Calibrating IceCube track reconstructions by using DM-Ice coincident events (2012-2020 data)
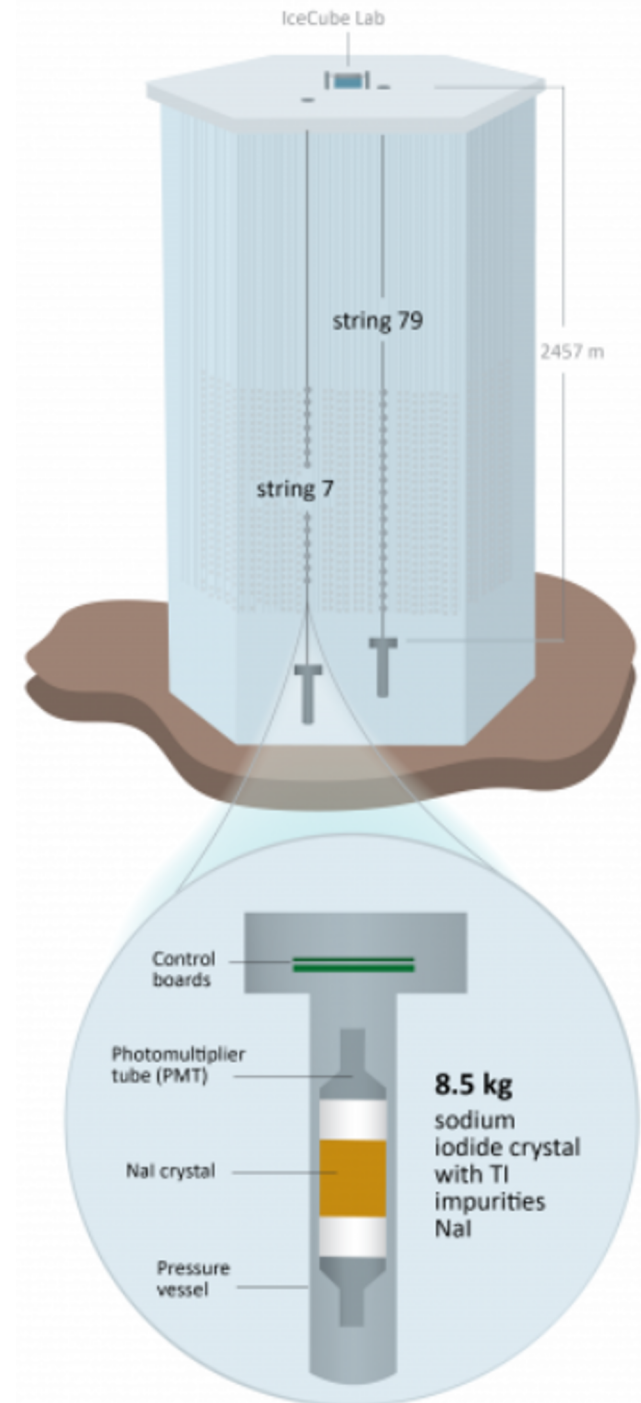
outline

1. Introduction
2. Previous analysis of DM-Ice17
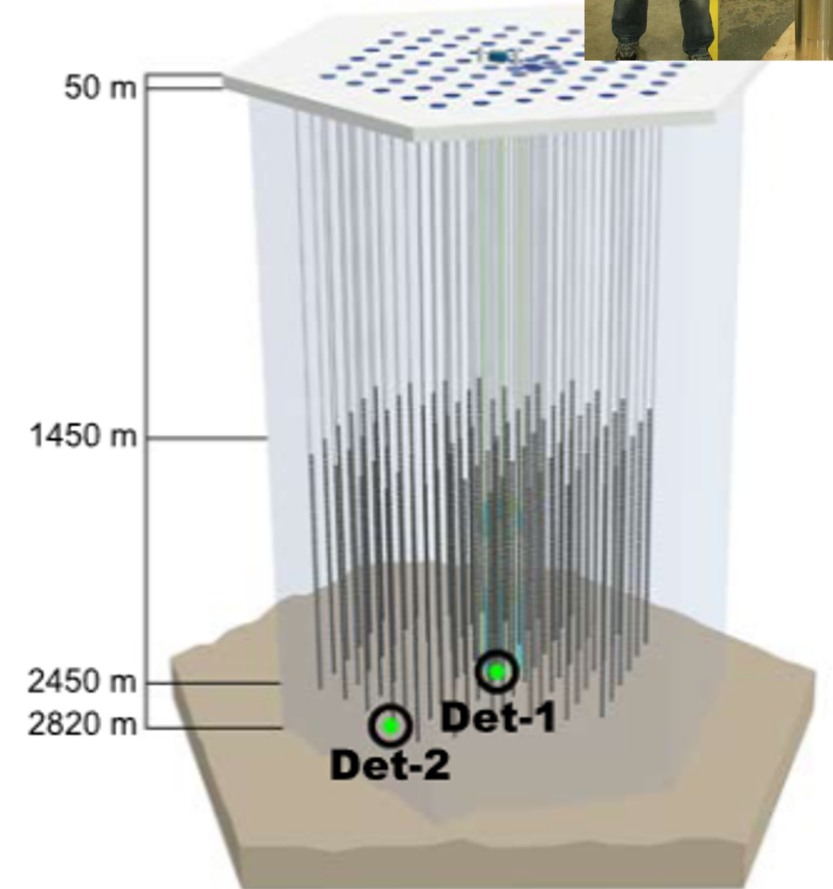3. DM-Ice for the Gen2 calibration
4. Current and planned work with DM-Ice17

Rogan Clark, Antonia Hubbard, Teppei Katori, Matt Kauer

Kings College London, Lawrence Livermore National Laboratory, University of Wisconsin-Madison

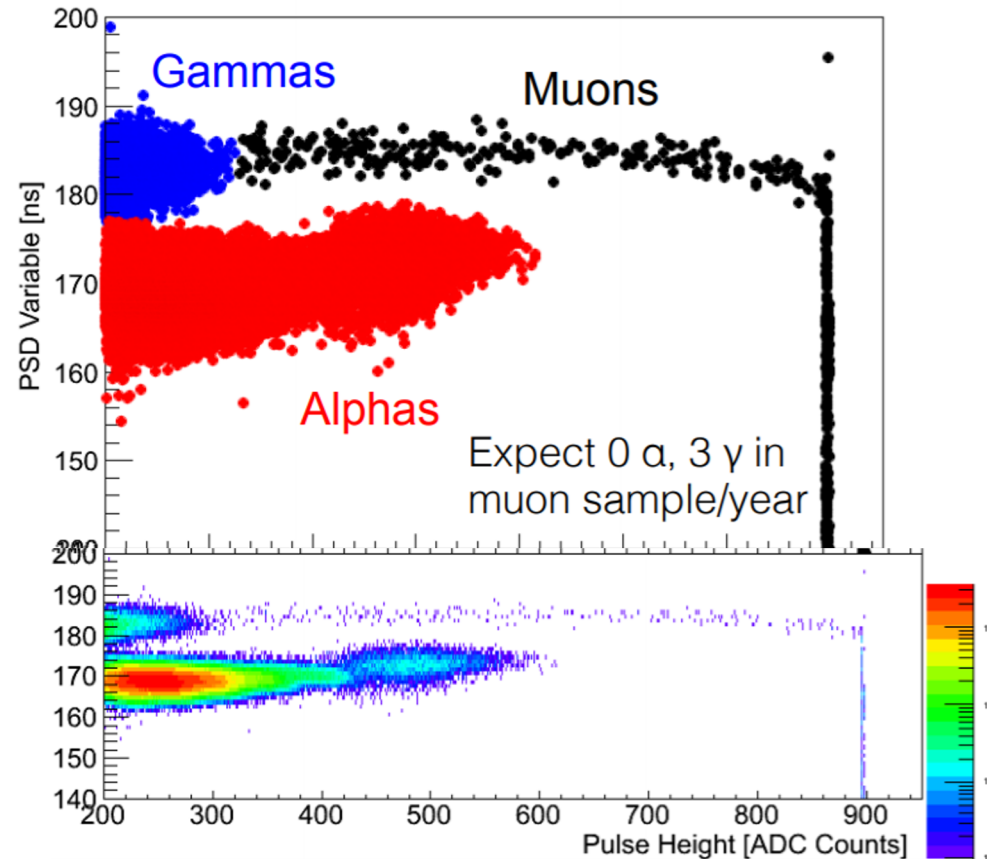IceCube-Gen2 calibration workshop, April 7, 2021
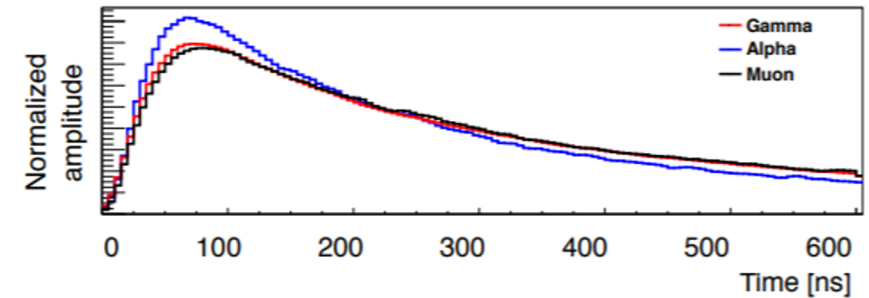
Outline

1 DM-Ice17: The Basics

- A pair of 8.5kg NaI(Tl) crystals located at the bottom of Strings 7 and 79, each optically coupled to 2 PMTs

- Initially installed for check of DAMA-LIBRA data modulation

36 cm

2 IceCube mainboards

5" NaIAD PMT

1.0 m

NaIAD NaI Crystal (8.5 kg)

SS Pressure Vessel

50 m

1450 m

2450 m
2820 m

Det-1

Det-2
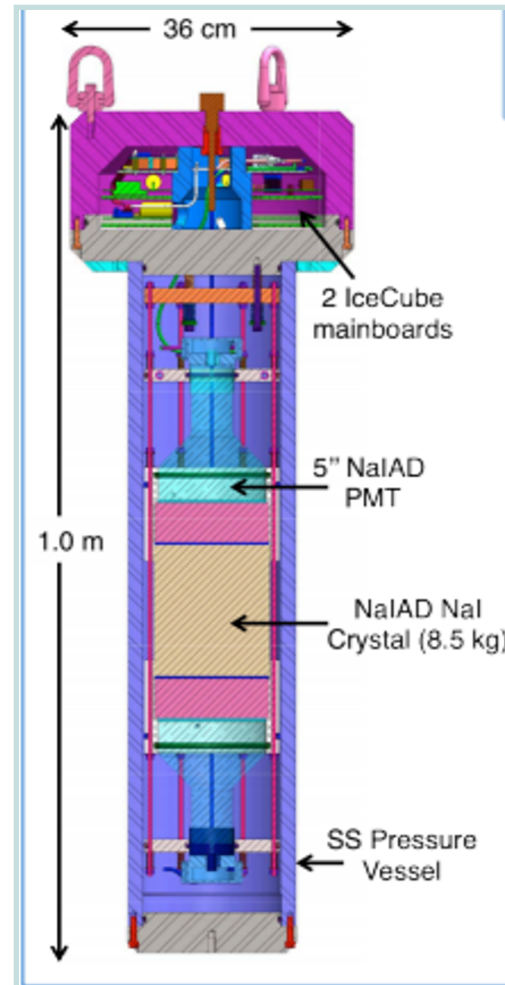
1 Pulse shape Particle Identification

Gammas

Muons

PSD Variable [ns]

Alphas

Expect 0 α, 3 γ in muon sample/year

Pulse Height [ADC Counts]

Muons are identified with their high energy depositions and pulse shape variable using the pulse height (h_i) at time (t_i):

$$\tau = \frac{\sum h_i t_i}{\sum h_i}$$

Normalized amplitude

— Gamma
— Alpha
— Muon

Time [ns]

<1 alpha per year
<3 gammas per year

Outline

5

2.Existing Studies

- https://wiki.icecube.wisc.edu/index.php/DMIce_Coincidence
- https://indico.cern.ch/event/378423/contributions/900461/ (VLVnT2015)
- 2.93±0.04 muon candidates per crystal per day
- 55% (Det1) and 30% (Det2)of DM-Ice muons had IceCube coincidence
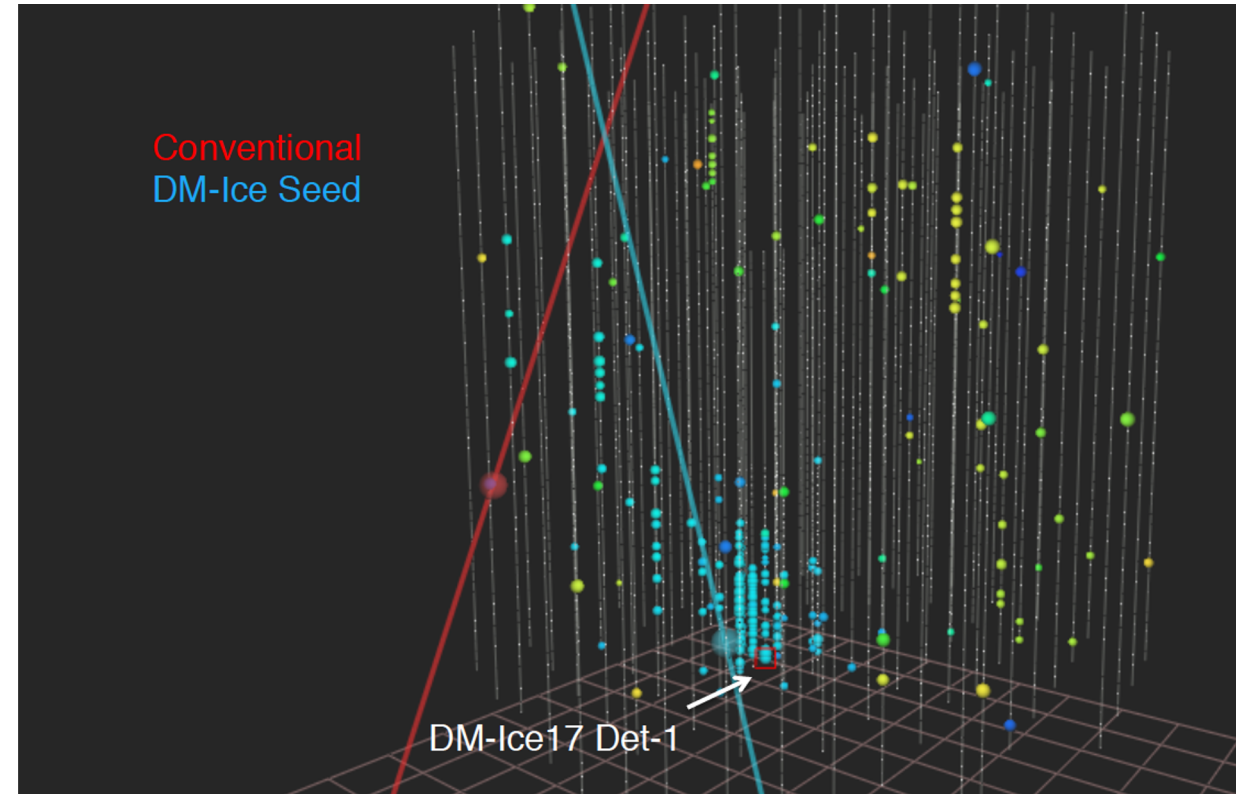- Muon annual modulation 12.3±1.7% is measured
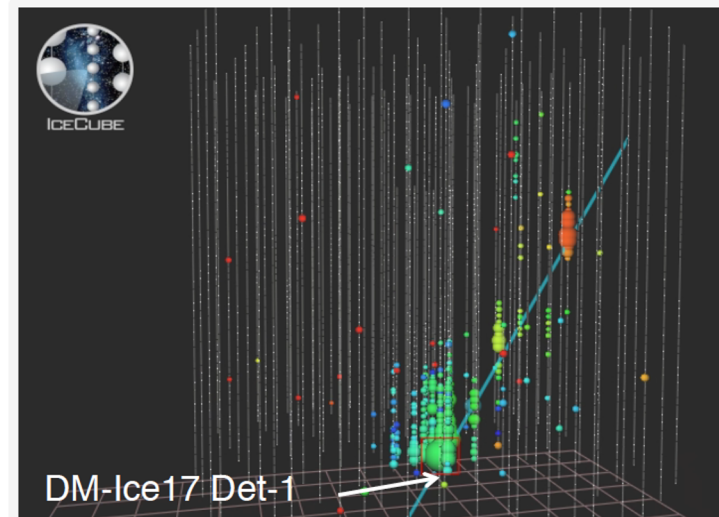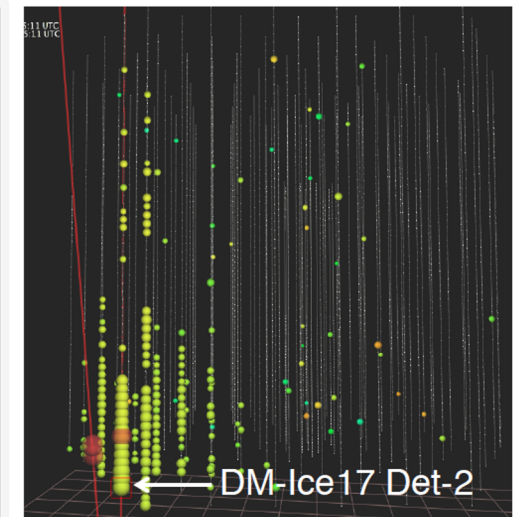
2.Track reconstruction studies

- DM-Ice17 tagged muons can be used to calibrate track reconstruction algorithm

- Zenith and azimuthal angle reconstruction biases can be studied from DM-Ice tagged muons (using DM-Ice hit as a seed, or force the reconstruction to pass it, or penalize the fit)

Conventional
DM-Ice Seed

DM-Ice17 Det-1

Outline

3.Moving into Gen2

- Two modules, at the bottom of strings 88 and 90
- Substituting for 250kg weight on other strings
- We see ~3 muons/day/det in DM-Ice17, ~ 34 muons/day total over both central modules

Penetrator

mDOM MB + ICM

4 PMTs

4 crystals ~12kg each

4 PMTs

Physics region

mDOM
DEgg
pDOM
POCAM
FOM
WOM
LOM
Pencil Beam

DM-Ice200

3.Moving into Gen2

- For IceCube calibration, would also be nice if we had something more able to track horizontal events (to improve azimuthal angular resolution).
- Potentially a DM-Ice-like module in the middle of the string?
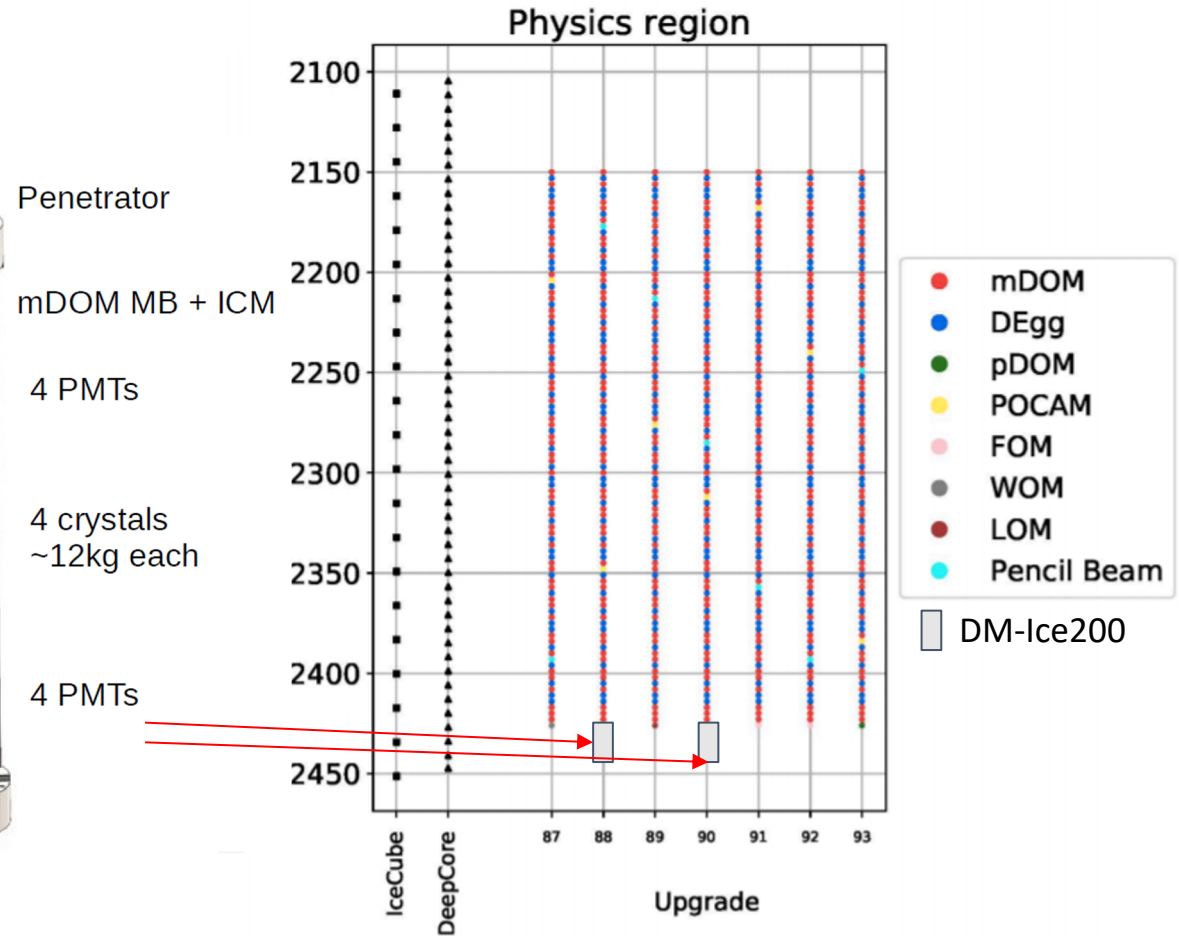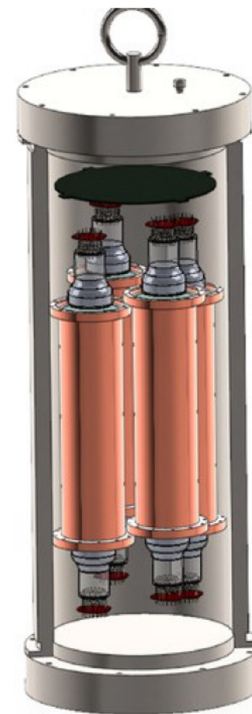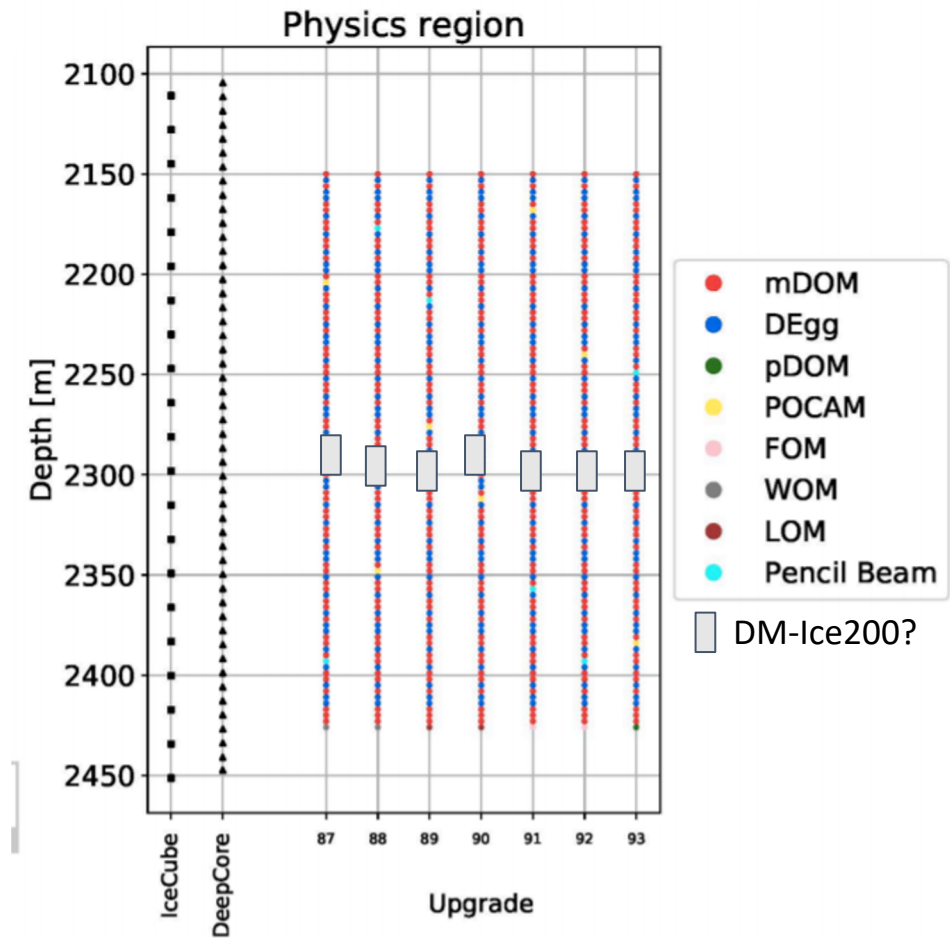
Outline

1. Introduction

2. Previous analysis of DM-Ice17

3. DM-Ice for the Gen2 calibration
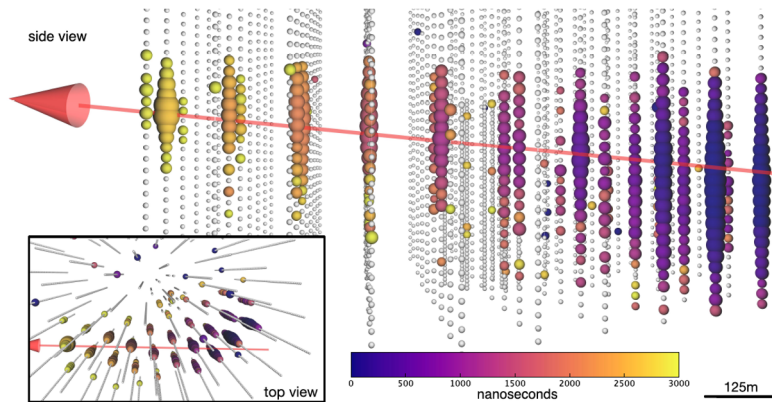
4. Current and planned work with DM-Ice17

4.Current and planned Work

- Focused around reworking muon tagging process created by Antonia to work on data post Feb 2015, following which several changes were made to DM-Ice17 operations
- Study track reconstruction bias using DMIce-IceCube coincidence events
- Search for DMIce-IceTop coincidence events

4 High Voltage increase

- In 2015, voltage on detector 1 (String 79) was increased, meaning the atwd1 channel saturates for all types of events - can no longer distinguish muons

- Using atwd2 for this detector for this time period, can achieve reasonable separation
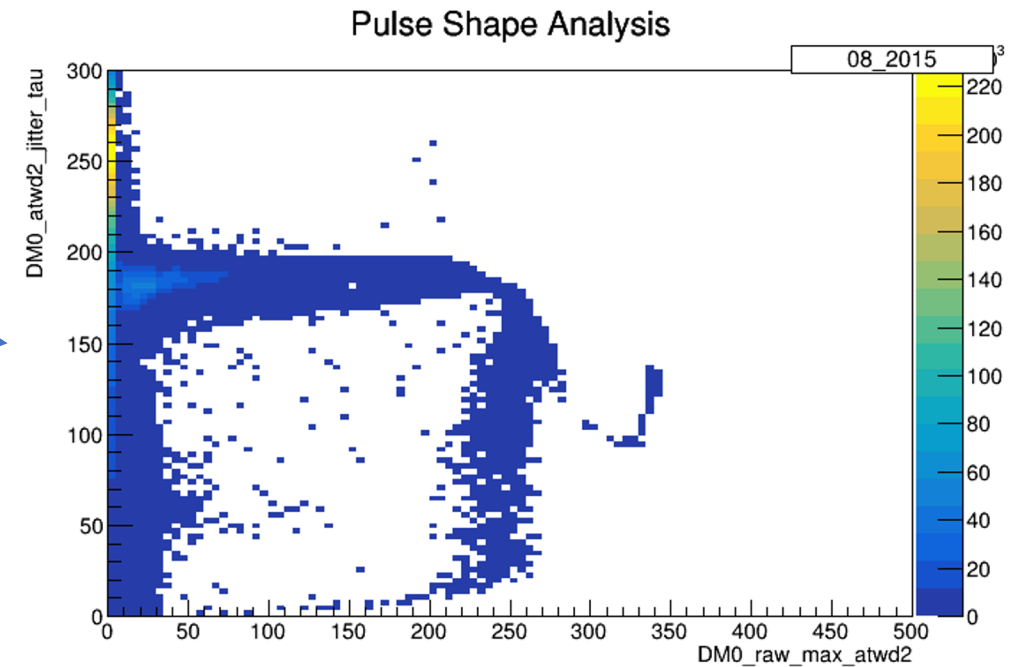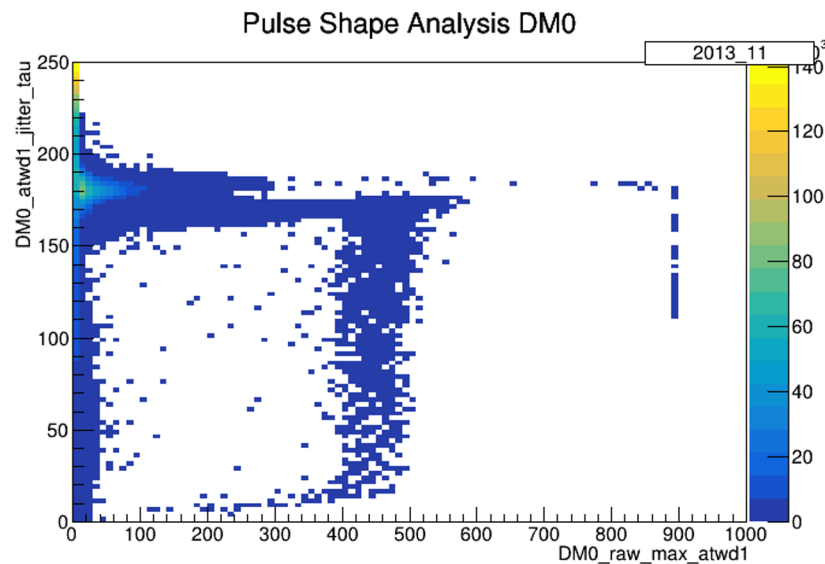
4 Low Peak dropout

- Omicron DAQ (installed in Feb 2016) contains a cut on atwd0 channel such that only high energy events in atwd0 are recorded in atwd1 (Same for atwd2 with atwd1)

- Low energy spread across all tau comes from EMI and caught darknoise

- Present in all DM-Ice PMTs
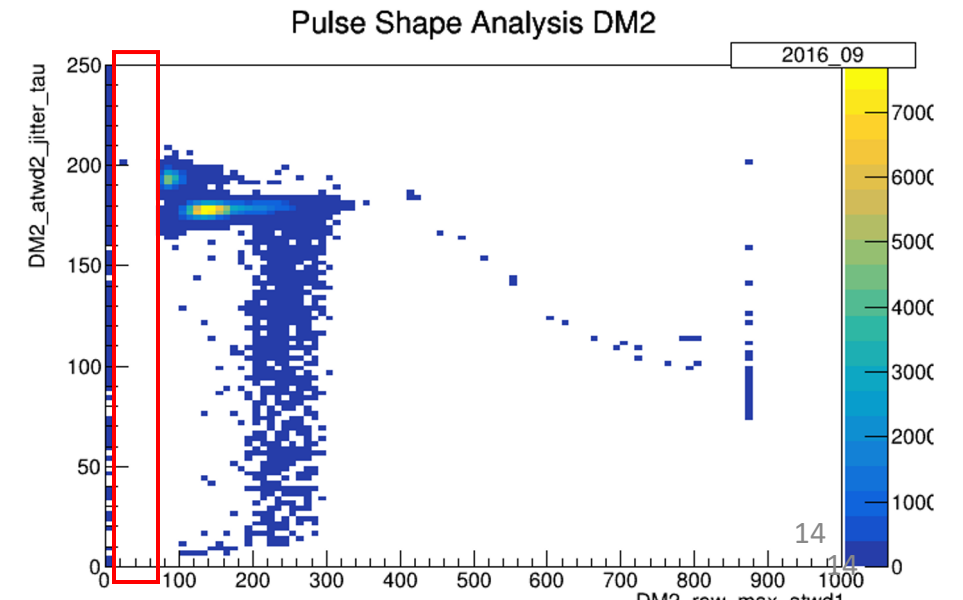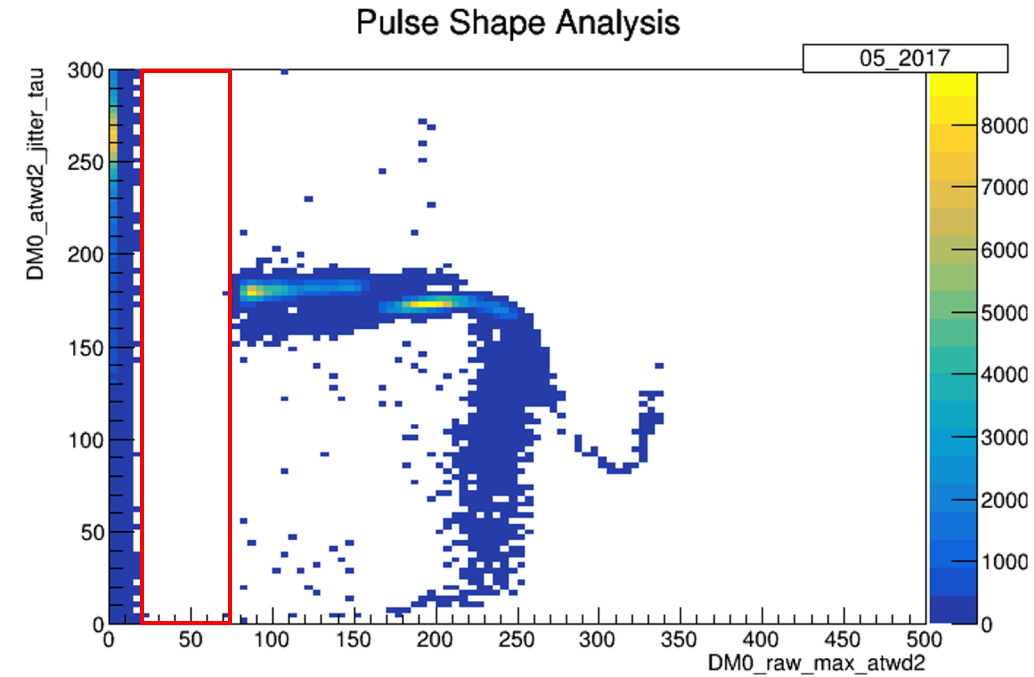
4 Splitting of muon line
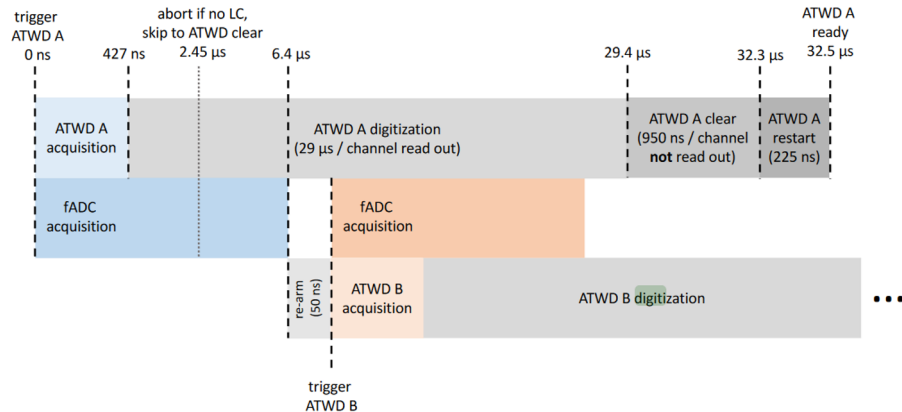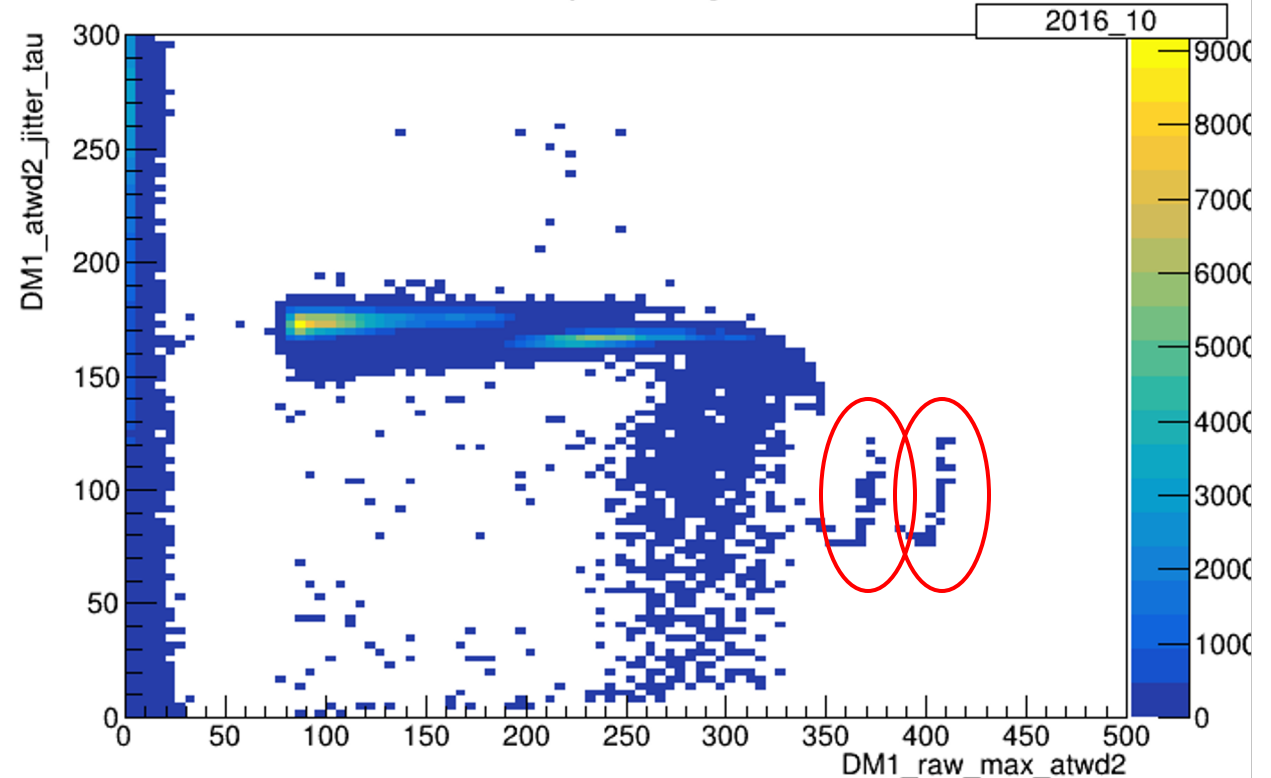
- Only obvious in PMT 1 (det1) and PMT2 (det2) – not in PMT 0 or 2
- Suggested to come from atwd0 bleeding into the lower amplification channels, with different level of bleed in each digitisation chip, accounting for both lines
  - Different level of effect in different PMT, accounting for no change in PMT0 and 3

4 Possible Improvements to Current Tagging

- Bismuth Polonium event cut
  - Could result in better purity when making parameters for finding muons from by making them easier to distinguish
  - Would rely on unique BiPo decay trace in PMTs

- Leap Second fixes
  - DM-Ice17 currently runs on its own timing setup
  - Could be better integrated with IceCube for future coincidence work

4 Using tagged muons in reconstruction

- Previous tests done with incorporating coincident events into MPEFit, either as a seed (bad), forcing the fit to go through DM-Ice (better) or penalising reconstructions further away from DMIce (also Good)

- Hope to test using other reconstruction algorithm and incorporating DM-Ice data into that, see if we can achieve an improvement

- Potentially display DM-Ice on Steamshovel

17

4 Integrating more with other detectors

- Potentially coincidences between IceTop, IceCube, and DM-Ice, but with low event rate due to small DM-Ice solid angle

- Would be ideal to incorporate DM-Ice into the current pDAQ processing
  - Potentially as some form of filter, similar to the current handling for IceTop

Extra Slides

3.Initial Plans

- 2 Modules

- Cotained in Titanium Module
    - Ø37cm x 120cm
    - 215kg (60kg wet)

- Crystal
    - 100kg NaI (Ø24cm x 50cm)
    - Alpha Spectra
    - IBS

- 12 3" PMTs (R12669-SEL)

- One mDOM mainboard + ICM

- Total estimated mass ~340kg per module

Penetrator

Mainboard + ICM

6 PMTs

100 kg NaI

6 PMTs
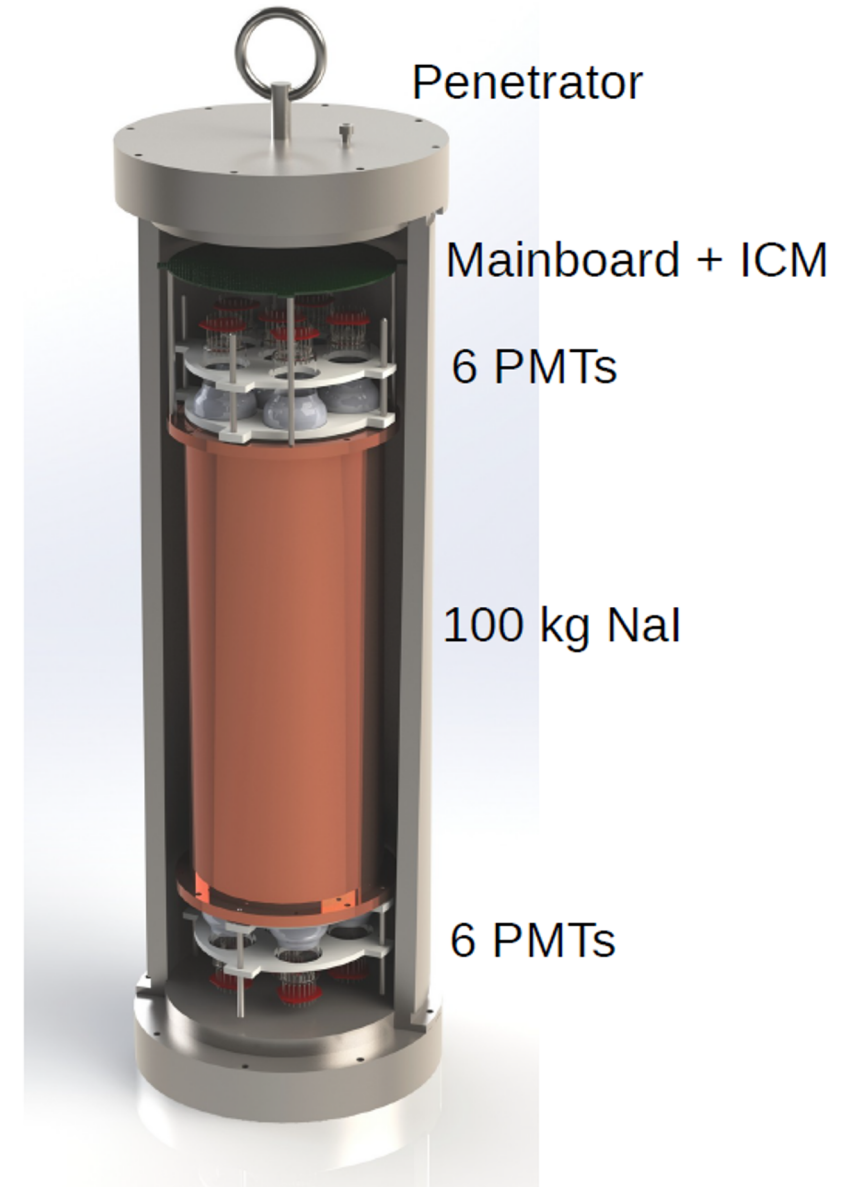
3. Upgrade Plans

- Planned crystal was too large for IBS to grow in time for DM-Ice production schedule

- Rework with a 4 crystal design for each detector
  - Ø10cm x 40cm
  - 12kg
  - Feasible to be grown in time for upgrade
- 8 PMTs

- Slight reduction in length (and cost) of Ti Pressure module

- ~96kg total

Penetrator

mDOM MB + ICM

4 PMTs

4 crystals
~12kg each

4 PMTs