Blind CRESST Data Analysis in the light of Time-Dependent Noise

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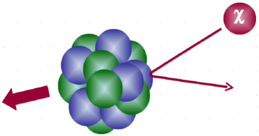
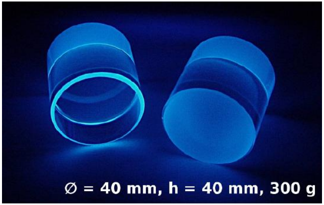
Direct Dark Matter Search with the CRESST Experiment

CRESST

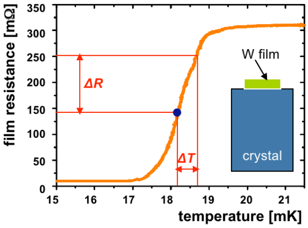
- aims for a WIMP detection via their elastic scattering off nuclei.



- uses scintillating $CaWO_4$ crystals as target material.

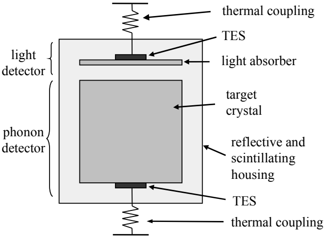


CRESST Detectors



- particle interactions in the crystal excite phonons
- temperature rise detected with Transition Edge Sensor (TES)

⇒ measurement of deposited energy (few keV)

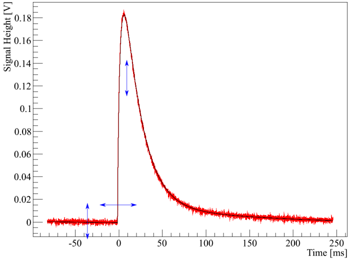


detector module:
simultaneous measurement of

- energy in crystal E
- scintillation light L

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

Standard Pulse Fit & RMS



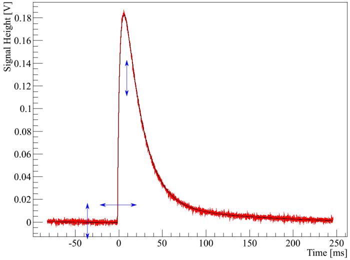
- thermal pulse: fit with standard event

⇒ Amplitude → Energy

⇒ "RMS of Fit [V]"

- The RMS is a generic parameter well suited to find events with different pulse shapes.

Standard Pulse Fit & RMS



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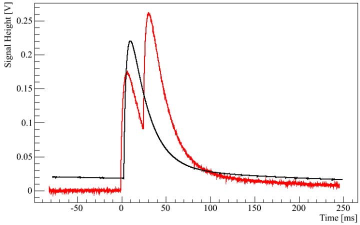
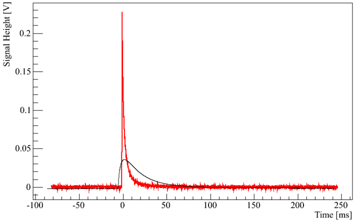


pile-up



direct hit of thermometer carrier

Blind Analysis & Contributions to the RMS

Blind Analysis

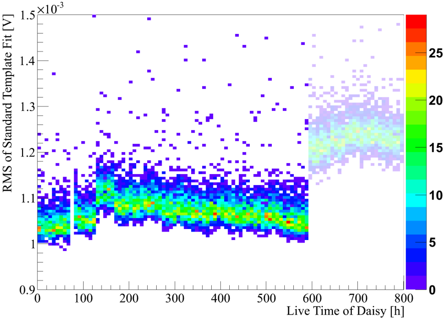
- Use small subset of whole data set to develop cuts $\rightarrow$ **Training Set**
- Application of cuts on data set without changes $\rightarrow$ **Blind Analysis**

Distinctive feature of the RMS

Two contributions:

1. differences in pulse shape between pulse and template
2. noise

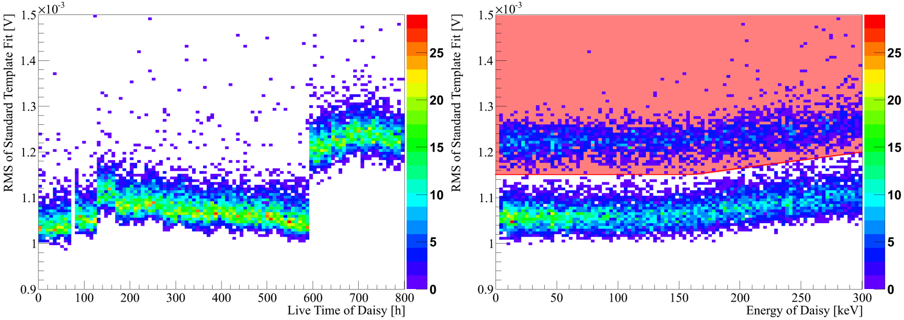
Time and Energy Dependence



- previous analyses: polygon cut to account for energy dependence
- time dependence prevents development of polygon cut on training set
- adjustment of the polygon cut on data set necessary

→ completely blind analysis impossible

Time and Energy Dependence



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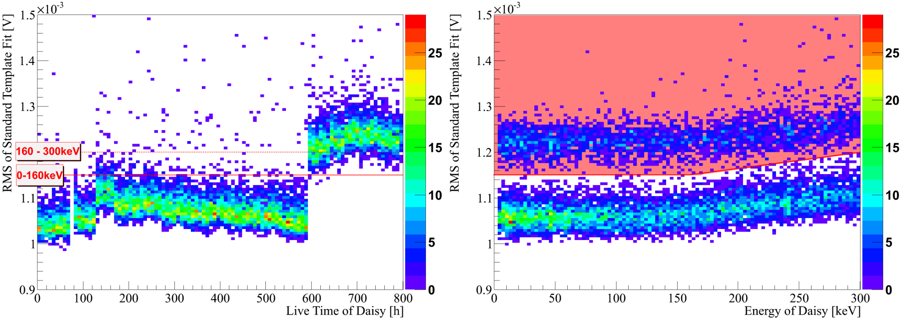

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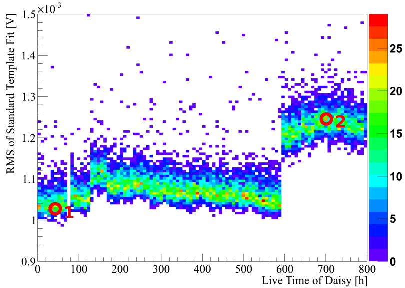
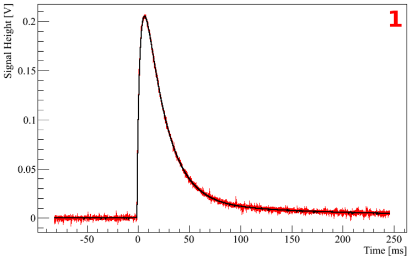
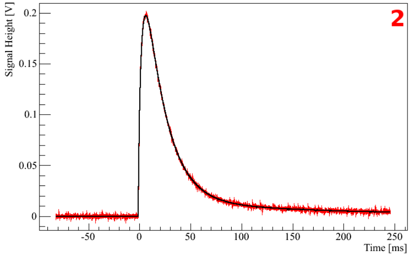
Fit Examples

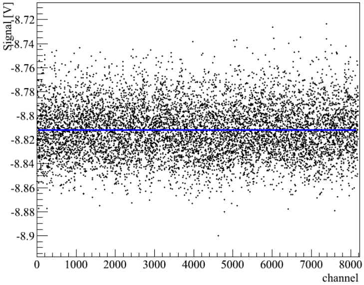






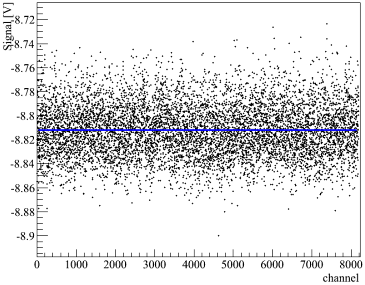
- nearly no influence of moderate noise changes on energy resolution
- adjustment of RMS cut to current noise level needed

Empty Baselines



Use straight line fit of empty baselines to detect changes in noise.

Empty Baselines



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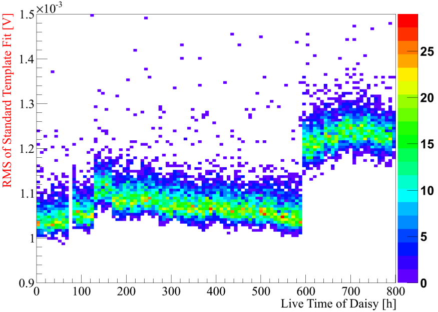

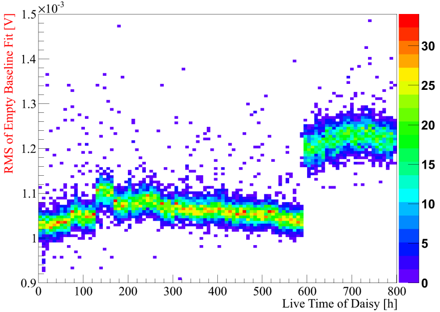

3D RMS Cut

Steps of new 3D RMS Cut

1. automatically find periods of constant noise
2. perform energy dependent cut, which is adapted automatically to different noise levels, within each period

Automatic Edge Finding

1. smooth/filter data (RMS vs. time)$\rightarrow$ convolution with Gaussian ($[f * g](t)$)
2. calculate derivative
3. find extrema of derivative

Effective Implementation: Canny Edge Detection

- core element: combination of step one and two via convolution with derivative of Gaussian: $\frac{d}{dt}[f * g](t) = [f * \frac{d}{dt} g](t)$
- width of Gaussian (σ) determines sensitivity of edge finding to noise

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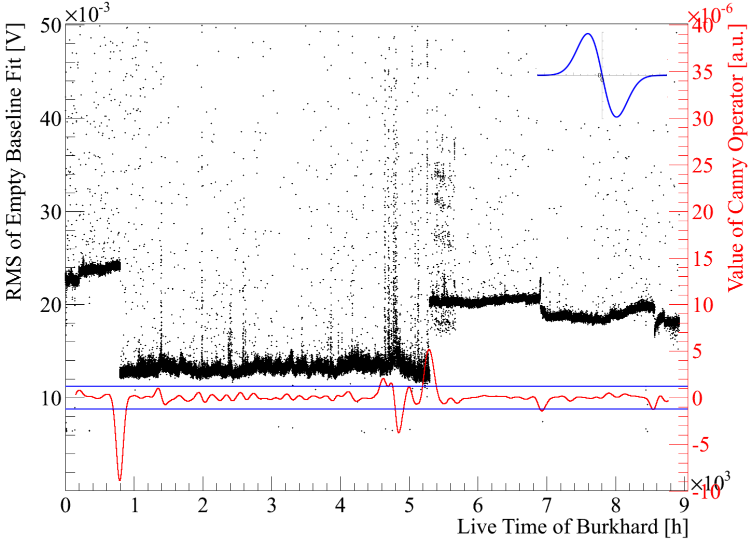
Automatic Edge Finding - Example



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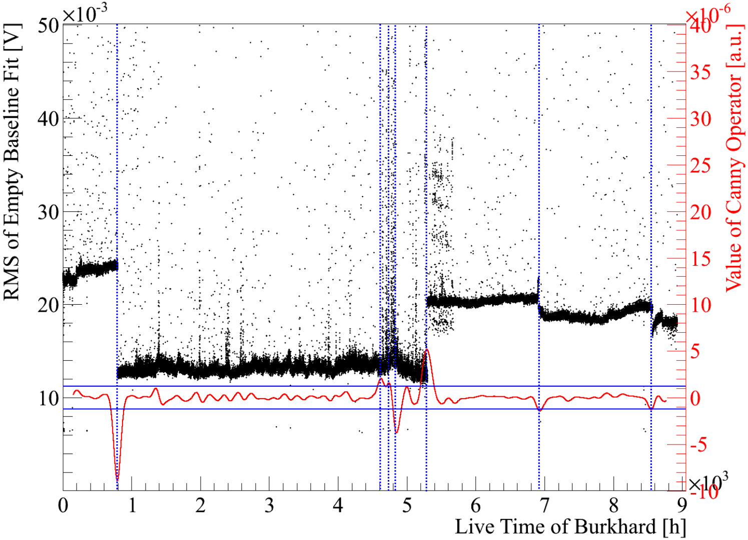
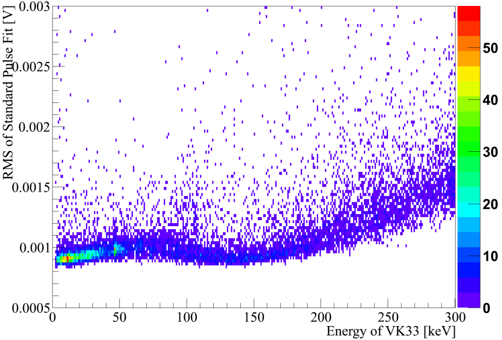


Energy Dependent RMS Cut



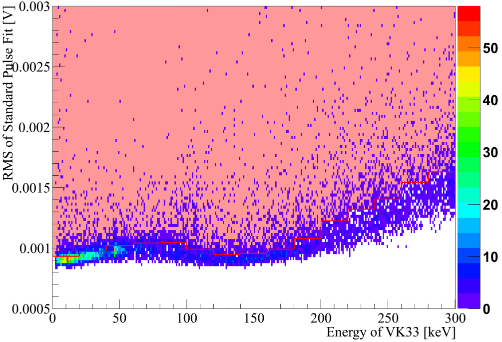
Method

1. sort events in energy bins
2. fit RMS distribution in each energy-bin using a Gaussian
3. cut all events with an RMS above a certain limit

Parameters

bin width	detector-specific (20keV)
cut limit	common for all detectors (1σ)

Energy Dependent RMS Cut



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Conclusion

3D RMS Cut

Steps:

1. automatic detection of periods of constant noise
2. sort events within each period in energy bins
3. determine bin-specific cut limit by fitting a Gaussian to the bin's RMS distribution

Advantages:

- Development of all relevant parameters on training set

→ Blind analysis possible

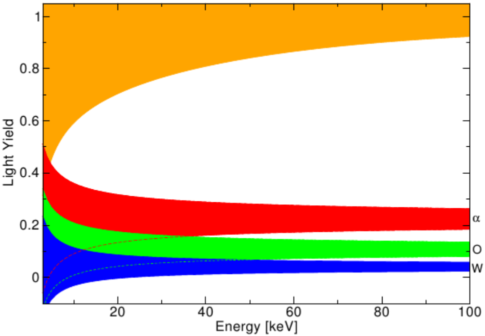
- Common cut parameter for all detectors

→ Enables to systematically study of influence of RMS cut on physics results

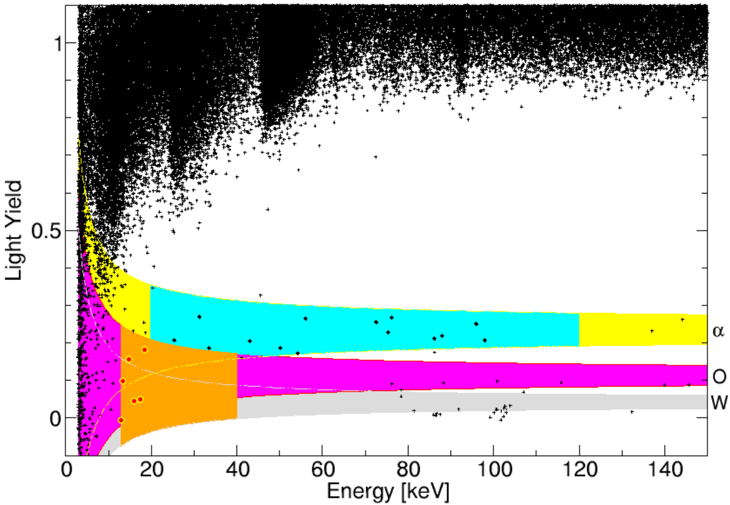
Backup Slides

Active Background Discrimination

- use **light yield** $\frac{L}{E}$ to distinguish between event types



Ligh Yield - Energy Plane incl. Acceptance Region



Composite Target Crystal