Diagnostic Neutral Beam System for the MST - First Results

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Outline

- Two Diagnostic Neutral Beams have been built by Institute of Nuclear Physics, Novosibirsk, Russia.
- Local measurements of equilibrium and fluctuating T_i, V_i (majority and minority).
- Major diagnostics are:
  - CHERS - impurity ions dynamics
  - Rutherford Scattering (RS) -majority ions dynamics
- Other diagnostics
  - Motional Stark Effect (MSE) - magnetic field
  - Beam attenuation - ion density
  - BES - density fluctuation
  - Line intensity ratio with He beam- T_e, n_e profile
  - Local CX target
  - LIF
- First results
- Future Plans

Beam Properties

Rutherford Scattering

- 20keV/4A He beam
- 2 neutral particle analyzers

CHERS, MSE

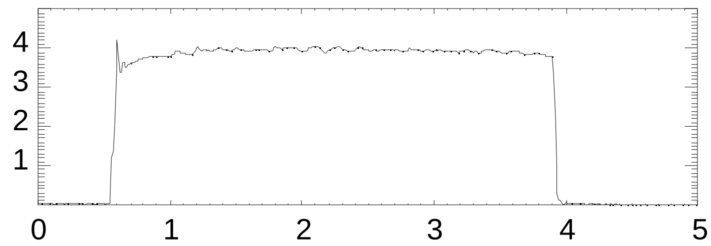
- 30keV/4A H beam

Duration	3 ms
Beam diameter	4 cm
Current density	0.4 A/cm^2
Radial resolution	15 cm (RS); 4 cm (CHERS)

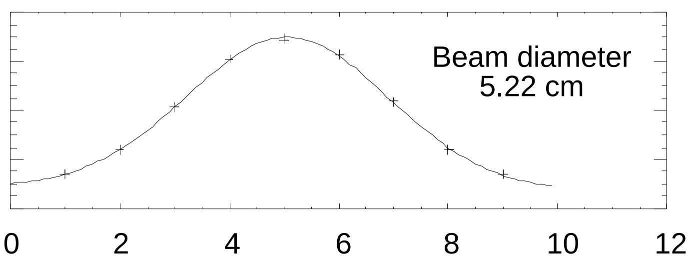
Beam Highlights

Hydrogen Beam
4A/30 keV

Beam Current (A)

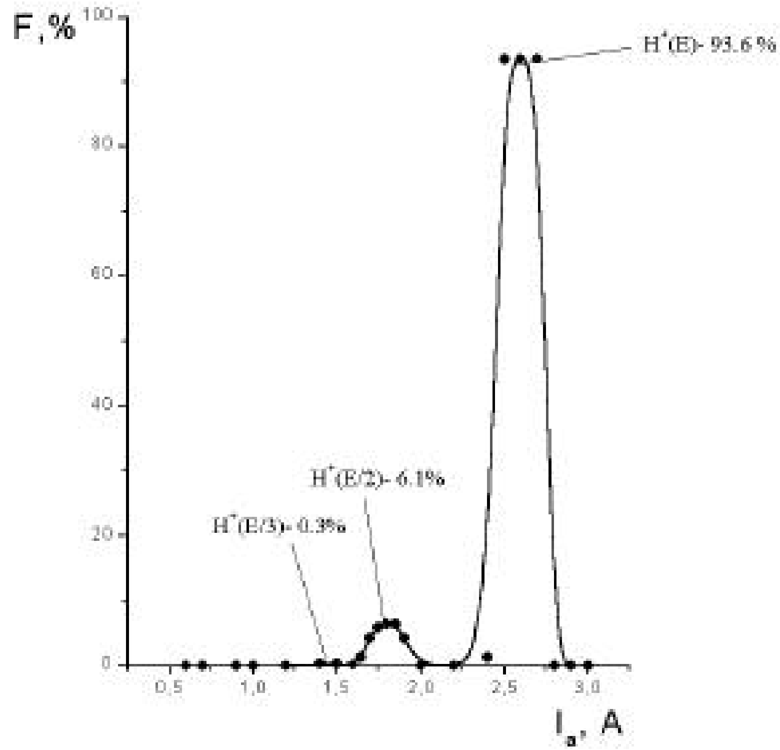


Beam Radial Profile (at 160 cm)



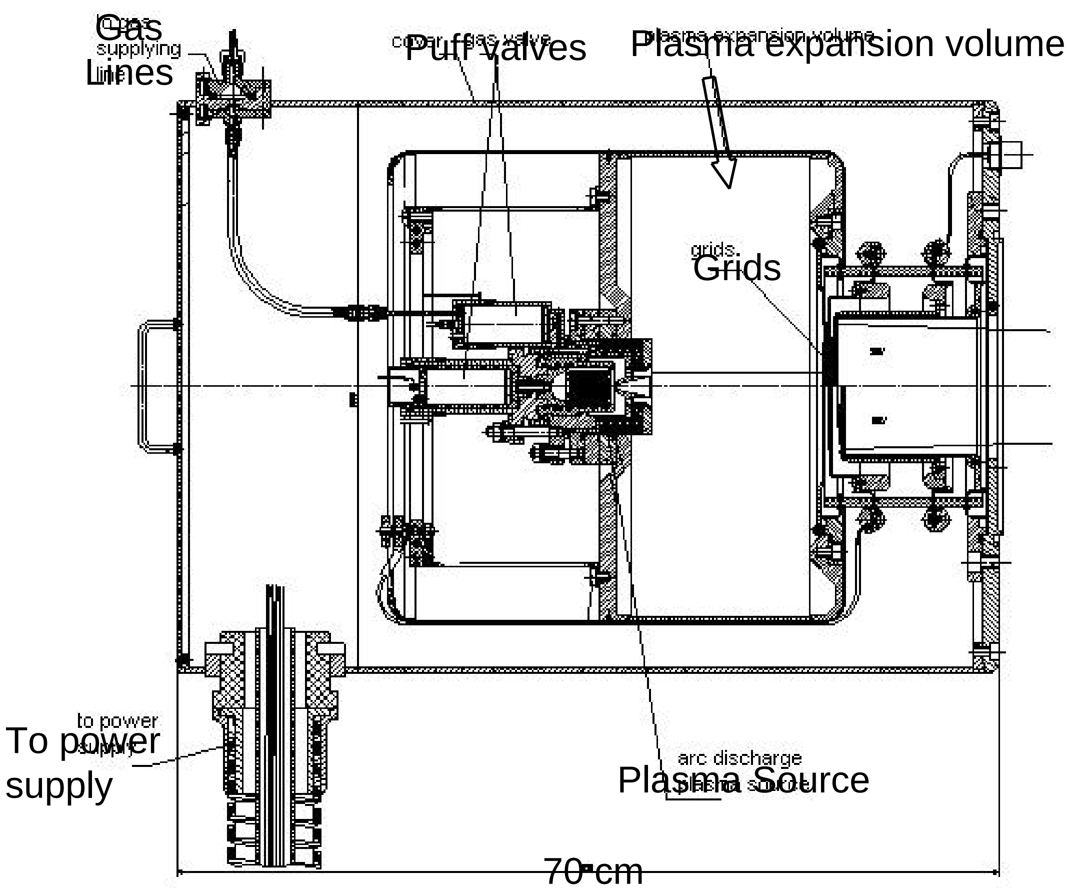
Measured
divergence
$\vartheta_T = 0.015\ \mathrm{rad}$

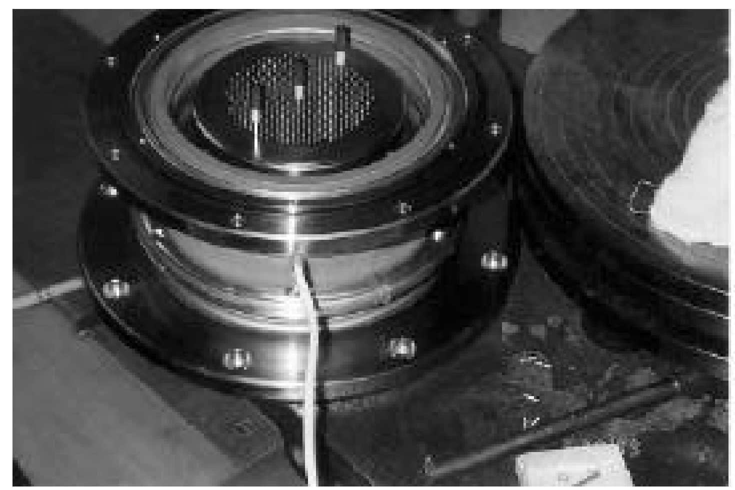
Mass composition as measured
by magnetic mass-analyzer



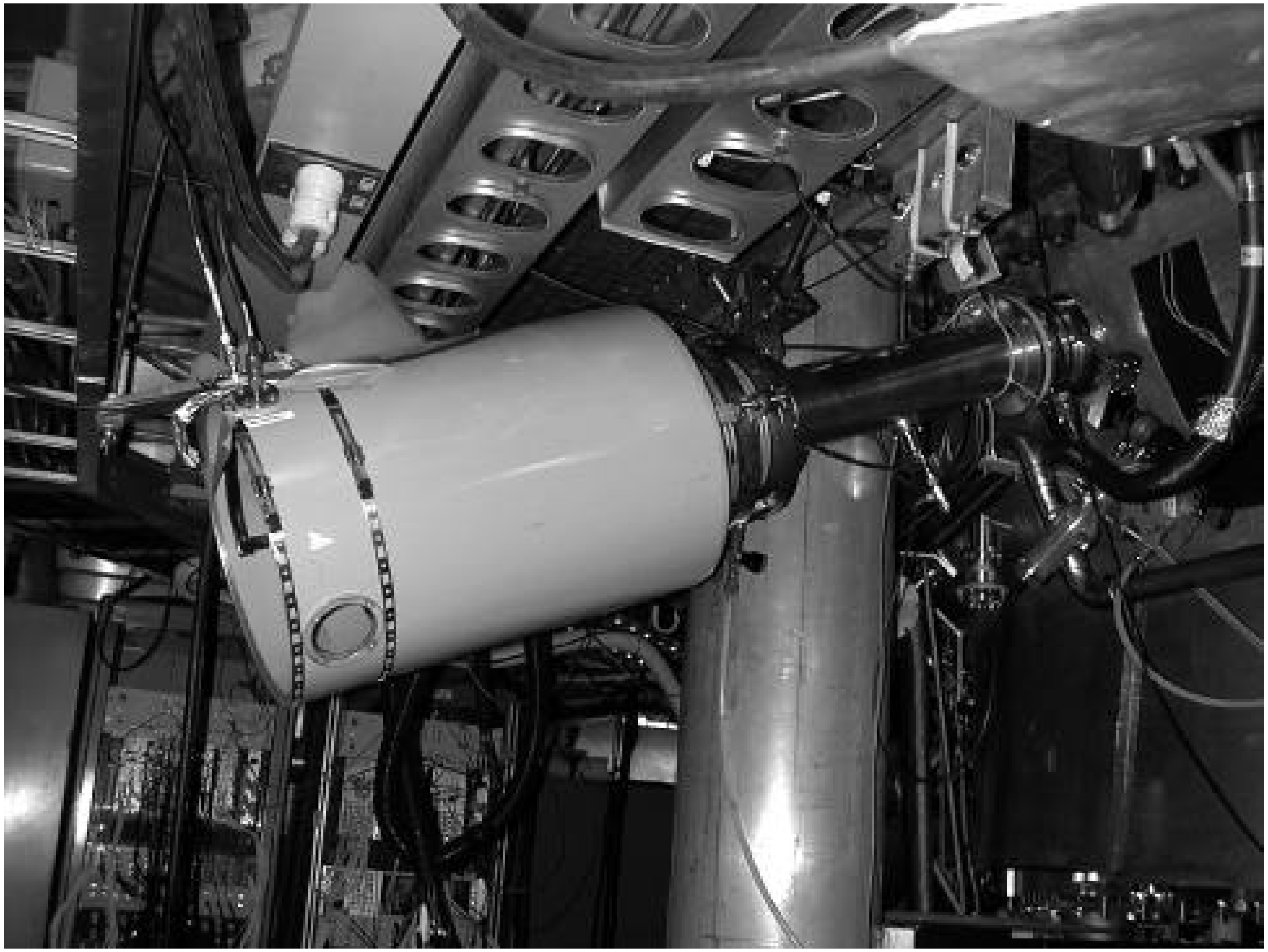
Low content of H_2^+ and H_3^+
is due to high density and
temperature of the source plasma.

DNB Layout


Gas Lines
Puff valves
Plasma expansion volume
Grids
To power supply
Plasma Source
70 cm



DNB for CHERS on MST



CHERS

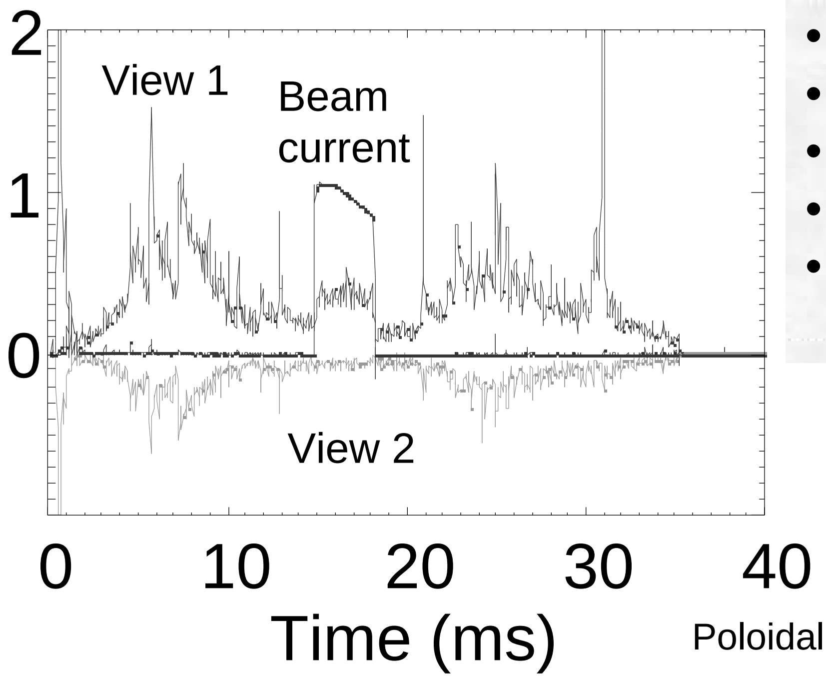
$$H^0 + A^Z \rightarrow H^+ + A^{(Z-1)^*}$$ Charge exchange produces ions in an exited state

$$A^{(Z-1)^*} \rightarrow A^{(Z-1)} + h\nu$$ followed by radiative decay

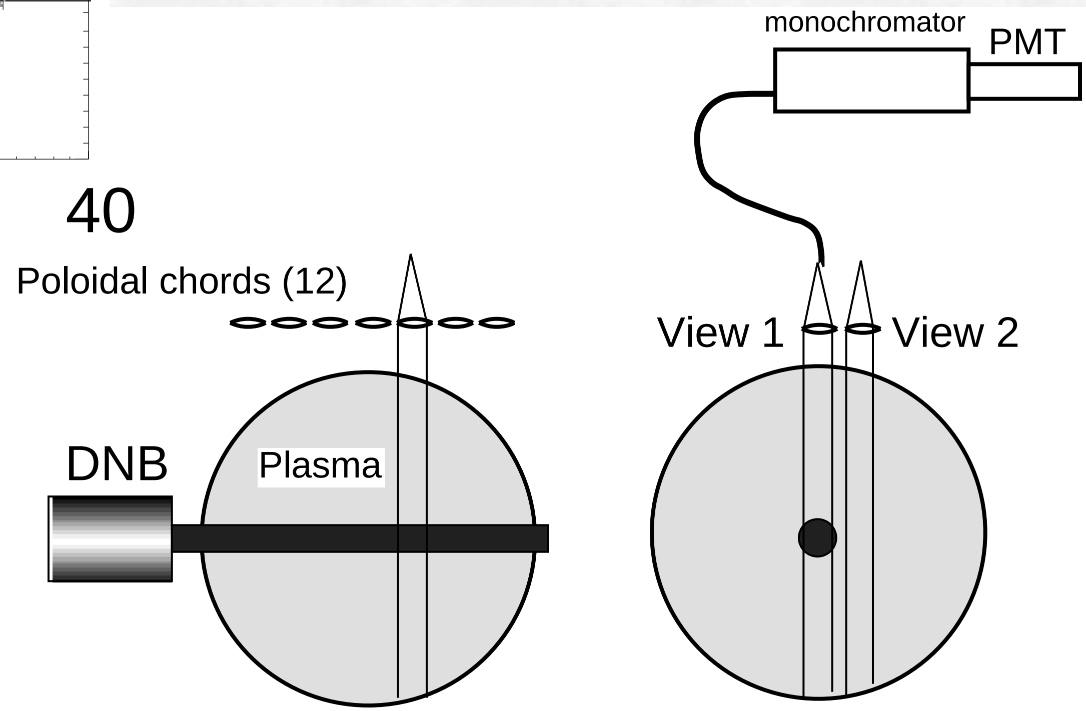
Doppler Spectrometer ⇒ T_i^Z, V_i^Z

- Locality is achieved by crossing the beam and the optical view path.
- Impurities - ambient O^{+8}, C^{+6}.
- Diagnostic is well-developed. MST already has a high resolution, fast Doppler spectrometer. A new spectrometer is being designed.

First CHERS Line Survey



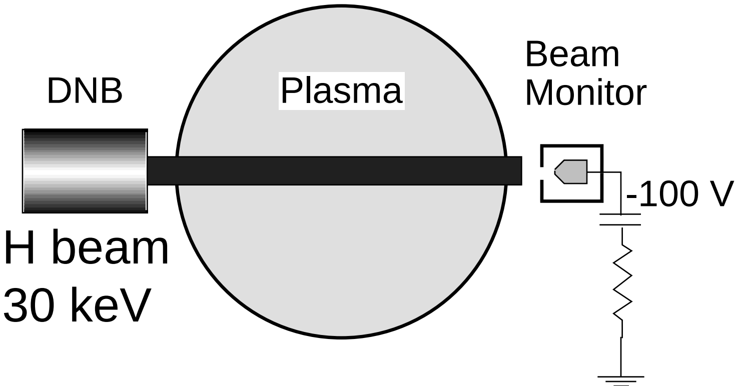
- 12 poloidal chords for profile measurements
- The brightest line C^{+6} 343 nm
- Beam induced enhancement observed
- Enhancement favors low density and high T
- New high throughput fast spectrometer is being designed.



Plasma Ion Density Measured via Beam Absorption

$$I = I_0 \exp - \int [n_e \frac{\langle \sigma_i^{el} v_{el} \rangle}{v_0} + n_i(\sigma_i^{ion} + \sigma_{cx})]$$

(neglecting impurities)



Electron impact ionization

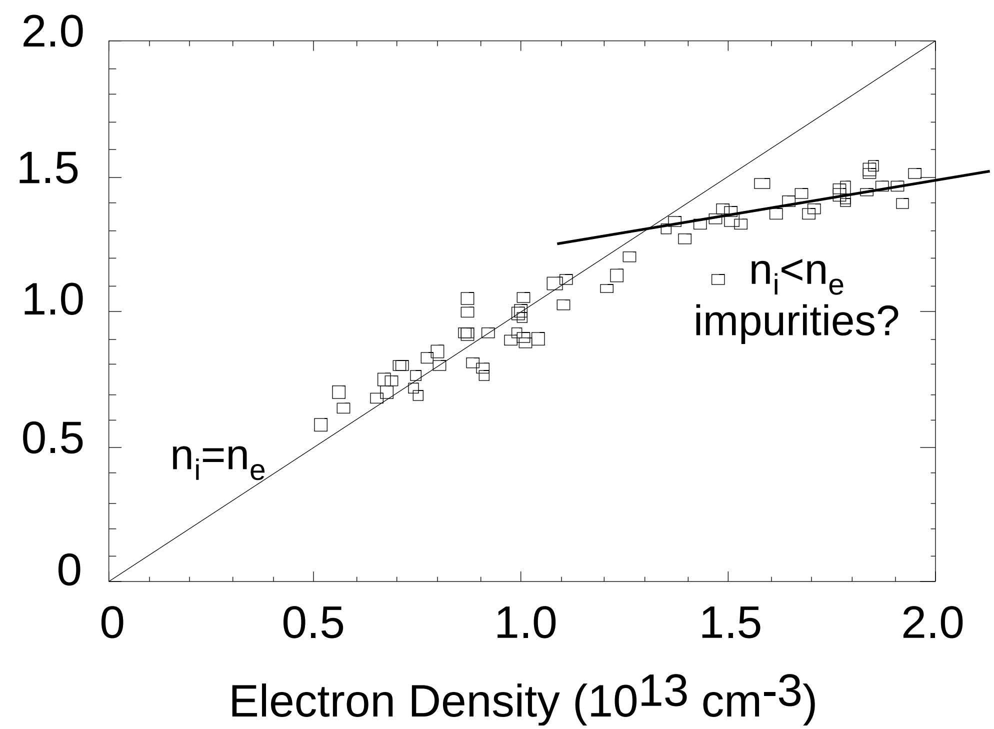
$$\frac{\langle \sigma_i^{el} v_{el} \rangle}{v_0} = 1.2\text{x}10^{-16}\ \text{cm}^2$$

Ion impact ionization

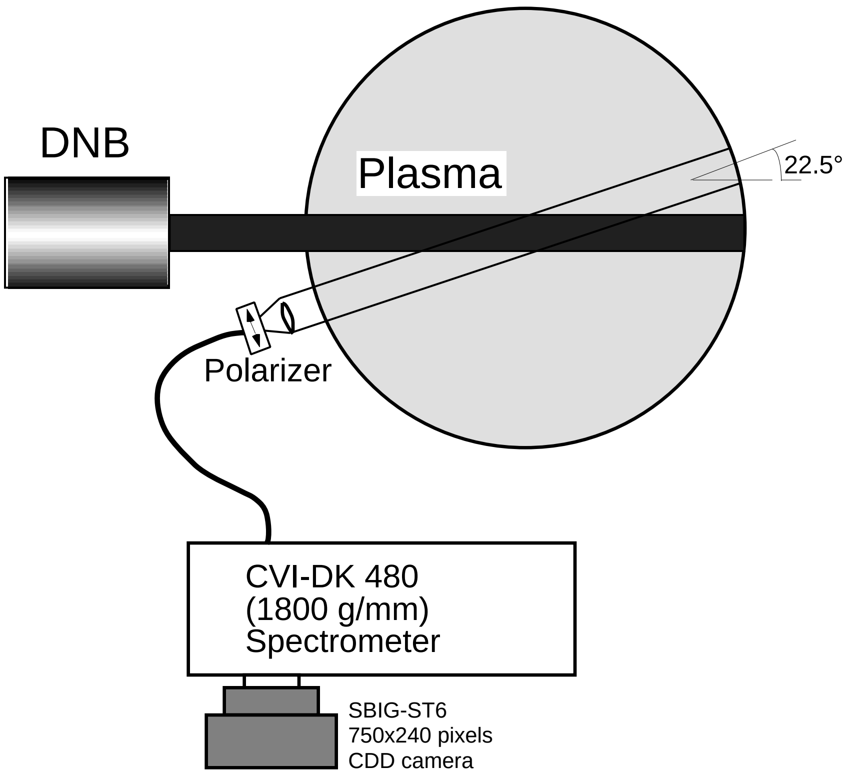
$$\sigma_i^{ion} = 1.5\text{x}10^{-16}\ \text{cm}^2$$

Charge exchange

$$\sigma_{cx} = 4\text{x}10^{-16}\ \text{cm}^2$$



MSE on MST



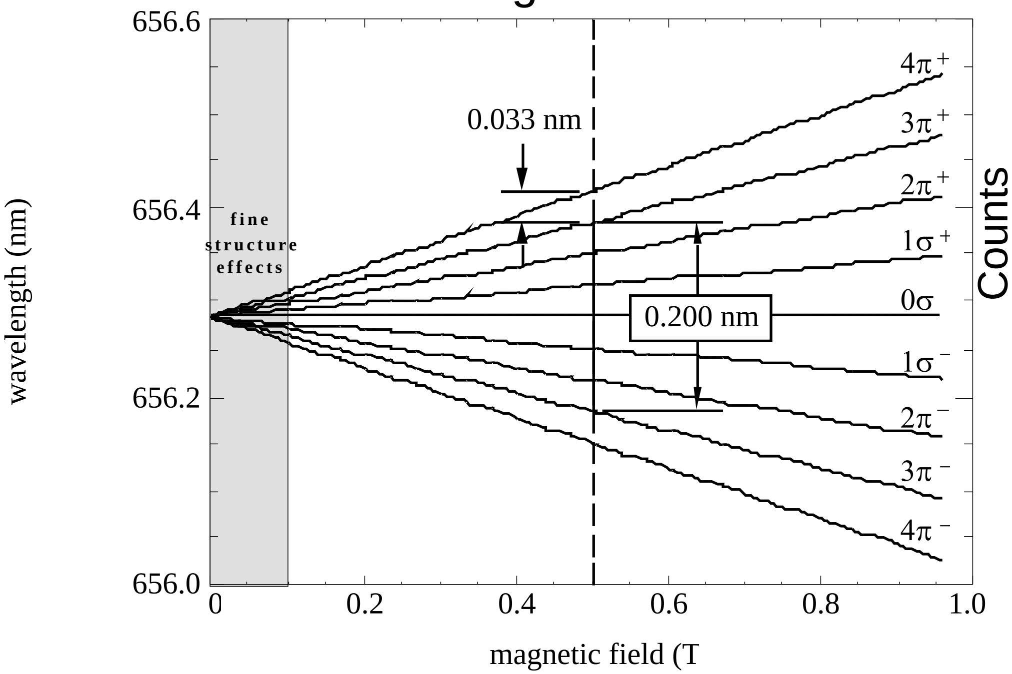
What is measured:
Splitting of H_α 656.3 nm beam emission line due to **vxB** electric field.

Beam:
30keV/4A Hydrogen

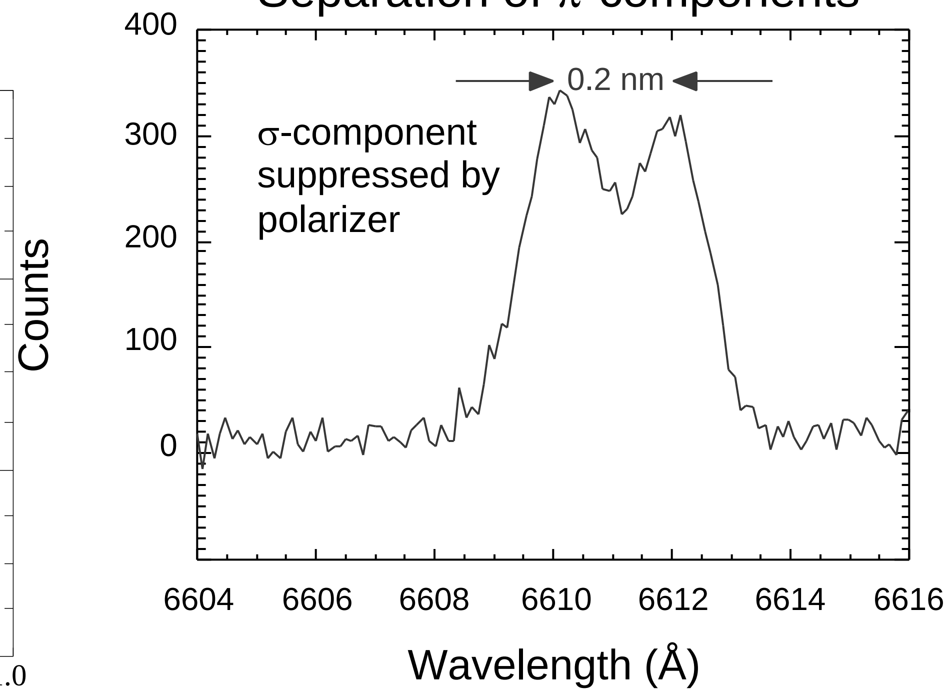
Separation from background H_α:
$\Delta\lambda$ = 4.8 nm

First MSE Results

Separation of Stark manifold components for 30 keV H beam vs. magnetic field.



Separation of π-components



Estimated emission spectra smearing due to imperfections of the beam and collection geometry is 0.086 nm.
We will have to estimate the relative magnitude of each of the π- and π+ components.

Measured spread 0.2 nm

3π ⇨ B_0 = 0.50 T

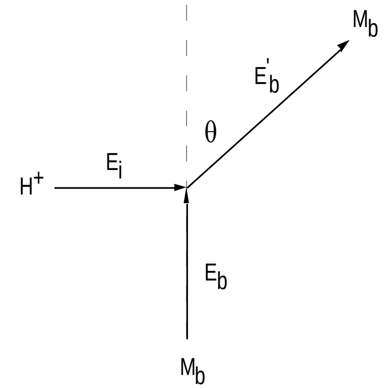
4π ⇨ B_0 = 0.38 T

RFP modeling (α-model) predicts B_0 = 0.44T

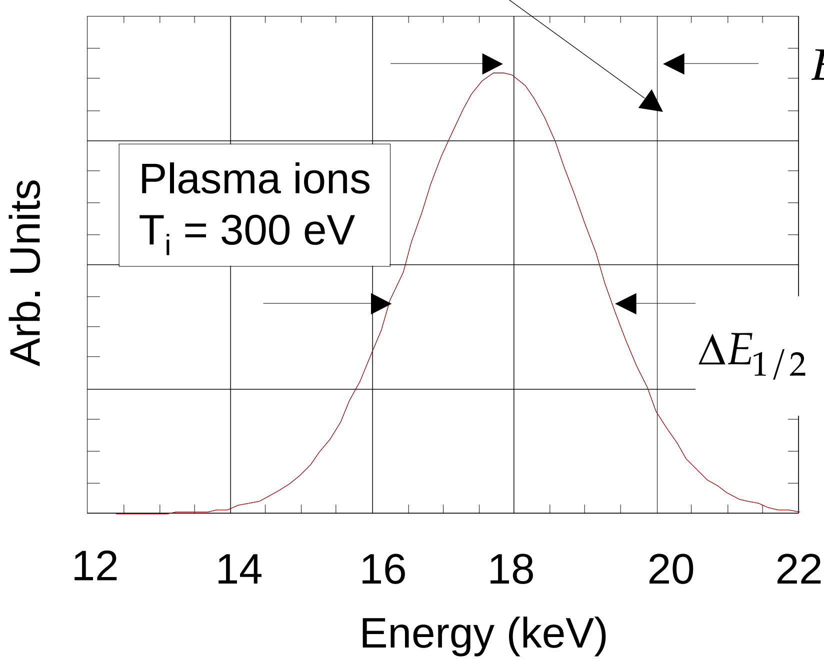
Rutherford Scattering

- Changes in the energy of scattered atom are related to the energy of plasma ion

$$E_b' = E_b\left(1-\frac{m_b}{m_i}\sin^2\theta\right) \pm 2\sin\theta\sqrt{\frac{m_b}{m_i}E_iE_b}$$



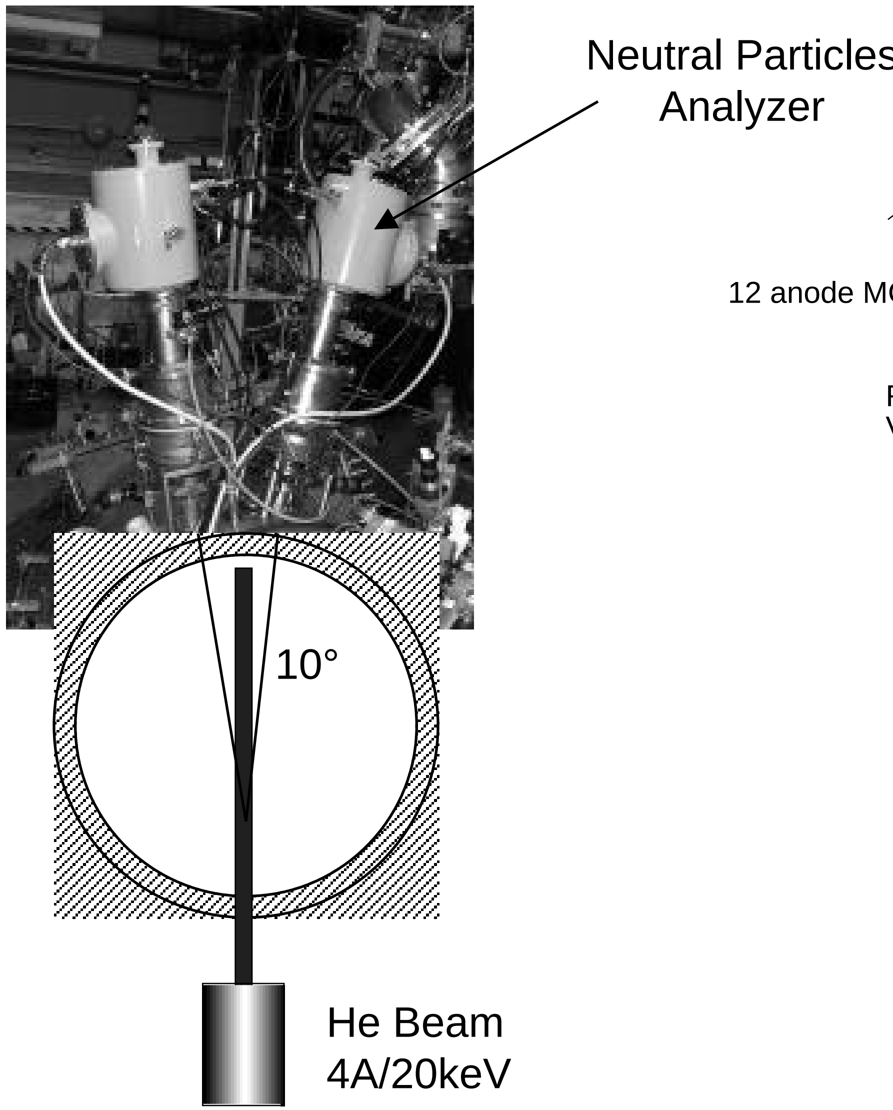
Simulated He Beam 20 keV scattering @ 10°

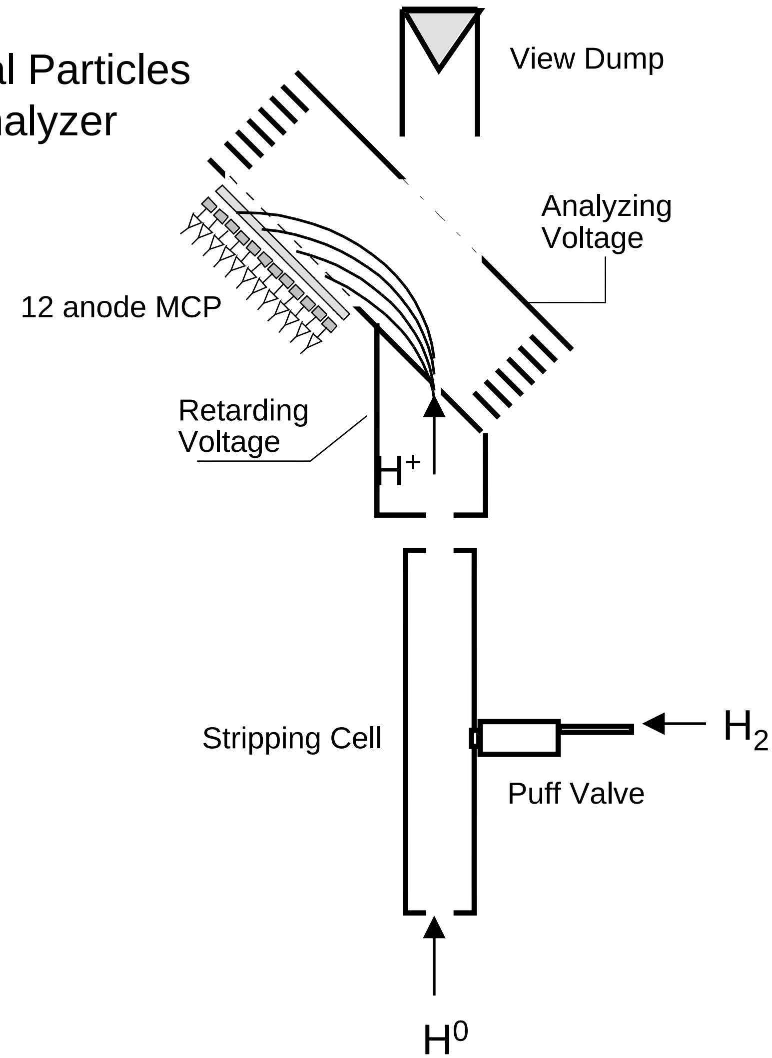


$$E_b\left(1-\frac{m_i}{m_b}\sin^2\theta\right) + V_{flow}\sin\theta\sqrt{\frac{m_b}{2}E_b}$$

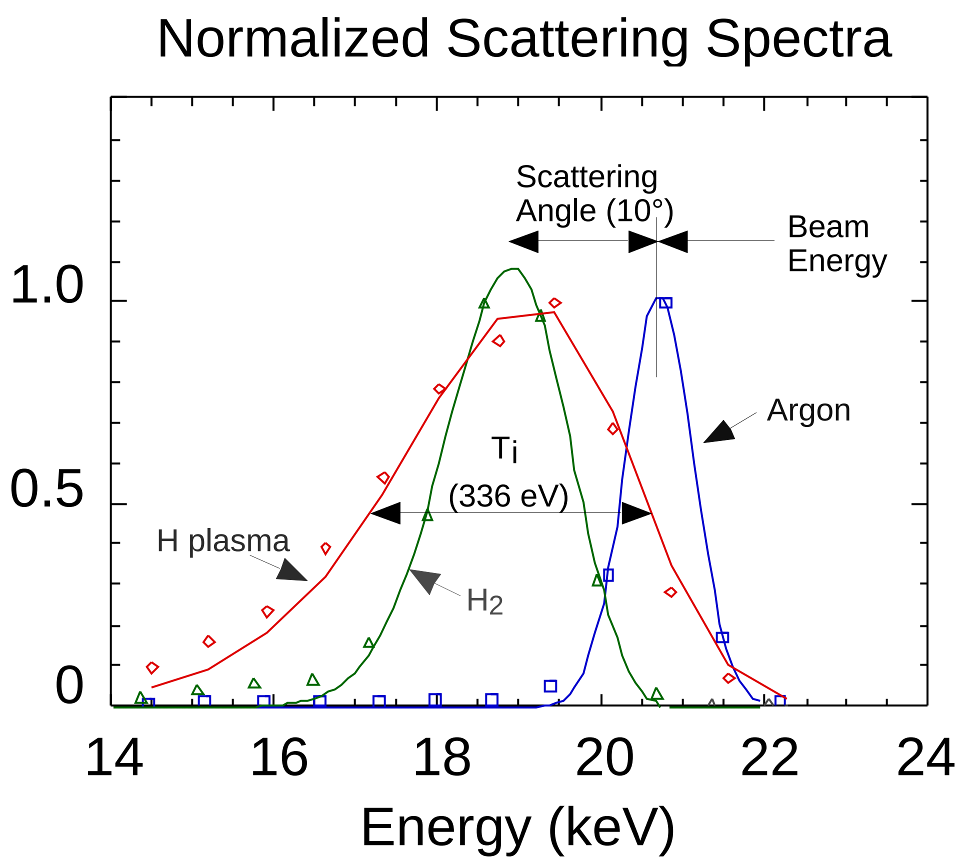
$$\Delta E_{1/2} = 4\theta\sqrt{E_bT_i\frac{m_b}{m_i}\ln 2}$$

RS Arrangement on MST



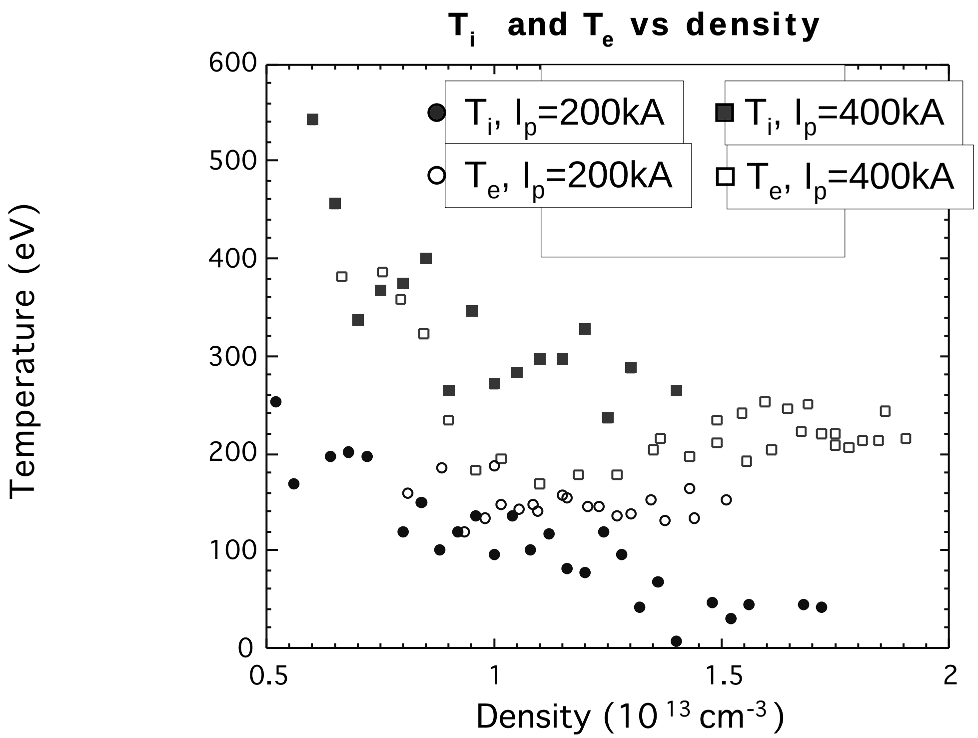


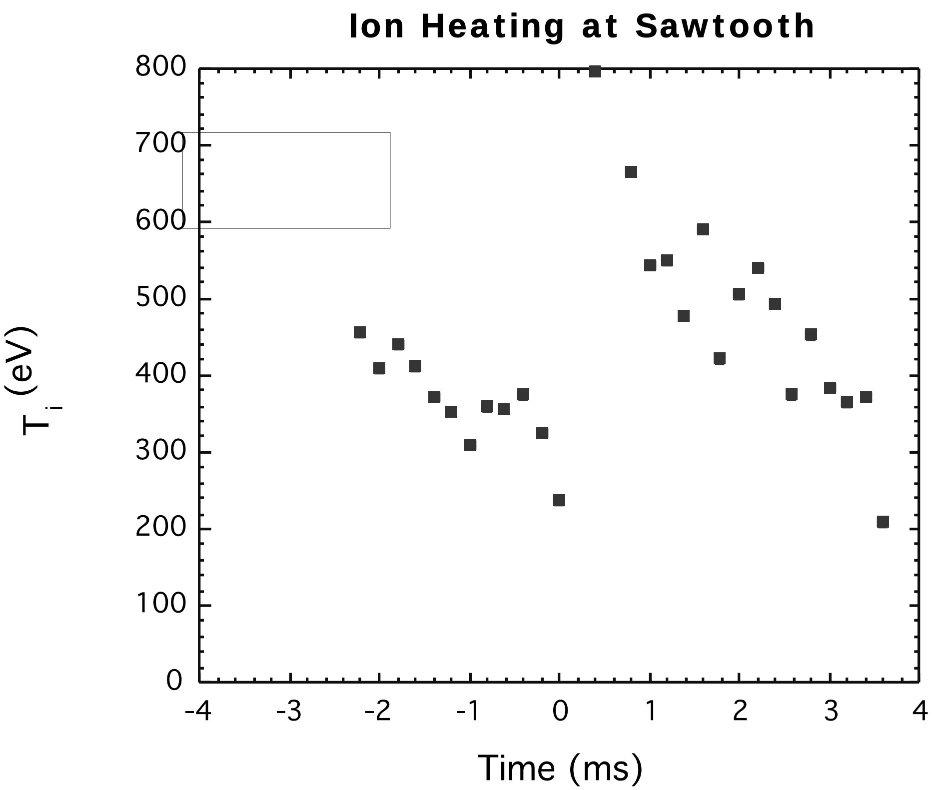
Measured Scattering Spectra



- Argon Peak
  - Position - beam energy
  - Width - beam energy spread
- Hydrogen Peak
  - Position - scattering angle
  - Width - beam angular spread, analyzer instrumental width
- Plasma Peak
  - Position - flow velocity
  - Width - ion temperature

Ion Temperature Measured with RS





Summary

- Three major DNB diagnostics have been tested on MST
  - Charge Exchange Recombination Spectroscopy (CHERS)
  - Rutherford Scattering (RS)
  - Motional Stark Effect (MSE)
- All three diagnostics appear to be functional.
- The beams have been operating very reliably.