Update on Light Gas Cerenkov: Design and Simulations

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For the SoLID Collaboration

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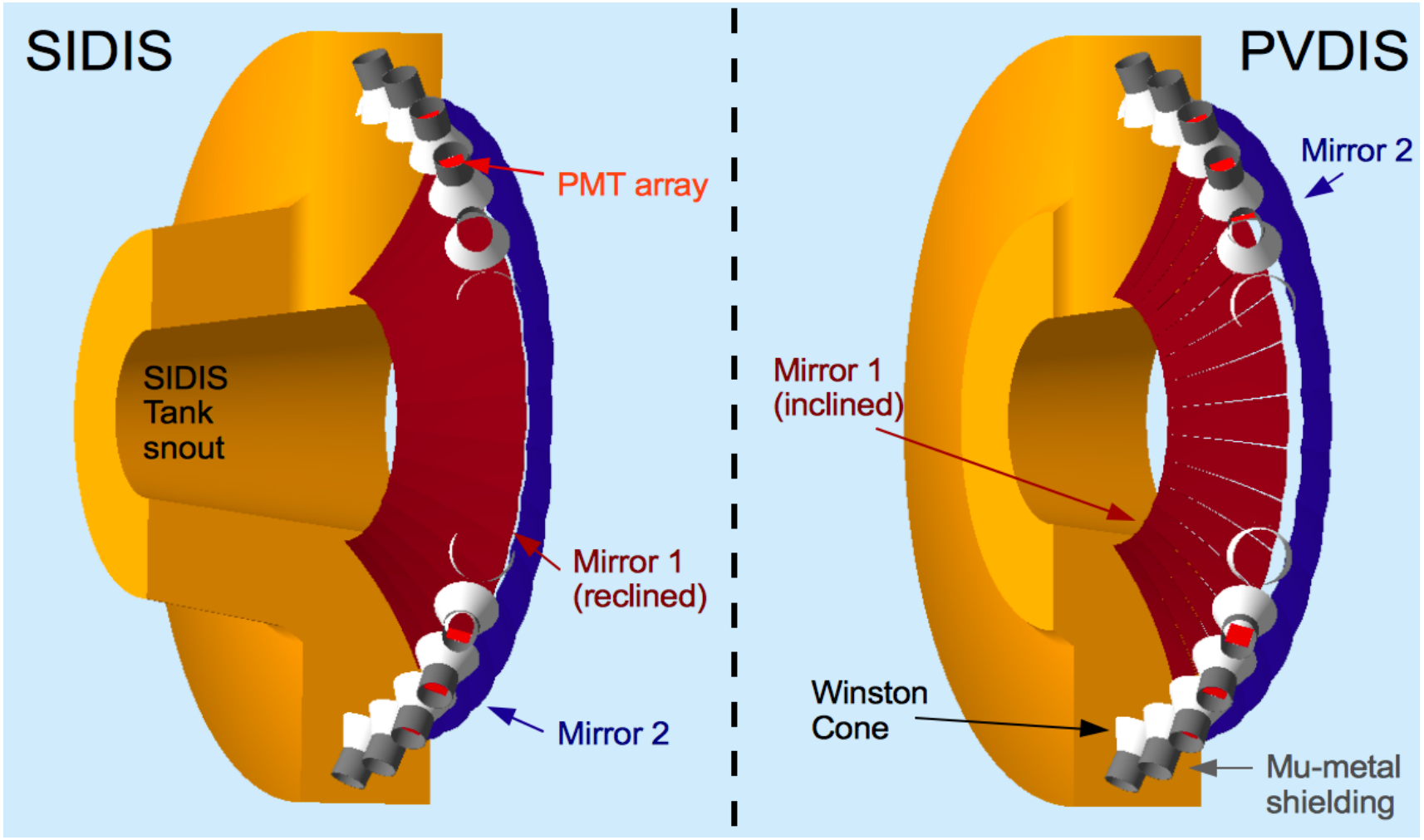
What's new since last update?

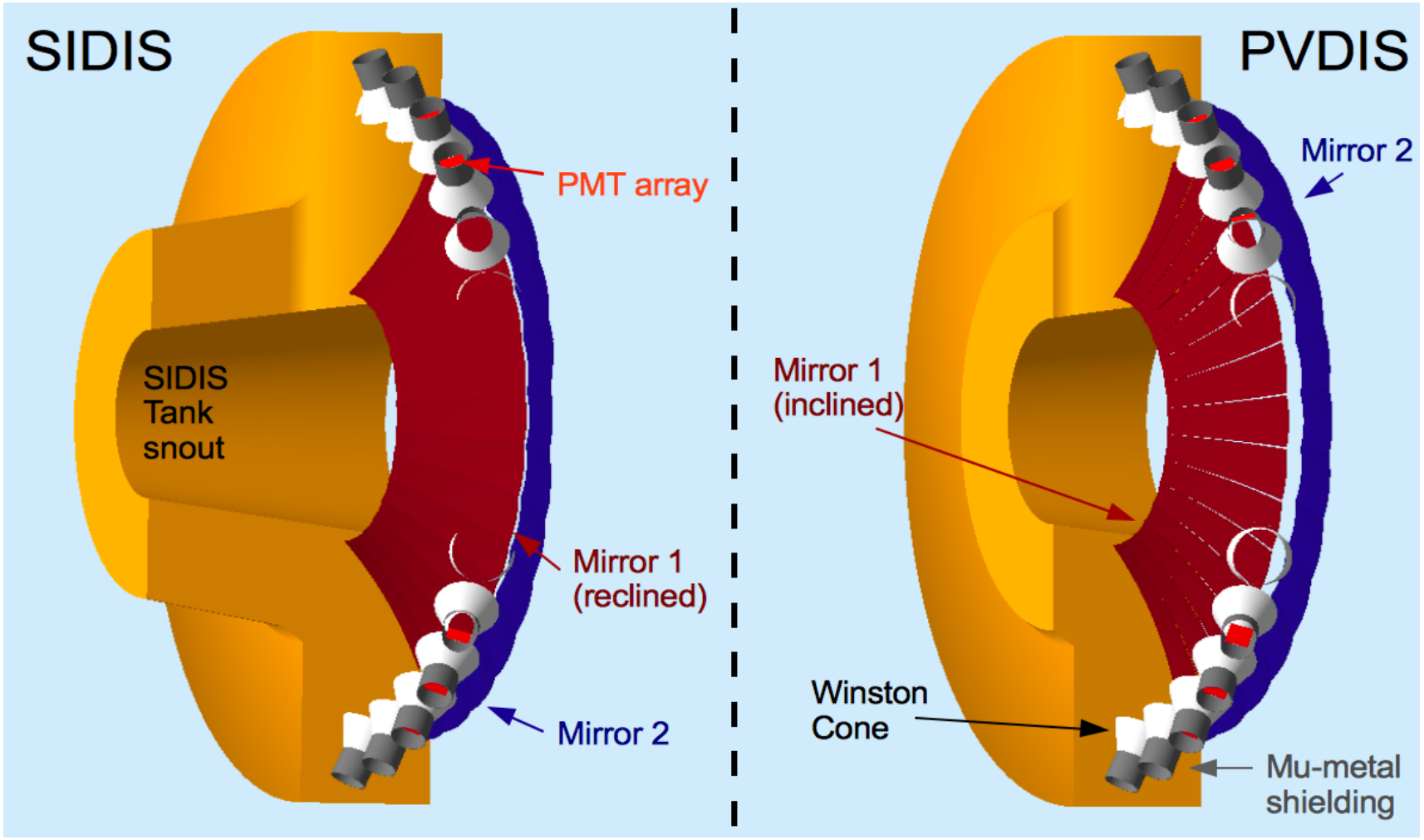
- Design:
  - Consolidation of SIDIS and PVDIS light gas Cherenkov into one design (with slight adjustments)
  - Engineering and construction considerations
- Simulation
  - Full GEMC simulation.
  - Latest design.
  - Low momentum pion backgrounds from GEANT4 low EM package (knock-ons and pair creation).

Consolidated Design



- The same mirror-1 is used in both SIDIS and PVDIS configurations, with an adjustment in orientation.
- The same PMTs and cones are used for both configurations with no adjustments.

Consolidated Design



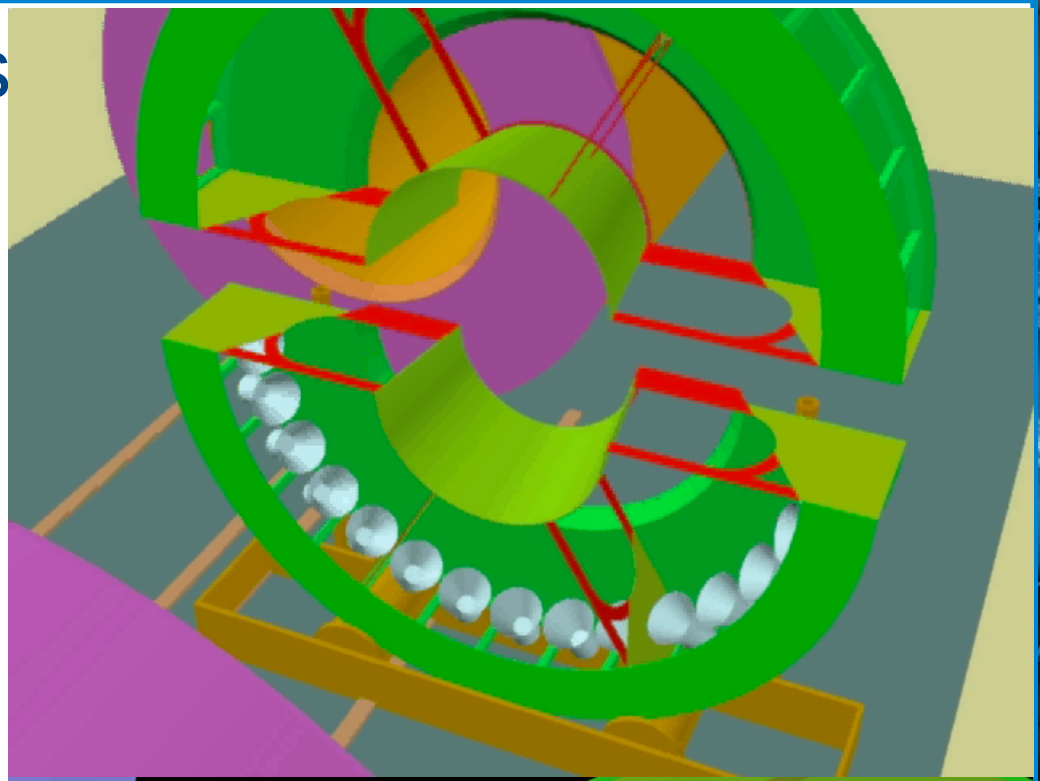
GOAL: Minimize overhead from switch between configurations.

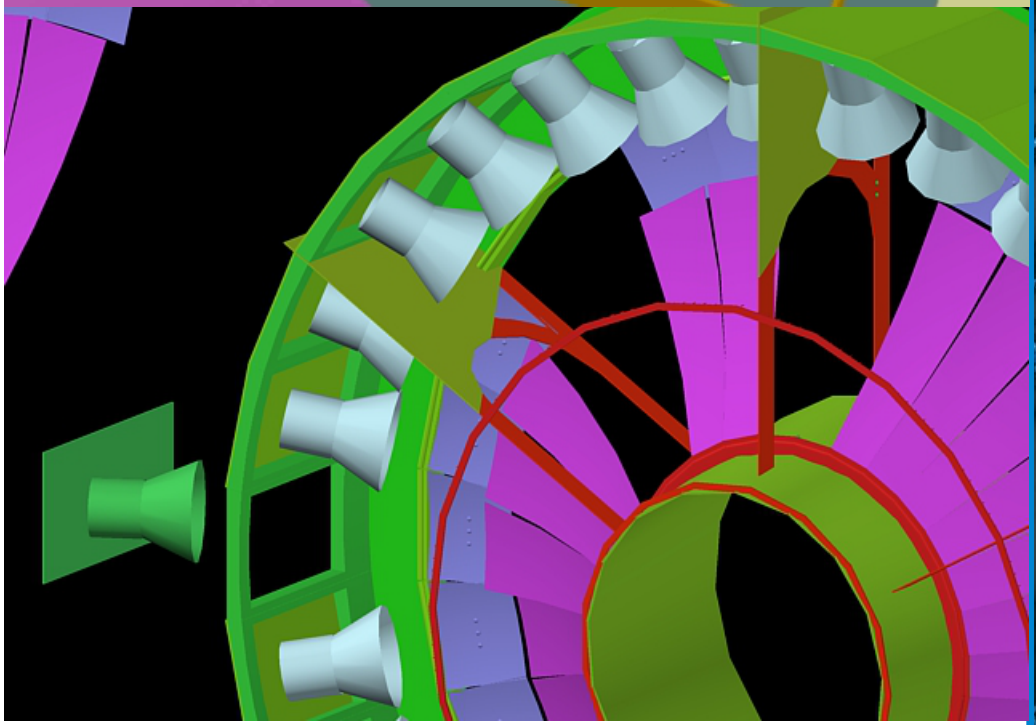
Some Specifications

Property	SIDIS	PVDIS
Mirror-1 Width (top)	35.92 cm	Same
Mirror-1 Width (bottom)	17.67 cm	Same
Mirror-1 Length	105.95 cm	Same
Mirror-1 Radius of Curv.	270.91 cm	Same
Mirror-1 Orientation	SIDIS Nominal	~8 deg rotation
Mirror-2 Width (top)	45.95 cm	Same
Mirror-2 Width (bottom)	37.06 cm	Same
Mirror-2 Length	59.26 cm	Same
Mirror-2 Radius of Curv.	157.99 cm	Same
Mirror-2 Orientation	PVDIS Nominal	Same
Cherenkov gas	CO_2	65% C_4F_8O, 35% N_2
Tank snout	IN	OUT
PMT array	3x3 H8500C-03	Same
Cone R (wide end)	21 cm	Same
Cone Height	30 cm	Same
PMT Offset	1.6 deg	Same
PMT Orientation	60 deg	Same

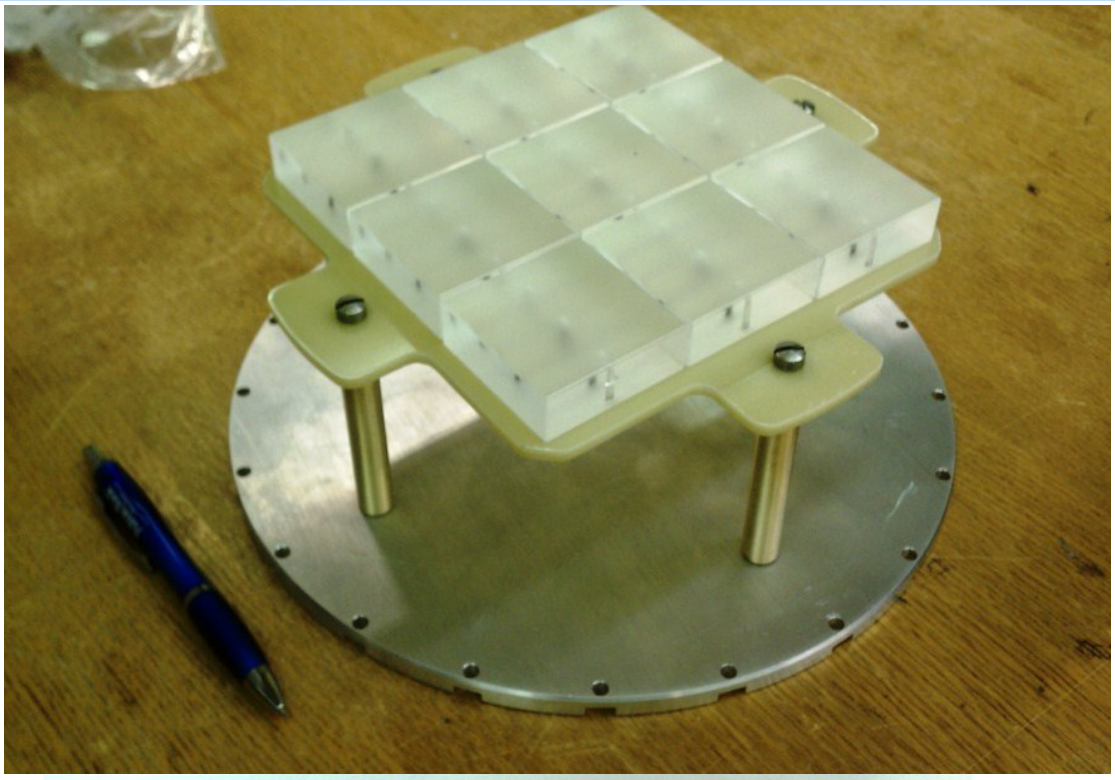
Engineering Considerations and Progress

- Preliminary Bi-section designs:
  - Four support beams per bisection creating 6 segments total.
  - Support beams are designed with the idea of maintaining acceptance.
- Access plate in every sector.
  - Easier access to PMT array / cone / magnetic shielding.





PMT array mount prototype



Component Construction

- Mirrors:
  - Blanks will be built by Composite Mirror Applications.
    - Material will be carbon fiber reinforced polymer (CFRP) with a rigid, internal core-reinforced, sandwich composite structure.
    - Optical surface requirements inline with LHCb RICH 1
    - Areal density less than or equal to 6 kg/m^2.
    - Mirror-1 weight: ~1.9 kg, Mirror-2 weight: ~1.4 kg
  - Al + MgF_2 Coating will be done by Tom Hemmick et al. at Stony Brook.
- Magnetic Shielding:
  - Constructed by Amuneal Manufacturing Corp.
    - Will consist of mu-metal Winston cone welded to a mu-metal cylinder that houses the PMT array.
    - Requires a reduction of magnetic field to 50 gauss or less in all directions for either BaBar or CLEO magnetic field.

Simulations: GEMC details

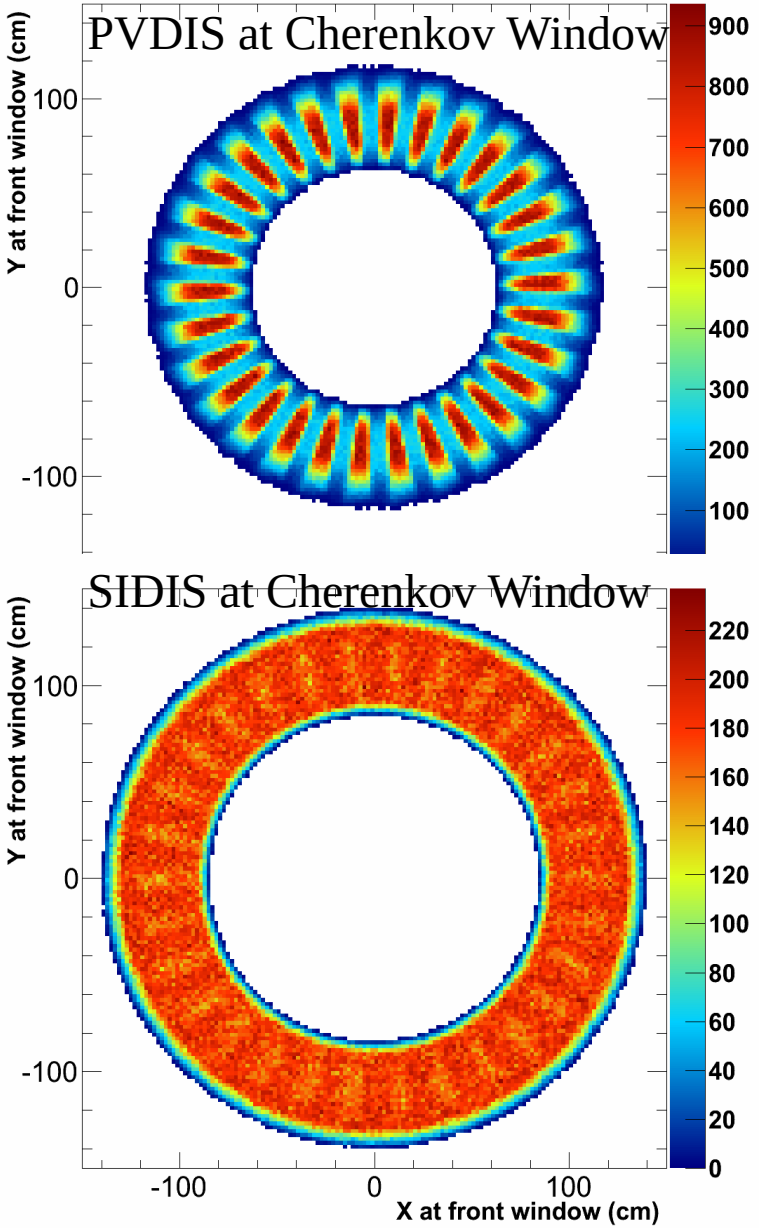
- GEMC uses a GEANT4 backend + GUI + MYSQL geometry / material properties database.
  - My GEMC uses geant4.9.5p01 and a modified “Mirrors” class to access reflection efficiencies.
- GEMC uses perl scripting to read / write to MYSQL database.
  - My database scripts does all needed geometry calculations when run. Changes to variables are input to script when geometry is built:
    - Example: ./go_geometry vars1.pl

Contains basic MYSQL access to database

Contains variable changes i.e. “M1Rcurv = 192.0;” would create the geometries with the Mirror-1 radius of curvature Changed from default to 192 cm.

Simulation Parameters

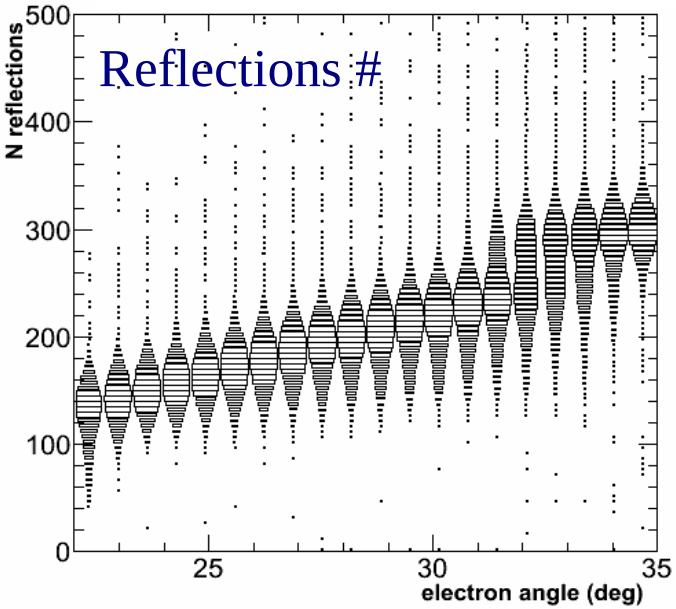
- DIS electron event generation (eicRate) for 11 GeV electrons off of H or 3He for PVDIS and SIDIS respectively.
- Pions are generated using the pion/electron rate tables (in theta vs momentum)
- Baffle acceptance is taken into account in the PVDIS simulations.
- Events are distributed over the 40cm target.
- Interactions with Cherenkov window generate knock-ons / pair creation.

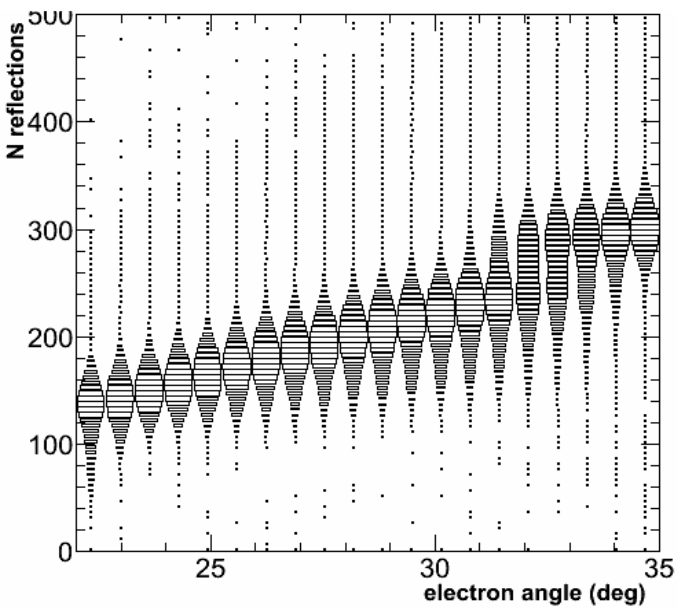


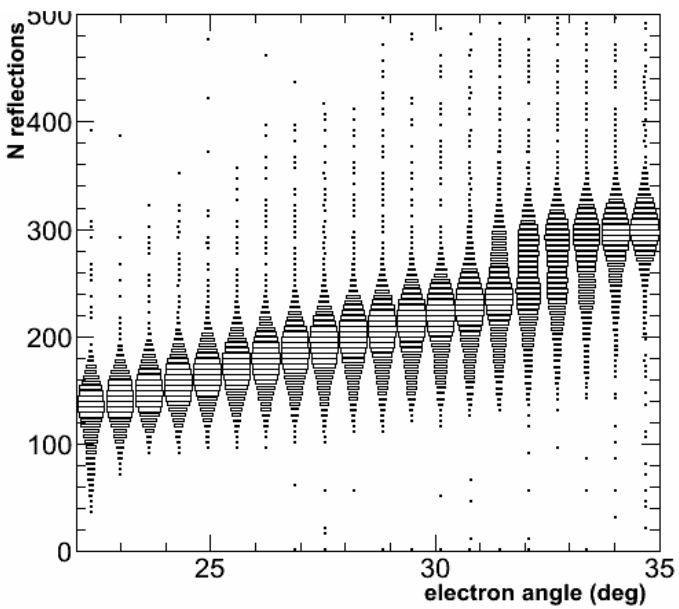
Simulations: Collection + Optical Efficiencies

- The efficiencies include the following possible loss of optical photons:
  - Geometric acceptance
  - Primary (off mirror) and secondary reflections (off cones)
  - PMT window optical properties
  - PMT quantum efficiency
  - PMT dead-area
- Interactions with the primary mirrors are summed to give the number of reflections.
  - Simulated mirrors have 90% reflection efficiency over all energies.
- Summed photoelectrons are over all PMT assemblies and are after the losses listed above.

PVDIS



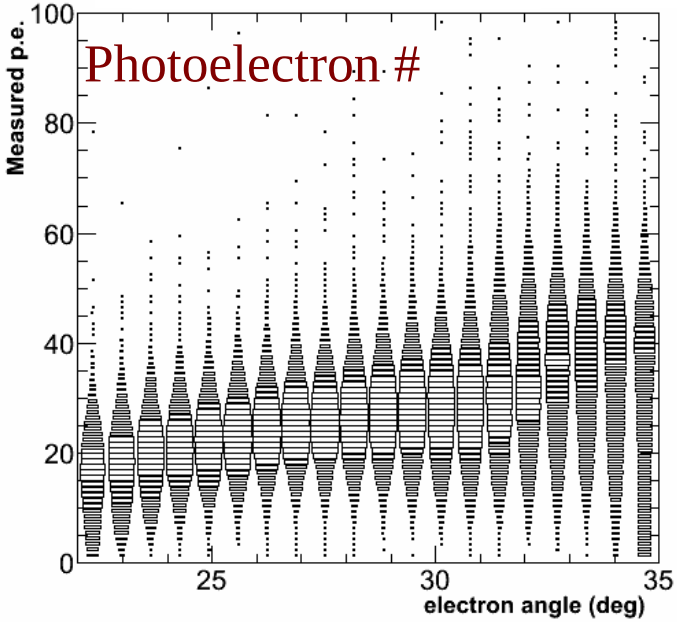


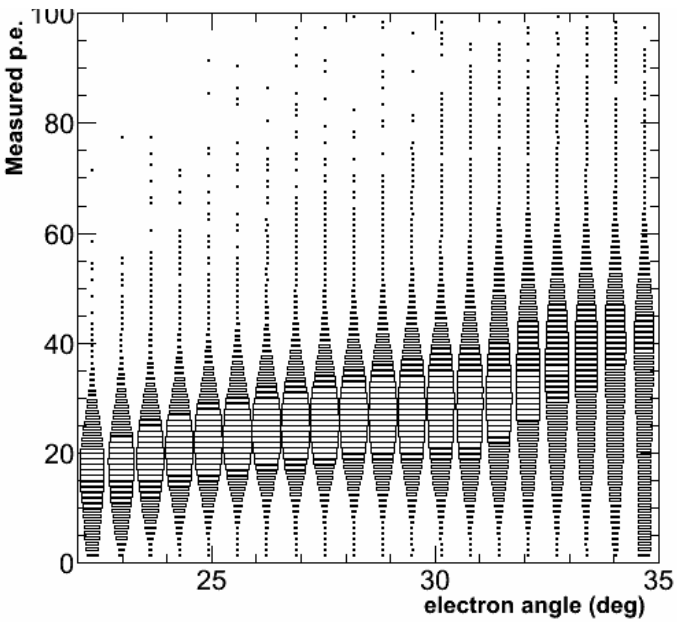


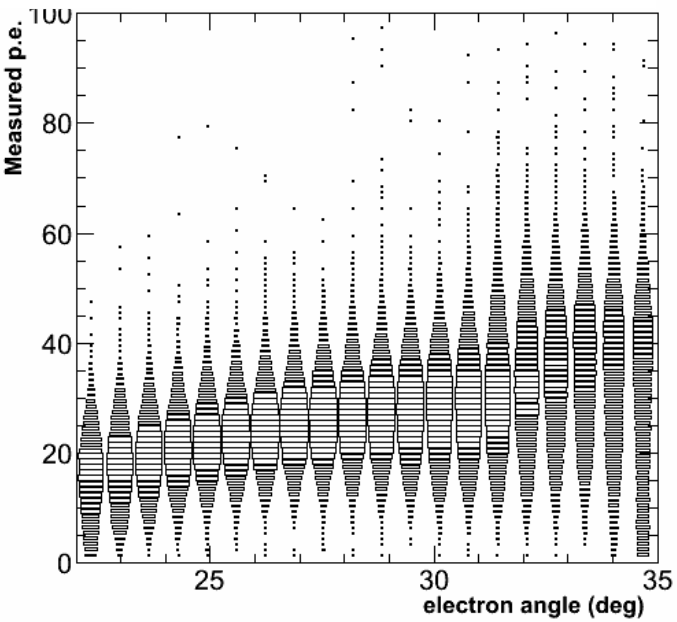
Z < -15cm

Z mid 30 cm

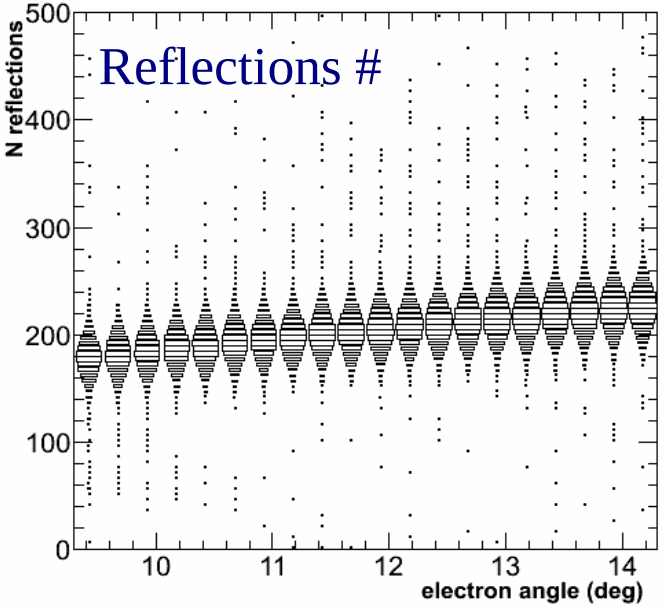
Z > 15cm

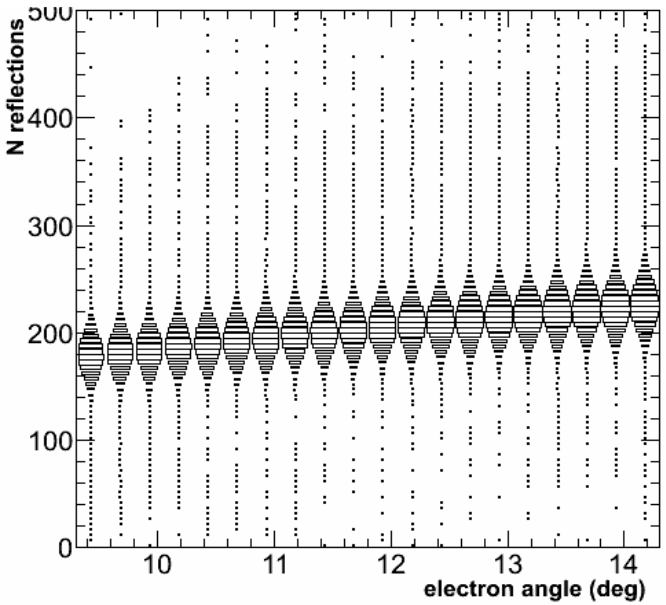


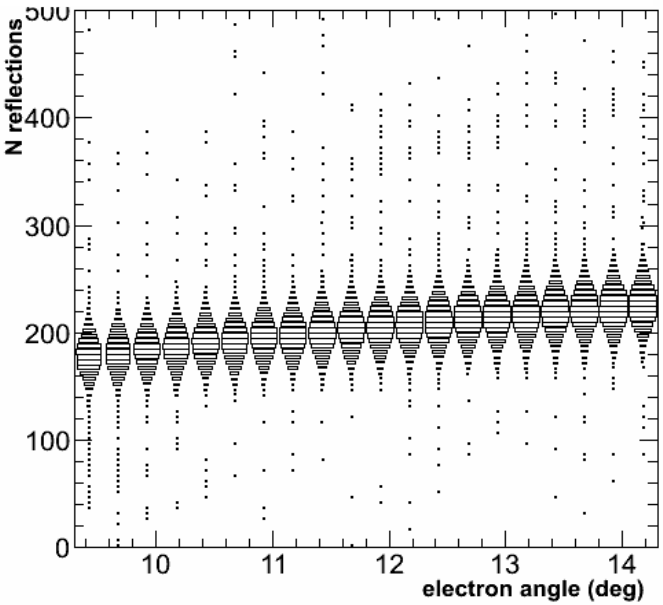




SIDIS







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Z mid 30 cm

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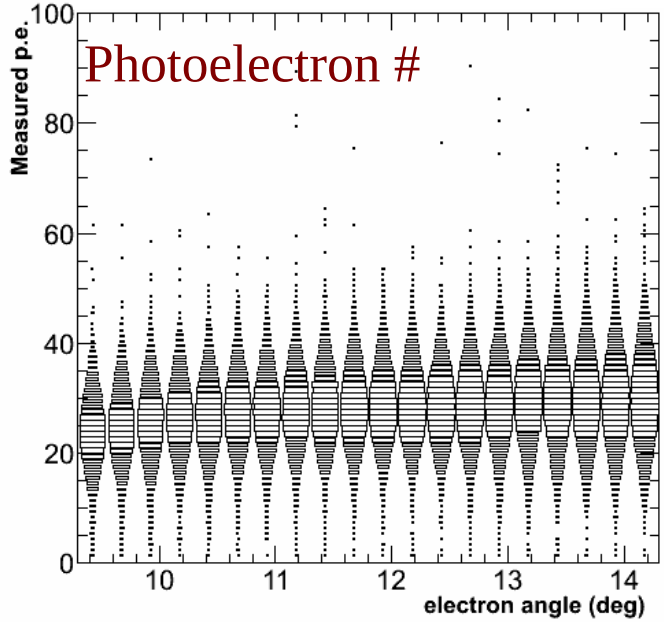
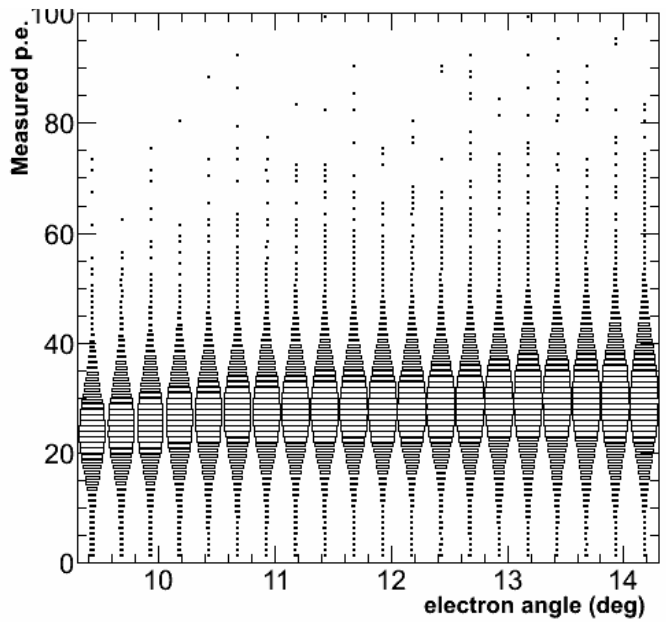
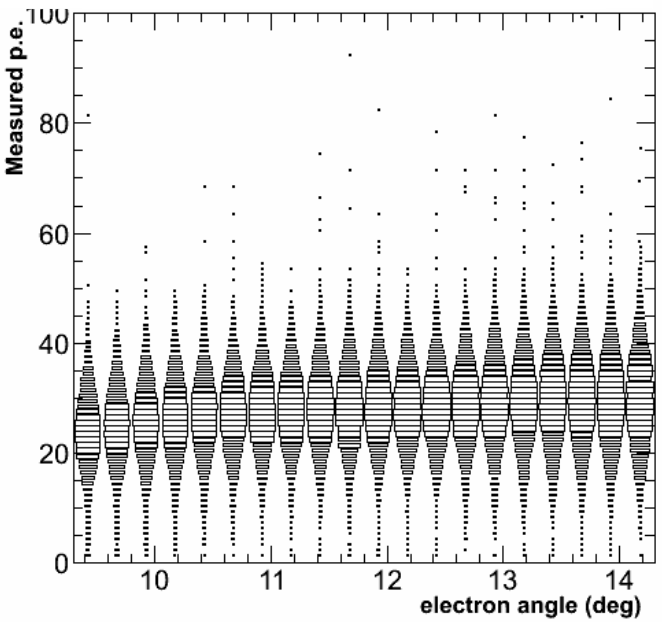
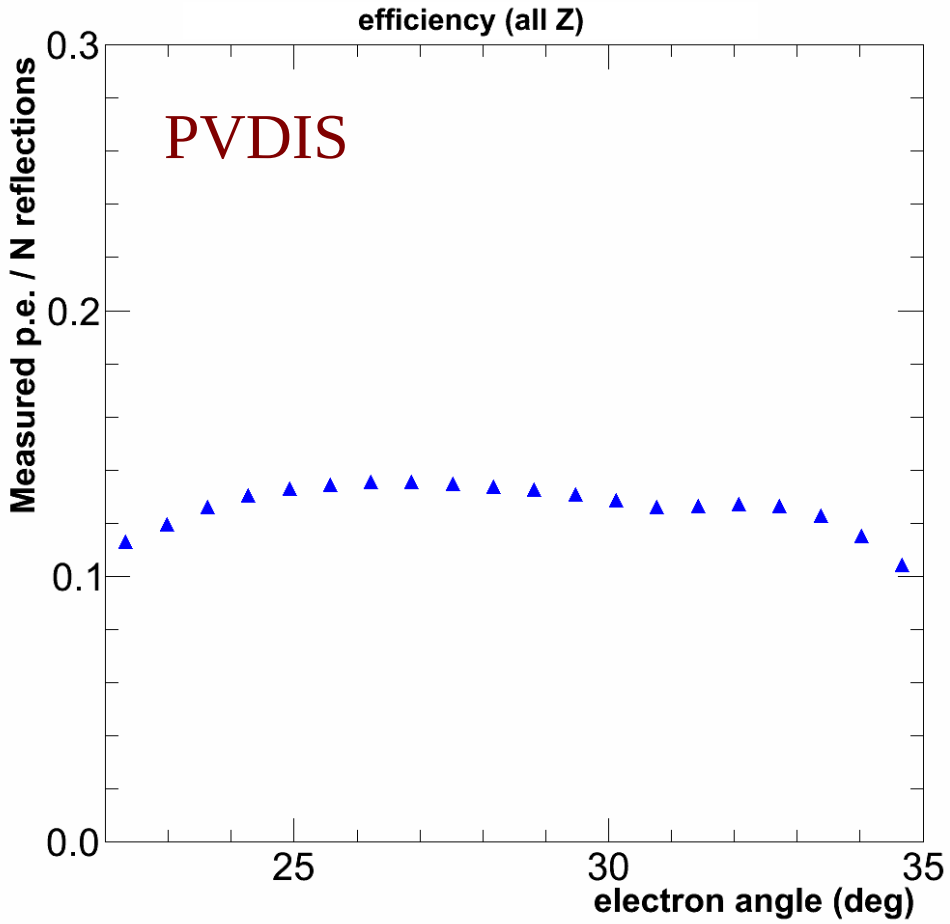
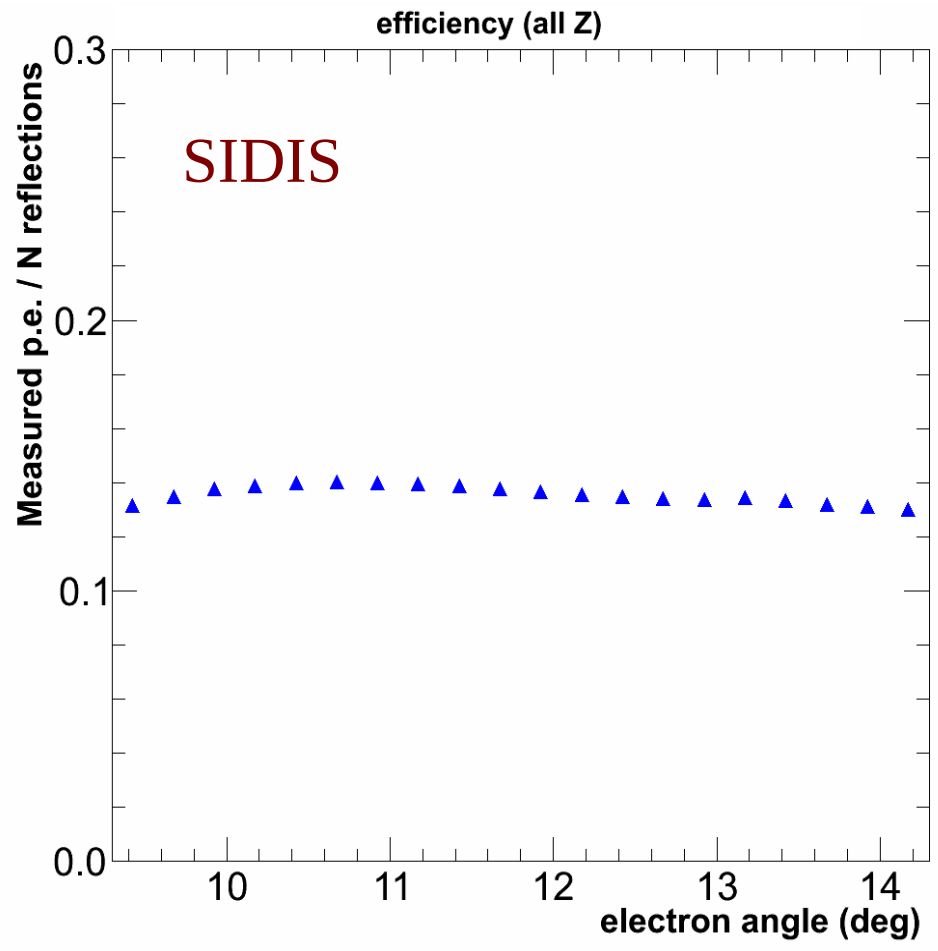




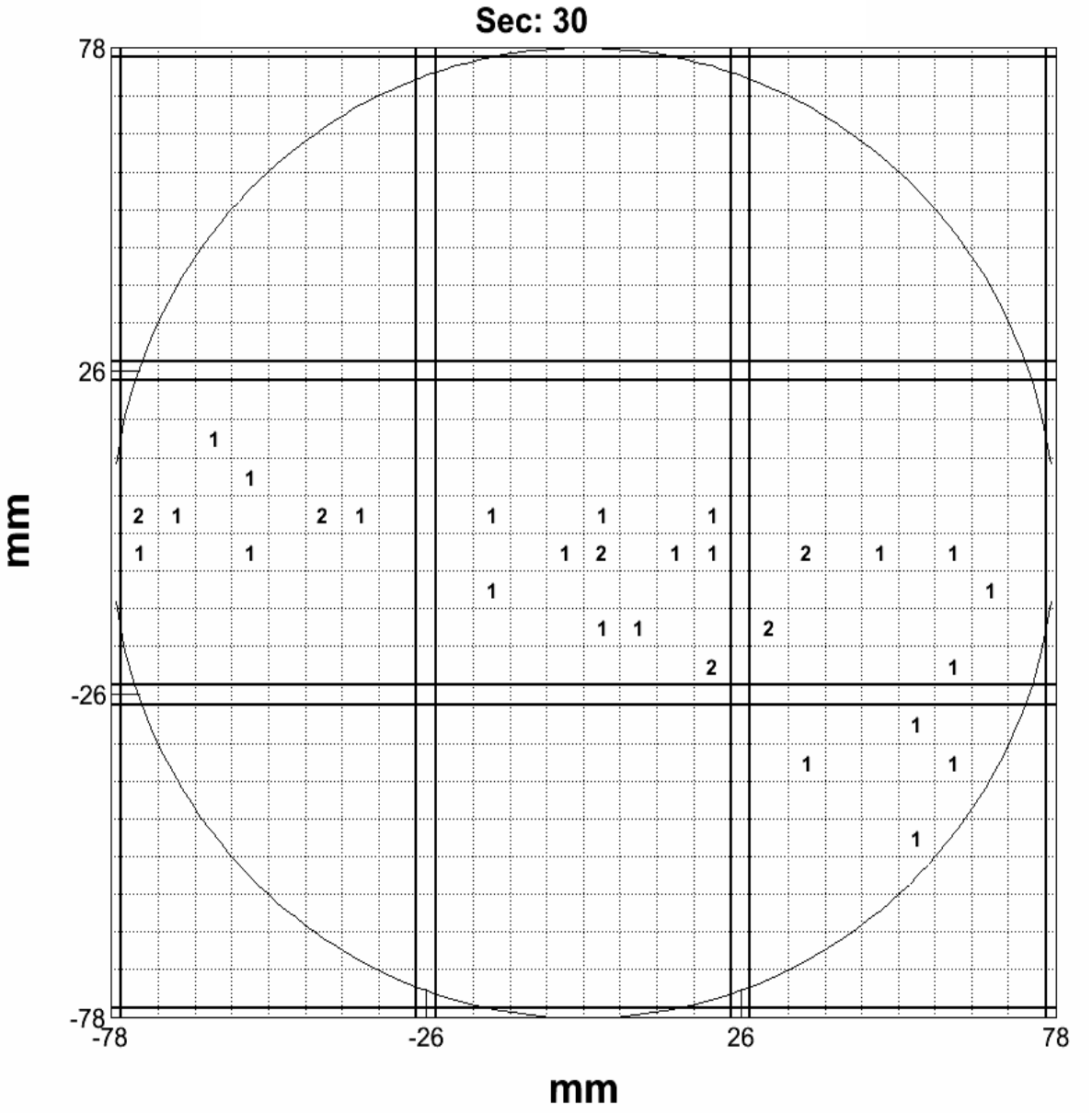


PVDIS / SIDIS Collection Efficiency



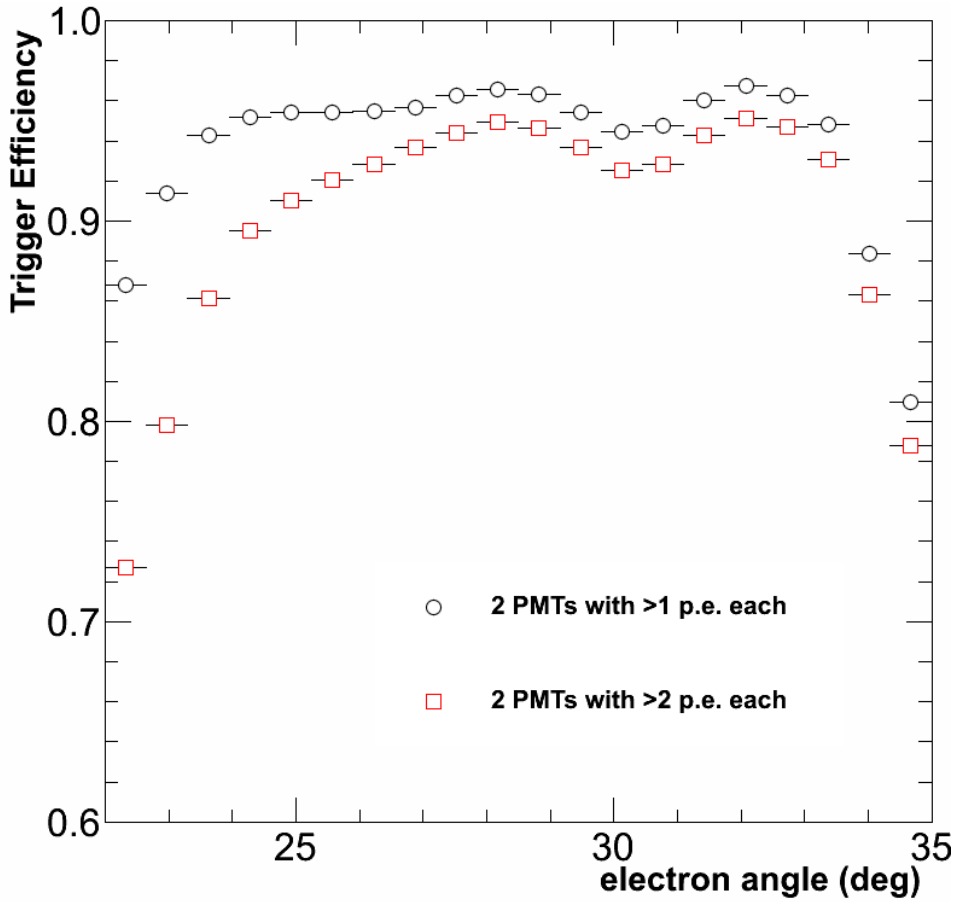


PMT Cherenkov trigger

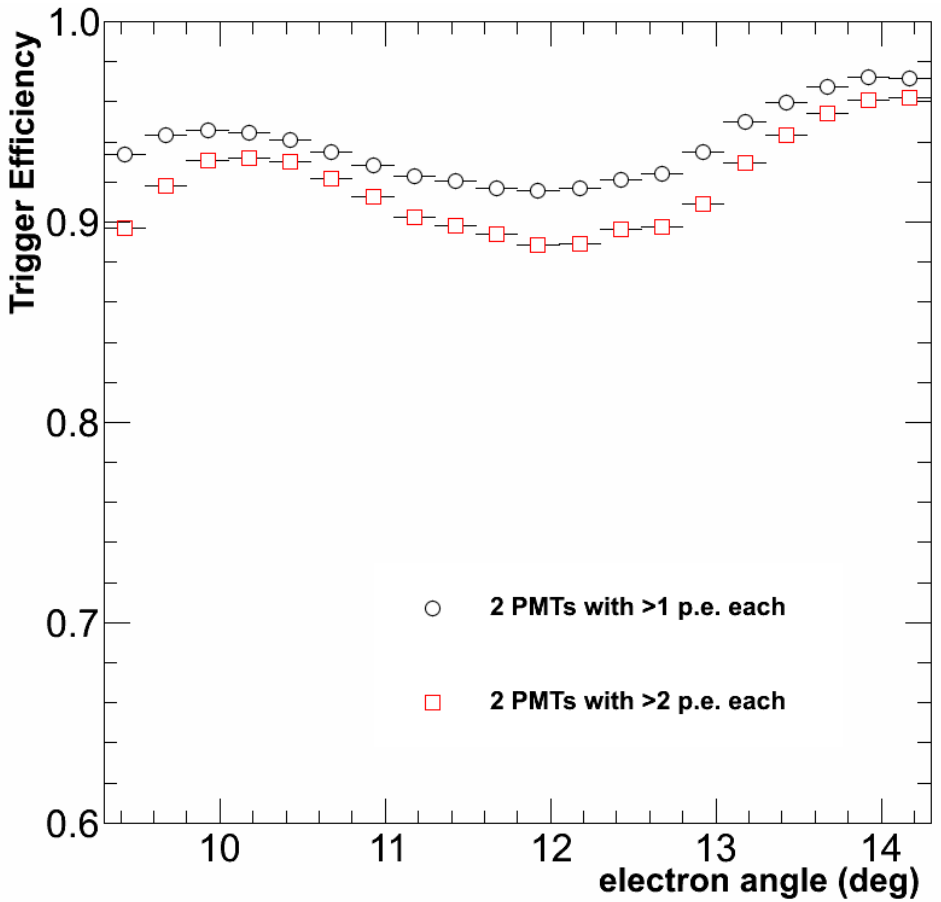


- 3 by 3 array of PMT assemblies (H8500C).
  - Each assembly is 8 by 8 array of pixel PMTs
- All photoelectrons from a single assembly will be summed.
- Then a coincidence circuit can be formed between assemblies with greater than 'X' p.e.'s.
  - 36 total ANDs (or only 18 if you only use adjacent assemblies)

Trigger Efficiencies

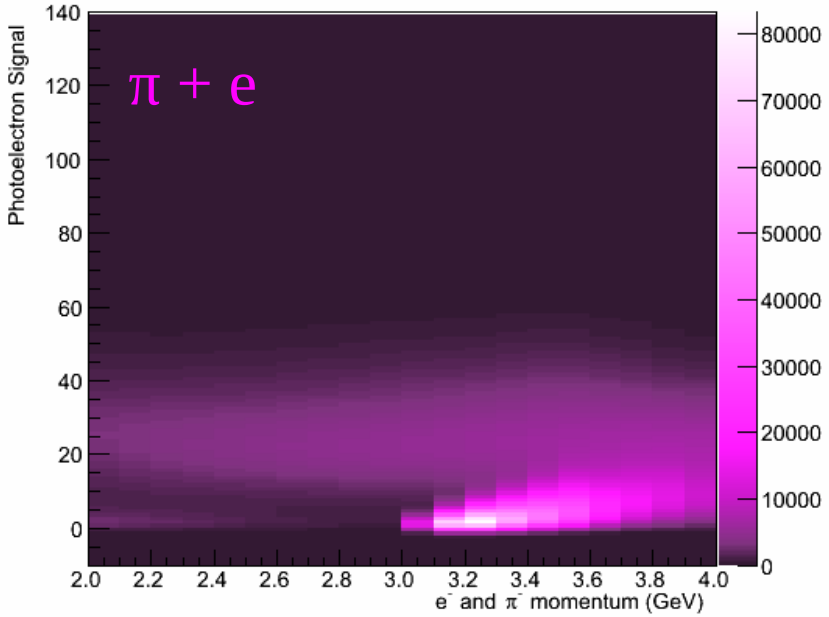


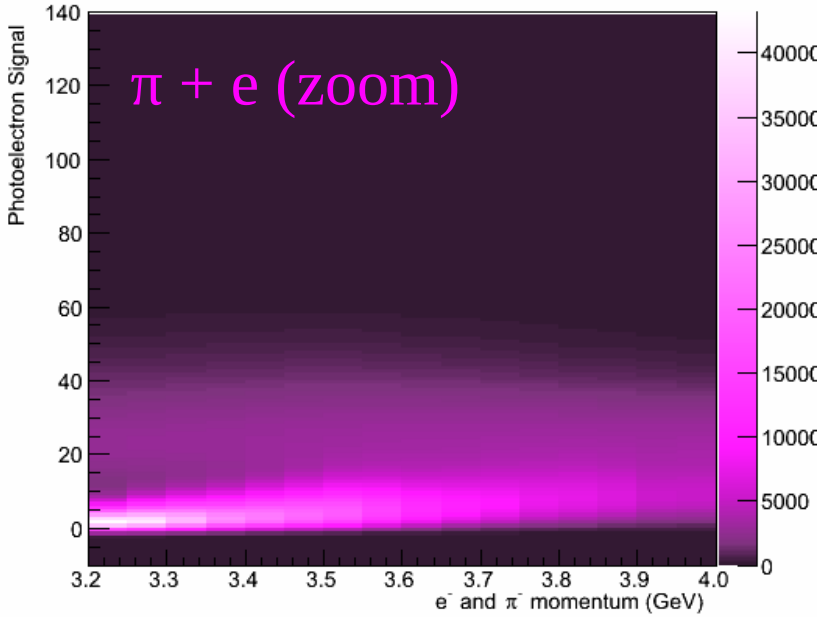
PVDIS

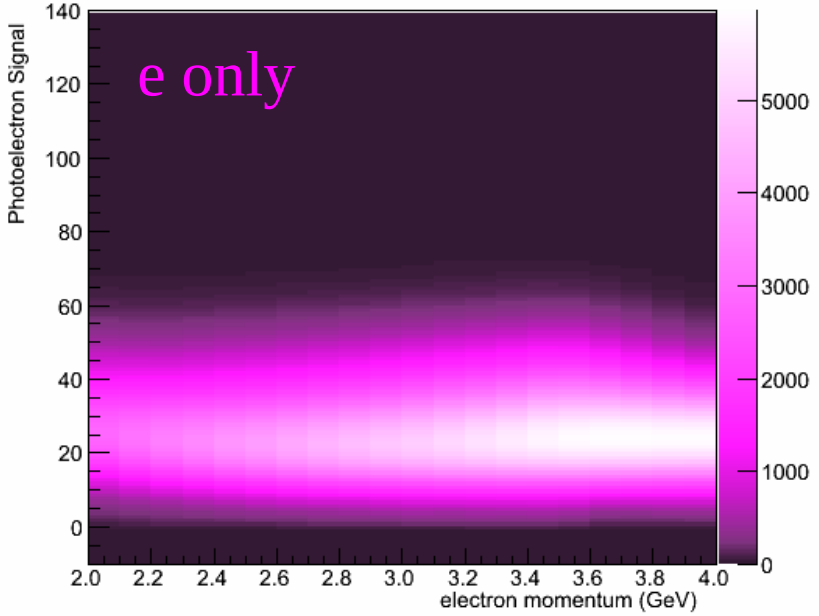


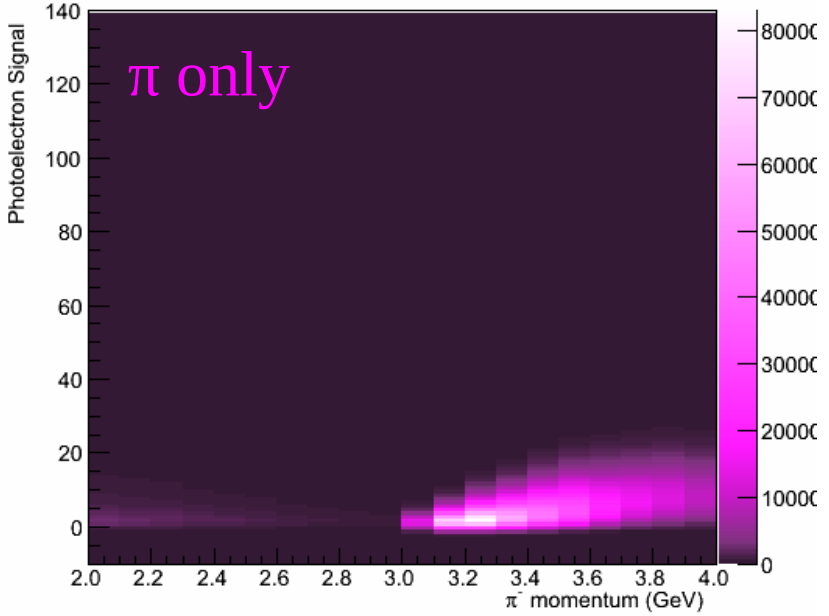
SIDIS

Pion Backgrounds **PVDIS**

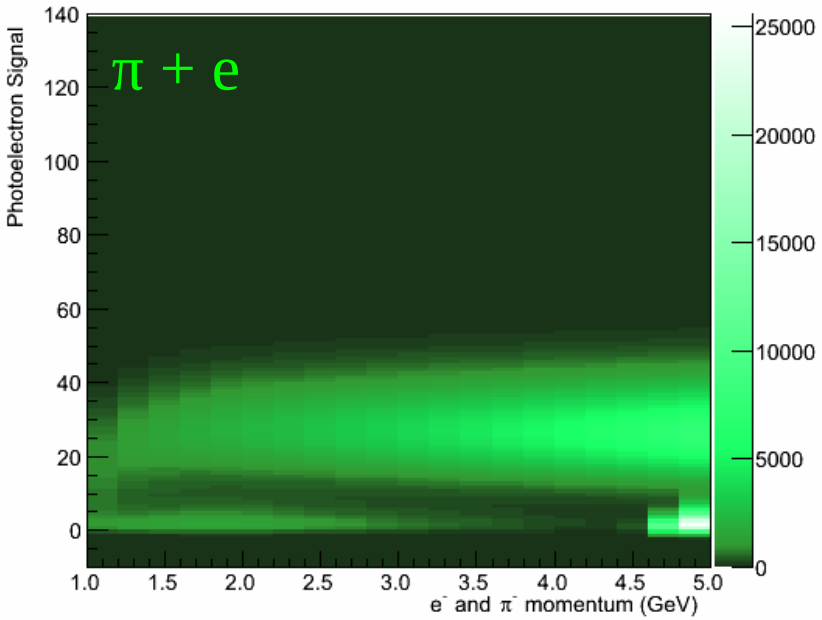


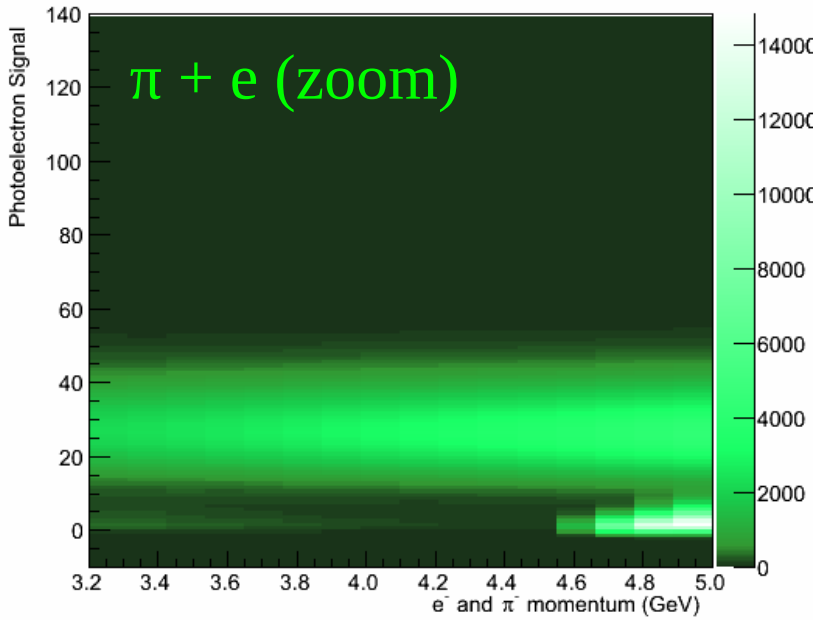


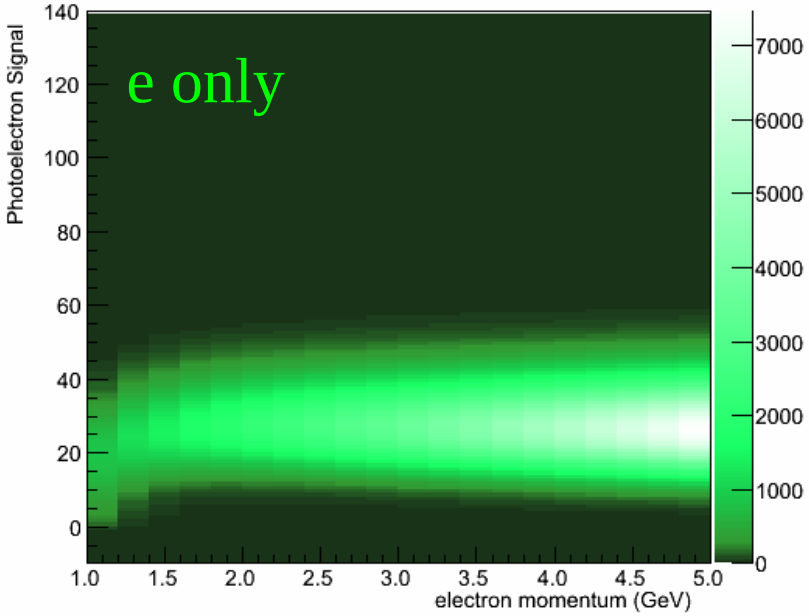


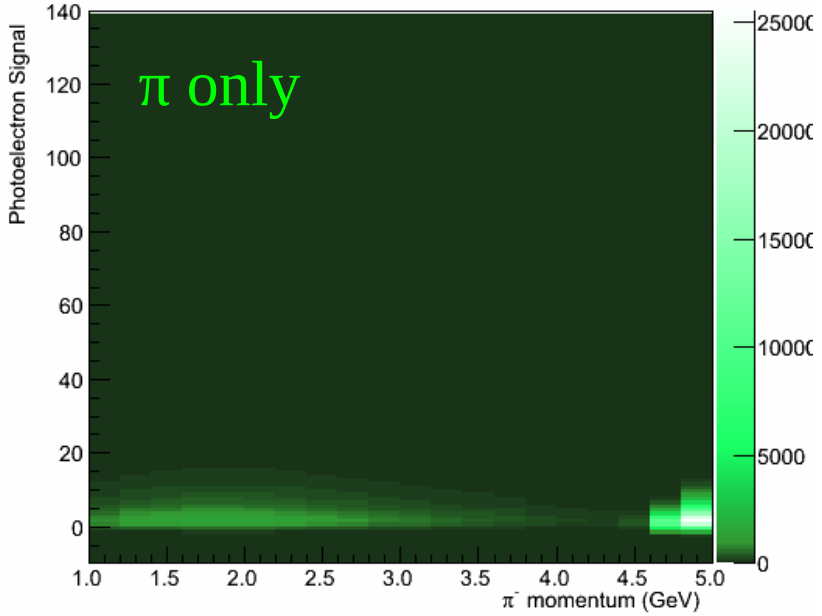


Pion Backgrounds **SIDIS**

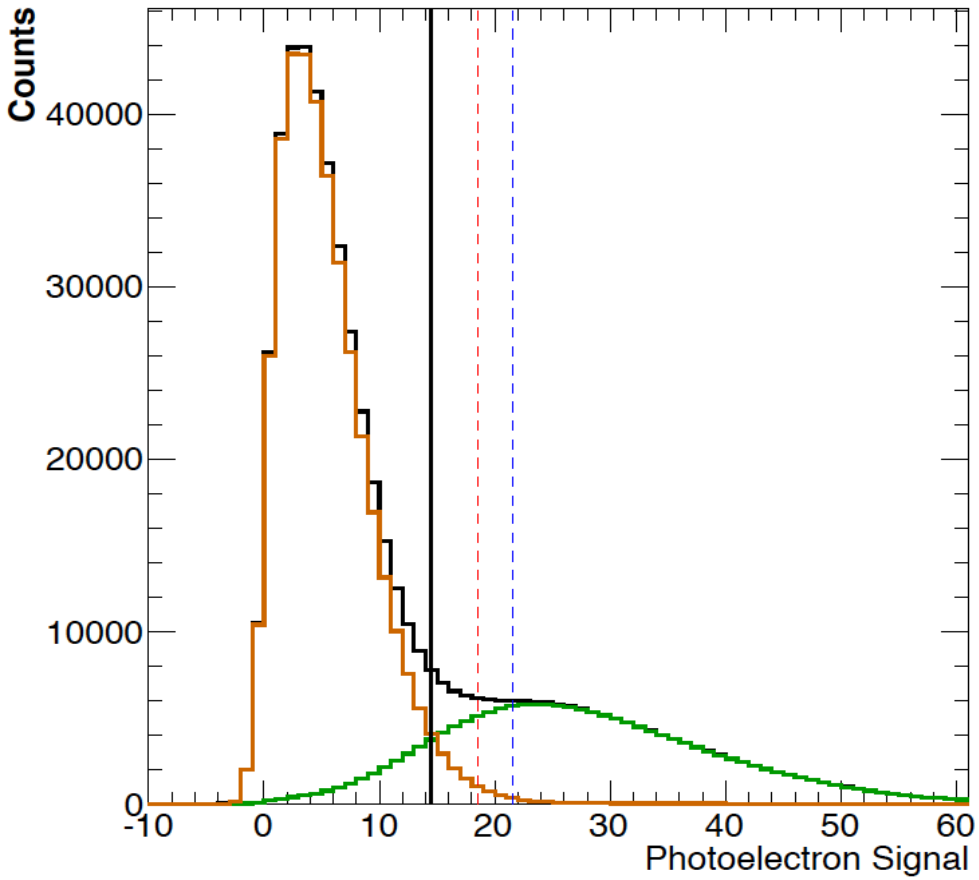


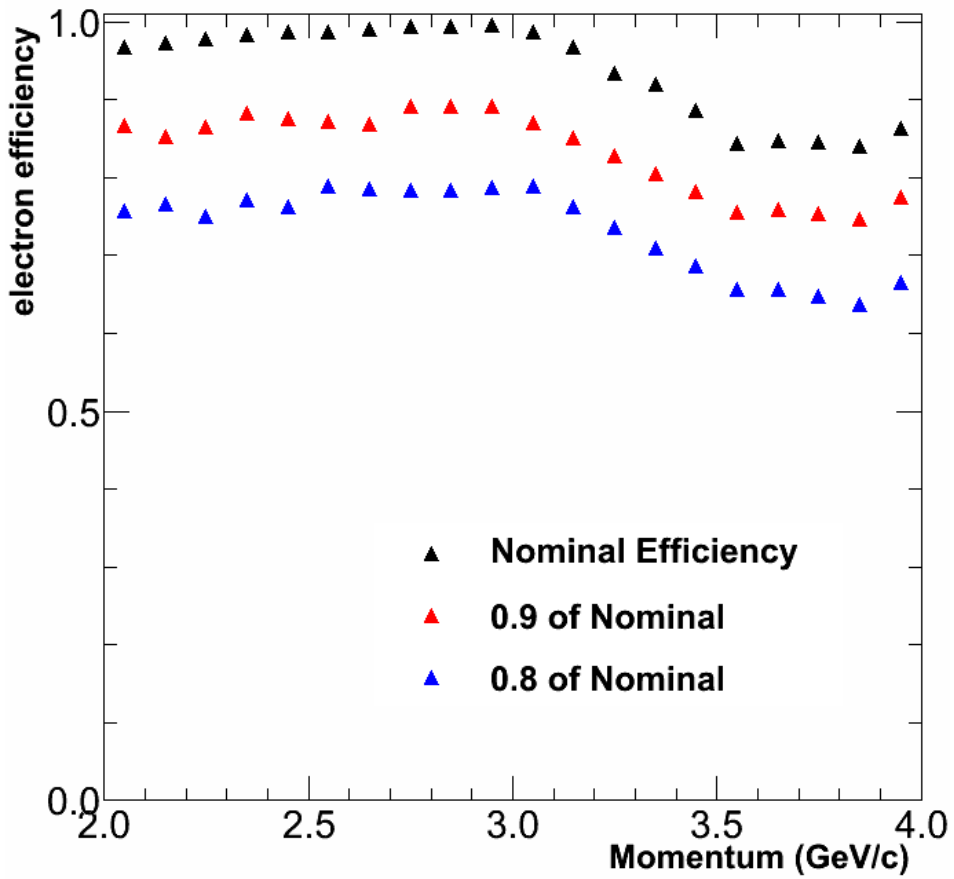






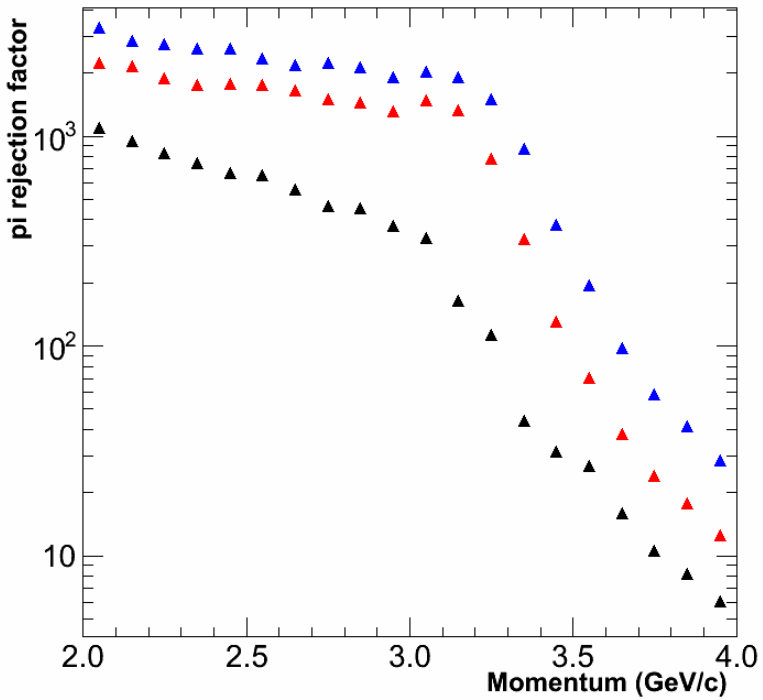
Pion Rejection - PVDIS

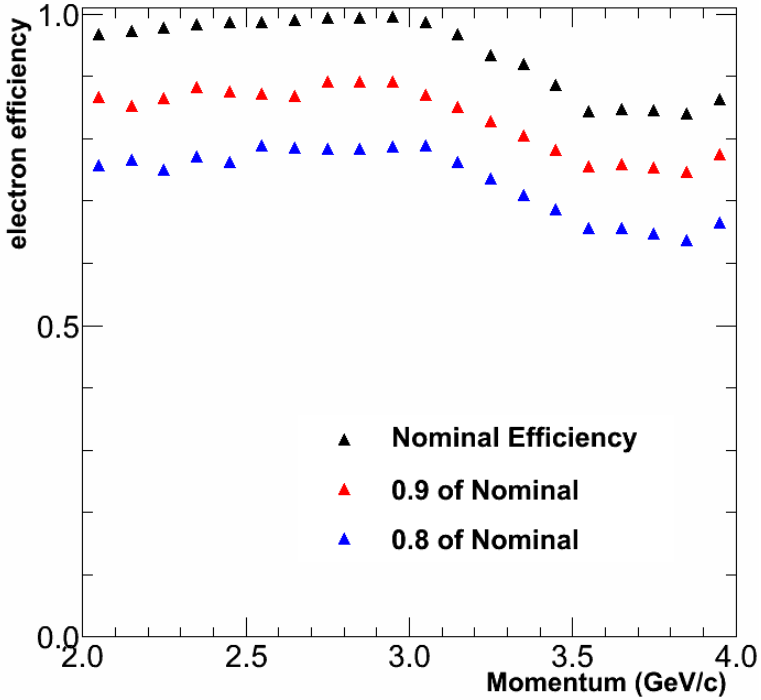


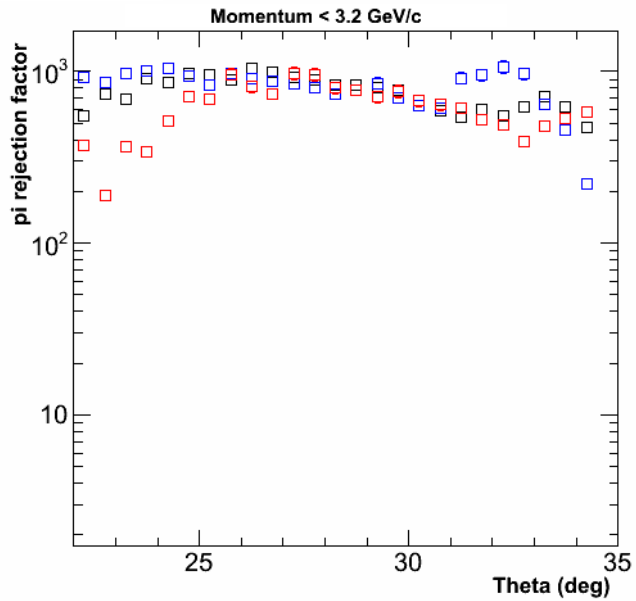


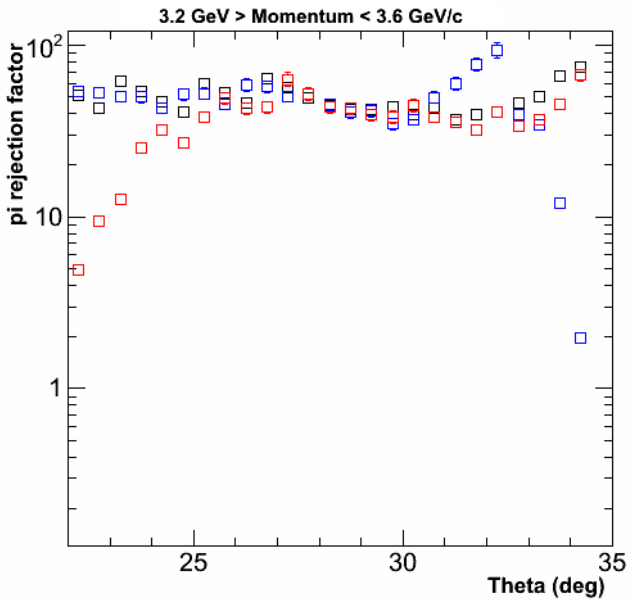
- Rejection per bin in momentum is shown at nominal efficiency (black line), 90% of nominal electron efficiency (red dashed) and 80% (blue dashed).

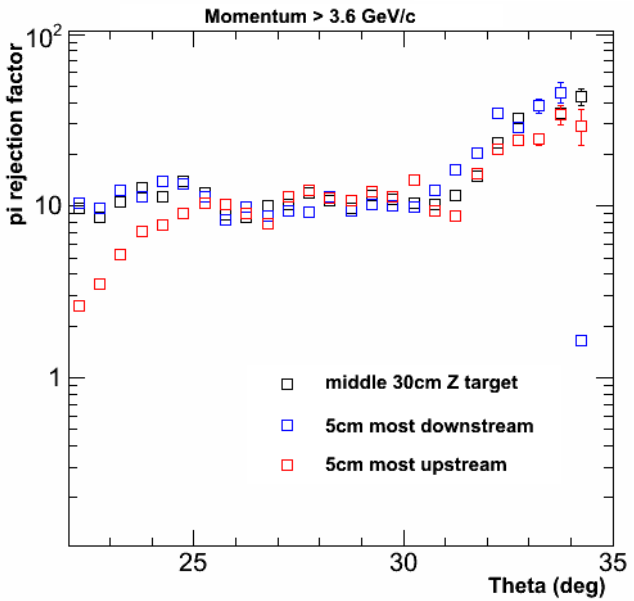
Pion Rejection - PVDIS



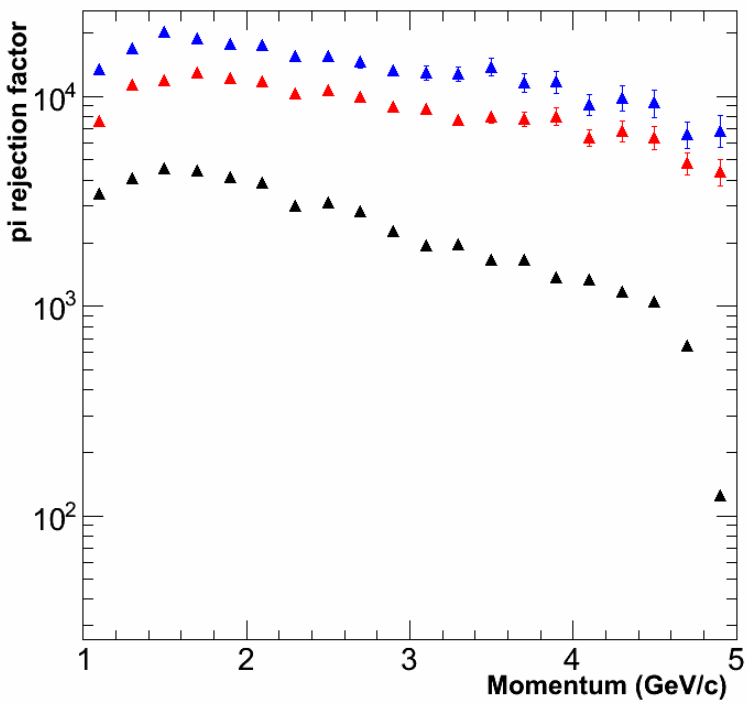


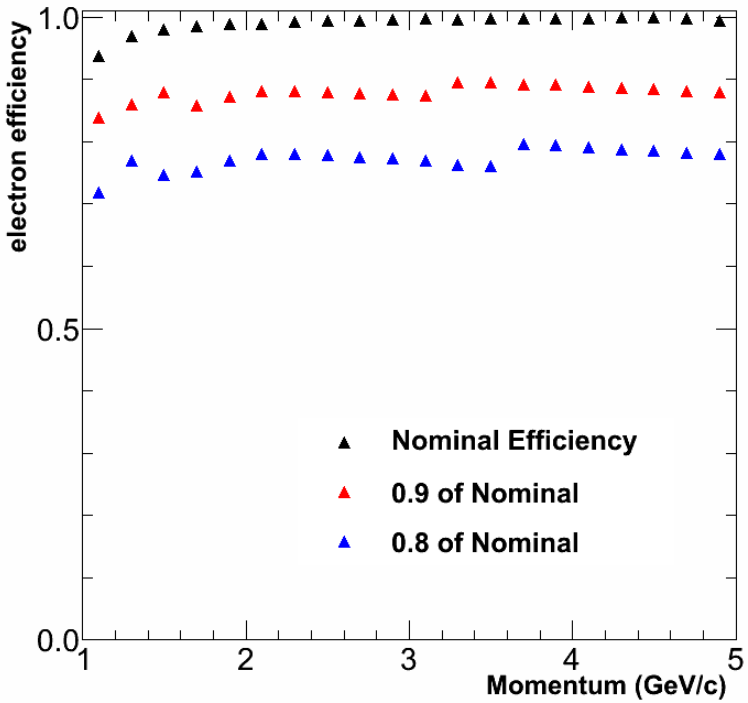


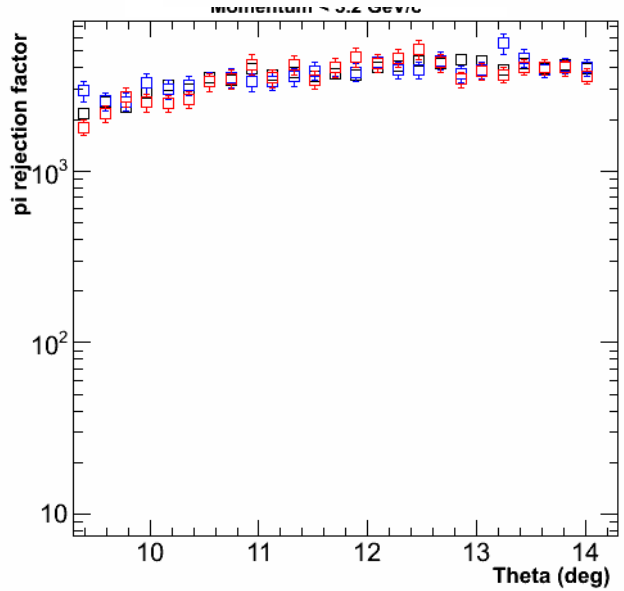


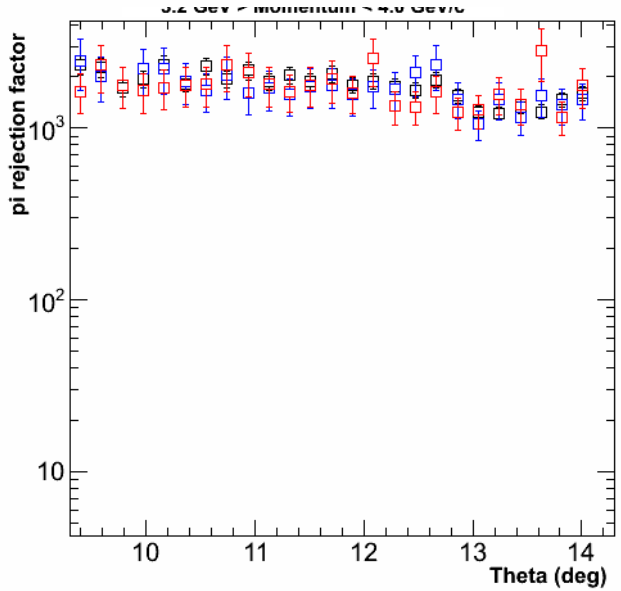


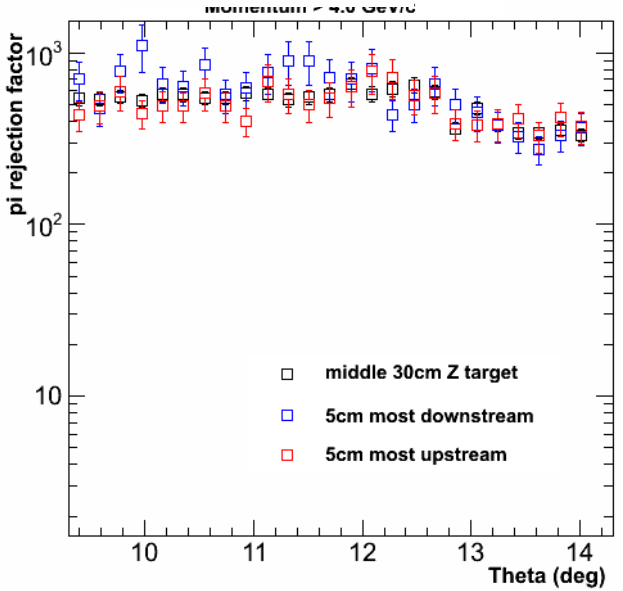
Pion Rejection - SIDIS









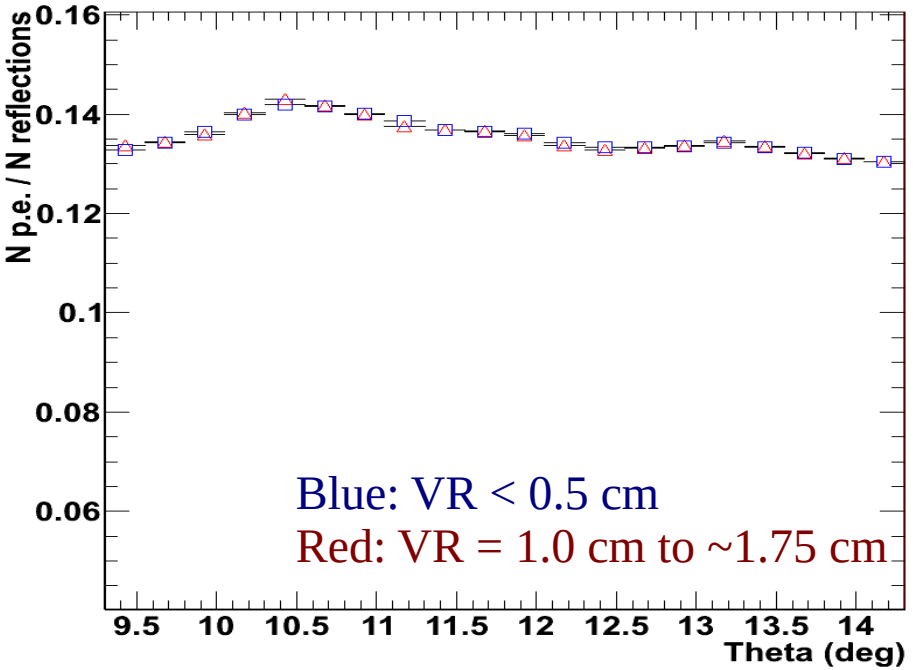


Budget Considerations

- Design was implemented with a strong desire to minimize costs through re-use of components between SIDIS and PVDIS without significant loss of efficiency for either configuration.
- Mirror cost (all + spares): $348,000 (prior: $540,000)
- PMTs (30 x 9 H850C0-03): $810,000 (prior: $810,000)
- 30 mu-metal cylinder / cones: $45,000 (prior: $90,000)
- Mirror coating: eff $0
- Total: $ 1,103,000 (prior: $1,400,000)

Dry-Run Review Questions:

- Effect of slow-raster (2.5 cm) on efficiencies:
  - Running simulation now to test the effects on a H target (closest thing I have to event generation on NH3)



- Use of Super Bialkali in PMTs?
  - H8500C-03 only uses standard bialcali (26% max q.e.)
    - "for technical reasons" (Hamamatsu representative via C. Pauly of the CBM collaboration). Will contact myself.
  - H8500C-mod100 uses super bialcali (35% max q.e.) but uses an 8 stage dynode and has a limited photon wavelength range (300 to 650nm).
    - Could use a wavelength shifter but additional simulation would need to be done to see if results show a net gain.

Dry-Run Review Questions (cont):

- H8500C's are noisier than other PMTs of same photocathode area: PMT dark rates may reach over 200 kHz. What's the plan?
  - By having a coincidence trigger of at least 2 photoelectrons in 2 separate PMT assemblies should provide enough discrimination to overcome the 200 kHz rate. A more detailed simulation could be performed with appropriate trigger logic and time windows.
  - Also ensuring PMTs do not overheat and using positive HV can help.
- Low-pass filtering of the the Cerenkov signal could be helpful if pulses are long enough.
  - This will be investigated with prototype PMTs and trigger electronics. Prototype expected this spring.

Dry-Run Review Questions (cont):

- Each PMT pixel in the assemblies have different gains. Vladimir Popov developed a method of matrix gain balancing that could be used to increase energy resolution and timing characteristics
  - Agreed. We plan on using the matrix gain balancing developed by Vladimir Popov.