SNS Next Laser Stripping Experiments

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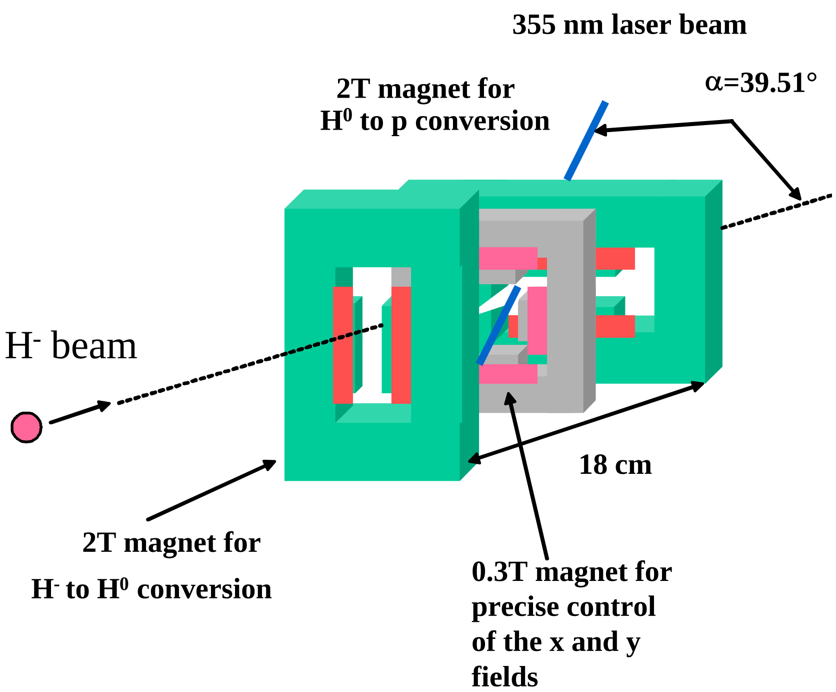
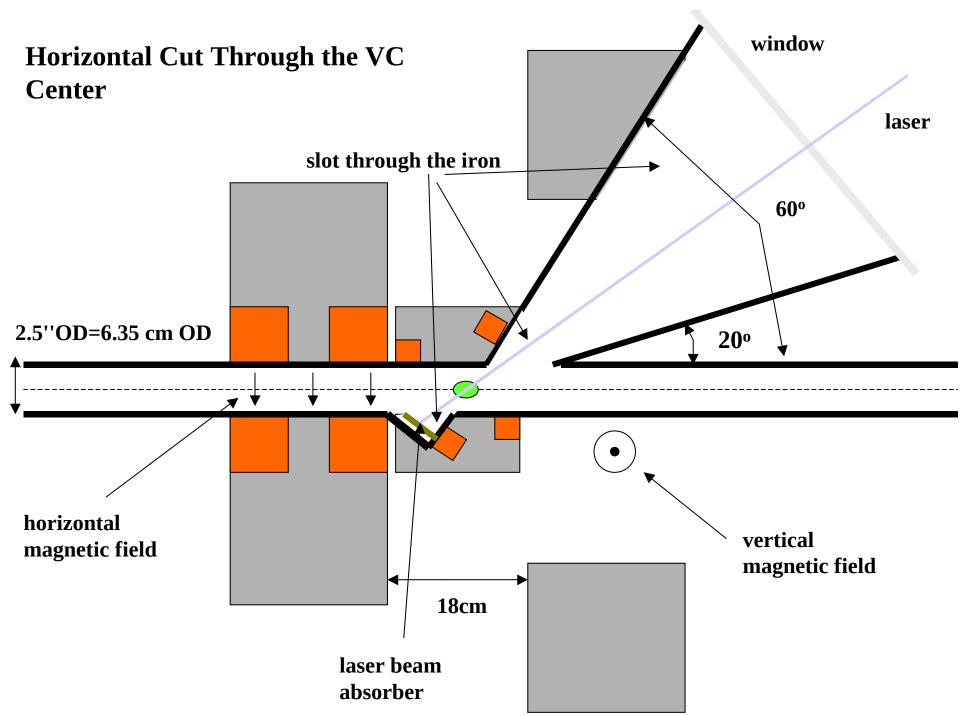
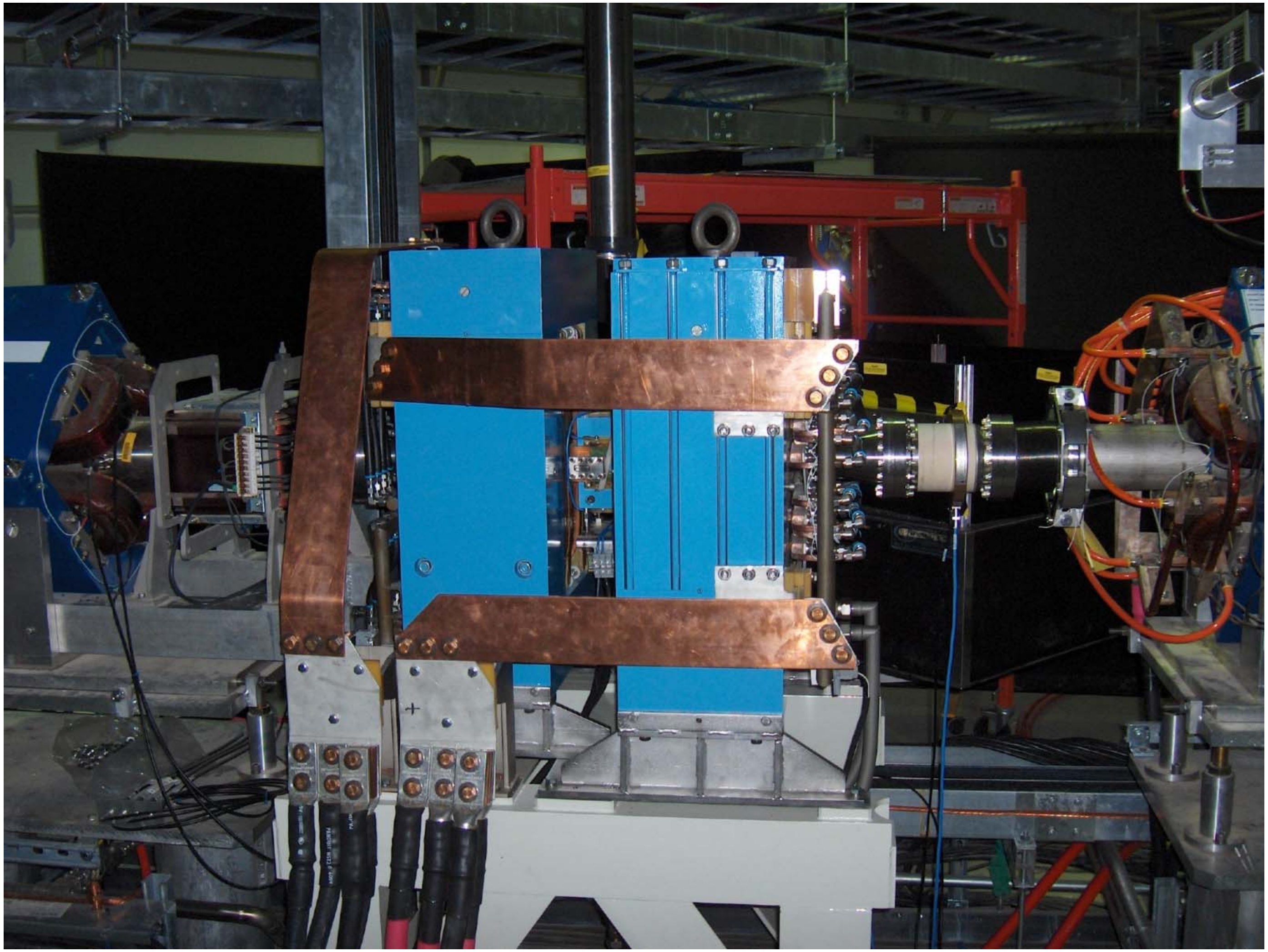
Proof-of-Principle Experiment Layout

- **Installed experiment hardware between the SNS linac exit and the linac beam dump**

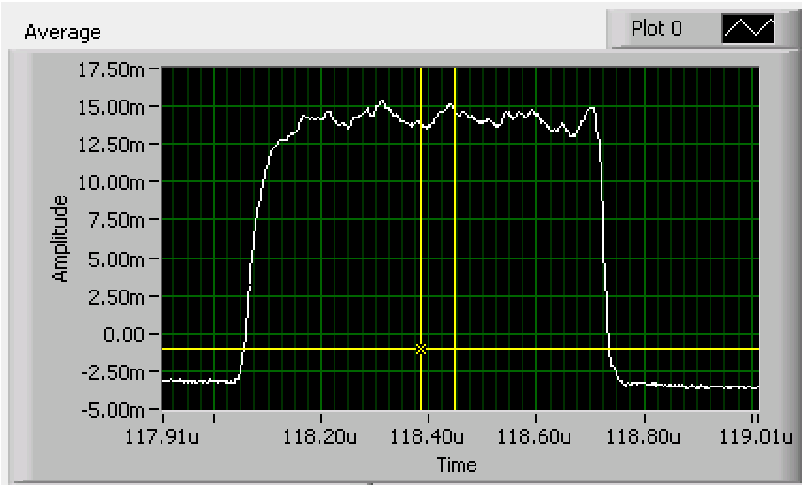


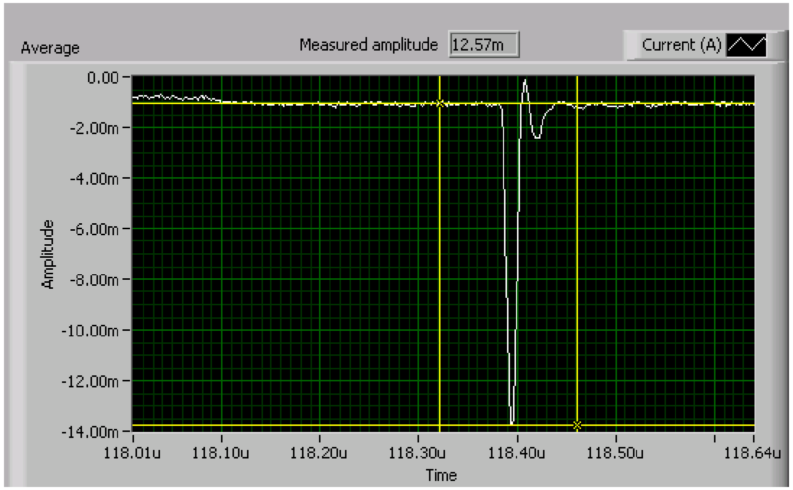


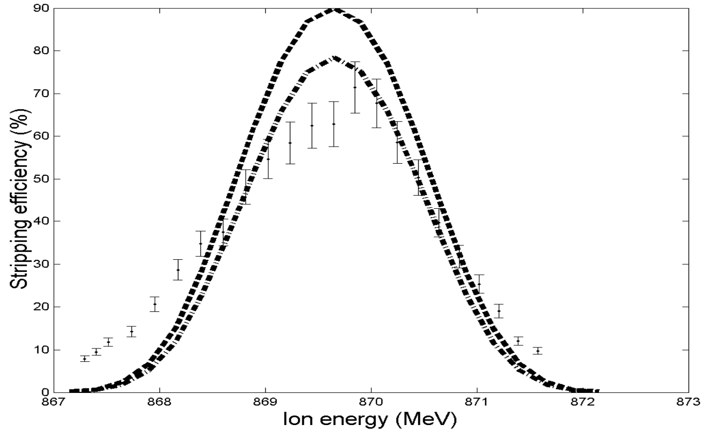
Laser Stripping Assembly

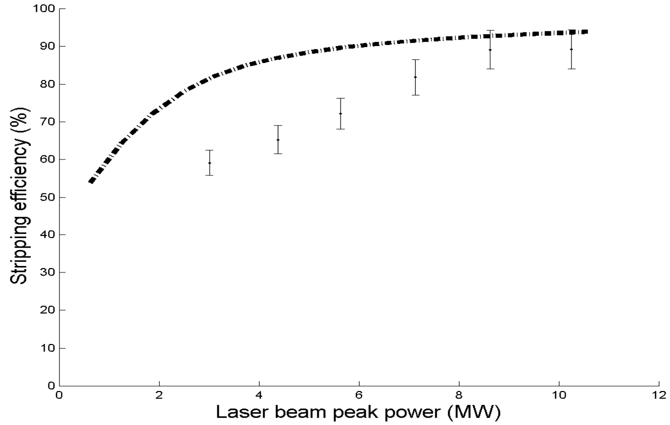


Experimental results









The maximal achieved efficiency: 0.85±0.1 (1st run) and 0.9 ±0.05 (2nd run)

Next Step – Proof of Practicality

I. Proof of Principle experiment confirmed good understanding of the process and validity of the models. Our theoretical expectations of ~90% efficiency were met.

II. We stripped few nanosecond beam. Direct scaling to the SNS requirements (60 Hz, 1 ms beam) is hardly practical: average laser power required: 10MW*0.06=0.6 MW !!!

III. Next step is to find ways to reduce required laser power and demonstrate feasibility by setting an intermediate stage experiment with beam parameters between the full SNS requirements and PoP experiment:

- > 90% stripping efficiency
- 1 – 10 us pulse width
- 1 – 10 Hz repetition rate
- techniques used should be scalable up to the SNS requirements

Laser beam power reduction:

- **Matching laser pulse time pattern to ion beam one by using mode-locked laser instead of Q-switched**

  ~ x25 gain

- **Using dispersion derivative to eliminate the Doppler broadening due to the energy spread**

  ~ x10 gain

- **Recycling laser pulse**

  ~ x10 gain

- **Vertical size and horizontal angular spread reduction**

  ~ x2-5 gain

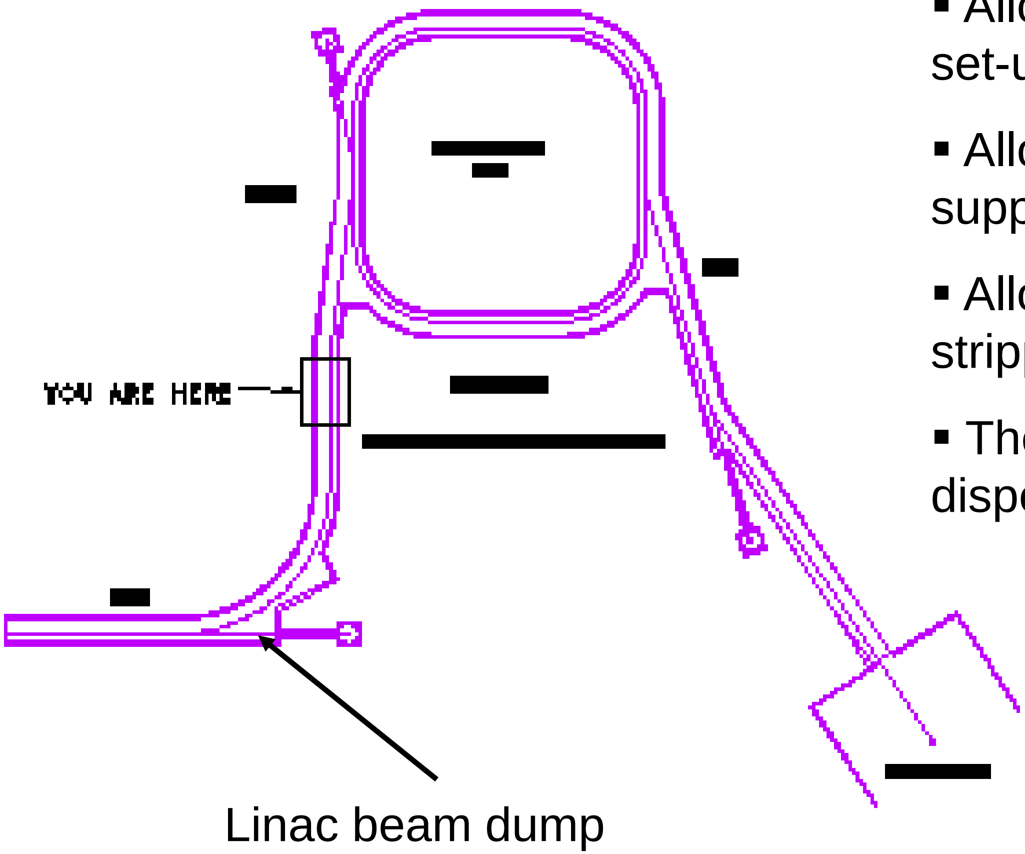
By combining all factors the required average laser power can be reduced to 50 – 120W, which is within reach for modern commercial lasers.

We would like to design an experiment validating all of the above techniques

Ingredients for experiment

- **Available location in SNS beam line**
- **Generate dispersion derivative**
- **Achieve proper transverse and longitudinal beam size**
- **High power mode-locked laser**
- **Laser light recycling equipment**
- **Stripping magnets (2)**
- **Beam diagnostics**
- **Auxillary equipment**

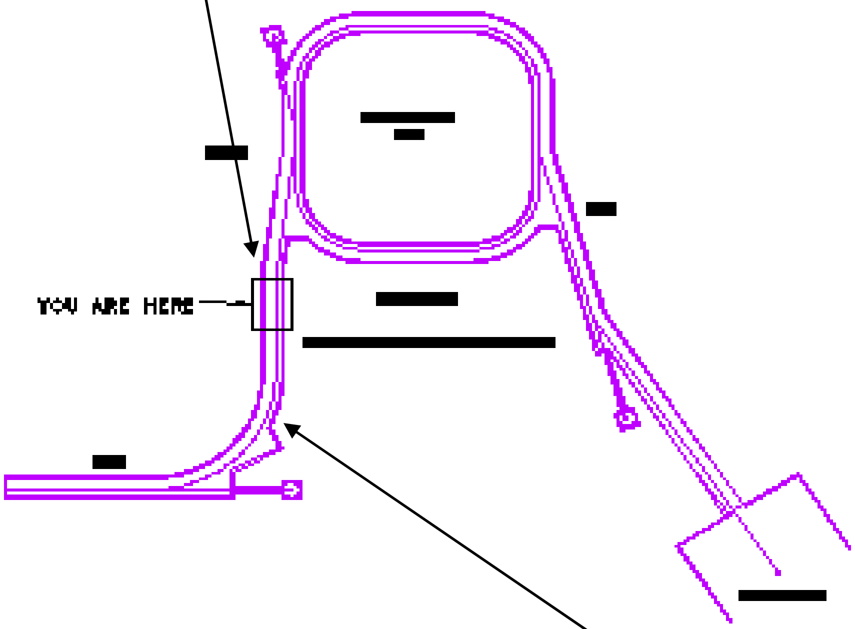
Proof of Principal Experiment Location



- Allowed semi-permanent experiment set-up
- Allowed to borrow arc magnet power supply to power stripping magnets
- Allowed aperture restriction by stripping magnet
- There is no possibility for creating dispersion and dispersion derivative

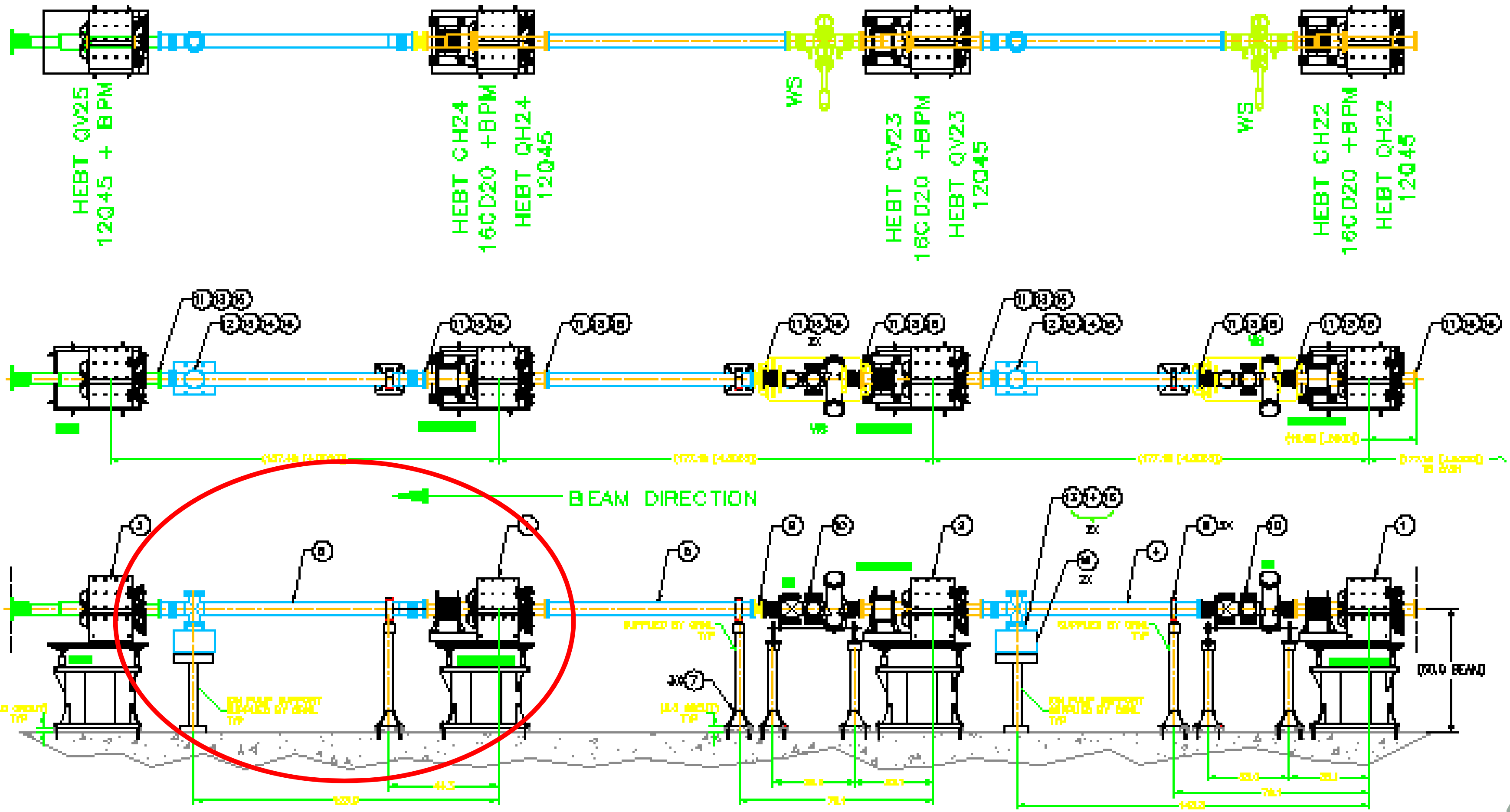
Possible Location for New Experiment

High Energy Beam
Transport Line (HEBT)

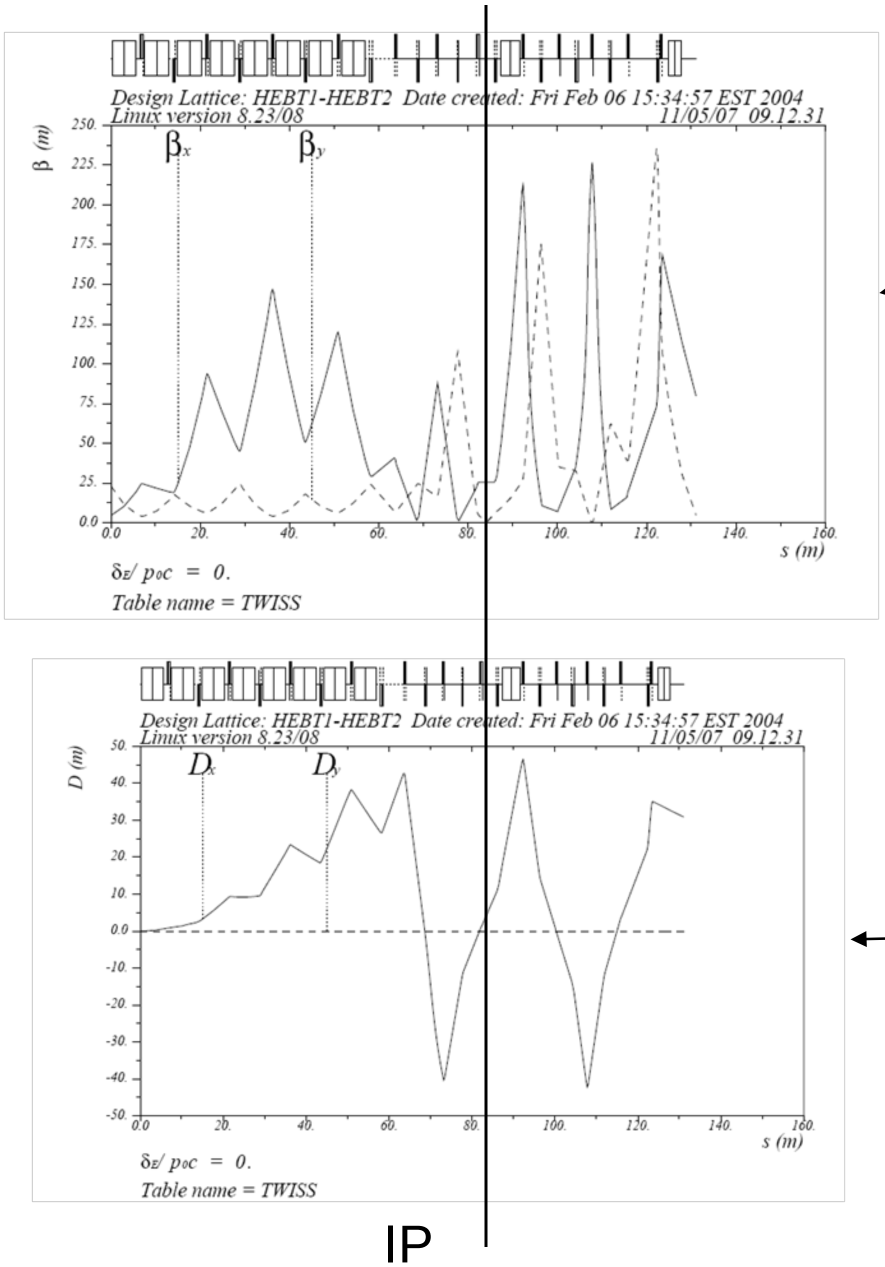


Arc dipole magnets can generate required dispersion function

Location (continued)



Transverse Ion Beam Optics (S. Cousineau)



Betax (solid), betay (dashed)

Main requirements:

1) Small vertical size;

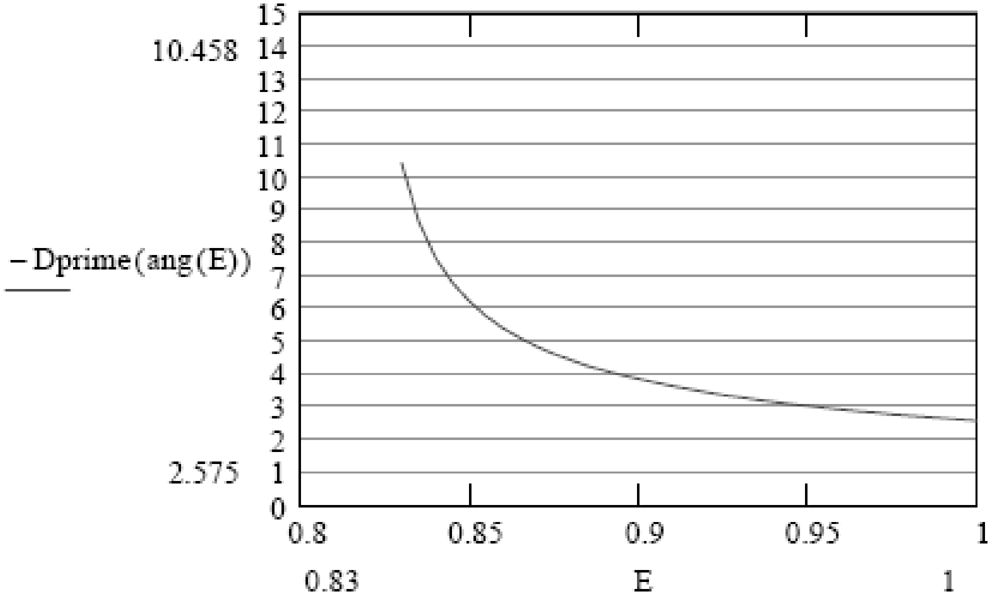
2) Large horizontal size, zero horizontal alfa;

3) D'=2.58

Dx

Beam Energy Low Limit

$$D' = -\frac{\beta + \cos\alpha}{\sin\alpha}$$



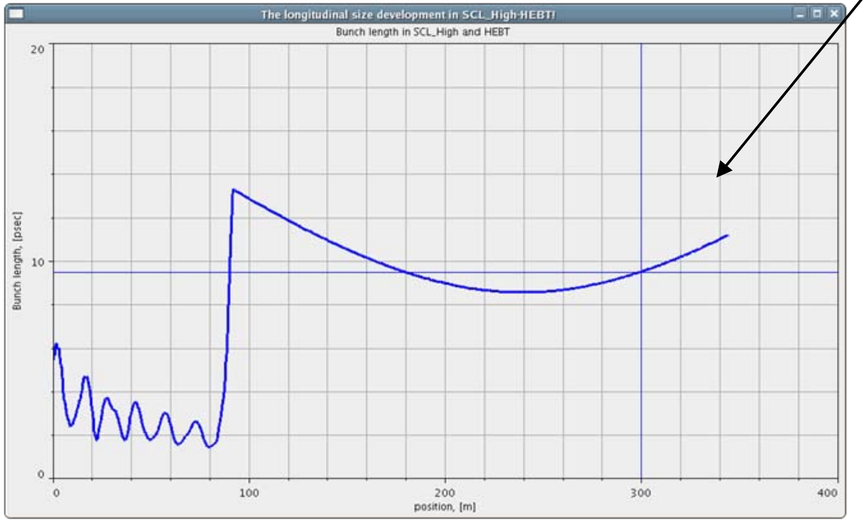
Required dispersion derivative is a very nonlinear function of energy.

840 MeV is absolute minimum for 355 nm.

1 GeV is minimum realistic value to obtain required dispersion with the existing HEBT magnets.

We use 1GeV as design energy for the experiment

Obtaining Small Longitudinal Bunch Size at Interaction Point (A. Shishlo)



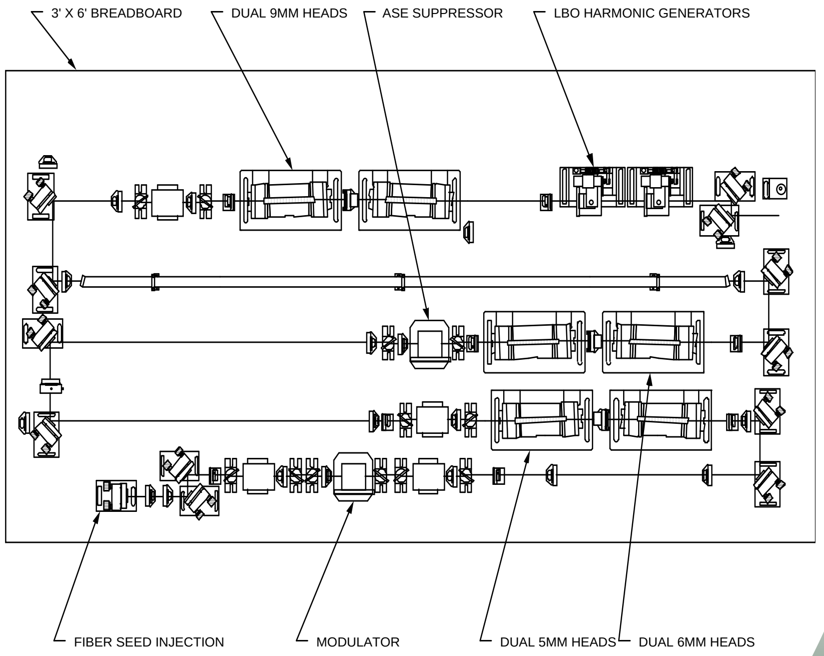
With the nominal SCL optics bunch length at the experiment location is too large (~100 ps FWHM) for conventional mode-locked laser

Ran simulations with phases of last 6 cavities optimized to squeeze the beam longitudinally. The resulting bunch length was 10 ps. Final beam energy reduced by 52 MeV as a trade off.

An attempt to squeeze beam in real experiment was not successful. Will try again next month

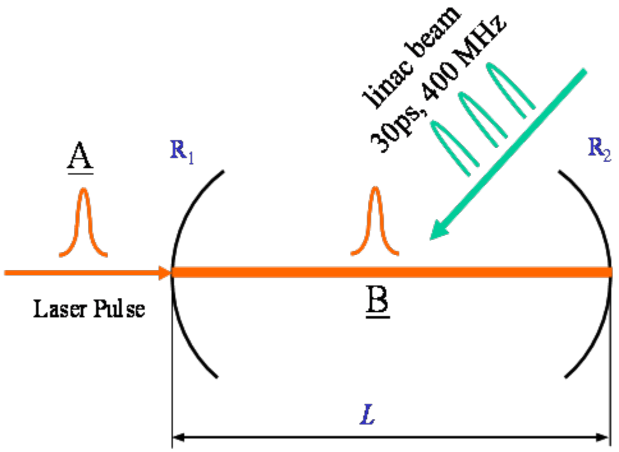
Laser parameters (Yun Liu)

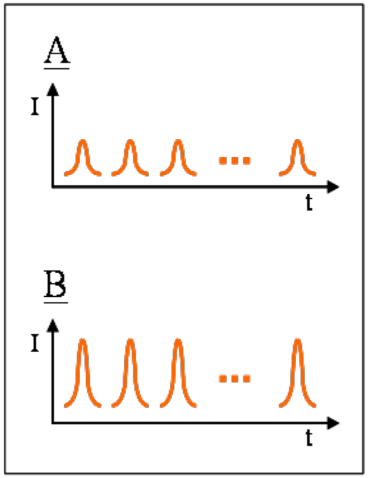
Parameter	Offered	Comment
Wavelength	355nm	
Energy	30 uJ	
Pulse Duration	10 µs	>10µs possible with programmable waveforms
SLM Oscillator	mode locked	
Temporal Profile	flat envelope	
Beam Diameter	~5mm	
Spatial Profile	Like Powerlite	Harmonics at laser
Beam Divergence	Like Powerlite	
Repetition Rate	10 Hz/402.5 MHz	Macropulse rate / micropulse rate
Shot to Shot Stability	3% RMS	for pulse envelope
Polarization	Vert	
Jitter	<50ns	Macropulse envelope
Interface	GUI	
Laser Head size	3' x 6' x 13"	Larger table available for upgrades
Cabinets	CAB35	
Electrical Requirements	30A 1 phase 220V	
Water Requirements	2 X Powerlite	



Laser has been delivered and is waiting for installation and commissioning

Laser Beam Recycling



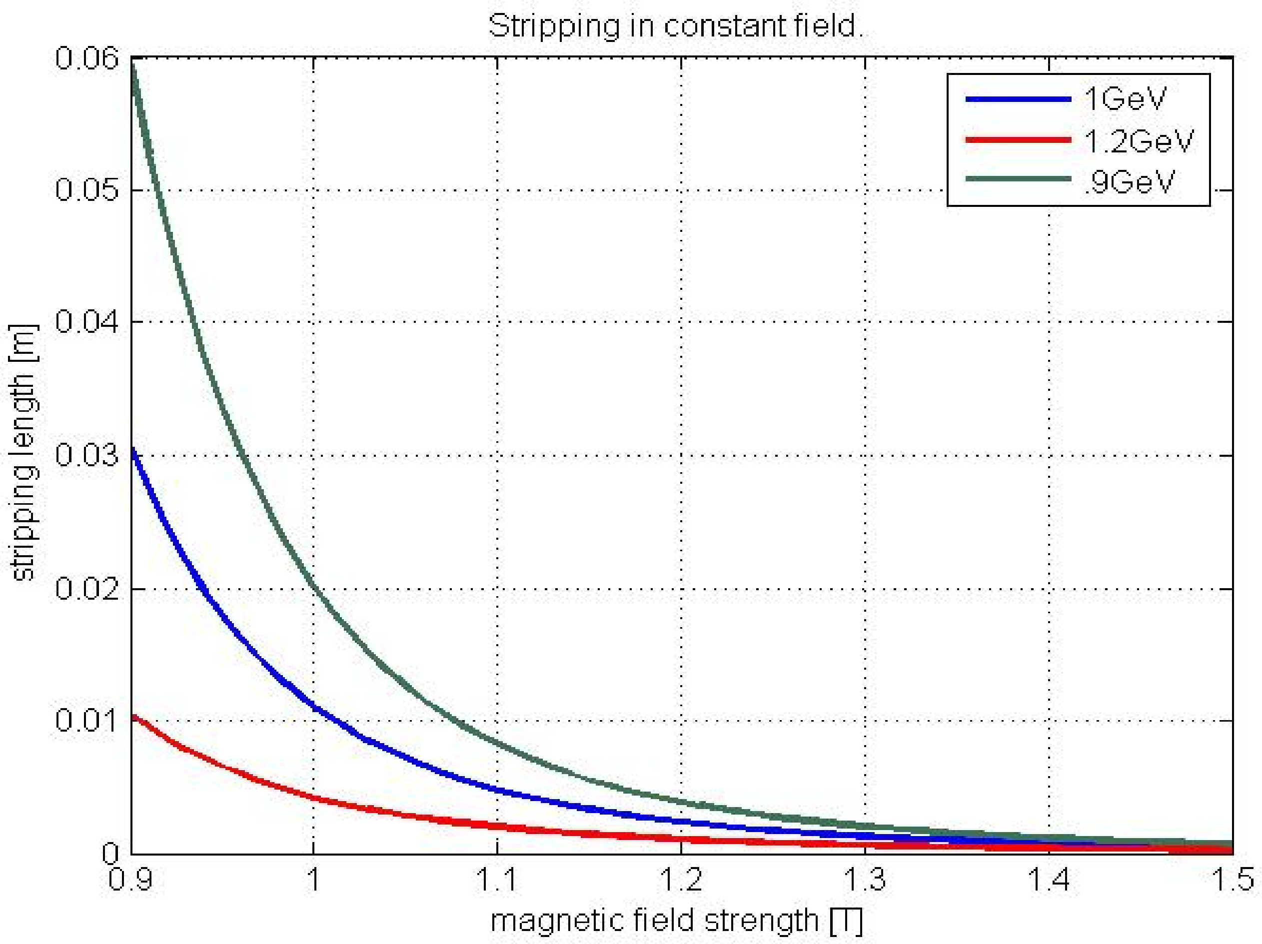


Only ~10^{-7} fraction of photons is “used up” in one collision –> it is tempting to reuse same laser pulse several times

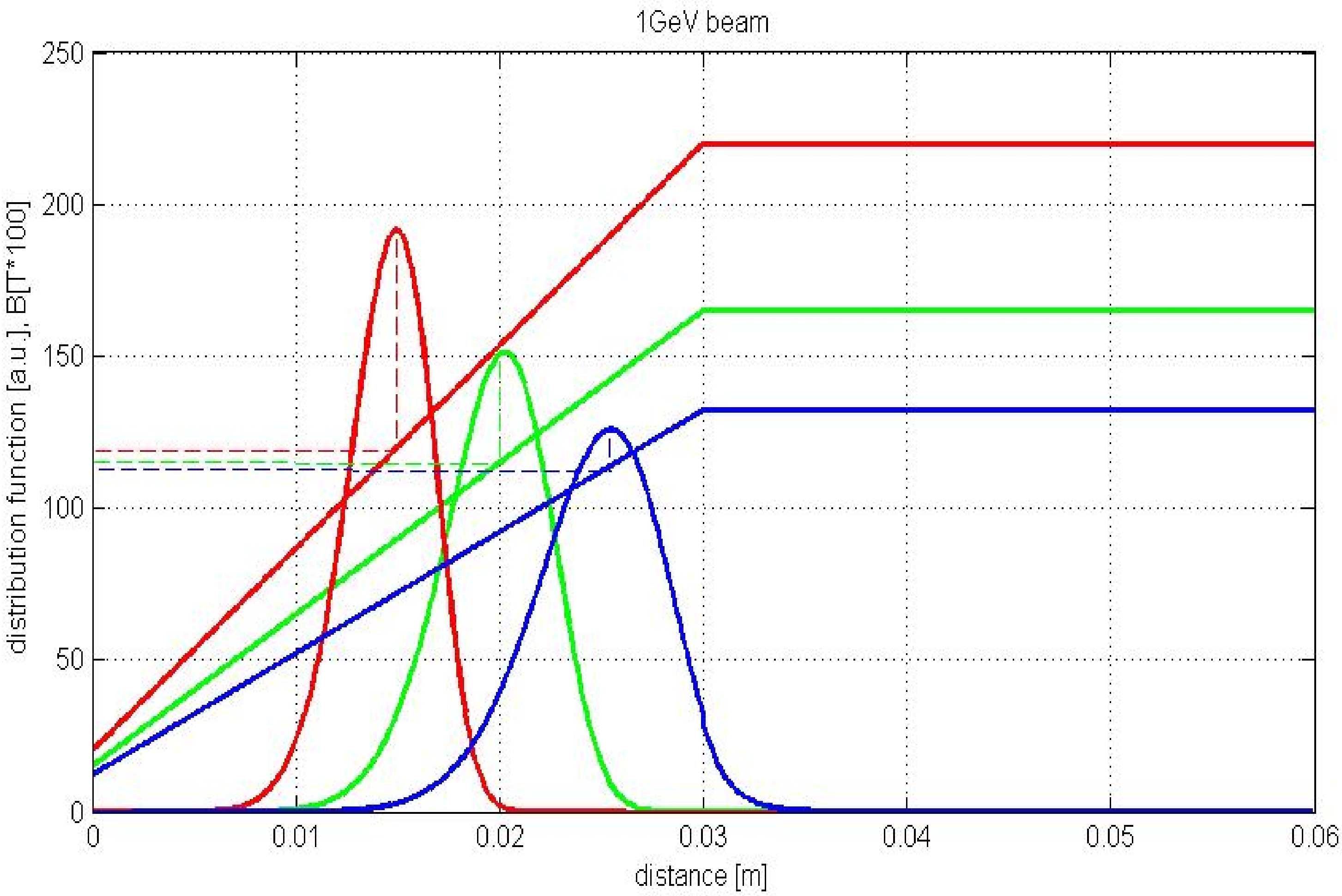
- Fabry-Perot cavity
  - High reflectivity mirrors at 355nm is difficult to obtain
  - Dimension stability requirements are very demanding
- Wavelength conversion in a cavity (no interference)

- Other solutions ???

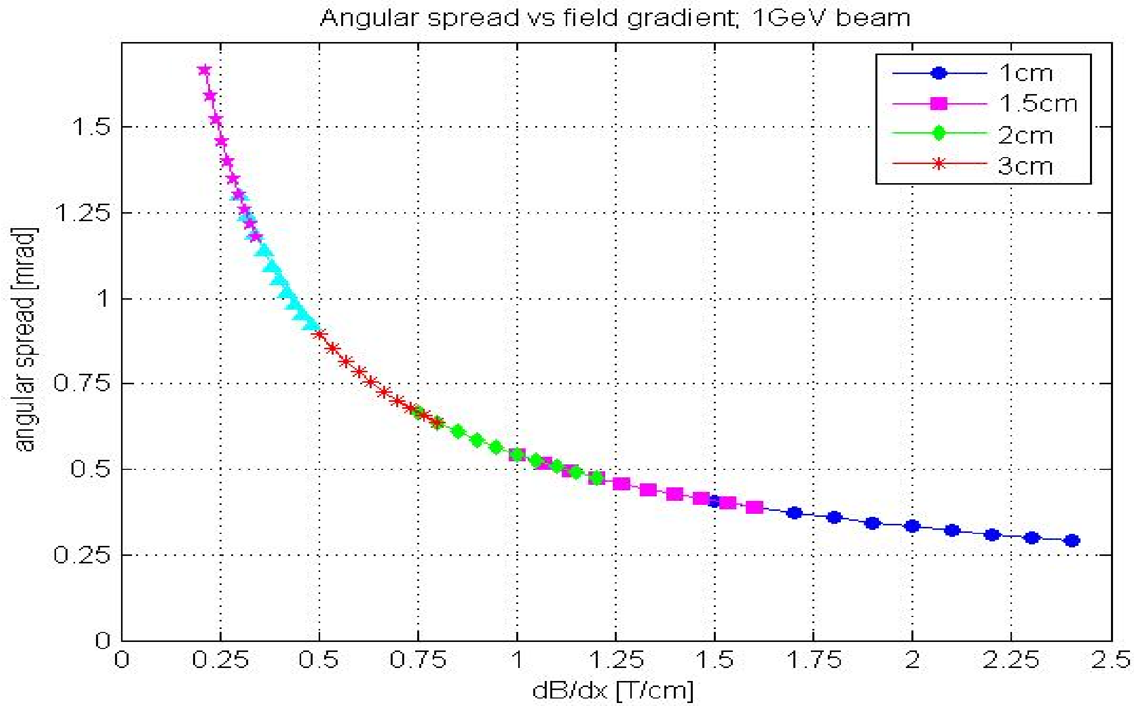
Required strength of stripping magnet



Probability of stripping in the edge magnetic field



Large magnetic field gradient is required to keep angular spread small

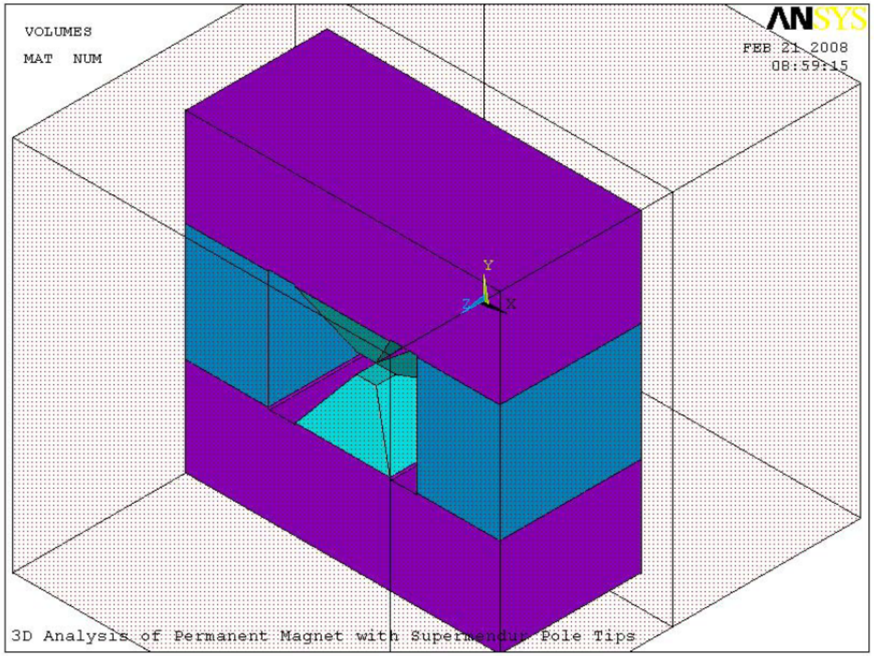


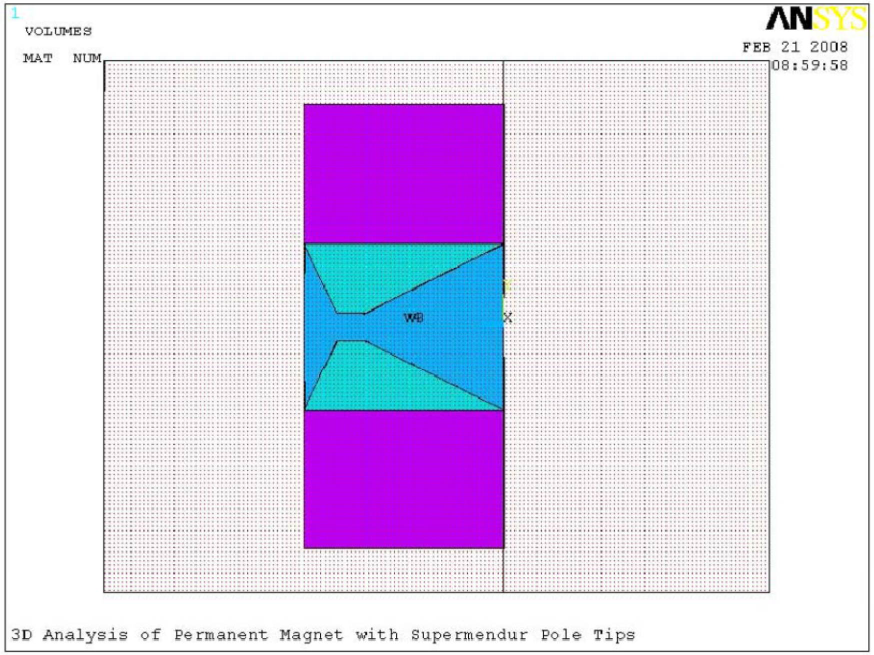
To achieve large magnetic field gradient a dipole magnet (conventional) has to have small aperture

Small magnet aperture in HEBT will not allow high power beam operation with small losses

- **Possible solution to the problem of small aperture is to use a compact permanent magnet dipoles sliding in and out of beam line in vacuum**
  - **Magnets are out for high power beam operation**
  - **Magnets are in for stripping experiment**

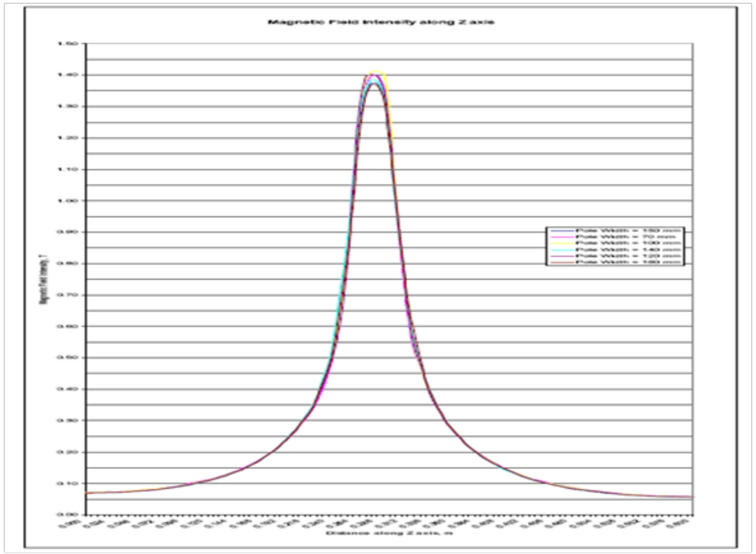
Dipole design (A. Menshov)



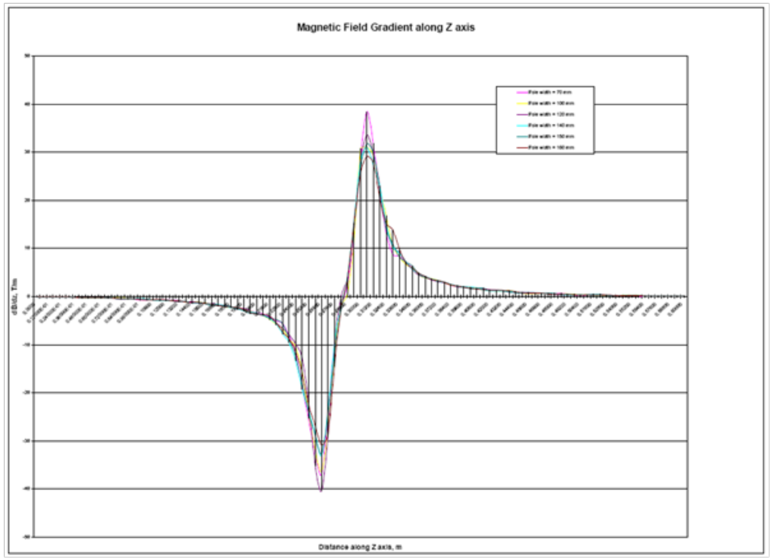


30 mm gap; 300 mm side length

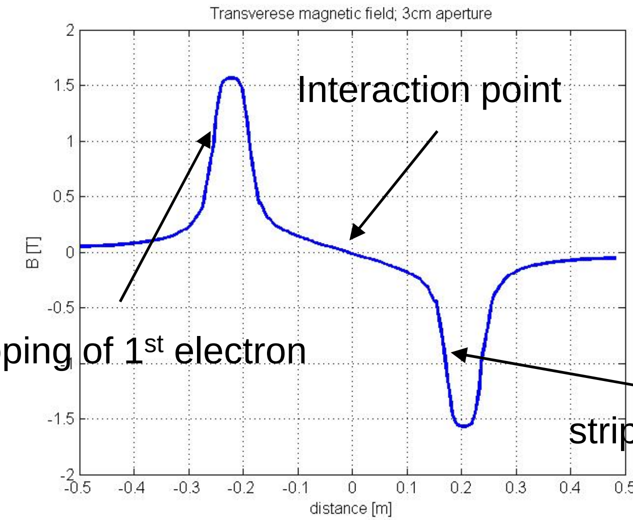
Field distribution along magnet axis



Magnetic field strength along axis



Magnetic field gradient along axis



Two magnets of opposite polarities provide zero magnetic field at interaction point

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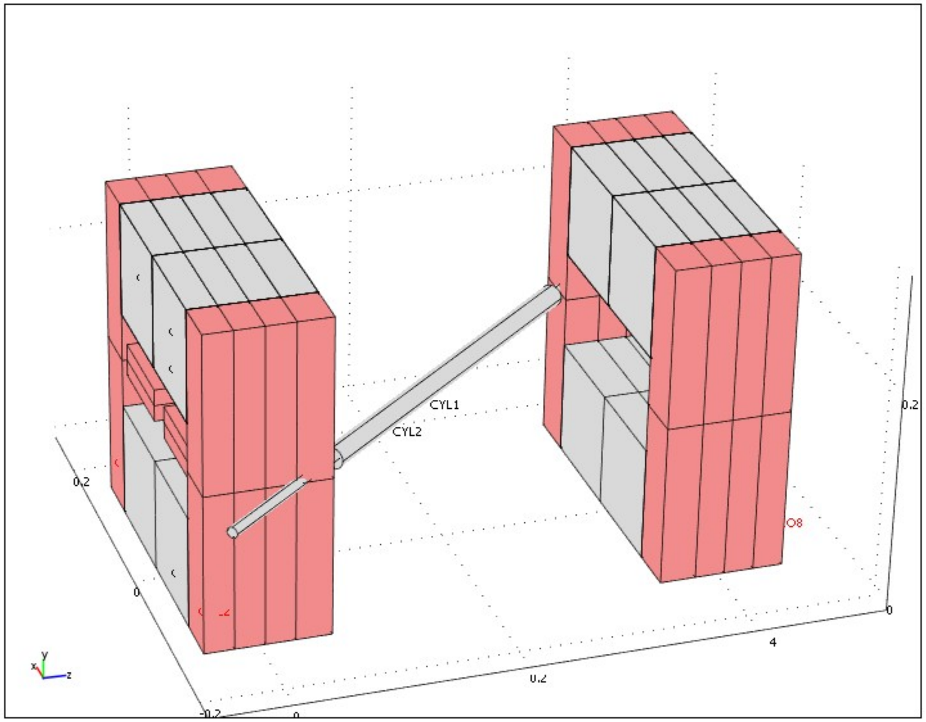
Where to put laser beam recycling cavity?



Can drill passages for laser light in magnet yoke

Hard to answer until we know how it looks like

Beam diagnostics for experiment

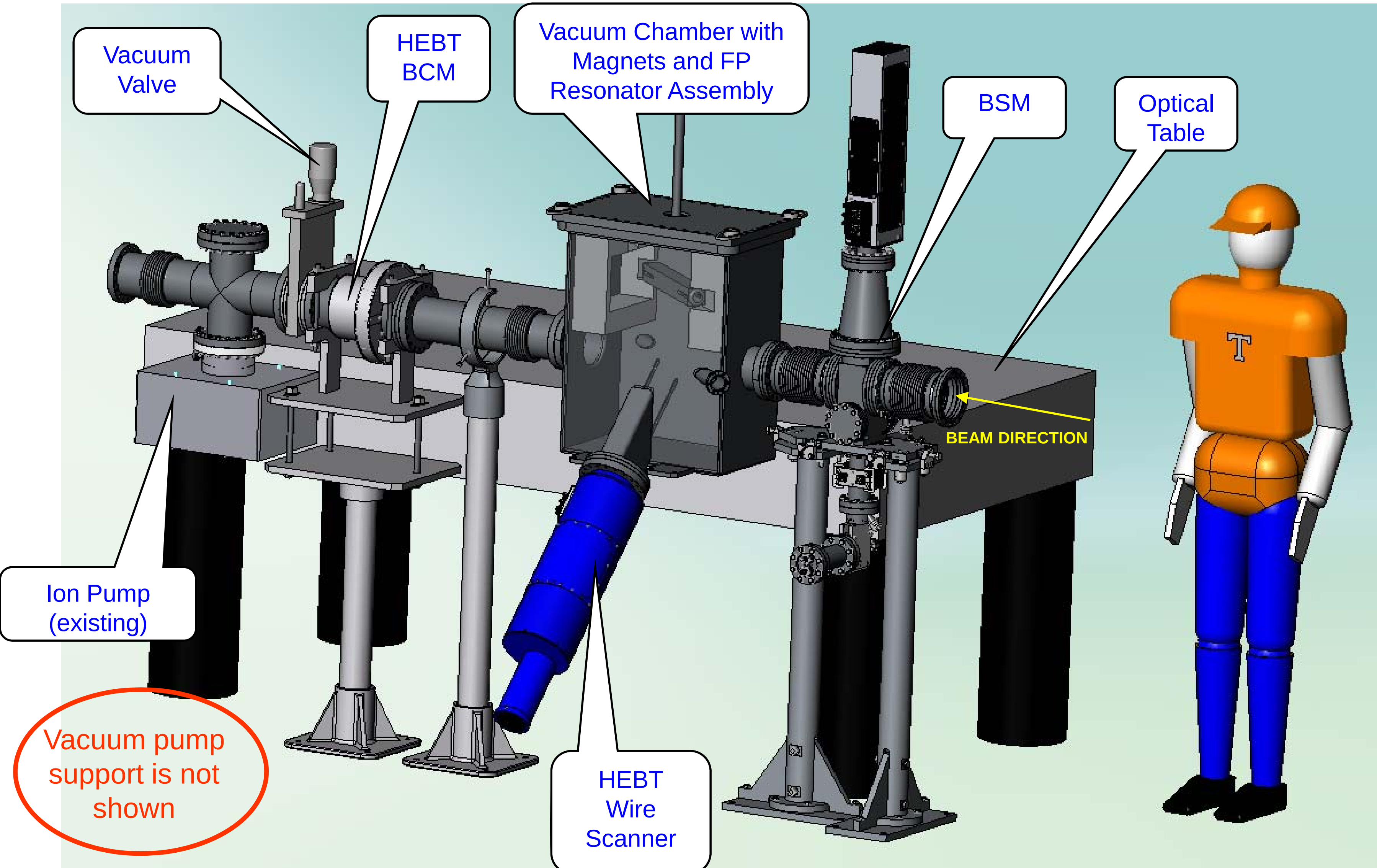
- **Wire scanner at the interaction point for measuring horizontal and vertical beam size, dispersion**

- **Beam Shape Monitor for measuring longitudinal bunch length**

- **Beam Current Transformer for measuring stripping efficiency**

Have all these devices available

Experimental setup layout



Ingredients for experiment check list

- **Available location in SNS beam line** X
- **Generate dispersion derivative** X
- **Achieve proper transverse and longitudinal beam size** X
- **High power mode-locked laser** X
- **Laser light recycling equipment**
- **Stripping magnets (2)**
- **Beam diagnostics** X
- **Auxiliary equipment**

Possible partial experiment scenarios

- Build and install diagnostics box only (no magnets, no laser, no recycling)
  - Demonstrate transverse and longitudinal beam size, dispersion
- Build and install diagnostics box with movable permanent magnets (no laser, no recycling)
  - Demonstrate transverse and longitudinal beam size, dispersion, angular distribution increase in stripping magnet
- Build and install diagnostics box with movable permanent magnets. Install laser (no recycling)
  - Demonstrate transverse and longitudinal beam size, dispersion, angular distribution increase in stripping magnet, less than 90% stripping efficiency