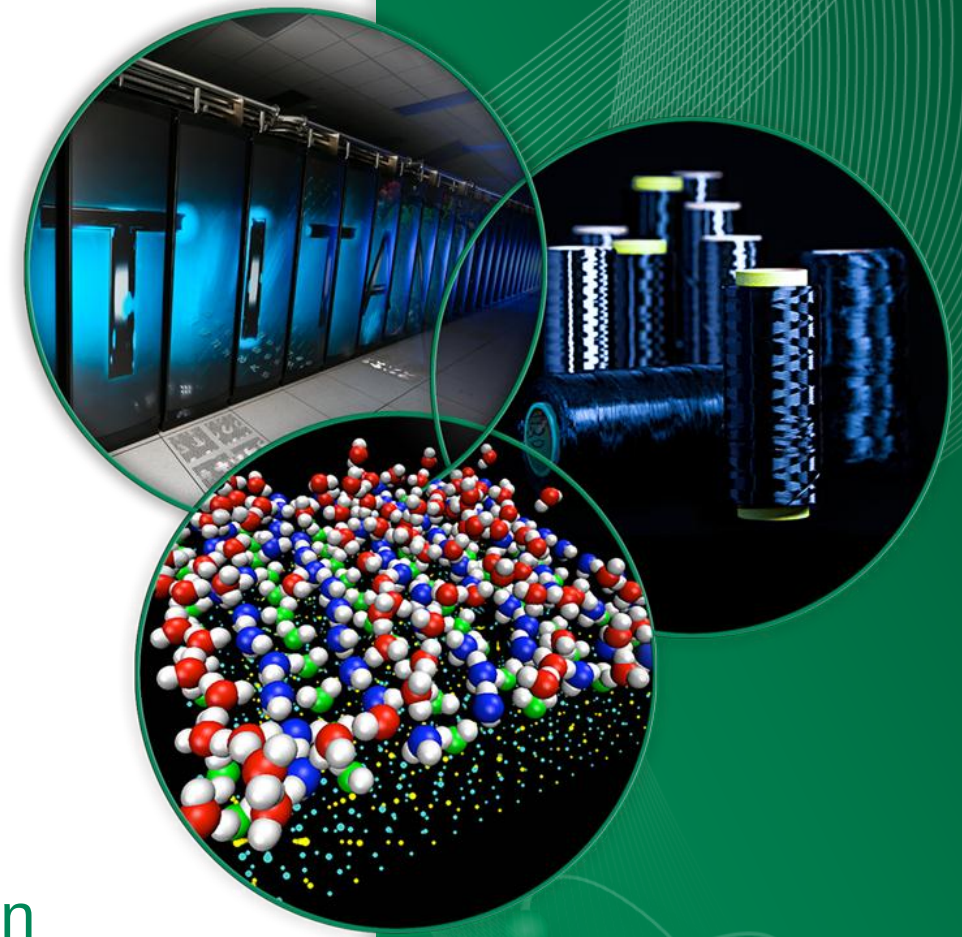
Laser Wire Based Parallel Profile Scan of H^- Beam at SNS



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Research Accelerator Division
Spallation Neutron Source
Oak Ridge National Laboratory

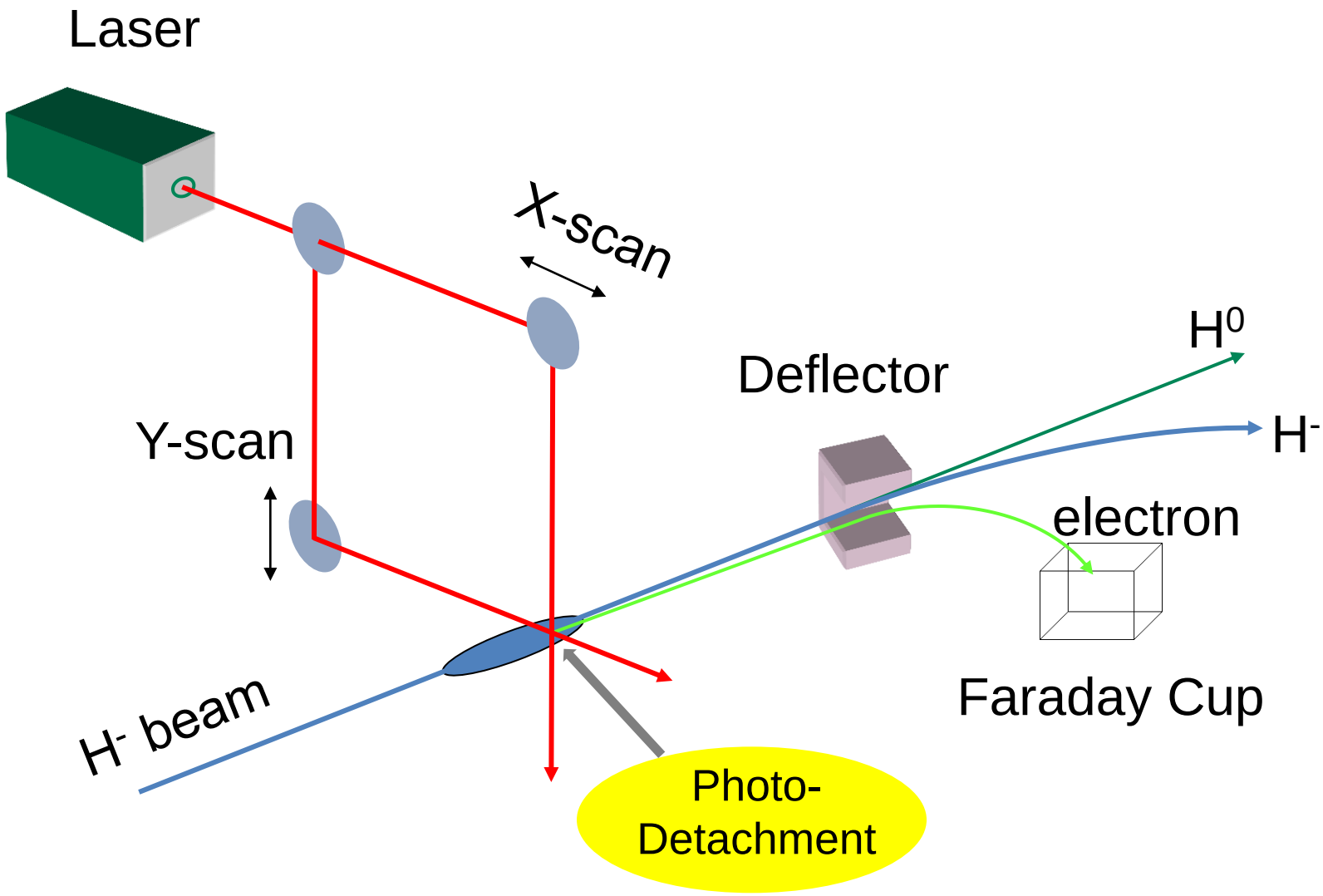
OUTLINE

- Motivation
- Principle of laser wire measurement
- System modifications for simultaneous profile scan
- 9-station simultaneous profile measurement results
- Commissioning experience on laser based diagnostics
- Conclusion

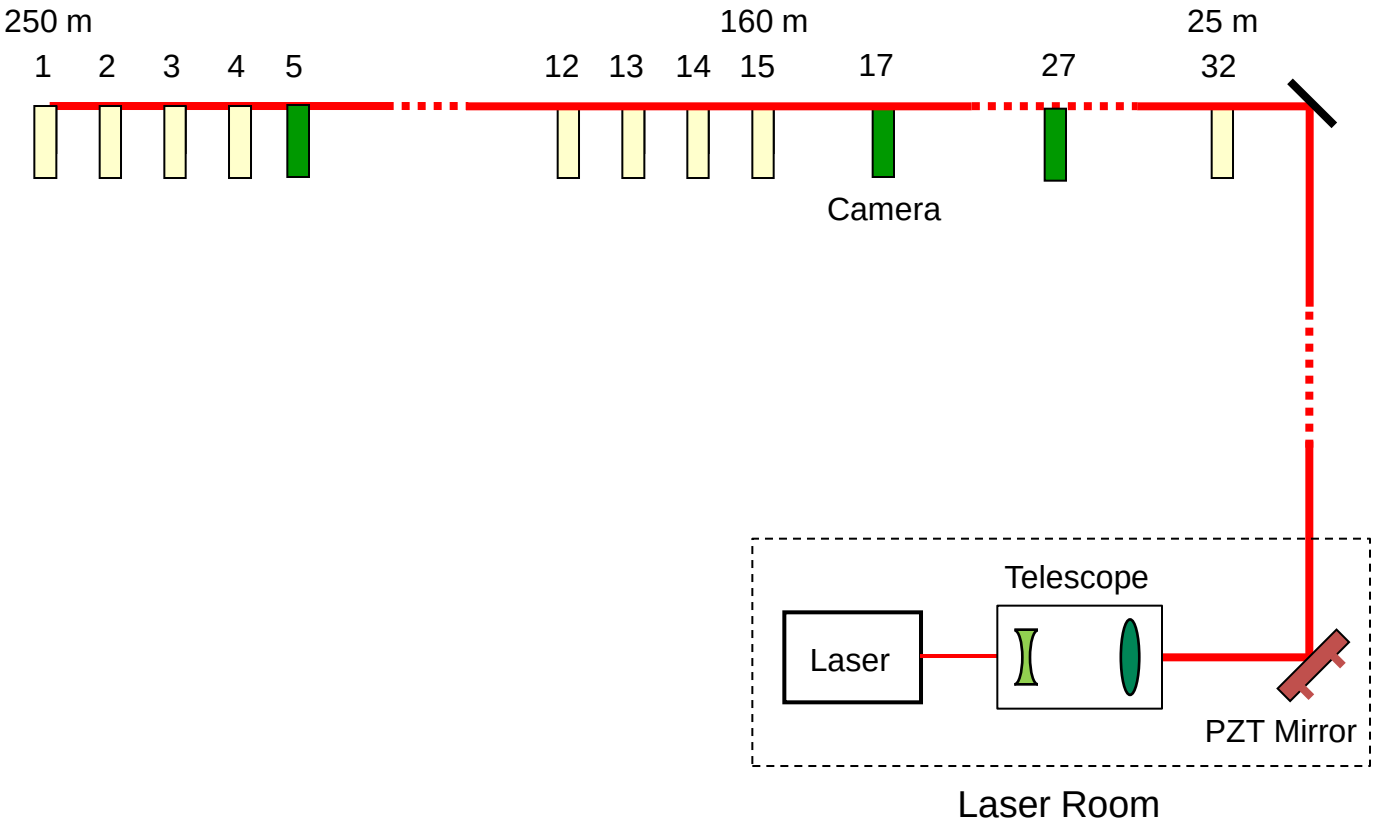
Motivation

- Advantages of laser wire profile/emittance monitor:
  - Measurement is non-intrusive and can be conducted on neutron production beam.
  - No moving parts in vacuum and therefore no risk to superconducting cavity.
  - Novel capability: measurement of profile/emittance of individual minipulses.
- Previously laser wire profile measurements have only been performed serially since a single light source is used.
- On the other hand, physics study such as the SCL modeling at SNS requires the measurement of H- beam profiles at different locations along the acceleration path and on different accelerator settings.
- A simultaneous profile measurement would be especially helpful to improve the efficiency and accuracy of the physics studies.

Principle of Laser Wire Measurement



SCL Laser Wire Profile Measurement System



Liu et al, *NIMA* **612** (2010) 241–253;

Appl. Opt. **49** (2011) 6816-6823.

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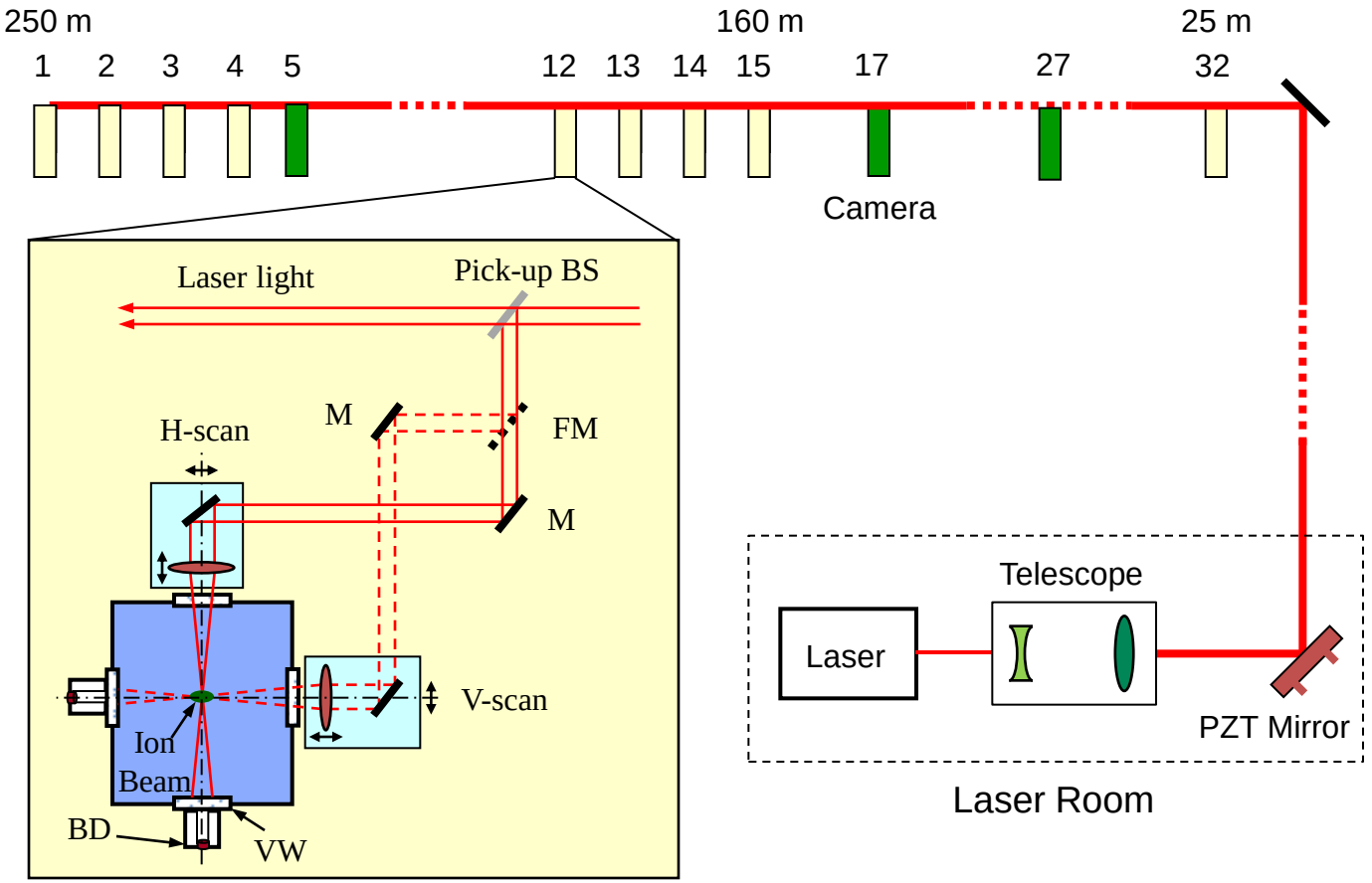

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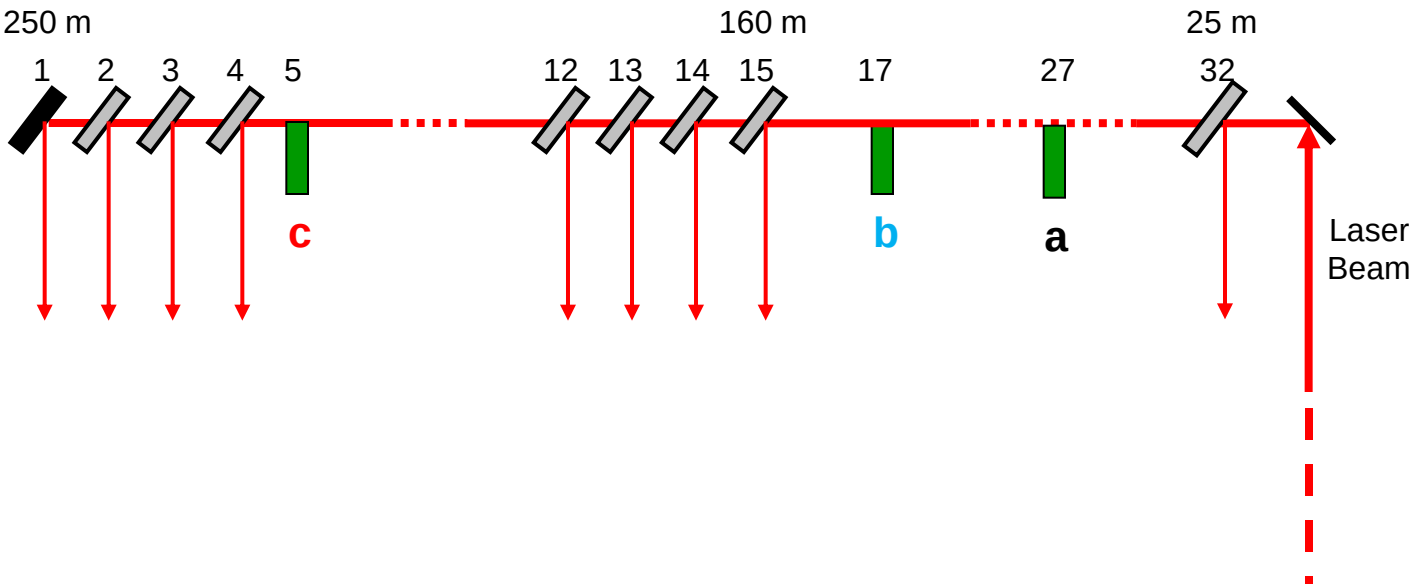
Laser Transport Line



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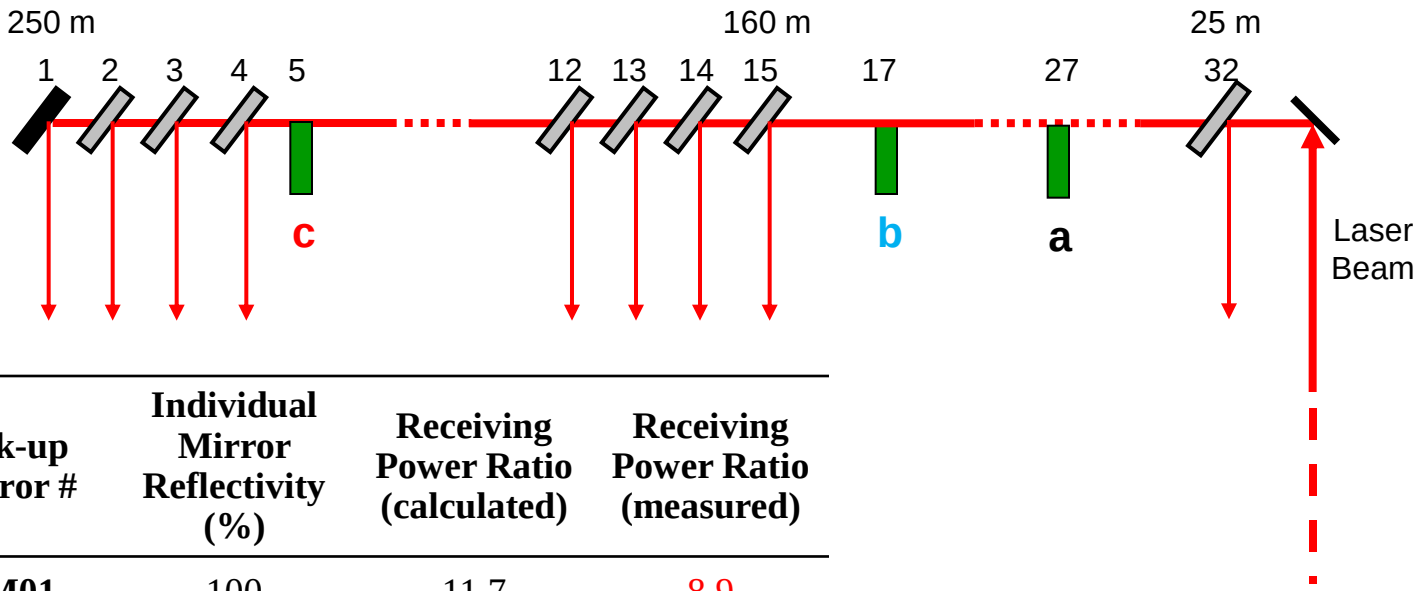
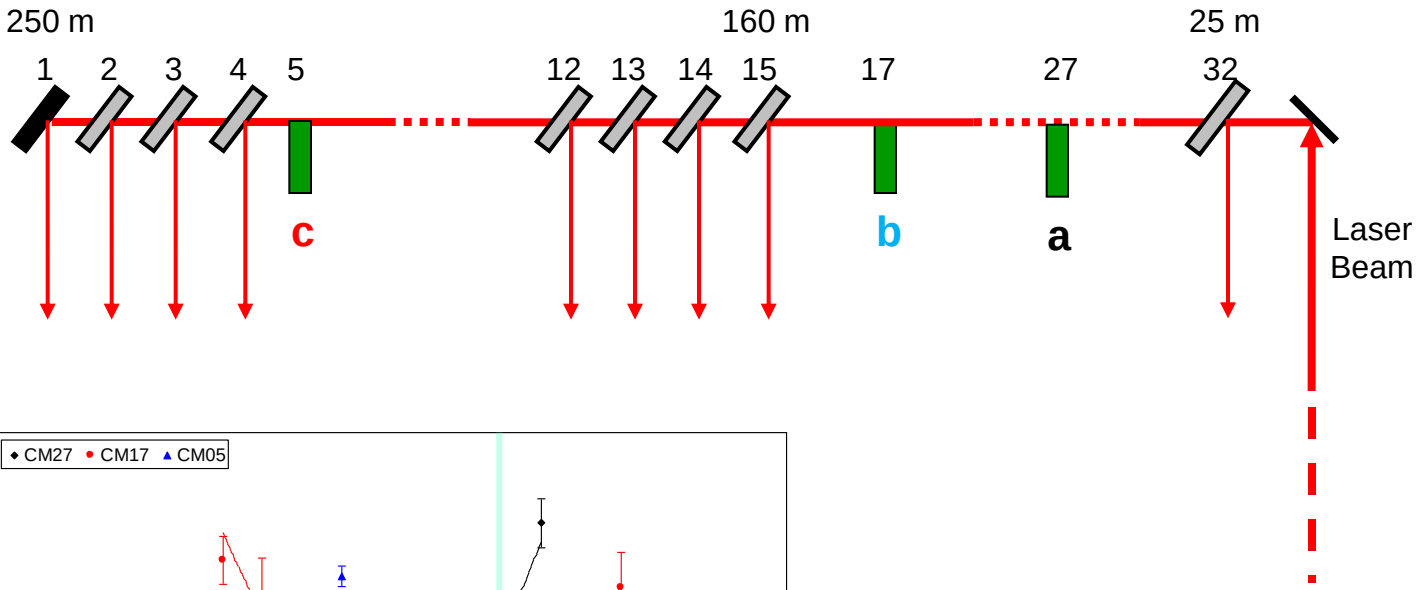
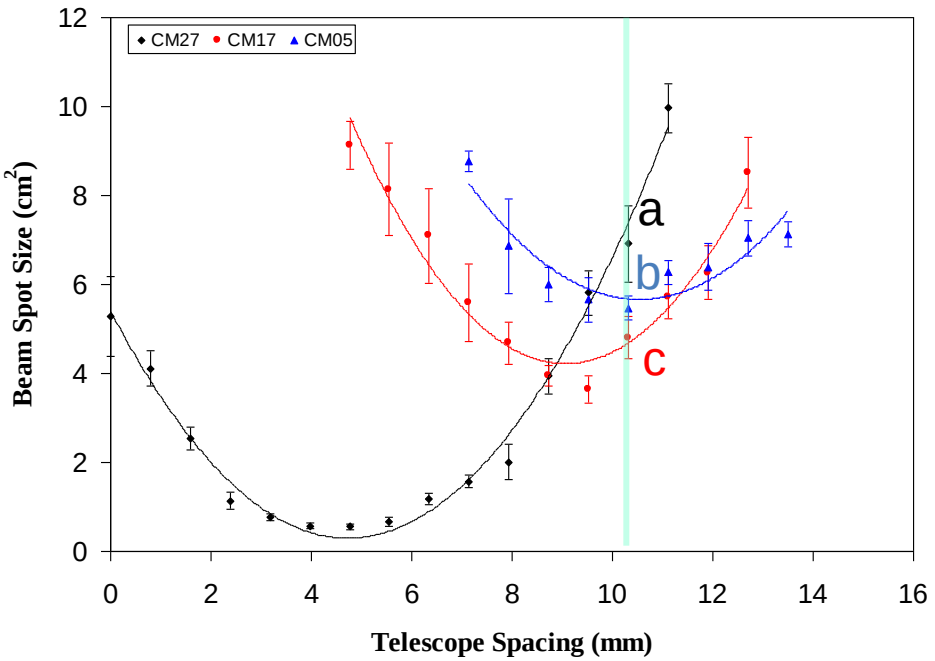


Pick-up Mirror #	Individual Mirror Reflectivity (%)	Receiving Power Ratio (calculated)	Receiving Power Ratio (measured)
CM01	100	11.7	8.9
CM02	50	11.7	11.4
CM03	33	11.7	9.3
CM04	25	11.7	11.6
CM12	20	11.7	12.7
CM13	20	14.6	13.8
CM14	10	8.1	10.2
CM15	10	9.0	8.7
CM32	10	10.0	8.2

Laser Transport Line





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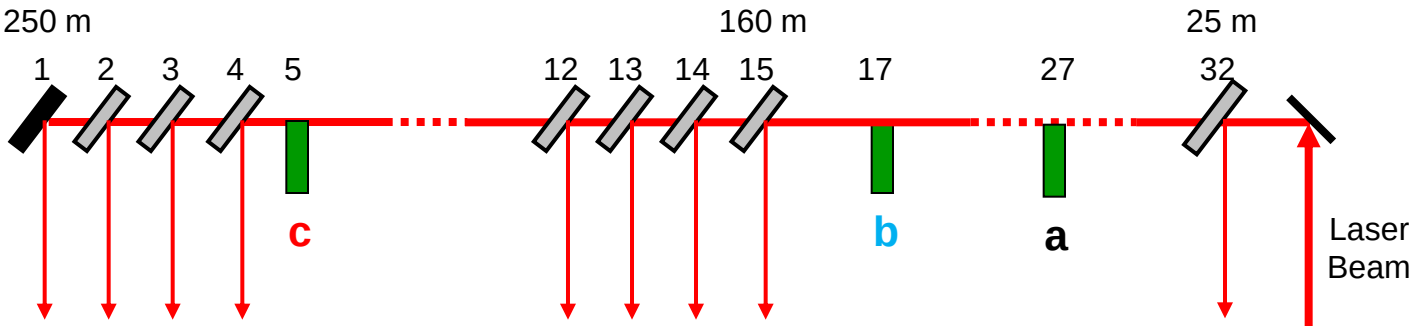
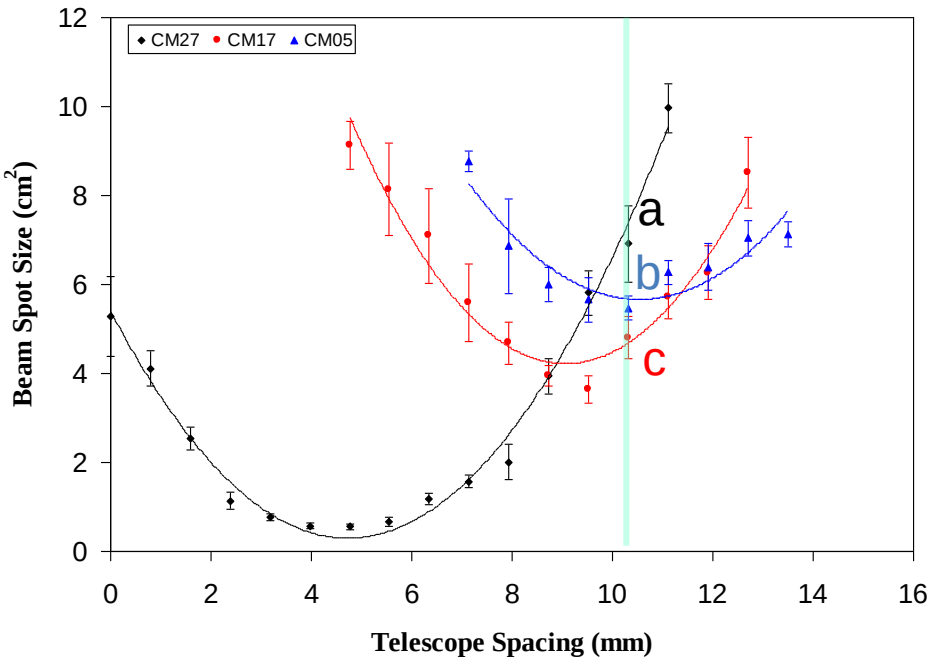
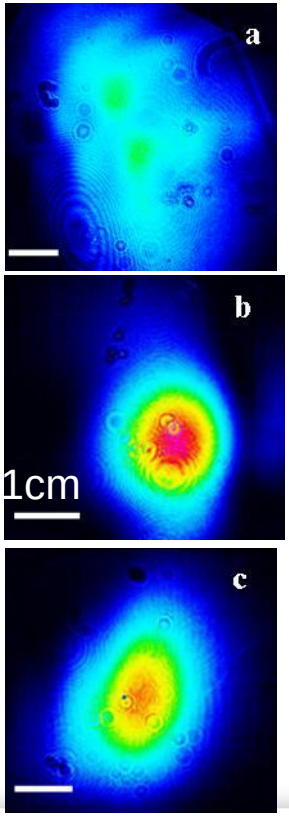
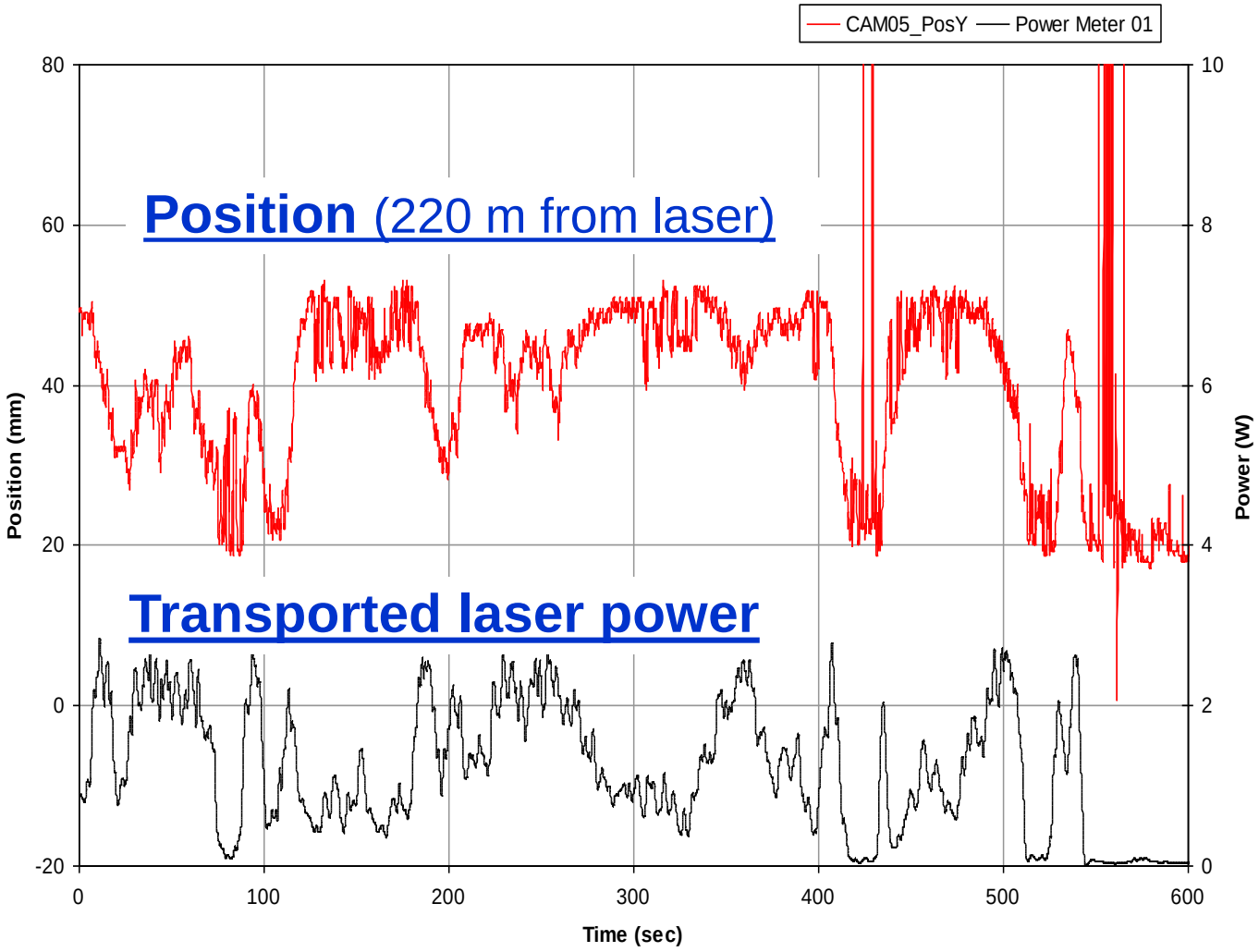






Laser Beam Pointing Stabilization



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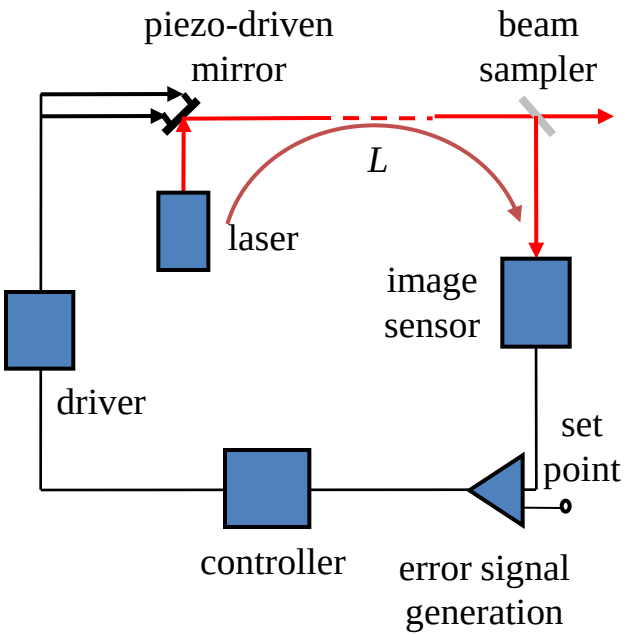
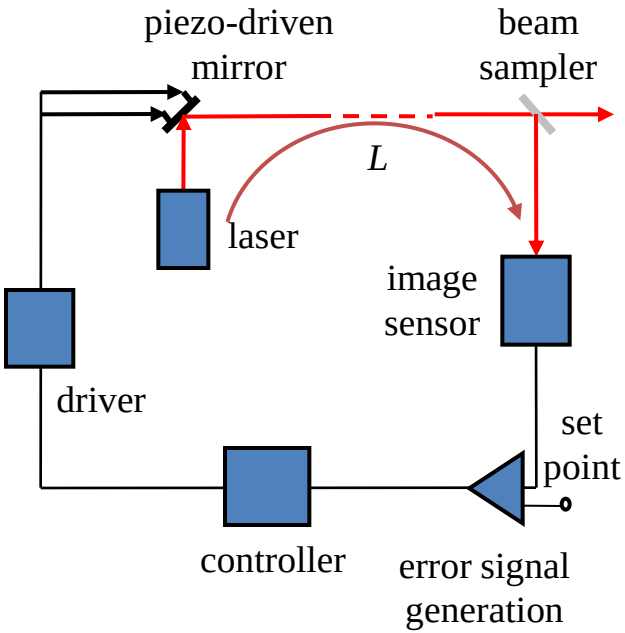
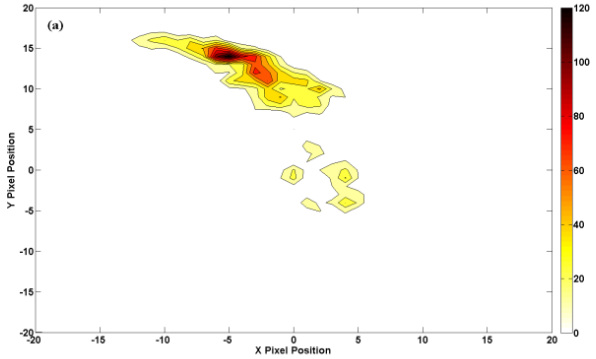


Laser Beam Pointing Stabilization



Feedback off



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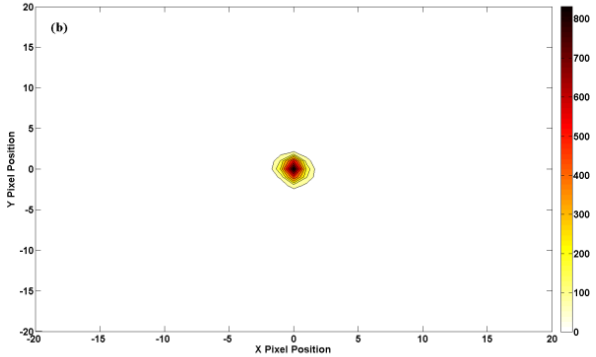
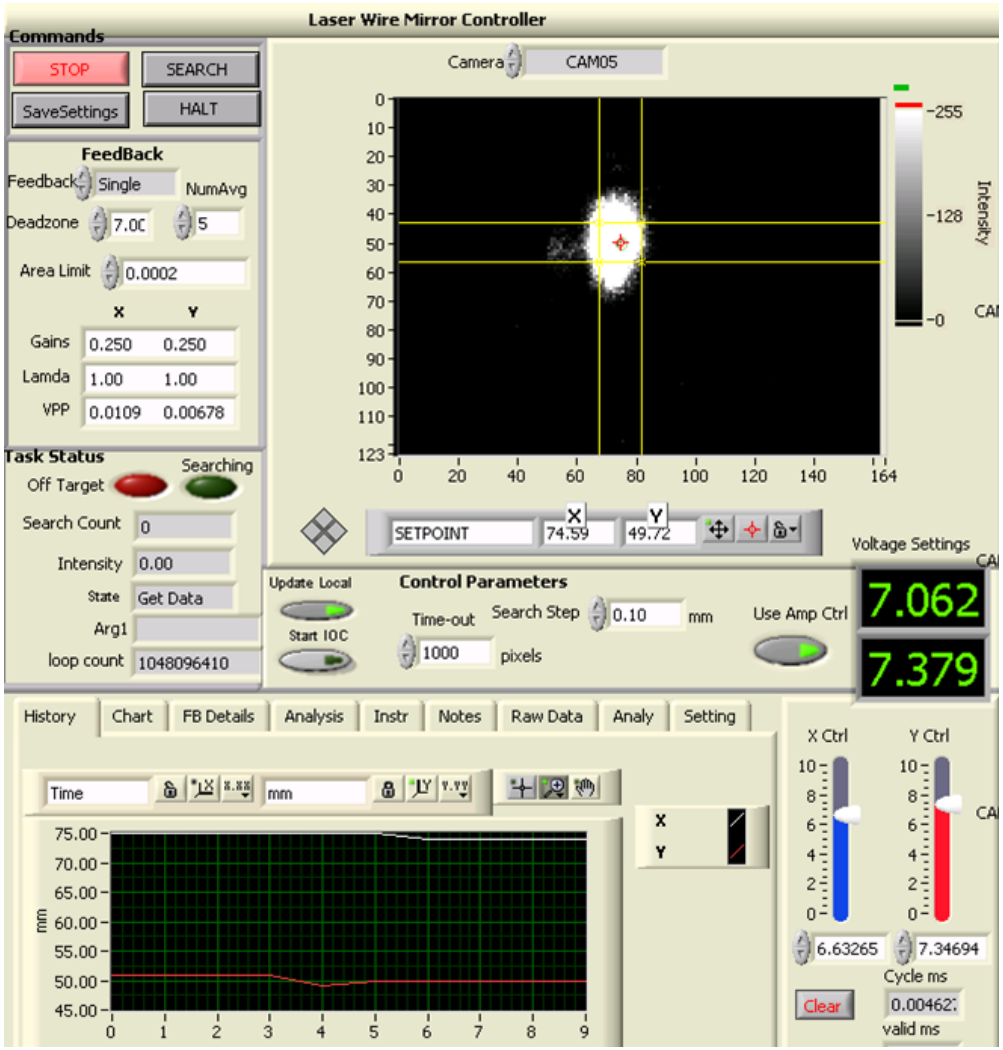


±1.25 mm @ 250 m

Hardin et al, *Opt. Express* **19** (2011) 2874-2885.

Laser Beam Pointing Stabilization



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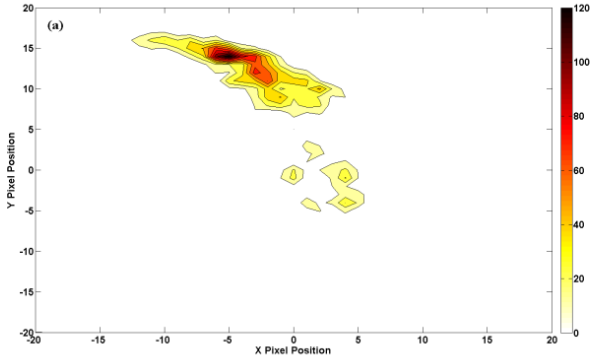
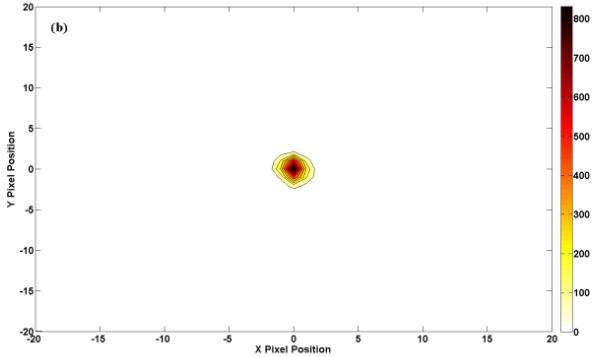


Feedback on



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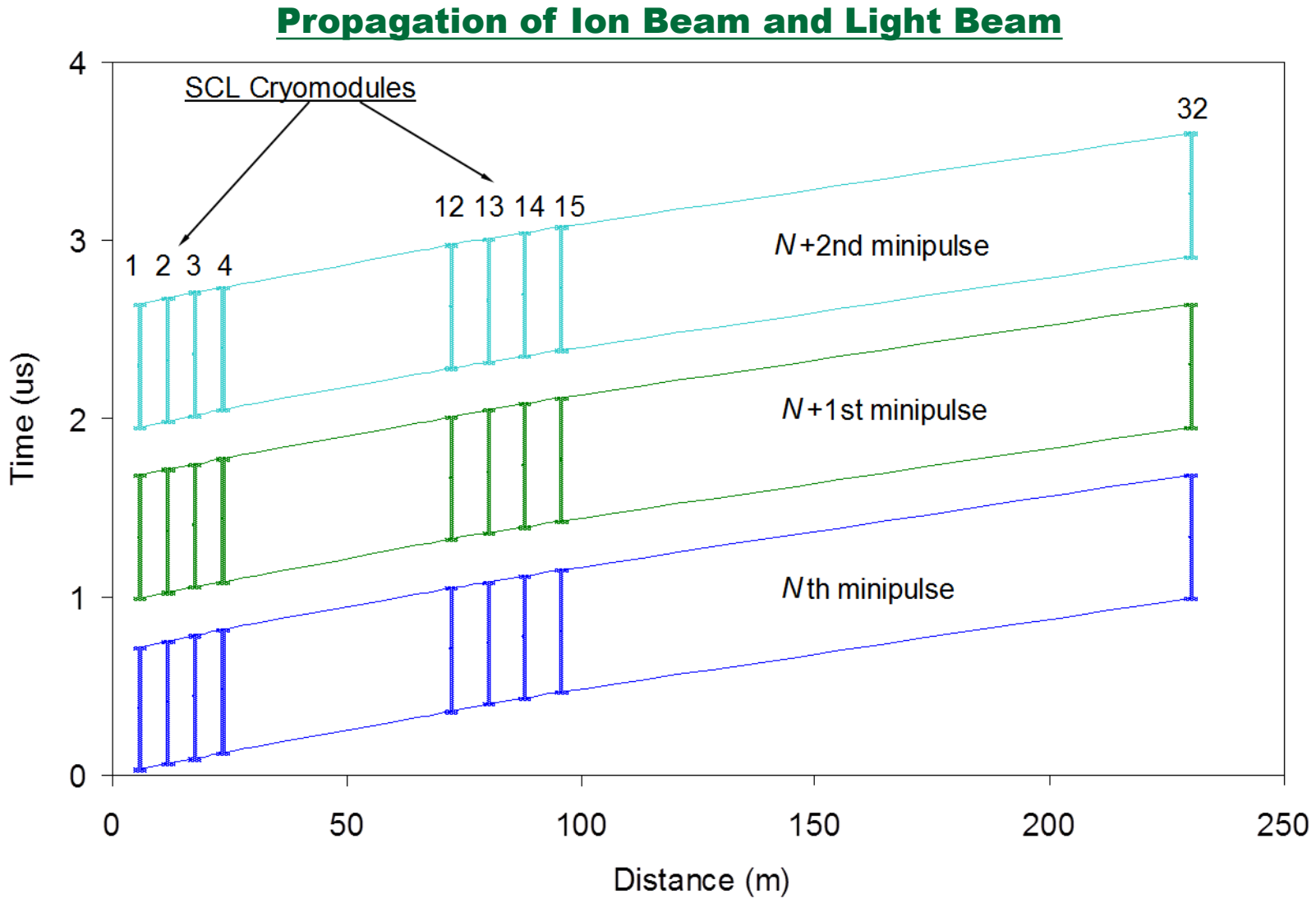
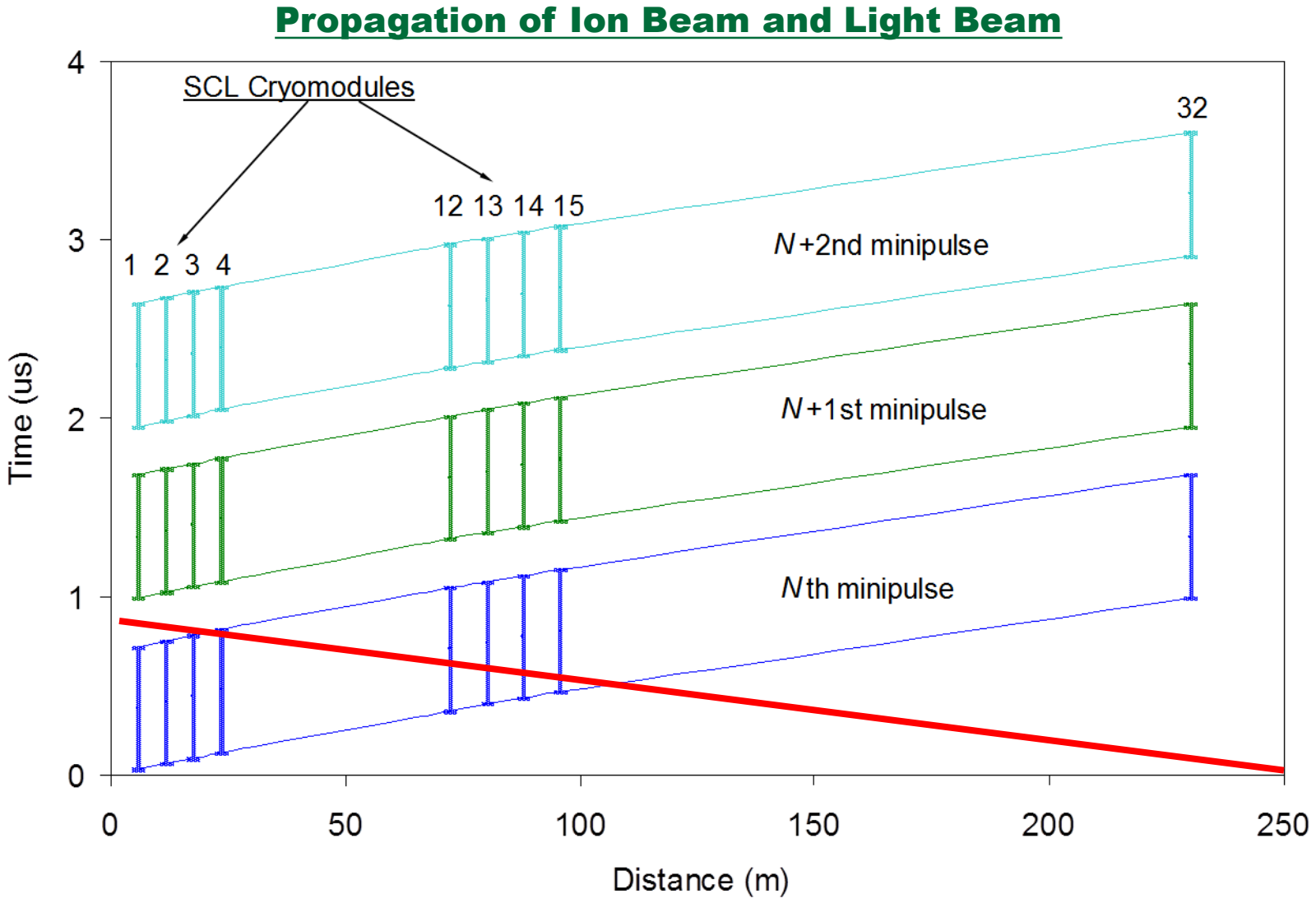
Phase Tuning between Laser and H- Pulses



Phase Tuning between Laser and H- Pulses



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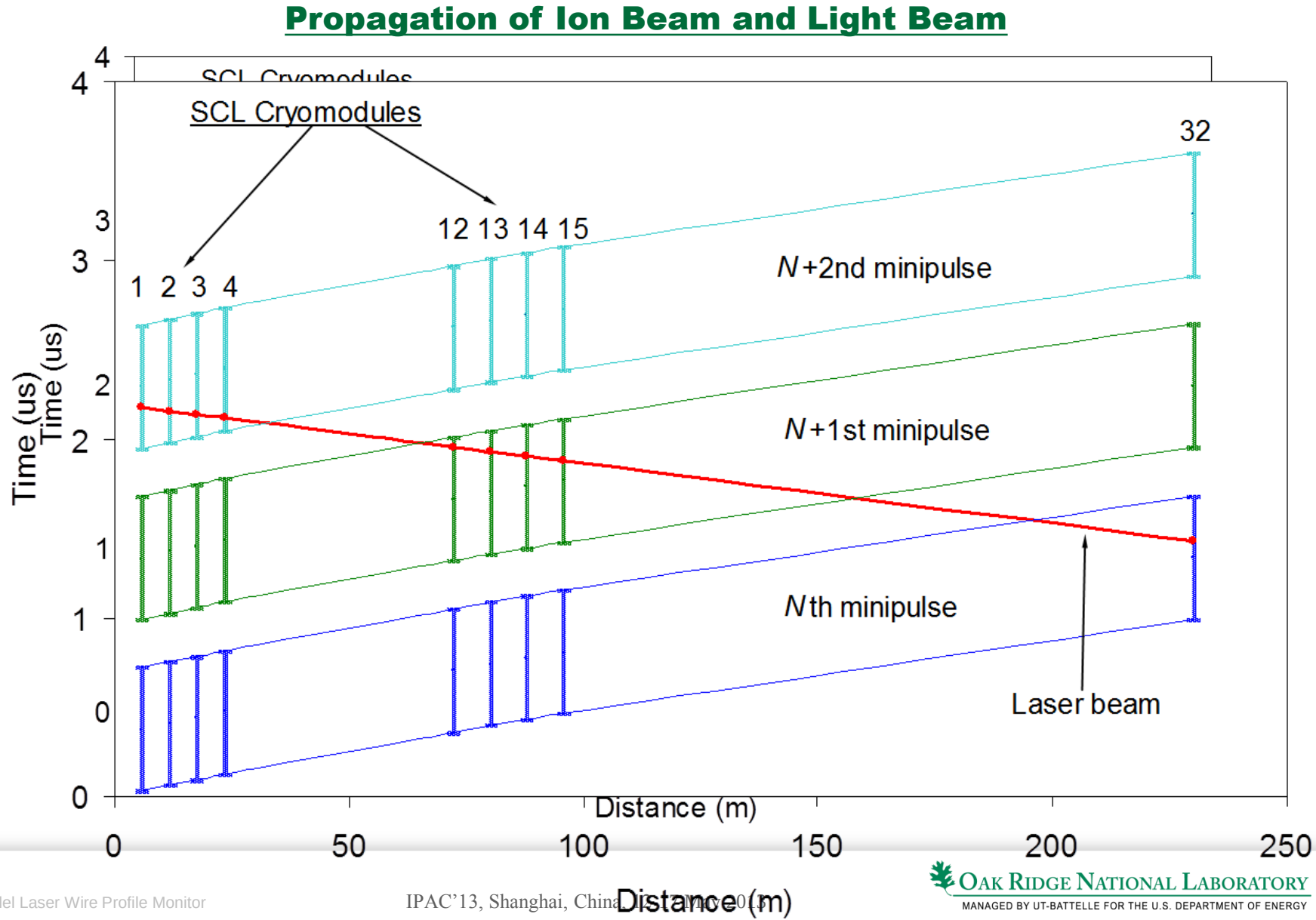
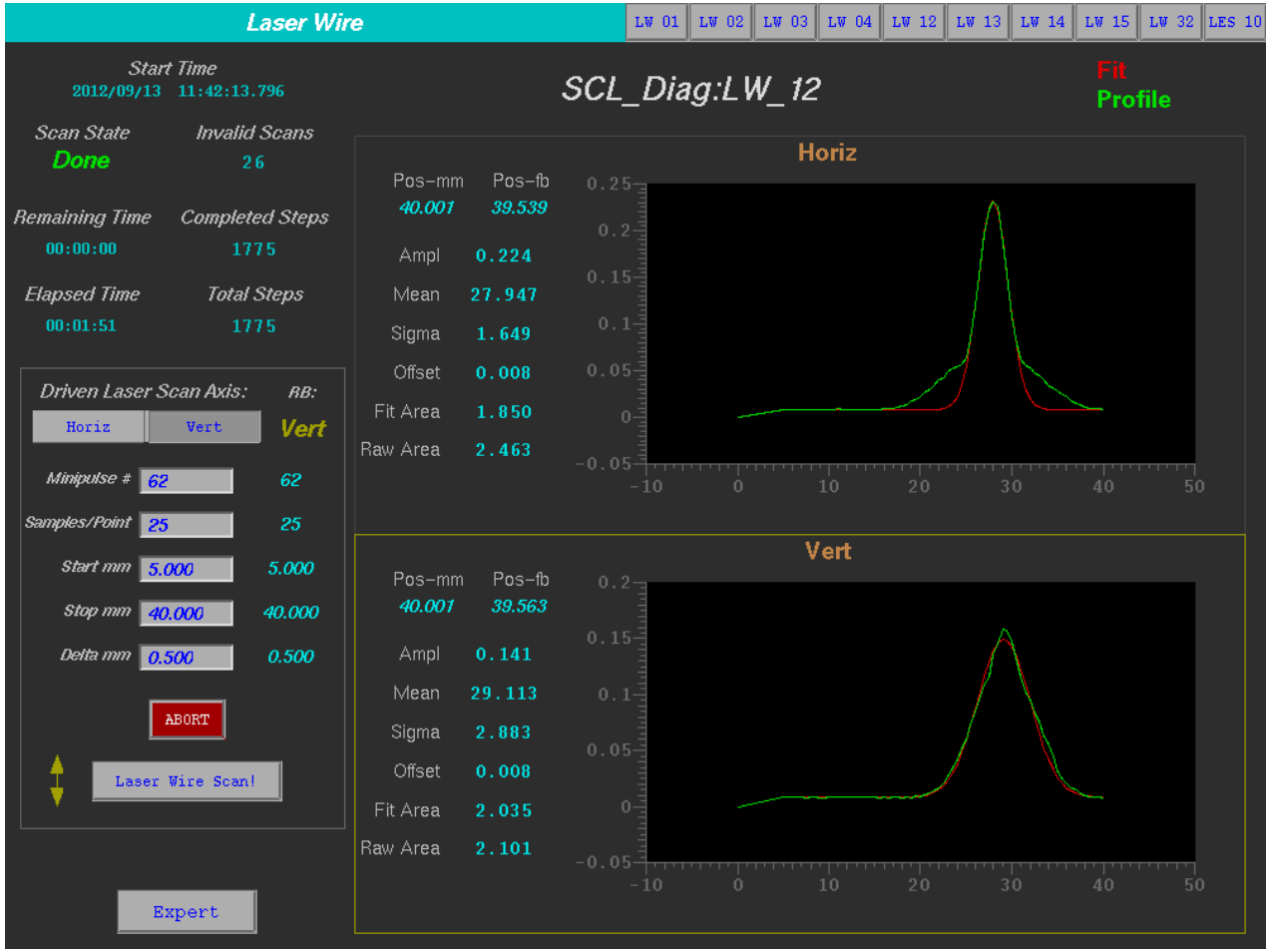


EDM Screens for Laser Wire System

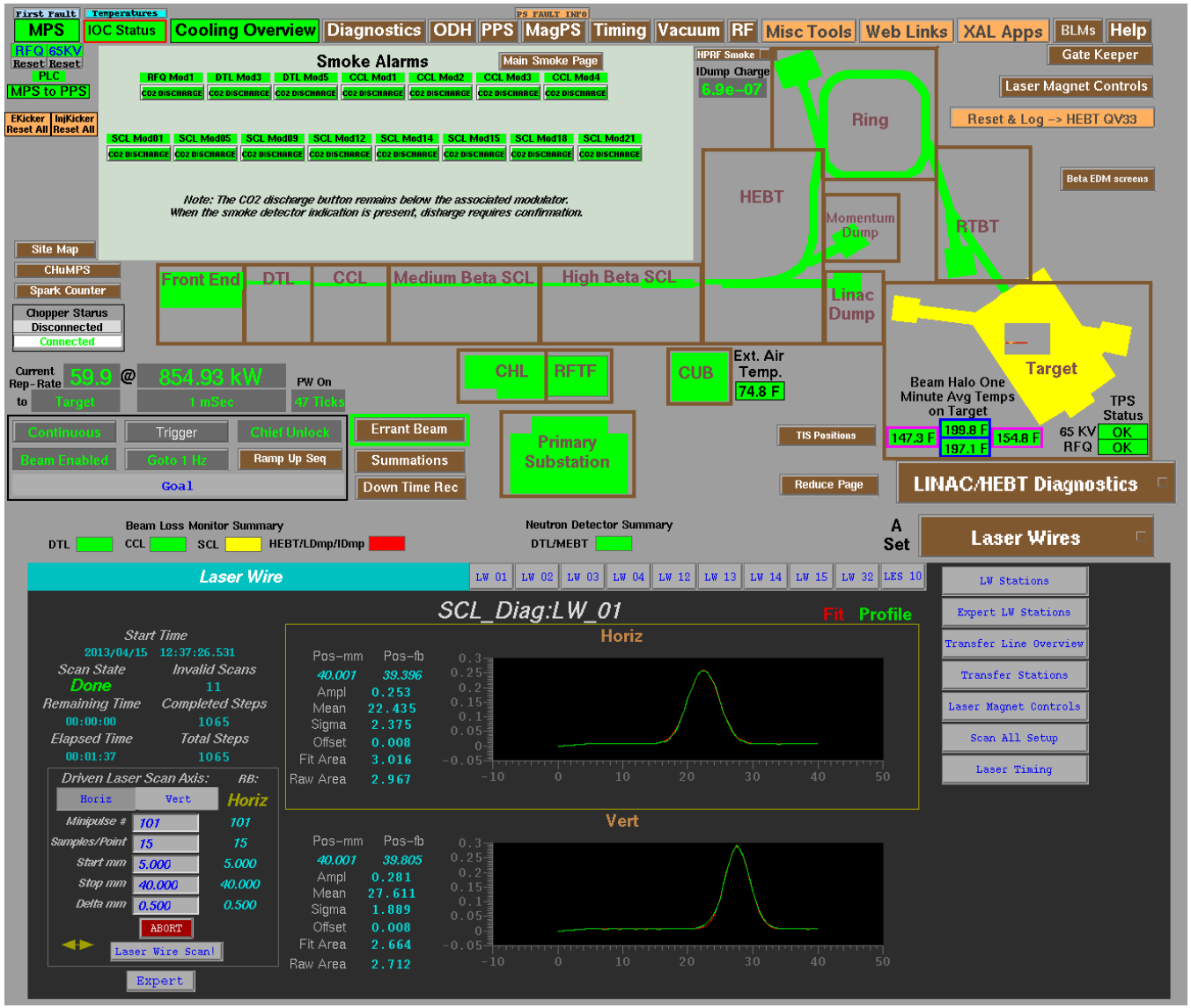
From EPICS, user can select one, multiple, or all scanners

EDM Screens for Laser Wire System



From EPICS, user can select scan range, step size, average number. Fitting is automatically conducted.

Simultaneous Profile Scan



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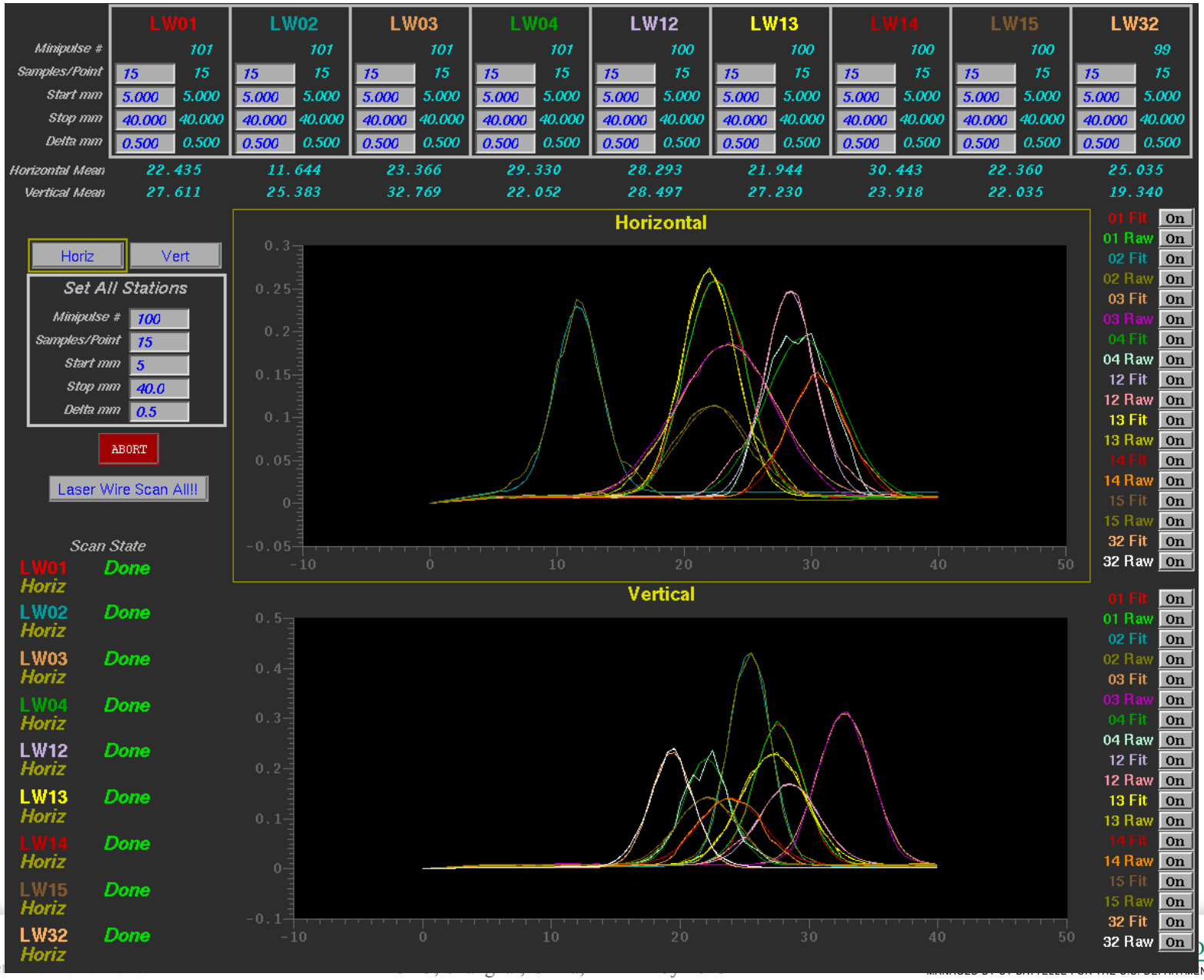
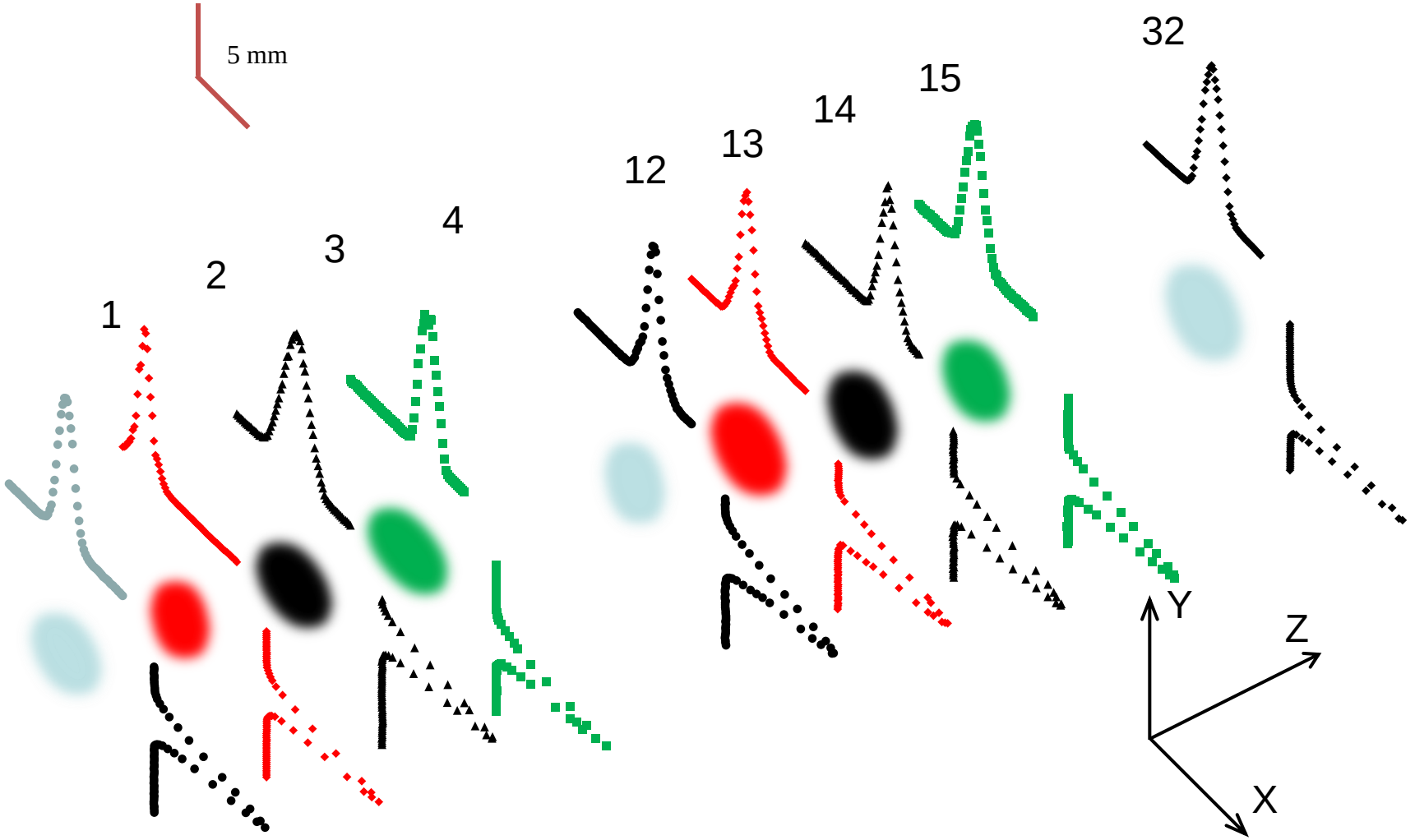


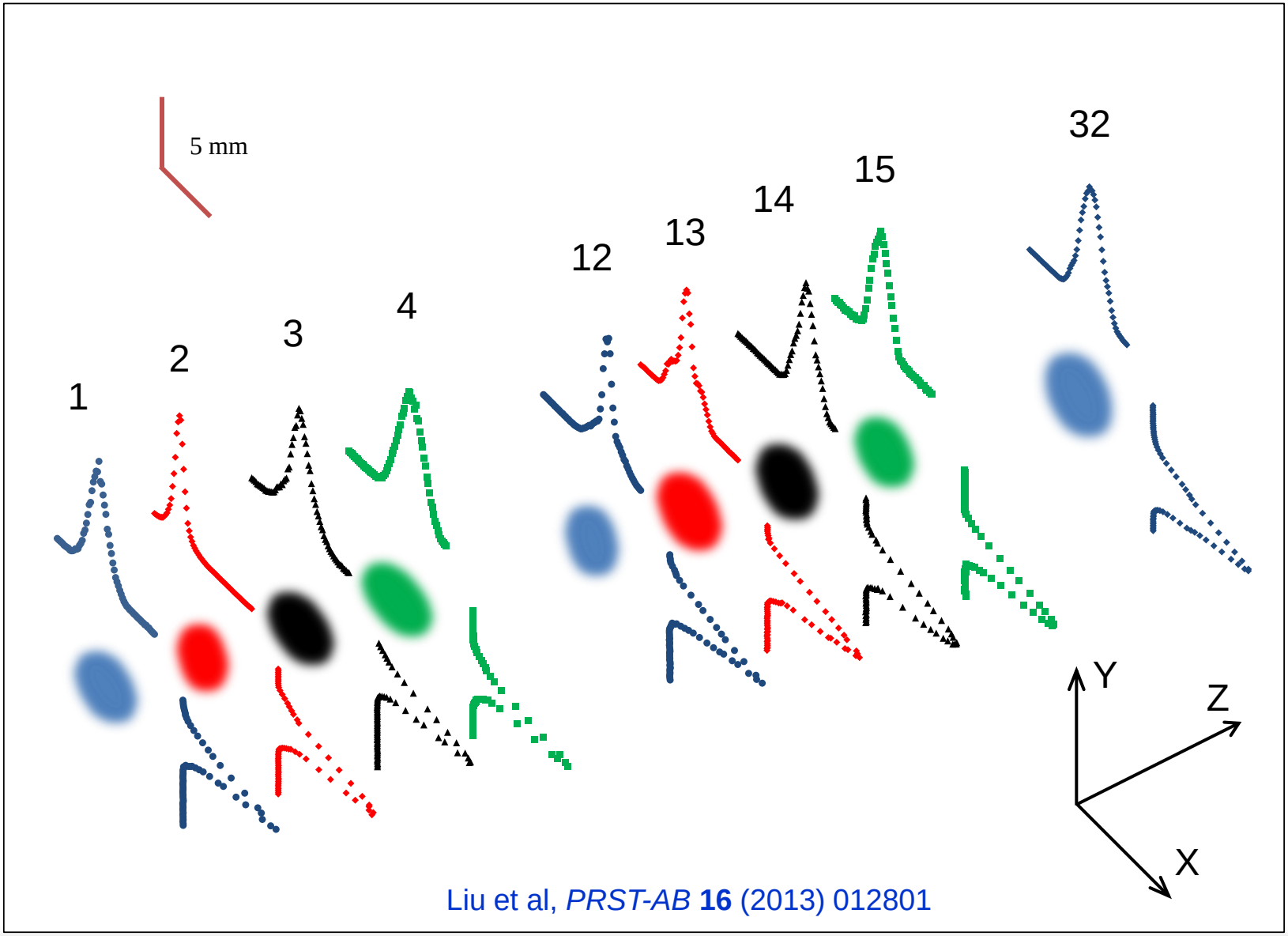
Estimated Beam Parameters (April 15, 2013)

Location	Amplitude (mV)	Beam Center (mm)	Beam Size (mm)	Offset (mV)	R^2
1H	**257±3**	**22.460±0.019**	**2.317±0.024**	**7.3±0.2**	**0.999**
1V	**274±3**	**27.62±0.016**	**1.966±0.018**	**7.6±0.02**	**0.999**
2H	**171±5**	**11.632±0.027**	**2.445±0.032**	**5.0±0.1**	**0.95**
2V	**404±5**	**25.316±0.010**	**1.717±0.014**	**5.8±0.1**	**0.996**
3H	**180±2**	**23.152±0.031**	**3.790±0.032**	**7.9±0.3**	**0.997**
3V	**316±4**	**32.776±0.017**	**1.991±0.023**	**8.7±0.2**	**0.997**
4H	**213±4**	**28.920±0.026**	**2.298±0.034**	**7.4±0.2**	**0.983**
4V	**205±5**	**22.020±0.025**	**1.852±0.029**	**8.4±0.2**	**0.988**
12H	**224±2**	**28.232±0.017**	**2.226±0.018**	**8.6±0.2**	**0.989**
12V	**158±2**	**28.412±0.022**	**2.4118±0.022**	**8.0±0.2**	**0.997**
13H	**234±2**	**21.844±0.018**	**2.576±0.020**	**9.5±0.2**	**0.984**
13V	**226±2**	**27.180±0.019**	**2.440±0.021**	**8.4±0.2**	**0.998**
14H	**136±2**	**30.396±0.028**	**2.470±0.030**	**7.3±0.2**	**0.997**
14V	**139±2**	**23.808±0.024**	**2.322±0.027**	**7.0±0.2**	**0.995**
15H	**108±1**	**22.060±0.034**	**2.734±0.033**	**8.2±0.2**	**0.998**
15V	**137±2**	**22.156±0.027**	**2.269±0.027**	**8.5±0.2**	**0.999**
32H	**135±1**	**25.020±0.013**	**2.796±0.016**	**3.6±0.1**	**0.998**
32V	**215±2**	**19.304±0.009**	**1.802±0.012**	**2.9±0.1**	**0.995**

3-D Visualization of Measured Profiles
(April 15, 2013)

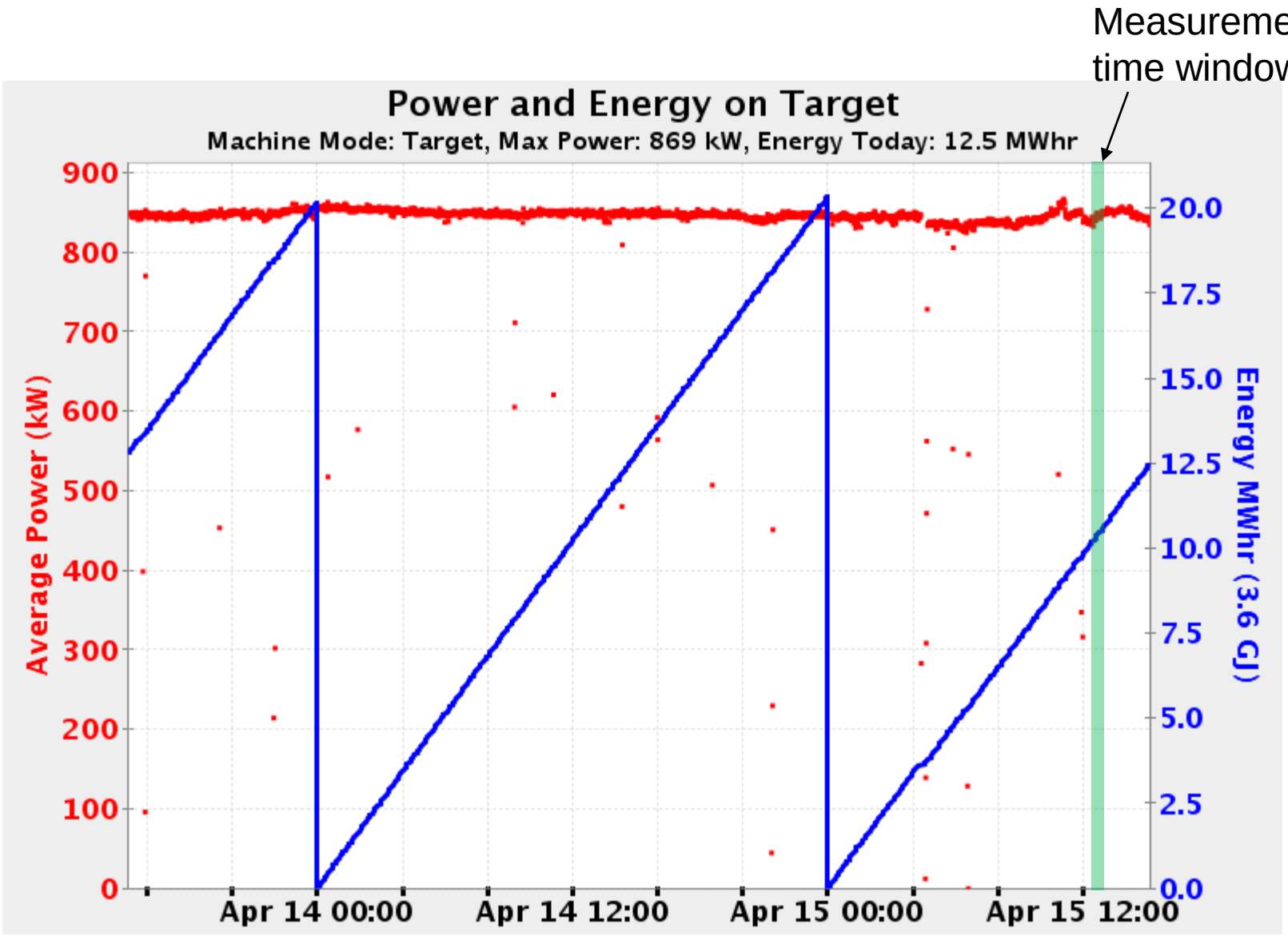


Profiles on September 13, 2012



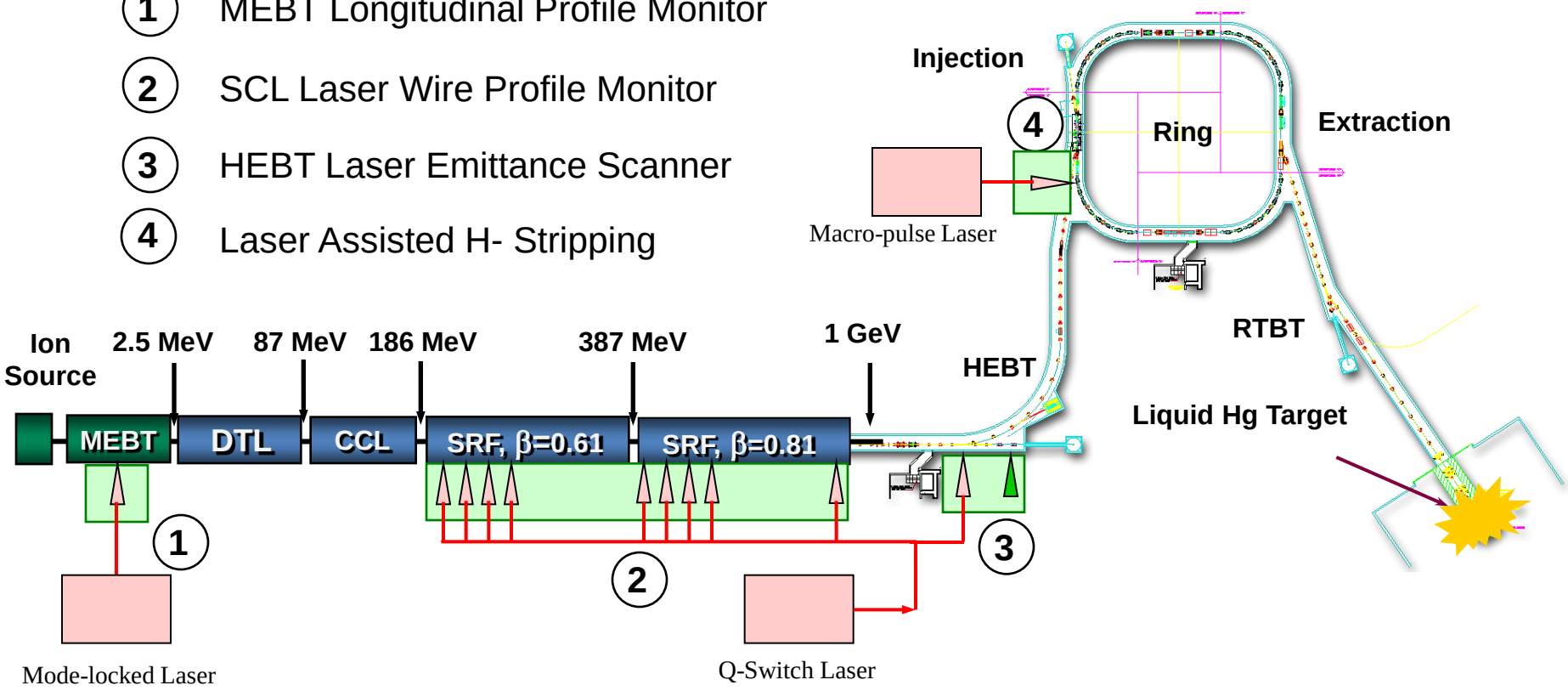
Liu et al, *PRST-AB* **16** (2013) 012801

Beam Status during LW Measurement



Laser Based H- Beam Diagnostics at the SNS Accelerator Complex

1. MEBT Longitudinal Profile Monitor
2. SCL Laser Wire Profile Monitor
3. HEBT Laser Emittance Scanner
4. Laser Assisted H- Stripping



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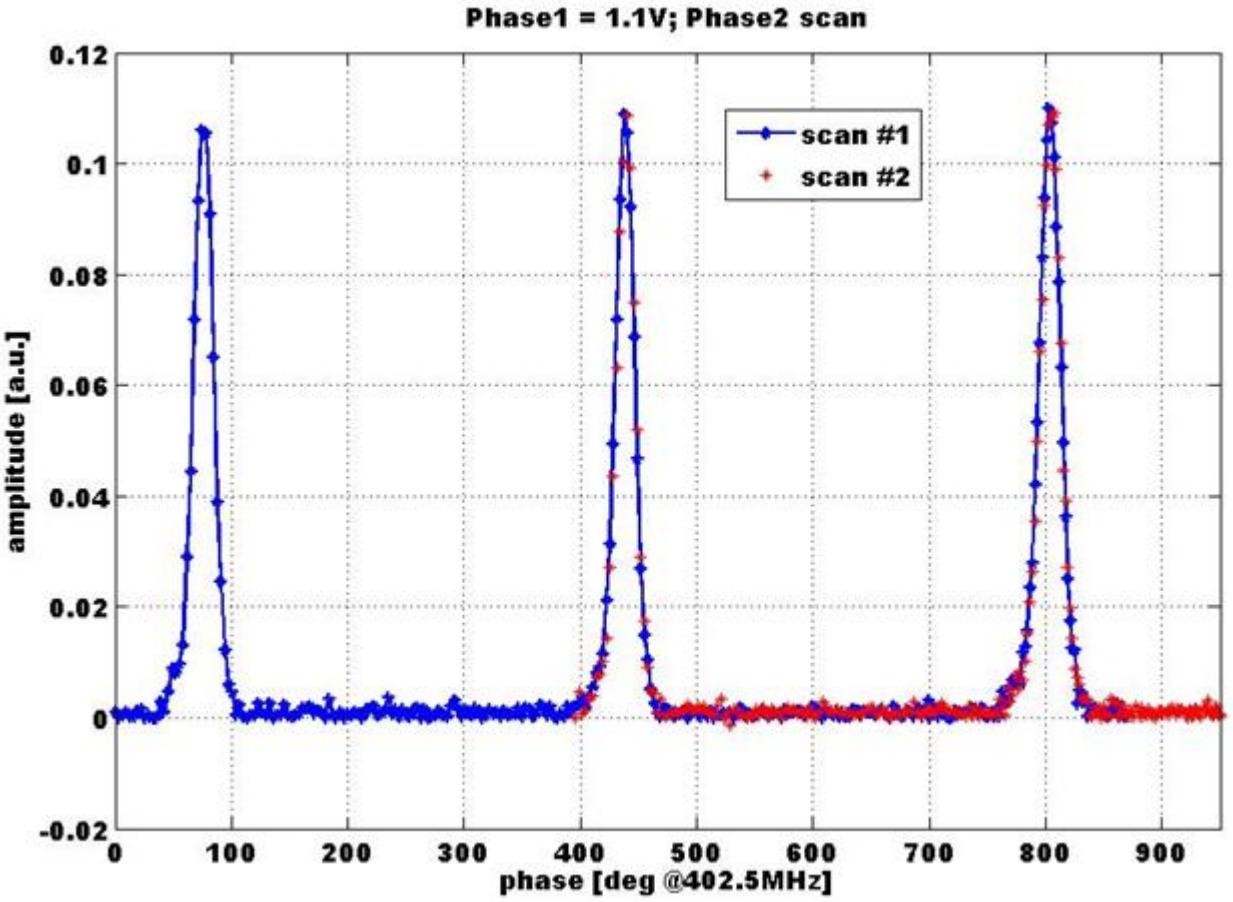

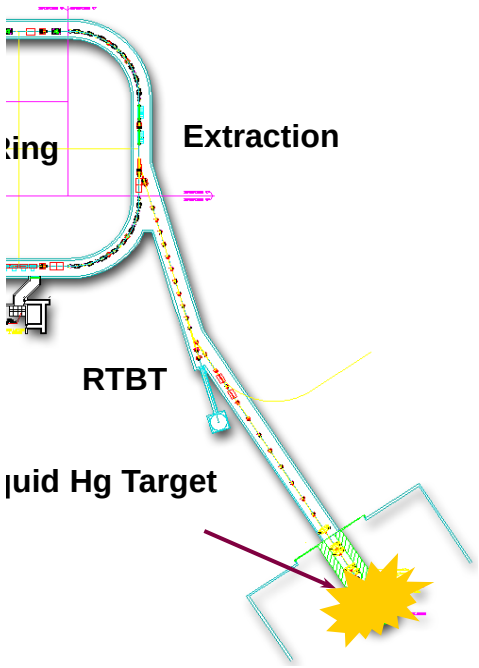

Mode-locked Laser

Q-Switch Laser

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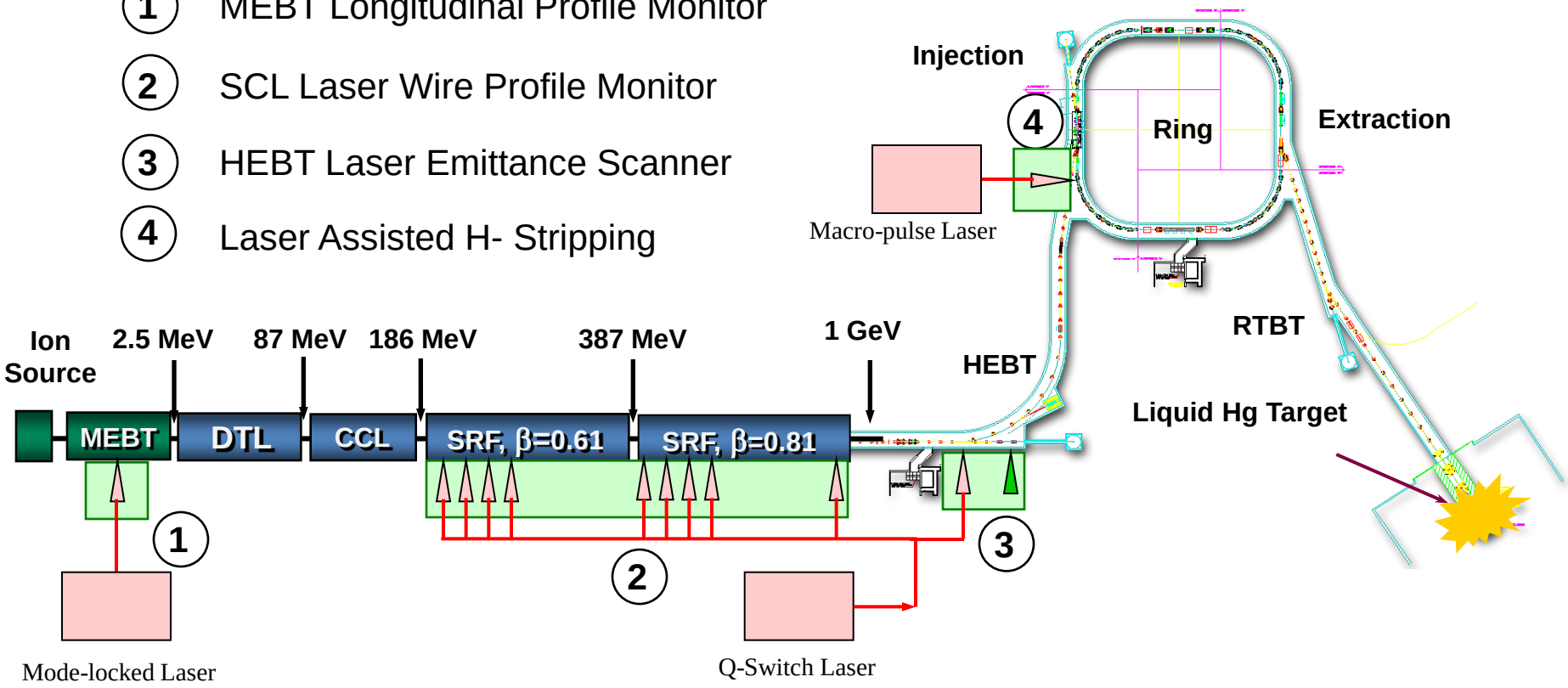

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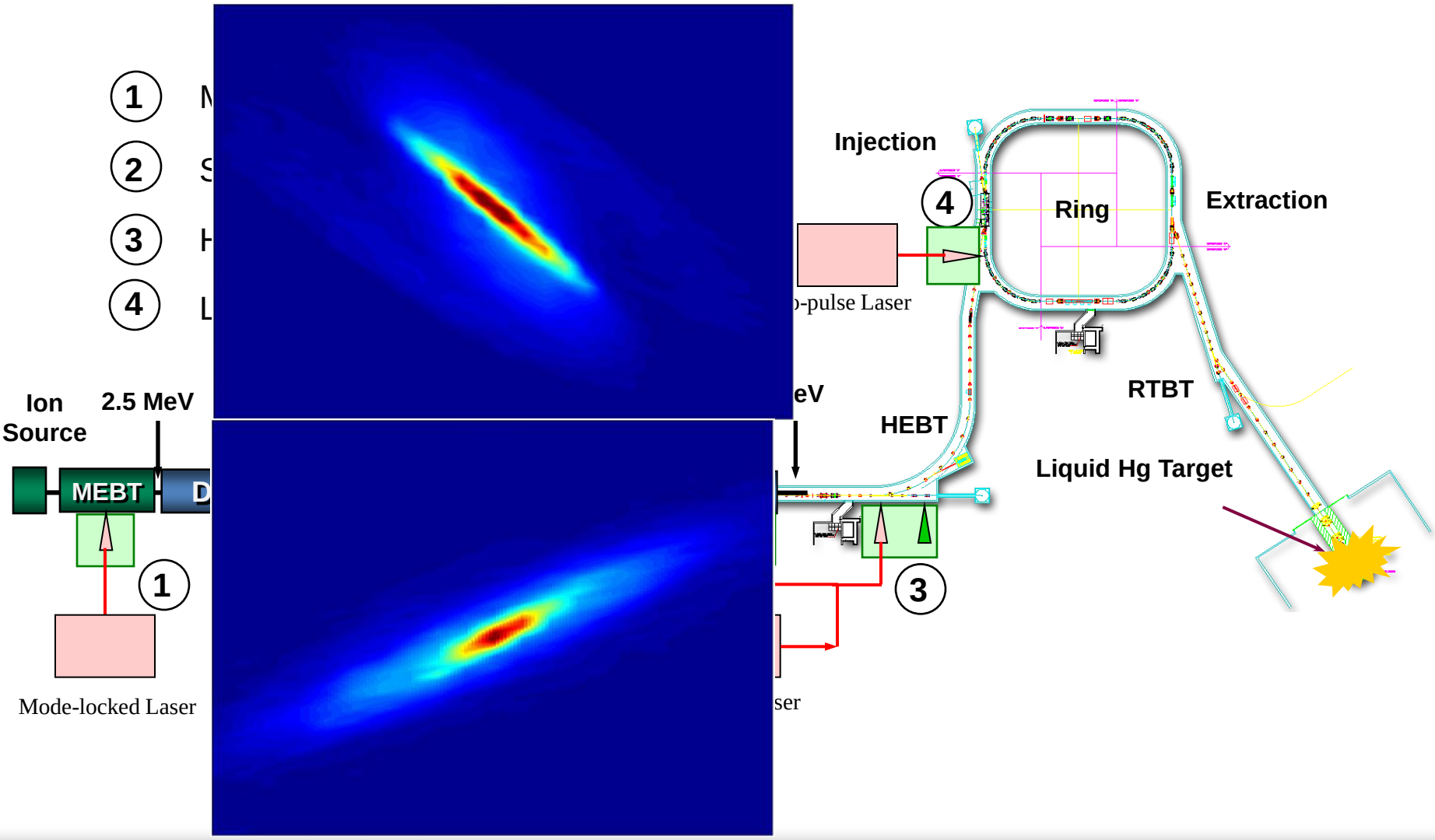

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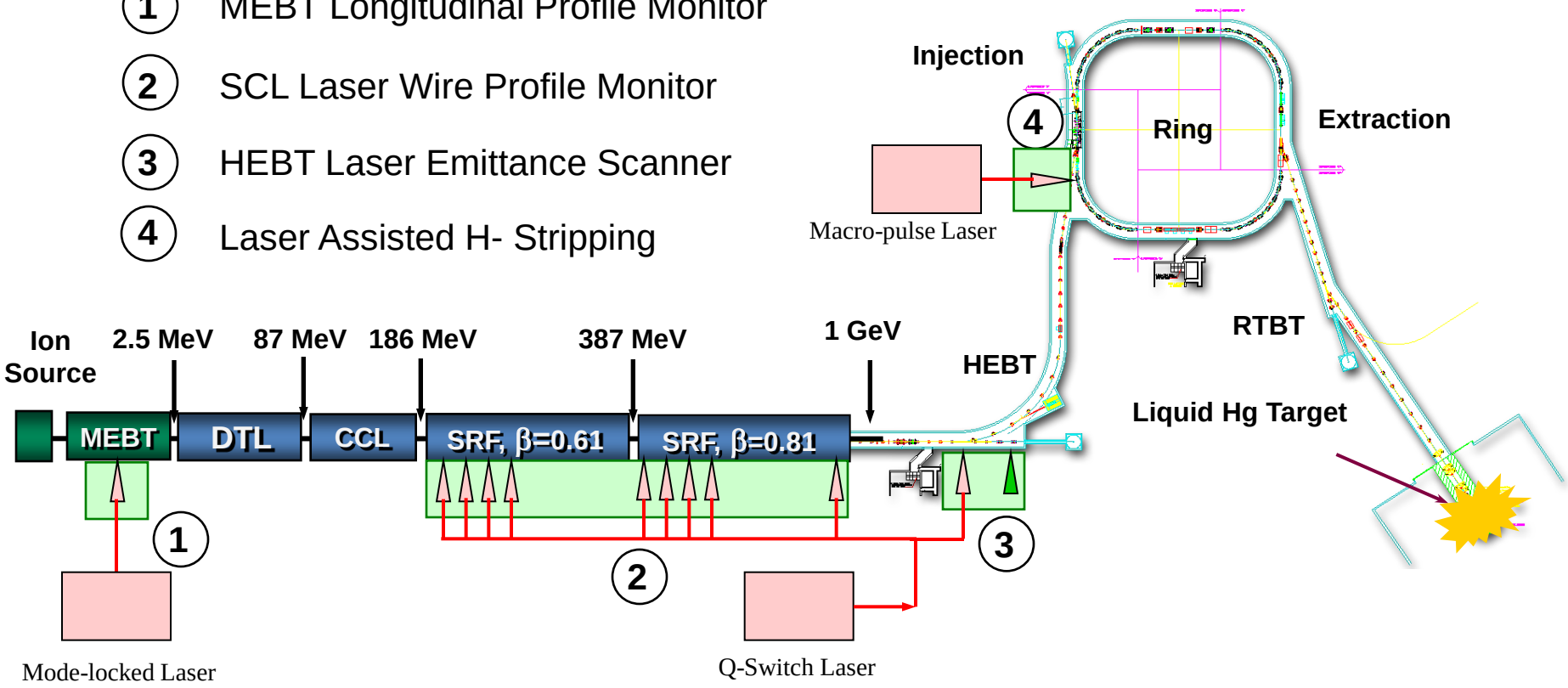

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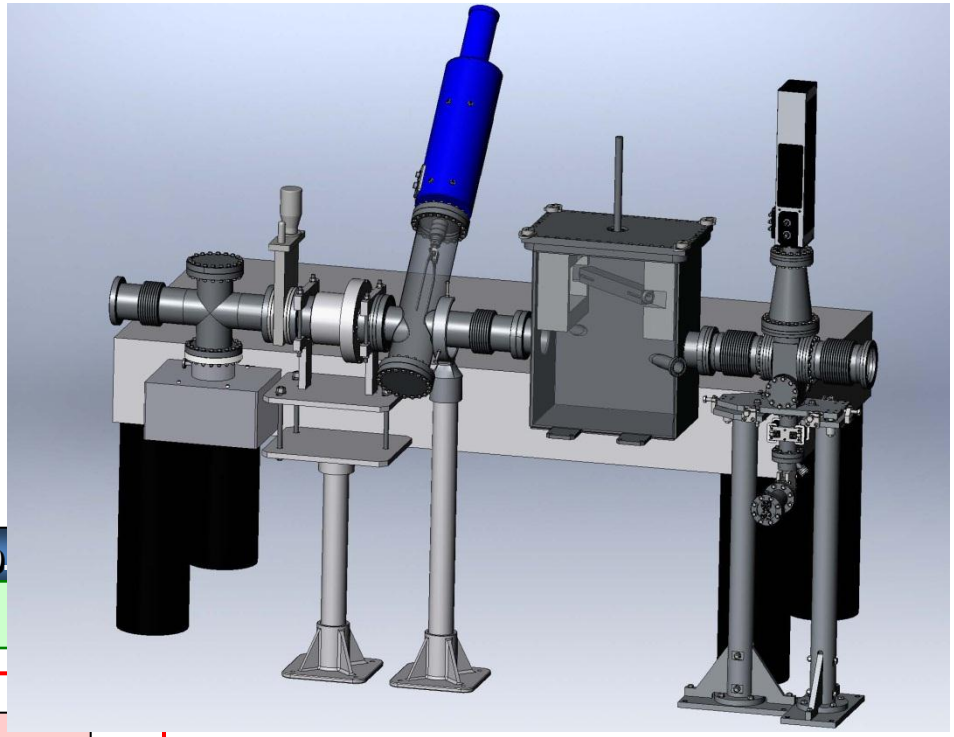

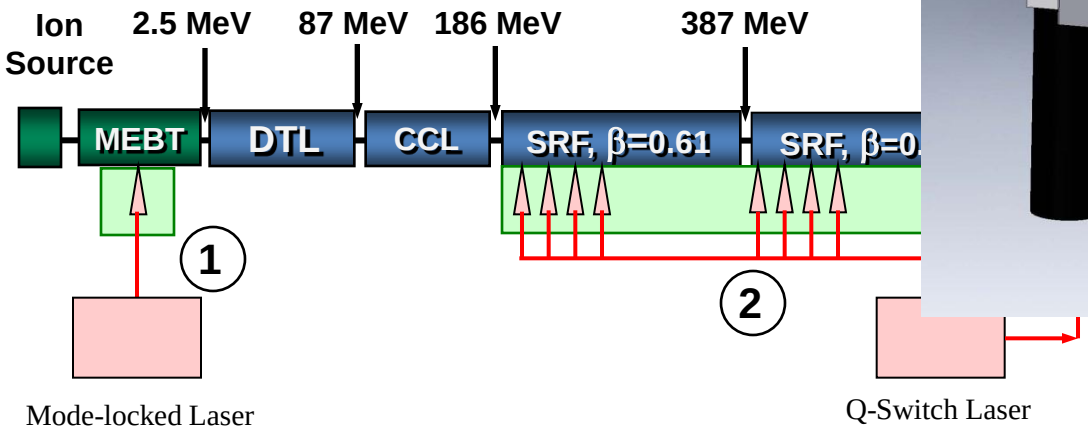

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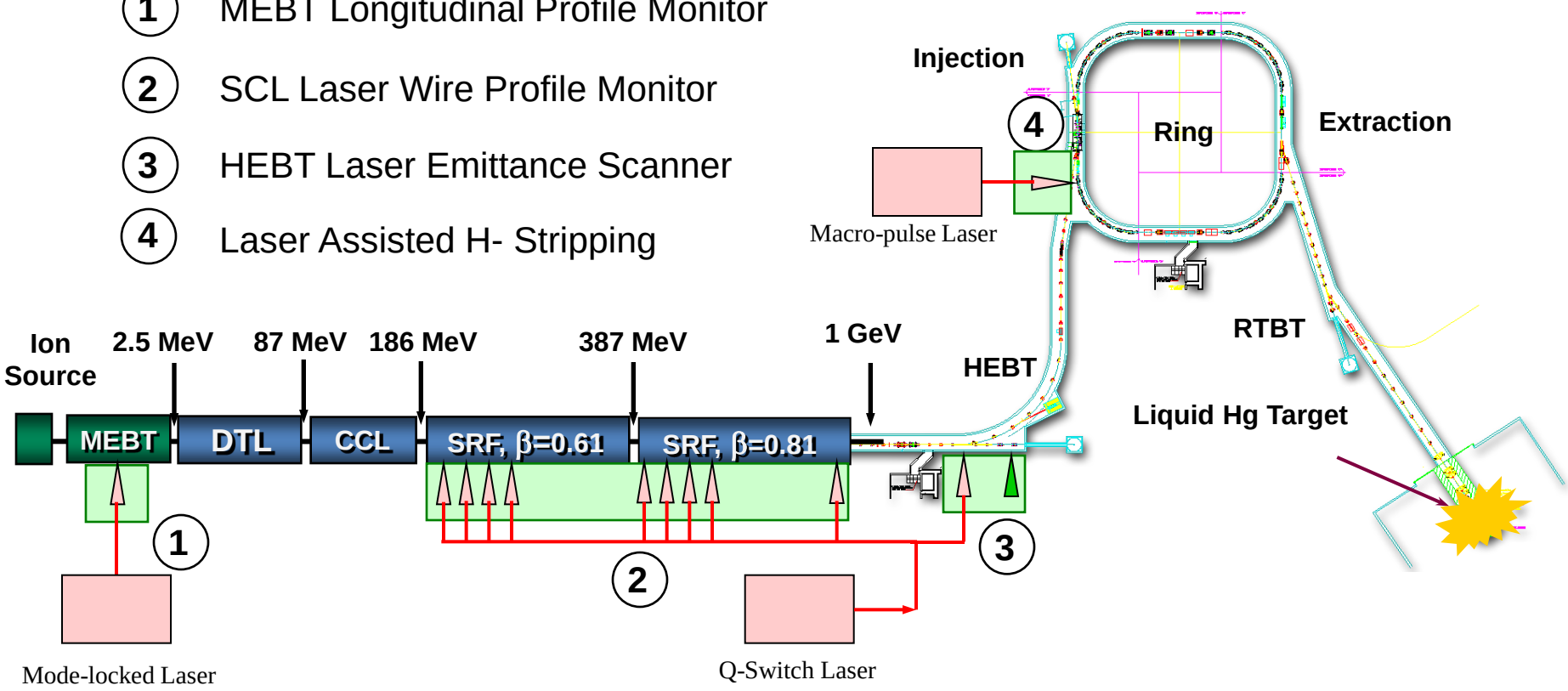

Commissioning Experience

Item	Findings	Solution
Laser Transport Line	Drift and vibration	Beam stabilization using active feedback Optical fiber based transport line (for low power)
Laser fluence	Over focusing of laser beam caused vacuum window breakdown	Avoid beam collimation optics close to measurement station. Ensure laser fluence below 1 J/cm^2.
Influence on beam	Electron collection magnets can cause tiny beam deflection	Correction magnet installed Orbit correction
Radiation hardness of laser	Laser driver (> 6 m from beam line) damaged in 1-2 days Unclear about laser head	Laser should be located outside the beamline for hadron machine
Image sensors	Gigabit Ethernet cameras (> 1.5 m from beamline)	Have to replace every 1-2 years
Motion control	Stepper motor (~ 30 cm from beam line); Picomotor actuators (1.5 m from beamline)	Stepper motors are very robust Open-loop picomotors have to be used

SUMMARY

- World-first demonstration of simultaneous H- beam profile scan using a single laser source.
- The system has been brought to operation level – a single push-button initiates profile scan at 9 locations of SCL (corresponding to energy levels of 200 MeV -1 GeV).
- A number of laser based instruments have been commissioned/developed at the SNS accelerator complex.
- Laser based beam diagnostics at accelerator facilities is reliable and realistic and provides a useful tool for beam tuning and physics study.