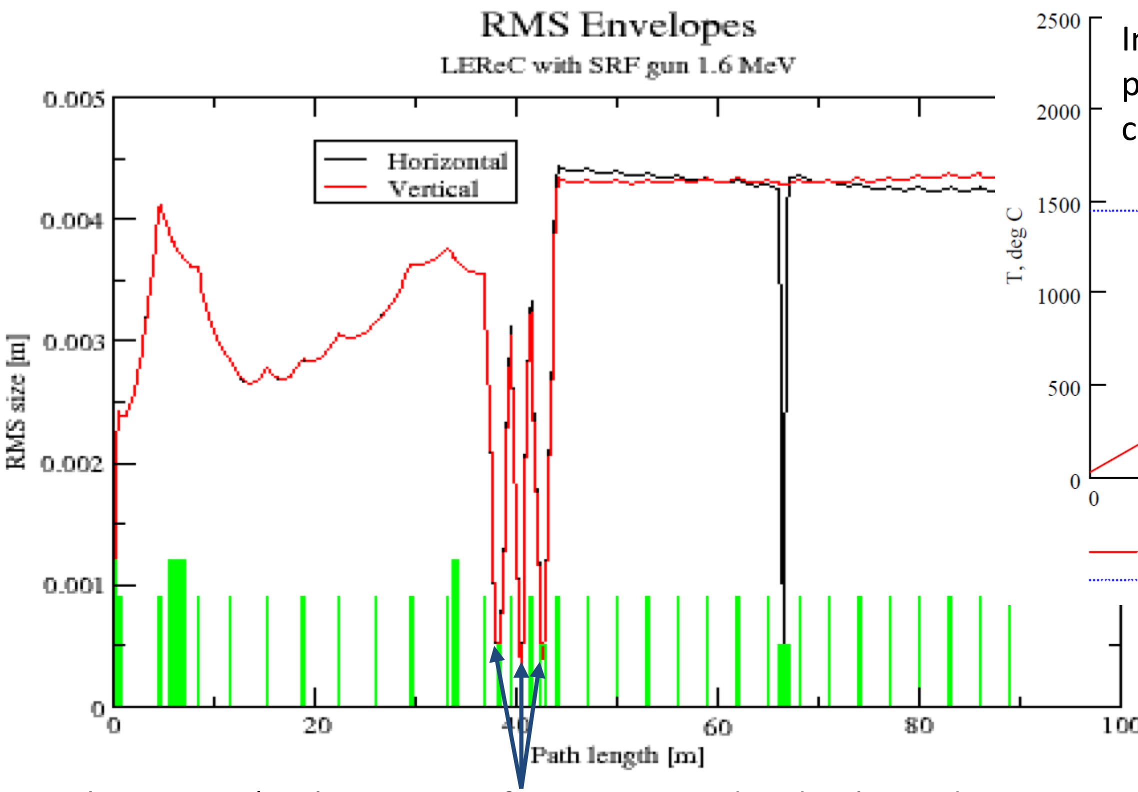
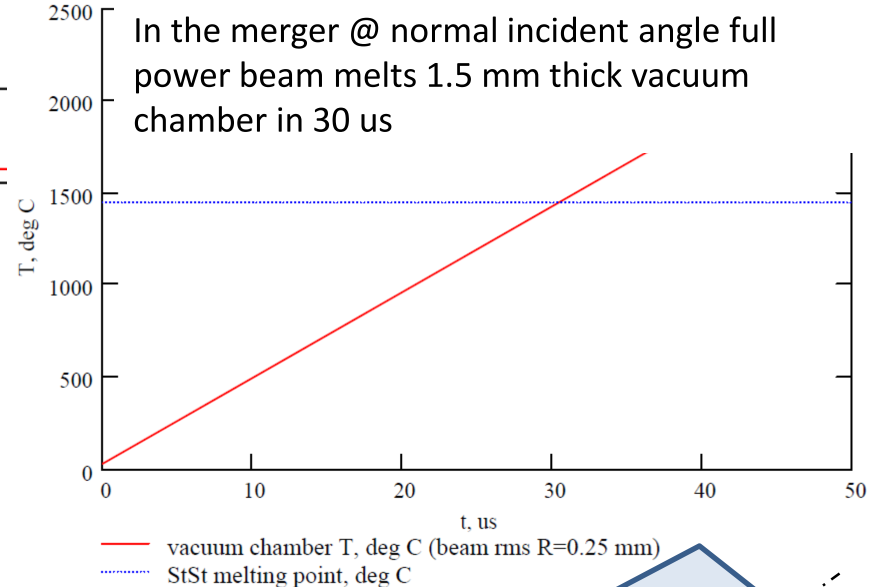
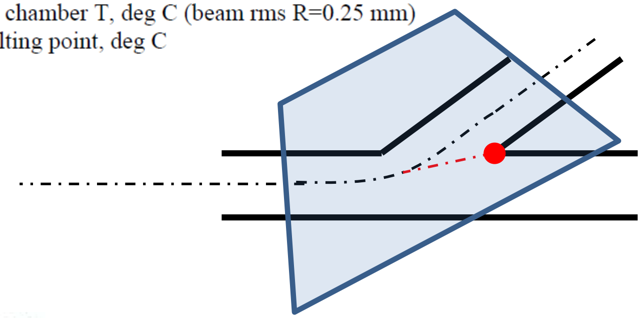
Estimates of required MPS reaction time

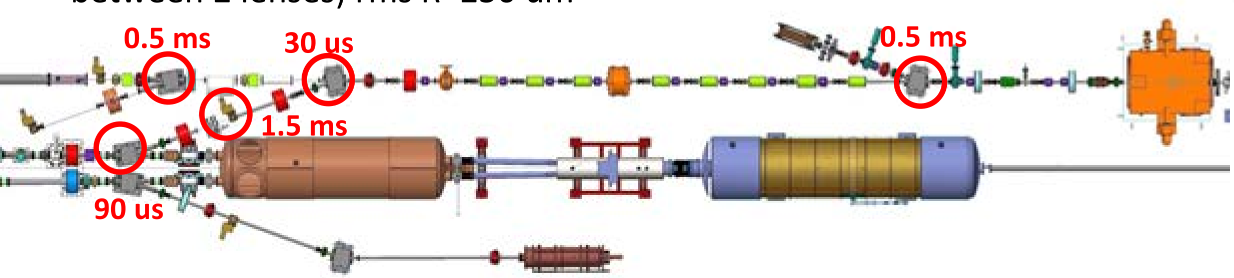


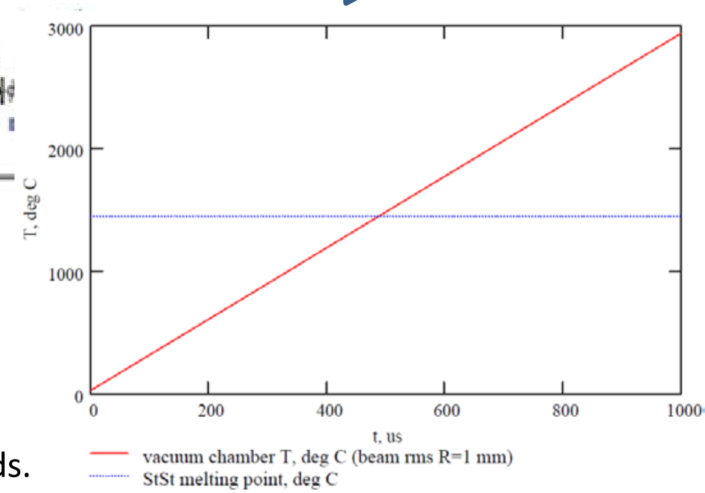
In the merger (at the centers of respective 20deg dipoles and in between 2 lenses) rms R=250 um

In the merger @ normal incident angle full power beam melts 1.5 mm thick vacuum chamber in 30 us









Typical beam rms R > 1 mm throughout the whole LEReC beamline.

For rms R=1 mm @ normal incident angle full power beam melts 1.5 mm thick vacuum chamber in 0.5 ms.

RF phase jump can happen in few us. Magnet fields change in many milliseconds.

Machine protection diagnostics

- Beam Loss Monitor (BLM):
  - used at every facility similar to LEReC;
  - reaction time (~ 10 us);
  - sensitive to beam losses (according to Bruce Dunham it doesn't even matter where you place BLM, as soon as there is a small uA level loss somewhere along the beamline the BLM is tripped off);
  - will it see signal from e-beam loss in RHIC tunnel background?
- Differential signal from Fast Current Transformers (FCTs) at the beginning and at the end of the beamline:
  - fast reaction time (~ 1 us);
  - is it accurate enough at nominal current (35 mA) ops?
- BPM with predefined beam position envelope (closes laser if beam trajectory deviates from BPM center by more than allowed):
  - Reaction time (~ 12 us);
  - Works in the whole range of machine parameters.

Commissioning, operation and machine protection

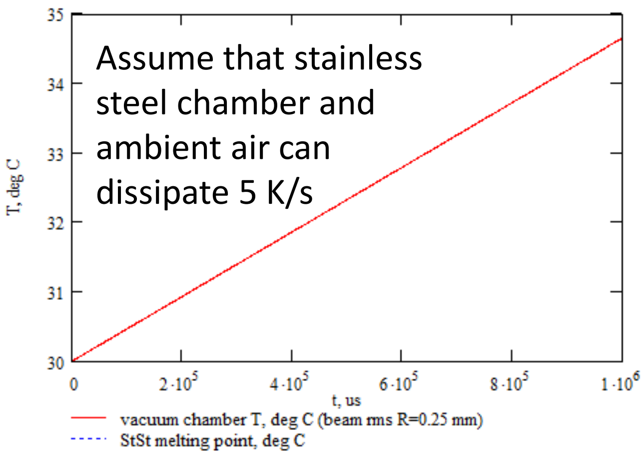
Mode of operation	Goals	Parameters	MPS
Pencil beam (2016-17, E=400 keV) (2018, E=1.6-2.6 MeV)	Roughly get beam energy and trajectory through the whole machine; find any rough errors in RF or magnets. BPM precision 100 um.	1 macro-pulse of 30 bunches per 1 second; each bunch is 30 pC. dE/shot=2.8 mJ; P=2.8 mW; I= 0.9 nA; Worst rms R=250 um; Worst case dT=1.2 K/sec.	none
Optics studies (2016-17, E=400 keV) (2018, E=1.6-2.6 MeV)	Set the optics for the full charge bunches; measure beam emittance; measure beam envelope throughout the CS. BPM precision 100 um.	1 macro-pulse of 9 bunches per 1 second; each bunch is 130 pC. dE/shot=3.6 mJ; P=3.6 mW; I= 1.2 nA; Worst rms R=250 um; Worst case dT=1.5 K/sec.	none
High current studies (2016-17, E=400 keV)	Explore possible gun trips at up to 10 mA current; set clearing electrodes.	9 MHz trains of macro-pulses (10 bunches 130 pC/bunch) per second. P=11 kW; I= 12 mA; Worst rms R=1 mm; Worst case dT=1450 K / 5 msec.	BPMs

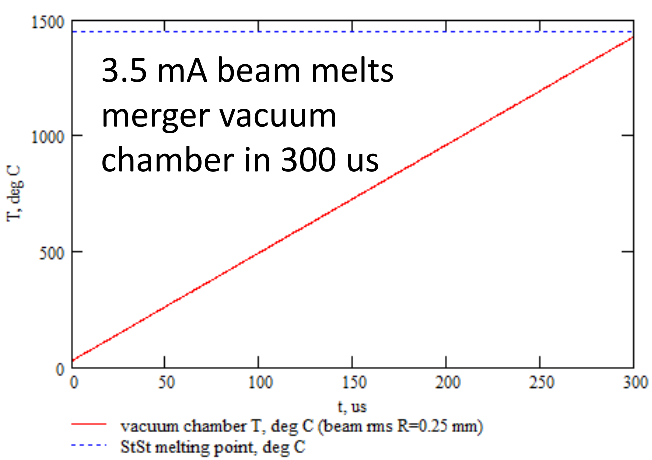
Commissioning, operation and machine protection (continued)

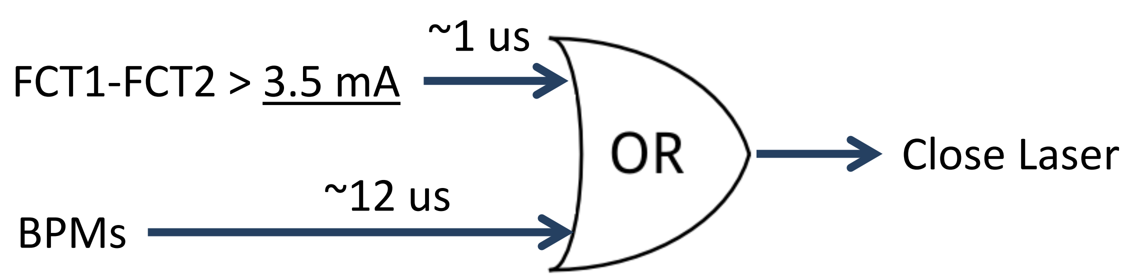
Mode of operation	Goals	Parameters (beam energy is 2.6 MeV)	MPS
RF studies (2018, E=1.6-2.6 MeV)	Fine tuning of RF system; measure energy spread.	250 us trains of macro-pulses (30 bunches 130 pC/bunch) per second. E/shot=27.6 J; P=27.6 W; I= 9 uA; Worst rms R=1 mm; Worst case dT=735 K / 250 usec.	BPMs; Interlock 20deg merger bend
High current studies (2018, E=1.6-2.6 MeV)	Explore gun trips at up to 10 mA current; set clearing electrodes.	9 MHz trains of macro-pulses (10 bunches 130 pC/bunch) per second. P=37 kW; I= 12 mA; Worst rms R=250 um; Worst case dT=1450 K / 90 usec.	BPMs; BLMs; differential FCT signal
Operation (2018, E=1.6-2.6 MeV)	Electron cooling	9 MHz trains of macro-pulses (30 bunches 130 pC/bunch). P=110 kW; I= 35 mA; Worst rms R=250 um; Worst case dT=1450 K / 30 usec.	BLMs; differential FCT signal

Required accuracy of fast detectors

- By combining fast detector and BPMs with beam position envelope one can relax the requirements to fast detector accuracy:







Both the large losses (> 10 % of the full current) and the small losses will be detected and the laser will be closed in timely fashion.

Conceptual design of fast MPS