Karlsruhe Institute of Technology

Edelweiss
Expérience pour DEtecter Les WIMPs En Site Souterrain

Latest results from the EDELWEISS Direct Dark Matter search

Klaus Eitel, Karlsruhe Institute of Technology, KCETA, IK

- DM search with Edelweiss-2
- Experimental set-up & new Ge detectors
- Published results & latest update
- Special muon&neutron investigations
- Future: Edelweiss-3 & EURECA

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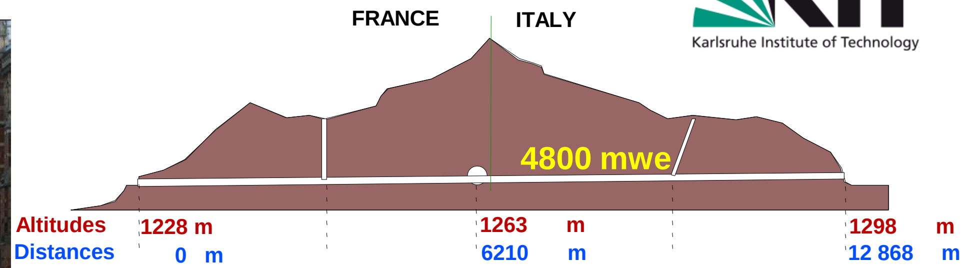
Latest res

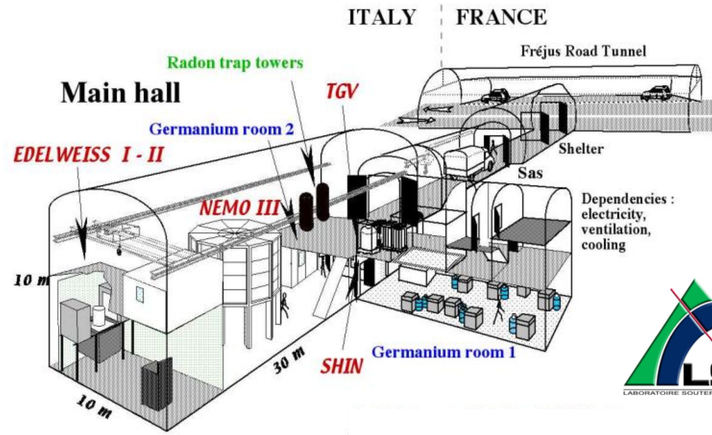
Direc

Klaus Eitel, Karlsruhe Institute of Technology, K

- DM search with Ede
- Experimental set-u
- Published results &
- Special muon&neu
- Future: Edelweiss-3

The EDELWEISS Collaboration





• CEA Saclay (IRFU & IRAMIS)	• Detectors, electronics, aquistion, data handling, analysis
• CSNSM Orsay	• Detectors, cabling, cryogenics
• IPN Lyon	• Electronics, cabling, low radioactivity, analysis, detectors, cryo
• Institut Néel Grenoble	• Cryogenics, electronics
• KIT: IK, IEKP +IPE (2010) Karlsruhe	• Vetos, neutron detector, background, analysis, electronics
• JINR Dubna	• Background, neutron, radon monitors
• Oxford University (since 2009)	• Detectors, cabling, cryogenics, analysis
• Sheffield University (since 2010)	• MC simulations

DM search with Edelweiss Ge bolometers

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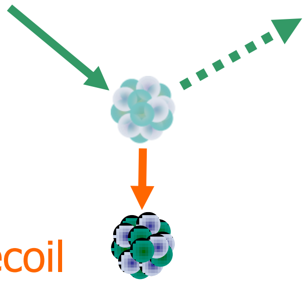
❖ **Direct detection of WIMPs** (Weakly Interacting Massive Particles)**:**

WIMP — Scatt. WIMP



Recoil nucleus → E_R ~10 keV

Count rate:

< 10^{-2} evt/kg/day!

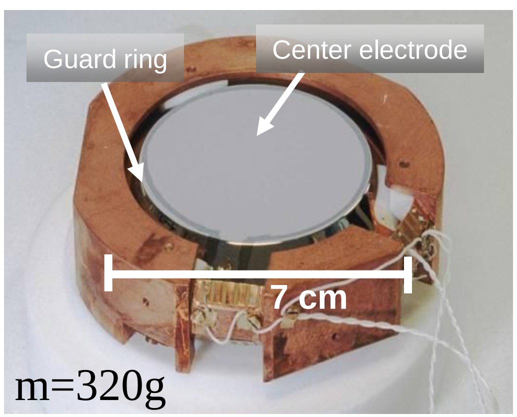
Challenges to overcome:

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

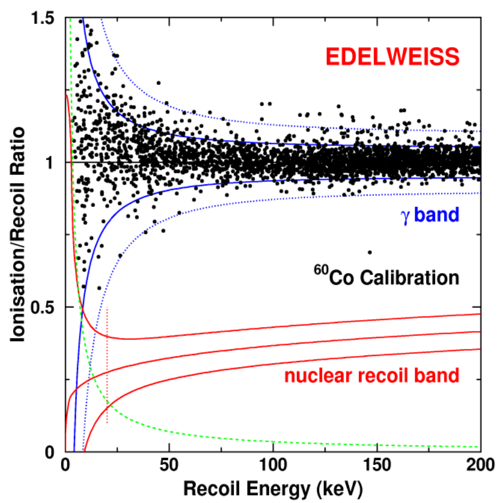
Way to go:

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

❖ **EDW:** bolometers of pure natural **Ge** @LSM (4800 mwe):



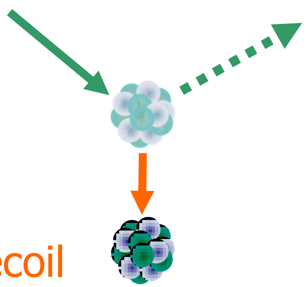
Ge/NTD



- **Simultaneous measurement**
  - **Heat** @ 17 mK with Ge/NTD thermometer
  - **Ionization** @ few V/cm with Al electrodes
- **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**

DM search with Edelweiss Ge bolometers

❖ **Direct detection of WIMPs** (Weakly Interacting Massive Particles)**:**



Count rate:

< 10^{-2} evt/kg/day!

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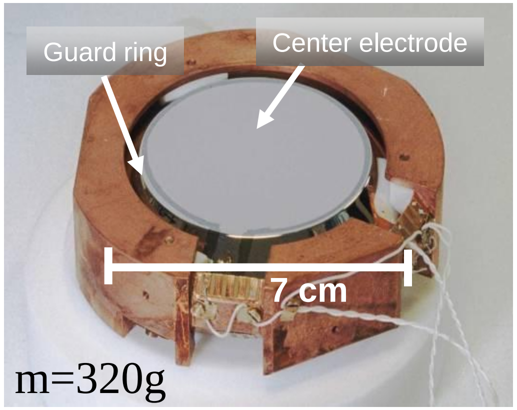
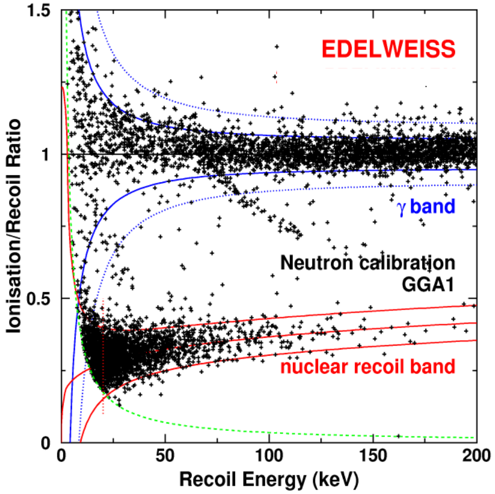


Ge/NTD



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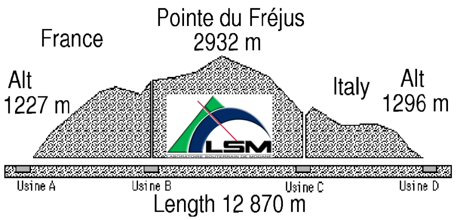
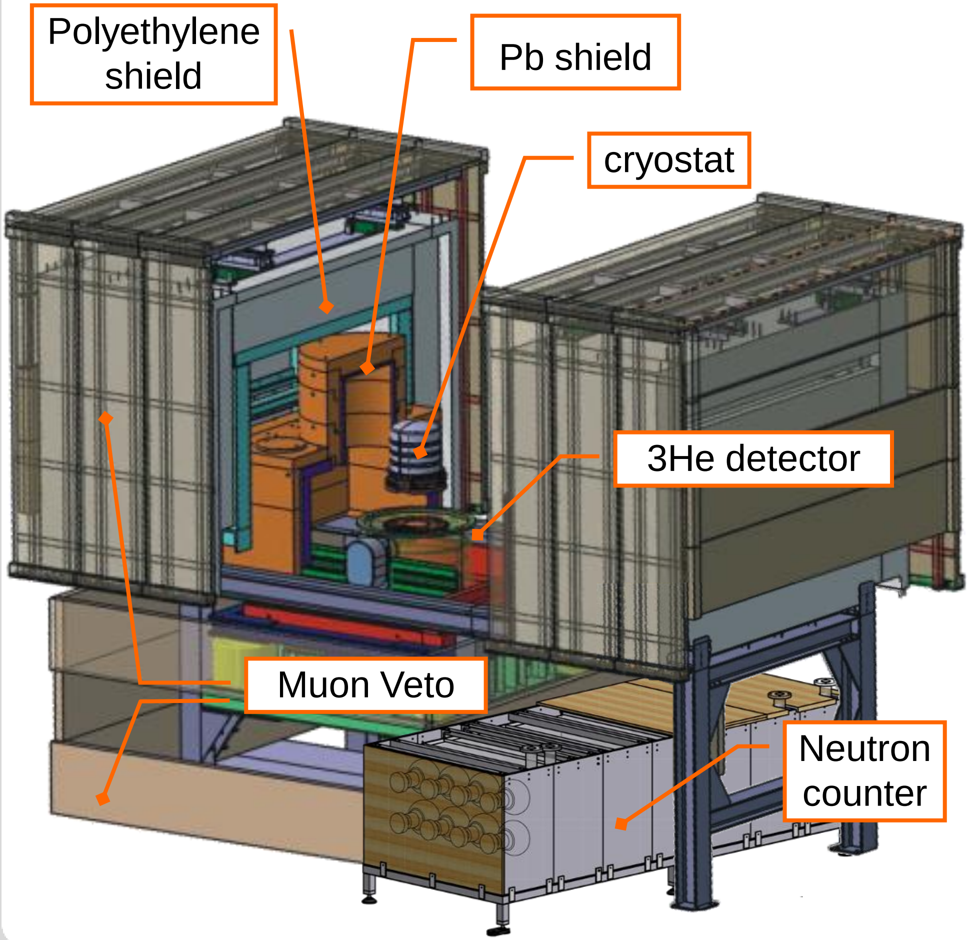
EDW-2 (3) experimental set-up



Shielding: ~ **4800 mwe**

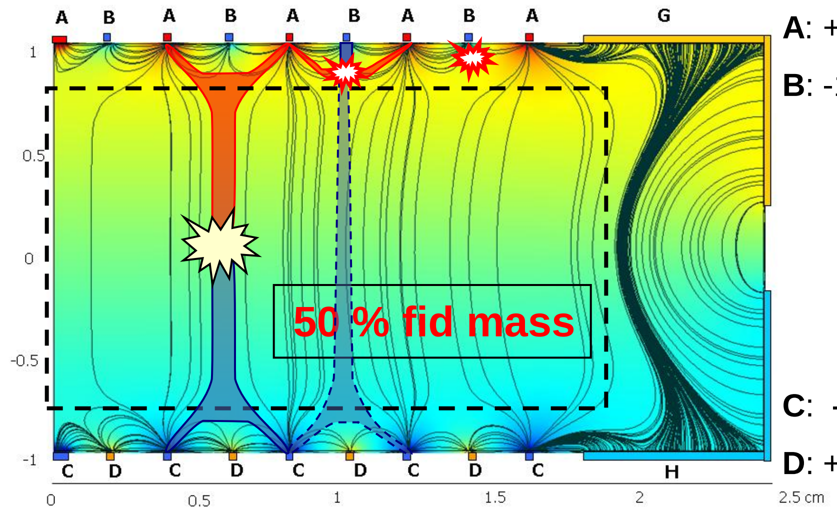
μ-flux: ~ **4-5 / m² / day**

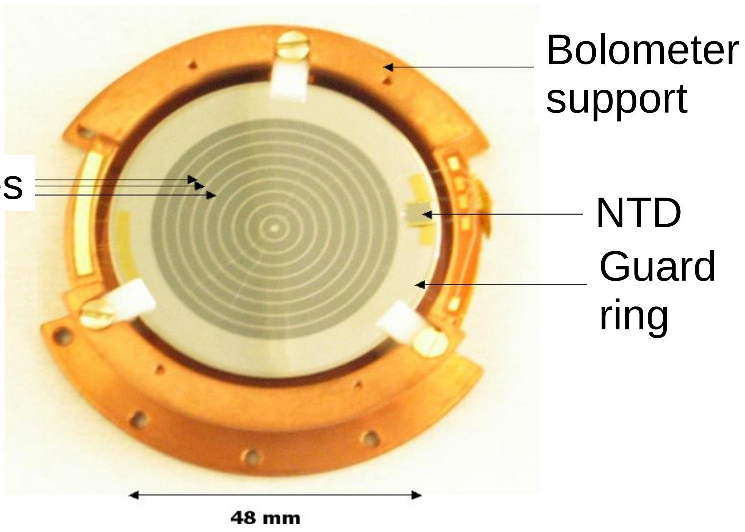


- **Goal** $\sigma_{\chi\text{-}n} = 5\cdot10^{-9}$ **pb**
- Cryogenic installation (18 mK) :
  - Reversed geometry cryostat, pulse tubes
  - Remotely controlled
  - **Can host up to 40 kg of detectors**
- Shieldings :
  - Clean room + deradonized air
  - Active muon veto (>98% coverage)
  - **PE** shield **50 cm**
  - **Lead** shield **20 cm**

  ⇒ **γ background reduced by ~3 wrt EDW-1**
- (Many) others :
  - Remotely controlled sources for calibrations + regenerations
  - Detector storage & repair within the clean room
  - Radon detector down to few mBq/m^3
  - thermal neutron monitoring (^{3}He det.)
  - study of muon induced neutrons (liquid scintillator 1 m^3 neutron counter)
- 12 cool-downs operated since 2006

ID-detectors with annular ring electrodes





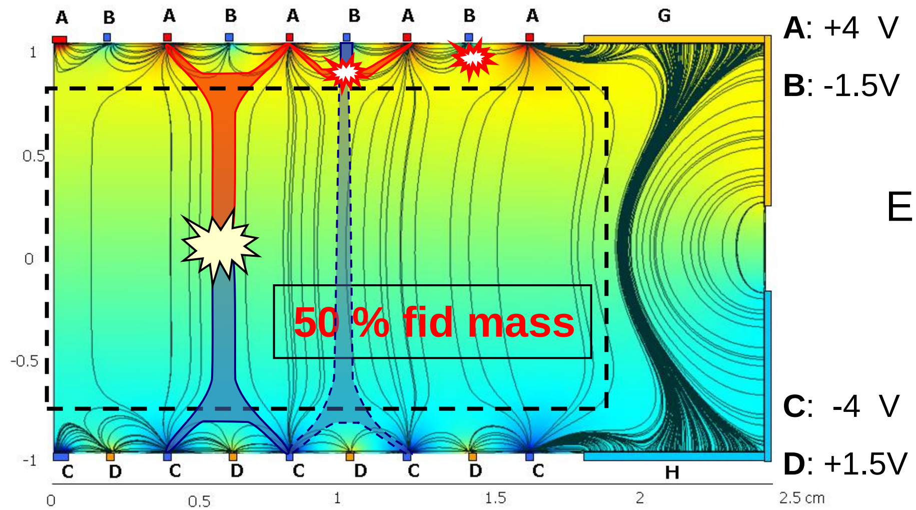
InterDigitized electrodes (**ID**):

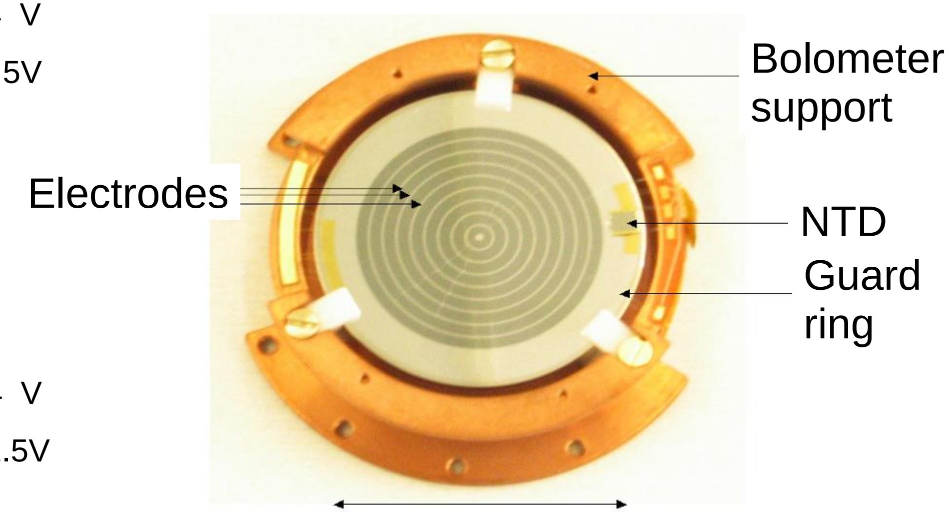
- Keep the EDW-I NTD thermal sensor
- Modify the E-field near the surfaces with interleaved electrodes
- Use 'a' and 'c' signals as 'collection' electrodes and 'b' and 'd' signals as vetos against surface events

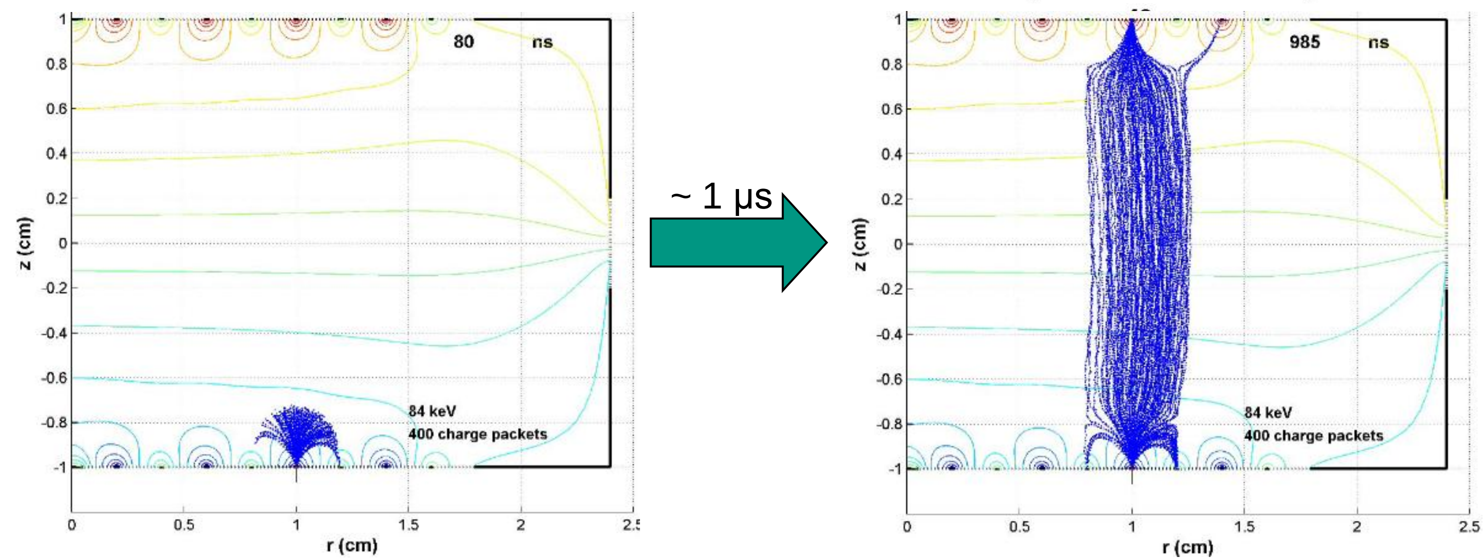
- 1 x 200g installed Nov. 2007, 1x200g + 3x400g tested in 2008;
- since Jan. 2009: 10 IDs are running (Run 12);

Phys Lett B 681 (2009) 305-309 (arXiv:0905.0753)

ID-detectors with annular ring electrodes







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Simulation : interaction under a collecting electrode

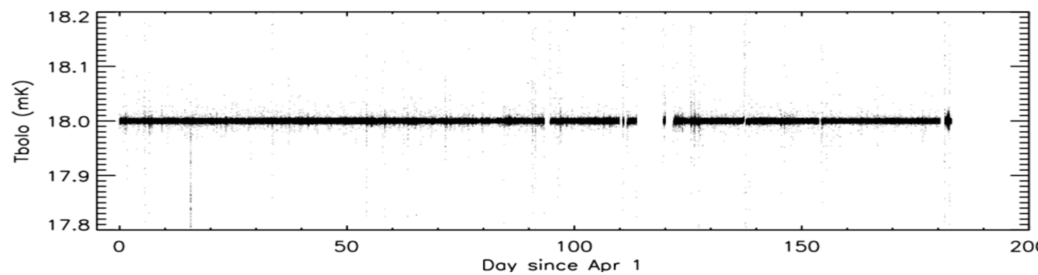
(no anisotropy effect taken into account)

WIMP search with ID detectors : «run 12»

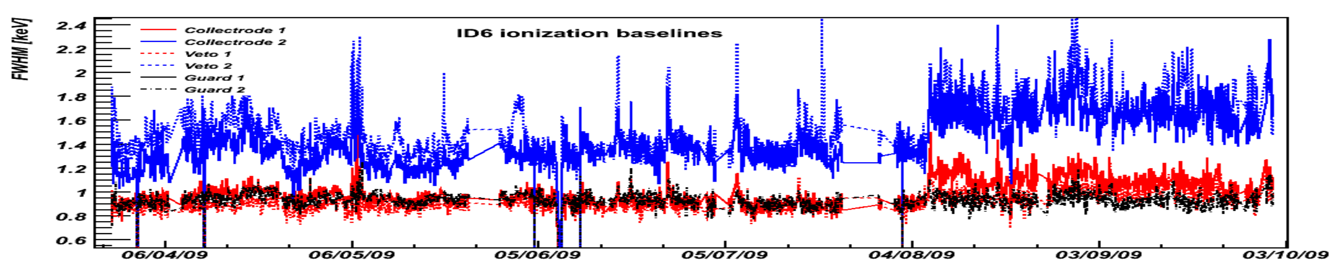
Data collected from April 1st 2009 to May 20th 2010

- 418 d total
- 322 d data (77% of 418)
- 305 d WIMP search (73% of 418)
- All detectors working
- 90% electronics channels ok
- 9/10 bolometers for physics
- 8 d gamma calib
- 5 d neutron calib
- 4,5 d «other»

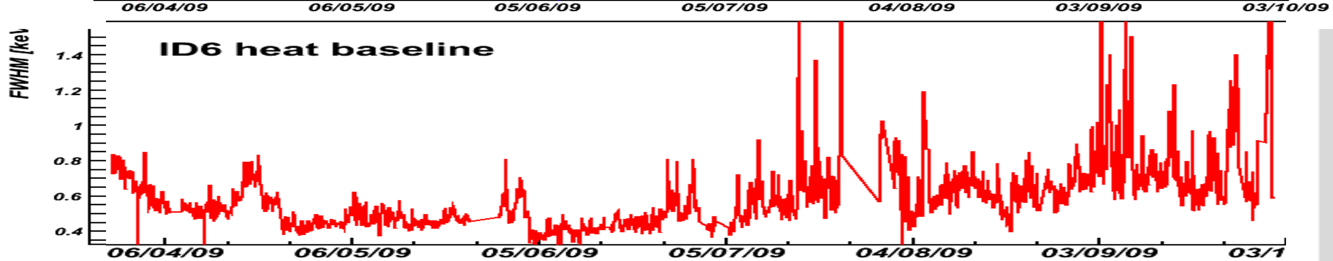
« One of the coldest place in the Universe » … Continuously at 18 mK during more than 1 year !



Ionization baseline



Heat baseline



Data analysis for first 6 months (Apr-Sep'09)

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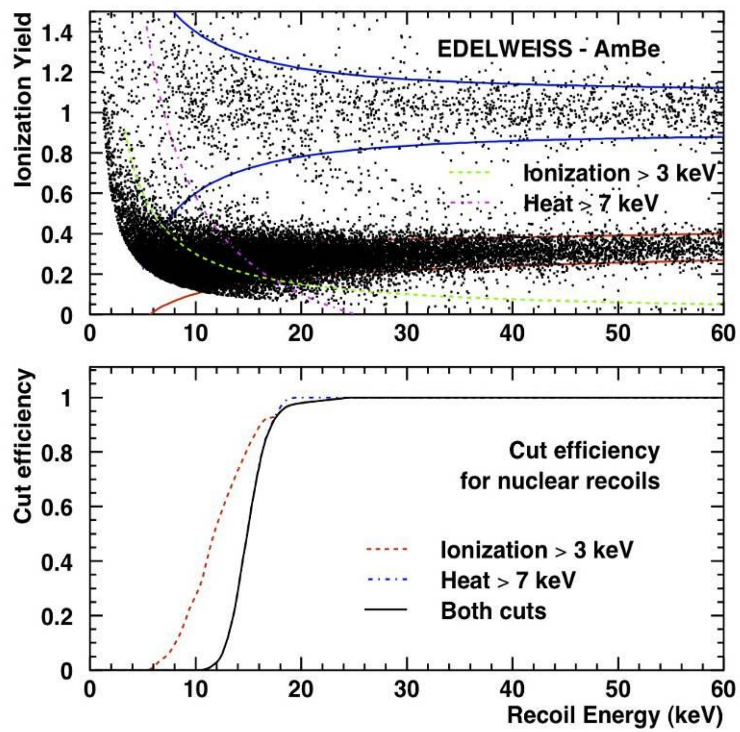
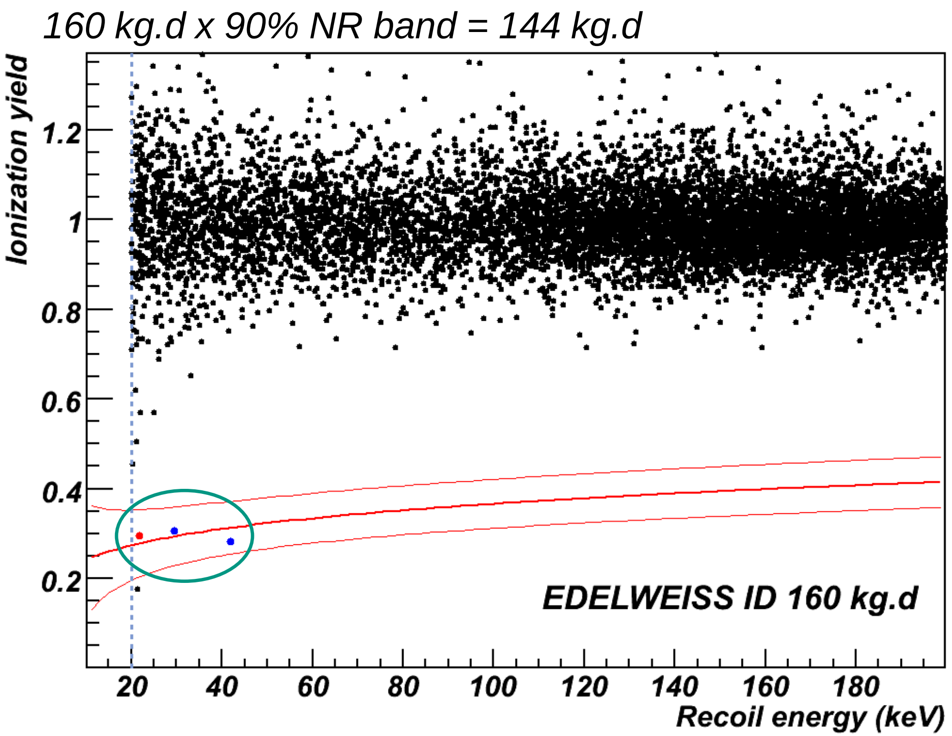
- 2 independent processing pipelines
- 9 out of 10 detectors are accepted
  (heat + coll.elect + 3/4 vetos&guards)
  10th detector → 1 veto & 1 guard are off
- Pulse fits with optimal filtering using instantaneous noise spectra
- Period selection based on *baseline noises*
  - **80% efficiency**
- Pulse reconstruction quality (χ^2)
  - ε = 97%
- Fiducial cuts based on ionization signals (→160g/det)
- ε = 90% nuclear recoil, gamma rejection 99.99%
- Bolo-bolo & bolo-veto coincidence rejection (ε>99%)
- WIMP search threshold fixed a priori *Erecoil > 20 keV*
  - 20 keV recoil far from efficiency thresholds
    (full efficiency achieved with ~3 keV ionization and ~7 keV heat thresholds):
    robust results independent of analysis details
- Agreement between the results of the two analyses

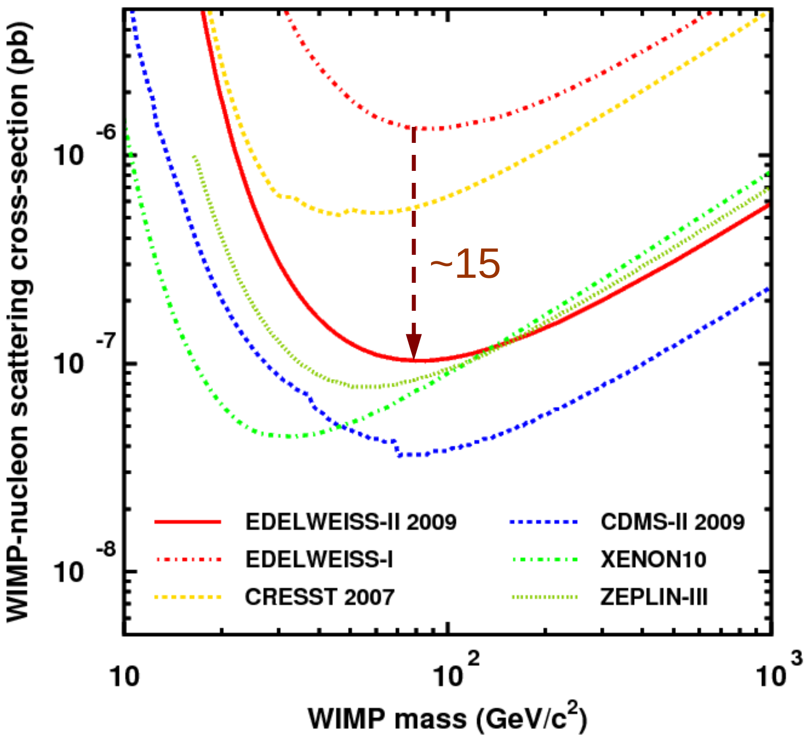
All detectors – neutron calibration



Phys Lett B 687 (2010) 294
(arXiv:0912.0805)

WIMP search : first result (1st 6 months)





Phys Lett B 687 (2010) 294
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WIMP search : first result (1st 6 months)

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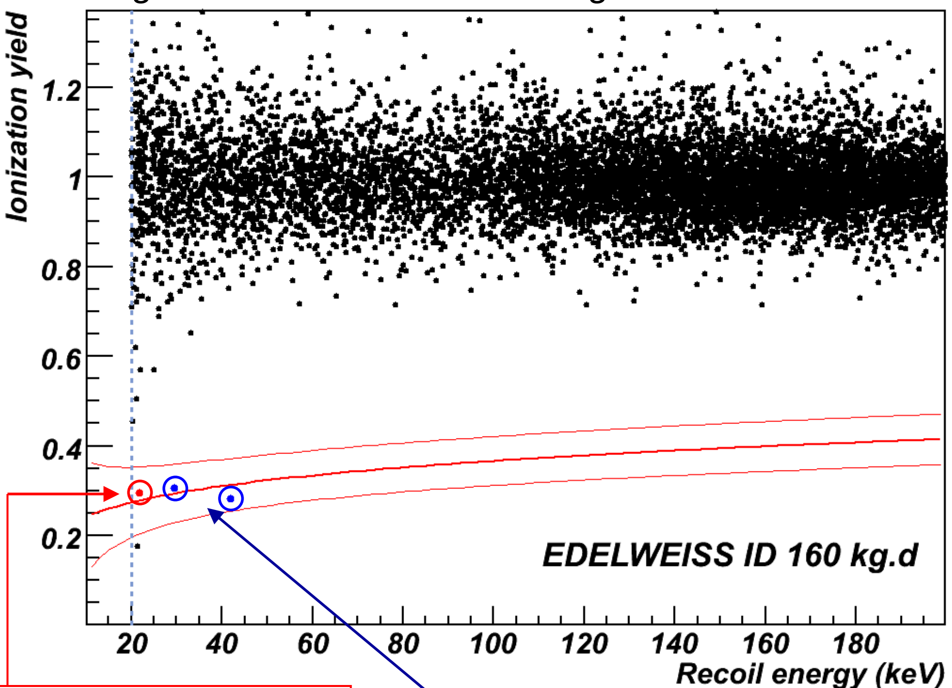
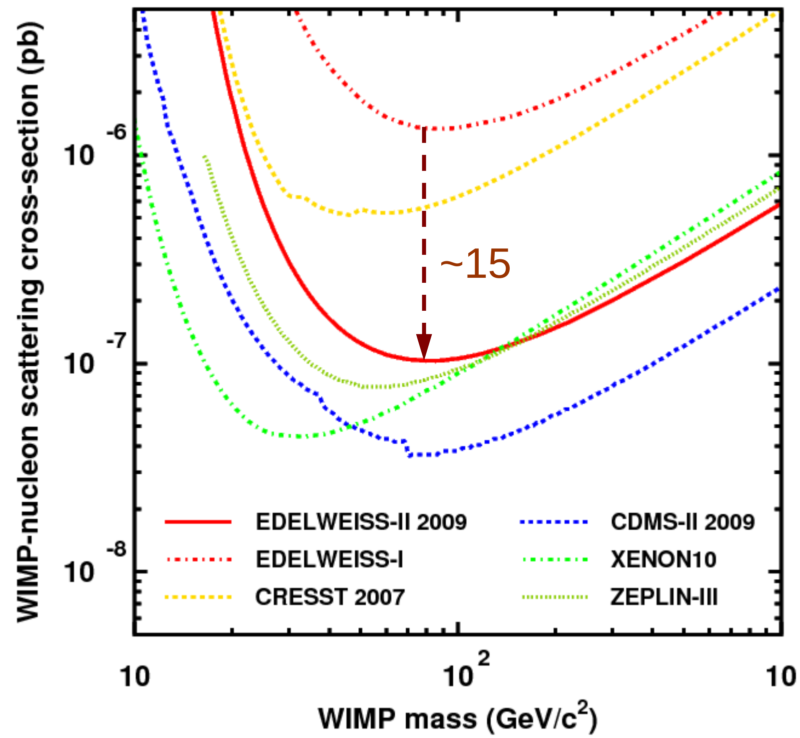
160 kg.d x 90% NR band = 144 kg.d





« WIMP candidate »
E_{recoil} = 21 keV

coincidences bolo-bolo+veto => muon-induced neutrons in fiducial volume

Phys Lett B 687 (2010) 294
(arXiv:0912.0805)

Background estimation (work in progress!):

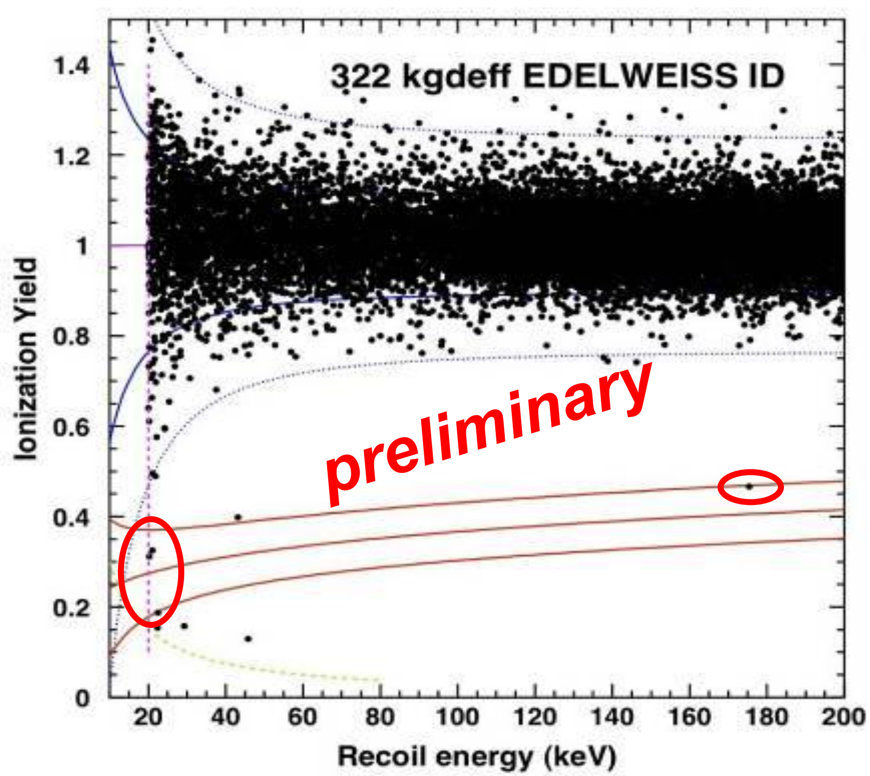
First estimation *from previous calibrations/simulations*

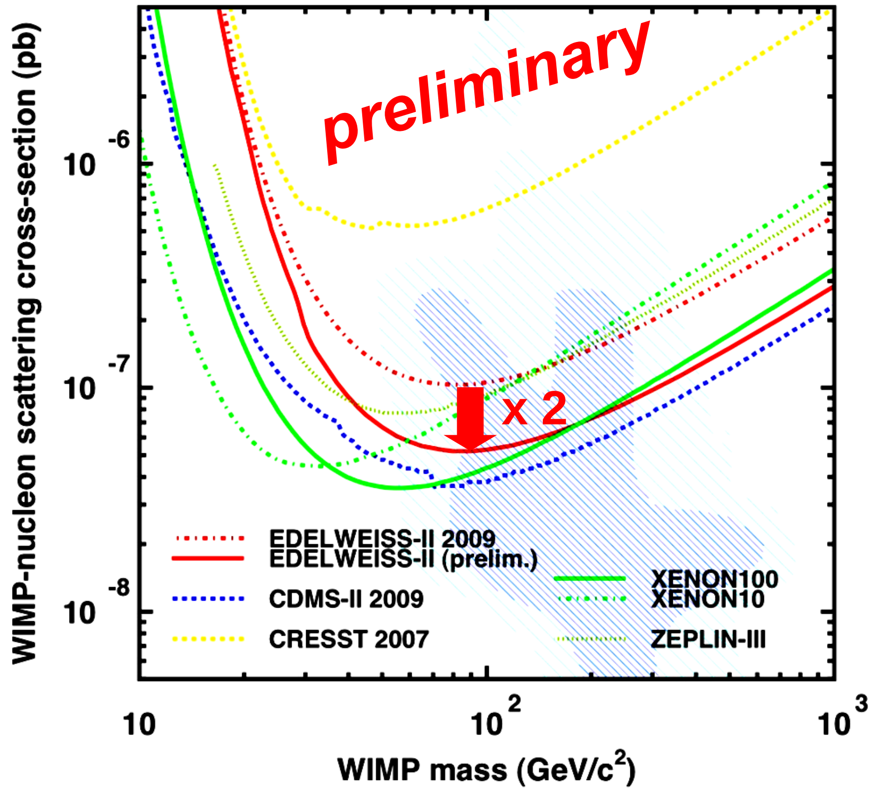
- gamma < 0.01 evt (99.99% rejection)
- beta ~ 0.06 evt (from ID201 calibration+obs. surf. evts)
- neutrons from ^{238}U in lead < 0.1 evt
- neutrons from $^{238}U+(\alpha,n)$ in rock ~ 0.03 evt
- neutrons from muons < 0.04 evt

< 0.23 evt

$P_{bkg}(1)$ = 21%

WIMP search : latest results (data up to May 20, 2010)





Preliminary result :

1^{st} analysis with same cuts as first 6 months, 2^{nd} analysis is ongoing

=> Increase in the sensitivity by factor of 2 (scales with statistics)

NR band: 3 events near threshold + 1 event @ 175 keV

Best limit 5.10^{-8} pb at M(WIMP)=80 GeV, BUT *background starts to appear ?*

Background sources (full Run)

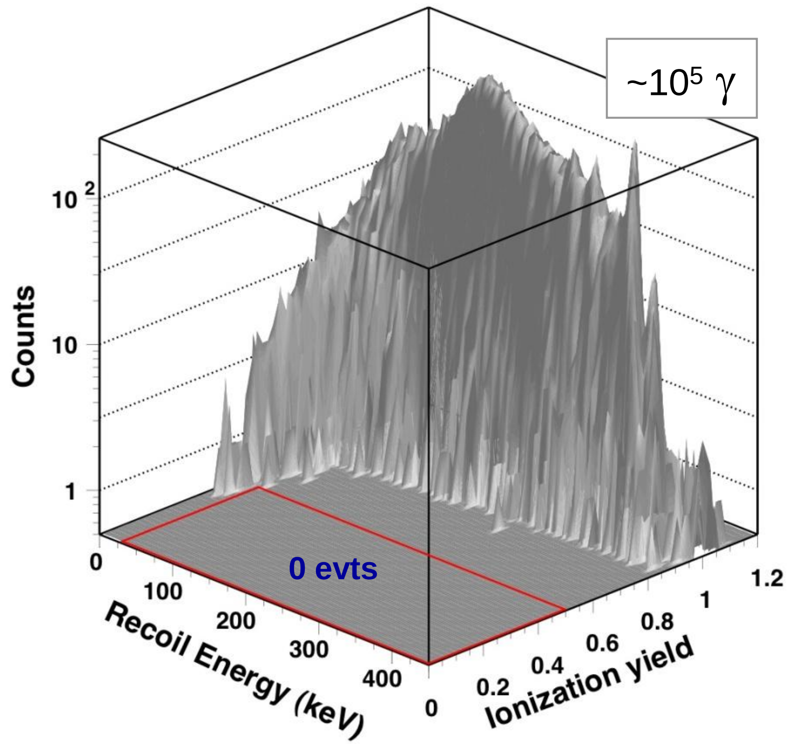
- *Gamma*: ^{133}Ba calib rejection x observed bulk γ < 1.0
- *Beta*: β source rejection x observed surface evts < 0.2
- *Neutrons from* μ's: μ veto efficiency x observed muons < 0.25
- *Neutrons from Pb*: measured U limits x Monte Carlo simul. < 0.1
- *Neutrons from rock*: measured neutron flux x Monte Carlo simul. < 0.1
  MC cross-checked w/ AmBe source outside shields

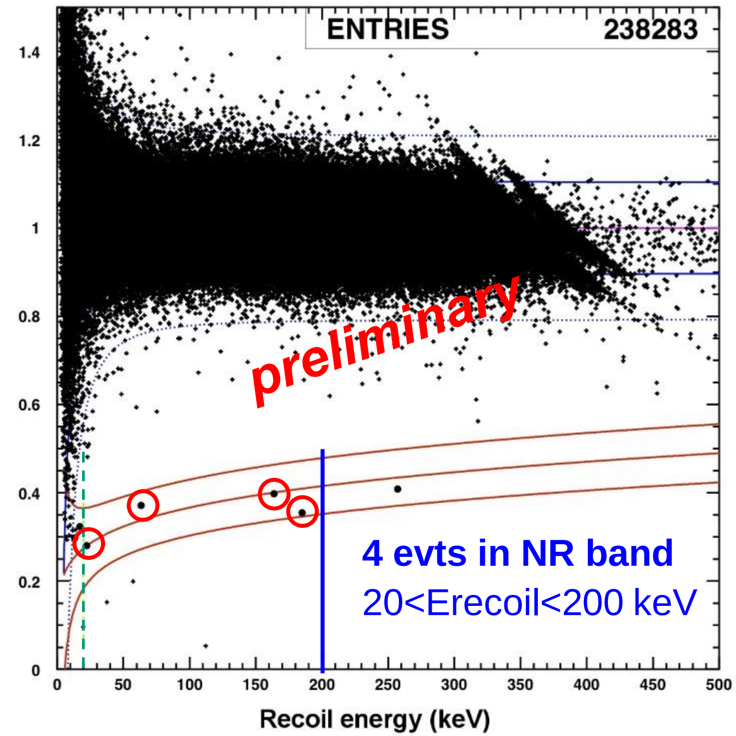
SUM (background) < 1.6 for the whole WIMP run (90% CL)
while 4 events are observed in WIMP run

=> Further investigation of the backgrounds and detector performance (calibration)

Gamma calibrations with ^{133}Ba: status

Phys Lett B 681 (2009) 305-309 (arXiv:0905.0753)





2 bolos, Gaussian behaviour, no cand event

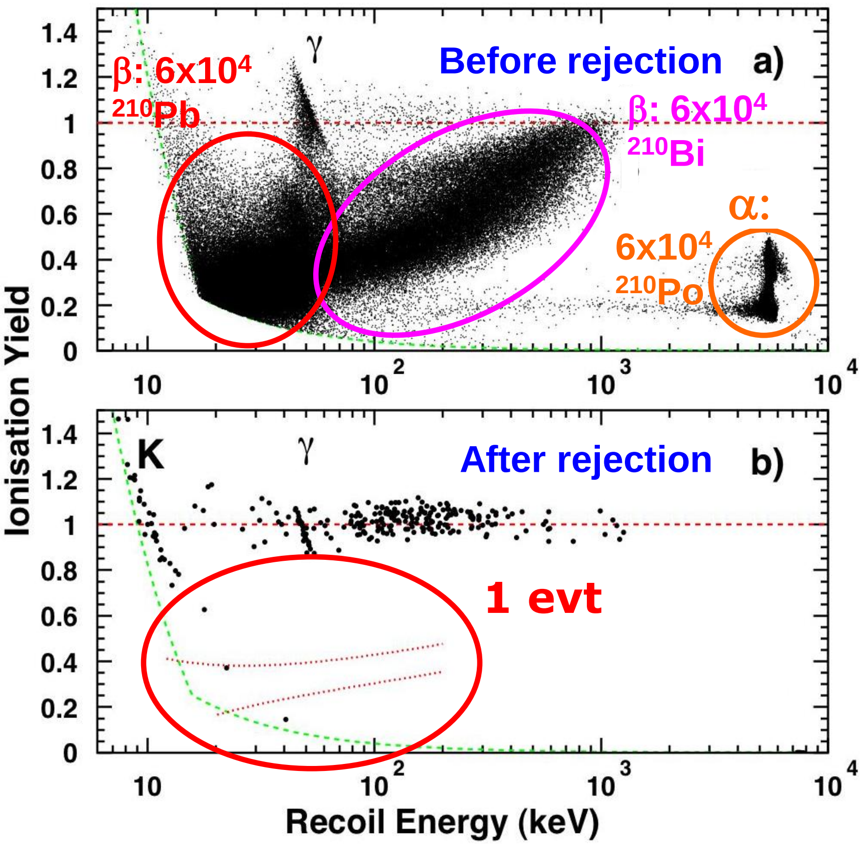
Stat x 2.4, all 10 detectors, 4 evts

- ^{133}Ba calib: 4 evts in 134 000 evts in 20-200 keV =>
  <1 evt expected in 16 600 evts in WIMP run (90% CL)
- Knobs to understand / improve:
  - Recombination e-h : optimise operation of polarization voltages, regeneration procedures
  - Pile up (high rates for γ calib!), multisite events : fast readouts on heat and ionization
  - 2 NTD heat measurements, segmentation

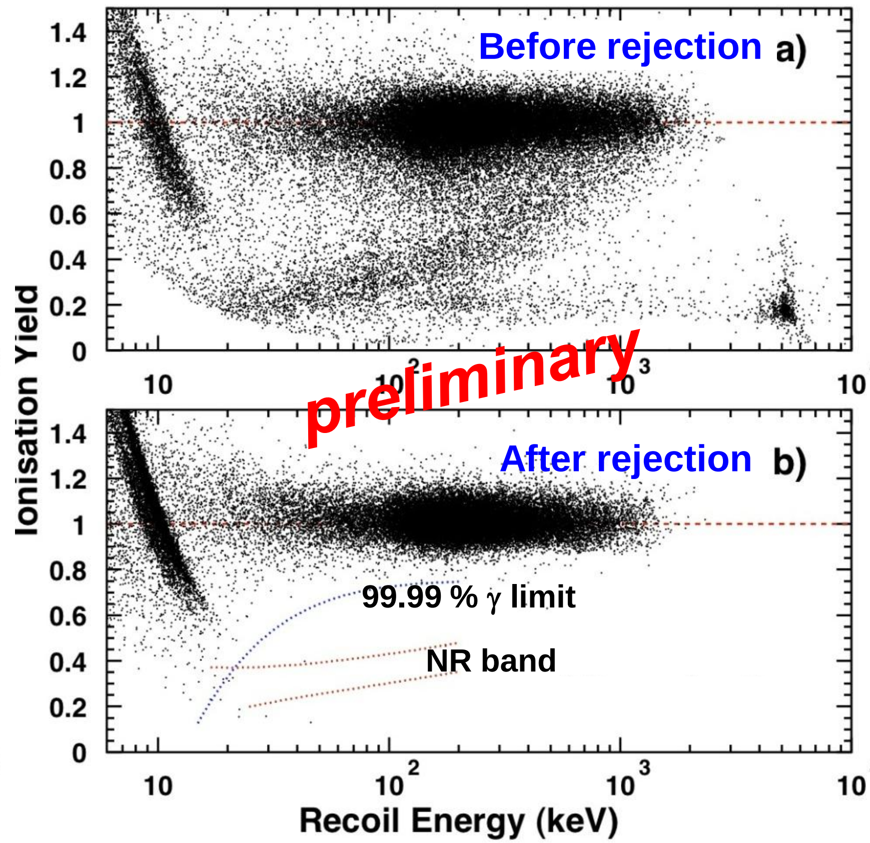
Beta calibrations & backgrounds

Phys Lett B 681 (2009) 305-309 (arXiv:0905.0753)

^{210}Pb calibration

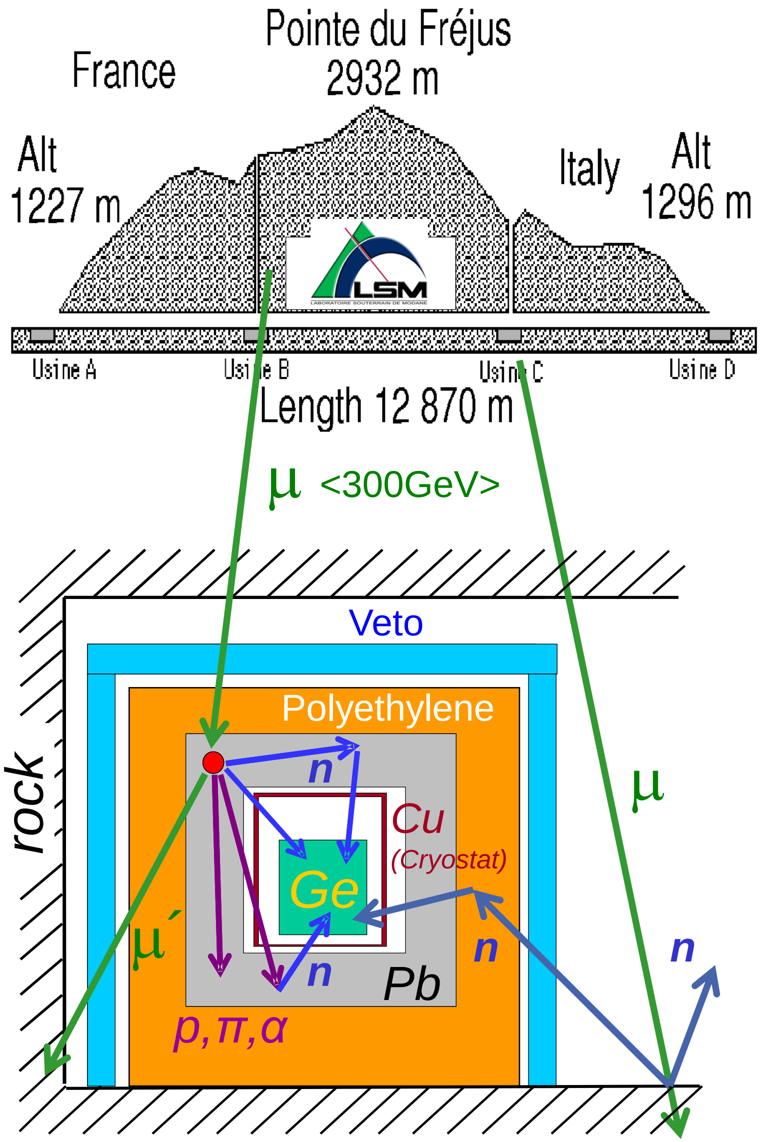


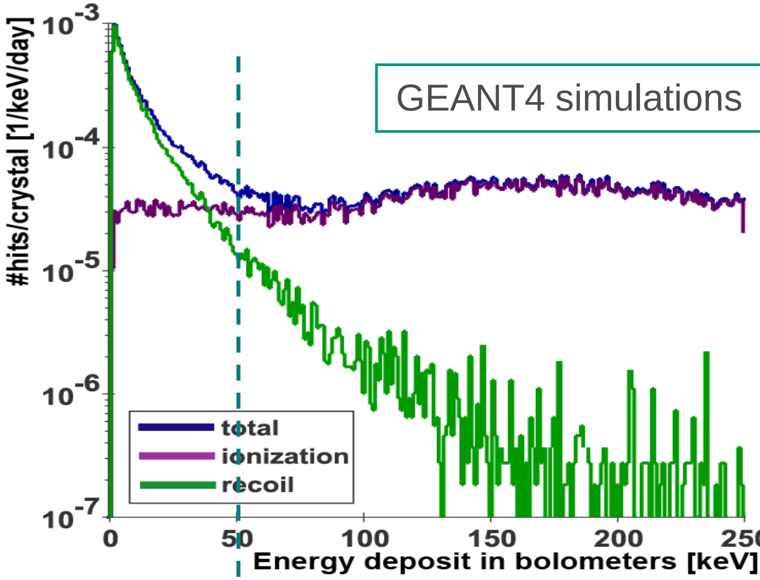
Data for WIMP search

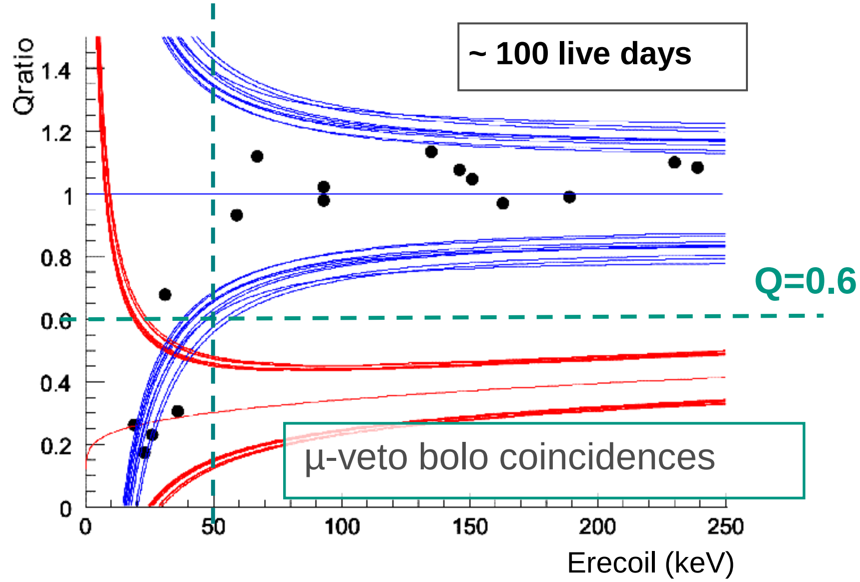


- Identified surface events in WIMP data: < 0.2 evt expected after rejection
- Knobs to improve: - change surface treatment
  - better energy resolutions

Investigation of μ-induced background







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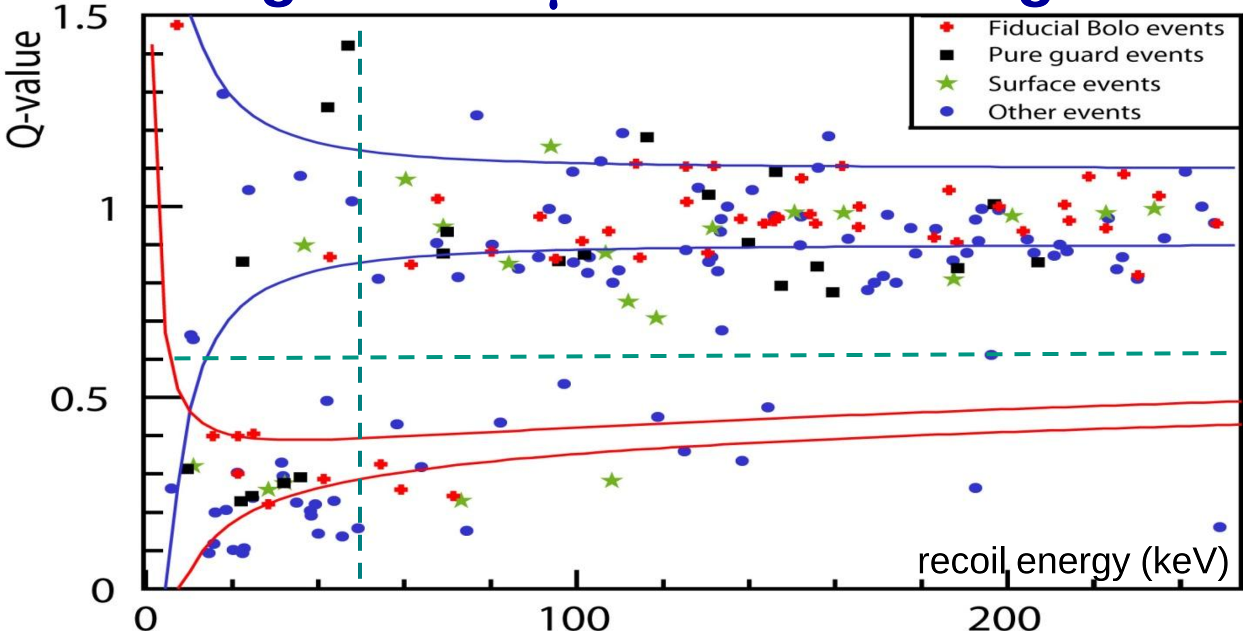
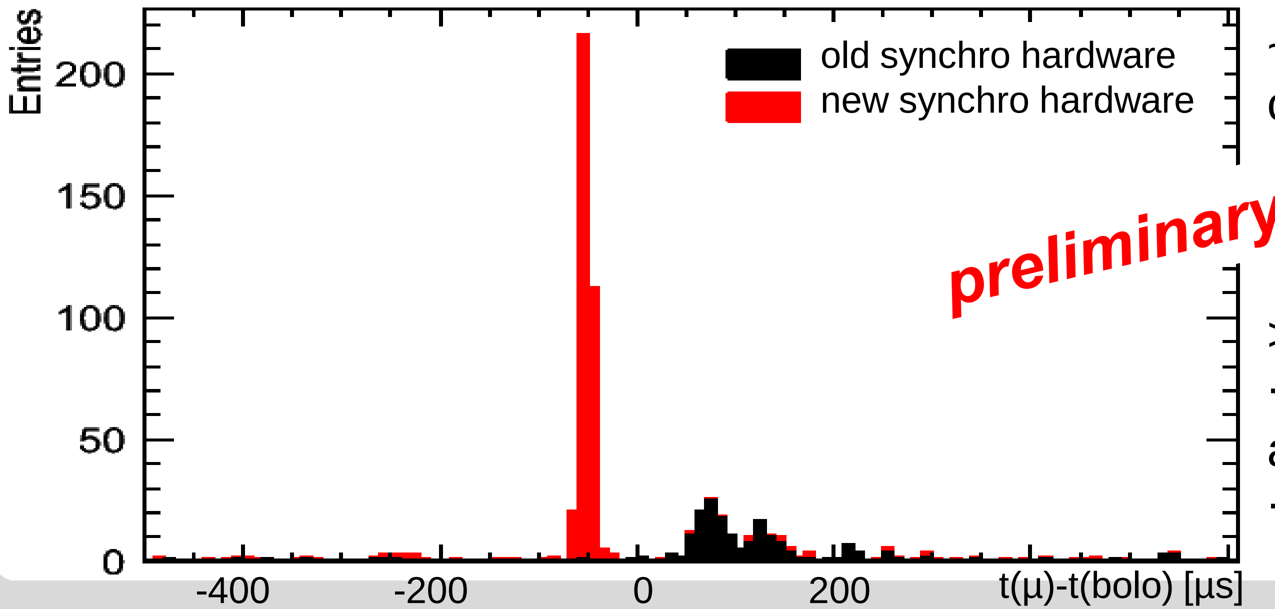




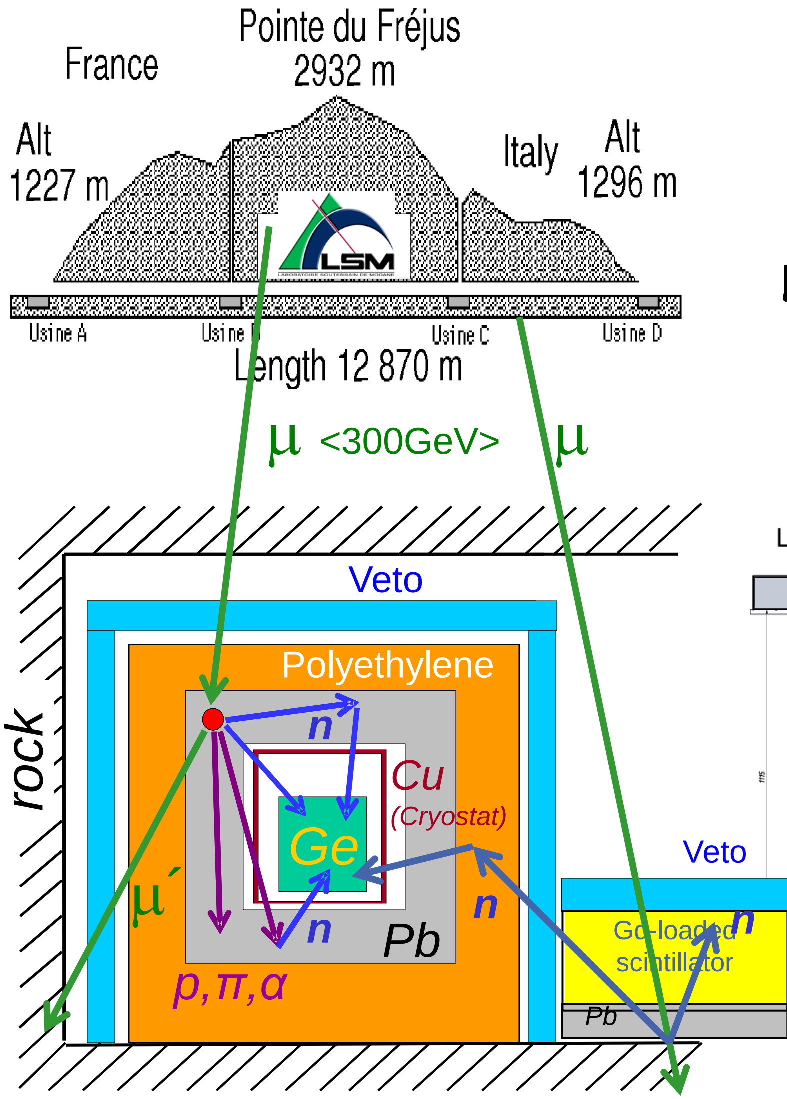
April 2009 – May 2010:

bolometer events
in coincidence
with muon veto
➔
~0.13 μ-induced evts
per kg.d.

~0.03 μ-induced neutron candidates per kg.d.

>1 bolo .and. $E_{rec,tot}$>7MeV:
→34 μ-induced bolo evts.
all in coinc. with μ veto
→μ det.eff >93.5% (90%CL)

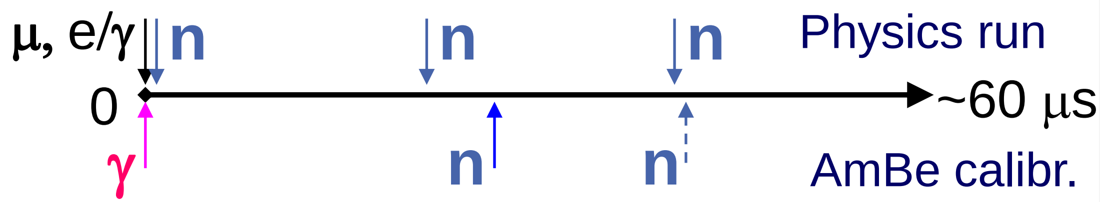
Investigation of μ-induced background

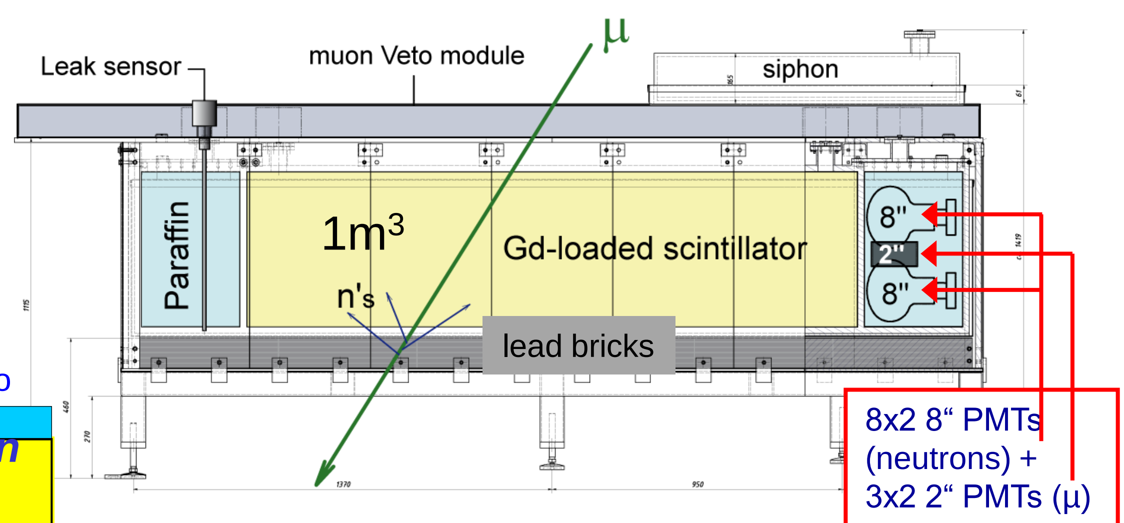


μ-induced neutron signal:

1. μ + delayed neutron(s)
2. multiple "delayed" neutrons

→ ~1 signal sequence per day:





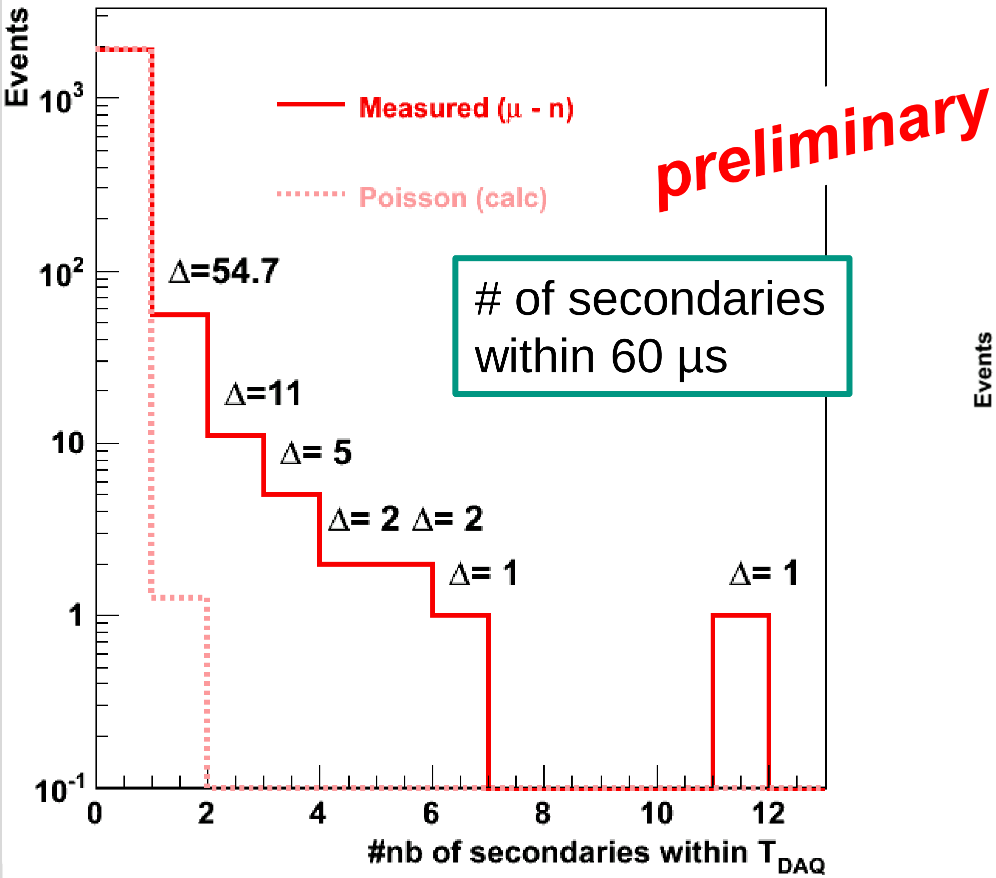
V. Kozlov et al., Astropart. Phys .34(2010)97.; arXiv:1006.3098

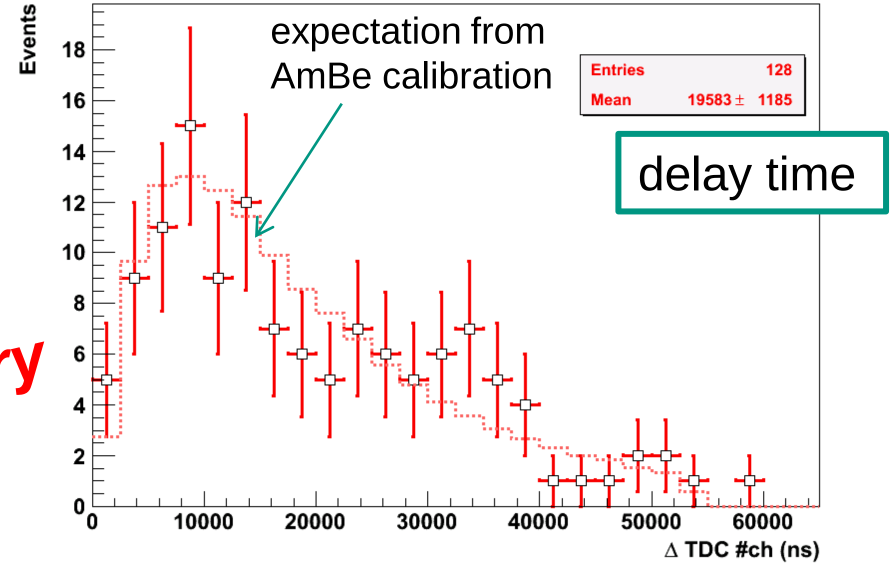
Investigation of μ-induced background

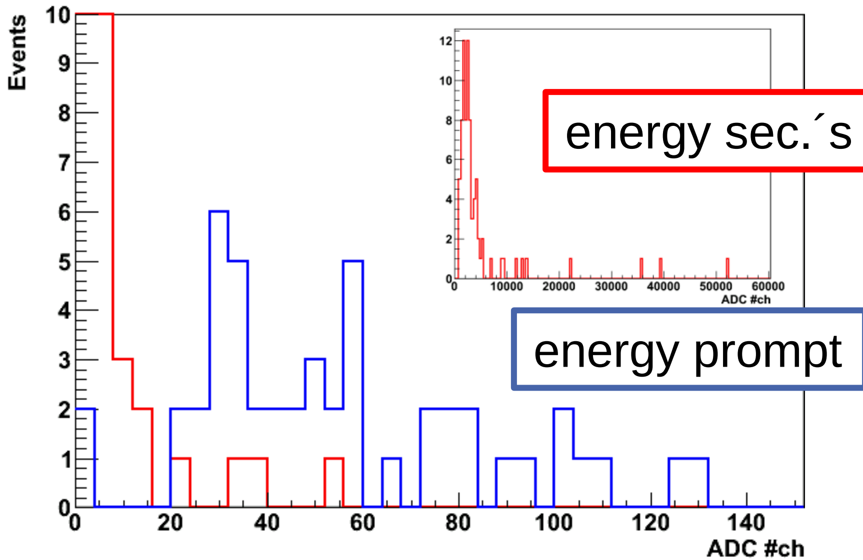
μ-induced neutron signal:

1. μ + delayed neutron(s)

357 live days; 1927 μ; 78 μ-n; 128 sec.´s





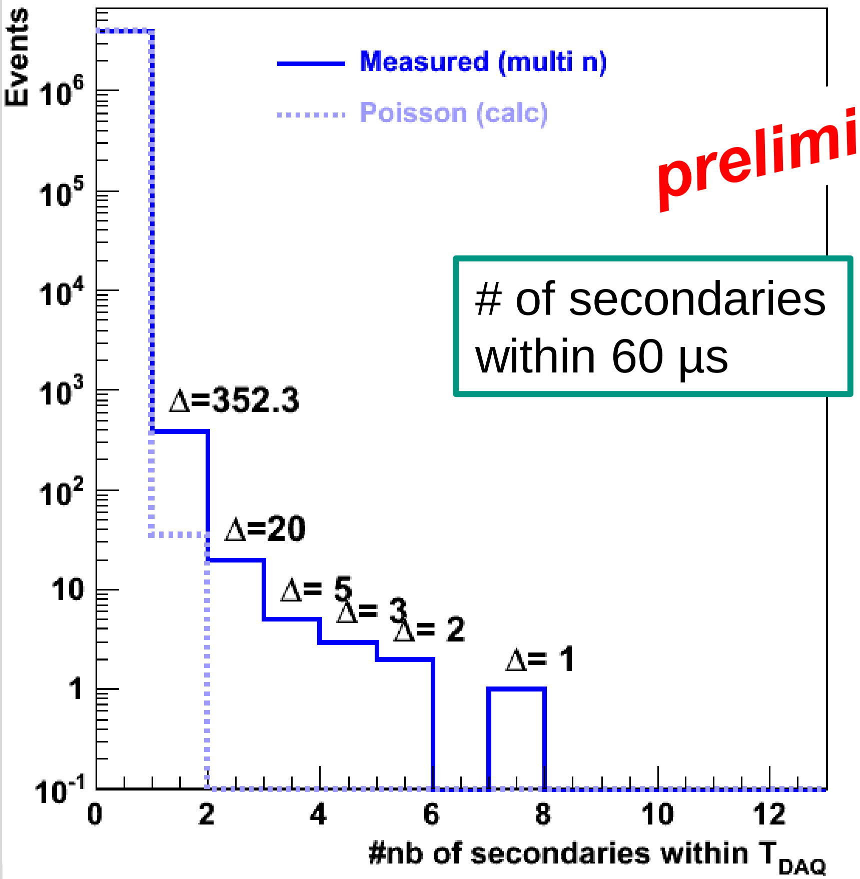


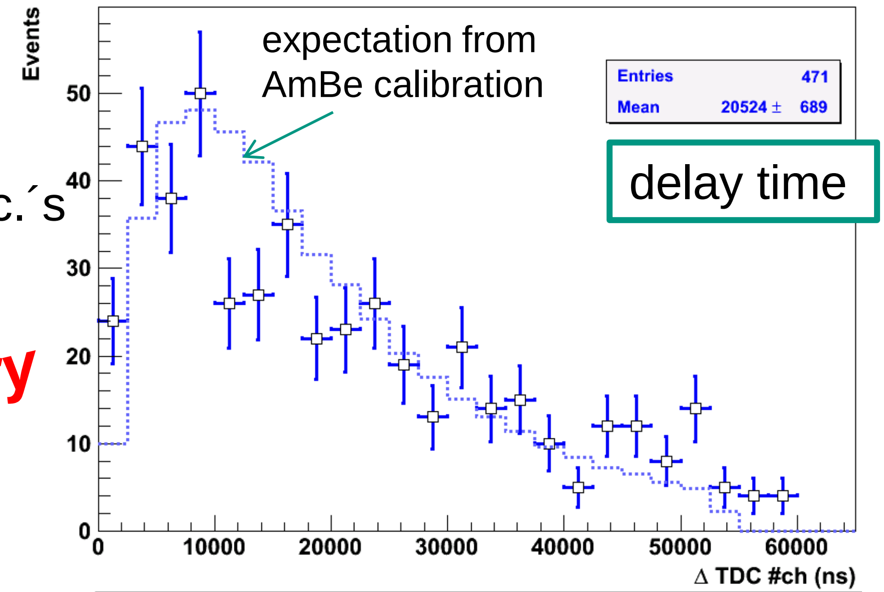
Investigation of μ-induced background

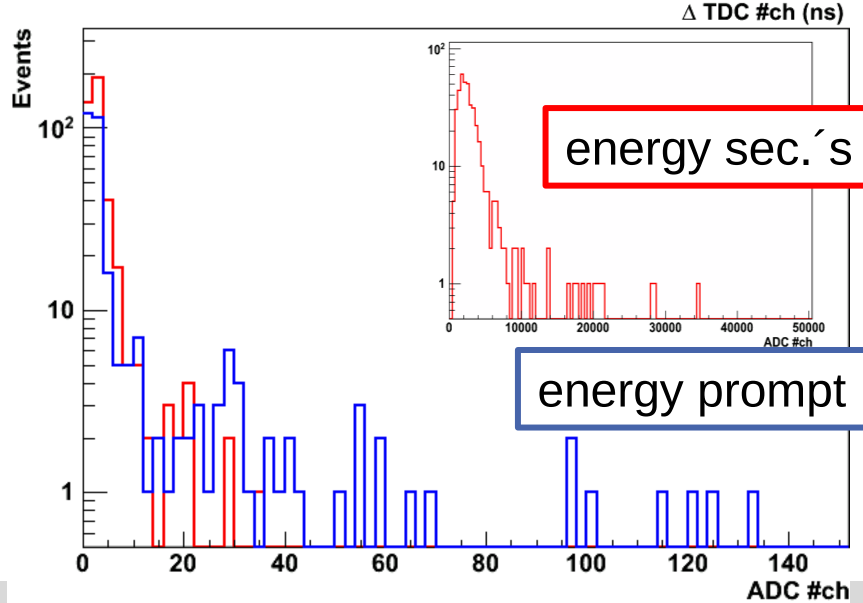
μ-induced neutron signal:

2. multiple "delayed" neutrons

337 live days; 418 mult.; 34.7 bg; 471 sec.´s



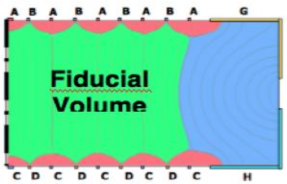


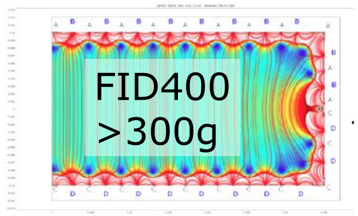


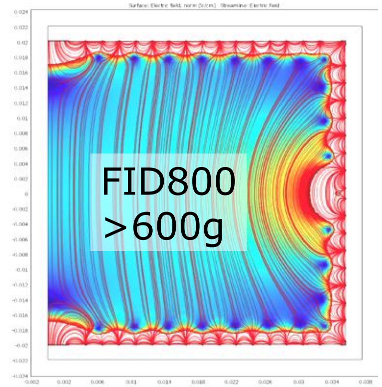
Next steps … Edelweiss-3

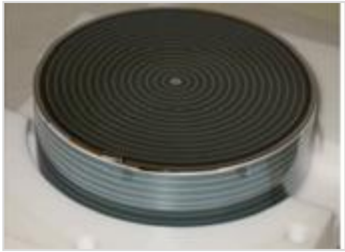
- Doubling/Quadrupling the fiducial mass: ID400 => FID400 => FID800

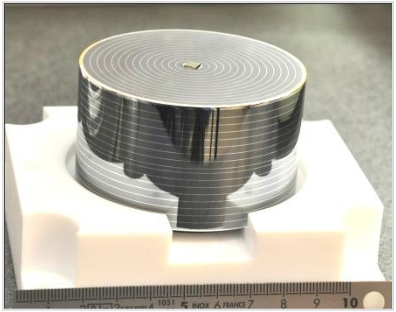
ID400 (160g)

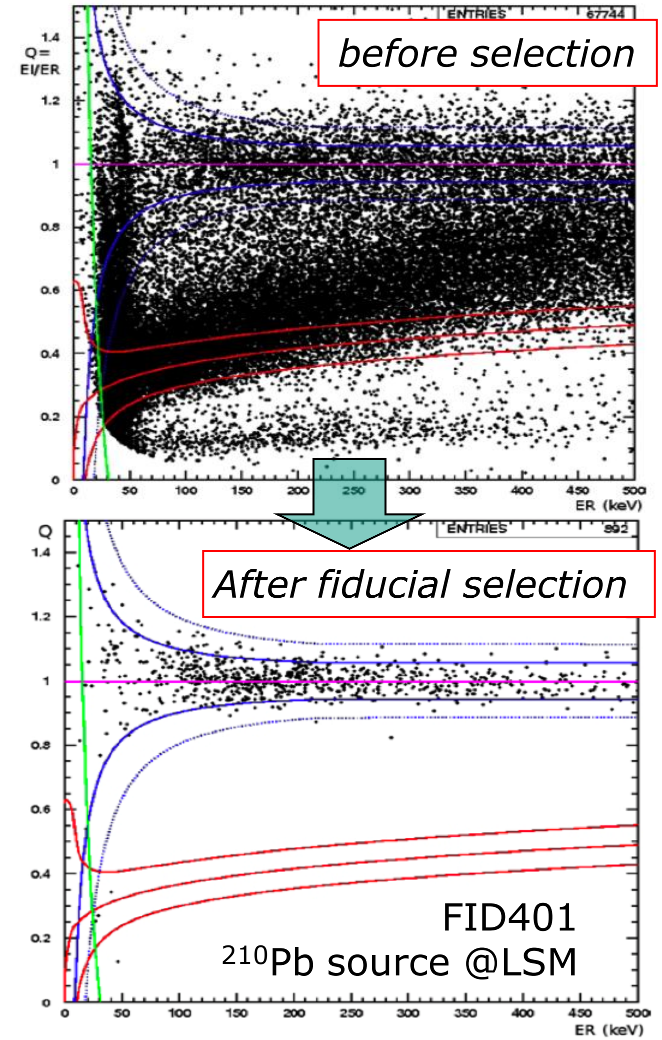












4 / 68000 for E>25keV

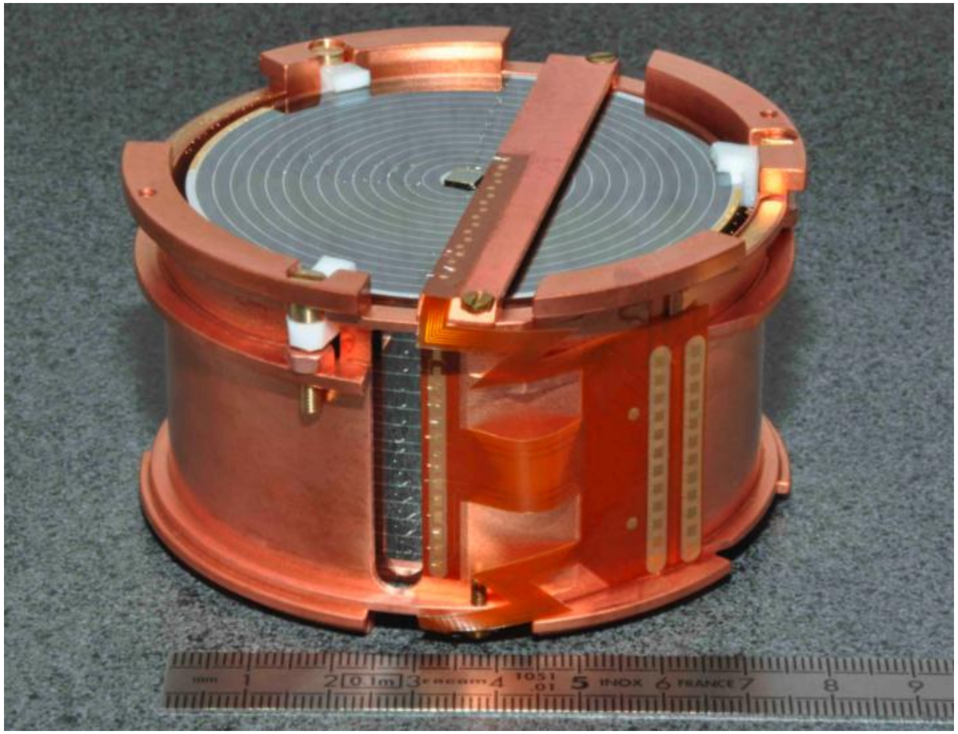
- **Goals:** with FIDs 400+800g program, continue doubling of accumulated exposure every year

  2011 = 1000 kg.d

  2013 = 3000 kg.d

Ongoing commissioning run

- July 3rd: 4 FID800 installed in LSM (+ 10 ID´s + 2 FID400)
- since July 27th: T<20mK

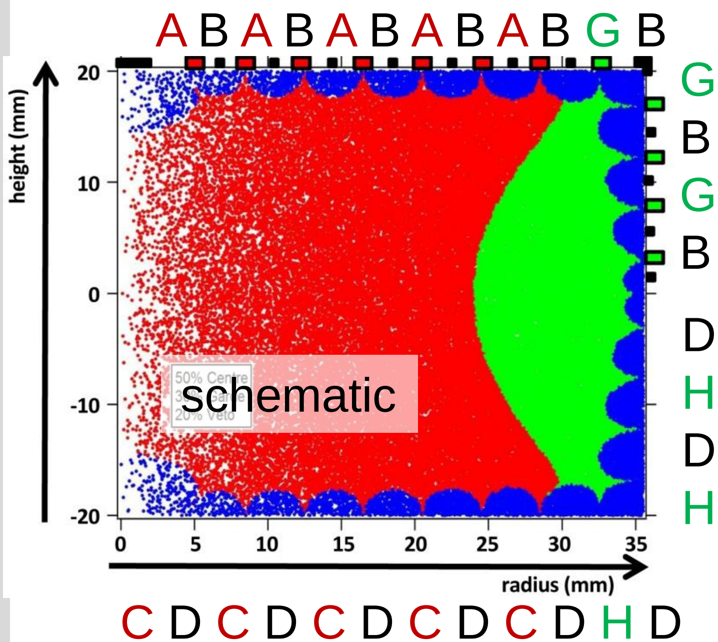


800 g detector, 2 NTD, 6 electrodes
2 «fiducial» volumes
218 ultrasonic bondings / detector

Ongoing commissioning run

>75% on A,C <25% on G,H,

no B,D (exclude surface evts)



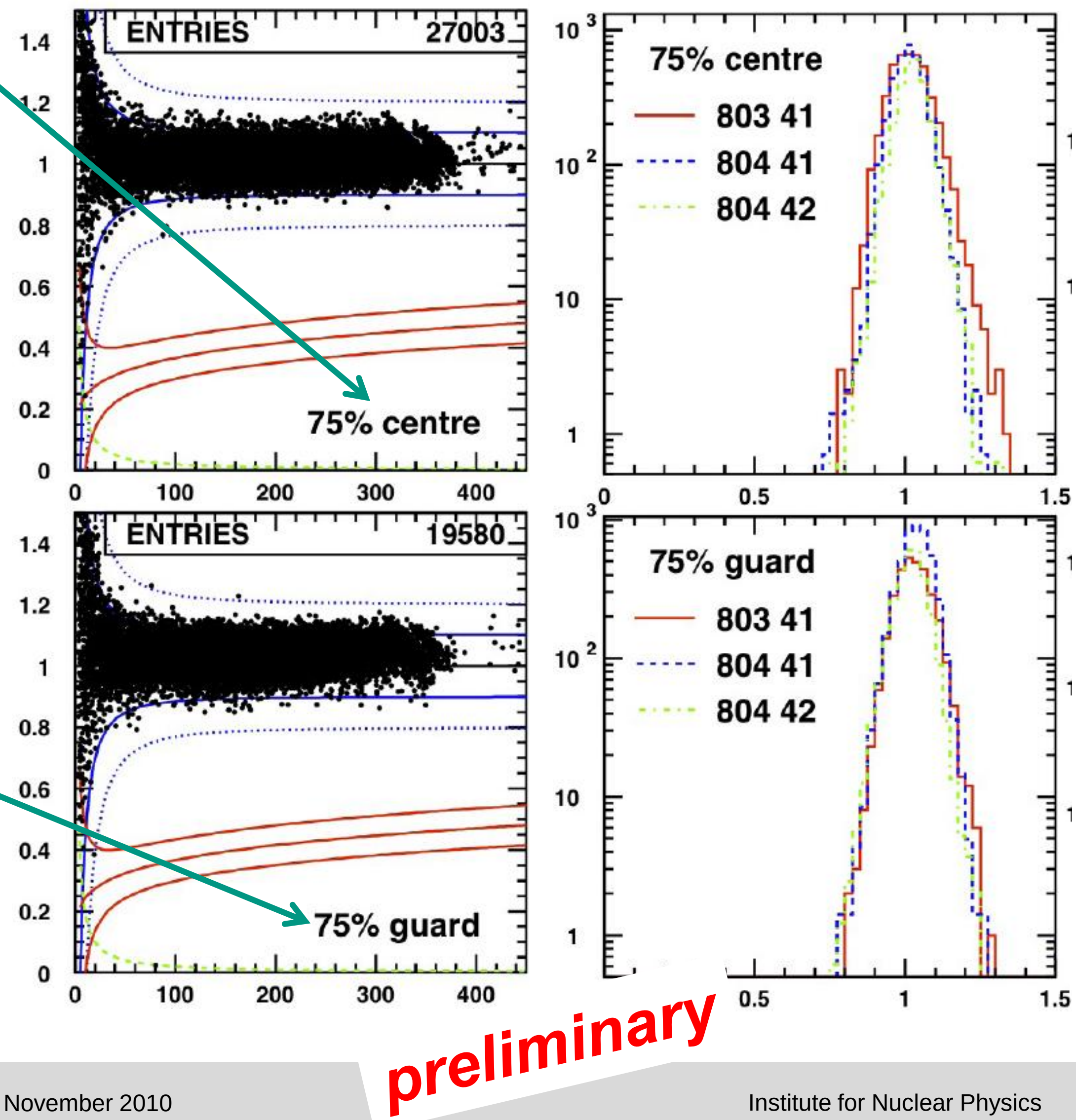
>75% on G,H <25% on A,C,

no B,D (exclude surface evts)

σ_{ion} as expected → long γ-calib.

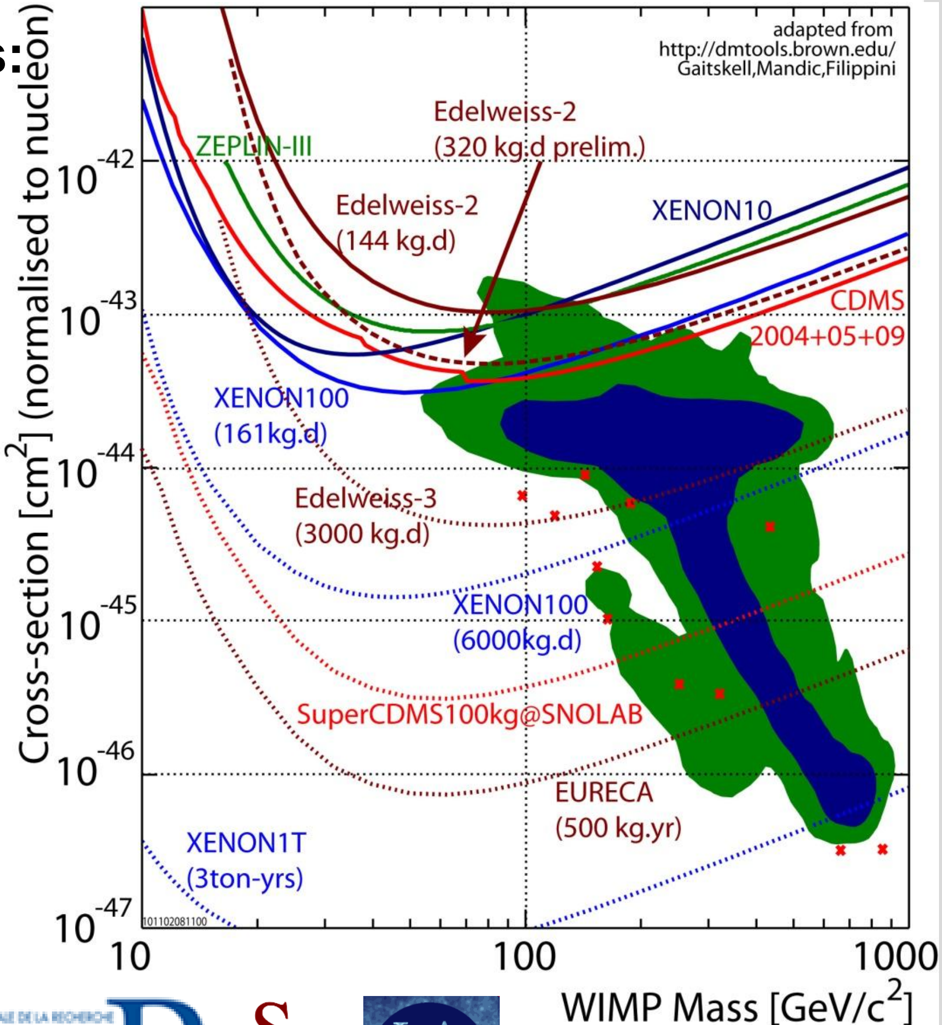
σ_{heat} as for ID400 detectors

γ-calibration with ^{133}Ba



Edelweiss summary & prospects

- **EDW new-generation ID detectors:**
  - robust detectors with redundancy and excellent beta rejection
  - muon&neutron investigations
  - preliminary analysis of 1 year data
    - no evidence for WIMPs so far
    - 5 x10^{-8} pb sensitivity achieved
- **new EDW-3 goal: 5 x 10^{-9} pb**
  - improvements wrt to future backgds
    - increased redundancy for ionisation and heat measurements
    - fast readout (multisite, pile up)
    - lower microphonics, internal PE shield
  - new prototypes: FID 800g
    - 2011 ➔ 1000 kg.d
  - build&install 40 detectors upgrade set-up
    - 2013 ➔ 3000 kg.d

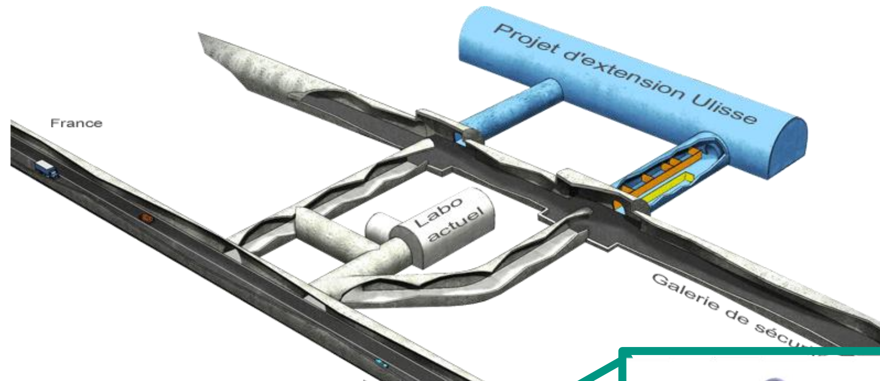


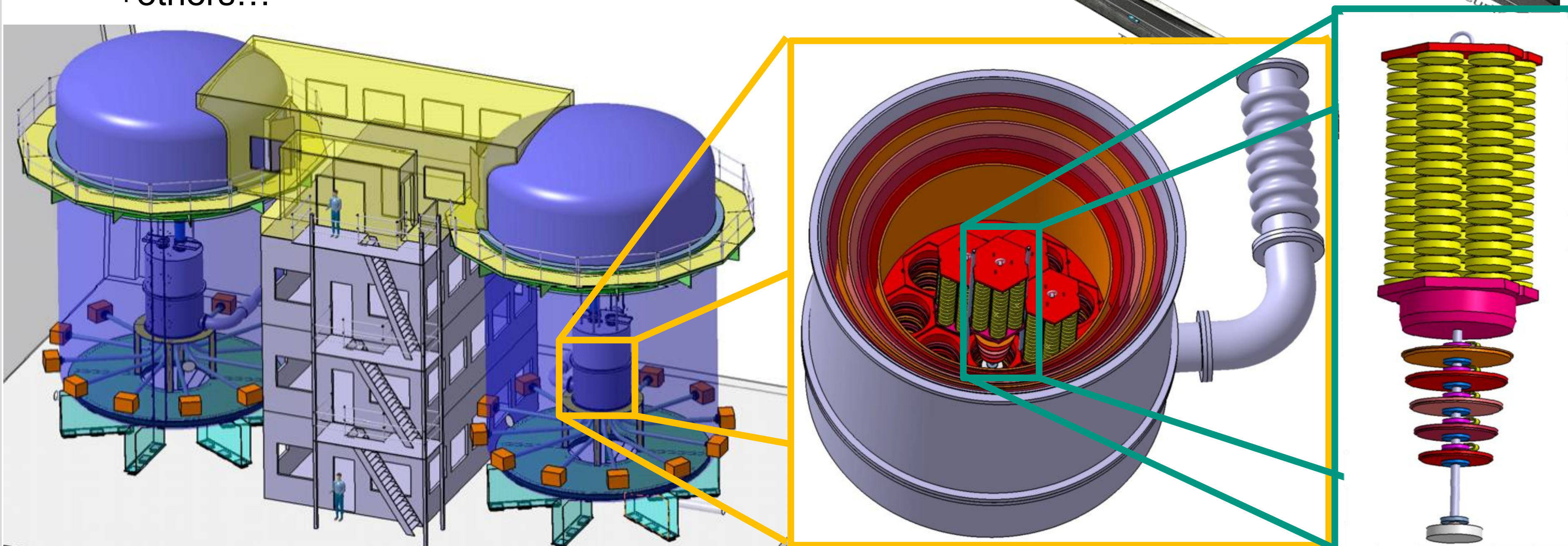
Further future: EURECA

http://www.eureca.ox.ac.uk/

Karlsruhe Institute of Technology

- EURECA goal: 10^{-10} pb, 500 kg to 1 tonne cryogenic experiment, multi-target
- “Generation 2” project with major efforts in background control, detector development, infrastructure
- Joint European collaboration of teams from EDELWEISS, CRESST, ROSEBUD, +others…





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- “Generation 2” project with major efforts in background control, detector development, infrastructure
- Joint European collaboration of teams from EDELWEISS, CRESST, ROSEBUD, +others…
- Part of ASPERA European Roadmap
- Preferred site: 60 000 m^2 ULISSE extension of present LSM (4 $\mu/m^2/d$), to be excavated in 2012/2013
- Fréjus status as of Sep 2010:

  first 600m of safety gallery excavated
- MoU between EURECA, SuperCDMS and GEODM collaborations:

On behalf of the EURECA collaboration	On behalf of the SuperCDMS collaboration	On behalf of the GEODM collaboration
Hans Kraus EURECA Spokesperson	Blas Cabrera SuperCDMS Spokesperson	Sunil Golwala GEODM Spokesperson