DSU Conference
June 2007, Minneapolis

Cryogenic Dark Matter Search in Europe

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Queen's University
Kingston, Canada

Introduction

- Search for nuclear recoils (NR) from WIMP interactions. Background mostly electron recoils (ER, from γ's, β's)
- Cryogenic detectors: thermal signal proportional to energy - independent (to first order) of type of interaction
- Measurement of second signal (ionization, scintillation) allows to discriminate between ER and NR events

$\Rightarrow$ Easy to determine energy scale, efficient event-by-event discrimination radioactive background

European experiments:
- CRESST (scintillation)
- EDELWEISS (ionization)
- ROSEBUD (scintillation, R&D)
- EURECA (future, scintillation and ionization)

CRESST

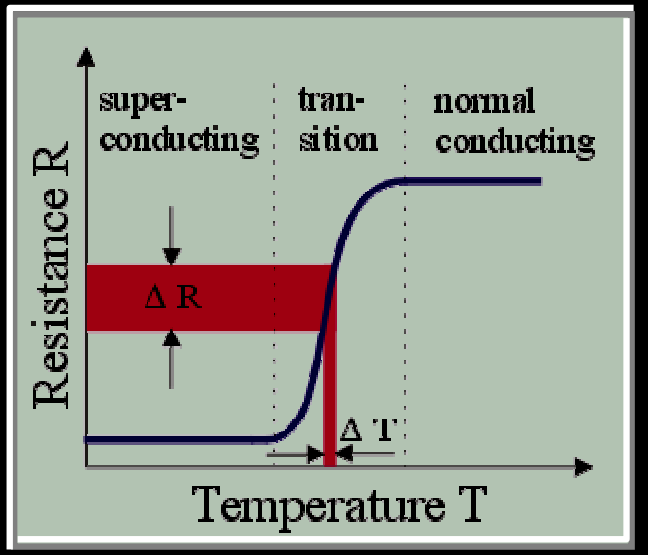
Cryogenic
Rare
Event
Search with
Superconducting
Thermometers

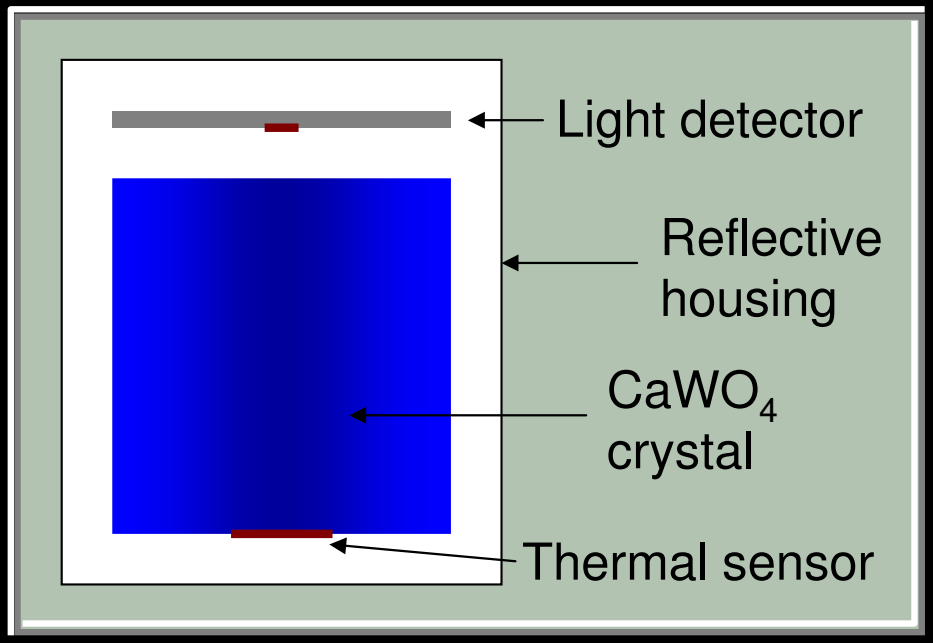
- Max Planck Institut für Physik, Munich
- Technische Universität München
- University of Oxford
- Universität Tübingen
- Laboratori Nazionali del Gran Sasso

G. Angloher, M. Bauer, I. Bavykina, A. Bento, C. Bucci, P. Christ,
C. Ciemniak, C. Coppi, C. Cozzini, F. von Feilitzsch, D. Hauff, S. Henry,
P. Huff, C. Isaila, Th. Jagemann, J. Jochum, M. Kimmerle, H. Kraus,
J.-C. Lanfranchi, R. Lang, B. Majorovits, J. Ninkovic, E. Pantic,
F. Petricca, S. Pfister, W. Potzel, F. Pröbst, Y. Ramachers, M. Razeti,
W. Rau, K. Rottler, S. Scholl, W. Seidel, M. Stark, L. Stodolsky,
A.J.B. Tolhurst, W. Westphal, H. Wulandari

CRESST

- Cryogenic scintillation detectors, $CaWO_4$
- Cryogenic light detector (Si)
- Reflective housing
- ∅ = 4 cm, h = 4 cm, m = 300 g
- Thermal readout: TES
- Transition temperature: 7 – 15 mK

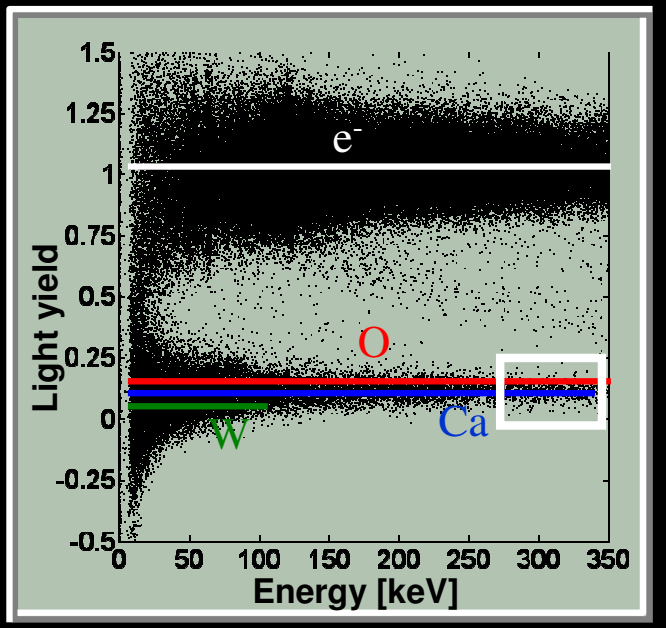


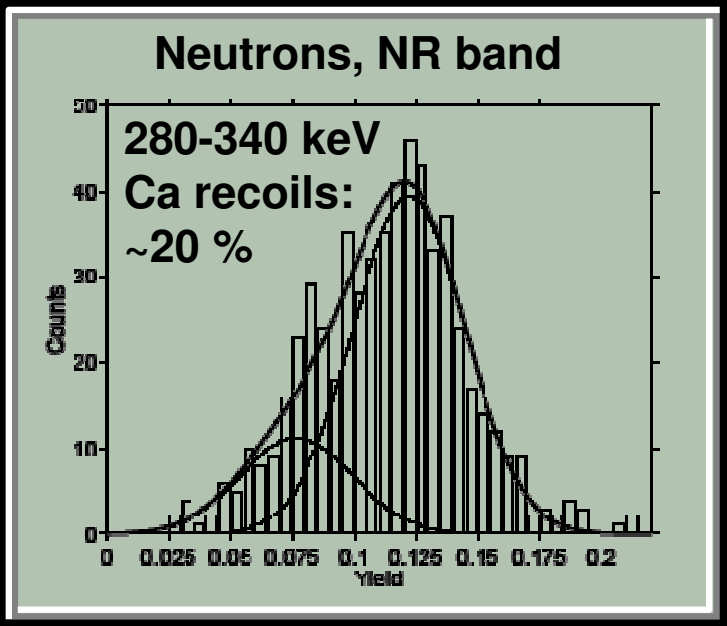


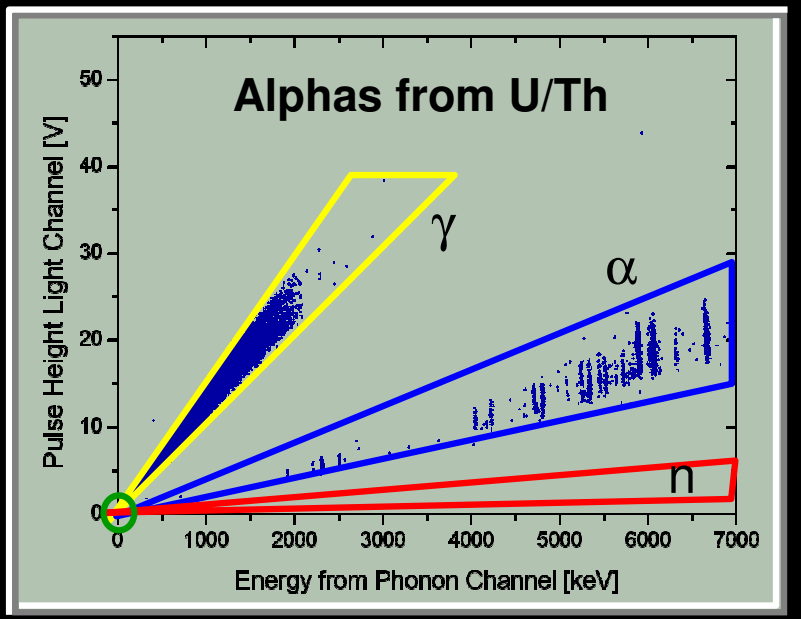
CRESST

Light yield

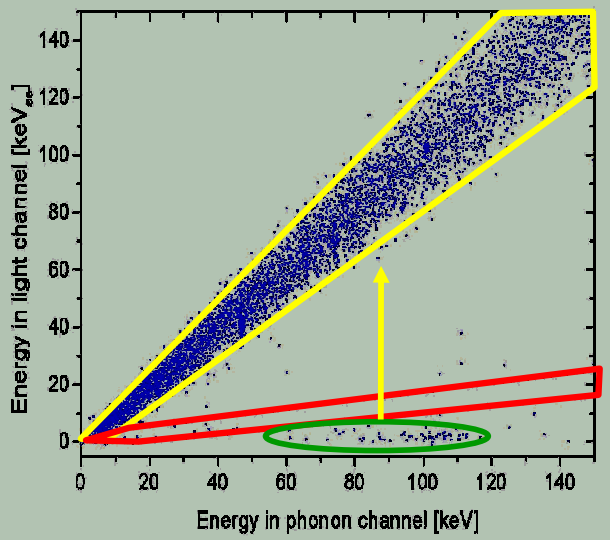
- For ERs about 1 % of the energy is collected in the light detector
- For NRs (neutrons from AmBe source) light yield is reduced by a factor of ~ 8
- Target has different nuclei (Ca, W, O), may have different light yield





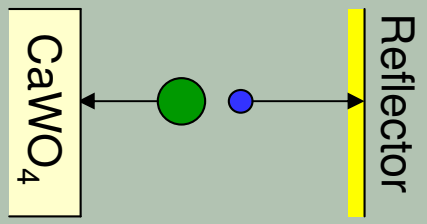


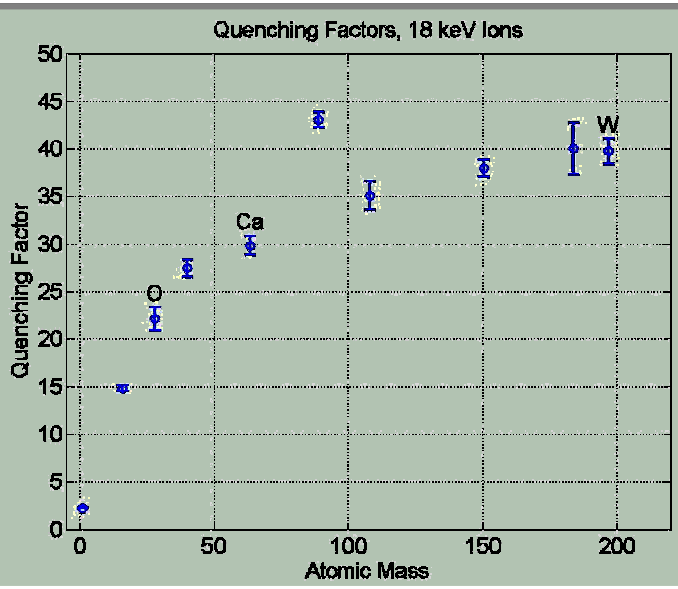
CRESST



- Light yield decreases with increasing mass
- Confirmed with ion irradiation and neutron scattering at room temperature
- Low temperature measurements (neutron scattering) in preparation
- Good resolution in light channel allows discrimination of neutrons (mainly O recoil) and WIMPs (prefer heavy nuclei: W)

Pb from alpha decay of ^{210}Po

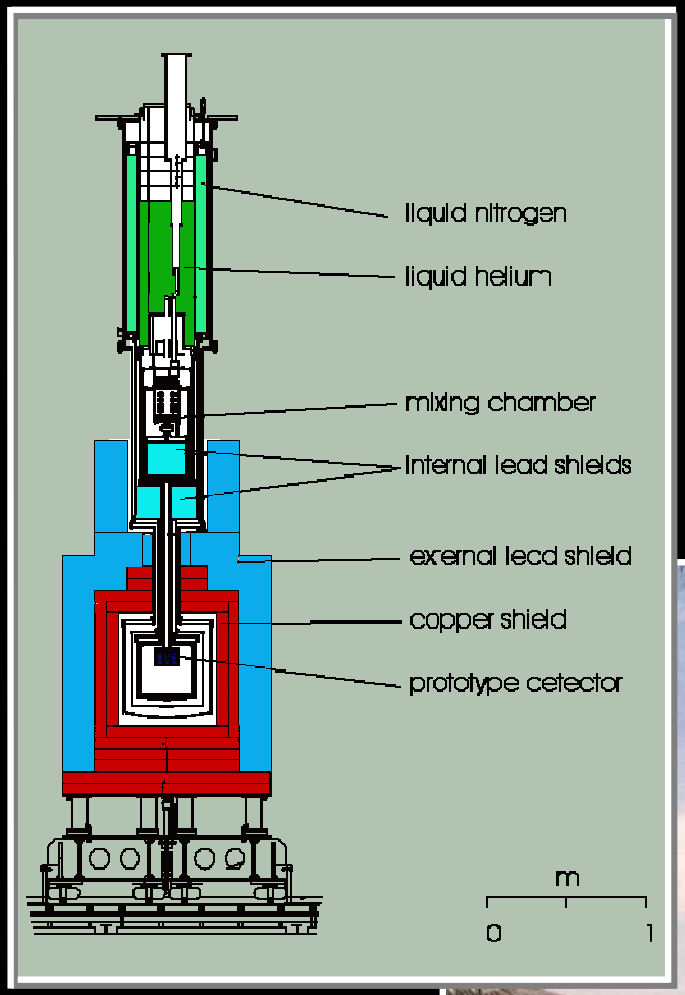




Quenching Factors from ion irradiation (18 keV, room temp.):

O: 14.8
Ca: 27.4
W: 40.0

CRESST


liquid nitrogen
liquid helium
mixing chamber
internal lead shields
external lead shield
copper shield
prototype detector
m
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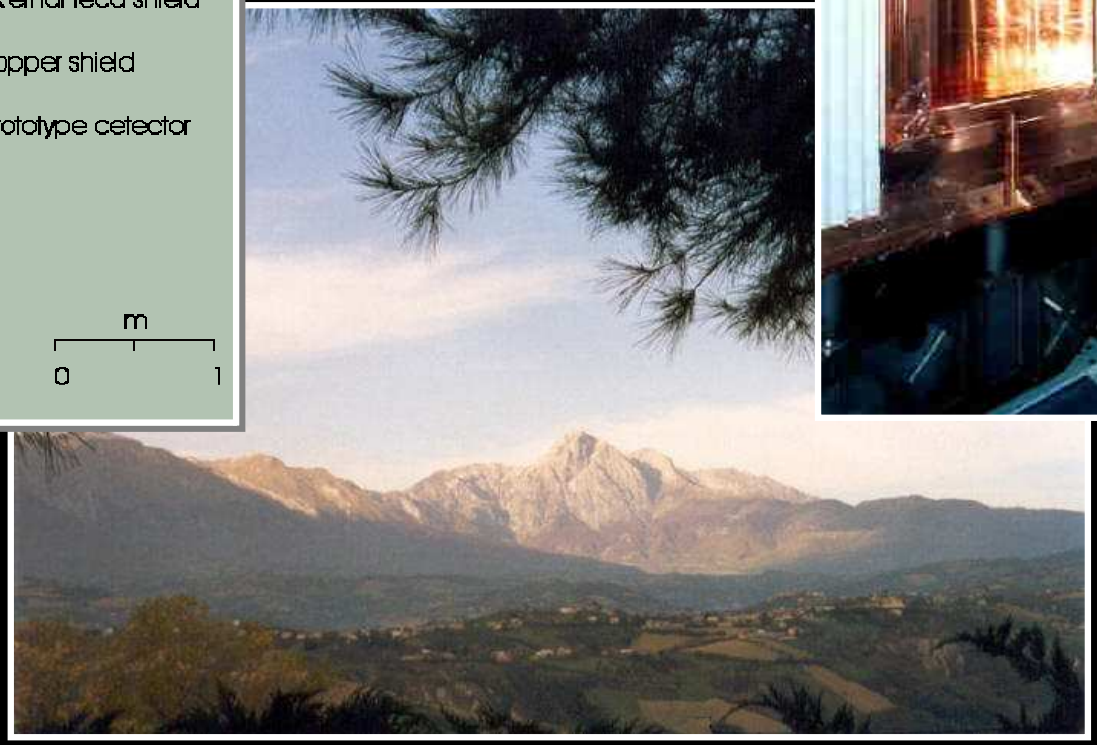
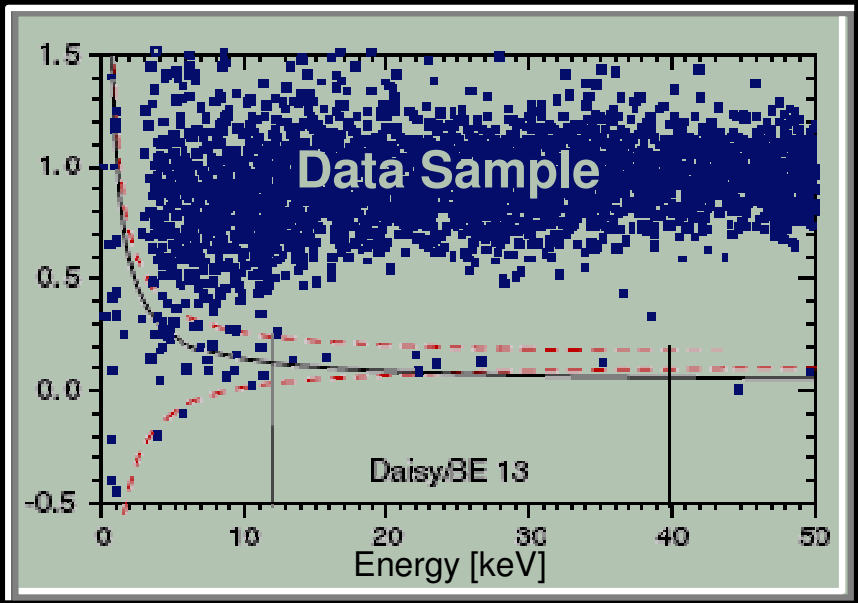
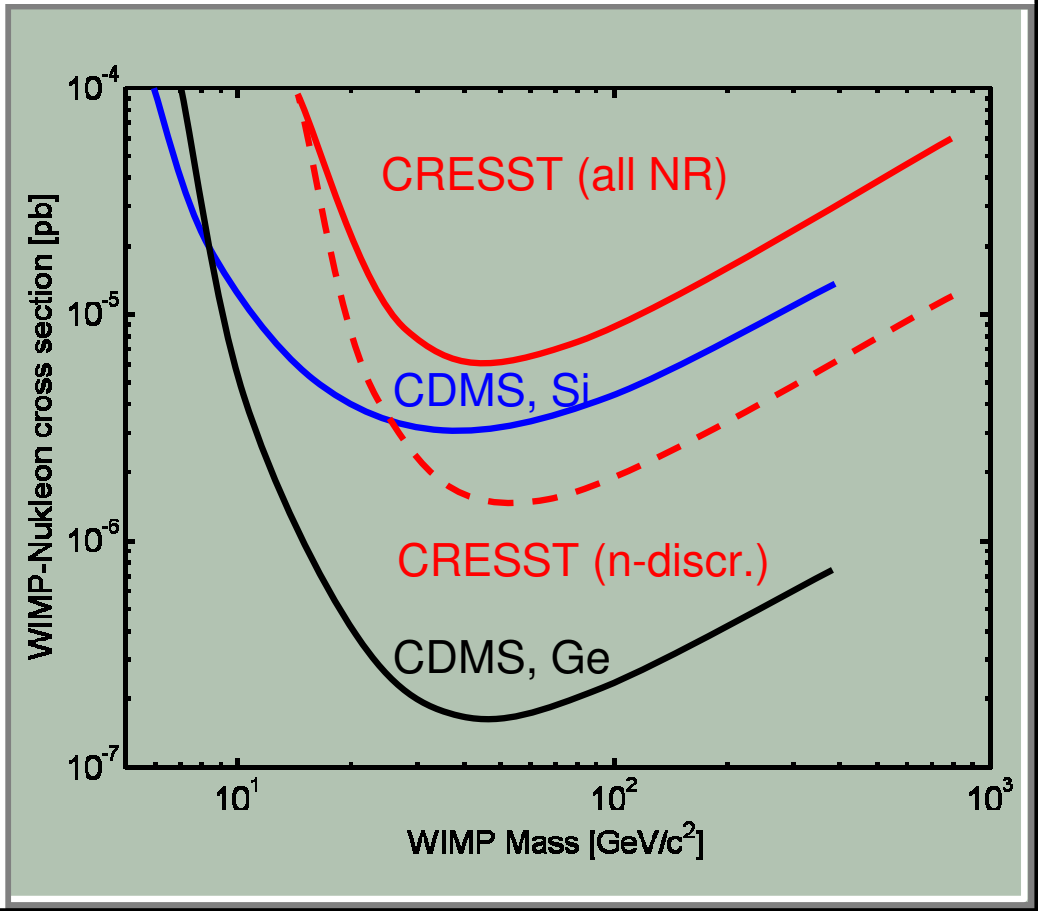
1



CRESST

- Gran Sasso-Lab: 3600 m w.e.
  2 detectors in 2004:
- ~ 20 kg d, 16 NR candidates
  (consistent with expected n-BG)
- One detector with good
  resolution in light channel:
- 10 kg d, 0 events in area where
  W signal is expected

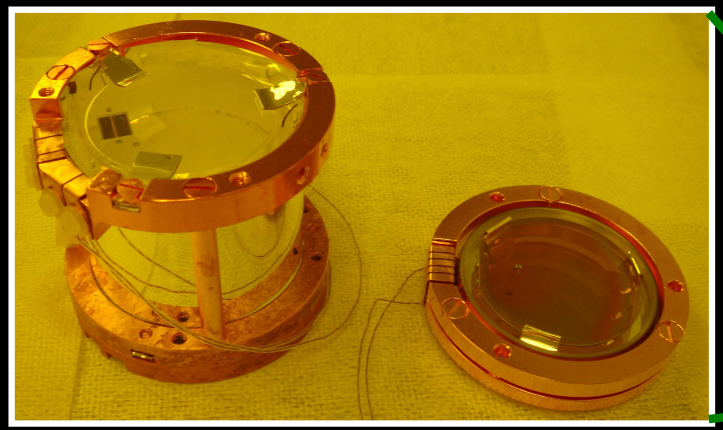


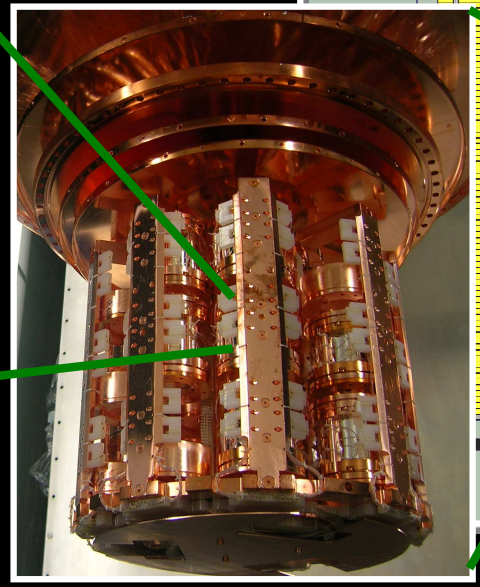


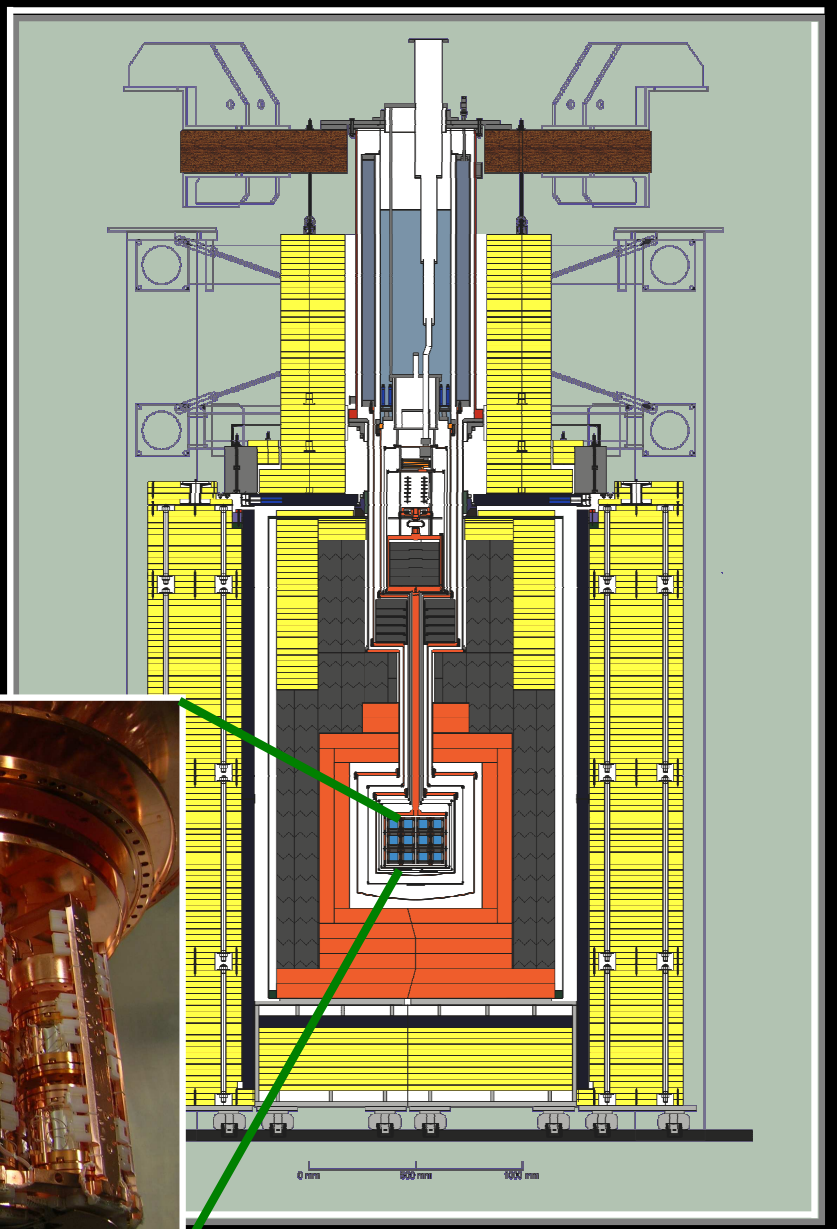
Astropart. Phys. 23 (2005) 325

CRESST

- Neutron shield, μ-veto installed
- Electronics/DAQ for up to 33 detectors (10 kg)
- First detectors installed
- Cryostat cold since November
- First measurement (3 modules) running since March (~ 25 kg d)
- Threshold $\lesssim$ 10 keV
- Expected sensitivity: O(10^{-8} pb)







EDELWEISS

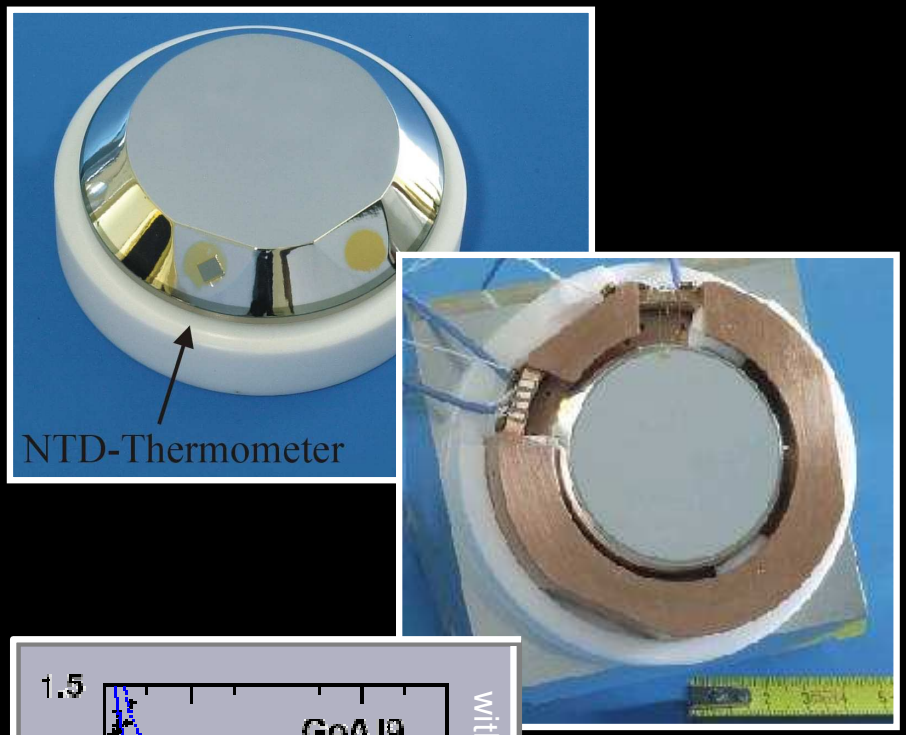
Expérience pour **DE**tecter **L**es **W**IMPs **E**n **Si**te **S**outerrain

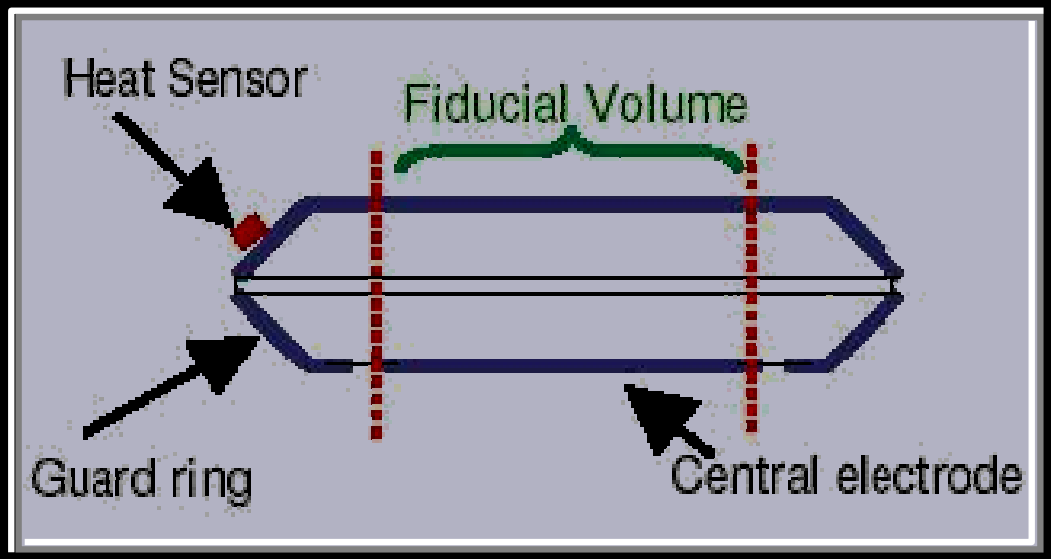
- CEA-Saclay DAPNIA/DRECAM
- CRTBT Grenoble
- CSNSM Orsay
- FZK/Univ. Karlsruhe
- IAP Paris
- IPN Lyon
- Laboratoire Souterrain de Modane

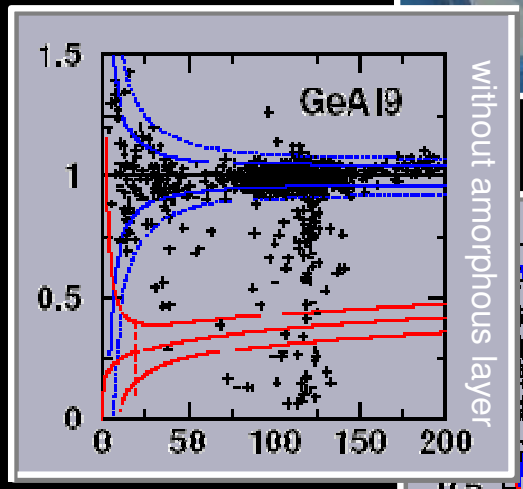
A. Benoit, L. Bergé, J. Bluemer, A. Broniatowski, M. Caussignac, B. Censier, M. Chapellier, A. Chantelauze, G. Chardin, F. Charileux, S. Collin, M. Combarieux, M. De Jésus, H. Deschamps, P. Di Stefano, Y. Dolgorouky, L. Dumoulin, K. Eitel, M. Fesquet, J. Gascon, G. Gerbier, C. Goldbach, E. Gremion, M. Gros, R. Gumbsheimer, S. Hassani, M. Horn, Y. Jin, A. Juillard, M. Karolak, H. Kluck, F. Lalu, R. Lemrani, A. de Lesquen, M. Luca, S. Marnieros, C. Marrache-Kikuchi, L. Mosca, X.-F. Navick, G. Nollez, P. Pari, B. Paul, H. Rodenas, V. Sanglard, F. Schwamm, L. Schoeffel, M. Stern, L. Vagneron

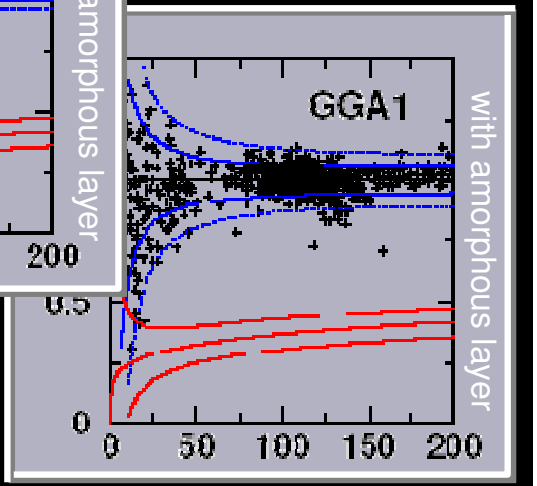
EDELWEISS

- Cryogenic ionization detectors, Ge
- ∅ = 7 cm, h = 2 cm, m = 320 g
- Al electrode for ionization readout (central and guard ring)
- α-Si / α-Ge layer (reduce surface effect)
- Thermal readout: NTD
- Operating temperature: 15 – 20 mK

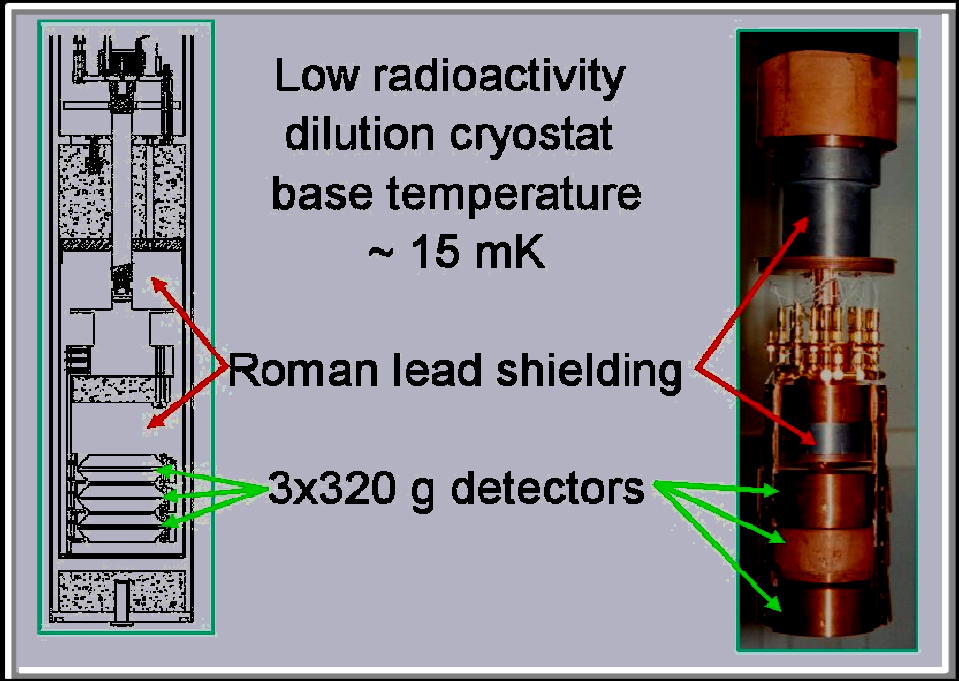


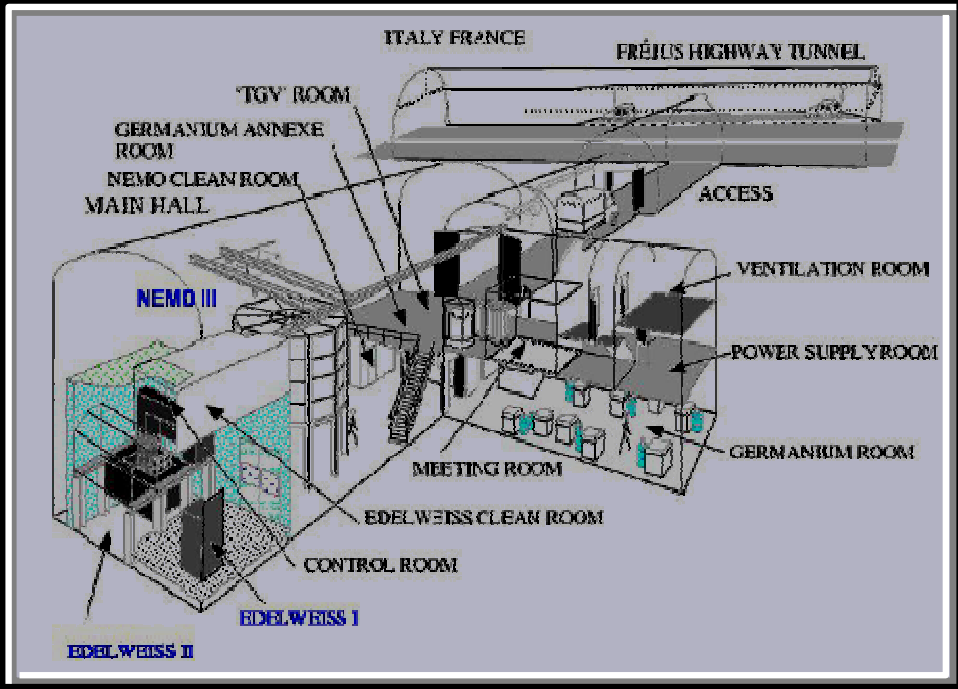






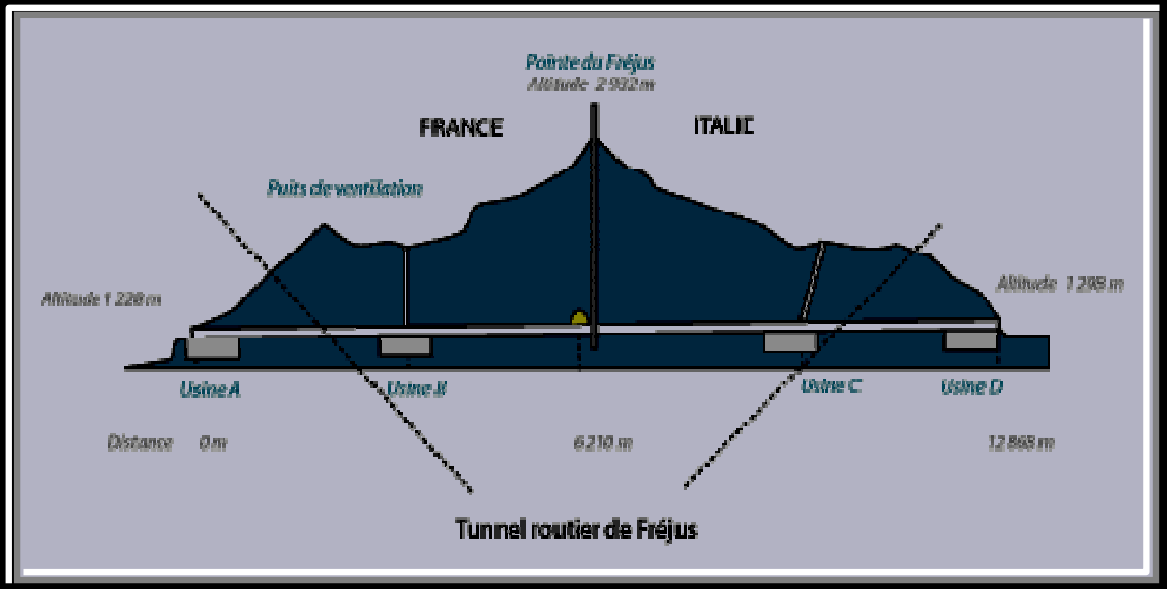
EDELWEISS





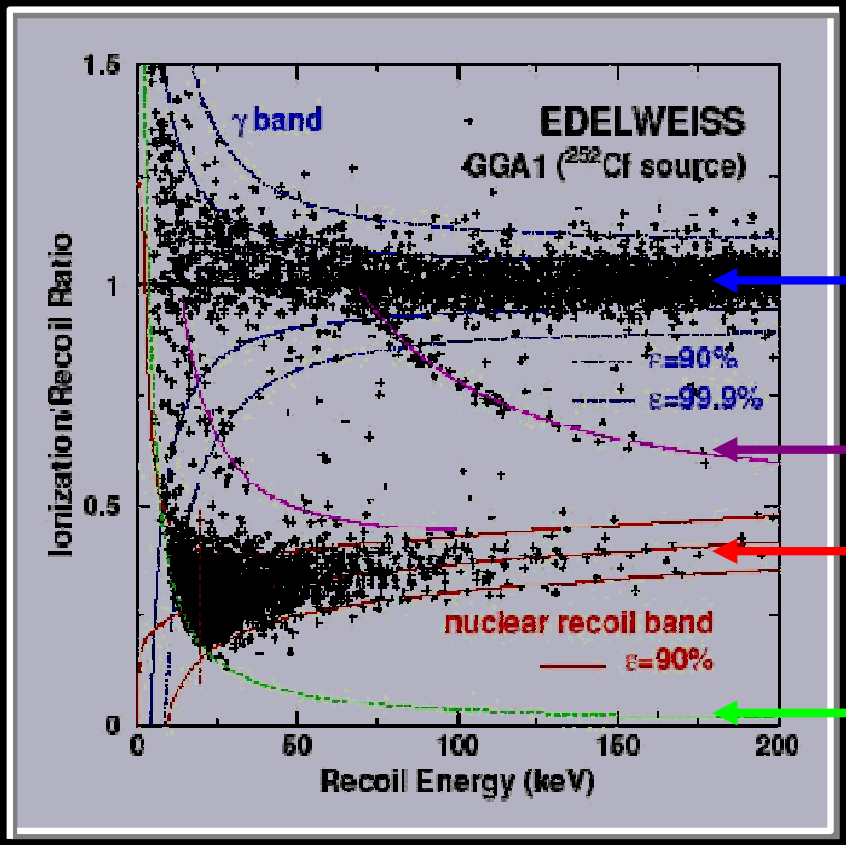
Shielding:

- Internal:
  7 cm old Pb
- External:
  10 cm Cu, 15 cm Pb,
  30 cm Paraffin
- Cosmic:
  4800 m w.e. of rock



EDELWEISS

Neutron calibration measurement



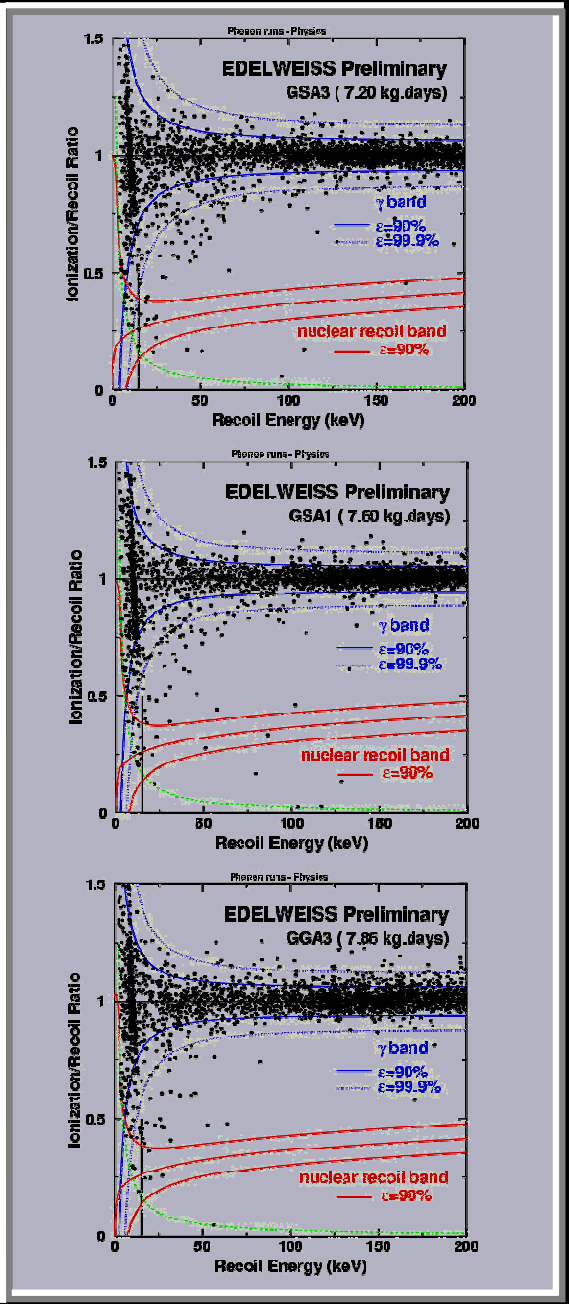
ER - band

Inelastics (NR + ER)

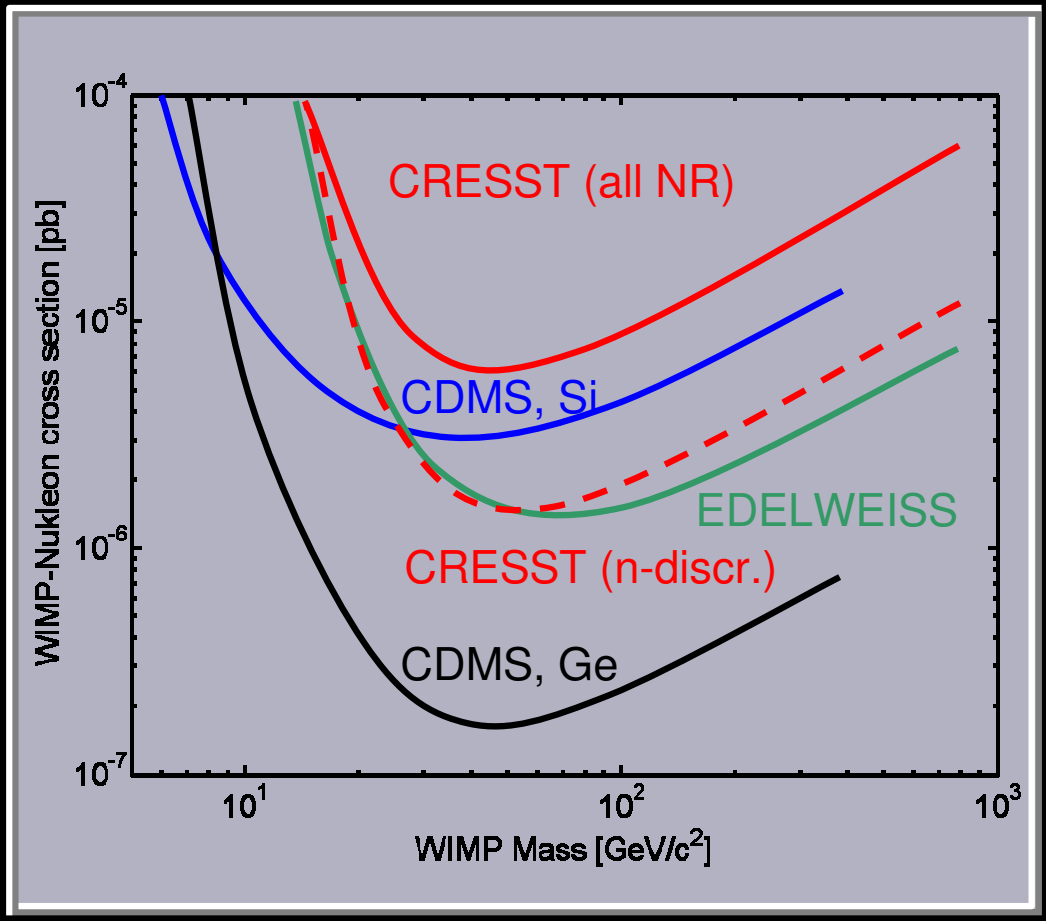
NR - band

Ionization threshold

EDELWEISS



- 2000-03: several runs
- Up to 3 detectors per run
- Total: 64 kg d, 40 NR candidates (consistent with BG from n or surface events)



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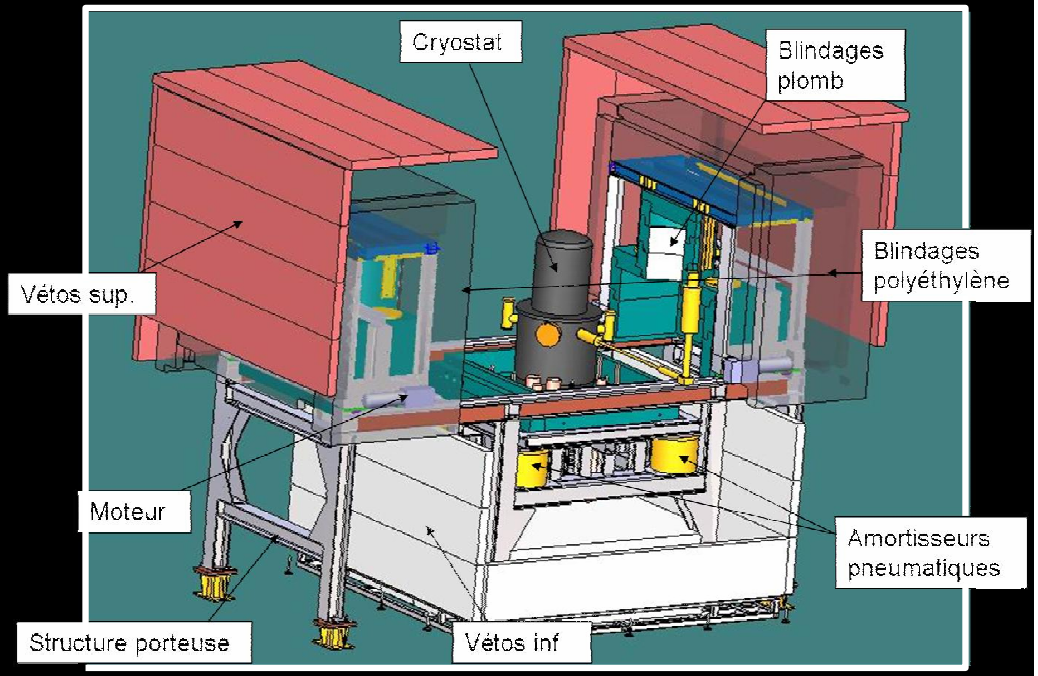
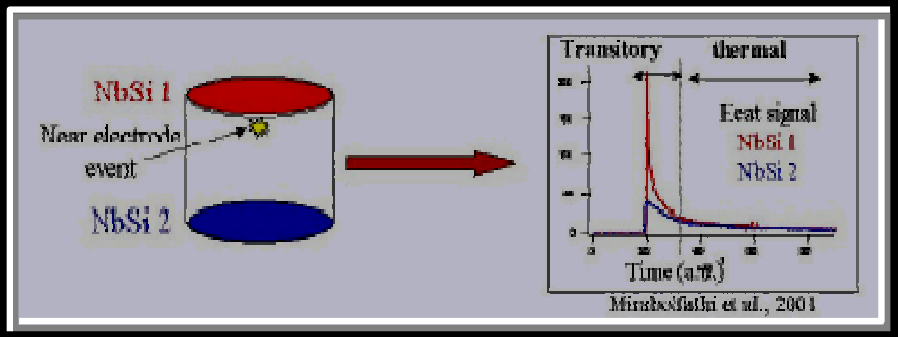
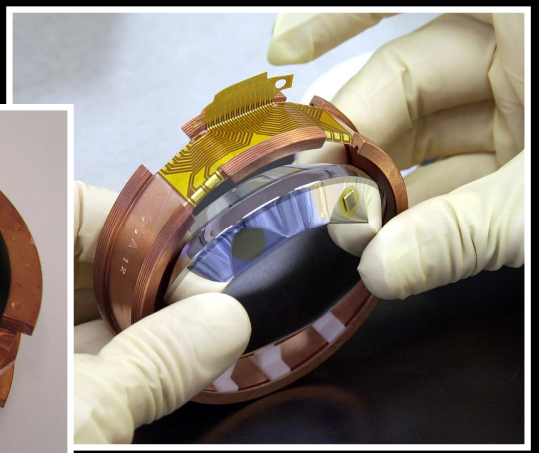
EDELWEISS

Completely new setup:

- New cryostat (for > 100 det.)
- Clean room class 100 (around cryostat)
- Radon reduced air (0.1 Bq/m^3)
- Improved γ and n-shielding (20 cm Pb, 50 cm PE)
- Muon veto (> 98 % coverage)
- New detector mounting (less, cleaner material), optimized NTDs
- Detectors with surface event rejection (double sided NbSi sensor, still under R&D)







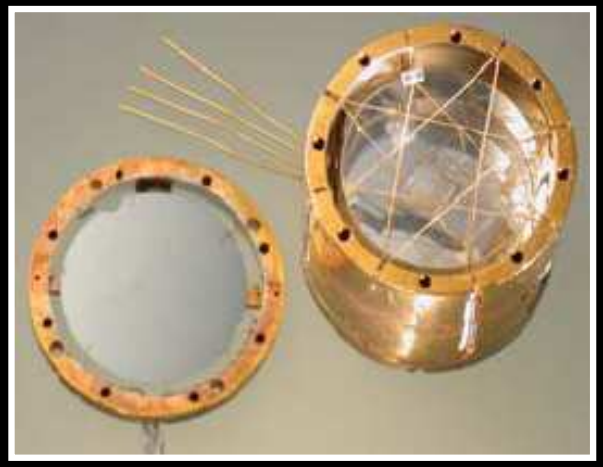
EDELWEISS

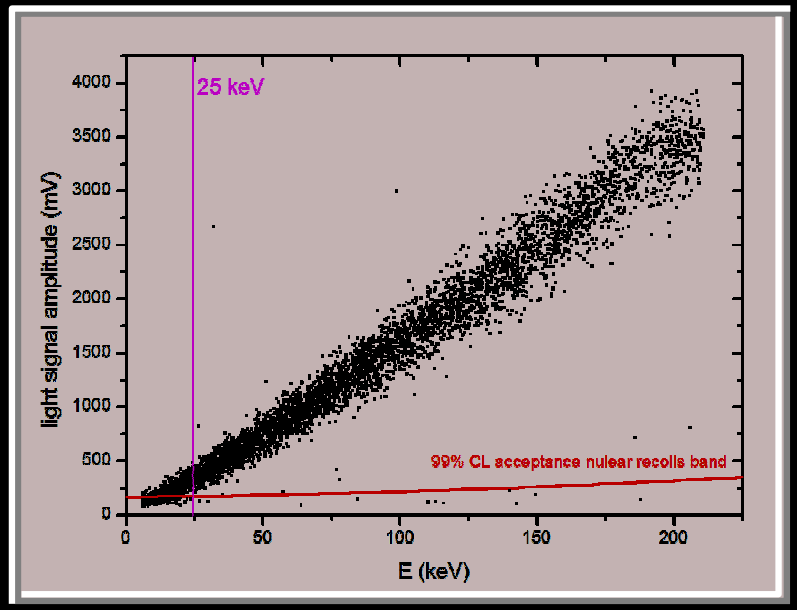
- New setup operating since 2006
- Since January: **22** 320 g Ge NTD detectors, **1** 70 g ^{73}Ge NTD det., **2** 200 g and **1** 400 g NbSi det.s, **1** scintillating Al_2O_3 detector
- About 2/3 of detectors are fully functional with good resolution
- Resolution: charge ok (1-2 keV), phonon: limited by microphonics (several keV)
- Cryo: stable as long as pulse tube cooler cooperates
- Noise / BG studies ongoing
- Physics starts this summer
- Sensitivity goal (present phase, 28 det.s, 8 kg): O(10^{-7} pb)
- Next phase (more detectors): 2009, sensitivity goal O(10^{-8} pb)

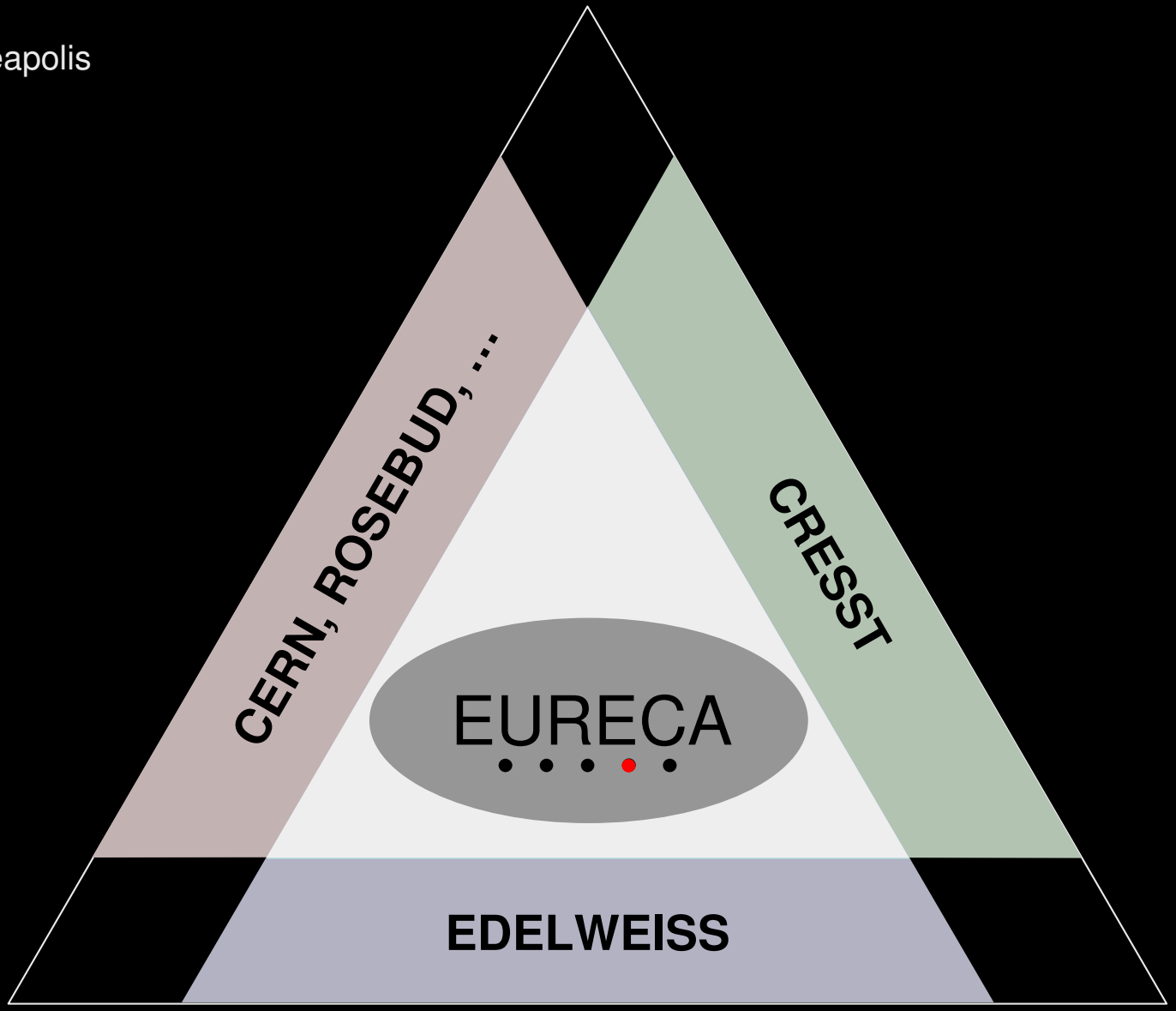
ROSEBUD

Universidad de Zaragoza - Institut d'Astrophysique Spatiale d'Orsay

- R&D for DM search with scintillating cryo detectors
- Test different materials (BGO, Sapphire, LiF, O(50 g) each)
- Thermal measurement with NTD (ca. 20 mK)
- Low BG setup: Laboratorio Subterráneo de Canfranc (LSC; 2450 m w.e.), Cu/Pb shielding, partial PE shield





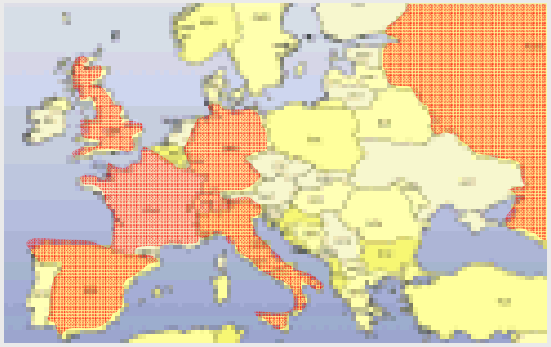


European **U**nderground
Rare **E**vent
Calorimeter **A**rray

EURECA

- Sensitivity goal O(10^{-10} pb) to test bulk of SUSY parameter space
- Target mass O(1 tonne)
- Different target materials:
  - identification of WIMP signal via A-dependence
  - improve sensitivity for spin-dependent interaction

- France
- Germany
- Italy
- Russia
- Spain
- United Kingdom
- CERN (Switzerland)



- CEA/DAPNIA & DRECAM Saclay
- CERN
- CNRS/CRTBT Grenoble
- CNRS/CSNSM & IAS Orsay
- CNRS/IPN Lyon
- DLNP Dubna
- FZK & Universität Karlsruhe
- Laboratoire Souterrain de Modane
- Laboratori Nazionali del Gran Sasso
- Max Planck Institut für Physik, Munich
- Technische Universität München
- Universidad de Zaragoza
- Universität Tübingen
- University of Oxford
- More groups interested in joining…

EURECA

- Some R&D funds available (individual groups)
- Co-ordination supported by the EU via the ILIAS network
- Applied for funding from EU for a Design Study (experiment infrastructure)
- Main project funding will have to be applied for at national funding agencies
- Close co-ordination with LSM (Modane underground laboratory) as possible location
- Main focus for the coming months: demonstrate technique with the presently running experiments

Conclusion

- Upgrade finished for both CRESST and EDELWEISS
- CRESST has ~1 kg target running, increase foreseen soon
- EDELWEISS has 27 detectors cold, about 2/3 performing well, still some commissioning work to be done, physics run to start this summer
- ROSEBUD: work on detector R&D
- Experiments in 3 different European underground laboratories (Italy, France, Spain)
- Focus European efforts for the future:

  EURECA - large scale project for European Dark Matter search with cryo detectors; early planning status, some R&D; applied for EU money (design study)