Event reconstruction in DEAP-3600 at SNOLAB

Sumanta Pal, University of Alberta
(on behalf of the DEAP-3600 collaboration)
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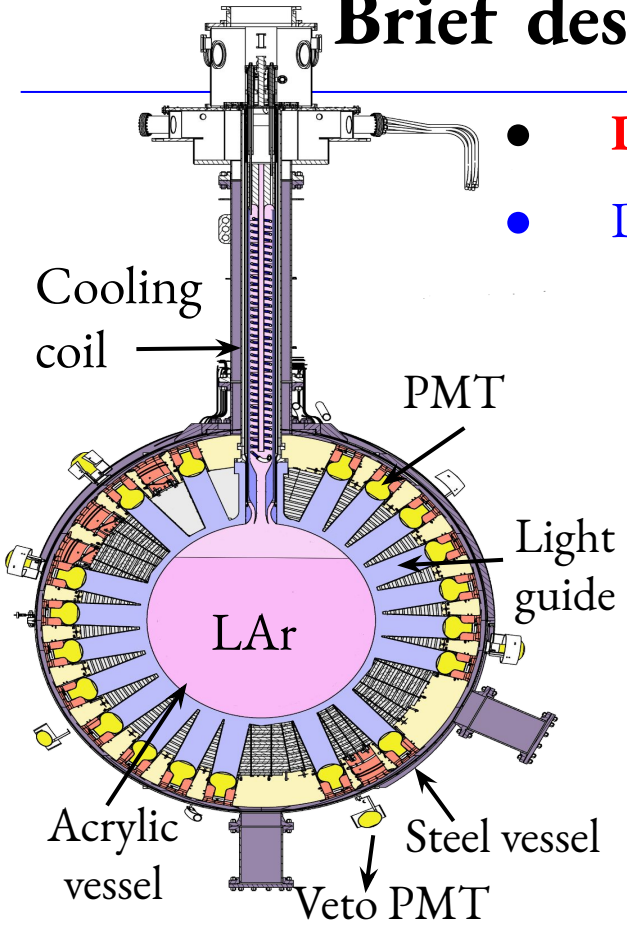
DEAP 3600

UNIVERSITY OF ALBERTA

Brief description of the DEAP-3600 detector



- **D**ark matter **E**xperiment with **A**rgon **P**ulse-shape discrimination
- Direct detection of Weakly Interacting Massive Particles (WIMPs)

- A single phase liquid argon (LAr) detector;
  - target mass ~3 tonne [1]
- Ultraclean Acrylic Vessel (AV) inner diameter 170 cm
- Search for LAr scintillation light signal due to argon nuclear recoils by WIMP dark matter
- TPB wavelength shifter on the AV surface: UV light (128 nm) → Visible light (420 nm) [2]
- 255 Hamamatsu R5912 HQE PMTs 8-inch dia
- PE detected (light yield): (6.1± 0.4) PE/keV_{ee}

[1] *Astroparticle Physics, Vol 108, March 2019, P 1-23*
[2] *JINST 12 P04017 (2017)*

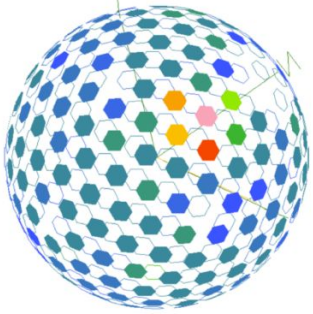
Event Reconstruction Techniques

- Determine the position of an event by fitting charge/timing information of the light signal recorded in a PMT

Two independent algorithms are developed

No. of photons-based algorithm

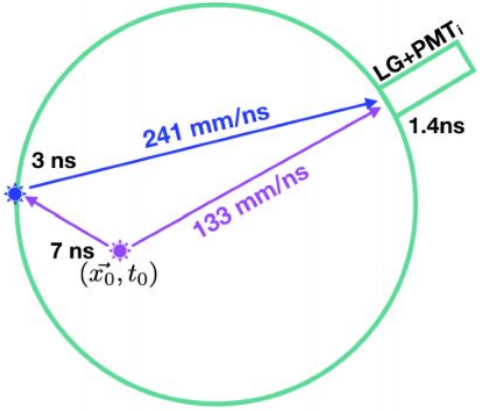
- Assume a single source of light
- Light intensity (therefore PEs in PMTs) ~ $1/r^2$
- Probability density functions (PDFs) trained with MC based on detailed optical model and PMT calibration
- Use all lights from 0-10000 ns



See Chris Jillings's talk: 'Pulse-Shape Discrimination in DEAP-3600'

Time residual-based algorithm

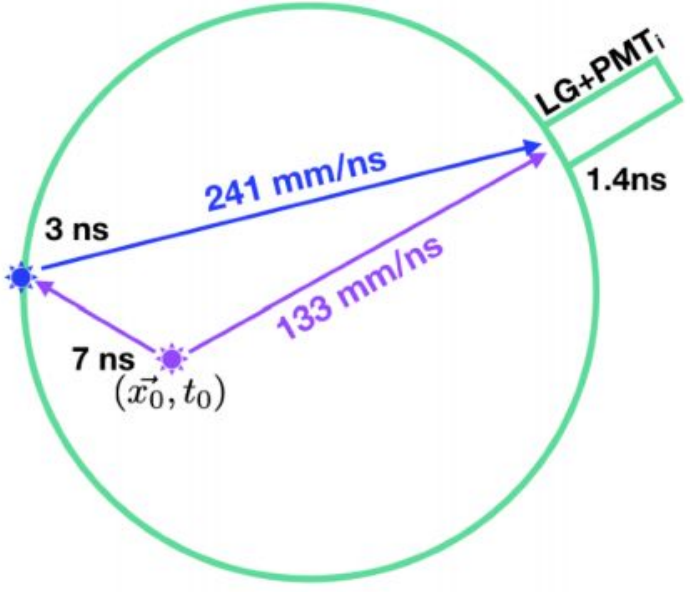
- Assume a single source of light
- Photon arrival time = event time + time of flight (TOF) + time delay (dimer decay, TPB response, PMT response)
- ONLY first 40 ns prompt light is considered because TOF dominates the time distributions.



Time residual based algorithm

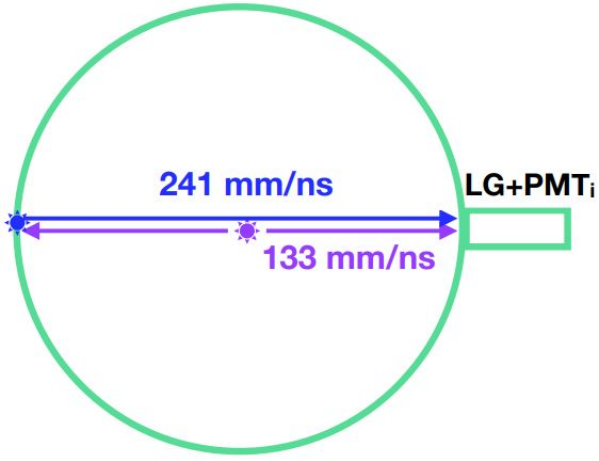
- Fit with intensity and time of arrival for the first 40 ns of prompt light
- Group velocity of UV light = 133 mm/ns
- Group velocity of visible light = 241 mm/ns
- Construct PDFs for light emitted at vertex x_0 and event time t_0 given PMT_i measures charge q_i

$$L(\{t_i, q_i\}; \vec{x_0}, t_0) = \prod_i P_i^{q_i}(t_i; \vec{x_0}, t_0)$$



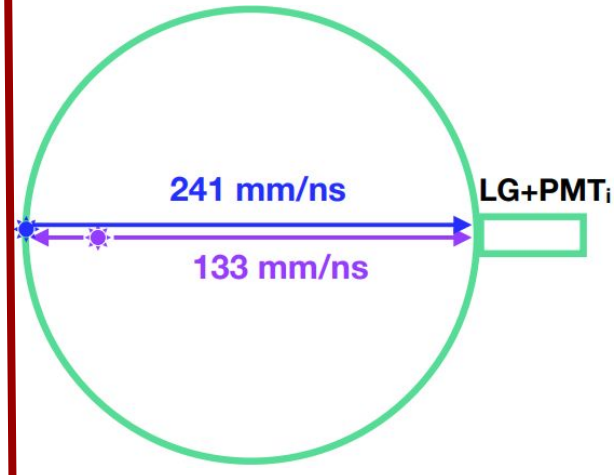
- Fit (x_0,t_0) by maximizing the likelihood function
- Convolve singlet decay time (7 ns), TPB response time (3 ns), and PMT/Light Guide (LG) response time (1.4 ns)

Event Topology



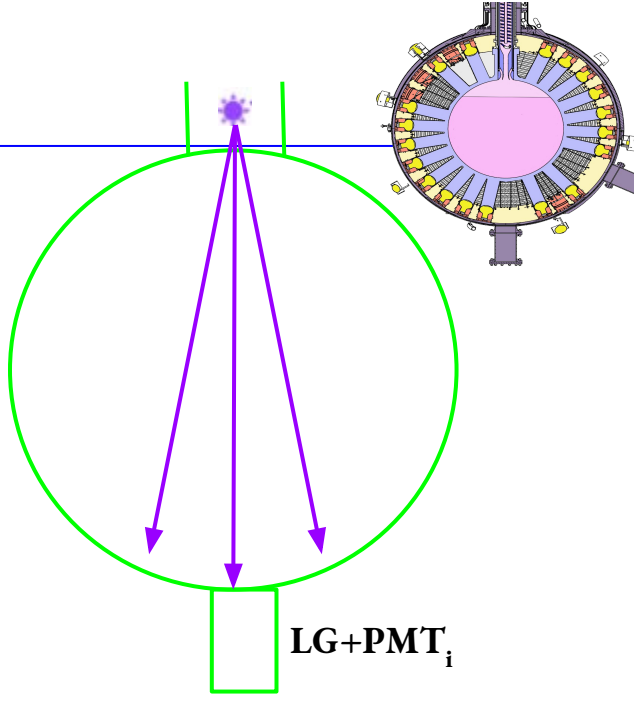
Events at central area:

- UV light always arrives first



Events relatively near AV surface

- Visible light arrives first to the far side PMTs
- Distinct time profile at some PMTs

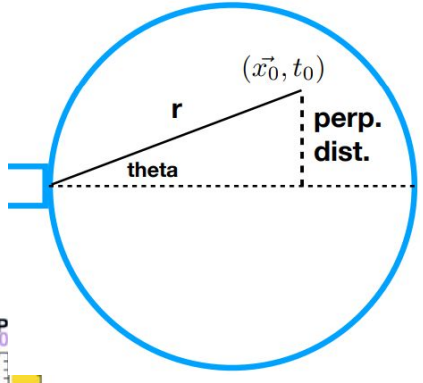


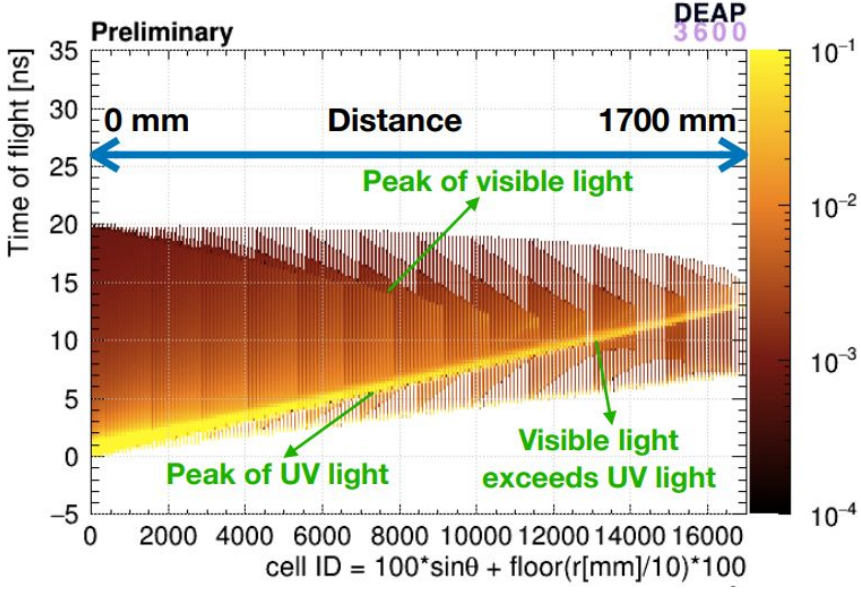
Events at the neck

- Visible light isotropically distributed to all PMTs
- Charge based reconstruct at lower z than time based.

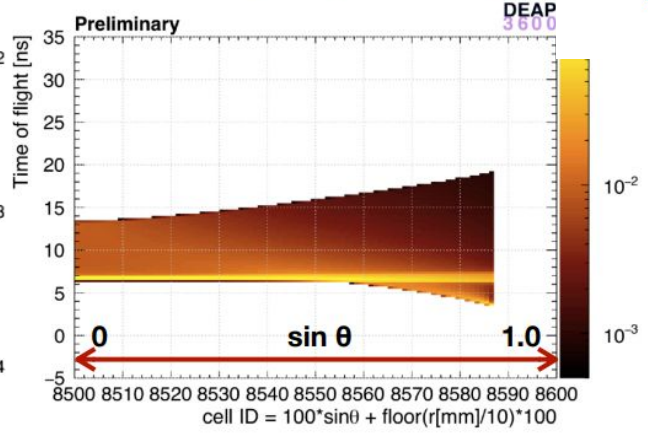
Construction of PDFs

- A grid of cells are defined in a coordinate system of distance to the light guide (LG) and the perpendicular distance away from the LG axis
  - with 1 cm spacing along distance and 0.01 spacing varying sin(θ)
- PDFs (proportional to photon intensity) as functions of time-of-flight (TOF) for each cell are calculated
- PDFs are interpolated at any sin(θ), and radius
- Cells are organized as the IDs shown below

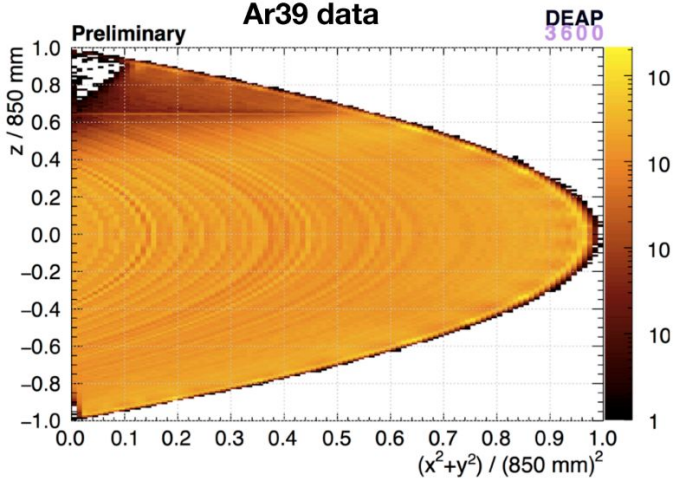


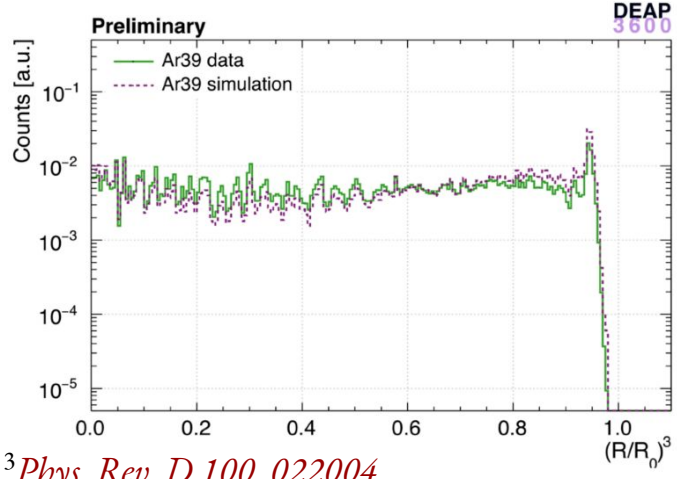


Part in range of [8500, 8600]

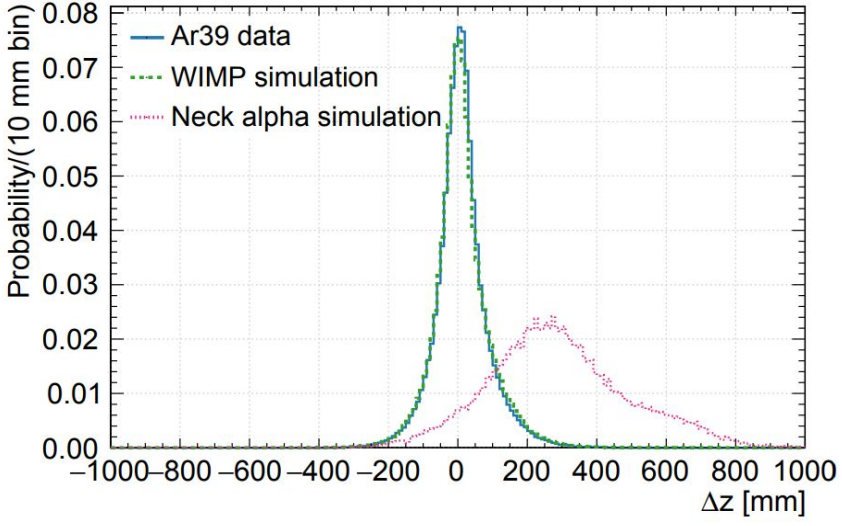


Reconstructed positions of Ar39 with photon timing algorithm





- Reconstructed positions of Ar39 events shows good uniformity overall



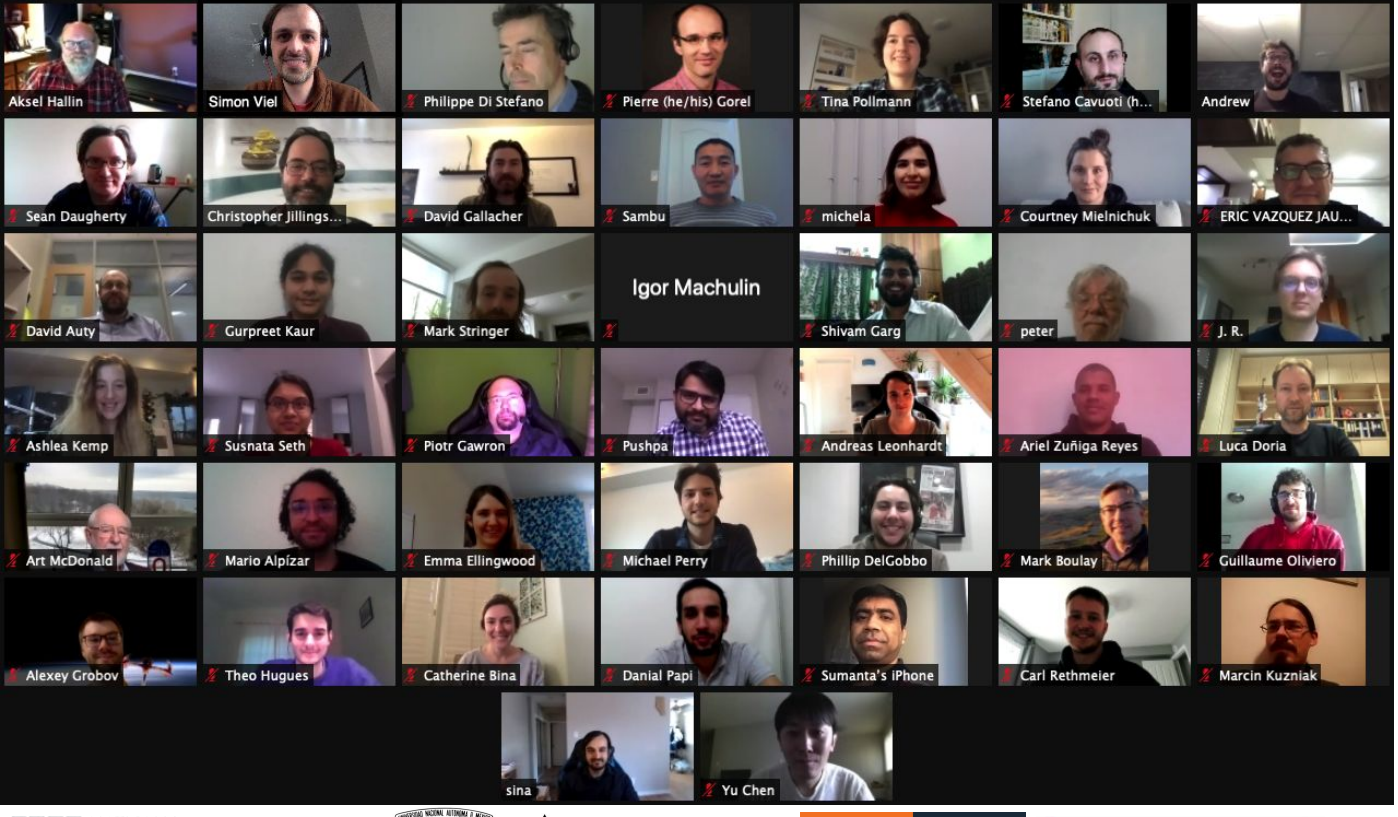
- Δz : difference between reconstructed z from two algorithms; time-residual based vs number of photons based algorithms[3]

[3] *Phys. Rev. D 100. 022004*

Summary and Current status

- Timing based position reconstruction performs good.
  - It is advantageous to neck events where charged based reconstruction method is insufficient.
- Several analysis tasks are ongoing to improve the Time-residual based position reconstruction
  - Algorithms to include
    - Dust hypothesis
    - Neck hypothesis
    - Electrostatic discharge events
    - Details of liquid-gas interface
  - All these algorithms complicates the PDF.

..... ***Thank you for listening*** .....



DEAP Collaboration: 95 Researchers in Canada, Germany, Italy, Mexico, Poland, Russia, Spain, UK, USA