Status of Preparations for a 10 μs Laser-Assisted H^- Beam Stripping Experiment

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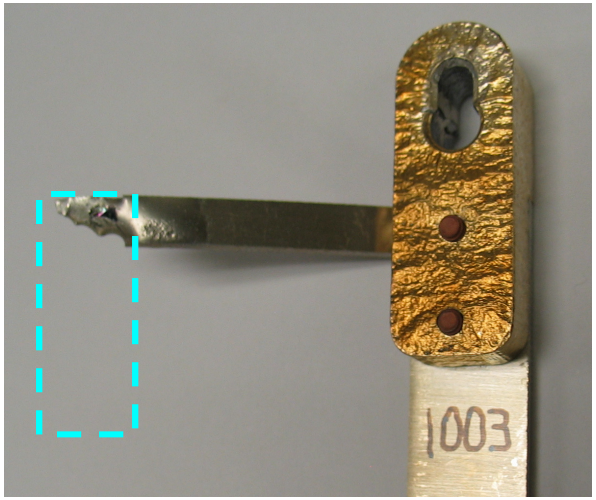
ORNL is managed by UT-Battelle
for the US Department of Energy

OAK RIDGE National Laboratory

Motivation

- Injection foils may not survive in beam powers >1.5 MW.
- Seeing many cases of foil damage at SNS.
- Laser-assisted H- stripping under development as a potential alternative for foils.

Bracket melted, fell off



“Successful” foil after 5 months in the beam.

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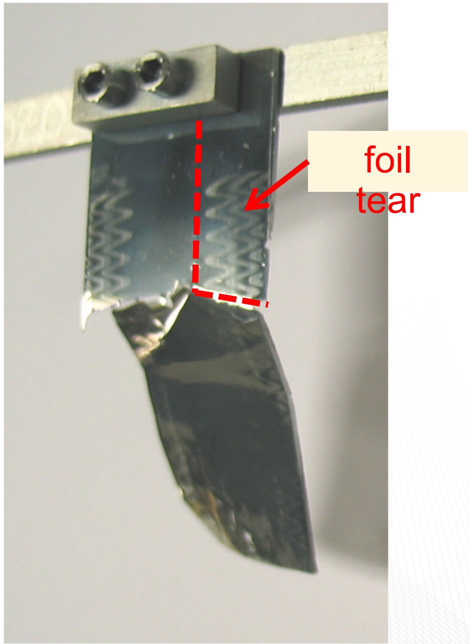

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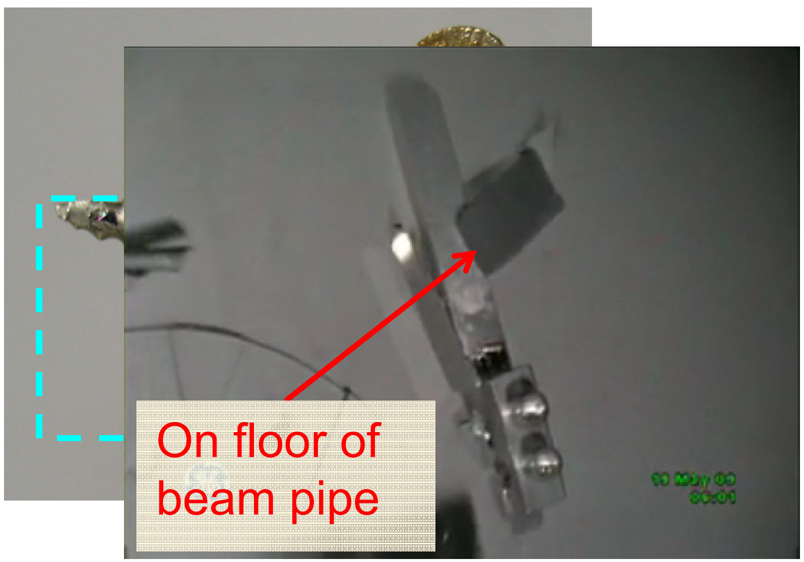

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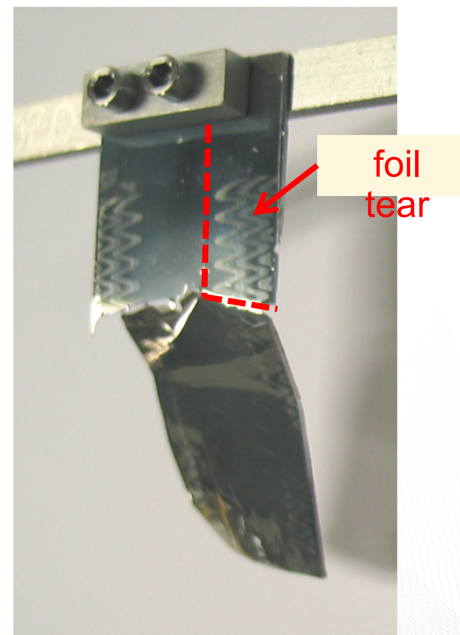

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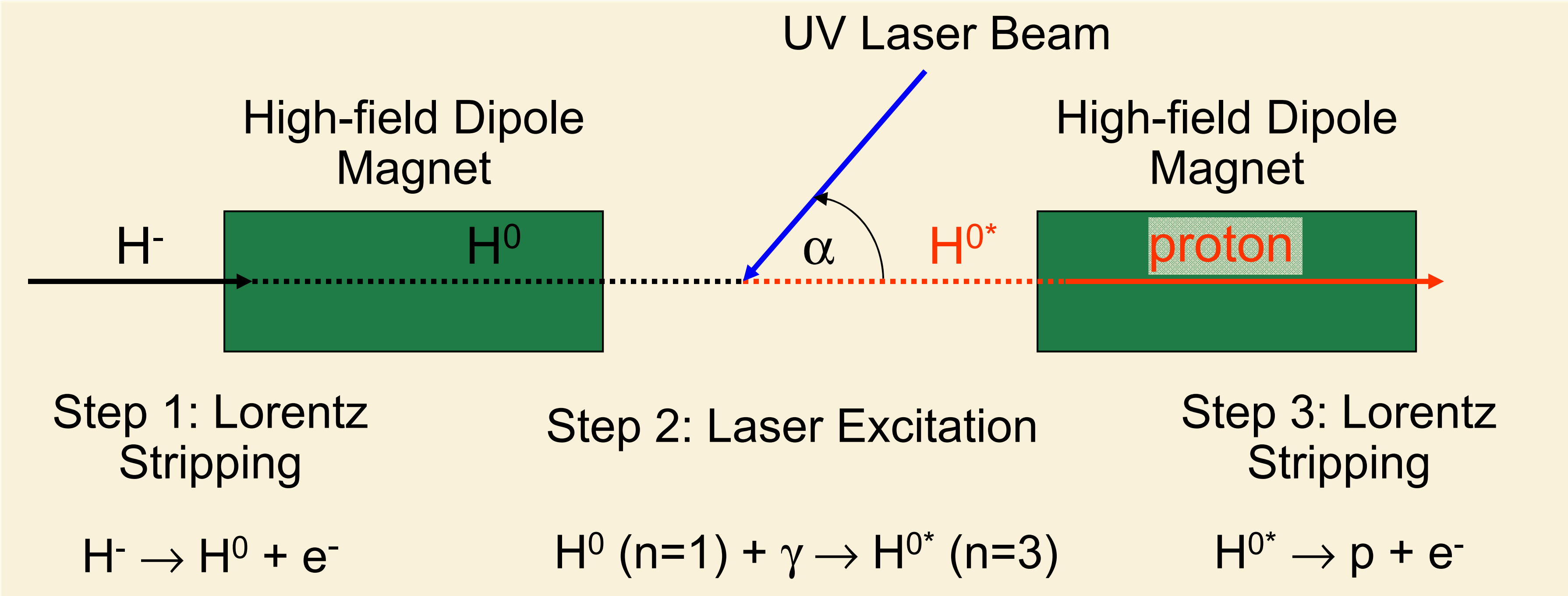
Review of 2006 Laser Stripping Experiment



- Demonstrated at SNS for a 6 ns H^- beam.
- Straightforward scaling from 6 ns to full duty cycle requires 600 kW average UV laser power. Not achievable.

Project Description

<u>Goal:</u> Demonstrate H^- laser-assisted stripping with 90% efficiency for a 5 – 10 μs, 1 GeV H^- beam.

- Experiment will employ methods to minimize the laser power requirement.
- Supported in part by a DOE HEP grant* that includes 1 postdoc, 1 graduate student, several undergraduates.
- A collaboration between ORNL, University of Tennessee, and Fermilab.

*DOE grant DE-FG02-13ER41967

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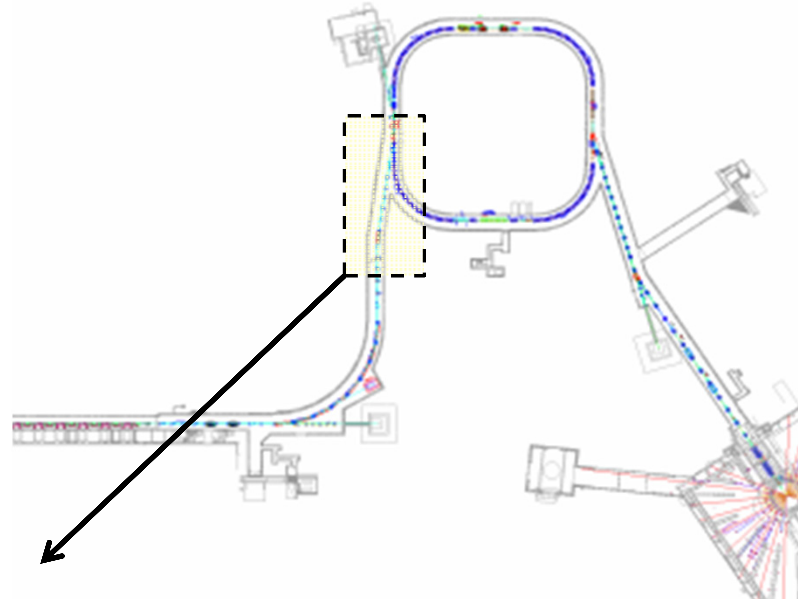
Part I: Experimental Configuration

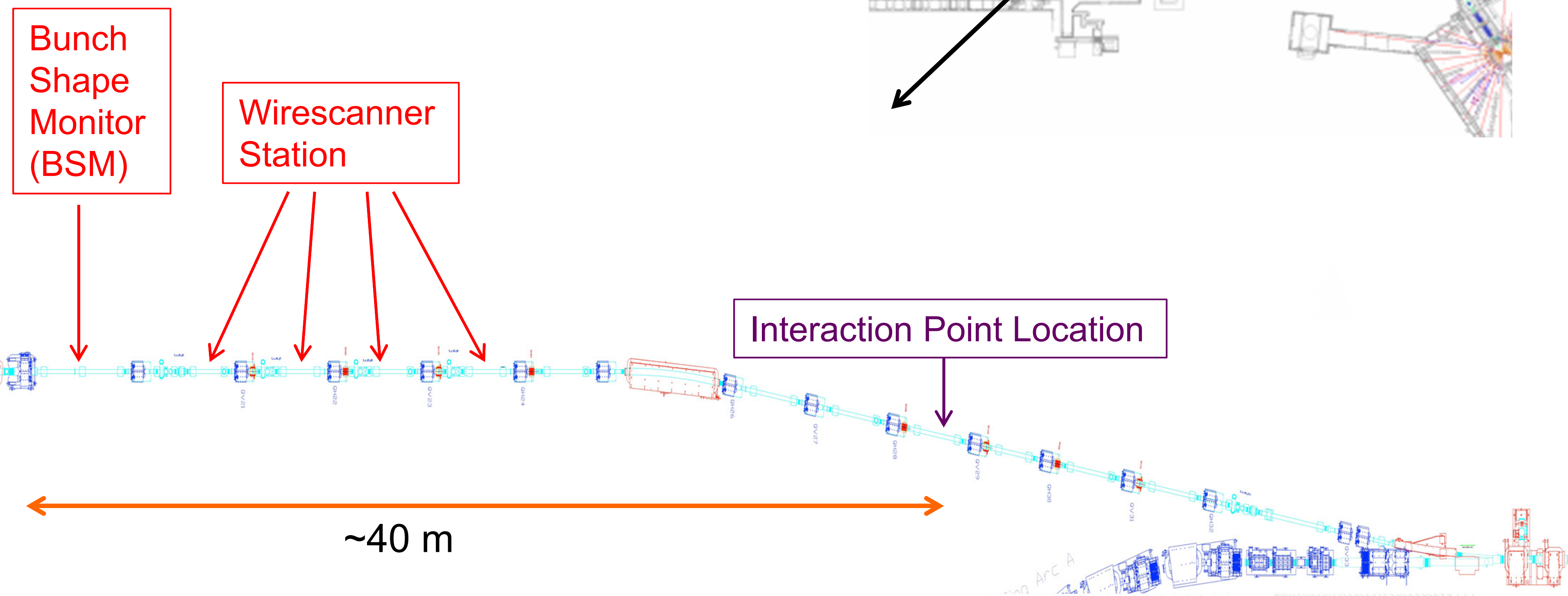
Design goals:

1. Achieve high efficiency stripping for 5 – 10 μs.
2. Protect the laser from radiation damage.
3. Prevent disruptions to production beam operations.
4. Provide schedule flexibility for the experiment.

Interaction Point Location

- IP is downstream of arc in empty drift.
- Has good optics flexibility.
- Diagnostics are 20 – 40 m upstream.
- Low radiation region.
- Reasonable waste beam scenario.





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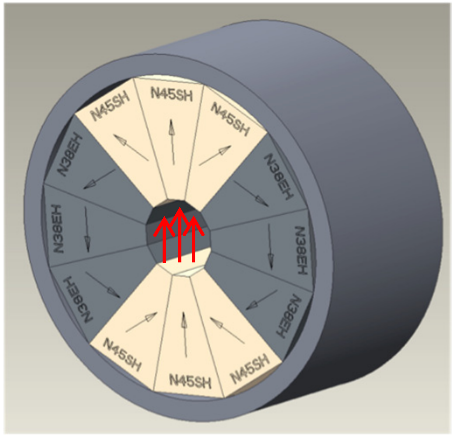
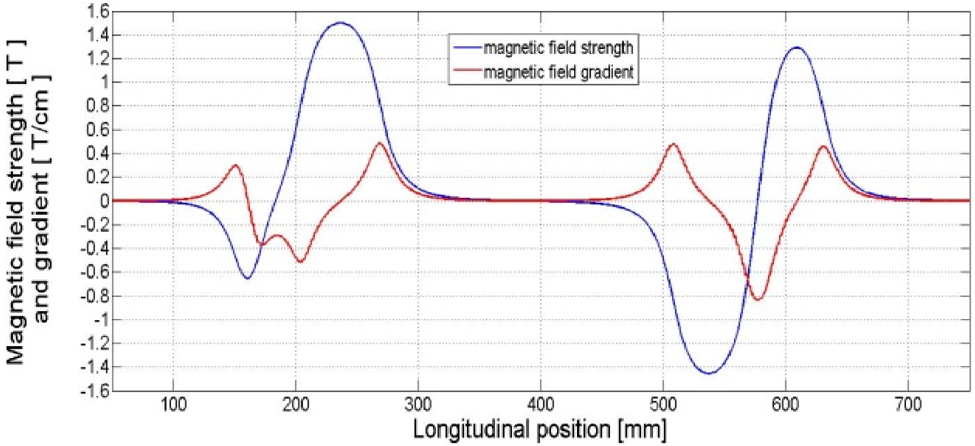
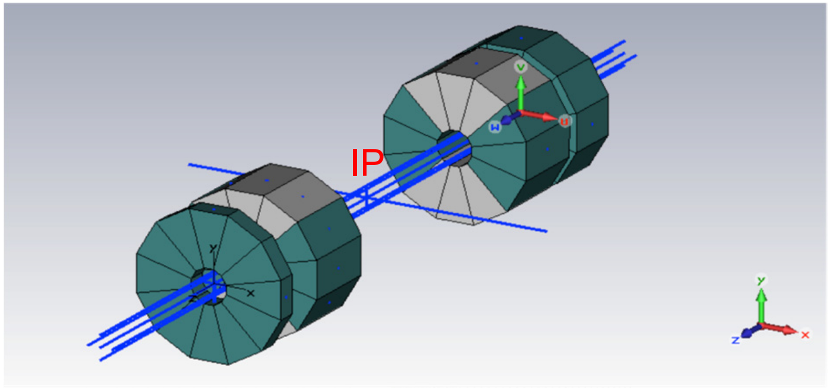
Stripping Magnet Design

Magnet Design:

- Permanent magnet Halbach array.
- 1.2 T field in stripping region.
- 40 T/m gradient (minimize emittance growth during stripping).
- Insertable + retractable from vacuum pipe.







See A. Aleksandrov, TUPRO117

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Laser Stripping Experimental Station

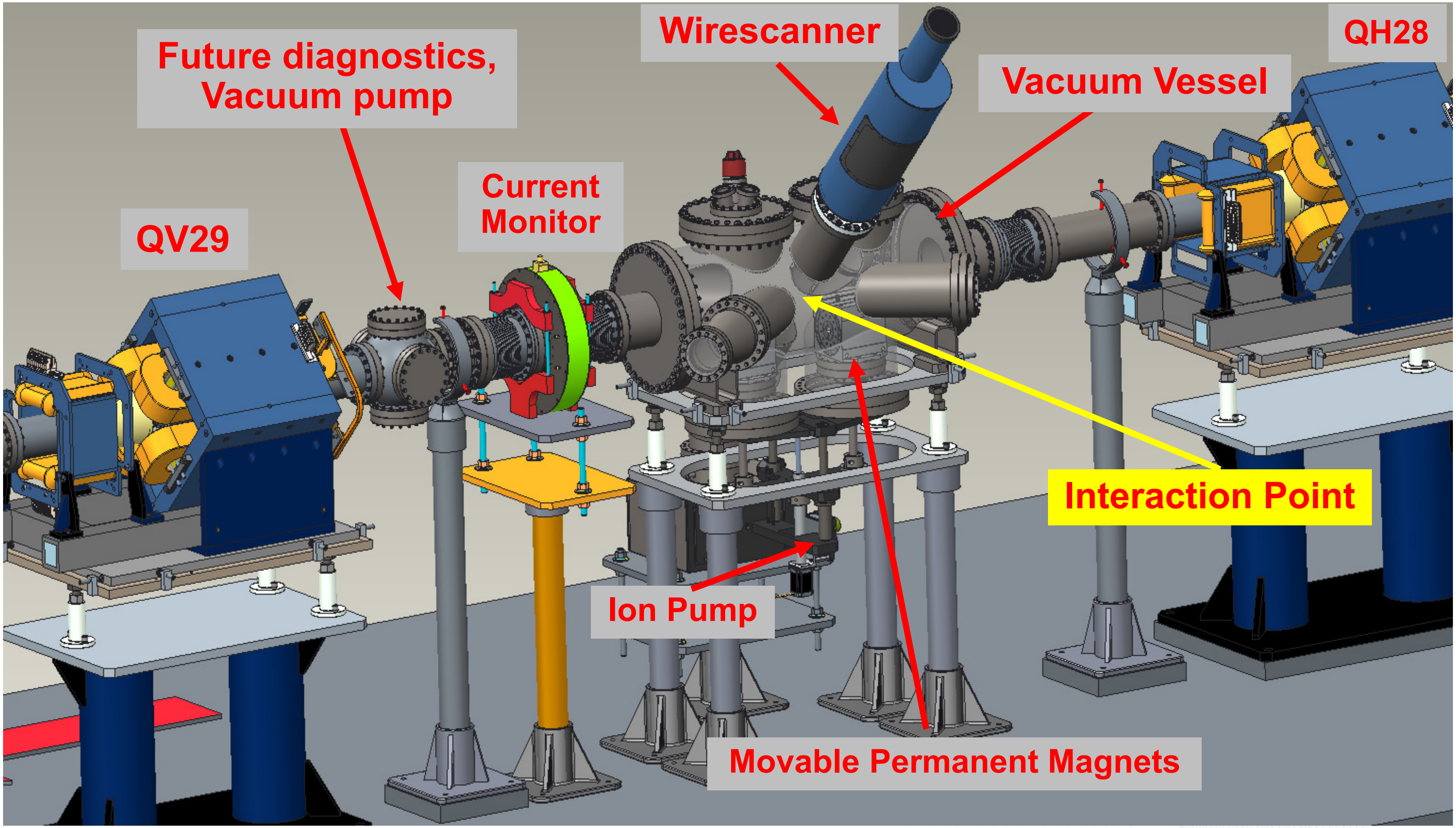

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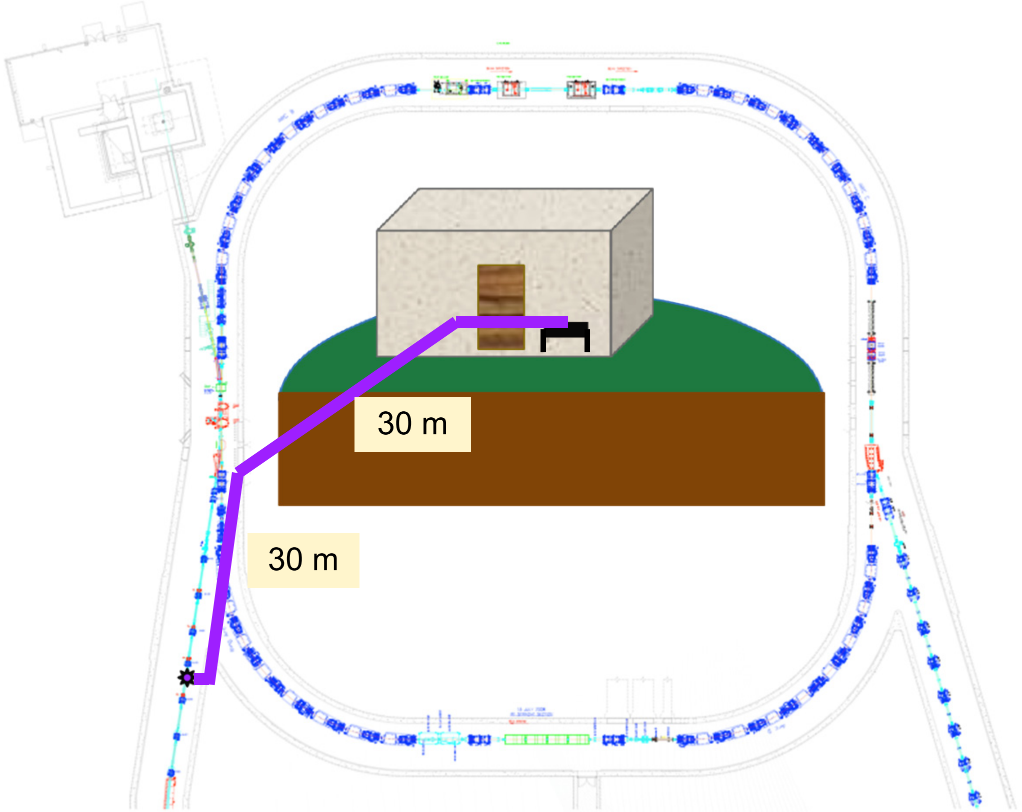
Fig. 40. General view of new LSP installation (QH28 – QV29 region)

Remote Placement of Laser

UV laser will be located in the Ring Service Building

- Advantages:
  - ✓ Protects laser
  - ✓ No moving laser in & out of tunnel for every measurement
  - ✓ Experiment schedule flexibility
- Challenges:
  - Space availability
  - Laser power loss in transport
  - Laser pointing stability



- Transport pipe ~70 m long, and requires ≥ 9 mirrors.

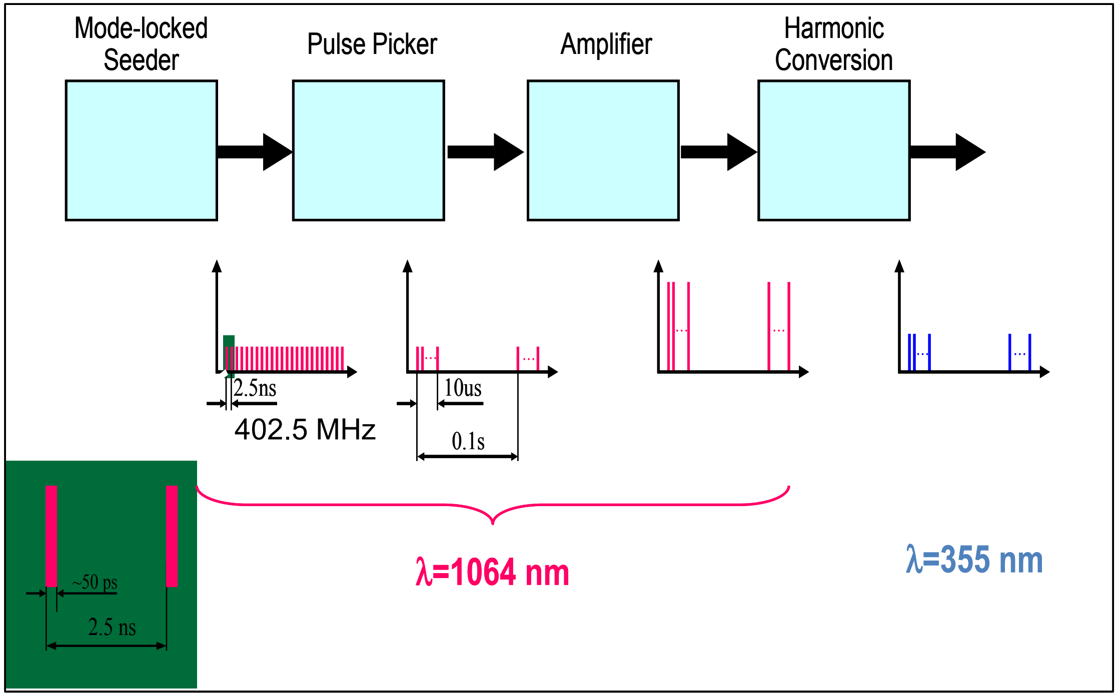
Part II: Parameter Optimization

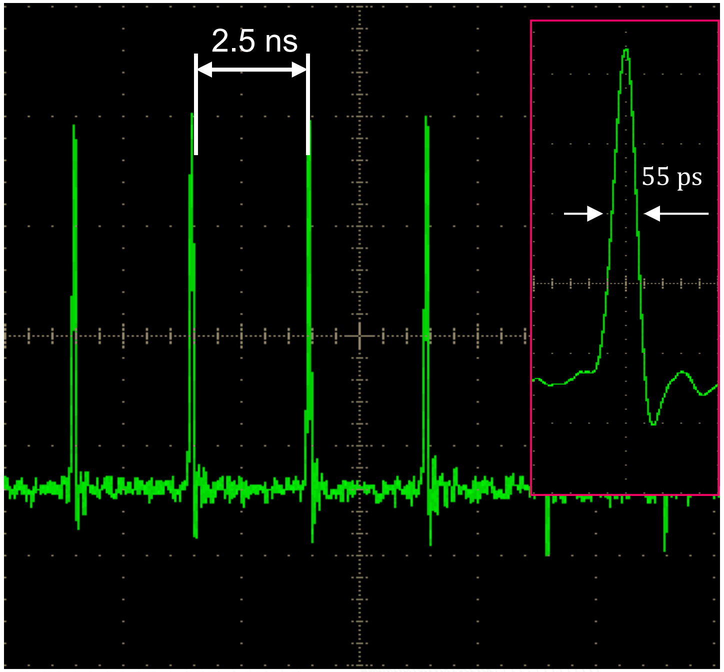
For the proposed configuration, need to minimize the required laser power and verify the available laser power:

1. Laser-ion beam temporal matching (✔ Complete).
2. Longitudinal bunch squeezing (✔ Complete).
3. Dispersion tailoring (✔ Complete).
4. Twiss optimization (In progress).
5. Assess laser power loss in transport (✔ Complete).

Laser-Ion Beam Temporal Matching

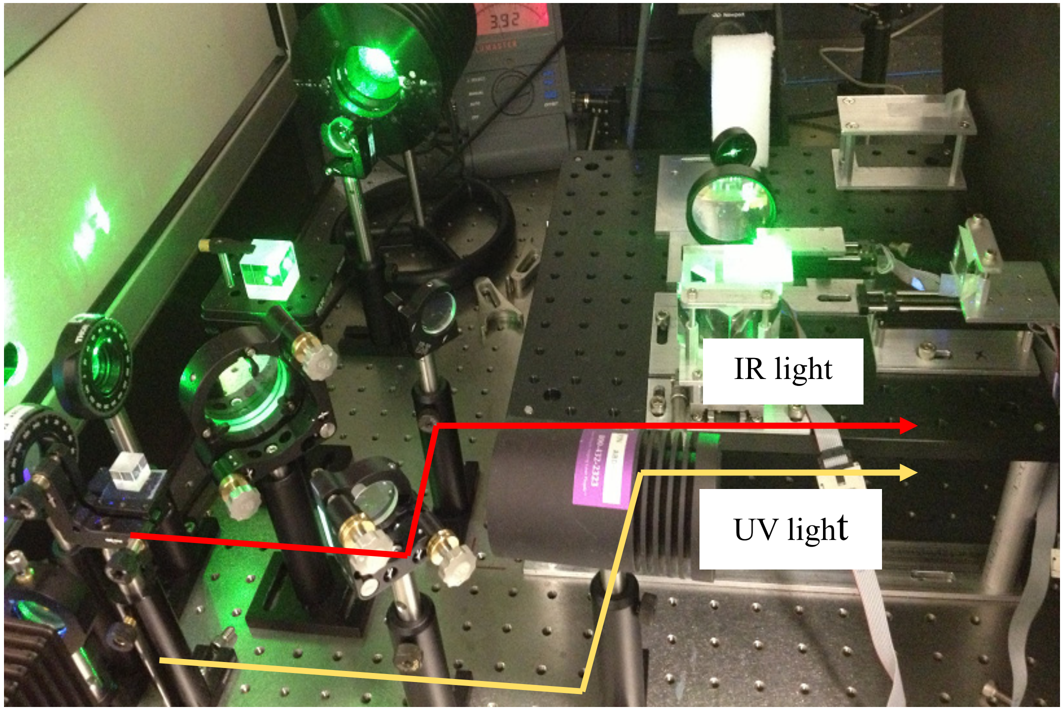
- Laser is a master oscillator power amplification (MOPA) system.
- Frequency tripled (1064 -> 355 nm)
- Macropulse structure: 10 μs @ 10 Hz
- Micropulse structure: 30-55 ps @ 402.5 MHz





UV Laser Power Measurement

- Detector bandwidth not high enough to measure UV pulse directly.
- Optical correlator built to automate this measurement.



Measured Laser Parameters

UV Peak Power	Pulse structure (micro / macro)
3.0 MW	32 ps / 10 μs
1.3 MW	54 ps / 10 μs
2.1 MW	54 ps / 5 μs

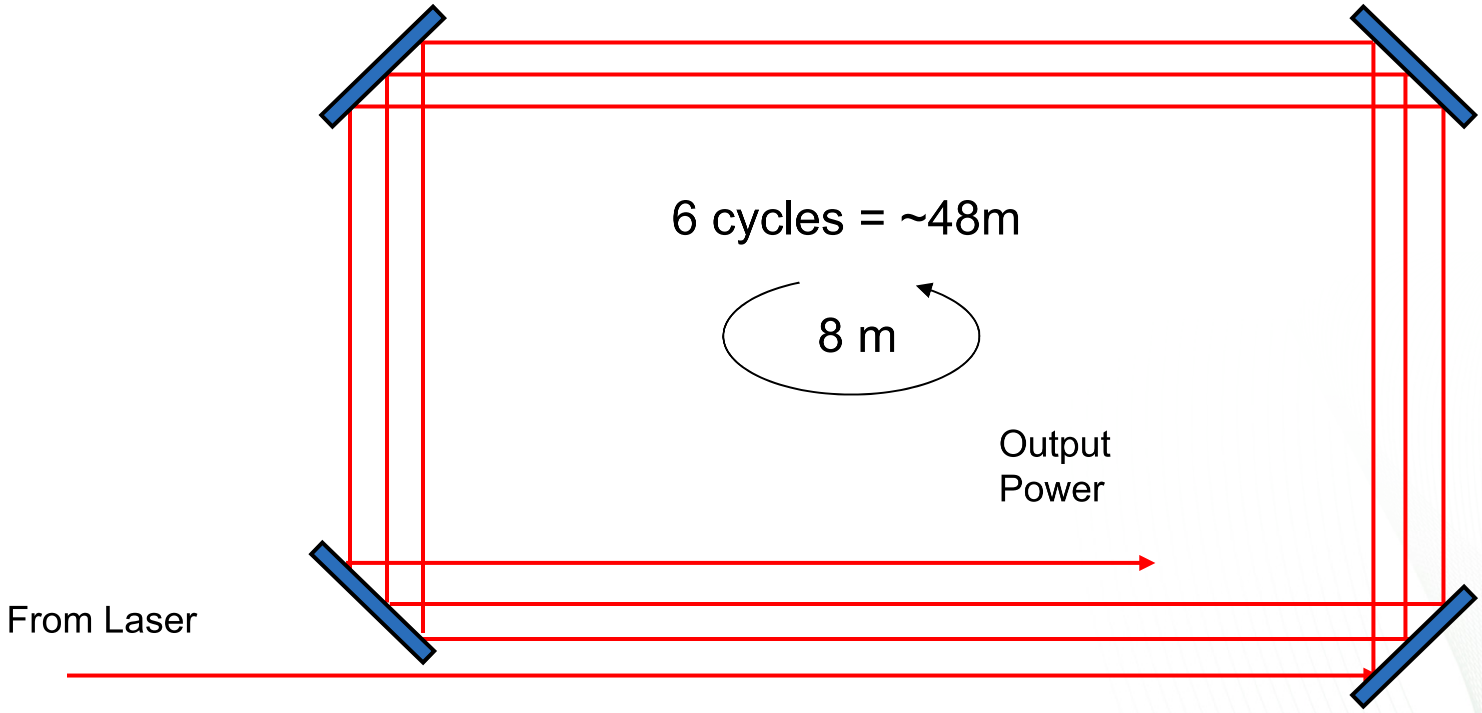
Sufficient to provide ~90% stripping efficiency.

Y. Liu, WEPME002

Laser Transport Mock-Ups

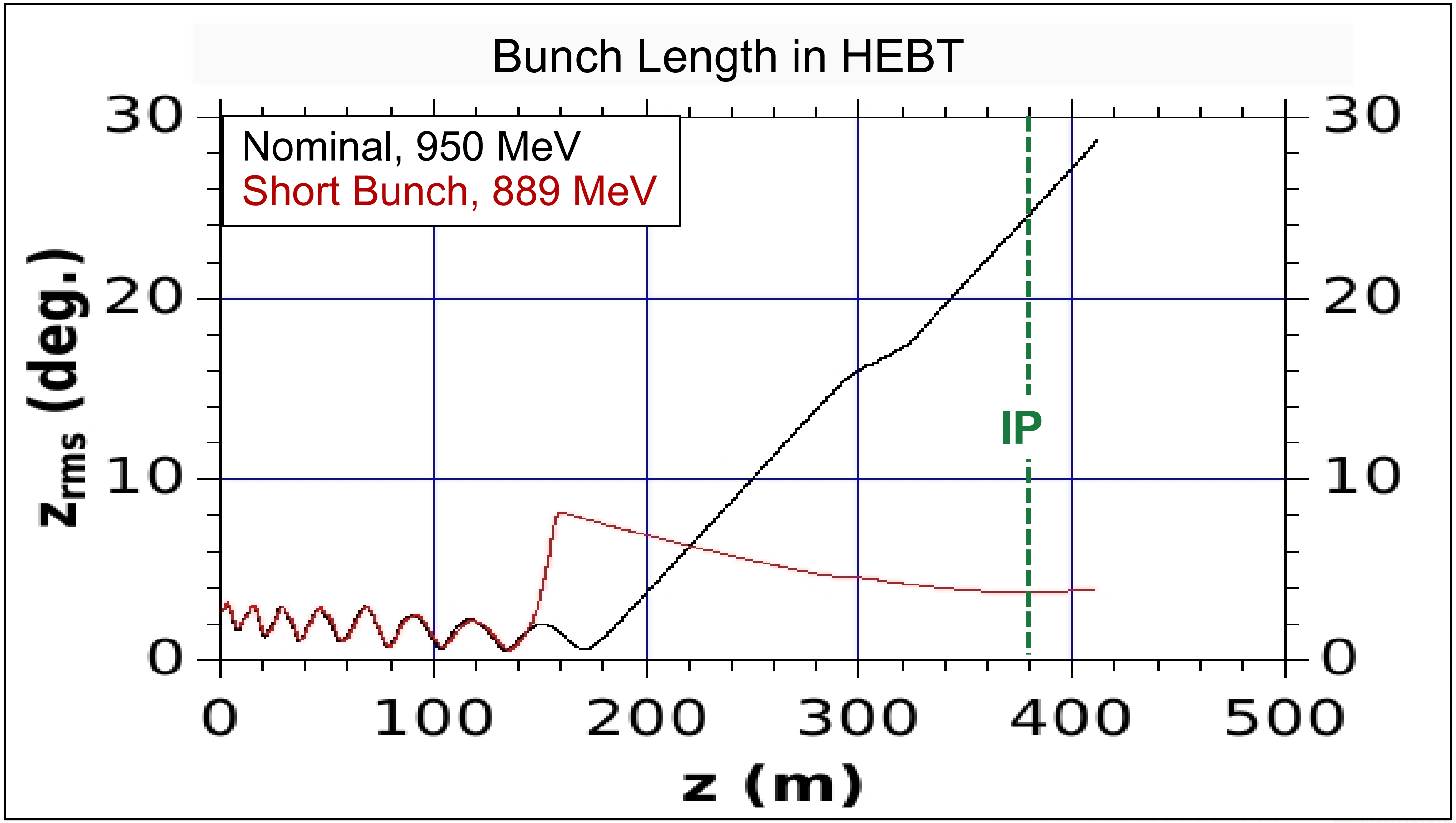
- Mirror losses measured to be ≤1%.
- ~48 m mock-up constructed to mimic laser transport line.
- Results: Expect ~ 1/3 power loss (Fresnel diffraction, higher order mode loss).

Conclusion: Remote laser placement is feasible.



Ion Beam Optics: Longitudinal

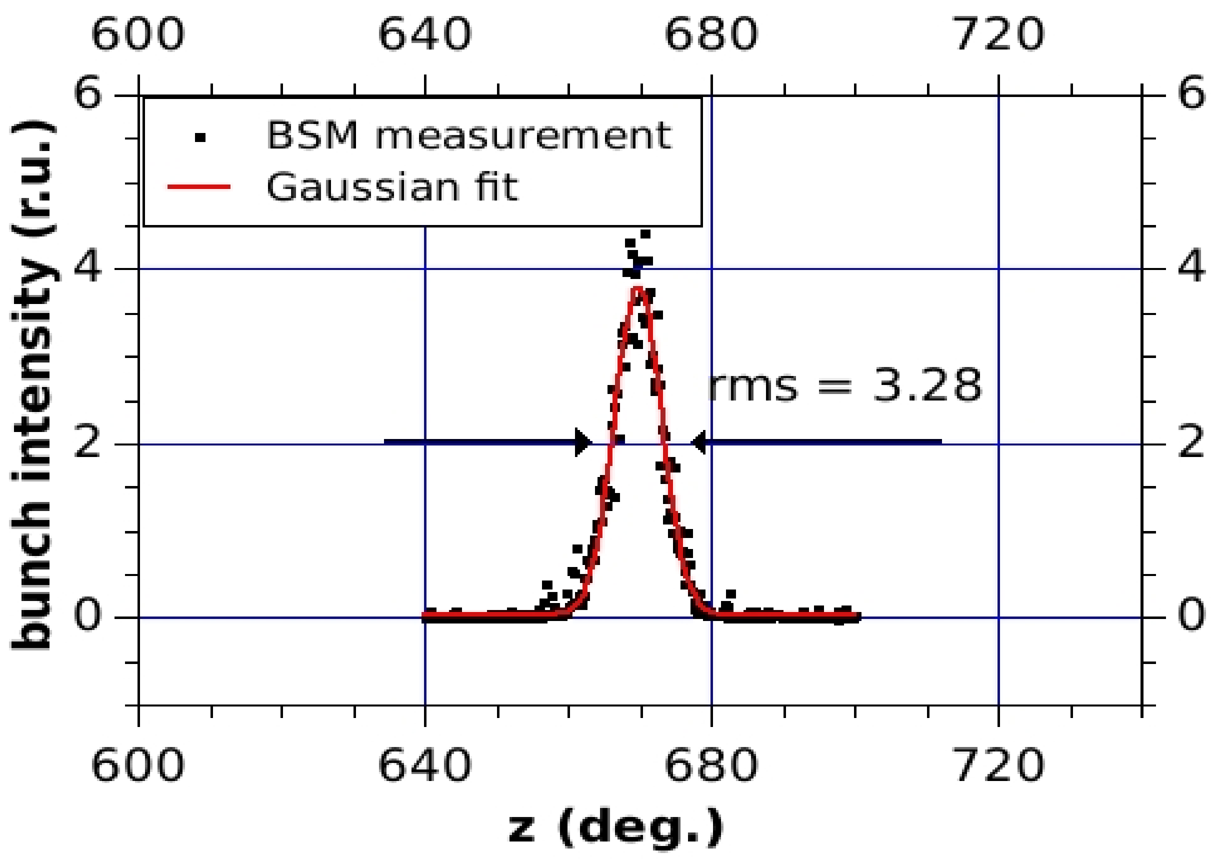
- Need to squeeze microbunch by factor of ~6 compared to nominal.
- Done by reconfiguring last 10 SCL cavities.



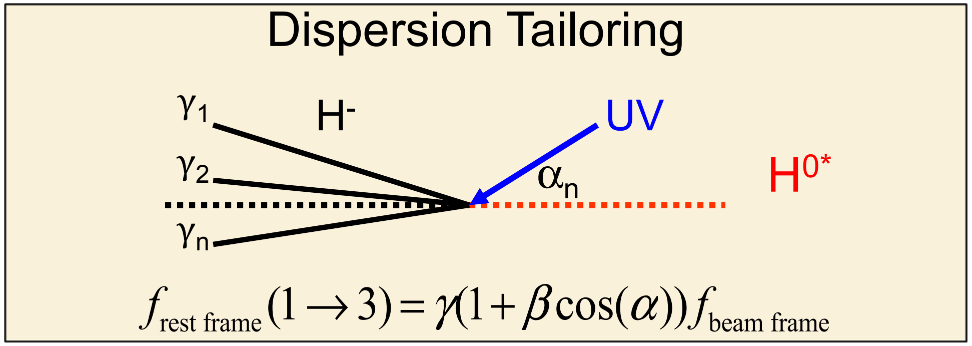
T. Gorlov, MOPRI103

Ion Beam Optics: Longitudinal

- H- micropulse width is limited by space charge: 3.45 ps per mA of charge.
- For 1 mA, we get 3.28 deg = 26.6 ps.
- Result is sufficient to ensure full coverage by laser pulse.

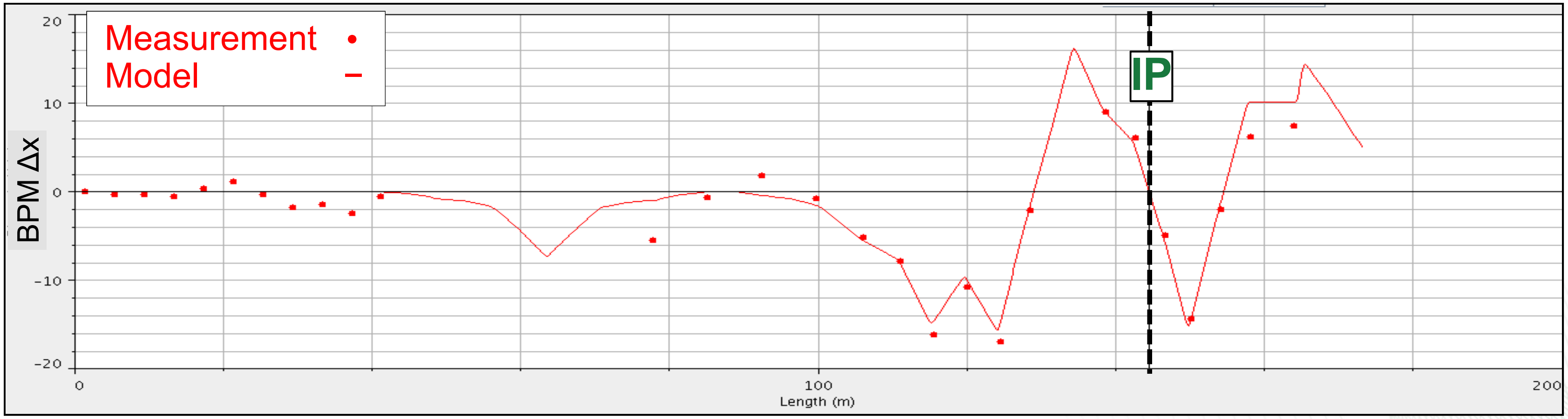


Progress on Ion Beam Transverse Optics



1. D = 0, D'= -2.6.: Eliminate majority of transition frequency spread. ✔ Complete
2. $\alpha_x = 0$, $\beta_x \approx$ large: Eliminate remaining transition frequency spread. In progress
3. $\beta_y \approx$ tiny, $\varepsilon_y \approx$ small: Small beam spot ←→ high laser power density. In progress

Measurement of Dispersion Function



Outline of Project Schedule

Due to DOE HEP grant, project is tied to a three year schedule (2013 – 2016).

Task	Comment
Year 1 (05/2013 – 04/2014)	
Parameter realization experiments (laser and ion beam)	Nearly complete
Choose location for IP and laser station, feasibility studies	Complete
Year 2 (05/2014 – 04/2015)	
Design of hardware	Ongoing
Fabrication of equipment	Ongoing
Installation of diagnostics	January 2015
Year 3 (05 2015 – 04/2016)	
Installation of remaining equipment	August 2015 & January 2016
Experiment	January – March, 2016

Stay Tuned!