Beam Induced Fluorescence Monitor (BIF) for High Current Heavy Ion Beams

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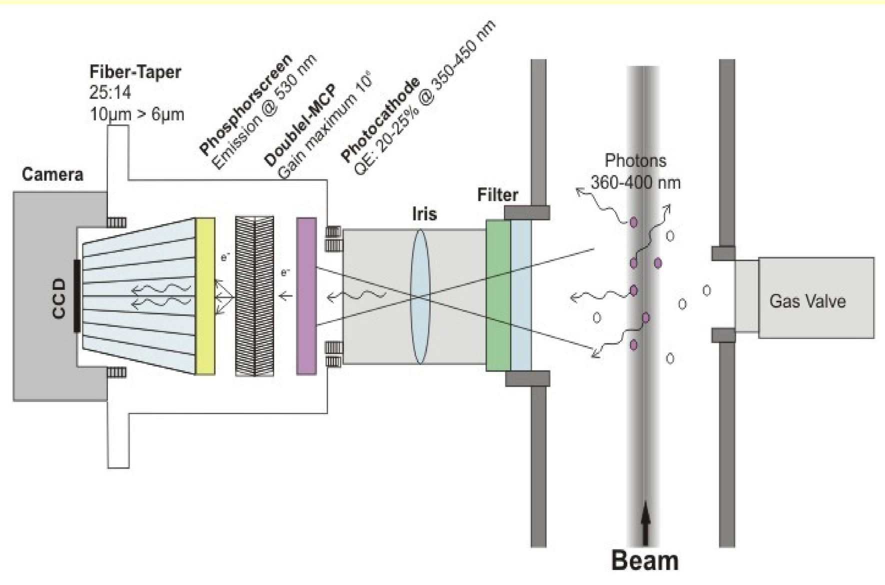
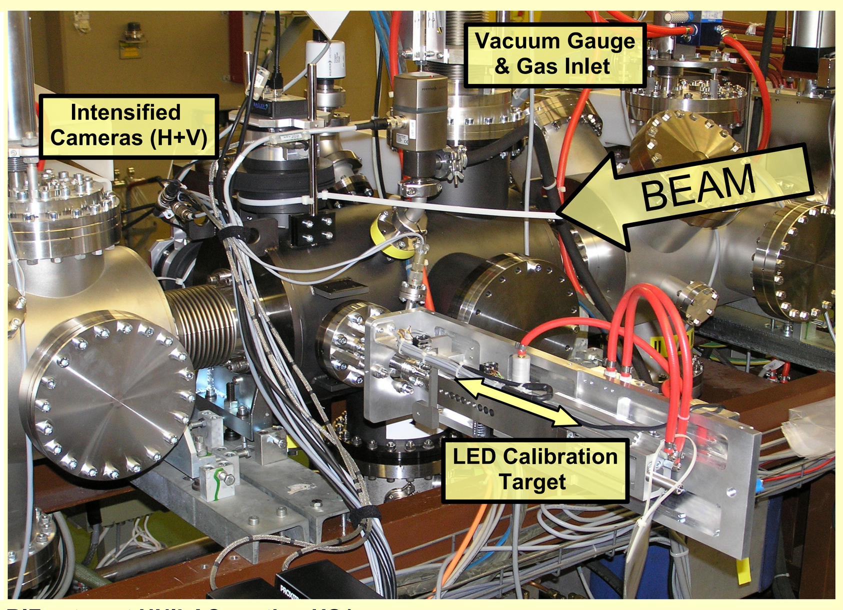
Abstract

For the Facility of Antiproton and Ion Research (FAIR), the heavy ion LINAC (UNILAC) at GSI has to be operated with high current. Therefore, non-intercepting beam diagnostics is mandatory. A new diagnostic device, the Beam Induced Fluorescence Monitor (BIF)[1] was developed and installed for transverse profile determination. Single photons, emitted by fluorescence of atomic collisions between the heavy ion beam and residual or injected gas are measured horizontally and vertically by intensified camera systems to achieve beam profiles.

Hardware Setup



BIF detection scheme



BIF setup at UNILAC section US1

Proxitronic Image Intensifier (custom designed camera system)

- Photocathode S 20, UV-Enhanced, Gateability: 100 ns
- Double MCP (V-Stack), ø 25 mm
- Phosphorscreen P46
- Fiber-coupled to Basler 311 f (b/w) CCD-Camera (½ inch)
  → Resolution: 25-30 lp/ mm

Diameter: 90 mm
Length: 40 mm

Proxitronic camera system

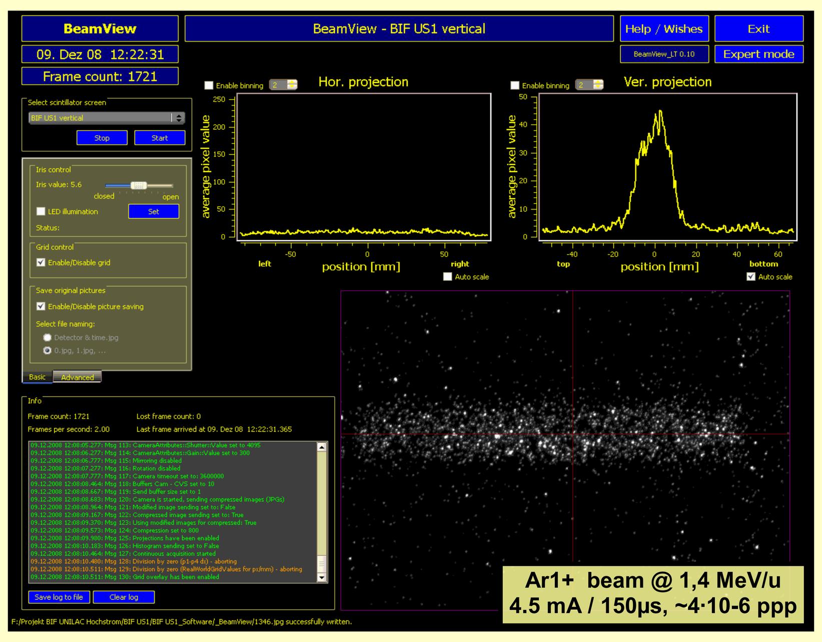
Optical Layout

- Pentax C1416ER: Focal length 16 mm, remote controlled iris
- Working distance: 195 mm
- Depth of field: 40 mm
  → Resolution: 4.5 pix/ mm

Gas Injection (Commercial Pfeiffer-System)

- Working gas: N_2 (other gases: He, Ar, Kr and Xe are recently tested)

BIF Operation

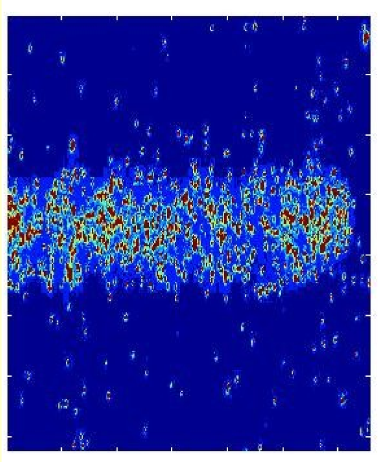


New Operation Software: BeamView [2]

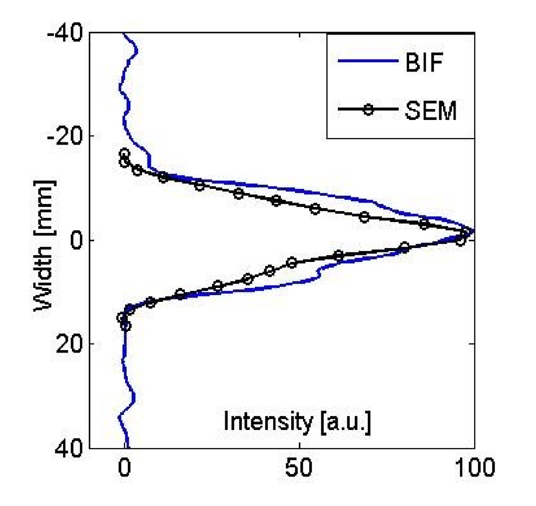
- Embedded Real-Time System (Compact Vision System, National Instruments)
  → LabView program for camera control and data-acquisition via FireWire
- Windows PC in the main control room
  → GUI in C++ with Qt-libraries
  → Image processing in C++
  → Remote control of all devices in C++ (timing, MCP gain, iris control, Gas-pressure, power-control)

Prove of functionality

Previous measurements on prototypes and experimental setups have basically demonstrated the functionality of the BIF method for different ions in the energy range from 1.4 to 750 MeV/u [3].



BIF Image



Horizontal profiles

For lower energies, Secondary-electron Emission Monitors (SEM) are standard profile diagnostics at GSI. For first validation of BIF measurements, the profiles are compared.

The horizontal profiles (average of 5 macropulses, 10 µs each) of a high current (4.5 mA) Ar^{1+} beam @ 1.4 MeV/u show good agreement in width and shape between both diagnostics.

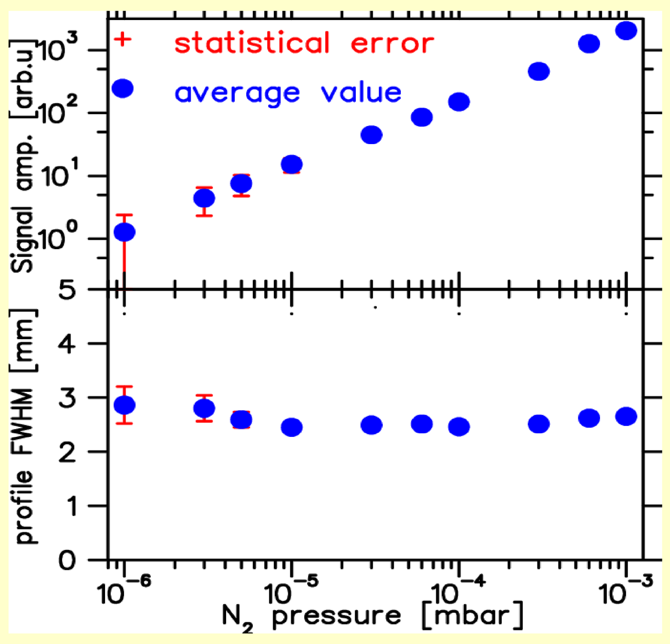
The signal intensity can be controlled by the following parameters:

- Nitrogen pressure (N_2)
- MCP Gain/ Phosphorscreen Gain
- Iris settings

Results

N_2 Pressure Variation

The most promising parameter for BIF operation is the variation of the N_2 pressure. It only effects the signal intensity but not the observed beamwidth. The average intensity and the FWHM are shown for pressure variation of three orders of magnitude. Below $2\cdot10^{-6}$ mbar, the low SNR leads to a huge error. Above $3\cdot10^{-6}$ mbar, the beamwidth remains constant and the intensity grows linear, as expected.



Measured beamwidth at UNILAC section X2

MCP Gain Variation

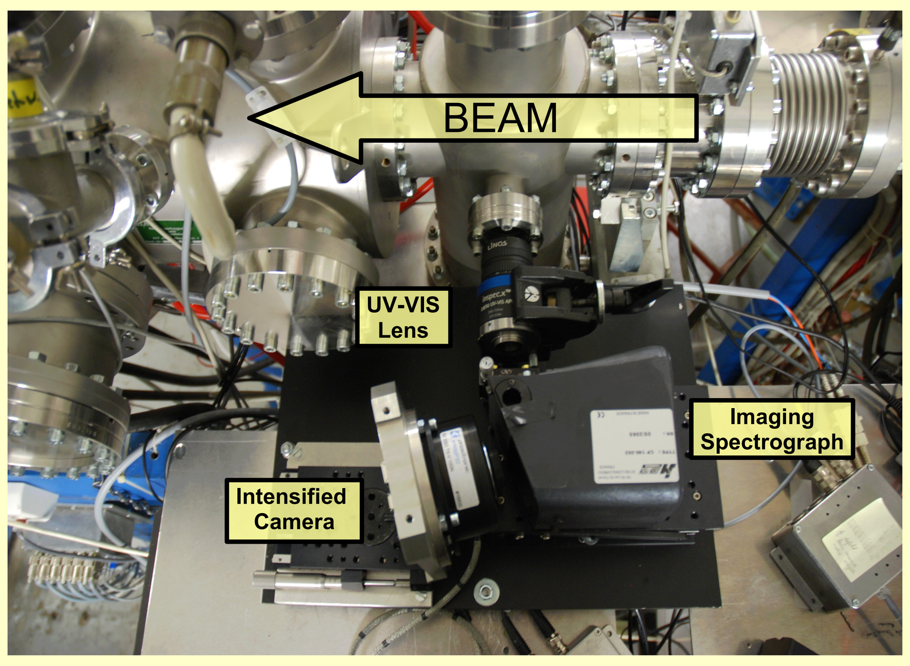
High MCP Gain leads to big white spots with an effect on the measured beamwidth. The influence of the Phosphorscreen Gain variation has to be investigated.

Iris Variation

Iris variation affects the depth of field which can also effect the observed beamwidth.

The extensive inspection of these parameters is an important issue to make BIF a reliable measurement system. Also the impact of filters to observe selected transitions [3] and the spectral composition of different working gases are investigated.

Spectroscopic Investigation



Experimental setup for spectroscopic measurements at UNILAC section X2

General information:
S^{6+} heavy ion beam (60 µA) @ 5.16 MeV/u
Working distance: 145 mm

Spectrometer:
HORIBA JOBIN YVON CP 140-202
Wavelength range: 190-800 nm
Average dispersion: 50 nm/mm
Focal length: 140 mm

UV – VIS Lens:
LINOS inspec.x
Chromatically corrected: 240-700 nm
Focal length: 50 mm
f-number: 2.8

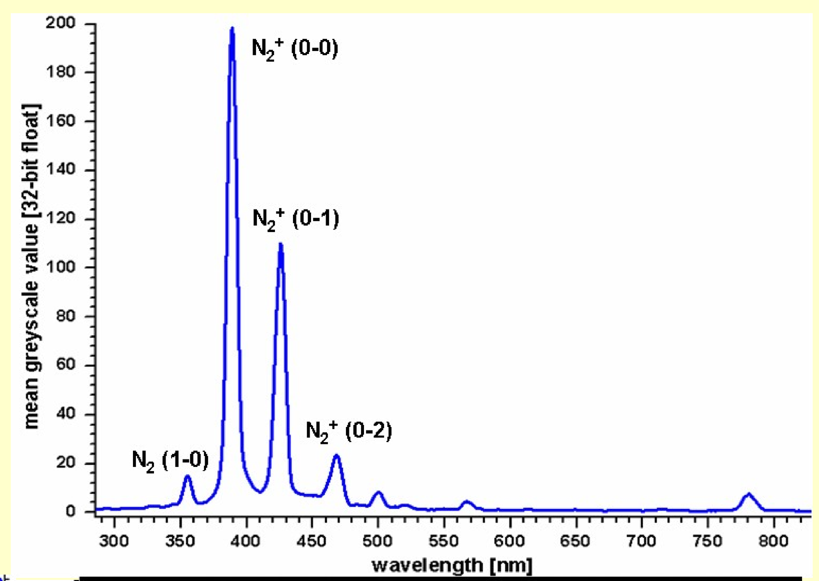
Nitrogen molecules are exited due to atomic collisions. The characteristic optical transitions for N_2^+:

$$N_2(X^1\Sigma) + Ion \rightarrow N_2^+(B^2\Sigma_u^+) + e^- + Ion$$
$$N_2^+(B^2\Sigma_u^+) \rightarrow N_2^+(X^2\Sigma_g^+) + \gamma\ (390 < \lambda < 471nm)$$

and N_2:

$$N_2(X^1\Sigma) + Ion \rightarrow N_2^+(...) + e^- + Ion$$
$$N_2(C^3\Pi_u) + e^- \rightarrow N_2(B^3\Pi_g) + \gamma\ (\lambda < 390nm) + e^-$$

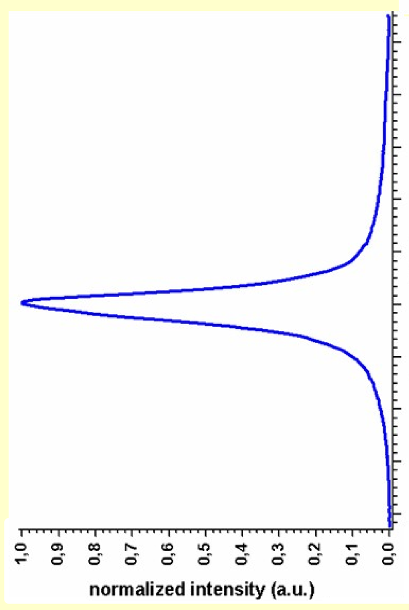
have been observed at 10^{-4} mbar nitrogen.

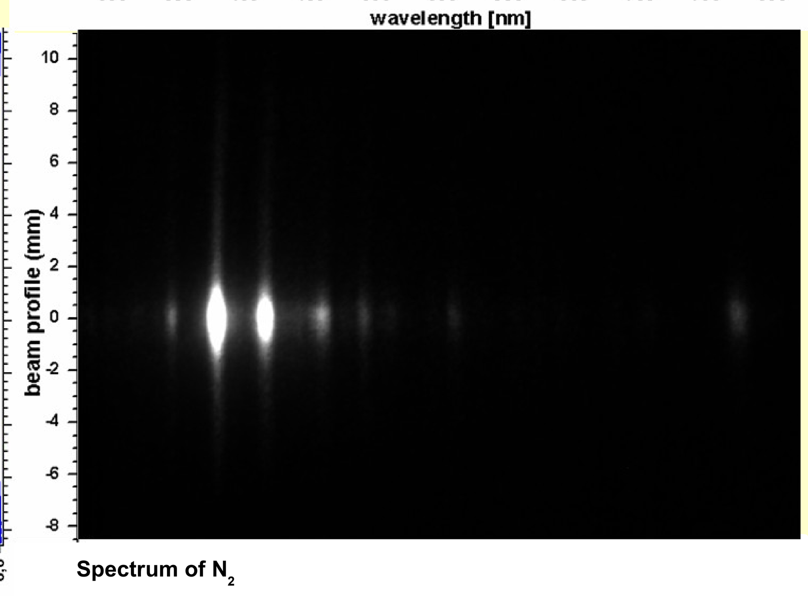


Beam Profile Parameters

Fit Model: Lorentz
Chi²/DoF = 0.00044
R^2 = 0.995
FWHM 1.33 ± 0.012 [mm]

The same beam profile was obtained for all spectral lines.





Spectrum of N_2

Conclusion

It is shown that BIF is an useful and reliable beam diagnostic device for high current heavy ion beams. Several BIF monitors will be installed along GSI LINAC and transfer line within the next two years.

The improvement of the BIF signal quality by optimizing the optical layout (e.g. lens, filters) and finding the best parameters for BIF operation will be performed.

Investigations on other working gases like He, Ar, Kr and Xe are in progress and show promising results. The influence on the measured beamwidth has to be studied in detail.

For the FAIR project, radiation hardness is a big issue that we're working on. Here, imaging fiber bundles and protective materials are proved [4].

References

[1] P. Forck et al., "Beam Profile Monitors on Residual Gas Interaction", DIPAC 2005
[2] R. Haseitl et al., "BeamView - A Data Acquisition System for Optical Beam Instrumentation", PCaPAC 2008
[3] F. Becker et al., "Beam Induced Fluorescence (BIF) Monitor for Transverse Beam Determination", DIPAC 2007
[4] F. Becker et al., "Beam Induced Fluorescence (BIF) Monitor for Intense Heavy Ion Beams", BIW 2008

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