The CRESST Dark Matter Search

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Project Status

Florian Reindl

Max-Planck-Institut für Physik

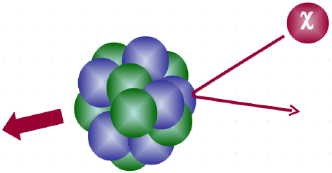
Annual Project Review
December 17th, 2012

Direct Dark Matter Search with the CRESST Experiment

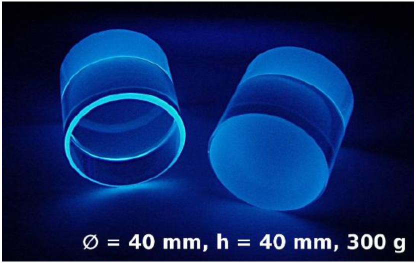
- **C**ryogenic **R**are **E**vent **S**earch with **S**uperconducting **T**hermometers
- **W**eakly **I**nteracting **M**assive **P**article

CRESST

- aims for a WIMP detection via their elastic scattering off nuclei.



- uses scintillating $CaWO_4$ crystals as target material.



CRESST Detectors - Schematic

- particle interactions in the crystal mainly excite phonons
- temperature rise ($\mathcal{O}(\mu K)$) detected with W thermometers

$\rightarrow$ measurement of deposited energy (few keV)

- small fraction of deposited energy $\rightarrow$ scintillation light

$\rightarrow$ add cryogenic light detector $\rightarrow$ detector module

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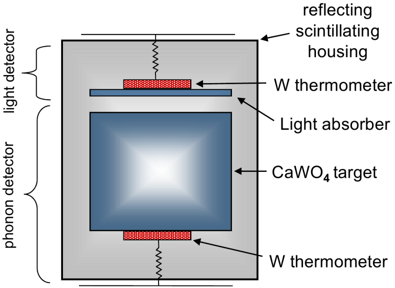
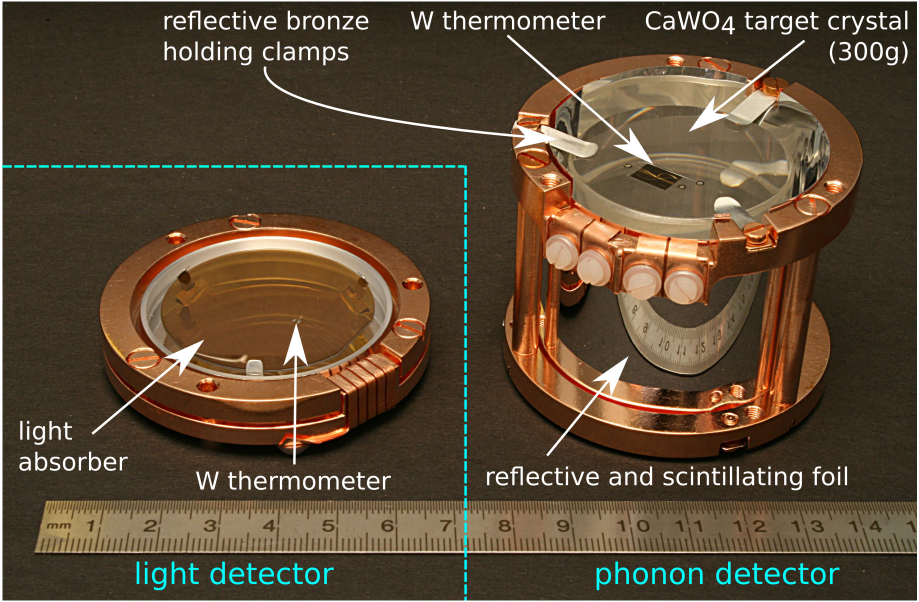


simultaneous measurement of:

- energy deposited in crystal E
- scintillation light L

$\rightarrow$ active background discrimination by light yield ($\frac{L}{E}$)

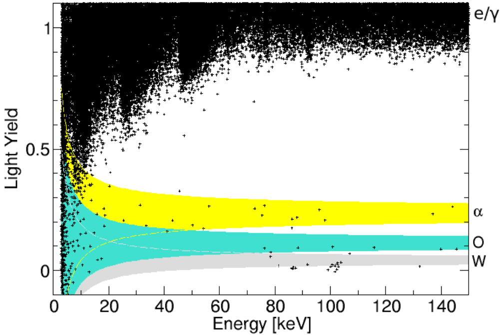
CRESST Detectors - Photograph of Opened Module



CRESST Detectors - Event-by-Event Discrimination

$$\text{light yield} = \frac{\text{light signal}}{\text{phonon signal}}$$

Different event types have a **characteristic** light yield.



excellent discrimination between:

- e^{-}-recoils: dominant radioactive background
- nuclear recoils: potential signal events

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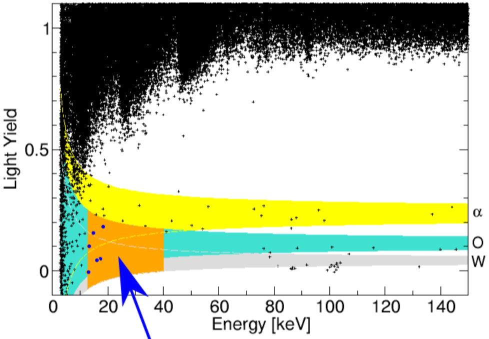

WIMP search region (ROI)
incl. O,Ca & W recoil bands

excellent discrimination between:

- e^--recoils: dominant radioactive background
- nuclear recoils: potential signal events

The Latest CRESST Run 32

- extensive physics run between June 2009 and April 2011
- 8 $CaWO_4$ modules used for Dark Matter analysis
- total net exposure (after cuts): **730 kg days**

- **67 events observed in WIMP search regions**
- data analyzed using maximum likelihood
- background only hypothesis rejected with high statistical significance ($> 4\sigma$)
- for final clarification: reduced background level required

- *Results from 730 kg days of the CRESST-II Dark Matter Search* Eur. Phys. J. C (2012) 72-1971; arxiv: 1109.0702

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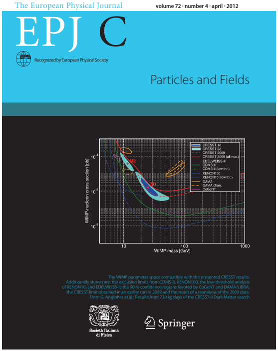
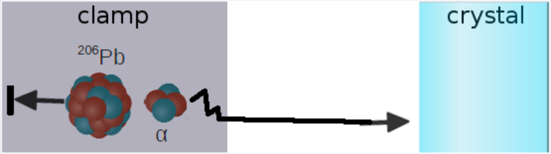


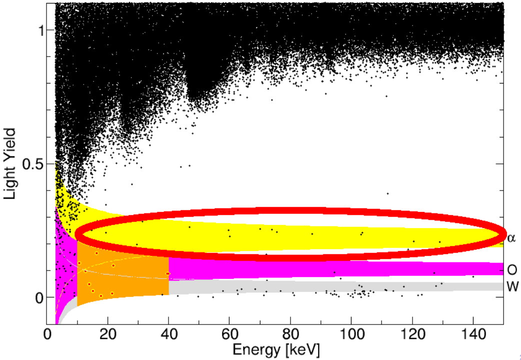
α and ^{206}Pb-Recoil Background

$^{210}\text{Po} \rightarrow {}^{206}\text{Pb}$ (103 keV) + α (5.3 MeV)

- α-decay in bulk material



- events in α-band with low energies, down to ROI



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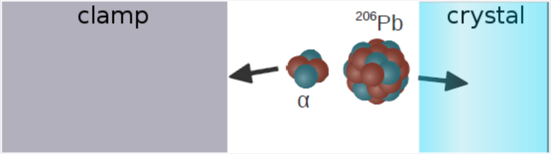
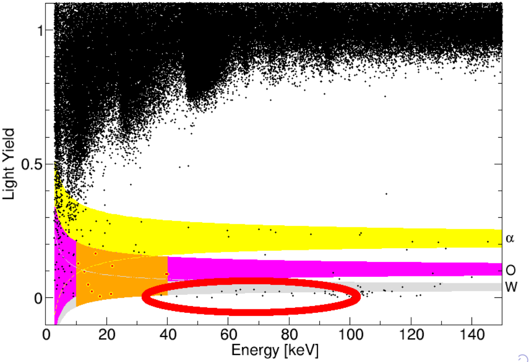
- α-decay on surface of surrounding material
- α hitting non-scintillating clamp



- events with:
  - energy down to ROI
  - light yield slightly below to W-band



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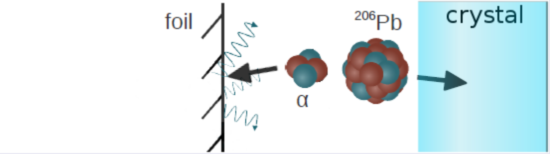
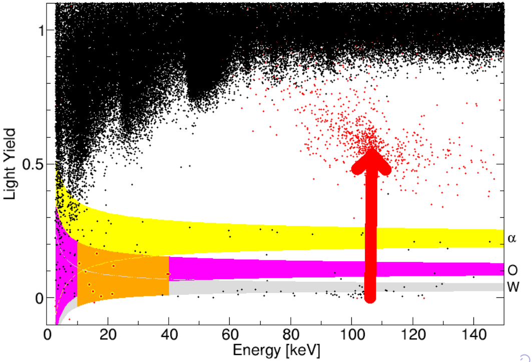


- veto by additional light signal (increased light yield)

$\rightarrow$ discrimination by pulse shape



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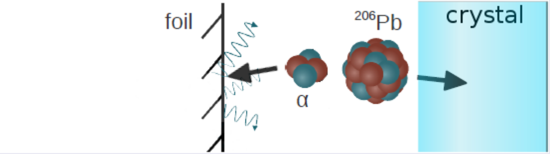

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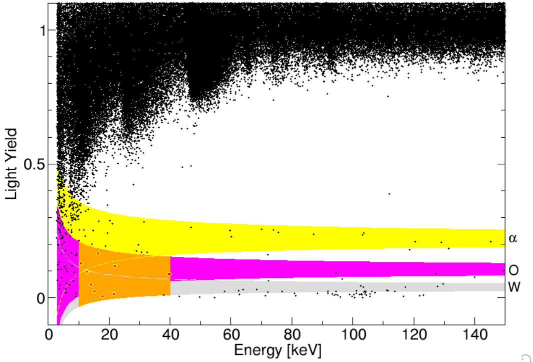
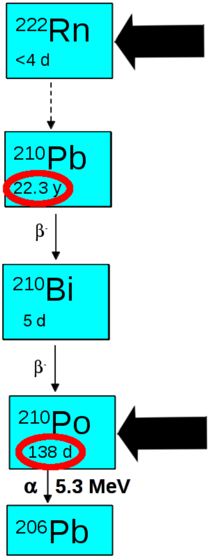


Origin of ^{206}Pb Recoil Background



- absorbtion of ^{222}Rn

→ ^{210}Po has to build up first → increasing rate

observation

- increasing rate at low energies (<<100keV)
- decreasing rate at full recoil energy ($\sim$ 100keV)

→ both origins contribute

→ **rate at low energies dominated by ^{222}Rn**

- direct deposition of ^{210}Po (in coating of clamps)

→ decreasing rate

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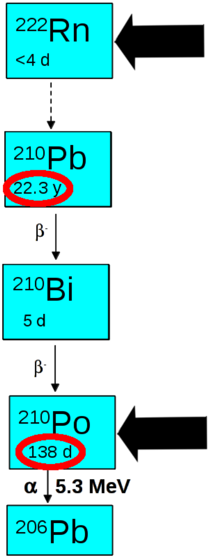

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Goals for the next Run

reduction of backgrounds

- eliminate low energy α-background
- significantly reduce ^{206}Pb recoil background
- additionally: lower external neutron background by one order of magnitude

increase of exposure

- 18 detector modules will be installed: roughly double target mass

New $CuSn_6$ Clamps

old clamps

- low energy α-background due to contamination in bulk material
- ^{206}Pb recoil background due to ^{210}Po or ^{210}Pb deposited on silver coated surface of clamps
- measured ^{210}Pb contamination: (6.9 ± 0.9)Bq/kg

new clamps

- ultra pure Sn + low background Cu
- careful control of all production steps
- Al sputtered coating to avoid Po contamination with electrically deposited Ag
- store in vacuum until assembly to avoid absorption of Radon

^{210}Pb Activity of Tin

K. Schäffner, PhD Thesis, in preparation

turn a piece of tin into a cryodetector

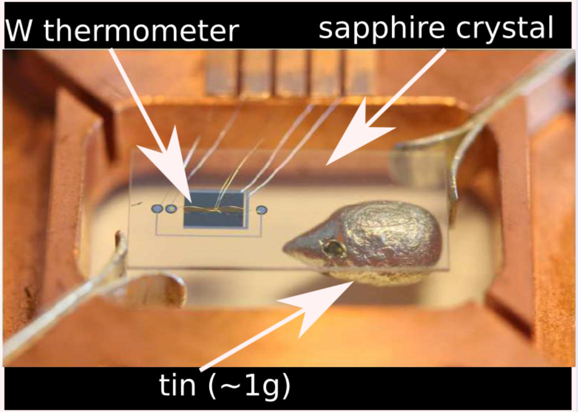
- tin is source and absorber
- count number of ^{210}Po-decays

$\rightarrow$ limit:
tin: < 28.2mBq/kg

$\updownarrow$

$CuSn_6$: < 1.7mBq/kg

- old clamps: (6.9 ± 0.9)Bq/kg



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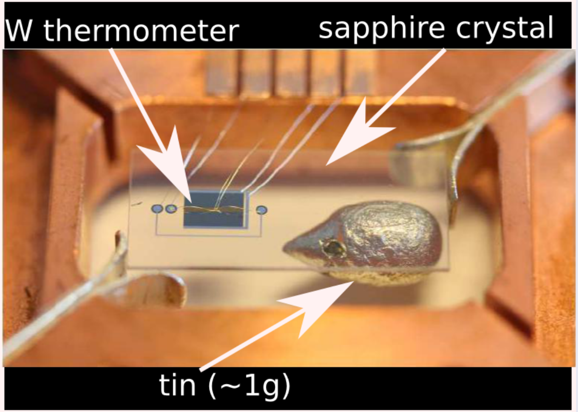

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Radon Background

strategies

- avoid exposure of detector material to Radon
- fully-scintillating detector designs (scintillation light as veto)

Radon Prevention

first attempts (in Munich)

- clean room at MPI unusable, because Radon concentration in ambient air is far too high
- mounting in glove-boxes flushed with nitrogen: handling too complicated

solution (at Gran Sasso)

- Use clean room supplied with Radon-filtered air from the CUORE experiment to assemble the detectors.
- Use same air supply to create Radon-pure atmosphere for mounting the detectors into the cryostat.

Both systems are ready to be used.

Radon Prevention

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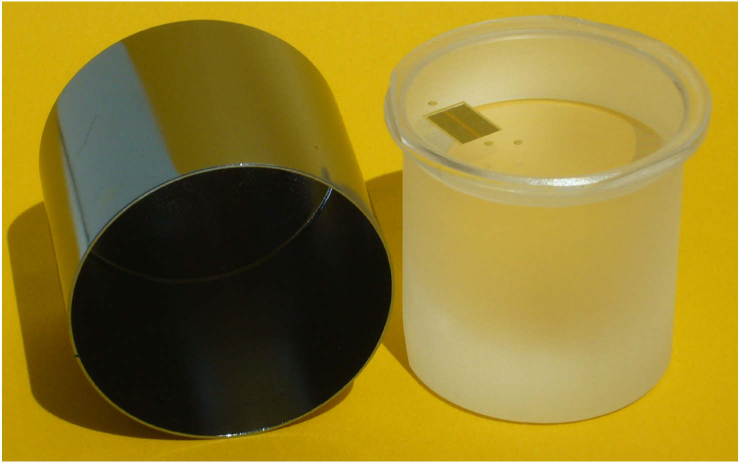
new clean room in CRESST hut at Gran Sasso

airtight box surrounding former clean room

Fully-Scintillating Detector Design

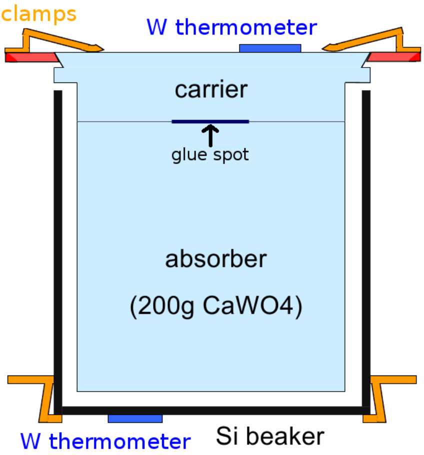


Fully-Scintillating Detector Design

- α-decay **inside** beaker: both α and recoil detected in module
- α-decay **outside** beaker: recoils nor α's can reach absorber crystal
- events in carrier and absorber discriminated by pulse shape

- detector design successfully tested
- 2 such detectors will be installed in the next run

- additional advantage: increased light signal



Sputtering in Reflective and Scintillating Foil

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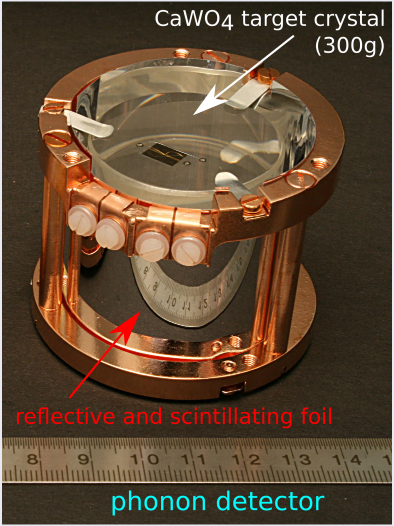
(^{222}Rn $\rightsquigarrow$) 21

- ^{210}Po-deca
- α absorbe
- ^{206}Pb nucl ... al

$\rightarrow$ low energy

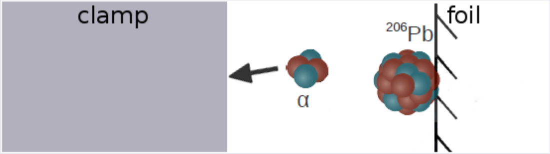
reminder



Sputtering in Reflective and Scintillating Foil

for additional safety: avoid the following rare process

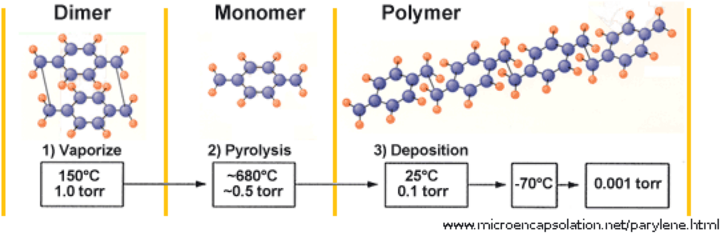
$(^{222}\text{Rn} \rightsquigarrow)\ ^{210}\text{Po} \rightarrow\ ^{206}\text{Pb}\ (103\,\text{keV}) + \alpha\ (5.3\,\text{MeV})$



- ^{210}Po-decay on surface of foil
- α absorbed in non-scintillating clamp (undetected)
- ^{206}Pb nucleus sputters light elements (e.g. C) reaching the crystal

→ low energy event with light yield comparable to Oxygen recoil

Parylene Coating of Reflective and Scintillating Foil



- Exposure of foil to Radon-contaminated air cannot be controlled (commercial product).

- strategy: cover/seal foil with Parylene to reset the foils "Rn-history"
- Parylene scintillates (twice as good as the foil)
- clean raw material available

Radon Background

strategies

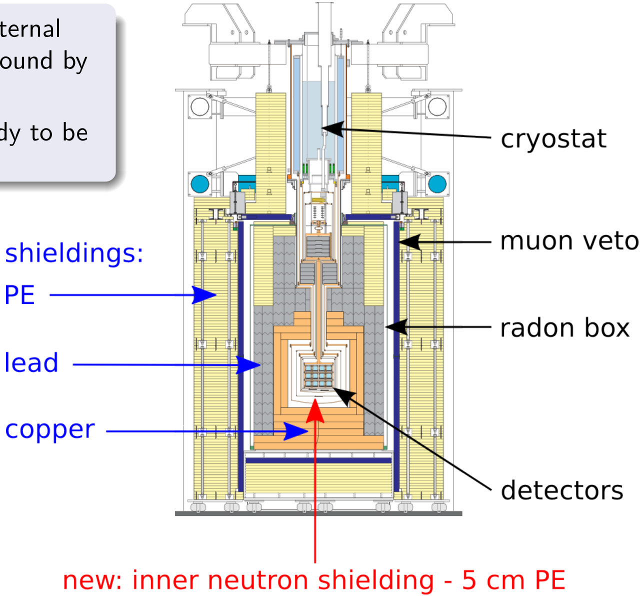
- avoid exposure of detector material to Radon
- fully-scintillating detector designs (scintillation light as veto)

next run

- 14 modules assembled and mounted under Radon prevention
- 4 modules with fully-scintillating detector design $\leftrightarrow$ active ^{206}Pb-recoil veto
- additional innovation: Parylene coating of scintillating and reflecting foil

Additional Neutron Shielding

- reduction of external neutron background by a factor >10
- shielding is ready to be mounted



Summary and Status of Preparations

- inner neutron shielding ready for installation
- cryostat gas handling and He recovery compressor renewed
- new clean $CuSn_6$ clamps prepared
- complete material to assemble 20 modules ready (only 18 will be installed)
- detector assembling and mounting using Radon-filtered air possible

detector assembly and mounting will start early next year

Perspectives for the Next Run

- $>$2t days of net exposure after two years of data taking
- confirm or reject excess (low mass WIMP scenario) with high confidence
- in case excess is rejected: competitive limit for higher mass WIMPs