GlueX FCAL Upgrade
Lead Tungstate Calorimeter for JEF Experiment

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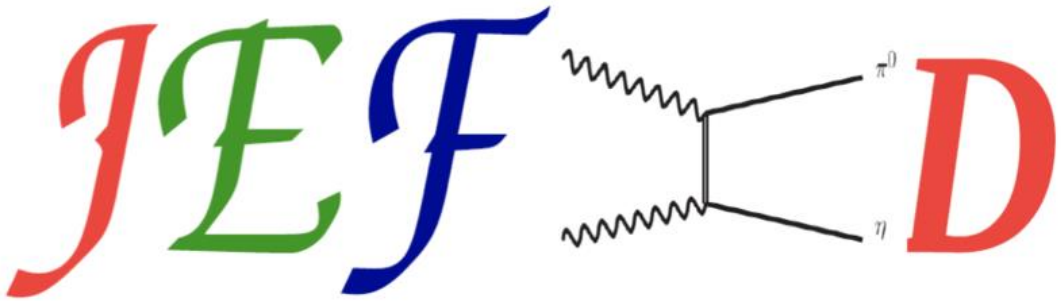
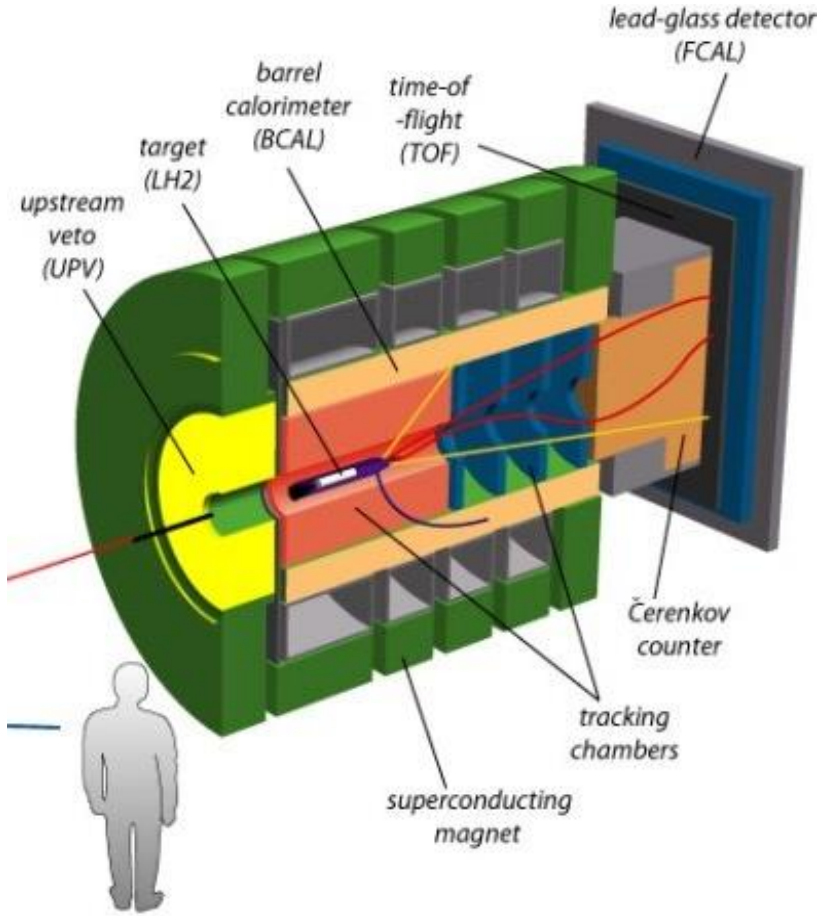
The Jefferson Eta Factory Experiment

- Goal: study decay modes of η/η’
  - Measure kinematics of more common η decays to learn more about quark masses
  - Measure kinematics of rare decays to constrain chiral perturbation theory models
  - Search for decays that violate conservation laws
  - Search for dark matter particles
- Final states all include π° and/or **γ**



The Jefferson Eta Factory Experiment

- Current challenges: inability to localize center/distinguish between EM showers from η decays



The Jefferson Eta Factory Experiment

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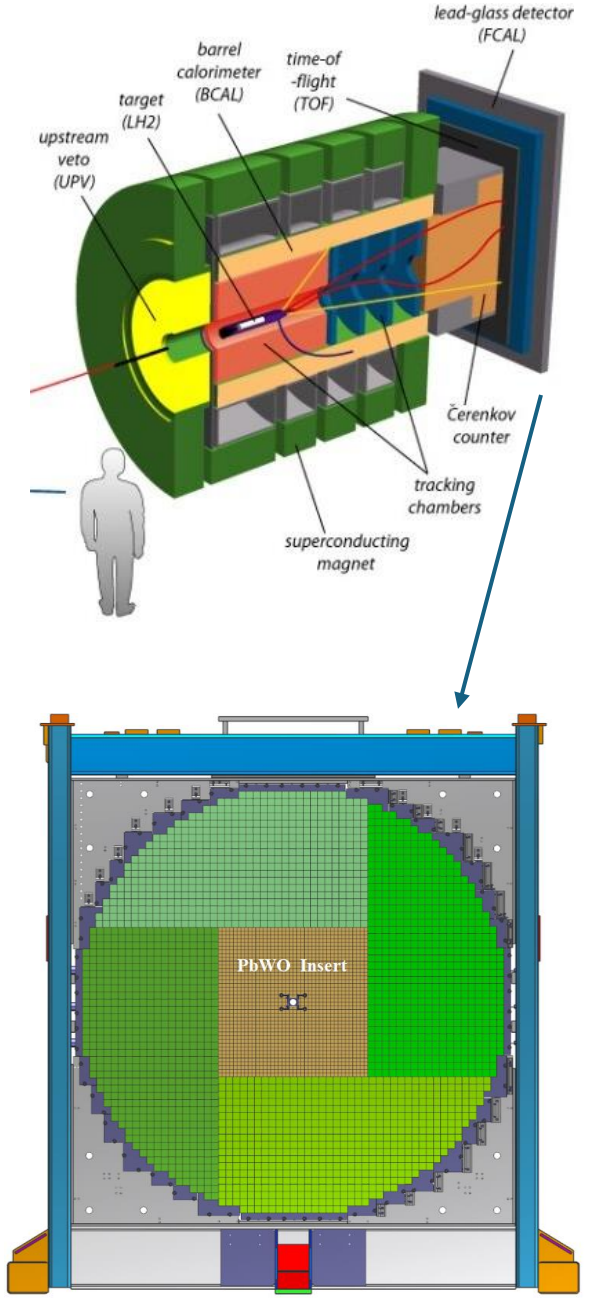
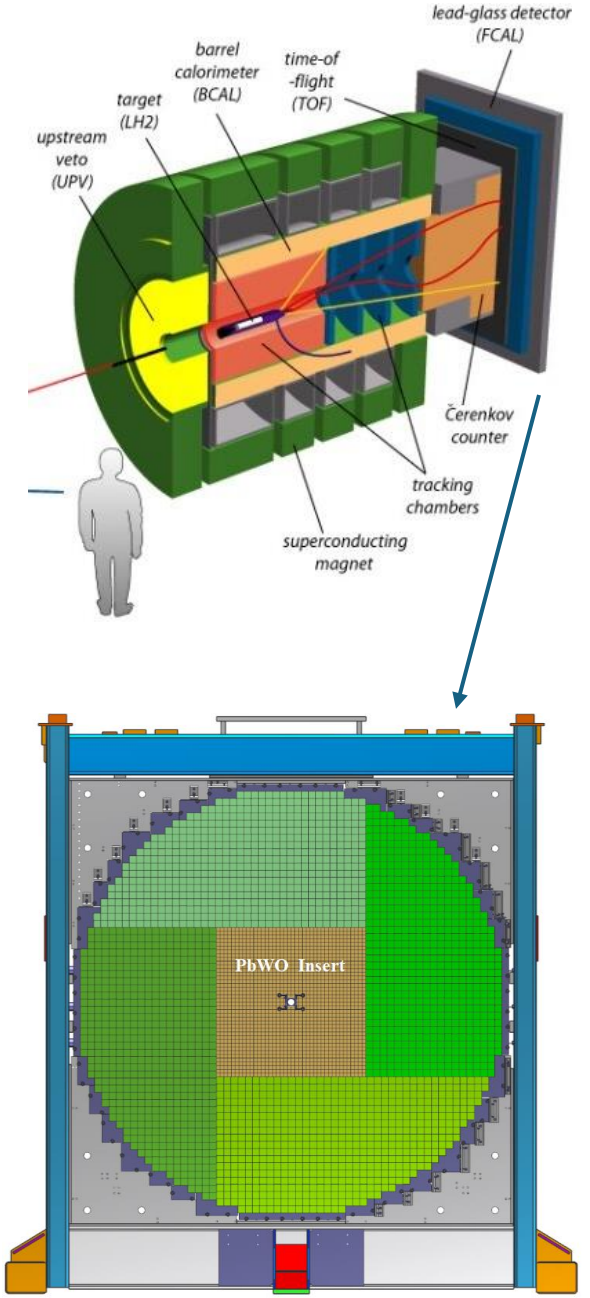
- What we need: improved granularity and resolution >> new eta calorimeter (ECAL) insert



The Jefferson Eta Factory Experiment

- Current challenges: inability to localize center/distinguish between EM showers from η decays
- What we need: improved granularity and resolution >> new eta calorimeter (ECAL) insert
- Proof of concept: successful prototype used in PrimEx-eta experiment



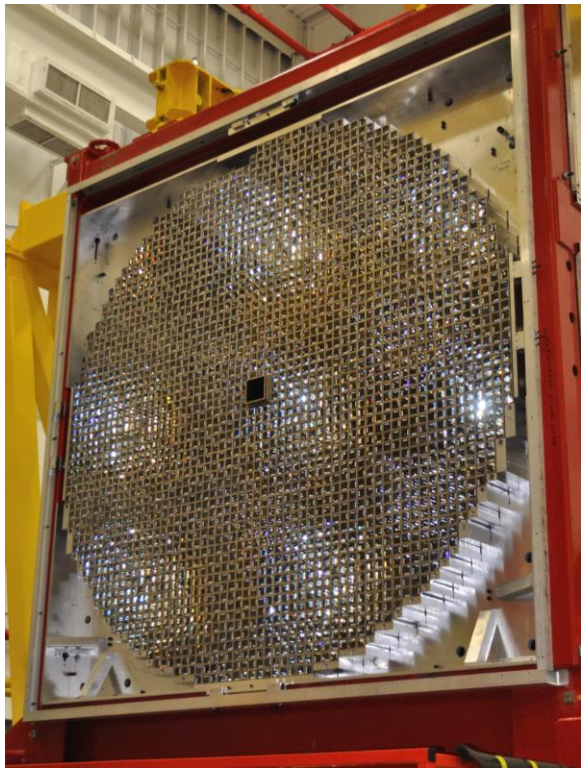

A
B
C

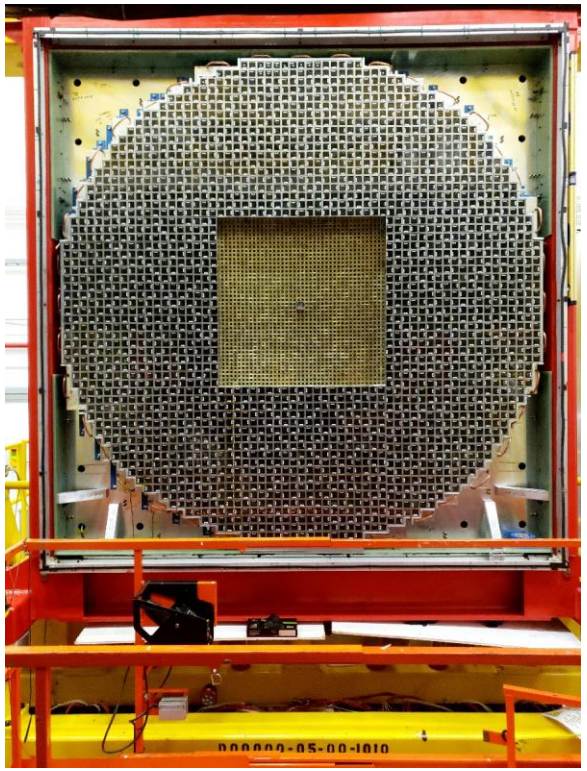
ECAL Insert

432 Pb-glass (4x4x40 cm^3) FCAL modules are replaced by 1596 $PbWO_4$ crystal (2x2x20cm^3) modules

The new ECAL modules will:

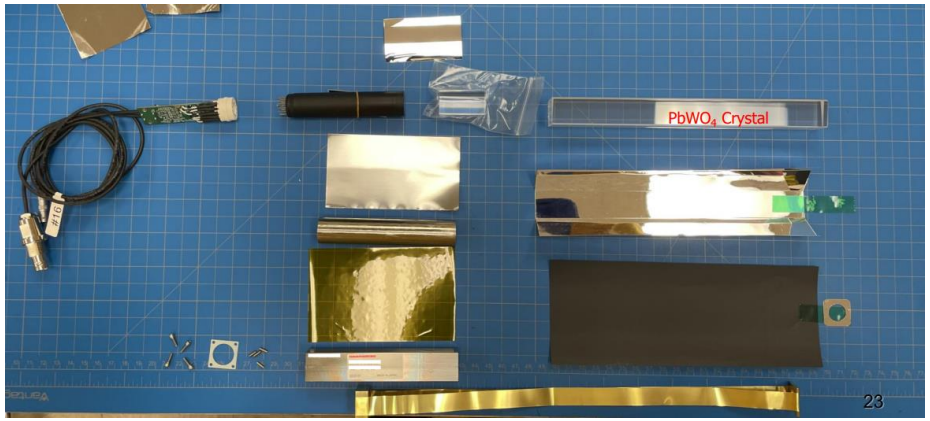
- Improve **energy** and **position resolutions** by a factor of **2**
- Improve **granularity** to reduce **shower overlaps** by a factor of **4**
- Improve **radiation resistance** by a factor of **10**

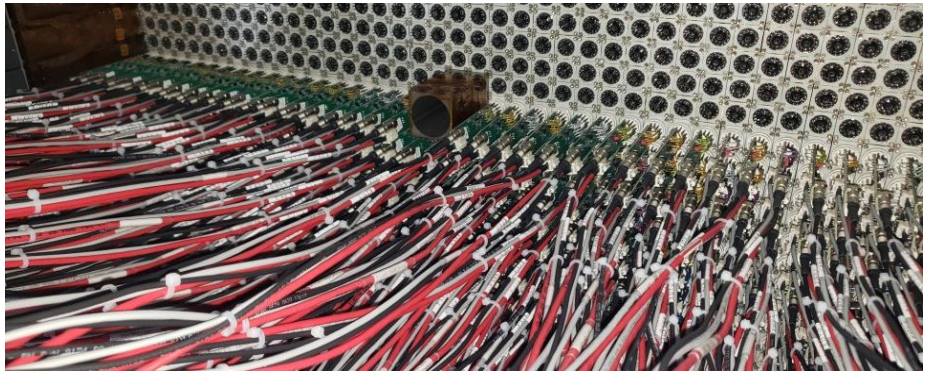




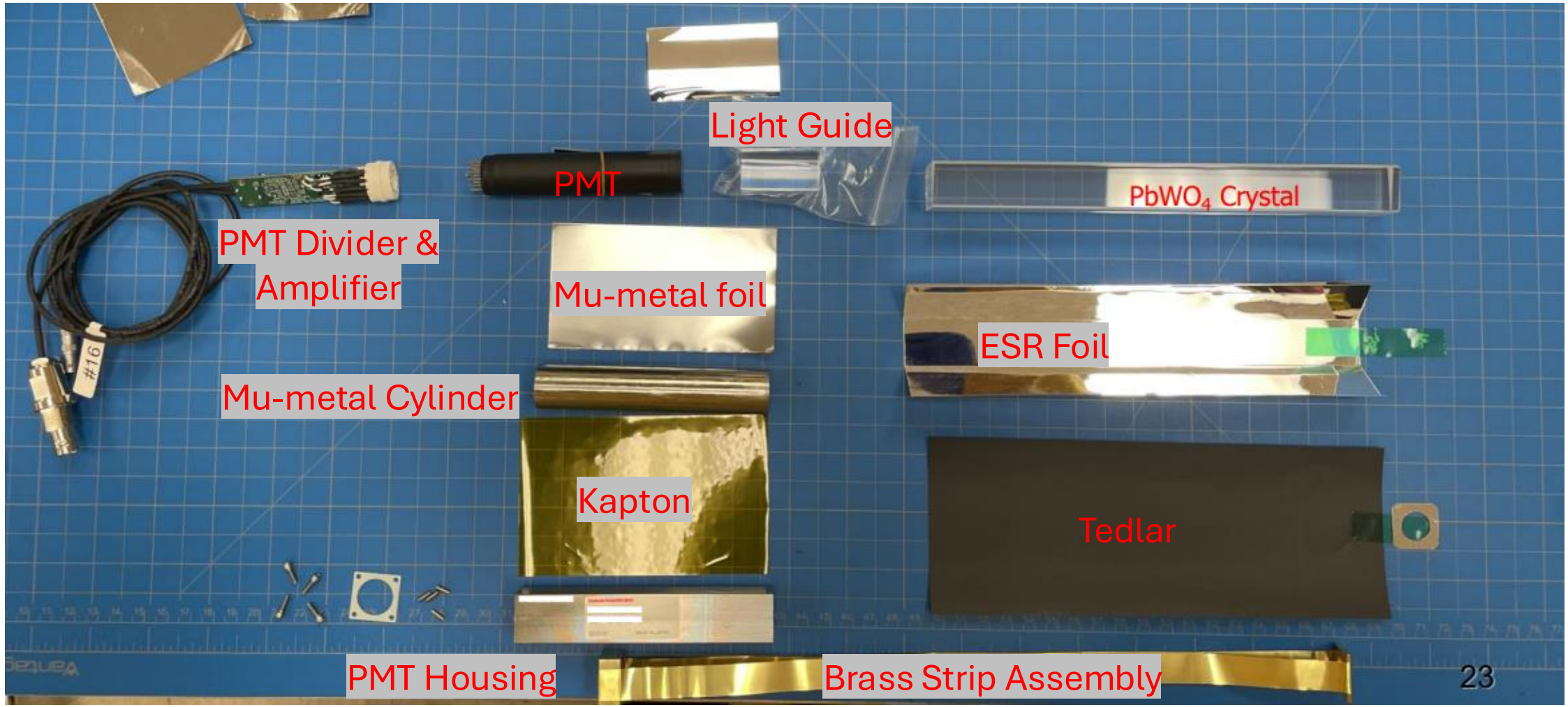
ECAL Modules

- Lead-tungstate ($PbWO_4$) crystals are scintillators – they convert ionizing radiation into light
- Photomultiplier Tubes (PMTs): devices that convert light into a measurable electric current
- The PMT housing and mu-metal foils will help reduce the effects of the external magnetic field on the PMT
- A high voltage divider is connected to **high voltage**, low voltage, and **signal** cables



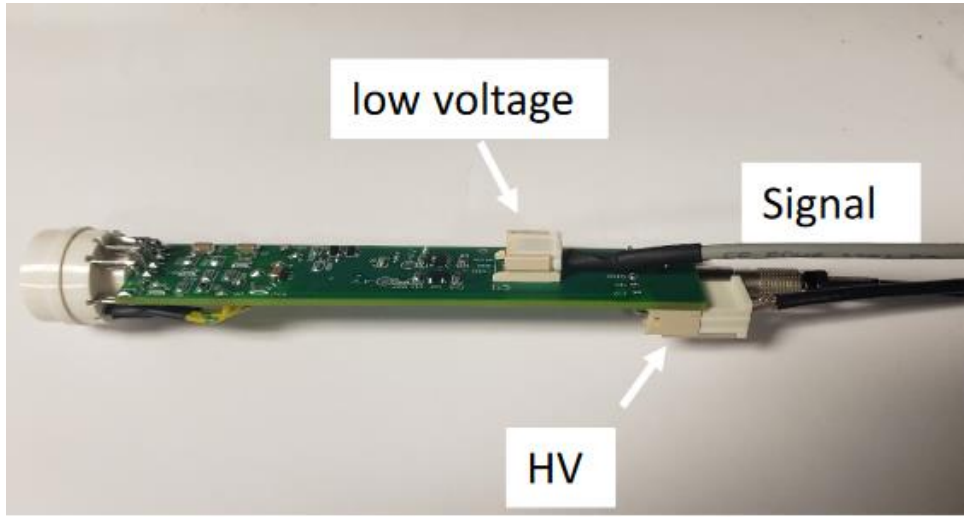


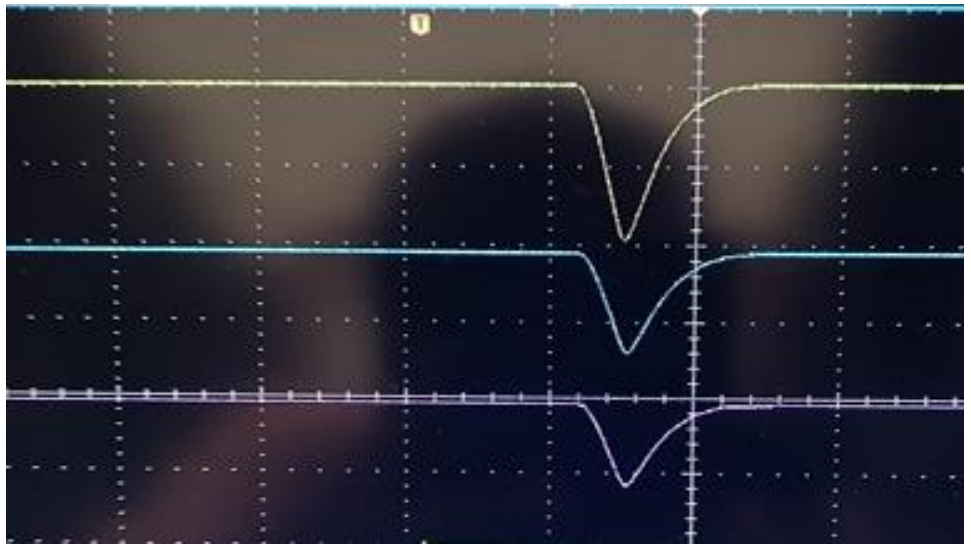
ECAL Modules - Build Your Own!



PMT Testing

- Each calorimeter module was tested using the Light Monitoring System (LMS):
    1. Activating an LED into the front of the module
    2. Recording and digitizing data
    3. Analyzing the signal via an oscilloscope
- Modules must be tested row by row to ensure consistent results across all 1596 output channels





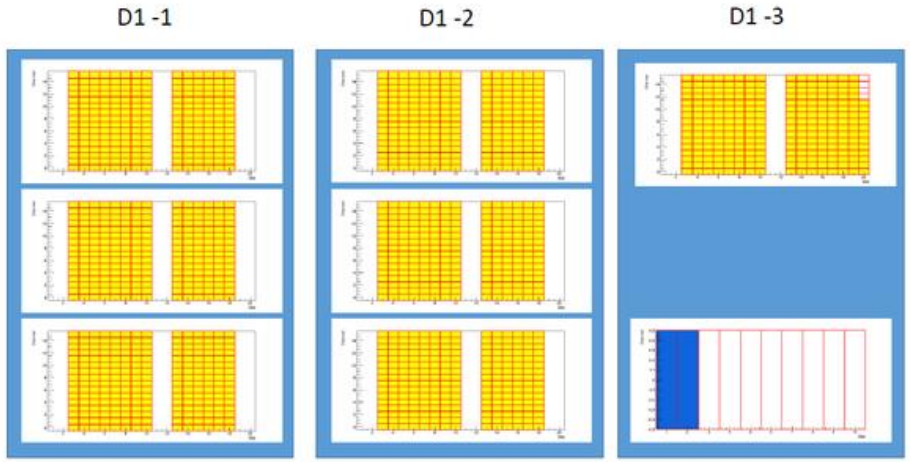
PMT Testing

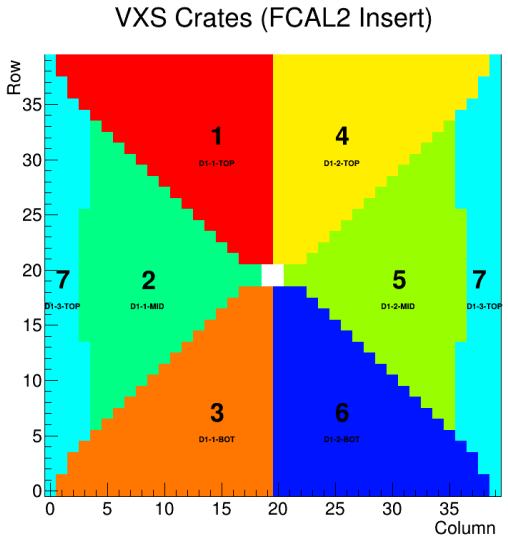
- All PMT testing was documented
- Common issues included:
  - Soldering defects
  - Component mix-ups (dividers, cables, etc.)
  - Broken connectors
- Some outliers remain – but within reason

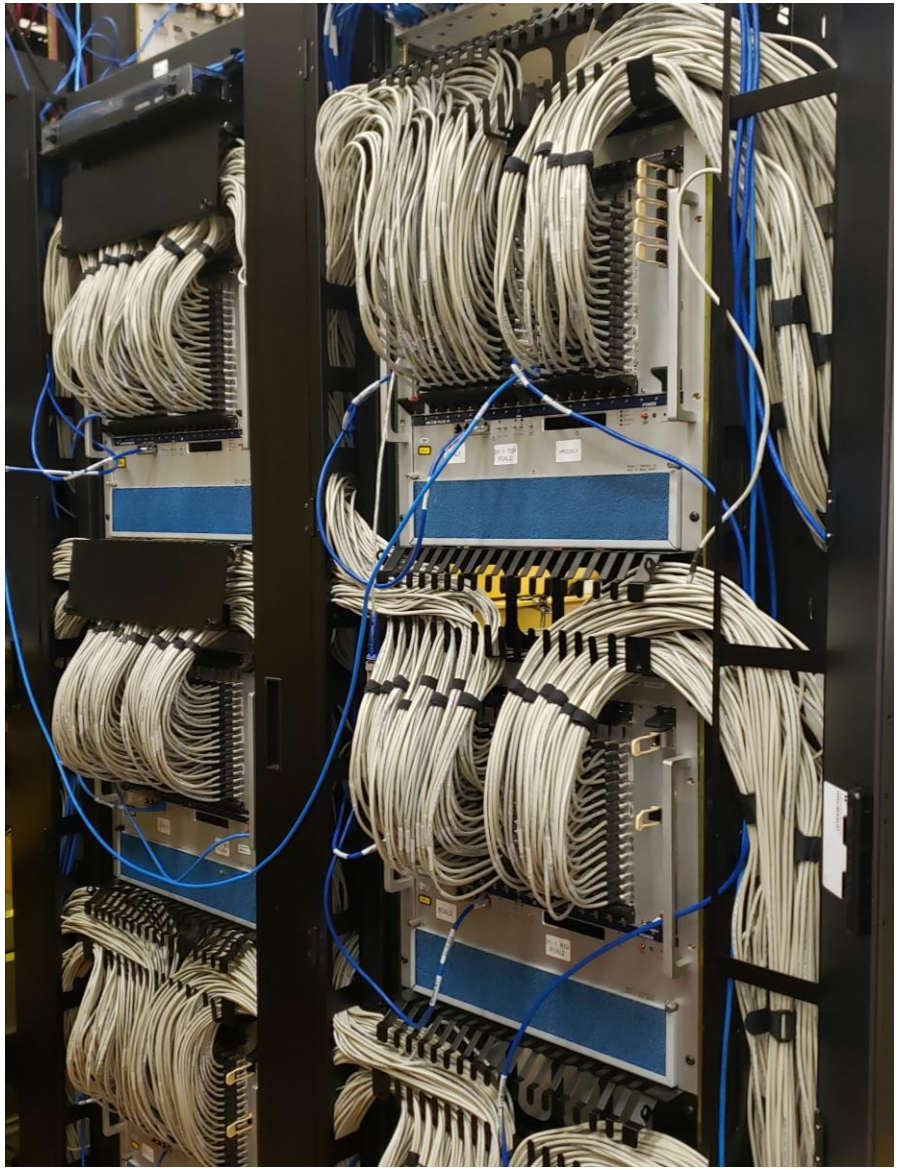
163	-18	-16	409	92			
164	-17	-16	411	132			
165	-16	-16	409	140	bad connector patch, panel side (0.0 uA) - corrected		
166	-15	-16	408	97			
167	-14	-16	409	134			
168	-13	-16	409	176			
169	-12	-16	408.2	236			
170	-11	-16	409	73			
171	-10	-16	408.4	151			
172	-9	-16	409	76			
173	-8	-16	408	92			
174	-7	-16	409	69			
175	-6	-16	409	147			
176	-5	-16	409.1	212	jumper fixed		
177	-4	-16	408.8	78			
178	-3	-16	409.6	81			
179	-2	-16	408.3	106			
180	-1	-16	408.3	79			
181	1	-16	408.5	30	bad connection - fixed		
182	2	-16	408.4	111.5			
183	3	-16	409.7	188			
184	4	-16	409	241			
185	5	-16	409	189			
186	6	-16	409	217			
187	7	-16	409	212			
188	8	-16	408.3	95			
189	9	-16	408.2	185			
190	10	-16	409	32			
191	11	-16	408.5	95			
192	12	-16	409	23			
193	13	-16	409	179			
194	14	-16	410.5	191			
195	15	-16	409	68			
196	16	-16	408.1	53			
197	17	-16	408.4	196	jumper fixed		
198	18	-16	409	31			
199	19	-16	408.4	150			
200	20	-16	409	189			
201	-20	-15	409	152			
202	-19	-15	408.3	148			
203	-18	-15	409	57			
204	-17	-15	410.7	113			
205	-16	-15	409	130			
206	-15	-15	409	136			
207	-14	-15	408.4	237			
208	-13	-15	409	171			
209	-12	-15	409	257			
210	-11	-15	409	214			
211	-10	-15	409	58			
212	-9	-15	409	107			

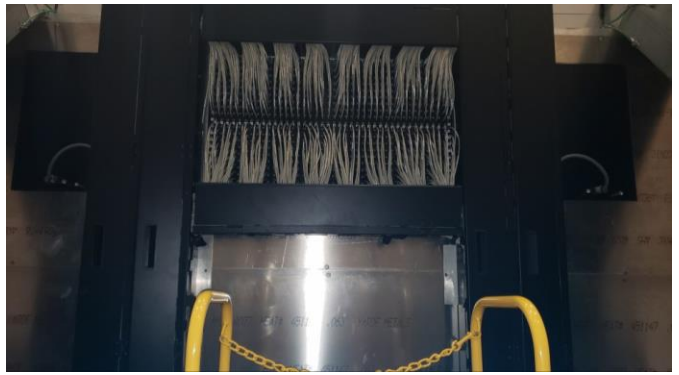
Cable Installation

- 7 cable crates
  - Divided into +/- Top, Mid, and Bottom
- Bundles from each crate were split and reorganized to connect to the patch panel
- All cables were first connected to the VXS crates and pulled under and through the detector platform to connect to the ECAL modules
- Excess length was stored underneath the detector









Cable Installation

Next Steps

- Finish PMT testing for the top half of the detector
- Software
- Start running in January 2025!

Extra Slides - PMT

Hamamatsu R4125

Tube diameter	Type No.	❶ Out-line No.	Spectral response ❷ Spectral response range (nm)	Curve code	Cathode characteristics ❸ Q.E. at peak Typ. (%)	❹ Lumi-nous Typ. (μA/lm)	❺ Blue sensitivity index (CS 5-58) Typ.	❻ Radiant Typ. (mA/W)	Anode characteristics ❼ Anode to cathode supply voltage (V)	❽ Lumi-nous Typ. (A/lm)	❻ Radiant Typ. (A/W)	❾ Gain Typ.	Dark current ❿ Typ. (nA)	Dark current ❿ Max. (nA)	Time response ⓫ Rise time Typ. (ns)	Time response ⓫ Transit time Typ. (ns)	Time response ⓫ T.T.S. Typ. (FWHM) (ns)
19 mm (3/4")	R1166	5	300 to 650	A-D	26	110	10.5	85	1000 ⑳	110	8.5×10^4	1.0×10^6	1	5	2.5	27	2.8
	R1450	6	300 to 650	A-D	27	115	11.0	88	1500 ㉕	200	1.5×10^5	1.7×10^6	3	50	1.8	19	0.76
	R3478	7	300 to 650	A-D	27	115	11.0	88	1700 ⑩	200	1.5×10^5	1.7×10^6	10	300	1.3	14	0.36
	R3991A-04	8	300 to 650	A-E	12	30	4.5	38	1500 ㉖	10	1.3×10^4	3.3×10^5	0.1	10	1.0	10	—
➡	R4125	6	300 to 650	A-D	27	115	11.0	88	1500 ㉑	100	7.7×10^4	8.7×10^5	10	50	2.5	16	0.85
	R5611A-01	8	300 to 650	A-D	26	90	10.5	85	1000 ㉖	50	4.7×10^4	5.5×10^5	3	20	1.3	12	0.8