SCL Laser Profile Monitor Design and Implementation

Halo 2003 Workshop

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S. Assadi, A. Aleksandrov, W. Blokland, A. DeCarlo, C. Deibele, P. Gibson, W. Grice, M. Hechler, T. Hunter, P. Ladd, J. Kelly, G. Murdoch, K. Potter, J. Pogge, D. Purcell, T. Shea, and D. Stout

Oak Ridge National Laboratory

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Outline:

1) Why Lasers rather than conventional carbon wires?

2) Optics Design

4) Electron detection, magnet design, transport line layout and more

5) Measurement results from MEBT and BNL 200 MeV line.

Multi National-Lab Diagnostic Collaborators

ORNL	ORNL diagnostic, Mechanical, Cryo, Alignment, magnet Design, electrical groups.
BNL	Peter Cameron, Roger Connolly, Craig Dawson, Chris Degen, Sheng Peng, Marty Kesselman, Bob Sikora,
LANL	Mike Plum, John Power, Bob Shafer, Jim Stovall
LBL	Larry Doolittle, Darryl Oshatz, Alex Ratti
SLAC	Joe Frisch , Keith Jobe, Marc Ross,Jim Crisp (FNAL), Bob Webber (FNAL)

The Spallation Neutron Source Partnership

~500 People work on the construction of the SNS accelerator

Oak Ridge, Tennessee

35° 49' N , 83° 59' W

Why Choose Laser-wire over Conventional Wire?

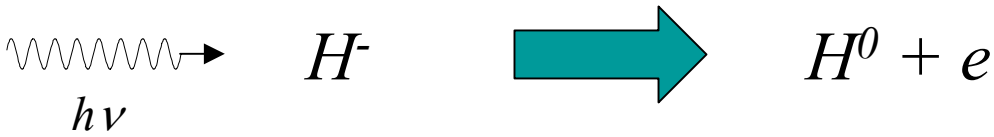
Conventional Wire

- Requires off-operation with 100 μs macro-pulses at low rep rate
- Ablation from the wire may contaminate the SRF cavity
- Signal to noise not a problem
- Maintenance requires vacuum access
- Very radiation hard

Laser Wire

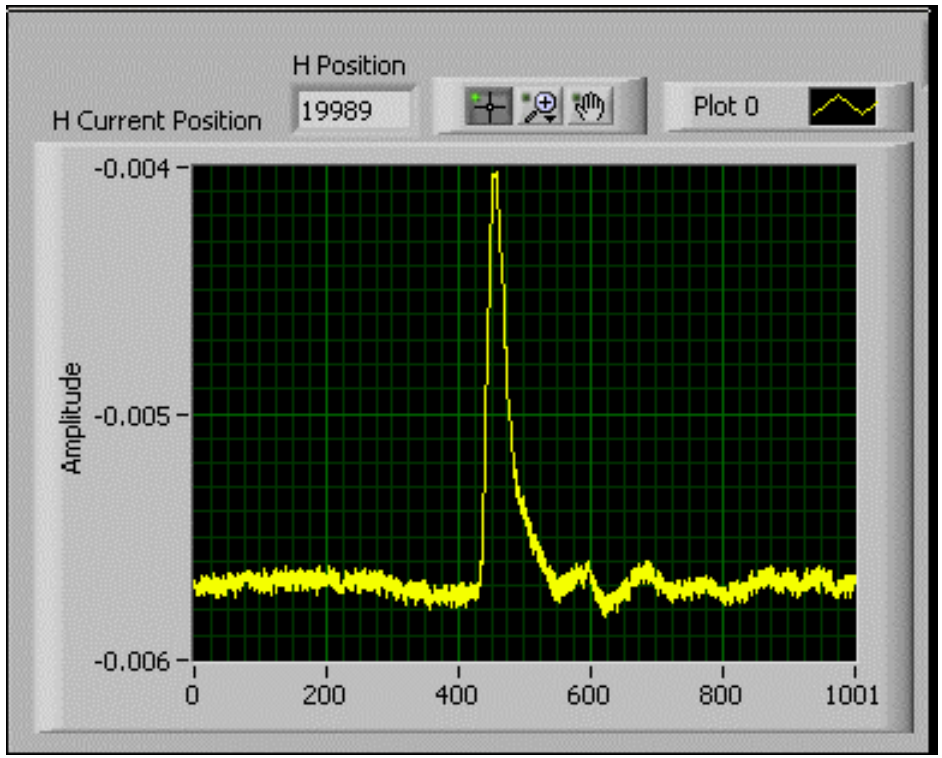
- Minimal impact on normal operation
- Virtually no impact on SRF cavities or vacuum
- Low signal to noise ratio on differential current measurements but excellent s/n using electron collector.
- No parts intersects beam directly
- Radiation hard @ λ<1500nm

What does the Laser do? Photo-neutralization



Requirements

- *High peak power*
- *Small spot size*
- *Transverse scan*
- *Temporal stability*
- *Detection*

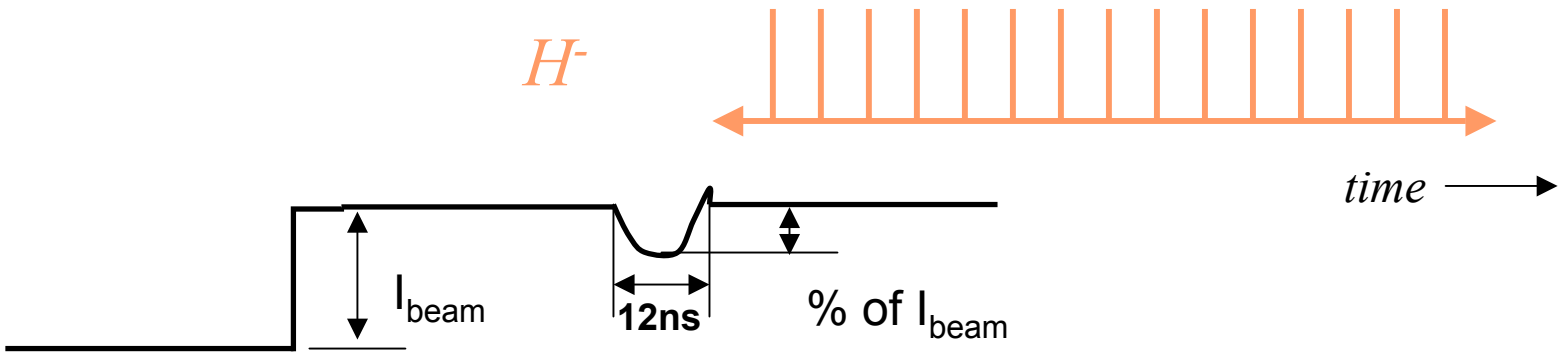


Cross-section is well known therefore stripping efficiency calculation is a matter of algebraic manipulation (tech. notes)

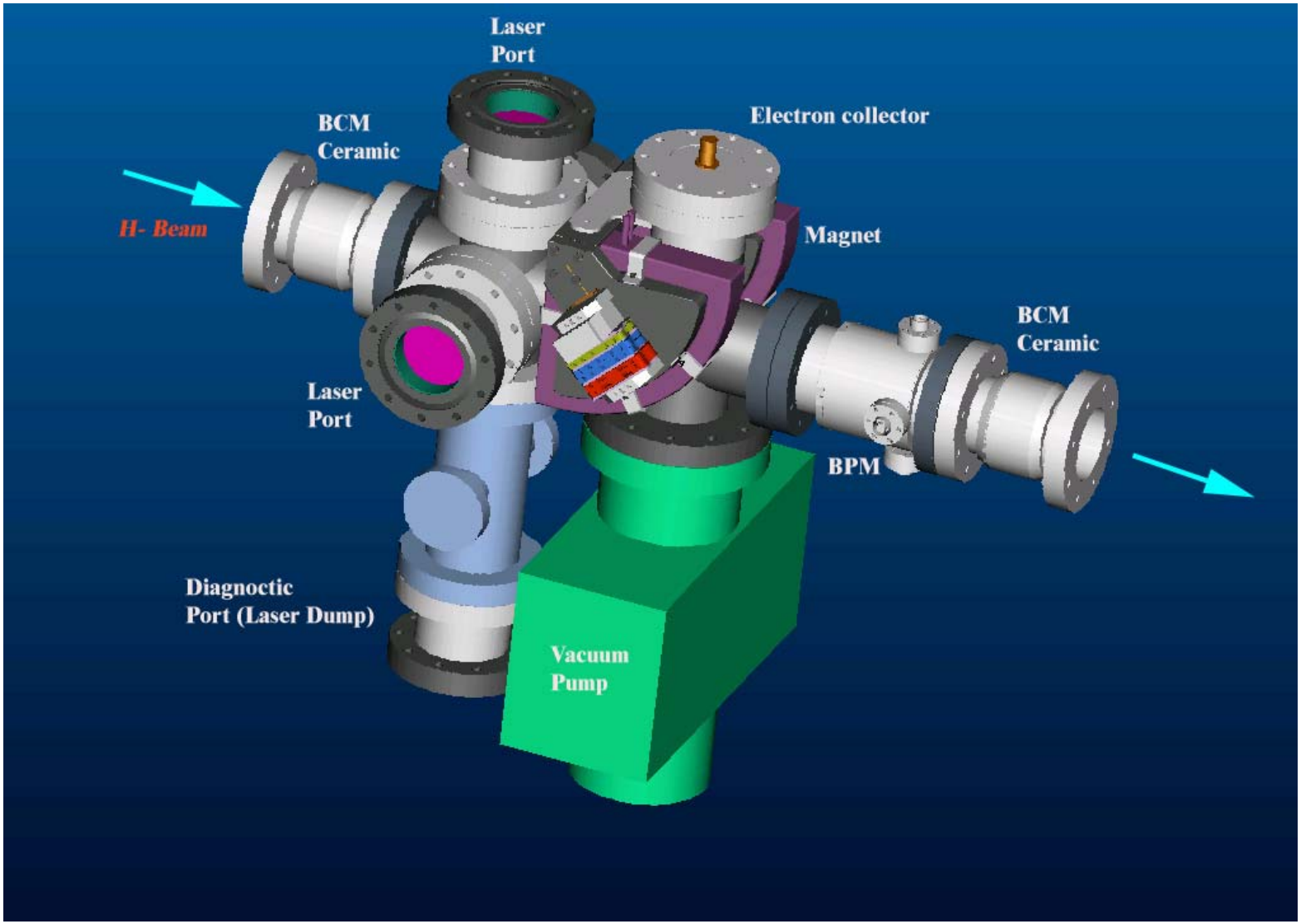
Calculated stripping efficiency r [%]

It is safe to assume stripping efficiency of 15%

		Nominal emittance			2 x Nominal emittance		
		1.5 x 2.5 mm	2 x 2 mm	2.5 x 1.5 mm	2 x 3.5 mm	2.8 x 2.8 mm	3.5 x 2 mm
200 mJ	300MeV	19%	23%	30%	14%	17%	23%
	1GeV	13%	16%	21%	9%	12%	16%
∞	-	20%	25%	33%	15%	18%	25%



Prototype Vacuum Box Installed on MEBT

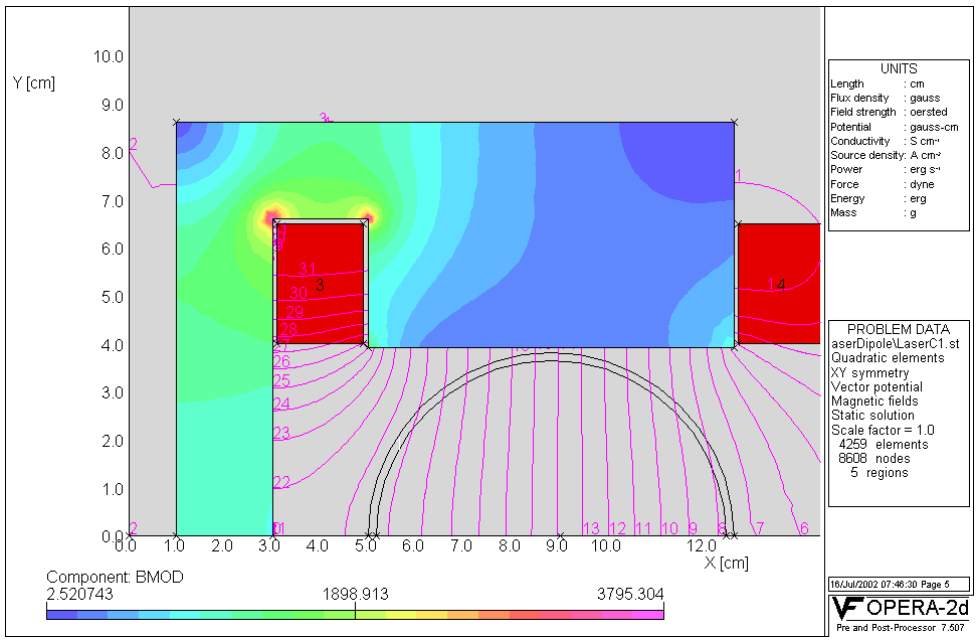


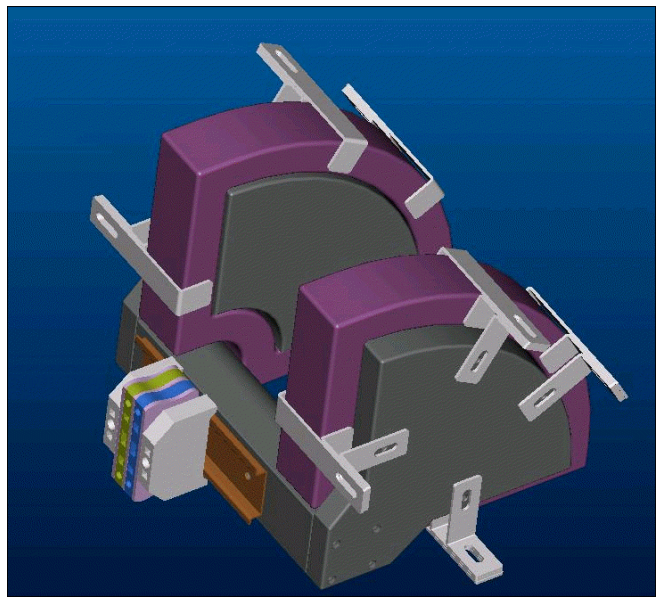
Required Magnetic Field to Collect Electrons in SCL:

Very Simple air cooled dipole magnet is designed

Table1.

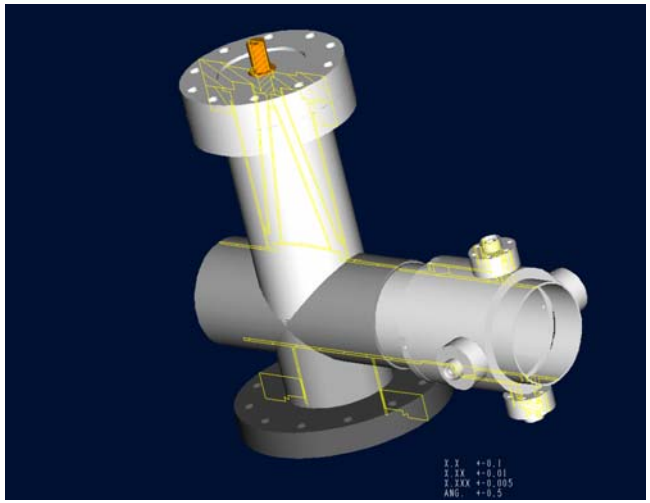
E[MeV]	186	204	223	241	259	277	296	314	332	351	369	387
B[Gs]	70	74	77	80	84	87	90	94	97	100	103	105
E[MeV]	438	489	540	591	642	694	745	796	847	898	949	1000
B[Gs]	113	121	128	136	143	150	157	163	170	177	183	190

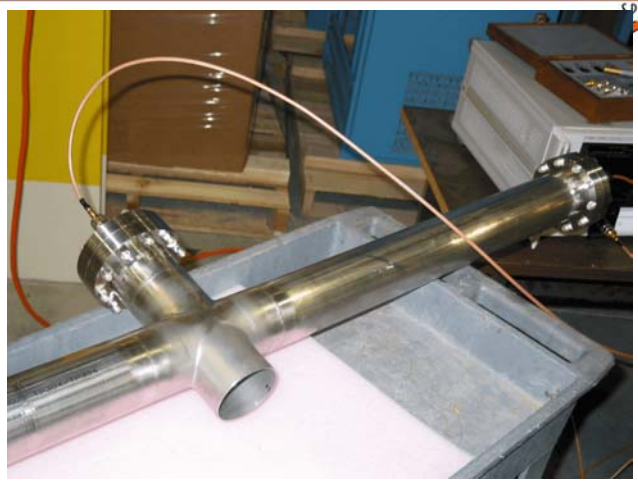




Direct measurement of the liberated electrons via the electron detector

Design



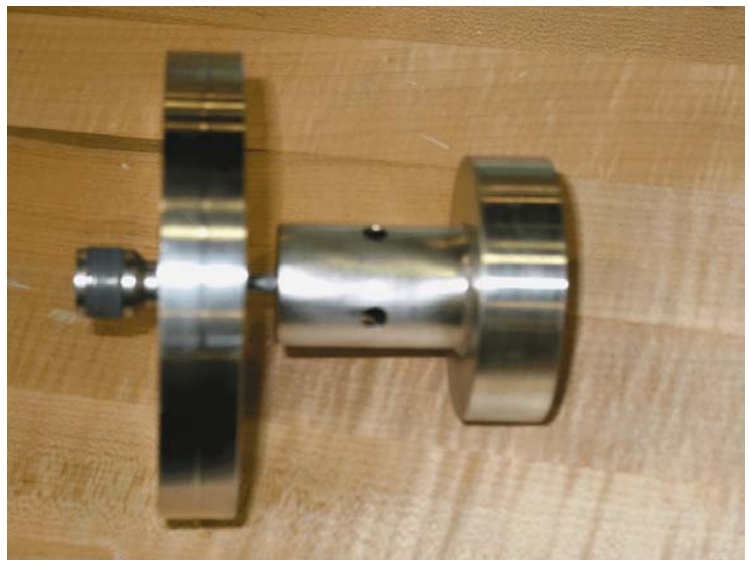


Testing

The design of the electron detector is complete and 75 dB of noise (rf) rejection is obtained

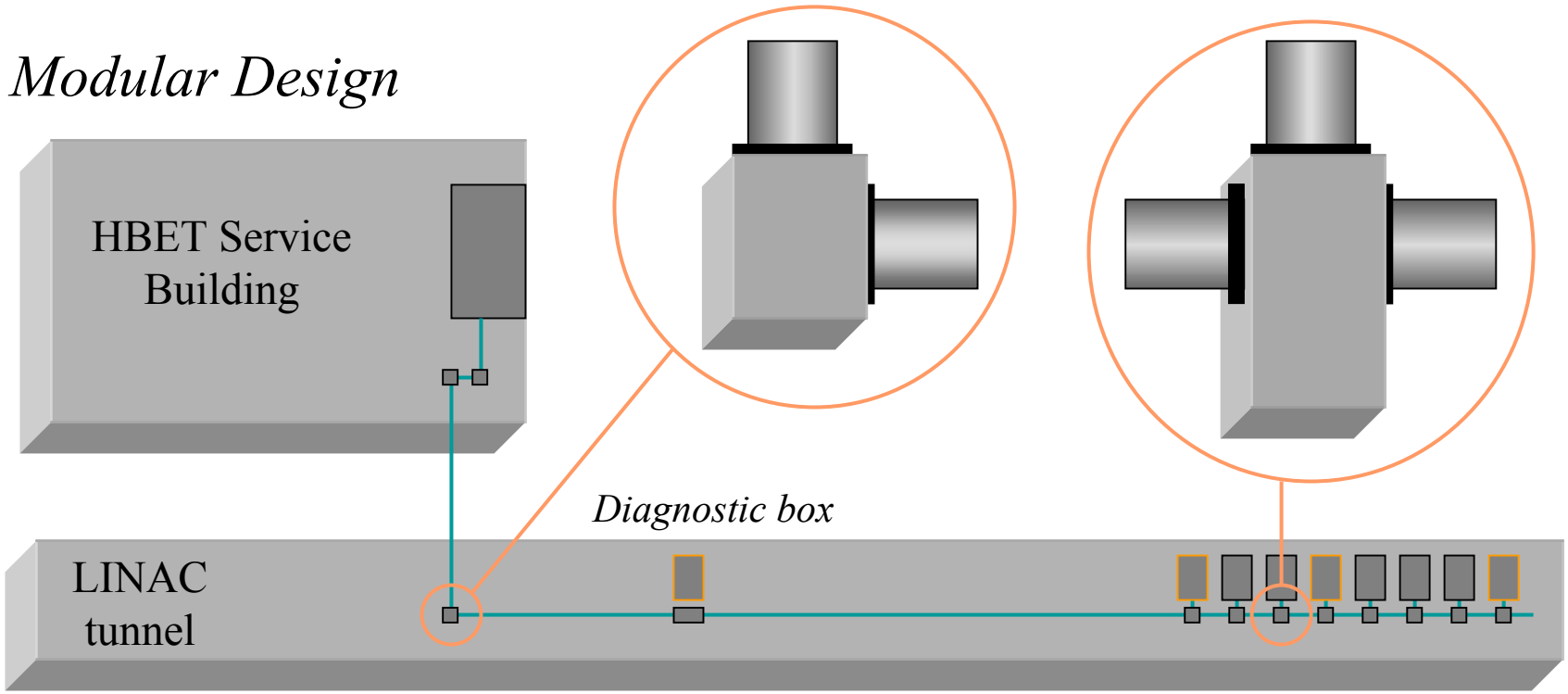
- Advantages:
  - –large number of electrons
  - –charge integrating amplifier similar to BLM
  - –Energy of electrons is well defined
  - –Electron beam is well collimated

- Drawbacks
  - –External magnets are required
  - –In vacuum collectors are required
  - –Might suffer from beam loss background



Prototype

Transport Line



- *Boxes secured to building walls, ceilings, etc.*
- *Designed to accept a variety of optical components*
- *Cable feedthroughs*
- *Pipes mounted between boxes*

4 LW from 186 MeV,

4 LW from 386 MeV

Laser Wires Locations

Tolerances and Optics Requirements

	Δx (μm)	Δy (μm)	Δz (μm)	$\Delta\phi_{yz}$ (mrad)	$\Delta\phi_{xz}$ (mrad)	$\Delta\phi_{xy}$ (mrad)
Focal point	1500	100	2000			
Scan assembly	375	25	100	10	1.3	.067
Focusing lens	375	25	100	Negligible effect	Negligible effect	Negligible effect

Steering mirrors	$\Delta\phi = 60$ μrad

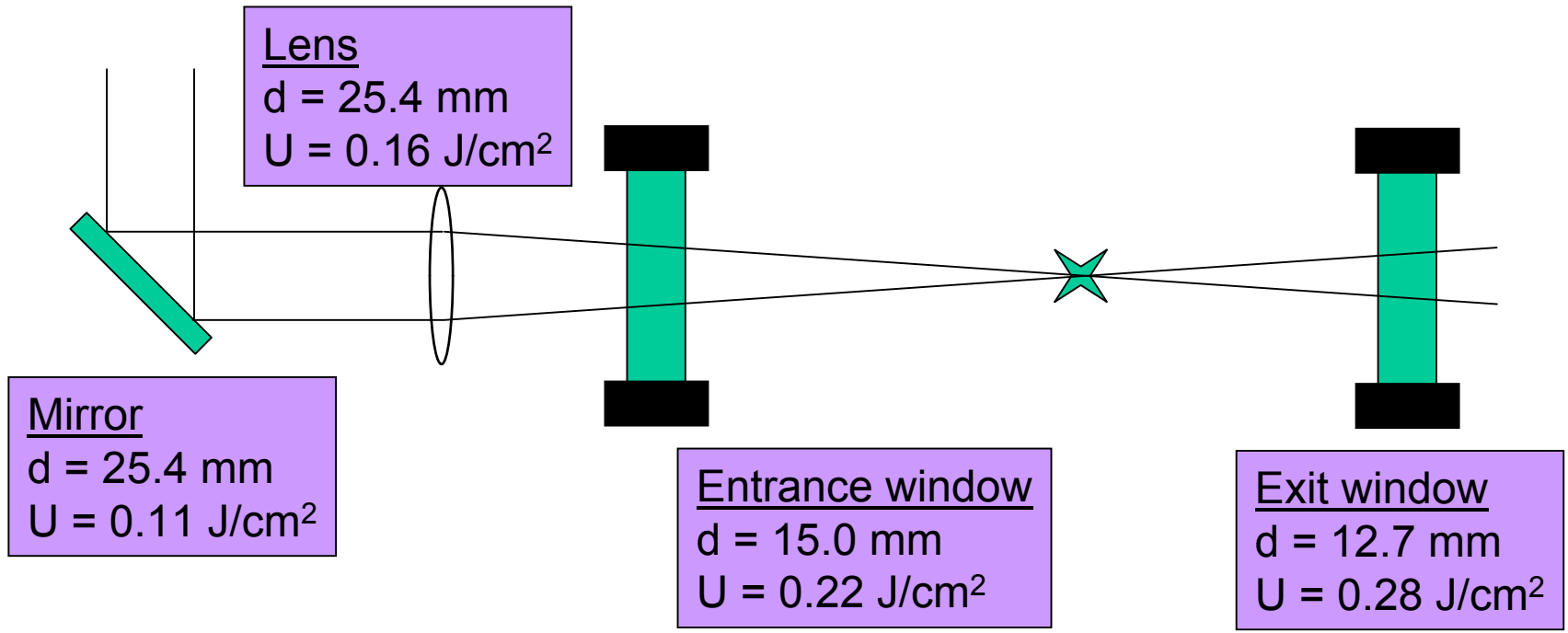
Optical Requirements

Beam size at target: 100μm – 2.0 mm
Beam size at windows: > 10 mm
Scan range: 35 mm (limited by window)
Lens travel: 30 mm
Beam stability at target: open question

Laser-Wire System

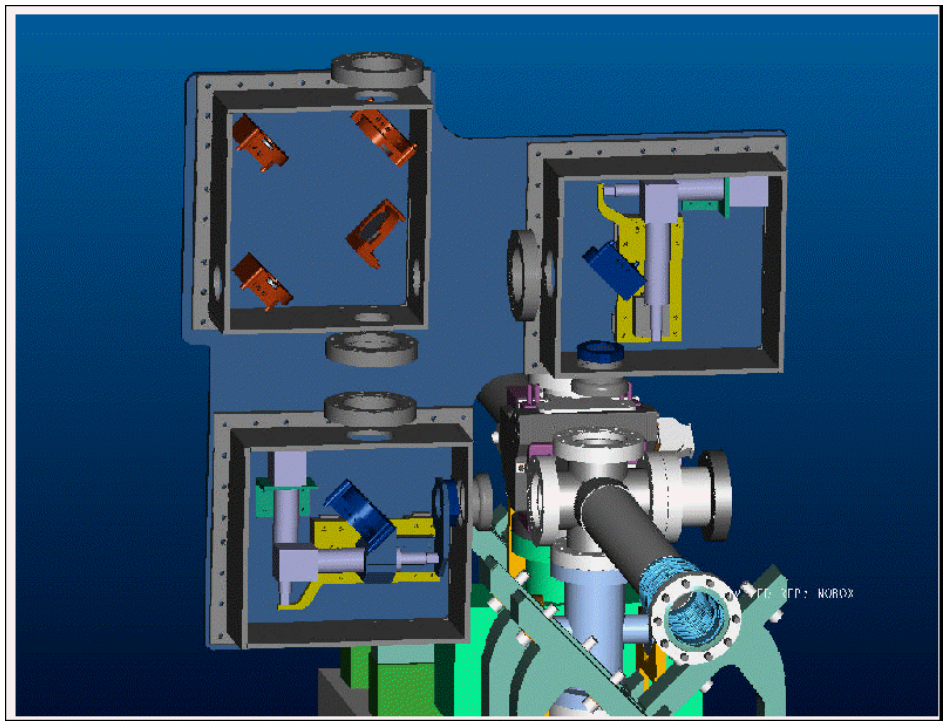
	Mirrors	Diagnostics
Laser Room	2-3	Beam profile Pulse intensity Pulse duration
Transport line	6	Beam size (4) Beam position(4)
Diagnostic	5	Beam size (2) Beam position (2)

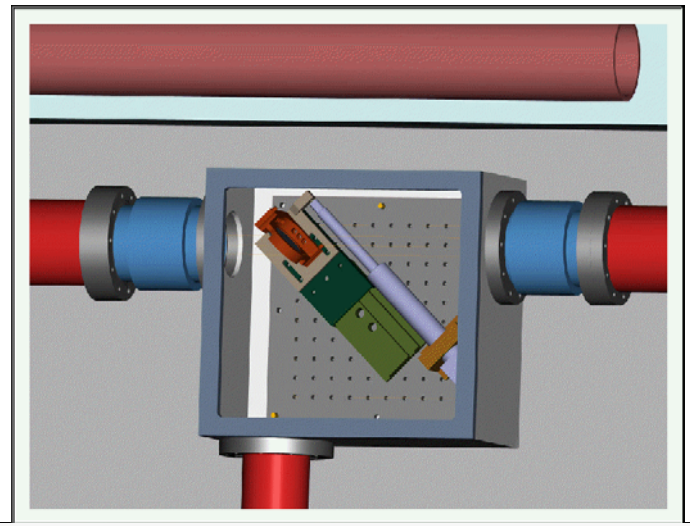
Spot sizes and peak energy densities for 200 mJ pulse

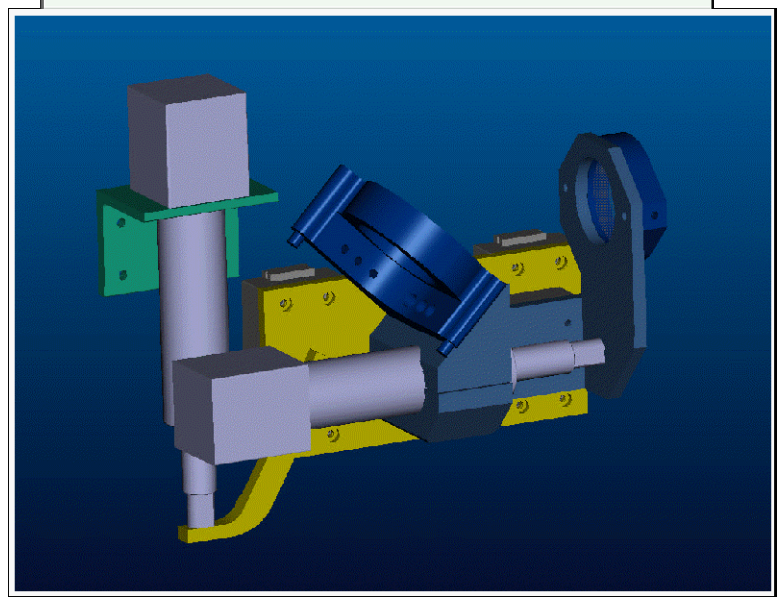


Damage threshold ~ 5 J/cm²

Warm Section with the laser wire beam boxes.







Off the shelf components
are used in the new design

Alignment Procedure

Pre-installation

•Scanning optics will be aligned on a bench.

•Position of aligned beam will be pinholed for installation.

Tunnel alignment

•Beam will be aligned incrementally.

•Transport line will be accessible at various locations.

Installation

•Steering mirrors will be used to divert the beam through the alignment pinholes. Some tweaking will be required.

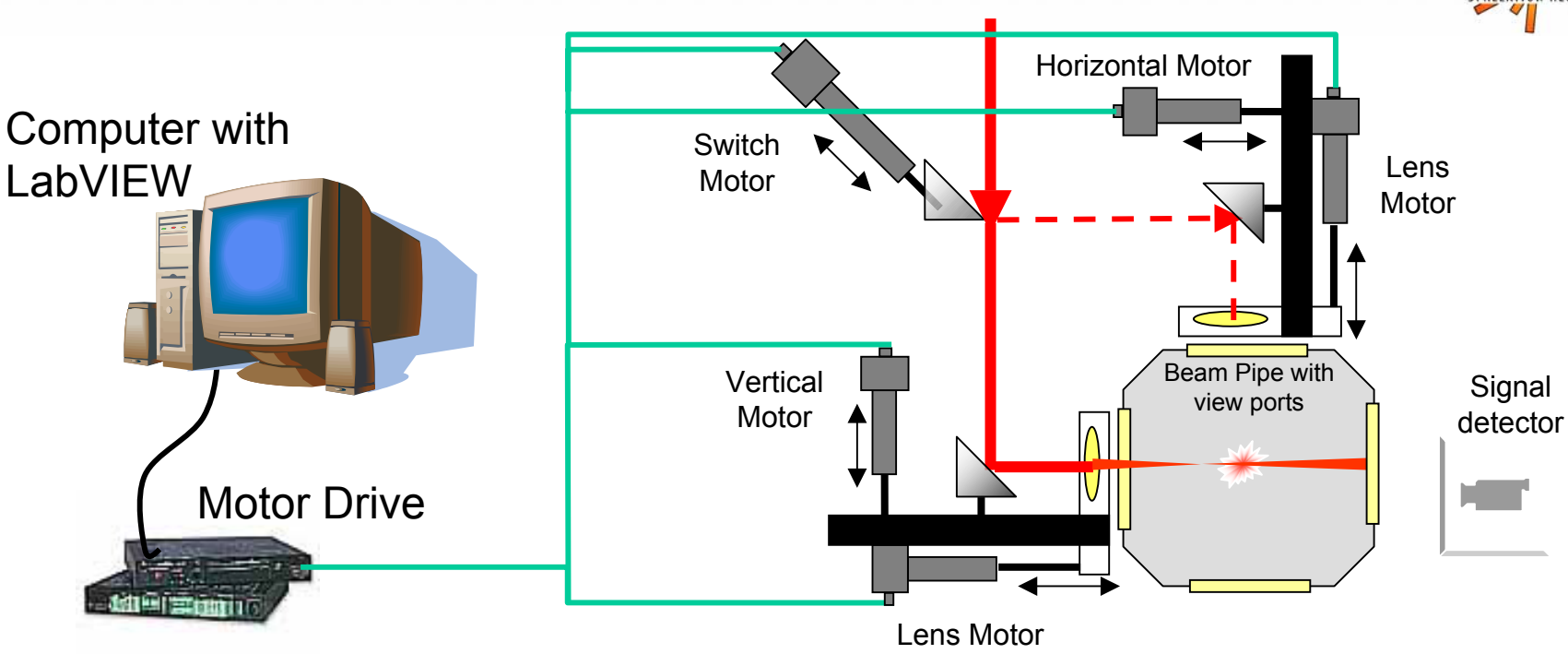
Day-to-day operation

•Alignment will be monitored during normal operation.

Laser-wire Data-Acquisition and Analysis

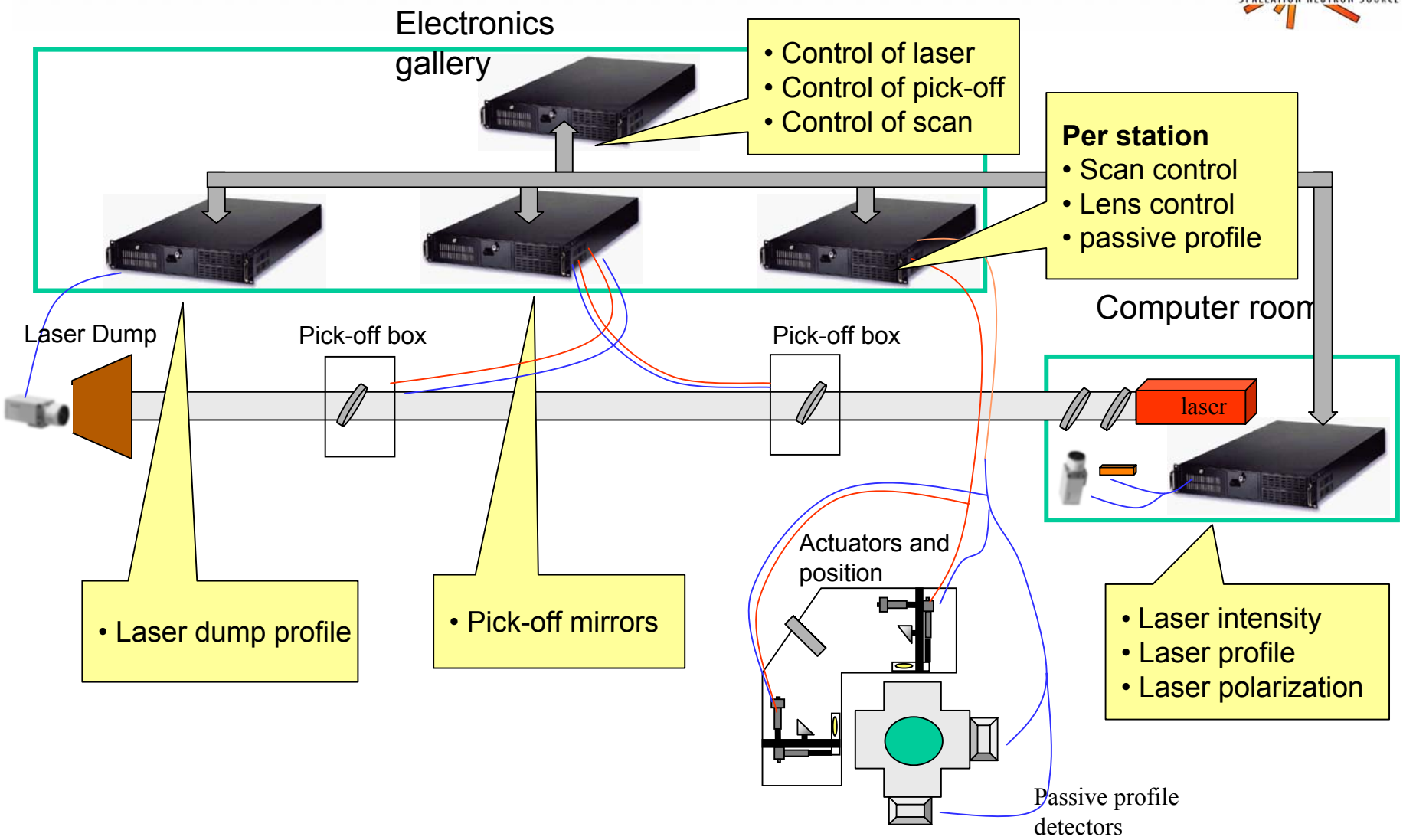
- Data-Acquisition
  - Acquire BCM, BPM, Electrode data at high speeds (possibly lower later) many times during one position (TDS 7404).
  - Acquire Laser Intensity and possibly spot size
- Analysis
  - Correct for Ion and Laser beam intensities
  - Fit and RMS calculation to profile
  - Calculate Laser spot size at Ion beam for correction
  - Possibly correct for position variation

Laser-wire Actuator System

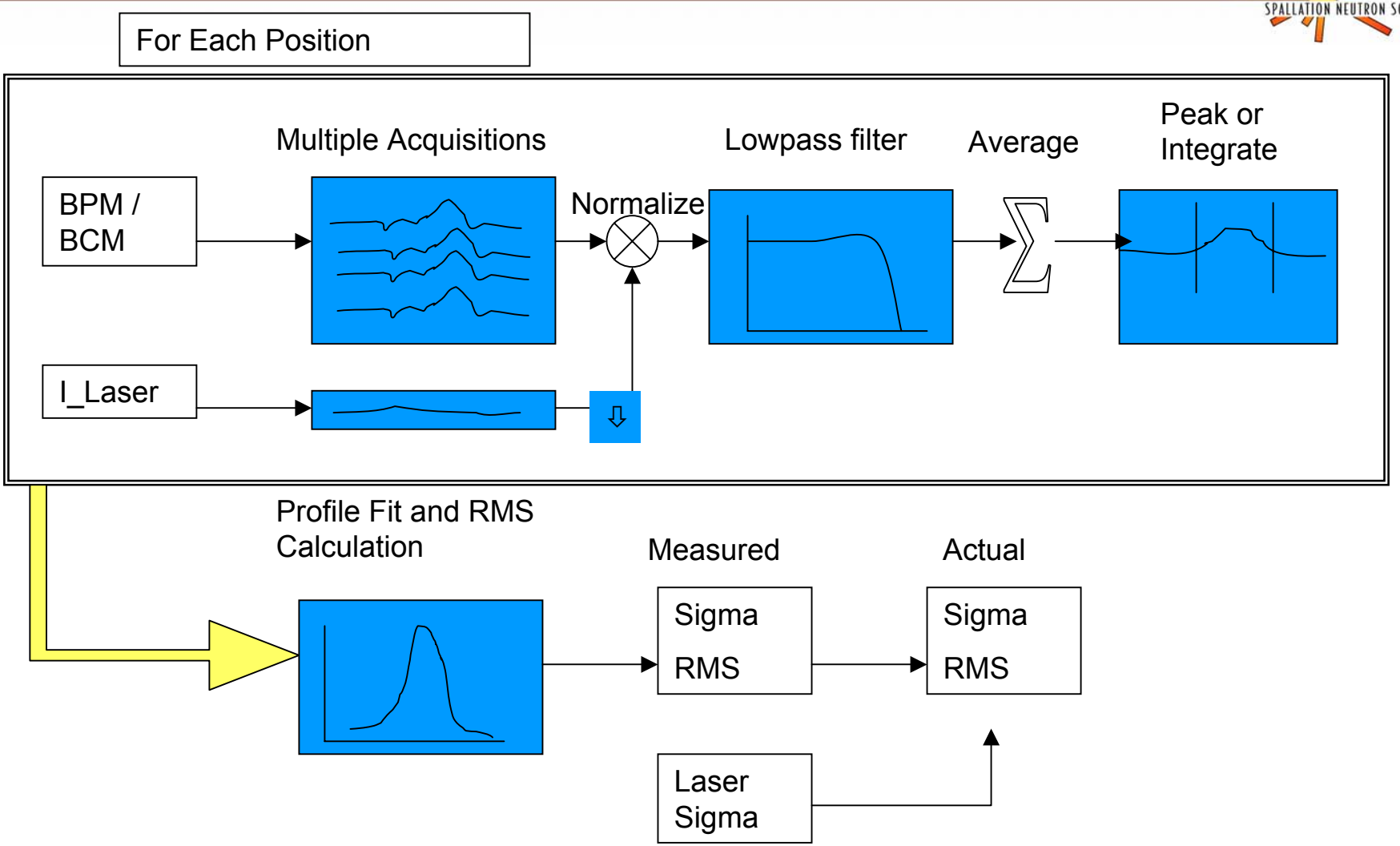


- A rack mounted 2U high PC (Desktop for test)
- NI PCI-7334 motion controller (inside PC) (x2 depending on switch mirror)
- PCI digitizer card (inside PC) (TDS 7404 for test)
- PCI Timing card (inside PC)
- NI MID-7604 4 axis stepper motor driver (1U drive) (x2)
- 4 Ultramotion HT17-075 radiation hard actuators with built-in potentiometer

Control Overview

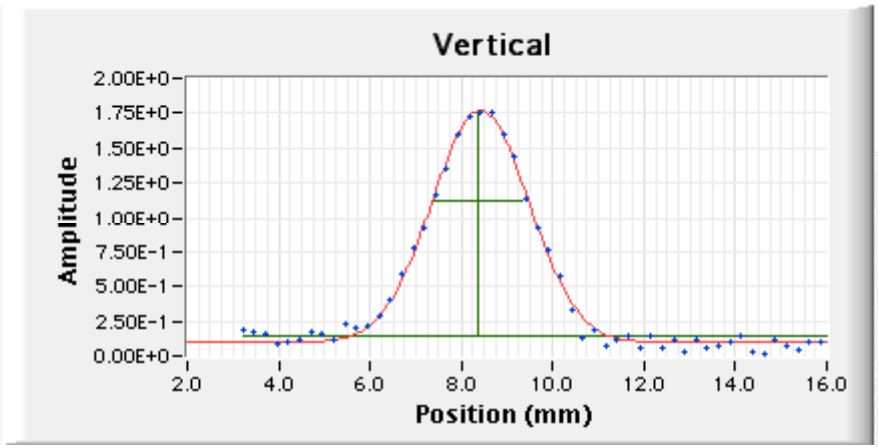


Laser-wire Analysis

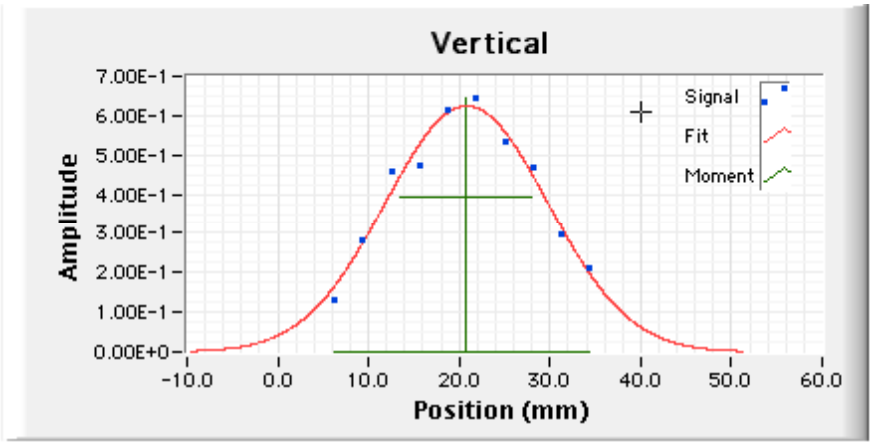


Assuming that the position of the Ion beam and Laser-beam are not varying during the acquisitions

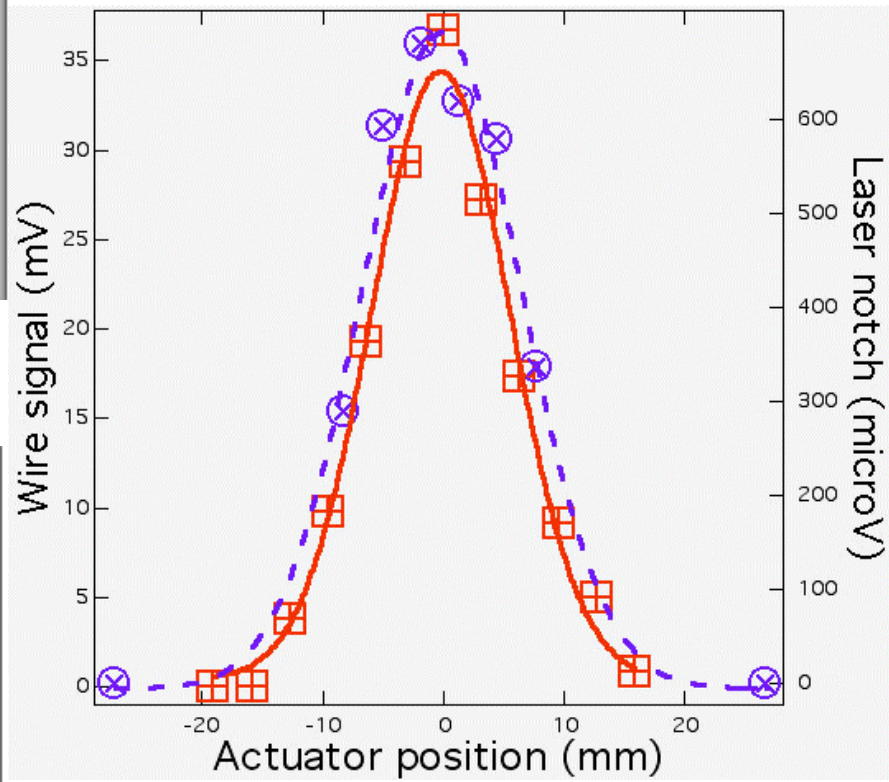
Successful Laser Profile Monitor Tests on SNS-MEBT at LBNL and BNL



Profile from the 2.5 MeV MEBT at Berkeley



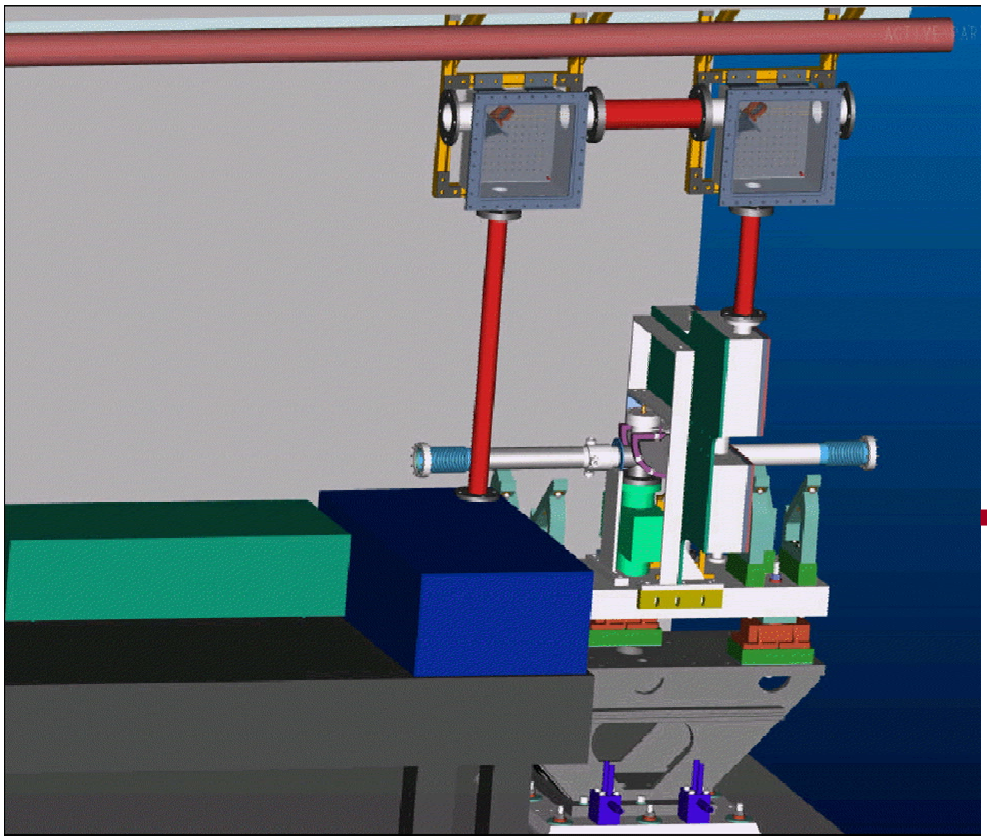
Profile from the BNL 200MeV LINAC



Comparison of Laser-wire and Carbon-wire data at BNL 200 MeV line

Courtesy of Roger Connlley

SCL Laser Profile Monitor – Tests on MEBT

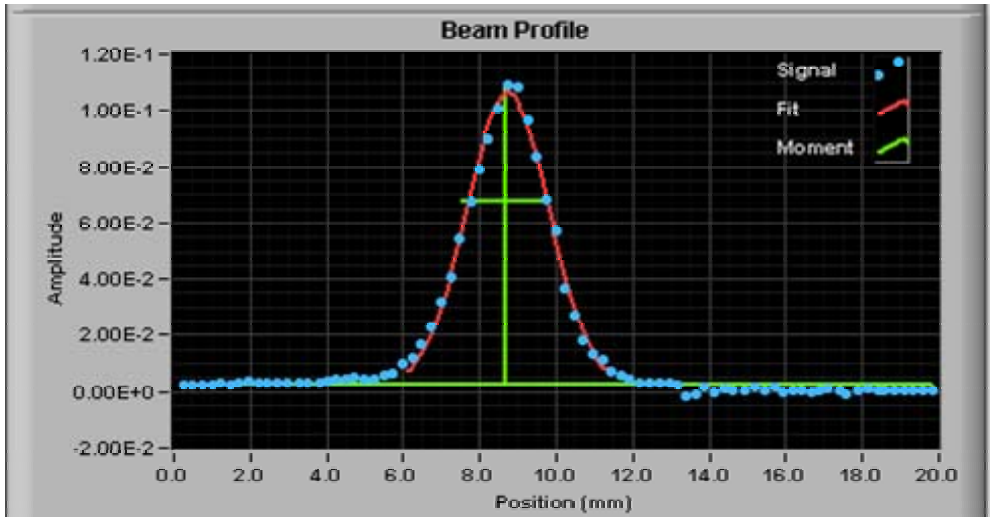


Courtesy of the ORNL Mechanical Group.

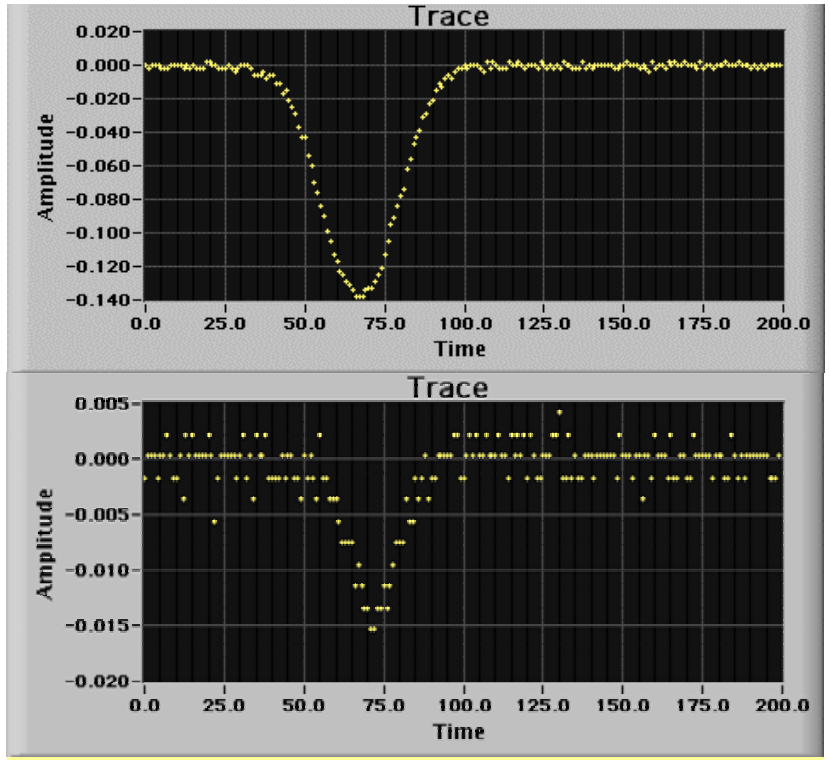
Prototype Station on MEBT

Profile Measurement with Laser

- Verification of electron collector for SCL laser profile monitor
- Reliable measurements to about **3 sigma**
- Expect even better performance with final electronics and coated windows

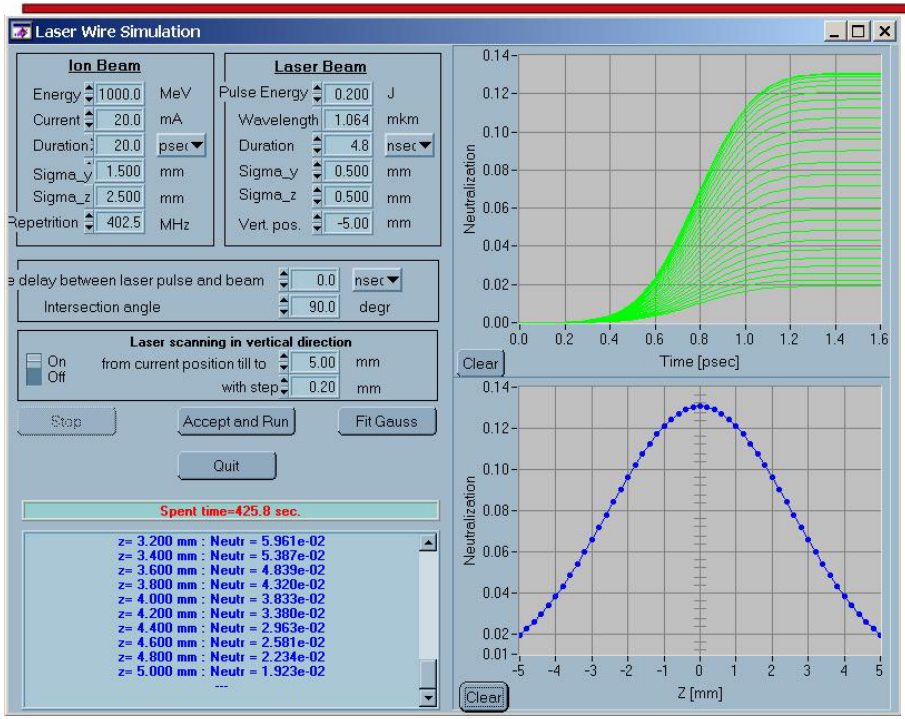


Horizontal Profile
1/25/2003 13:06
Gaussian fit plotted out to 2.5x Sigma
Sigma = 1.07 mm



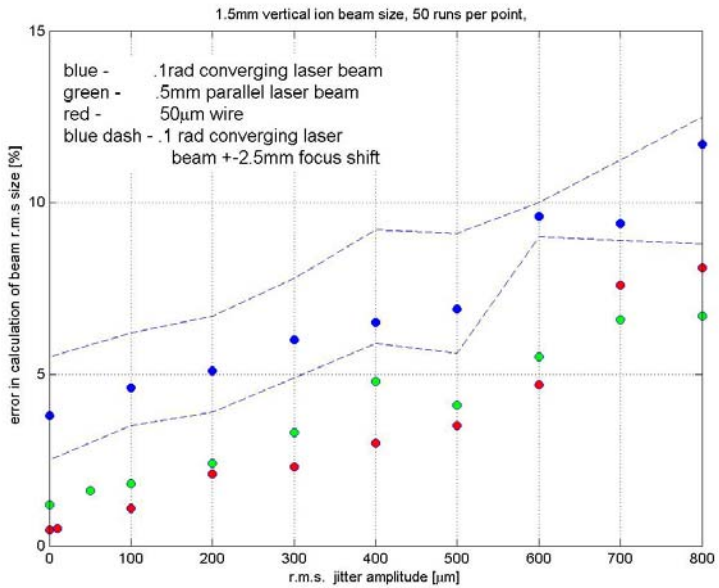
Signal from electron collector
Top: laser intercepting beam core
Bottom: laser intercepting beam tail

Modeling and jitter analysis guides our design



Models being developed by Sasha Aleksandrov and Victor Alexandrov from BINP

branch at Protvino



Dependence of error upon jitter amplitude for:

1. Converging laser beam
2. Parallel laser beam
3. Thin wire

Conclusion:

1) Successful test of the SNS Laser Profile Monitor is demonstrated.

2) Direct collection of the electrons allows us to measure the profiles up to 3 sigma.

3) Modeling has shown the laser beam jitter is not a problem.

4) We are in the process of installing the HeNe laser for vibration testing.

ORNL Laser Wire Design Team

Alignment: Joe Error
Data acquisition and analysis: Wim Blokland
Electron Collector: Craig Deibele
Electronics: James Pogge
Installation: Dave Purcell, Anthony Webster
Mechanical Design Team: Graeme Murdoch, Dan Stout, Arnold DeCarlo , James Kelly, Kerry Potter
Mechanical Design Advisory Team: Peter Ladd, Mike Hechler, Paul Gibson.
Magnet design: Ted Hunter
Optics: Warren Grice
Physics: Sasha Aleksandrov
Project Lead: Saeed Assadi