Edelweiss-II Dark Matter Search: Status and first results

Silvia SCORZA
Université Claude Bernard-
Institut de Physique nucléaire de Lyon

CEA-Saclay IRFU + IRAMIS (FRANCE),
CNRS/Neel Grenoble (FRANCE),
CNRS/IN2P3/CSNSM Orsay (FRANCE),
CNRS/IN2P3/IPNL Lyon (FRANCE),
CNRS-CEA/Laboratoire Souterrain de Modane (FRANCE),
JINR Dubna (RUSSIA),
Karlsruhe Institute of Technology (GERMANY),
OXFORD University (UK)

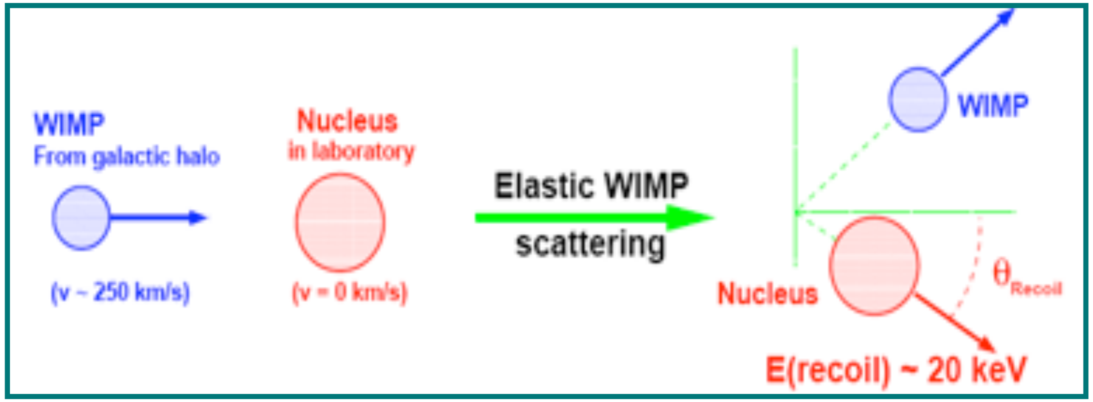
- Direct Search
- Edelweiss-II
- New ID detectors
- First six-month results
- Outlook

Edelweiss
Expérience pour DEtecter Les WIMPs En Site Souterrain

IPNL Lyon

Direct Search Principle

Detection of the energy deposited due to **elastic scattering** off target nuclei



- **Event Rate** :

  < 1 ev /kg/week

- **Recoil Energy** :

  1 – 100 keV

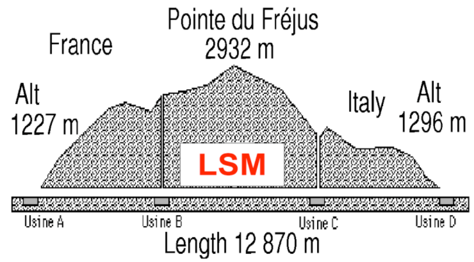
- **Low energy threshold**
- **Large detector mass**
- **Low background**

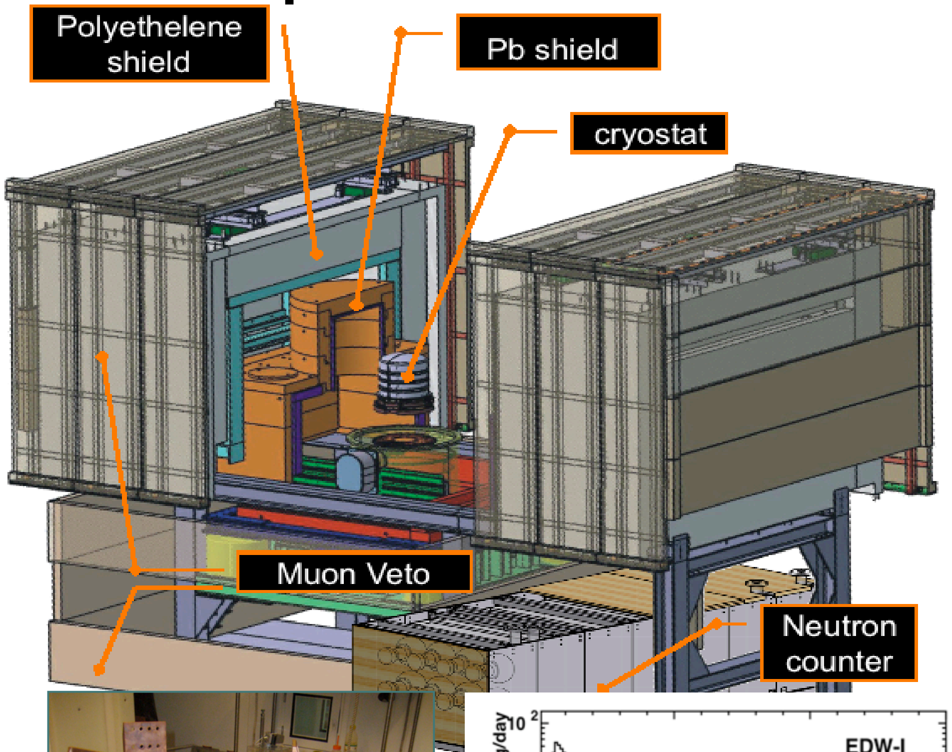
  Radio – purity

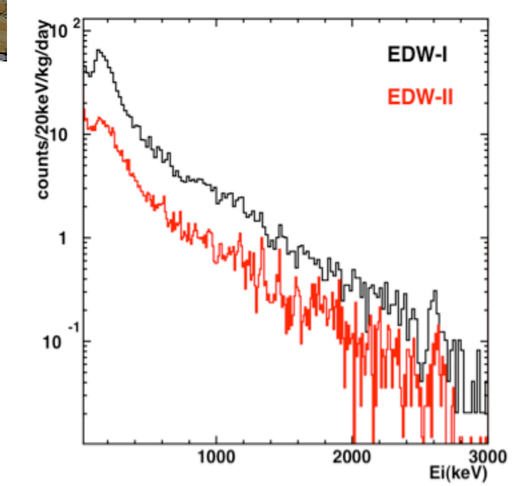
  Active/passive shielding

  Deep underground sites

EDELWEISS @





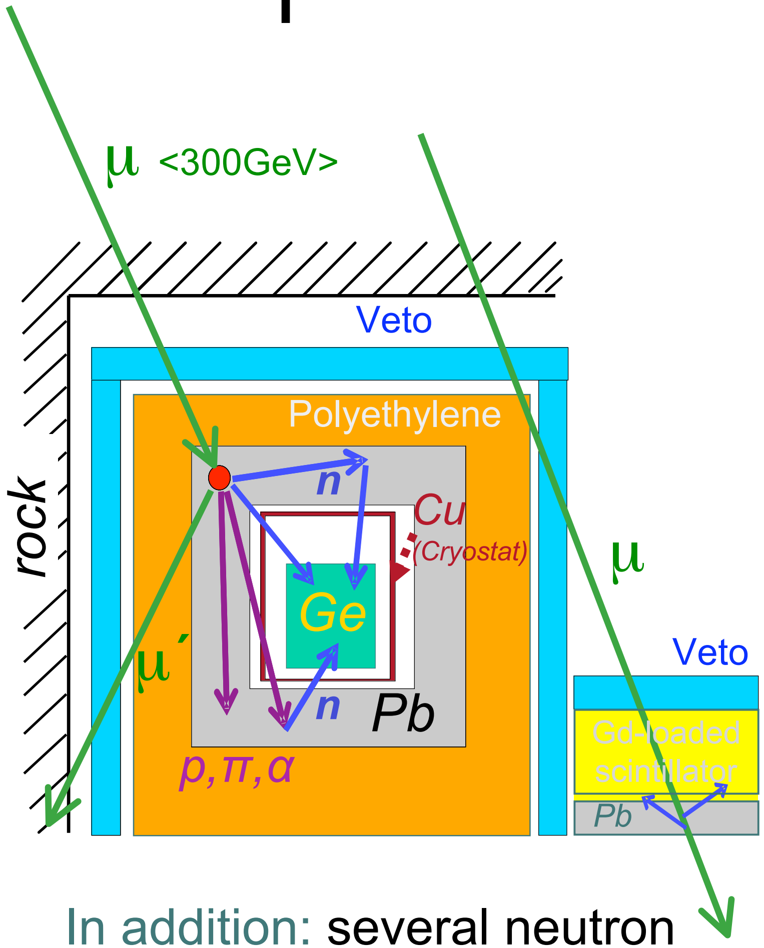


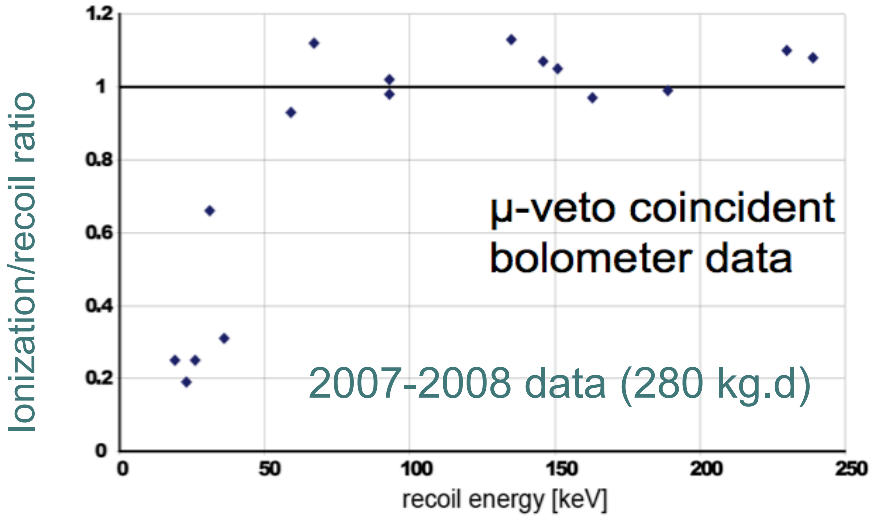
- Installed at LSM in Frejus Tunnel (4 muon/day/m^2)
- Goal: **EDW-I × 100**
  10^{-8}pb, <0.002 evts/kg/d
- 5 kg Ge, can host up to 40 kg
- Simple/reliable detectors
- Alternative surface events rejection based on charge signal
- Strict control of material selection/ Cleaning procedure/ Environment
- Gamma shield (20cm lead)

$\Rightarrow \gamma$ background reduced by ~ 3 wrt EDW1

- Neutron shield designed for <10^{-8}pb
  - 50cm polyethylene
  - Active muon veto (>98% coverage)

μ-veto: tags interaction due to muons





In addition: several neutron flux measurements carried out near the experiment

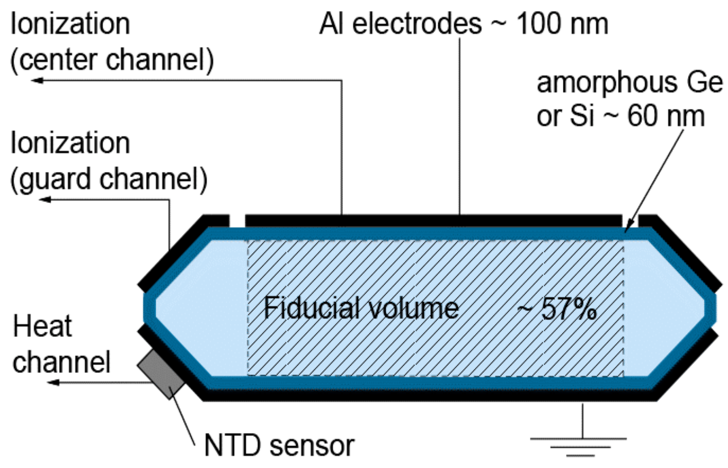
- GEANT4 expectation:
  - ~0.03 evt/kg/d
  - ~0.004 neutron/kg/d above 20 keV recoil
- Measurement:
  - 280 kg.d in 2007-2008 +160 kg.d in 2009
  - ~0.04 evt/kg/d
  - 0.011+-0.005 nucl.rec./kg/d above 20 keV

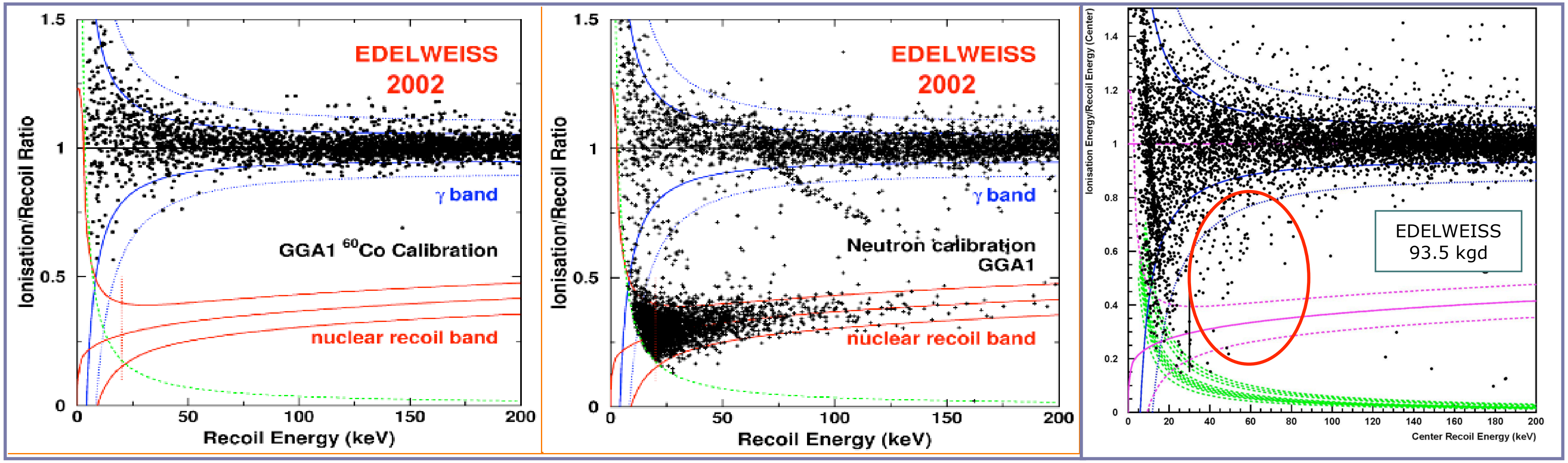
EDW-I Detectors

- Simultaneous measurements:
  - **Ionization** @ few V/cm with Al electrodes
  - **Heat** @ 20 mK with **NTD** sensor
- Different Ionization/Heat energy ratio for nuclear and electronic recoils

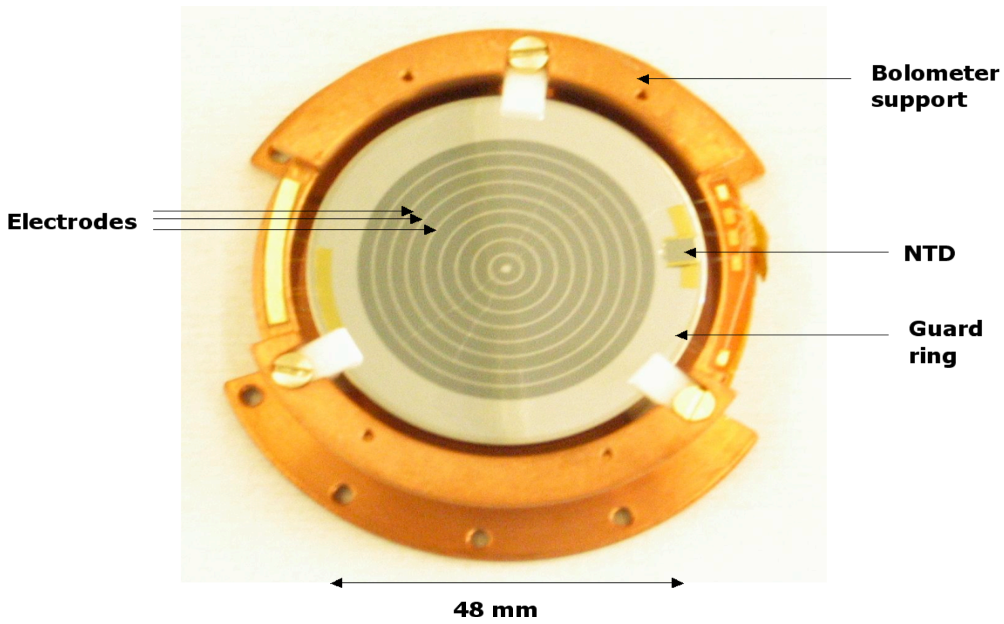
Event by event background rejection

Limitation : surface interactions

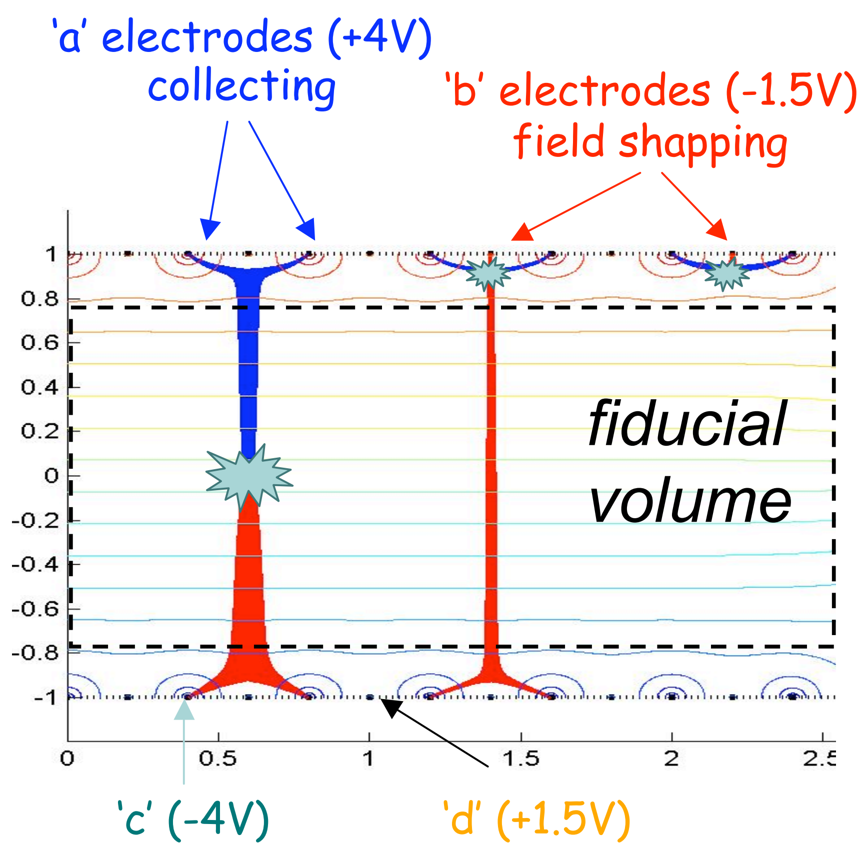




InterDigit detectors

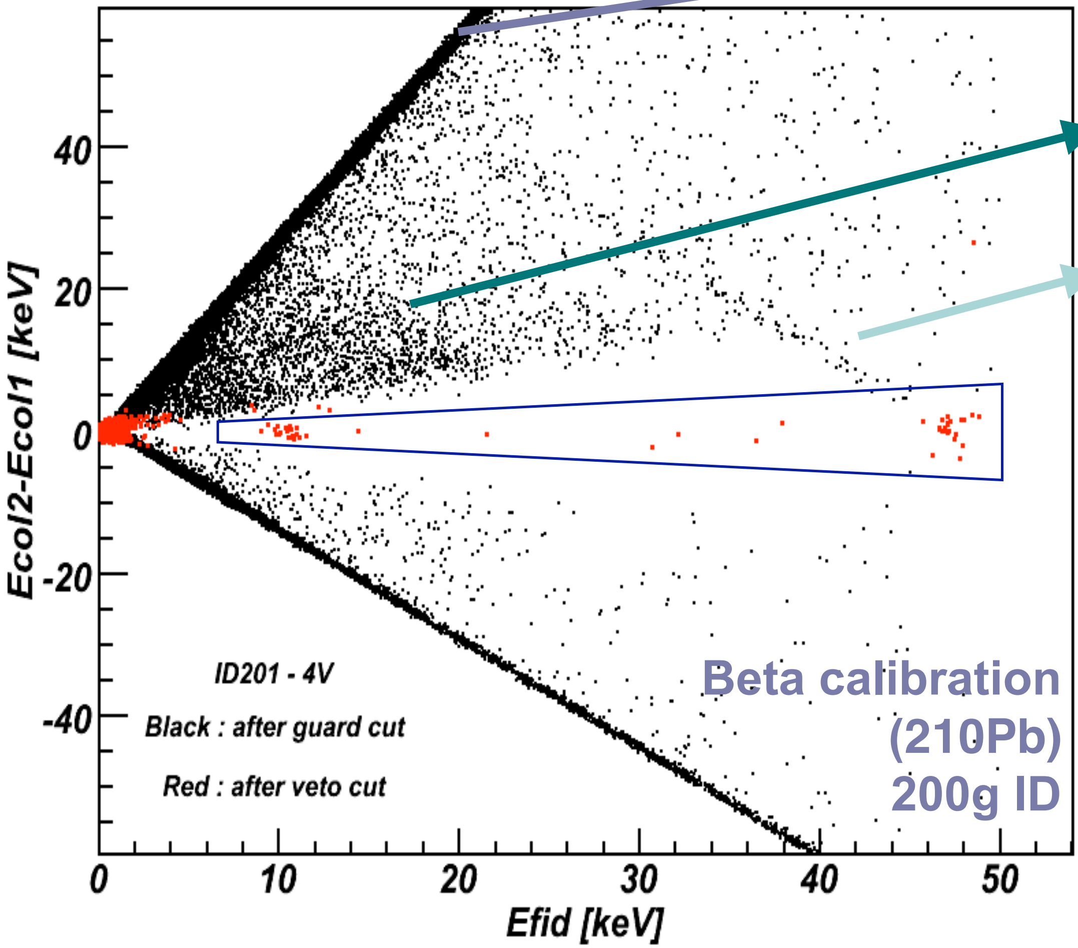


- EDW-I NTD heat sensor
- E-field modified near surface with interleaved electrodes
- 'b'+'d' signals -> vetos % surface



First detector built 2007
1x200g + 3x400g tested in2008
10x400g running since beginning 2009

Surface event discrimination



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

“single side”
surface events (E1=0)

“3 electrodes” events
near-surface events (low field)

46 keV γ ray line (0.5mm depth)

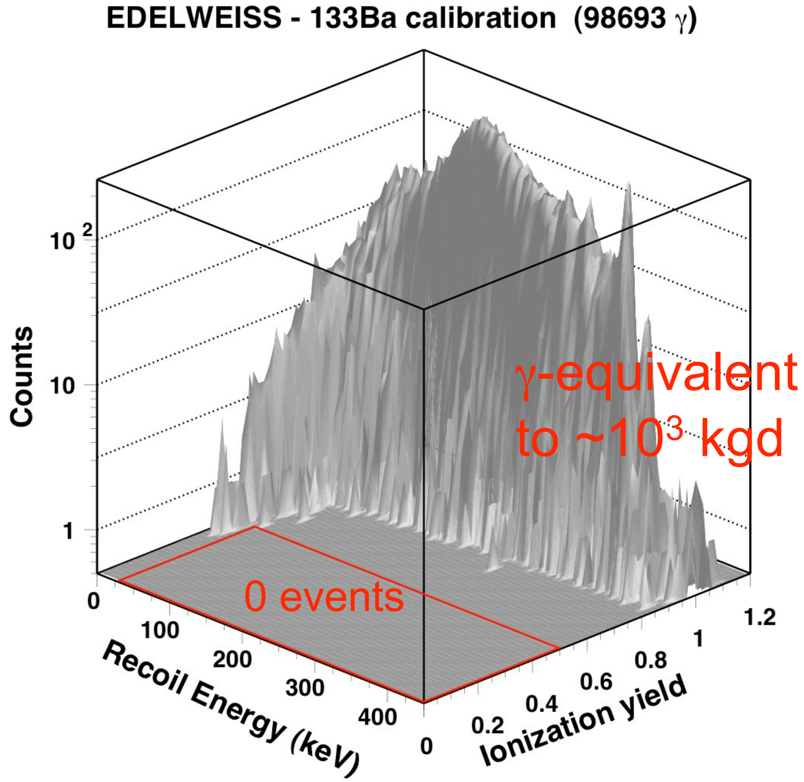
Fiducial volume
« ***Veto + guard*** » cut (red points) +
« ***E2 = E1***» criterium (blue box) : strong redundancy !

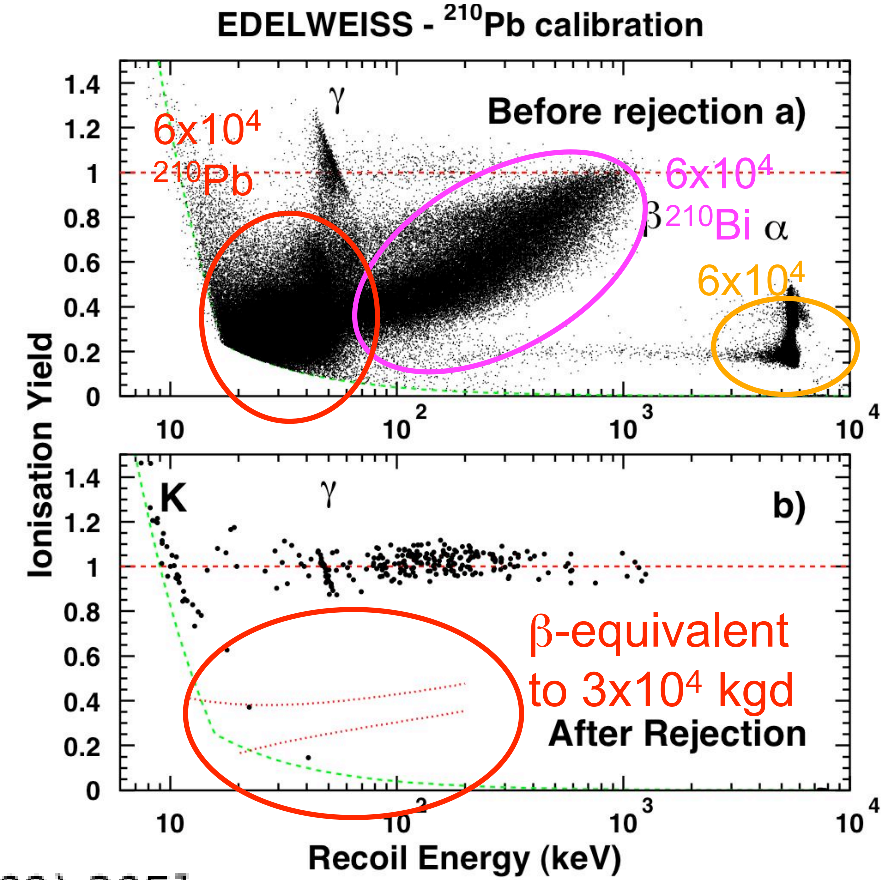
Surface and volume events are completely separated !

Overall β rejection $1/10^5$

ID detector rejection

- Gamma rejection of 400g
  - ~1 month calibrations
- Beta rejection of 200g





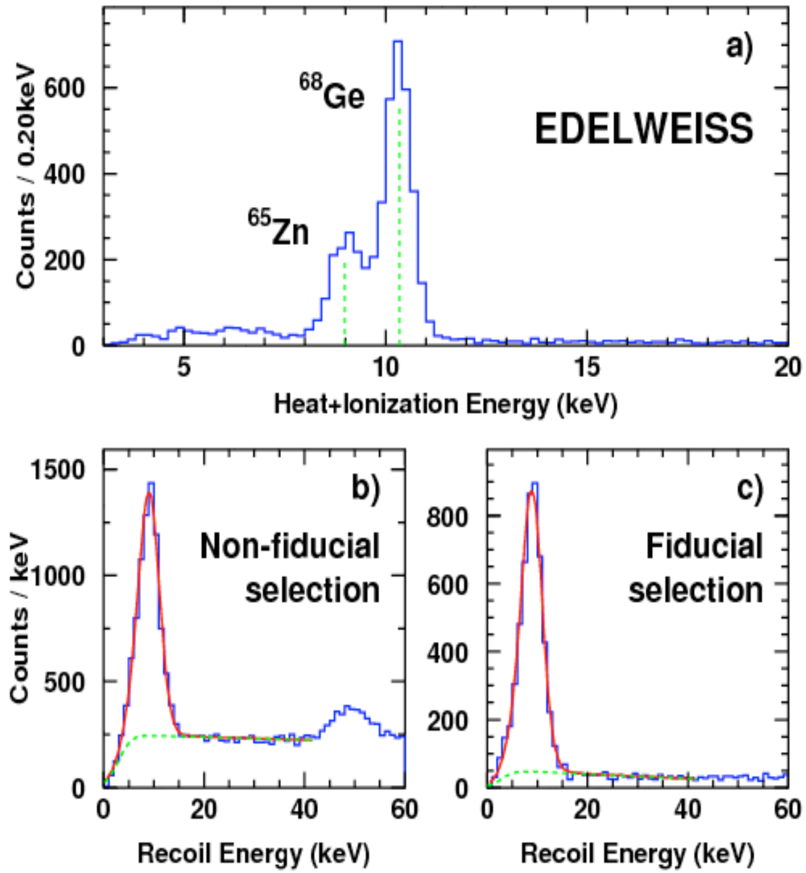
[PLB 681 (2009) 305]

Fiducial volume measurement

- Cuts based on ionization signals only (FidIon1=FidIon2, all other electrodes consistentt with noise)
- Measurement with cosmogenic lines:
  - ^{68}Ge and ^{65}Zn isotope lines at 9.0 and 10.4 keV
  - Homogeneously distributed in the volume of the cristal
  - Real-condition measurement of fiducial cuts efficiencies at low energy in WIMP search conditions (baselines, voltages…)
- Fiducial volume = 166g ± 6

  => 160g, conservative value

  consistent with estimations based on neutron calibration data



Data analysis of first 6 months

- Two independent processing pipelines

  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):

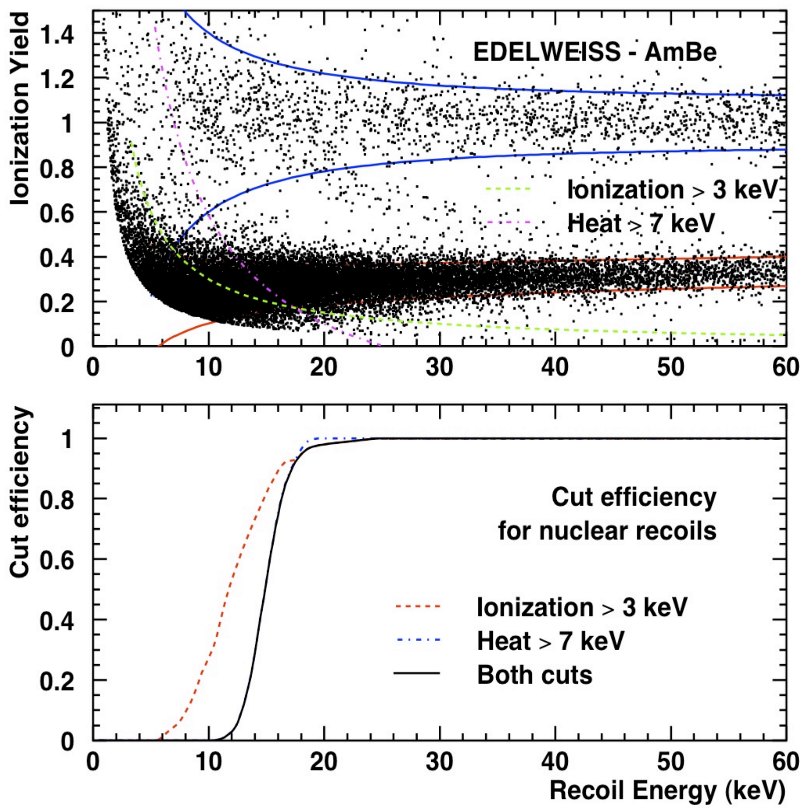
  robust results independent of analysis details

- Period selection based on baseline noises

  → **80% efficiency**
- Pulse reconstruction quality (chi2)

  → 97%
- **Fiducial cuts** based on ionization signals (160g)
- ε = 90% **nuclear recoil, gamma rejection** 99.99%
- Bolo-bolo & bolo-veto coincidence rejection (ε>99%)

All detectors – neutron calibration

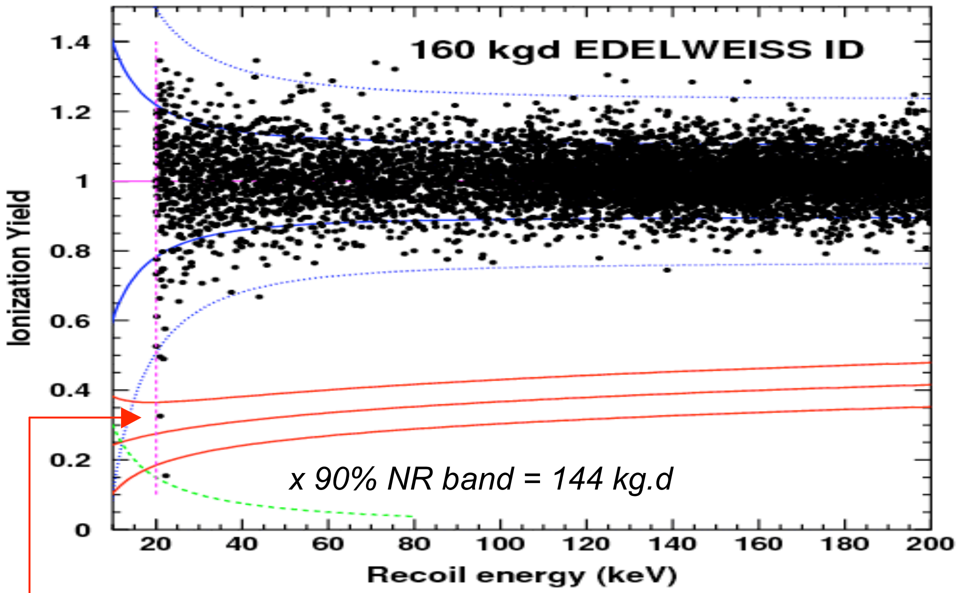


Agreement between the results the two analyses

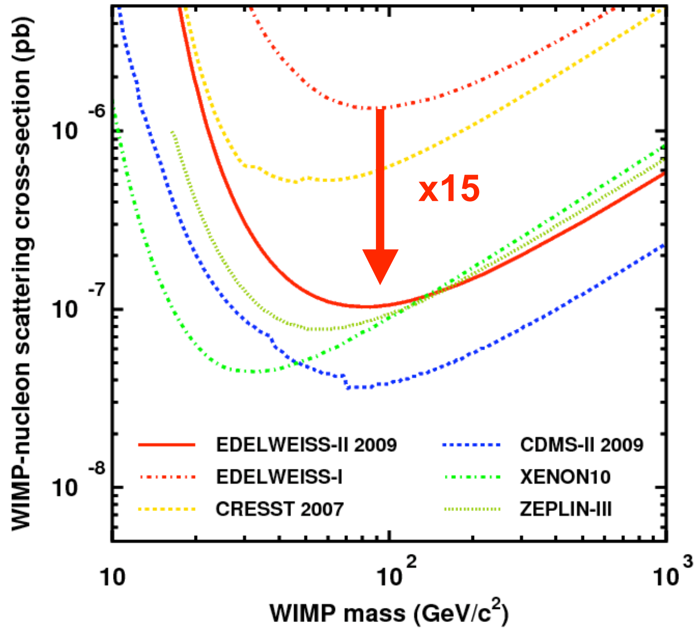
EDELWEISS-II: First Results

Background reduced wrt EDELWEISS-I by a factor 50

arXiv:0912.0805s



« WIMP candidate »
Er = 21 keV



End of January:
~ x1.75 exposure,
Run continues
until spring

Background 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

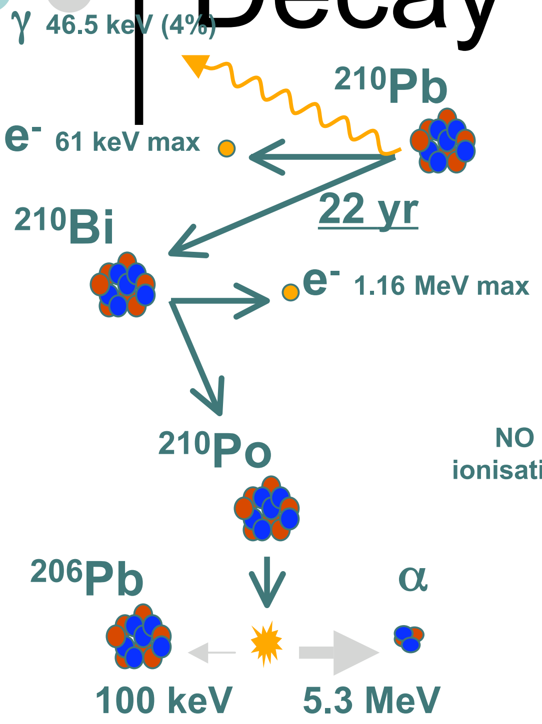
Conclusions/Outlook

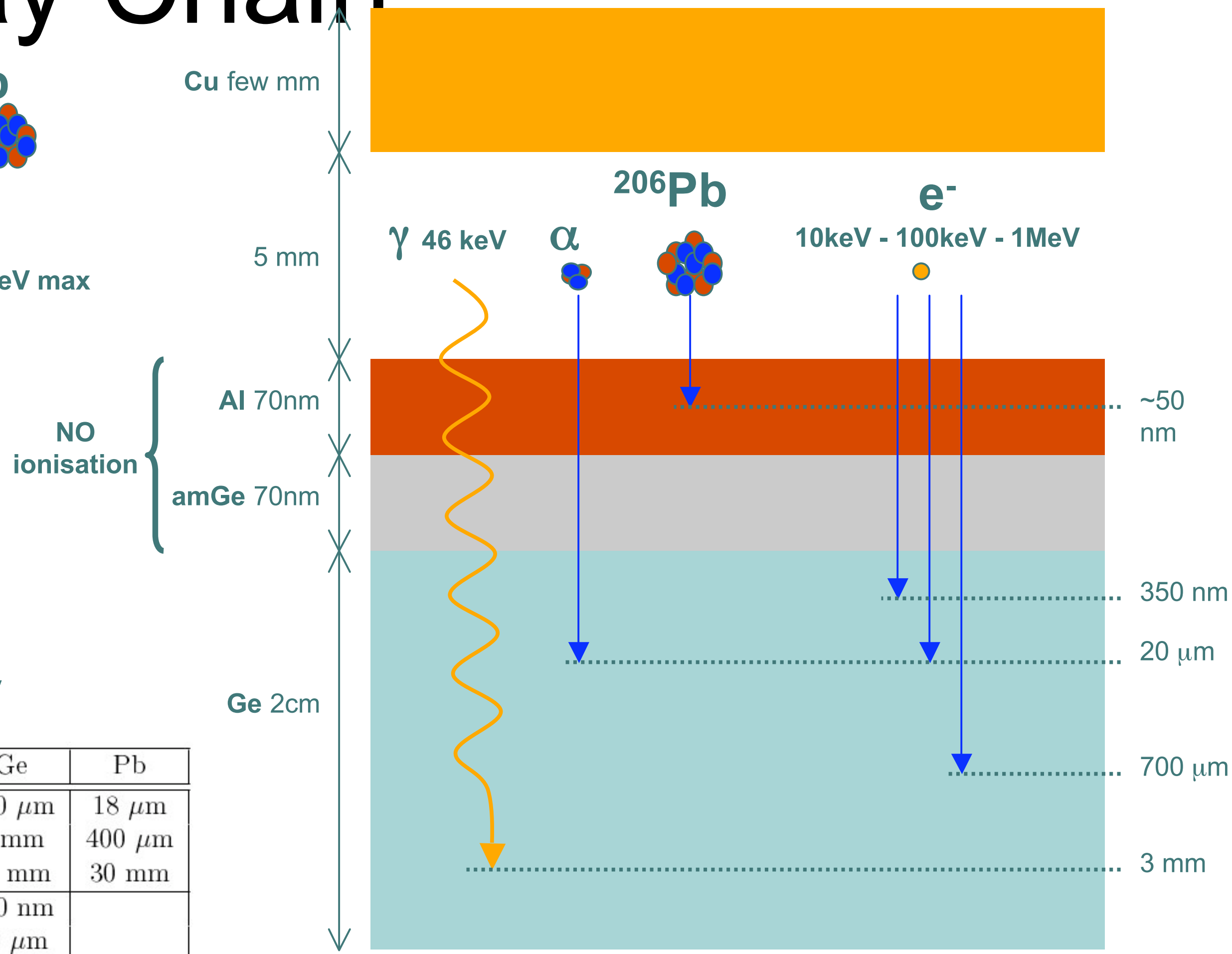
- Significant reduction in α, β and γ backgrounds relative to EDELWEISS-I
- New generation ID detectors
  - Robust detectors with redundancy and very high beta rejection
  - First 160kg.d => WIMP limit @ 10^{-7}pb, 1 evt observed
  - X2 exposure in Spring (+lower thresholds & improved bkg estimations)

- Prototype of ID detectors with larger fiducial volumes currently tested (FIDs 400g+800g) with goals:
  - 2011 = 1000 kg.d
  - 2012 = 3000 kg.d
- Long term: EURECA (European Underground Rare Event Calorimeter Array): beyond 10^{-9} pb, major efforts in background control and detector development

This is the end…

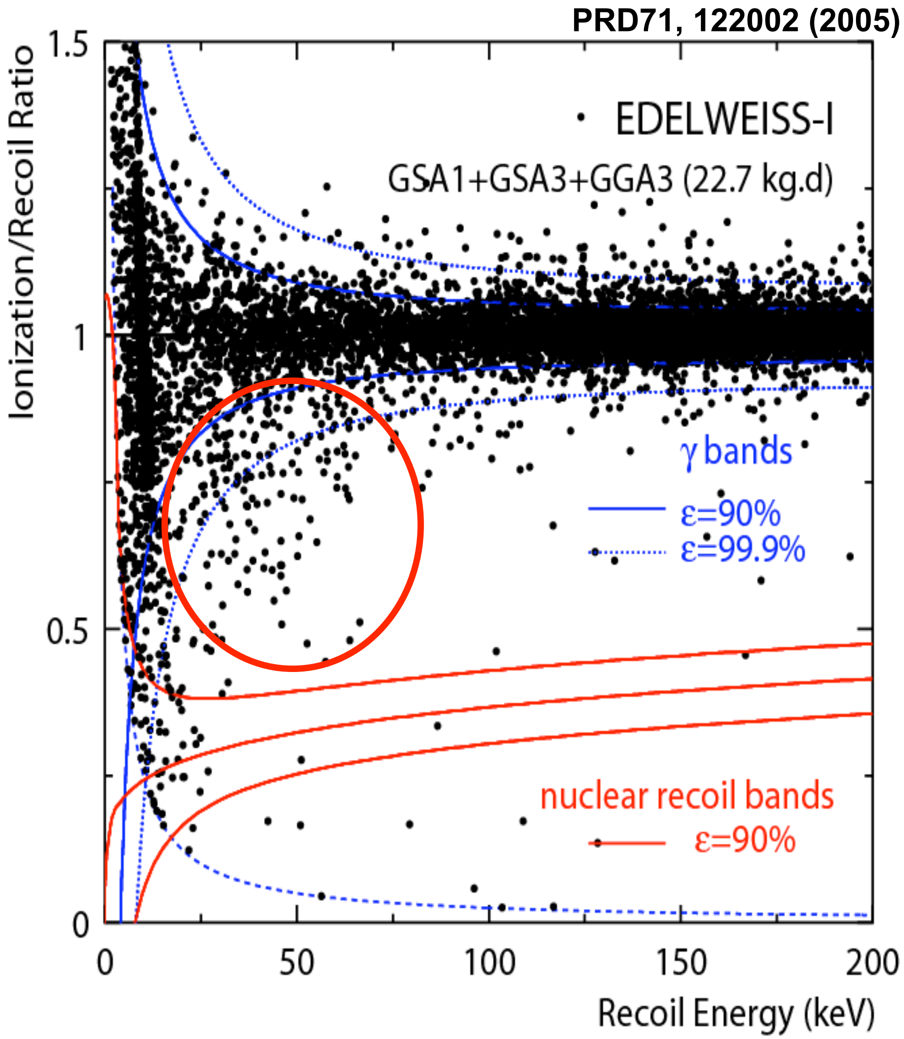
Decay Chain





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	

Edw-I limiting background

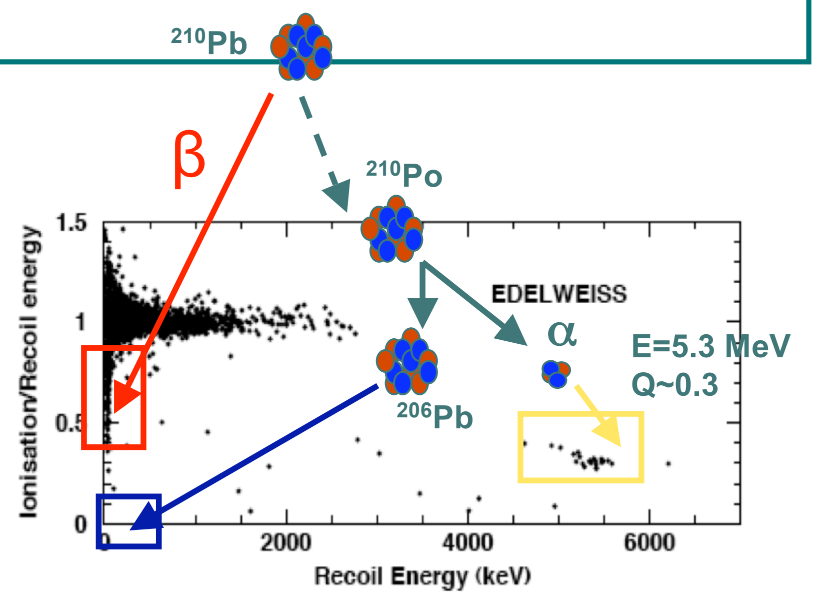


Problem:

Surface electron recoils

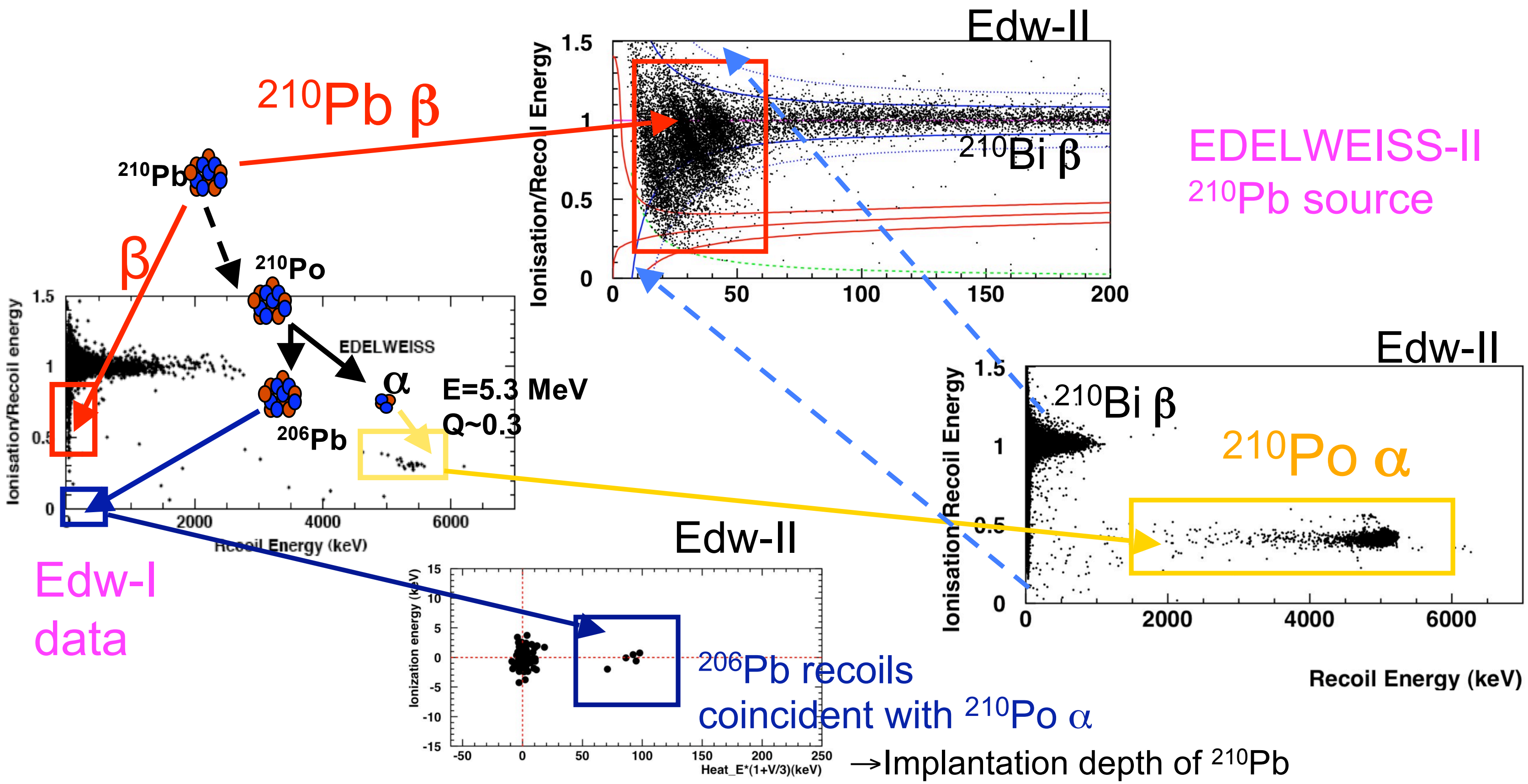
Interpretation:

- **Bad charge collection** (trapping and recombination)
- **Indications of ^{210}Pb contamination** (exposition to Radon):
  - α rate ~ e rate ~ 5 /kg.day



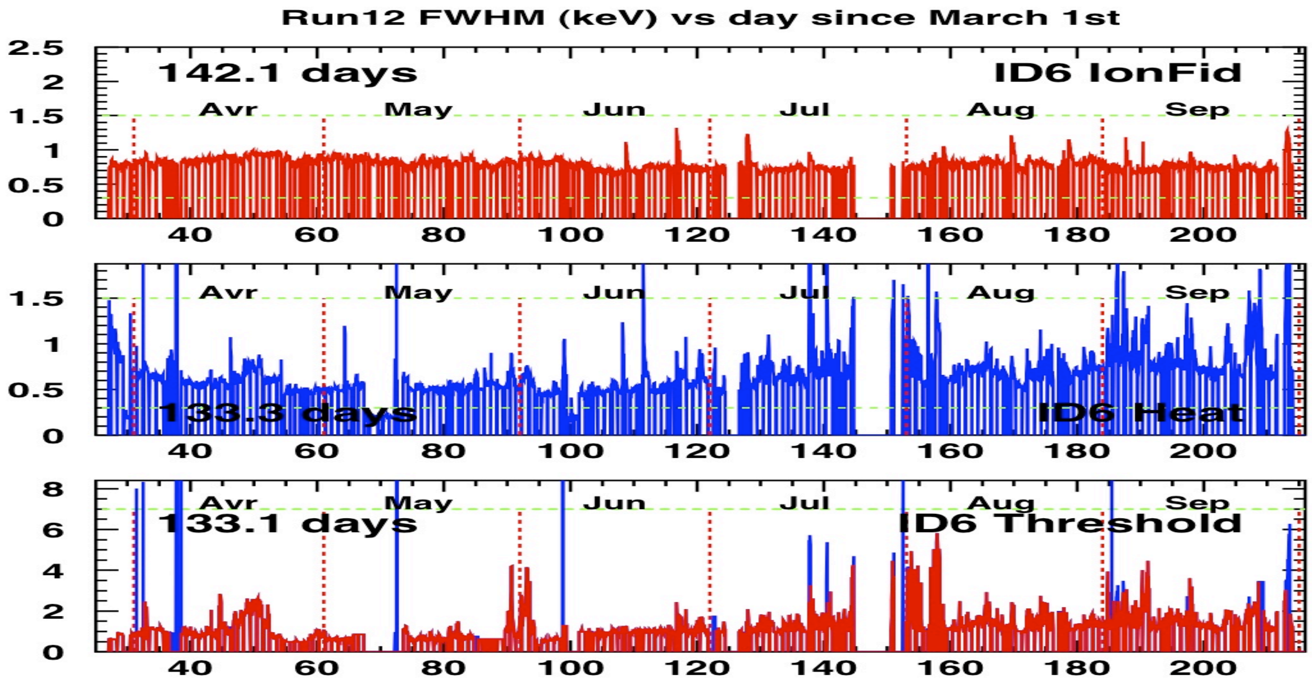
EDELWEISS-II ^{210}Pb source calibration

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

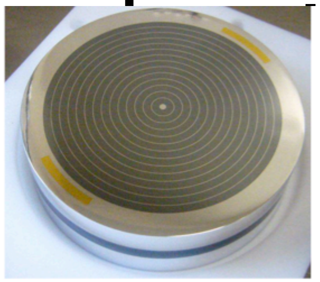


First WIMP search with ID detectors

- 10 ID (400 g units, 160g fiducial) tested/built/installed/run in 2008-2009
- First assessment of technology in real physics run: 144 kgd / ~6 months
  - Reliability: 9/10 detector used for physics
  - >50% physics running efficiency (wrt to 186 days x 1.6 kg_fiducial)
  - *Average resolutions*: σ ~ 400 eV ionization, 500 eV heat

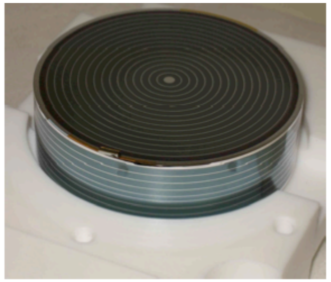


Increasing the fiducial



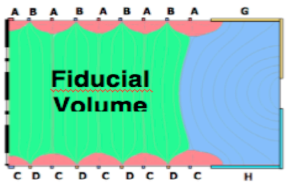
ID401 to 405:
Φ 70mm, H 20mm, 410g

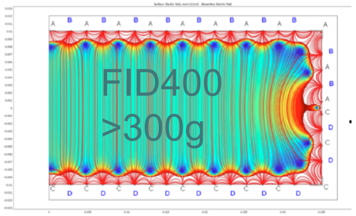
ID2 to ID5:
Φ 70mm, H 20mm, 410g

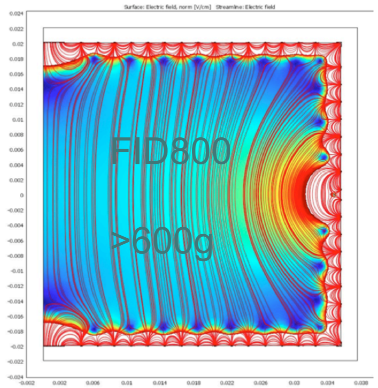


FID401 and FID402:
Φ 70mm, H 20mm, 410g

ID400
160g

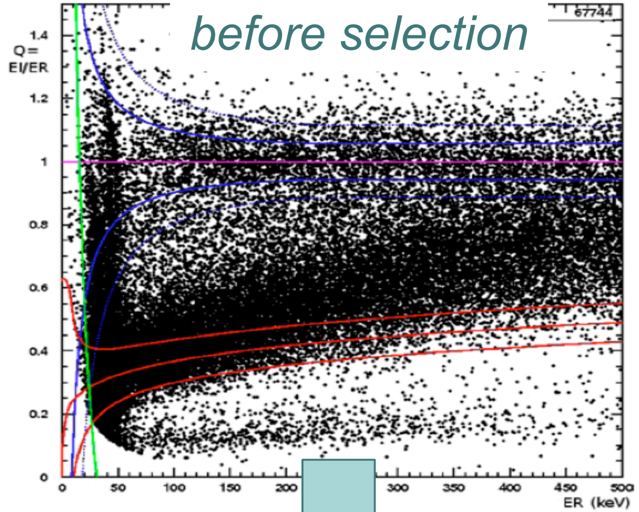


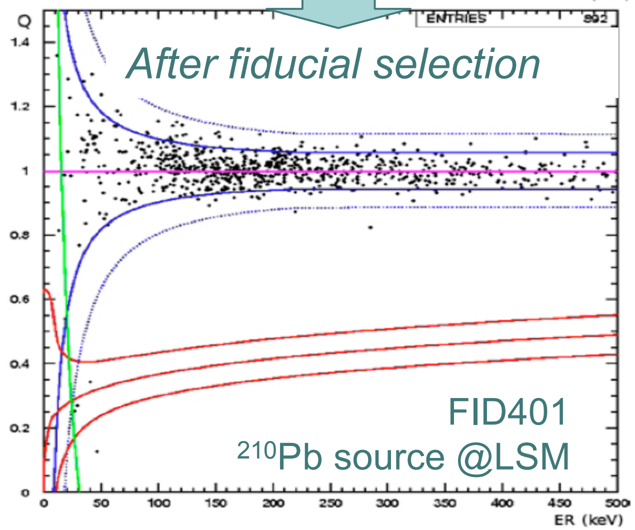




Doubling/Quadrupling the fiducial mass:
ID400 => FID400 => FID800

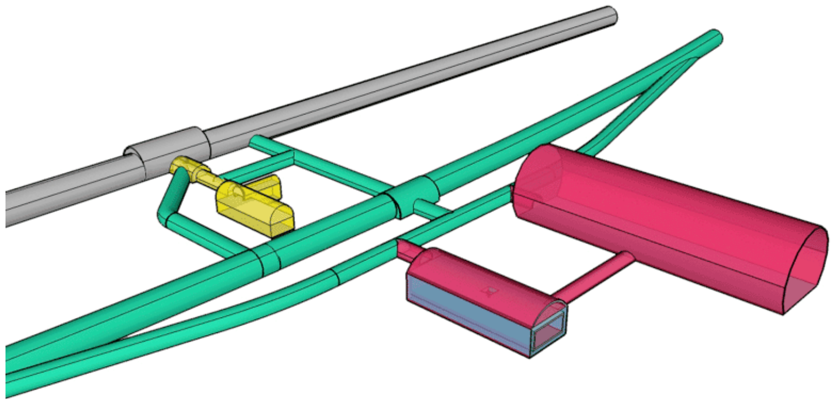
FID beta rejection @ LSM :
4/68000 for E>25keV

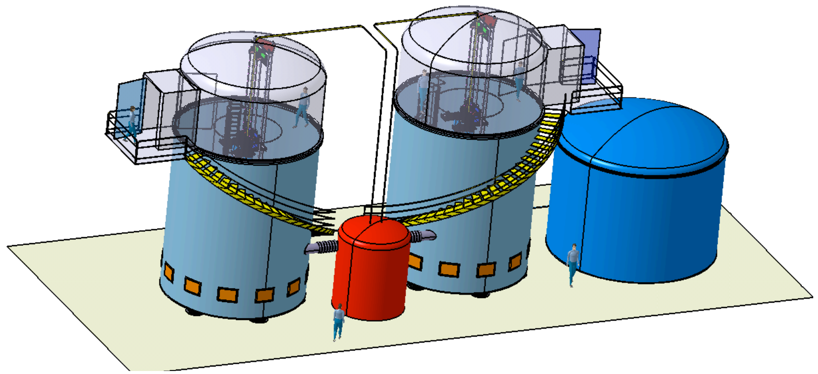




Future: EURECA

- EURECA: beyond 10^{-9} pb, major efforts in background control and detector development
- Joint effort from teams from EDELWEISS, CRESST, ROSEBUD, CERN, +others…
- >>100 kg cryogenic experiment, multi-target
- Part of ILIAS/ASPERA European Roadmap
- Prefered site: 60 000 m^3 extension of present LSM (4 $\mu/m^2/d$), to be dug in 2011-2012

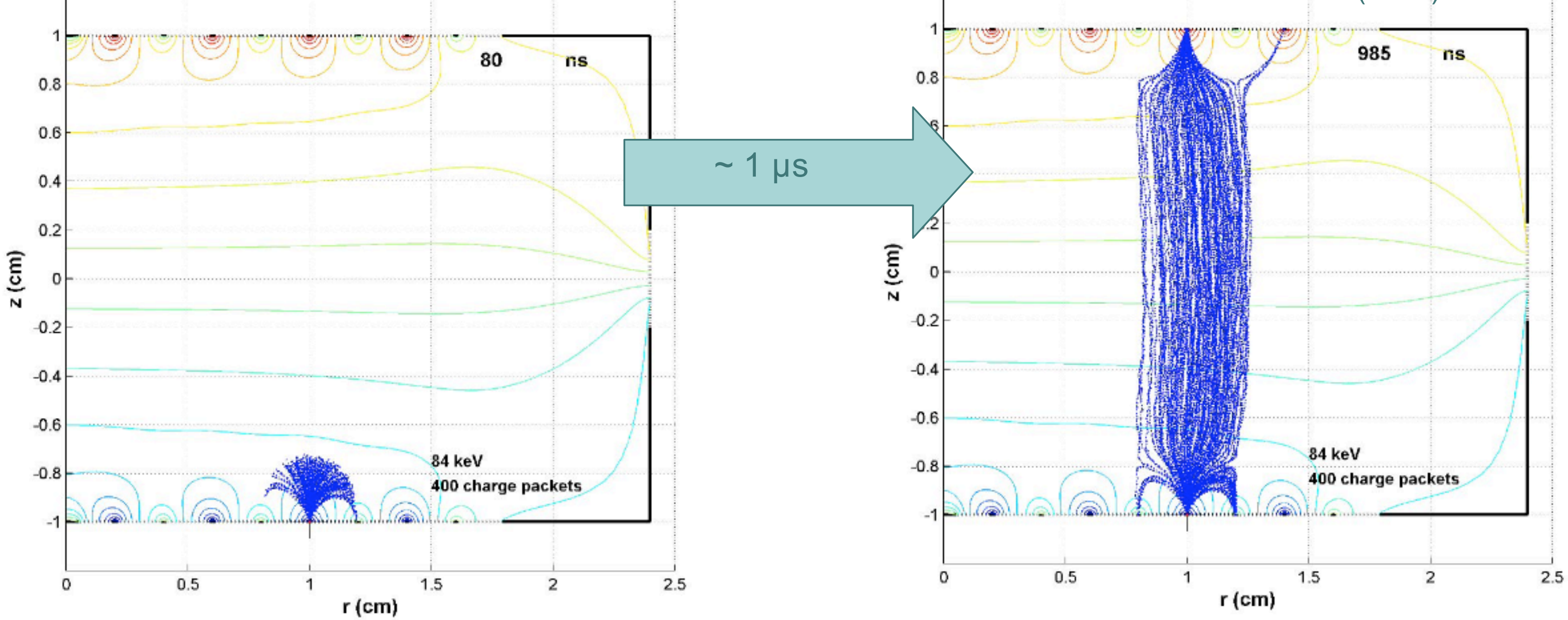




Charge propagation in a ID detector

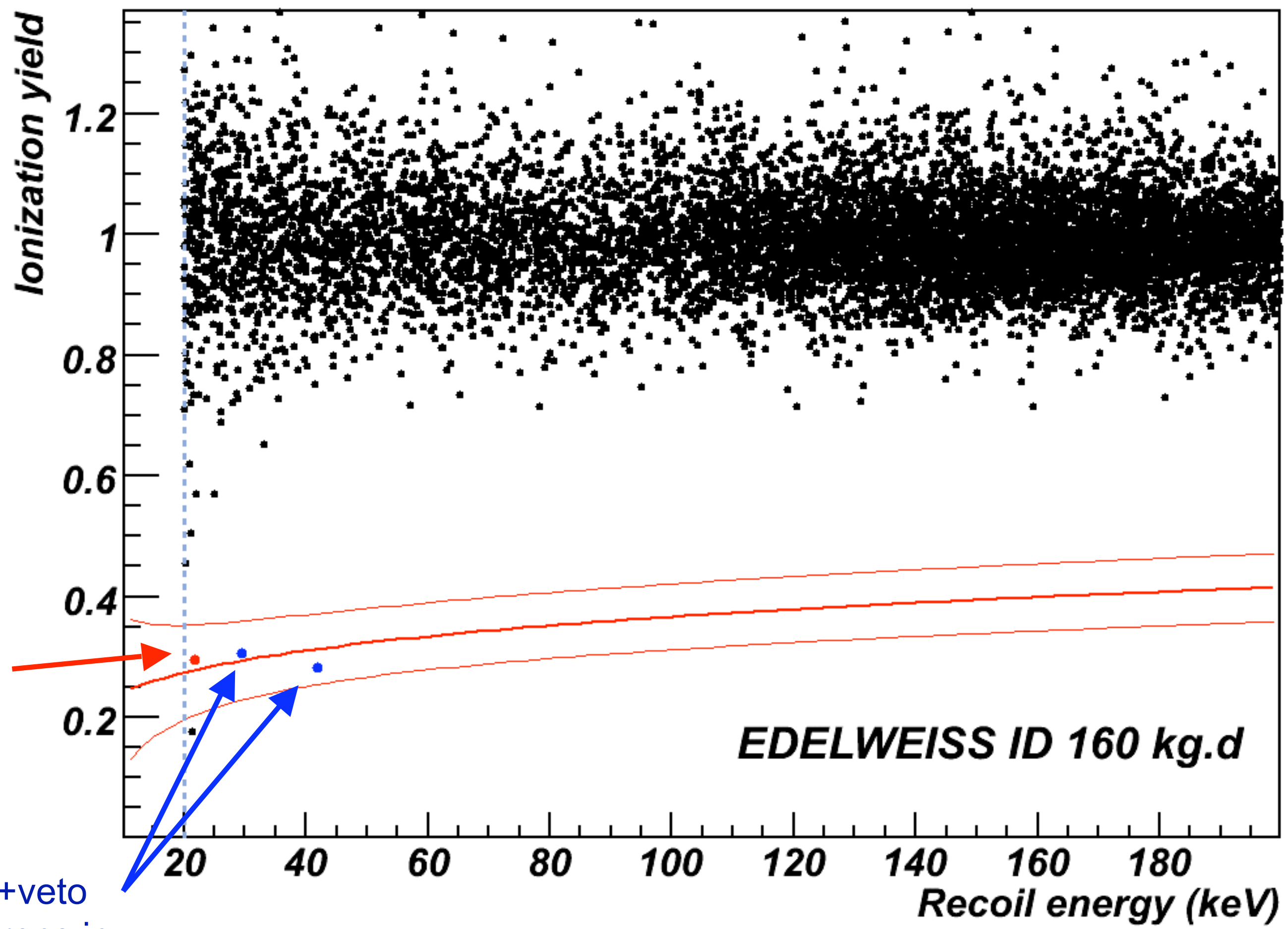
- Initial expansion of the charge cloud due to Coulomb interactions is sufficient to generate charges in the vetos even in
  - - regions of low electric field
  - - regions just under the collecting electrodes

PLB 681 (2009) 305



WIMP search : first result

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

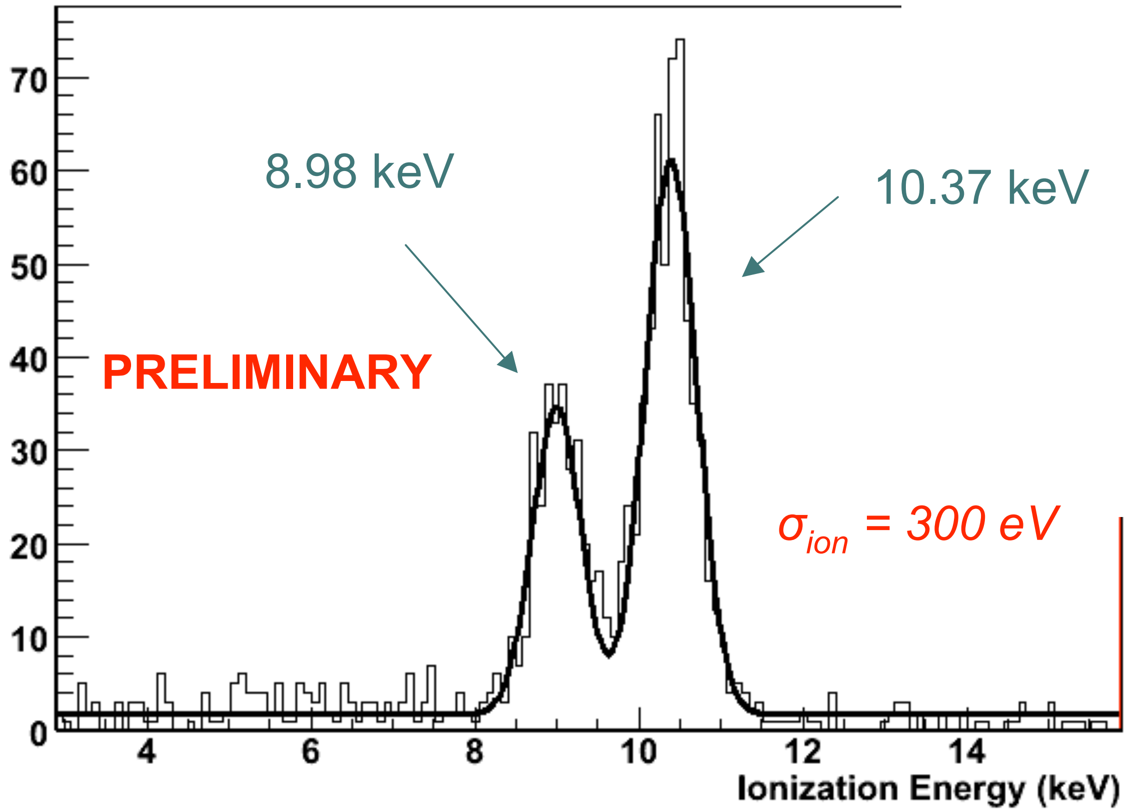


« WIMP candidate »
Er = 21 keV

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

Ionization resolution of IDs

Background ionization spectrum, ID3+ID401
After fiducial cuts



- 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