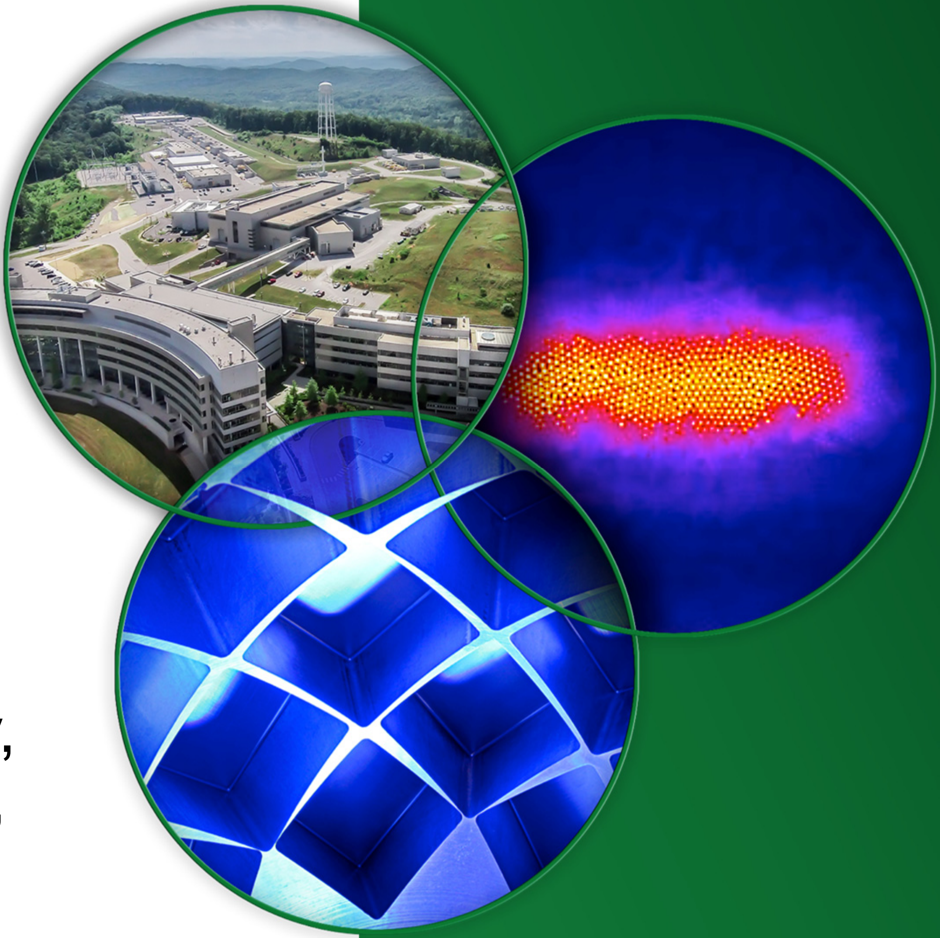
First Results of Laser Stripping of a 10 μs, 1 GeV H^- Beam at the SNS Accelerator



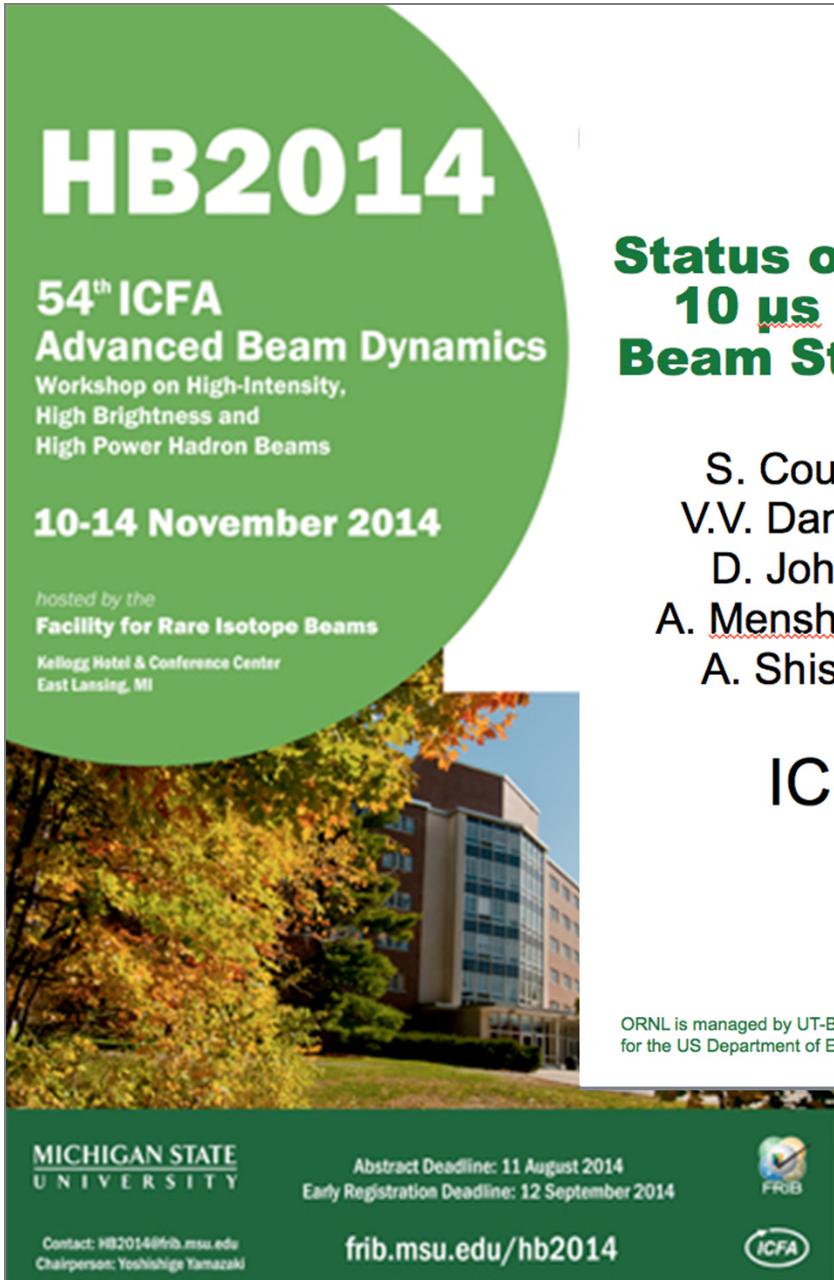
S. Cousineau,

A. Aleksandrov, C. Long, T Gorlov, D. Johnson, M. Kay, Y. Liu, M. Plum, A. Rakhman, A. Shishlo

HB2016, Sweden

July 04, 2016


HB2014
54th ICFA
Advanced Beam Dynamics
Workshop on High-Intensity,
High Brightness and
High Power Hadron Beams
10-14 November 2014
hosted by the
Facility for Rare Isotope Beams
Kellogg Hotel & Conference Center
East Lansing, MI
Plenary Speakers
Richard Baartman (TRIUMF)
Riccardo de Maria (CERN)
Nobuhisa Fukunishi (RIKEN)
Stuart Henderson (FNAL)
Hideaki Hotchi (J-PARC)
Mats Lindroos (ESS)
Thomas Roser (BNL)
Peter Spiller (GSI)
Jie Wei (MSU)
Hongwei Zhao (IMP)
MICHIGAN STATE UNIVERSITY
Abstract Deadline: 11 August 2014
Early Registration Deadline: 12 September 2014
FRIB
Contact: HB2014@frib.msu.edu
Chairperson: Yoshishige Yamazaki
frib.msu.edu/hb2014
ICFA



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

S. Cousineau, A. Aleksandrov, V.V. Danilov, F. Garcia, T. Gorlov, D. Johnson, Y. Liu, N. Luttrell, A. Menshov, M. Plum, A. Rakhman, A. Shishlo, Y. Takeda, Y. Wang

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

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IT WORKED!!!

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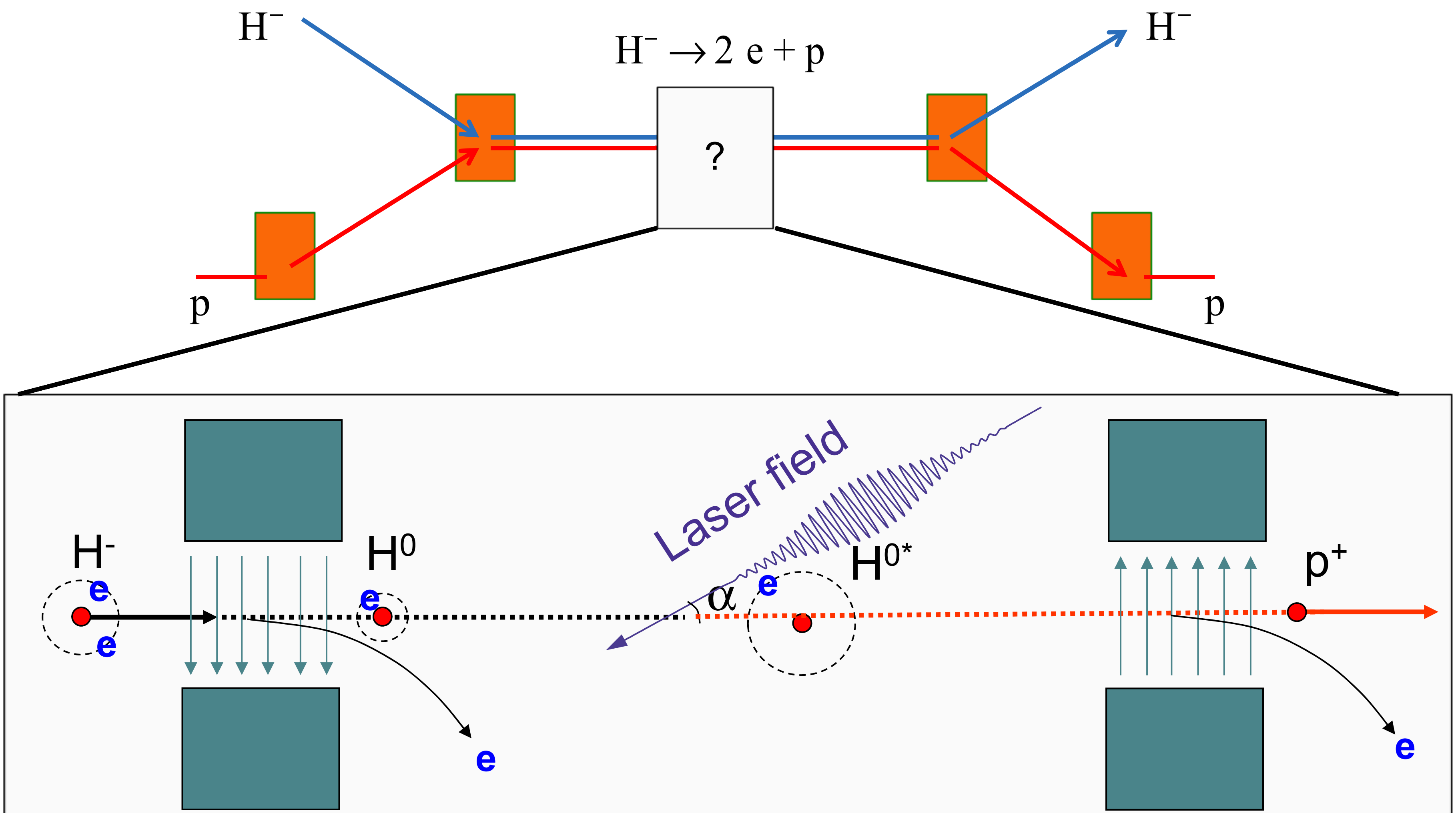
Laser Assisted Stripping Concept

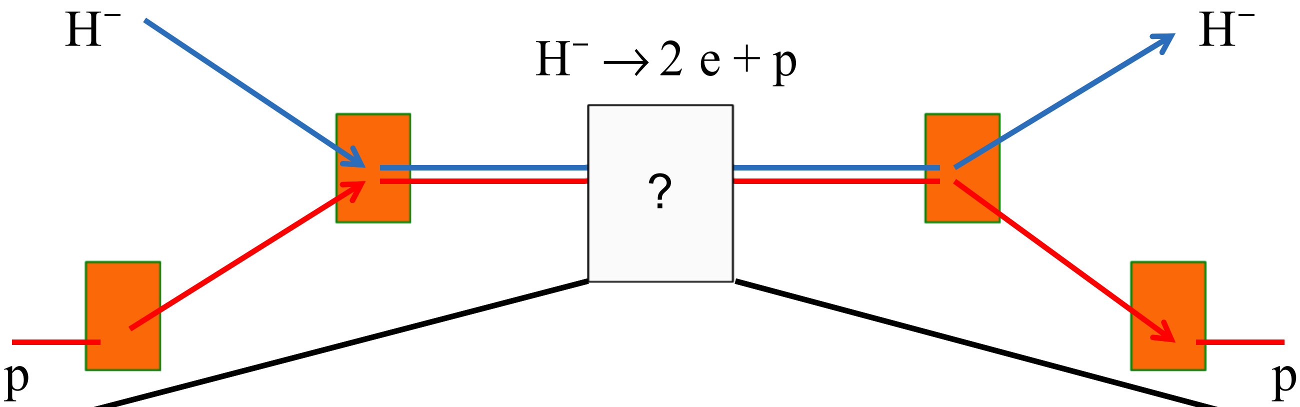


Step 1:
Lorentz Stripping
$H^- \rightarrow H^0 + e^-$

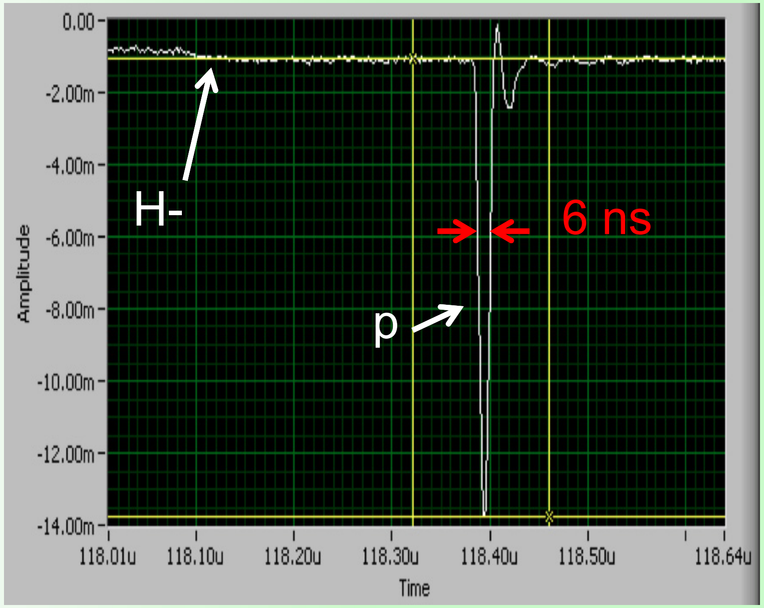
Step 2:
Laser Excitation
$H^0 + \gamma \rightarrow H^{0*}$

Step 3:
Lorentz Stripping
$H^{0*} \rightarrow p + e^-$

Laser Assisted Stripping Concept



2006 Proof of Principal Experiment

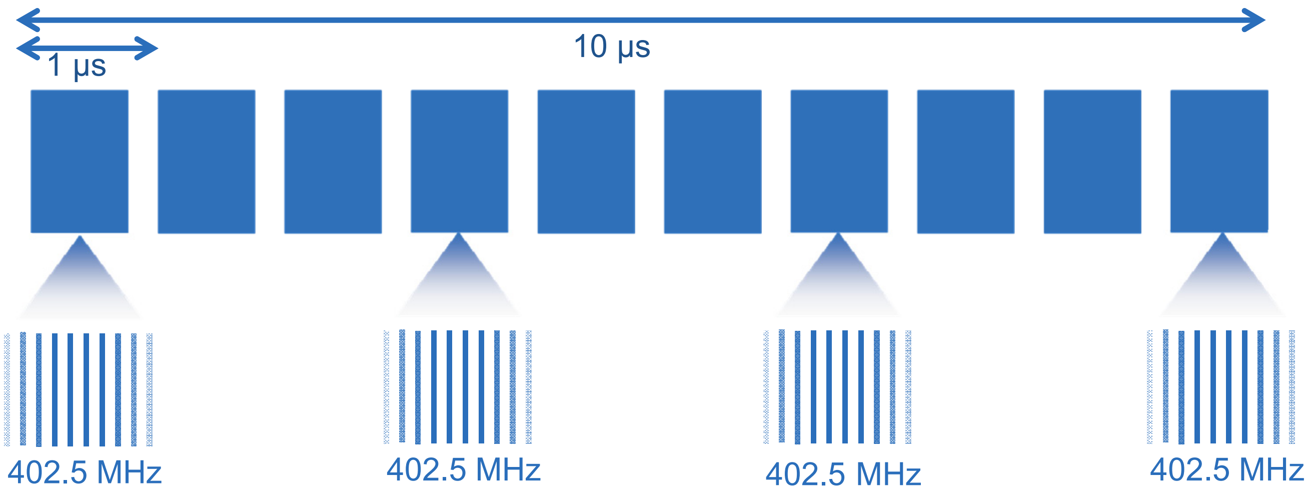


Experiment conducted with
- 10 MW UV laser.
- Diverging laser
- Laser in tunnel

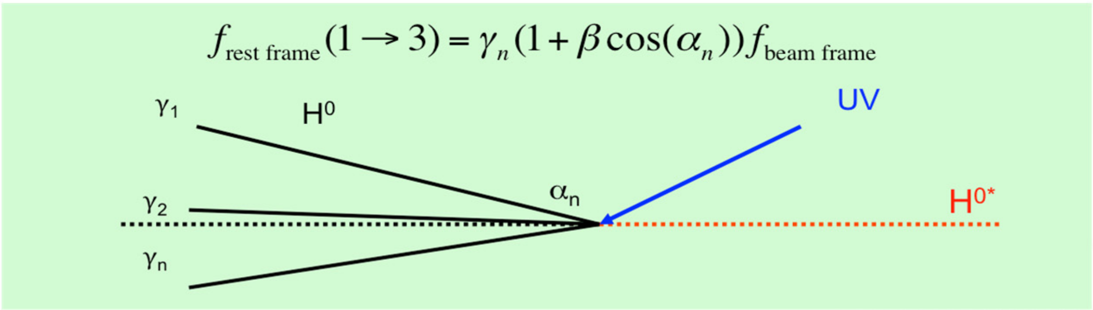
Straightforward scaling to 1 ms requires: **~600 kW average UV laser power (way too much!)**

Laser Power Savings Techniques

- Temporally match laser to ion beam 402.5 MHz structure. 10 μs burst



- Apply dispersion tailoring to reduce transition frequency spread.



- Squeeze beam longitudinally and vertically to maximize photon density and overlap: <1 mm vertical beam size, < 35 ps FWHM longitudinal size..
- Enforce α_x=0 at interaction point.

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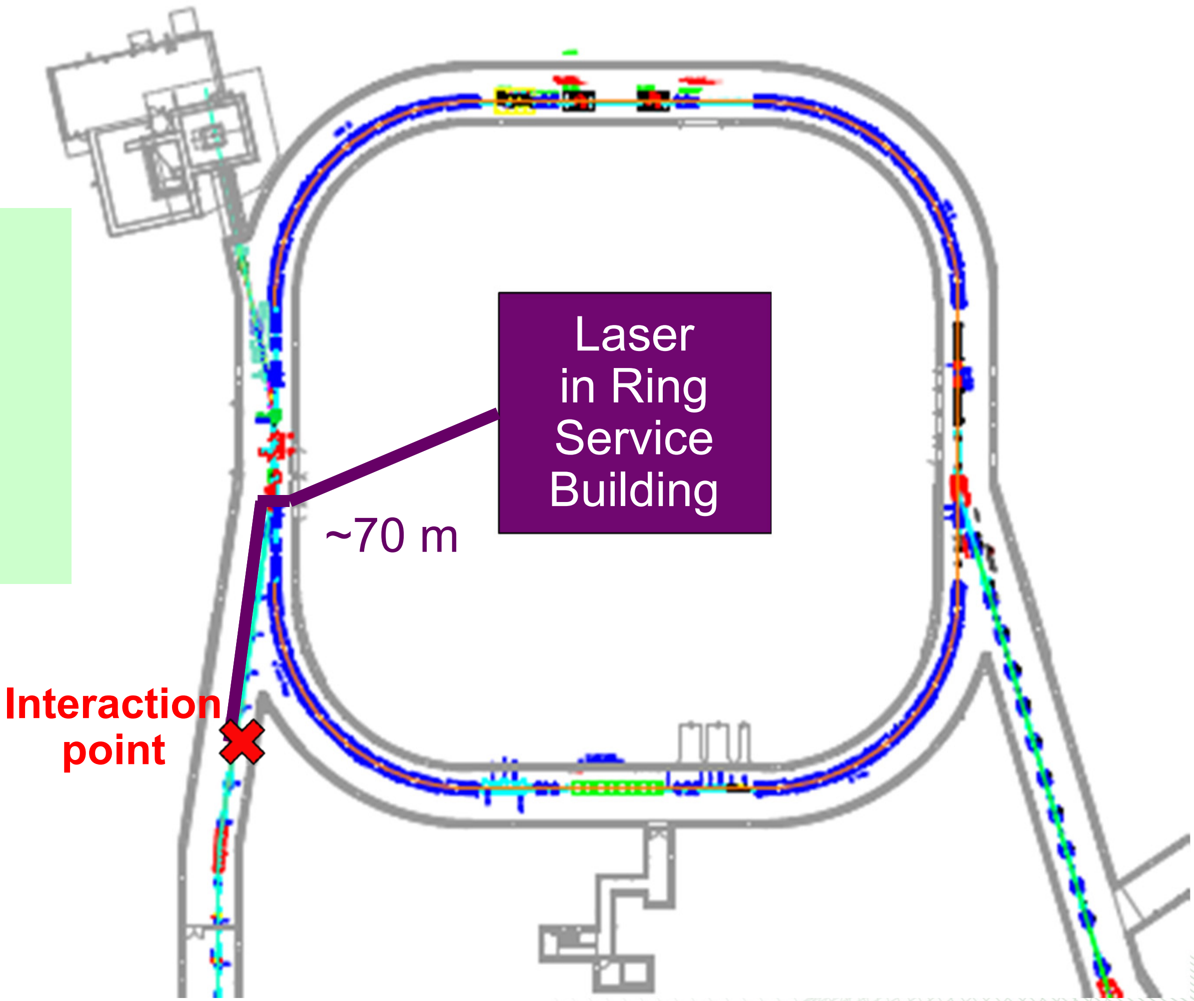
Configuration of 10 μs Experiment

- Experiment is in the transport line to the ring (HEBT)
- Laser is located remotely in Ring Service Building (RSB)

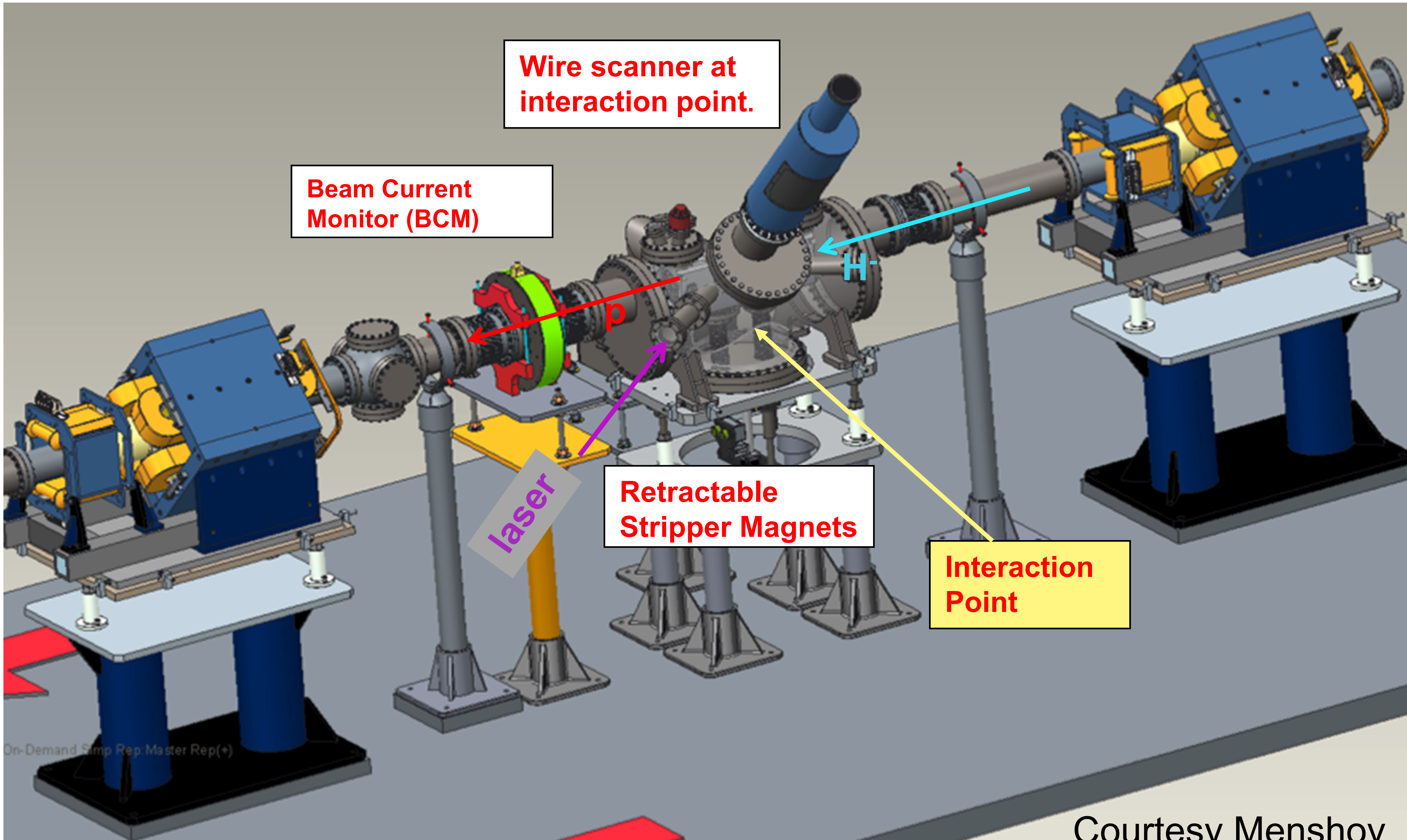
70 m + 9 mirrors in transport.

Concerns:

- Laser power loss
- Pointing stability

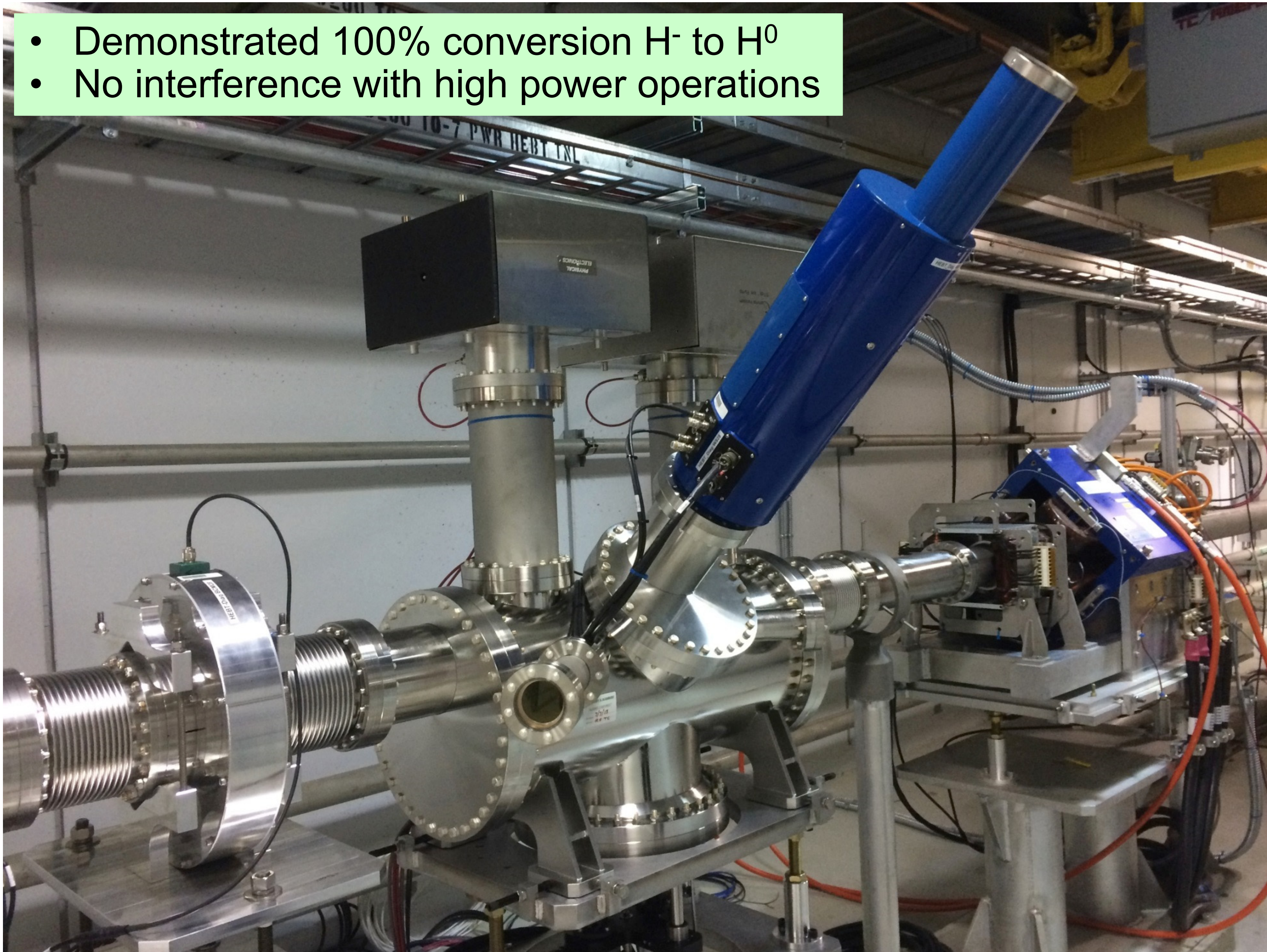


Engineering View of Experimental Vessel



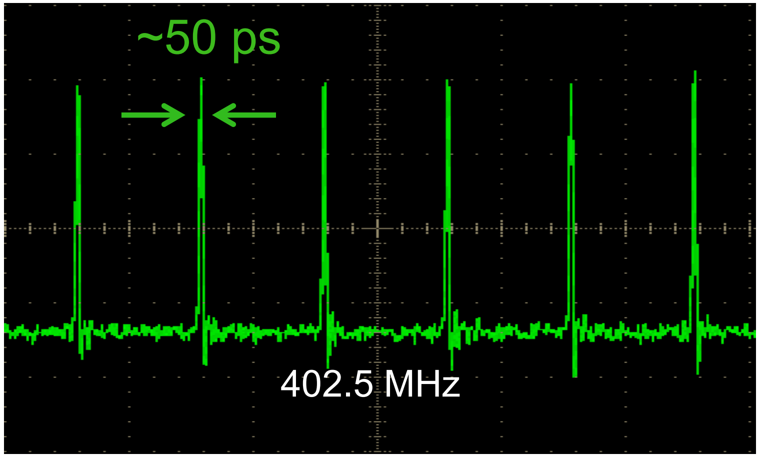
Installed Experimental Vessel

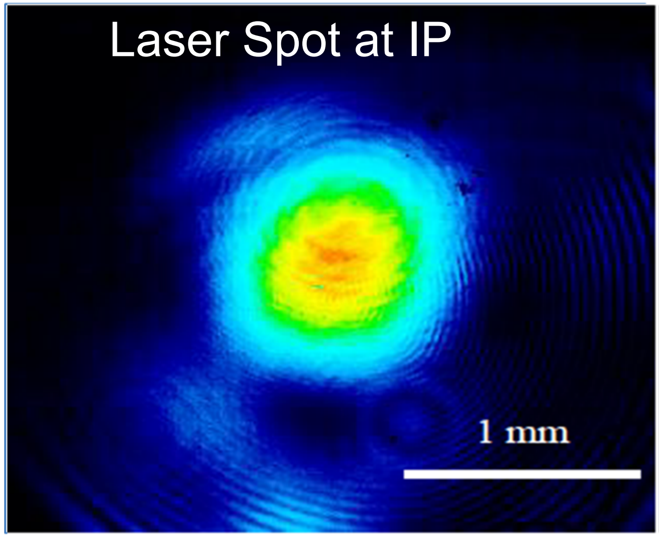
- Demonstrated 100% conversion H^- to H^0
- No interference with high power operations

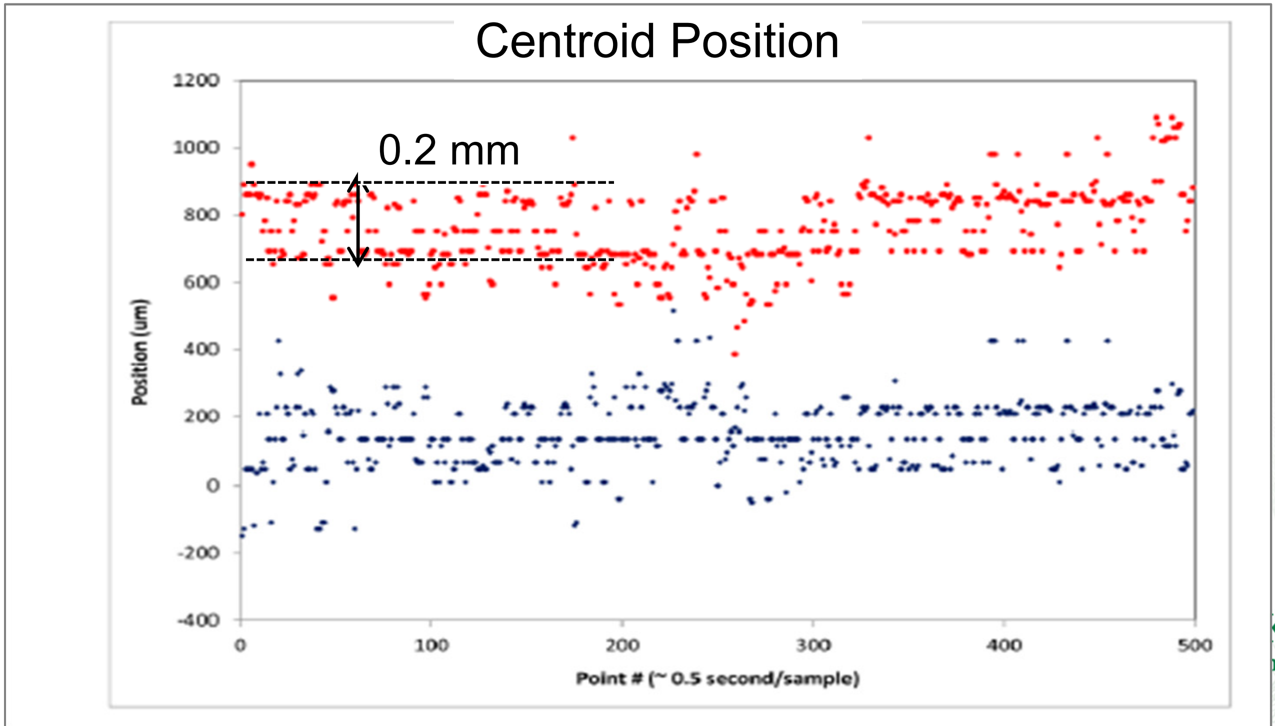


Laser At Interaction Point

Laser Temporal Structure



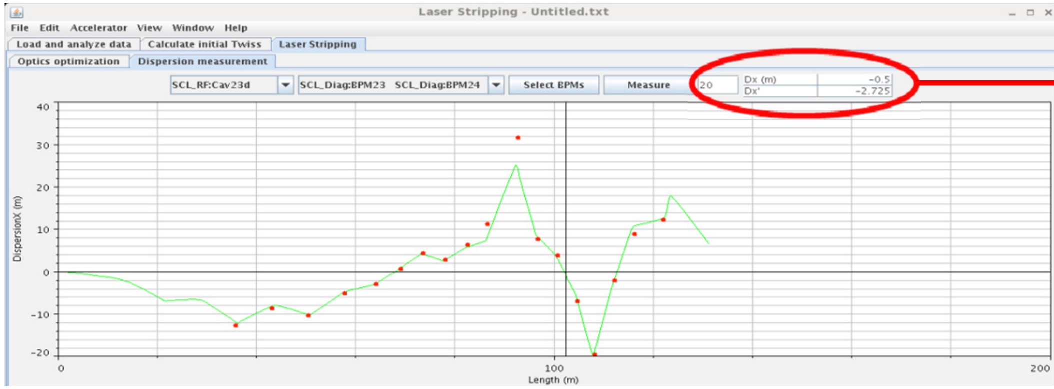




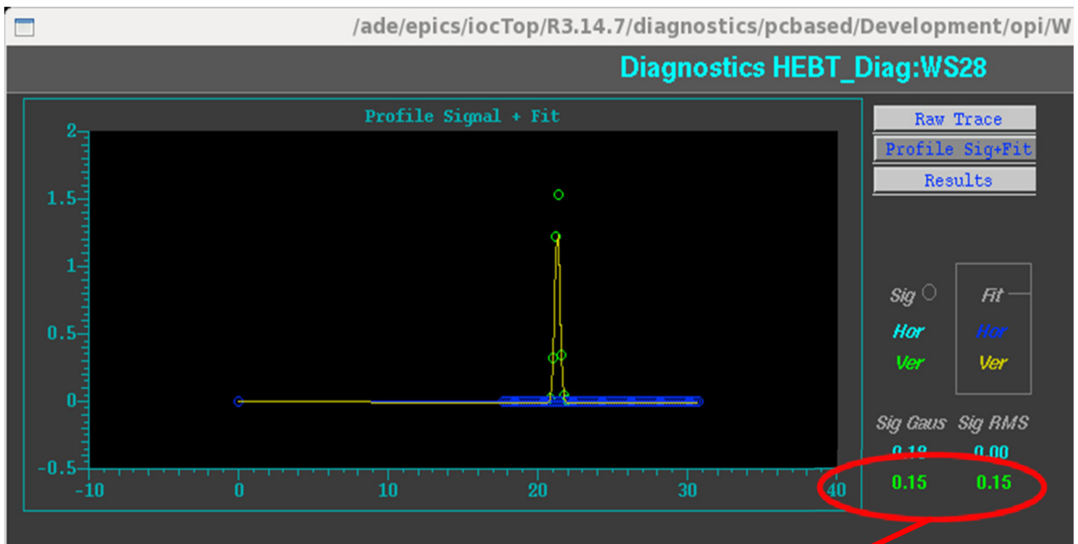
Final Measured Laser Parameters at IP

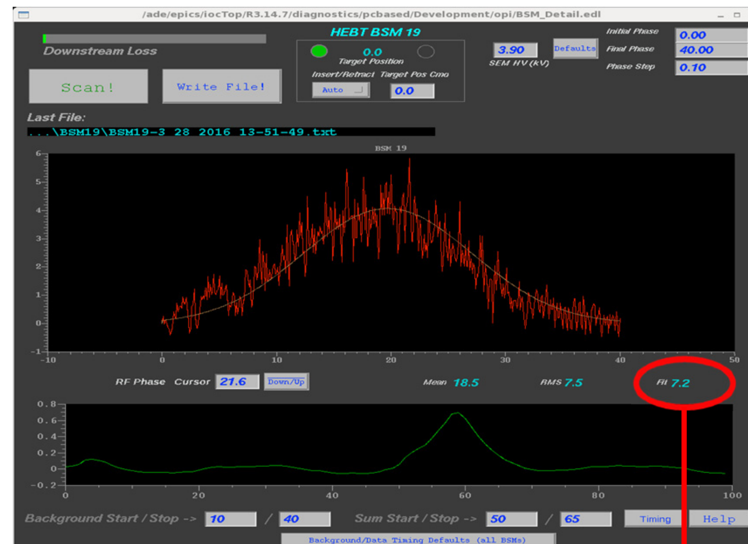
Parameter	Required (Design)	Delivered
Remote Station Laser Parameters		
Macropulse length	10 us	10 us
Micropulse width	> 30 ps	30 – 50 ps (adjustable)
Peak Power in RSB	1.5 MW	2.5 MW (at 35 ps)
In Tunnel Laser Parameters		
Transmission Efficiency	60%	70%
Maximum Peak Power	1 MW	~2 MW
Pointing stability at IP		±0.10 mm (H) ×±0.11 mm (V)
Horizontal divergence at IP	2 mrad	2.6 mrad
Vertical size at IP	0.8 mm	1.1 mm

Ion Beam Configuration During Experiment



D=0, D'=-2.7, as desired





σ_v= 0.15 mm

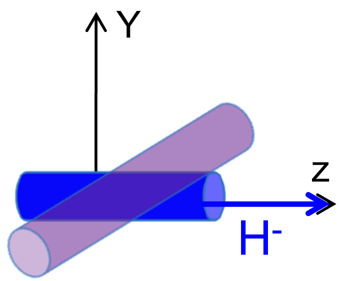
Would have preferred < 0.1 mm, but good enough.

$\sigma_l \leq 7.2°$

Limited by bunch shape monitor resolution.

Laser-Ion Beam Alignment: Vertical Position

Need to vertically align laser and ion beams:



Complicated by the need to also phase match the laser and ion beam.

Slightly laser and beam frequency to introduce a sweep over all phase:

f_{laser} = 402.51 MHz

f_{beam}= 402.50 MHz

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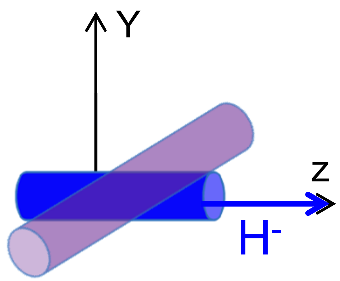

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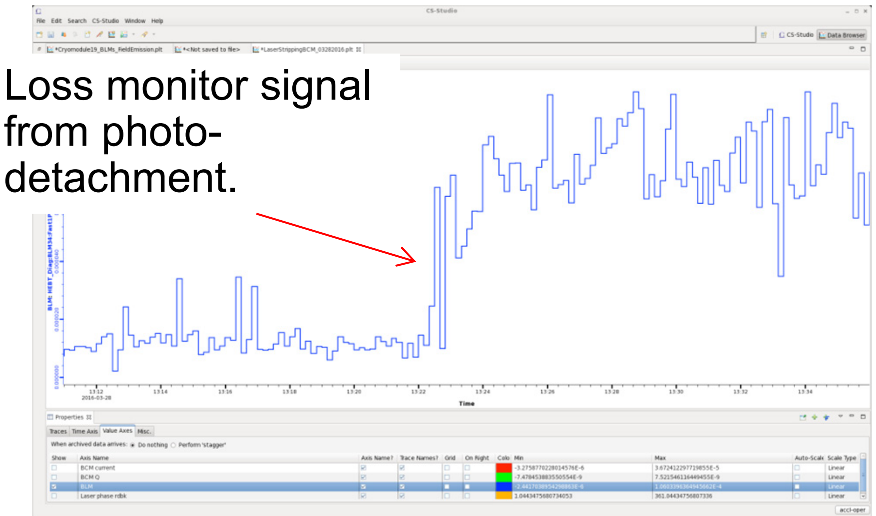
Method 1: Steer laser or ion beam, look for beam loss by photo-detachment.



Loss monitor signal from photo-detachment.

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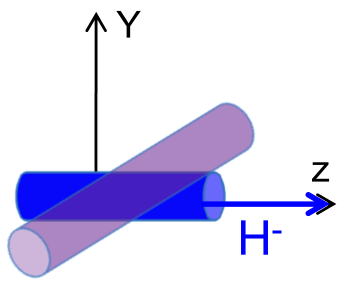

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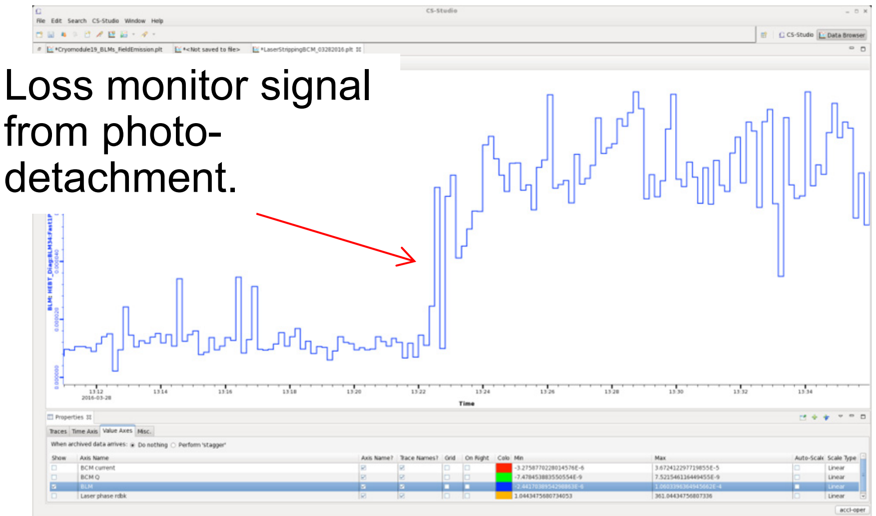
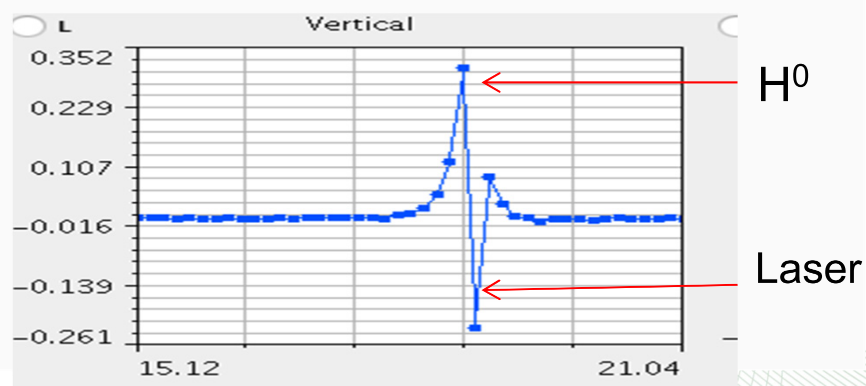
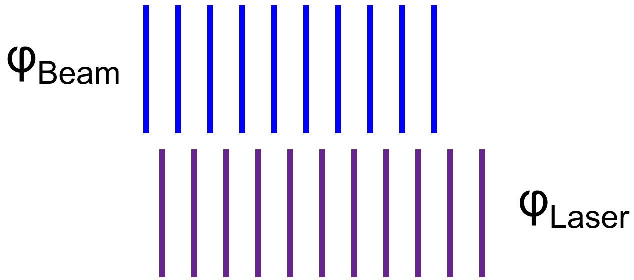


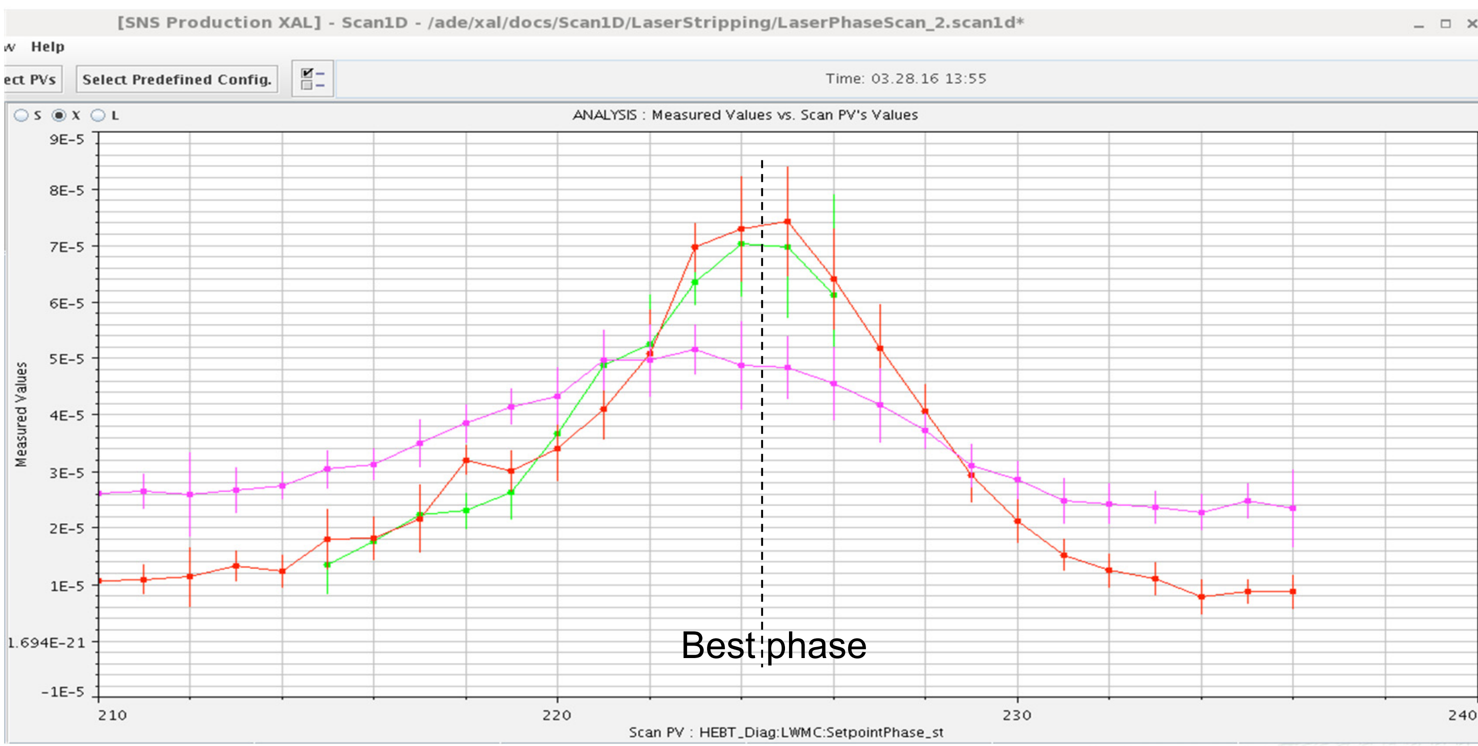
Method 2: Look for ion and laser beam on interaction point wirescanner.



Laser-Ion Beam Alignment: Phase

- After vertical alignment accomplished, restore laser to 402.5 MHz.
- Sweep laser phase and look for beam loss from photo-detachment.





First Attempt – No Stripping

Final steps:

1. Insert stripping magnets, confirm H^0 conversion.
2. Vary laser incoming angle to find tune resonant frequency.

➔Only indication of correct angle is stripped beam.

We saw NOTHING.

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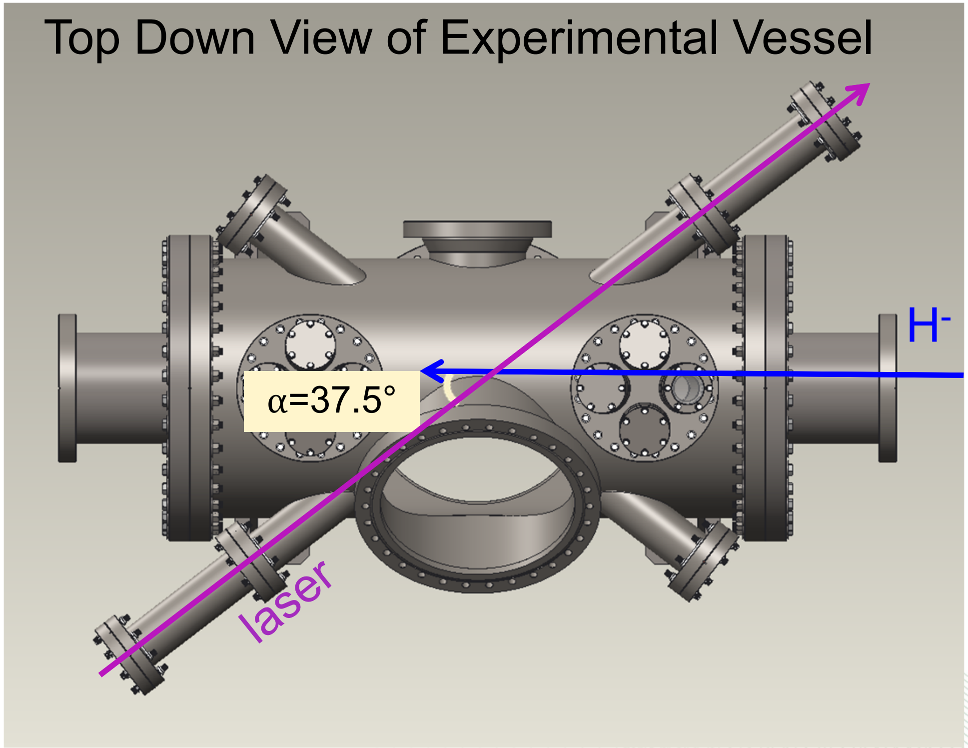
   ➔Only indication of correct angle is stripped beam.

We saw NOTHING.

Back to the drawing board…We realized:

- Vessel was designed for 987 MeV, α=37.5°.
  (Due to concerns over SCL performance.)
- 2 years later we had forgotten this -- set the experiment up for 1 GeV, α=39.7°
- Resulted in incorrect resonant excitation frequency for H^0.



Second Attempt – First Signature

"You have to really use your imagination…" – Mike Plum

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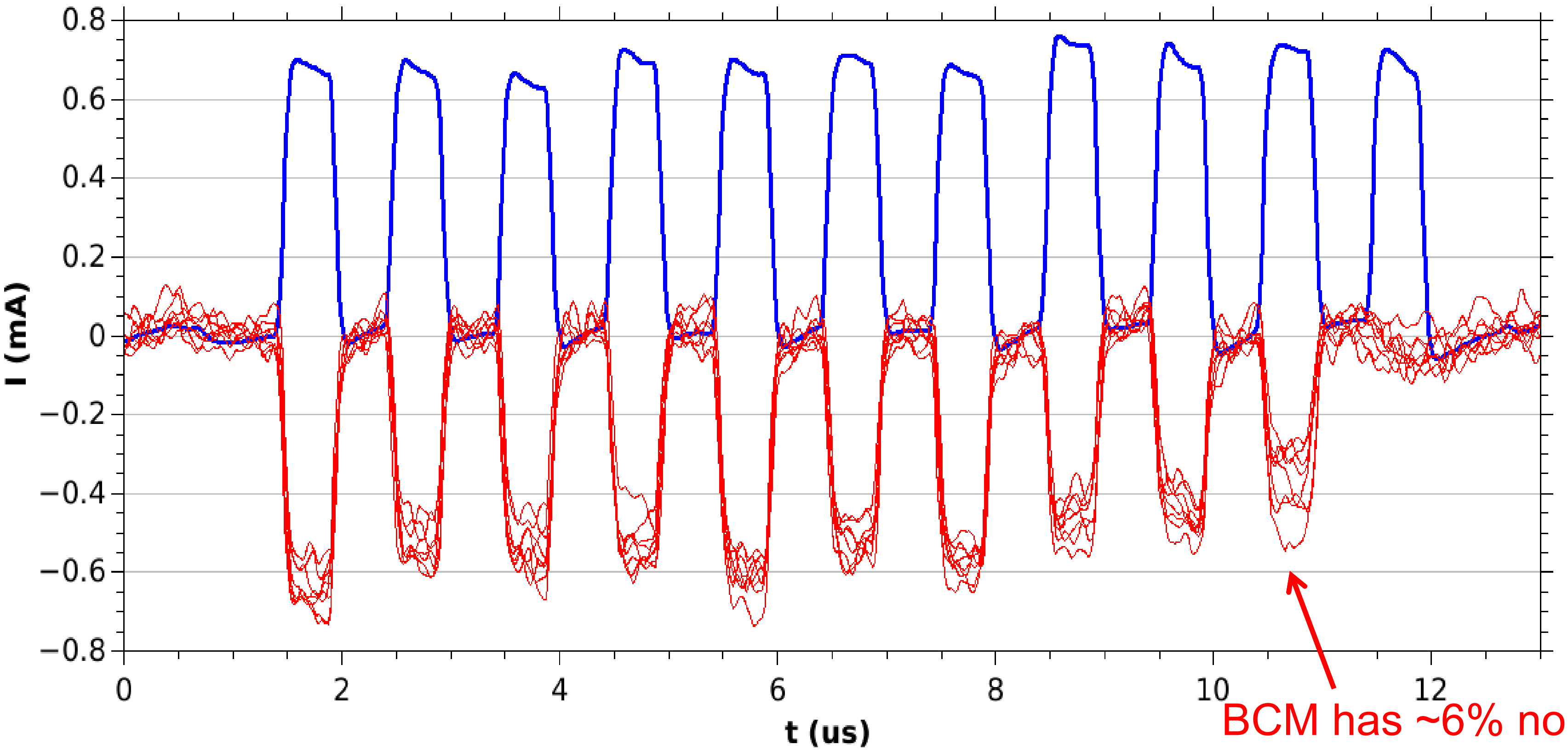
Final Results and Estimated Efficiency

March 28, 2016

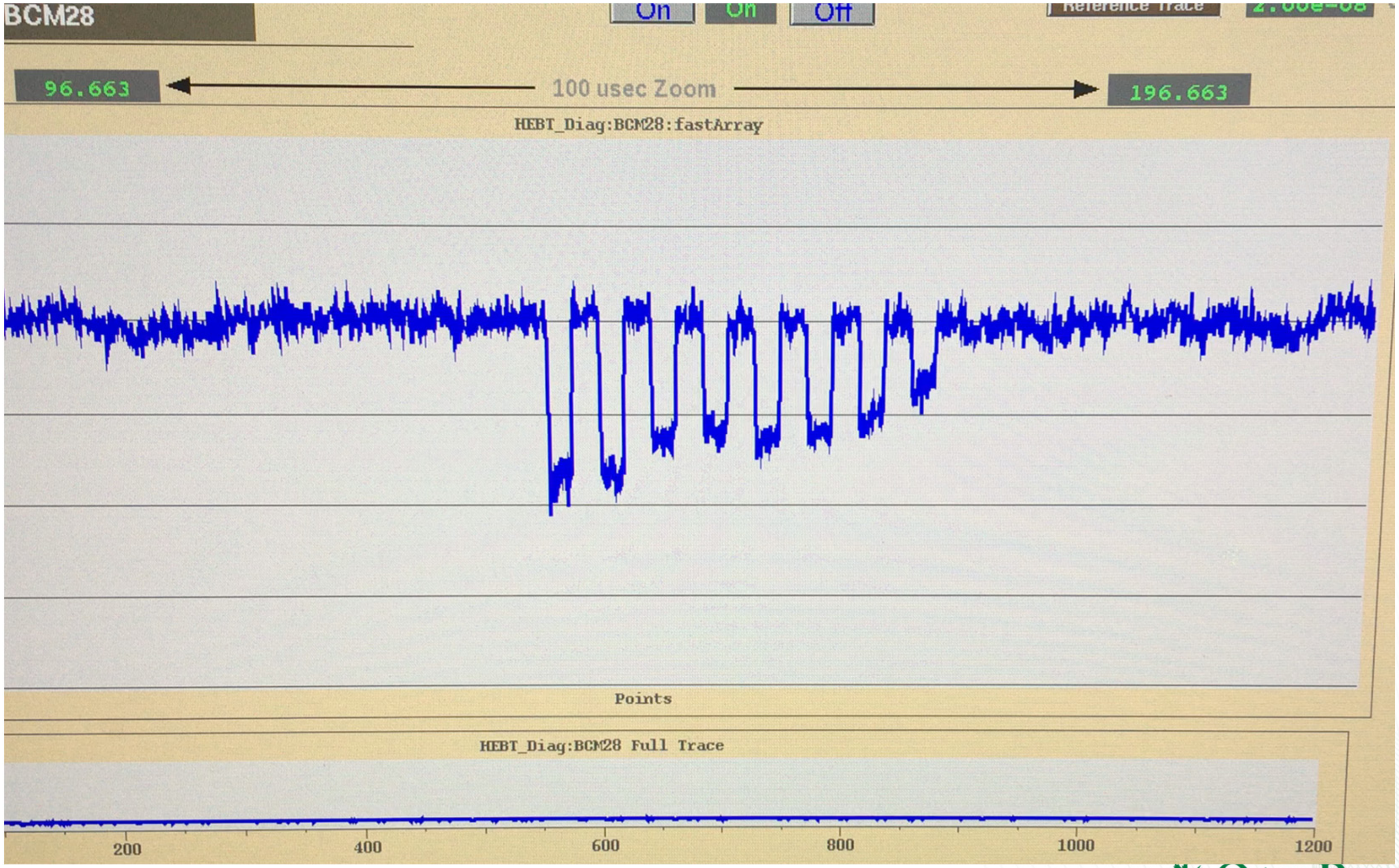


BCM has ~6% noise.

Stripping efficiency > 90% (exact value pending)

Impact of Laser Jitter

- Due to laser jitter, the stripping efficiency varied pulse by pulse
- This made fine tuning very difficult.



Continuing Work On:

1. Final stripping efficiencies.

1. Parameter sensitivities:
   I. Impact of dispersion tailoring on stripping efficiency
      - Measured for D'=nominal, D'=half, D'=0 (no tailoring)
   II. Efficiency vs. laser power.