



HTCC update

CLAS12 software workshop

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Outline

- HTCC overview
- Simulation
- Calibration
- Reconstruction
- Previous results
- Current results
- Addressing the issues
- Future steps

HTCC



High Threshold Cherenkov Counter

- Purpose: e/π sep.
- Radiator Gas (18.8m^3): CO_2 (1atm)
- Mirror thickness: $135\text{mg}/\text{cm}^2$
- Pion threshold: $4.7\text{ GeV}/c$
- Number of Channels: 48
- Light readout: 5" PMTs (Quartz)
- Coverage in θ & ϕ : $5^\circ - 35^\circ, 360^\circ$

HTCC in the last six months

In transit



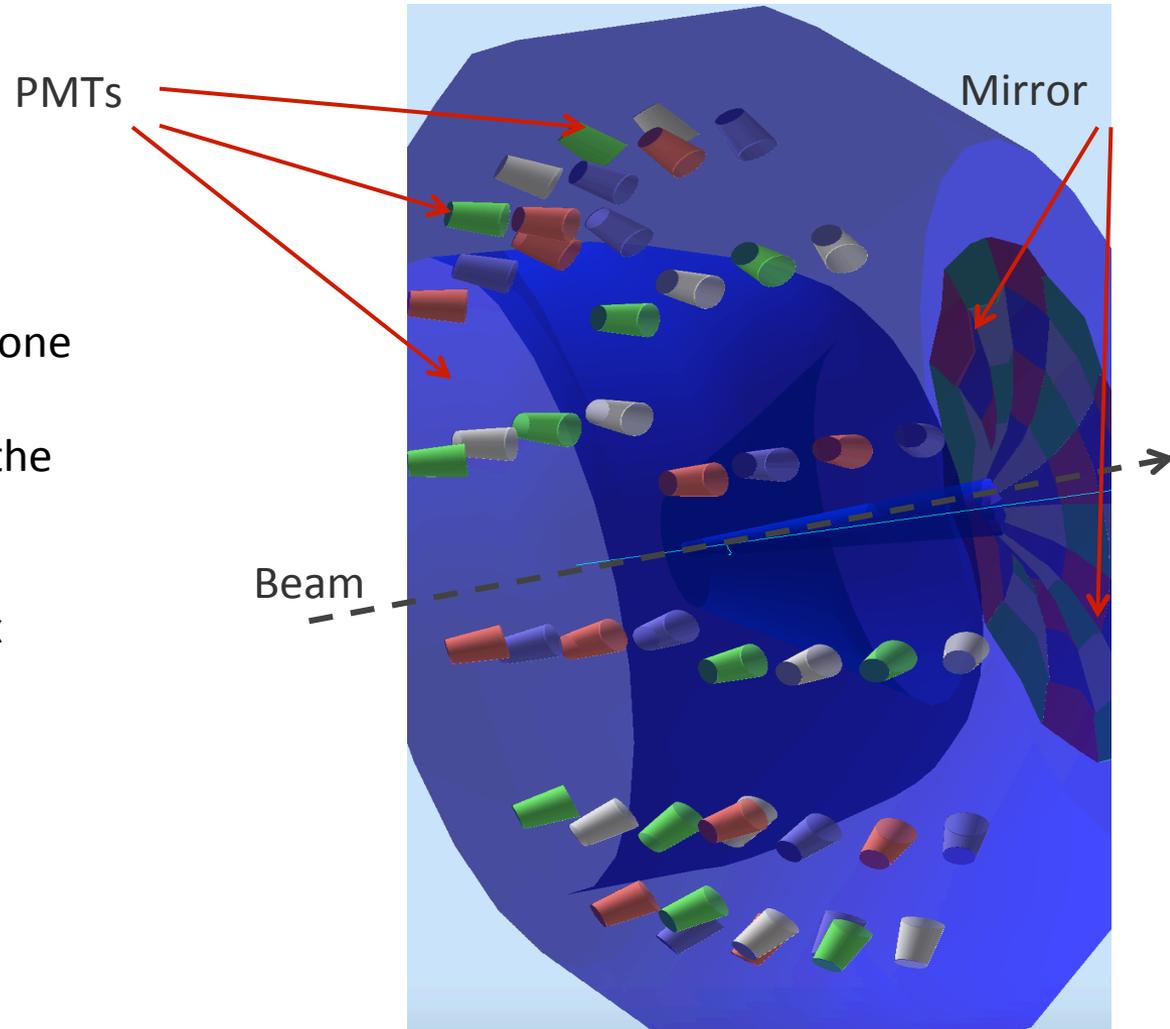
In the Hall during KPP



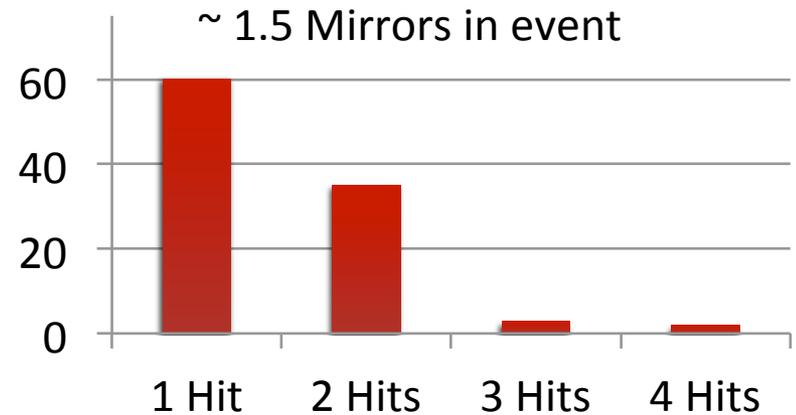
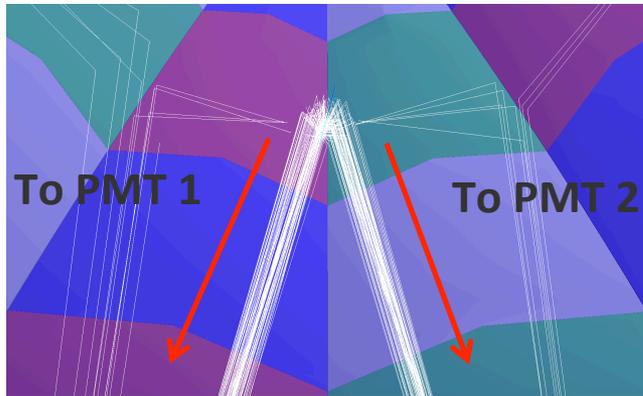
In the Hall after KPP, under tests



- Full HTCC geometry
- Measured mirror and Winston cone reflectance
- Realistic Quantum Efficiency of the PMT with Quartz Entry Window
- Realistic CO₂ gas transparency
- Realistic CO₂ gas refraction index

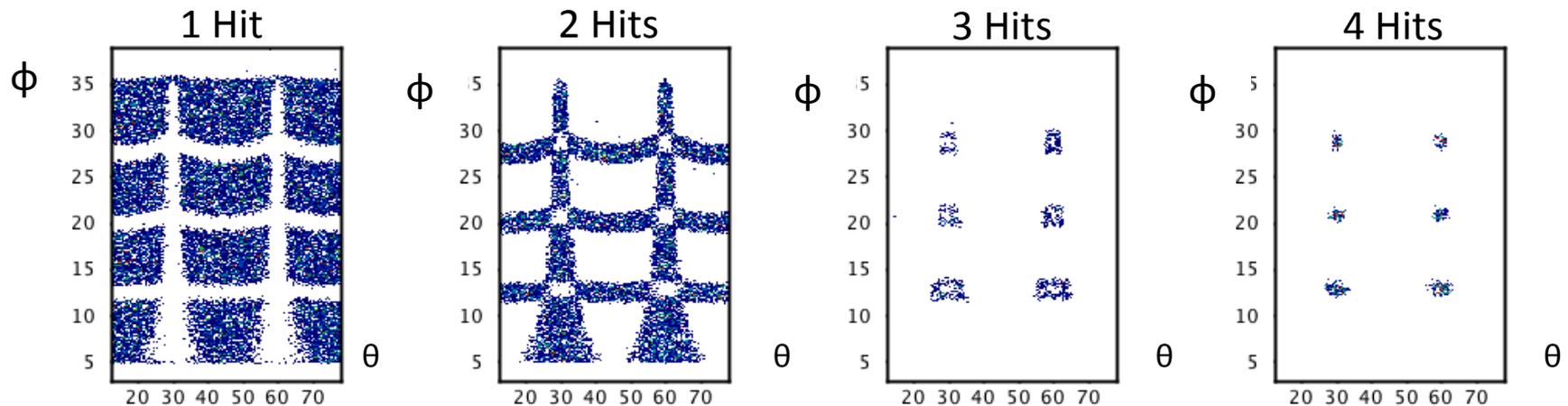


Reconstruction: clusters



Cerenkov radiation from single electron may split between mirrors and is collected by different PMTs

Geometrical pattern of single- and multiple hit events:



Data processing

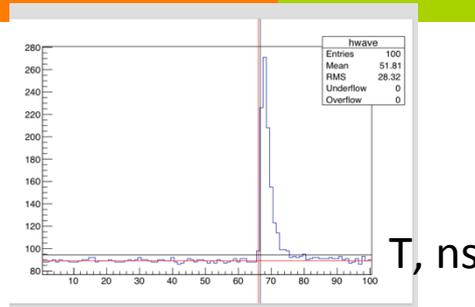
FADC channel

Decoding

Sector, halfsector, ring

Reconstruction

θ, ϕ
(x, y, z)



FADC spectrum in time, Mode1

```
sector ( BYTE ) : 4
layer ( BYTE ) : 2
component ( SHORT ) : 4
order ( BYTE ) : 0
ADC ( INT ) : 3060
time ( FLOAT ) : 136.000
ped ( SHORT ) : 103
```

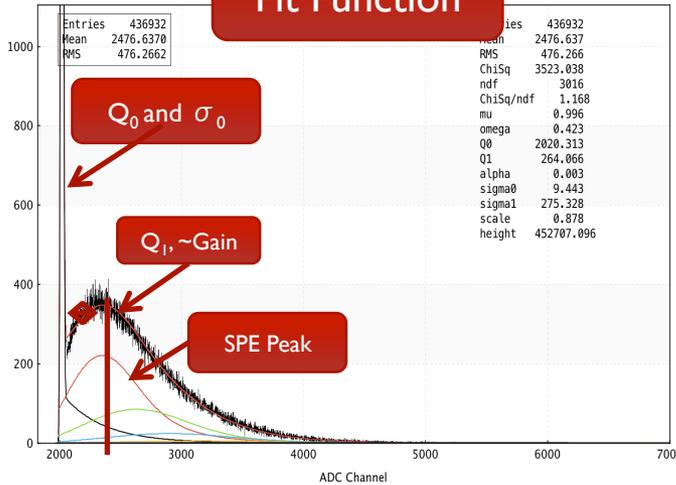
Calculating pulse size
and time based on
threshold value

```
id ( SHORT ) : 0
nhits ( SHORT ) : 3
nphe ( SHORT ) : 44
time ( FLOAT ) : 136.632
theta ( FLOAT ) : 0.196
dtheta ( FLOAT ) : 0.038
phi ( FLOAT ) : 1.136
dphi ( FLOAT ) : 0.151
x ( FLOAT ) : 13.473
y ( FLOAT ) : 29.031
z ( FLOAT ) : 164.051
```

Calculating absolute
signal strength and
coordinate based on the
PMT calibration

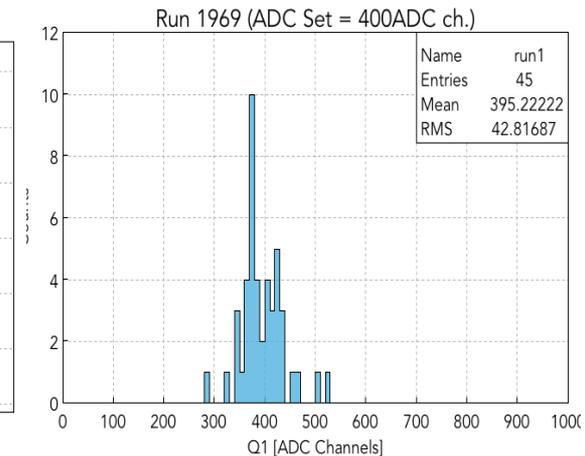
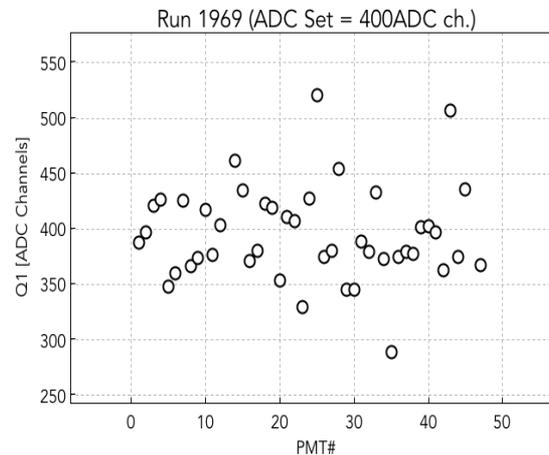
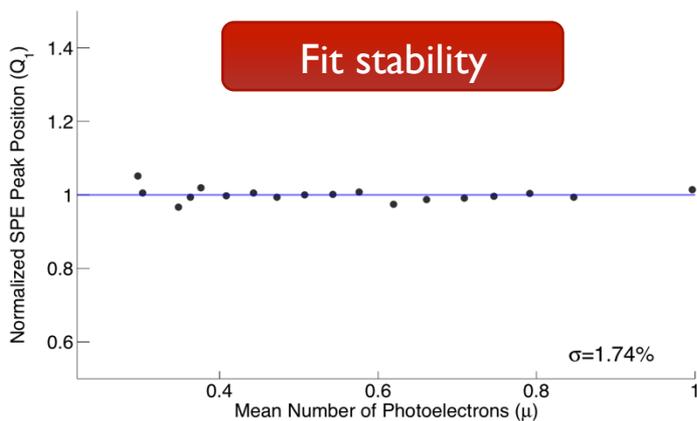
Calibration procedure

Fit Function



- Gain match with a SPE peak fit function with LED light pulser runs
- Successful HV Gain Match at two gain settings (225 and 400 channels per s.p.e)
- Most Channels matched within $\pm 10\%$.

Gain Match



Previous results

- HTCC worked properly during the whole KPP run;
- Data were cooked and analyzed immediately;
- As a part of the KPP run it met the DOE requirements;
- Signals from all 48 PMTs were extracted;
- Average number of Nphe is 19.4 for a single hit events (expected to grow when account for multiple hit events);
- Signals from 8 PMTs of sector 2 were extracted using different ways of electron ID;
- There are differences between different PMTs in the same ring to understand.

Data analysis

Two approaches for the electron ID:

- DC and EC/PCAL
 - Have tracks, better possibilities to select good electrons
 - Limited to sector 2 (8 PMTS)
 - **Time correction**
 - **Cluster reconstruction**
 - **Large statistics, access to spectrum of all 8 PMTs**

- PCAL
 - Based on geometrical match between hits in PCAL and HTCC
 - No tracks
 - Can access all 48 PMTs
 - **Time correction**
 - **Cluster reconstruction**
 - **PCAL Fiducial cuts**
 - **Large statistics, access to spectrum of all 48 PMTs**

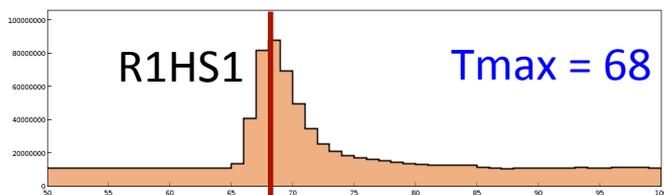
Datasets

- - runs 809& 810 (**inbending, 225** FADC channels/npe, 6 sectors trigger, large statistics)
- - run 753 (**inbending, 400** FADC channels/npe, 6 sectors trigger)
- runs 792 – 797 (**outbending, 400** FADC channels/npe, **S2 trigger only**)

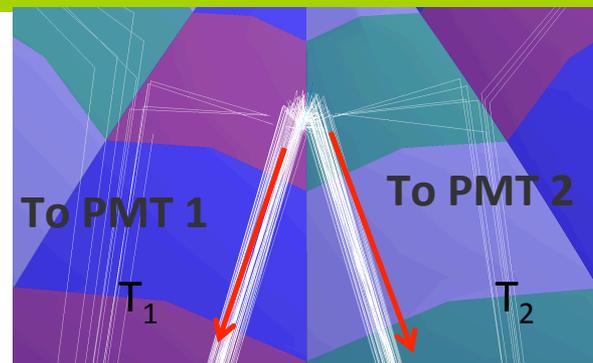
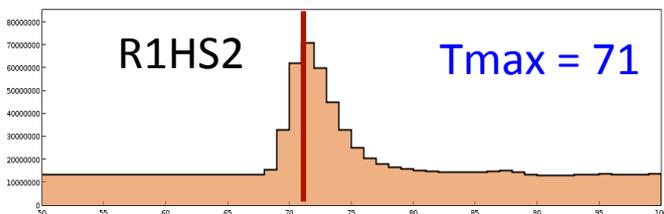
Timing correction

If $|T_1 - T_2| > T_{thr}$ hits from the same events can be identified as belonging to different events hence cluster is not reconstructed properly. Very low T_{thr} carries higher risk of letting hits from other processes into same cluster.

Using LED data:



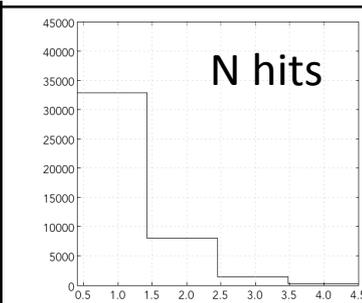
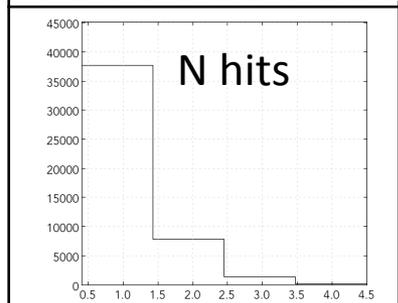
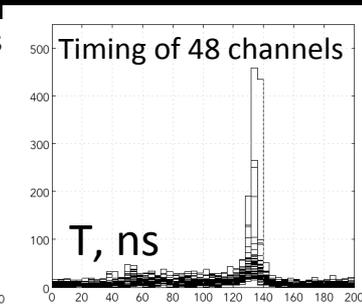
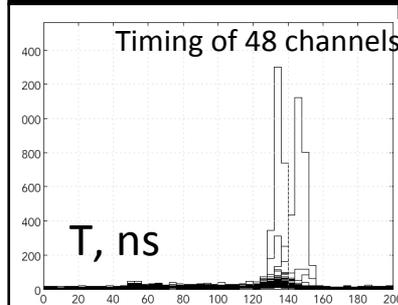
$\Delta T = 12 \text{ ns}$



Timing is better aligned

Number of multiple hits events increased

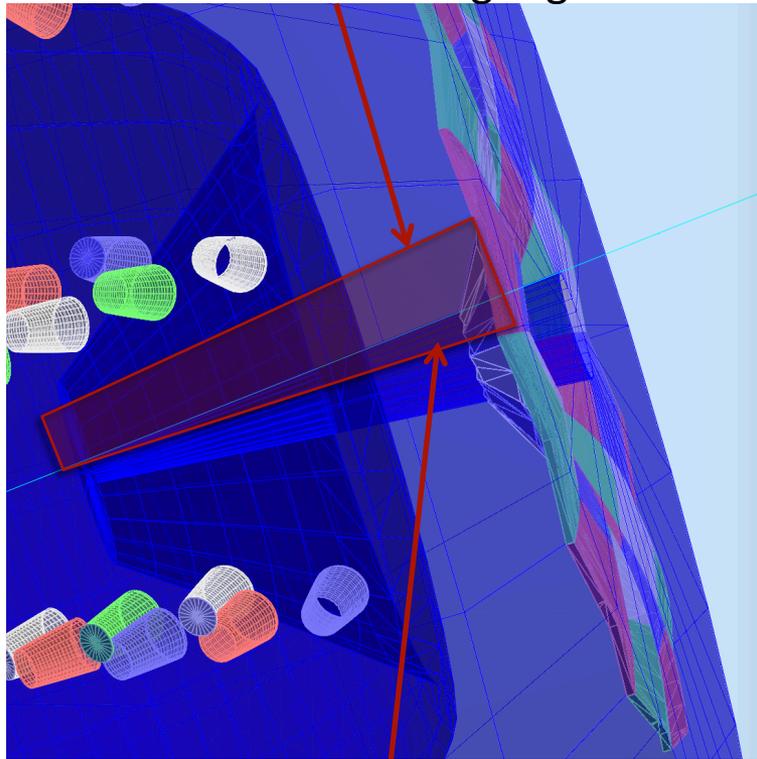
Before correction After Correction



- Corrections for each channel were introduced and uploaded to *ccdb*
- Cluster reconstruction algorithm correct timing for each channels

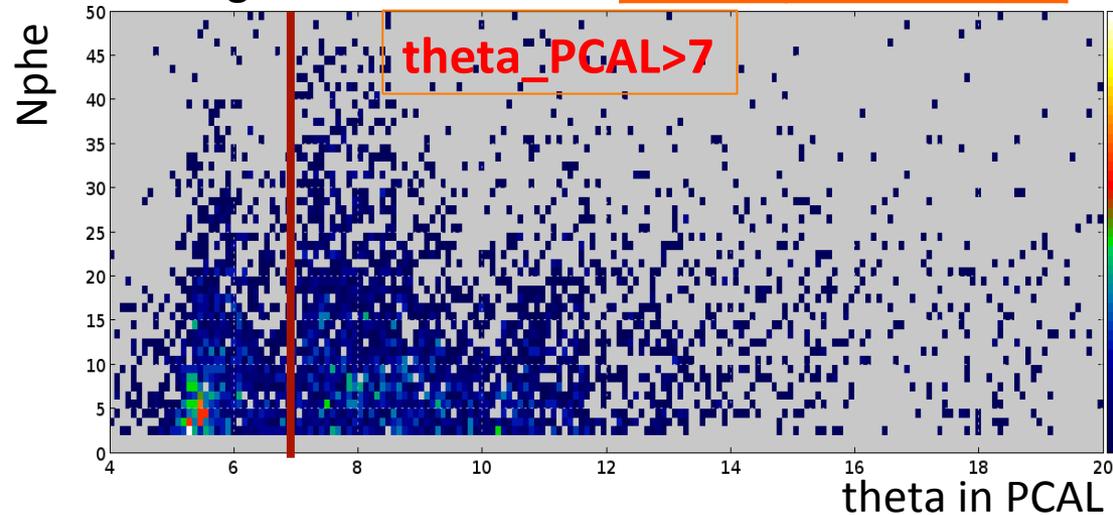
PCAL fiducial cut

For the track incident at low polar angle part of the Cherenkov light goes to mirror



Cerenkov Cone
on the borders of mirror
Expect ~ 2 degrees on the
low edge of R1

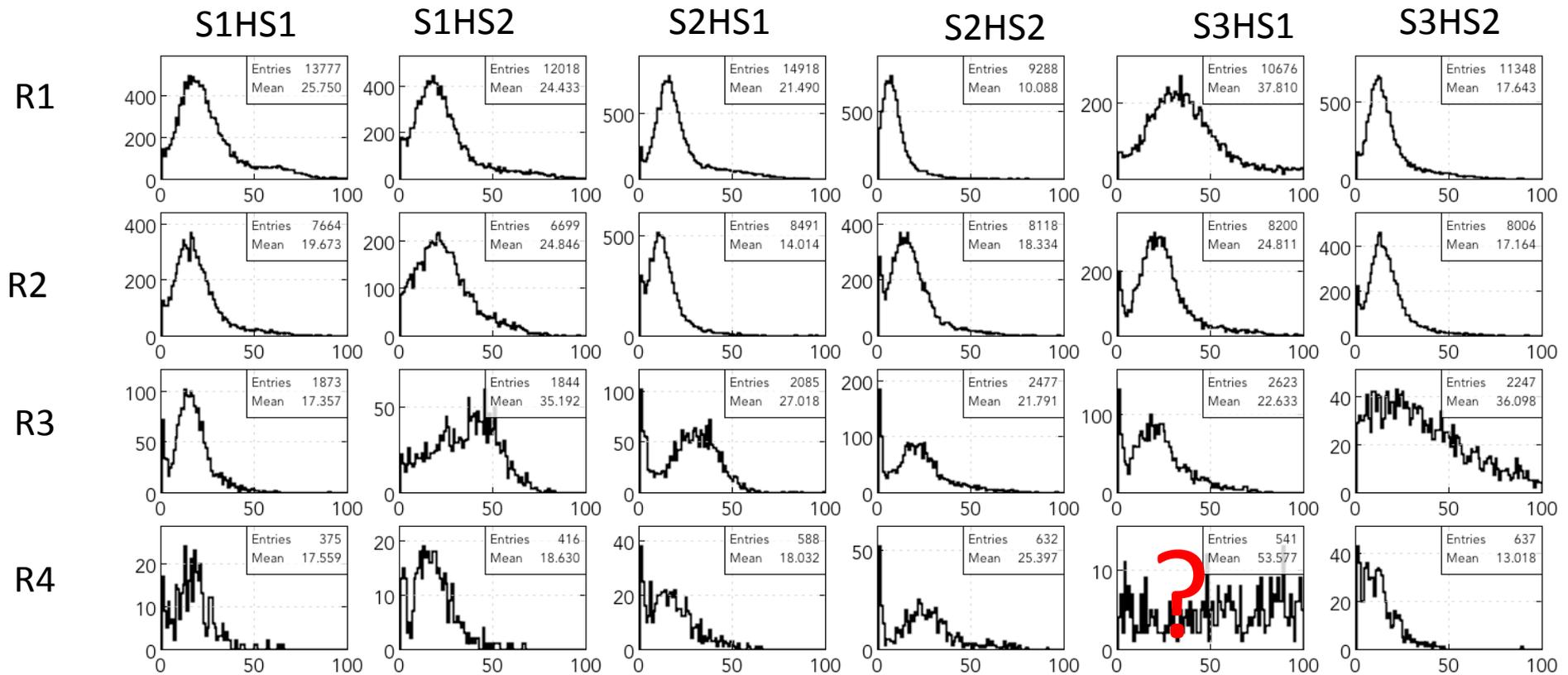
Border	Cone, degree
R4/R3	2.6
R3/R2	2.4
R1/R2	2.2



- This does not happen in DC as DC acceptance starts at higher azimuthal angle;
- This procedure does not have to be applied during usual data analysis but is required to better understand detector performance.

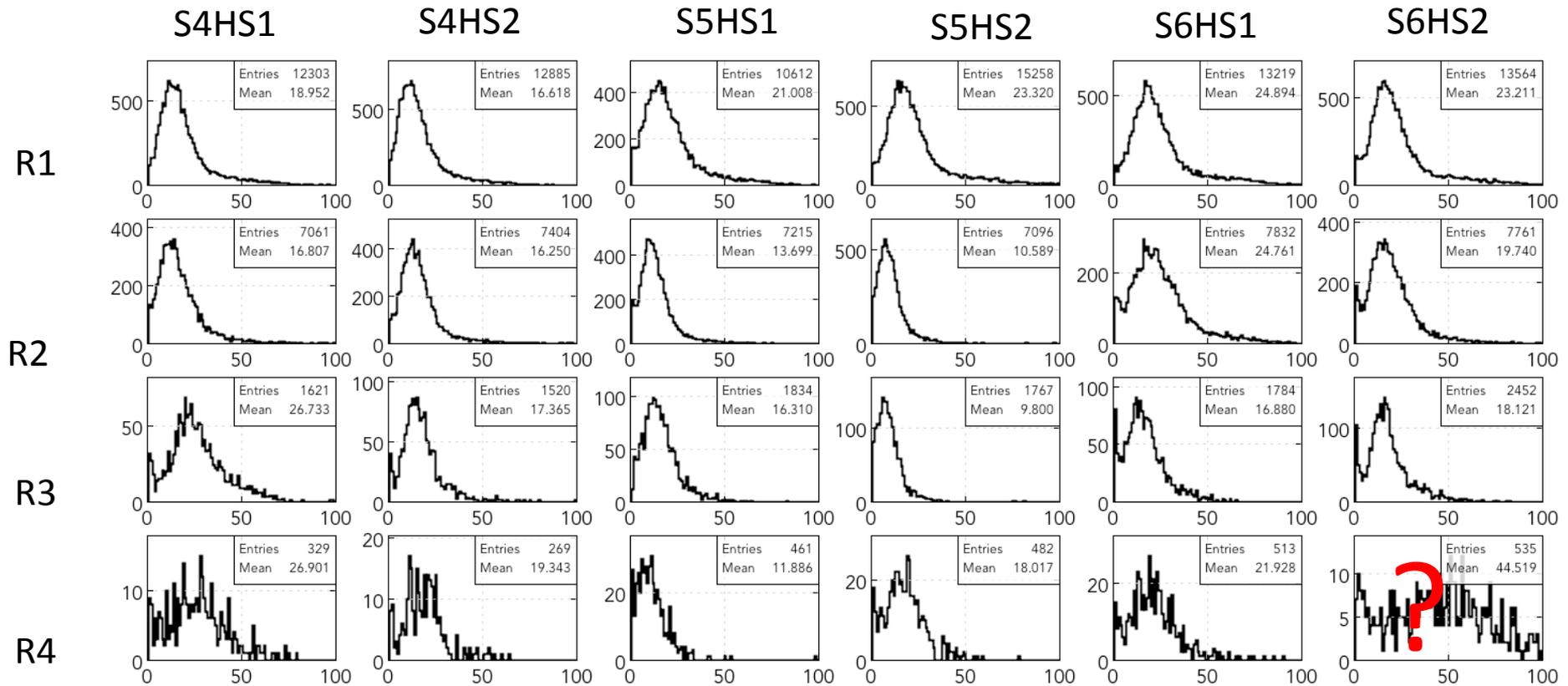
Part of the Cherenkov light at very low polar angle ($< 5^\circ$) goes into the hole and is lost

inbending, 225, individual PMTs sectors 1 - 3



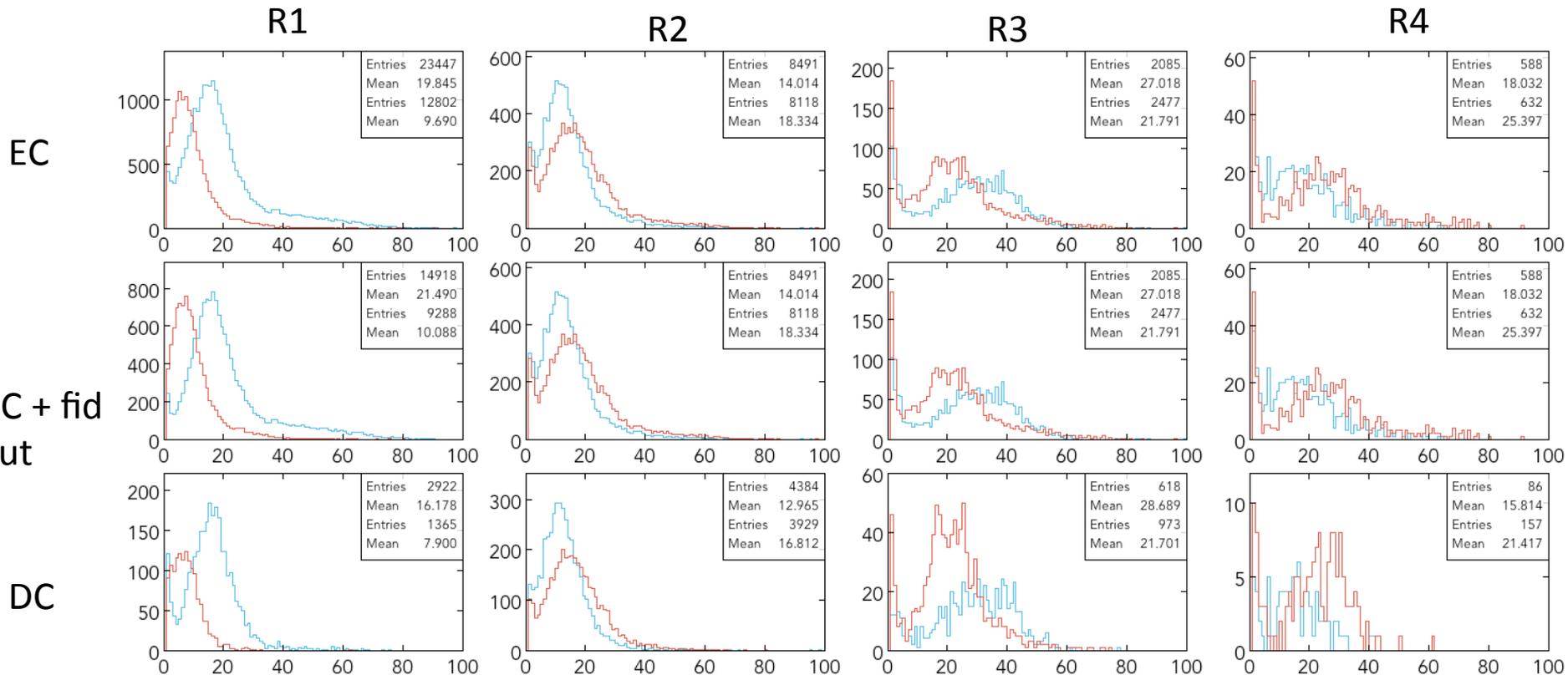
23 channels are operational, one is questionable

inbending, 225, individual PMTs, sectors 4 - 6



23 channels are operational, one is questionable

Inbending 225, Sector 2



We actually see Nphe spectrum @ Ring 4

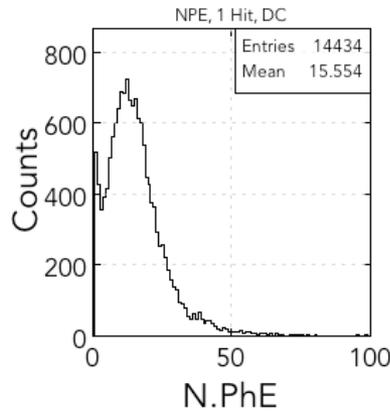
HS1

HS2

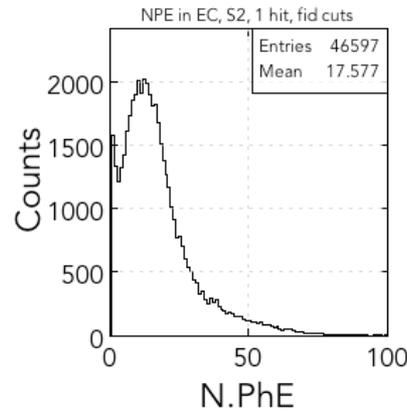
inbending, 225, summary

DC, S2

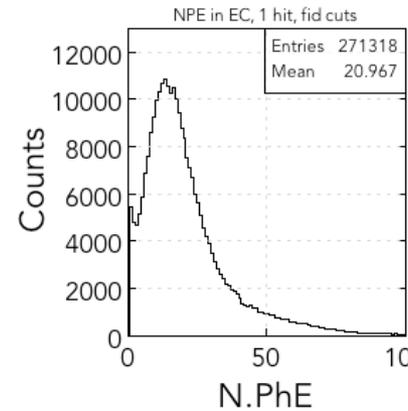
1 hit



PCAL, S2

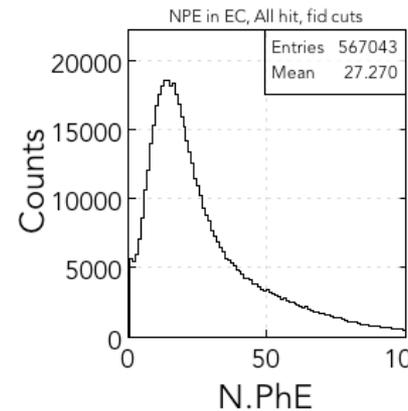
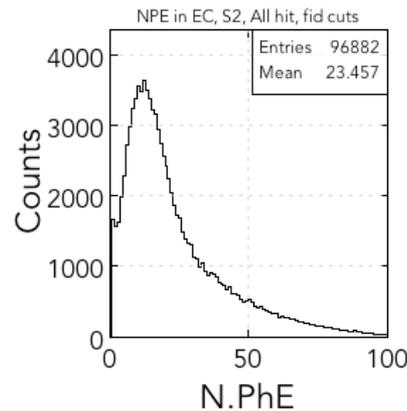
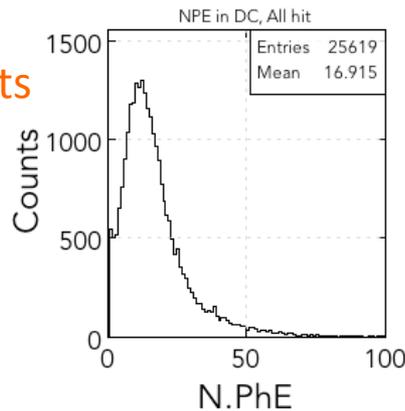


PCAL, all sectors



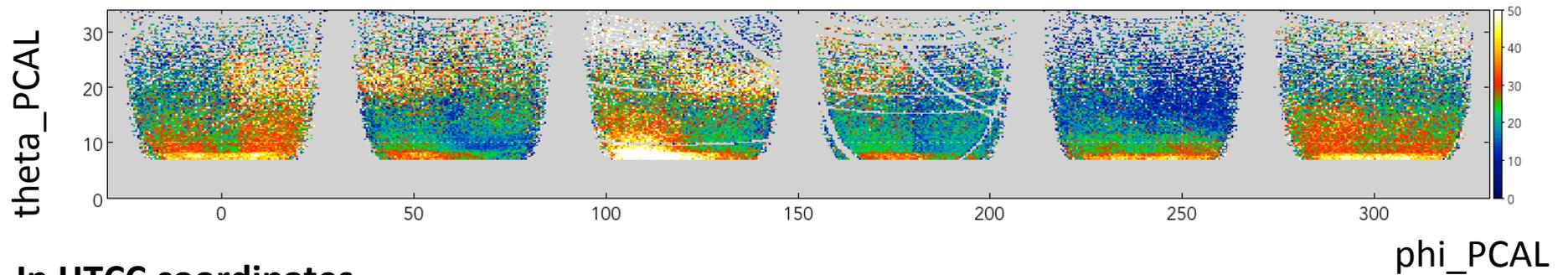
Increase in average number of Nphe; spike at very low Nphe is significantly reduced.

All Hits

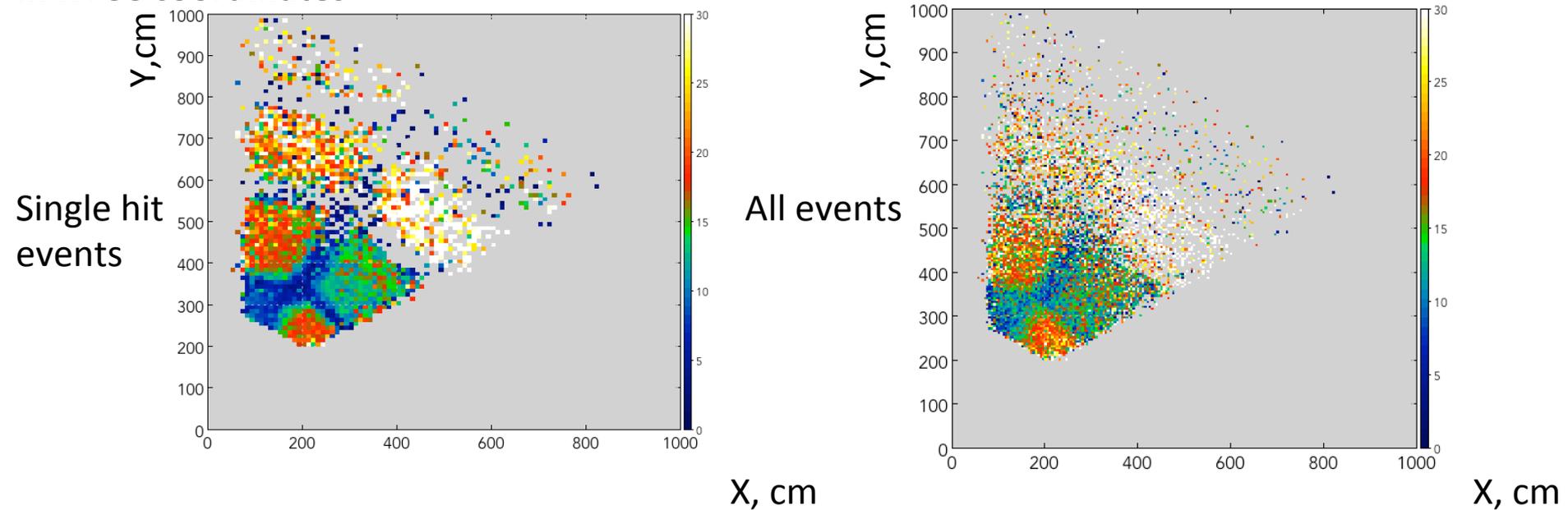


Efficiency

In PCAL coordinates



In HTCC coordinates



consistency

1 hit events	Inbending, 400		Inbending, 225		Outbending 400	
	DC	PCAL	DC	PCAL	DC	PCAL
R1HS1	16.9	20.5	16.2	21.5	18.4	17.3
R1HS2	8.9	10.9	7.9	10.1	8.6	9.3
R2HS1	13.3	12.4	13	14	12.5	12.3
R2HS2	18.9	17.6	16.8	18.3	19	18
R3HS1	19	15.9	28.7	27.1	18.6	15.1
R3HS2	23.8	22.9	21.7	21.8	24	21.1
R4HS1	14.8	17.9	15.8	18	12.5	16.6
R4HS2	26.2	26	21	25.4	17.3	24
Overall, S2	15.1	16.7	15.5	14.6	15.6	17.6
Overall, 6 sec		21.1	n/a	n/a		21

R3 and R4 has limited statistics in all runs but inbending 225

	Inbending, 400				Inbending, 225				Outbending 400			
	DC		PCAL		DC		PCAL		DC		PCAL	
	1 hit	All hit	1 hit	All hit	1 Hit	All hit	1 hit	All hit	1 Hit	All hit	1 hit	all hit
Overall, S2	15.1	17.4	16.7	23.1	15.5	17.2	14.6	20.9	15.6	16.9	17.6	23.5
Overall, 6 sec	n/a	n/a	21.1	27.4	n/a	n/a	n/a	n/a	n/a	n/a	21	27.3

Addressing the issues

➤ Difference between different PMTs:

- improvements in reconstruction;
- improvements in calibrations;
- additional checks of the HTCC performance.

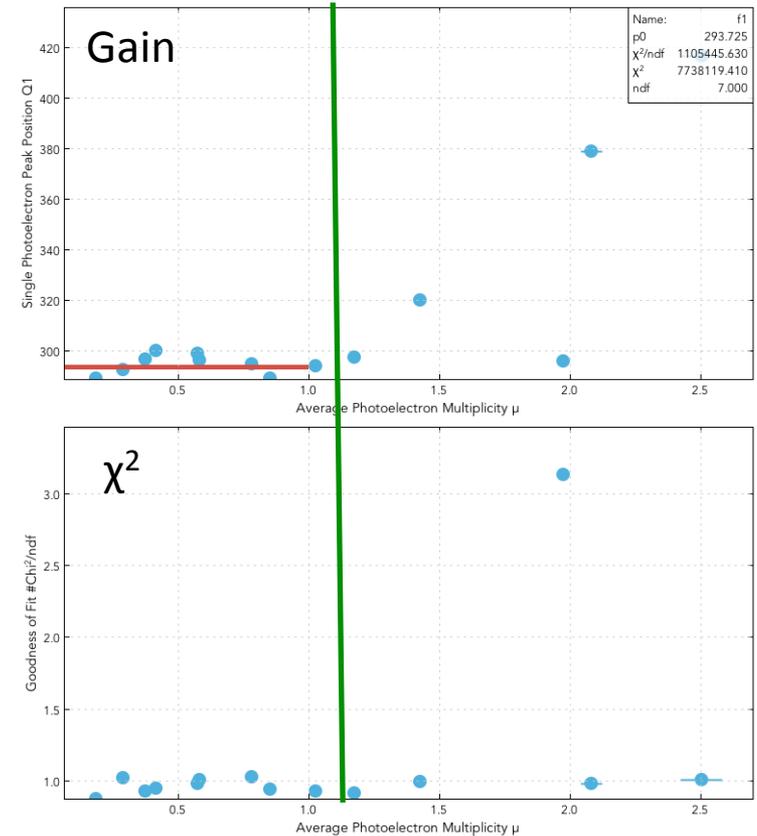
➤ Some PMTs underperform

- Assembling list of the bad PMTs using both KPP data and calibration runs;
- Testing of the spare PMTs and dividers to pick best candidates to be used as replacements.

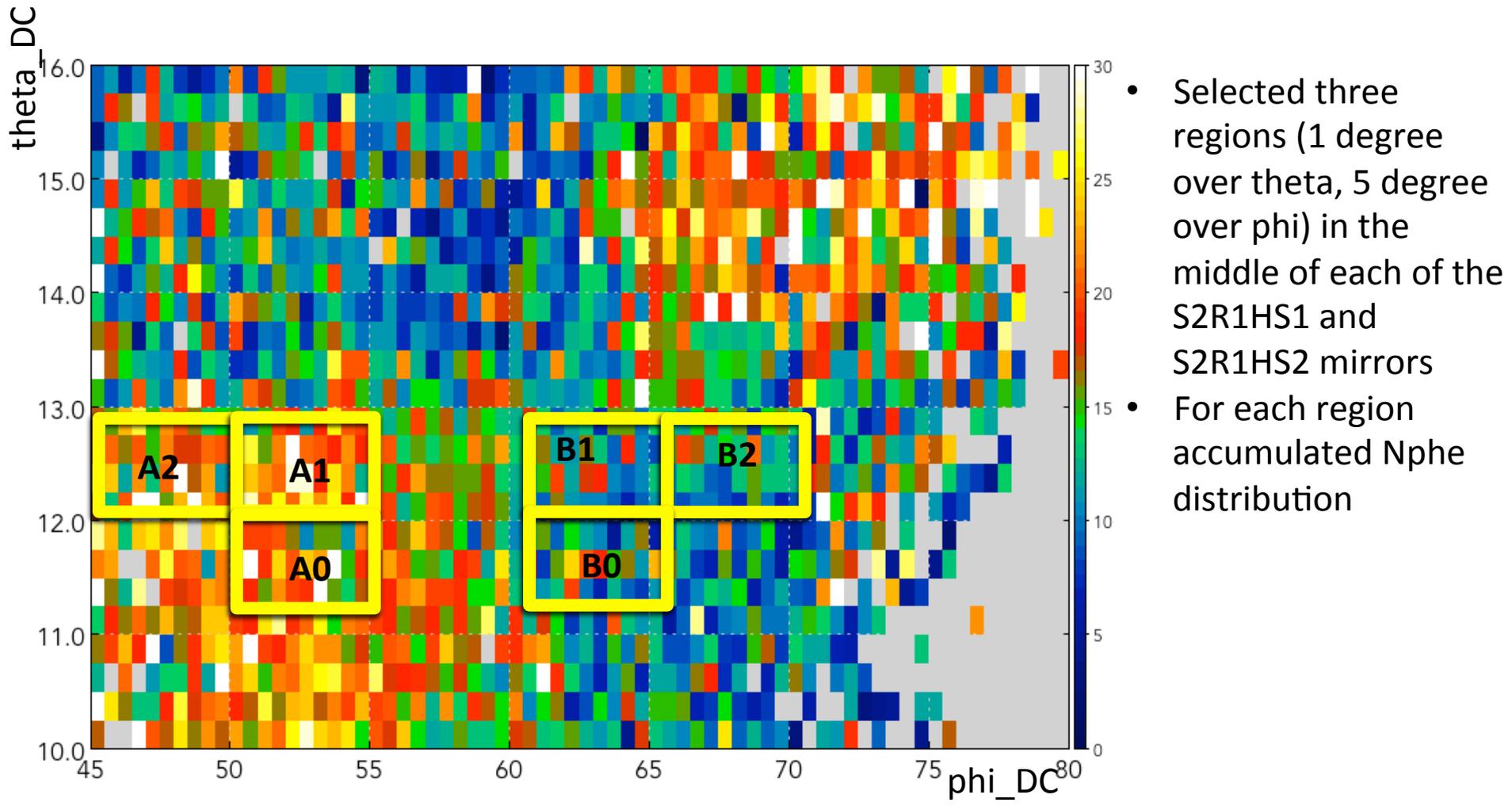
Calibration revisited

- LED controller was modified to allow for a smaller step size in LED brightness;
- HTCC was fully cabled on the floor of the Hall B;
- Significant amount of data is taken at different HV values (used in the KPP) and optimal LED brightness range was established for the purpose of calibrations;
- Fits are performed in this LED brightness range to extract the position of the SPE peak

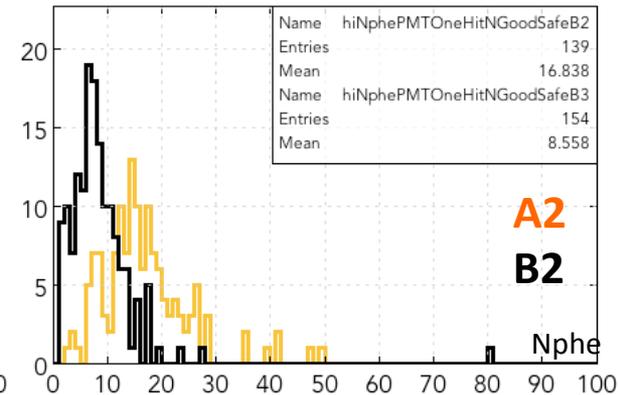
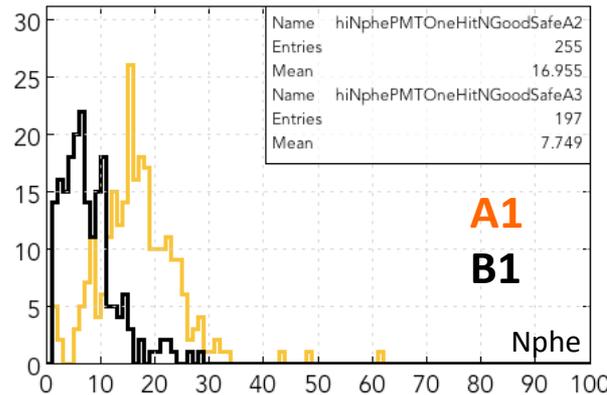
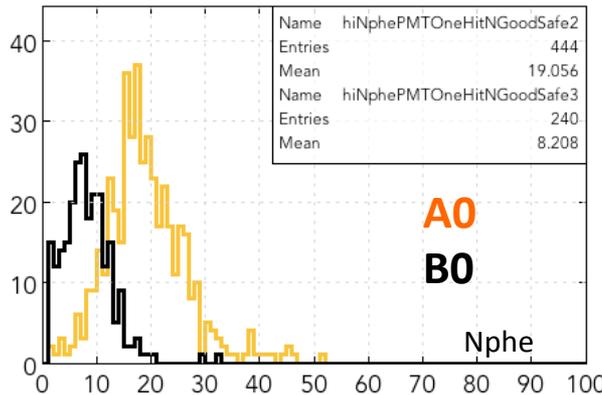
Reliable region



Response uniformity



Response uniformity and calibration

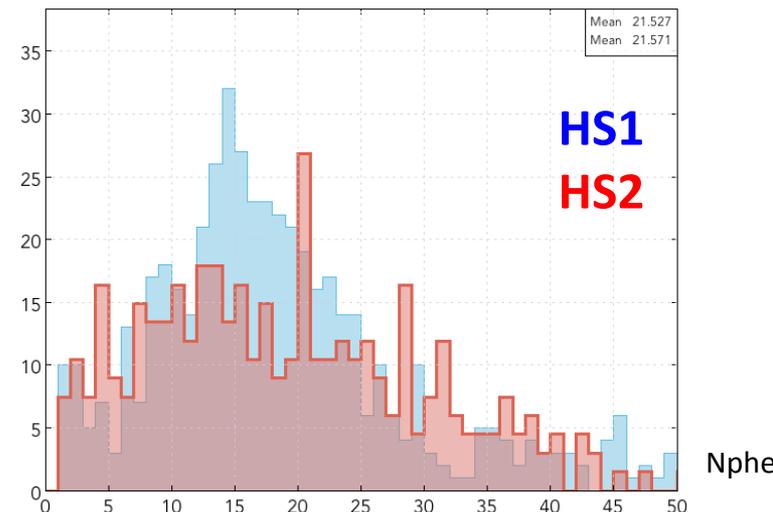


Asymmetry holds

Is asymmetry a calibration issue?

Sample of the data was reconstructed with gain for the channel S2R1HS2 divided in half, i.e. peak position should go to the same position. Histograms are normalized to **HS1**.

The width of the HS2 signal is much larger



Summary

- Signals and spectrum from all 48 PMTs were extracted;
- Signals and spectrums from 8 PMTs of sector 2 were extracted using different ways of electron ID;
- Clusters were reconstructed from the data on the individual hits;
- Timing alignment and PCAL fiducial cuts are introduced;
- Efficiency of the HTCC is calculated in the HTCC coordinates;
- Average number of Nphe is in a good agreement with estimations;
- Average number of Nphe is consistent between runs at different gains;
- Several PMTs are underperforming;
- There is still difference between responses of different PMTs in the same ring to understand.