Title: Measurement of the Radiopurity of Acrylic for the DEAP-3600 Dark Matter Experiment

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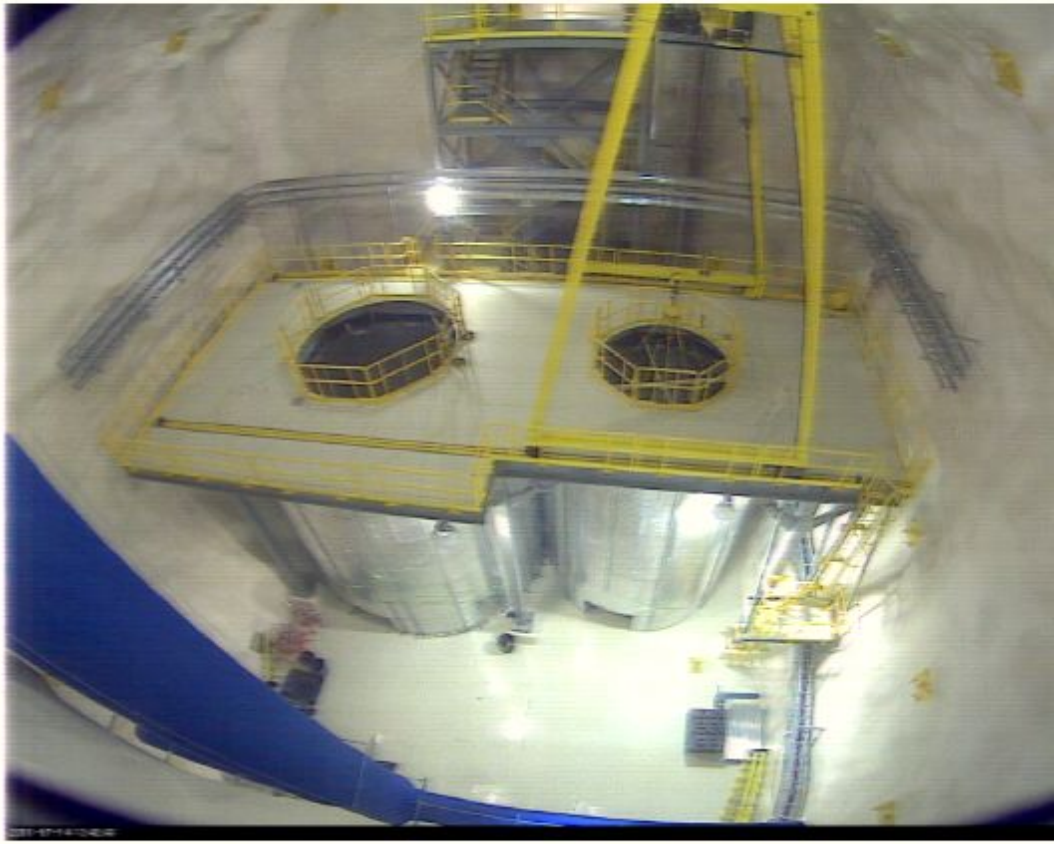
Abstract: The DEAP-3600 single-phase liquid argon detector at SNOLAB will increase the sensitivity to spin-independent WIMP-nucleon scatters by two orders of magnitude, allowing for the possibility of dark matter particle detection. The spherical detector will contain 3600 kg of liquid argon in an 85 cm radius acrylic vessel surrounded by 255 photomultiplier tubes (PMTs). After a collision between a WIMP and an Ar-40 nucleus, the scintillation light from the recoiling nucleus will be collected by PMTs. The separation of background events from WIMP events is critical. Detector materials contain levels of uranium and thorium, and these decay chains contain alpha, beta, and gamma decays. Alpha particles near the surface of the acrylic vessel are perhaps the most difficult background. A fraction of the alpha energy, or the recoiling nucleus from the alpha decay, could misreconstruct in the fiducial volume and result in a false candidate dark matter event. The maximum concentrations in the DEAP-3600 acrylic are 0.3 ppt, 1.3 ppt, and 1.1 x 10^-8 ppt for U-238, Th-232, and Pb-210, respectively. The concentrations of U-238, Th-232, and Pb-210 in the bulk acrylic will be measured by vaporizing acrylic, collecting the residue, and counting the contamination in a high-purity germanium well detector.

Outline

- Introduction
  - SNOLAB
  - Dark Matter and DEAP
  - Backgrounds
- Acrylic Assay
  - Vaporization System
  - Gamma Spectrometry
  - Simulation



SNOLAB

- 6800 ft level Vale Creighton Mine near Sudbury, ON
- 2 km rock for shielding from cosmic rays
- 5,000 m^2 underground CLASS 2000 cleanroom
- experiments: dark matter and neutrino physics

Dark Matter

- rotation curves of spiral galaxies
- gravitational lensing
- galaxy formation
- galaxy collisions
- cosmic microwave background

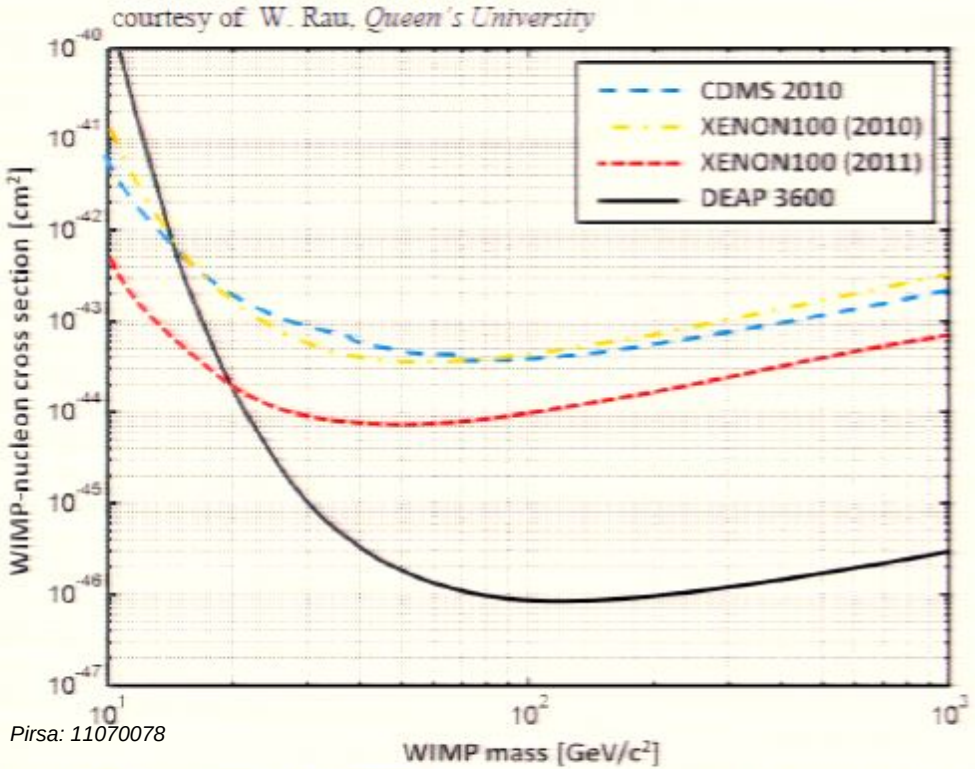
WIMP

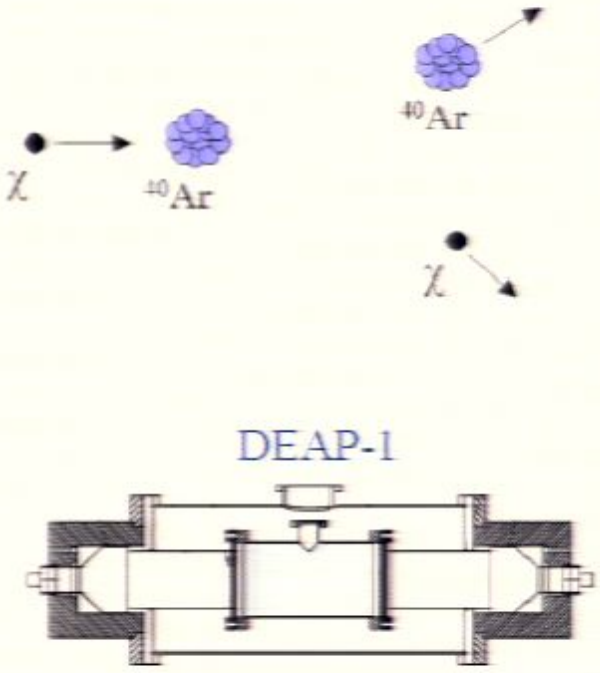
(**W**eakly **I**nteracting **M**assive **P**article)

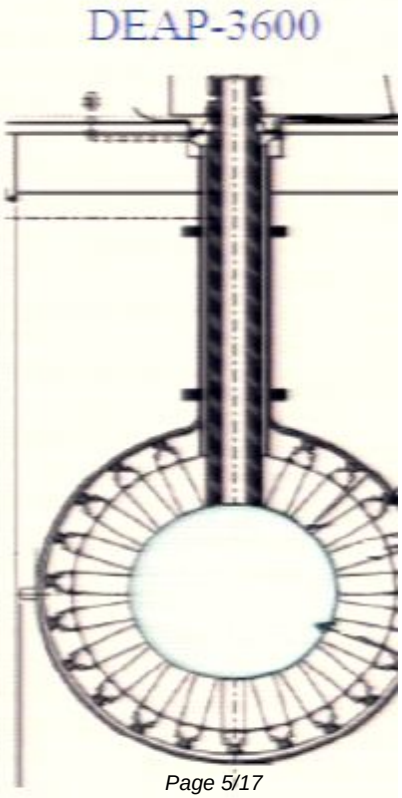
- direct detection by interaction with matter

DEAP (Dark matter Experiment with Argon PSD)

- detect WIMP (χ) directly by observing nuclear recoil of ^{40}Ar, scintillation after collision







Backgrounds

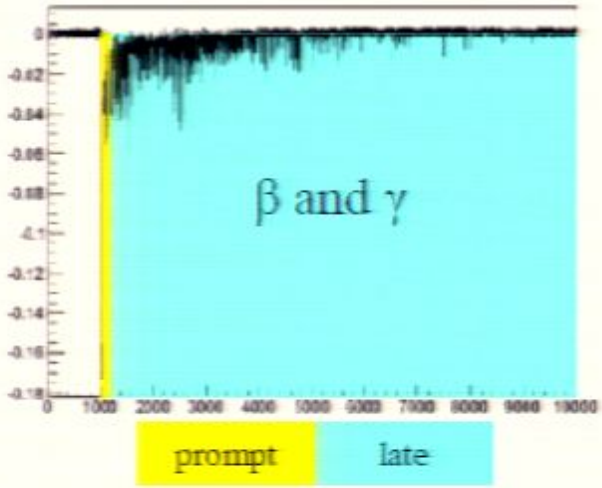
- must distinguish WIMP signal from backgrounds
- two types of backgrounds
  - nuclear recoil

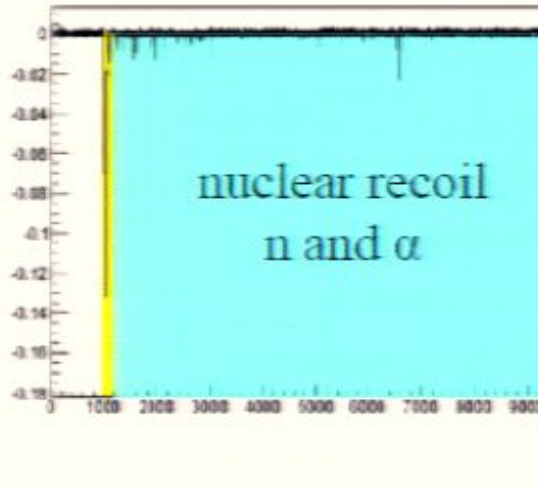
    n and α
  - electromagnetic (EM)

    β and γ

PSD (Pulse Shape Discrimination)

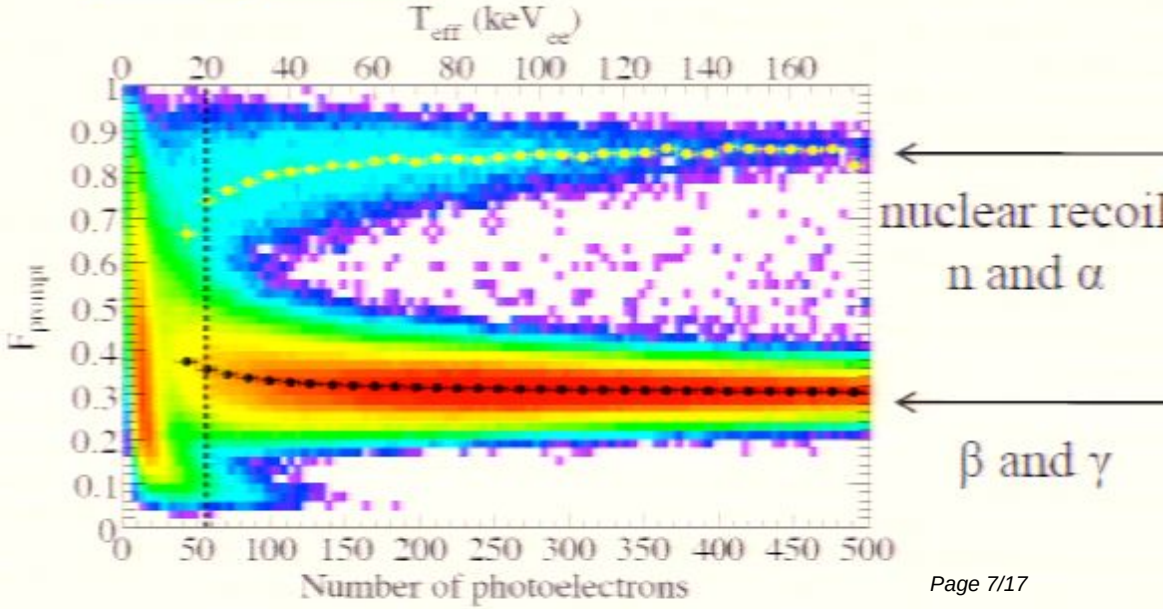
- based on scintillation timing to discriminate between EM and nuclear recoil events





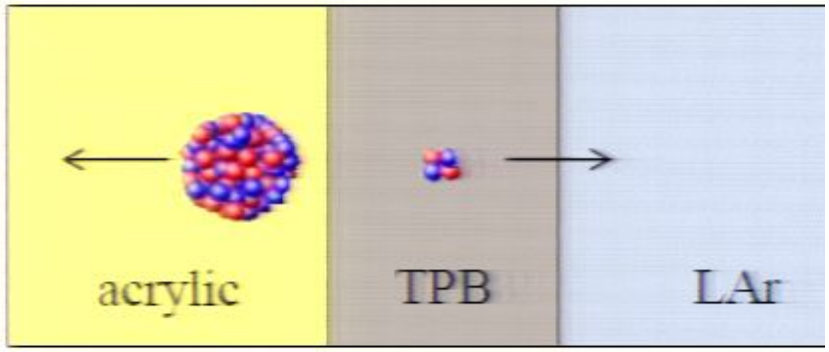
- fraction of prompt light

$$F_{prompt} = \frac{\text{PromptPE(150 ns)}}{\text{TotalPE(9 μs)}}$$



Backgrounds from acrylic

- α from acrylic interacts with TPB or liquid argon
- false candidate dark matter event
- 80 μm surface of acrylic vessel
- assay acrylic for impurities



maximum tolerable concentrations:

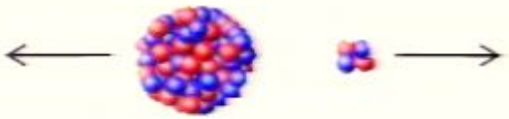
0.3×10^{-12} g ^{238}U / g acrylic

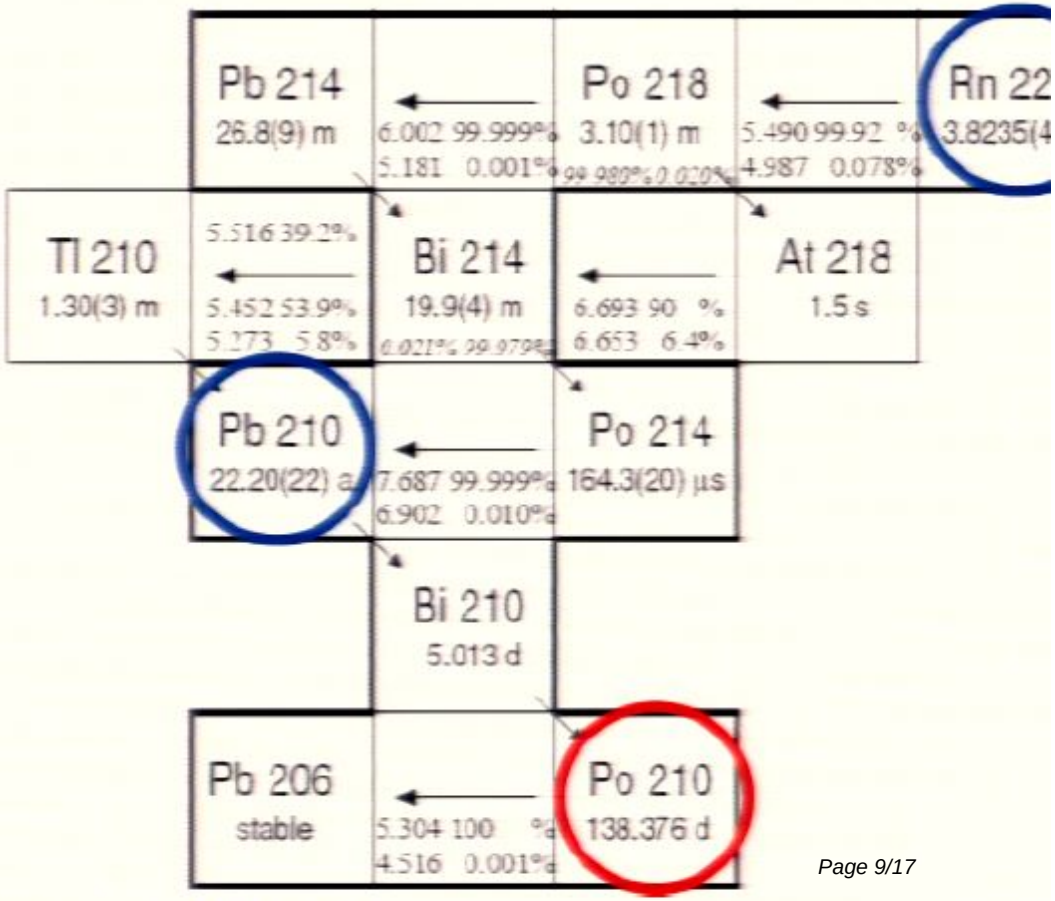
1.3×10^{-12} g ^{232}Th / g acrylic

1.1×10^{-20} g ^{210}Pb / g acrylic

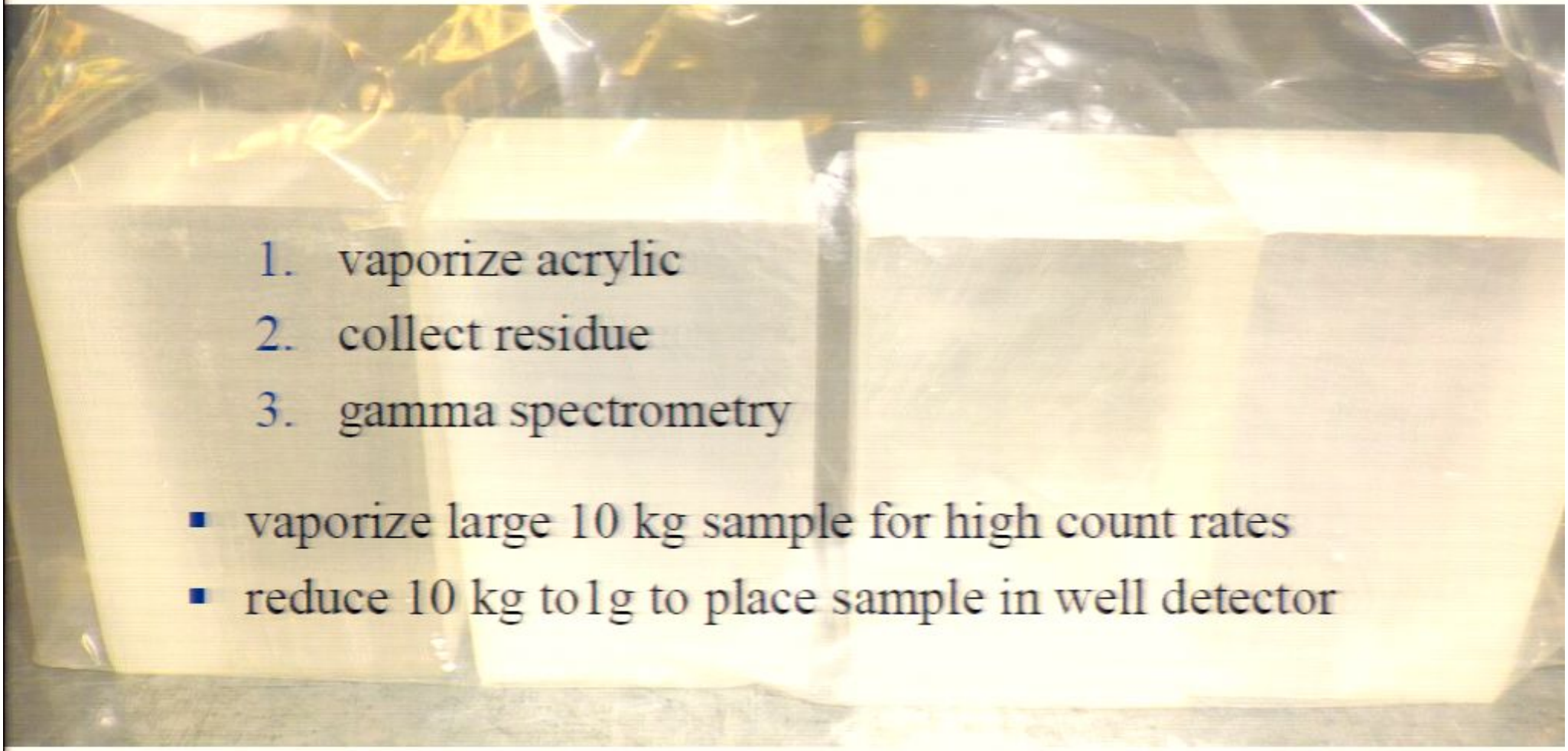
Source of background

- manufacturing
- ^{222}Rn in air diffuses into surfaces of components
- ^{210}Pb ($t_{1/2} = 22$ y)
- ^{210}Po, α-emitter
- α backgrounds
- bulk acrylic





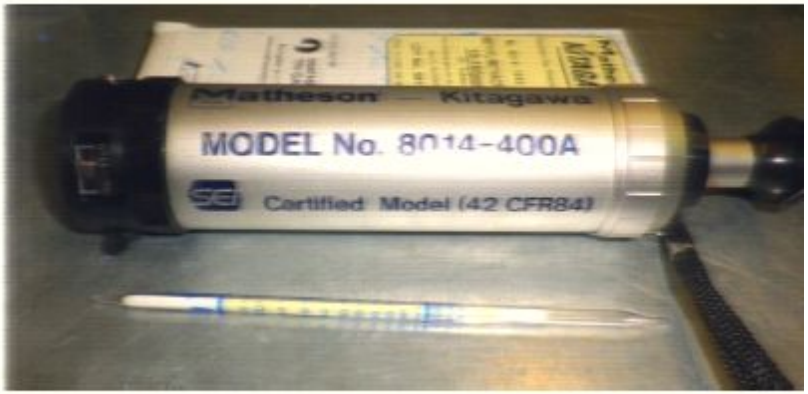
Acrylic assay



MMA (Methyl methacrylate)

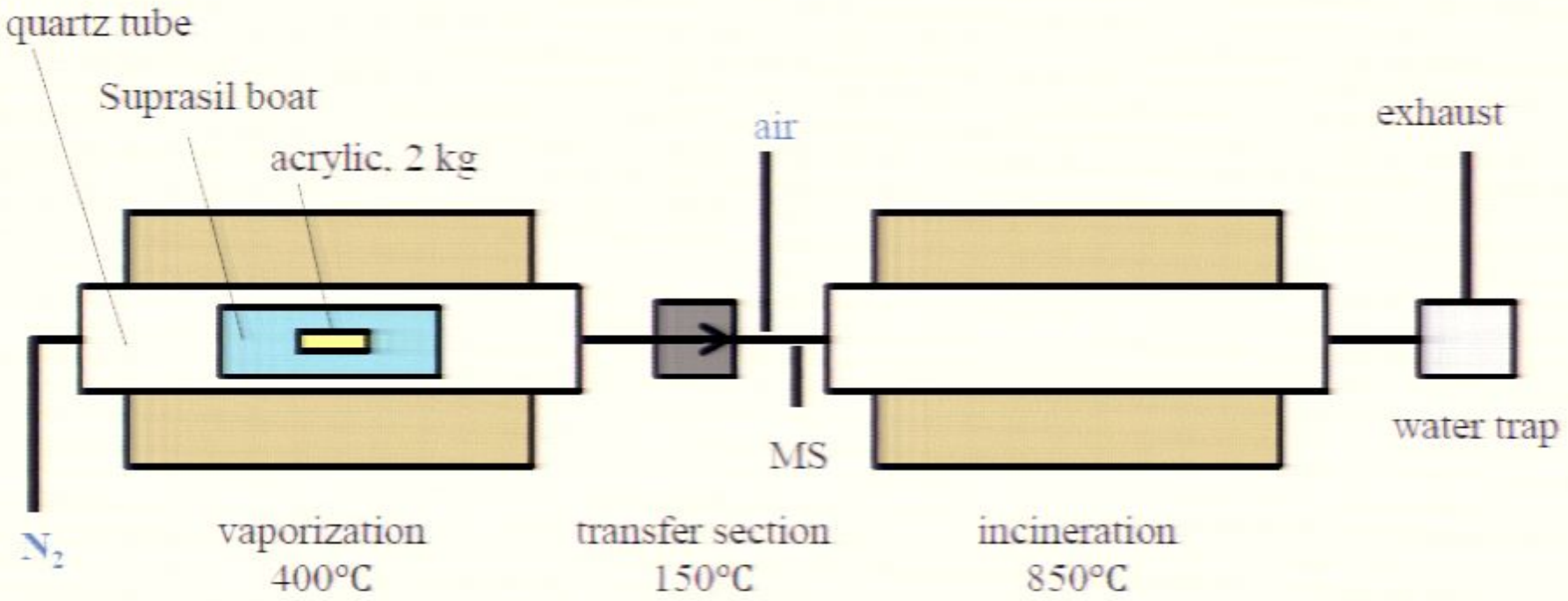
- acrylic is PMMA $(C_5O_2H_8)_n$
- vaporization produces MMA vapour
- $CH_2=C(CH_3)COOCH_3$

- exposure not a major hazard
- Matheson detector tubes



- unpleasant odour
- incinerate MMA
- $C_5O_2H_8 + 6O_2 \rightarrow 5CO_2 + 4H_2O$

Acrylic vaporization system

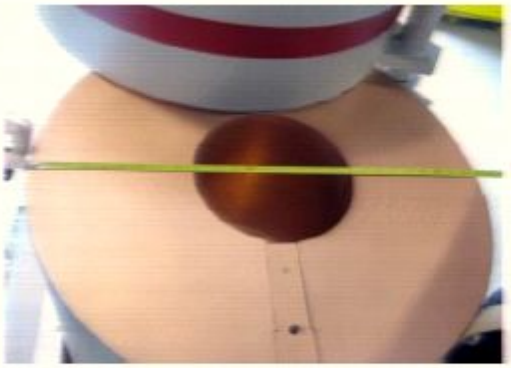


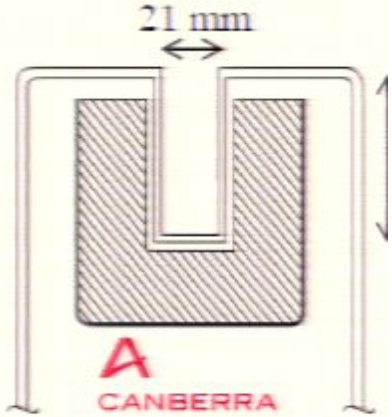
- boiling point: 100°C
- autoignition temperature: 435°C
- flammable limit in air by volume: 1.7 - 8.2%


Thermo
Thermo

HPGe well detector

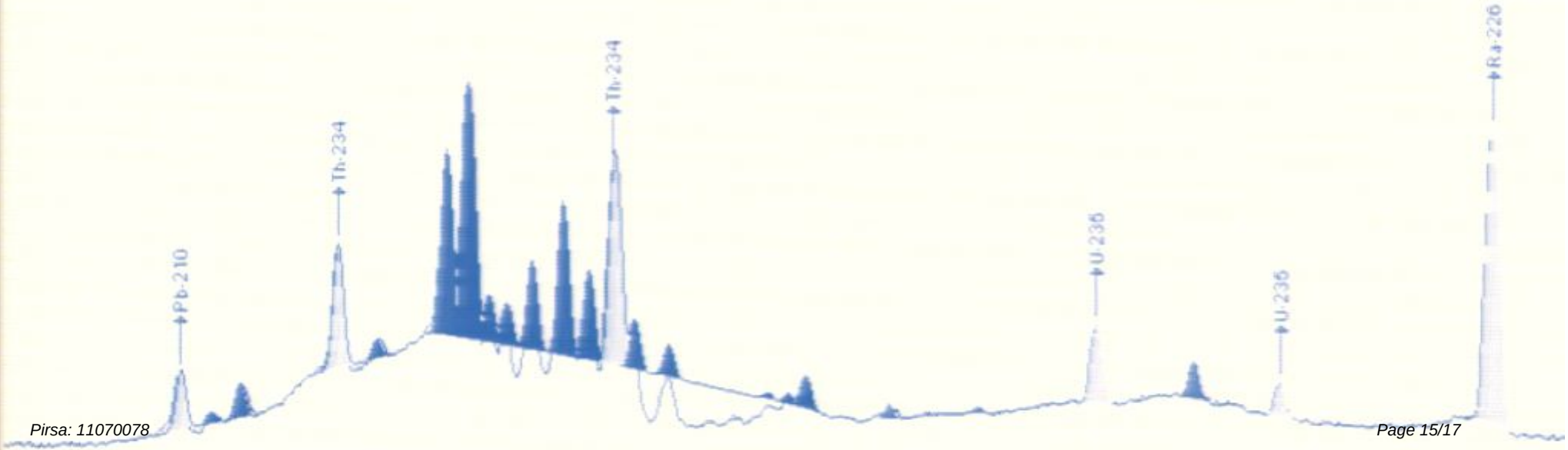
- ultra low-background
- 4π geometry
- sensitive to low energy γ-rays
- high efficiency





Simulation

- characteristic energies of gamma-rays in ^{238}U, ^{232}Th, and ^{210}Pb
- expect 1 count/day in each energy region
- must understand backgrounds to the measurement
- compare experimental results to simulations



Conclusion

- DEAP-3600 extends sensitivity for dark matter detection
- backgrounds must be understood at unprecedented levels
- acrylic assay with acrylic vaporization system

Acknowledgements

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