Constraints on Low-Mass WIMPs from PICASSO

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University of Alberta for the PICASSO Collaboration
IDM Chicago, July 25 2012

IDENTIFICATION OF DARK MATTER

IDM 2012 CHICAGO

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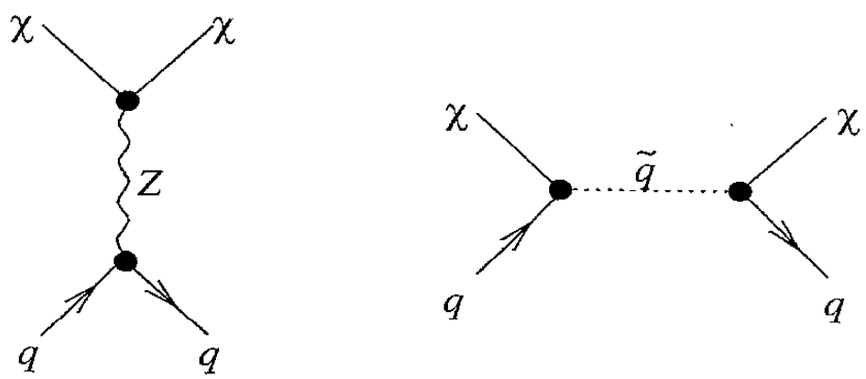
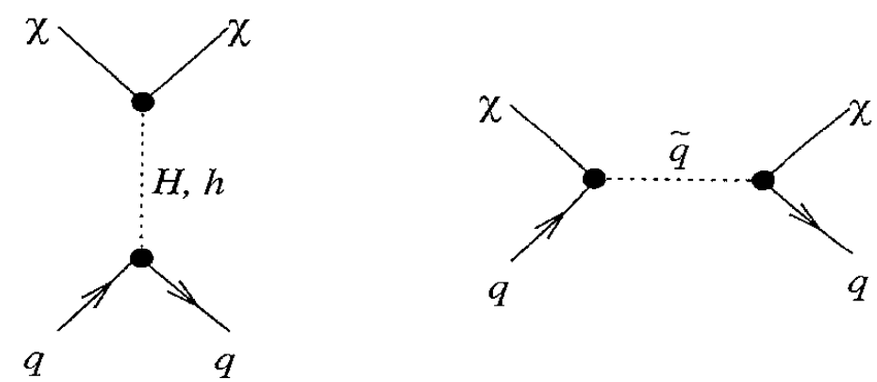
Spin-Dependent or Spin-Independent Interaction



Axial-vector, Spin-dependent

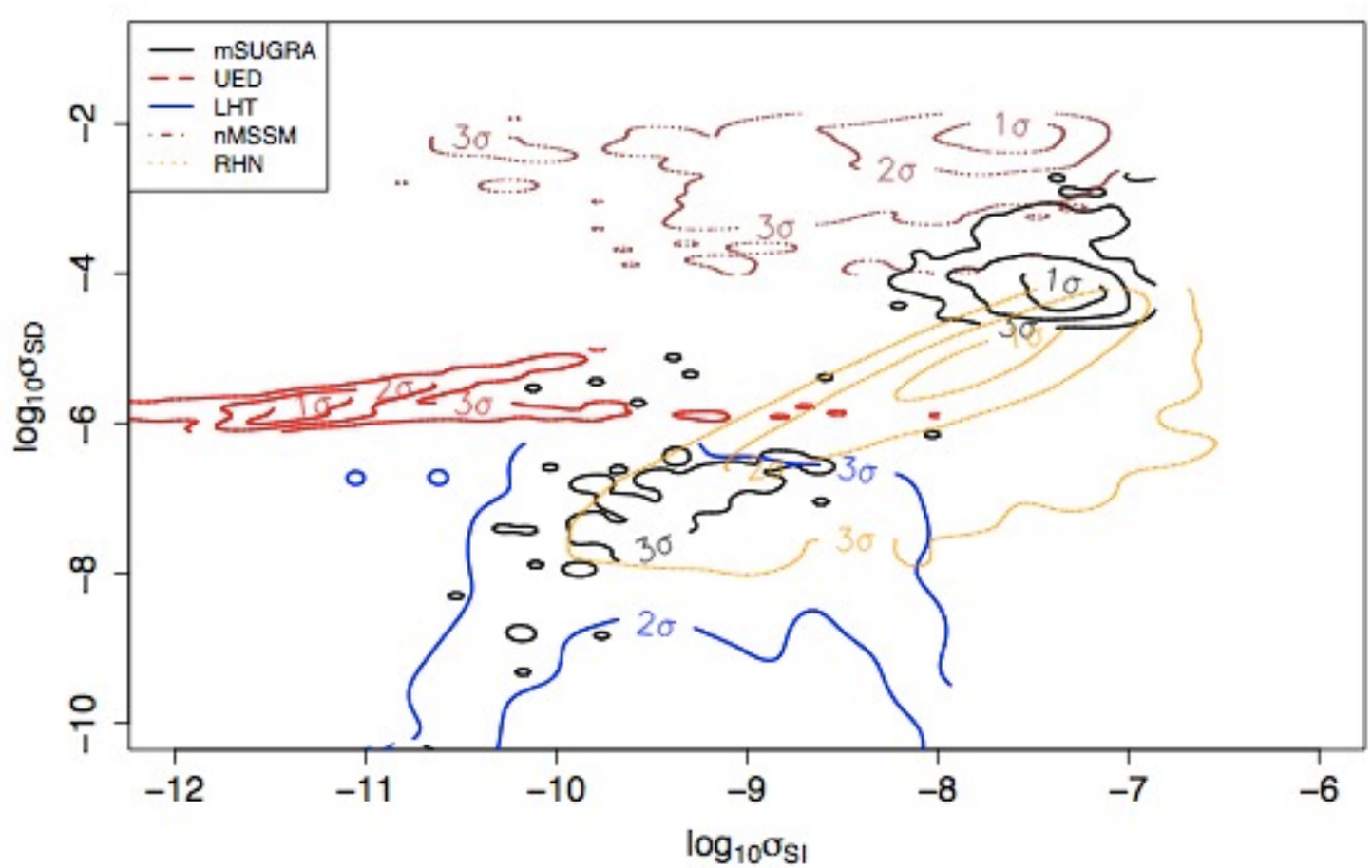


Scalar, spin independent

- The neutralino is a superposition of Higgsino, "Zino" and "photino", depending on the model.
- A spin-carrying, Majorana type neutralino would interact by Z exchange and squark interaction

Spin or no Spin

- In order to identify what model of physics is realized, both SI and SD cross sections should be measured.



Barger, V., Keung, W.-Y., & Shaughnessy, G. (2008). Spin dependence of dark matter scattering. *Physical Review D*, *78*(5), 056007

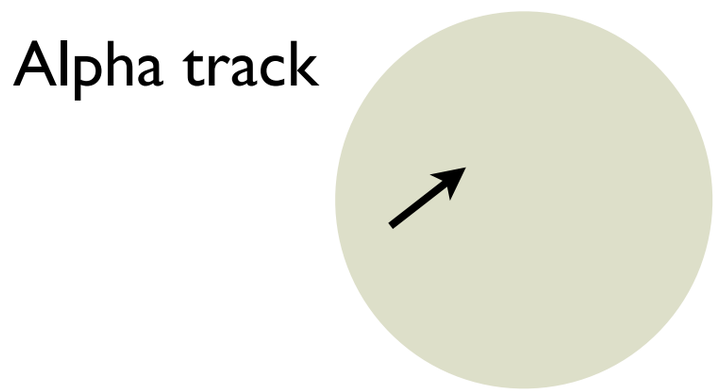
PICASSO

- Project in Canada to search for Supersymmetric Objects.
- The experiment is located at SNOLAB in Sudbury, Ontario.
- Collaboration has members from Canada, the US, the Czech Republic, and India.

Superheated Droplet & Alpha Track

- Freon droplets suspended in gel matrix.
- Each droplet is like a mini-bubble chamber.
- Nucleations are triggered along the charged particle track and initiate a phase transition.

Superheated Droplet & Alpha Track



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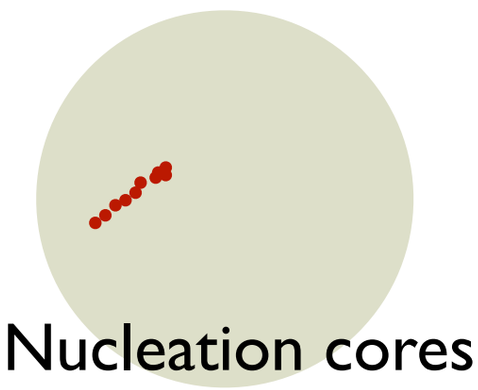

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Superheated Droplets and Nuclear Recoils

- Recoil track is much shorter.
- Typically only a single nucleation will occur.
- Much larger dE/dx will still initiate phase transition and cause bubble to explode.

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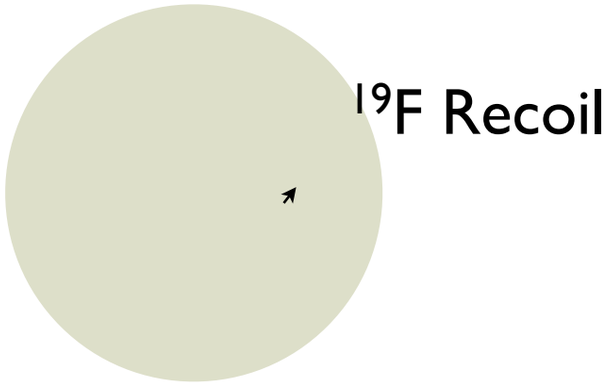

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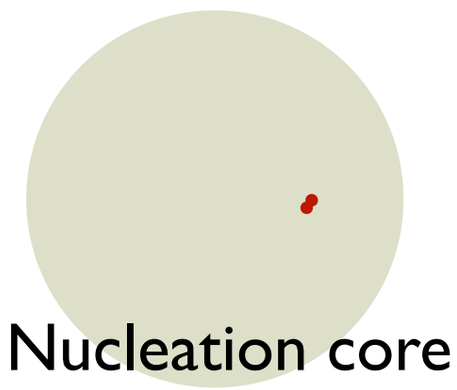

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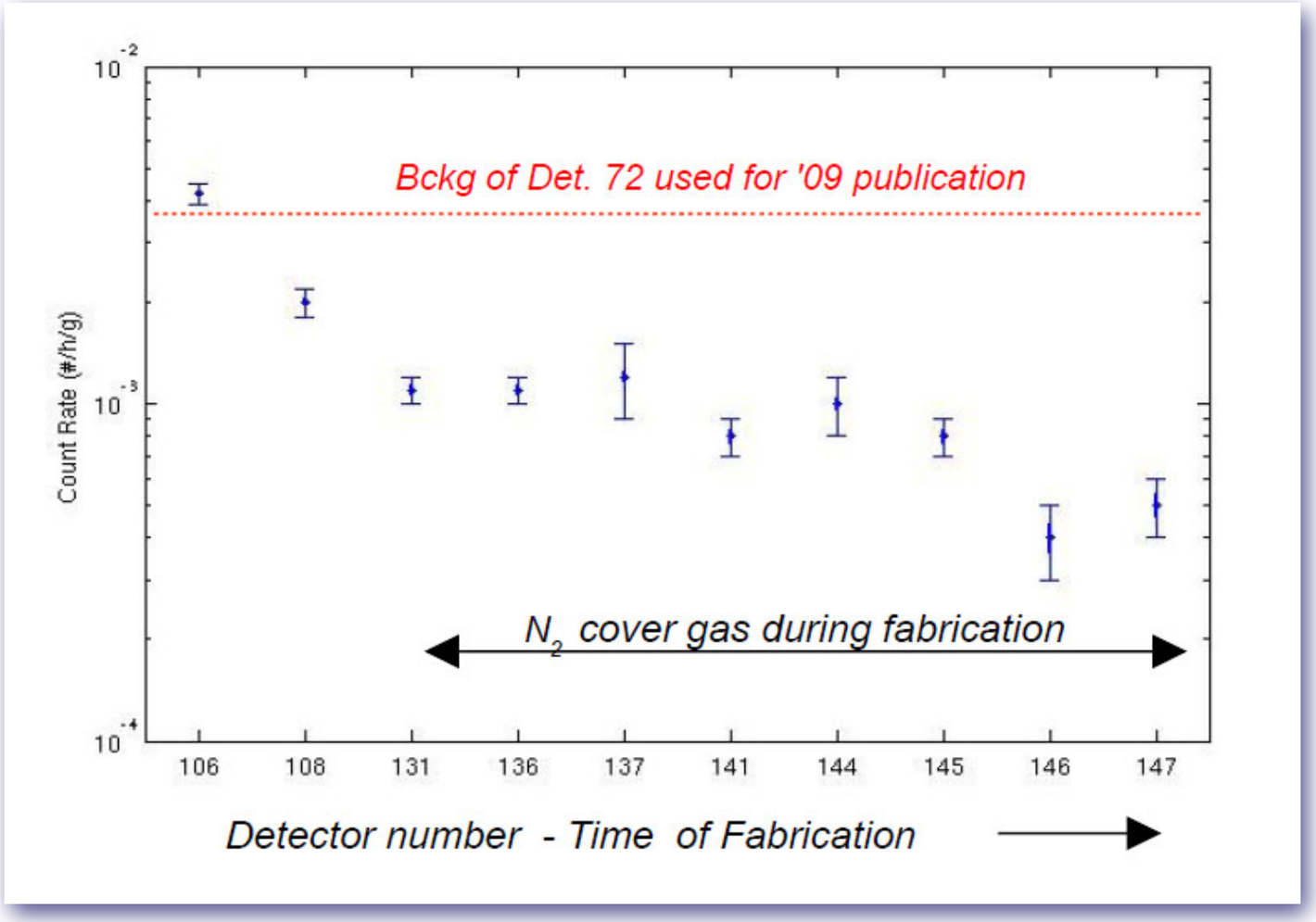
Detector

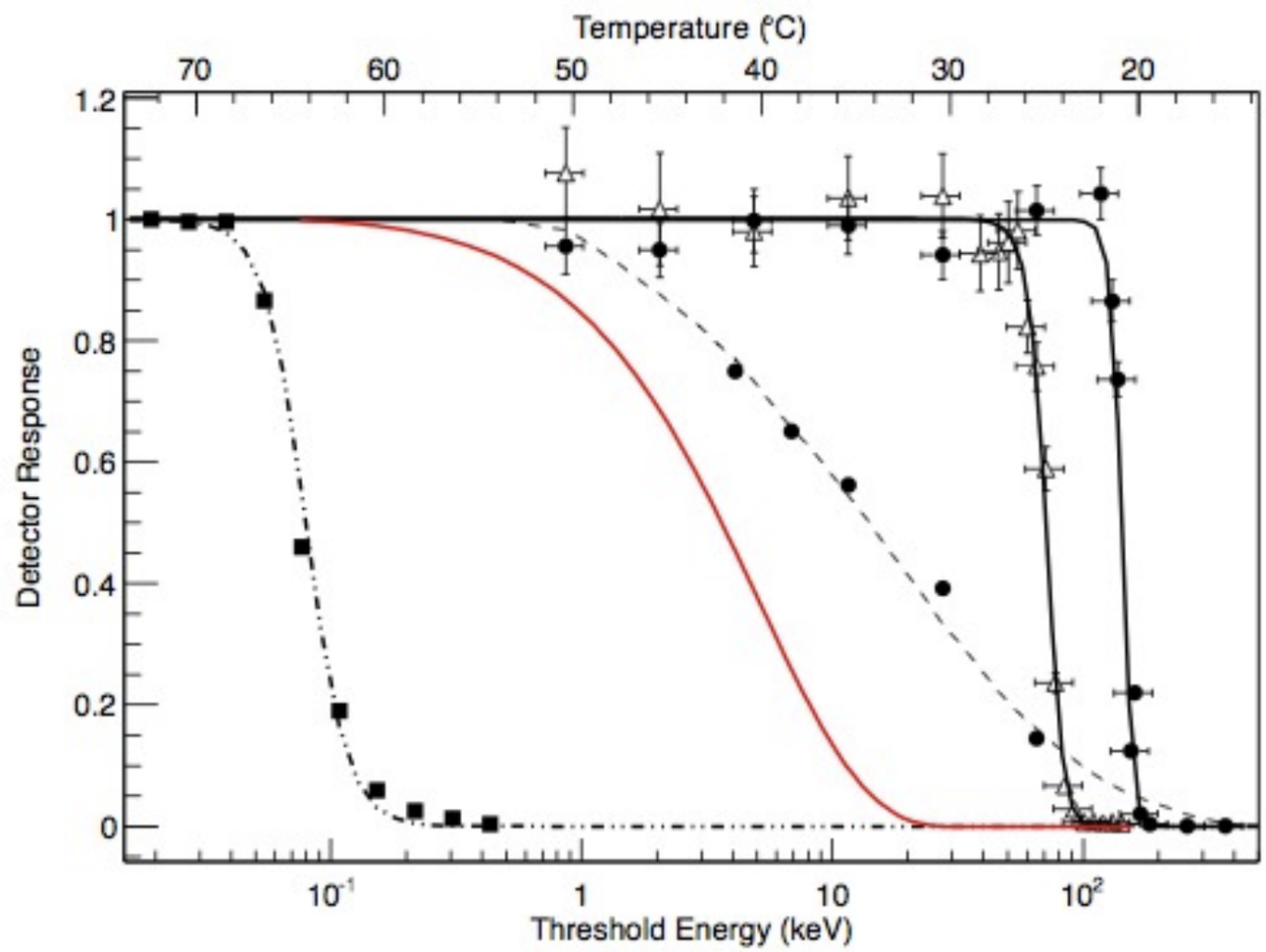
- Contains gel matrix to keep superheated droplets suspended.
- No longer uses CsCl to match density of droplets to gel.
- We have increased purity and reduced background in every generation of detector.

Purification



- Continued efforts to improve purification have resulted in lower internal background levels in the gel matrix.

Detector Response



- Threshold detector, with different response to different types of radiation:
  Alphas have the lowest threshold, MIPs the highest.
- A 50GeV WIMP would have a response as shown

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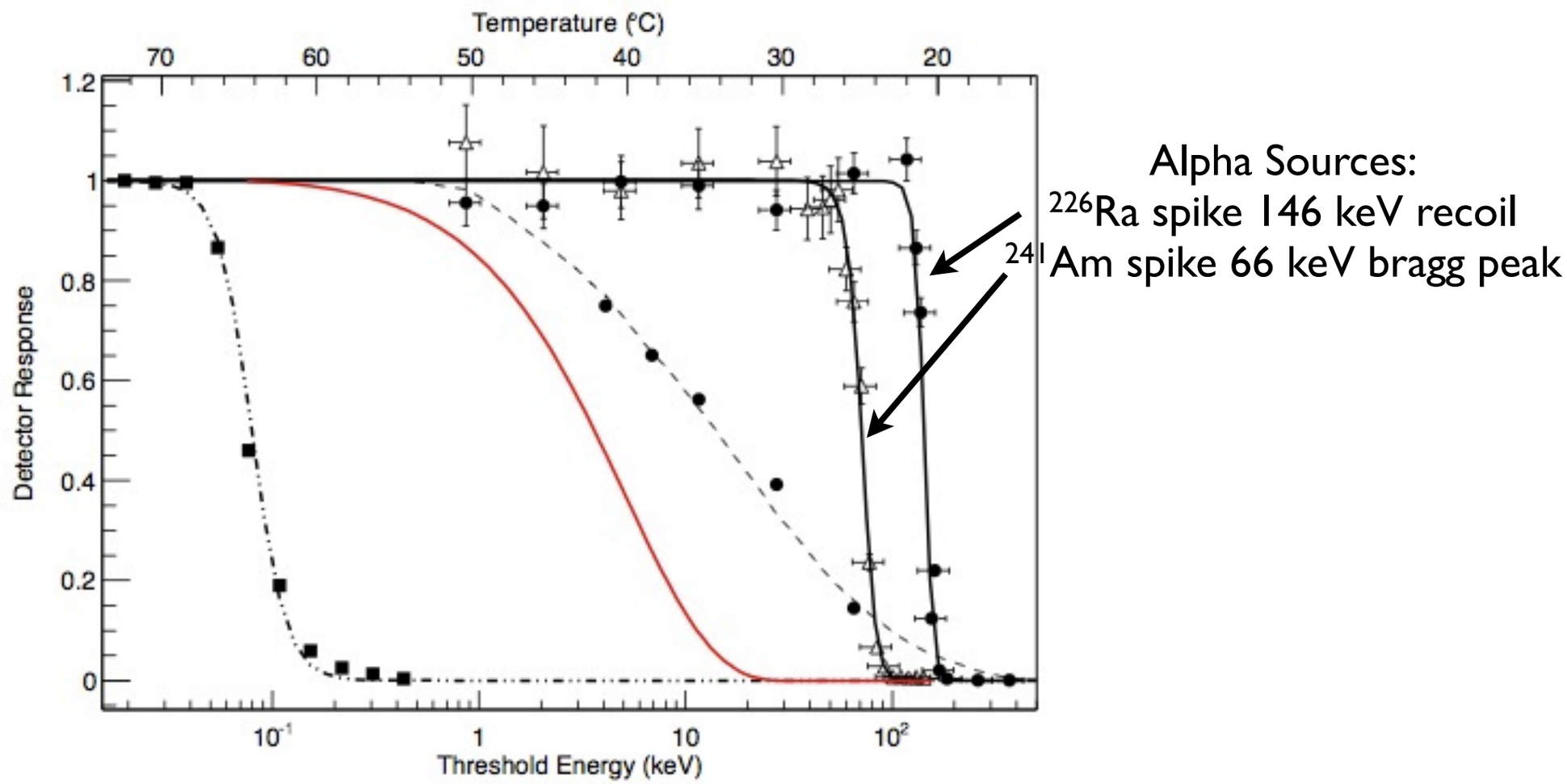
Detector Response



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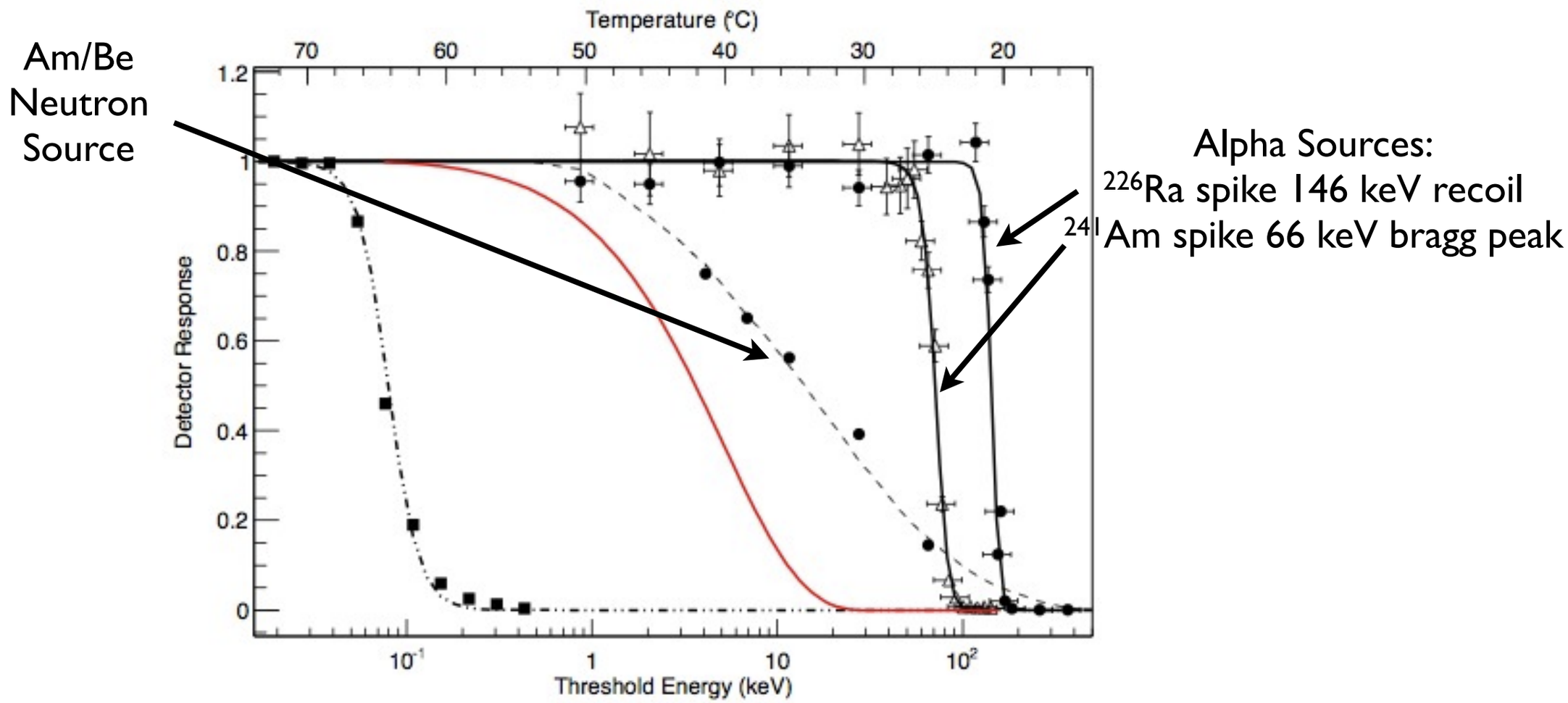

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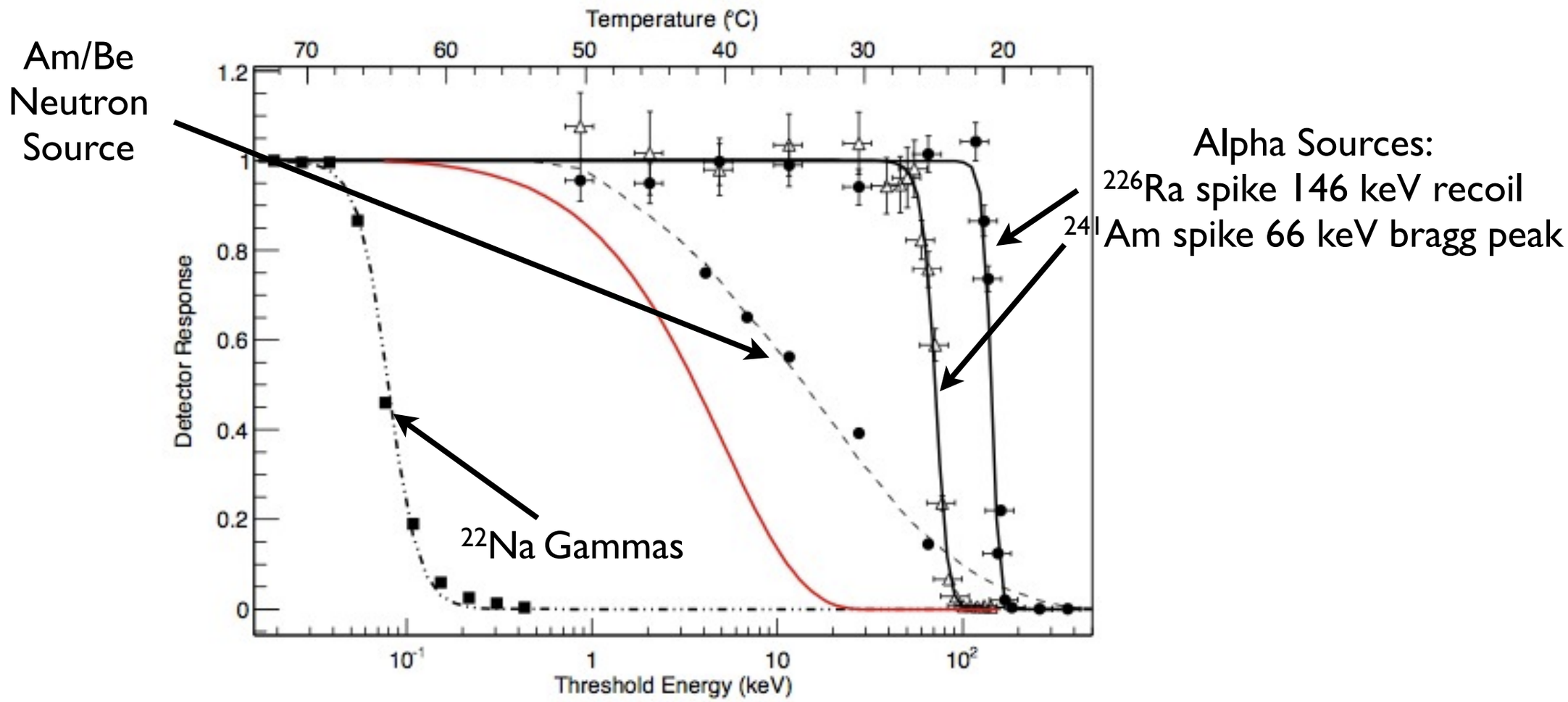

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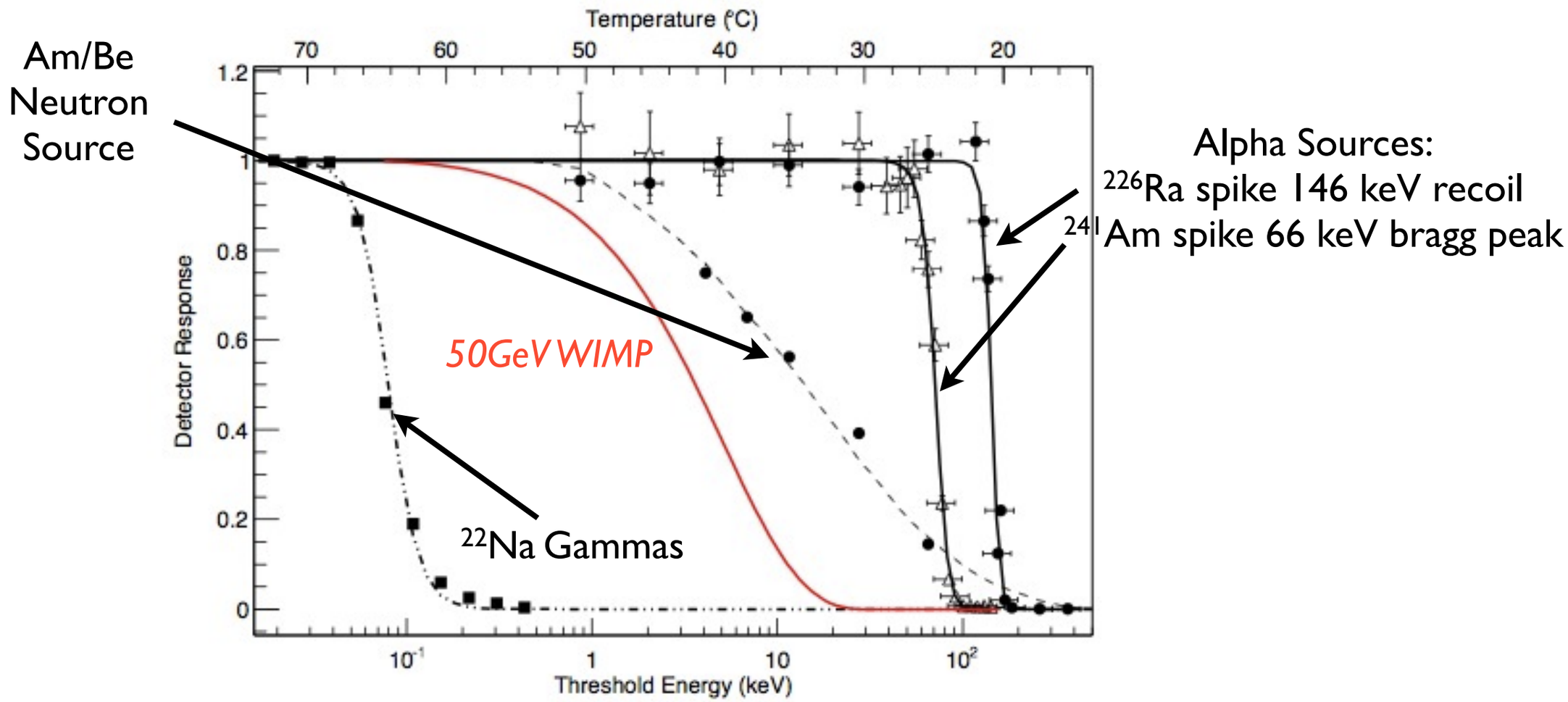

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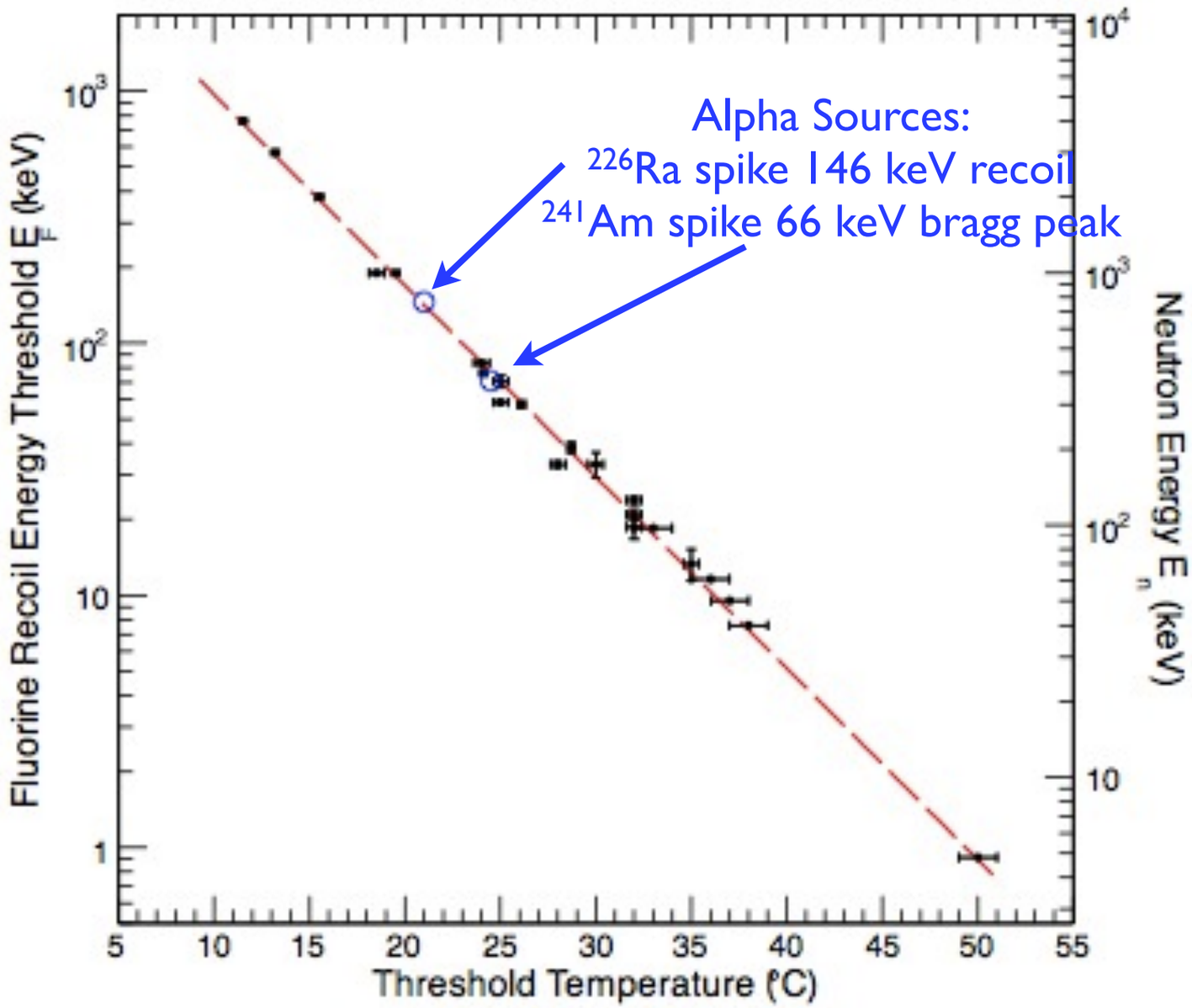
Calibrated Energy Threshold



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- Our threshold is now calibrated down to 0.8 keV!

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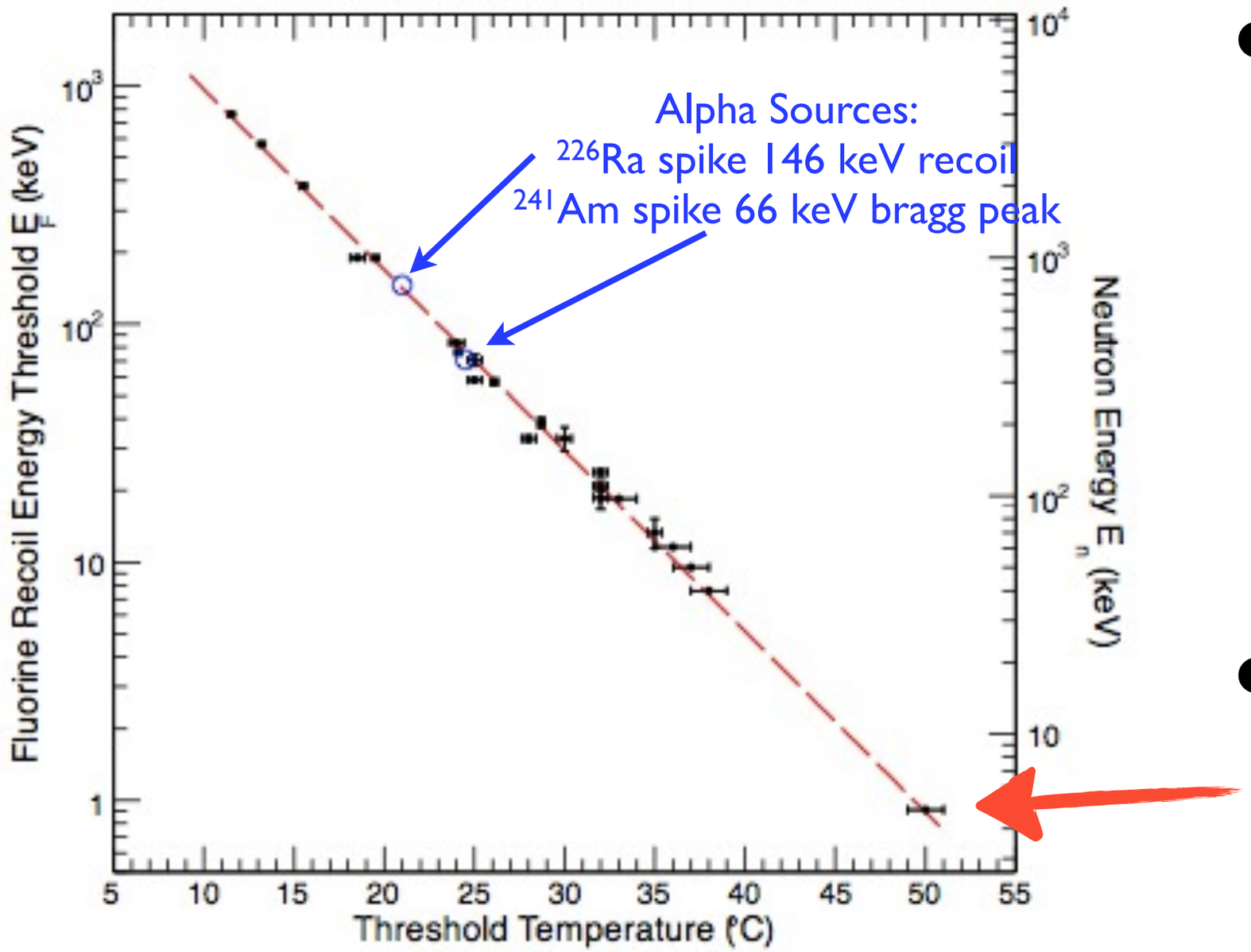

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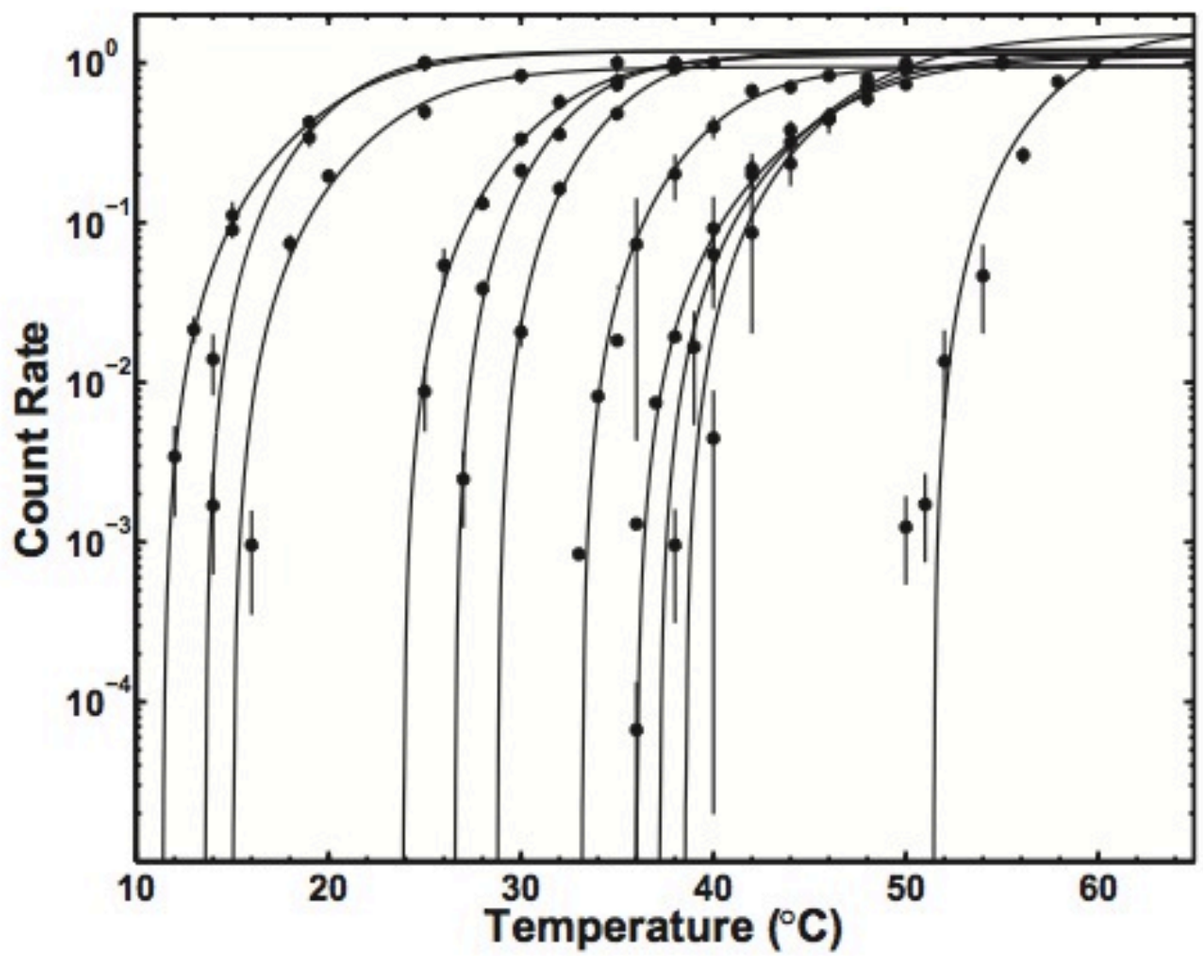
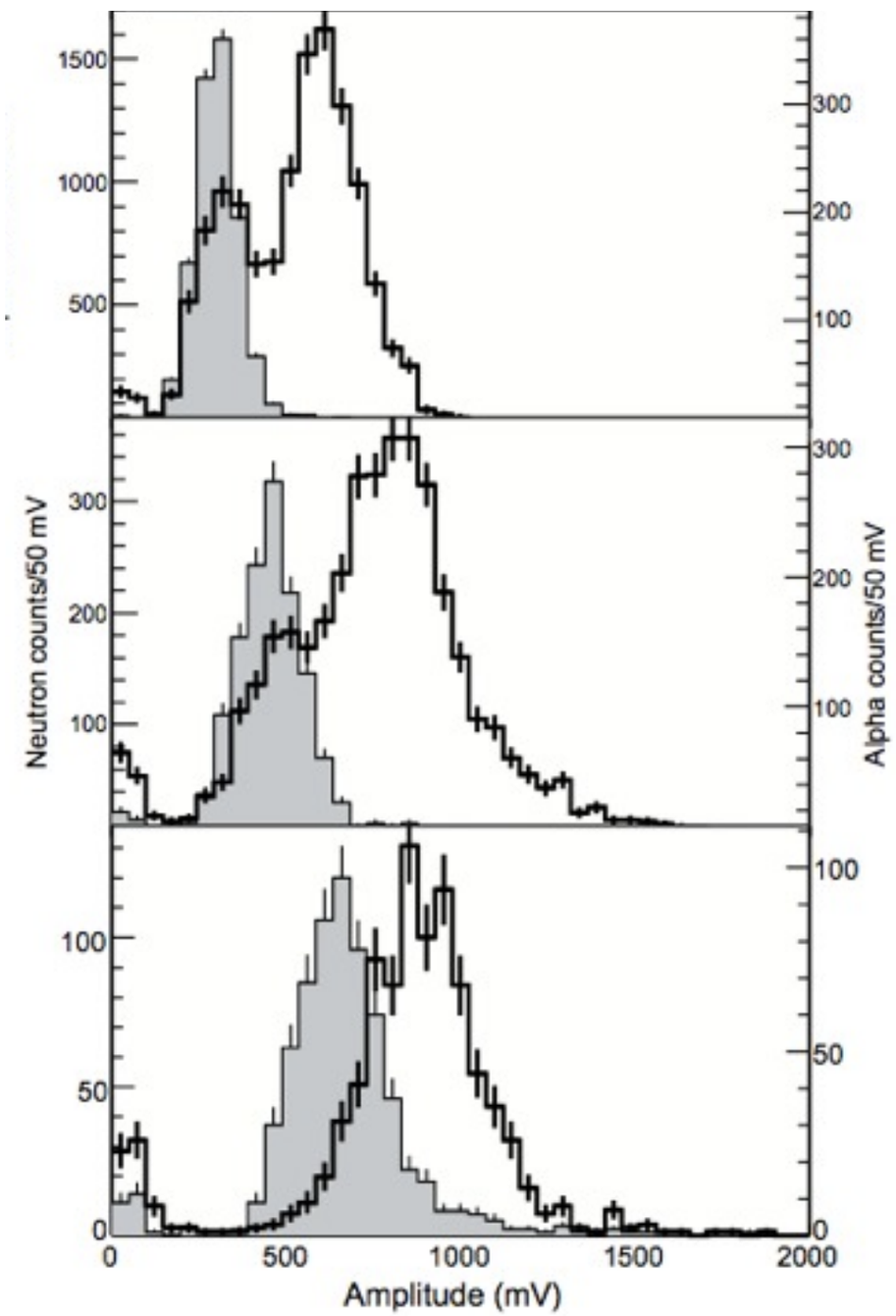
Detector Calibration



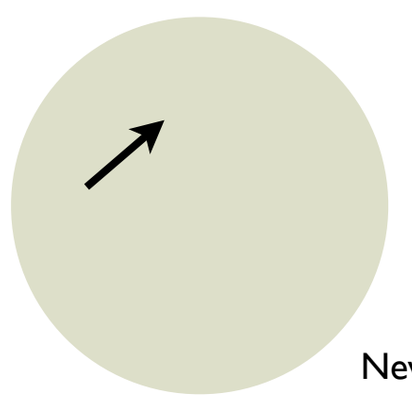
- Detector response to mono-energetic neutrons with decreasing energies down to 4.8 keV.
- The neutrons are from $^{51}V(p,n)^{51}Cr$ and $^{7}Li(p,n)^{7}Be$ reactions.

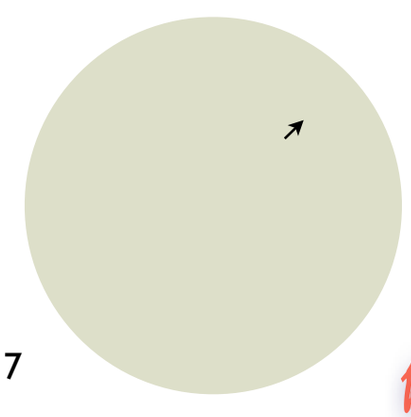
S Archambault et al 2011 New J. Phys. 13 043006

Acoustic Discrimination



- We discovered that the acoustic signal of the bubble nucleation contains information about the type of particle interaction. The signal amplitude is larger for alpha interactions.





New Journal of Physics 10 (2008) 103017

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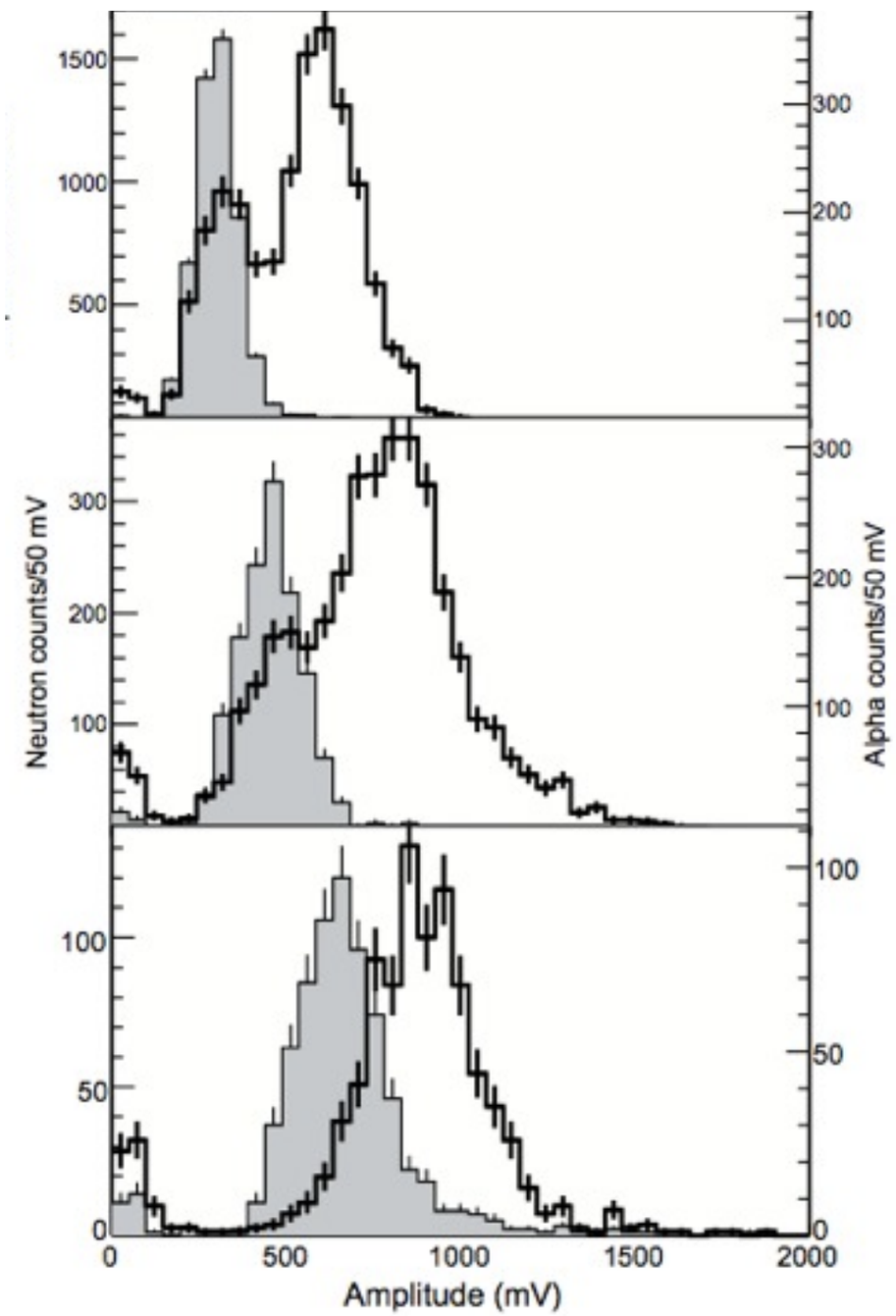

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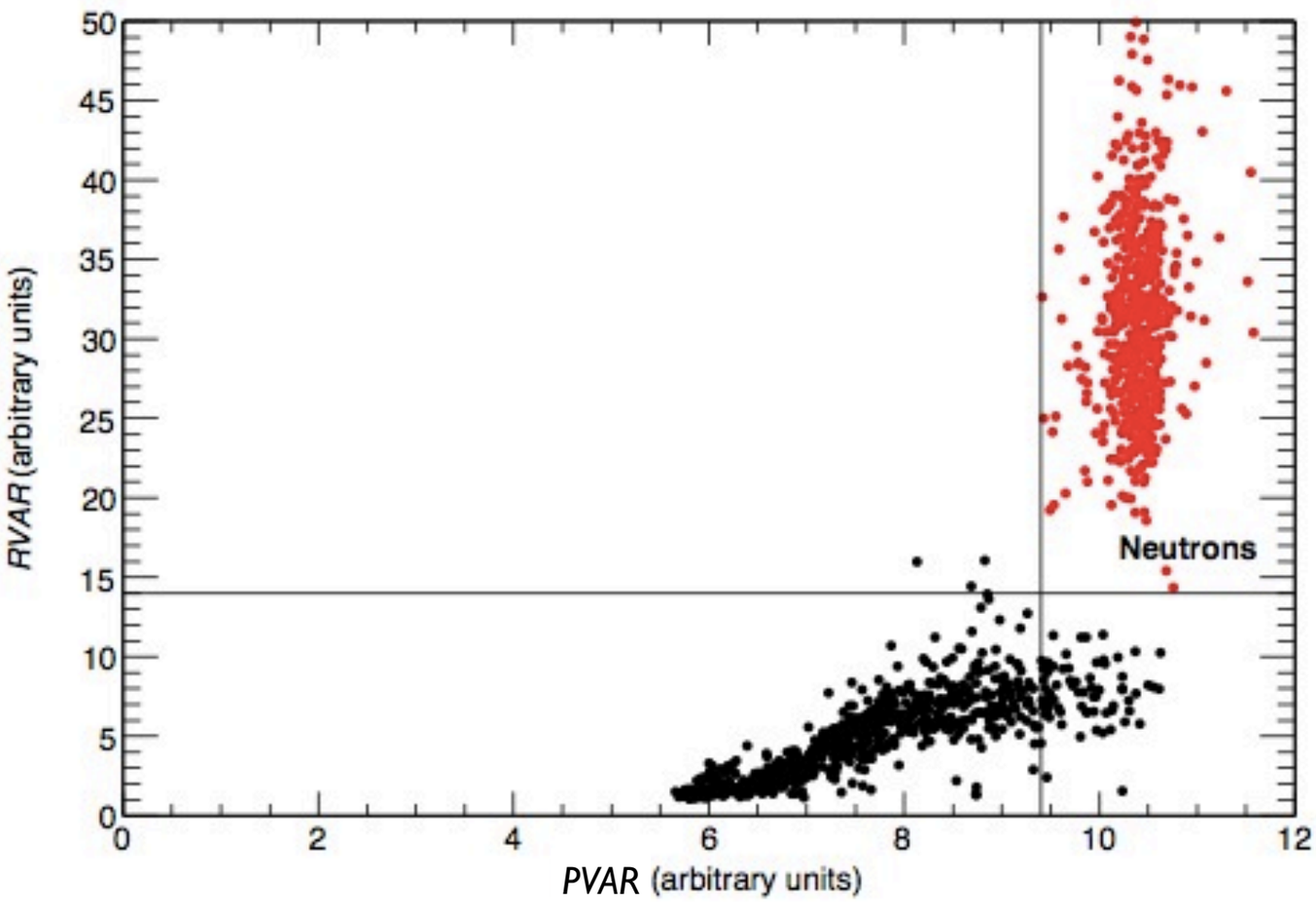
Progress since 2009

- Moved the experiment to larger space within SNOLAB.
- Upgraded DAQ to double the bandwidth. This improves background rejection.
- Several new properties of the existing data are now exploited in the 2012 analysis.

Neutron Background

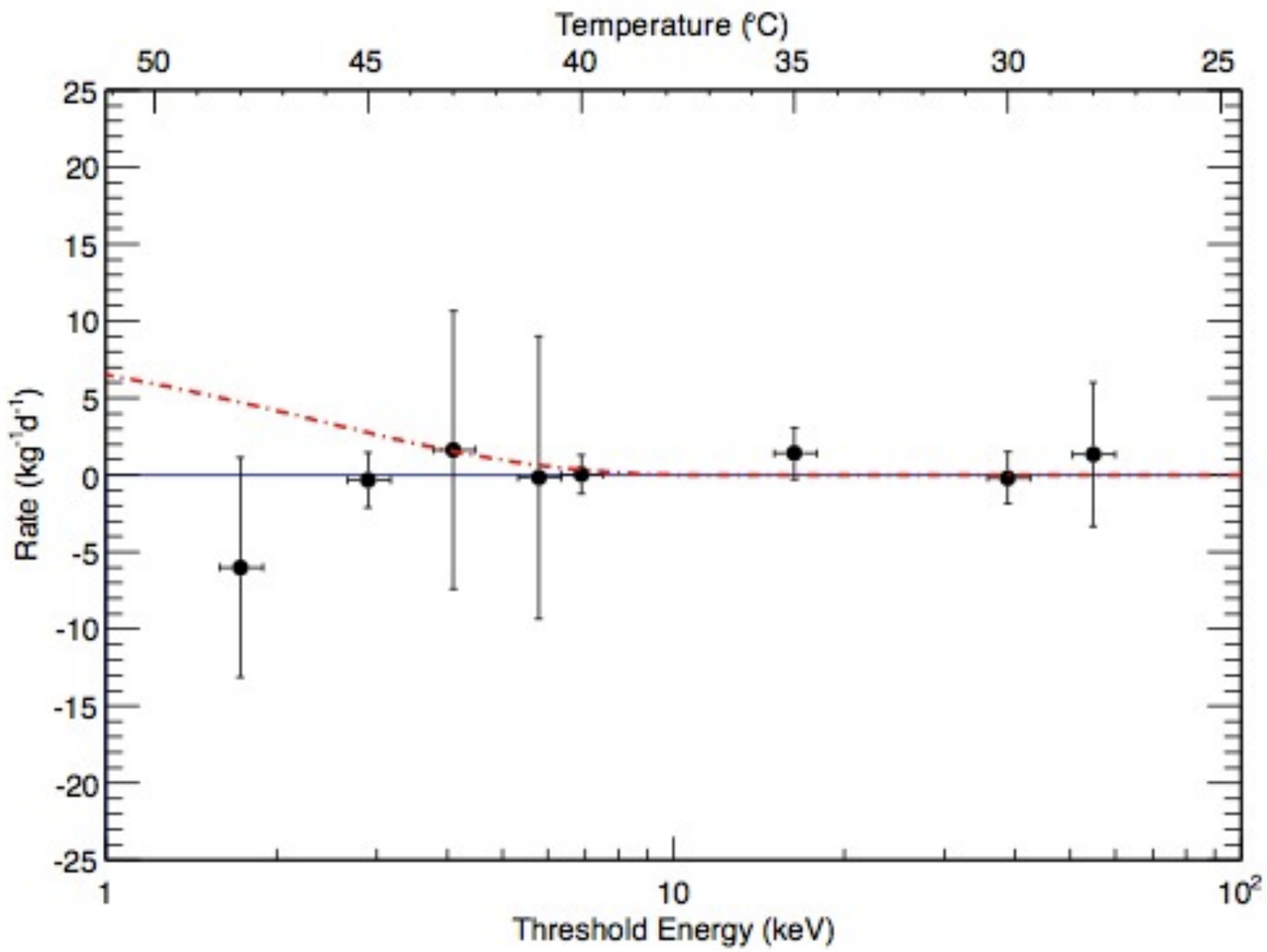
- The new system has 60 cm of water shield around the detectors, the old one only had 30cm.
- The neutrons shielding efficiency is larger than 99.6% compared to 98% in the old setup.
- We do not expect to be able to pick up any neutron events in the exposure of 115 kgd (in the old setup).

Event Selection



- The old *PVAR*, a measure of the acoustic power of the event is also used.

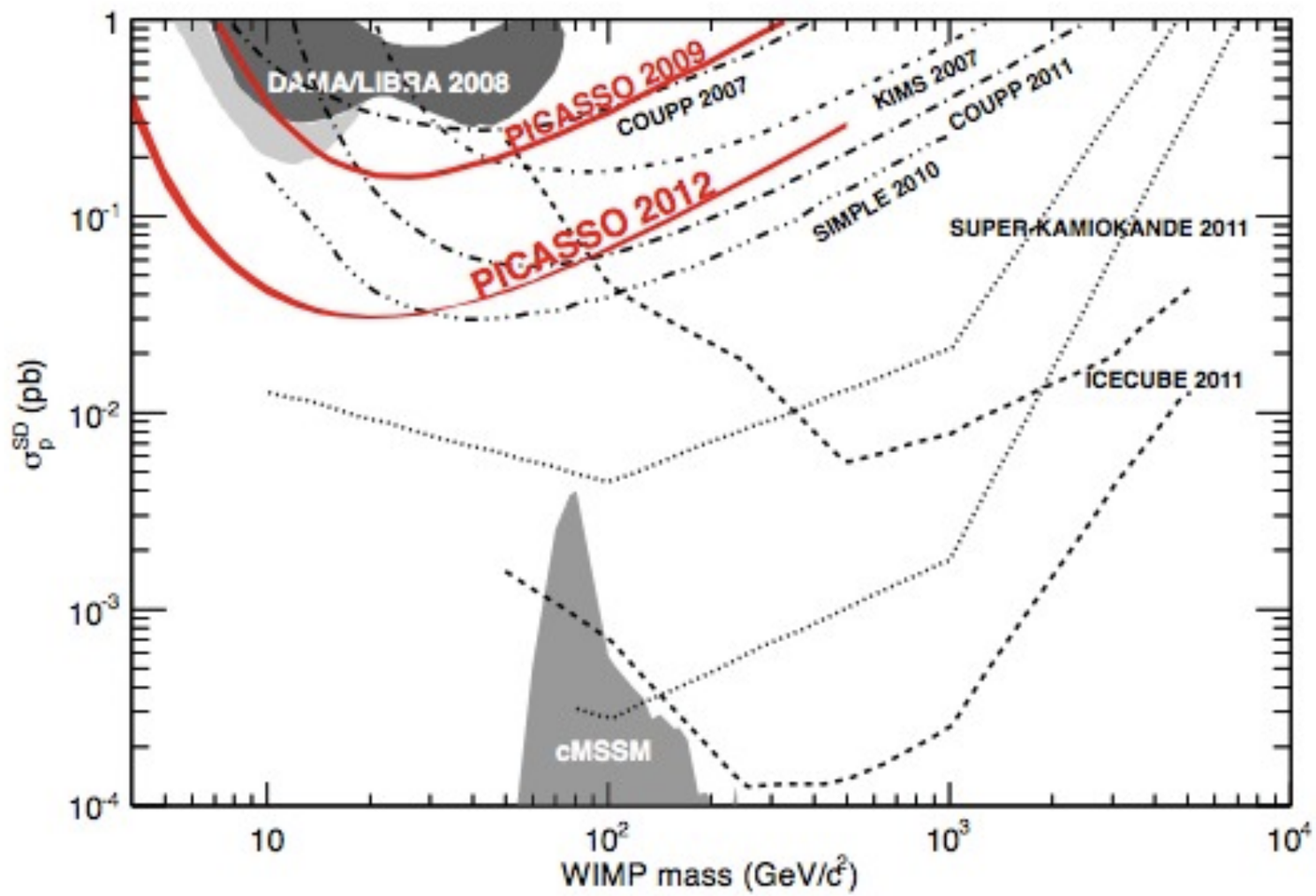
- New variable *RVAR*, quantifying the rise time behaviour allows to efficiently discriminate acoustic background up to 48°C (1.7 keV threshold).



2012 Data

- Data set of 115kg days of exposure.
- Background subtracted data from all 10 detectors as function of threshold energy.
- WIMP with 7 GeV mass and 1.2×10^{-4} pb shown.

Results: Spin Dependent



Archambault, et al., Physics Letters B, 711(2), 153–161.

- Best limit of σ_{SD} = 0.032 pb (90% C.L.) for WIMP masses around 20 GeV.
- (Width of the 2012 curve is from varying the resolution parameter a from 2.5 to 7.5)

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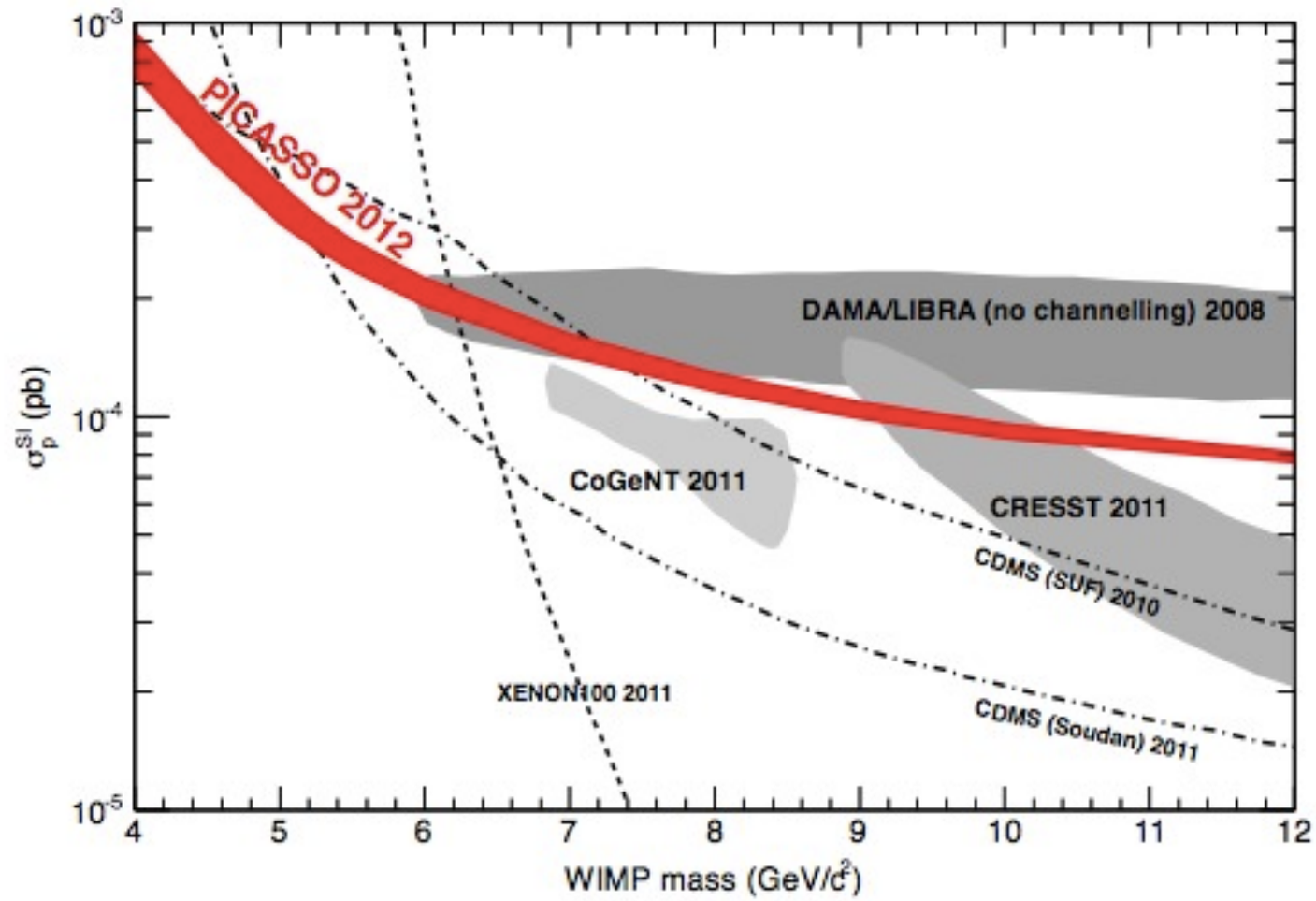
Results: Spin-Independent



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- Due to the light target nucleus PICASSO is competitive at the low end of the mass spectrum, 7 GeV:
  $\sigma_{SI} = 1.41 \times 10^{-4}$ pb (90% C.L.)

Future

- The PICASSO will not pursue droplet detectors past the current phase.
- The droplet detector has allowed us to study interactions in superheated C_4F_{10} in detail.
- Goal for background less large detector using C_4F_{10}.

Summary & Outlook

- PICASSO has analysed the complete data set of the original SNOLAB setup.
- Since then the experiment has moved, the data acquisition has been upgraded and the neutron shield has been enhanced. Many new analysis tools and features were developed.
- PICASSO is currently exchanging all detectors by new, low background saltless detectors. The new detectors show exceptional rate behaviour in the current data taking.
- With new DAQ and improvements in the analysis we expect to reach a sensitivity of at least one order of magnitude below the current limits. These upgrades will also allow us to make full use of the acoustic discrimination.
- PICASSO is developing a large scale detector.