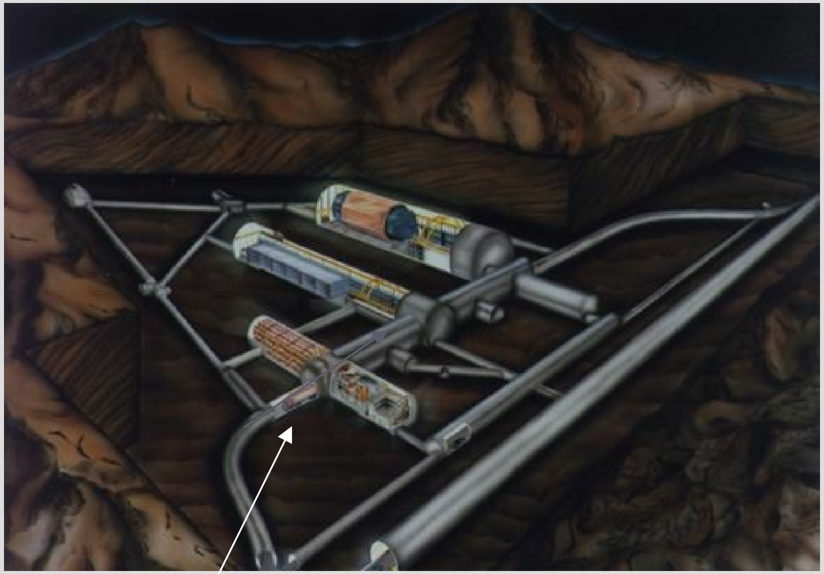
CRESST

Cryogenic Rare Event Search with Superconducting Thermometers



CRESST

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Technische Universität München

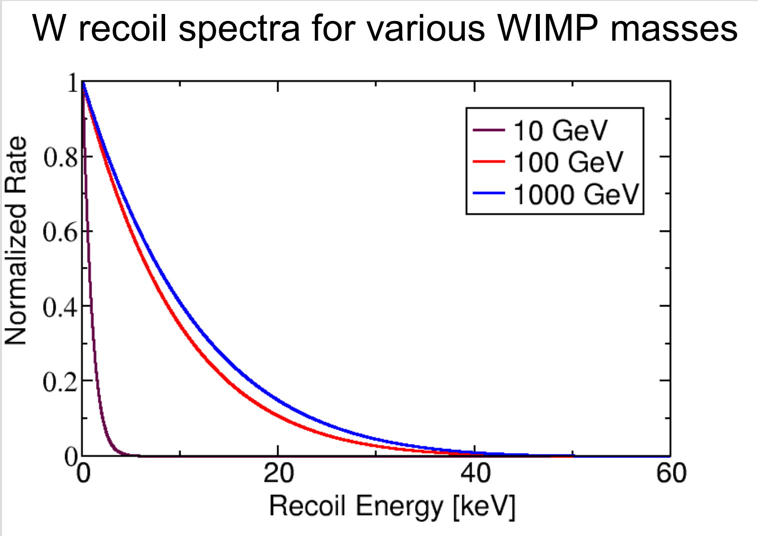
Laboratori Nazionali del Gran Sasso

Universität Tübingen

Outline

- Direct WIMP detection and CRESST detectors
- First results from present run (preliminary)
- Future

Detector Requirements for direct detection



- Small energy transfers to nucleus
- Featureless spectrum just above threshold
- Very low event rate < 0.1/kg/day. Large class of MSSM models predict 0.1 /kg/year to 0.1/kg/day

There is background

- Shielding: underground, lead+copper shielding,neutron shielding, muon-veto
- discrimination of β- and γ-background

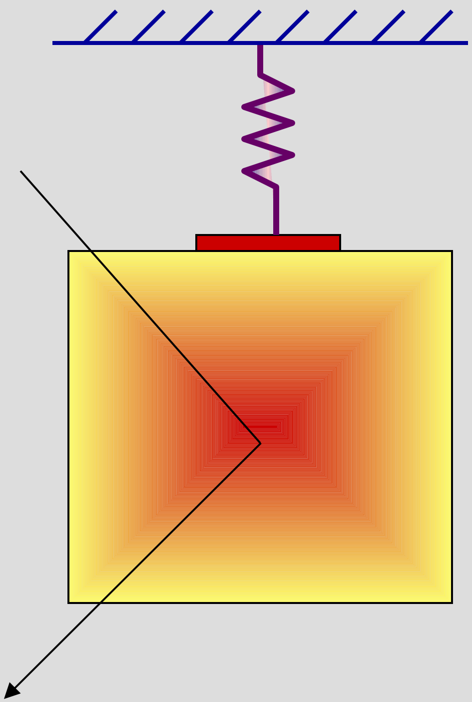
Identification of a WIMP-signal

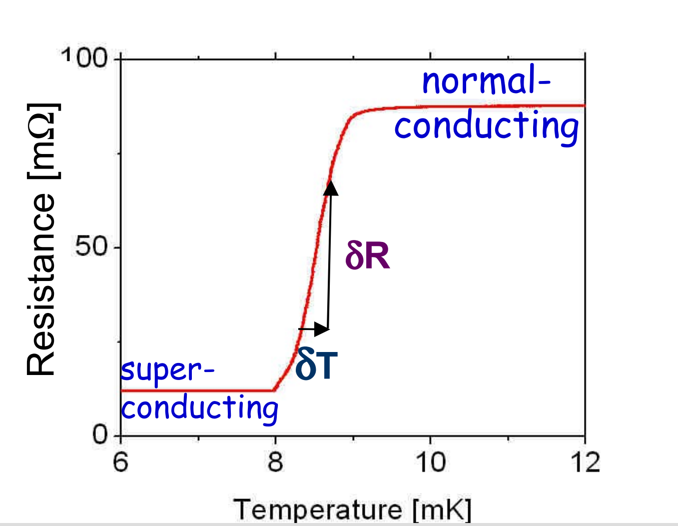
The trouble starts if you see a signal

- **Annual modulation**
  you have to prove that your background is constant in time !
  and your detector runs stable

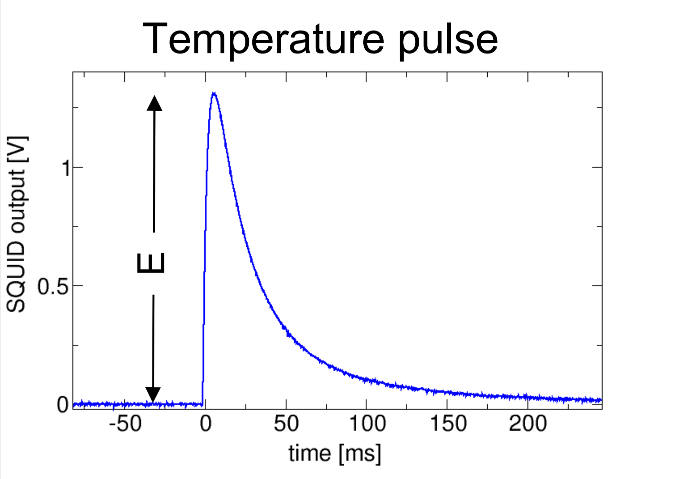
- **Use different target nuclei in same detector**
  cross section for background depends differently on target nucleus (mass) than WIMP-scattering
  unique feature of CRESST Detectors

CRESST type cryogenic Detectors





SQUID based read out circuit
Width of transition: ~1mK, keV signals: few μK
Longterm stablity: ~ μK

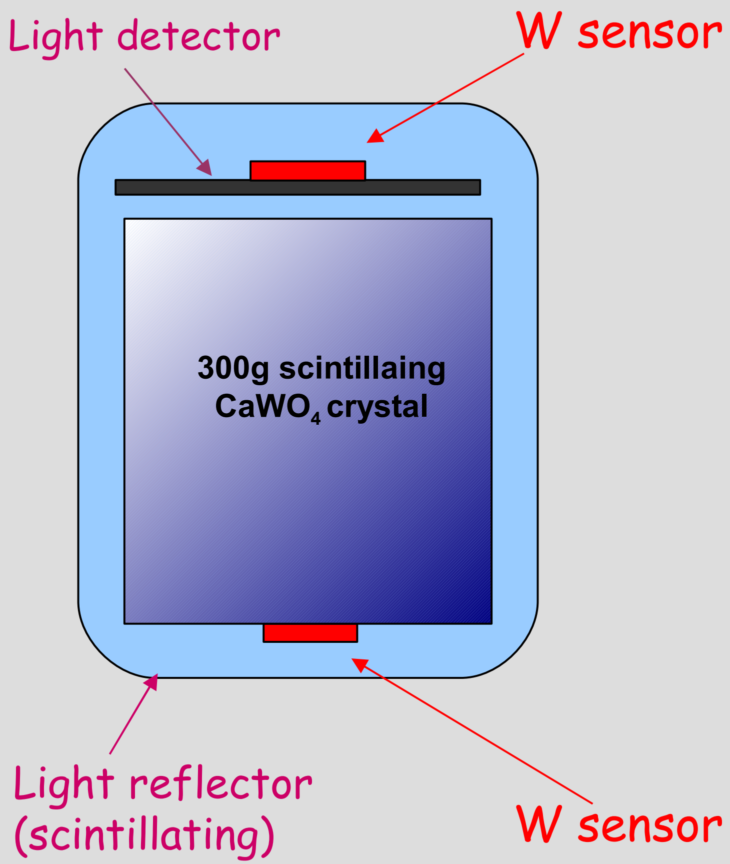


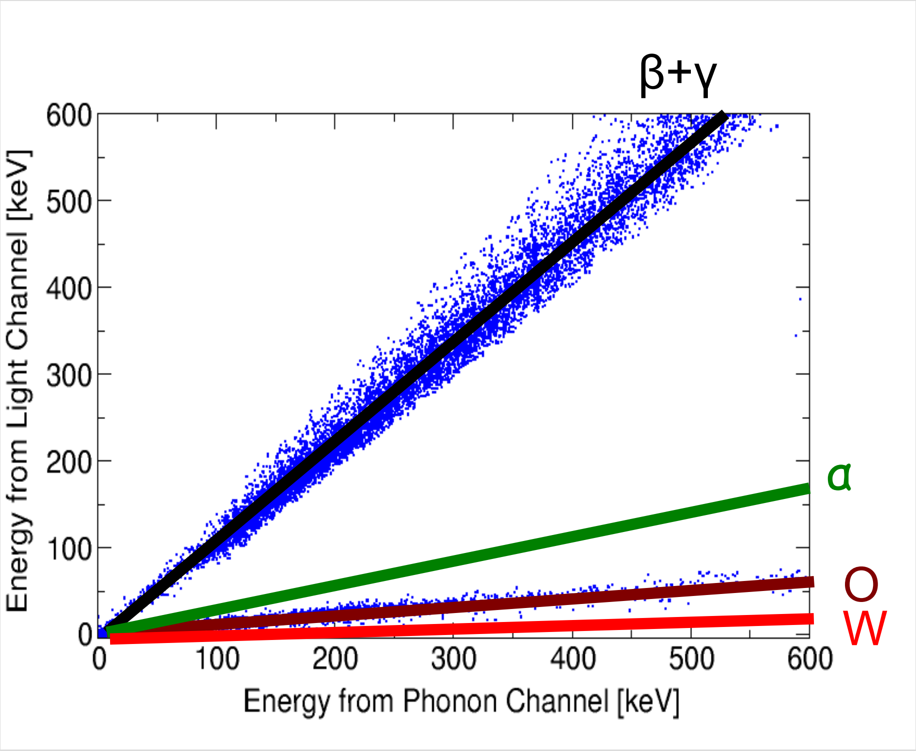
Advantages of technique:

- measures deposited energy independent of interaction type
- Very low energy threshold and excellent energy resolution
- Many different target materials

CRESST-II Detectors

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

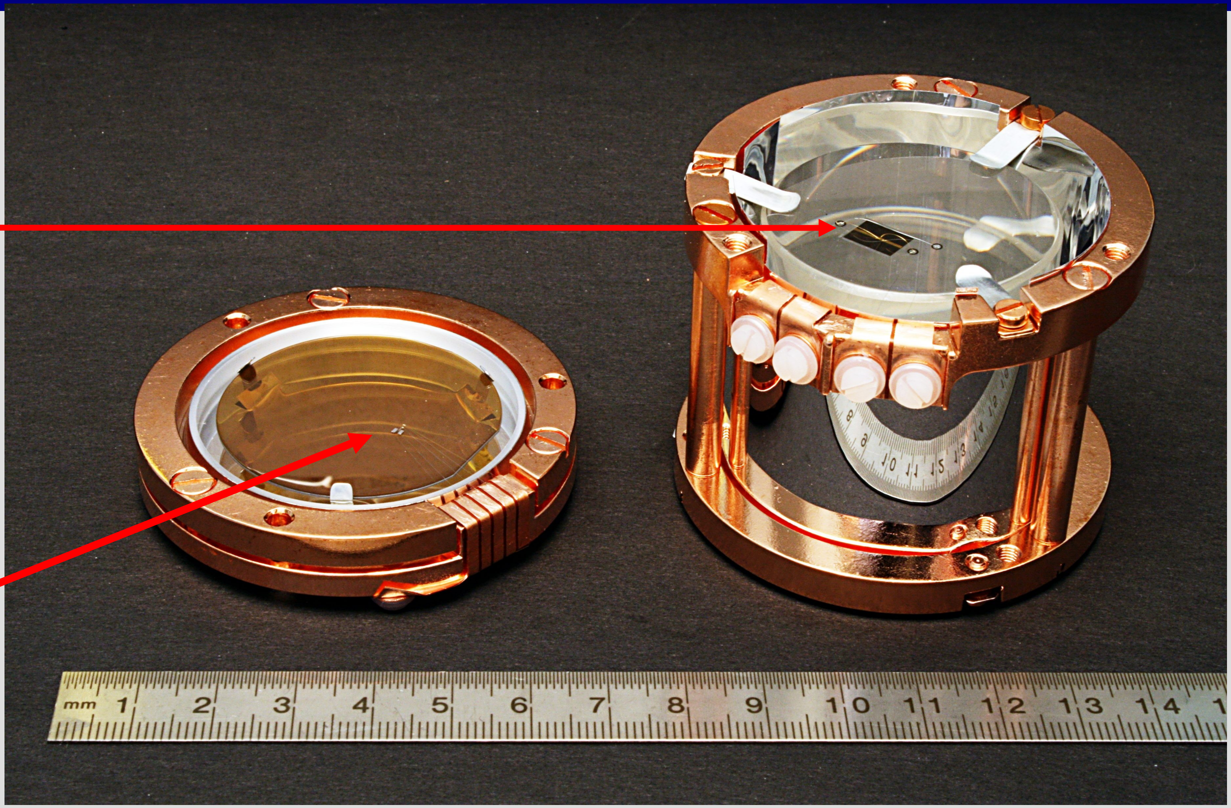


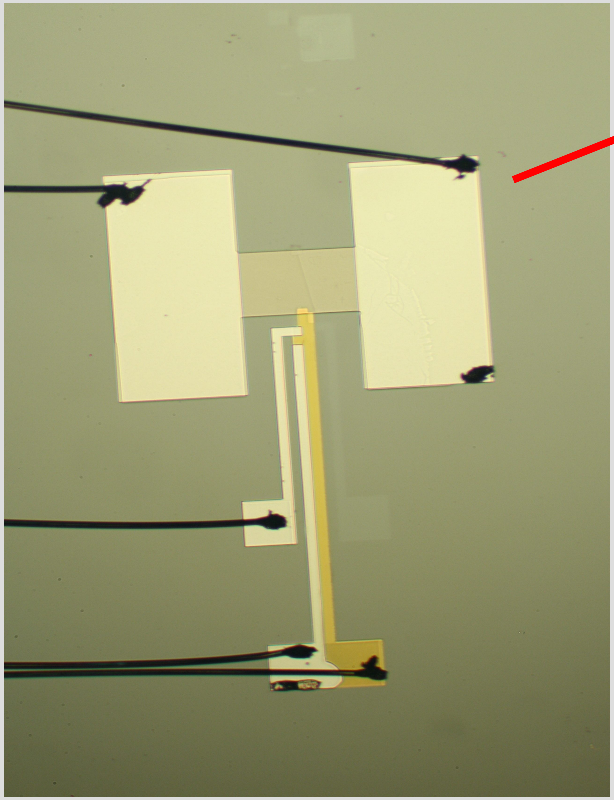


Discrimination between neutrons and WIMPs possible

300 g CRESST-II Detector Module

The phonon detector:
300 g cylindrical $CaWO_4$ crystal. Evaporated tungsten thermometer with attached heater.





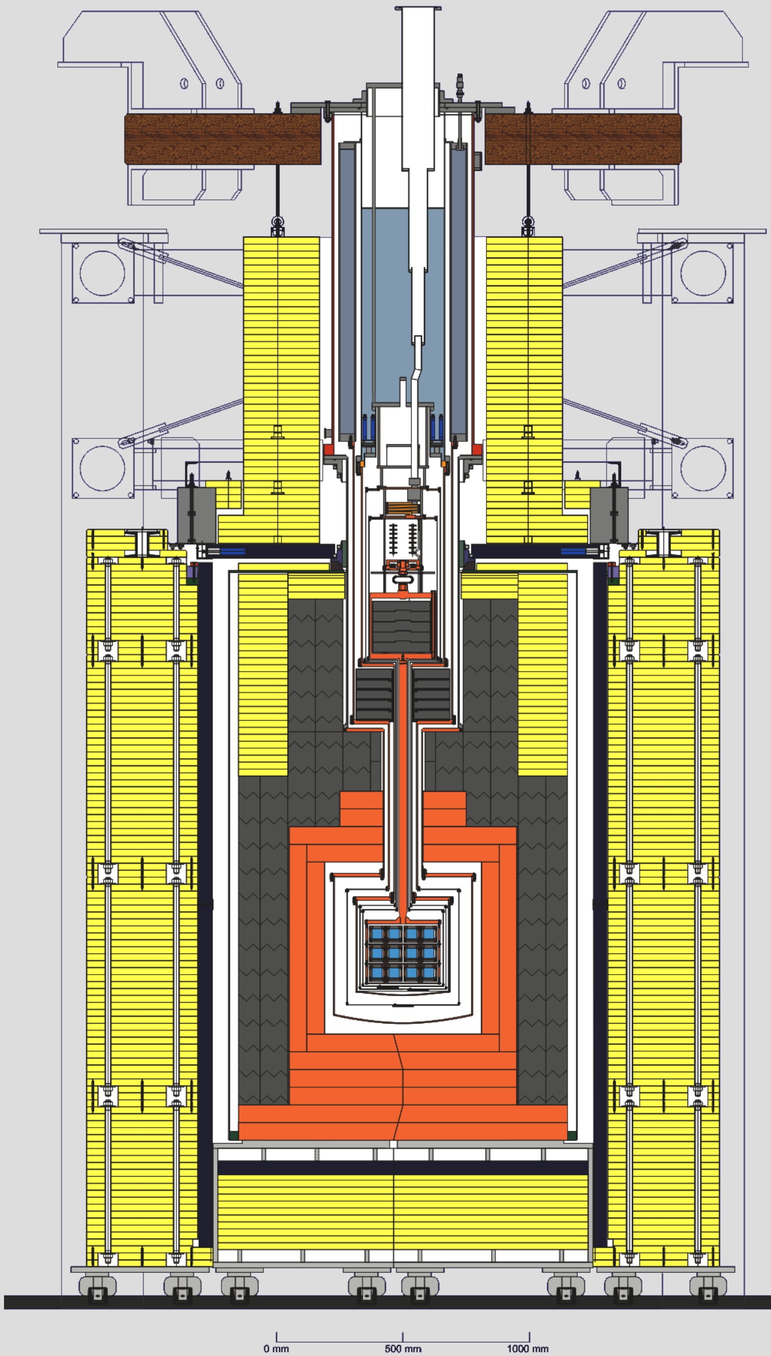
The light detector:
Ø=40 mm silicon on sapphire wafer.
Tungsten thermometer with attached aluminum phonon collectors and thermal link.
Part of thermal link used as heater

CRESST-II: up to 33 detector modules

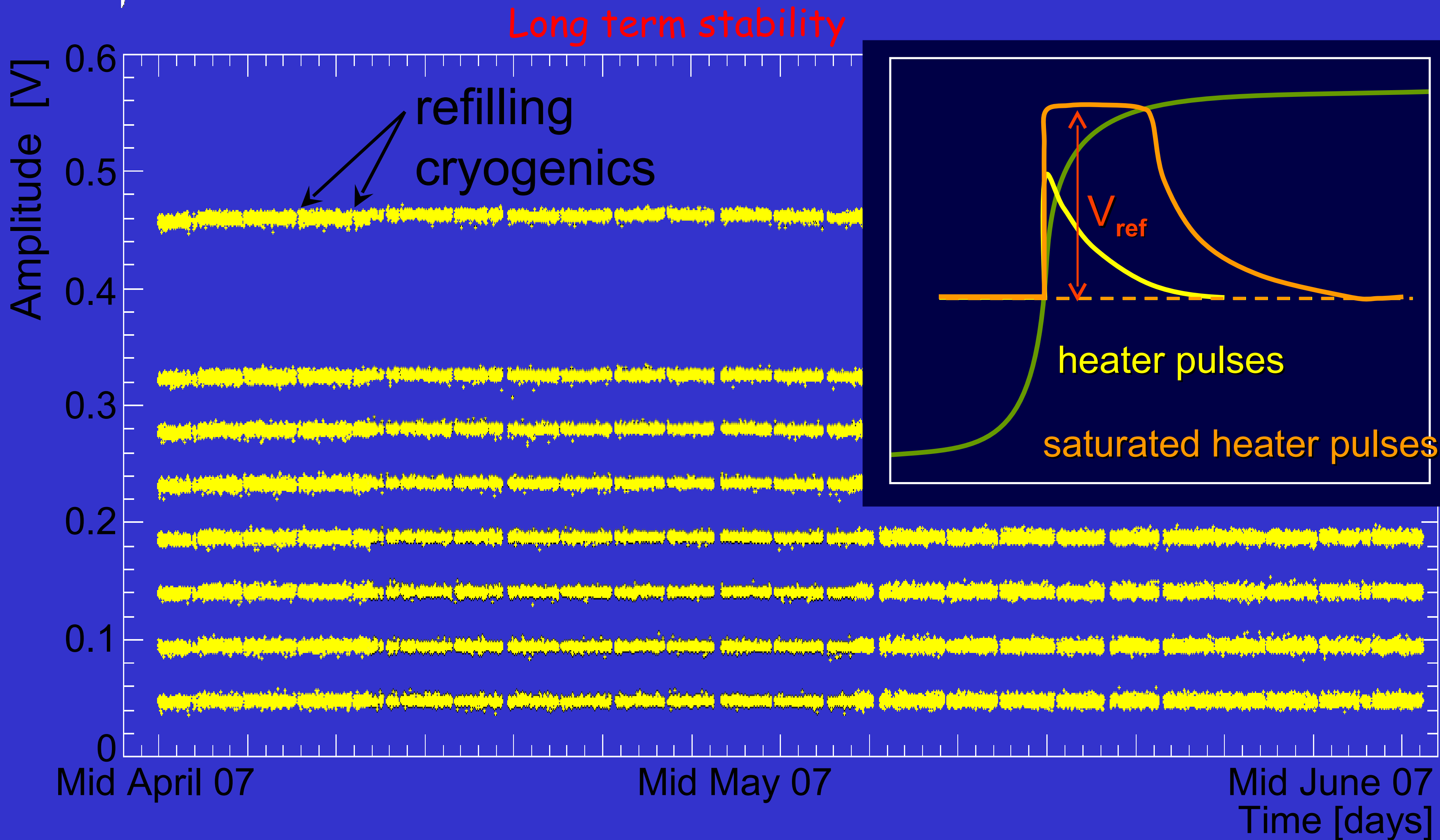
CRESST set-up at LNGS

passive shielding:

- underground laboratory
- 45 cm PE (12 tons)
- muon-veto
- radon box
- 20 cm lead (24 tons)
- 14 cm copper (10 tons)
- use only radio-pure materials

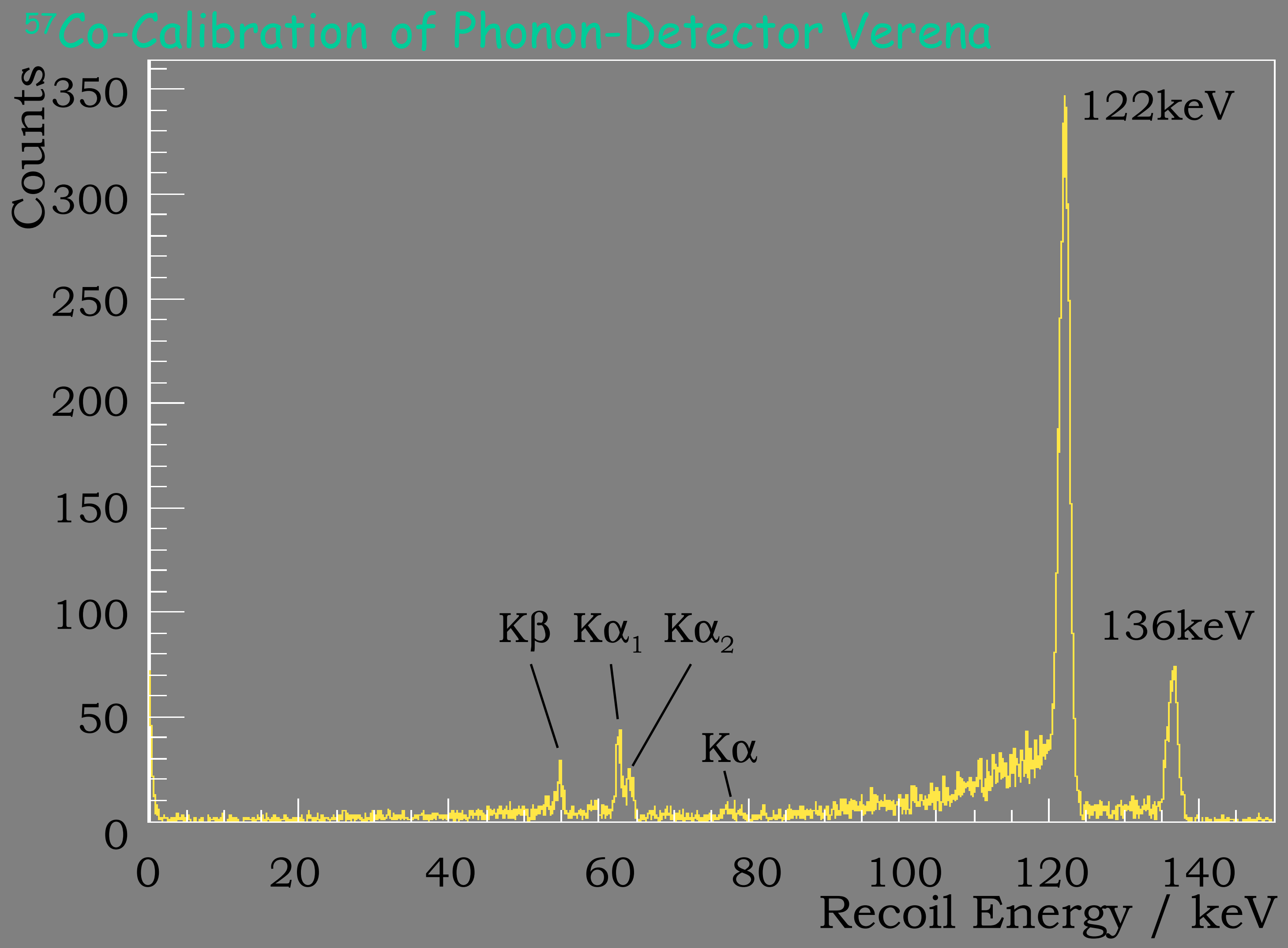


Commissioning run - Stability

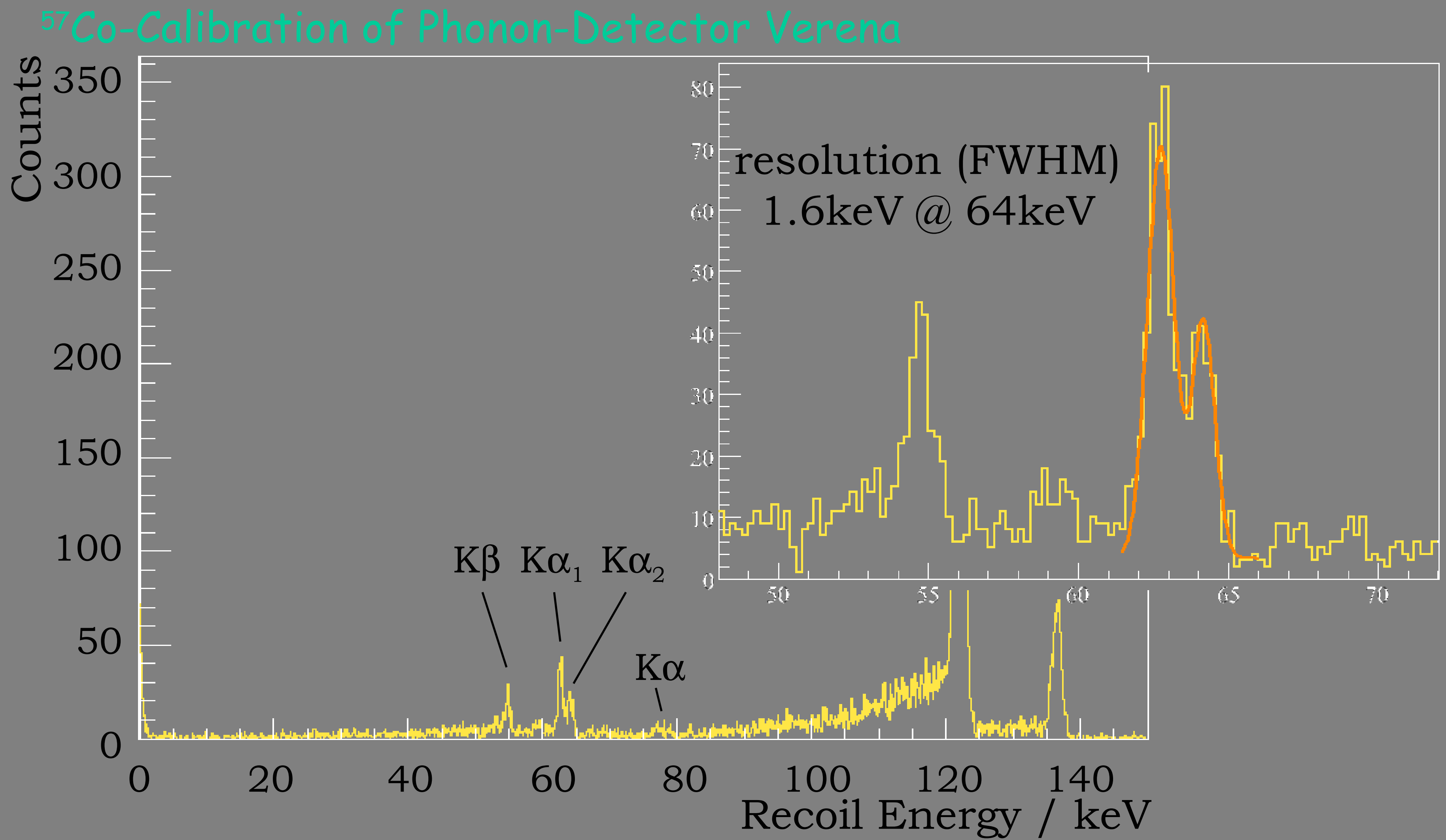


Trigger efficiencies are measured

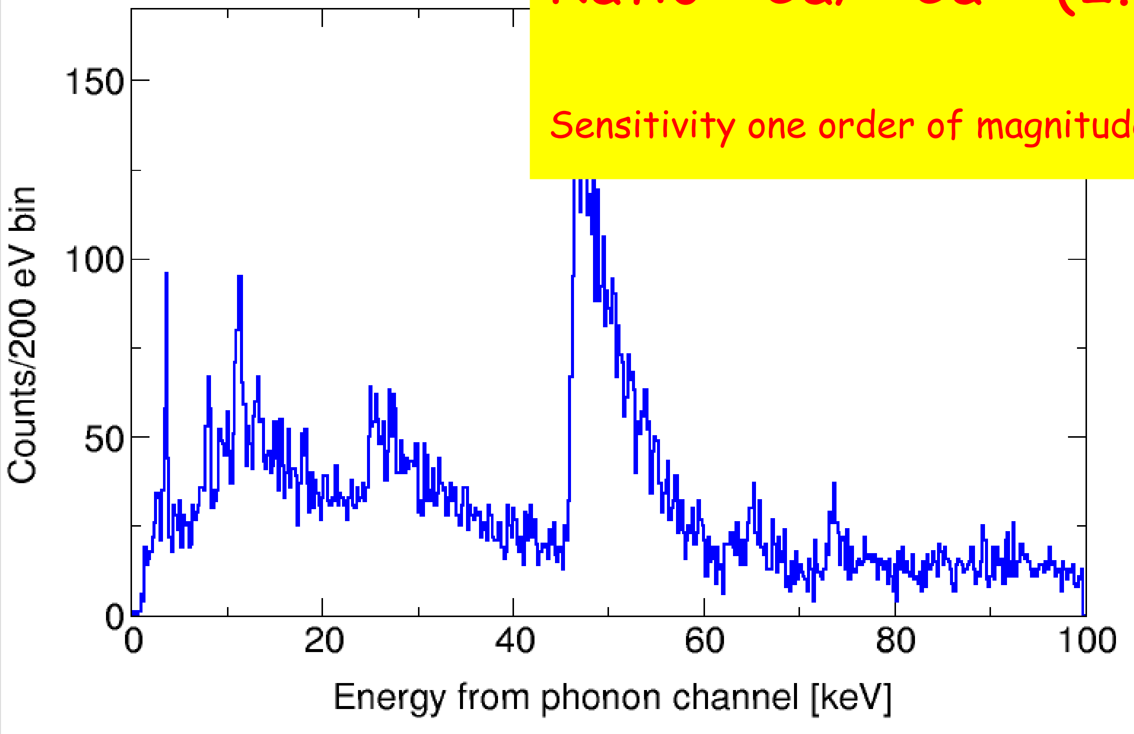
Co-Calibration



Co-Calibration



Spectral features at low Energies



Ratio $^{41}Ca/^{40}Ca = (2.2 \pm 0.3) * 10^{-16}$

Sensitivity one order of magnitude better than other methods

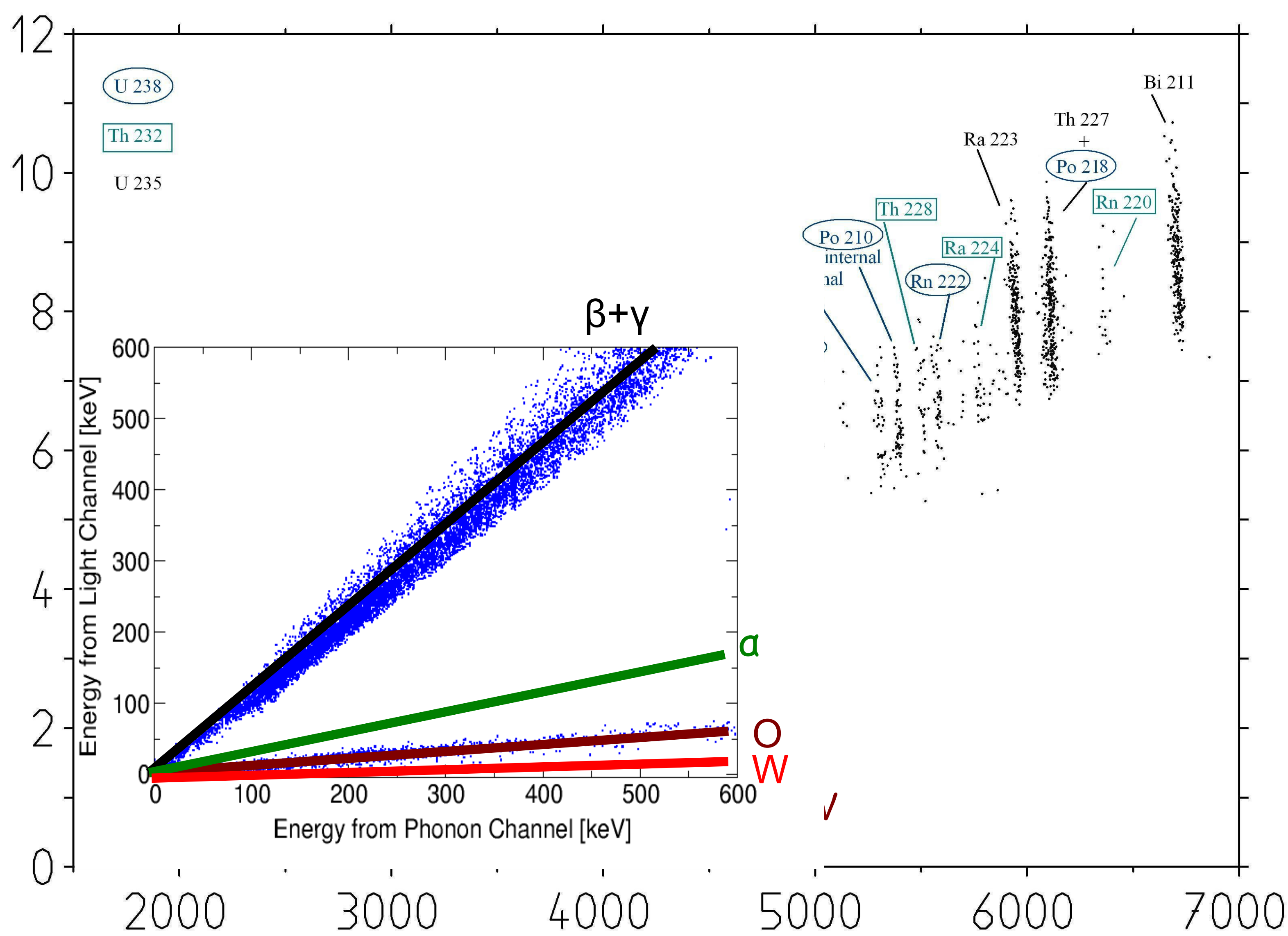
keV

^{41}Ca 3.61 keV found @3.6 keV

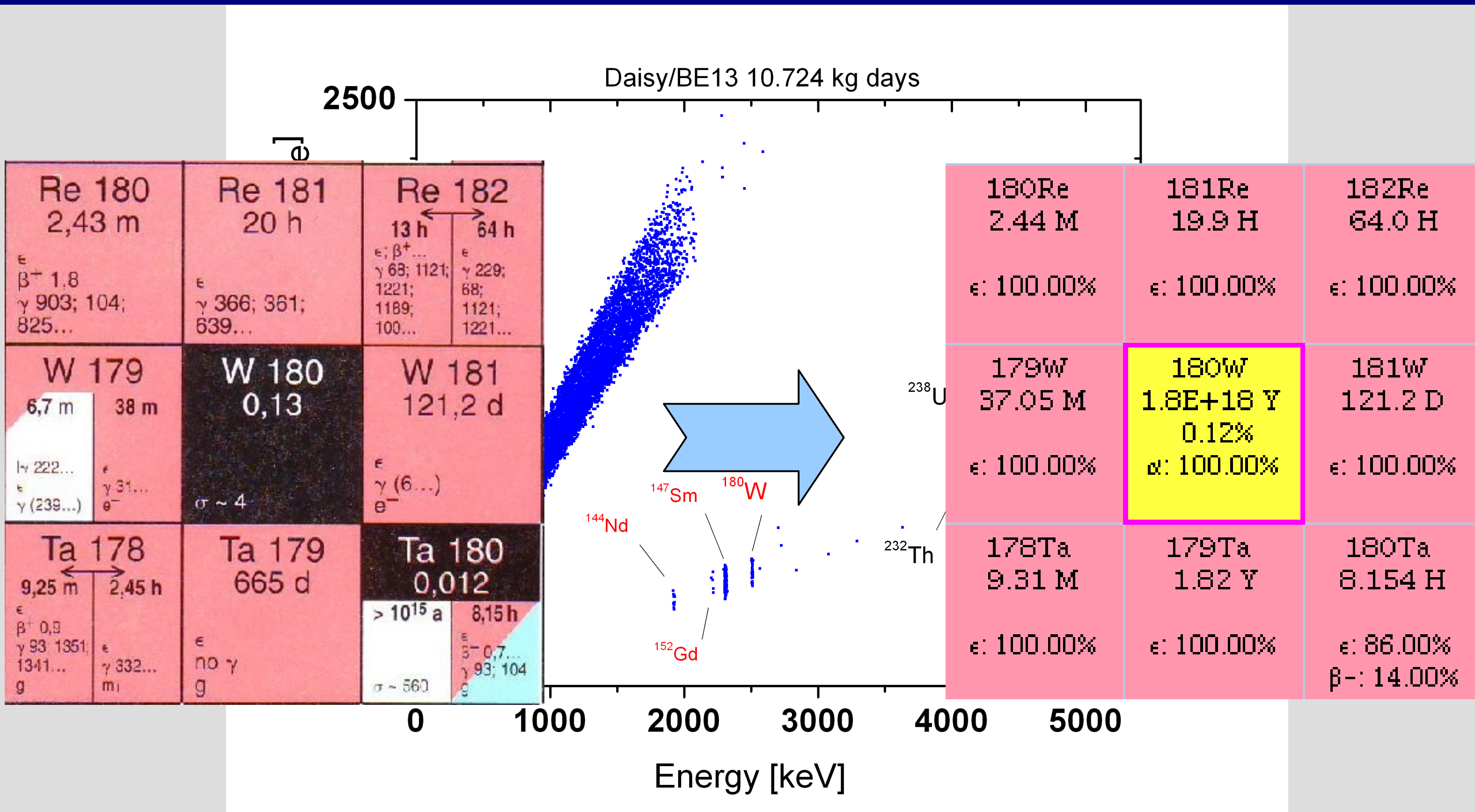
^{210}Pb 46.5 keV @ 46.5 keV

- Very precise energy calibration
- Lines down to 3.6 keV identified with excellent energy resolution of 300 eV.

Identification of α-Emitters



^{180}W



^{180}W now listed unstable in tables with 1.8×10^{18} years half life

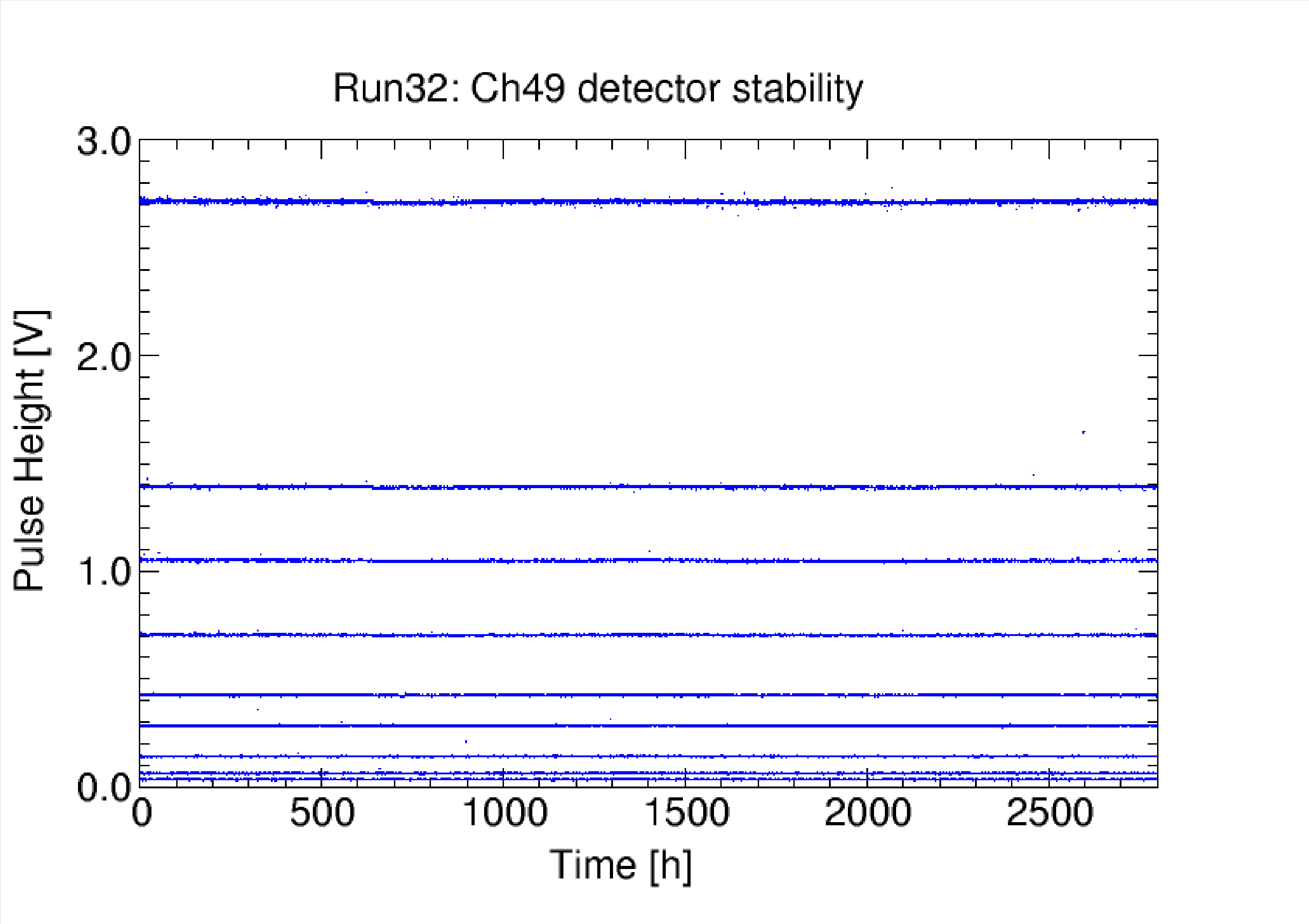
Q = (2516.4 ± 1.1 (stat.) ± 1.2 (sys.)) keV

Present run

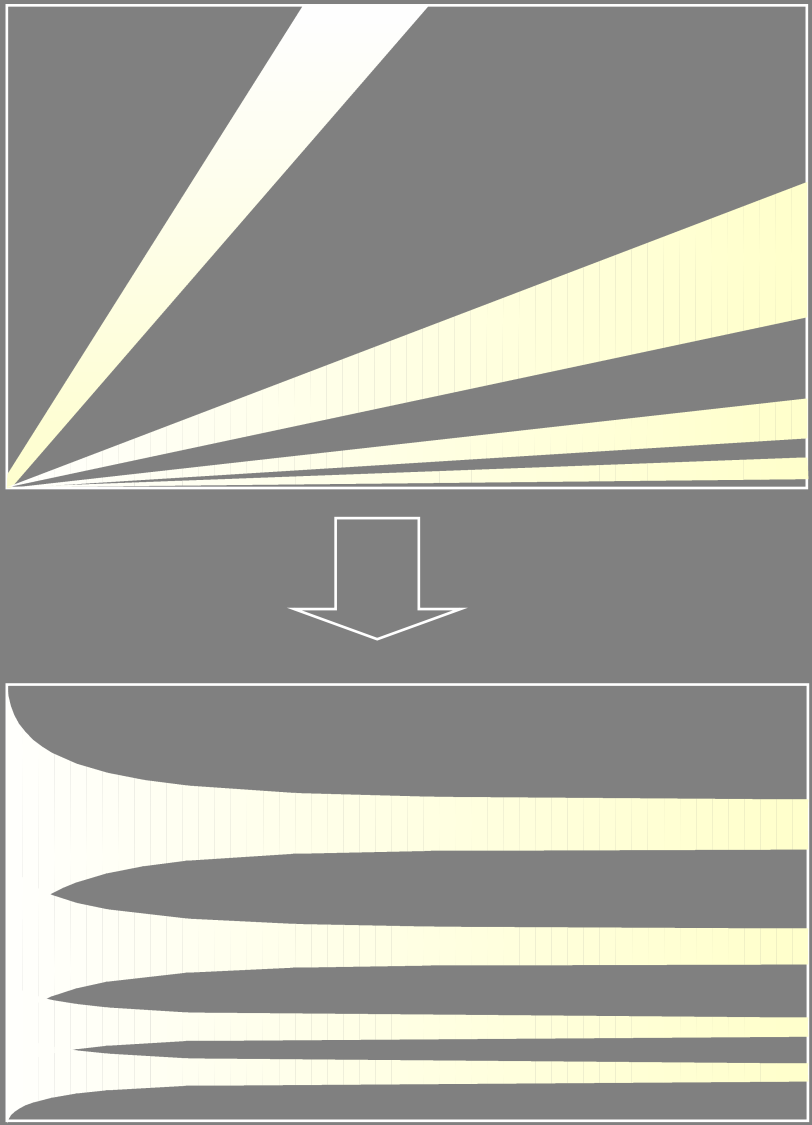
All results preliminary

- running since summer 2009
- 10 detectors running (1 $ZnWO_4$)
- Clamps not covered with scintillator
- data analysis is still in progress
- No neutron calibration yet
- Data discussed are from 9 $CaWO_4$ detectors (333 kgd)

Stability


Run32: Ch49 detector stability
Pulse Height [V]
3.0
2.0
1.0
0.0
0
500
1000
1500
2000
2500
Time [h]

Data

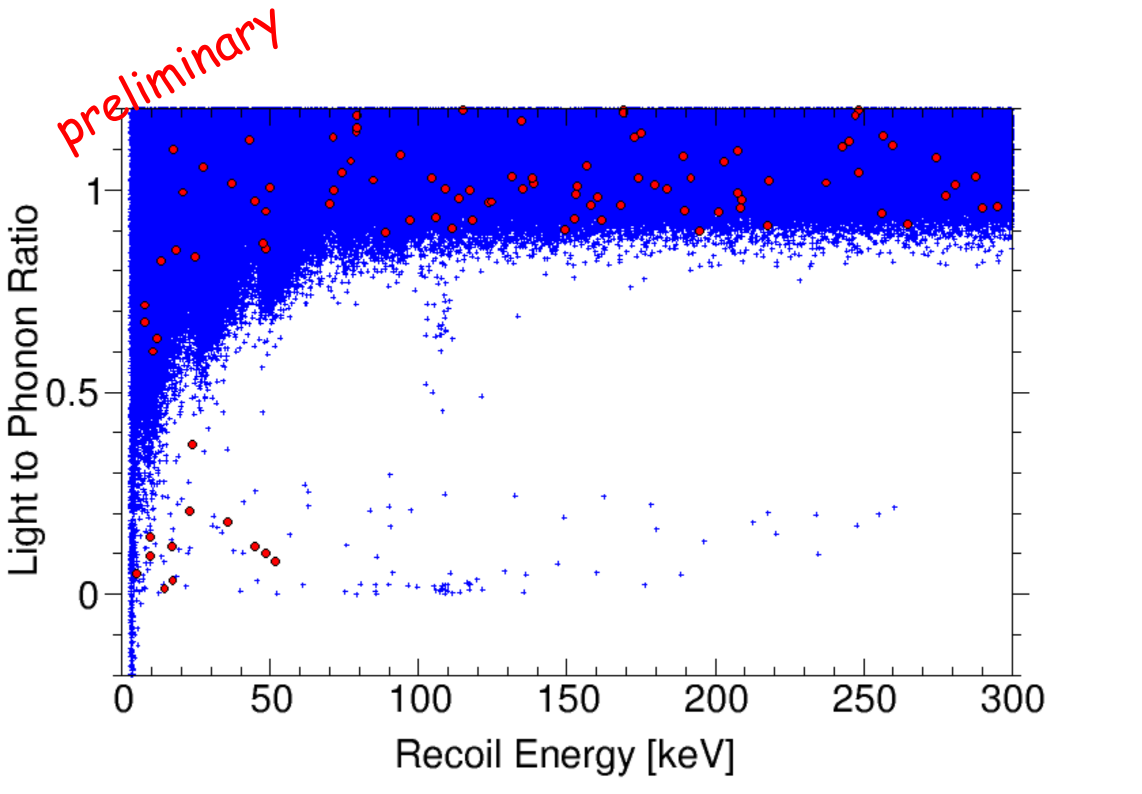


Light versus phonon-energy

Light yield versus phonon-energy

Data

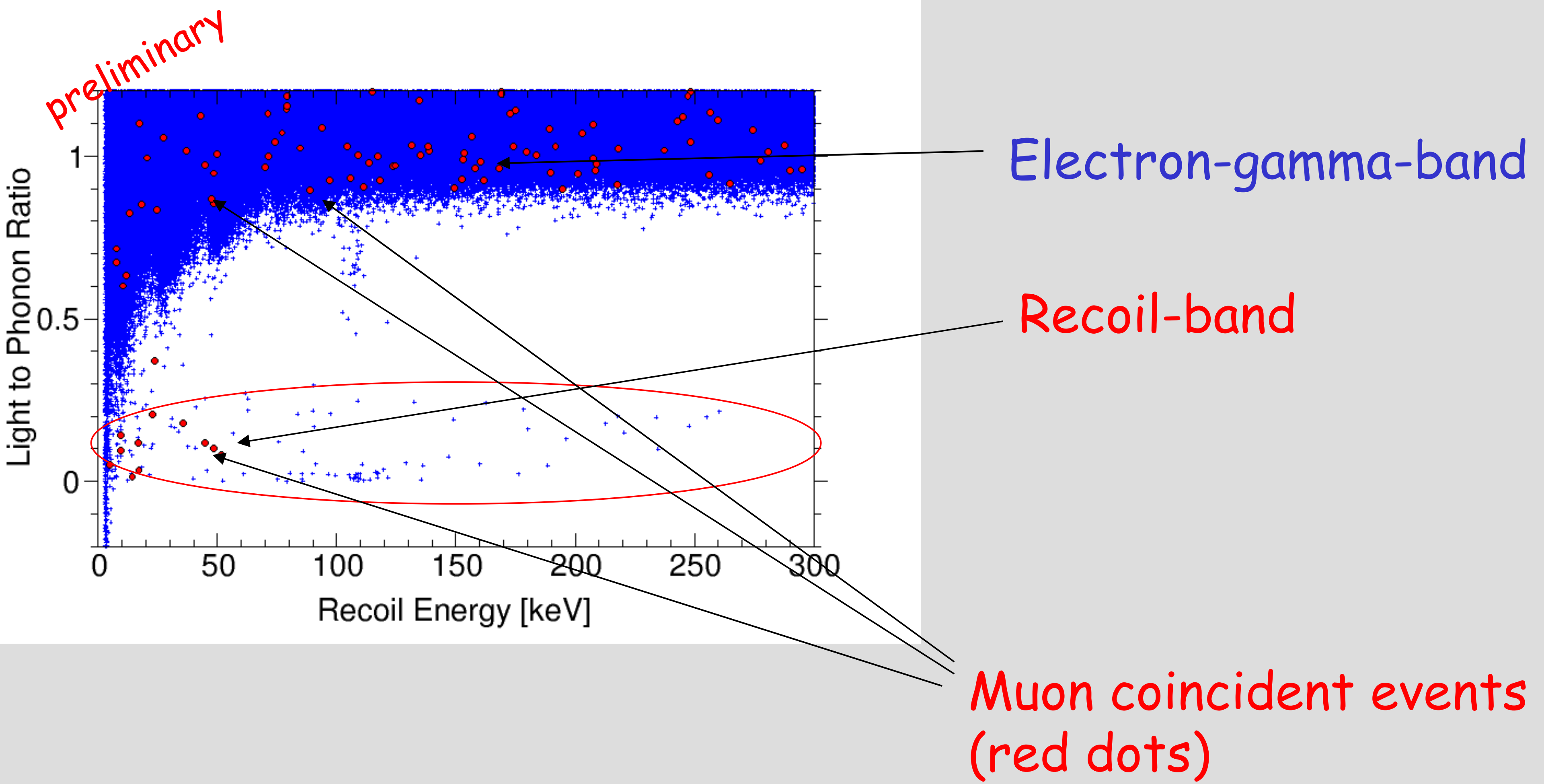
Several detectors added



Data

Several detectors added

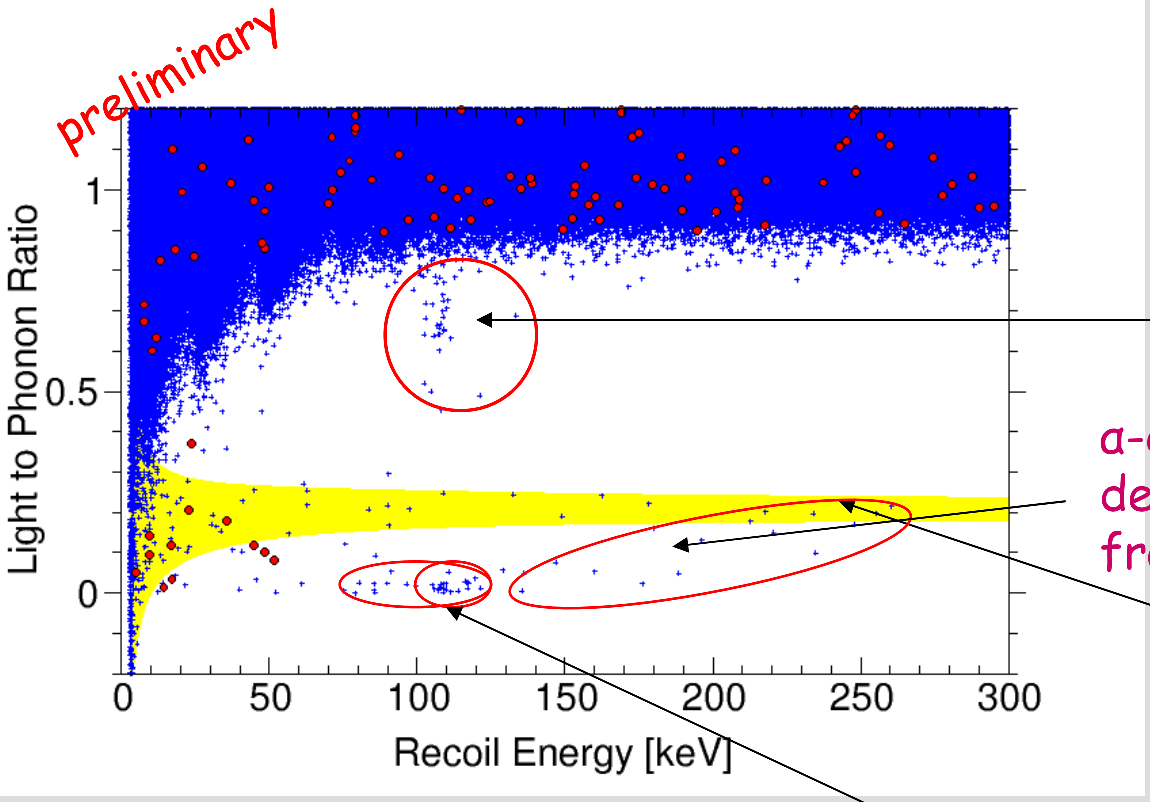
main structures



Data

Several detectors added

α-decay related structures



mainly related to uncovered clamps

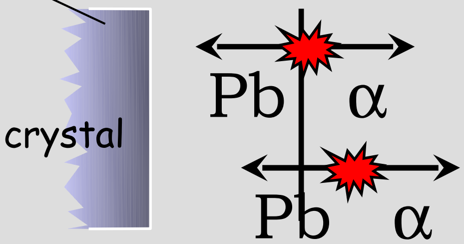
Recoiling nucleus hits crystal
α hits scintillating holder

α-emitter at crystal surface deposits nuclear recoil + fraction of α-energy

α-band

Full α-analysis in progress

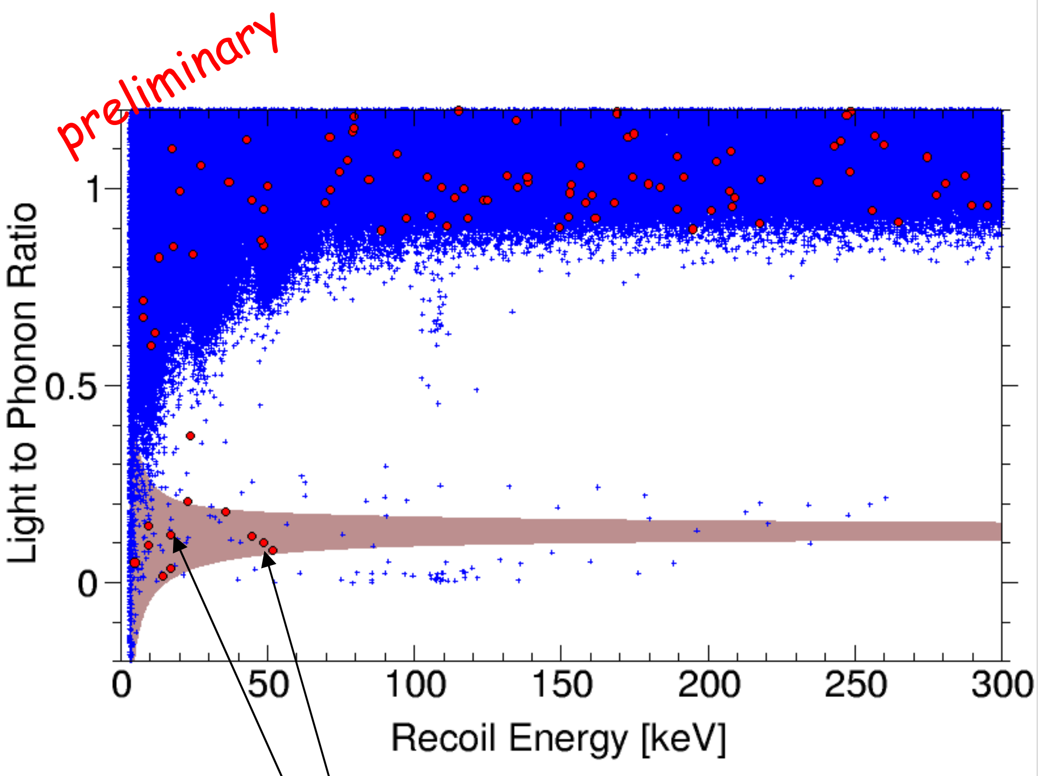
$^{210}Po \rightarrow {}^{206}Pb$ (104keV) + α (5.4MeV)



Drawn bands only schematic

Data

Several detectors added



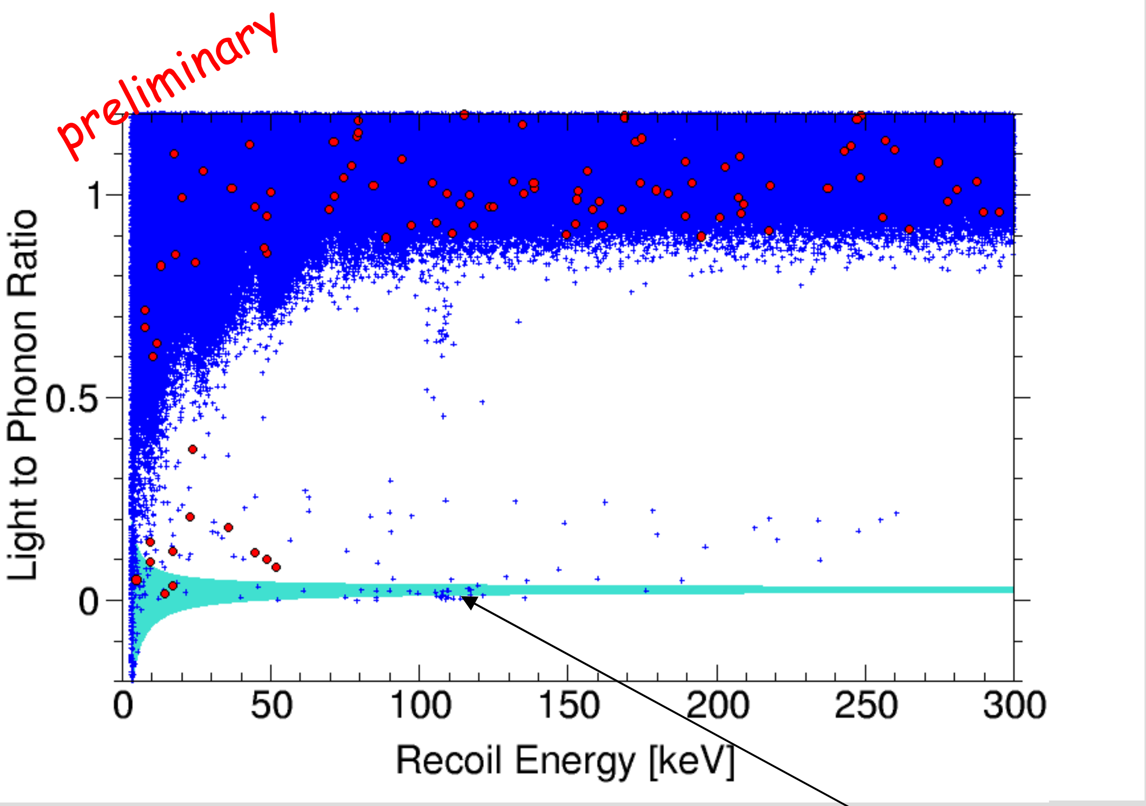
Oxygen recoil band

Oxygen recoils caused by muon induced neutrons

Drawn bands only schematic

Data

Several detectors added



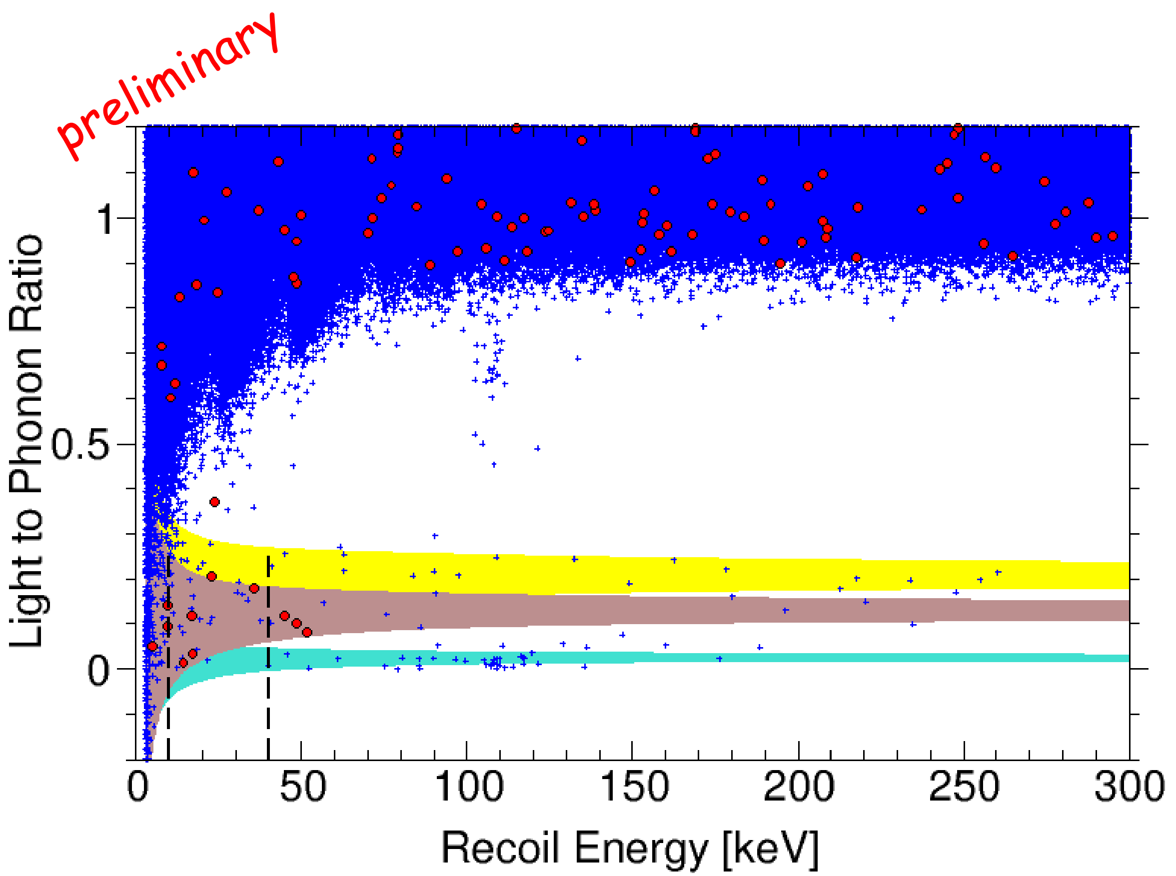
W-recoil band

Pb-recoils tend to be below W-band

Drawn bands only schematic

Data

Several detectors added

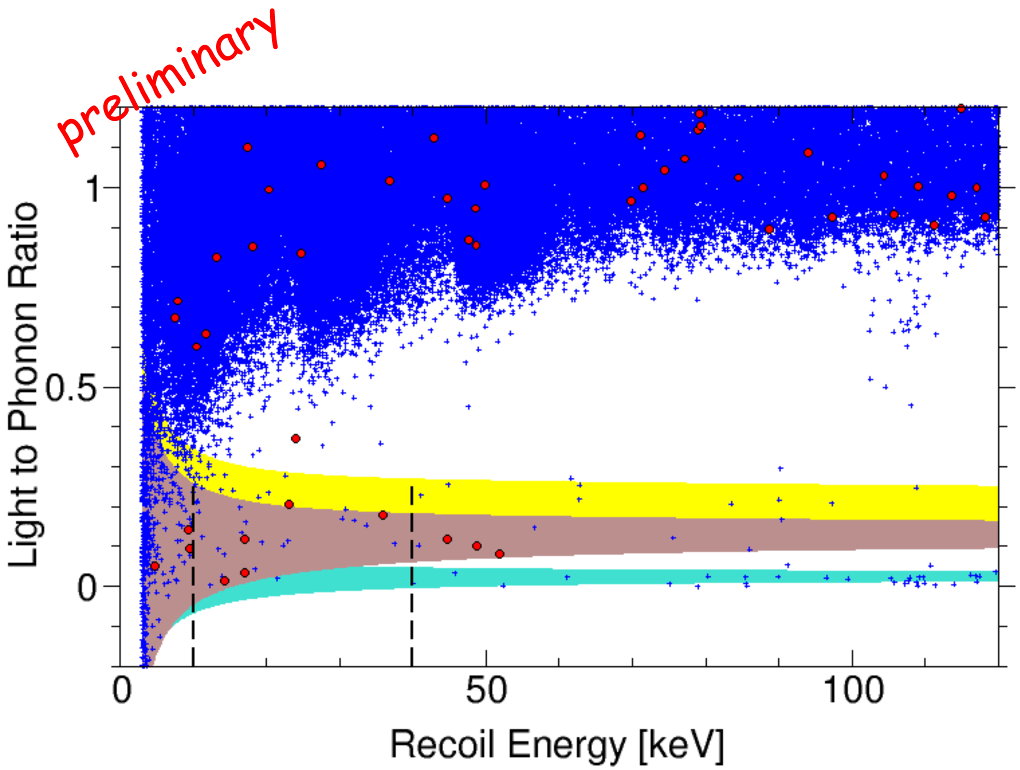


events can be attributed to identified processes

Drawn bands only schematic

What does this mean for heavy WIMPs

Several detectors added



$\sigma_{WIMP} \sim A^2$

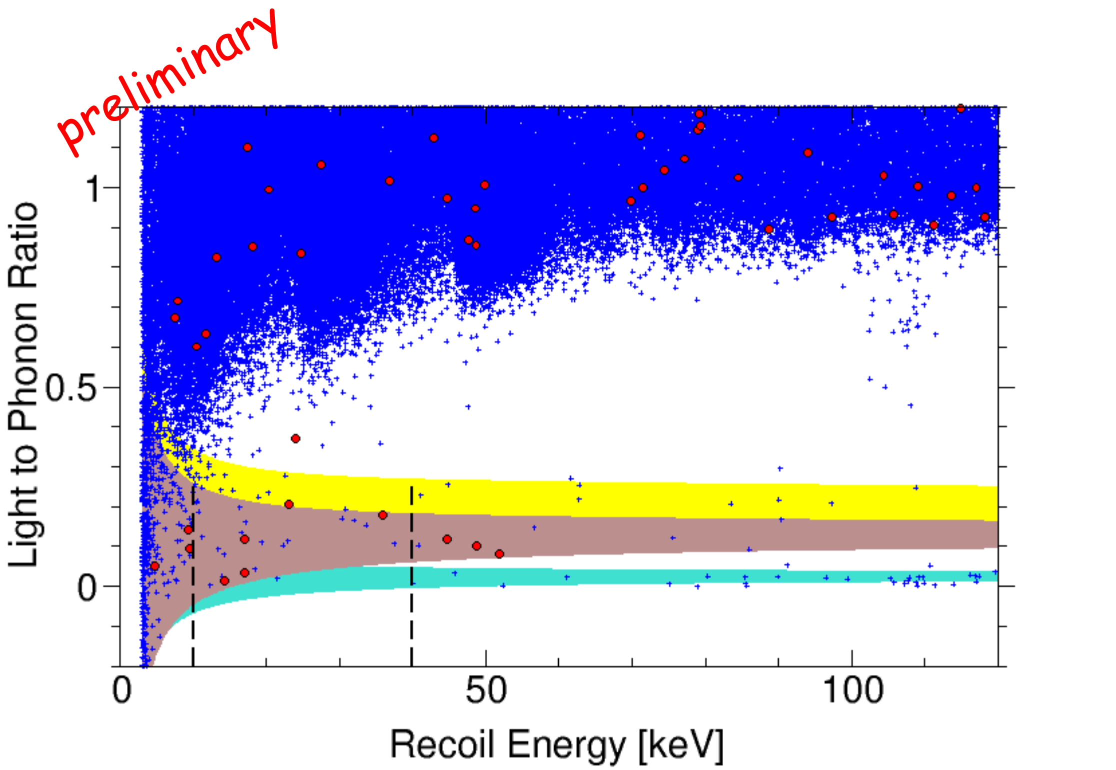
WIMPs show up in W-Band

- Rate in all detectors equal within statistics
- Neutron calibration still needed

Limits deduced from overlap-free W-band reach upper 10^{-8}pb range

What is going on in the Oxygen Band

Several detectors added



- Rate in all detectors equal within statistics
- decrease summer winter there but statisticallly not yet significant

Neutrons ?

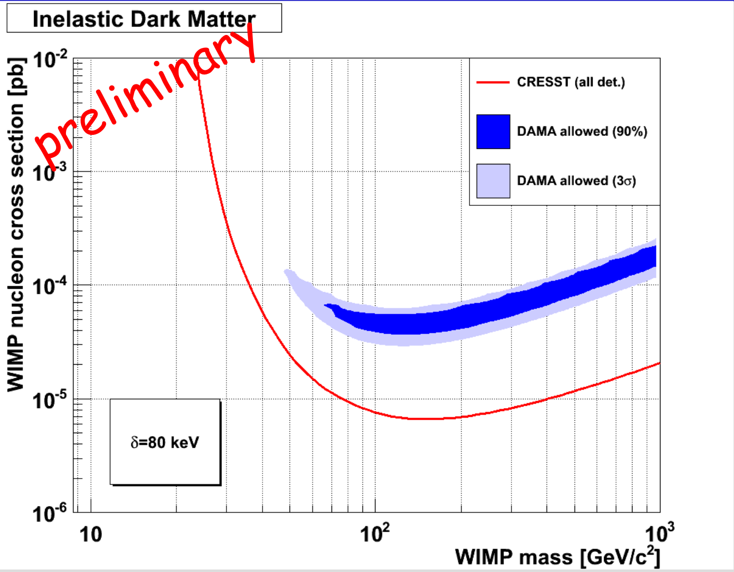
- Rate to high for external neutrons
- „internal“ neutron source only if low energetic

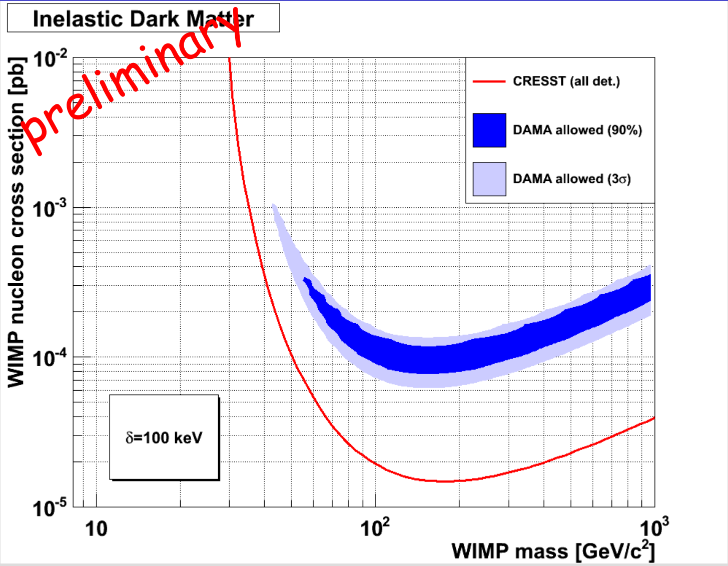
Low mass WIMPs ??

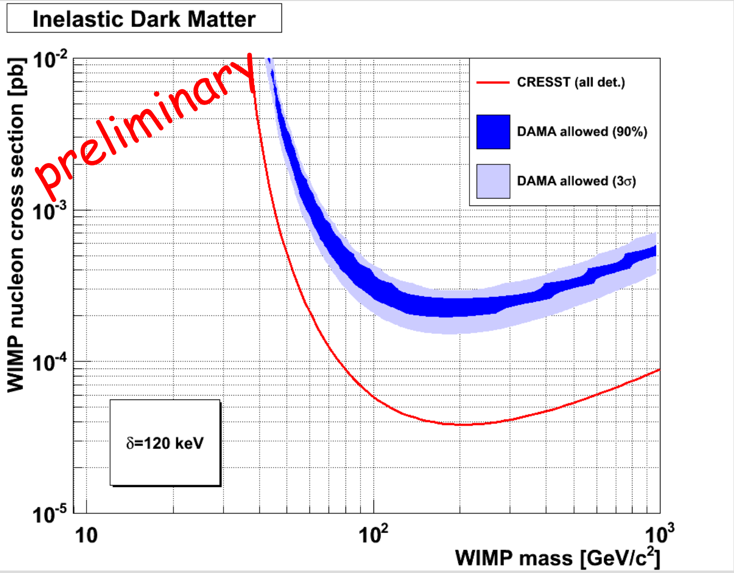
A combined analysis of all recoil-bands is in preparation

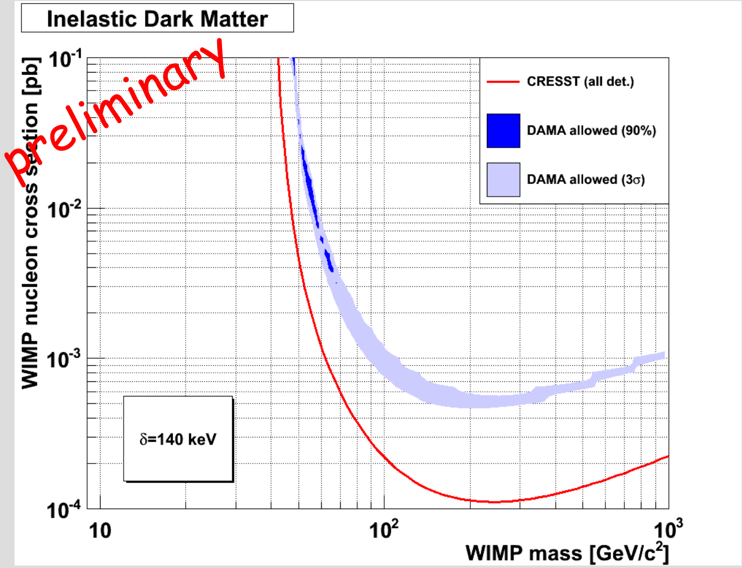
More statistics is needed

Inelastic Dark Matter









Deduced from full W-band

Next steps

- Continue measurement over summer
- Develop and test scintillator covered clamps in CRESST R&D-Cryostat at LNGS
- Develop neutron monitoring detector ($CdWO_4$ or LiF)
- Make a run with scintillator covered clamps (strong reduction for α-decay induced events) and neutron monitor

CRESST III

Features:

50 kg total mass (fiducial volume)

Excellent background discrimination

Different target nuclei and therefore
unique Dark Matter Identification capabilities

housed in present CRESST set-up

Modifications and developments needed

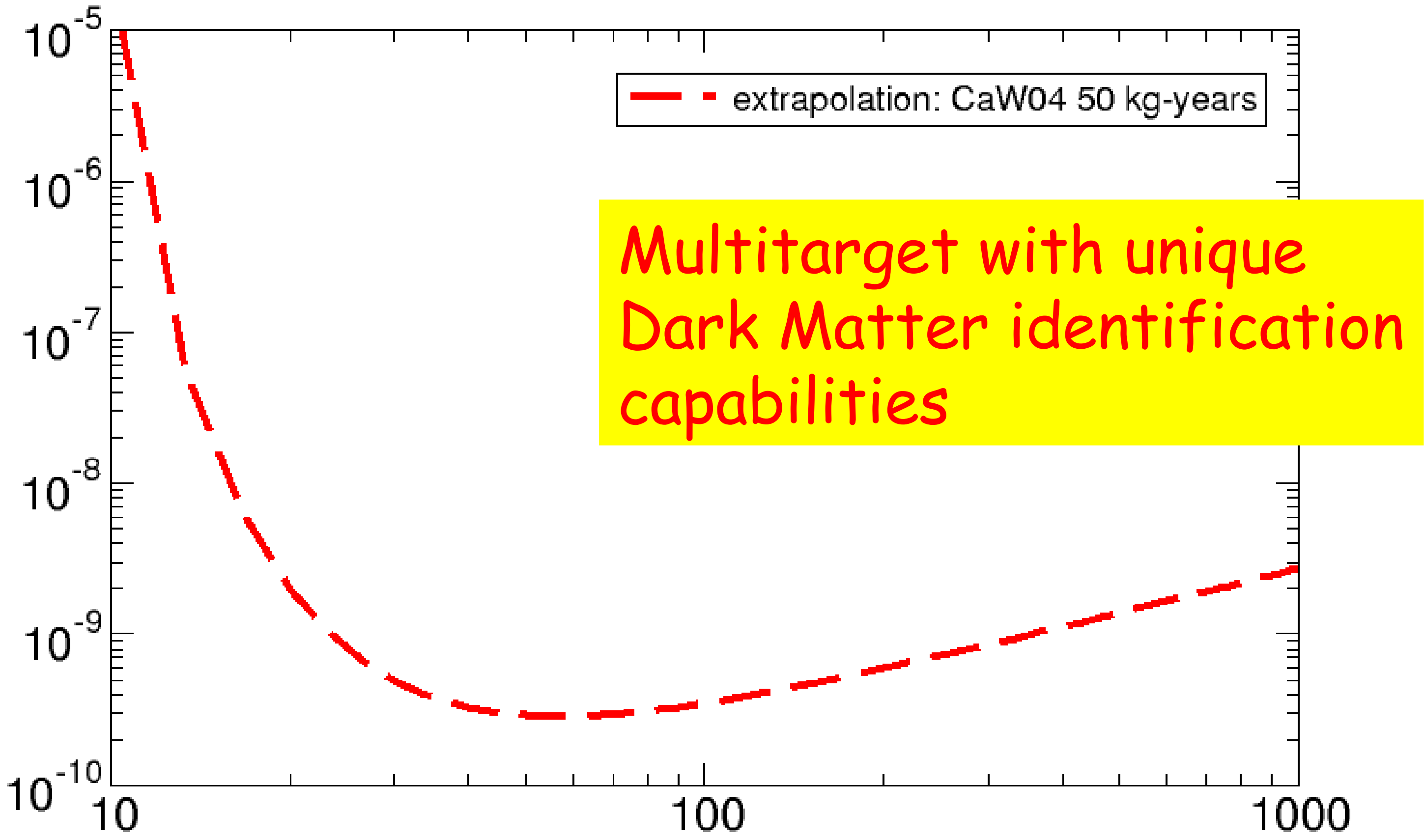
Increase experimental volume by factor 3
(modify cryostat and shielding)

Increase detector size by factor 5

Develop low mass holders with higher packing density

Keep number of readout channels and electronics

sensitivity



Conclusions

- CRESST detectors are very powerful and able to perform precision measurements
- The multi-target approach (in the same set-up) is a powerful tool for DM identification and unique for CRESST
- CRESST is now in a very exciting phase
- Inelastic Dark Matter scenario becomes very unlikely to explain DAMA results
- CRESST III will cover the most interesting parameter space and will have a unique DM-particle identification capability

Thank You