EURECA

The European Future of Dark Matter Searches with Cryogenic Detectors

H Kraus
Oxford University

European Underground Rare Event Calorimeter Array

- Started March 2005; based on EDELWEISS and CRESST, with additional groups joining.
- Target materials: Ge, $CaWO_4$, etc (A dependence)
- Mass: above 100 kg towards 1 ton
- CRESST-II and EDELWEISS-II are EURECA R&D
- Aligned with Roadmap Recommendations: Multiple targets and multiple techniques

The Collaboration

CRESST, EDELWEISS, ROSEBUD + CERN

United Kingdom
- Oxford (H Kraus, coordinator)

Germany
- MPI für Physik, Munich
- Technische Universität München
- Universität Tübingen
- Universität Karlsruhe
- Forschungszentrum Karlsruhe

Russia
- DLNP Dubna

CERN

France
- CEA/DAPNIA Saclay
- CEA/DRECAM Saclay
- CNRS/CRTBT Grenoble
- CNRS/CSNSM Orsay
- CNRS/IPNL Lyon
- CNRS/IAS Orsay

Spain
- Zaragoza

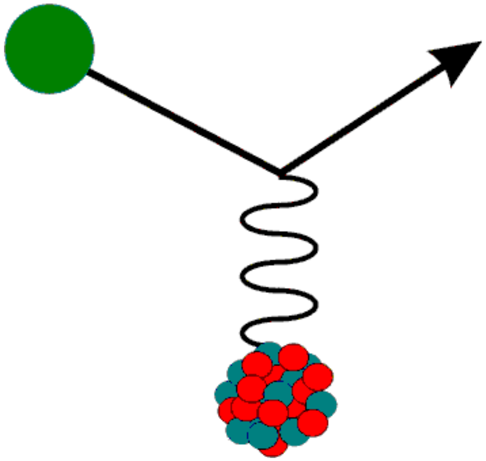
Ukraine
- Kiev

EURECA Members

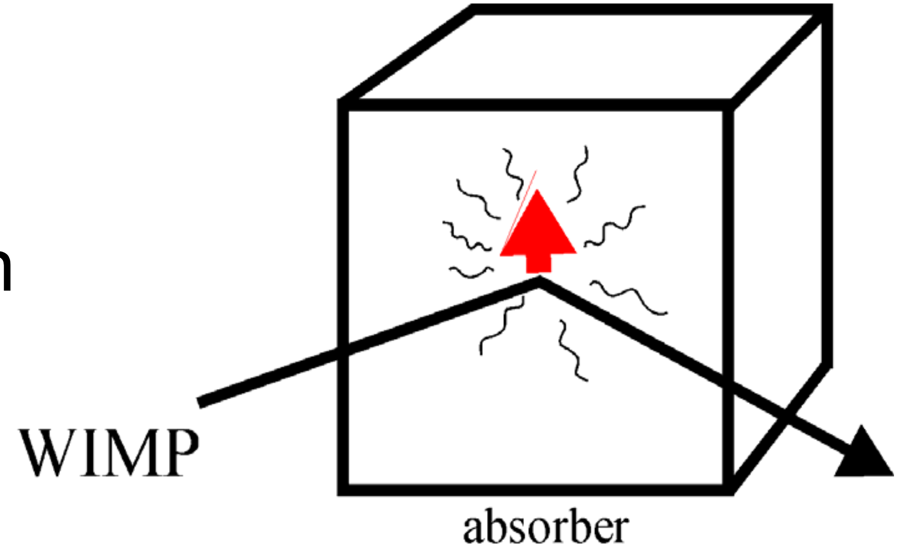
E Armengaud, M Bauer, I Bavykina, A Benoit, A Bento, L Berge, O Besida, J Bluemer, L Bornschein, A Broniatowski, G Burghart, Ph Camus, A Chantelauze, M Chapellier, G Chardin, F Charlieux, Ch Ciemniak, S Collin, Ch Coppi, N Coron, O Crauste, F Danevick, E Daw, M de Combarieu, M de Jesus, P de Marciliac, X Defay, H Deschamps, G Deuter, Ph di Stefano, G Drexlin, D Ducimetiere, L Dumoulin, K Eitel, F v Feilitzsch, D Filosofov, P Forget, Ph Gandit, E Garcia, J Gascon, G Gerbier, H Gironnet, H Godfrin, S Grohmann, M Gros, D Hauff, F Haug, S Henry, S Herve, M Horn, P Huff, J Imber, S Ingleby, Ch Isaila, J Jochum, A Juillard, M Karolak, M Kiefer, M Kimmerle, **H Kraus**, V Kobychev, V Kudryavtsev, F Lalu, J-C Lanfranchi, R Lang, A Lubashevsky, M Luca, M Malek, S Marnieros, M Martinez, R McGowan, V Mikhailik, V Mokina, A Monfardini, S Nagorny, X-F Navick, A Nikolaiko, T Niinikoski, E Olivieri, Y Ortigoza, E Pantic, P Pari, B Paul, G Perinic, F Petricca, S Pfister, C Pobes, D Poda, R Podviyanuk, W Potzel, F Proebst, J Puimedon, S Roth, K Rottler, S Rozov, V Sanglard, M-L Sarsa, K Schaeffner, S Scholl, S Scorza, W Seidel, H Seitz, O Shkulkova, A Smolnikov, M Stern, L Stodolsky, P Sullivan, M Teshima, B Tolhurst, A Tomasello, A Torrento, L Torres, V Tretyak, L Vagneron, J-A Villar, W Westphal, J Wolf, E Yakushev

111 people (63 FTE) = ∑ (Cresst, Edelweiss, Rosebud, a.o.)

Direct Detection of WIMPs



Heavy Boson Exchange



$45 < M_W\ [\mathrm{GeV}] < 1000$

$30 > \lambda_W\ [\mathrm{fm}] > 1.4$

$v_{rms} \sim 270$ km/s

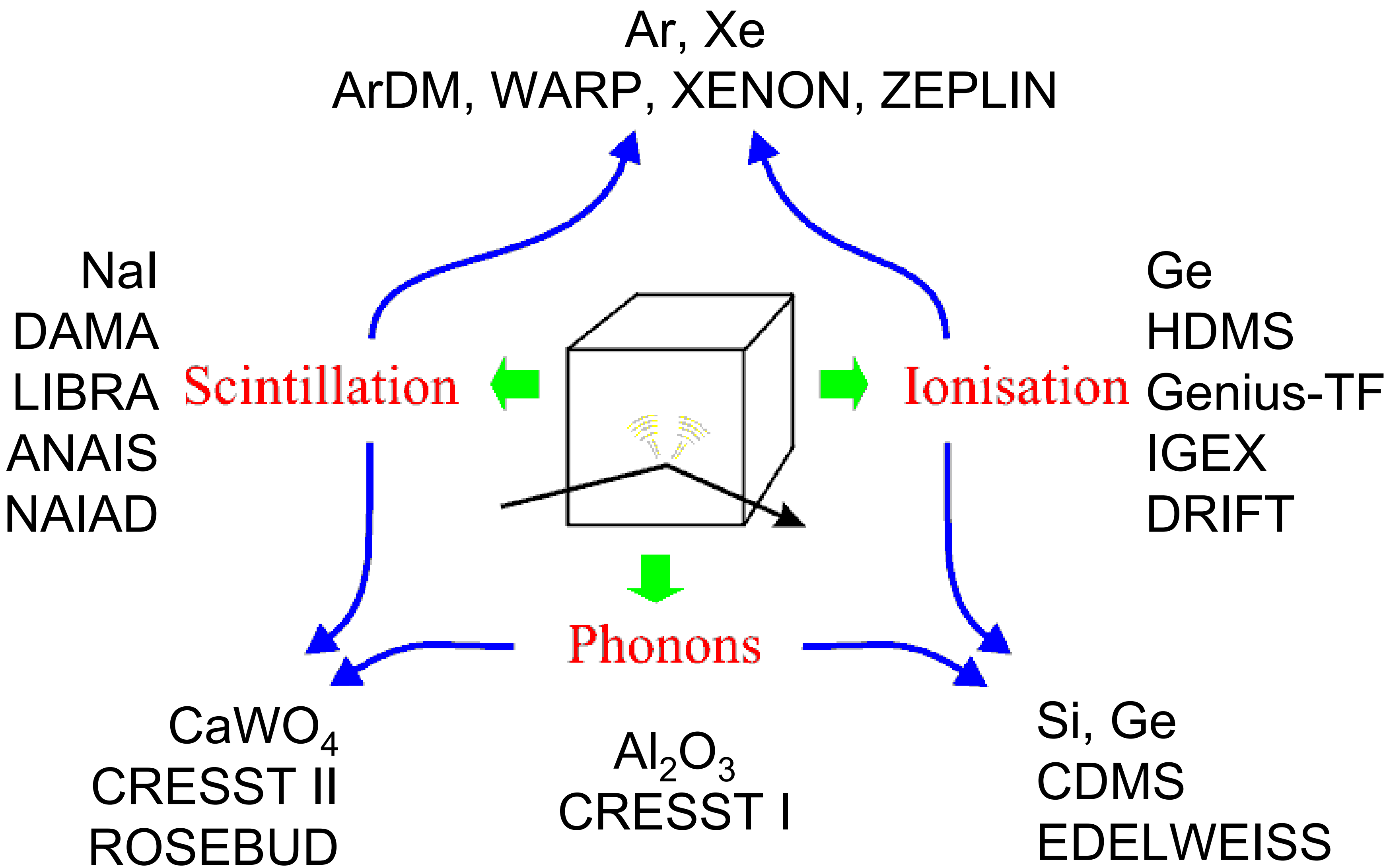
$\rho_{CDM} \sim 0.3\ \mathrm{GeV}/c^2$

$$E_R = E_0 \cdot \frac{4 M_W M_N}{(M_W + M_N)^2} \cdot \frac{1}{2}\left(1 - \cos\theta^*\right)$$

$$\approx\ 0.4\ \mathrm{keV} \cdot \frac{M_W}{\mathrm{GeV}}$$

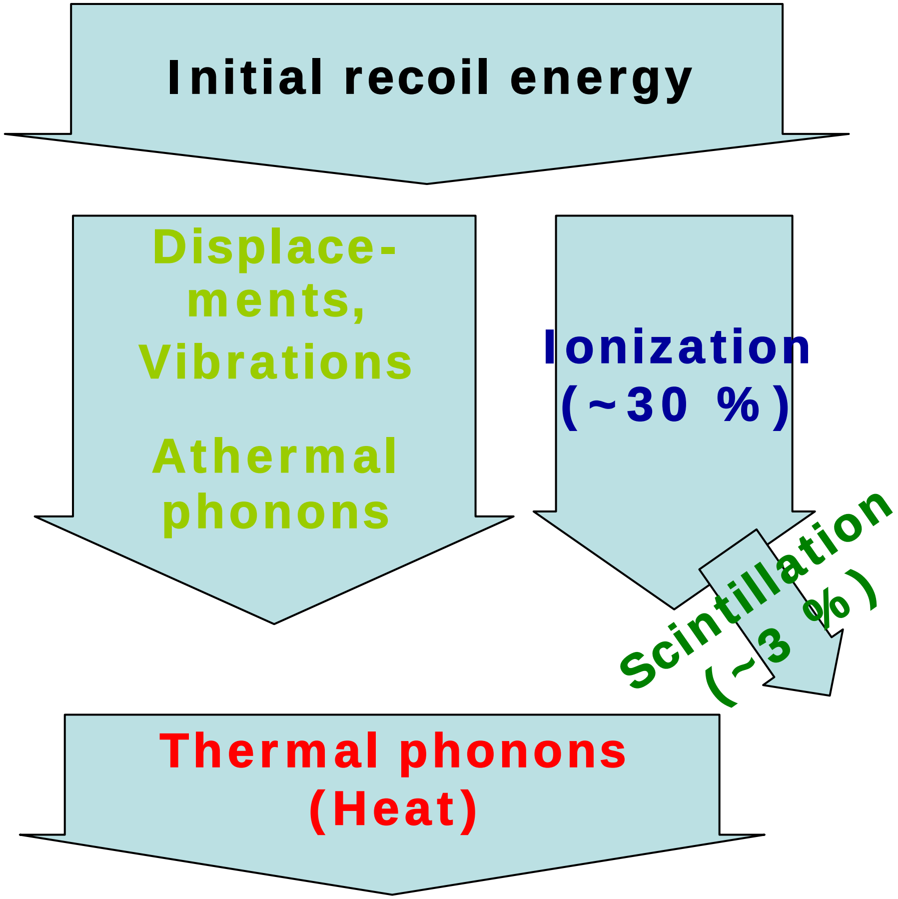
Direct detection via WIMP scattering by nuclei: $E_R \sim$ tens of keV

Detection Techniques



Cryogenic Techniques

Combination of phonon measurement with measurement of ionization or scintillation



Phonon: most precise total energy measurement

Ionization / Scintillation: yield depends on recoiling particle

Nuclear / electron recoil discrimination.

The Parameter Space

$\sigma = 10^{-6}$ pb:

~1 event/kg/day

~0.1 now reached

$\sigma = 10^{-8}$ pb:

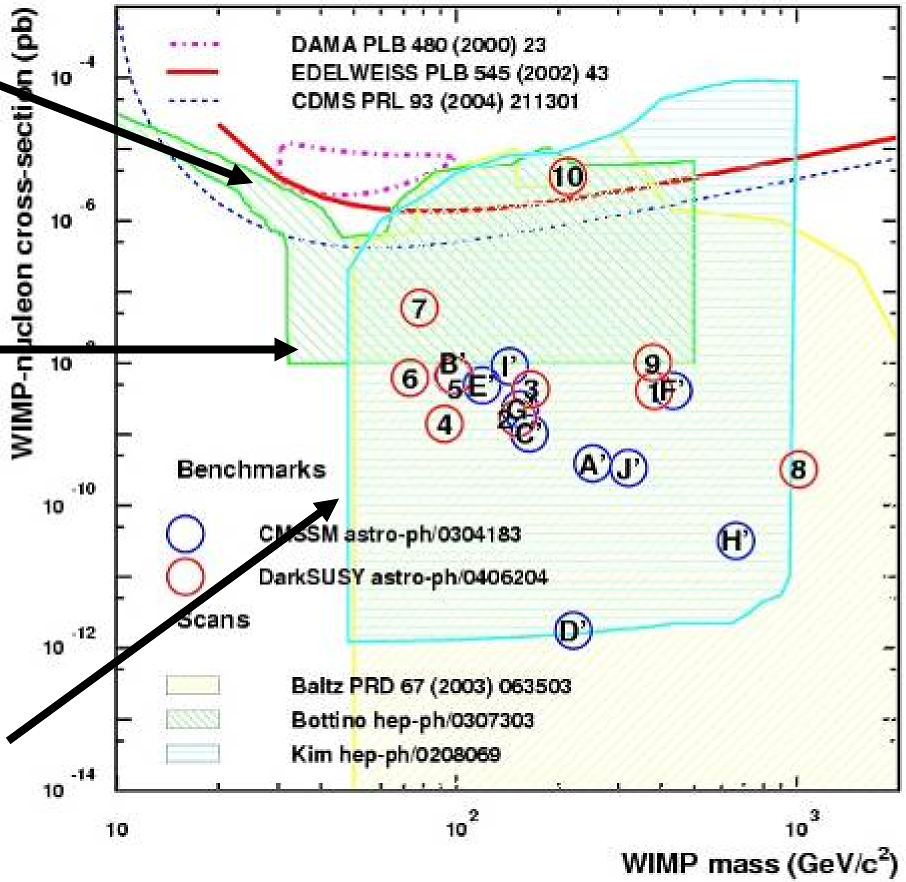
~3 events/kg/year

Aims of phase II experiments

$\sigma = 10^{-10}$ pb:

~30 events/ton/year

Next generation requires further x100 improvement!



Physics Aims / Requirements

Probe currently most favoured cross section in the region 10^{-8} pb to 10^{-10} pb.

This requires a target mass of ~ 1000 kg to get few evts / y.

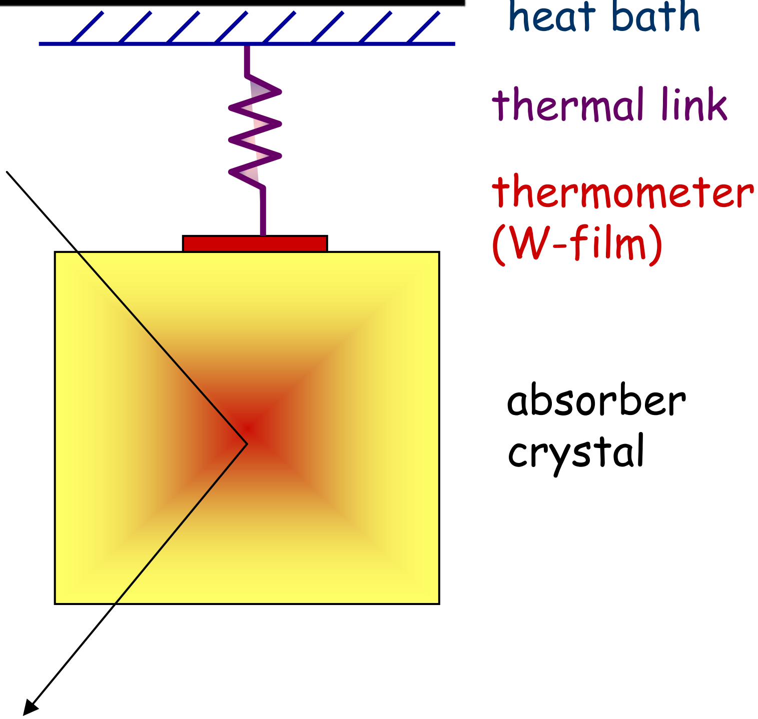
Use cryogenic detectors, which are scalable, mature technology.

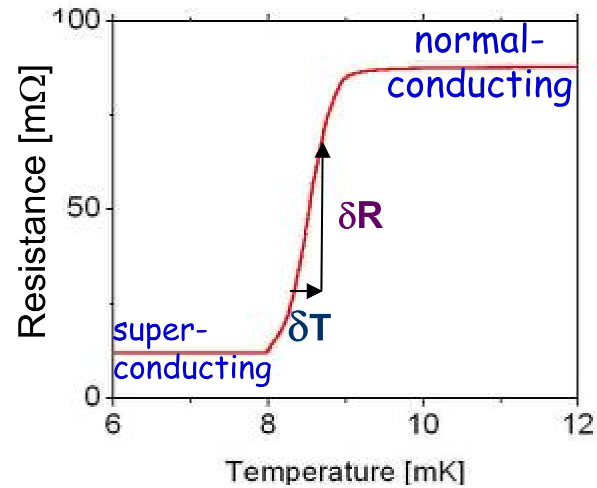
Cryogenic detectors offer excellent discrimination nuclear / electron recoil, energy resolution and large potential for further background rejection.

Use range of target materials for positive identification of signal.

Use complementary cryogenic detectors in common volume to reduce systematics.

CRESST – Detectors

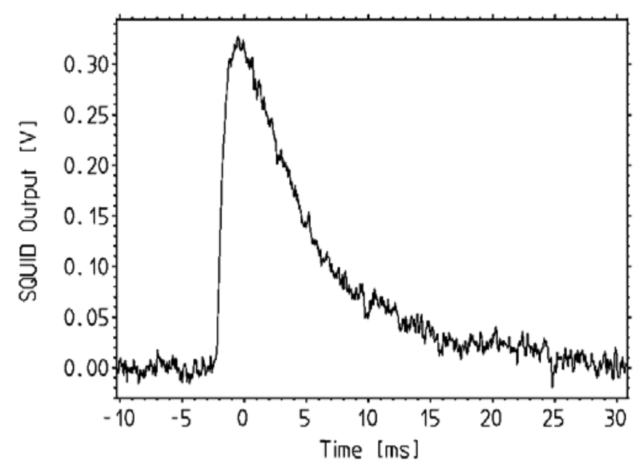




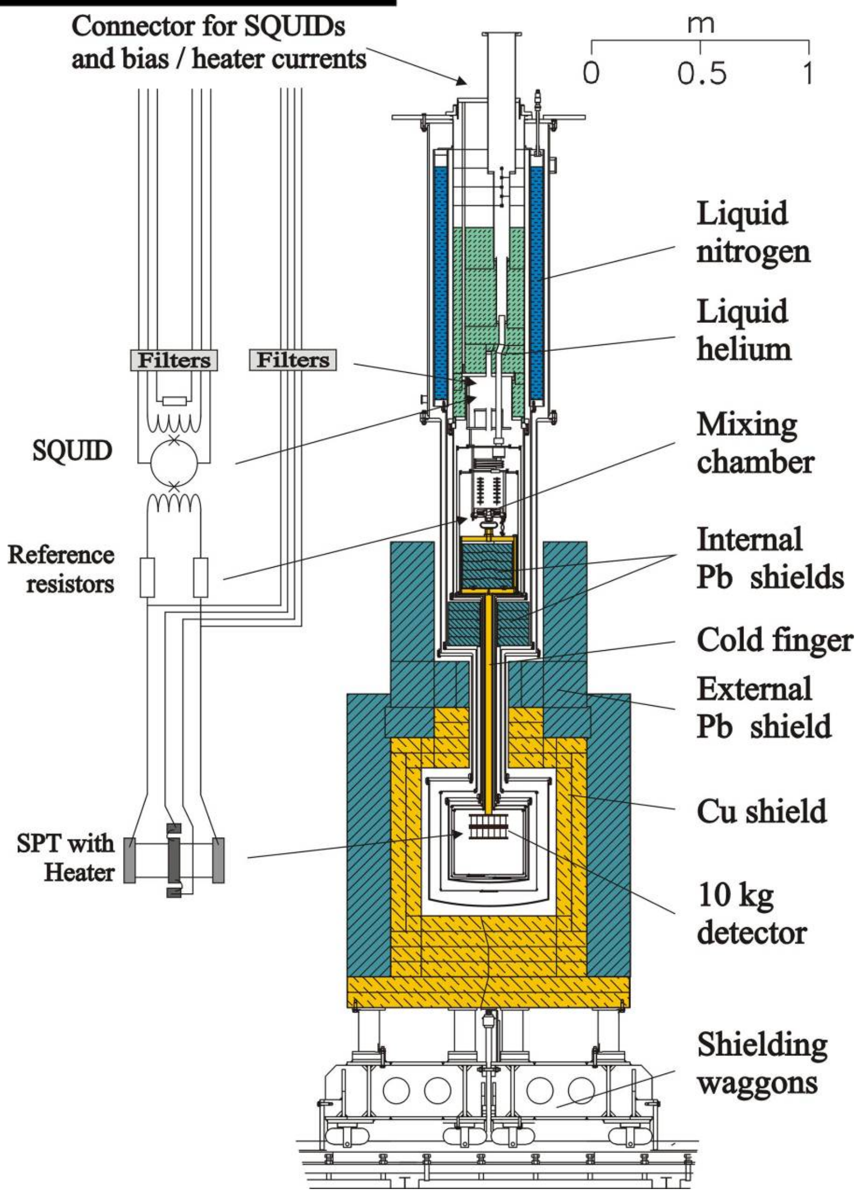
Width of transition: ~1mK
Signals: few μ K
Stablity: ~ μ K

Particle interaction in absorber creates a temperature rise in thermometer which is proportional to energy deposition in absorber

Temperature pulse (~6keV)

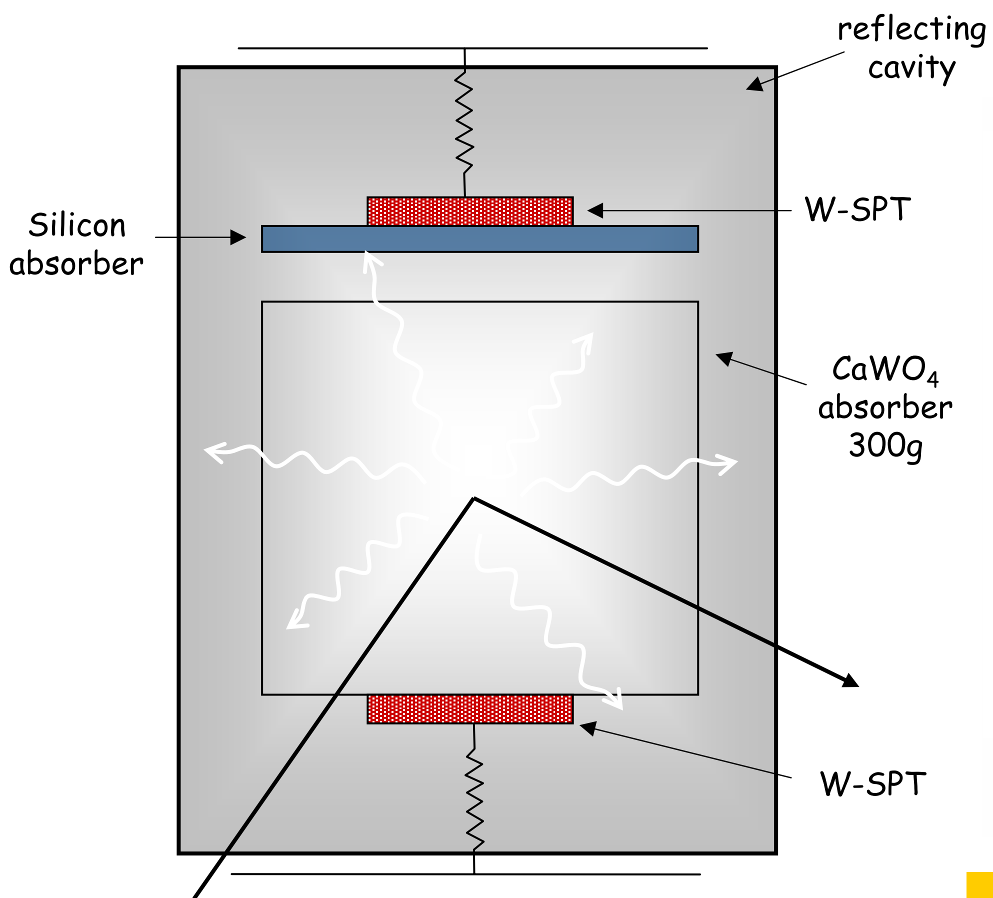


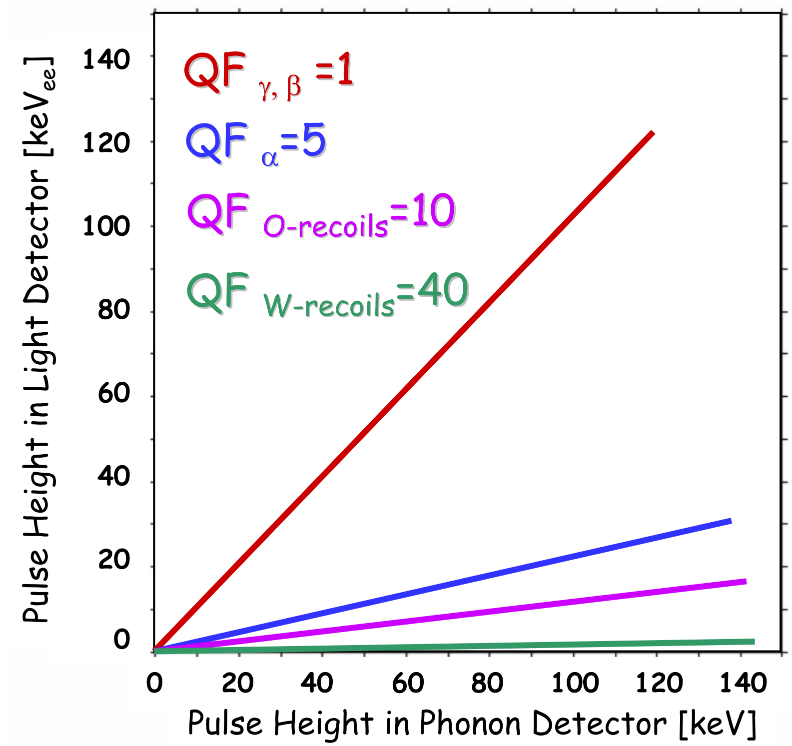
CRESST at Gran Sasso



Phonon – Scintillation

Discrimination of nuclear recoils from radioactive backgrounds (electron recoils) by simultaneous measurement of phonons and scintillation light

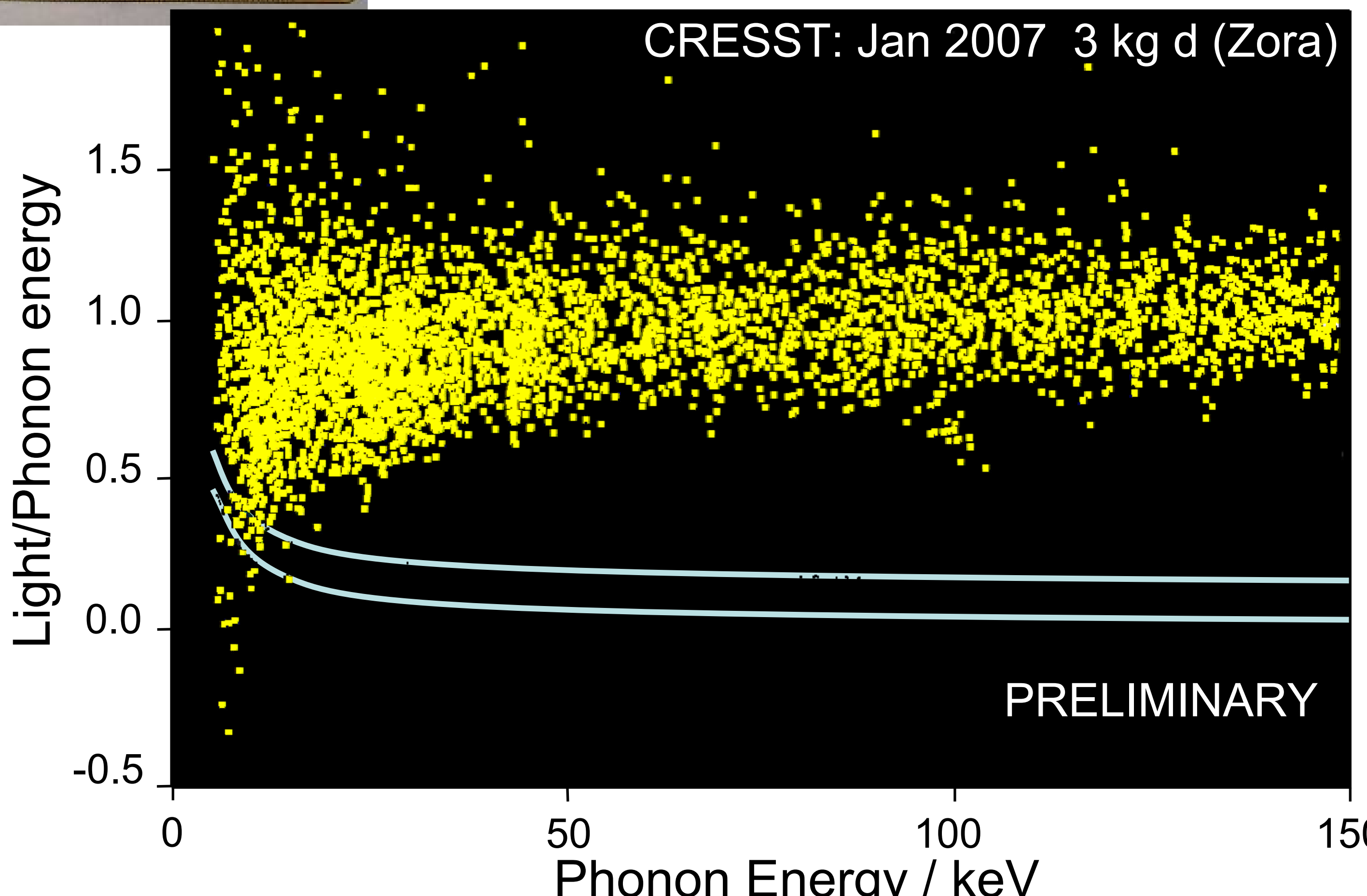




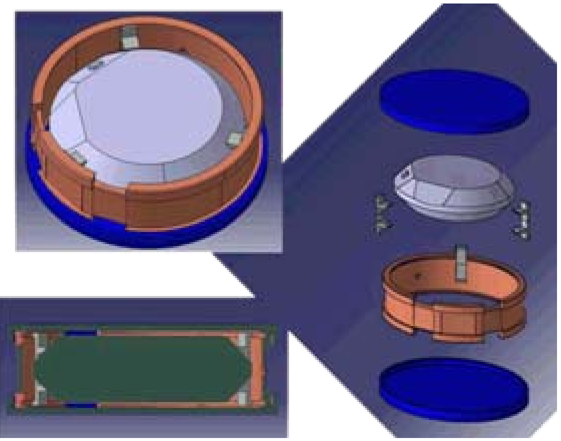
good rejection:	99.7%	> 15 keV
	99.9%	> 20 keV

CRESST Detectors

- Over 20 years experience
- Mature technology
- Many materials scintillate



EDELWEISS Detectors



23 × 320g Ge / NTD :

- 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) : goal **keV resolution**
- New holder and connectors (teflon and copper only)

Installed and running

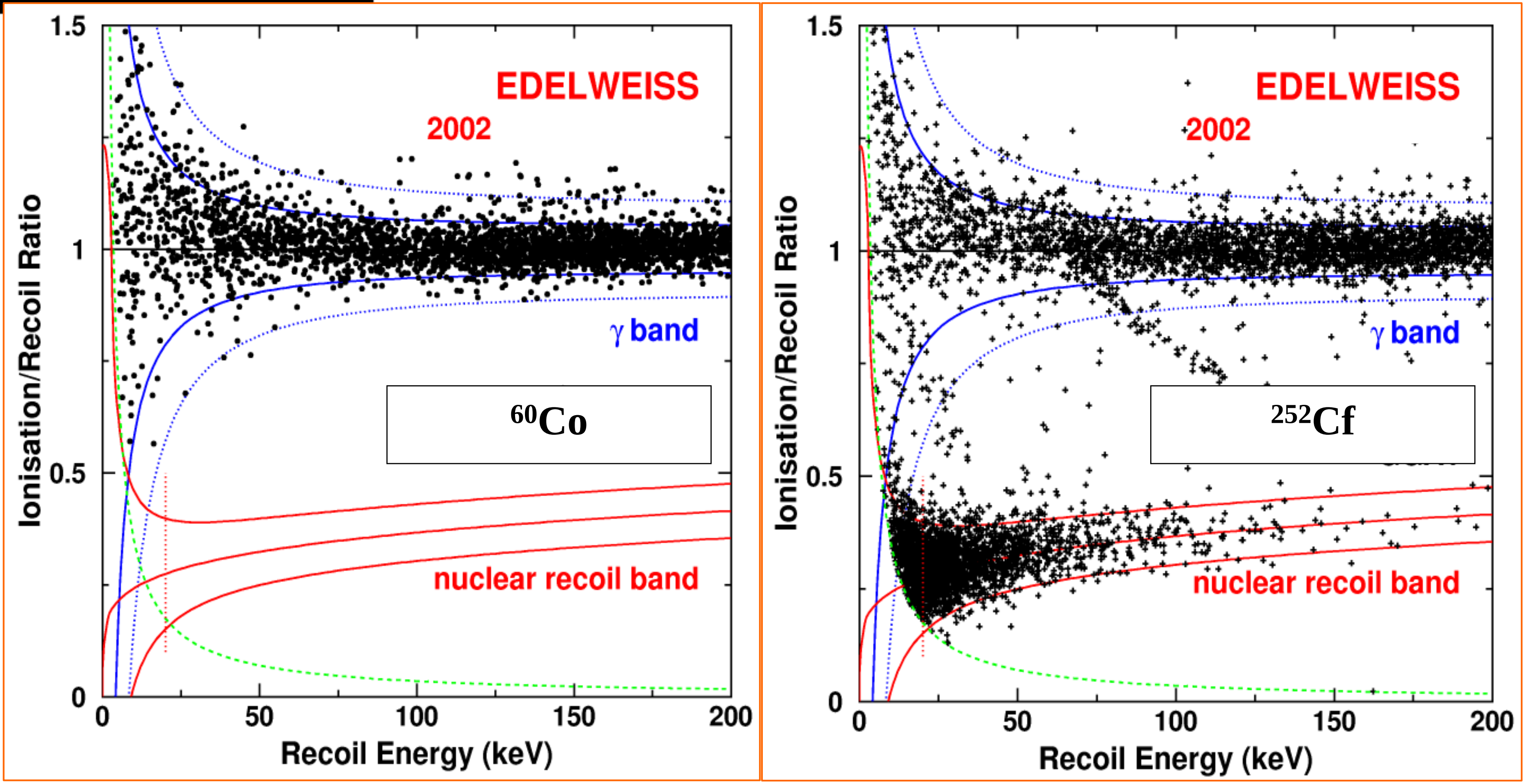
7 × 400g Ge / NbSi detectors :

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

4 installed and running

EDELWEISS: 9 kg of Ge running
(CDMS 5.5 kg running)

Phonon – Ionisation

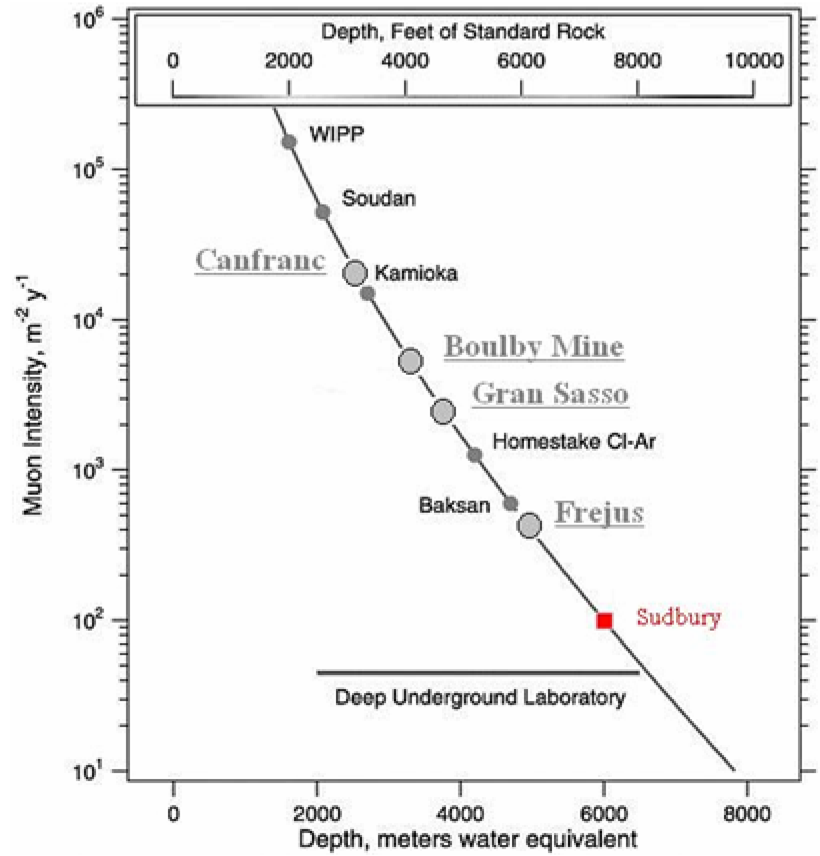


Excellent resolution in ionisation and phonon signals.

Clean γ-calibration data: no event below Q = 0.7.

Underground Laboratory

The EURECA infrastructure
A unique opportunity for integration between experiment and laboratory –



Deepest site in Europe (4800 mwe)

Known and «good» site (low convergence, dry, stiff rock)

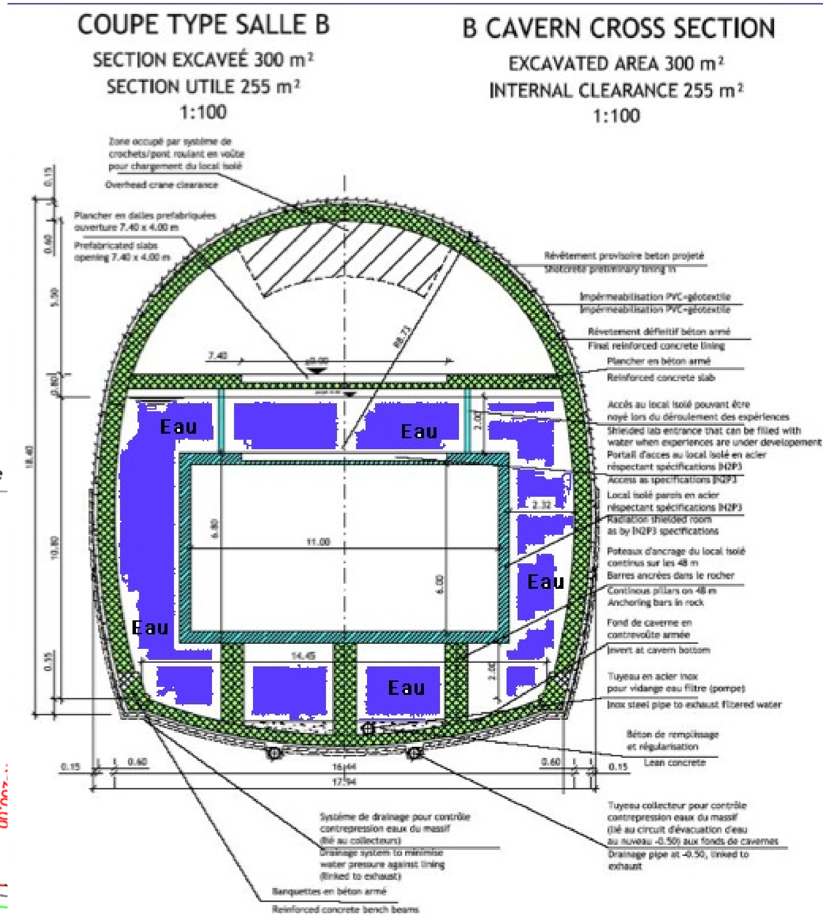
Central location in Europe, easy access (plane, train, car)

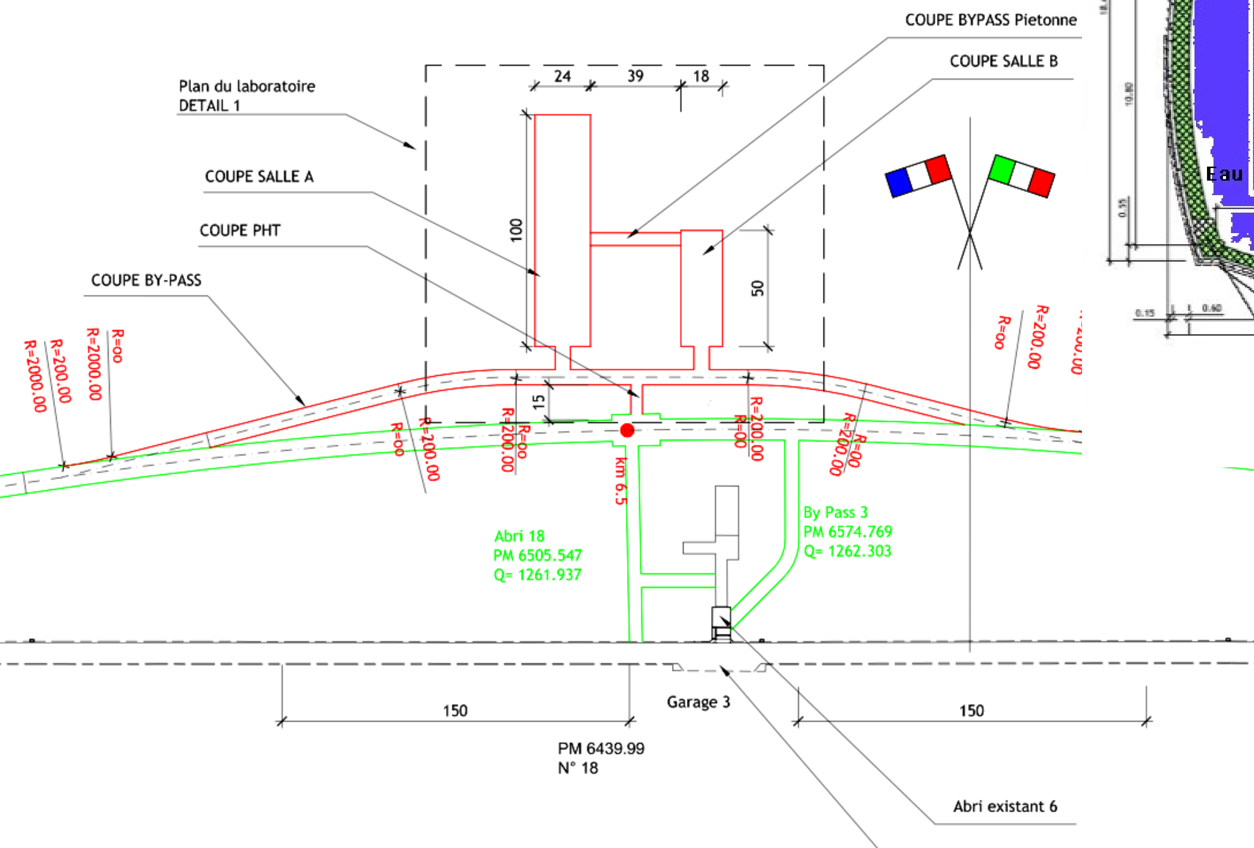
23 years experience in running such platform

EURECA in LSM

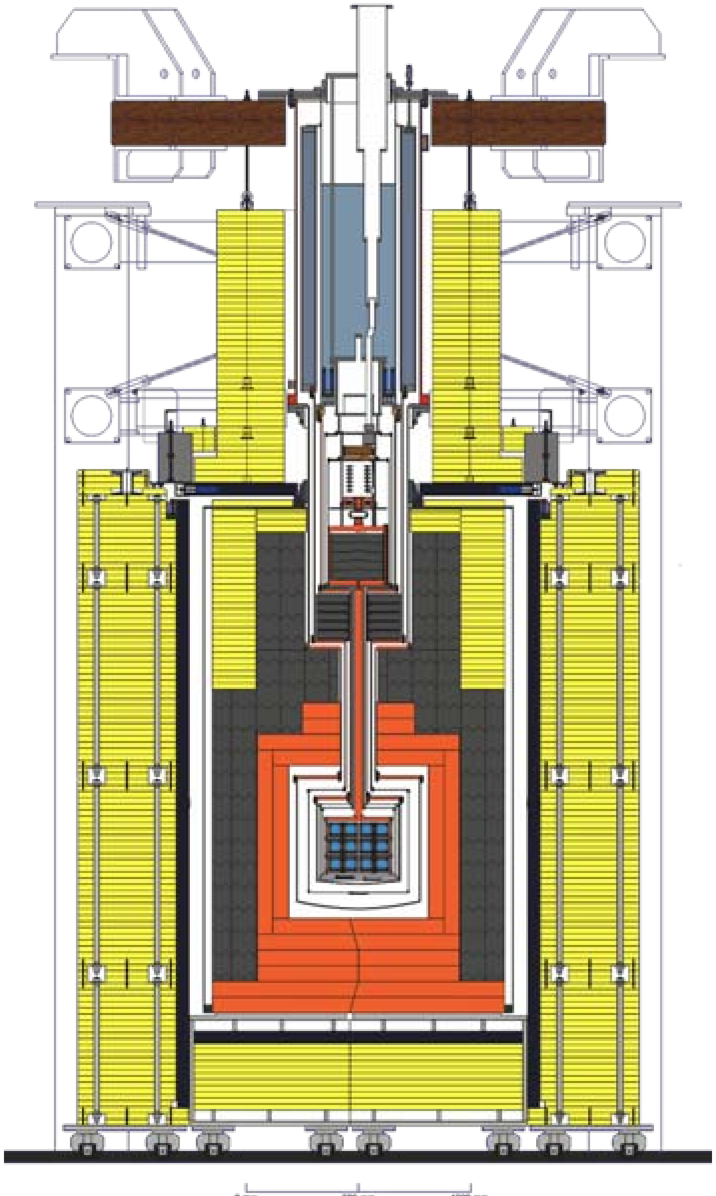
Submarine / Swimming Pool

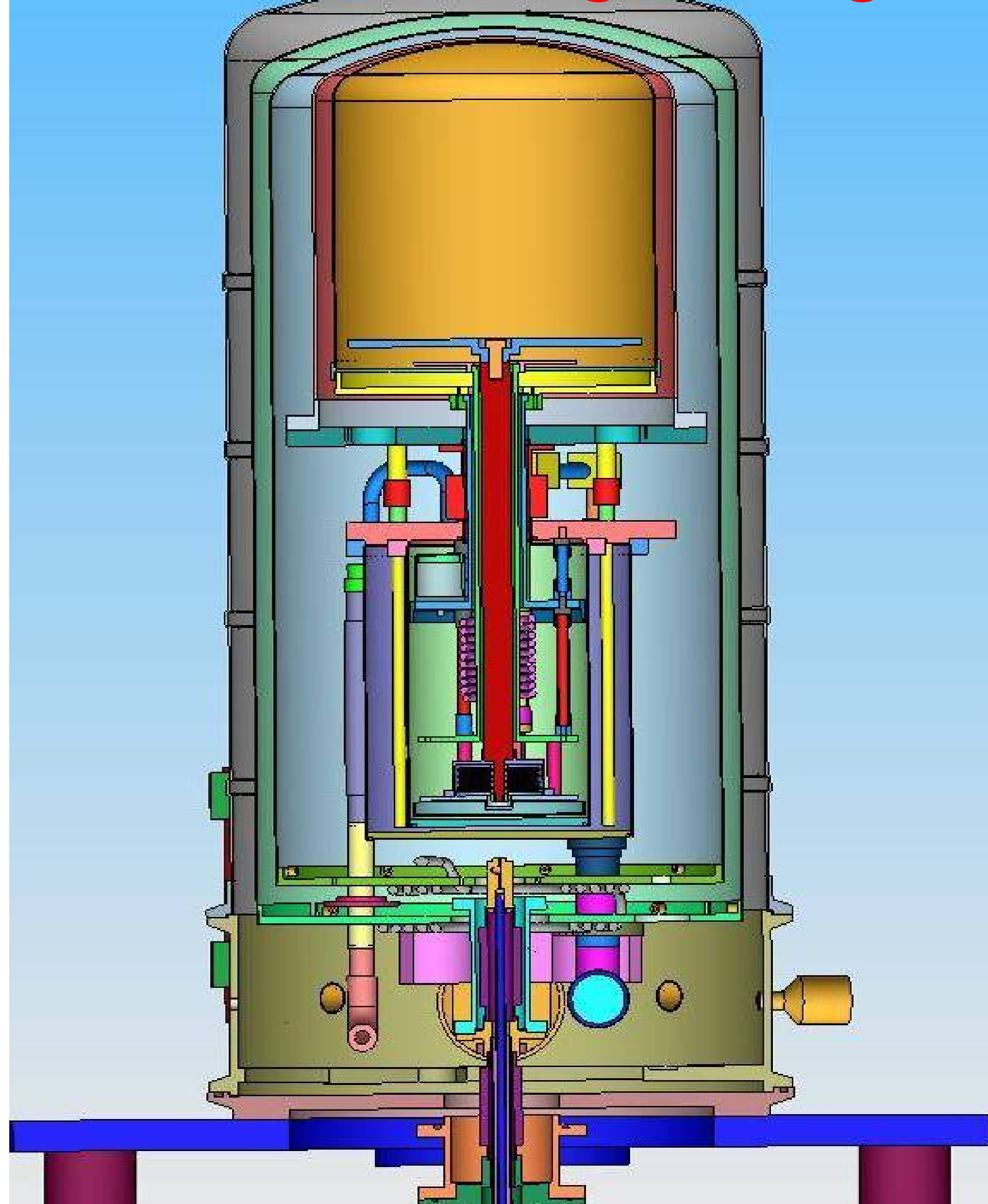
Clean Infrastructure





Cryostat and Shielding Designs





Readout Systems and DAQ

- ~1000 channels per unit (~6000 -- ~10000 total)
- low + high impedance amplifiers for scintillation and germanium detectors
- Same back end for SQUID and FET front end

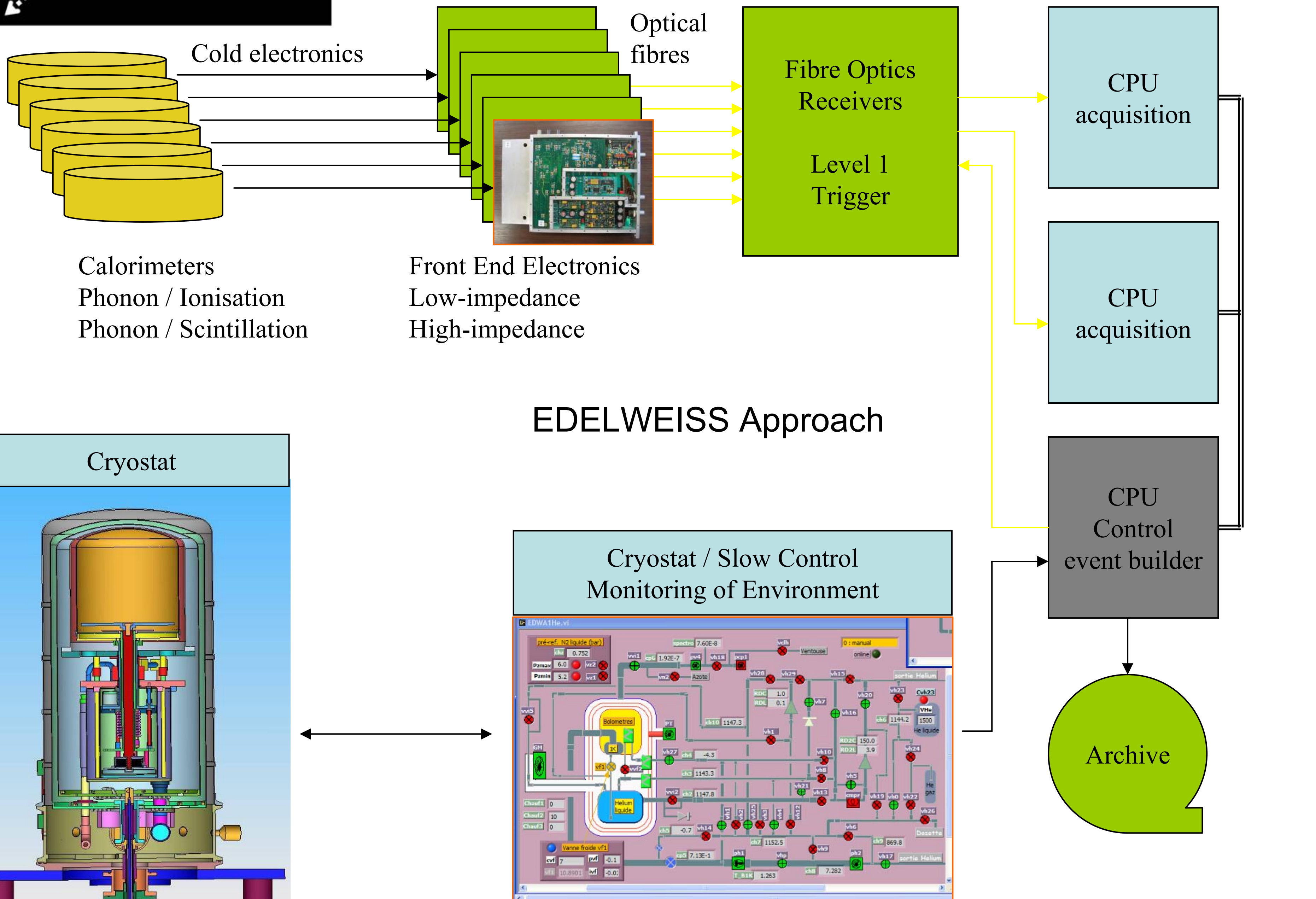
We need to …

- Reduce the size and complexity of electronics
- Reduce the number of wires – multiplexing?
- Digitize at an early stage.

Research and Demonstration needed for …

- Avoiding crosstalk
- Minimizing electromagnetic interference

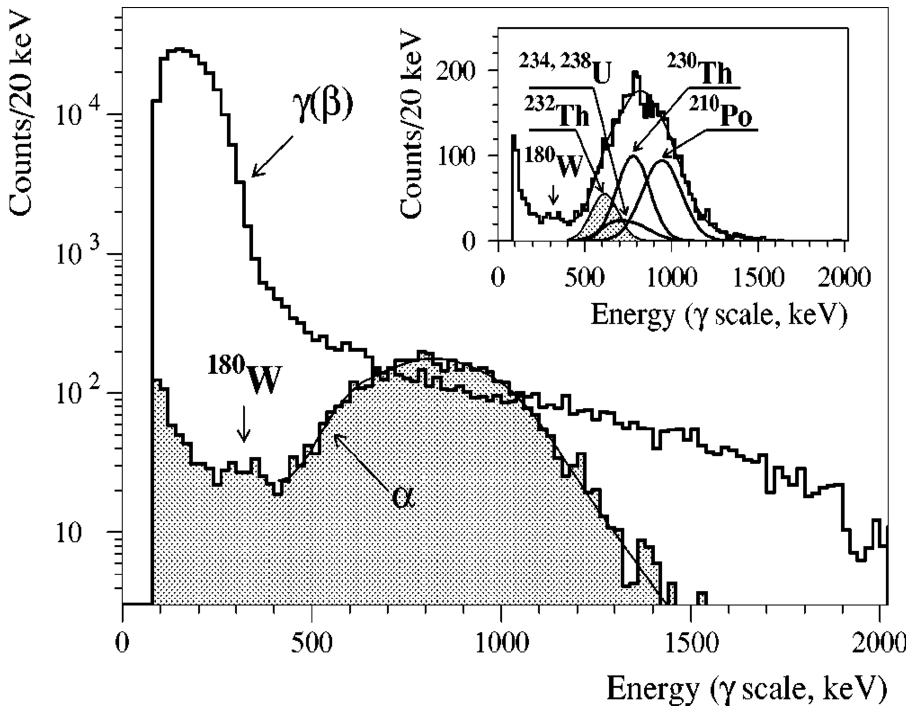
Readout Systems and DAQ



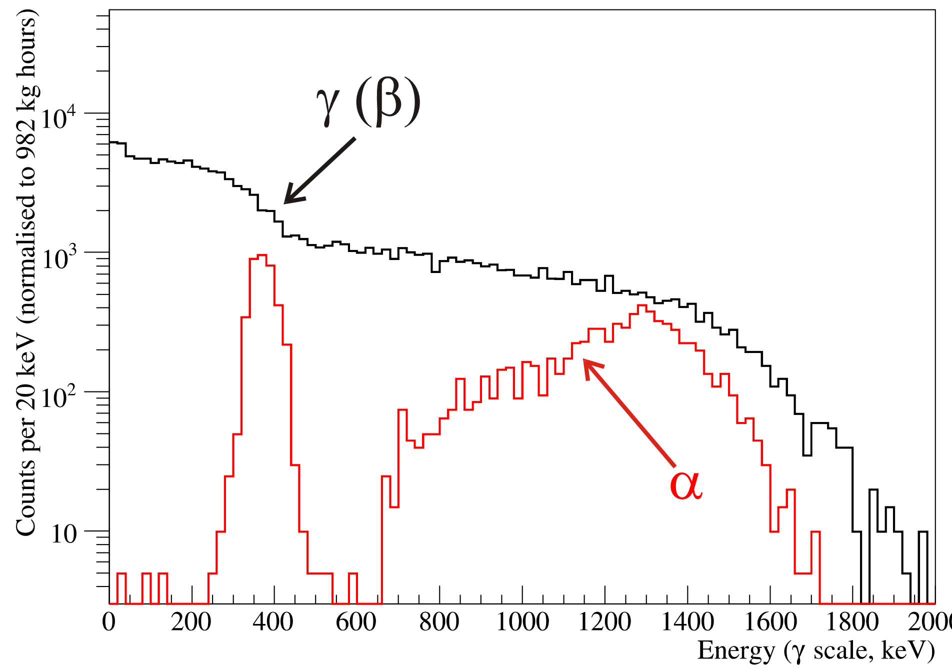
α – β/γ Discrimination

A ‘standard’ scintillator (pulse shape discrim.)

Scintillation part of a phonon – scintillation detector (CRESST)

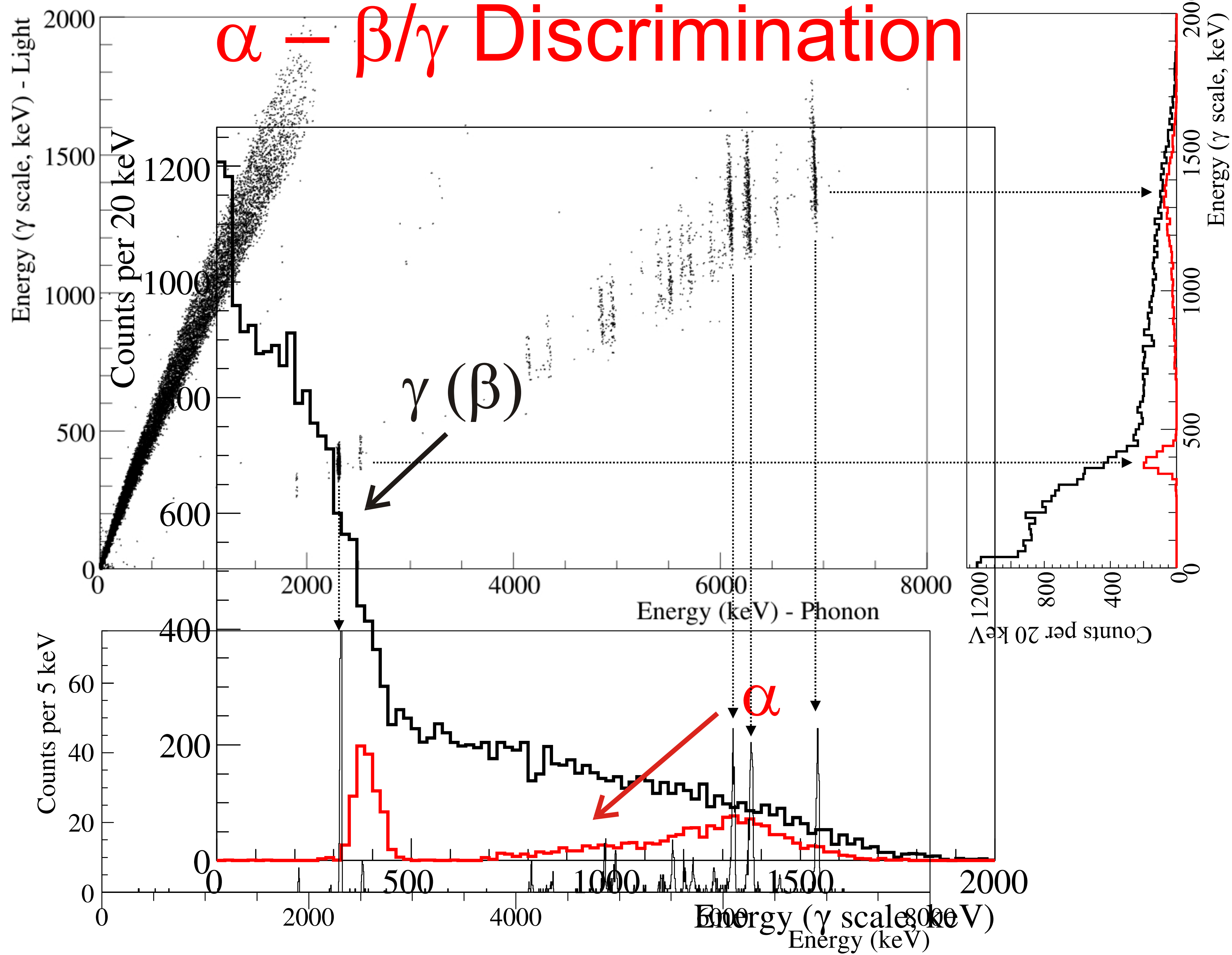


Danewich et al – Kiev
($^{116}CdWO_4$ – 330 g, 2975 hrs)

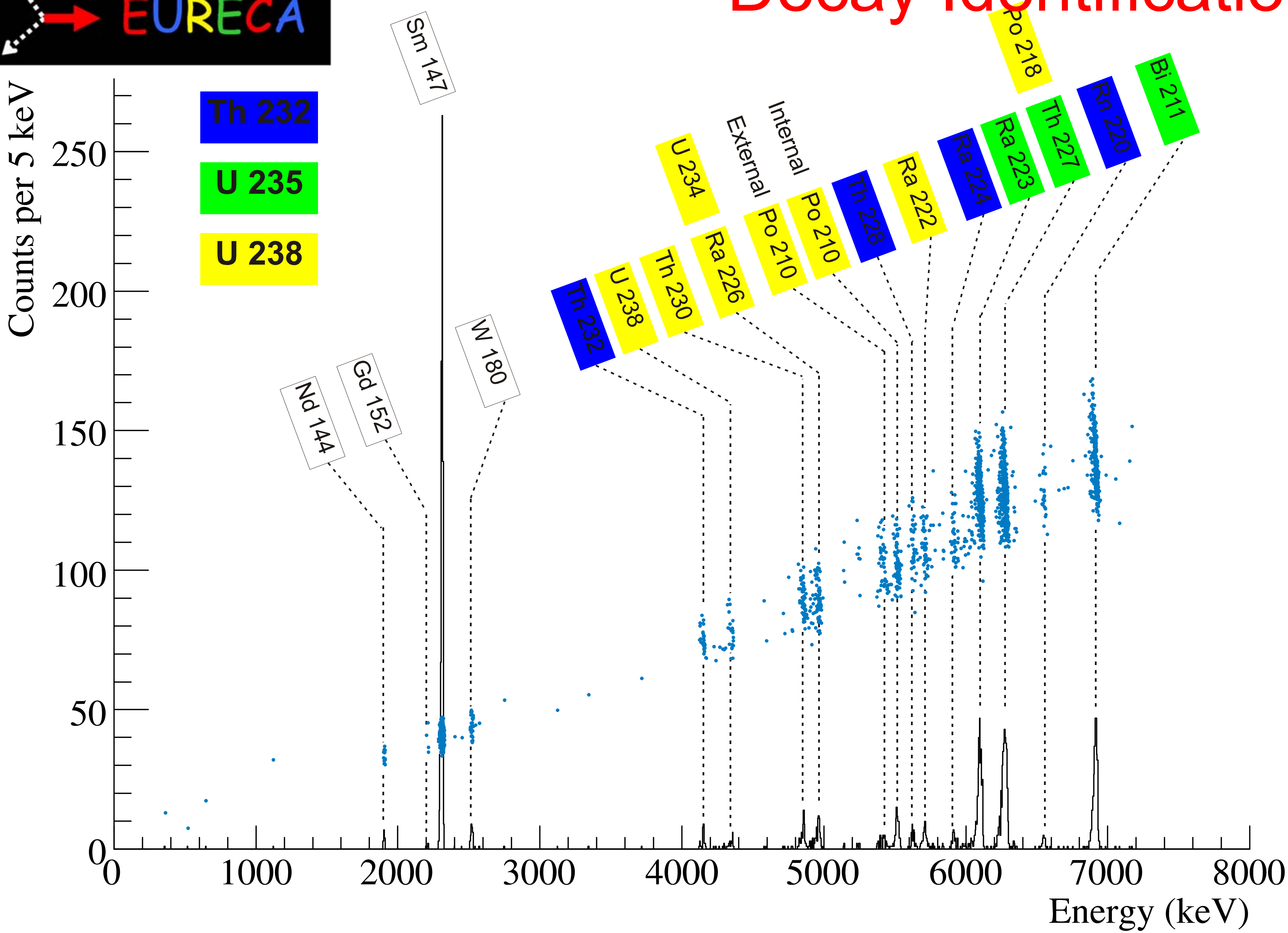


CRESST – LNGS
($CaWO_4$ – 300 g, 633 hrs)

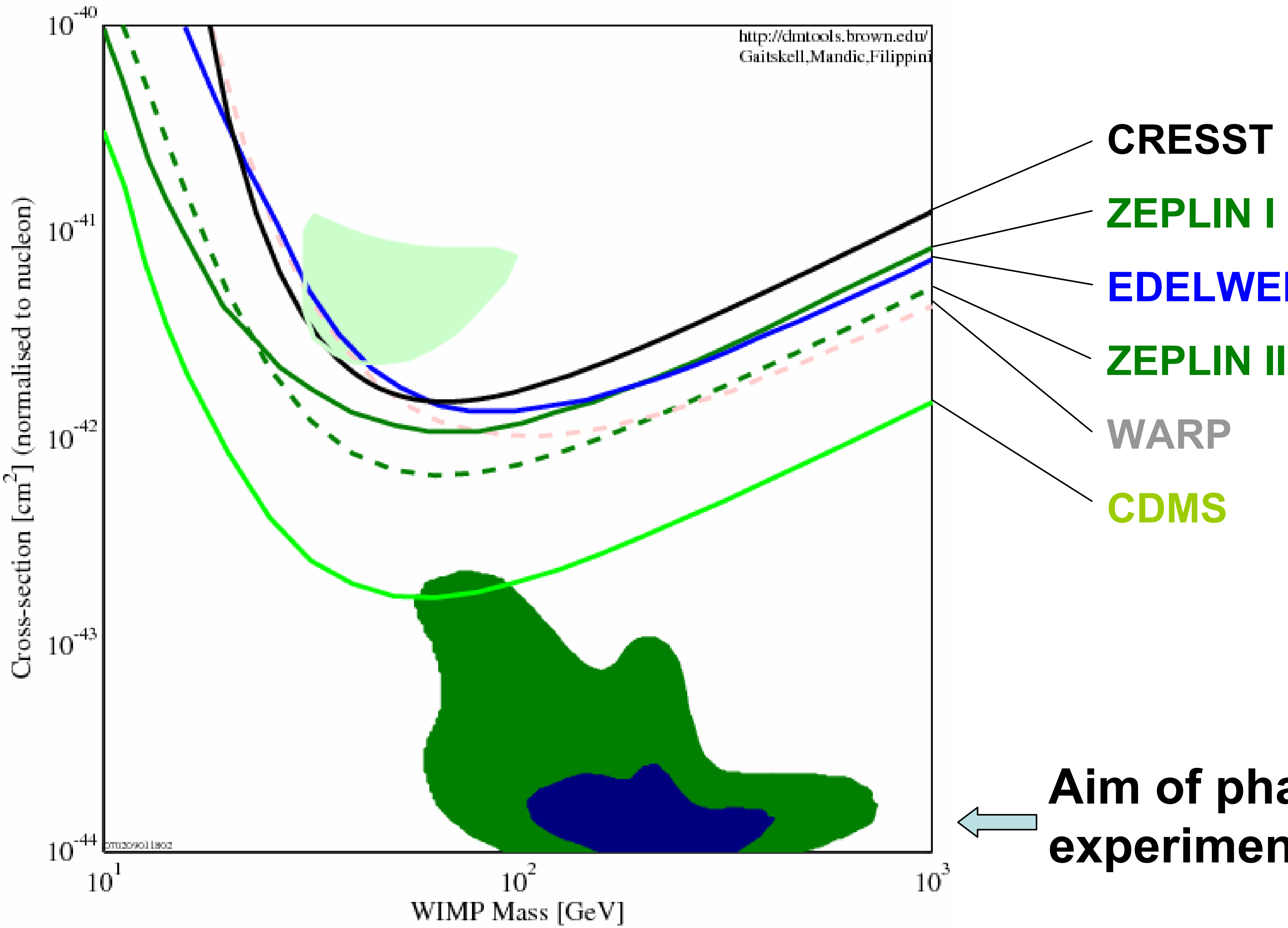
α – β/γ Discrimination



Decay Identification

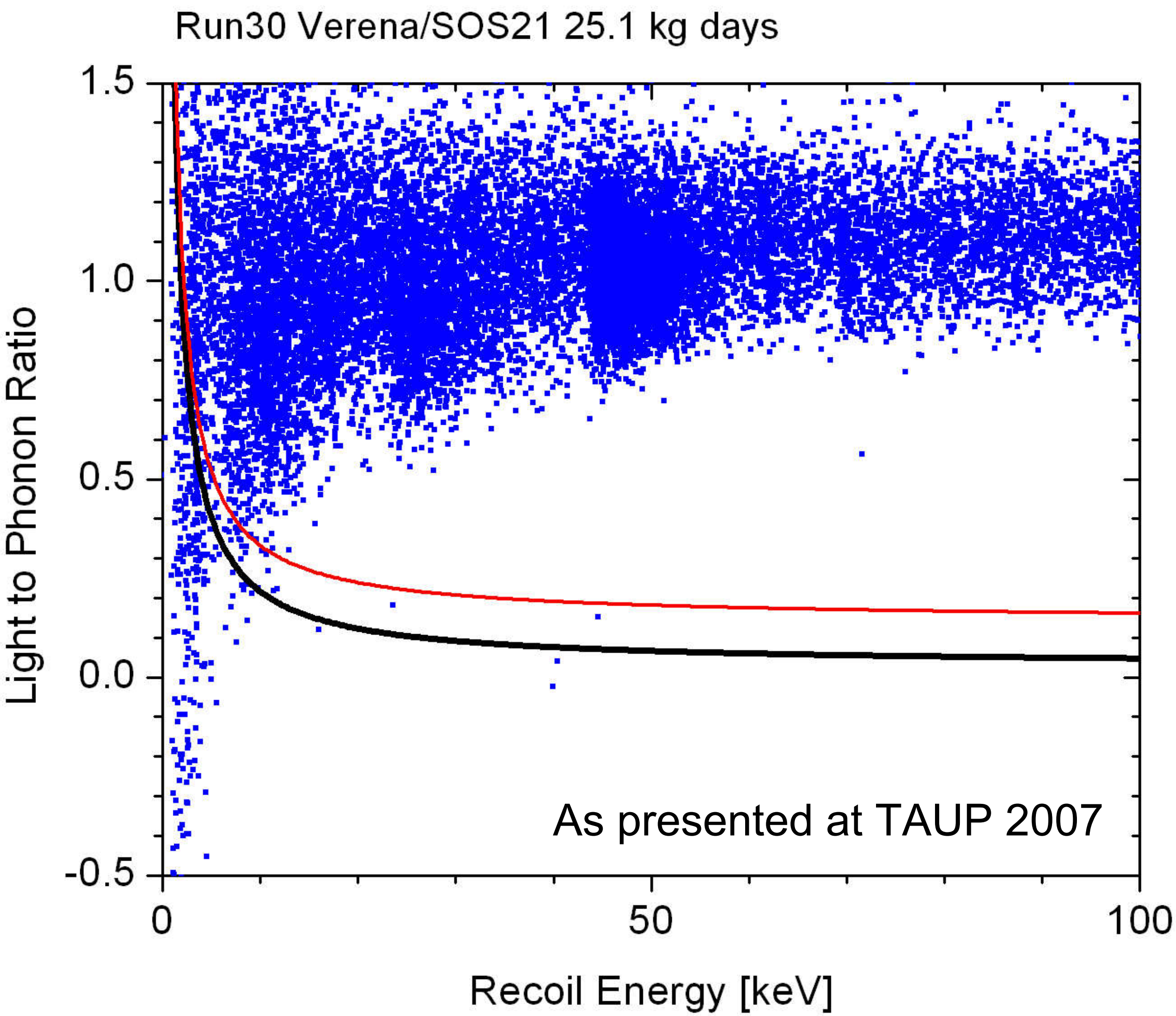


Limits (Feb 2007)

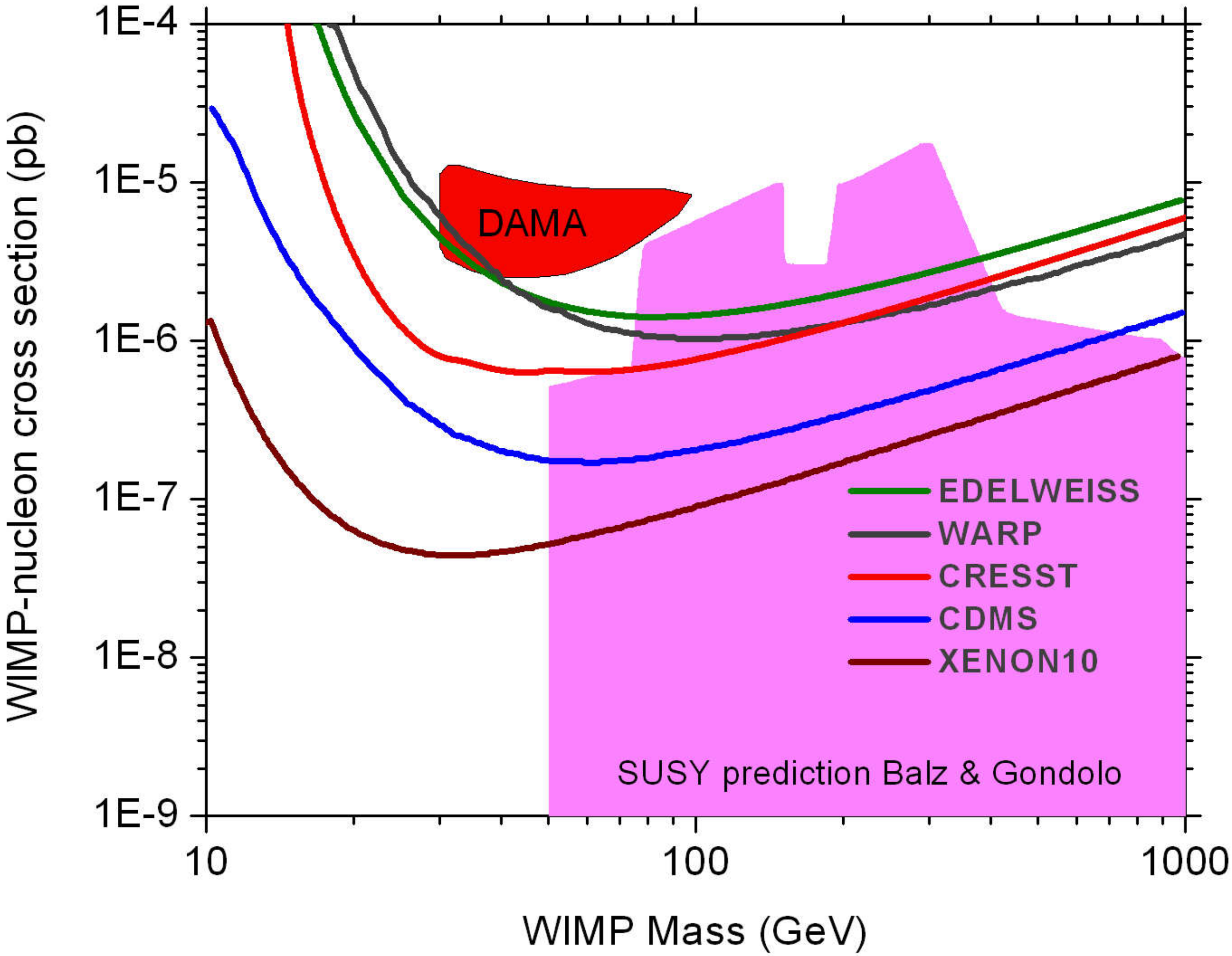


Aim of phase II experiments

Preliminary CRESST Data



Limits (Nov 2007)



Summary

CRESST / EDELWEISS are taking data again

EURECA: uniting European Cryogenic Dark Matter Searches

Multiple Targets and Multiple Techniques in One Common Setup

2010: CRESSTII, EDELWEISS II (10^{-8} pb)

From 2010: Start EURECA Construction

Then: towards full EURECA setup (10^{-10} pb)