EDELWEISS-II WIMP search at low energy

based on arXiv :1207.1815

(submitted to PRD rapid comm.)

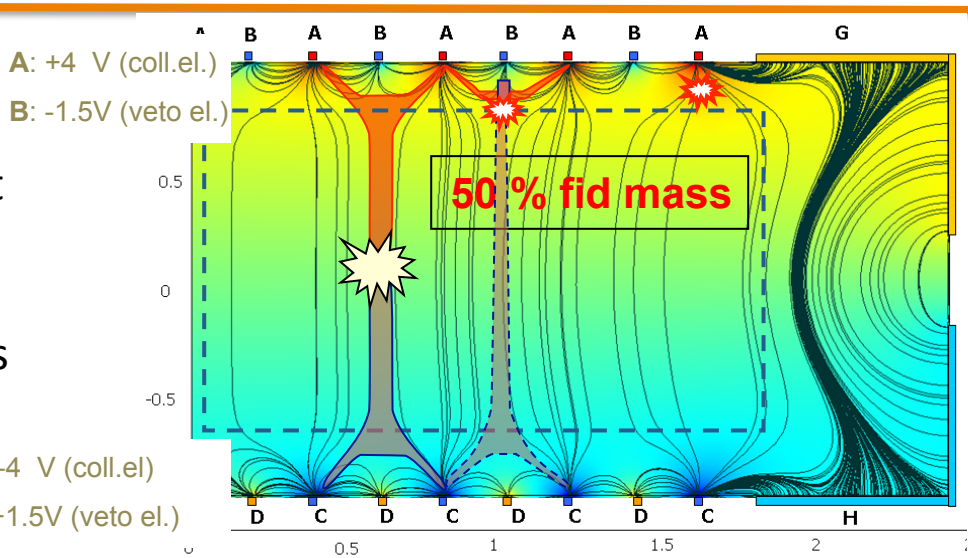
Véronique SANGLARD

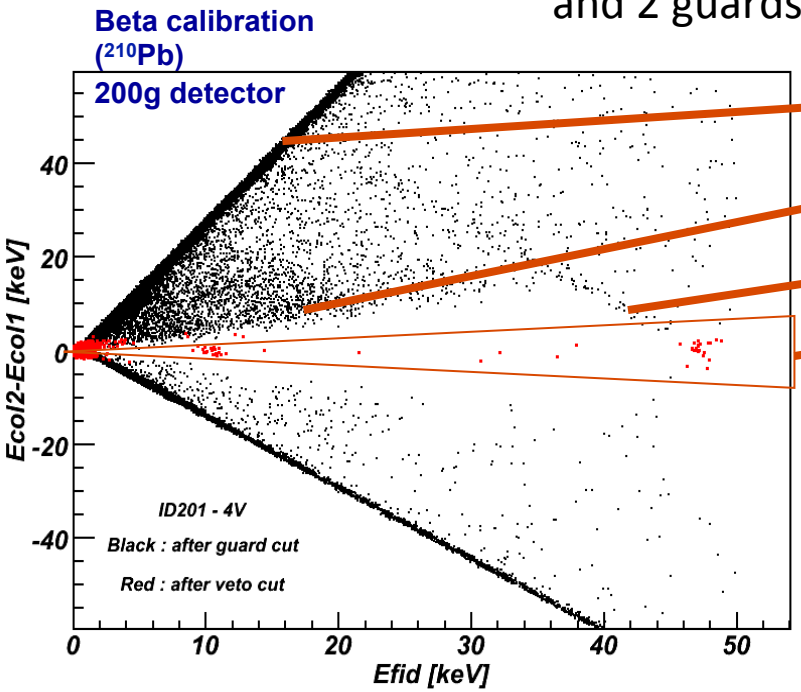
sanglard@ipnl.in2p3.fr

IPNL/IN2P3/UCBL-1

EDELWEISS detectors – ID

- 400g Ge detectors
- Interdigitized electrodes (against surf. evts)
- 1 heat channel + 6 ionisation channels (2 fiducial, 2 vetos and 2 guards)





« single-side » surface events $E_{col1}=0$

« 3-electrodes » surface events

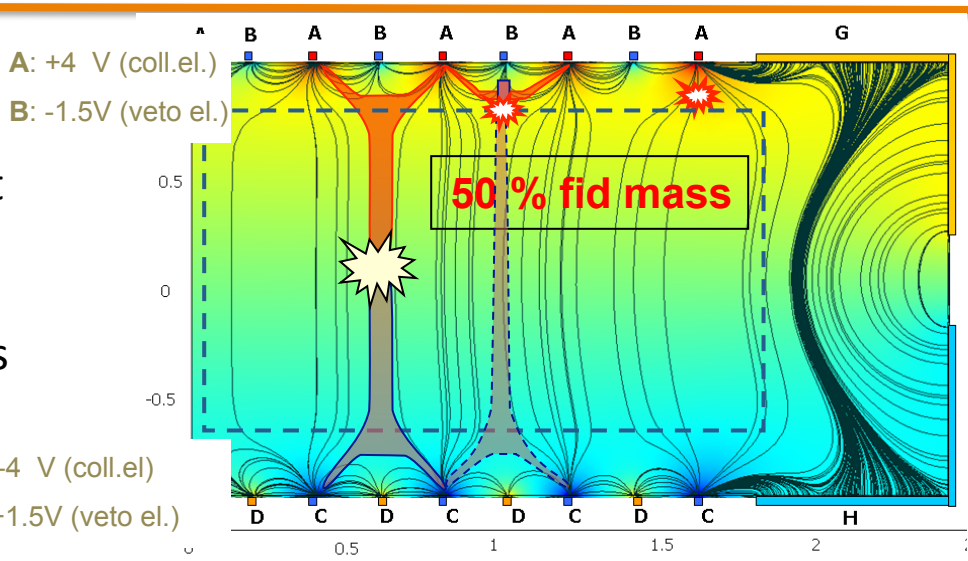
46 keV gamma-ray line

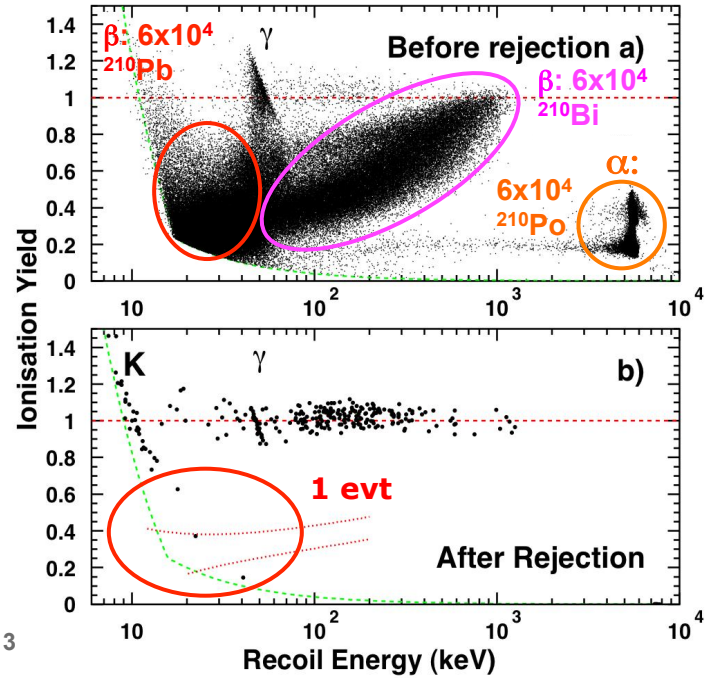
fiducial volume events $E_{col1}=E_{col2}$

Surface and volume events are completely separated

EDELWEISS detectors – ID

- 400g Ge detectors
- Interdigitized electrodes (against surf. evts)
- 1 heat channel + 6 ionisation channels (2 fiducial, 2 vetos and 2 guards)





Surface events rejection:

- intentional ^{210}Pb source: 6 x 10^4 events total
- requiring no signal on veto electrodes: 1 event left

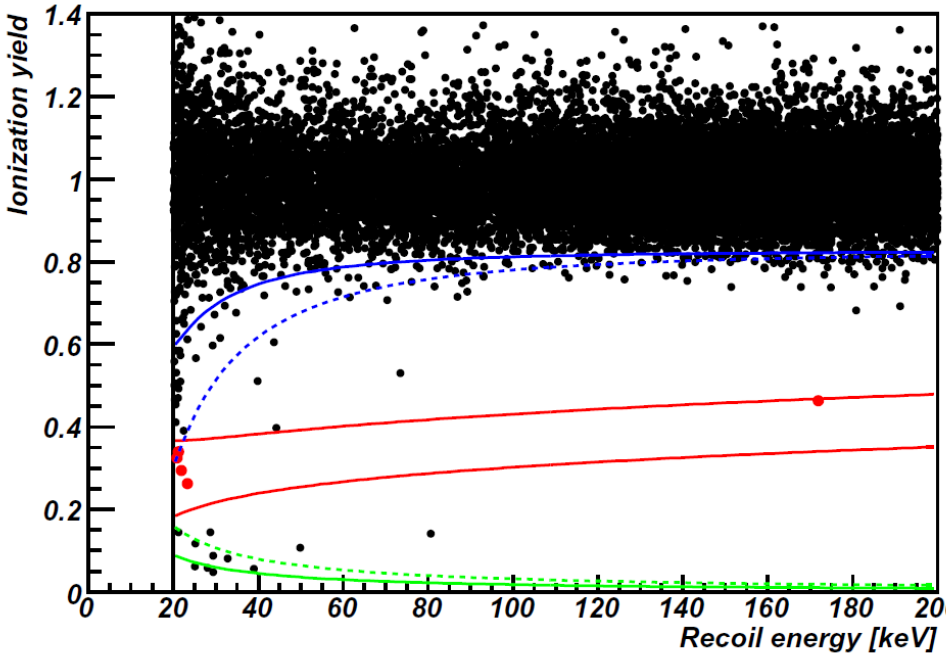
→ rejection factor for surface events of

6 x 10^{-5} (90% CL)

Phys Lett B 681 (2009) 305

Results for « standard » analysis

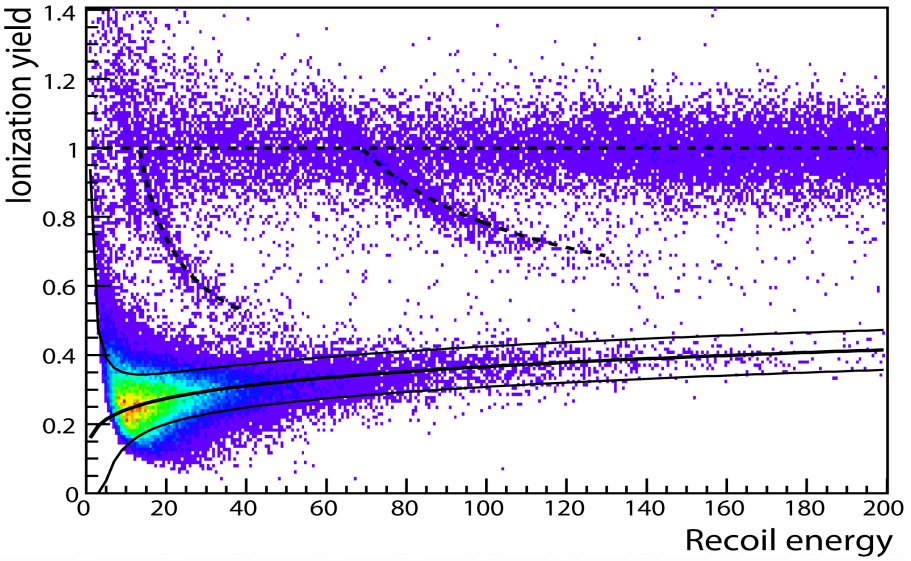
- Data taken in 2009-2010 with ID detectors (10 x 400 g)
- Quality cuts :
  - Noisy periods (baseline measurement)
  - Pulse-fit chisquare (χ^2)
  - Fiducial selection (ionisation)
- Results :
  - 384 kg.d fiducial exposure
  - 5 evts in WIMP box selection :
    - $20 < E_R < 200$ keV
    - NR recoil band @ 90 %

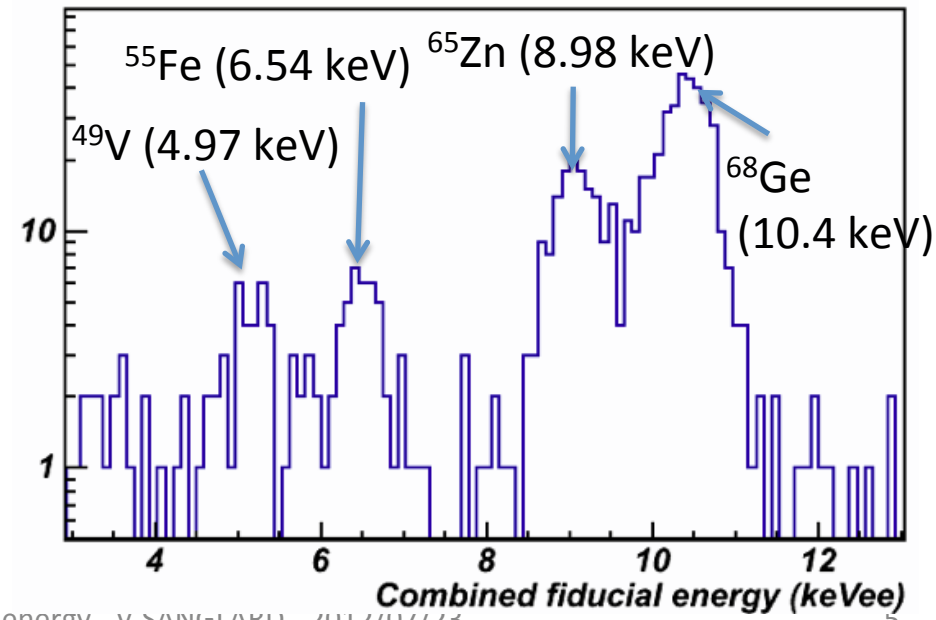


- Limits (using « Optimal Interval Method) :
  $\sigma < 4.4\ 10^{-8}$ pb for $M\chi = 85$ GeV/c^2
- Phys. Lett. B **702** (2011) 329

Motivations for low energy analysis

- Search for WIMP induced nuclear recoils below 20 keV with 2009-2010 ID data
- New analysis – Independent results
- We are sensitive to NRs below 20 keV down to 5 keV
- Sub-keV baseline resolutions on some detectors
  - Heat : 0.8 keV
  - Ionisation : 0.7 keV
- But background discrimination and efficiency control are more difficult





Data selection

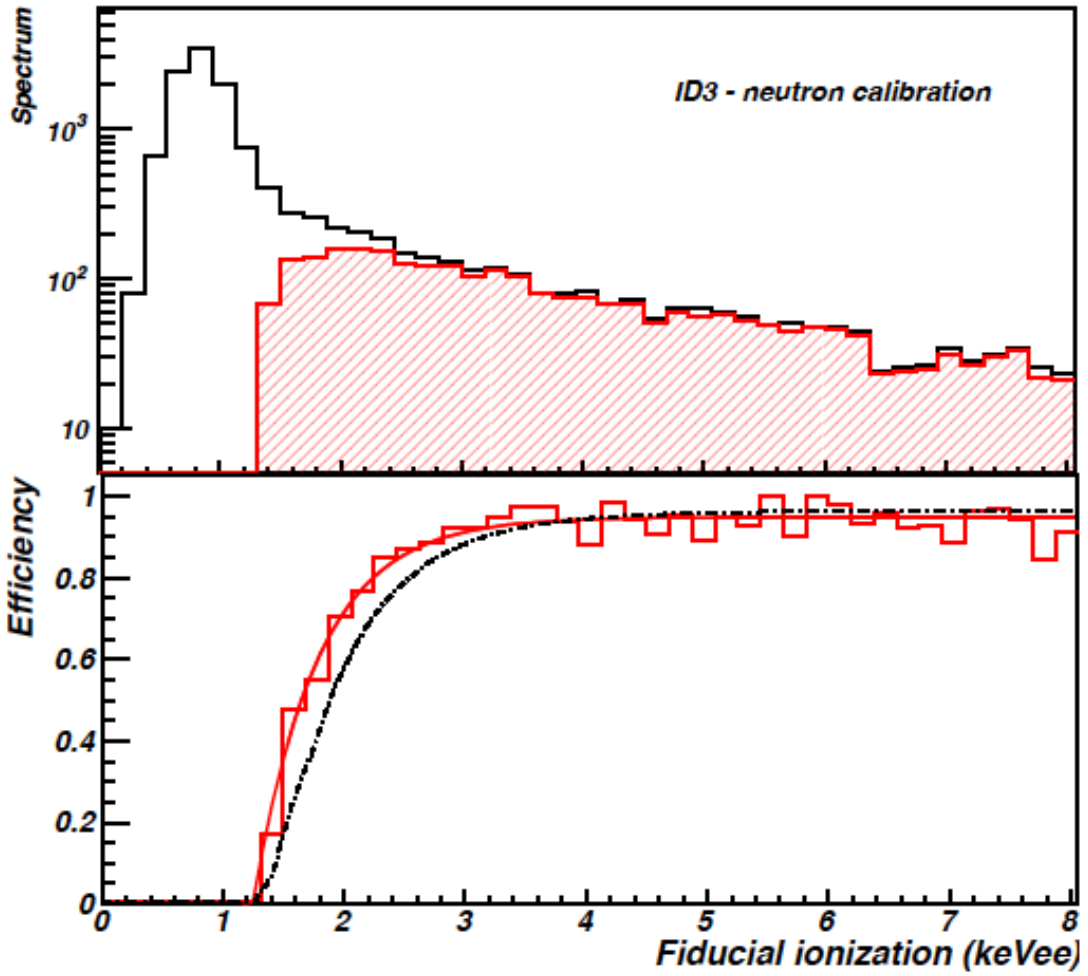
- Rejection of bad detectors for the present analysis
  - Missing electrode, ^{210}Pb pollution, large low-energy gamma background
  - Keep only 4 detectors
- Remove noisy periods
  - Cut on the baseline of each channel
- Cut on heat pulse-fit χ^2 (99 % efficiency)
- Remove coincidences (99.8 % efficiency)
- Fiducial selection
  - No signal on vetos, no signal on guards
  - No difference between fiducial electrodes

  } Independent energy efficiency
- $\Delta t < 30$ µs for pulse on fiducial electrode (rejection of ionisationless evt)
- Combined fiducial $E_{ion} > 5\sigma$

  ⇒ Fiducial exposure : 113 kg.d

Efficiency of the ionisation cut

- Ionisation cuts = energy dependent cuts
  - E_{ion} > 1.4 – 1.9 keV
  - Δt < 30 µs
- Use neutron calibration :
  - Low energy evts
  - WIMP like pulses
- Black curve : before cut
- Red curve : after ionisation cut
- 50% efficiency at 2 keV
- Compatible results obtain with γ calibration



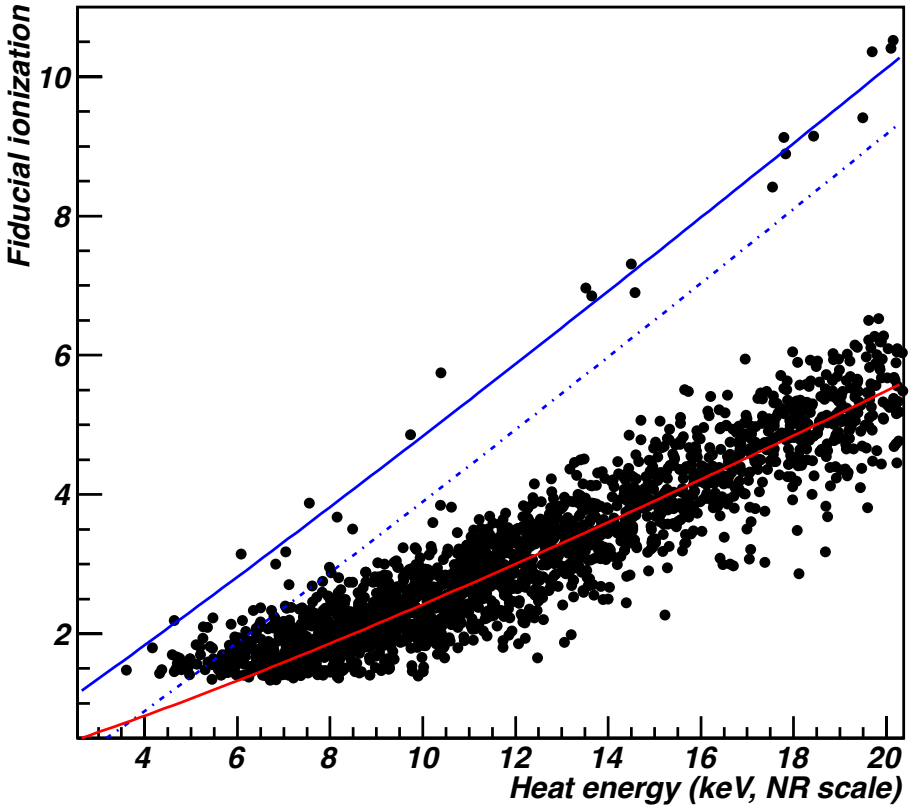
New estimator for E_R

- Low energy analysis ⇨ search for NRs near threshold
  - Need an estimator with a very good (gaussian) resolution
  - Assumption : events due to NR

$$E_{heat} = \frac{E_{rec}}{1+V/3}\left(1+\frac{V}{3}\,0.16\,E_{rec}^{0.18}\right)$$

- New presentation in (E_{ion}, E_{heat}) plane
- Errors on E_{ion} and E_{heat} are independent
- For an electron recoil, E_R overestimates energy by factor 2

AmBe calibration for ID3



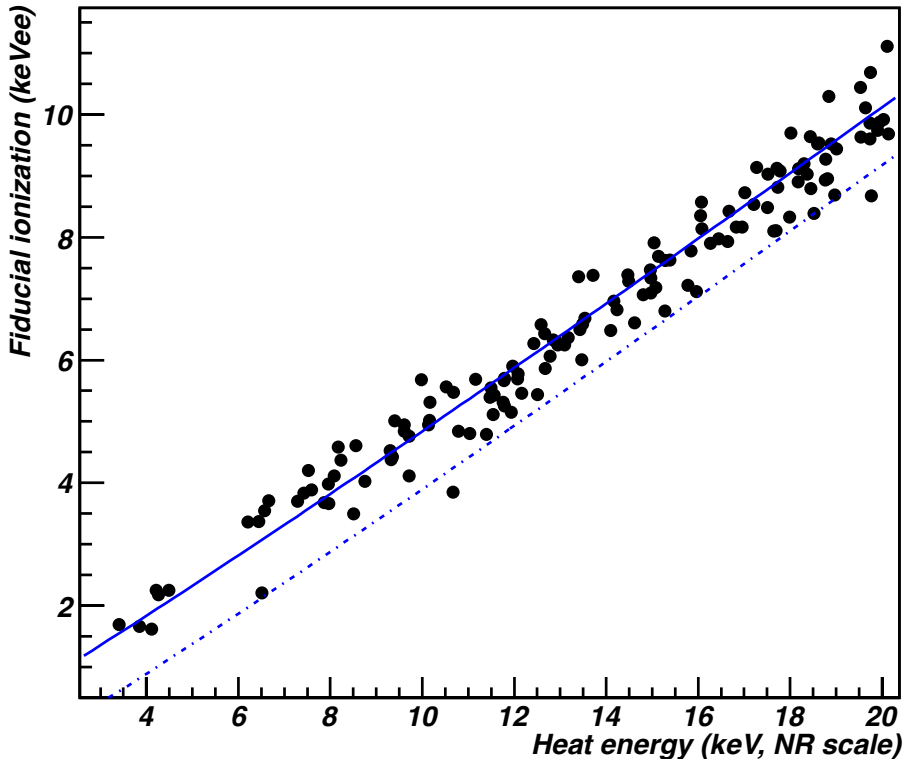
New estimator for E_R

- Low energy analysis ⇨ search for NRs near threshold
  - Need an estimator with a very good (gaussian) resolution
  - Assumption : events due to NR

$$E_{heat} = \frac{E_{rec}}{1+V/3}\left(1+\frac{V}{3}\,0.16\,E_{rec}^{0.18}\right)$$

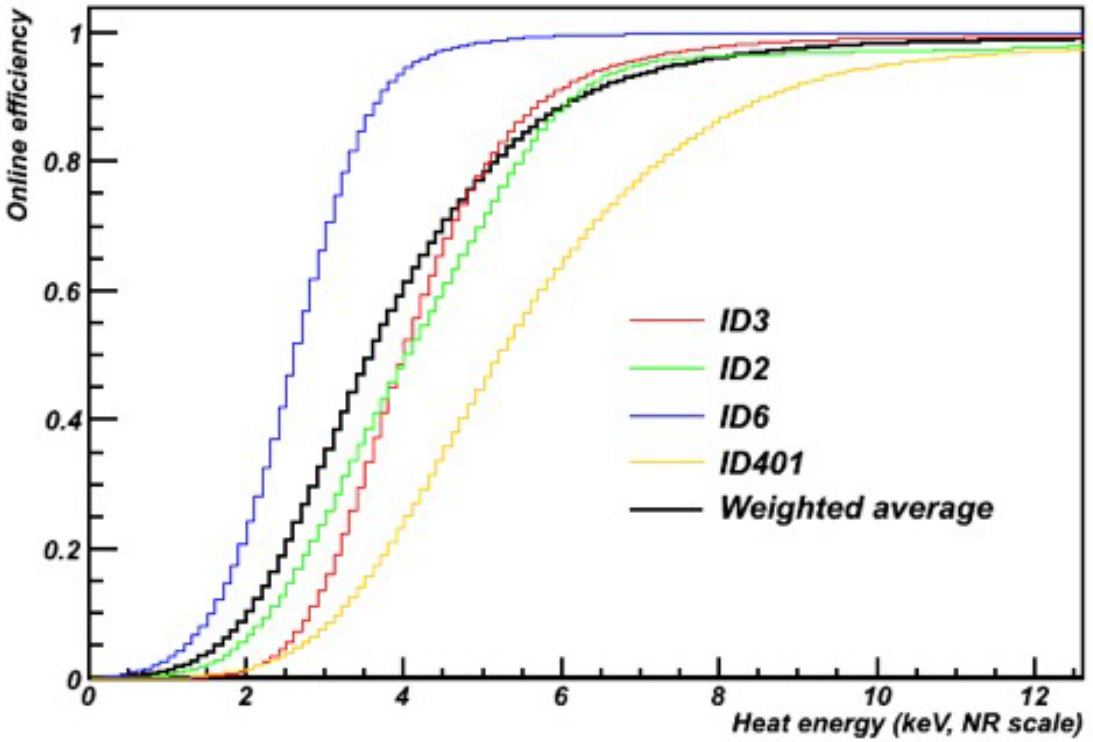
- New presentation in (E_{ion}, E_{heat}) plane
- Errors on E_{ion} and E_{heat} are independent
- For an electron recoil, E_R overestimates energy by factor 2

^{133}Ba calibration for ID3



Online efficiency

- Online threshold induces an efficiency dependence on E_{heat}
- Trigger threshold vary during run depending on noise conditions
- Method tested with γ calibration
- Trigger efficiency for WIMP search :
  - 78 % @ 5 keV
  - 90 % @ 6.3 keV



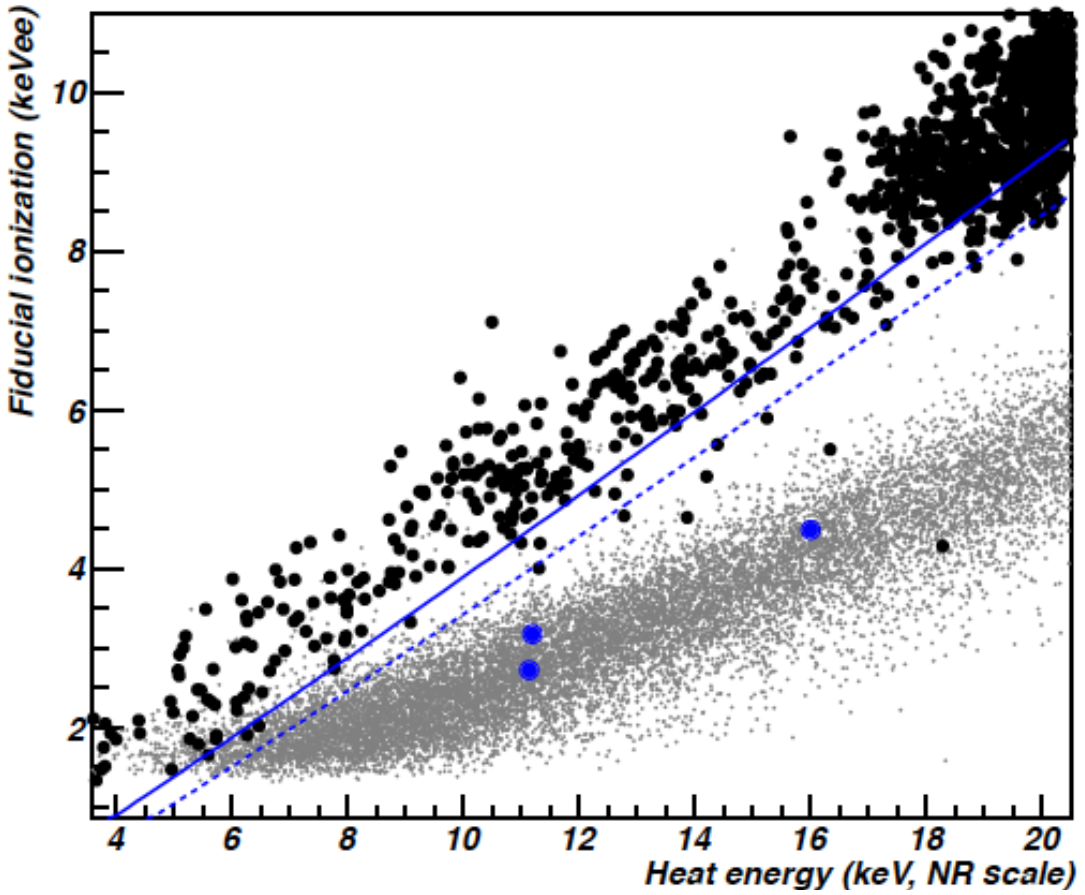
$$\epsilon_{\text{online}}(E_r) = 0.5[1 + \text{Erf}((E_r - E_{\text{thresh}})/\sigma\sqrt{2})]$$

Estimated background

- Ionisationless events :
  - rejection factor of the ionisation cut = 10^{-6}
  - negligible contribution
- Neutron < 1.7 evt for E_R = 5-20 keV
  - MC simulation + activity measurements of material
  - Most probable value ~ 1 evt
- Fiducial gamma background < 1.2 evt
  - 2.5 % of observed gamma in energy range where WIMP search region is limited by 95 % gamma rejection cut
- Surface events
  - Events rejected
  - No measured rejection factor in the range 5-20 keV

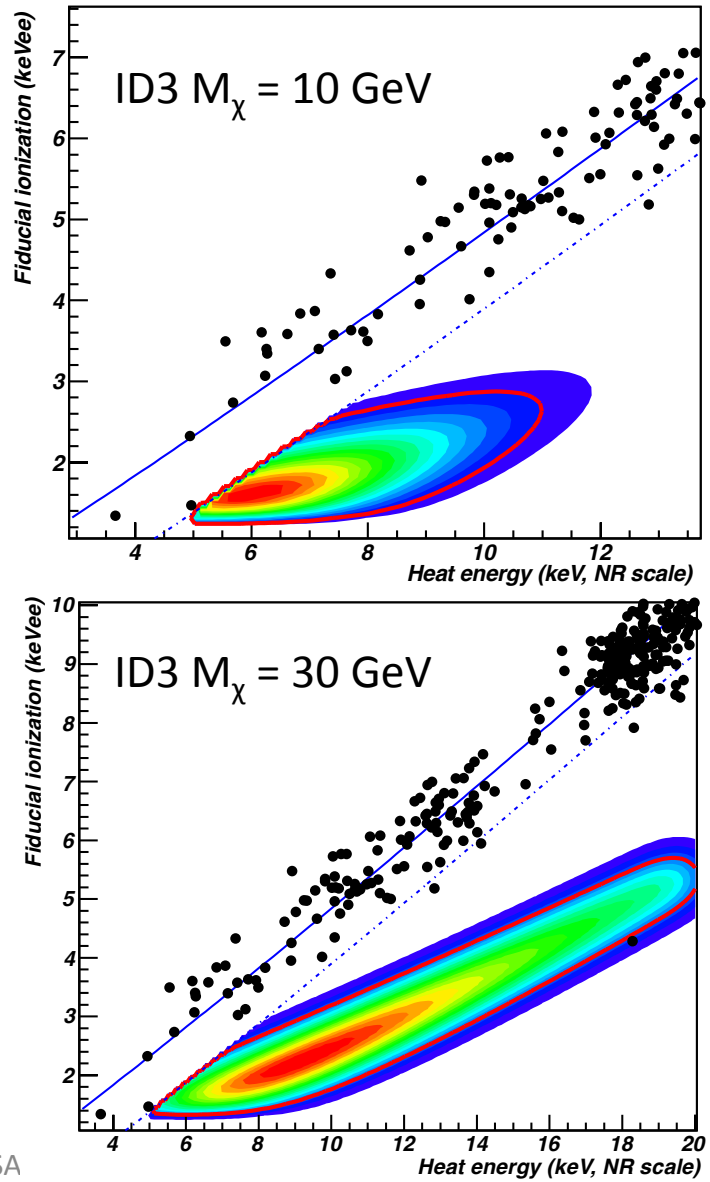
Results

- Events recorded in 113 kg.d
- In gray = neutron calibration
- In blue = event in WIMP search region
- Blue lines = 95 % gamma-ray rejection
- Events recorded compatible with expected background

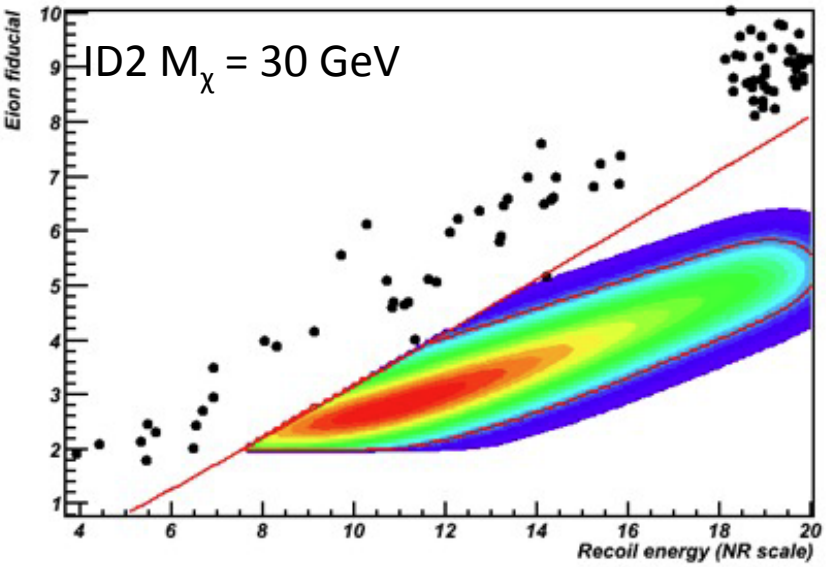


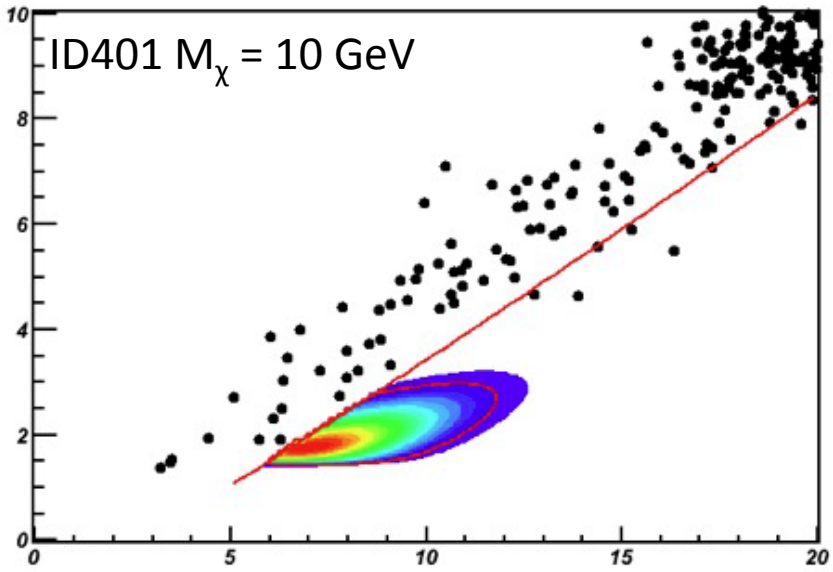
WIMP search region definition

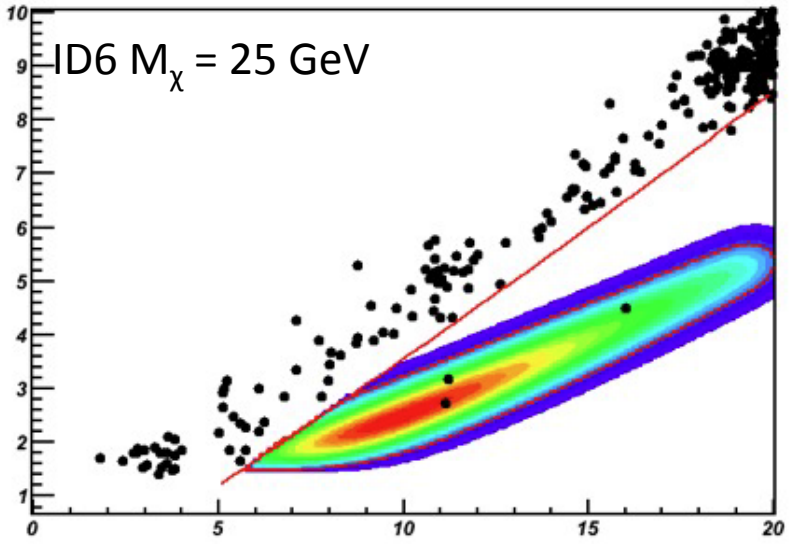
1) WIMP induced NR spectrum as a function of ER
2) Taking into account E_{heat} and E_{ion} thresholds $\Leftrightarrow$ taking into account resolutions on fiducial ionisation (ER scale) and heat (NR scale)
3) We obtain WIMP signal density in the (E_R, E_{ion}) plane
4) WIMP search region = region containing 90 % of WIMP signal density below gamma rejection cut (red curve)

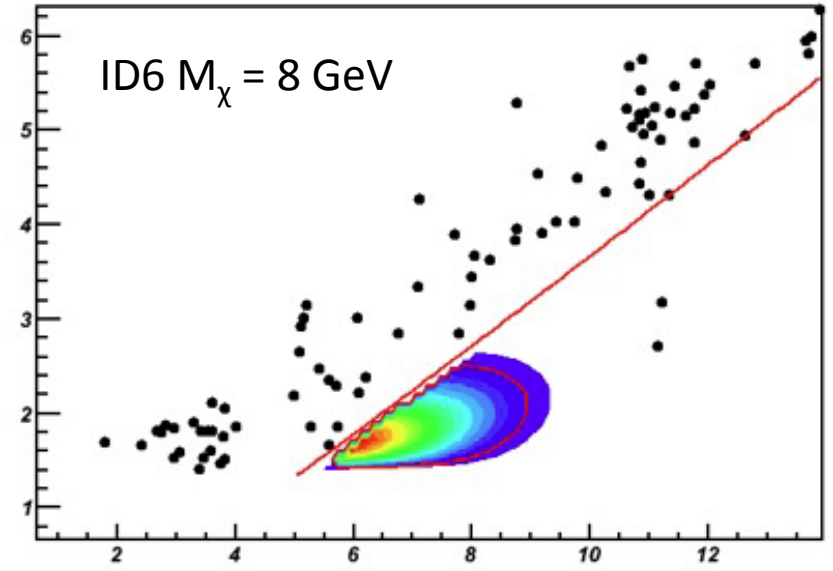


Other detectors results



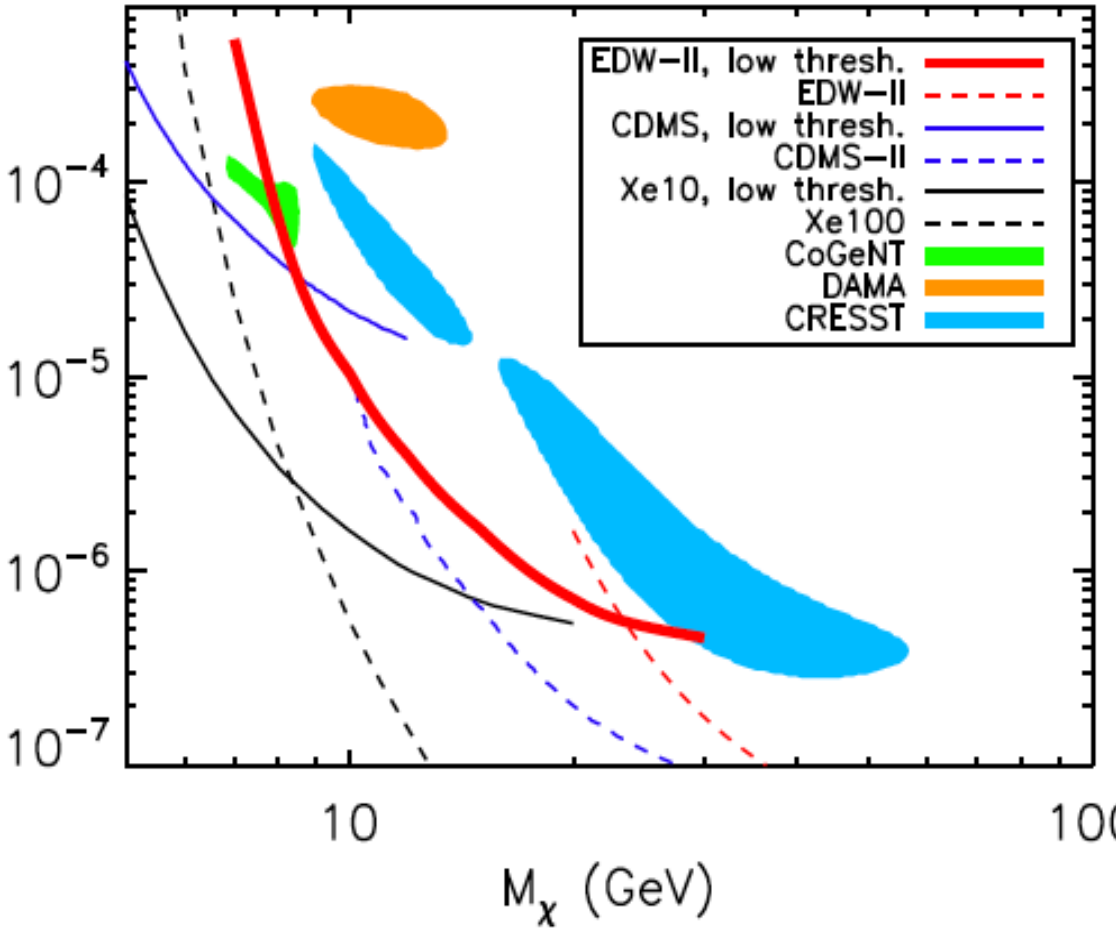






Limits on σ_{SI} as a function of M_χ

- Add events in the four detectors located in the WIMP search region
- Compute 90 % CL limit with Poisson statistics for M_χ = 7-30 GeV/c^2
- All events considered as WIMP candidate (no background subtraction)
- Results extends significantly sensitivity of EDELWEISS-II @ low mass



Exp : $\sigma = 1.0 \times 10^{-5}$ pb for $M\chi$ = 10 GeV (1 evt)

$\sigma = 7.2 \times 10^{-7}$ pb for $M\chi$ = 20 GeV (3 evt)

Conclusion & Perspectives

- ID detectors have good resolutions, excellent particle discrimination and efficiency @ low energy to make an analysis for low WIMP mass
- Almost background-free study
- Good test of the surface event rejection @ low energy for ID detectors
- Results extends significantly sensitivity of EDELWEISS down to $M_\chi = 7\ GeV/c^2$
- FID, new generation of EDELWEISS detectors have better heat and ionisation resolutions ⇨ improvement of the limit @ low mass