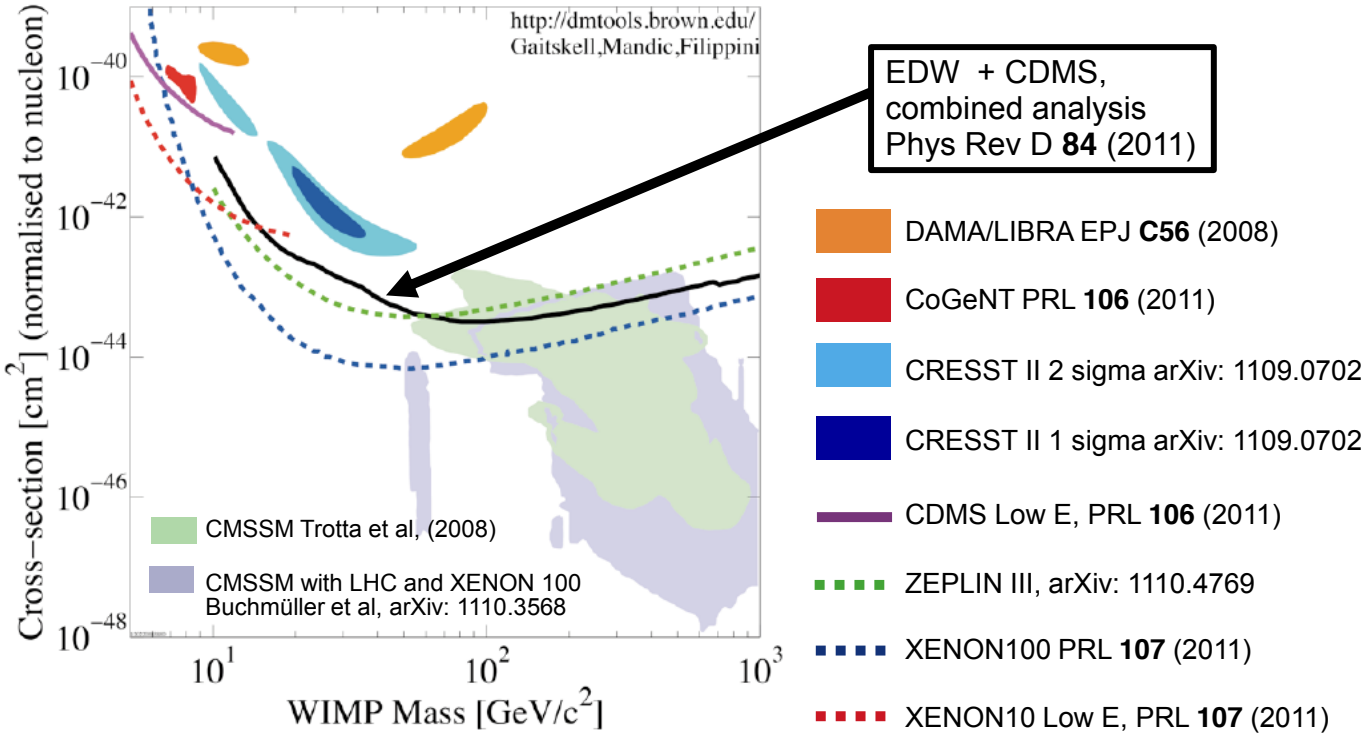
3 evts bg expected 20<E<100 keV (≈<0.9 γ, 0.3 ß, 1.8 n)

→ 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

results in parameter space σ_χ vs. m_χ

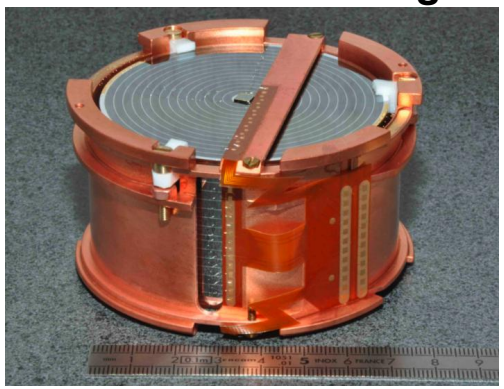
EDW (384kgd; [20-200keV], 5evts → σ_{SI} < 4.4 x 10^{-8} pb; M_{WIMP} = 85 GeV/c^2)
CDMS (~379kgd; [~10-100keV], 4 evts; σ_{SI} <3.8 x 10^{-8} pb; M_{WIMP} = 70 GeV/c^2)



Edelweiss III 2011

increase target mass

→ **40 detectors à 800g**



2 NTD, 4 (6) electrodes
[2 «fiducial» volumes]
218 ultrasonic bondings
per detector

reduce neutron background

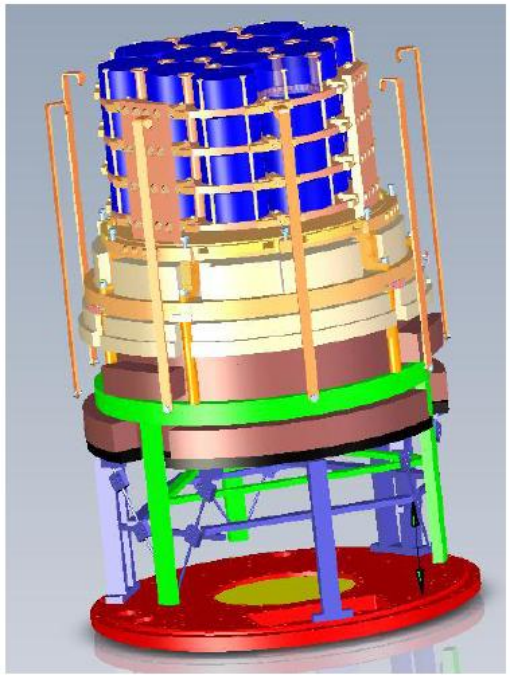
→ **new cryostat design**

new arrangement of Ge

new Cu mounting layers

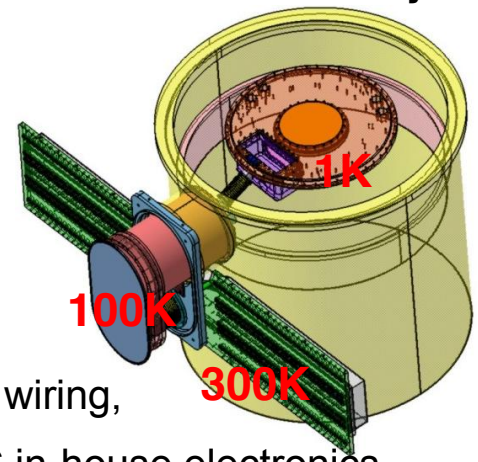
new internal PE shield

modified cryogenics



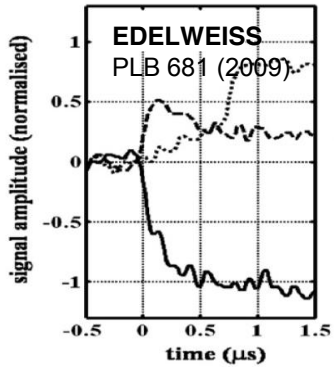
modify electronics & DAQ

→ **240 channels + auxiliary det.´s**



new wiring,

ADC in-house electronics



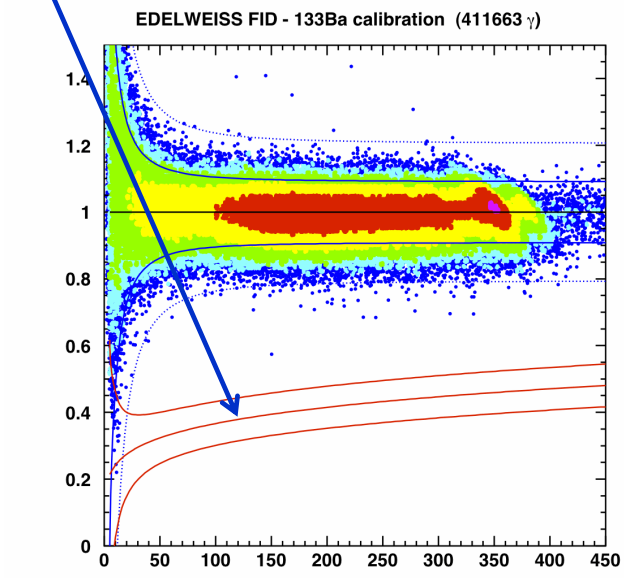
new event-based readout scheme

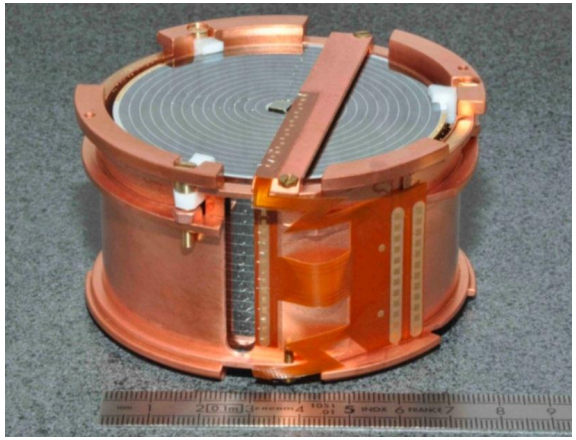
(DAQ crate similarly used by KATRIN/AUGER)

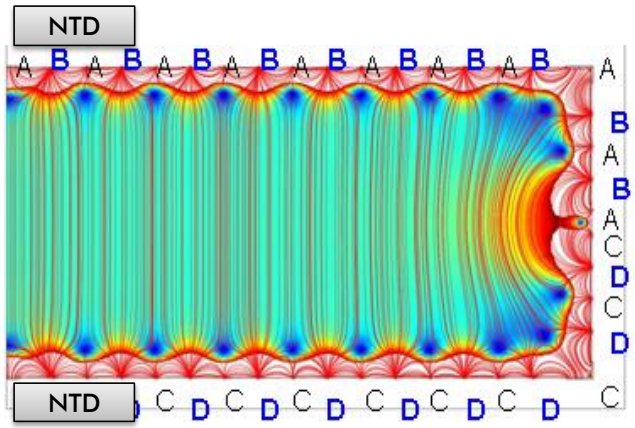
Bigger, better, anyway needed!!

FID-800 detectors

- 800g crystals, fiducial mass >600g
- Improved background discrimination:
  0 NR events / 4×10^5 γ
  (ID detectors 6 NRs / 3×10^5 γ)





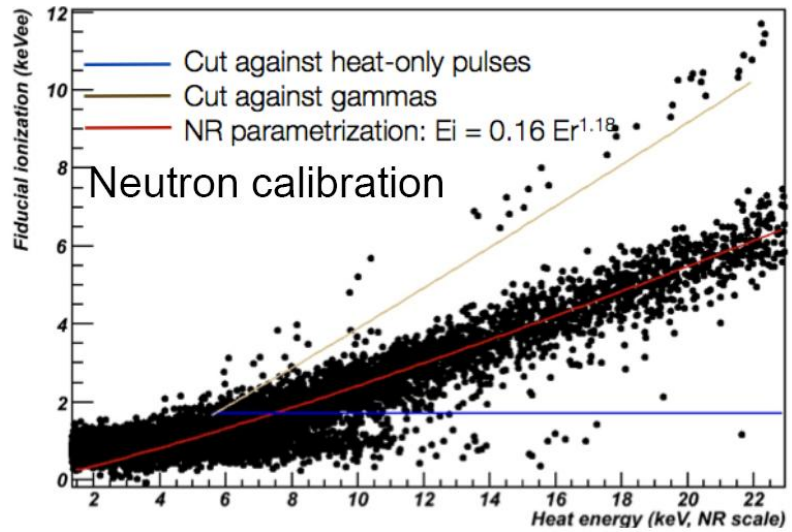


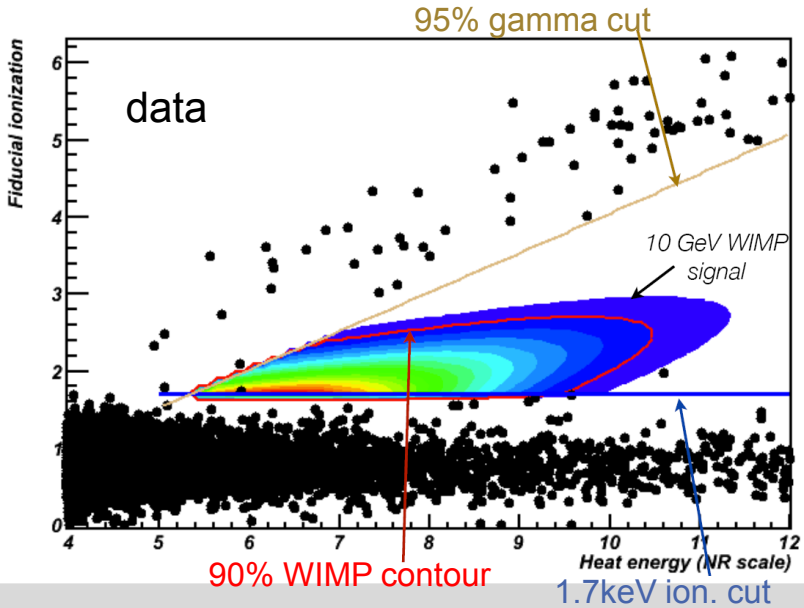
New detectors, new problems…

- The FID 800 g have leaking problems between some electrodes, for not well understood reasons (new supplier,lateral electrodes,high field at the side of electrodes..)
- *We are trying some solutions, more distance between electrodes,thicker insulation under electrodes…in progress.*
- A deep understanding of the charges path (*they are not following the electric field line, which give a new image of the fiducial volume*) was undertaken by A.Broniatowski at CSNSM.Theses studies are essential to have a clear picture of how a detector is working.

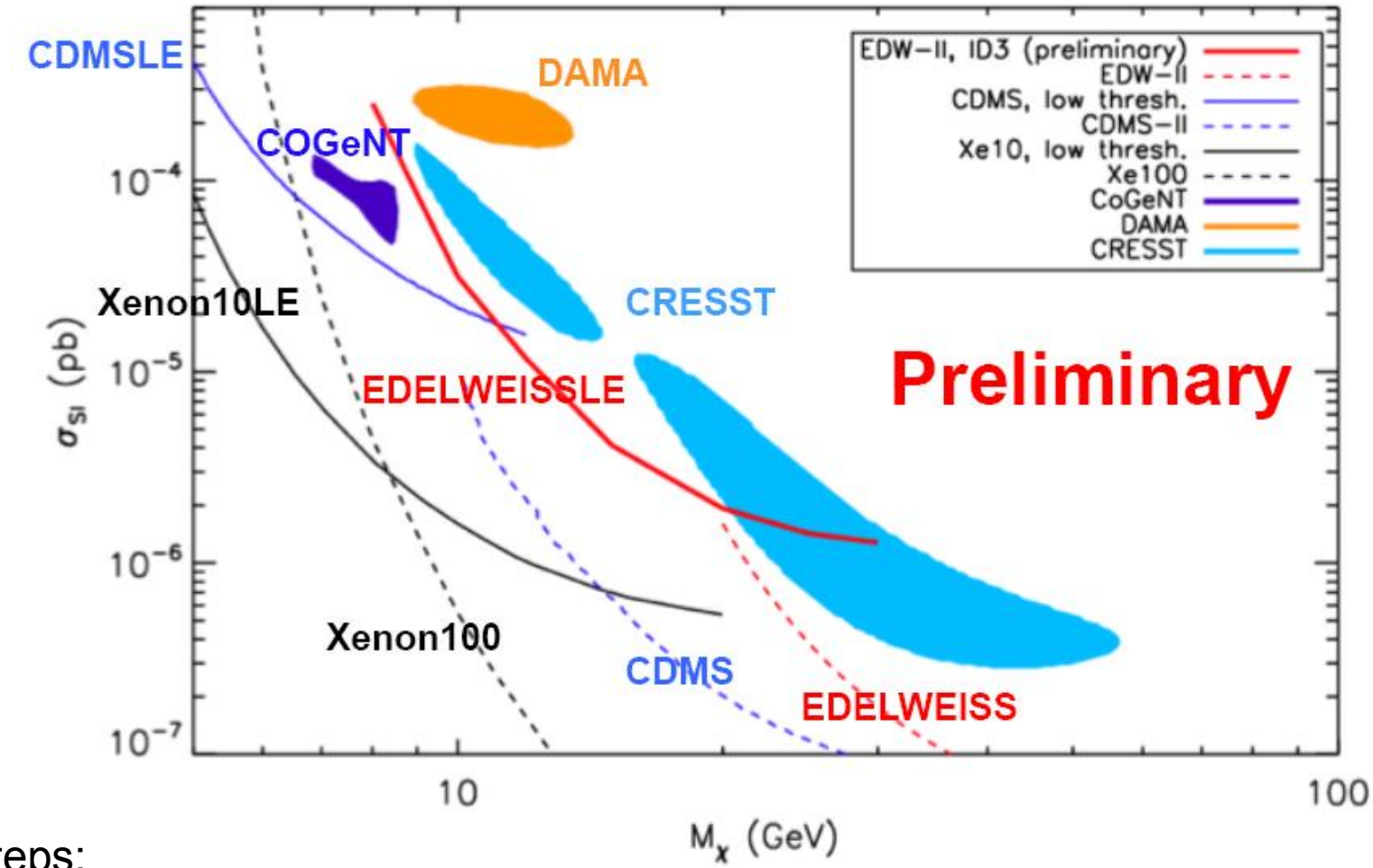
EDELWEISS-II
low-E investigation

- Choice of detector with best resolutions in heat and ionisation (ID3)
- Study fid-ionization vs Er (calculated from heat assuming all evts are NR) → **sensitivity down to 6 keV$_{nr}$**
- NR region contaminated by "heat only" evts and γ → cuts → data 198d ok, **31 kg.d**
- For each WIMP mass, count no. of events inside 90 % acceptance region
- Typically between **8 and 30 GeV**, data contain **1 to 3** events
- Expected background ~ 1
- No signal → consider all events as potential NR and set Poisson limits





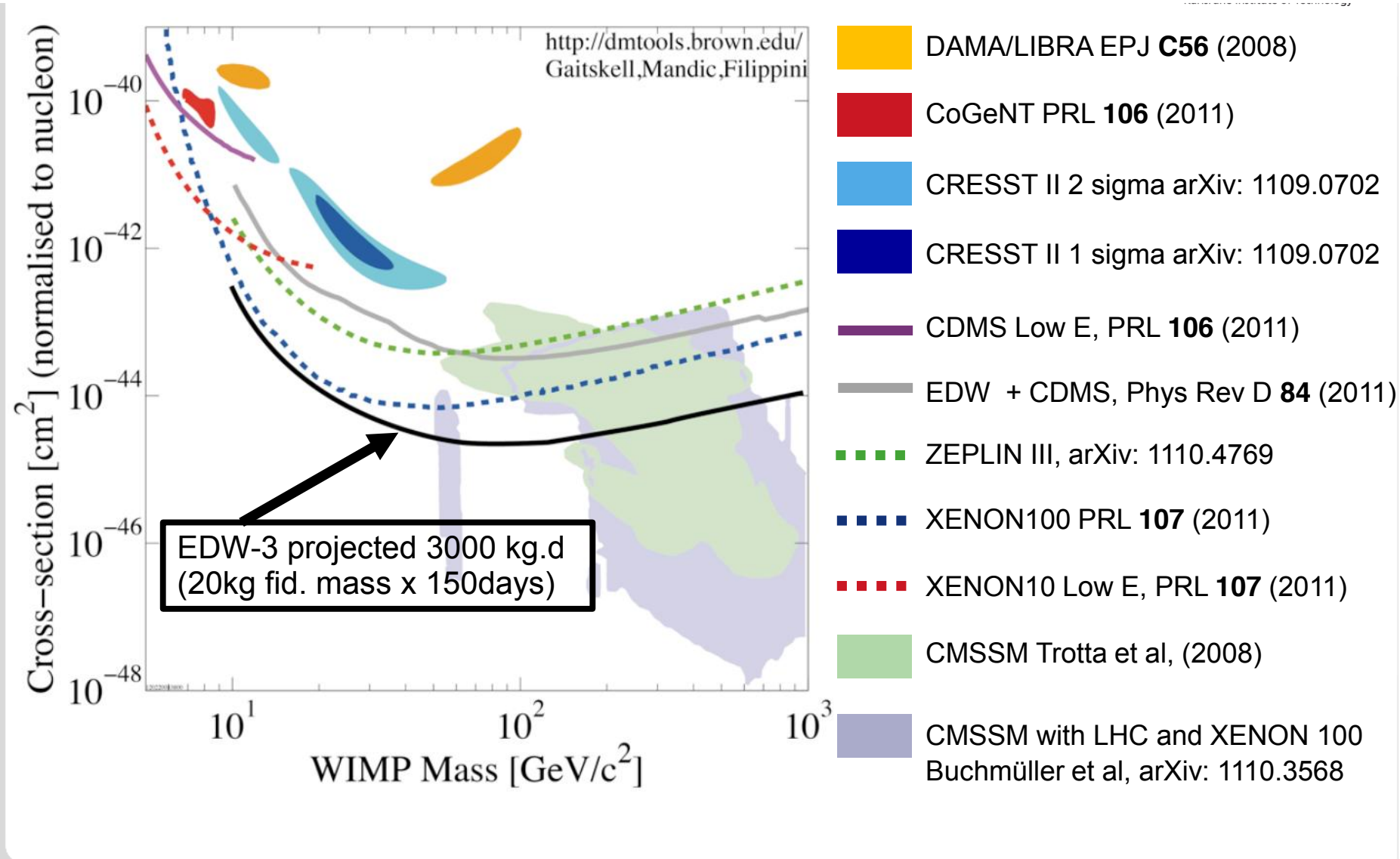
Low energy analysis



next steps:

- use other detectors
- R&D on sensors (ionisation and heat) → few 100eV threshold

Edelweiss III in …2014?

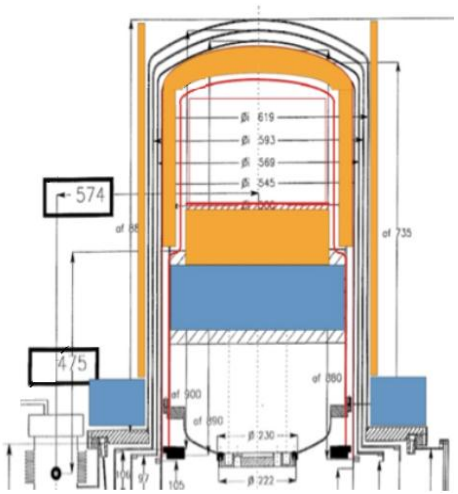


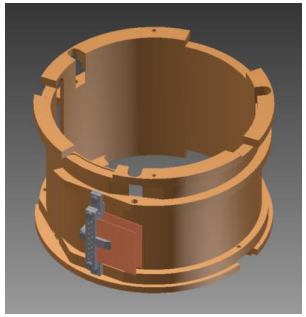
Futur

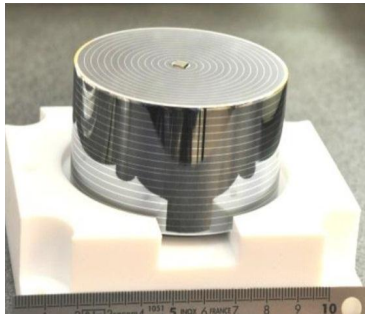
EDELWEISS III

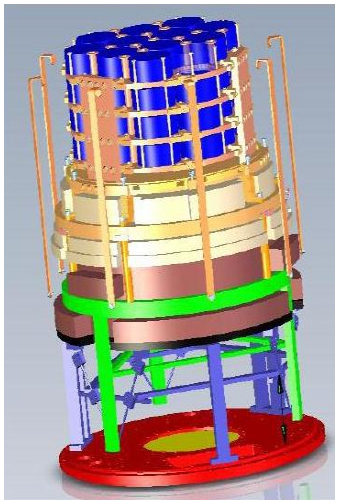
Increase detector mass
Decrease background

- Search for dark matter to 5×10^{-9}pb
- 40 FID-800 detectors installed 2012
- New Kapton cabling, connectors
- New cold electronics
- New cryostat design
- New internal PE shield
- New copper thermal shield









Other cryogenic dark matter searches

CDMS – Soudan mine, cryogenic phonon - ionization germanium detectors

Ongoing collaboration

Will join forces to build EURECA

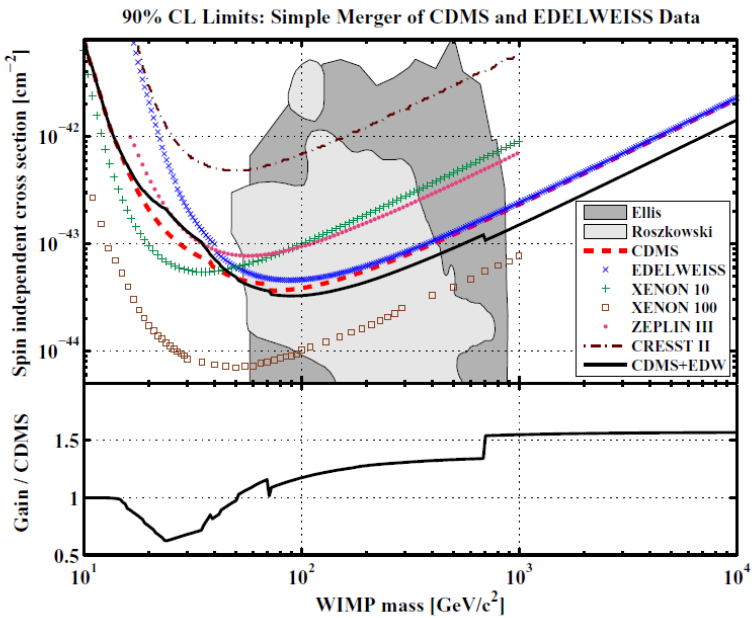
CRESST – Gran Sasso, cryogenic phonon – scintillation detectors ($CaWO_4$)

Cooperation

CDMS – EDELWEISS combined limit

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

- Combined data from germanium detectors 614kg days
- 3.3×10^{-8}pb excluded at 90GeV
- Improved limit for high mass WIMPs



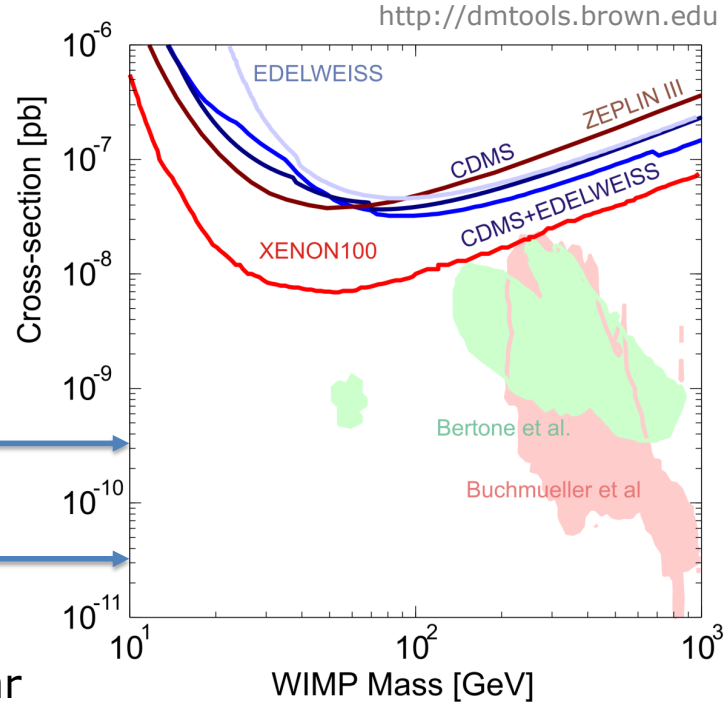
Cooperation , suite

- Exchange of information between CDMS and EDELWEISS/EURECA
- Cryogenie
- Low radioactivity
- More in the futur ? It depends also of the futur of the two stream, US and EU

European Underground Rare Event Calorimeter Array

EURECA phase I – 150kg
→ 3×10^{-10}pb

EURECA phase II – 1000kg
→ 3×10^{-11}pb



Signal ~1event/tonne/year

Need 1-tonne cryogenic detector, radiopure environment, excellent background discrimination

To test a dark matter signal: Multi-target detector

EURECA Collaboration

EDELWEISS + CRESST + ROSEBUD collaborations + new members

France
- CEA: IRFU, IRAMIS
- CNRS: CSNSM, IPNL, Institut NÉEL, IAS, ICMCB

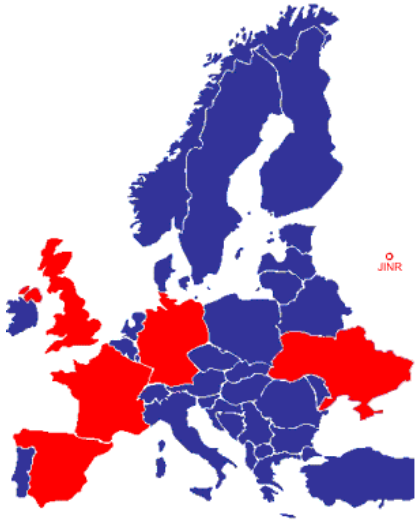
Germany
- MPI Munich
- TUM
- Universität Tübingen
- Karlsruhe Institute of Technology

Russia
- JINR Dubna

Spain
- Universidad de Zaragoza

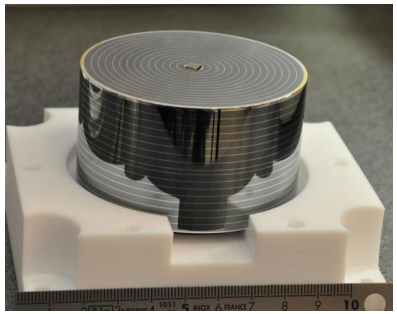
Ukraine
- INR Kiev

United Kingdom
- University of Oxford
- University of Sheffield



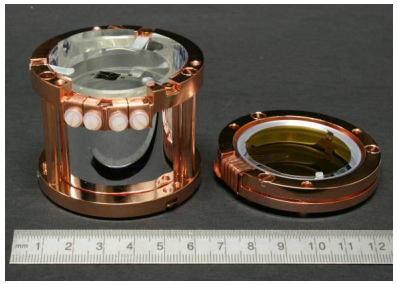
EURECA detectors – options:

EDELWEISS type: FID-800, 800g Ge phonon-ionization detectors with surface event rejection. NTD-Ge sensors

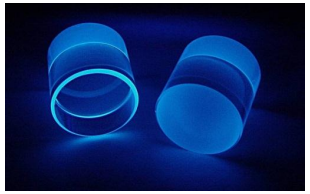


Further mass increase?

CRESST type: 300g $CaWO_4$ phonon-scintillation detectors. Tungsten TES sensors



New scintillator materials?



EURECA: 10^{-5} gamma rejection or better above 10keV threshold

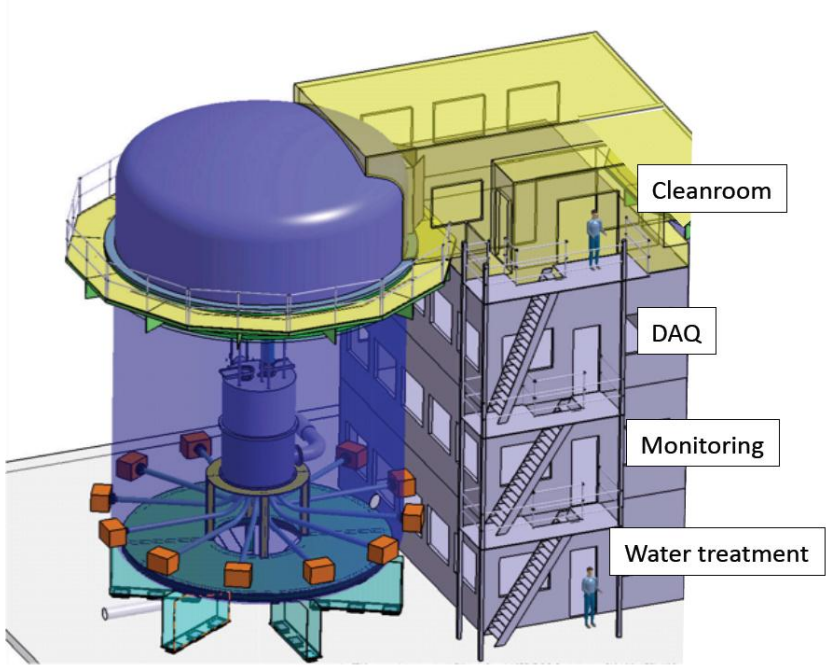
EURECA water tank

Passive shield

PMTs to detect Cherenkov light from cosmic muons

Veto events due to muon induced neutrons

Simulations: <0.3 NR events/year in 1012kg Ge



Radiopurity

LSM Ge detector lab

Screen materials using ultra low background HPGe detectors

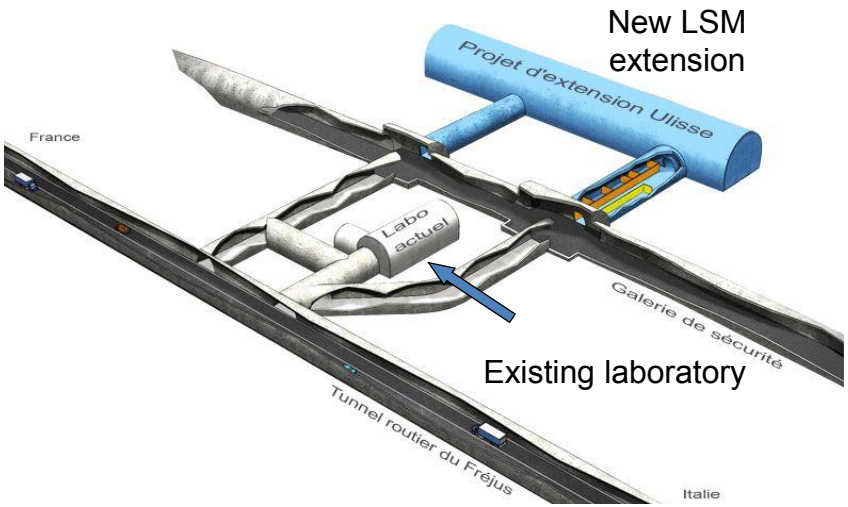
Store materials underground to minimise cosmogenic activation

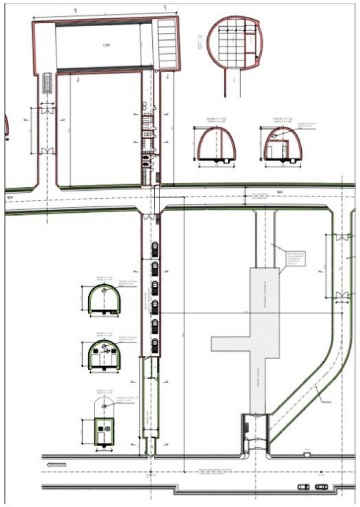
Clean surfaces to remove contamination

GEANT4 model → expected background event rates:

Source	Material	Mass kg	Contaminations U/Th, ppb	Gamma-rays events/kg/day/keV	Neutrons events/year
Screens, Cu parts	Cu	3000	0.005	0.005	0.03
Support rods	Cu-Ni alloy	100	0.1	0.002	0.5
Cables, 10 mK	Cu, Kapton	2	0.5	0.003	0.02
Holders	Kapton	0.2	1	0.0008	0.01
Holders	PTFE	0.5	0.1	0.0003	0.2
Screws	Cu, Zn	10	0.2	0.005	0.03
Electrodes	Al	0.0001	200	0.0002	0.05
Connectors	Cu, Delrin	1	1	0.0001	0.03
Cables	Cu, Kapton	5	0.5	0.0001	0.03
Neutron shielding	CH_2	500	0.1	0.001	0.4
Electronics (FET)	FR4	1	2000	0.002	0.03
Water shielding	Water	1 kt	0.001	0.001	0.003
Total				0.02	1.3

EURECA site:
Laboratoire Souterrain de Modane

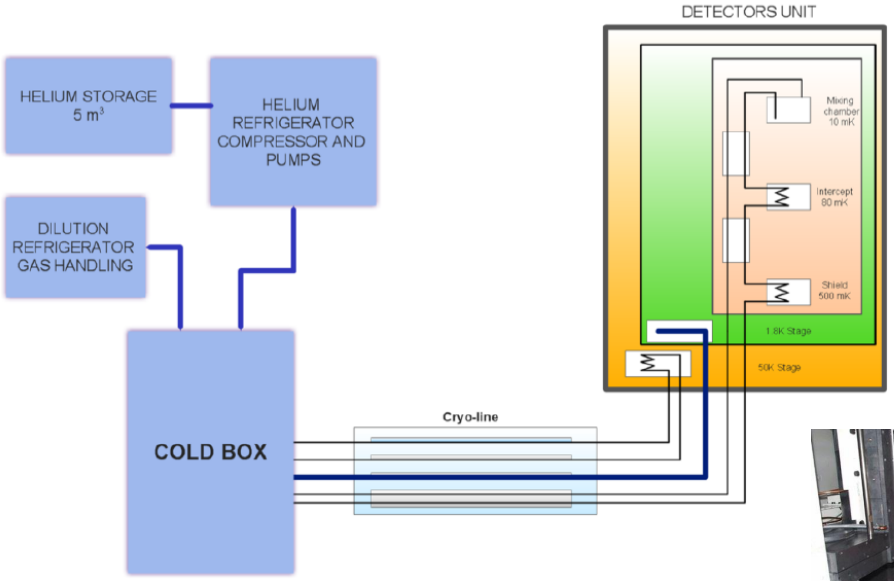




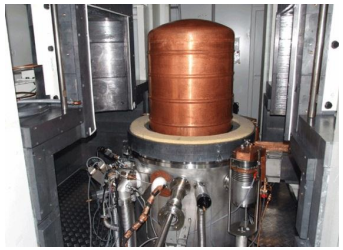
LSM
Laboratoire Souterrain de Modane

EURECA Cryostat

How to cool a 1-tonne detector to 10mK



Inside water tank – radiopure materials



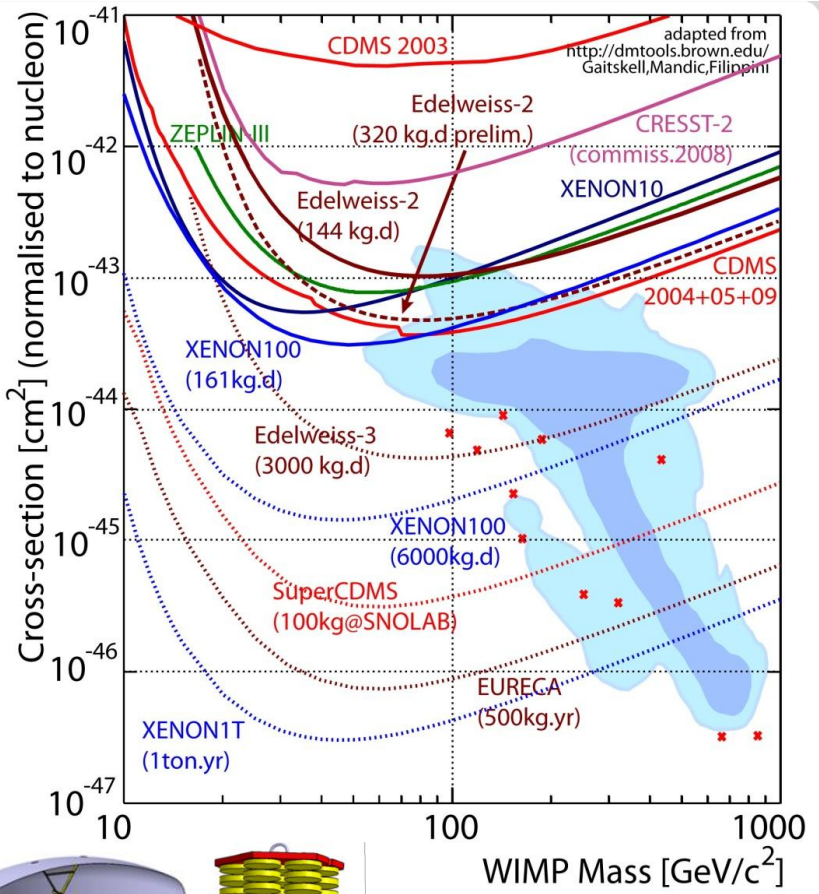
EDELWEISS cryostat

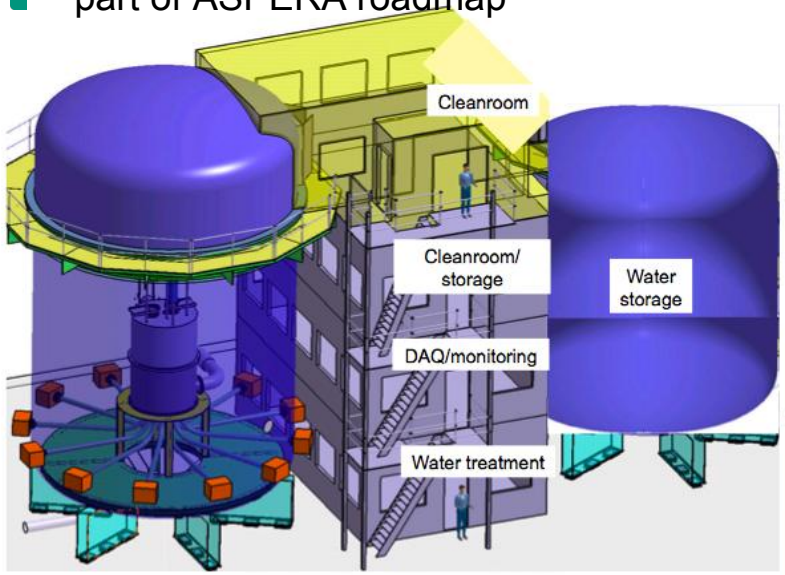
Summary

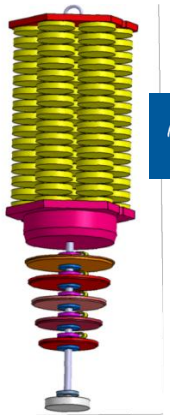
- Edelweiss-II: Direct WIMP search with cryogenic germanium detectors
- Interleaved electrodes allow surface event rejection
- Ten 400g Ge-ID detectors – 384 kg day
- 4.4×10^{-8}pb excluded for 85GeV WIMP
- Edelweiss+CDMS 3.3×10^{-8}pb
- Edelweiss-III: Aim: 5×10^{-9}pb, FID-800 detectors
- EURECA: Aim: 10^{-10}pb, next generation European cryogenic dark matter experiment

future: EURECA

- EURECA goal: 10^{-10} pb, 150kg → 1000kg, multi-target, bgd ~ 10^{-5} evts/(kg.d)
- EDW, CRESST, ROSEBUD, +others…
- coordinated cooperation with SuperCDMS (1st joint meeting Oct 7, 2011)
- CDR by summer 2012
- facility type (DM, 0nbb,...)
- part of ASPERA roadmap







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Alliance for Astroparticle Physics

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bmb+f - Förderschwerpunkt Astroteilchenphysik

Großgeräte der physikalischen Grundlagenforschung

A personal conclusion

- Running after the wind is a very healthy exercise

- *Qui vit sans folie n'est pas si sage qu'il croit (La Rochefoucault)*