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PICASSO

Searching For Dark Matter With PICASSO

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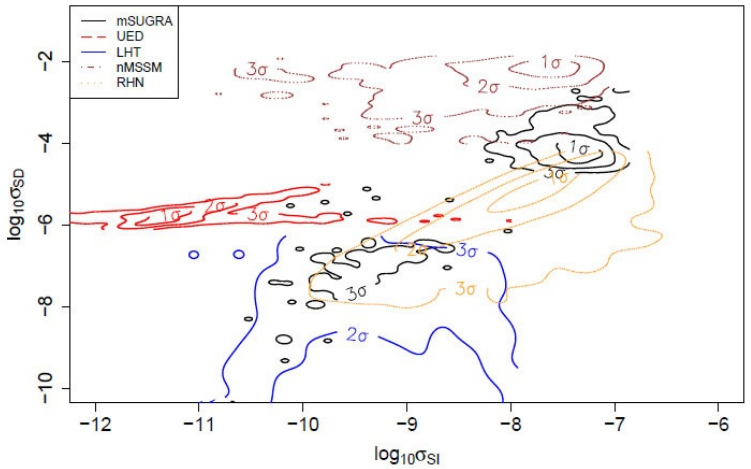
18th June 2014
CAP Congress

PICASSO

- Project in CAnada to Search for Supersymmetric Objects located in SNOLAB, Sudbury Canada
- Collaborators from Canada, USA, Czech Republic and India

- Completed running December 2013
- Superheated liquid droplet detector with C_4F_{10}
- ^{19}F most favourable target for spin dependent interactions

Allows complementary probe of WIMP parameter space



Barger, Keung, Shaughnessy (2008) Phys Rev D 78(5) 058007

Superheated Liquids

- Based on Bubble Chamber principle
- Liquid temperature and pressure controlled in meta-stable state
- If sufficient energy (>E_{min}) is deposited within radius (<R_{min})…

$$E_{dep} = \frac{dE}{dx} \cdot R_{\min} \geq E_{\min}$$

$$E_{\min} \equiv \frac{16\pi}{3\times\eta} \frac{\gamma^3(T)}{(\Delta P(T))^2}$$

$$R_{\min} \equiv \frac{2\gamma(T)\varepsilon}{\Delta P(T)}$$

$\Delta P(T)$ = superheat

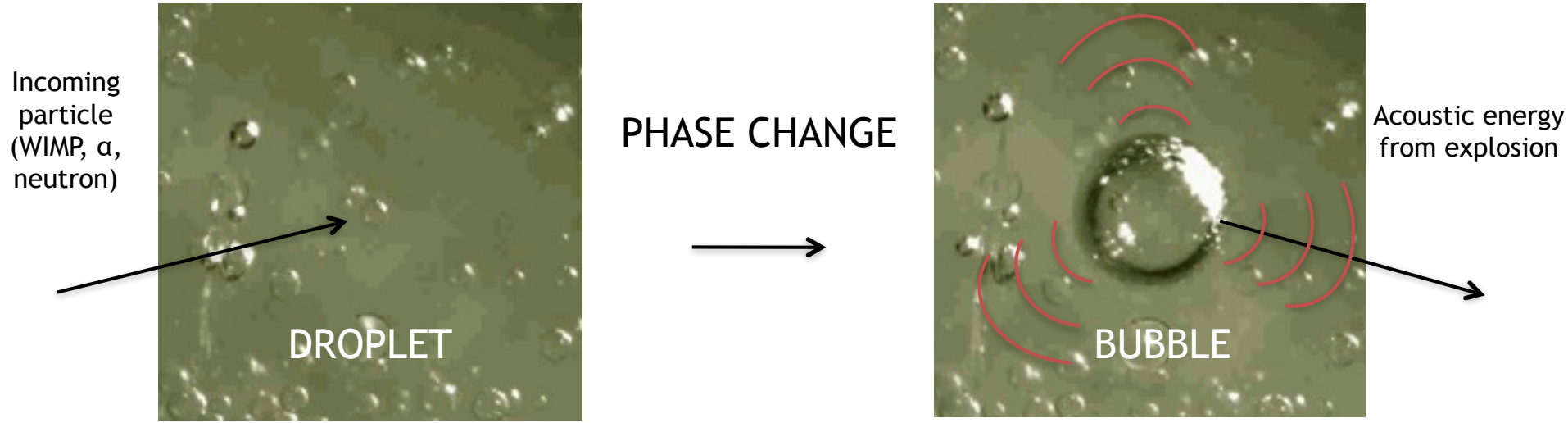
$\gamma(T)$ = Surface tension

ε = critical length factor

η = energy convers. efficiency

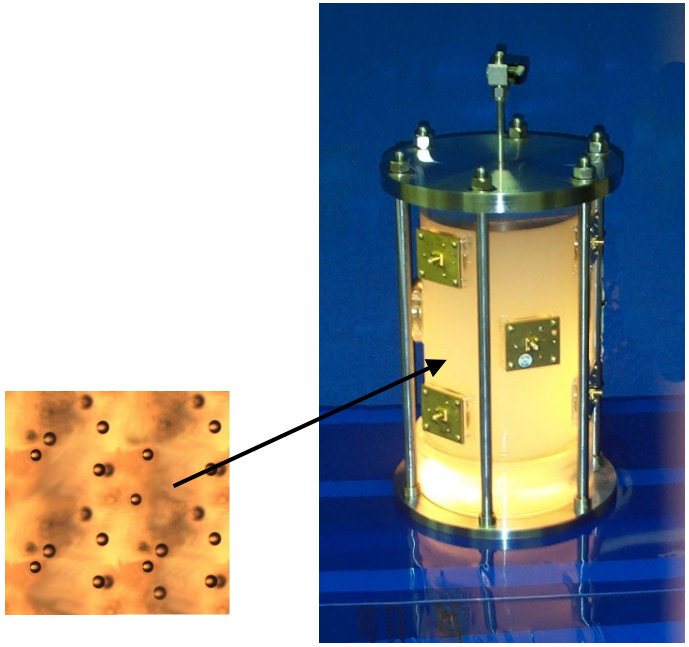
A. Plante, Poster

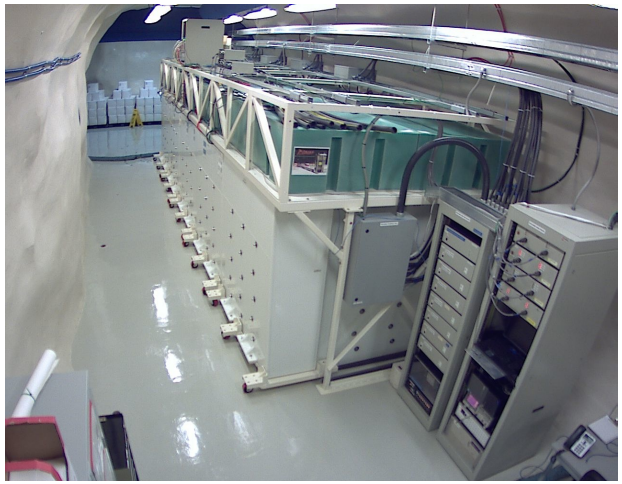
- …phase change occurs and a bubble forms



PICASSO Detector

- Modular detector (32 modules)
- Uses C_4F_{10} droplets of ~200 μm diameter
- Suspended in polymerised aqueous gel matrix
- In 4.5L acrylic cylindrical container
- 9 piezoelectric transducers record sound
- Detectors housed in pressure and temperature control units
- 40-50 hr data taking runs followed by 11 hr pressurisation

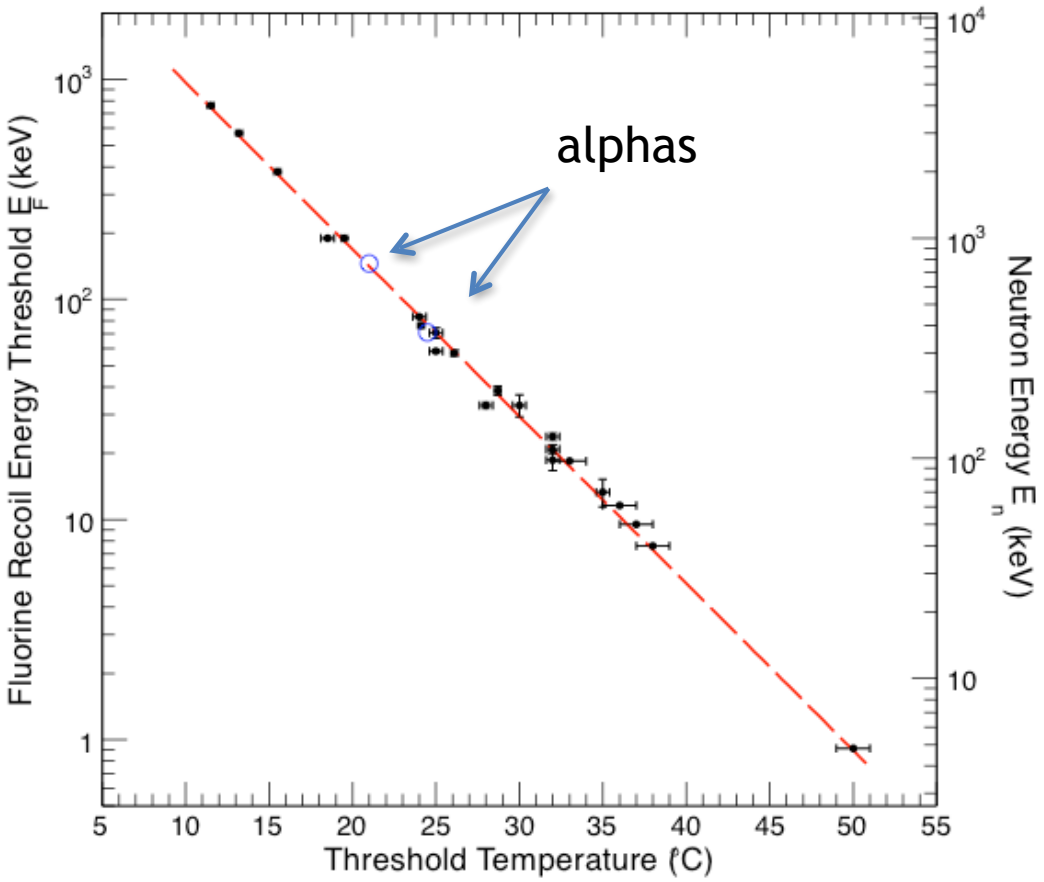




Energy Threshold

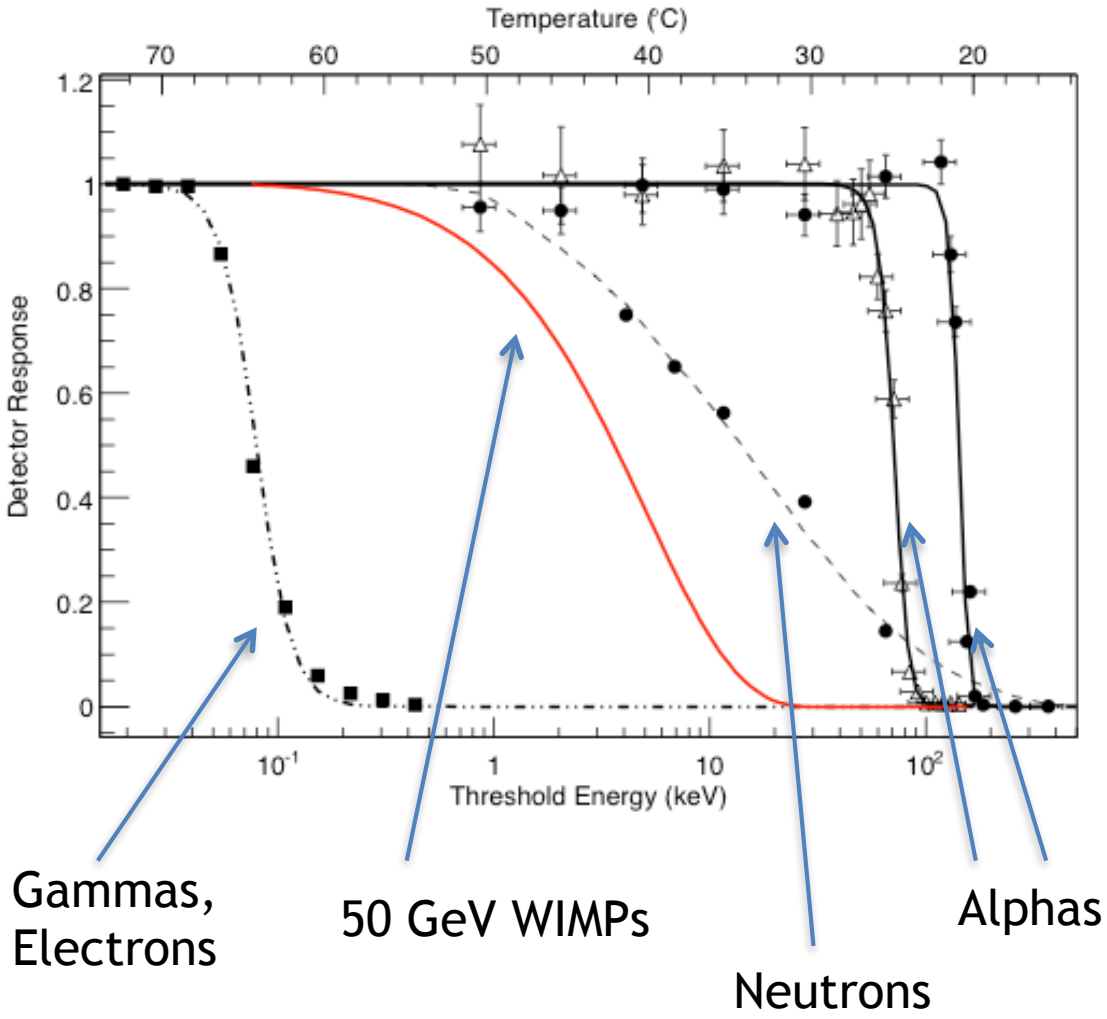
- Threshold controlled by operating temperature
- Calibrations with mono-energetic neutron beam of energy threshold
- Alpha measurements consistent with neutron calibration
- Measure to 0.86 keV

Allows probe of low mass WIMP parameter space



M Laurin, Friday

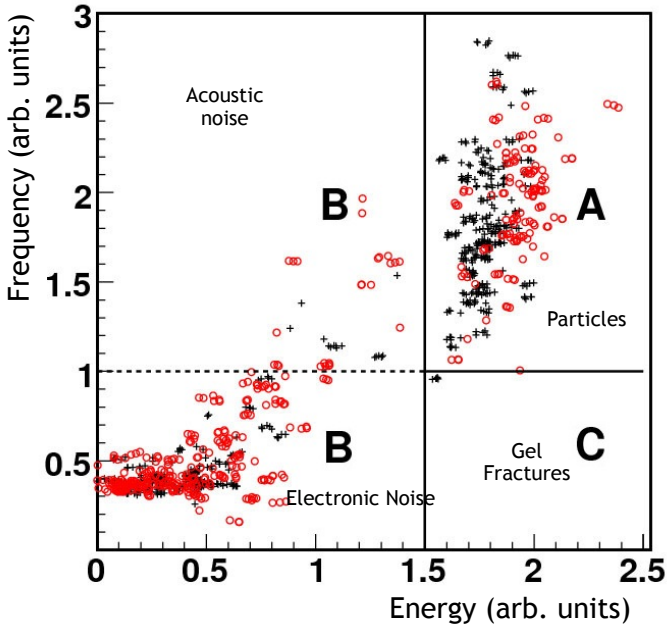
Detector Response



- At PICASSO operating temperatures (<50 °C) gammas and electrons suppressed by 8 orders of magnitude.
- Neutron background controlled by underground lab and water shielding
- Alpha particles main background

Measure rate at different thresholds and search for increase due to WIMP at low thresholds

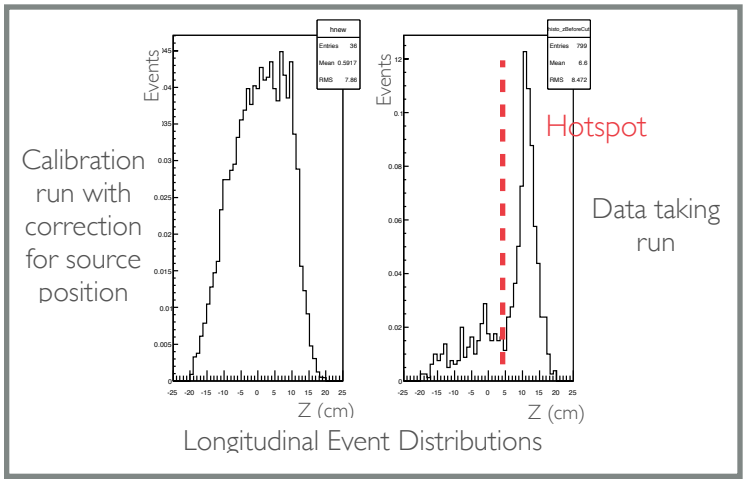
Event Selections



Black – Neutron Calibration Run
Red – Data Taking Run

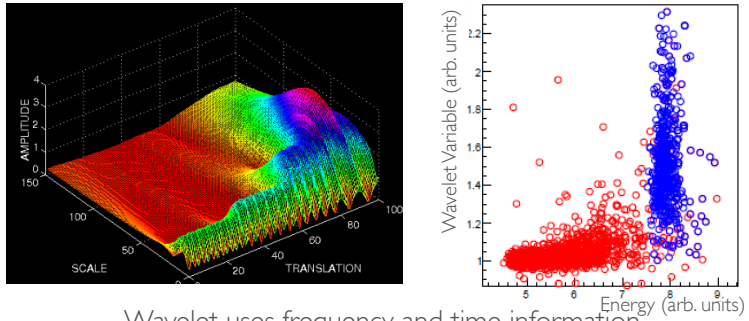
- The acoustic signal from bubble formation recorded and used in analysis.
- Events are selected using:
  - Acoustic energy
  - Signal rise time
  - Signal shape (new)
  - Frequency (wavelet) (new)
  - Event localization within detector (new)
  - Correlation with other events in time (burst cut)

- Event localization ,Identify high activity 'hotspots'
- 70% reduction in background rate for 30% loss in active mass

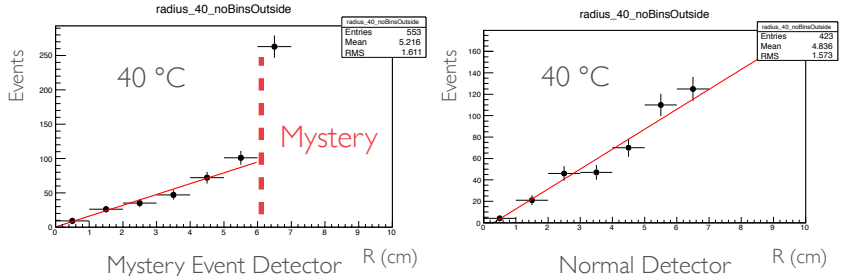


Mystery Event Rejection

- Class of background with increasing rate at high temperature
- Only found in some detectors and with very large and inconsistent rates…
- …therefore not a WIMP signal!

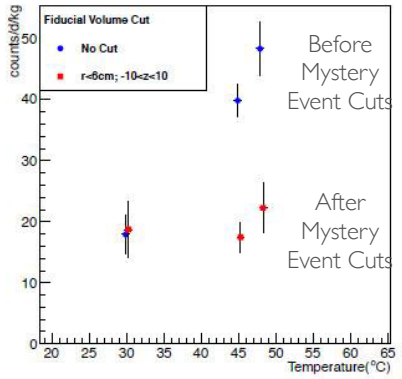


Wavelet uses frequency and time information
Additional separator

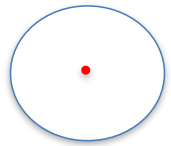


Radial Event Distributions
Corrected for Resolution Effects at Edge

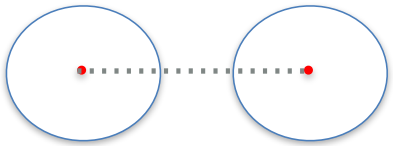
- Wavelet cut using frequency and time information to remove 'mystery events'
- Fiducial cuts to remove 'mystery events'
- Both cuts remove same events
- Allows threshold to extend to 0.8 keV



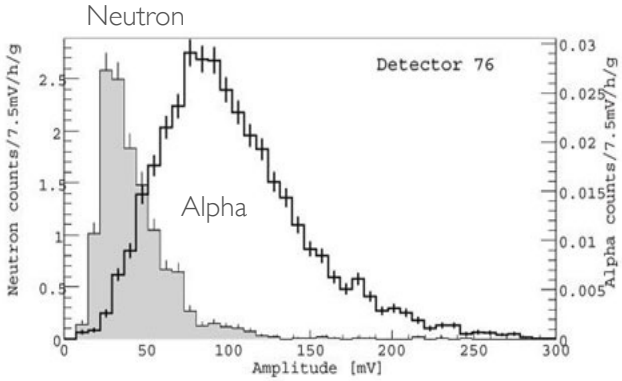
Neutron Alpha Discrimination



Nuclear recoils have point-like bubble nucleation



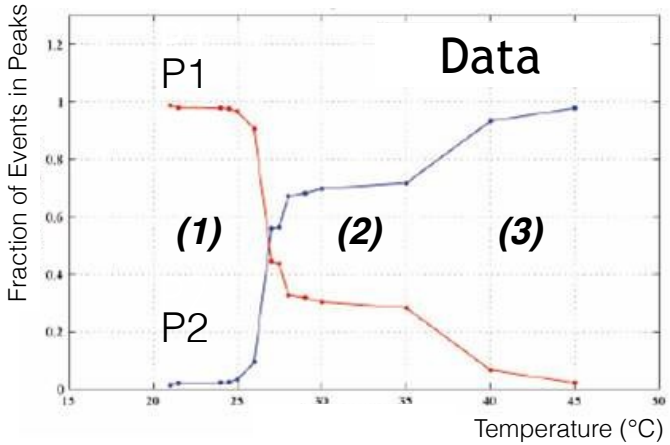
Alpha recoils have track-like bubble nucleation due to nuclear recoil and Bragg peak

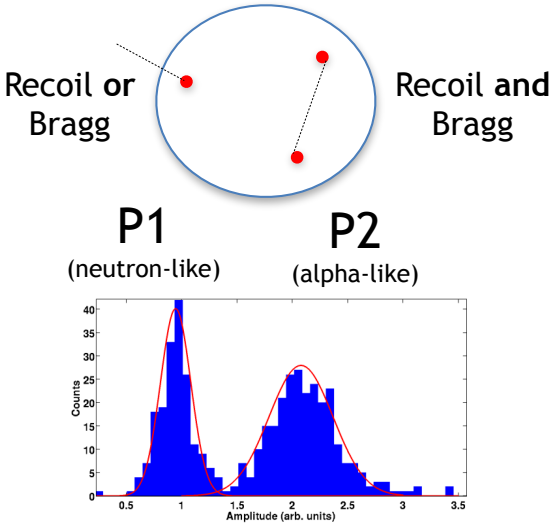


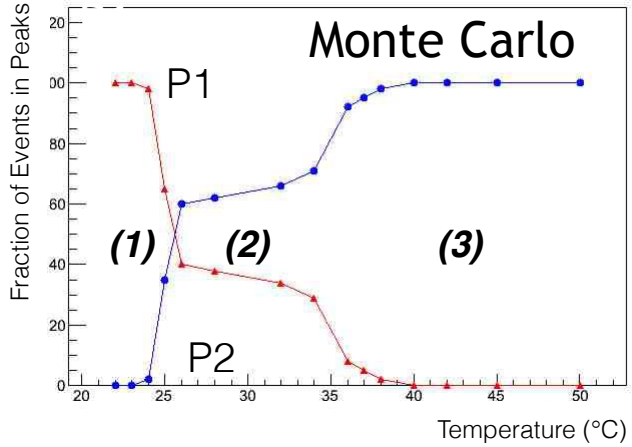
- Alpha particles are louder than neutrons (if fully contained within droplet)
- Efforts to clean-up backgrounds and improve resolution to aid discrimination
- Can PICASSO be background free…?

Alpha Neutron Discrimination

Complicated to discriminate in droplet detectors.
Depends on origin of alpha particle (inside or outside droplet), size of droplet and temperature.





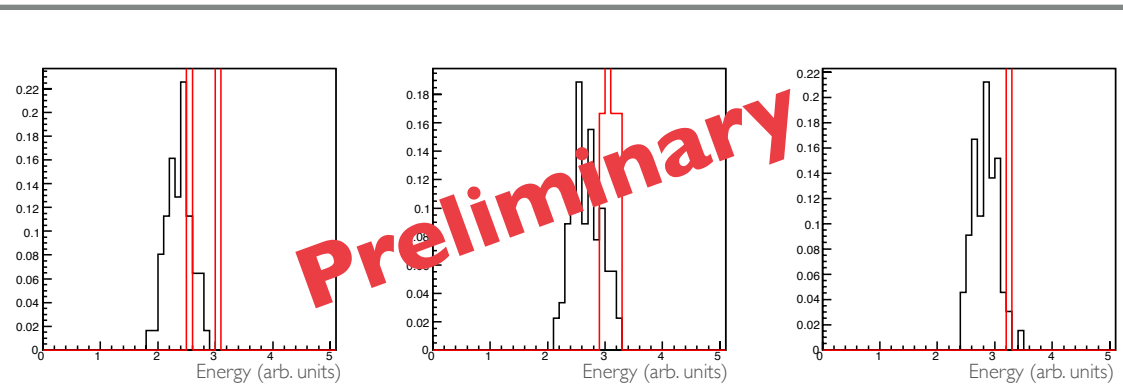


(1) - Below alpha threshold, nuclear recoil nucleations (P1) only
(2) - Nuclear recoil and alpha Bragg peak if fully contained within droplet
(3) - Sensitive to full alpha track, nuclear recoil and alpha track (P2)

However, events from gel matrix (outside droplet) always have only one nucleation point

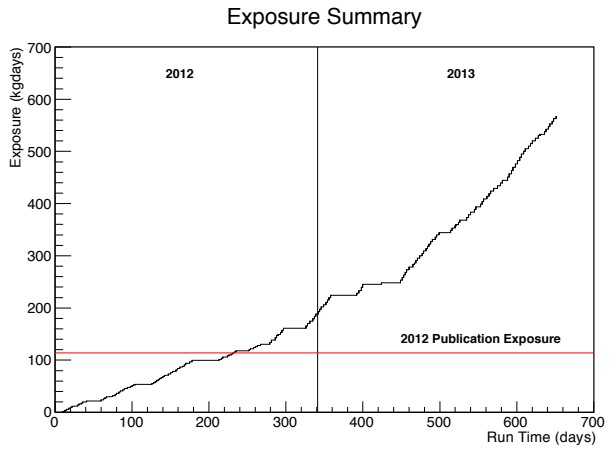
Final Results

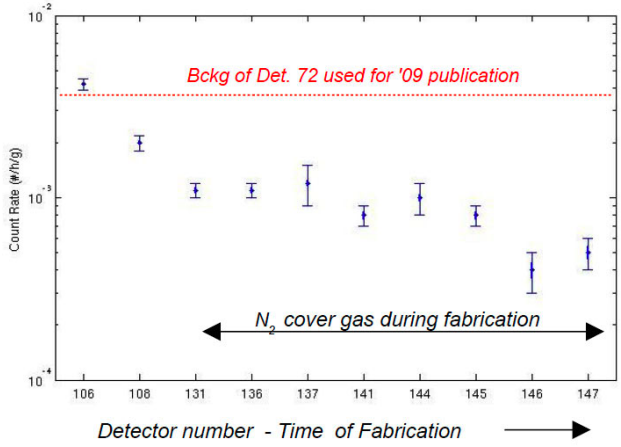
Can PICASSO be background free…?



Black - Neutron Calibration; Red - Data Taking Run

- …possibly!
- Certainly significant reduction in background rate
- Final results soon…





Large exposure and lower background contamination

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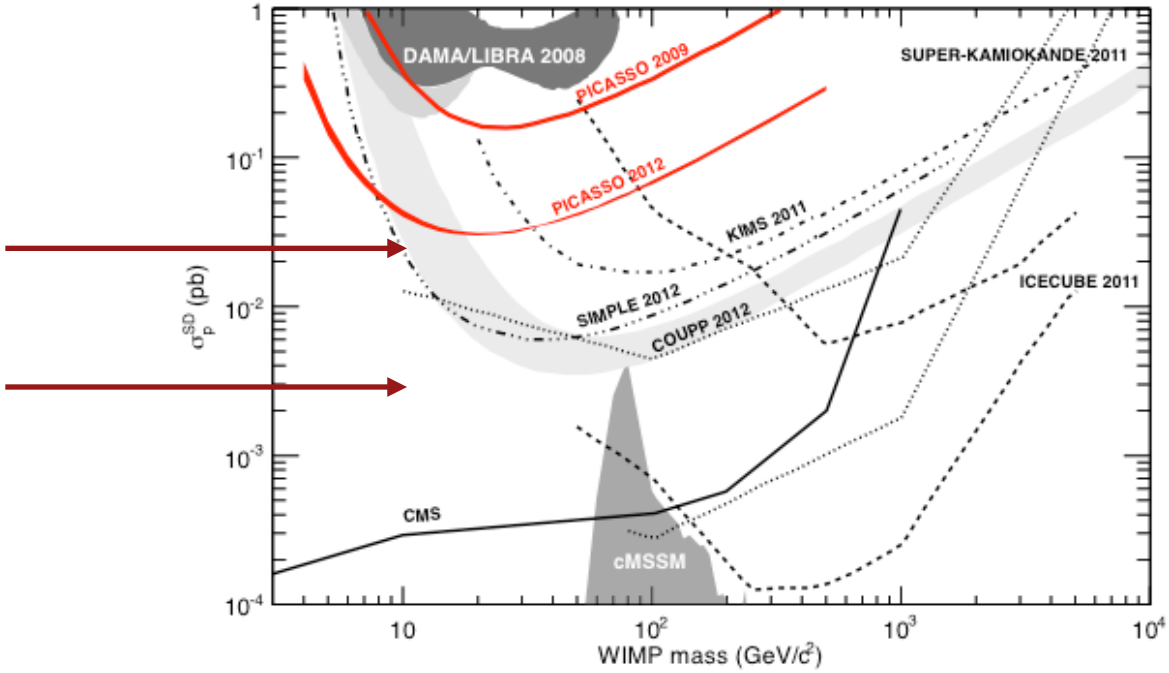
Spin Dependent Dark Matter Limits



Expected final results
depending on amount of discrimination possible

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The Future

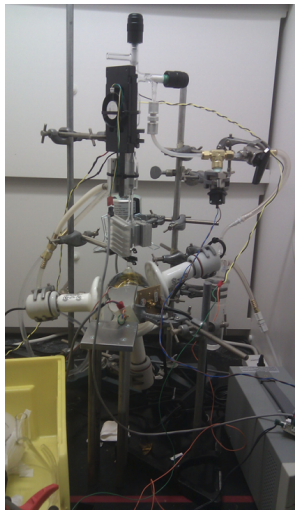
- Move to bulk liquids to improve discrimination
- PICO Collaboration

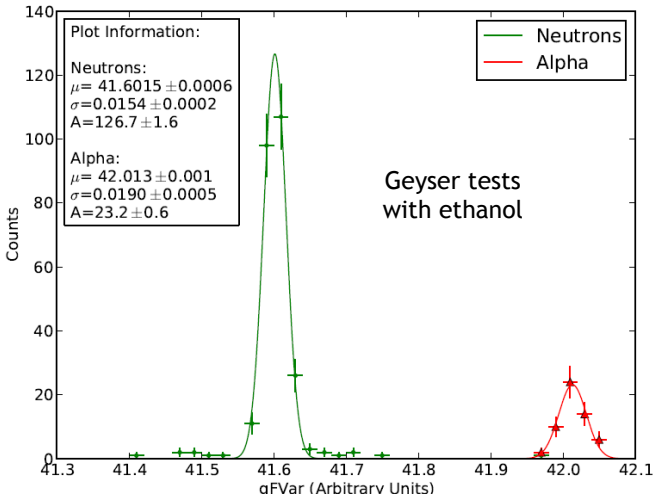
  A. Robinson, Wednesday
- Bulk bubble chambers (PICO-2l)

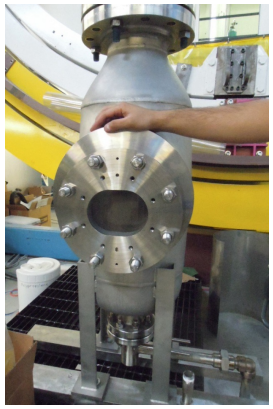
  C .Amole, Thursday

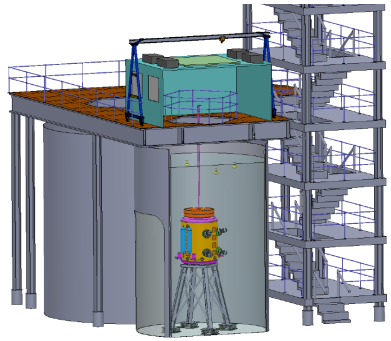
  R. Podviyanuk, Thursday
- Bulk condensation chambers (‘geysers’)

  P. Mitra, Thursday
- Ton scale detector (PICO-250)









Conclusions

- Superheated liquid detectors with a ^{19}F target allow:
  - Study of spin dependent WIMP physics
  - Construction of low background detectors (rejection of gamma, electrons and alphas)
  - Studies down to low threshold and WIMP mass
- PICASSO has produced successful results and will publish final results soon
- Best published SD exclusion of $M_W = 20$ GeV with $\sigma_P = 0.032$ pb (90%CL)
- PICO will build on the Canadian leadership established by PICASSO in the field of superheated liquid dark matter detectors