Results of the CRESST Commissioning Run 2007

4th Patras Workshop

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J.-C. Lanfranchi, Technische Universität München

Outline

- CRESST Detection Method
- CRESST after upgrade
- Commissioning Run 2007
- Present Status
- The Future

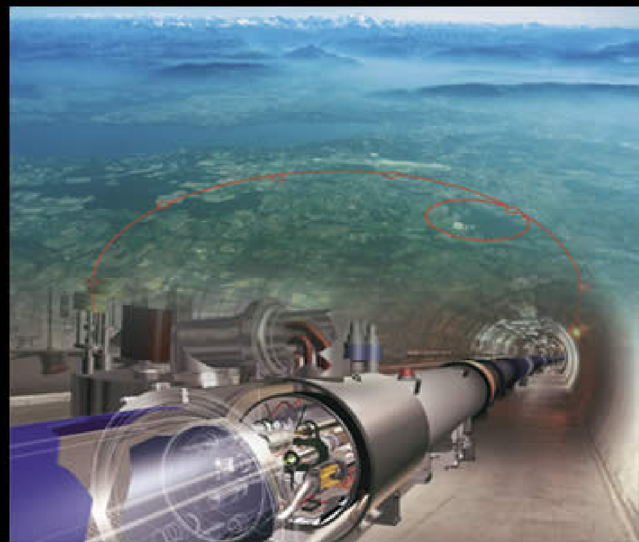
Dark Matter Detection

Gravitational

Direct

Indirect

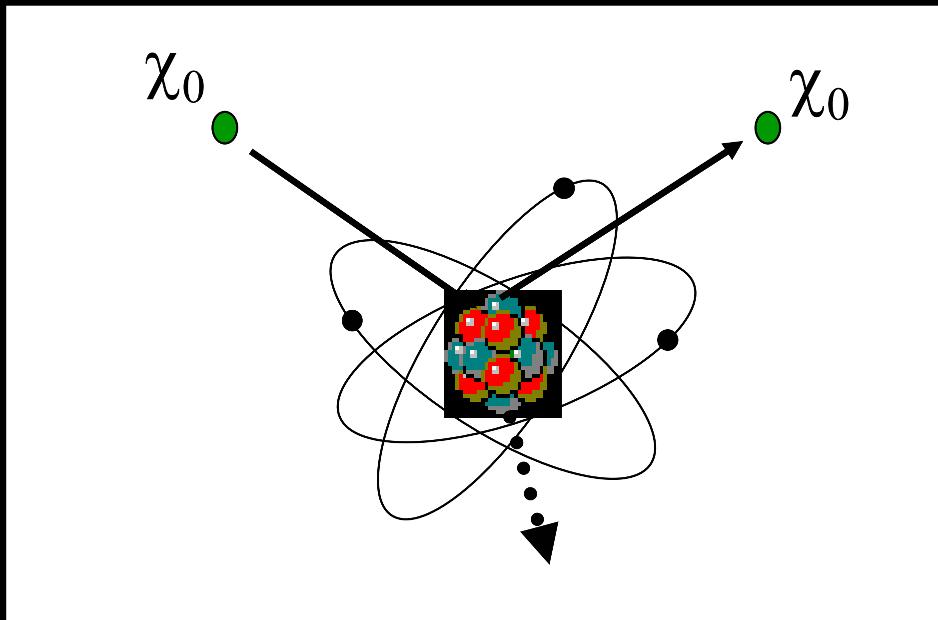
Production



Direct Dark Matter Search with Cryogenic Detectors

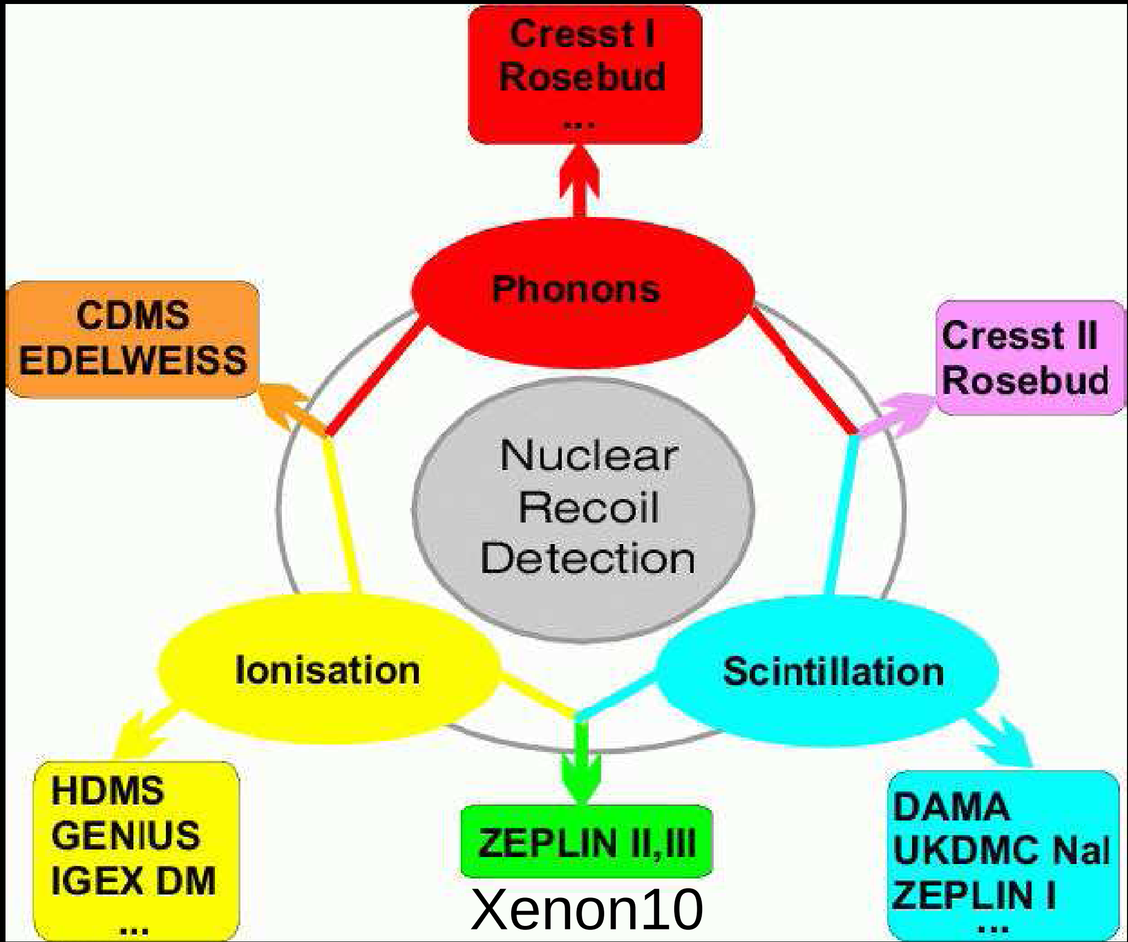
Search for a well motivated DM candidate: WIMP
(Weakly Interacting Massive Particle)

➔ Signature:nuclear recoil in the target mass of a cryogenic detector



➔ Critical issue: background !

Direct Detection Techniques



Phonon: most precise total energy measurement

Ionization / Scintillation: yield depends on recoiling particle

Nuclear / electron recoil discrimination.

Combination of different techniques

$\Rightarrow$ Active suppression of the background induced by electron recoils ($\gamma+\beta$)

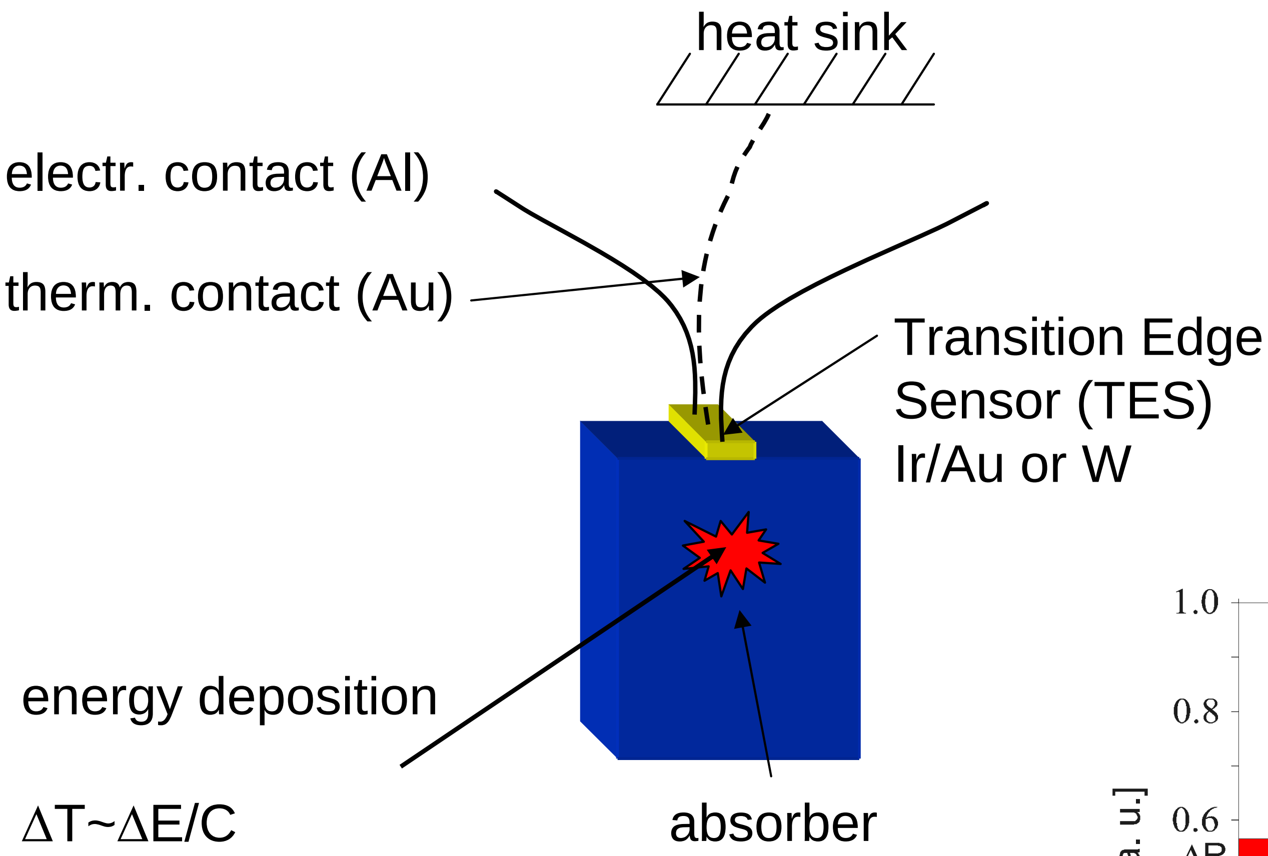
DM Detection with CRESST

Background rejection method: **phonon & light**

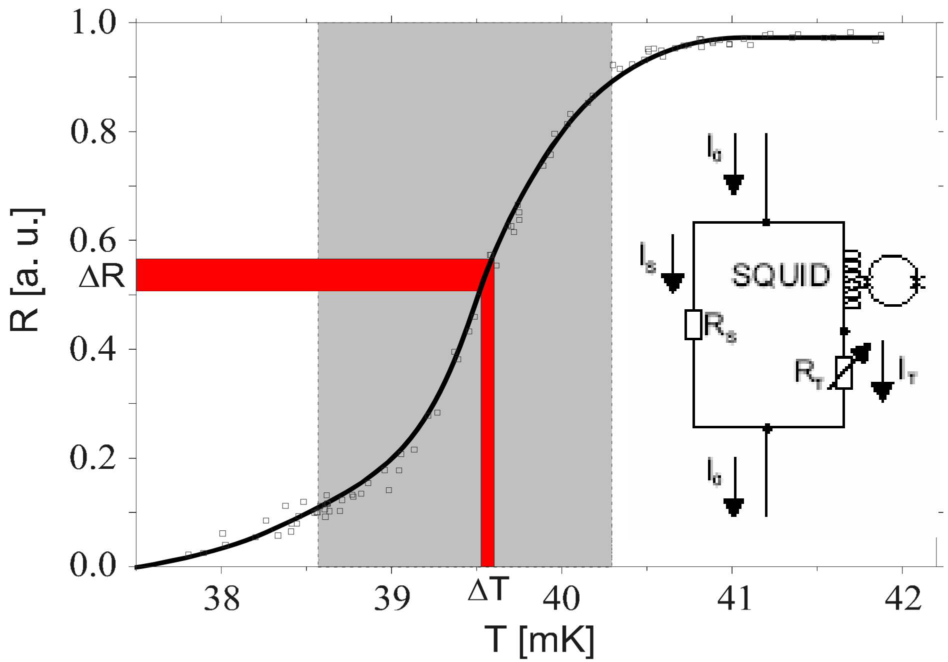
Both signals are recorded by **2 individual** cryodetectors

CRESST cryodetectors are based on **superconducting** phase transition sensors

TES-Cryodetectors



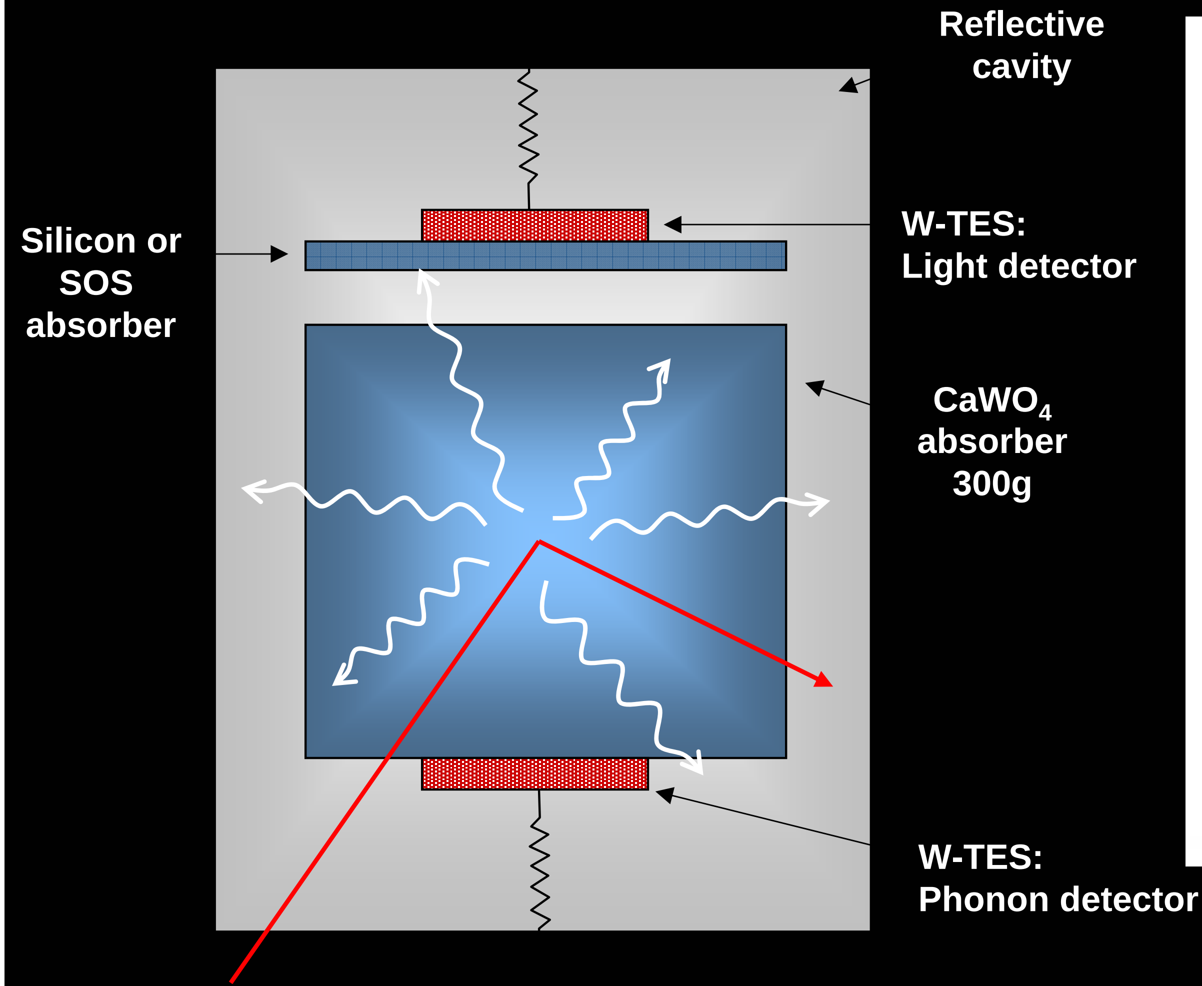
Stabilization of TES in the transition region between normal-/superconducting state

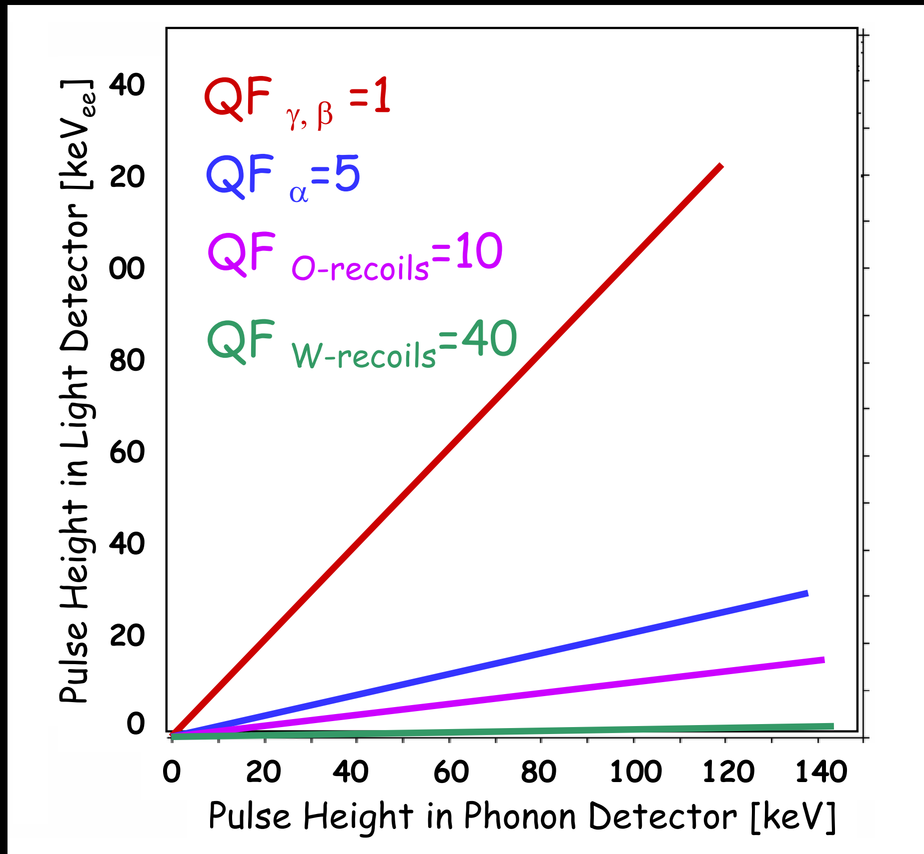


Read out of TES via SQUIDs

The CRESST Detectors

Discrimination of radioactive background by simultaneously measuring phonons and $CaWO_4$ scintillation light

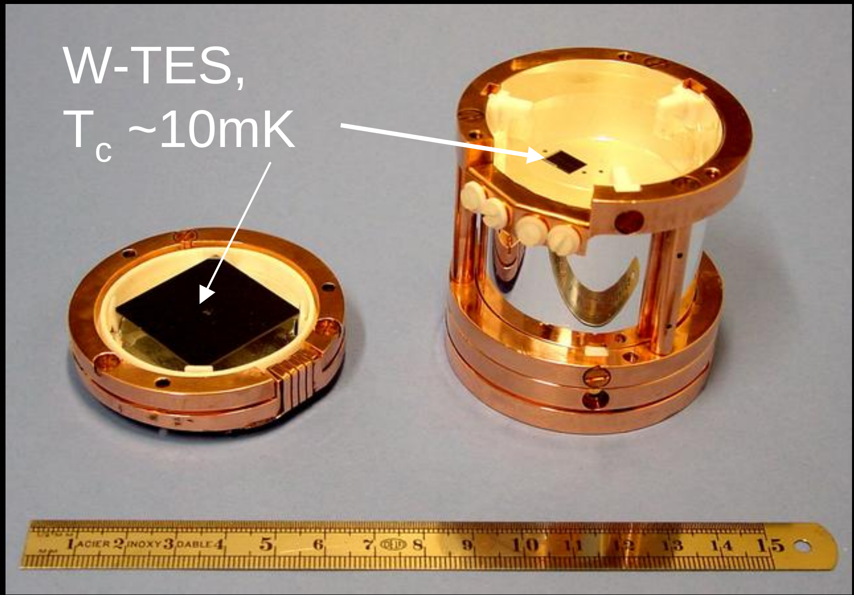




Every particle has a different quenching factor QF

QF = photon light signal / particle light signal (both of same energy)

CRESST Detector Modules

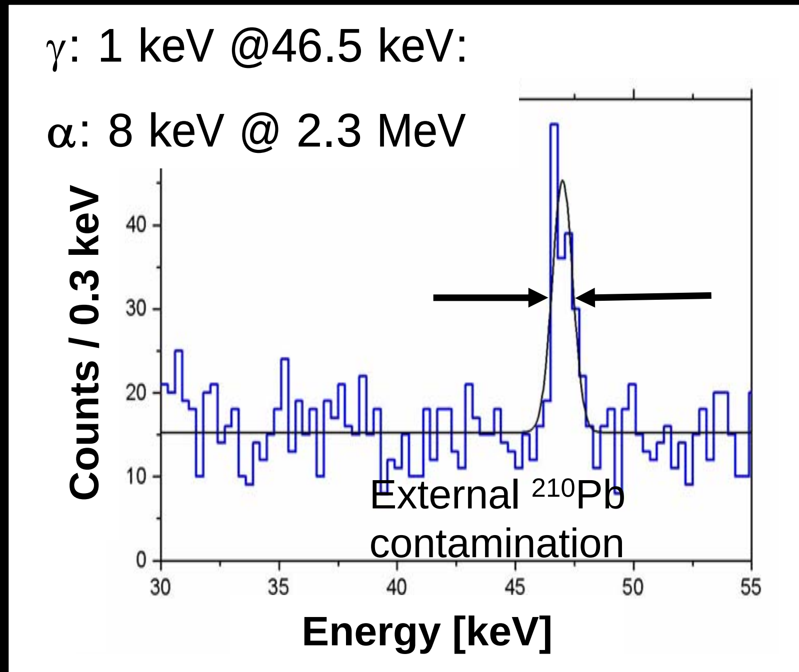


Target / phonon detector:
cylindrical $CaWO_4$ single crystal
Mass: ~300g
∅ 40mm, height 40mm

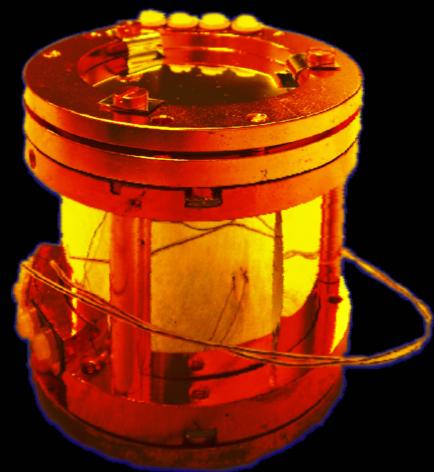
Light detector:
$30x30x0.4mm^3$ Si or SOS
W-TES & phonon collectors
α-phase tungsten: $6x8\ mm^2$

Light yield for γ's: ≤ 1 % !

Typical detector performance:

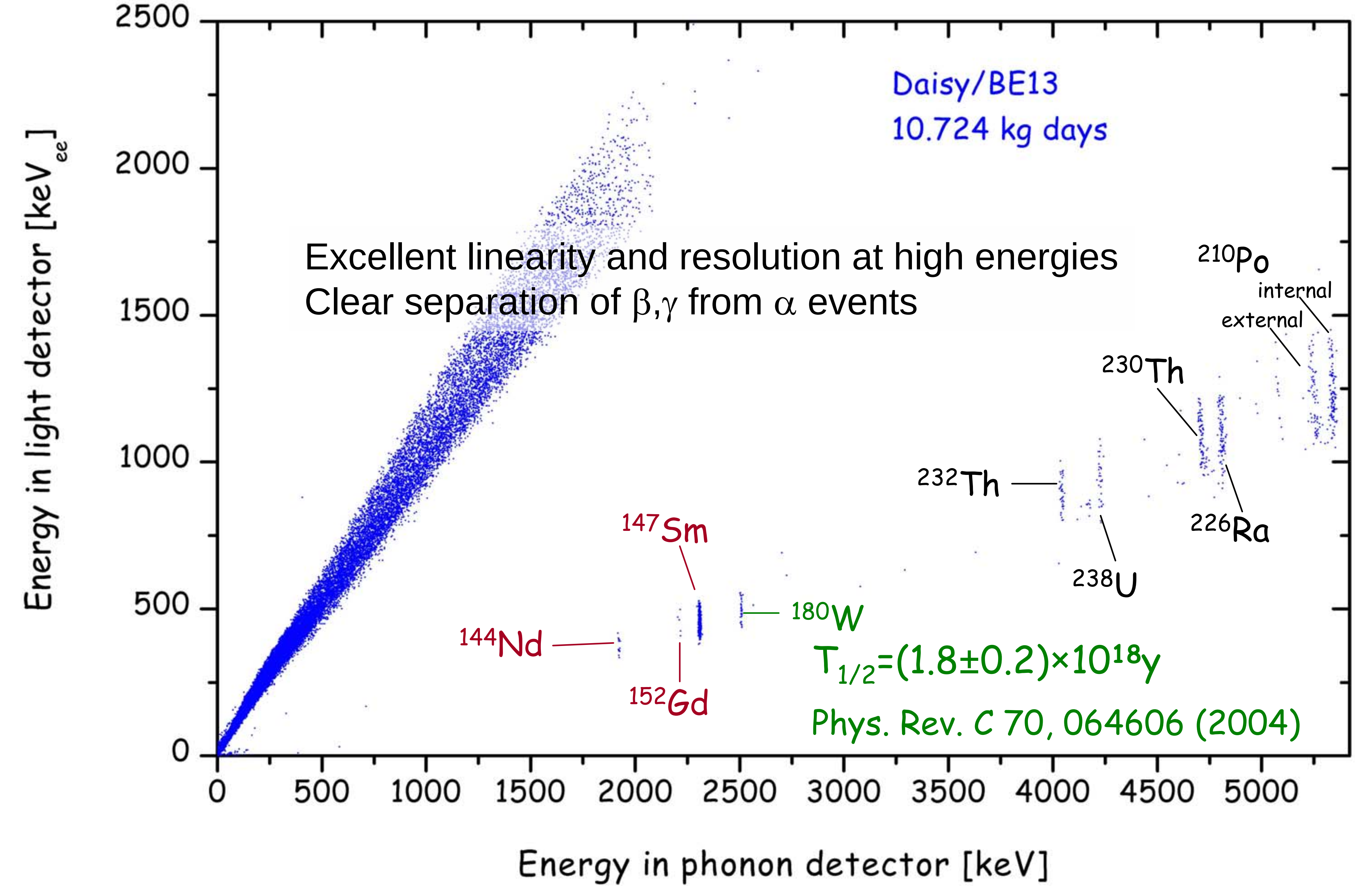


Mounted detector module:



CRESST II capacity: **~10kg $CaWO_4$**

CRESST II background rejection



CRESST at L.N.G.S.

Cryogenic Rare Event Search with Superconducting Thermometers

Max-Planck-Institut für Physik

University of Oxford

Technische Universität München

Laboratori Nazionali del Gran Sasso

Universität Tübingen

Features of CRESST II

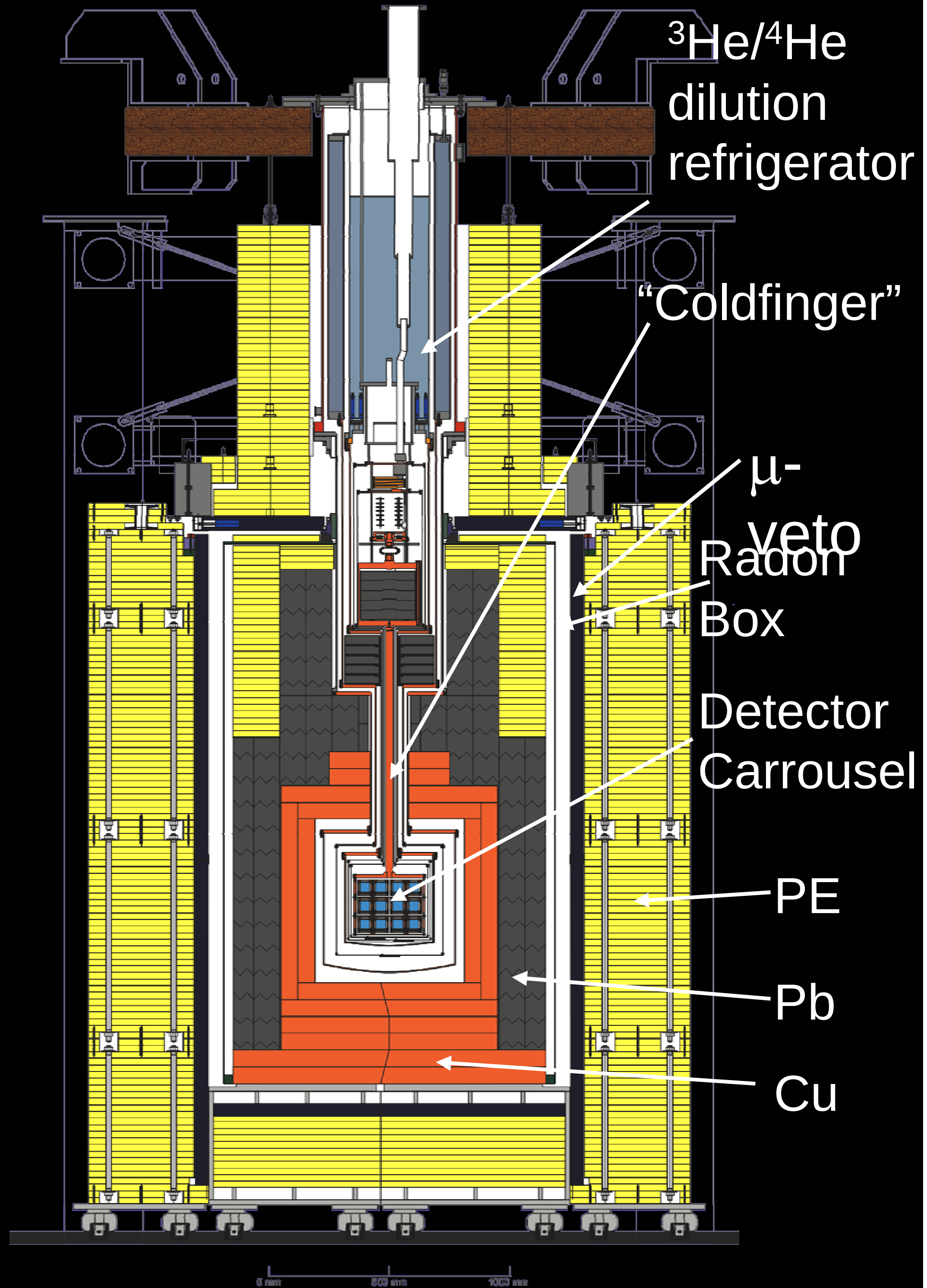
- final target mass : ~10 kg $CaWO_4$
- threshold lower than 15 keV (recoils)
- excellent background discrimination
- **identification of recoiling nuclei**
  (powerful tool for positive determination of WIMP signal)

Goal (full target mass):

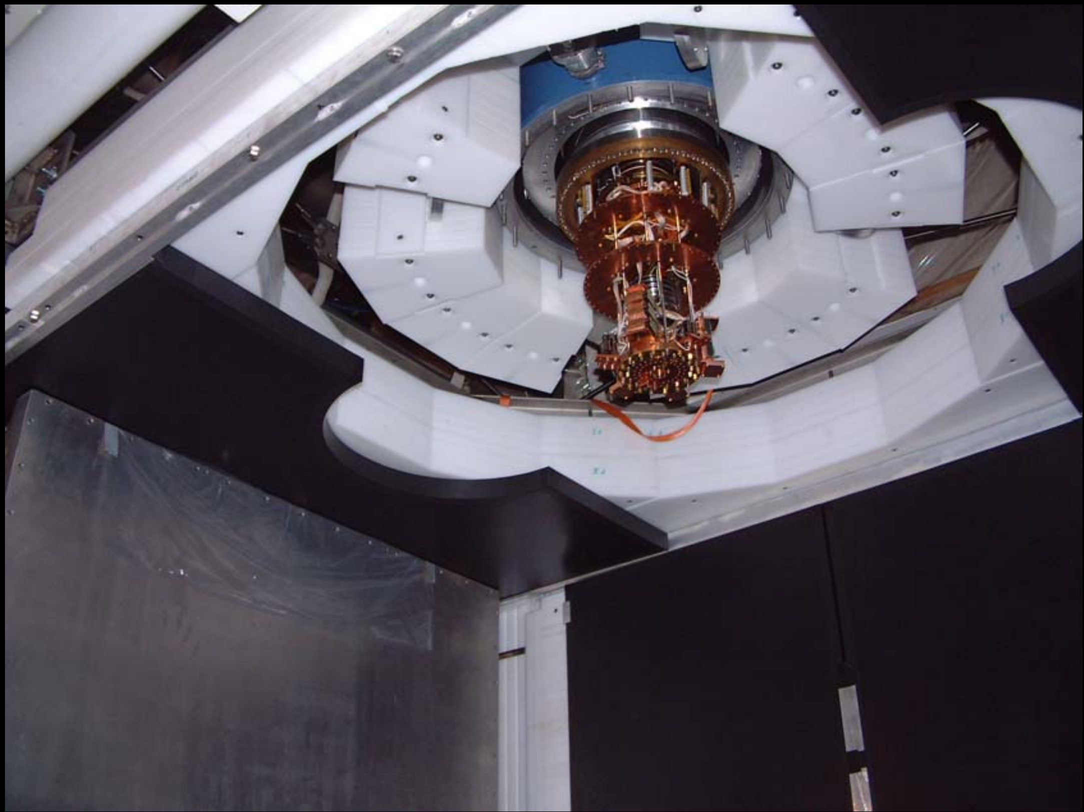
Sensitivity better than 10^{-8}pb

Upgrade: I to II

- Experiment moved from Hall B to Hall A @ L.N.G.S.
- rock overburden ~3600m.w.e.
- 45 cm polyethylene (PE) shielding
- plastic scintillator μ-veto
- New detector support structure
- New detector holders
- 66 SQUID channels
- New Wiring
- New DAQ
- ^{57}Co Calibration source lift



PE shielding and muon veto

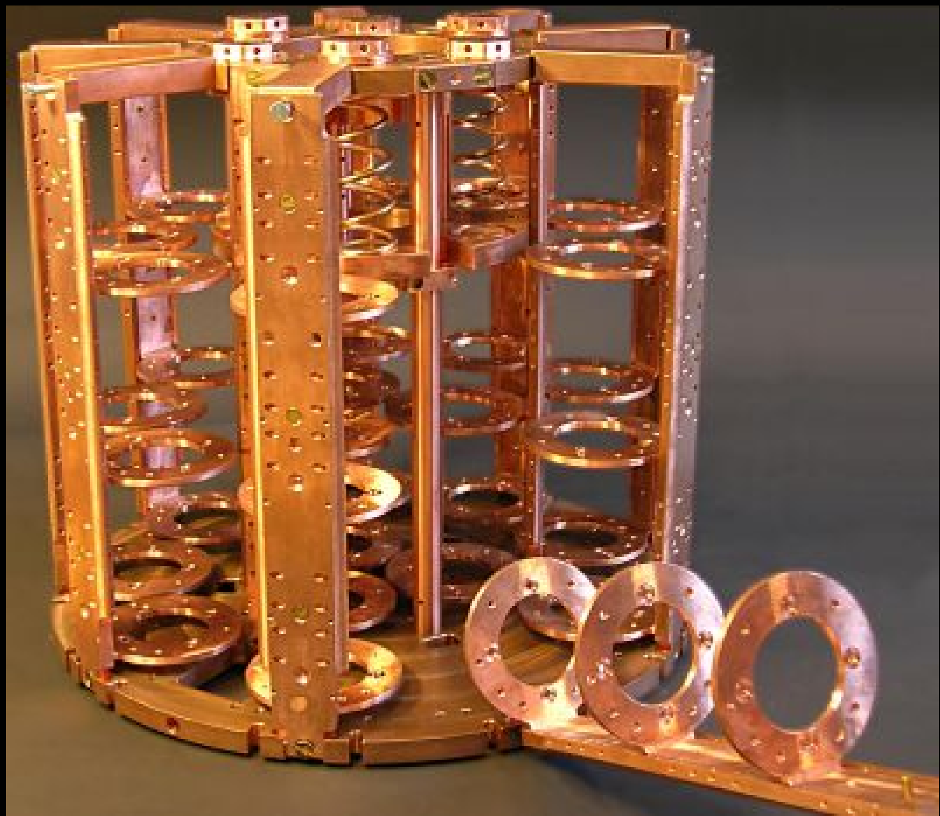


50 cm PE – shielding (12 tons)

Plastic scintillator muon veto

Inside the Cryostat

High purity Cu support structure for
33 detector modules

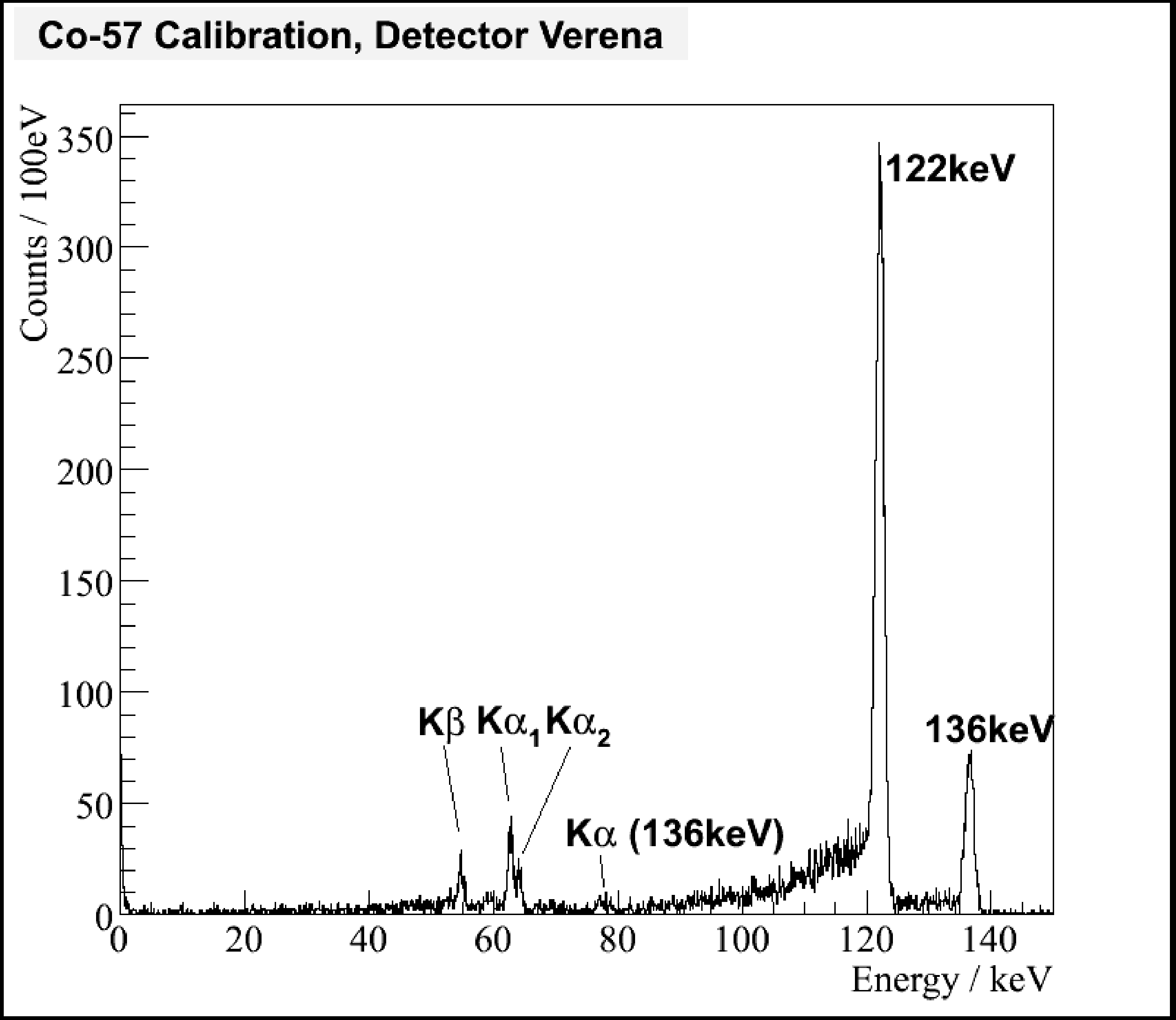


Start of Run30 October 2006

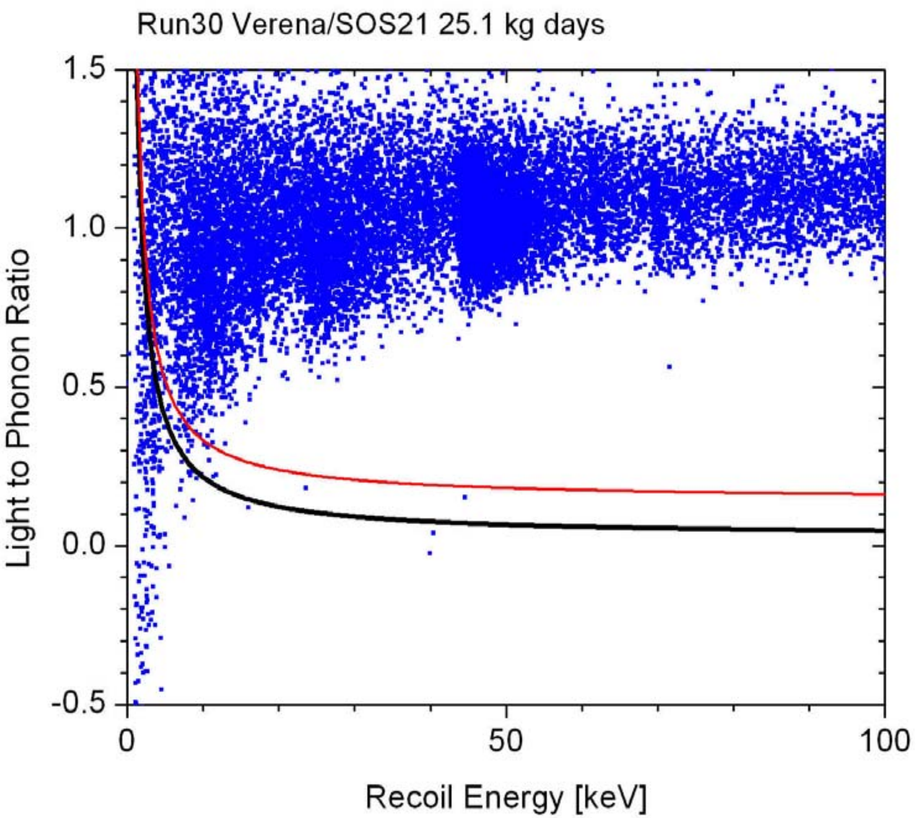
Commissioning Run

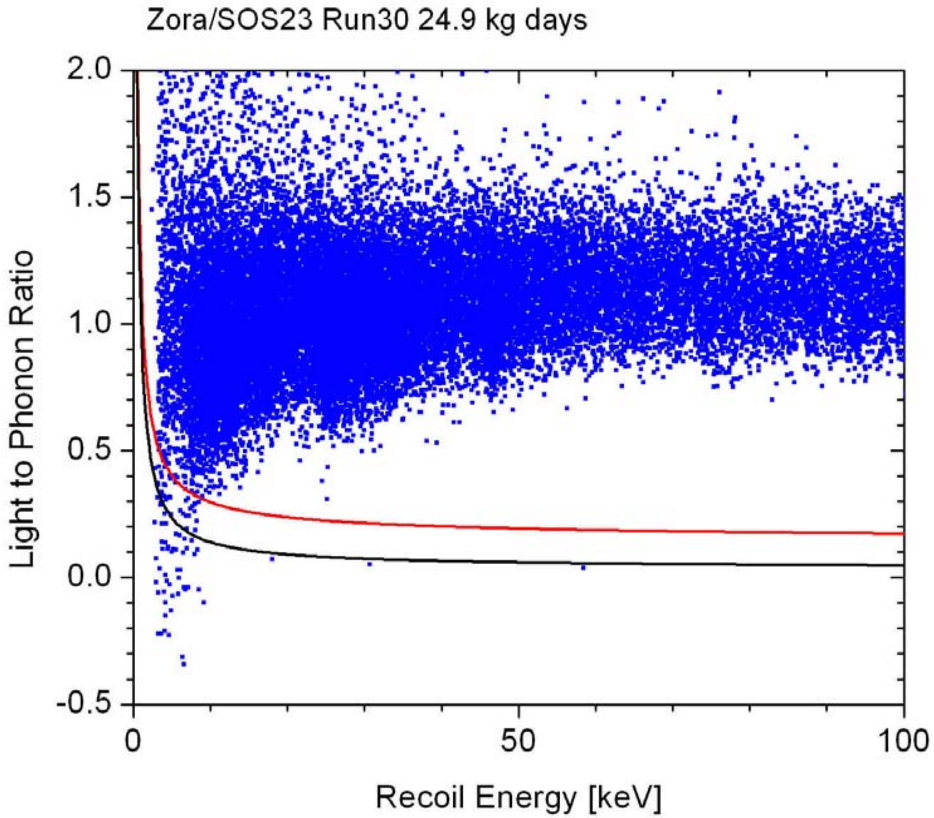
- 9 modules placed
- Cryostat cooled down
- Tuning of the upgraded elements
- Run30 in 2007 with 2 $CaWO_4$ detector modules

Phonon Detector Performance



Discrimination and Background

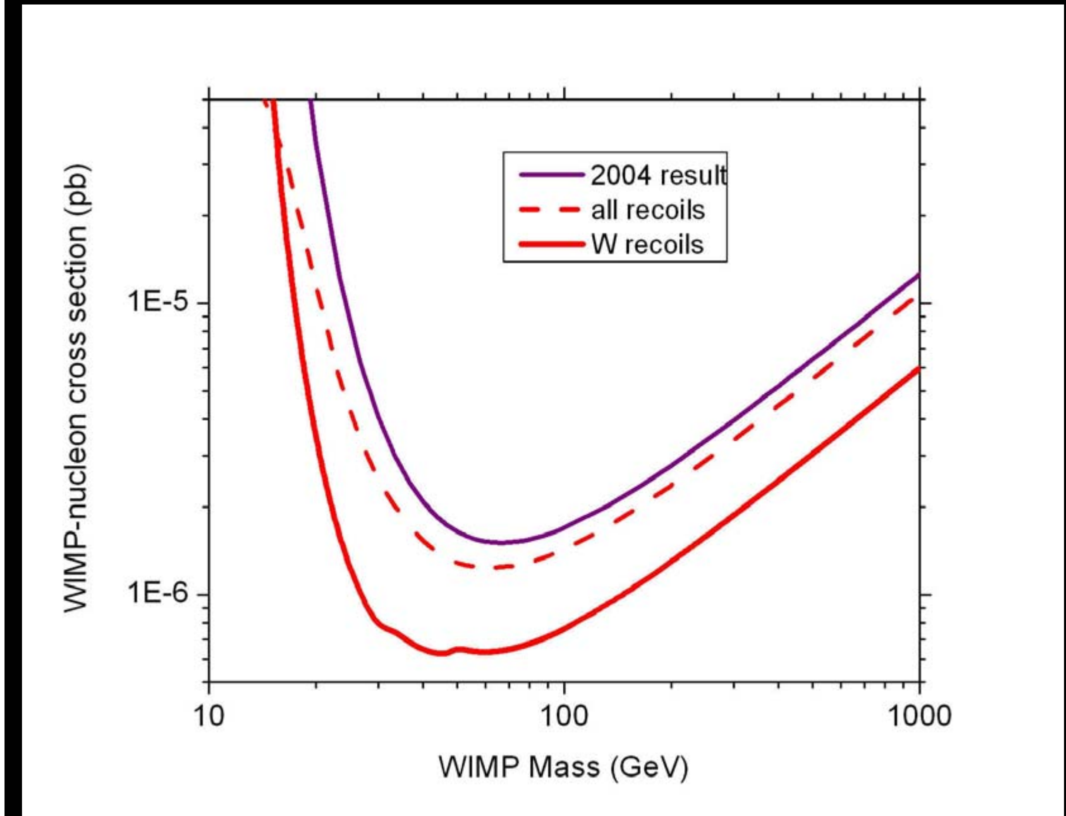


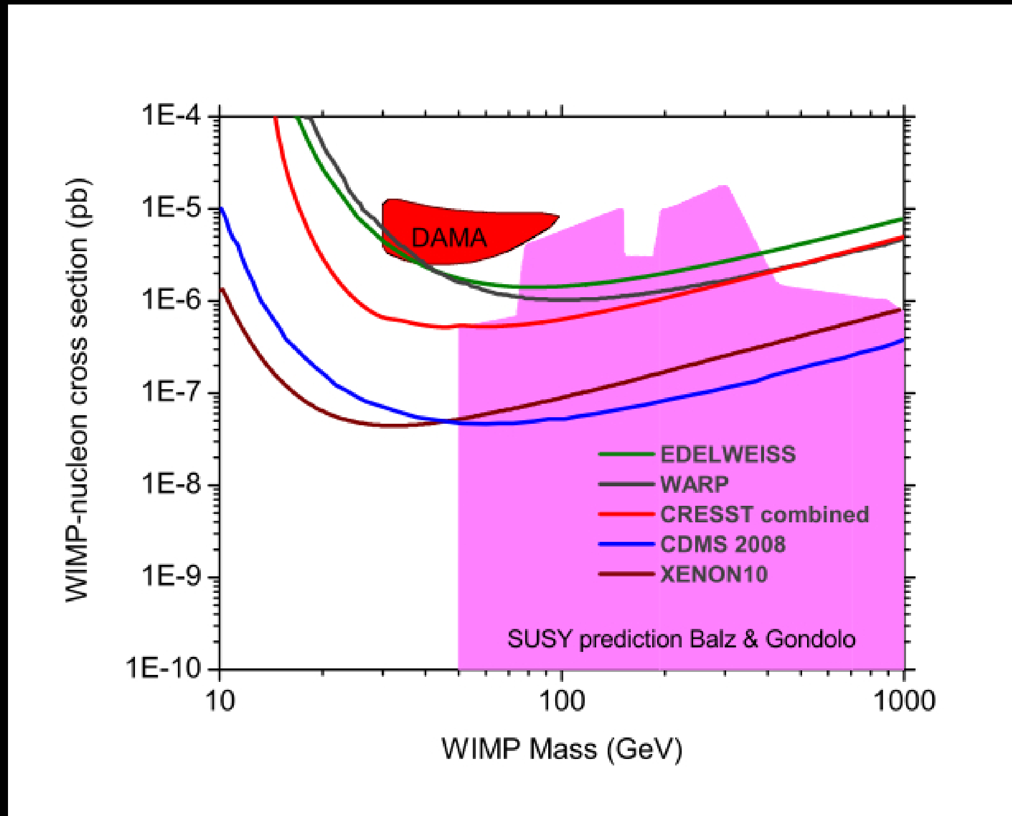


Origin of background ?

- Neutrons → hole in shielding now fixed
- α-emitters → detector clamps are now scintillating

Limit after Run30





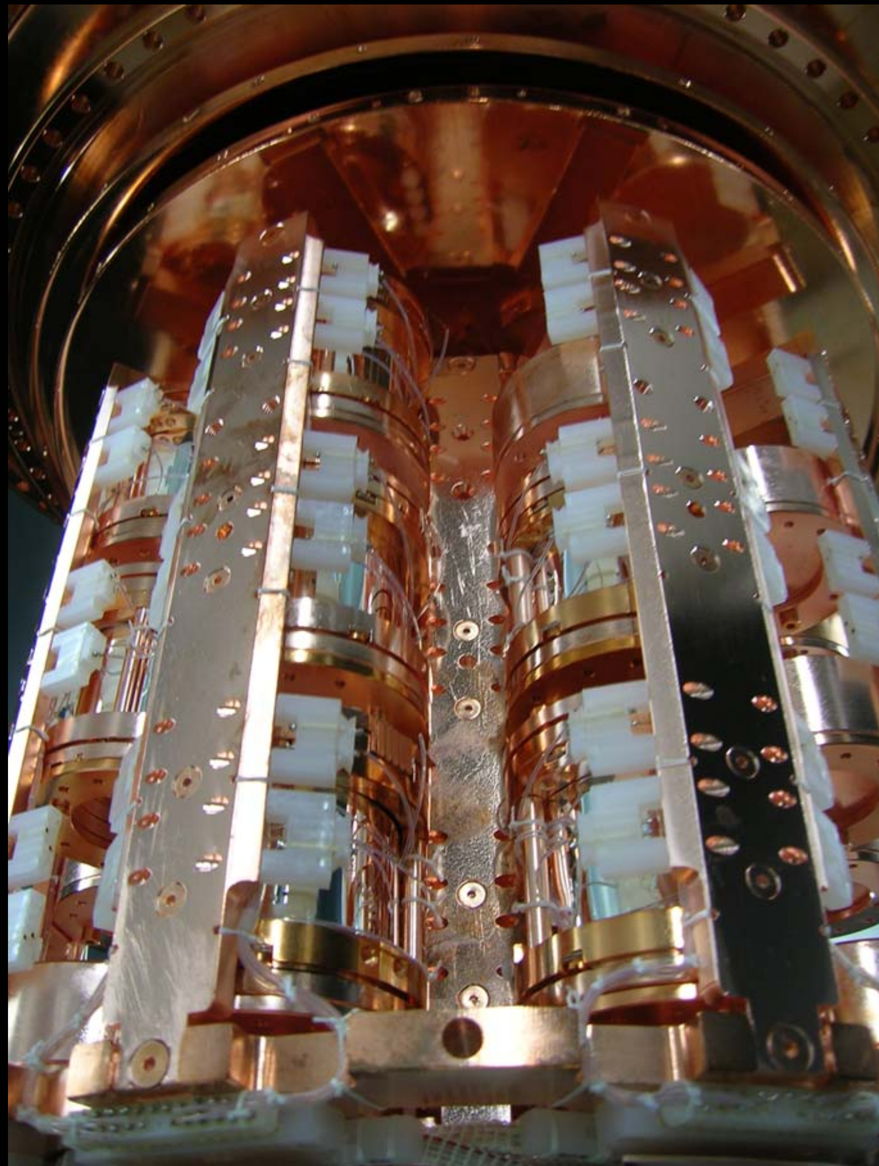
Limit for spin-independent WIMP-nucleon cross section of **~6 × 10^{-7}pb** obtained with 2 detector modules

Conclusions

- CRESST II has been upgraded to host 10kg of target material, i.e. 33 detector modules à 2 read out channels
- CRESST has successfully finished its commissioning run in 2007
- CRESST has the unique capability to identify the recoiling nucleus
- Increase of detector modules for „Physics Run“ possible up to ~10kg
- Goal: reach sensitivity better than 10^{-8} pb
- CRESST along with EDELWEISS and ROSEBUD are the basis for the future experiment EURECA

Run31- Physics Run - Status

- Cryostat closed
- 17 detector modules (~5 kg $CaWO_4$)
- Presently: cooling down of cryostat
- Detectors start reaching their operational temperature
- Promising test of new detector design: composite design
- Test of new target material: $ZnWO_4$



Today & Tomorrow

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

~1 event/kg/day

~0.1 now reached

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

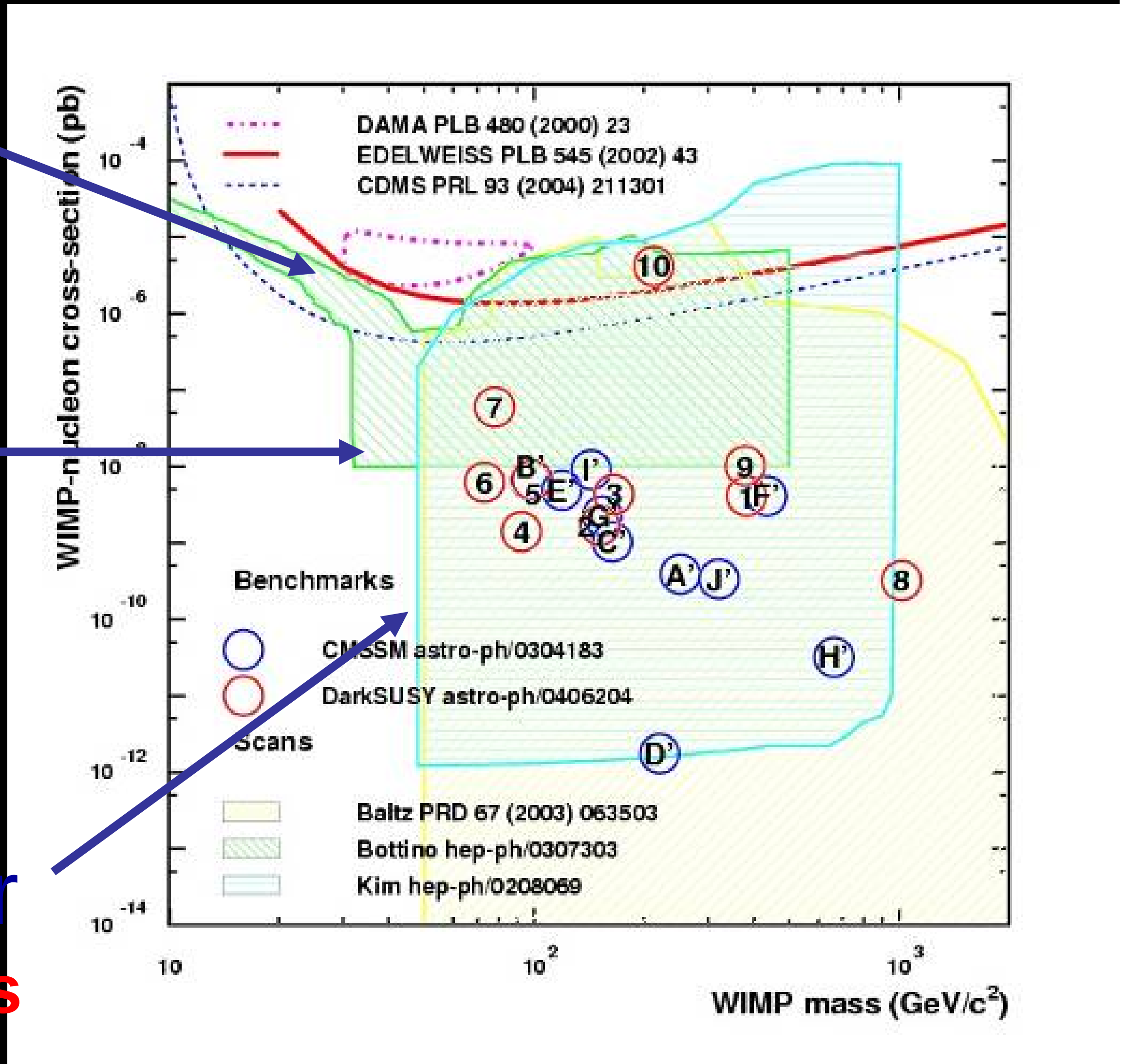
~3 events/kg/year

Aims of phase II experiments

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

~30 events/ton/year

Next generation requires further x100 improvement!



The European Future of Dark Matter Searches with Cryogenic Detectors

European Underground Rare Event Calorimeter Array

- Aim: explore scalar cross sections in the 10^{-9} to 10^{-10} pb region with a target mass of up to one tonne
- Started March 2005; based on EDELWEISS and
  CRESST, with additional groups joining
- Multitarget approach: Ge, $CaWO_4$, ...
- Mass: above 100 kg towards 1 ton
- CRESST-II, EDELWEISS-II and ROSEBUD are EURECA R&D
- Aligned with European 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

DNLP Dubna

France

CEA/DAPNIA Saclay

CEA/DRECAM Saclay

CNRS/CRTBT Grenoble

CNRS/CSNSM Orsay

CNRS/IPNL Lyon

CNRS/IAS Orsay

Spain

Zaragoza

CERN

Towards an Experiment on the Tonne Scale

- Neutron calibration facility in Garching presently for $CaWO_4$ at mK temperatures:
  - setup of a $^3He/^4He$ dilution refrigerator with SQUID read-out
  - experience in producing dedicated light-phonon detector for high count rates

- Investigation of other target materials ($ZnWO_4$, $PbWO_4$, LiF, ...)
- Development of composite detector design
- R&D on Neganov-Luke amplified light detector

Additionally:

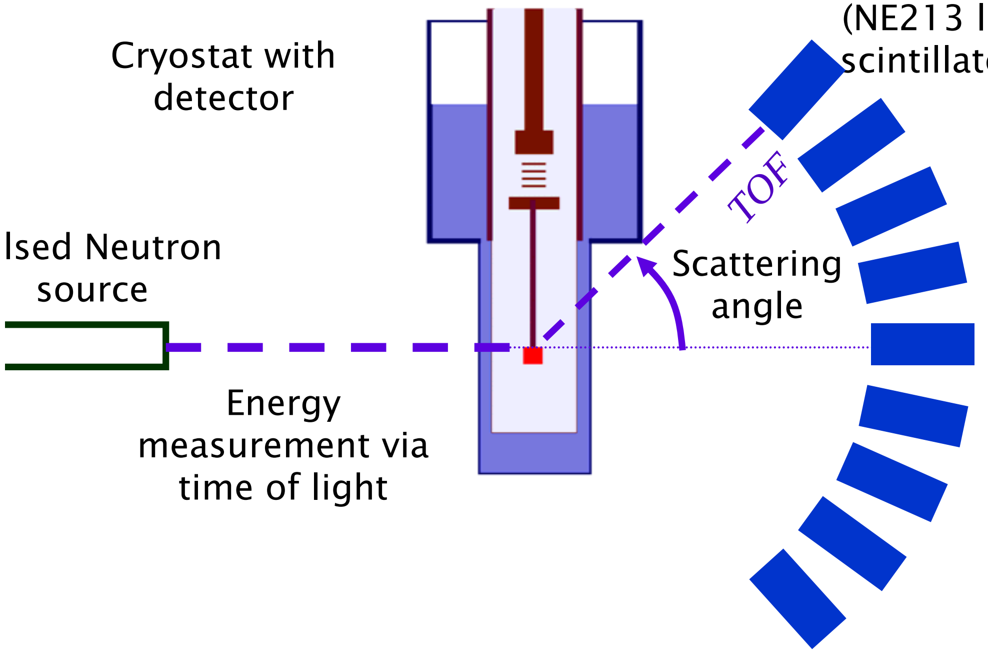
- First $CaWO_4$ single crystals grown in Garching
  - new Czochralski crystal furnace
  - crystals under investigation: γ-spectroscopy, scintillation properties, ...

- Construction of a new UGL (~100m^2, 15m.w.e.) able to host 2 test cryostats, adjacent to old UGL, 1 cryostat

add ons …

Neutron Calibration Facility

- Motivation: measurement of bulk quenching factors at operational temperature (mK) of the cryogenic detector



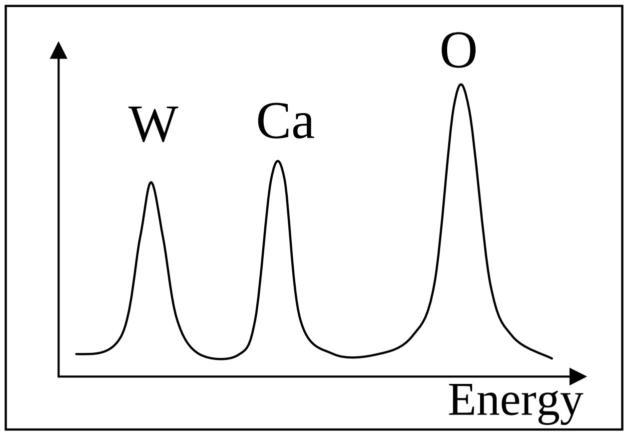
Neutron production: p(^{11}B,n)^{11}C
E_n = 11MeV

use mono-energetic source

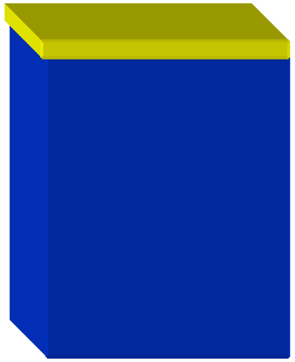
observe fixed scattering angle

measure energy of scattered neutrons

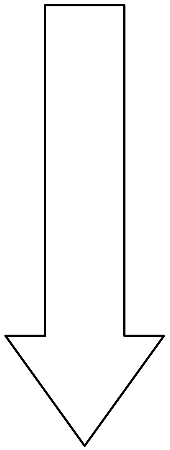
There is only one possible recoil energy for each nucleus



Classical & Composite Detector Design

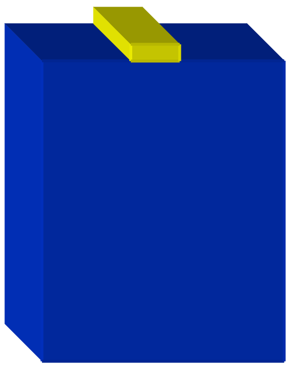


Classical design:



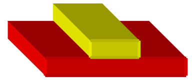
1. Thin film deposition directly onto absorber
2. Structurization:

> photolithographic process
> (reactive ion) etching
> additional sputtered or evaporated structures



All production steps can have negative effects on the TES and/or the absorber crystal

Composite design:



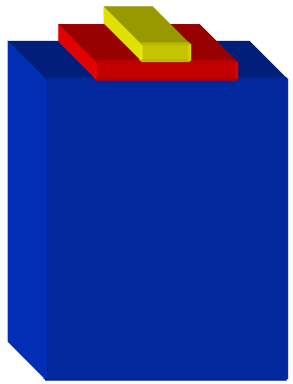
Production of (several) TES on individual substrate(s):
„free“ choice of substrate
„free“ choice of TES (W,Ir/Au, ...)

Separation of processes

Individual production, analysis and treatment of the main absorber

Assembling:

> Attach TES substrate to main absorber by glueing



Identifying Decay Times