Calibration Central Deployment System (CDS)

WCTE Workshop

25/11/2020

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Contents

- Introduction to CDS (Central deployment system)
  - Calibration goals and design
  - Areas for new/existing groups getting involved
- Physics impact study
  - Including software documentation
  - Simulations of WCTE in WCSim
  - Reconstruction using fiTQun
- CDS prototyping
  - Diffuser ball prototype
  - Testing of the system

Calibration using Laser Ball

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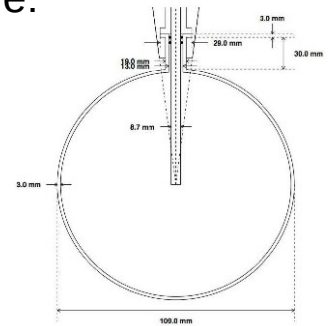
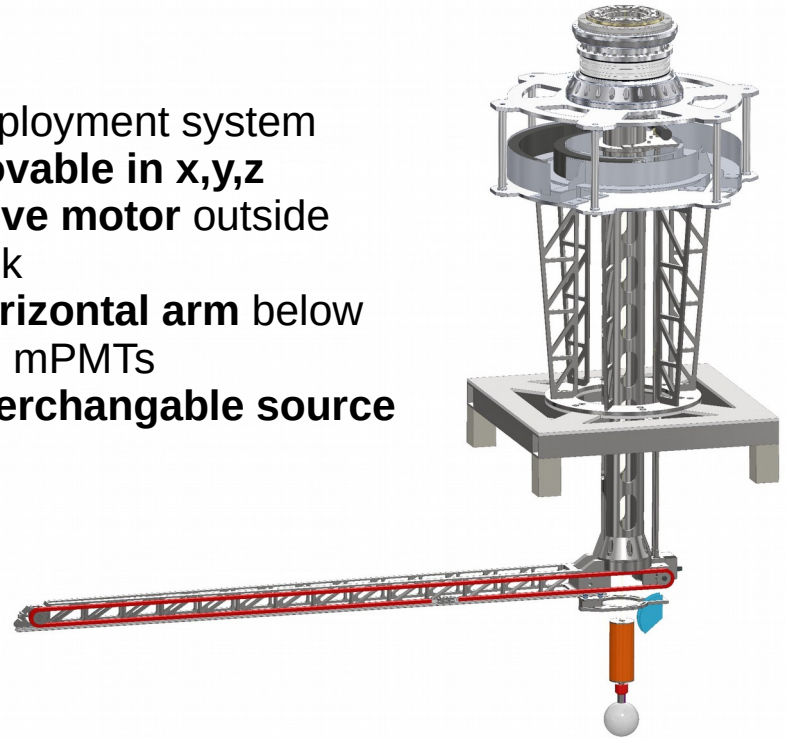
- **Imperial** group is **designing/fabricating** a laser **diffuser ball** and associated **deployment system** for **HK/IWCD/WCTE** to measure:
  - **Geometry**
  - **Water**
  - **Reflections**
  - **PMT response**
  - **Timing**



- Build on SNO/SNO+/DEAP3600 design
- Quartz glass flask
  - Suspended glass spheres
  - Optical gel/resin

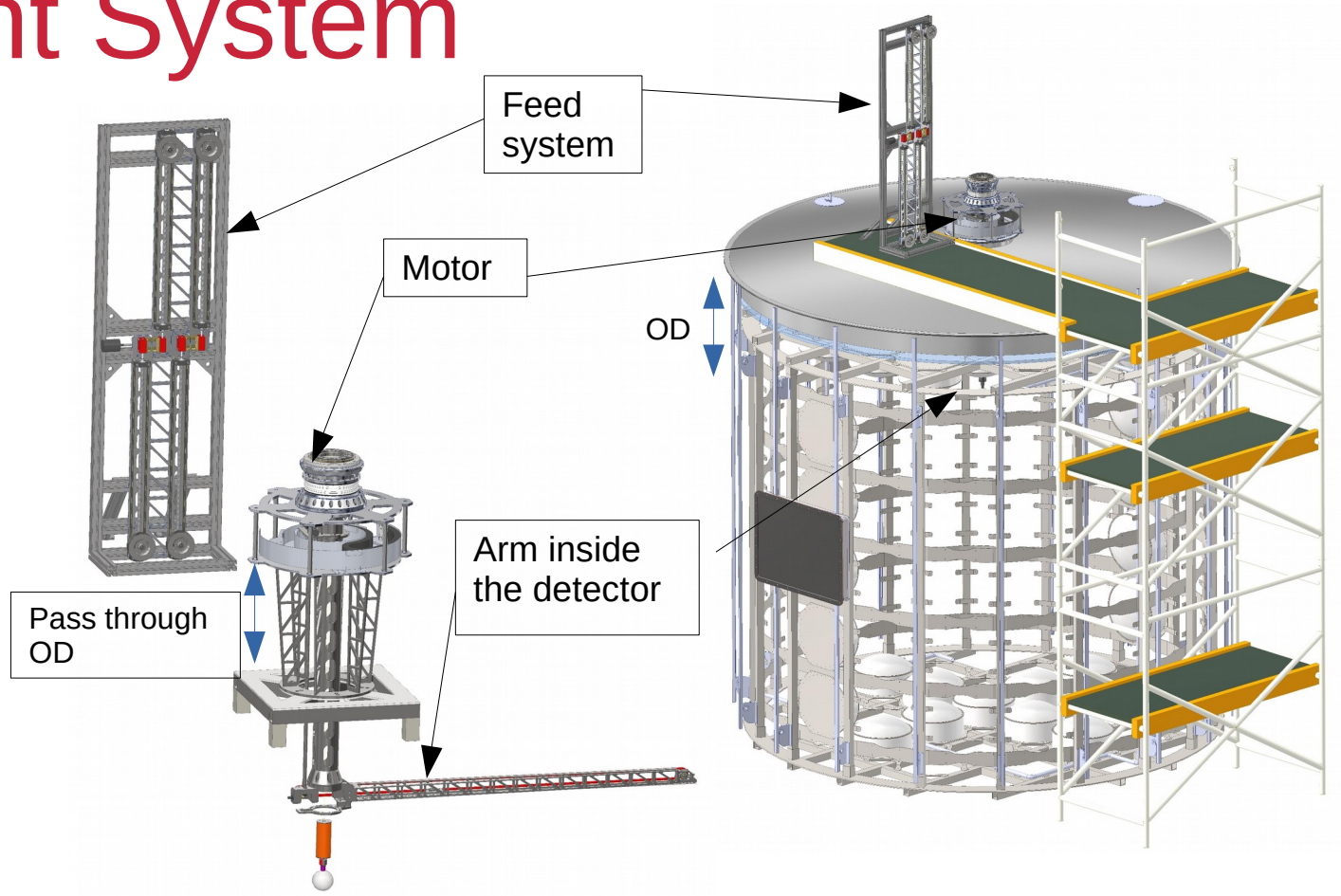
Deployment system design by O.Jeremy

- Deployment system **movable in x,y,z**
- **Drive motor** outside tank
- **Horizontal arm** below top mPMTs
- **Interchangable source**



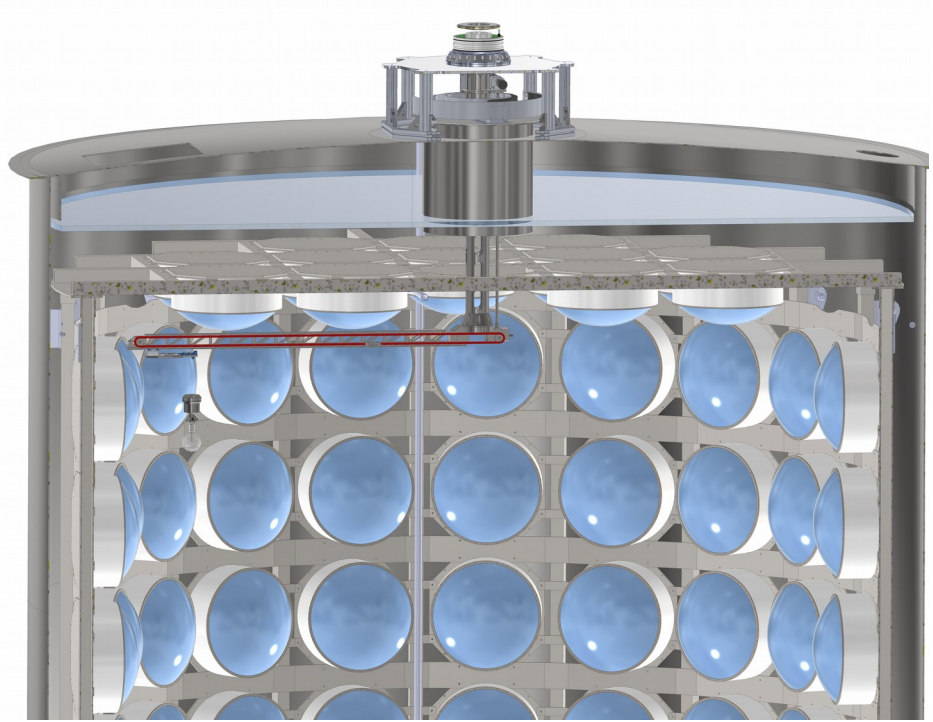
Deployment System (CDS)

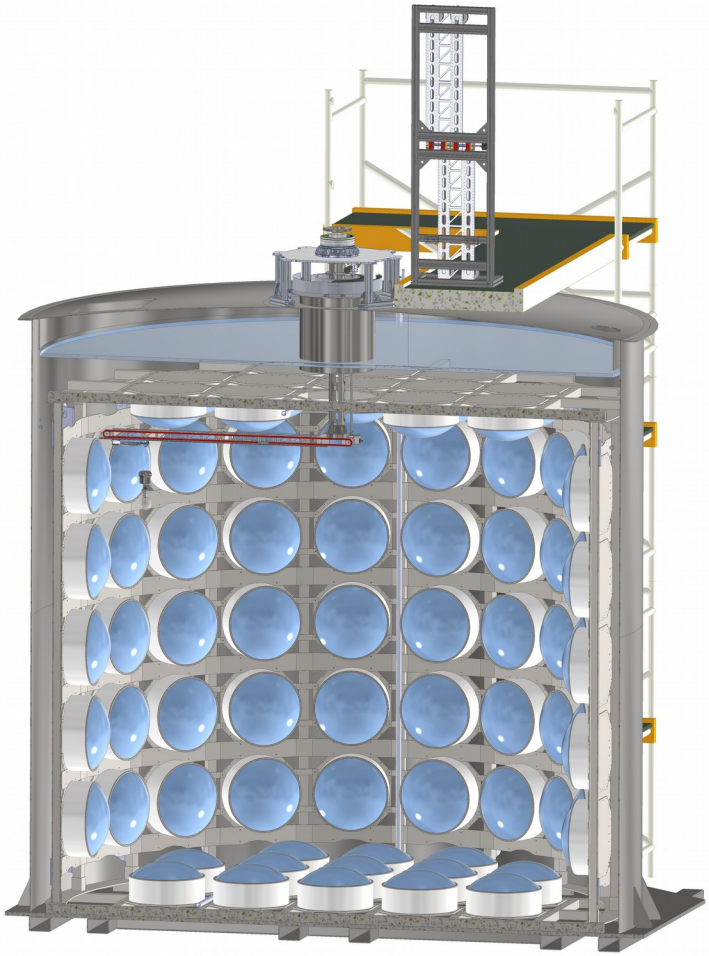
- Fibre feed system sits on tank lid
- CDS mounted on lid, shaft and support passes through the OD
- Arm sits inside the detector



Mounting of CDS

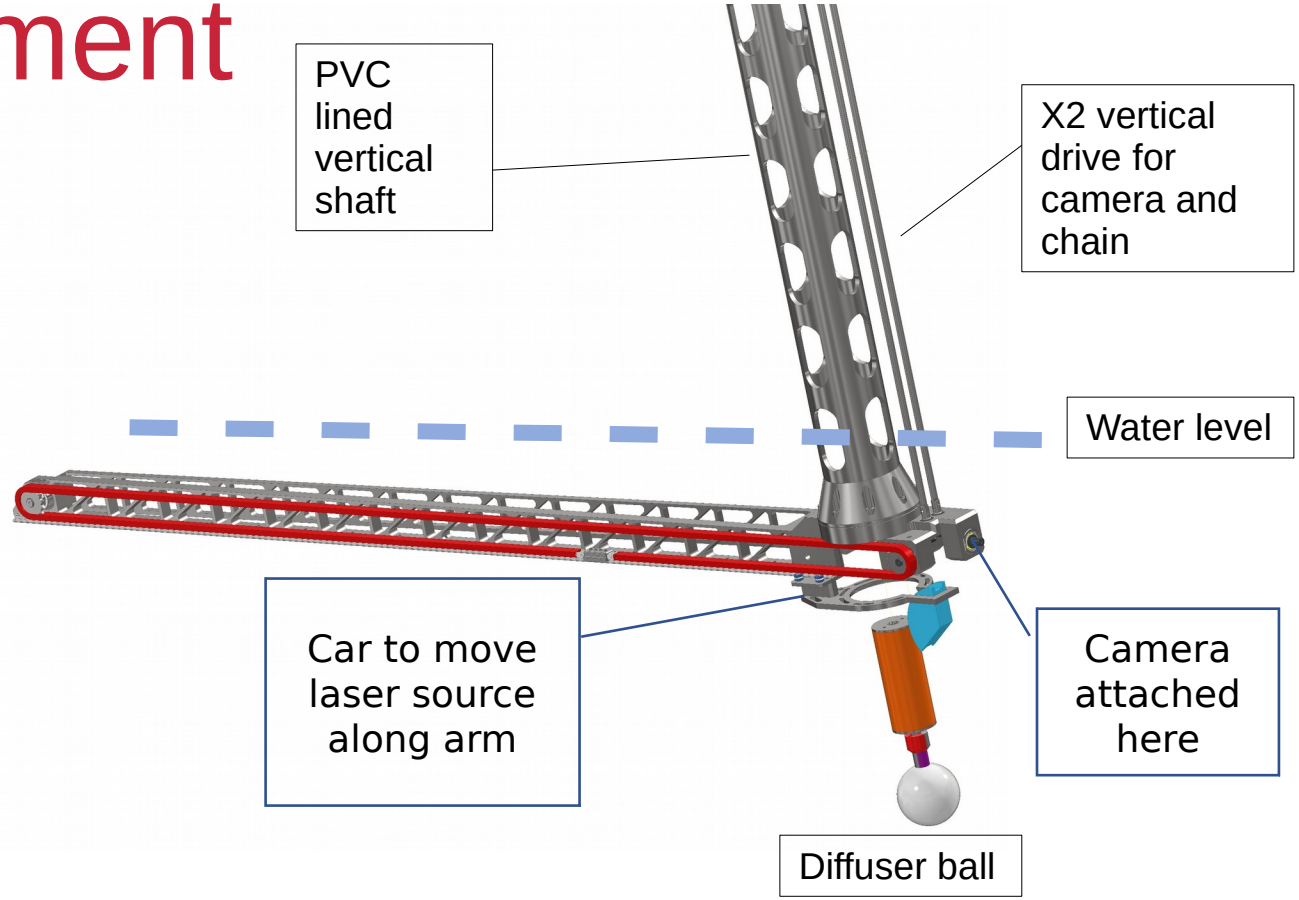
- Current plan is to mount the CDS off the tank lid.
- FEA analysis will be done in the future





Source deployment

- CDS is designed such that the calibration sources are interchangable
  - Hollow central shaft
  - Can use this system to deploy radioactive sources
  - Mounted camera for photogrammetry
- Max diameter = 90mm (currently investigating designs with 150mm diam)



Positional Accuracy

Preliminary calculations

X – Magnetic linear encoder **+/- 2.5mm**
Limit switches will also be included to limit travel of the car

Y – Optical encoder **+/- 2mm resolution**

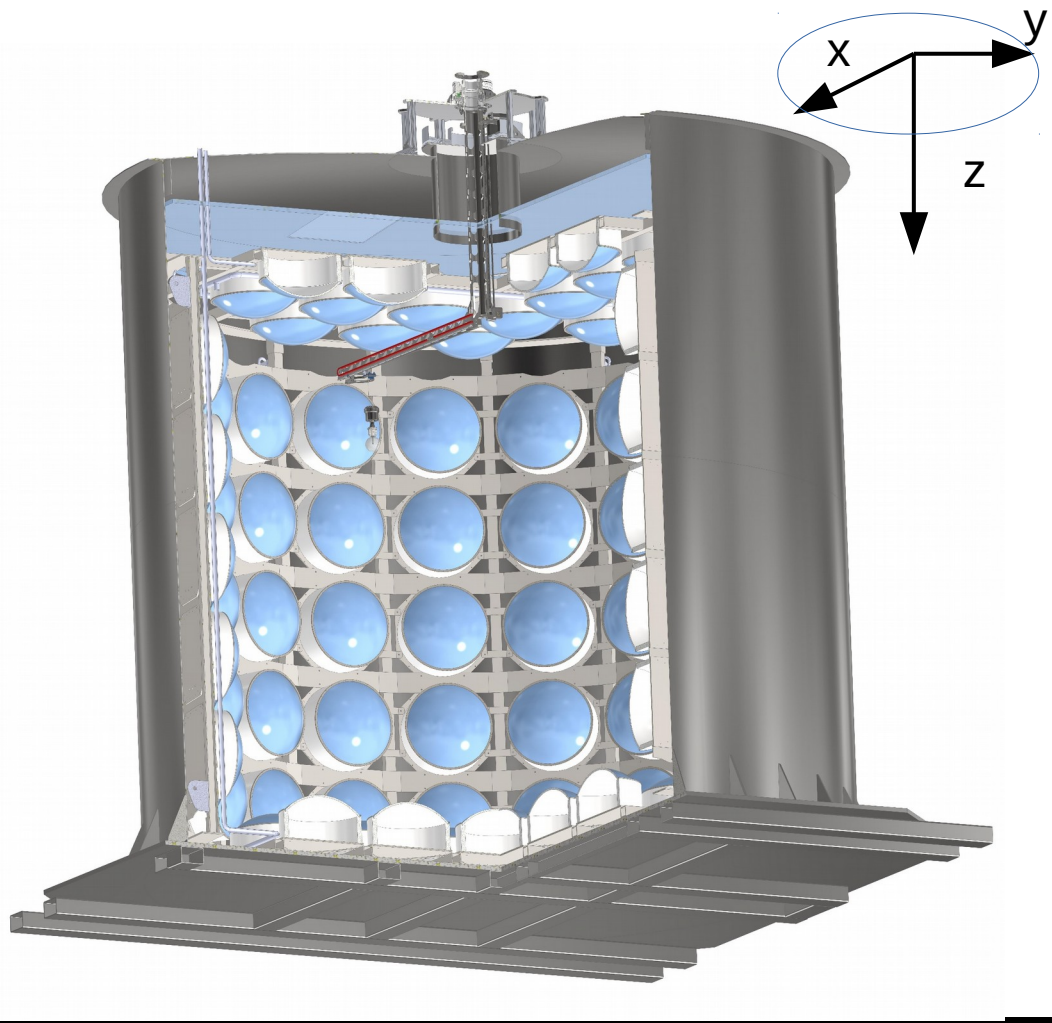
Z – Magnetic Rotary Encoder **+/- 4 mm**

Axis:

X – horizontal plane

Y – circular (arm sweeping)

Z – vertical plane



CDS – Interchangable sources

- So far only discussed the diffuser ball to be made at Imperial
  - CDS is designed such that the calibration source can be changed as long as it has a diameter < 90mm
  - **Now exploring** a larger sized diffuser ball and therefore looking at **larger shaft** (currently **up to 150mm**)
  - **Potential for more groups to get involved and develop radioactive sources for example**
    - **Contact Mark Scott or myself to get involved.**

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Shadowing Study

- The **deployment system** will be **permanently located inside IWCD/WCTE**
  - **NEED TO KNOW EFFECT ARM HAS ON RECONSTRUCTION**
  - For **accurate simulations** and physics studies, the **design** must be **included** in **simulations**
  - **I have incorporated a CAD interface into WCSim: CADMesh** (single header distribution)
  - **Easily add complex objects** (like calibration sources) into the simulation which would be too difficult to create from primitives
  - **Update the simulation quickly** during the R&D process
  - **Define properties** for imported object using **usual G4 method**

- A **shadowing/reflection** study was required for **design/material feed back** to the engineers
  - Too much reflection? → Coat horizontal arm in anti-reflective coating

Simulation in WCSim

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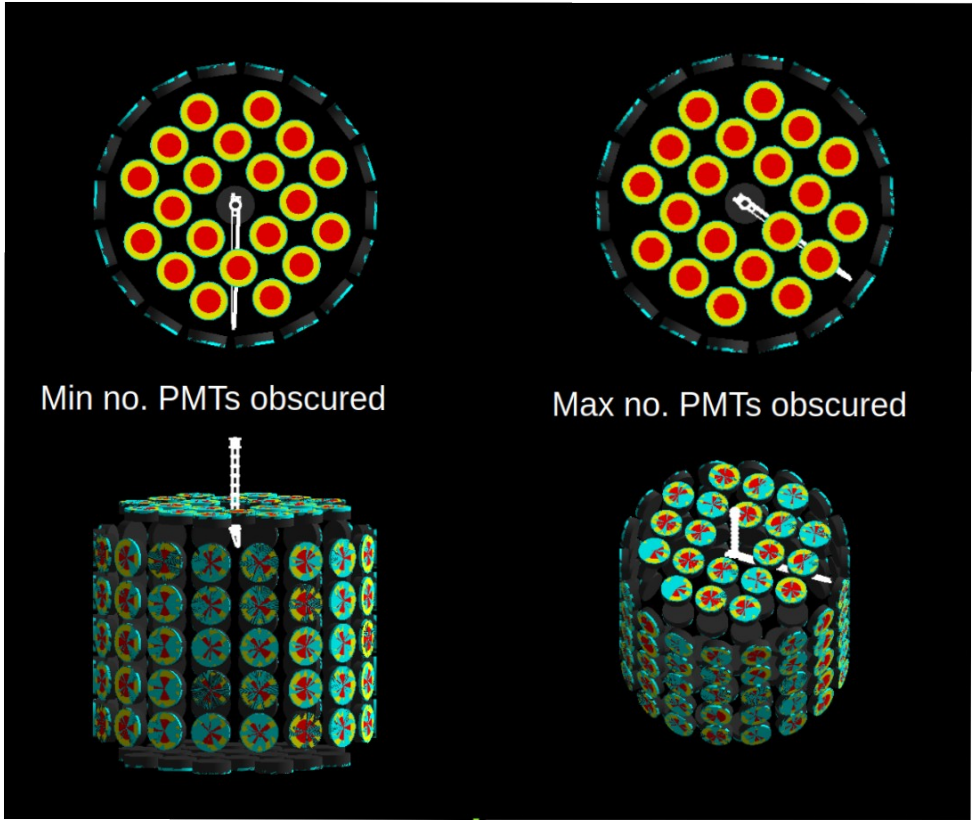
- WCTE WCSim is on github here and is currently public (contact Patrick for questions):
  - https://github.com/WCTE/WCSim.git
- Documentation for installing the relevant versions of ROOT and Geant4 are here:
  - https://wcte.hyperk.ca/documentation/simulation-and-analysis

- FiTQun repository is currently private (need adding by Cris Viella)
  - Current version is v6r0
  - To use for WCTE, the necessary tuning files can be downloaded by running the “source_for_HK.sh” script. See fiTQun instructions.
    - https://github.com/nuPRISM/WCSim/pull/48
    - Contact myself and patrick to get involved in using/developing software

Simulations of WCTE

- Current design is for WCTE → **use WCTE WCSim**
  - **Remove top centre mPMT** to accommodate for vertical shaft
  - **Simulate deployment system** inside detector in **several positions** (as well as without system)
    - **Horizontal arm obscusing minimum** and **maximum** number of **PMTs** possible
- For physics related shadowing study, **simulate 10k, 500MeV electrons** from 4 different locations in the tank.
  - **Apply fiTQun reconstruction algorithm**
  - **N.B. Study is also being done with 300MeV electrons and 500MeV muons**

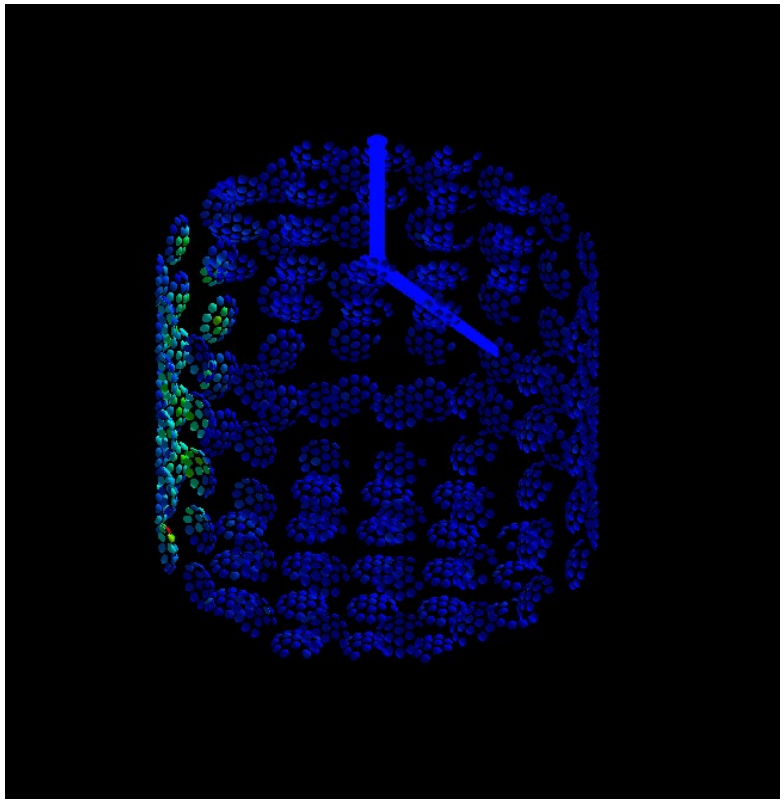


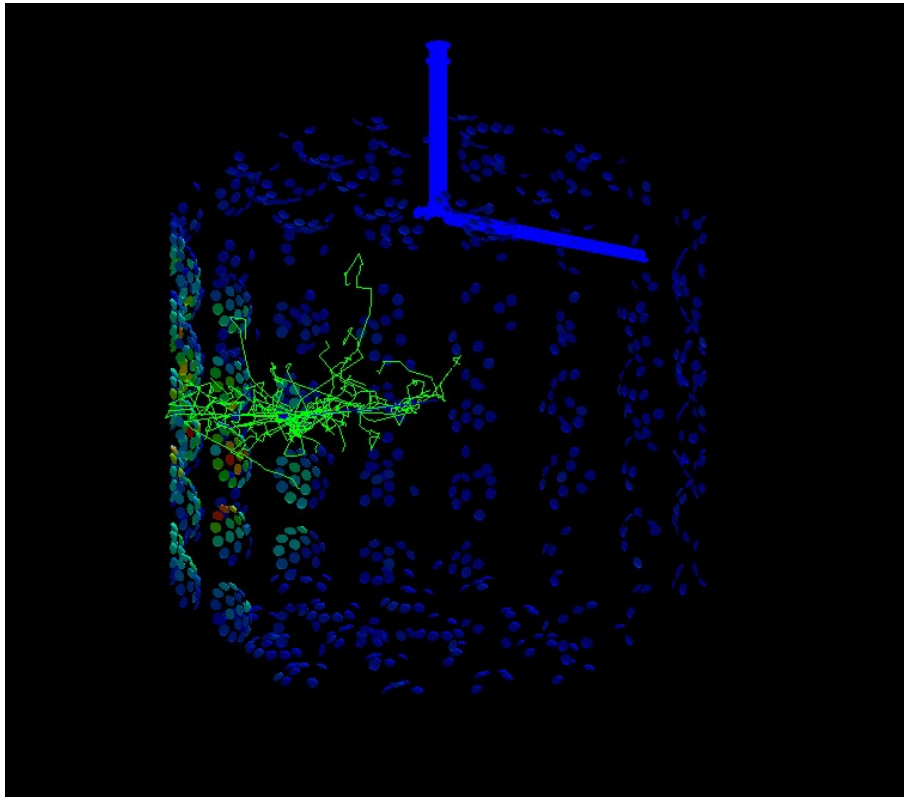
Simulations of WCTE

- Study shown is for 500MeV electrons (the study is also being done with 300MeV e-, 500MeV mu and 300MeV mu however this is not shown today)
  - 500MeV e- represent a worst case scenario wrt scattering
- Shown today is an MC comparison between 4 beam positions **(500MeV e-)** and **4 geometries**
  - **2 beam positions in the main slides**, see back up for the remainder
    - Direction always (0,0,-1) pointing away from the arm, with positions
      - **(0,0,0) – representetive of beam pipe extended to centre of detector**
      - (0,-85,0)
      - (0,85,135)
      - **(0,0,165) – representetive of beam pipe close to detector wall**

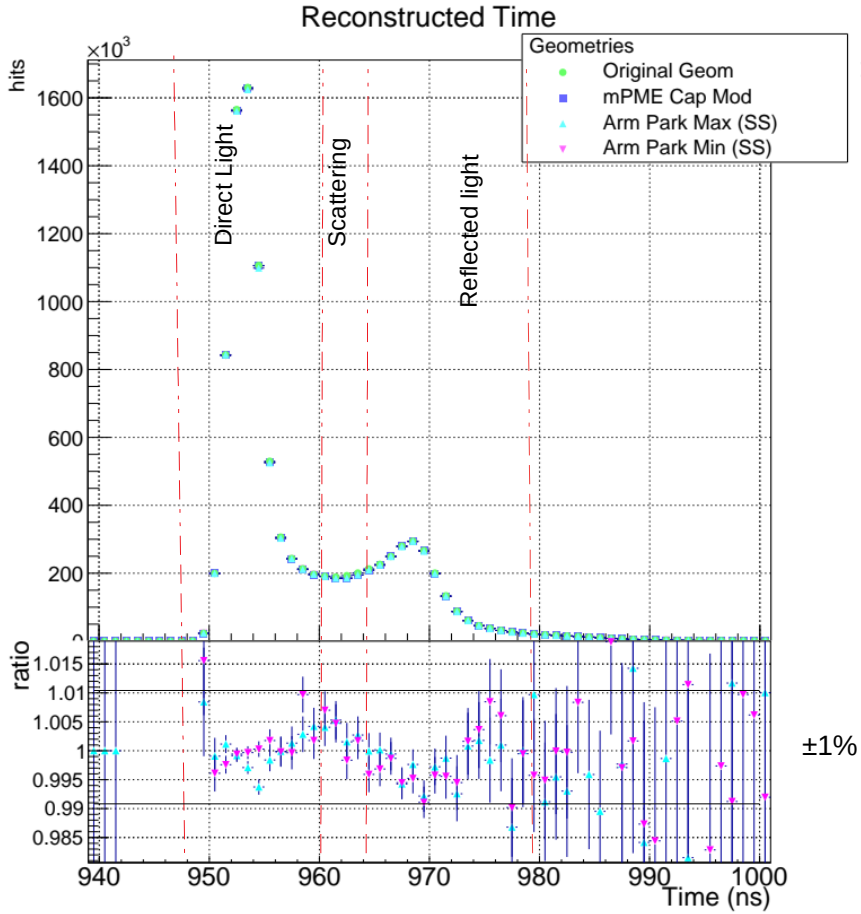
500MeV e-, dir (0,0,-1), pos(0,0,0)

Beam pipe at centre

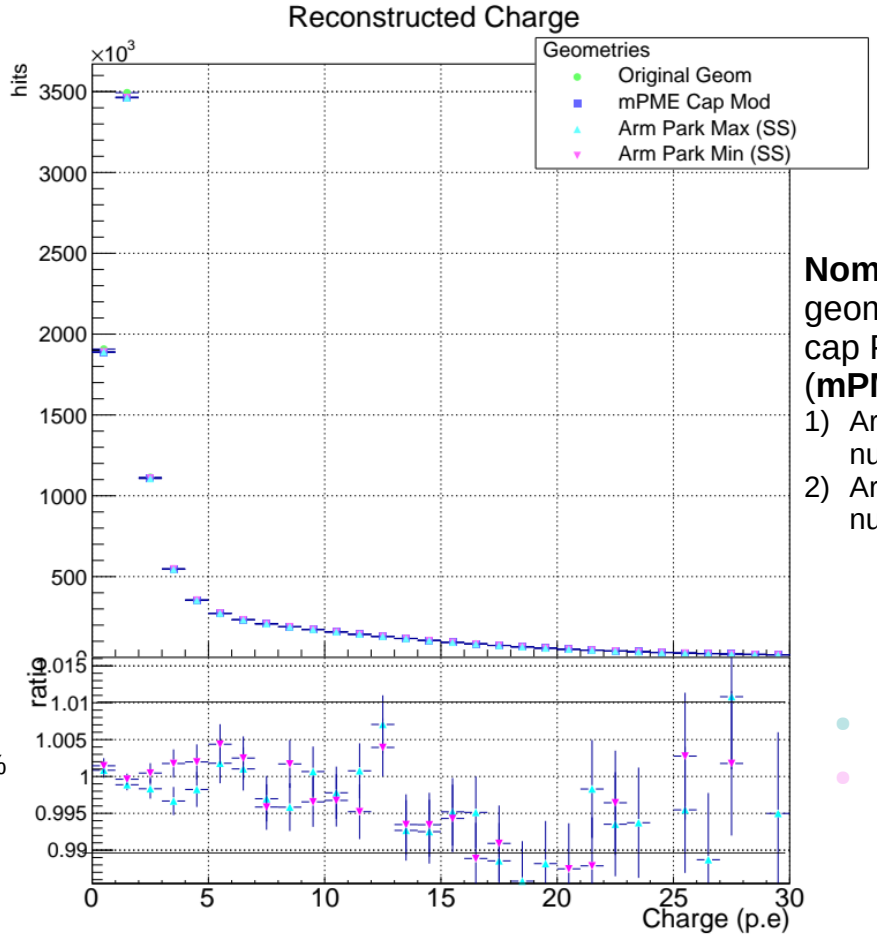




Reconstructed Time & Charge: dir (0,0,-1), pos(0,0,0)



±1%



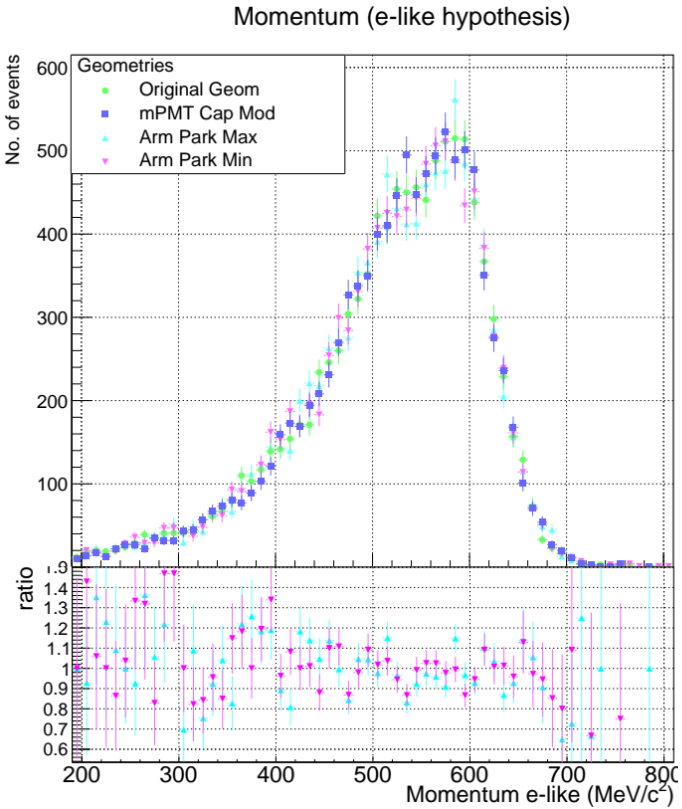
Nominal MC here is the geometry with the central cap PMT removed (**mPMT cap mod**)

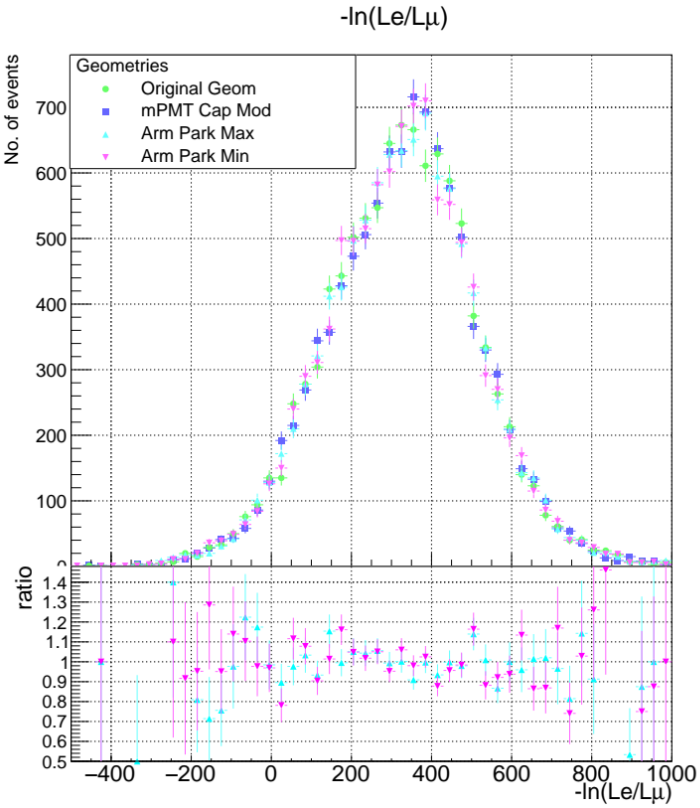
1) Arm park max = max number of PMTs obscured
2) Arm park min = minimum number of PMTs obscured

- Max/nominal
- Min/nominal

FiTQun reconstruction Momentum & PID

	Original	-1 PMT	Arm (max)	Arm (min)
Momentum MeV/c (mean)	519.1	520.8	518.8	518.5
-nll (mean)	325.9	329.6	327.6	326

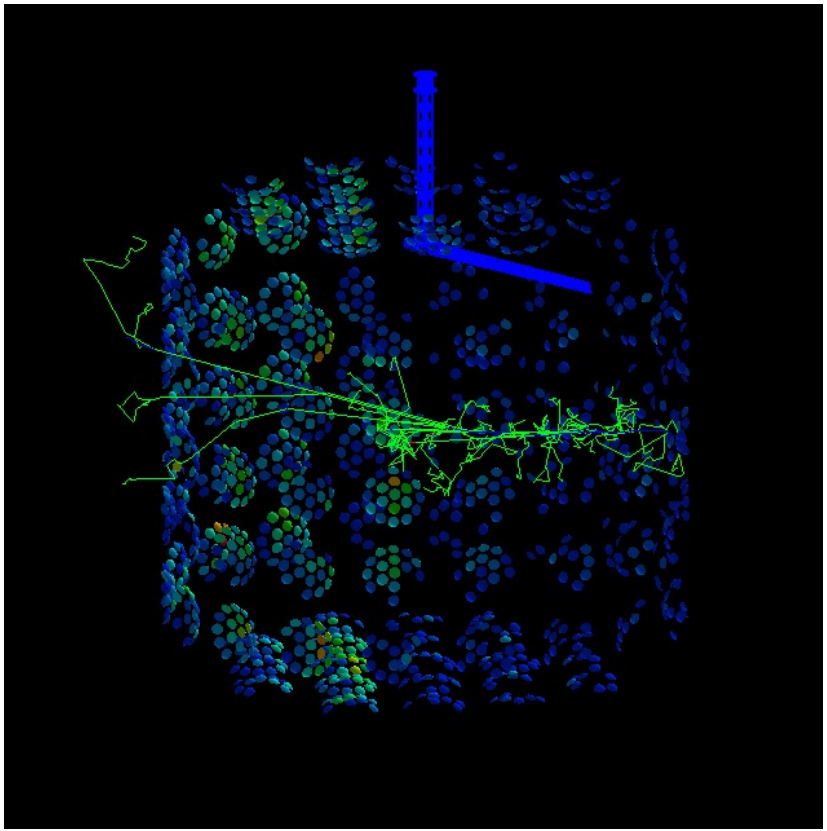


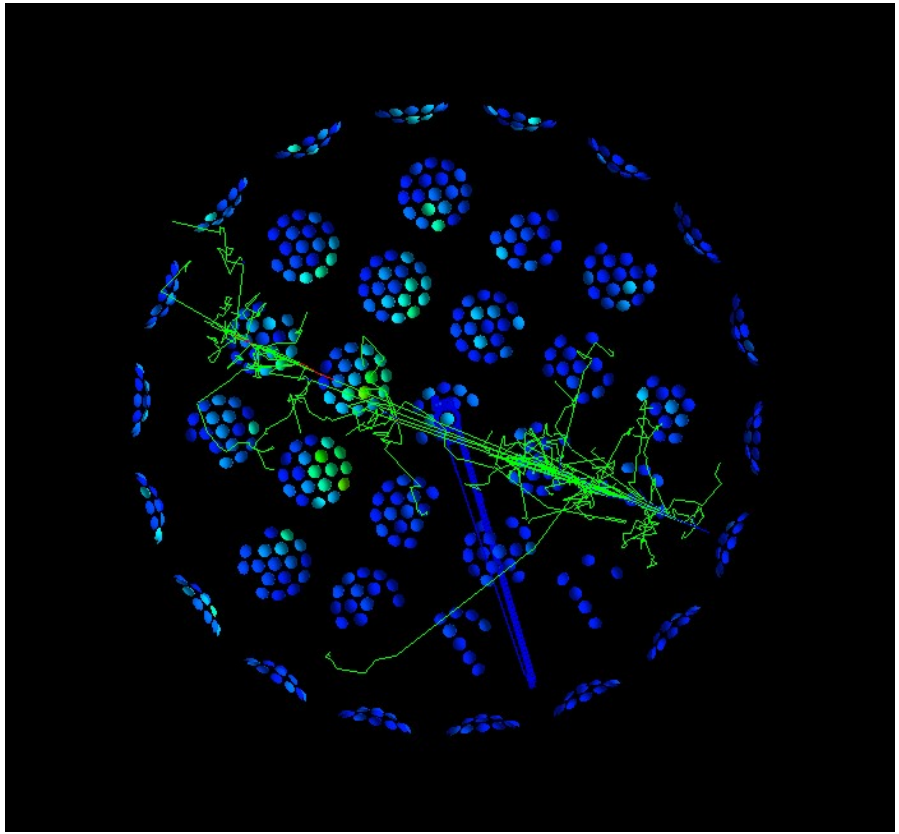


- Largest difference in reconstruction is due to removing mPMT on top cap
  - Lose information
  - See PID parameter
- Arm can be parked in either position in this case
- Distributions for each geometry mostly consistent to within statistical error

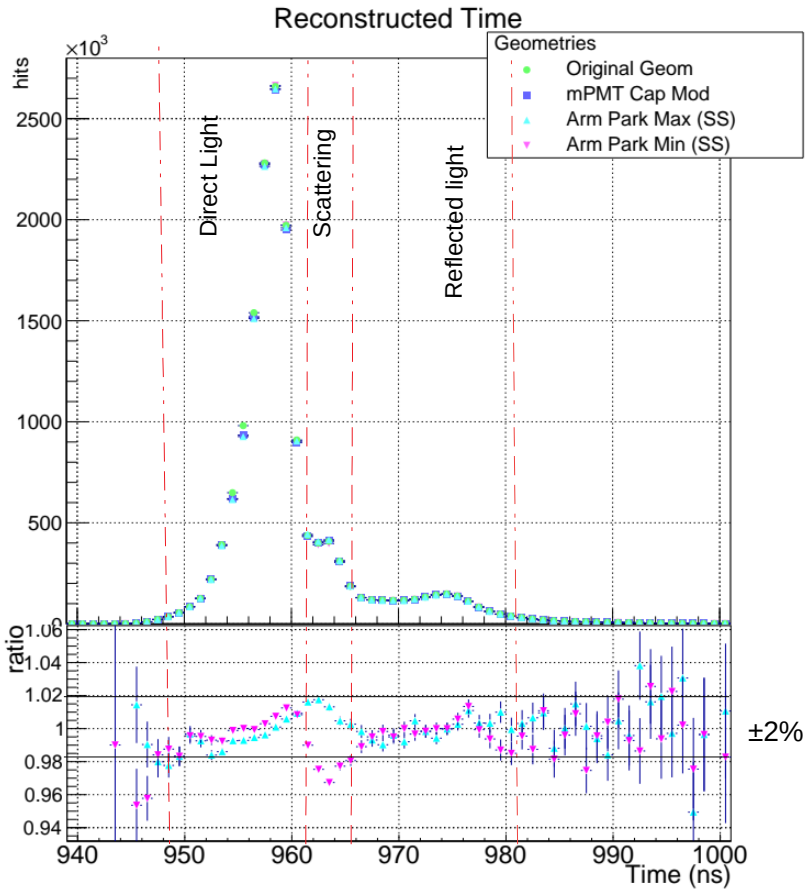
500MeV e-, dir (0,0,-1), pos(0,0,165)

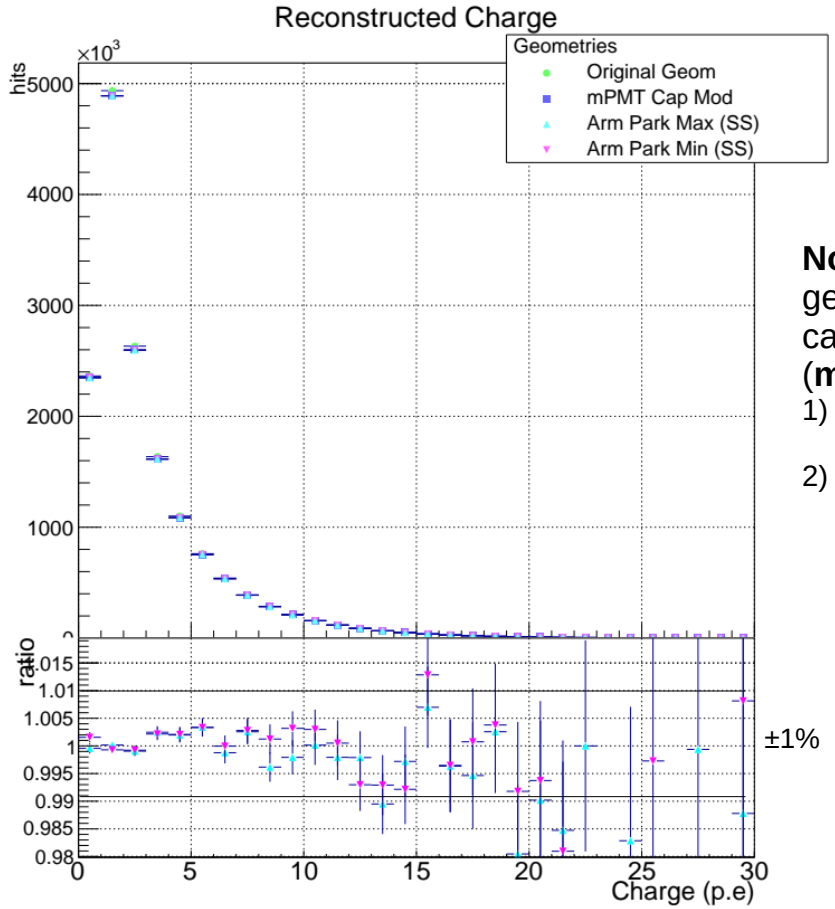
Beam pipe close to wall





Reconstructed Time & Charge: dir (0,0,-1), pos(0,0,165)





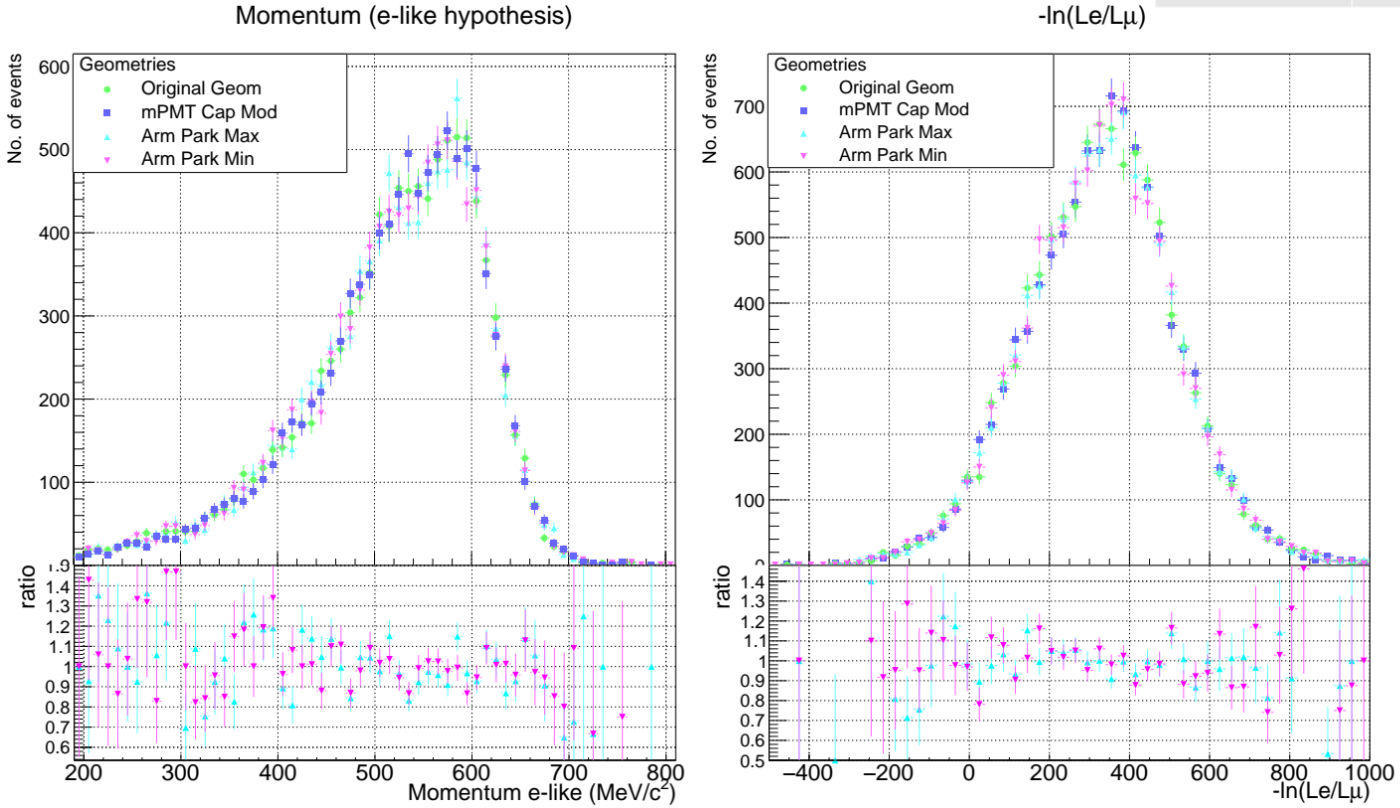
Nominal MC here is the geometry with the central cap PMT removed (**mPMT cap mod**)

1) Arm park max = max number of PMTs obscured
2) Arm park min = minimum number of PMTs obscured

- Max/nominal
- Min/nominal

FiTQun reconstruction Momentum & PID

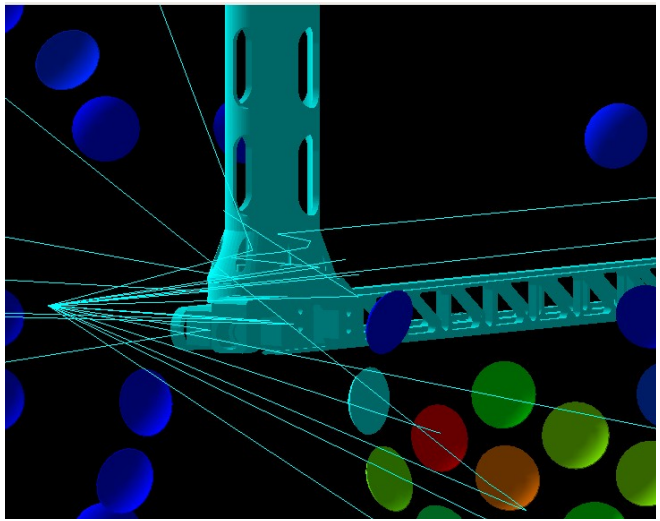
	Original	-1 PMT	Arm (max)	Arm (min)
Momentum MeV/c (mean)	518.8	519.9	520.1	520.1
-nll (mean)	466.5	457.9	457.2	459.6

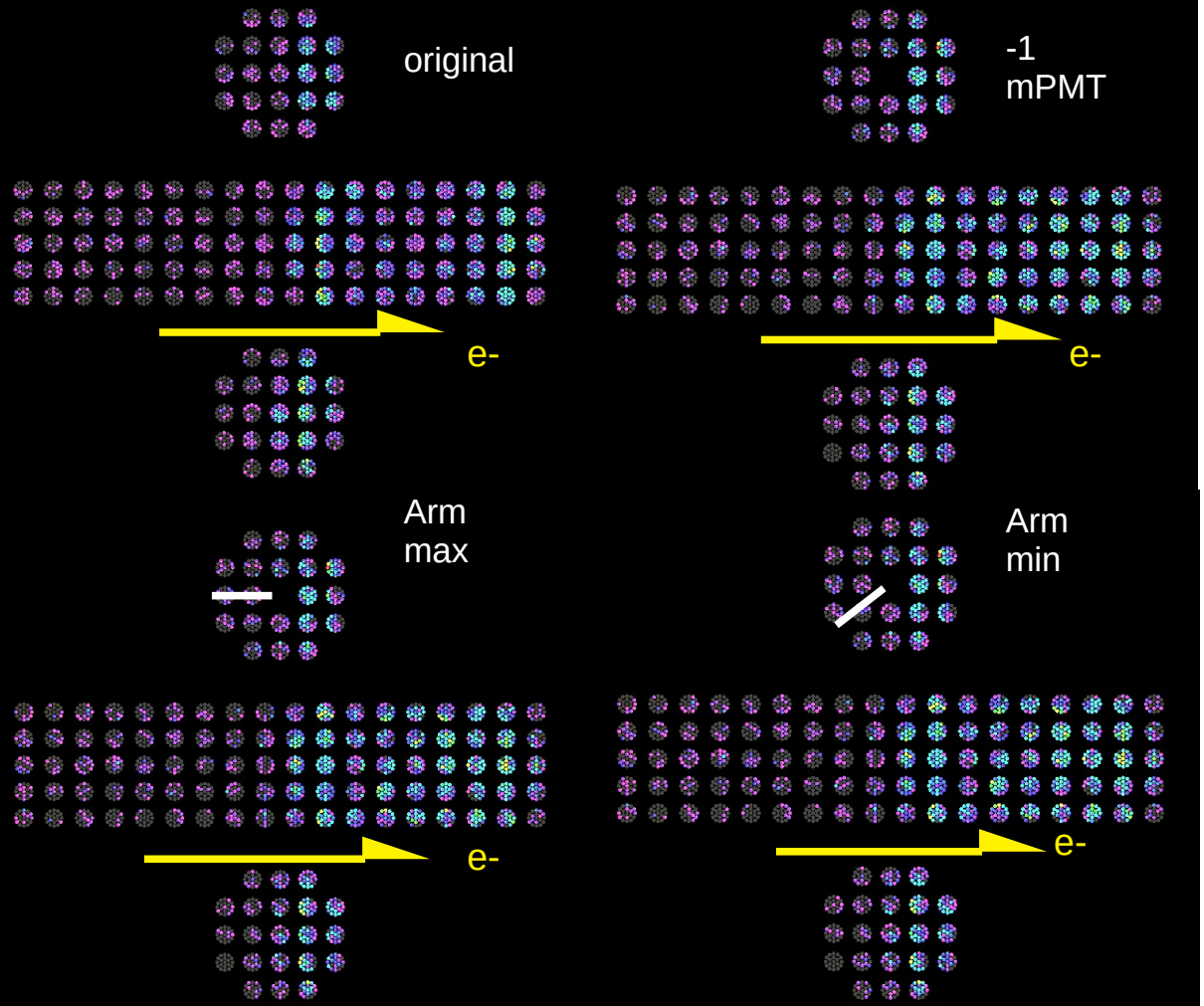


- Can make similar conclusion for this position as for (0,0,0)
  - Position of the arm has very little effect on reconstruction
- Distributions for each geometry mostly consistent to within statistical error

Event comparison

- Hits displayed in charge
- Largest difference in hit patters after removing one PMT
- Likely scattering from the arm is coming from the shaft, not the arm





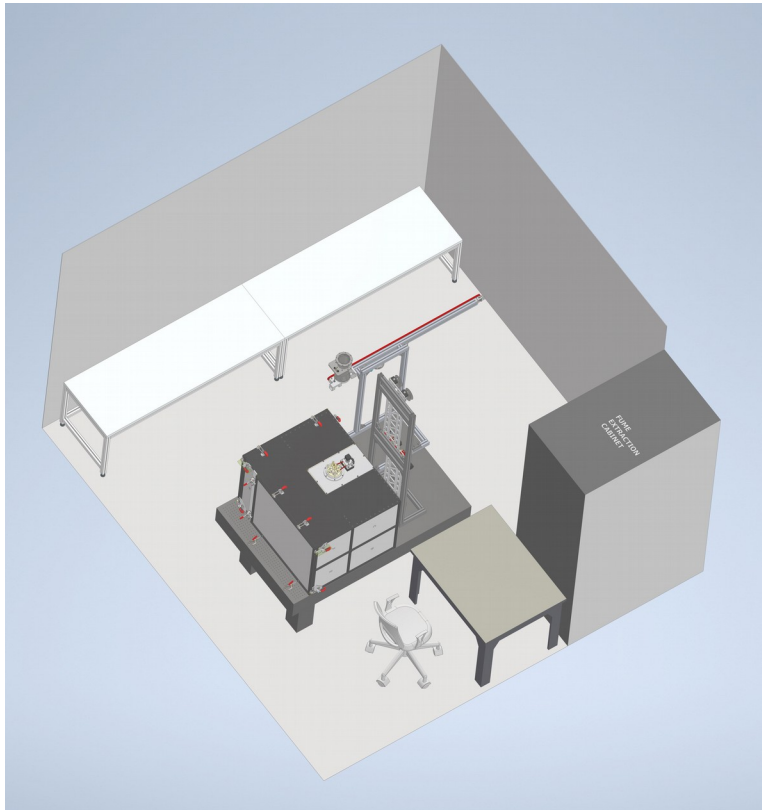
Summary of simulation results

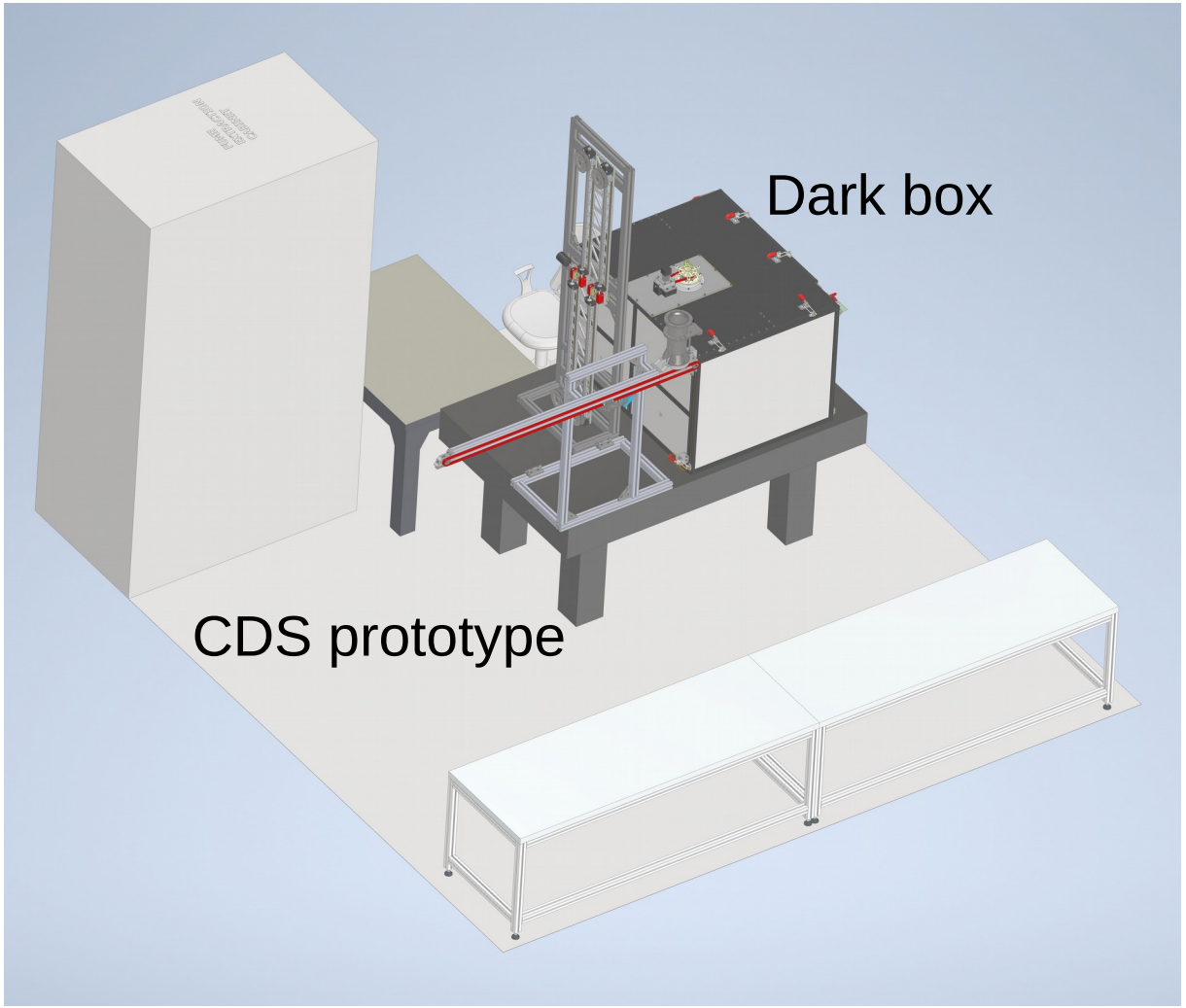
- We see **some reduction in direct light when the CDS is parked in the position obscuring 3 mPMTs** (as expected)
  - **Reduction of max 2% across all MC produced** (see backup for other beam positions)
- **Presence of the arm has most effect on the scattered and reflected light**
  - **Max variation is ~4%** when the particle is originating close to the tank wall (and the cone is largest/overlapping with the CDS position)
  - **Maximum variation in charge across all MC is ~1%**
- **FiTQun reconstruction shows largest effect on reconstruction is caused by removing mPMT from top cap**
  - **Arm positions don't have much effect on reconstruction in these cases**
    - See shift in PID parameter
  - No real effect on vertex reconstruction

Prototyping at Imperial

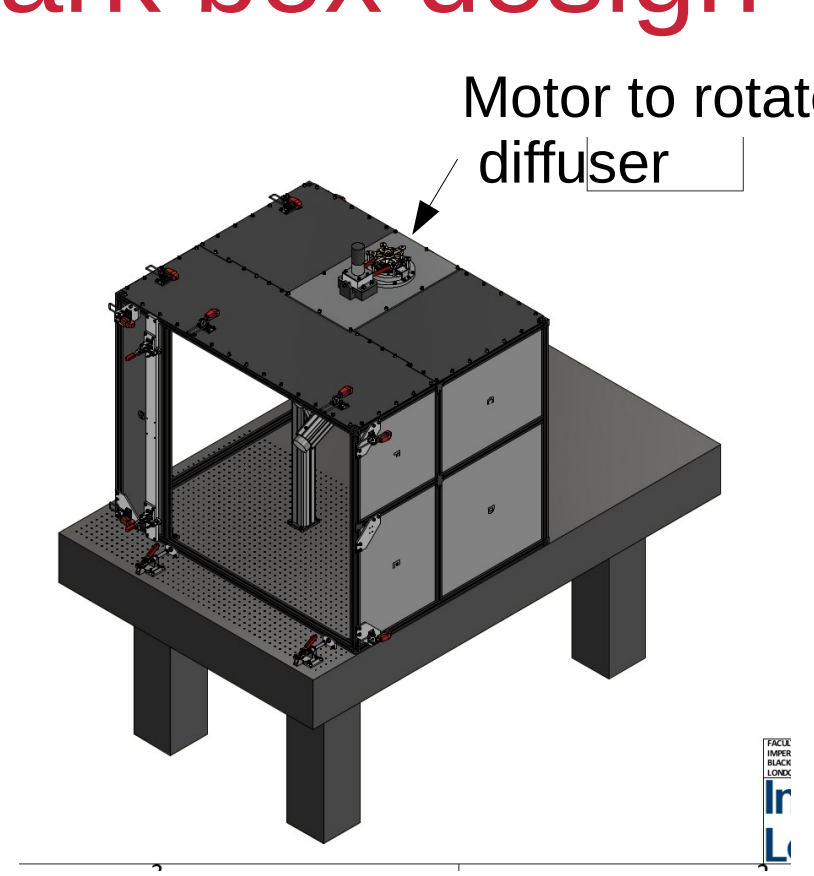
- Objectives:
  - Make diffuser ball based on SNO/DEAP design
  - Build dark box to test uniformity of light exiting diffuser ball
  - Build full scale prototype of CDS being developed for WCTE
  - (All designs and drawings by O.Jeremy)

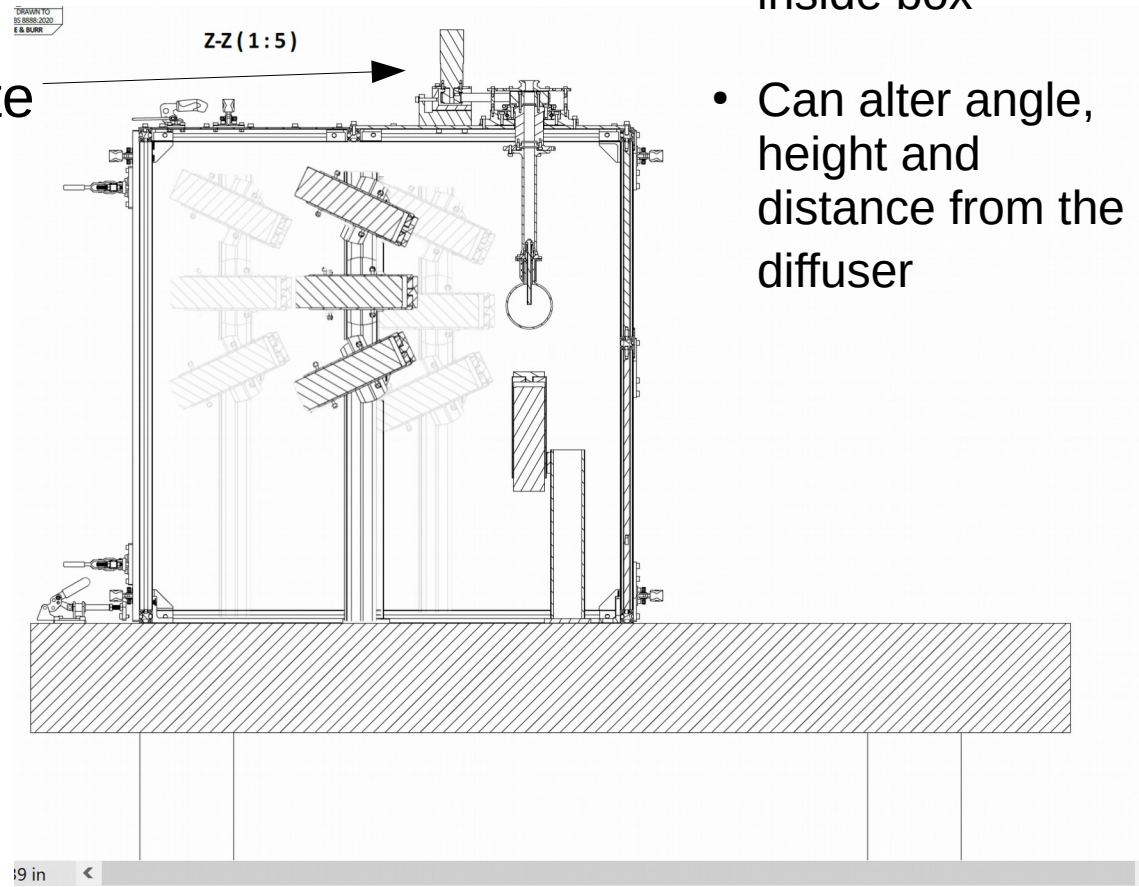
Lab set up





Dark box design

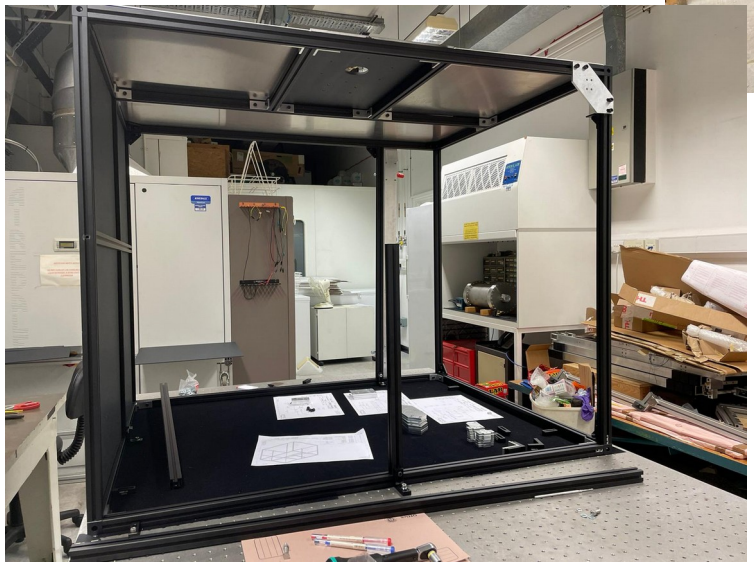


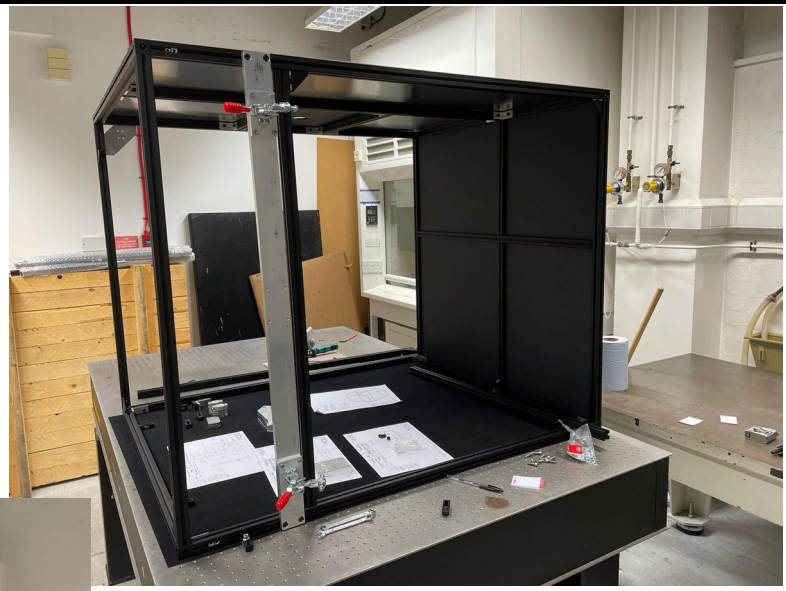


- Array of 4 PMTs inside box
- Can alter angle, height and distance from the diffuser

Progress on dark box

Roof panels and other stainless steel parts will be spray painted/covered with black flocking.





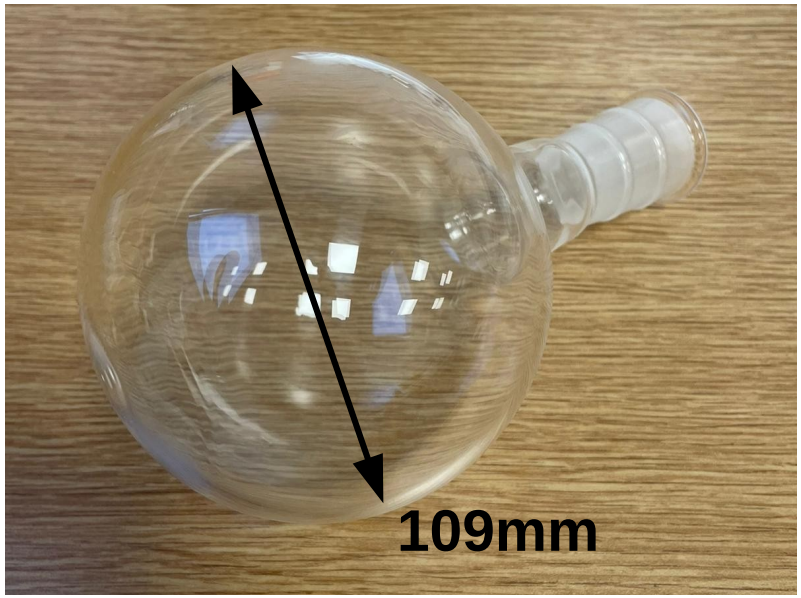
Dimensions: 1125mm x 900mm x 900mm

Telescope flocking for blackout material

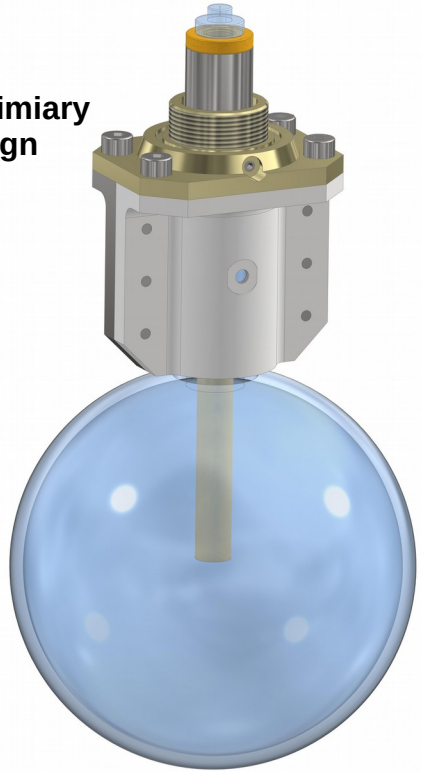
Diffuser ball

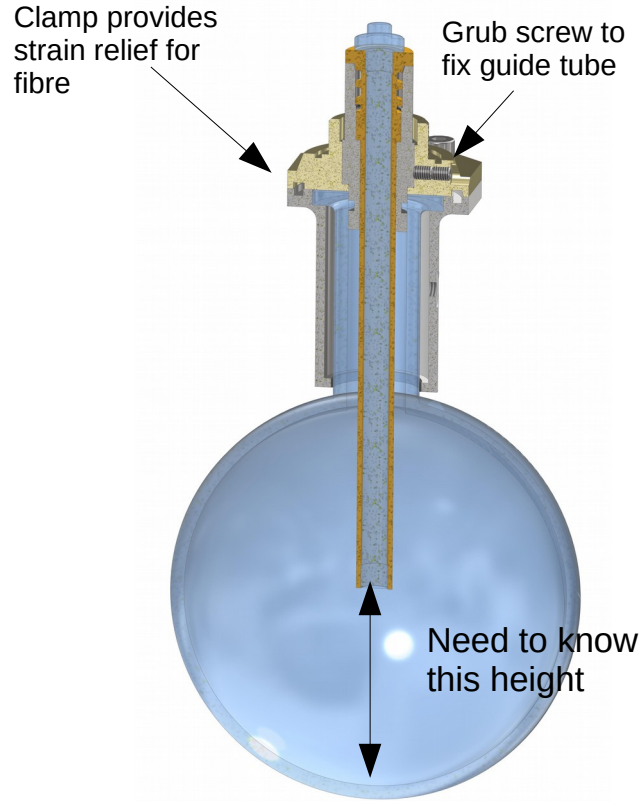
Clamp designed to hold flask and also hold guide tube in place for inserting fibre after filling with glass bead/gel solution.

Flask we have currently is 109mm diam. Current CDS design requires 90mm flask.



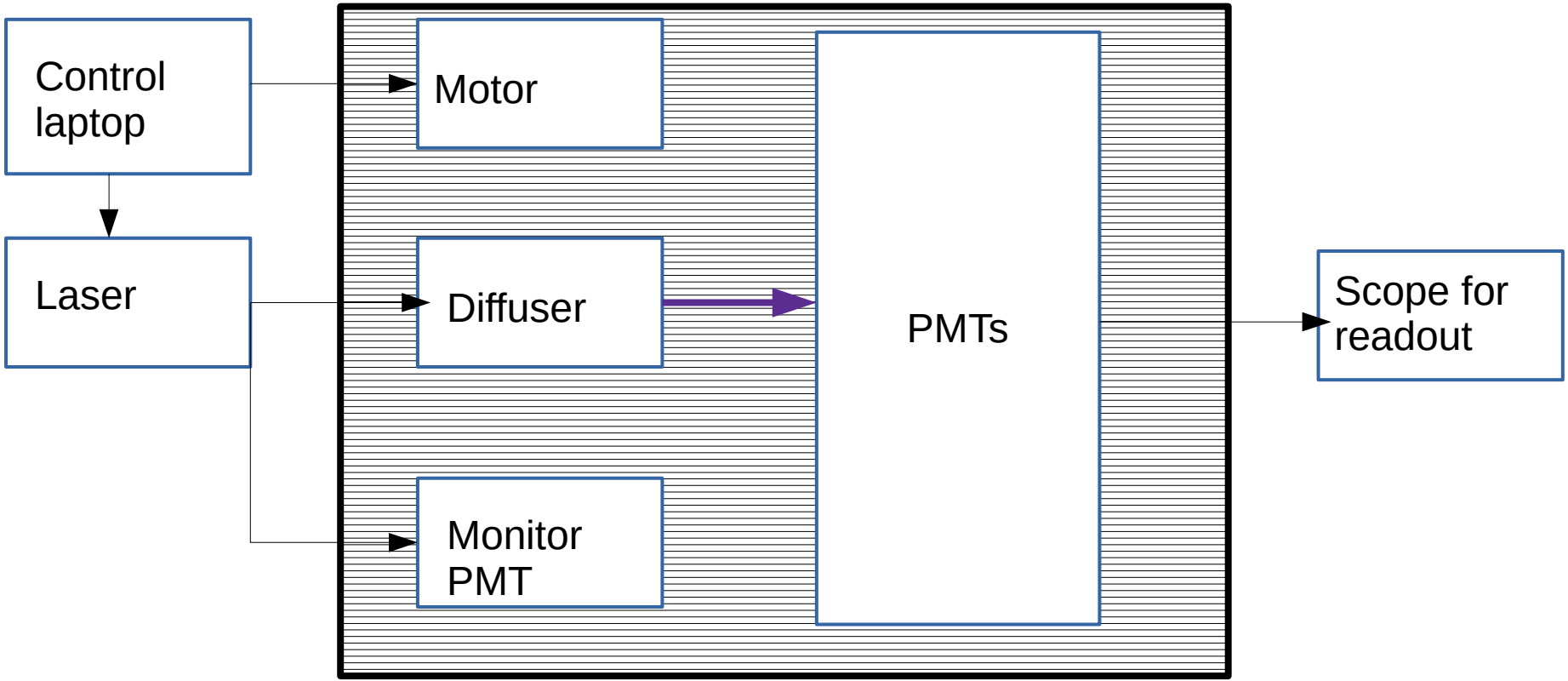
Prelimiary design





Architecture of set up

Motor control by MIDAS control software and
Laser control by software developed by Matej



Summary

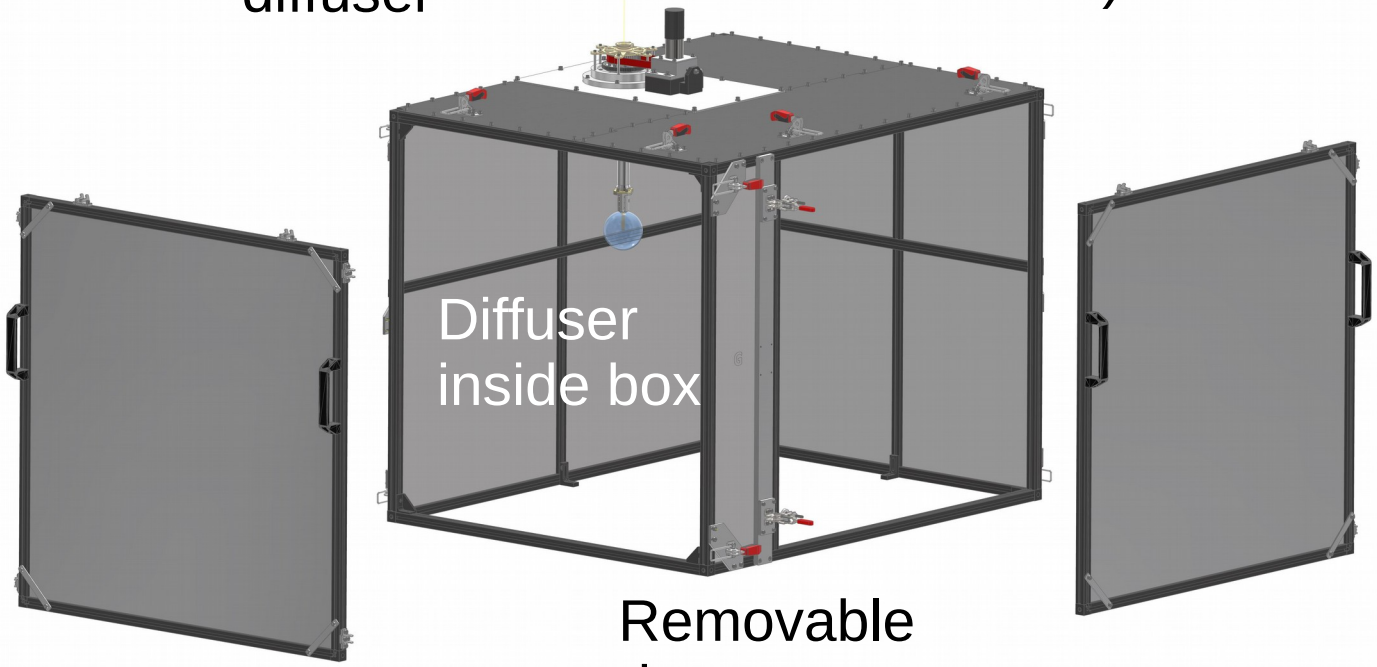
- **Shadowing study on CDS is almost completed**
  - So far **no significant reduction in reconstruction capability**
    - Next step will be to tune fiTQun to include the CDS in the geometry
- **Designing work for the CDS is ongoing**
  - Possibility to change design for larger sources
  - **Opportunity for other groups to get involved in developing radioactive souces**
- Lab set up for prototypes is going well
  - Will be fabricating diffuser ball and testing in the new year along with full scale CDS

Back Up

Dark box design

PMT array will also be inside box, including monitor PMT (see next slide)

Motor to rotate diffuser



Removable doors

Diffuser ball

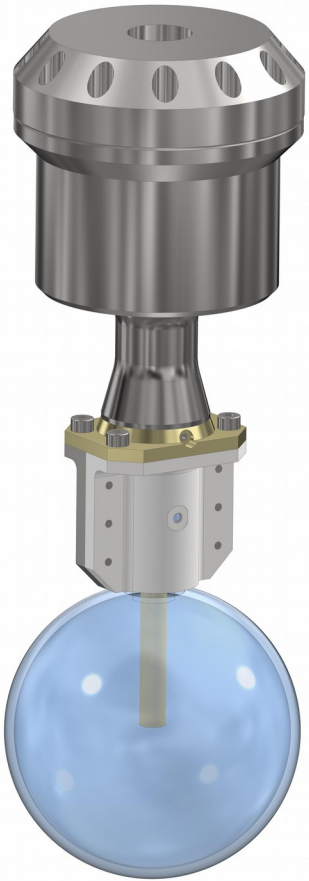
Two modifications for use in dark box and with CDS:

1. Tubing attached to clamp to position diffuser in dark box

2. Tungsten Carbide weight attached to clamp for use with CDS

1.

2.

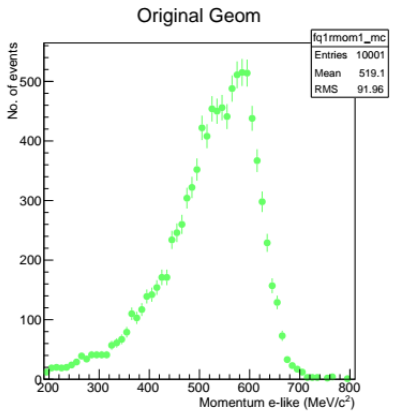


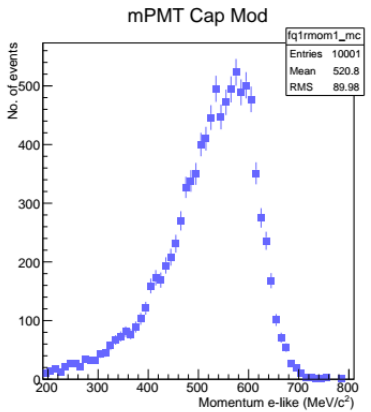
Electronics

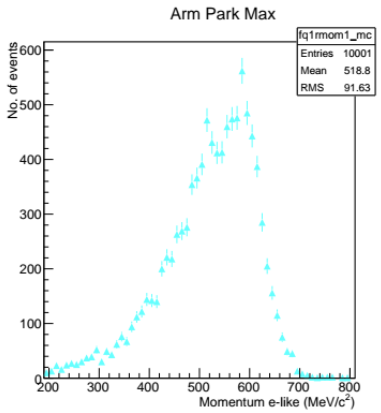
- Laser : Tamadenshi LBD 405-200
  - Coupled to 405nm ±5nm, 1→2 50/50 pure silica fibre splitter (Gooch & Housego/GouldFO)
- PMTs : 4 x Hamamatsu H2431-50
  - 0.36ns TTS
  - 0.8ns rise time
- Monitor PMT : 1 x Hamamatsu H10721-110
  - Same as monitor PMT used in UKLI system at SK

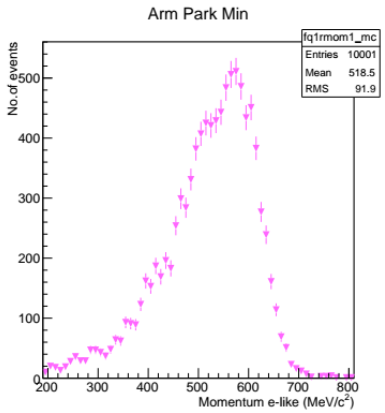
FiTQun reconstruction - 500MeV e-, pos 0,0,0

Momentum (e-like hypothesis)

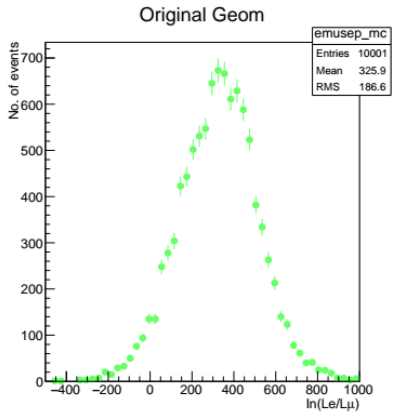


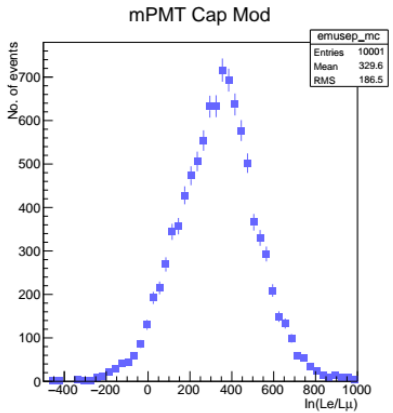


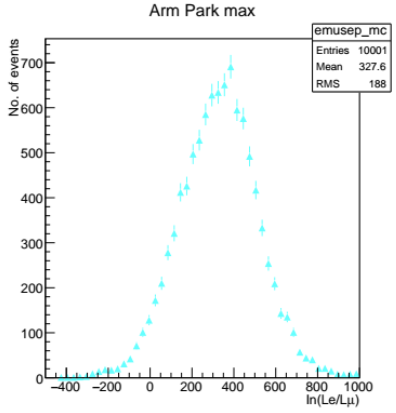


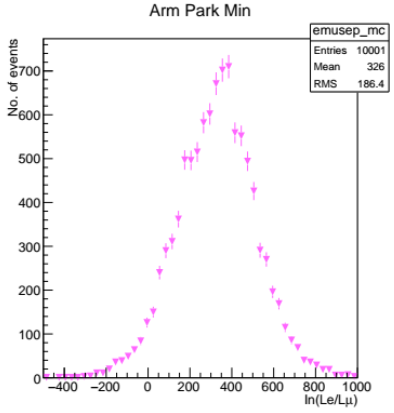


-ln(Le/Lmu) – PID pram





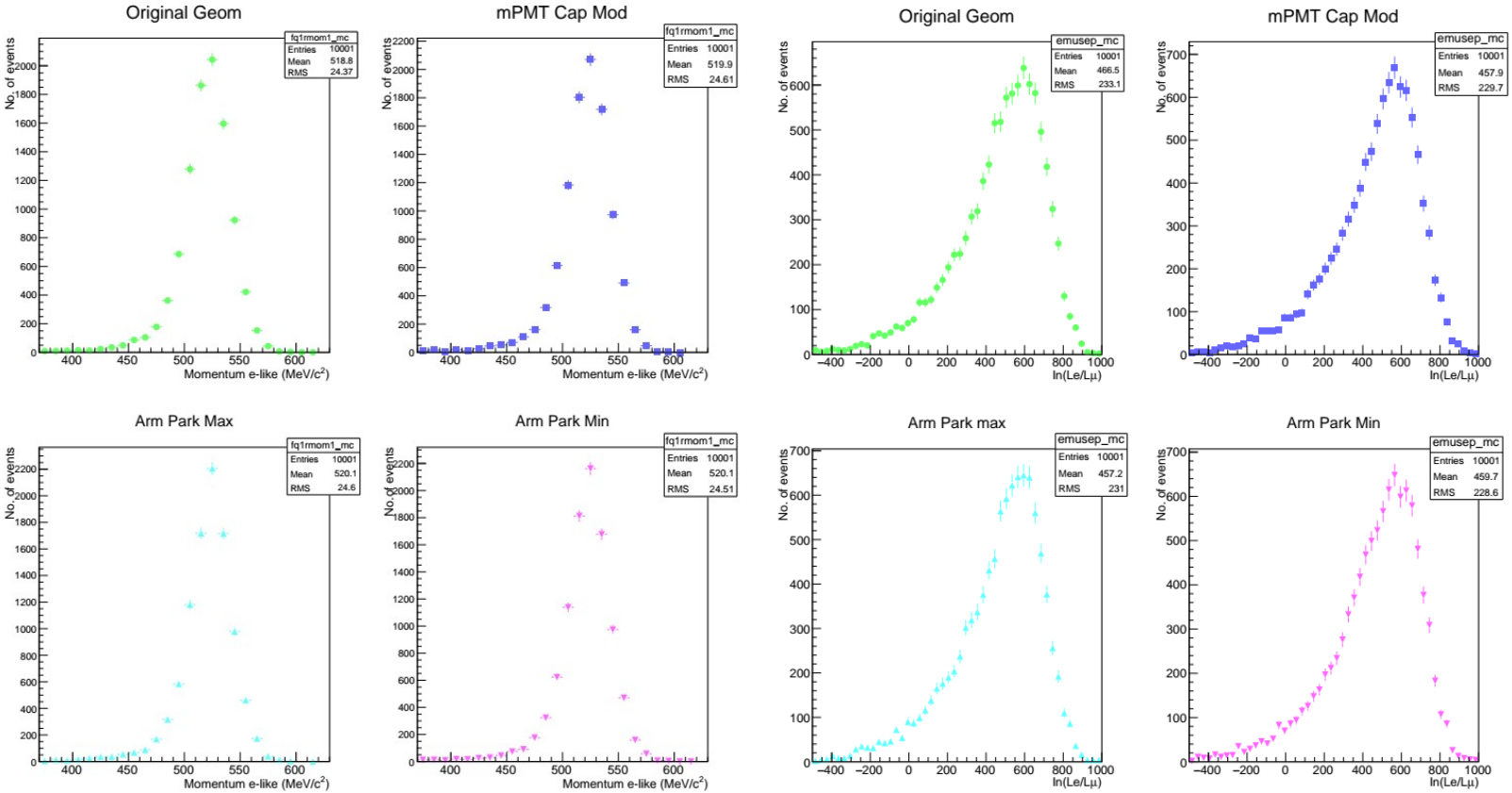




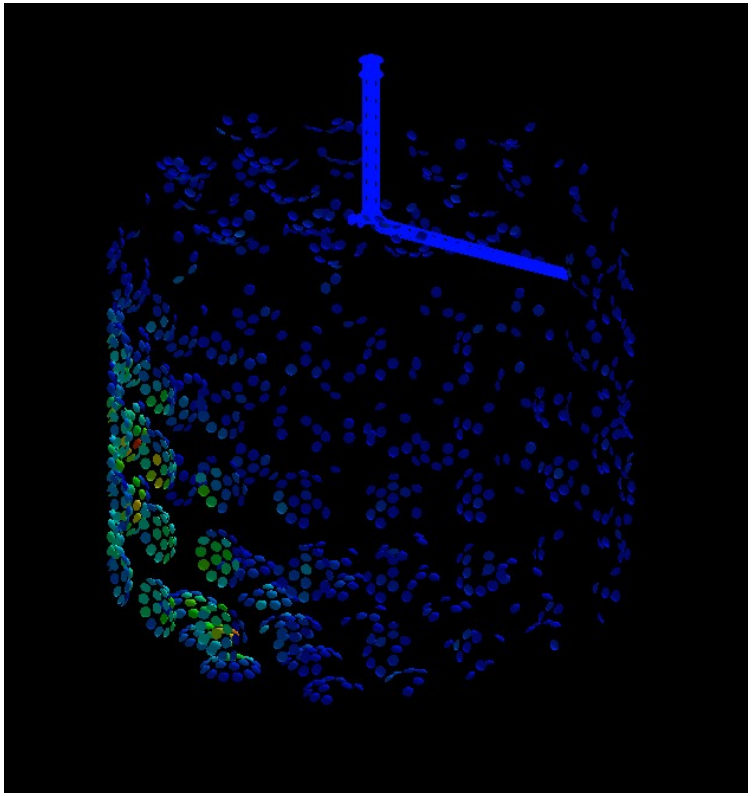
FiTQun reconstruction - 500MeV e-, pos 0,0,165

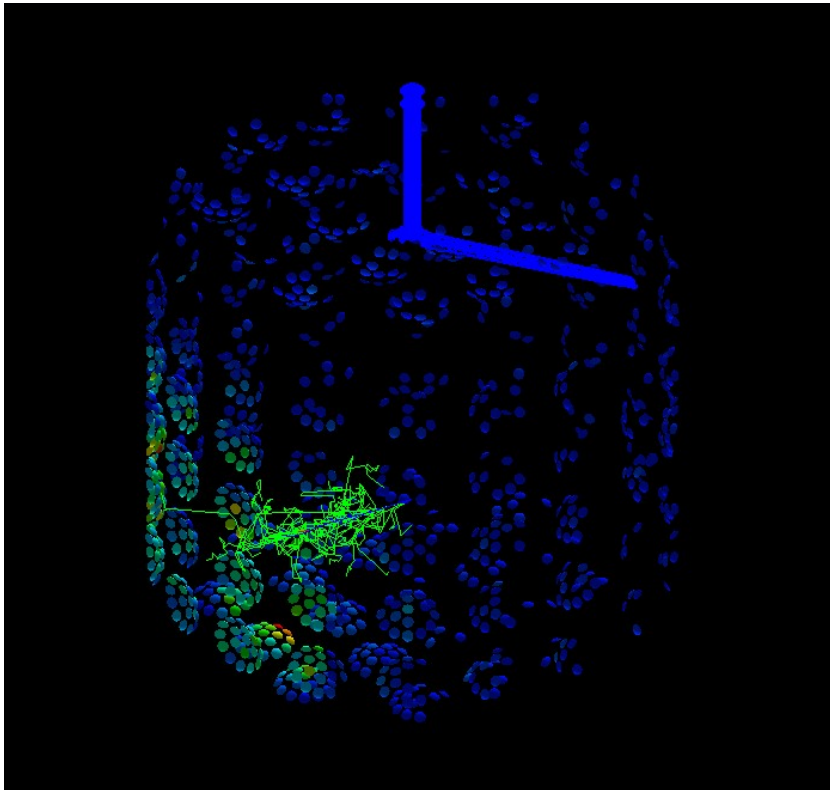
Momentum (e-like hypothesis)

-ln(Le/Lmu) – PID pram

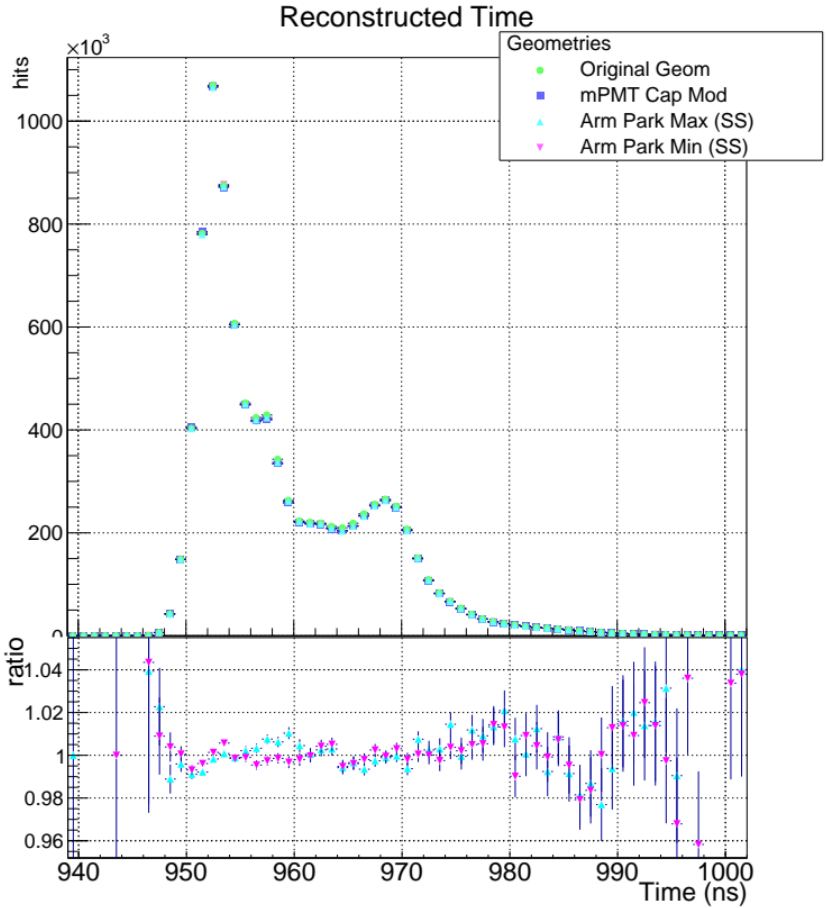


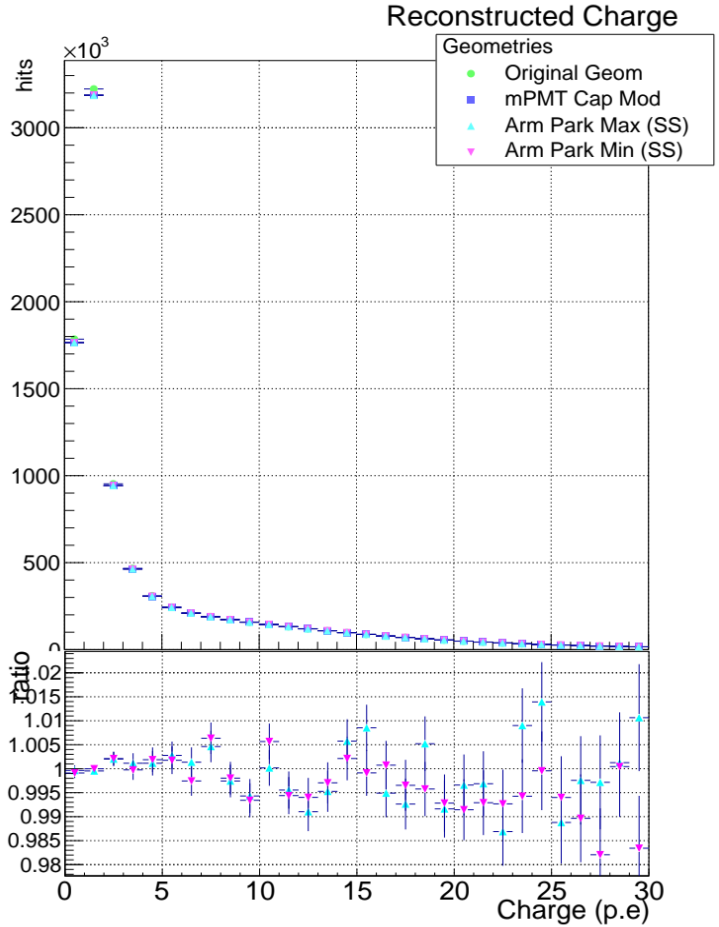
500MeV e- dir (0,0,-1), pos(0,-85,0)





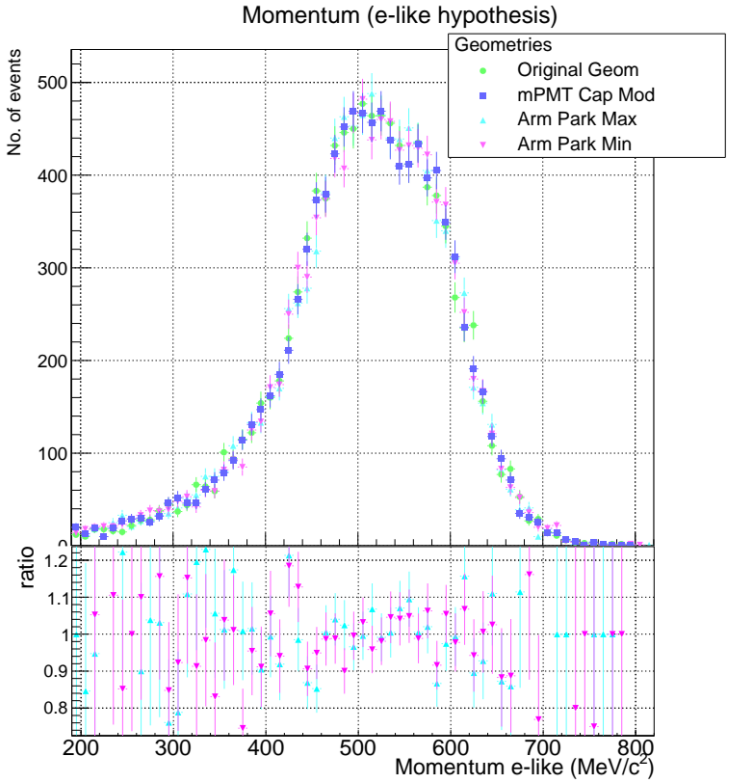
Reconstructed Time & Charge: dir (0,0,-1), pos(0,-85,0)

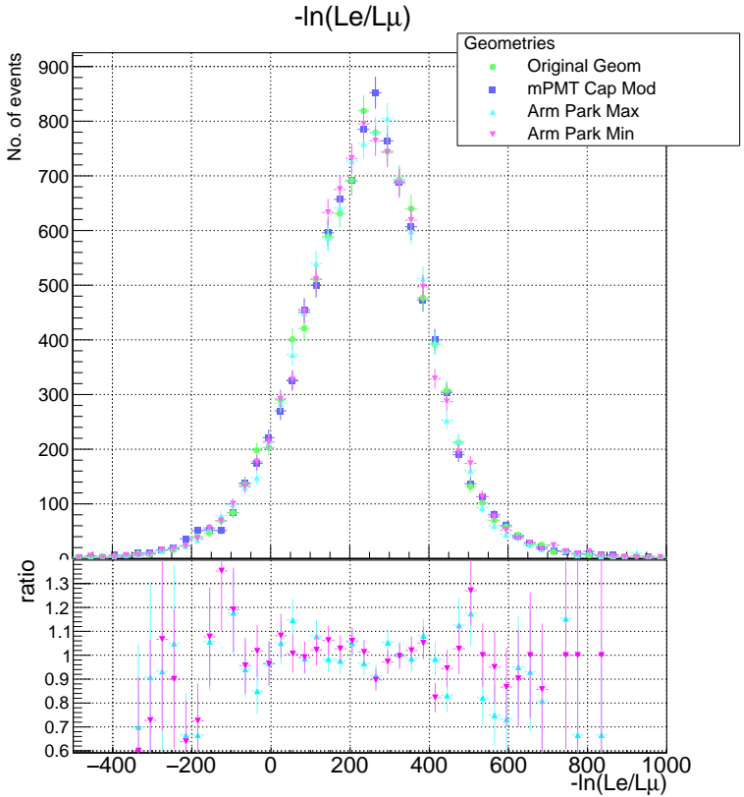




FiTQun reconstruction Momentum & PID

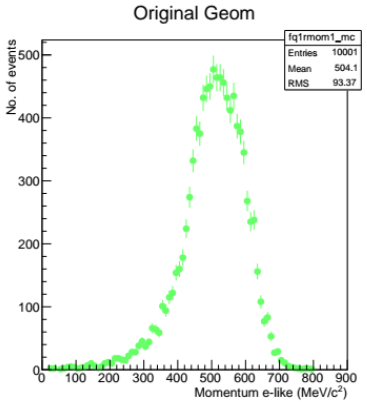
	Original	-1 PMT	Arm (max)	Arm (min)
Momentum MeV/c (mean)	504.1	503.6	503.3	504
-nll (mean)	235	235.7	235.1	235.1

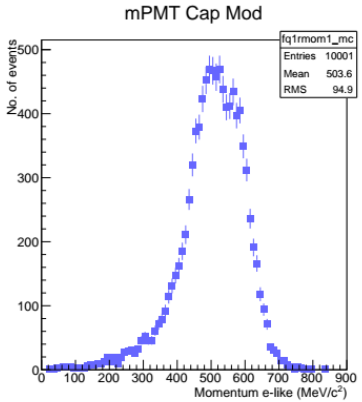


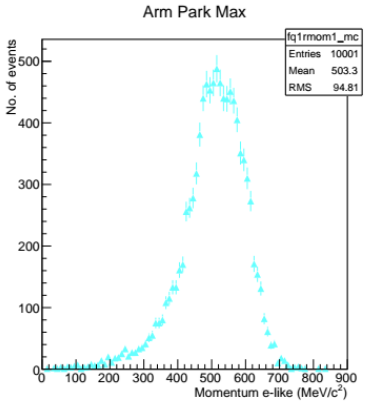


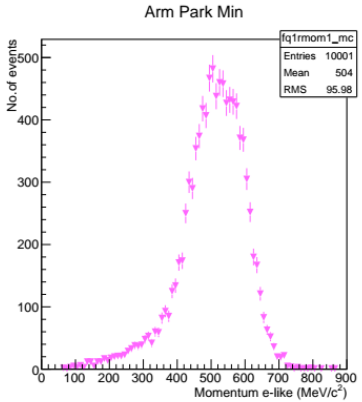
FiTQun reconstruction - 500MeV e-, pos 0,-85,0

Momentum (e-like hypothesis)

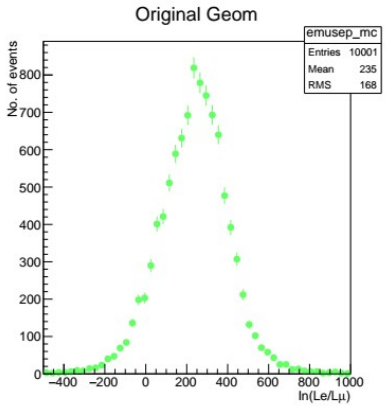


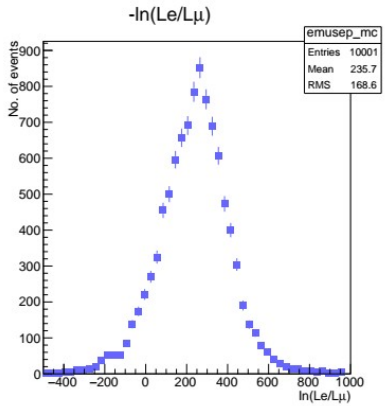


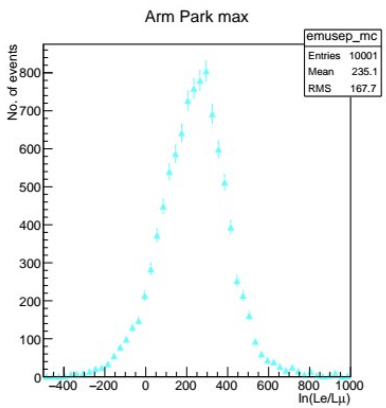


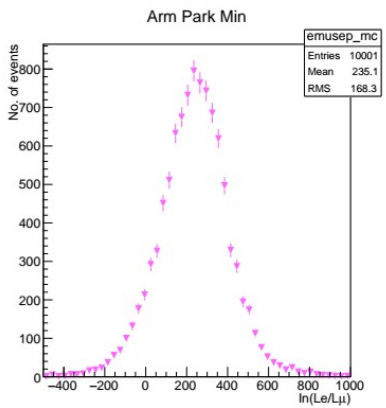


-ln(Le/Lmu) – PID pram

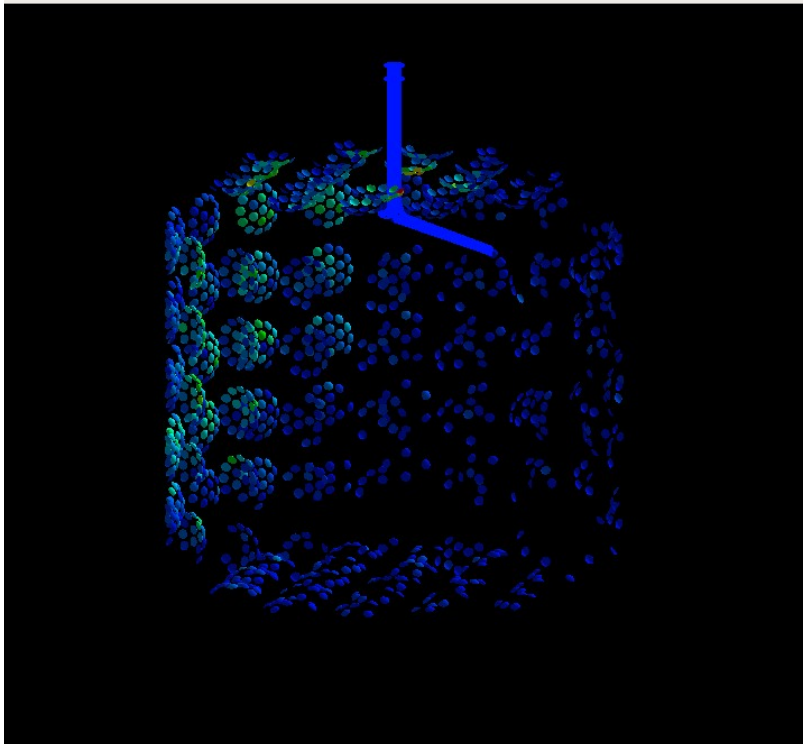


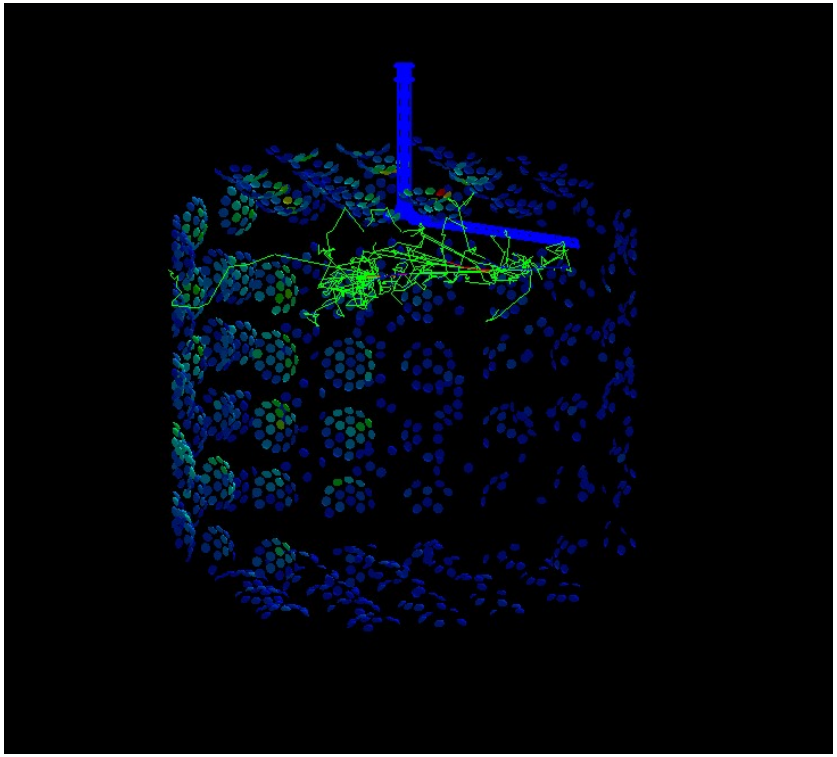




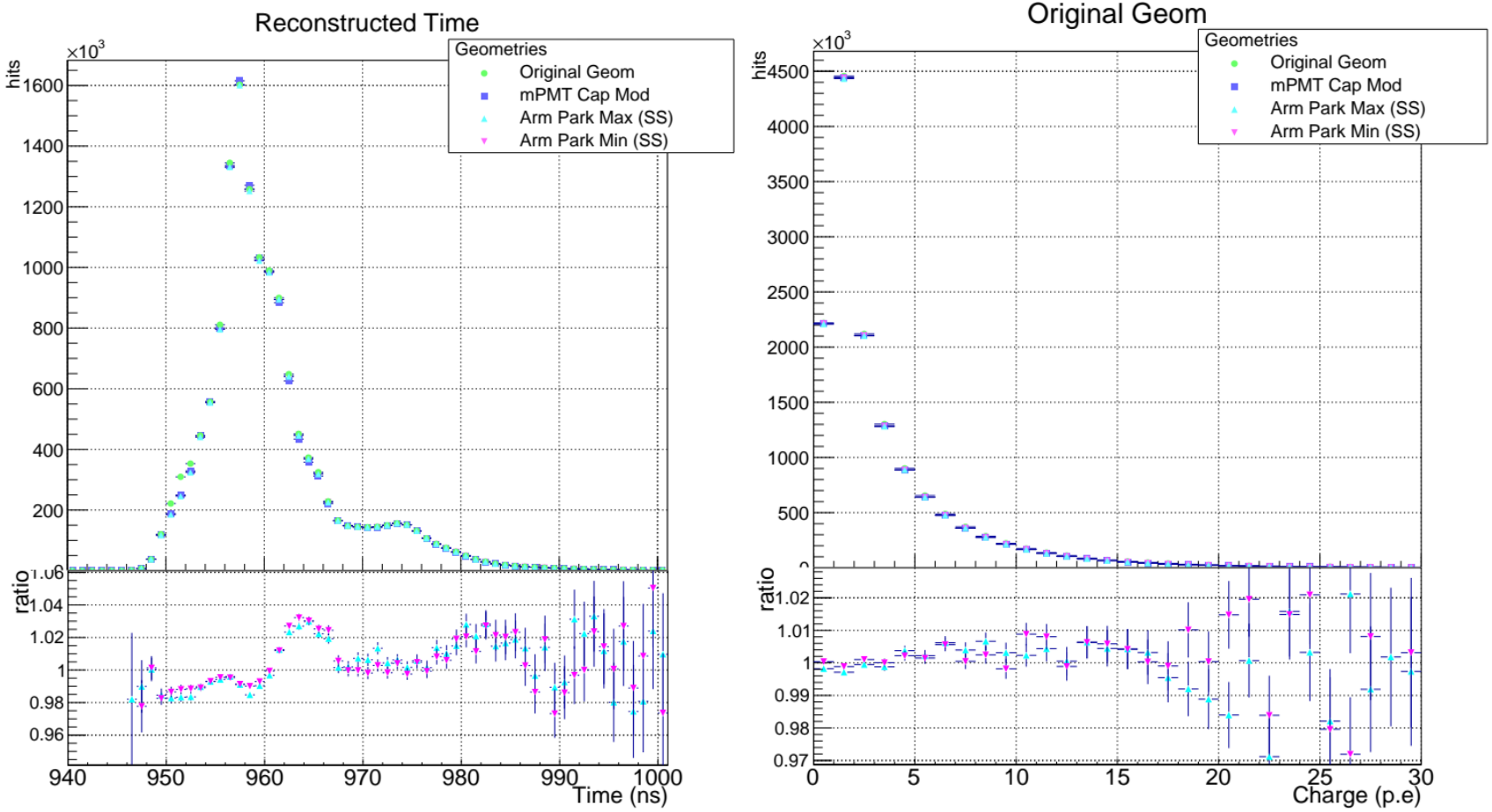


500MeV e-, dir (0,0,-1), pos(0,85,135)



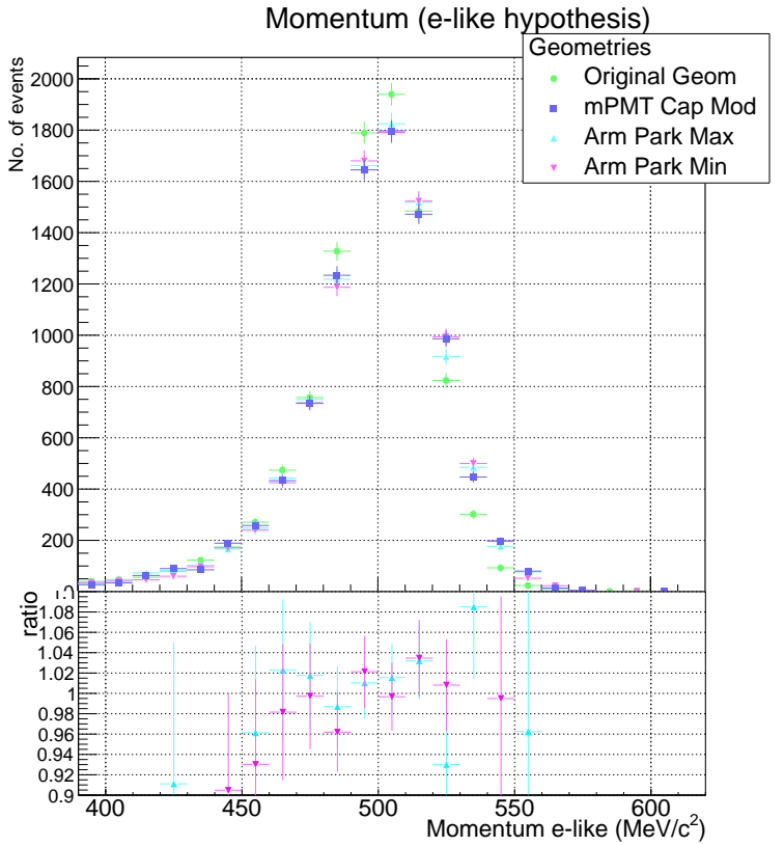


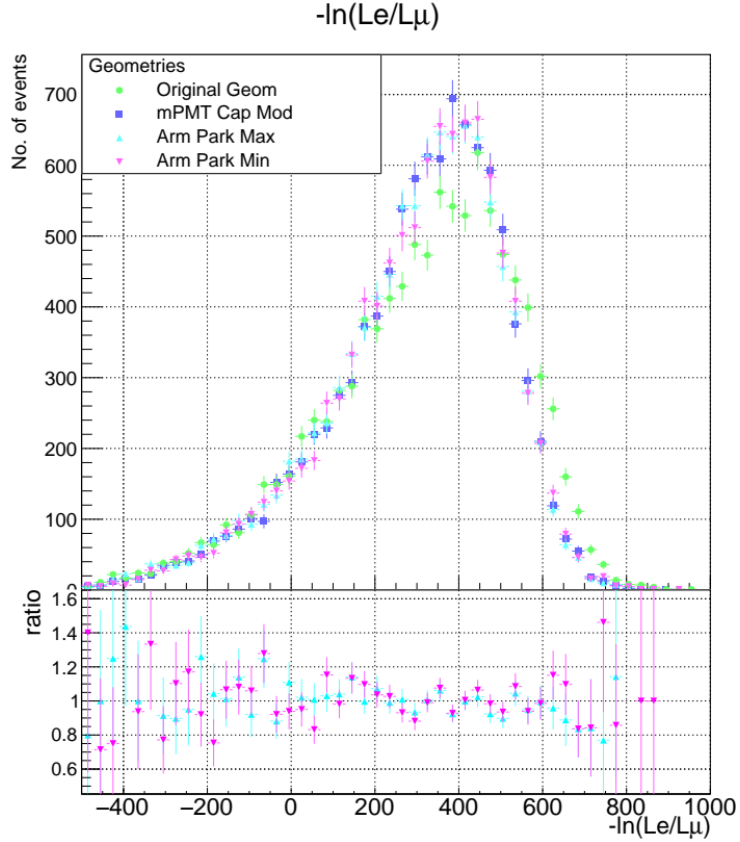
Reconstructed Time & Charge: dir (0,0,-1), pos(0,85,135)



FiTQun reconstruction Momentum & PID

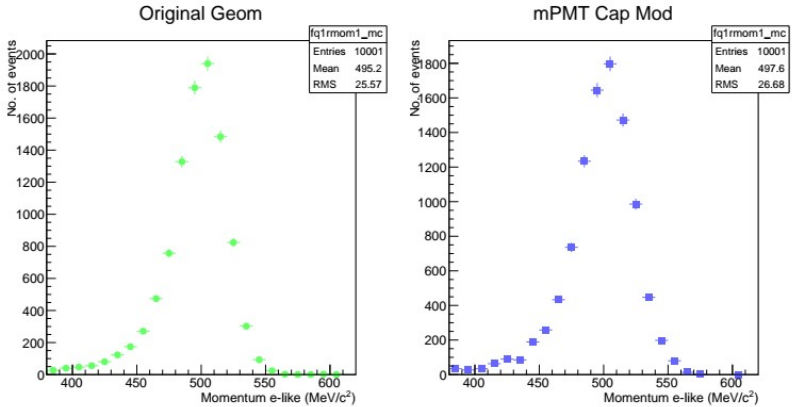
	Original	-1 PMT	Arm (max)	Arm (min)
Momentum MeV/c (mean)	519.1	520.8	518.8	518.5
-nll (mean)	325.9	329.6	327.6	326





FiTQun reconstruction - 500MeV e-, pos 0,85,135

Momentum (e-like hypothesis)



-ln(Le/Lmu) – PID pram