Searching for Dark Matter with CRESST (EURECA)

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Cryogenic Phonon – Scintillation Detectors

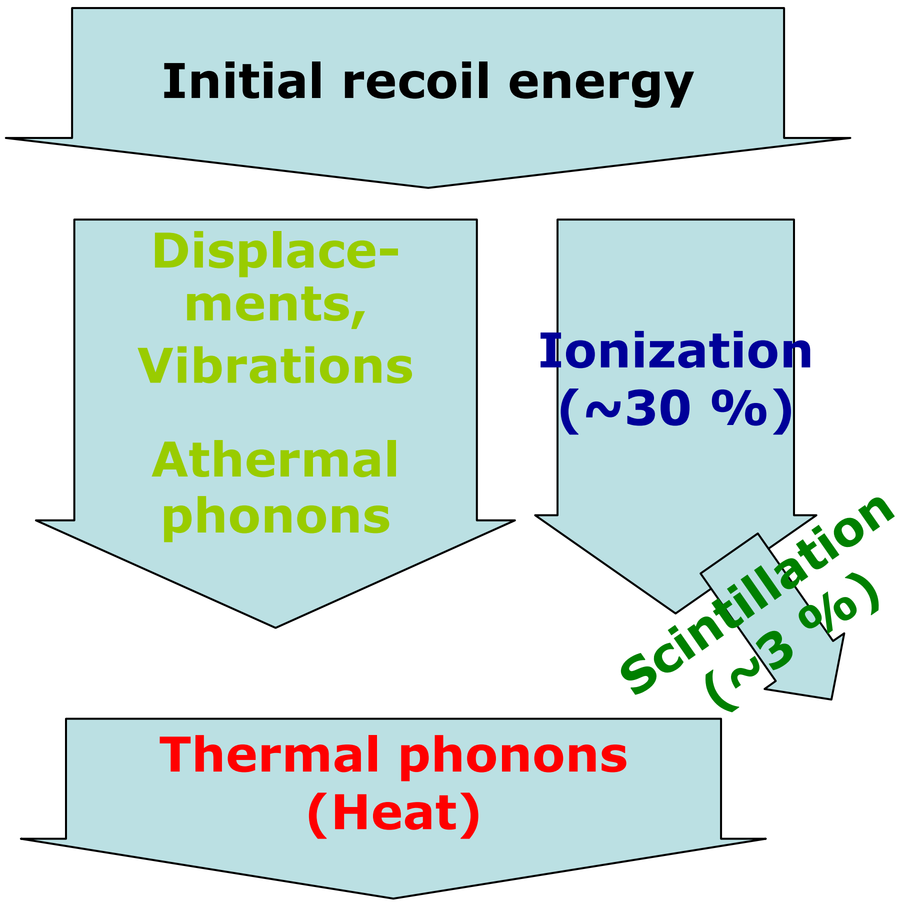
The CRESST setup in Gran Sasso

CRESST – recent results

Migration towards EURECA

Cryogenic Techniques

Combination of phonon measurement with measurement of ionization or scintillation

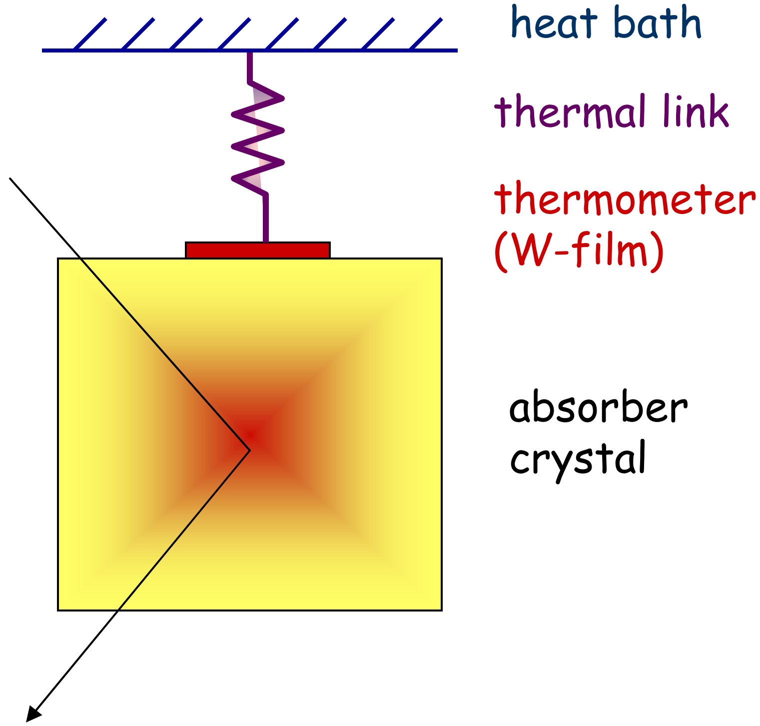


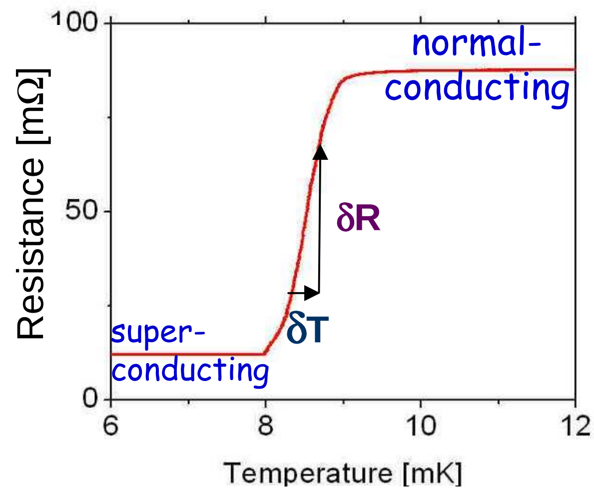
Phonon: most precise total energy measurement

Ionization / Scintillation: yield depends on recoiling particle

Nuclear / electron recoil discrimination.

Detectors used in CRESST

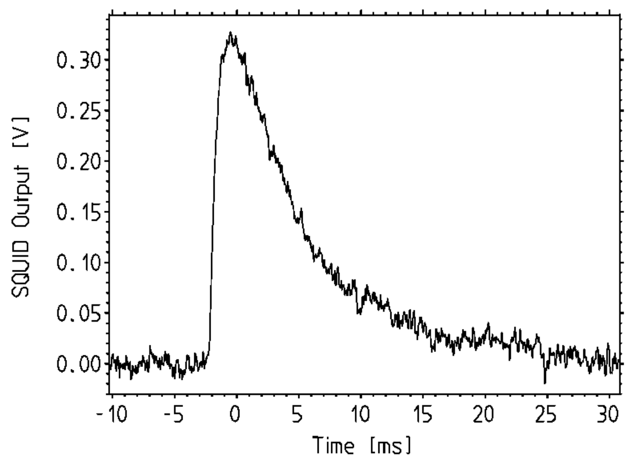




Width of transition: ~1mK
Signals: few μ K
Stablity: ~ μ K

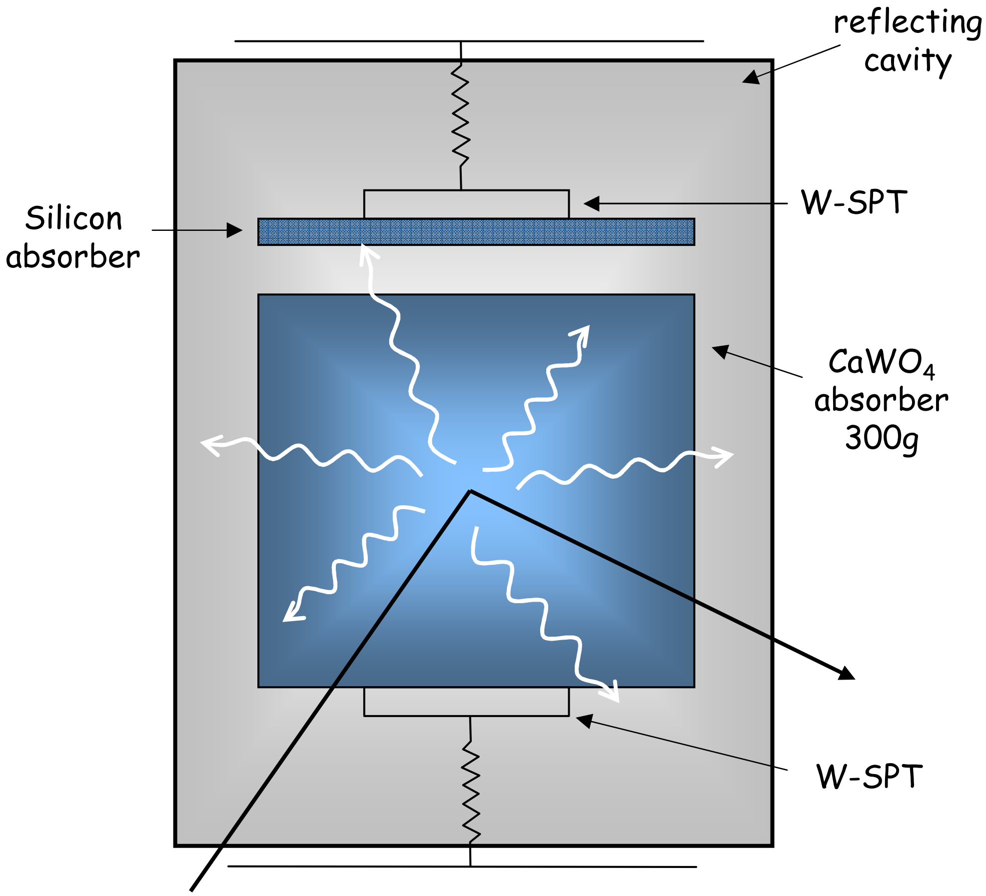
Particle interaction in absorber creates a temperature rise in thermometer which is proportional to energy deposit in absorber

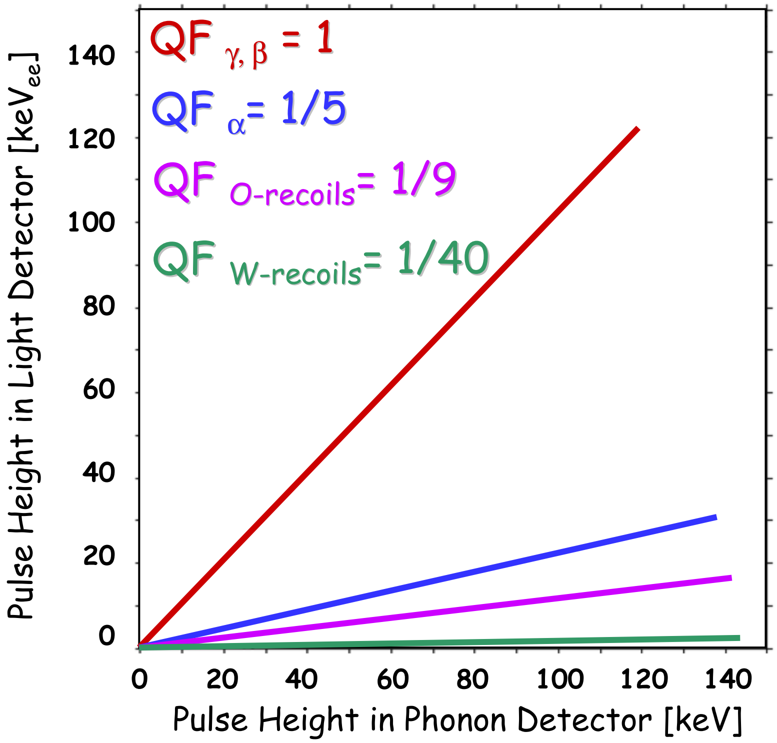
Signal pulse (~6keV)



Phonon – Scintillation (CRESST)

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



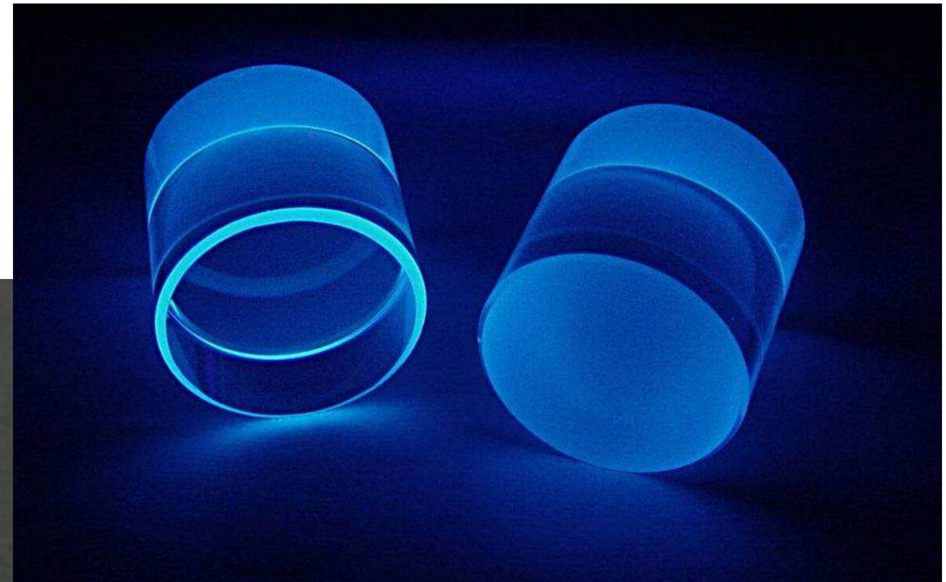


EURECA

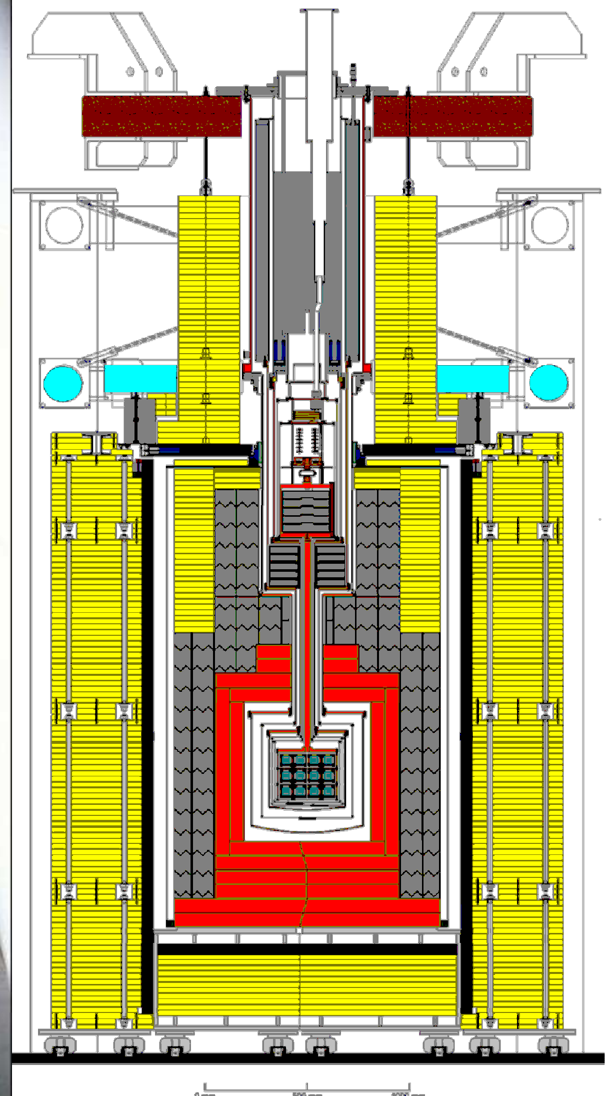
CRESST – Detector Module

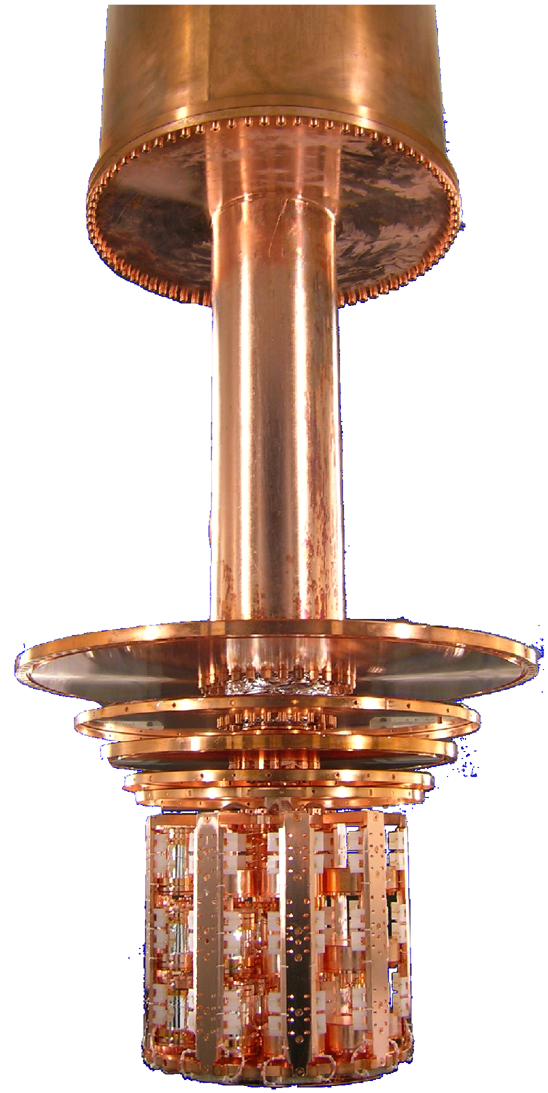
$CaWO_4$: h = 40mm, ∅ = 40mm

m = 300g

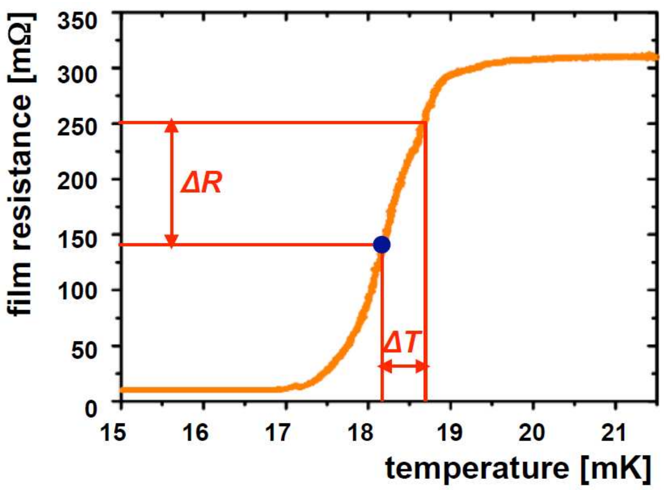


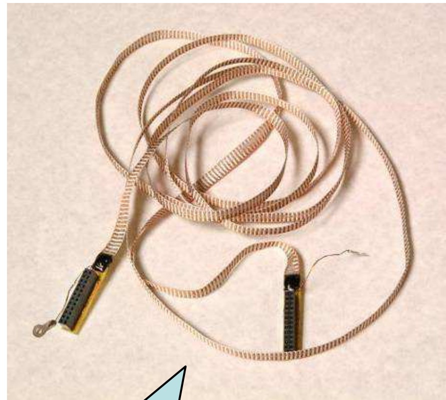
CRESST in Gran Sasso

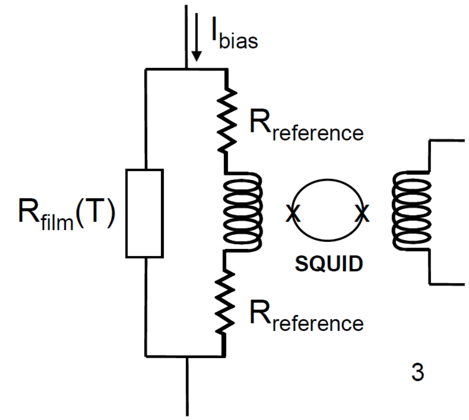




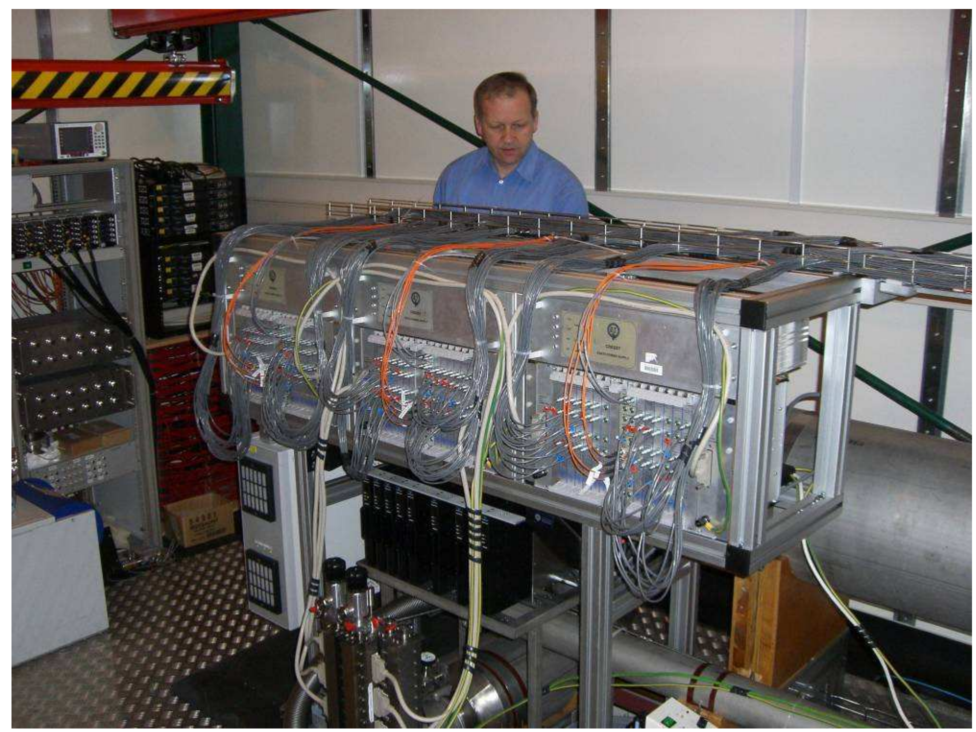
66-channel SQUID Readout System







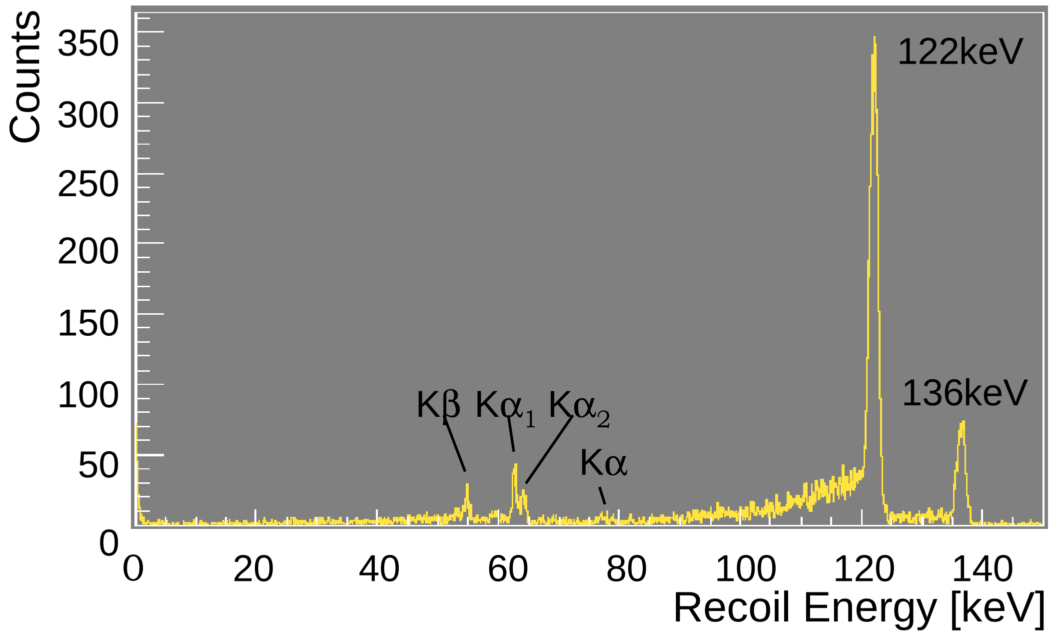
Specially made cryo-cables



Electronics allows full remote control of detector operation → optimization of detector running parameters reduced threshold

Detector Capability

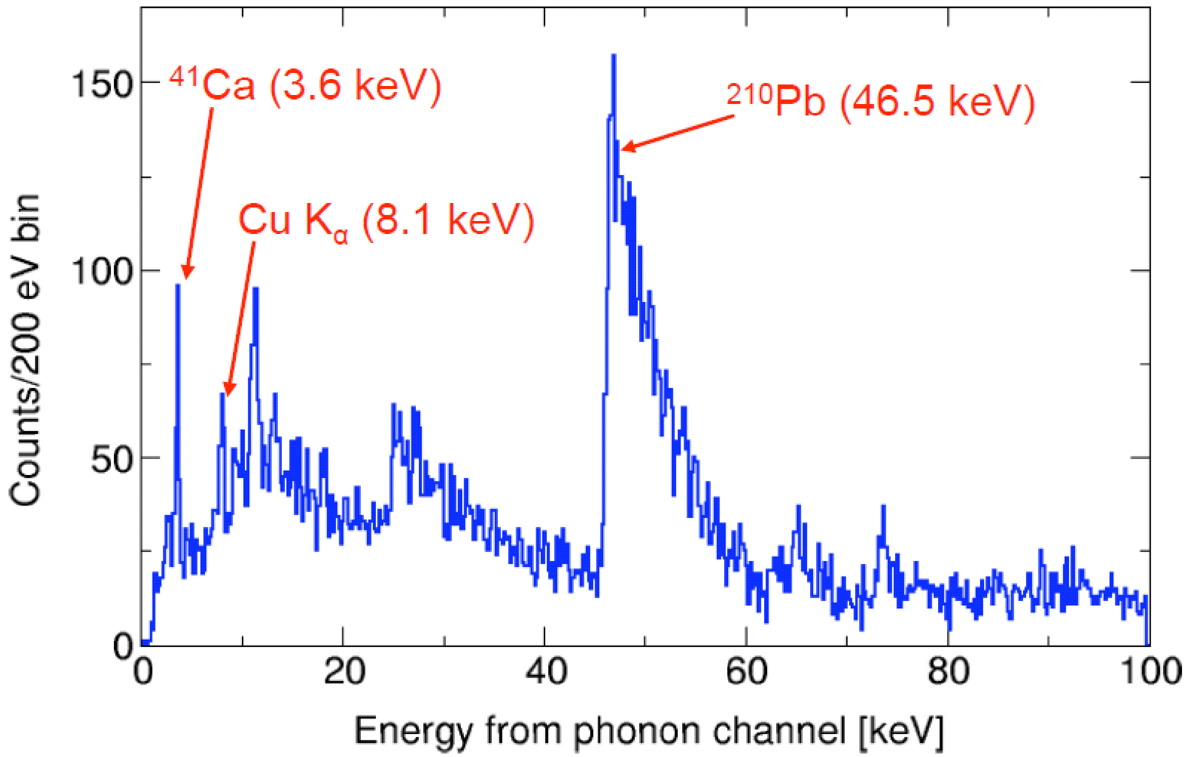
Example of a ^{57}Co calibration:



Example of a Background Spectrum:

Resolution at low energy ~ 300 eV (FWHM)

Threshold ~ 1 keV

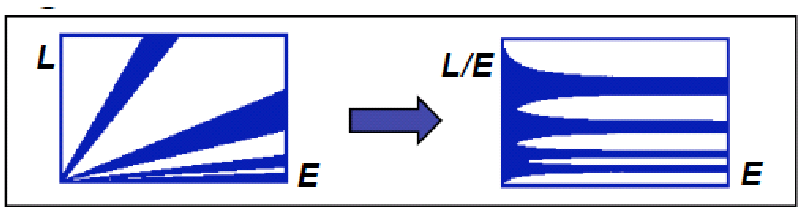


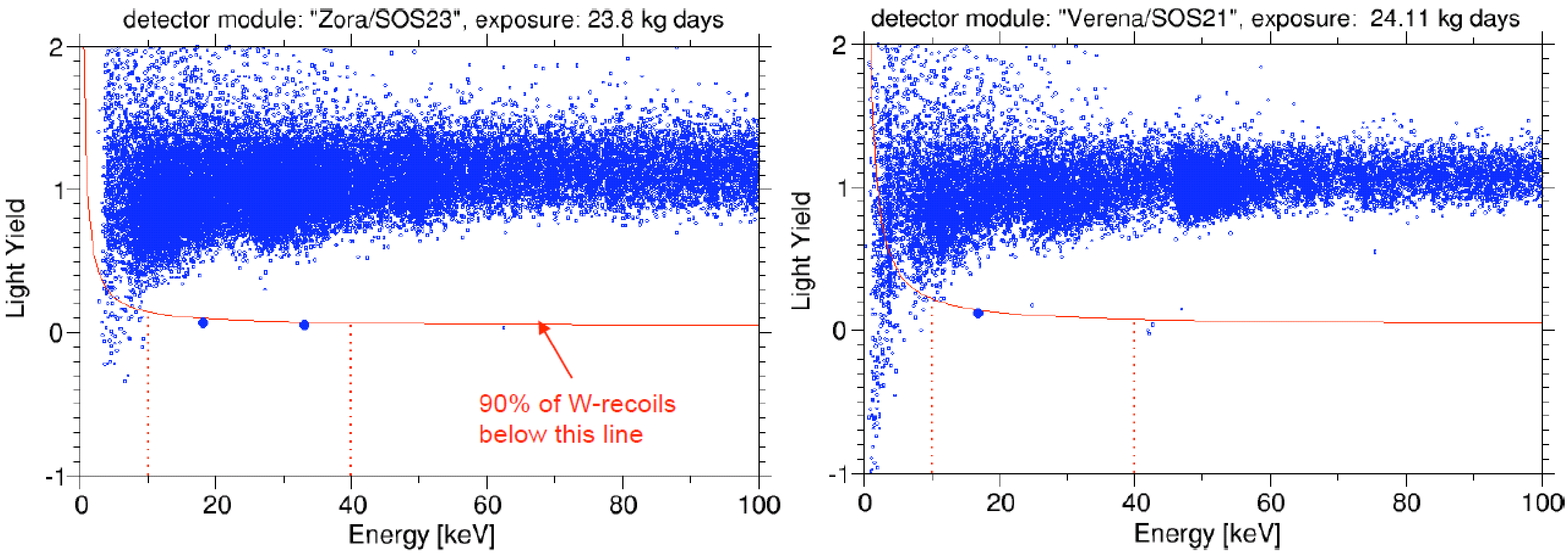
Results from extended commissioning run (2007)

Two modules running

Total exposure 48 kg.days

Very stable operation possible





β/γ background rejection works very well

3 tungsten recoil candidates in 10 – 40 keV acceptance region

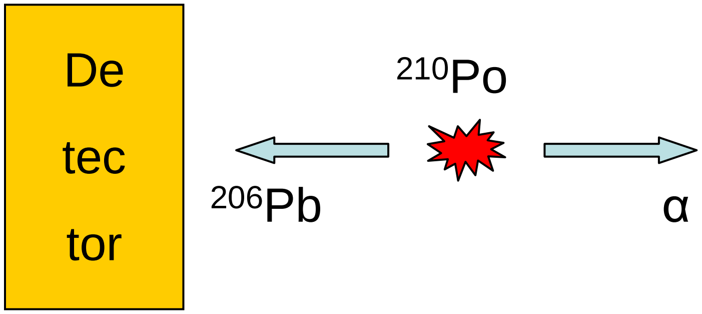
Possible Causes for Nuclear Recoil Candidates

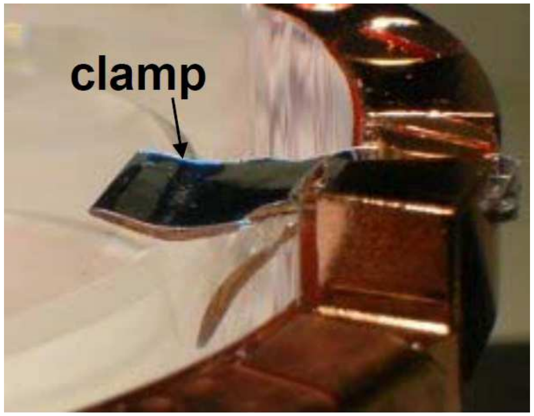
1. Neutrons

   Shielding improved

2. Recoil nuclei from surface α-decay

   can be vetoed with scintillating foil, however, weak point: clamps, holding crystal were not completely covered with scintillator

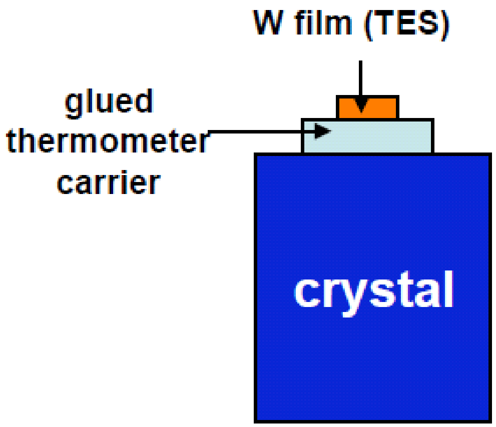




Strategies for 2008 run:

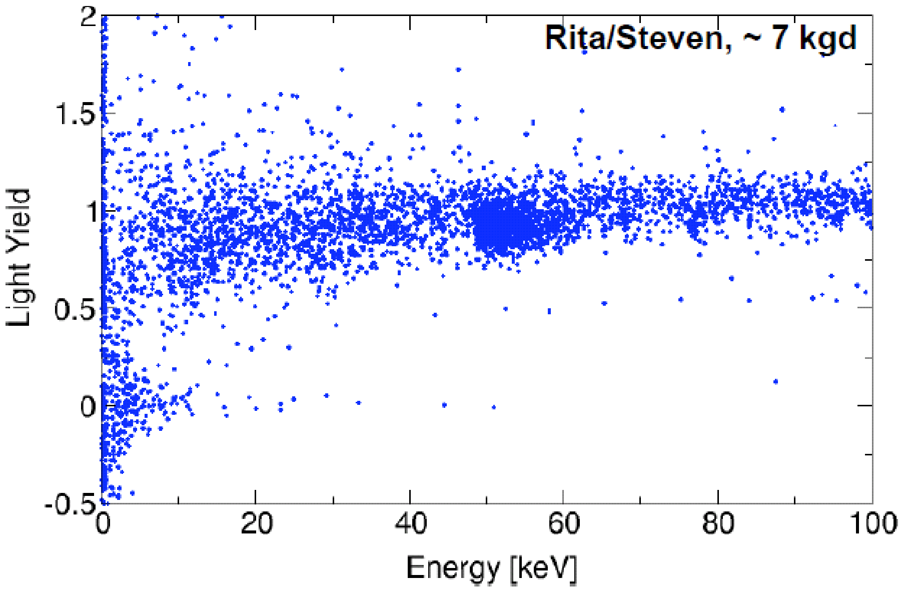
Cover clamps with scintillating epoxy.

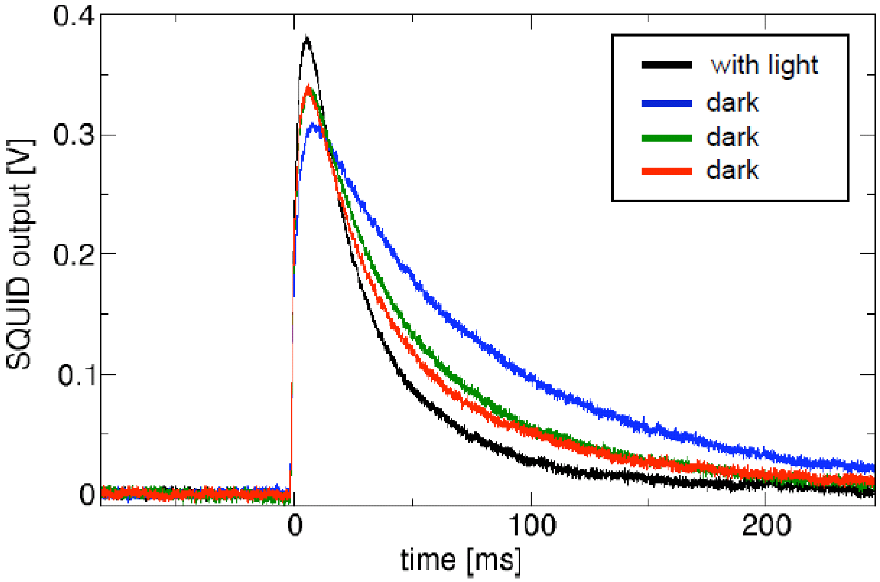
Implement new technique with glued thermometers for improved scintillation yield.



Background Run: Aug – Dec 2008

9 modules operated; but saw varying number of no-light events





Properties of no-light events:

Many (not all) show different pulse shape

Rate decreases with time

Lower rate with pure metal clamps

➔ Detector effect: too hard clamping (cracks, particle-like pulses), stress relaxation (in scintillating plastic, longer pulses)

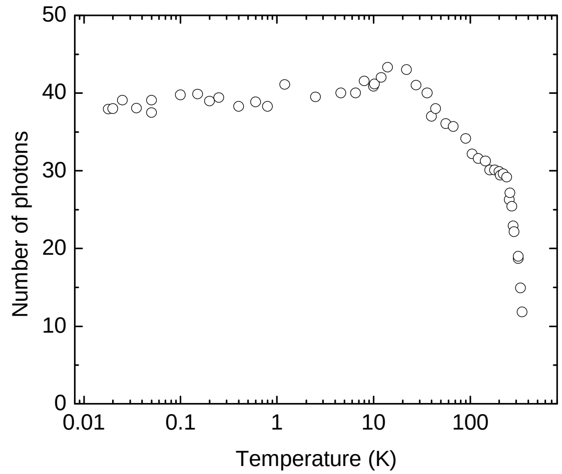
Measures taken and Status 2009

- All crystals equipped with **new clamps**
  - thinner material → **softer**
  - material: only bronze, **no plastic coverage**
  - **non-scintillating**: need for even higher cleanliness during detector production and mounting to avoid nuclear recoil background

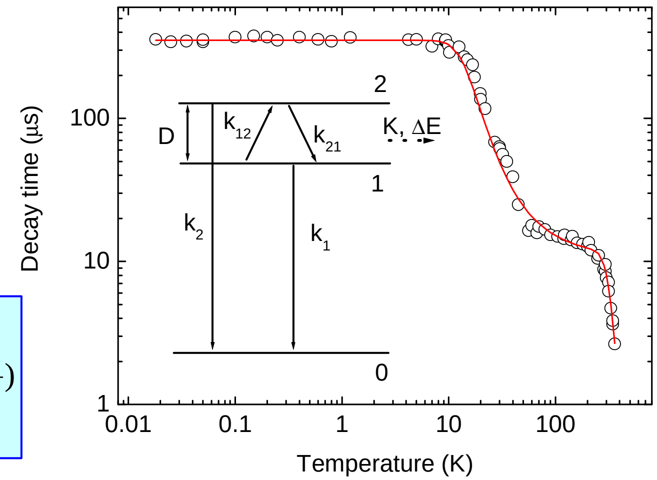
- New run successfully started in June 2009
  - 9 detector modules operational
  - Cryostat still cooling, more modules may come into transition
  - Calibration run has been performed
  - Background run ongoing
  - Situation with no-light events unclear (need more exposure)

Scintillating Targets for Rare Event Searches

$CaWO_4$ – (primary CRESST material): good first choice



$$\frac{1}{\tau} = \frac{k_1 + k_2 \exp(-\frac{D}{kT})}{1+\exp(-\frac{D}{kT})} + K\exp(-\frac{\Delta E}{kT})$$

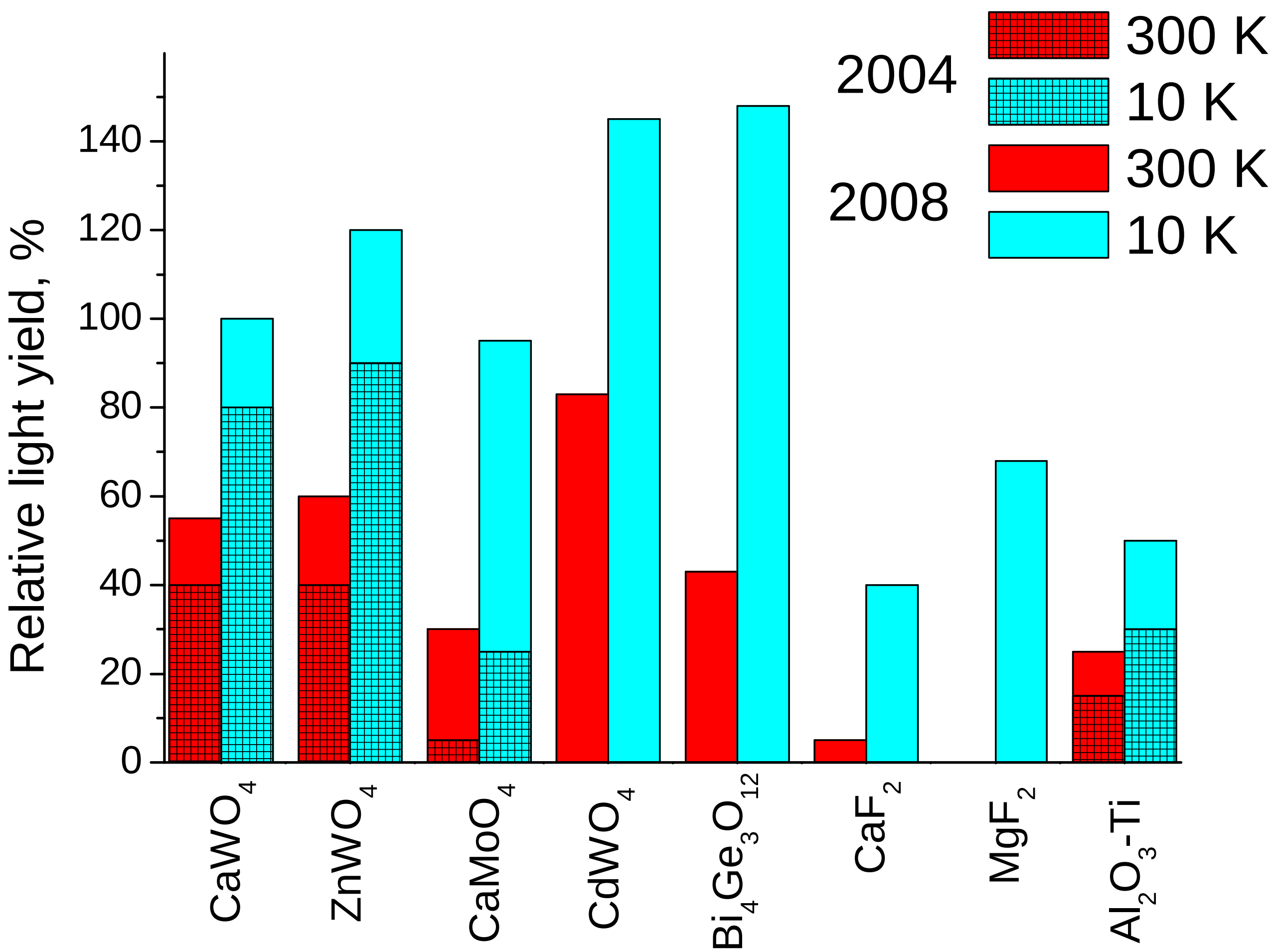


$ZnWO_4$ – (additional target): attraction: lower intrinsic radioactivity, potentially higher light yield

$CaMoO_4$– complementary target with ‘better’ quenching factor for nuclear recoils

Al_2O_3-Ti – bolometer in EDELWEISS setup

Comparison of light yields



Light Yield of a few targets is already satisfactory, further improvement possible *(doping, tuning of growth condition, post-treatment)*

The EURECA Collaboration

CRESST, EDELWEISS, ROSEBUD + CERN, others

United Kingdom

Oxford (H Kraus, coordinator)

Germany

MPI für Physik, Munich

Technische Universität München

Universität Tübingen

Universität Karlsruhe

Forschungszentrum Karlsruhe

International

JINR Dubna

CERN

France

CEA/IRFU Saclay

CEA/IRAMIS Saclay

CNRS/Neel Grenoble

CNRS/CSNSM Orsay

CNRS/IPNL Lyon

CNRS/IAS Orsay

Spain

Zaragoza

Ukraine

Kiev

EURECA in LSM

Timeline:

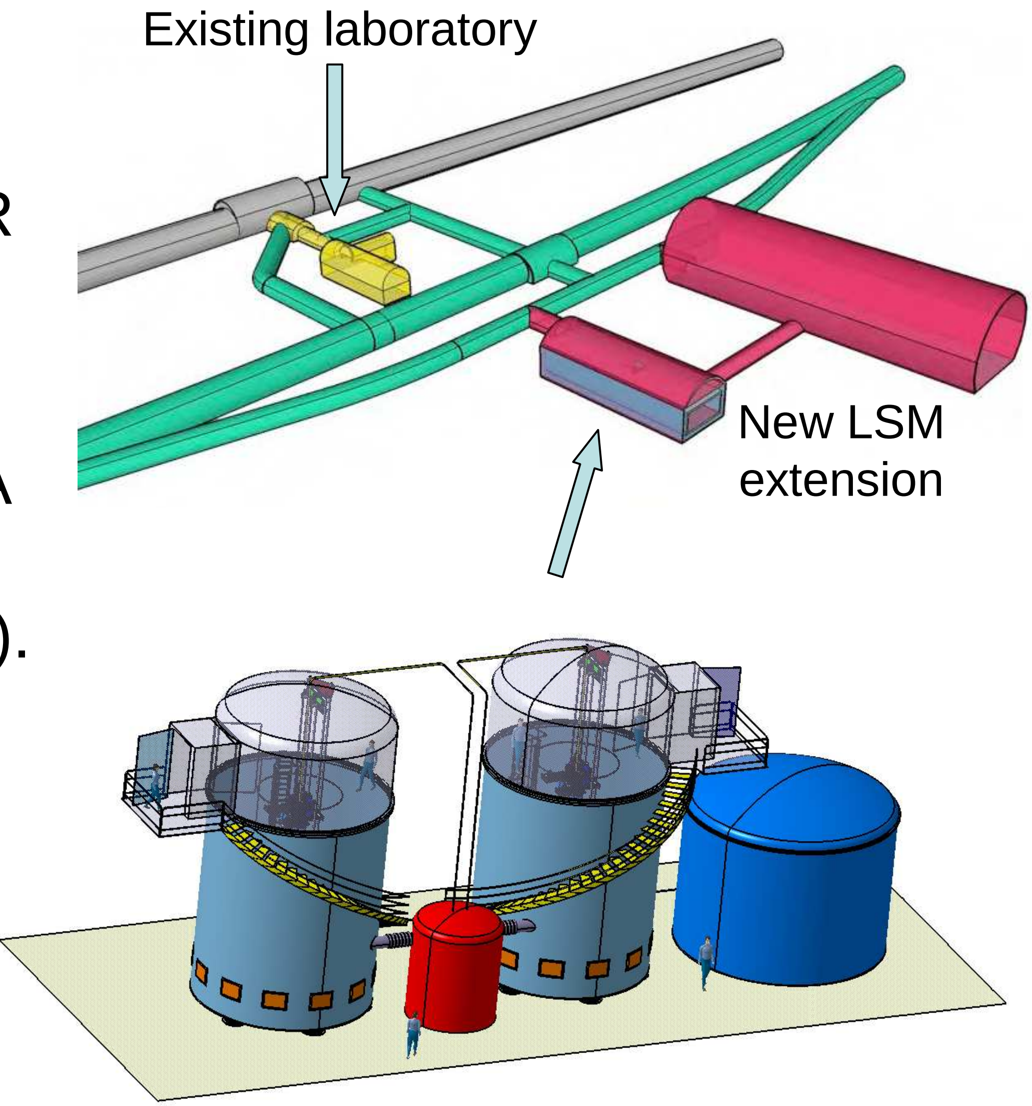
2009/10: Design Study → TDR

2011/12: Digging out of LSM extension begins. In parallel, begin construction of EURECA components away from LSM. Aim for ~100kg stage (10^{-9} pb).

2014: LSM extension ready to receive EURECA.

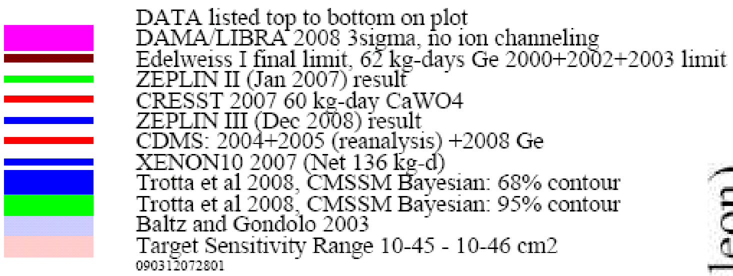
2015: Begin data taking and in parallel improve and upgrade.

2018: One tonne target installed.



Possible EURECA Facility Layout

Science Results and Aims



~1 evt/kg/day

~3 evt/kg/year

Aim of ton-scale experiments

~30 evt/ton/year