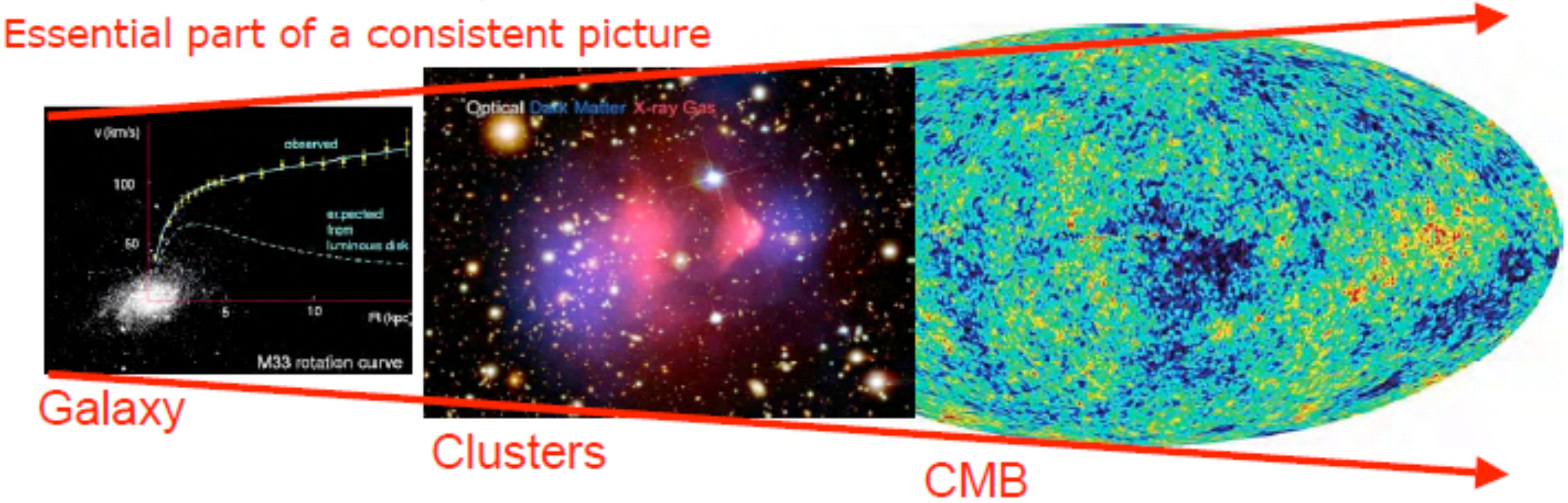
Direct Dark Matter Search with EURECA

APERA Technology Forum 2010

Schloss Nymphenburg

Motivation for Dark Matter Detection

- Cold Dark Matter present at all scales in the Universe...



Present picture of the universe:

Search for a well motivated Dark Matter candidate:

WIMP = Weakly Interacting Massive Particle

Detection principle:

Direct detection via nuclear recoil measurement

Where to go ...

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

~1 event/kg/day

~ 0.1 now reached

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

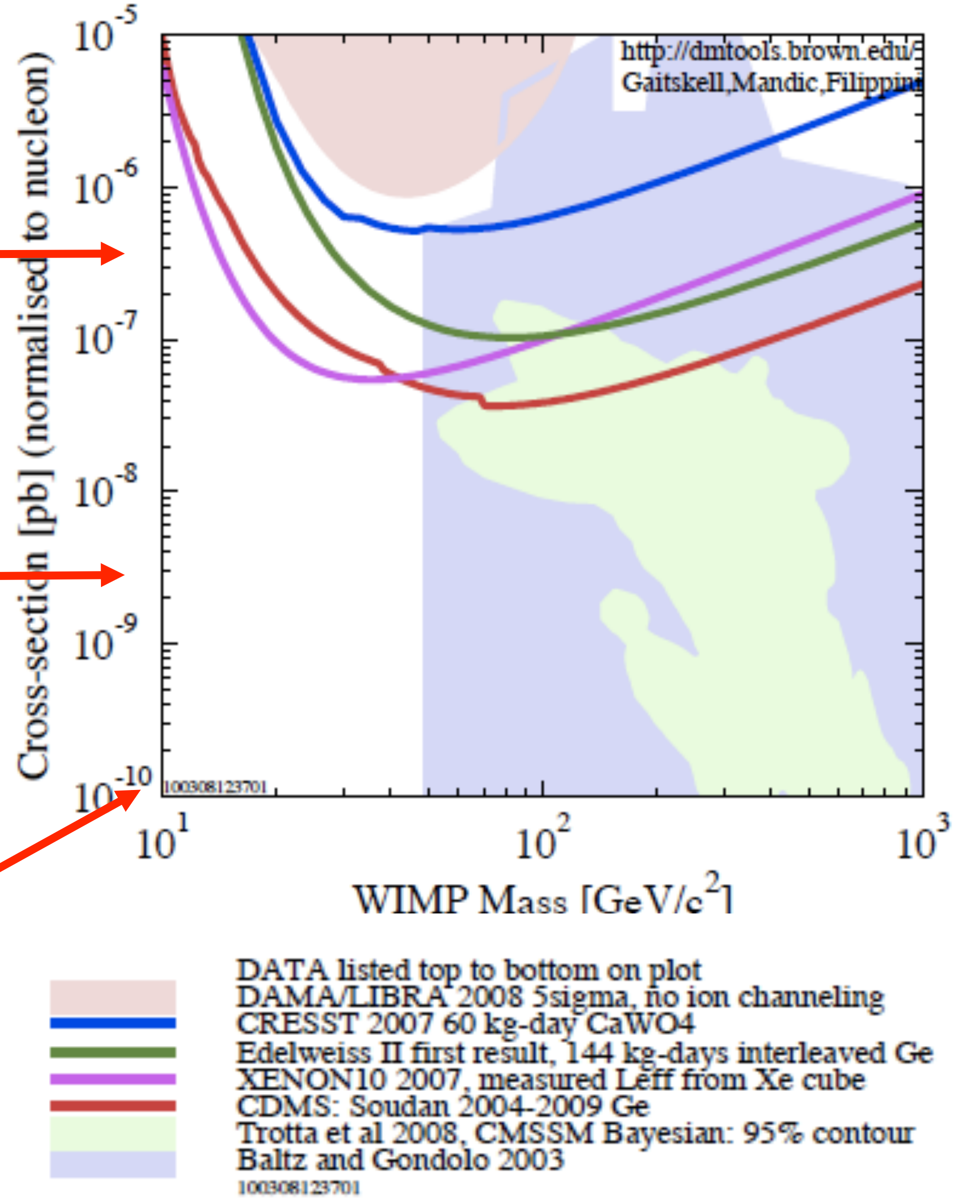
~1 event/kg/year

Present phase II experiments

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

~10 events/ton/year

Next generation requires further x100 improvement!



EURECA

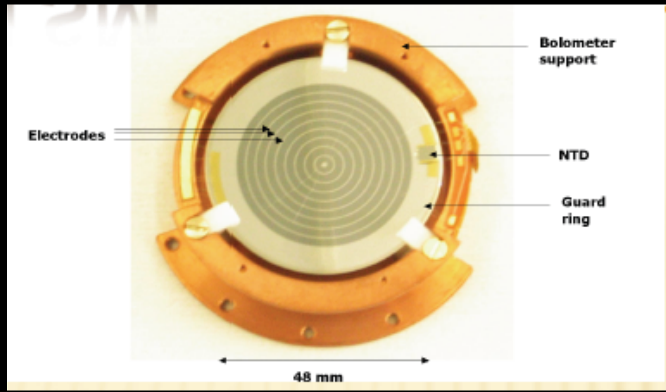
European Underground Rare Event Calorimeter Array

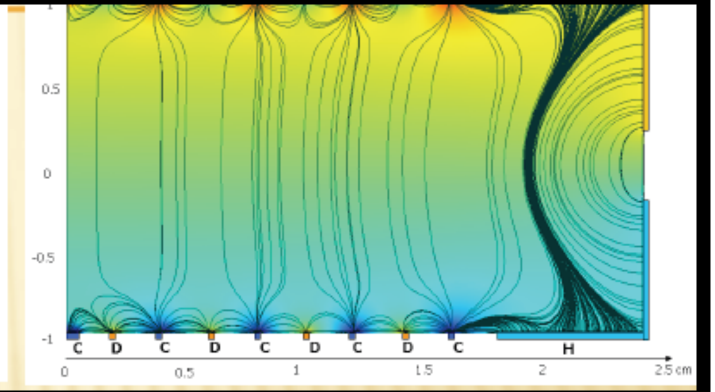
- Direct detection of Dark Matter via nuclear recoil measurements
- European Future of Dark Matter Searches with Low-temperature detectors (~10mK)
- Started March 2005; based initially on **CRESST**, **EDELWEISS** and **ROSEBUD**, with additional groups joining
- Target materials: Ge, $CaWO_4$, $ZnWO_4$ etc. (check A^2 dependence)
- Mass: above 100 kg towards 1 ton
- CRESST-II and EDELWEISS-II are EURECA preparation
- Aligned with European astroparticle roadmap recommendations: multiple targets and multiple techniques

EURECA Combining Detection Techniques

Phonon - Charge (EDELWEISS)

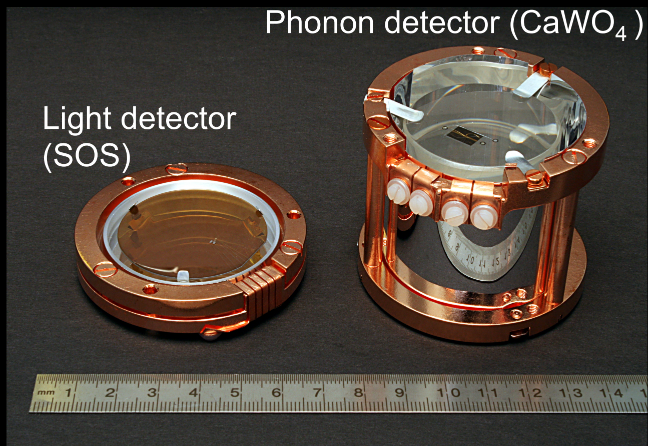
Ge detectors with surface event rejection (interdigit)

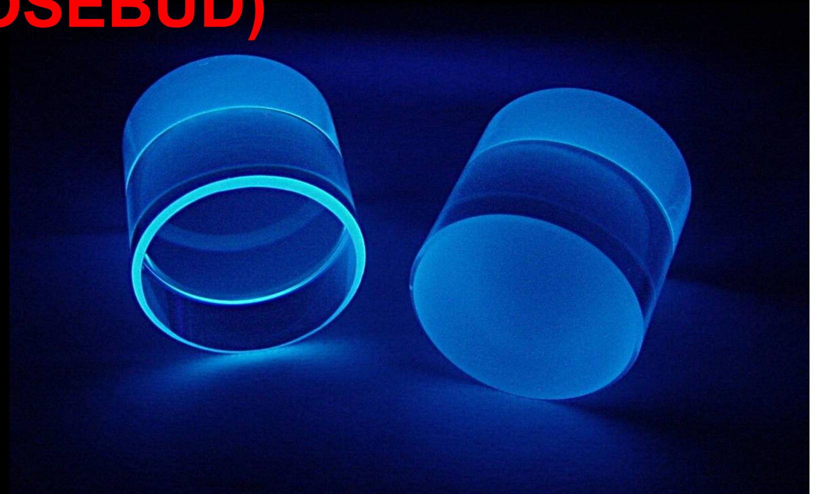




Phonon - Scintillation (CRESST, ROSEBUD)

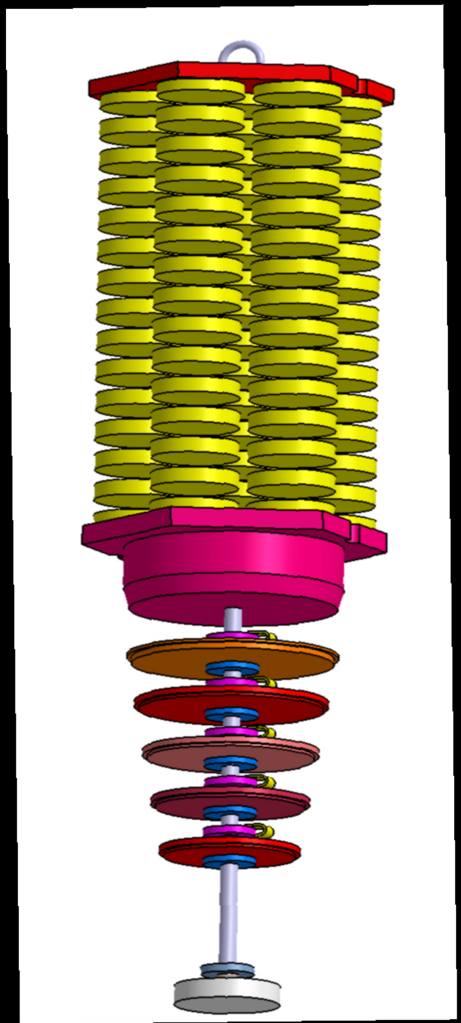
Event by event discrimination in scintillating $CaWO_4$ detectors

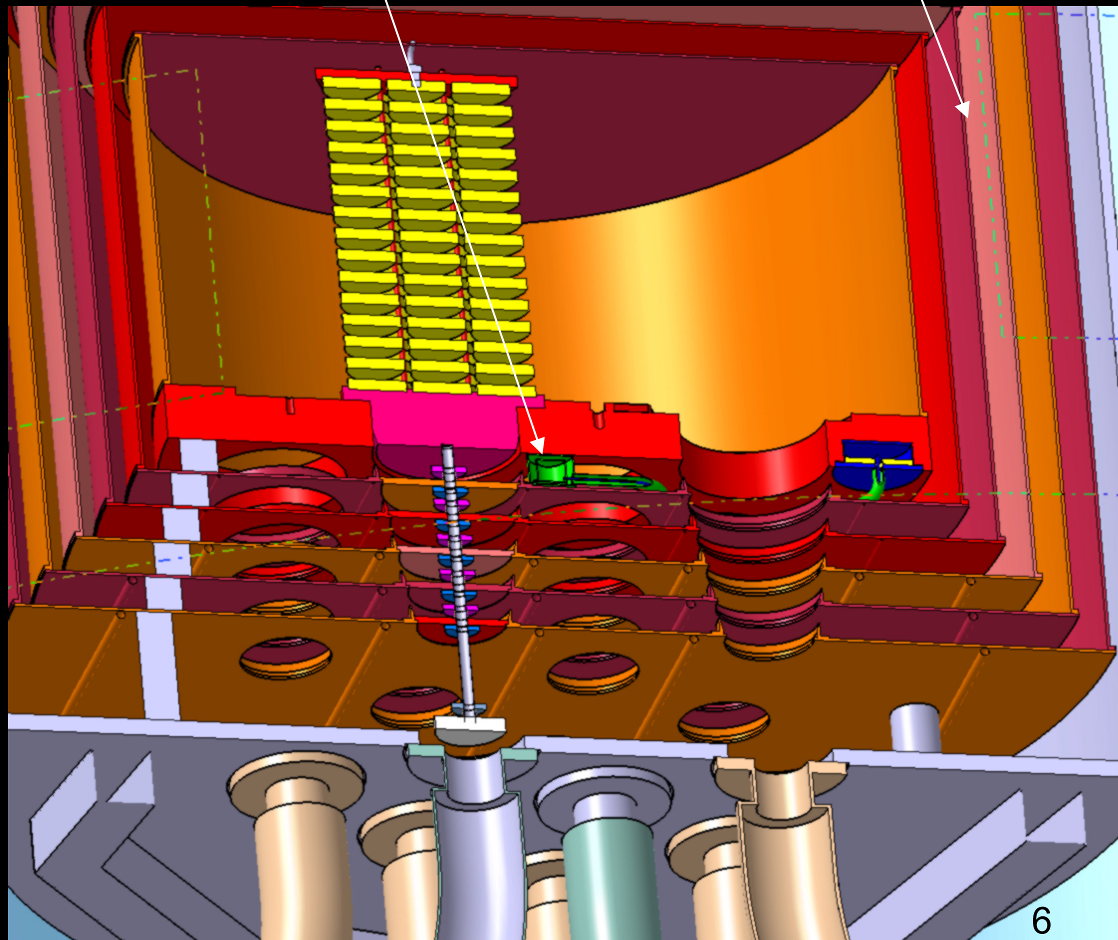




Phonon-scintillation technique allows flexibility in choice of target materials: $ZnWO_4$, $CaMoO_4$, BGO, Al_2O_3, NaI ...

Preliminary Cryostat Design





Present Design of EURECA at LSM Extension

Planned extension

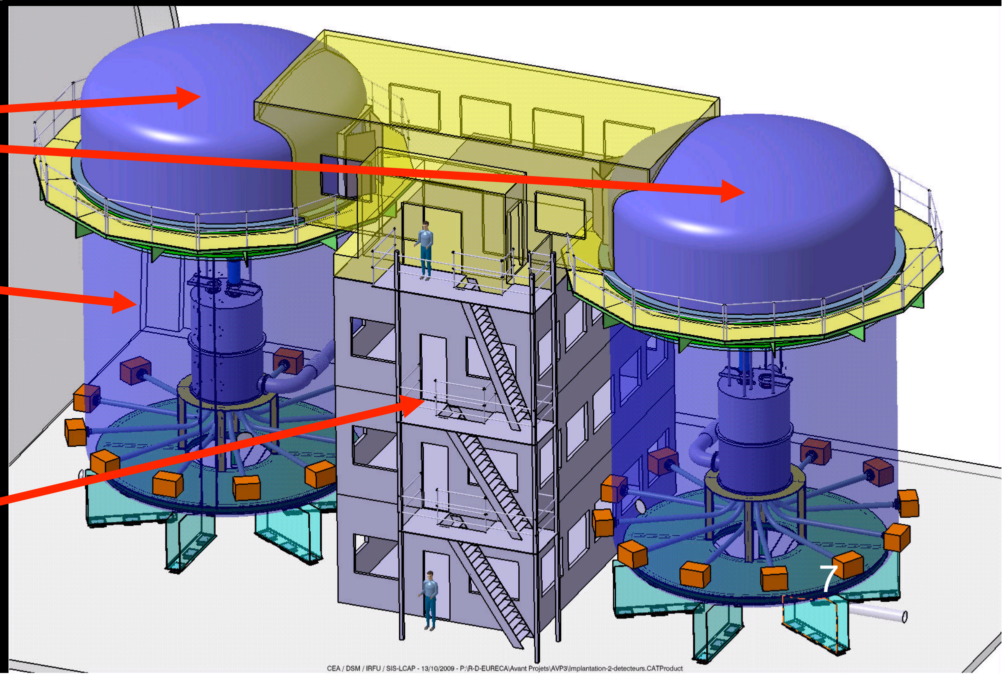
Existing LSM laboratory

2 individual cryostats

Shielding: ~3m of water

Instrumented water (PMTs) acting as active muon-veto

Cleanrooms and infrastructure



PMT Specifications

- > 100 photo sensors for the active muon veto (water Cherenkov detector) of the EURECA detector
- 5“ – 8“ diameter PMTs exhibiting high quantum efficiency in the ultra-violet
- Final number of PMTs depends on results of design study

PMT Requirements

Design phase (2010-2011):

PMTs from industry with best achievable quantum efficiency in the ultra-violet and cost-effective auxiliary electronics

Prototyping phase (2012-2013, depending on ULISSE timescale):

~10 PMTs and auxiliary electronics for design confirmation -> decision on number of PMTs needed

Construction phase (2013- ...):

Need for full number of PMTs (100 - 200) and auxiliary electronics

R&D of PMTs and Electronics for EURECA

- PMTs for water-Cherenkov using „standard technology“ (i.e. 8“ PMTs)
- **PMT issues:**

  choice of PMTs in terms of intrinsic purity, encapsulation of PMTs, no real R&D needed
- **Auxiliary electronics issues:**

  ➡ R&D might be necessary e.g. for development of low-noise and low-power and high resolution analogue-to-optical coupling at T=100K

  ➡ Conversion of preamplified signals analogue-to-optical via LEDs

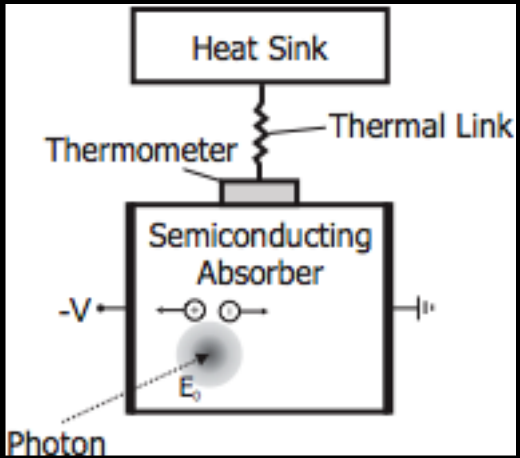
  ➡ Extraction of low-temperature detector signals via 10m of optical fibre through water tank to outside electronics for digitisation and further processing

Conclusions

- EURECA is next generation direct Dark Matter search experiment based on low-temperature detectors
- Needs in terms of PMTs rather modest >100PMTs for water Cherenkov detector as muon veto
- No „real“ R&D necessary for PMTs
- For auxiliary electronics „partial“ R&D required

Additional Slides

Neganov-Luke Amplification for Light Detection



Neganov-Luke amplification principle:

• Incident photons create electron-hole pairs in semiconductor crystal

• Drift of charge carriers in an external electrical field generates additional phonons

➔ **Amplification of phonon signal:**

$$E_{tot} = \left(1 + \frac{eU}{\varepsilon}\right) E_0$$

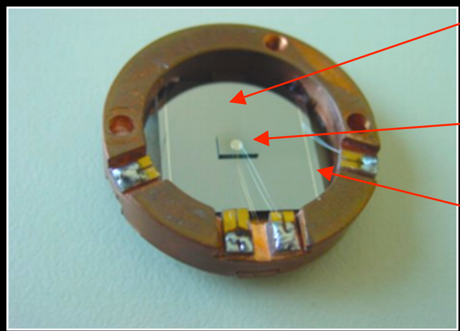
Detector design:

• Avoid diffusion of metals (e.g. gold) into semiconductor lattice

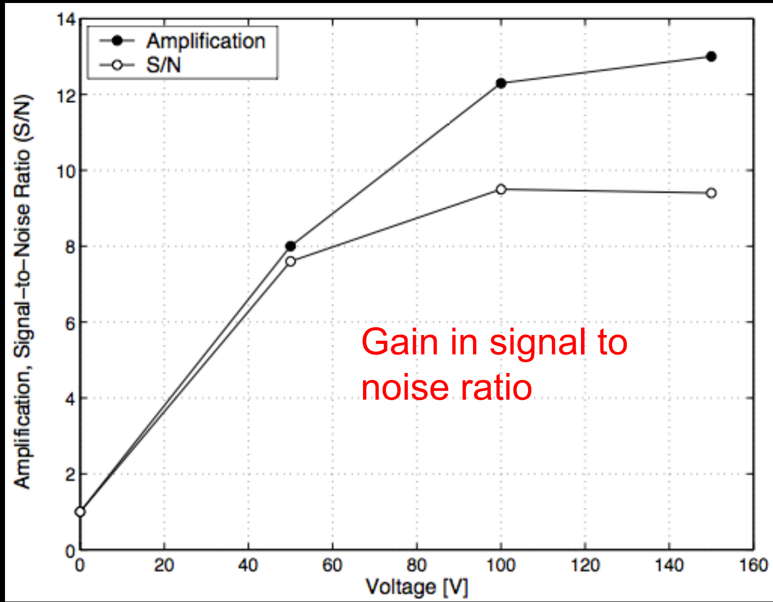
➔ Composite detector design (CDD)

• Iridium-gold transition edge sensor (TES) with tunable T_c (~20-60mK)

• Main photon absorber: silicon with evaporated aluminum electrodes



Ultrasensitive Light-Detectors

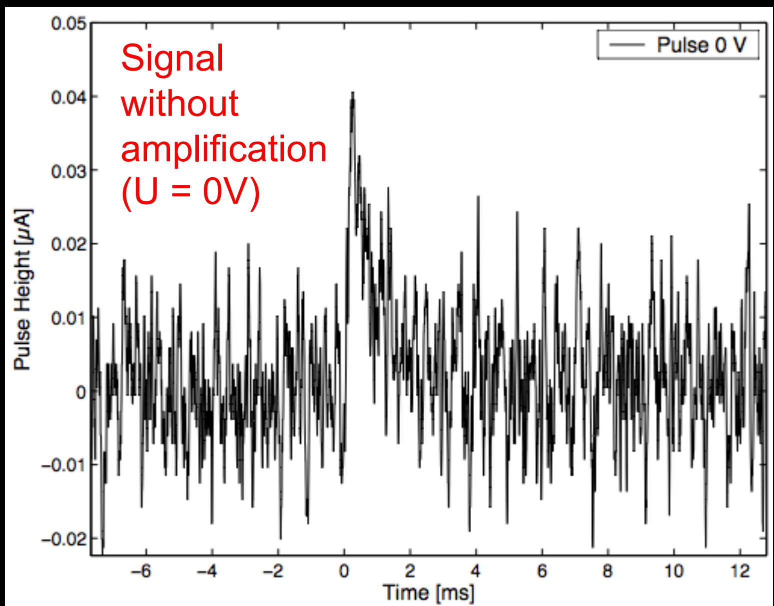


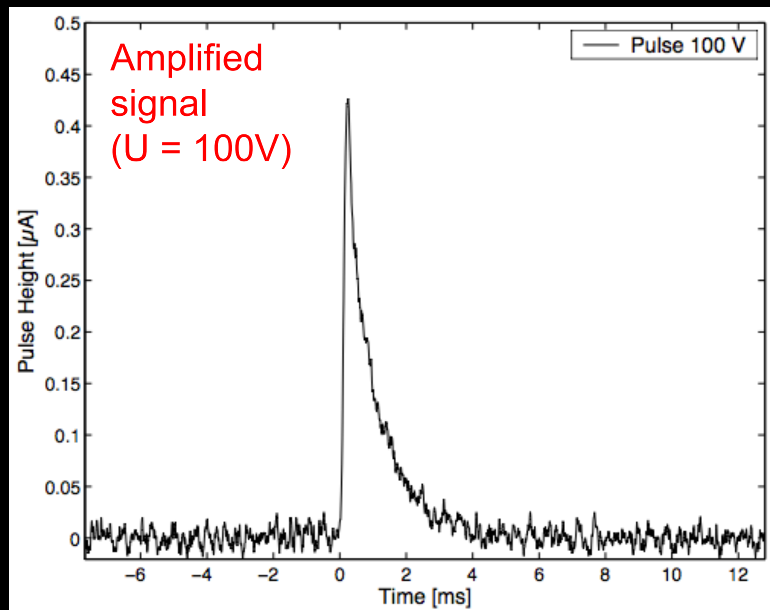
- **Amplification up to a factor of 13**
- **Gain in signal-to-noise ratio: ~10**

➔ High relevance for direct Dark Matter search with light-phonon technique (CRESST/EURECA)

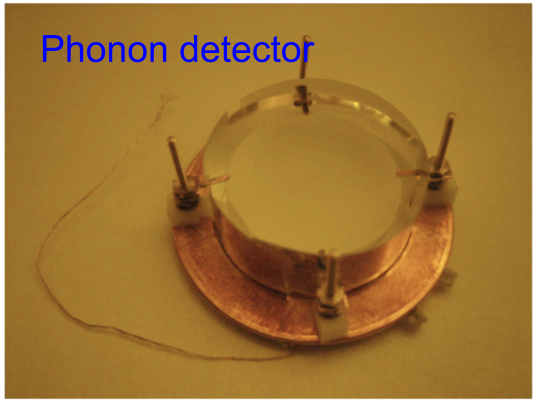
➔ Enhanced separation threshold of electr. and nucl. recoil bands (at low phonon energies)

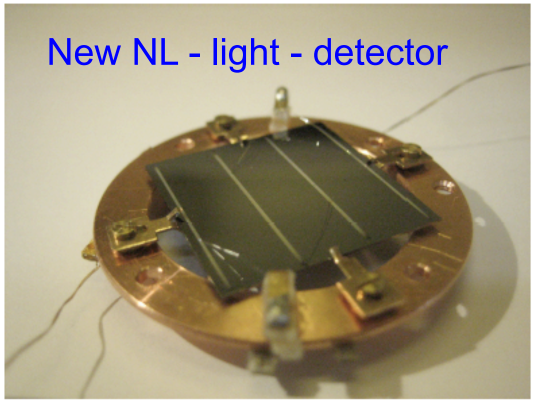
➔ More accurate determination of Quenching Factors (QFs)

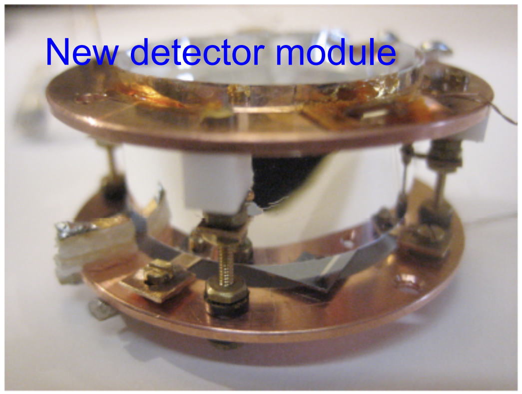




Neutron Scattering with Improved Light-Detection







➔ **Tested successfully during beamtime in April 2010**