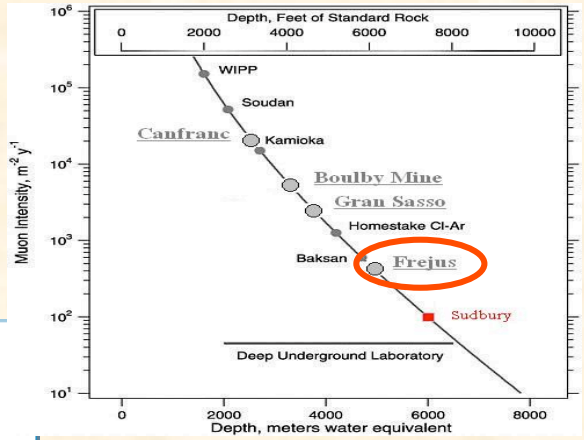
EDELWEISS-II

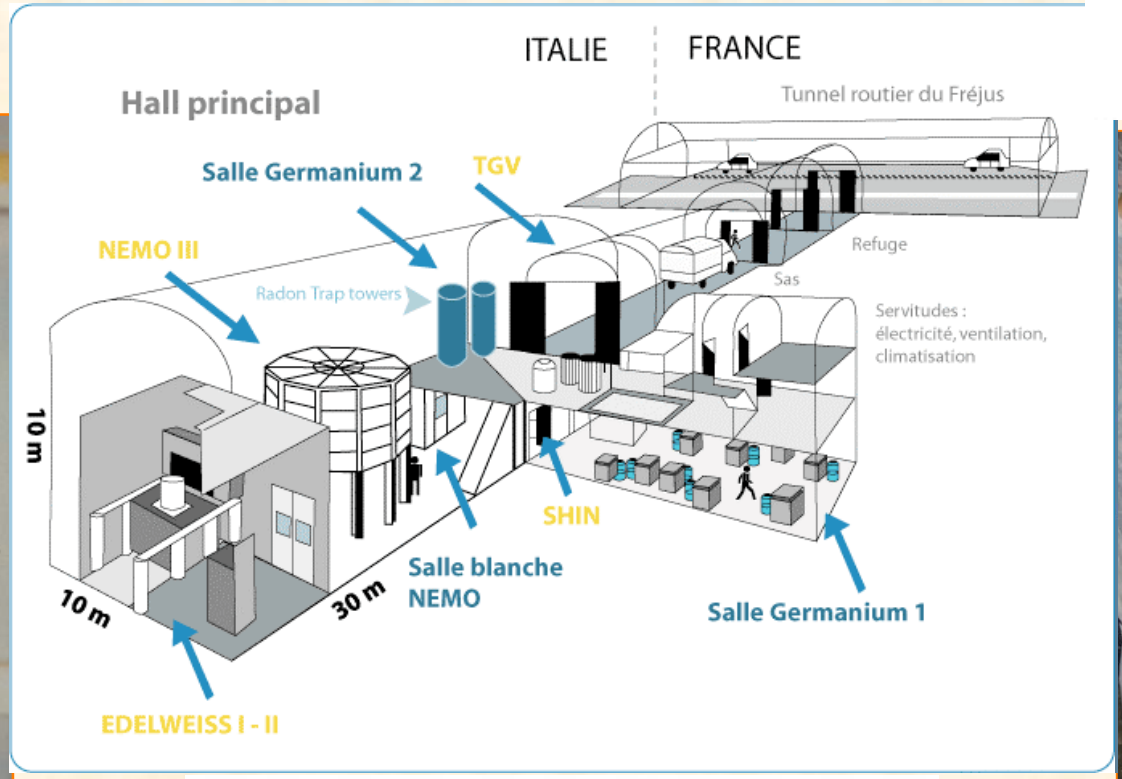
-EDW I reminder
-current status and future of EDWII
-short report on DAMNED
-few words on EURECA

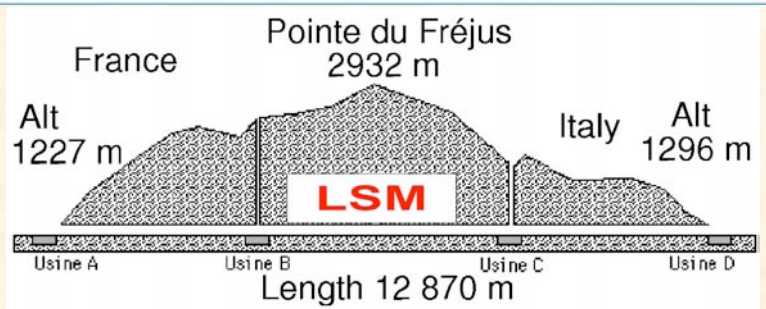
Hunt for Dark Matter, Fermilab may 10th 2007

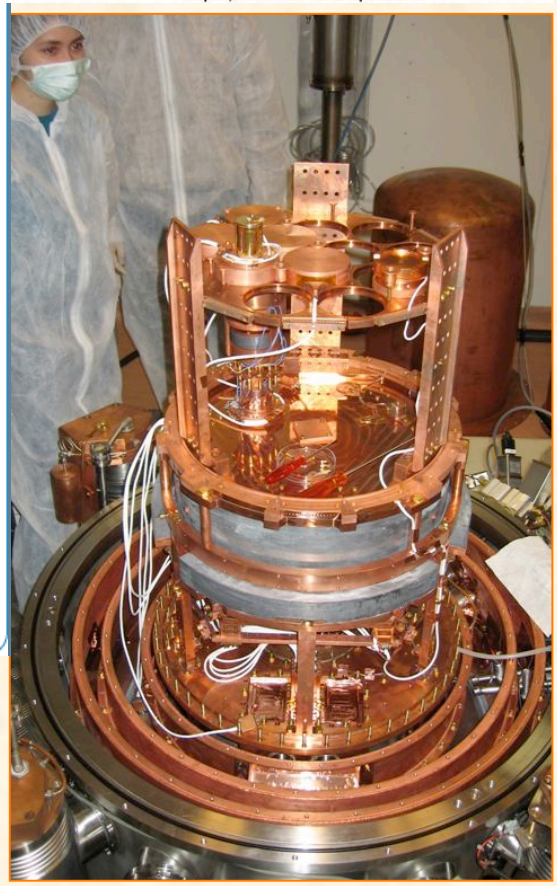
Gilles Gerbier
DAPNIA/SPP

EDELWEISS @ LSM (Frejus lab)









EDW I => 2004

EDW II 2007 =>

EDELWEISS Collaboration

♦ **CEA Saclay (DAPNIA & DRECAM)** **Detectors, electronics, acquisition, background, analysis,**

SPP : E. Armengaud, O. Besida, G. Chardin, **G. Gerbier**, (L. Shoeffel, A de Lesquen, L Mosca) SEDI : H. Deschamps, M. Fesquet, M. Gros, S. Hervé, M. Karolak, X-F. Navick, B. Paul, SPEC : (M. Chapellier), P.Pari,

Temporary contributions SEDI/SIS : M. Carty, T. Chaleil, P. Lotrus; F. Nizery, J.L. Ritou, F. Senée

Post-doc/ATER : R. Lemrani, F. Schwamm *Thesis : E. Grémion, A. Chantelauze (cotutelle FZK)*

♦ **CSNSM Orsay** **Detectors, cabling, cryogenics, analysis**

L. Berge, A. Broniatowski, D. Carré, S. Collin, L. Dumoulin, A. Juillard, F. Lalu, S. Marnieros

Post-doc/ATER : Emilano Olivieri *Thesis : O. Crauste, X. Defay, Y. Dolgorouki, C. Nones*

♦ **IPN Lyon** **Electronics, background, analysis, detectors**

F. Charlieux, M. De Jésus, P. Di Stefano, J. Gascon, M. Stern, V. Sanglard, L. Vagneron

Post-doc/ATER : *Thesis : M. Luca, S. Scorza*

♦ **IAP Paris** **Low radioactivity, analysis**

C. Goldbach, G. Nollez

♦ **CRTBT Grenoble** **Cryogenics, electronics**

A. Benoit, M. Caussignac, H. Rodenas

♦ **FZ/ Universität Karlsruhe** **Vetos, background**

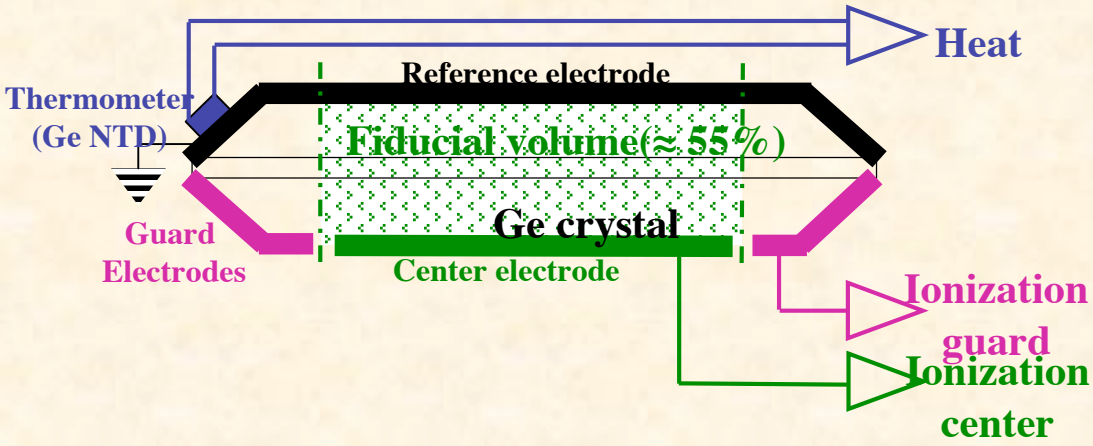
J. Blümer, K. Eitel, H. Kluck *Thesis : M. Horn, A. Chantelauze (cotutelle FZK)*

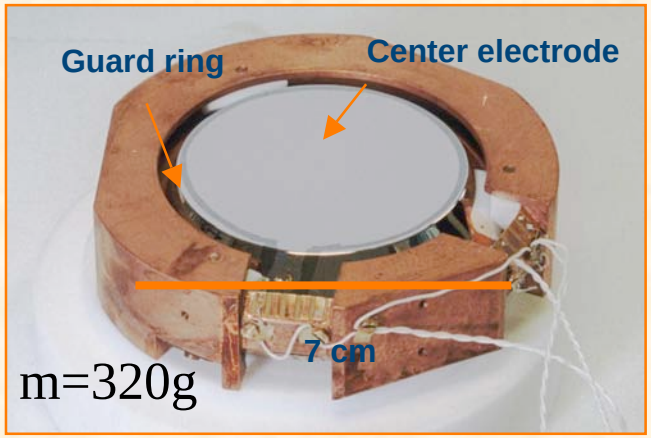
♦ **JINR Dubna** **Background**

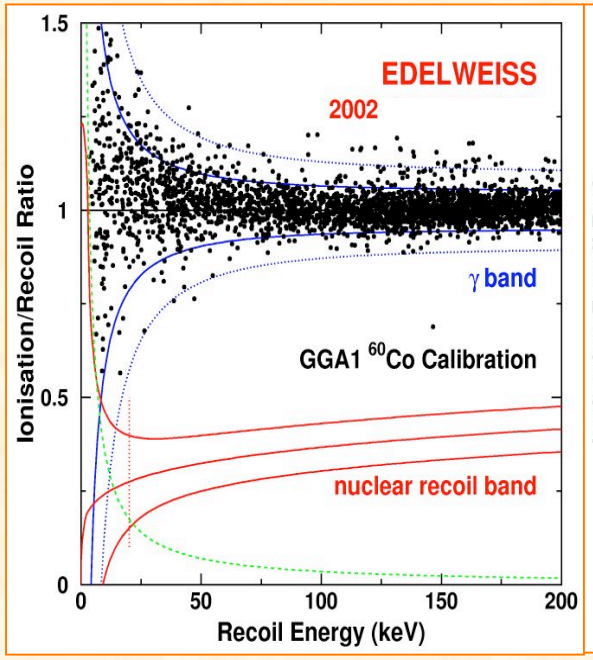
E. Yakushev, A. Smolnikov *Thesis : A. Lubashevski, L. Perevozchikov*

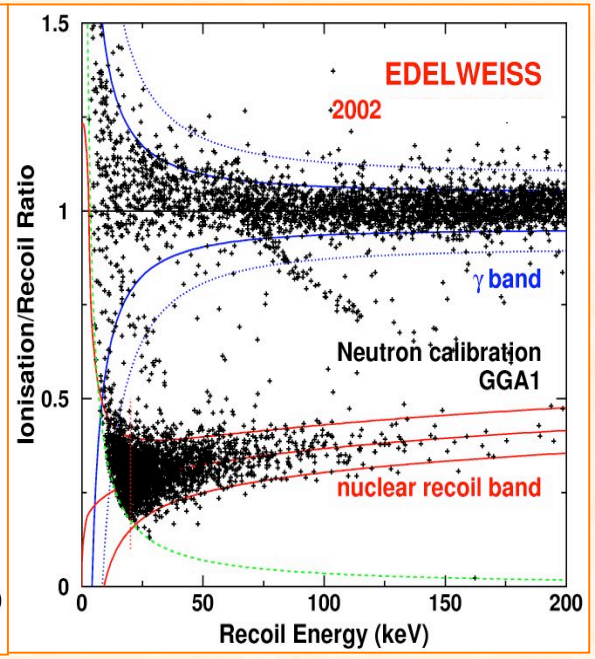
⇒ ≈ 55 persons (35 FTE), 11 thesis, 3 post-docs

EDELWEISS-I Ge NTD Heat and ionization detector







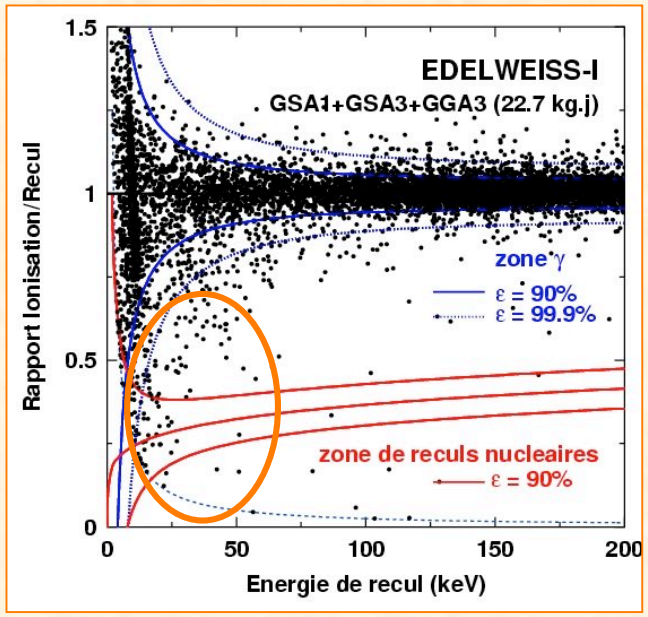


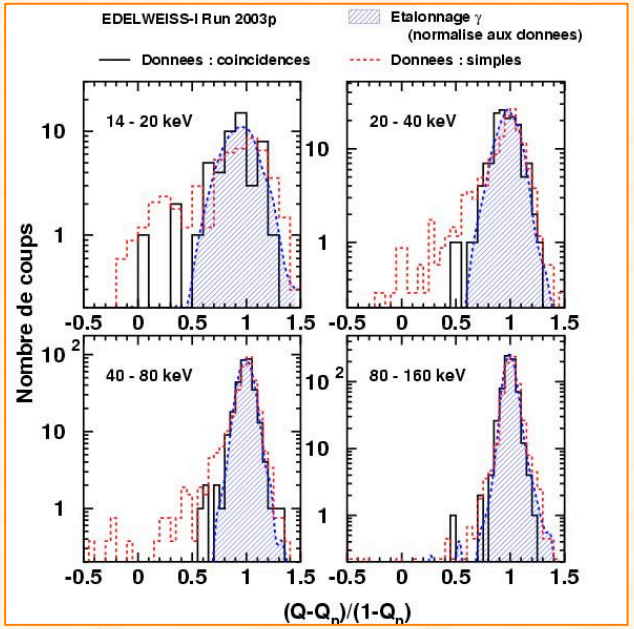
- **Simultaneous measurement**
  - **Heat** @ 17 mK with Ge/NTD thermometer
  - **Ionization** @ few V/cm with Al electrodes
- **Evt by evt identification** of the recoil
- Q=Eionization/Erecoil
  - **Q=1 for electronic recoil**
  - **Q≈0.3 nuclear recoil**

⇒ discrimination γ/n > 99.9% for Er> 15keV

EDELWEISS-I limiting background

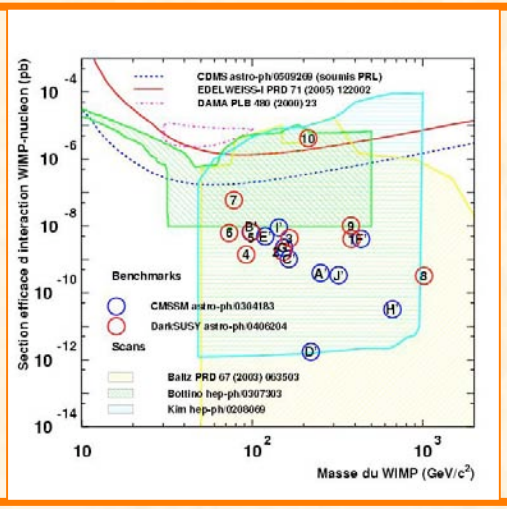
(V. Sanglard and S. Fiorruci thesis)





- **Background in the physics data taking**
- **Leakage down to the recoil band…**

+ Yellin =>



- **Neutrons** : 2 events expected (MC),
  - 1 n-n coincidence observed
- **Surface electrons recoils** :
  - bad charge collection (trapping and recombination)

- Not visible on coincidence events
- **Evidence of Radon contamination :**
  - α rate ≈ e- rate ≈ ions recoils ≈ **5/kg.day**

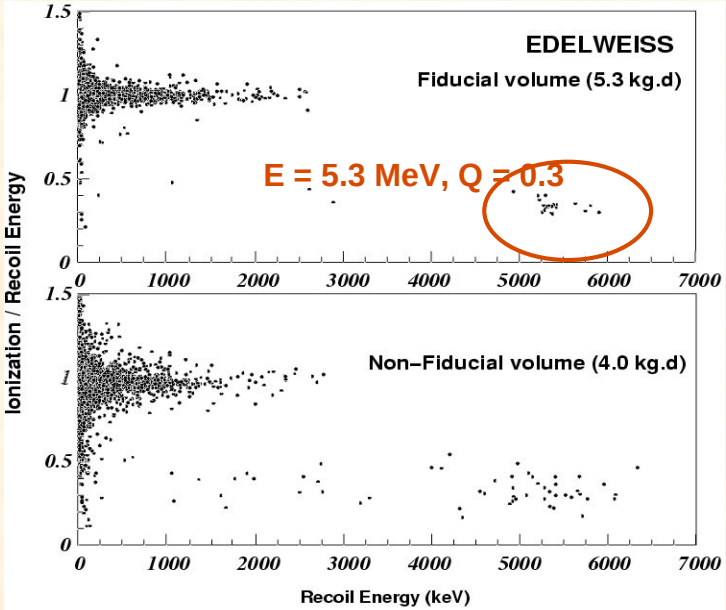
Surface background interpretation in EDELWEISS I

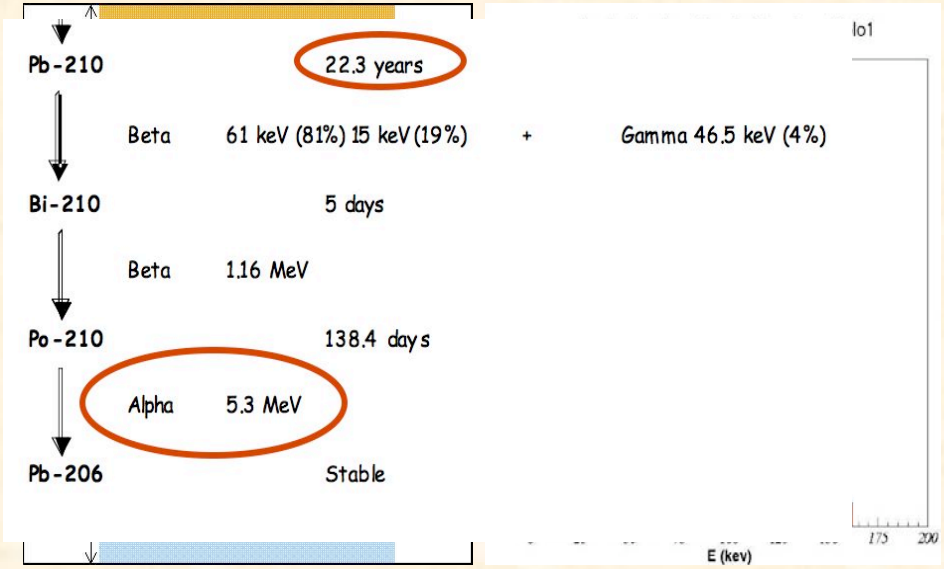
- Peak at E=5.3 MeV and Q~0.3 (400/m^2/d)
  → surface α's from ^{210}Po

- No ^{206}Pb recoil peak at 100 keV (observed as heat-only events)
  →suggest ^{210}Pb implanted in Cu, not Ge.

- **Rate of surface β's consistent with ^{210}Pb hypothesis**
  - but does not exclude possible contribution from ^{14}C

→ Plan to remove Cu covers between detectors





EDELWEISS-II in few words

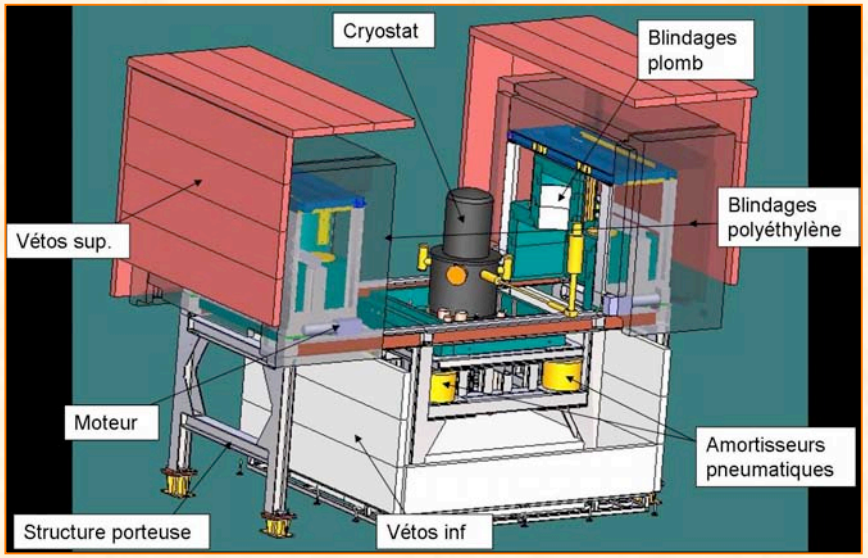
- Go to Edelweiss II, with 30 kg (100) with a milestone @ 10 kg (30)

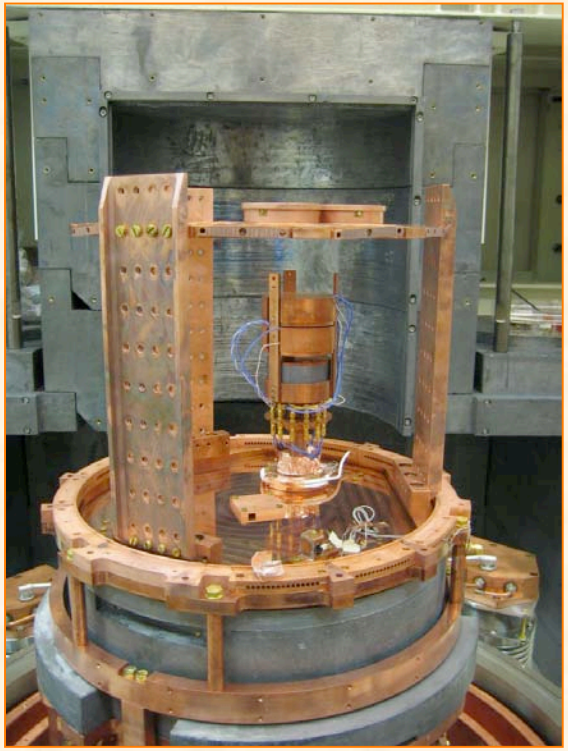
- Preliminary studies started 1999
- **Implantation in the LSM started summer 2004**
- ≈ 3.8 MEuros equipments (for the 1st funded stage of 28 detectors)

- First cryogenic test with bolometers jan 2006
- **8 bolometers** operated for debugging up to end feb 2007
- Now 28 bolometers operated
- **In // R&D for passive and active rejection**

- **Goal *100 in sensitivity : $\sigma_{w\text{-}n} \approx 10^{-8}$ pb (phase 100)**
- R&D for EURECA (**$\sigma_{w\text{-}n} \approx 10^{-10}$ pb)**

Improvements : Backgrounds



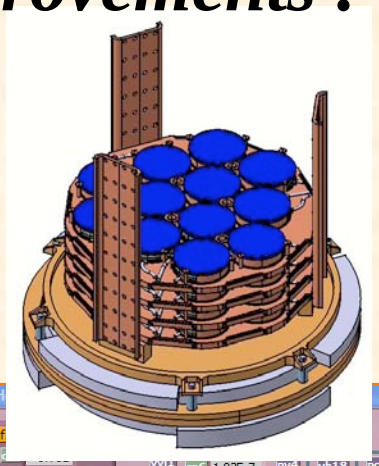


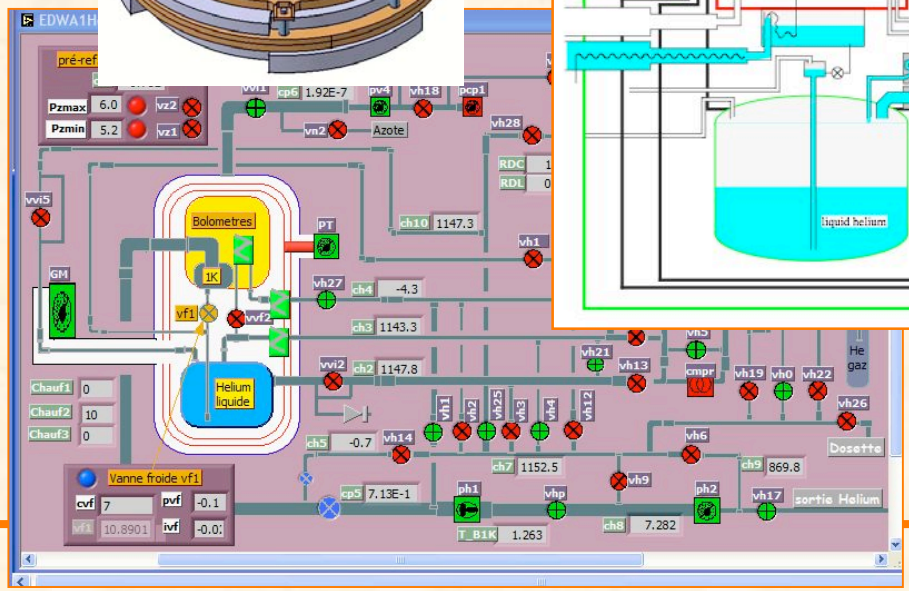
- **Radiopurity**
  - Dedicated HPGe detectors for systematic checks of all materials
  - **Clean Room** (class 100 around the cryostat, class 10 000 for the full shielding
  - **Deradonized air** (from NEMO3 radon trap)
  - 20 cm Pb shieding
- **Neutron Shielding**
  - EDW-I : 30cm paraffin
  - EDW-II : **50 cm PE** and better coverage
- **μ veto** (>98% coverage)
  - Neutron detectors in coincidence with veto under development (Karlsruhe/Dubna)

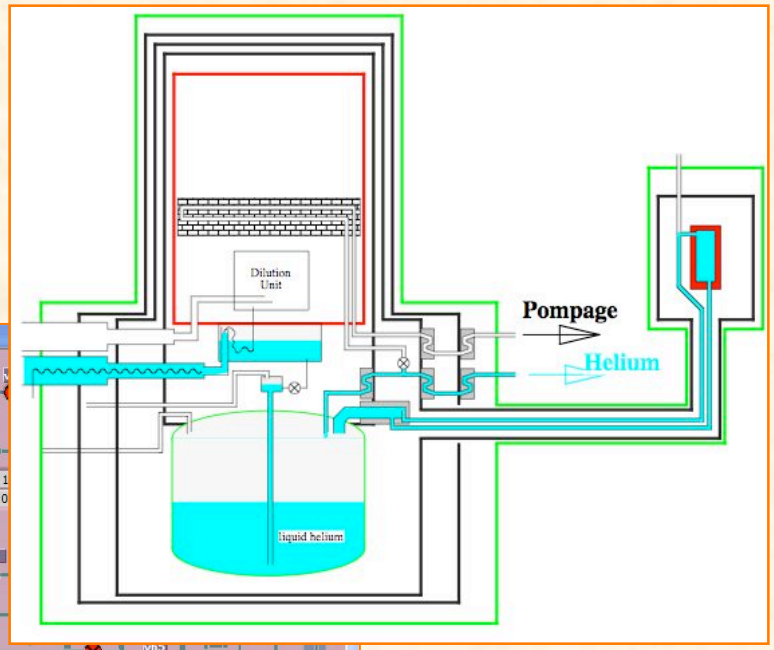
- =>**Expected sensitivity (EDW-I * 100)**
  $\sigma_{w-n} \approx 10^{-8}$ pb (phase 100)
  0.002 evt/kg/day (Er>10keV)
  = neutron coming from high energy μ interacting in the rock

Installation

Improvements : Cryostat

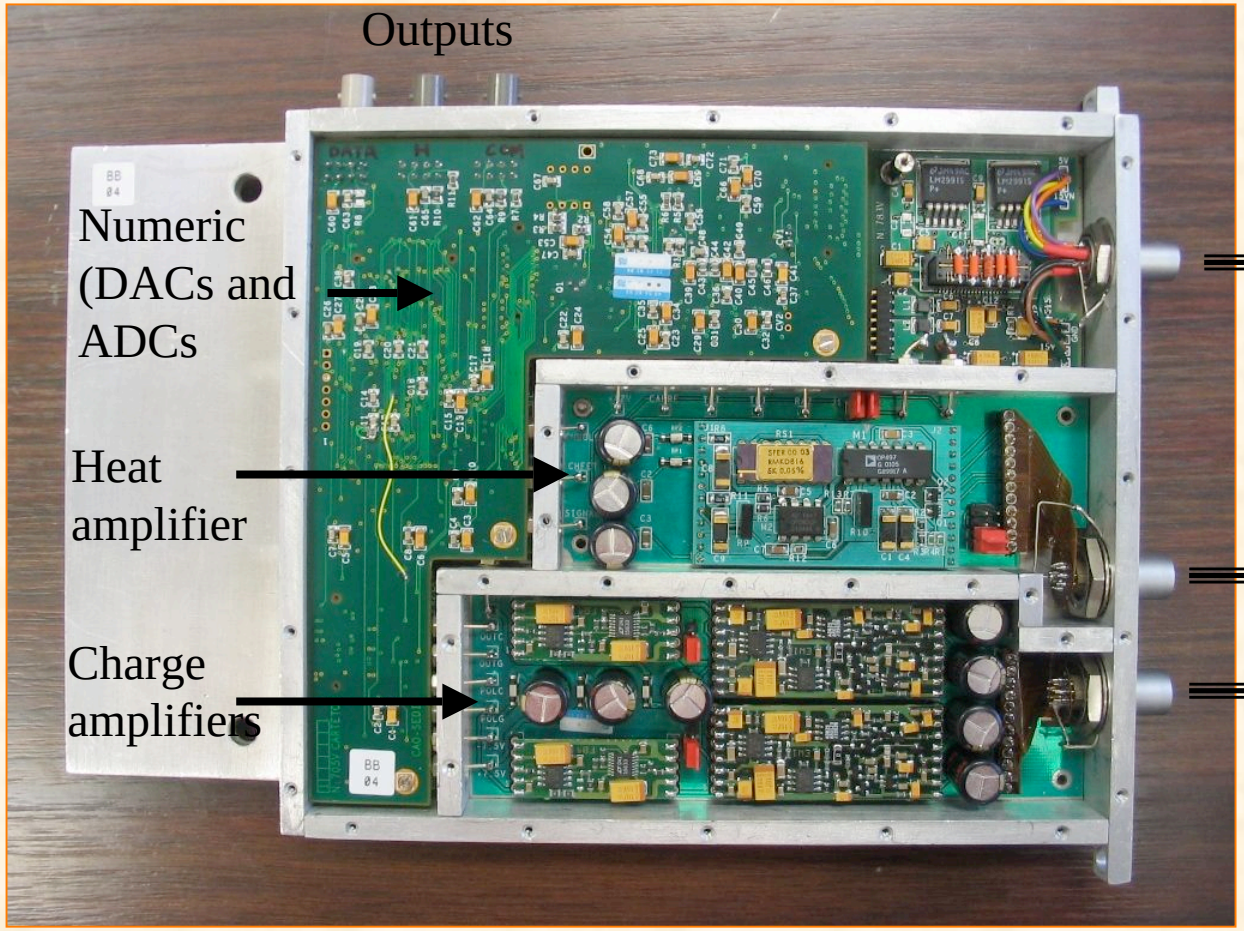






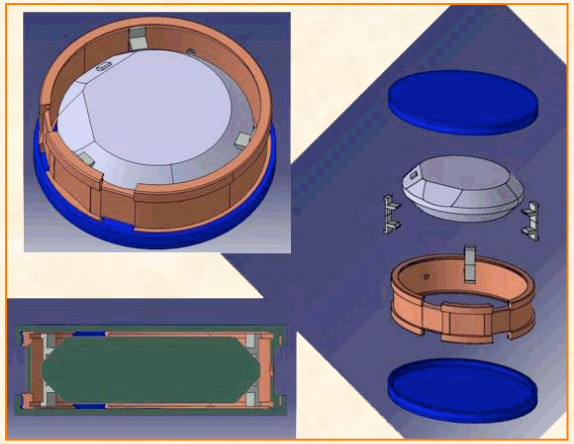
- ♦ Reversed geometry
- ♦ Nitrogen free : 3 Pulse tube (50K and 80K screens) and 1 He cold vapor reliquefier (consumption ≈ 0)
- ♦ large volume 50l ⇒ **Self shielding**
- ♦ **up to ≈ 120 detectors** ⇒ **More statistics**
- ♦ Compact and hexagonal arrangement ⇒ **More coincidence (n bkg)**
- ♦ **Cryostat fully controlled by automate**

Improvements : electronics



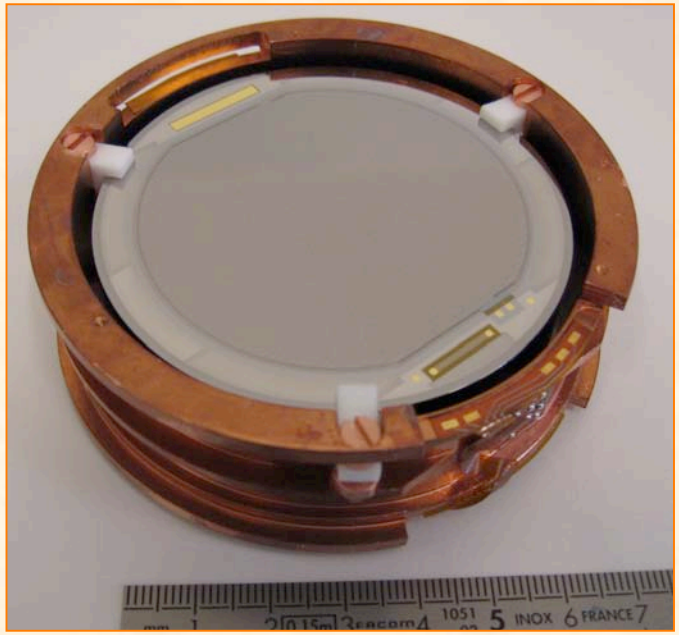
- Bolometer Boxes developed by CEA and IN2P3, plugged directly on the cryostat
- **Heat modulation and charge bias by programmable DACs**
- **Continuous** 100 kHz **digitization**, output by optical fibers

Improvements : detectors : status @ march 2007



23*320g Ge/NTD installed

- Developed by CEA Saclay and Camberra-Eurisys
- Amorphous Ge and Si sublayer (**better charge collection for surface events**)
- Optimized NTD size and homogeneous working T (16-18 mK) : **keV resolution**
- New holder and connectors (Teflon and copper only)



- 7*400g Ge/NbSi detectors = goal

- Developped by CSNSM Orsay
- 2 NbSi thin films thermometer for **active surface events rejection**
- Still under R&D with 200g detectors in labs.

2 * 200 g mounted

+ R&D…

28 detectors installed

22 * 300 g NTD
1 * 70 g Ge73 NTD
1 scintillator/phonon det
2 200g NbSi (600Angs)
1 400 g NbSi (125 Angs)

Get rid of surface events

- Main limitation to the sensitivity : due to trapping and recombination, surface events are misscollected and **can mimic nuclear recoils**
- **Most of the EDELWEISS R&D is concentrated to this problem**

2 approaches :

- **Passive rejection :**
  - *** reduce beta emitters contamination**
    - Detectors without copper screen, coatings, reprocessed detectors
  - *** improve the charge collection for surface event (amorphous Ge/Si layer)**
    - Physics of the charge collection, trapping, surface charge, regeneration (B. Censier Thesis)
    - Physics of the Ge and Si amorphous sublayer
  - *** absorb beta's**
    - Detectors with thick electrodes

Goal *5

- **Active rejection : identification of the surface events**
  - **Pulse shape analysis of the charge signals** (but high bandwidth ⇔ low noise) localization of the event
  - **Detectors sensitive to athermal phonons ⇒ Ge/NbSi detectors (Y. Dolgorouki thesis, E. Olivieri Post-doc)**
  - **Interdigitzed electrodes (X. Defay thesis, F. Shwamm Post-doc) ANR Interdigit CSNSM-Saclay (A Broniatowski, XF Navick)**

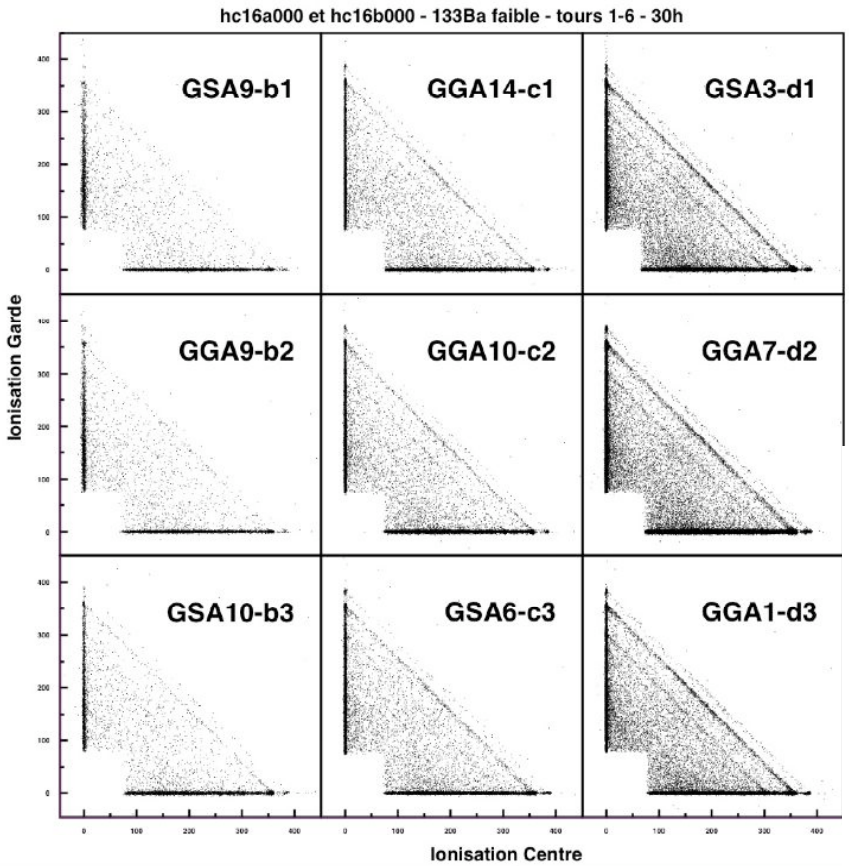
Goal *10-20

Some results from 28 bol commissioning runs (1)

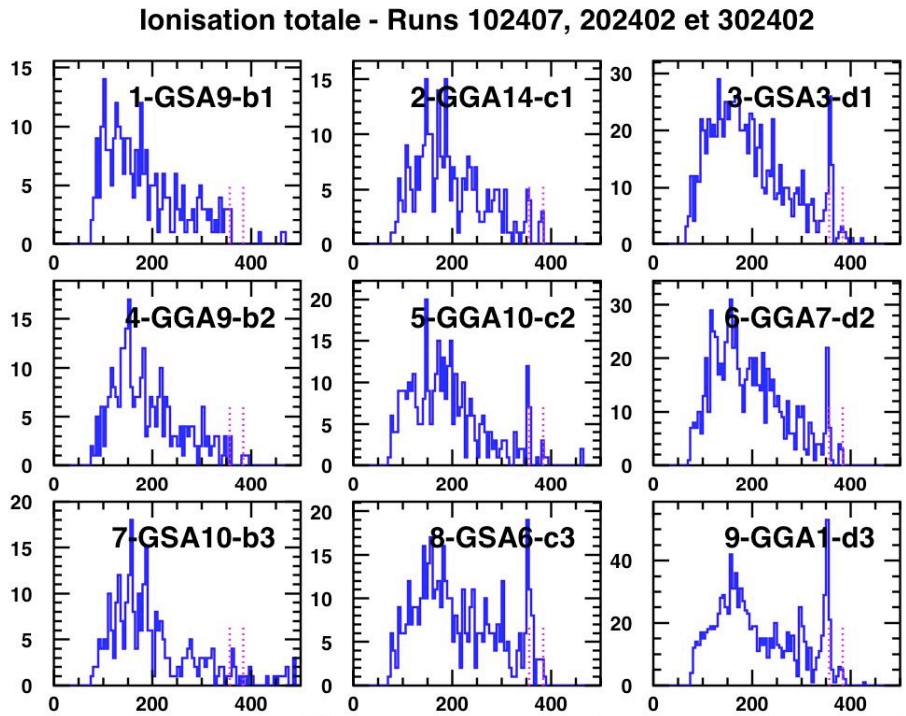
- Resolution
  - Charge : at around 2 keV (some of order 1 keV)
  - Heat : still limited by noise induced by « cold making » machines (pulse tubes, reliquefier) few keV to 5 keV (<1 keV in EDW1)
- Stability with time
  - Cryo : ok when working, but still pbs with pulse tubes
  - Noise : can be improved
- Reproducibility between detectors (NTD)
  - Out of 21 : 2/3 are ok = 3 channels with good resolutions

Calibrations with 133 Ba

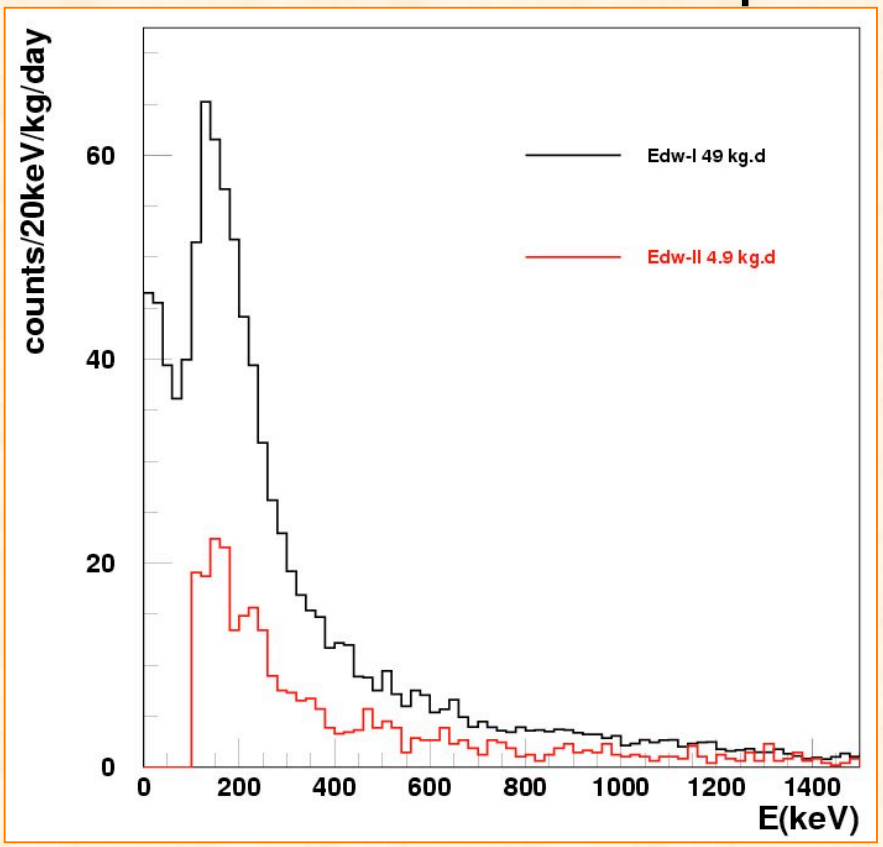
example of ionisation monitoring plot

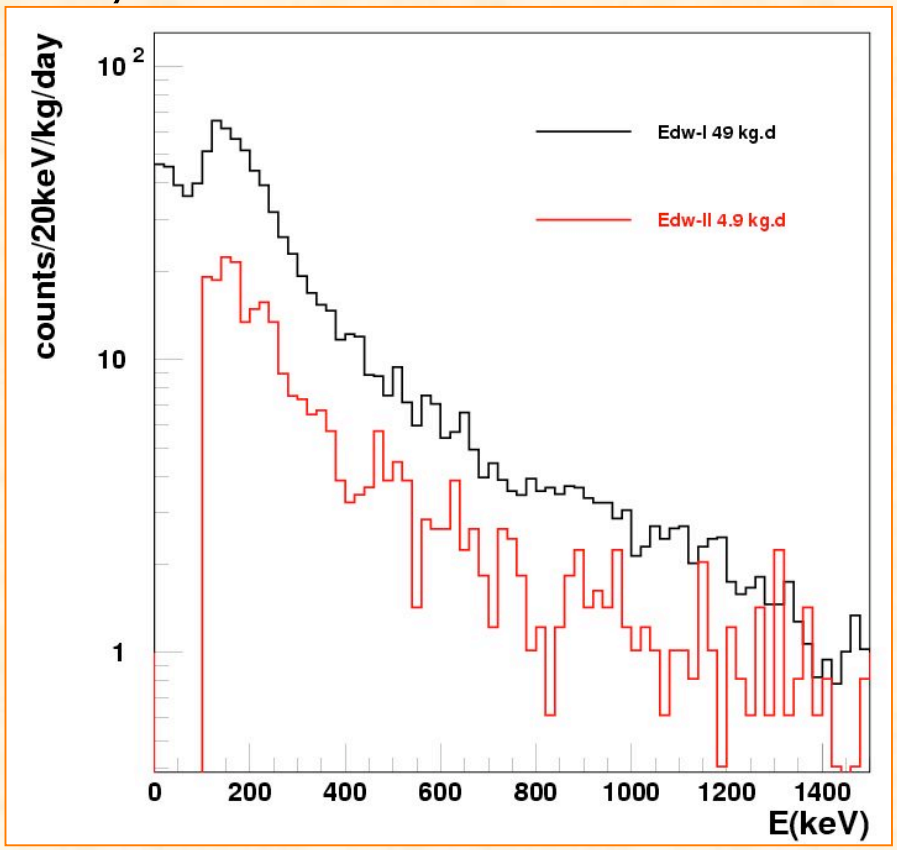


3 towers



Gamma spectrum, total rate





♦EDW-I γ rate ~ 700 evts/kg/day for E>100keV

♦EDW-II shows rates around 300 evts/kg/day for E>100keV (lowest slice has even lower values)

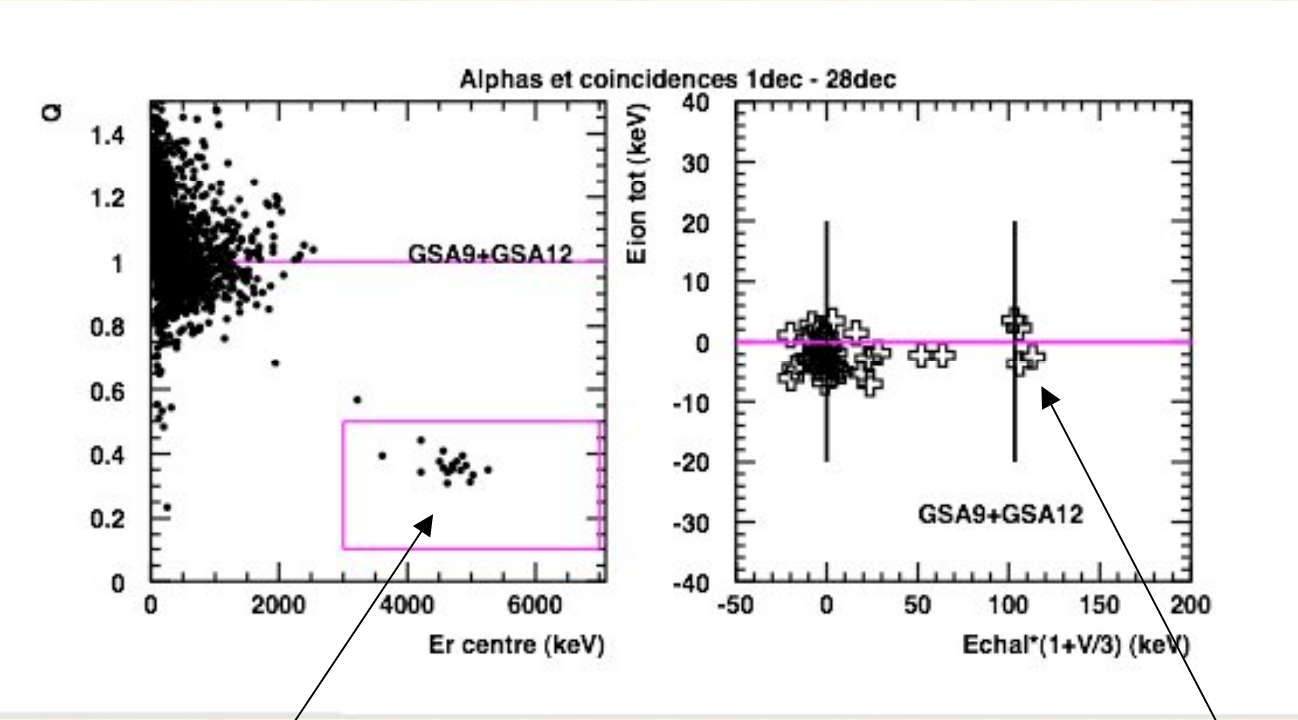
Alphas and Beta's

- Alphas = indicator of beta contamination
- First test with no copper covers
  - Observation of coincidence 206Pb recoil / 5.3 MeV alpha
  - => comparable rates to EDW1 => Ge surface and copper
- Reprocess of 2 detectors in jan 07
  - => fitted between Ge > no significant improvment
  - last 2 weeks data shows rates consistant with most contamination from Ge surface

- Beta rate (low energy)
  - data taking on going with thresholds around 10 keV with 8 detectors

Alphas from ^{210} Po decays

- Observed coincidences alpha / 206Po recoil

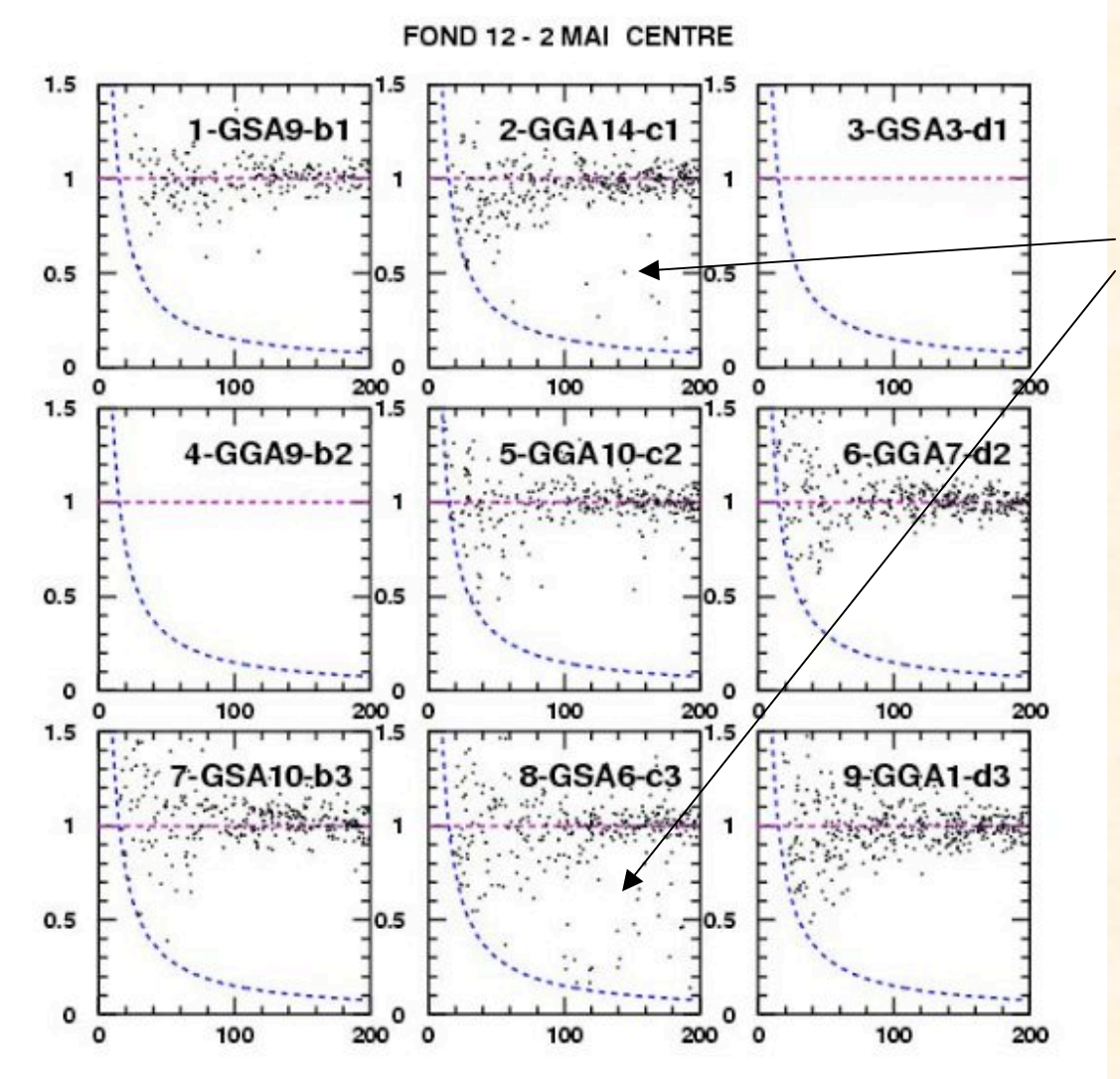


5.3 MeV alpha

100 keV recoil, no ionisation

Low energy « Q plots » : preliminary

all data, no cut on noisy periods/bad « regeneration »

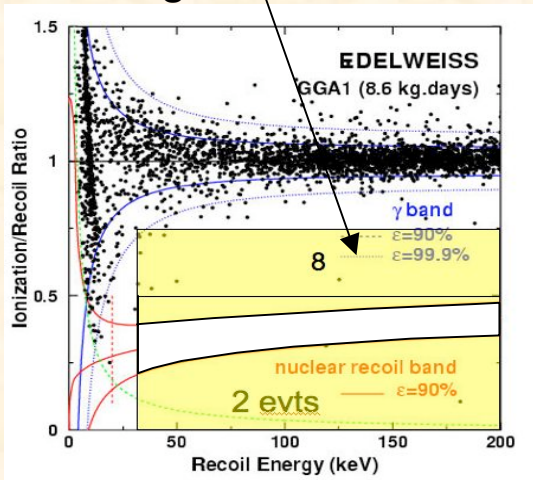


-Threshold @ 7.5 keV,
2 kg.d /detector

-Effect of poor regeneration of detectors to avoid space charge effects (GSA12,GSA9)
-Being tuned

-Beta contamination @ E<80 keV being studied

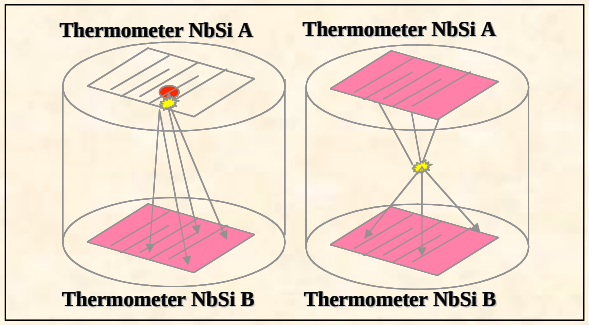
-Quality of data monitored by rate in control region

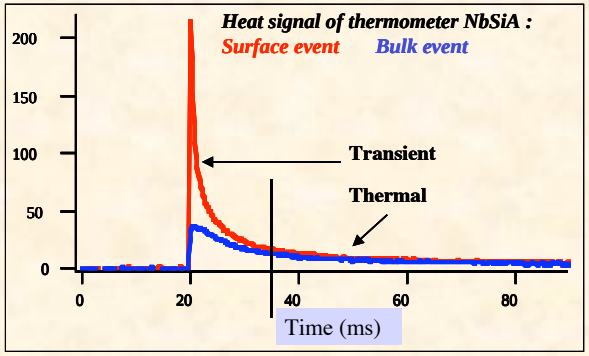


Ge/NbSi detector
Identification of surface events

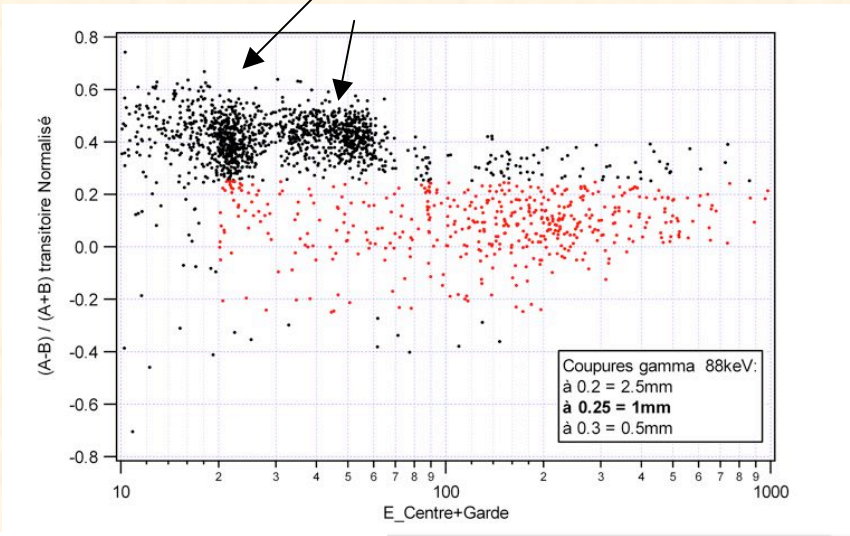
· **Enhancement of athermal signals for near surface events**

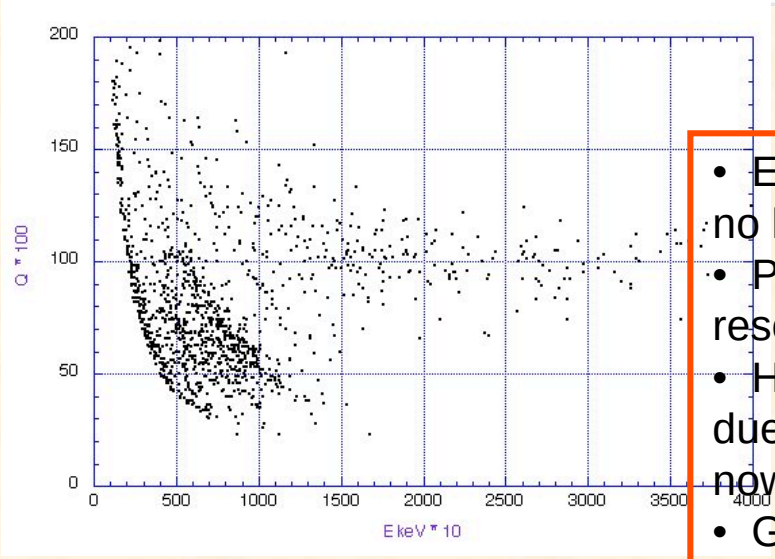
· Thermal signals are related to the deposited energy





Optimised 200 g with .5 mm spacing exposure to a source of 109Cd electrons @ 18 62 84 keV

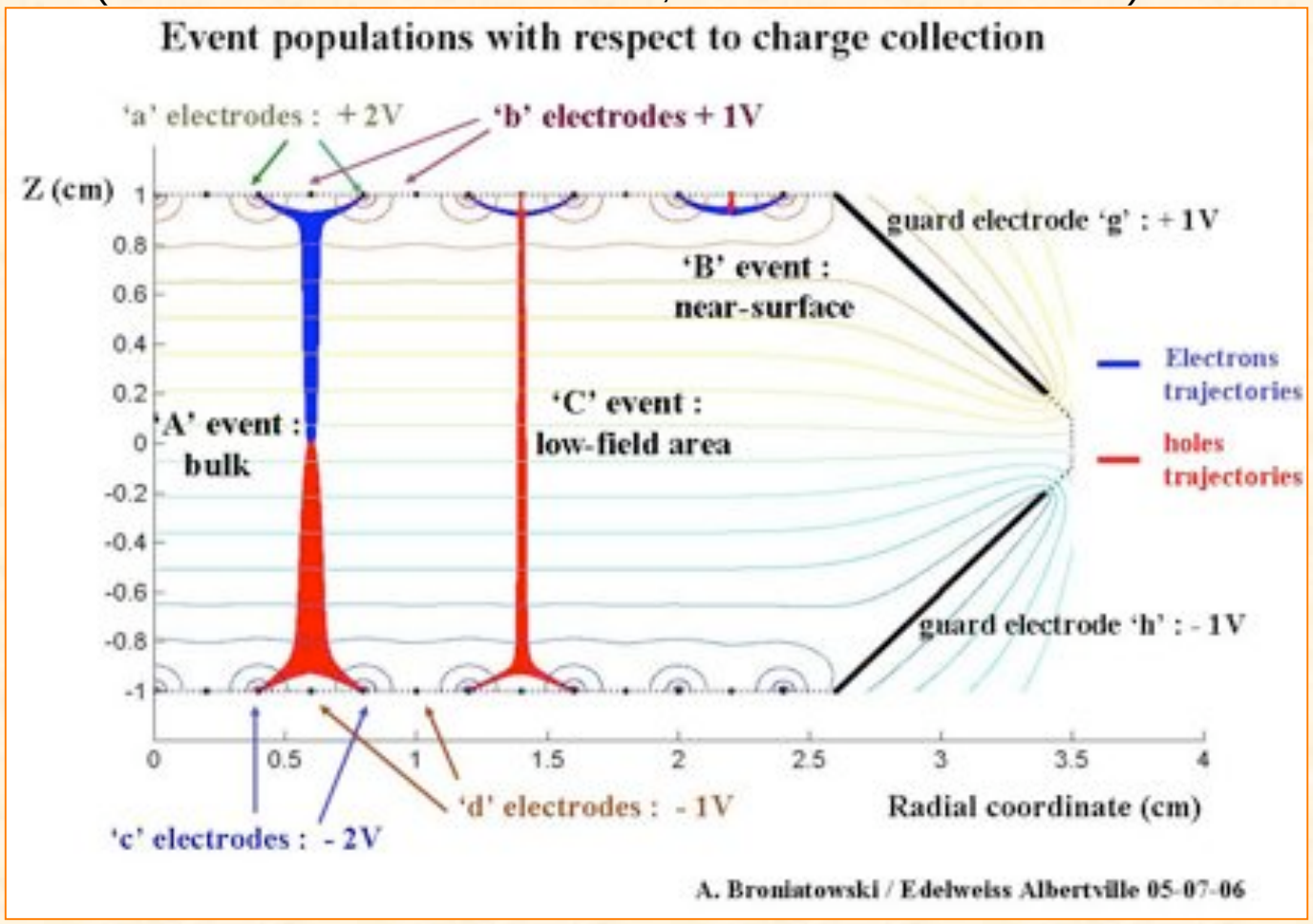




- Excellent rejection with no low loss of signal
- Poor sensitivity and heat resolution for these data
- Heat capacity excess due to electrode Nb film, now replaced by Al film,
- Gain of factor 4 obtained on last prototype

Identification of surface events with interdigitised electrodes

(A Broniatowski IN2P3/CSNSM, XF Navick CEA/DAPNIA)



Simulations of charge migration and collection within germanium

-3 years experimental and modelisation program financed by ANR (France)
-Some first results @ LTD 12 ?

Performance estimation

	Exposure/ time	Nb evts in ΔE 30-200 keV = ROI	Rate evts/kg.d in ROI	σ limit @ M=80 GeV pb (90%CL)	Nature of estimation
EDW1 3 dét	62 kg.d	6 evts	0.1 <0.15	1.6 10^{-6}	Result
EDW2 21 NTD 7 NbSi	120 kg.d /**32d** 120 kg.d /**88d**	0 evts	<0.02	2 10^{-7} 2007	Hyp : fact ≥5 ^{210}Pb fact ≥5 rejsrf
EDW2 100 det	1200kg.d / **60d**	0 evts	<0.002	2 10^{-8} 2009	Hyp optimist : fact 5 * 10
EDW2 100 det	12000kg.d / 600 d	120 evts back	=0.01 sig<36evts	3 10^{-8}	Hyp pessimist: fact 10 back subtract

NB : NTD = 330g, fid vol=56 %
NbSi = 400g, fid vol=50 %

New web based tool for Dark Matter hunters developed within ILIAS

(Rachid Lemrani Saclay DAPNIA for « N3 » ILIAS DM network)

Welcome to the

DArk
Matter
Network
Exclusion
Diagram

tool web page

Direct detection :

Spectra : Experimental energy spectra

Limits : Experimental limits on WIMP-nucleon cross sections

It is aimed to provide the Dark Matter particle hunter community a tool :
- to compare, evaluate the sensitivity of DD experiments under different assumptions, theoretical and experimental
- to evaluate and quantify in a unified way the complementarity of the Indirect detection approach
- to include the interpretation of experimental data within theoretical models (SUSY)
- to ultimately attempt an integrated analysis of DM also using the LHC results

This tool is expected to evolve with the inputs from users
This tool is an ILIAS initiative

ILIAS related Links

Dark Matter N3 network web page

ILIAS web site

External Links

Dark Matter Limit Plot Generator

DarkSUSY

SoftSUSY

Micromegas

Suspect

Upper Limit Software by Yellin

http://pisrv0.pit.physik.uni-tuebingen.de/darkmatter/

… waiting for

Bloody
Long
Expected
Super
Symmetry
Experimental
Discovery

web page

Spectra and limits with unifieds conventions

Experimental spectra

	Label	WIMP mass (GeV)	A of Target	Exposure (kg.days)	WIMP-nucleon cross section (pb)
next		50	72.6	10	1E-7

- GALACTIC HALO PROPERTIES
- NUCLEAR FORM FACTORS
- THEORETICAL OR WITH EXPERIMENTAL PARAMETERS
- I - PARAMETERS FOR EXPERIMENTAL RESULTS (general)
- II - PARAMETERS FOR HEAT/IONISATION BOLOMETERS

Below you can choose to clear all tables, to combine recursively with previous result or to add a new result

Add

Click to run

Experimental spectra

- Quenching
- Resolution
- Efficiency

As function of energy :
Quenching : Lindhard
Resolution : a + b √ E

With possibility to enter a binned dependence on energy

I - PARAMETERS FOR EXPERIMENTAL RESULTS

I-1 Quenching

	Type
next	Q = a Er^b

I-1-a Quenching : Q = a Er^b (for b=0 quenching=constant=a)

	a	b
next	0.36	0.

I-1-b Quenching : n_bins bin_2 bin_1 bin_2 ... bin_n val_1 val_2 ... val_n example : 1 0.3

	quenching in bins
next	1 1

I-2 Resolution

	Type
next	FWMH = a + b E^0.5

I-2-a Resolution : FWMH = a + b E^0.5

	a	b
next	0	9.8

I-2-b Resolution : n_bins bin_2 bin_1 bin_2 ... bin_n val_1 val_2 ... val_n example : 2 10 0.1 0.2

	resolution in bins
next	1 0

I-3 Efficiency

Efficiency : n_bins bin_2 bin_1 bin_2 ... bin_n val_1 val_2 ... val_n example : 2 10 0 1

	efficiency in bins
next	1 5 20 0 0.5 0

Extraction of limits

- By comparison of the expected spectra to the observation:
  - Using poisson statistics (number of observed events)
  - Using Feldman - Cousin approach (number of observed events and expected background)
  - Entering directly your limit on the rate

LIMIT ON RATE

	Method	Observed events / Limit on rate	N_Background
next	1. single sided	0	0

1. single-sided poissonian up to 20 events then gaussian (Nevents+1.28 sqrt(Nevents))
2. FeldmanCousin(Nobserved,Nbackground)
3. Directly enter the limit on the rate

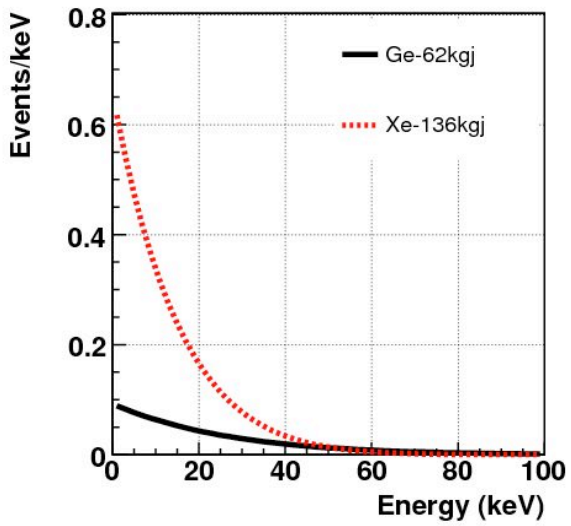
OUTLOOK

- Spin-dependant cross sections
- Expected annual modulation
- Interpreting positive signal
- Different Galactic Halos
- Different models (DarkSUSY)

-Ultimately integrated analysis within SUSY ie of Dir Det, Ind Det and Tevatron/LHC data

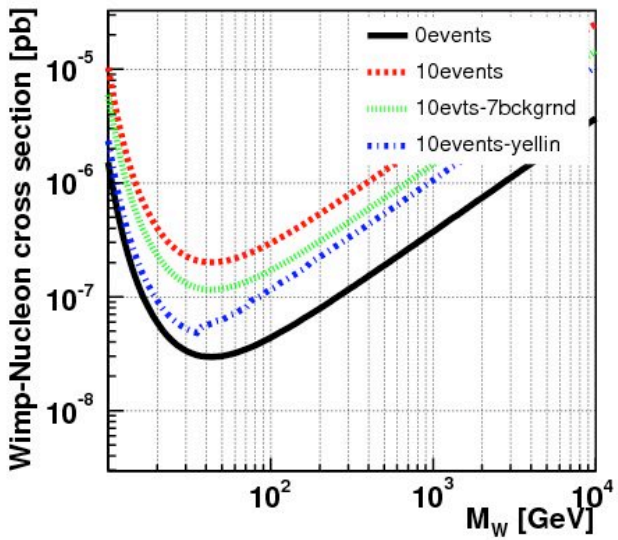
Xenon comparison with Ge

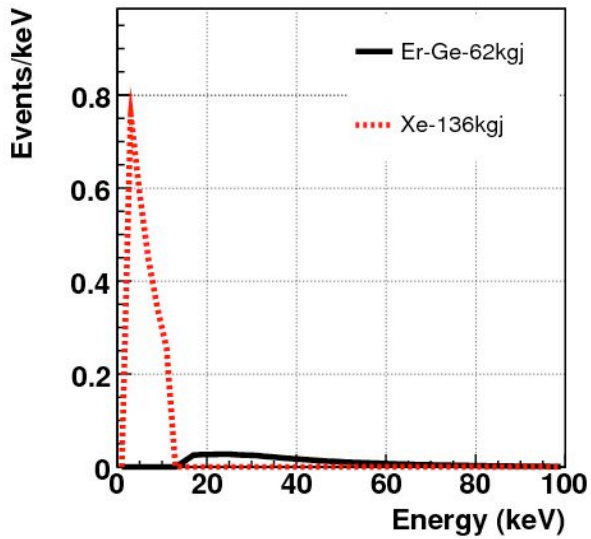
- Example, Xe seems more sensitive than Ge, how, given different thresholds, quenching factors, efficencies… ?



Theoretical spectra

M 100 GeV σ 10^{-7} pb





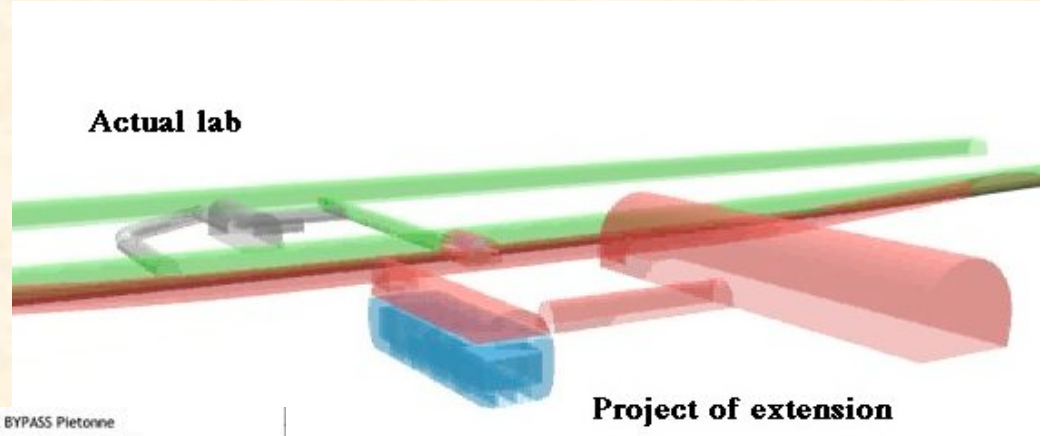
Experimental expected spectra

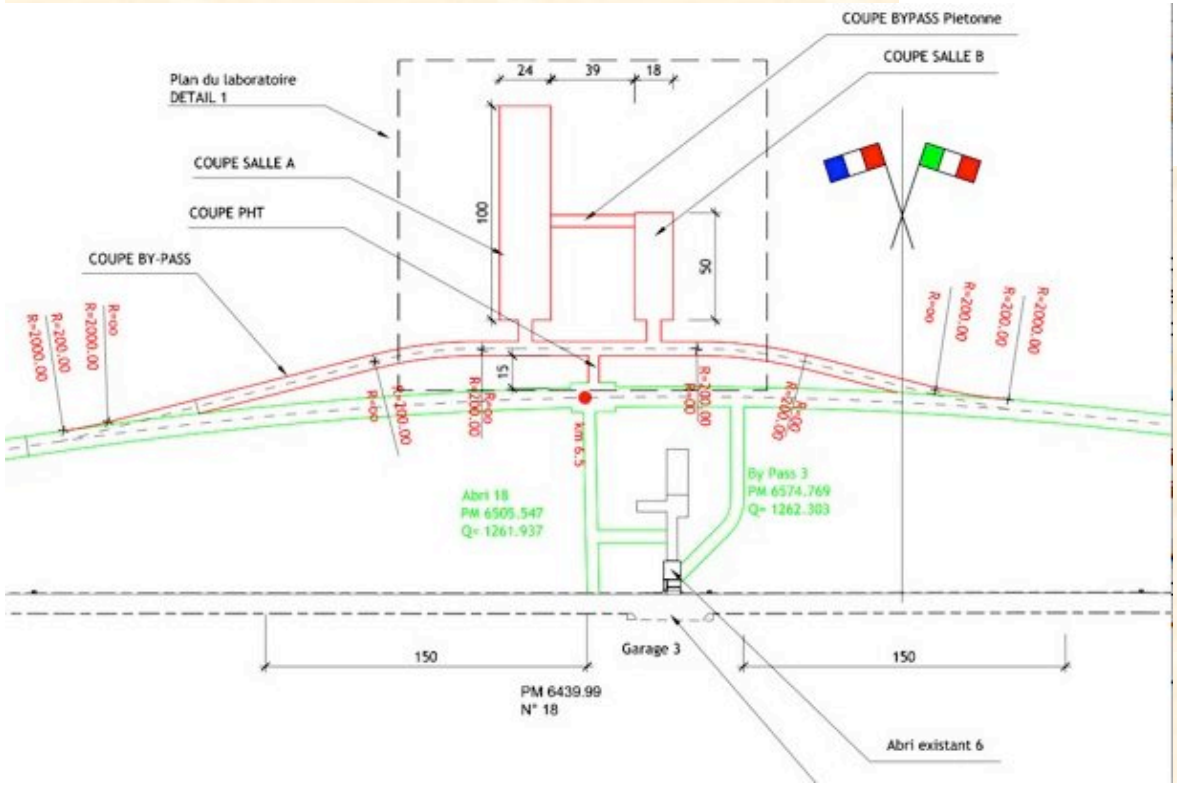
EURECA I

- To reach ultimate goal of 10^{-10} pb
- A « facility » to host 1 ton of cryogenic detectors
- A multi target approach
- « Open access » facility to be studied
- A Design Study proposal just submitted to EC infrastruture support program call
- Project of integration in projected future extension of Frejus lab
  - Safety gallery will be dig by 2012=> opportunity
  - Deepest, most convenient access in Europe
  - Integrated water shield

EURECA II

- Time scale 2013
- Total cost 50-90 M€





- CRESST
- EDELWEISS
- ROSEBUD
- CERN
- …

=>13 countries

Conclusions / outlook

- Phase 28 -9 kg- on good tracks
  - DM physics run by this summer
- Interesting times !
  - lot more data and handle on quality, backgrounds
  - NbSi film detectors close to validation
- Real background free and large efficiency
- Preparing « simple » and efficient detectors
- Phase 100 det -30 kg- will allow to go towards 10^{-8} 10^{-9} goal : 2.5 M€ funding to be asked this year
- Anticipating 10^{-10} pb goal with EURECA, a large european collaboration for 1 T cryogenic experiment