Optimization of Beam Induced Fluorescence Monitors for Profile Measurements of High Current Heavy Ion Beams at GSI

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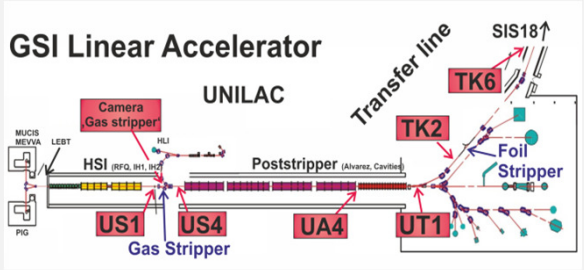
Abstract

To cope with the demands of the Facility for Antiproton and Ion Research (FAIR) for high current operation at the GSI Heavy Ion Linear Accelerator UNILAC non intercepting methods for transverse beam profile measurement are required. In addition to intercepting diagnostics like Secondary Electron Emission Grid (SEM-Grid) or scintillating screens, the Beam Induced Fluorescence (BIF) Monitor, an optical measurement device based on the observation of fluorescent light emitted by excited nitrogen molecules, was brought to routine operation. Starting with the first installations in 2008 and consequent improvements, successively six monitors were set up in the UNILAC and in the transfer line (TK) towards the synchrotron SIS18 and used as a standard diagnostic tool to observe the high intensity ion beam at kinetic energies between 1.4 and 11.4 MeV/u.



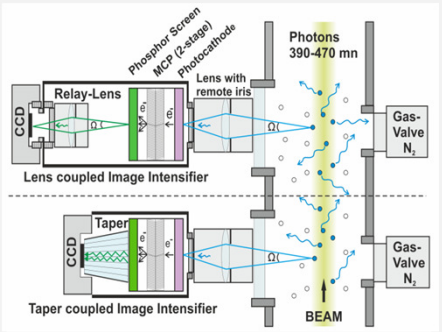
BIF	US1	US4	UA4	UT1	TK2	TK6
CCD H Coupling V	Taper Taper	Relay Relay	Taper Taper	Relay Relay	Taper Taper	Taper Relay
Energy [MeV/u]	1.4	1.4	11.4	11.4	11.4	11.4
Typical charge states :						
Argon	1+	11+	11+	11+	11+	18+
Nickel	2+	14+	14+	14+	14+	26+
Tantalum	4+	24+	24+	24+	24+	62+
Uranium	4+	28+	28+	28+	28+	73+

Installations

Along GSI linear accelerator UNILAC and transfer line, six BIF monitors are installed. Each monitor consists of two perpendicularly mounted image intensified cameras to measure transversal beam profiles in horizontal and vertical plane simultaneously. The monitors are placed to observe changes of the beam at stripping locations or during acceleration.

The BIF detectors are non-invasive and able to measure the beam position and achieve transversal beam profiles at dedicated positions within one linac pulse. A systematic check of the alignment over the whole linac and transfer line can be done with the BIF monitors.

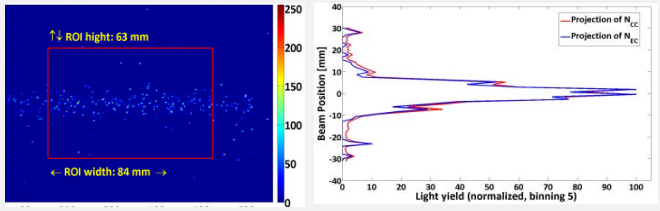
Detector Setup



To observe the fluorescence of the ion beam interaction with the nitrogen gas molecules at lowest gas pressures, custom designed image intensified camera systems (ICCD) from ProxiVision® with a 2-stage multichannel plate (MCP) are required, preferably to enable single photon counting. Two different types are used, a fiber-tapered coupled CCD, where the CCD chip is glued to the fiber-taper and a relay-lens coupled CCD with C mount standard.

Operational parameters

- N_2 gas pressure
- iris opening
- MCP high voltage



Modes for data analysis

Event counting (EC) mode

- requires a high intensifier gain for efficient single photon detection
- relies on bright, well separated event signatures.

➢ **total light yield N_{EC} = number of events**

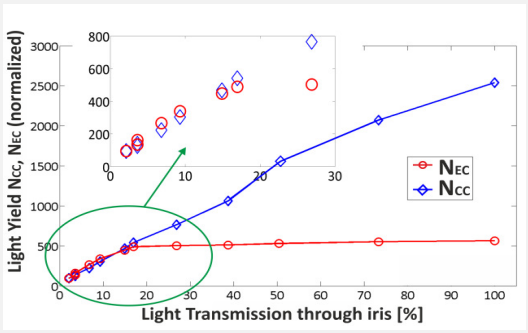
➢ **Profiles** are constructed of each event's vertex (x/y)

Charge collection (CC) mode

- intensifier gain is adjusted to avoid camera saturation at the expense of some detection efficiency
- overlap of detected events is not a problem as long as no saturation occurs

➢ **total light yield N_{CC} = integration over the CCD matrix**

➢ **Profiles** are projections of the matrix

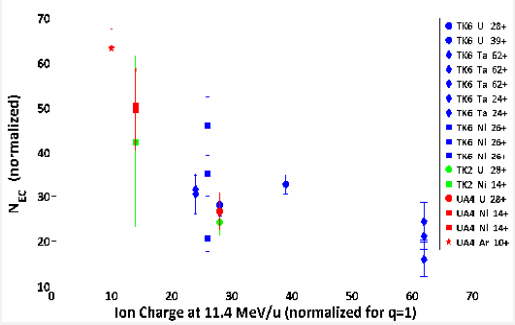


Events overlap at ~200 counted events in the ROI, they can not clearly be separated.
Charge collection mode has higher dynamic, is more robust and reliable for operating

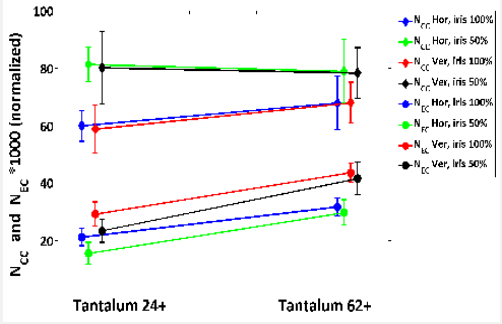
q² Dependency

$$N_{EC}\,,\,N_{CC} \propto \frac{dE}{dx}_{Proton} \cdot q^2$$

Comparison of measurements, taken from
- different camera systems & settings
- various ions and charge states
- various beam parameters (current, position, size...)



Measurements, taken from
- same BIF installation (horizontal & vertical camera)
- Tantalum beam stripped & unstripped
- constant beam currents



data is normalized in respect to the gas pressure, the iris setting, the number of particles per pulse, the differential energy loss for a proton of 11.4 MeV/u in nitrogen and to the square of the ion charge state

Conclusions

- All installed BIF detectors offer a reliable measurement of transversal beam profiles for high current beams.
- For operation, the data analysis is done in the charge collection mode, due to the higher dynamic and robustness.
- For future permanent installations, the relay-lens coupled image intensifiers are preferred, due to the easier maintenance.
- The q² dependency between multiple different measurements and detectors could roughly be shown.
- A further, dedicated experiment at two different charge states of a tantalum beam at the same detector could prove the q² dependency.

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