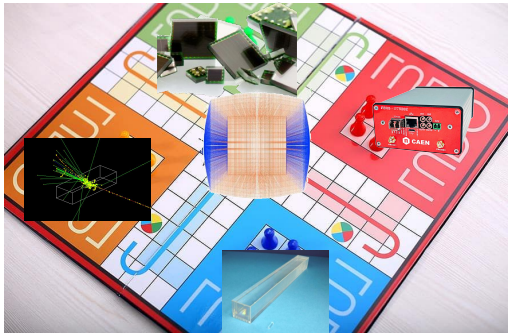
CalVision general meeting

Progress on dual readout crystals

Bob hirosky and Junjie Zhu

13 July 2022



Comments/TOC

This is not a workplan (yet)

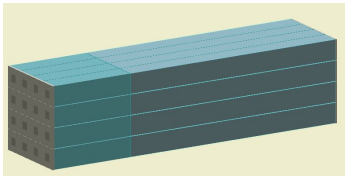
Summary of what we have to get started with and ideas for next steps towards crystal test beams

- Testbeam MC status
- Materials and sensors
- Test equipment
- Electronics and DAQ

Single module / small matrix GEANT model

Github repo for latest small simulation tool: https://github.com/UVa-Calvision/singlebar2

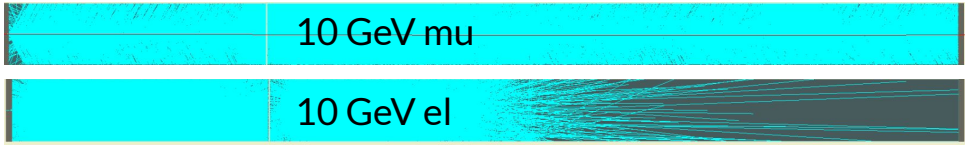
- Modified from Yuhiu's code at UMD that used for plots in the proposal
- Implement dual xtal geometry similar to proposal with wrappers, 1(2) front(rear) SiPMs
- SiPM models include separate surface material and optional impedance matching layers, light baffles
- Many geometry and material parameters available in cfg file , including matrix definition
- Various improvements to geometry and tracking code
- Based on Geant 9, libraries fetched using CVMFS



I hope we can maintain* this as a relatively painless install use it as training ground for students (and anyone else) to jump quickly in and do some interesting work in GEANT.

*ease of setup, working examples out of the box,...

Cherenkov light only, no propagation



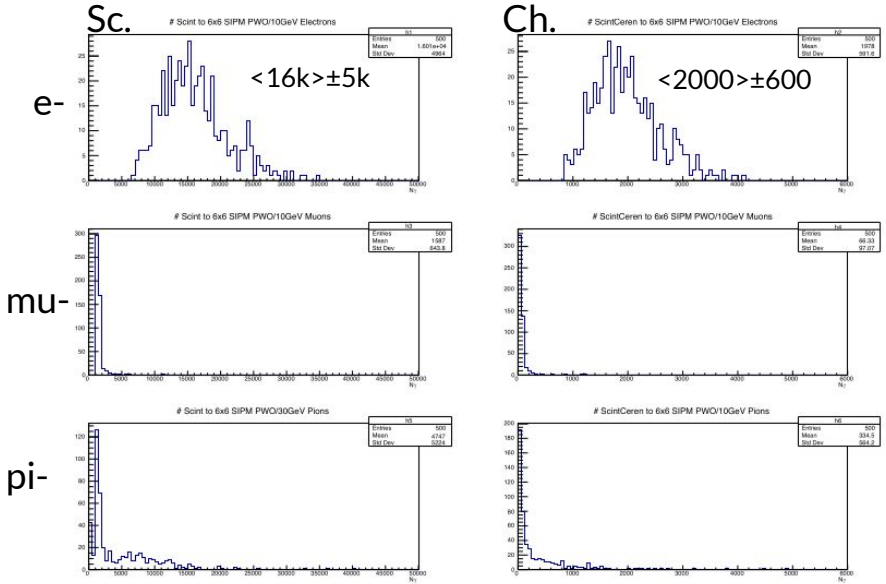
Simple studies (eg, easy things to do)

PWO 67+180mm , 16x16mm^2 face

Full optical sim of 500 events of single bar configuration

Large fluctuations from:
Molier Rad?
SiPM coverage?
Interesting to study!

Photons collected in 6x6 rear SiPM, E=10 GeV, PWO



<N> photons collected vs impedance matching (xtal <-> SiPM)

<u>Cherenkov</u>

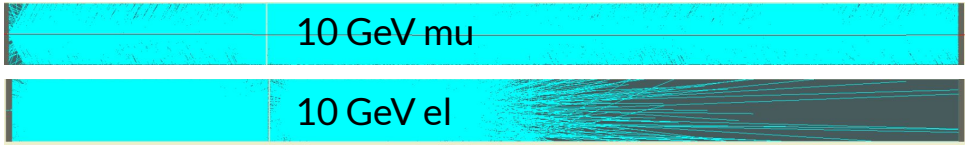
AIR:	664
OpticalGrease:	1738
Silicone:	1978

<u>Scint</u>

AIR:	890
OpticalGrease:	14331
Silicone:	16006

SiPM PDE(λ) not included

Cherenkov light only, no propagation



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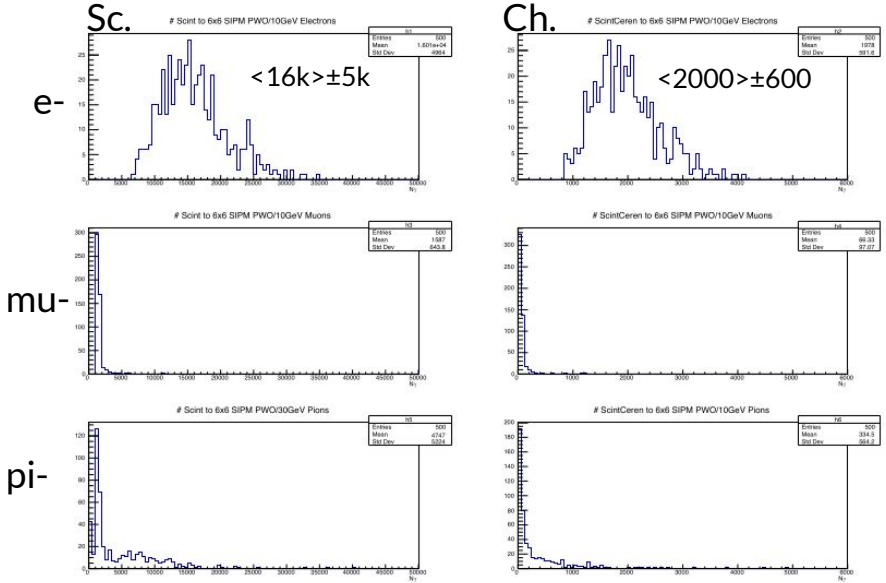


Examples of CPU time for simulation (2.6GHz Xeon)

Single module
10 GeV particles / 1 event

PWO

mu-	~10 s
pi-	~28 s
e-	~173 s

BGO

e-	~585 s

Some initial goals for GEANT

Ultimately we will want to tune the model this will require data

- Improvements to material descriptions, eg measured xtal properties
- Define benchtop (cosmics, sources, laser excitation) and beam studies to ~quantitatively verify Geant modeling for different xtals
- Also perform with optical filters appropriate for separation of C/S light for different xtals

Other topics of interest

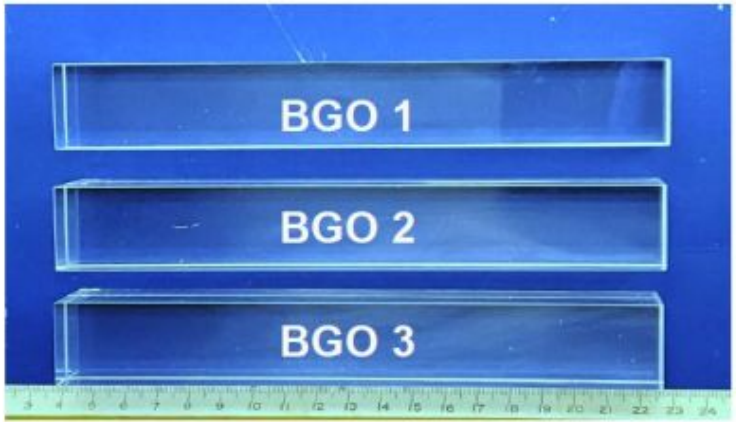
- Studies of possible saturation of SiPMs: eg S light leakage in C light sensor, dynamic range needed for sensors
- Distribution of sensors
- Alternate light collection geometry, for example central mounted S light sensor + tapered light guide to C light sensor

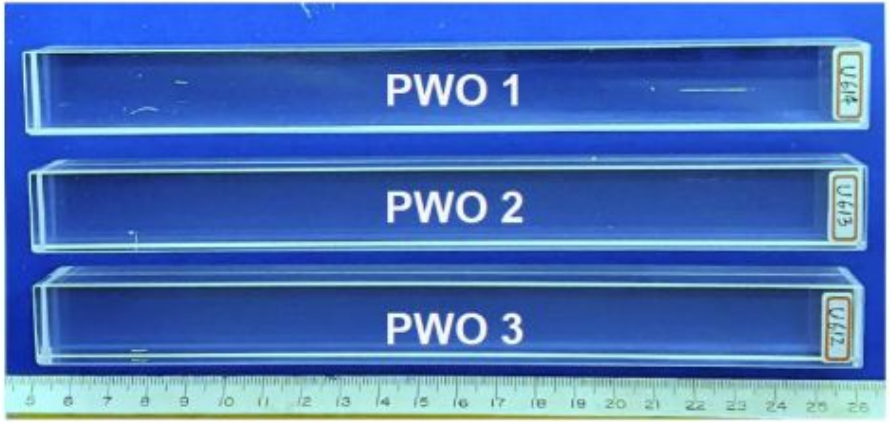
- Extending studies to EM scale matrix, xtal size and material optimizations
- Develop model/framework to parametrize optical tracing as in CMS as an early step (also SiPM response)

Industrial scale GEANT

- Will need REAL GEANT experts to get this off the ground!

BGO and PWO crystals (In hand)





ID	Dimension (mm^3)	#	Polishing
BGO-1,2,3	25×25×180	3	All faces
PWO-1,2,3	20×20×200	3	All faces

Plus another BGO crystal with a dimension of 25×25×60 mm^3

J. Zhu

Crystal test results (done by R.Y. Zhu and C. Hu)

BGO	EWLT (%)	Light Output (p.e./MeV)	Energy Resolution (%)	Light Response Uniformity (%)
BGO-1	72.2	733	17.0	2.2
BGO-2	73.8	739	16.9	2.4
BGO-3	74.6	722	17.0	2.9
Ave	73.5	731	17.0	2.5
rms/Ave (%)	1.4	1.0	0.2	12

PWO	EWLT (%)	Light Output (p.e./MeV)	Energy Resolution (%)	Light Response Uniformity (%)
PWO-1	59.9	31	101.4	5.1
PWO-2	63.0	28	107.2	4.5
PWO-3	61.7	29	103.2	2.6
Ave	61.5	29	103.9	4.1
rms/Ave (%)	2.1	3.6	2.4	26

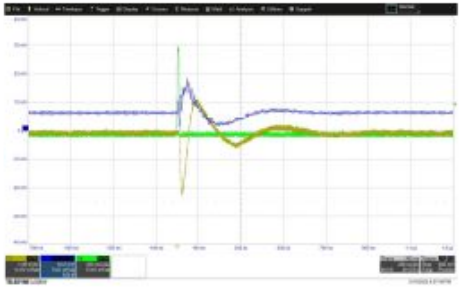
Plus other measurements: X-ray excited luminescence, Longitudinal/Transverse transmittance, Pulse Height Spectra, Light Output, Decay time

J. Zhu

Readout setup

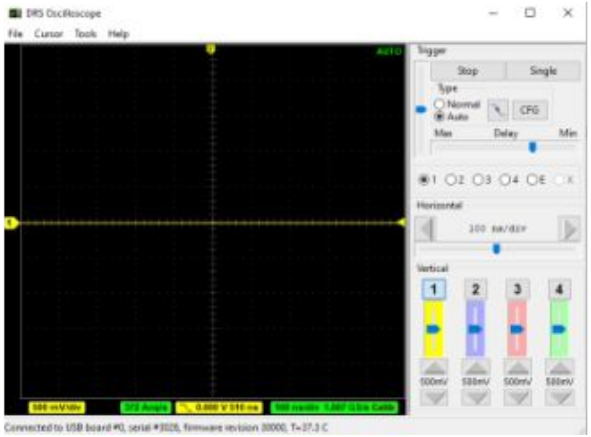
Oscilloscope: Lecroy waverunner 8404m

- Python script readout from Ethernet port (modified from https://www.tlatorre.com/cgit/lecrunch/)
- 4 channel sampling, with an extra external trigger channel
- 4 GHz, up to 40 Gbps



DRS4 evaluation board

- 4 channel sampling, with an extra external trigger channel
- 1V peak-to-peak input. 1024 points per sampling. Up to 5 Gbps.
- Readout GUI available (similar to an oscilloscope), readout via USB2.0



Similar @ UVa

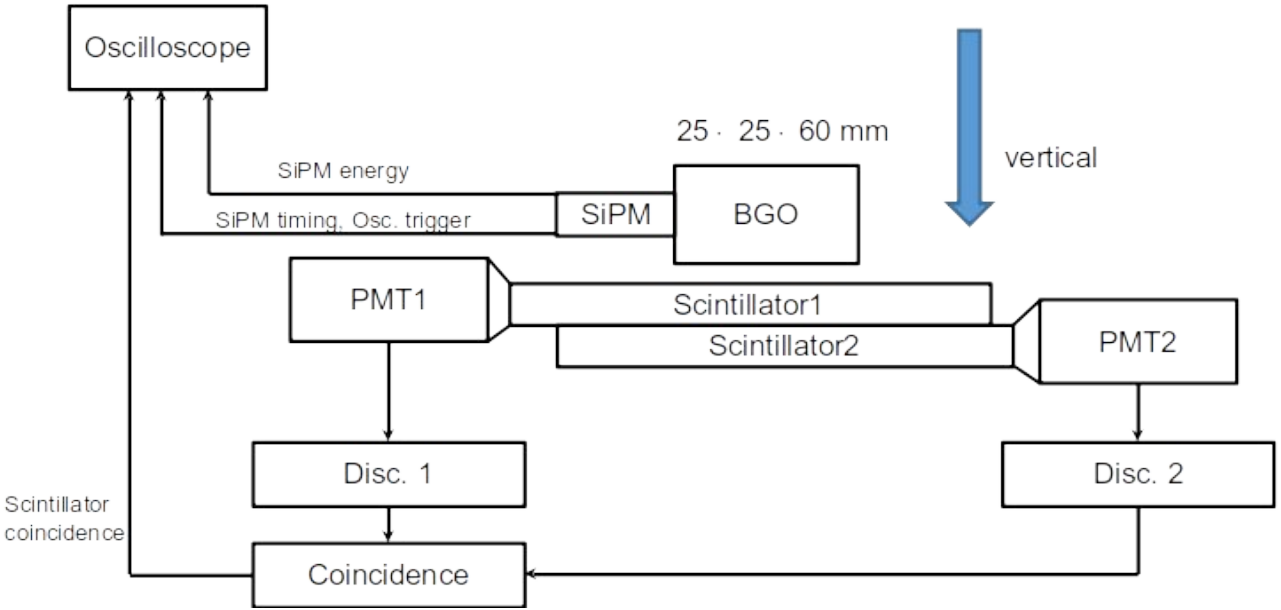
- Lecroy and Agilent scopes
- DRS Eval Boards
- 16 Channel DRS unit

Good software/DAQ experience, eg Waverunner + DRS systems used in numerous testbeams.

- Recently acquired a 64-channel CITIROC unit

Cosmic ray test setup

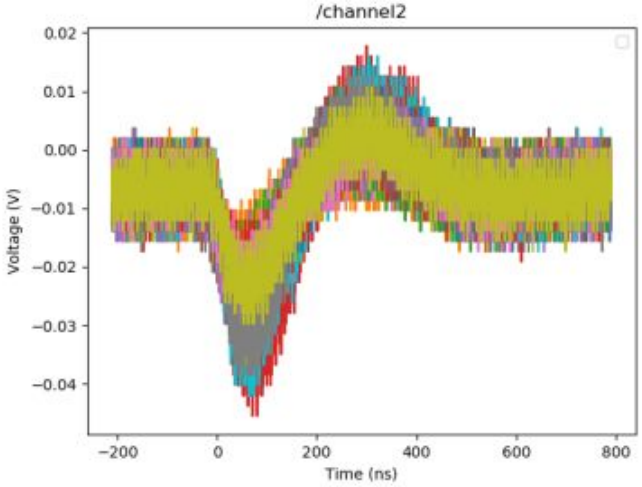
- SiPM S14160-3015PS, 3x3 mm^2, pixel pitch: 15 um
- Vbr=38 V, Vop=42 V
- Scintillator overlapping area = 14· 15 cm^2
- Direct trigger with the SiPM timing signal
- Scintillator coincident signal recorded to confirm cosmic muons
- Read out scintillation light (no SiPM output observed if not attached to the crystal)



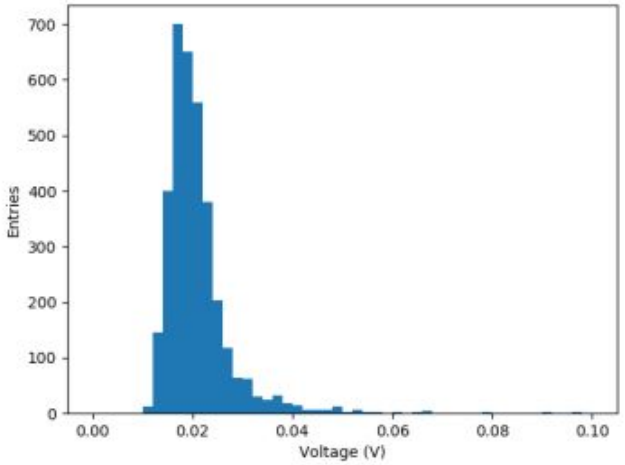
J. Zhu

Cosmic ray result

- 6110 SiPM direct triggers in 12.5 h, average rate = 0.14 Hz
- Among all SiPM triggers, 3500 events have scintillator coincidence.



SiPM energy waveform 50 samples with scintillator coincidence. A 200 MHz 10 mV peak-to-peak sine-wave noise is found for this output (mainly due to the HV power supply we used)

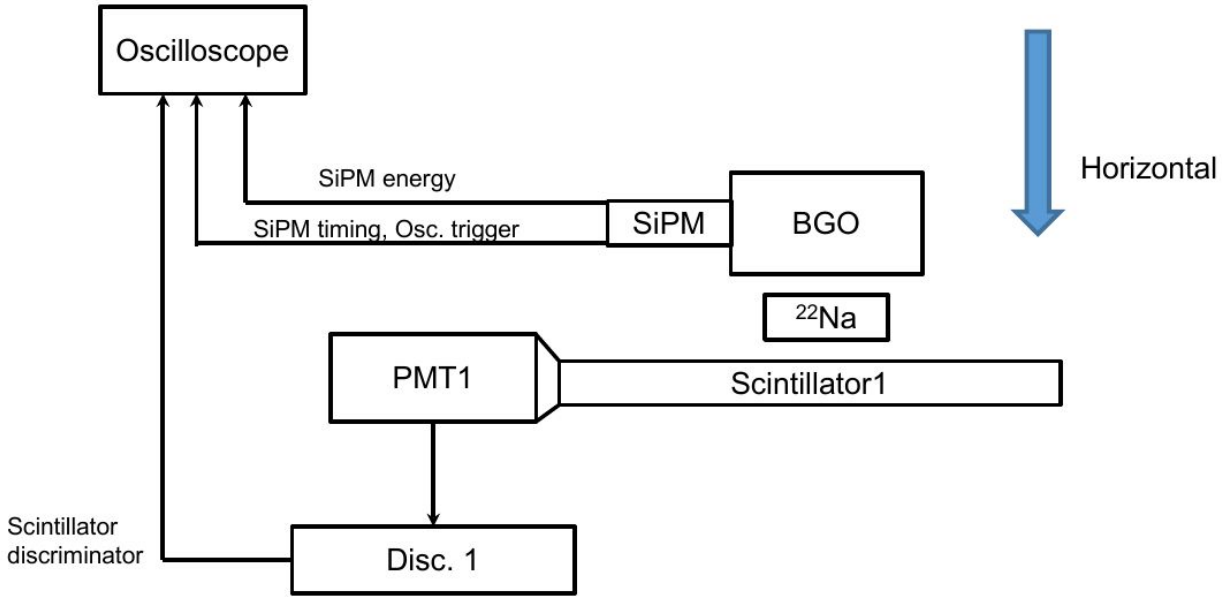


SiPM energy amplitude histogram with scintillator coincidence (rare large signals excluded).

J. Zhu

^{22}Na test setup

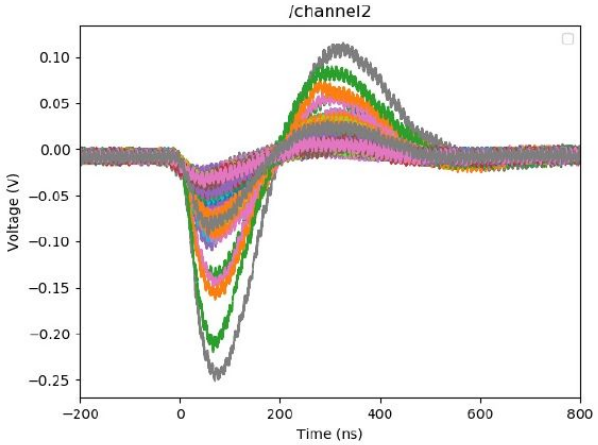
- SiPM Vbr=38 V, Vop=43 V (at the time we did not realize the HV supply shows a wrong voltage reading so it is different from the cosmic ray setup)
- ^{22}Na source (e^+ source ◊ γγ 1 uCi, purchased two years ago) placed in between BGO and scintillator1 (horizontal back-to-back setup)
- Direct trigger with the SiPM timing signal
- Scintillator coincident signal recorded to confirm cosmic muons



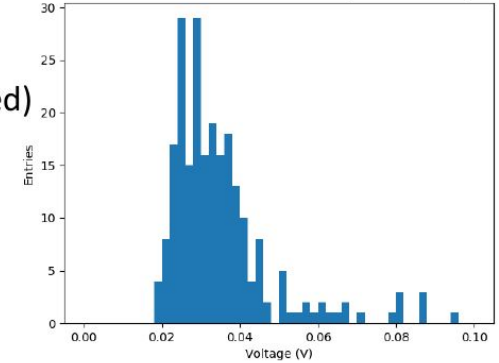
J. Zhu

^{22}Na test setup

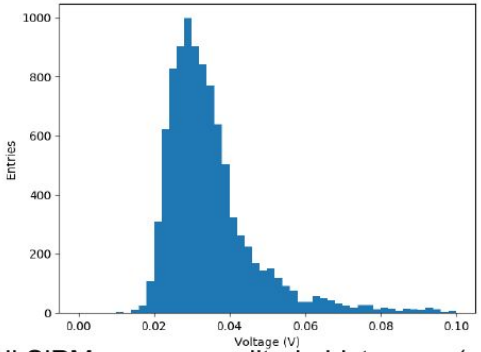
- 9668 SiPM direct triggers in 11.5 h, average rate = 0.22 Hz (small acceptance for the SiPM, and no scintillation photons detected due to the incident of 511 keV photons)
- Among all SiPM triggers, only 238 events have scintillator signals (scintillator positioned differently this time and less cosmic muons expected)



SiPM energy waveforms with scintillator signals (238 events).



SiPM energy amplitude histogram with scintillator signals (rare large signals excluded)

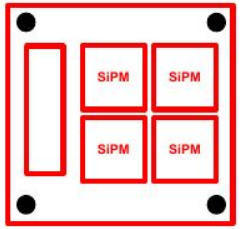


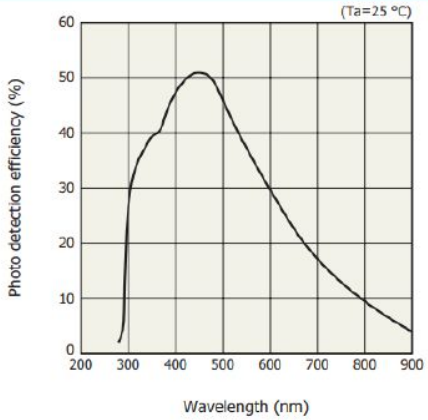
All SiPM energy amplitude histogram (rare large signals excluded)

J. Zhu

Larger-area SiPMs

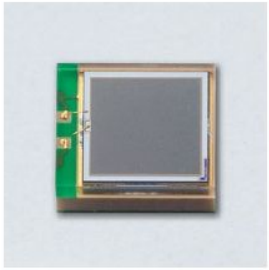
S14160-6050HS 6x6 mm^2
Pixel pitch: 50 um

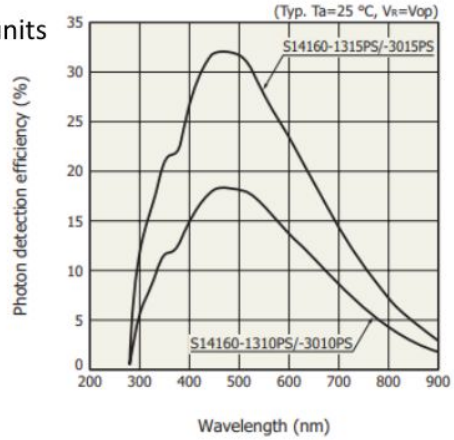




Checked with Hamamatsu and was told that they can ship 8 units to me in one week ($90 per unit) → $67 per unit if we purchase 50 units

The one we have now: S14160-3015PS 3x3 mm^2
Pixel pitch: 15 um





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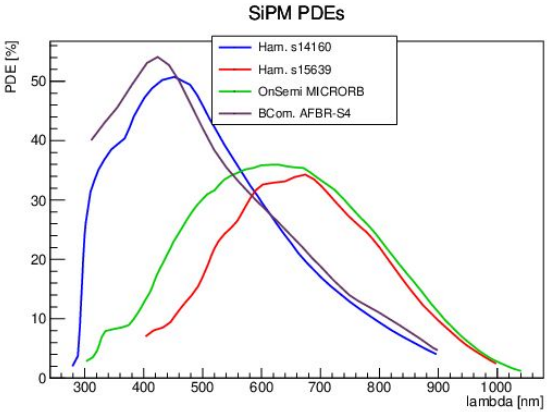
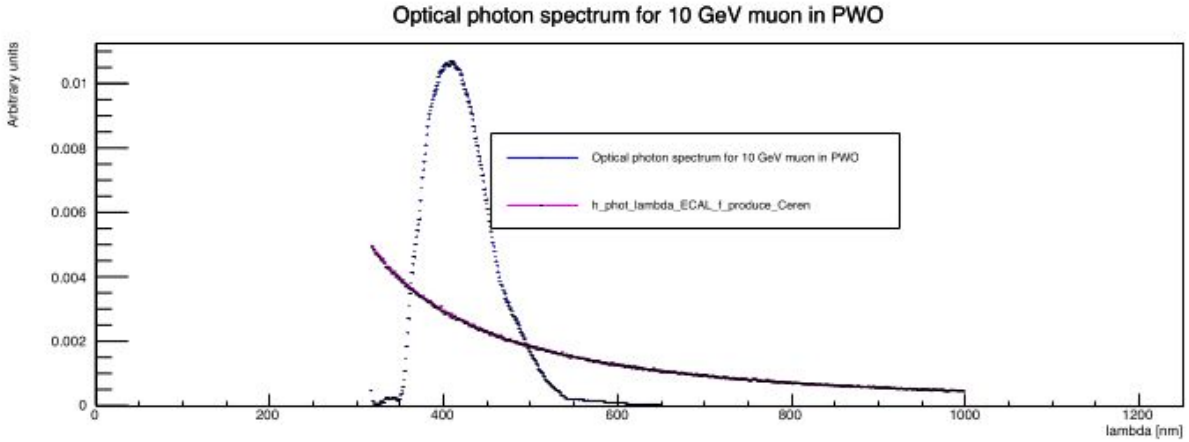
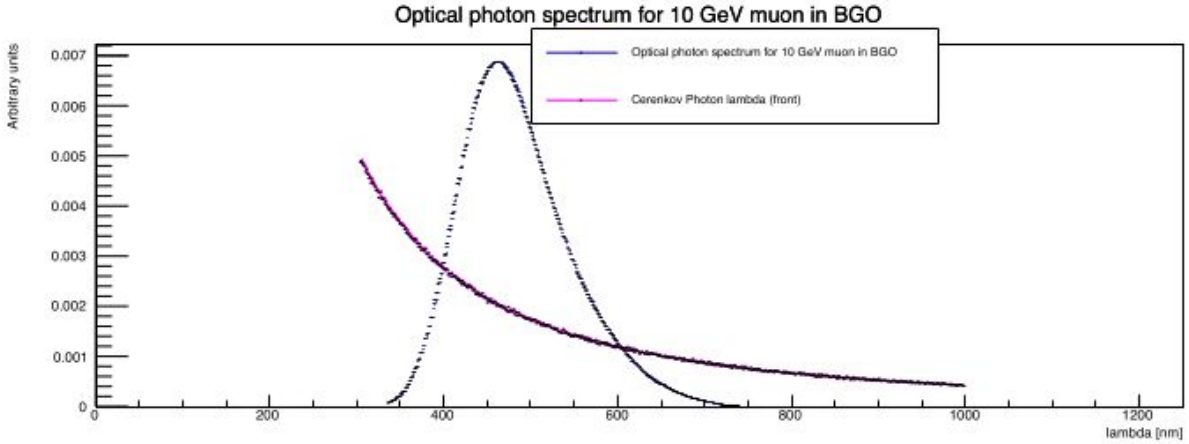
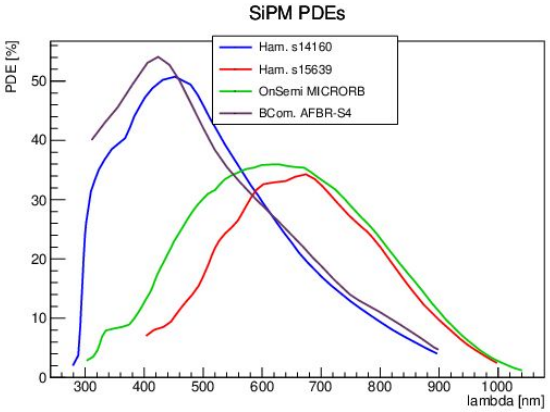
Range of PDEs for other larger cell size SiPMS



Scintillation spectrum from our GEANT model



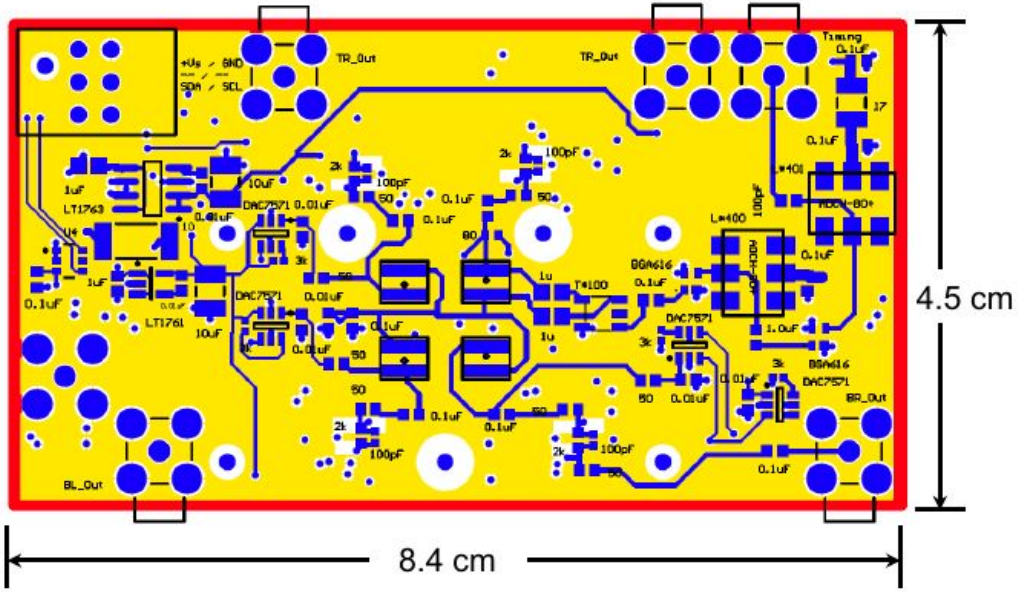




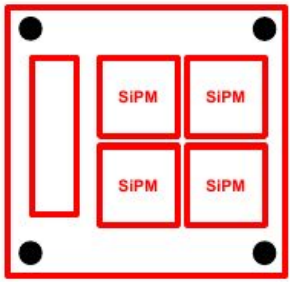
4-channel SiPM readout board (From B. Hirosky and T. Anderson)

Modification thoughts:

- Bigger foot print for 6*6mm SiPM (6.4*6.4mm for S14160-6050HS, or 6.85*7.35mm for S13360-6050PE)
- Daughterboard holding 4 SiPMs, with connector at one edge and standoffs at four corners (TBA)

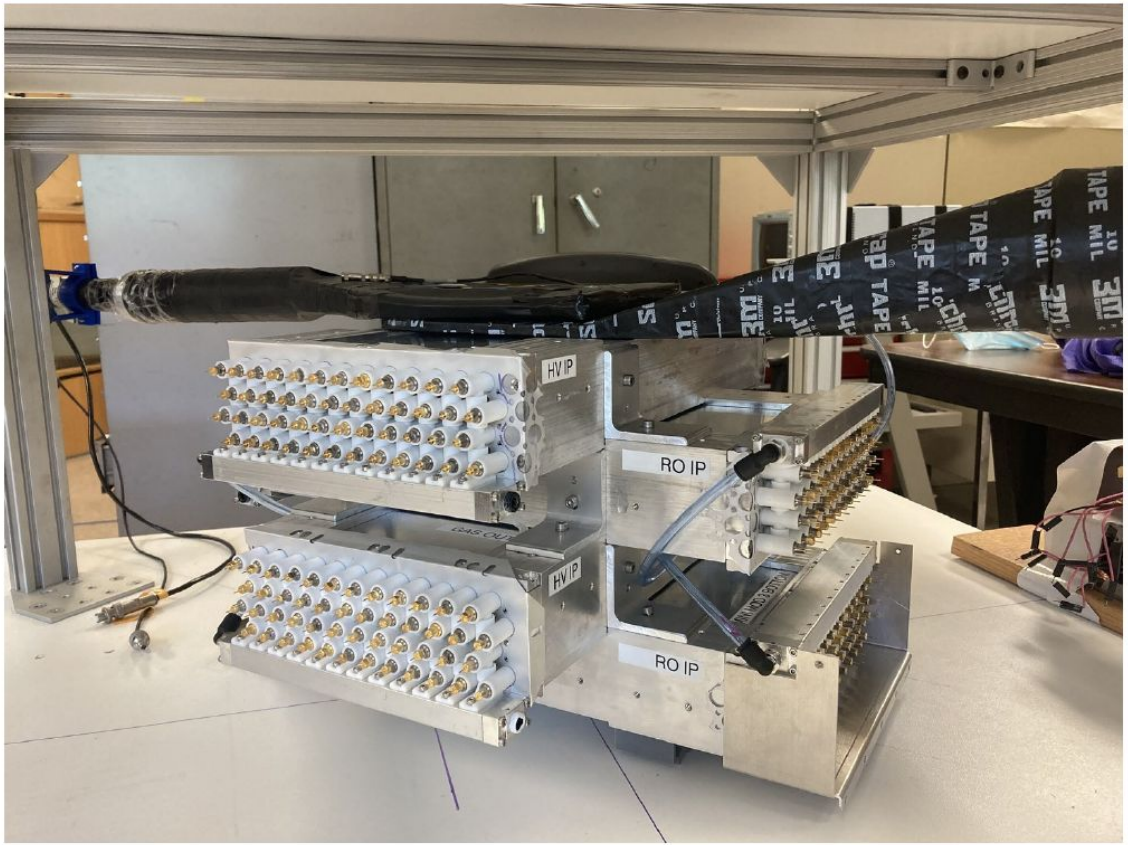


- Used in multiple test beams
- Fast and slow signal outputs
- DACs for per SiPM bias adjustment
- Typically used w/ scope/digitizer readout



Will debug new CITIROC DAQ in parallel

Small-diameter Monitored Drift Tube

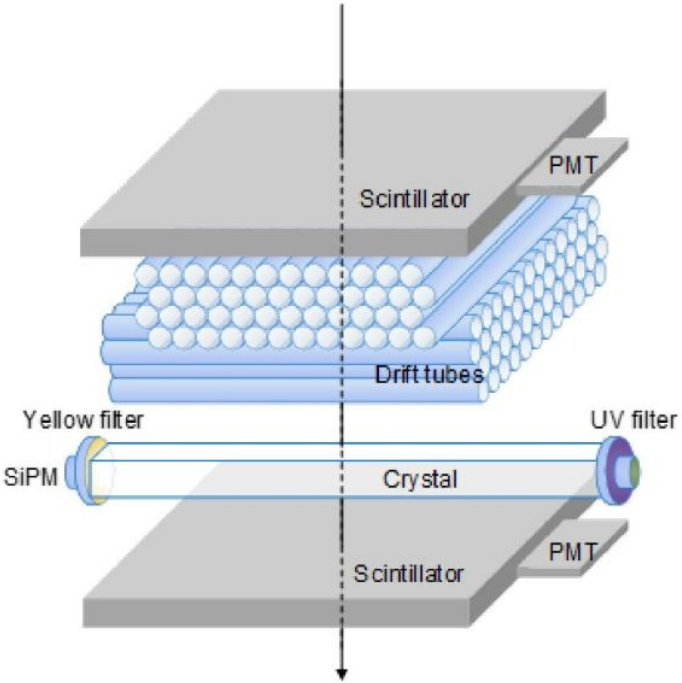


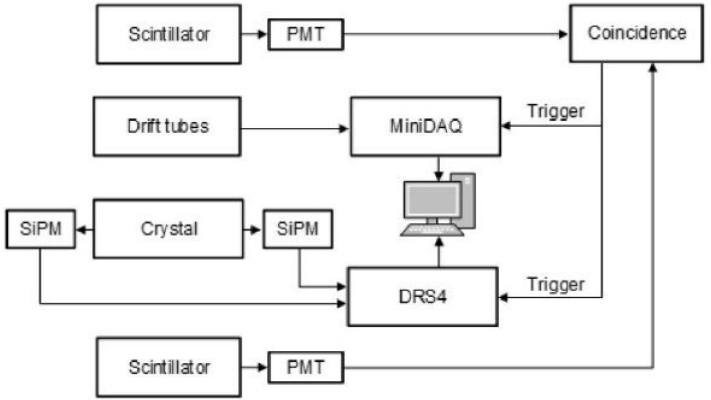
Built 6 sMDT chambers (4 shown here), to be used to determine the muon position and direction
Collecting frontend mezzanine cards (chips designed at Michigan and MPI, boards produced by MPI)

J. Zhu

Next plan

Important to have large-area SiPMs





J. Zhu


The way to get started is to quit talking and start doing.
Walt Disney
quotefancy