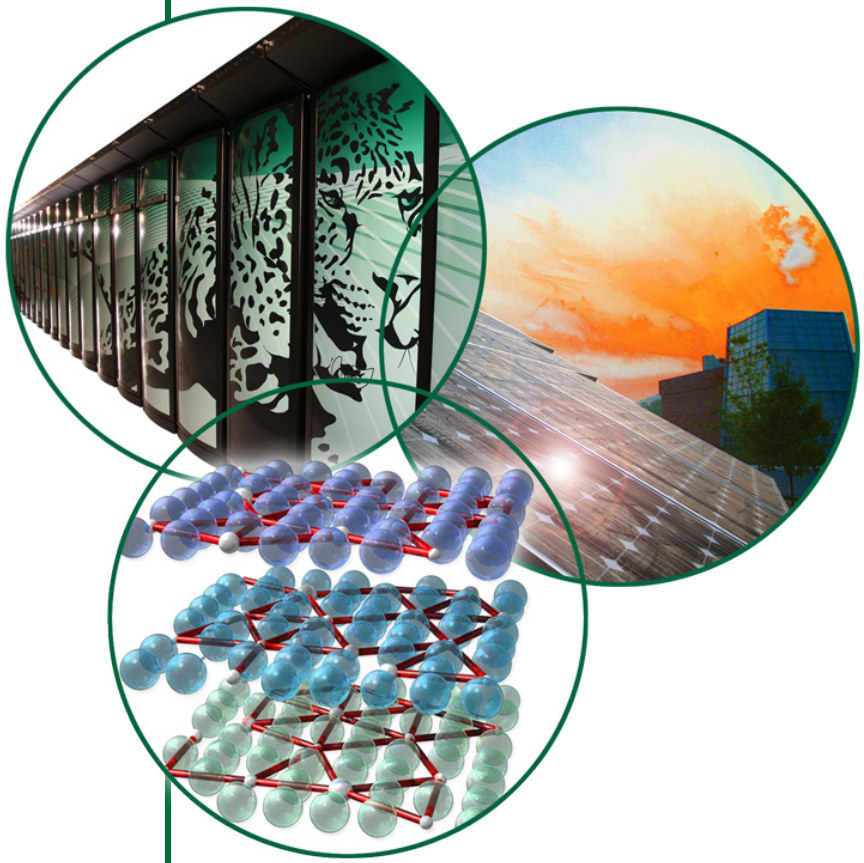
Laser Based Diagnostics for Measuring H^- Beam Parameters

Yun Liu on behalf of
Beam Instrumentation Group

Research Accelerator Division

Spallation Neutron Source

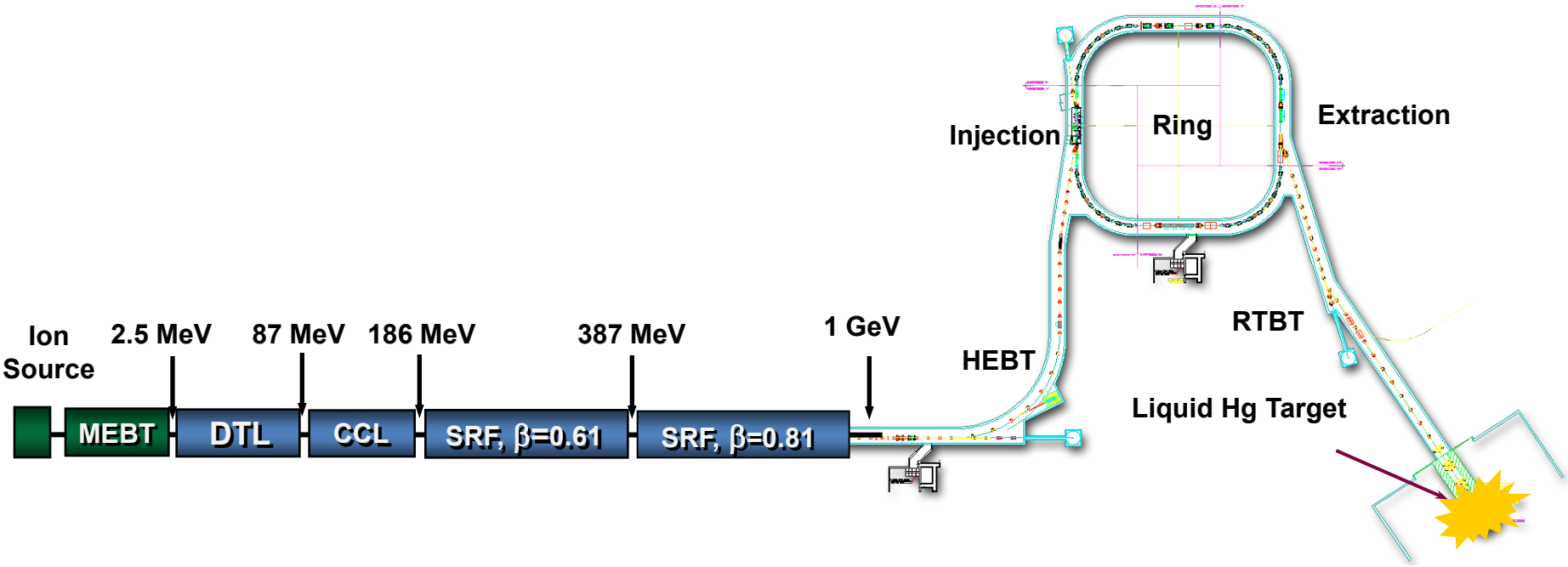
Oak Ridge National Laboratory



OUTLINE

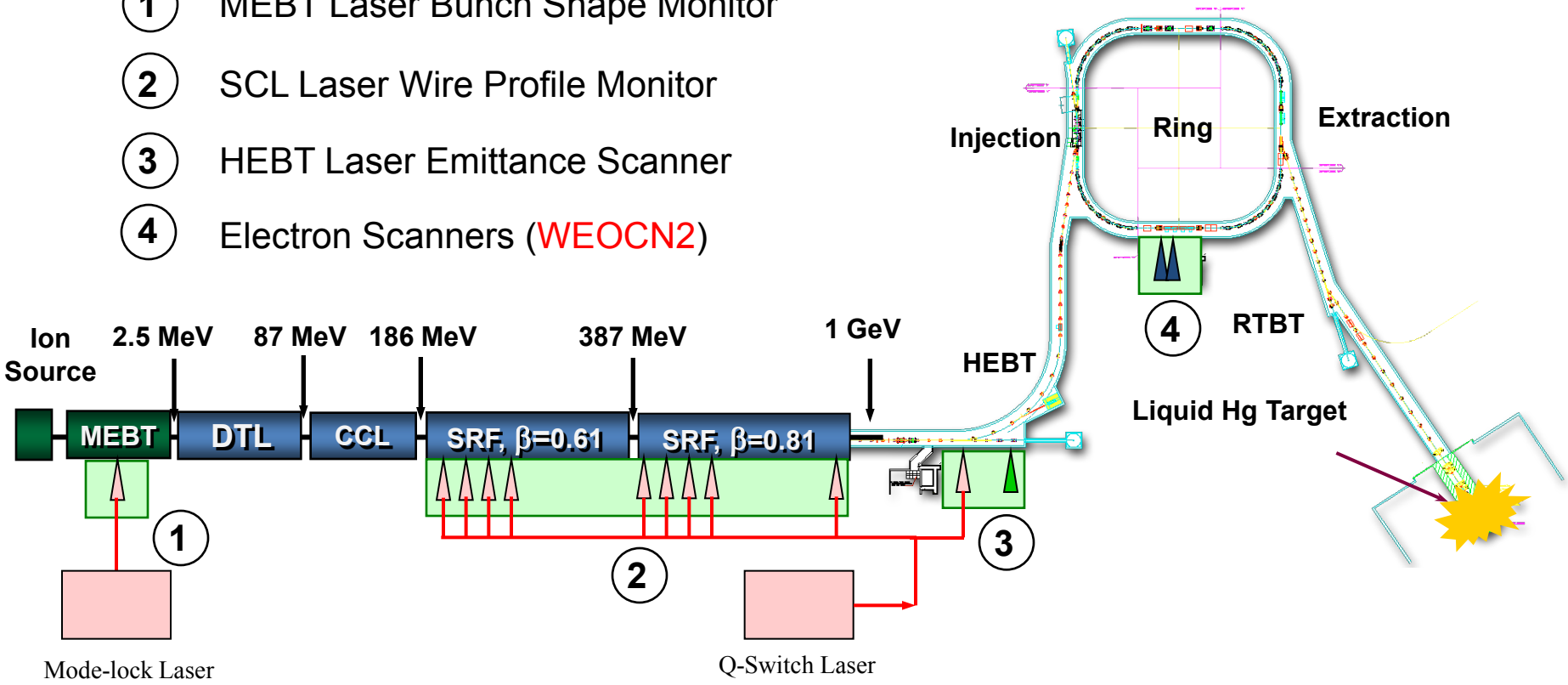
- Overview of laser based H^- beam diagnostics
- SCL laser wire profile monitor
- HEBT laser emittance scanner
- MEBT laser bunch shape monitor
- Commissioning experience
- Conclusion

Non-invasive Beam Profile Diagnostics at SNS



Non-invasive Beam Profile Diagnostics at SNS

1. MEBT Laser Bunch Shape Monitor
2. SCL Laser Wire Profile Monitor
3. HEBT Laser Emittance Scanner
4. Electron Scanners (WEOCN2)



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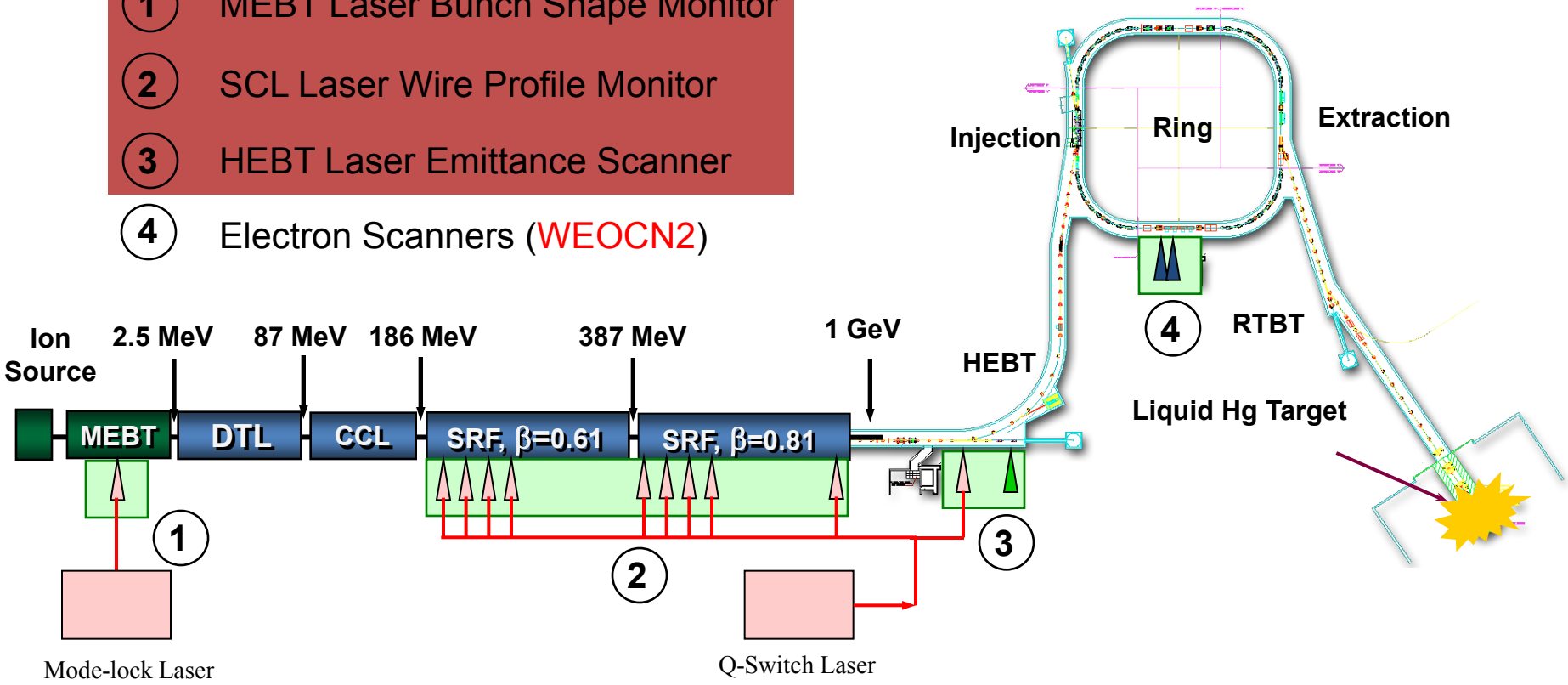
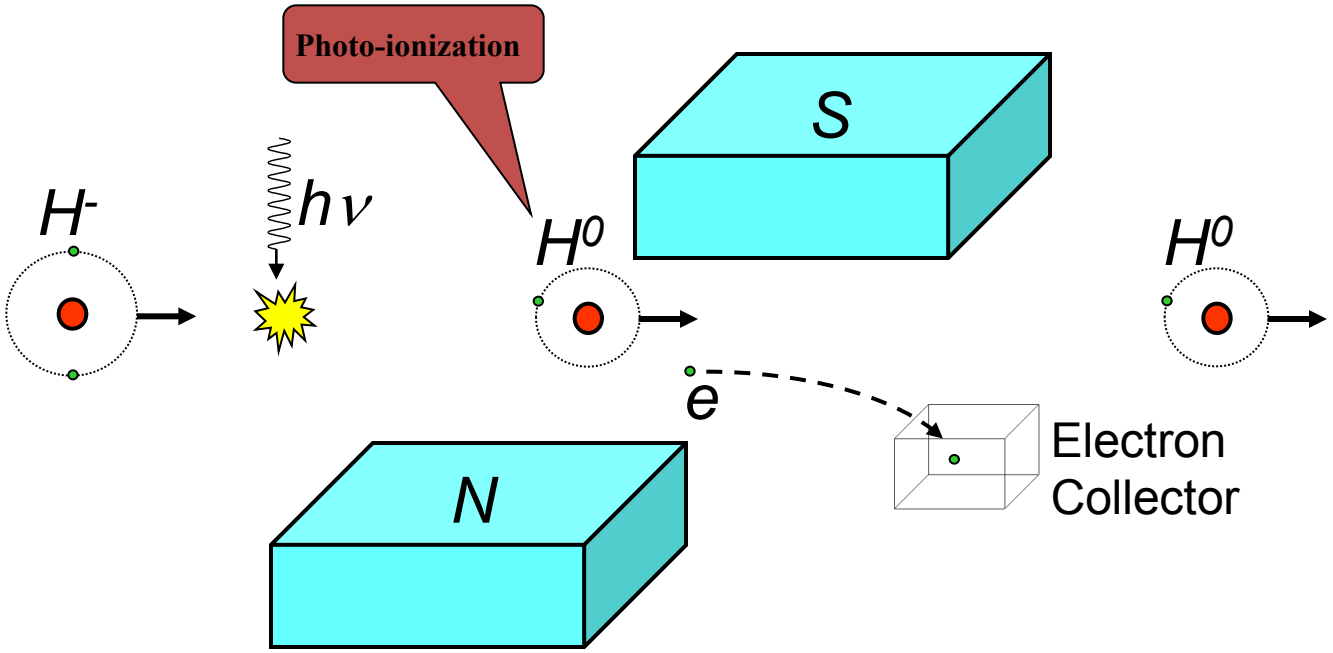
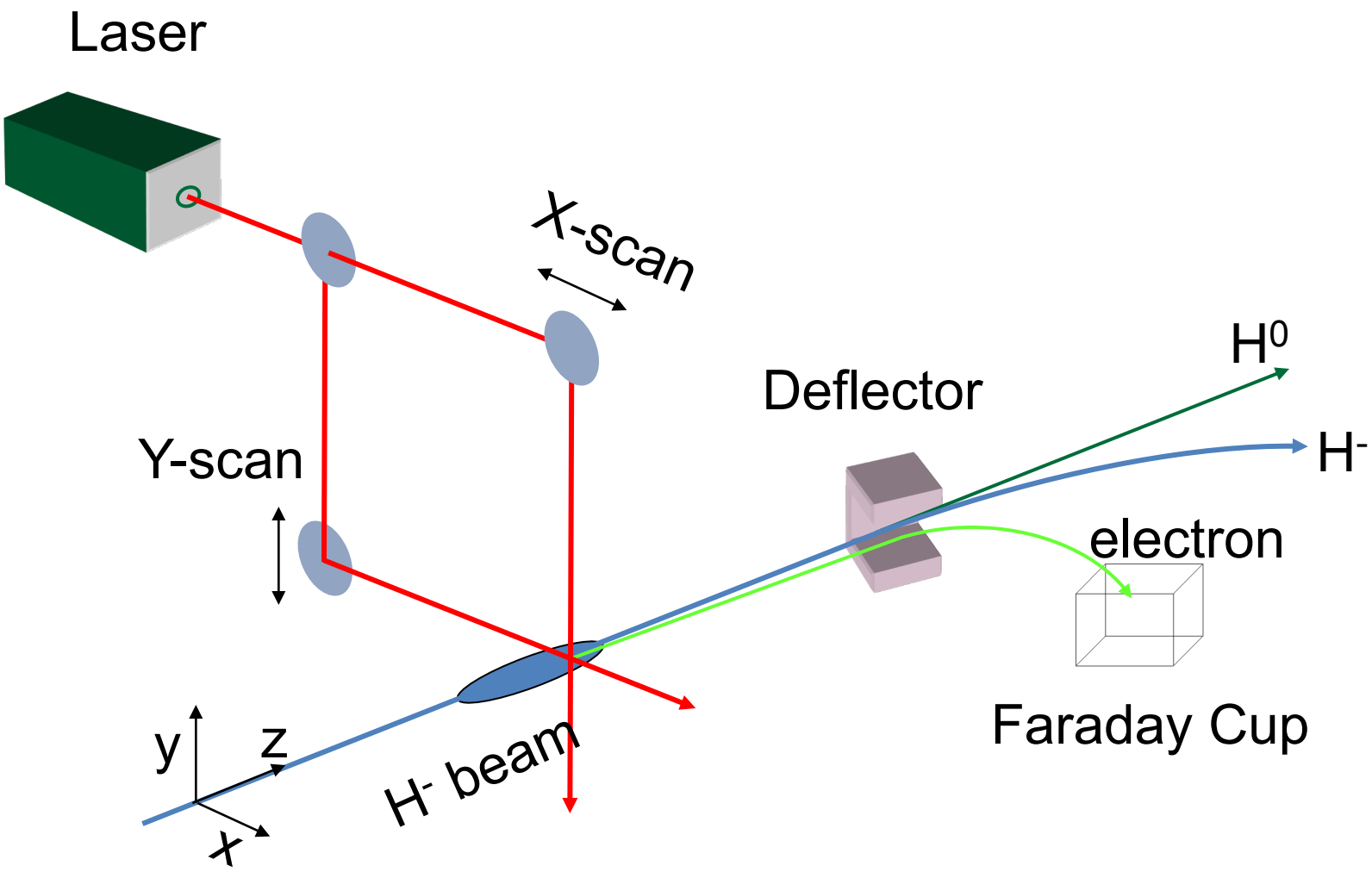


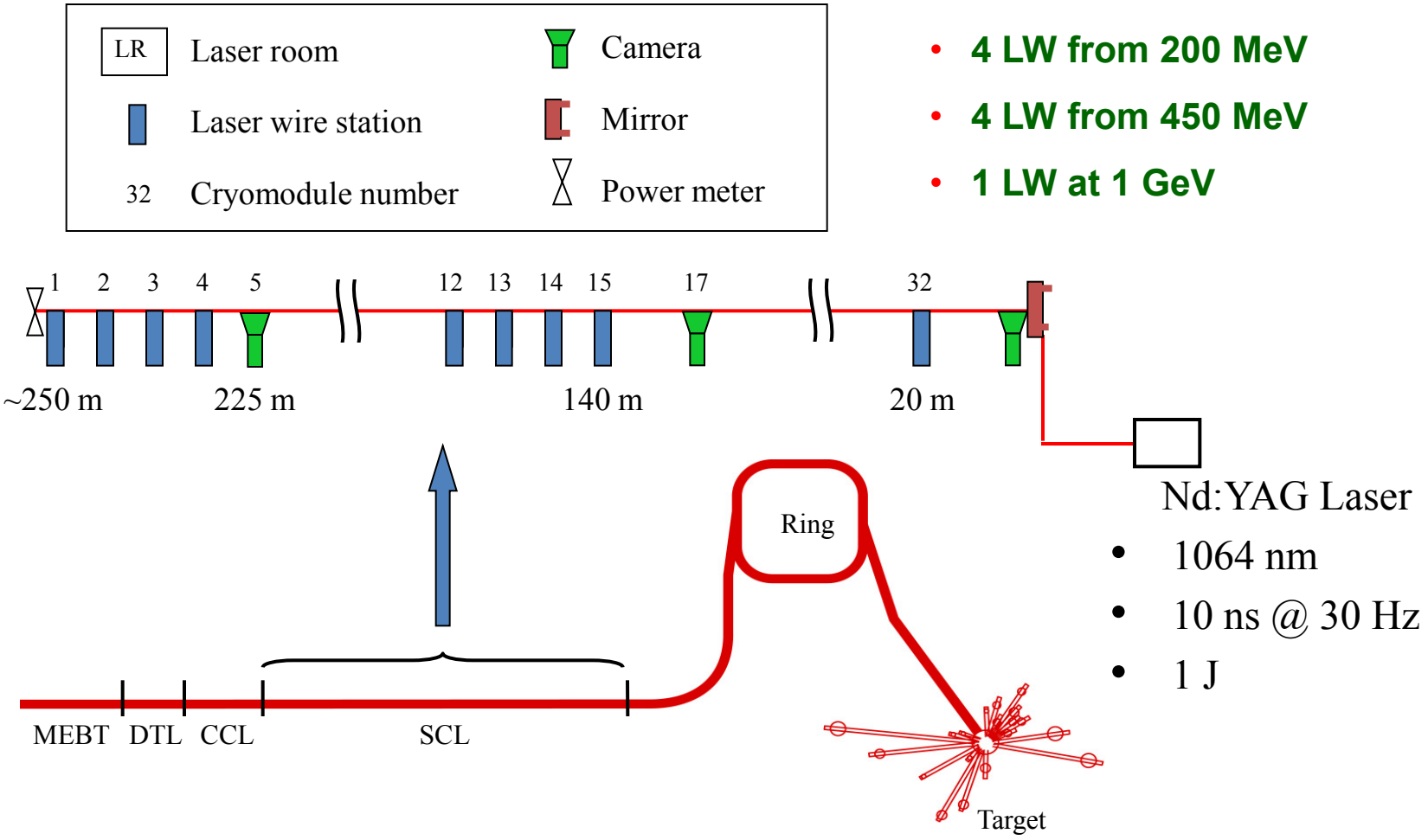
Photo-ionization – Physics behind Laser Based Ion Beam Diagnostics



Laser Wire Profile Monitor



Layout of the SNS Laser Wire Profile Monitors



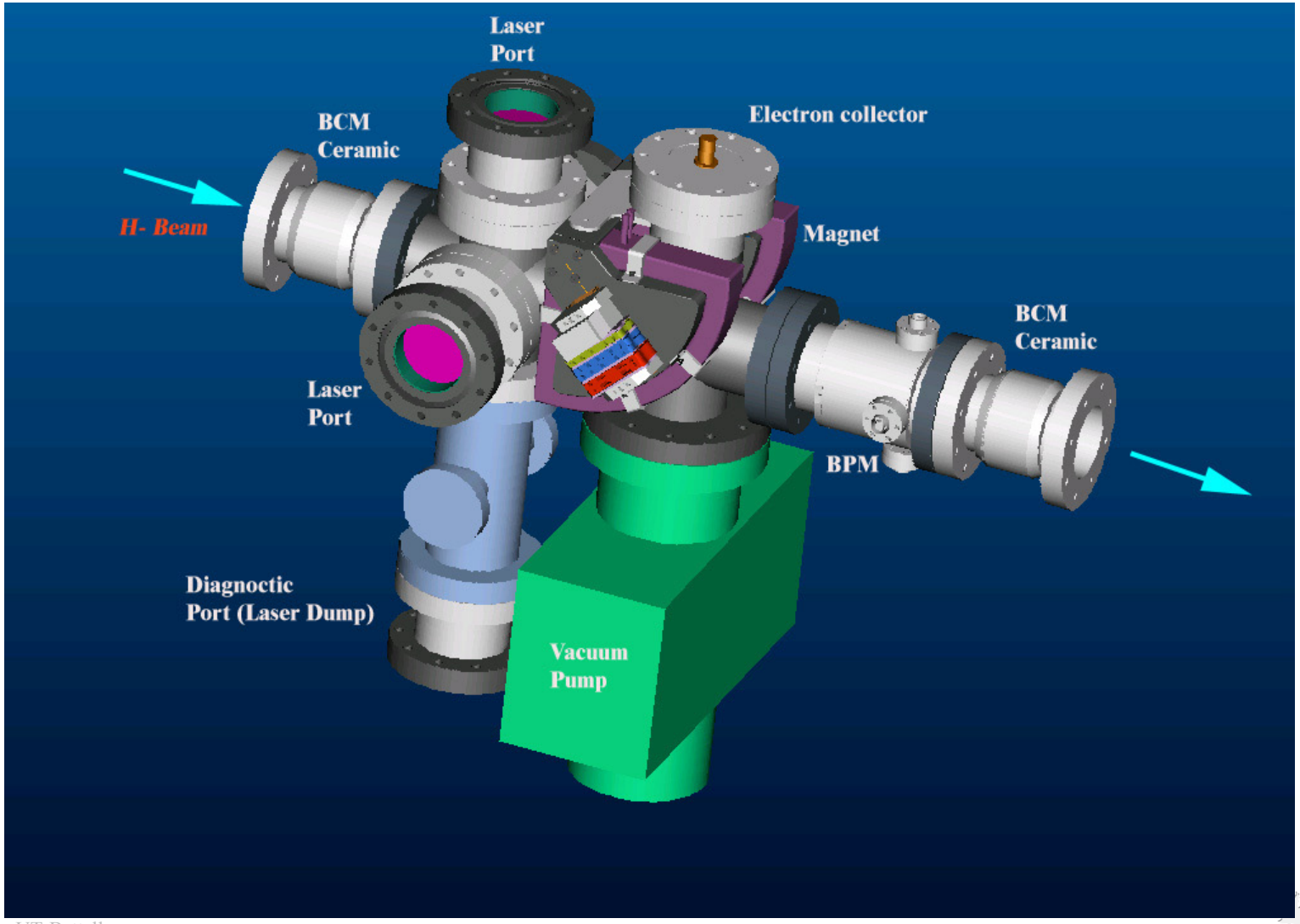
- **4 LW from 200 MeV**
- **4 LW from 450 MeV**
- **1 LW at 1 GeV**

Nd:YAG Laser

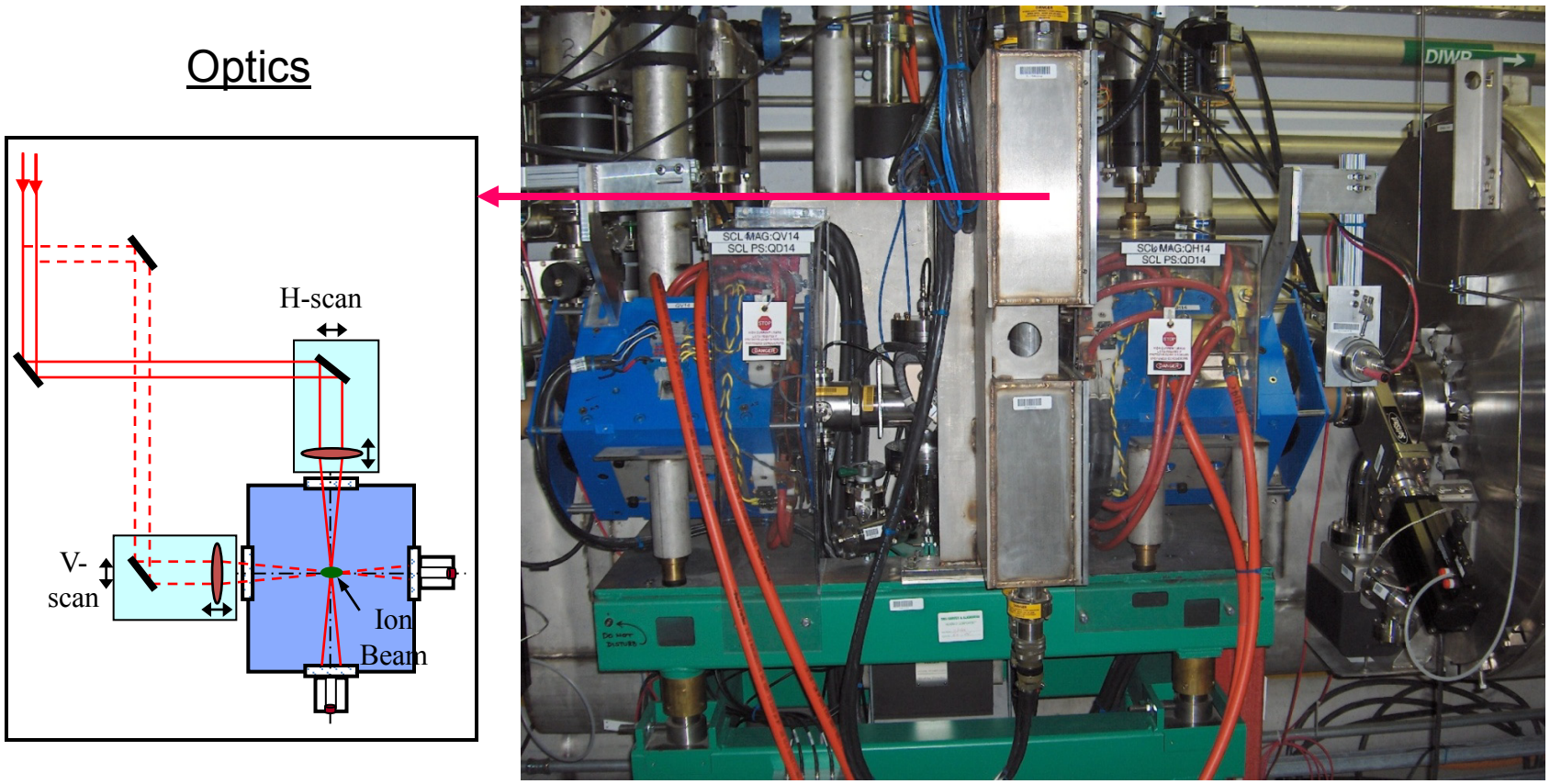
- 1064 nm
- 10 ns @ 30 Hz
- 1 J

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

Laser Wire Station (design)



Laser Wire Station (implementation)



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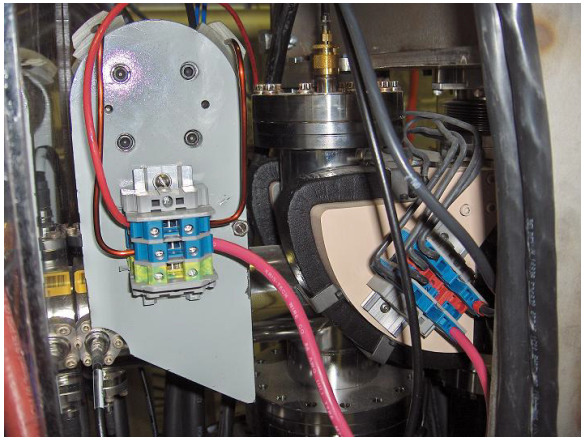
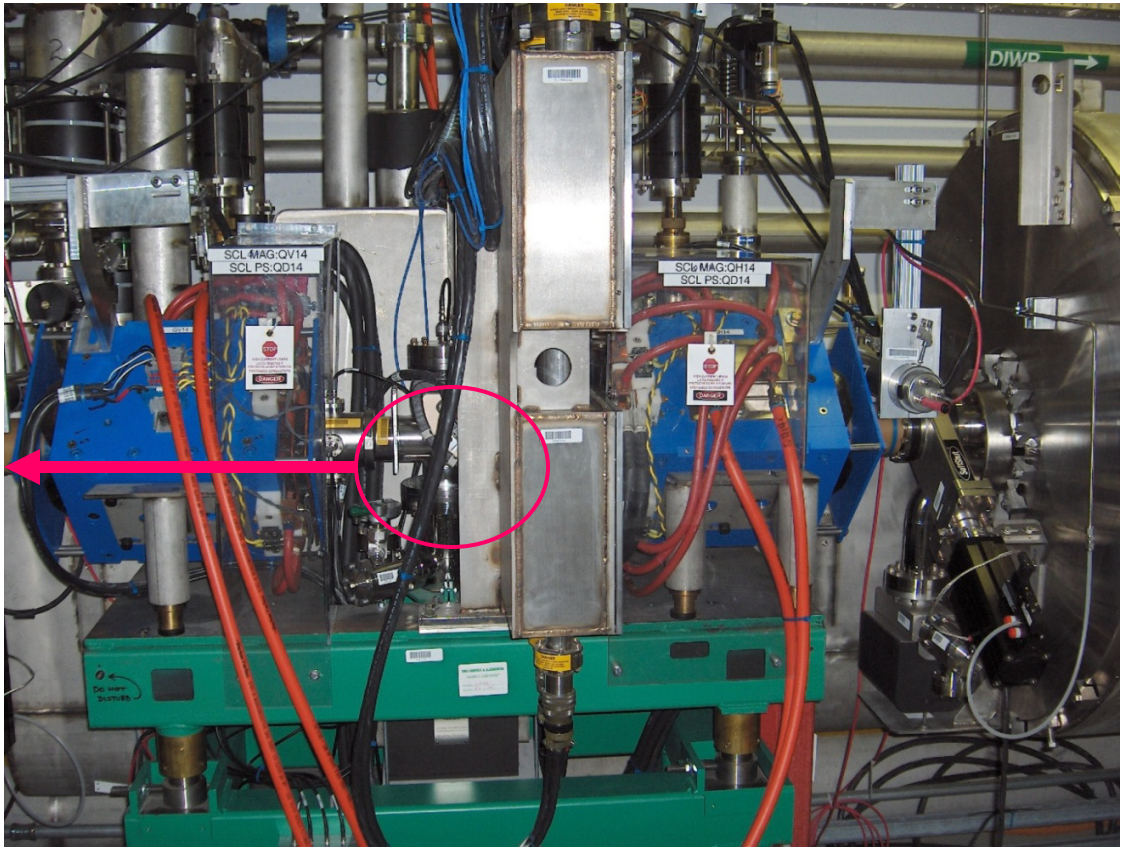
Laser Wire Station (implementation)

Correction magnet

Collection magnet





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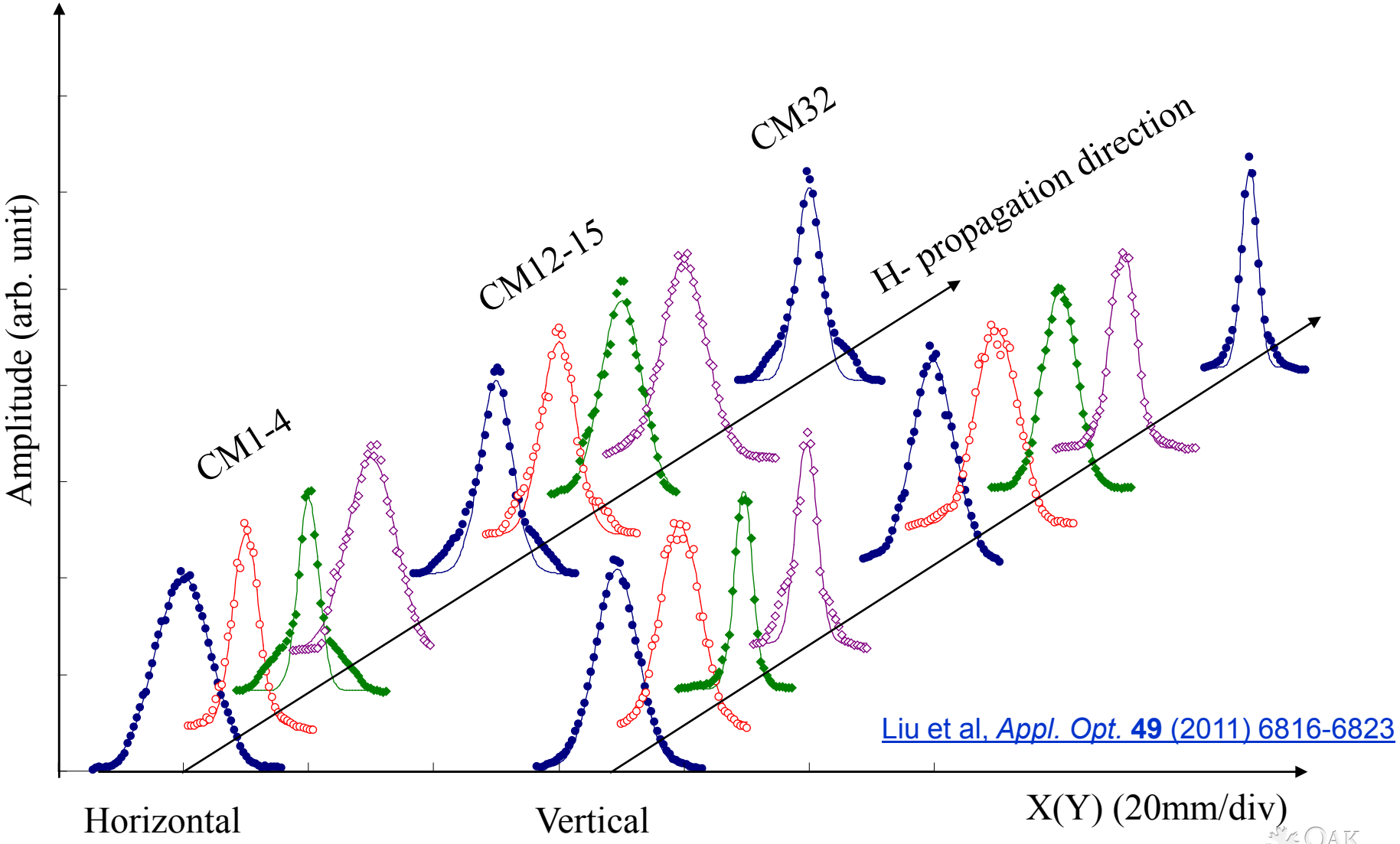
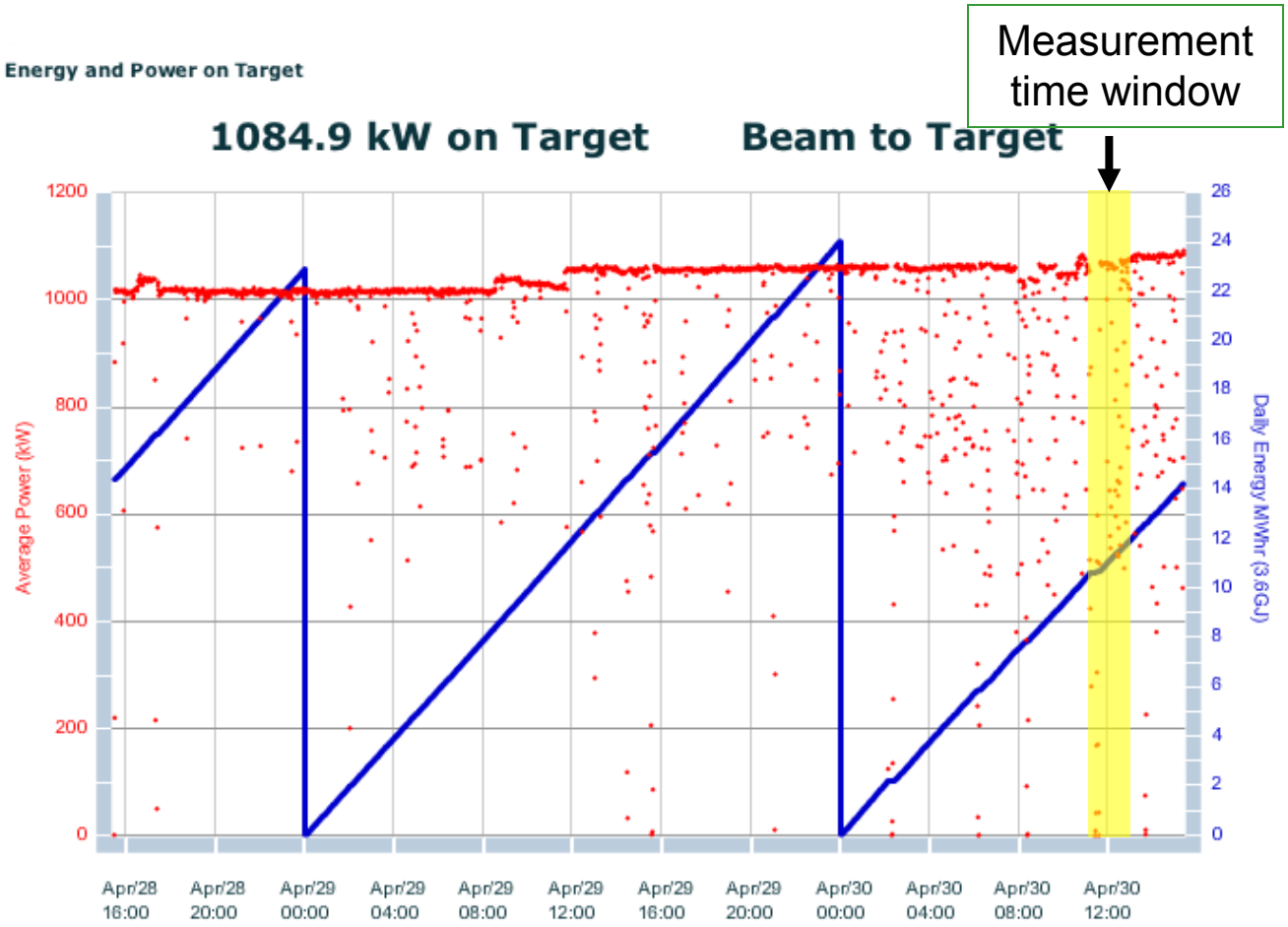
1-MW H- Profiles Measured by Laser Wire at SCL

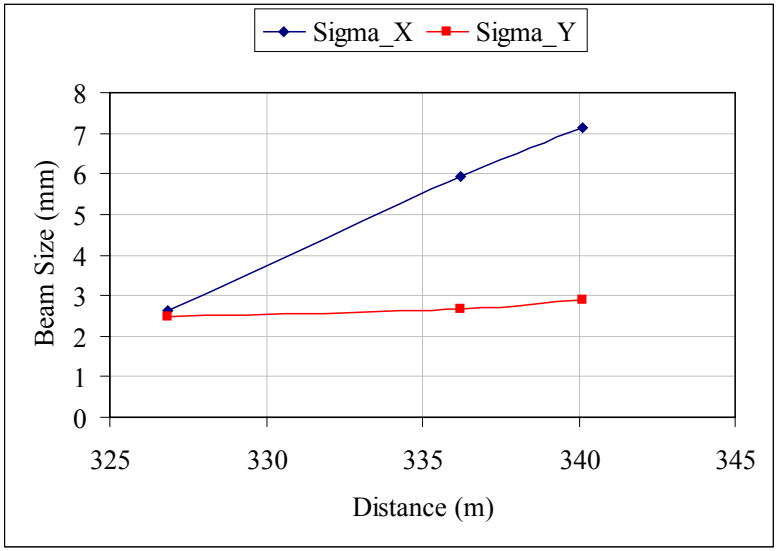


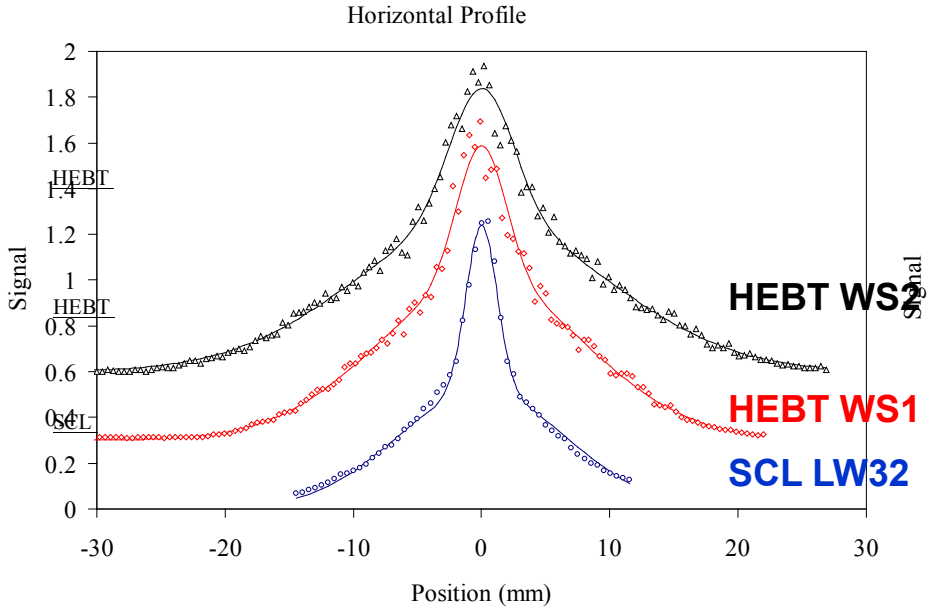
Liu et al, *Appl. Opt.* **49** (2011) 6816-6823

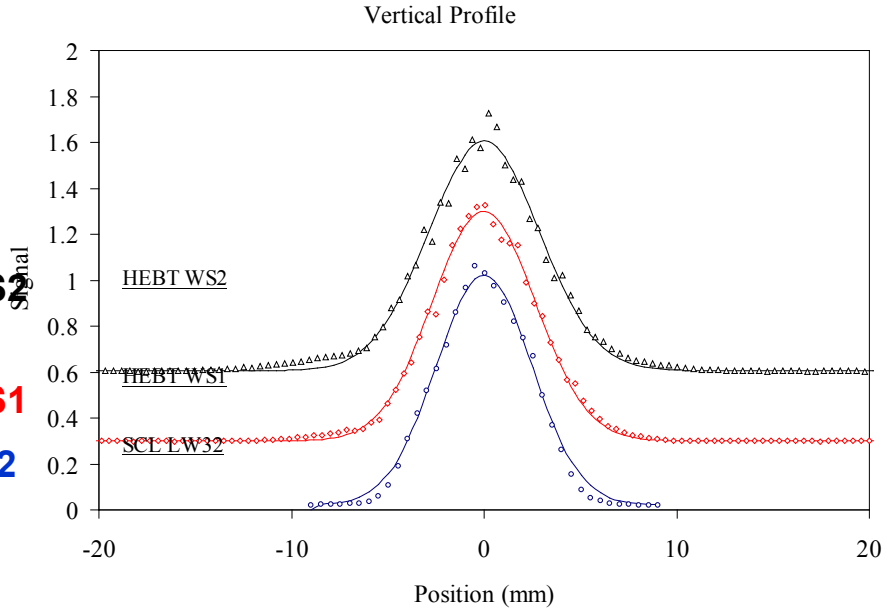
1-MW H- Profiles Measured by Laser Wire at SCL



	Magnet Setting		Sigma_ X	Sigma_ Y	Distance
SCL Mag QH32	**0.1**	**SCL LW 32**	**2.64**	**2.49**	**326.841**
SCL Mag QV32	**0.1**	**HEBT WS1**	**5.94**	**2.67**	**336.2245**
SCL Mag QH33	**0.1**	**HEBT WS2**	**7.13**	**2.88**	**340.1351**
HEBT_Mag QV01	**0.2**				
HEBT_Mag QH02	**0.1**				

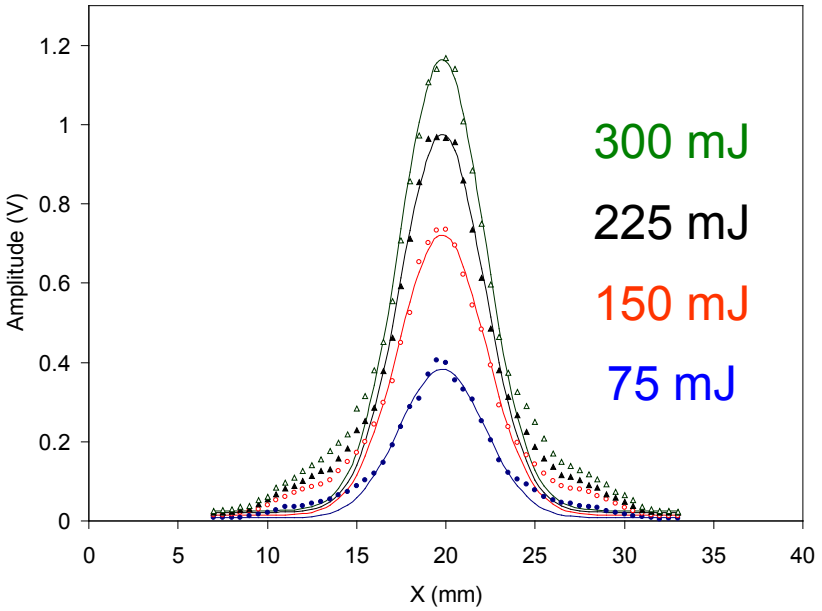


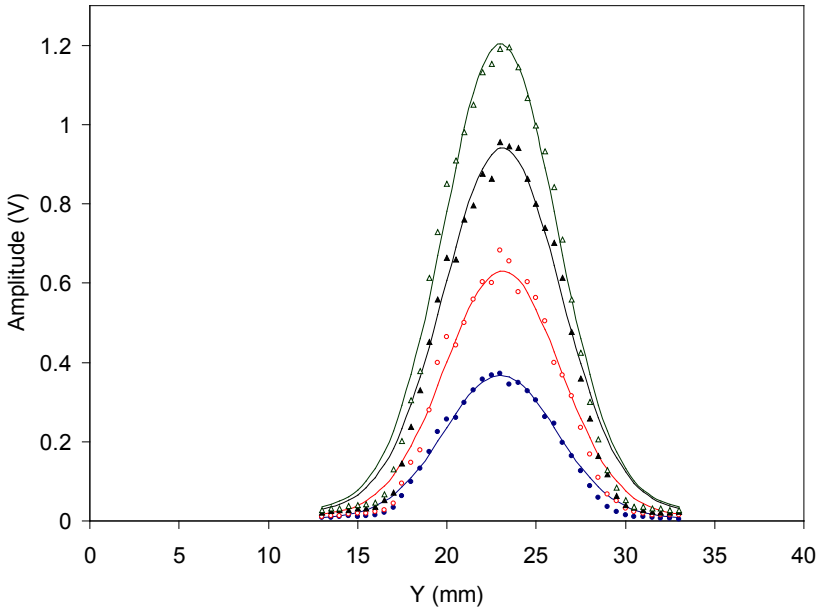




Work performed by Y. Zhang and Y. Liu

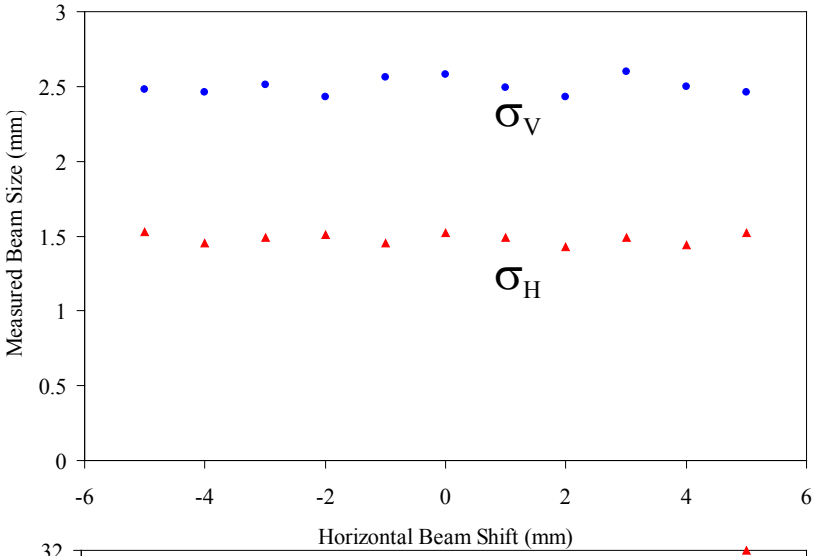
Effects of Laser Pulse Energy

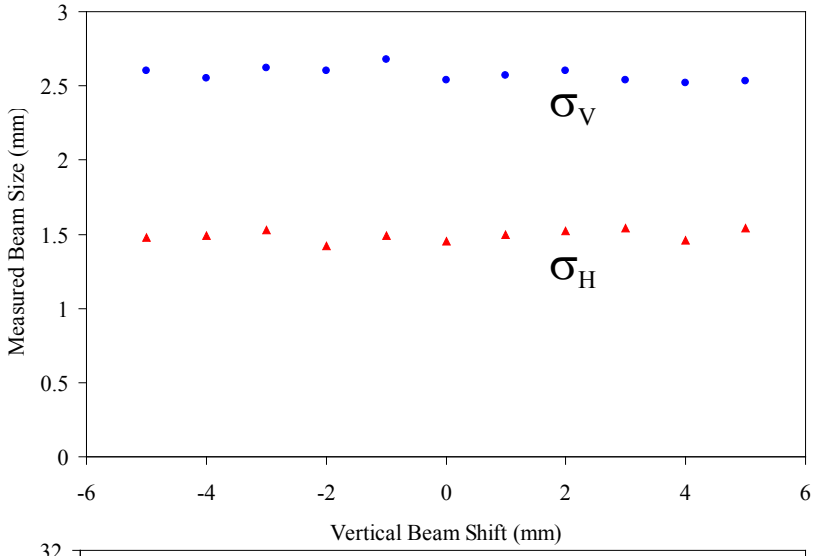


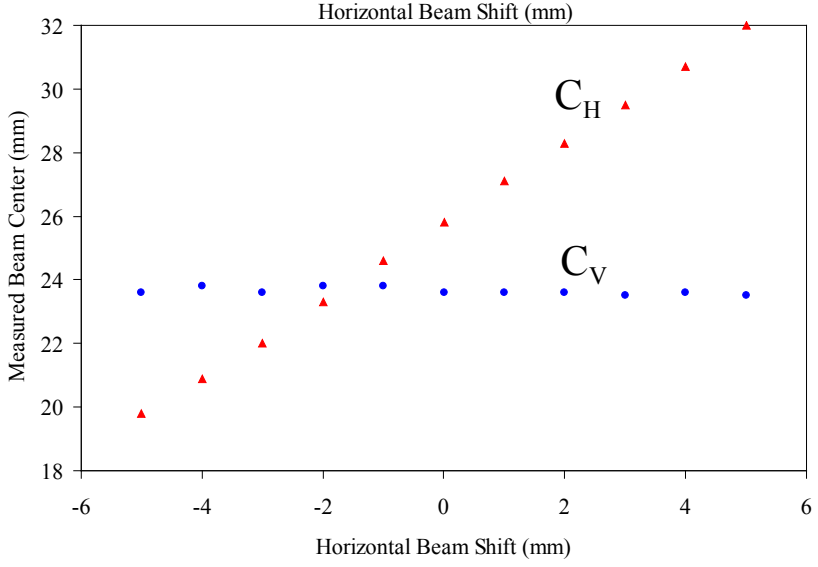


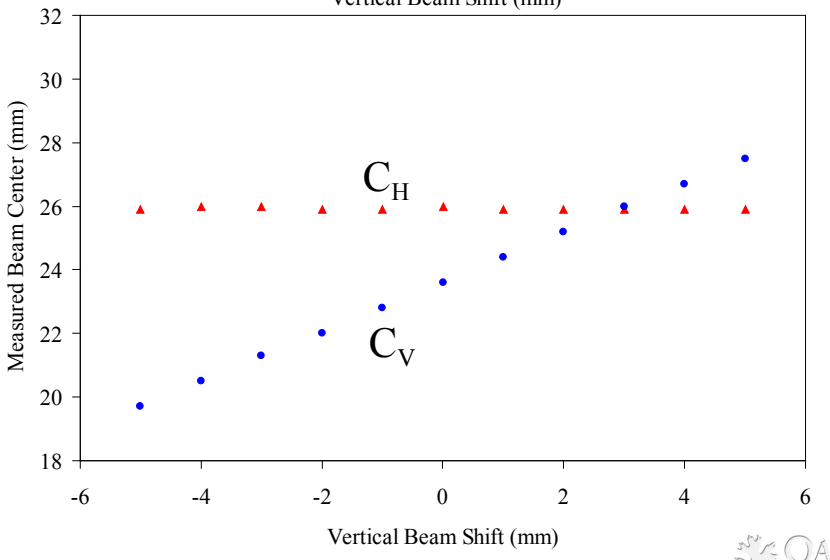
Laser pulse energy (mJ)	σ_H (mm)	σ_V (mm)	C_H (mm)	C_V (mm)	A_H (V)	A_V (V)
75	2.4	3.2	19.8	23.0	0.38	0.36
150	2.4	3.2	19.8	23.1	0.71	0.62
225	2.4	3.3	19.8	23.1	0.95	0.92
300	2.4	3.2	19.8	23.0	1.14	1.18

Effects of Ion Beam Position



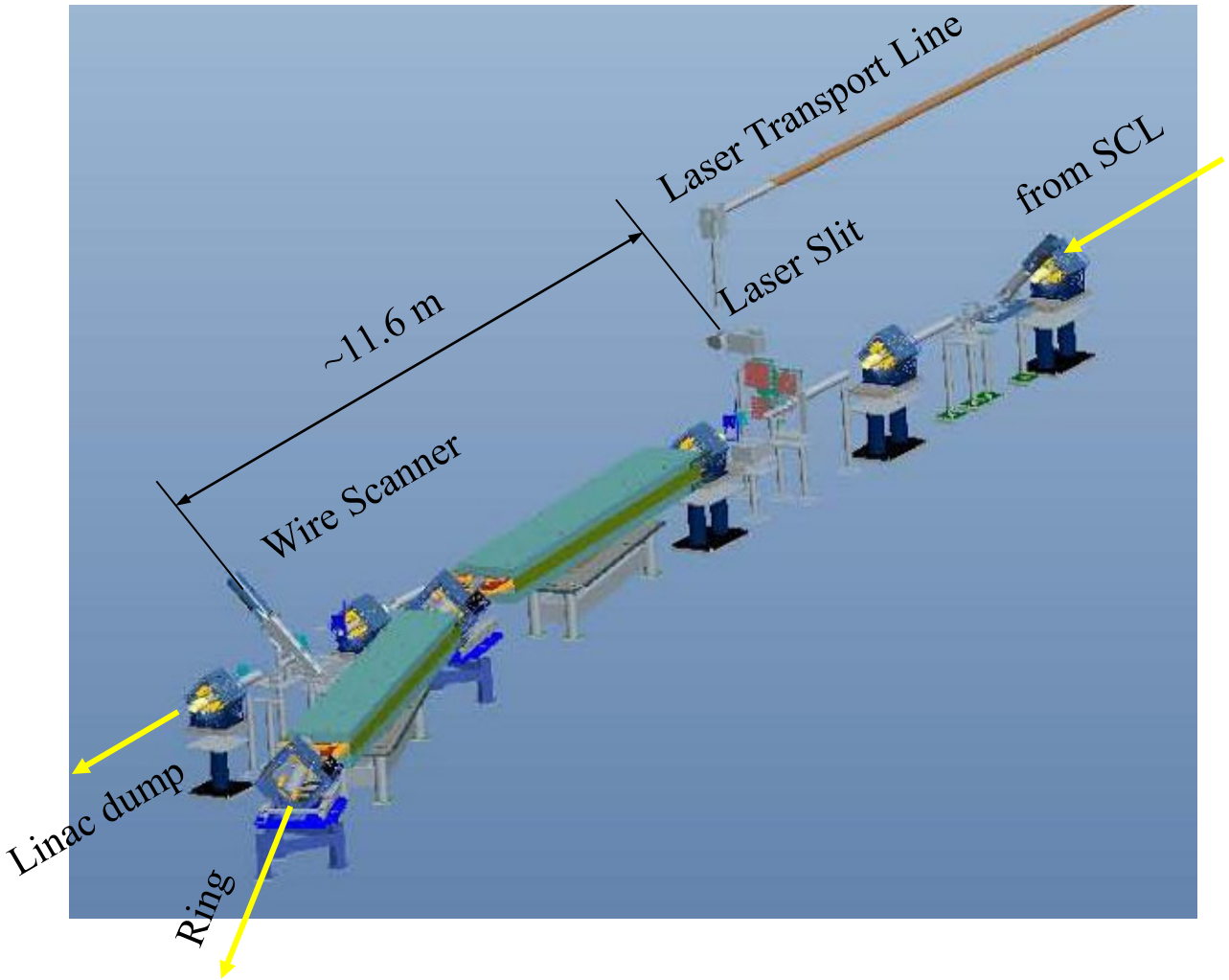






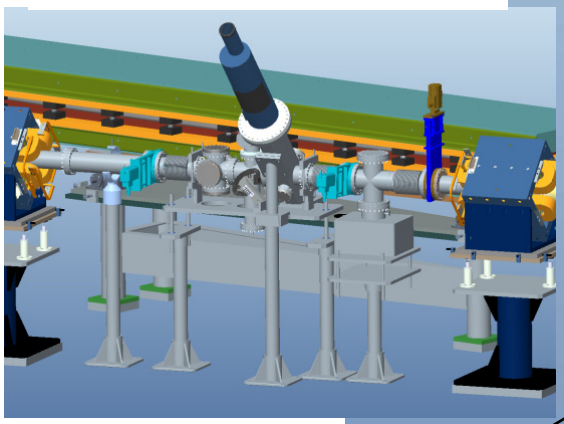
PAC11 (March 30, 2011, New York) Liu et al, *Appl. Opt.* **49** (2011) 6816-6823

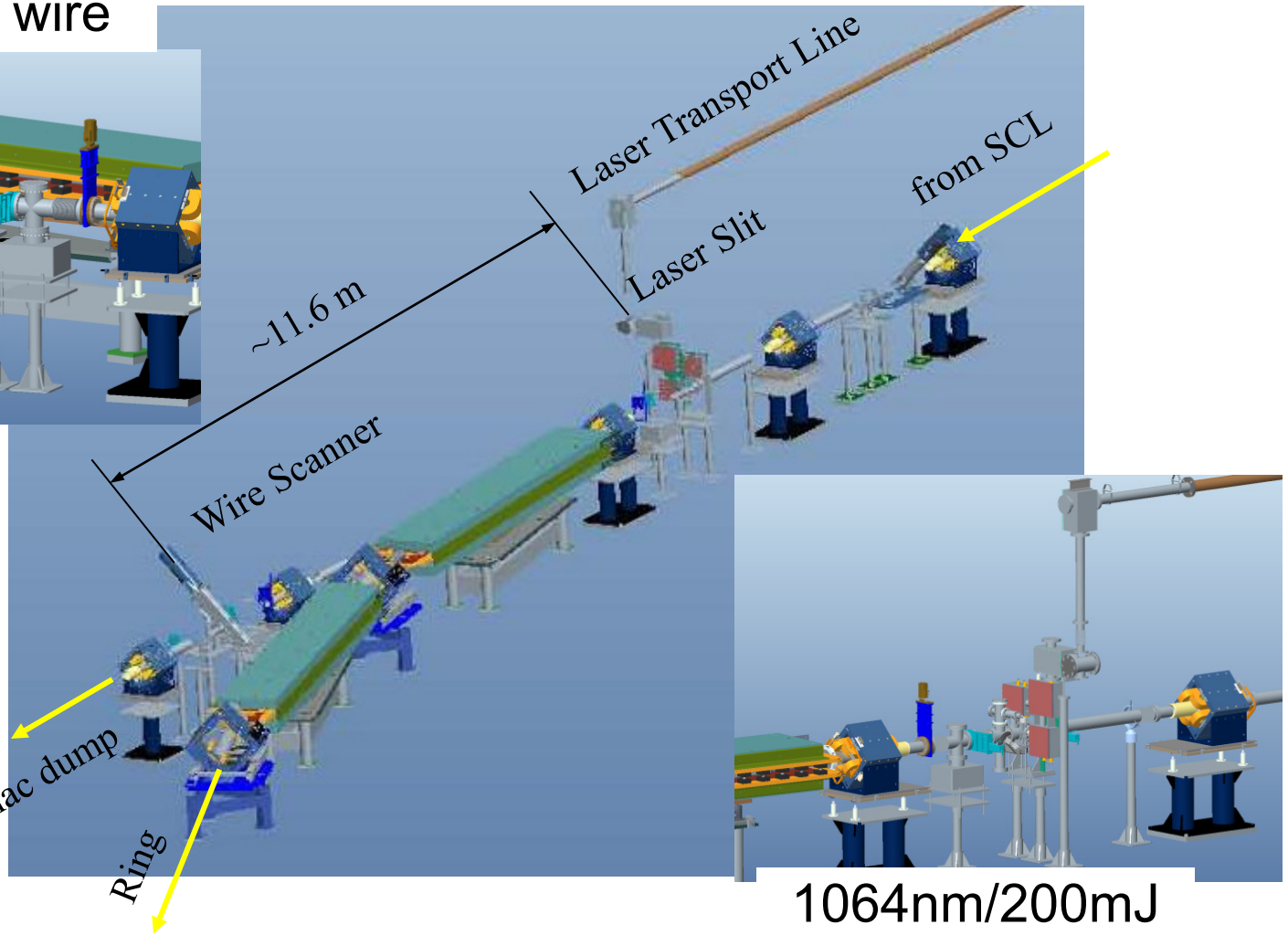
HEBT Laser Emittance Scanner (design)



HEBT Laser Emittance Scanner (design)

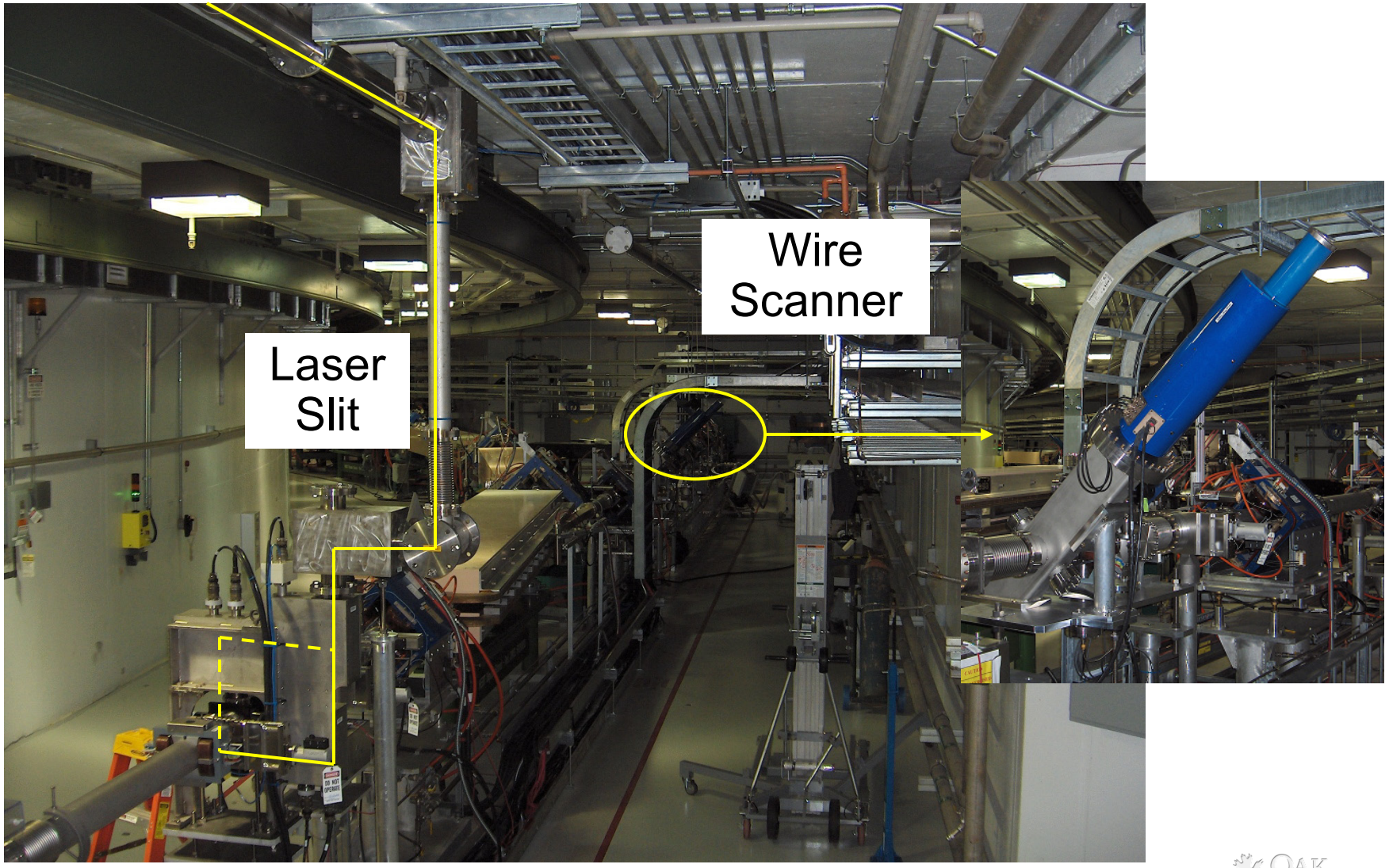
ϕ50 um Ti wire



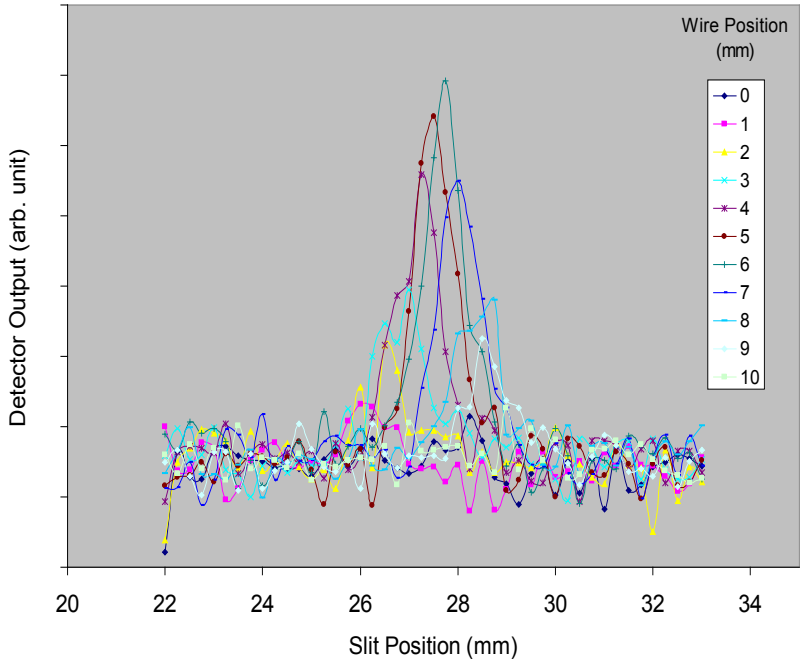


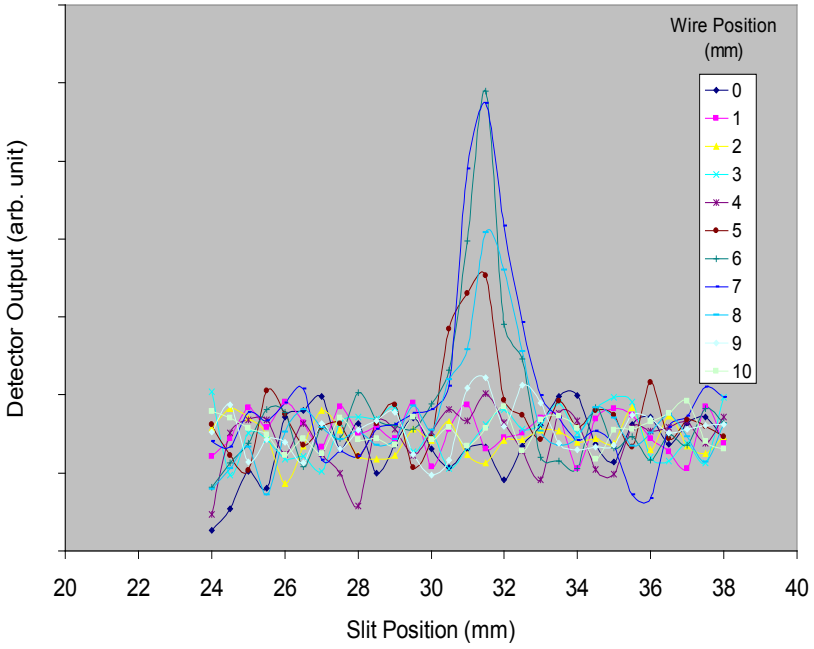
1064nm/200mJ
laser pulse

HEBT Laser Emittance Scanner (implementation)

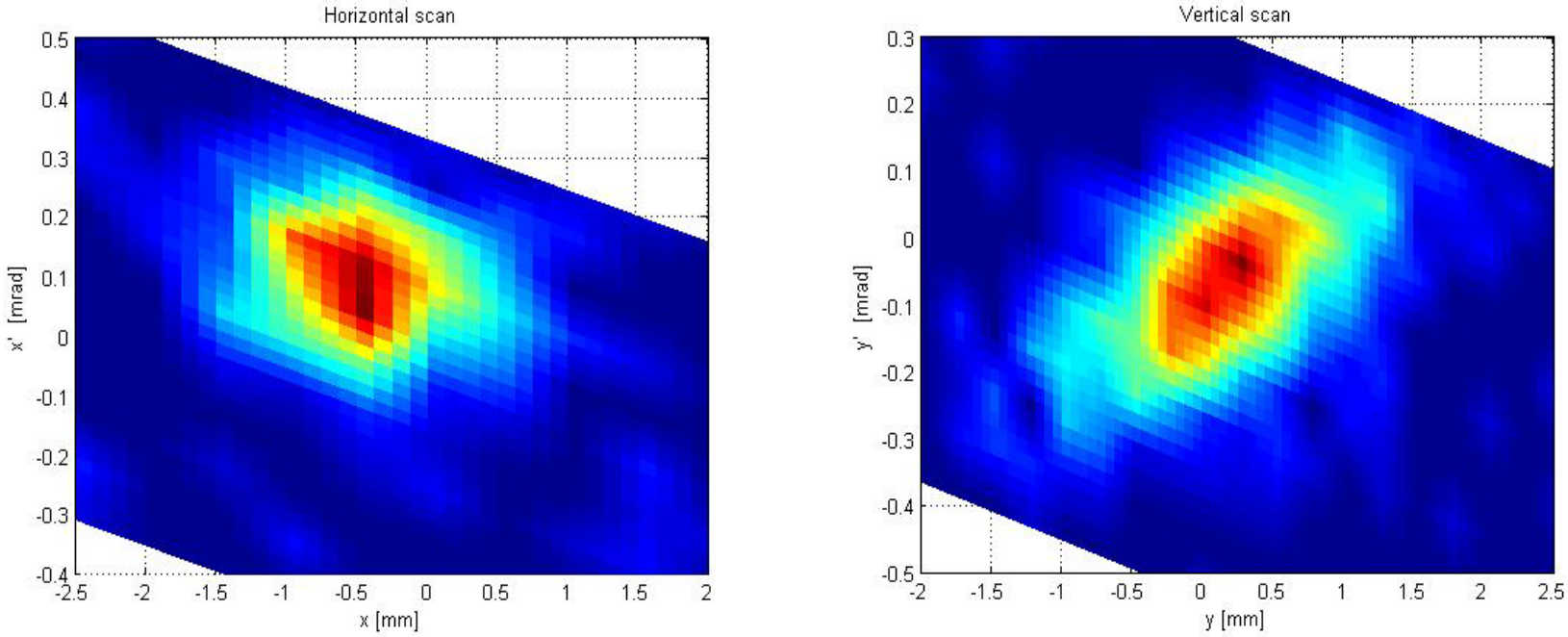


Laser Emittance Measurement
Step 1: $H^- \rightarrow H^0 + e^-$ with Laser Wire
Step 2: $H^0 \rightarrow p^+ + e^-$ with Wire Scanner





Emittance Measurement



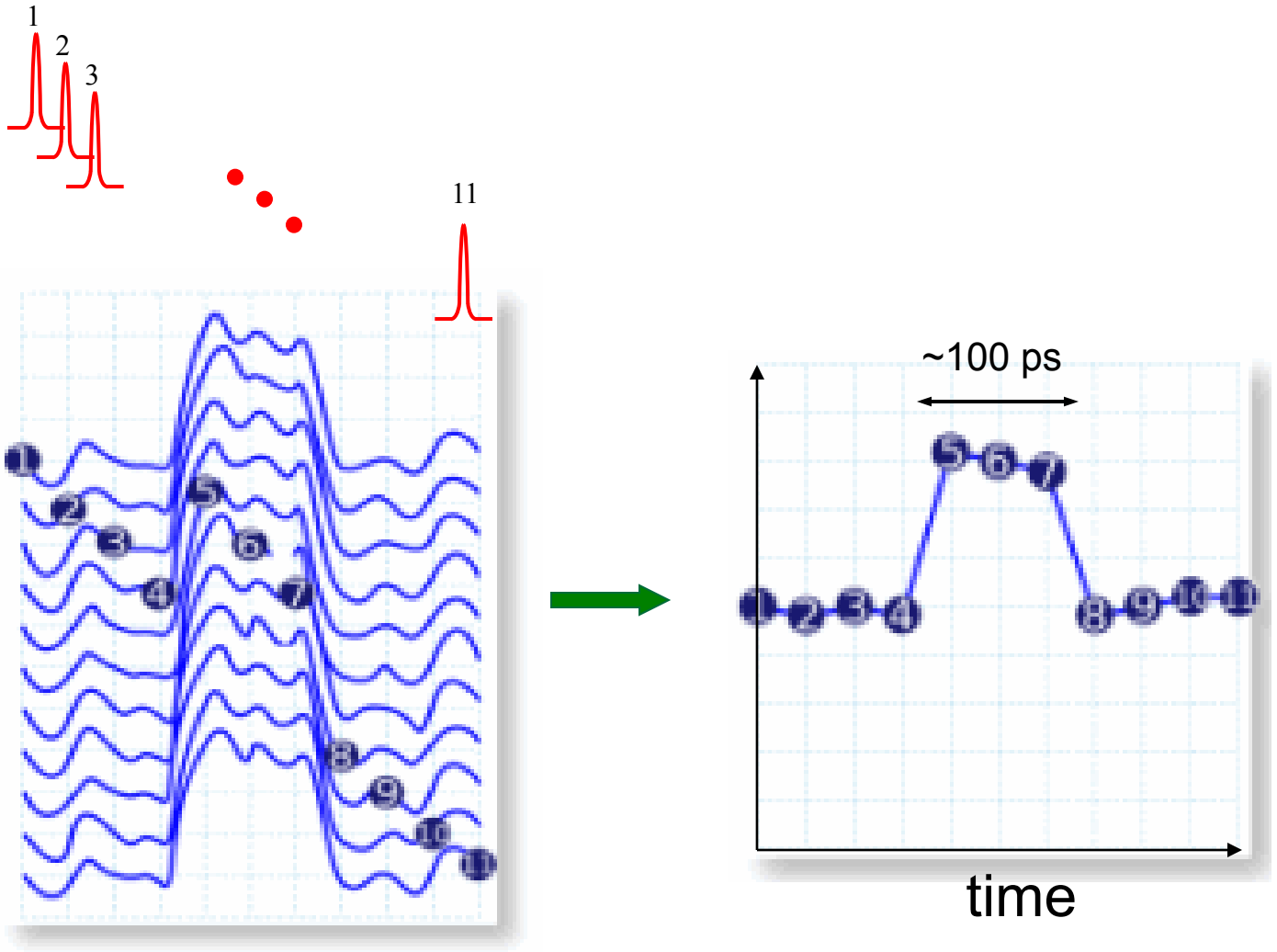
Measured emittance: ~ 0.2 mm·mrad

Signal-to-noise ratio will be improved through optimization of signal amplification and wire scanner scheme.

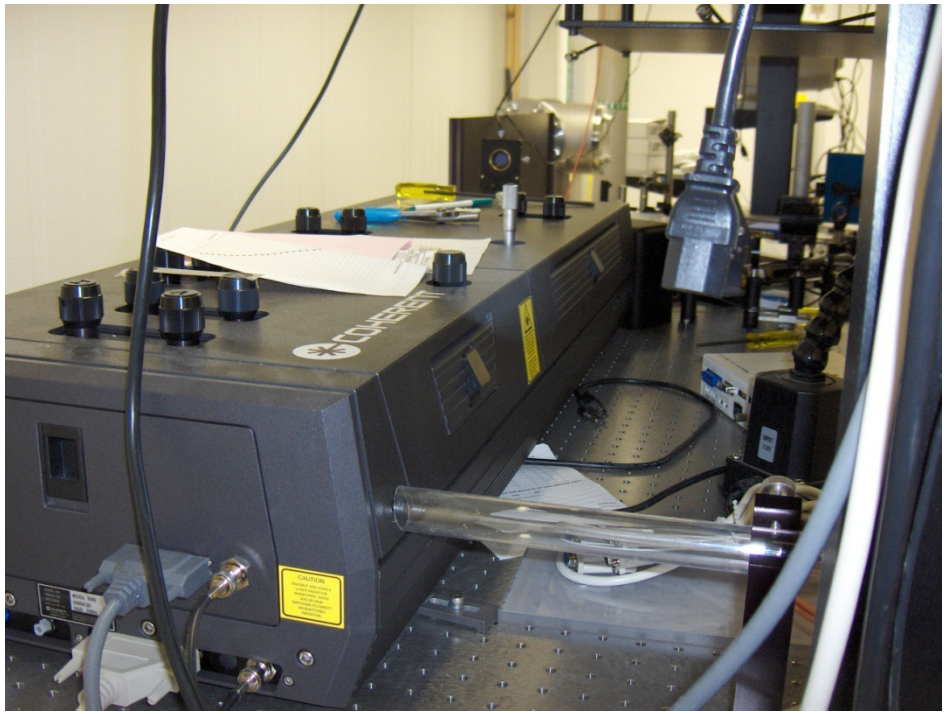
Laser Bunch Shape Monitor: a laser probed sampling oscilloscope

Laser pulses

H- pulses

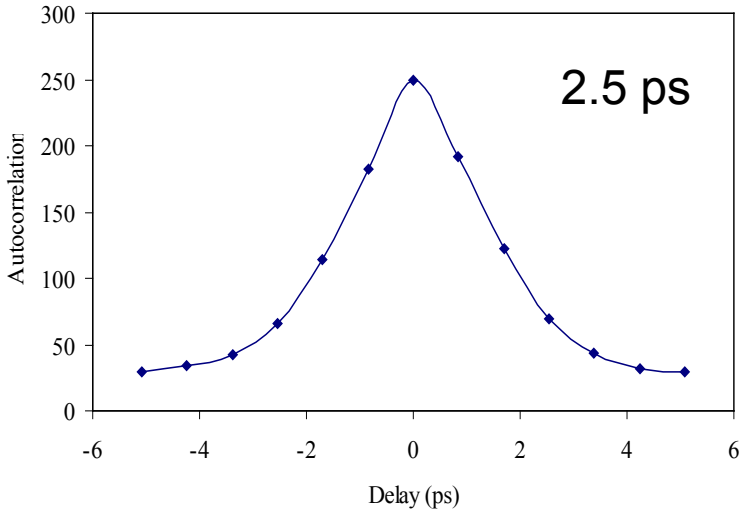


Mode-Locked Ti:Sapphire Laser

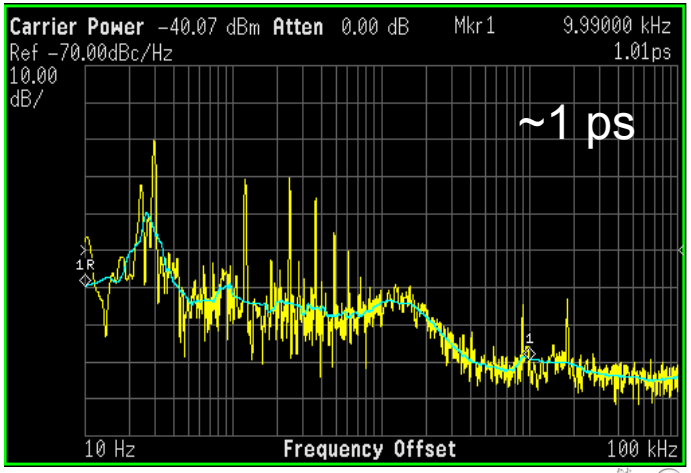


Repetition rate: 80.5 MHz (5th sub-harmonic of the accelerator clock)

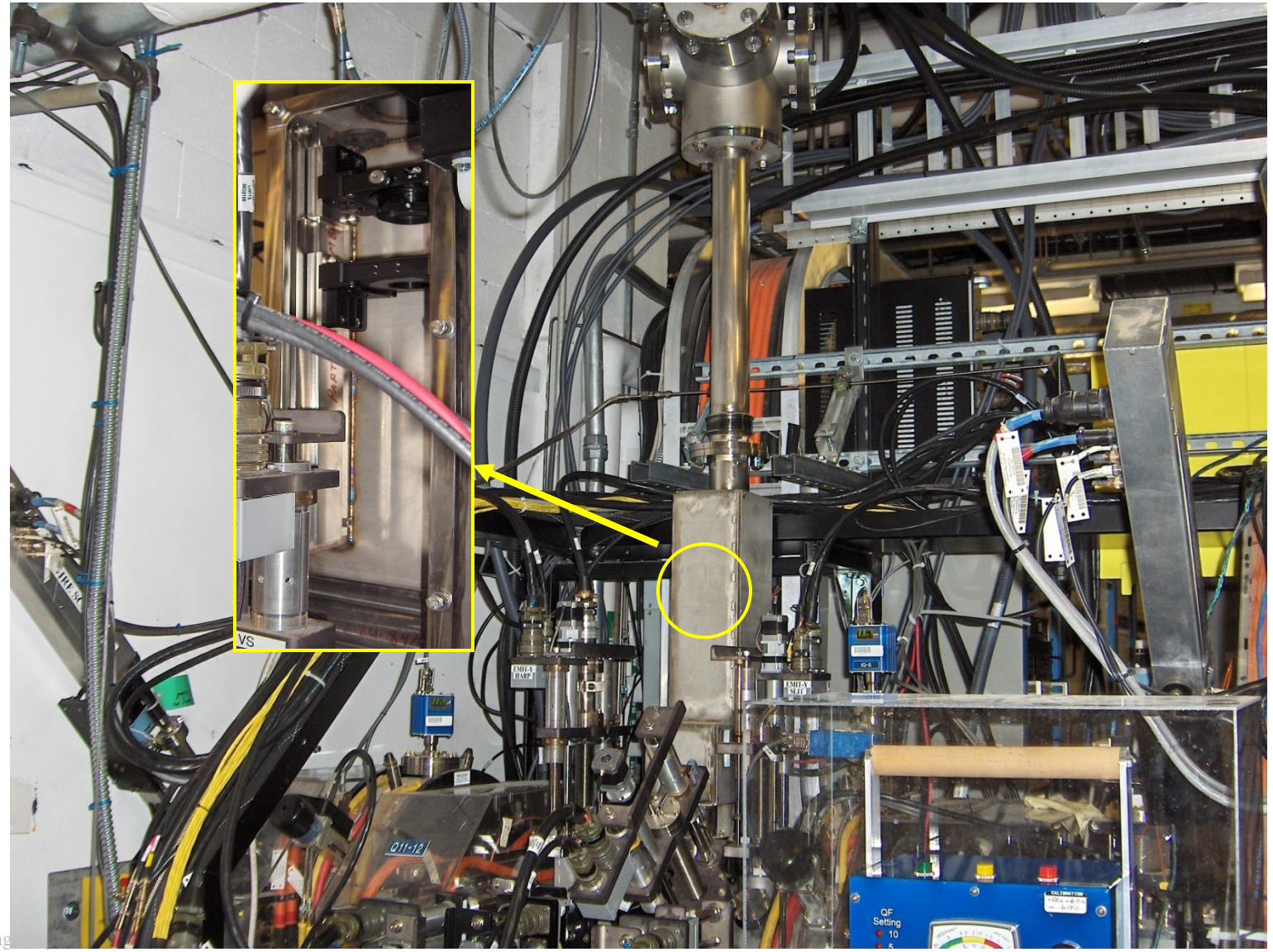
Pulse Width



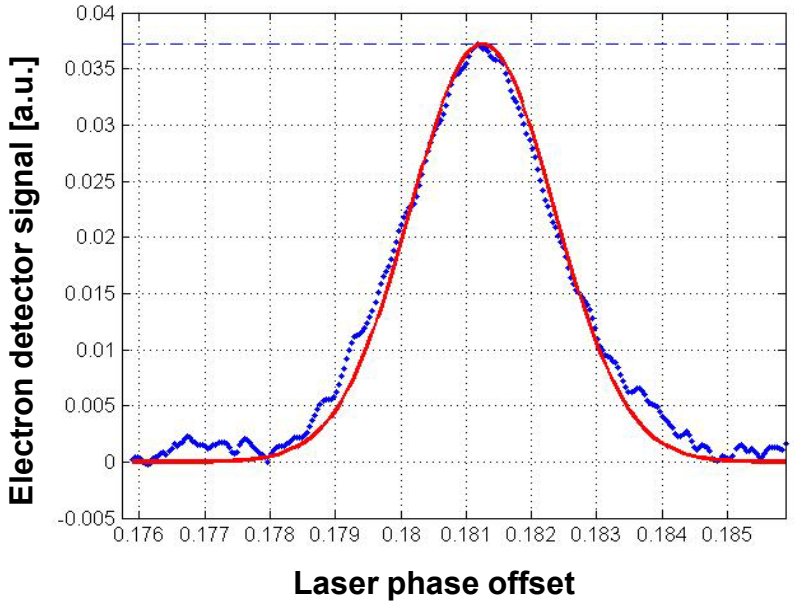
Timing jitter



Laser Interception Site



Preliminary Measurement using Mode-Locked Laser and MCP at 2.5MeV



RMS size: ~ 110 ps

Saeed, *Proc. EPAC 2006*, p. 3161-3163.

Experiments are ongoing to investigate fiber transmission

- Damage threshold
- Launch efficiency
- Output beam quality
- Pulse jitter
- Pulse width broadening

Effects of Radiation

All optics related components are enclosed within ¼" thick stainless steel boxes

Hardware	Distance from beam line	Findings
Radiation Hardened Laser (Big Sky U1064-HN)	Laser head (~ 1') Driver (>20')	Laser driver was damaged within 1-2 days. Not clear about head.
Optics stepper motors motorized flippers	~ 1'	No damage found
Picomotor actuators	> 5'	Open-loop (ν8301) is OK. Close-loop (ν8310) encoder was damaged
Optical power meter heads (Ophir L50(150A))	> 5'	No damage found
Gigabit Ethernet cameras (Prosilica GE640)	> 5'	1 of 4 was damaged

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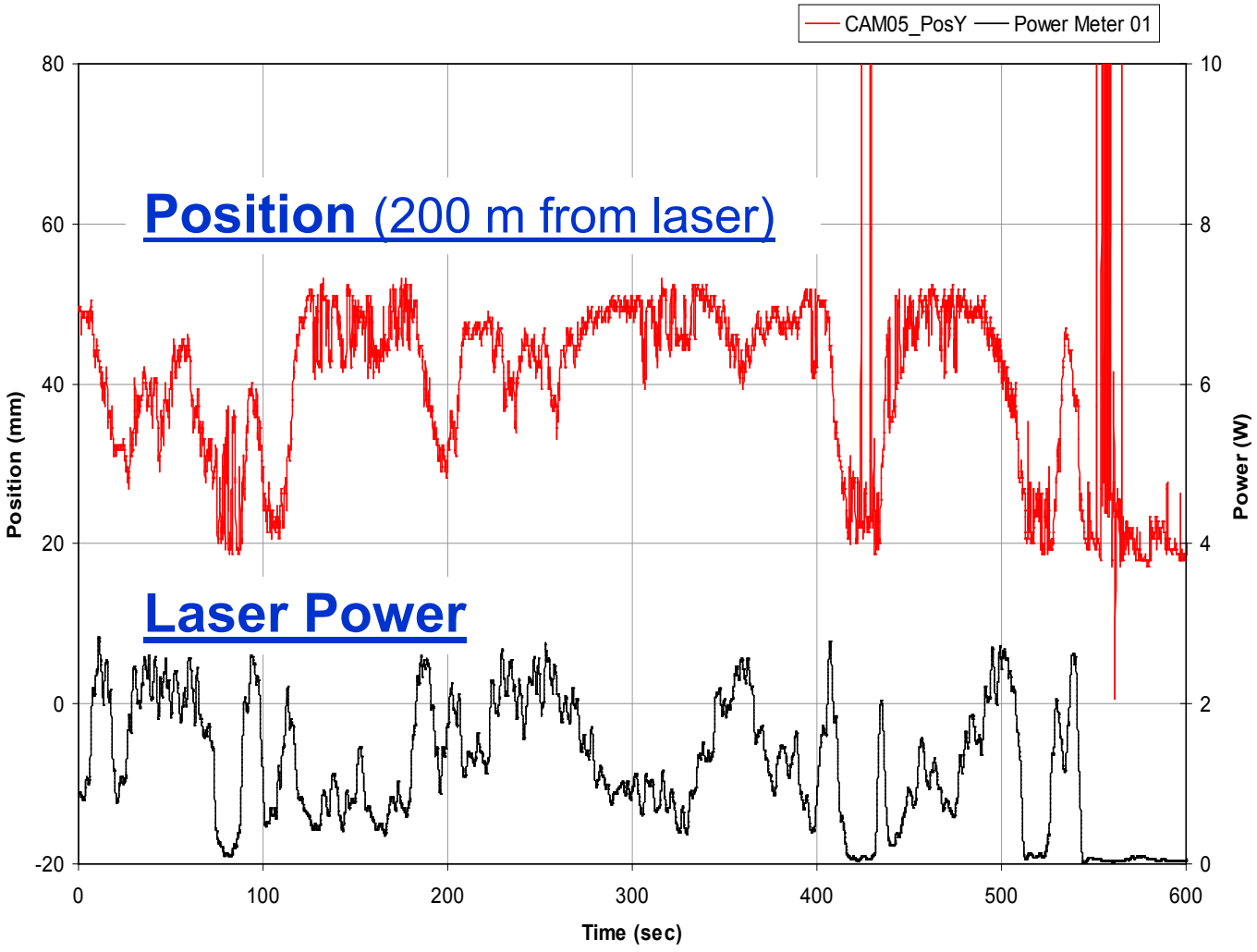
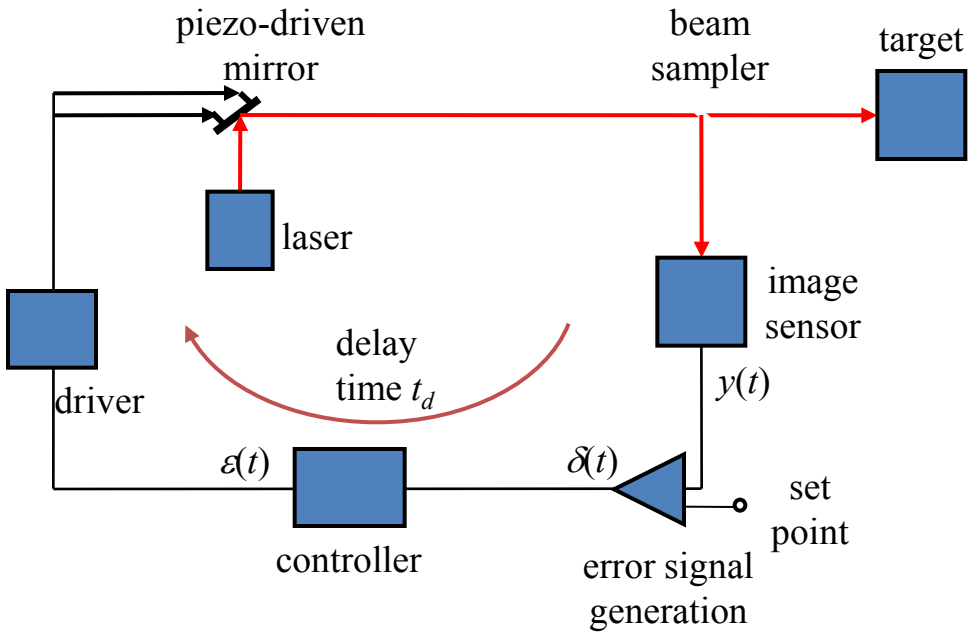
Laser Beam Pointing Instabilities

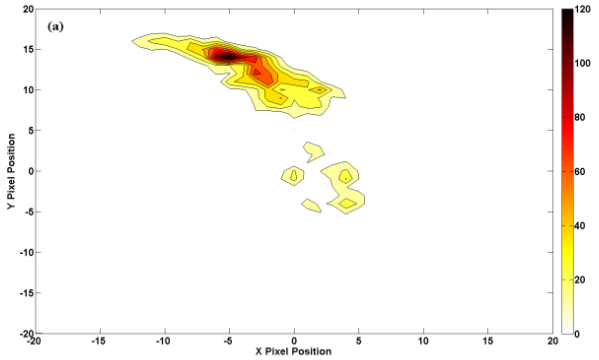


Laser Beam Position Stabilization with Feedback Control

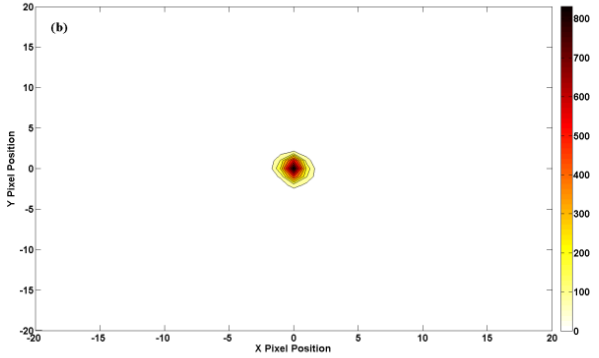


$$y(t) = x(t) + g\varepsilon(t - t_d),$$
$$\varepsilon(t) = \lambda\varepsilon(t - t_d) + k\delta(t),$$
$$\delta(t) = Y_T - y(t).$$

Feedback off



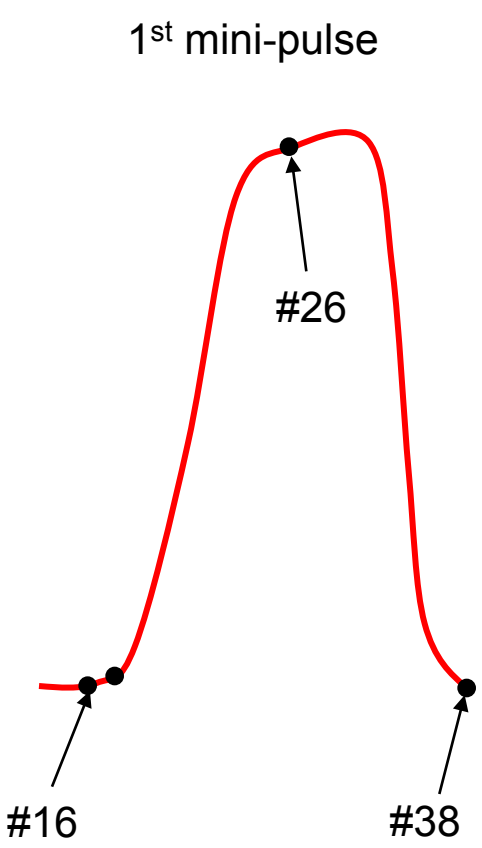
Feedback on

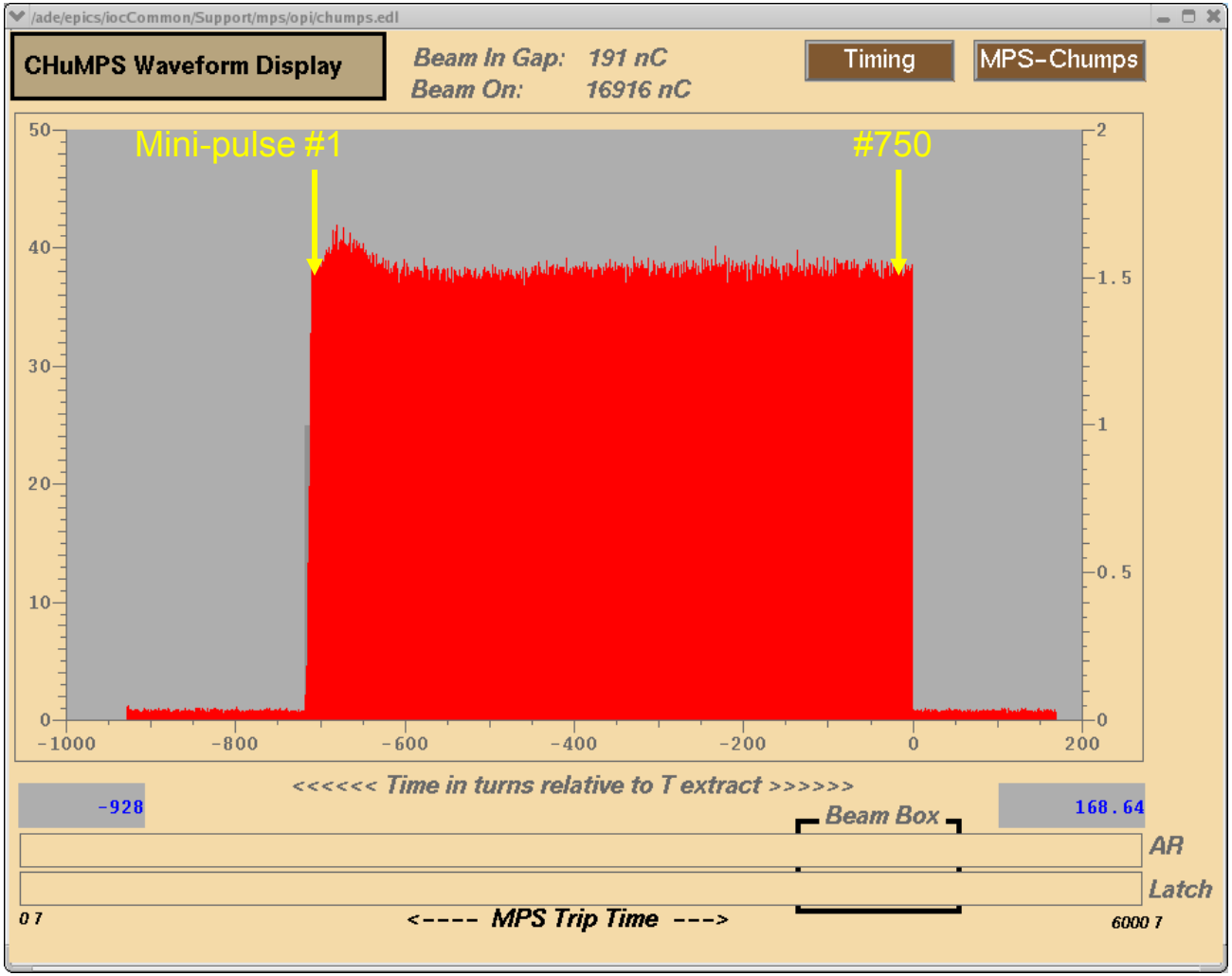


±1.25 mm @ 250 m

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

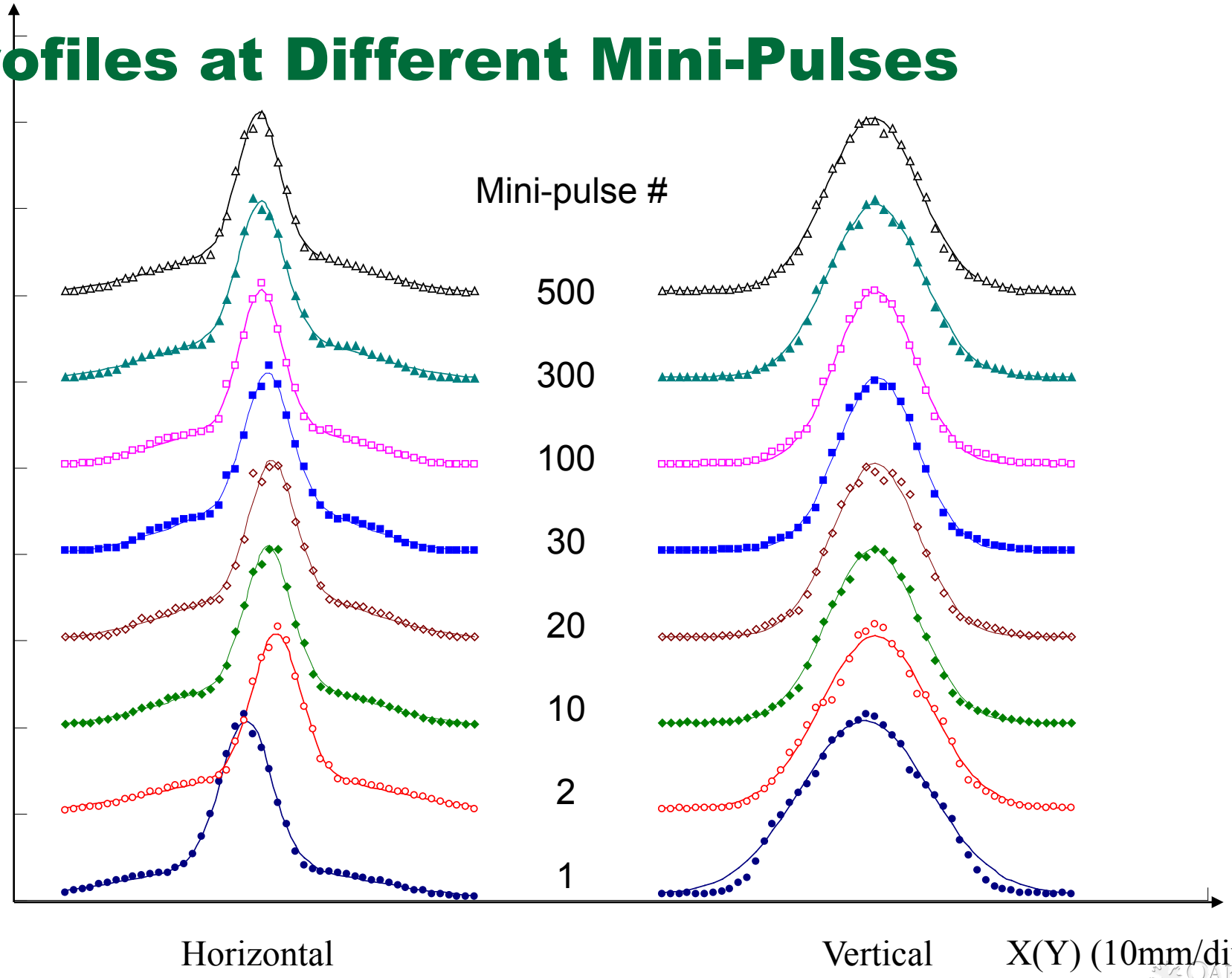
Longitudinal Scan of Beam Train with Laser Wire





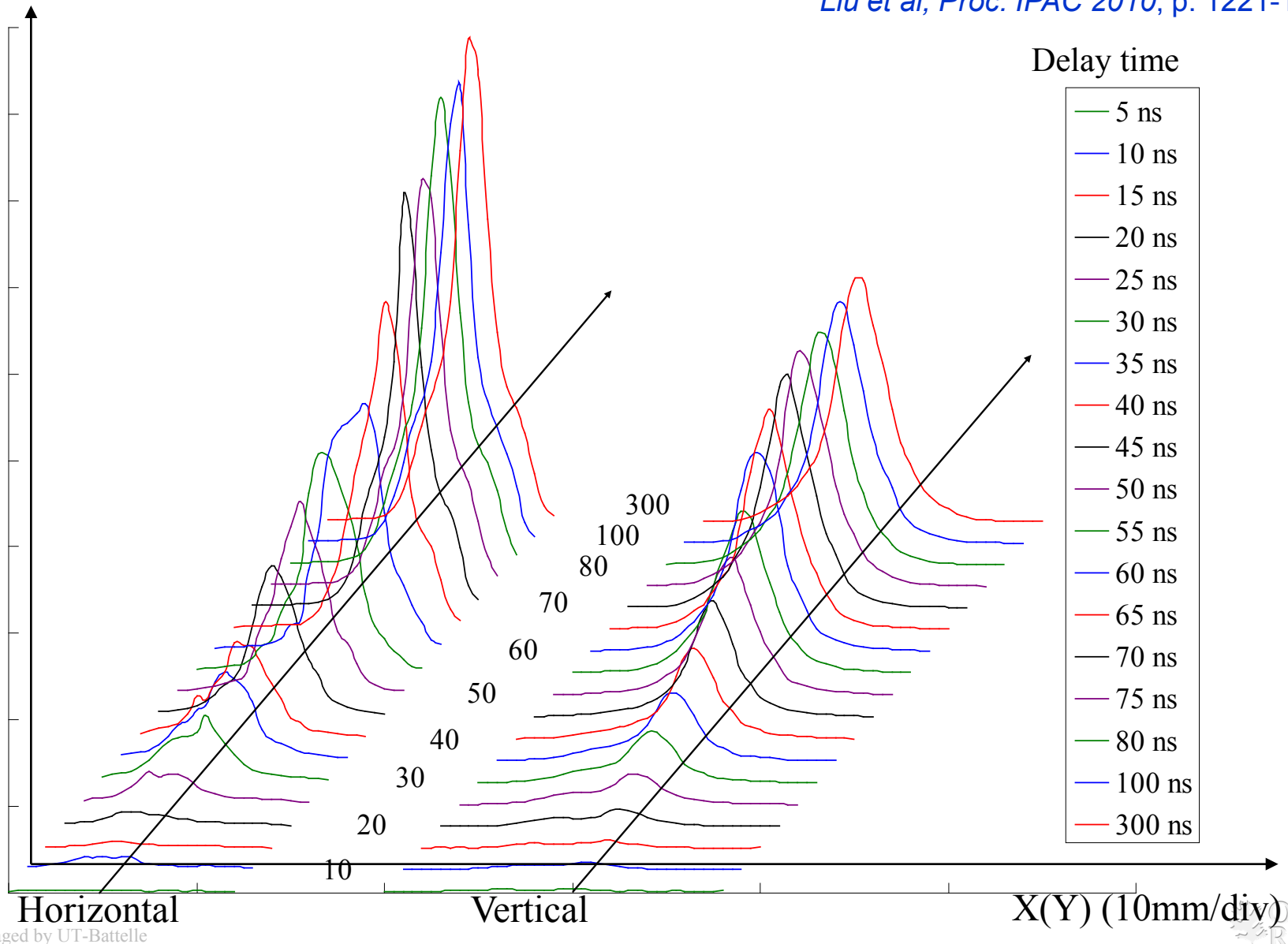
Laser-beam interaction location (unit: sub-rev turn, ~30 ns)

Profiles at Different Mini-Pulses



Profiles within a Single Mini-Pulse

Liu et al, Proc. IPAC 2010, p. 1221-1223.



Summary

- Three different types of laser based diagnostics have been developed at SNS for measuring H^- beam parameters
- World-first large scale, operational laser wire system has been implemented at SNS-SCL. Profile measurement has been conducted on 1 MW, neutron production beam.
- Laser emittance scanner has been commissioned at SNS HEBT.
- Laser based bunch shape monitor is being developed at SNS MEBT.
- Laser based ion beam diagnostics at accelerator facilities is reliable and realistic and can provide novel capabilities.
- More laser based diagnostics are expected as a result of applying fast-growing laser technology.