# The EDELWEISS DM search Phase II to Phase III

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on behalf of the EDELWEISS Collaboration

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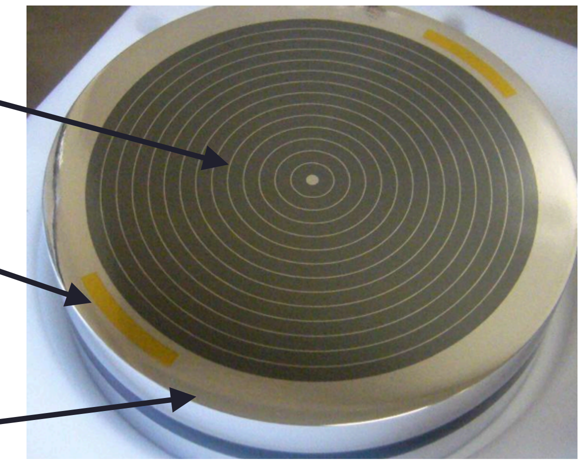
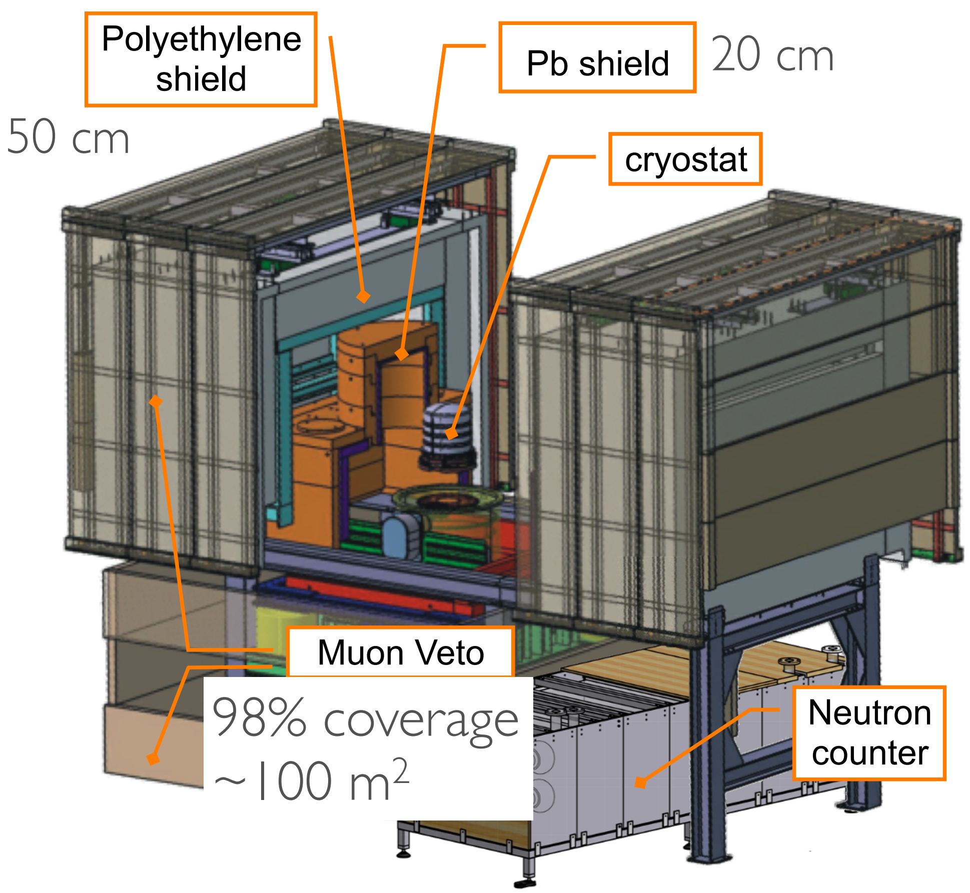
LSModane (CEA/CNRS)

# Edelweiss II at LSM (Frejus Tunnel)

- Cryogenic Ge Direct DM Search
- Charge/Heat detection
- 10 x 400 g detectors 2008-2010




Gadolinium-loaded Scintillator to measure muon-induced neutron flux

Reverse Cryostat

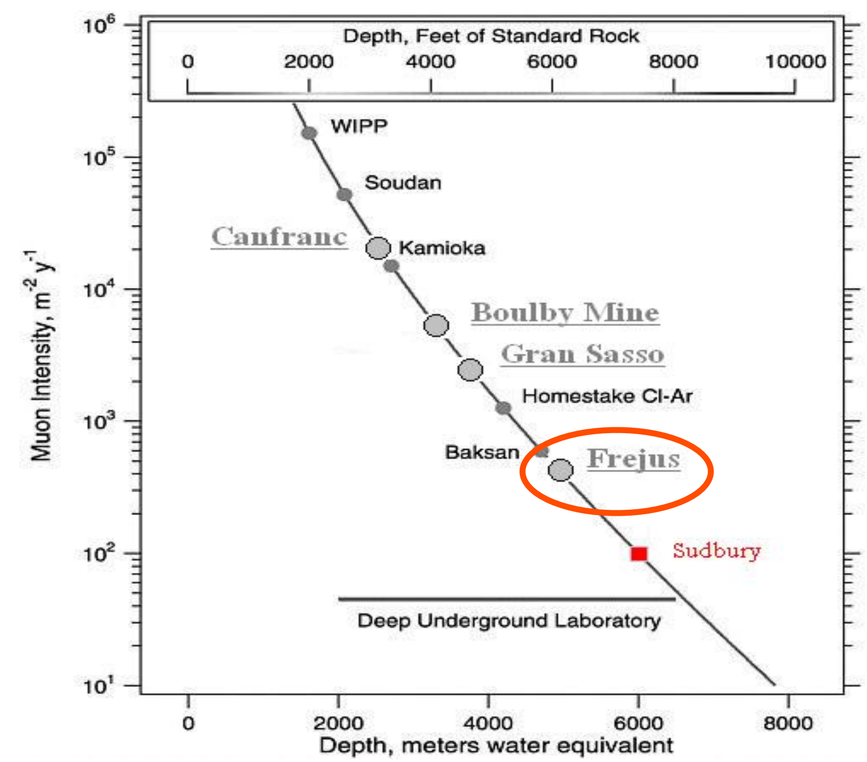
18 mK (up to 40 kg)

Clean room +
Deradonized Air

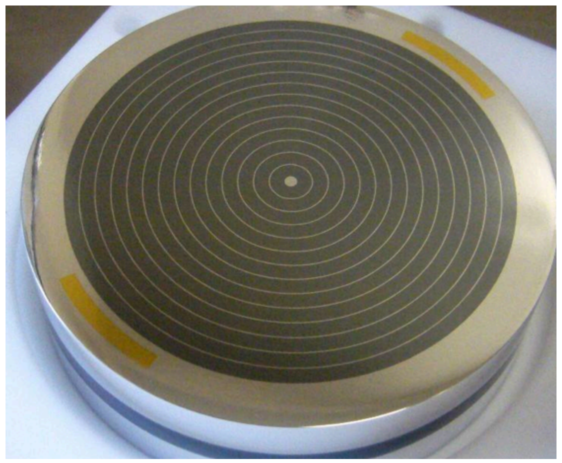
Radon detector (~ mBq/m$^3$)

3He thermal neutron counter
~few $10^{-9}$ n/cm$^2$/s

4800 m.w.e.
4.1 +- 1.0 muons / m$^2$ / day



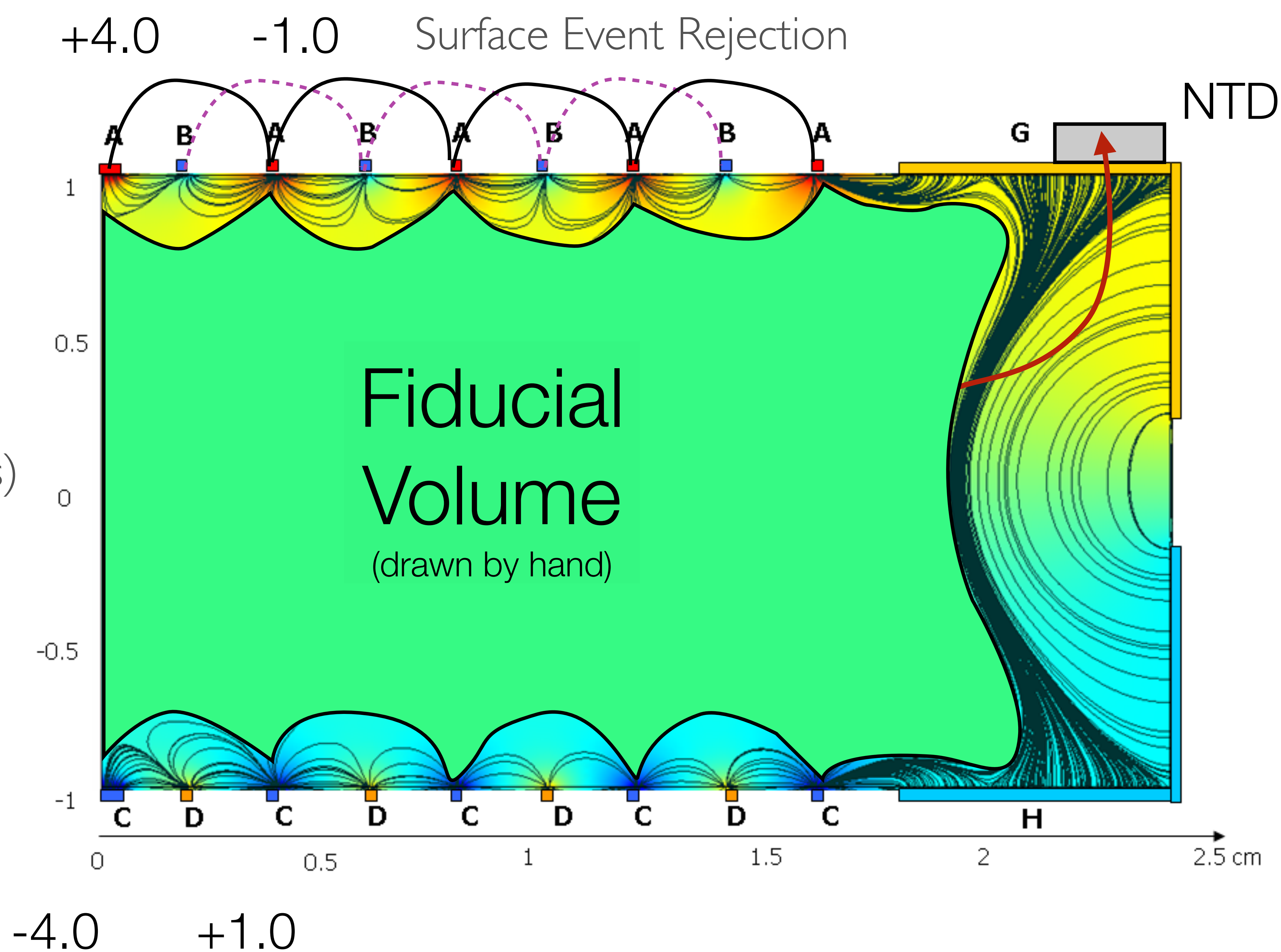
# An Edelweiss Detector



$E_{recoil} \sim E_{heat}$
(after N-L corrections)

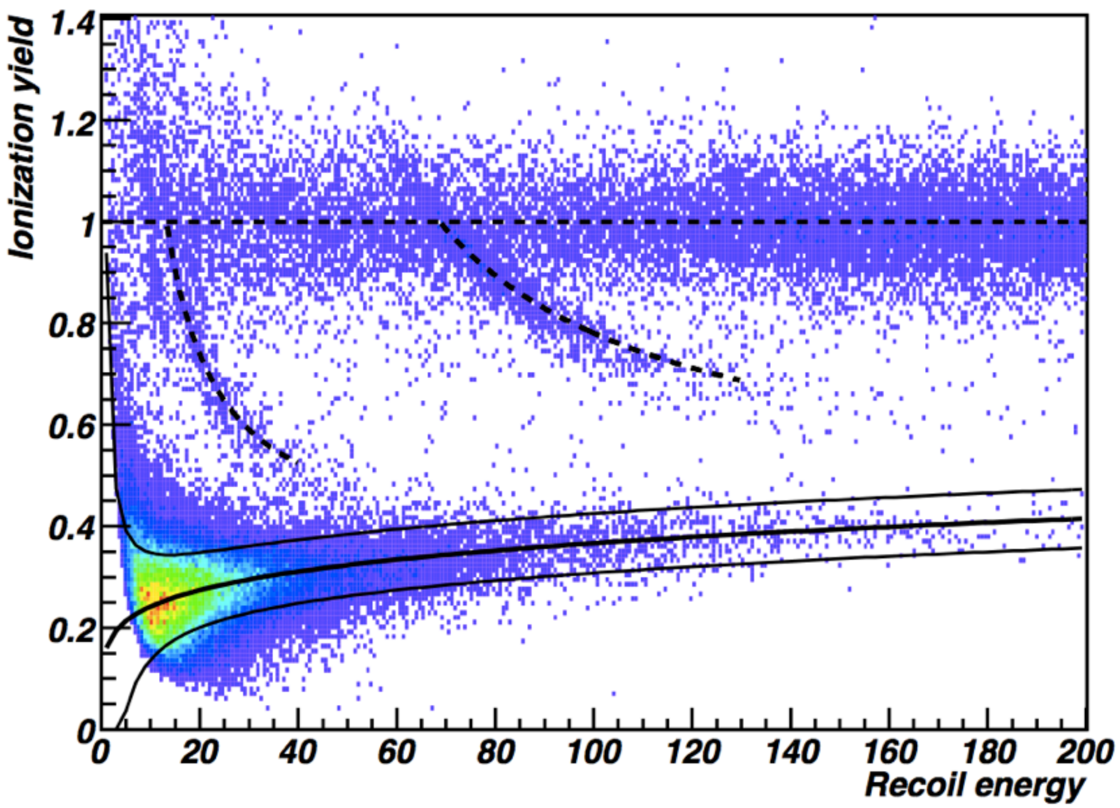
Ionization Yield
$E_{ionization} / E_{recoil}$

Ge nucleus recoil
~1/3 fewer
electron-hole pairs

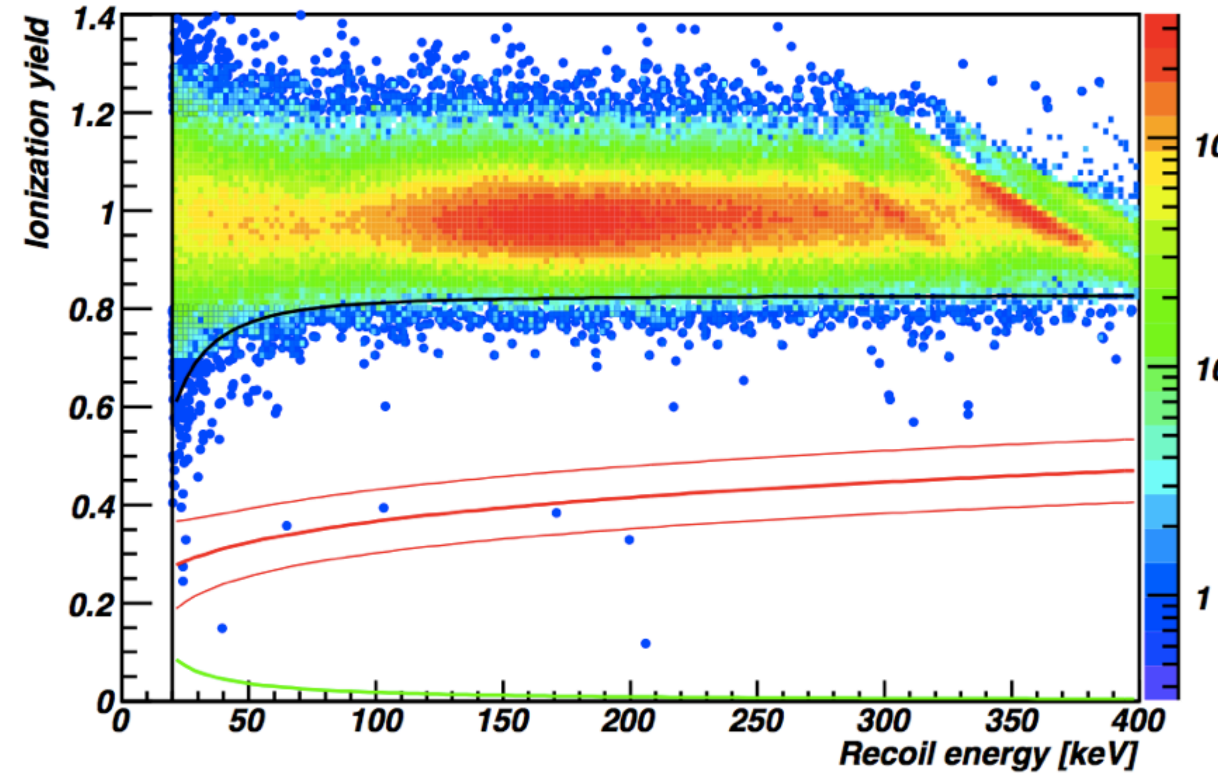


# Gamma Band and Nuclear Recoil Band

neutrons




$^{133}$Ba (347k events)




Ge recoil Ion yield = $0.16\ E_{rec}^{0.18}$

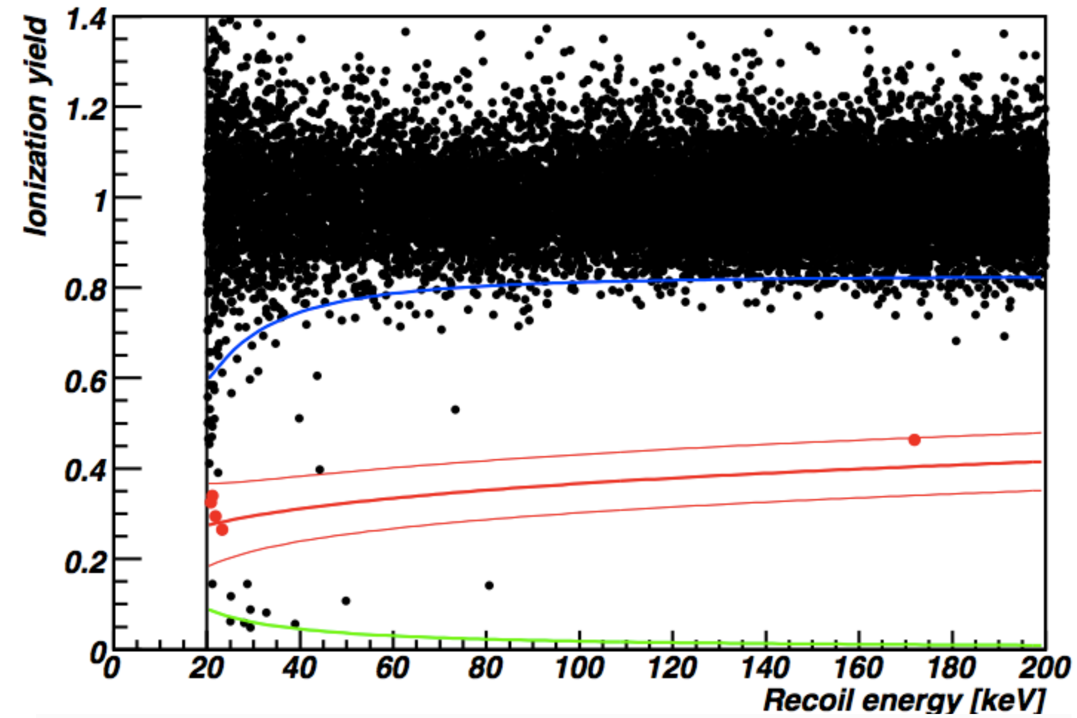
1 NR for every 30k gammas between 20 and 200 keV

P. Di Stefano, et al., Astropart. Phys. 14 (2001) 329.
O. Martineau, et al., Nucl. Instrum. Meth. A 530 (2004) 426.

A. Broniatowski, et al., Phys. Lett. B 681 (2009) 305.

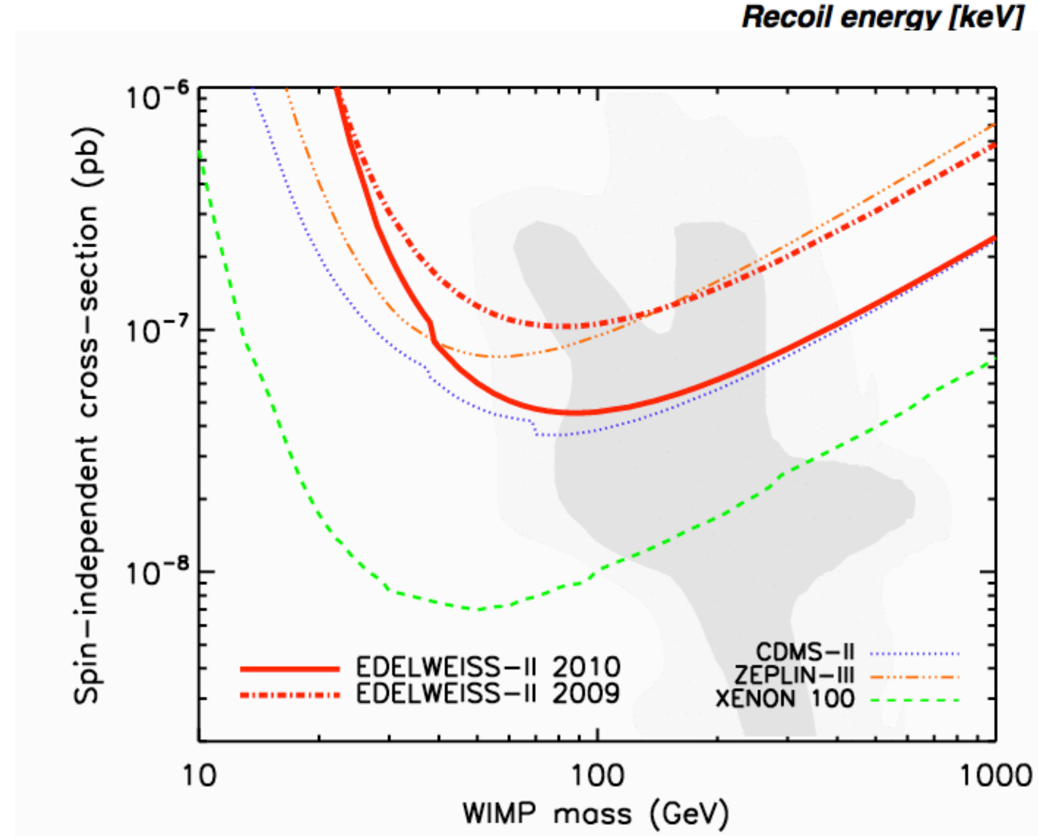
# Edelweiss II Results. Data from 2008 - 2010

- Ionization Yield ($E_{ion}$ / $E_{recoil}$) v $E_{recoil}$
- July - Nov 2008 and April 2009 - May 2010
- 427 kg * days
- 384 kg * days in 90% NR band
- 5 events in NR band



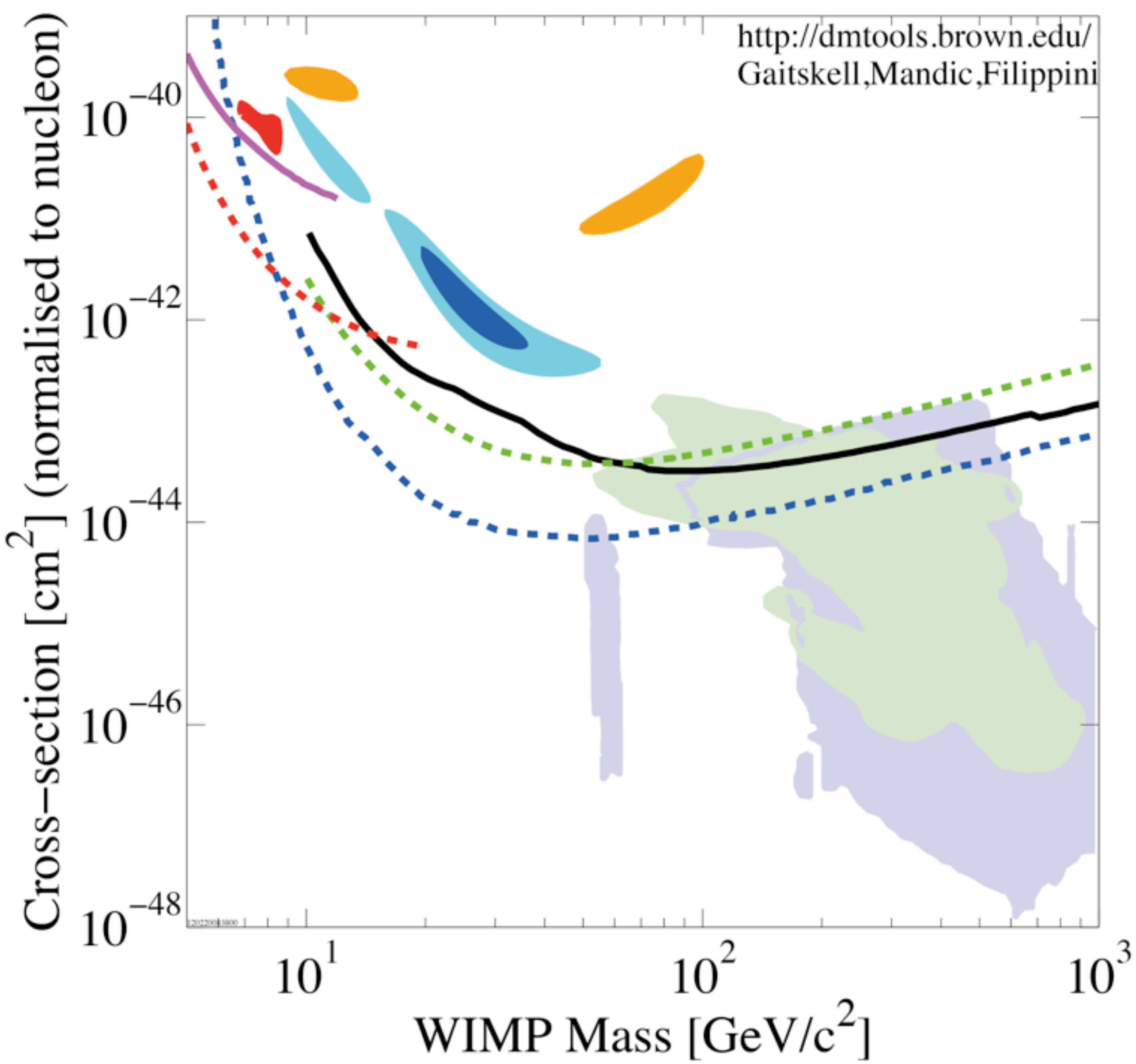

WIMP Halo
local density of 0.3 GeV/$c^2$
Maxwellian velocity distribution
$v_{rms}$ = 270 km/s
$v_{Earth}$ = 235 km/s
$v_{escape}$ = 544 km/s

$\sigma_{SI}$ < 4.4 x $10^{-8}$ pb at 90% CL for
$M_{WIMP}$ = 85 GeV/$c^2$




E. Armengaud, et al., Phys. Lett. B 702 (2011) 335–329.

# Direct Detection Current Status




DAMA/LIBRA EPJ **C56** (2008)

CoGeNT PRL **106** (2011)

CRESST II 2 sigma arXiv: 1109.0702

CRESST II 1 sigma arXiv: 1109.0702

CDMS Low E, PRL **106** (2011)

CDMS + EDW, Phys Rev D **84** (2011)

ZEPLIN III, arXiv: 1110.4769

XENON100 PRL **107** (2011)

XENON10 Low E, PRL **107** (2011)

CMSSM Trotta et al, (2008)

CMSSM with LHC and XENON 100
Buchmueller et al, arXiv: 1110.3568

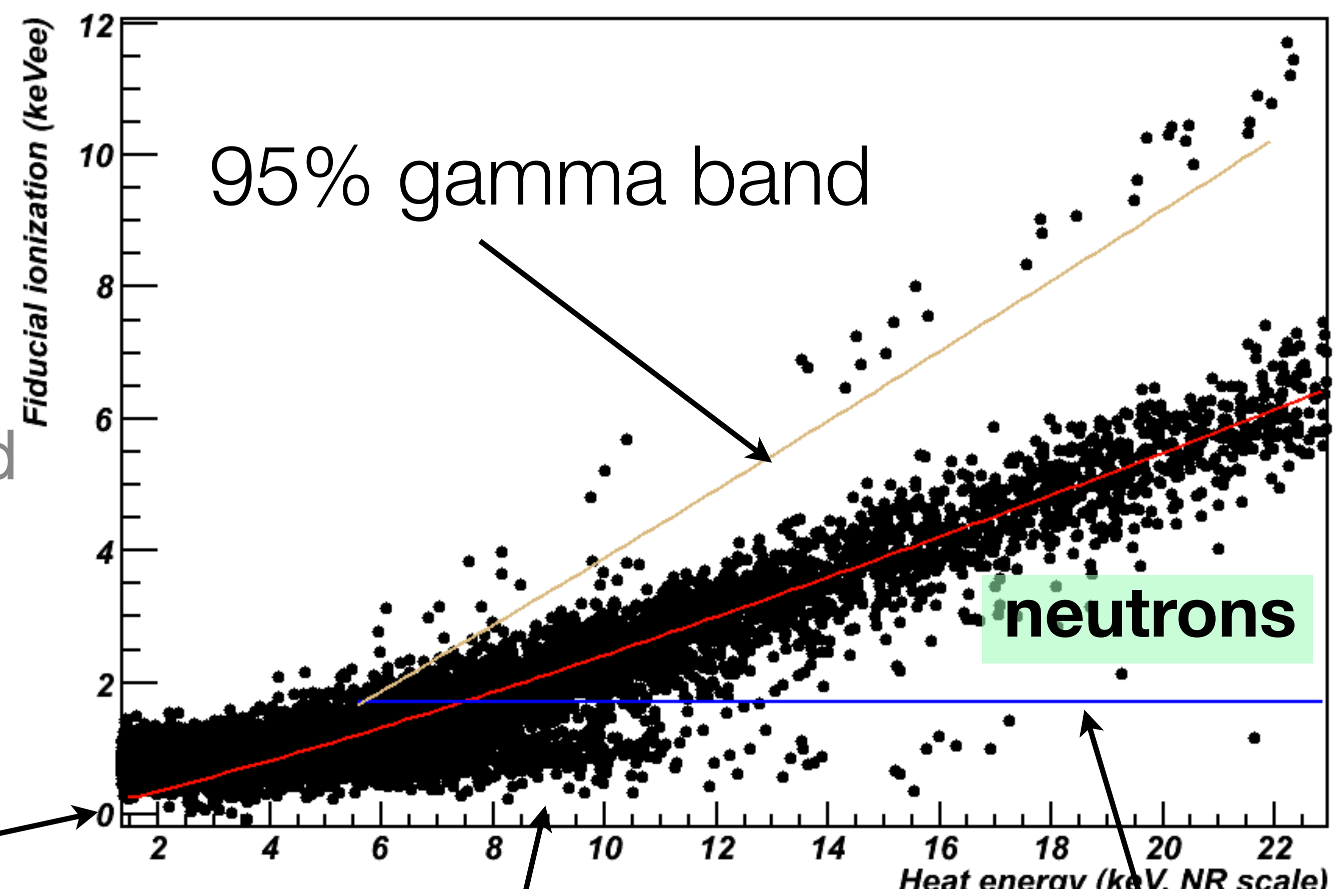
# ***Preliminary*** Low Energy Analysis of ID3

- Search below 20 keV
- Neutrons to 5 keV
- Energy based on heat only

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

- Chi2 cut on heat pulses
- Fiducial events (no veto/guard)
- Online trigger efficiency measured by calibration of ADU threshold value

Strong ($10^5$ n/s) AmBe neutron calibration 2010 placed outside of all shielding and muon veto




consistent with $0.16 \, E_{rec}{}^{0.18}$

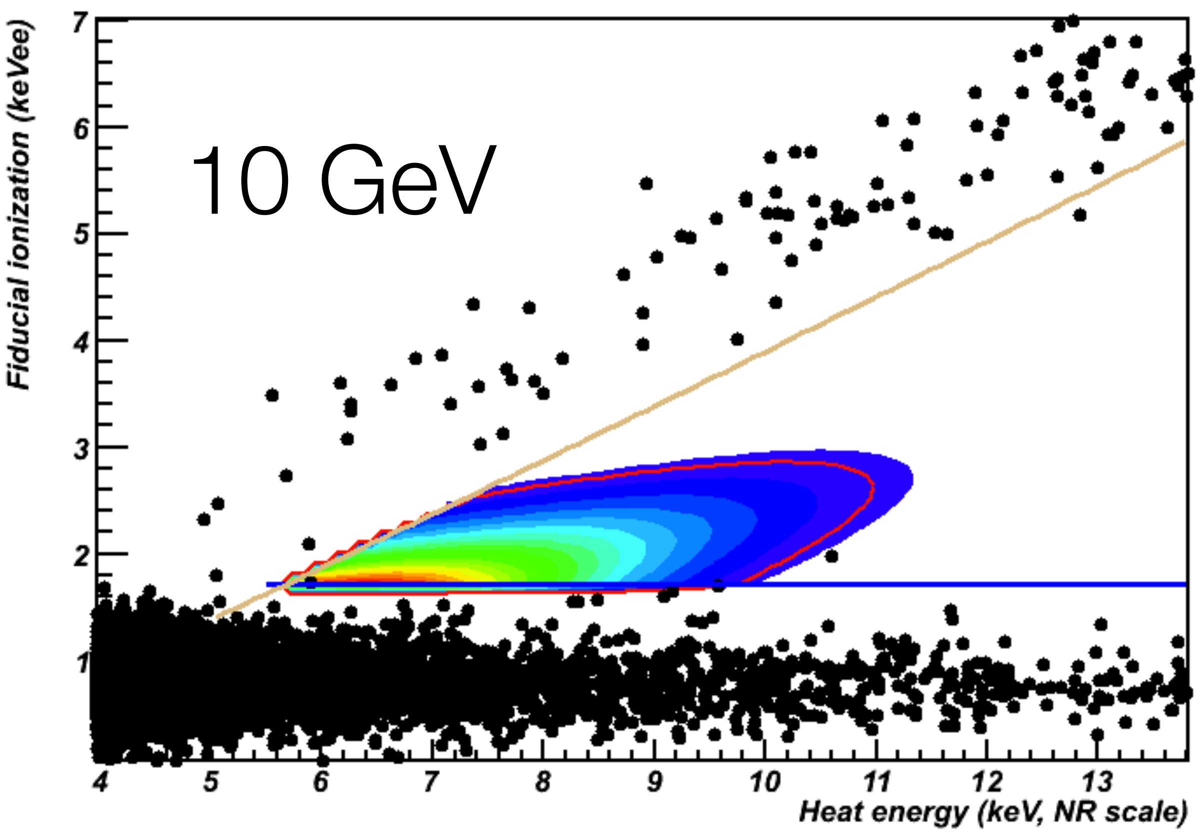
NR ionization yield (red line)

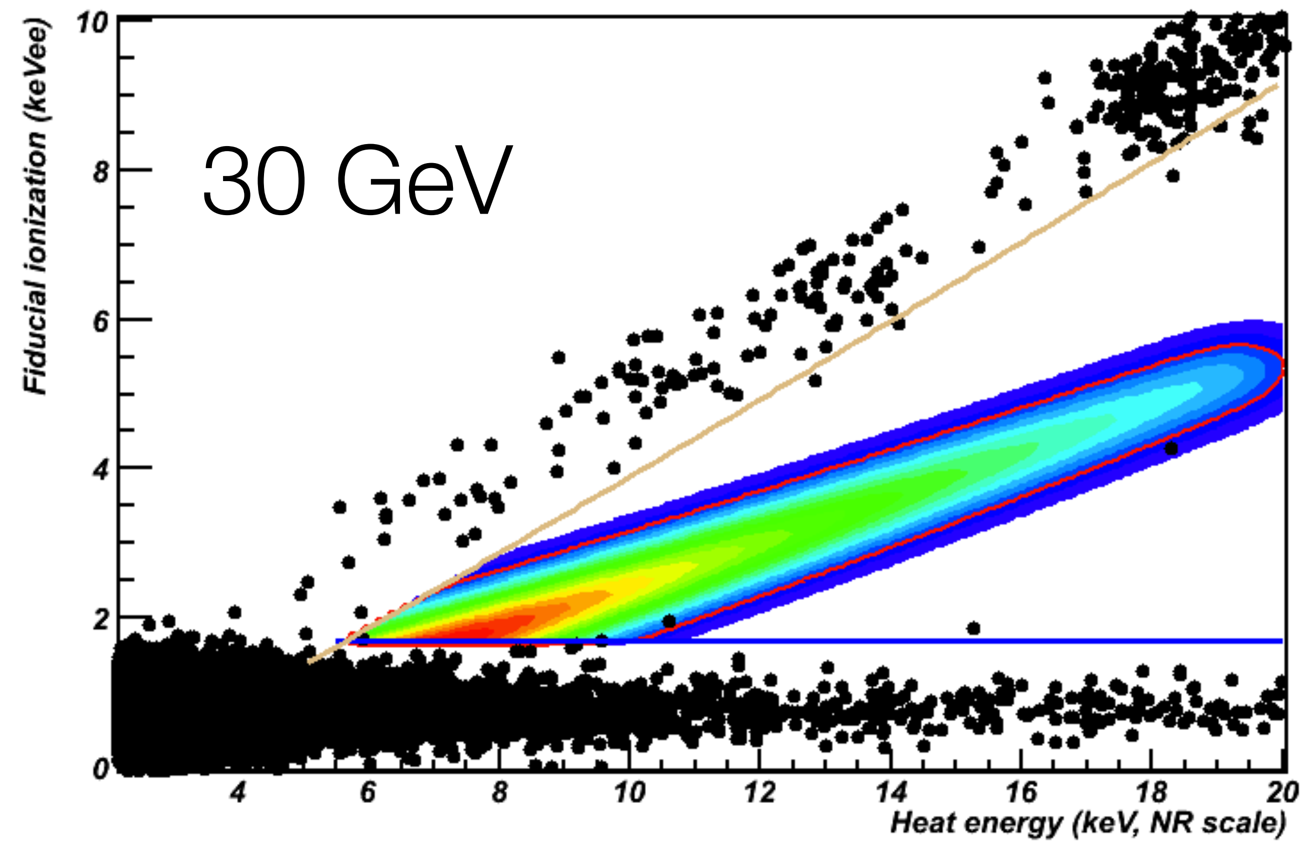
heat only events

Ionization threshold (1.7 keV)

# WIMP search : ID3 low-energy background data

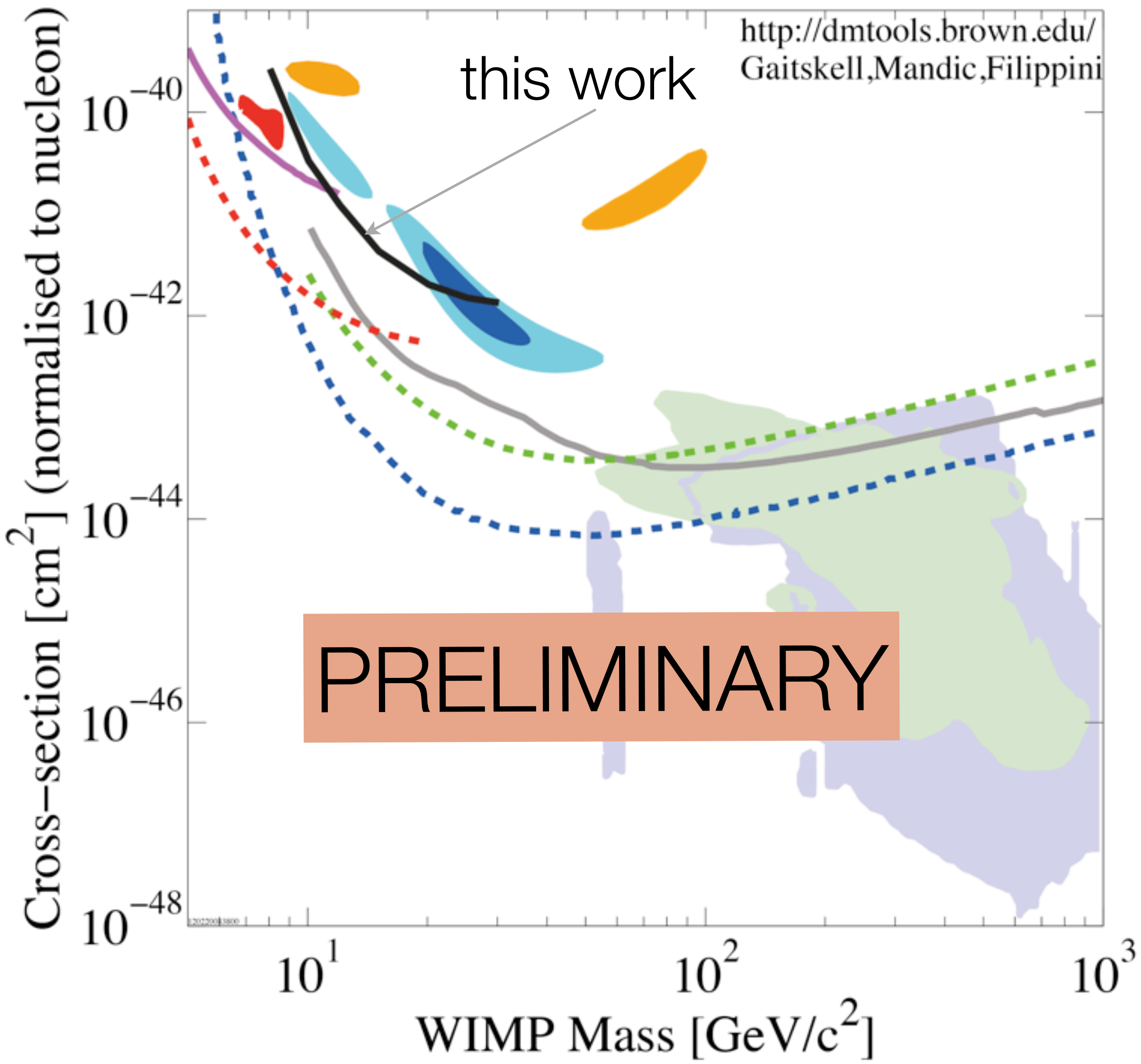
198 live days. Same data in both plots (different scale)



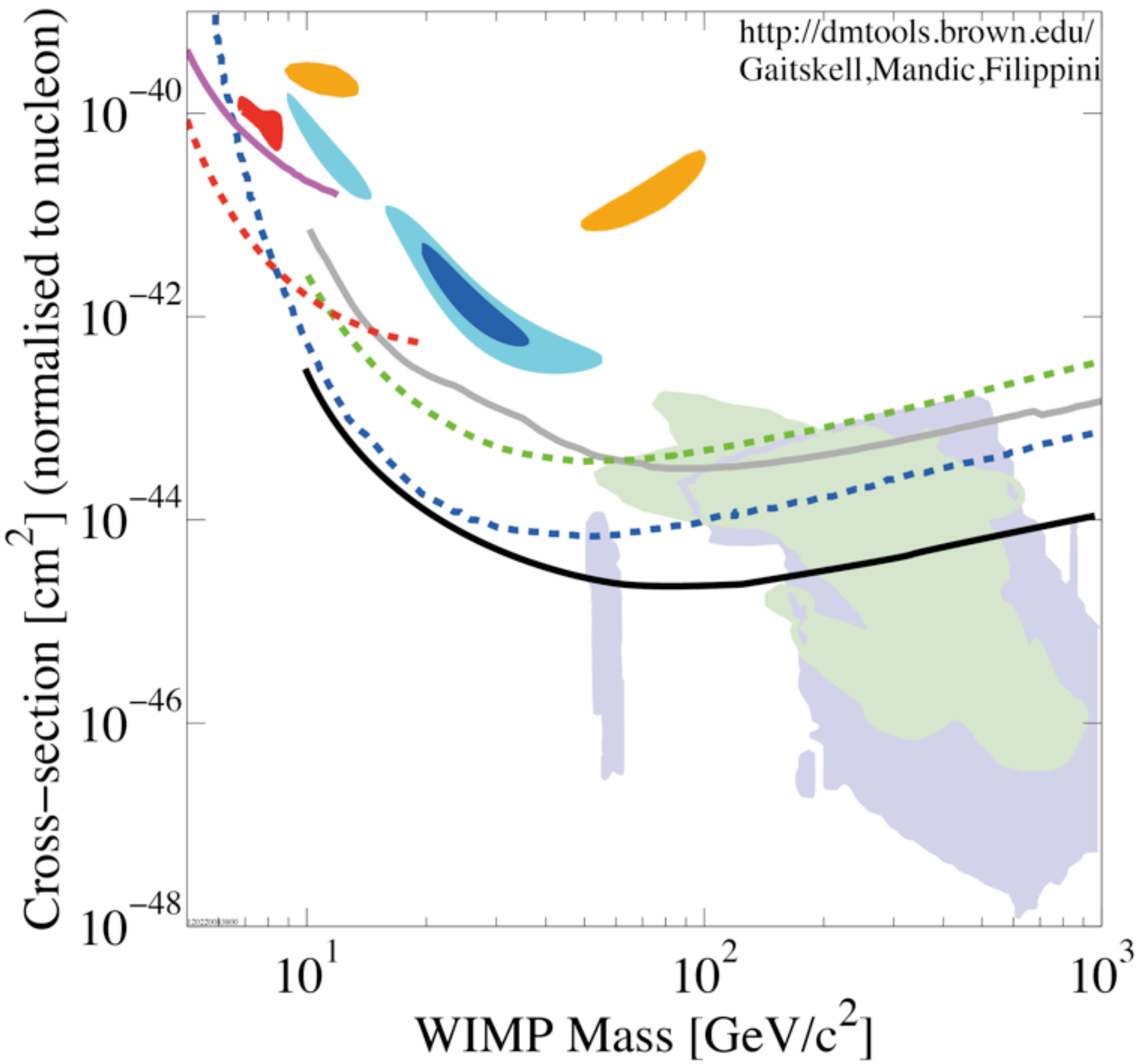

- Compute the density of a WIMP signal for a given mass (using measured resolutions and efficiencies) : colour contours
- Count the WIMP candidates within a ROI fixed to have 90% efficiency to the WIMP signal **(red contour)**
- No convincing signal (from 1 to 3 candidates depending on $M_X$); derive 90% CL limit on $\sigma_{SI}$ from Poisson statistics
- Estimated backgrounds:
    ~ 0.25 events from heat-only pulses (using a background model)
    ~ 0.5 events from fiducial gamma-rays
    ~0.5 neutrons
    No significant surface event background (compare to CDMS) !!!

# Preliminary low-mass WIMP limit ~ 30 kg.d




- Combination with detectors of equivalent performance (in progress)
- Limited by Heat Only events
- ID3 detector (this analysis) has best resolution
- Poisson limits (optimal interval to come)
- (2 NTDs per bolometer in EDW III)

# EDELWEISS III

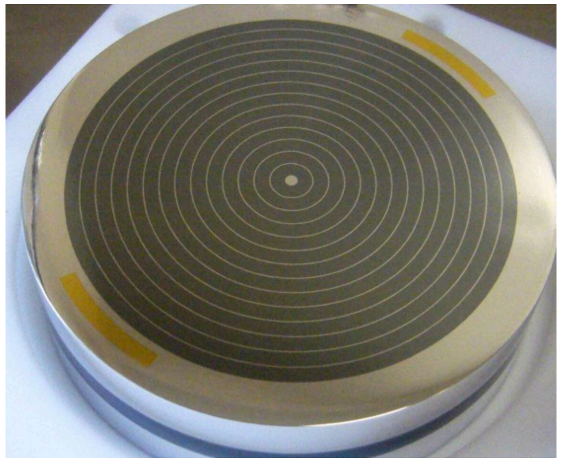


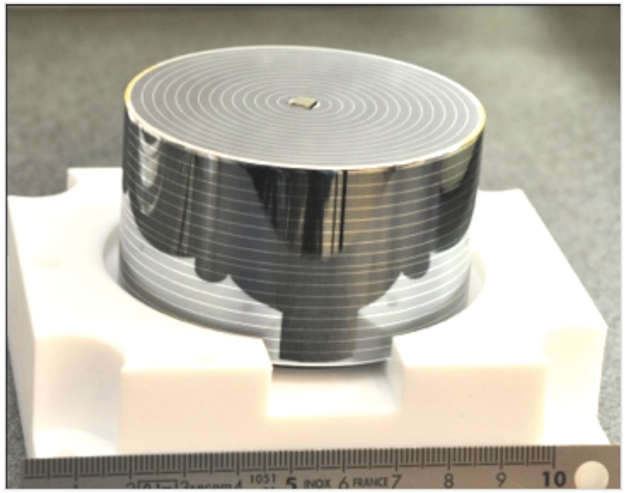

## Goals

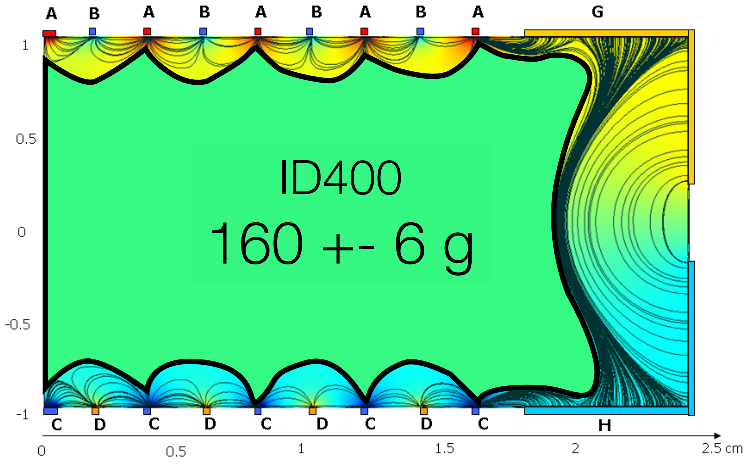
- 3000 kg day exposure
- Explore low mass region
  - consistently < 1 keV FWHM ionization resolution
- Reduce background by factor of 10
  - shielding, material selection
  - further quantify gamma/surface rejection

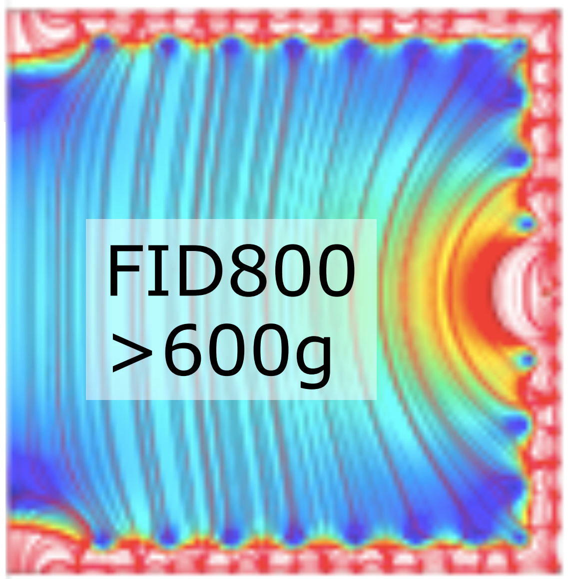
# Increased Exposure: More detectors and Fiducial Volume

- Inter-Digitized -- Fully Inter-Digitized
- ~40% -- > 75%
- 400g -- 800g
- 40 new detectors
- 150 live days = 3000 kg days
- ~1 detector fabricated per week
- ~20 detectors ready by summer
- Expected full delivery Fall 2012



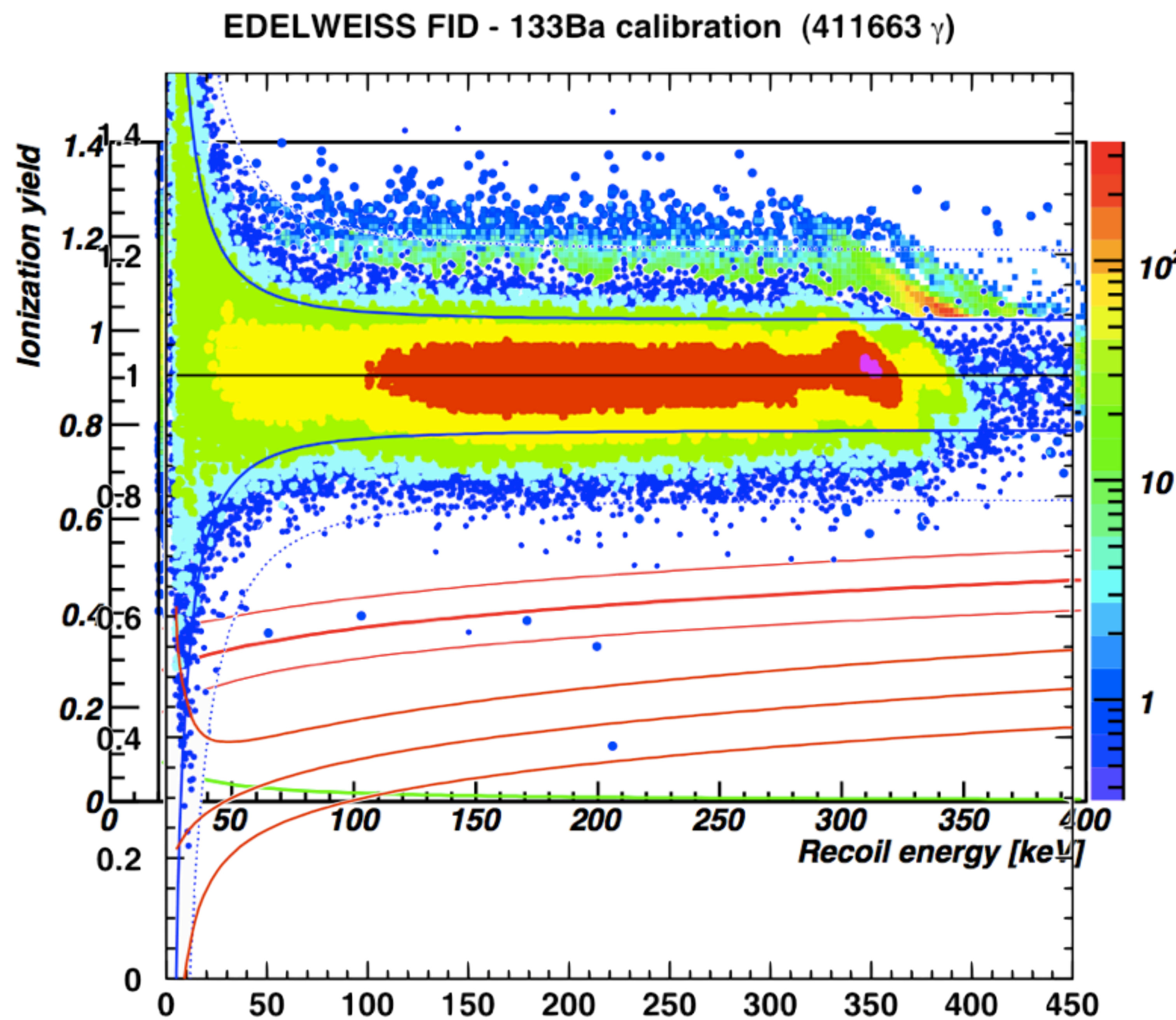




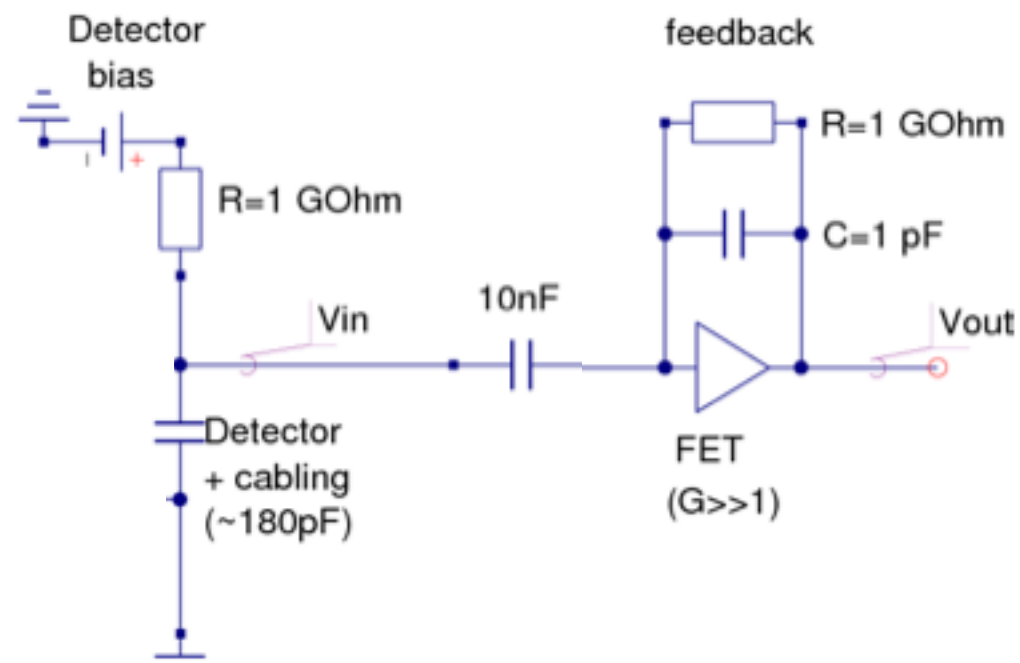
# Gammas

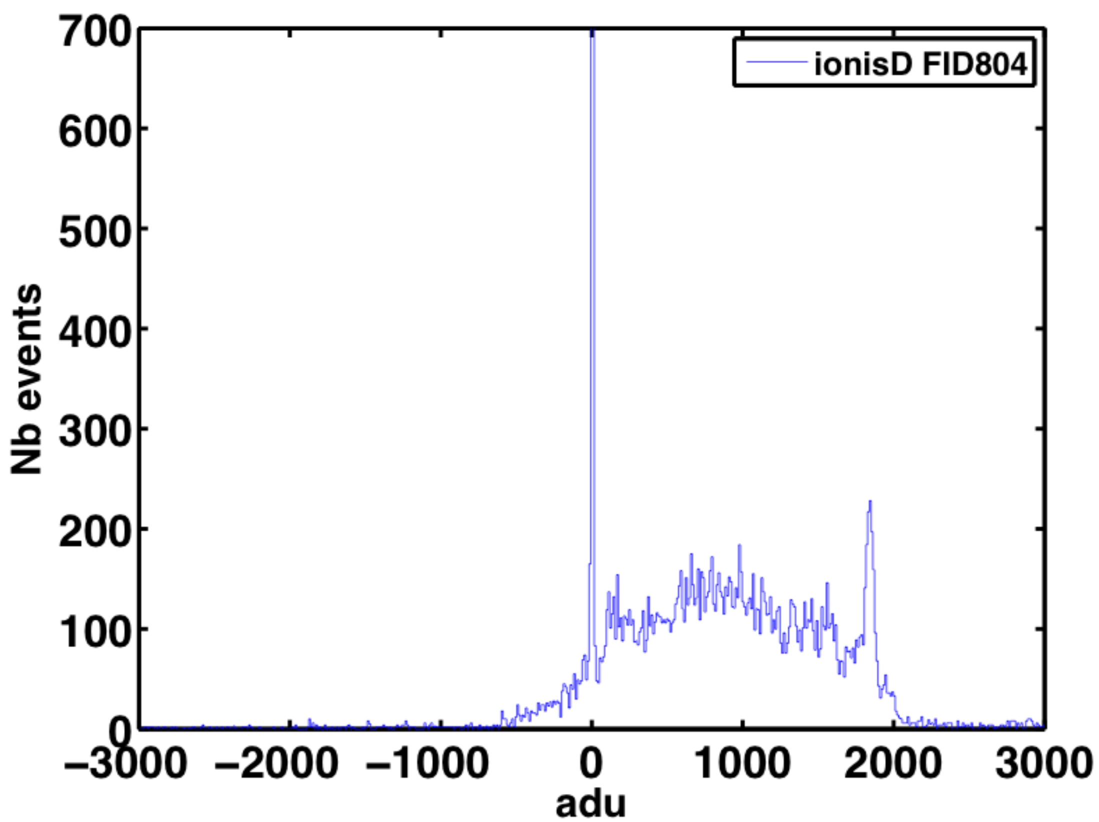
- Run12 ID: 6 events in NR band out of 300k events
- FIDs show better gamma rejection (400k events)
- Low Field regions on edges of ID detectors eliminated by FID

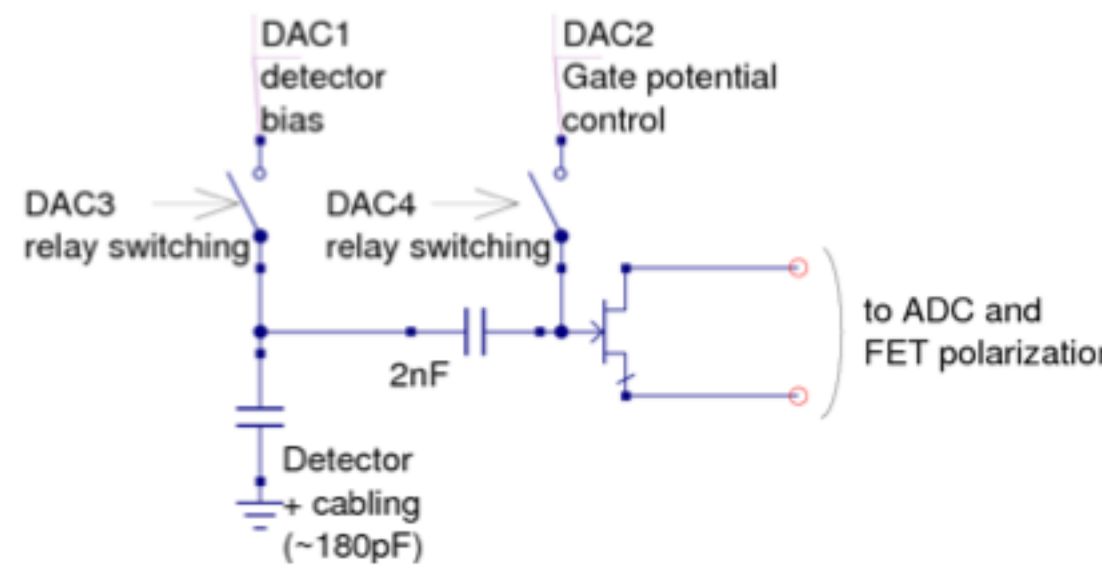


# Efforts to improve Energy Resolution

- New Front-End Electronics (in progress)
- No Feedback Resister on FET
- Relays recharge electrodes, reset FET
- < 1 keV FWHM baseline resolution (500 eV)



# Backgrounds in Edelweiss II

Ambient Neutrons:

| Source | Material | Mass (kg) or thickness (cm) | U/Th concentrations | # Events |
|---|---|---|---|---|
| Hall walls | Concrete | 30 cm | 1.9 / 1.4 ppm | $< 0.10$ |
| Hall walls | Rock | 300 cm | 0.8 / 2.5 ppm | $< 0.01$ |
| Shielding | Lead | 20 cm (40 tonnes) | $< 0.01$ ppb U | $< 0.08$ |
| Shielding | Polyethylene | 50 cm | 0.4 / $< 0.5$ ppb | $< 0.05$ |
| Support | Stainless steel | 0.6 cm ($\sim$200 kg) | 0.4 / $< 1$ ppb | $< 0.01$ |
| Support | Mild steel | 8.6 tonnes | 0.4 / $< 1$ ppb | $< 0.04$ |
| Cryostat | Copper | $\sim$500 kg | $< 0.3$ / $< 0.5$ ppb | $< 0.03$ |
| Electrodes | Aluminium | $< 0.03$ g | $< 1000$ ppb U/Th | $< 0.01$ |
| Crystal holders | PTFE | $\sim 20$ g | $< 0.2$ / $< 0.5$ ppb | $< 0.01$ |
| Connectors | Al, plastics | 0.32 kg | 170 / 110 ppb | $< 0.40$ |
| Cables | PTFE | $\approx 1.35$ kg | 0.8 / $< 1.5$ ppb | $< 0.66$ |

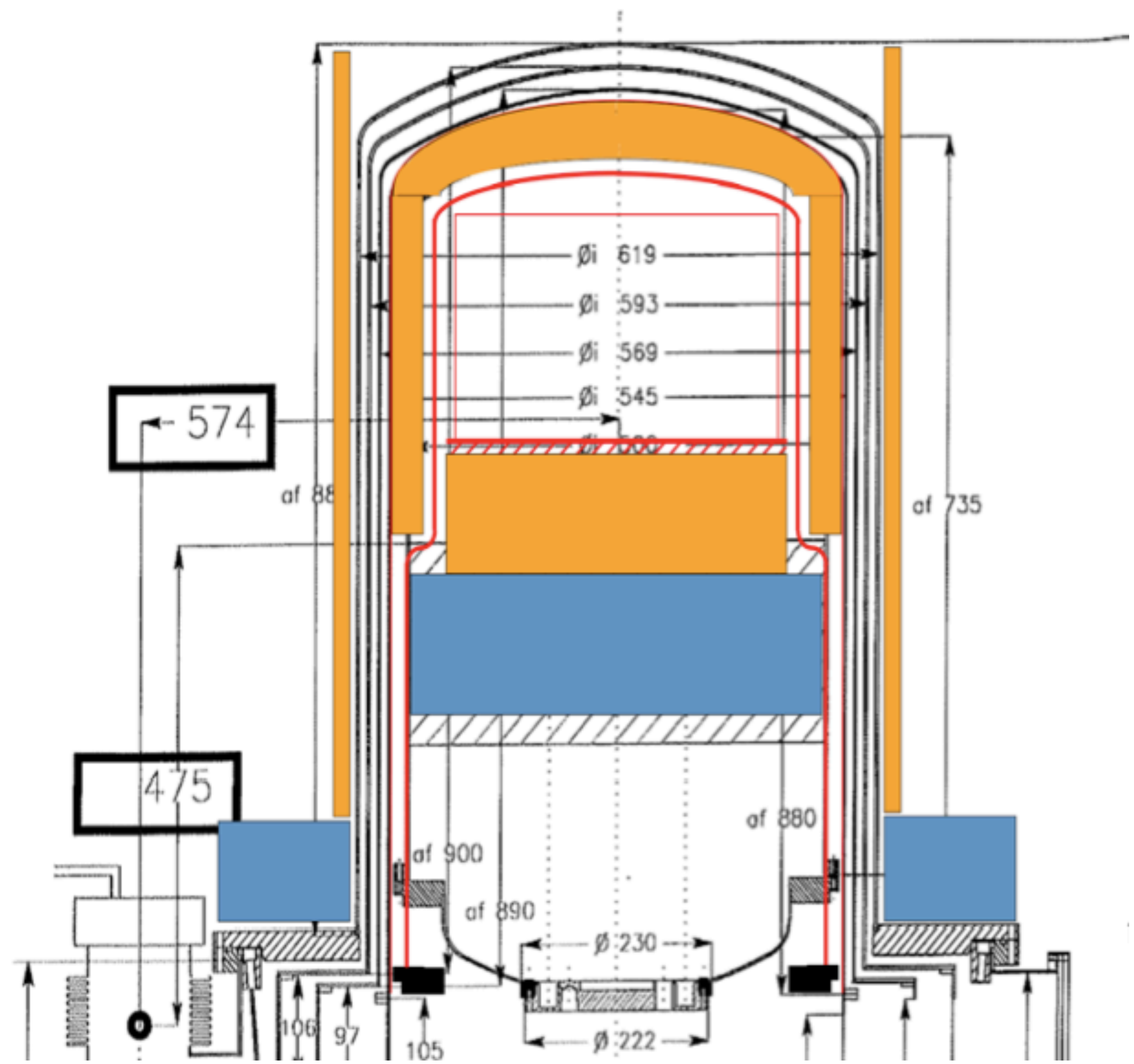
Radiopurity measurements + GEANT4 Simulation of neutron background

- Measured neutron spectrum
- SOURCES4A spectrum

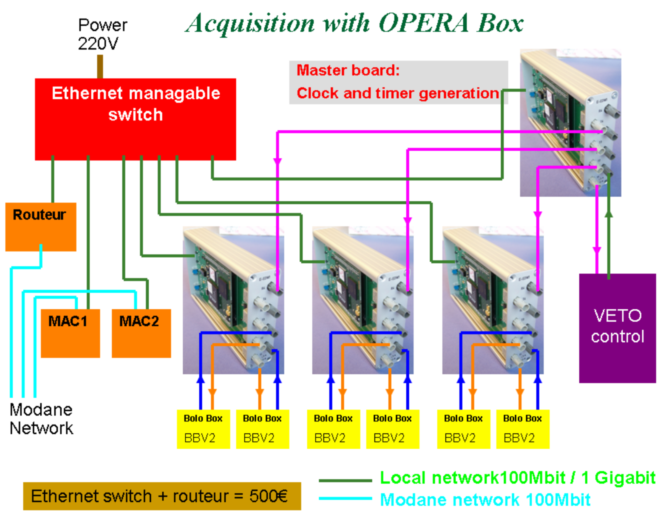
| | | |
|---|---|---|
| Muon-Induced Neutrons (not rejected by Muon Veto) | < 0.4 | measured |
| Total Neutron Background | < 1.8 | |
| Gamma Contamination of NR Band | < 0.9 | measured |
| Surface Event Contamination NR Band | < 0.3 | measured |
| **Total Background Estimate in NR Band** | **< 3.0** | Our Current Best Estimate |

# Neutron Shielding

- Factor 6 reduction in neutrons
- Redesigned Cryostat, internal detector galette.
- Block neutrons from Pb Shield and cables/connectors
- Add Inner PE Shielding
- PE Radiopurity Measurement
- Material selection improvements for cables and connectors
- Cryostat design to be finalized in next month.

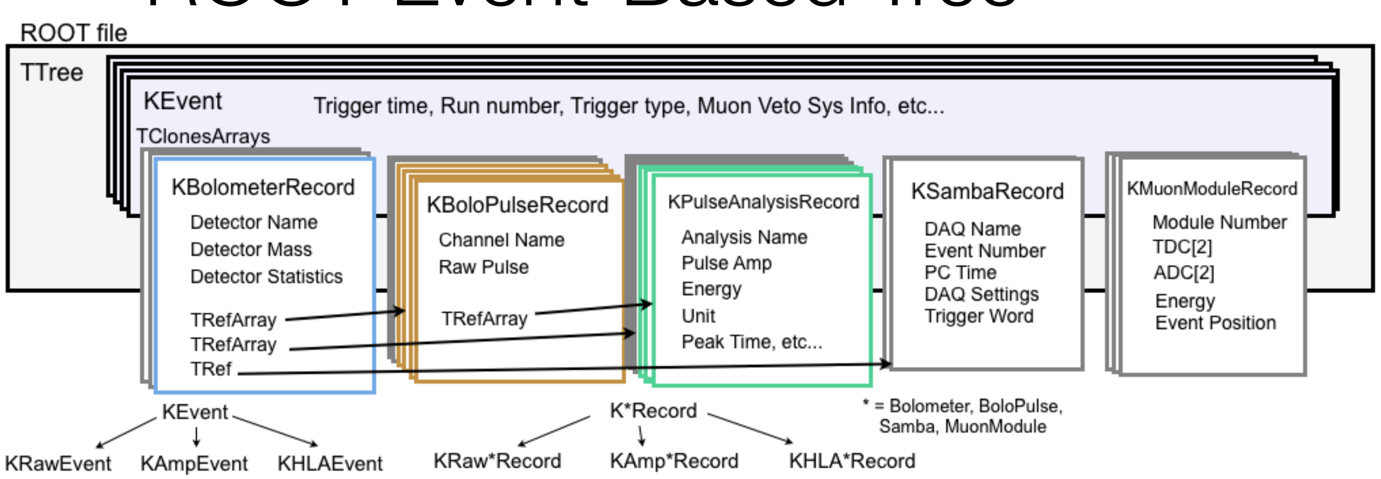


# Data Management for 40 x 6 channels

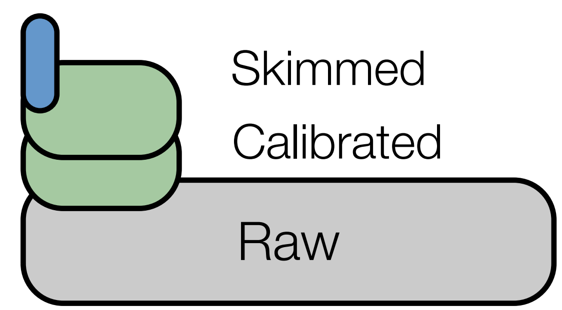



Single Crate
Eliminates Hardware Issues
Event Building
Muon Veto + Other Subsystems
Scalable

## ROOT Event-Based Tree




## Multi-tiered




~1 GB
~50 GB
~5 TB

Database Driven DAQ and Data Process Monitoring System

DAQ Conditions
Metadata
Data Processing Records
Data location

Apache CouchDB

# Conclusions

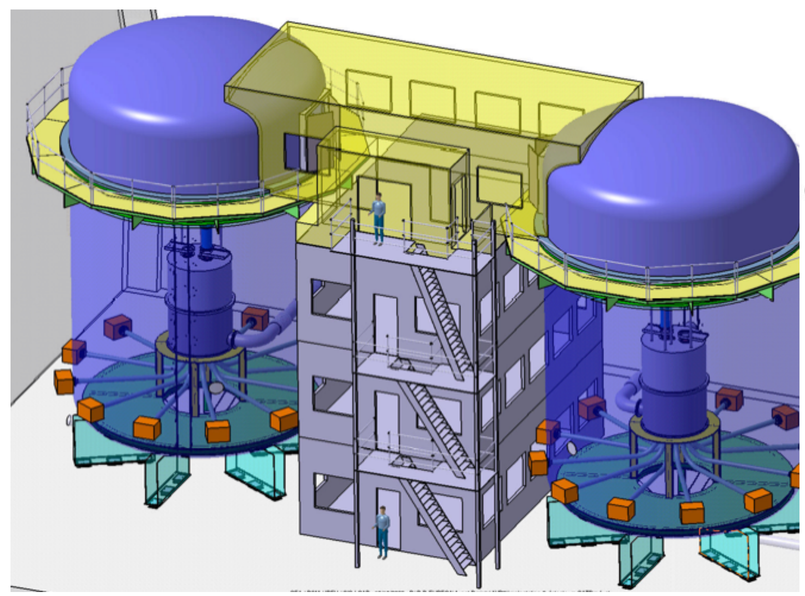
- EDW II Run12 low energy analysis to proceed detector by detector. Initial results indicate sensitivities to masses lower than previously reported by EDW.
- EDW III ....
  - Fabricating a new detector each week: Fall 2012 full 40-detector array
  - Redesigning cryostat / cables / shielding / electronics
  - Optimizing pulse amplitude estimate algorithms
  - Data management in place to handle expected large data set.
  - Currently taking gamma calibration data to further quantify gamma rejection capabilities
  - Characterizing NTDs. Two NTDs per detector to study heat only events.
  - Plan to take data on ~20 detectors starting early this summer

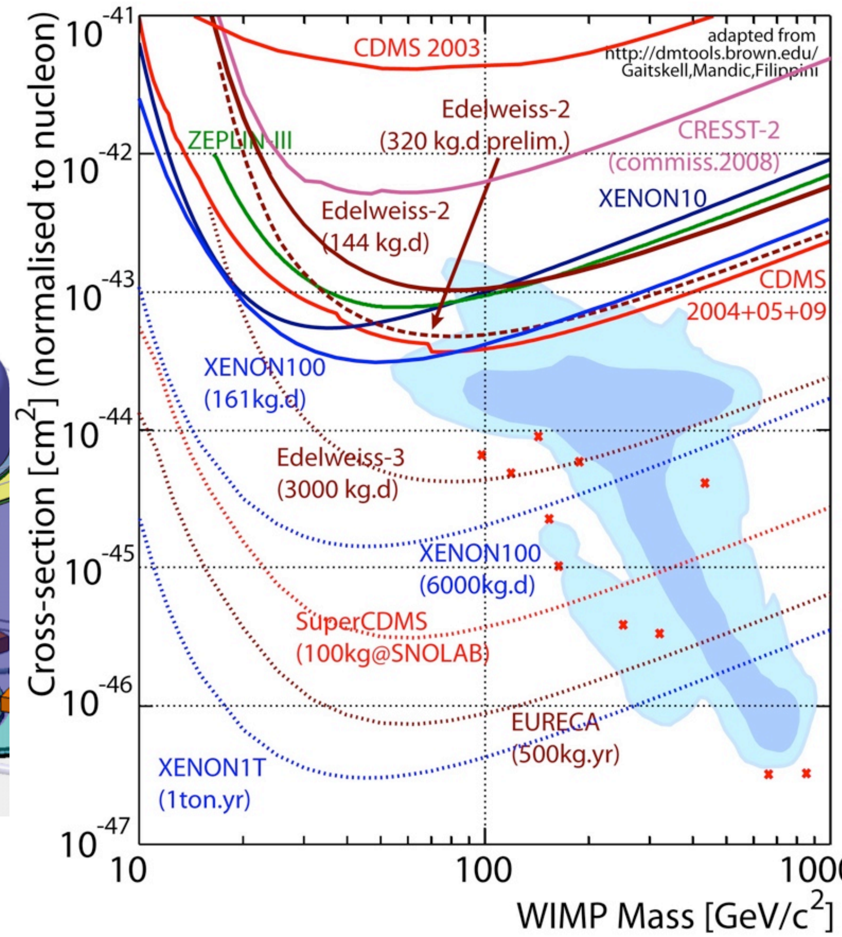
# Outlook: EURECA

Multi-target (Ge, $CaWO_4$)
Phase 1 (2015): 150 kg
Full Scale: 500 - 1000 kg
$10^{-10}$ pb sensitivity

EDELWEISS, CRESST, Rosebud + others

LSM or possible extension






HELMHOLTZ | ASSOCIATION

Alliance for Astroparticle Physics

New Alliance of Universities and Institutes in DE.
Similar to MultiDark structure in Spain
Affiliation with Institutes outside of DE (US: Kavli in Chi)
funding possibilities exist within this framework
5 Year Funding Cycle - EURECA R&D