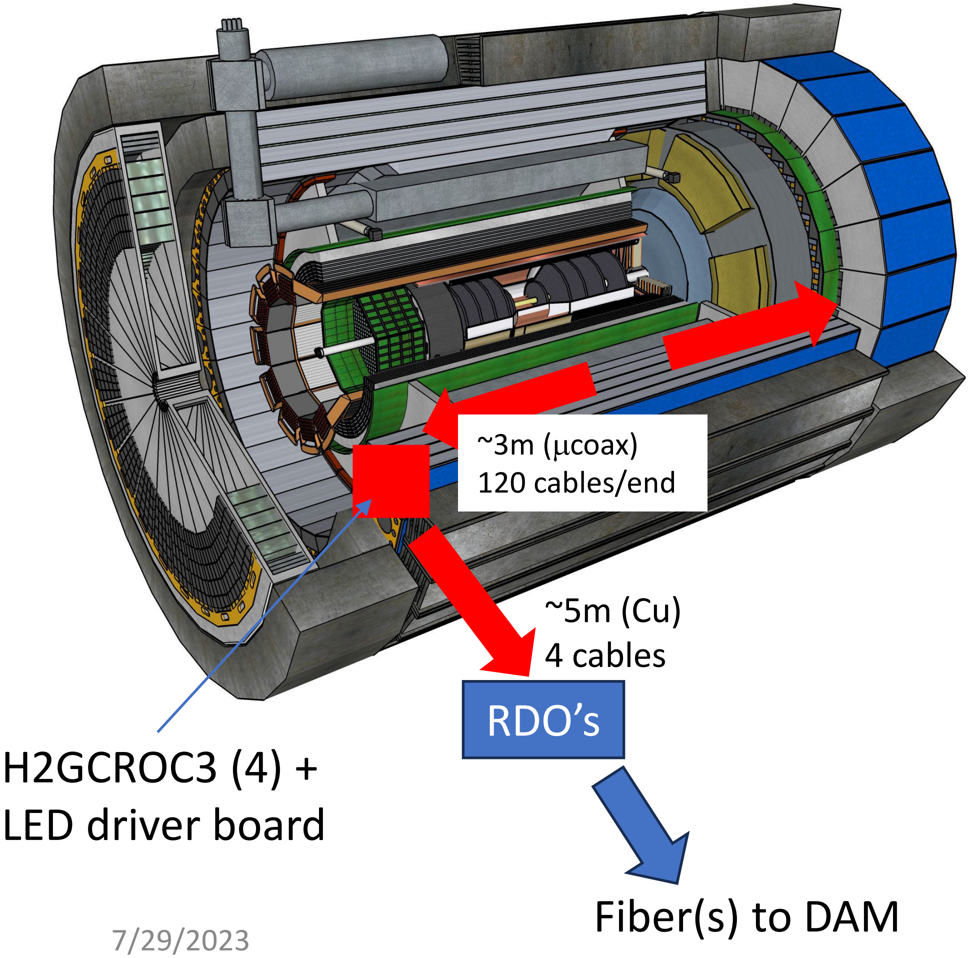
Barrel HCAL Electronics Chain and Requirements

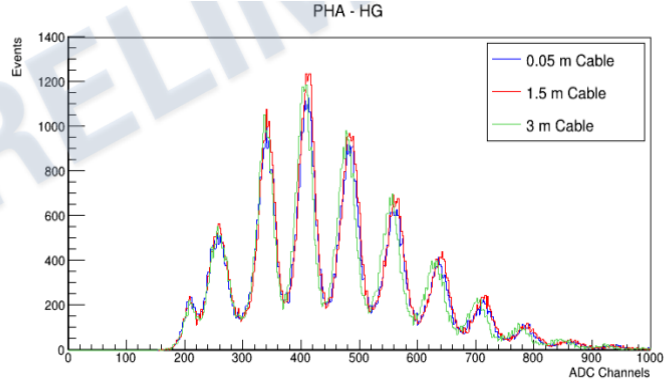
J. Lajoie

D. Anderson

Iowa State University

Readout Chain

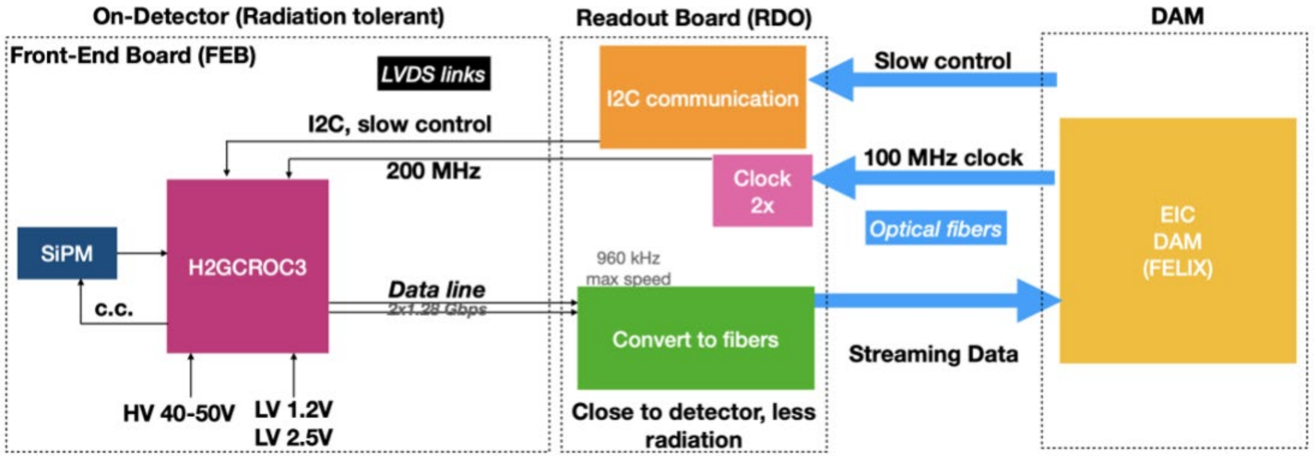




Energy loss along a cable with remote SiPM

One sector -> 8 H2GCROC3 boards. Cable SiPM's out to end of barrel HCAL to keep accessible for maintenance.

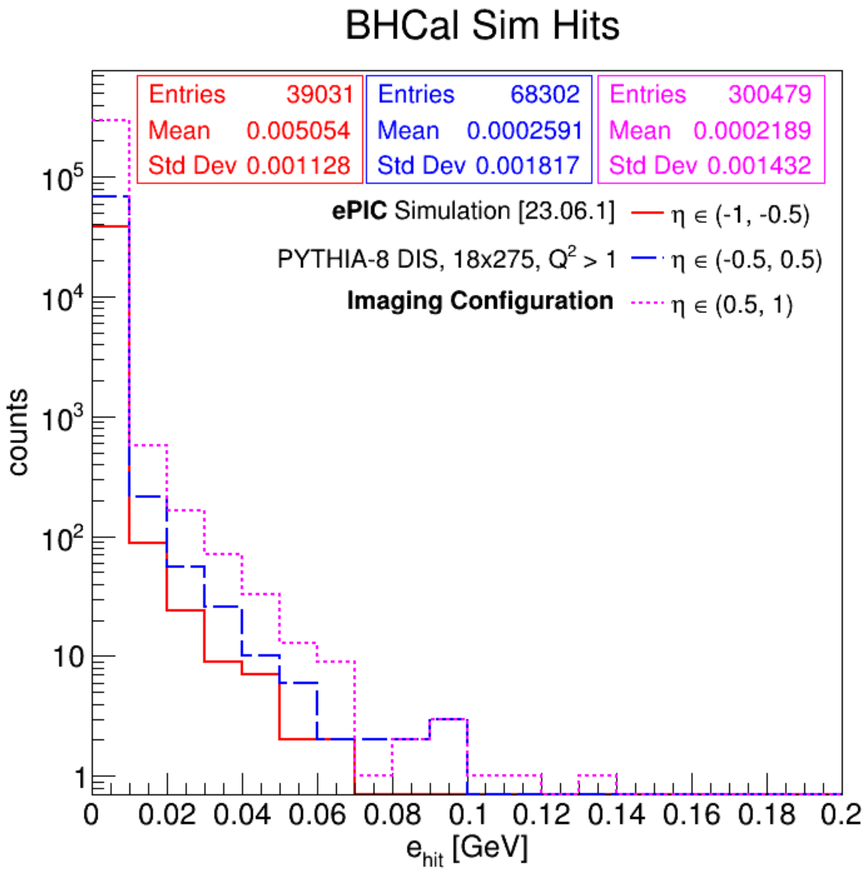
LFHCal readout hierarchy (after the upgrade)



SiPM Specifications

Barrel Hadronic Calorimeter		
Parameter	**Specification**	**Notes**
Active Area	3mm x 3mm	
Pixel Size	15 micron	
Package Type	surface mount	
Peak Sensitivity	~460 nm	
PDE	~25%	
Gain	~2 x 10^5	
DCR	1kHz typical/2kHz max	
Temperature coefficient of Vop	<60 mV/C	
Direct crosstalk probability	<1%	from S14160-3015PS, not specified for S12572-015P
Terminal capacity	~500pF	
Packing granularity	N/A	
Vop variation within a tray	+/-0.1V	sPHENIX was +/- 0.04, 0.1V is from Hamamatsu quote, should be OK
Recharge Time	N/A	probably should have a spec here, but not sure from datasheets?
Fill Factor	~50%	yields approximately 40k pixels
Protective Layer	Silicone or epoxy resin (n=~1.55)	this probably doesn't need to be a spec for oHCAL?
	NB: Specifications set to match sPHENIX - Hamamatsu S12572-015P	
	Crosschecked against datasheet for Hamamatsu S14160-3015PS	

Readout Requirements – Dynamic Range



This is the distribution of energy deposited in the scintillating tiles (*visible* energy) in an ePIC simulation of 18x275 GeV DIS events (10k events total). The regions are split in rapidity, and the higher overall energy deposition at positive rapidity is visible.

0.3 GeV of *visible* energy corresponds to ~1300 SiPM pixels firing
Single muon requirement sets lower limit at ~26 pixels
(see backup, using sPHENIX calibration and new SiPM).

ePIC plans to use the Hamamatsu S14160-3015PS SiPM, operated at ~3.6×10^5 gain (about 4V over breakdown, or ~42V). The terminal capacitance of the S14160-3015PS is 530pF at V_{op}. Therefore, the junction capacitance is

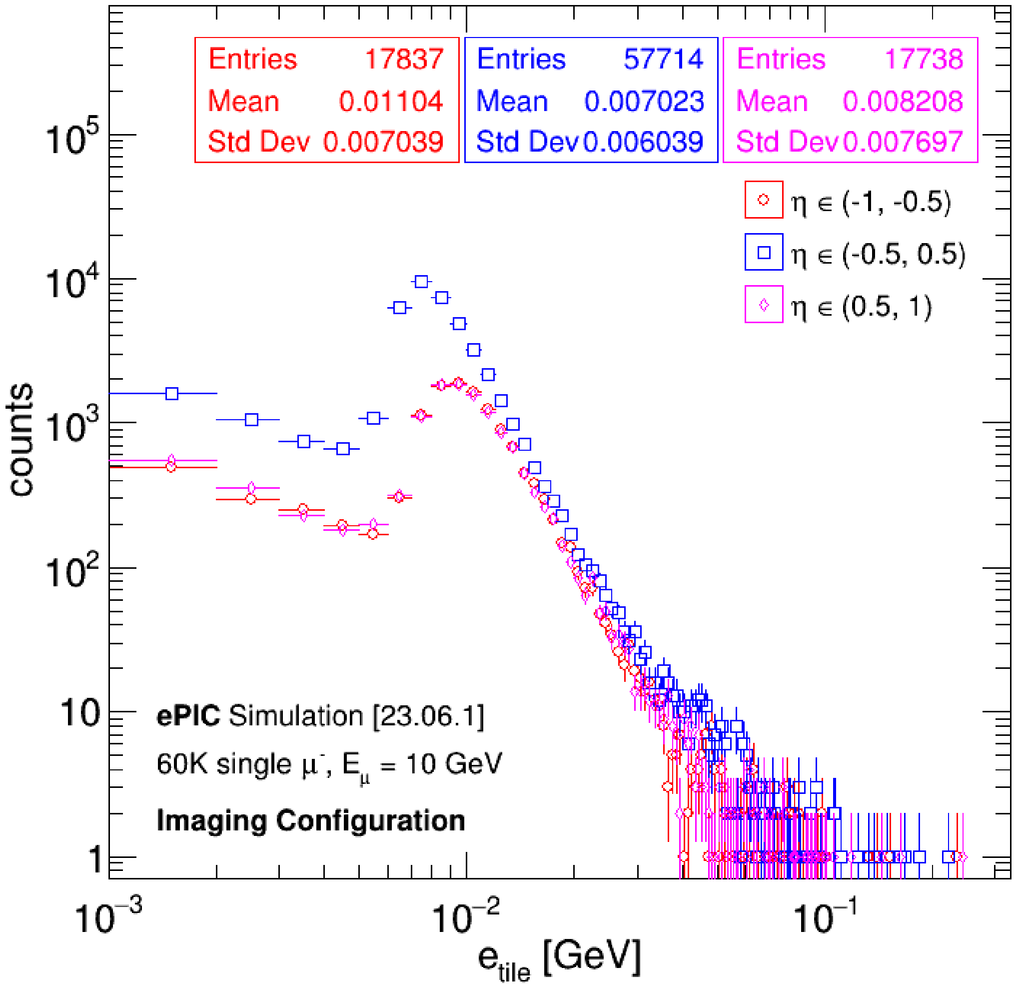
$$C_J = \frac{C_T}{N_{pix}} = \frac{530pF}{39984} = 13\text{fF}$$

This gives a single pixel charge output of $Q = C_J \Delta V$ = 13fF x 4V = 52fC

Combined with the dynamic range of fired pixels (26-1300) this means the charge range we would see is 1.3 – 68 pC. Of course, we would want more resolution in the lower range from the HGCROC ADC and then resolution at higher amplitudes from the TOT.

The H2GCROC3 expected range is 1-16pC (ADC), 16-320pC (TOT)

Muons in Simulation



Single muon peak in simulations is at 0.01 GeV/tile

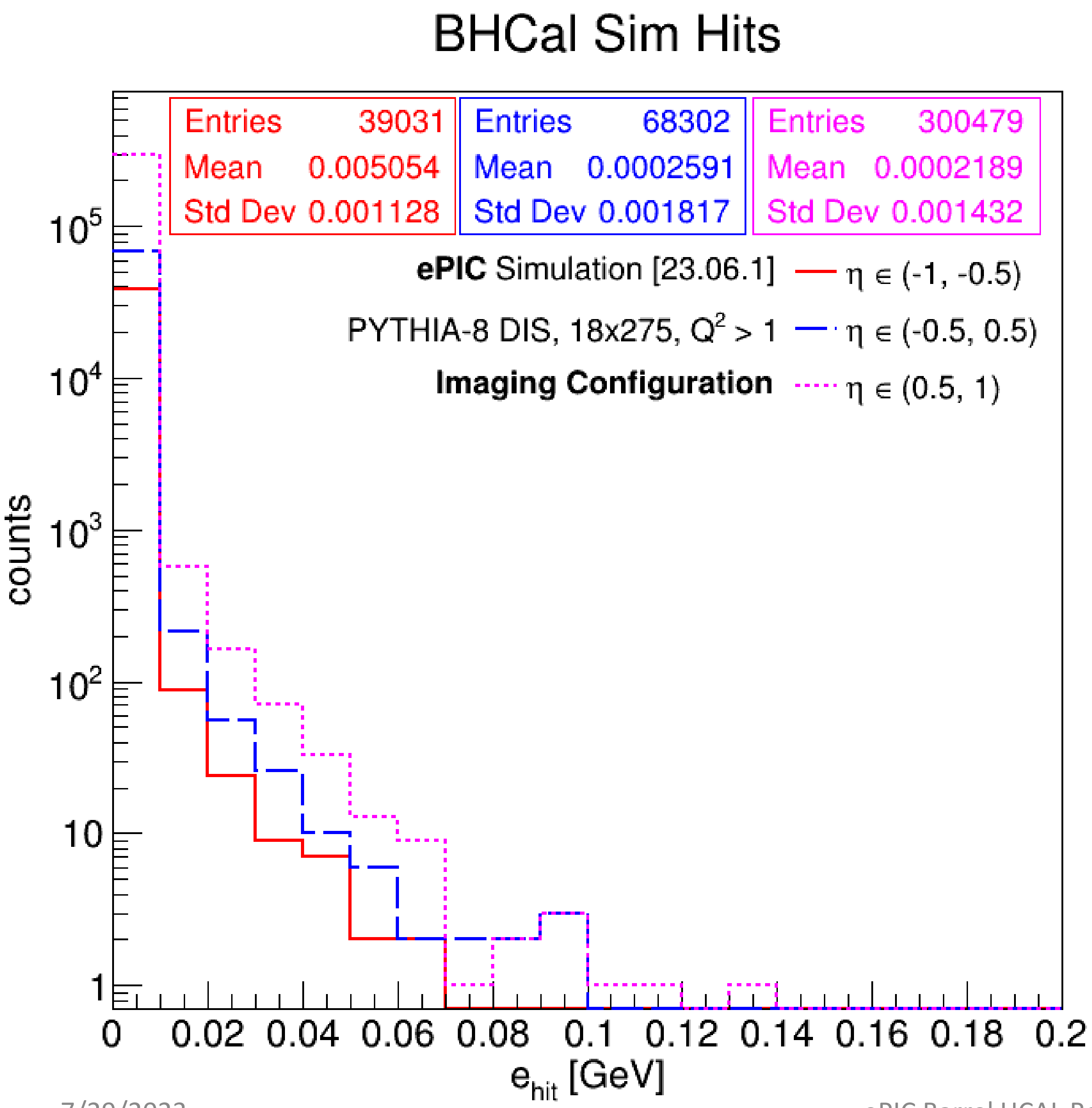
This corresponds to:

0.01 GeV * 3200 pixels/GeV * (0.32/0.25) = 41 pixels

This is a lower than the sPHENIX tower estimate using the sampling fraction (~100 pixels). Close to the lower end of the dynamic range of the H2GCROC, but still within in.

Will need to worry a lot about noise to make sure the MIP peak is not swamped. May be able to mitigate incoherent noise by adding scintillators.


BACK UP



This is the distribution of energy deposited in the scintillating tiles (*visible* energy) in an ePIC simulation of 18x275 GeV DIS events (10k events total). The regions are split in rapidity, and the higher overall energy deposition at positive rapidity is visible. (Simulation and plot courtesy of Derek Anderson, ISU.)

How does this compare to sPHENIX?
sPHENIX had a range to 50 GeV total energy in a tower (5 scintillators). Correcting for the sampling fraction and number of scintillators in a tower:

50 GeV*0.03/5 = 300 MeV

is the equivalent single scintillator slat energy for sPHENIX. So, this is not all that different from the sPHENIX requirements.

sPHENIX sees ~16000 pixels per GeV of *visible* energy in the scintillator (per Jin Huang, 7/21/22 email and 2016 sPHENIX test beam).

16000 pixels/GeV/5 scintillators = 3200 pixels/GeV (ePIC)

So 0.3 GeV of *visible* energy corresponds to ~960 SiPM pixels firing. (As we know already, we are not using anything like the full range of the 40k pixels in the SiPM, so linearity issues with the SiPM should not be a concern.)

At the other end of the spectrum, a MIP muon loses about ~1GeV in traversing the HCAL from inner to outer radius. This corresponds to:

1 GeV * 0.03 * 3200 pixels/GeV = ~96 pixels/scintillator

We need a little bit of room on the lower end, so let’s say 20 pixels.

So – the dynamic range in fired pixels we want in ePIC is in the range of ~20-1000 pixels.

(**TO DO** – look at the tile energy distribution for single muons to get an understanding of efficiency.)

sPHENIX used the Hamamatsu S12572-015P-02 SiPM, operated at ~10^5 gain (about 3V over breakdown, or ~68V). The terminal capacitance of the S12572-015P-02 is 320pF at V_{op}. Therefore, the junction capacitance is

$$C_J = \frac{C_T}{N_{pix}} = \frac{320pF}{40000} = 8\text{fF}$$

This gives a single pixel charge output of $Q = C_J \Delta V$ = 8fF x 3V = 24fC

ePIC plans to use the Hamamatsu S14160-3015PS SiPM, operated at ~3.6×10^5 gain (about 4V over breakdown, or ~42V). The terminal capacitance of the S14160-3015PS is 530pF at V_{op}. Therefore, the junction capacitance is

$$C_J = \frac{C_T}{N_{pix}} = \frac{530pF}{39984} = 13\text{fF}$$

This gives a single pixel charge output of $Q = C_J \Delta V$ = 13fF x 4V = 52fC

The S14160 has a 32% QE, compared to the S12572 which was 25%. So the dynamic range of fired pixels is:

20 – 1000 pixels x (0.32/0.25) = 26 - 1300

Combined with the dynamic range of fired pixels (26-1300) this means the charge range we would see is 1.3 – 68 pC. Of course, we would want more resolution in the lower range from the HGCROC ADC and then resolution at higher amplitudes from the TOT.