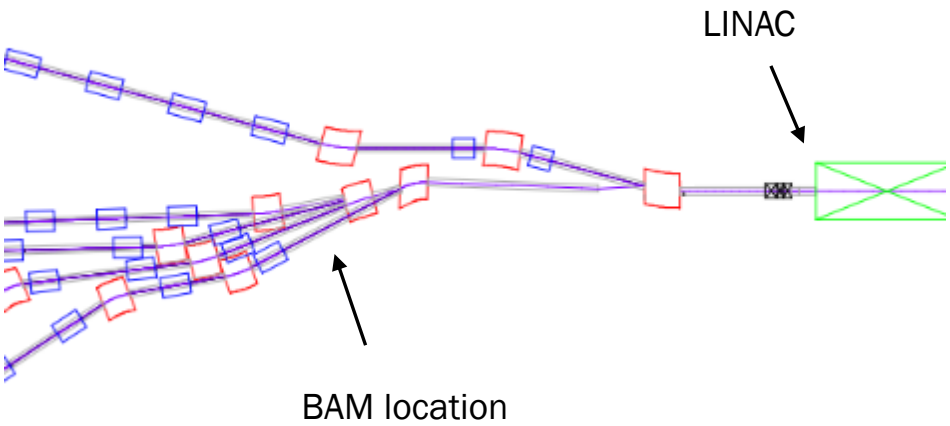
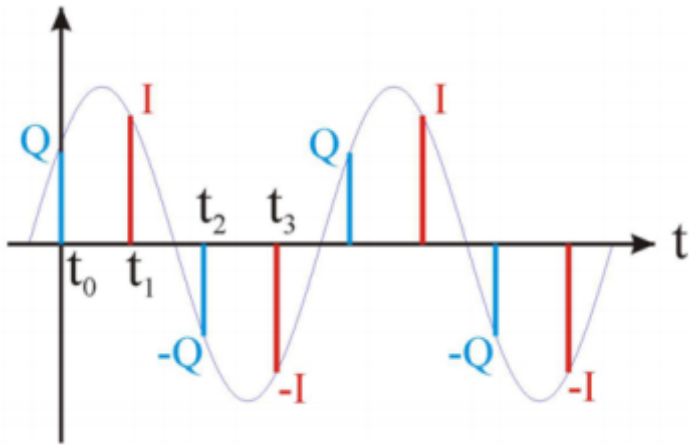
# Bunch Arrival Monitors

CBETA operation requires precise control of the timing/phase of the bunch entering the linac.



In the injector we use RF BPMs for measuring phase.




Synchronous quadrature detection (as in LLRF system)

Injector RF BPM electronics

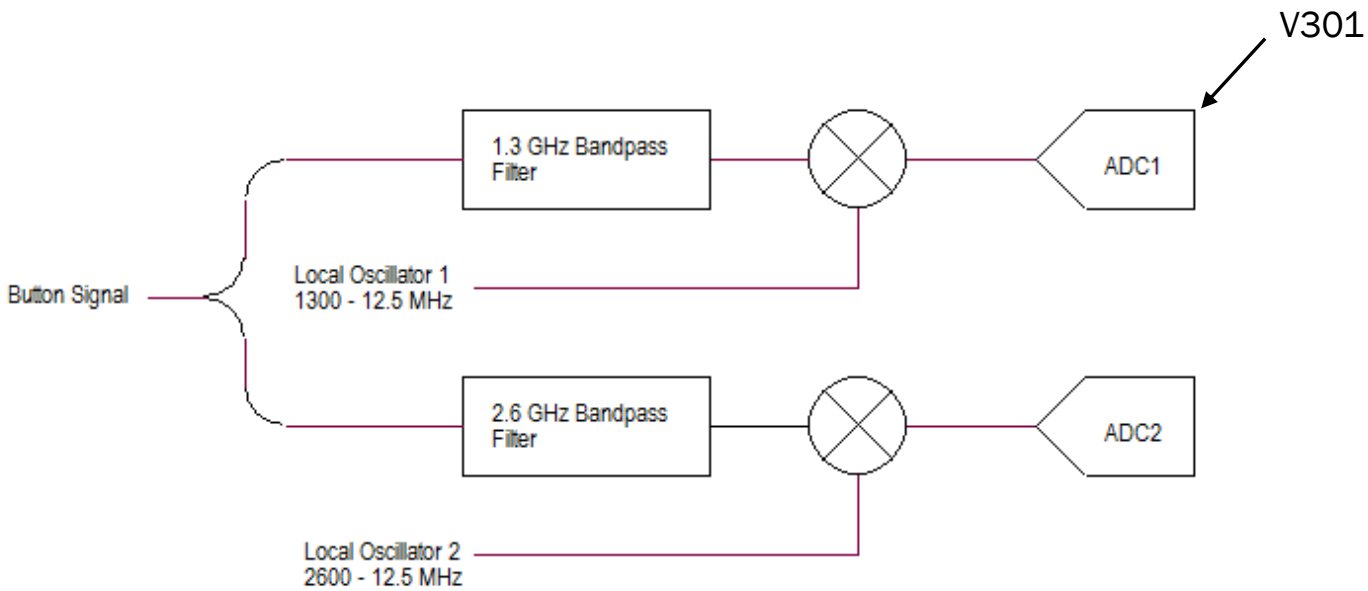
- 1300 MHz RF
- Laser at 1300 or subharmonic
- LO at 1300 – 12.5 MHz
- ADC clock at 50 MHz

are all phase locked.

The phase of the IF signal relative to the ADC clock is a direct measure of bunch phase relative to 1300 MHz reference.

The existing RF BPM electronics don't work in the presence of multiple beams.

However in the spreaders there are only two beams. Measurement of amplitude and phase at two harmonics does work – amplitude and phase of two beams can be reconstructed.

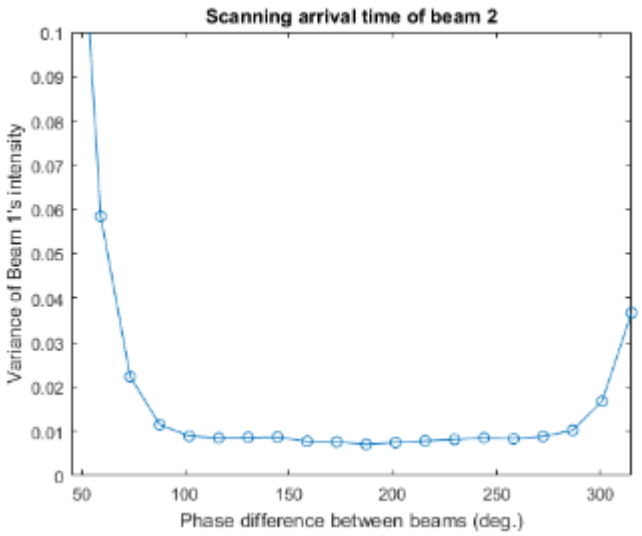


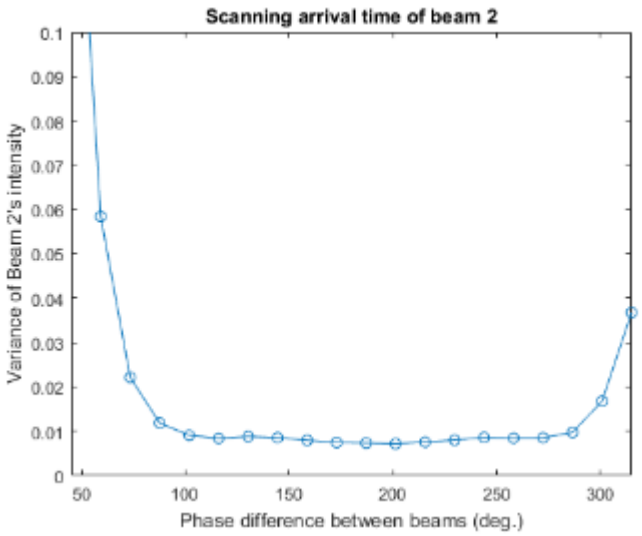
**Test 1: Arrival time of beam 2**

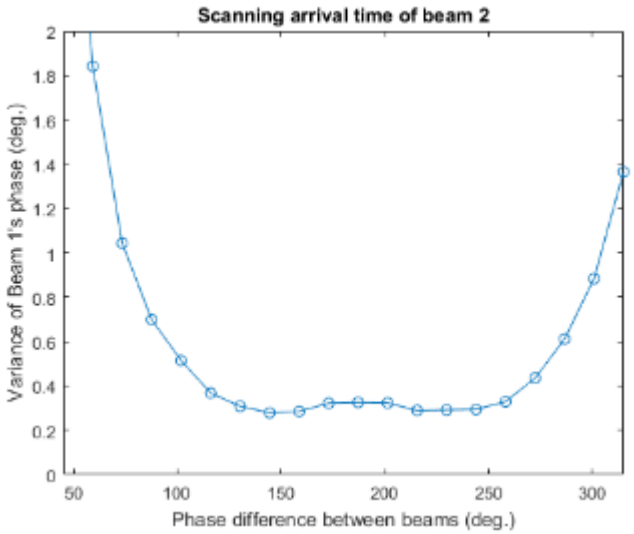
- Beams have equal intensity
- Add noise to I,Q at the 1% level

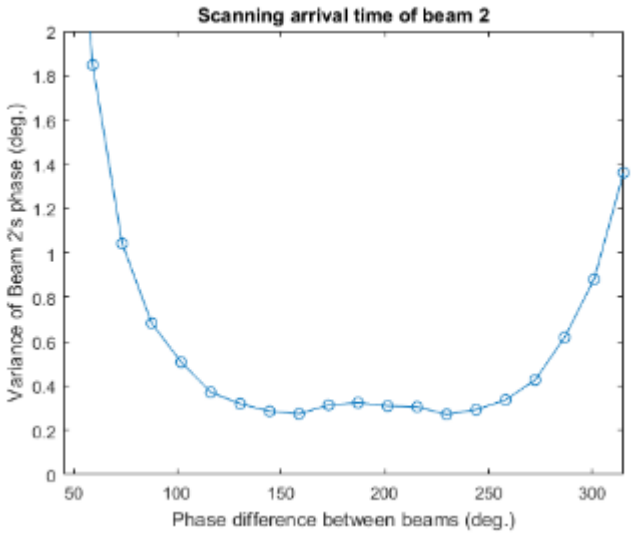
**Result:**

- For equal intensity beams, algorithm works well for arrival phase differences from ~90-270 degrees.
- When the beams are close to overlapping, solution becomes degenerate and method breaks down



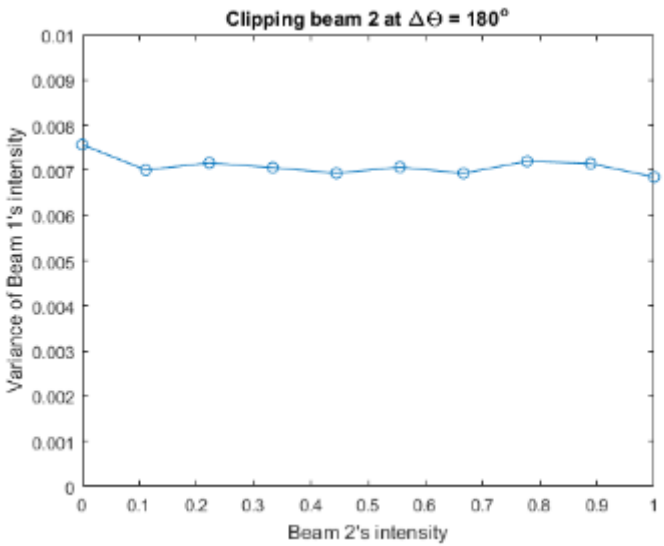



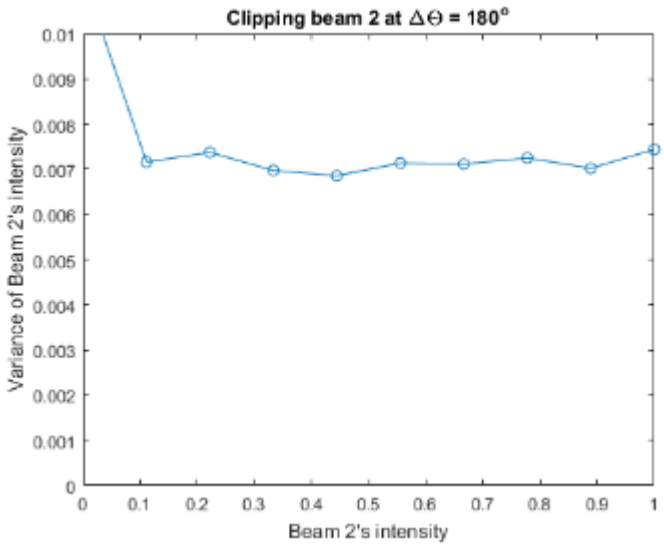
**Test 2: Intensity of beam 2**

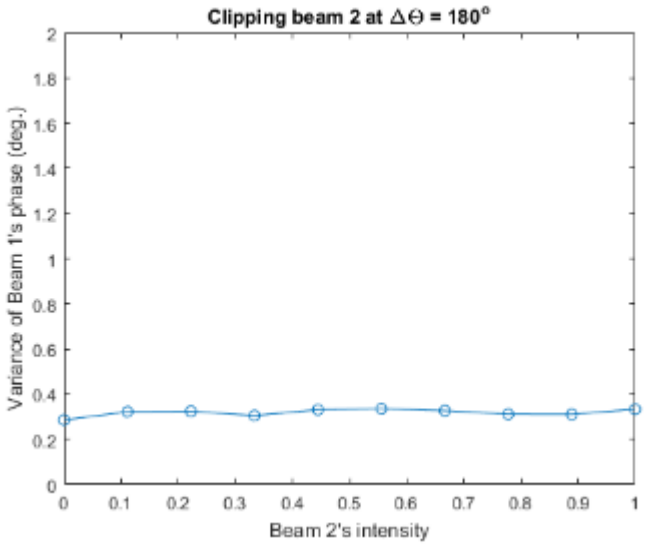
- Beams are 180° out of phase
- Add noise to I,Q at the 1% level

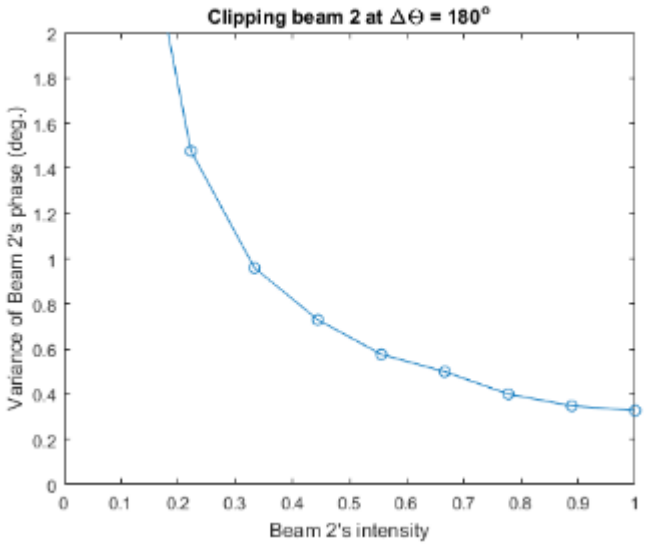
**Result:**

- Intensity is well-determined for both beams
- Phase has ~degree level error or better for transmission greater than 20%

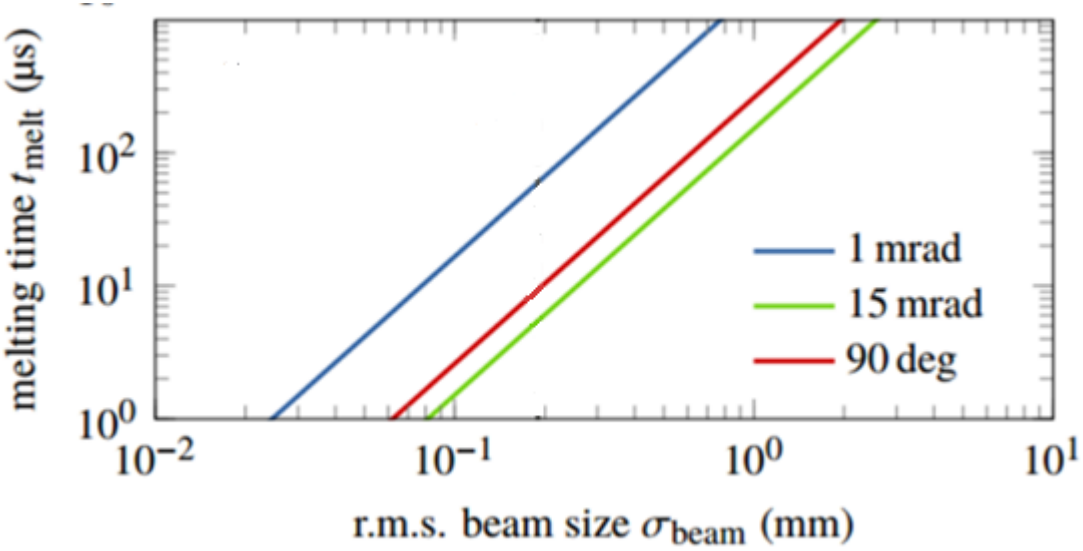


## Fast Hazard - high current




Melting time for 100 mA, 50 MeV electron beam incident on 3 mm thick aluminum beam-pipe.

Proceedings of IPAC2014, Dresden, Germany THPRI091

**MACHINE PROTECTION CONSIDERATIONS FOR bERLinPro***

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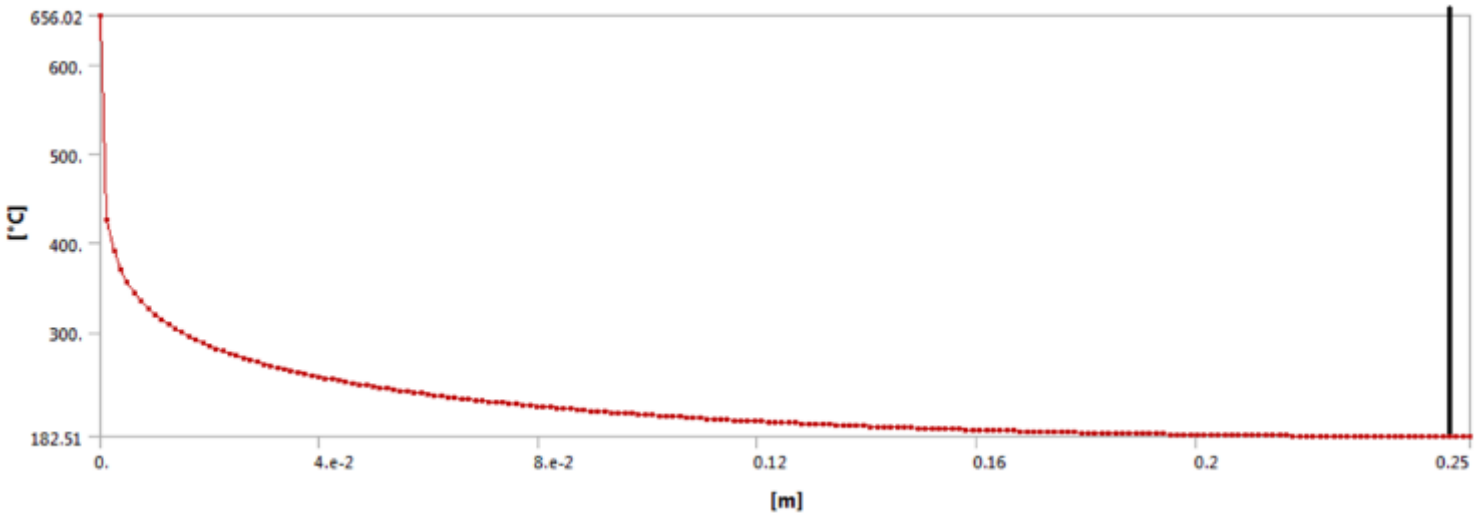
Slow Hazard – continuous
loss at low current

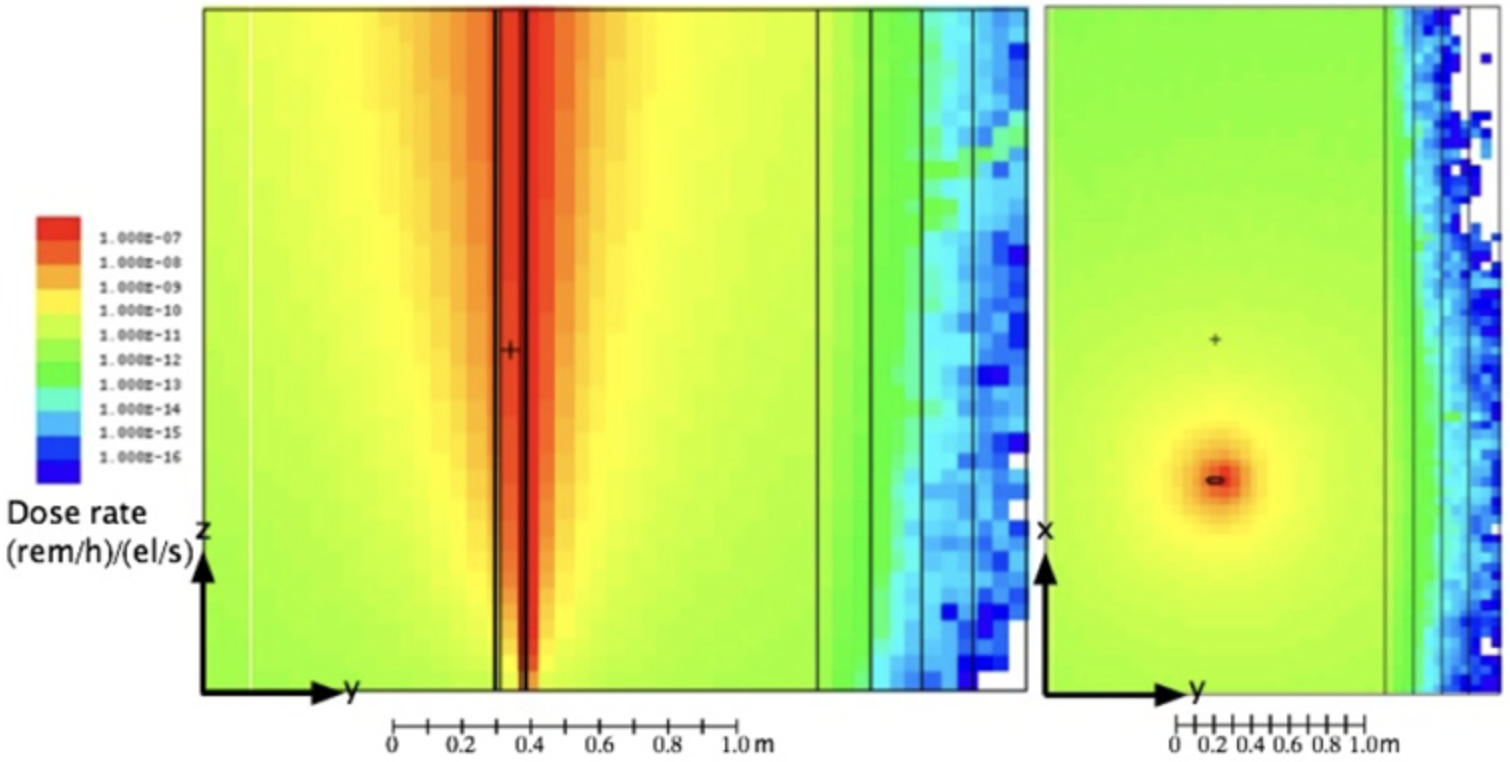



ANSYS model, 170 watts, 0.1 mm diameter beam, perpendicular incidence on 3 mm thick, 500 mm diameter Aluminum disk, air cooling one side

Combine this with Geant4 models of energy deposition to identify a 'Safe Current' below which one can run without possibility of damage to CBETA beampipe:

~ a few uA

However




Dose rate calculation for 1 uA → ~ 60 kRad/hr near beampipe

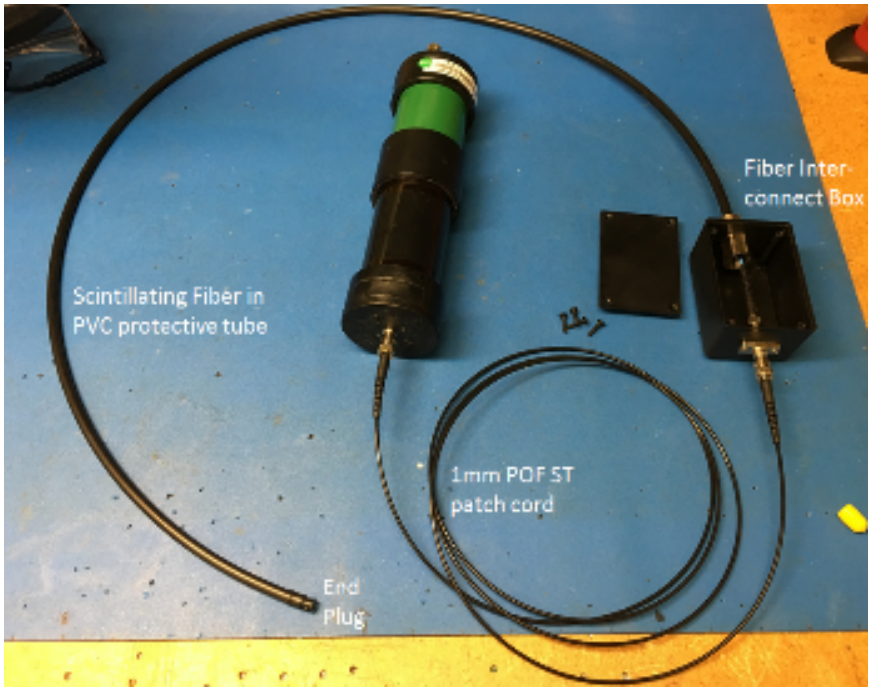
Potential hazard to permanent magnets

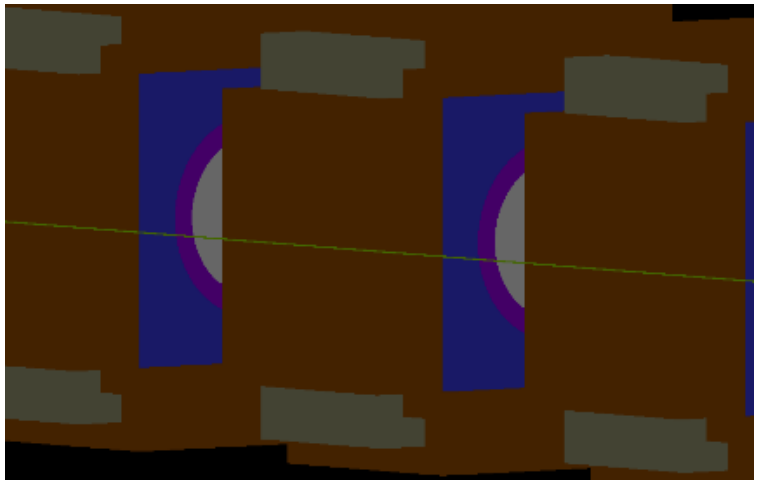
# Machine Protection

Need a Beam Loss Monitor System capable of

1. responding to high current (mA) losses on a micro-second time scale
2. monitoring continuous low current losses (uA)

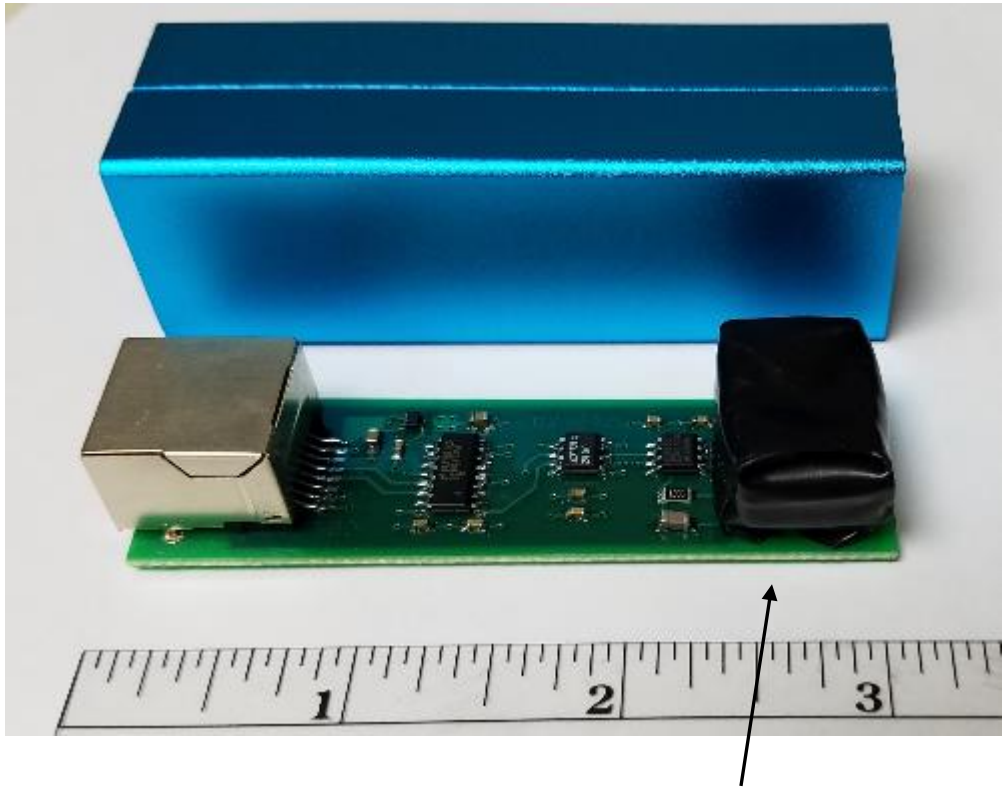
## Fast BLM



1 mm scintillating fiber running along both sides of magnets

## Slow BLM




- Small
- Inexpensive
- B field OK
- 7.5 Hz update rate

# Machine Protection

## ERL Operations Interlocks

Delivering the laser to the photocathode in the ERL gun requires opening multiple shutters.

## Personnel Protection Shutter

The Personnel Protection shutter can only be opened after the personnel protection system becomes ready (area searched and secured). This is also a pre-requisite for enabling the Equipment Protection Shutters.

## Equipment Protection Shutters

The Equipment Protection shutter can only be opened after the Equipment Protection Ready Chain is complete. Closes quickly ( ~ a few uS ) upon detection of a fault by Fast Shutdown System.

# Machine Protection

Equipment Protection Ready Chain:

- Gun (SF6, HVPS)
- Vacuum / Gate Valves
- Magnet and Magnet Power Supplies
- RF
- Radiation Monitors (slow)

Fast Shutdown System:

- PPS
- EPS (above items)
- Gun HV
- RF
- Dump Raster / Quad Detector / Temperatures
- Beam Loss Monitors