Direct dark matter search with the CRESST-III experiment

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24 - 28 July 2017
Sudbury, ON, Canada

TAUP Topics in Astroparticle and Underground Physics

The collaboration

HEPHY
Institut für Hochenergiephysik

University of Oxford

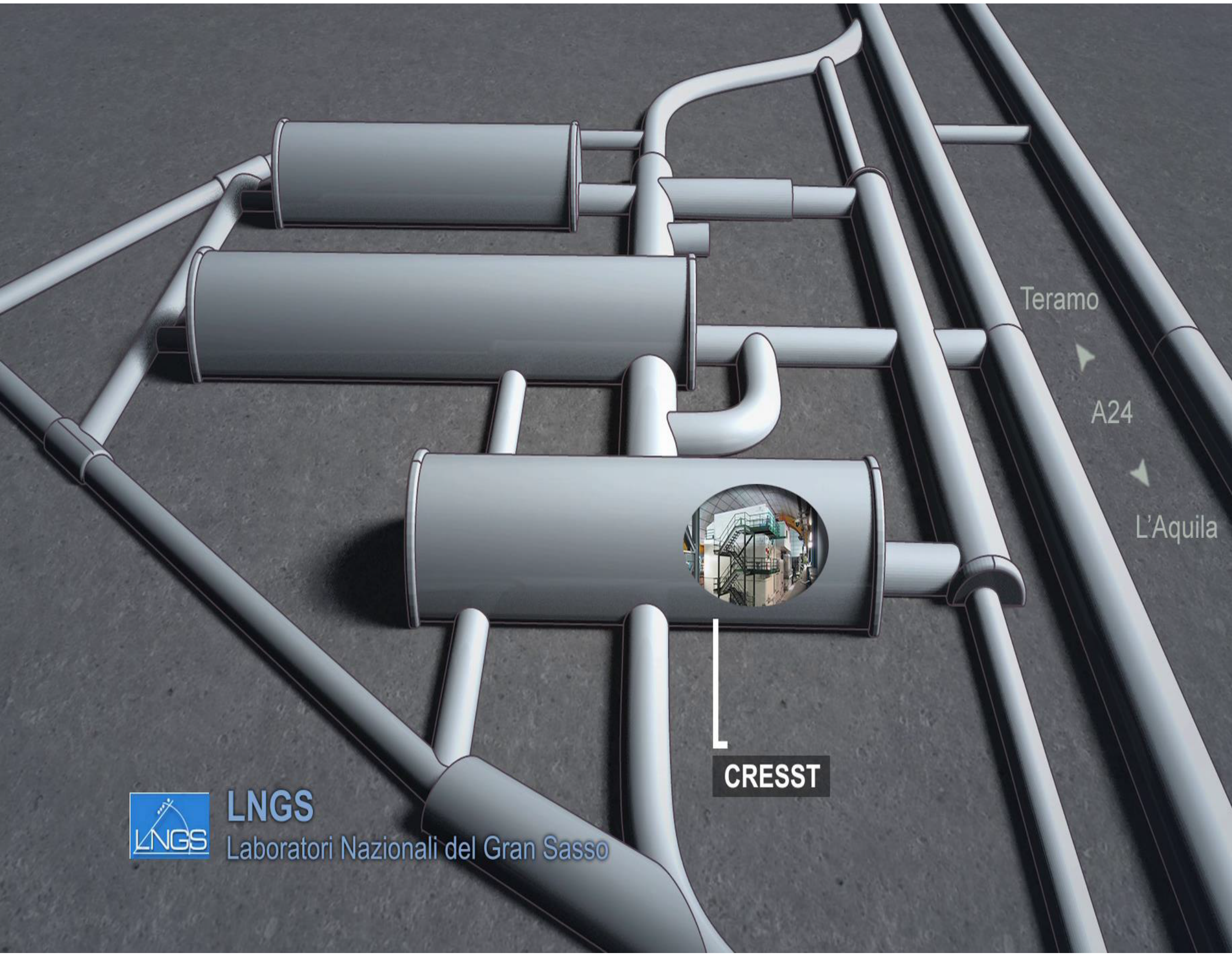
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

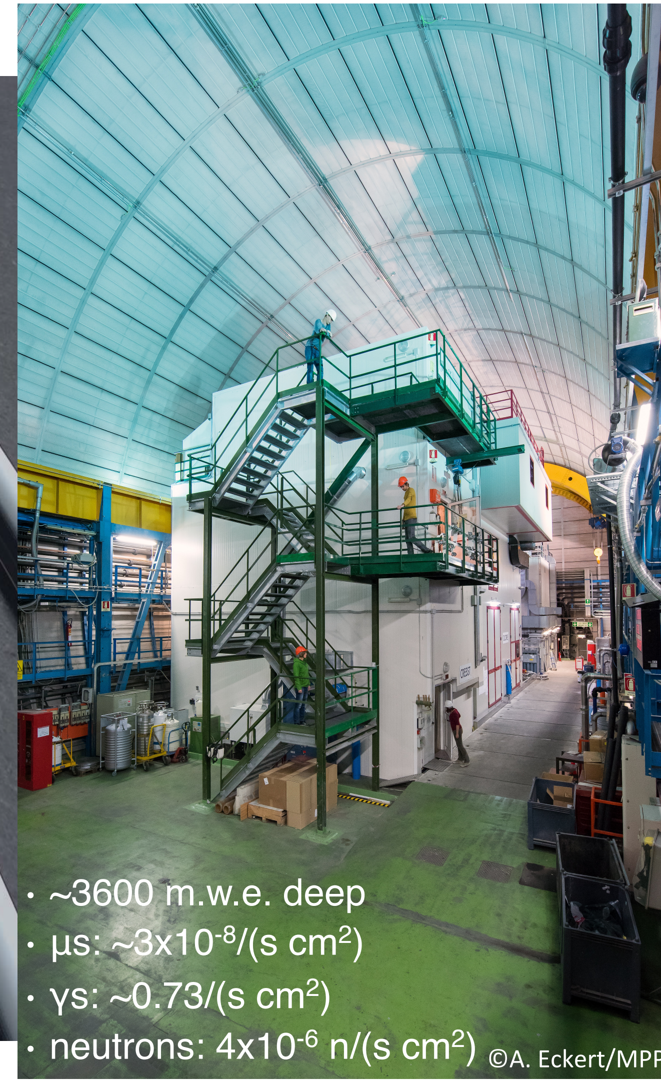
Eberhard Karls Universität Tübingen

Technische Universität München

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

LNGS





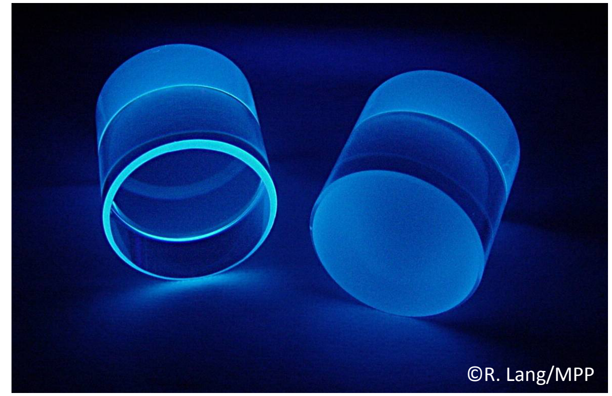
- ~3600 m.w.e. deep
- μs: $\sim 3 \times 10^{-8}/(s\ cm^2)$
- γs: $\sim 0.73/(s\ cm^2)$
- neutrons: $4 \times 10^{-6}\ n/(s\ cm^2)$

CRESST detectors

Scintillating $CaWO_4$ crystals as target

Target crystals operated as **cryogenic calorimeters** (~15mK)

Separate **cryogenic light detector** to detect the scintillation light signal



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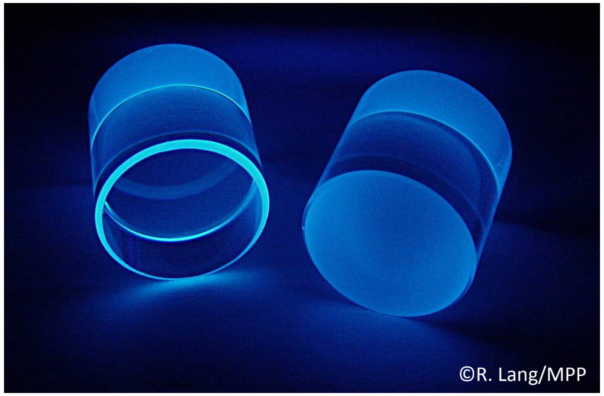
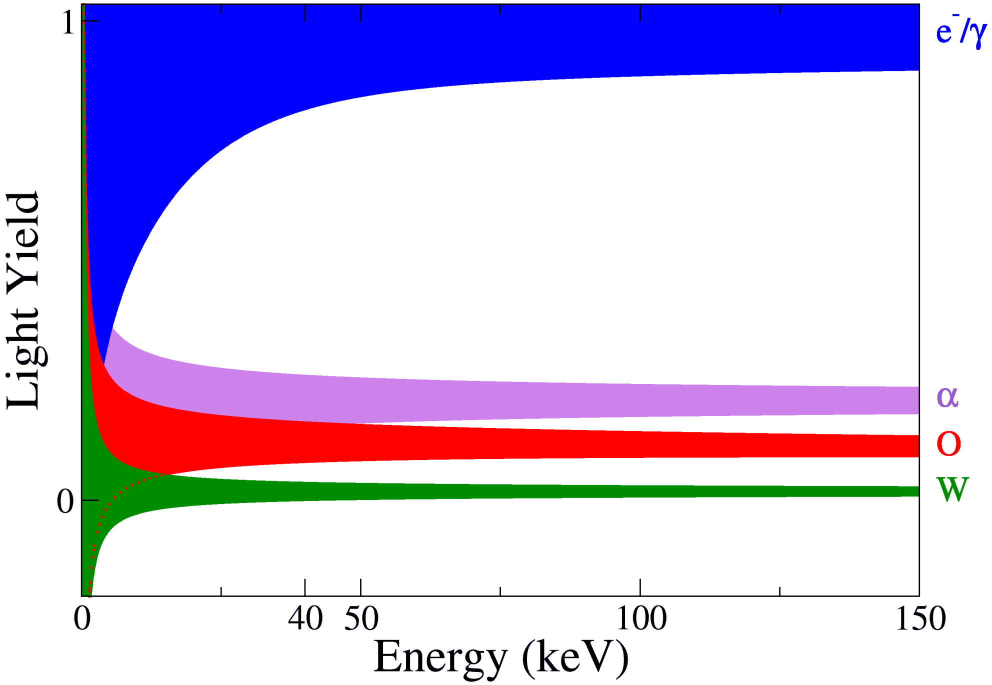


Light Yield = Light signal/Phonon signal

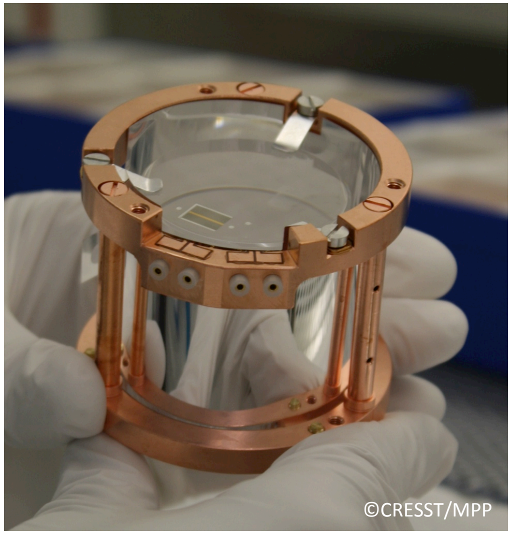
Characteristic of the event type

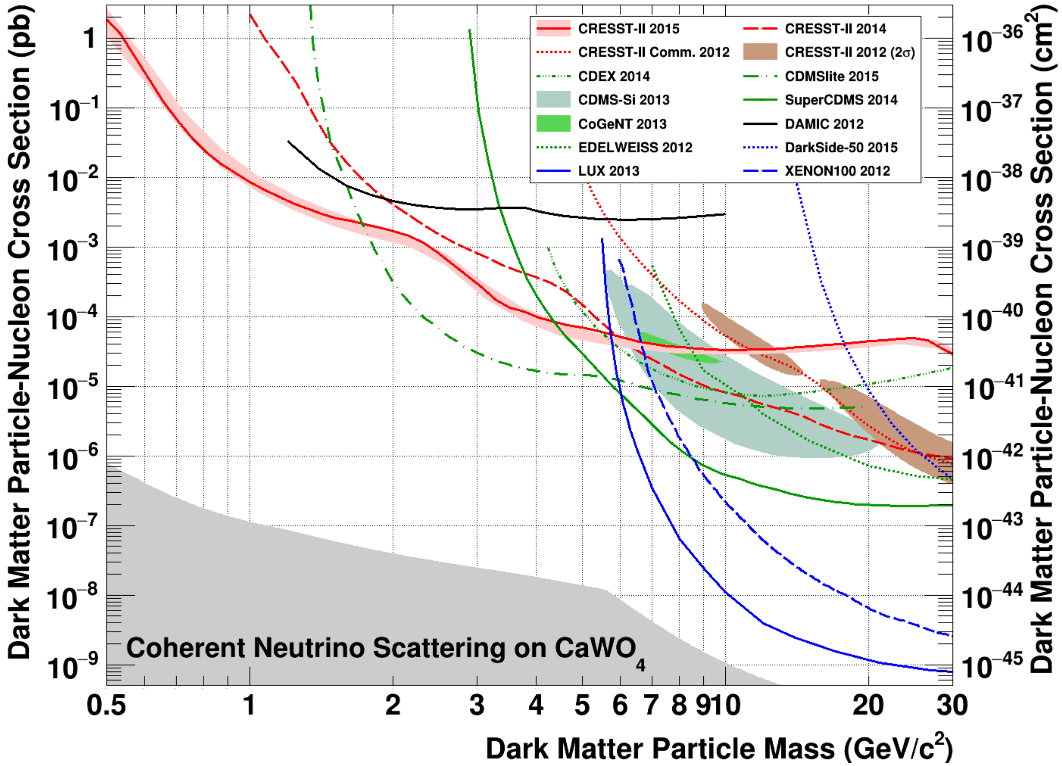
Discrimination between potential signal events (**nuclear recoils**) and dominant radioactive background (**electron recoils**)



CRESST-II results (TAUP 2015)

Crystal: Lise - background level ≈8.5 counts/(keV kg day)
Threshold: 307eV
Resolution: 62eV at zero energy





June 15th
Until ~~today~~ world-leading below $1.7 GeV/c^2$
Exploring new parameter space down to $0.5 GeV/c^2$

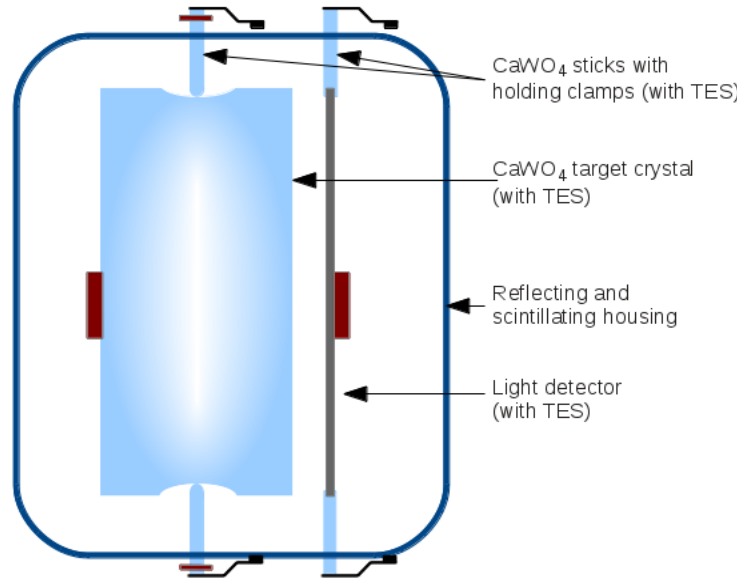
Hunting light dark matter requires a low threshold!

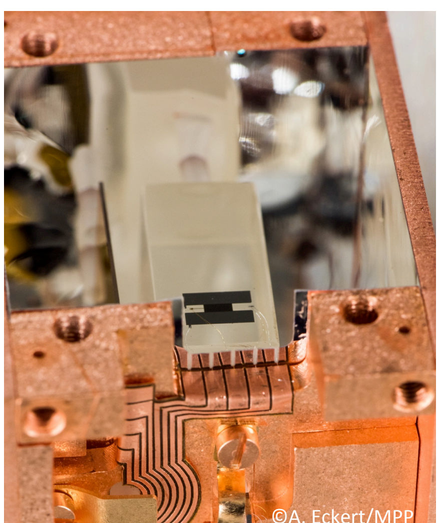
CRESST-III low threshold detectors

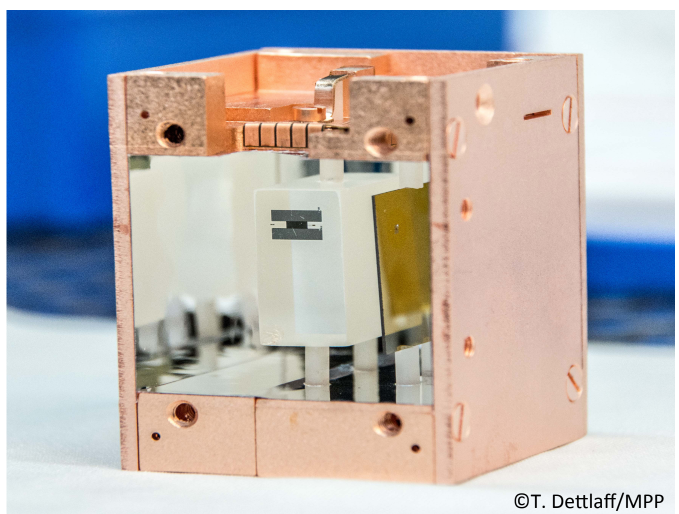
Detector layout optimized for low mass dark matter
Radical reduction of dimension

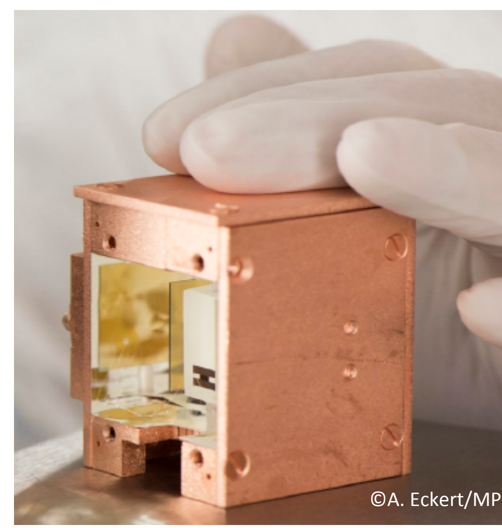
- Cuboid crystals of $(20\times20\times10)\text{mm}^3$ (**≈24g**)
- Self grown crystals **≈3 counts/(keV kg day)**
- **100 eV threshold**
- Fully scintillating housing
- Instrumented sticks

} **Veto surface related background**

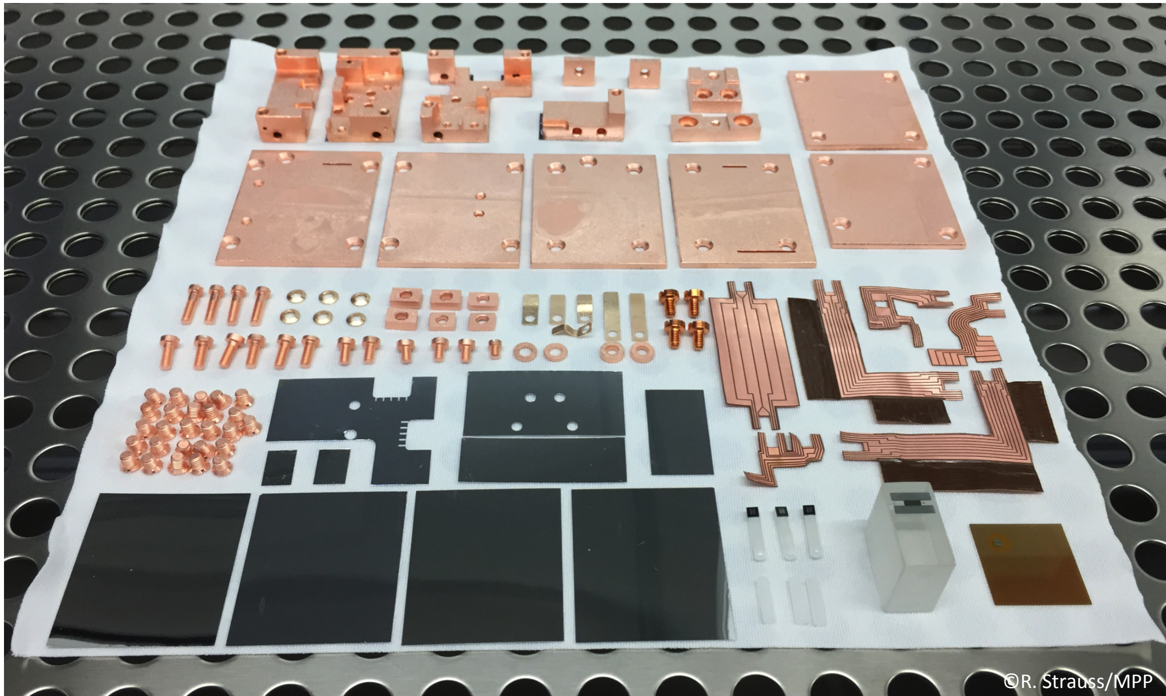


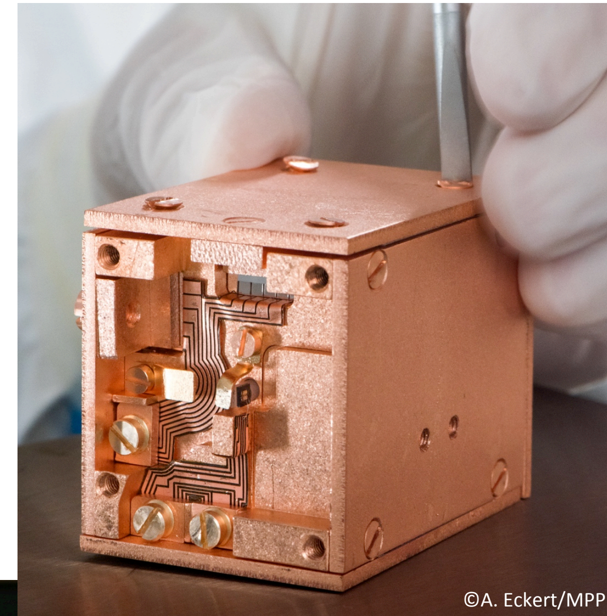


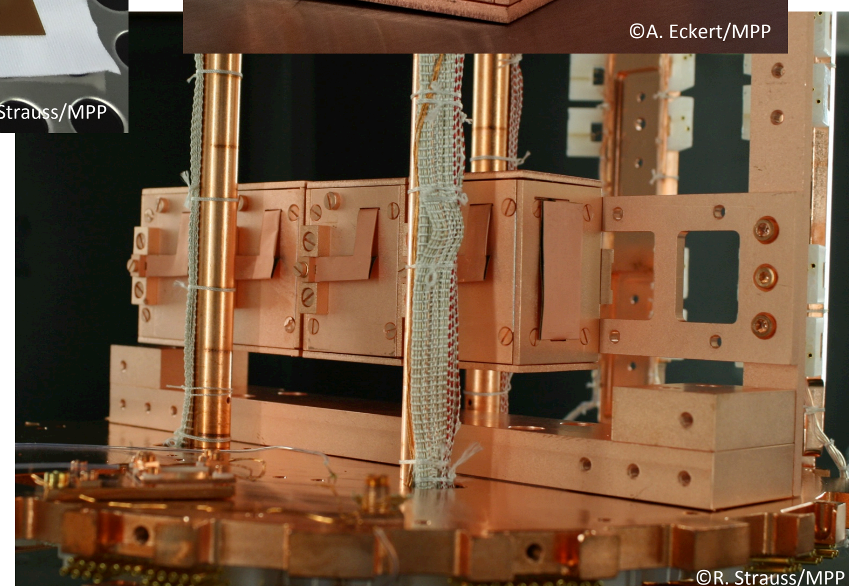




CRESST-III Phase 1







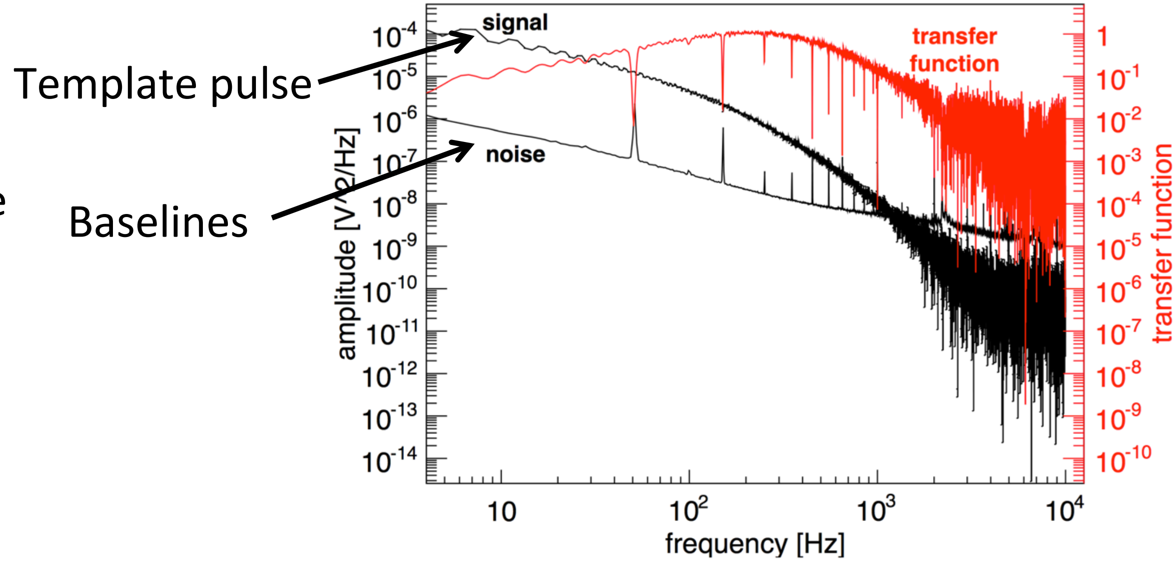
Data taking started July 2016

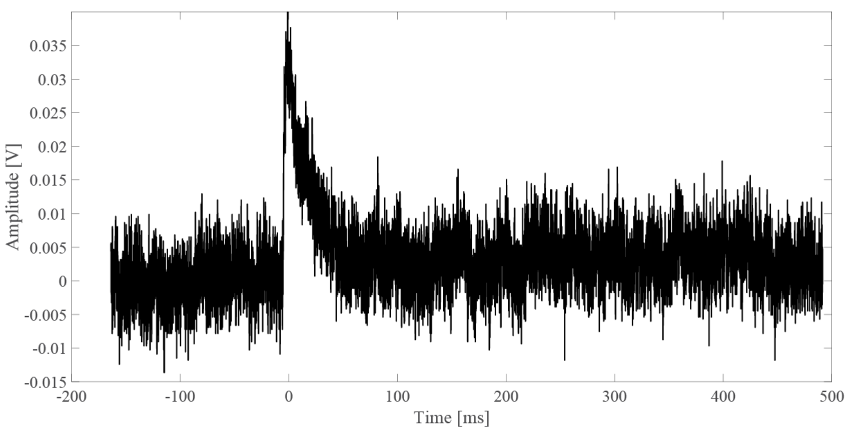
- High statistics gamma calibration
- High statistics neutron calibration
- 20% of DM data as training set

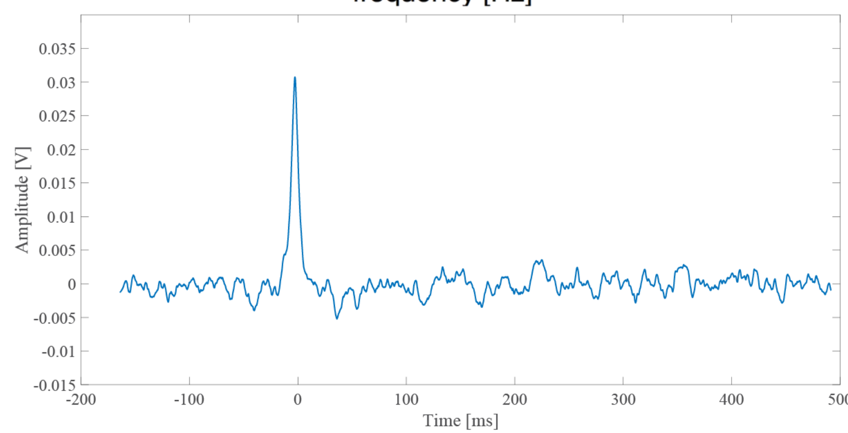
Optimum filter

Pulse-height evaluation with optimum filter

The **Gatti-Manfredi filter** is an optimum filter which maximize the ratio between the amplitude of the treated pulse and the noise RMS





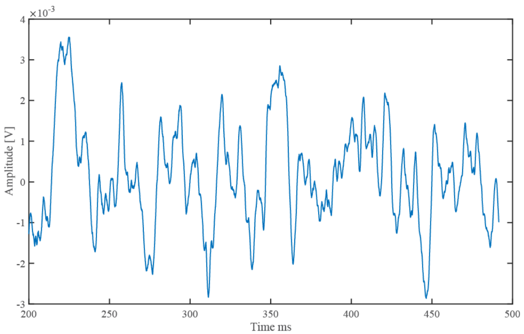


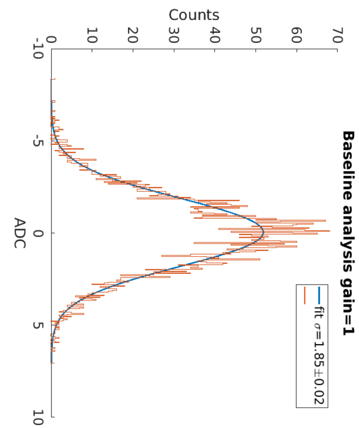
Typical improvement in resolution by using the optimum filter: factor 2-3

Optimum trigger – Detector A

Optimum filter for threshold analysis

Typical base line trace

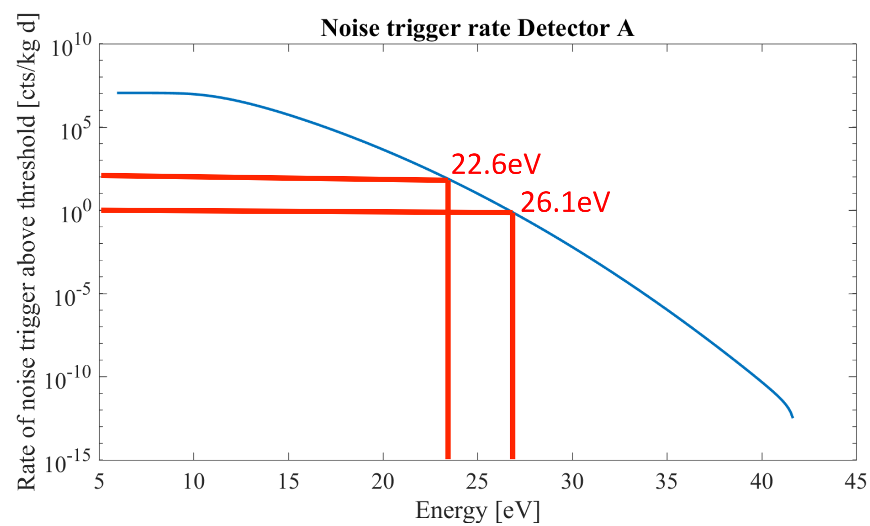




Histogram of a typical baseline trace

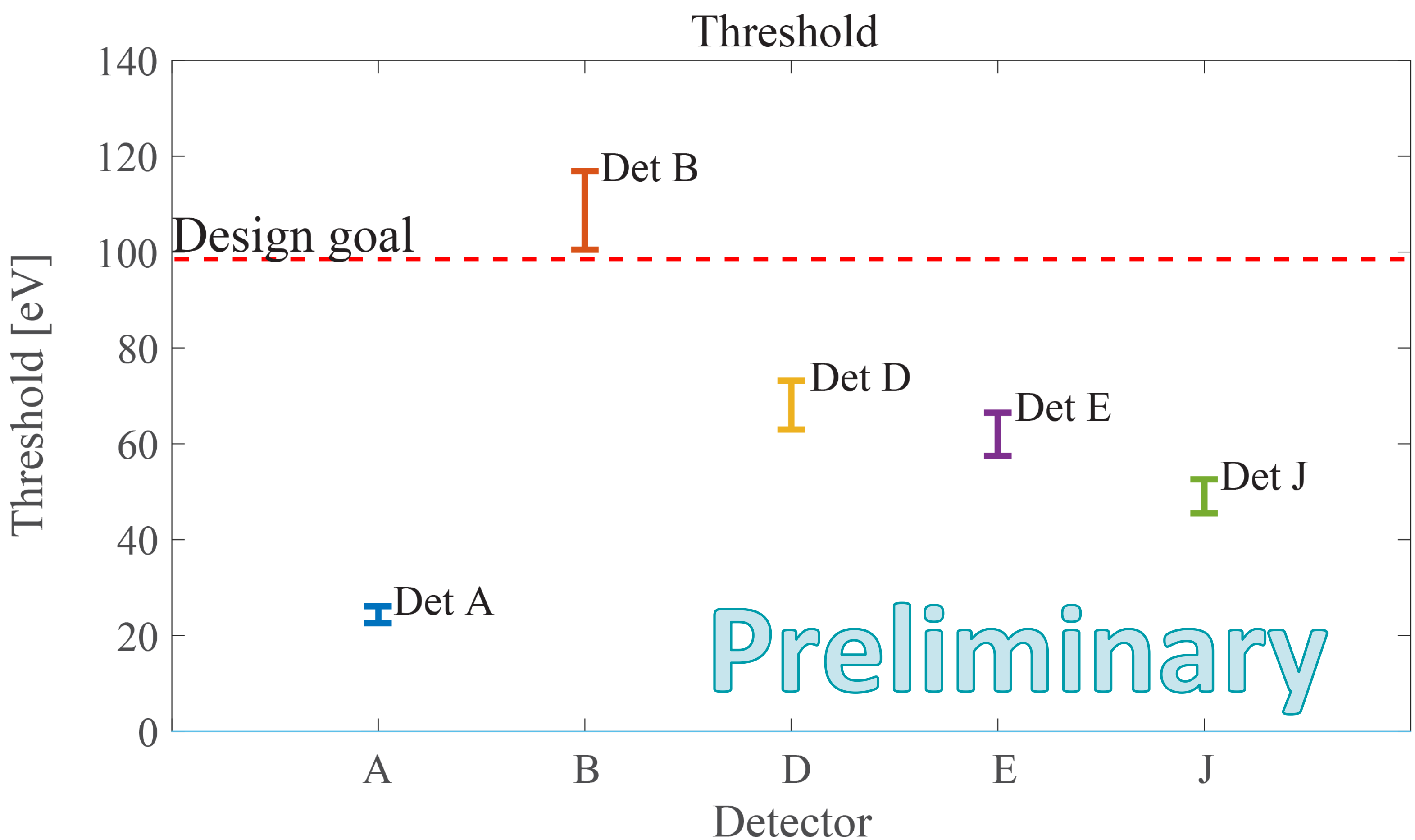
- Continuous sampling of raw data (new DAQ for CRESST-III)
- Study the noise distribution after optimum filter in order to set the threshold

Analytical description of amplitude distribution in empty baselines



New frontier in direct dark matter detection

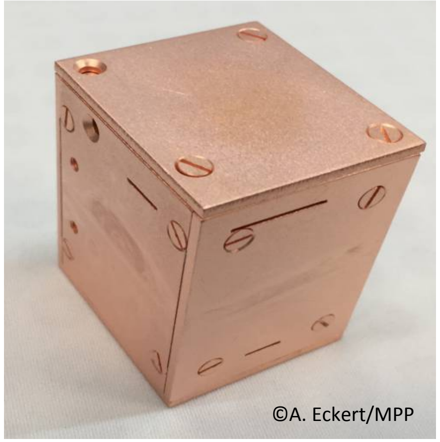
Optimum thresholds



5 detectors reach/exceed CRESST-III design goal

Detector A

Analysis started (of course) from detector A



Data taking period:	31.10.16 - 05.07.17
Non blind data (dynamically growing):	20% randomly selected
Detector mass:	24g
Total exposure:	2.39 kg days
Net exposureafter rate/stability cut (control of operating point and noise conditions):	2.21 kg days
Analysis threshold:	100 eV

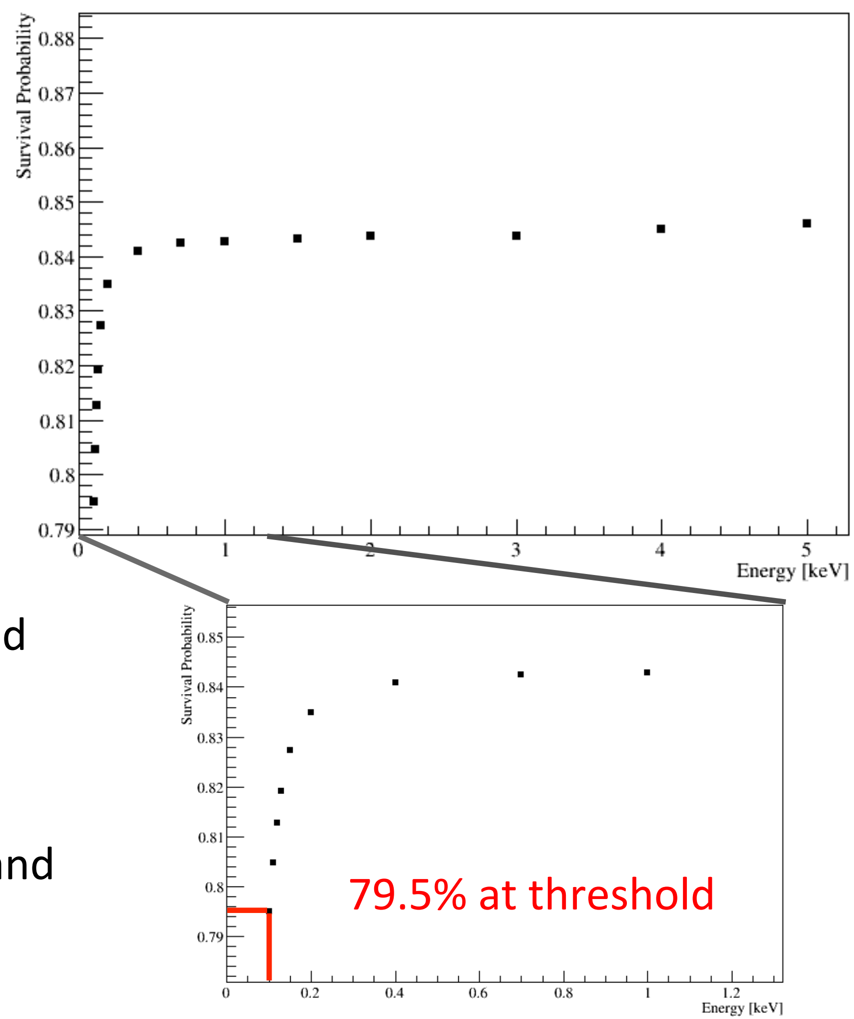
Detector A – 100eV threshold analysis

Selection criteria and efficiencies

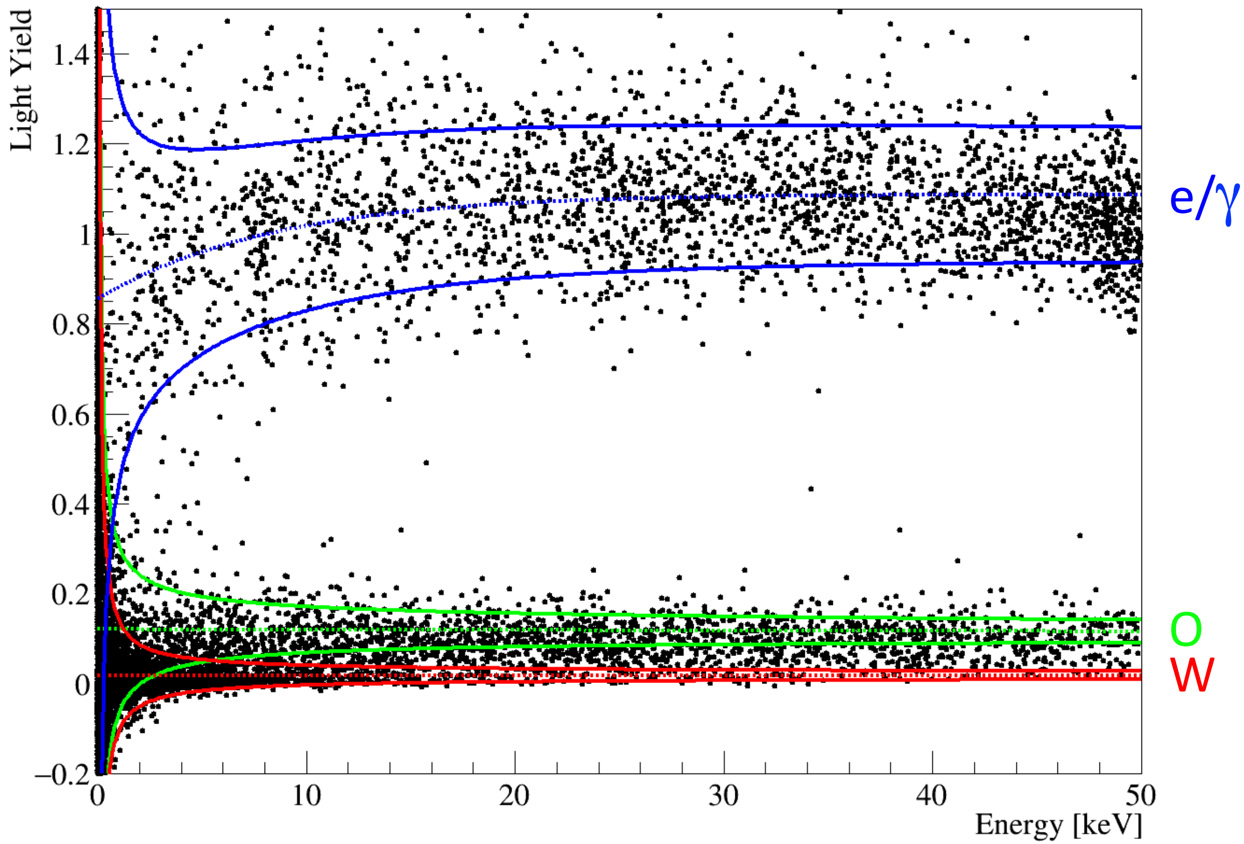
Selection criteria to remove pulses where a correct determination of the amplitude is not guaranteed
Designed on non blind data (20% of dark matter randomly selected) not included in the final exposure

- Data quality
  events which cannot properly be analyzed
- Pulse shape
  e.g events in iSticks, pileup
- Coincidences
  for the time being only with muon veto and iSticks

Survival Probability of Nuclear Recoil Events After Cuts



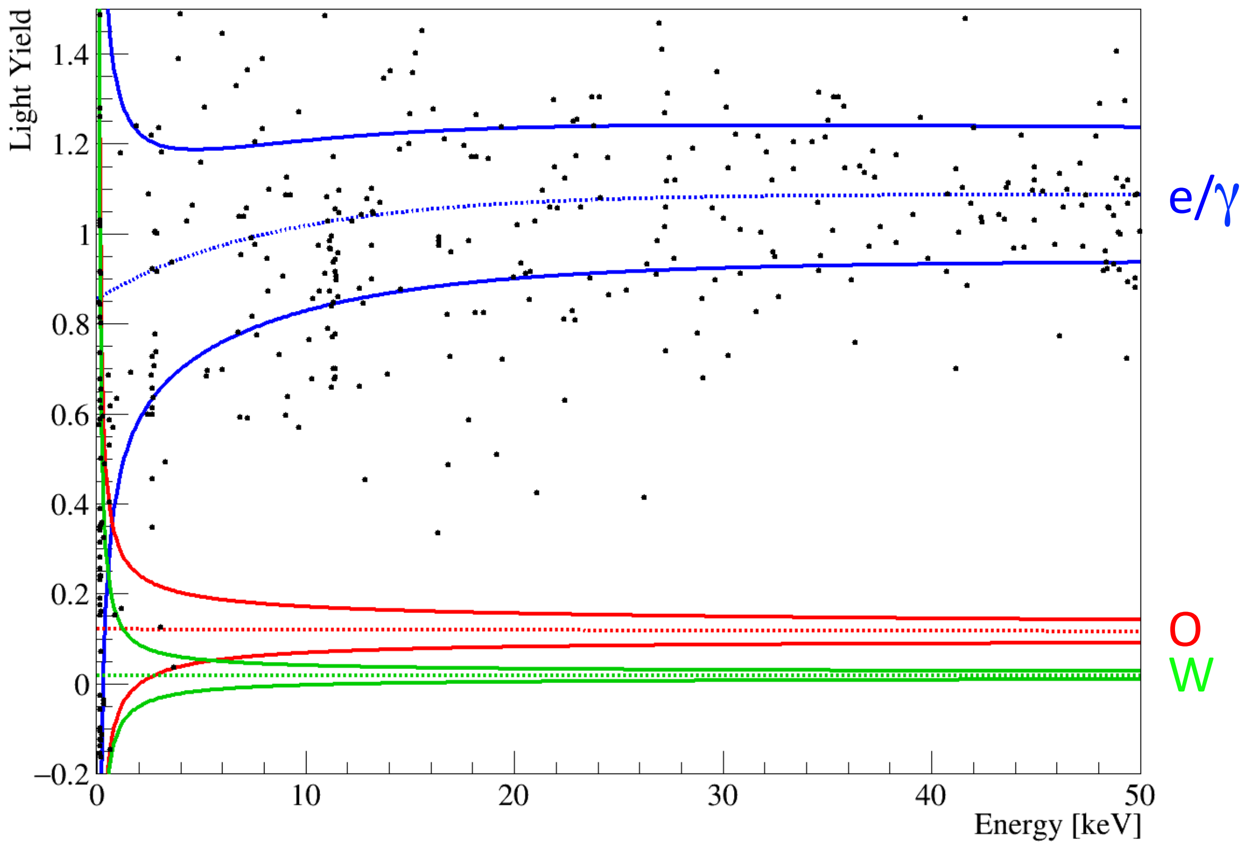
Detector A – neutron calibration



Detector A – 100eV threshold analysis

The blind data - LY vs. Energy

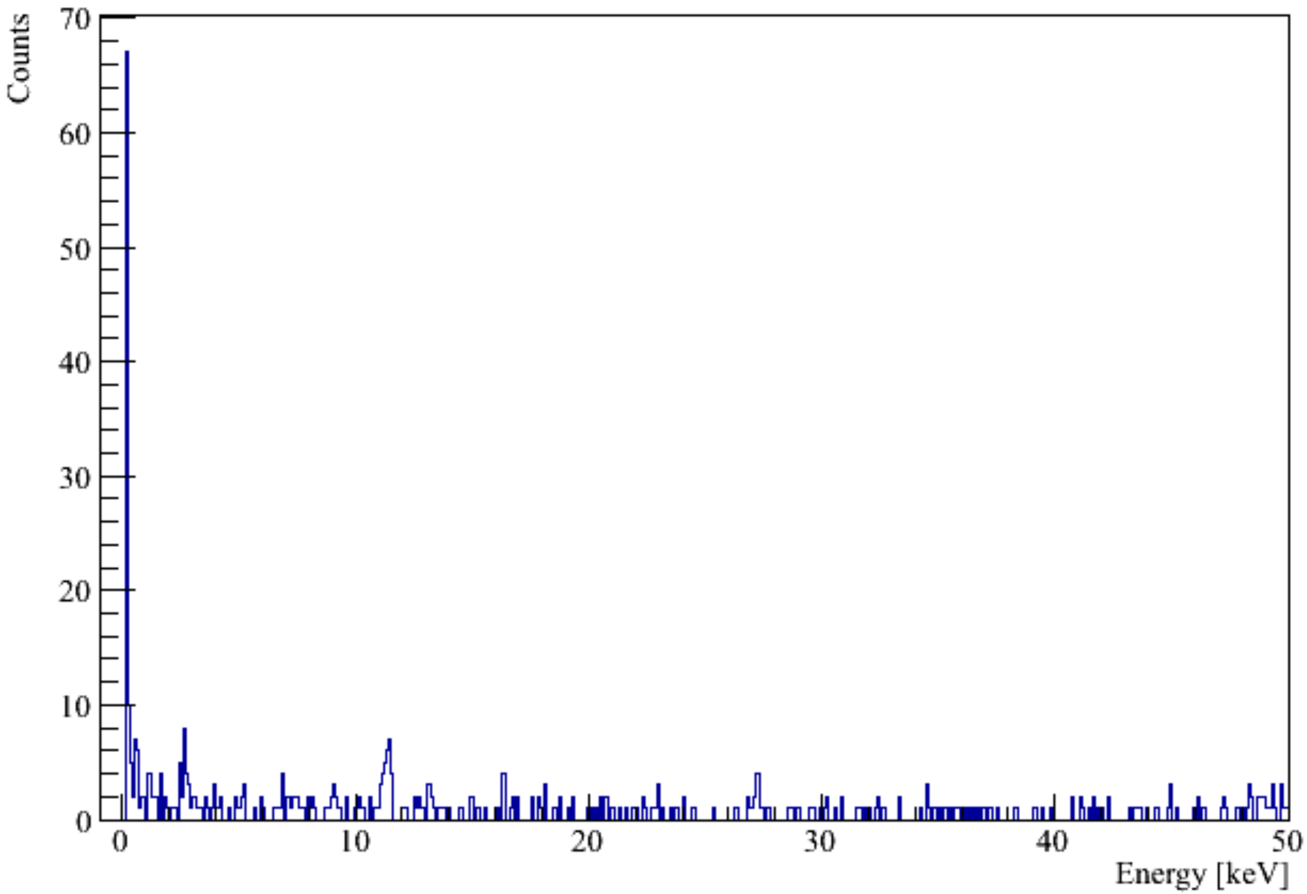
Unblinding for energies >100eV on July 10^{th}



Detector A – 100eV threshold analysis

The blind data – Energy spectrum

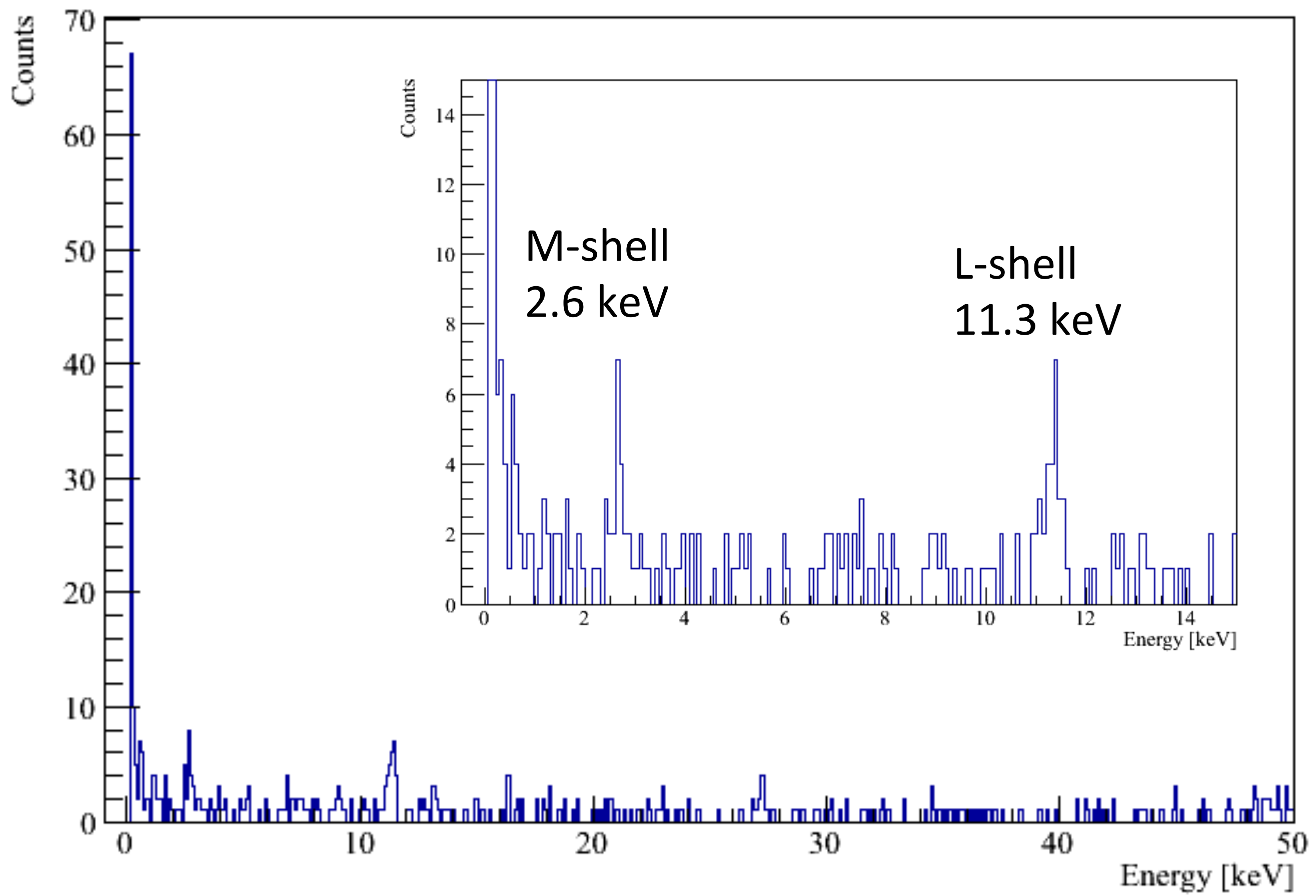
Background in energy range 1-40keV ≈3.5 counts per (kg keV day)



Detector A – 100eV threshold analysis

The blind data – Energy spectrum zoom

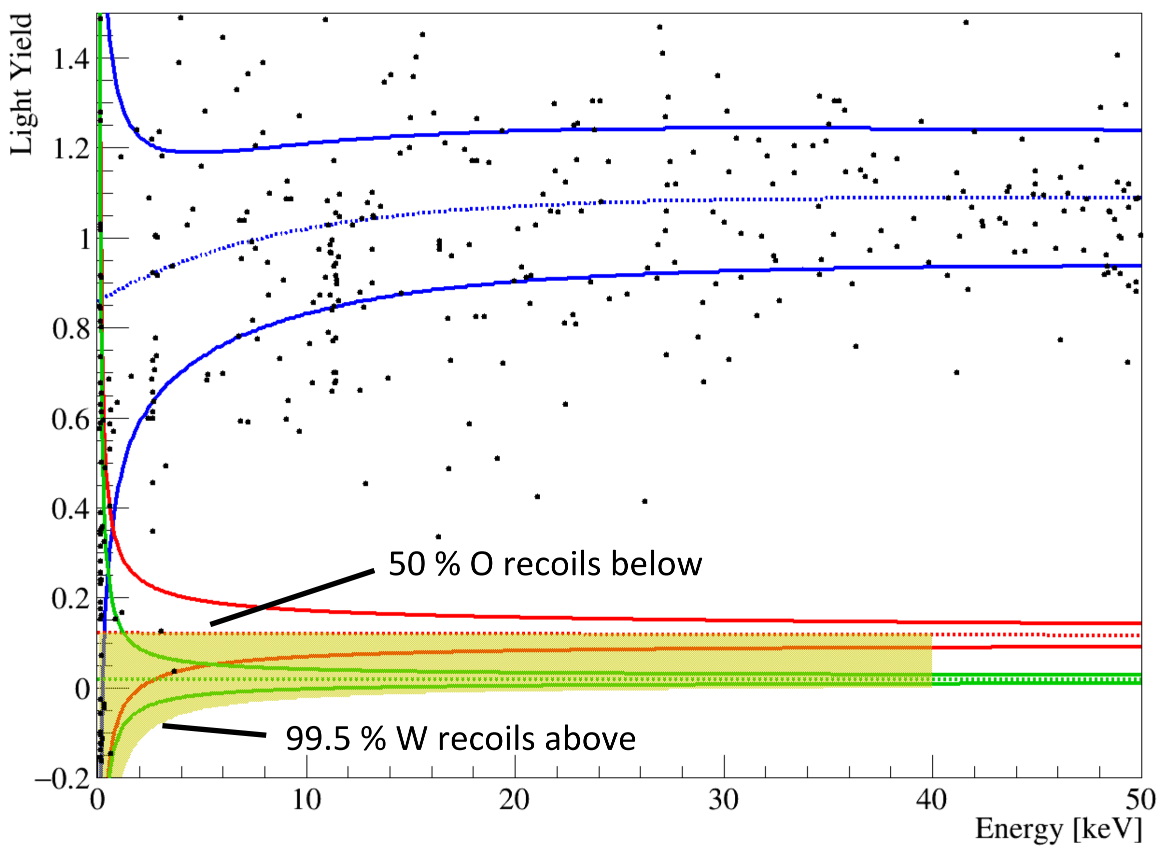
$^{179}Ta + e^{-} \rightarrow ^{179}Hf + \nu_e$ (1.8y)



Detector A – 100eV threshold analysis

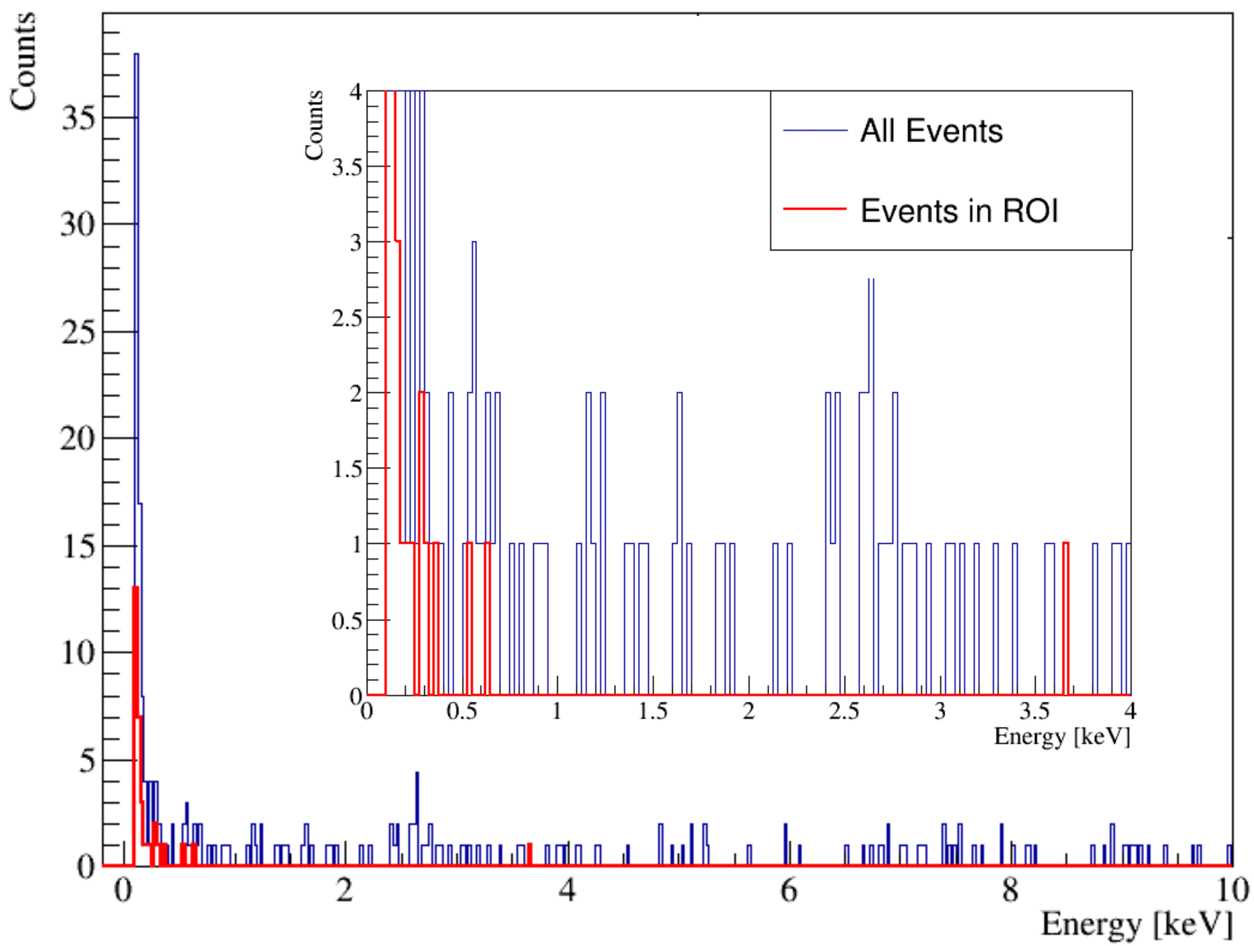
The blind data – Acceptance region

Acceptance region chosen before unblinding



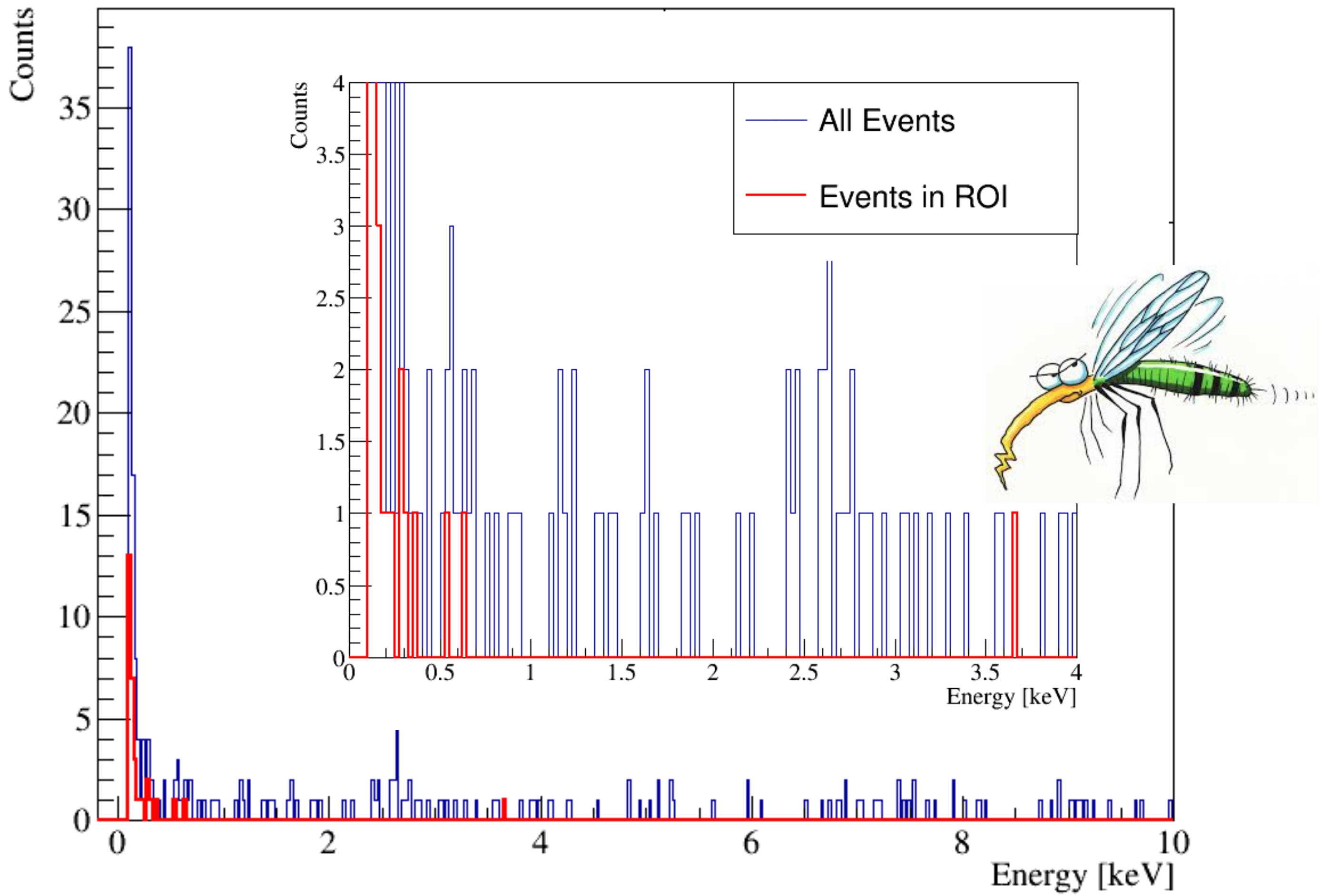
Detector A – 100eV threshold analysis

The blind data – Energy spectrum accepted events



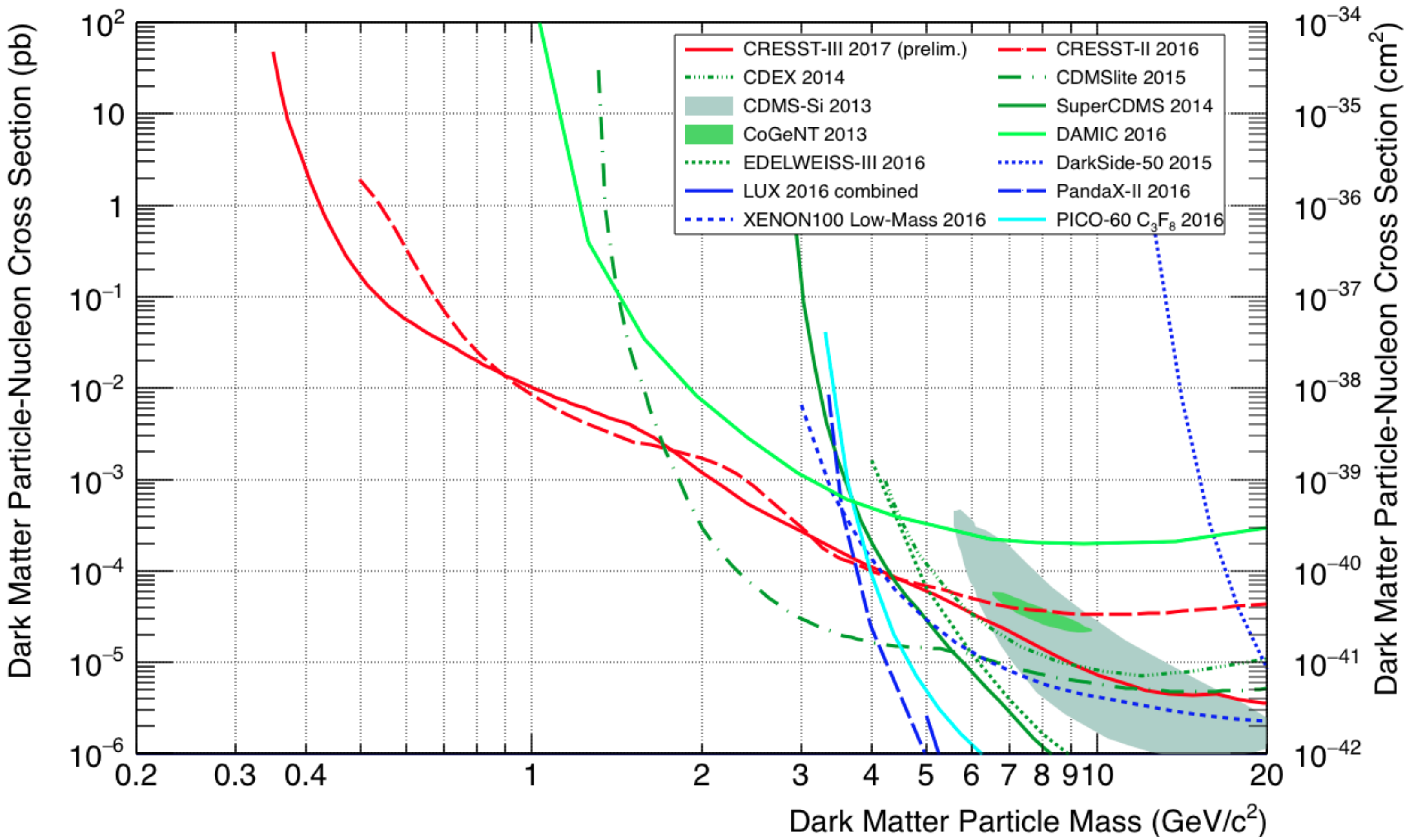
Detector A – 100eV threshold analysis

The blind data – Energy spectrum accepted events



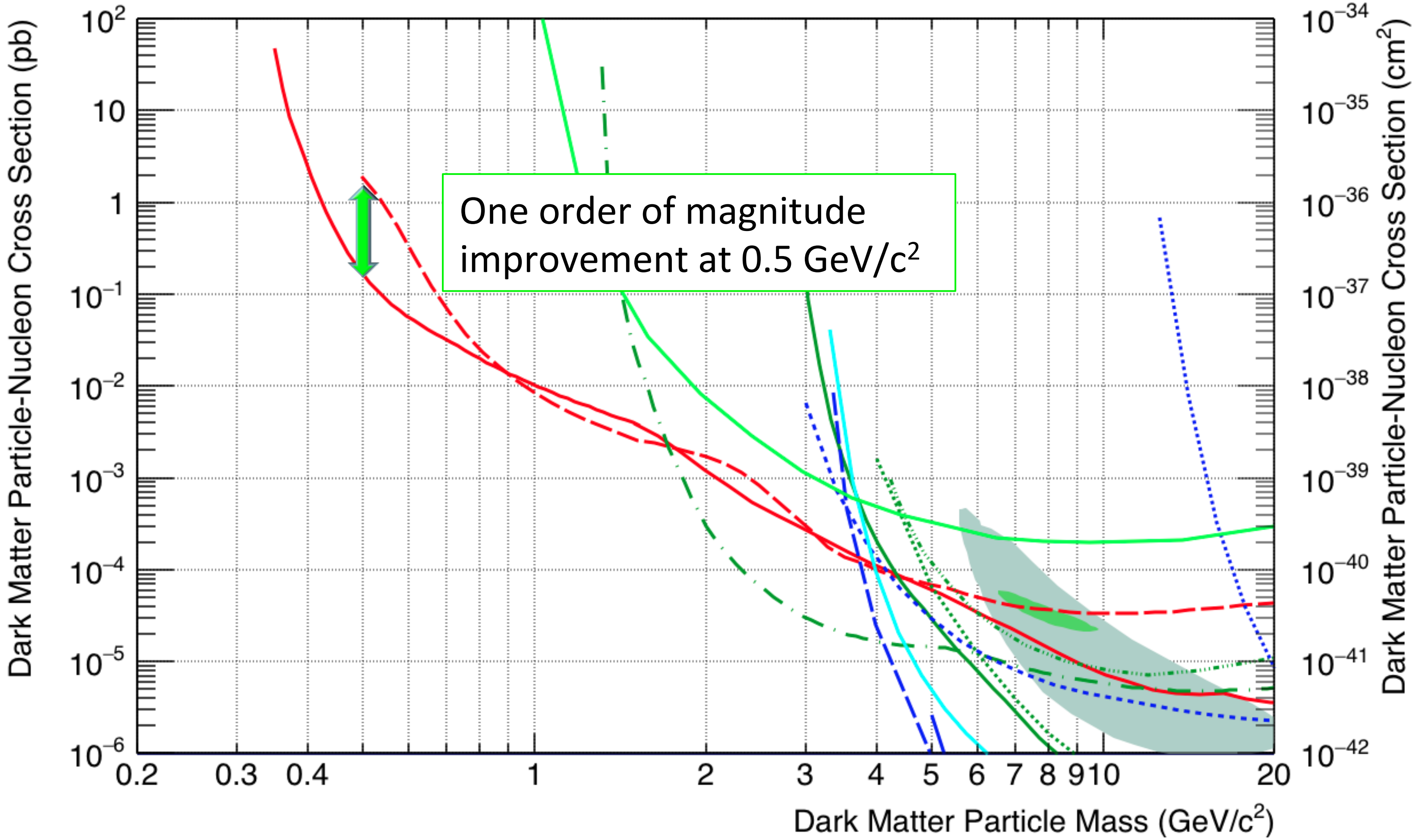
Detector A – 100eV threshold analysis

The exclusion limit



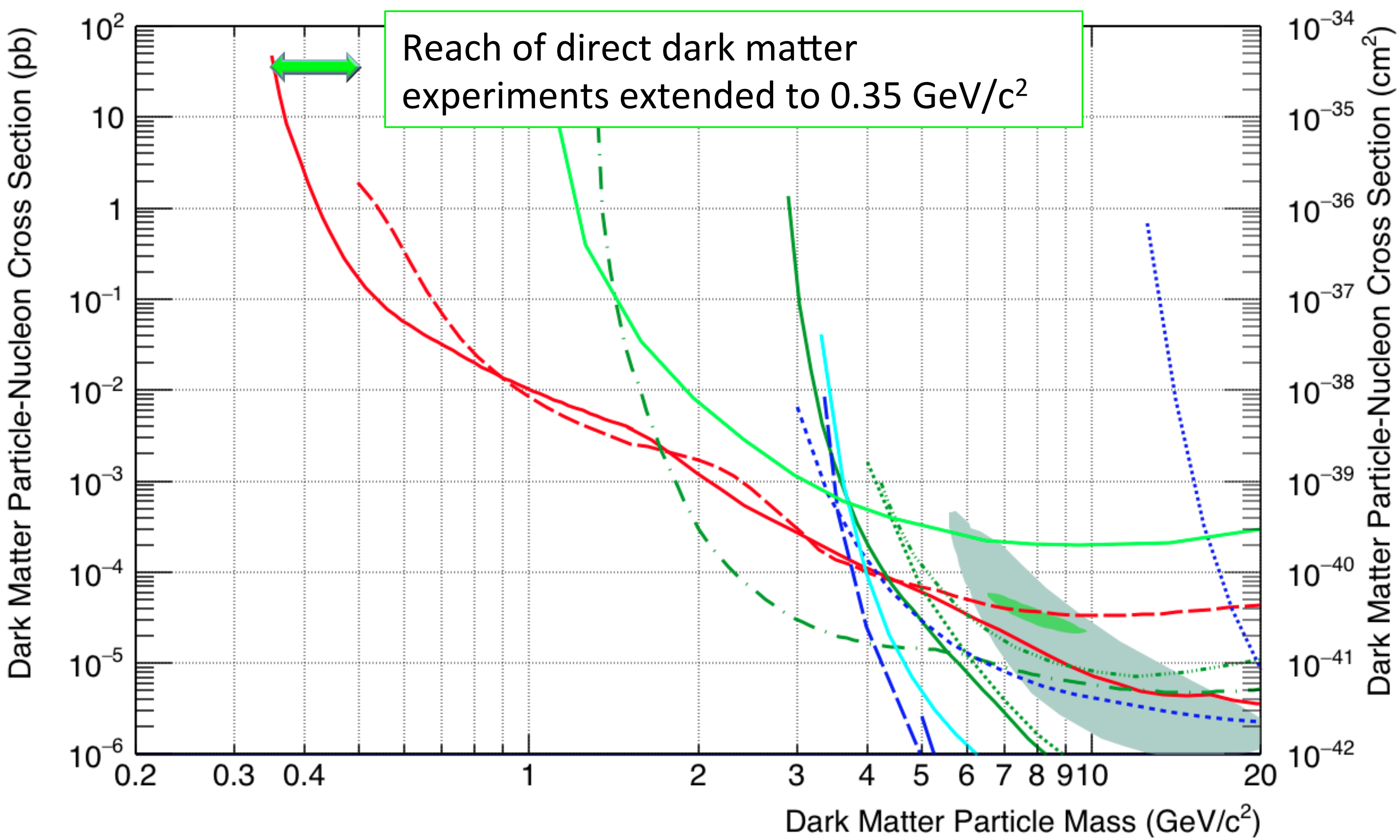
Detector A – 100eV threshold analysis

The exclusion limit - improvements



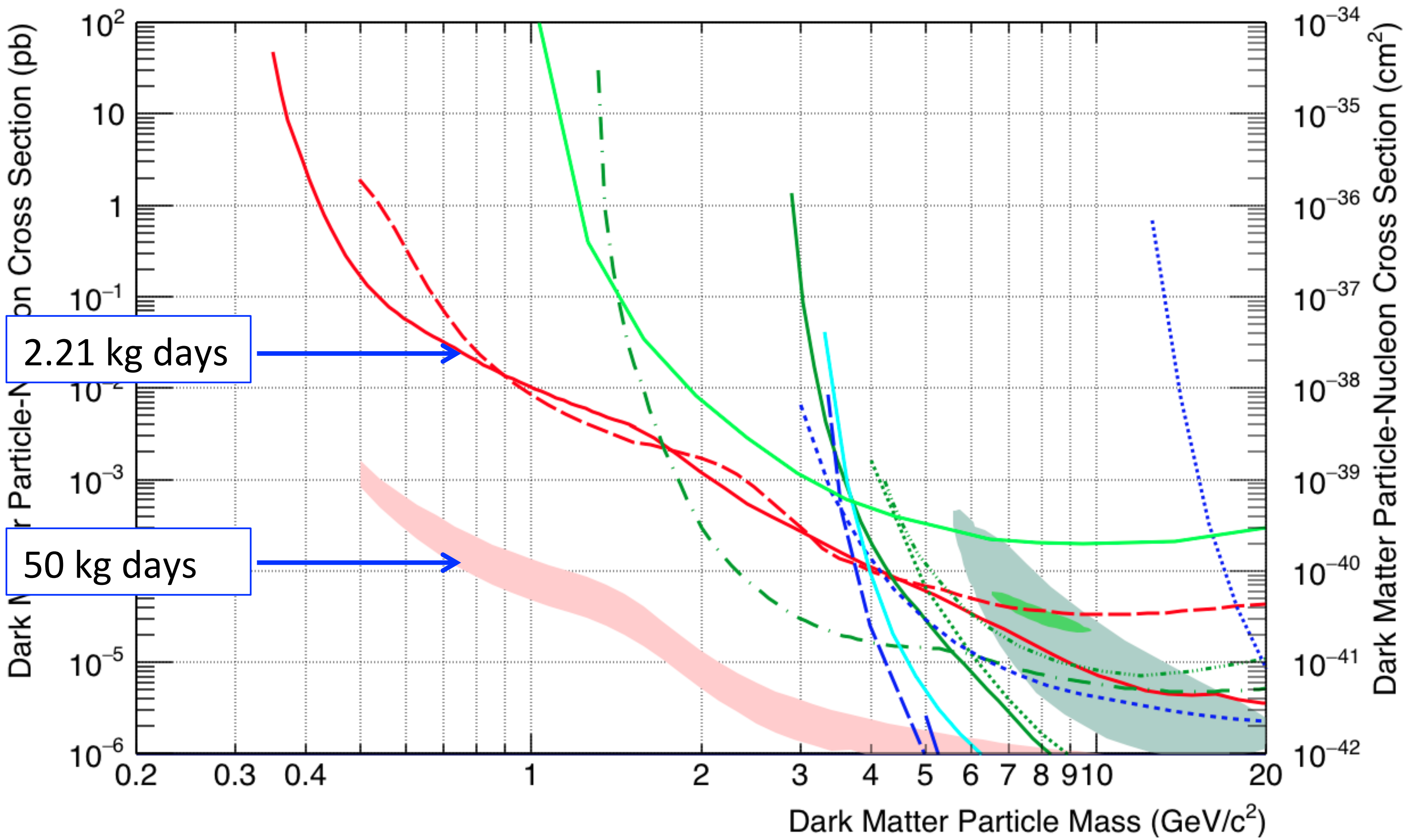
Detector A – 100eV threshold analysis

The exclusion limit - improvements



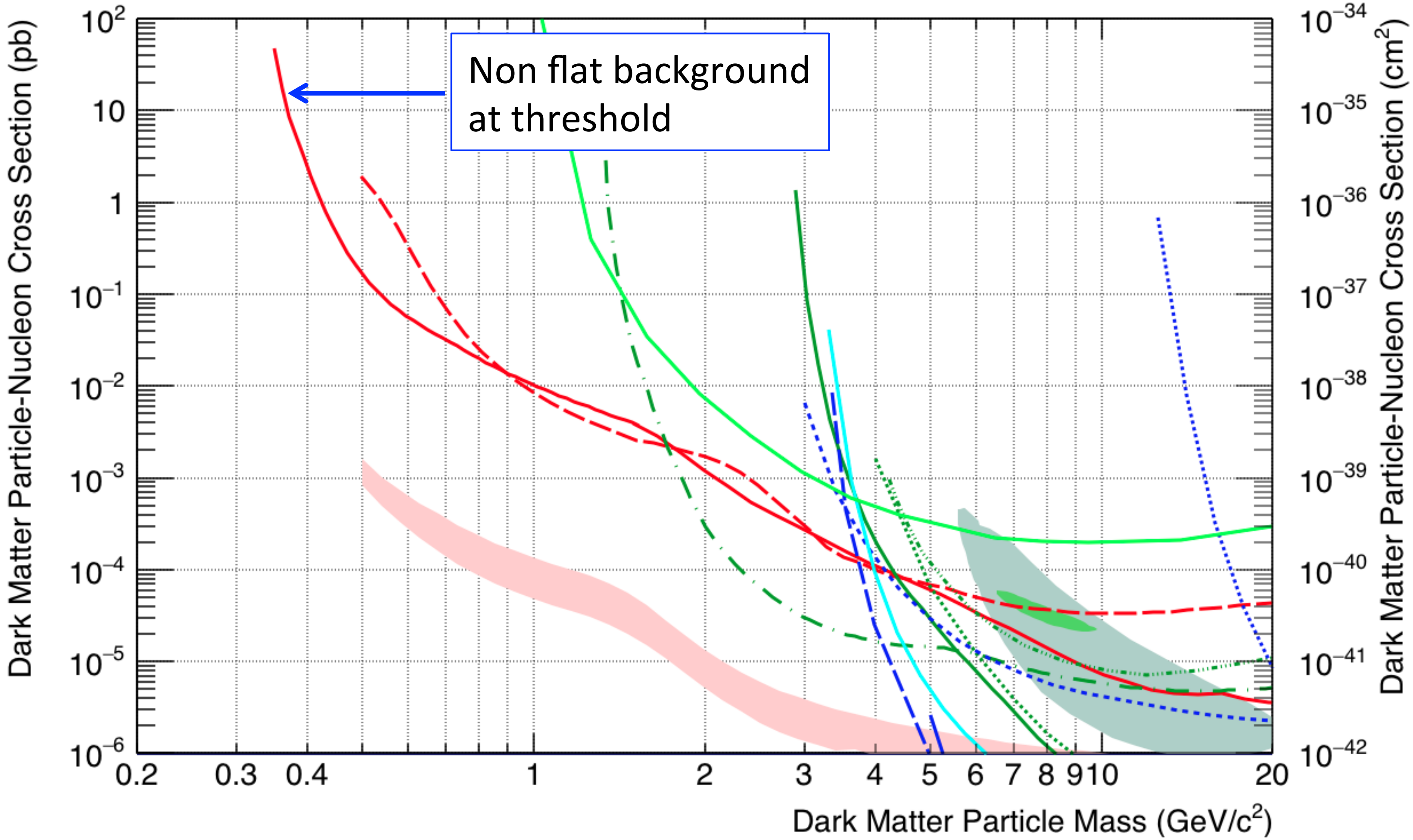
Detector A – 100eV threshold analysis

The exclusion limit - limitations



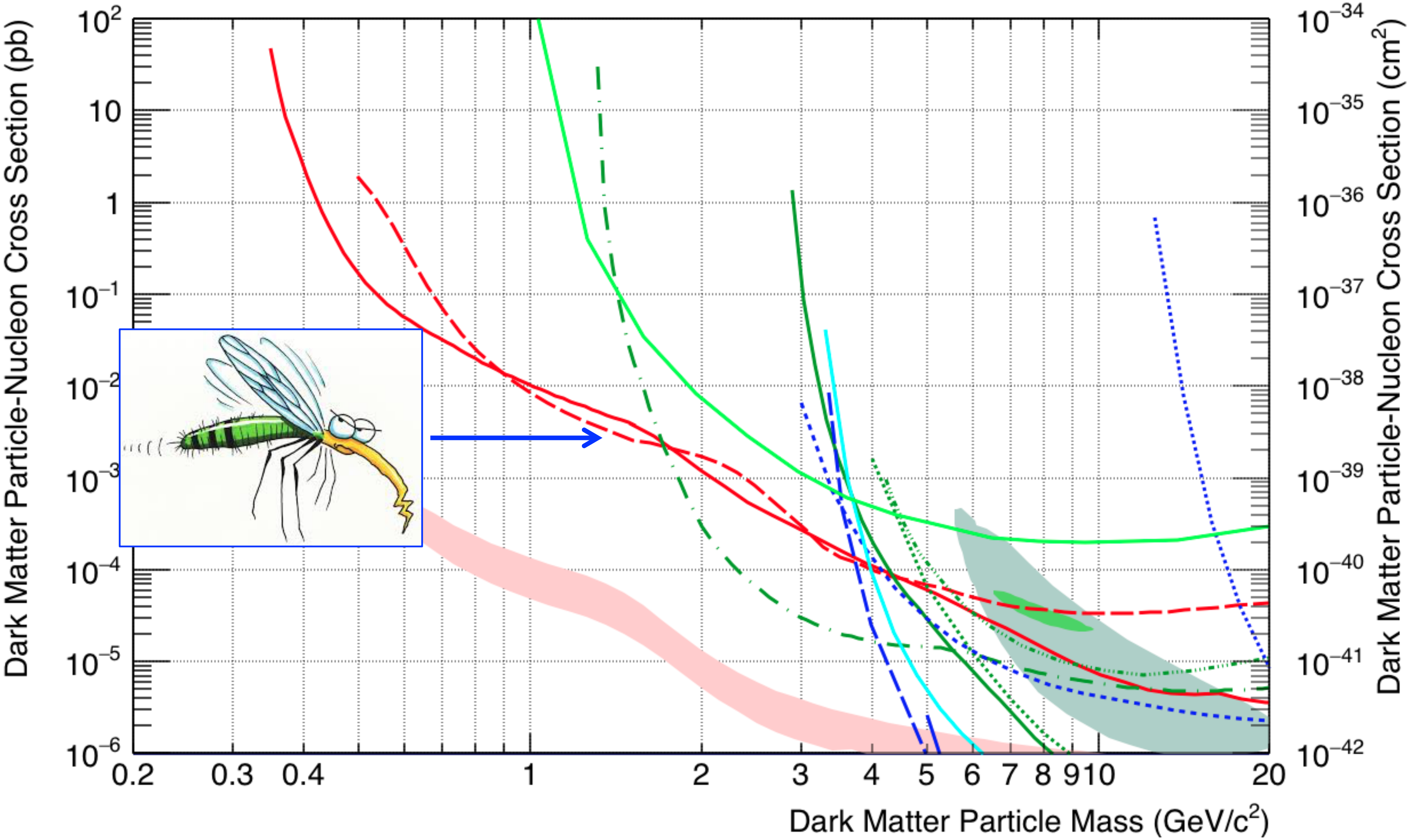
Detector A – 100eV threshold analysis

The exclusion limit - limitations



Detector A – 100eV threshold analysis

The exclusion limit - limitations



This is just the beginning

3 times lower optimum threshold (than 100eV analysis threshold) for detector A

3 other detectors with thresholds << 100eV

3 times more statistics → deeper understanding of backgrounds

In the meanwhile we continue to take data

New frontiers…
… new potentials…
… new challenges!