WNPC 2012

Dark Matter Detection with DEAP 3600

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The DEAP Collaboration

The Mystery of Dark Matter

- Hints from Observational Astronomy, e.g.: rotation curves, gravitational lensing, orbital speeds of galaxies in cluster environments, anisotropies of the CMB ...
- WMAP: A quarter of the energy density of the universe is made of Dark Matter
- Does not interact via the electromagnetic or strong forces, may interact via the weak force

How To Detect WIMPs

- Create DM particles in accelerators on Earth (LHC)
- Indirect detection: products of DM interactions (Pamela, Fermi)
- Detect DM recoil interactions using sensitive detectors

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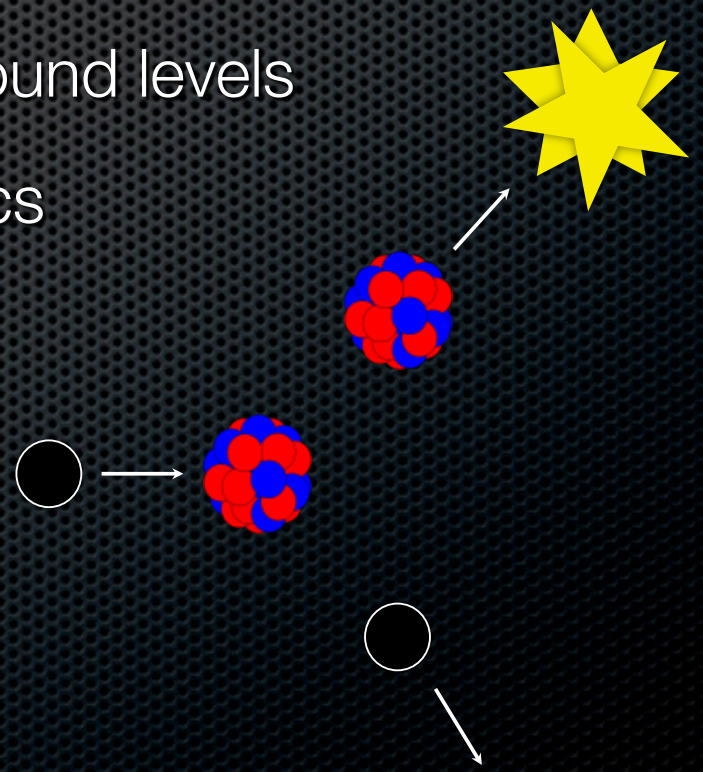
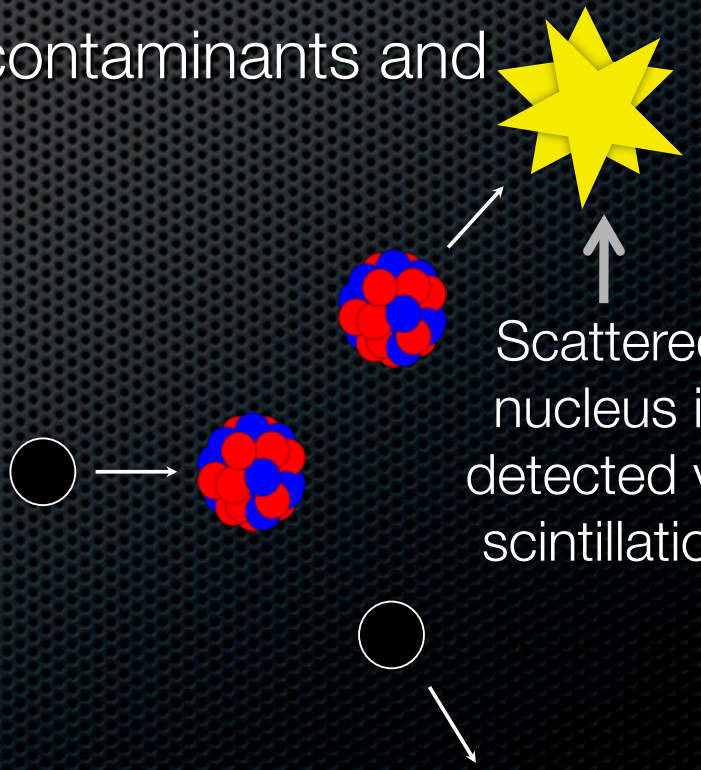
How To Detect WIMPs

- Detect DM recoil interactions using sensitive detectors
- Elastic scattering of DM particles off of target material
- Detectors must have low background levels
- Detectors must have high statistics



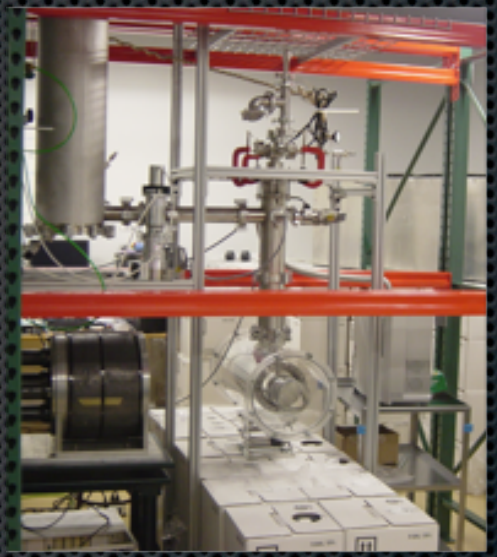
How To Detect WIMPs

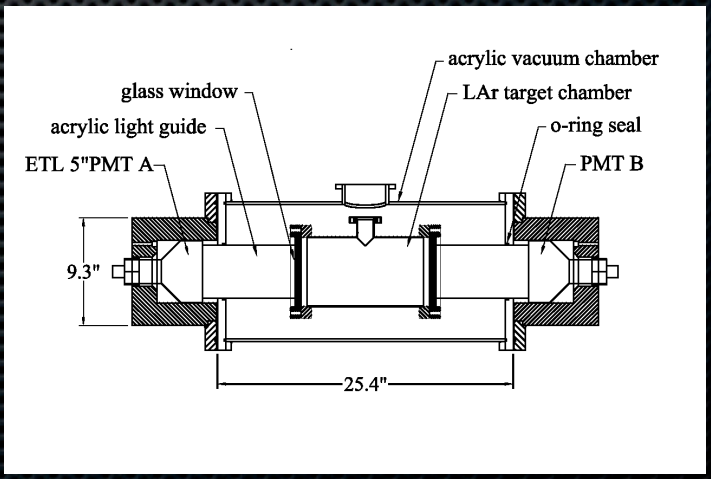
- Elastic scattering of DM particles off of target material
- Argon used as target material in DEAP
- Simple to purify from radioactive contaminants and light absorbers
- High scintillation yield
- Large target masses possible
- Inexpensive



DEAP-1 Detector

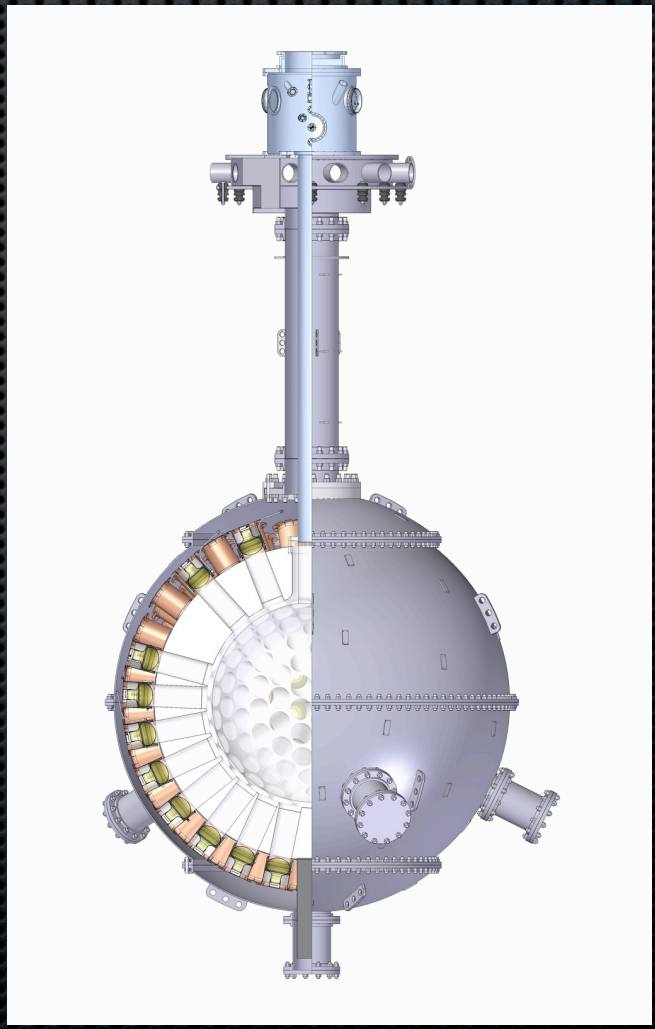
- 7 kg detector, two PMTs
- Development of liquid argon and background reduction methods





DEAP-3600 Detector

- 3600 kg target (1000 kg fiducial mass)
- sealed, ultra-clean acrylic vessel
- 255 8-inch PMTs (75% coverage)



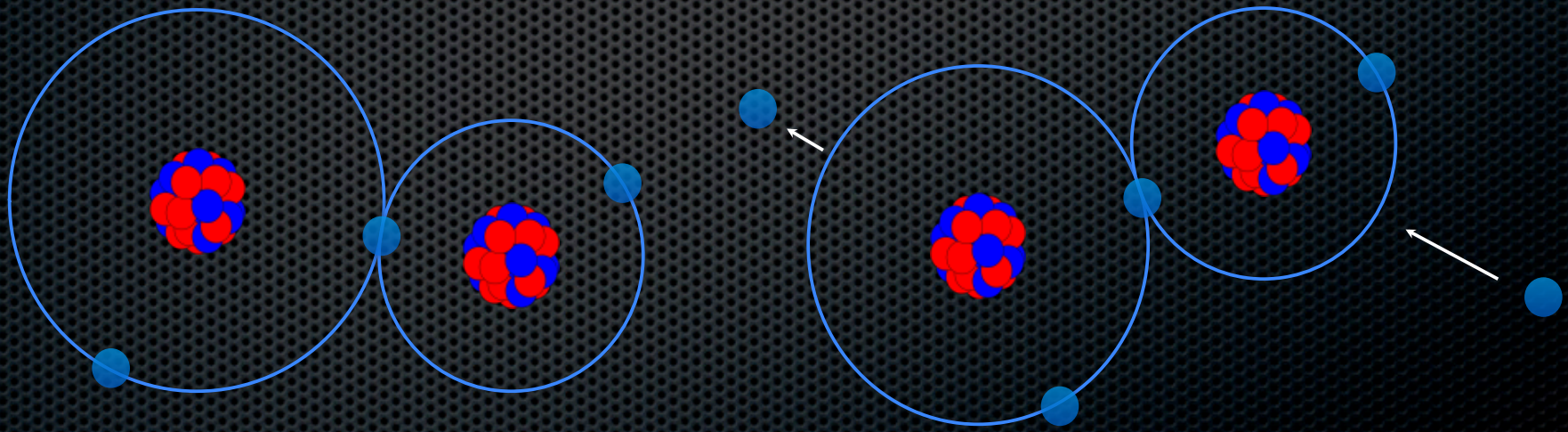
Backgrounds

Expected background: ~0.1/tonne/year

- β / γ **events**
  - dominated by ^{39}Ar (1 Bq/kg)
  - Powerful pulse-shape discrimination technique
  - Depletion of argon to reduce ^{39}Ar population by at least 25

Pulse Shape Discrimination

- Single phase: PSD based on scintillation light only
- Why this works: excited diatomic molecules (excimers) produced in argon form in two ways:



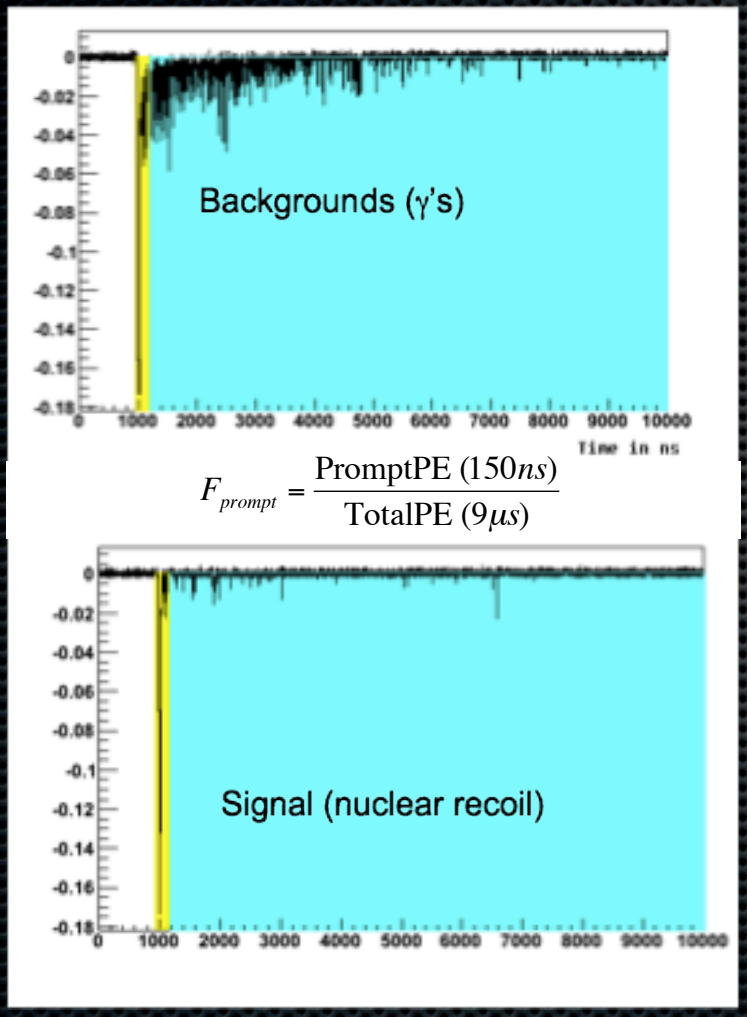
excited atom combines with another atom

ionized atom combines with another atom, *recombines with electron*

Pulse Shape Discrimination

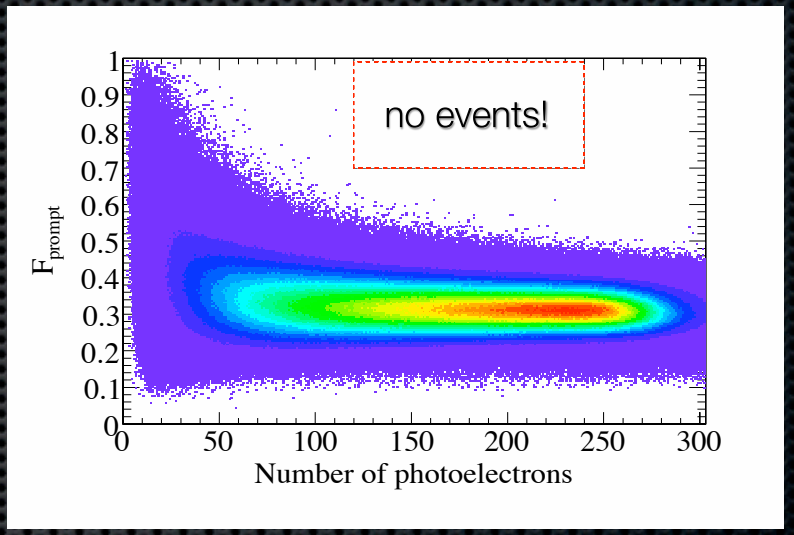
- Single phase: PSD based on scintillation light only
- Excimer has a singlet (short-lived) state and a triplet (long-lived) state
  - *Gamma Events*: free electron density is low so excimers have an opportunity to interact with bound electrons where [singlet state] + e^- → [triplet state] + e^-
  - *Recoil events*: free electron density is higher so there is less chance that more triplet states are formed

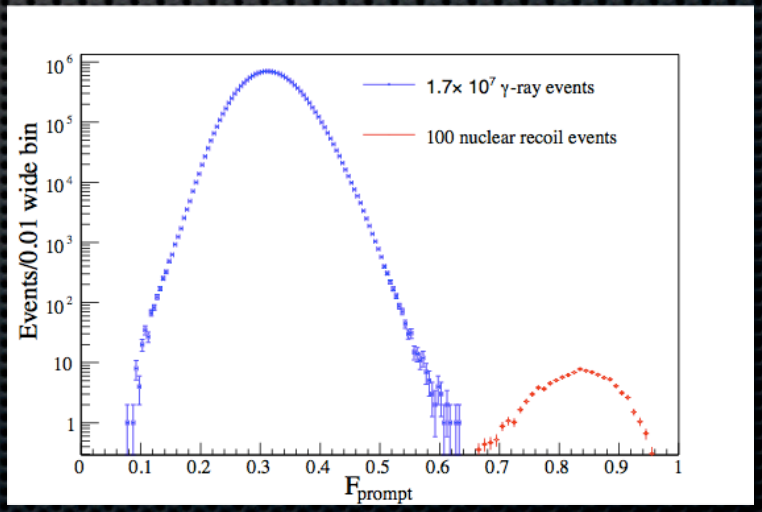
Pulse Shape Discrimination



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

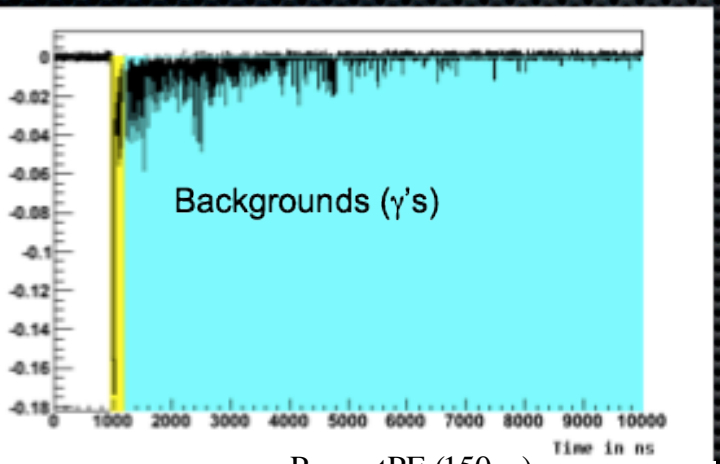
No gamma-ray events seen in nuclear recoil region





triple-coincidence gamma-ray events

Pulse Shape Discrimination



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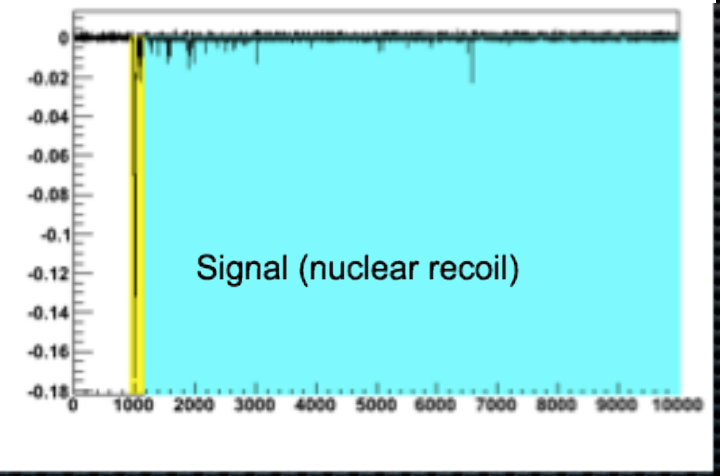

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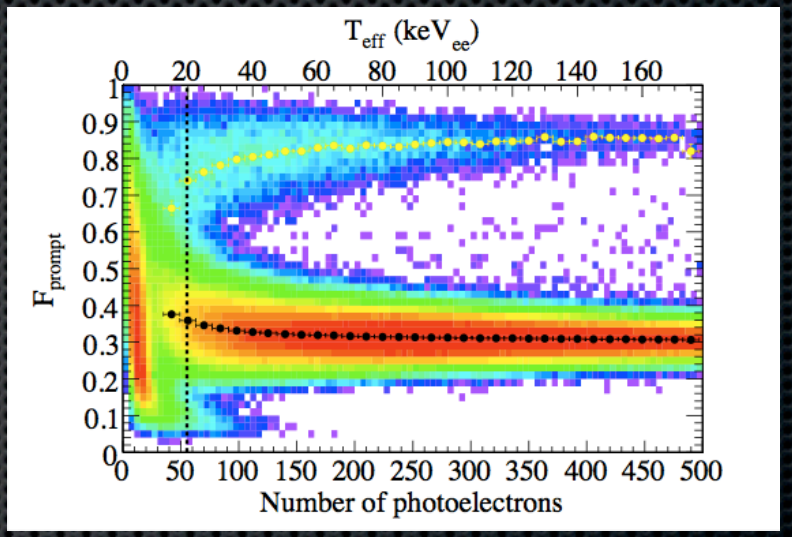
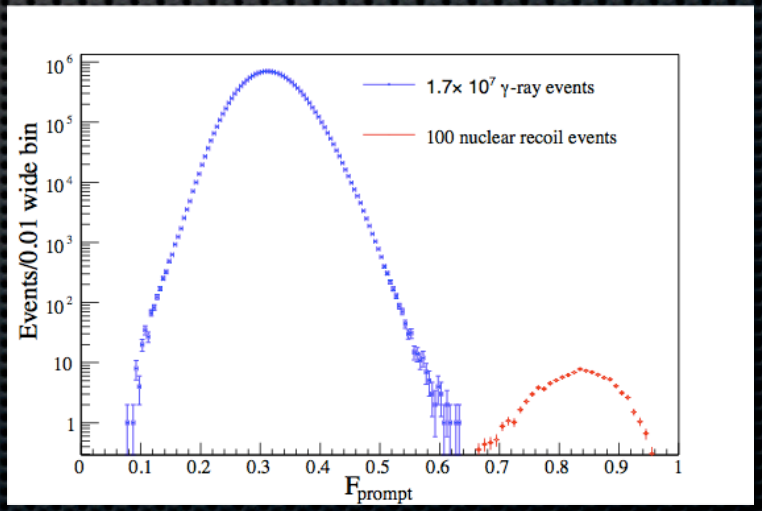




neutron and gamma ray events from an Am-Be calibration source

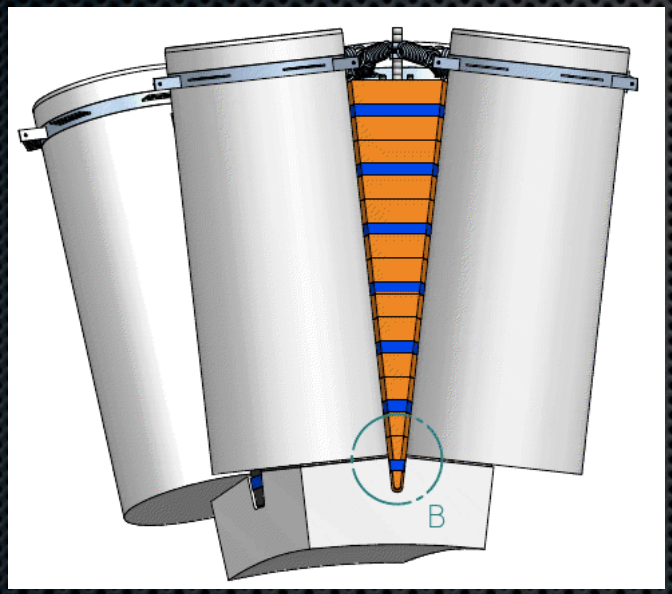
Backgrounds

Expected background: ~0.1/tonne/year

- **Neutron / Alpha events**
  - (α, n) from surrounding rock
  - (α, n) from PMTs and hardware
  - μ-induced

Neutron Shielding

- 8.5 m diameter water tank for external neutrons



- Light guides and filler blocks provide shielding from hardware neutrons
- Shielding from depth of experiment (6000 m water equivalent)

Backgrounds

Expected background: ~0.1/tonne/year

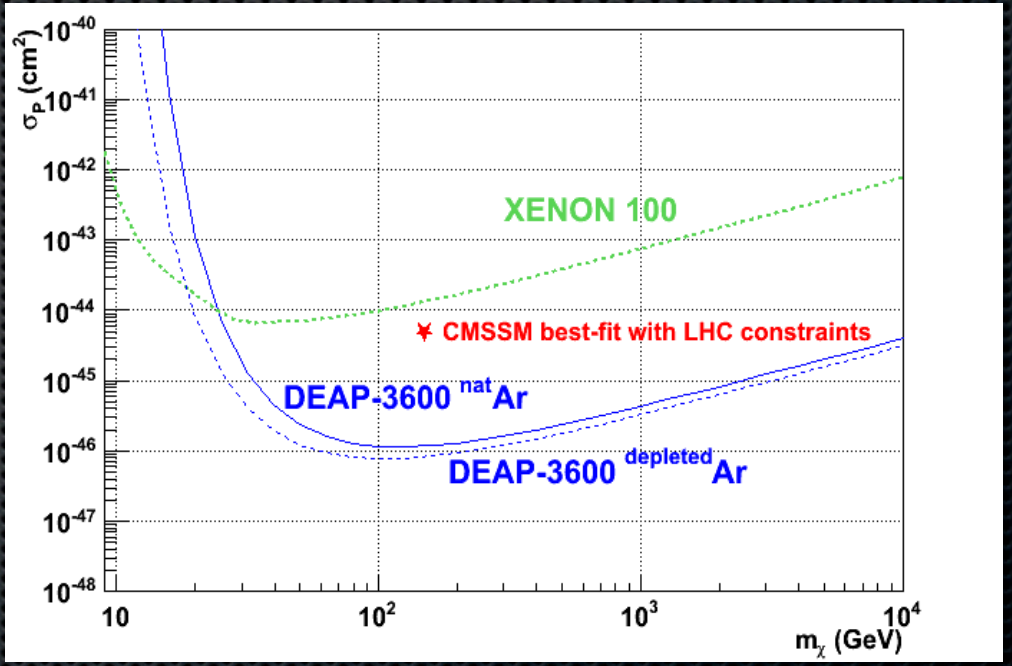
- **Surface Events**
  - Radon long-lived daughter ^{210}Pb (22 yr half life)
  - Acrylic surfaces exposed to radon during construction

Mitigation of Impurities

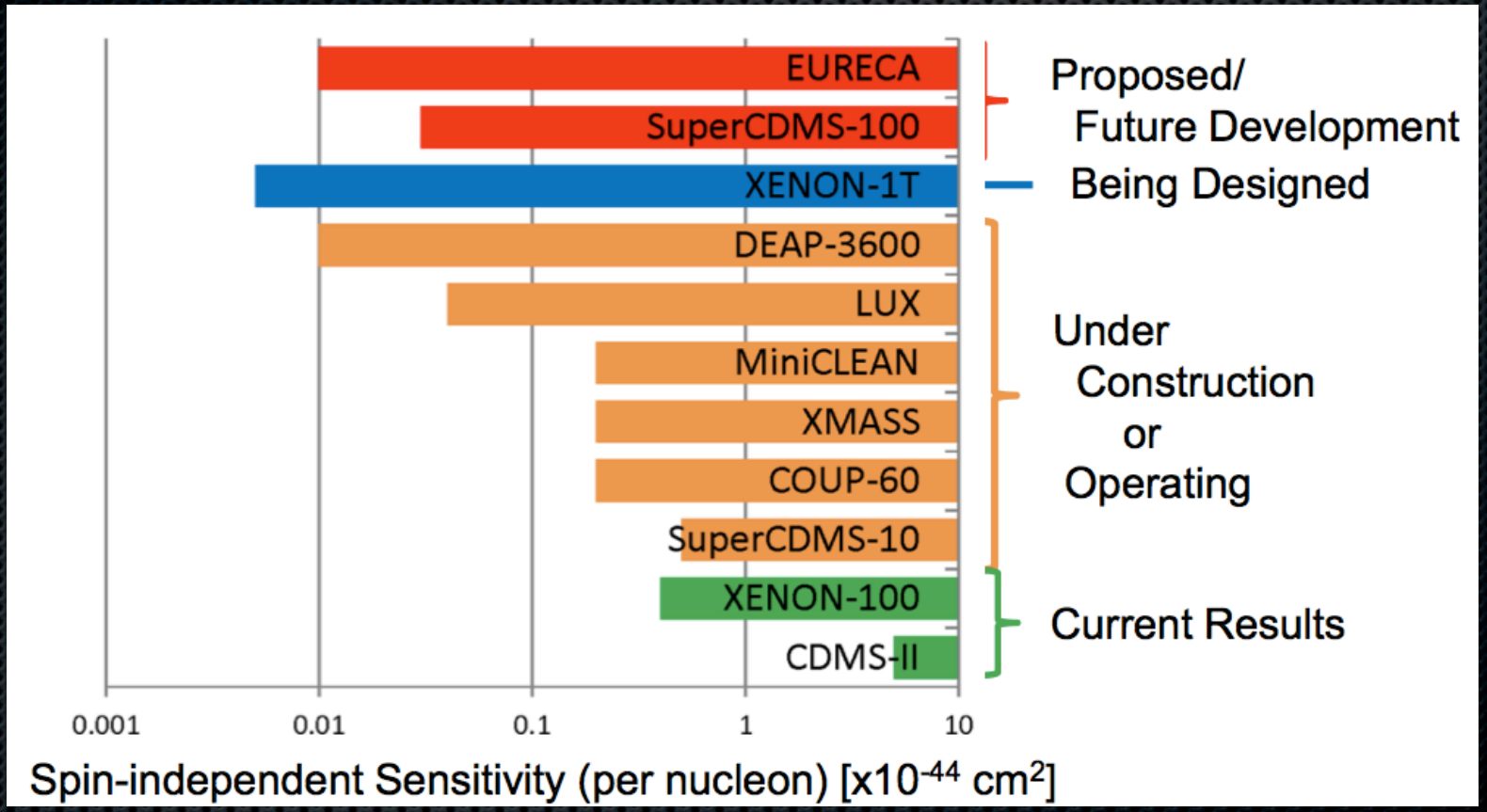
- Mechanical resurfacer to clean surfaces in situ
  - Debris flushed away with ultrapure water
- Careful limits on radon exposure and material selection
- Careful choice of fiducial volume, vertex reconstruction

Comparison to other high-sensitivity searches

- 1000 kg 3-year run allows for 10^{-46} cm^2 (SI) sensitivity, 60 keV$_r$ threshold, natural argon

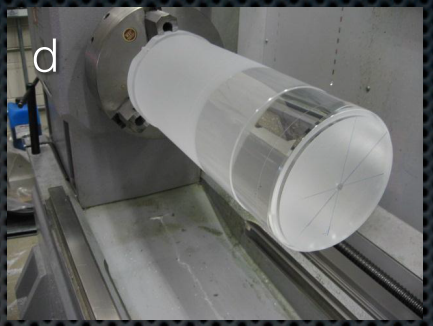


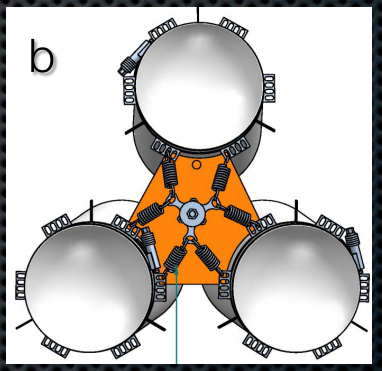
Comparison to other high-sensitivity searches



- DEAP 3600 well-positioned for leading sensitivity

Current Status





(a) Resurfacer: Assembled, commissioning started at Queen's

(b) Filler Blocks: design is finalized

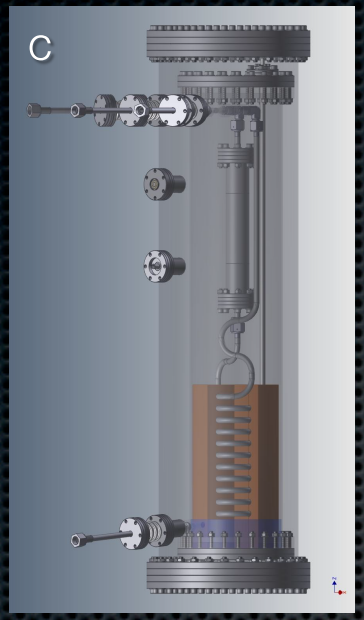
(c) Acrylic Vessel: Thermoforming panels at RPT Colorado

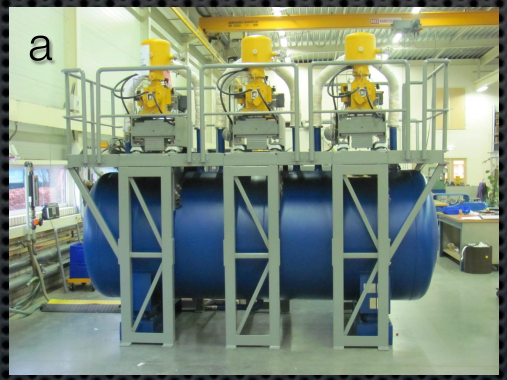
(d) Light Guides: machining started at TRIUMF

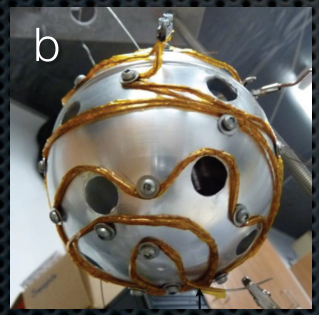
DEAP-3600 Acrylic Vessel Panel in Grand Junction, Colorado

Operations to commence in 2013

Current Status







(a) Cryocooler and LN2 dewar system: ready for acceptance testing at Stirling Cryogenics

(b) TPB deposition source: successful operation of large-scale TPB vacuum deposition source

(c) Purification System: demonstrated that welds and pipes can be cleaned through citric acid passivation

(d) 20" vessel: cool-down testing

Operations to commence in 2013

DEAP Collaboration

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