The DEAP Search For Dark Matter

IOP HEPP APP 2014

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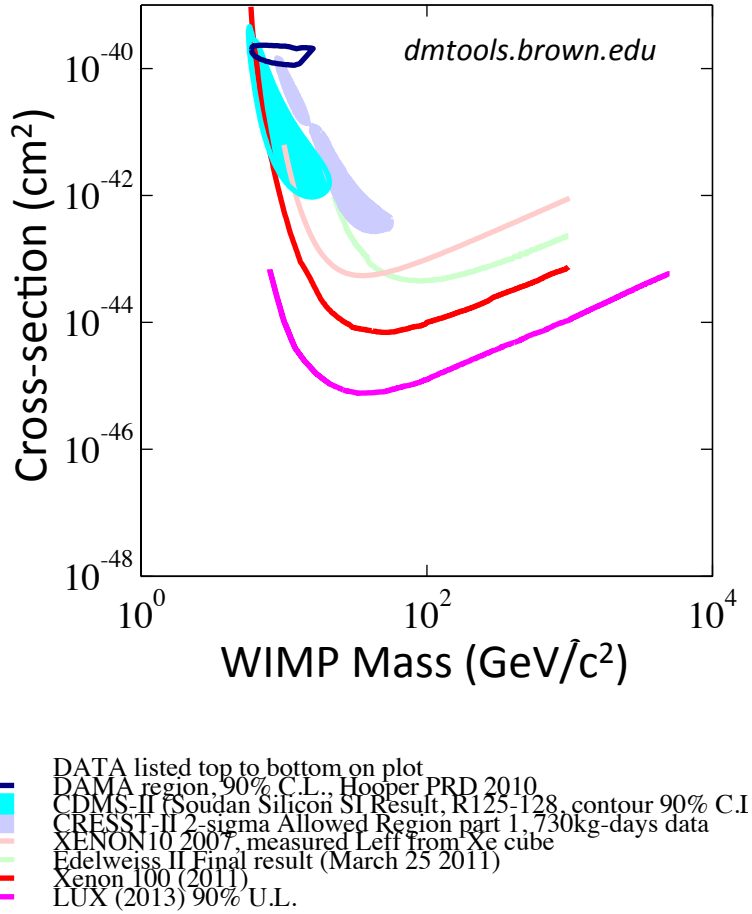
On Behalf of the DEAP-3600 Collaboration

Outline

- The DEAP Program
- Calibration Systems & first ex - situ data
- Construction Status
- Outlook

Current Dark Matter Picture

- Dark matter proposed to explain astronomical observations
- Planck* measurement recently increased amount of dark matter in the Universe to 27%!
- Weakly interacting massive particles (WIMPs) are a leading candidate
- Require very low and well understood backgrounds



*arXiv:1303.5076

What is DEAP-3600?

- **D**ark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination
- DEAP-3600: Liquid Argon (LAr) detector
  - 3600 kg LAr, 1000 kg fiducial mass
  - SNOLAB – Sudbury, Ontario
  - 6800 feet underground = 6000 m.w.e
  - Single phase detector

- Single phase – No gaseous amplification region
  - No electron drift requirements
  - 4π PMT coverage

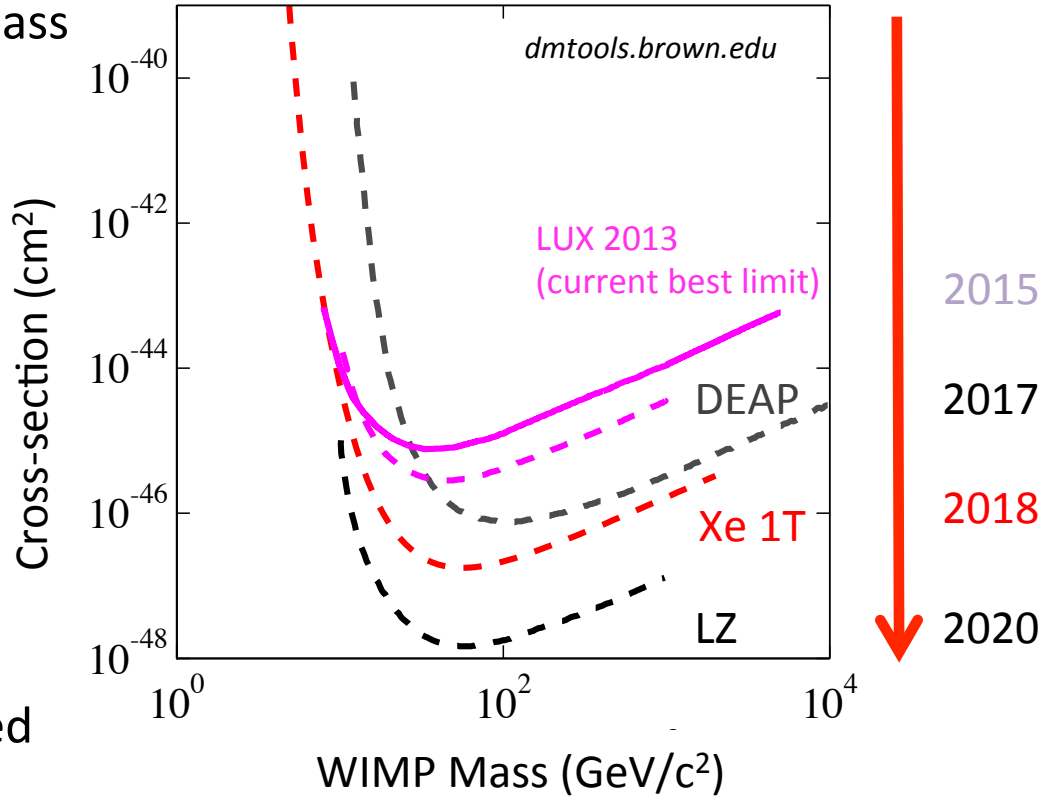
  ➔ Detector scalability to O(kTonne)

- Why Argon?
  - Ar transparent to 128nm scintillation photons
    - Large fiducial masses
  - Well separated singlet and triplet state lifetimes
  - Easy to purify and inexpensive

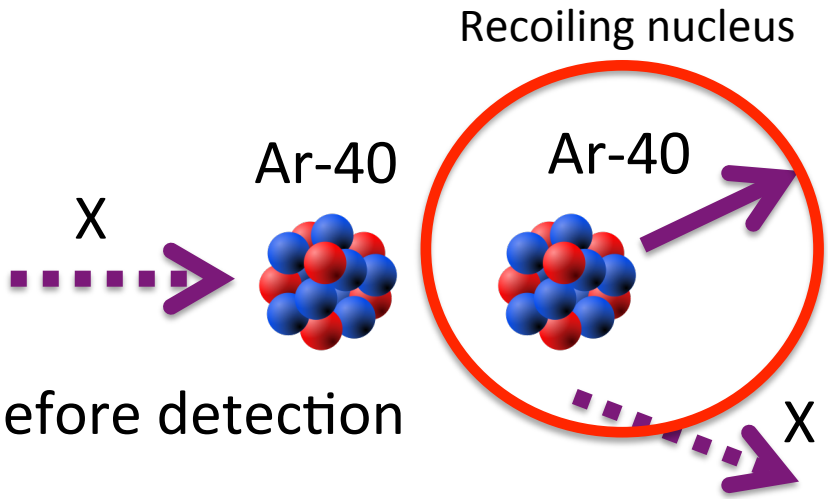
1000 kg argon target & 3 year run allows ~10^{-46} cm^2 sensitivity (SI) with ~15 keVee (60 keVr) threshold (bkgd limit)

How does DEAP-3600 fit in?

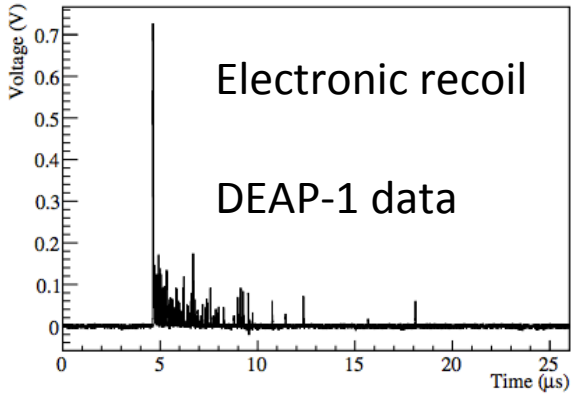
- Will set a worlds best spin independent measurement on a competitive timescale:
  - 10^{-46} cm^2 for 100 GeV WIMP mass (3 years)
  - Better sensitivity for higher mass WIMPs
  - Current best limit: LUX 2013
  - 1 month to exceed Xe-100
  - 2 months to achieve current LUX sensitivity
  - 1 year to exceed LUX projected final sensitivity

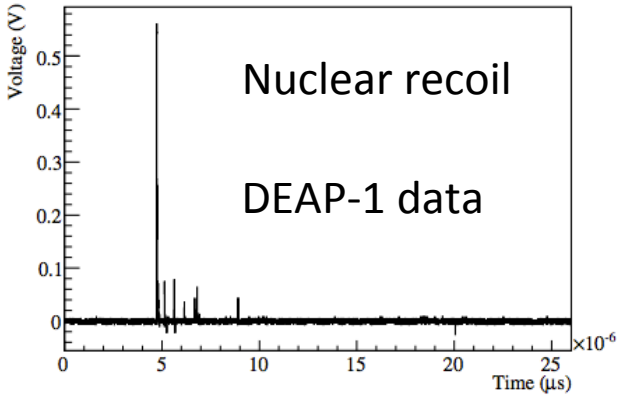


DEAP-3600 Signal

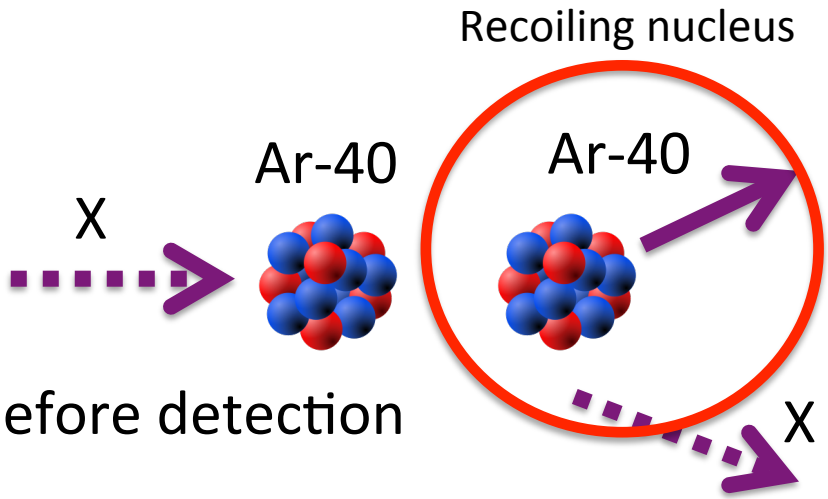


- What do we see?
  - Ionisation from recoiling nucleus
  - 128nm light wavelength shifted before detection by photomultipliers
- Ar singlet and triplet excited states have well separated lifetimes (7ns vs. 1.5us)
- Electronic and nuclear recoils produce different ratios of singlet and triplet states therefore…





DEAP-3600 Signal



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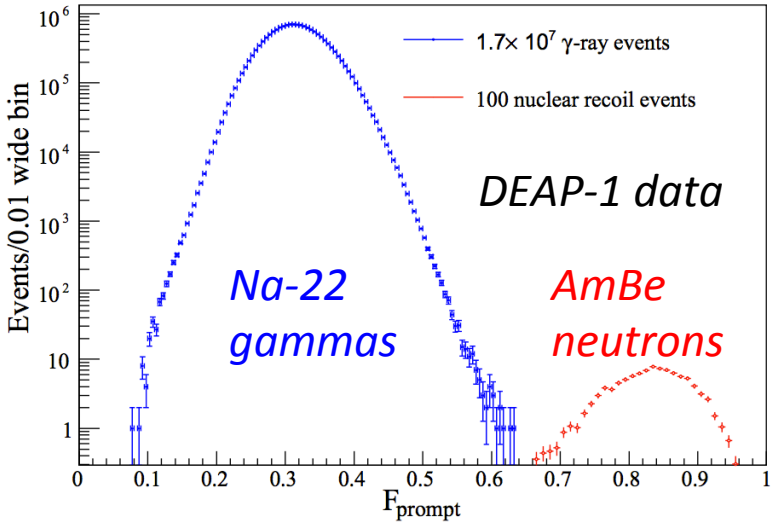
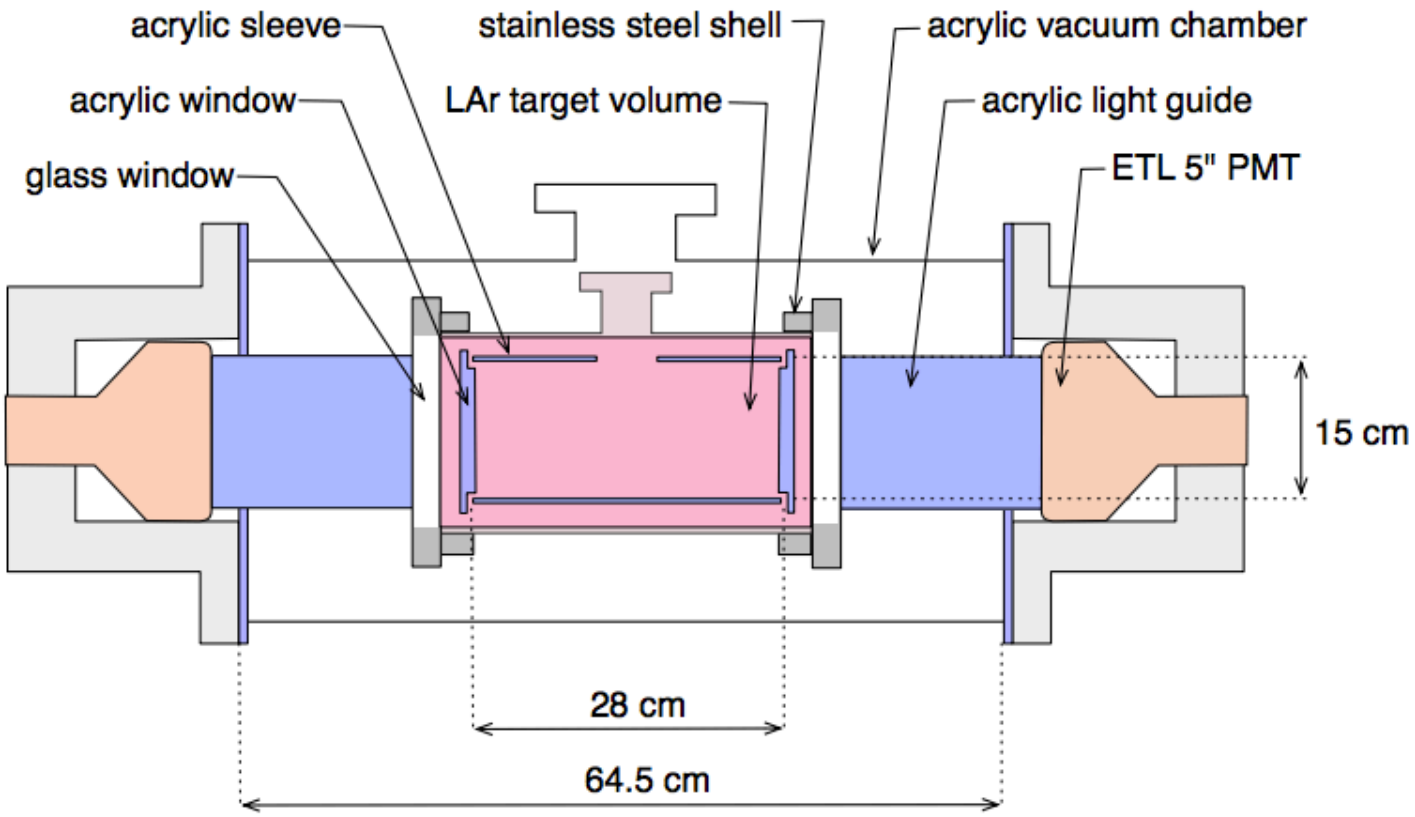
- Electronic and nuclear recoils produce different ratios of singlet and triplet states therefore
- Pulse Shape Discrimination (**PSD**):
  - Separate electronic and nuclear recoils using timing
  - $F_{prompt} = PE_{prompt}/PE_{total}$
  - Prompt window: -50 ns ➔ 150 ns

arXiv:0904.2930

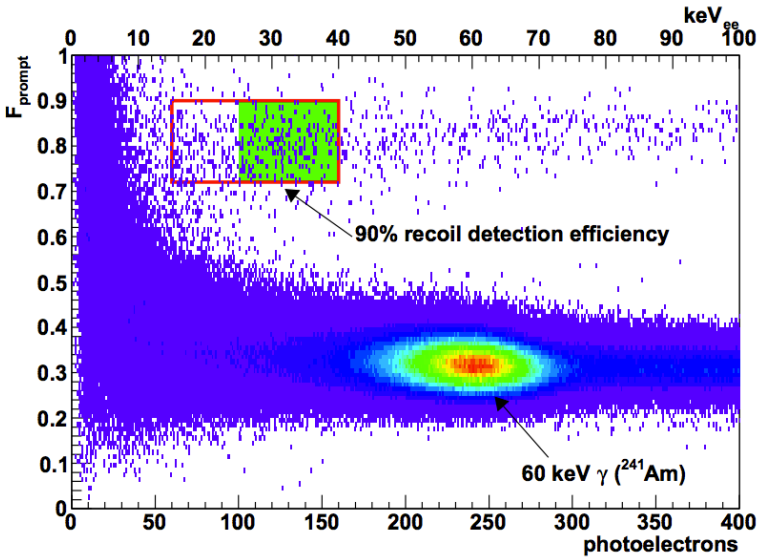


DEAP-1: 7kg LAr Prototype Detector



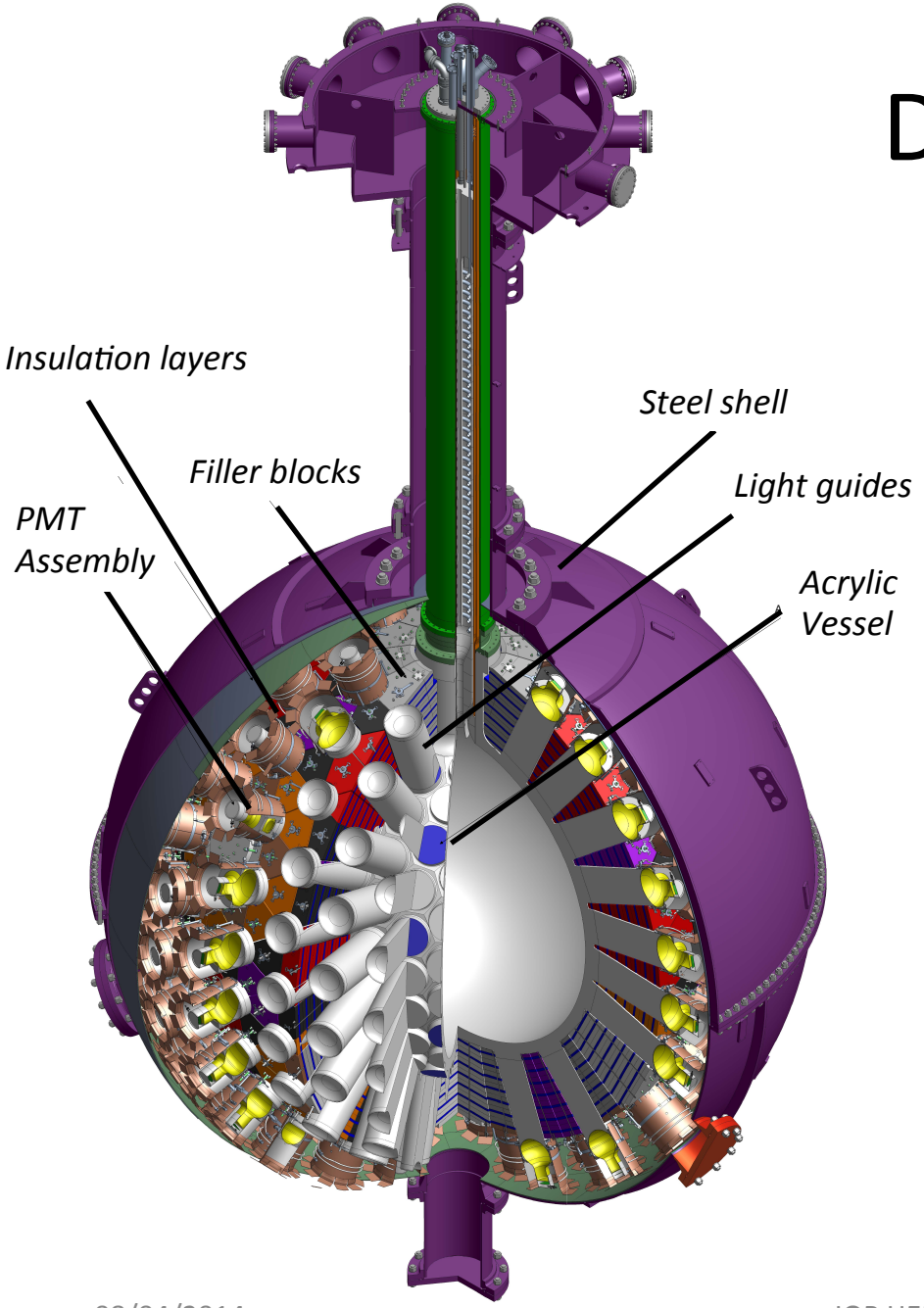
DEAP-1

- PSD (*Updated result of arXiv:0904.2930*):
  - 3×10^{-8} suppression (stat. limited) of γ's seen in DEAP-1 (25 keVee)
  - light yield of ~4 PE/keV
  - Region of interest: 100 – 160 PE, Fprompt > 0.7



- Backgrounds (*arXiv:1211.0909*):
  - Principle backgrounds from Rn-222 decay chain coming from Uranium decay chain
    - Rn-222: 3.83 day lifetime (~20 minute Ar cycling)
  - Surface background < 100 μBq/m^2 achieved in DEAP-1
    - Material assays x10 lower limit in DEAP-3600

DEAP-1 results used to project DEAP-3600 sensitivity

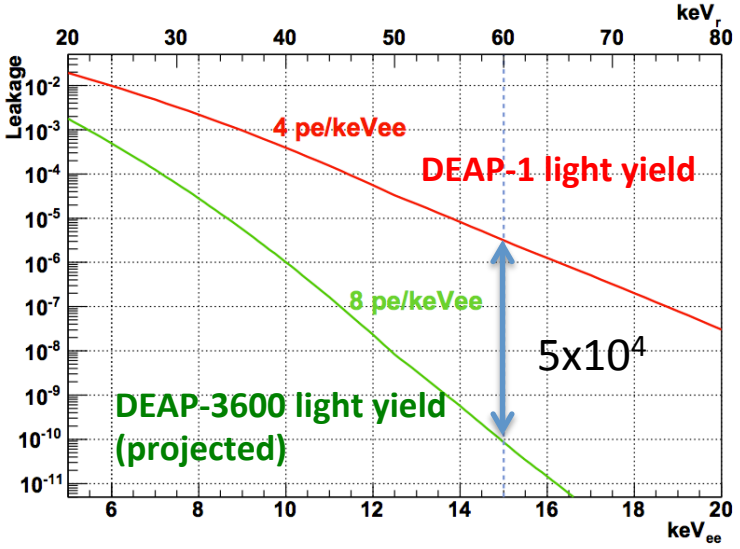


DEAP-3600 Detector

- LAr housed in sealed ultraclean acrylic vessel
- 255 8-inch Hamamatsu R5912 HQE PMTs
  - 32% QE, 75% coverage
- Acrylic vessel & light-guides provide PMT neutron shielding
- Tetraphenyl-butadiene (TPB) used as wavelength shifter (128nm to 430nm)
- Cosmic veto
  - SNOLAB (2km underground)
  - Detector submerged in 8m diameter water tank

DEAP-3600 Backgrounds

- **β/γ events:**
  - Ar-39 dominant rate – 1 Bq/kg. Removal using PSD
  - Leakage scales with light yield
- **Neutron recoils:**
  - (α,n) - very strict material controls: achieved with ex-situ material assays
  - Muon induced – SNOLAB ~2km underground + active cosmic veto
- **Surface alphas:**
  - Rn daughters and other surface impurities.
  - Resurface acrylic surface in-situ, fiducial volume cuts, limit radon (trap)

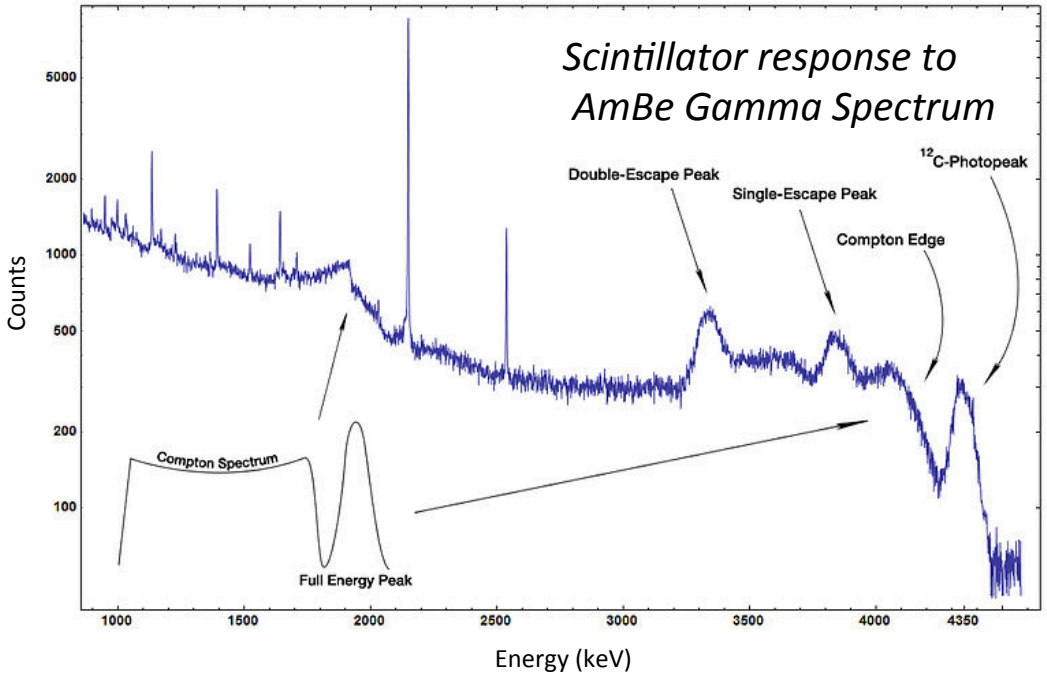


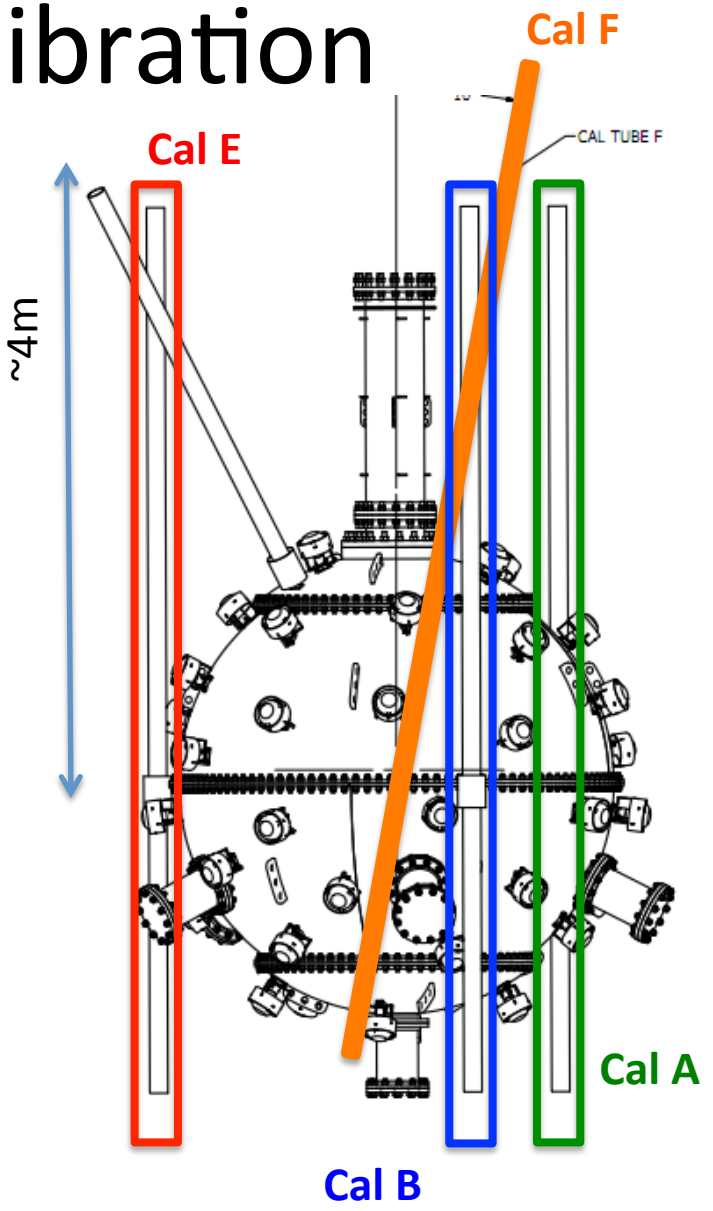
Background (in Fid Vol)	DEAP-3600 Goal
Radon in Ar	< 1.4 nBq/kg
Surface α's	< 100 μBq/m^2
Neutrons (all sources)	< 2 pBq/kg
Ar-39	< 2 pBq/kg
Total (3 tonne-yr)	**< 0.6 events**

For 10^{-46}cm^2 sensitivity over 3 year exposure (1000 kg fiducial volume) requires < 0.6 background events

Gamma & Neutron Calibration

- Tagged Na-22 and AmBe-neutron sources
- Na-22: Map detector with well understood gamma spectrum
  - Cal F loops around detector
- AmBe: Populate detector with WIMP-like recoil events



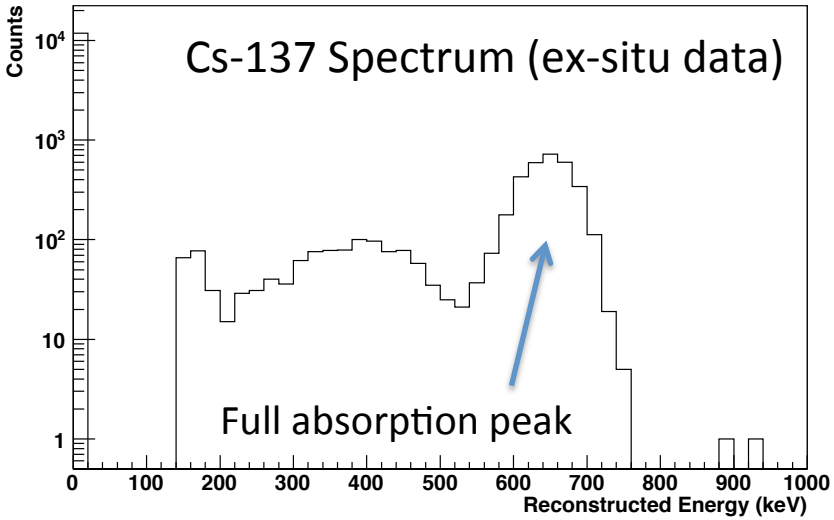


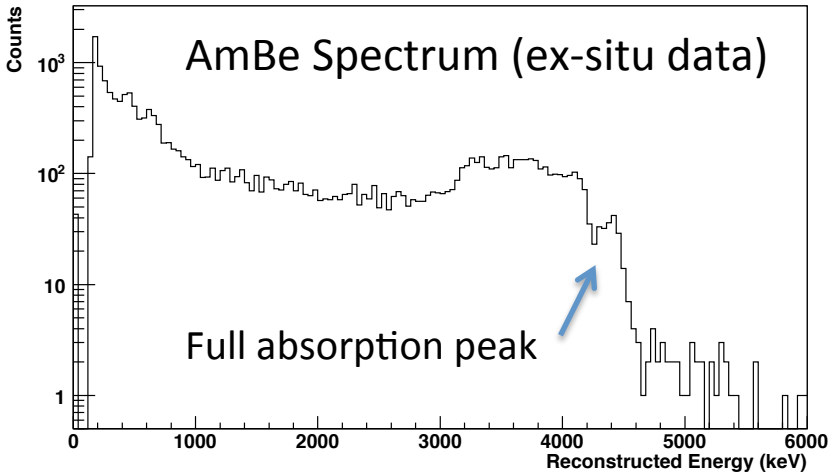
Neutron Calibration Ex-situ data

- Tagged 74 MBq AmBe source

$Am^{241} \rightarrow Np^{237*} + \alpha$
$\alpha + Be \rightarrow C^{12*} + n$
4.4MeV from C^{12*} de-excitation

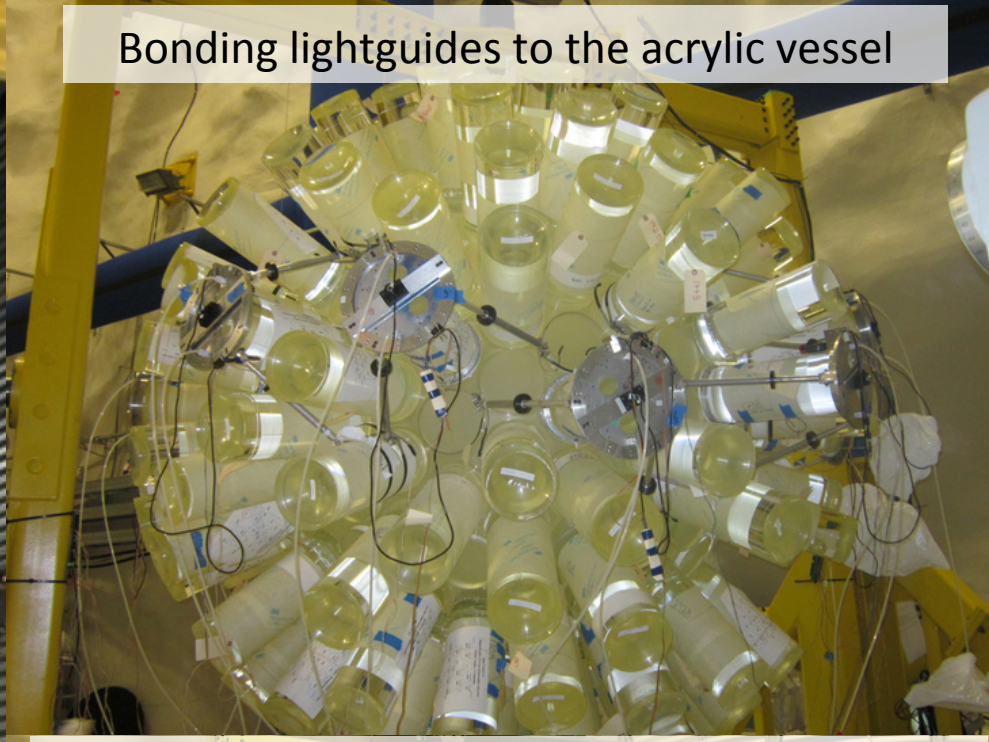
- Two 5x4cm NaI crystals encapsulate source
- Simulation estimate: 100 hours to get 10,000 single neutron scatters in DEAP
- Expect ~20% gammas (AmBe) to deposit > 500keV energy in NaI crystal
- Ex-situ measurement of efficiency in agreement with simulation



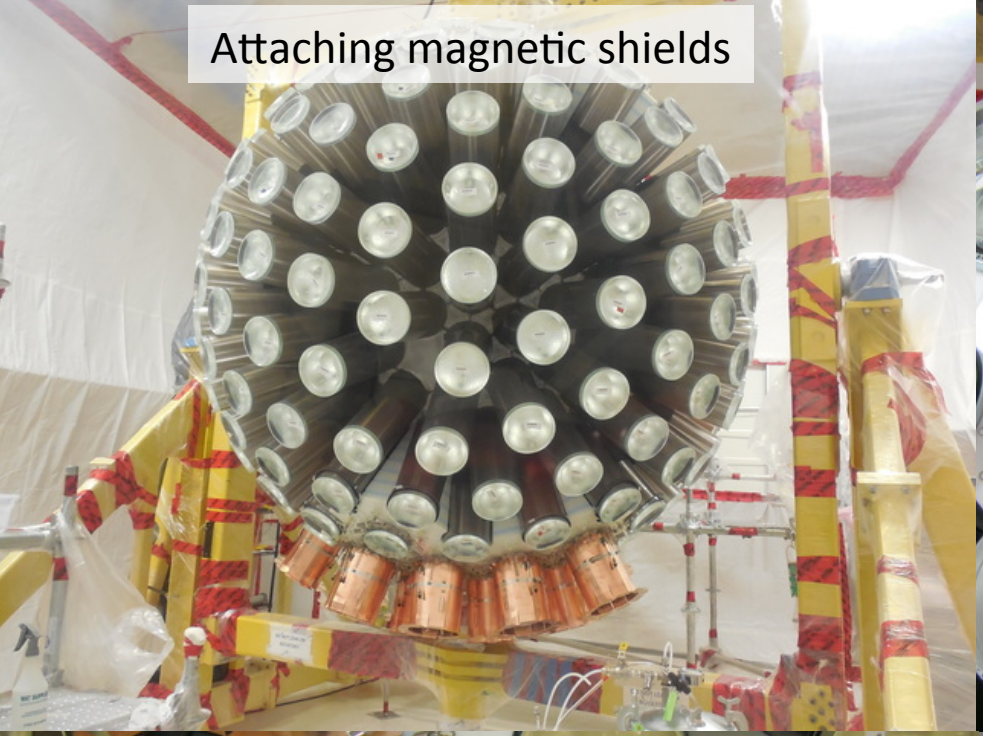


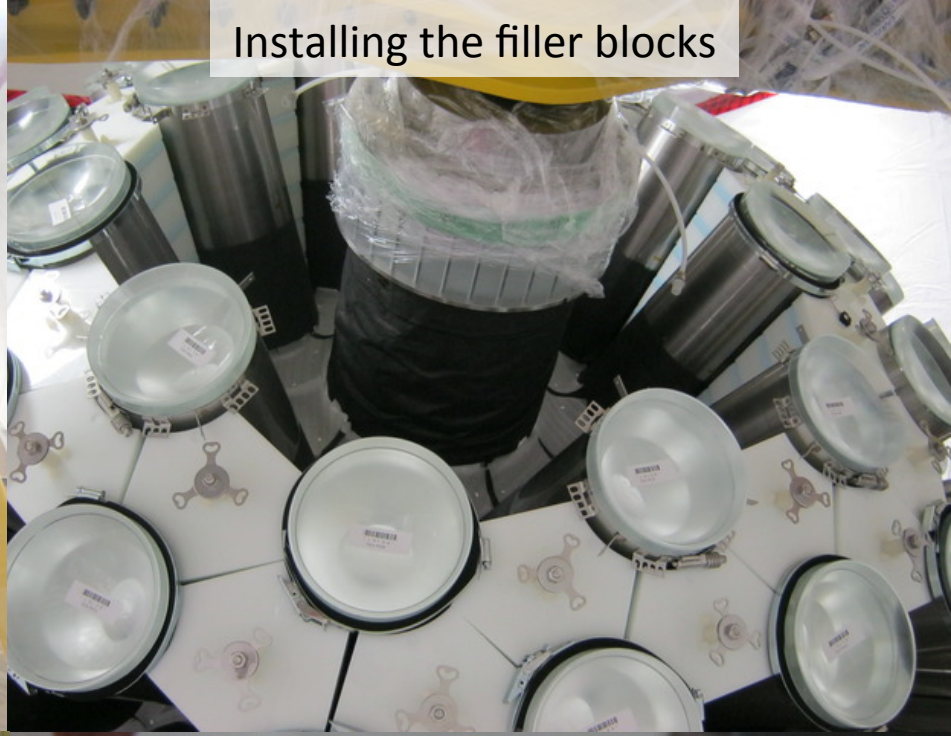
Vacuum testing the steel sheel

Bonding lightguides to the acrylic vessel

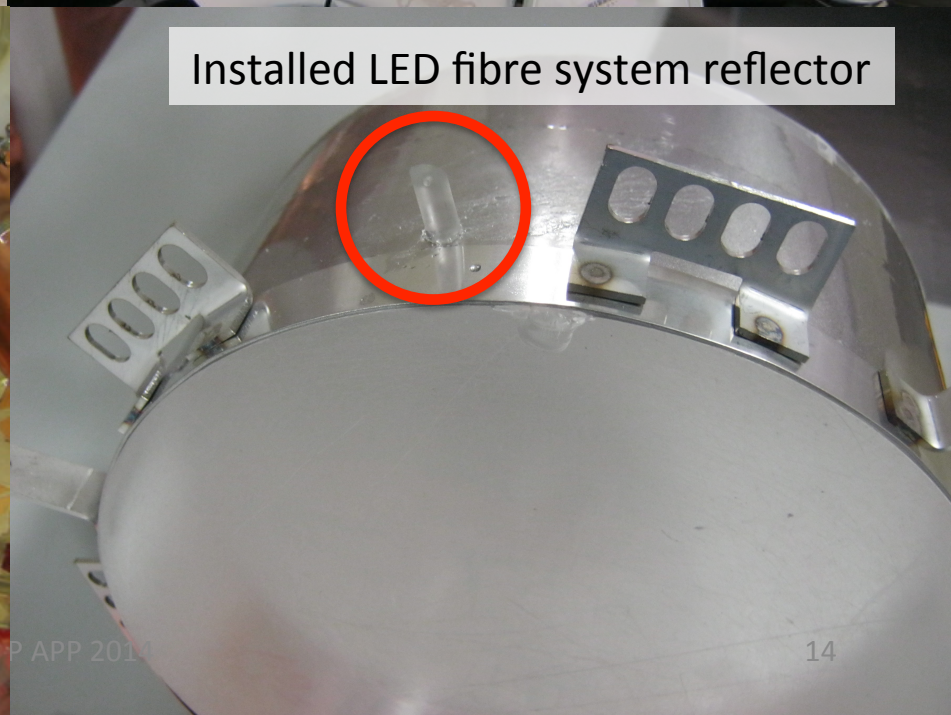


Completed acrylic vessel – lightguide assembly


Attaching magnetic shields


Installing the filler blocks

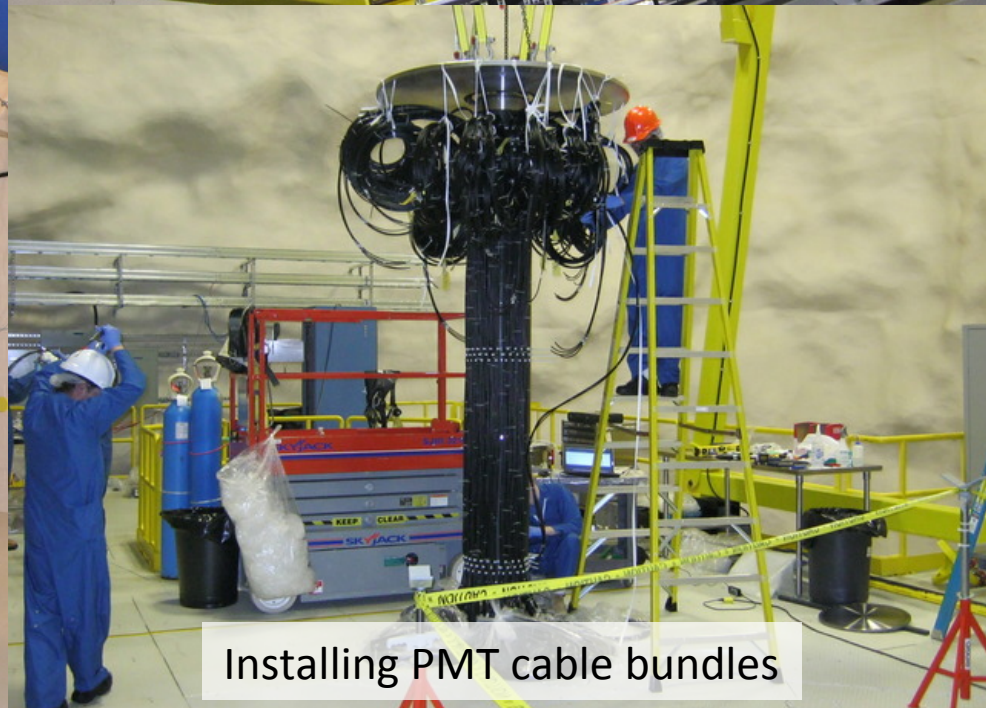
PMT Installation


Installed LED fibre system reflector

Acylic vessel in the annealing oven

DEAP-3600 (r) and MiniCLEAN (l) water tanks

Cryocoolers & argon storage dewar


Installing PMT cable bundles

Conclusions and Outlook

- May 7th: DEAP-3600 PMT installation completed and detector sealed
  - Start resurfacing
  - Start calibration commissioning of the detector with the optical fibre system
- Fill with gAr July
- 5 weeks to cooldown
- Commissioning May - September
- Begin physics run October 2014

First result early 2015!

Full sensitivity 3 years $10^{-46}cm^2$

Thank you and Stay Tuned!

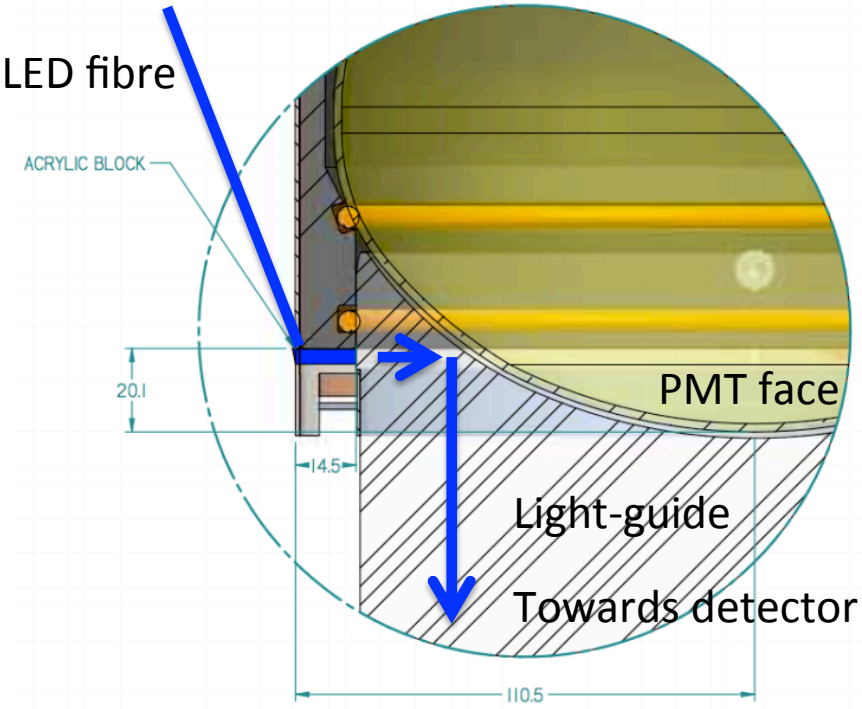
Me

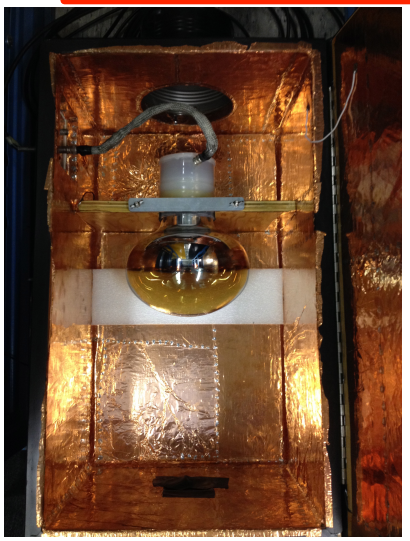
Backup

Optical Calibration

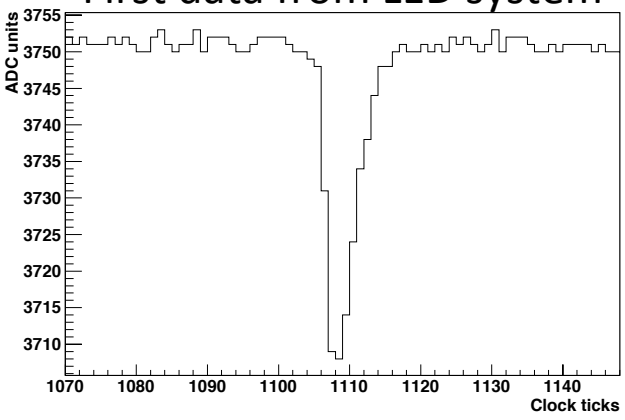
- 3 systems:
  - LED fibre system
  - LED/Laser-ball
  - Neck laser

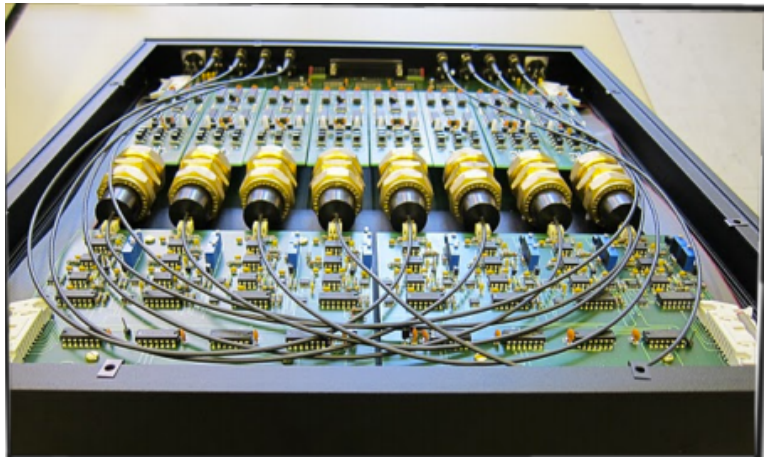
- PMT timing & gain calibration/monitoring
  - Fast rise time (1 clock tick = 4ns)
- AV/light guide monitoring
- Run during commissioning and physics run

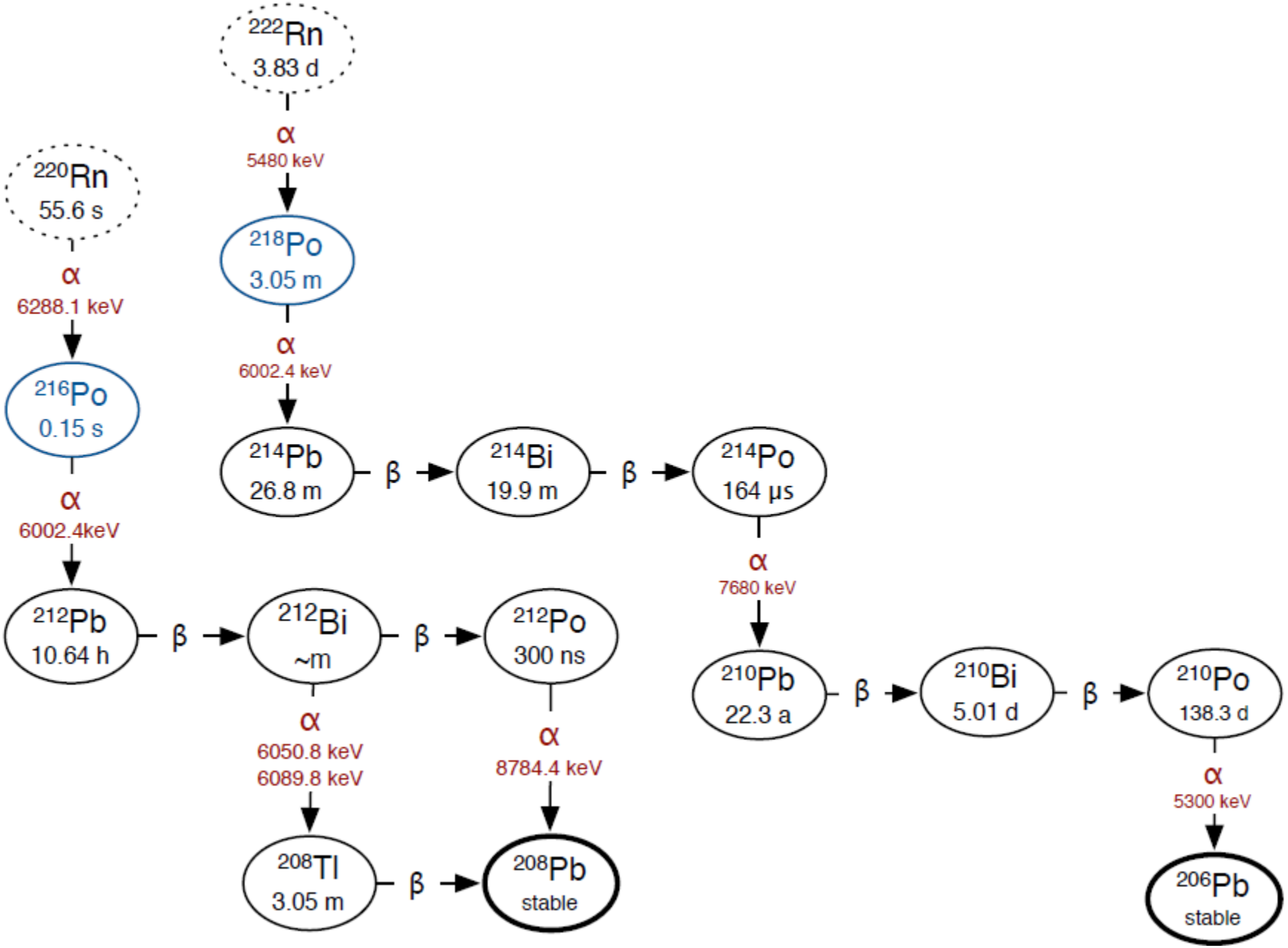




First data from LED system






222Rn
3.83 d
α
5480 keV
220Rn
55.6 s
218Po
3.05 m
α
6288.1 keV
α
6002.4 keV
216Po
0.15 s
214Pb
26.8 m
β
214Bi
19.9 m
β
214Po
164 µs
α
6002.4keV
α
7680 keV
212Pb
10.64 h
β
212Bi
~m
β
212Po
300 ns
210Pb
22.3 a
β
210Bi
5.01 d
β
210Po
138.3 d
α
6050.8 keV
6089.8 keV
α
8784.4 keV
α
5300 keV
208Tl
3.05 m
β
208Pb
stable
206Pb
stable