Status of the Photosensor Testing Facility (PTF) at TRIUMF

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University of British Columbia

6th Open Meeting for the Hyper-Kamiokande Project
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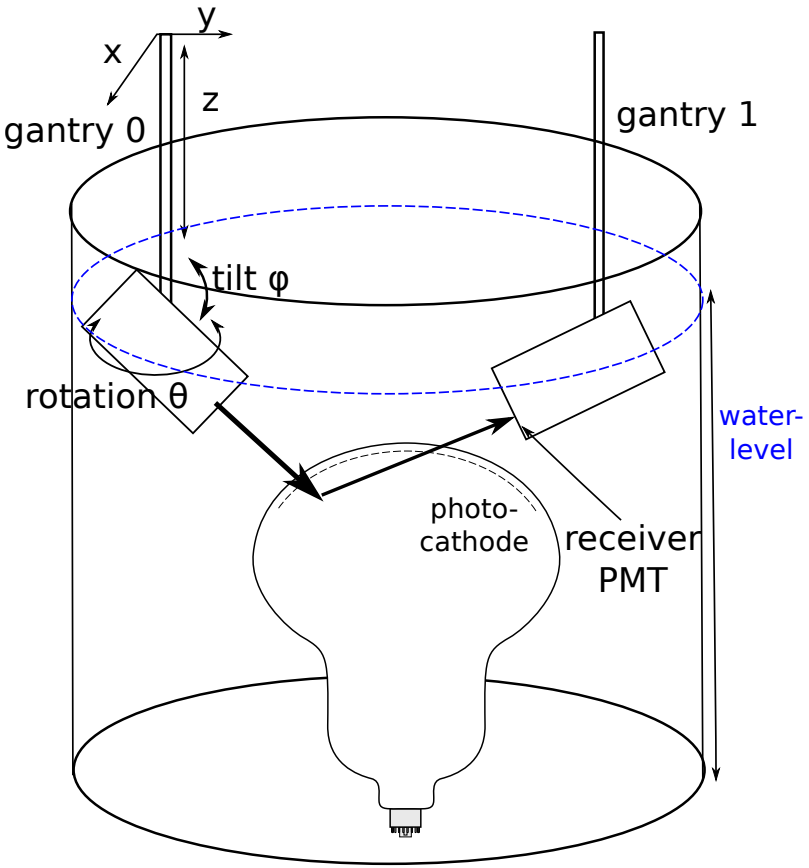
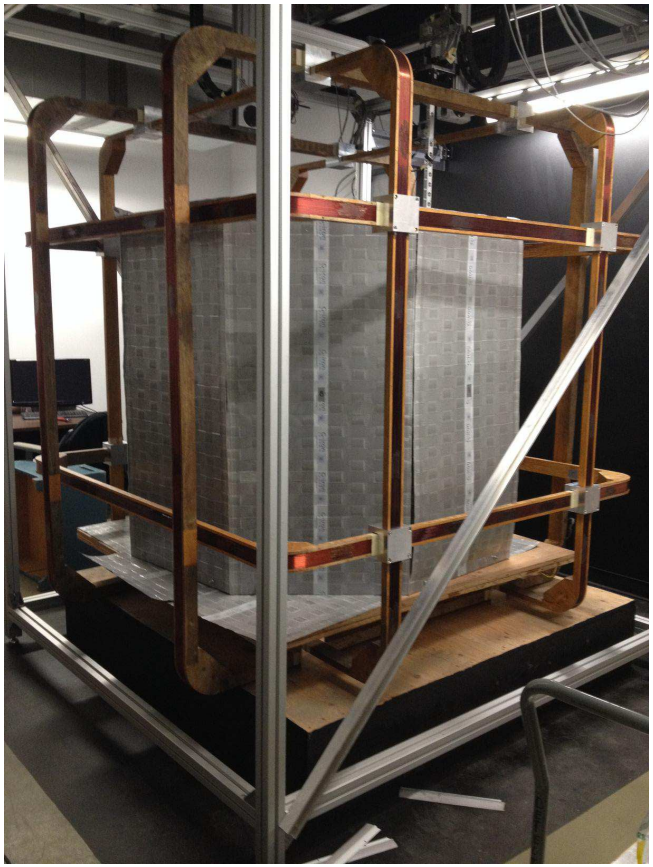
Objectives

Characterize and study optical properties of PMTs under consideration for HK and near detector.

- Measure PMT acceptance.
- Map reflectivity of PMT: important for reconstruction algorithms.
- Measure wavelength and magnetic field dependence.
- ...

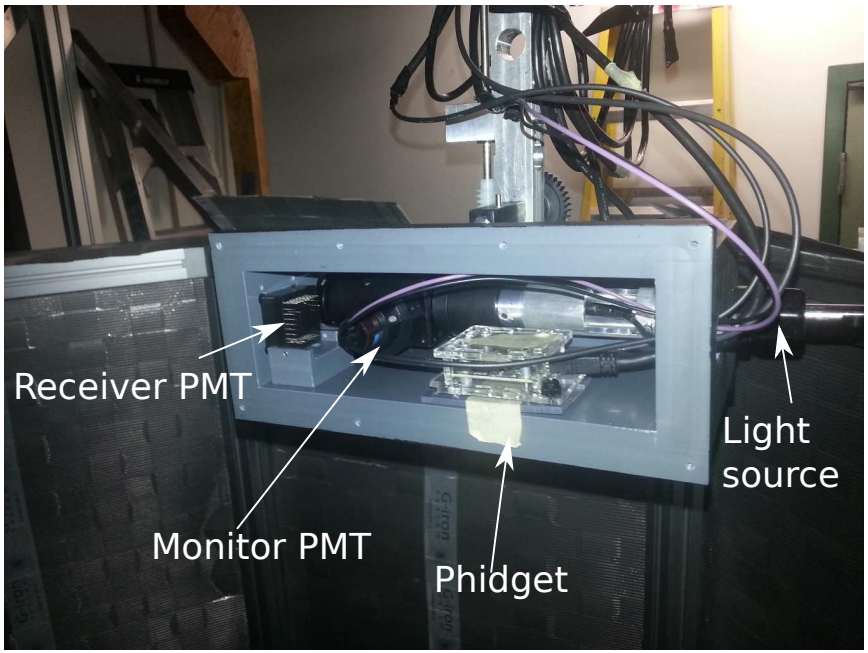
The PTF setup

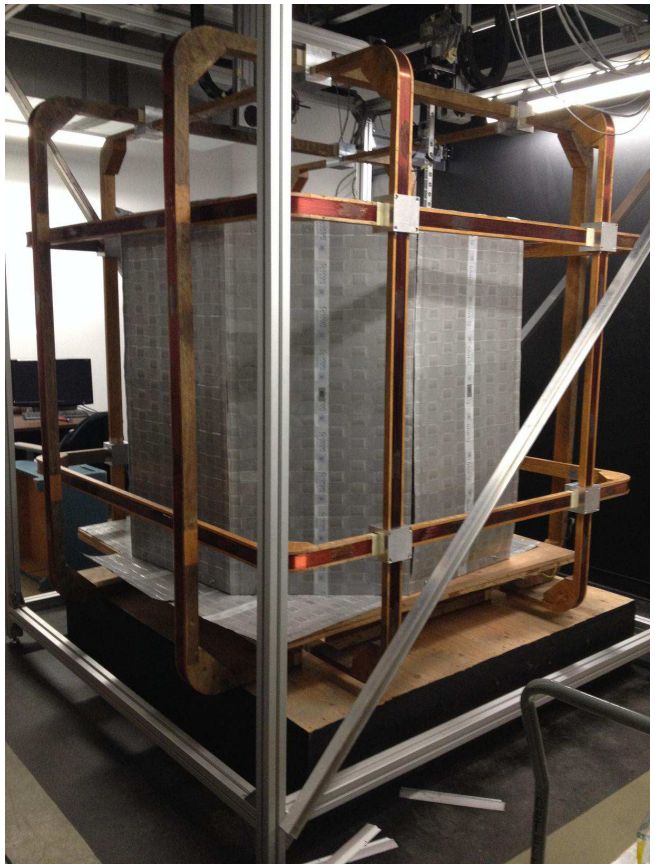




- 5 stepping motors for each of two manipulator arms (gantries) ⇒ 5D (x,y,z, rotation, tilt)
- Optical box contains USB powered board with 3-axis magnetometer, accelerometer and gyroscope (*Phidget*).
- Active cancellation with Helmholtz coil, passive cancellation with two layers of g-iron.
- Light shielding with dark curtains.

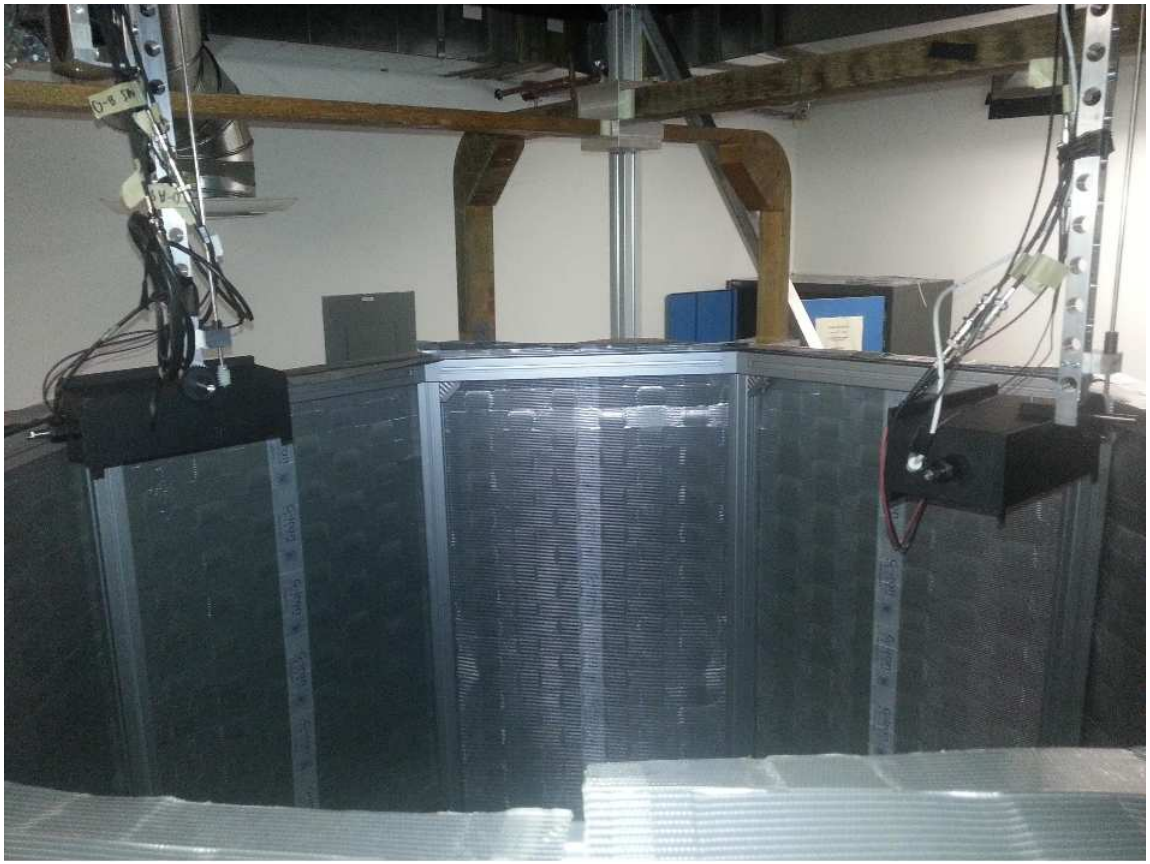
The PTF setup





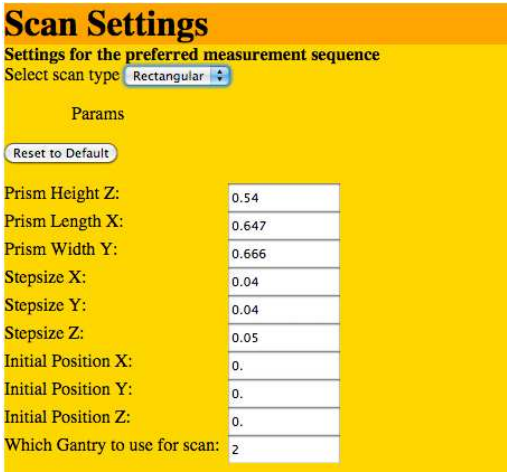
- Waterproof optical box with laser, monitor and receiver PMT attached to the head of the gantry arm.
- Multiple light sources: 405 and 467nm pulsed laser, Xe lamp with several filters.
- Collimator, polarizer and beam splitter.

Mechanical system: alignment



- Improvement of mechanical stability and reliability.
- Alignment of boundaries of X, Y and Z motion for both gantries with respect to each other up to 2 mm and maximize phase space.
- Alignment of rotation axis: needs to be improved.
- February: Full survey and realignment using laser trackers.
- Alignment measurements and measurement accuracy studies under development.

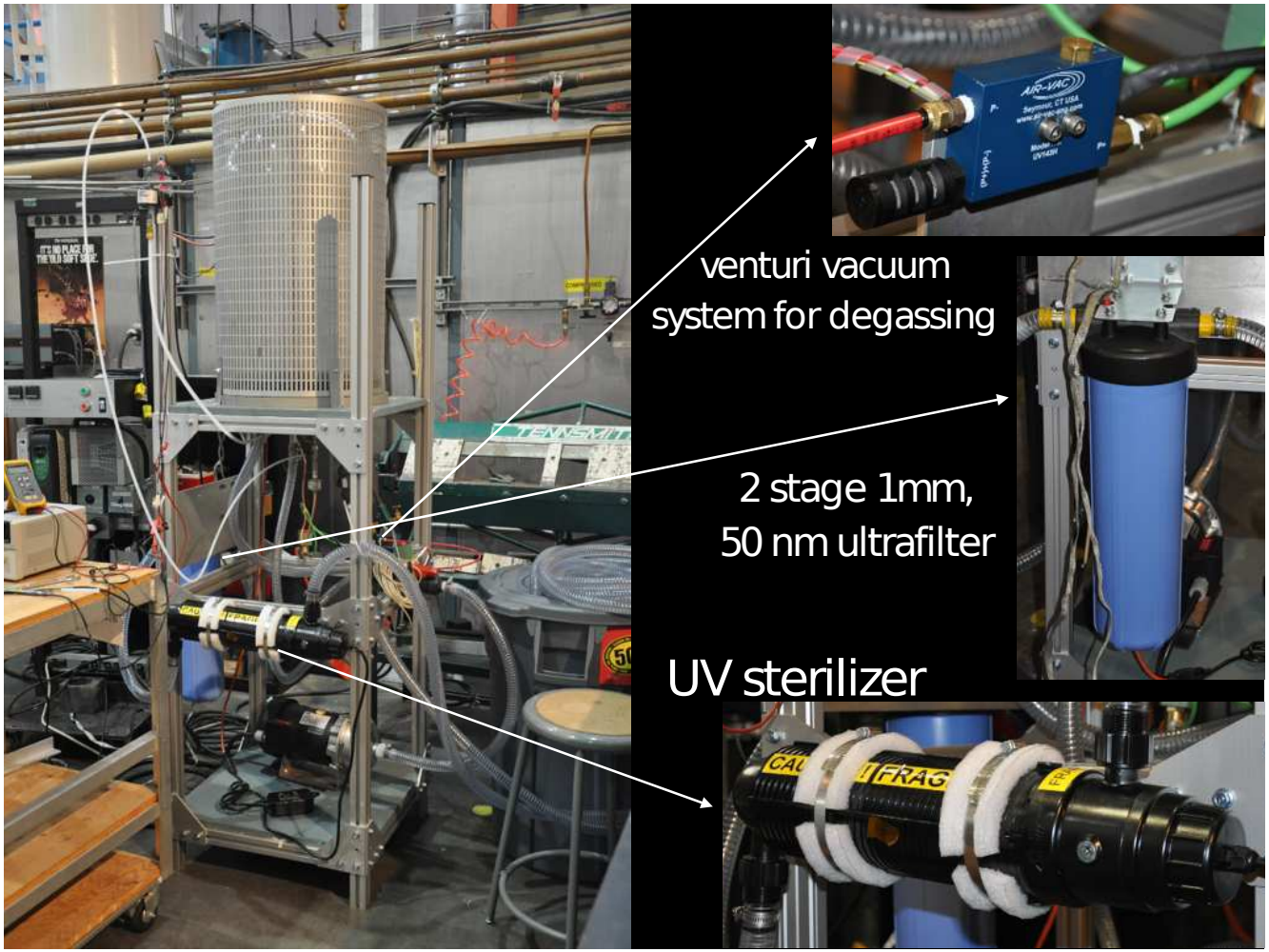
DAQ software



Run	Start Time	Stop Time	Pedestal?	Light source	Laser power	Attenuation(dB)	Comments
752	Wed Nov 19 16:32:55 2014	Wed Nov 19 16:33:15 2014	n	None	0	0	Test run logging
753	Wed Nov 19 18:13:11 2014	Wed Nov 19 18:13:20 2014	n	None	0	0	Test run logging
754	Wed Nov 19 18:26:01 2014	Wed Nov 19 18:26:17 2014	n	None	0	0	Test html table
755	Wed Nov 19 18:28:03 2014	Wed Nov 19 18:28:22 2014	n	None	0	0	Test html table
756	Wed Nov 19 18:29:06 2014	Wed Nov 19 18:29:14 2014	n	None	0	0	Test html table
757	Wed Nov 19 18:38:17 2014	Wed Nov 19 18:38:38 2014	n	None	0	0	Test html table
758	Wed Nov 19 18:44:03 2014	Wed Nov 19 18:44:21 2014	n	None	0	0	Test root tree
759	Wed Nov 19 18:52:08 2014	Wed Nov 19 18:52:25 2014	n	None	0	0	Test root tree
760	Wed Nov 19 18:55:59 2014	Wed Nov 19 18:56:07 2014	n	None	0	0	Test root tree
761	Wed Nov 19 19:14:07 2014	Wed Nov 19 19:14:20 2014	n	None	0	0	Test root tree
762	Wed Nov 19 19:16:12 2014	Wed Nov 19 19:16:21 2014	n	None	0	0	Test root tree
763	Wed Nov 19 19:18:22 2014	Wed Nov 19 19:18:32 2014	n	None	0	0	Test root tree
764	Wed Nov 19 19:23:35 2014	Wed Nov 19 19:25:48 2014	n	None	0	0	Test root tree
765	Wed Nov 19 19:37:28 2014	Wed Nov 19 19:37:54 2014	n	None	0	0	Test root tree
766	Thu Nov 20 17:45:56 2014	Thu Nov 20 17:46:22 2014	n	None	0	0	Short scan for testing new tree
767	Thu Nov 20 17:47:11 2014	Thu Nov 20 17:50:39 2014	n	None	0	0	Short scan for testing new tree

- DAQ and control of PTF through MIDAS.
- Improvements of the DAQ software: increase of phase space for scans and reliability of long scans.
- User friendly interface for taking measurements.
- New measurement sequences being tested: alignment, reproducibility, normal incidence scans,...
- Automatic conversion of MIDAS files to ROOT files with a flat tree structure.
- Automatic run logging.

Water system



- Water pumping and purification system ready.
- Tests in the PTF for early March when tank is in place.
- Particle counters for water quality monitoring installation at end of March.

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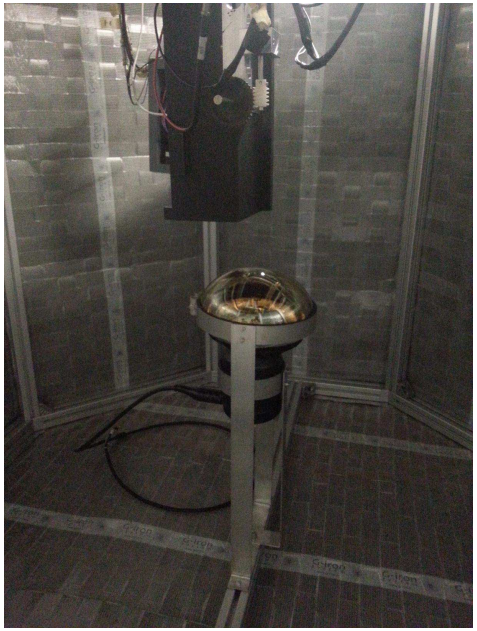
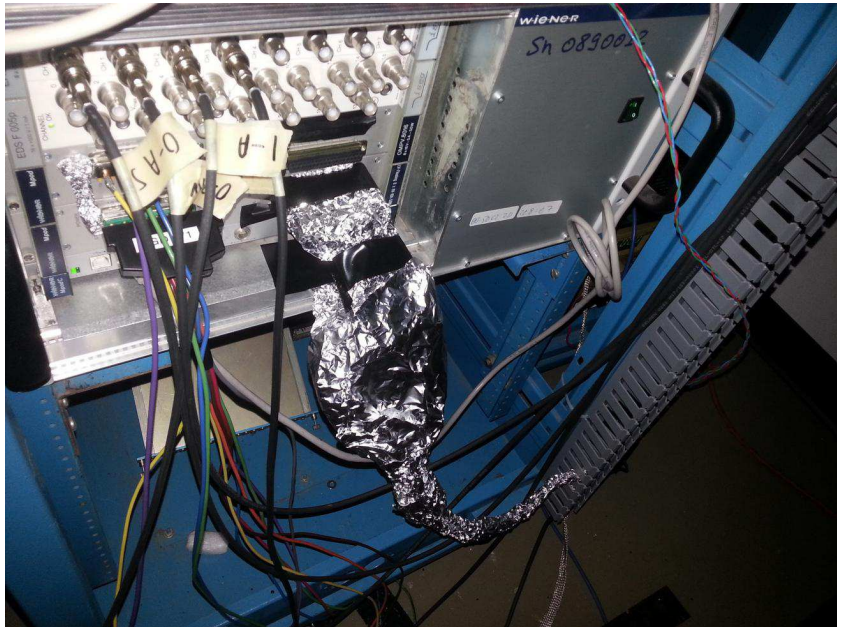
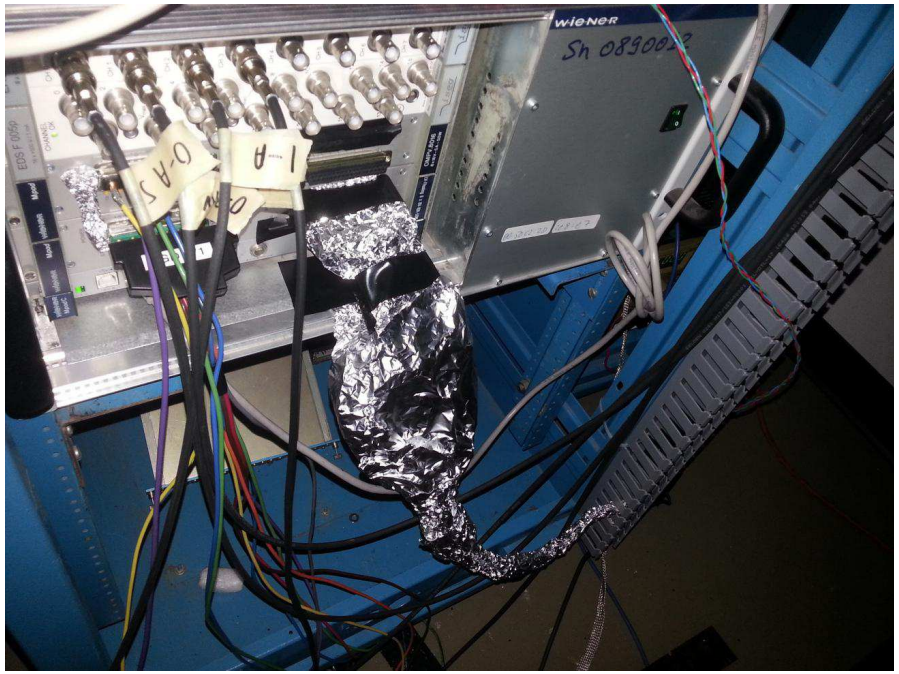
HPD setup in PTF: noise control





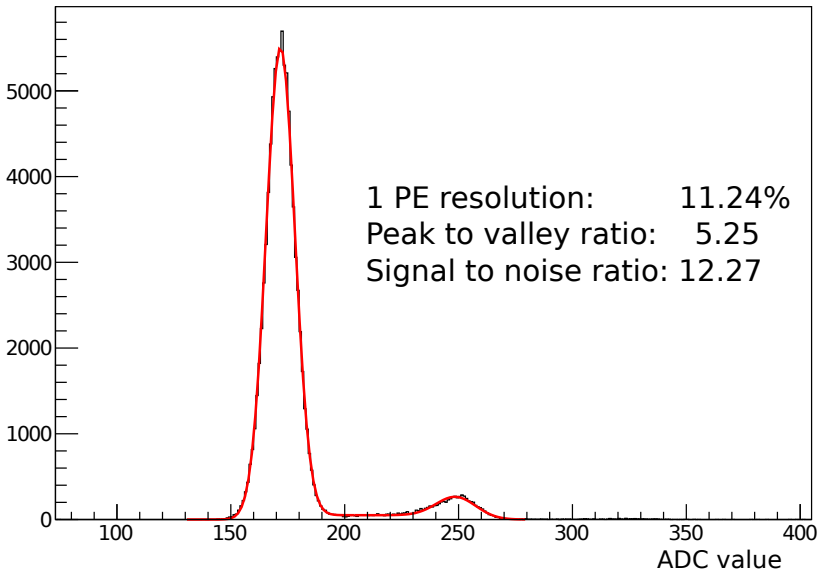
- July 2014: 8" HPD prototype arrives at TRIUMF.
- Proper shielding and grounding of power supply cables crucial for noise reduction.
- Motors switched off during measurement to limit noise from motor controller.
- Increased AD bias voltage to almost maximum rating (340V) by increasing LV control voltage (2.33 to 2.8V).

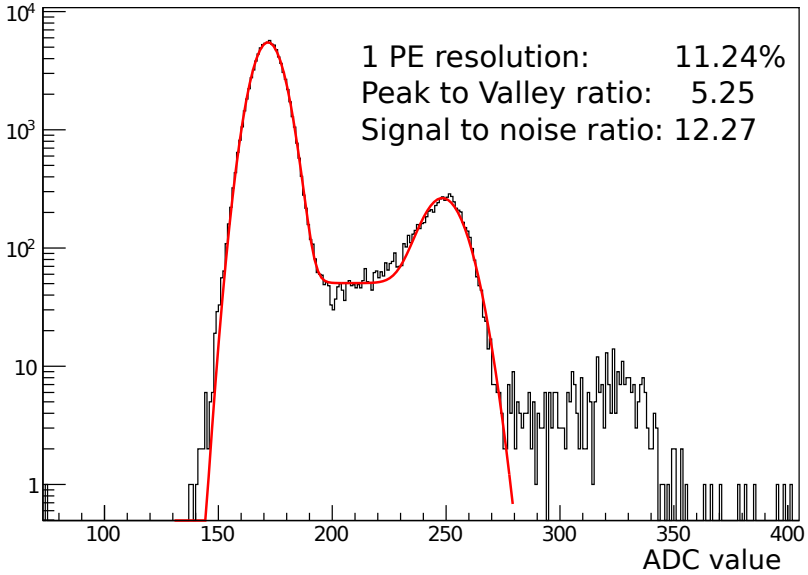
HPD signal



- Motors switched off during measurement to limit noise from motor controller.
- Properly shielding and common grounding of power supply cables crucial for noise reduction.
- Increased AD bias voltage to almost maximum rating (340V) by increasing LV control voltage (2.33 to 2.8V).

8” HPD pedestal and single PE distribution

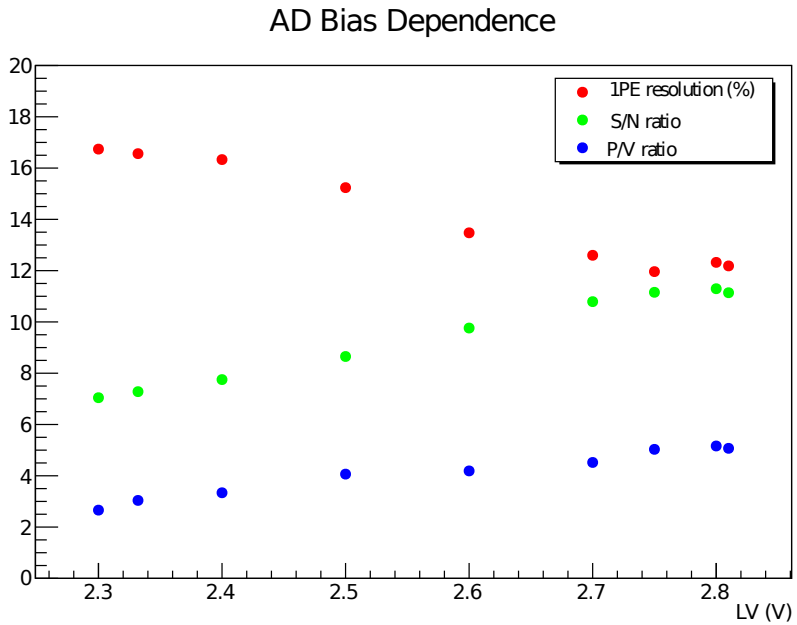


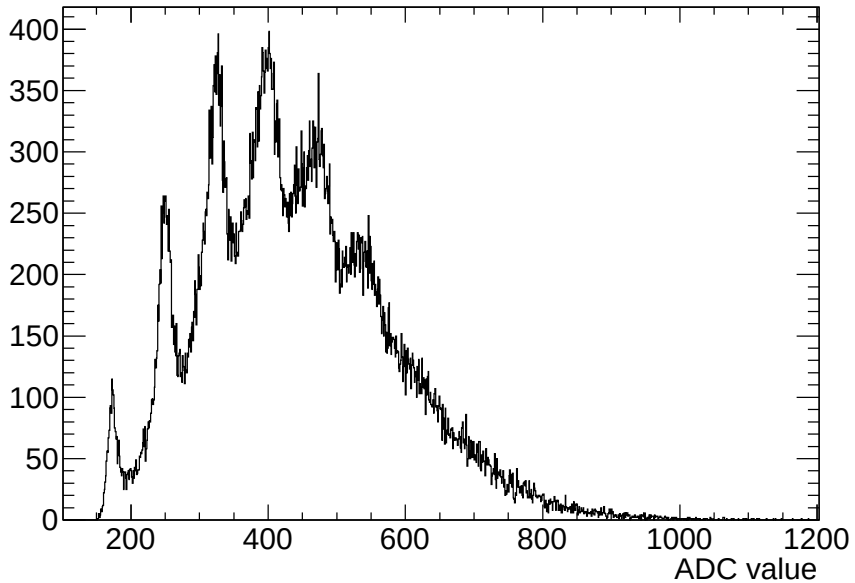


- Excellent 1pe resolution.
- Very good peak to valley ratio and signal to noise[1] ratio.

[1] Signal to noise ratio = ratio of SPE peak to pedestal sigma

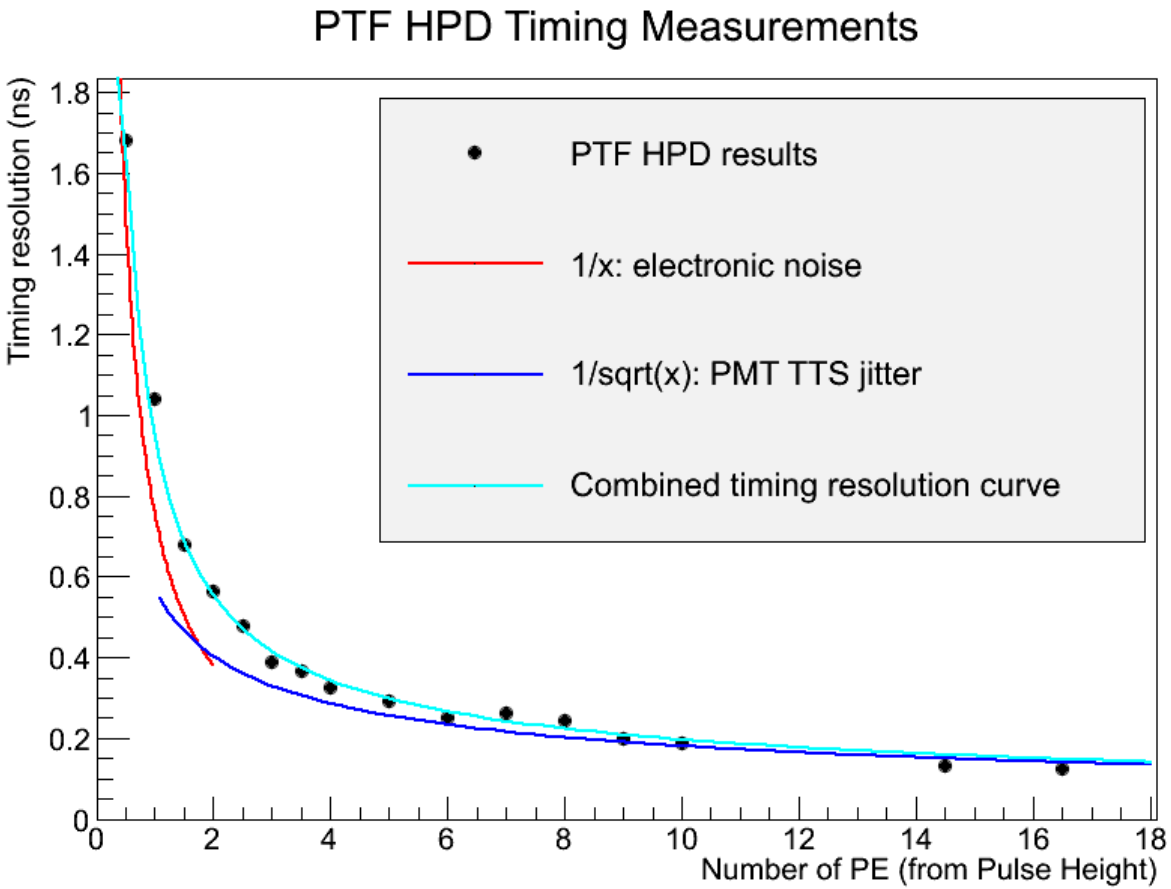
8” HPD pedestal and single PE distribution





- Optimal 8” HPD performance at PTF at LV control voltage of about 2.75-2.8V.
- Individual PE peaks become very clear up to 5 PE in charge distribution.

HPD timing resolution



- Fire laser at HPD.
- Use 500 MHz digitizer (Caen V1730) for acquiring waveform of monitor PMT and HPD.
- Width of Δt = fitted monitor PMT LE time - fitted HPD PMT LE time is resolution.

HPD performance at PTF

	8" HPD @Kamioka	8" HPD @PTF (LV: 2.8V)
1PE resolution σ/μ	12%	11.2%
Peak to valley ratio	5.2	5.25
Signal to Noise	12	12.3
Timing resolution σ (ns)	1.1	1.05

- Same performance of 8" HPD in PTF as in Kamioka after improved noise control.
- Next: Dark noise, pulse shape and stability (gain, DN).
- PTF in good shape for 20" PMT measurements.

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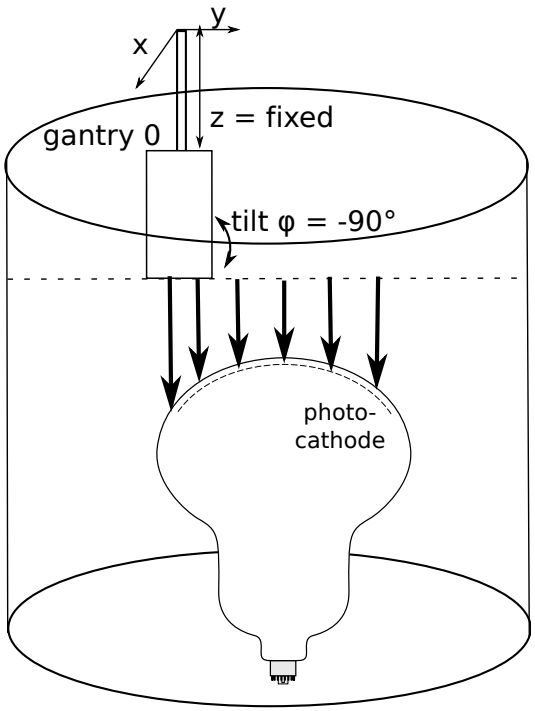
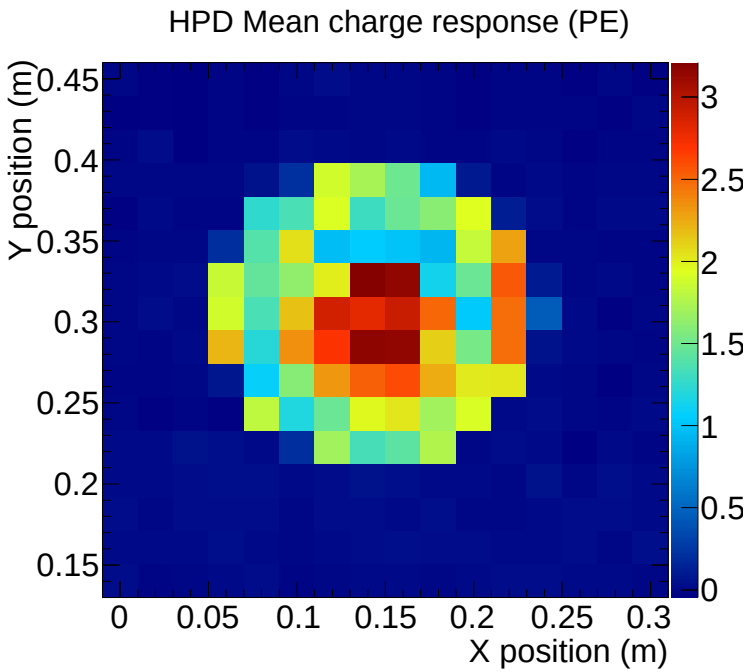
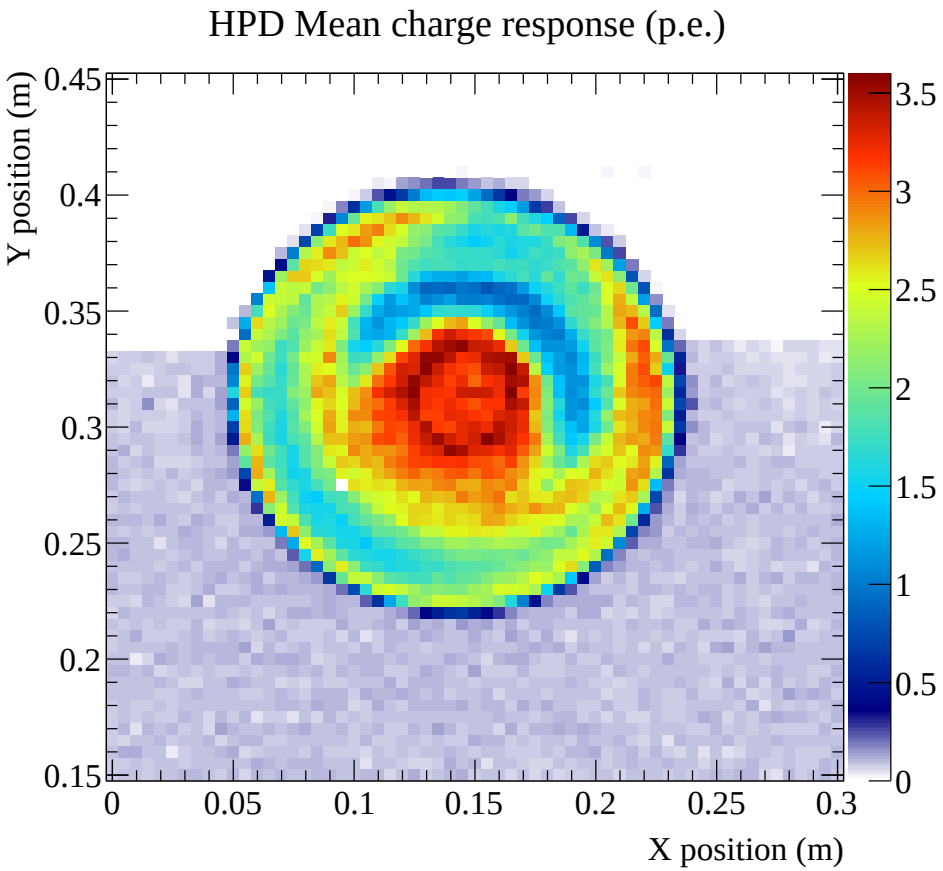
8” HPD: first intensity map

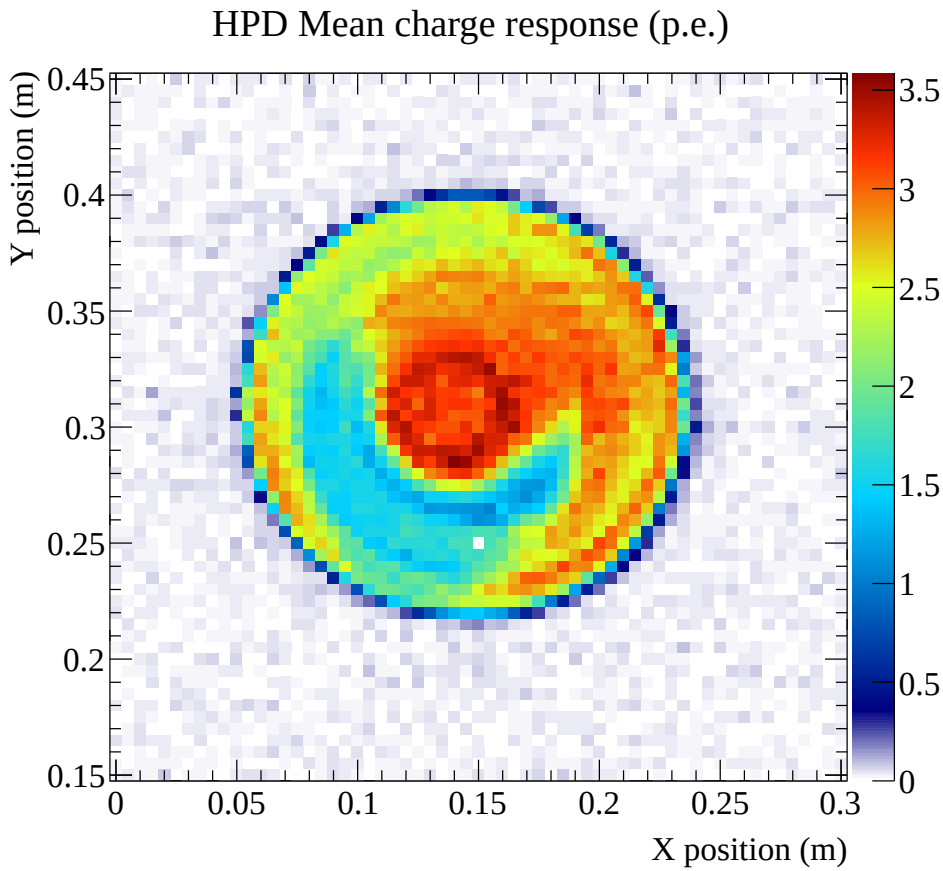




- Scanning the PMT with the laser pointing vertically downwards in 2cm steps.
- Using fixed pedestal subtraction and 1PE gain here to calculate average PE per point.
- Real asymmetry? $\rightarrow$ Rotate PMT.
- Actual acceptance should be measured with normal incidence: need PMT curvature and new measurement sequence.

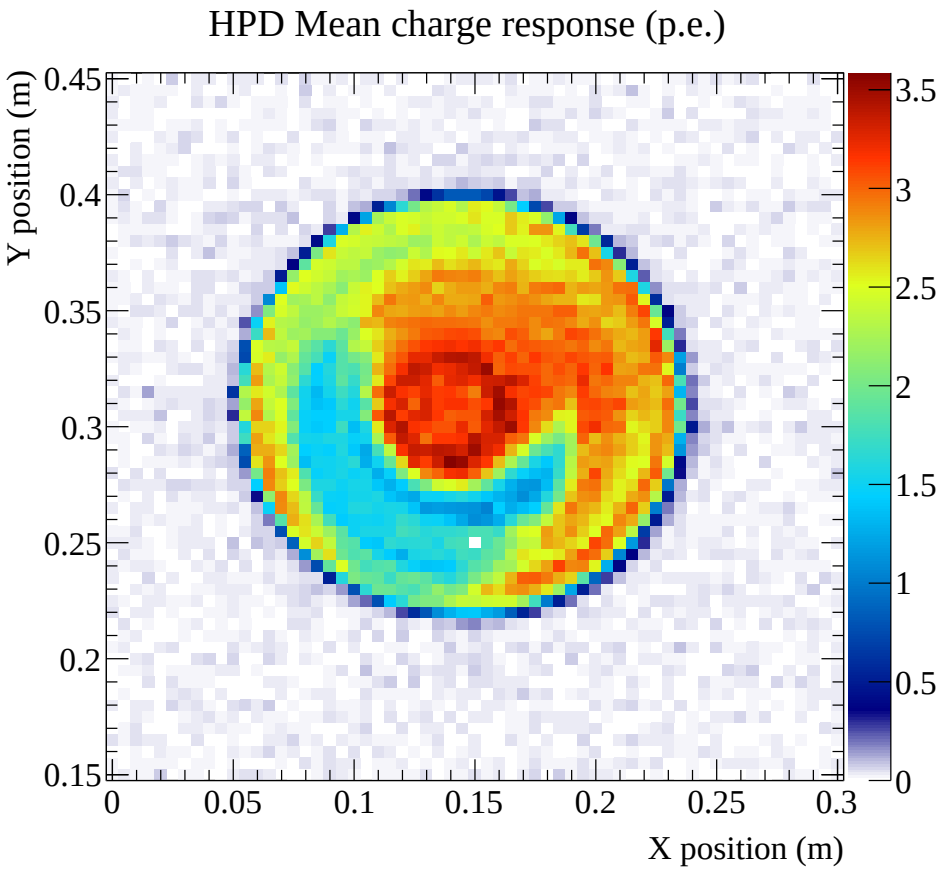
HPD vertical 5mm scan with two HPD orientations



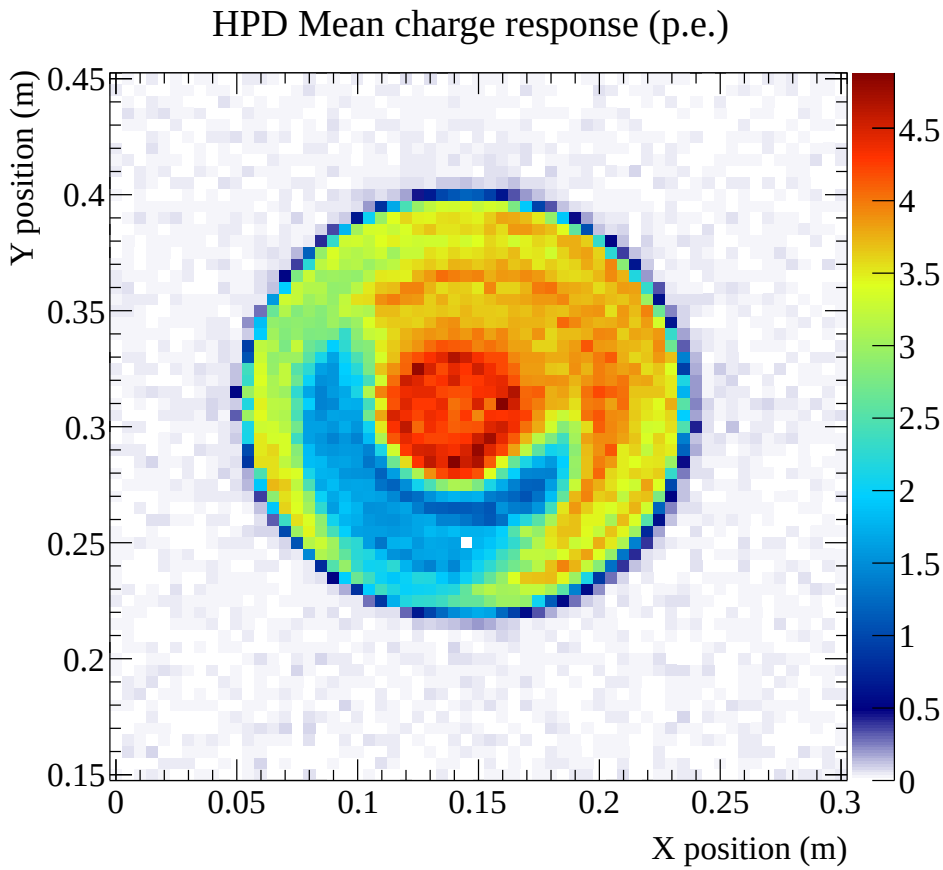


- Fine grained scan shows interesting non uniform pattern with large local variation.
- Circle with increased intensity possibly from internal reflection on metal inside the PMT (also observed by Hamamatsu).
- Pattern rotates as HPD rotates.
- Next: low intensity scan to map gain dependency.

HPD vertical 5mm scan with two wavelengths



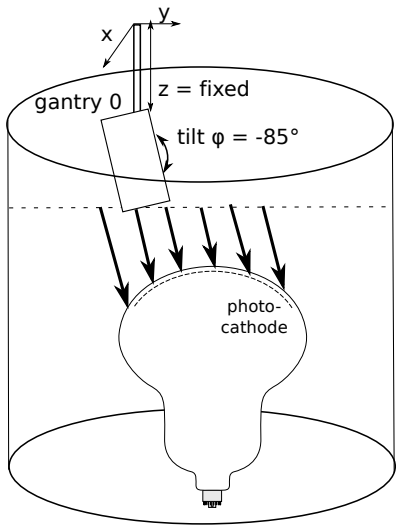
405nm

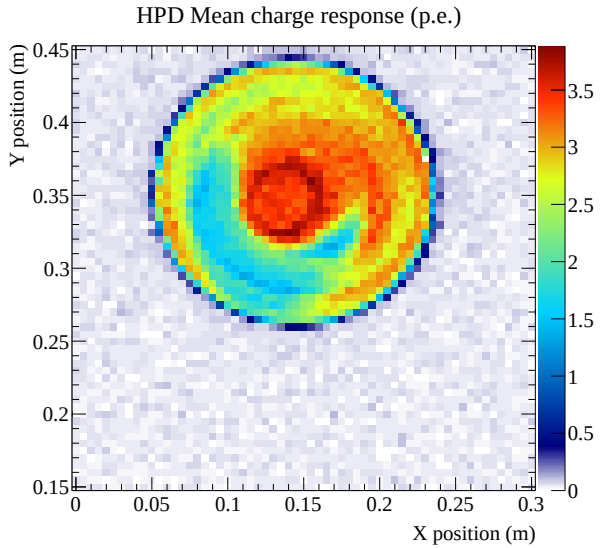


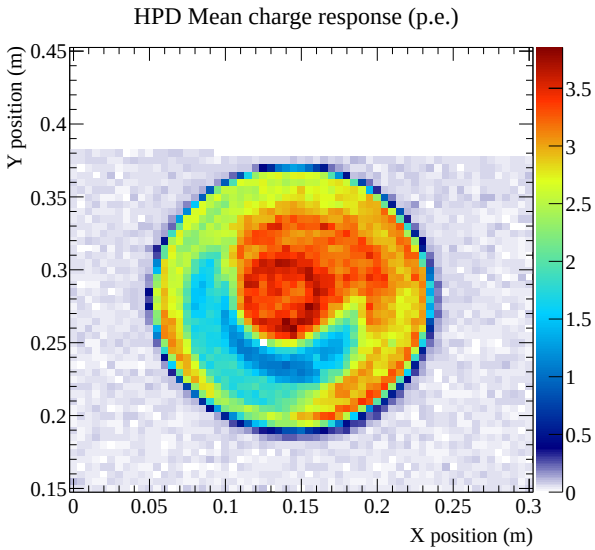
467nm

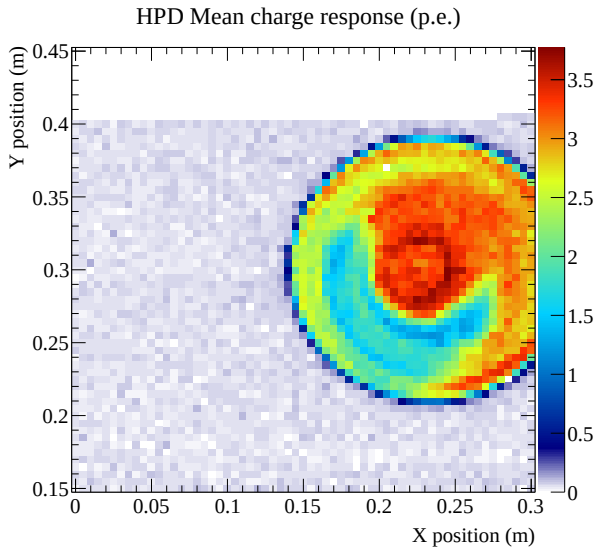
- Different laser intensity for both!
- Similar pattern seen in both wavelengths.

HPD vertical 5mm scan with 5° tilt



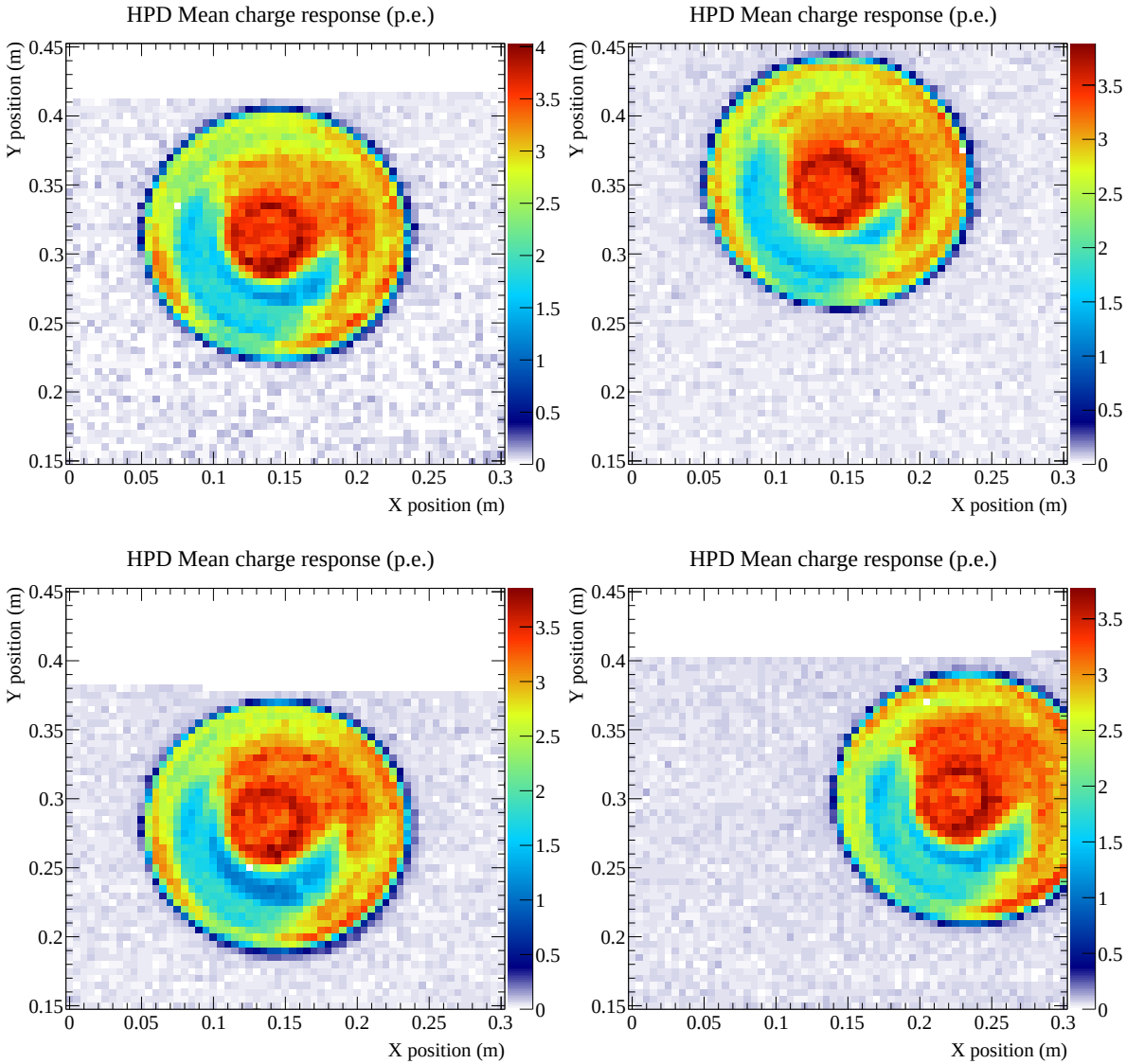






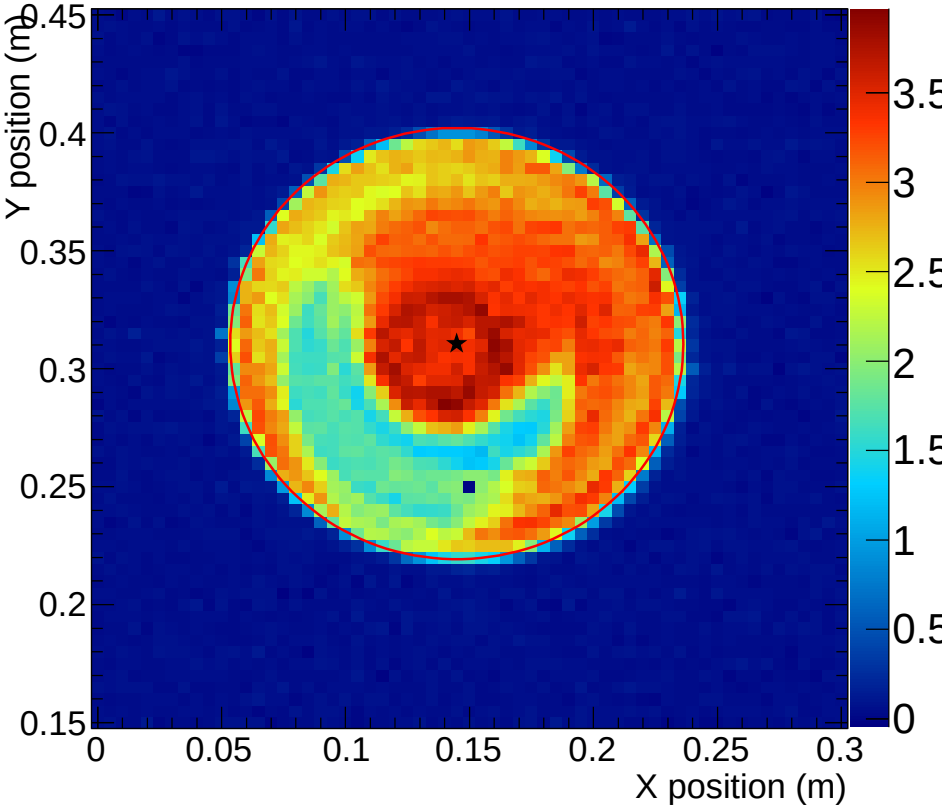
- Similar pattern seen, although different HPD cross section scanned.

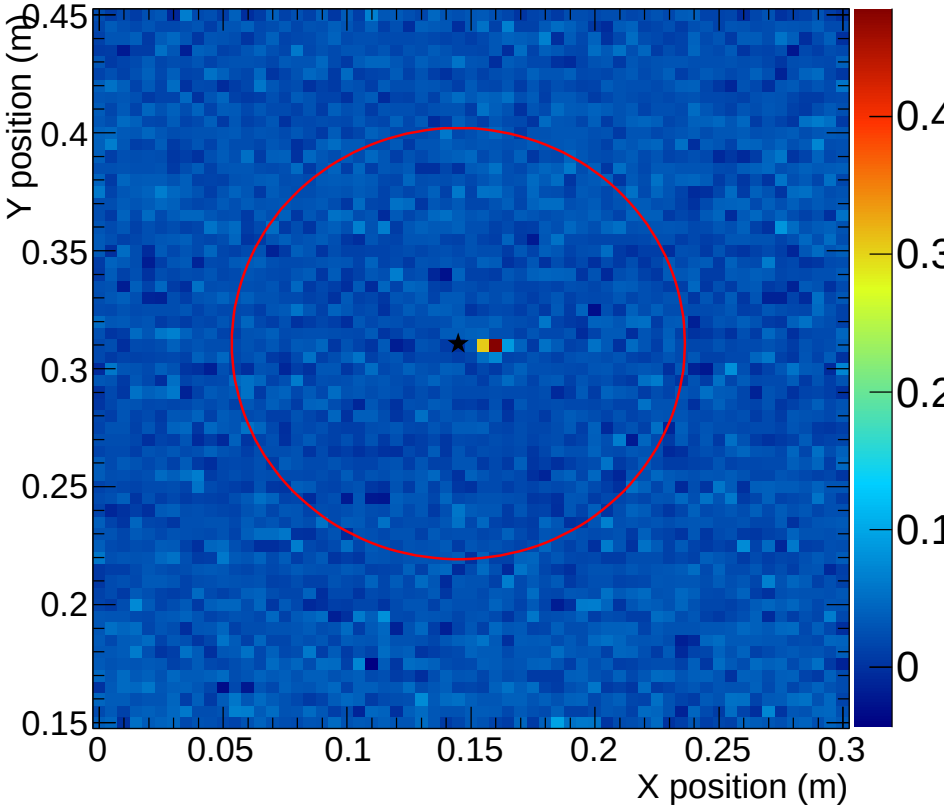
HPD vertical 5mm scan with 5° tilt



- Similar pattern seen, although different HPD cross section scanned.

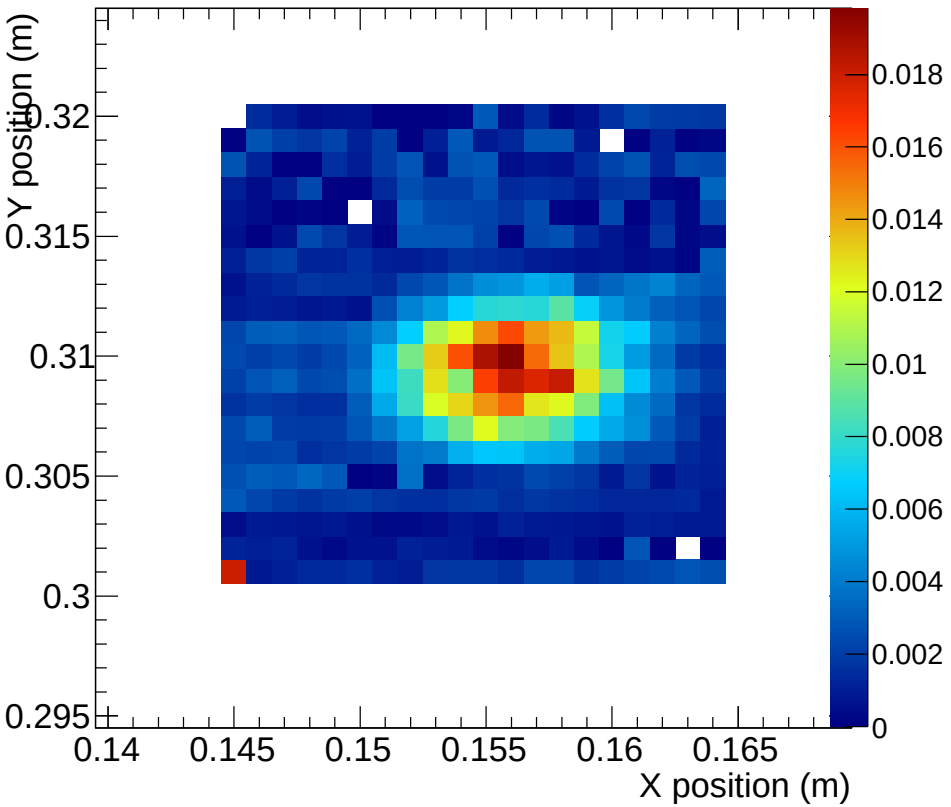
HPD receiver PMT

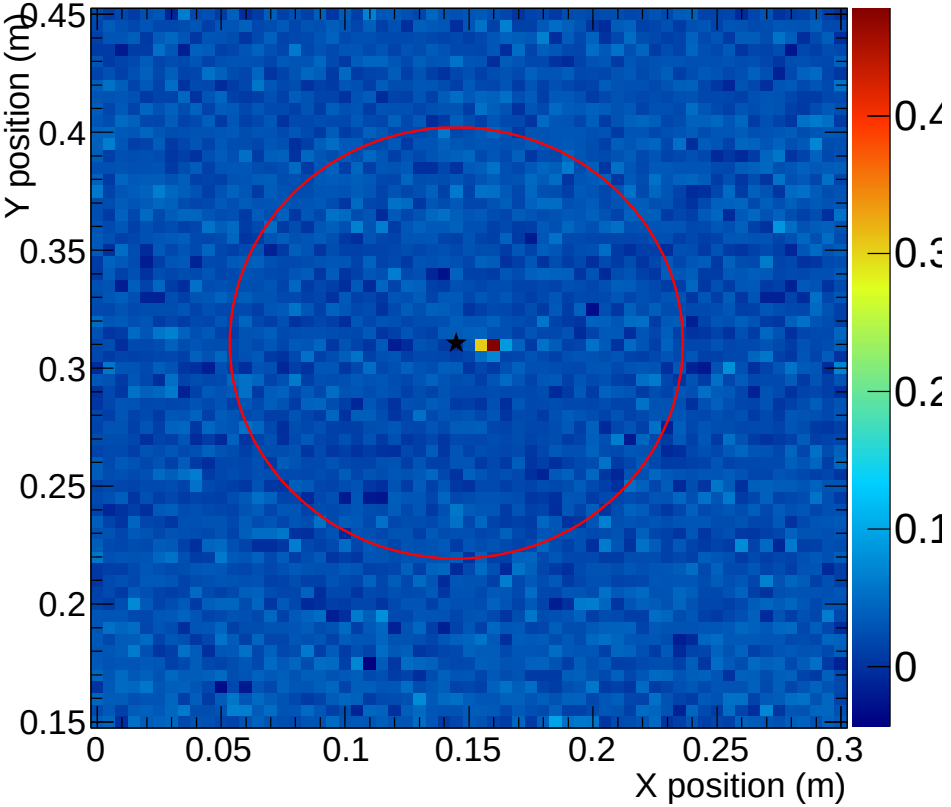




- Fitting circle using bins with number of PE between 0.45 and 1.2.
- Inner circle seems offset from center of circle.
- Use center of PMT sphere in gantry coordinate system for acceptance, measure height manually.
- Probably only one bin where reflected photon is seen, matches offset of receiver PMT wrt laser.

HPD receiver PMT





- Detailed mm stepsize scan shows profile of reflected light!

Summary

- Improvements in both software and hardware of PTF.
- Setup at PTF shows same excellent HPD performance as setup in Kamioka.
- Water system is ready to be tested in-situ.
- February: finalize 8" HPD performance characterization, normal incidence and angular acceptance studies.
- Improvement of alignment and measurement of reproducibility and accuracy.
- Measurement of PMT curvature and study of effect on normal incidence measurement.
- 3 20" PMTs will arrive at TRIUMF mid/end of Feb: preparation for installation in tank ongoing.
- March: First measurements in water.

THANKS

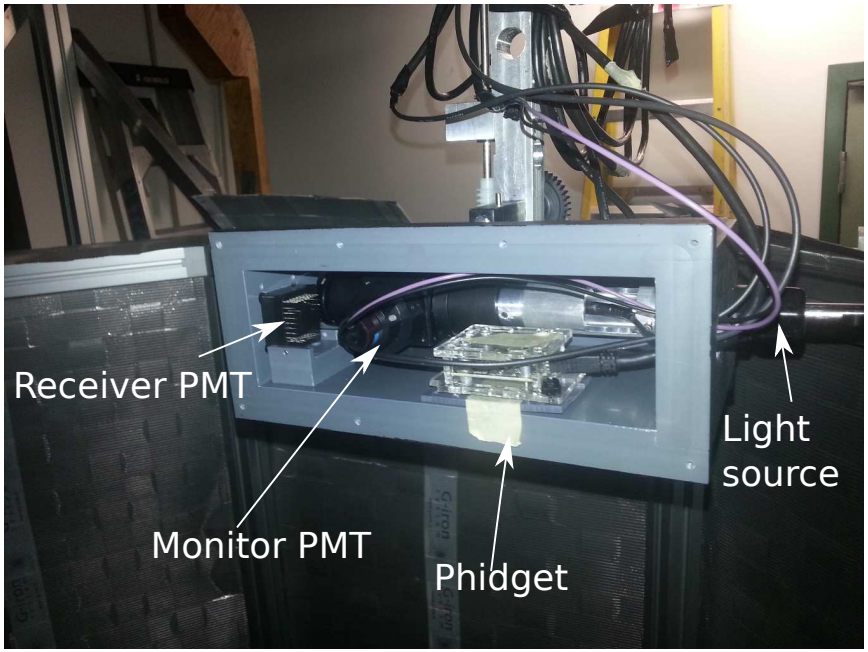
UBC, TRIUMF and visitors:
Sophie Berkman, Ben Krupicz, Patrick de Perio, Wayne Faszer, Tom Feusels, Mark Hartz, Akira Konaka, Harish Kugel, Thomas Lindner, James Linqiao Liu, Philip Lu, Andy Miller, David Morris, Corina Nantais, Carl Reithmeier, Fabrice Retière, Mark Scott, Nils Smit-Anseeuw, Yusuke Suda, Hiro Tanaka, Shimpei Tobayama, Peter Vincent, Michael Wilking, Stan Yen, Aaron Zimmer

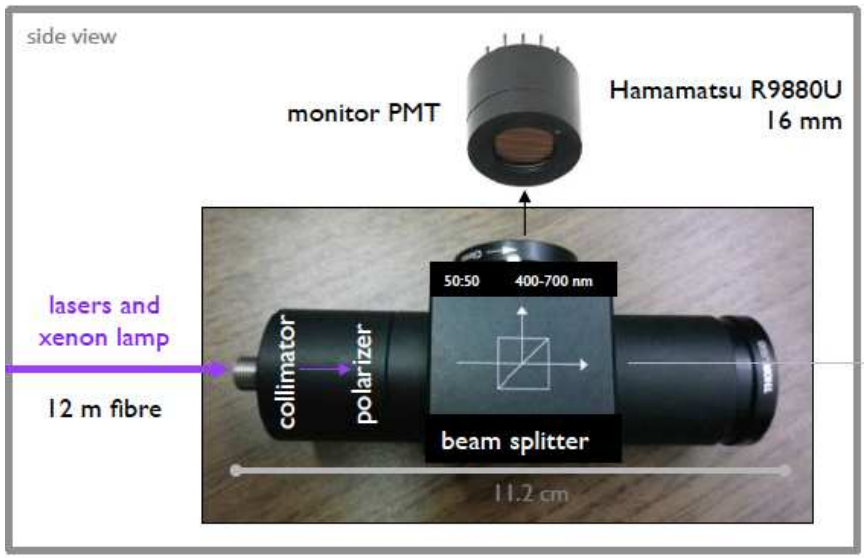
Backup

Magnetic field compensation

- In addition to the Earth magnetic field, presence of additional magnetic fields (eg. from TRIUMF Cyclotron).
- Active cancellation with Helmholtz coil, passive cancellation with two layer of g-iron.
- Field scans with phidgets mounted on gantry arms.
- Calibration of offsets in magnetometer on phidget using accurate Gaussmeter (up to 0.1mG).

Optical system





- Light sources: 405nm pulsed laser and Xe lamp with filters.
- Connected through fiber to optical boxes.
- Collimator, polarizer, beam splitter.
- Monitor PMT and receiver PMT.

HPD signal before noise reduction