Status Update on the CRESST Dark Matter Search

Florian Reindl (MPP Munich)
on behalf of the CRESST Collaboration

16th Lomonosov Conference, Moscow

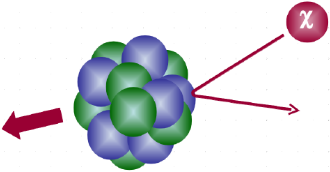
Outline

1. Introduction
2. Findings of the Previous Run
3. The Current Run
4. Status and Perspectives

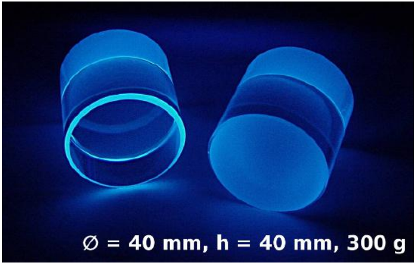
Direct Dark Matter Search with the CRESST Experiment

- **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.

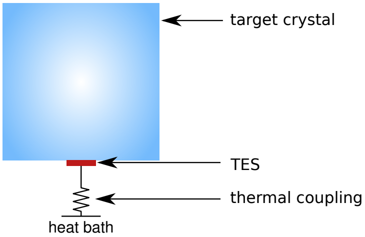


- uses scintillating $CaWO_4$ crystals as target material.

CRESST Detectors - Schematic

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

→ measurement of deposited energy (few keV)



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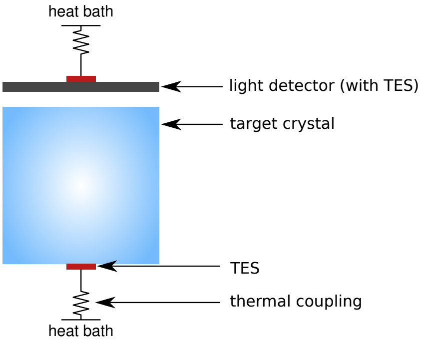
- small fraction of deposited energy → scintillation light

→ add cryogenic light detector → detector module



simultaneous measurement of:

- energy E deposited in crystal
- scintillation light L

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

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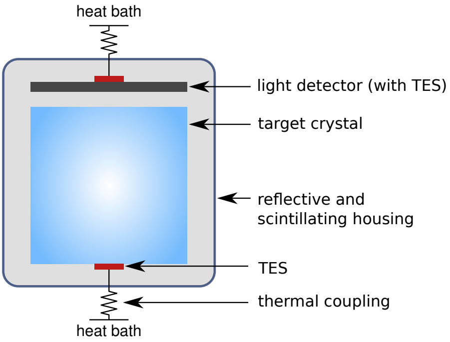

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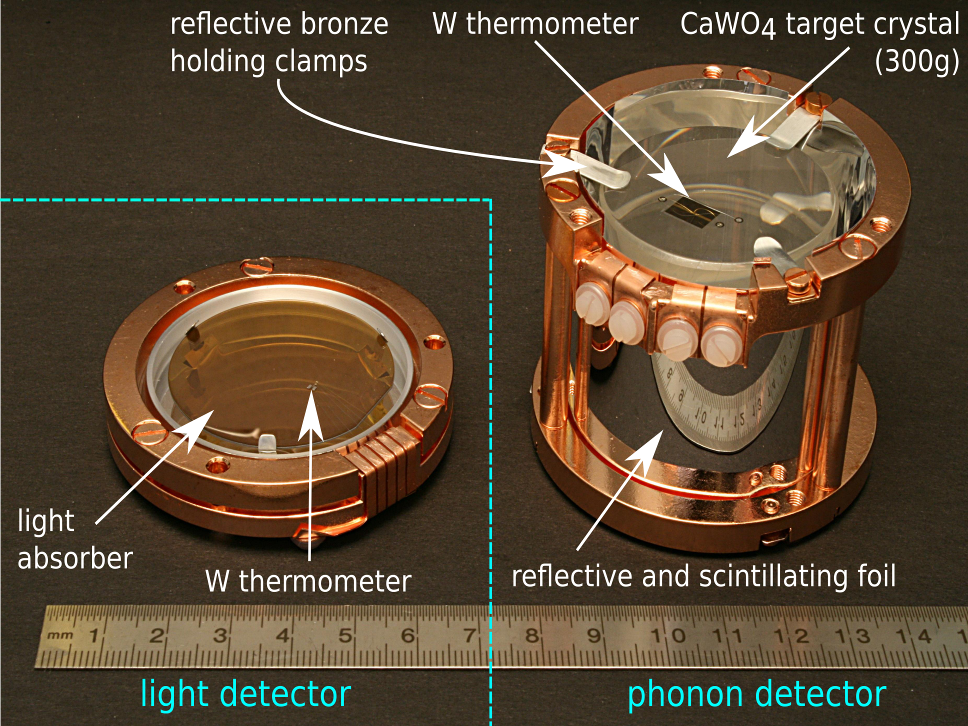
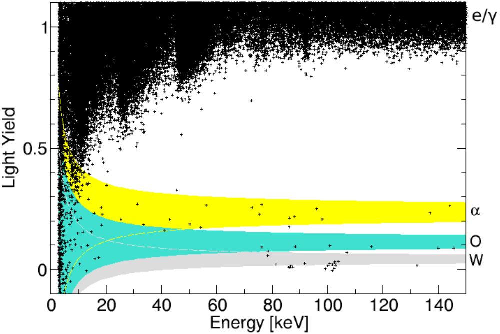

reflective bronze holding clamps
W thermometer
$CaWO_4$ target crystal (300g)
light absorber
W thermometer
reflective and scintillating foil
mm 1 2 3 4 5 6 7 8 9 10 11 12 13 14
light detector
phonon detector

CRESST Detectors - Event-by-Event Discrimination

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

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



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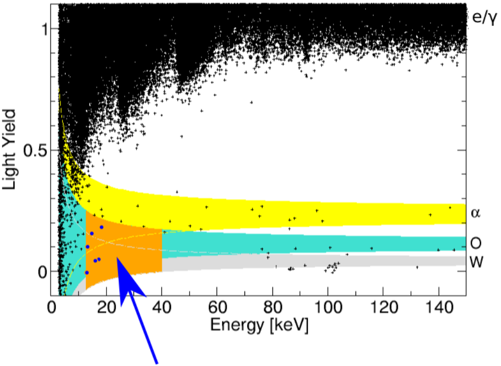

WIMP search region (ROI)
incl. O,Ca & W recoil bands

excellent discrimination between:

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

The Previous 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**

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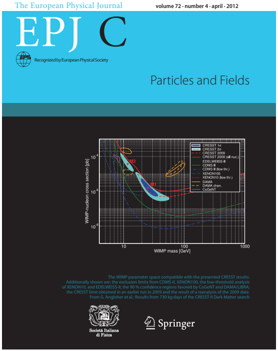
- **67 events observed in WIMP search regions**
- data analyzed using maximum likelihood
- *Results from 730 kg days of the CRESST-II Dark Matter Search* Eur. Phys. J. C (2012) 72-1971



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Recognized by European Physical Society

Particles and Fields

The WIMP parameter space compatible with the presented CRESST results. Additionally shown are: the exclusion limits from CDMS-II, XENON100, the low-threshold analysis of XENON10, and EDELWEISS-II; the 90 % confidence regions favored by CoGeNT and DAMA/LIBRA; the CRESST limit obtained in an earlier run in 2009 and the result of a reanalysis of the 2009 data. From G. Angloher et al.: Results from 730 kg days of the CRESST-II Dark Matter search

Società Italiana di Fisica

Springer

Result of the likelihood analysis

	M1	M2
e/γ-events	8.00 ± 0.05	8.00 ± 0.05
α-events	$11.5^{+2.6}_{-2.3}$	$11.2^{+2.5}_{-2.3}$
neutron events	$7.5^{+6.3}_{-5.5}$	$9.7^{+6.1}_{-5.1}$
Pb recoils	$15.0^{+5.2}_{-5.1}$	$18.7^{+4.9}_{-4.7}$
signal events	$29.4^{+8.6}_{-7.7}$	$24.2^{+8.1}_{-7.2}$
m_χ [GeV]	25.3	11.6
σ_{WN} [pb]	$1.6 \cdot 10^{-6}$	$3.7 \cdot 10^{-5}$
statistical significance	$4.7\ \sigma$	$4.2\ \sigma$

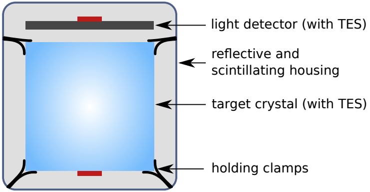
- background only hypothesis rejected with high statistical significance

→ additional source of events needed

- WIMPs would be a source with suitable properties

for final clarification: reduced background level required

Bck. Induced by ^{210}Po $\rightarrow$ ^{206}Pb (103 keV) + α (5.3 MeV)

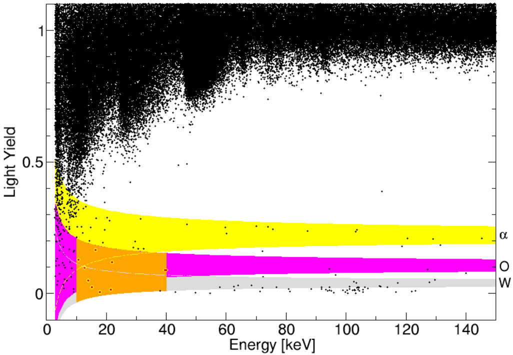


light detector (with TES)

reflective and scintillating housing

target crystal (with TES)

holding clamps



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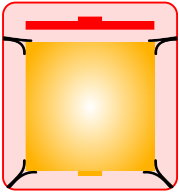
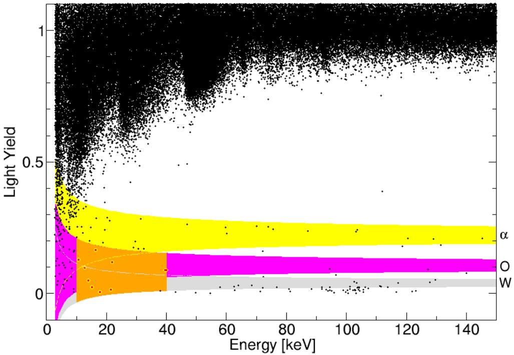


light signal

phonon (and) light signal

no signal



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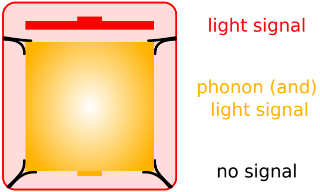

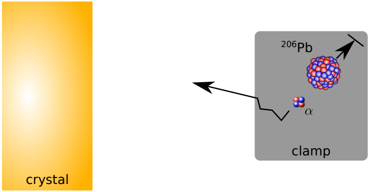

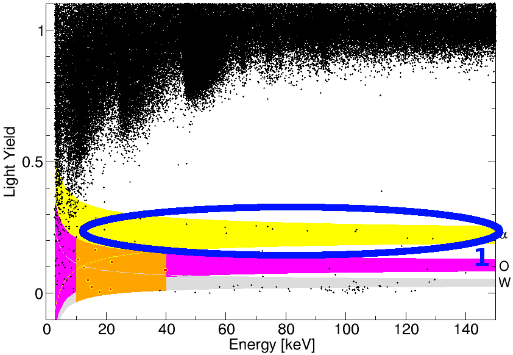

① decay inside clamp material

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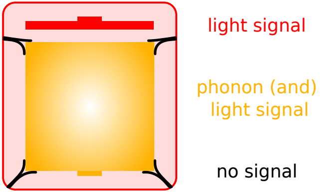

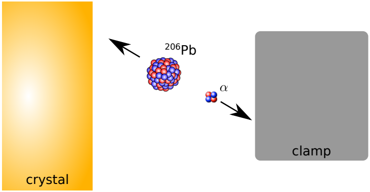

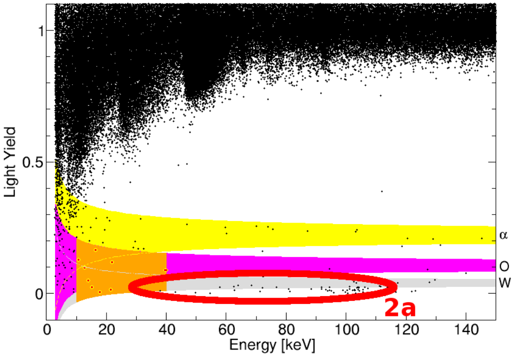

1. decay inside clamp material
2. decay on or slightly below surface of clamp
   - (a) α hitting clamp → **no** scintillation light

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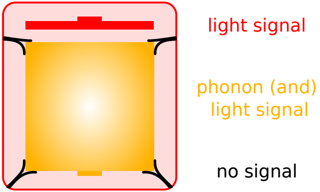

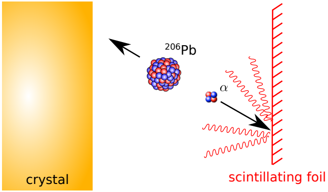

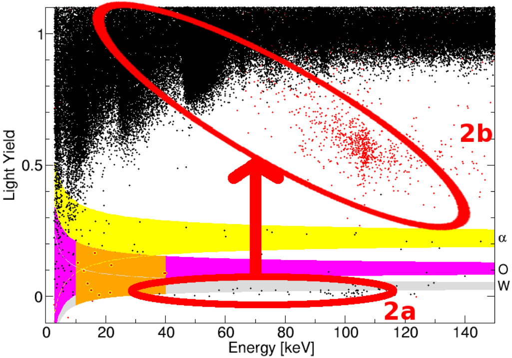

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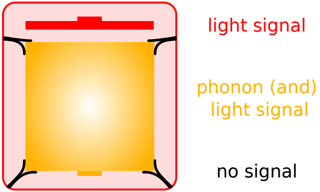

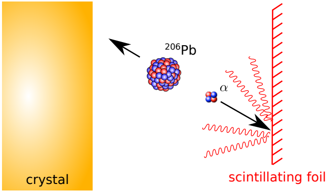

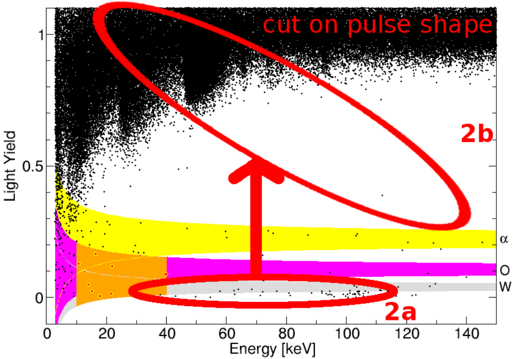

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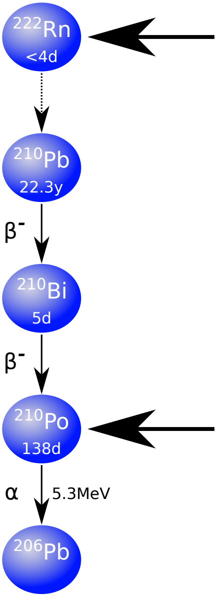
Origin of ^{206}Pb Recoil Background



- absorption of ^{222}Rn

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

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

→ decreasing rate

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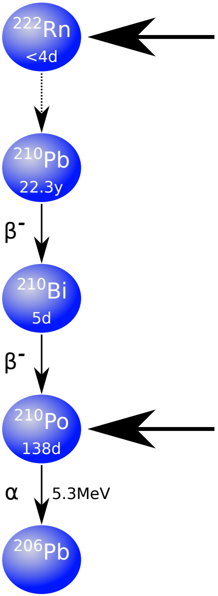

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observation

- increasing rate at low energies (<<100keV)
- decreasing rate at full recoil energy (∼ 100keV)

→ both origins contribute

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

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

→ decreasing rate

Goals for the Current Run

- reduction of α-induced backgrounds:
  - eliminate low-energy α-background
  - significantly reduce ^{206}Pb recoil background

- reduce external neutron background by an order of magnitude:
  - an additional inner PE-shielding was installed

- increase of exposure:
  - 18 detector modules were installed: roughly double target mass

Reduction of ^{210}Po $\rightarrow$ ^{206}Pb $+ \alpha$ Background

two possible stategies:

conventional detector design

requirements:

- radio-pure raw material
- avoid exposure of detector material to radon

fully-scintillating detector design

requirements:

- no stress-relaxation events (events with small phonon but no associated light signal)

New $CuSn_6$ Clamps

old clamps

- low energy α-background due to contamination in bulk material

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

new clamps

- ultra pure Sn (<28.2mBq/kg) + 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

Radon Prevention

- Clean room supplied with radon-filtered air from the CUORE experiment was used to assemble the detectors.
- Same air supply was used to create radon-pure atmosphere to mount the detectors in the cryostat.

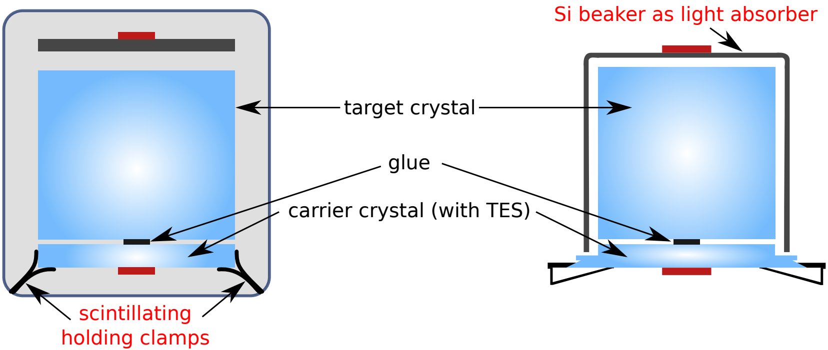
Radon Prevention

new clean room in CRESST building at Gran Sasso

airtight box surrounding former clean room

- Clean t was used to
- Same e detecto

Fully-Scintillating Designs



Si beaker as light absorber

target crystal

glue

carrier crystal (with TES)

scintillating holding clamps

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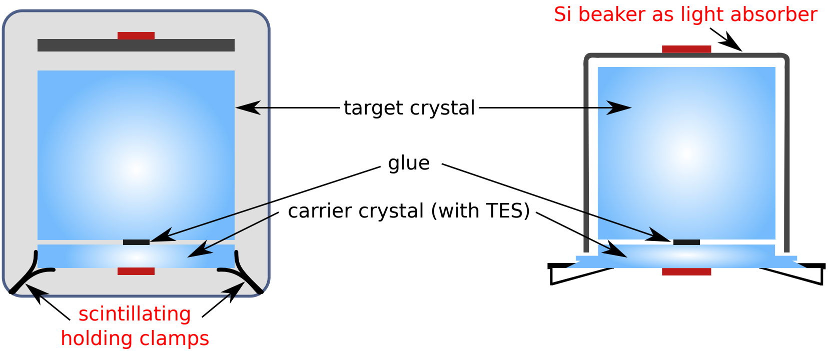

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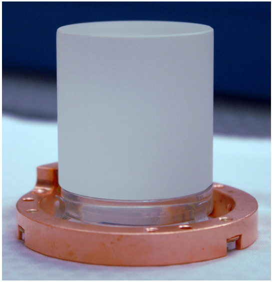

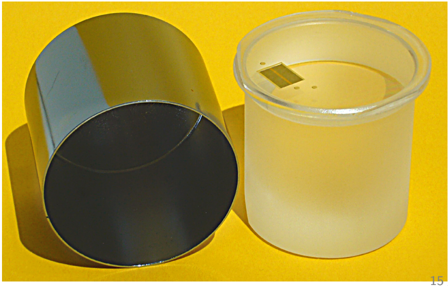

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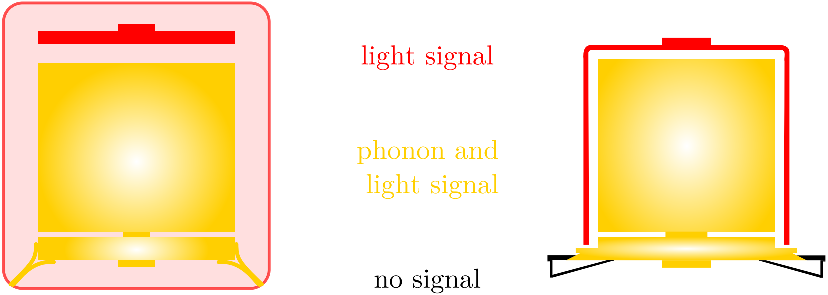


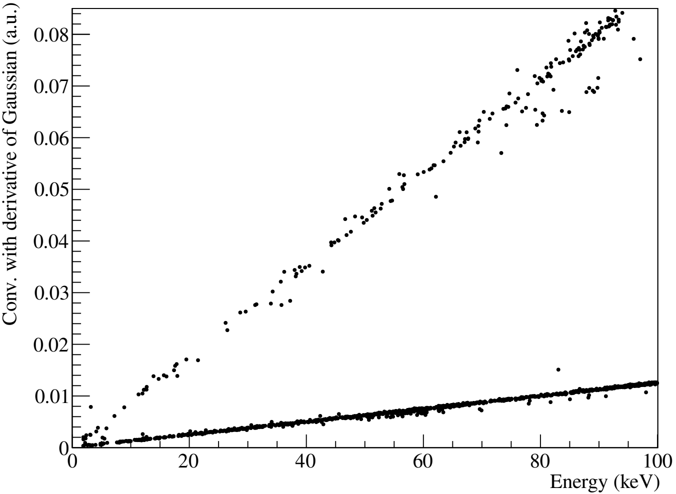
light signal

phonon and light signal

no signal

crucial: discrimination between events in carrier and target crystal

Discrimination of Events in Carrier Crystal



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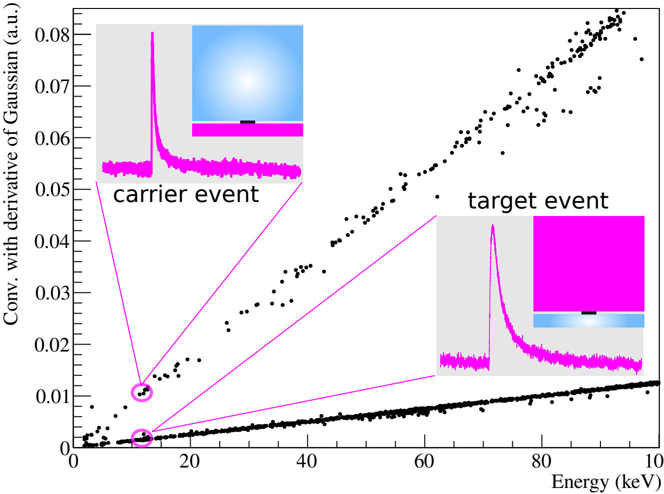
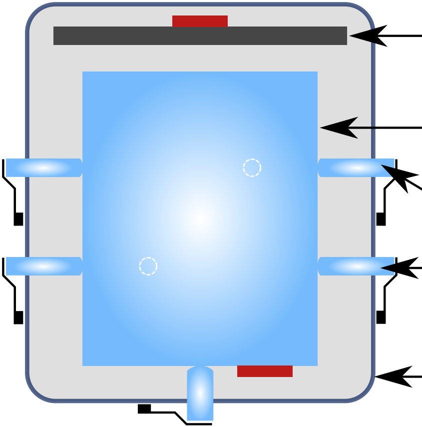


Discrimination proven down to energies of interest.

Fully-Scintillating Detector Design III



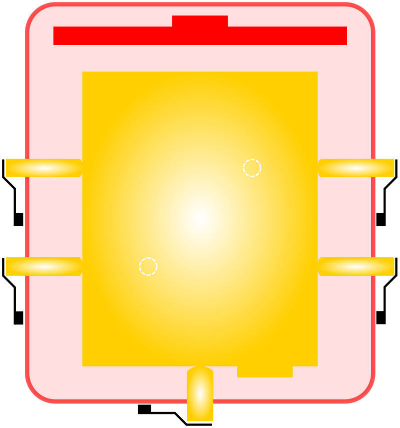
light detector (with TES)

block-shaped target crystal

$CaWO_4$ sticks
(with holding clamps)

reflective and
scintillating housing

Fully-Scintillating Detector Design III



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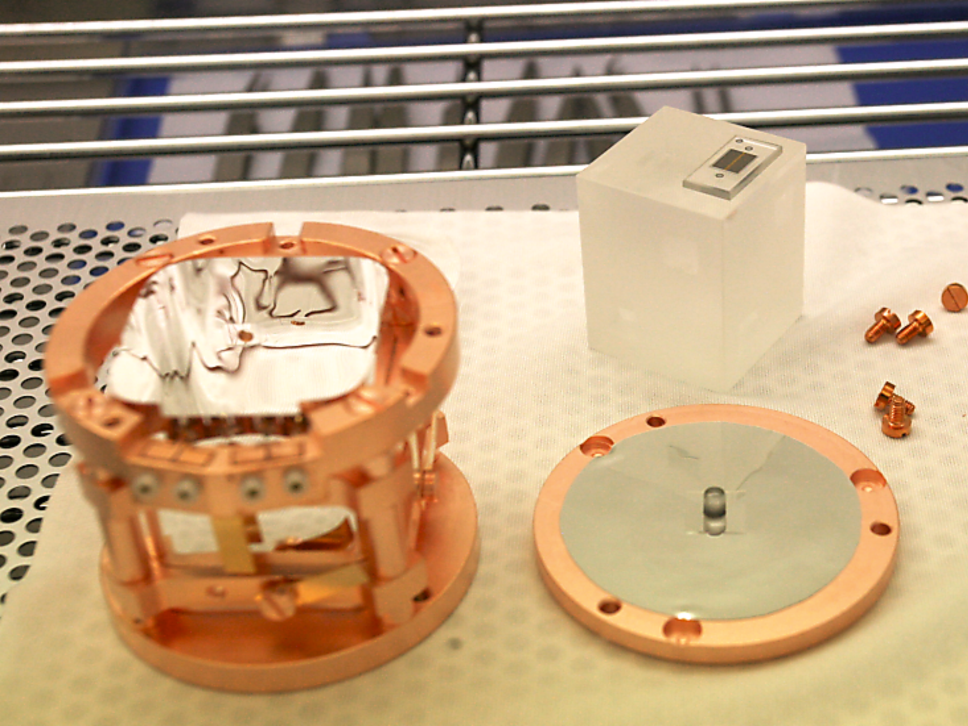


Reduction of $^{210}\mathrm{Po} \rightarrow {}^{206}\mathrm{Pb} + \alpha$ Background

two possible stategies:

$\swarrow \quad \searrow$

conventional detector design

requirements:

- radio-pure raw material
- avoid exposure of detector material to radon

$\Downarrow$

12 modules in current run

fully-scintillating detector design

requirements:

- no stress-relaxation events (events with small phonon but no associated light signal)

$\Downarrow$

2 of each of the 3 designs → 6 modules in current run

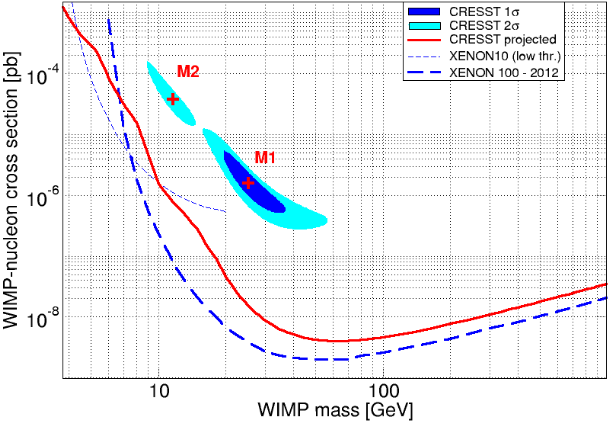
Status

- cool-down in May 2013
- all 18 detector modules are operational
- $\gamma-$calibration finished

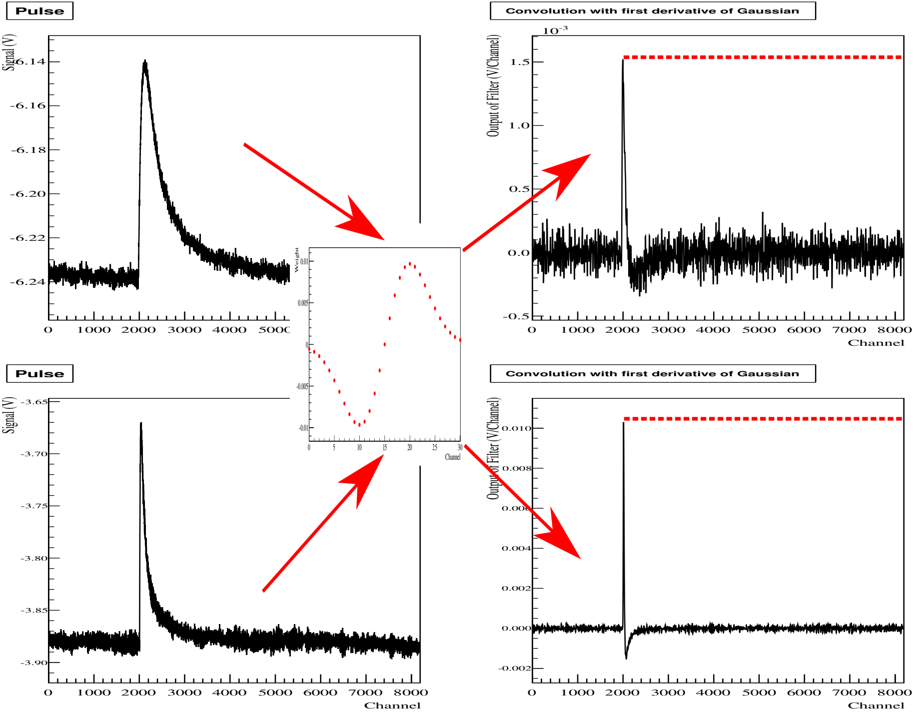
→ Dark Matter data is taken since August 2013

Perspectives

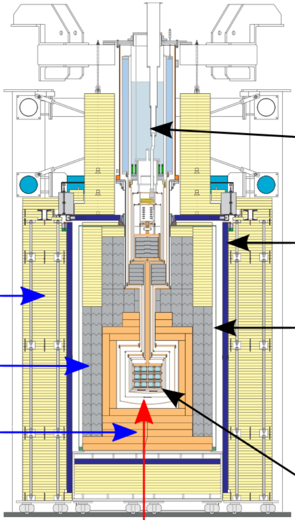
- $>$2t days of net exposure after two years of data taking
- confirm or reject excess signal (low mass WIMP scenario) with high confidence
- in case excess is rejected: competitive limit for a wide WIMP-mass range



Backup


Pulse
Signal (V)
-6.14
-6.16
-6.18
-6.20
-6.22
-6.24
0
1000
2000
3000
4000
5000
Convolution with first derivative of Gaussian
10^{-3}
Output of Filter (V/Channel)
1.5
1.0
0.5
0.0
-0.5
0
1000
2000
3000
4000
5000
6000
7000
8000
Channel
Weight
0.01
0.005
0
-0.005
-0.01
0
5
10
15
20
25
30
Channel
Pulse
Signal (V)
-3.65
-3.70
-3.75
-3.80
-3.85
-3.90
0
1000
2000
3000
4000
5000
6000
7000
8000
Channel
Convolution with first derivative of Gaussian
Output of Filter (V/Channel)
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
0
1000
2000
3000
4000
5000
6000
7000
8000
Channel

Experimental setup at Gran Sasso Underground Laboratory



cryostat

muon veto

radon box

detectors

shieldings:

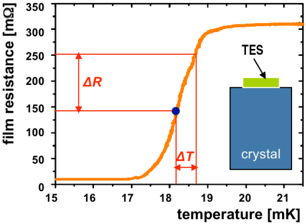
PE

lead

copper

new: inner neutron shielding - 5 cm PE

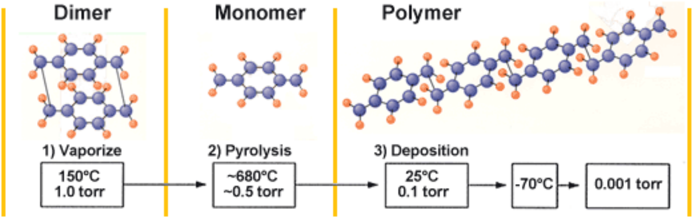
CRESST Detectors - Schematic



- particle interactions in the crystal excite phonons
- detectors are operated at mK temperatures
- temperature rise ($\mathcal{O}(\mu K)$) detected with Transition Edge Sensor (TES)

→ measurement of deposited energy (few keV)

Parylene Coating of Reflective and Scintillating Foil



www.microencapsolation.net/parylene.html

- 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 well as the foil)
- clean raw material available

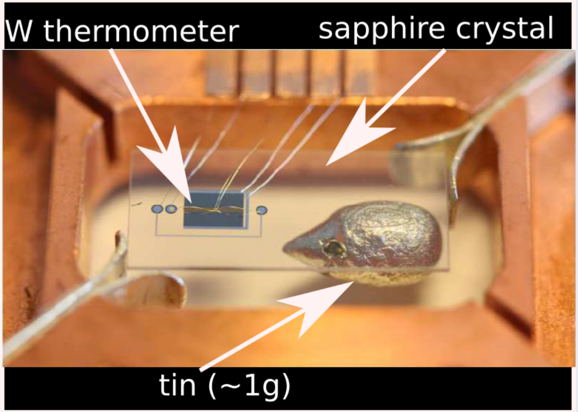
^{210}Pb Activity of Tin

K. Schäffner, PhD Thesis, 2013

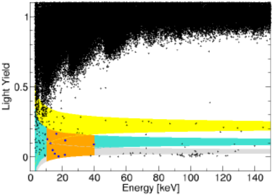
turn a piece of tin into a cryodetector

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

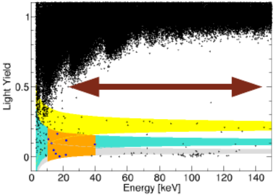
→ limit:
tin: < 28.2mBq/kg



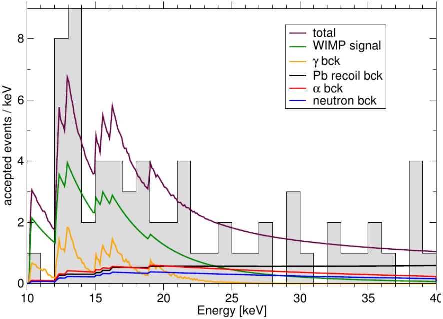
Spectral Distribution of Signal Events



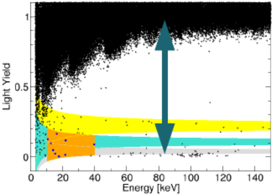
Spectral Distribution of Signal Events



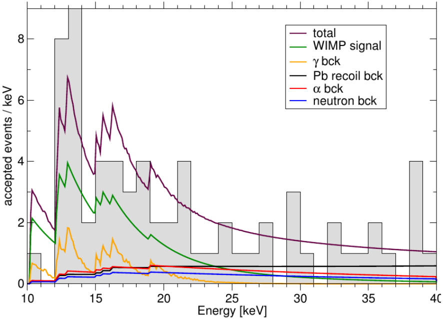
energy distribution (only M1)



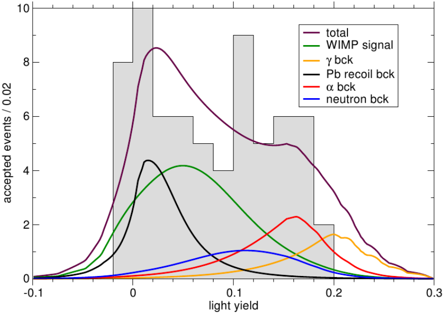
Spectral Distribution of Signal Events



energy distribution (only M1)



light yield distribution (only M1)

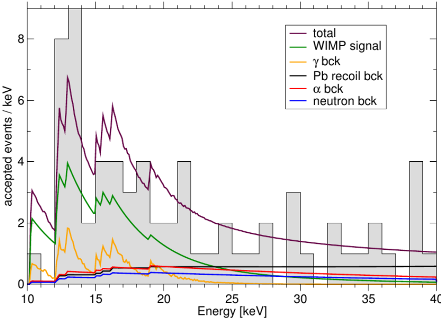


Spectral Distribution of Signal Events

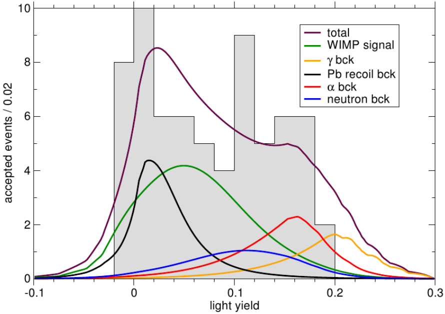
- shape of energy spectra of γ-leakage and possible WIMP signal seem compatible

$\rightarrow$ underestimation of γ-leakage?

energy distribution (only M1)



light yield distribution (only M1)



Spectral Distribution of Signal Events

- shape of energy spectra of γ-leakage and possible WIMP signal seem compatible

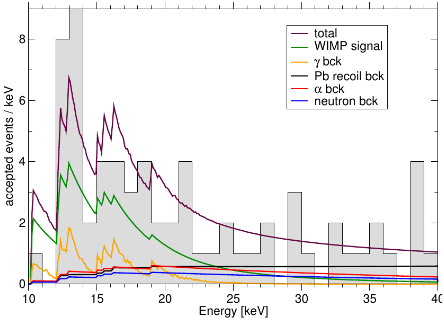
→ underestimation of γ-leakage?

but

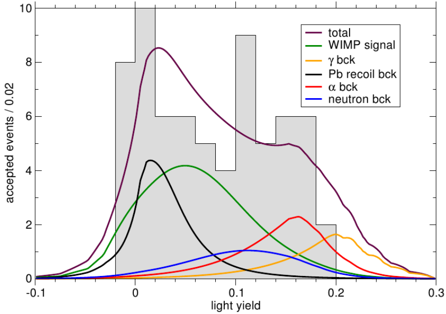
- γ-leakage appears at high light yields
- possible WIMP signal at low light yields

→ γ-leakage ruled out as explanation for the excess

energy distribution (only M1)



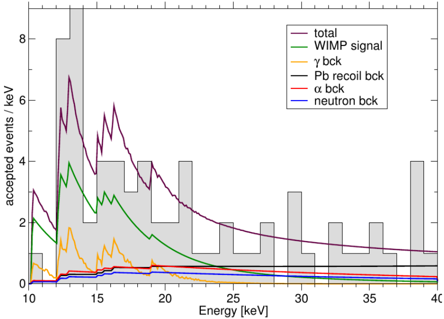
light yield distribution (only M1)

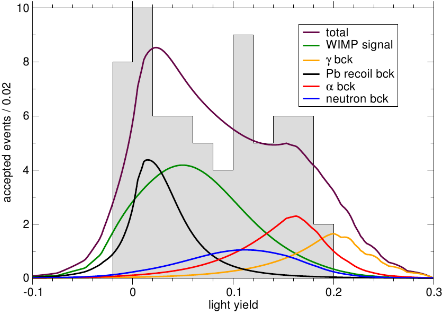


Spectral Distribution of Signal Events

The other way round:

- Only the Pb recoil background has similar light yield as the possible WIMP signal


energy distribution (only M1)


light yield distribution (only M1)

Spectral Distribution of Signal Events

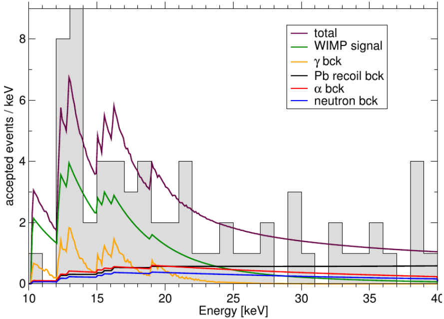
- energy spectrum of Pb recoils incompatible with possible WIMP signal

but

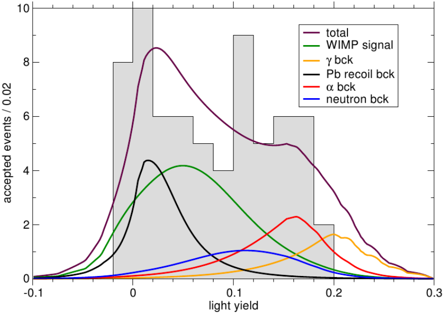
The other way round:

- Only the Pb recoil background has similar light yield as the possible WIMP signal

energy distribution (only M1)



light yield distribution (only M1)



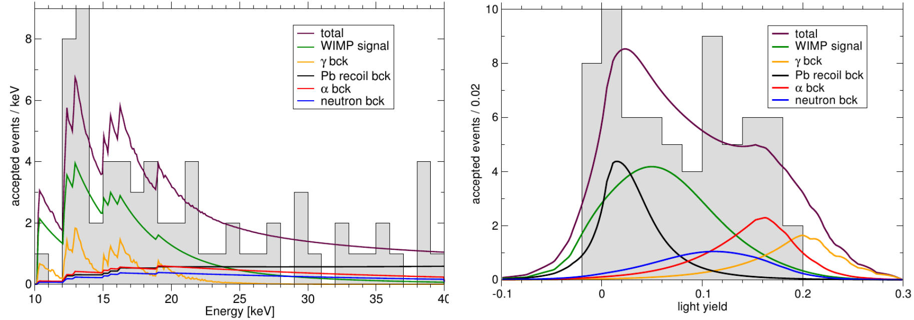
Spectral Distribution of Signal Events

Conclusion:

- Simultaneous measurement of phonon and light is crucial to discriminate a possible WIMP signal from background.
- The excess can not be explained with the known backgrounds alone.

energy distribution (only M1)

light yield distribution (only M1)



The Almost Current WIMP Paramater Space