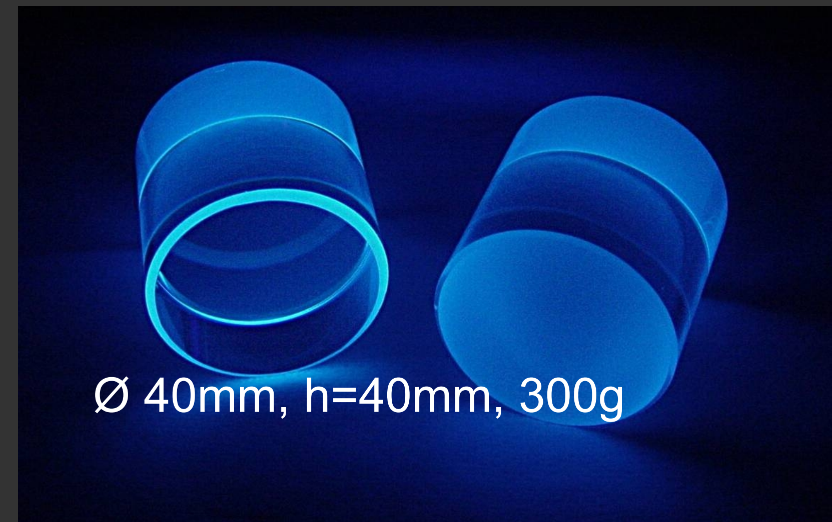
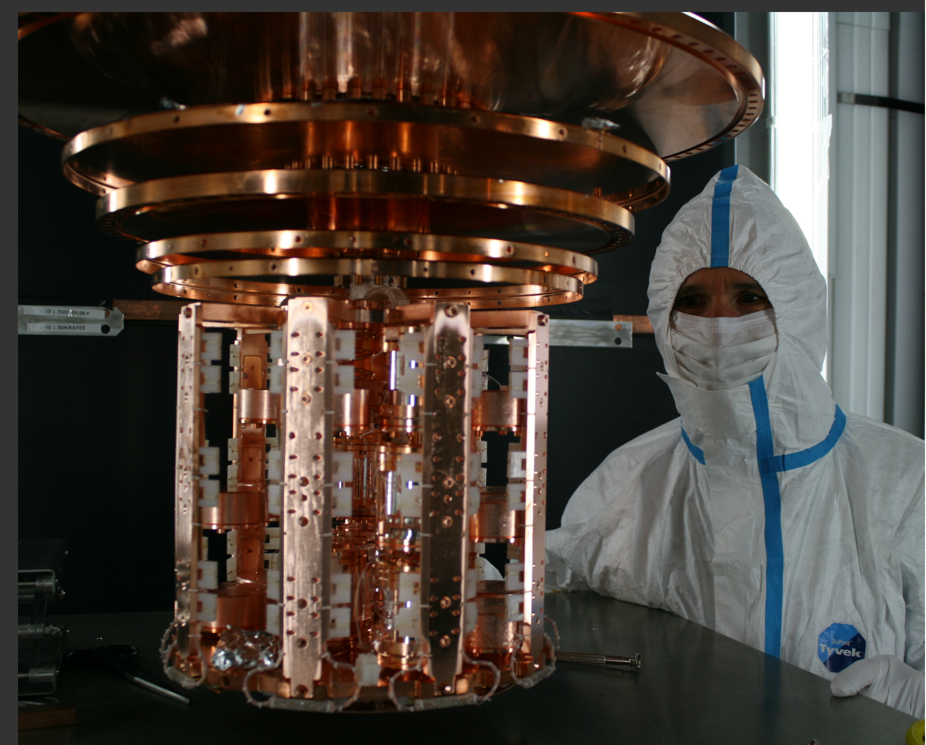
The CRESST Dark Matter Search

Collaboration
MPI für Physik, Oxford University,
TU München, Universität Tübingen
Laboratori Nazionali del Gran Sasso
High Energy Physics Institute Vienna



- Cryogenic Dark Matter search
- Located in hall A of LNGS
- Scintillating $CaWO_4$ target crystals
- Up to 33 crystals in modular structure (10 kg target)



Outline

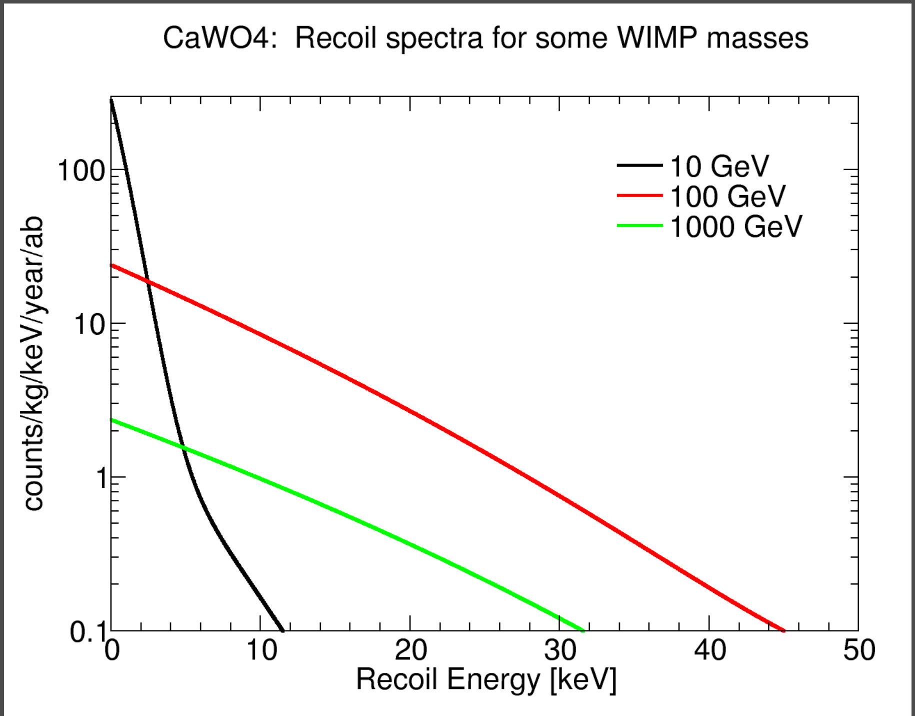
- Challenges of direct detection
- CRESST detector concept
- Result of last run
- Effort made to decrease background in present run
- Conclusion and outlook

WIMP direct detection challenge

Detection via elastic scattering off target nuclei in detector material

Experimental challenges:

- Low recoil energies: few 10 keV
- featureless spectrum just above threshold
- low event rate: few events/ kg/year



Typical background rates deep underground:

- radioactive β/γ-background: some 10000/kg/year
  → need detectors with efficient nuclear recoil discrimination
- neutrons from α-n and spontaneous fission in rock: some 100 /kg/year
  → need massive moderator around experiment
- high energetic neutrons from muons in rock and Pb/Cu shield: some 10 /kg/year
  → need muon veto

CRESST setup at LNGS

Liquid He

Mixing chamber

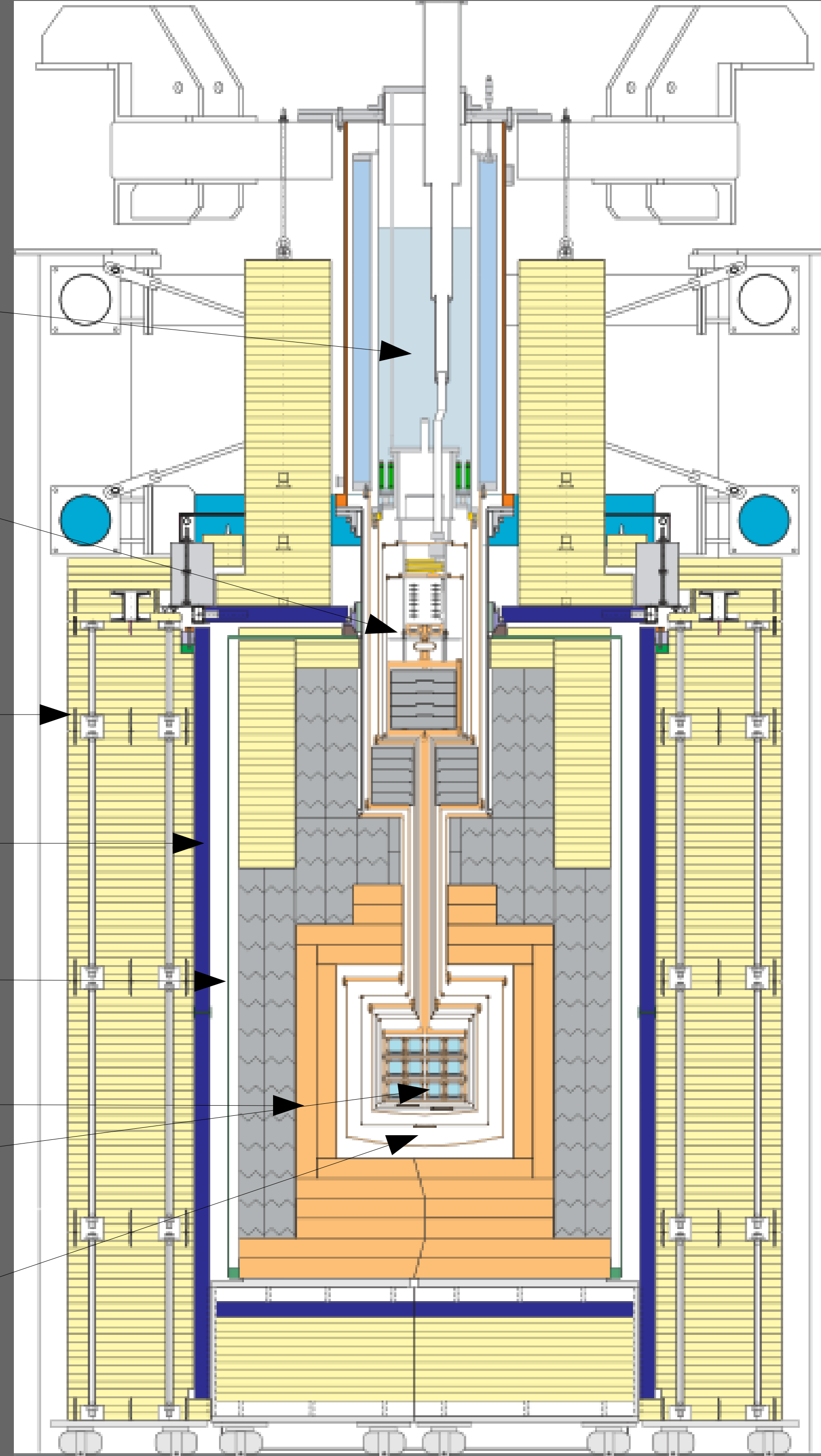
Neutron shield 45 cm PE

Muon veto

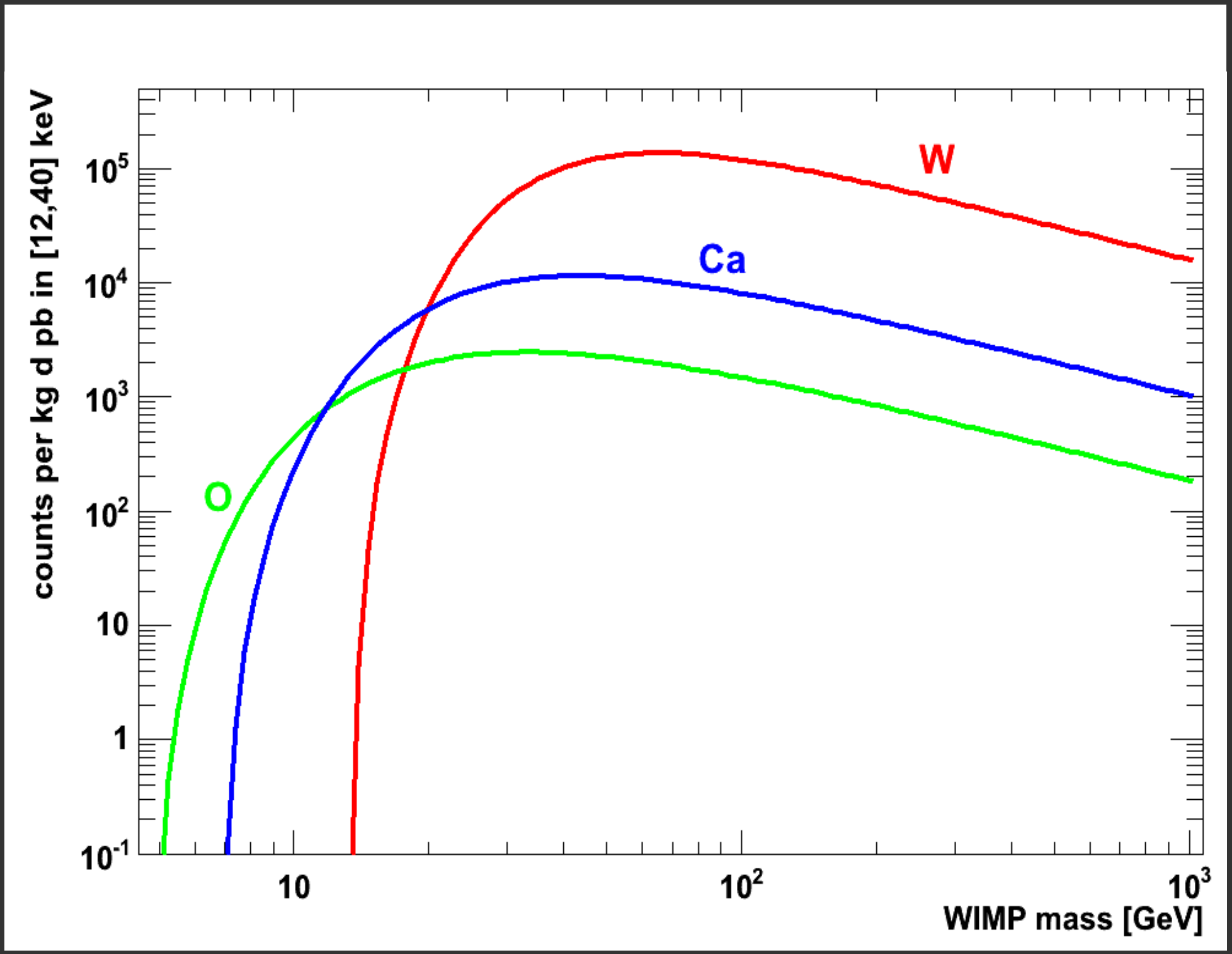
Radon box
20cm Pb
14 cm Cu

Detectors

New: inner neutron shield
5 cm PE



Types of Recoils in $CaWO_4$



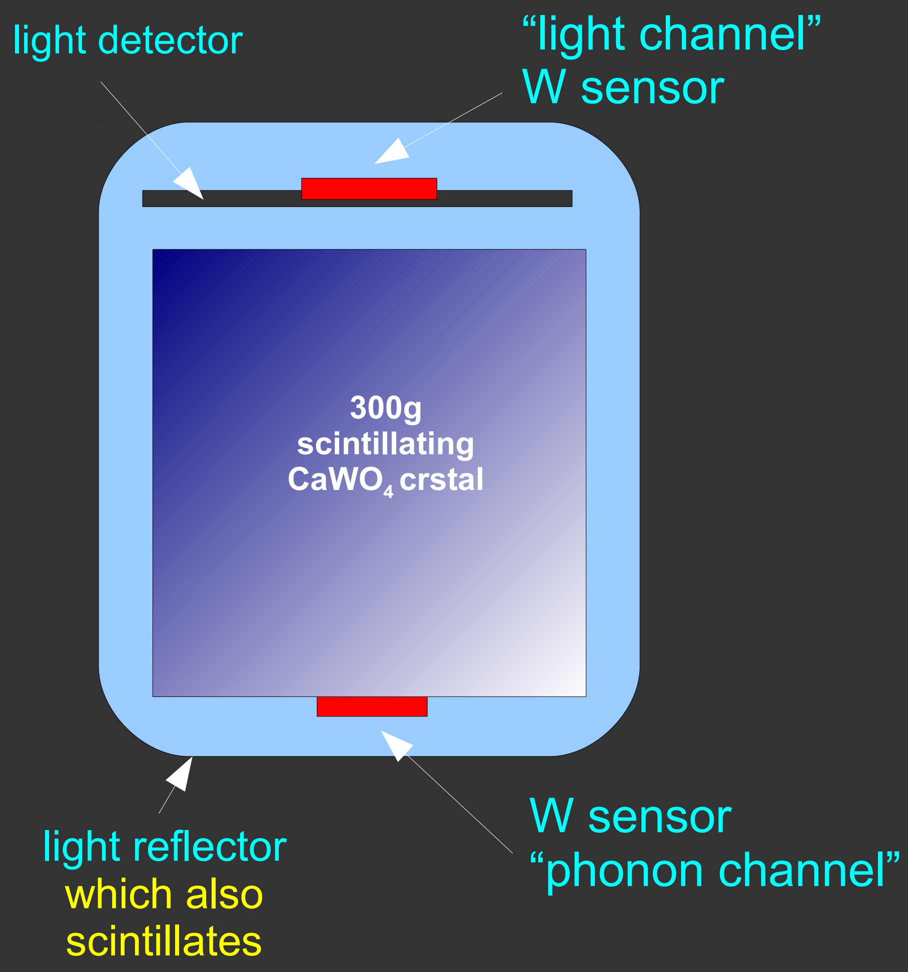
Assuming:

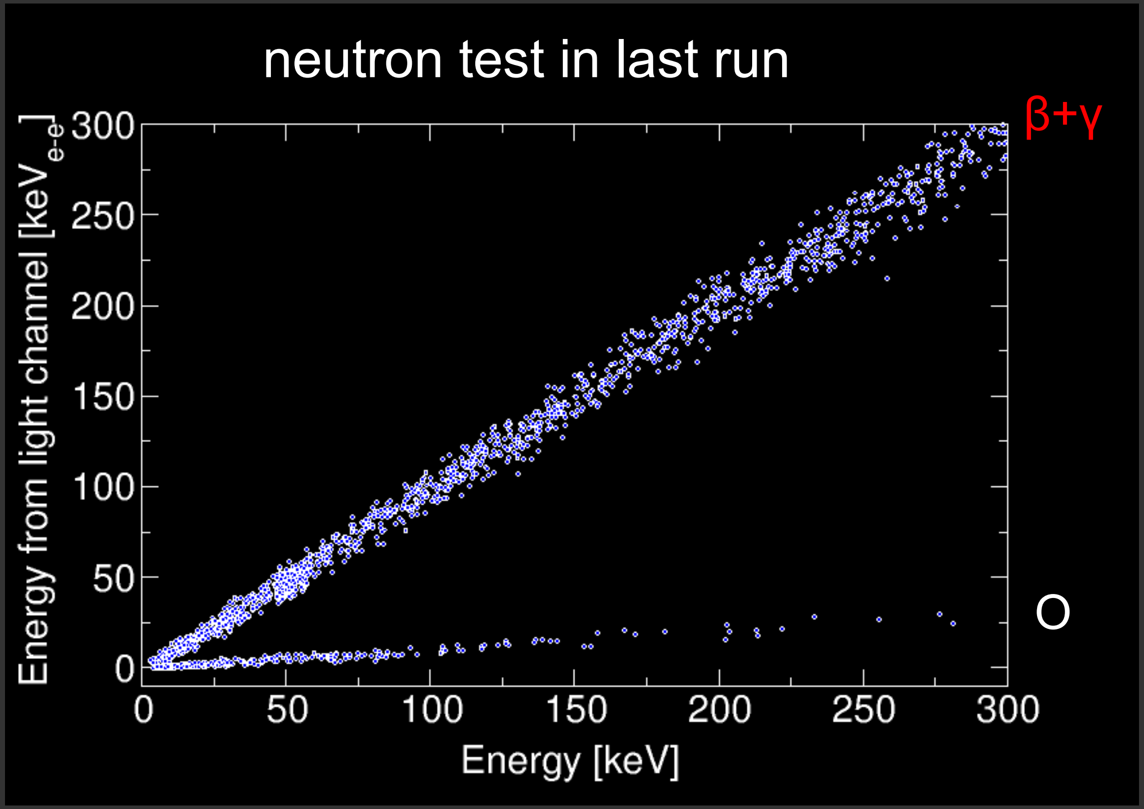
- $\sigma \propto A^2$
- detection in 12 to 40 keV range

- Tungsten dominates at larger WIMP masses due to $\sigma \propto A^2$
- Calcium important around 10 GeV
- For M<10 GeV only oxygen above threshold

→ type of recoils, together with the recoil energy spectrum, offers very detailed information on mass of possible WIMP

CRESST Detectors



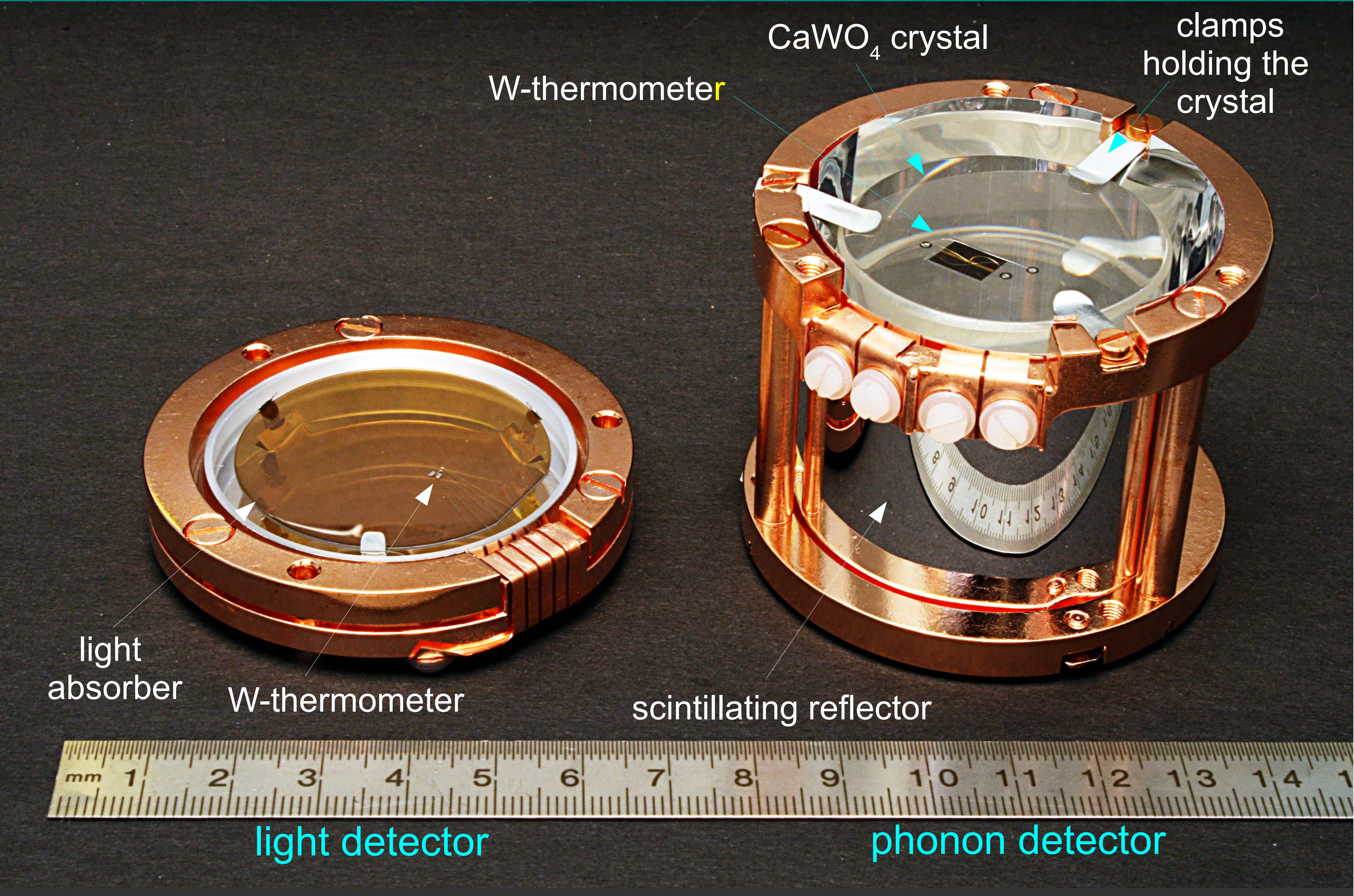


→ Phonon channel measures deposited energy with sub keV resolution and accuracy

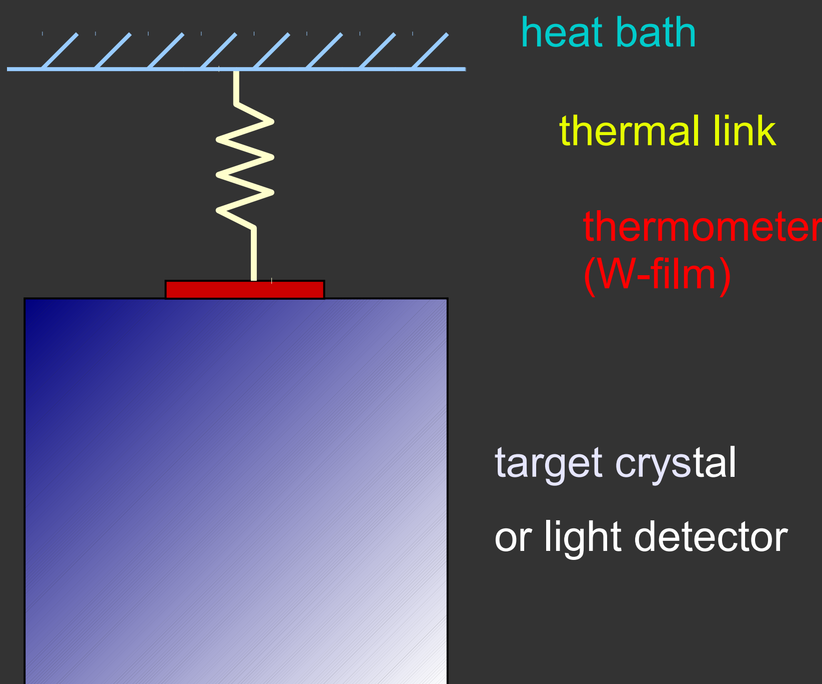
→ Light channel serves to distinguish types of interaction

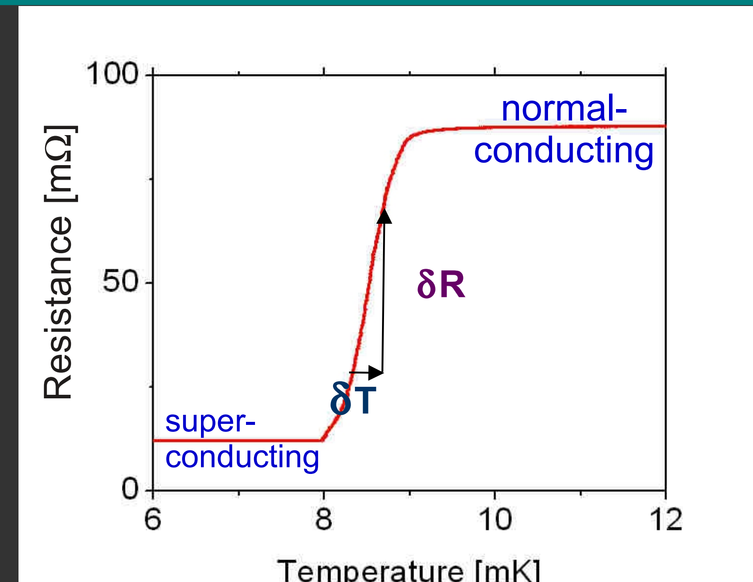
→ Types of recoiling nuclei distinguished by different slopes in energy-light plane

300 g Detector Module



CRESST type cryogenic calorimeters



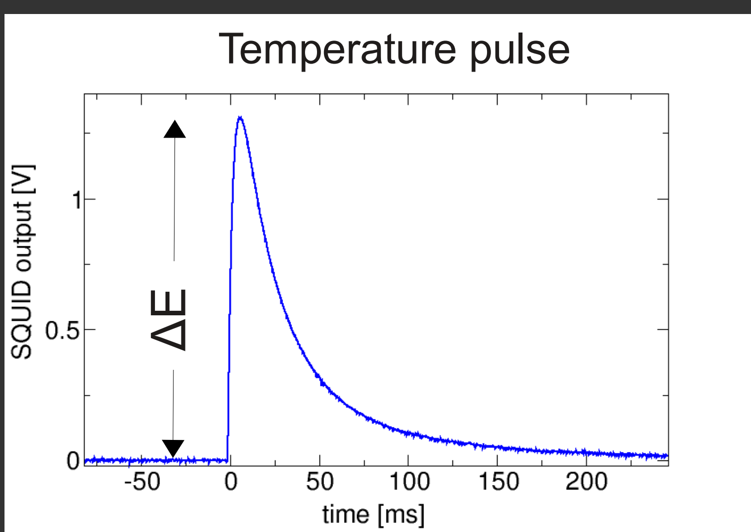


SQUID based read out

Operating temperature: 10 to 20 mK

Width of transition: ~1mK, keV signals: ~ µK

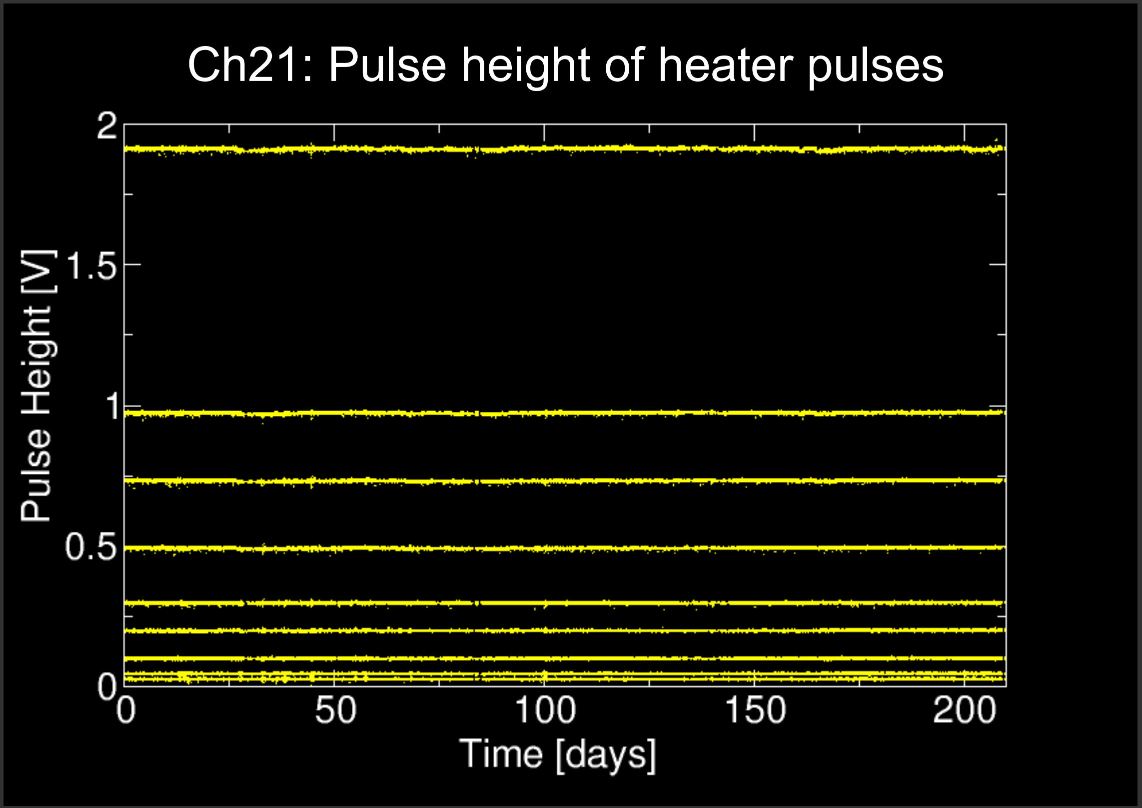
Longterm stability: ~ µK

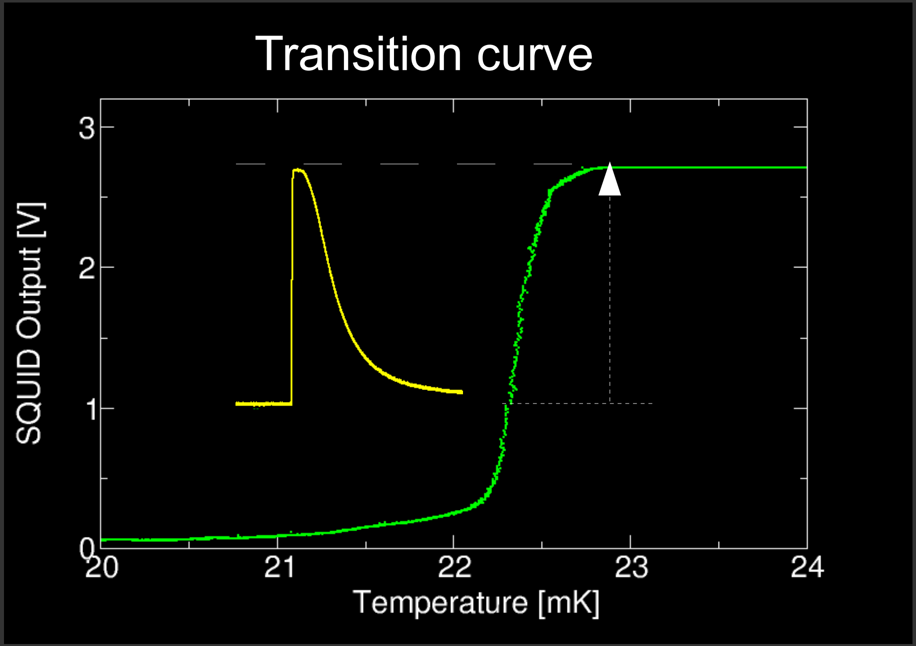


Advantages of technique:

- Precise calorimetric measurement of deposited energy
- Low energy threshold and excellent energy resolution
- Different materials

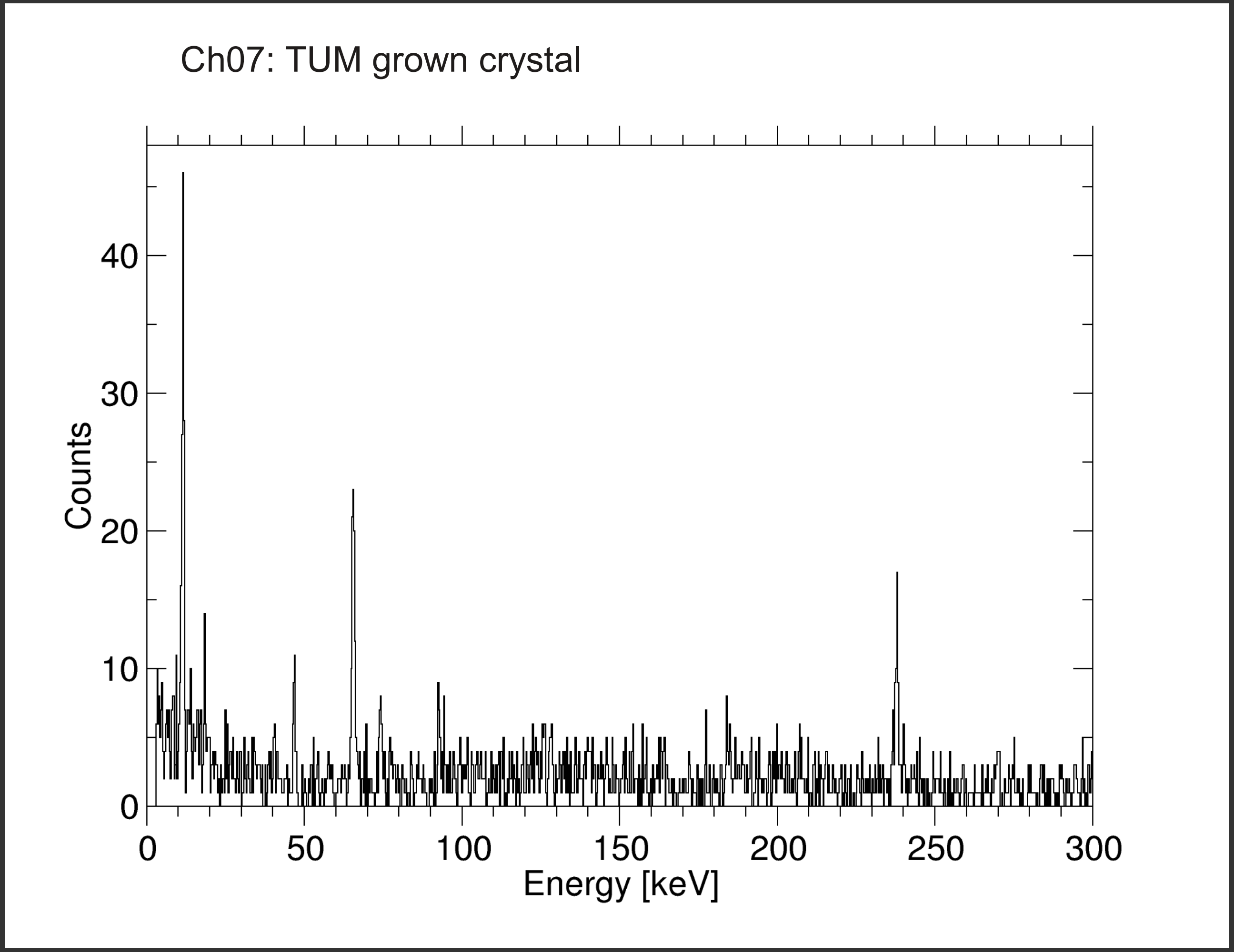
Stability of Energy Response





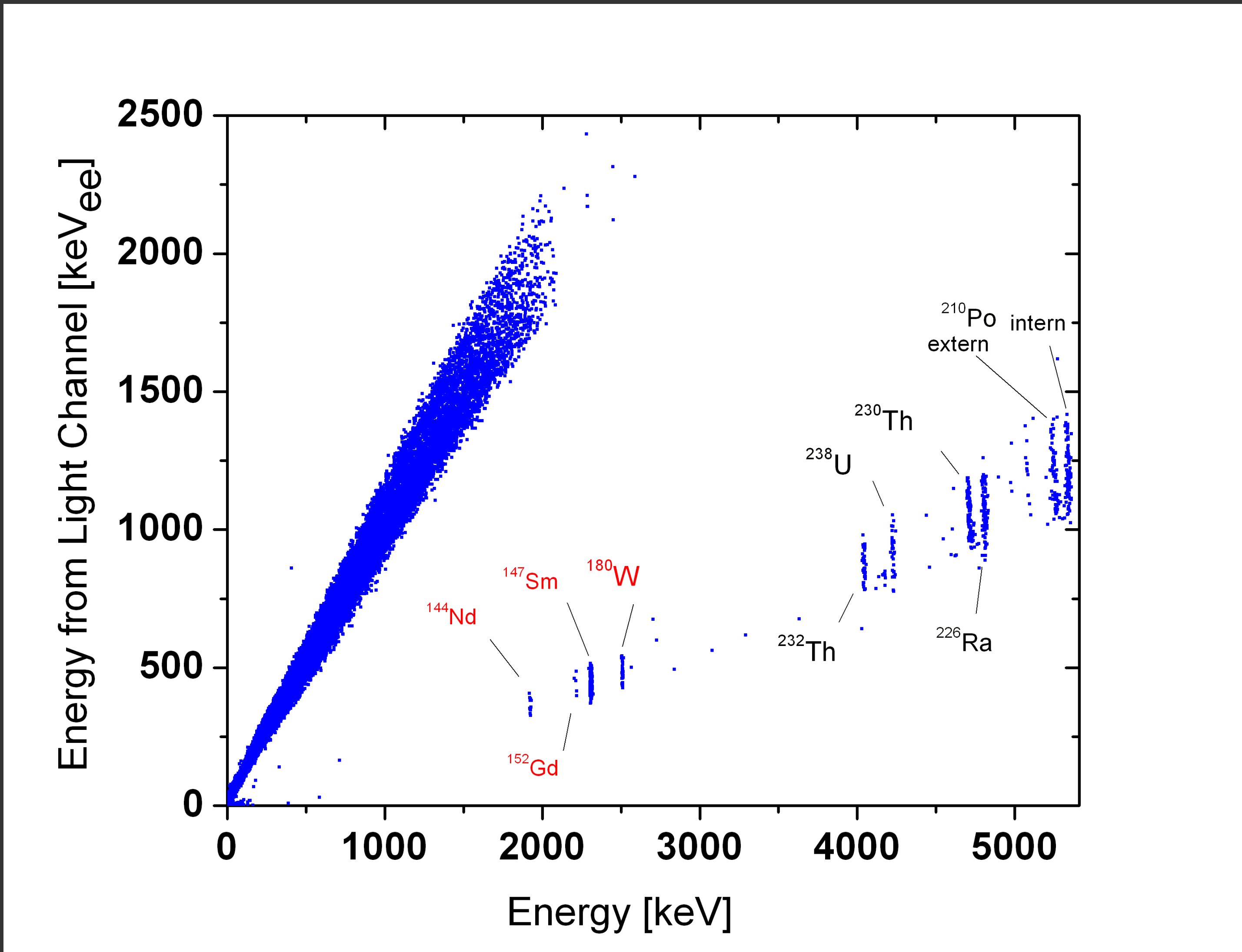
- Each W thermometer equipped with electrical heater
- Operating temperature controlled with large heater pulses
- Calibration continuously monitored with heater pulses
- Measure trigger efficiency close to hardware threshold (2 keV typical, 600 eV on some channels)

Detector performance at low energies



- excellent energy resolution (< 500 eV) and precise energy calibration at low energies

Detector Performance in wide energy range



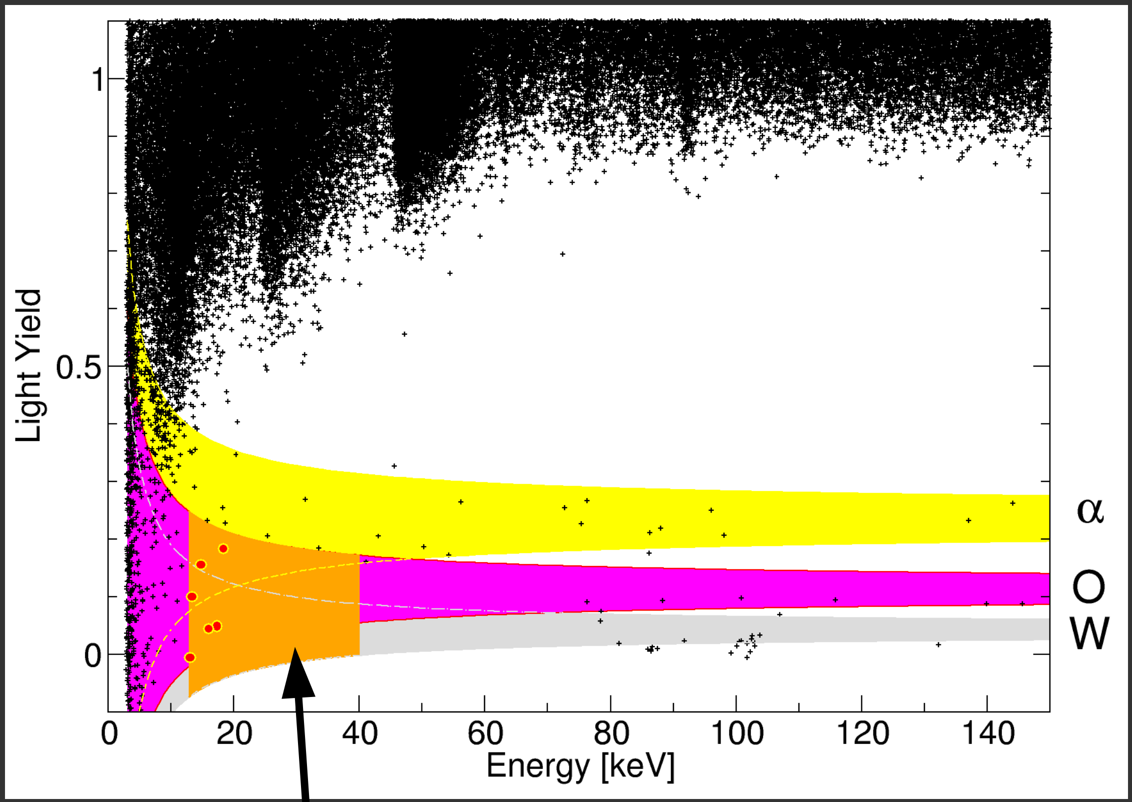
- Good energy resolution and linearity in wide energy range
- Identification of alpha emitters inside crystal

External and internal ^{210}Po peaks separately measure bulk and surface contamination

Discrimination of Event Types

$$Light\ Yield = \frac{E_{light}}{E_{phonon}}$$

Event types characterized by different light yield



- efficient discrimination of nuclear recoils from β/γ-background
- WIMP signals expected in nuclear recoil bands at E<40 keV

WIMP search region ROI includes O, Ca, and W bands

The previous CRESST run

- Extended physics run from June 2009 to April 2011
- 8 $CaWO_4$ modules used for Dark Matter analysis
- Net exposure after cuts: 730 kg days
- 67 events observed in WIMP search region
- Data analyzed with 2d likelihood fit of signal and background model

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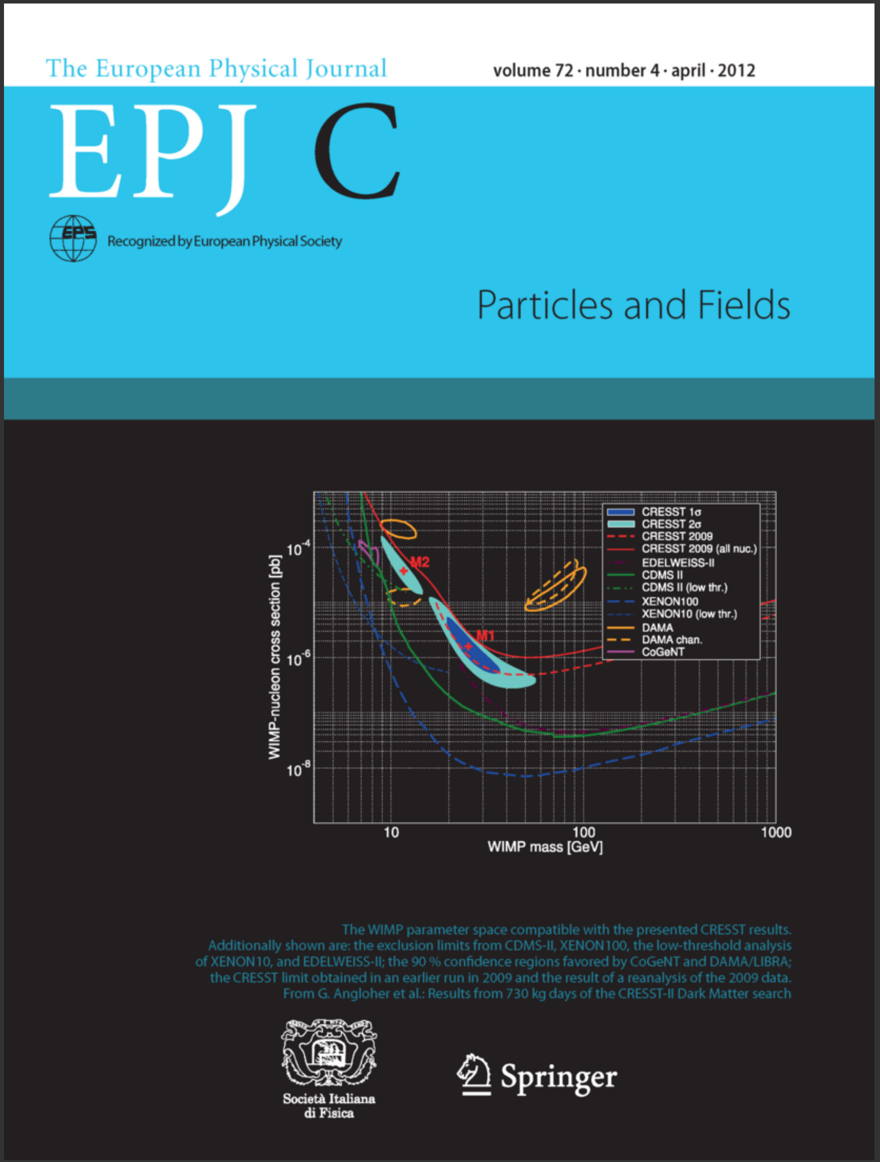


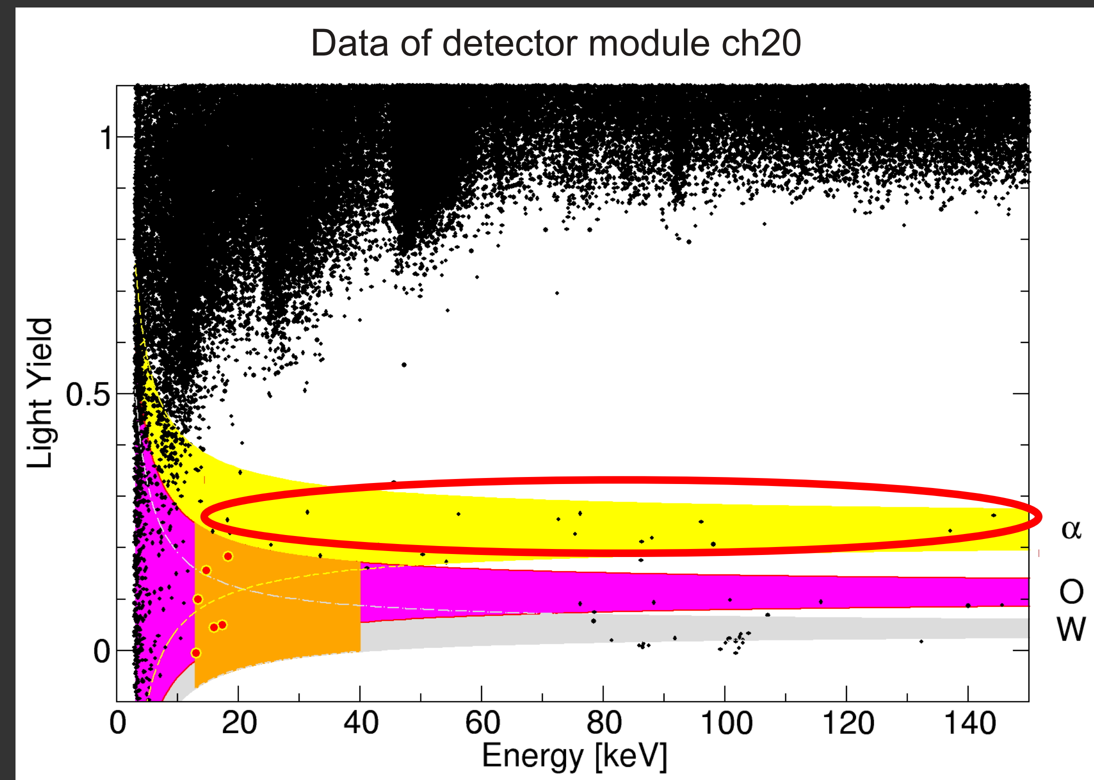
Results of likelihood analysis of previous run

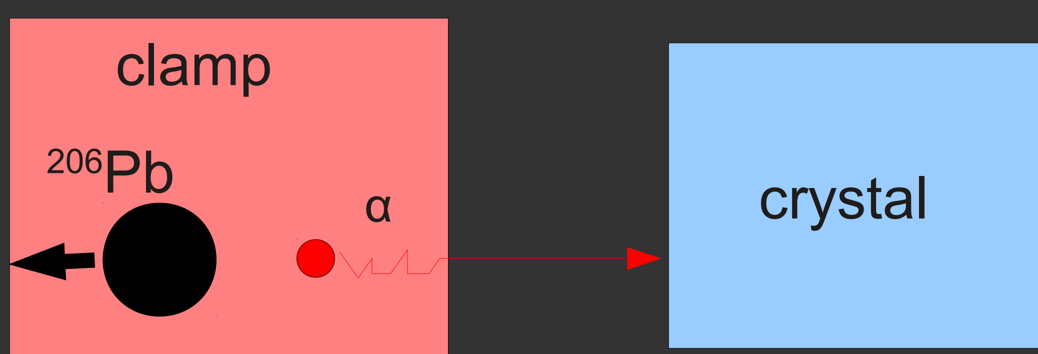
	M1	M2
e/γ-events	8.00 ± 0.05	8.00 ± 0.05
α-events	$11.5^{+2.6}_{-2.3}$	$11.2^{+2.5}_{-2.3}$
neutron events	$7.5^{+6.3}_{-5.5}$	$9.7^{+6.1}_{-5.1}$
Pb recoils	$15.0^{+5.2}_{-5.1}$	$18.7^{+4.9}_{-4.7}$
signal events	$29.4^{+8.6}_{-7.7}$	$24.2^{+8.1}_{-7.2}$
m_χ [GeV]	25.3	11.6
σ_{WN} [pb]	$1.6 \cdot 10^{-6}$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

- Background only hypothesis rejected with rather high statistical significance (>4σ)
- Background contributions still relatively large
- Reduction is necessary for ultimate clarification
  → next run

α-background in previous run

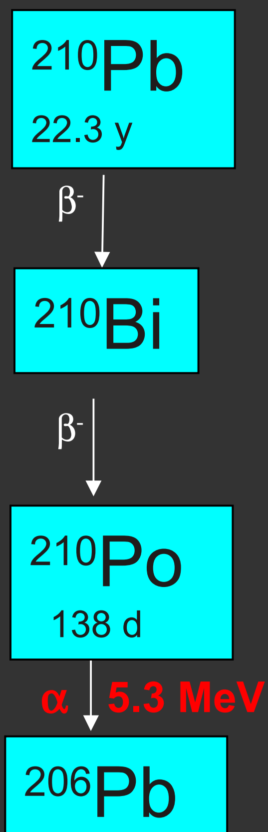
- α-events at low energies down to ROI from ^{210}Pb contamination of bronze material of clamps

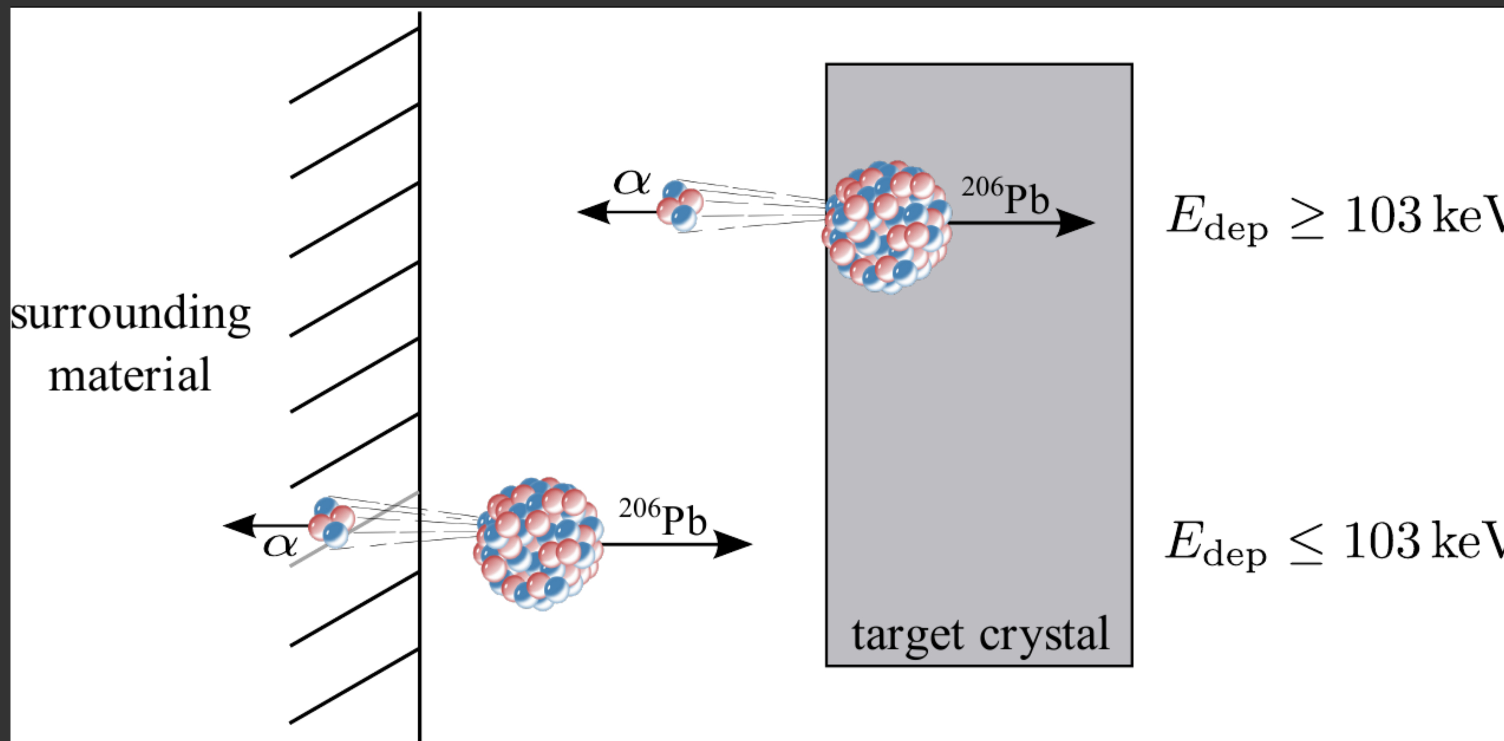




^{206}Pb Recoils from α-Decays on inner Surface

^{210}Pb is first long lived isotope in chain after ^{222}Ra

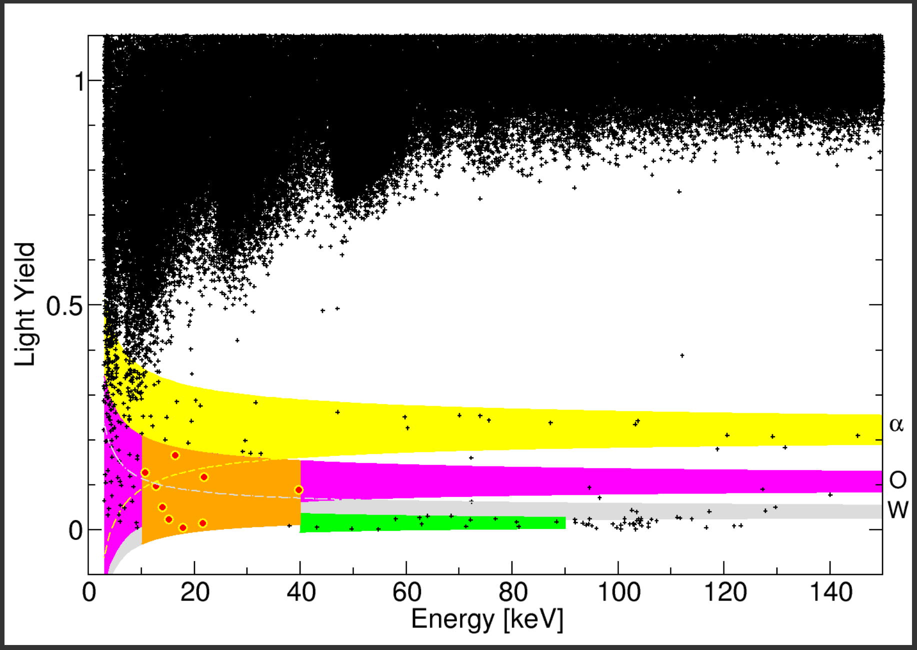


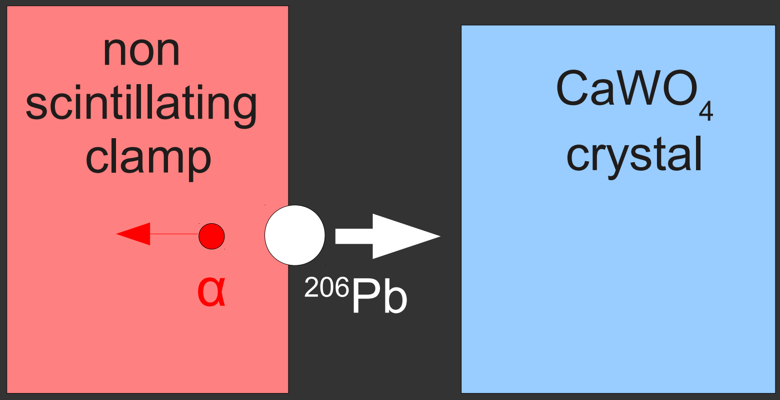


- ^{210}Pb on surfaces of crystal and surrounding material
- ^{206}Pb recoils with E<100 keV from surrounding surfaces
- Light yield of Pb similar to W recoils
- Extra light from alpha in completely scintillating housing would allow to veto all ^{206}Pb recoils
- previous **run: clamps only non scintillating surface inside module**

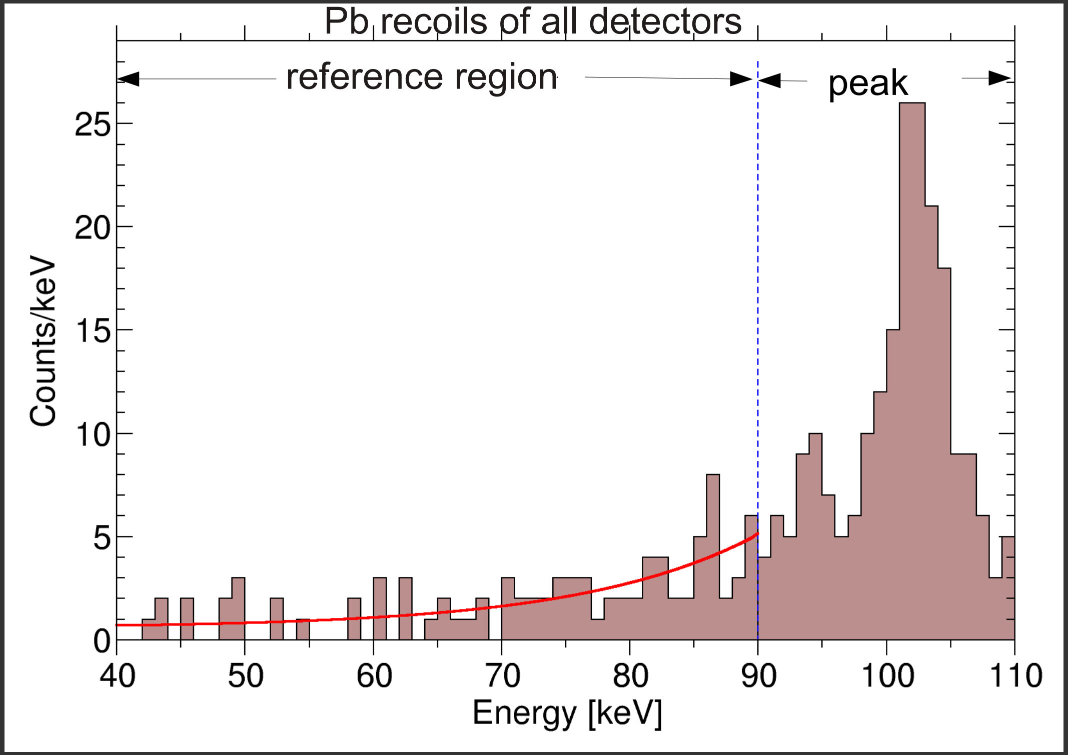
^{206}Pb Recoil Background in last run

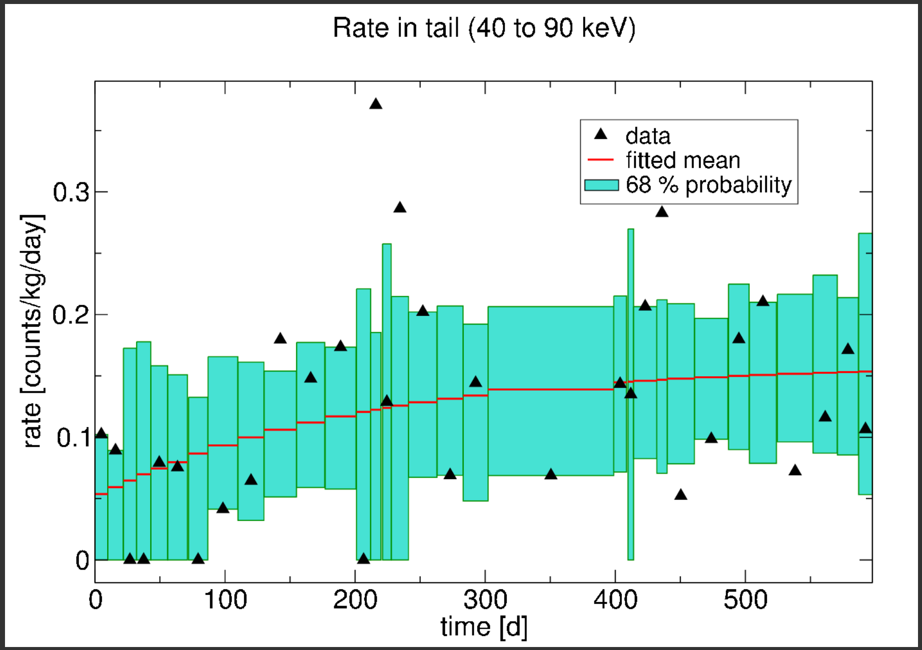
- Module with highest ^{206}Pb background
- Visible tail of ^{206}Pb recoils in Pb-band, slightly below W-band, extending from ~100 keV to ROI





^{206}Pb recoil background from surface of clamps





$^{210}Pb \xrightarrow{22.3\ y} {}^{210}Bi \rightarrow {}^{210}Po \xrightarrow{138\ d} {}^{206}Pb + 5.4\ MeV\ \alpha$

- Rate in tail increases with half life of ^{210}Po (138 d)

→ ^{210}Pb deposited at surface of clamps shortly before beginning of run

→ Exposure of clamps to radon in air most likely responsible for this background

Aims of the present run

- Completely eliminate low energy alpha background

- Reduce ^{206}Pb recoil background from surface alpha decays significantly (~factor of 10)

- Improve shielding of external neutrons by factor of ~10 by additional neutron shield inside Pb/Cu shield

→ Signal events should clearly dominate

- Increase of exposure:
  18 installed modules should roughly double target mass

Reduction of α-background in present run

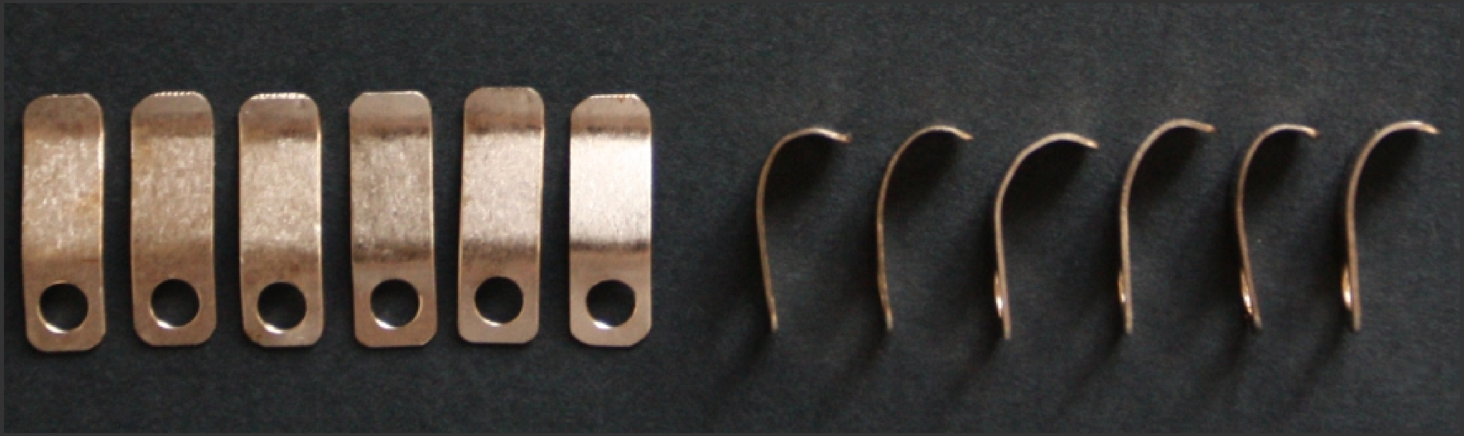
Low energy alphas in last run from contaminated bronze material of clamps

New $CuSn_6$ clamps to avoid this background

→ ultra pure (7n) Sn + low background Cu and careful monitoring of all production steps

→ Sputter coating with high purity Al (avoid Po problem with electrolytically deposited Ag)

→ no contact with radon polluted air after fabrication



Expect to strongly reduce alpha background with these new clamps

Reduction of Pb recoil background in present run

- Background of Pb recoils in last run due to radon exposure of clamps after production

Staged strategy:

1) Avoid any radon exposure of clamps and detector material after production
   → Detector modules assembled in clean room facility in CRESST building at Gran Sasso under particle free condition in radon free air
   → Detector modules mounted in cryostat in radon free air
   → Reflecting foils and scintillator rings of 6 modules covered with parylene to reset radon exposure history of reflecting foil

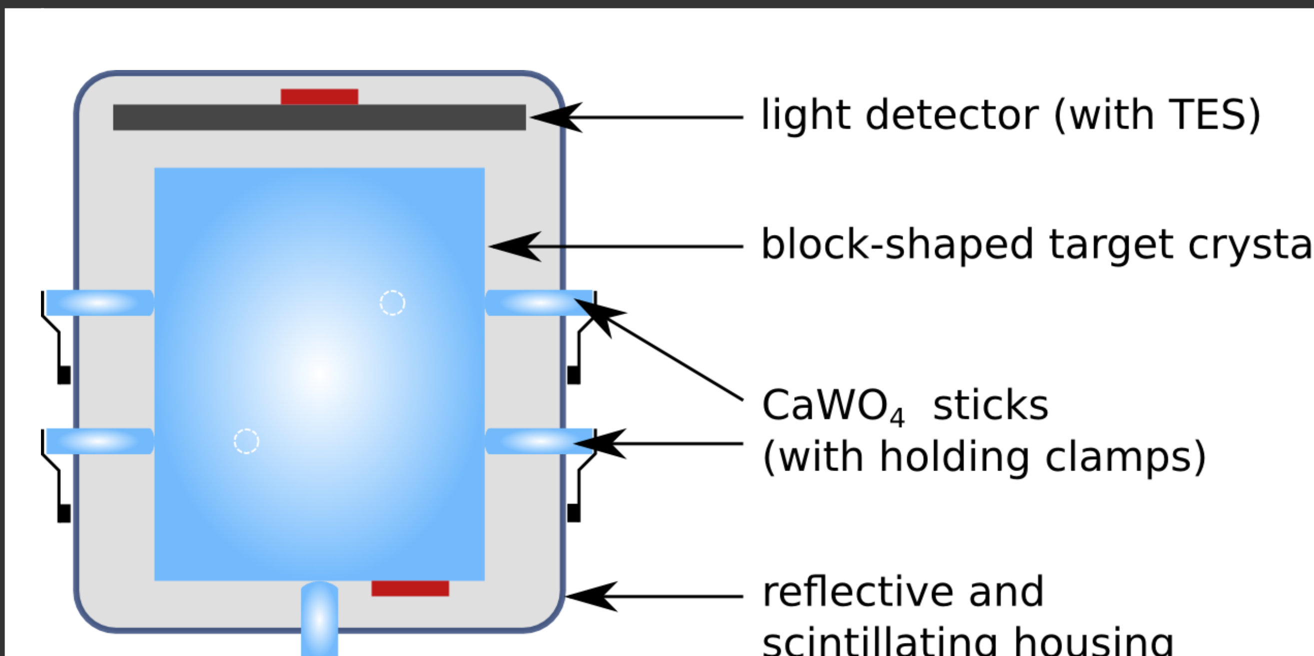
   12 conventional modules in present run entirely relying on radon prevention

2) New detector layouts with active rejection of Pb recoils

   6 modules with 3 different designs in present run

Modules with active rejection of Pb recoils (1)

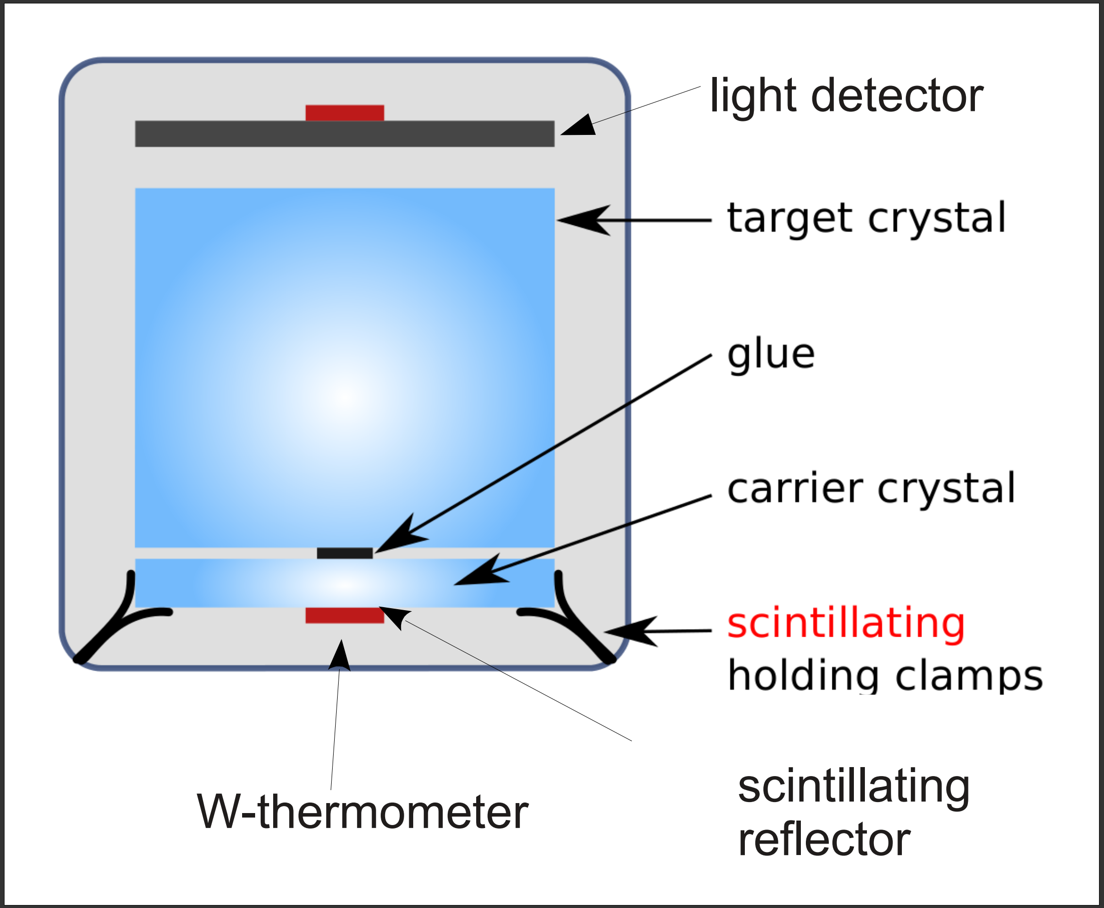
Fully scintillating design: Target crystal held by $CaWO_4$ sticks

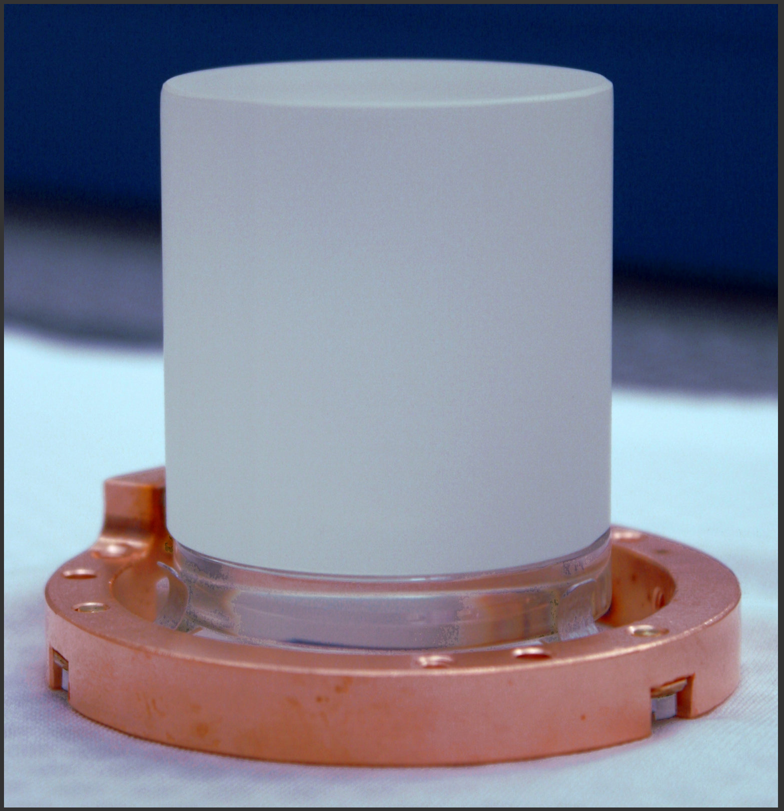


- All inner surfaces of the detector module are scintillating and each α-particle makes light
- Extra light of alpha particle lifts ^{206}Pb recoil above recoil bands

Module with active rejection of Pb recoils (2)

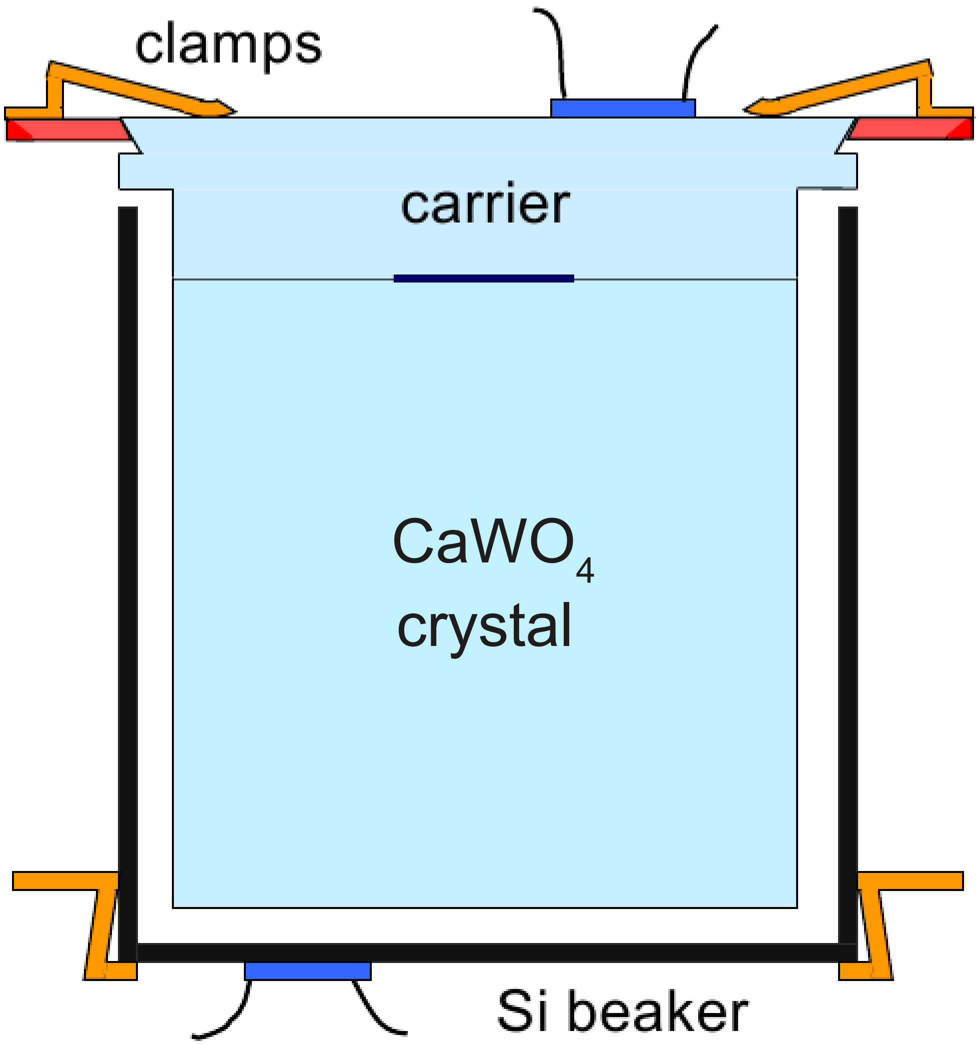
Fully scintillating housing: Crystal held by scintillating clamps on thermometer carrier





- Events in carrier and crystal have different pulse shape
- Relaxation events without light from scintillating plastic coverage of clamps can be distinguished

Modules with active rejection of Pb recoils (2)



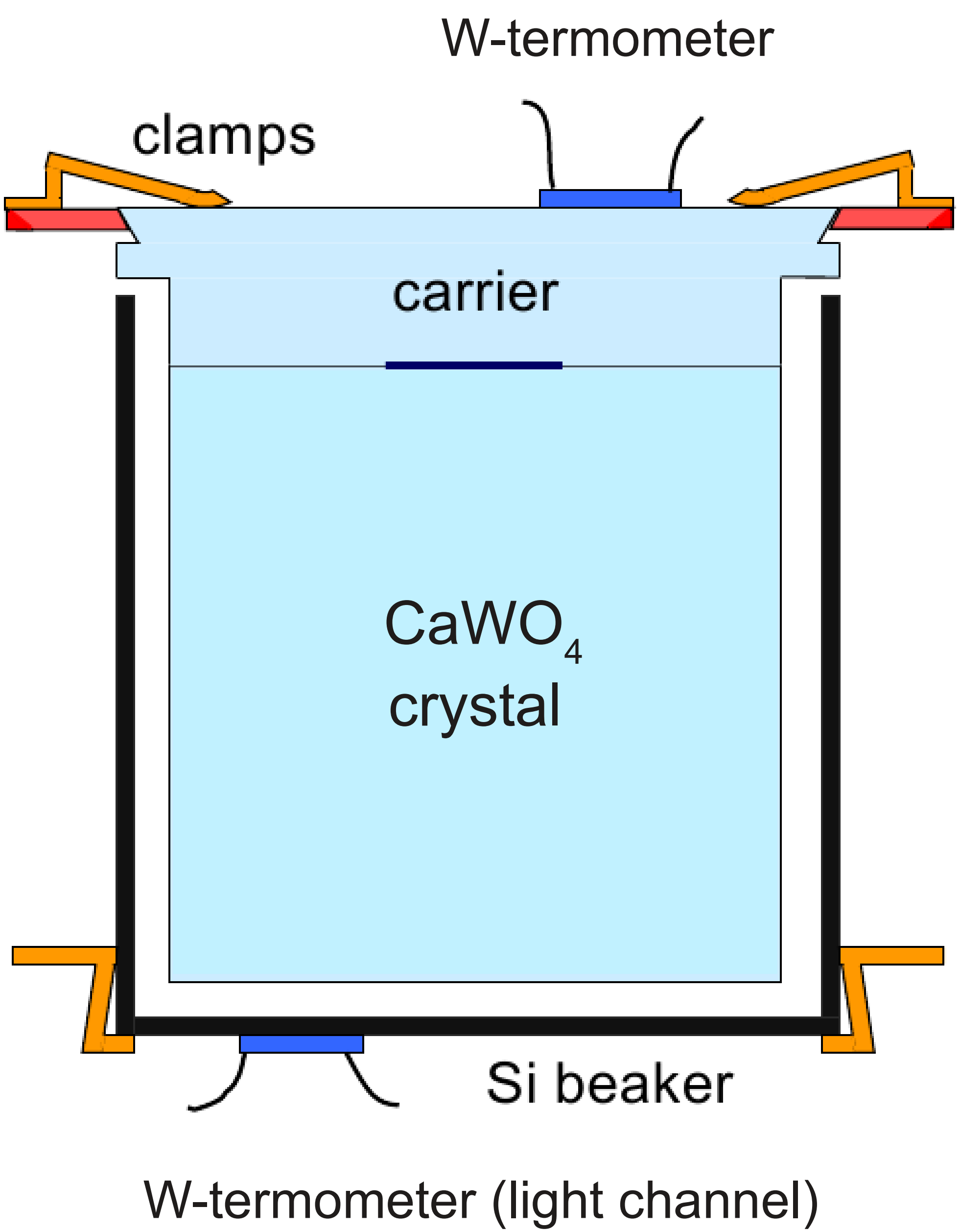
Full discrimination of recoils from alpha decay on surfaces:

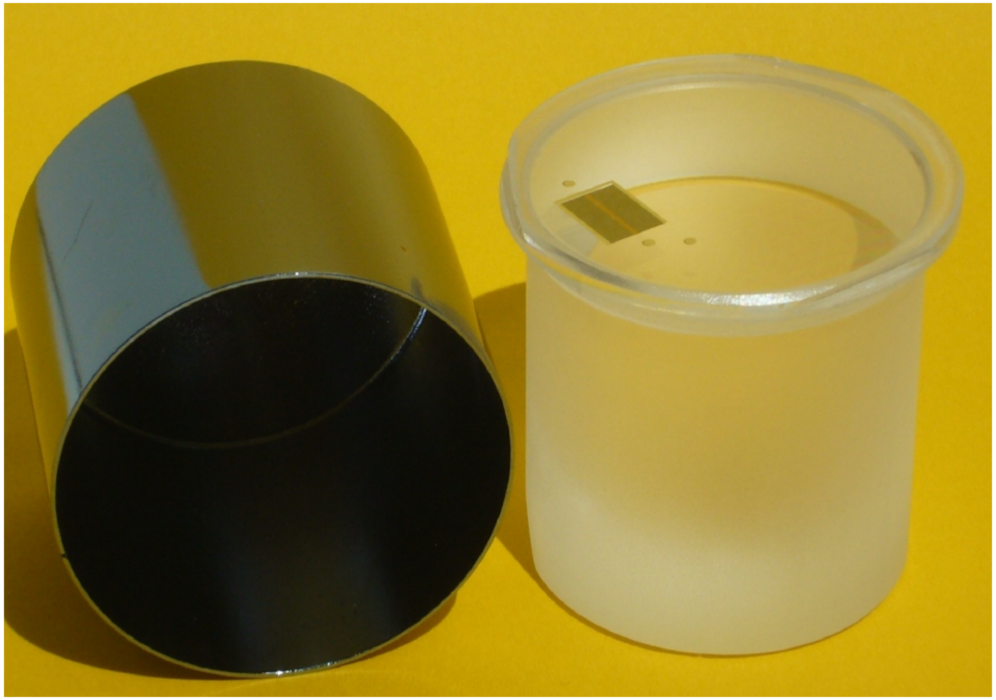
Inner surface:
Both, alpha and recoil nucleus deposit full energy in detector module

Outer surface:
Recoil or alpha reaches either carrier or Si beaker, not the $CaWO_4$ crystal

Concept requires:
Events in carrier can be efficiently discriminated by pulse shape of phonon signal

Modules with active rejection of Pb recoils





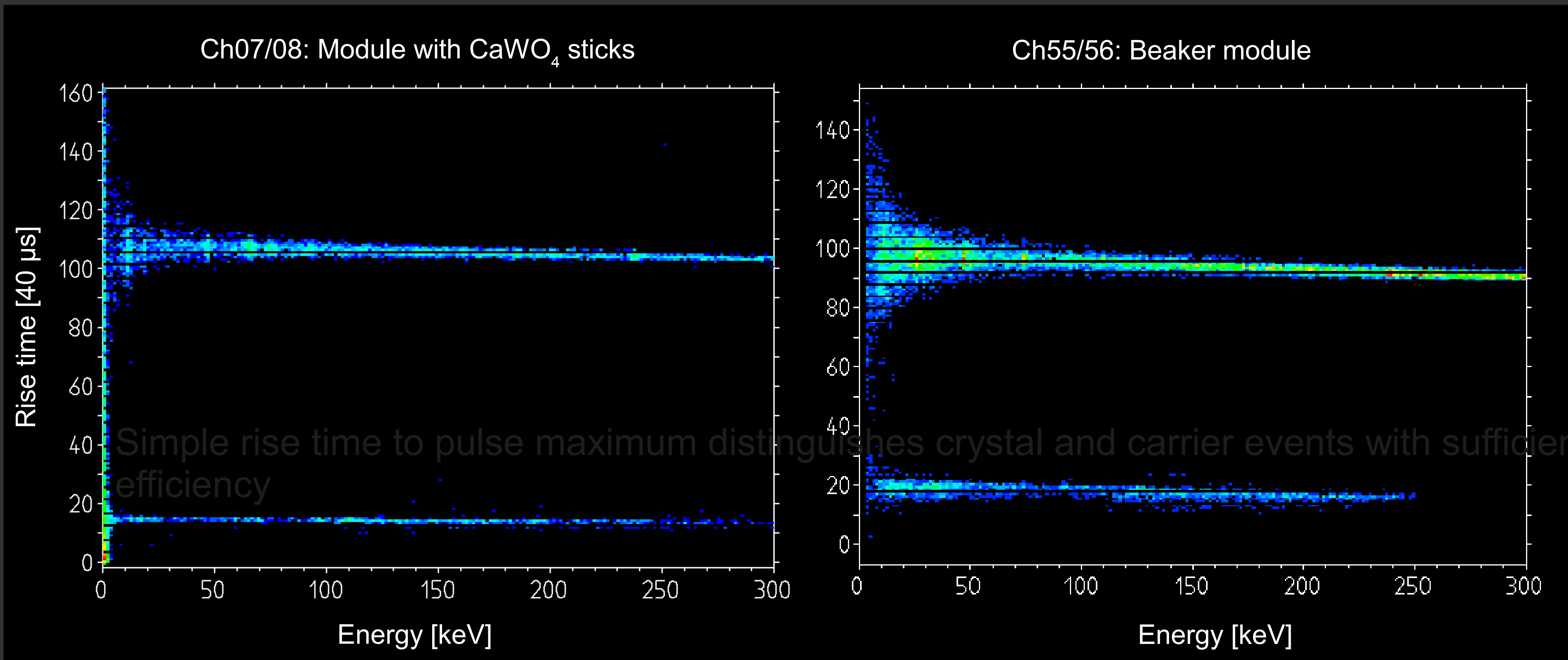
First glance at data of present run

Status of run 33:

- Cooling of crystat in May
- Setting up detectors and calibration in June and July
- Data taking since July 30
- Data until December will be used for defining cuts which then will be applied in later in blind analysis

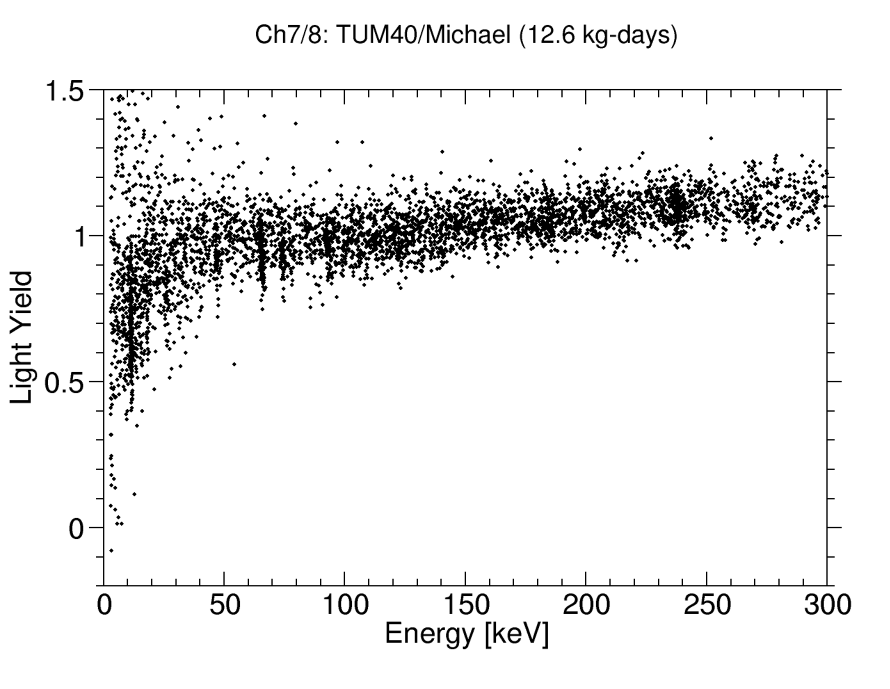
Will show some data from July 30 to October 9, **very preliminary !!**

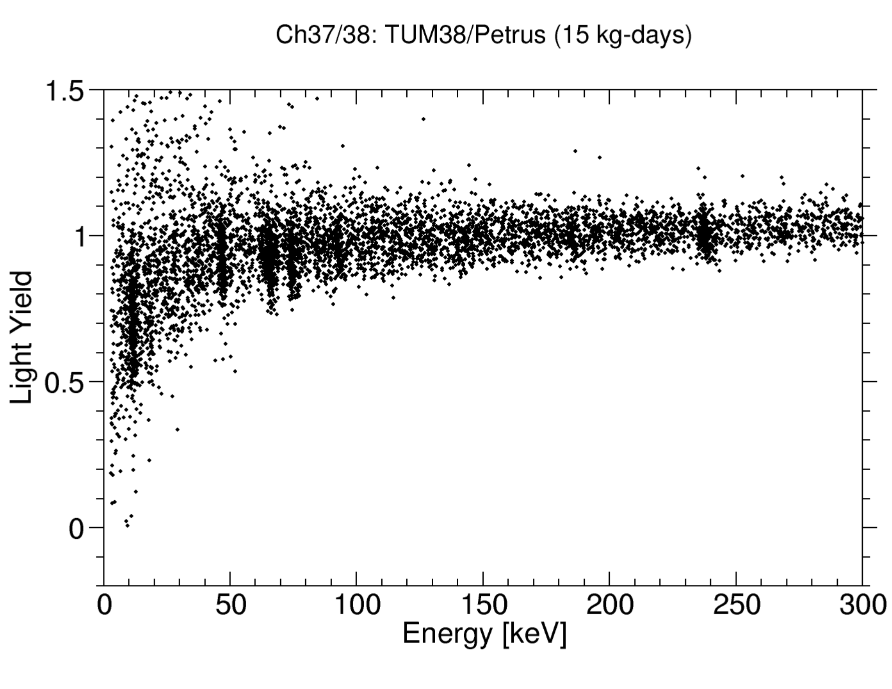
A first glance at the data: modules with active rejection

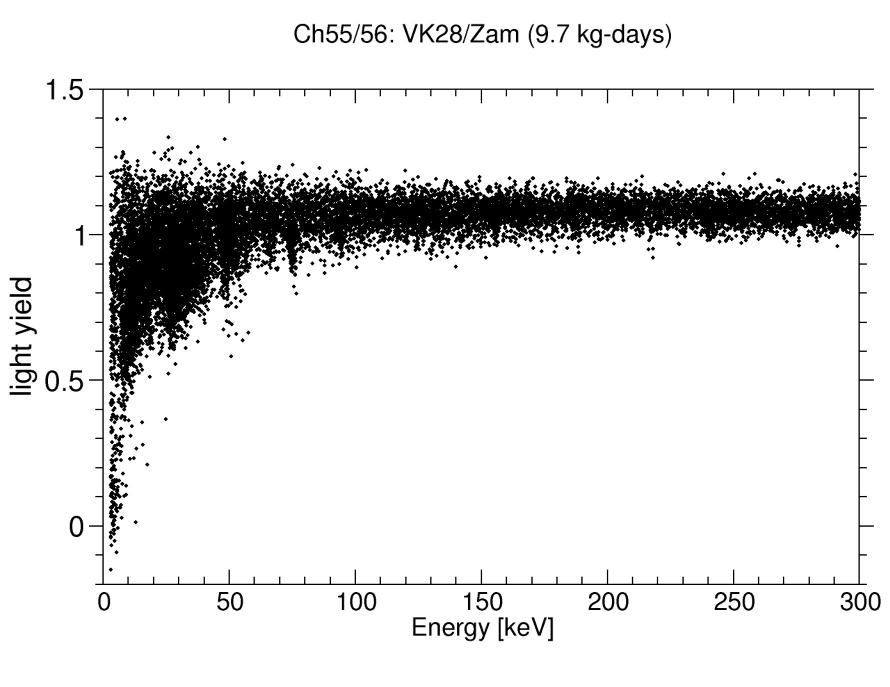


- Simple rise time to pulse maximum distinguishes events in thermometer carrier with sufficient efficiency

A first glance at the data: modules with active rejection

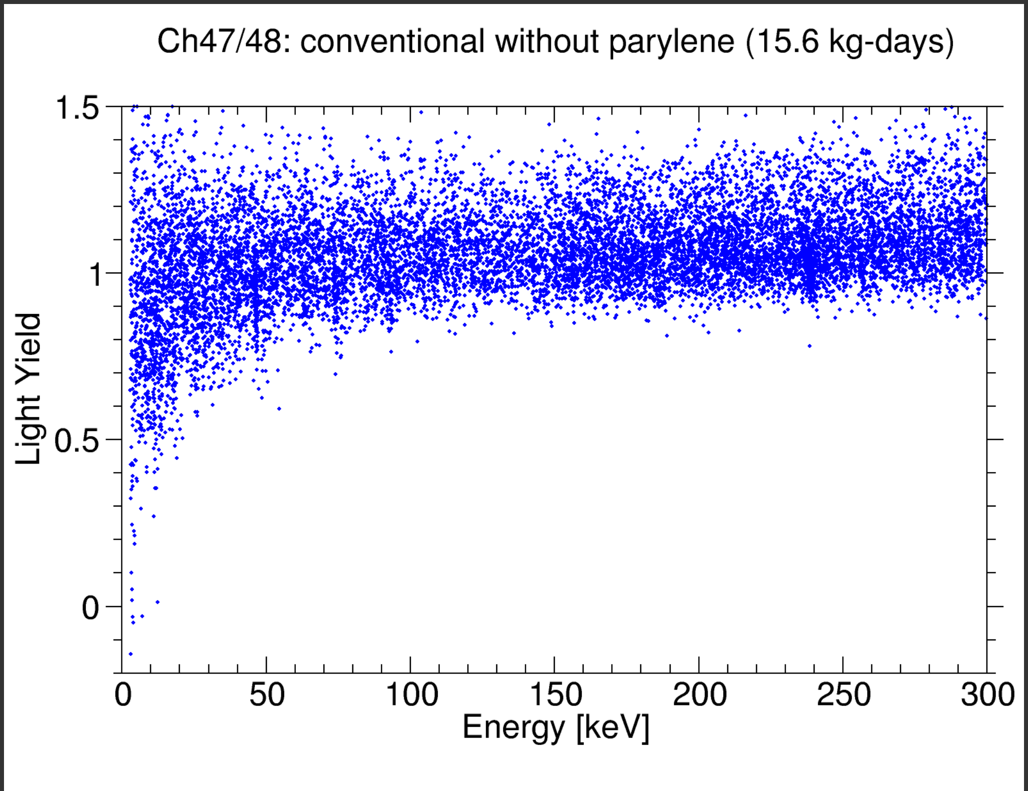


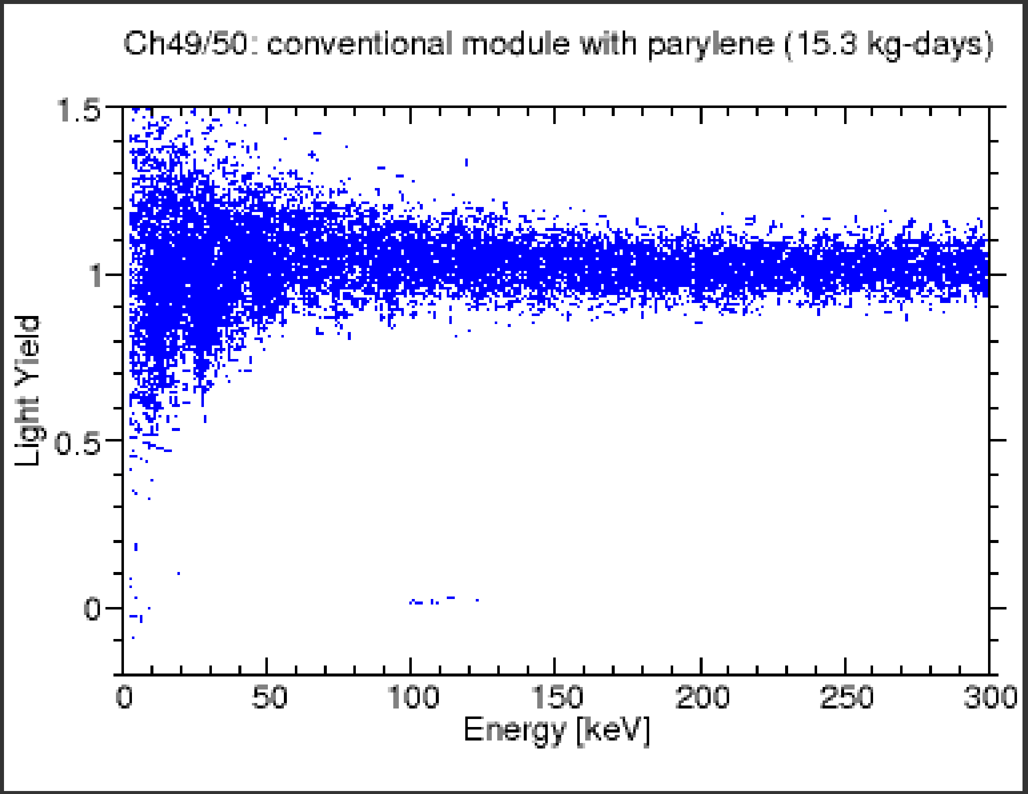




- No α or ^{206}Pb backgrounds in 37.3 kg days
- With rate of previous run :
  expected ~5 α's and 5 Pb recoils

Conventional modules relying on radon prevention

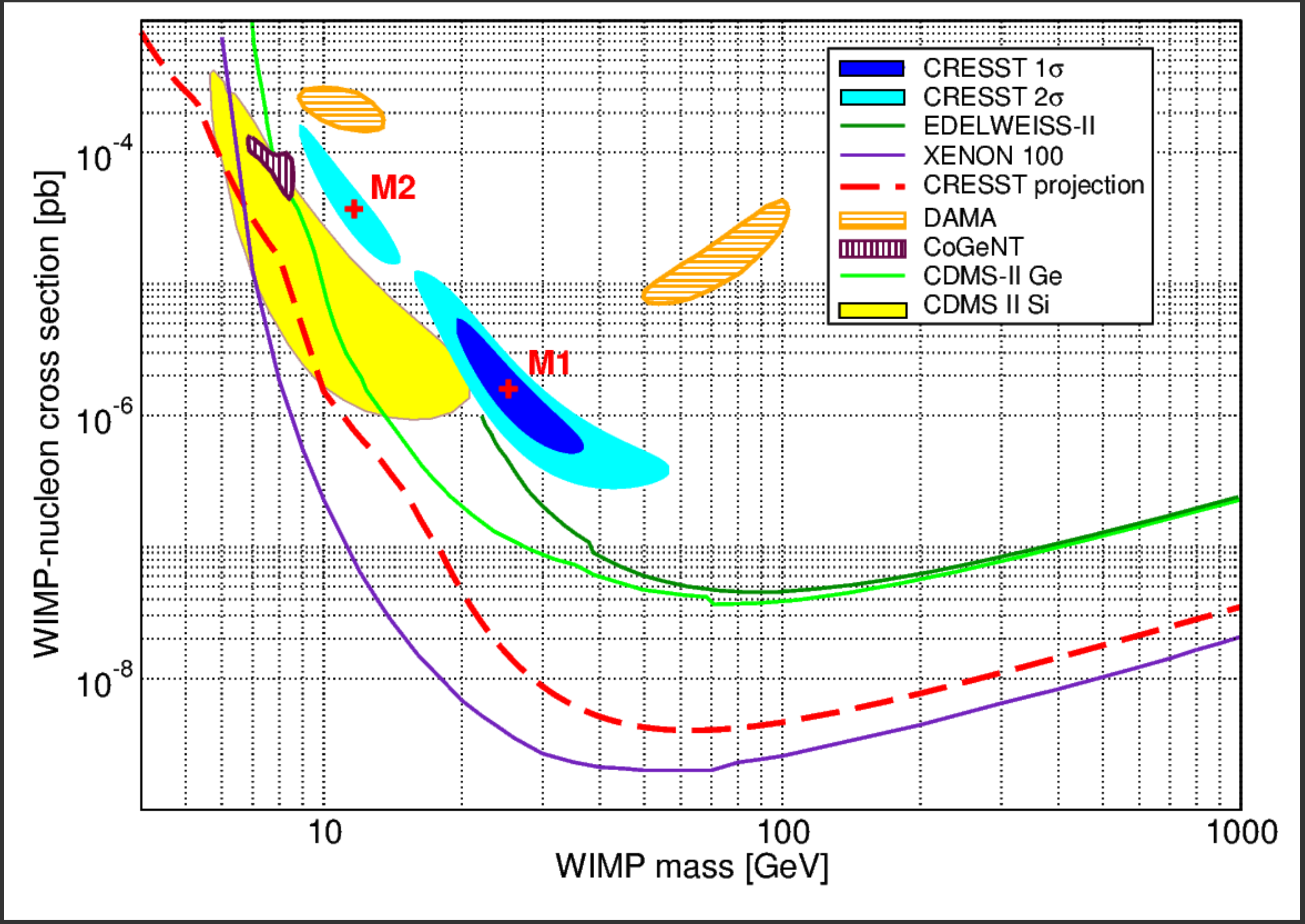




- Very likely background in conventional modules lower than in previous run
- One event in ROI in Ch49/50
- Pb recoils at or above 100 keV on Ch49/50 (as expected)
- Some conventional modules show events slightly below 100 keV, might be from ^{210}Pb on clamps or low yield foil events. Needs more exposure to fully understand

Status and Perspectives of new Run

- Data taking since August 2013
- Expect ~2000 kg-days of data within 2 years
- Either confirm or reject low mass WIMP scenario with high confidence
- Competitive limit for higher mass WIMPs if no low mass WIMP is found



Thank You