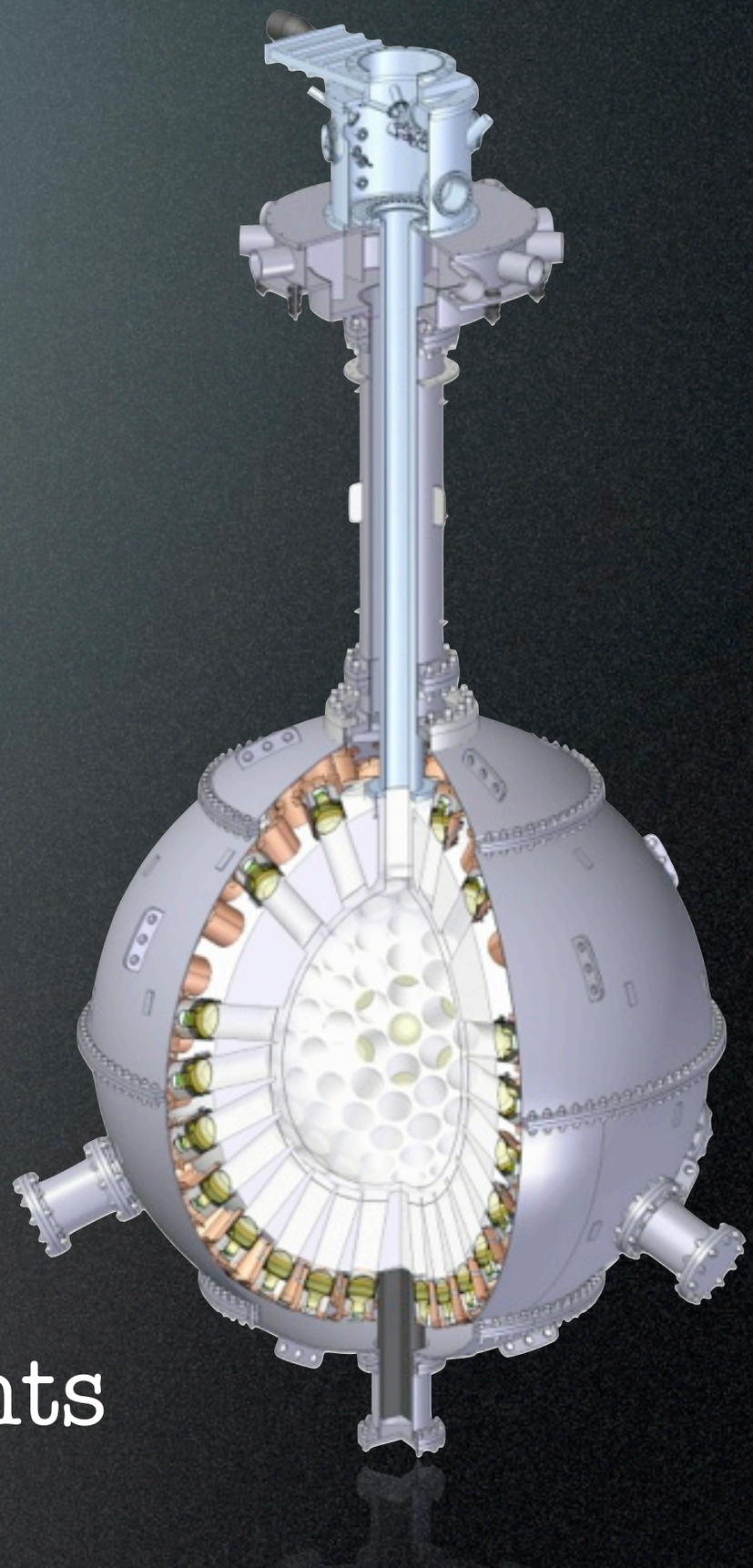
DEAP-3600

Simon JM Peeters



Content

- Overview
- Backgrounds
- Recent highlights
- Summary

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DEAP collaboration

University of Alberta

D. Grant, P. Gorel, A. Hallin, J. Soukup, C. Ng, B.Beltran, K. Olsen, R. Chouinard, T. McElroy, S. Crothers, S. Liu, P. Davis, and A. Viangreiro

Carleton University

K. Graham, C. Ouellet, Carl Brown

Queen's University

M. Boulay, B. Cai, D. Bearse, K. Dering, M. Chen, S. Florian, R. Gagnon, V.V. Golovko, P. Harvey, M. Kuzniak, J.J. Lidgard, A. McDonald, C. Nantais, A.J. Noble, E. O'Dwyer, P. Pasuthip, T. Pollman, W. Rau, T. Sonley, P. Skensved, L. Veloce, M. Ward

Rutherford Appleton Laboratory

P. Majewski

Royal Holloway University of London

J. Monroe, J. Walding, A. Butcher

SNOLAB/Laurentian

B. Cleveland, F. Duncan, R. Ford, C.J. Jillings, M. Batygov

SNOLAB

I. Lawson, K. McFarlane, P. Liimatainen, O. Li, E. Vazquez Jauregui

TRIUMF

F. Retiere, Alex Muir, P-A. Amaudruz, D. Bishop, S. Chan, C. Lim, C. Ohlmann, K. Olchanski , V. Strickland

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S.J.M. Peeters

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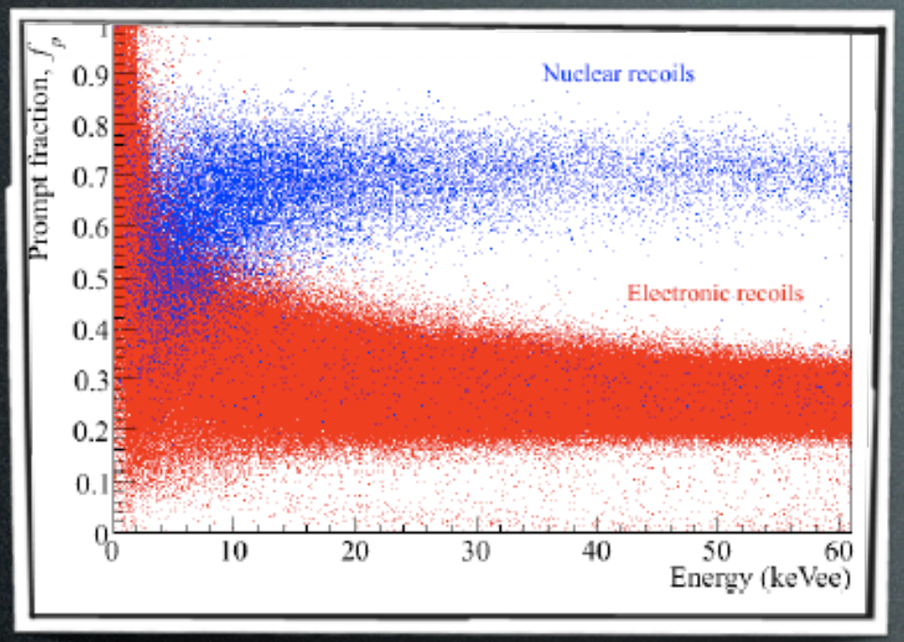
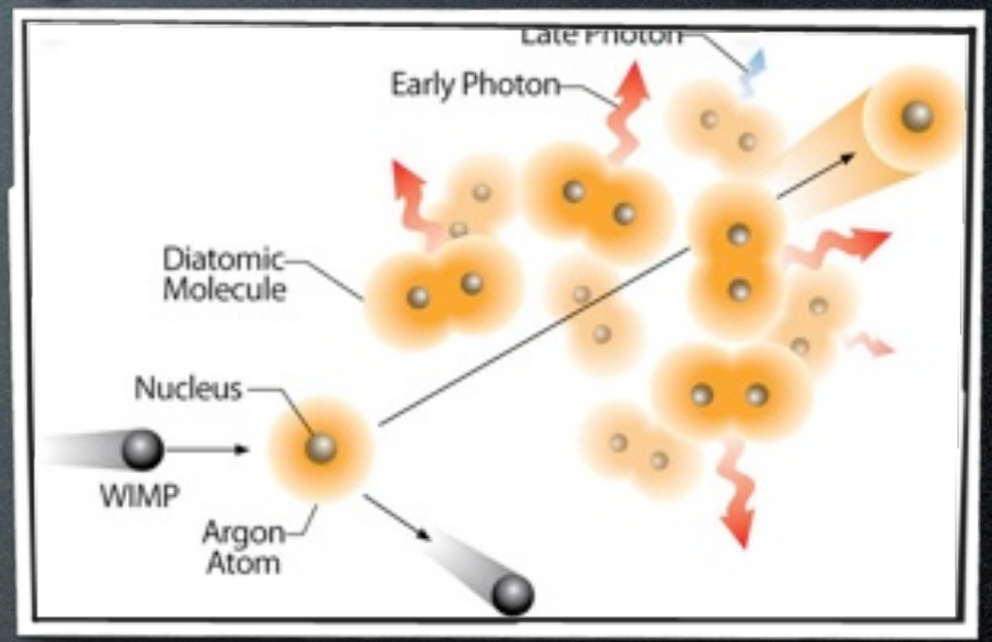
Overview

Pulse Shape Discrimination (PSD)

LAr scintillates with a prompt and slow component:





identify and reject electronic backgrounds

Important for LAr: ^{39}Ar beta (1 Bq/kg)

McKinsey & Coakley, Astropart. Phys. 22, 355 (2005)
Boulay and Hime, Astropart. Phys. 25, 179 (2006)
Lippincott et al., Phys.Rev.C 78:035801 (2008)

Achieved e^- leakage $<3\times10^{-8}$ in 120-240 photo-electron window (Jillings, CAP '11)
Expected $<1\times10^{-10}$ for DEAP-3600 for the same PE window

Single-phase LAr detectors possible because of rejection power from timing, potential for kT scale detectors.

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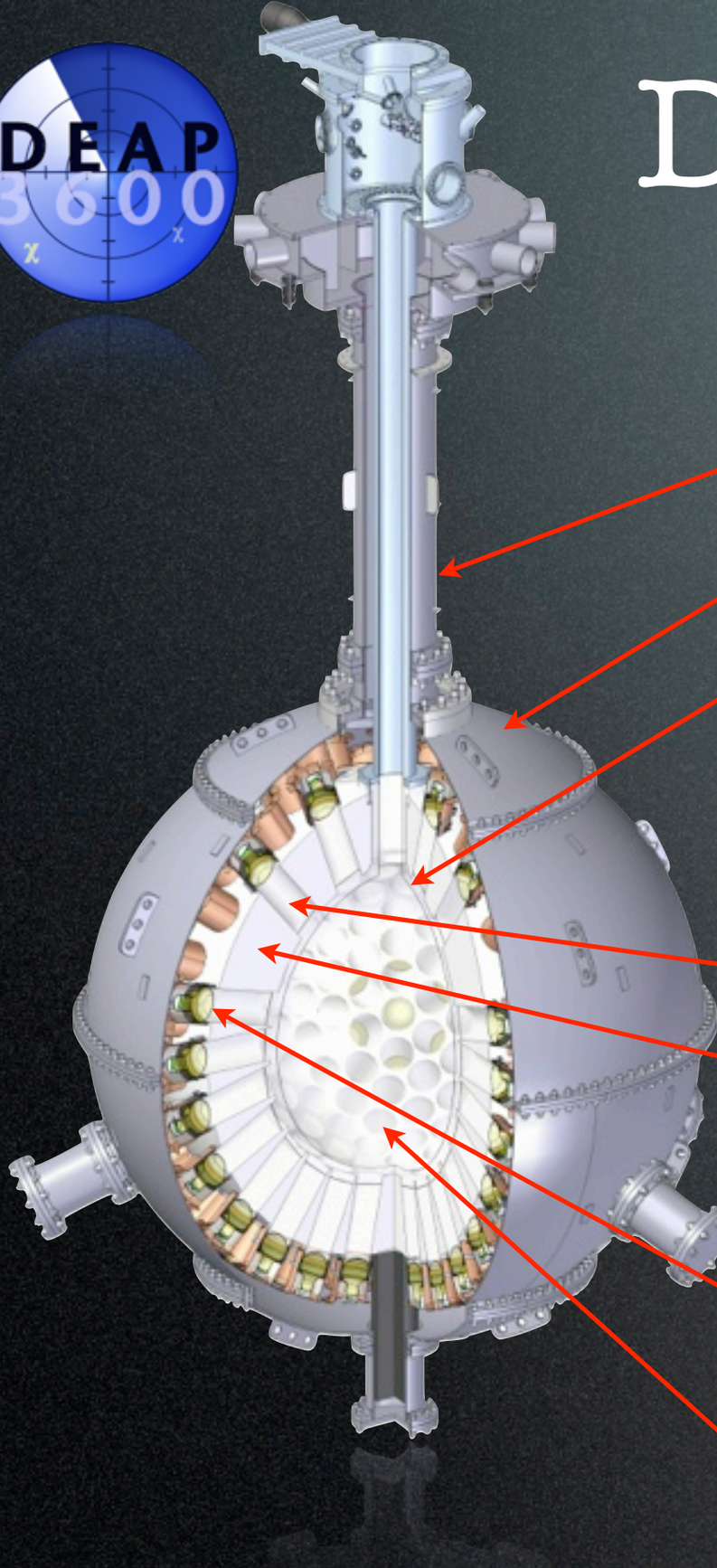
DEAP3600 design



- Neck
- Steel shell
- Acrylic vessel (AV) with TPB scintillator layer
- Acrylic light guide
- High density polyethelyne filler material
- 255 Hamamatsu R5912 HQE PMTs
- 3600 kg LAr

Detector in 8 m water shield, instrumented with veto PMTs

@ 6000 mwe

DEAP-3600 Specifications

Parameters	Value
Light yield	8 pe per keVee
Nuclear quenching factor	0.25
Analysis threshold	15 keVee (60 keVr)
Total Argon mass (radius)	3600 kg (85 cm)
Fiducial mass (radius)	1000 kg (60 cm)
Position resolution at threshold (cons, design spec)	10 cm
Position resolution at threshold (ML fitter)	< 6.5 cm
Background specifications	**Target**
Radon in Argon	< 1.4 nBq/kg
Surfaces α's (tolerance using cons. pos. res.)	< 0.2 μBq/m^2
Surfaces α's (tolerance using ML fitter pos. res.)	< 100 μBq/m^2
Neutrons (all sources, in fiducial volume)	< 2 pBq/kg
$\beta\gamma$ events, dominated by ^{39}Ar (after PSD)	< 2 pBq/kg
Total backgrounds	**< 0.6 events in 3 tonne-years**

ArXiv:1203.0604

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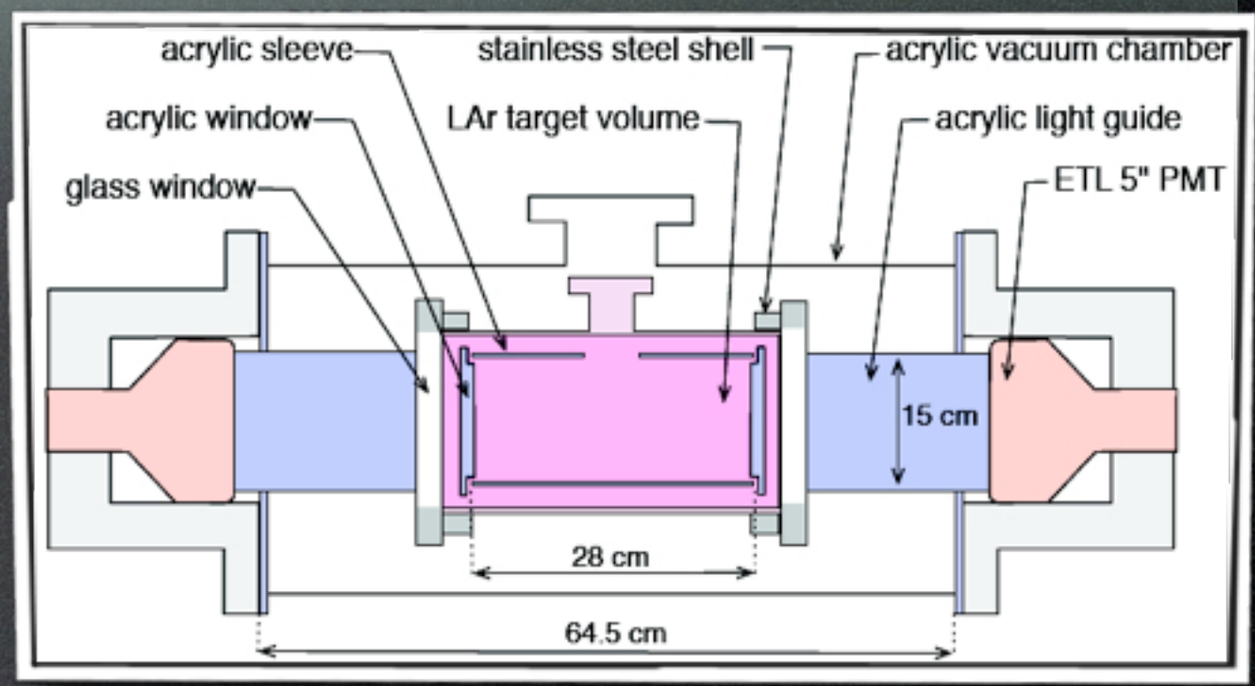
Backgrounds

Surface background reduction in prototype

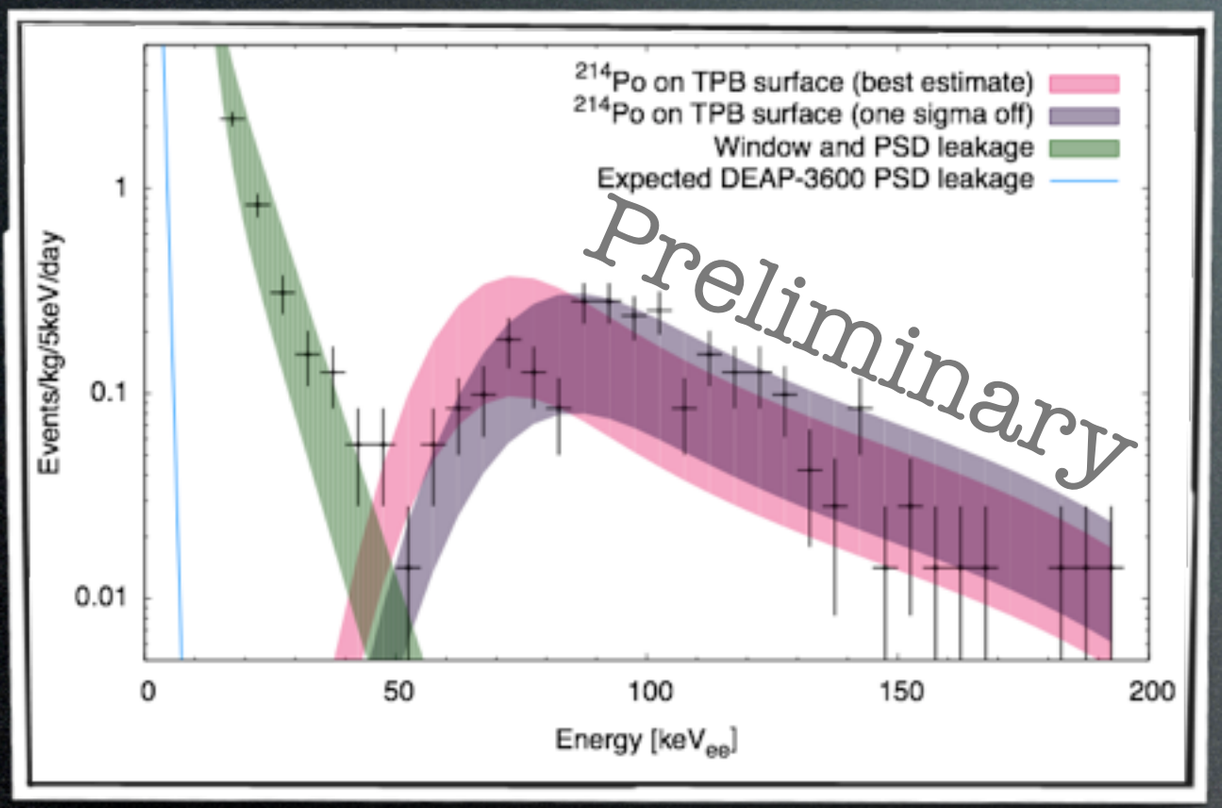
Date	Background Rate (in WIMP ROI)	Configuration	Improvements for this rate
April 2006	20 mBq	First run (Queen's)	Careful design with input from materials assays (Ge γ couting)
August 2007	7 mBq	Water shield (Queen's)	Water shielding, some care in surface exposure (< a few days in lab air)
January 2008	2 mBq	Moved to SNOLAB	6000 m.w.e. shielding
August 2008	400 μBq	***Clean v1* chamber at SNOLAB**	Glove box preparation of inner chamber (reduce Rn adsorption/implantation on surfaces)
March 2009	150 μBq	***Clean v2* chamber at SNOLAB**	Sandpaper assay/selection, PTFE instead of BC-620 reflector ,Rn diffusion mitigation, UP water in glove box, documented procedures; Rn Trap.
March 2010	**130 μBq**	***Clean v3* chamber at SNOLAB**	Acrylic monomer purification for coating chamber. TPB purification.
Feb 2011	**~10 μBq**	***Clean v4/v5* chamber at SNOLAB**	Inner chamber redesign to remove "Neck Light" events



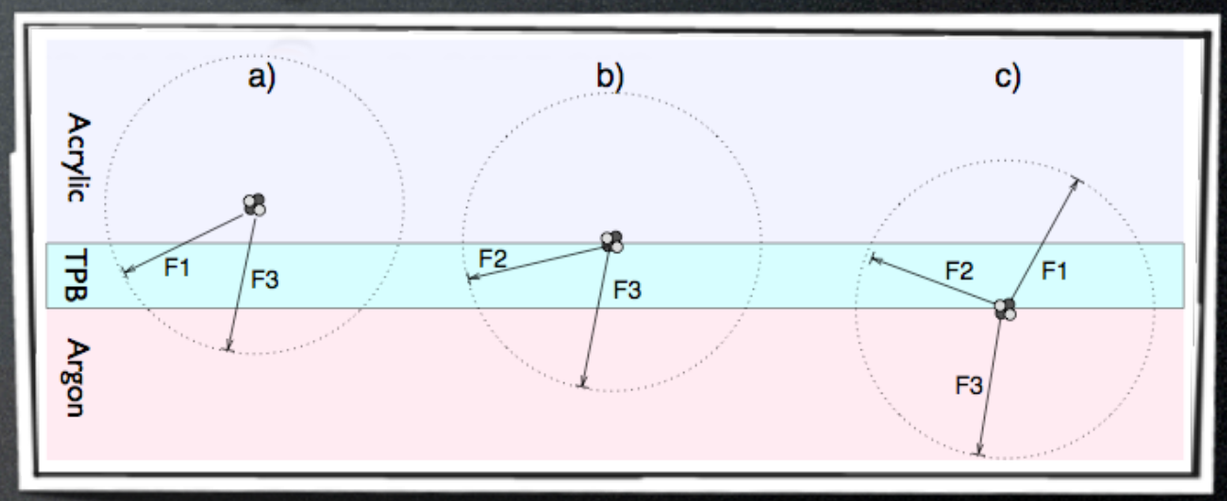
DEAP-1

Backgrounds in DEAP1 v5

10 μBq in 120-240 pe region



Demonstrated a detailed understanding of surface alpha backgrounds



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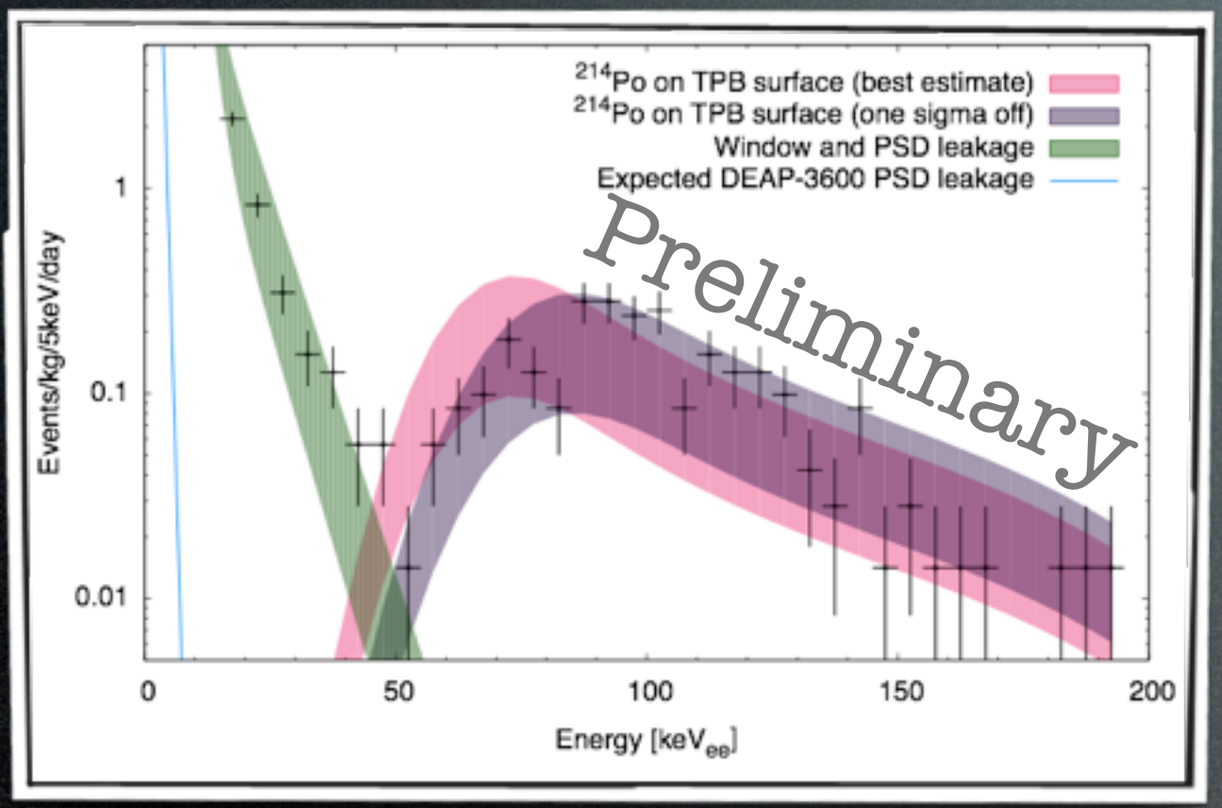
Backgrounds in DEAP1 v5

10 μBq in 120-240 pe region



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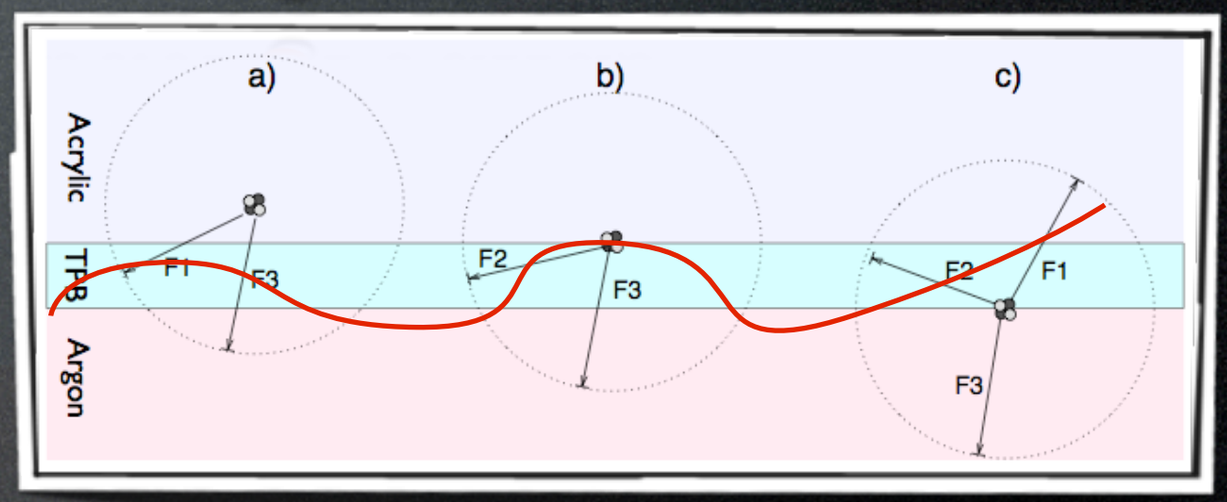

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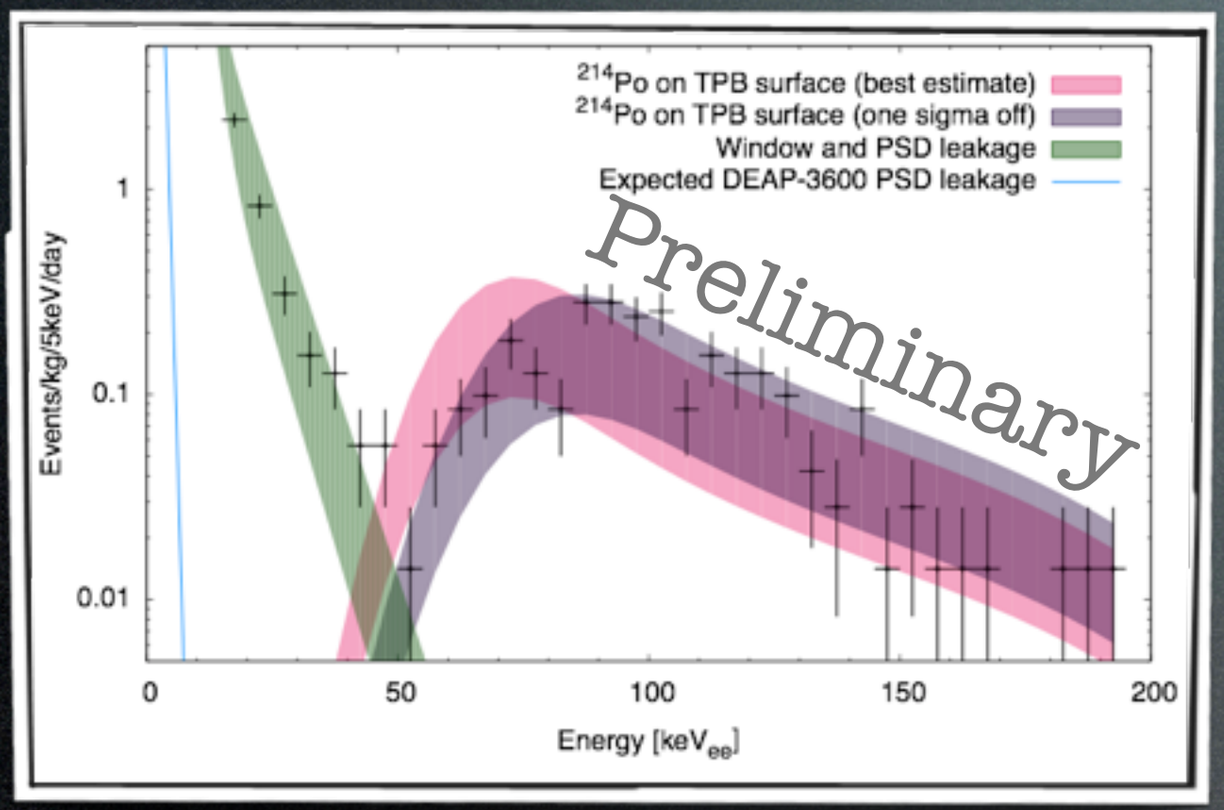
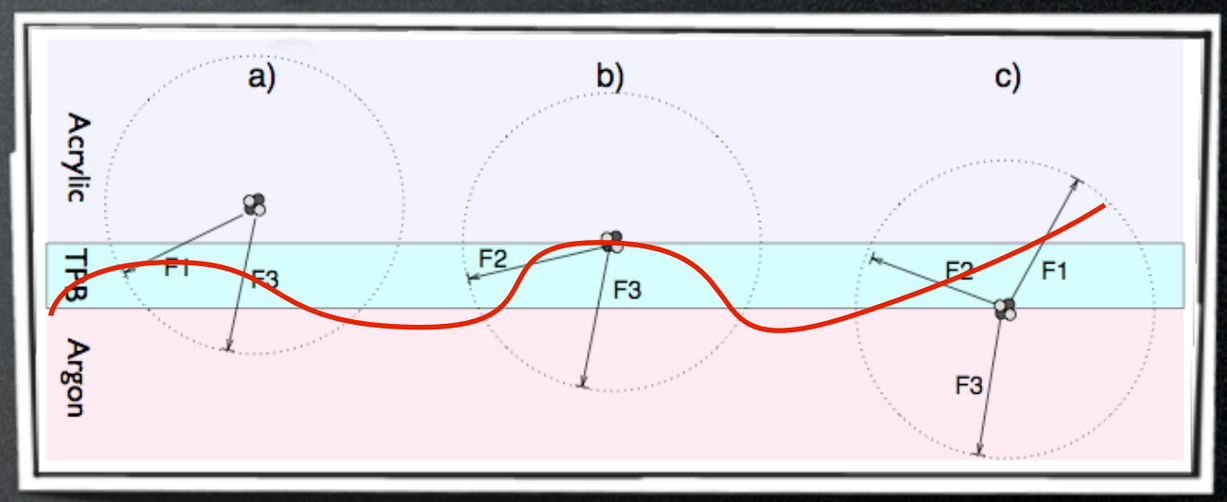
Backgrounds in DEAP1 v5

10 μBq in 120-240 pe region



Demonstrated a detailed understanding of surface alpha backgrounds



By-product: "Surface roughness interpretation of CRESST-II result": arXiv:1203.1576
Accepted for publication in Astropart. Phys.

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Recent highlights

Cavity status at SNOLAB

- Cavity and platform are ready
- Water shield has been installed

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Cryocooler and LN_2 system

Delivery and acceptance at SNOLAB (April 2012)

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DEAP-3600 vessel constructed and delivered to University of Alberta (June 2012) for machining of light guide stubs

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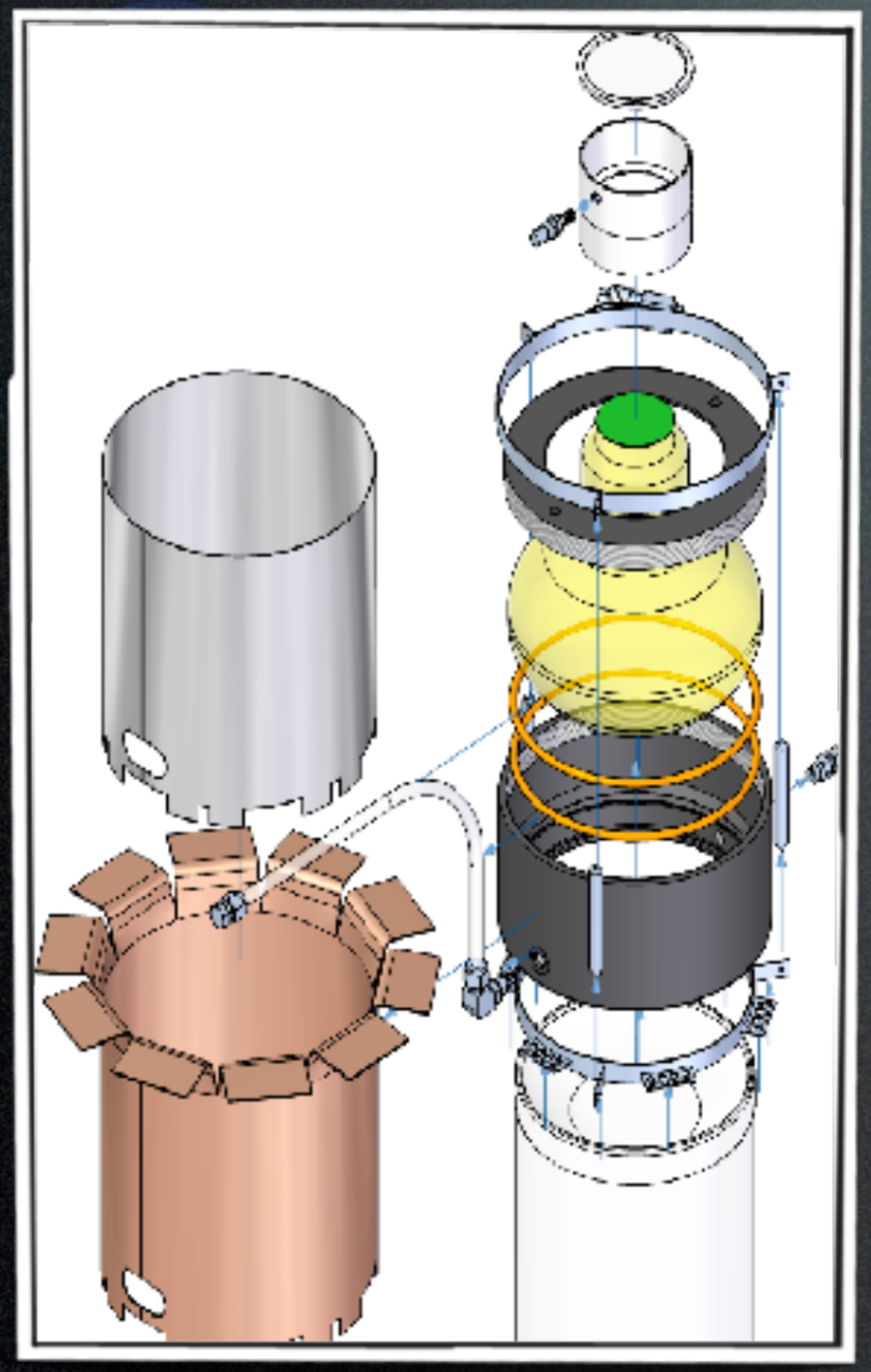
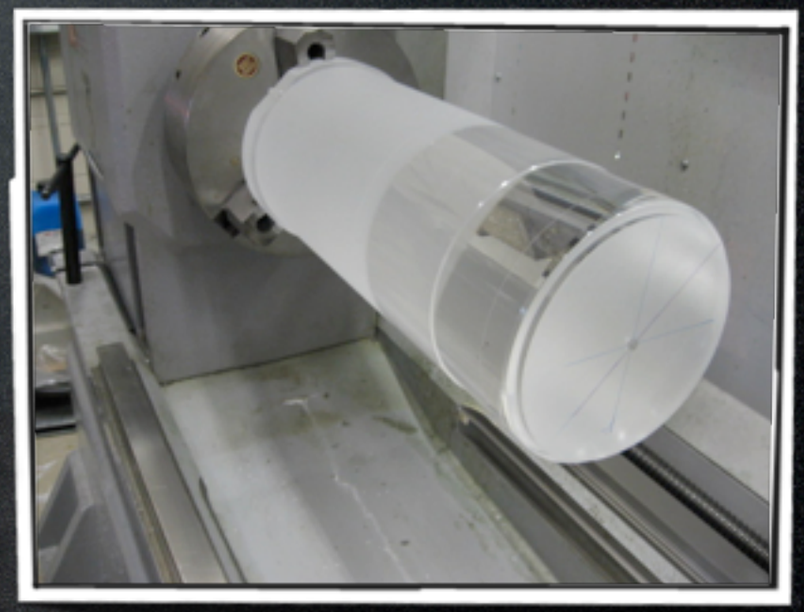
Light guide and PMTs



PMT assembly:
components
have been
prototyped,
purchased (PMTs,
testing is underway),
or quotes are
being received.

Lightguides:
Radiopure acrylic
bonded and shipped
to TRIUMF
Jan 2012
for machining



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Acrylic resurfacer

- Being commisioned at Queen's University on test blocks
- Resurfacer will be emanated to demonstrate radon load before shipping to SNOLAB

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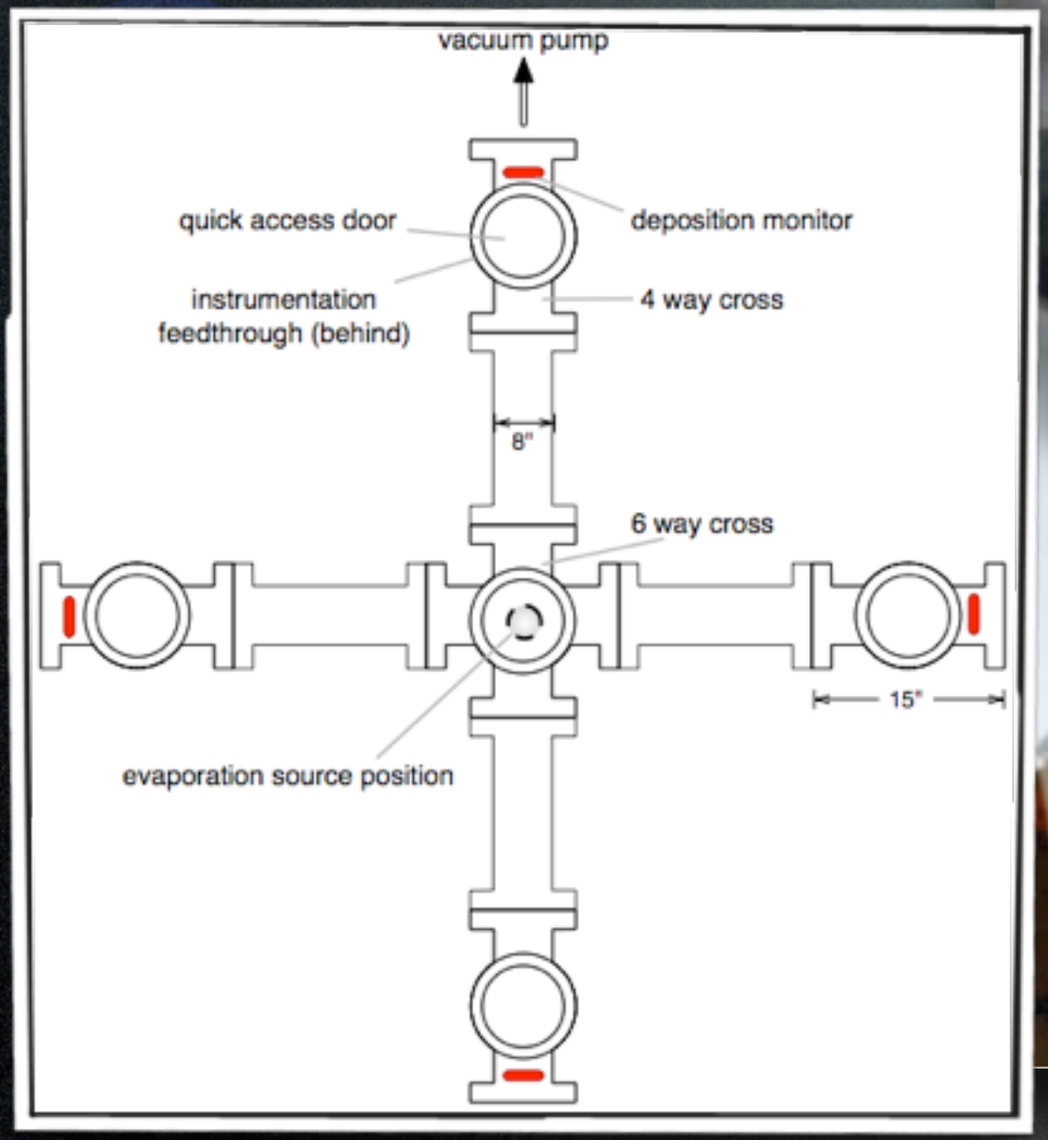
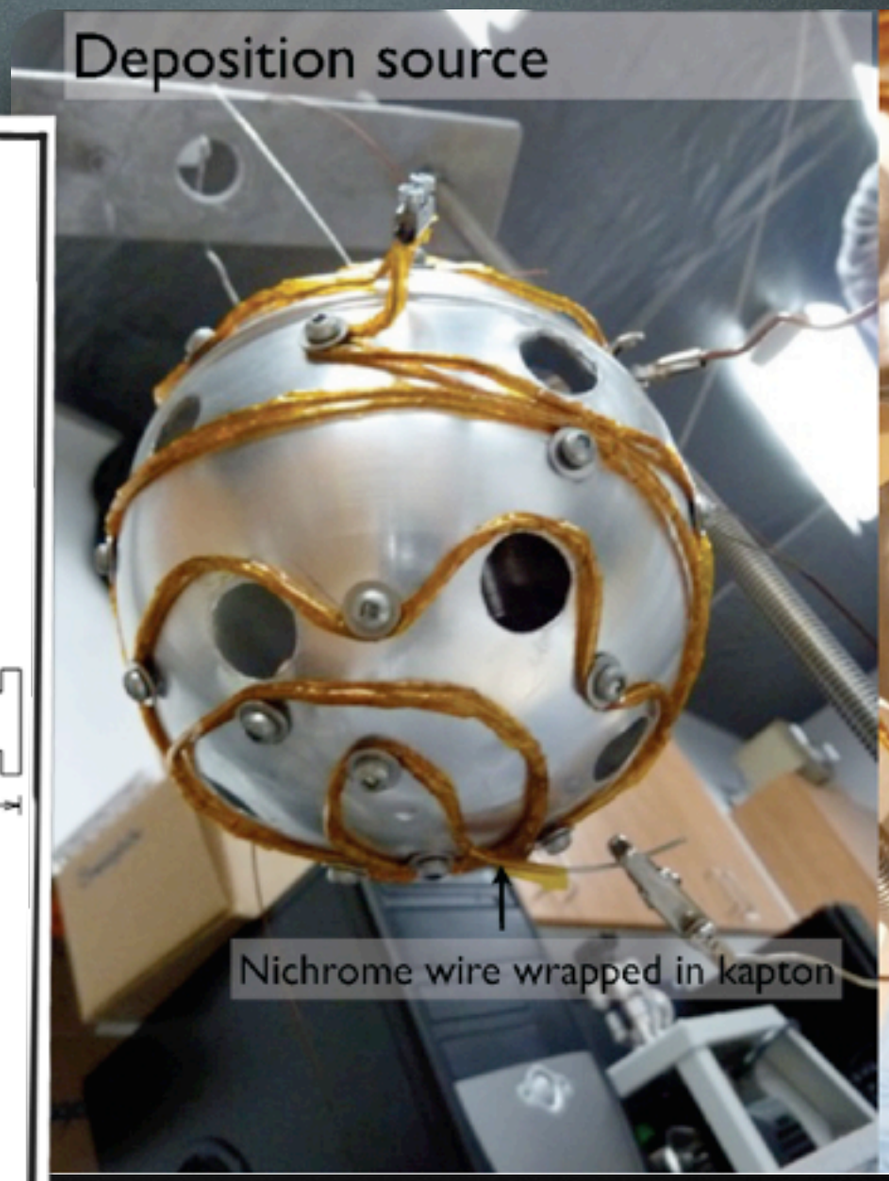
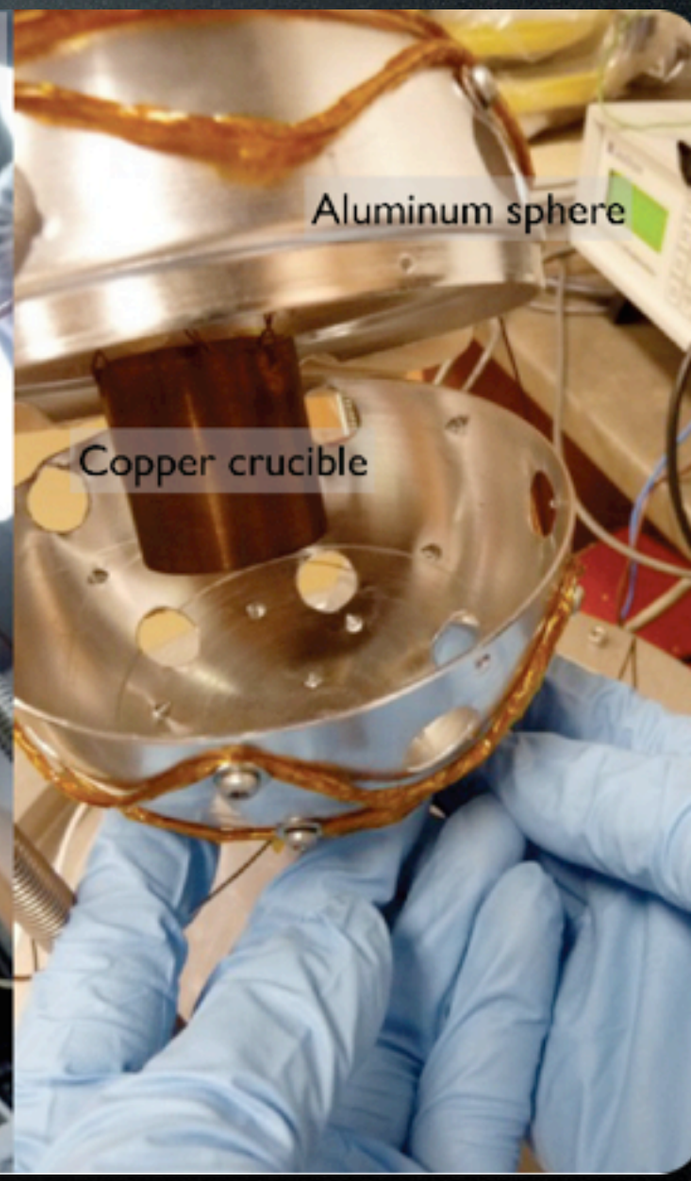
TPB deposition







Deposition source has been successfully demonstrated at Queen's University in evaporation test stand.

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Calibration programme

Characterise the response in energy, radius and fPrompt

Calibration using tagged gamma sources

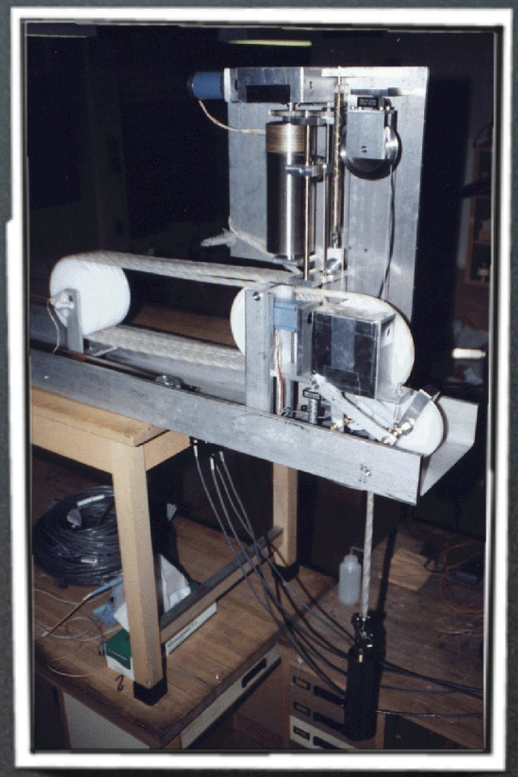
^{60}Co (1.17 and 1.33 MeV γ) ; ^{22}Na (e+,1.274 keV γ);^{137}Cs (0.662 keV γ)

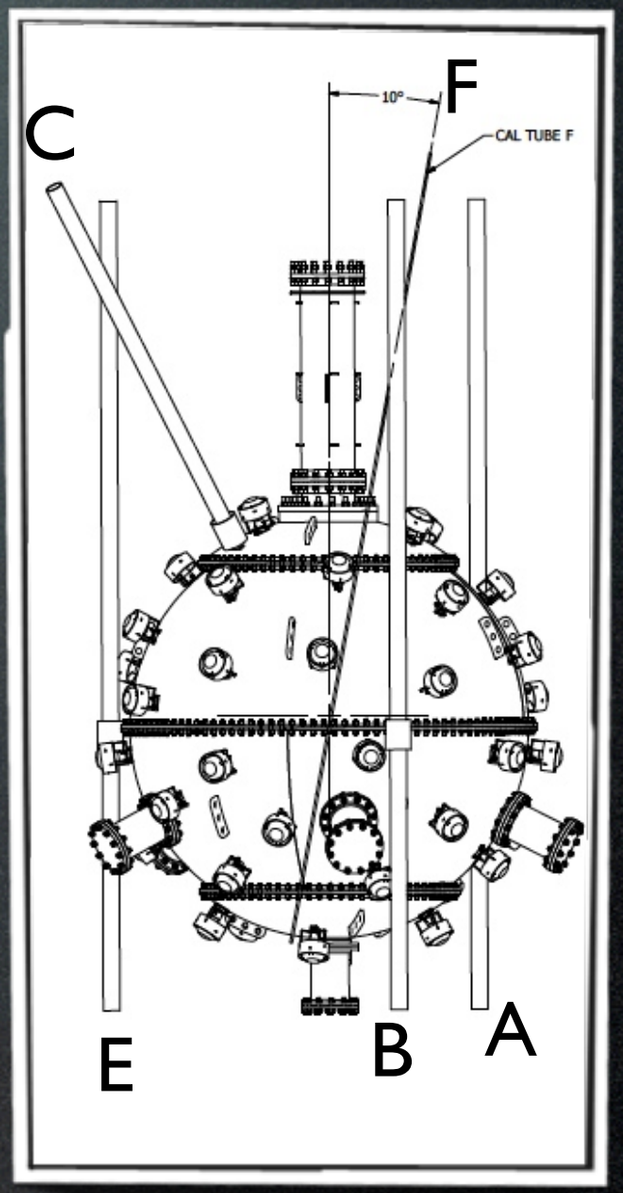
Neutron calibration

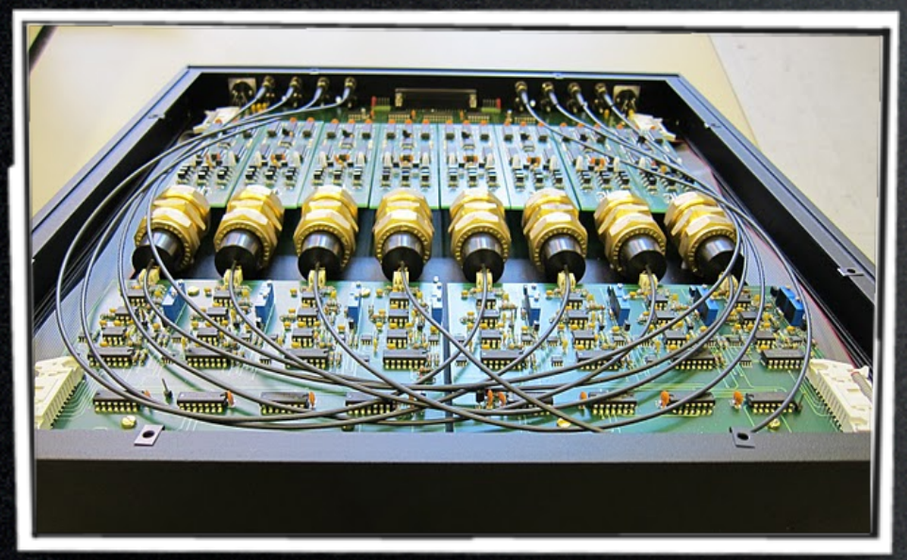
Deployable, pulsed D-D generator

Optical calibration

LED/fibre optical injection system
LED ball calibration pre and post TPB deposition
266 nm laser injection via the neck to excite TPB







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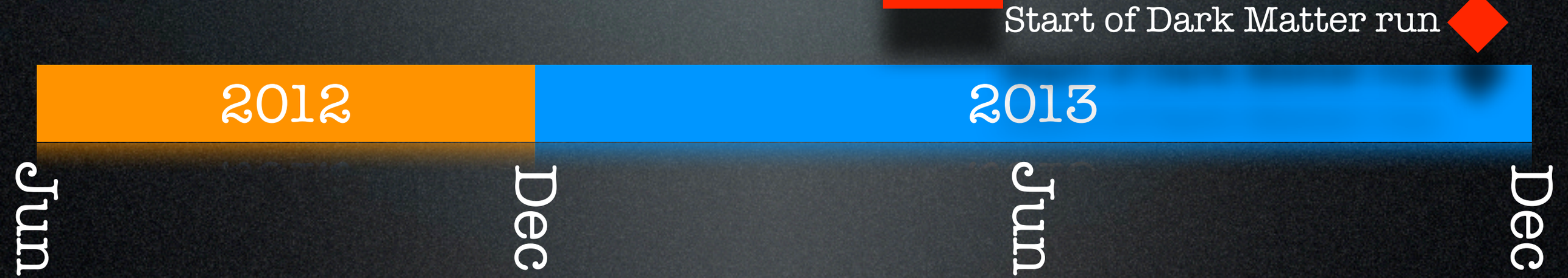
Project overview

Detector assembly and commissioning

Resurfacing

Apply TPB

Start of Dark Matter run



Overview of the timeline for DEAP-3600

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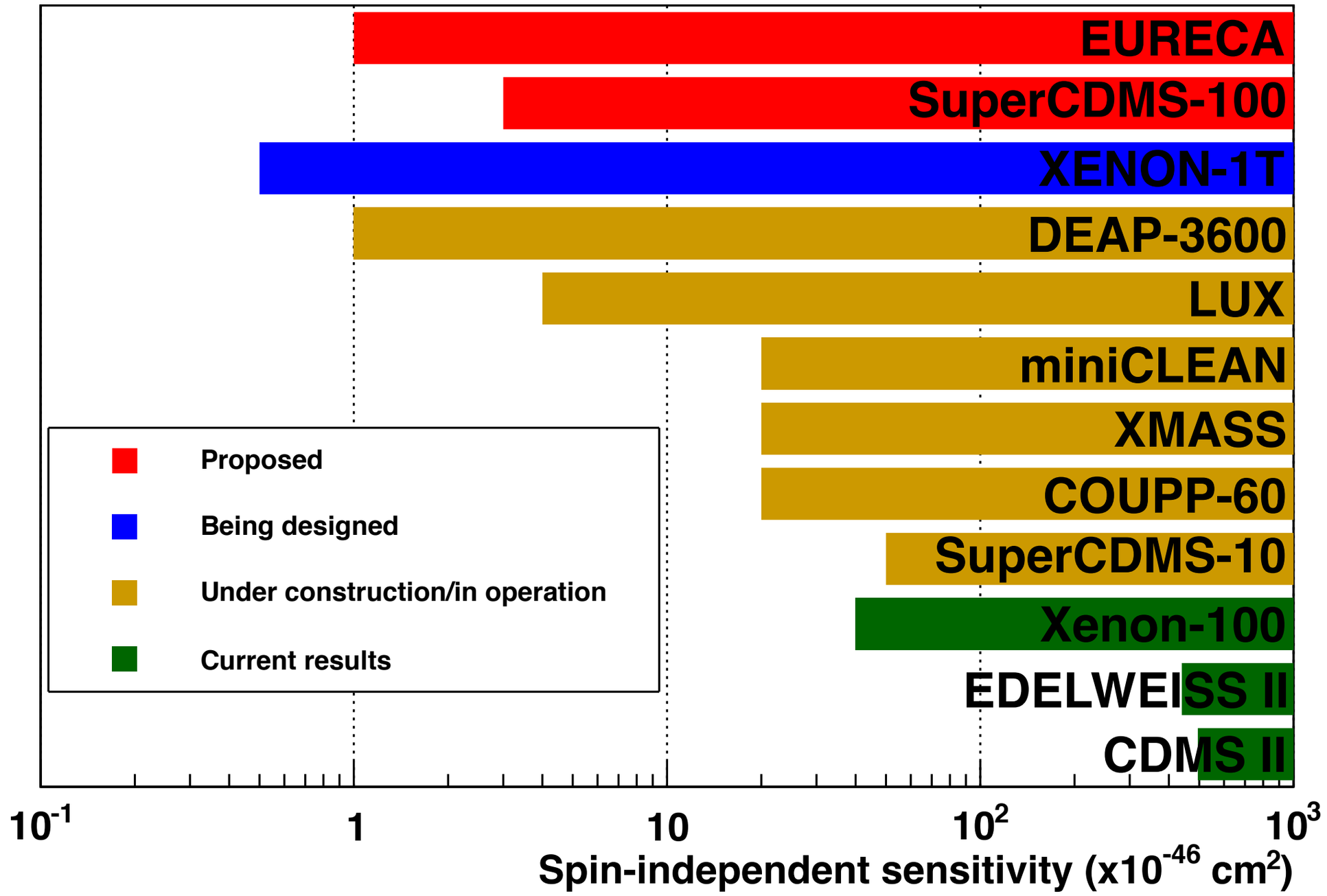
Summary



DEAP-3600 in context

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Conclusions

- Single-phase LAr has a unique potential for direct detection of dark matter
- DEAP-3600 is well-positioned for leading sensitivity with a very good discovery potential
- Main detector components have been purchased, are being machined and construction is about to start
- Expect data taking to start in end of 2013

Stay tuned!

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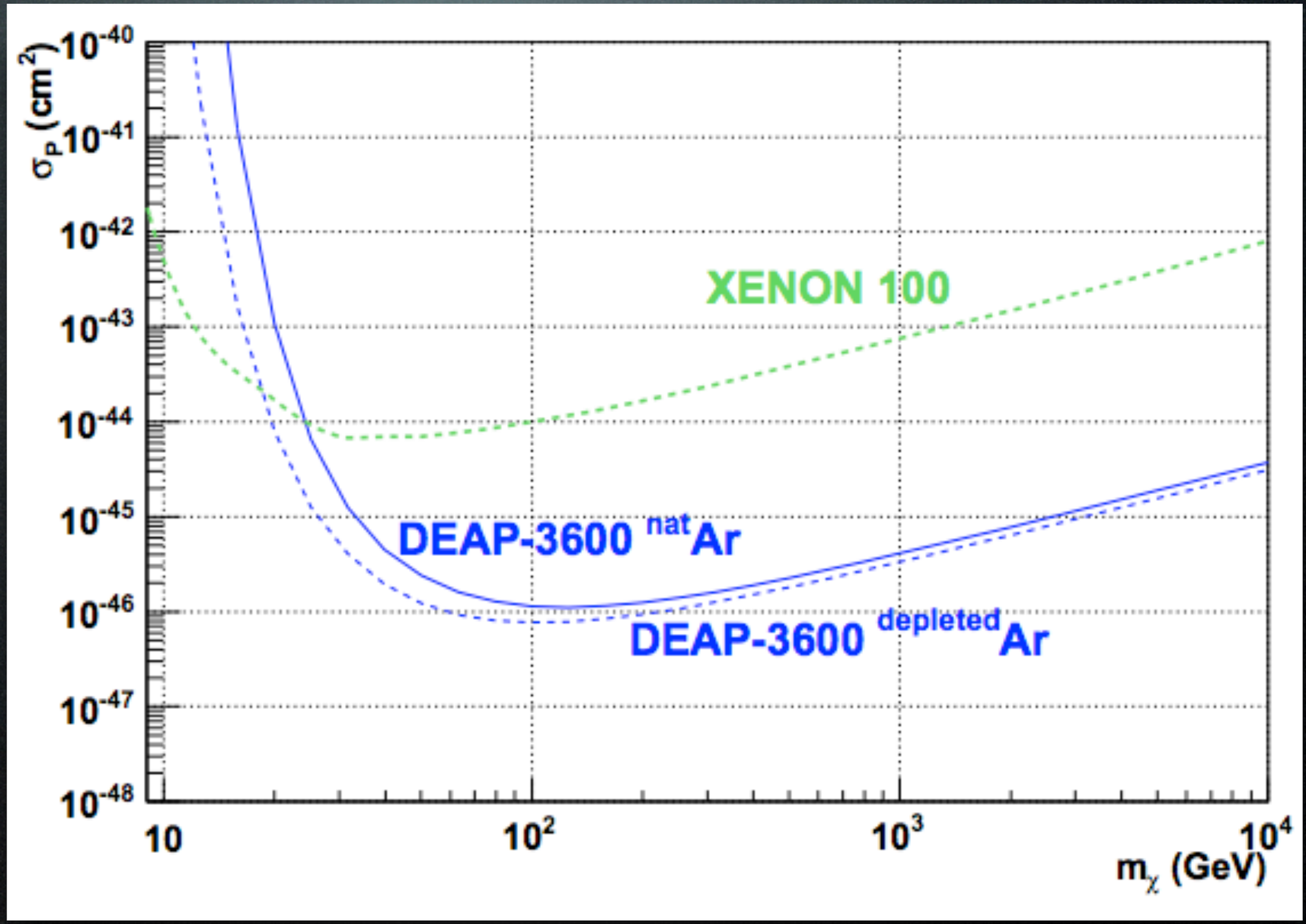
Thank you for your attention!



DEAP-3600 sensitivity, current* Xenon-100 limits for reference

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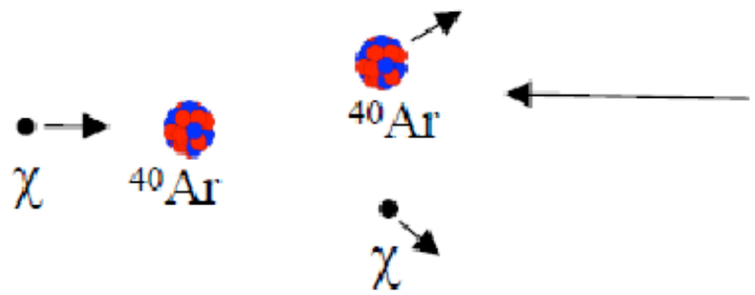
Direct WIMP detection with liquid argon



Scattered nucleus (with several 10's of keV) is detected via scintillation in liquid argon.

Pulse-shape discrimination (PSD) is very powerful in argon, allows for suppression of background β/γ events.

Projected pulse shape discrimination (PSD) in argon allows threshold of approx. 20 keV_{ee} (60 keV_r)

1000 kg argon target allows 10^{-46} cm^2 sensitivity (spin-independent) with ~20 keV_{ee} threshold (~65 keVr) threshold, sufficient to mitigate ^{39}Ar

Liquid argon
- is easily purified and has a high light yield
- is well-understood, allows for very simple scintillation detector
- has an easily accessible temperature (85K)
- allows a very large detector mass (~tonne) with uniform response (few % light yield uniformity)

DEAP-1 (7 kg)
DEAP-3600 (3600 kg)

Mark Boulay, Queen's

WIMP detection in LAr

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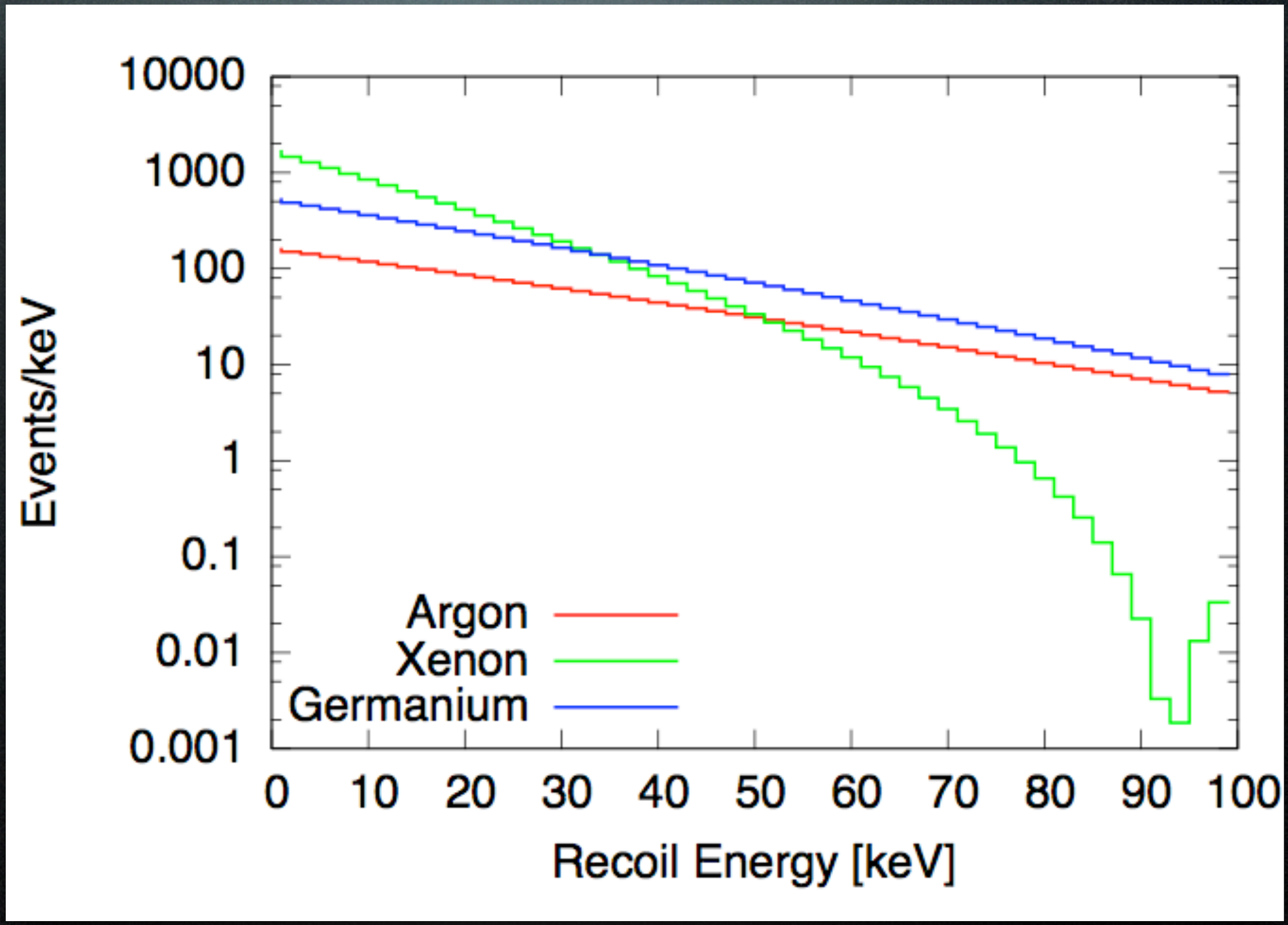

WIMP spectrum

(100 GeV, 10^{-7} pb, 365 tonne year)

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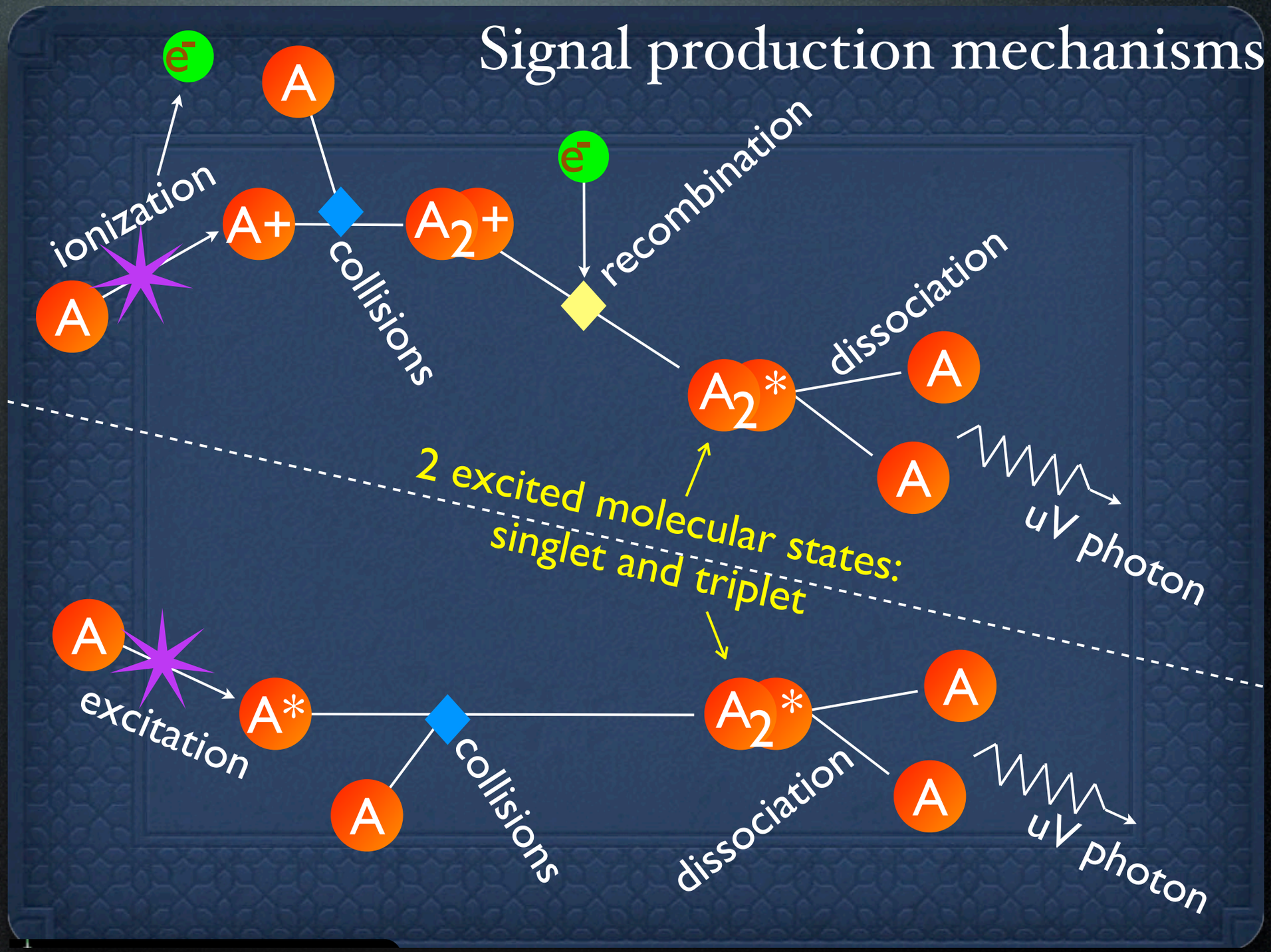

LAr scintillation

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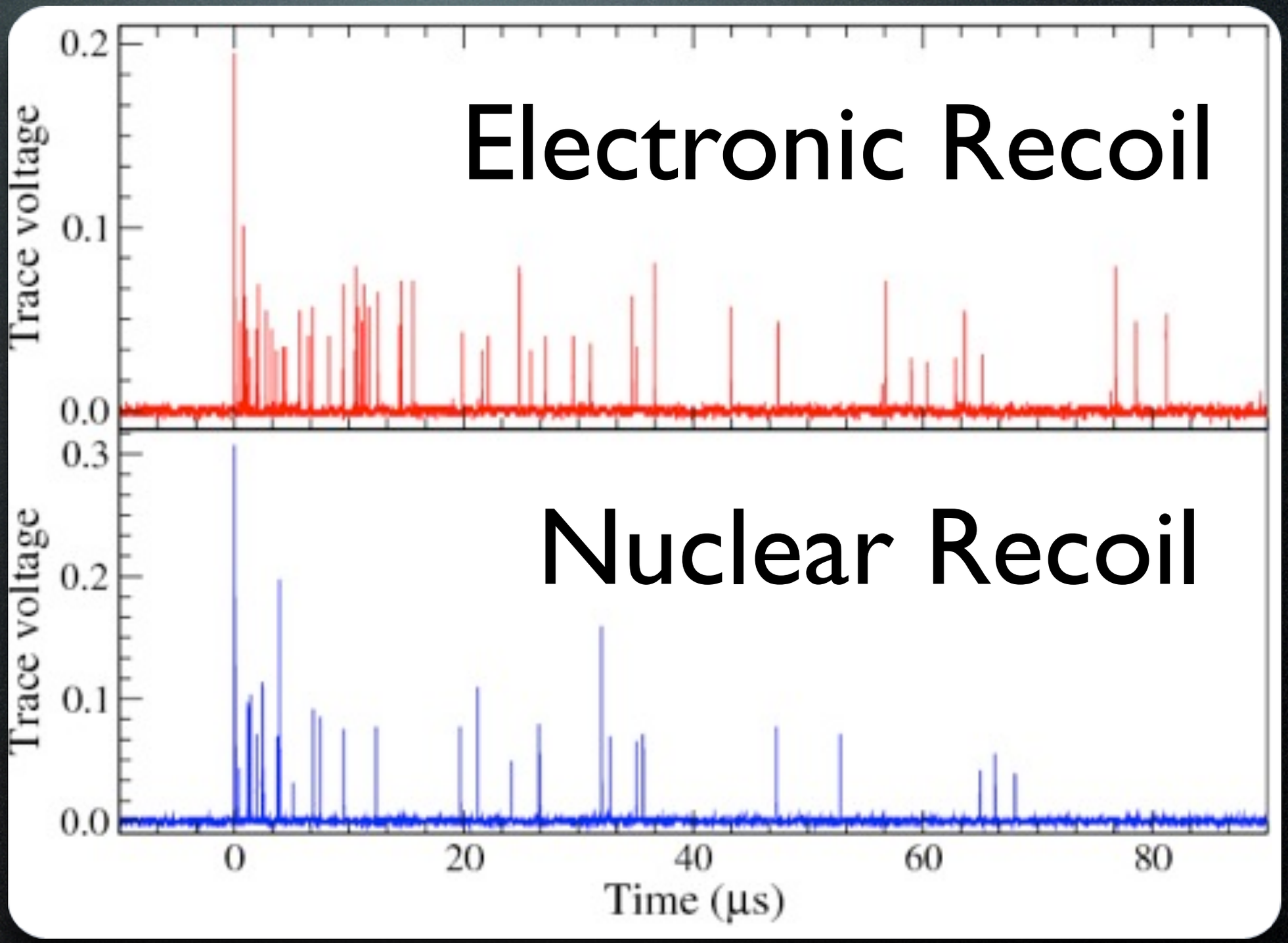

PSD in LAr

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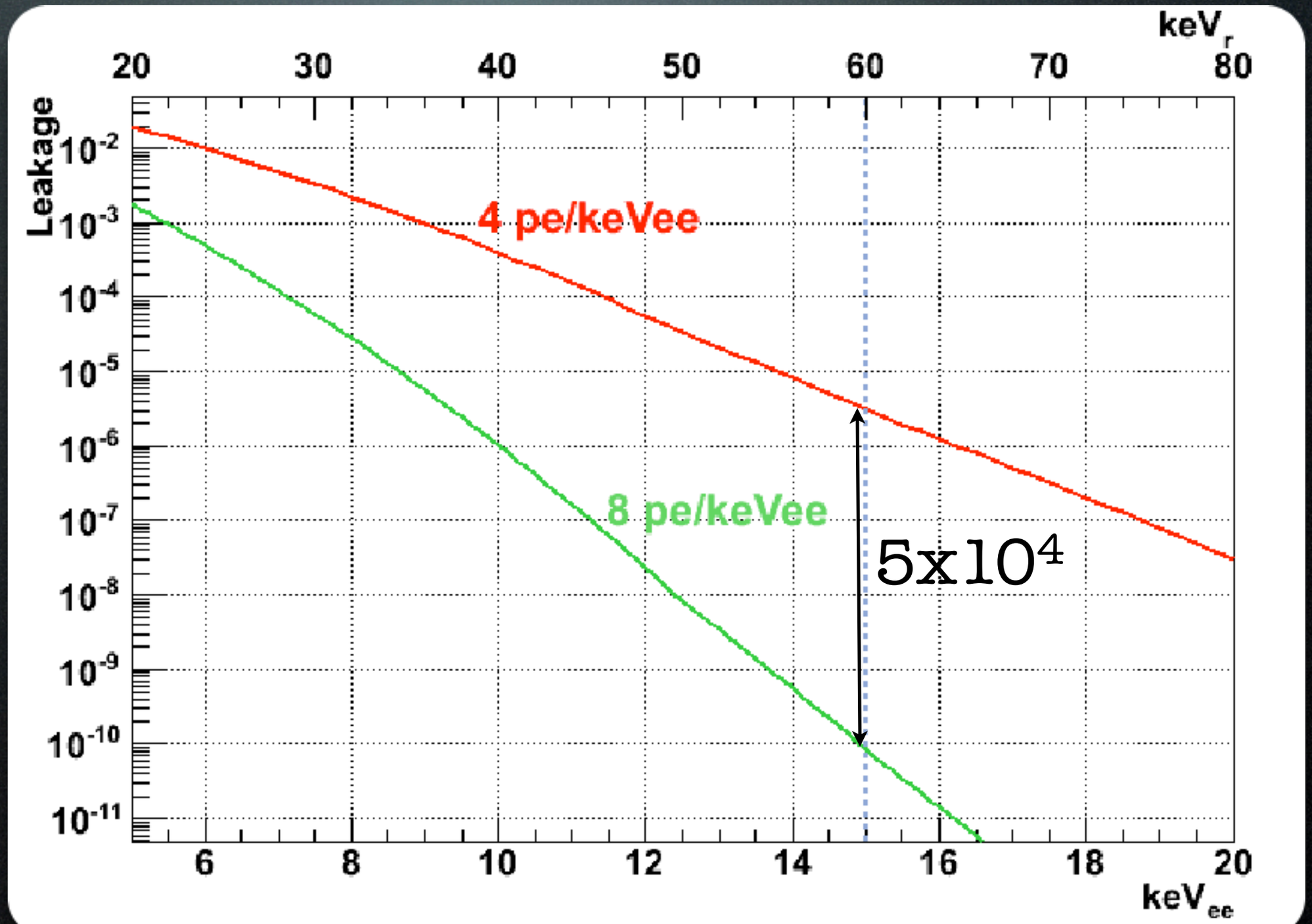

Maximise light yield!

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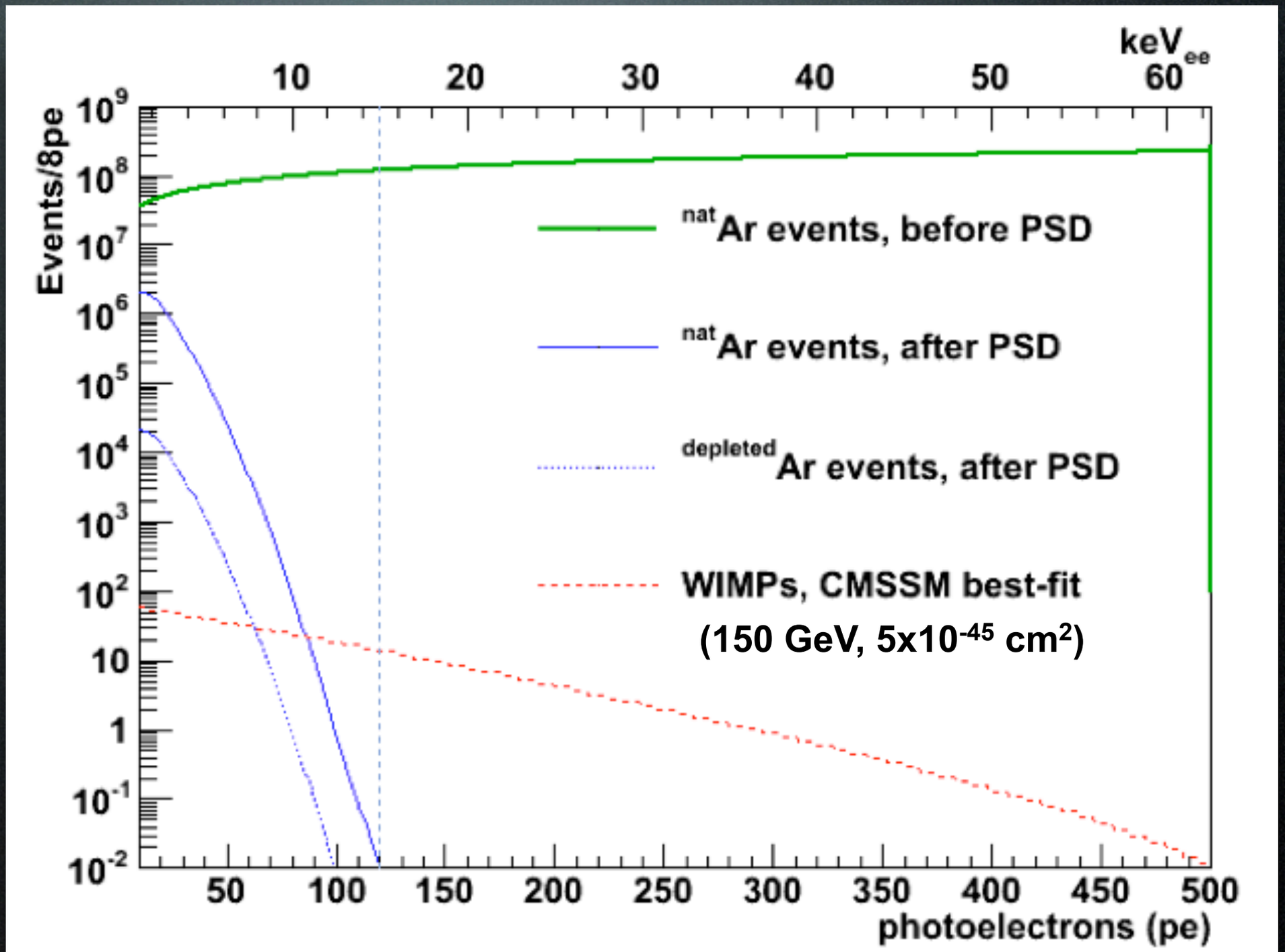

PSD in DEAP-3600

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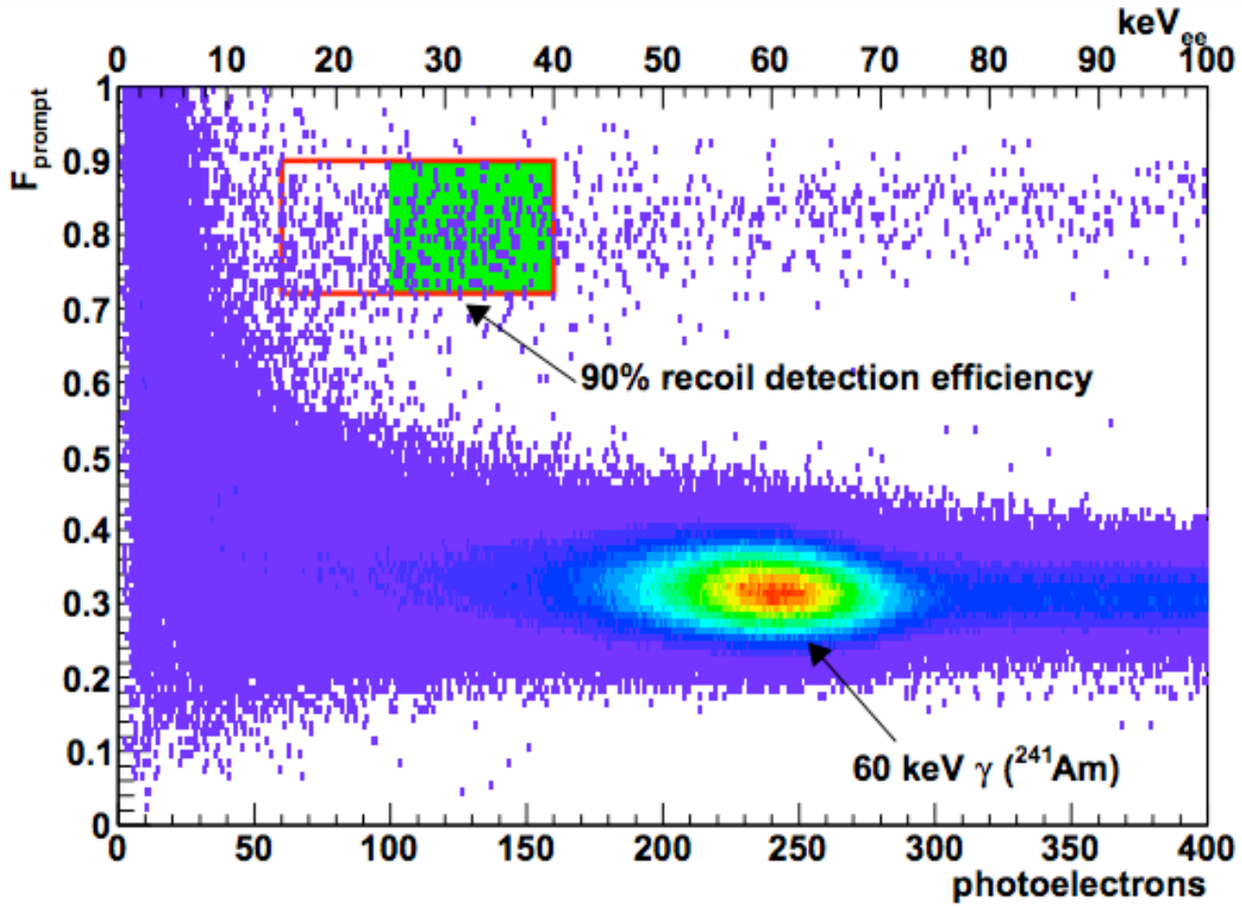

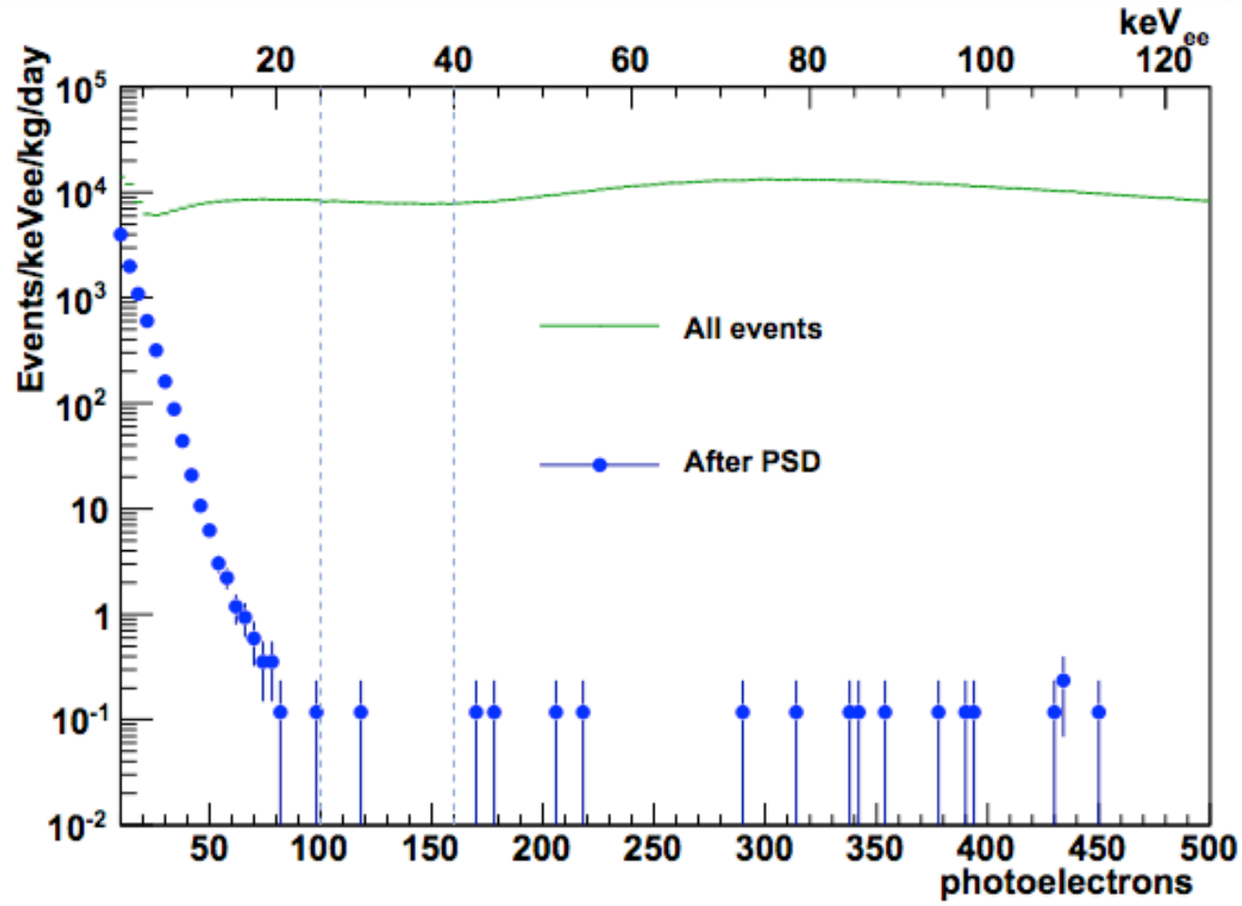

Results from the DEAP-1 7-kg liquid argon prototype detector at SNOLAB. (Left) Neutrons (high-F_{prompt} band) and γ's (low-F_{prompt} band) from an untagged AmBe source. The boxes show F_{prompt} regions with 90% detection efficiency, with DEAP-3600 and DEAP-1 thresholds. (Right) Backgrounds in the DEAP-1 prototype. The low-energy "wall" is from γ backgrounds that are not removed by PSD; high-energy events are from radon and surface contamination. In the energy region from 25 to 40 keVee, the backgrounds correspond to approximately 100 μBq/m^2.

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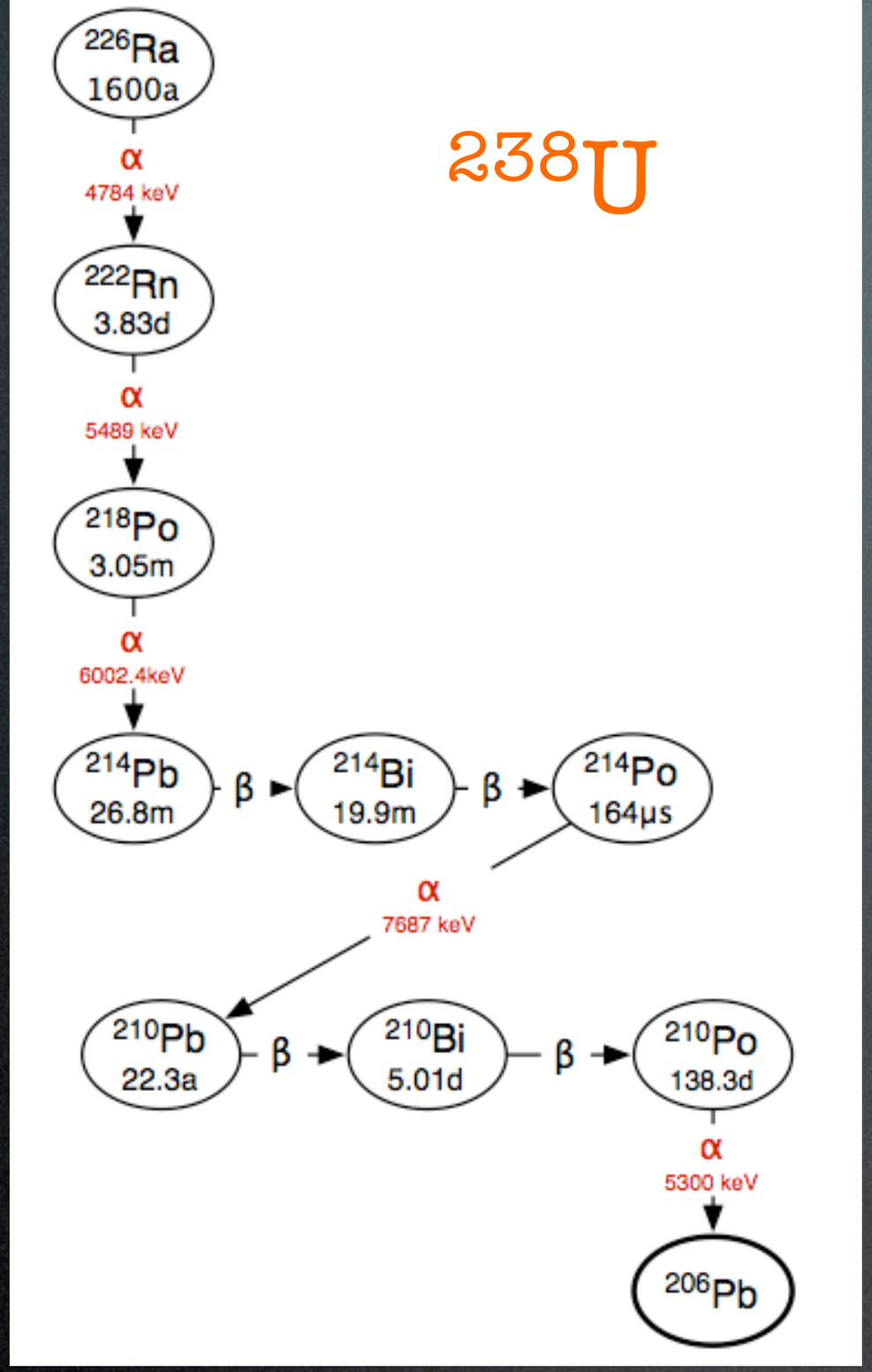
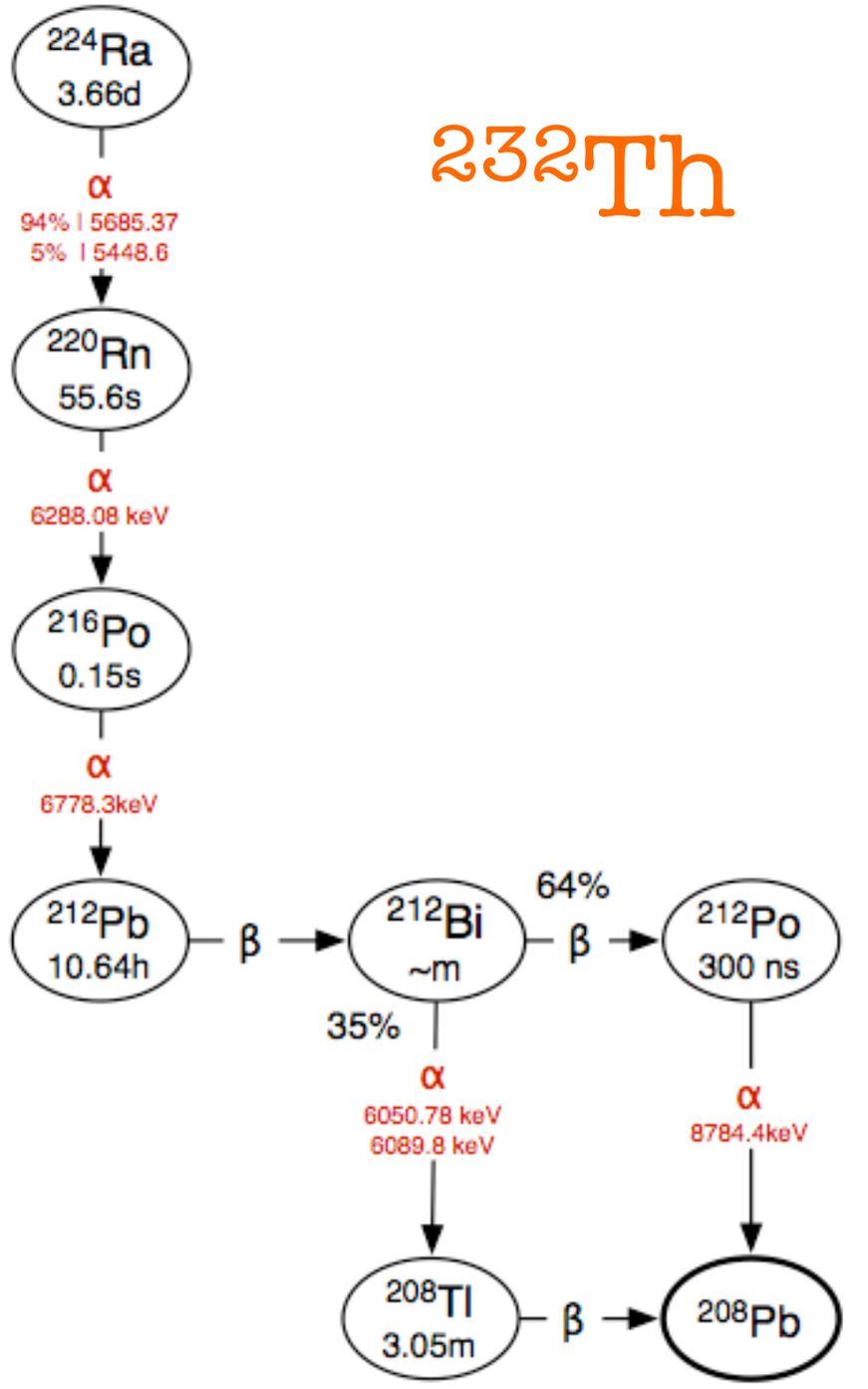


238U



232Th

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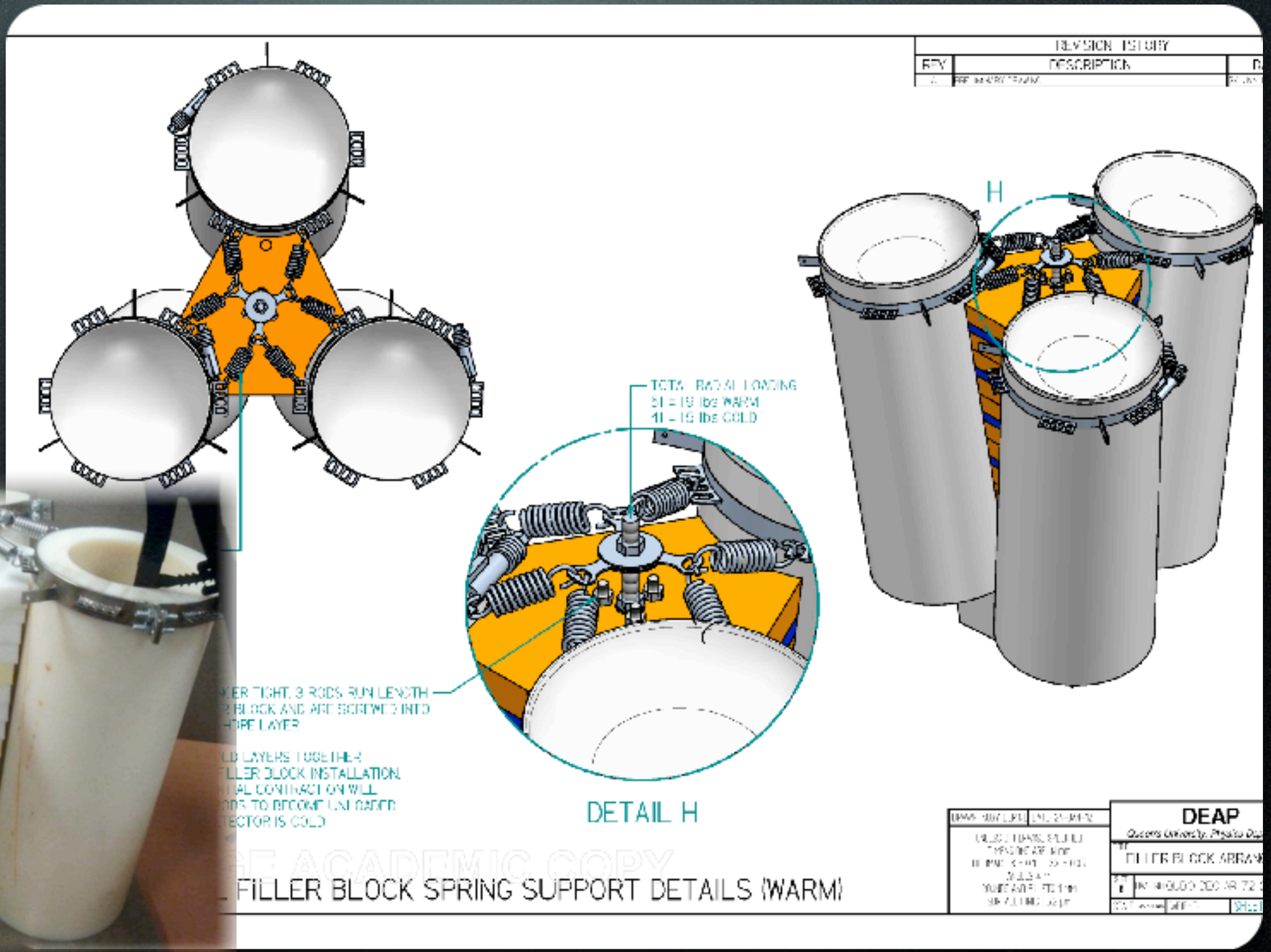

filler block prototype

32 Dark Attack 2012, Simon JM Peeters

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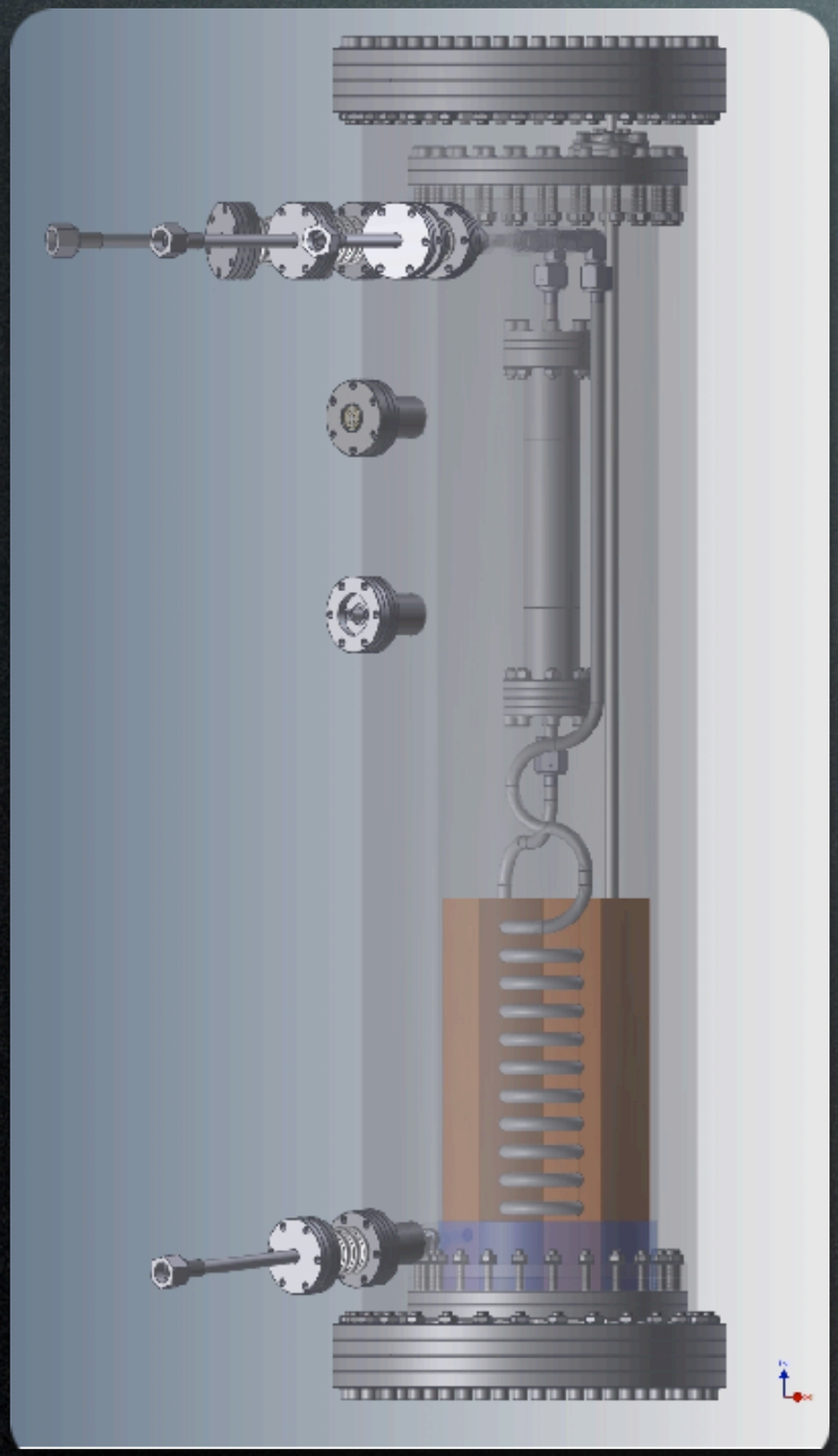
Radon purifier



Internal filter design
W. Rau (Queen's)
and E. O'Dwyer
M.Sc. thesis

Mechanical Design
and Thermal FEA
From Vance
Strickland
(TRIUMF/Carleton)

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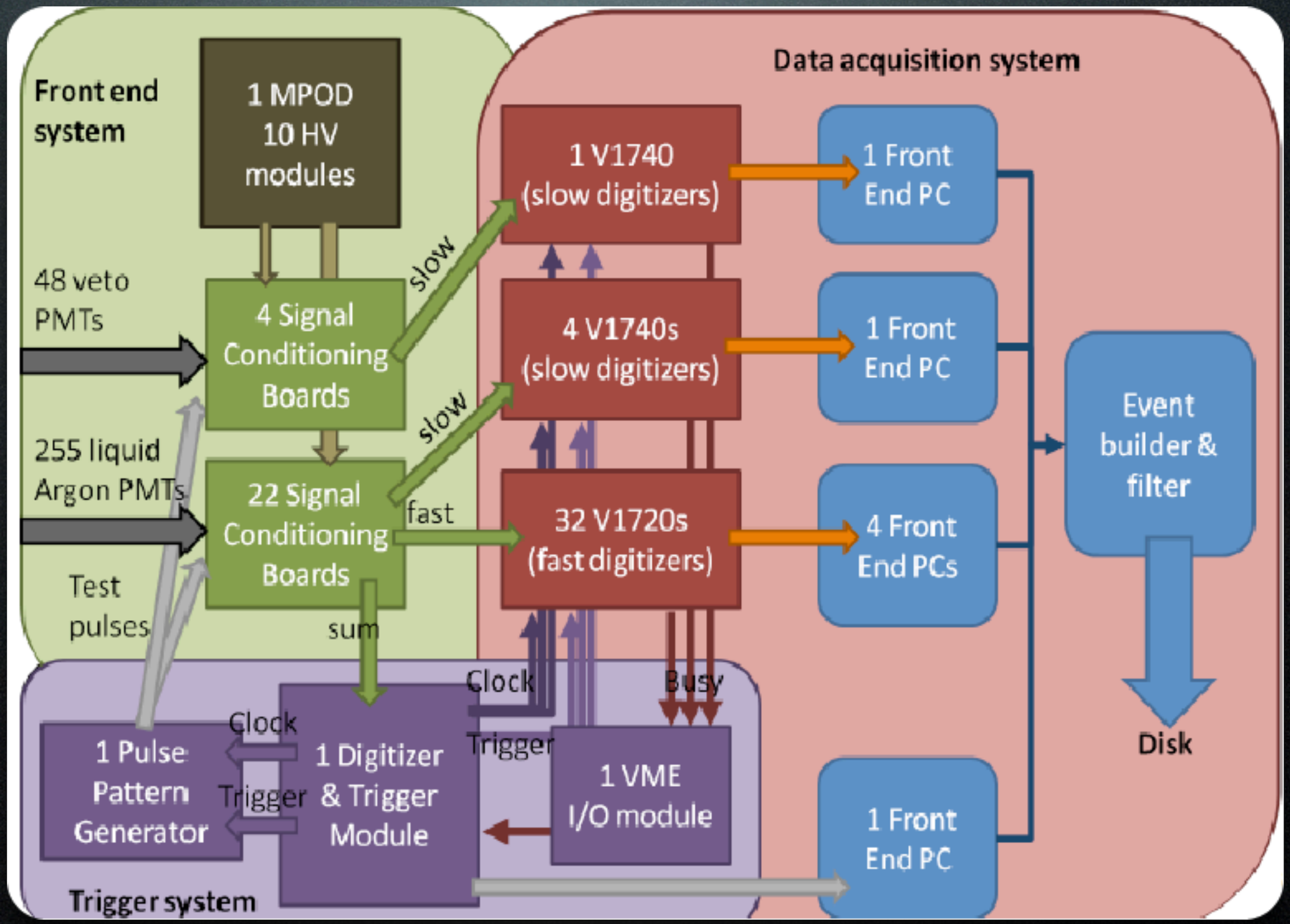

Electronics conceptual design

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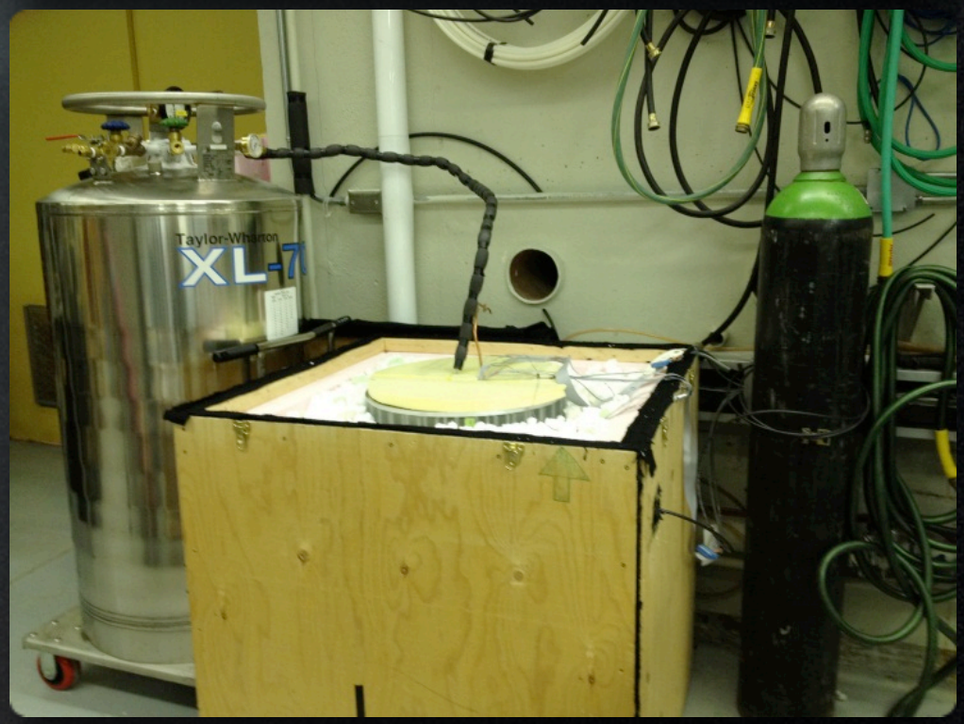

20” vessel + cooling tests

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Set-up at TRIUMF

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