Search for Dark Matter: Results from DEAP-1 and status of DEAP-3600

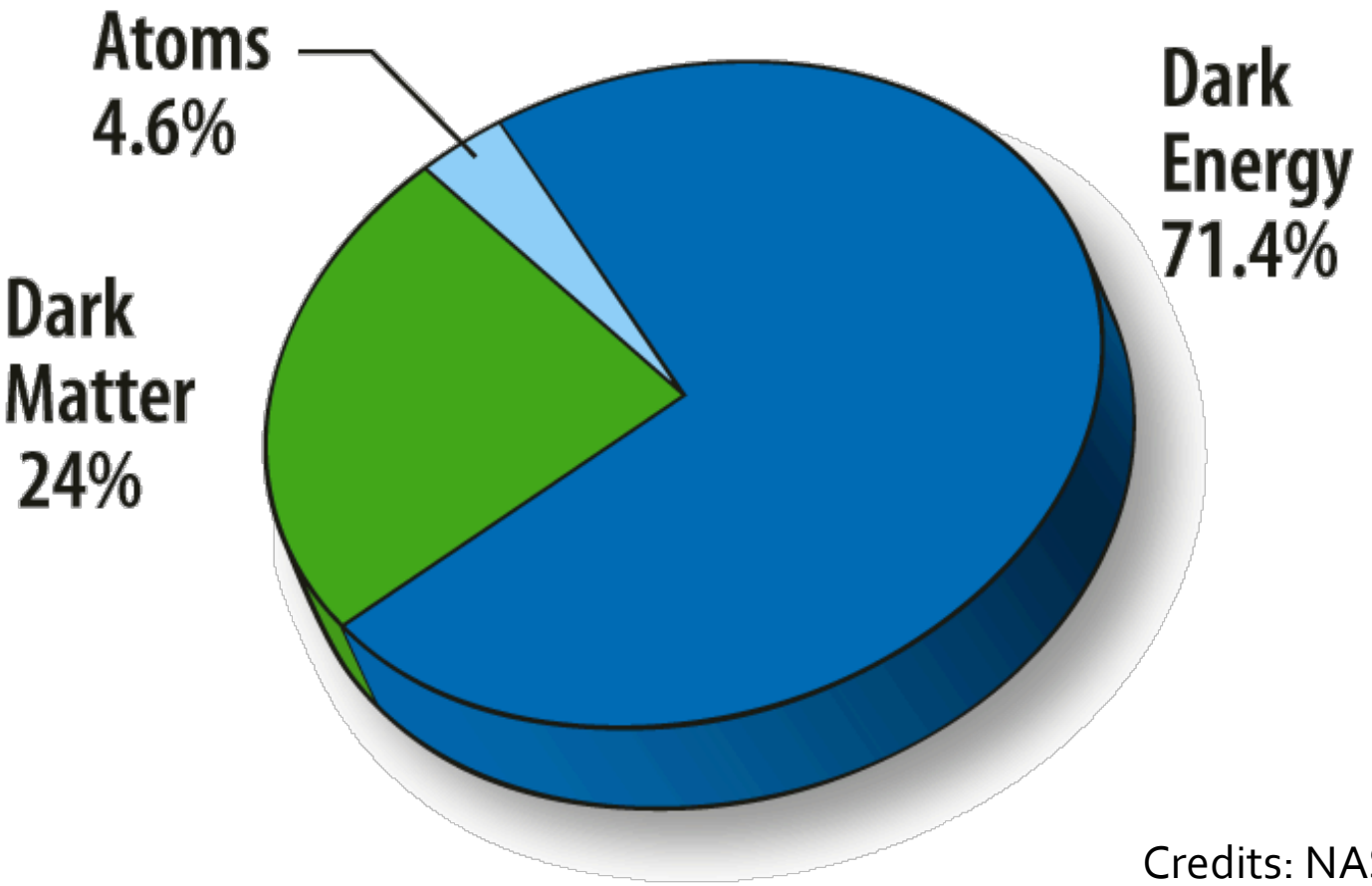
Pierre Gorel for the DEAP collaboration

UNIVERSITY OF ALBERTA

13-02-19

Lake Louise Winter Institute

WMAP 9 years results

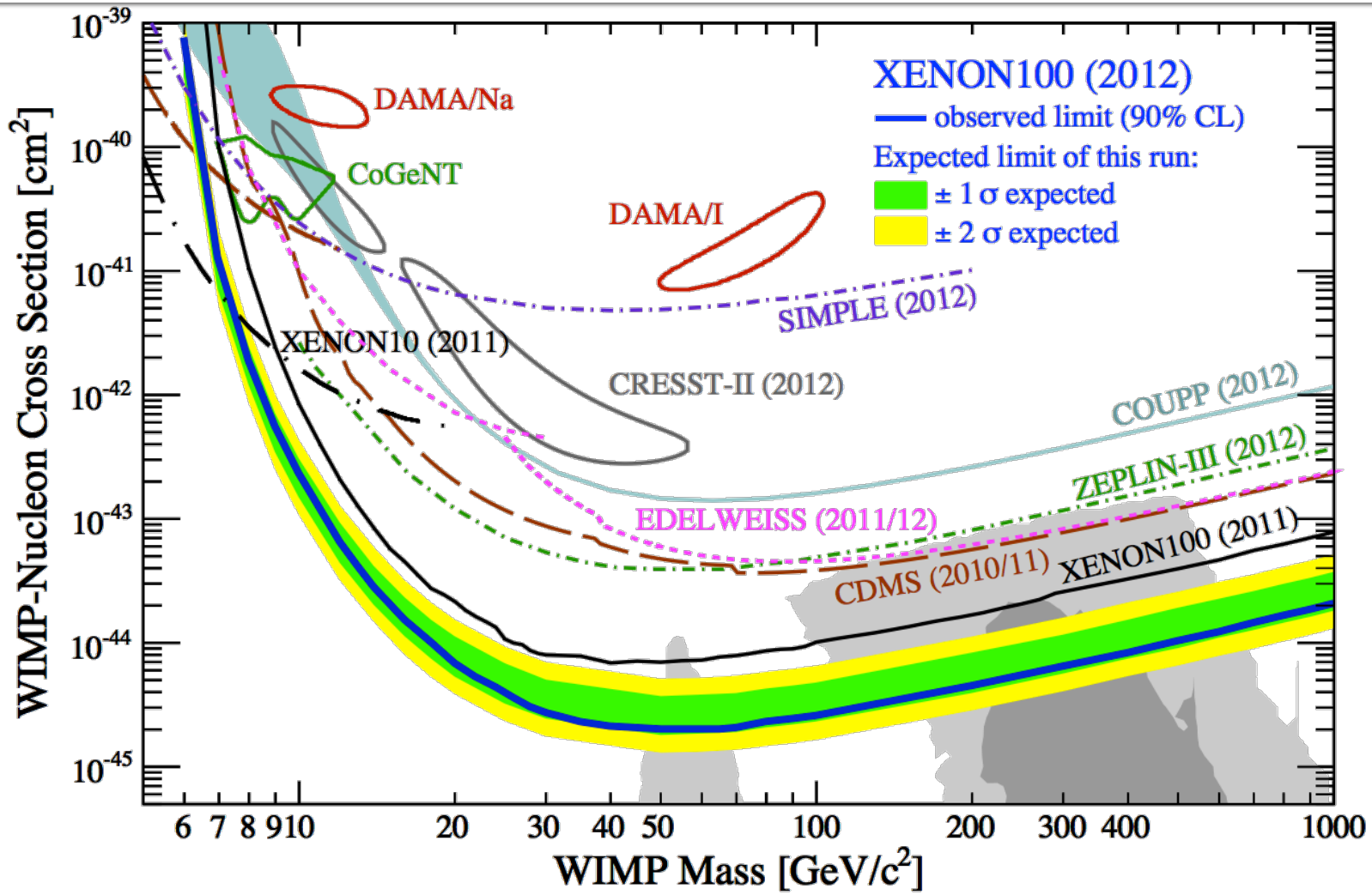


Credits: NASA/WMAP

Dark Matter Candidates

- Axions
- Sterile neutrinos
- Hidden sector dark matter
- …
- Weakly Interacting Massive Particle
  - Arise from favored Standard Model extensions
  - Possible to detect (elastic scattering on nucleus)
  - Potentially account for all the Dark Matter

WIMP sensitivity limits (spin-independent)



Phys. Rev. Lett. 109, 181301 (2012)

Liquid Argon scintillation and Pulse Shape Discrimination

Liquid Argon scintillation

$$Ar_2^* \rightarrow Ar + Ar + photon$$

Singlet Triplet

LArgon scintillation	Singlet (~7ns)	Triplet (~1.6μs)
Electron	23%	67%
Nucleus	75%	25%

- Different lifetime
- Populated according to Linear Energy Transfer

➢ Pulse shape discrimination (PSD)

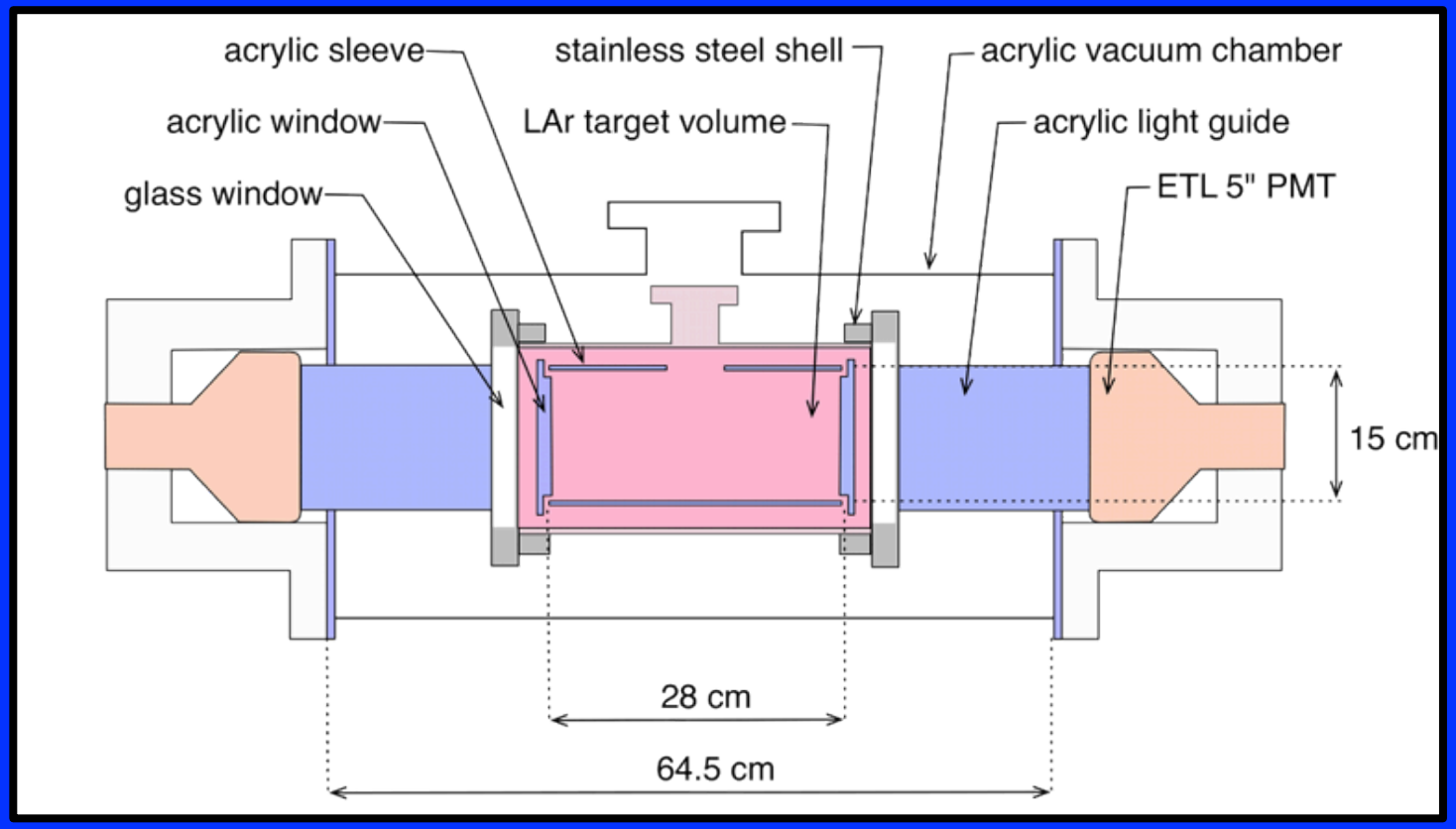
- Scintillator transparent at the emitted λ (128nm for Argon)

Results from DEAP-1

Test bed: DEAP-1 (7kg)

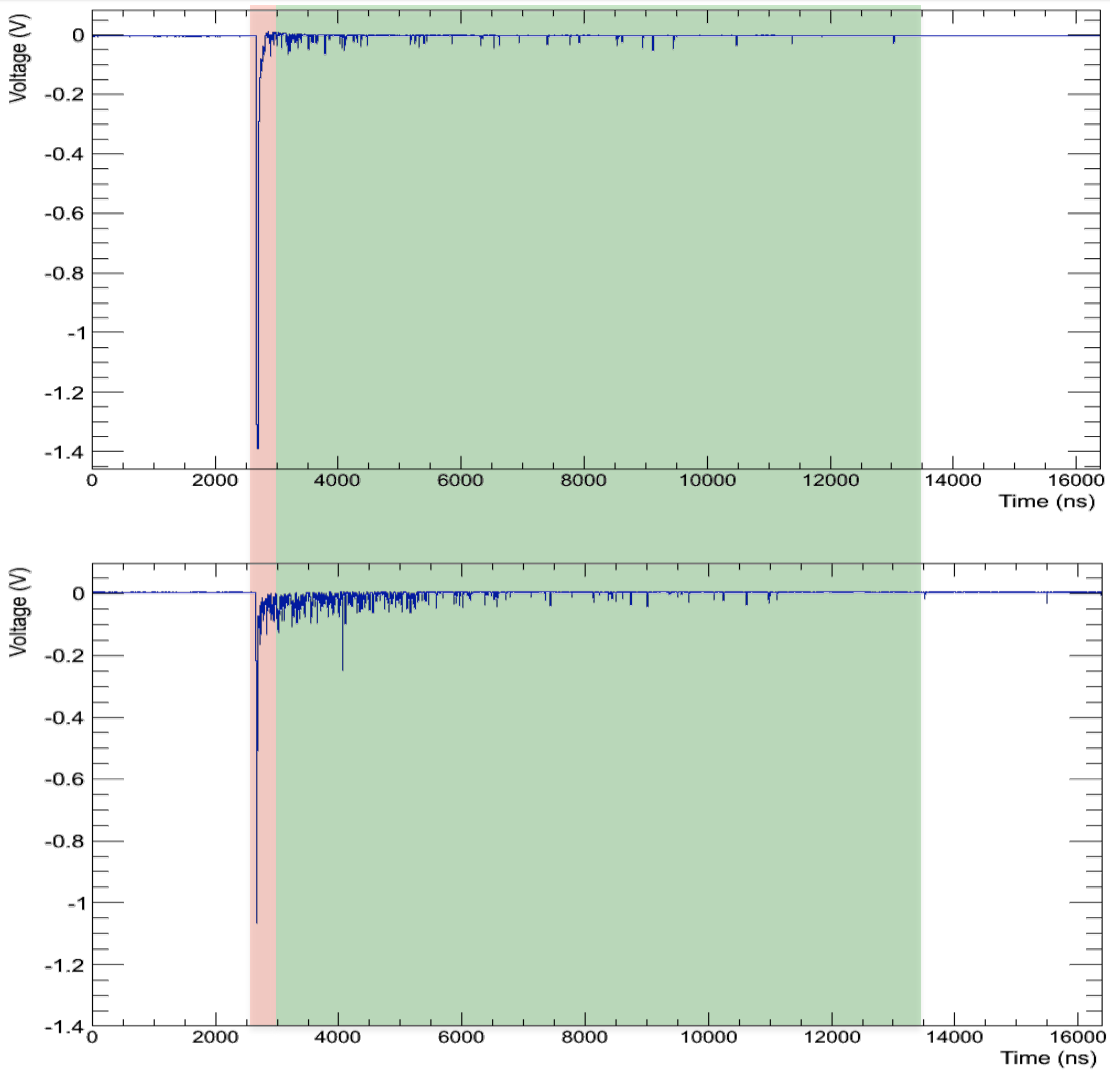
- Pulse Shape Discrimination
- Backgrounds
- Simulation tuning
- Acquisition test bed
- LAr handling

Test bed: DEAP-1 (7kg)



60 cm thick Water shield

PSD with DEAP-1 : PMT signal

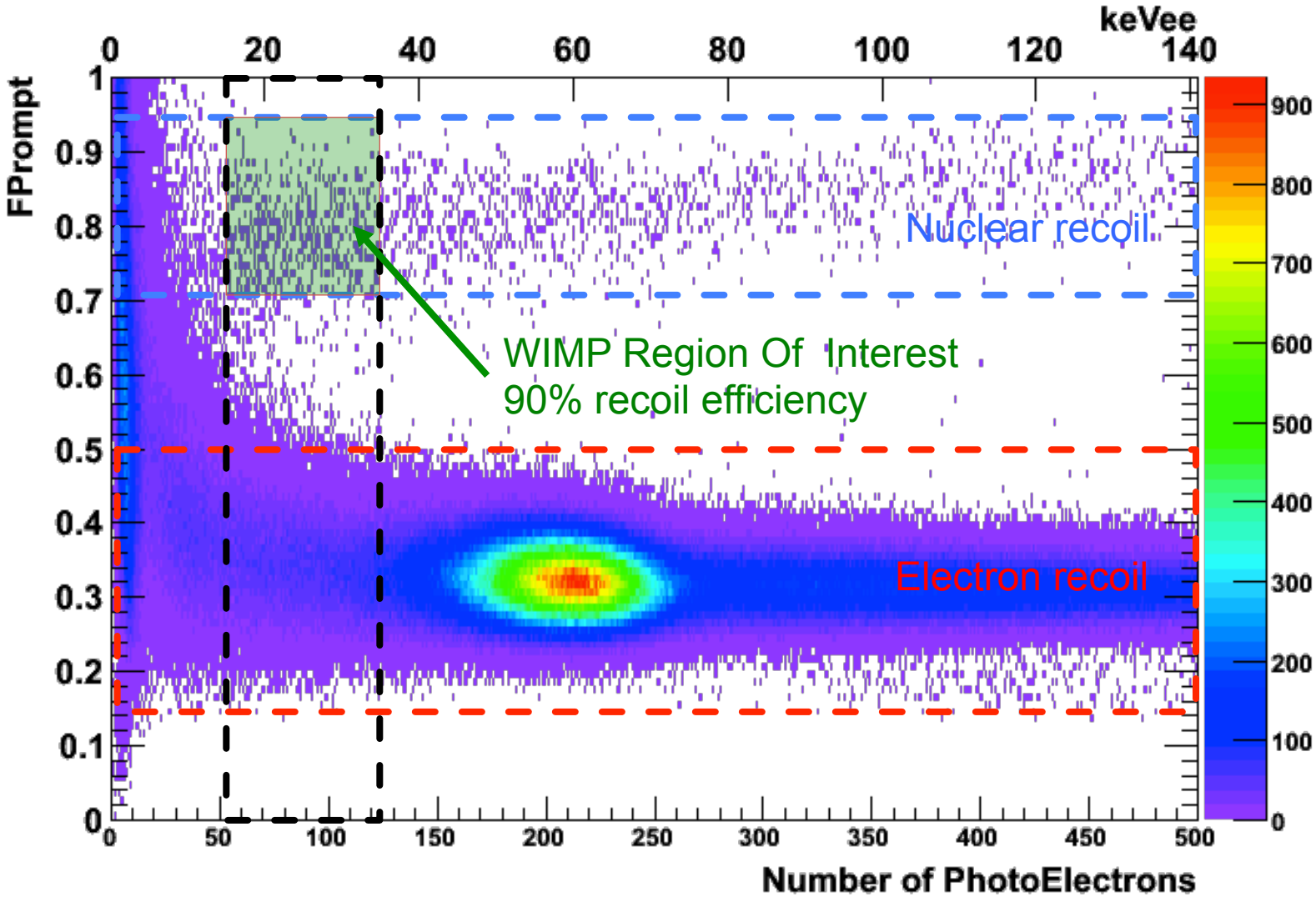


$$\text{FPrompt} = \frac{N_{prompt}}{N_{prompt} + N_{Late}}$$

Prompt : 0-150ns

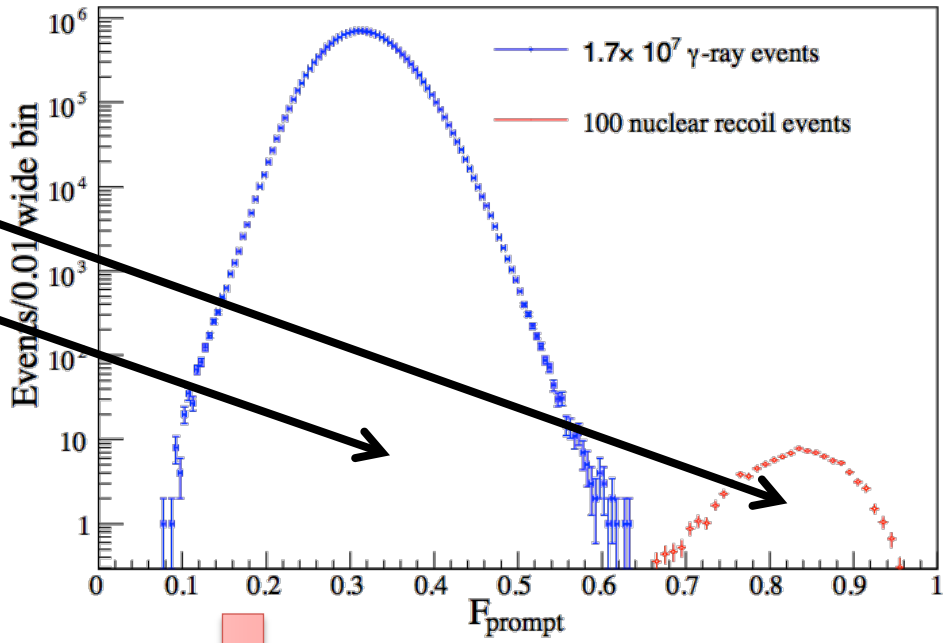
Late: 150ns-10μs

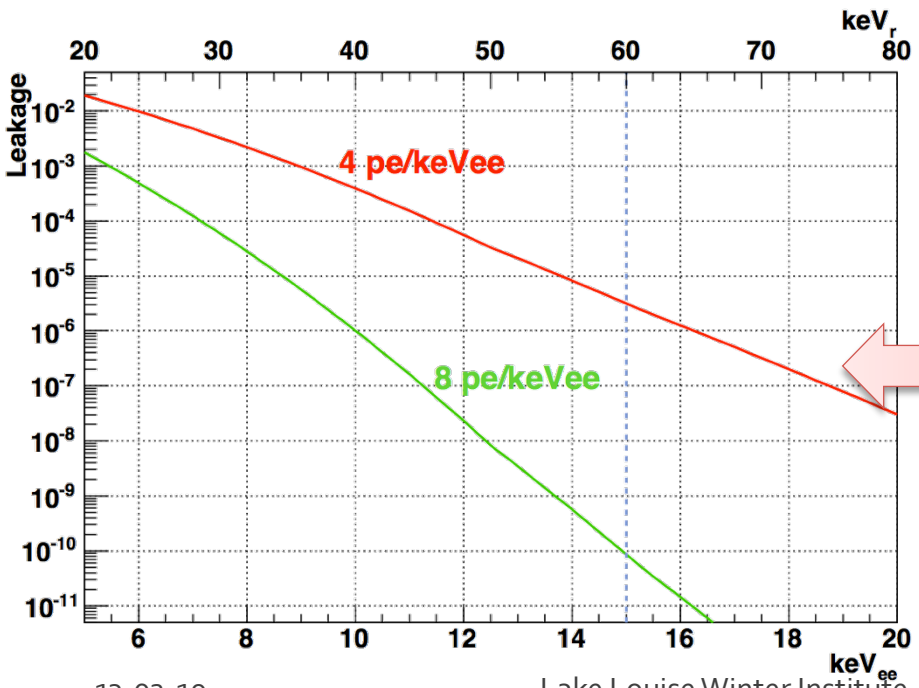
Discrimination γ-β/recoil (DEAP-1)



PSD evaluation

- High FPrompt :
  AmBe source
- Low FPrompt :
  ^{22}Na tagged source





Simple statistical model

Model predicts 10^{-10} at 60keV$_r$ with 8 PE/keV

arXiv/1203.0604

Backgrounds in DEAP

- γ/β
  - ^{39}Ar decay
  - Rock

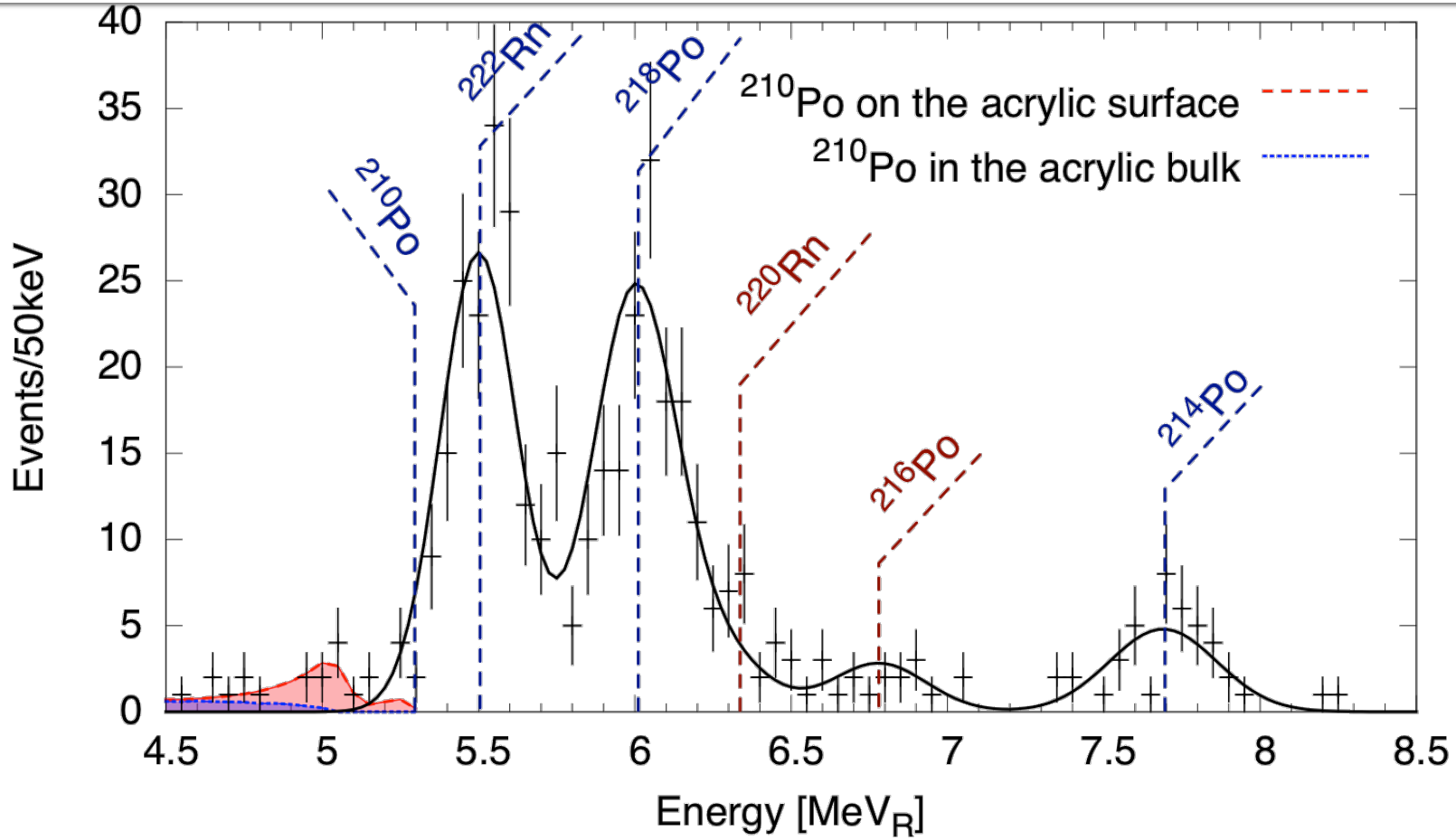
  } Main contribution → discriminated by PSD

- Neutrons
  - Muon spallation
  - (α,n) and fission

  } Shielding + Material selection

- Alpha
  - ^{238}U and ^{232}Th decay chain (^{222}Rn and ^{220}Rn)

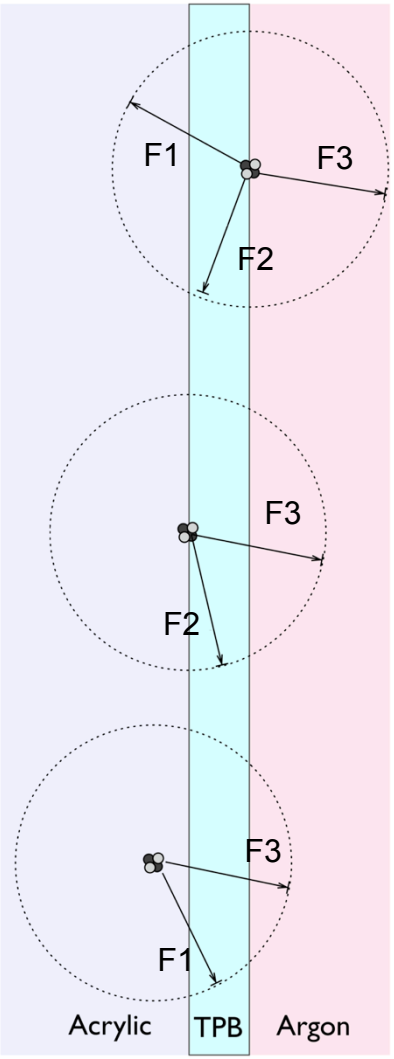
High energy alphas in DEAP-1

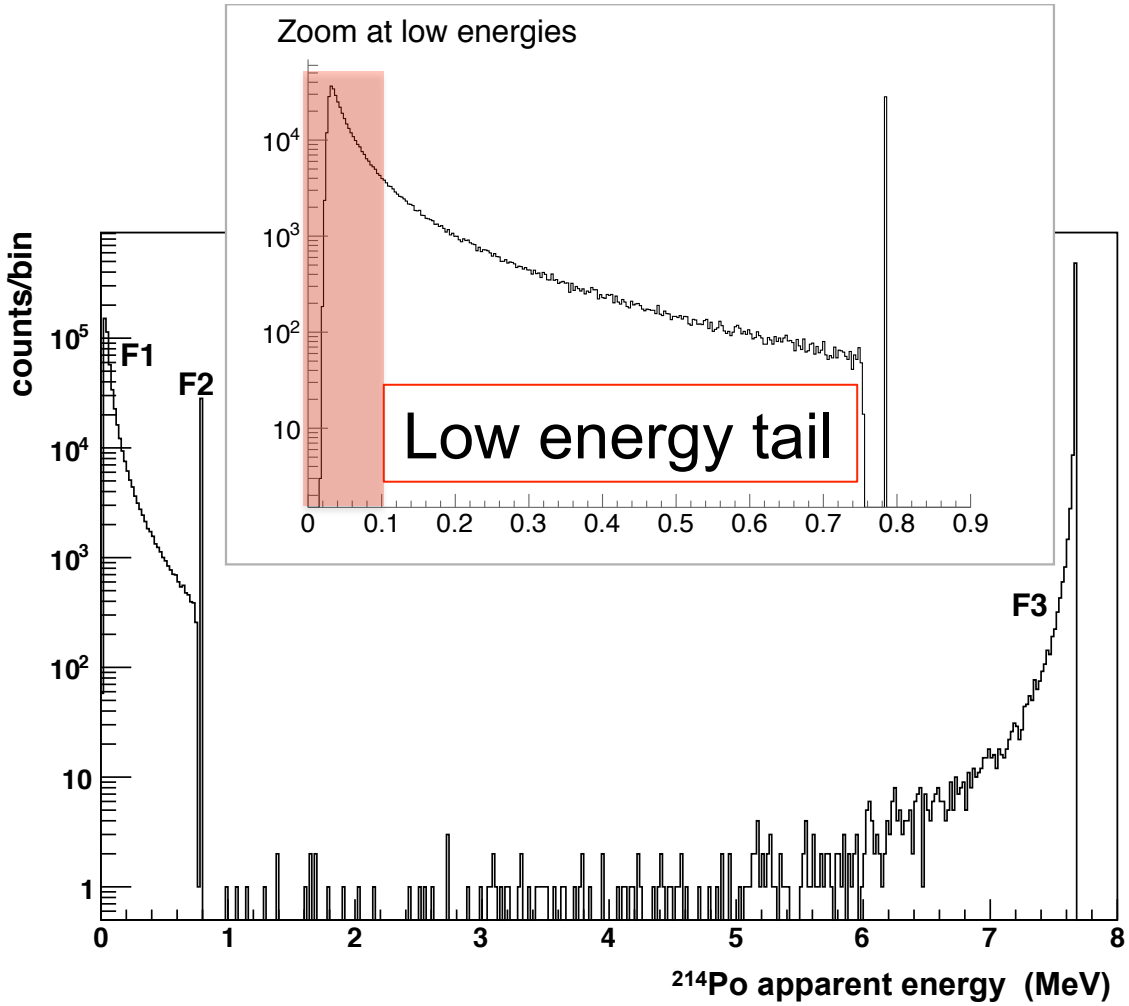


α contamination besides Rn daughters < 3.6×10^{-5}Hz

arXiv:1211.0909

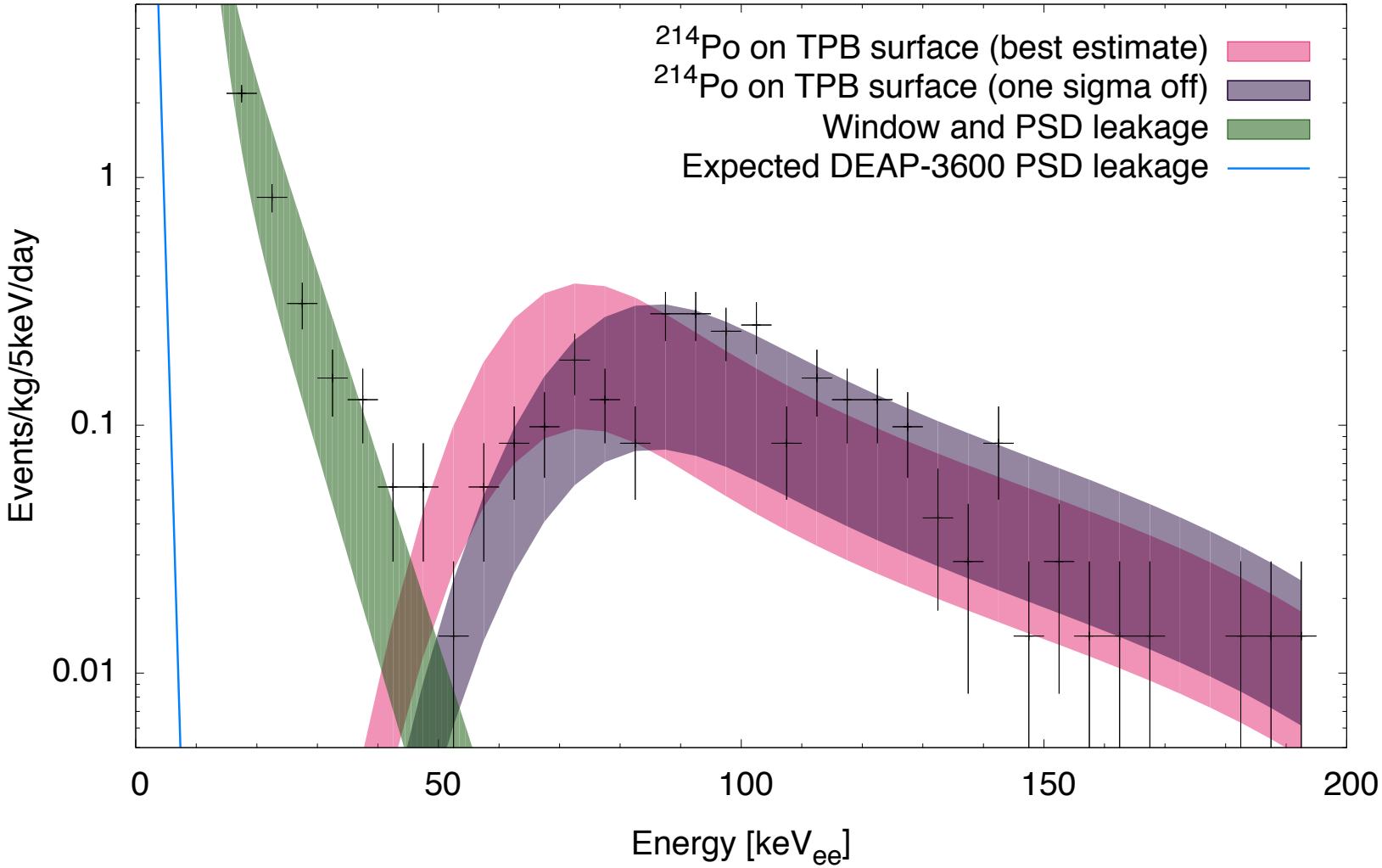
Particular case of the surface α's





arXiv:1211.0909

Background at low energy

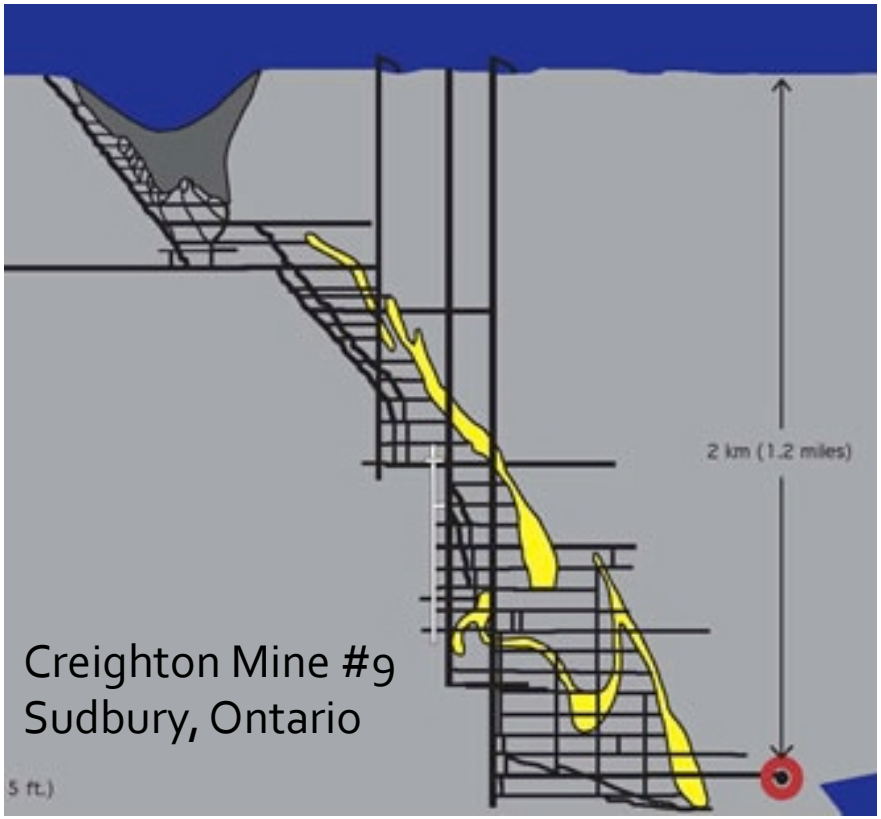


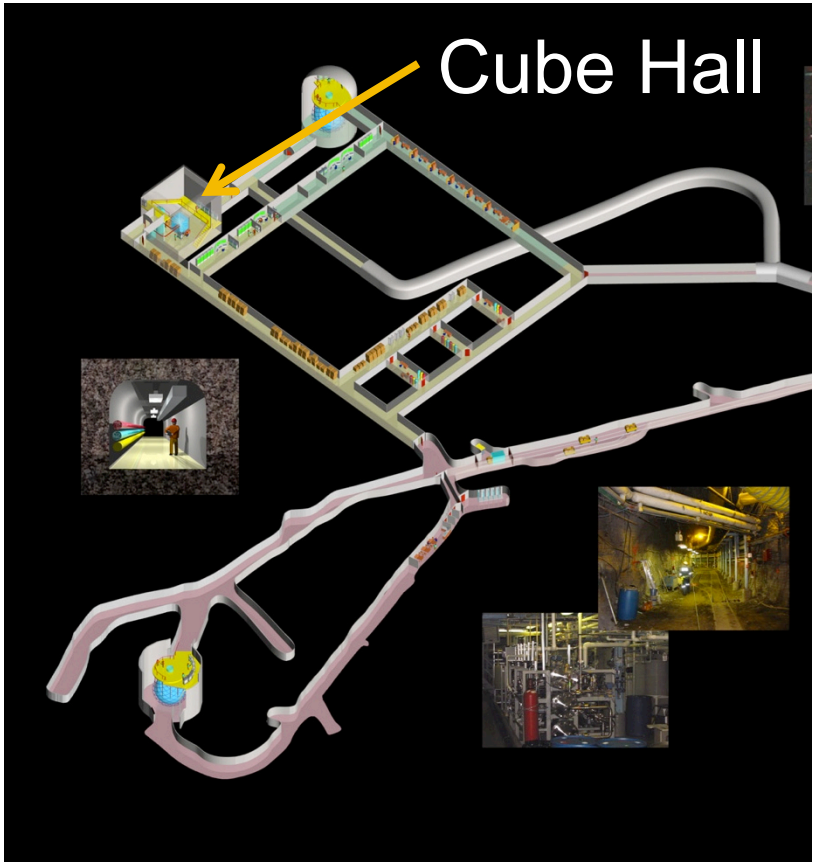
arXiv:1211.0909

Status of DEAP-3600

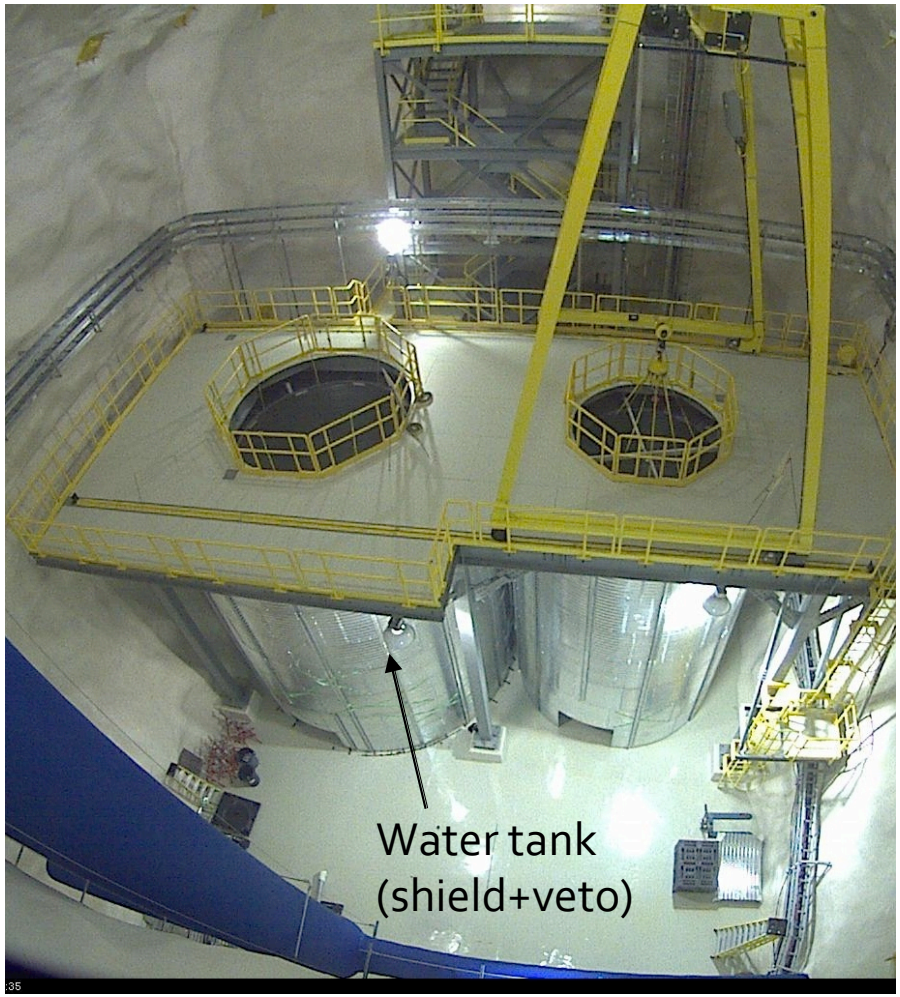
DEAP-3600 @ SNOLAB

- 2km underground→0.29 muons /m^2/day
- 5000m^2 of clean space

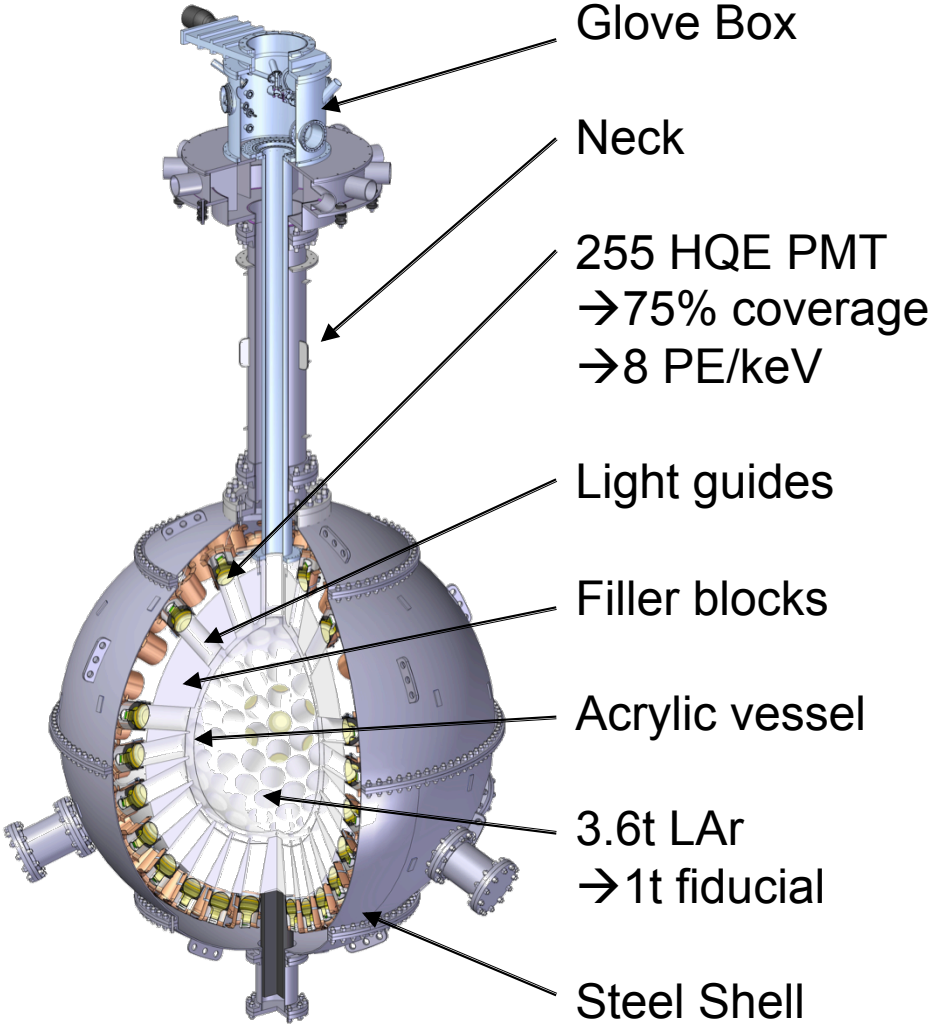




DEAP3600: single phase LAr



Courtesy: SNOLAB



Courtesy: Koby Dering

Background targets

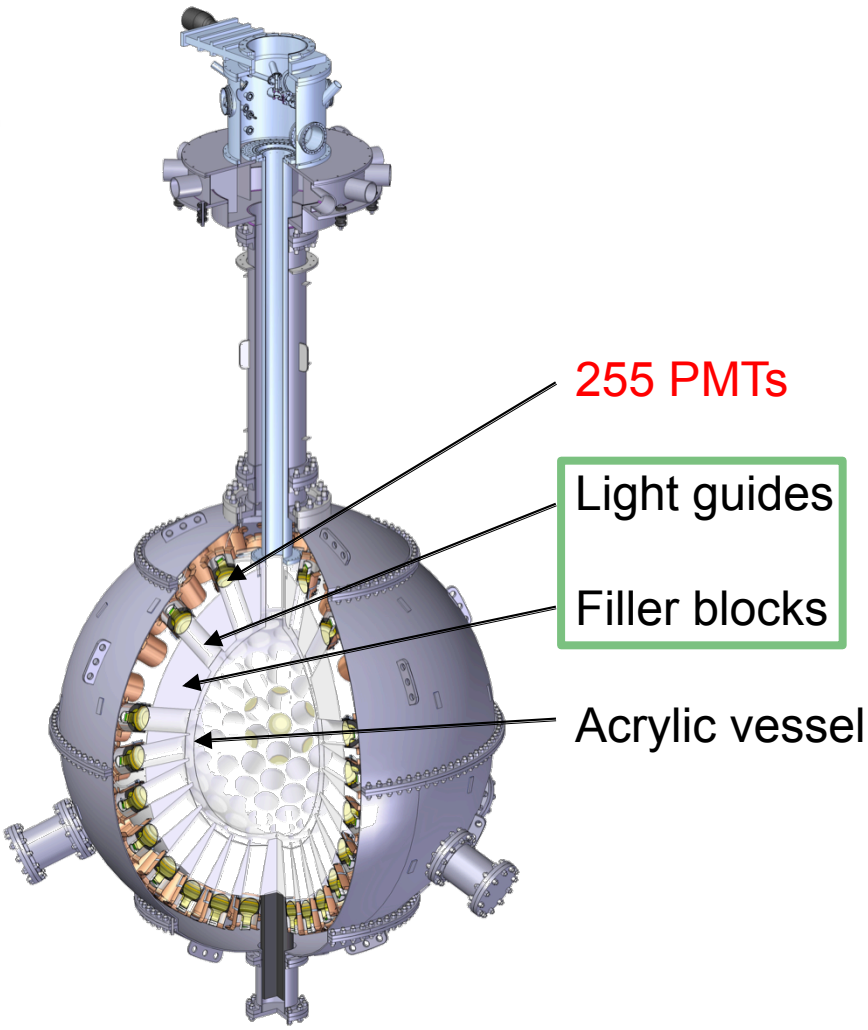
Background	Target
Radon in argon	< 1.4 nBq/kg
Surface α's (tolerance using conservative pos. resolution)	< 0.2 mBq/m^2
Surface α's (tolerance using ML position resolution)	< 100 mBq/m^2
Neutrons	< 2 pBq/kg
β/γ, dominated by ^{39}Ar	< 2 pBq/kg
Total Backgrounds (3 Tonne-year in fiducial volume and Region of Interest)	**< 0.6 events**

Radiopurity Requirements: Neutron Backgrounds

- Intensive simulation program:
  - Neutron production, detection and shielding efficiency verified with DEAP-1
  - Shield geometry and thicknesses determined by simulations
- U/Th related backgrounds:
  - Active assay program (U/Th/Pb/Rn emanation)
  - Strict control of Radon exposure to detector materials

Review the Neutron backgrounds

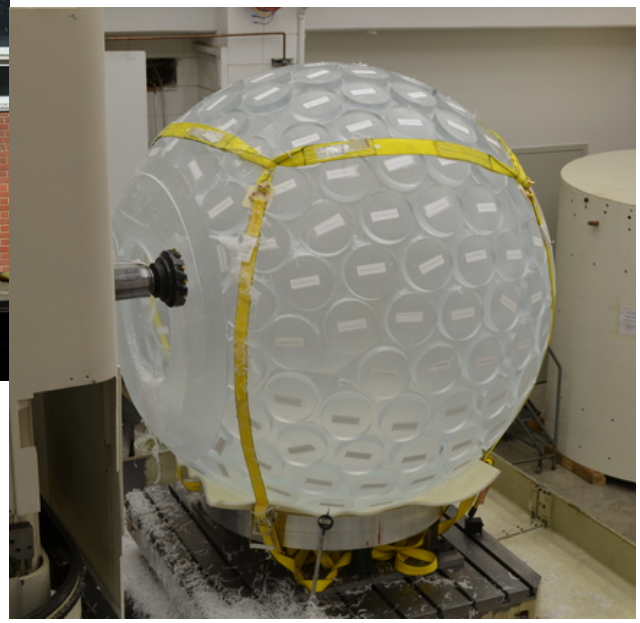
(In 3 years)	# of neutrons (produced)	Events in ROI
Acrylic vessel	<44 (Ge γ-assay)	<0.096
Light guides	<127 (Ge γ-assay)	<0.015
Filler blocks	<173 (Ge γ-assay)	<0.034
PMTs	2.6×10^5	0.140
PMT mounts	7565	0. 010
Rn emanation	<44	<0.081
Rn deposition (3 months construction)	38	0.010
Other sources		0.04
Total	**$<2.7 \times 10^5$**	**<0.35**



Courtesy: Koby Dering

Acrylic Vessel (AV) construction

Thermoforming

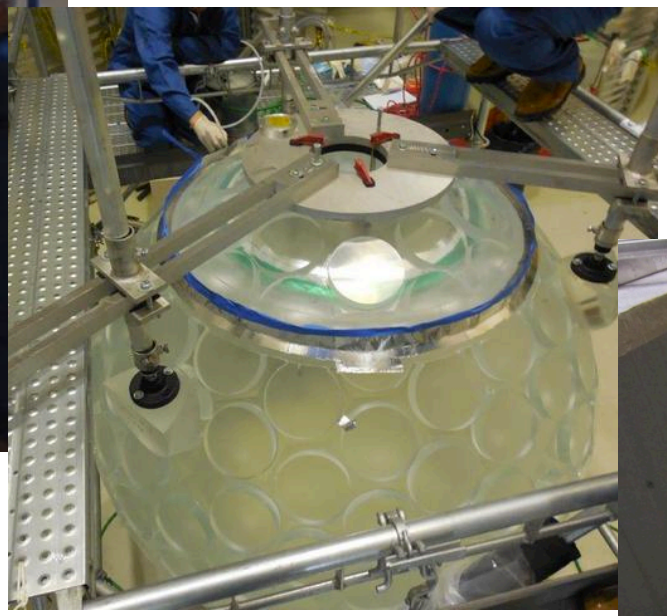


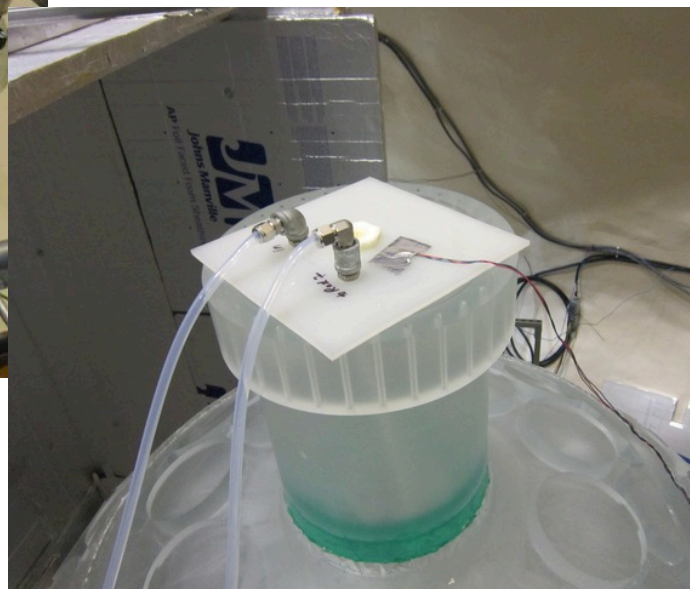
Machining (University of Alberta)

Acrylic Vessel construction (con't)

Shipped underground

Collar and neck bonded





Annealing with a Reduce Radon Air

Steel shell

Electropolished inside
(Rn emanation)

Welded underground

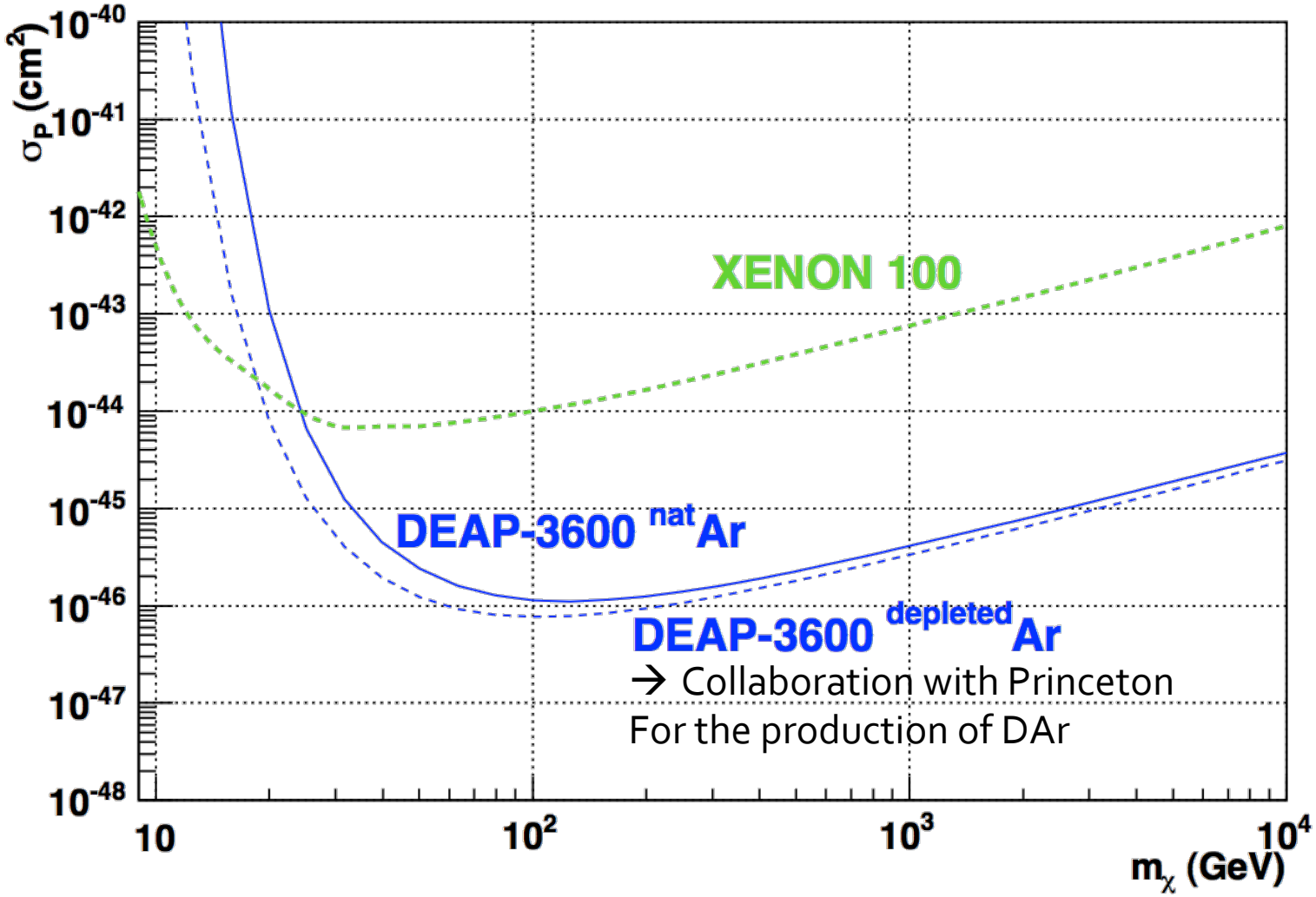
Coming in the next months…

- Bonding of the light guides
- Installation of the Photomultipliers
- Installation of the filler blocks
- Cabling
- Setup of the steel shell
- Resurfacing of the inside of the AV
- TPB evaporation
- Setup of the neck (thermosiphon)
- Hook up of the acquisition and tests

Extensive calibration program

Calibration Tools	Optical Response	Energy Reconstruction	Radius Reconstruction	Detector response and stability vs time
LED, lasers, in-situ single PE tails	✔	✔		✔
Gamma sources (tagged ^{22}Na, ^{60}Co, ^{137}Cs)		✔	✔	✔
Neutron sources (DD generator, AmBe)		✔	✔	✔
In-situ radioactivity (^{39}Ar, U, Th gammas)	✔	✔	✔	✔

Expected Sensitivities



→ Collaboration with Princeton
For the production of DAr

arXiv:1203.0604v1

Summary

- DEAP-1 run during 4 years, gathering much experience on the PSD and backgrounds
- DEAP 3600 will reach a sensitivity of $10^{-46}cm^2$ for a WIMP mass of 100 GeV
- Extensive radiopurity control program
- Detector being built as we speak. The commissioning should start by the end of the year.

Collaboration

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