Commissioning and Calibration of the DEAP-3600 Dark Matter Detector

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(for the DEAP-3600 collaboration)

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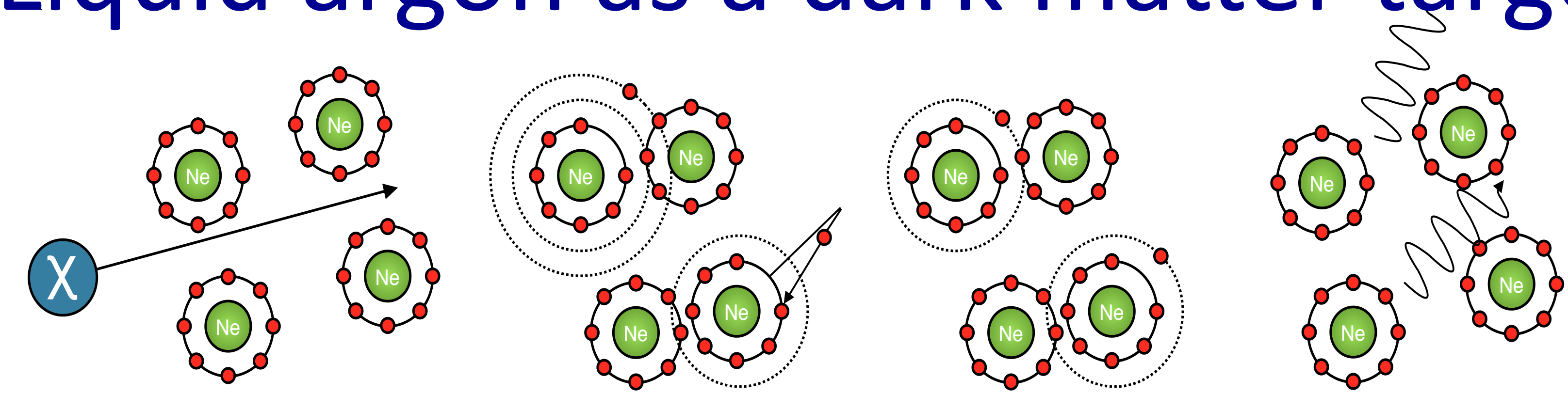
Liquid argon as a dark matter target

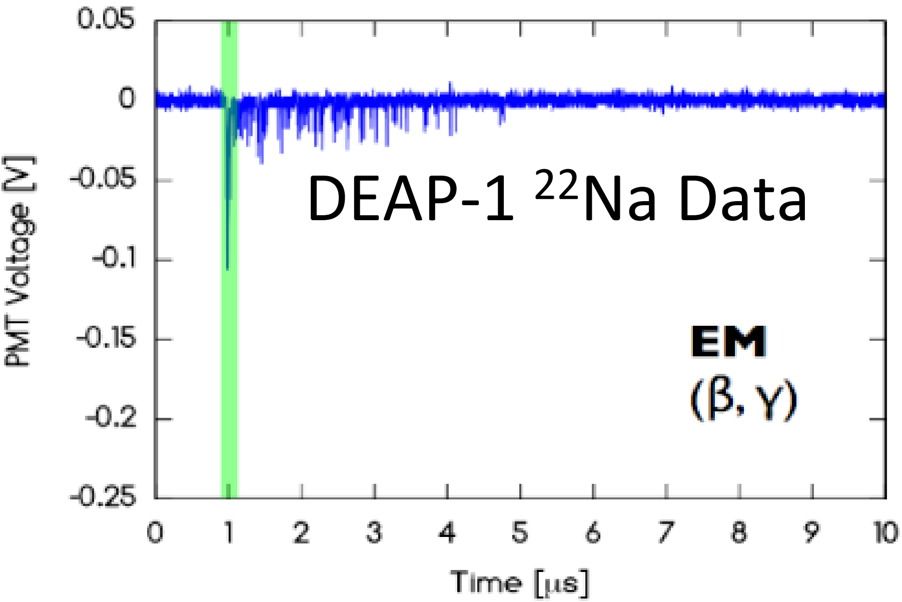


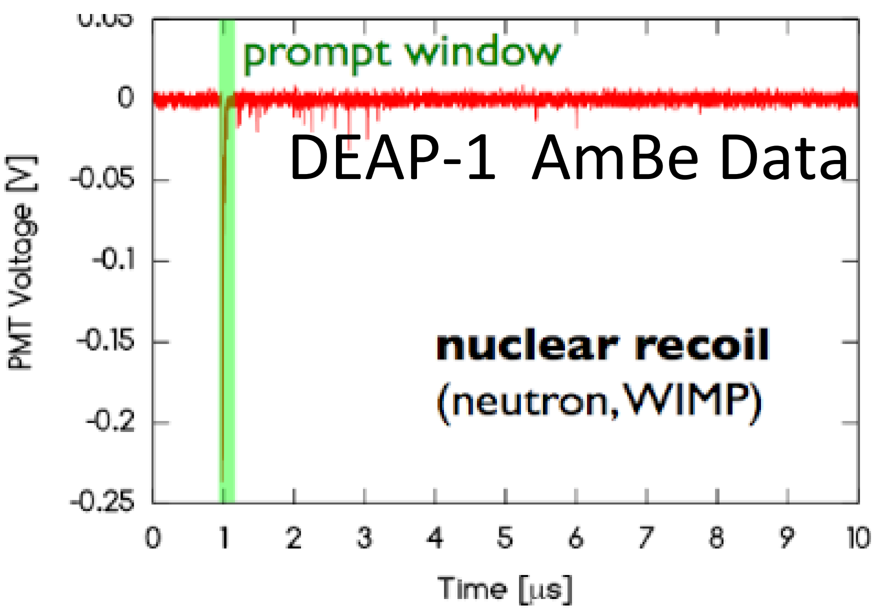
Excitation and ionisation excimer formation de-excitation radiative decay

- Ionization of ultra high purity liquid argon (LAr) allows the production of excited dimers (singlet and triplet states)
- The decay of these states into the repulsive ground state is the origin of argon scintillation light (128 nm)
- Electronic and nuclear recoils produce different ratios of singlet and triplet states
- The singlet and triplet states have well separated lifetimes[1] (7ns versus 1.6 μs)
- Electronic and nuclear recoils have different timing profiles

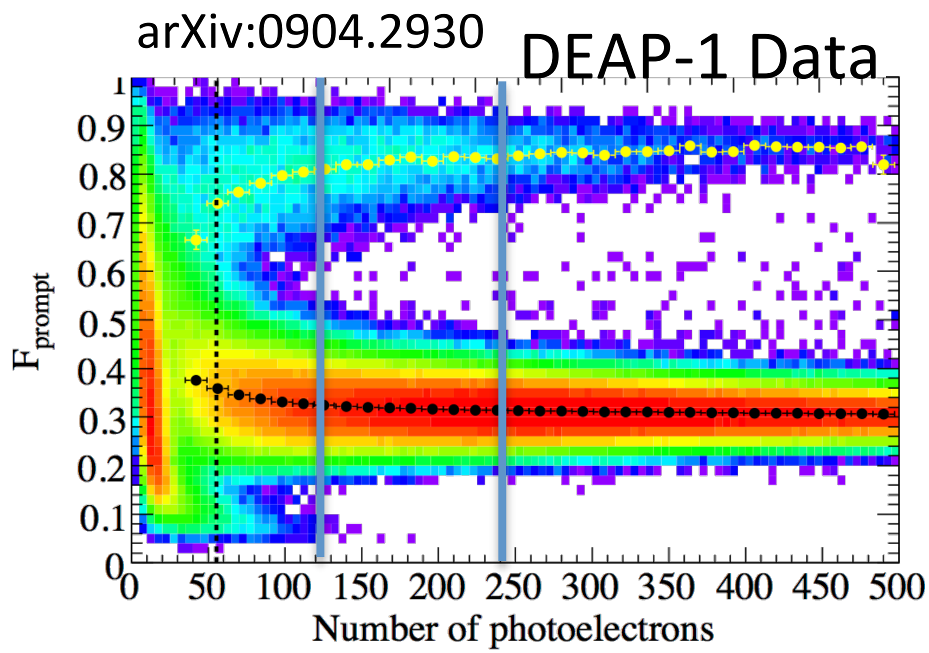
[1] Hitachi A., et al. Phy. Rev. B 27:5279, May 1983

LAr pulse shape discrimination (PSD)

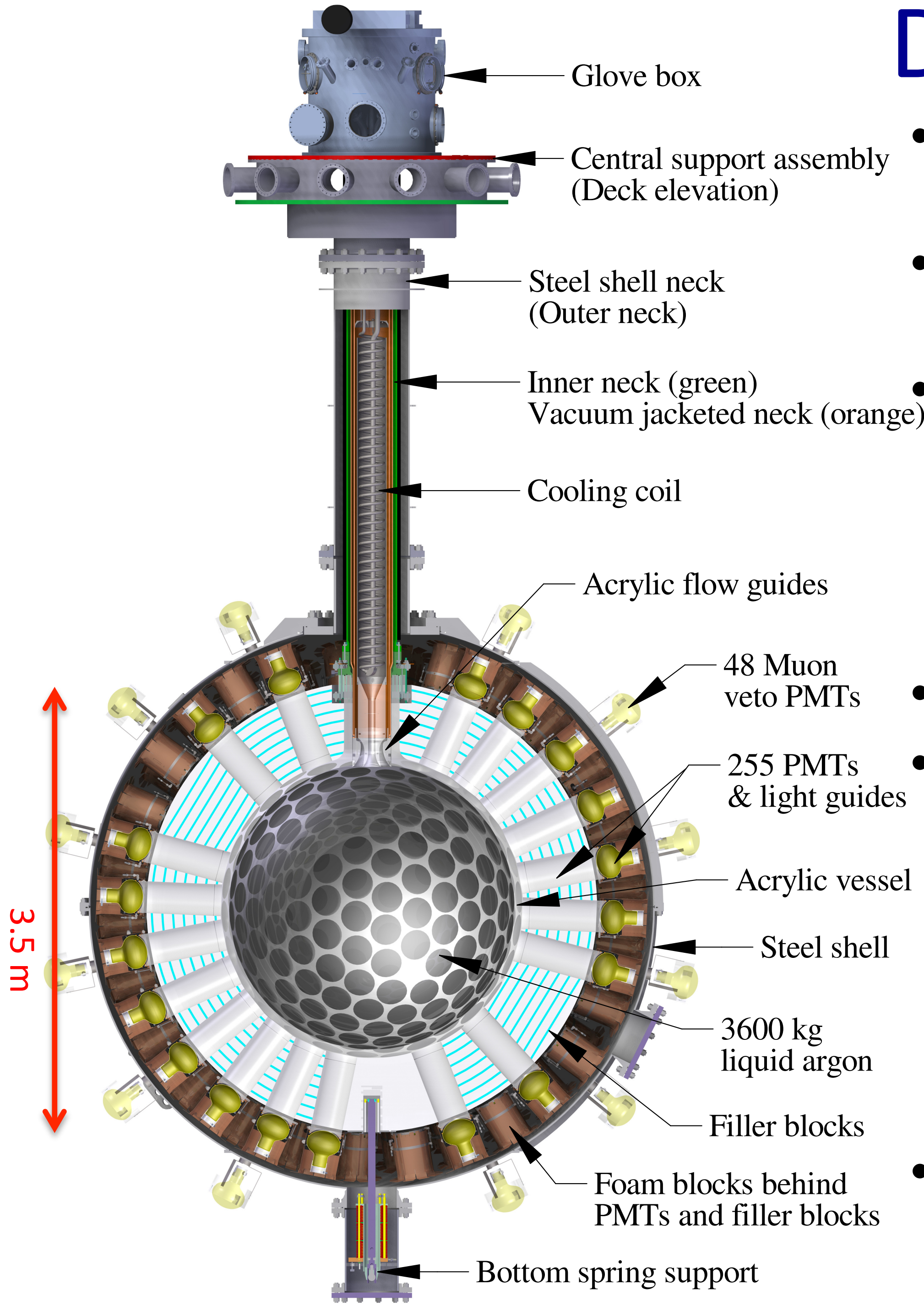




Electronic signal from PMT: photo electron counting ($F_{prompt}=N_{prompt}/N_{total}$)



Single phase LAr: scintillation channel is sufficient to provide excellent PSD against electronic recoil background and no ionization readout is needed

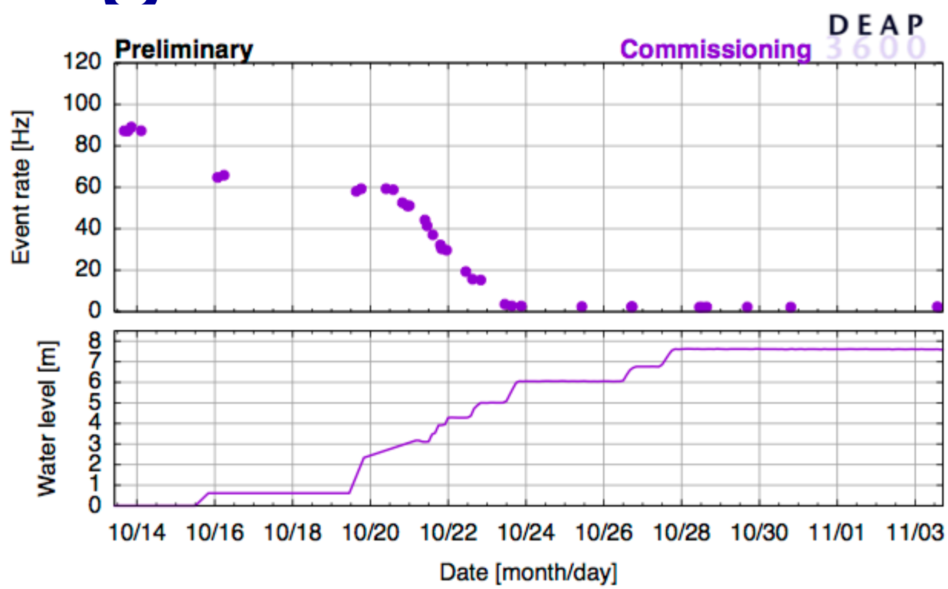


DEAP-3600 detector

- Situated at SNOLAB, Sudbury, ON, Canada
- 3600 kg LAr target (1000 kg fiducial volume)
- Ultraclean Acrylic vessel (AV)
  - Resurfaced in-situ to remove Rn daughters after construction
  - Deposited TPB uniformly on AV (shifting VUV light to blue spectrum)
- 255 PMTs (8”)
- Shielding against
  - Neutrons: Light guides and polyethylene filler blocks
  - Gammas and cosmic muons: 8 m diameter ultra pure water veto tank, instrumented with PMTs, surrounds the steel spherical shell
- 8 PE/keV$_{ee}$ projected light yield

Projected Backgrounds

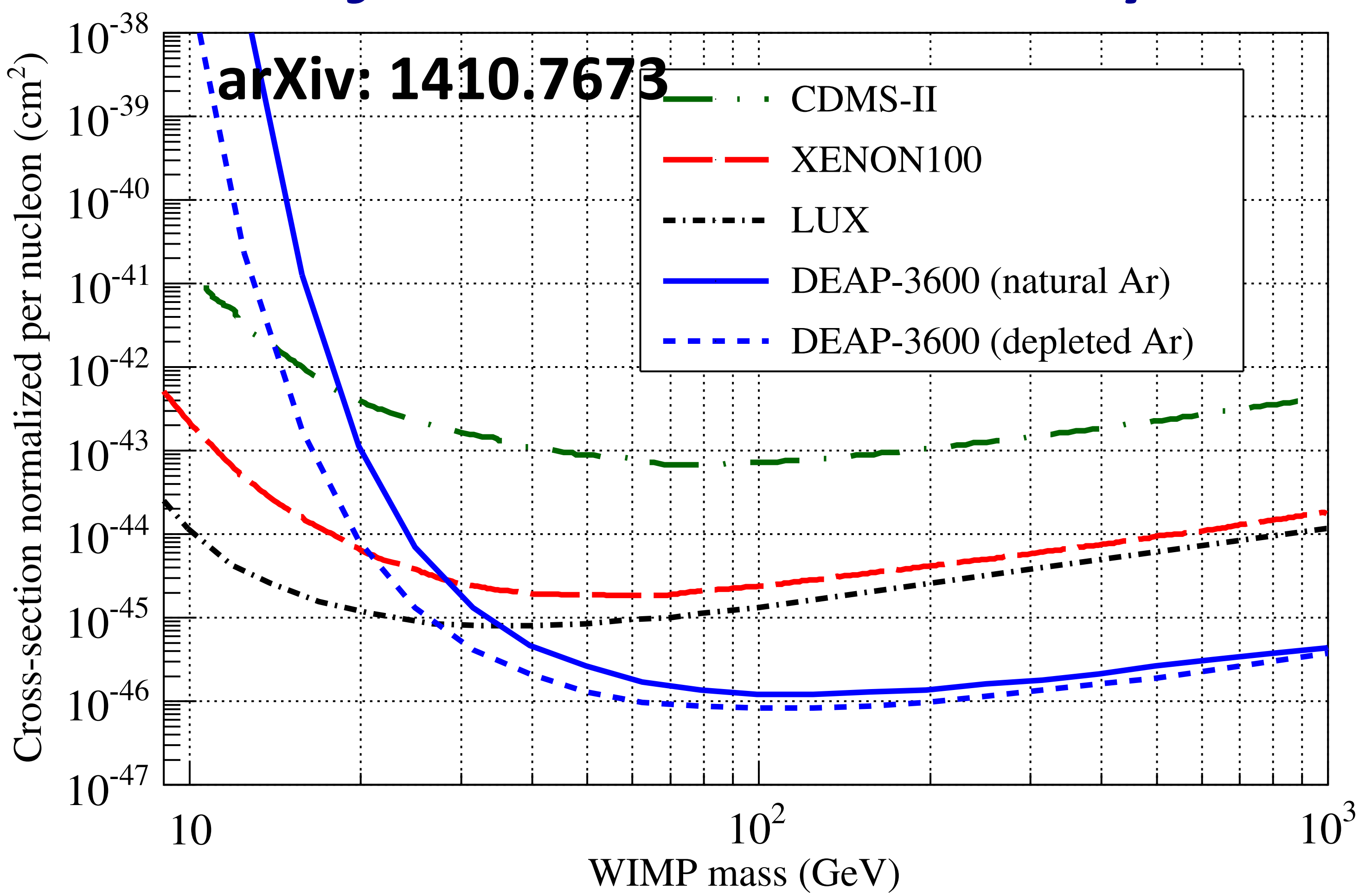
- β/γ events from natural Ar: ^{39}Ar (1 Bq/kg)
  - PSD reduces ^{39}Ar by > 10^{10}
- Neutron recoils: (α,n) fission and μ-induced
  - Controlled by strict material screening and assay
  - Shielding: Light guides and polyethylene filler blocks, instrumented water veto
- Surfaces: Rn daughters
  - Ultra pure AV (^{210}Pb purity < 1.1 x10^{-19} g/g for 0.1 events/3 years)
  - Resurfacing acrylic vessel to reach bulk background levels
  - Passivation of argon wetted components
  - Limited exposure to radon
  - Position reconstruction + fiducialisation
    - See Navin Seeburn's talk



Background	Raw No. Events in energy ROI	Fiducial No. Events in energy ROI (3 years)
Neutron	30	<0.2
Surface α	150	<0.2
Ar-39 (natural)	1.6 x10^9	<0.2

Energy ROI: 60-120 keVr

Projected sensitivity

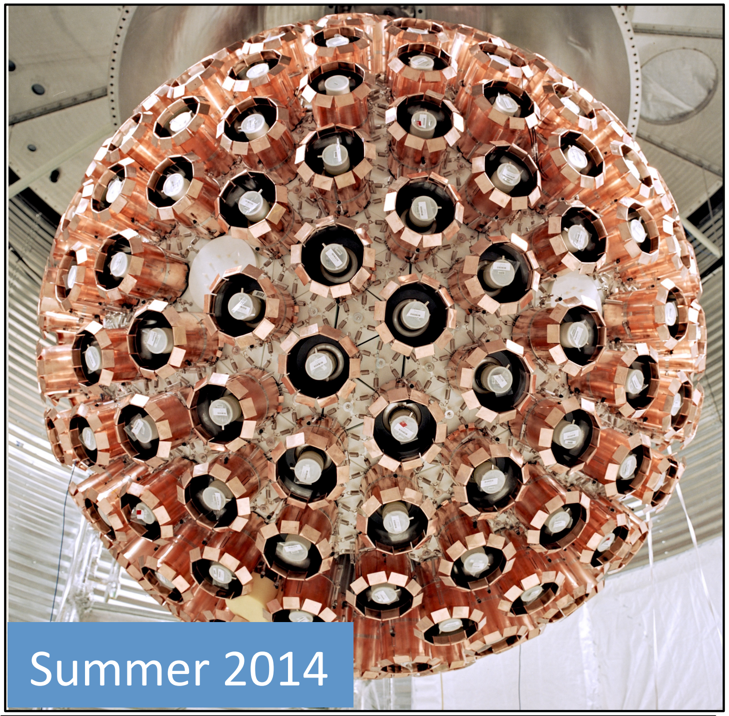


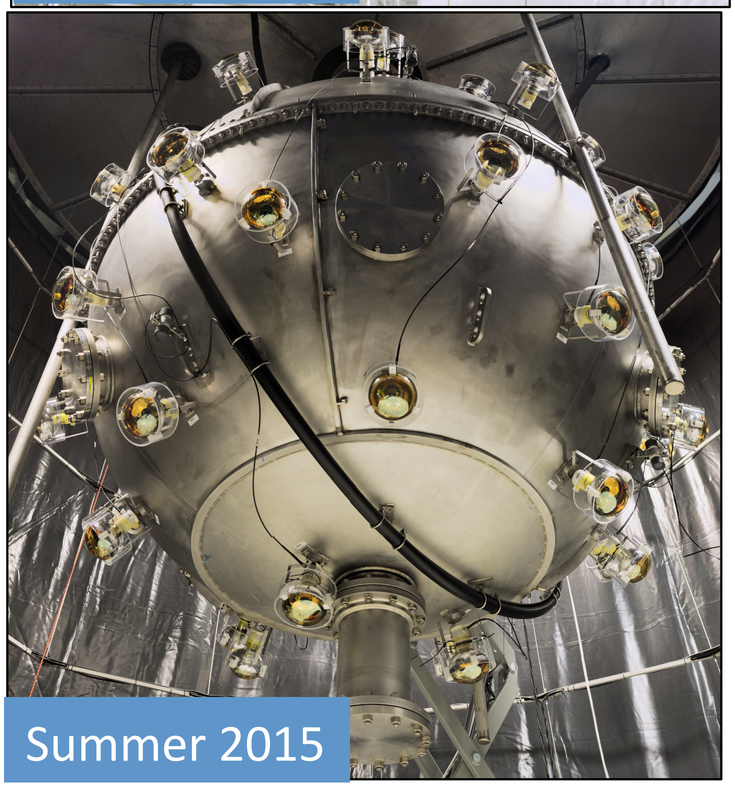
- An Order of magnitude increase in sensitivity over current results[1] at 100 GeV
- 10^{-46} cm^2 sensitivity at 100 GeV for 3 years physics run with a 15 keV_{ee} threshold

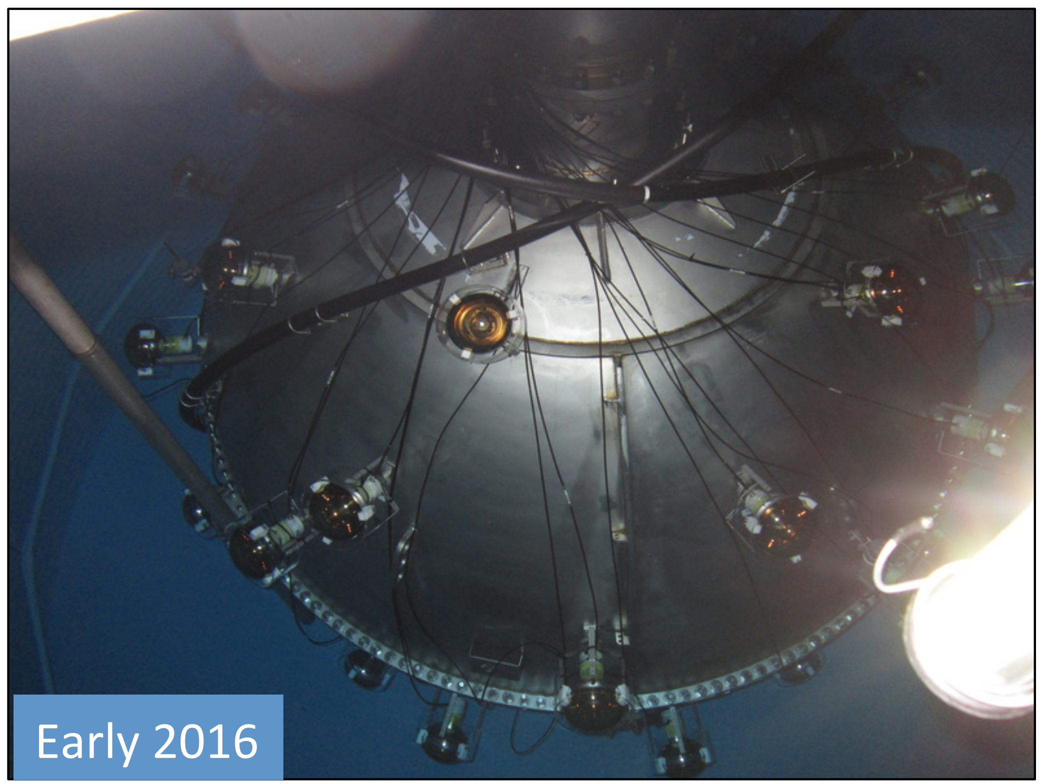
[1] CDMS collaboration, Science 327 (2010) 1619
E. Aprile et al. (XENON), Phys. Rev. Lett. 109 (2012) 181301
D. Akerib et al. (LUX), Phys. Rev. Lett. 112 (2014) 091303

Current status

- PMT commissioning and detector optical calibration data taking since Feb 2015
- Currently cooling down the detector and taking commissioning data with gaseous Ar
- External radioactive source deployment are ongoing
- Physics data taking this spring





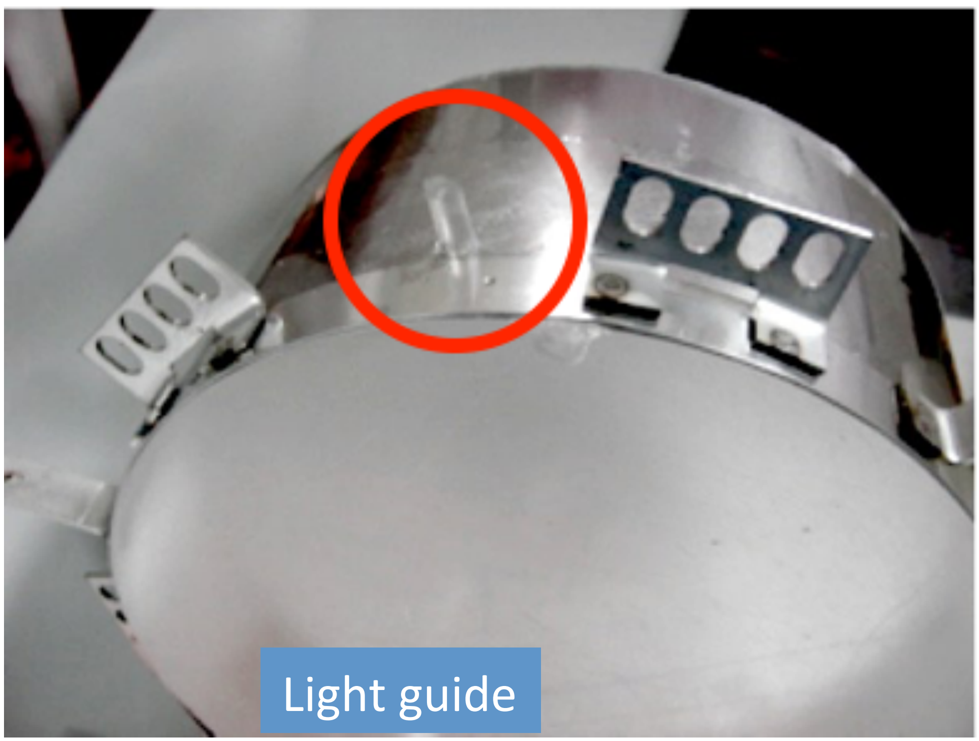


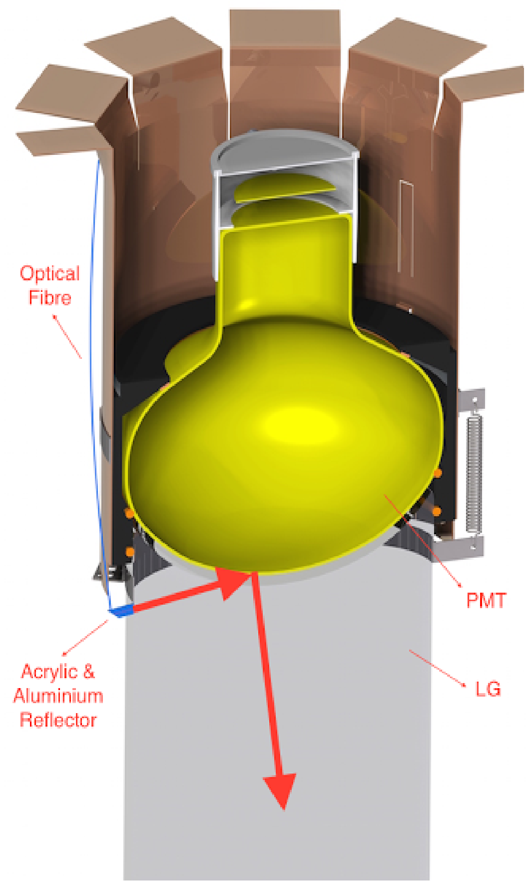
Calibration commissioning

- DAQ has been running since February 2015
- PMT charge and time calibration is now routine
- Light injection system
  - Acrylic and Aluminium Reflectors and Fibre Optics Systems (AARFS) operated
  - Laserball deployed before filling with Ar
- Neutron and Gamma calibration ongoing

AARFS

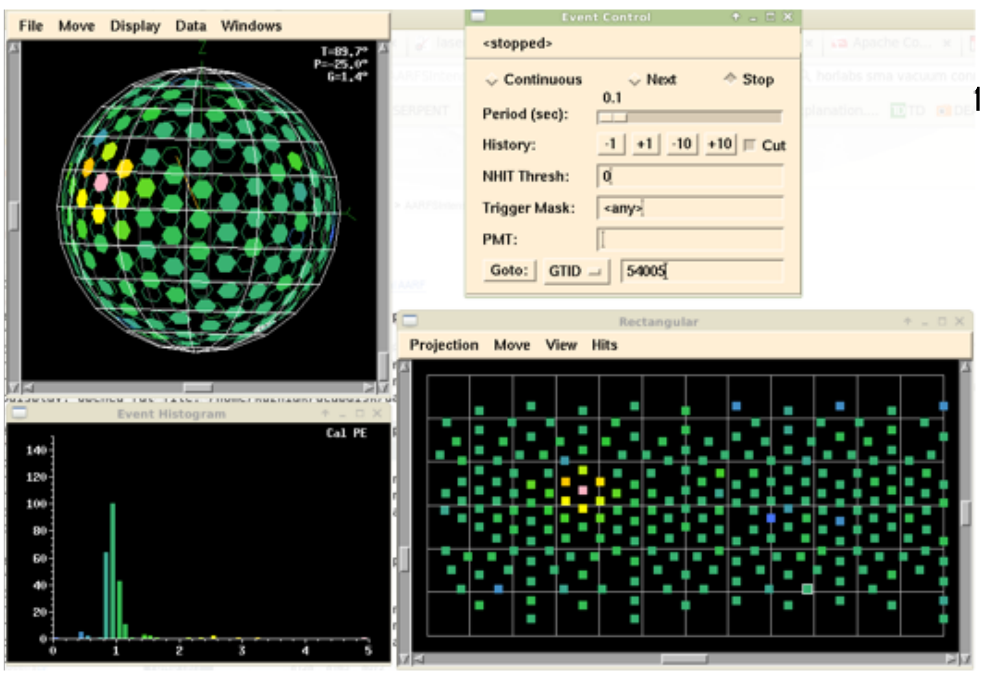
- Aluminium coated stubs bonded to 20 light guides around the detector
- Deliver light via fibres directed at a PMT
- Light is reflected in to the detector
- 435 nm LED
- Non-isotropic light injection



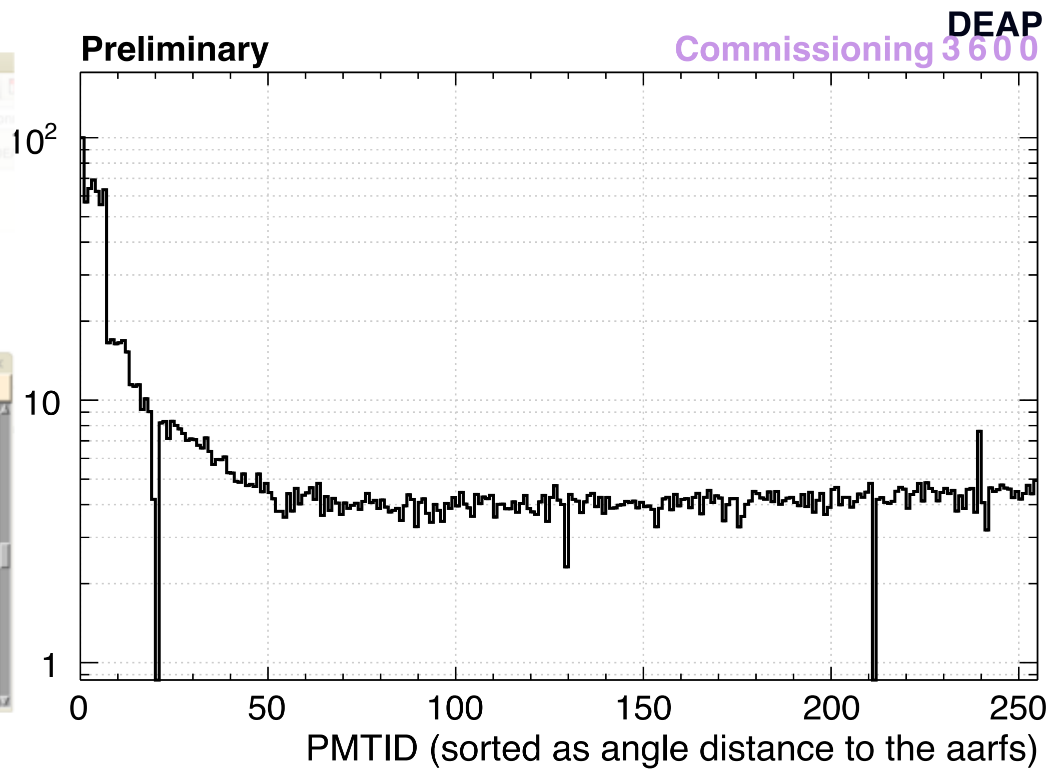


Uses of AARF data

- PMT response
- Scattering optical measurement
- Detector optical stability
- PMT relative efficiency
- SPE calibration



AARF data



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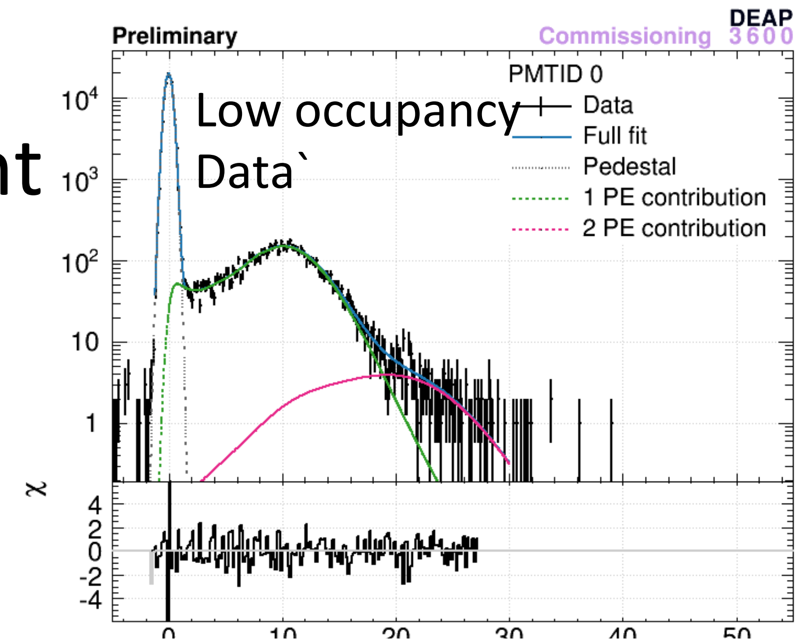
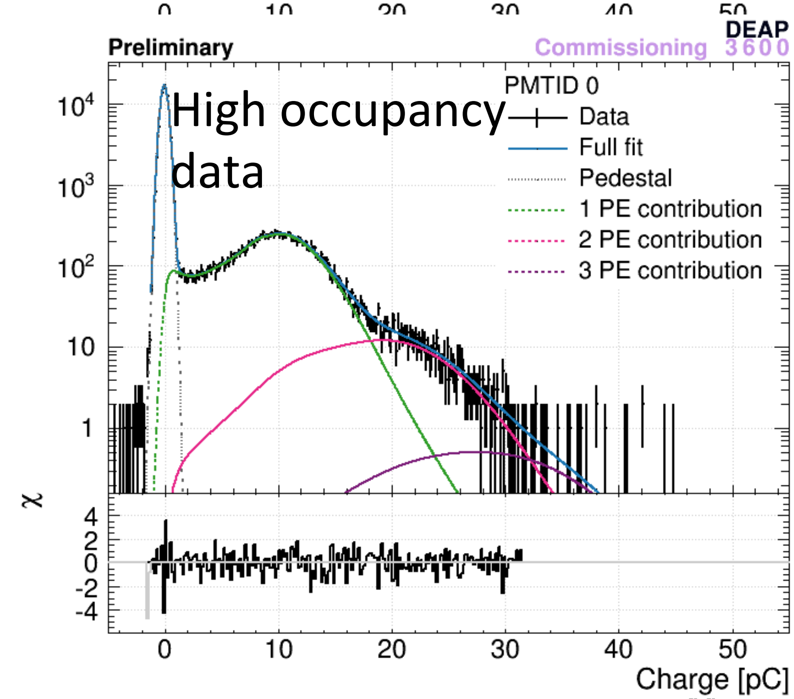


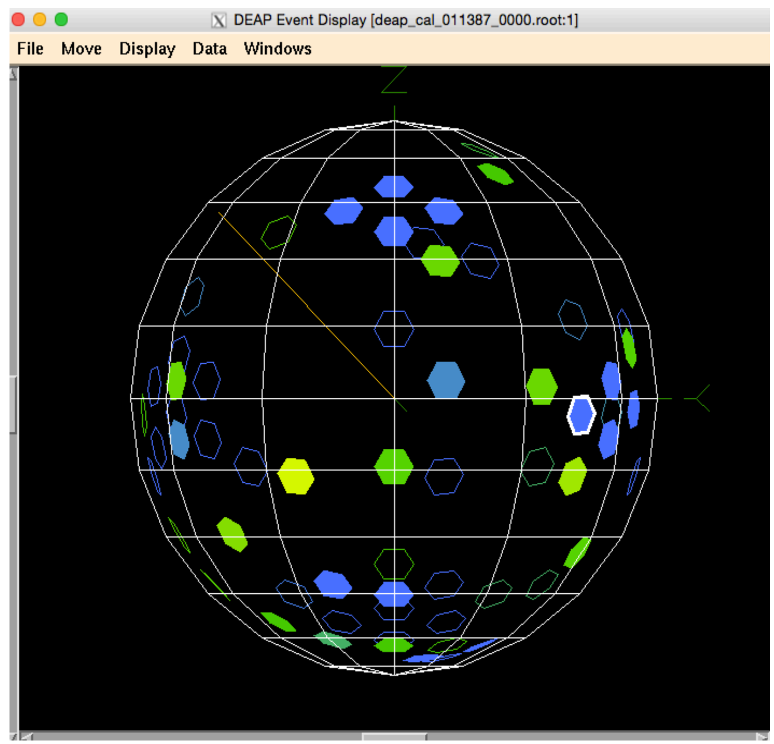
AARF calibration is currently performed once a day in order to monitor detector stability



Laserball

- Made of a PFA flask filled with diffuser
- Deployed at summer 2015
- Multi-wavelength laser system (375 nm, 405 nm and 445 nm)
- Sub-ns laser pulser
- Data collected at different positions and angles
- Isotropic source

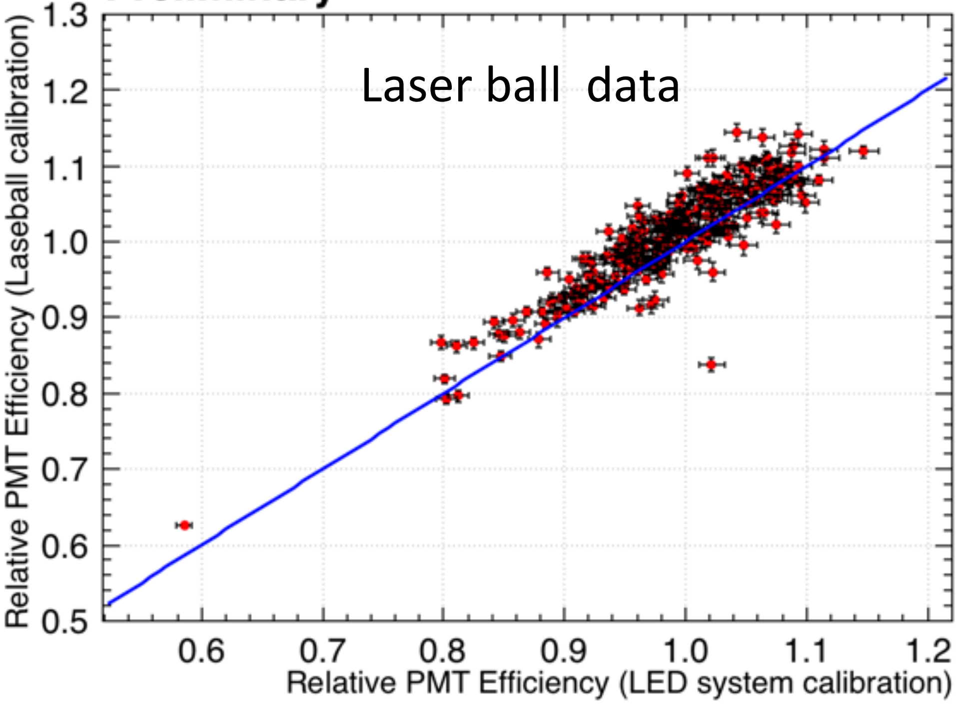
Laserball data



Uses of laserball data

- Relative PMT time offset
- PMT relative efficiency
- Detector optical model

Preliminary



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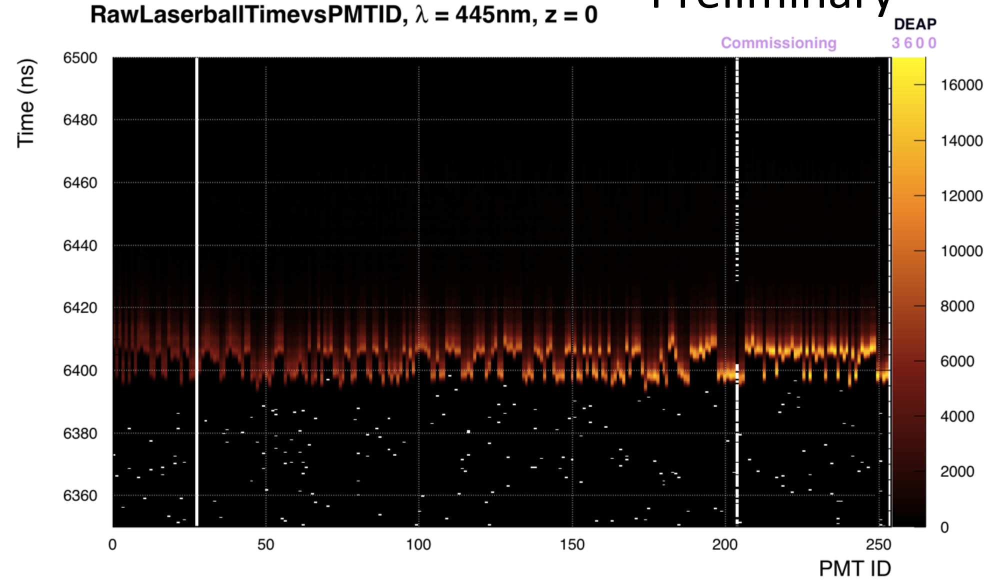
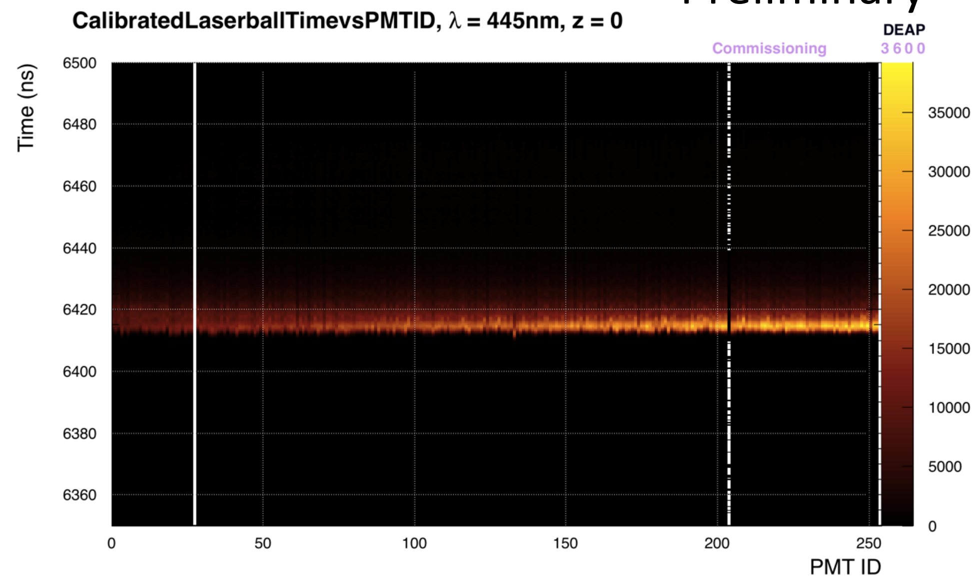


See Franco Lazia's poster

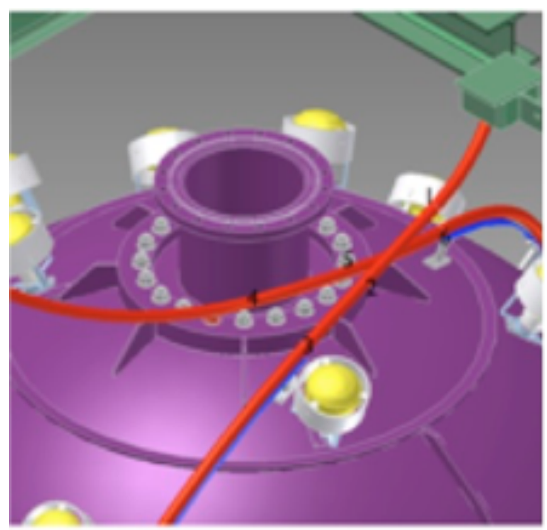
Preliminary

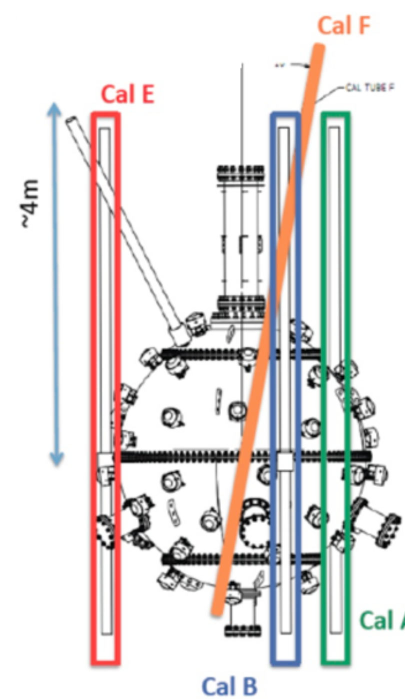


Neutron and gamma calibration

- External Th-232 source has been deployed during vacuum and gaseous runs
- LAr calibration via tagged AmBe and ^{22}Na sources
- Equator calibration via Cal A, B and E
  - Provides equal distance calibration set at different ϕ (azimuth angle)
- Looped tube Cal F
  - Provides equal distance calibration set at different θ
  - Calibration of neck region
- Commissioning and gaseous Ar data taking with AmBe and ^{22}Na sources this month


Gamma and neutron system





Summary and Conclusion

- The construction of the DEAP-3600 has finished
- Cool down is started
- The DAQ and PMTs have been running in a stable configuration since February 2015.
- Extensive calibration program was performed before filling with Ar
- We are fine tuning the optical model of the detector using the optical calibration data
- External calibration data taking is on going
- Will start physics data taking this spring