# Light Gas Cherenkov Detector for SoLID

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Temple University

SoLID Dry Run
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# Detector Configurations and Requirements

- The LGC is designed to accommodate two primary configurations:
  - SIDIS
  - PVDIS

- Each configuration has different:
  - incident particle angle / momentum ranges
  - luminosity
  - background profiles
  - space constraints

- Goal is to have each configuration provide a pion rejection above 99% *when combined with the calorimeter*.

# Detector Configurations and Requirements

- The LGC is designed to accommodate two primary configurations:
  - SIDIS
    - 1 to 5 GeV
    - ~7 to 15 deg
  - PVDIS
    - 2 to 4 GeV
    - 22 to 35 deg
- Each configuration has different:
  - **incident particle angle / momentum ranges**
  - luminosity
  - background profiles
  - space constraints

- Goal is to have each configuration provide a pion rejection above 99% when combined with the calorimeter.

# Detector Configurations and Requirements

- The LGC is designed to accommodate two primary configurations:
  - SIDIS
    - 15uA on $^3$He
  - PVDIS
    - 50uA on D / H

- Each configuration has different:
  - incident particle angle / momentum ranges
  - **luminosity**
  - background profiles
  - space constraints

- Goal is to have each configuration provide a pion rejection above 99% when combined with the calorimeter.

# Detector Configurations and Requirements

- The LGC is designed to accommodate two primary configurations:
  - SIDIS
    - Forward Calorimeter
    - Additional Gems
  - PVDIS
    - Baffles

- Each configuration has different:
  - incident particle angle / momentum ranges
  - luminosity
  - **background profiles**
  - space constraints

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  - SIDIS
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  - luminosity
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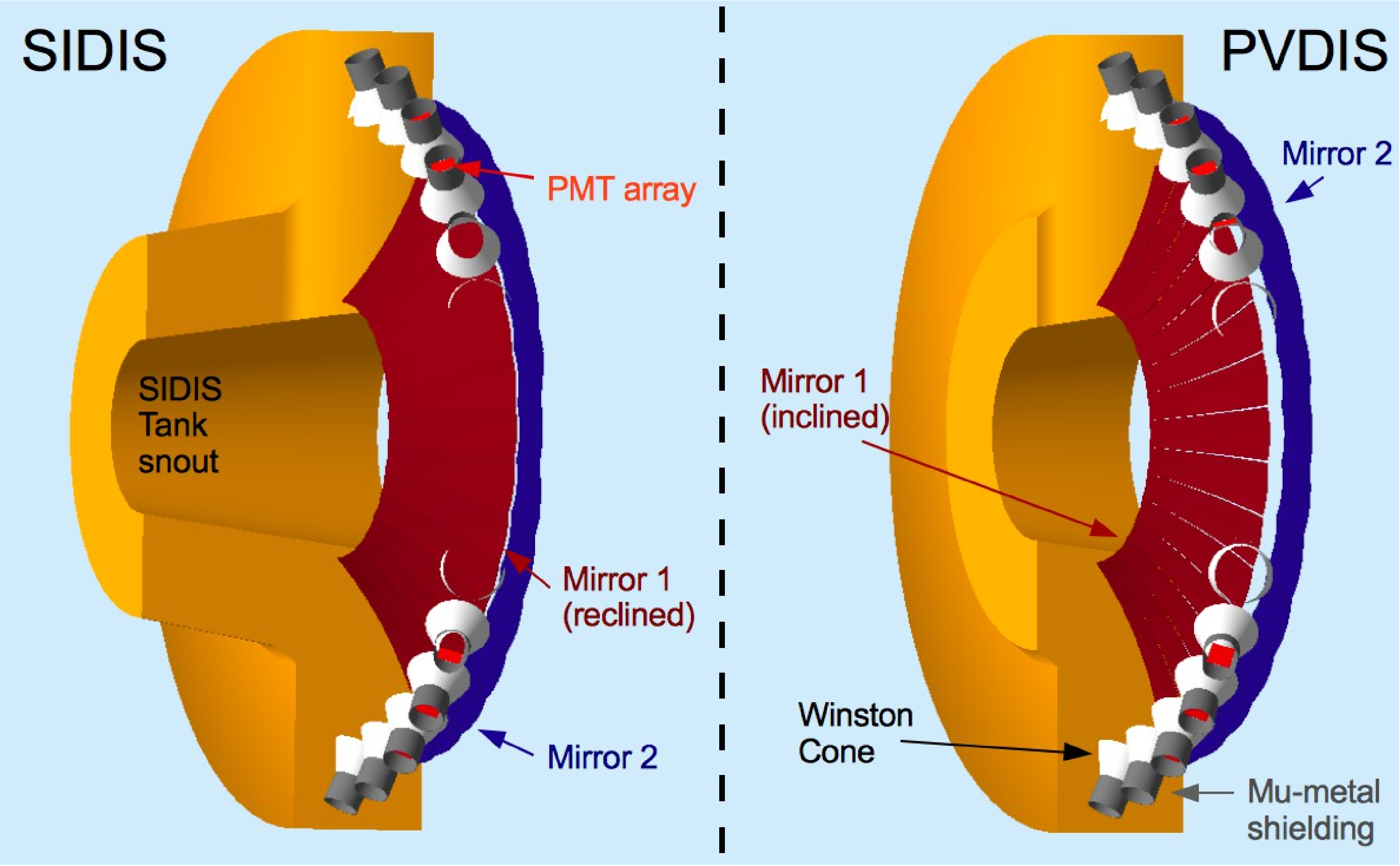
# LGC geometric / material characteristics

- Cherenkov is designed to maximize component use between the two configurations.



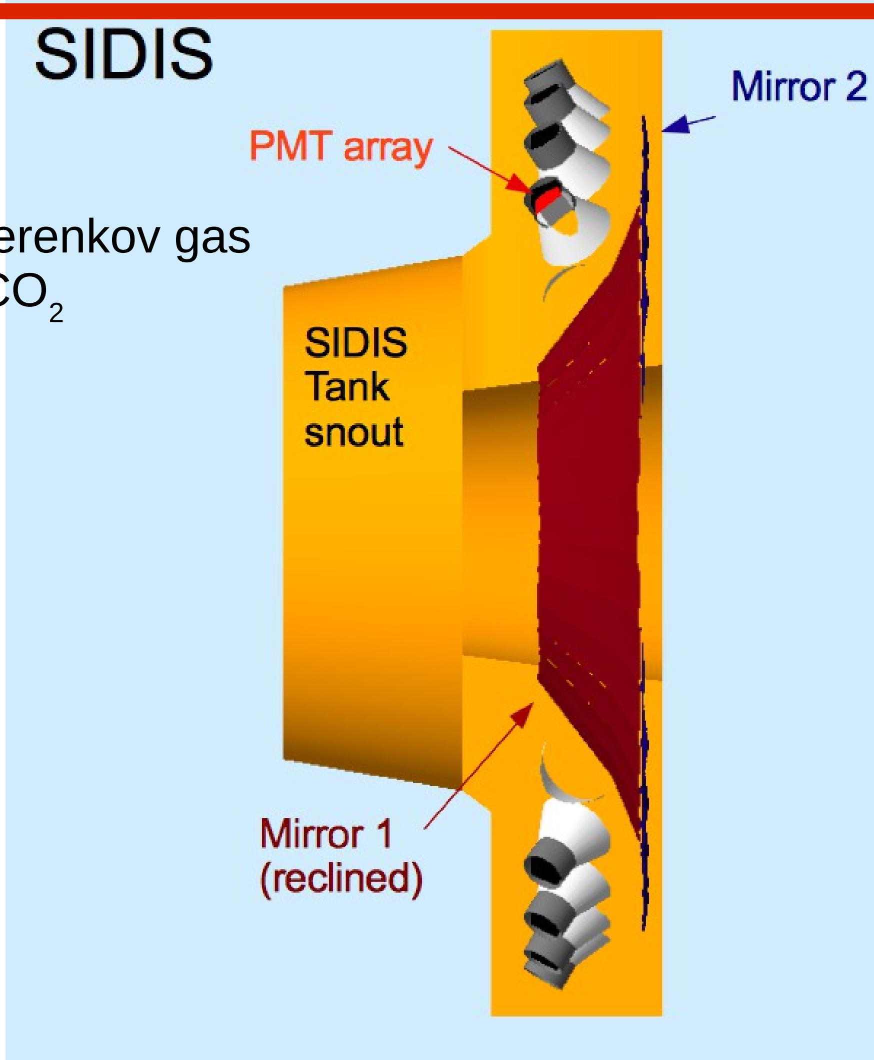
# Tank

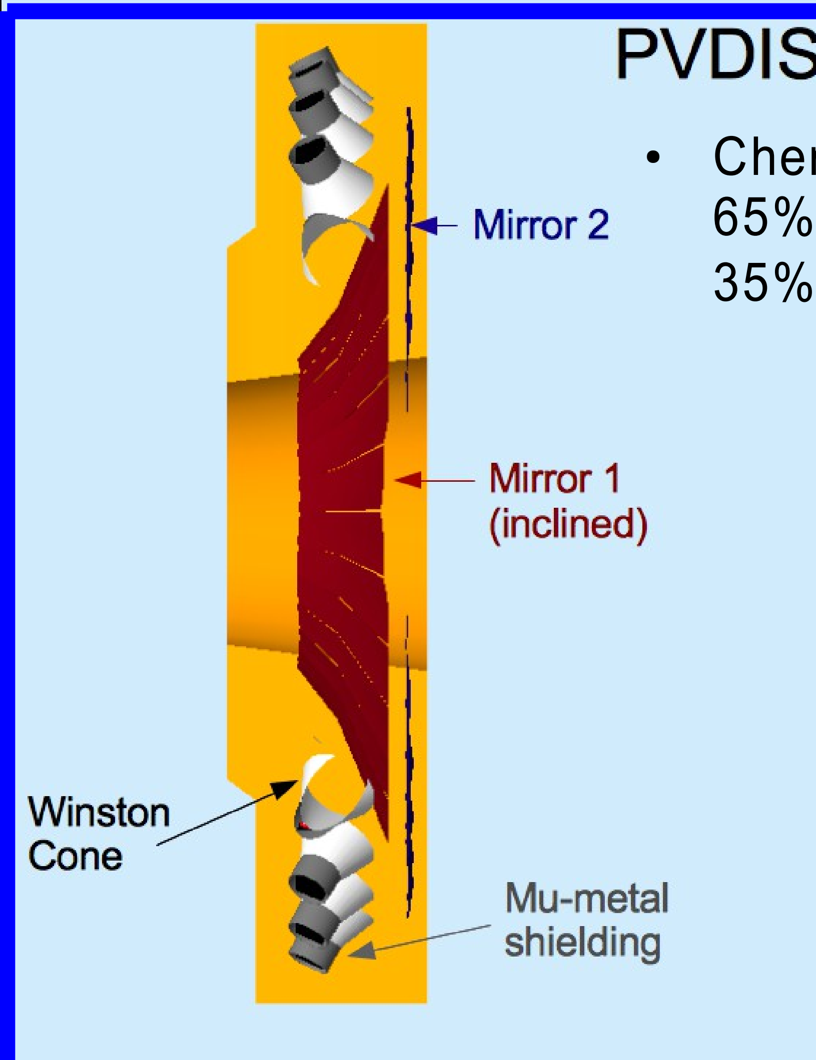
- Primary tank toroidal shape:
  - 105 cm length
  - 71 to 85 cm inner radius
  - 265 cm outer radius

**Common**

- Windows
  - Polyvinyl fluoride (Tedlar)
    - 1.45 $g/mm^3$ density
  - 0.05 mm entrance window
  - 0.1 mm exit window

Cherenkov gas is $CO_2$



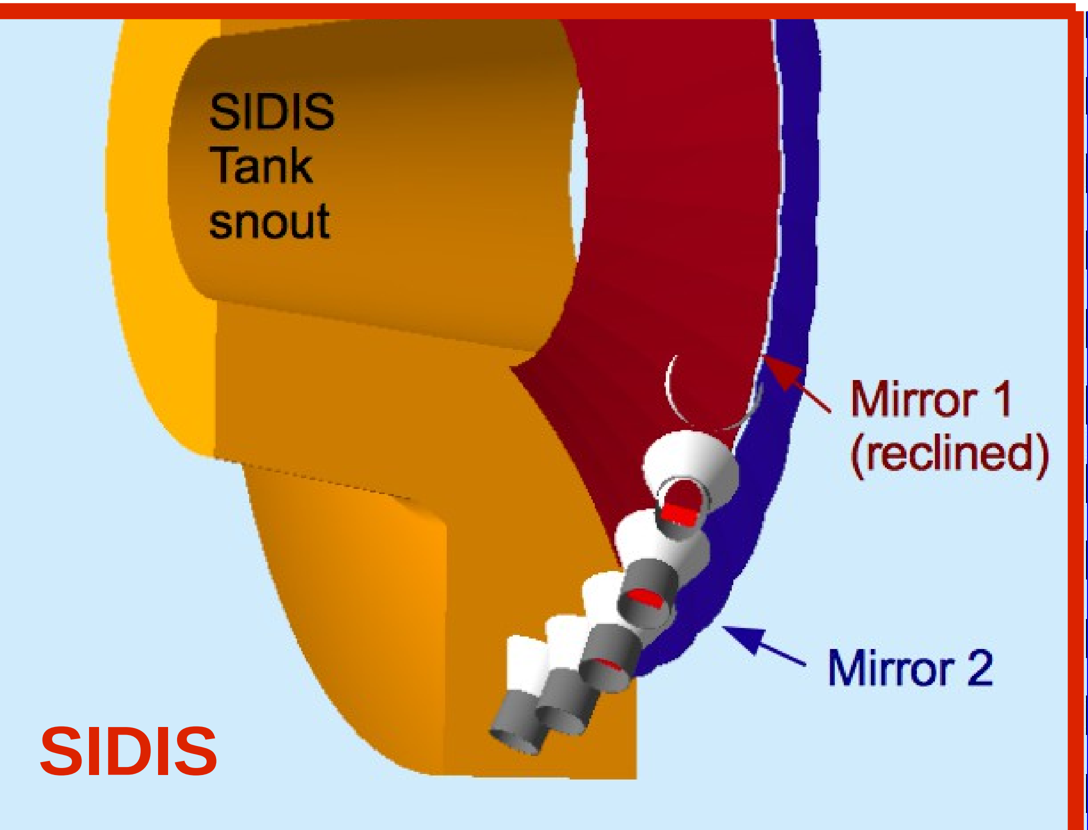



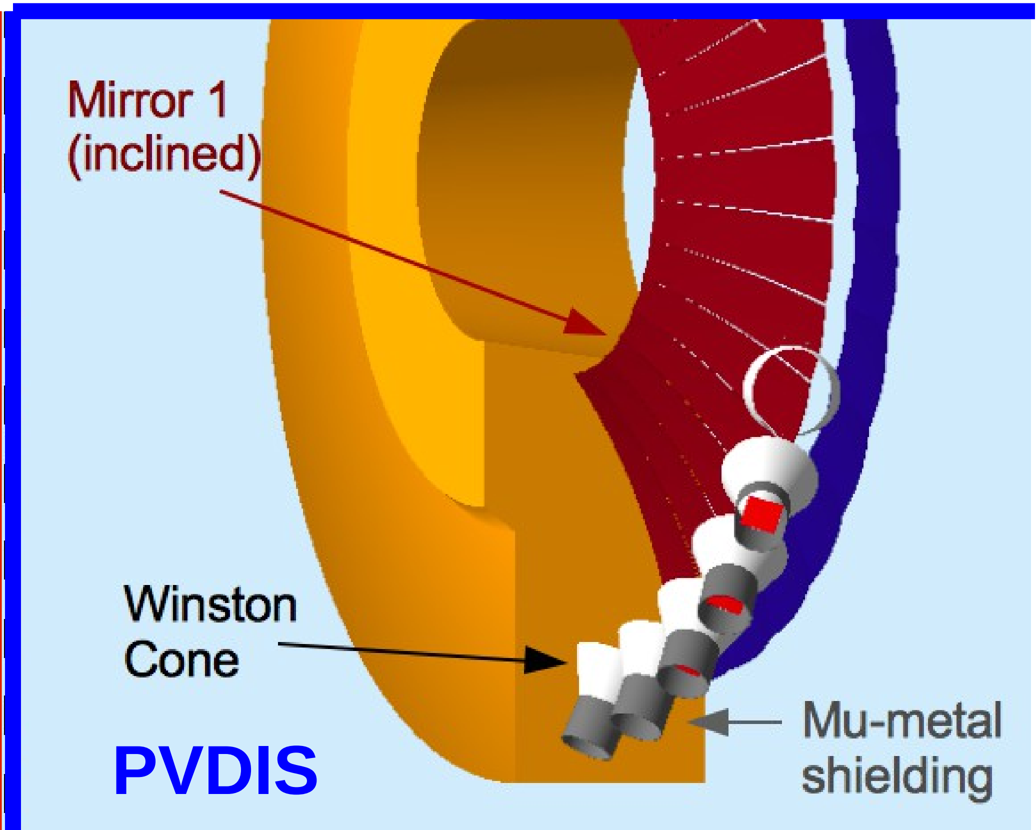

- Cherenkov gas is 65% $C_4F_8O$ and 35% $N_2$

# Mirrors

- 30 sectors (defined by baffle segmentation)
  - 2 spherical mirrors per sector (60 mirrors total)
- Blanks are Carbon Fiber Reinforced Polymer [CFRP] (Same as LHCb RICH)
  - Areal density < 6 $kg/m^2$
  - Reflective coating provided by Stony Brook (Al / $MgF_2$ )
    - Total reflective area per mirror is roughly 0.3 $m^2$

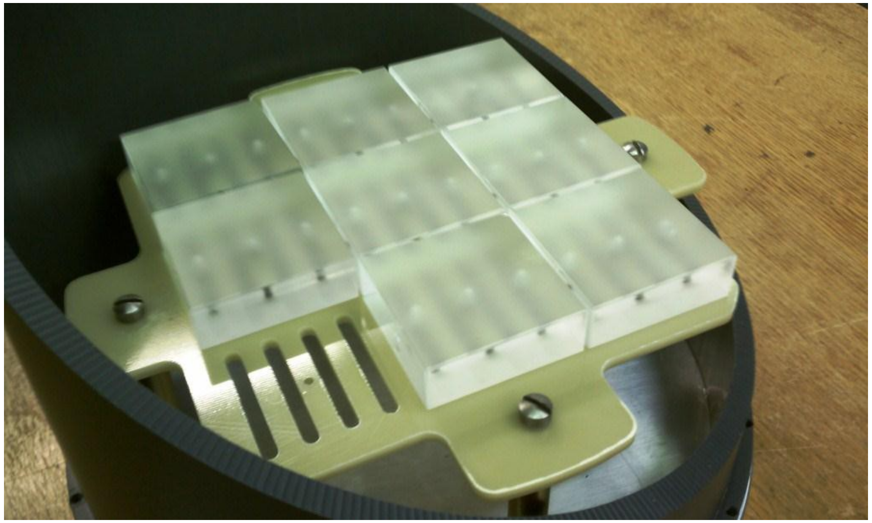
**Common**



# PMT Assembly

- All components are common without adjustment between both configurations.
- PMT assembly is:
  - **3 x 3 array** of Hamamatsu H8500C-03 maPMTS
    - 64 pixel PMT array for each H8500C
    - Average QE ~ 15%
  - **Reflective cone**
  - **Mu-metal shielding.**
    - 0.04” thickness with 0.125” thick steel reinforcement
    - Reduce $B_T$ and $B_L$ from 95 and 135 gauss (respectively) to < 50 gauss.



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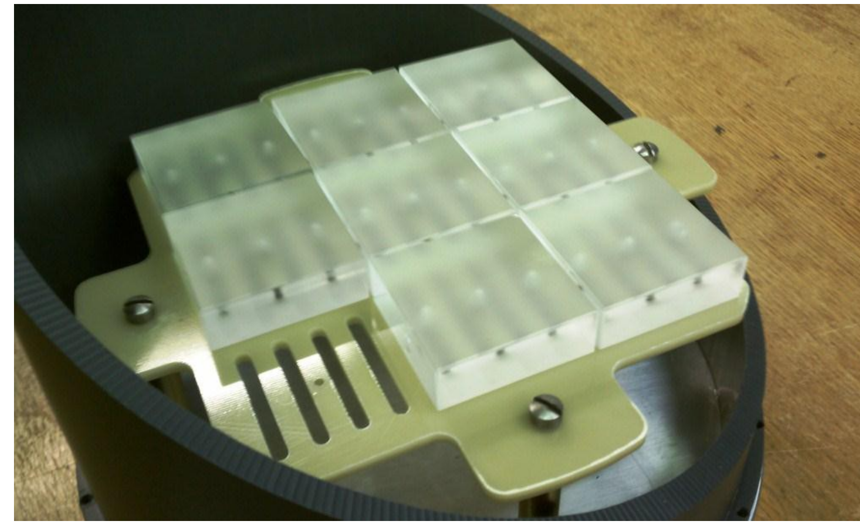

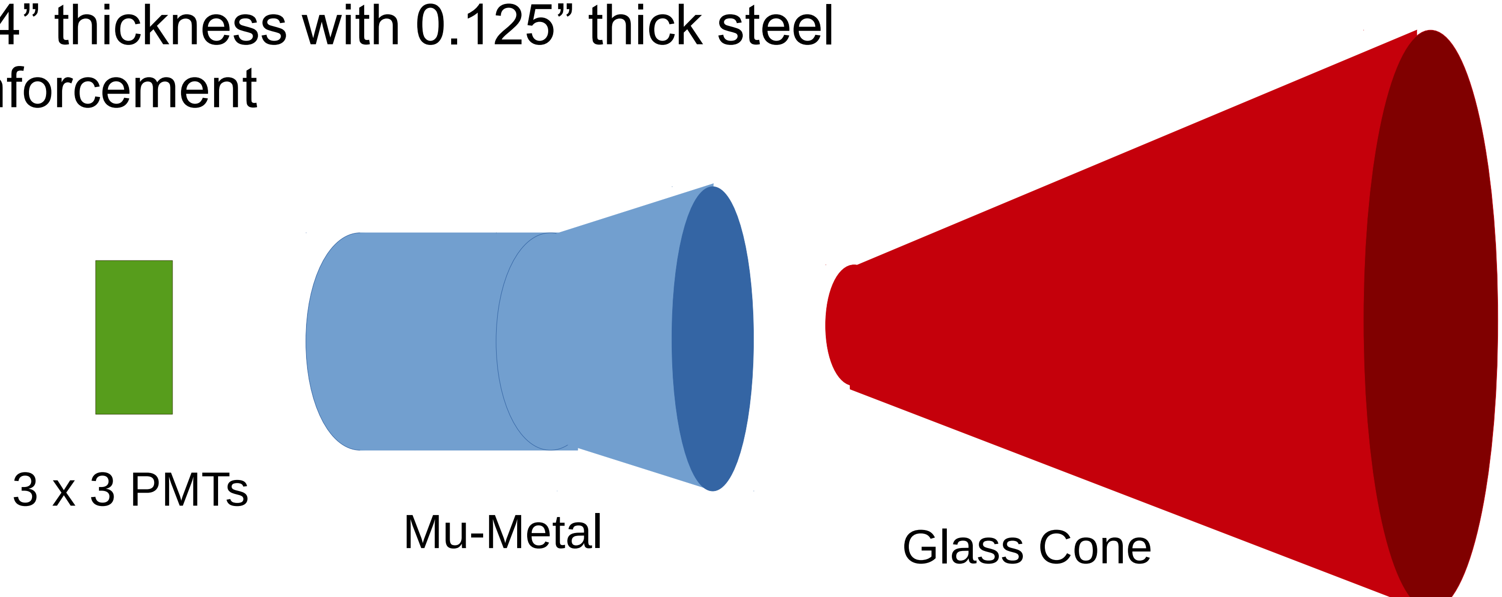

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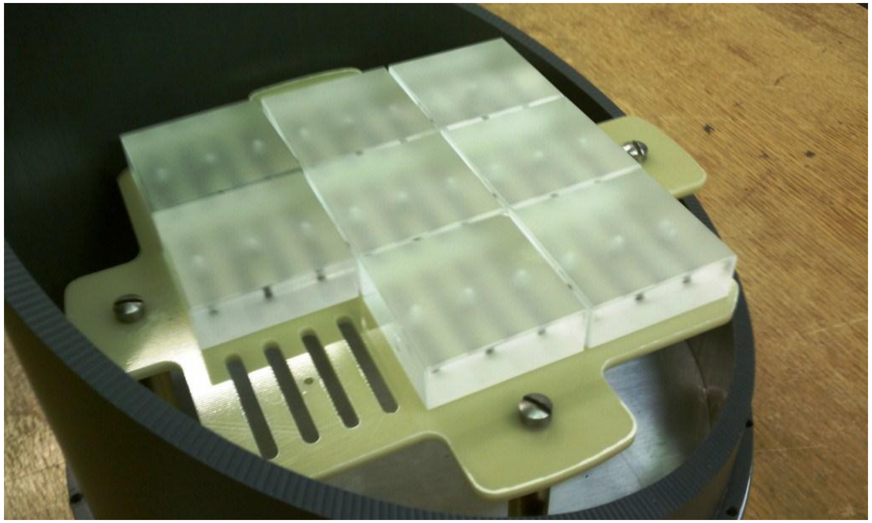
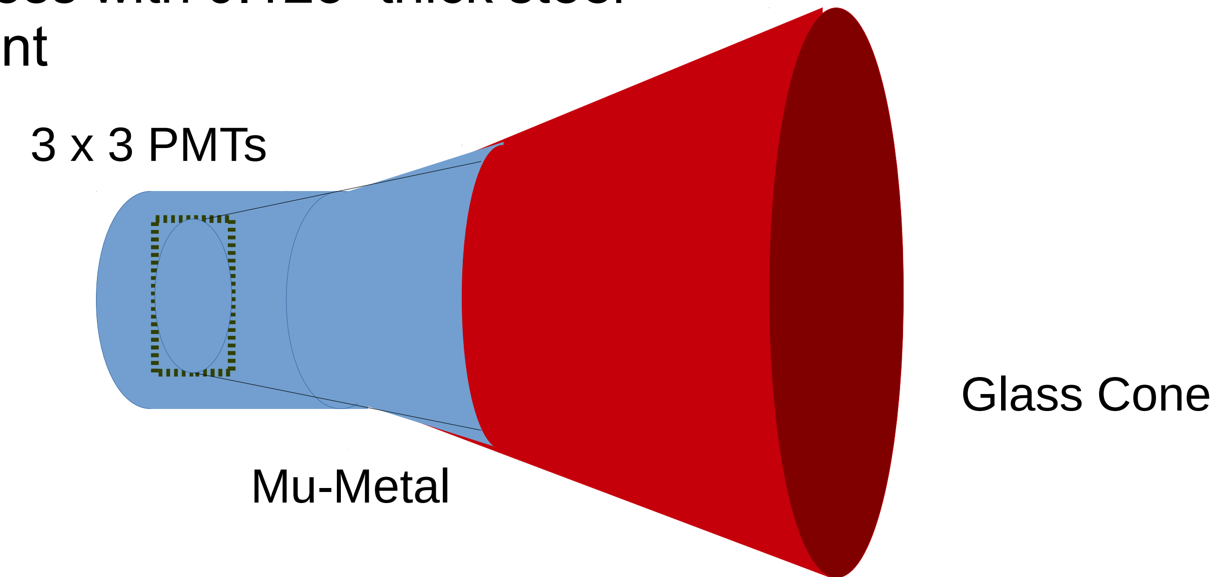




# Simulation for pi rejection

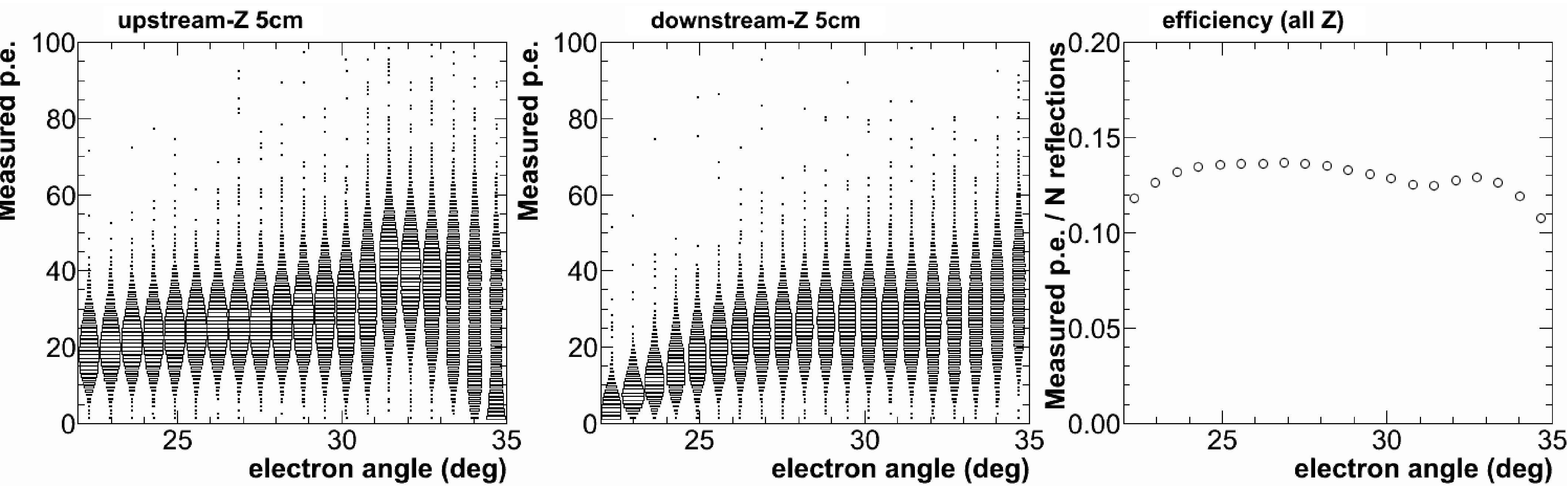
- Event generation:
  - Electrons from electron generator eicRate.
  - Pions from eicRate (Wiser)
  - Uniformly distributed along target length.
- Propagate tracks out of target to LGC window
  - All interactions are handled by GEMC / Geant4
  - All materials from SoLID design are included in the transport.
  - CLEO magnetic field map is used.
- Simulate Cherenkov radiation through gas and collect optical photons.
  - Collection is recorded at the PMT on a p.e. per pixel level.
  - QE as a function of photon energy is taken into account.
  - Pion triggers below Cherenkov threshold are primarily from delta rays.

# Total Collection Efficiency for Electrons

- Calculated as # optical photons detected at PMT divided by # reflections from spherical mirrors. Includes:
  - Reflection efficiencies
  - Quantum efficiency (dominant)
  - Geometrical acceptance
- Aside: These simulations were done with older baffles and geometries! (circa 2012).
  - I can easily run all numbers again with latest baffles / geometries. It just takes CPU hours on the farm.
  - I don't expect any major changes.

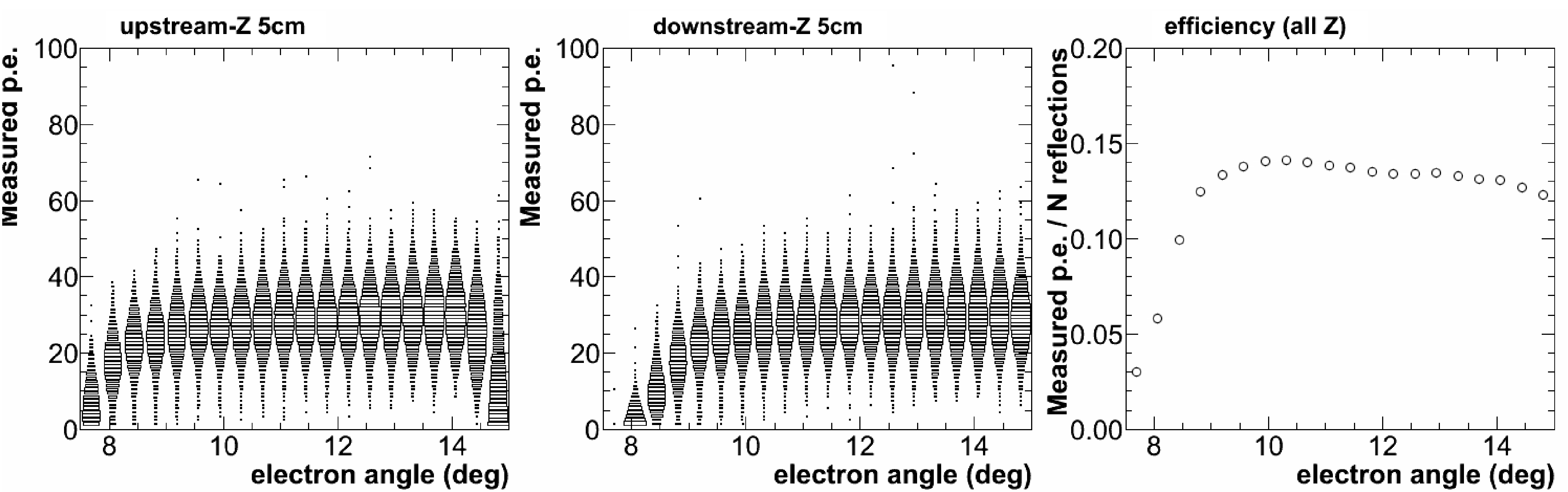
# Second Aside on Simulations

- All of these simulations are done with a personally modified GEMC 1.8 (additional reflectivity options + small changes).
  - Getting harder to collect all dependencies and install a working version with my modified GEMC.
  - Need to upgrade and update!
    - Should be done in scope of larger simulation efforts.


upstream-Z 5cm
downstream-Z 5cm
efficiency (all Z)
Measured p.e.
Measured p.e.
Measured p.e. / N reflections
electron angle (deg)
electron angle (deg)
electron angle (deg)

# PVDIS

# SIDIS


upstream-Z 5cm
downstream-Z 5cm
efficiency (all Z)
Measured p.e.
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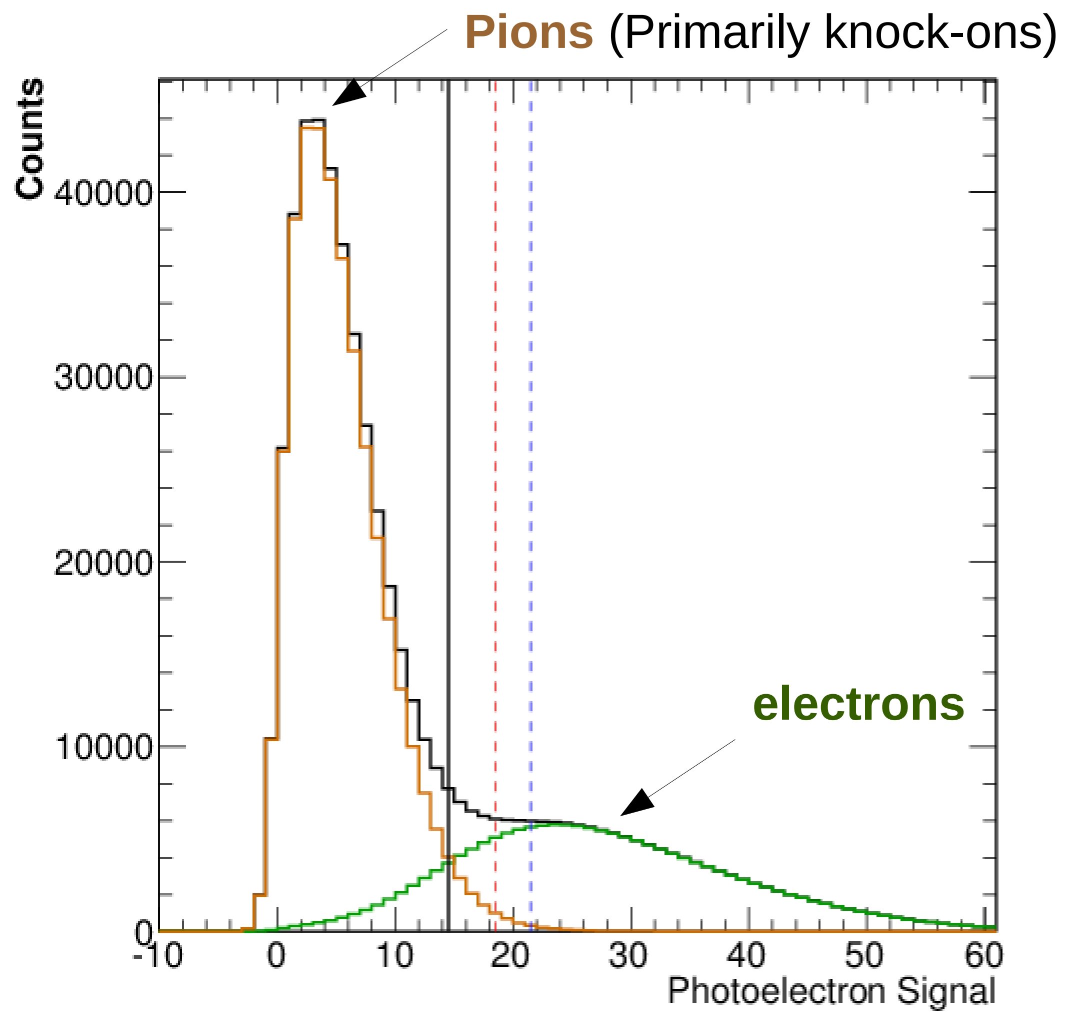
electron angle (deg)
electron angle (deg)
electron angle (deg)

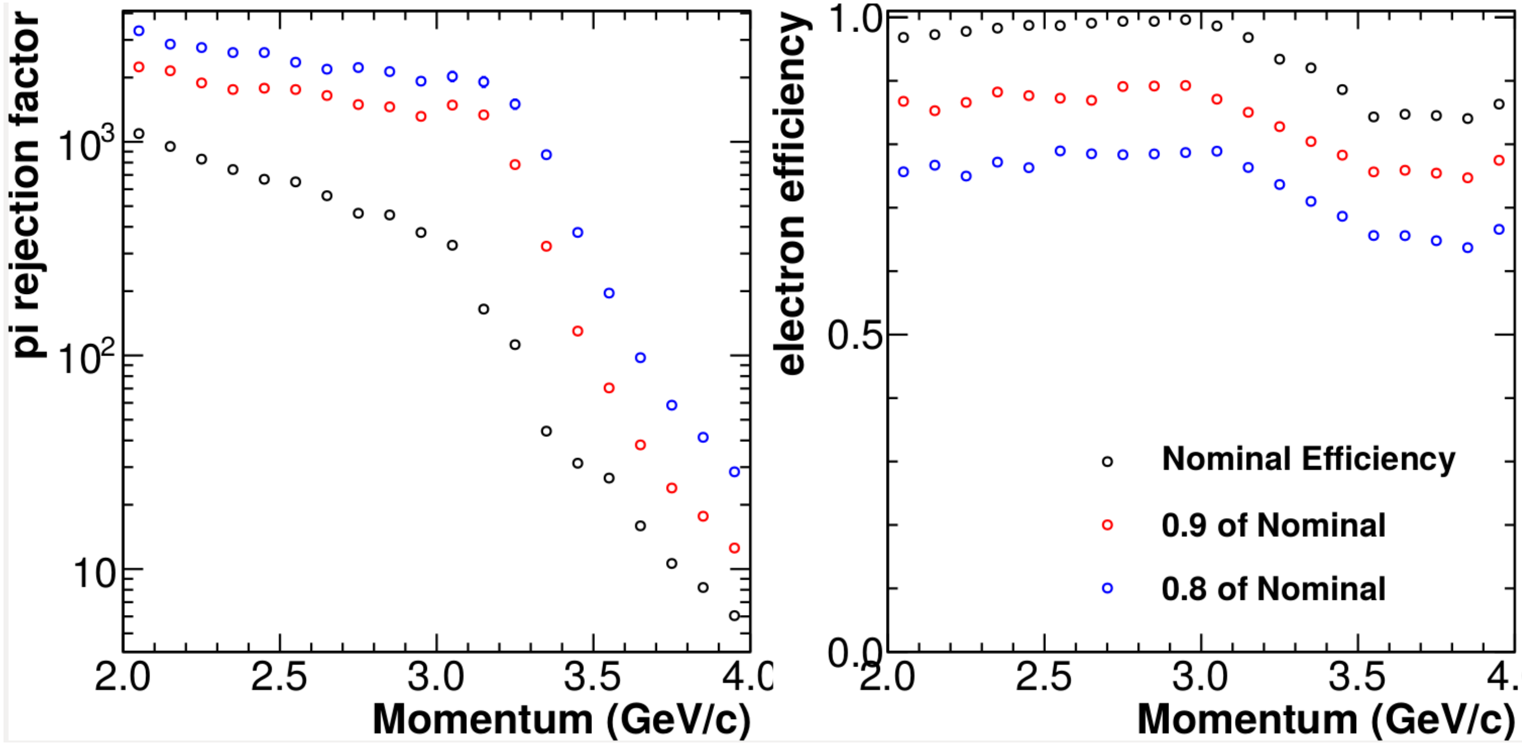
# Pion / electron signal

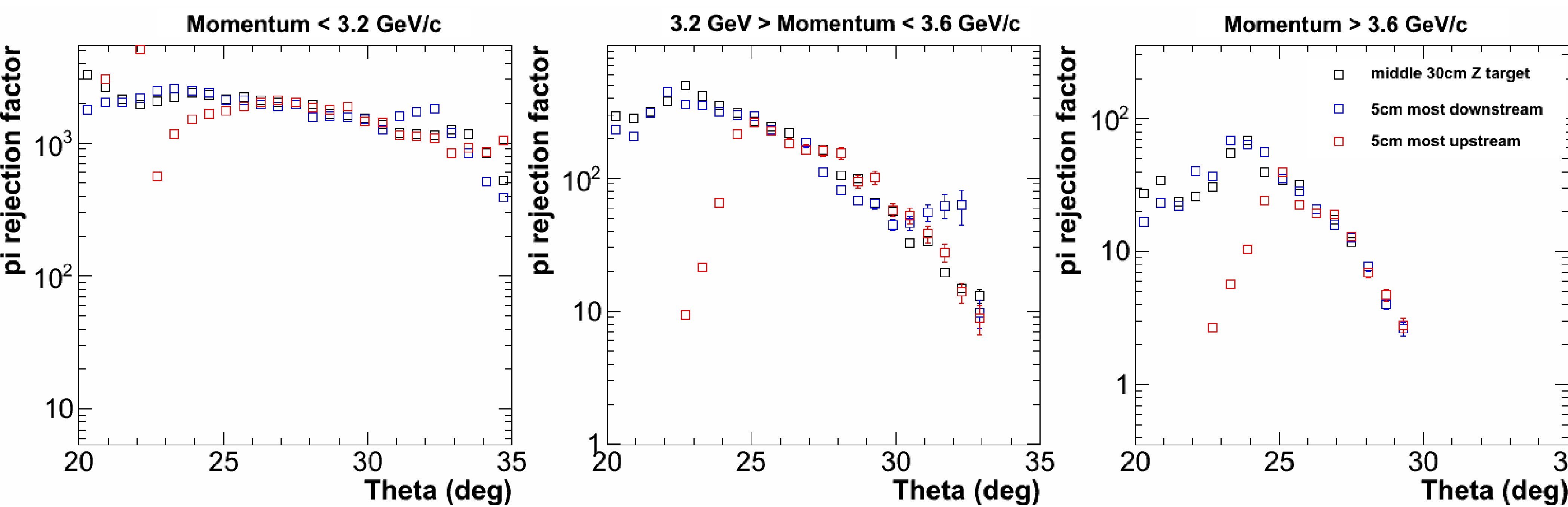
- Sample of collected PE signal:
  - (This MC is for track momentum below pion radiation threshold)
- Three settings possible pion rejection setting shown:
  - Nominal
  - 90% of Nominal
  - 80% of Nominal



# PVDIS

pi rejection factor is the inverse pi acceptance after selection cut.



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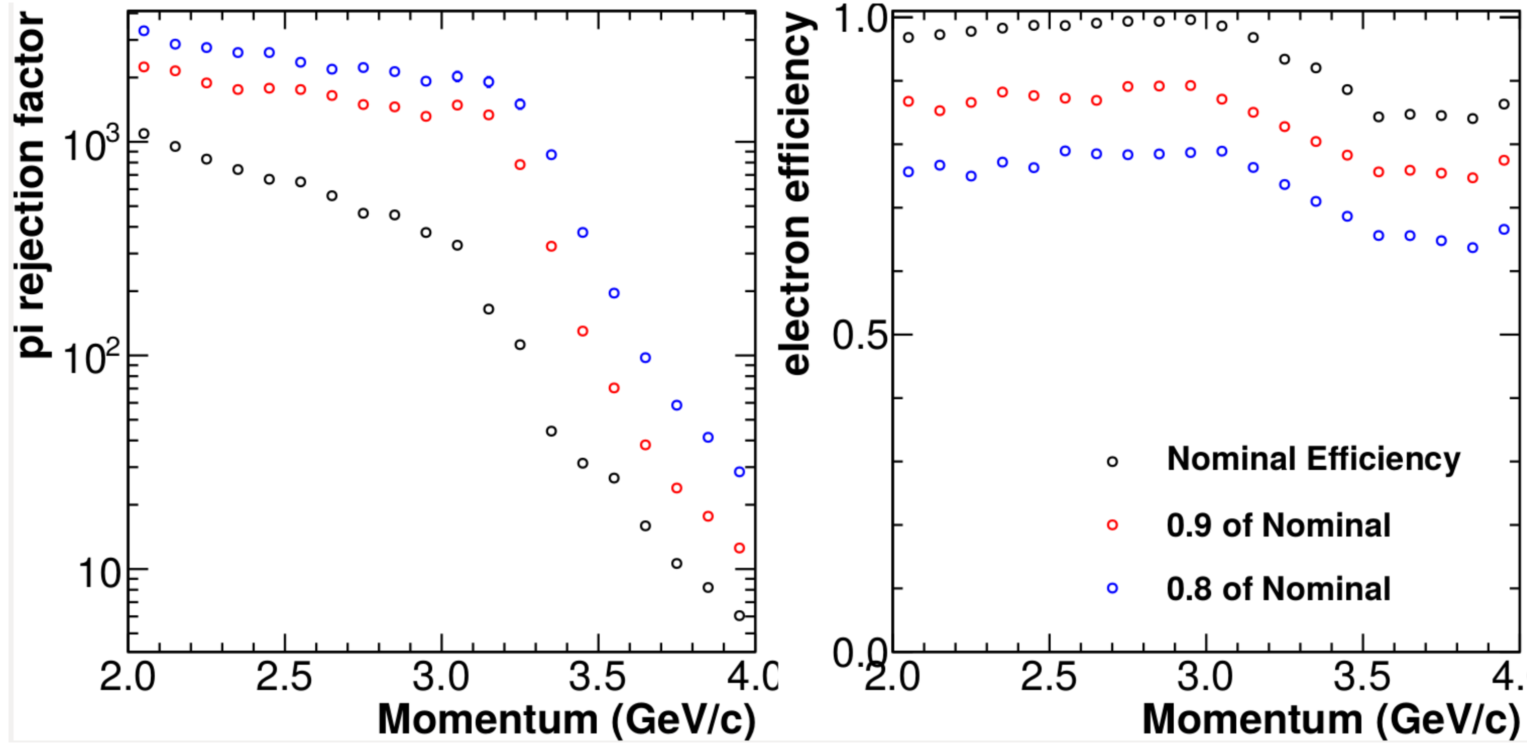
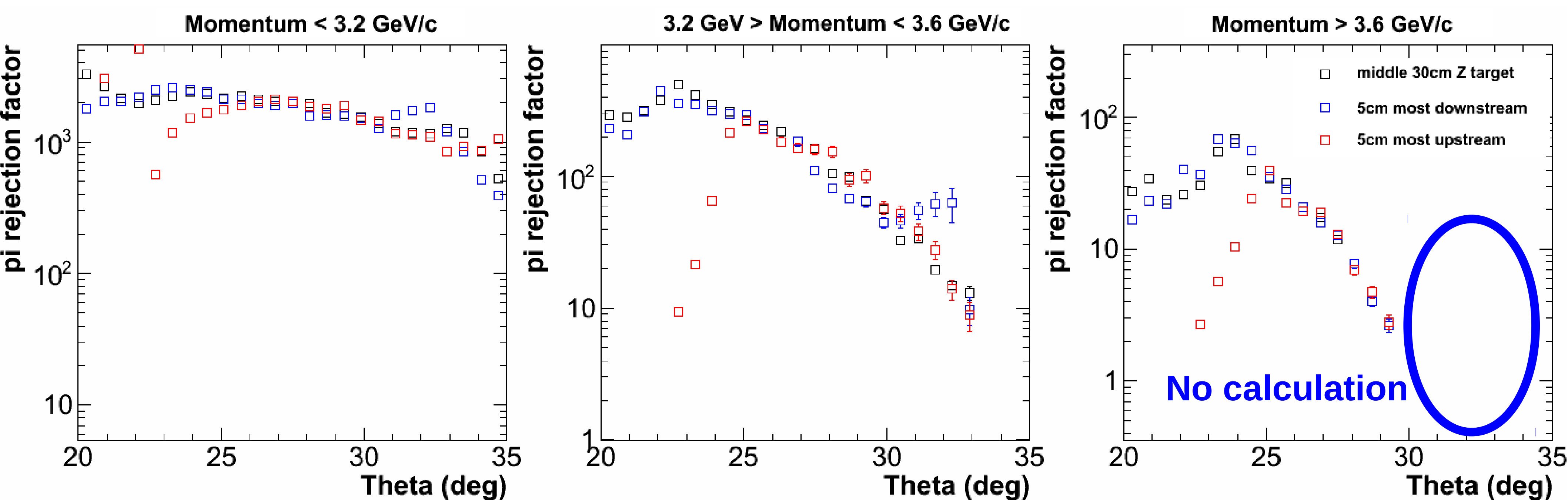
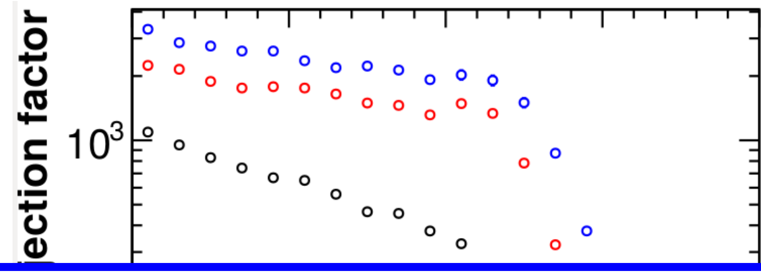
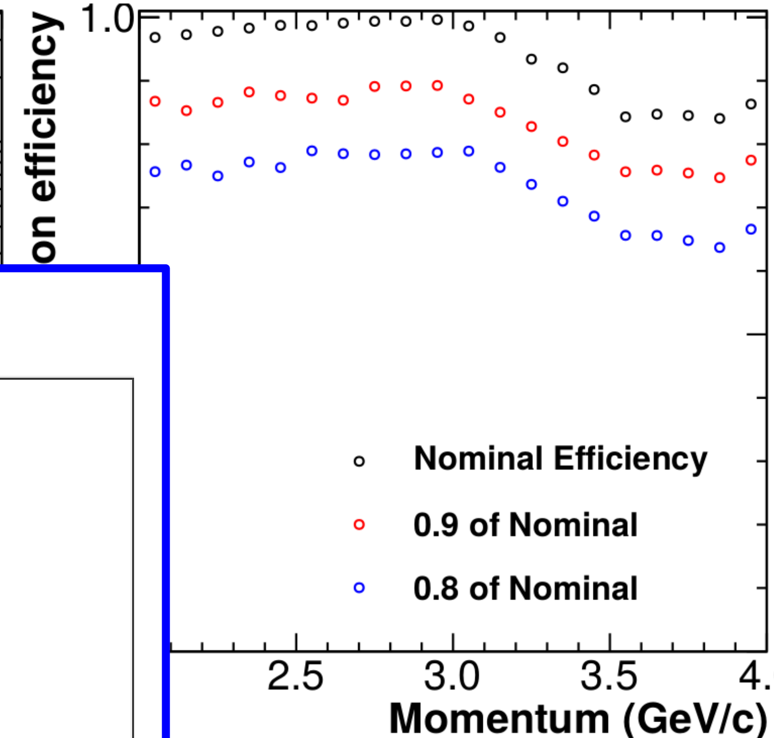


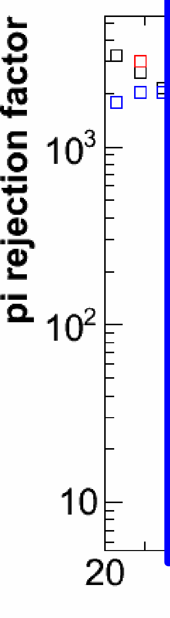



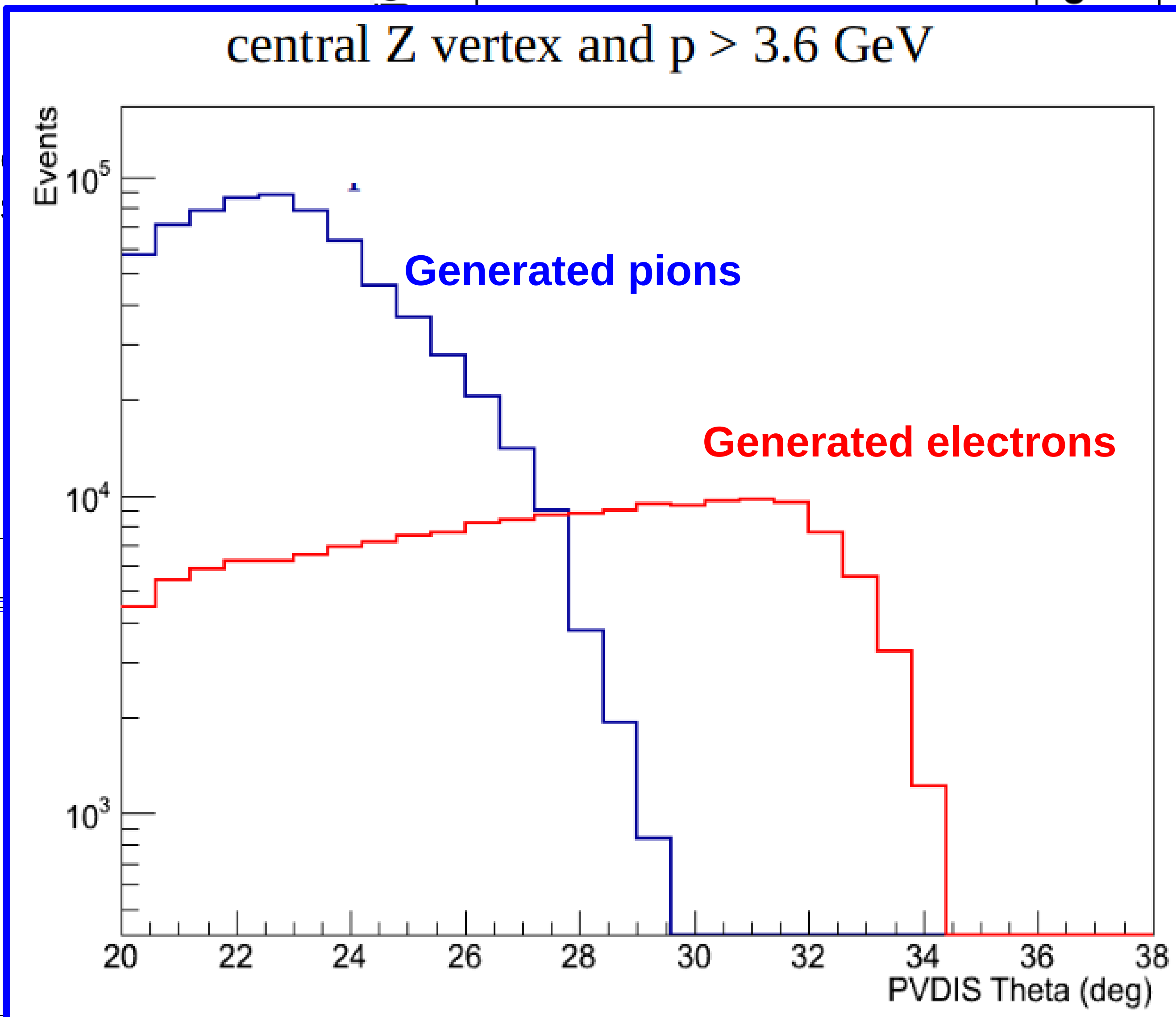
# PVDIS

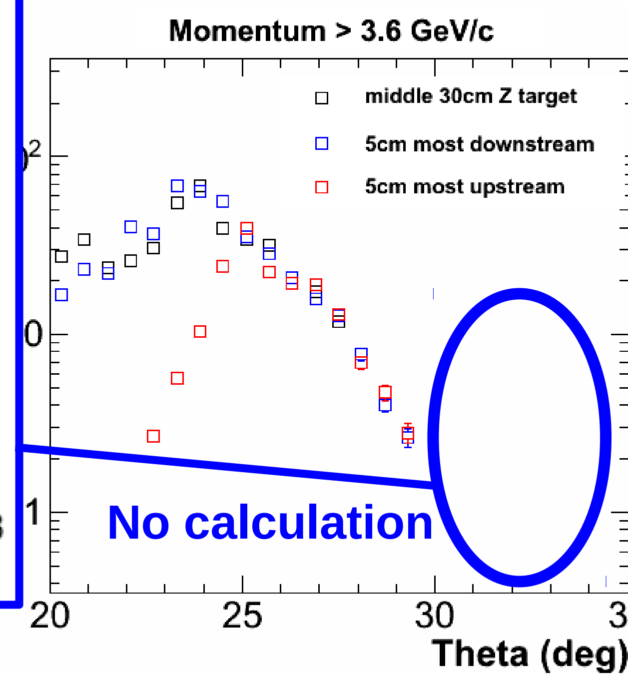
pi rej
invers
after



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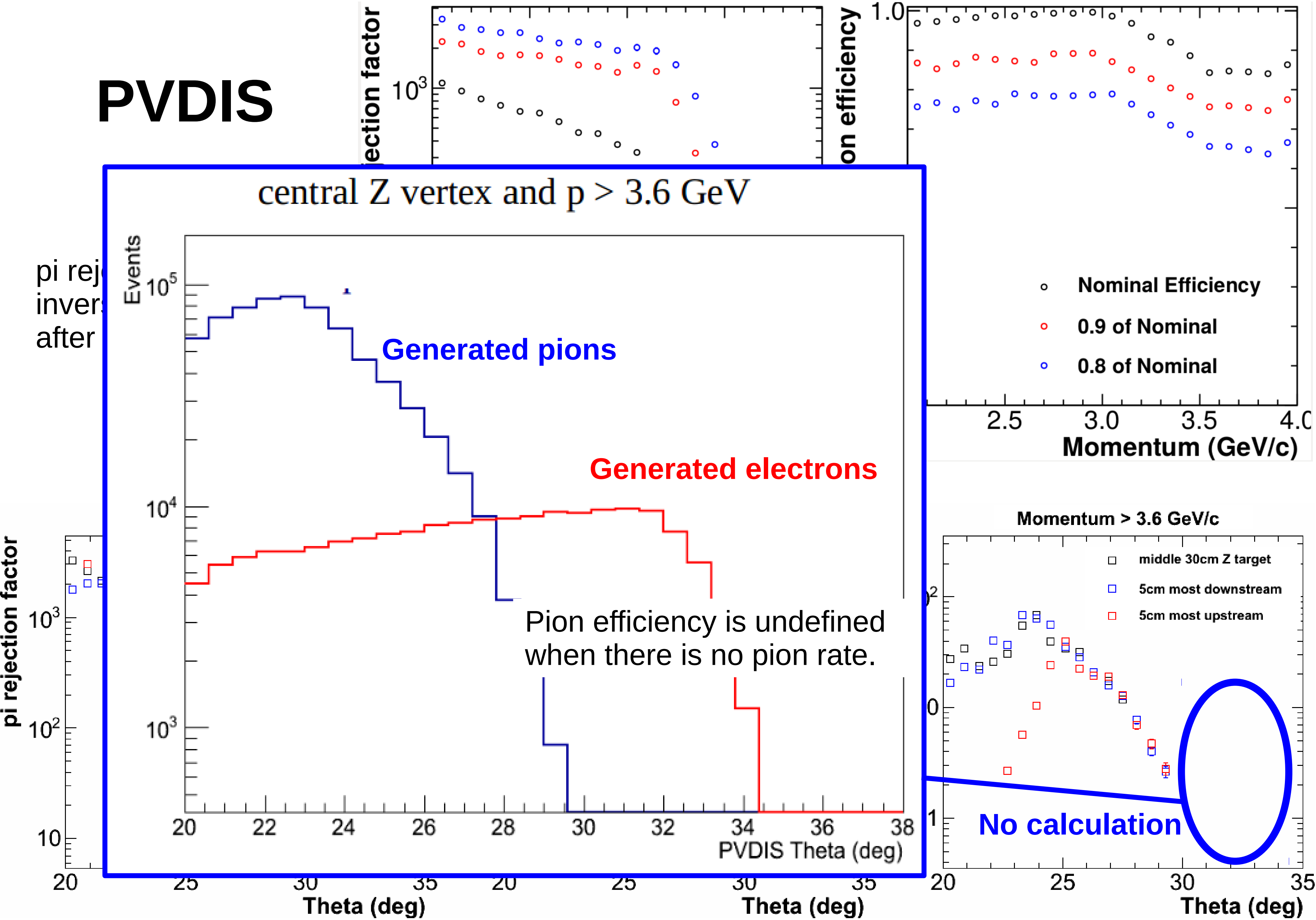

# SIDIS

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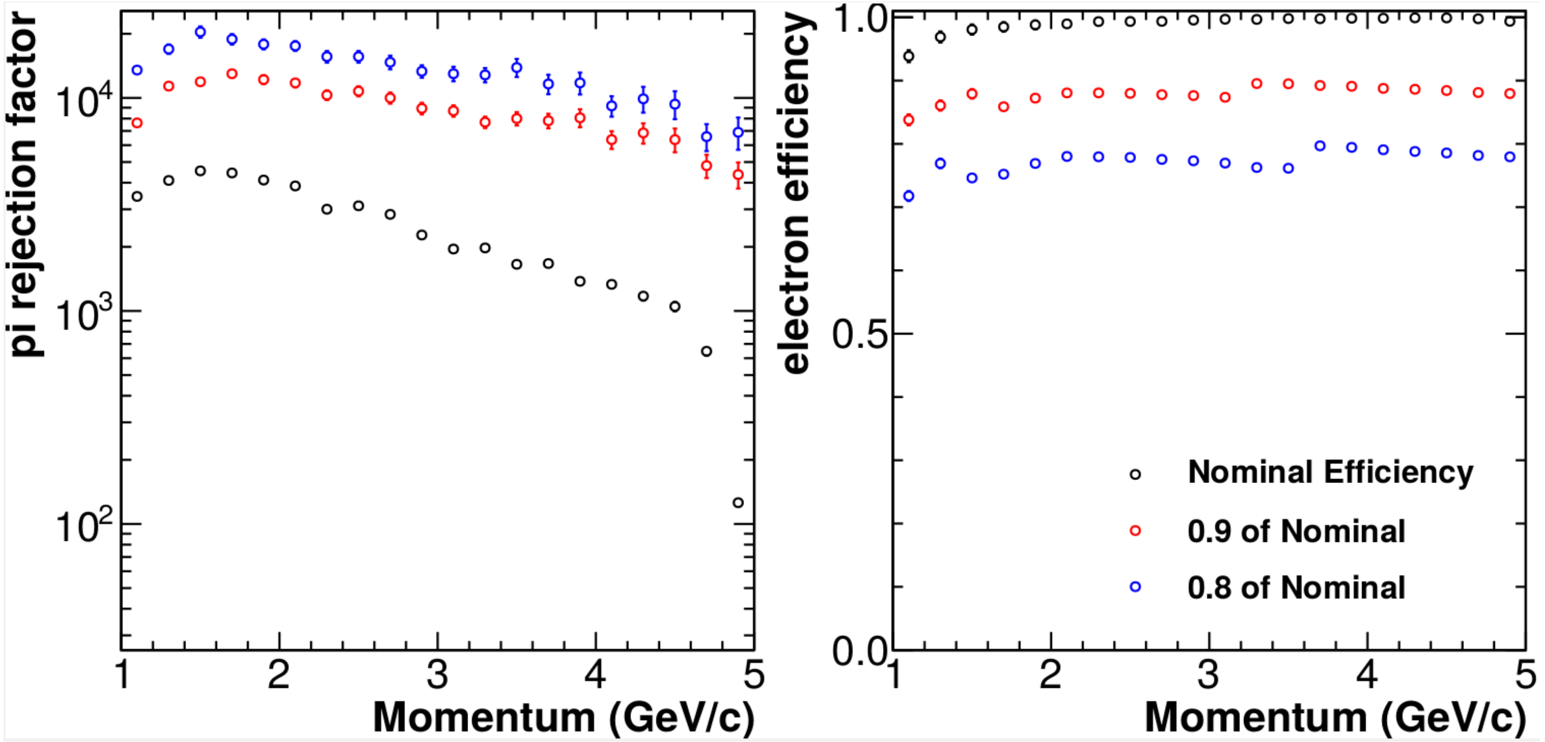
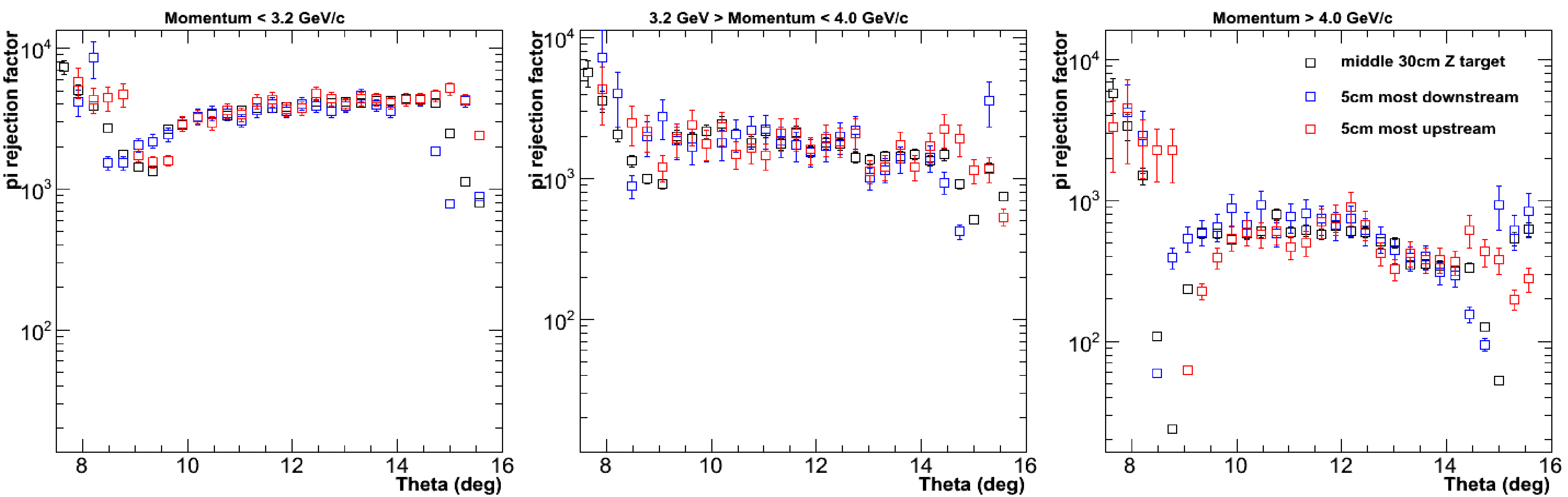


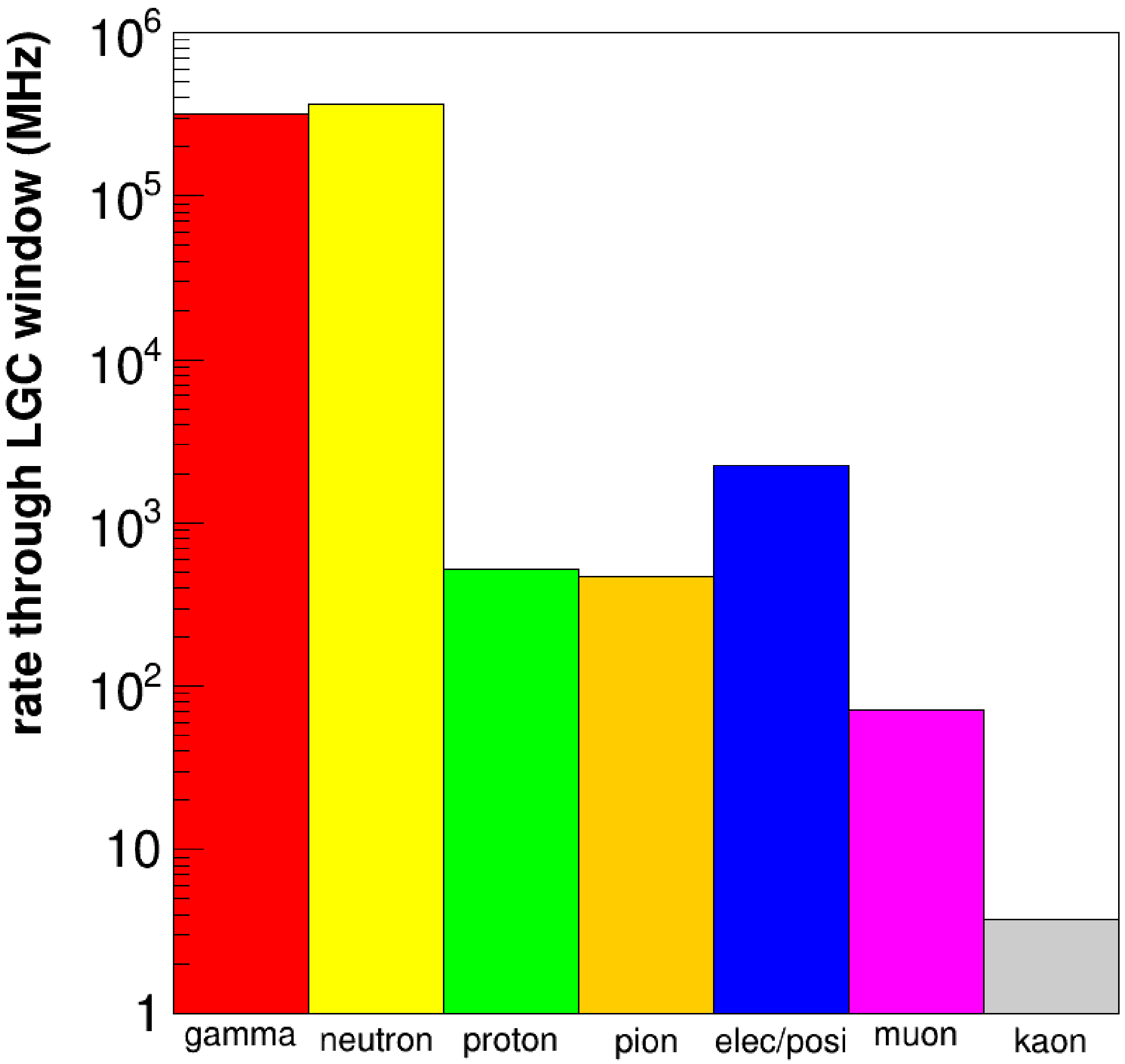



# Secondary backgrounds

- All pion rejection shown on previous slides only considers the primary source of pion contamination from pion production at the beam / target nucleon vertex (via Wiser)
- Other sources of background come from secondary particle production.
  - Secondary background simulation is done by putting an 11 GeV electron beam on target in GEMC / Geant4.
    - 200M events are simulated per “pass” on the ifarm.
      - This equates to 0.64 micro-seconds of beam.
    - Geant4 physics list QGSP_BERT controls all EM / hadronic reactions.

# Rate of particles through LGC entrance window (PVDIS)

- Aside: Now using latest baffle configuration
- High luminosity + large acceptance = large rates
  - High rates can be handled, but care must be taken!
- Total rate through the LGC window for PVDIS.
  - Integrated over all momentums.



# Rate of particles through LGC entrance window

- Aside: Now using latest baffle configuration
- Rate through the LGC window.
  - Only cherenkov radiation candidates.

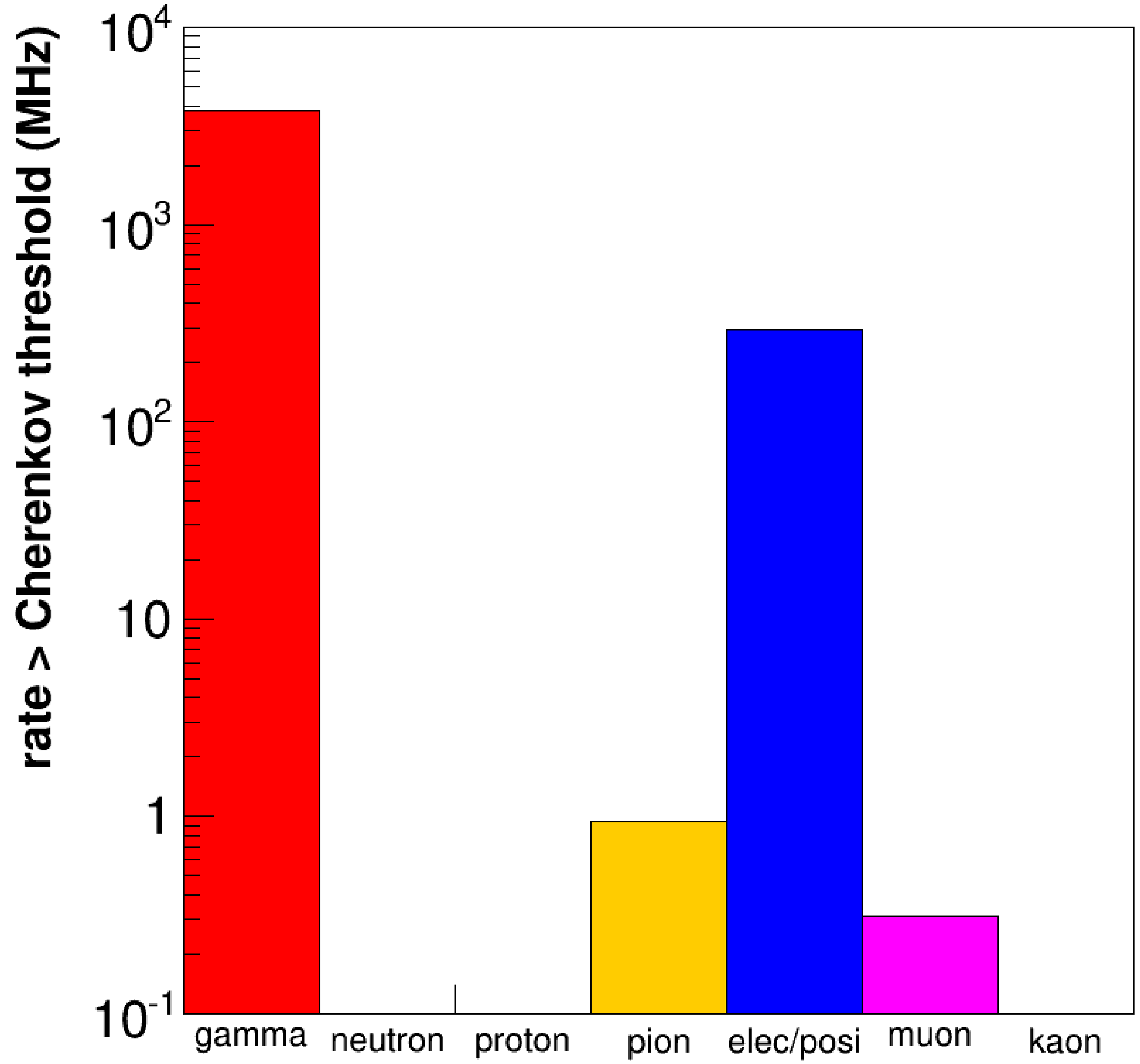
Energies > LGC threshold

(10 MeV **gamma**/**electrons**)

(3 GeV **pions**)

(2.4 GeV **muons**)

(11 GeV kaons)



# Accidental trigger rates per sector

- SIDIS accidental rates are relatively small.
- PVDIS rates are greater, but improved overtime with better baffle design.

| **PVDIS** | Old 6 plane baffle (MHz) | Not as old 11 plane baffle (MHz) |
|---|---|---|
| 1 or more pe's per sector | 4.94 | 2.99 |
| 2 or more pe's per sector | 3.44 | 1.93 |
| 1 or more pe's in two different PMTs | 2.50 | 1.56 |

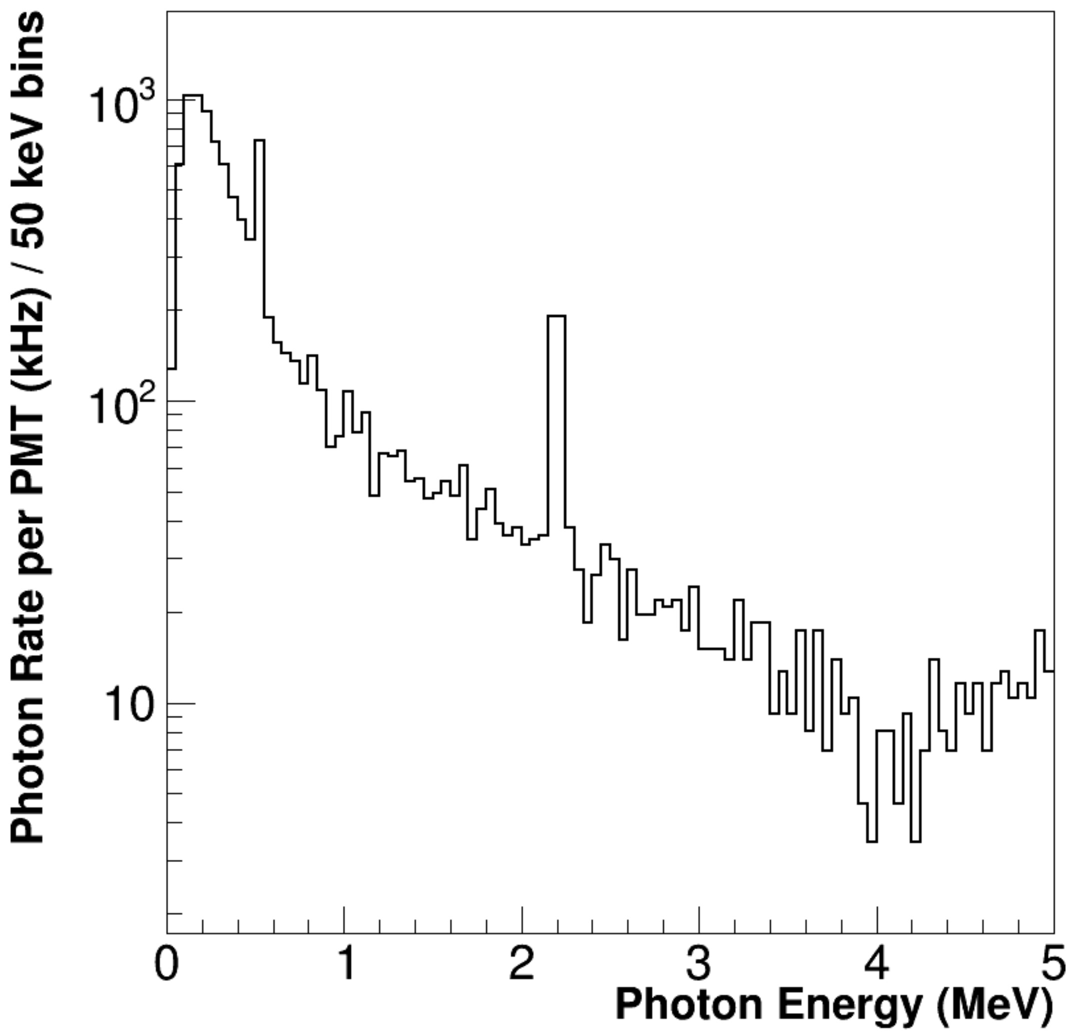
| **SIDIS** | Rate per sector (MHz) |
|---|---|
| 1 or more pe's per sector | 0.319 |
| 2 or more pe's per sector | 0.219 |
| 1 or more pe's in two different PMTs | 0.128 |

PVDIS needs updating with latest geometries / baffles.

Rates are large, but manageable:
EC + LGC gives < 20 kHz per sector

# Photons direct on PMTs

- Non-optical photons that interact with the maPMTs may also cause some background.
  - First step: Simulate the rate of these photons incident on the PMTs:
  - Two obvious peaks.
    - Neutron capture with hydrogen in carbon fiber mirrors.
    - e+ e- annihilation
  - Low energy photon rate still dominated by electron production.



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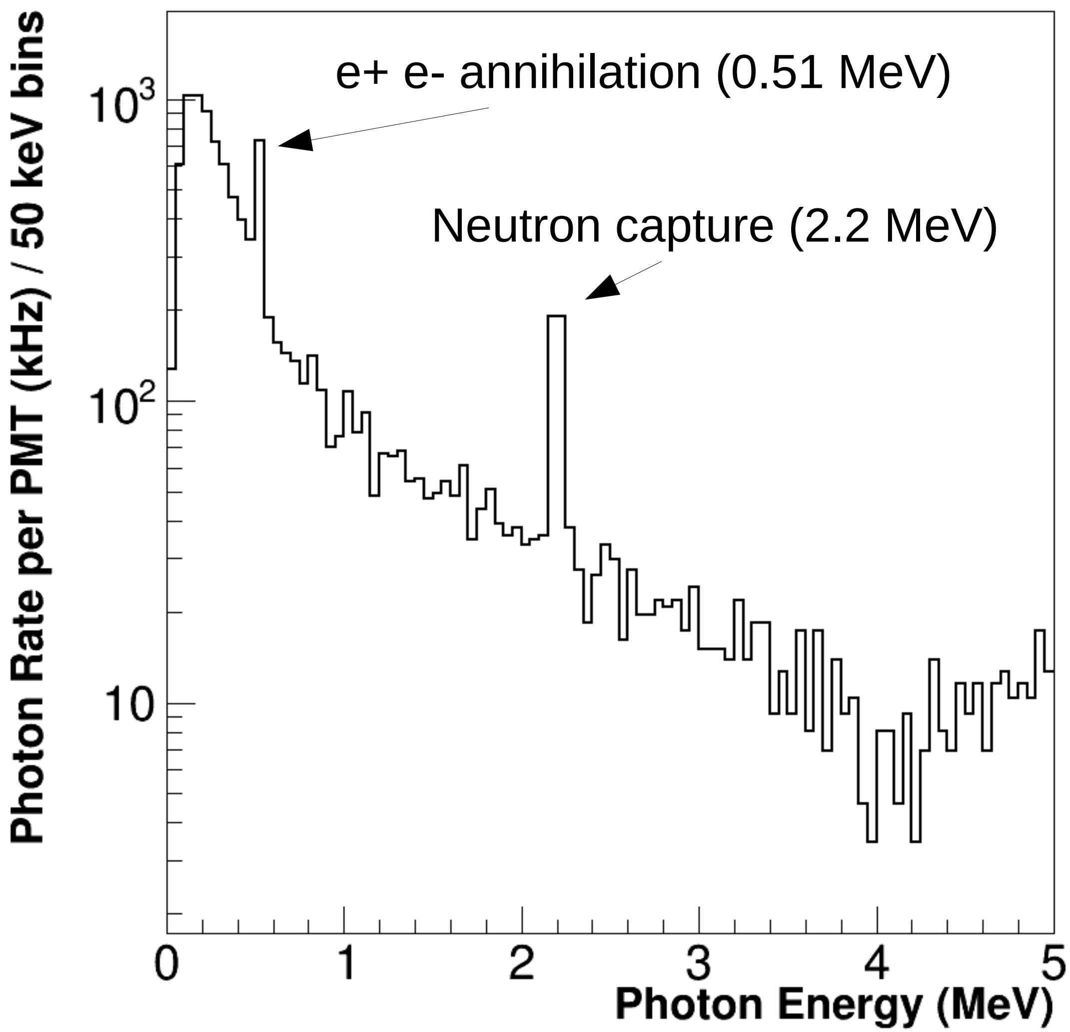
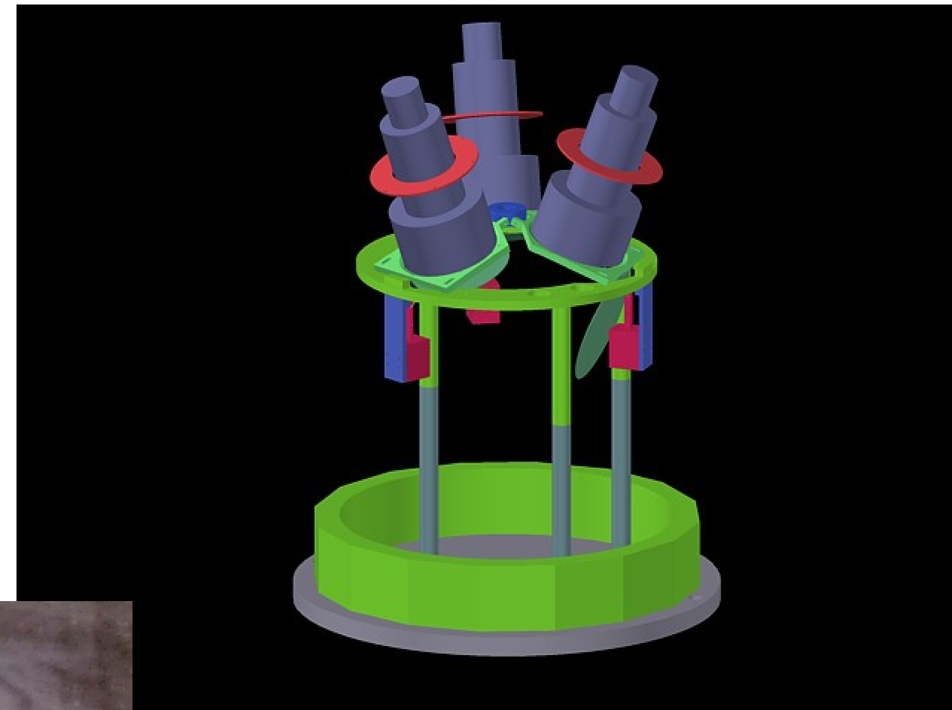
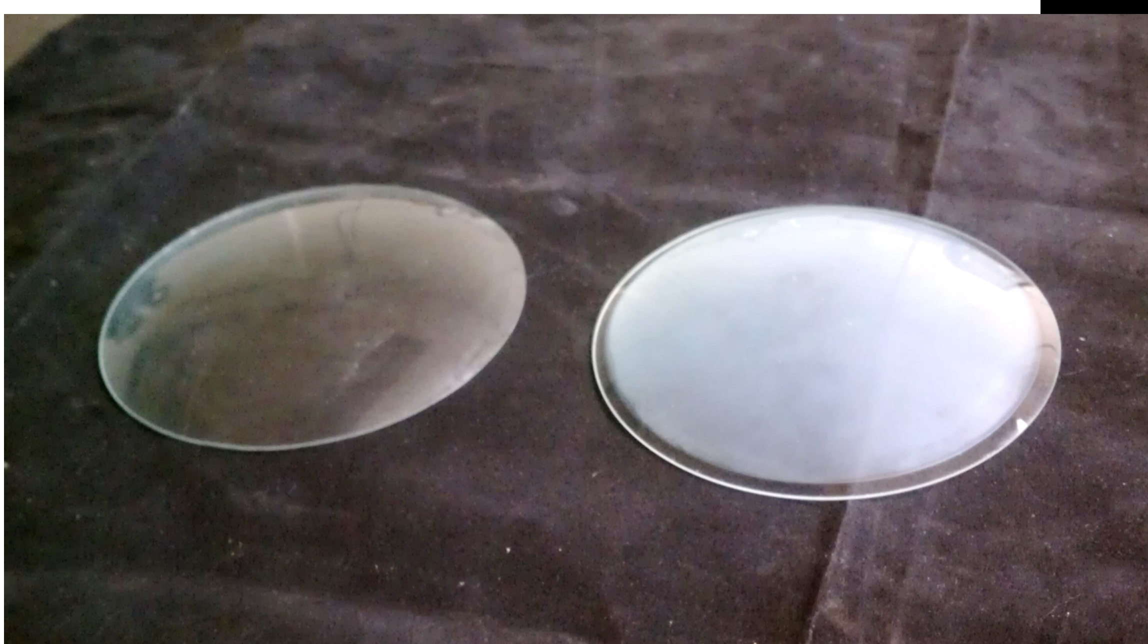


# Continuing Improvements

- Wavelength shifter for PMTs:
  - Temple is currently coating and testing the clas12 LGCC PMTs with p-Terphenyl.
  - Could increase photoelectron output by 50%.



Coating apparatus



Face plate coating:
Before and after

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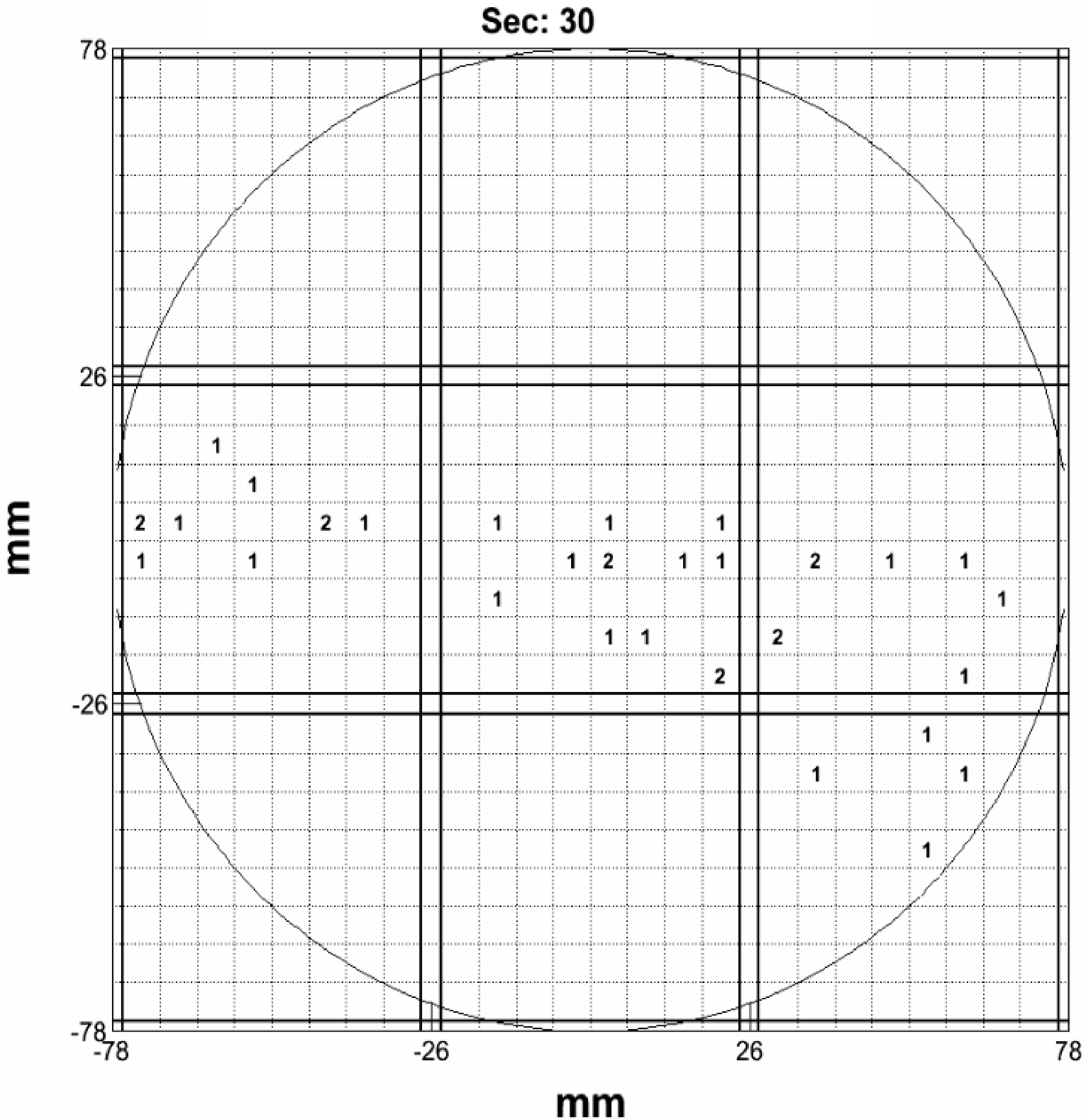
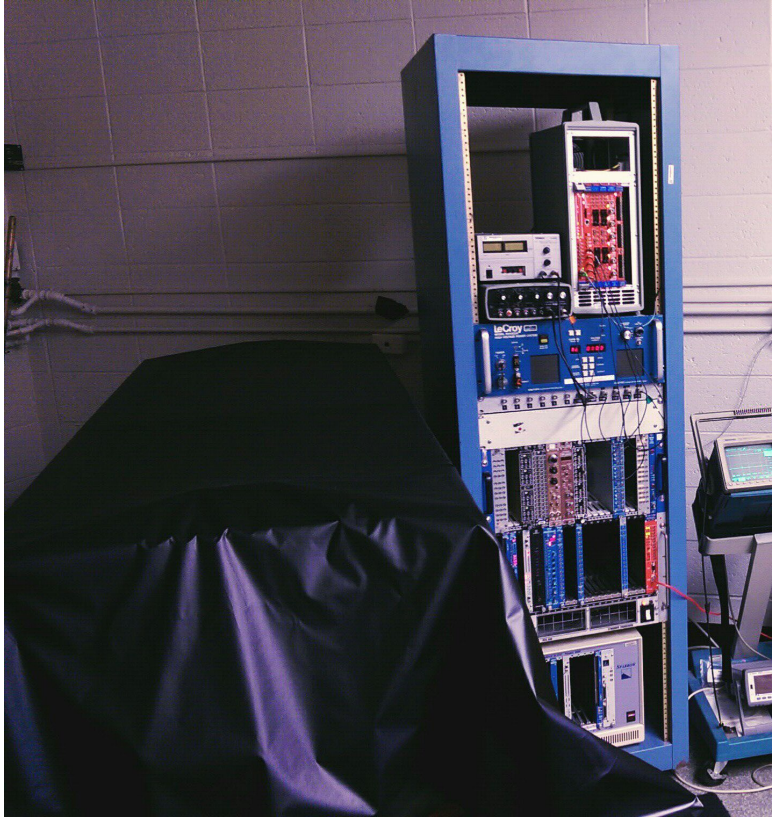
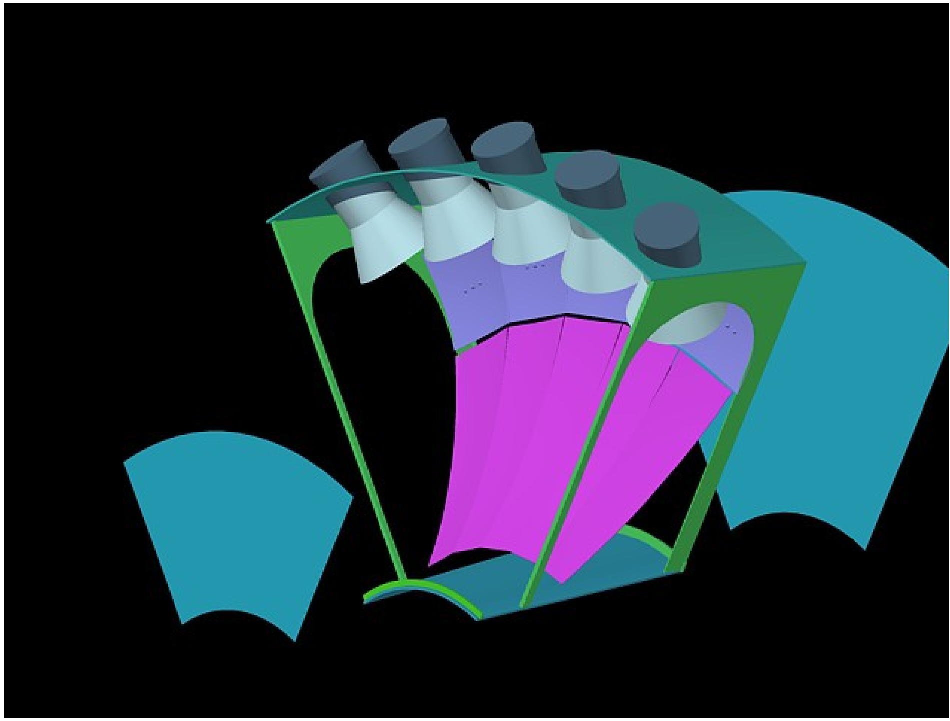



- Pattern of photoelectron signal could be recorded (binary signal per pixel) with a MAROC chip.
- Binary output together with pattern recognition (Neural Net?) could provide limited tracking information.
  - Possibly useful for background suppression or better pion rejection.

# Prototyping



- 1st stage (Pre-R&D)
  - maPMT / DAQ testing
  - small Cherenkov tank
  - With electron source → test more realistic PMT response.
  - Ideally with a single aluminized / polished CFRP mirror



- 2nd stage (1st – 2nd year DOE)
  - Construction of 1/6th of total SoLID detector.
    - 5 combined sectors → to be used in final detector.
    - Prototype 1/6th size tank.

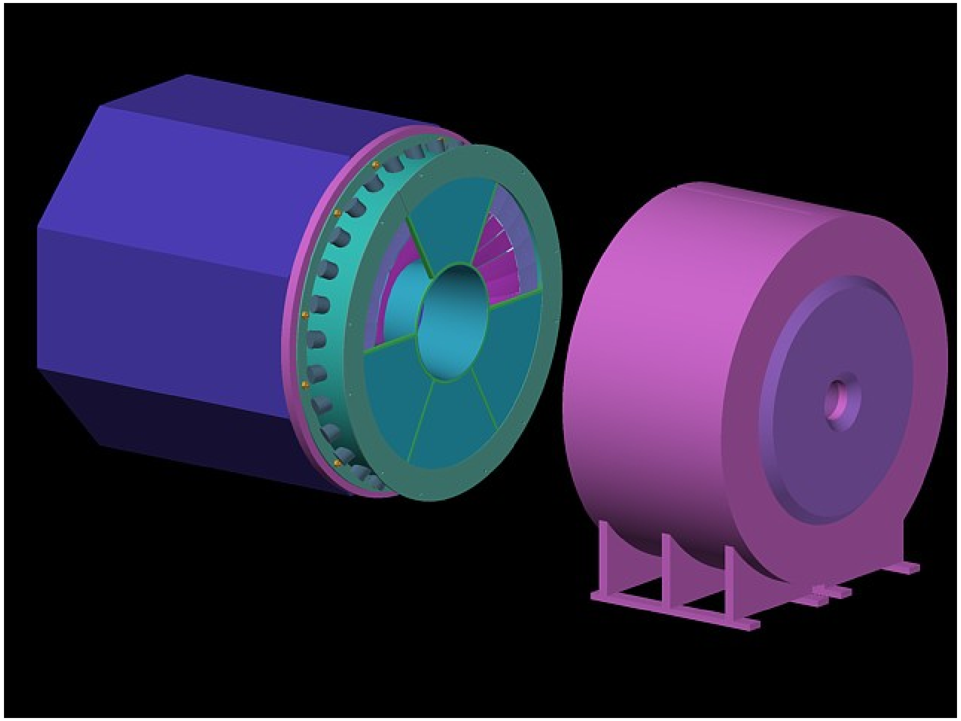
# Budget

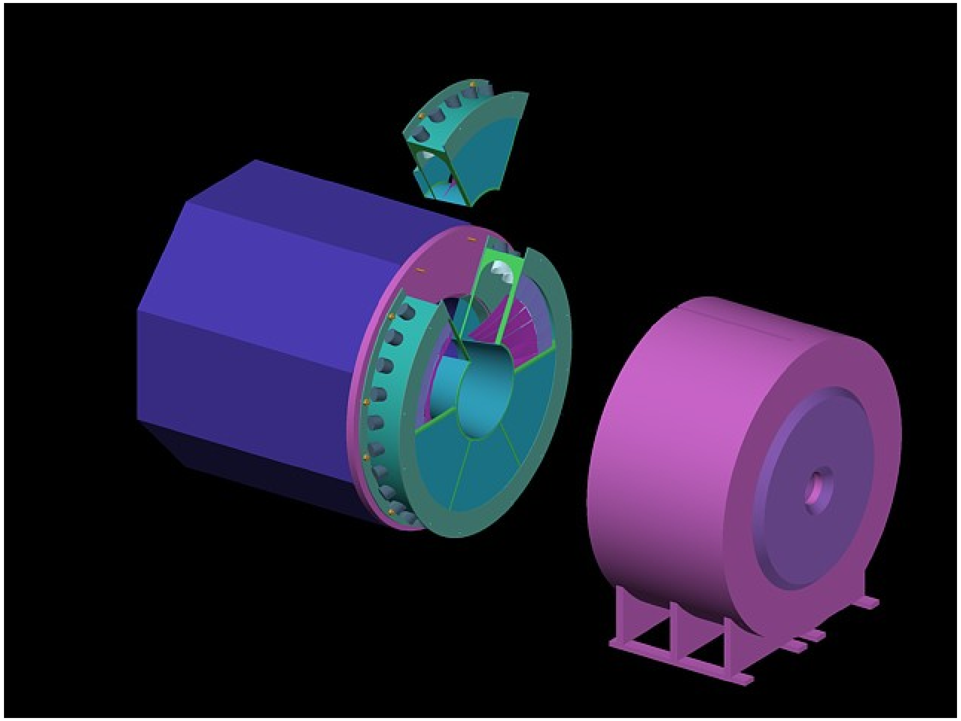
# Conclusion

- The SoLID LGC is designed to meet the requirements of the SIDIS and PVDIS experimental programs while maximizing inter-component use (minimizing cost).
- Extensive GEMC / Geant4 simulations have been performed testing signal, backgrounds, and pion rejection.
- Continuing efforts to study (and reduce) simulated EM / hadronic backgrounds.
- Wavelength shifting and PMT pixel pattern analysis are being investigated and may lead to even better LGC performance.

# Backups

# LGC support and engineering





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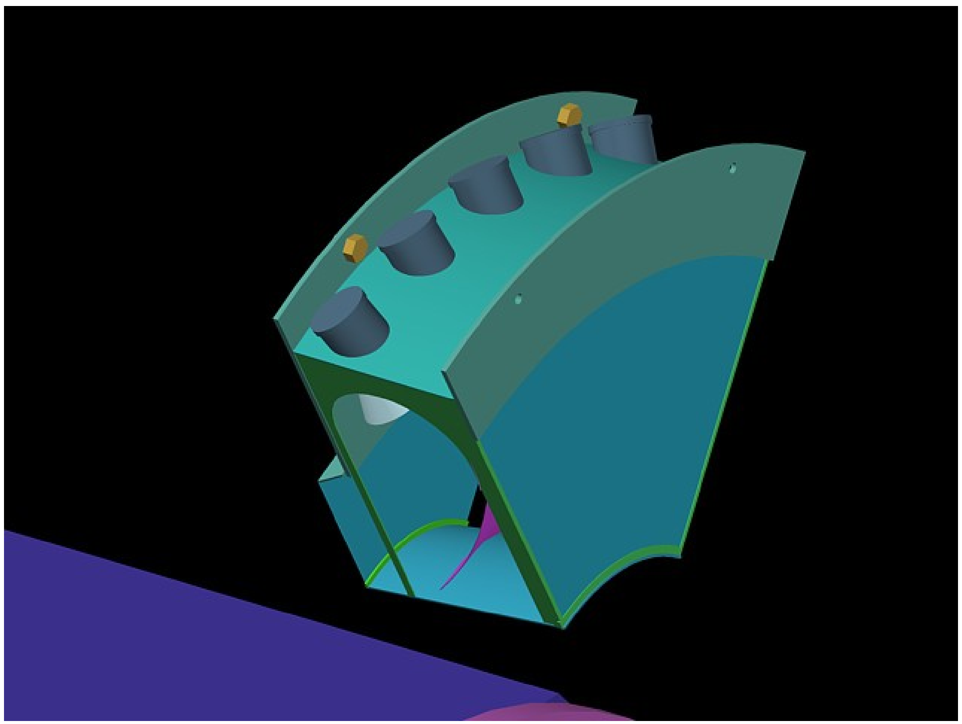

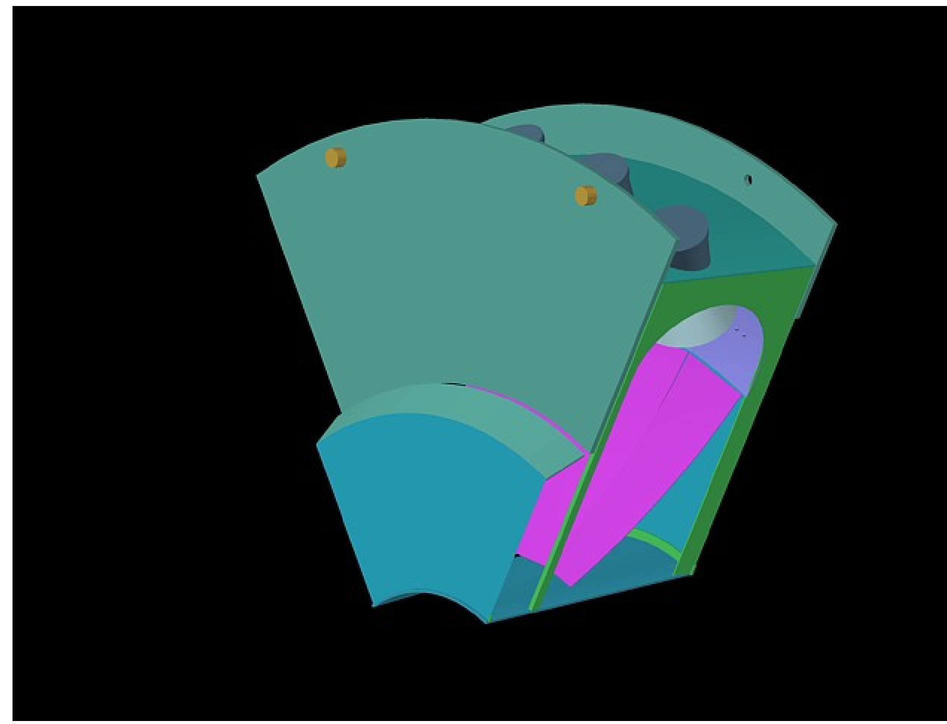

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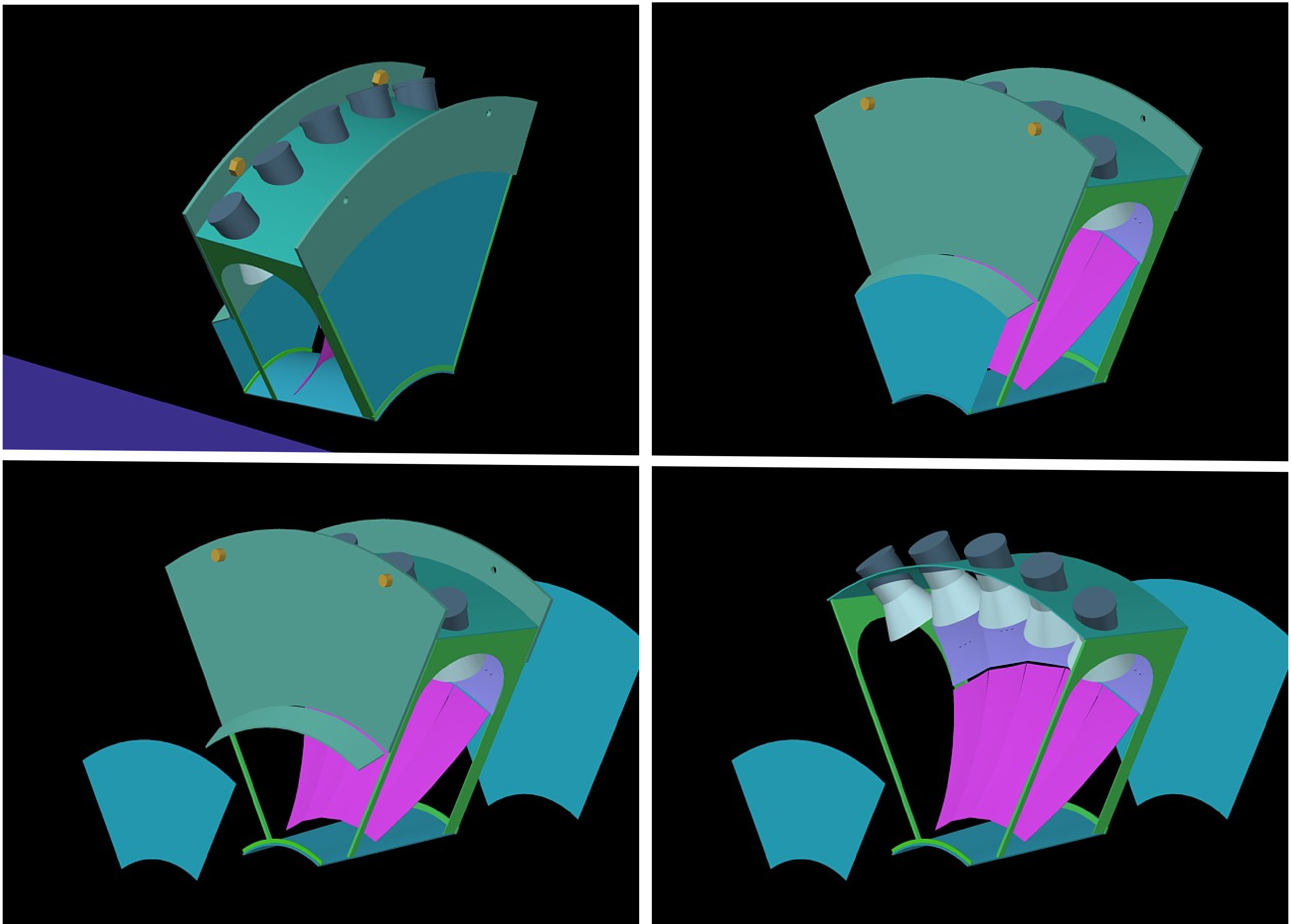
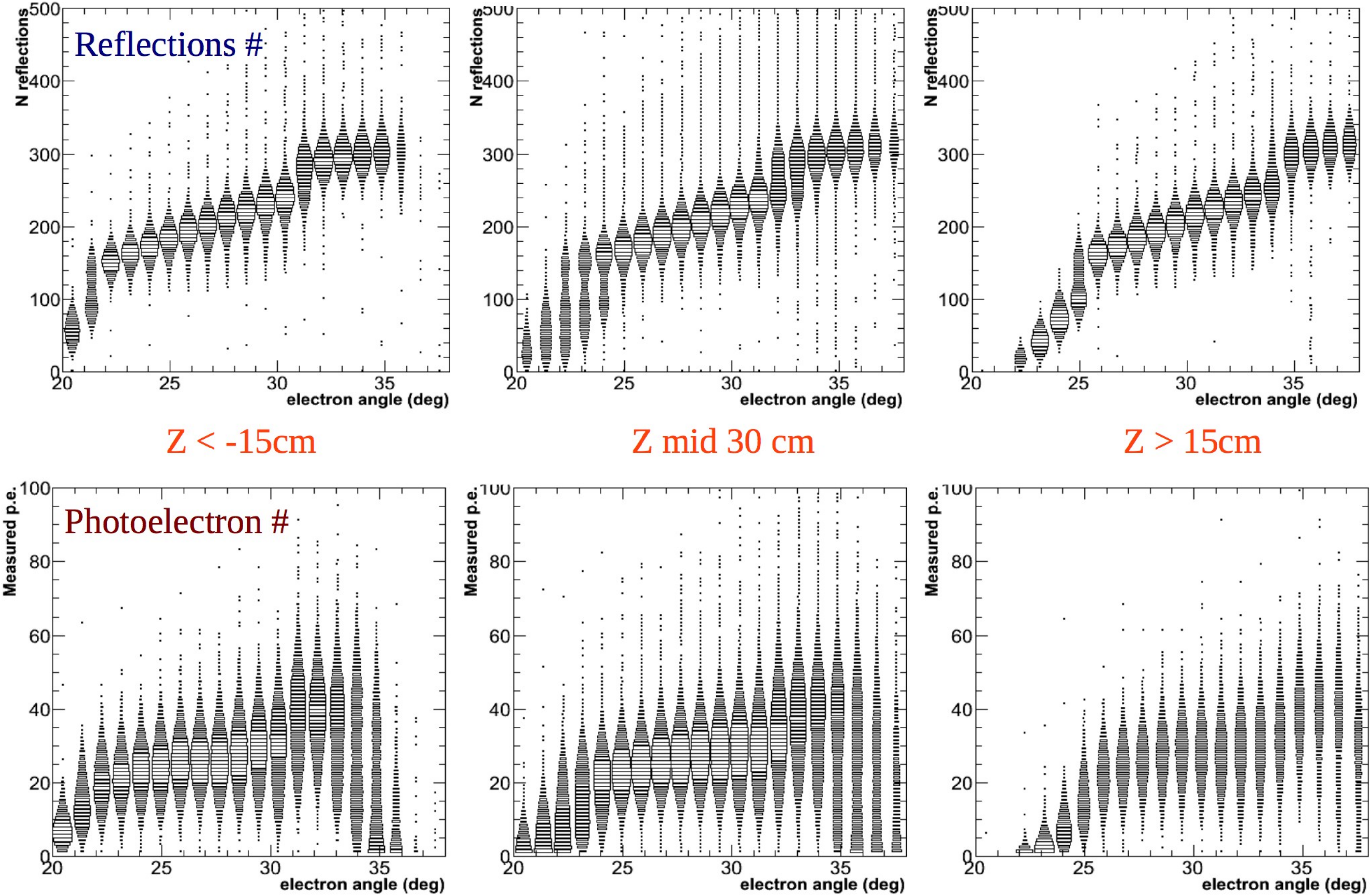
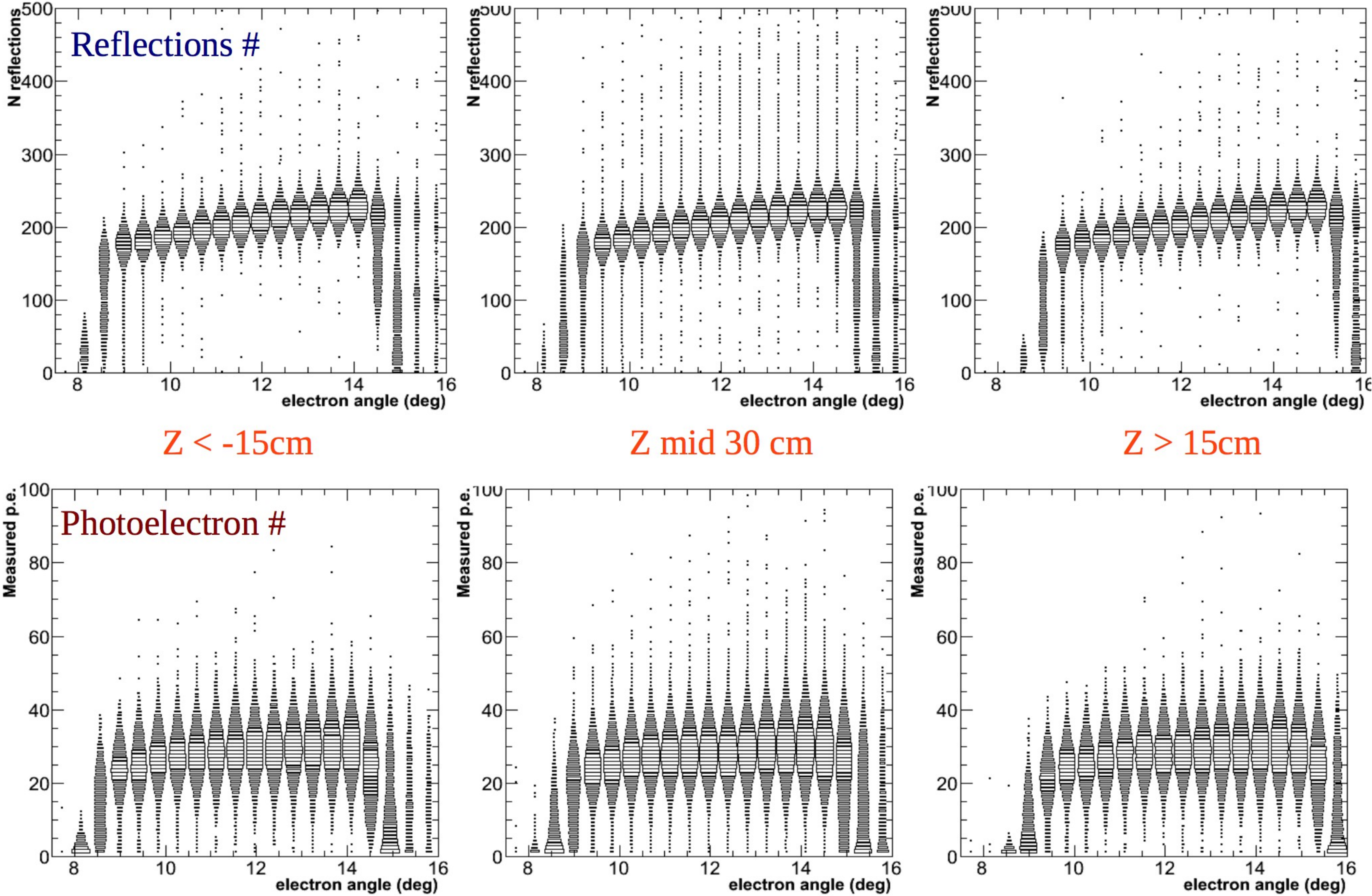


# PVDIS


Reflections #
N reflections
electron angle (deg)
Z < -15cm
Z mid 30 cm
Z > 15cm
Photoelectron #
Measured p.e.
electron angle (deg)

# SIDIS


Reflections #
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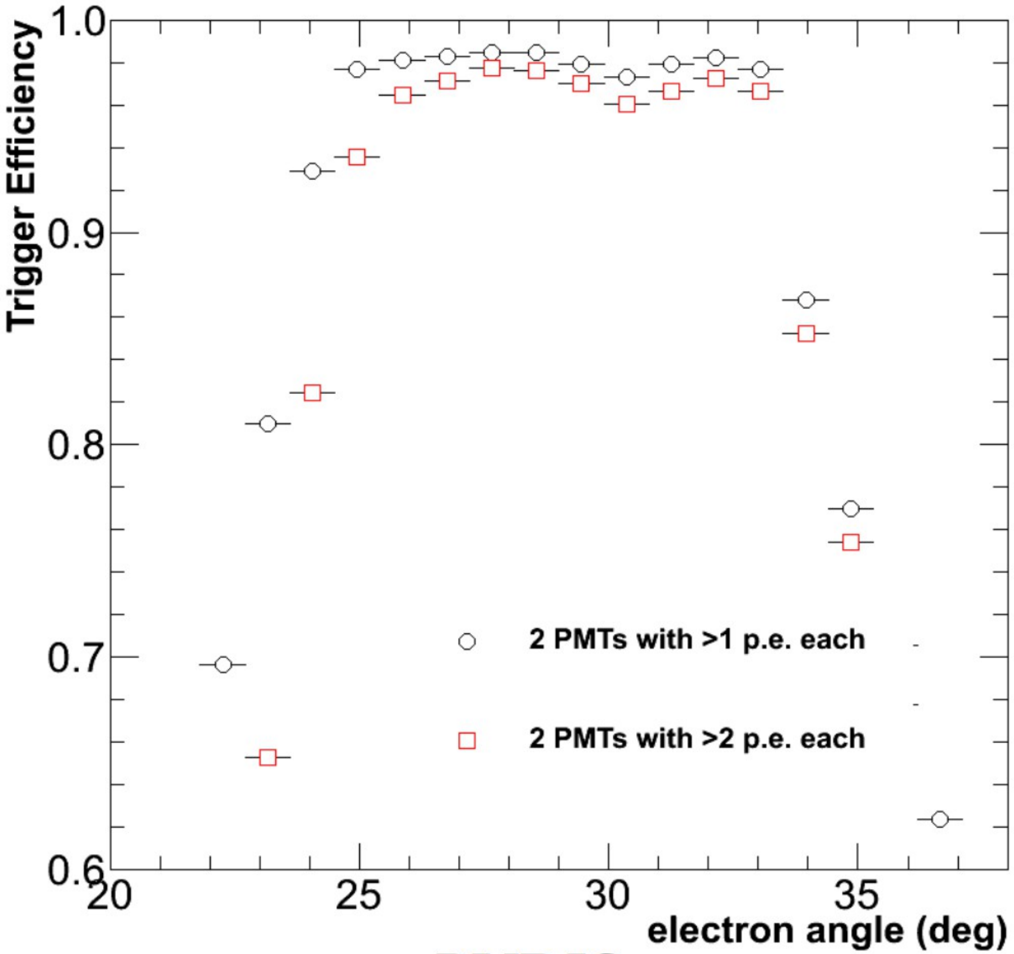
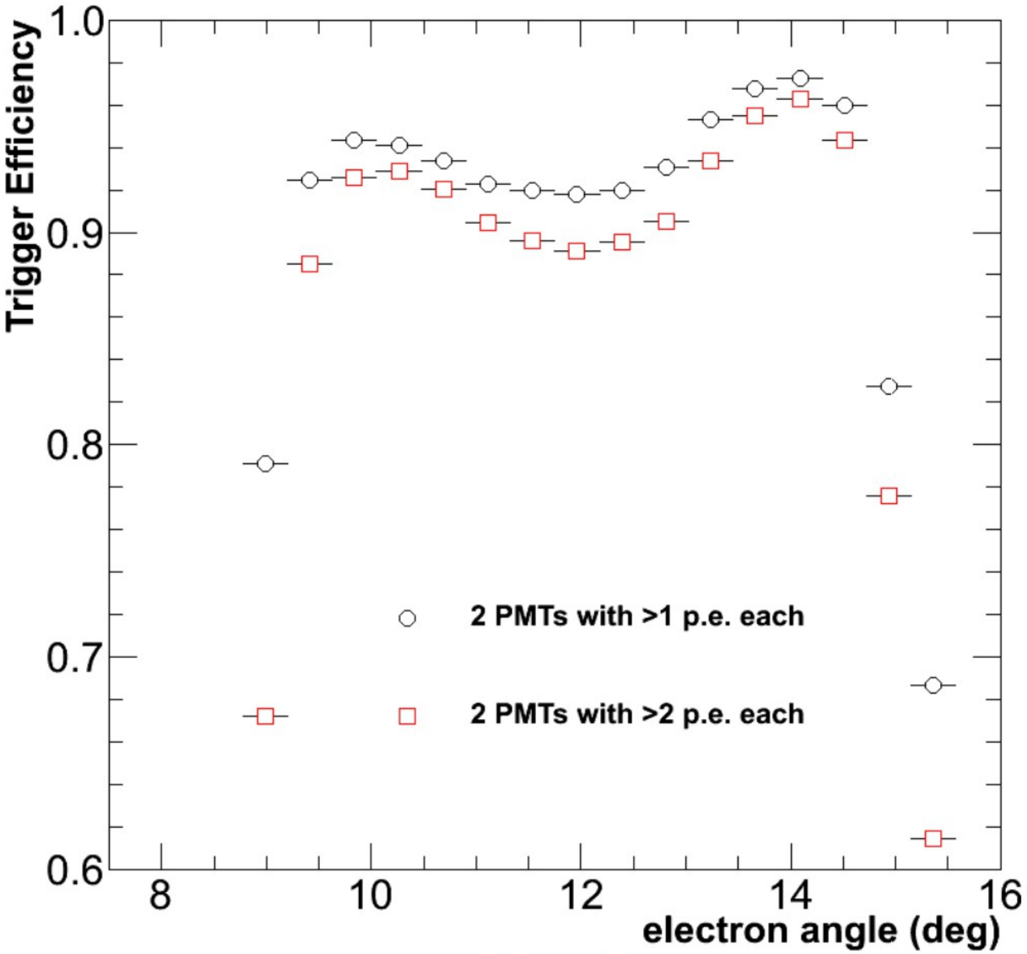
electron angle (deg)
Z < -15cm
Z mid 30 cm
Z > 15cm
Photoelectron #
Measured p.e.

# Trigger Efficiencies




PVDIS




SIDIS

# PMT in Magnetic Field