

CLAS12 Forward Detector PCAL

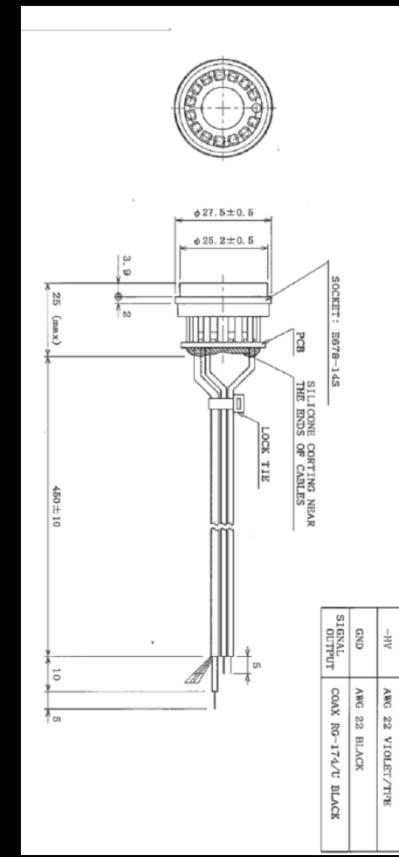
Status of the Photomultiplier Tube/Base
Assembly & Testing

K. Giovanetti

Nick Herge, Lee Dunnavan, Brian Isherwood, Tyler Mullins

James Madison University

Parts



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Assembly

- CAP
 - Connectors & GND
- Spacers
 - Cut to 1.6, cut in half
- Base assembly
 - Combine Cap, spring, spacer, base
 - Solder HV, signal and GND
 - Label as a unit

- Tape tube end with electrical tape



Optional Step

Test each base for correct voltage at the pins



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Record status and measurement

- MYSQL database on JMU computer
- PHP web database access tool

Status-to-date

- 350 assemblies delivered to JLAB
- 150 assemblies finished at JMU
- 1100 bases wired, soldered, labeled tested

Light Tightness Verified

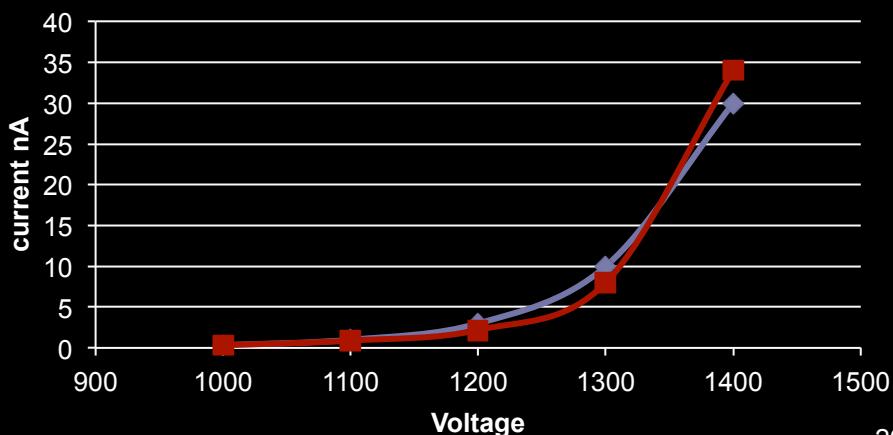


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DC results

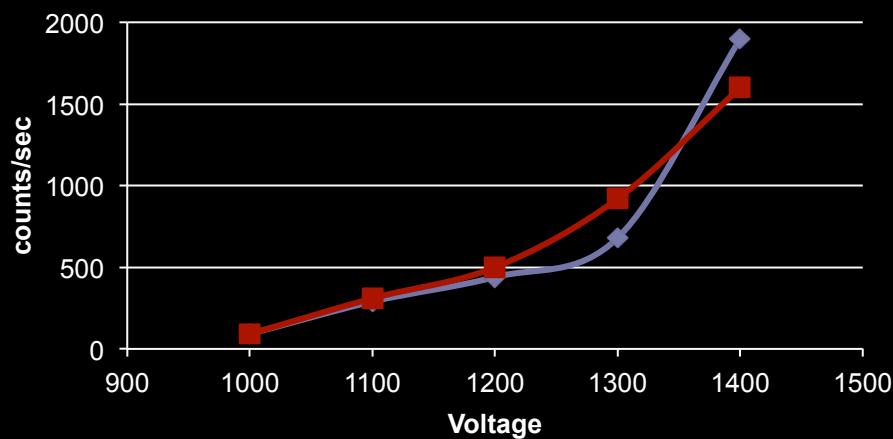
Tube CT3216

dark current nA



JMU DC 0.15 nA
Ham. DC 0.36 nA

Counts above 10 mV



V voltage	mV disc	c/s counts	nA I
1000	10	90	0.3
1100	10	290	1
1200	10	440	3
1300	10	680	10
1400	10	1900	30

Reasonable Compression

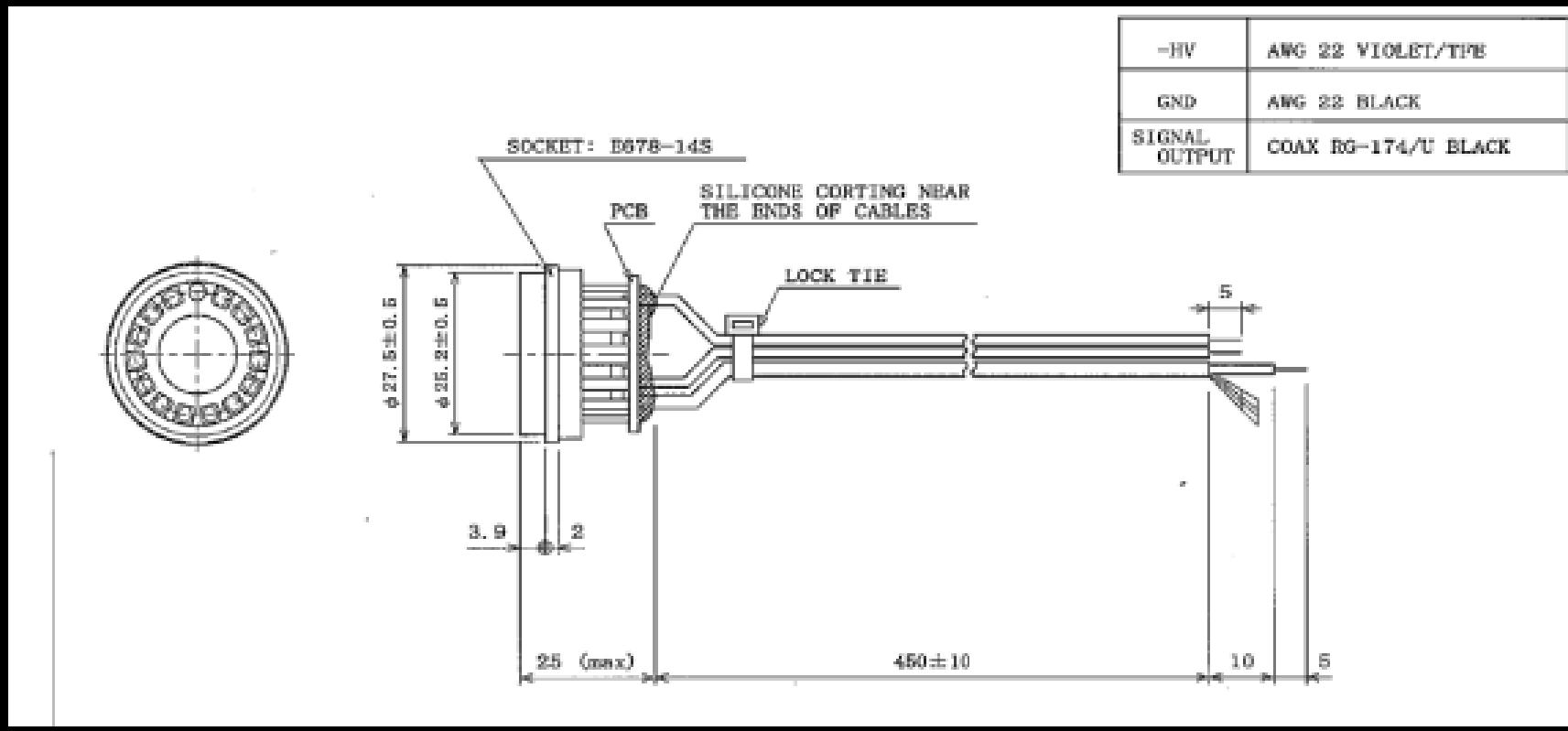
- kilogram-force (kgf) → force 1kg in earth's gravity ~ 10 N
- Hamamatsu specifies force < 10 kgf



length in	after cut	cap ext. in	mass kgf	pre. Mass kgf
1.6	1.575	0.1	0.60	0.35

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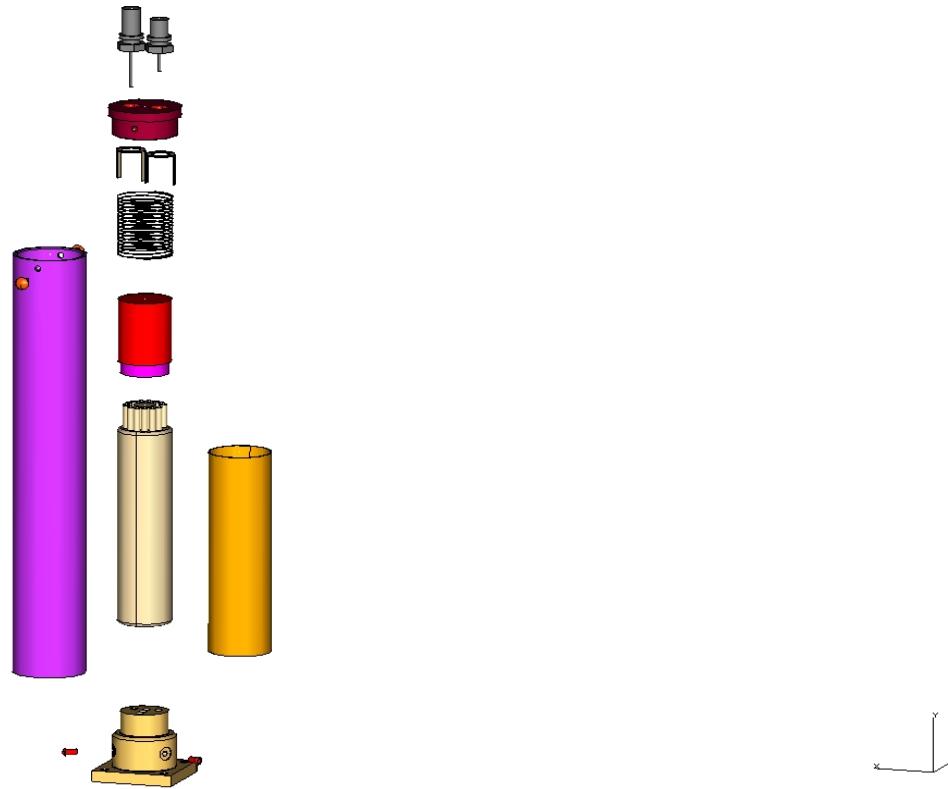
Base



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PMT and Housing (JLAB)

- Upgrade to incorporate Hamamatsu base boards



General assumptions:

{FE→far end; NE→near end}

<u>characteristic</u>	<u>value</u>	<u>unit</u>	<u>description</u>
Maximum Energy	500	MeV	Most energy in a single channel
MIP energy	10	MeV	
Required sensitivity	1	MeV	
Longest Scintillator	424	cm	V-layer
Maximum attenuation	25%		FE event is 25% less than NE
Shortest Scintillator	4.2	cm	U-Layer
Pb Thickness	2.2	mm	PCAL design
Scintillator Thickness	1	cm	PCAL design
Scintillator width	4.5	cm	PCAL design
Scintillators/readout channel	5		PCAL design

General assumptions: cont.

Total U-V-W (longitudinal)	15		PCAL design
sectors	6		
scintillators/sector U (transverse)	84		U view-> 40 double readout
scintillators/sector V (W) (transverse)	76		V (W) -> 24 double readout
readout/view U,V,W	64		192/sector
Total readout channels	1152		
Number of WLS Fibers	2		
Fiber Kuraray Y-11 DC	1	mm	
Y11 peak	476	nm	Kuraray specification
Extruded Polystyrene Scintillator	Fermi Lab		JLAB test results

General assumptions: cont.

pe yield	11	pes/MeV	JLAB test results
Resolution (PCAL+FEC) TOTAL	10%/rootE	%	
pe contribution to Resolution	2%/rootE	%	Crude upper limit
Readout split	33.3%	to ADC	ADC/TDC splitter
Max Readout Voltage	2	V	FADC proposed specs
Max Readout channel	4096		12 bit digitization
Read out frequency	250	MHz	FADC proposed specs
Signal FWHM	11	ns	JMU measurement

EC Achieved

■ Position Resolution	2-3 cm
■ Energy Resolution	(10-12)%/ \sqrt{E}
■ PE Yield	3.4 pe/MeV
■ Time Resolution	< 0.5 ns

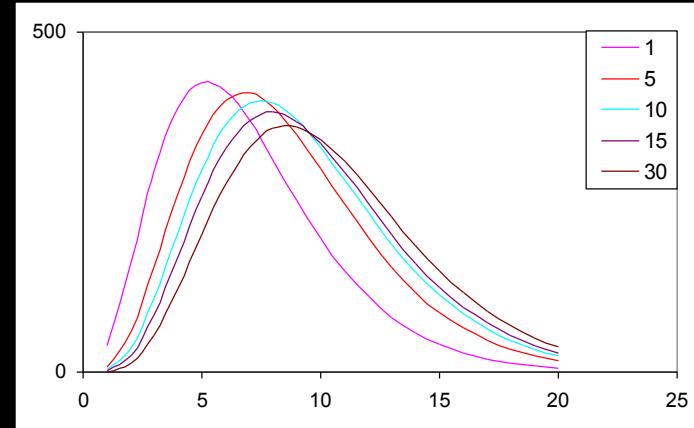
DESIGN GOALS →

- e/γ energy resolution $\sigma/E \leq 0.1/\sqrt{E(GeV)}$.
- Position resolution $\delta r \approx 2$ cm @ 1 GeV.
- π/e rejection greater than 99% at $E \geq 1$ GeV.
- Fast (< 100 nsec) total energy sum for the event trigger.
- Mass resolution for 2-photon decays $\delta m/m \leq 0.15$
- Neutron detection efficiency > 50% for $E_n > 0.5$ GeV
- Time-of-flight resolution ≈ 1 nsec

PCAL / EC

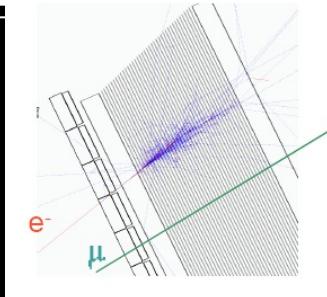
Maintain And Improve Performance

	layers	RL	cm
1 layer	1	0.42	1.22
Module	3	1.25	1.52
PCAL	15	6.25	18.30
EC fwd	15	6.25	18.30
EC bkwd	24	9.99	29.28
EC	39	16.24	47.58
total	54	22.49	65.88

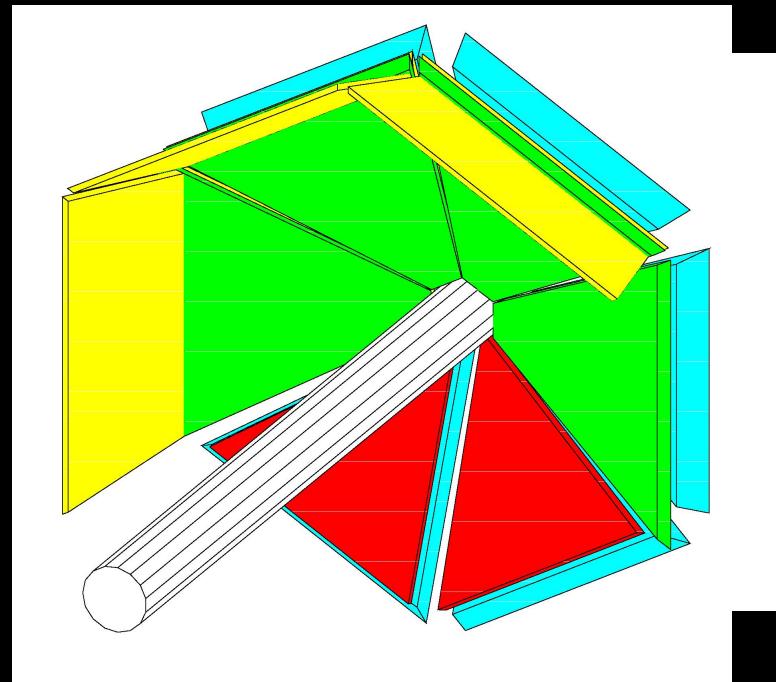


Energy GeV	1	5	7	11
Shower Max tmax (RL)	6.8	9.1	9.6	10.2
Distance (cm)	19.9	26.7	28.1	30.0
Distance (layers)	16.3	21.9	23.0	24.6
Containment 2.5 tmax (cm)	49.7	66.7	70.2	75.0
2.5 tmax (fraction)	0.75	1.01	1.07	1.14

PCAL Design

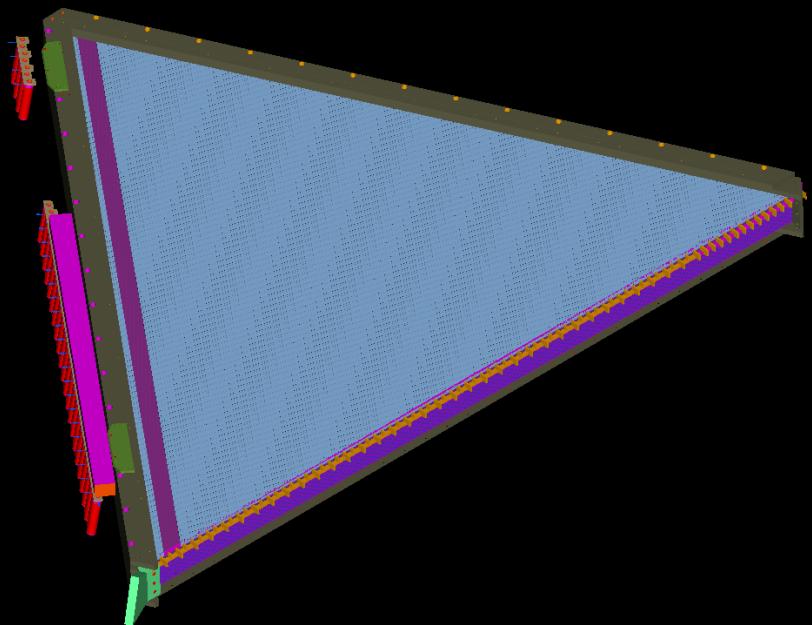
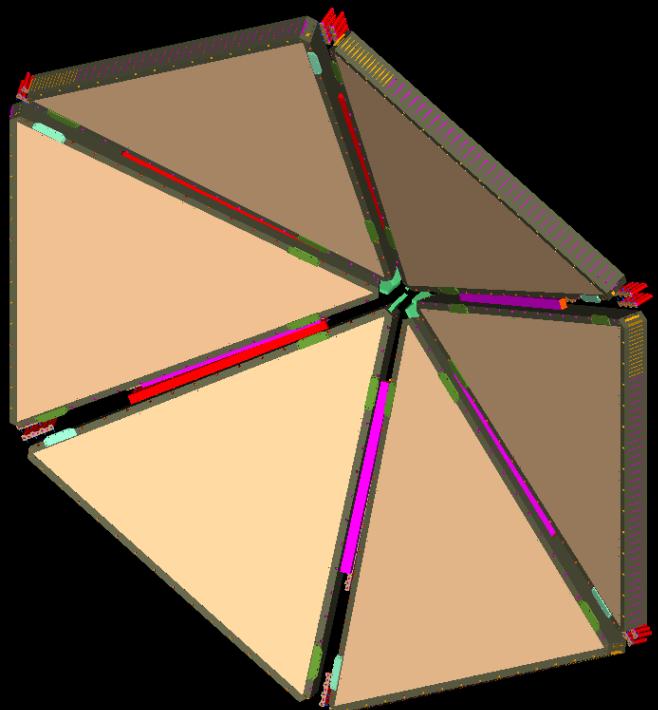


- ❑ Alternating Pb (2.2mm)/Scintillator (10 mm)
- ❑ Scintillator Width
 - ❑ 4.5 cm
 - ❑ 9cm [double width readout]
- ❑ U,V,W Readout
- ❑ Cover the EC ~4m Sides
- ❑ WLS Light Readout
 - ❑ 3 fibers



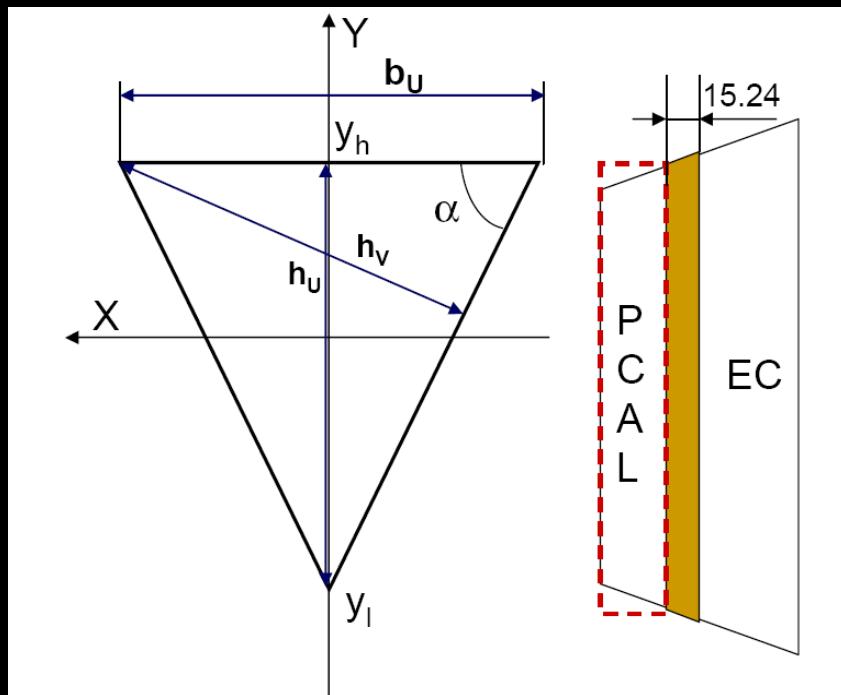
PCAL Components

Maximize Light Yield/ Minimize Cost



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PCAL: Dimensions & Location



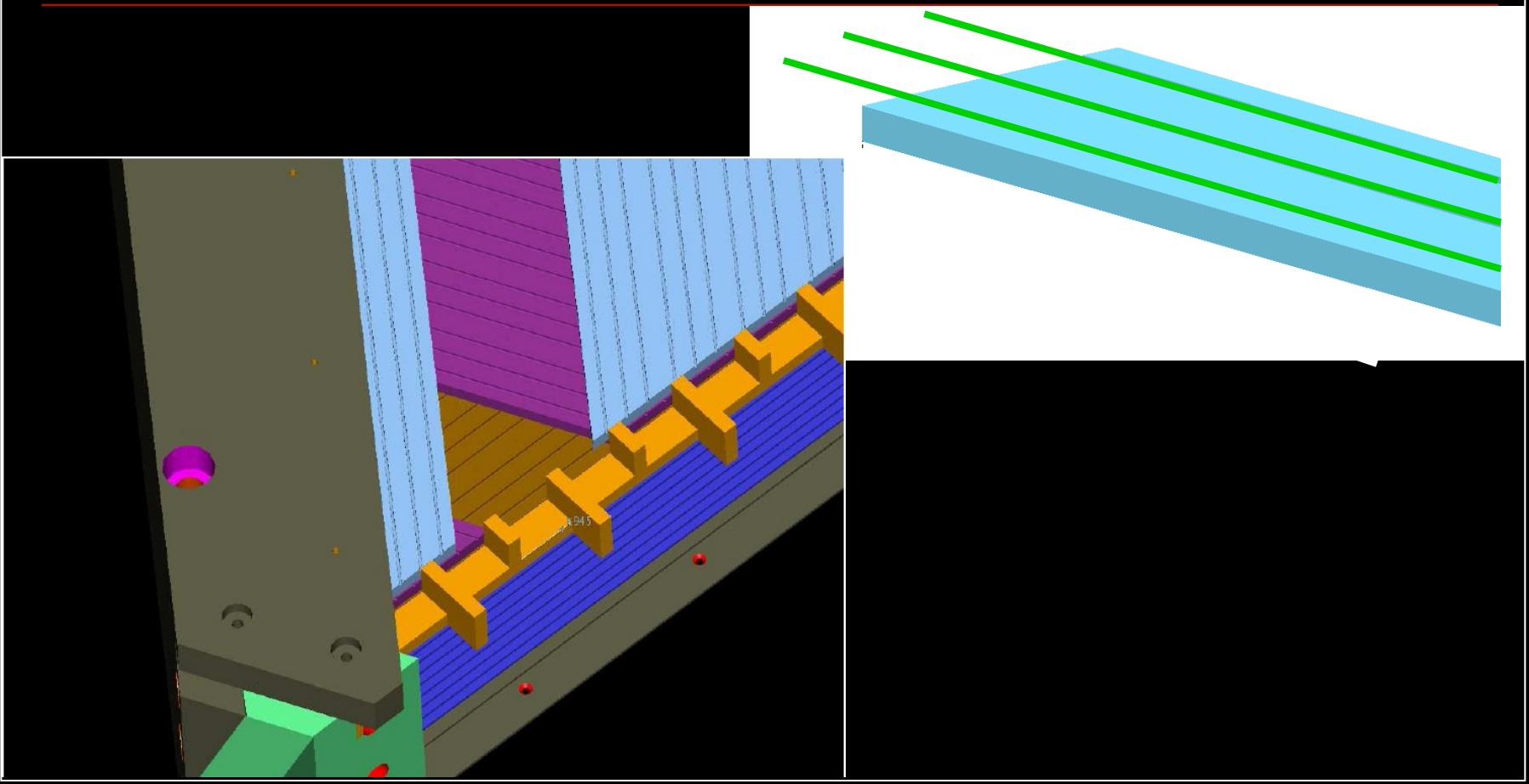
The first layer of scintillators of EC will have: $h_u=372.93$, $b_u=381.86$

The last layer of PCAL scintillators projected from the EC will be:

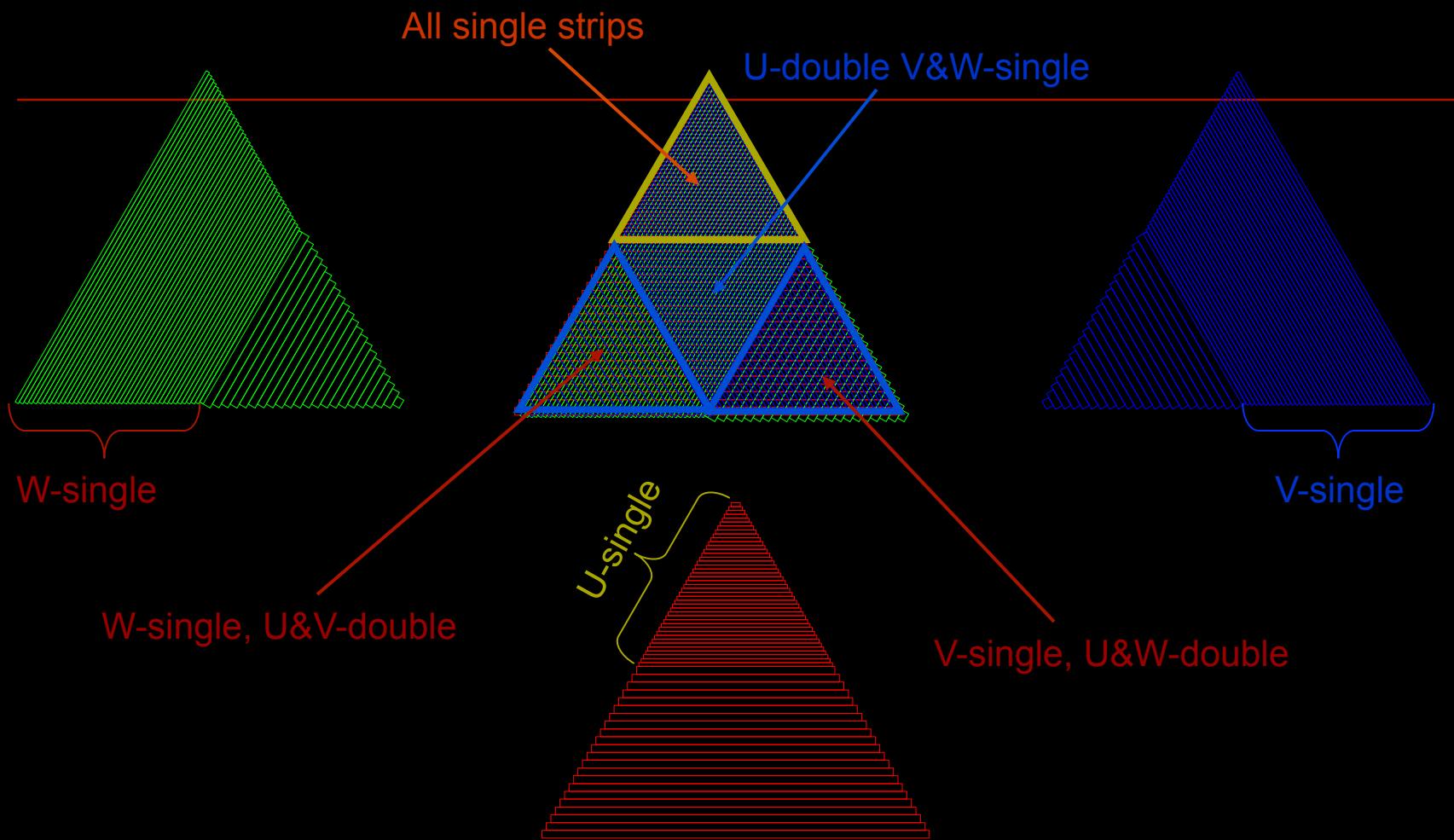
$h_u=360.3$, $b_u=368.97$
Height for V/W $h_v=328.43$

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Maximize Light Yield/ Minimize Cost



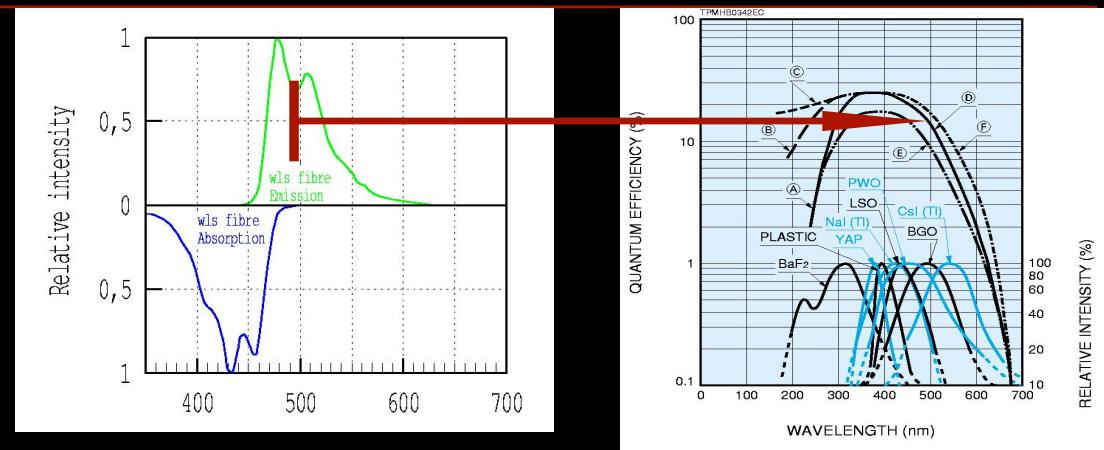
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Selection Of The PCAL Components

Scintillator-WLSF-PMT combination
with reasonably high
photo-electron
statistics at low cost



Choice for the scintillator, WLS fiber, and PMT is :

Fermi Lab extruded scintillators, 4.5x1 cm² with 3 grooves

Kuraray, 1mm diameter Y11 single clad

HAMAMATSU R6095 selected with Q.E.>16% @ 500 nm

Expected photo-electron yield ~11p.e./MeV for 3 fibers (yield for EC readout from the test measurements was ~8.4p.e./MeV)