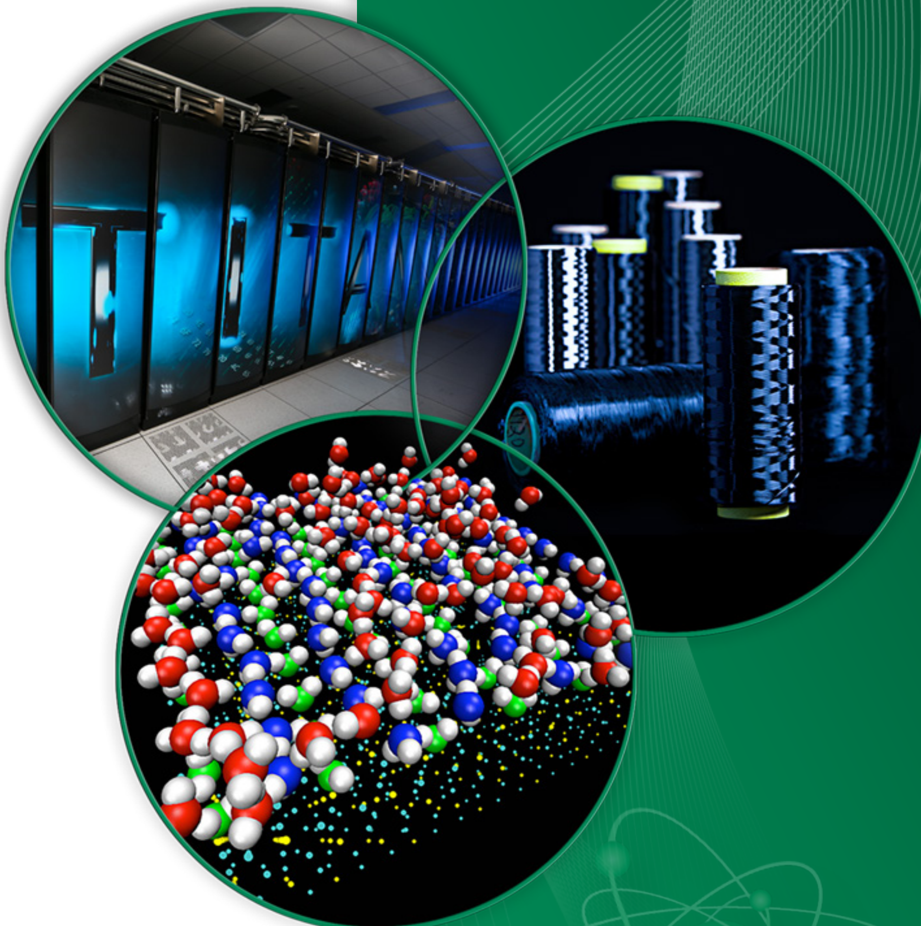
Longitudinal Laser Wire at SNS



A. Zhukov

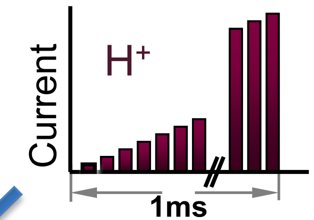
Spallation Neutron Source
Oak Ridge National Laboratory

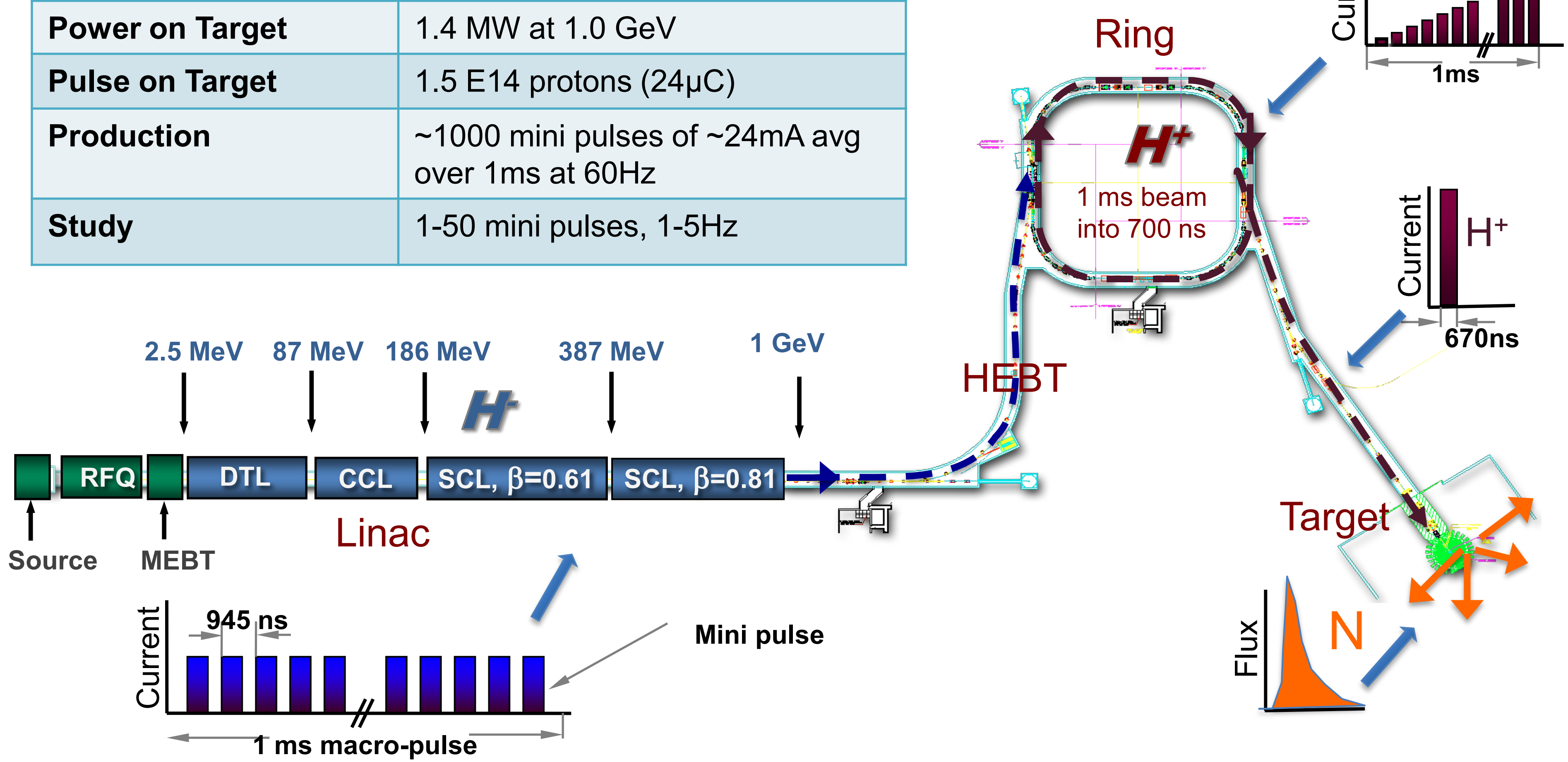
* ORNL/SNS is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725

Spallation Neutron Source

- Neutron scattering facility to research properties of materials
- 1 GeV Protons create neutrons through spallation in Hg target

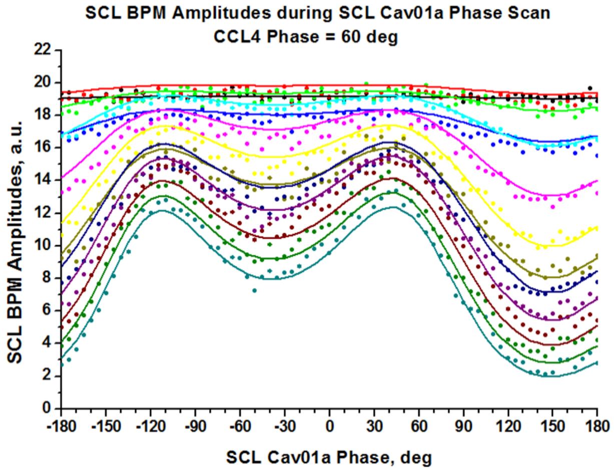
Power on Target	1.4 MW at 1.0 GeV
Pulse on Target	1.5 E14 protons (24μC)
Production	~1000 mini pulses of ~24mA avg over 1ms at 60Hz
Study	1-50 mini pulses, 1-5Hz



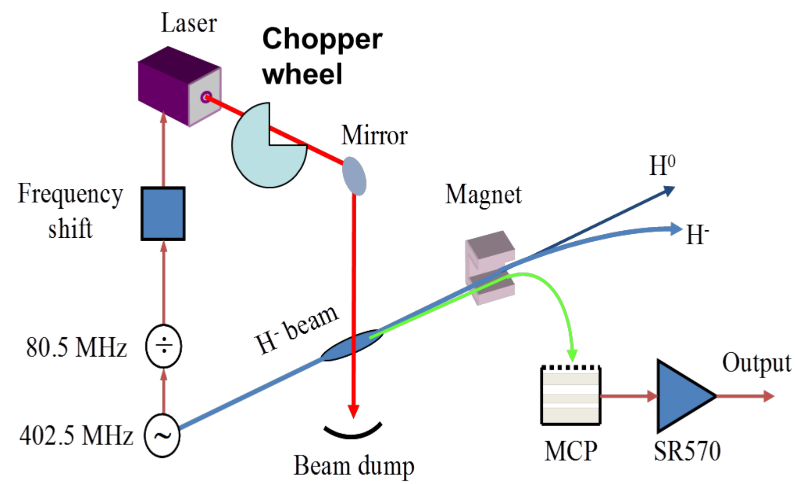


Longitudinal size measurements

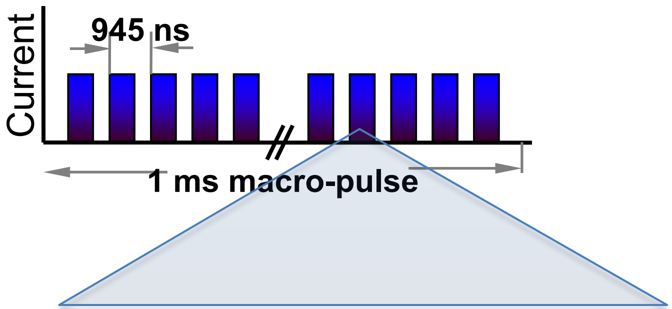
- BSM (Feschenko device)
  - Wire is used to strip electrons
  - RF deflector selects particular phase
  - Interceptive technique
  - Impossible to use in production
- BPM amplitude measurements vs. BPM position
  - Requires cavity scan and cavity blanking
  - Impossible to use in production
  - Requires beam dynamics model
- Laser wire
  - Number of striped electrons is negligible for ion beam
  - Completely non-intrusive
  - Can be used in production or studies

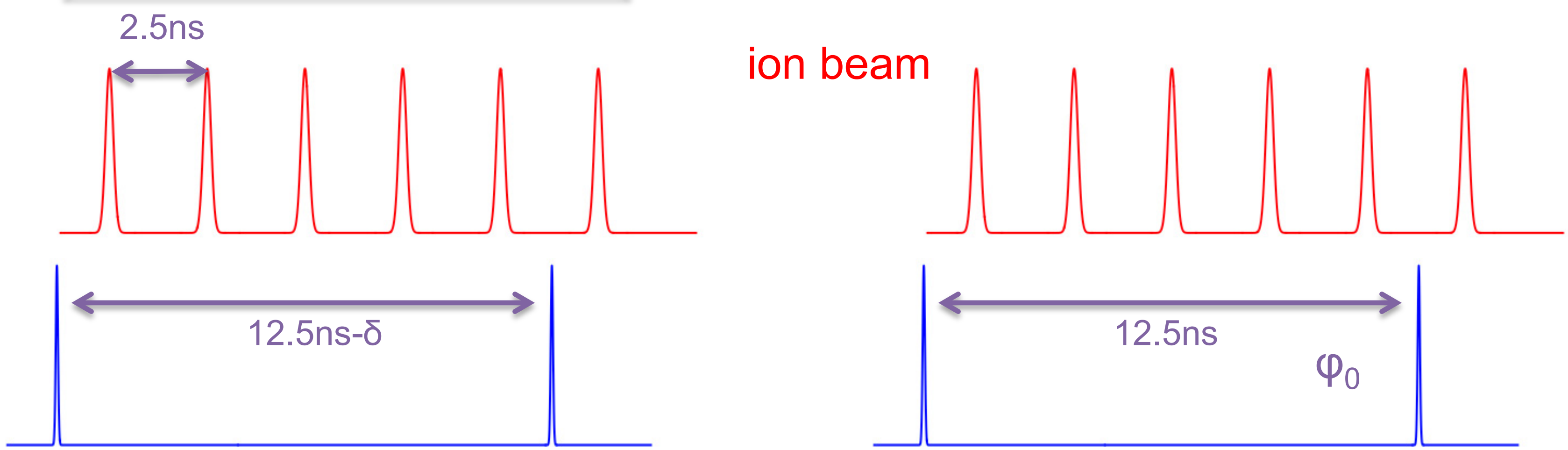


Theory of operation



Laser detaches the electrons from the 2.5MeV H^- ions in the MEBT. The detached electrons are deflected by a magnet to be collected by an MCP



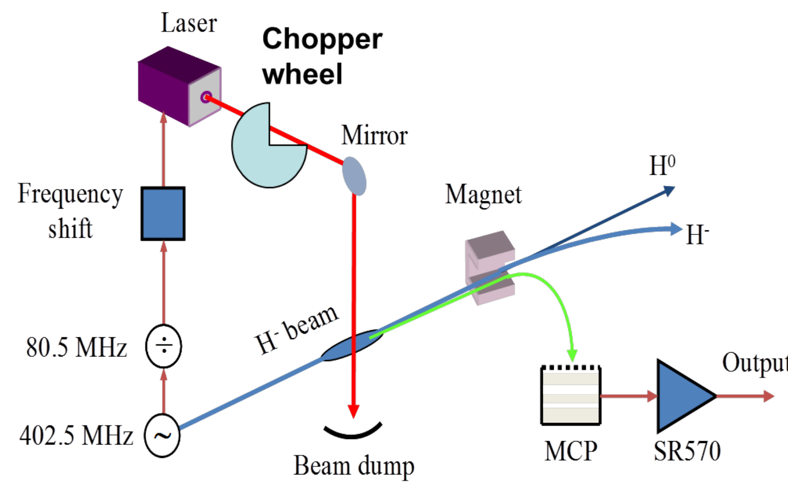


Frequency offset

laser

Phase shift

Theory of operation



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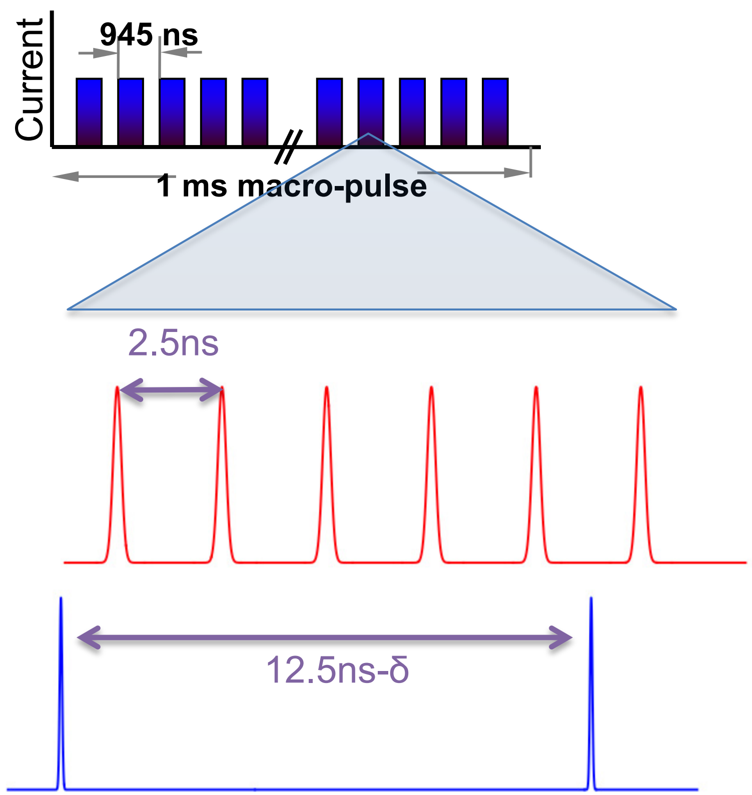
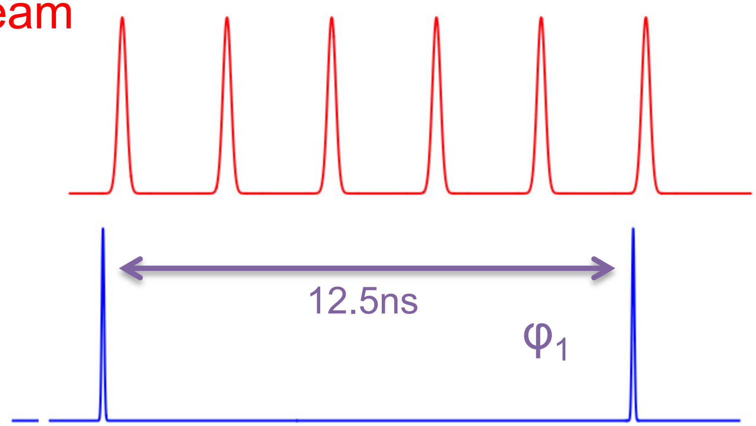


ion beam

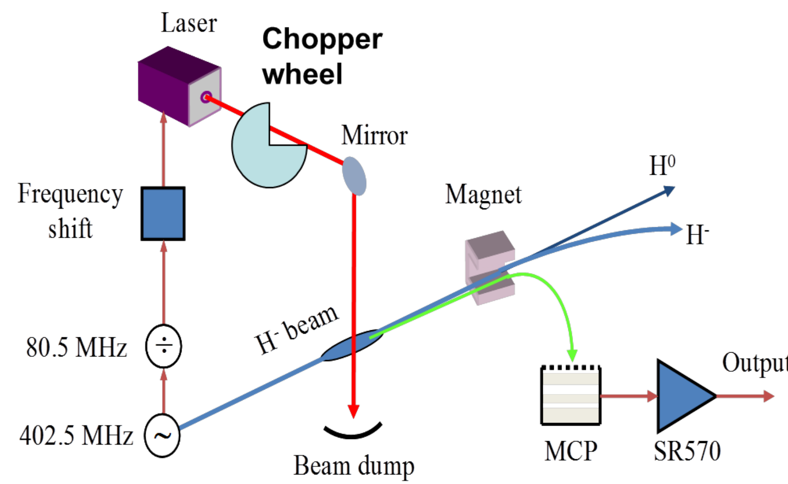


Frequency offset

laser

Phase shift

Theory of operation



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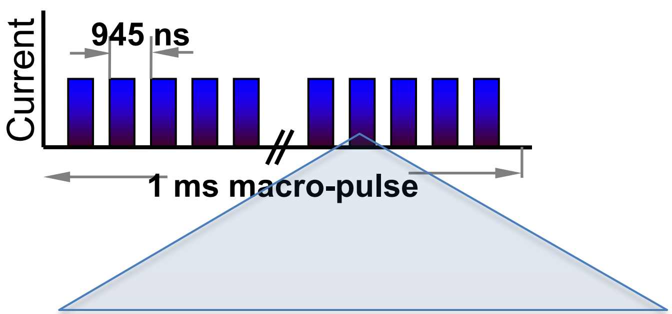

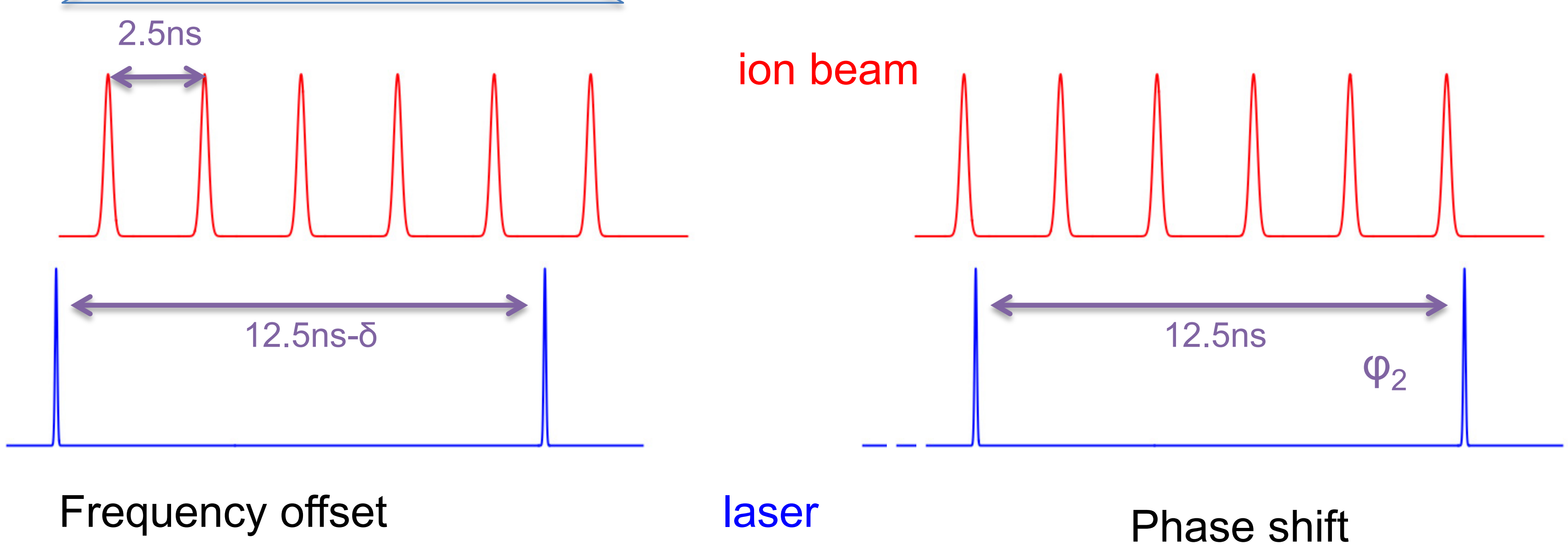

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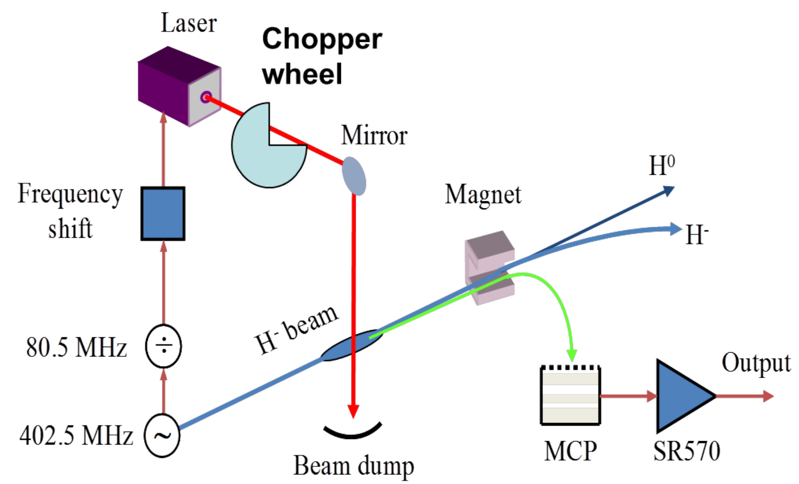

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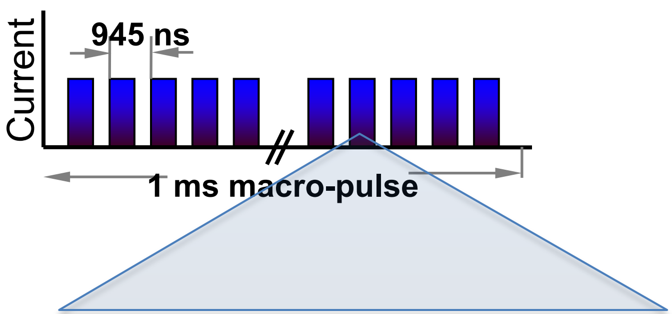
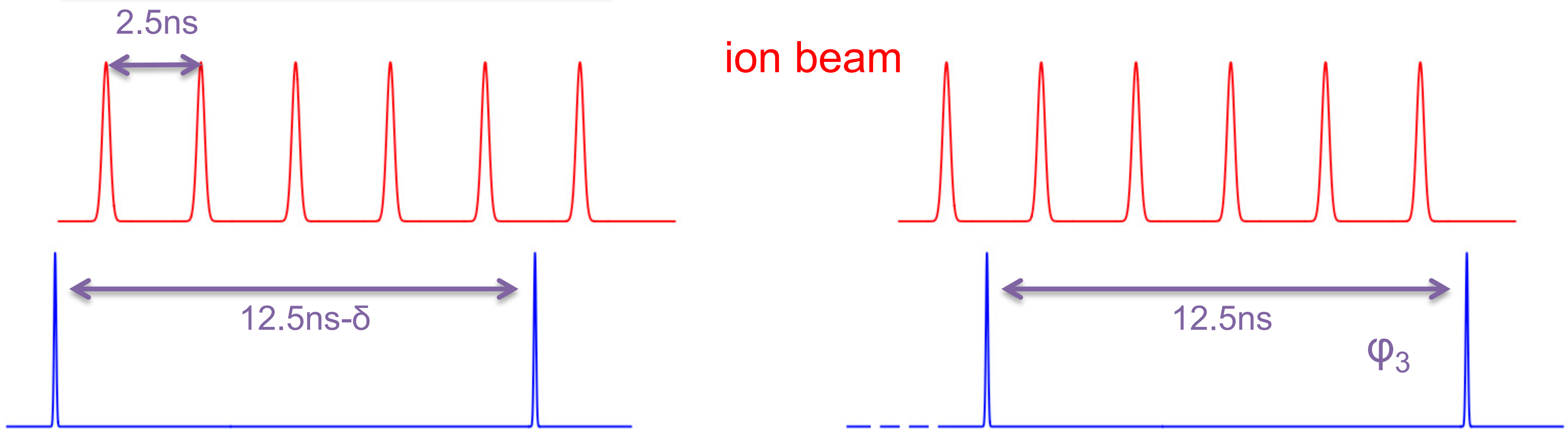


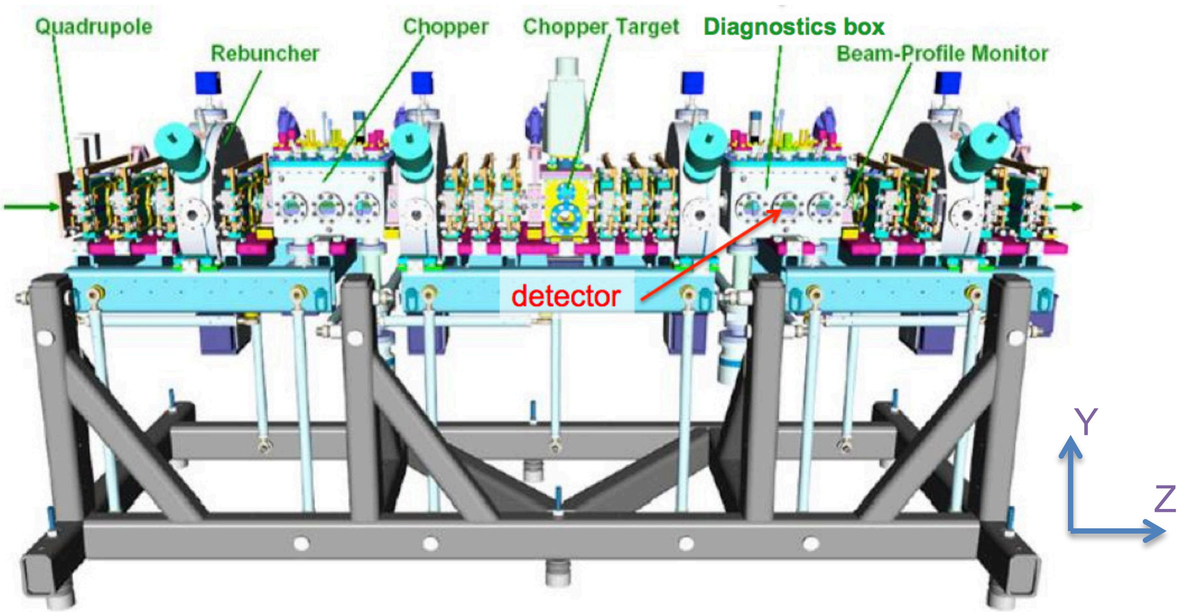


Frequency offset

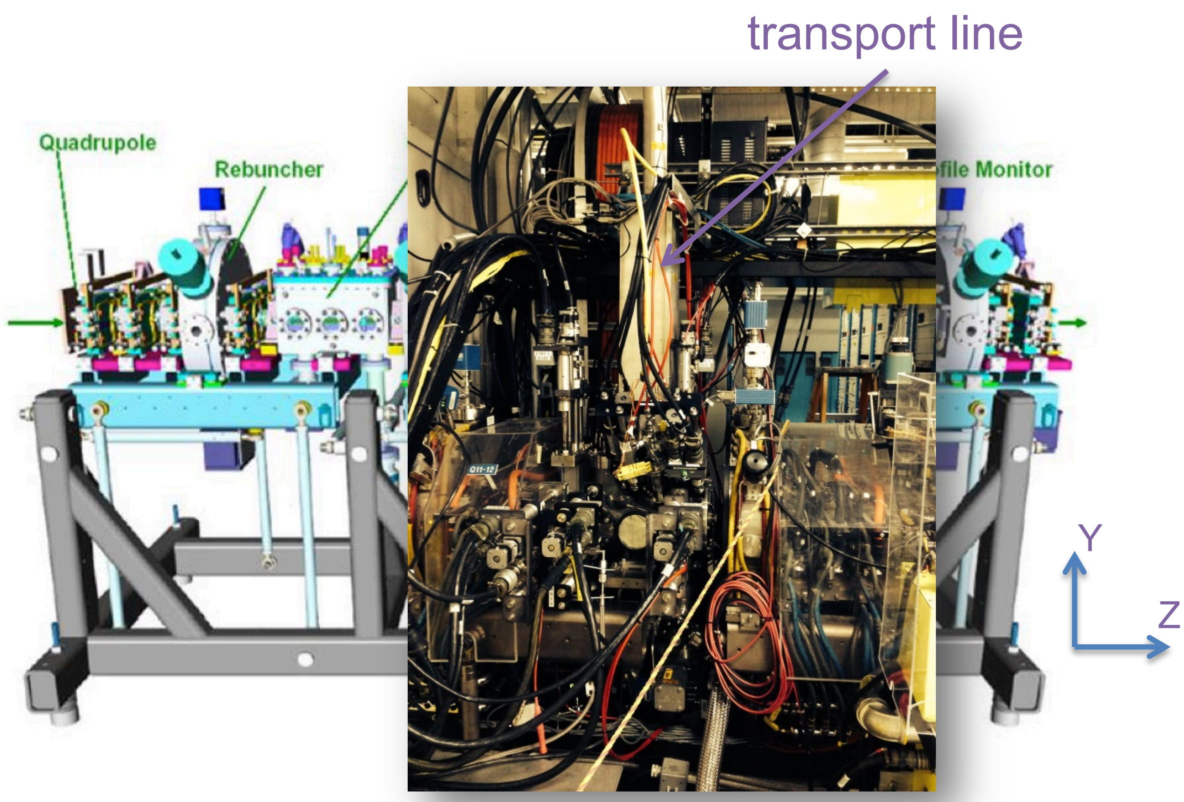
laser

Phase shift

Layout


Quadrupole
Rebuncher
Chopper
Chopper Target
Diagnostics box
Beam-Profile Monitor
detector
Y
Z

Layout



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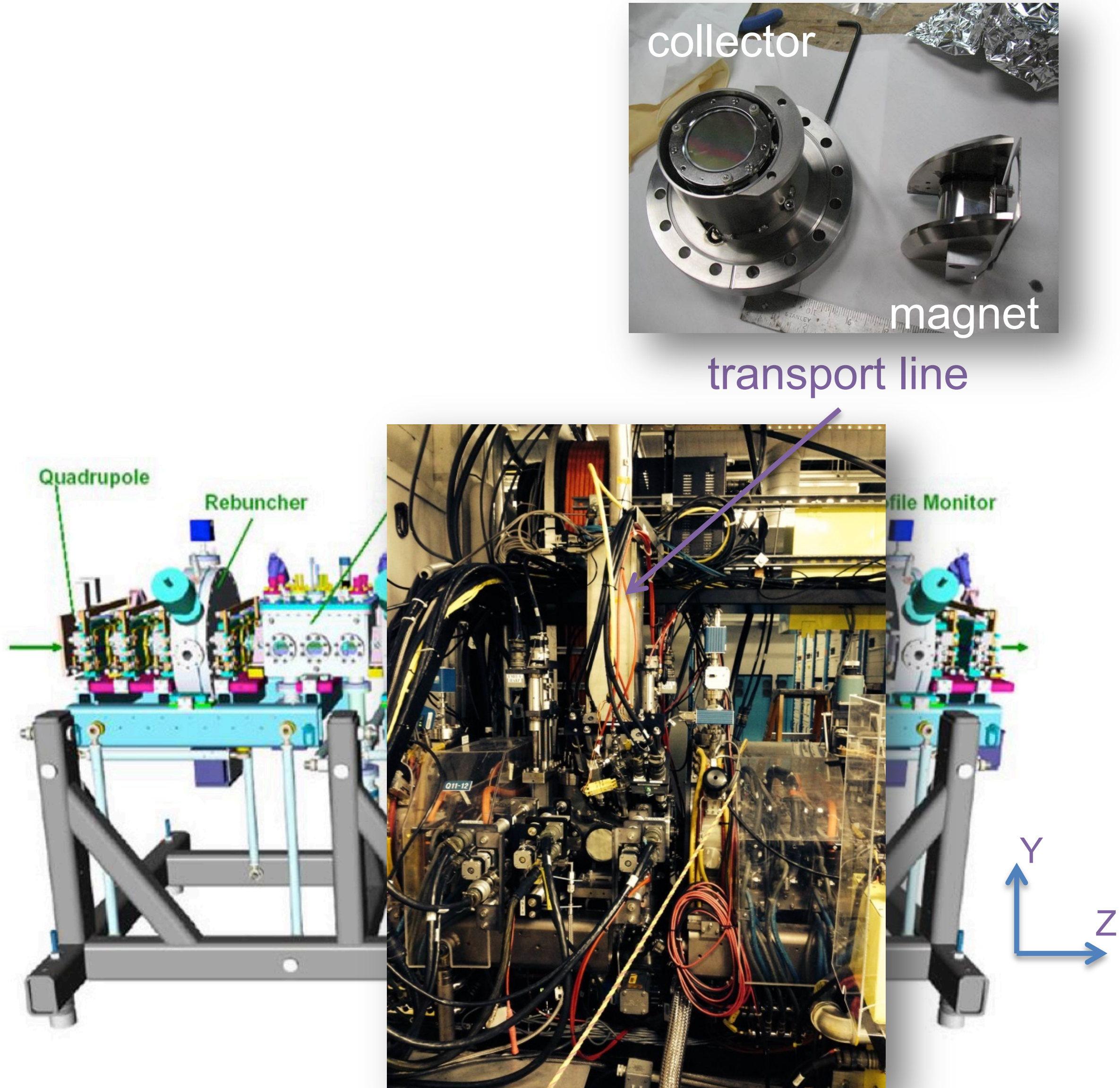

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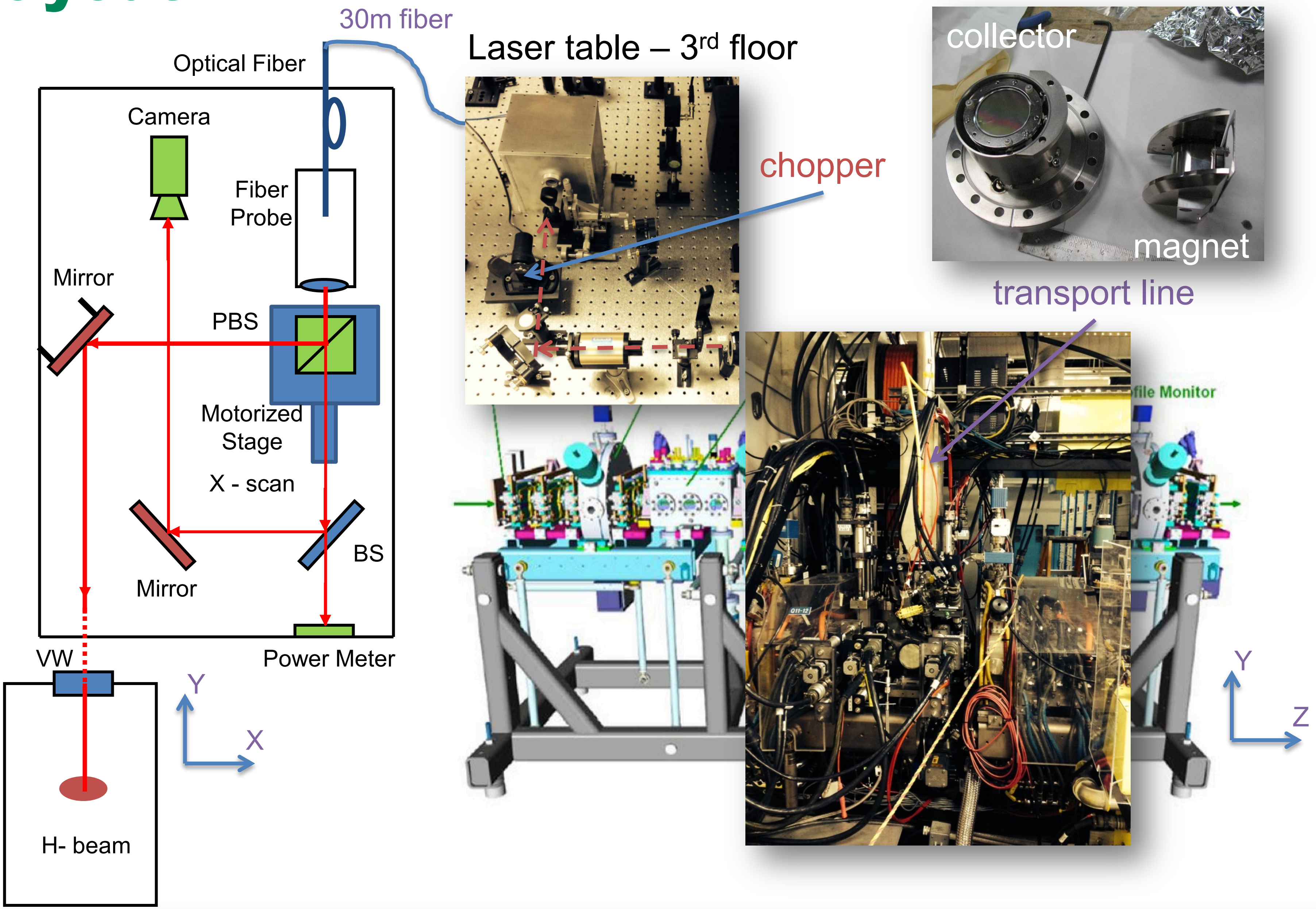
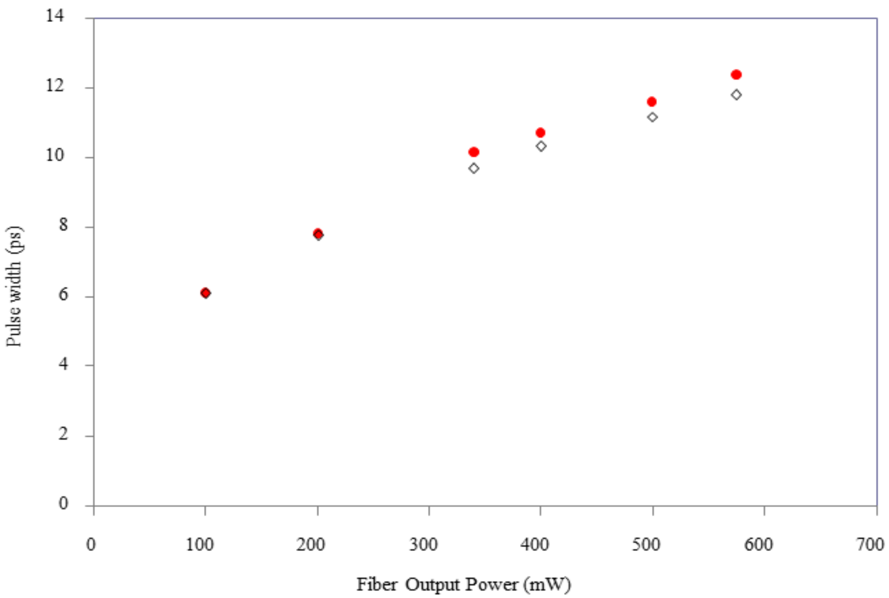
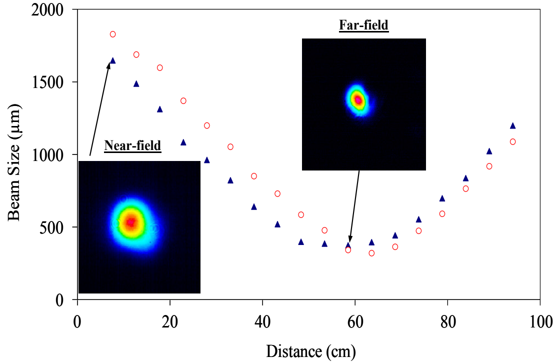

30m fiber
Optical Fiber
Camera
Fiber
Probe
Mirror
PBS
Motorized
Stage
X - scan
BS
Mirror
Power Meter
VW
H- beam
Y
X
Laser table – 3rd floor
chopper
collector
magnet
transport line
Y
Z

Laser



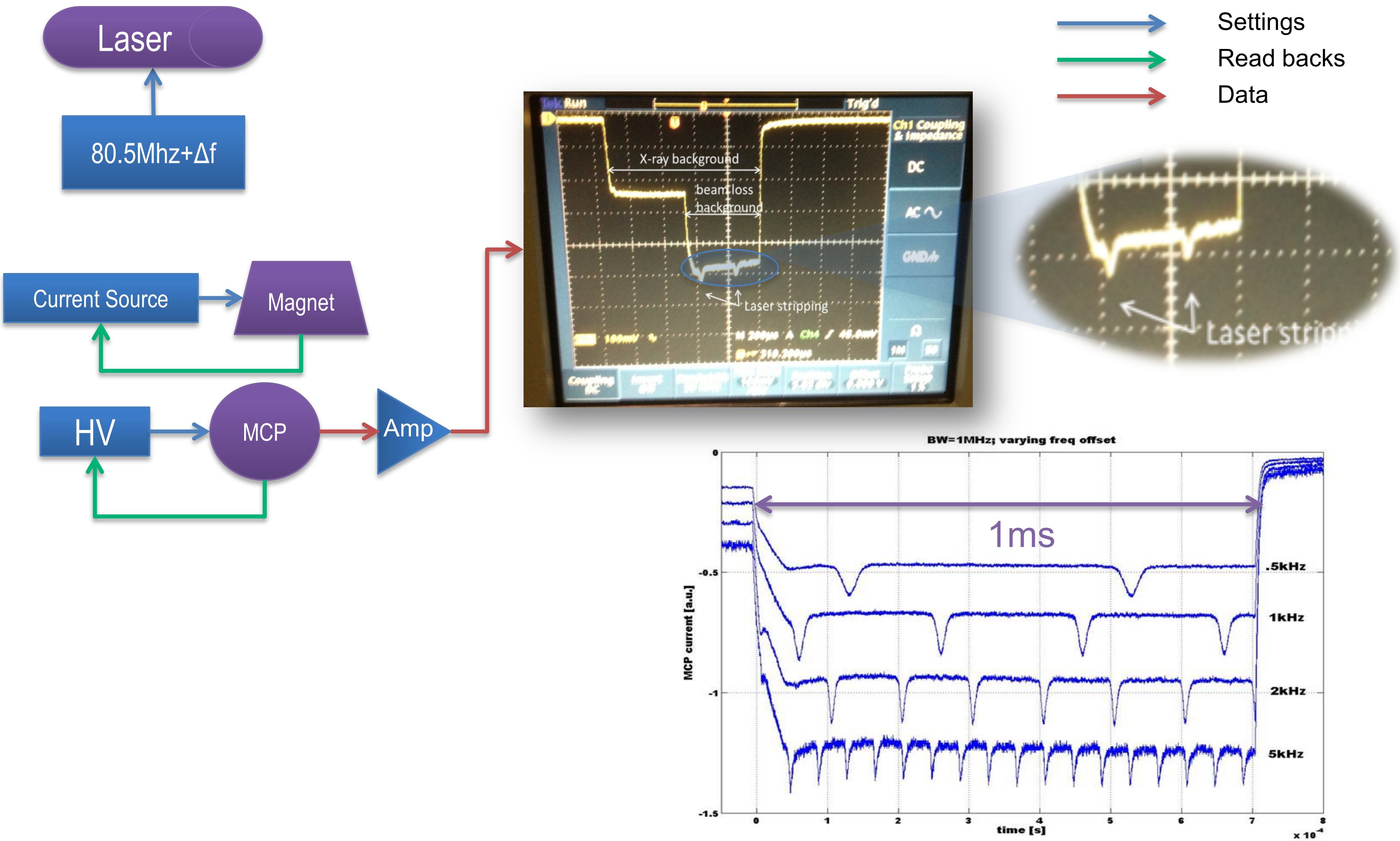


Beam size vs. distance from collimation lens after the fiber propagation

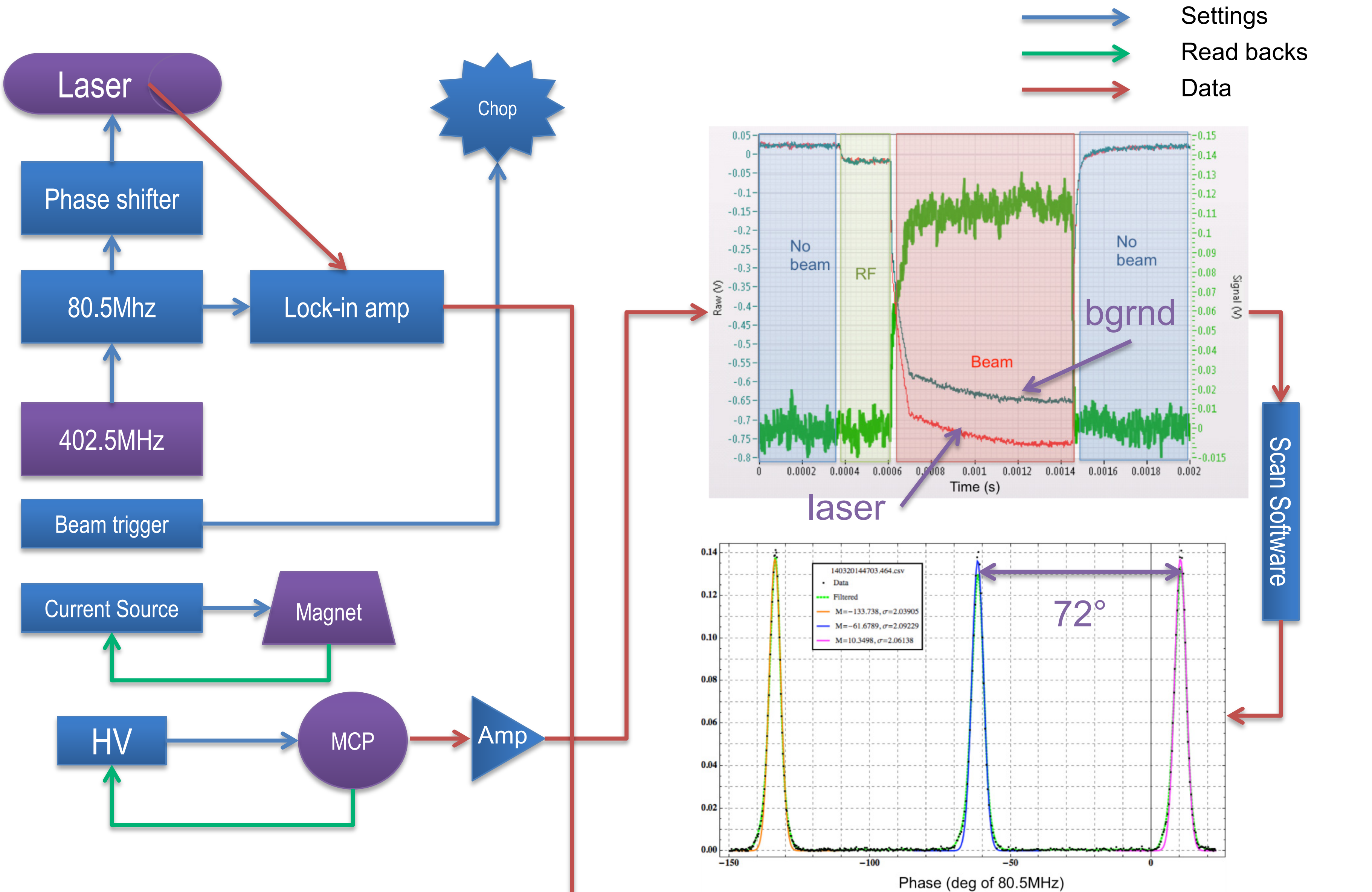
Mira 900 Ti:sapphire mode-locked laser

- pumped by a 10W Verdi-V10 solid-state laser
- synchronized to a stable RF source at 80.5MHz with a Coherent Synchro-Lock controller.
- pulse width (FWHM) of 2.5ps.
- peak power is variable up to 5kW.
- 30m long polarization-maintaining LMA fiber from Nufern
- fiber output pulse width ~ 10ps
- photo-ionized electron charge over one macro-pulse ~10pC
- wavelength 800nm

Experiment setup: Frequency Offset

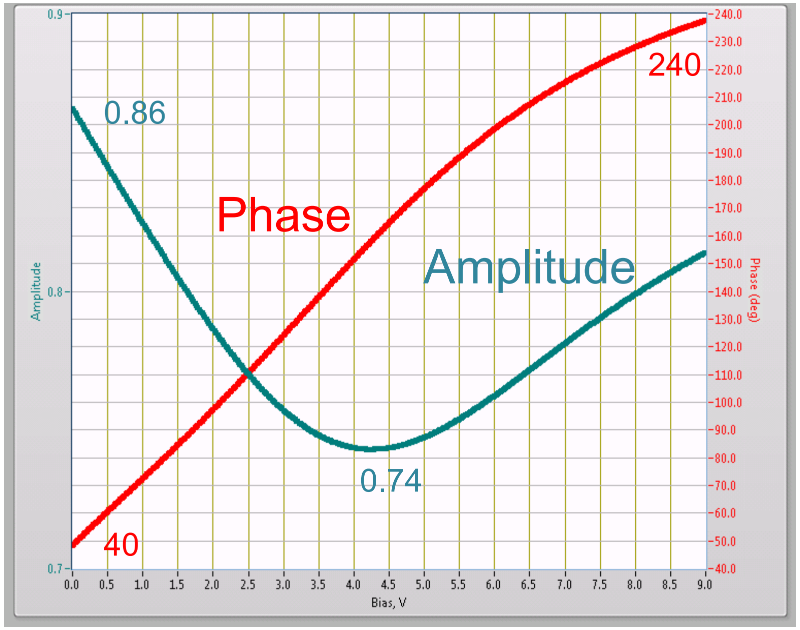


Experiment setup: Phase Shift

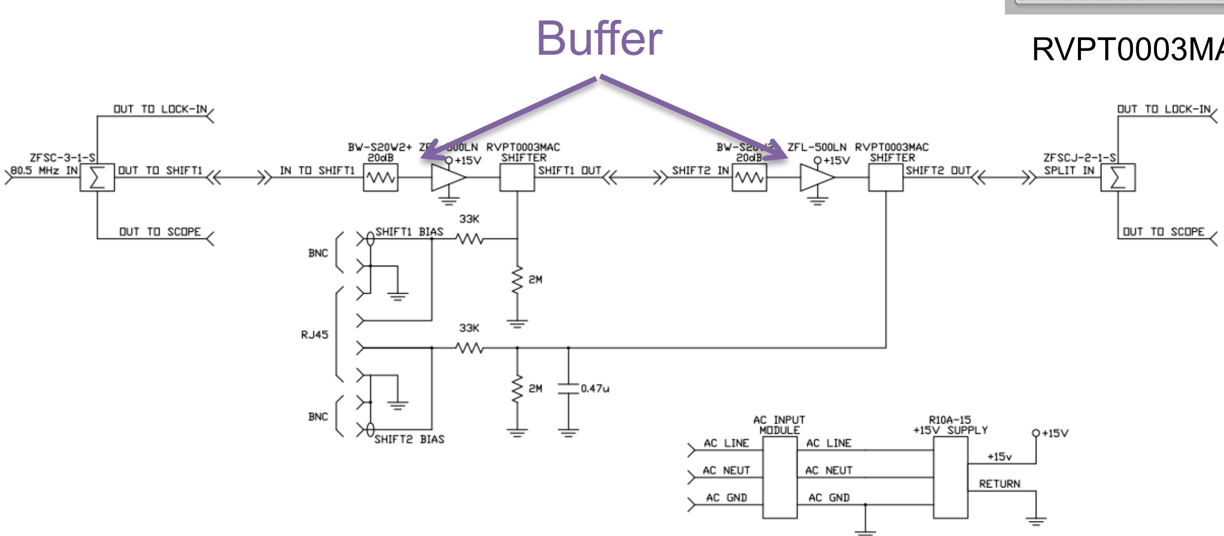


Phase shifting can be tricky

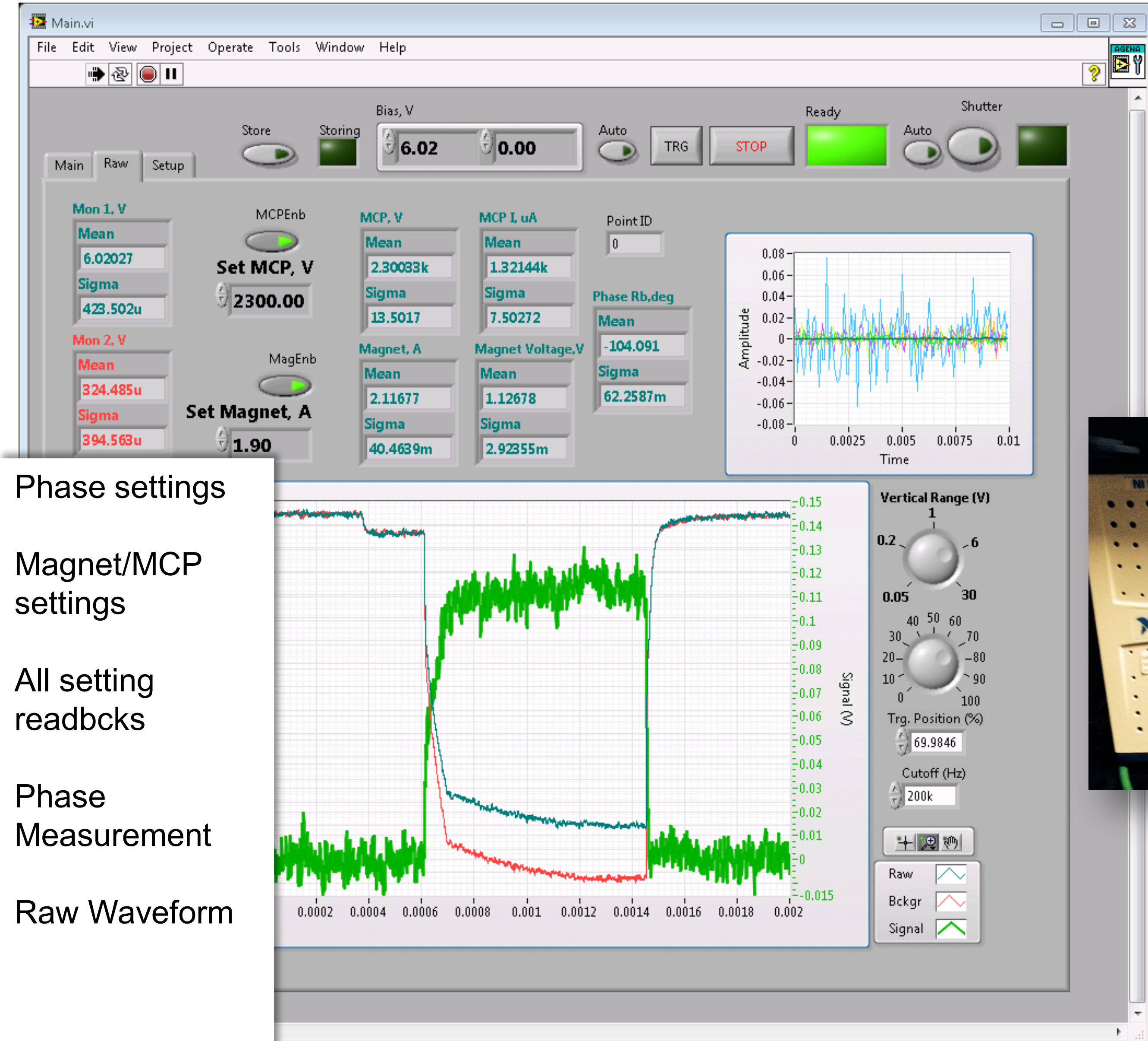
- Two phase shifters connected in series
- Phase vs. bias non-linear
- Amplitude vs. bias not flat
- Second phase depends on first bias due to amplitude being non-flat
- Calibration independent phase measurement needed
- Photodiode inside laser enclosure connected to lock-in amplifier serves for phase monitoring
- Phase shifter needs to be buffered or it will contaminate base 80.5MHz and lock-in won't measure phase correctly



RVPT0003MAC phase shifter: phase/amplitude vs. bias



Data acquisition



Phase settings

Magnet/MCP settings

All setting readbcks

Phase Measurement

Raw Waveform

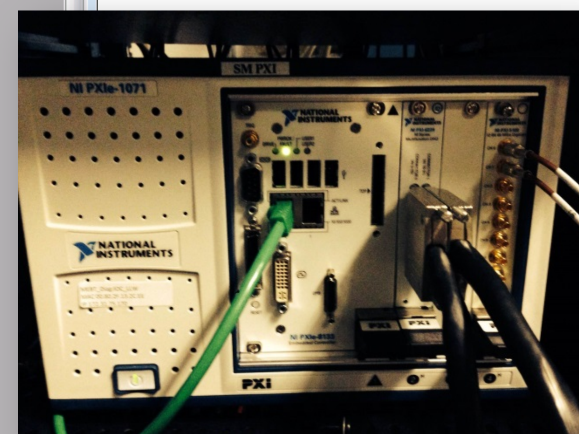
MCP/magnet – custom

Phase measurement: SR844

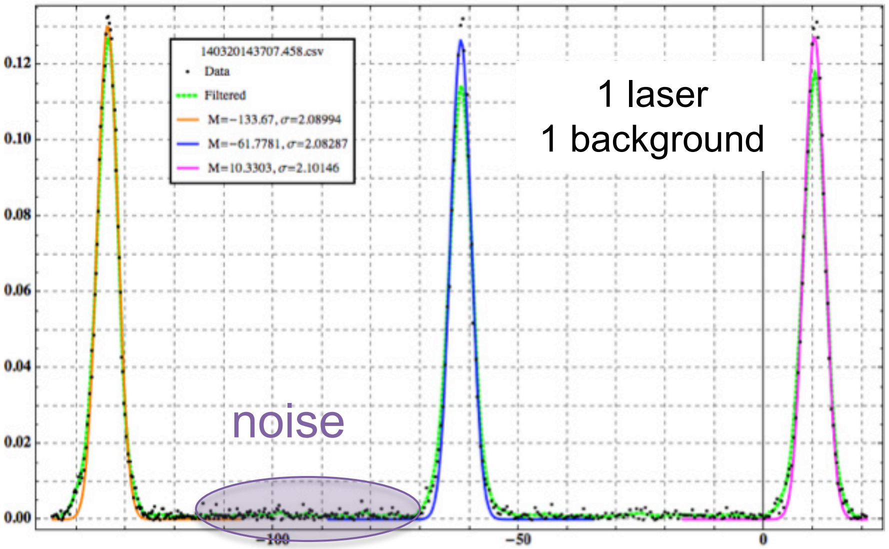
Signal digitizing: NI 5105

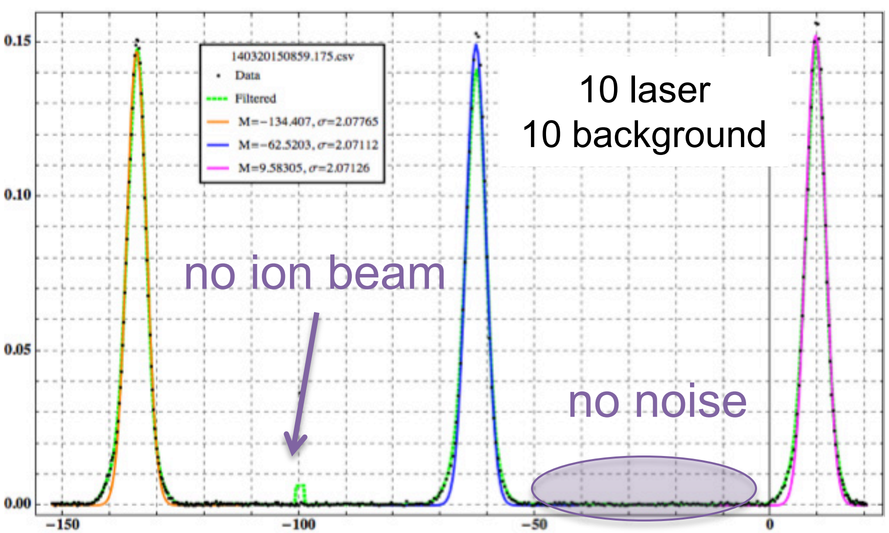
Read back: NI 6229

Integration: PXI crate



Can we average background?



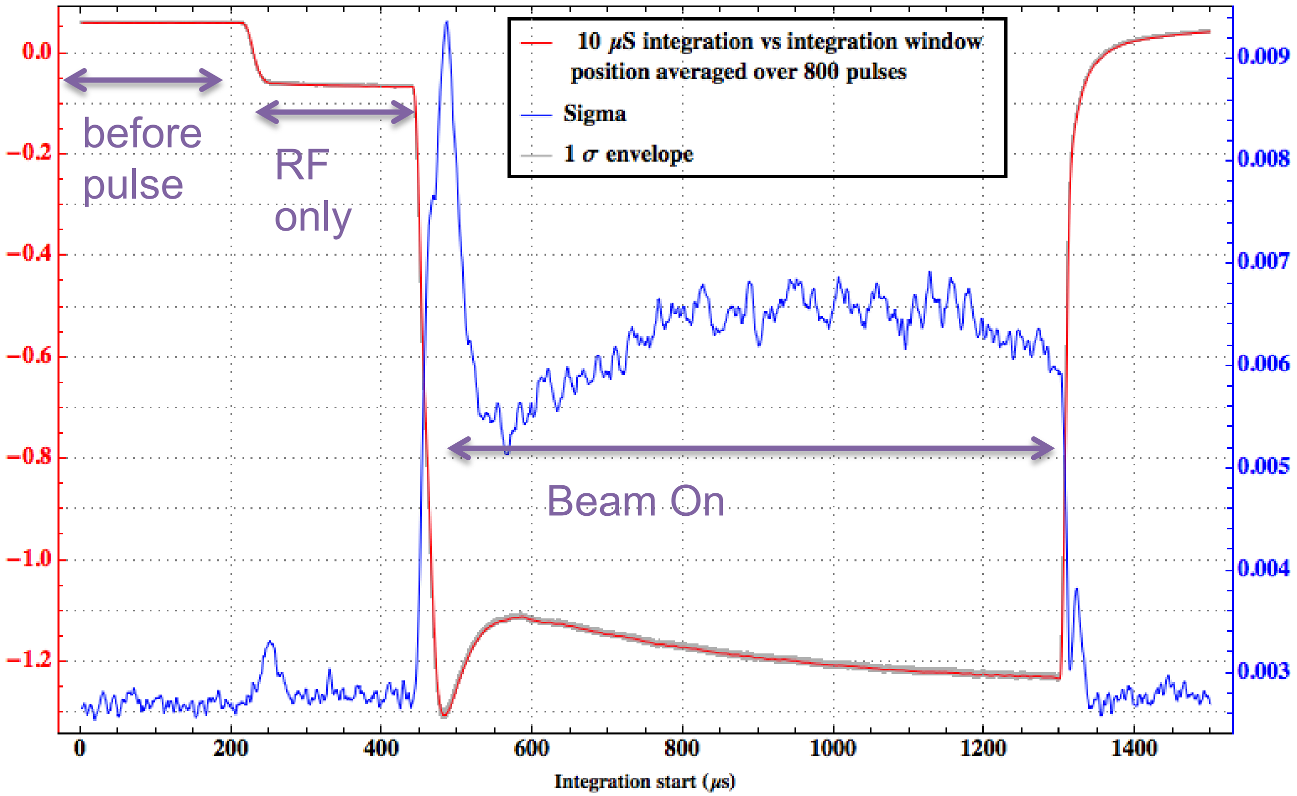


If we stay at the same phase for several pulses, we can significantly reduce noise by simple averaging over total number of samples.

It works for background, signal and phase measurement.

Averaging is fast at 60Hz

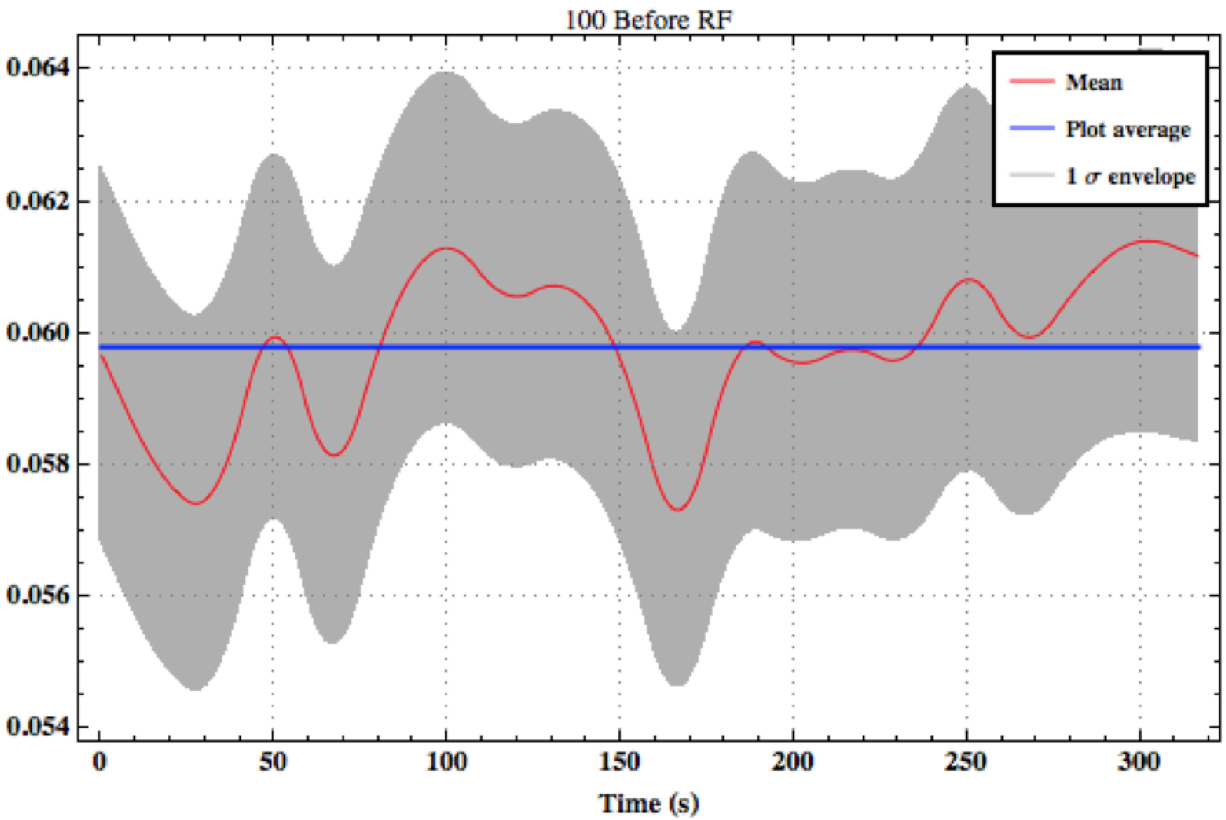
Averaging of background at 60Hz



Collect background (no laser involved) data ~ 60Hz.
Partition data in batches of 1000.
For every pulse calculate integral I[t] over [t0, t0+10uS].
For every t average the integral over batch.

For several t plot I[t] vs. batch number

Averaging of background at 60Hz



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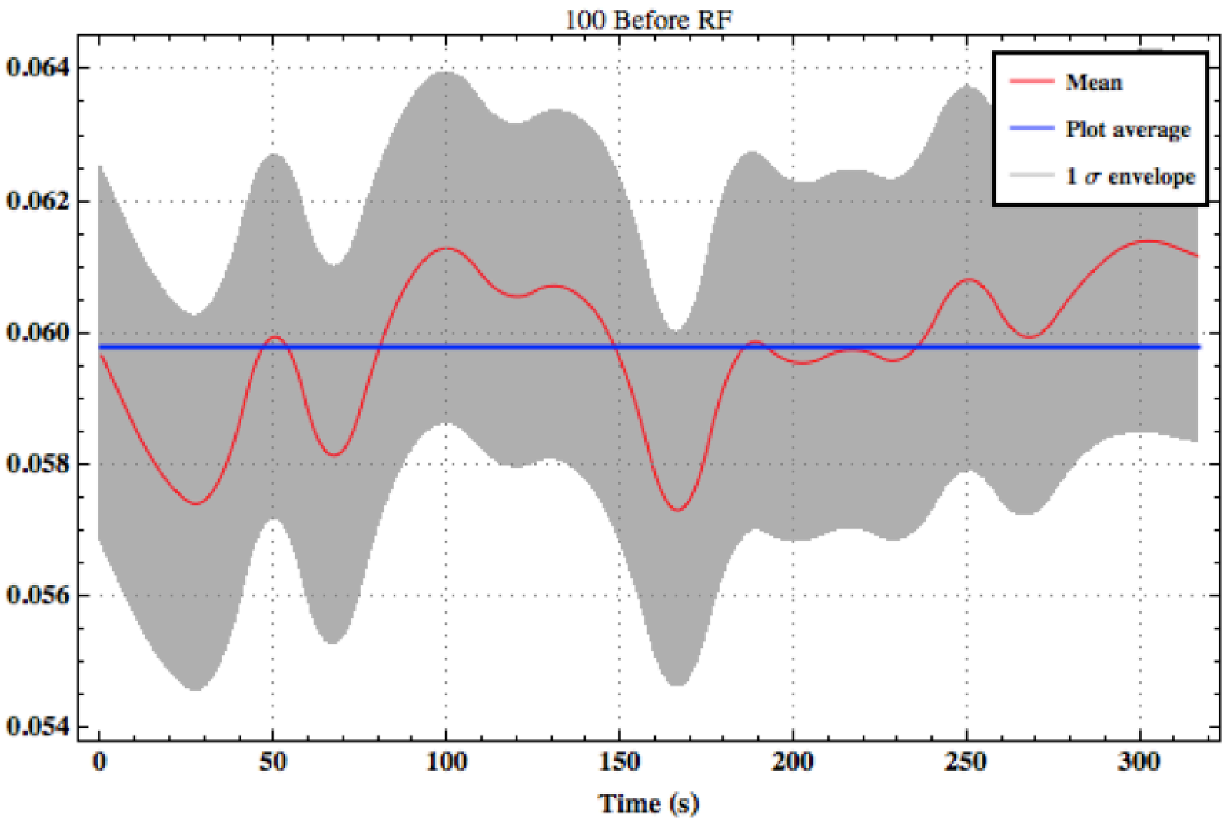

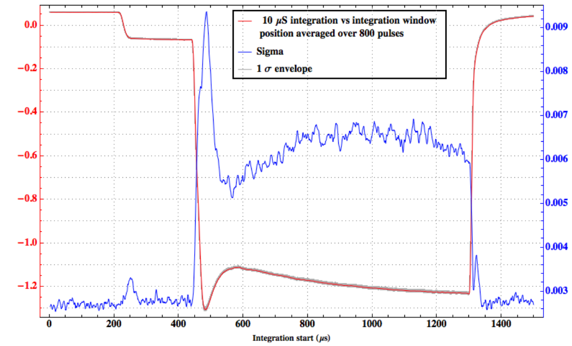

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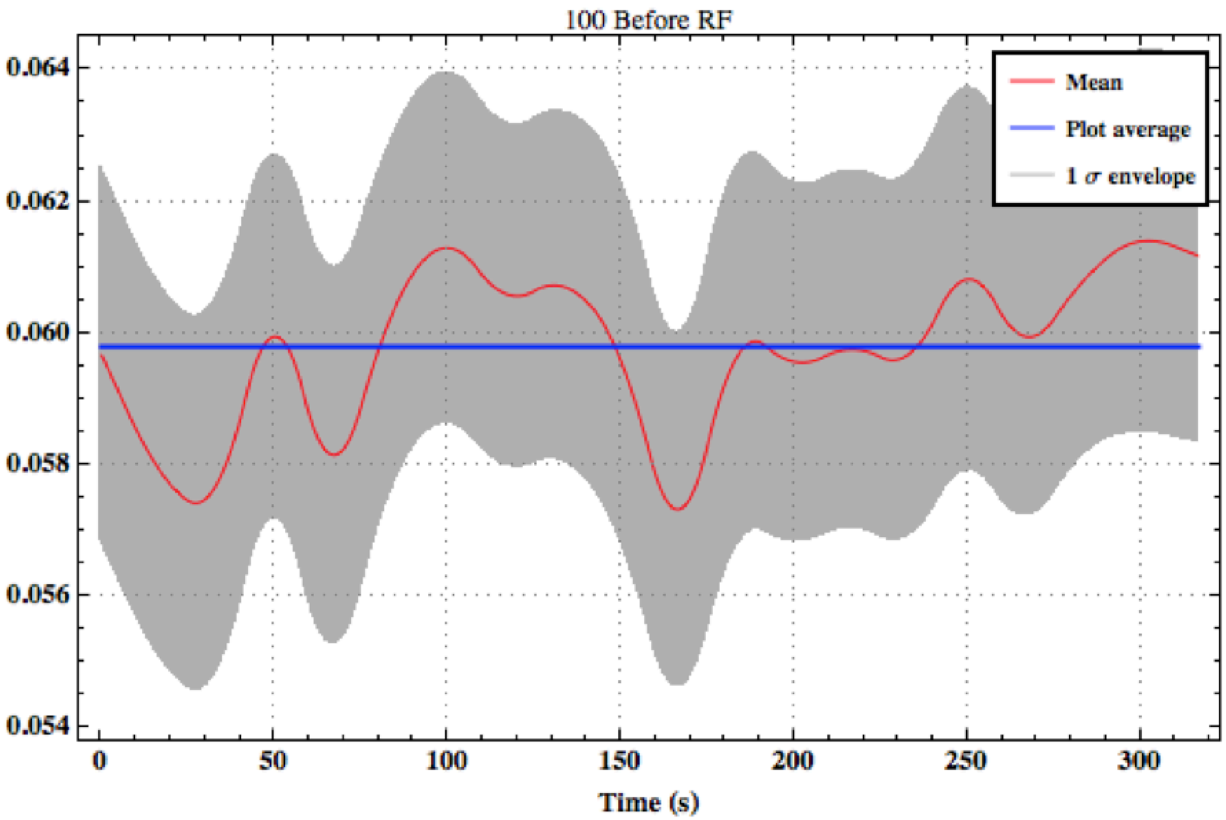

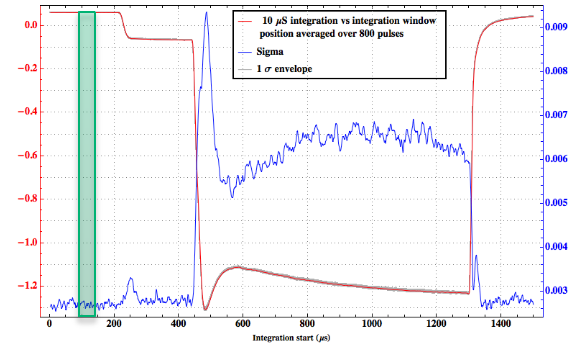

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IBIC'14 MOCYB3 A.Zhukov, A. Aleksandrov, Y. Liu Longitudinal Laser Wire at SNS

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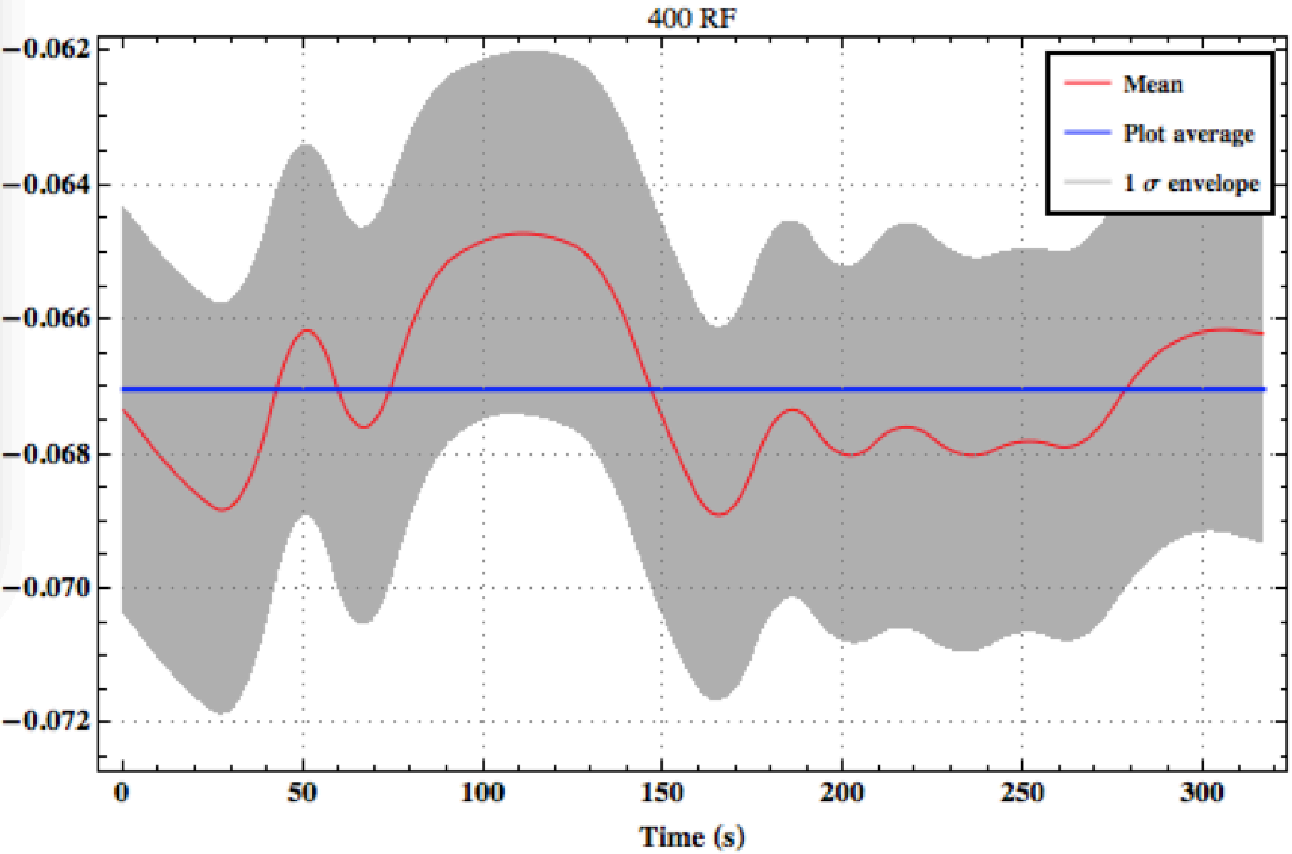

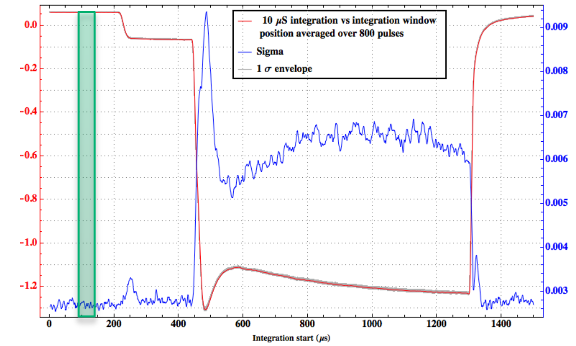

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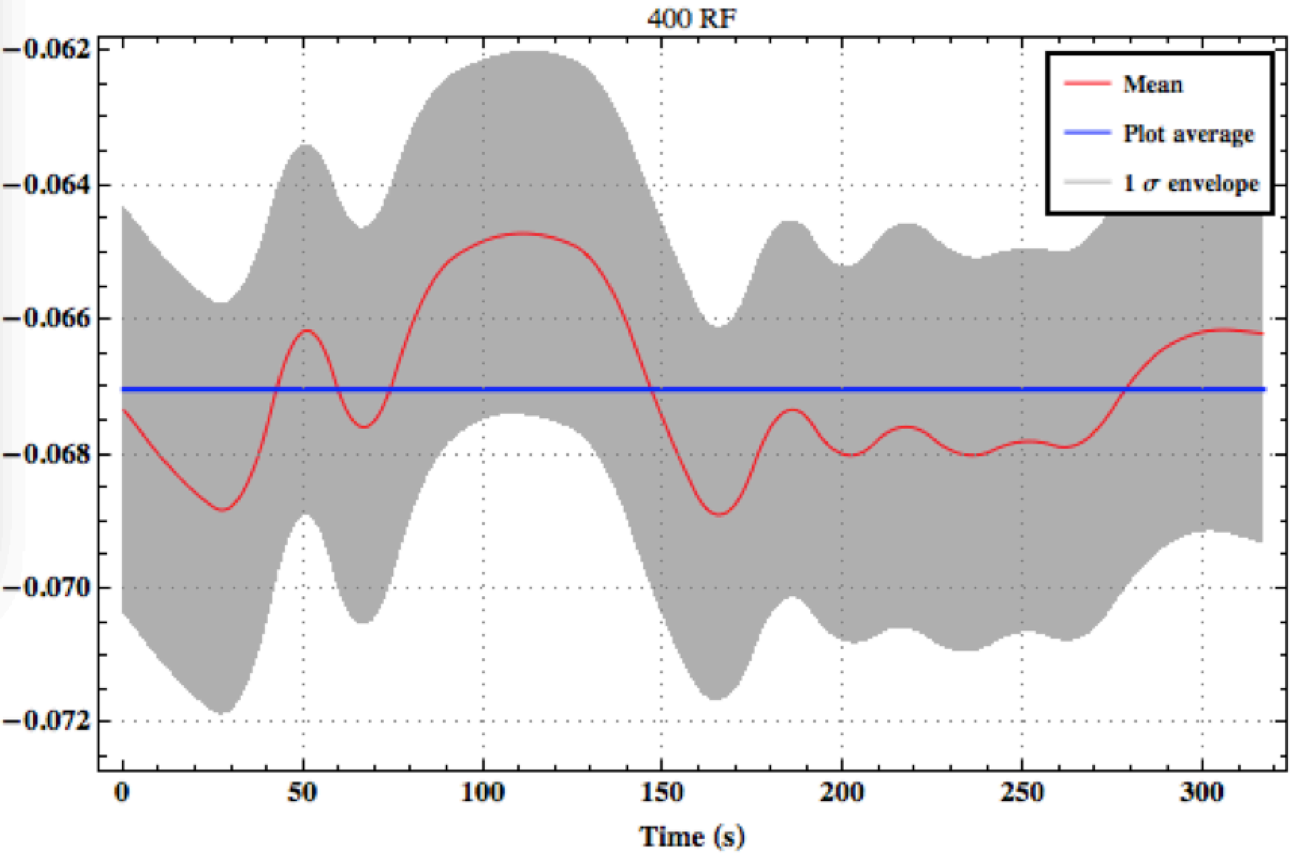

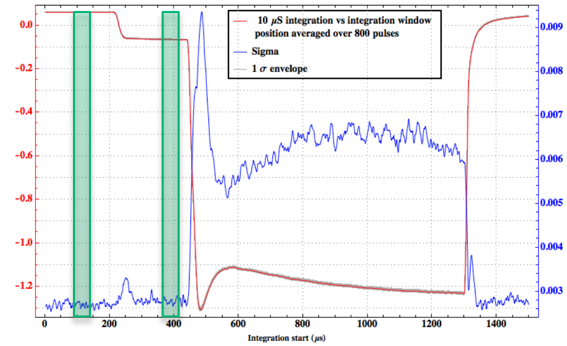

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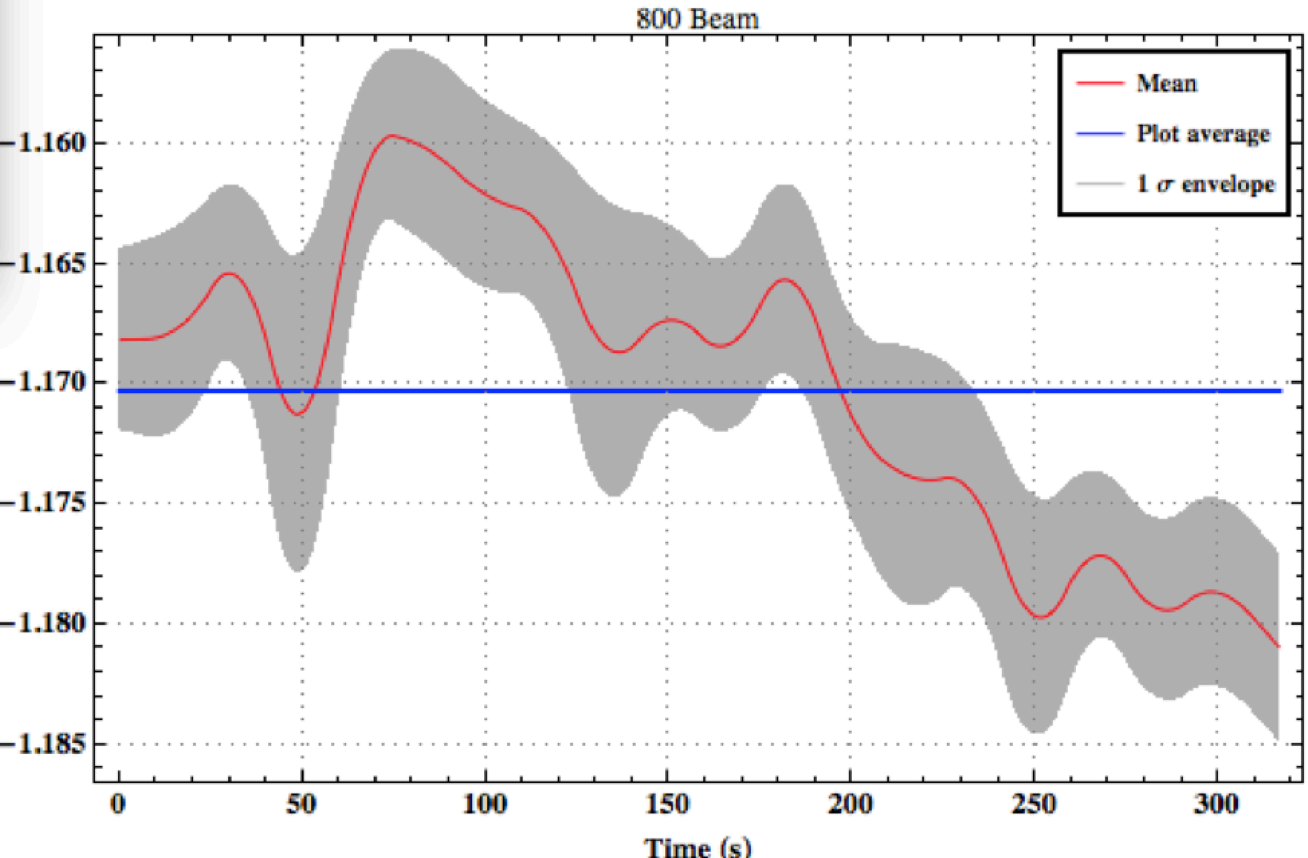

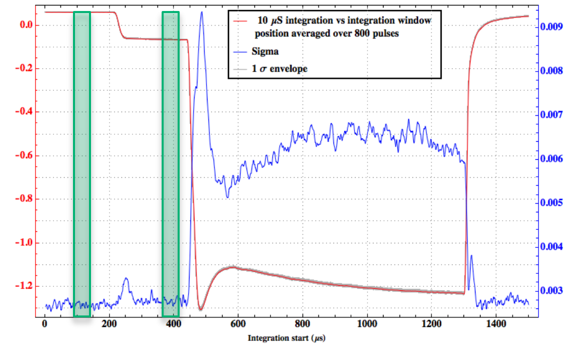

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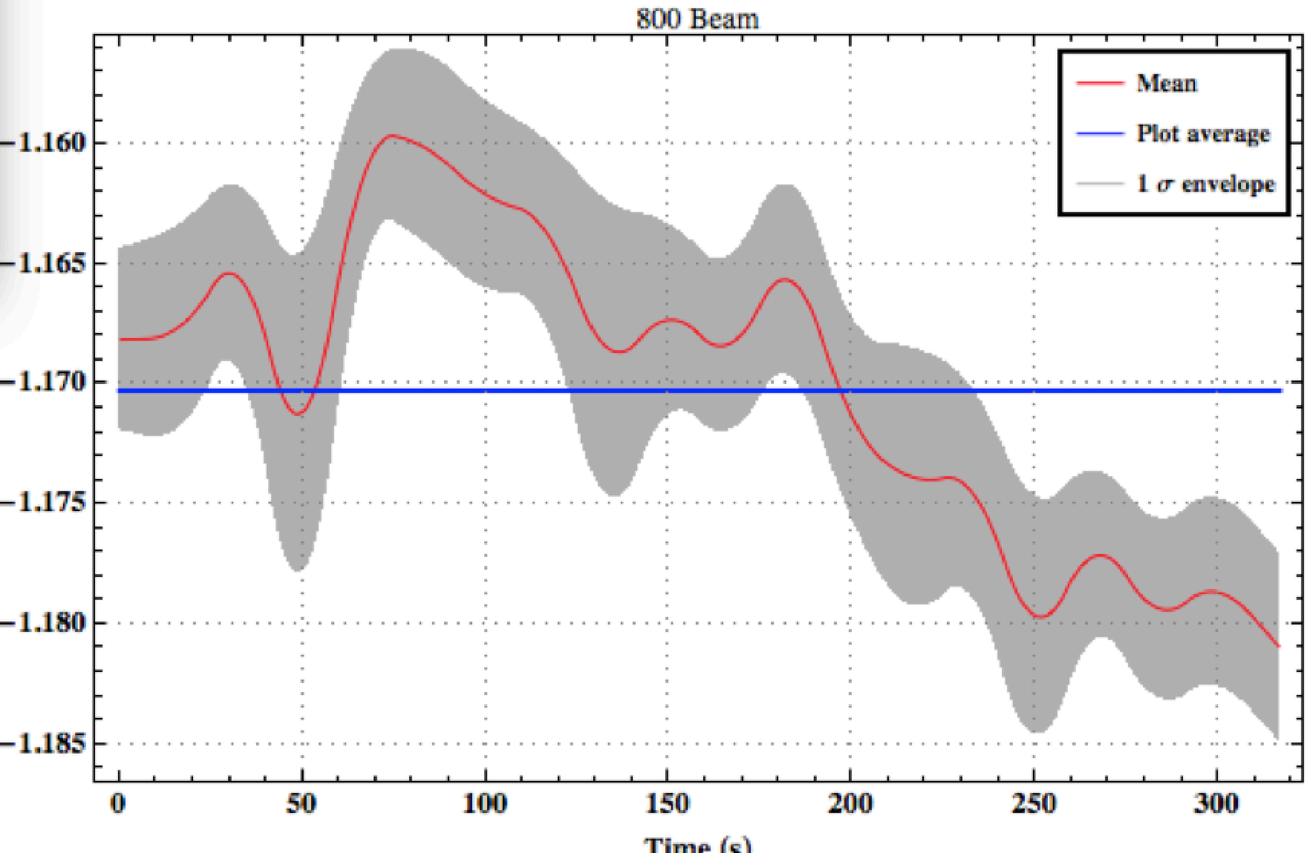

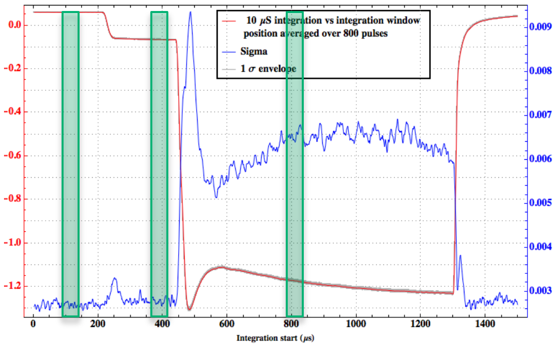

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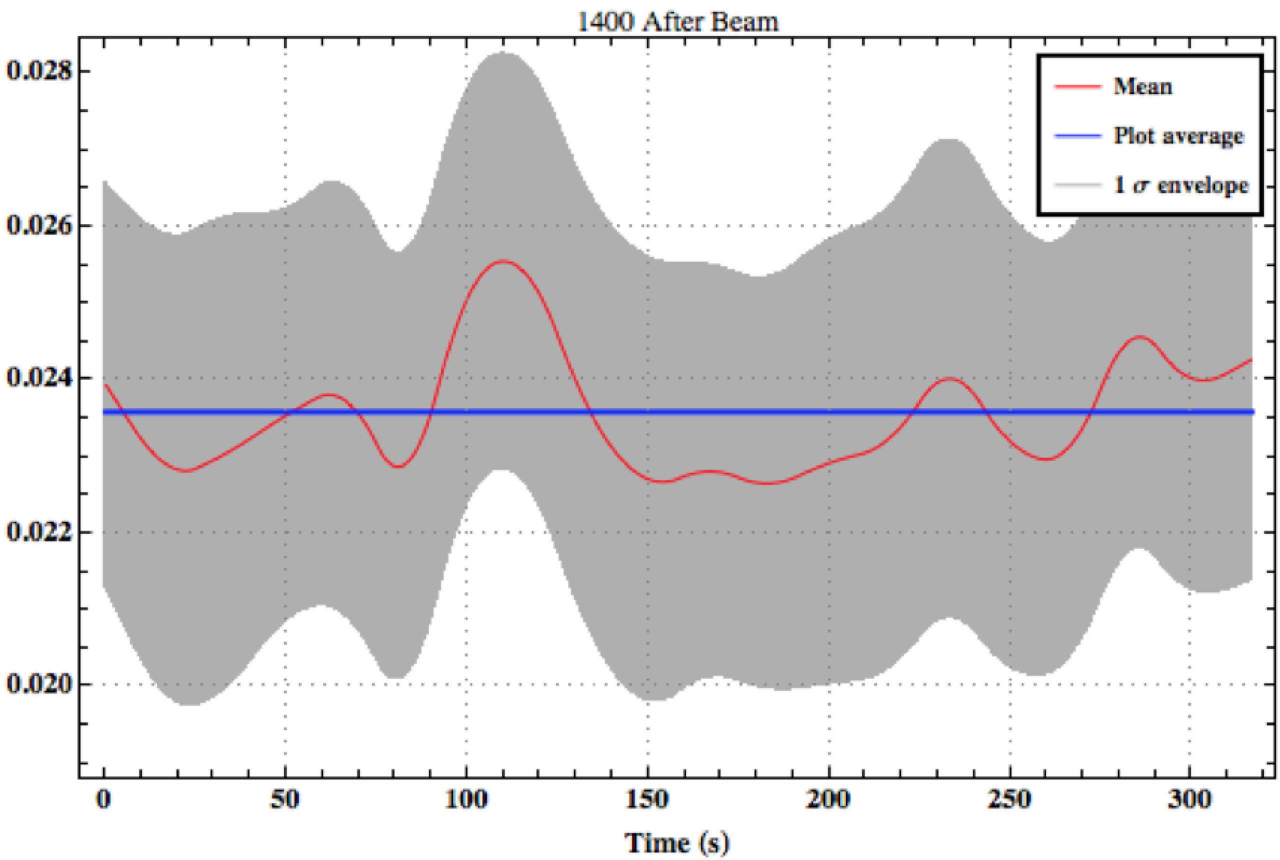

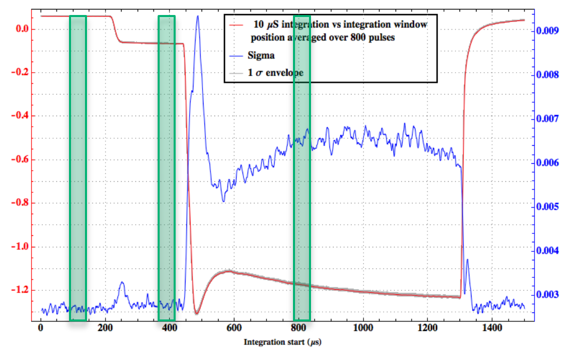

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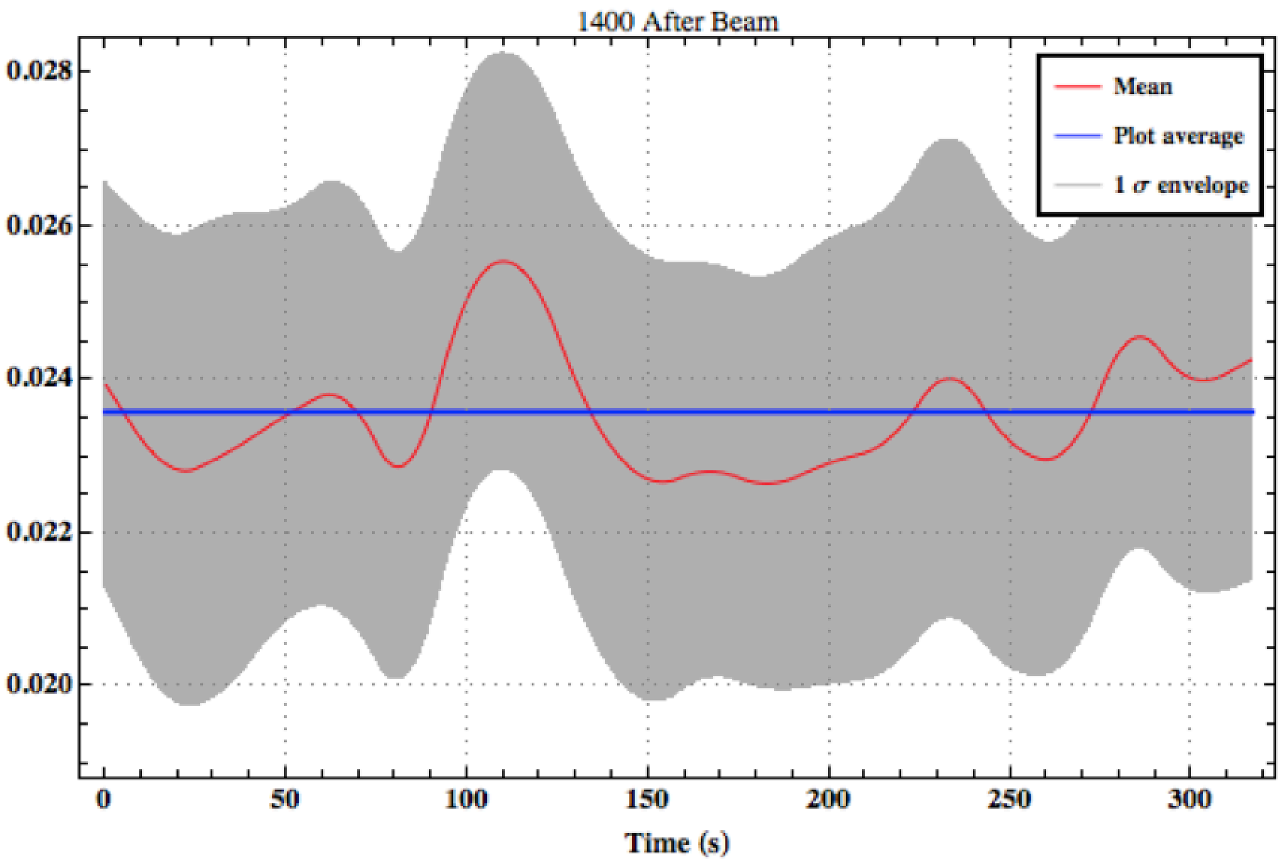

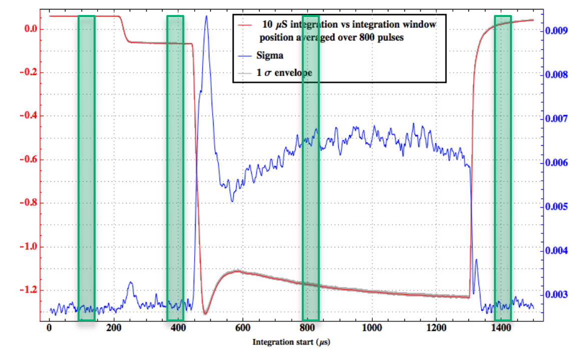

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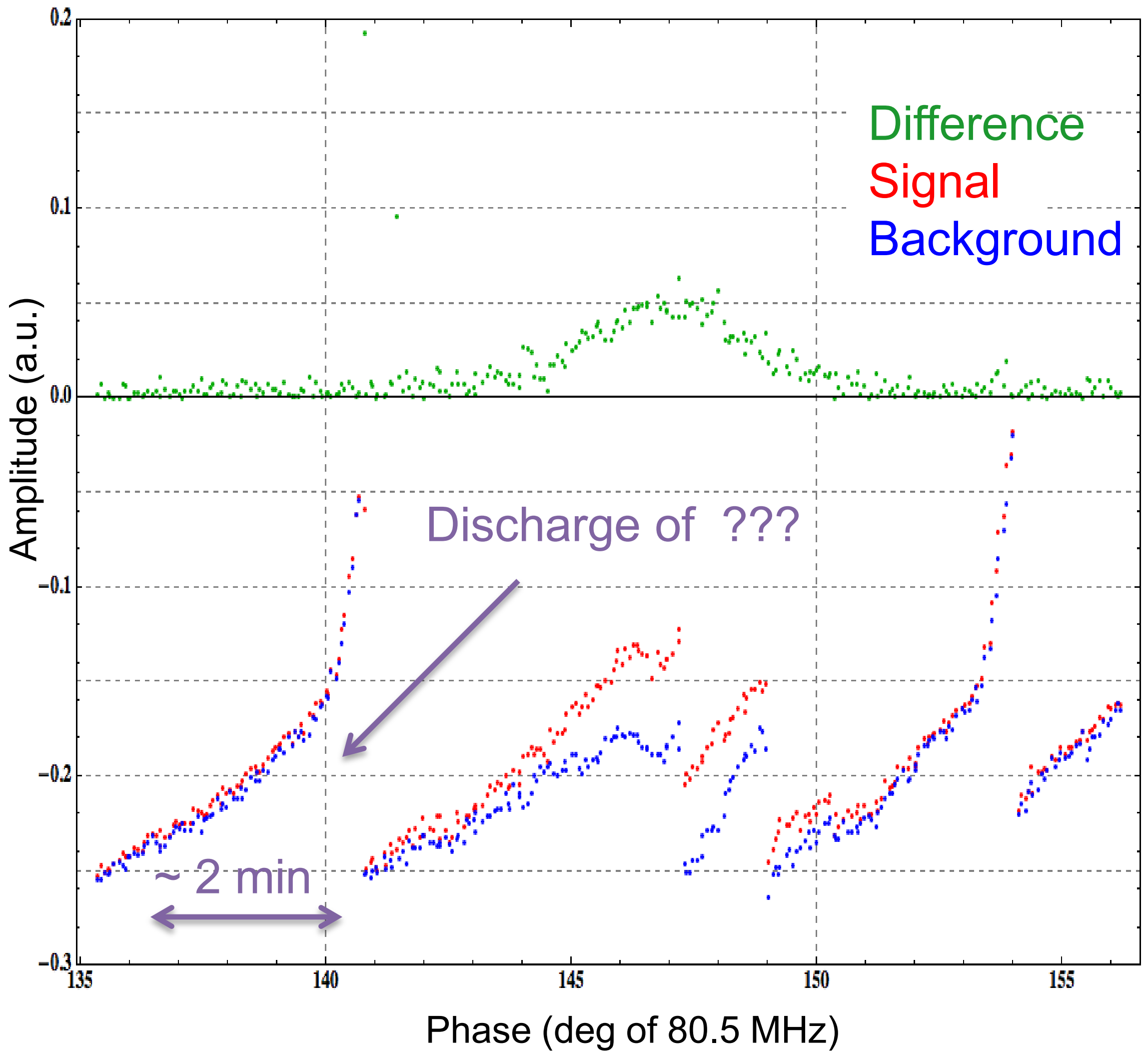
Averaging doesn't work for 50uS pulse



Background conditions change at short pulse and low repetition rate

No slow drift anymore

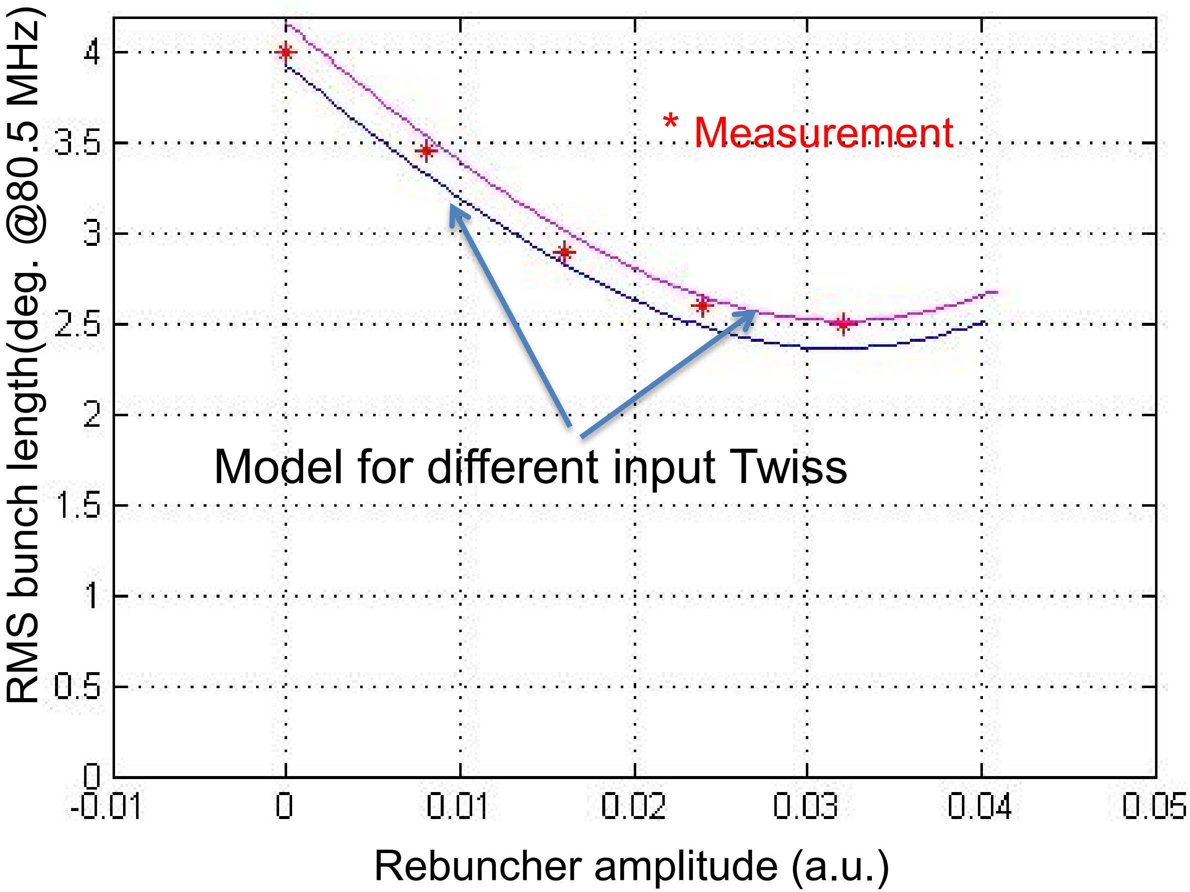
Unknown origin of "jumps"

Looks like some sort of slow charging/fast discharging behavior

Limits measurements of low current beams ~ 7mA

Impossible to measure no space charge beams

Sanity check – “quadrupole” scanning



Qudrupole focusing

Plot transverse size vs. quadrupole strength.

Fit with parabola

Calculate transverse emittance.

RF focusing

Plot longitudinal size vs. rebuncher amplitude

Fit with parabola

Space charge

Calculate longitudinal emittance

Conclusions

- The LBSM is operational
- We can reliably measure production beam at 60 Hz with accuracy of at least 0.5° (or even better with averaging)
- Background during production full beam is no issue.
- The measured bunch size is ~10°, but design size is ~15°. It is hard to come up with a measurement imperfectness that shrinks the bunch.
- Background during accelerator studies with 50uS beam are affected by fast evolving background that prevents us to measure low current beams.
- We will continue exploring our options to reject background:
  - Will try faster detector to detect 80.5MHz
  - Will try optimizing magnet field to improve signal/background ratio
  - Will try to find the source fast changing background