SHMS / HMS Detector System Summary / Updates (Mostly Cerenkov Updates)

B. Sawatzky (JLab)

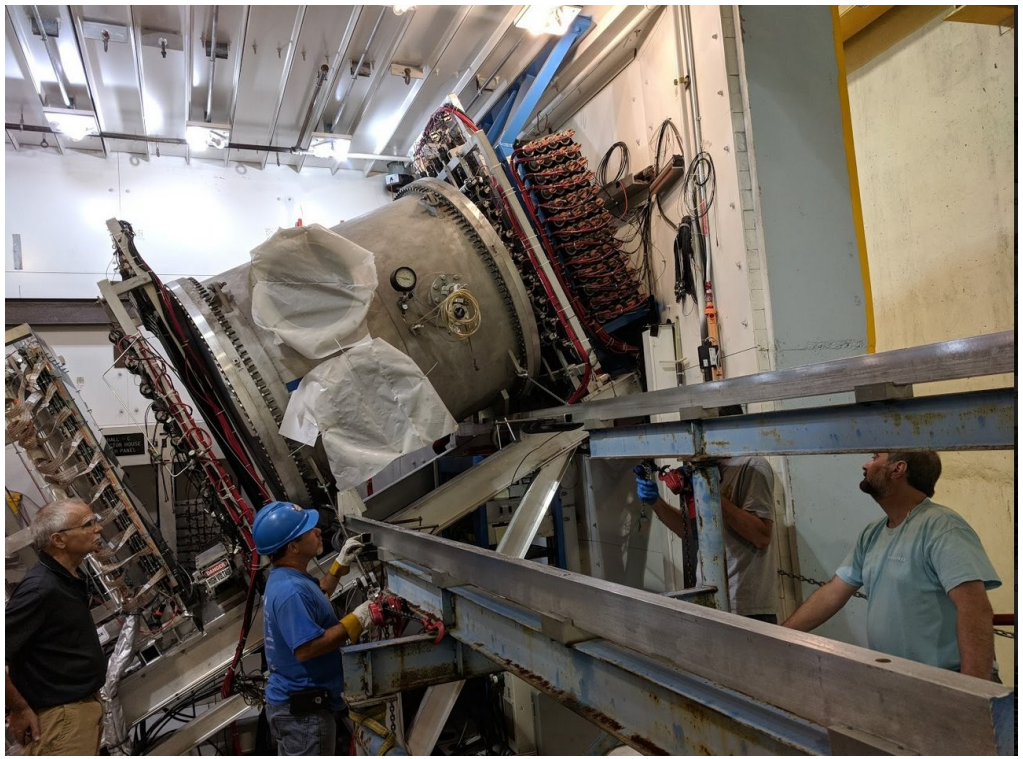
Summary as of June 2018

- ***Generally* Detectors/DAQ are working as planned**
  - → Calibrations, cross-checks are in progress
    - » See upcoming Hall A/C collaboration meeting and Analysis workshop!
  - → SHMS gas Cerenkov yields are lower than predicted, investigations underway
    - » SHMS **NGC** has one very noisy PMT
      - Spare PMT available, will be replaced this summer
    - » SHMS **NGC** yield *may* be concern at high momentum settings (> 7 GeV/c)?
      - May want to be conservative with PID expectations at such settings?
    - » SHMS **HGC** yields are also lower than predicted
  - → HMS mirrors found to be badly damaged
    - » Seems probable it has been like this for years (since 2008/9?)
    - » Spare mirrors located and being installed now

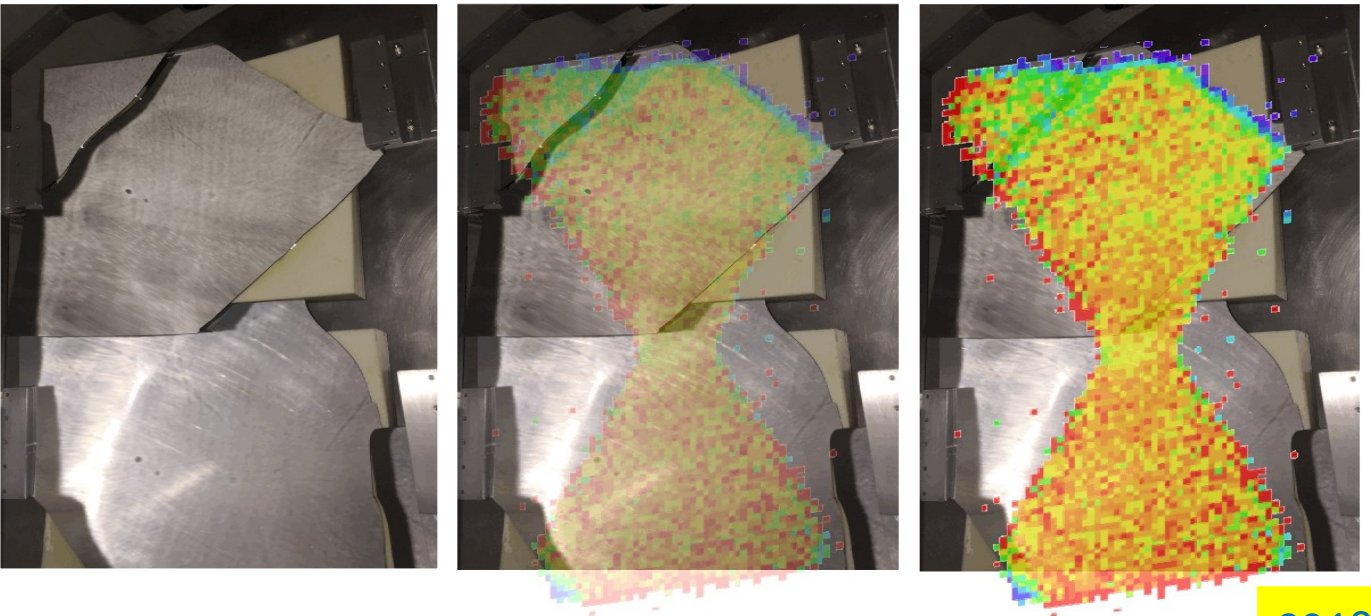
HMS
Gas Cherenkov

HMS Cerenkov Mirror Replacement

- Completed over Summer
  - → Kudos to Howard F. and Tech staff
- Went well
  - → Both mirrors replaced with good spares
  - → Focus checked and optimized
- HMS Cerenkov performance seems to be fully restored



HMS Cerenkov(OLD): Have we really been taking data that way, or did the mirrors just break after the "Spring-18 Run"?



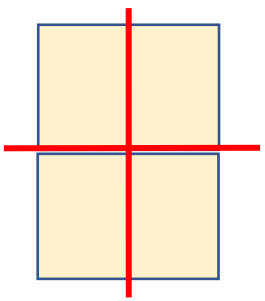
2018

2003

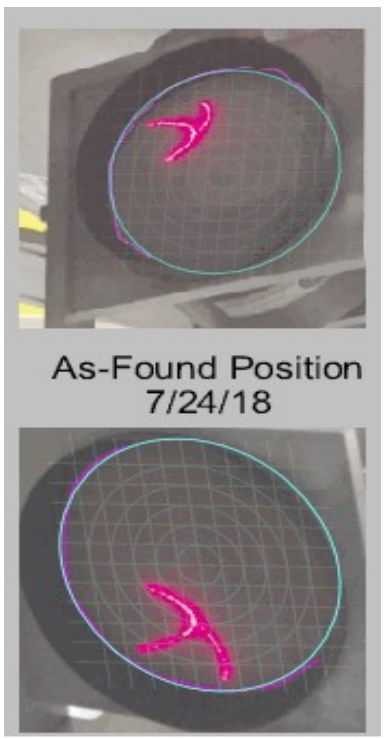
Certainly the mirrors were broken during the (end of) "Spring 18", at least.
They may have been broken (breaking?) for a very long time.

Slide from H. Fenker (June 2018)

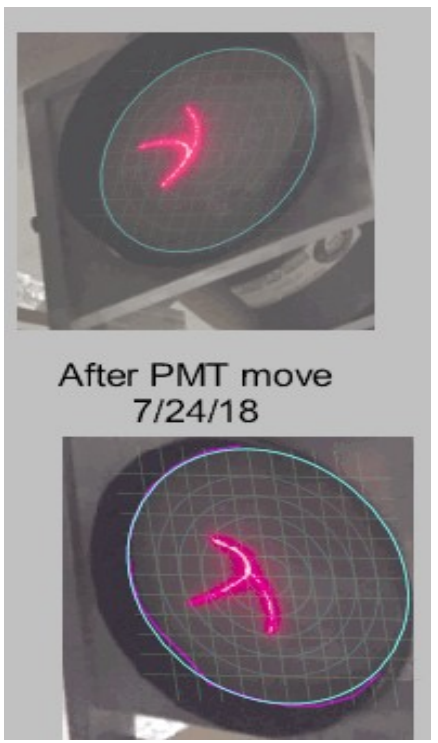
- **HMS gas Cerenkov**
  - Results guided the mirror alignment procedure
    - Laser lines projected on mirror ⎵ Ideal pattern on PMT face
    - Yielded performance improvement beyond just replacing broken mirrors

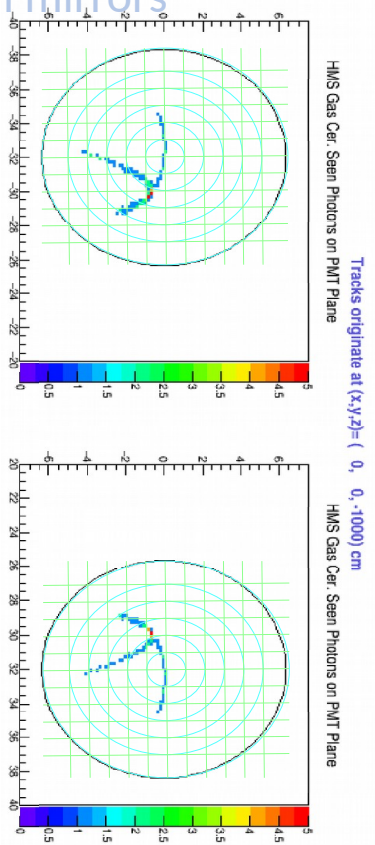


Laser Patterns at Mirrors



20 minutes later





*Moving PMTs is easier and less risky than re-aiming mirrors.

Calculated pattern that should be seen on PMT faces for crossed-lines laser. (Note that PMT circles shown are at X= ±32cm. Mirrors are nominally at X= ±30cm.)

https://hallcweb.jlab.org/doc-private/ShowDocument?docid=997

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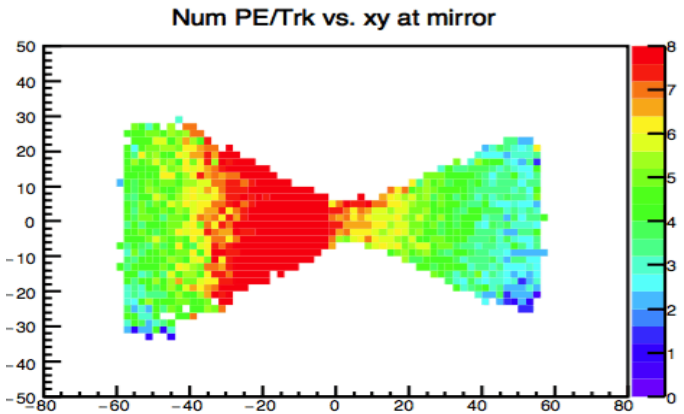
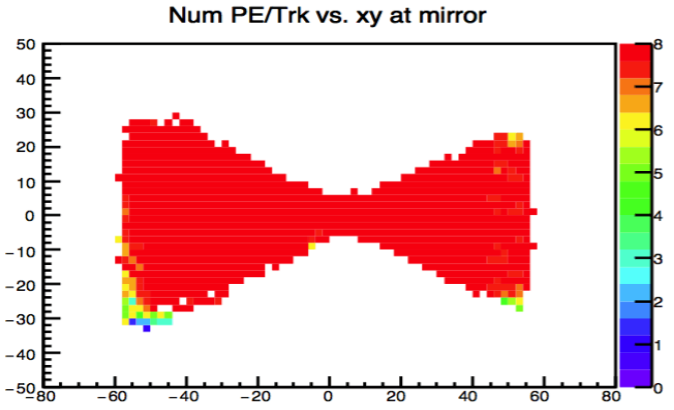
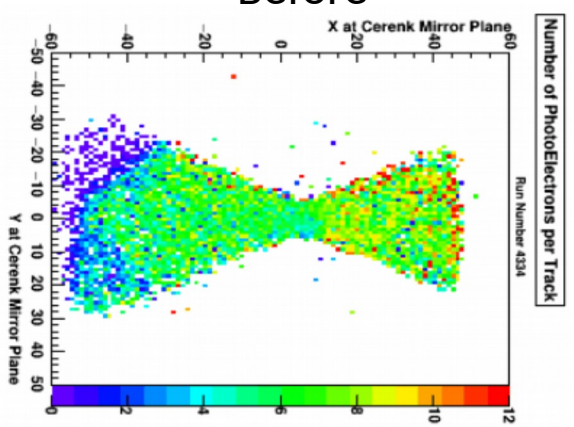


Simulation

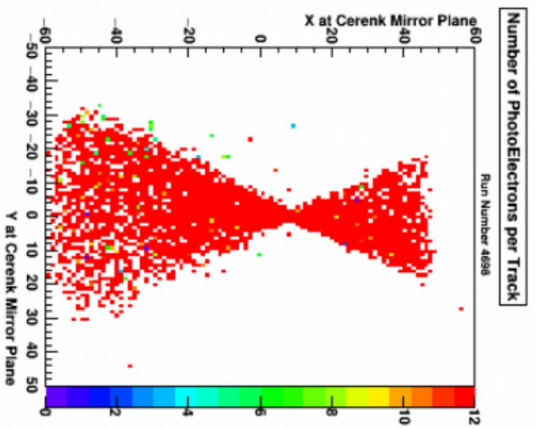


Before



Data

After



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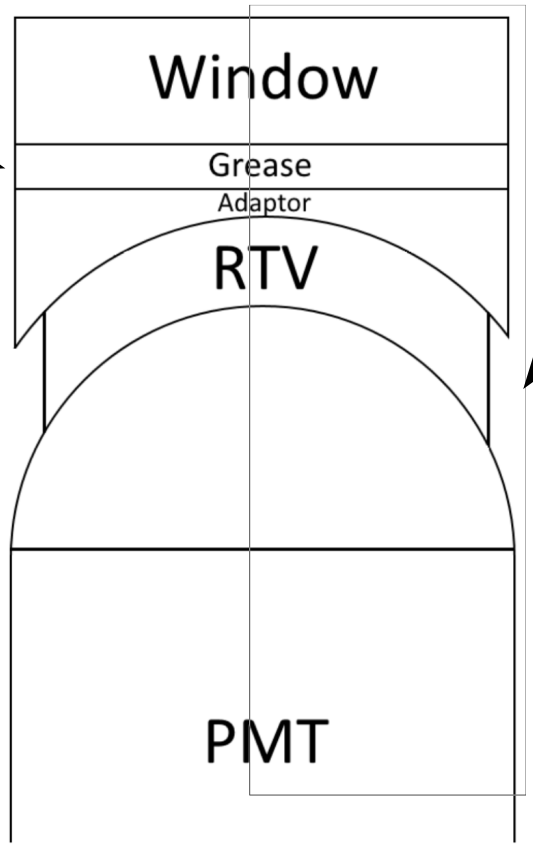
SHMS
Heavy Gas Cherenkov

SHMS Heavy Gas Cerenkov (HGC)

- SHMS HGC
  - → 4 mirrors
    - » ~90% reflection to 200 nm
  - → 4 UV glass PMTs
    - » Good QE down to ~200 nm
  - → Tank can be pumped to vacuum then filled to (partial-)pressure
- Typical fill
  - → 1 atm of C_4F_80
  - → pion threshold = ~2.6 GeV/c
- Expected npe yield
  - > 25 photo-electrons
  - → Seeing less than that...

Original SHMS HGC PMT Optical Config

Removed from PMT1, 2 in Nov 2017



- These replaced with a stand-off ring in PMT1 in Spring 2018 run.
  → Same procedure applied to all 4 PMTs prior to Fall run

- RTV layer measured
  → ~0.14 mm (PMT1)
  → ~0.06 mm (PMT2)
  → Consistent with earlier finding that removal did not improve performance

SHMS HGC (Heavy Gas Cerenkov)

- SHMS HGC had lower npe then predicted during Fall 2017, Spring 2018 runs
  - → 13–15 pe vs >25 pe at 1 atm C_4F_8O
- Low yield theories investigated and eliminated in last year
  - → ~~Poor mirror reflectivity~~
  - → ~~Poor mirror focus~~
  - → PMT optical coupling absorbing UV?
    - » ~~Optical grease between PMT adapter and gas window?~~
    - » ~~RTV joint between PMT and PMT adapter?~~
    - » ~~PMT adapter not quartz?~~
- Last things to check...
  - → Directly measure PMT QE in the UV range
    - » Will also measure UV absorption of quartz gas window and quartz PMT adapter while we're at it...
  - → Completed in July 2018

* Ref: Update on Dec/Jan Running

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  - → ~~Directly measure PMT QE in the UV range~~
    - » ~~Will also measure UV absorption of quartz gas window and quartz PMT adapter while we're at it...~~
  - → Completed in July 2018
    - » No problems found, everything was within spec...

* Ref: Update on Dec/Jan Running

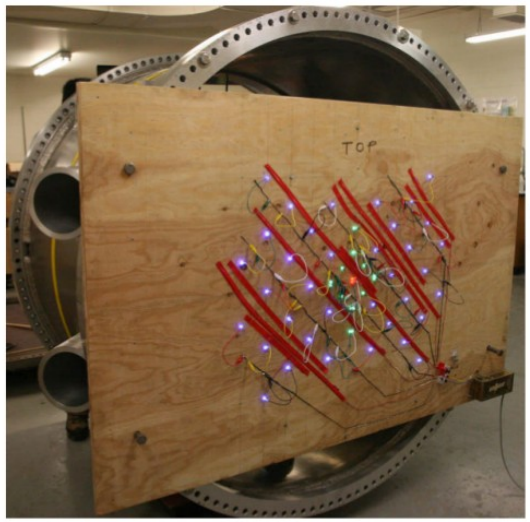
Conclusions and Follow-up Prior to Fall 2018

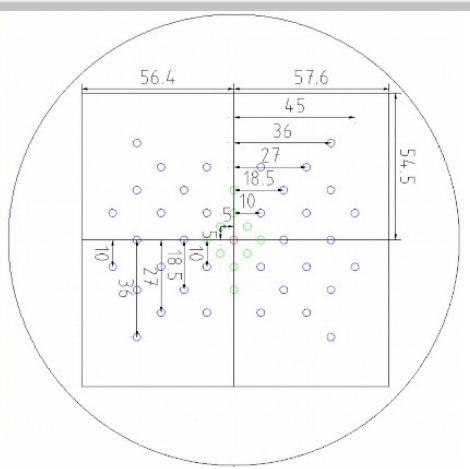
- SHMS HGC PMTs really *are* UV glass
- Quartz gas windows and quartz PMT adapters *are* transparent in UV
- RTV layer cuts enough that we should remove it, but is NOT a major problem
  - → *Before* and *After* npe response of PMT1 *in production* showed no/minimal improvement after removing RTV layer...

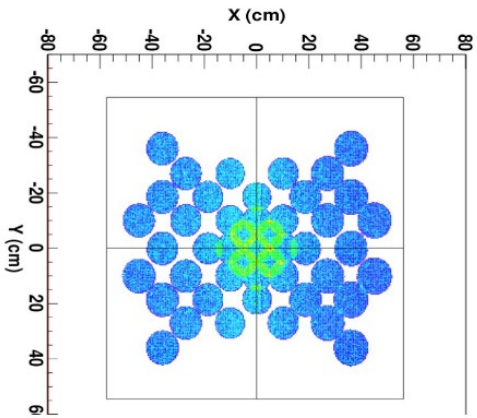
- Steps completed prior to Fall Run
  - → Removed RTV, quartz adapter, etc from upper PMTs
  - → Re-insert bottom PMTs
  - → Reinstall HGC in stack

- Regina group checked mirror alignment and made some small adjustments
  - → Hope was to improve collection efficiency overall with some minor impact on collection associated with central tracks

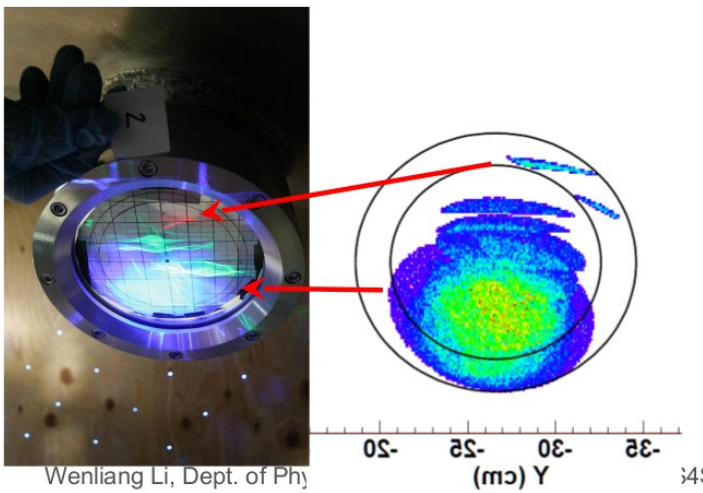
SHMS HGC Alignment Apparatus







Geant 4 simlation



- **LED alignment Array (Xmas tree)**
  - Colored **LED**s: **Red**, **Blue** and **Green**
  - Replicate photon envelope
  - Compared to MC
- **Significantly helped us aligning the detector**

Wenliang Li, Dept. of Phy ...4S0A2, Canada.

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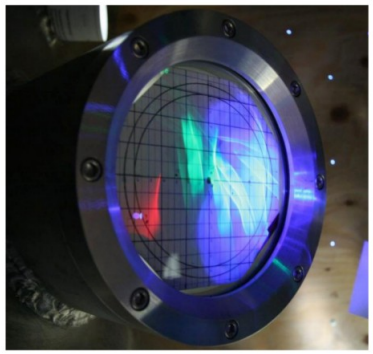
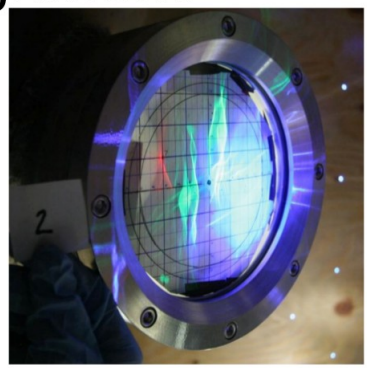
Before and After Fall 2018 Alignment

- Goal was to ensure light from greater majority of HGC acceptance was guaranteed to hit PMT. This required shifting the single, central, red LED response toward the PMT edge.

Old Alignment

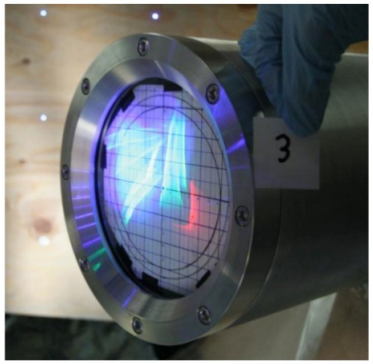
PMT 1

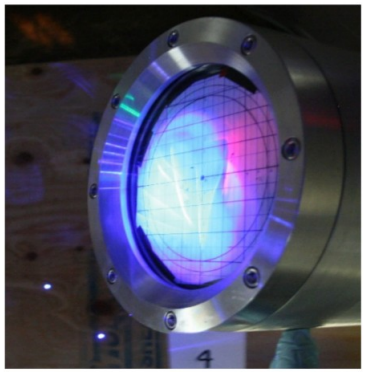




PMT 2

PMT 3

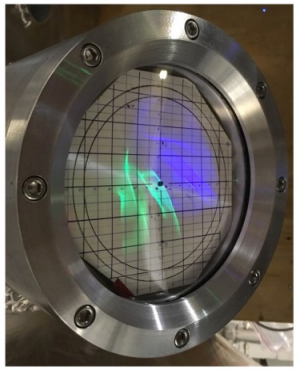




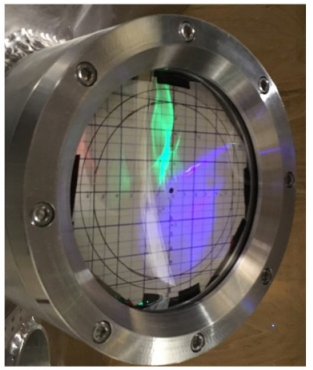
PMT 4

New Alignment

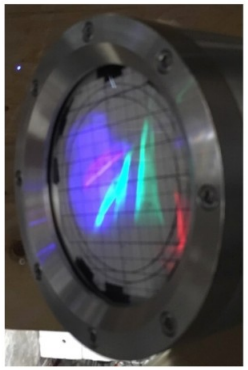
PMT 1



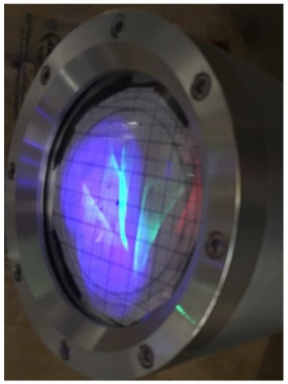
PMT 2



PMT 3



PMT 4



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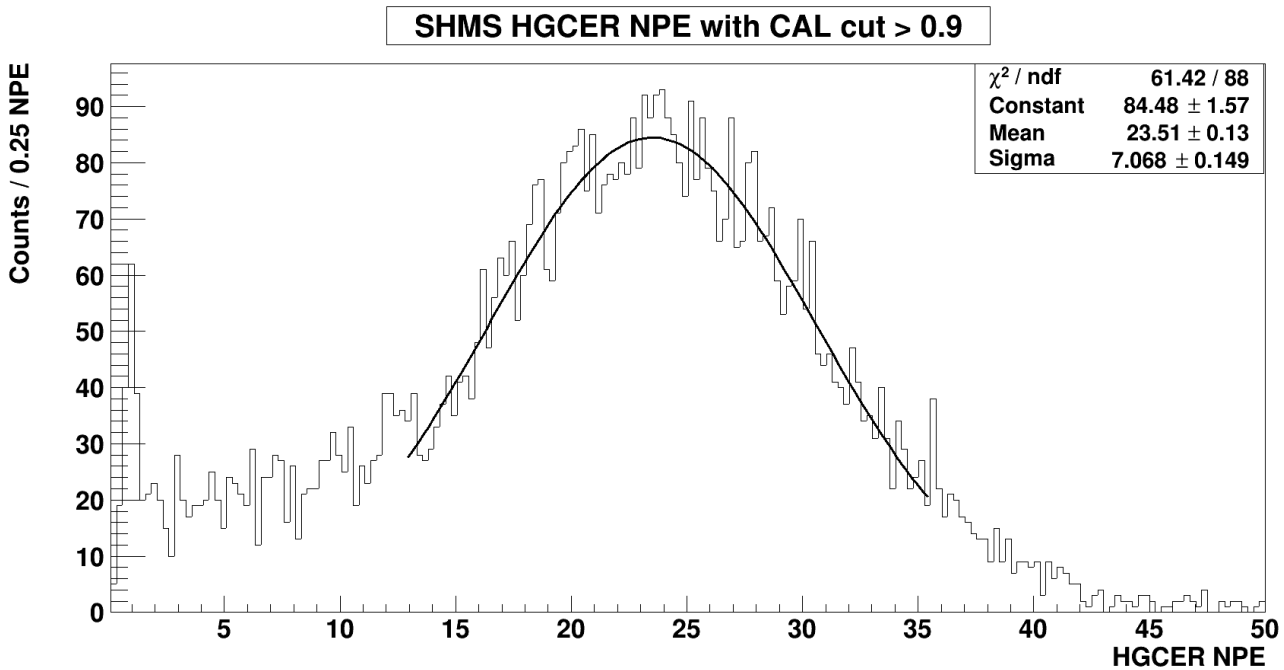
SHMS HGC Performance in Fall 2018

https://logbooks.jlab.org/entry/3599771

- New results puzzle me...
  - → Early conclusion was big improvement of 15 → 25 npe for electrons!
  - → Plot from Sept 29 analysis by Regina group



SHMS HGC Performance in Fall 2018

https://logbooks.jlab.org/entry/3599771

- New results puzzle me...
  - → Early conclusion was big improvement of 15 → 25 npe for electrons!
  - → This would be great, but...

- All changes in optical path were tested in-situ during Spring run and found to have minimal impact (+1–2 npe, max)
  - → Removal of optical grease
  - → Removal of RTV layer
  - → Removal of quartz adapter

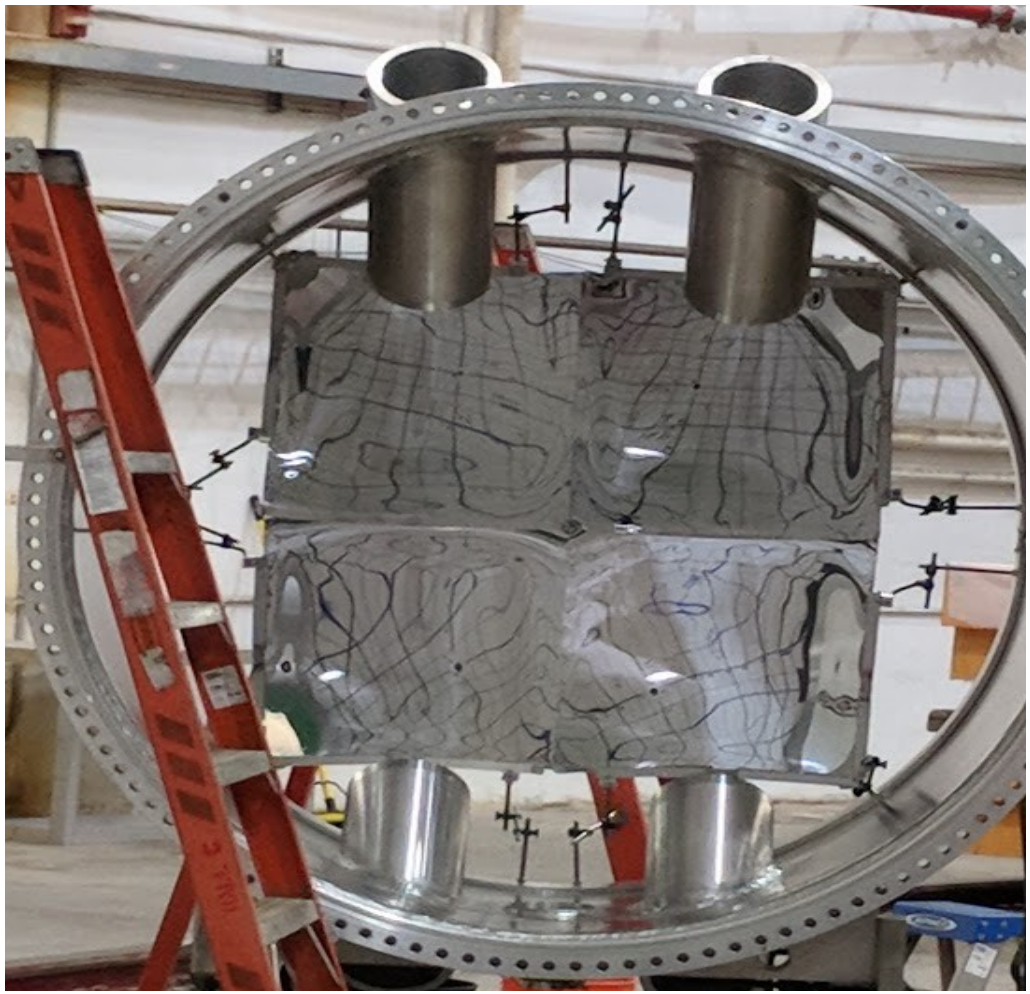
- Which leaves just the adjustment in mirror focus done prior to Fall 2018 run

SHMS HGC Performance in Fall 2018

https://logbooks.jlab.org/entry/3599771

- New results puzzle me...
  - → Early conclusion was big improvement of 15 → 25 npe for electrons!
  - → This would be great, but...
- The change in mirror focus was fairly minor...
  - → Studies were done in Spring placing cuts to constrain electron tracks to pass through selected positions on mirror(s), could never get more than ~15 npe
  - → LED 'spot' images moved few cm on PMT face in Fall 2018 refocusing effort
    - » I don't understand how both observations can both be true...
      - Cerenkov ring diam is significantly smaller than the mirror dimensions
      - There had to be *some* region of a mirror that focused 100% of its photons on its PMT in the Spring, why were we unable to find it and see a high npe yield?
      - If no region of any mirror could focus all rays onto a PMT, then a cm level shift of the mirror focal point on the PMT face shouldn't make a huge difference...

Mirror focus “by eye”

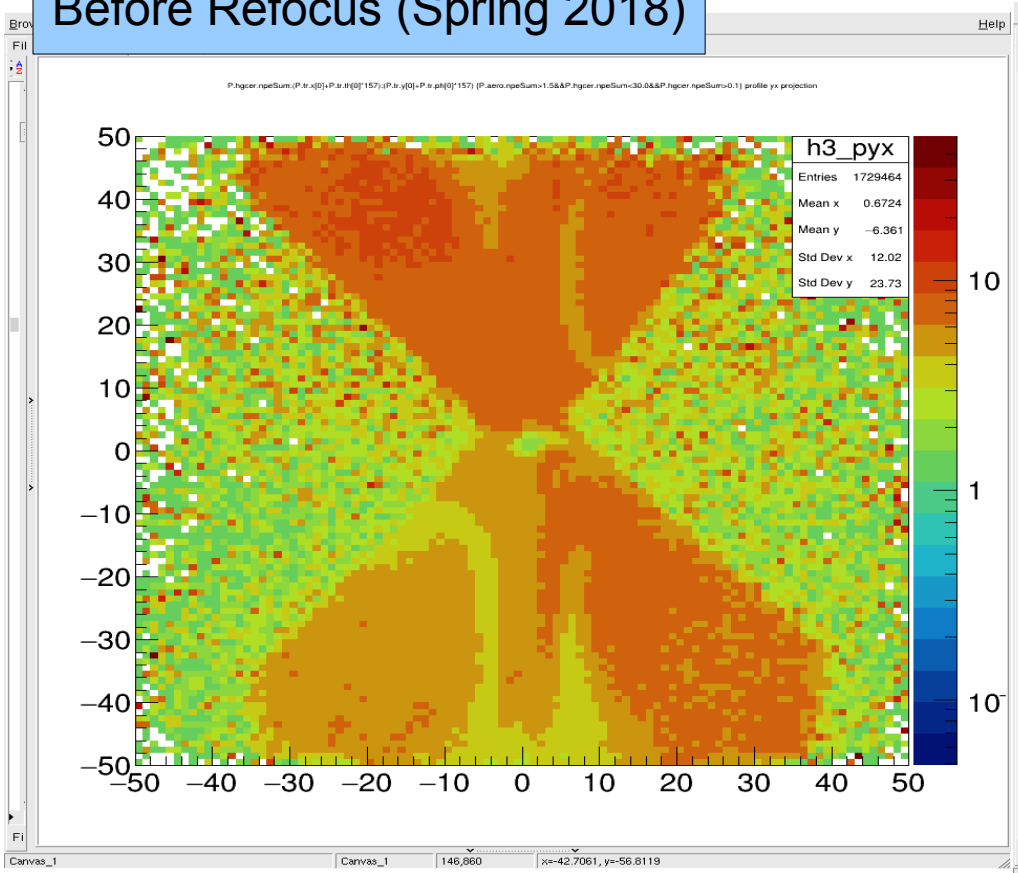


- Grid pattern seen in mirrors is reflection of gridded paper target on PMT surfaces
  - → No obvious dead zones
  - → Most of the light reflecting off the mirror seems to intersect with the PMT surface.
- Not sure how shifting mirror focus could generate 2x the npe yield overall without us being able to see the same maximal yields by placing cuts on mirror regions.

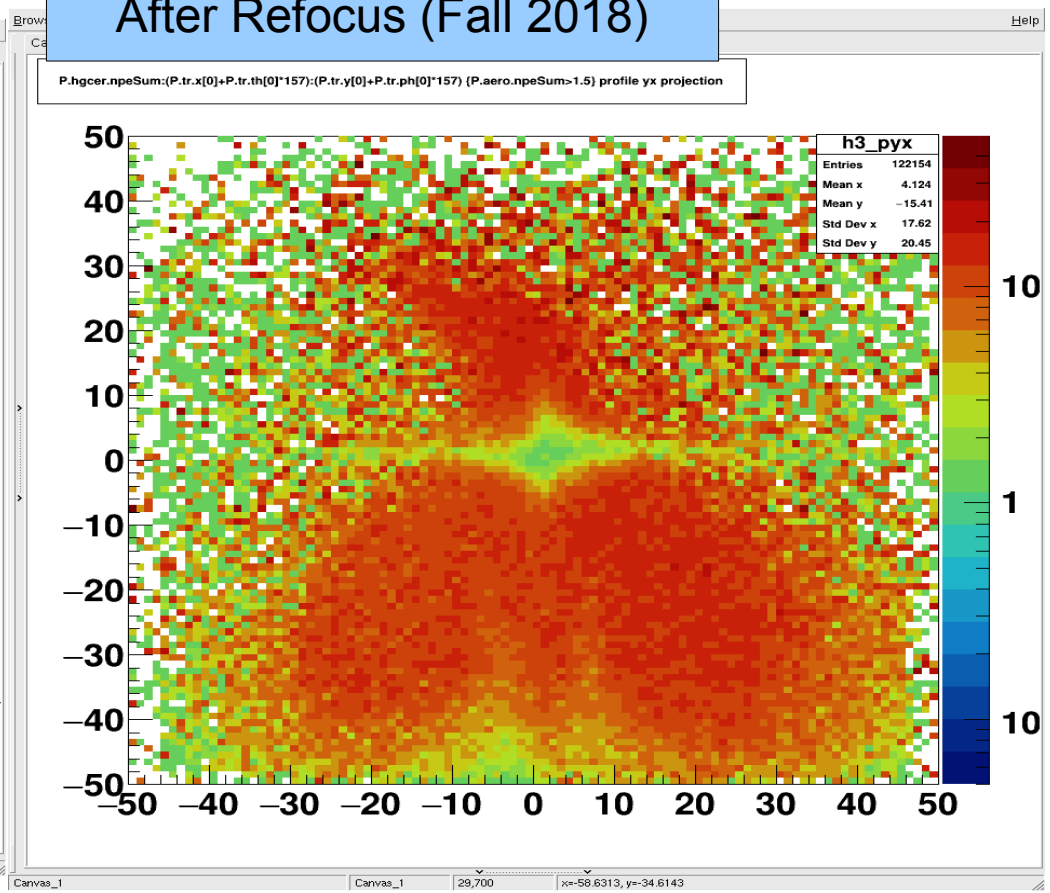
Hole in SHMS HGC Acceptance Grew

- https://logbooks.jlab.org/entry/3608378

Before Refocus (Spring 2018)

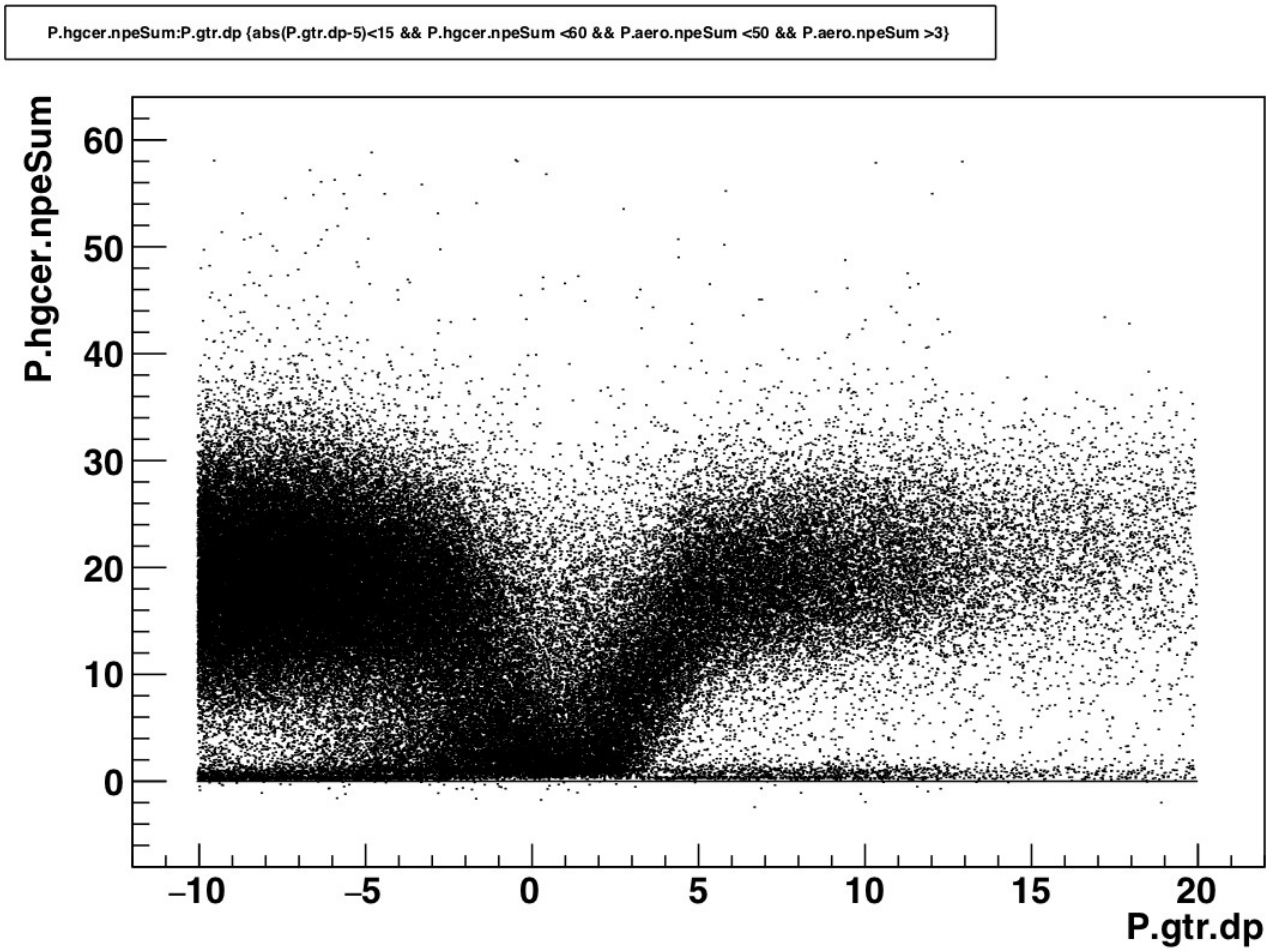


After Refocus (Fall 2018)



Hole in SHMS HGC Acceptance Grew

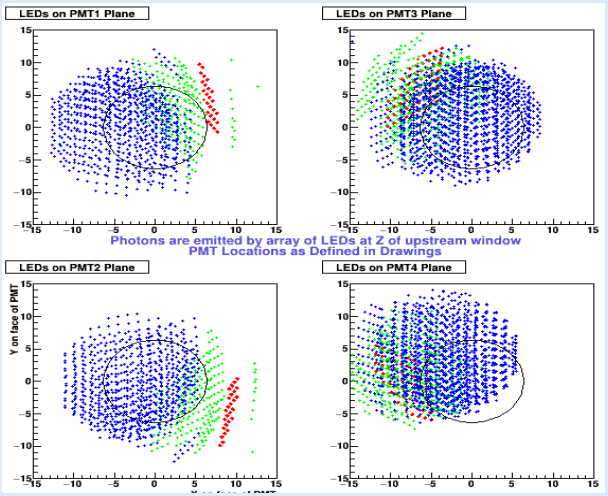
- Also seen in larger 'dip' in npe yield in the central delta region
  - → Will clearly impact PID in that region.
- Unfortunately this does seem to be 'real' and not an artifact of cuts, kinematics, etc...

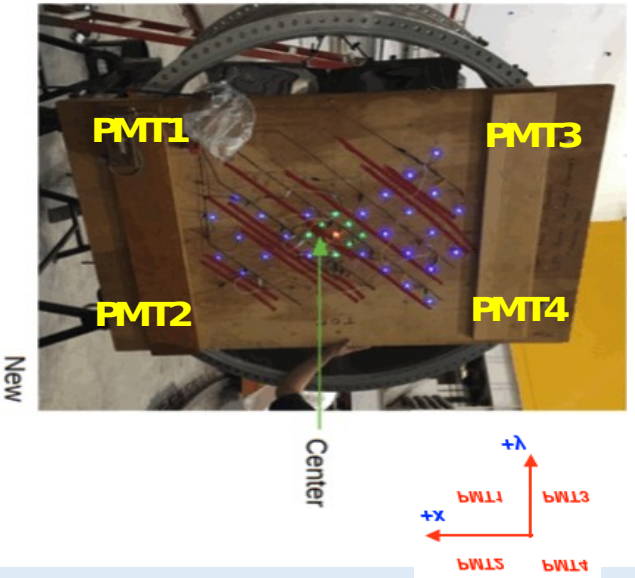


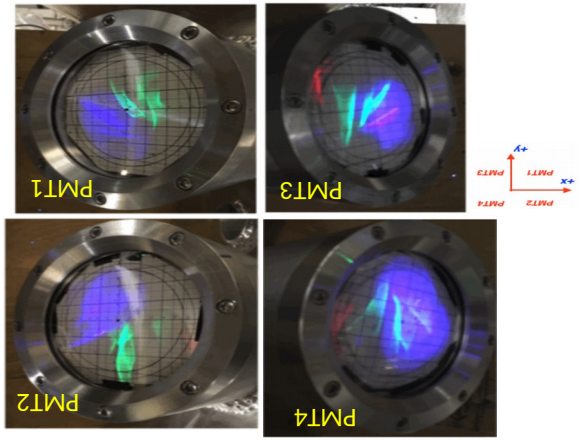
(Plot by D. Gaskell)

- **SHMS Heavy-Gas Cerenkov**
  - Compare colored LED patterns as projected onto PMTs

With the ideal mirrors ‘aligned’ in the simulation like this:

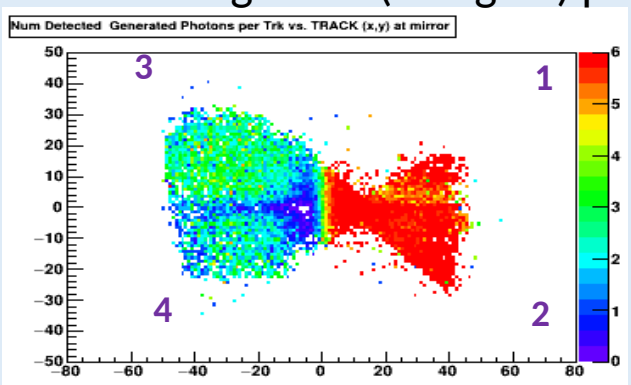




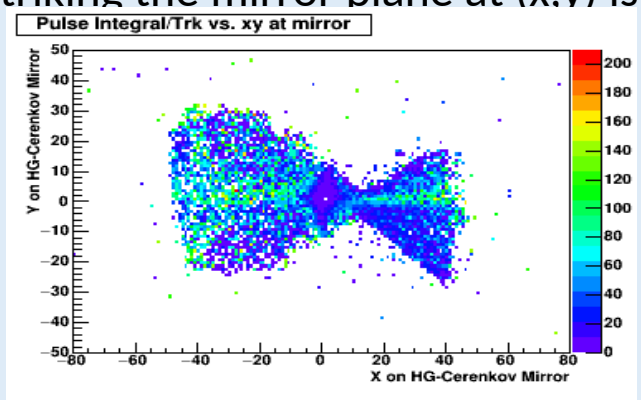


Note: PMT layout above matches the scatterplot layout, not the physical arrangement of PMTs.

when I generate 6 Cerenkov photons along each ‘real’ track path, the average NPE (or signal) per track striking the mirror plane at (x,y) is



SIMULATION: #photons/track



DATA: goodAdcPulseInt/track

I can simulate loss of signal along cracks, but not shadows or enhancements.

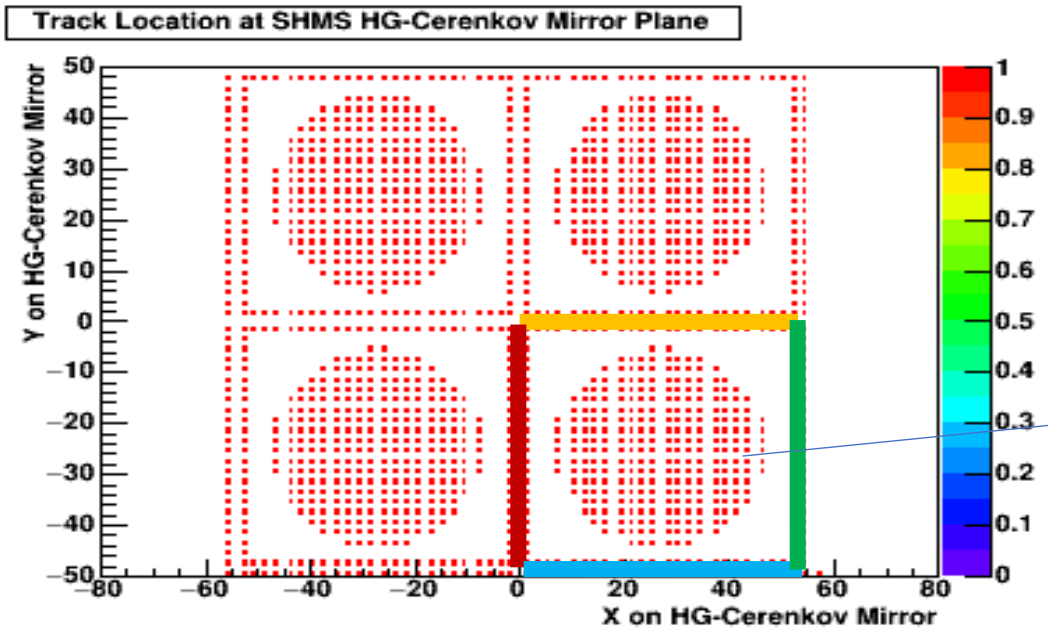
Fenker 29 Nov 2018

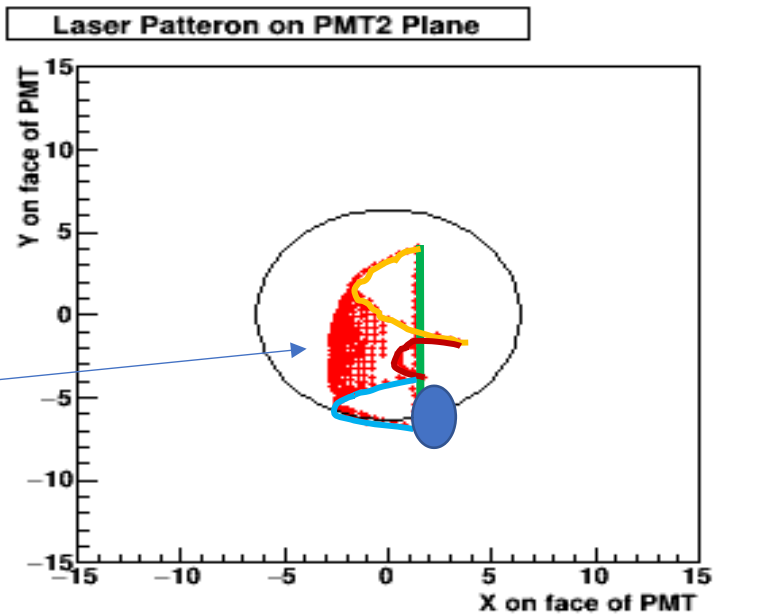
https://hallcweb.jlab.org/doc-private/ShowDocument?docid=997

- **SHMS Heavy-Gas Cerenkov**
  - Laser lines map onto PMT faces

https://hallcweb.jlab.org/doc-private/ShowDocument?docid=997

Fenker 29 Nov 2018





Mapping of light rays from mirror to PMT face. Rays originate 10m in front of mirror plane. Colored lines along mirror perimeter above map onto similarly colored lines on face of PMT. PMT2 is used in this example. The blue oval approximates the projection of its photocathode onto the mirror plane.

This study could be used to attempt to align mirrors/pmts just as was done in the HMS.

We would need to open the HGC outside the SHMS and set up the laser beam to see the pattern on PMT faces.

Near Term and Future Plans...

- Restoring the 'old' focus is relatively straight forward, BUT will require at least 5 days
  - → Remove HGC from Stack
  - → Pull (heavy) gas windows
  - → Mount alignment 'xmas tree'
  - → Match the old alignment images (documentation is great, and helps a lot here)
  - → Button up
  - → Leak check tank
  - → If all good, reinstall in Stack
- Next window for this: *January?*

- "Hail Mary" fix in November
  - → Regina group and I installed some 'Winston Cones' between PMT and gas window
    - » Installation time ~ 1 shift
    - » HGC stays in stack
    - » Gas/vacuum seals not touched
    - » Increase 'effective' PMT diameter 5" → 6"
    - » Hopefully catch photons being lost at perimeter?

SHMS HGC “Winston Cone” Patch

- “Hail Mary” fix in November
  - → Regina group and I installed some 'Winston Cones' between PMT and gas window (all 4 PMTs)
    - » HGC stays in stack
    - » Gas/vacuum seals not touched
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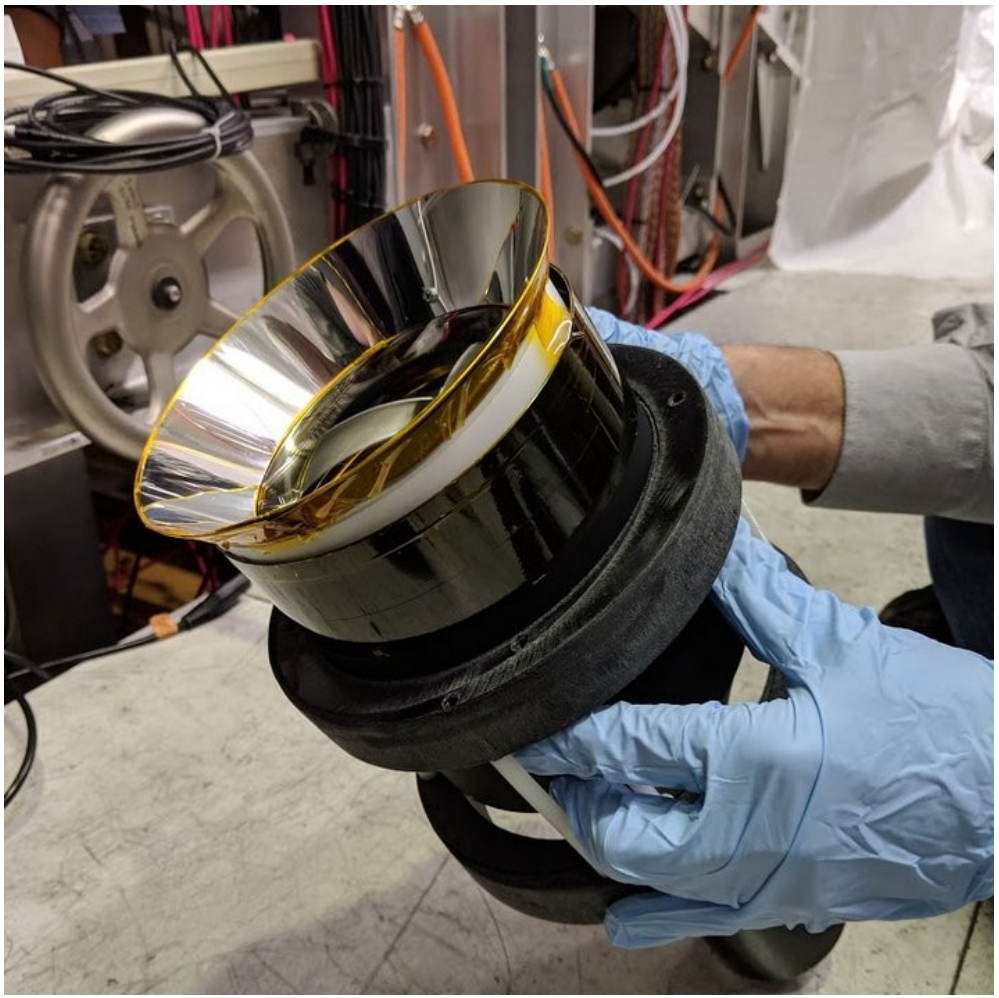
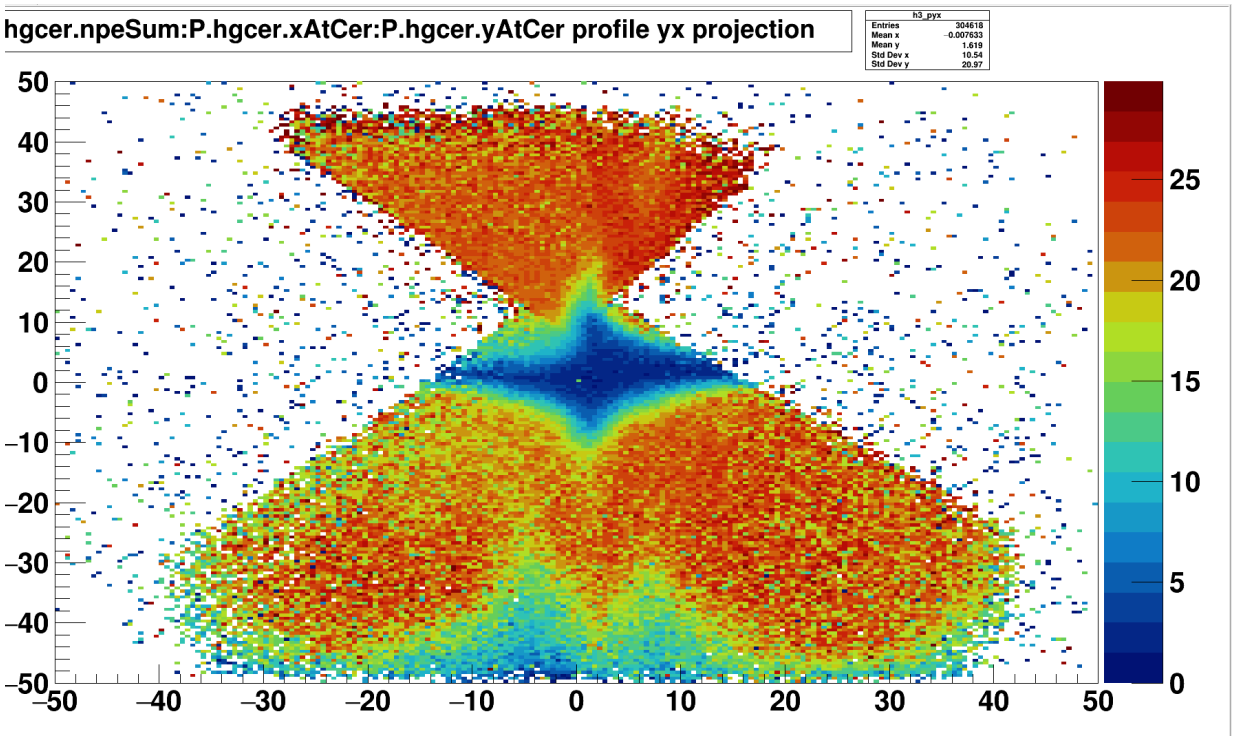


SHMS HGC “hole” still present...

- Unfortunately no (significant) improvement
  - → Direct comparison is tricky (different kinematics)
  - → No worse than before, at least...
- Need to proceed with “Plan A”
  - → Alignment check
  - → Alignment restoration

R. Ambrose (U of Regina)
https://logbooks.jlab.org/entry/3633305



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  - → Remove HGC from Stack
  - → Pull (heavy) gas windows
  - → Mount alignment 'xmas tree'
    - » Match the old alignment images
  - → Do “Laser Check” based on Howard's sim (worked for HMS)
  - → Button up
  - → Leak check tank
  - → If all good, reinstall in detector stack
    - » refill with C_4F_8O
- Next window for this: *January?*

SHMS / HMS Summary as of December 2018

- ***Generally* Detectors/DAQ are working as planned**
  - → Calibrations, cross-checks continue
    - » See upcoming Hall C collaboration meeting in January
  - → HMS Cerenkov fully restored

- **SHMS Gas Cerenkov are not performing to design yet…**
  - → SHMS Noble Gas Cerenkov (NGC) yields are still a question mark...
    - » NGC is idle on the Hall C floor (noisy PMT will be replaced Summer 2019)
    - » NGC yield *may* be concern at high momentum settings (> 7 GeV/c)?
      - May want to be conservative with PID expectations at such settings?
  - → SHMS Heavy Gas Cerenkov (HGC) yields are also an issue...
    - » Overall npe yields are not well understood
      - Better now than Spring 2018 (but I don't understand why)
    - » "Hole" in acceptance needs to be addressed
      - Next opportunity is Jan 2019 (check alignment, realign)
    - » Verify models, improve understanding, and move forward from there...

Questions?

BACKUP SLIDES

“Band” structure in SHMS HGC
npe yields vs position

“Banding” in SHMS HGC npe Yields

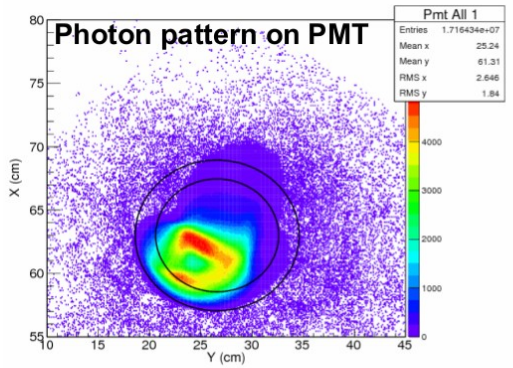
Also seen in Simulation

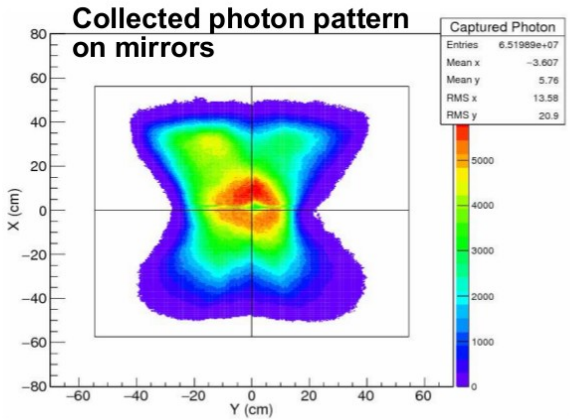
Optics Simulations - 7 GeV/c π @ 0.95 atm

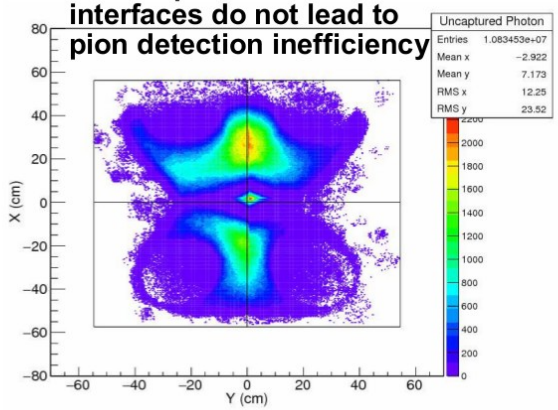
Cherenkov cone angle largest at 7 GeV/c (2.84°) → light hardest to focus.

GEANT4 Simulation includes:

- -C_4F_{10} properties vs wavelength
- -Measured 4 mirror oblateness
- -Measured AL reflectivity vs wavelength
- -Quartz adapter losses vs wavelength
- -PMT efficiency vs wavelength







Details in JLAB-PHY-12-1697 (M.Sc. thesis)

Garth Huber, huberg@uregina.ca

“Banding” in SHMS HGC npe Yields

Data (Spring 2018)

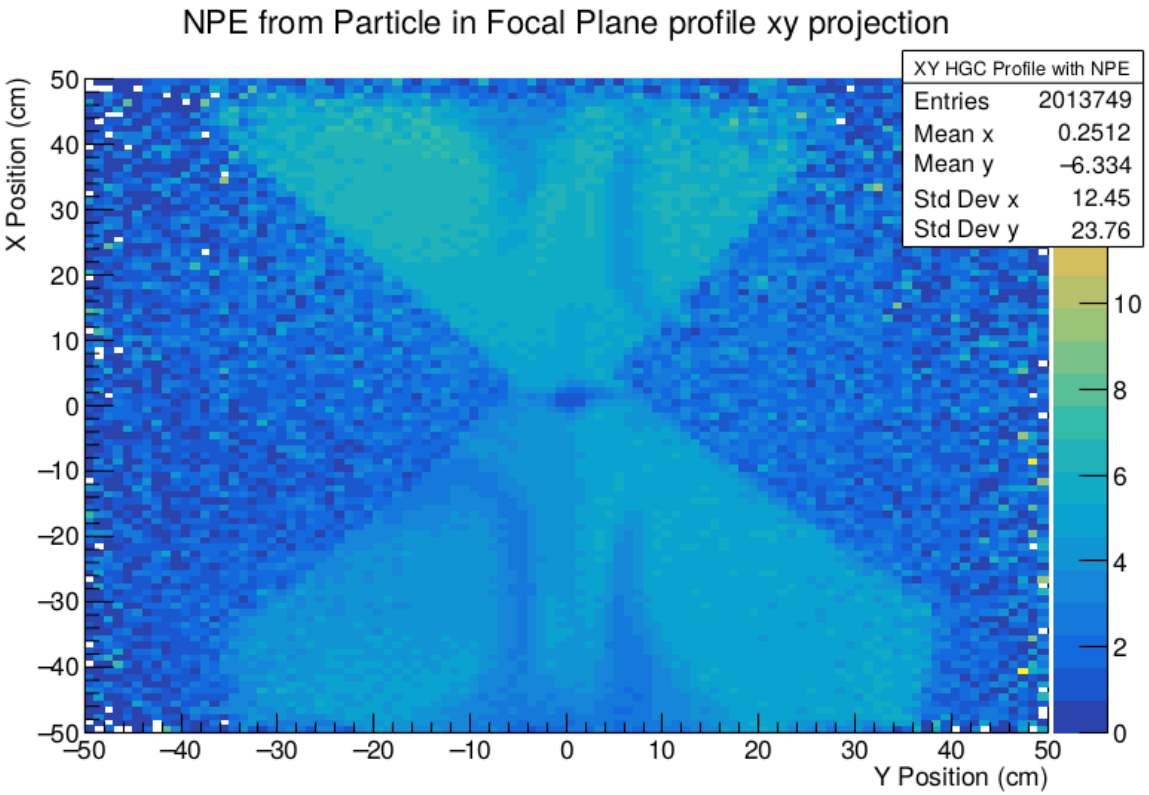


Figure 6: Number of photoelectrons received in the HGC across the mirror plane. Color axis refers to the number of photoelelectrons. Run 1583.

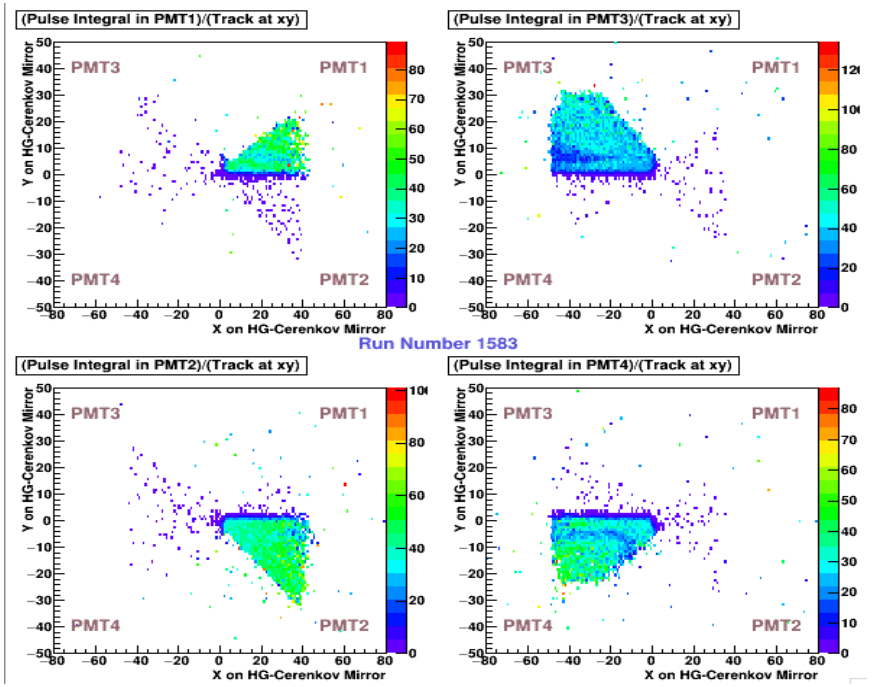
Crosstalk????

Plot goodAdcPulseInt from each PMT vs. (x,y) of TRACK at mirror plane…

… and see more crosstalk after new alignment. I assume it is optical, but maybe it is electronic.

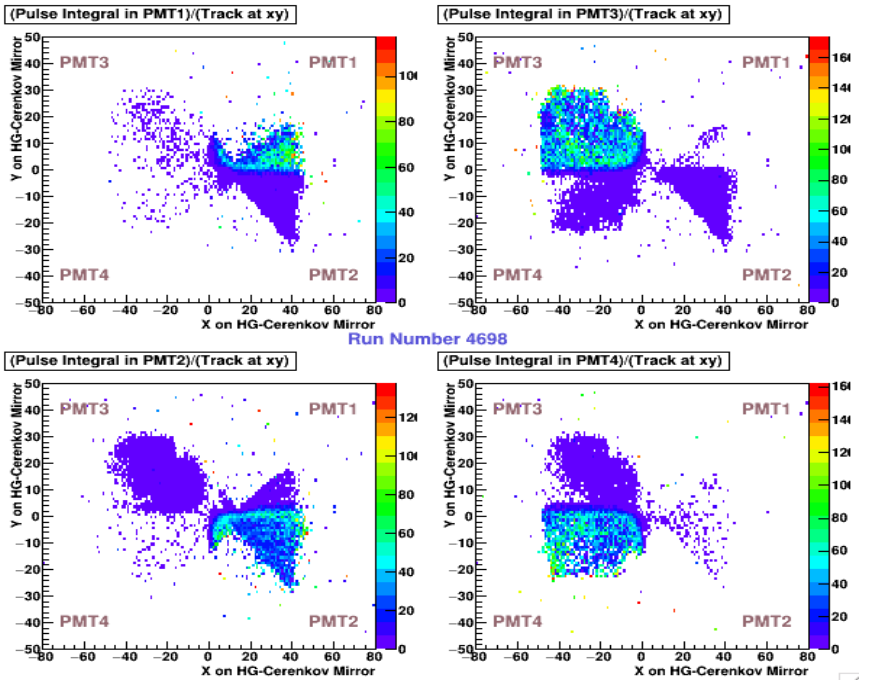
$$Z(x,y) = \frac{\sum_{i=1}^{N(x,y)} ADC_i}{N(x,y)}$$

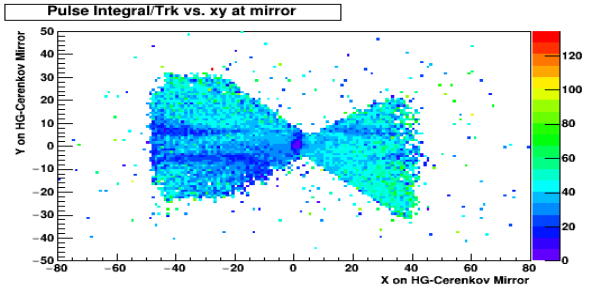
BEFORE



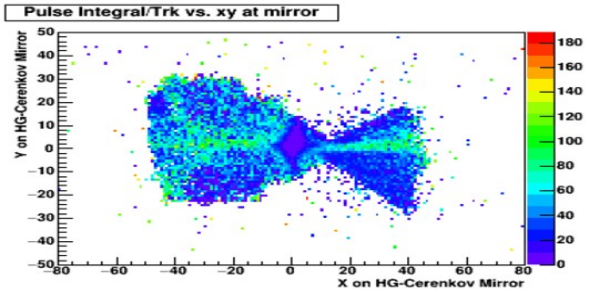
each PMT

AFTER

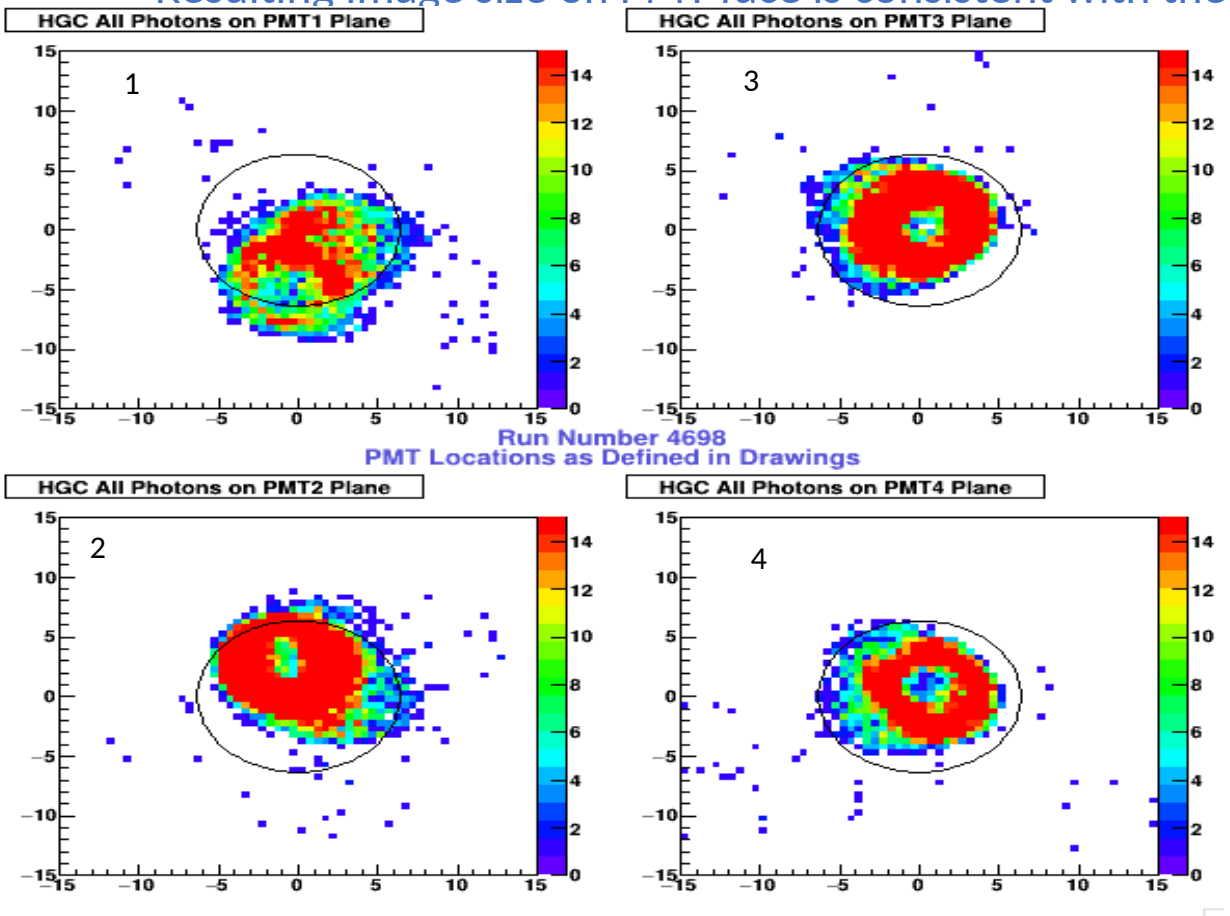




Sum of PMTs goodAdcPulseInt



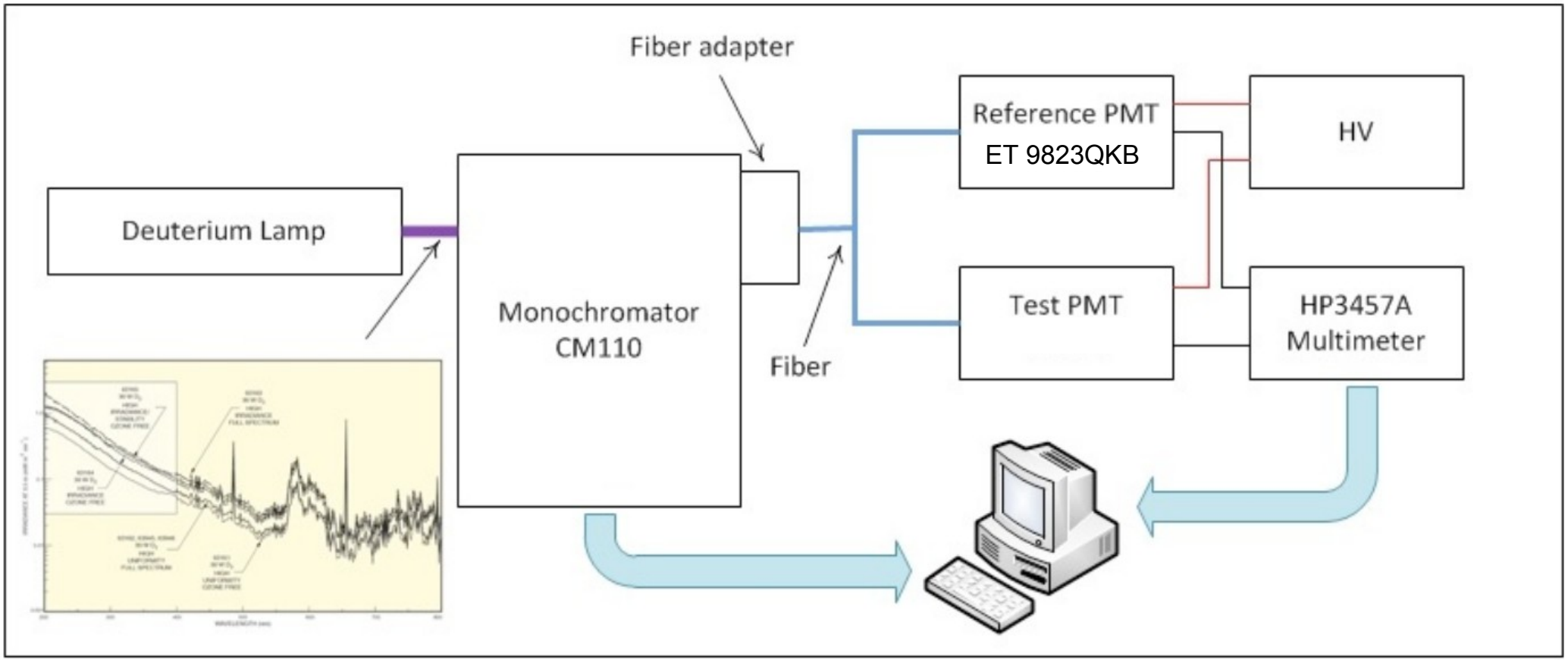
- **SHMS Heavy-Gas Cerenkov**
  - Determine ‘Image’ size of Physics Tracks on PMT face:
    - For each reconstructed particle track (real data) radiate 6 Cerenkov photons along length of each track through Cerenkov gas. Propagate them to the PMTs.
    - Resulting image size on PMT face is consistent with the 5-inch PMT



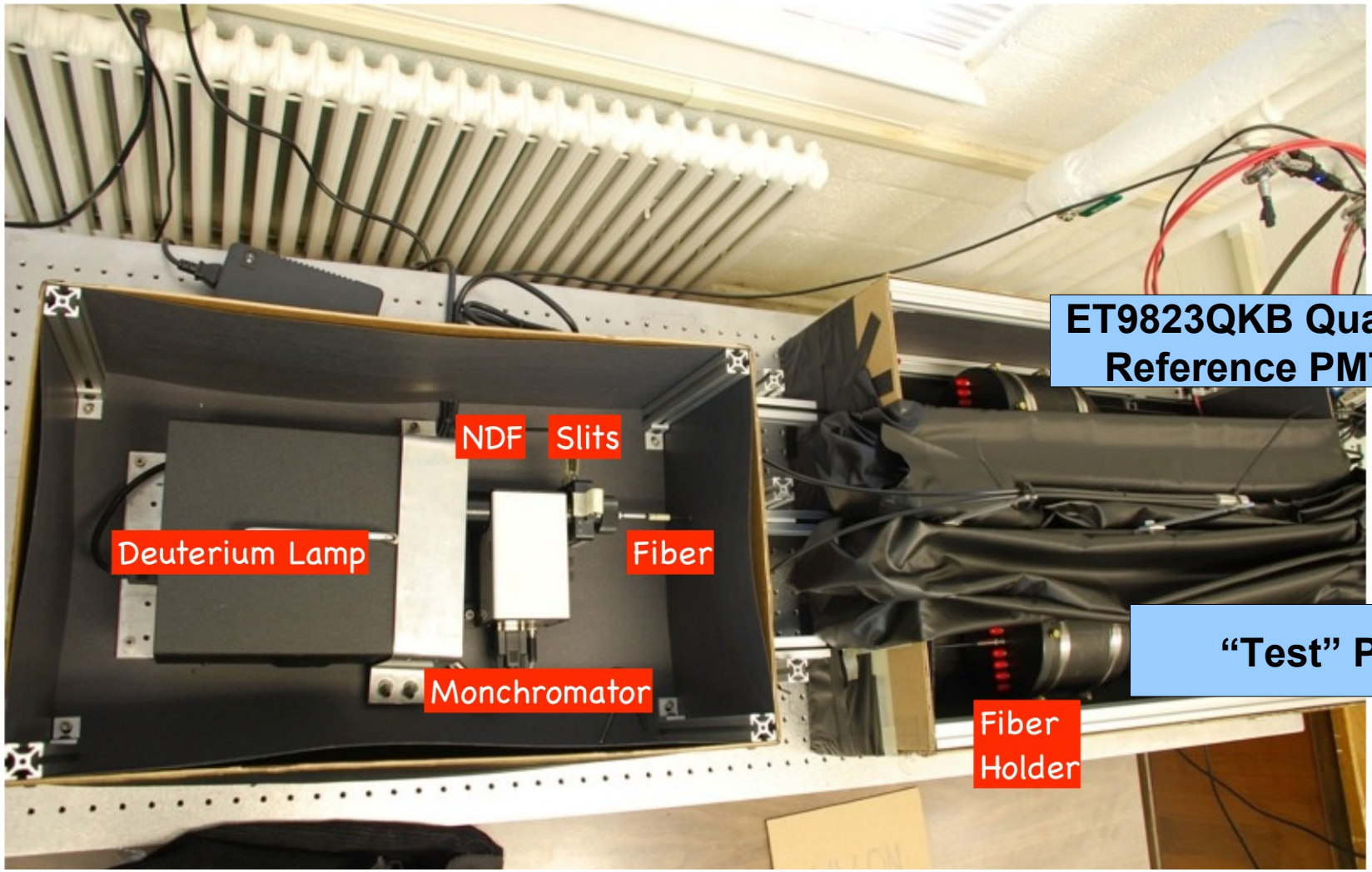
Note: mirror shapes are taken as perfect spherical sections. Alignment is arbitrary in this run.

Test PMTs at UVa

UVa PMT Test Stand



UVa PMT Test Stand

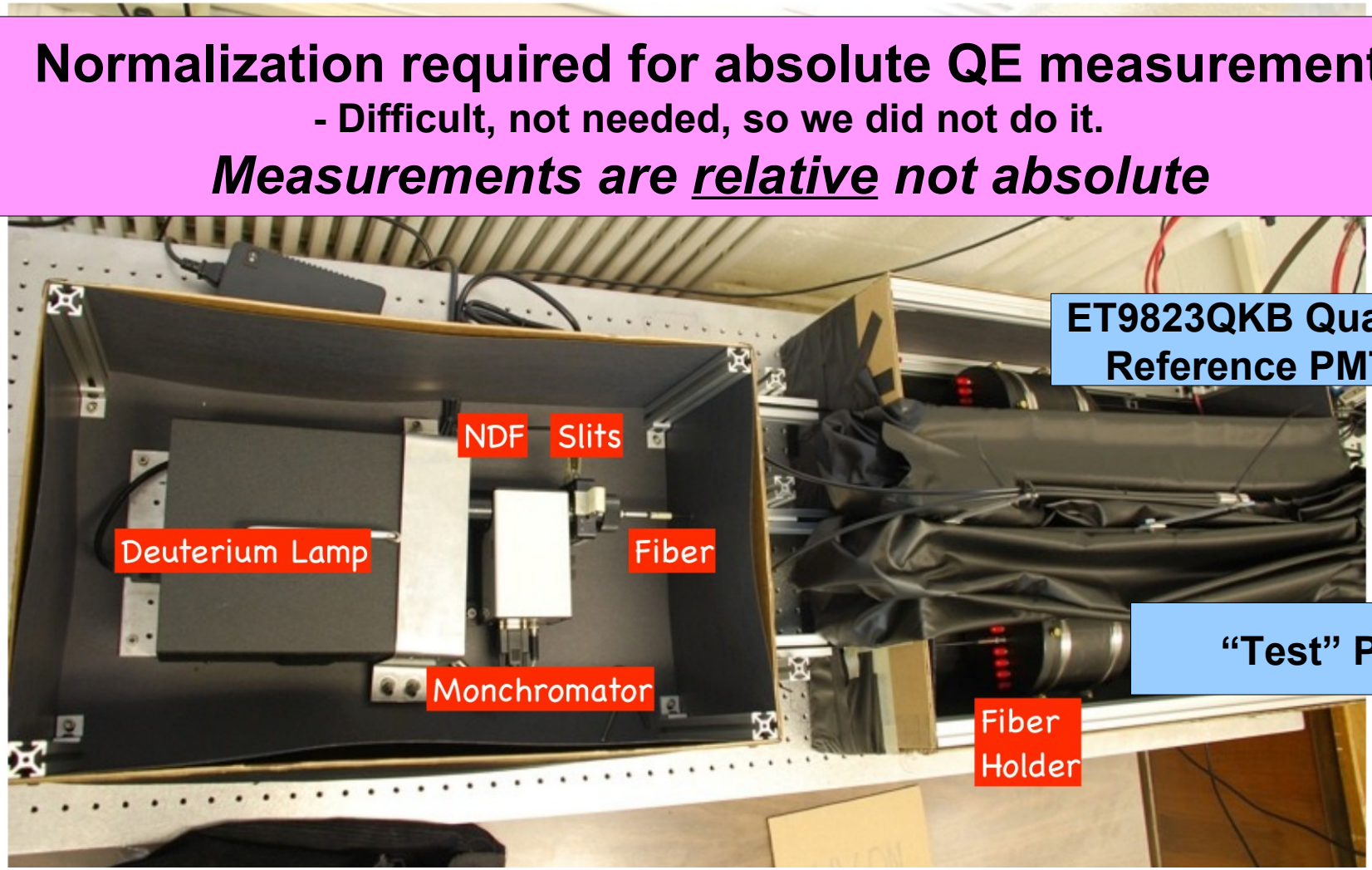


UVa PMT Test Stand

Normalization required for absolute QE measurement

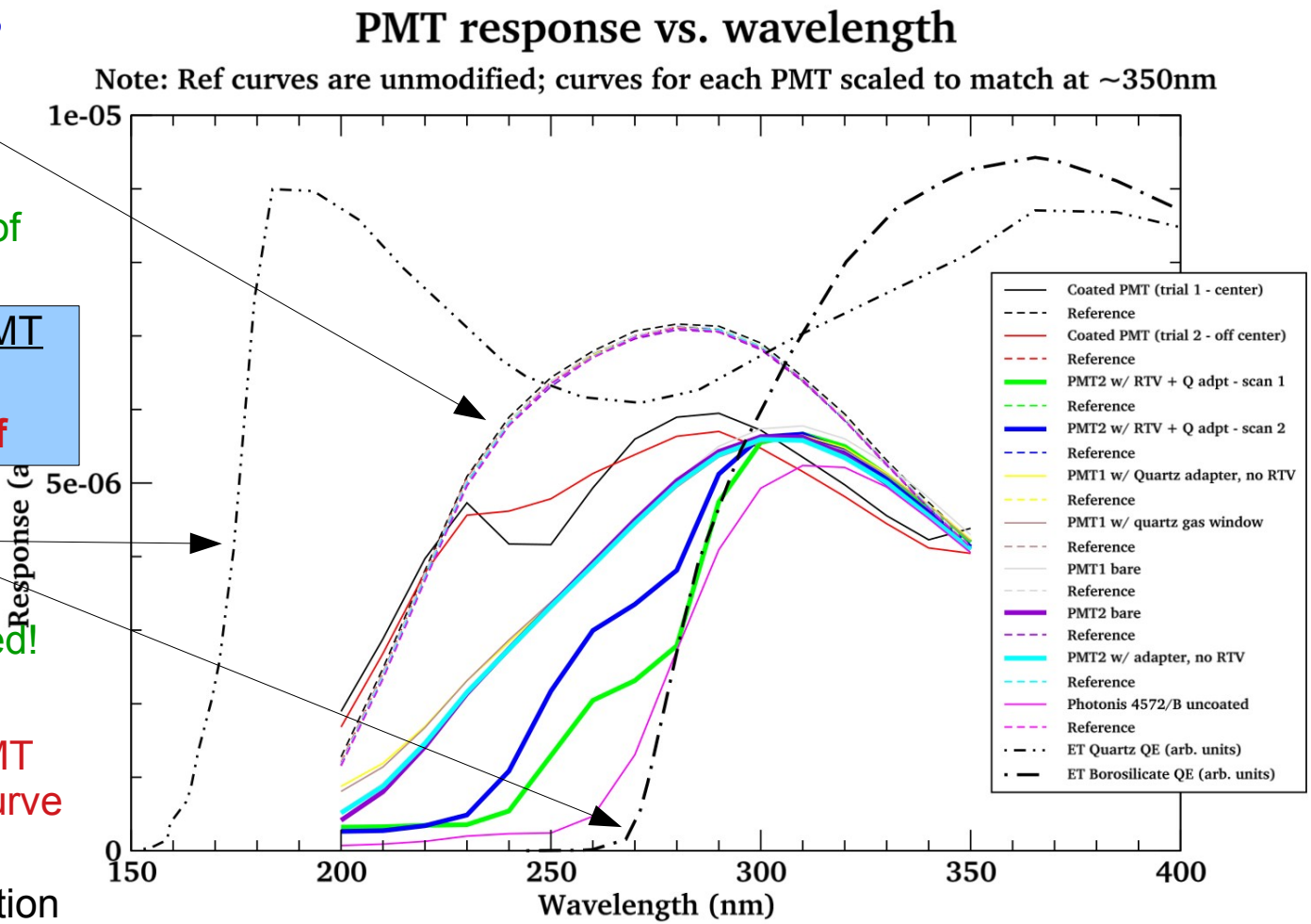
- Difficult, not needed, so we did not do it.

Measurements are relative not absolute



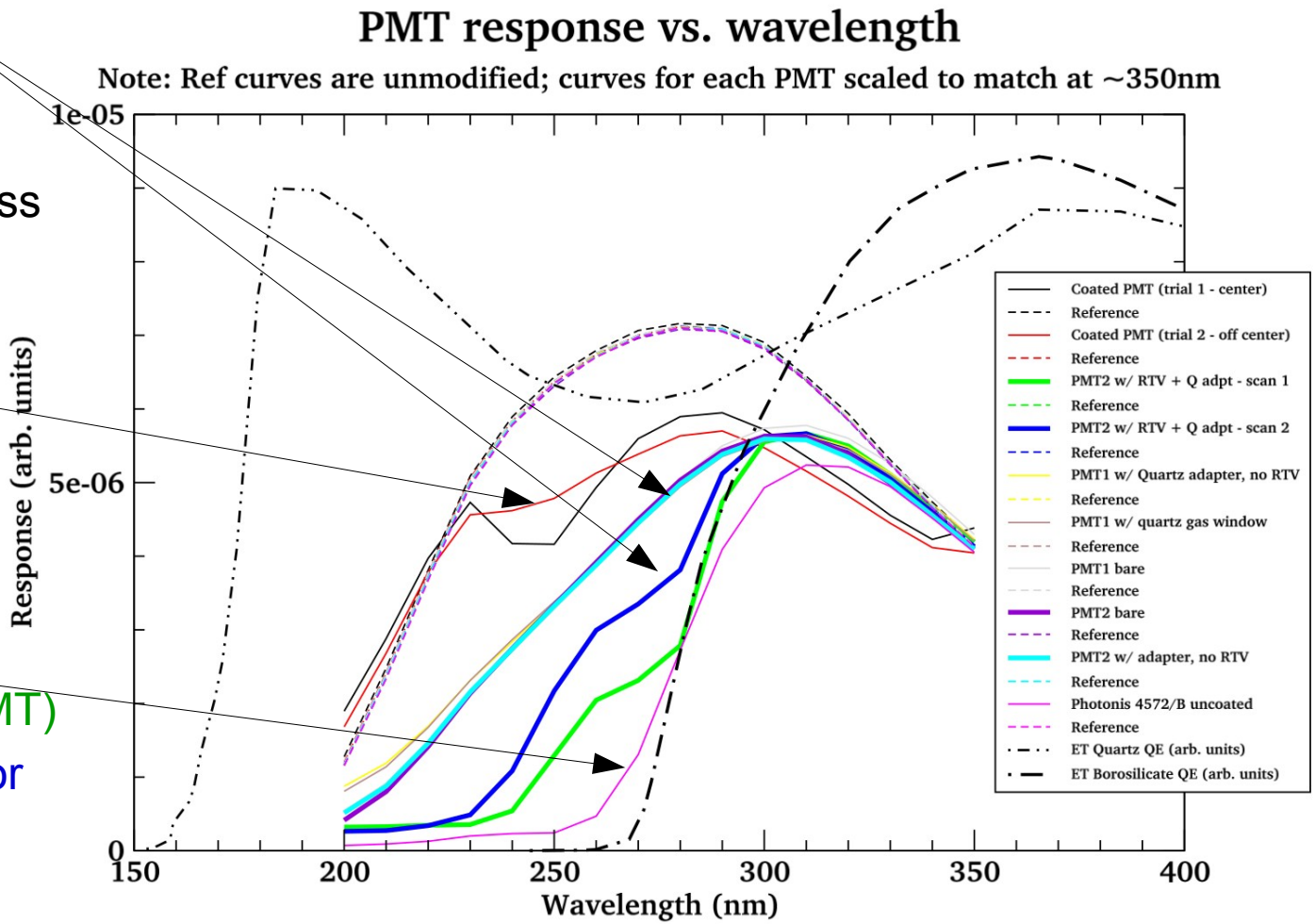
Interpretation Notes

- 'Reference' PMT is ET 9823QKB Quartz-face (dashed curves)
  - → monitors lamp stability
  - → reflects spectral response of the system as a whole
  - → Represents “Best Case” PMT response
    - » **Compare PMTs to Ref**
- Dash-dotted lines indicate QE curves for (ET) Quartz and Borosilicate PMT
  - → w/ arb. scaling factor applied!
- **NOTES:**
  - → Difference between Ref PMT response and quartz QE curve reflects system response
    - » Lamp intensity, absorption in fibers, etc



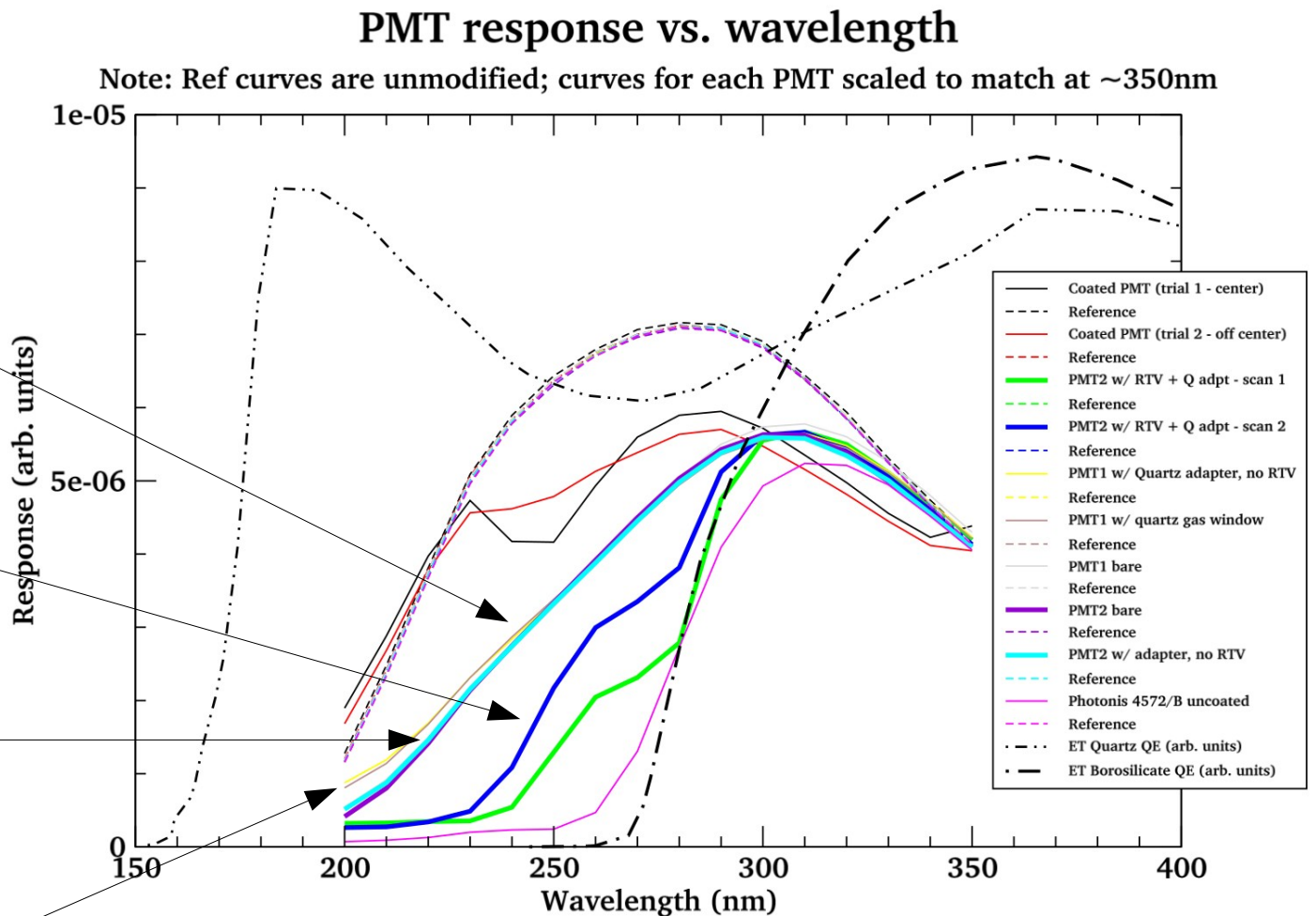
PMTs Under Test

- Tested 4 'JLab' PMTs
  - → PMT1, PMT2
    - » HGC prod. PMTs
    - » Hamamtsu UV glass
    - » Different optical elements involved
  - → 'Coated PMT'
    - » Photonis 4572/B from Hall A, Borosilicate PMT w/ p-terp. coating
  - → Photonis 4572/B uncoated (different PMT)
- NOTE: Arbitrary scale factor between each PMT type
  - → Compare shapes only



'Production' PMT responses

- PMT1 (light lines)
  - → Prod. PMT that had all 'interface' parts removed
    - » no adapter, no RTV, no opt. grease
  - → As expected
- PMT2 (heavy lines)
  - → Production PMT
    - » w/ adapter + RTV
      - – degraded
    - » adapter + RTV layer (0.06 mm) removed
      - – same response as PMT1
- Quartz glass PMT adapter and gas window tested
  - → transparent (no impact)



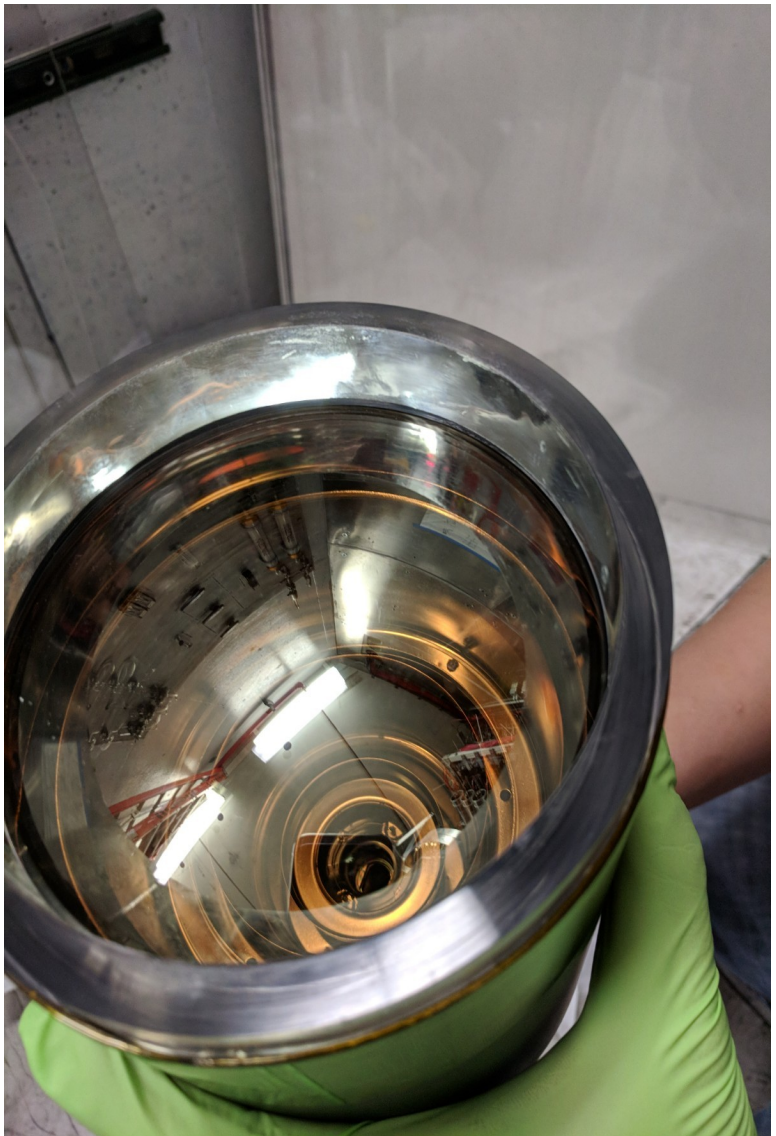
SHMS HGC Optical Configuration

PMT with Quartz Adapter Attached

Side view of quartz adapter on PMT 1 (now removed)

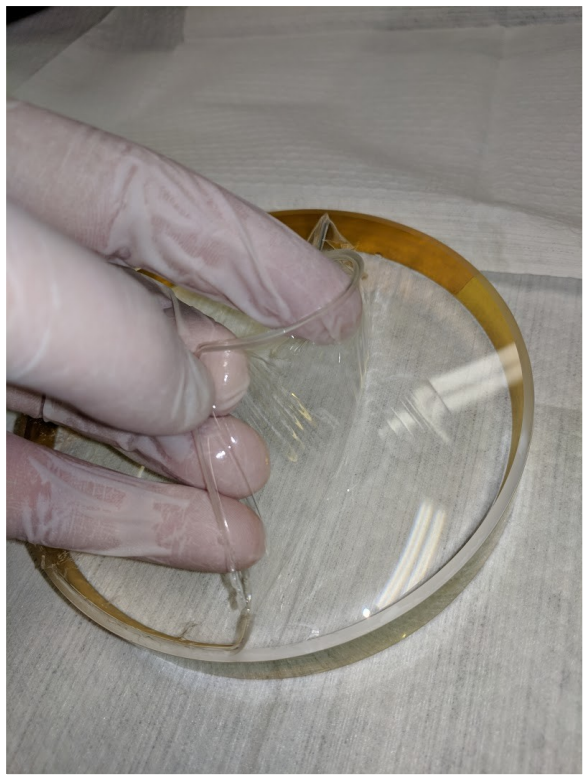
Note: Yellow color is due to kapton tape around perimeter of quartz adapter, NOT radiation damage.

SHMS HGC PMT 'Ring'



PMT2 Quartz Adapter Removed

- Quartz adapter on PMT2 removed at UVa
- PMT2 RTV layer thickness
  → 0.06 mm



Both SHMS and HMS running since Fall 2017

Hall C production running began in January 2018

Detectors/DAQ (generally) performing well

- Hodoscopes < 98% efficient (4/4 planes)
- Wire chambers < 99% efficient
- Good tracking, Good energy resolution

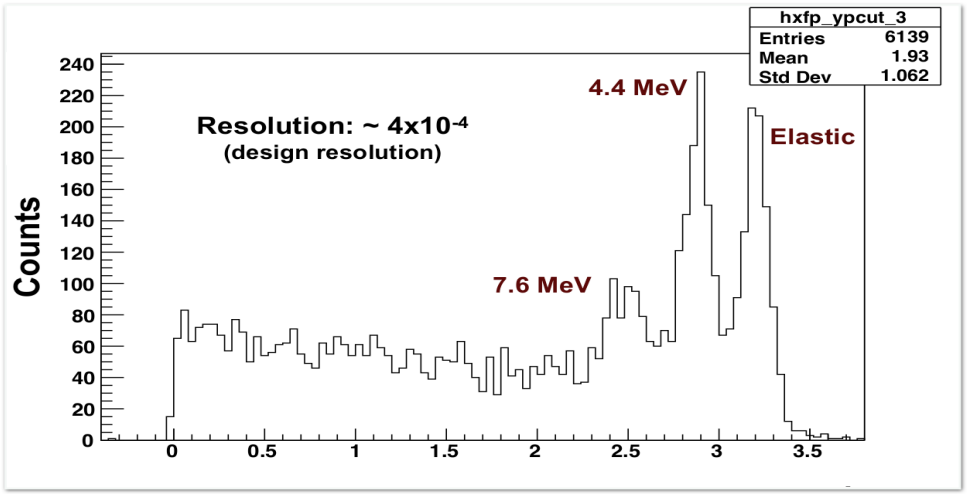
Analysis, Calibrations underway!

But…

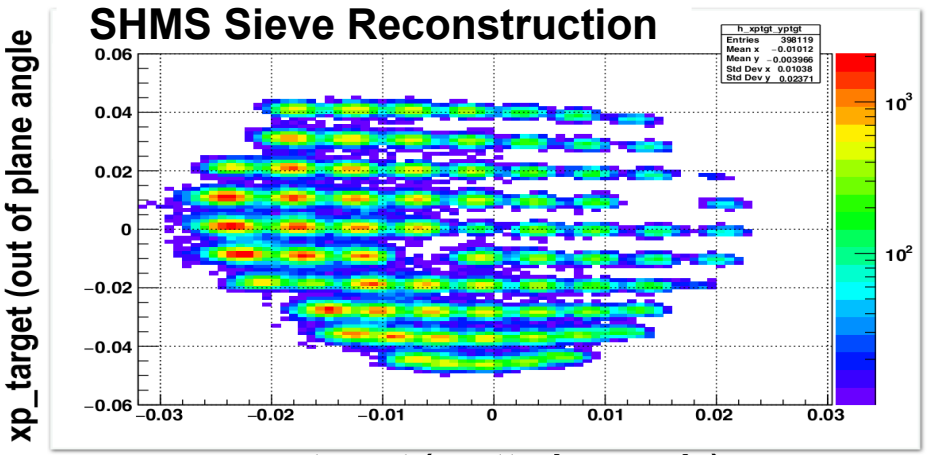
- SHMS HGC has lower npe yield than predicted (13 pe vs >25 pe), investigate over Summer 2018
- SHMS NGC yield is lower than predicted, may want to be conservative with PID performance at high momenta (ie. large neon fraction)?
- HMS HGC mirrors found to be damaged
  - Spares available(!), repair underway now

Plots on right from Commissioning data taken last December, January

- See also: Update on Dec/Jan Running (D. Dutta, Jan 2017 Hall C Collab. Meeting)
- See also: Upcoming Hall A/C Meeting / Analysis Workshop!

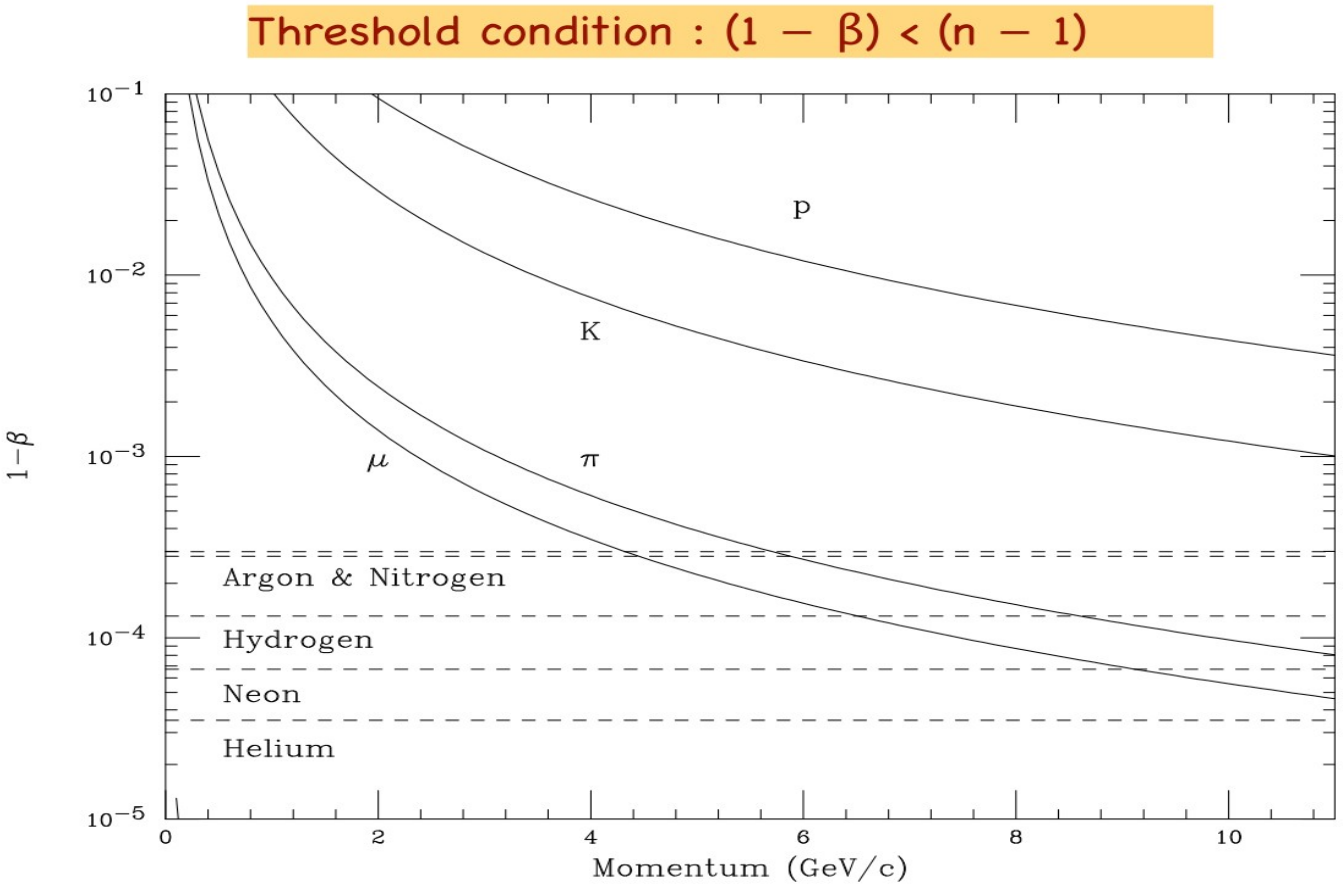


plot from M. Jones



using COSY matrix elements without any optimization

SHMS NGC (Noble Gas Cerenkov)



Concern:

As neon fraction rises, the npe yield drops. At 100% neon, it is down by a factor of ~3–4 from 100% Argon.

Simulation:

~40 p.e. (100% Ar)

~ 9 p.e. (100% Ne)

[~ 55 p.e. (CO_2) *estimated*]

Data:

~ 17 (100% Ar)

~ 25 (100% CO_2)

→ ~ 3.8 p.e. (Ne)

NOTE: VERY PRELIMINARY!

HClog 3519060

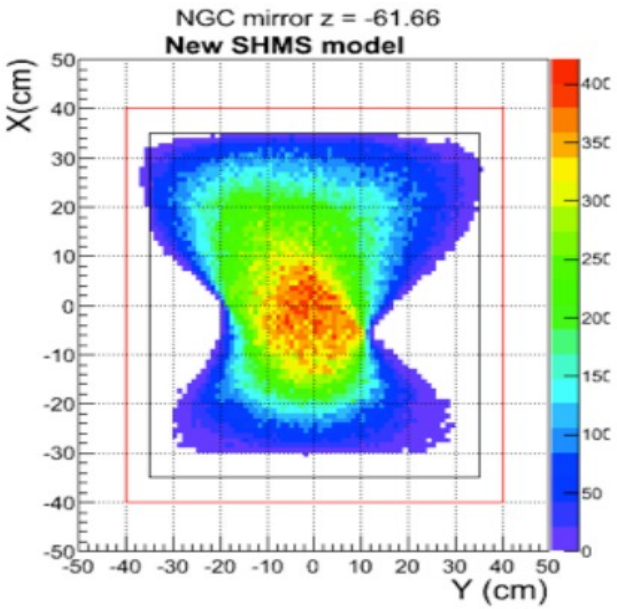
Slide from D. Day (Hall C ERR)

Choice of gases

Argon up to 6 GeV and a mixture of Argon and Neon up to 11 GeV

SHMS PID Requirements : negative polarity

Experiment	p (GeV/c)	Req'd $e^-:\pi^-$ Disc.	Spec'd NG Cerenkov	Spec'd Calorimeter	Total Expected
E12-06-101 (Fpi-3)	2.2 - 8.1	$4.5 \bullet 10^3$:1	50:1 (HMS Cerenkov gives up to 300:1 now)	>200:1 (1000:1 above 6 GeV/c)	$>10^4$:1
E12-06-104 (σ_L/σ_T)	5.4 - 5.8	10^3:1			
E12-07-103 (pion factorization) (d)	2.4 - 8.5	10^3:1			
E12-06-105 (x>1)	4.8 -10.6	$5 \bullet 10^3$:1			
E12-06-110 (c)	2.2 - 6.8	10^3:1			
E12-06-121 (g_2^n, d_2^n)	6.3 - 7.5	$>10^2$:1			



4 overlapping spherical mirrors

R = 135 cm, 43 by 43 cm

2 m of active length

Noble gas at 1 Atm

Slide from D. Day (Hall C ERR)