MUSE WP3: Muon Laser Calibration System

The Mu2e calorimeter laser system

C.Ferrari

INO-CNR and INFN, Pisa, Italy

M. Cordelli, S. Miscetti, D. Pasciuto

Laboratori Nazionali di Frascati, INFN, Italy

MUSE General Meeting 23th-25th Oct 2019

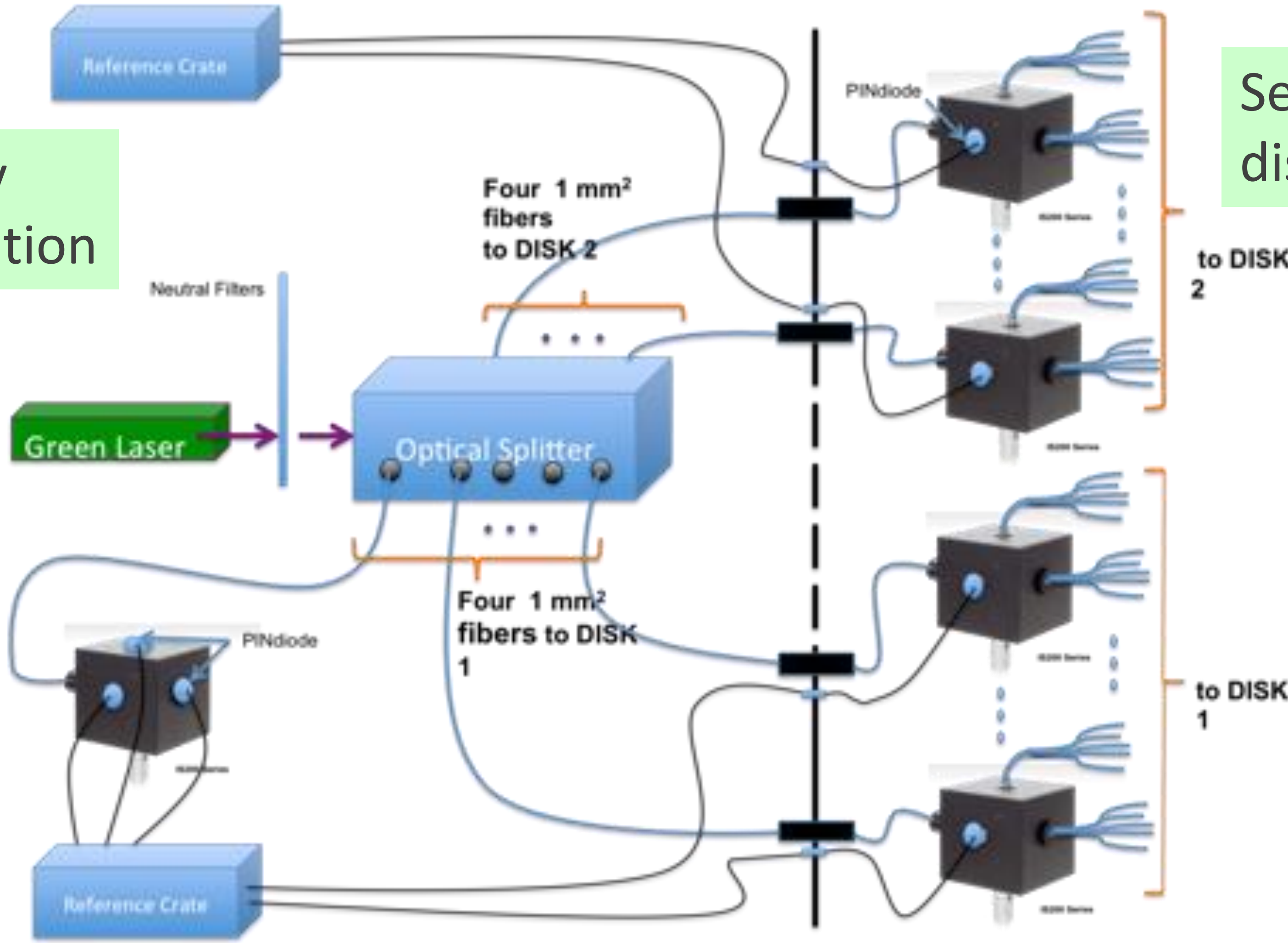
Outline

- Primary distribution system
- Secondary distribution system
- Test with SiPMs
- Test on Monitors

Mu2e Laser System Scheme

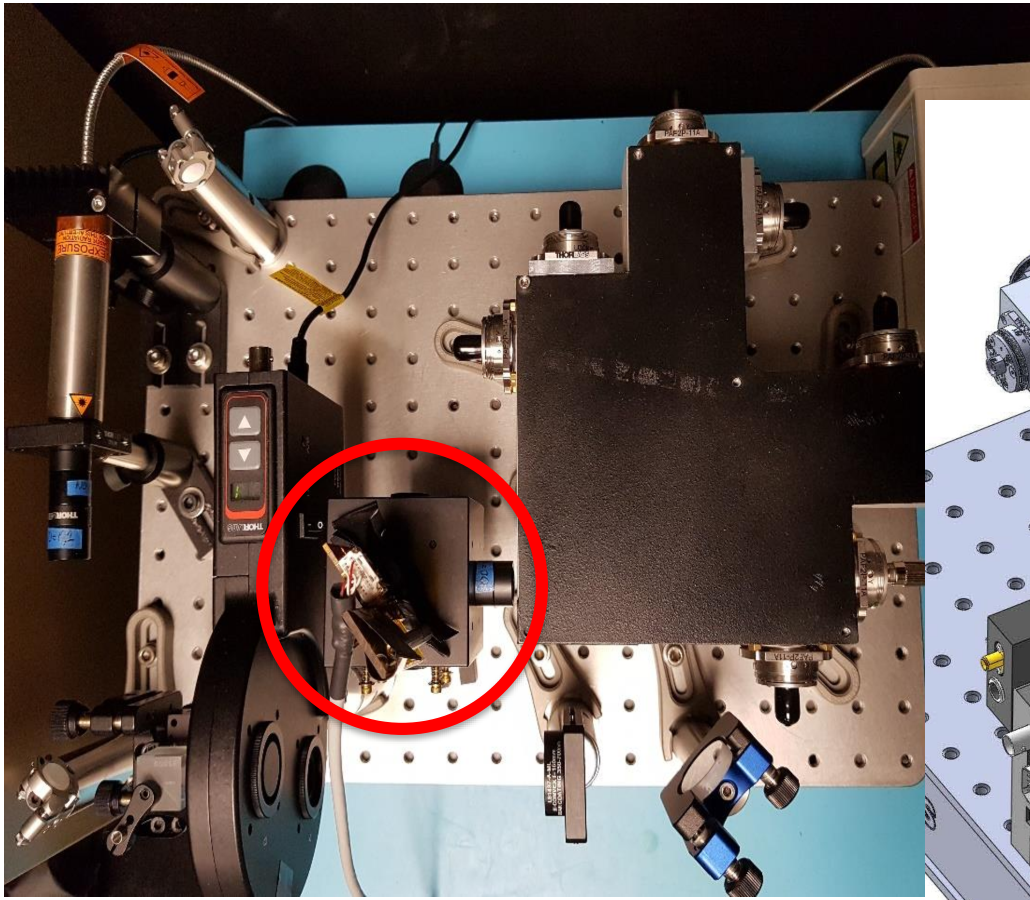
Primary distribution

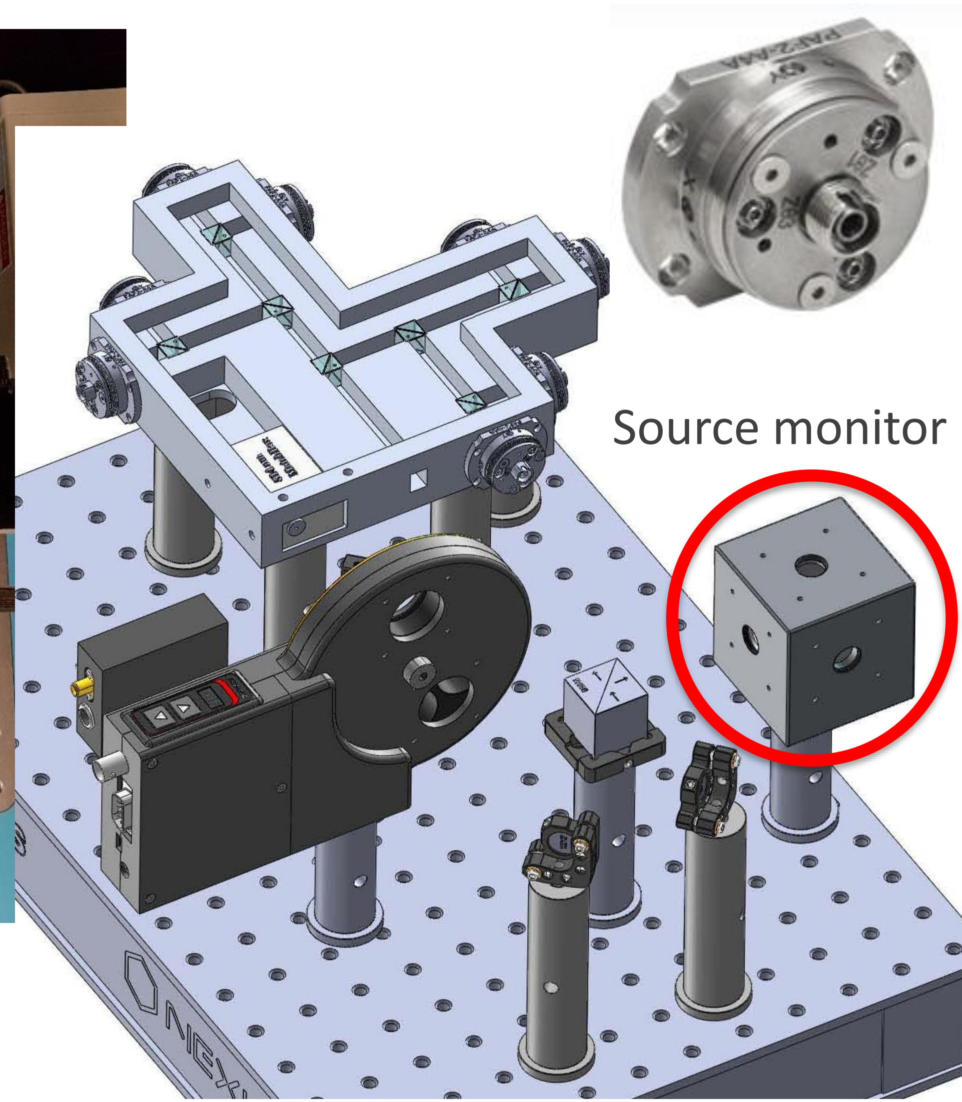
Secondary distribution



Fermilab

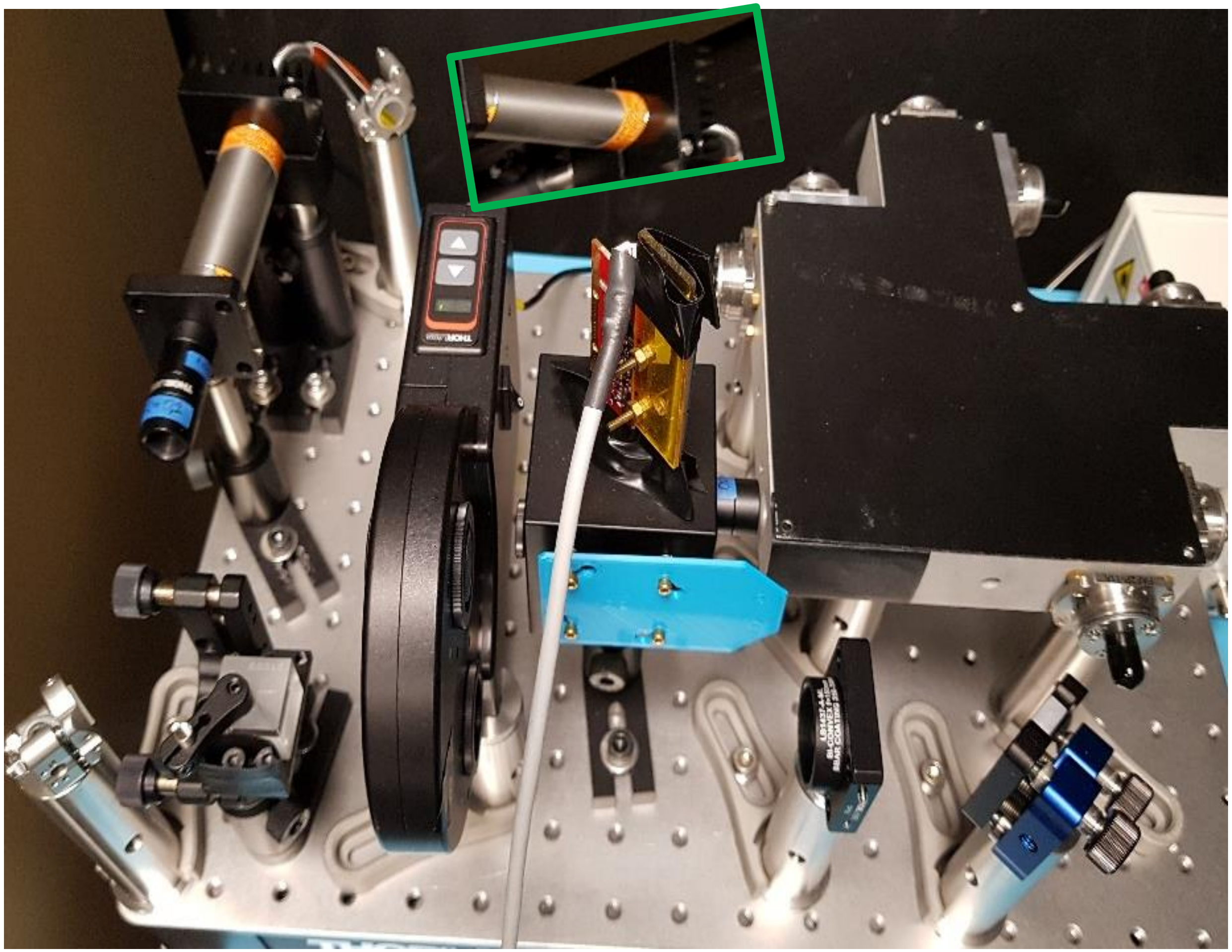
Primary distribution system



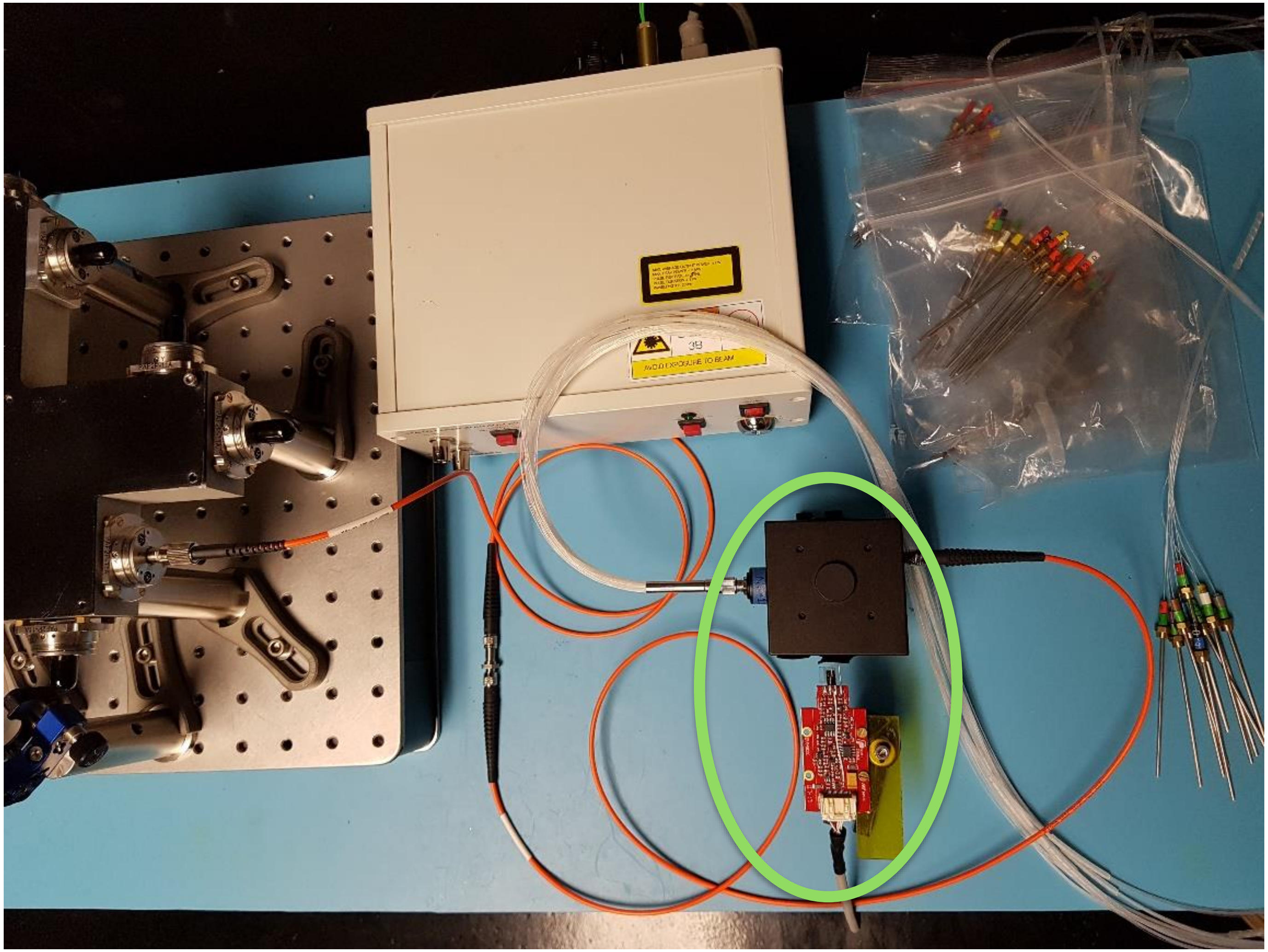


- New lens
- New cube splitter
- Room for a spare laser

Primary distribution system – spare laser



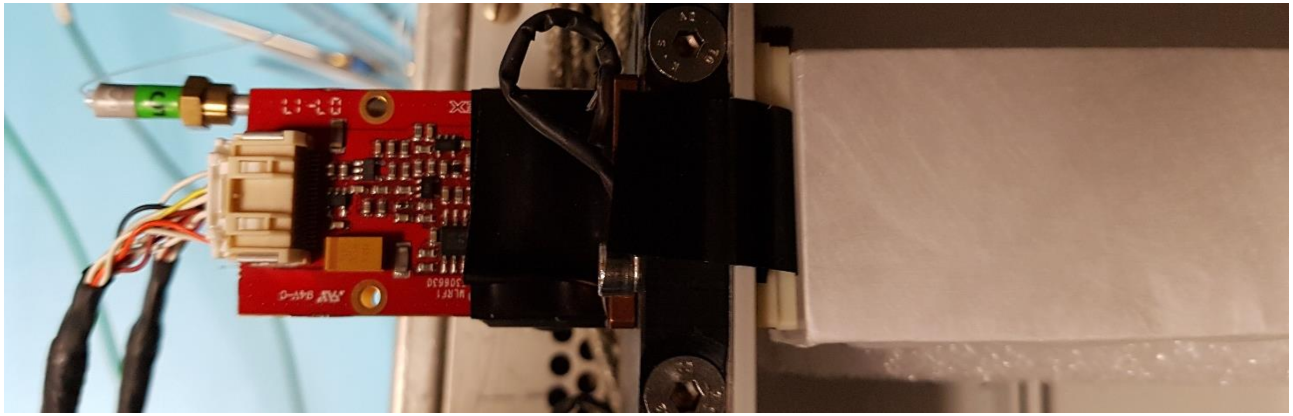
Secondary Light distribution system

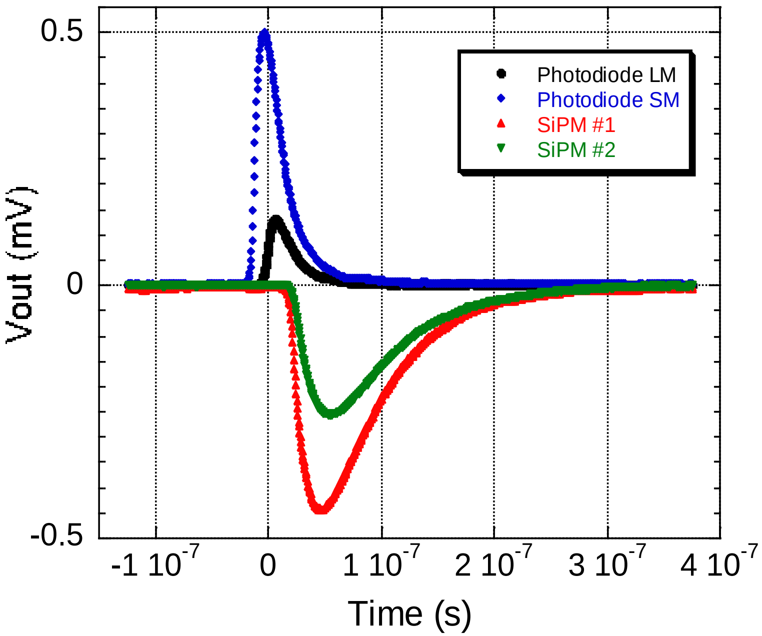


Local monitor

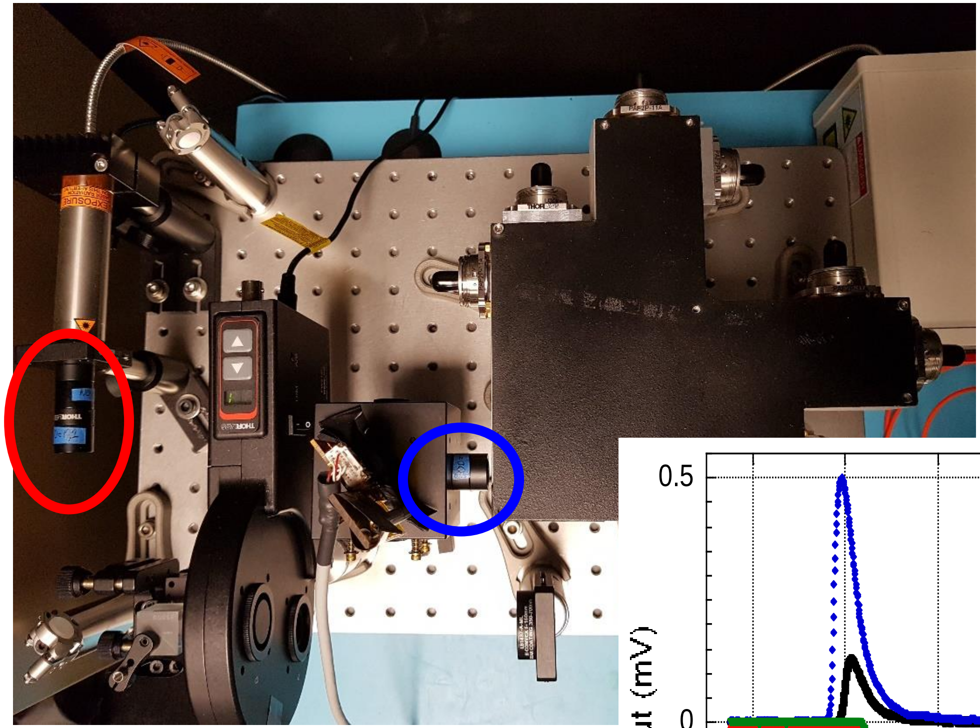
Fermilab

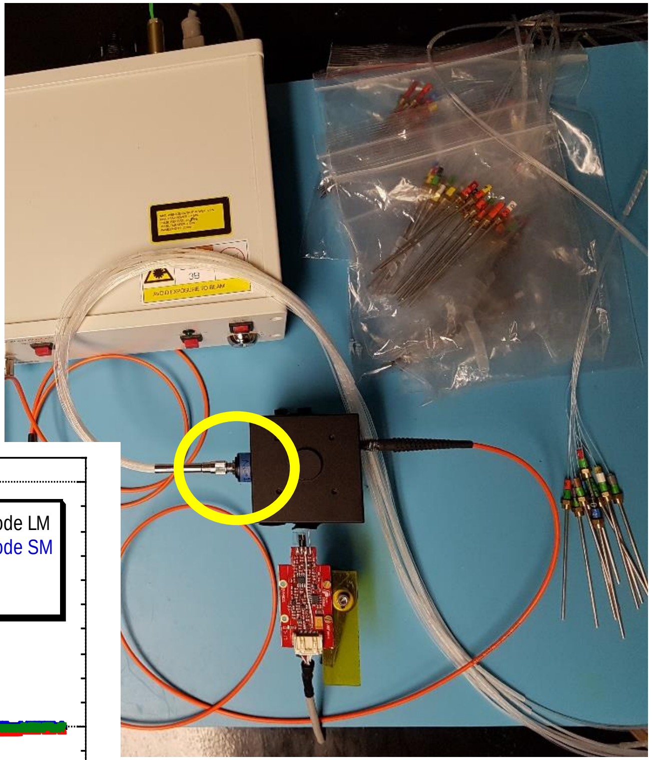
SiPM + Crystal

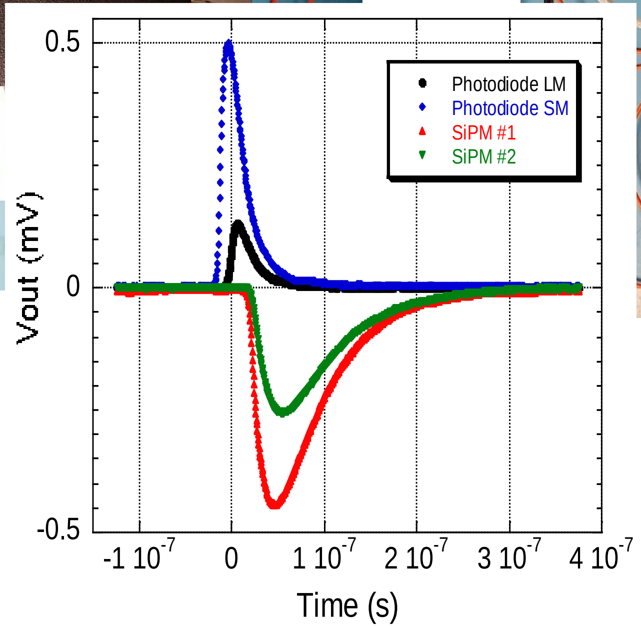




Neutral filters







Energy budget

The estimated overall transmission is $T = 10^{-7}$

We need 3000 photoelectrons/photosensor

=> The laser must provide $3*10^{10}$ photons/pulse

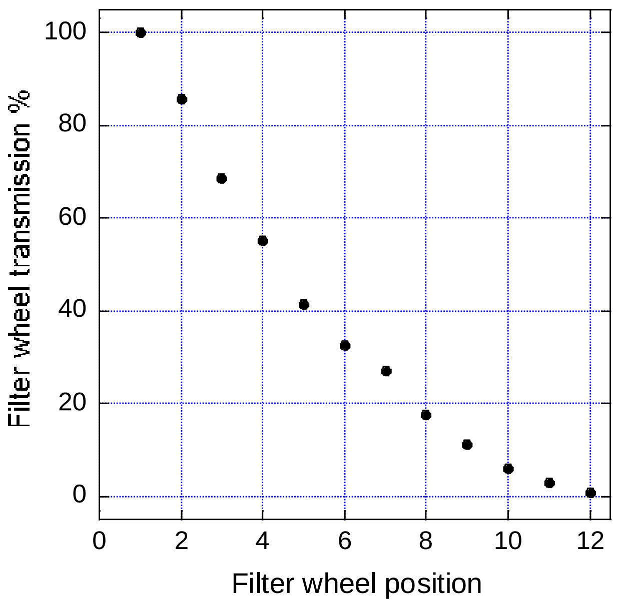
@ 500 nm 1 photon = 0.4 aJ

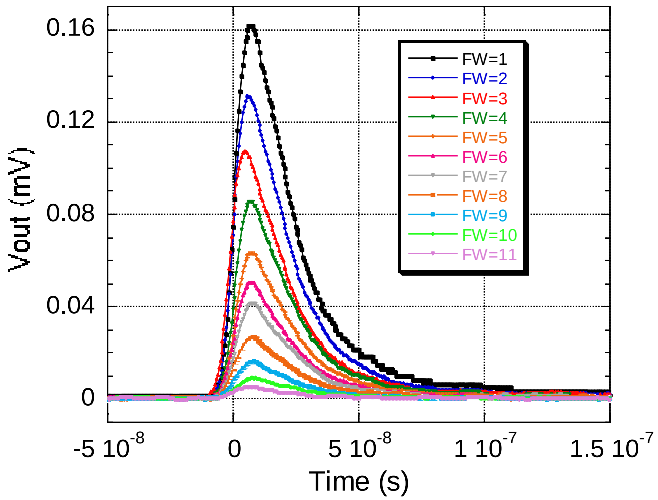
=> ***The laser must provide 12 nJ/pulse***

Component	Transmission
Laser	**9.5 μJ/pulse**
Neutral filter = 1.3	*5%*
Mirror + cube 50:50	52%
Mirror+Lens+Splitting+ Collimator+1m Fiber	5%
70 m fiber	60%
Optical feedthrough	70%
10 m fiber	90%
Integrating sphere	0.003%
Neutral filter = 1.3	*5%*
Fiber bundle	98%
Crystal	50%
SiPM collection area	18%
SiPM PDE	20%

Filter wheel scan

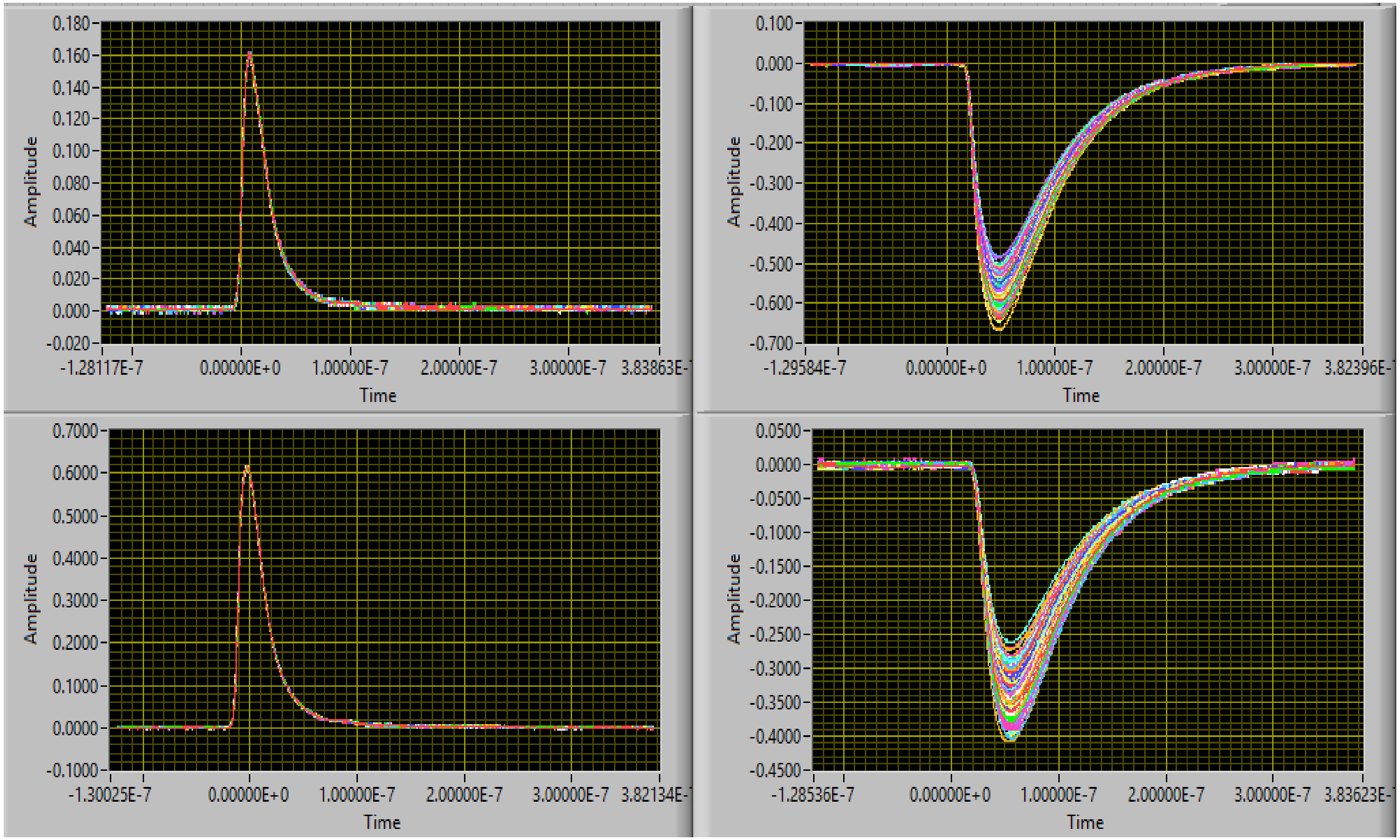
Filter wheel pos	Th trans. %	Out after FW (mW)	Trans. %	Fiber out (mW)
1	100	1263	100	52.5
2	80.6	1083	85.7	44.5
3	64.5	866	68.6	34.7
4	50.8	697	55.2	27.8
5	39.0	526	41.6	20.4
6	31.6	410	32.5	16.1
7	25.0	341	27.0	13.3
8	16.1	223	17.7	8.4
9	10.1	140	11.1	5.33
10	5.05	76.9	6.09	2.91
11	2.52	35.9	2.84	1.35
12	0.96	10.73	0.85	0.39





SiPM waveforms

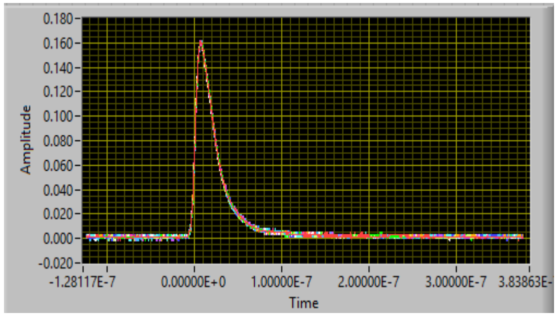
Persistency plot 600 waveforms



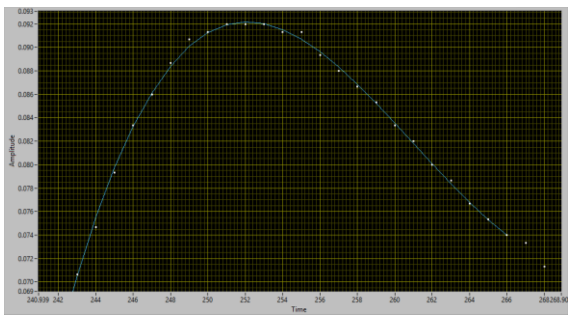
Photodiodes SiPMs

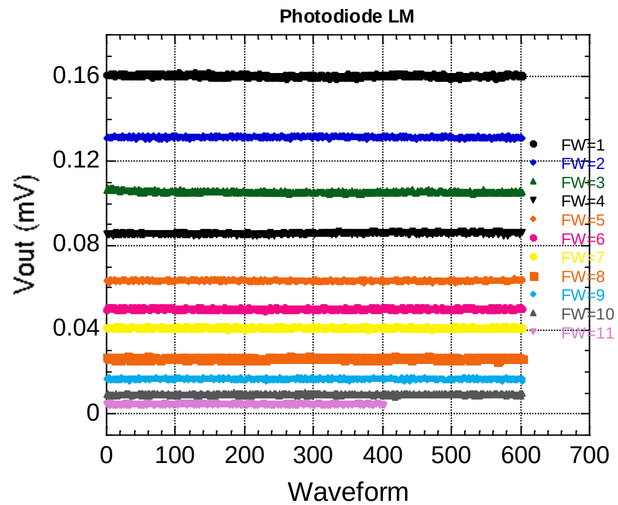
Fermilab

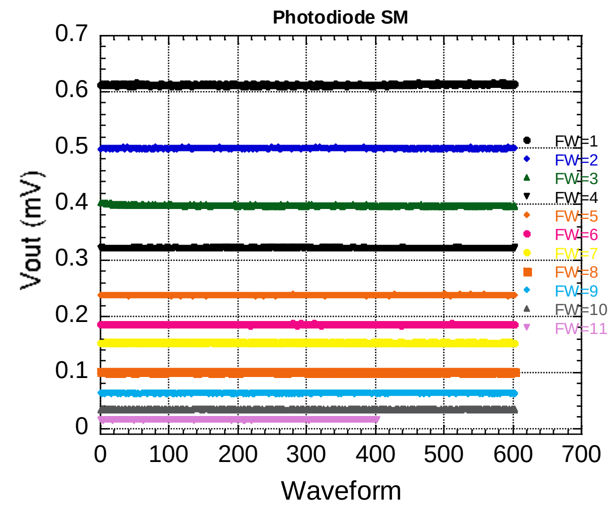
Pk-to-pk amplitude

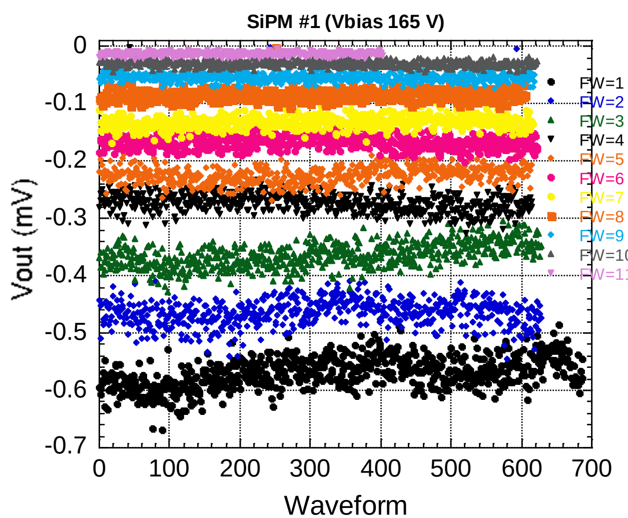


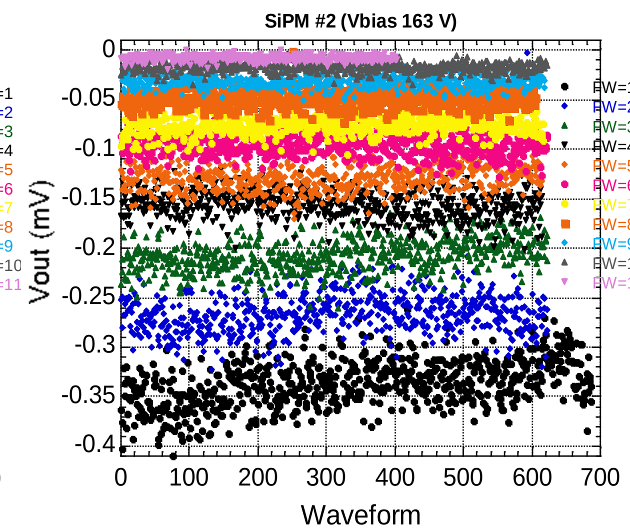
Baseline is the average of the first 200 points







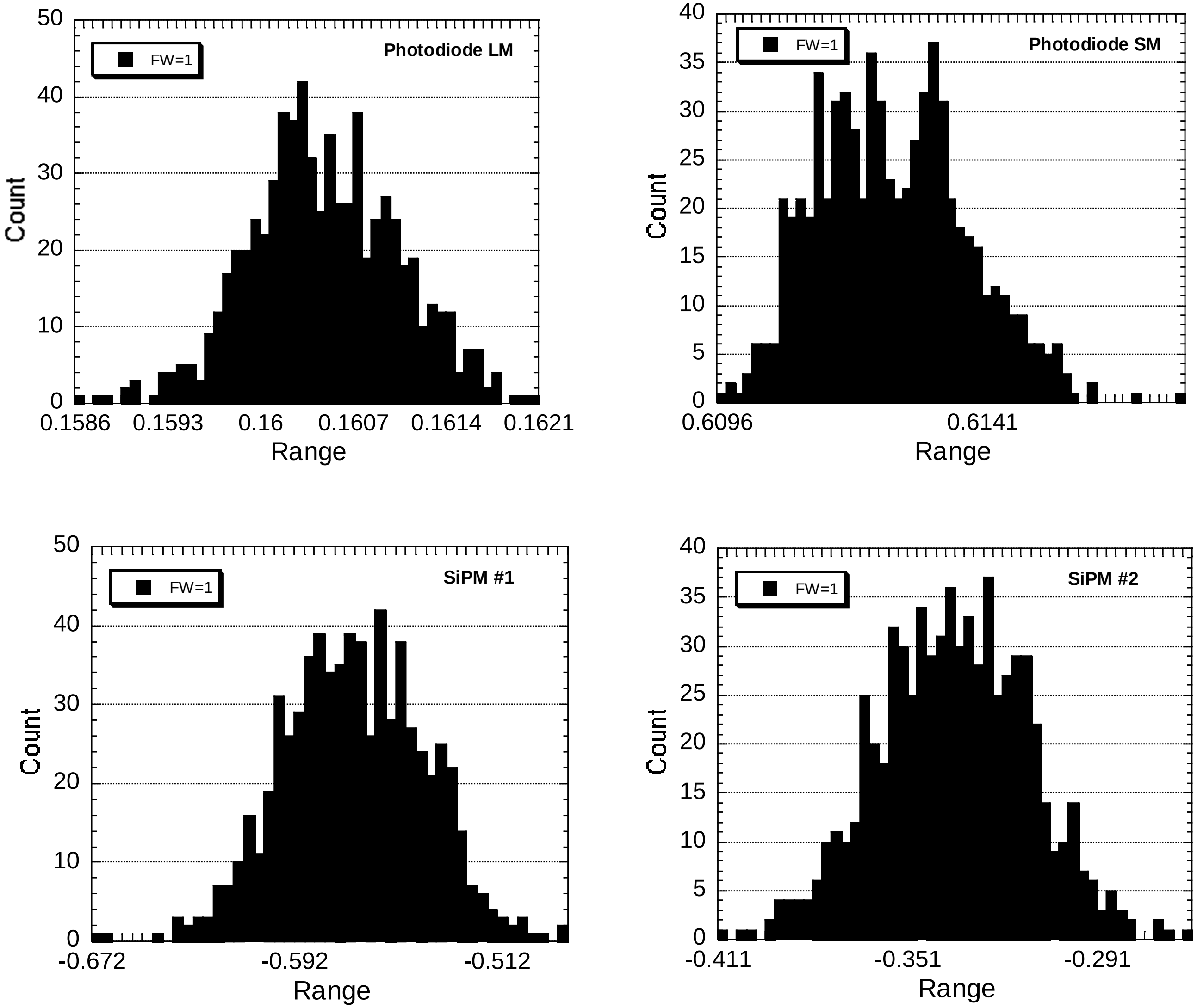




Distributions

600 waveforms

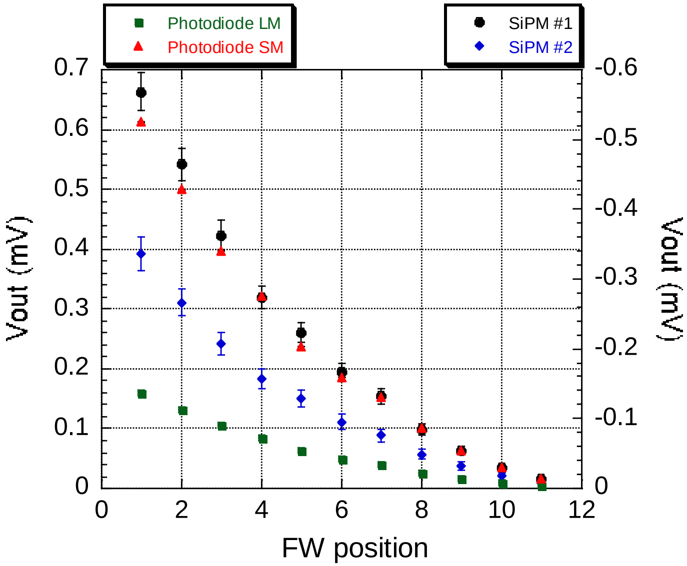
FW = 1



Mean and the standard deviation

FW	Ph LM	sd	Ph SM	sd	SiPM #1	sd	SiPM #2	sd
1	1.605E-1	5.623E-4	6.126E-1	1.266E-3	-5.687E-1	2.780E-2	-3.365E-1	2.371E-2
2	1.314E-1	4.224E-4	4.996E-1	8.856E-4	-4.643E-1	2.245E-2	-2.666E-1	1.877E-2
3	1.054E-1	4.717E-4	3.976E-1	1.118E-3	-3.632E-1	2.133E-2	-2.074E-1	1.603E-2
4	8.571E-2	4.605E-4	3.217E-1	5.678E-4	-2.732E-1	1.570E-2	-1.567E-1	1.373E-2
5	6.329E-2	3.449E-4	2.378E-1	5.602E-4	-2.243E-1	1.402E-2	-1.291E-1	1.225E-2
6	4.991E-2	3.483E-4	1.855E-1	5.064E-4	-1.666E-1	1.181E-2	-9.554E-2	1.050E-2
7	4.086E-2	3.489E-4	1.531E-1	4.704E-4	-1.320E-1	1.074E-2	-7.579E-2	8.596E-3
8	2.652E-2	3.568E-4	1.013E-1	3.943E-4	-8.444E-2	7.730E-3	-4.900E-2	7.640E-3
9	1.666E-2	3.336E-4	6.316E-2	3.911E-4	-5.439E-2	6.446E-3	-3.219E-2	5.732E-3
10	9.300E-3	3.176E-4	3.420E-2	3.579E-4	-2.972E-2	5.129E-3	-1.742E-2	4.560E-3
11	4.612E-3	3.184E-4	1.571E-2	3.262E-4	-1.326E-2	3.040E-3	-8.181E-3	2.982E-3

Graphs



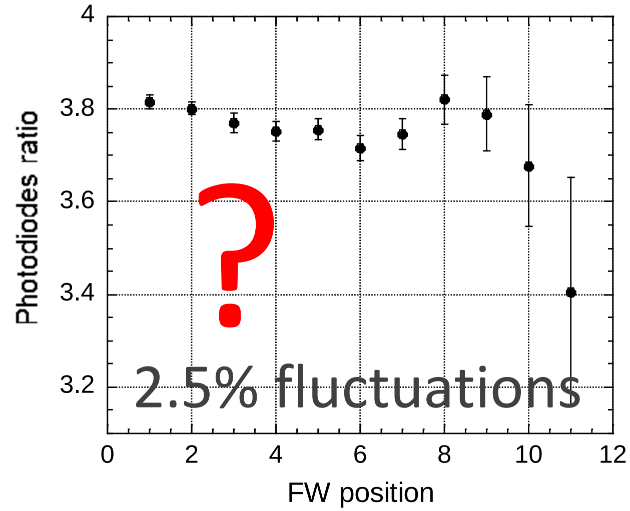
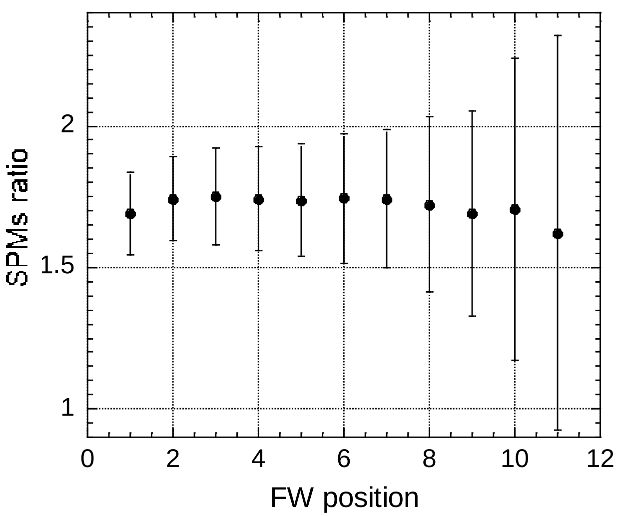
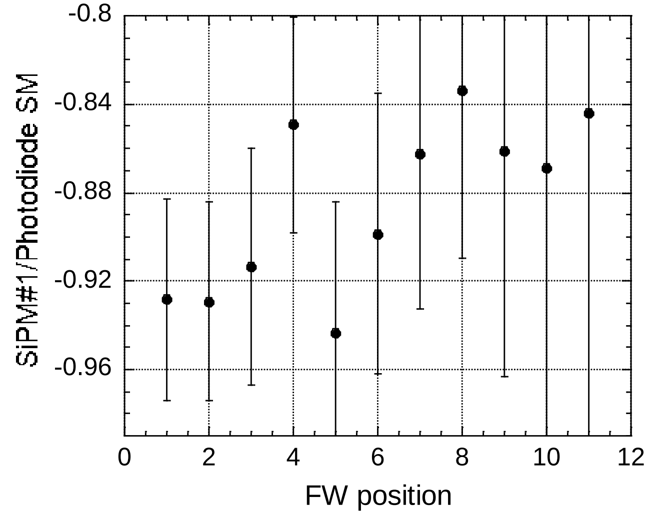


Table Instability?

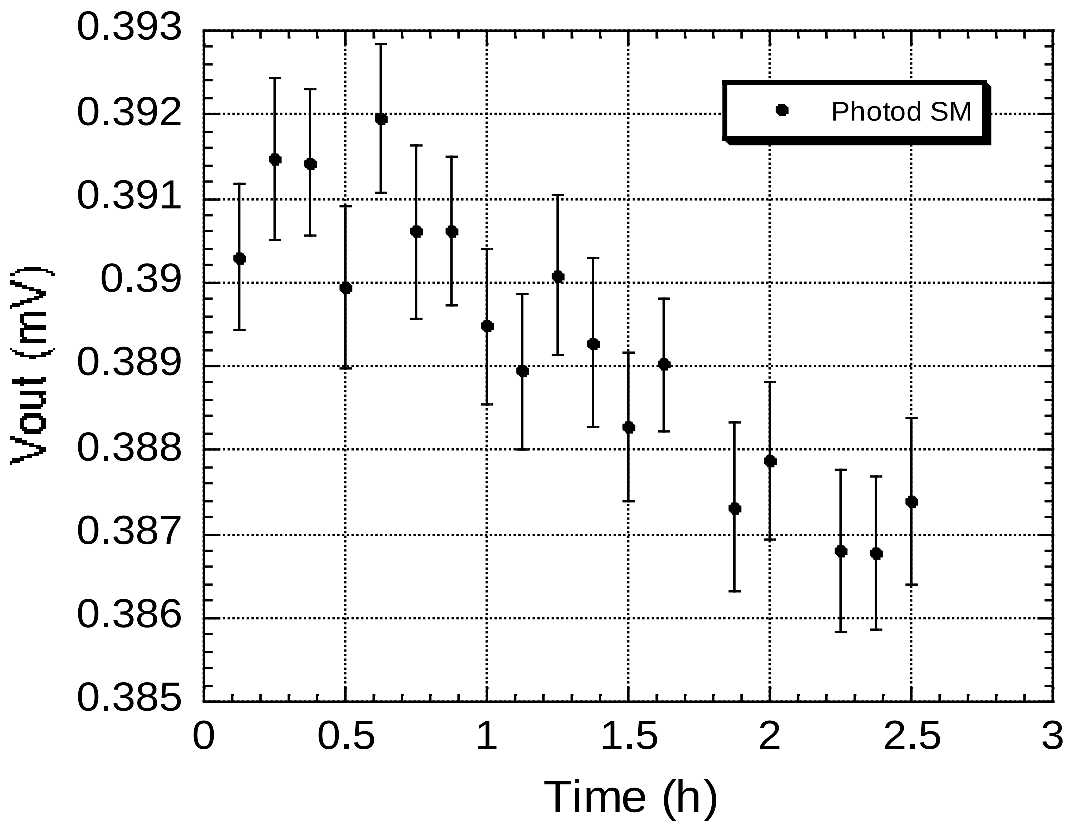




Should cancel laser fluctuations

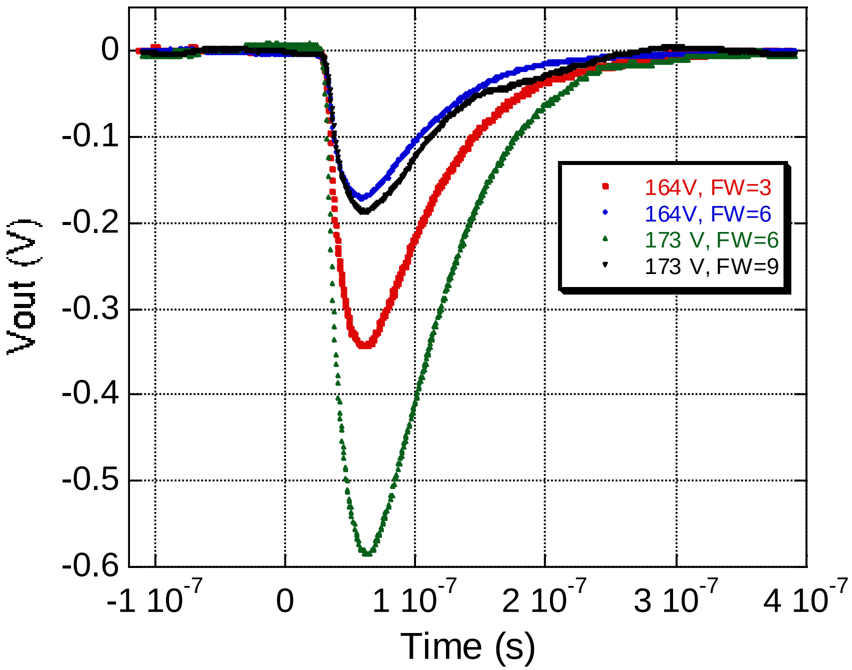
Laser stability

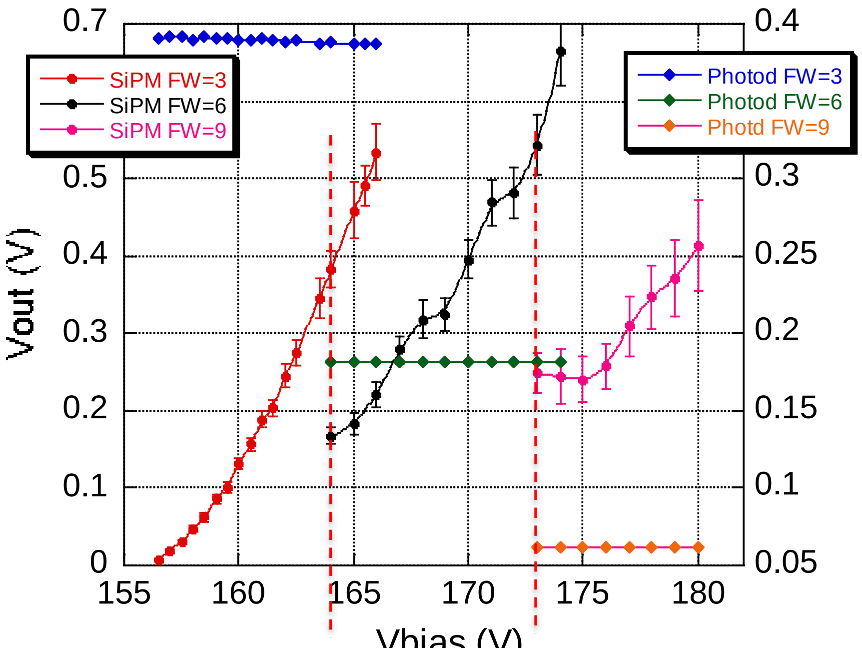
0.5 %/hour drift: laser or Ph+electronics



SiPMs bias scan

Tree filter wheel positions
(3 = 68%, 6=32%, 9=11%)

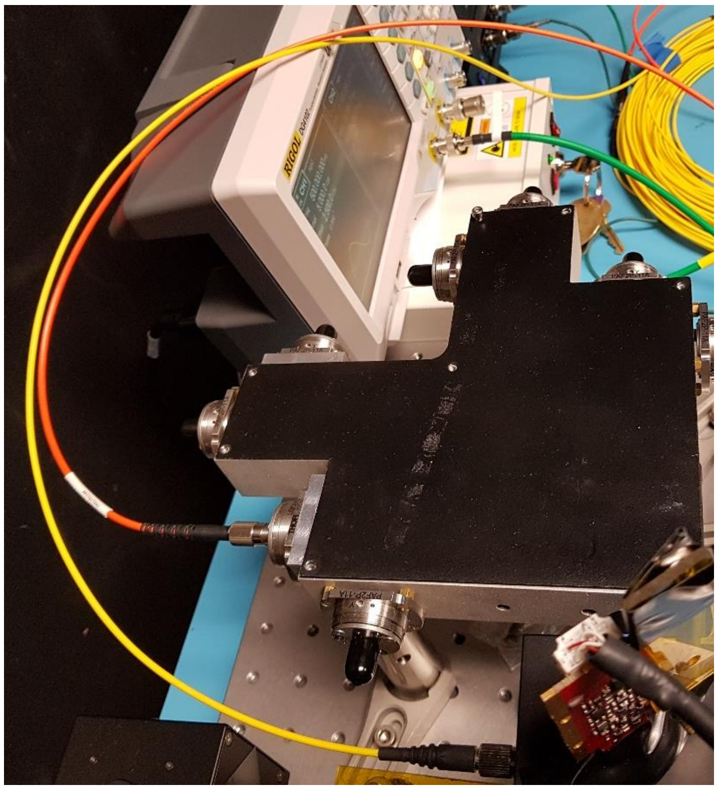


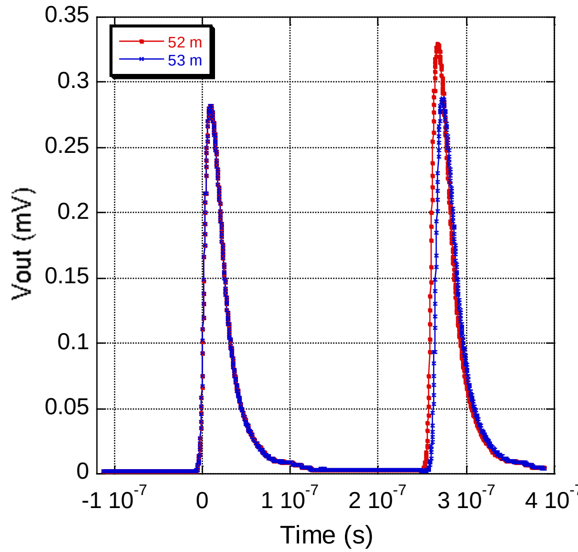


Fermilab

Setup for fibers length measurements

Connect the fiber to the collimator and to the SM sphere





Δt_{52m} = 2.5830 E-7

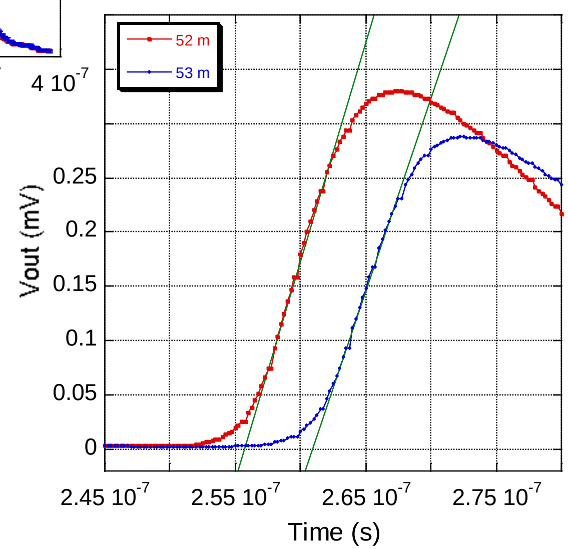
σ = 4 E-12

Δt_{53m} = 2.6355 E-7

σ = 1 E-11

The time delay introduced by the 1 m long fiber is δt = 5.25 ns.

As the refraction index of pure Silica is 1.461 (@ 532 nm), the expected value would be 4.87 ns

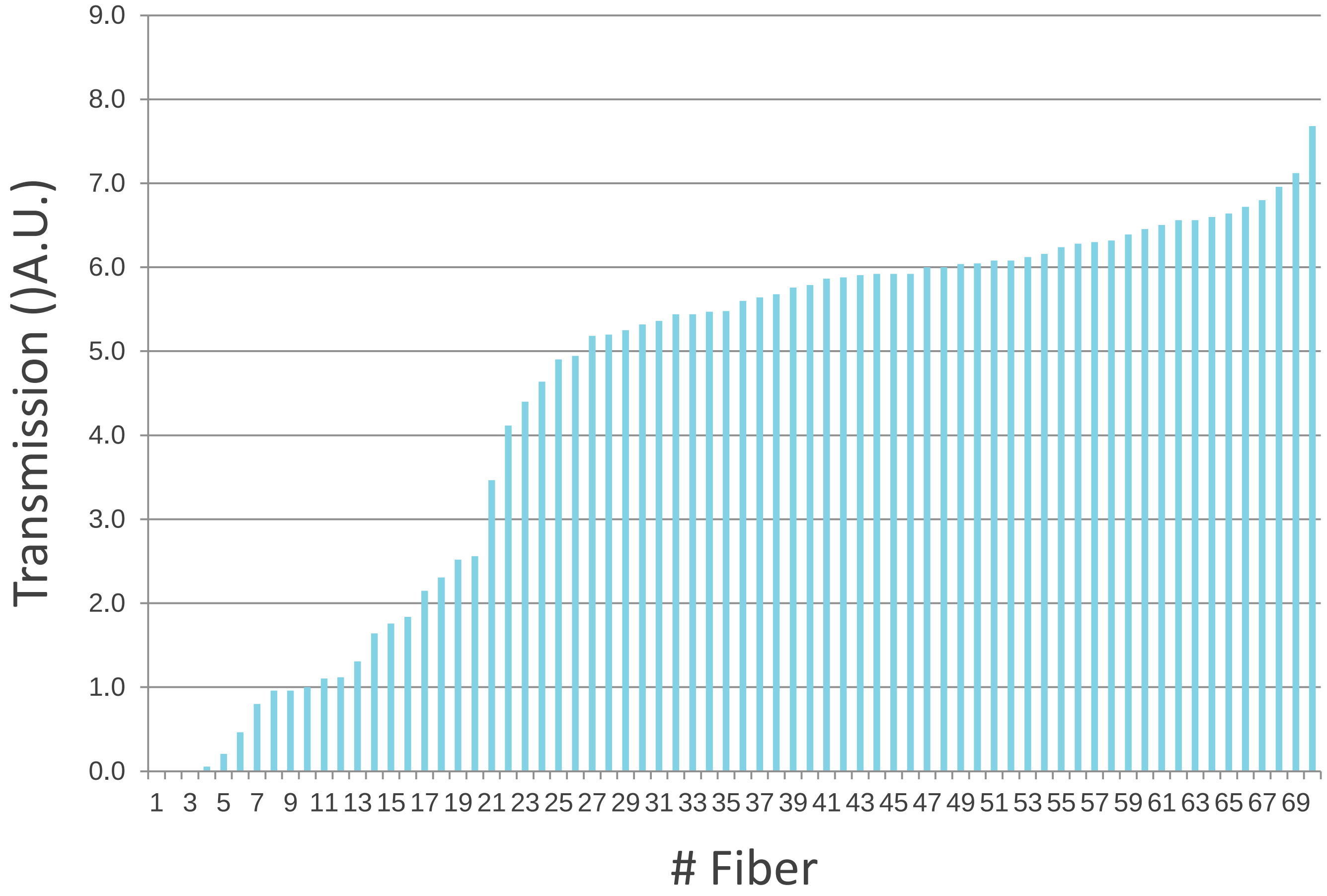


To do list

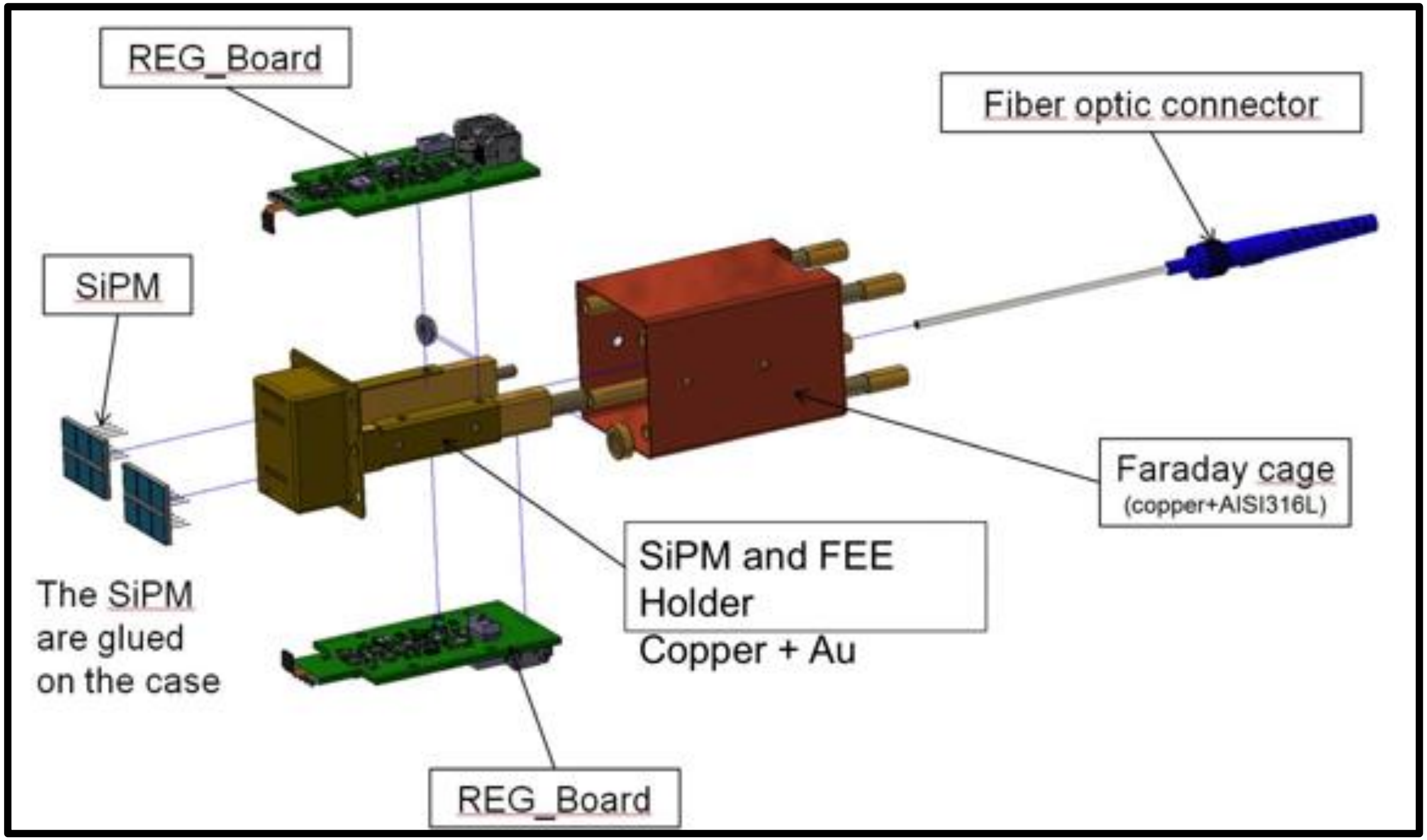
- Test the optical feedthrough (just delivered at FNAL)
- Test again photodiodes stability
- Select photodiode (Hamamtsu, mod. s1226 or s12698); waiting for gamma irradiation test
- DAQ & TDAQ integration

SPARE

Fiber bundle transmission



End point of the light distribution chain



Distribution in the Disk

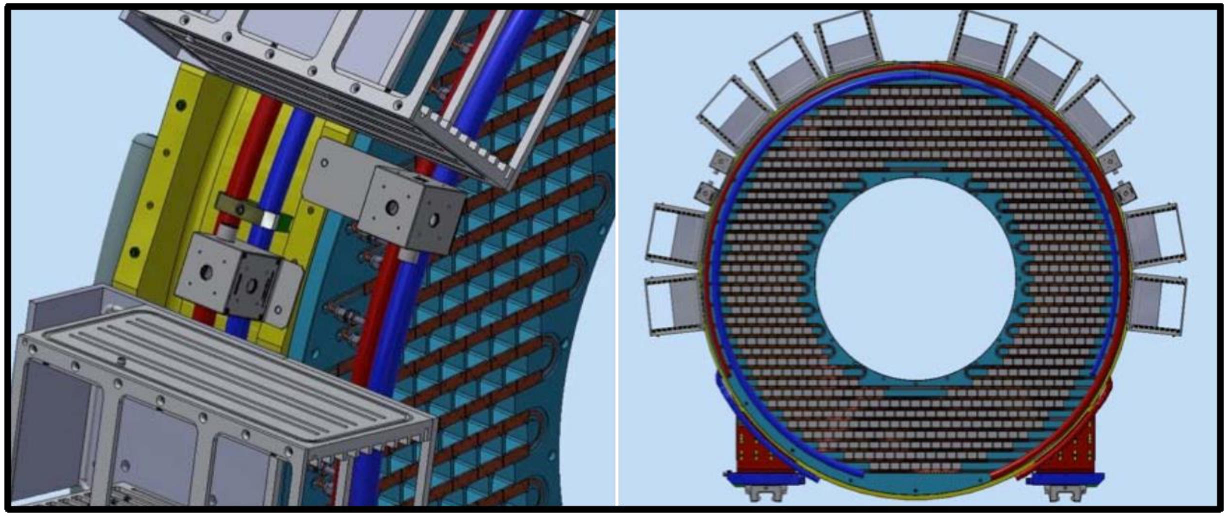


Figure 6: (Left) Positioning of spheres in the outer disk and (right) disk transversal view.

There will be 8 60 meters (400 um diameter) fused silica lqunching fibers going from the DAQ room to the IFB. Through Optical Feed-throughs other 8 “10” m fibers will arrive to the Disks to 8 Diffusing Spheres. **They will be routed in the same path of LV/HV services**

Option to move the sphere at higher height down to lower position is being studied (with the CAD) in order not to interfere with Tracker alignment.

Routing of the fiber bundles in the Back disk is also under study. It will be completed once the routing of FEE cables will be frozen.

TDAQ integration

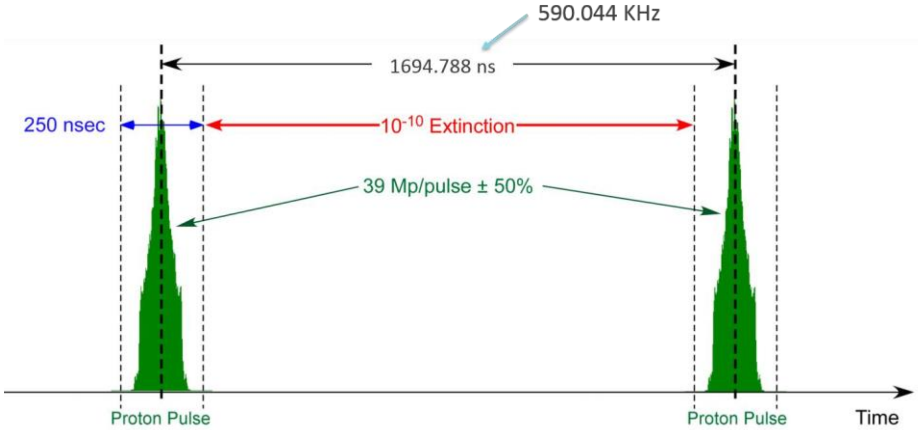


Figure 1. A spill consists of ~25,000 proton pulses (250ns wide) spaced by 1695ns.

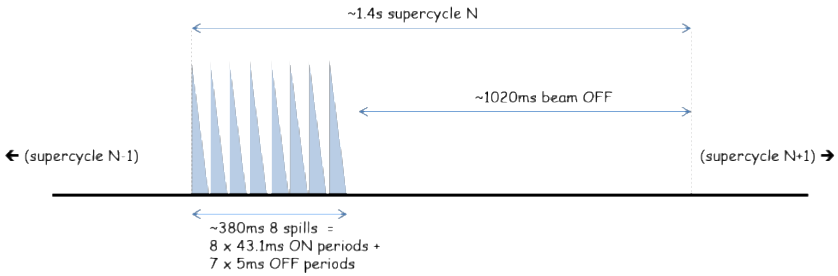


Figure 2. The anticipated supercycle timeline is ~1.4 s and consists of 8 spills each spaced by 5 ms. The phase of proto arrival may change for each spill.

We will receive from the TDAQ one copy of the encoded clock and a Control Optical Link. Our plan is to drive the laser system at very low frequency (0.1-0.2 Hz) and synchronize the arrival time of the calibration signals in a beam off period. Specific markers can be sent by the T-DAQ in the beam-off period and will be used for this synchronization. Special runs in the beam-ON period are foreseen to study the effect of the beam flash on the gain.

In order to acquire the data from the monitoring box (4 Photodiodes) in the T-DAQ room we will use 1 calorimeter like ROC so that we will receive here in input: (1) one system Clock Fiber and (2) one Control Optical Fiber. In output, we will provide 1 data fiber for readout. During calibration runs, we will acquire also another "special" calorimeter like ROC to read-out the 8 monitoring Pin Diodes inside the DS.

Safety consideration

→ The combination of rate and power makes the Laser a CLASS 3B
→ It has to be enclosed (Laser, Wheel, Primary Distribution)
→ Fiber end on the SiPM will have a peak power of few pJ .. so no problem here

→ The only problem will be in the IFB region (feed-throughs)
Here the output light of the 8 launching fibers will be very high.
Appropriate signage is needed here.

Primary Distribution system