# EDELWEISS-2 Dark Matter Search: recent results with new detectors

**Valentin Kozlov**

(Forschungszentrum Karlsruhe)

for **the EDELWEISS collaboration**

## HEP 2009 (Krakow, 16-22 July)

- DM search with Edelweiss
- Experimental set-up
- New detectors
- Status of data-taking
- Muons & neutron background

# The EDELWEISS collaboration

♦ **CEA Saclay (IRFU & IRAMUS)** — **Detectors, electronics, acquisition, background, analysis,**
E. Armengaud, O. Bessida, M. Chapellier, G. Gerbier, M. Gros, S. Hervé, M. Karolak, X-F. Navick, P.Pari, B. Paul
*Post-doc:* M. Hannewald — *Thesis :* A. Chantelauze (cotutelle FZK), J. Domange BDI

♦ **CSNSM Orsay** — **Detectors, cabling, cryogenics, analysis**
L. Berge, A. Broniatowski, D. Carré, S. Collin, L. Dumoulin, F. Lalu, S. Marnieros
*Post-doc/ATER:* C. Nones, E. Olivieri — *Thesis :* O. Crauste, J. Domange

♦ **IPN Lyon** — **Electronics, background, analysis, detectors**
C. Augier, F. Charlieux, M. De Jésus, P. Di Stefano, J. Gascon, A. Juillard, V. Sanglard, L. Vagneron
*Thesis :* MA. Verdier, S. Scorza

♦ **CRTBT Grenoble** — **Cryogenics, electronics**
A. Benoit

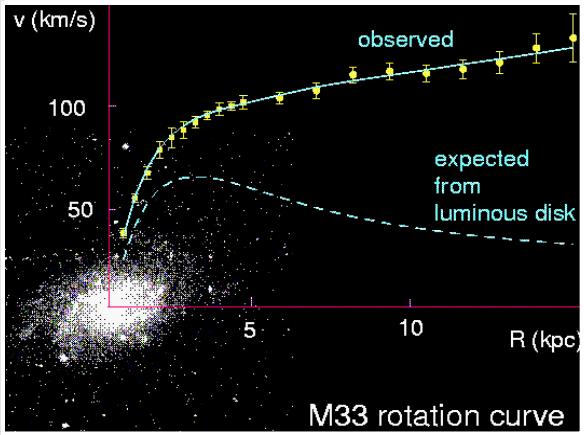
♦ **FZK/ Uni Karlsruhe (TH)** — **Muon veto, neutron counter, background**
J. Blümer, K. Eitel — *Thesis :* A. Chantelauze (cotutelle CEA), H. Kluck
*Post-doc:* **V.Yu. Kozlov**

♦ **JINR Dubna** — **Monitoring of ambient neutron and Rn background**
E. Yakushev, S. Semikh — *Thesis :* A. Lubashevski, L. Perevozchikov

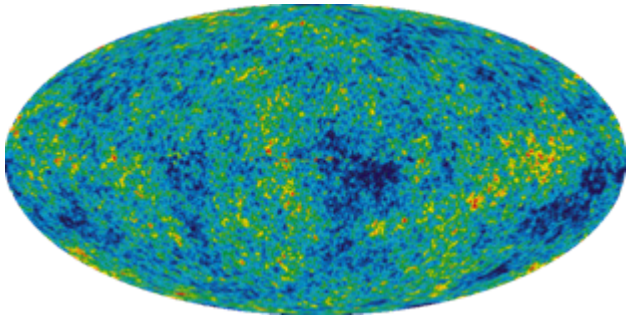
♦ **Oxford University** — **High impedance sensors, wiring**
H. Kraus, S. Henry — *Thesis :* S. Ingleby, J. Imber, A. Brown
*RA:* V. Mikhailik

# Why and How?

F. Zwicky
1898-1974

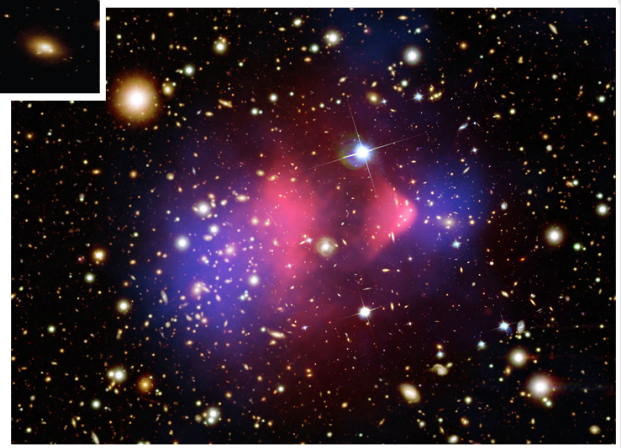




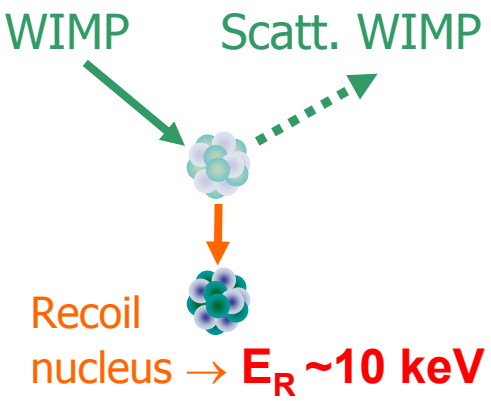


**DM searches:**
**Prof. E. Aprile,**
**Tue 21st, 9:00**

**Bullet cluster**



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




Count rate:

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

**Challanges to overcome:**

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

**Way to go:**

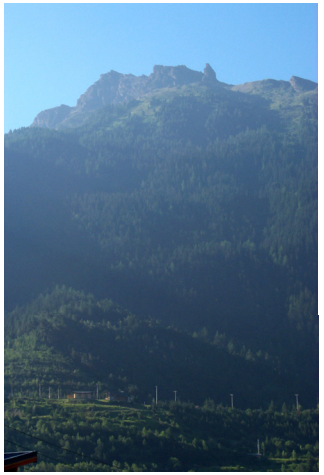
- **low radioactivity;**
- **powerful rejection;**
- **background knowledge;**



Forschungszentrum Karlsruhe GmbH
und Universität Karlsruhe (TH)
HELMHOLTZ GEMEINSCHAFT
Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

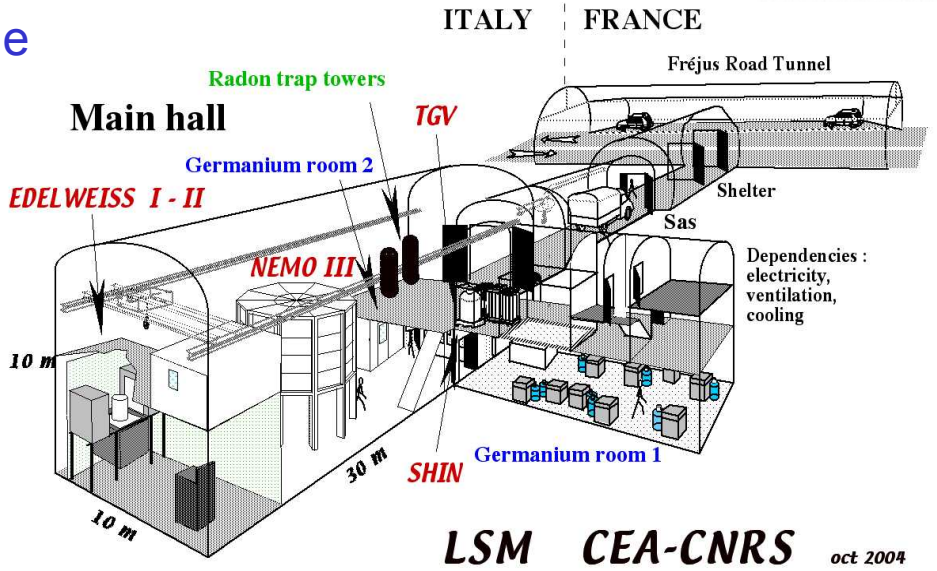
# Ge bolometers for WIMP search @ LSM

## LSM: Laboratoire Souterrain de Modane

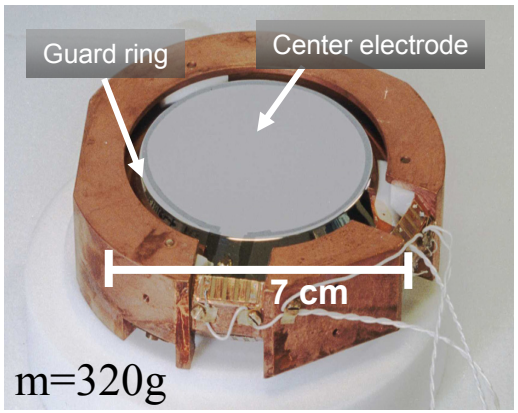


**Shielding:**
~ 4700 mwe

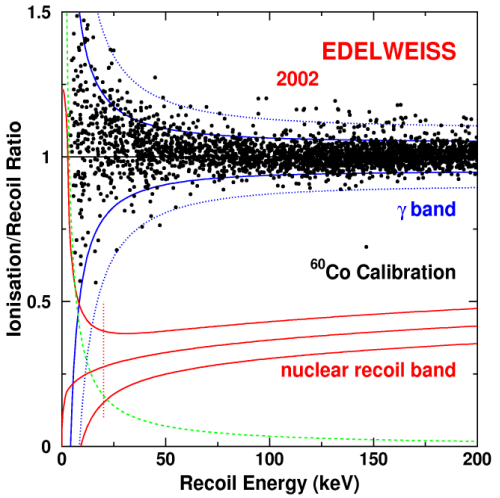
**μ flux:**
~ 4 / m$^2$ / day




## EDW: Bolometers of pure natural Ge:




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**

# Ge bolometers for WIMP search @ LSM

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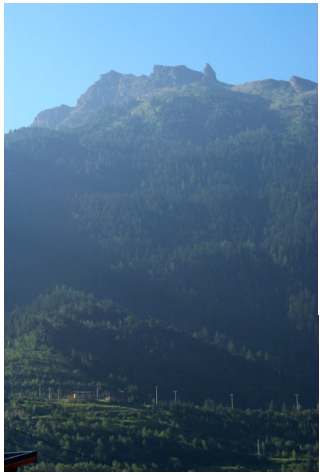

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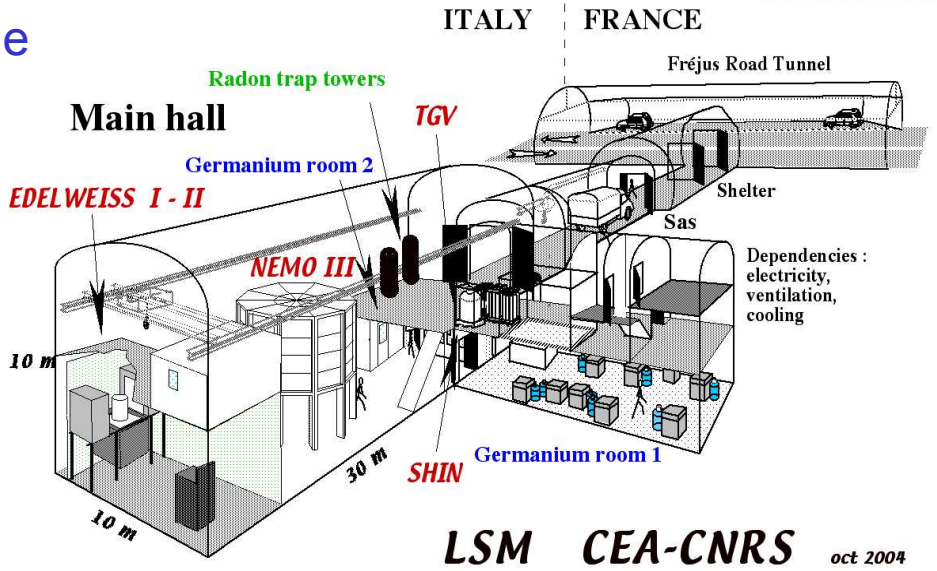


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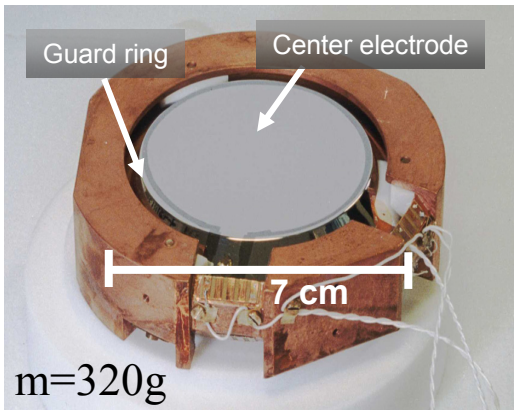
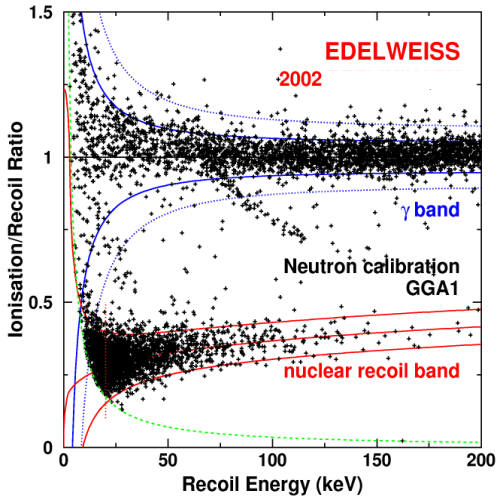



Ge/NTD

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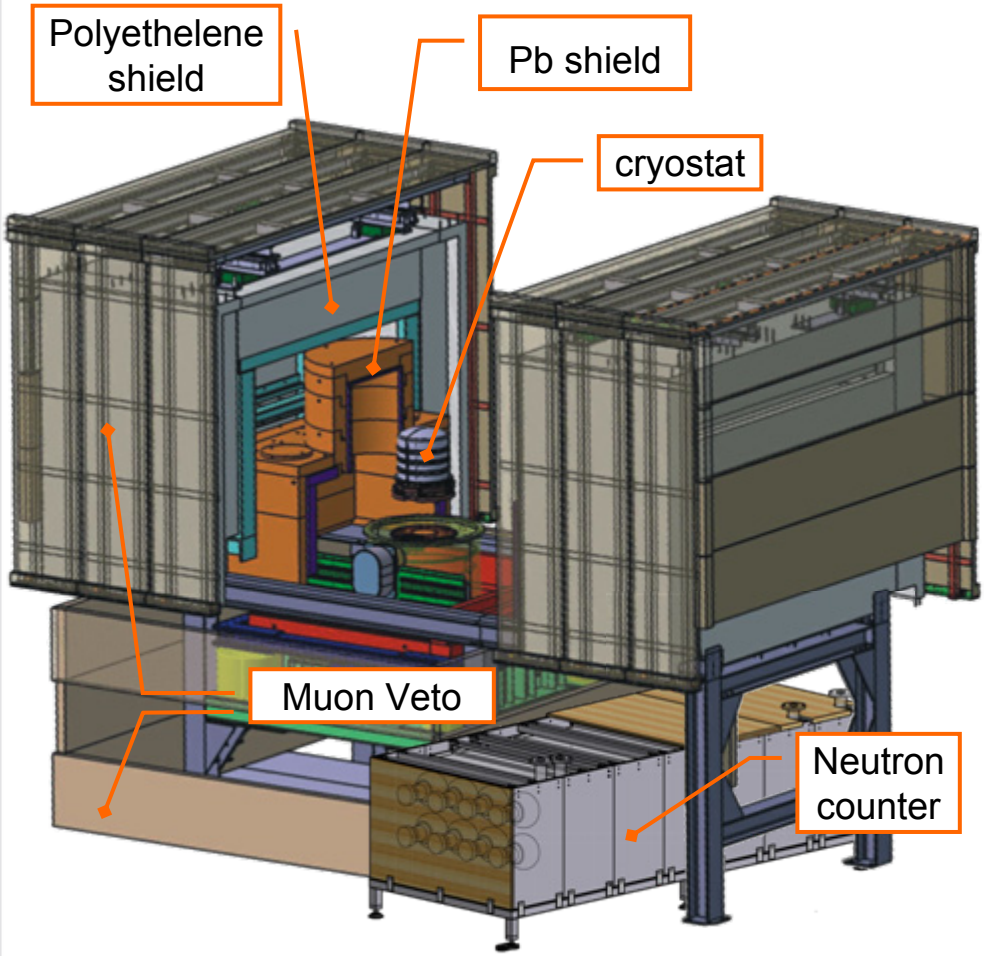
# EDW II experimental set-up

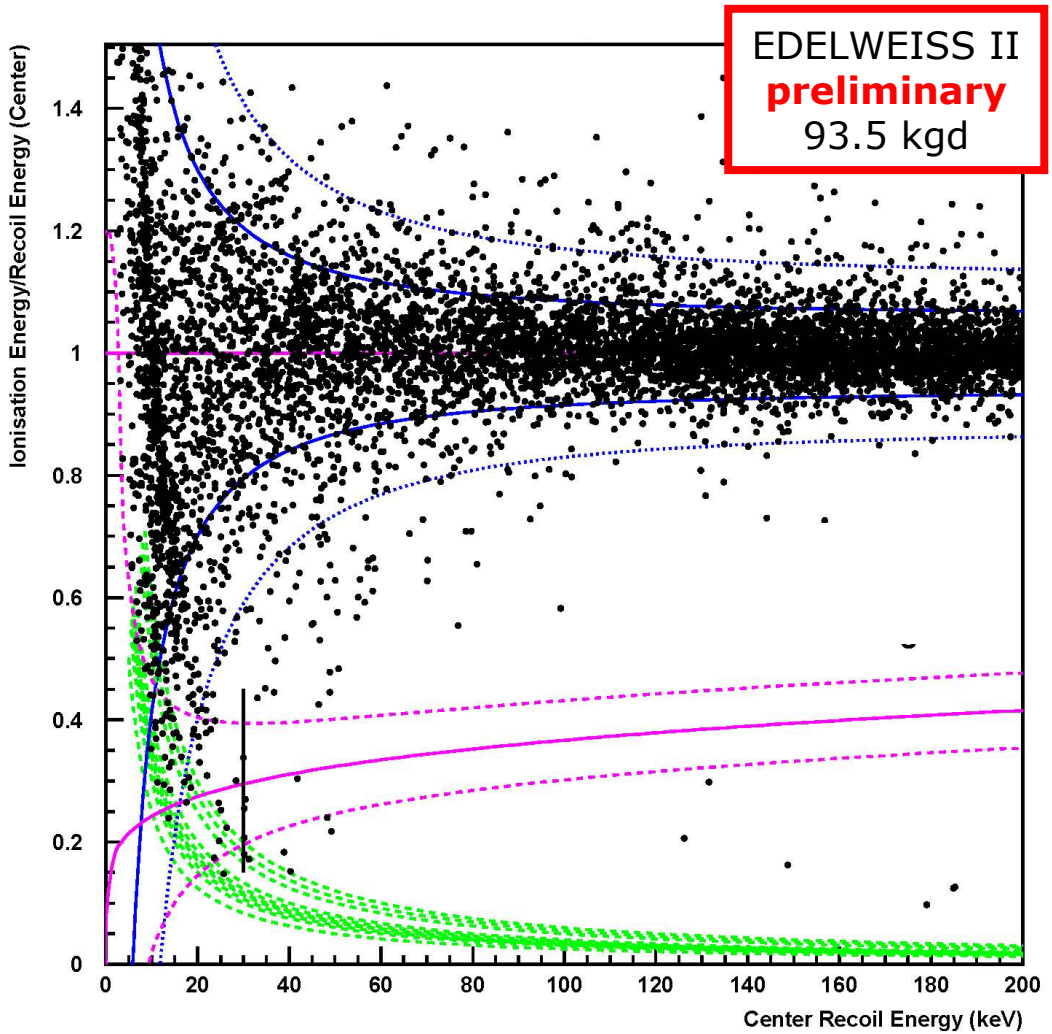



- **radiopurity**
  dedicated HPGe detectors for systematic checks of all materials
- **clean room** (class 100 around the cryostat, class 10000 for the full shielding)
- **deradonized air** (from NEMO-3)
- **neutron shielding**
  - **20 cm** Pb shielding
  - **50 cm** PE and better coverage
- **active μ veto** (>98% coverage)
  + μ-n coincidence measurement
- **up to 110 detectors**
  - Ge/NTD + (Ge/NbSi) + **new ID**
- **expected sensitivity: EDW-I × 100**
  $\sigma_{\chi\text{-}n} \approx 10^{-8}$ **pb** (12 kg tot. mass, 2011)
  = **0.002 evts/kg/day** ($E_r$>10keV);
  // neutrons from μ DIS in the rock (G4):
  ~$10^{-4}$ evts/kg/day

# Ge/NTD bolometer: physics data

- Background is reduced by **x3** for γ and **x2** 210Pb
- 93.5 kg.day at 30 keV threshold
- 3 events observed in nuclear recoil band
- Evidence for events with incomplete charge collection (surface electron recoils: trapping, recombination)

=> Limited rejection capabilities!



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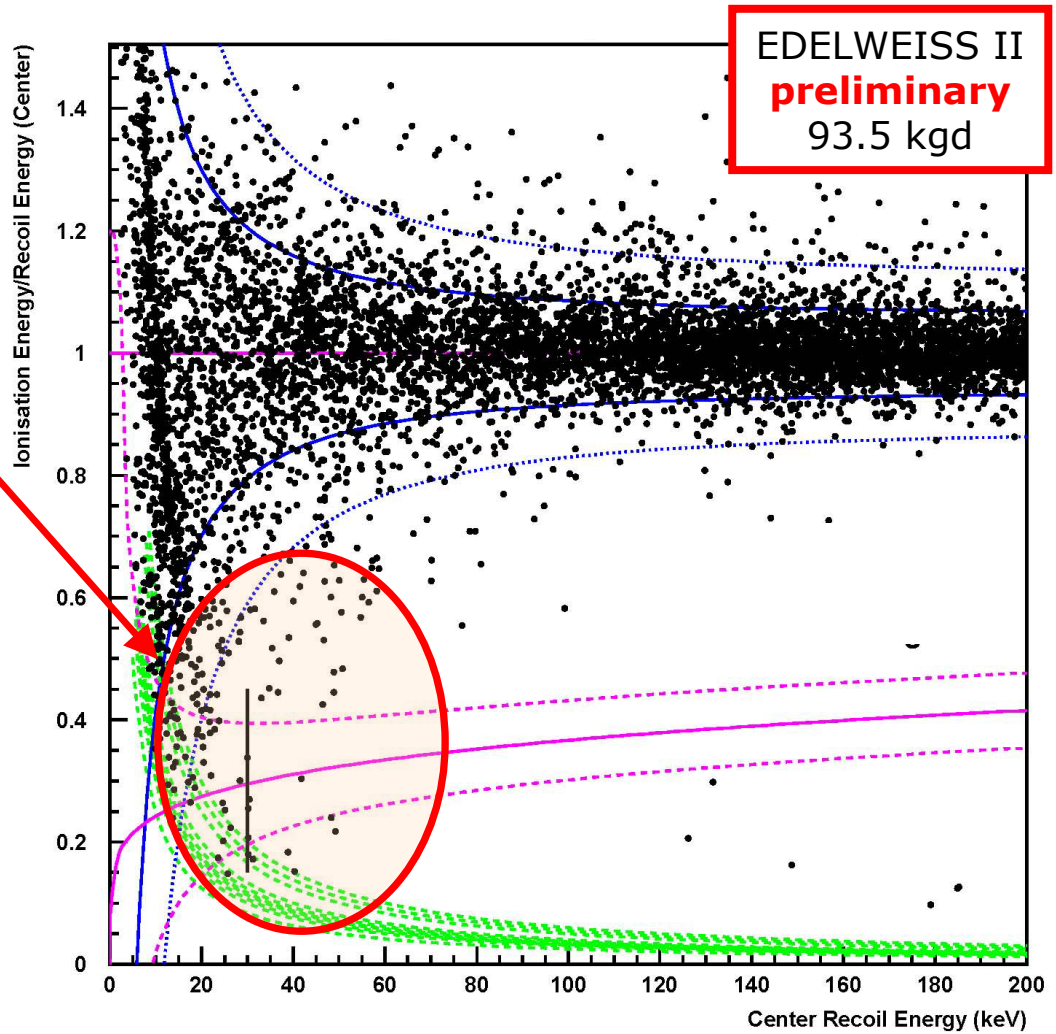

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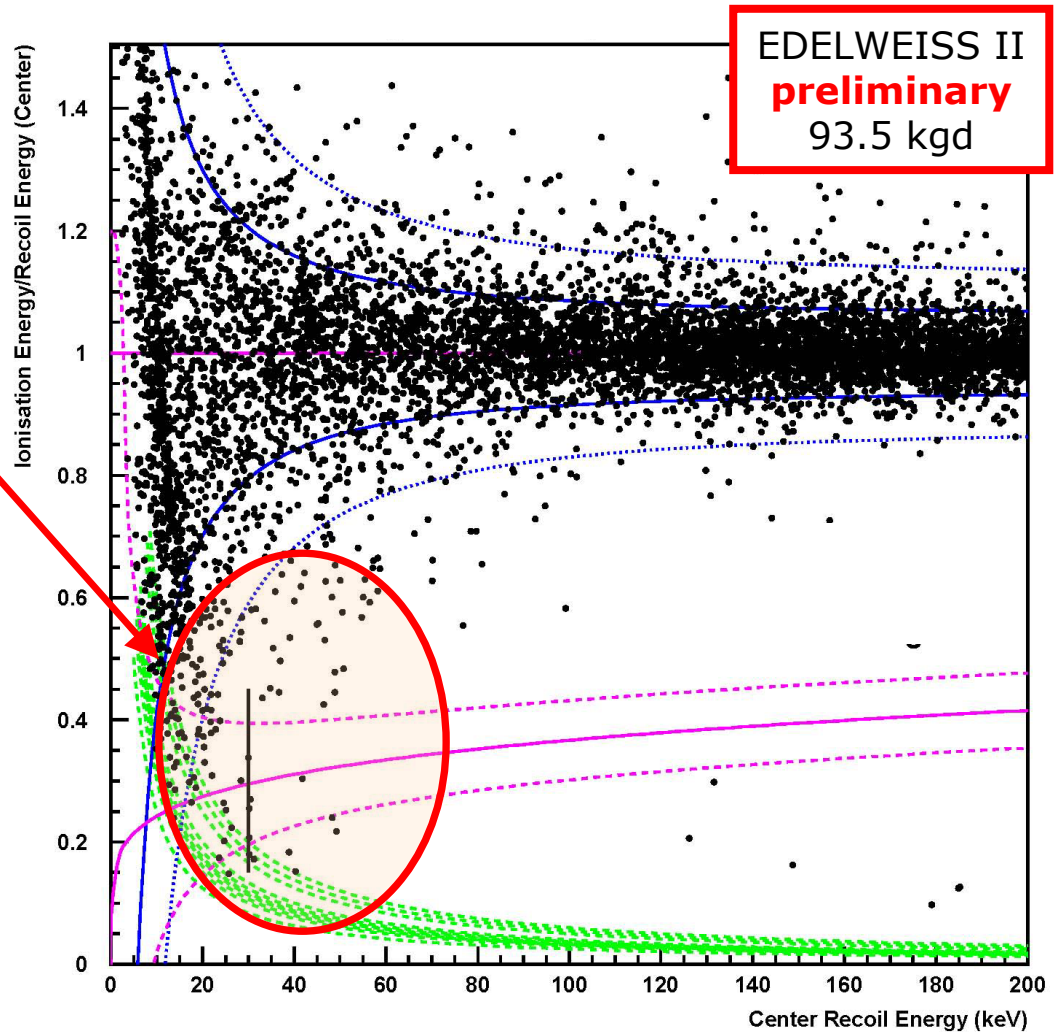
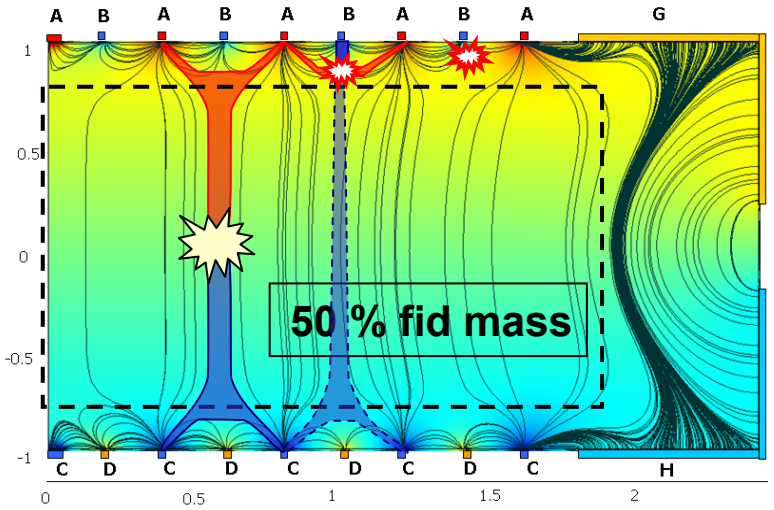



**To reach $10^{-8}$ pb sensitivity**

- Need ~2500 kgd at 15 keV threshold
- Need ~$10^4$ rejection for gammas
- Need to reject expected ~5000 β from 210Pb

# ID-detectors with annular ring electrodes

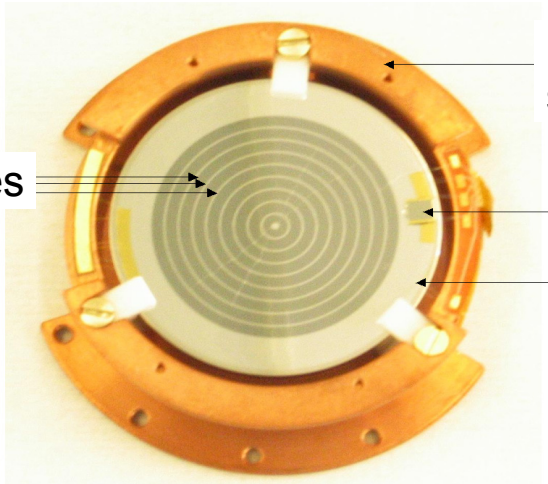



**A**: +4 V

**B**: -1.5V

**C**: -4 V

**D**: +1.5V




InterDigitised electrodes (**ID**): 1 x 200g installed Nov. 2007, Jan. 2009: 10 IDs running

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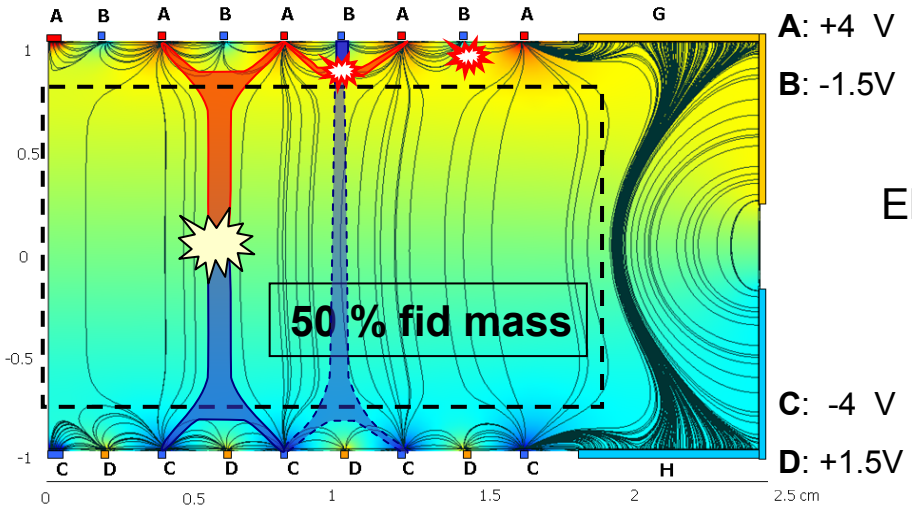
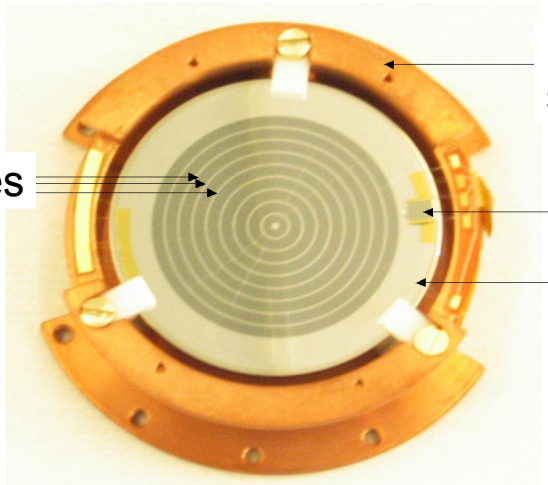
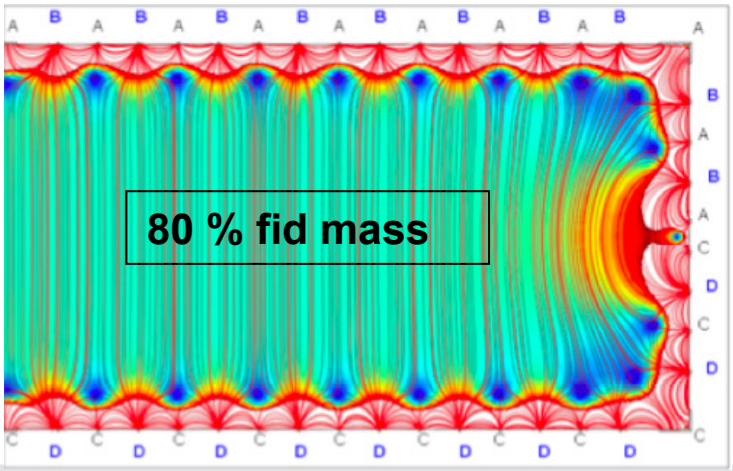
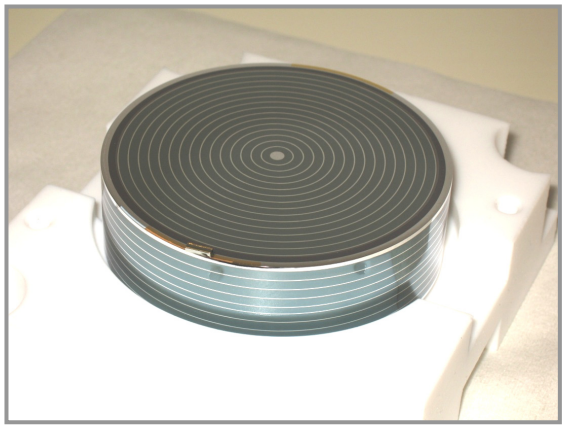



InterDigitised electrodes (**ID**): 1 x 200g installed Nov. 2007, Jan. 2009: 10 IDs running

…Next step is Full Interdigitised (FID):

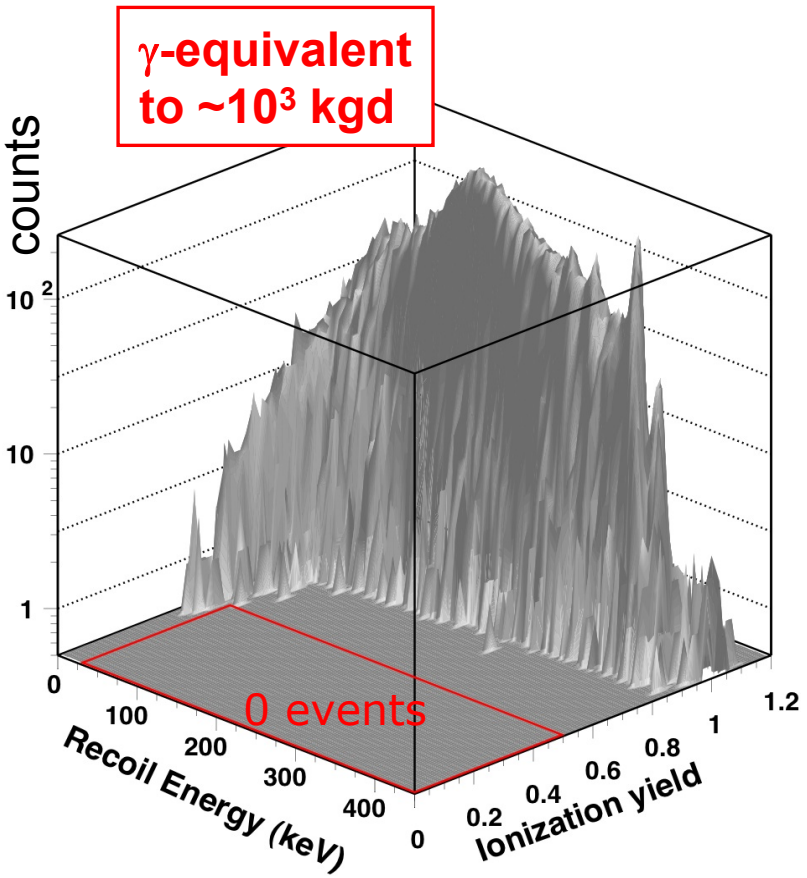


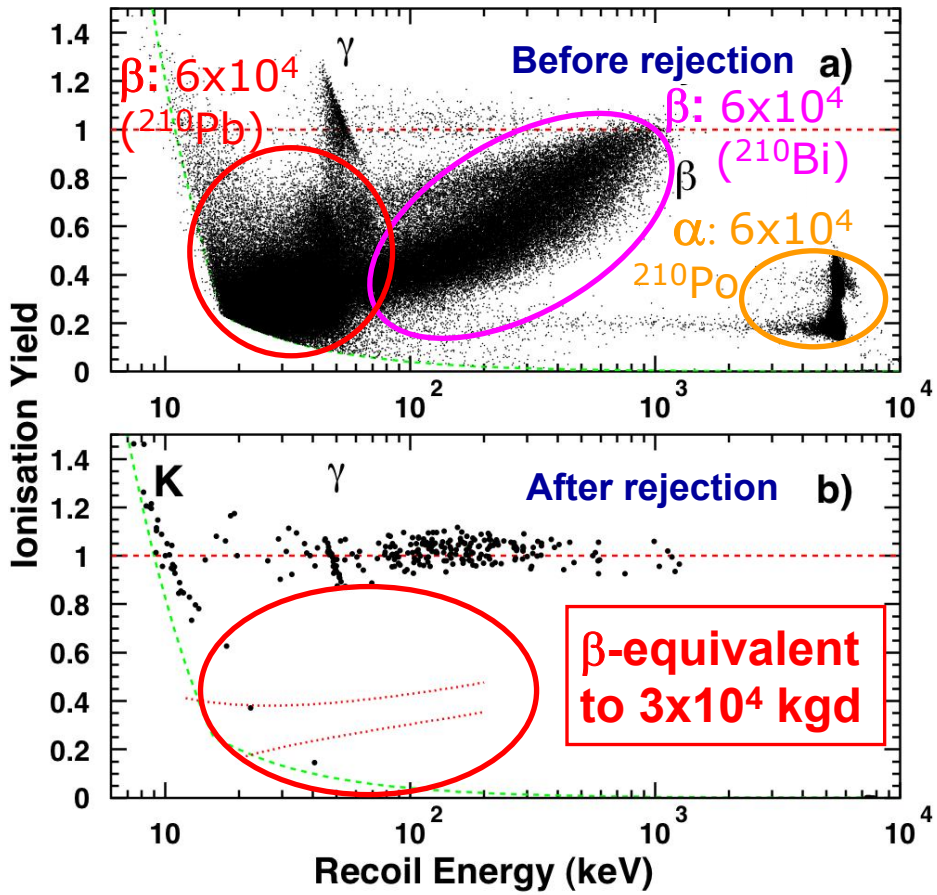



# ID-detector performance

- Gamma rejection
  ~1 month **$^{133}$Ba** calibration (~$10^5$ γ´s)

- Beta rejection
  **$^{210}$Pb** source on 200g ID

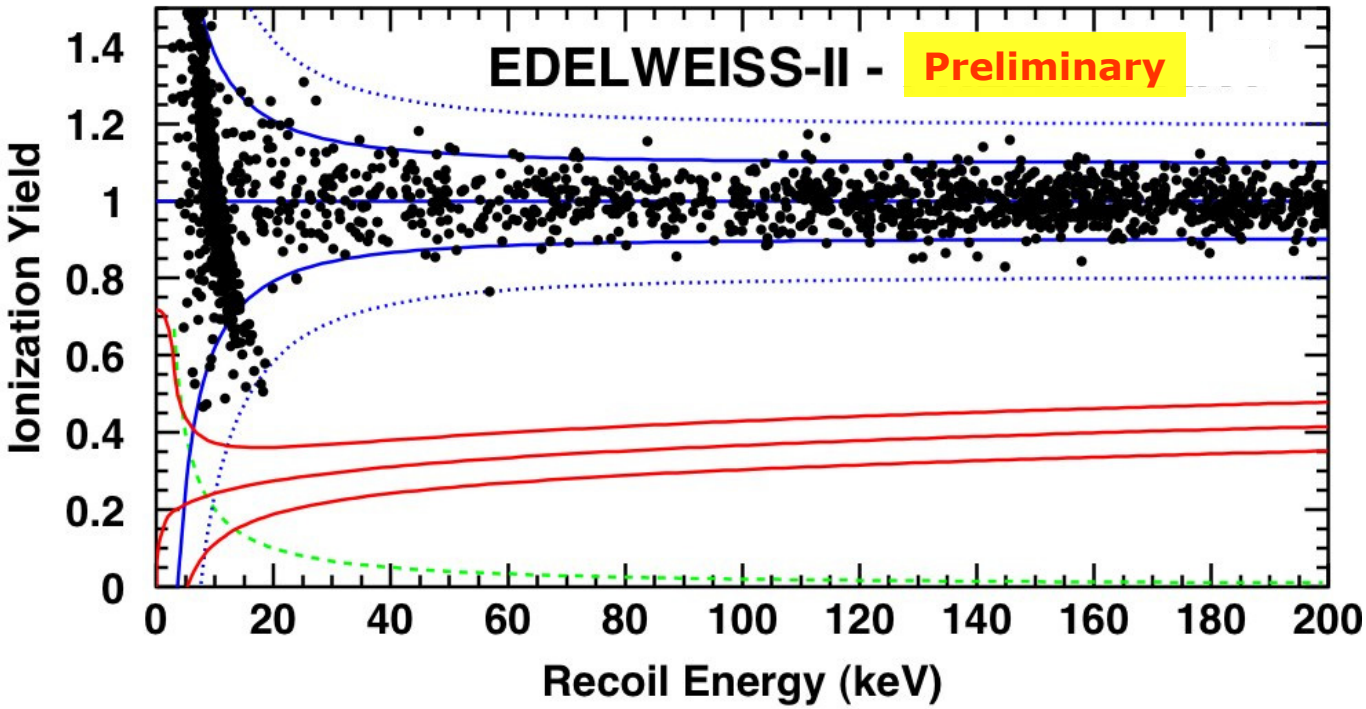



arXiv:0905.0753v1 [astro-ph.IM], PRL submitted

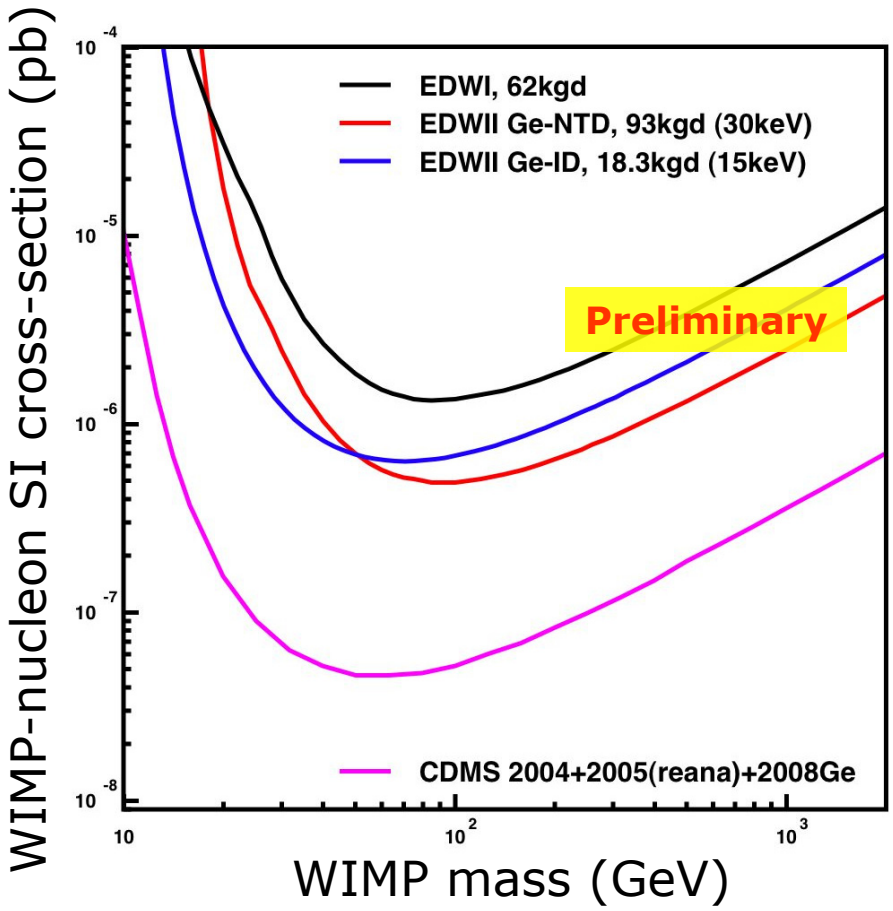
# ID bolometer: physics data

- 1 x 400g + 1 x 350g detector
- <15 keV threshold achieved for exposure of 18.3 kg.days
- no events in (or around!) nuclear recoil band



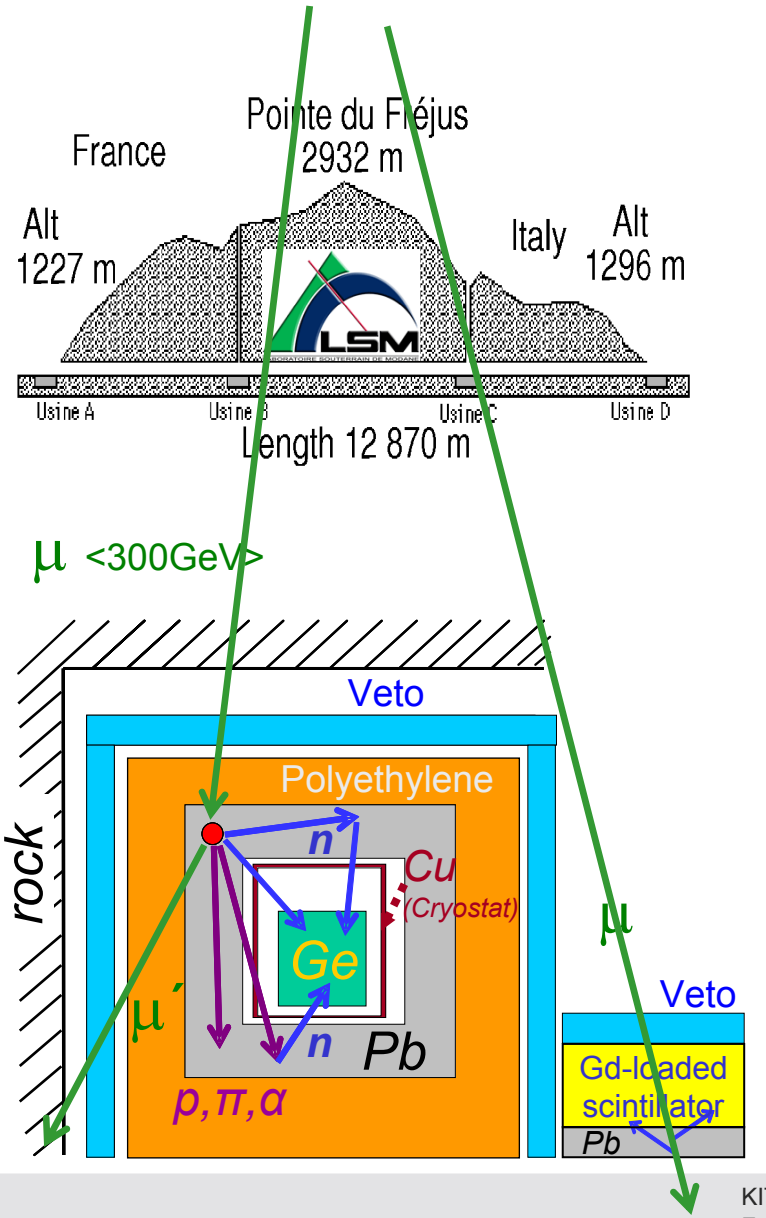
# Limits with GeNTD and ID detectors

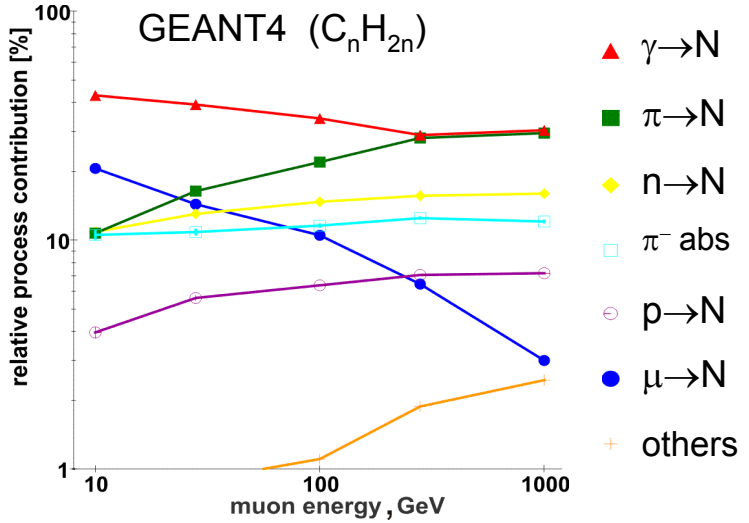
- **93.5 kgd GeNTD** (XI.2007 - III 2008)
  - 11 detectors x 4 months
  - 30 keV threshold
  - 3 events observed in nuclear recoil band
- **18.3 kgd ID** (VII.2008 – XI.2008)
  - 2 detectors x 4 months
  - 15 keV threshold
  - No nuclear recoils
  - No evts outside $\gamma$ band
- **Jan. 2009: 10 ID detectors**
  - x20 improvement by 2010: **$4 \times 10^{-8}$ pb** (expectation)
  - More detectors to be built in 2009

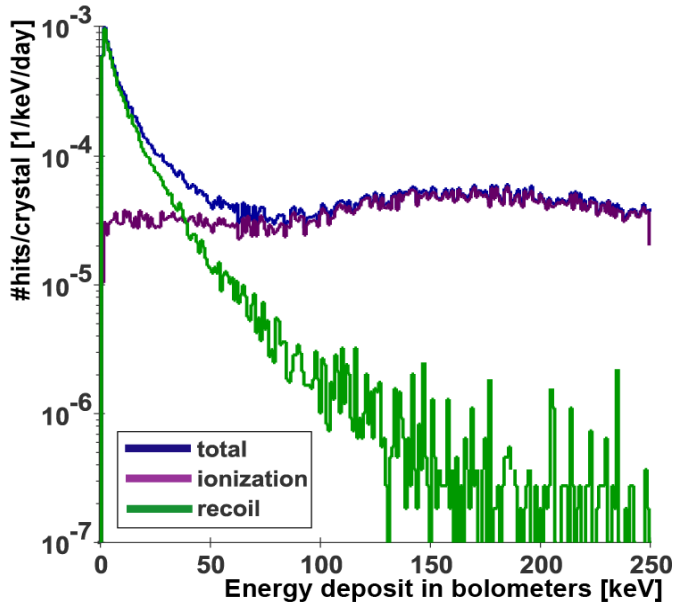



*more data to analyze...*

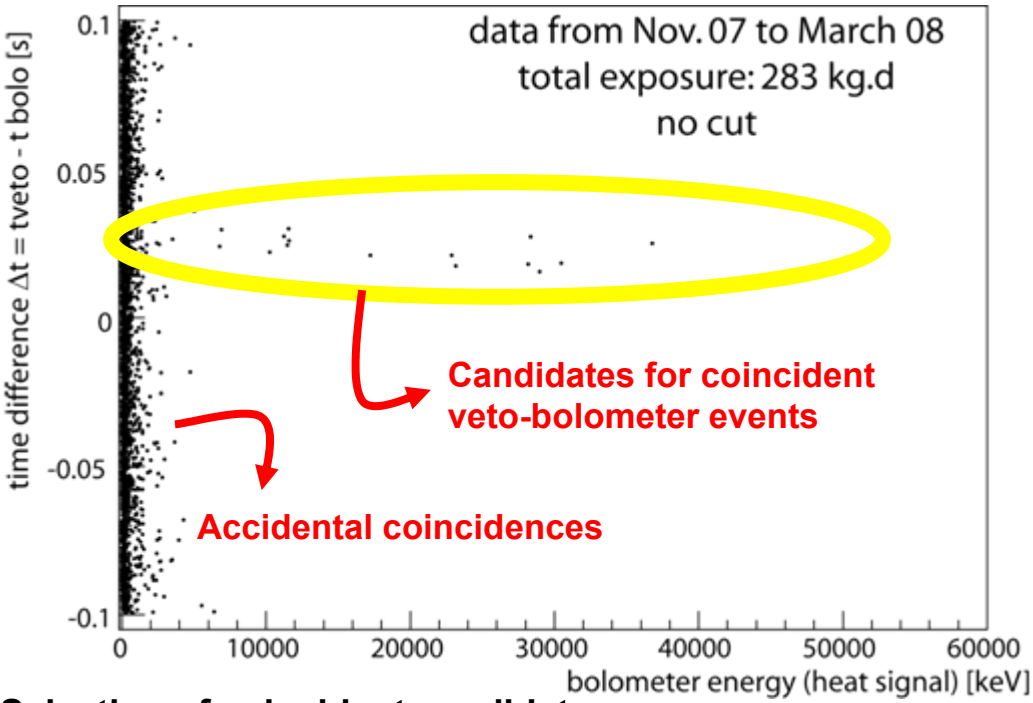
# μ-induced events: simulations

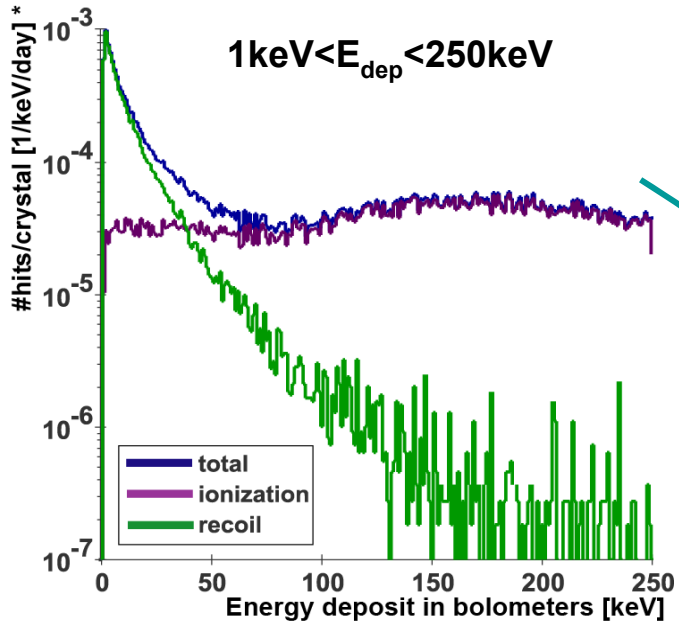


# Coincidences in μ-veto system and Ge bolometers




Geant 4 simulation of μ-induced Ge-hits

**Selection of coincident candidates:**

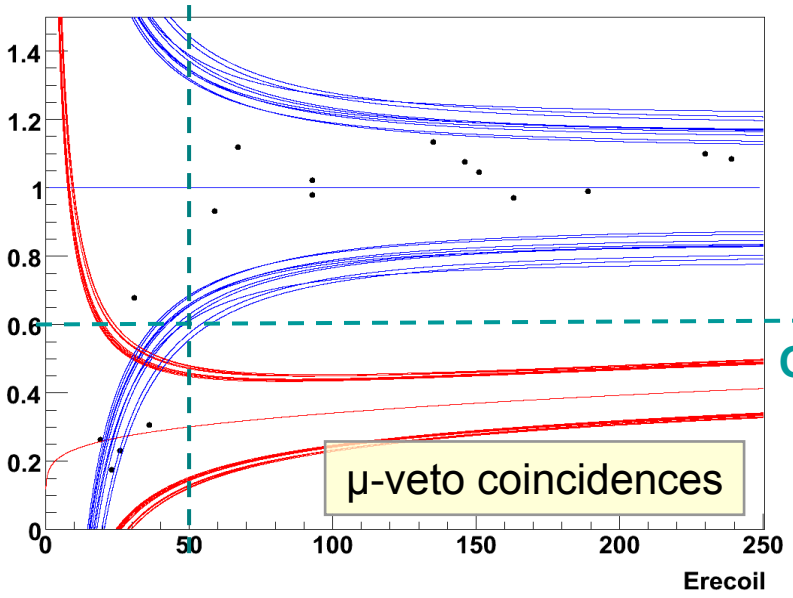
- **> 1 veto module hit**
- **15 ms < Δt < 35 ms**

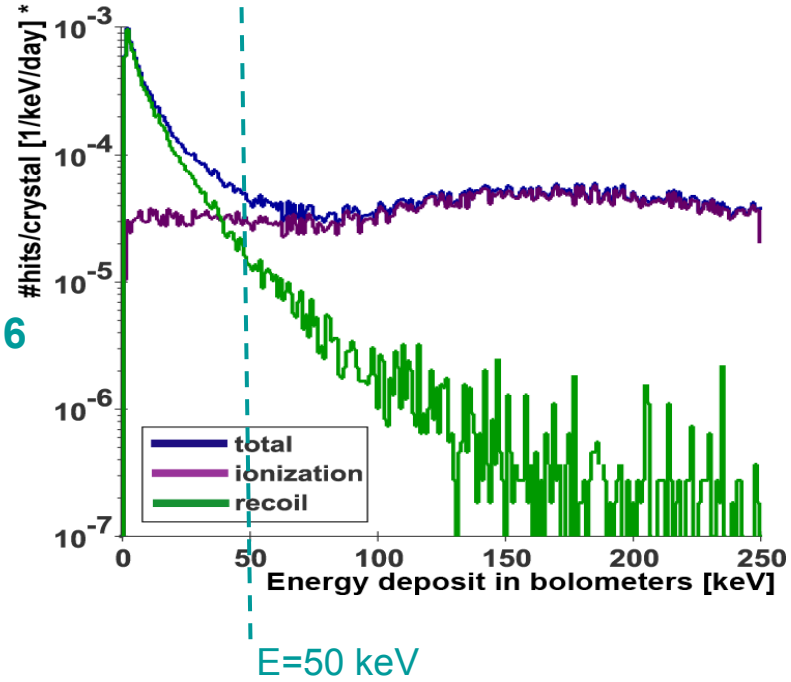
| | $E_{recoil}$ < 250 keV | $E_{recoil}$ > 250 keV |
|---|---|---|
| measured events | 16 | 28 |
| expected accidentals | 3.7 ± 0.2 | 2.9 ± 0.2 |
| excess coincidences | 12.3 ± 4.2 | 25.1 ± 5.5 |
| signal/background | 3.3 ± 1.4 | 8.7 ± 2.4 |

**Expected from Geant4 simulation:**
**~0.03 events/kg.d**

**Measured:**
**0.04 events/kg.d**

# Bolo - μ-veto coincidences: μ-induced n´s?



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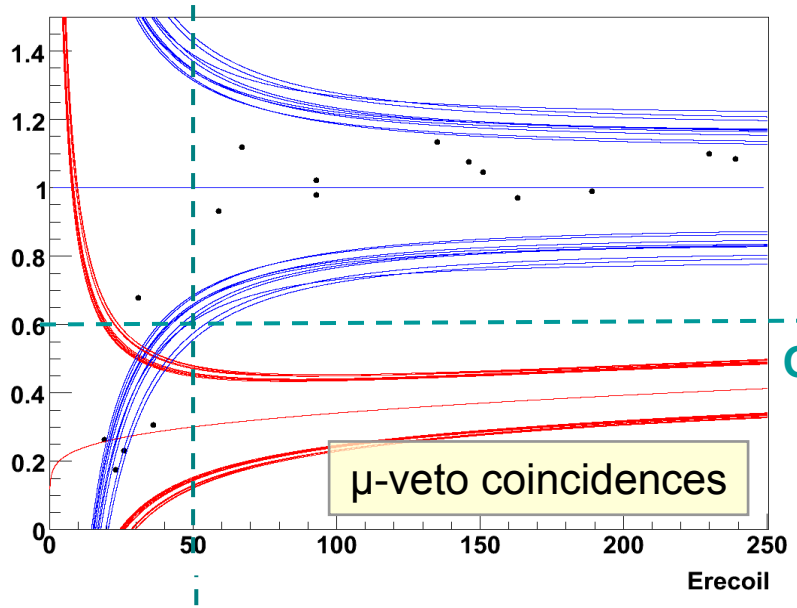
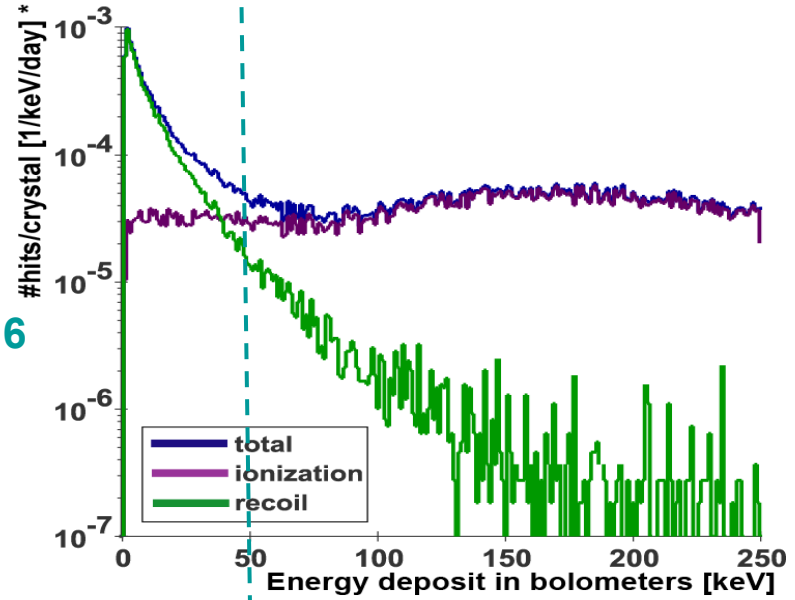
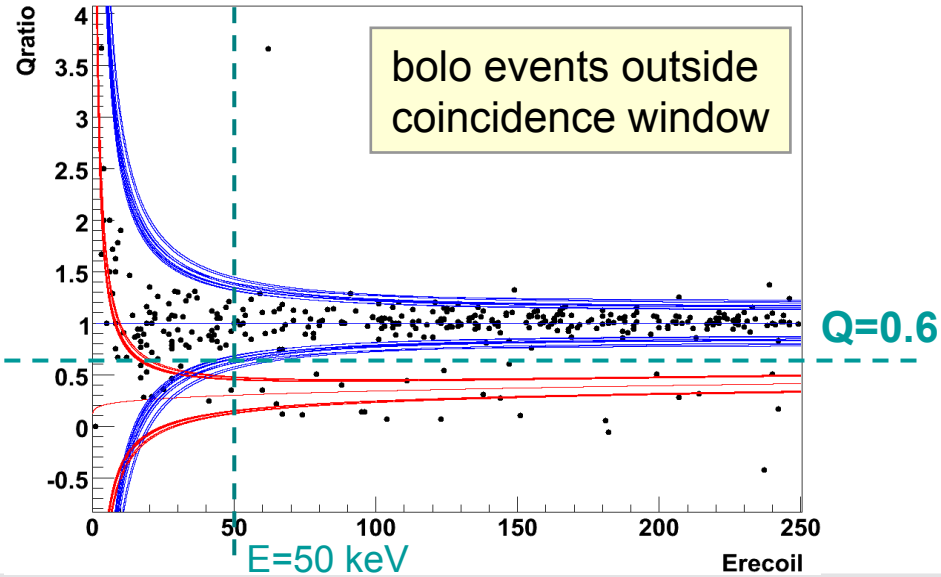


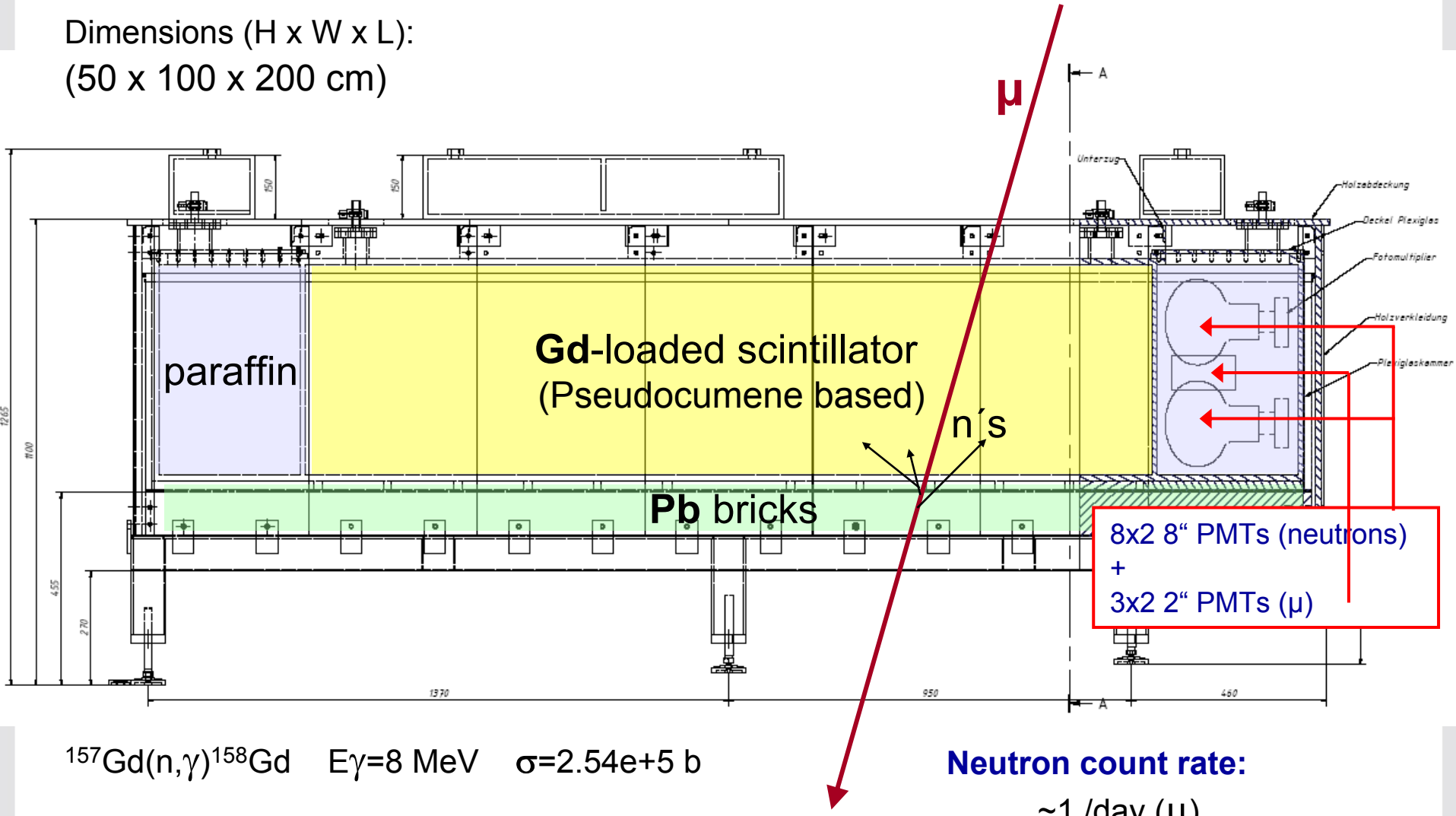




=> most likely!

# Neutron counter (NC) principle

Dimensions (H x W x L):
(50 x 100 x 200 cm)




$^{157}Gd(n,\gamma)^{158}Gd$ $E\gamma$=8 MeV $\sigma$=2.54e+5 b

**Signature:** μ-**n** coincidence or multiple **n**‘s

**Neutron count rate:**

~1 /day (μ),
~8000 /day (radioactivity)

# Neutron co

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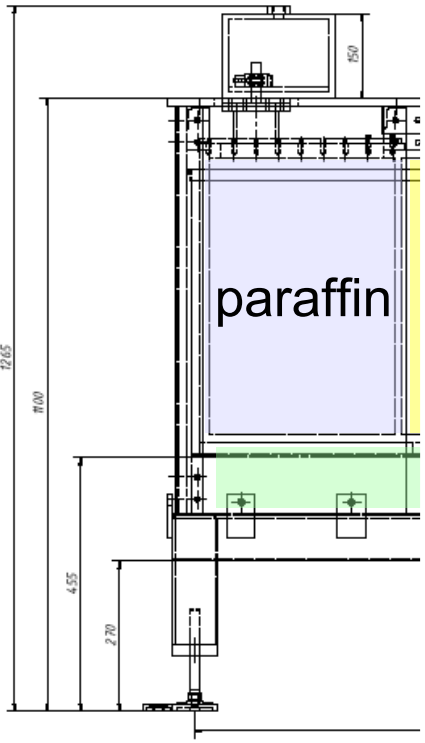
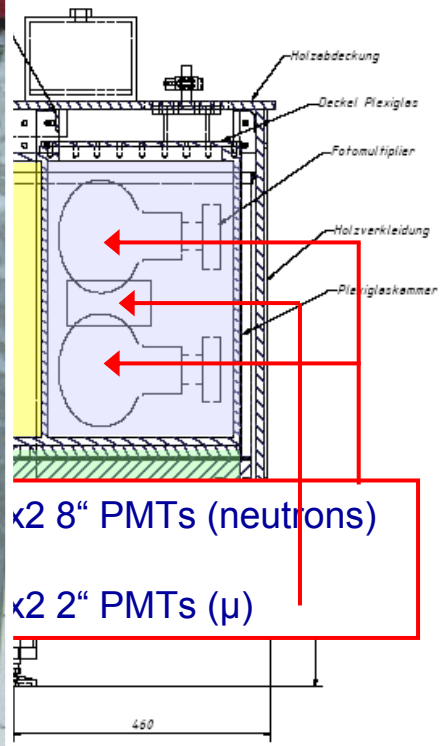
(50 x 100 x 200








x2 8“ PMTs (neutrons)

x2 2“ PMTs (μ)

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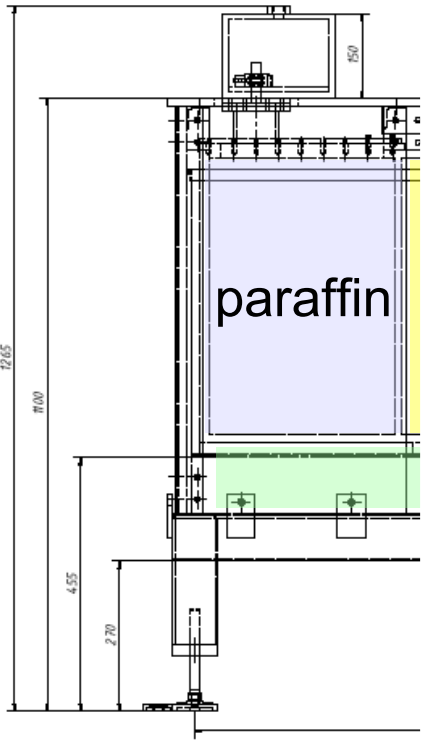



$^{157}Gd(n,\gamma)^{158}Gd$

**Signature:** μ-n

Installed: Sep 2008
Data taking: Nov 2008 - ...

**Data-taking,**

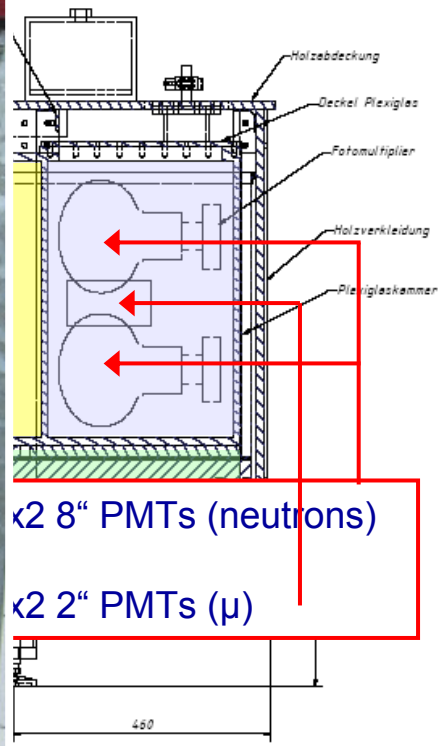
**AmBe, 60Co calibration runs,**

**LED control,**

**Data analysis:**
**-> first neutrons are seen,**

**Simulations**

**are ongoing ...**

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x2 2“ PMTs (μ)

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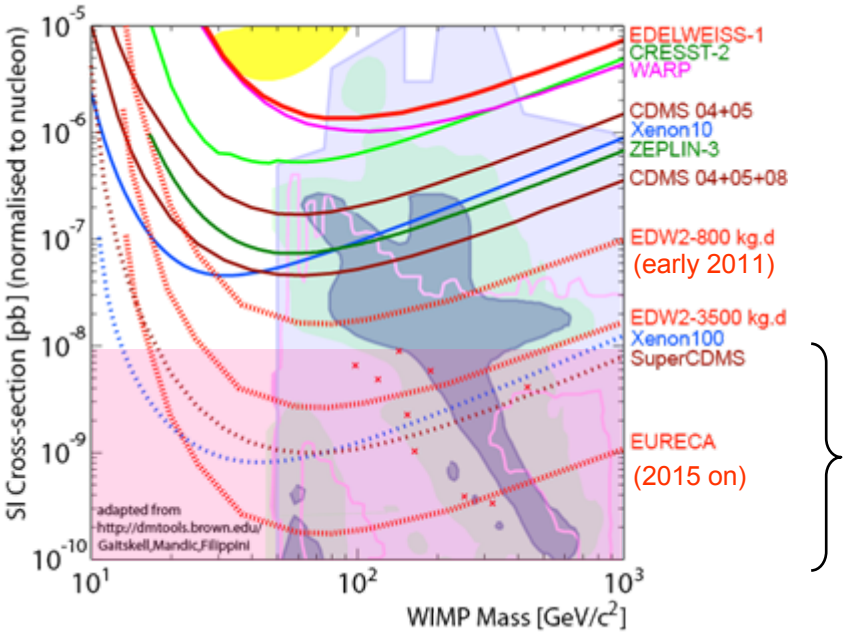
/day (radioactivity)

# EURECA, LSM extension





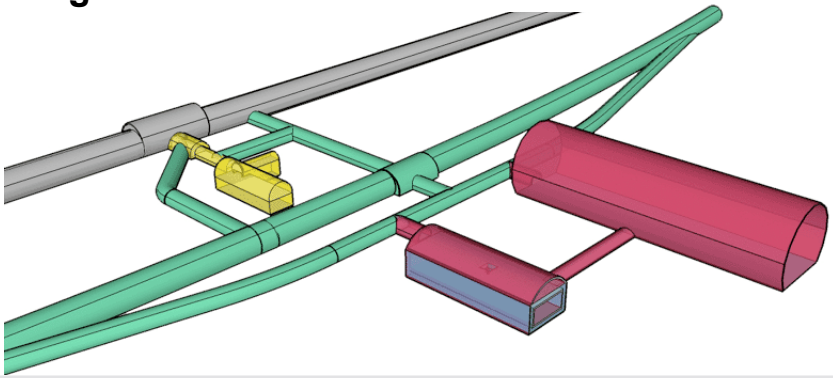
# To probe $10^{-8} \div 10^{-10}$ pb;
# 100 kg - 1 ton Cryo detector;
# ~$10^{-5}$ evts / (kg day)

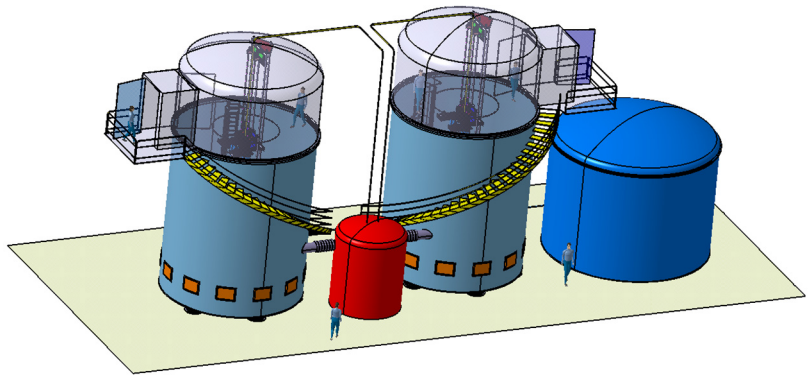
# CRESST + EDELWEISS
+ ROSEBUD + CERN + ... ;

ASPERA

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

**Fréjus road safety tunnel: approved!**
**=> good chance for LSM extention!**





# Summary

EDELWEISS II:

- ✓ Scientific goal is **$10^{-8}$ pb**;
- ✓ New ID detectors:

  # Significantly better event selection: $\gamma$ / $e^-$ / surface (**$4x10^{-8}$ pb** expected by 2010);

  # Robust fabrication and operation;
- ✓ Control of muons;
- ✓ Neutron background studies.

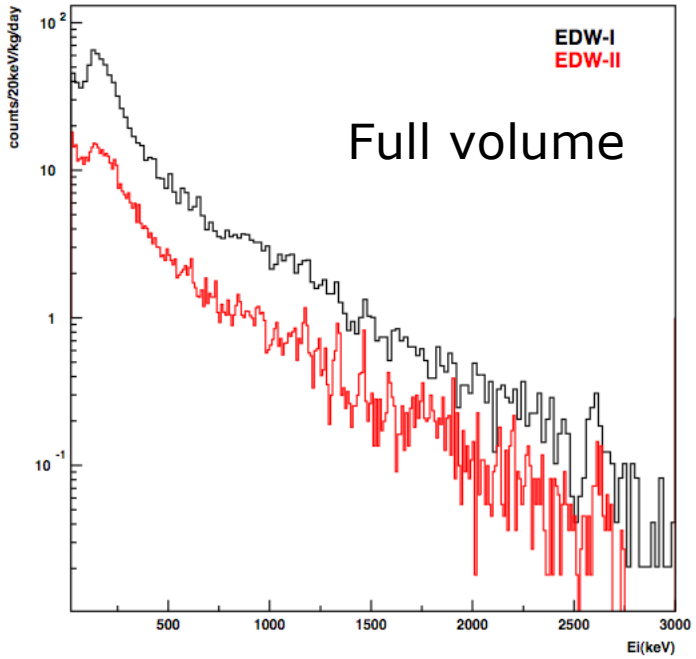
=> Road to 1 ton experiment, EURECA

# Additional slides

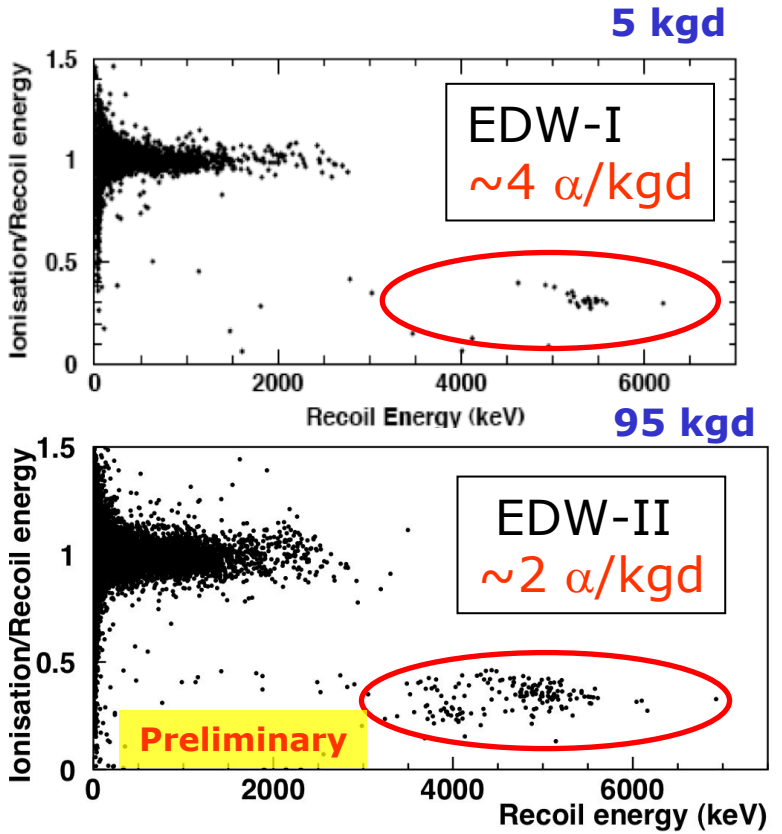
# ADDITIONAL SLIDES

# GeNTD data: improved background

- Gamma background reduction of **x3** relative to EDELWEISS-I
- $^{210}$Pb-chain background: reduction of **x2** relative to EDELWEISS-I

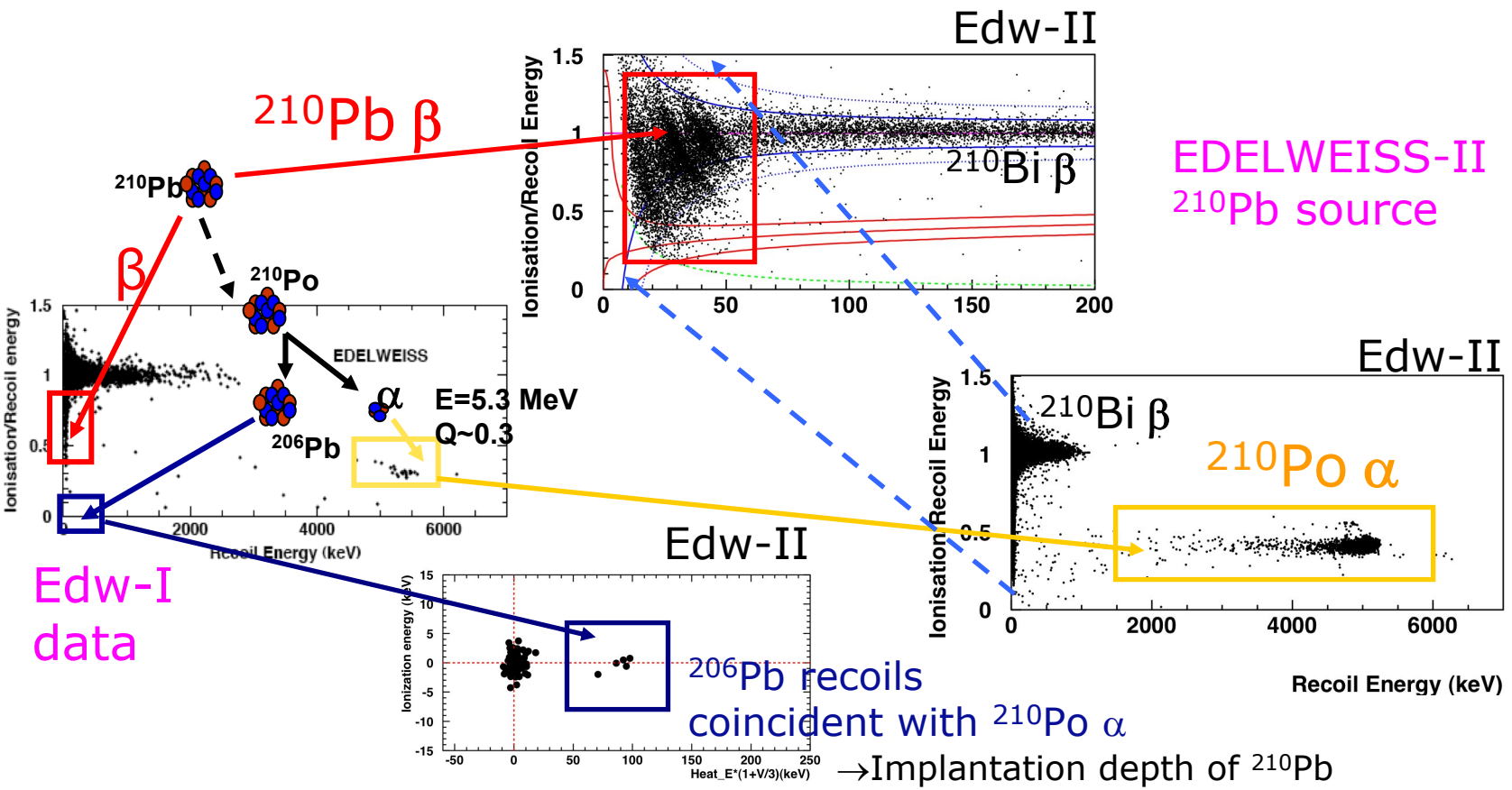



Further bkg reductions after fiducial + coincidence cuts, and in ID



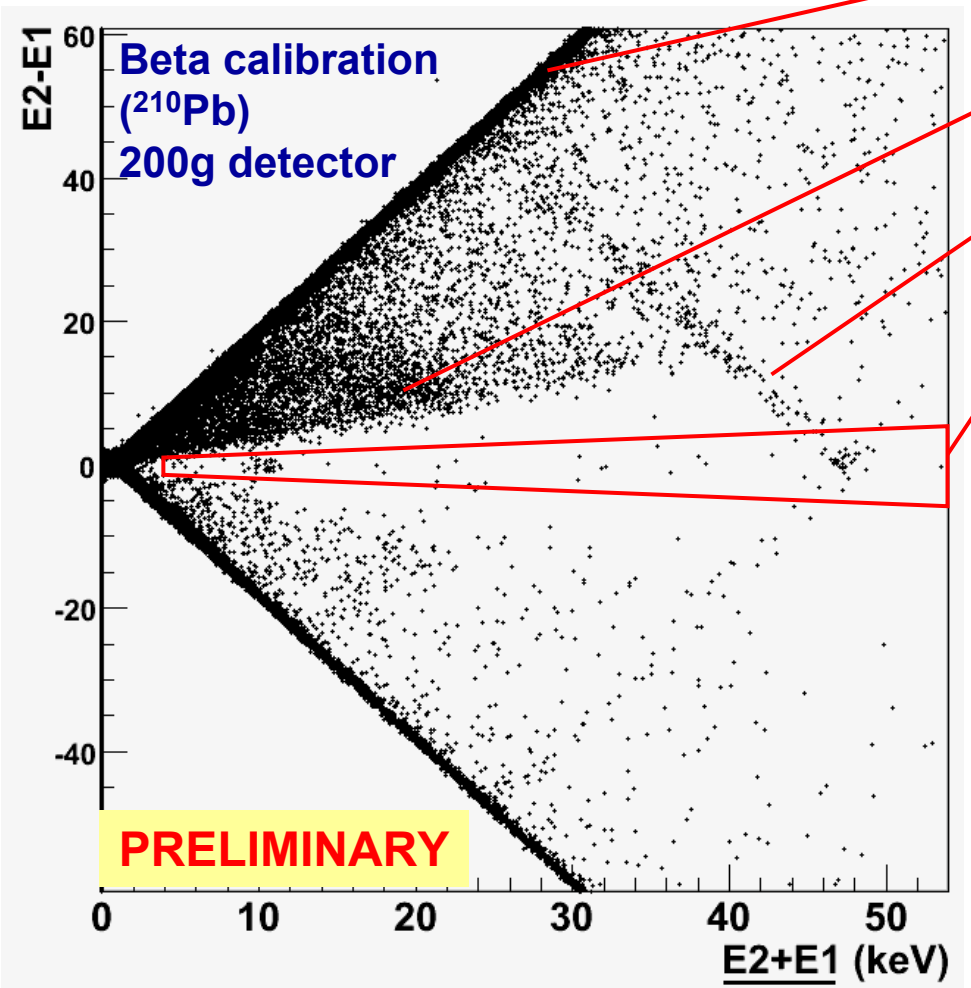
# EDELWEISS-II $^{210}$Pb source calibration

- Confirms interpretation of EDW-I bkg as $^{210}$Pb surface β.
- Response of detectors to this important background



# An outstanding surface event discrimination with IDs

*E1 = energy of top collecting electrode*
*E2 = bottom collecting electrode*




«single-side» surface events : *E1=0*

«3-electrode» surface events

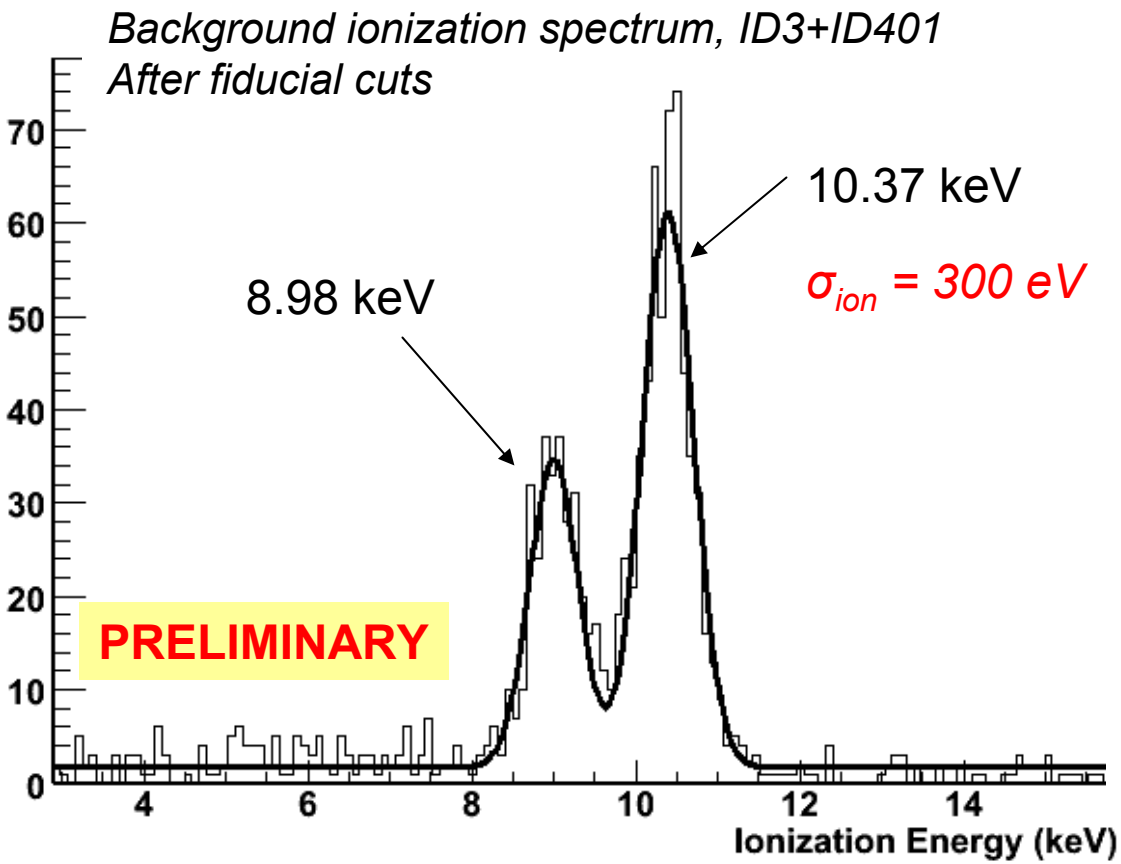
46 keV gamma-ray line

fiducial volume events : *E1 = E2*

- *A combination of cuts is made on the 4 signals of electrodes*
- *Example presented here : cut on the difference of signals between 2 collecting electrodes*

- Surface and volume events are completely separated !
- From β calibration : overall rejection ~ $1/10^5$

# Ionization resolution of IDs



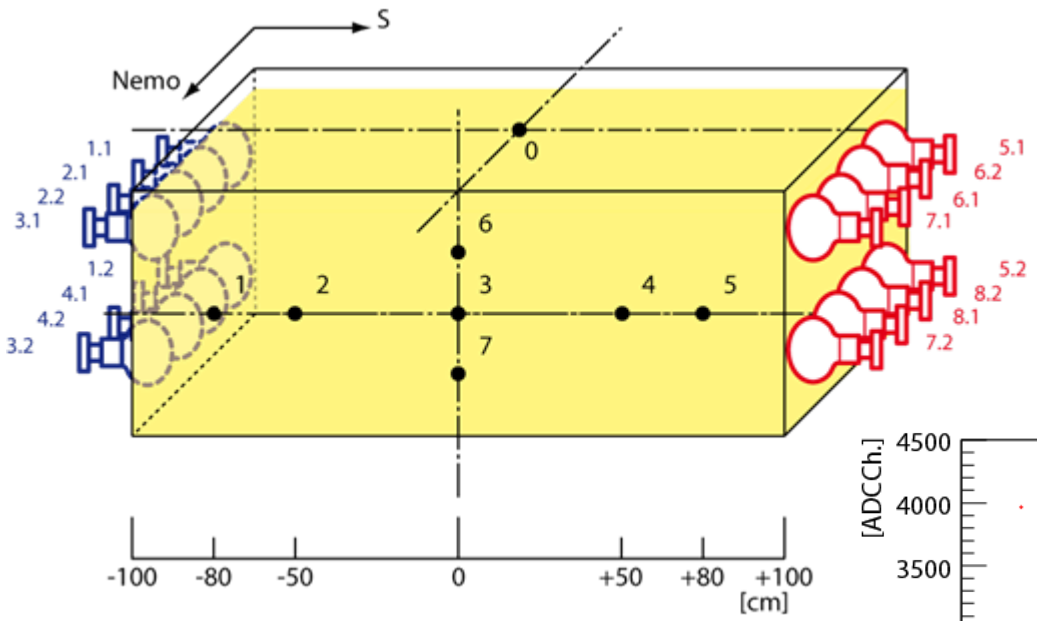

• Ionization resolution important to get a good recoil threshold

• Approx. ~ 20 kg.d of background data with two 400g detectors (2008 data)

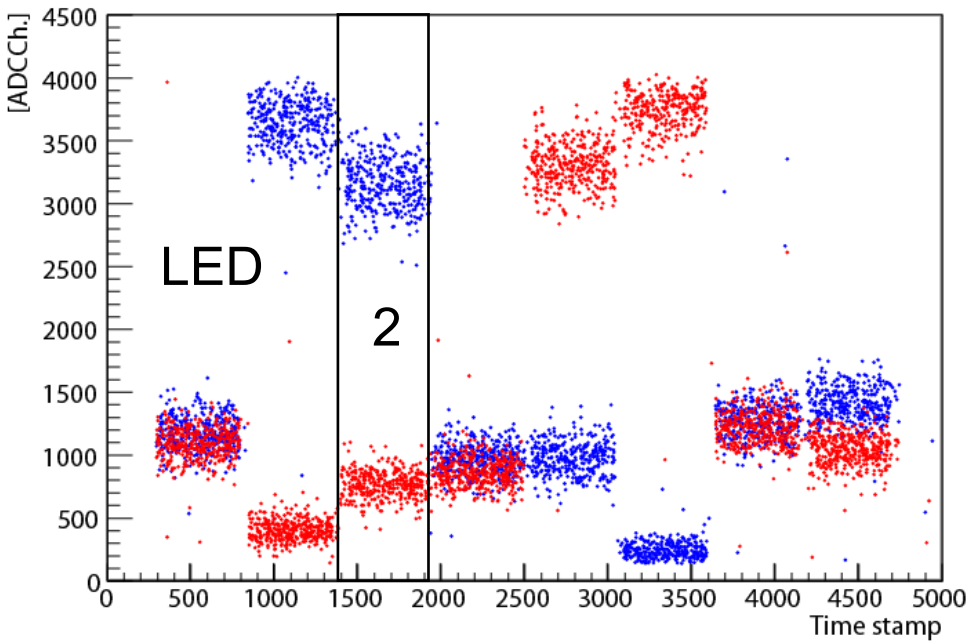
• Background dominated by the cosmogenic lines at ~10keV

• Good and stable energy resolution

# LED monitoring of scintillator: basics

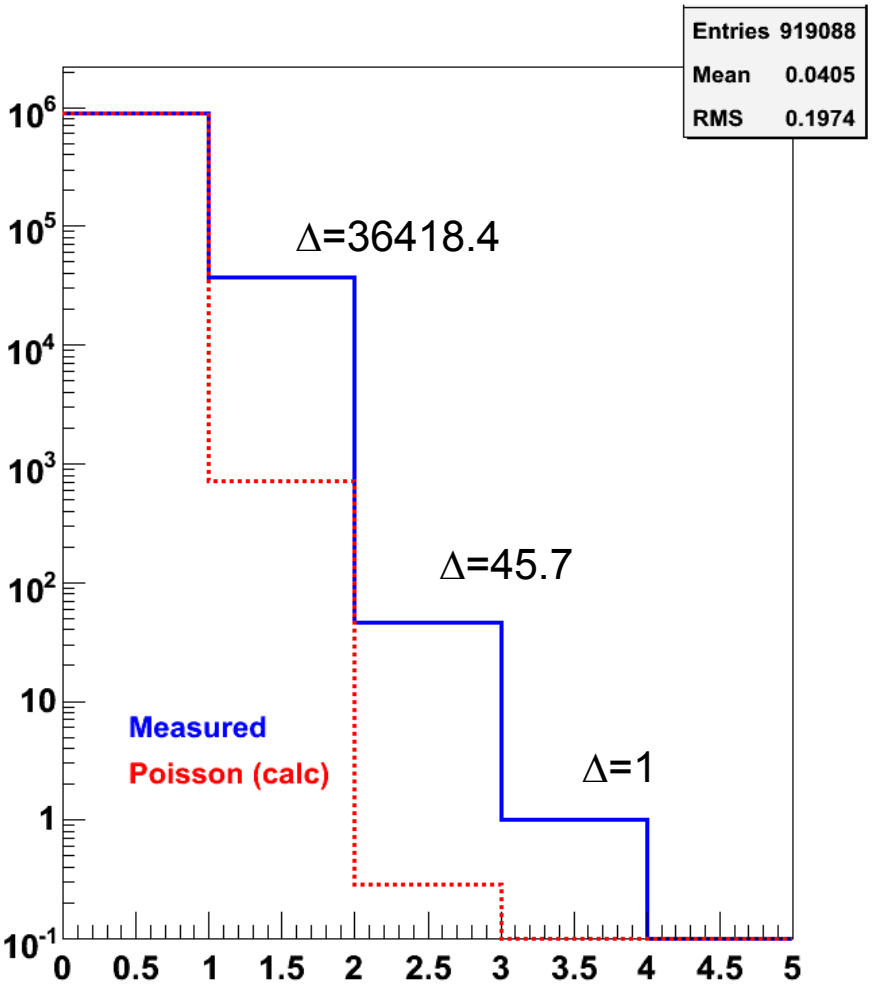



ratio r = near PMT / distant PMT
→ indicator scintillator stability




Using ns light pulser to simulate scintillation light
→signal source for monitoring

# AmBe neutron measurement: secondaries




- Neutron source ~20 n/s,
- $T_{DAQ}$=53.4 μs
- ~17 hours

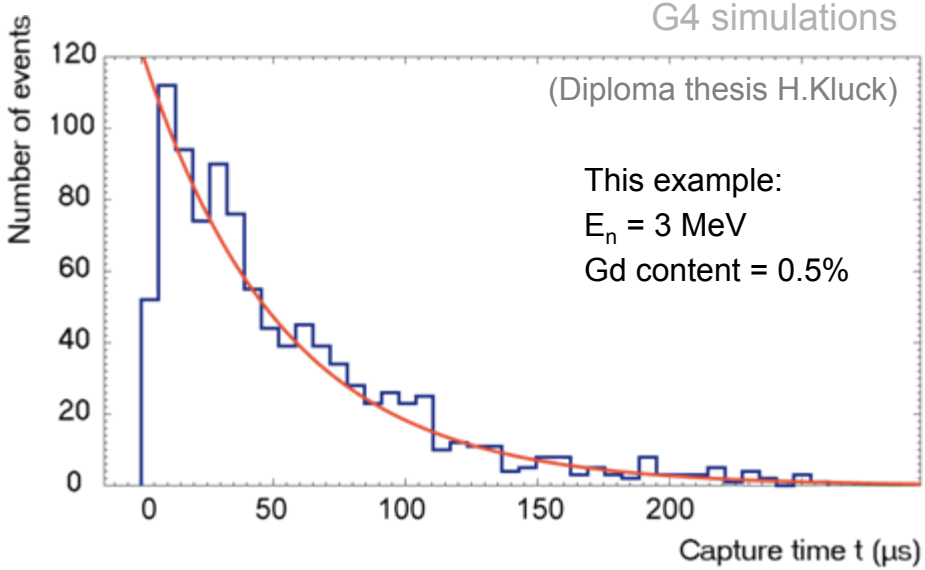
(Δt>1000 ns to avoid PMT after-pulses)

# AmBe neutron measurement: $\Delta t_{sec}$

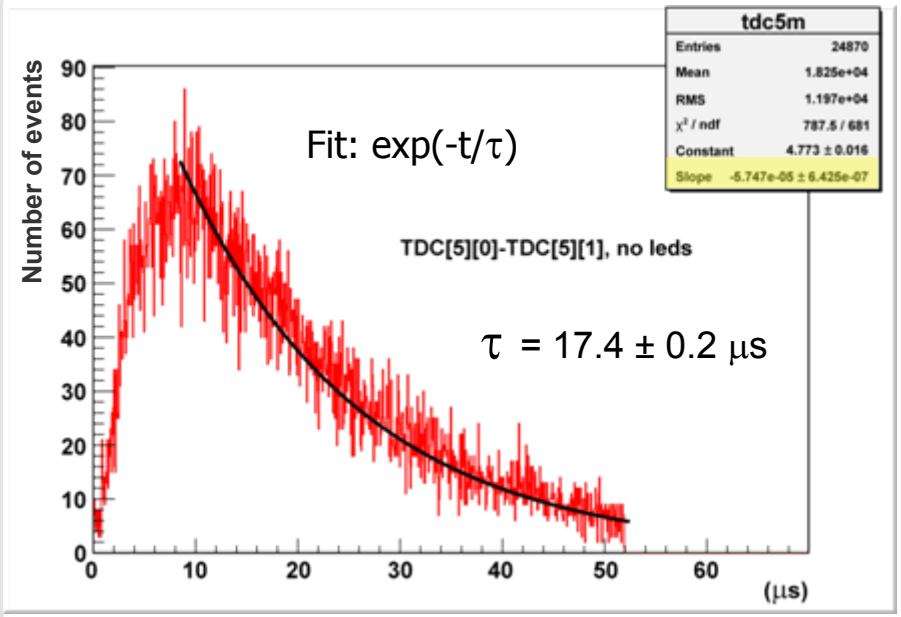
**AmBe** source: ~20 n/s

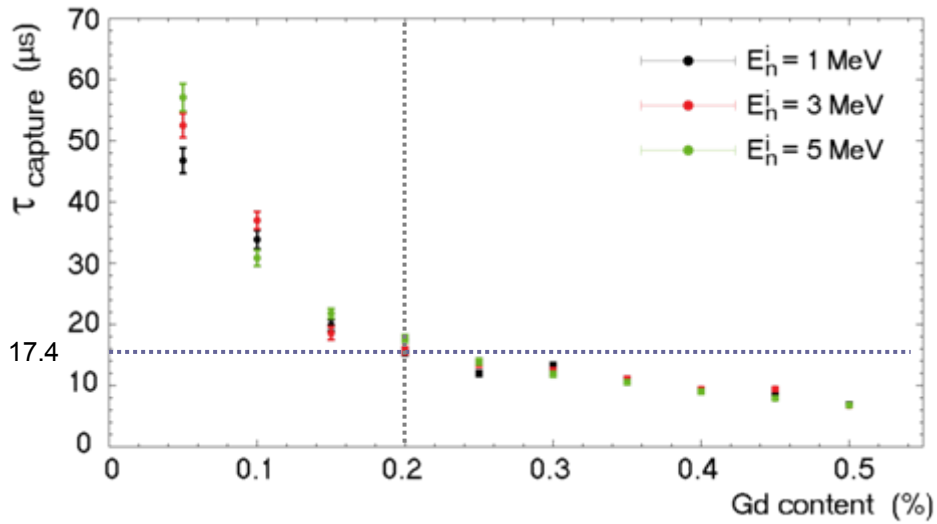
$E_n$ up to ~11 MeV, max. 3 MeV

G4 simulations

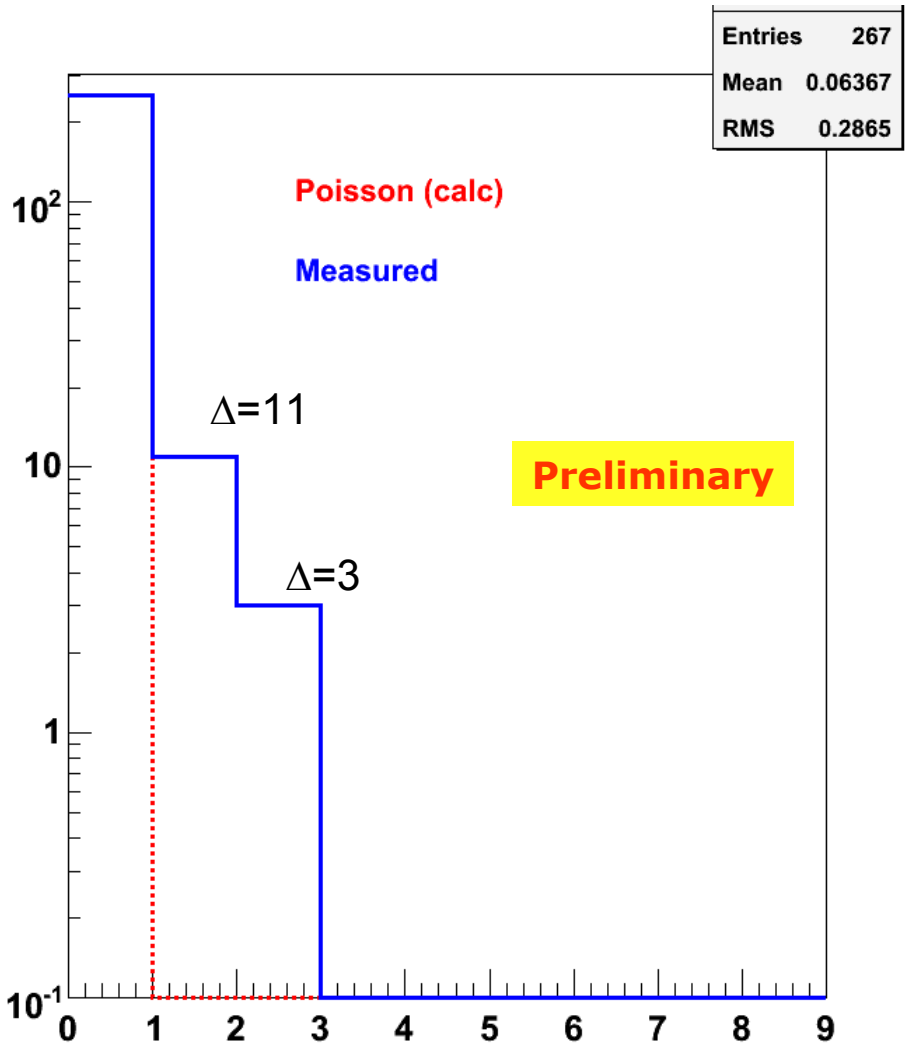


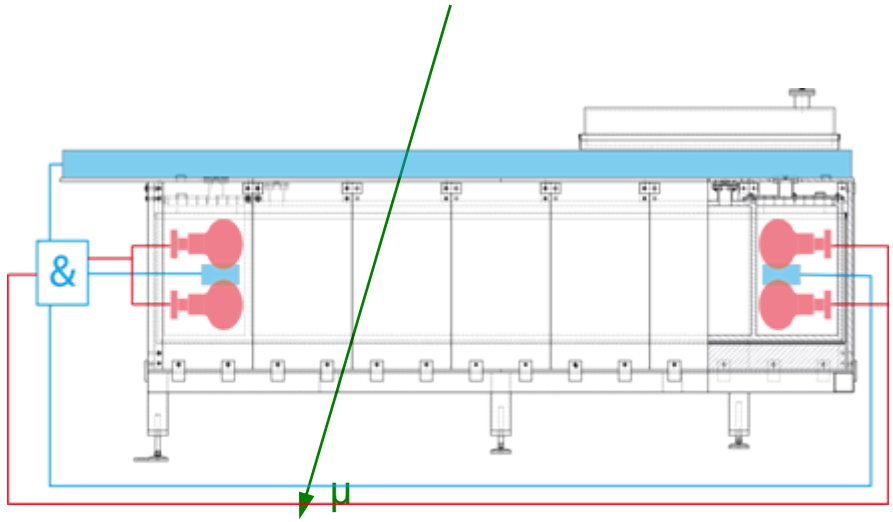

Measurement



# Coincidence with μ-veto system: secondaries

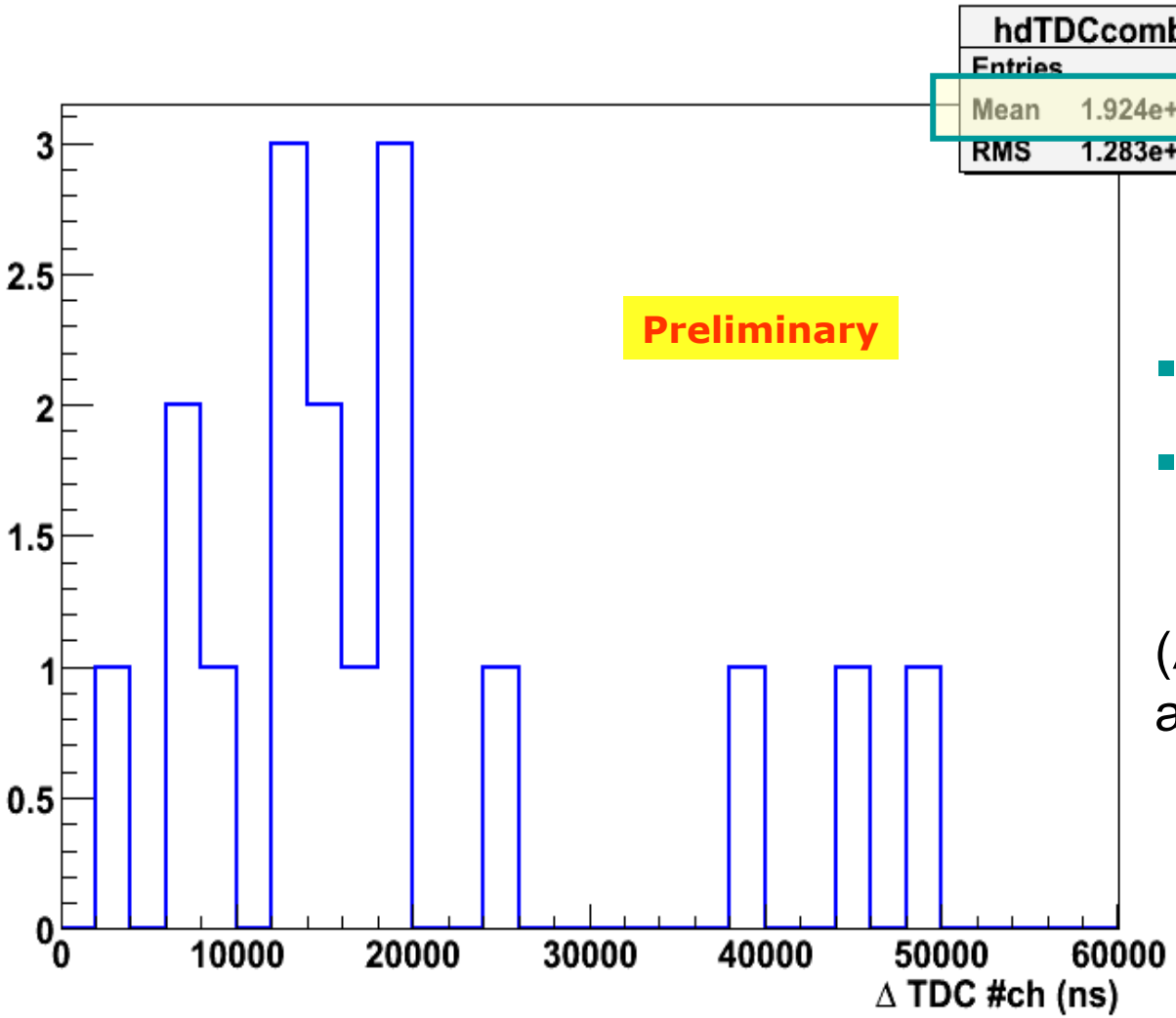



- Coincidence between μ-Veto and neutron counter
- $T_{DAQ}$=53.4 μs
- ~51 days

(Δt>200 ns to avoid PMT after-pulses)

# Coincidence with μ-veto system: $\Delta t_{sec}$




- $<\Delta t_{sec}(AmBe)>$ = 18.3μs
- ~51 days

(Δt>200 ns to avoid PMT after-pulses)

**→Candidates for μ induced n's!**