

HCal: Status and Readiness

Juan Carlos Cornejo on behalf of the HCal Working Group

Active members: S. Barcus, **V. Brio (student)**, J.C. Cornejo, D. Jones, J. Napolitano, **S. Seeds (student)**, B. Quinn, B. Wojtsekhowski

[Q1] HCAL-J Introduction

SBS needed a hadron calorimeter for 2.5 - GeV hadrons with:

- 95% efficiency with trigger threshold at 25% peak signal
- Spatial Resolution with average 5 cm (rms)
- Since Time of Flight will be used to cut out inelastics:
 - Need ~ 1.0 ns rms time resolution \rightarrow 80% trigger efficiency for GEN.
 - 1.0 ns is acceptable, but < 1.0 ns preferred.
 - Goal: time resolution closer to 0.5 ns rms.

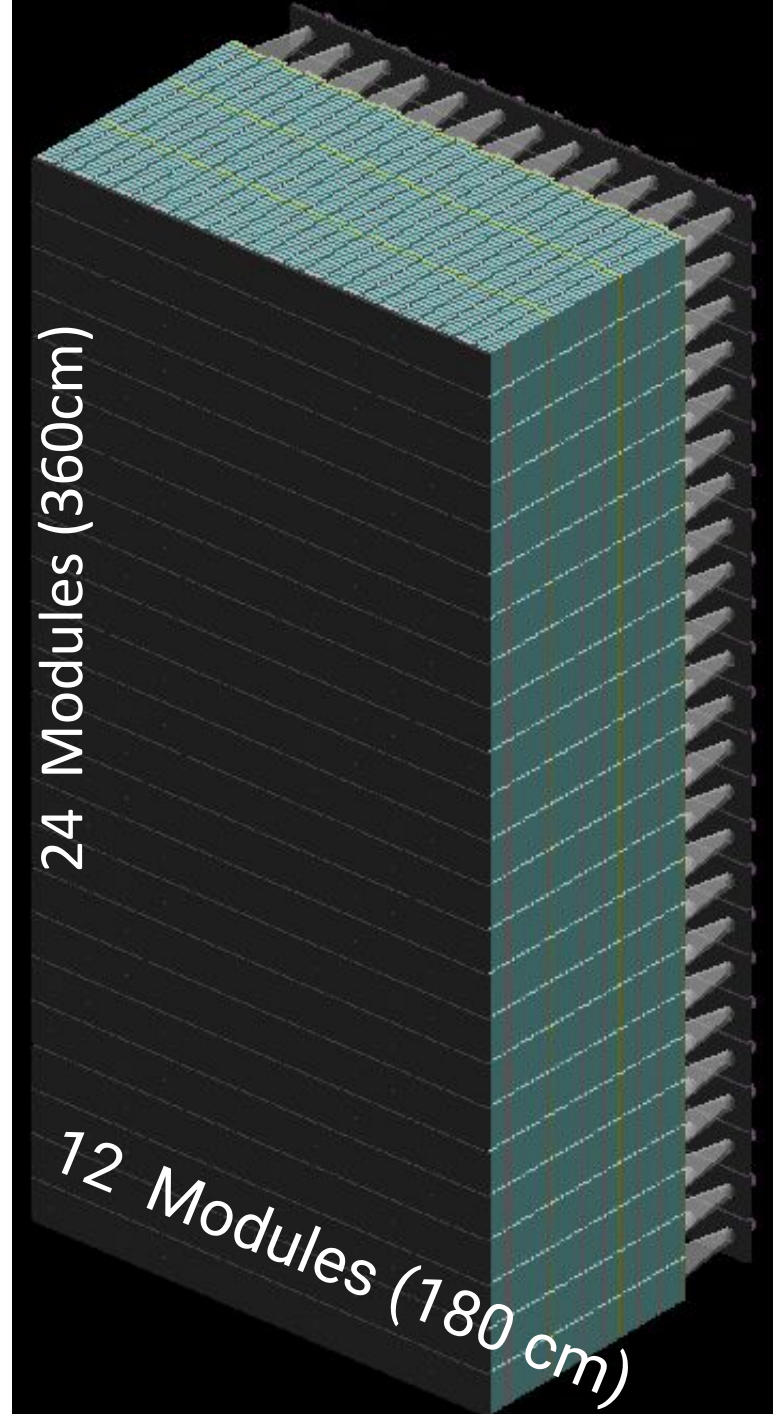
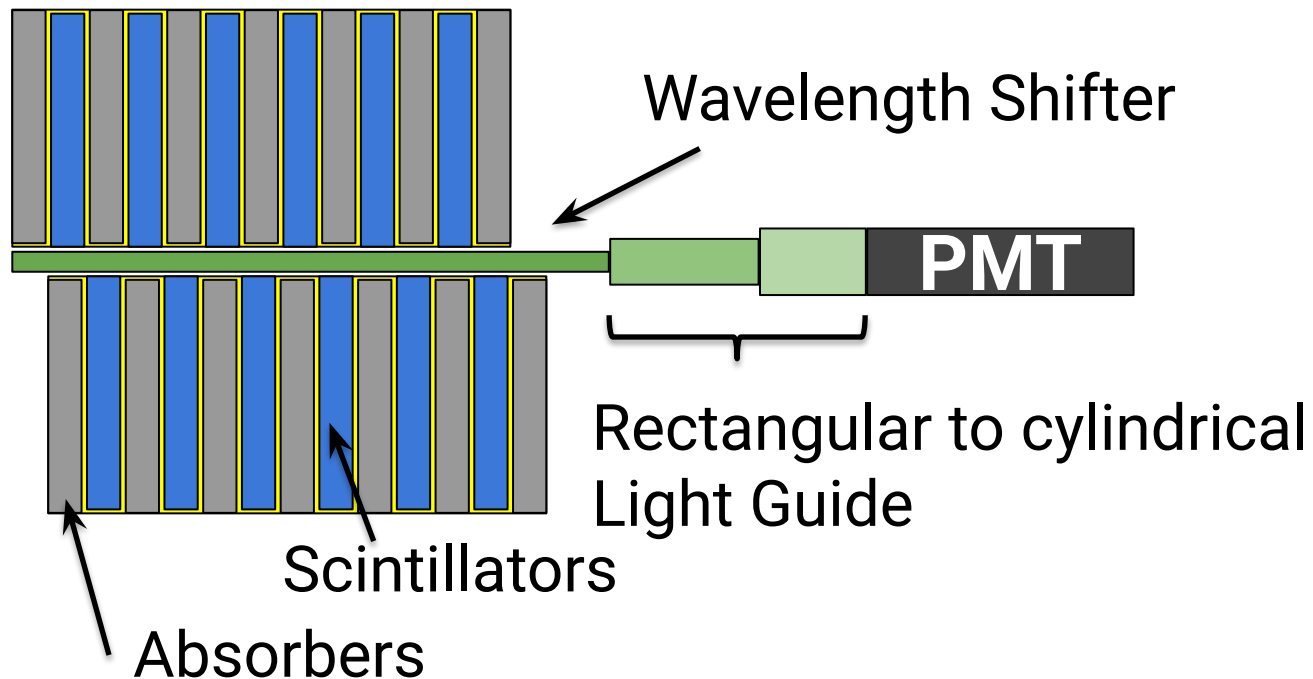
Design:

HCAL-J (HCal) was modeled after HCAL1 from COMPASS, with a few changes:

- Using faster scintillator and wavelength shifter.
 - 0.5% PPO, fabricated by Fermilab optimized light yield with attenuation.
- Moving the wavelength shifter to the center.
 - Maximises light output (since it uses smaller scintillators).
- Use 2" PMTs that are faster and better quantum efficiency.

[Q1] HCal Design (continued)

- Each module is 15 cm x 15 cm x ~1 m
 - Plus light guide and PMT at end
- 40 layers scintillators + iron per module
 - Staggered to increase light output

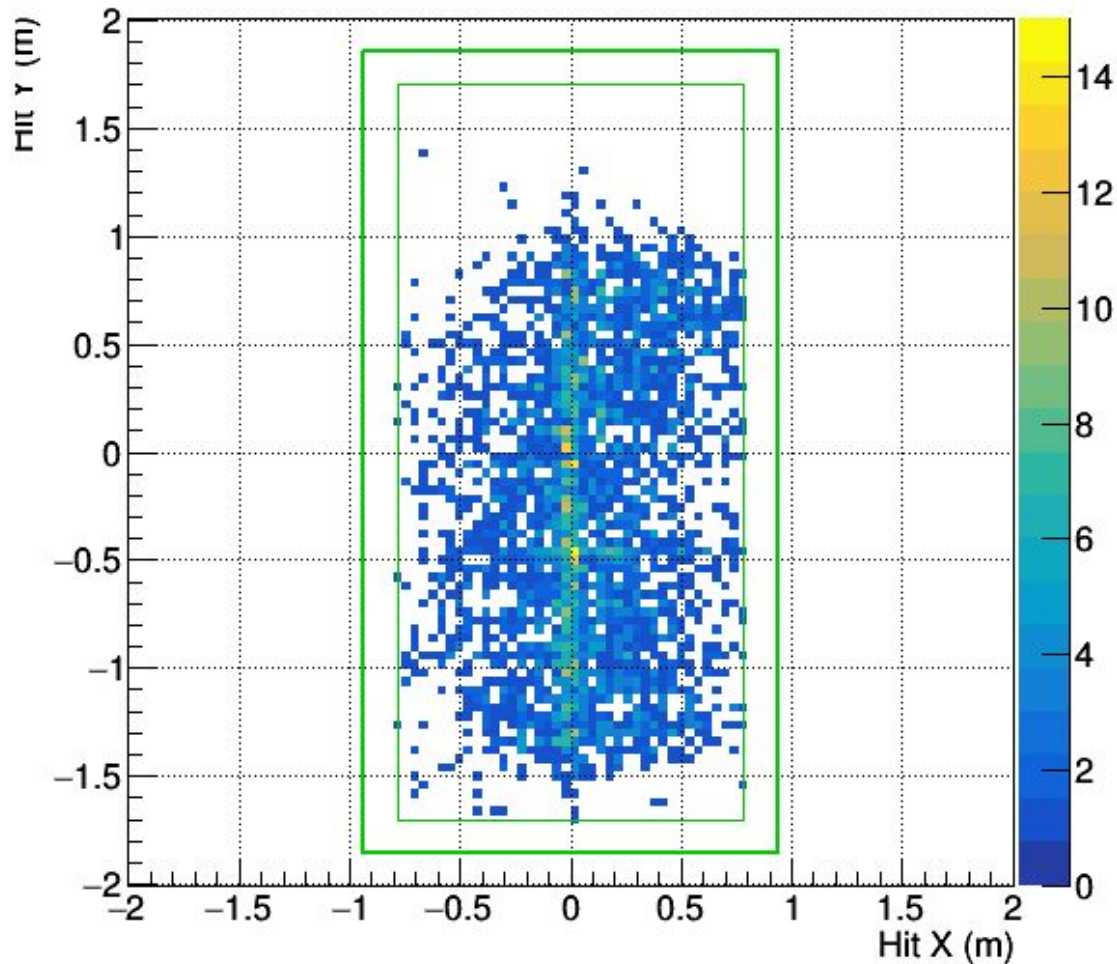


[Q1] HCAl Efficiency

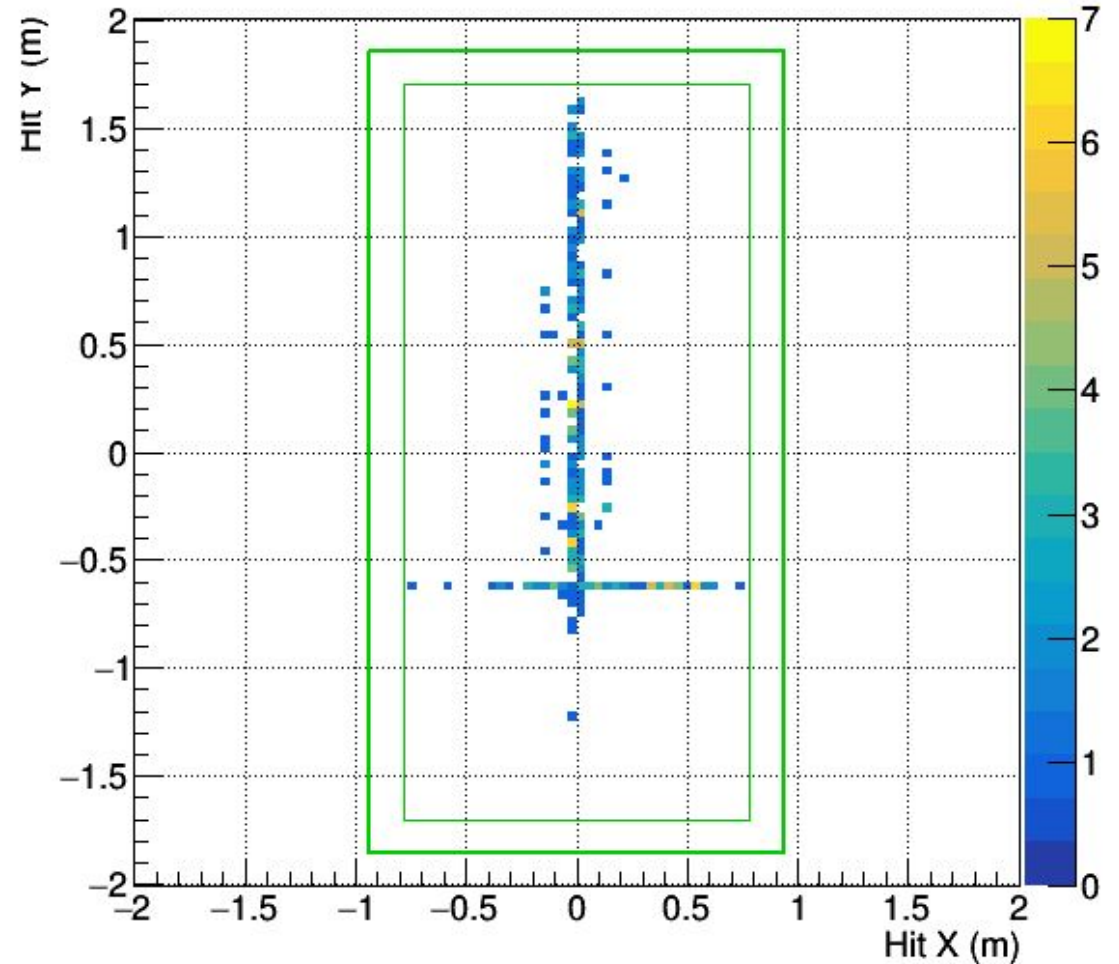
A nucleon is not-detected if it is below the $\frac{1}{4}$ energy peak threshold.

<3% of nucleons will not shower (no interaction with the iron)

Kin07 - Neutron Positions (no interaction)

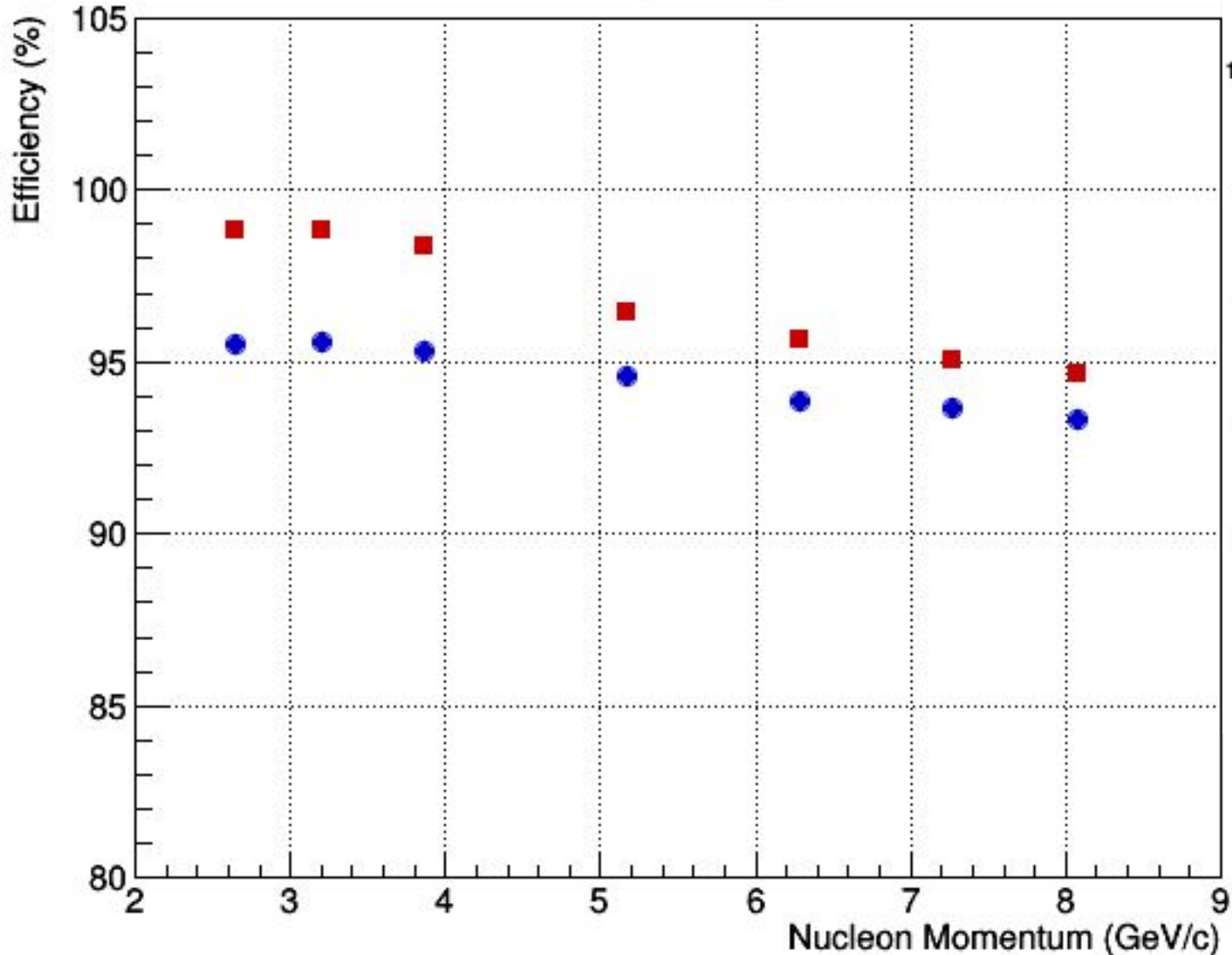


Kin07 - Proton Positions (no interaction)

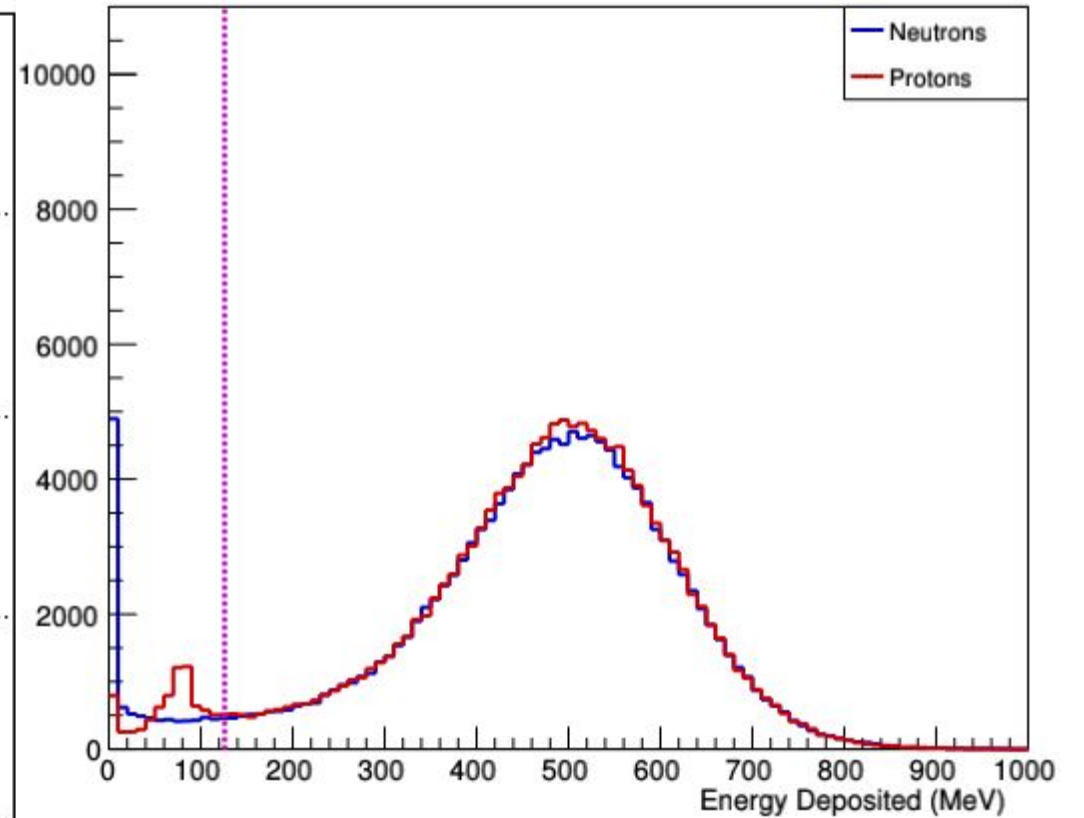


[Q1] HCAL Efficiency

HCAL Efficiency ($E_T = 1/4 E_{\text{peak}}$) (4x4 cluster)



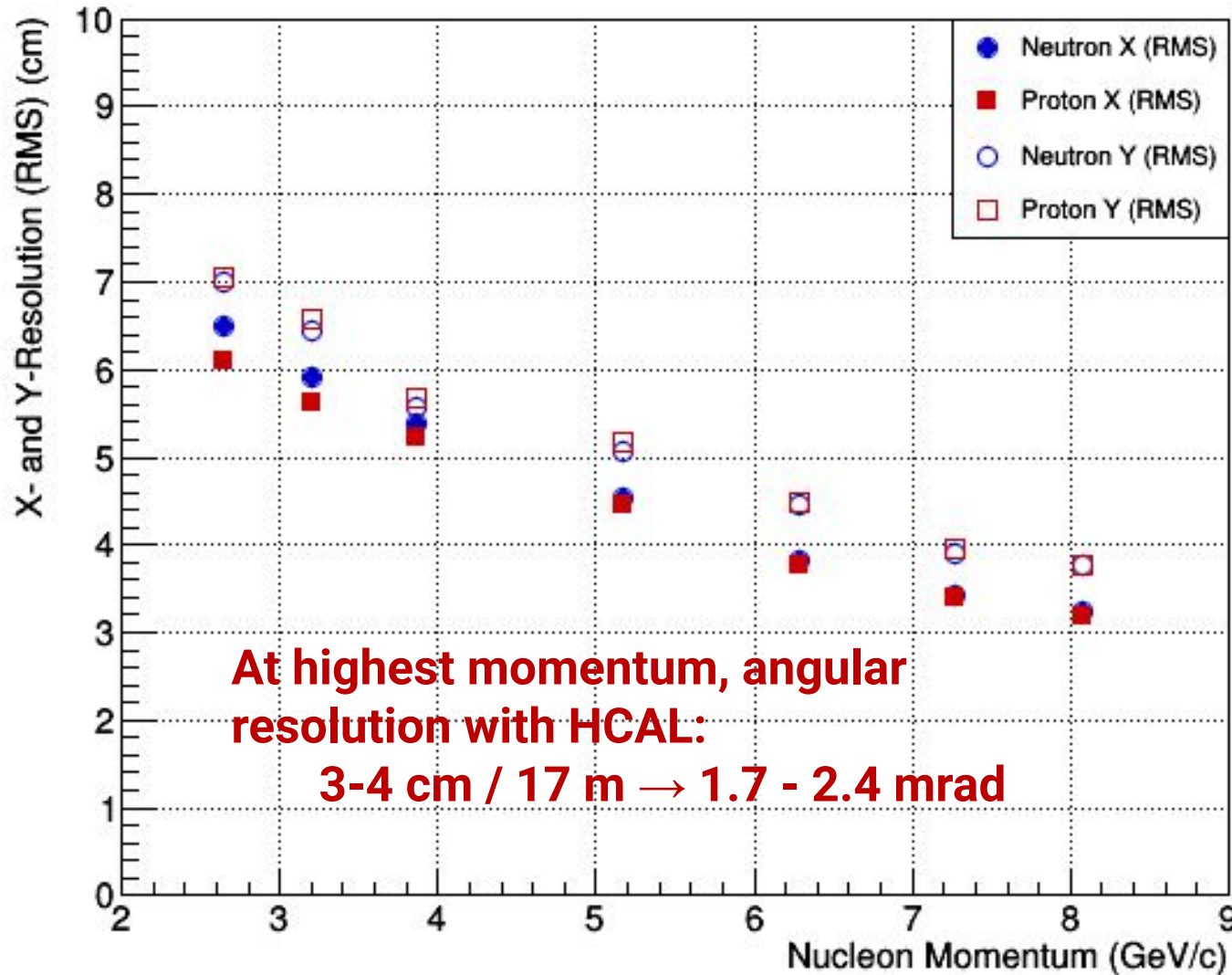
P=8.08 GeV/c Energy Deposited (3x3 cluster, GMn acceptance)



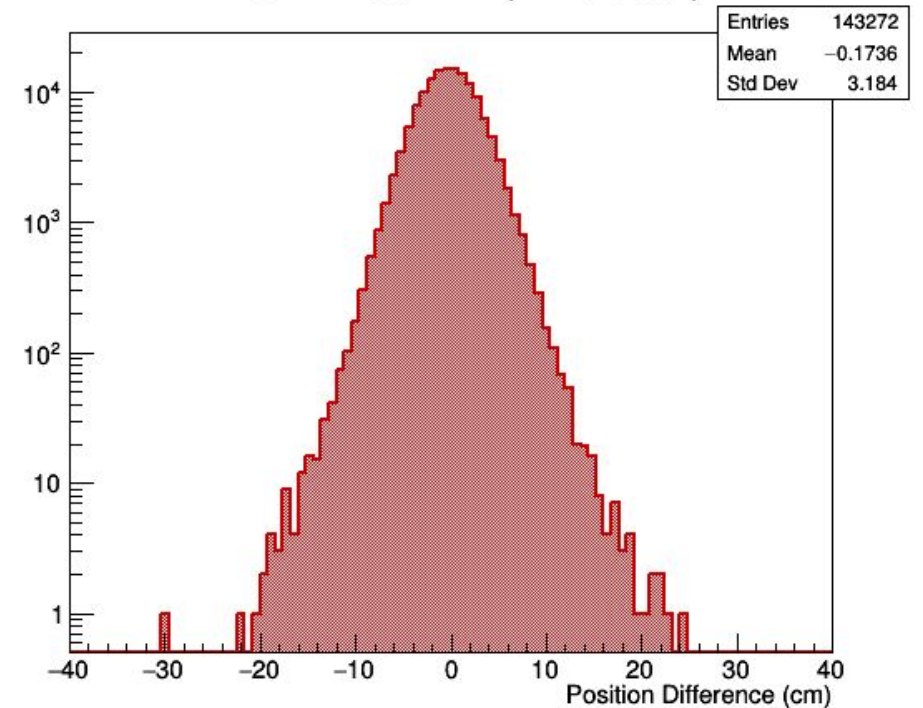
Efficiency for protons reduces faster due to higher threshold removing more and more of the minimum ionizing protons.

[Q1] HCal Spatial Resolution

HCal Spatial Resolution (4x4 cluster)



Kin07 - Proton ΔX (4x4 cluster)



Used g4sbs to compute expected nucleon position on HCal minus computed g4sbs position in 4x4 cluster

[Q2] Detector Inventory and Status

	Have[/Need/Diff]	Name	Location and/or Comments
	4	Sub-assemblies	TestLab
	16	HCal LED Fiber boxes	On HCal
*	4/8/-4	HCal LED Power boxes	4 in TestLab, 4 assembling at CMU
	2	Cosmic Paddles	Above HCal
*	192/196/+4	XP2262 PMTs (12-stage)	10 need greasing
	96/106/+10	XP2282 PMTs (8-stage)	On HCal
	1	Detector Stand & Mezzanine	On-site (maybe already in the Hall?)
	set	Floor plates	Hall A
	1	DC Power supply (~5 V)	In Test Lab (spares at CMU)
	1	HV NIM supply (positive voltage)	In Test Lab

* incomplete or needs attention

[Q2] Front End Electronics Inventory and Status

Have[/Need/Diff]	Name	Location and/or Comments
3	Racks	Test Lab
7	NIM Crates	Test Lab Racks
10	Patch Panels	Test Lab Racks
18	Splitter Panels	Test Lab Racks
18	PS 776 NIM Amps	Test Lab Racks
19	PS 706 Discriminators	Test Lab Racks
* 0/18/-18 channels	NIM Discriminator with remote controller	Should exist somewhere at JLab, need to find
* 0	DAC or other remotely controlled voltage source for above discriminators	Need to get from somewhere, either VME based DAQ or something else
18	16-channel Summing Modules	Test Lab Racks
* 0/4/-4	4 quad summing modules for "super cluster"	Need to determine if they are still needed

* incomplete or needs attention

[Q2] DAQ Inventory and Status

	Have[/Need/Diff]	Name	Location and/or Comments
	4	Racks	Test Lab, DAQ (PP,VXS,computer) + HV
	2	VXS crates (with CPU + TI)	Test Lab racks
	2	LeCroy HV crates with RPi controller	Test Lab racks
	300/292/+8	LeCroy HV channels (25 cards total)	Test Lab racks
*	18/19/-1 [†]	FADC	Test Lab racks, missing 1 for reference signal
	5	F1TDC	Test Lab racks
	2	FADC SD	Test Lab racks
	1	F1TDC SD	Test Lab racks
	2	VTP	Test lab racks
	1	“DVCS” Pulser	Test Lab racks
*	??	Need 9 ethernet plugs for 2x (Crate + ROC + VTP + HV) + 1x for Computer	Have sufficient at Test Lab via 2 unmanaged switches. Are we taking these to the hall?

* incomplete or needs attention experiments

[†] Will need an additional FADC to verify threshold on summing modules for future

[Q2] Cable Inventory and Status

	Have[/Need/Diff]	Name	Location and/or Comments
	288	100 m RG58 for FADC	Test Lab
*	"288"	100 m RG58 for TDC	BigBite & ECal have them, we need to swap with the 300x 50 m cables we have in the Test Lab. Scott coordinating with Mark.
*	12/28/-16 [†]	100 m RG58 for Summing modules + cosmic paddles + LED pulse,data & clock signal	Missing 16x cables for this [†]
*	13	75 m HV multi-core cables (RG59?) 24 channels each	Test Lab mounted on HCal. One box needs to be mounted so that it can be used for cosmic paddles.
*	0/1/-1	BB Trigger Cables (as short & fast as feasible)	Need to secure
	288	12 m PMT - Amp cables	Test Lab between detector and racks.
	288x many	miscellaneous cables (< 3m) that connect between amp and splitters, discriminators, F1s, etc..	Test Lab there is sufficient "small" varying length cables to connect all needed channels

* incomplete or needs attention [†] If we don't use the FADCs for the summing modules, then we actually wouldn't need 18 of these cables.

[Q3] Personnel: Active HCal Working Group

Note, FTEs listed below are for the pre-beam period. Not listed are personnel working on dependencies.

Scott Barcus	JLab	Postdoc	≥75% FTE	On-site
Vanessa Brio	Catania	Grad Student	≥50% FTE	Remote ¹
Juan Carlos Cornejo	CMU	Postdoc	≥50% FTE	Remote ¹
Donald Jones	Temple	Research Professor	<25% FTE	On-site
Jim Napolitano	Temple	Professor	<25% FTE	Remote
Sebastian Seeds	UConn	Grad Student	≥50% FTE	On-site
Brian Quinn	CMU	Professor	<25% FTE	Remote ²
Bogdan Wojtsekhowski	JLab	Staff Scientist	<25% FTE	On-site

1. Available to travel to support the move or “installation,” but this is dependent on any covid related travel restrictions.

2. On-site sabbatical in “Fall.”

[Q4] Preparations for Moving HCal to the Hall

Pre-move tasklist (more details provided later in talk)

- Re-grease remaining ~10 PMTs 2 FTE Days - Scott
- De-cable TestLab setup 5 FTE Days - Scott
- Assemble and mount remaining LED Power boxes 5 FTE Days - Brian

Timeline (approximate, dependent on Jessie's schedule)

- Two weeks prior to move: begin de-cabling process.
- Late March/early April: HCal moves to the hall.
- April to Mid May: Expect no access to HCal (~5 weeks).

Does equipment need to be moved in a certain sequence?

- No special sequence requested by HCal group for move, assembly of the four sub-assemblies **does require a specific stacking order.**

[Q5] HCal Preparations in the Hall for Beam

Re-cable HCal*

15-18 FTE Days - Scott

Thread long signal and HV cables from HCal Mezzanine to DAQ hut: [Scott, Sebastian, Vanessa, Juan Carlos - 72 hours]

DAQ side: Connect HV on DAQ area (mount HV cable boxes and connect short HV cables): [1 person - 6 hours]

DAQ side: Connect short signal cables from patch panel to FADC/TDC [1 person - 12 hours]

DAQ side: Connect cables from FADC to patch panel [1 person - 8 hours]

FE side: Connect 12 m cables from Amp to HCal [1 person - 24 hours]

If these can remain connected during the move, it won't be needed. However, in case it is needed:

FE side: Connect small cables from Amp to splitters, from splitters to Disc and Summing Modules [1 persons - 24 hours]

Time & Sync all trigger lines (BB trig, HCal trig, Cosmics, LED)

Grad student

Acquire and distribute clean air to each PMT.

Scott/Juan Carlos

Full scope not yet defined, missing: distribution system with splitters and tubing.

Power distribution to HCal Mezzanine (Front End Electronics)

Jack will be our point of contact.

* Both covid social distancing guidelines, as well as guidelines for prevention of repetitive work injuries were taken into consideration when estimating the time required for completion of these tasks.

[Q6] HCal Commissioning and Calibrations with Beam

The following items are not listed in any particular chronological order.

- Verify HV settings are adequate for expected proton & neutron signal
 - Can compare against calibrated HV curves from Cosmics in the TestLab and/or Hall.
- Measure proton detection efficiency via $H(e,e')p$.
 - Will be performed for each Q^2 in GMn.
 - Efficiency defined as ratio of detected electrons with and without found proton.
- Measure neutron detection efficiency via $p(\gamma,\pi^+)n$ with π^+ detected by LHRS and look for corresponding neutron on HCal.
 - Will not be able to illuminate full acceptance range of HCal due to smaller overall acceptance of the LHRS.

[Q6] HCal Software and Event Displays

- Decoding done with SBS-Offline and Hall A Analyzer [Juan Carlos]
 - Already mature and actively used in Test Lab setup with cosmics and LEDs
 - Extending capabilities collaborative effort with BigBite Shower group
 - HCal will have specific decoding/processing of LEDs [Juan Carlos]
- Replay script components
 - HCal [Juan Carlos et al]
 - LHRS [Bob et al]
 - BigBite [BigBite group]
- HV curve calibration script [Sebastian]
- LED/gain online monitoring [Vanessa]

[Q6] HCal Software and Event Displays

- Event Displays and Online Monitoring [Juan Carlos/Scott]
 - Expect to have general HCal health checks, including: “heat map image” showing average detector signal, rates, waveform, reconstructed time, pedestal, reconstructed positions of clusters, etc....
 - Capability to step event-by-event.
- Slow Controls [Scott]
 - HV reconfiguration can be done more efficiently without GUI.
 - Monitoring HV similar to how Hall C does it.

[Q7] Documentation

- Operation Manuals and Instructions
 - <https://sbs.jlab.org/cgi-bin/DocDB/private/ShowDocument?docid=70> [Scott]
 - Operational restrictions for detector [Gregg Franklin original author → Juan Carlos to take over]
 - <https://sbs.jlab.org/cgi-bin/DocDB/private/ShowDocument?docid=71>
 - Missing: LED safety information → will be added soon
- Shift Worker How-tos [who will take the lead?]
 - DAQ operation/configuration documentation [Juan Carlos]
 - LED operation [Juan Carlos]
 - Replay/Online monitoring instructions [Scott]
 - HV operations [Scott]
- Interactive Documentation [Scott]

[Q7] “Interactive Documentation”

```
(base) skbarcus@Neuromancer:~/JLab/SBS/HCal/Schematics/My_Maps/GUI$ python HCal_GUI.py
PMT Module 1 : amplifier channel = b6-01 , fADC channel = f6-00 , HV channel = L6.0
PMT Module 2 : amplifier channel = b6-03 , fADC channel = f6-02 , HV channel = L7.0
PMT Module 3 : amplifier channel = b6-05 , fADC channel = f6-04 , HV channel = L6.1
PMT Module 4 : amplifier channel = b6-07 , fADC channel = f6-06 , HV channel = L7.1
PMT Module 5 : amplifier channel = b6-09 , fADC channel = f6-08 , HV channel = L8.0
PMT Module 6 : amplifier channel = b6-11 , fADC channel = f6-10 , HV channel = L9.0
PMT Module 7 : amplifier channel = b6-02 , fADC channel = f6-01 , HV channel = L8.1
PMT Module 8 : amplifier channel = b6-04 , fADC channel = f6-03 , HV channel = L9.1
PMT Module 9 : amplifier channel = b6-06 , fADC channel = f6-05 , HV channel = L10.0
PMT Module 10 : amplifier channel = b6-08 , fADC channel = f6-07 , HV channel = L11.0
PMT Module 11 : amplifier channel = b6-10 , fADC channel = f6-09 , HV channel = L10.1
PMT Module 12 : amplifier channel = b6-12 , fADC channel = f6-11 , HV channel = L11.1
PMT Module 13 : amplifier channel = b4-13 , fADC channel = f4-12 , HV channel = L6.2
PMT Module 14 : amplifier channel = b4-15 , fADC channel = f4-14 , HV channel = L7.2
PMT Module 15 : amplifier channel = b5-13 , fADC channel = f5-12 , HV channel = L6.3
PMT Module 16 : amplifier channel = b5-15 , fADC channel = f5-14 , HV channel = L7.3
PMT Module 17 : amplifier channel = b6-13 , fADC channel = f6-12 , HV channel = L8.2
PMT Module 18 : amplifier channel = b6-15 , fADC channel = f6-14 , HV channel = L9.2
PMT Module 19 : amplifier channel = b4-14 , fADC channel = f4-13 , HV channel = L8.3
PMT Module 20 : amplifier channel = b4-16 , fADC channel = f4-15 , HV channel = L9.3
PMT Module 21 : amplifier channel = b5-14 , fADC channel = f5-13 , HV channel = L10.2
```

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132
133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204
205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228
229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272	273	274	275	276
277	278	279	280	281	282	283	284	285	286	287	288

Scott made a GUI to easily find details on any module.

PDF with details on each connection exists, but GUI is more convenient.

Thanks to all who helped with HCal possible

Gregg Franklin for the many years he worked on design, development and managing the construction of HCal. Thanks to **INFN/Università degli Studi Di Catania** for their major financial funding of HCal (40%) as well as a significant time and personnel contributions from the following **Vanessa Brio, Vincenzo Bellini, Cattia Petta, Leonard Re, Cettina Sutura, Francesco Tortorici**. Thanks to the many institutions involved including, but not limited to, CMU, INFN/Catania, JLab.

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Finally, thanks to the Hall A Technicians and JLab engineers and everyone else who has contributed in the past.

On behalf of the active HCal group: S. Barcus, **V. Brio (grad student)**, J.C. Cornejo, D. Jones, J. Napolitano, **S. Seeds (grad student)**, B. Quinn, B. Wojtsekhowski