The DEAP-3600 Experiment

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IOP HEPP & APP Conference

Outline

- Dark Matter and DEAP-3600
- Calibration System
- Construction Status

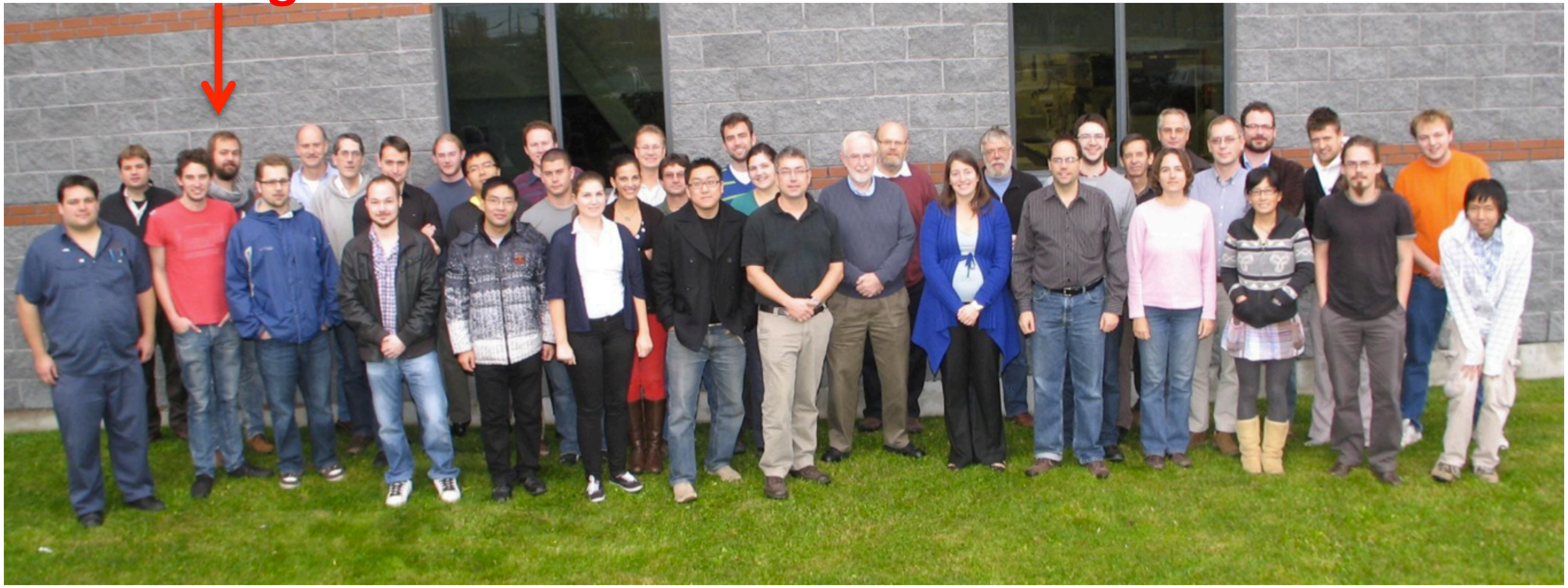
Royal Holloway
University of London

Collaboration

- University of Alberta
- Carleton University
- Queens University
- SNOLAB/Laurentian
- SNOLAB
- TRIUMPF
- Rutherford Appleton Laboratory
- Royal Holloway, University of London
- University of Sussex

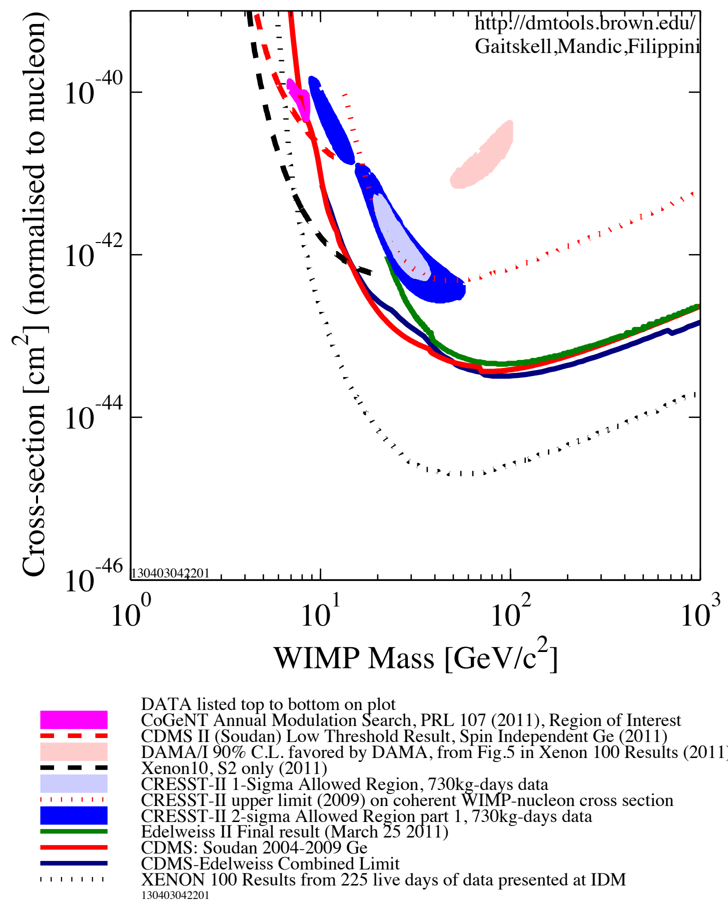
70 collaborators

Me again



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

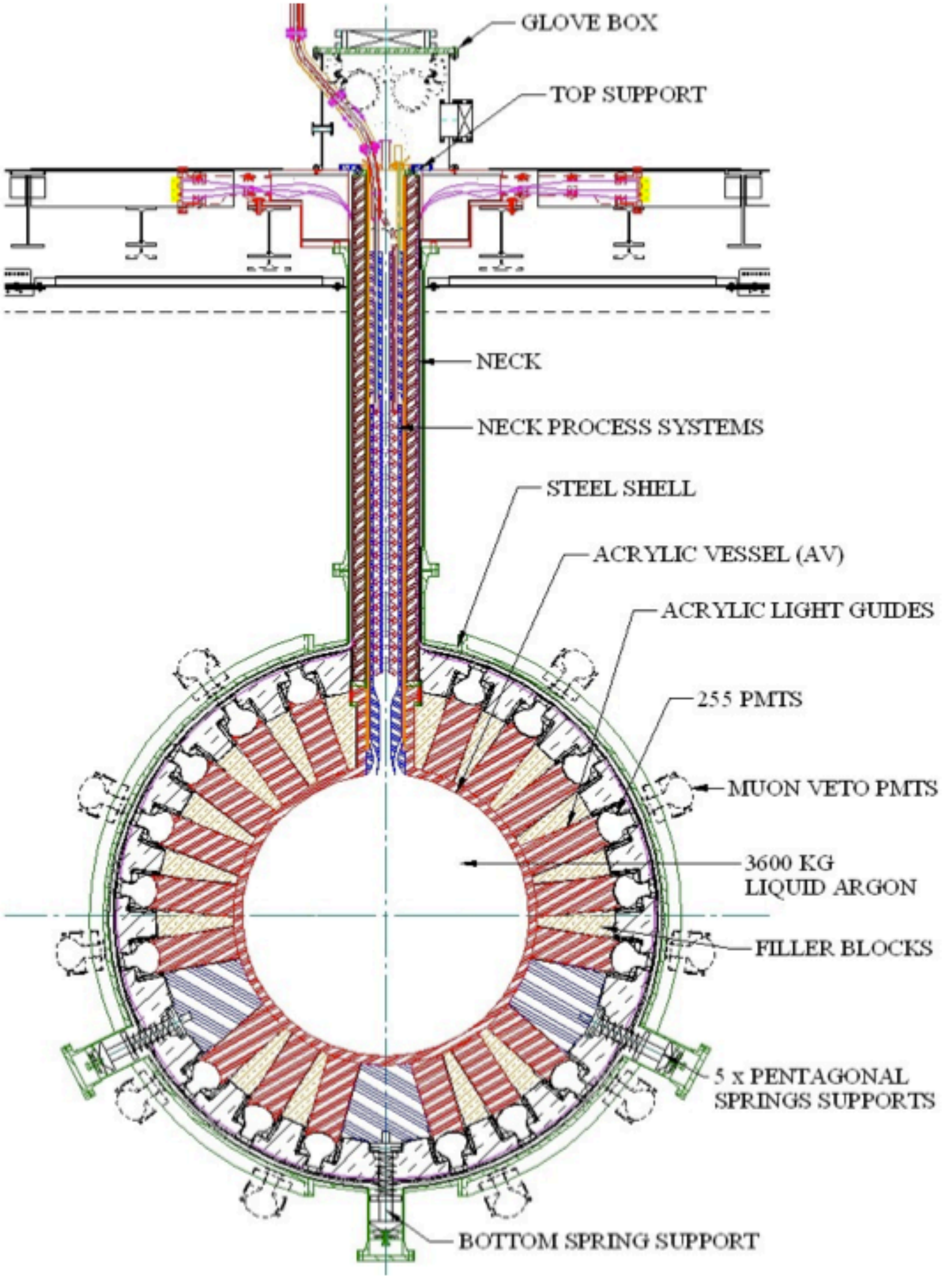


What is DEAP-3600?

- **D**ark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination
- DEAP-3600: Liquid Argon (LAr) detector
  - 3600kg LAr, 100kg 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

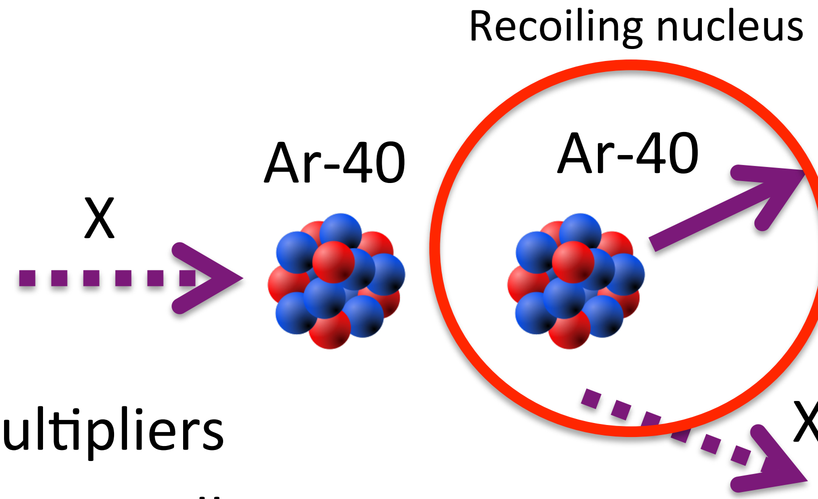
- Why Argon?
  - Ar transparent to 128nm scintillation photons
    - Large fiducial masses
  - Well separated singlet and triplet state lifetimes



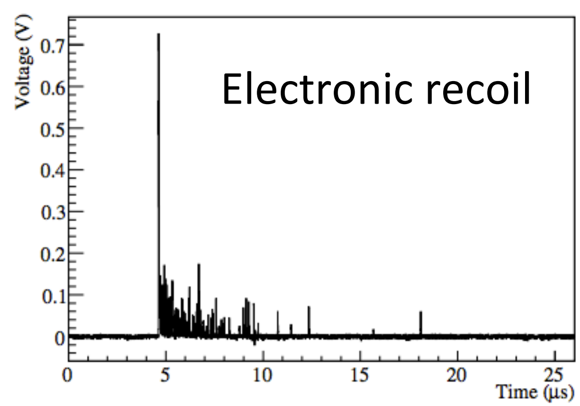
The Detector

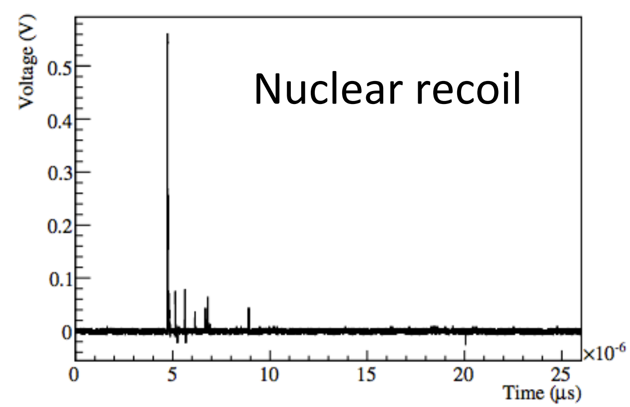
- LAr housed in sealed ultraclean acrylic vessel
- 255 8-inch Hamamatsu R5912 HQE PMTs
  - 32% QE, 75% coverage
- Acrylic vessel & light-guides provide neutron shielding
- Tetraphenyl-butadiene (TPB) used as wavelength shifter (128nm to 430nm)
- Detector submerged in 8m water tank
  - Cosmic veto

DEAP-3600 Signal

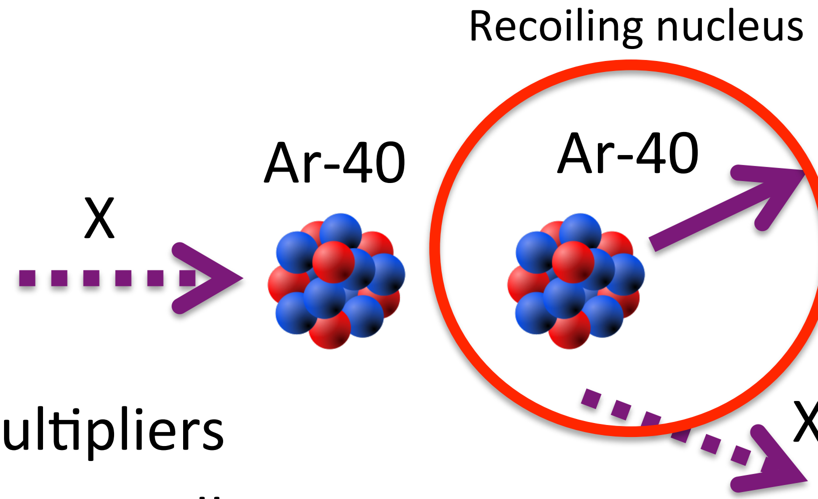


- What do we see?
  - Ionisation from recoiling nucleus
  - 128nm light detected by photomultipliers
- Ar singlet and triplet excited states have well separated lifetimes (4ns vs. 1.5us)
- Electronic and nuclear recoils produce different ratios of singlet and triplet states therefore…





DEAP-3600 Signal



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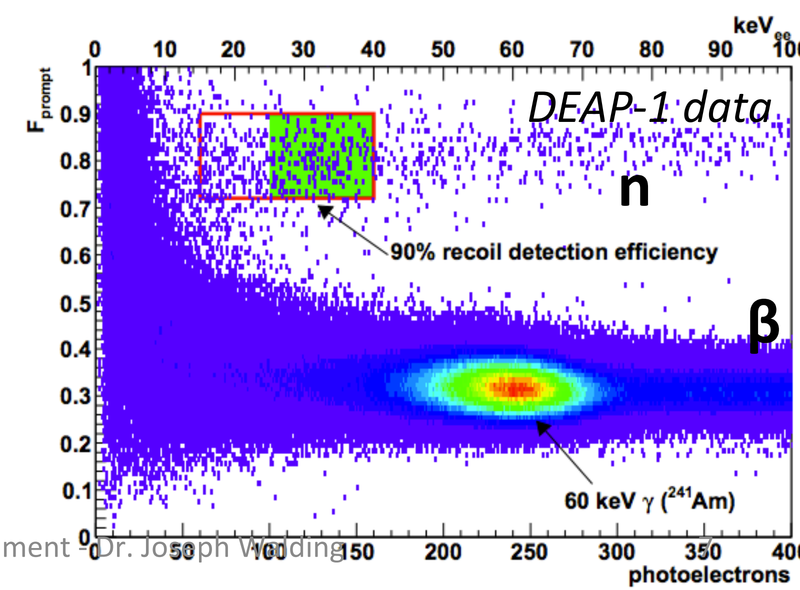
- Pulse Shape Discrimination:
  - Separate electronic and nuclear recoils using timing
  - $F_{prompt} = PE_{prompt}/PE_{total}$



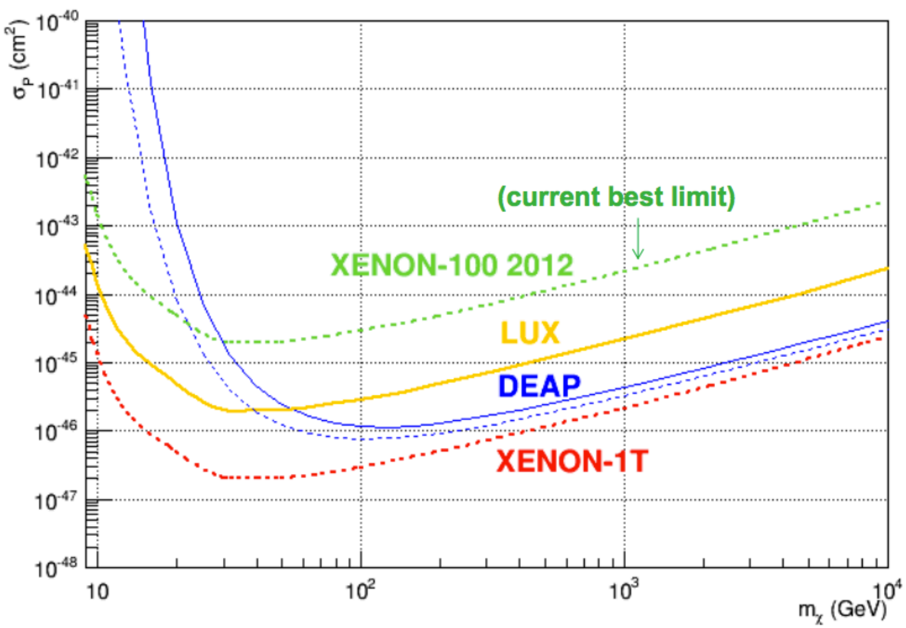
DEAP-3600 Backgrounds

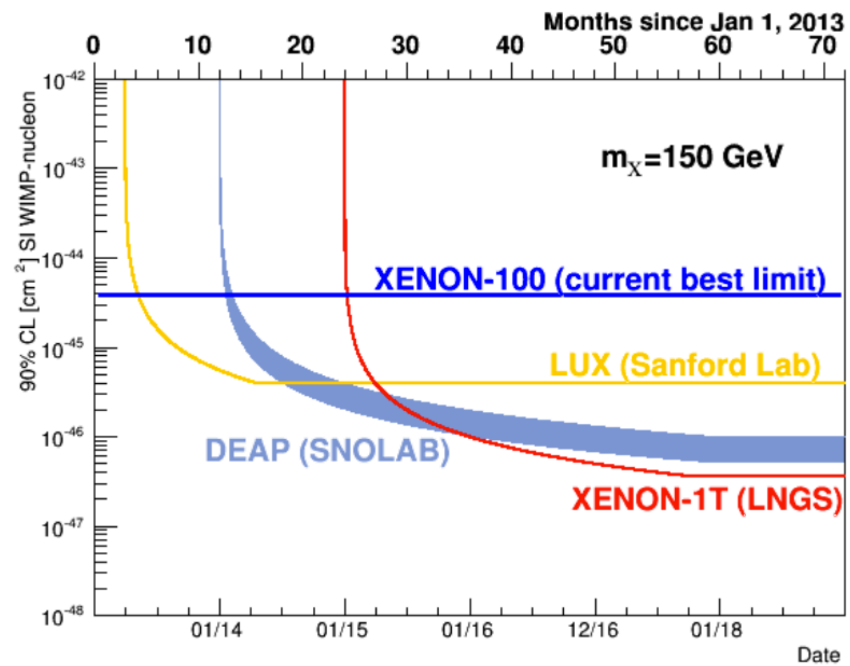
- Major background is Ar-39 beta decays
  - 1Bq/kg in Argon
- PSD allows reduction in fiducial volume to 2pBq/kg!

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
Background Events (Ar-39)	< 2 pBq/kg
Total (3 tonne-year in Fid Vol in ROI)	**< 0.6 events**

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)
  - Xe-100: Current best limit
- DEAP will exceed Xe-100 sensitivity with 1 month of data
  - 1 year - Exceed LUX





Calibration Systems

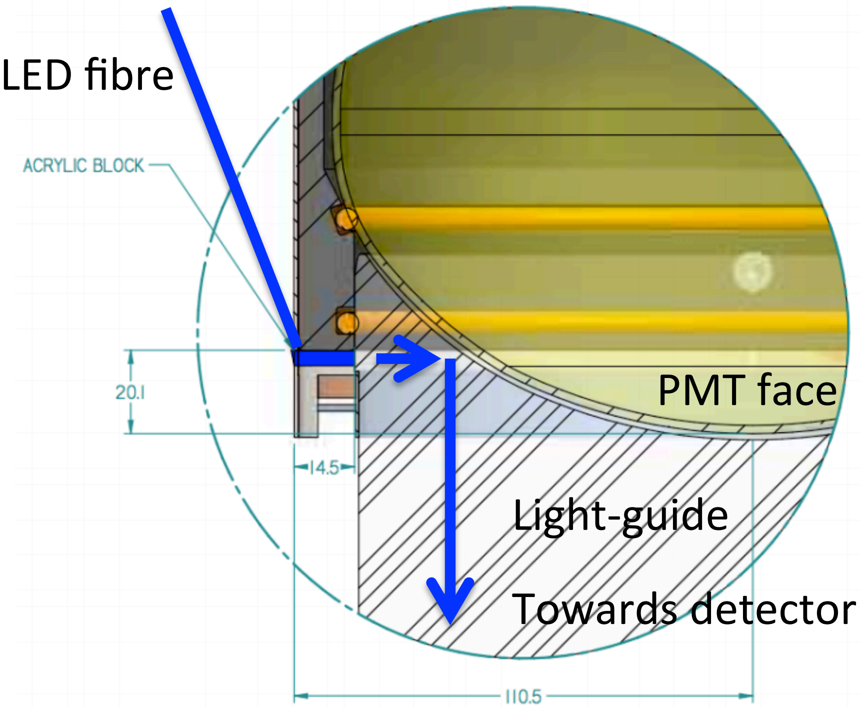
- Three calibrations systems
- Optical, gamma source and neutron source
  - UK responsible for delivery
- And one for free: Ar-39

- What do we want to calibrate?
  - Energy scale (PE/keVee): Gamma, Ar-39, Optical
  - Radial reconstruction: Neutron, Gamma
  - Prompt photon fraction: Gamma, Ar-39
  - Detector uniformity & stability: Optical, Ar-39
  - ROI validity: Neutron, Ar-39
- Calibration data vital during commissioning and data run

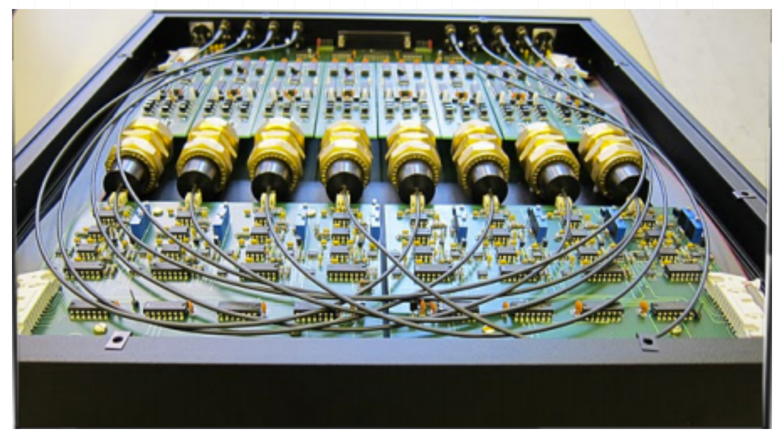
Optical Calibration

University of Sussex

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



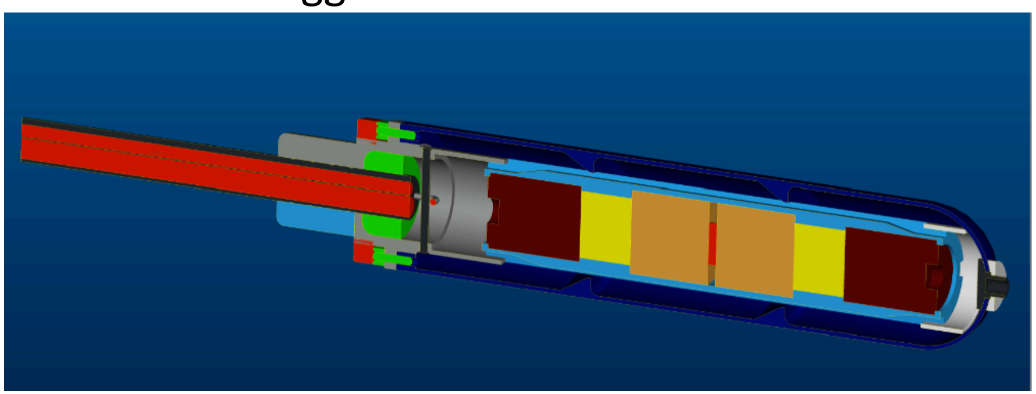
- PMT timing & gain calibration/monitoring
- AV/light guide monitoring
- Run during commissioning and physics run

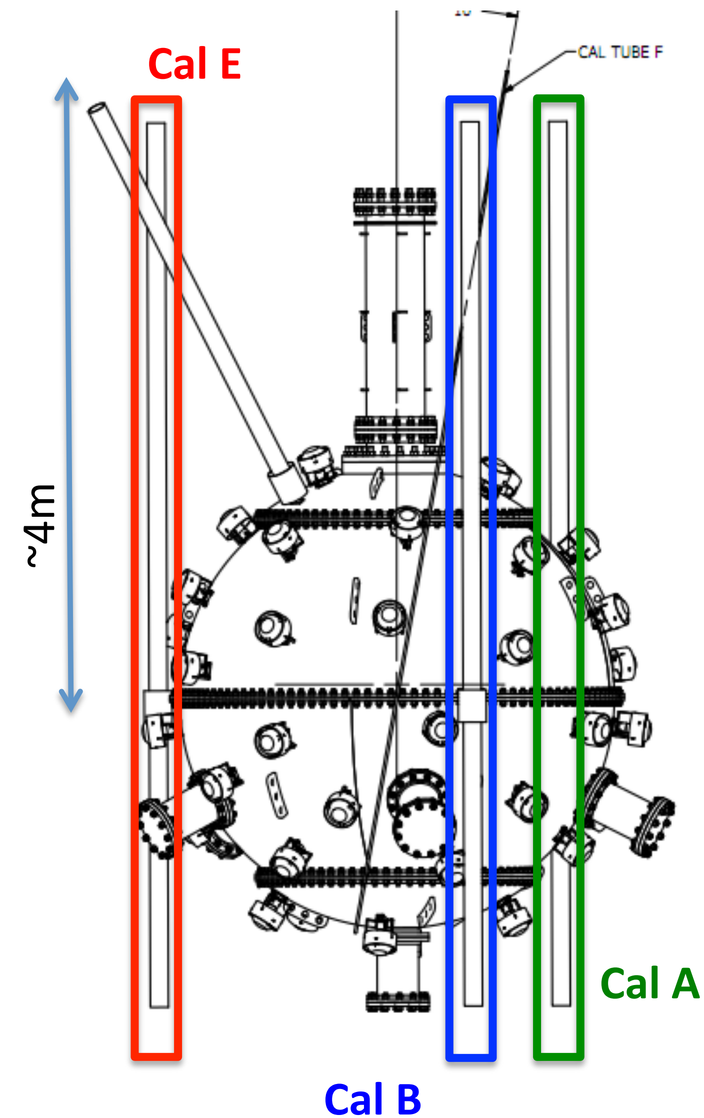


Gamma Calibration
RAL

- Tagged Na-22 source lowered in external calibration tubes
- Map detector with well understood gamma spectrum
- Used to calibrate PMTs

Tagged NA-22 source canister

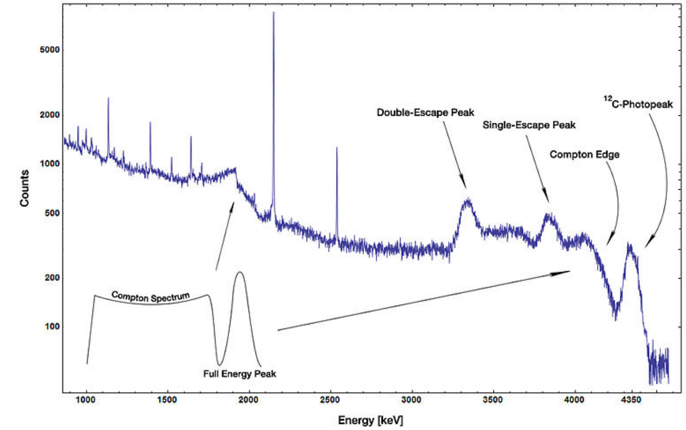




Neutron Source Calibration

RHUL

AmBe gamma spectrum

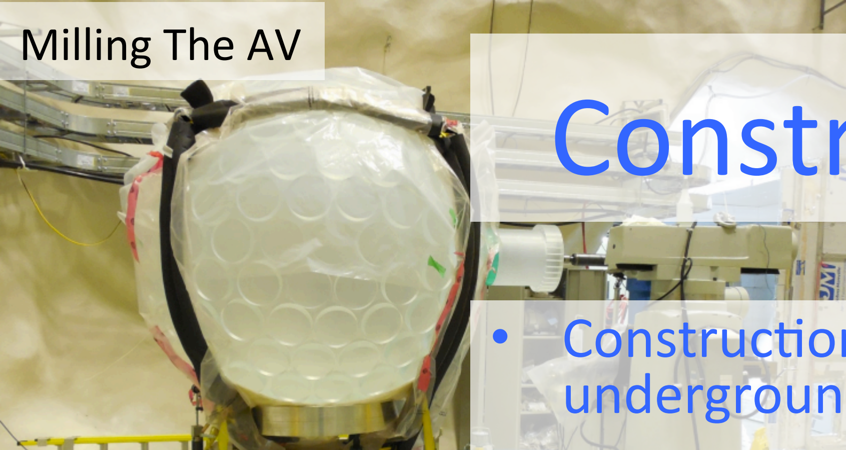


- Neutrons irreducible dark matter background
- Deploying a neutron source allows study of detector response to neutrons
  - Multiple scatters
  - ROI leakage

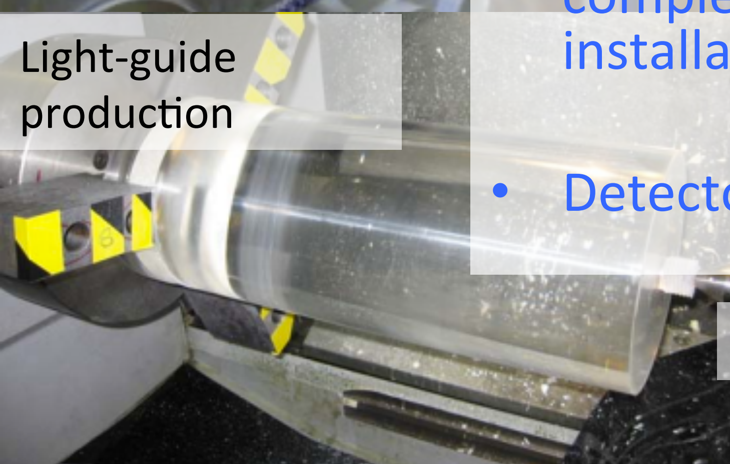
- System built to deploy tagged AmBe (α-n) source at various locations around detector
- Deployment system is constructed and tested
  - 4.5mm deployment precision
- Studies ongoing to determine neutron tagging method

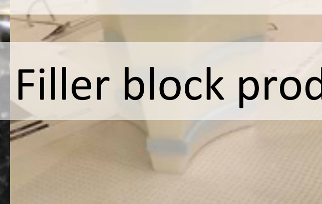
Construction Status

- Construction and installation underground progressing well
- Acylic vessel (AV) shipped underground: Dec 8, 2012
- AV prepped & annealed for bonding: Dec 2012 - Jan 2013
- Steel shell and structural steelwork completed. Steel shell is in final installation position hanging from deck
- Detector filling date early January 2014

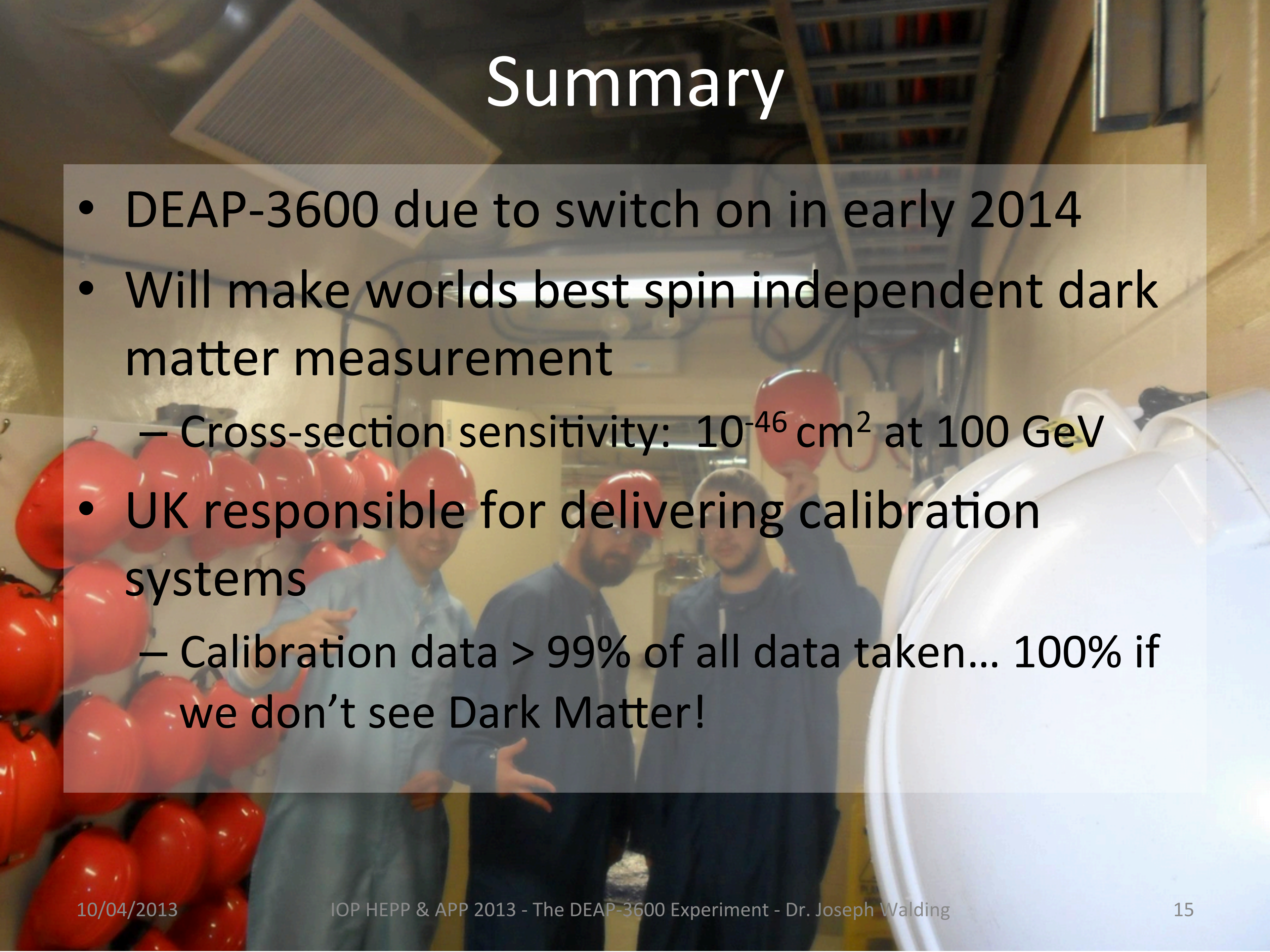

Milling The AV


Light-guide mount test


Light-guide production


Filler block production


Steel shell vacuum tests



Summary

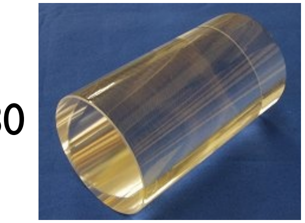
- DEAP-3600 due to switch on in early 2014
- Will make worlds best spin independent dark matter measurement
  - Cross-section sensitivity: 10^{-46} cm^2 at 100 GeV
- UK responsible for delivering calibration systems
  - Calibration data > 99% of all data taken… 100% if we don't see Dark Matter!

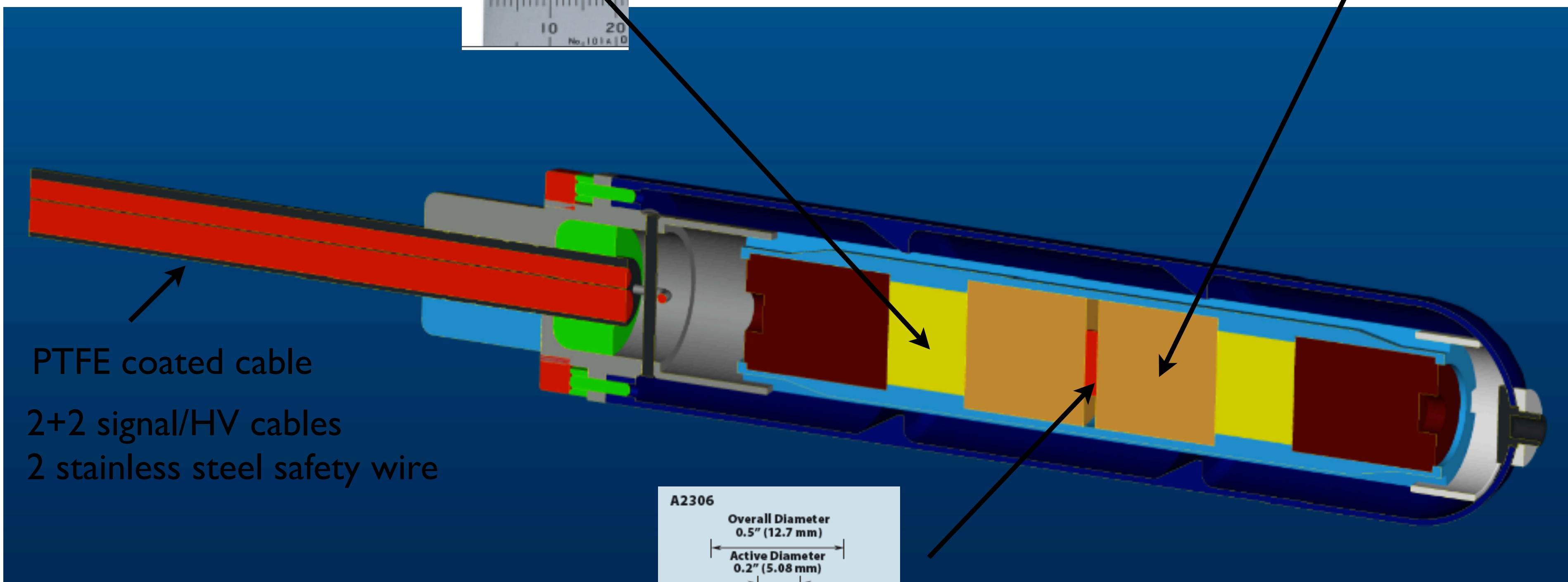
Backup

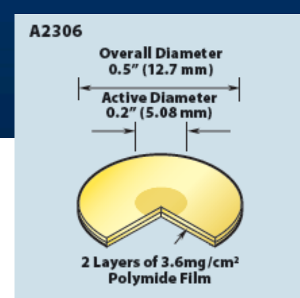
Gamma Source Calibration - *RAL*

Hamamatsu R9880U:
gain 10^6
QE: (380/420 nm) 35/30 %

Saint-Gobin LYSO / BrilLanCe 380
crystal 20 mm diam x 2 mm



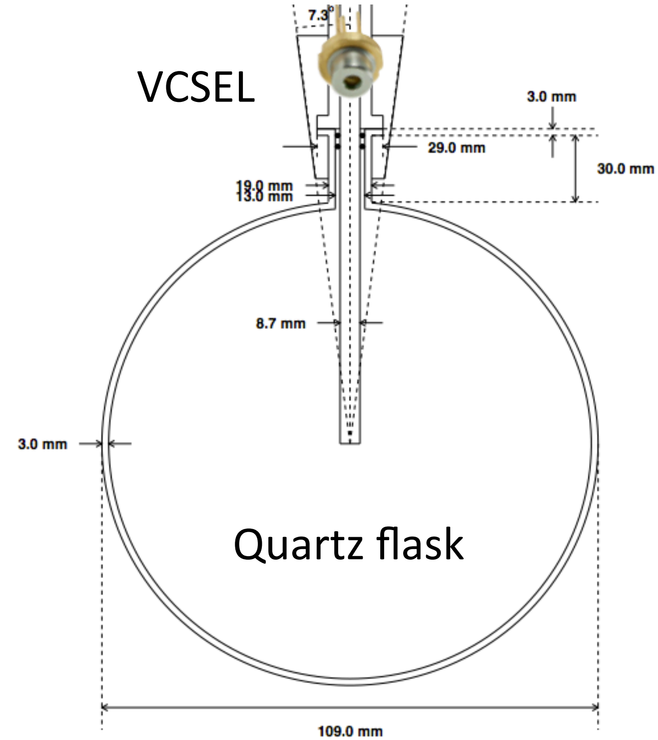




Na-22 source from High
Technology Sources Ltd

Optical Calibration

University of Sussex



- Calibrate detector components during construction, commissioning and data-taking
  - LAr, TPB, Acrylic vessel, Light-guides, PMTs
  - Continuous monitoring
- 3 systems:
  - LED fibre system
  - LED/Laser-ball
  - Neck laser

- Vertical cavity surface emitting laser (VCSEL) diffused in quartz flask
- Lowered into DEAP through neck
- Deployed before and after TPB deposition
- Calibrate Light-guide pre-TPB
- Determine TPB thickness

Optical Calibration

University of Sussex

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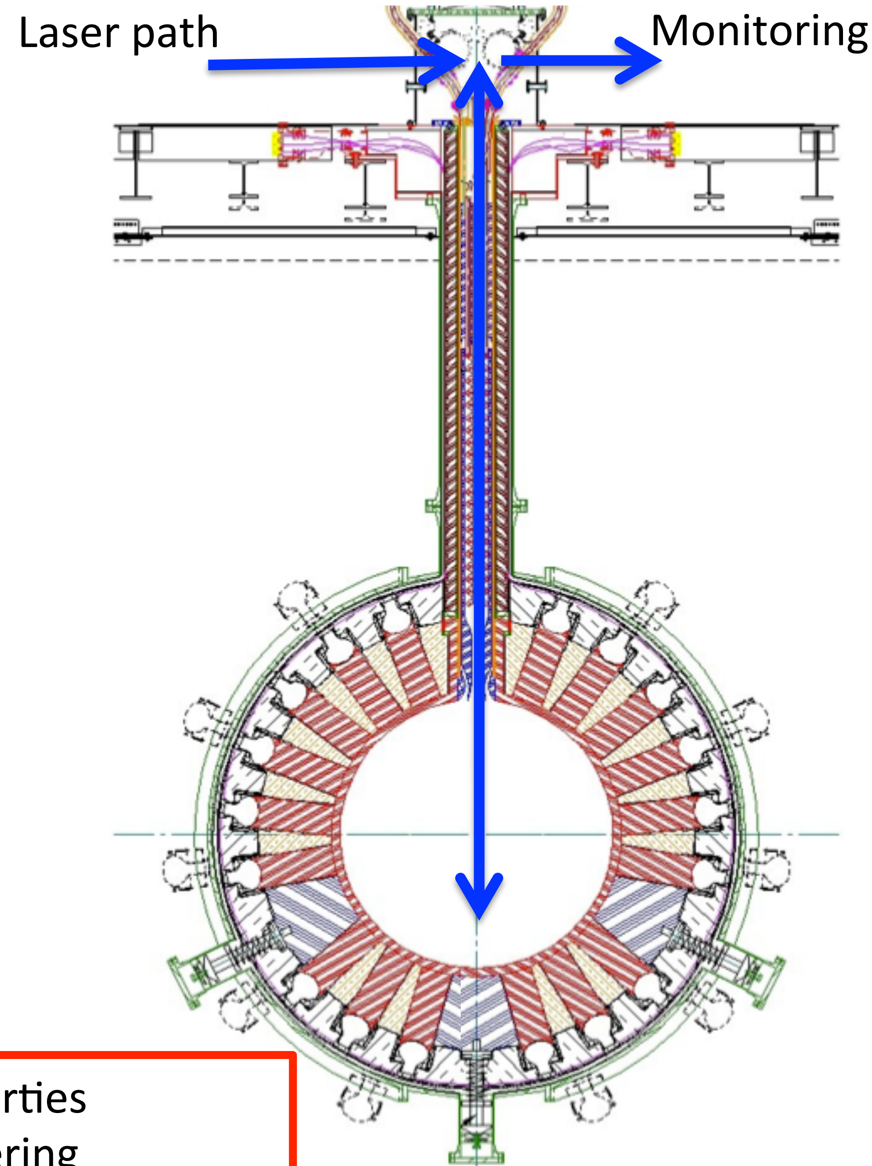

- Monitor TPB properties
- Measure LAr scattering
- Run during commissioning and physics run