Overview of Beam Instrumentations for High-Power Operation of the Spallation Neutron Source



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Beam Instrumentation Group Leaser

SNS/ORNL

OUTLINE

- **Overview of Beam Instruments**
- **SCL Laser Profile Monitor Project**
- **Recent results**
- **Challenge**
- **Future plan**

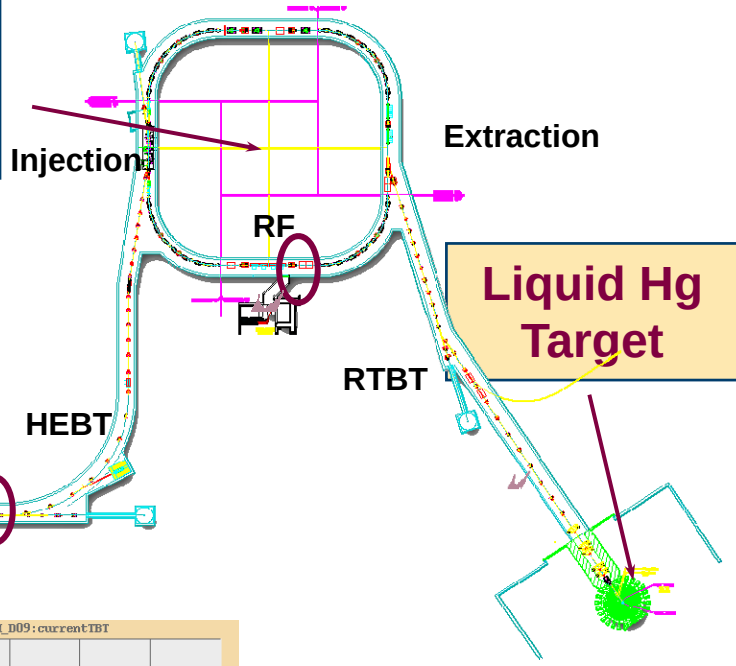
The Spallation Neutron Source



SNS Accelerator Complex

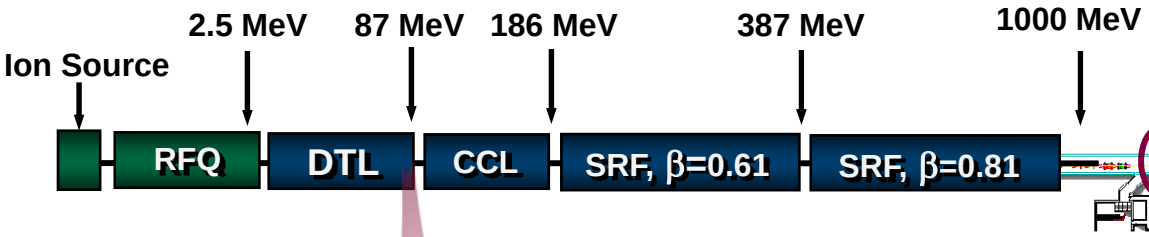
Front-End:
Produce a 1-msec long, chopped, H- beam

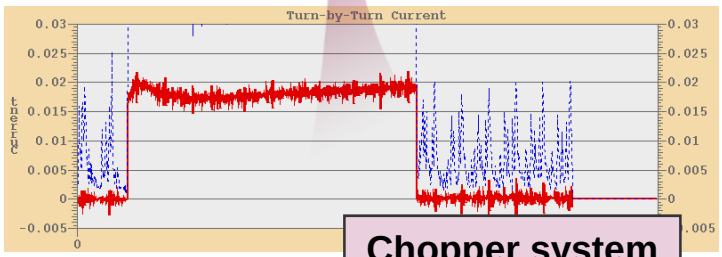
Accumulator Ring:
Compress 1 msec long pulse to 700 nsec



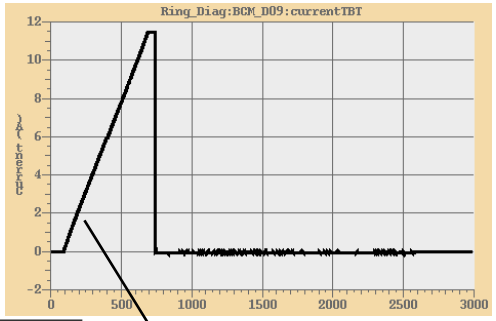
Liquid Hg Target

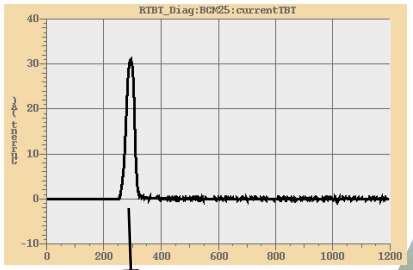
1 GeV LINAC

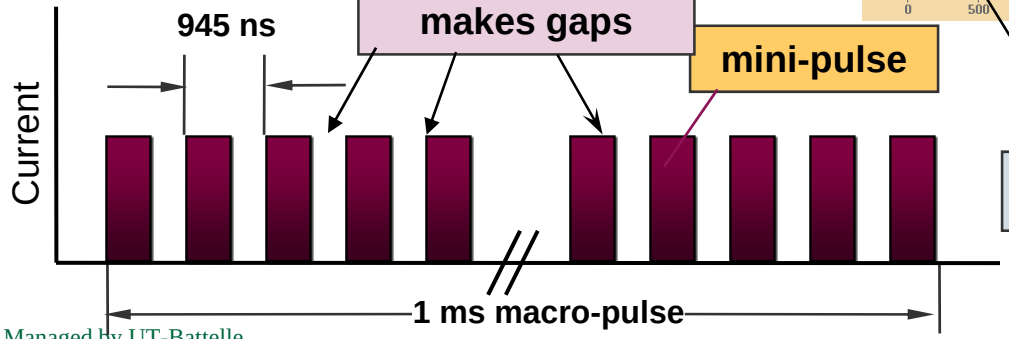




Chopper system makes gaps





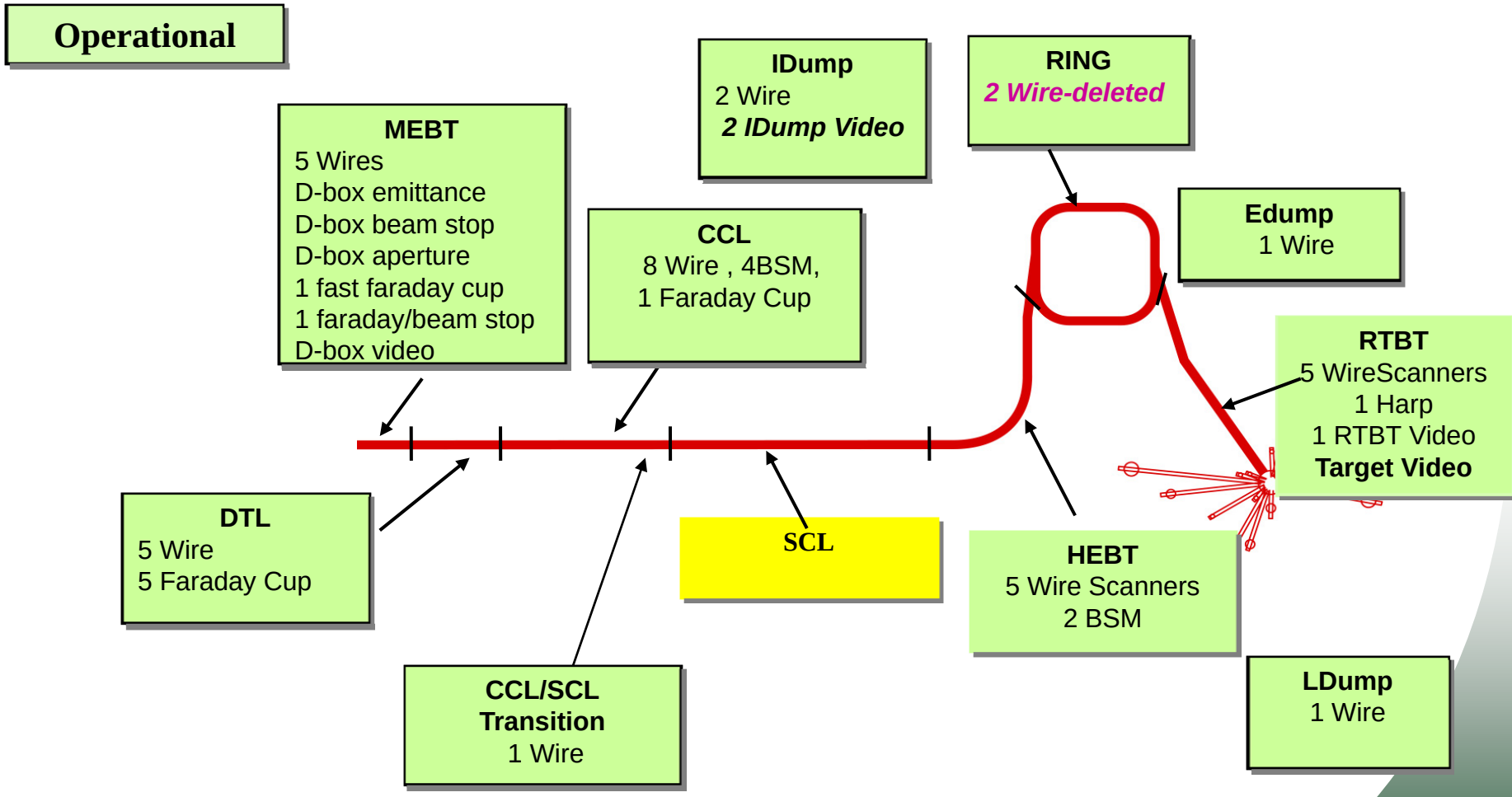


Accumulation

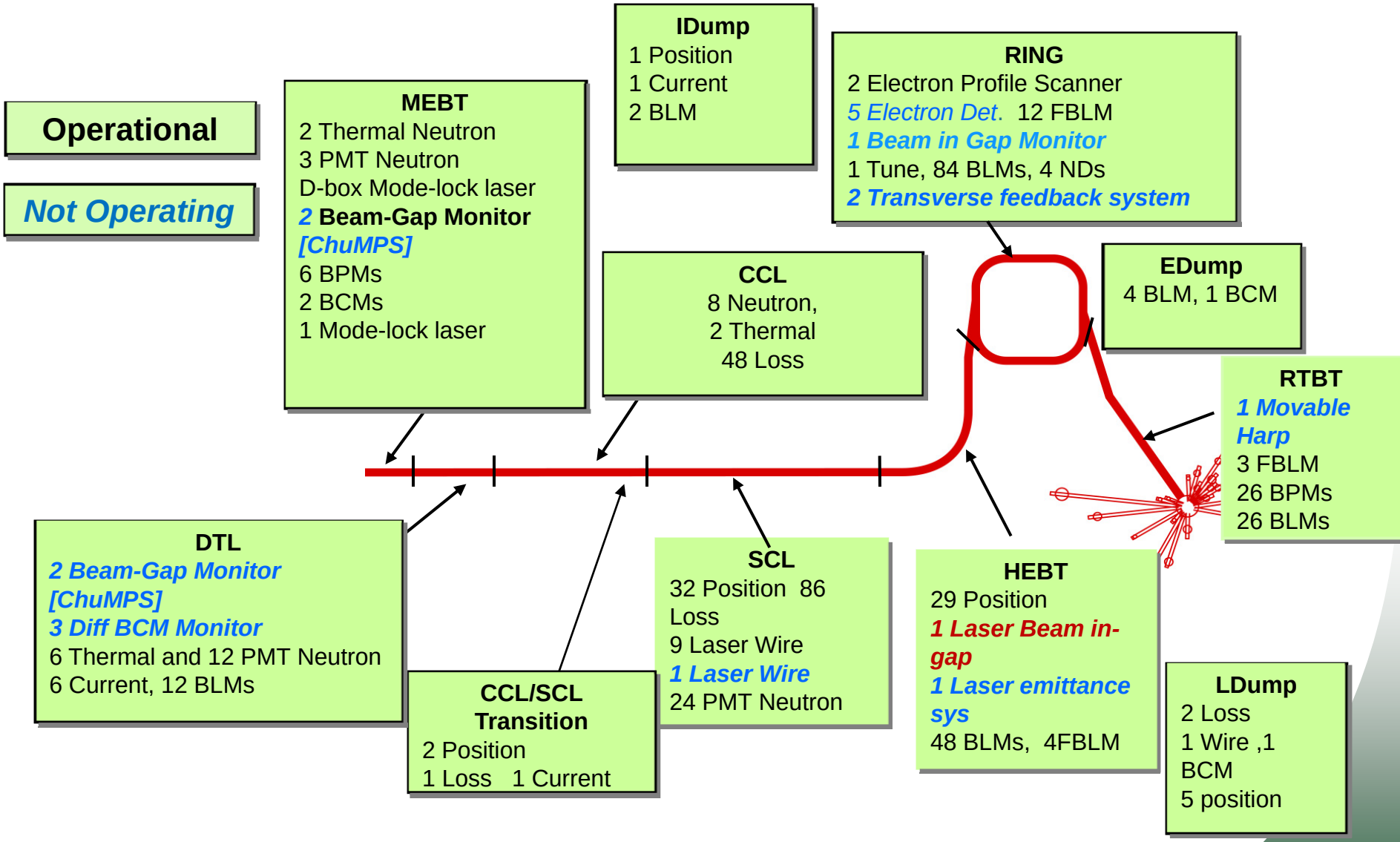
700 nsec Pulse

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Interceptive Beam Instrumentation Systems



Non-Interceptive Beam Instrumentation Systems



Quick History and Facts about SNS

The SNS is a short-pulse neutron source, driven by a 1.4 MW proton accelerator [presently at .54 MW].

SNS will be the world's leading facility for neutron scattering research with peak neutron flux ~20–100x ILL, Grenoble

SNS construction project, a collaboration of six US DOE labs, was funded through DOE-BES at a cost of 1.4 B$

SNS will have 8x beam power of ISIS, the world's leading pulsed source user facility, Stepping stone to other high power facilities, expected to achieve 1.4 MW in two years.

Motivation to Add &/or Modify More Beam Instruments

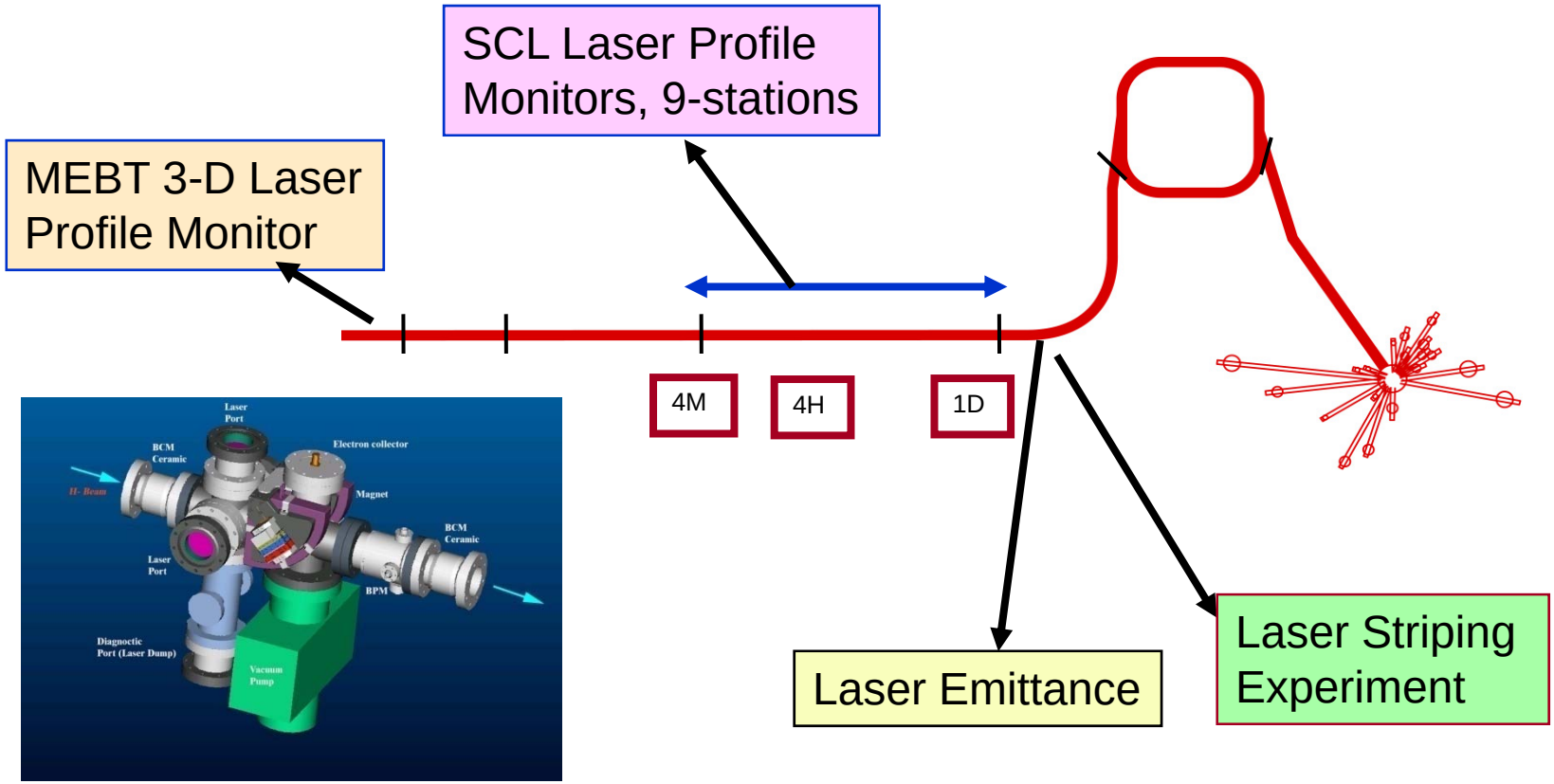
- **Improve reliability**
- **Improve user friendliness – i.e. automation, additional features –**
- **Support, diagnose "unexpected" events – i.e. Spark detectors, LEBT and RFQ RGAs**
- **Accelerator Physics requests – Laser emittance system.**
- **Allow "parasitic" studies; IPM, electron profile monitor. Different types of BLMs.**

Continue: Motivation to Add &/or Modify More Beam Instruments

- **60 Hz Beam Accounting [Never was in the plan]**
- **Low Energy Beam Loss Measurements , WGF4- A. Zhukov's talk**
- **Differential Current Measurements in DTL/CCL**
- **High Power Operations.– e/p Instabilities, use of digital active transverse feedback system for the Ring. WG F- (wed) – Craig Deibele's talk**
- **Ring Electron Profile Monitor, BINP collaboration with SNS, initial results by W. Blokland in this talk.**
- Computation of Space-Charge Effects in Allison Scanner and Its Application to the Measurement of Emittance by Timofey Gorlov

ORNL-SNS Laser Diagnostic Activities

1) MEBT Mode-lock laser initially in 1-D – 9/2004
2) SCL Nd:YAG 1064 nm Laser, 9-station – 9/2005
3) Laser Stripping test Nd:YAG, 3ed harmonic -- 8/2005
4) Working on making SCL Laser system turn-key -- to present

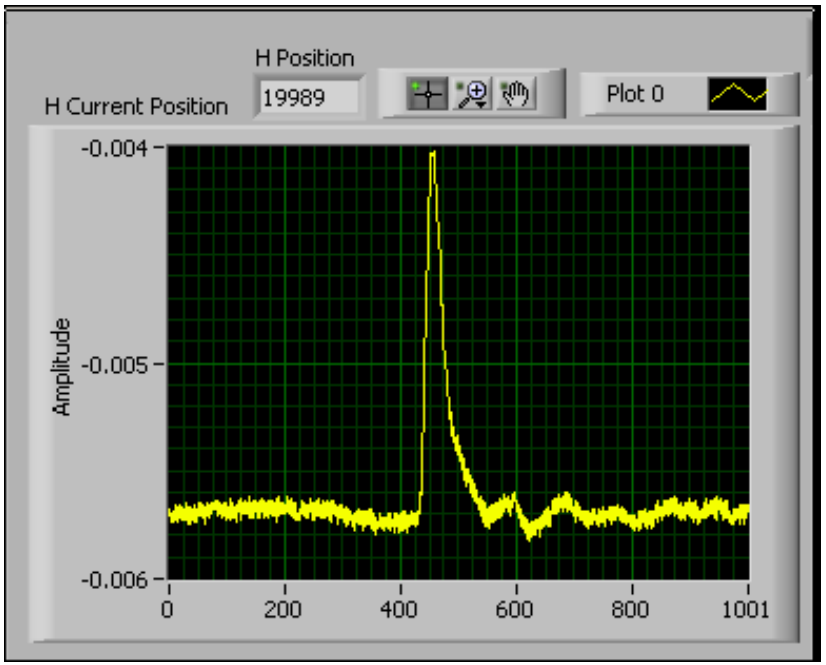


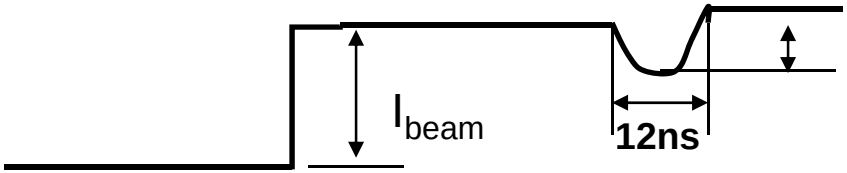
What does the Laser do? Photo-neutralization



Requirements

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



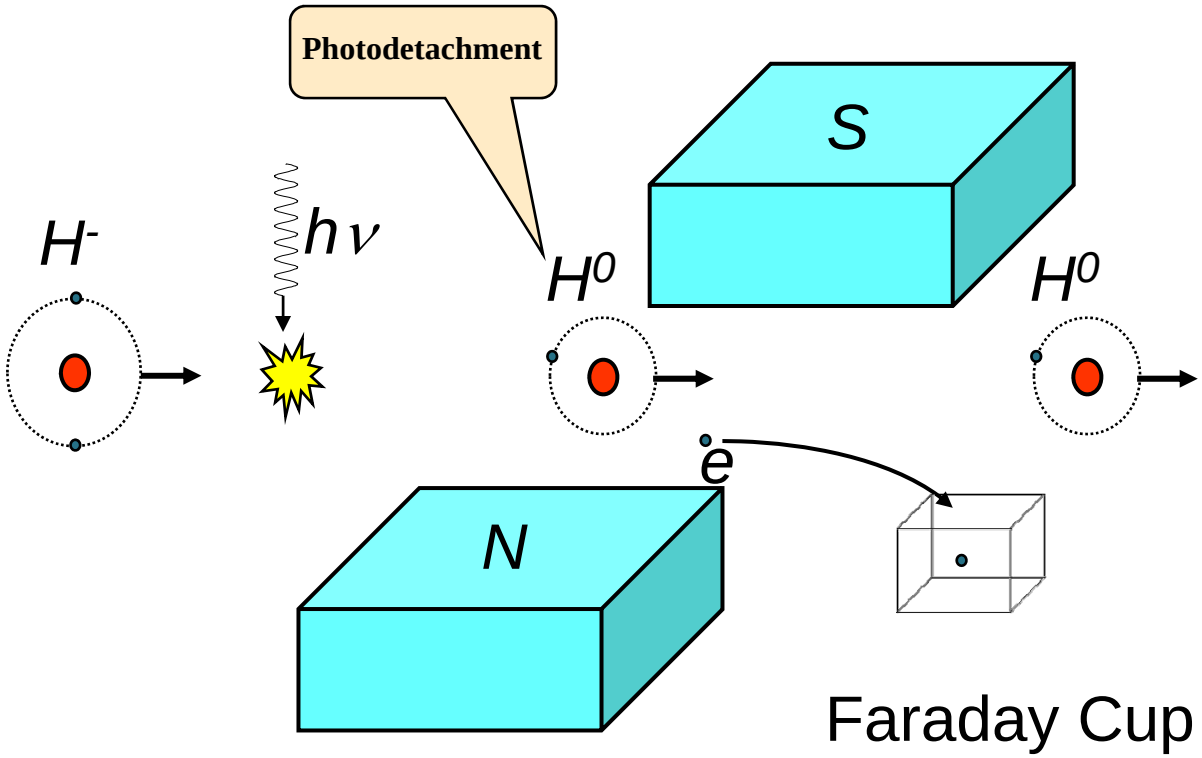




Cross-section is well known therefore stripping efficiency calculation is a matter of algebraic manipulation

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Principle of Laser Wire, direct electron current measurement at SNS.



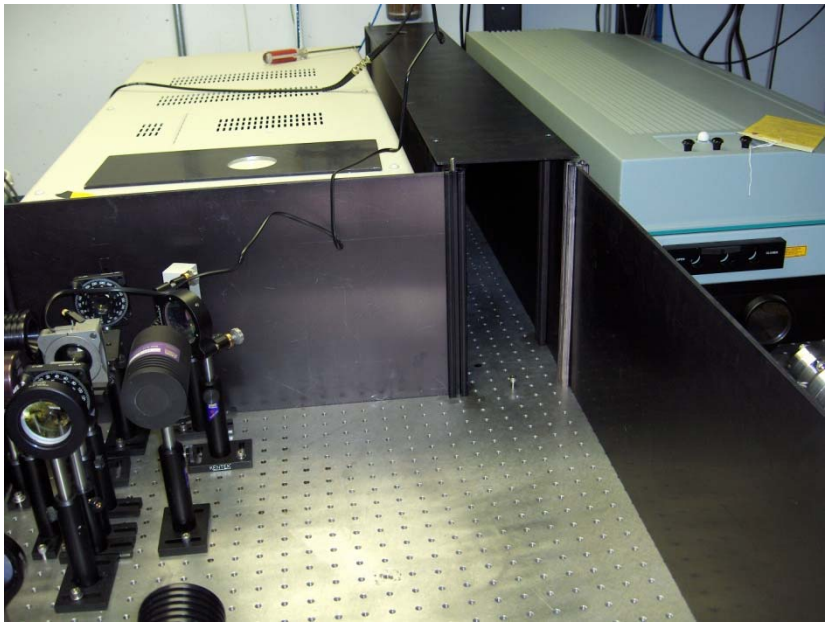
- Detected electron number is proportional to the ion density

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Redundant Lasers are available for the SCL.

- High pulse energy
- Small spot size
- Single wavelength
- Pointing stability
- Temporal stability

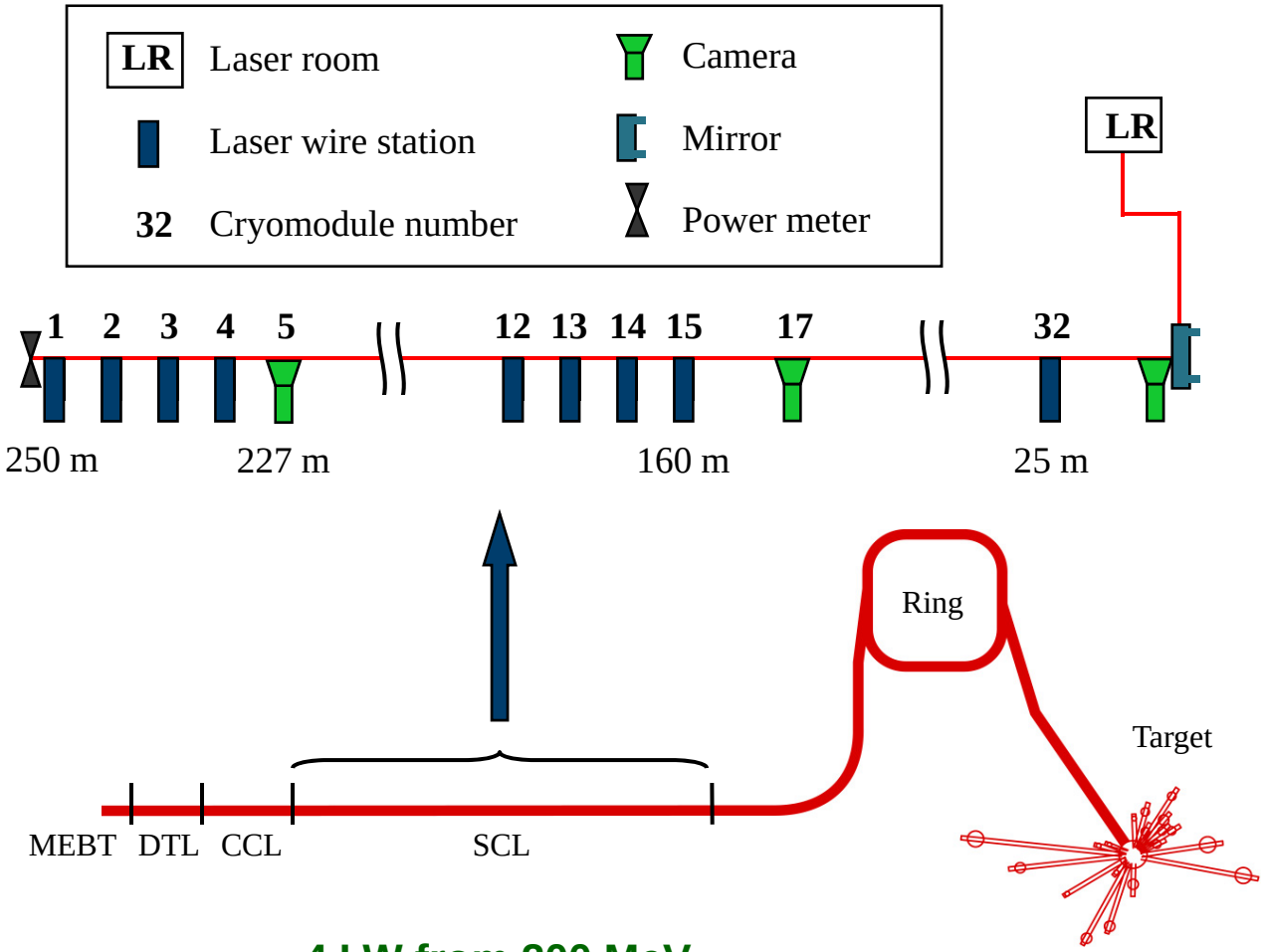
Laser Room



Requirements:

- Q-switched Nd:YAG laser
- λ = 1.06 μm
- f_{rep} = 30 Hz, T_w = 7 ns
- E_p = 50 – 200 mJ
- Injection seeded
- Timing synchronized to SCL

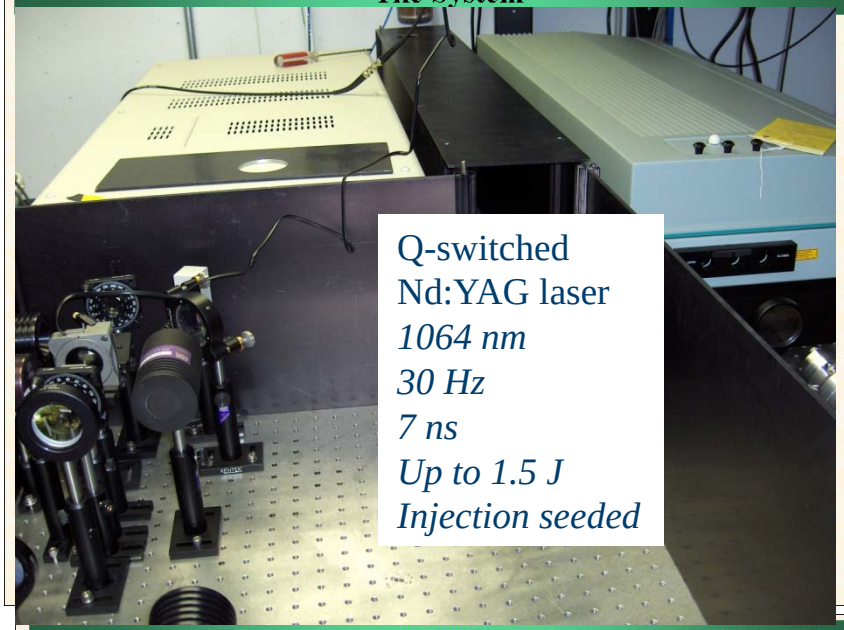
Layout of the SCL Laser Wire System



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

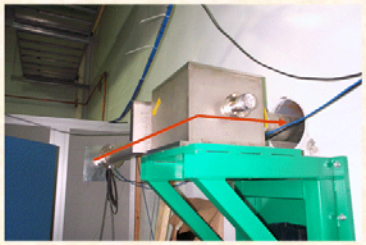
SCL Laser Transport Line

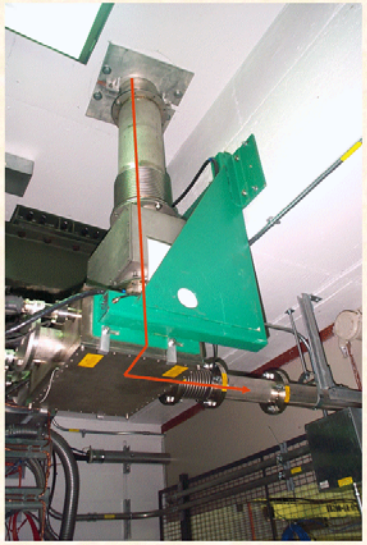
The System



Q-switched
Nd:YAG laser
1064 nm
30 Hz
7 ns
Up to 1.5 J
Injection seeded

The System

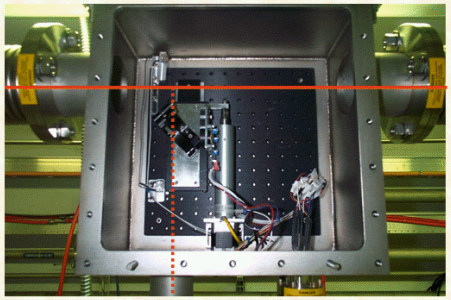




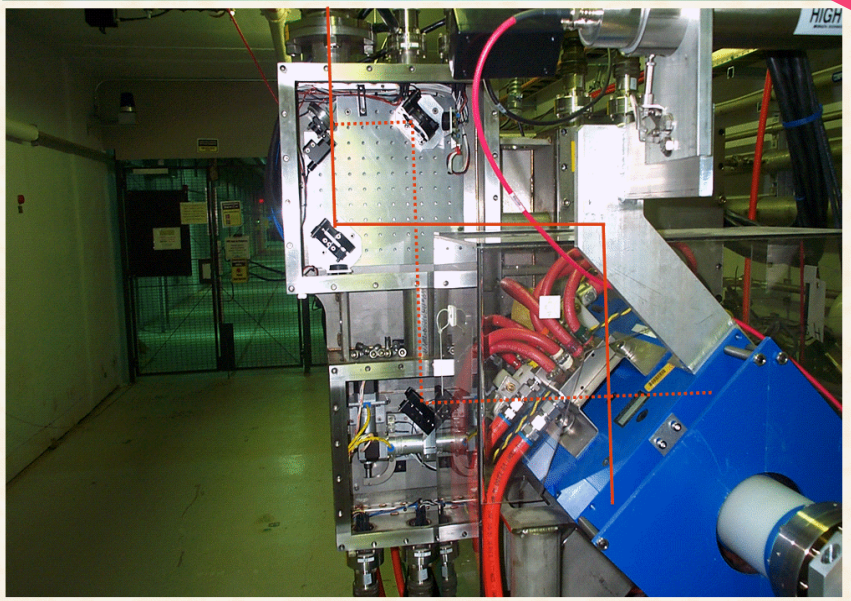
- *Note Safety Features*

The System

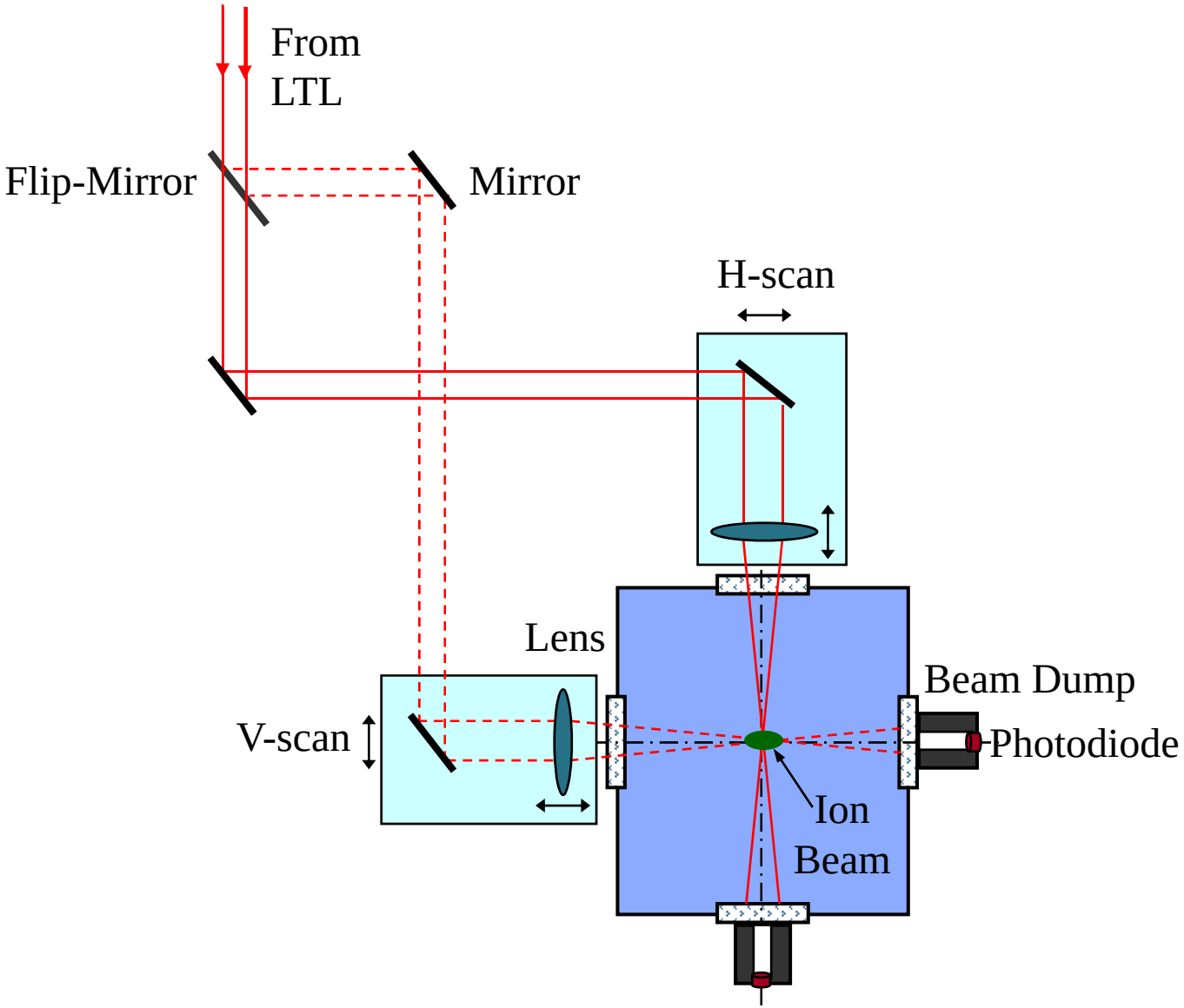




The System



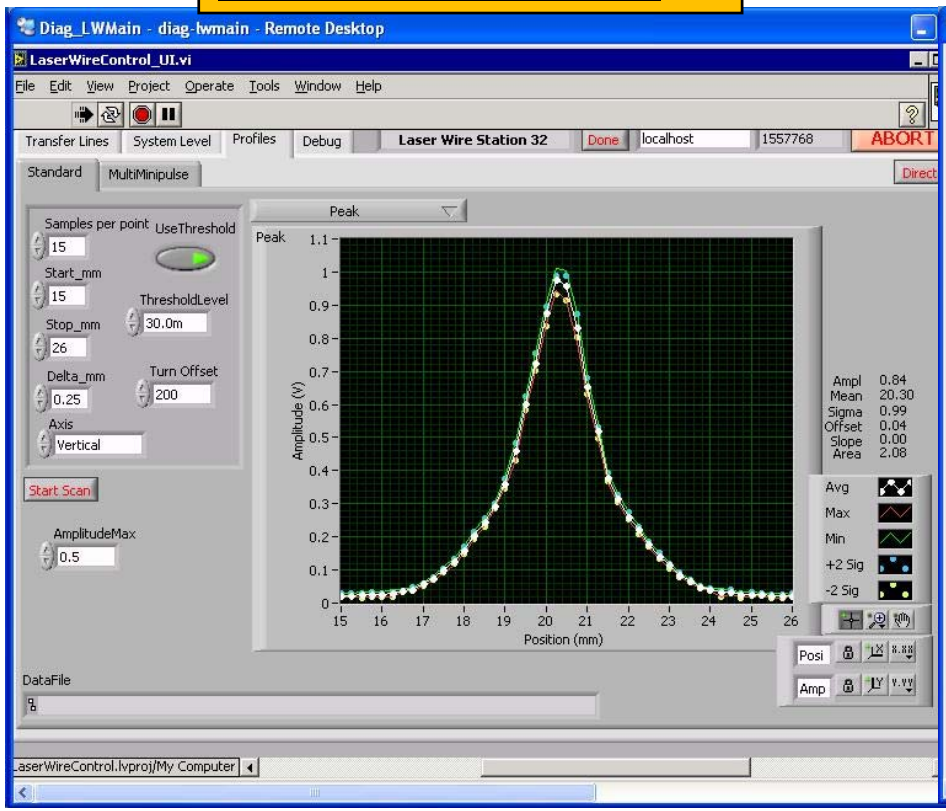
Schematic of Laser Wire Station Optics



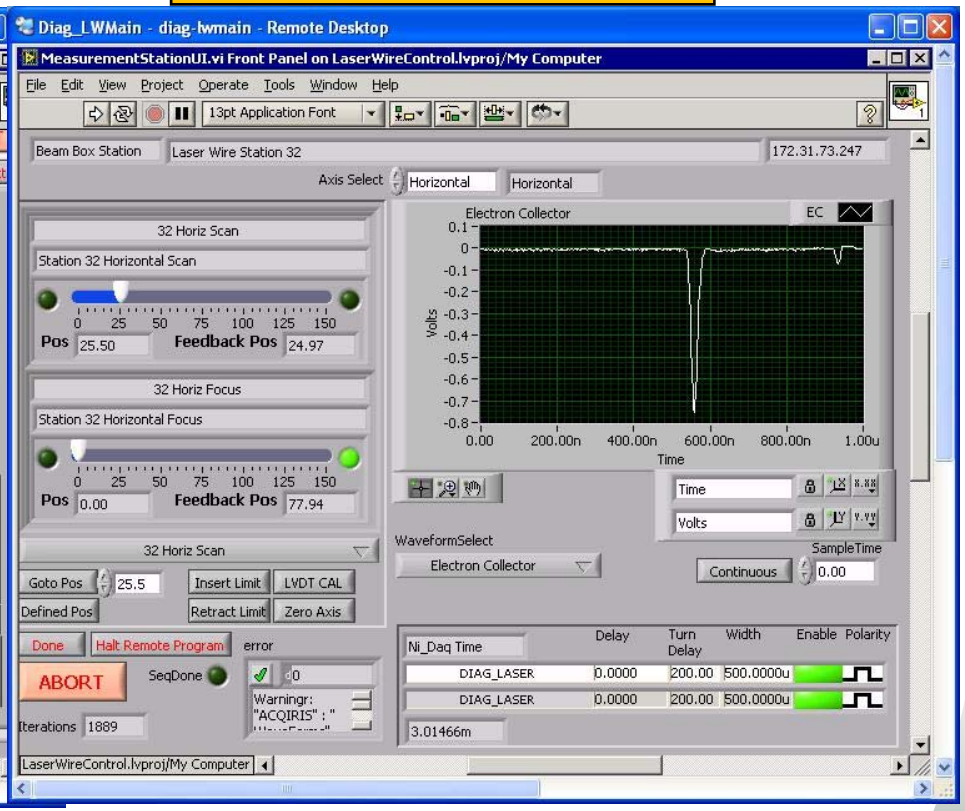
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Top-Level Software Controls all Stations and collects Data.

Profile Measurement



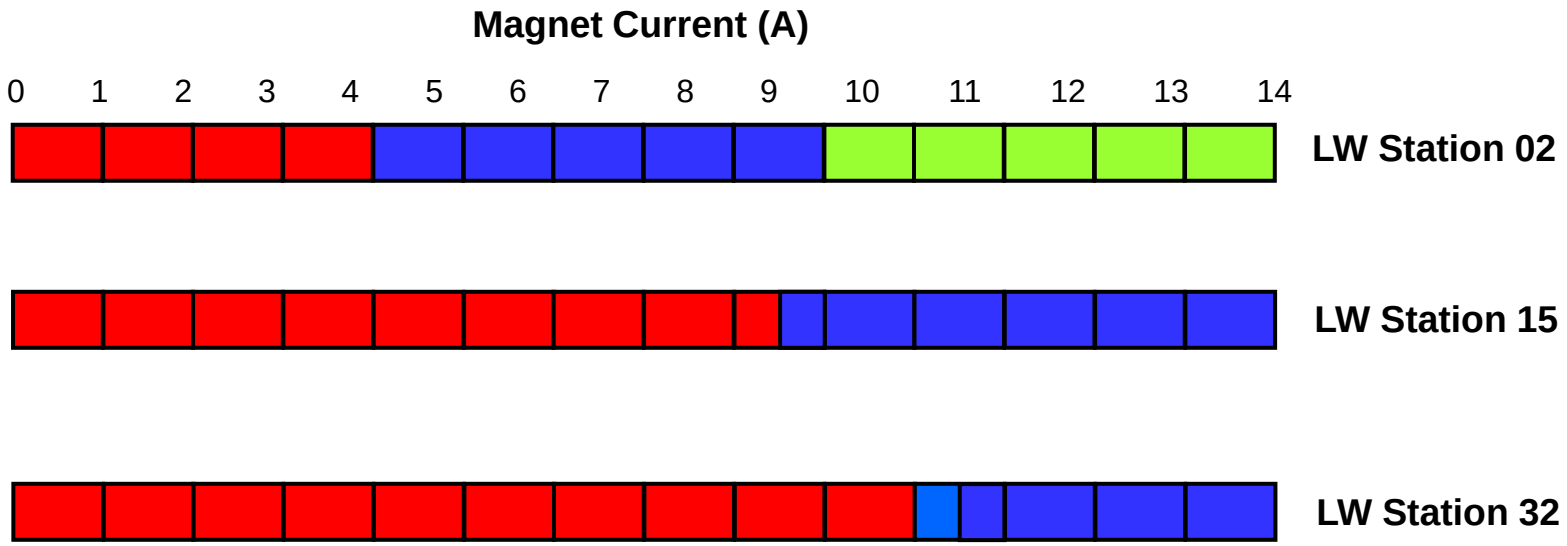
LW Station Diagnostics

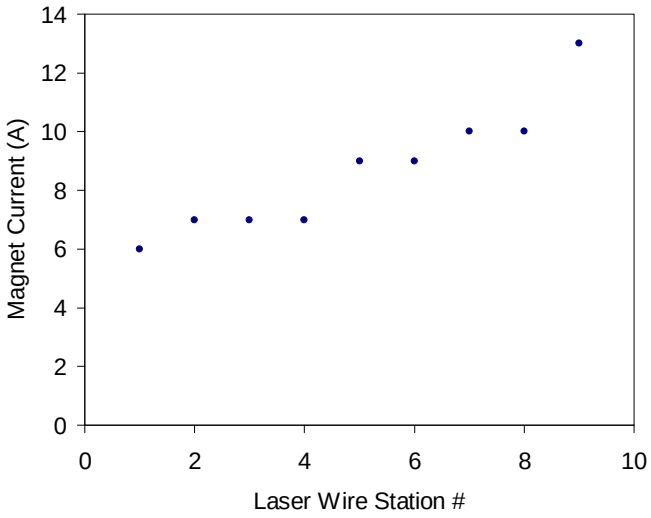


User specifies station, axis, scanning range/step/ave. number, controls timing, and data acquisition

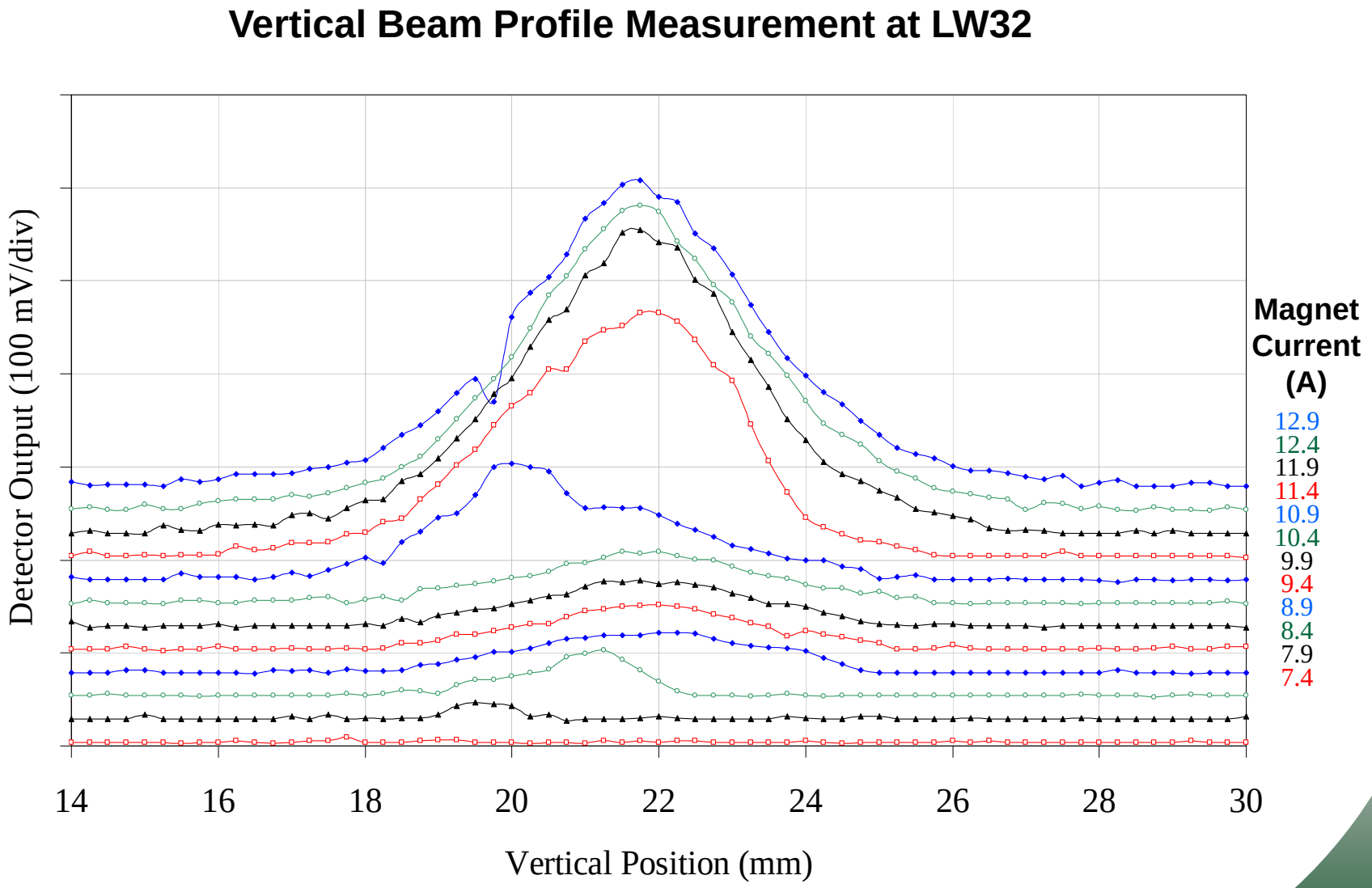
User monitors laser beam position, lens focus, electron collector output raw signal

Effects of LW Magnet Current

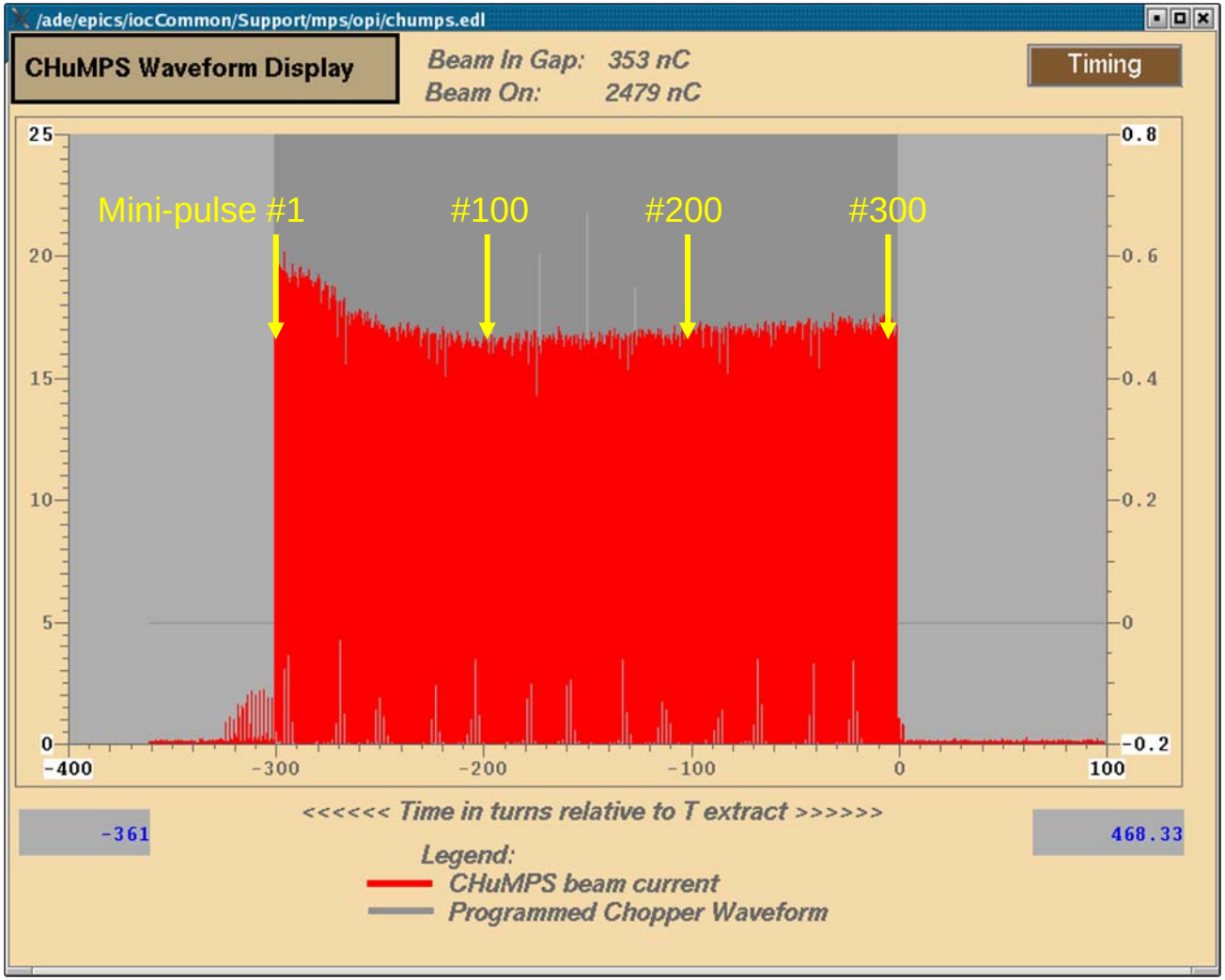




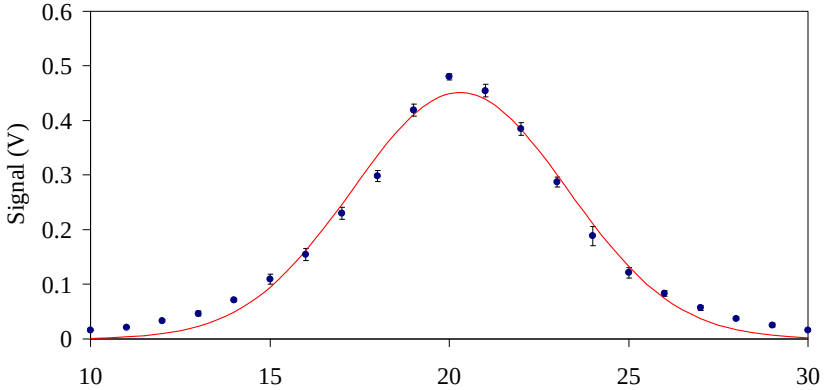
One challenge that is solved Effects of LW Magnet Current

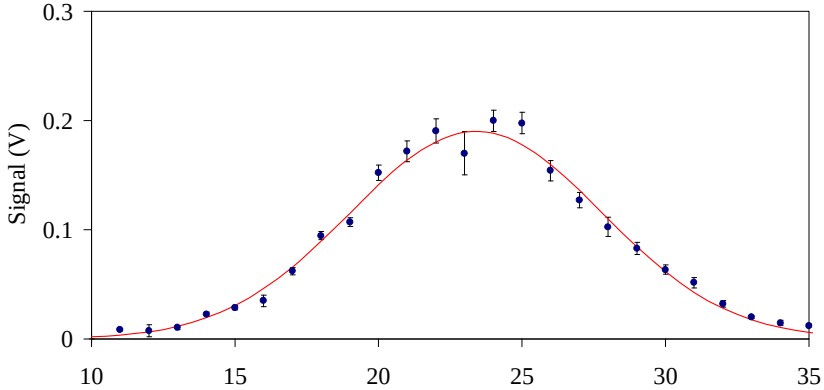


Advantage of Laser is to be able to scan the entire Macro-pulse.

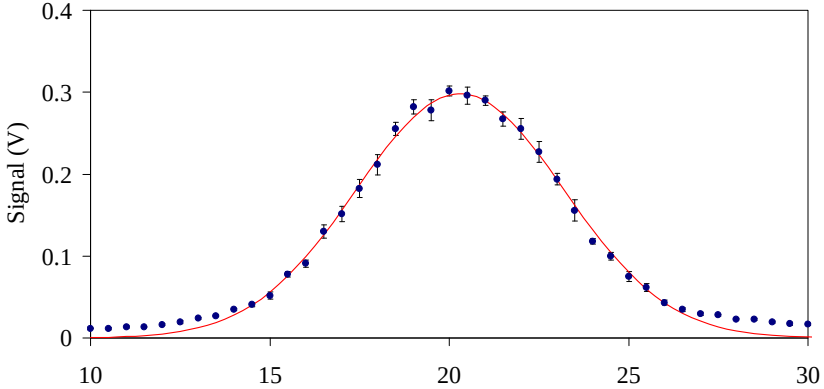


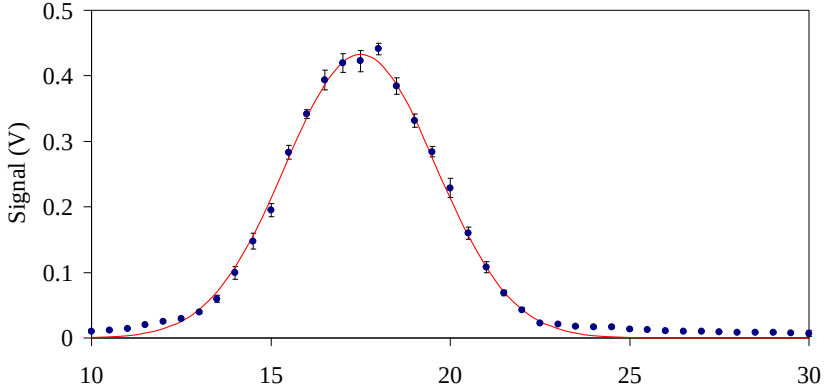
Beam Profile Measurements



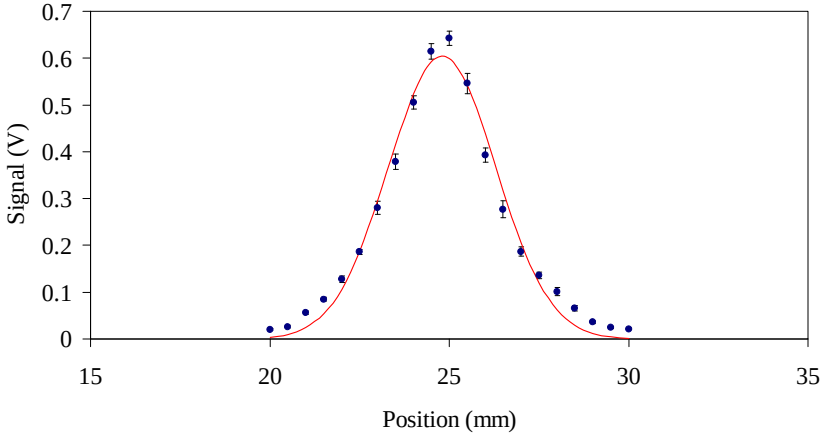


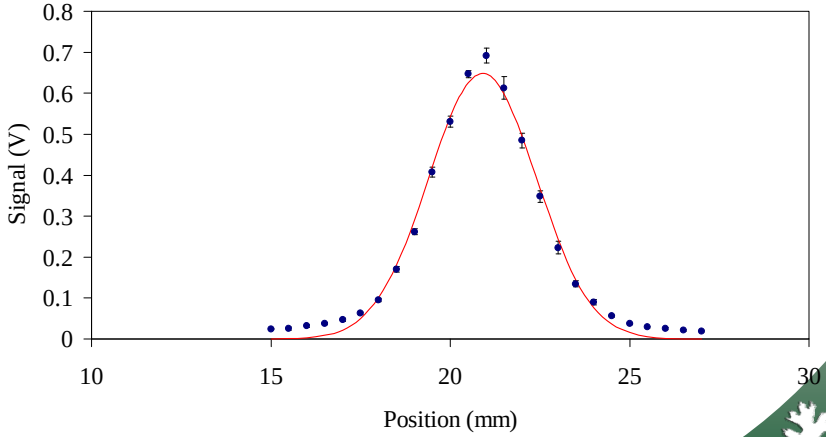
LW1





LW5

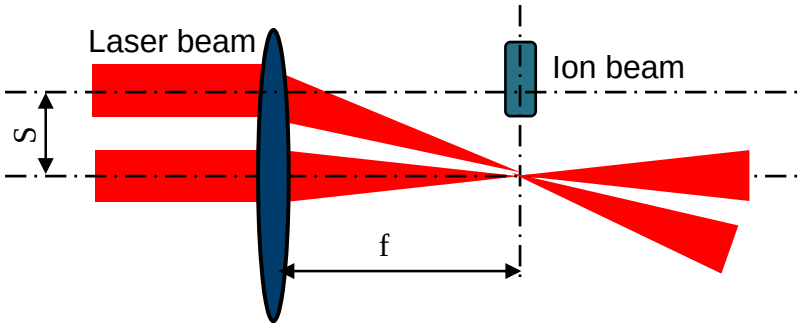




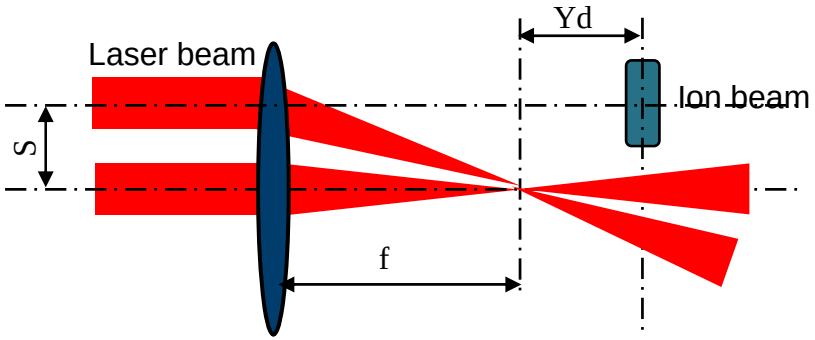
LW9

Realistic Laser Beam with respect to H-

Laser beam shifts on the lens surface

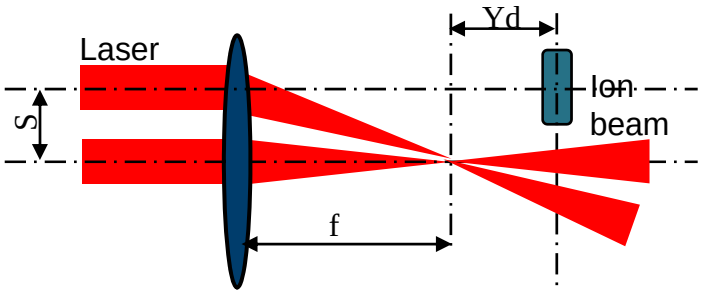


Laser beam shifts + Ion beam shifts from waist

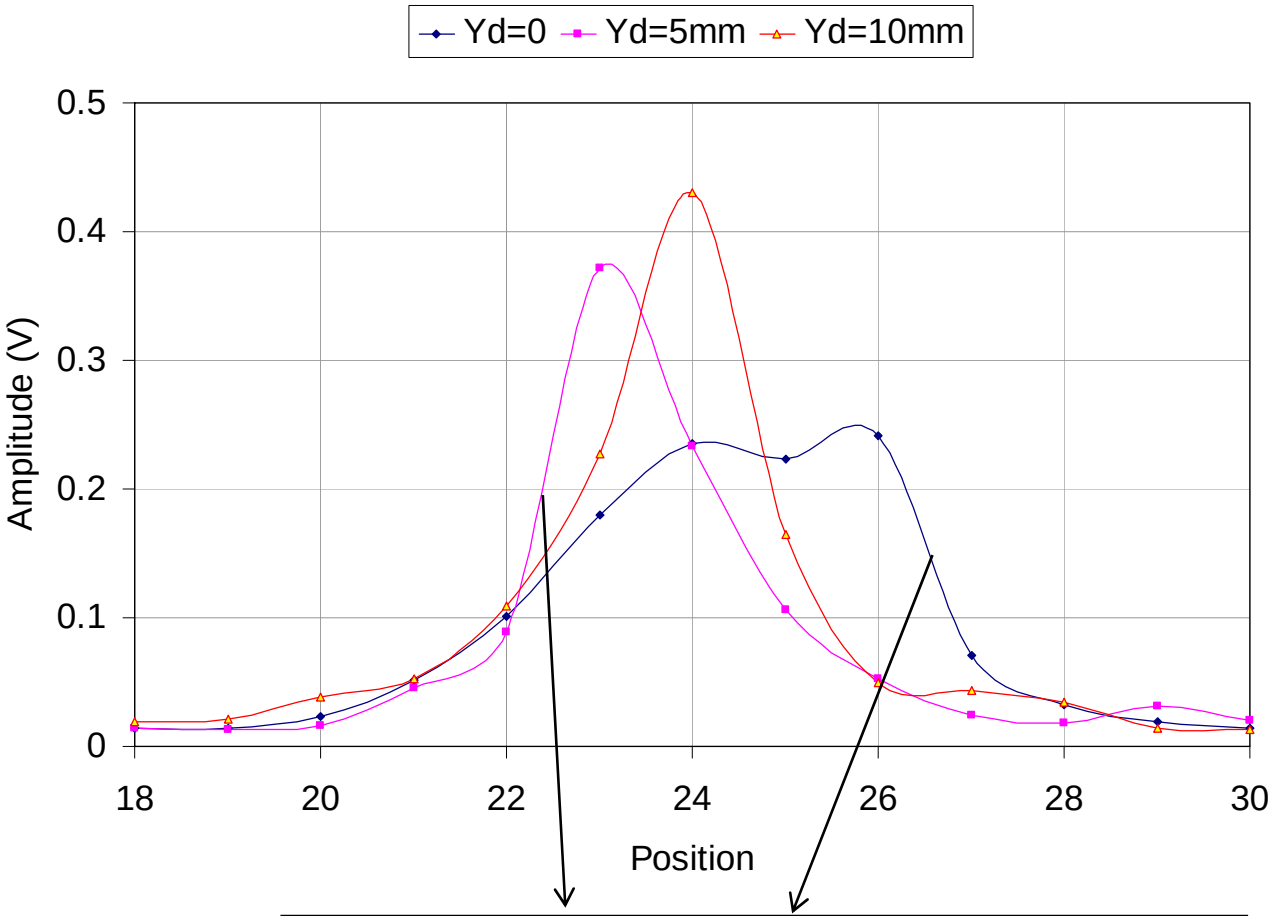


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Challenge! Experimental Measurements



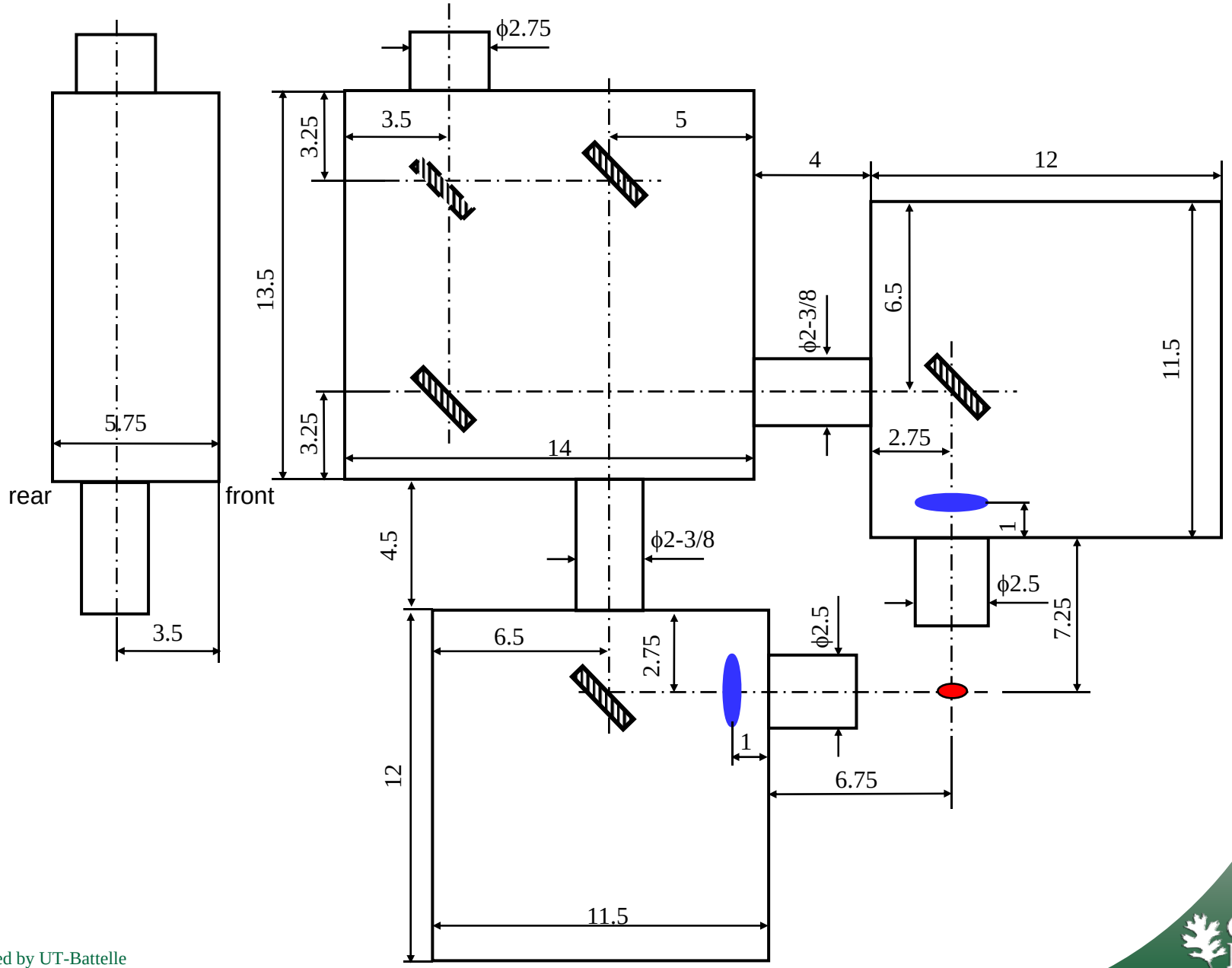
Measured profile as a function of lens position at LW14V



Why do we get poor profiles in this case

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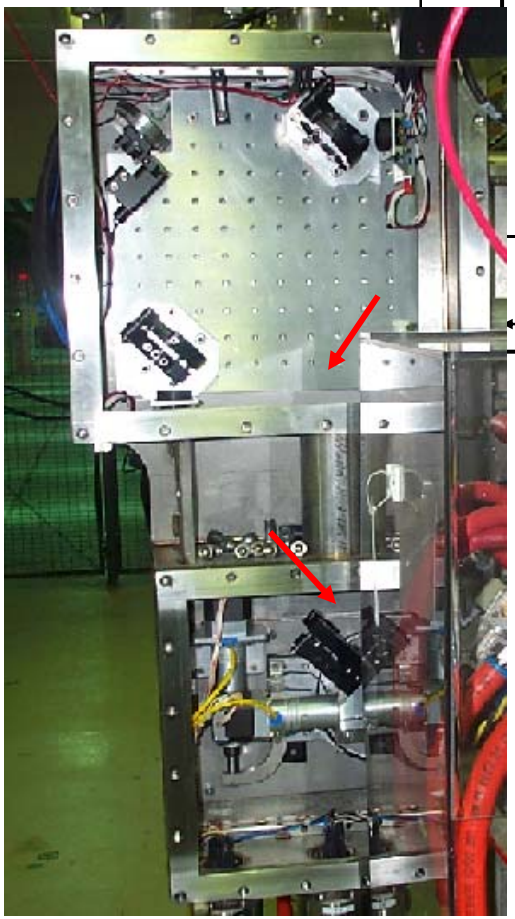
Current Laser Wire Box

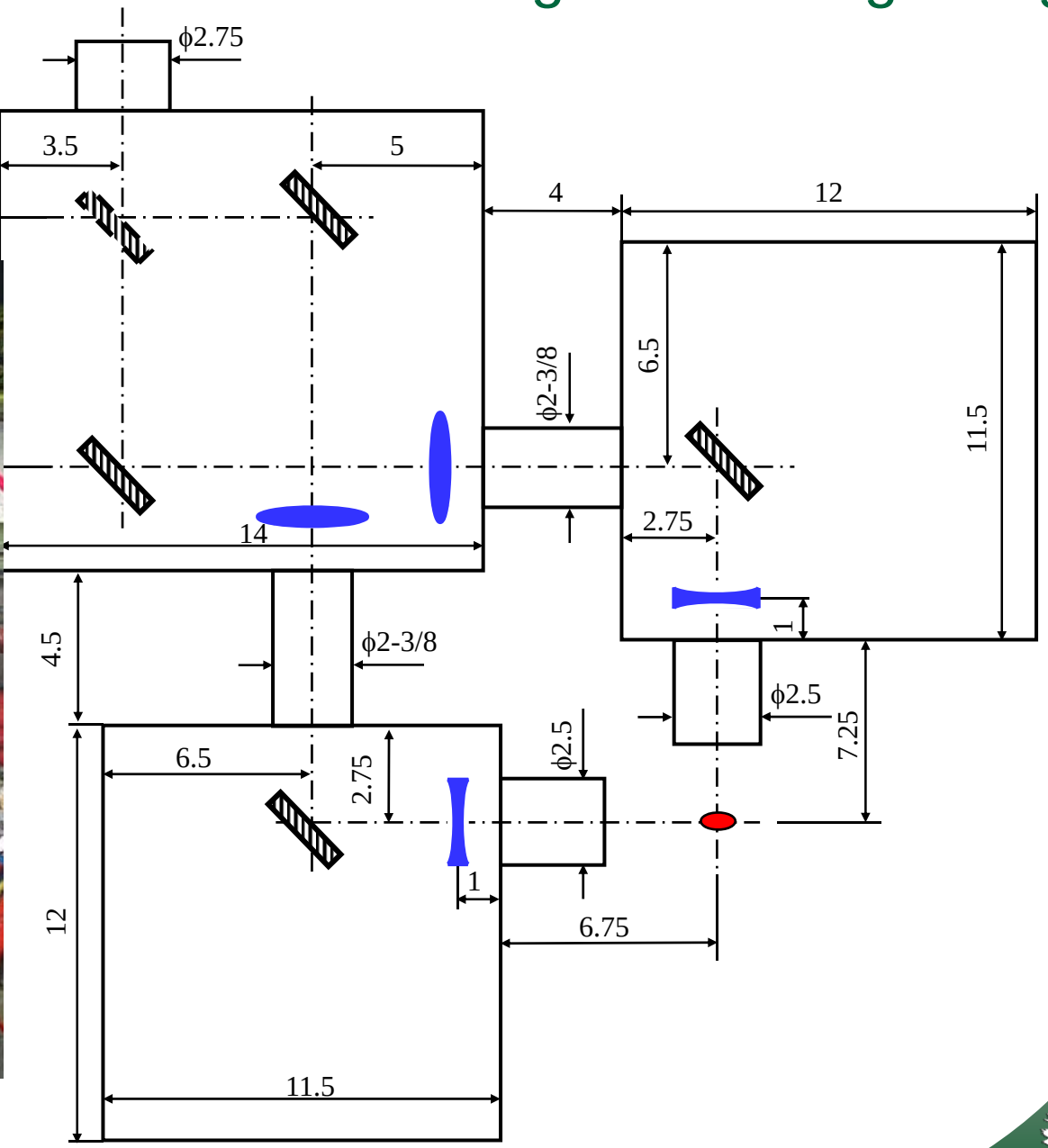


WGF01- HB2008 8/26/2008

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Revised Laser Wire Box Design to Bring Larger Travel Range





WGF01- HB2008 8/26/2008

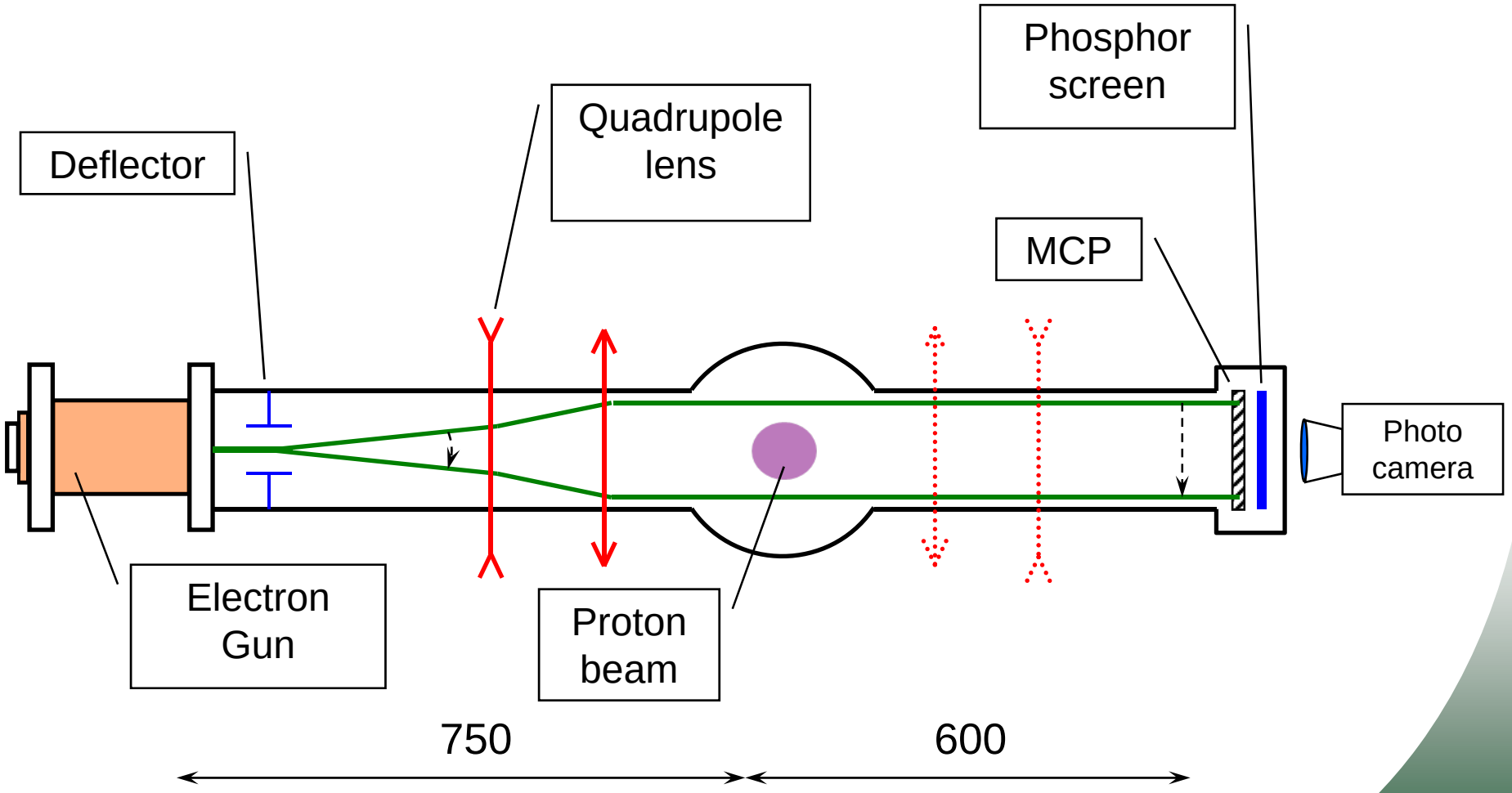
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SUMMARY of Laser Profile Monitor

- **Profiles have been measured at all 9 stations**
- **Operational parameters have been investigated and optimized**
- **Software platform has been improved**
- **Issues of radiation and stability are looked into and solutions are provided**
- **Future plan**
  - **Secure system reliability**
  - **Optimize/document operational procedure**
  - **Identify technical problems and work on solutions**

Electron beam Transverse Profile Monitor

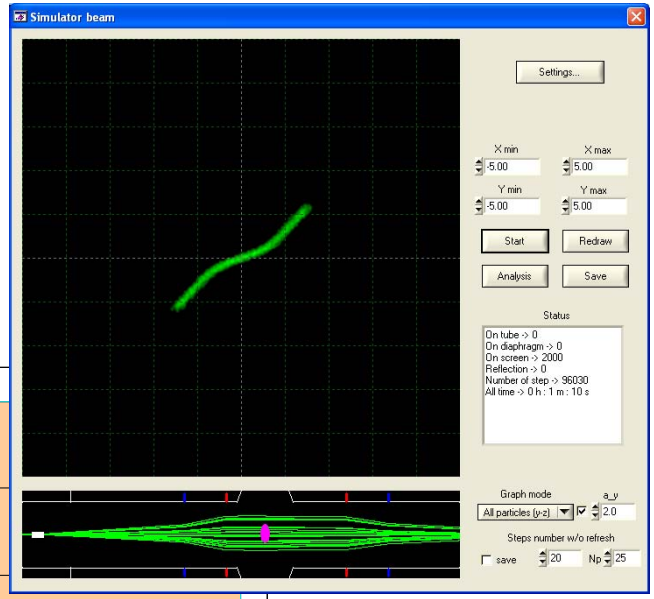
Layout of the proposed EBP for SNS Accumulator Ring by BINP

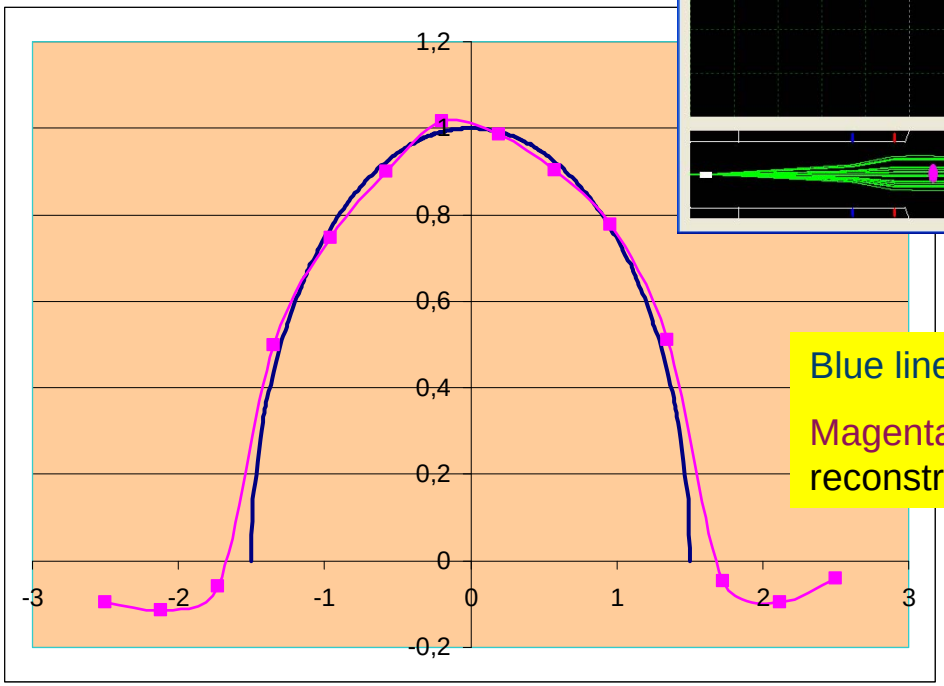


Collaboration on Design and Construction of Electron Beam Profile Monitor Between SNS-ORNL and BINP, Novosibirsk, Russia has started

Simulation

Alexander Starostenko





Blue line – theoretical profile,

Magenta + square – reconstructed profile

Probe beam:

Energy=75keV,

Scan.-parallel,

3^{rd} ,4^{th} quads - **ON**

Proton beam:

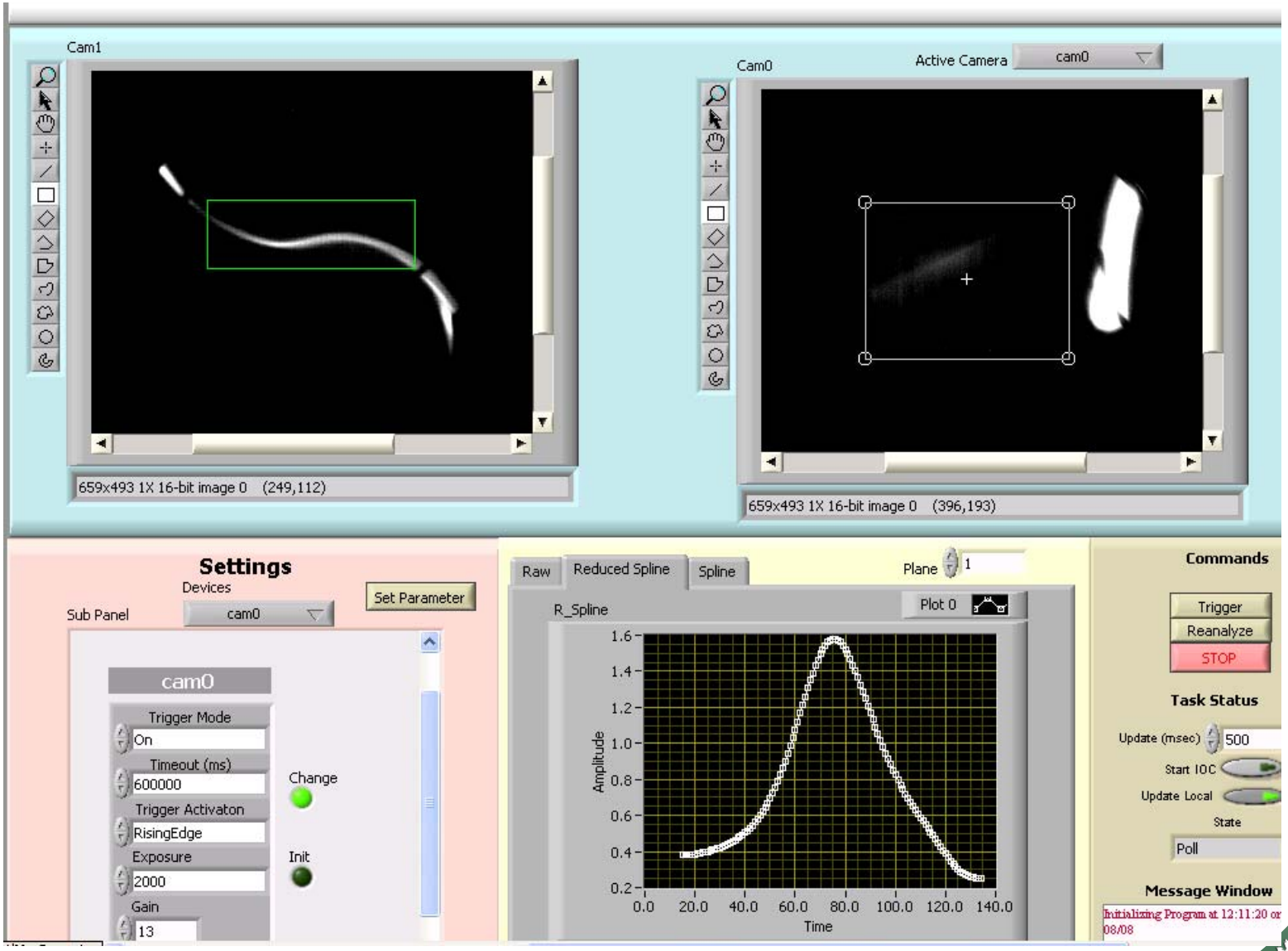
Energy=1GeV

Np=$\mathbf{1*10^{13}}$

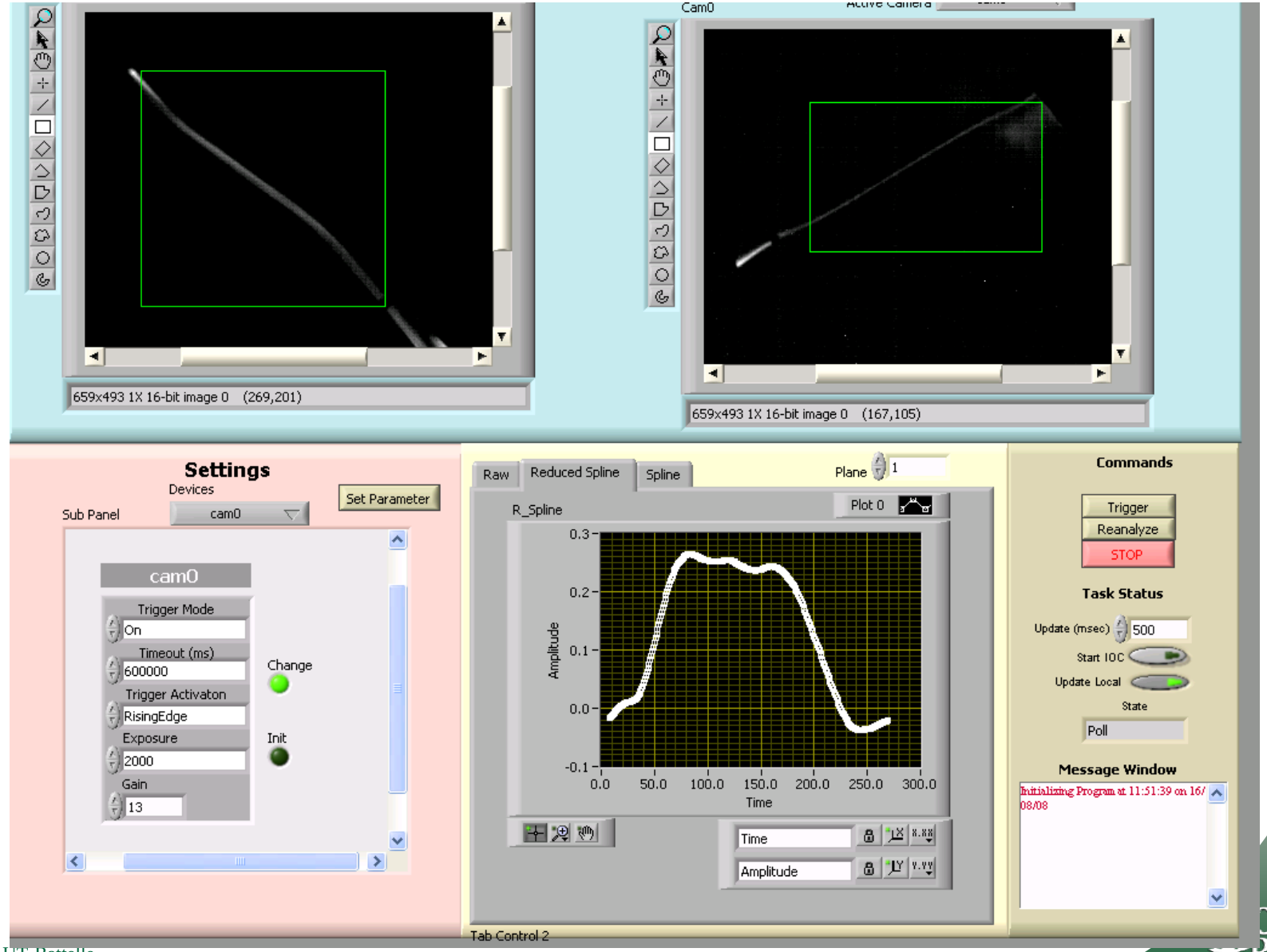
Transverse size r=1.5cm

Round uniform transverse distribution

Horizontal Profile after 500 turn, 8 Micro-Coulomb of charge in the Ring.



Vertical Profile after 500 turn, 8 Micro-Coulomb of charge in the Ring ---- Another useful tool!



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Thanks