Tests for Beam Induced Fluorescence monitor

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Introduction

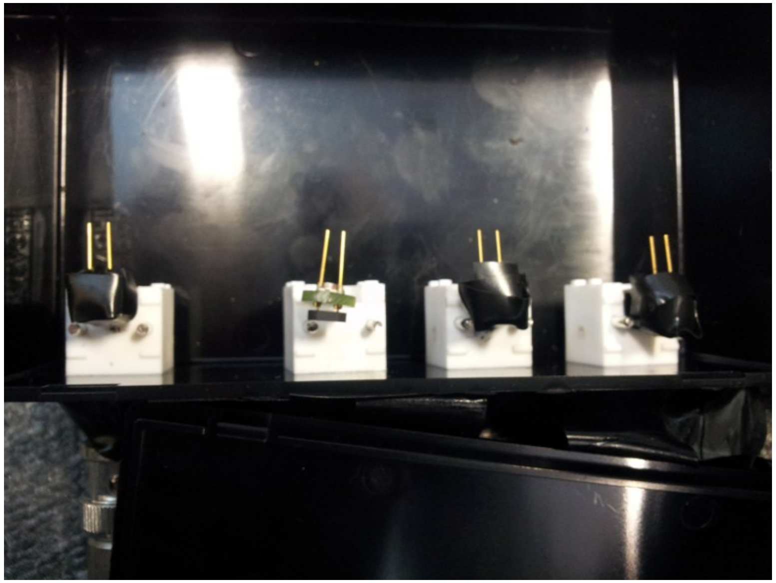
Presenting hardware tests we have done for the BIF monitor, and briefly a few issues we've encountered and future tests we are planning to do:

- MPPC in radiation environment
- Amplication and noise issues to read MPPC signals
- Optical fiber tests
- Optical system tests

MPPC in radiation environment

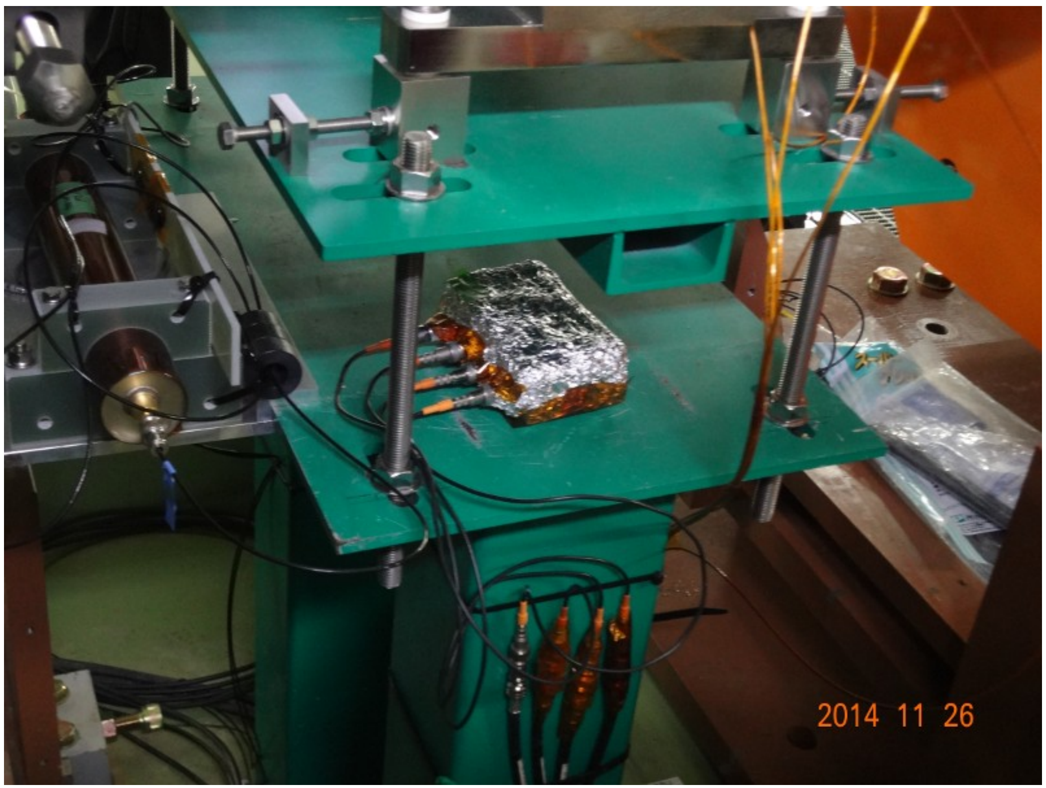
- Would like to use Hammatsu MPPC to detect fluorescence light: cheap, fast, sensitive to low number of photons
- But have dark noise and not designed to work in radiation environment, as would be the case near the beam pipe
  → can we use them for this monitor?
- Put some MPPC near the beamline to see how their properties change due to beam induced radiations.
  As we will be integrating their response over ~10 ns periods for the monitor, mainly interested in changes in:
  - dark noise
  - gain (size of the response for a given number of photons)

  and any 'signal' induced by the passage of the beam
- Tested 2 models of MPPC
  - S12571-010C: 10k pixels, 10µm pixel size
  - S12571-050C: 400 pixels, 50µm pixel size



MPPC in radiation environment
First test

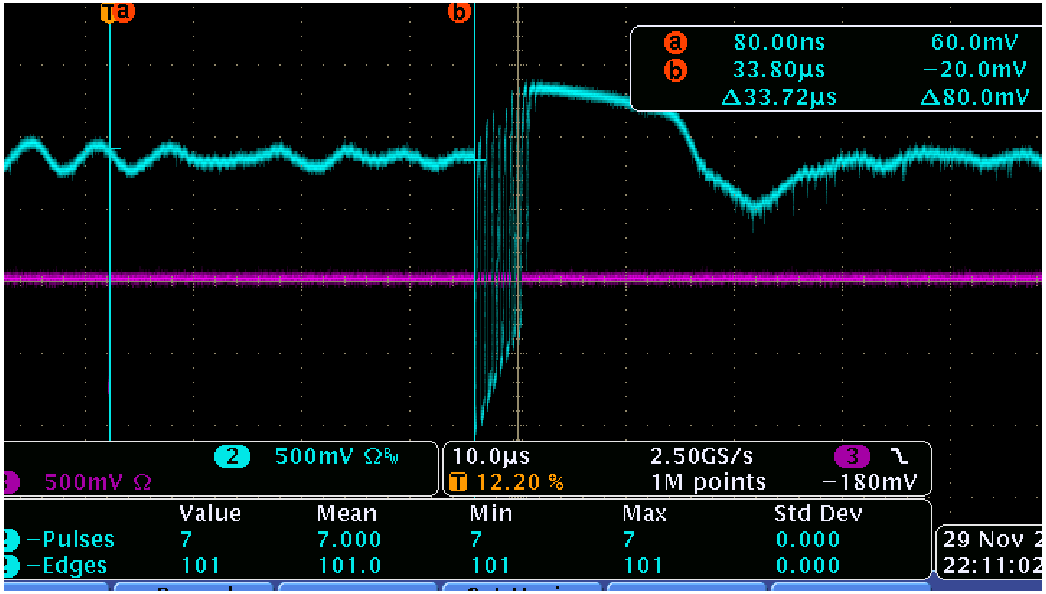
First installed the MPPCs close (~30 cm) to the beam pipe and one of the SSEM monitors:



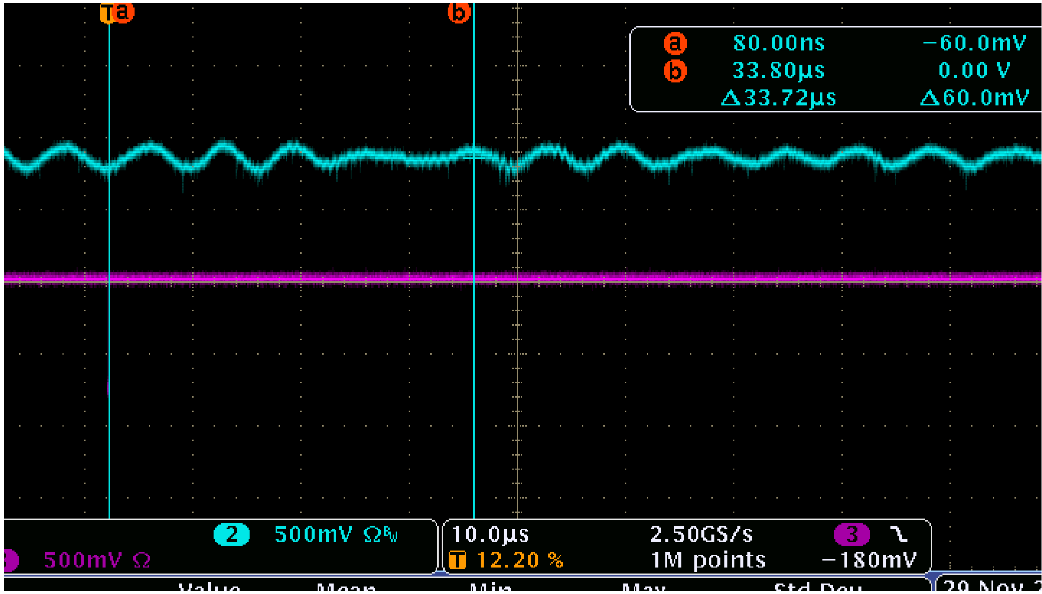
Beam induced signal
First test

Passage of the beam induces a rather large signal when the SSEM are inserted in the beam trajectory, negligible when they are not in

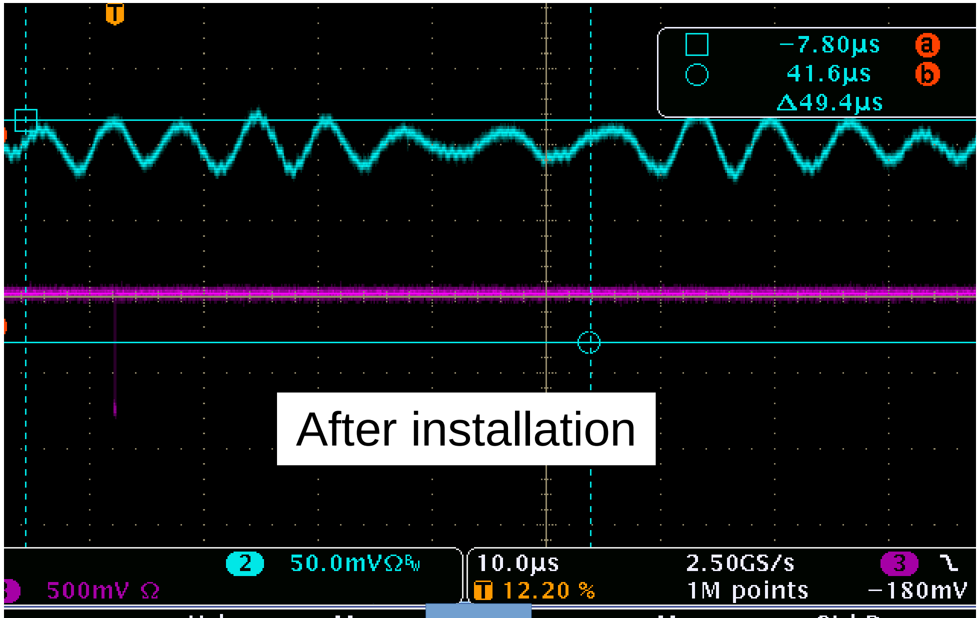
SSEM in



SSEM out

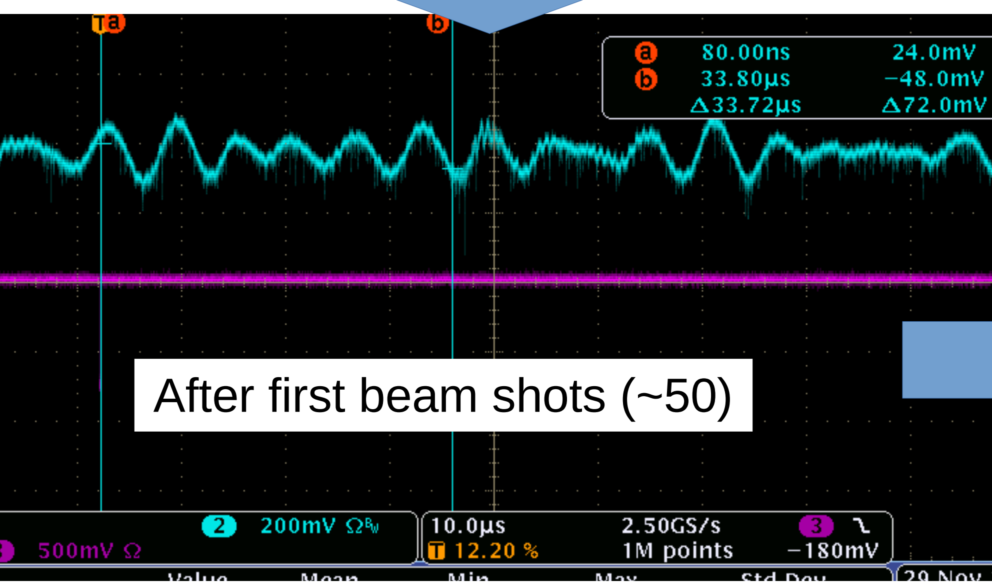


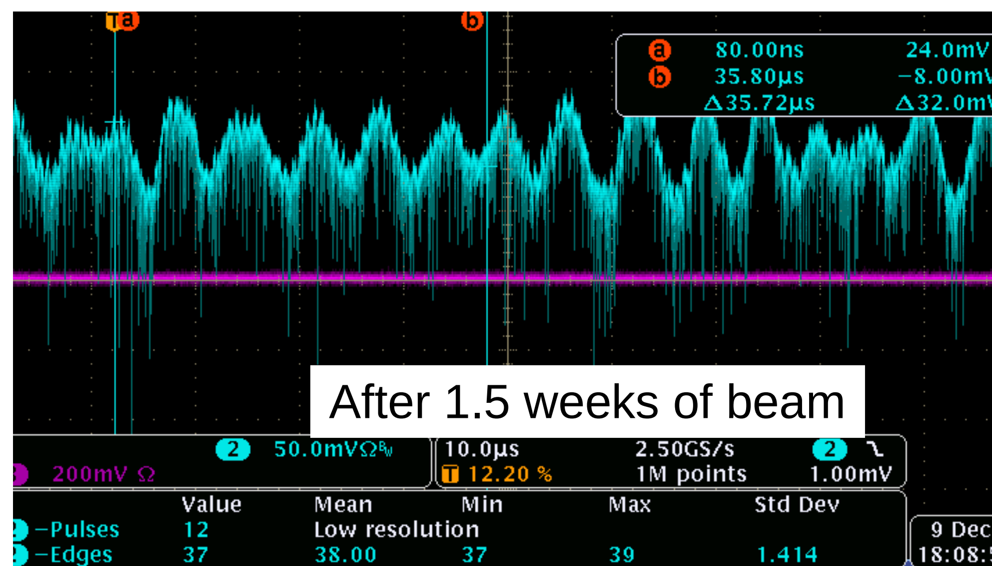
MPPC in radiation environment
Effect of radiation



Radiation induced by the beam had quite a visible effect on the MPPC signal.

Increase in the dark noise rate and amplitude





MPPC in radiation environment
Effect of radiation – noise rate

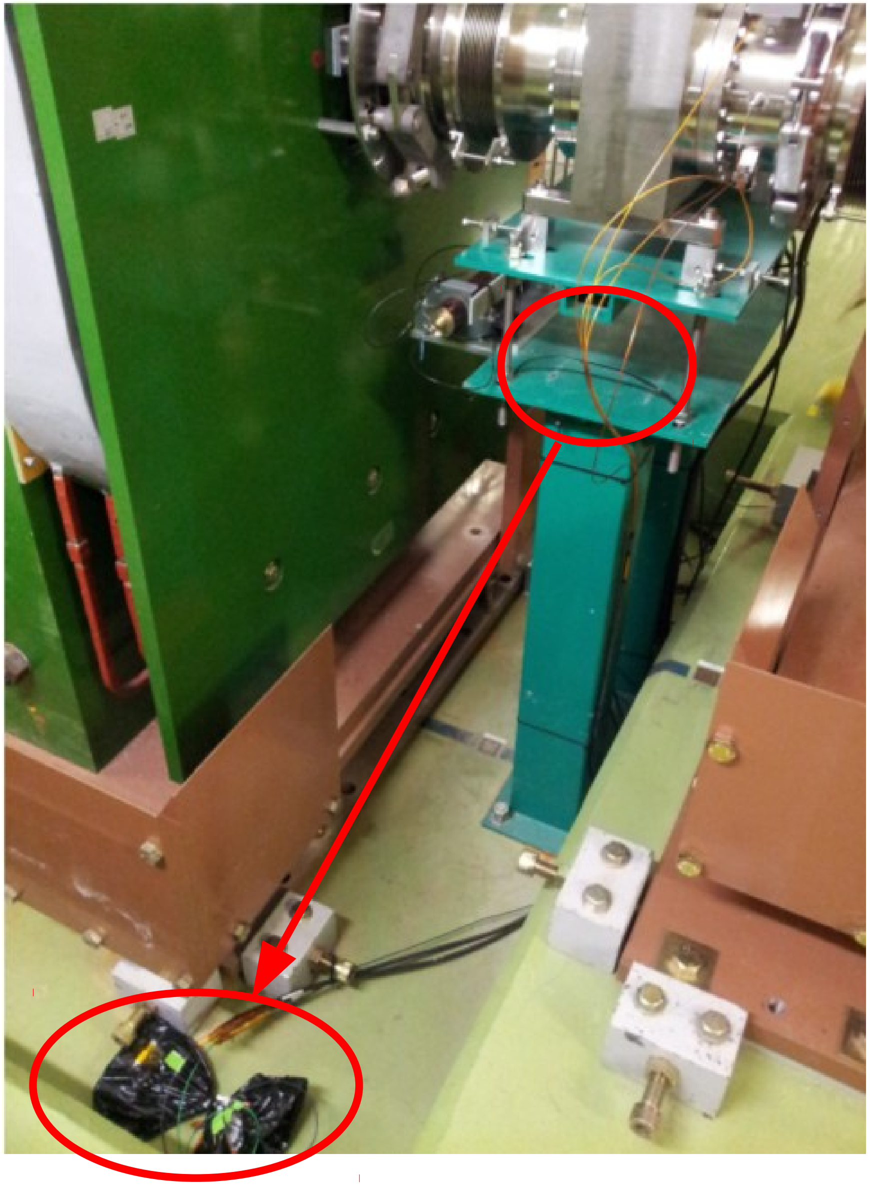
We put 2 MPPC of each model near the beamline, comparing dark noise rates before and after irradiation (approximate measurements, calculated over a 1.2 ms time window)

MPPC #	Model	Manufacturer rate @ 25 °C	Measurement before irradiation	Measurement after irradiation
1	S12571-010C	142 kHz	124 kHz	19.6 MHz
2	S12571-010C	138 kHz	129 kHz	19.4 MHz
3	S12571-050C	84.5 kHz	71 kHz	Too high to measure
4	S12571-050C	76.8 kHz	78 kHz	Too high to measure

Increased by a factor ~150 after 1 month near the beam line

MPPC in radiation environment
Second test

Increase in dark noise seen in the first term would probably be an issue for long term operation.
Tried to put new MPPCs further from the beam pipe: 30 cm → 1.5 m



MPPC in radiation environment
Second test – noise rate

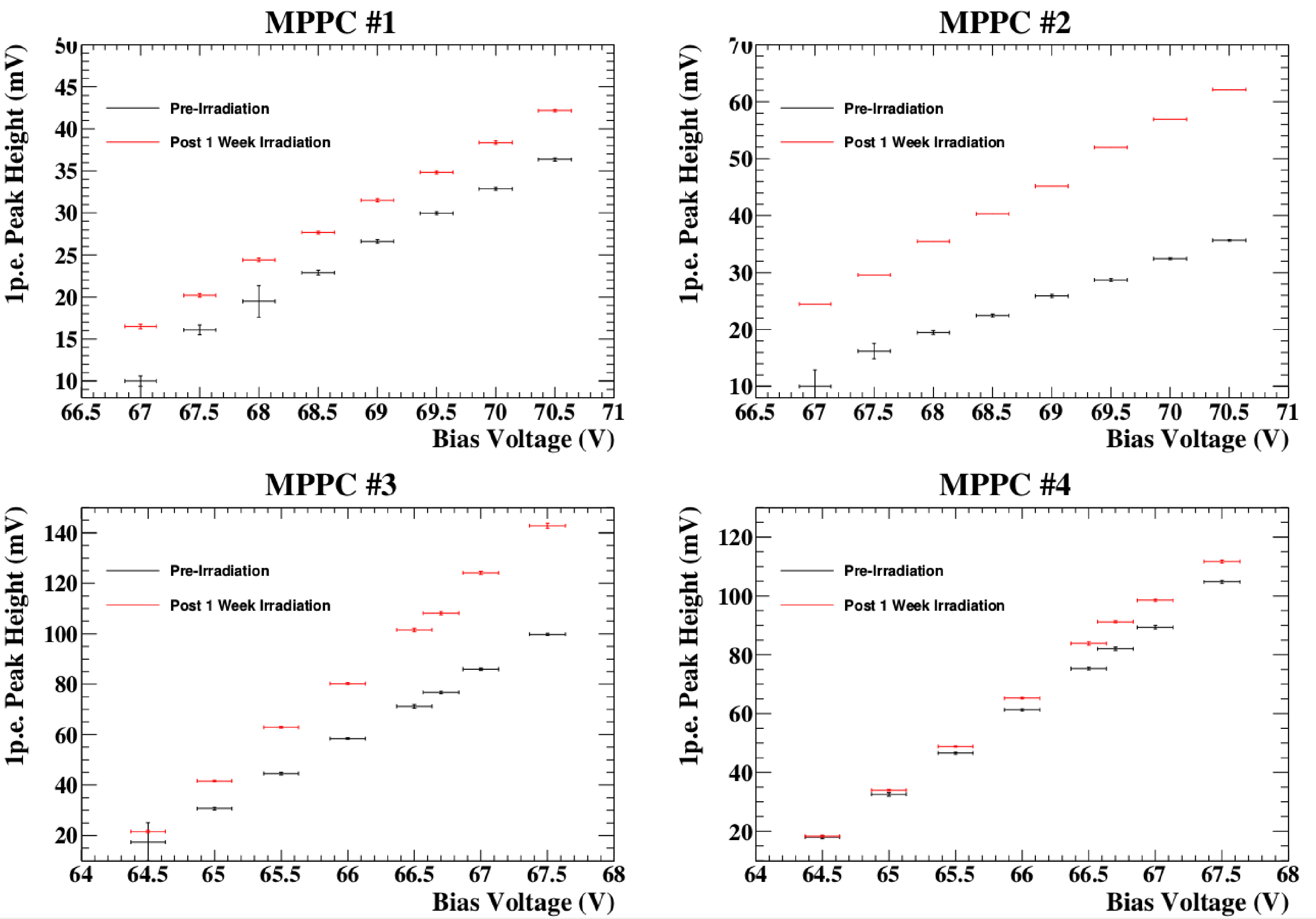
Also see a significant increase of the noise rate in that position after a week of beam.
MPPC with less pixels but of larger size show a larger increase in noise rate.

MPPC #	Model	Manufacturer rate @ 25 °C	Measurement before irradiation	Measurement after irradiation
1	S12571-010C	154 kHz	132 kHz	415 kHz
2	S12571-010C	141 kHz	119 kHz	322 kHZ
3	S12571-050C	85.1 kHz	59 kHz	484 kHZ
4	S12571-050C	79.5 kHz	55 kHz	354 kHz

To use MPPC for this monitor, would need to put them significantly further away.
Have placed new MPPCs in a side tunnel (~30m away from beam pipe) where radiations should be order of magnitude lower. No results yet.

MPPC in radiation environment
Second test – gain

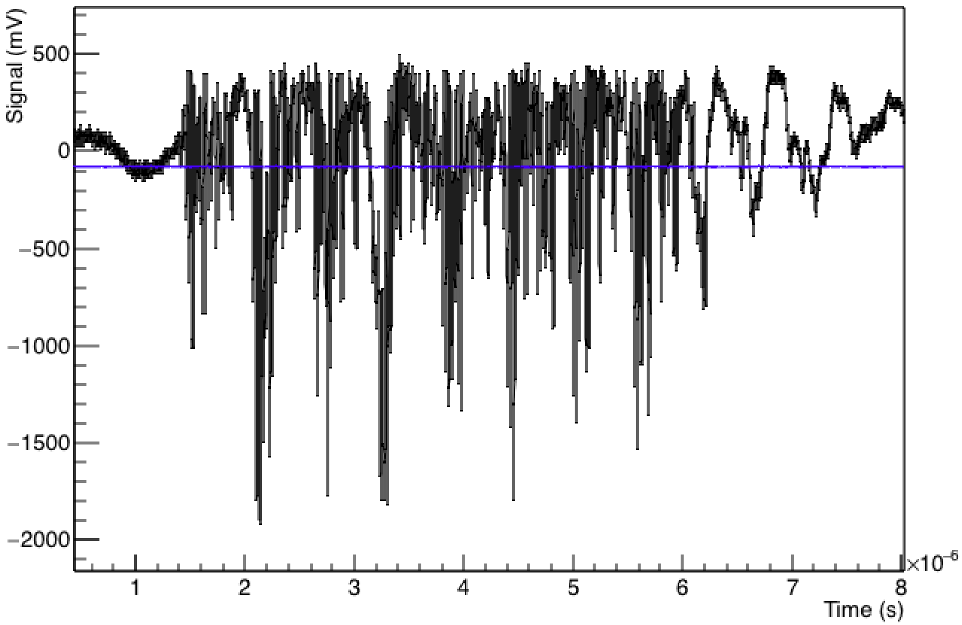
Also saw an increase in gain due to irradiation:



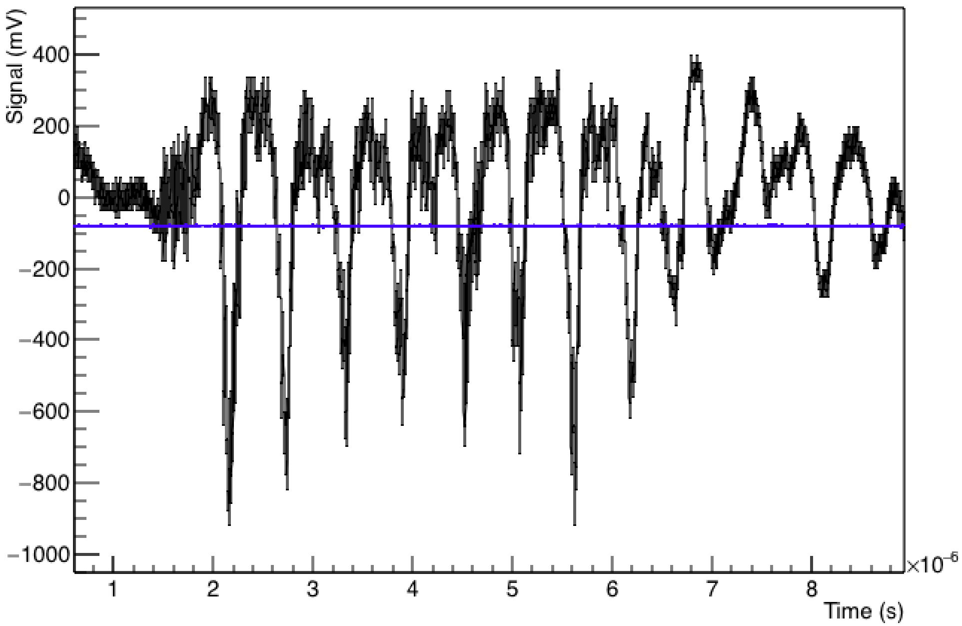
Beam induced signal
In the side tunnel

Surprisingly enough, we see a beam induced signal when the MPPC are in the far away position, both with and without the SSEM inserted

<u>SSEM in</u>



<u>SSEM out</u>



Pattern is different from what we saw with the MPPC close to the beam pipe, and this signal is still there when the MPPCs are not powered...

Suspect it is due to an extension cable (additional ~20m cable) we added to go to this far away position.

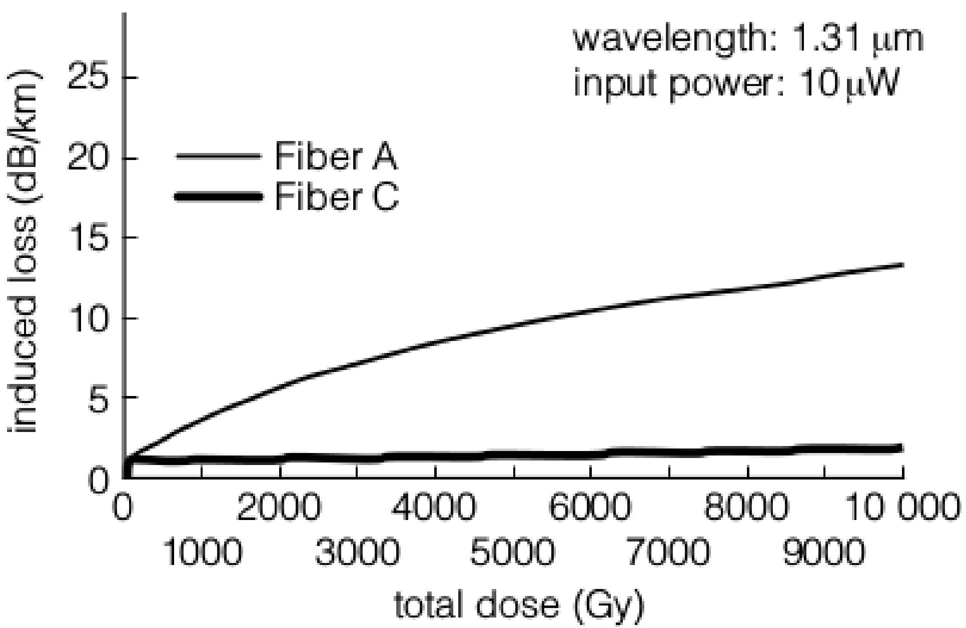
Plans for optical fiber test

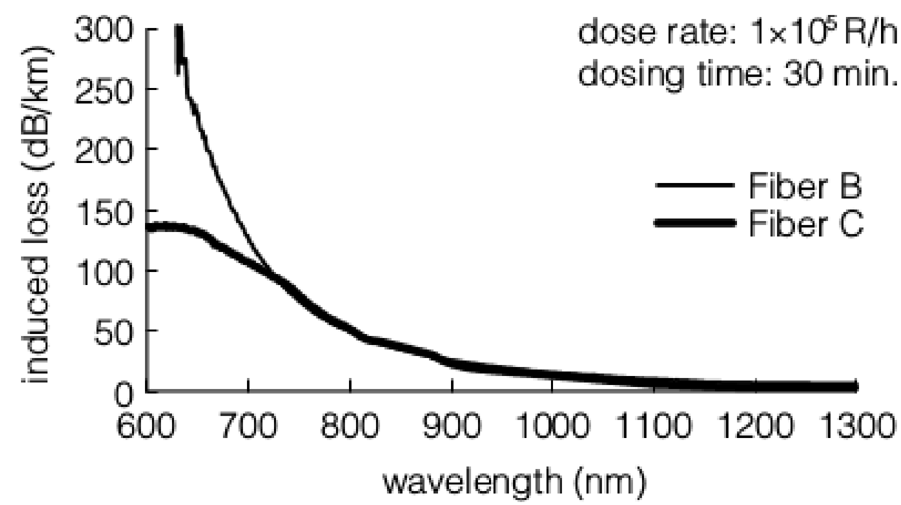
- If we put MPPC far away from the beam pipe, will need to transport the fluorescence light all the way to their position

- Considering radiation hard fibers from Fujikura for this.

Fiber No.	Material		OH content of core glass (ppm)	Manufacturing process for core glass	Fluorine content (wt%)		Δn* (%)	Core diameter (μm)	Cladding diameter (μm)
	Core	Cladding			Core	Cladding			
A	SiO_2	F-SiO_2	< 1	Plasma method	0	1.4	0.35	8.3	125
B	F-SiO_2	F-SiO_2	< 1	VAD method	0.2	1.6	0.35	8.3	125
C	F-SiO_2	F-SiO_2	< 1	VAD method	0.8	2.2	0.35	8.3	125

*: Relative refractive index difference

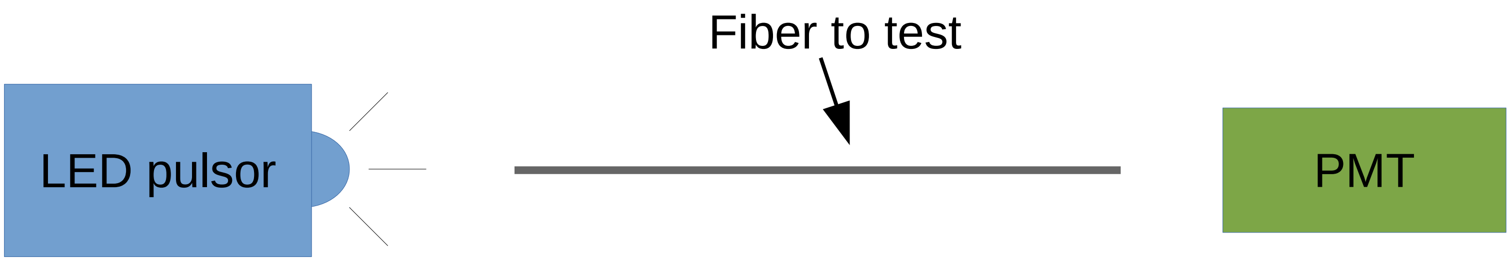




From Fujikura Technical Review, 2008

Plans for optical fiber test

- Fujikura fibers seem to be optimized for larger wavelengths than what we would use
  Plan to measure attenuation length for the wavelengths 450-650 nm

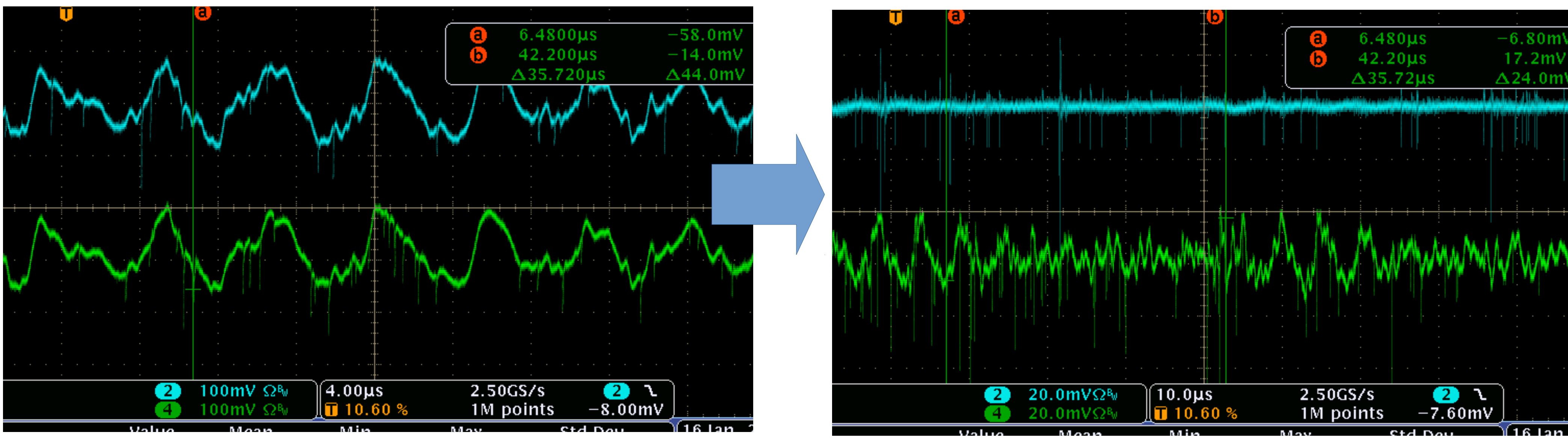


- Do the measurement with a short (~1 m) and a long (~30m) fibers to check attenuation length matches specification

- Redo the measurements after putting the fibers near the beamline to check effect of radiation

Amplifications and noise issues

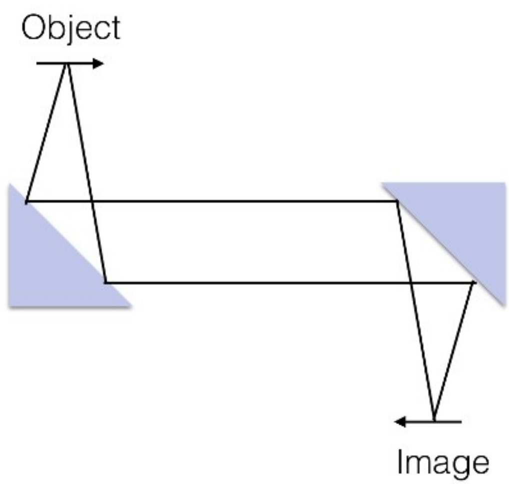
- MPPC signal is quite small and needs to be amplified (~80 mV for 1 pe after 100x amplification)
- In this test setup, the MPPC are in the beam tunnel but the amplifier is at the surface, after a ~100m cable.
- During beam operation see some noise on the cables that gets amplified as well
- Saw we could cut this noise with an RC high pass filter, not sure if it is suitable for a monitor



Looking at possible alternatives:
- using a rad hard amplifier to put amplification close to the MPPC
- other way of filtering: digital filters, matched filtering....

Test of the optical system

Considering using an off-axis parabolic mirror system to focus the image on the fibers bundle.



Would test some Thorlabs mirror for this:

- 101.6 mm mirror diameter
- 152.4 mm effective focal length
- 400-700 nm wavelength
- No spherical aberration, but coma

To test the system, use an integrating sphere as object: