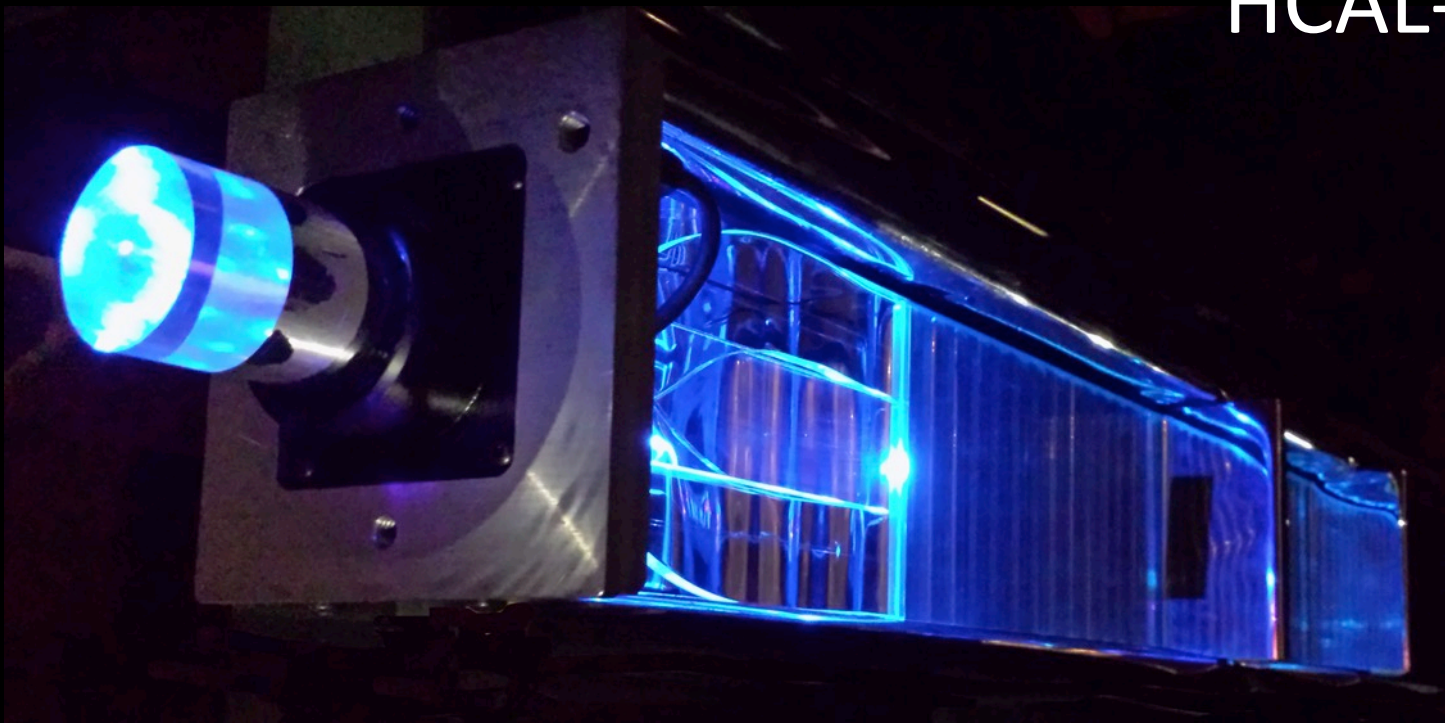


HCAL-J Status

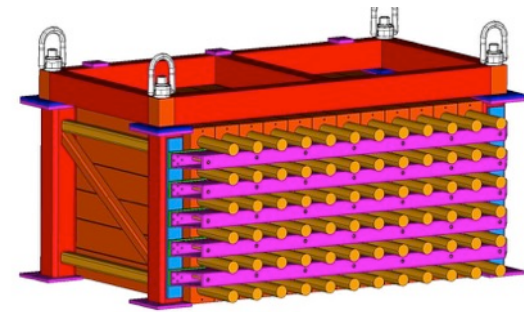
G.B. Franklin
Carnegie Mellon
June, 2017



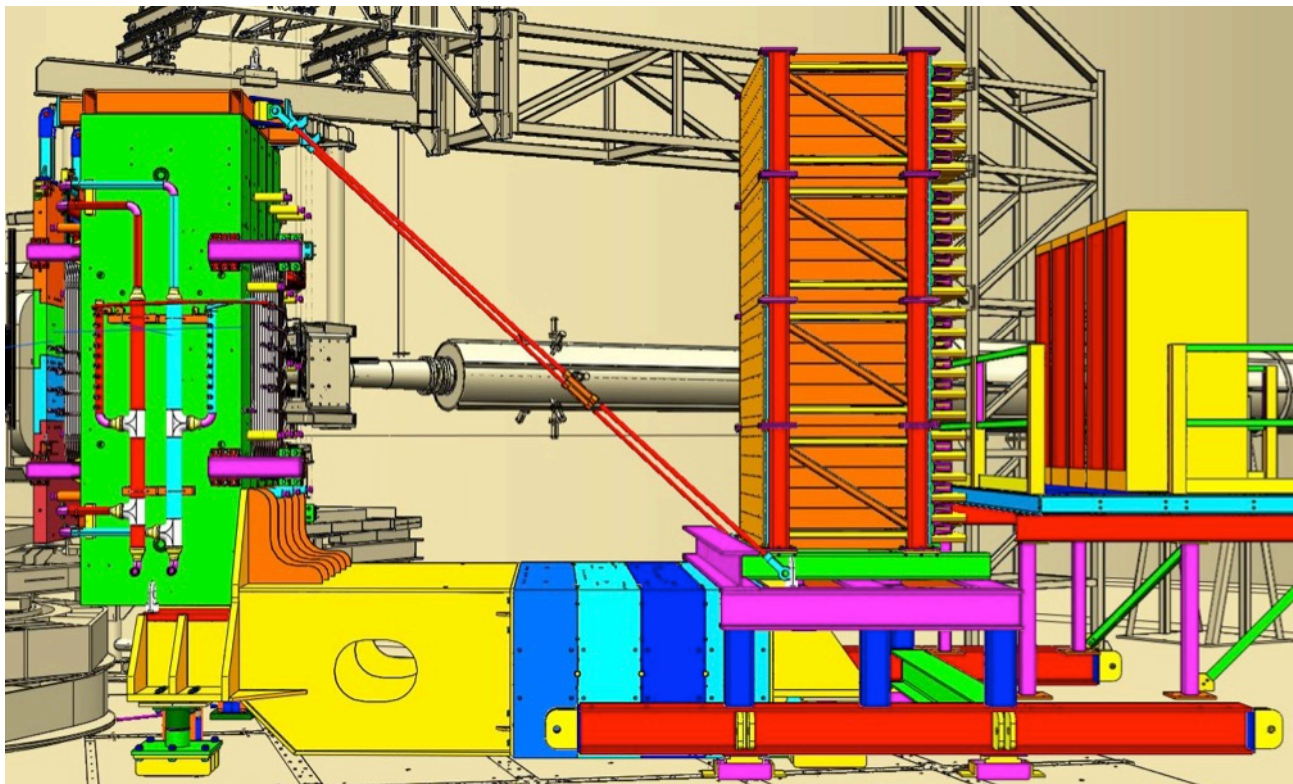
1. Design and Performance Issues
2. Module Construction (completed)
3. Ongoing/future work

HCAL-J Components

- HCAL-J array: 12 modules x 24 modules
(288 modules, 6 ft x 12 ft. ~40 tons)
- 4 crane-able subassemblies
- Docks with cable-gantry/electronics mezzanine
- Sits on HCAL-J Stand



Sub-assembly
(lifting frame attached)



Performance Requirements

Energy Resolution:

- 95% efficiency with trigger threshold at 25% of avg signal

Spacial Resolution:

- 5 cm rms

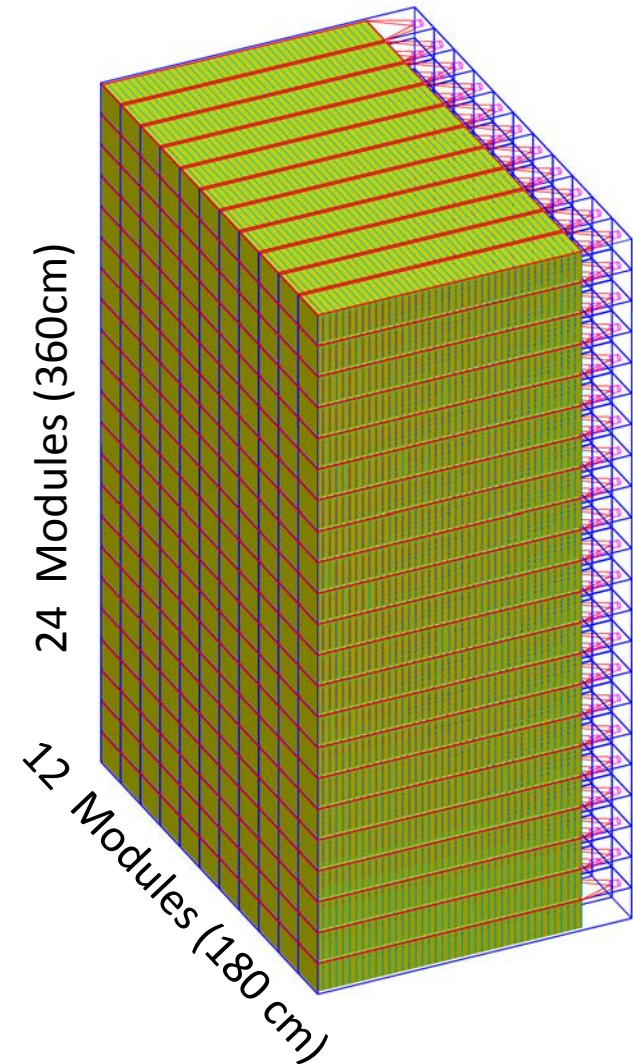
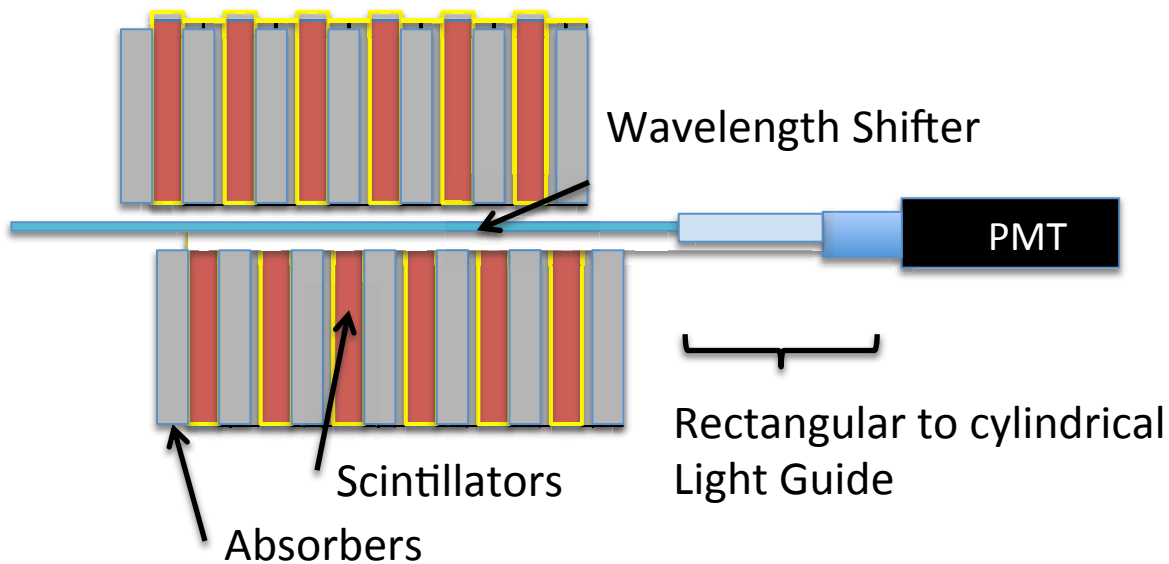
Timing:

- TOF used to cut out inelastics
- 1.0 ns rms time resolution -> 80% trigger efficiency for GEN
- Acceptable, but <1.0 ns preferred
- Goal: time resolution closer to 0.5 ns rms.

HCAL-J Design

Modular Design:

- 15 cm x 15 cm x ~ 1m modules
- 40 layers scintillator and iron per module
- 288 Modules (39 tons)

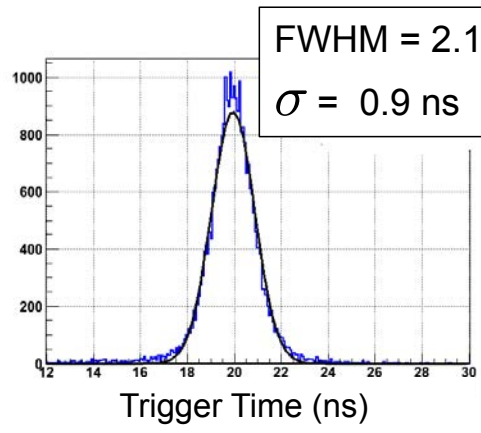
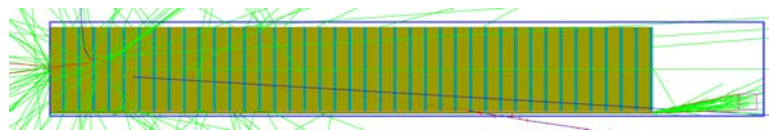


HCAL-J concept is based on COMPASS HCAL1, but...

- Faster scintillator and wavelength shifter
- Wavelength shifter moved to center
- 2 inch PMTs faster, better quantum efficiency

288 modules for JLab HCAL

Geant4 Timing Simulations



Simulation using COMPASS parameters

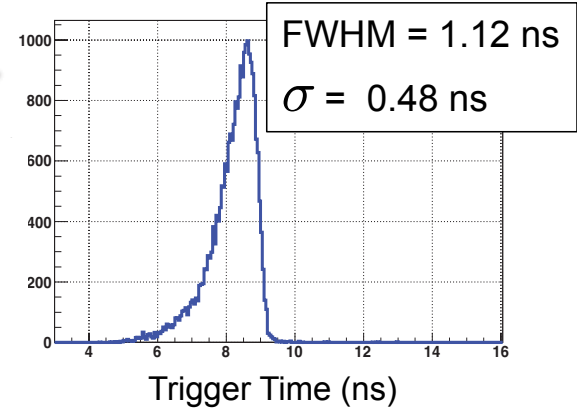
Agrees with published COMPASS HCAL performance



Waveshifter decay time
8 ns \rightarrow 3.5 ns

PMT rise time
10 ns \rightarrow 2.5 ns

Maximize N_{pe}
0.5 \rightarrow 1.0 cm scint.



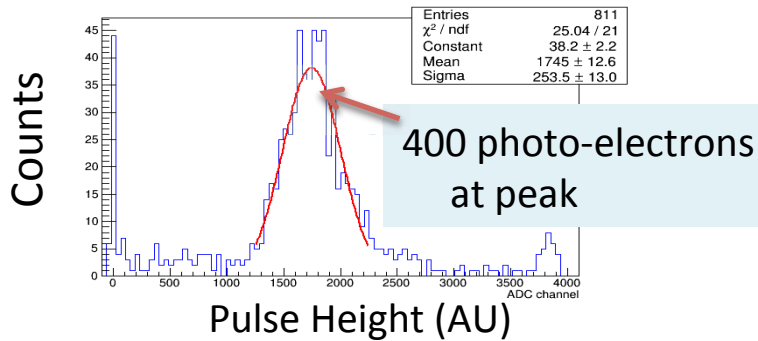
Simulation using faster waveshifter dye and PMTs

Meets SBS requirements

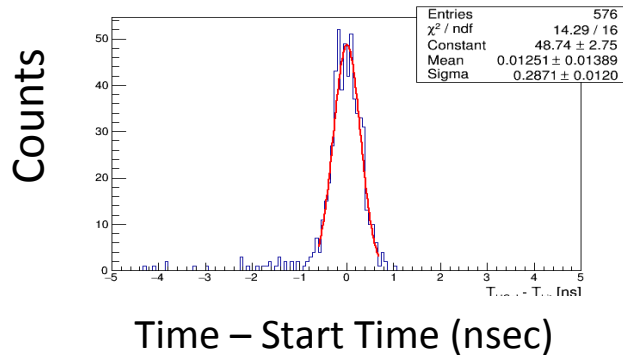
To be confirmed with prototype HCAL module

HCAL-J Performance

- March 2014 Prototype #4 Cosmic Ray Test
- Achieved **277 ps** resolution for cosmics (Predicted < 300 ps)



Improved light guide: Yields x2 photoelectrons



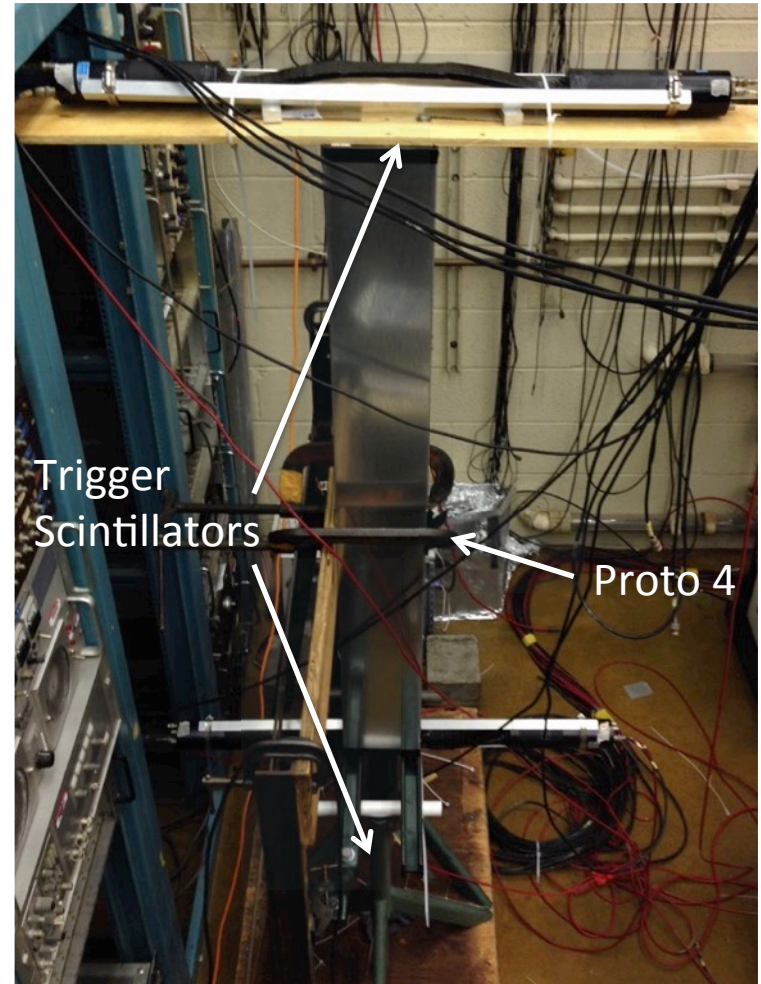
277 ps rms time resolution

Implication for 2.7 GeV Neutrons

1.65 ns (COMPASS design)

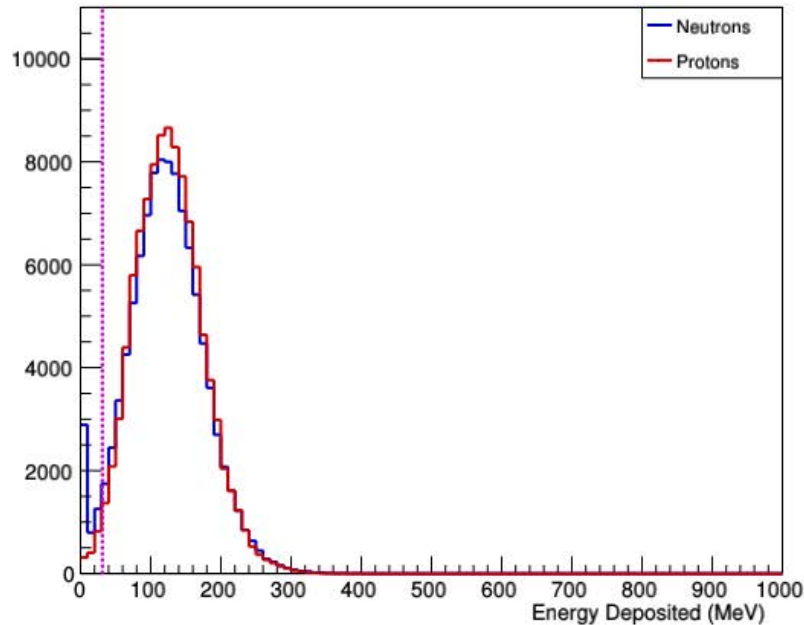


0.75 ns (CMU design)

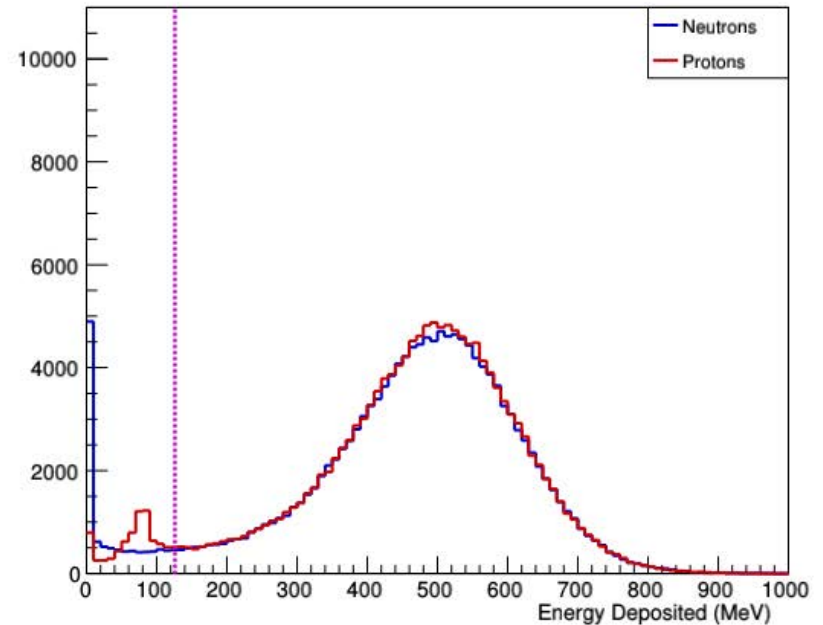


Geant4 Energy Resolution Studies

P=2.64 GeV/c Energy Deposited (3x3 cluster, GMn acceptance)

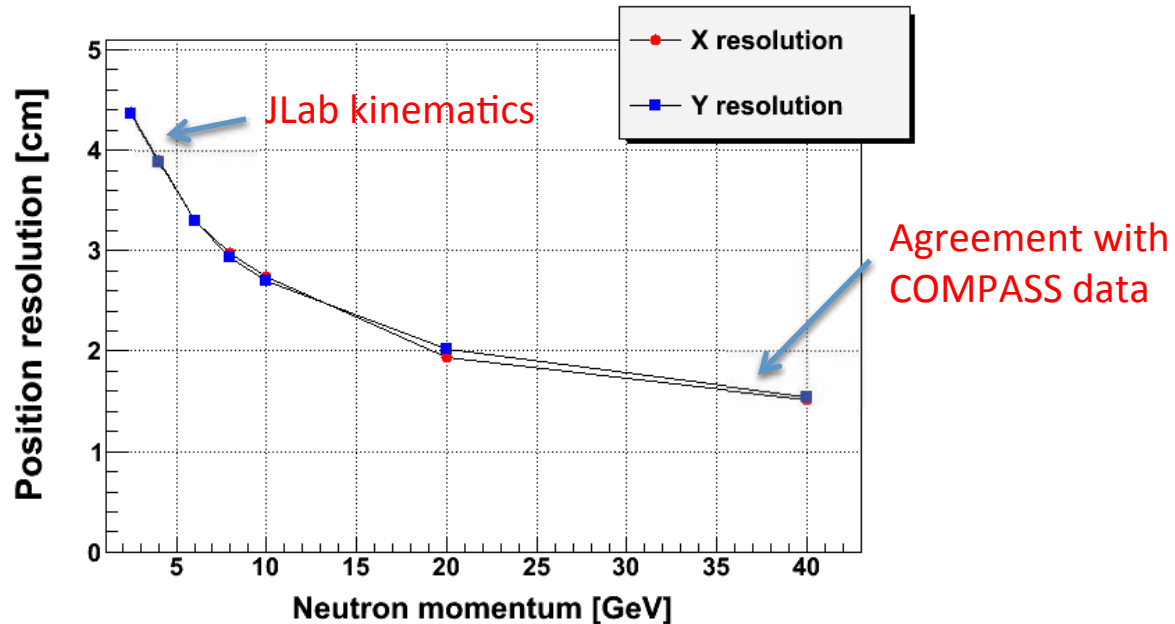


P=8.08 GeV/c Energy Deposited (3x3 cluster, GMn acceptance)



| | Energy | 2.5 GeV | 5.2 GeV | 7.3 GeV | 8.0 GeV |
|--|--------|---------|---------|---------|---------|
| Resolution: σ/E | | 48% | 31% | 27% | 22% |
| Efficiency at $\frac{1}{4}$ mean signal: Neutrons | | 95.1% | 94.5% | 93.6% | 93.2% |
| Efficiency at $\frac{1}{4}$ mean signal: Protons | | 98.4% | 97.1% | 95.2% | 94.8% |

Geant4 Spatial Resolution Results

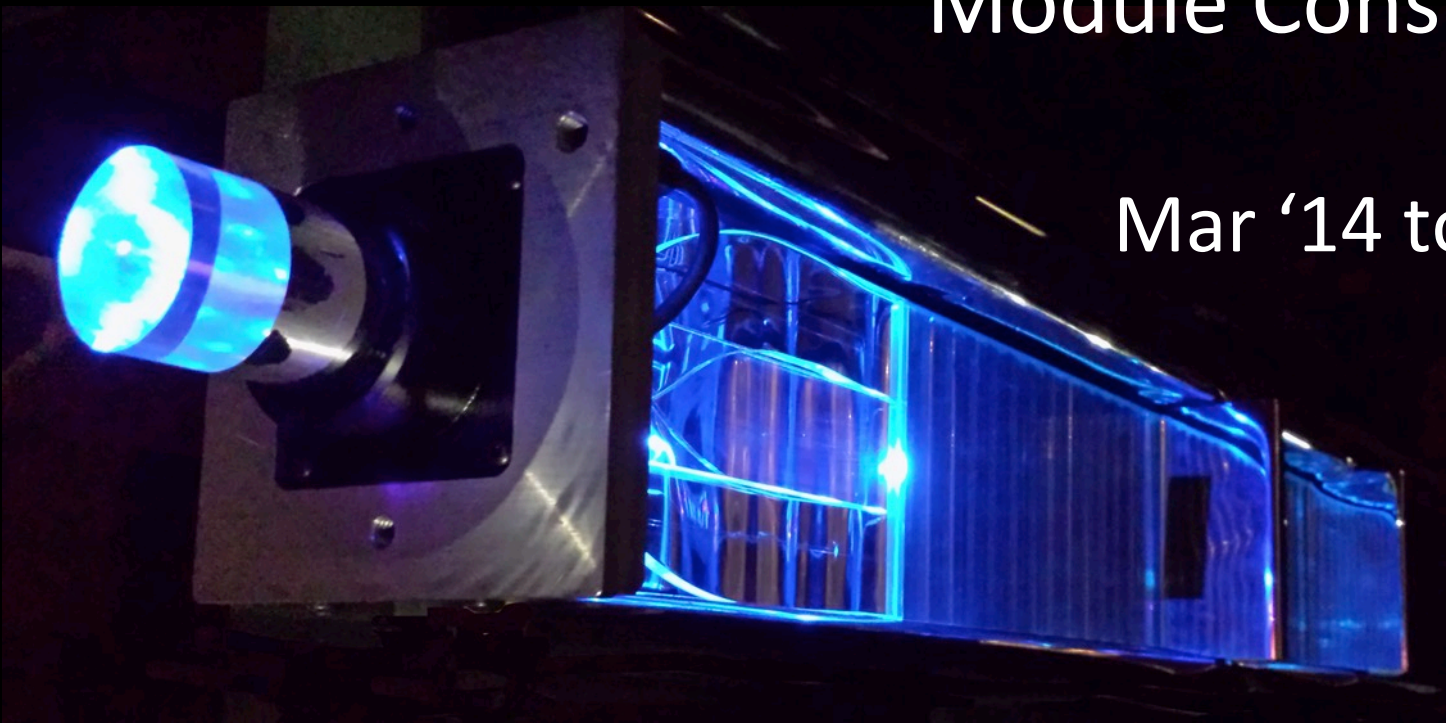


Achieves required angular resolution with HCAL positioned 17 m from target:

5 cm / 17 m → **3 mrad resolution**

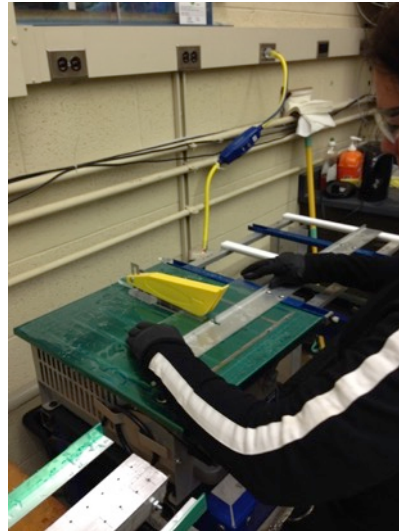
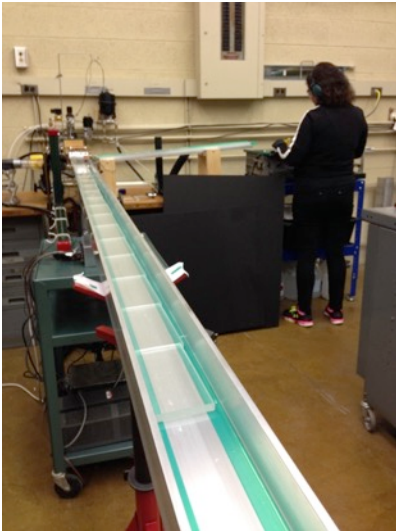
Module Construction

Mar '14 to May 17



24,000 scintillators

- Mar '14: FNAL delivers 3.6 km of custom extruded scintillator
- Aug '14: Custom saw and cleaning/drying system completed
- Dec '14 Completed cutting 24,000 scintillators

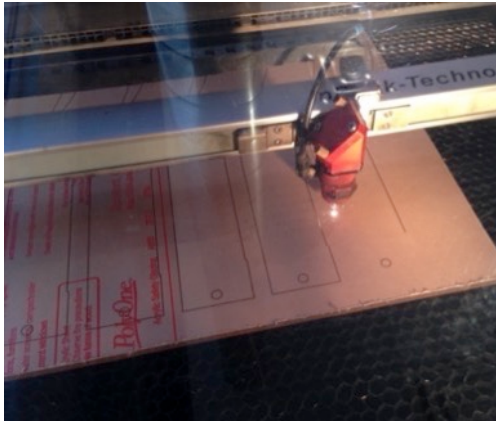


22,200 iron absorbers

- 24.4 tons
- Funded by JLab and INFN
- Manufactured by Astro Machine Works
- Oct '14: Completed



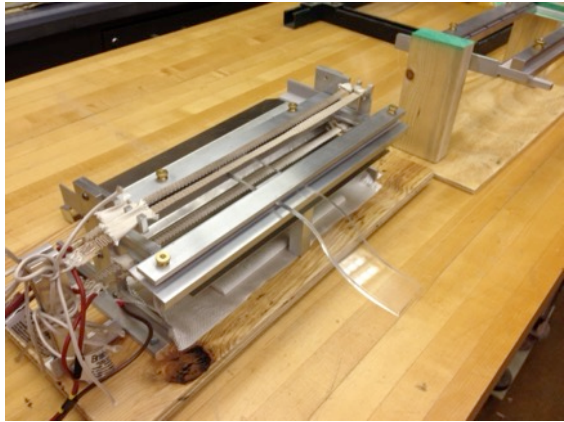
Novel Light Guide Production



Laser Cutting Dog Legs
90 seconds each



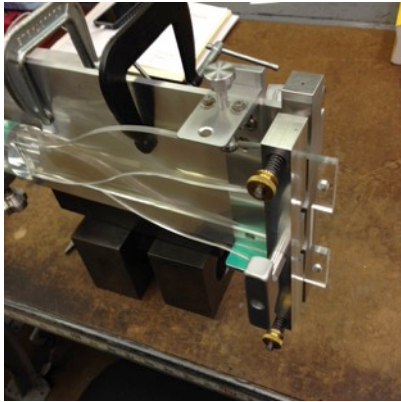
Oxy-hydrogen
Flame Polishing



Bending Jig
Radiant Heater



Milling



Gluing Jig
Solvent Welding

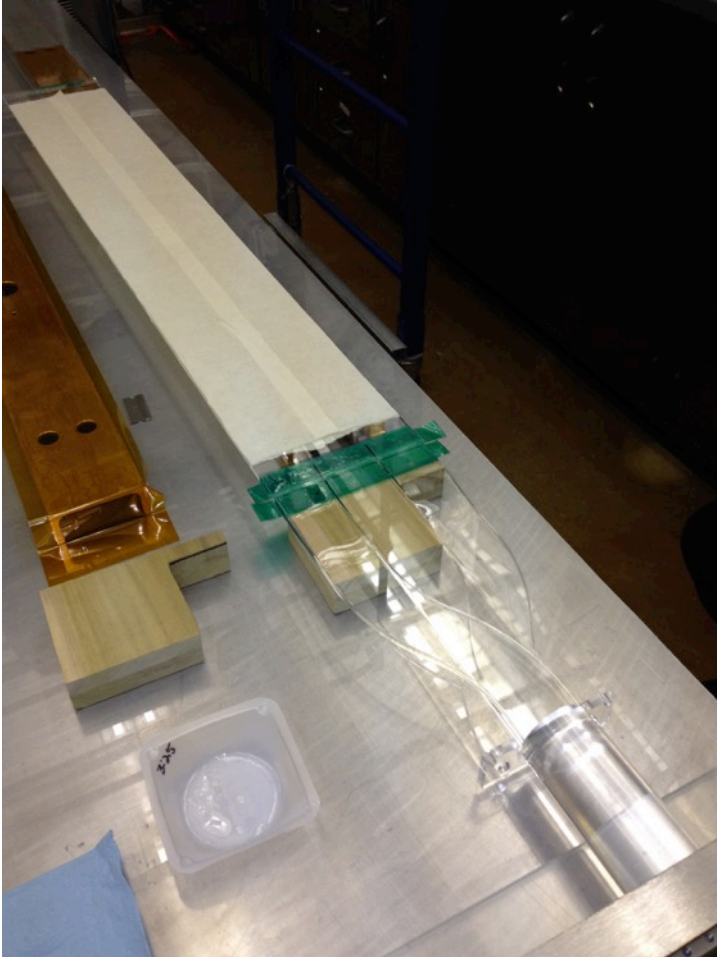


300 Light Guides



300 Light Guides Wavelength Shifters Glued to Light Guides

- St. Gobain BC-484 Wavelength Shifters purchased by INFN



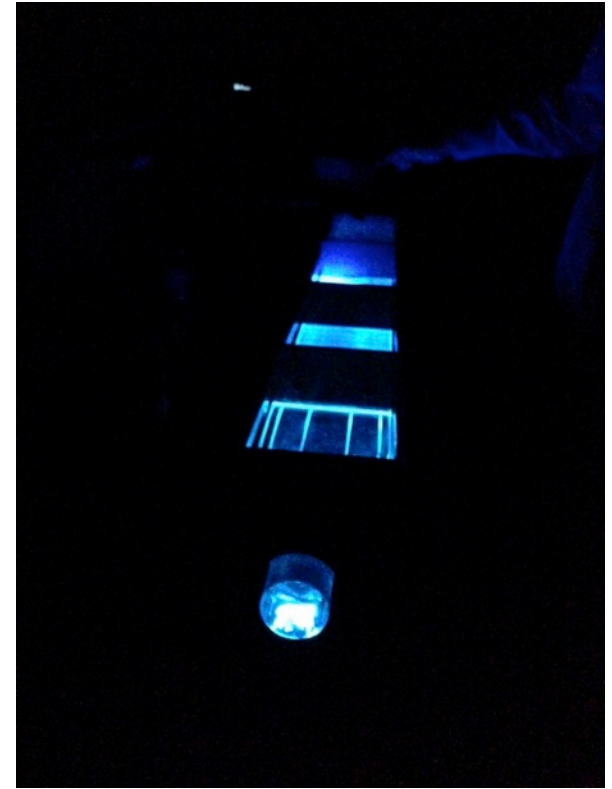
HCAL-J Module Assembly



Shell with ribs



Half-loaded Module



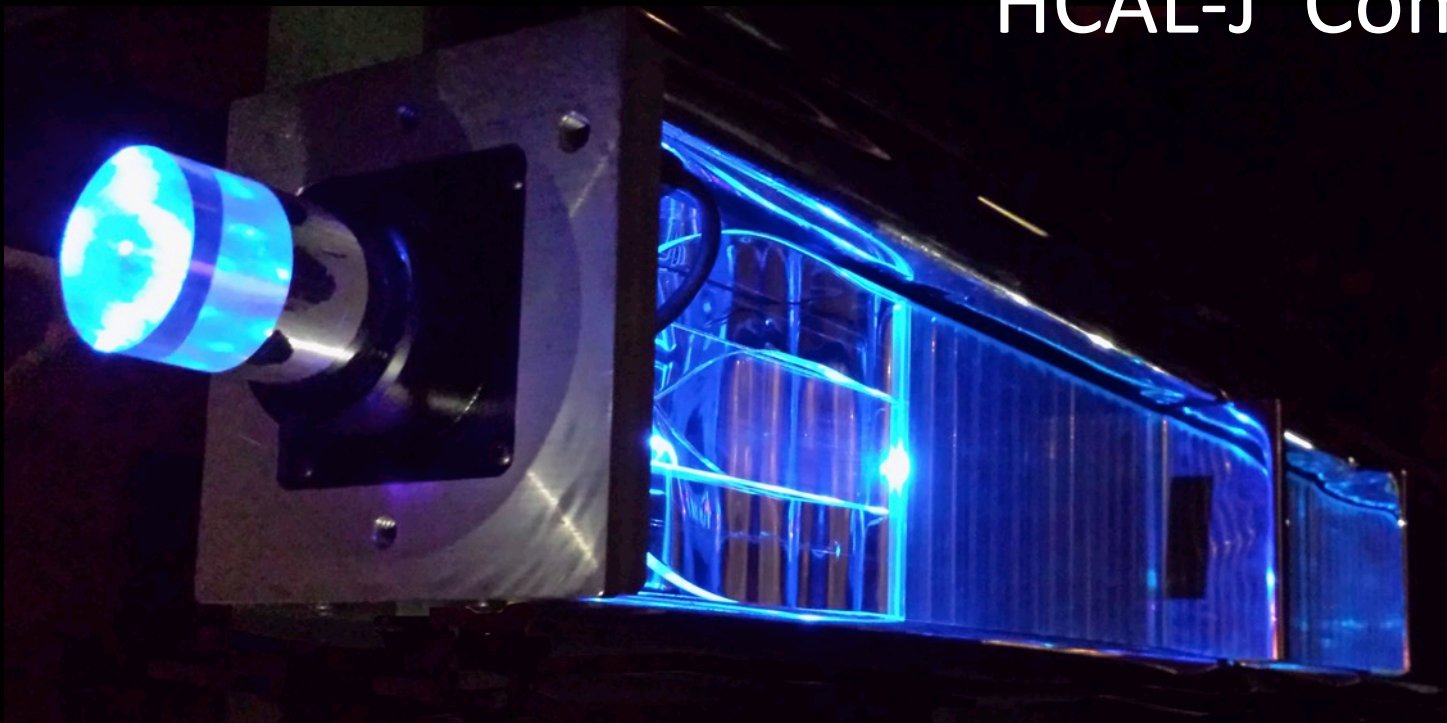
Half-loaded Module
lit with UV laser

HCAL-J Module Assembly

- **Module #290 Completed May 8th**



HCAL-J Completion



1. Subassembly
2. Cable Gantry and Stand
3. Electronics and Cabling

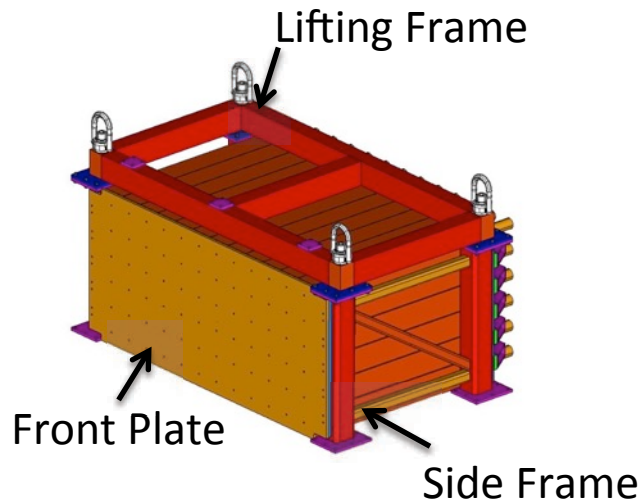
4 HCAL-J Craneable Subassemblies

- Structural components
- Lifting Hoist
- “U-pender”

Mini-subassembly tests at CMU

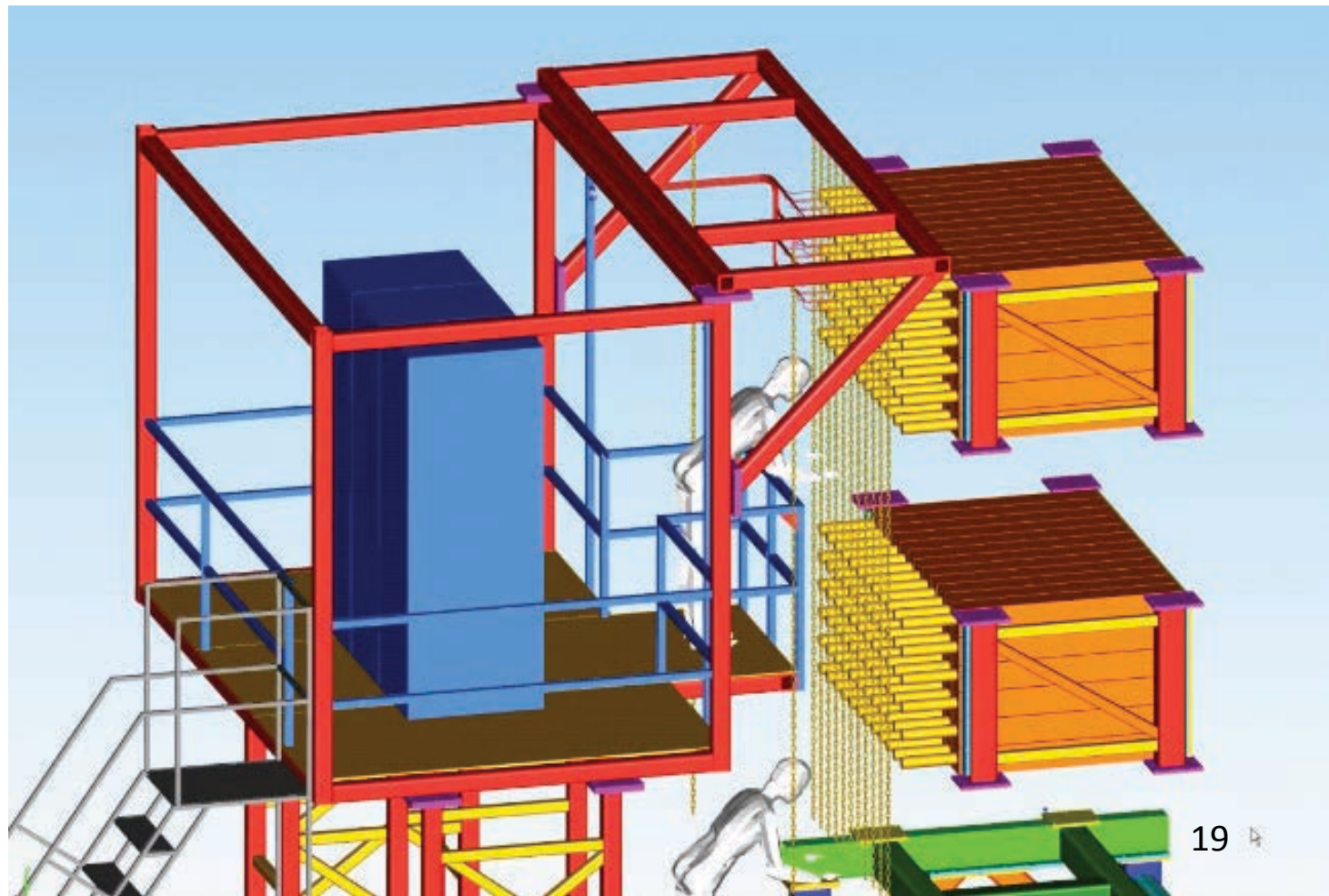
First full subassembly assembled July

- 2 weeks for 1st module
- 1 week each for next 3



Cable Gantry

- Preliminary design
- Vertical chains to support cabling
- Racks for amplification, signal splitting, and fast OR
- Designed for “fast” de-connection/connection of cables



Future Work

- | Task | Responsibility |
|---|------------------|
| • Summer 2017 at JLAB | |
| • Assemble 1 sub-assembly | (CMU/JLAB) |
| • Mock-up mini-cable gantry with unistrut | |
| • Need sub-assembly hoist and JLAB crane operator | |
| • Complete cable gantry design | (Jlab Engineers) |
| • Summer 2017 at CMU | |
| • Full prototype of pulser system | |
| • Full length cable attenuation tests | |
| • Purchase pulser components | |
| • Fall 2017 / Spring 2018 | |
| • Sub-assembly #1 cosmic commissioning | (CMU) |
| • JLAB PMT base assembly (need ~100) | (CMU) |
| • Assemble all subassemblies | (CMU/JLAB) |
| • Fabricate signal and HV patch-panels, etc. | (CMU) |
| • Stand and Cable Gantry construction | (JLAB) |
| • Fall 2018 | |
| • Continue cabling and tests | (CMU) |
| • Dec. 2018-- Ready | |