Non-Intercepting Beam Diagnostics for High Power LINACs

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Non-intercepting diagnostics is required for:

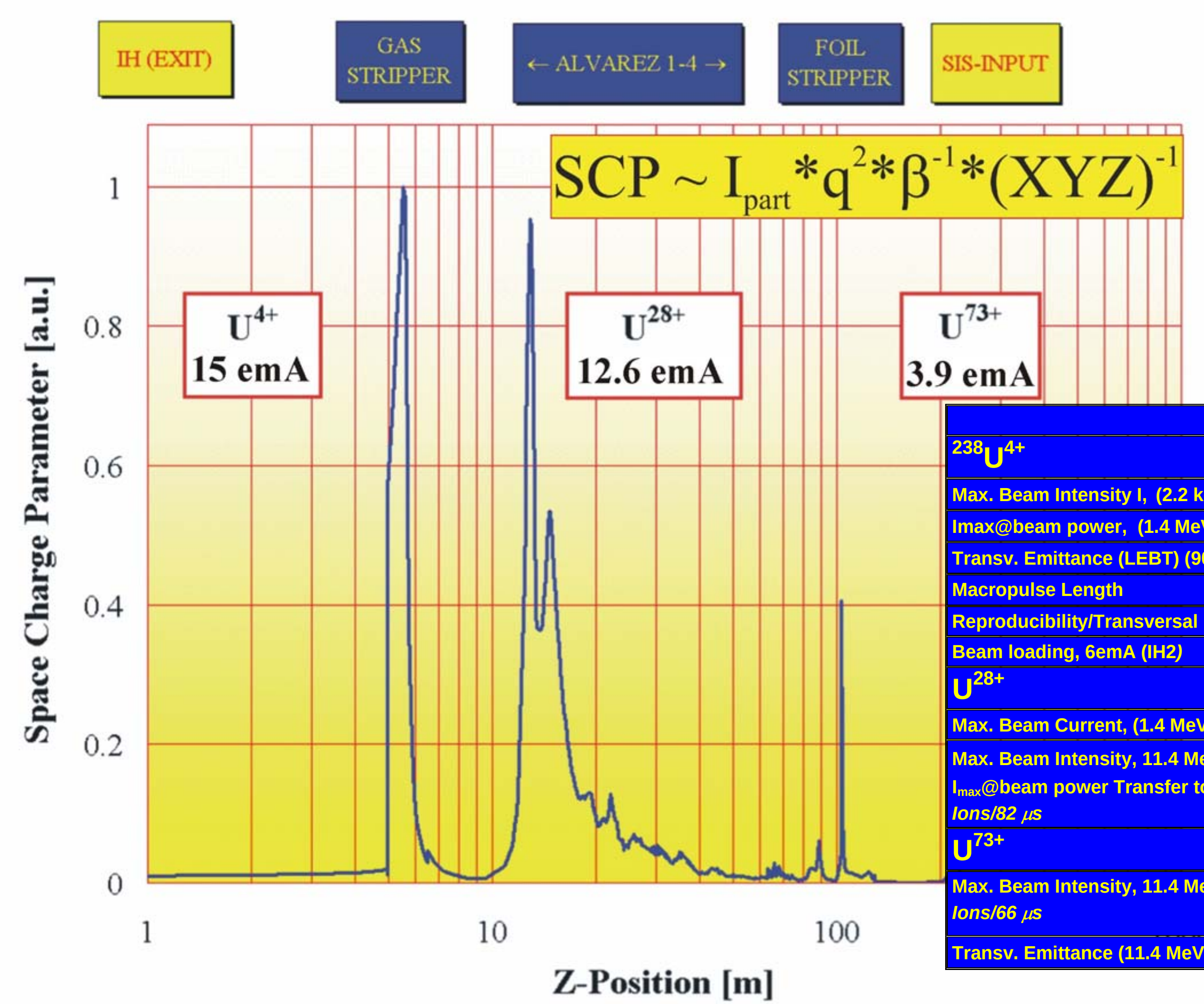
→ Preventing the devices from melting by the beam power

→ LINAC: Monitoring of the full macro-pulse including time-varying processes

Outline of the talk:

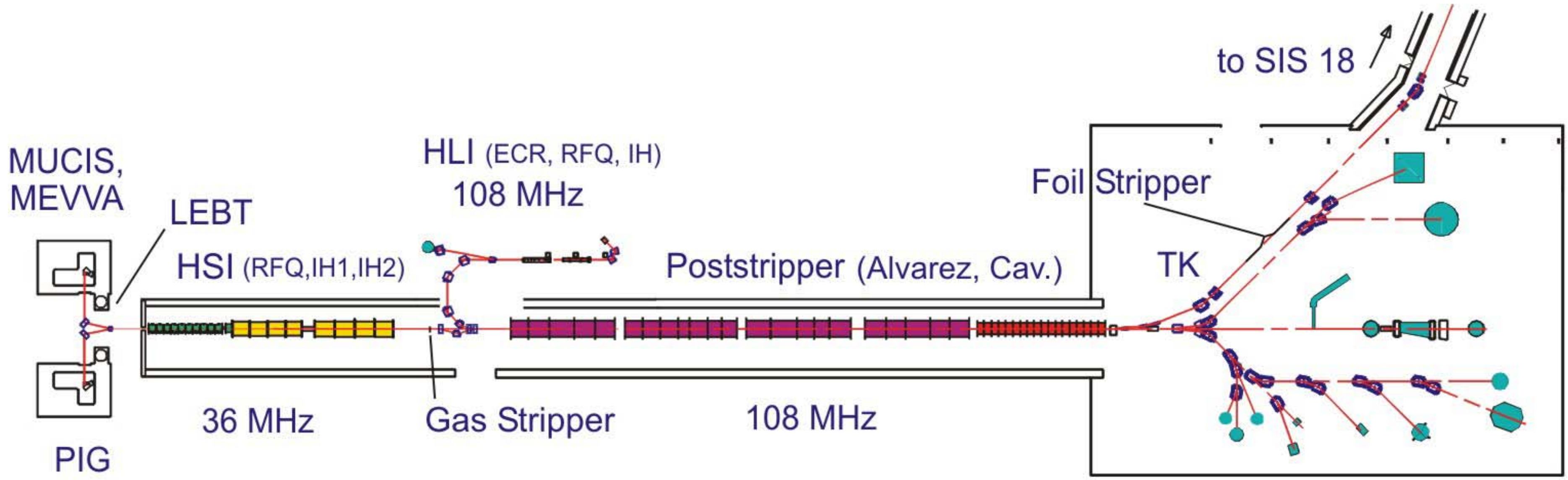
1. Beam Induced Fluorescence (BIF) Profile Monitor
2. Novel device for Bunch Shape Determination

Unilac as an injector for FAIR

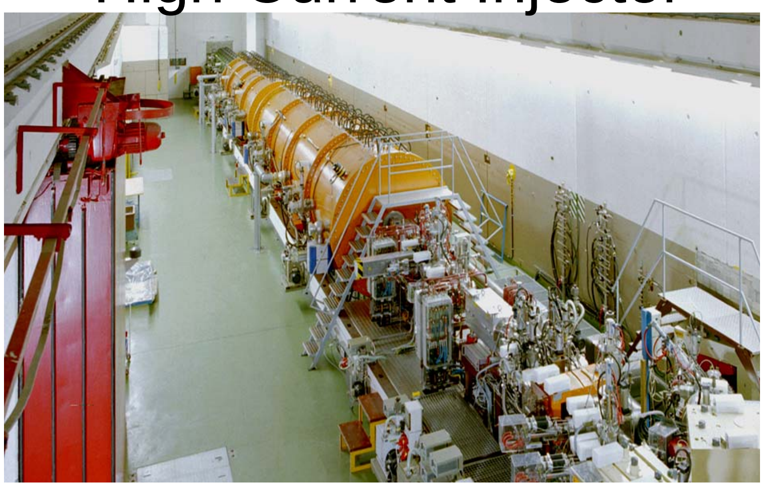


	Measured	required for FAIR
$^{238}U^{4+}$		
Max. Beam Intensity I, (2.2 keV/u)	16 emA	20 emA
Imax@beam power, (1.4 MeV/u)	6.5 emA @545 kW	18 emA@1500 kW
Transv. Emittance (LEBT) (90%, total)	140 π·mm·mrad	120 π·mm·mrad
Macropulse Length	150 µs	150 µs
Reproducibility/Transversal Emittance	±4.5%	-
Beam loading, 6emA (IH2)	300 kW	710 kW (18 emA)
U^{28+}		
Max. Beam Current, (1.4 MeV/u)	5.0 emA	15.0 emA
Max. Beam Intensity, 11.4 MeV/u, I_{max}@beam power Transfer to the SIS18 *Ions/82 µs*	4.5 emA@440 kW *$8.1 \cdot 10^{10}$*	15.0 emA@1453 kW $2.7 \cdot 10^{11}$
U^{73+}		
Max. Beam Intensity, 11.4 MeV/u, *Ions/66 µs*	2.0 emA *$1.1 \cdot 10^{10}$*	3.5 emA $2.0 \cdot 10^{10}$
Transv. Emittance (11.4 MeV/u) (90%, tot.)	10.0 π·mm·mrad	7.0 π·mm·mrad

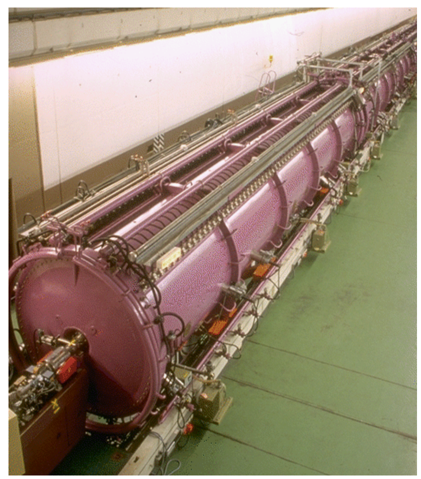
The GSI UNIversal Linear ACcelerator



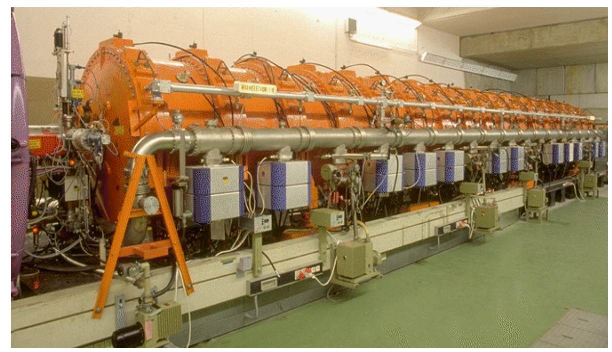
High Current Injector



Alvarez

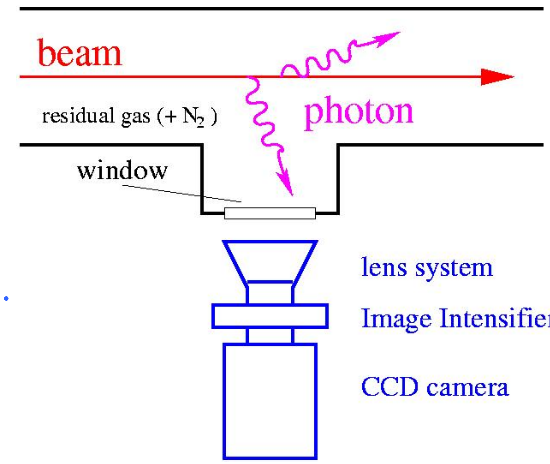


Single Gap Resonators



Beam Induced Fluorescence BIF

BIF method realized at
Los Alamos, Saclay, CERN, UNI-Frankfurt, GSI, COSY ….

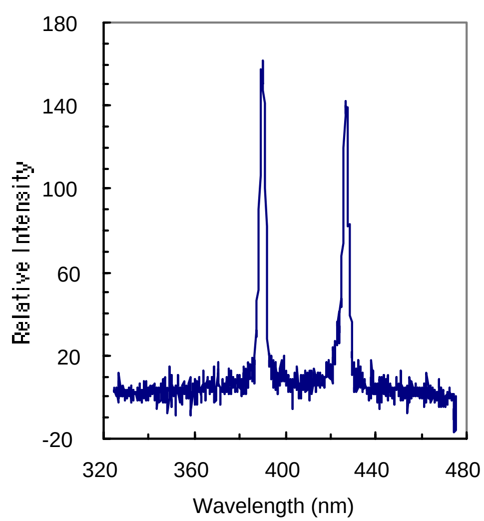


Physics of fluorescence for N_2 residual gas:

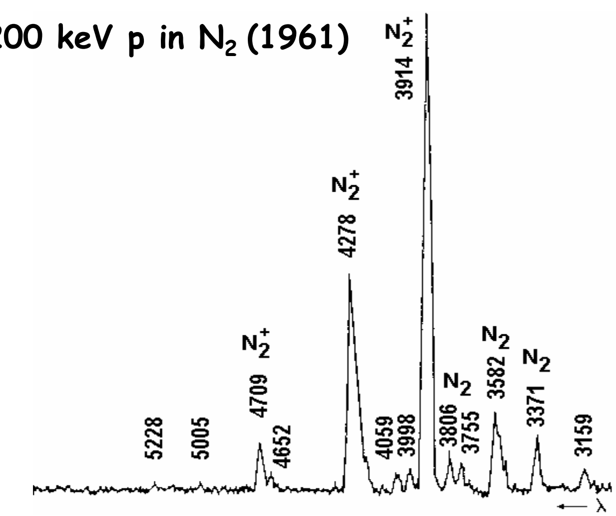
- Due to the beam's energy loss, the residual gas molecules are excited
- Decay of N_2^+ levels generate light, wavelength range 390 nm < λ < 470 nm.
  Lifetime about τ = 60 ns.

N_2 Spectrum at LANL (D. Gilpatrick et al.)

for p at MeV energy and $5*10^{-5}$ mbar



Fluorescence of 200 keV p in N_2 (1961)

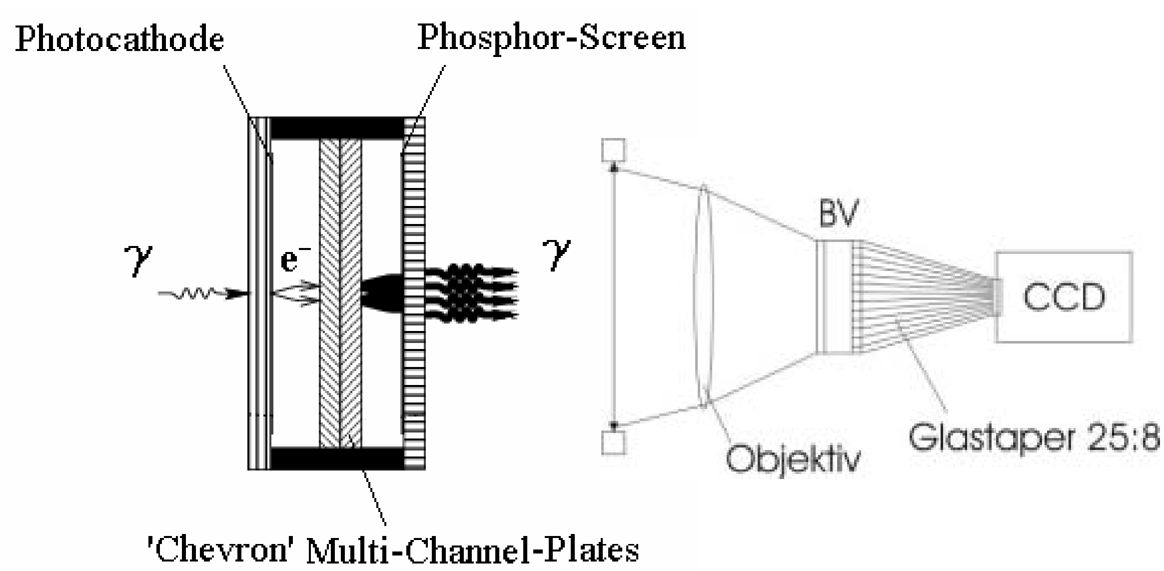


In addition: 1 to 25 GeV at CERN PS and SPS. Signal strength: ≈3.5 keV per *one* detectable photon

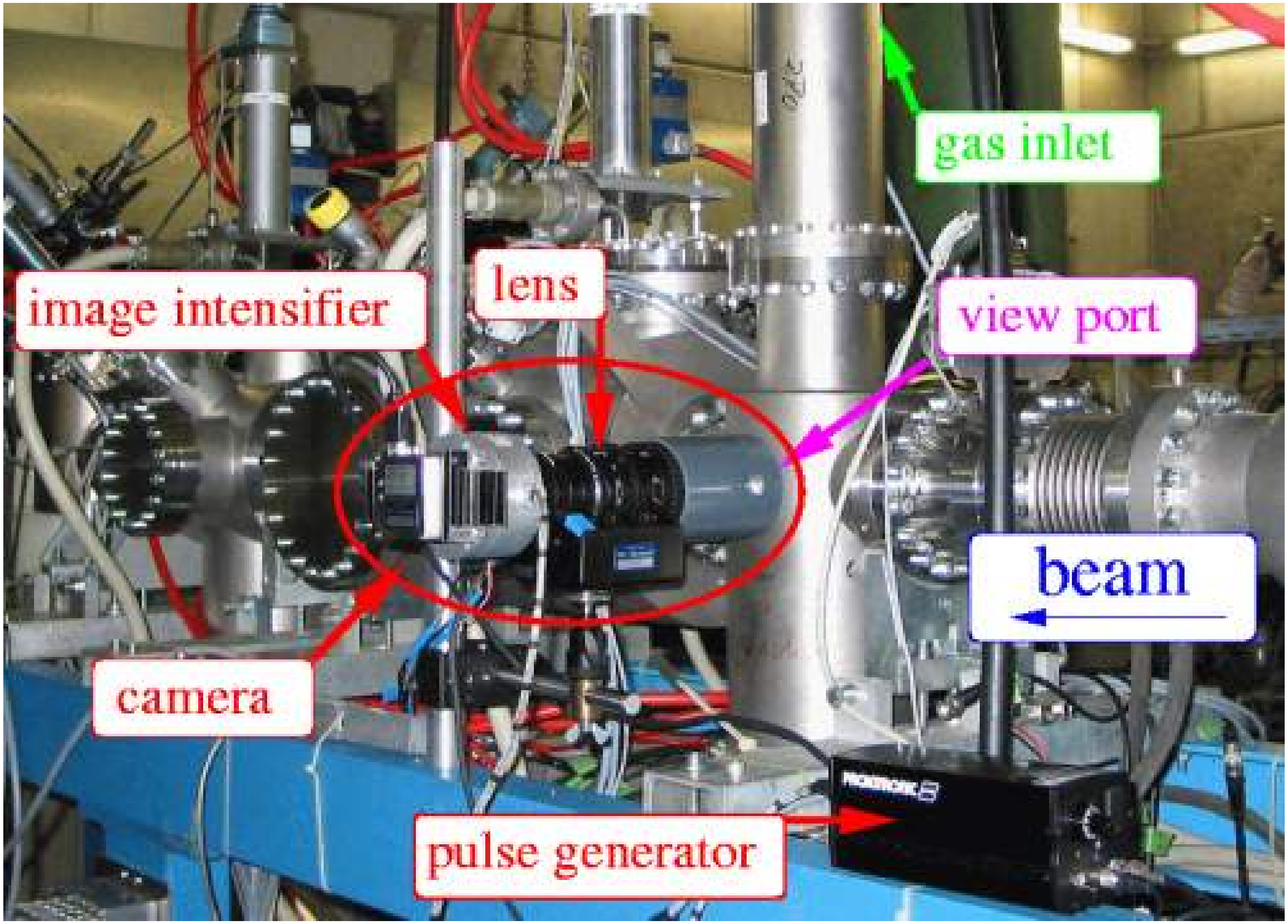
Image Intensifier used at GSI-LINAC

Technical realization of image intensifier at GSI:

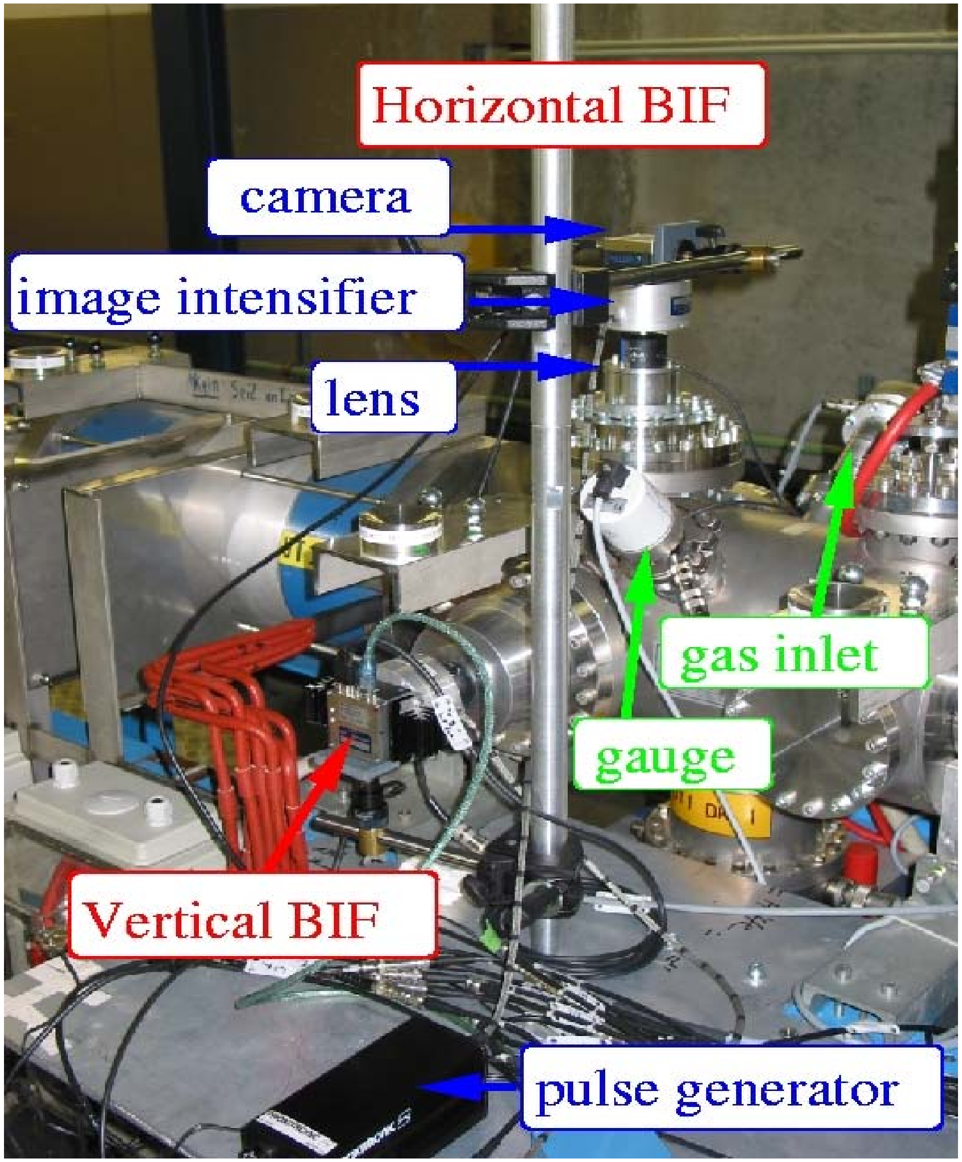
- Photo cathode : photon-to-electron conversion, 25 to 30 % efficiency
- *Two* step MCP (25 mm diameter): 10^6 fold amplification, switch-able within 100 ns
- P 46 phosphor: electron-to-photon conversion, 300 ns decay, 530 nm wavelength
- Minifying taper coupling to CCD chip (1/2"): 10% transmission
- Digital camera (Basler A302fs): FireWire interface
- Cost 15 k€/camera

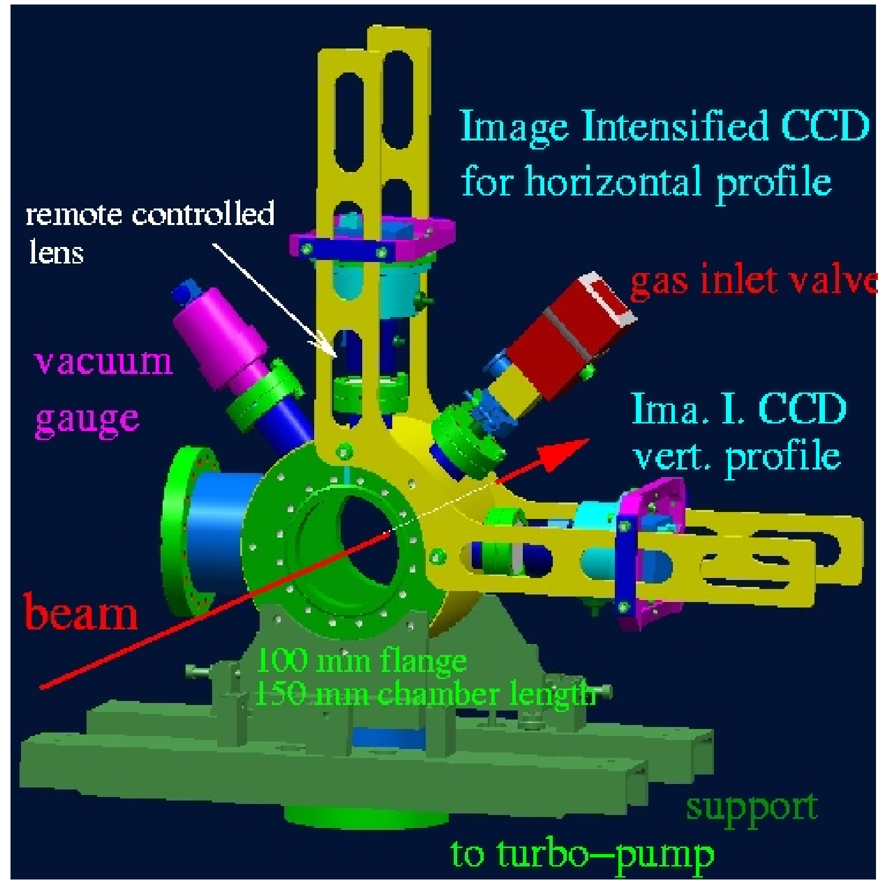


Test Setup at GSI-UNILAC (ver)



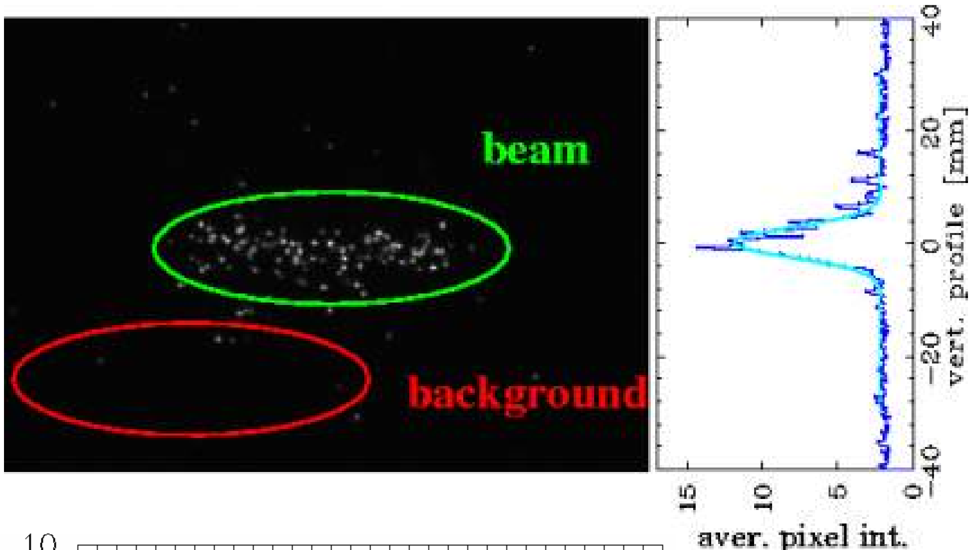
Prototype at GSI-LINAC (hor & ver)

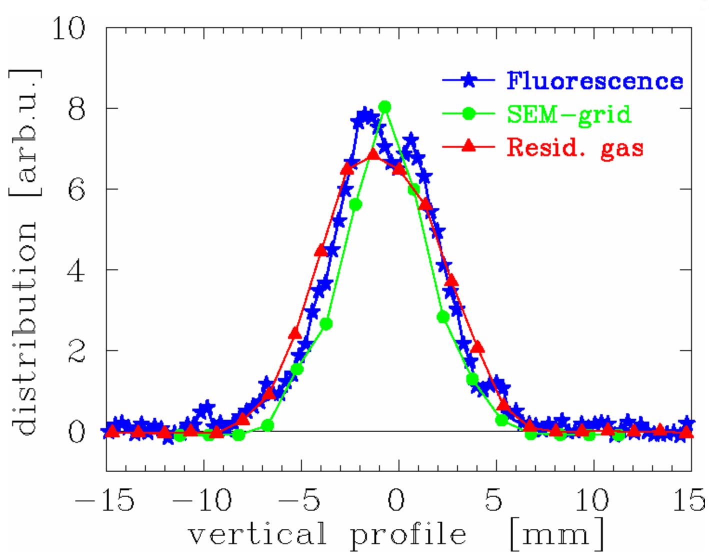




Installation behind Alvarez (11.4 MeV/u)

Typical Result at GSI-LINAC





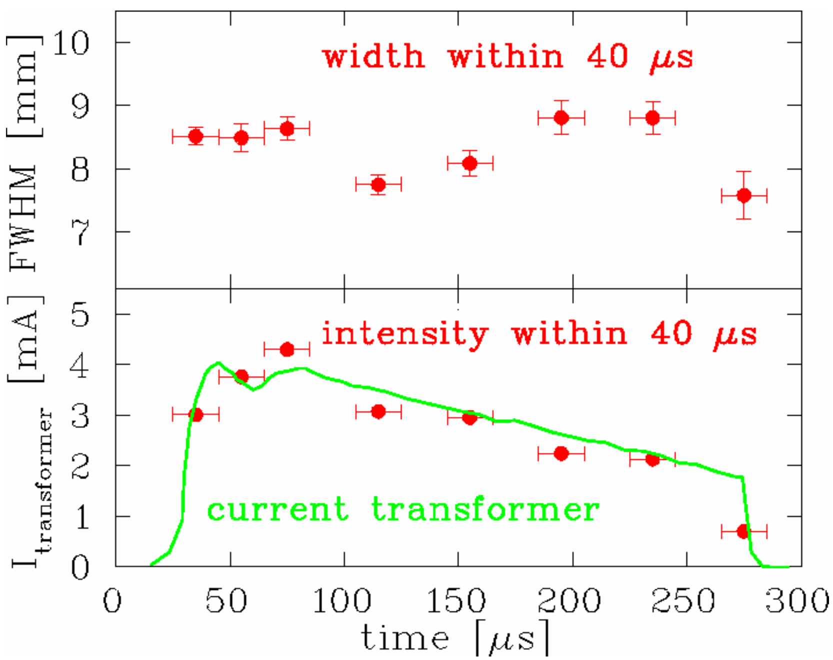
Example at GSI-LINAC:

4.7 MeV/u Ar^{11+} beam, I=2.5 emA, corresp. to 10^{11} particles, *one Single* macro pulse of 250 μs, *vacuum pressure:* p=10^{-5} mbar (N_2)

Features:

- Non-intersecting
- Single photon counting
- High resolution (here 0.3 mm/pixel), can easily be matched to application
- Variability by binning and averaging
- Low background
- Reliable method, as proven by comparison to standard methods

Application of Beam Induced Fluorescence Method



Variation during the macro pulse detectable:

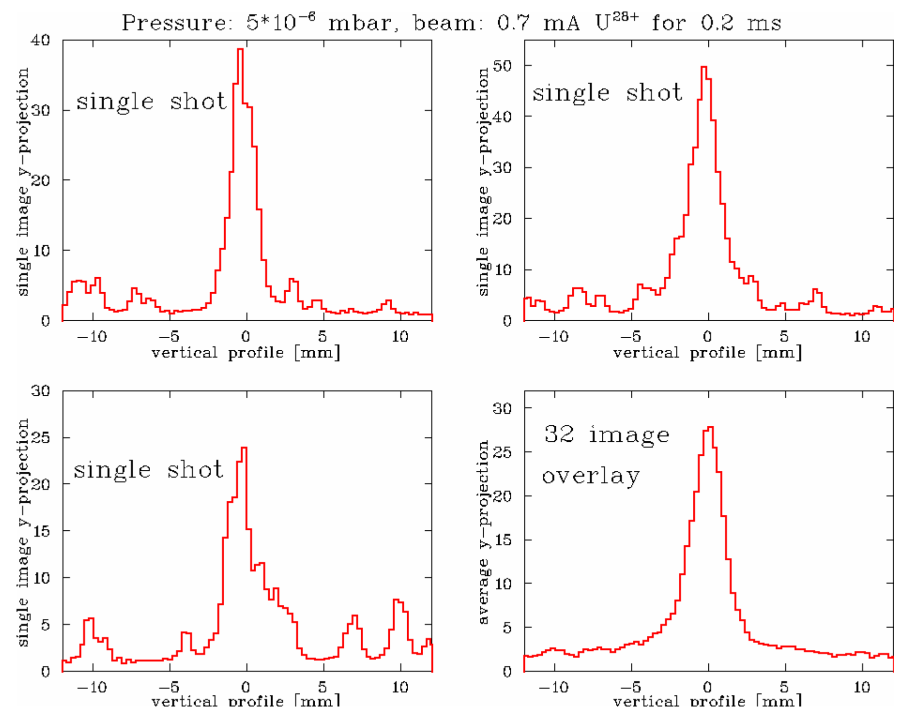
Switching of image intensifier within 100 ns

→ Time window during macro-pulse

Statistical behavior:

→'Offline' optimization

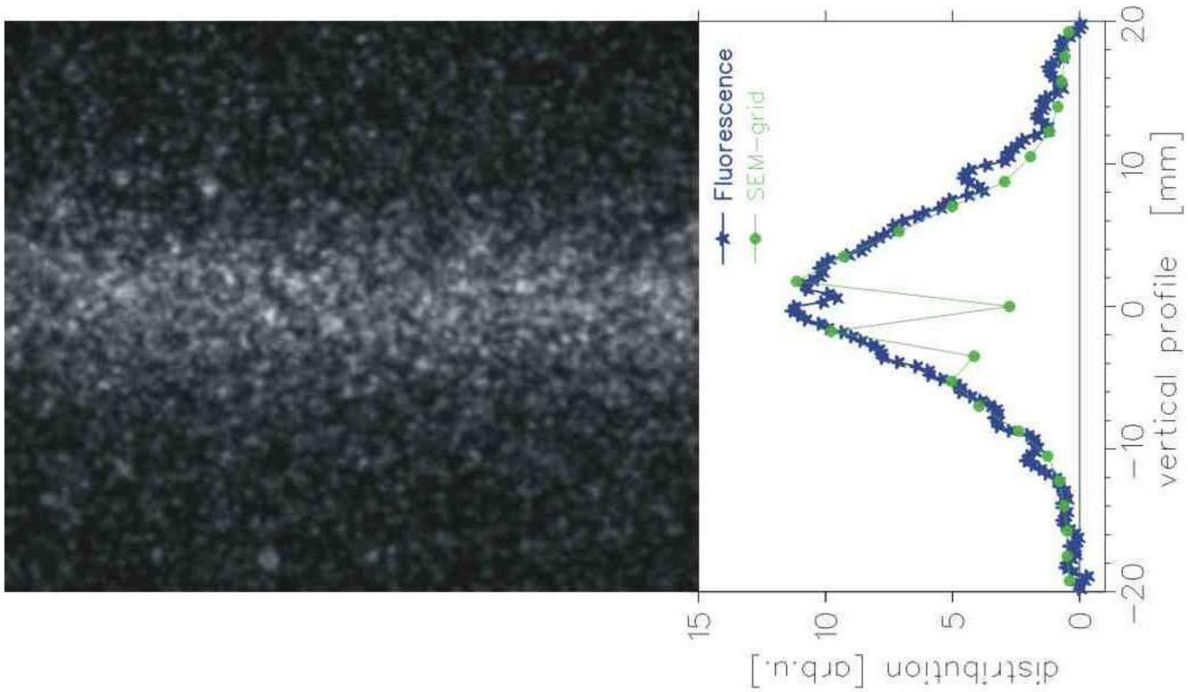
statistics ↔ integration time ↔ resolution



First Measurement with Prototype

Installation at UNILAC tunnel:

- No degeneration (camera) due to radiation dose within 1 year
- Reliable operation possible



Local pressure bump required:

typ. 10^{-6} to 10^{-4} mbar

(restricted to ≅1 m)

...but no influence on beam

determined by:

- Transmission
- Bunch shape
- TOF
- Injection efficiency
- *Schottky.*

Parameter: 11.4 MeV/u U^{28+} 2emA 100 μs, p= mbar, 20 pulses

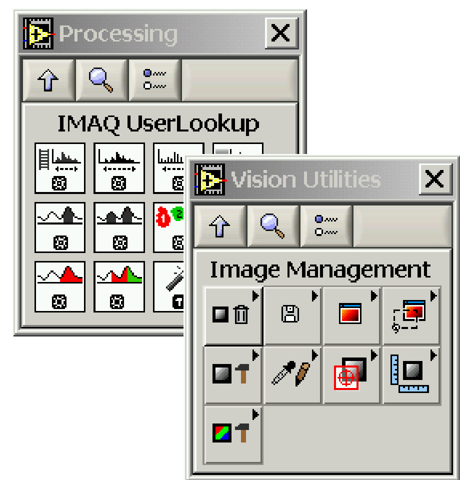
Digital Interface for Firewire

Digital camera offers:

- no loss of data-quality due to cable
- versatile trigger
- variable exposure time

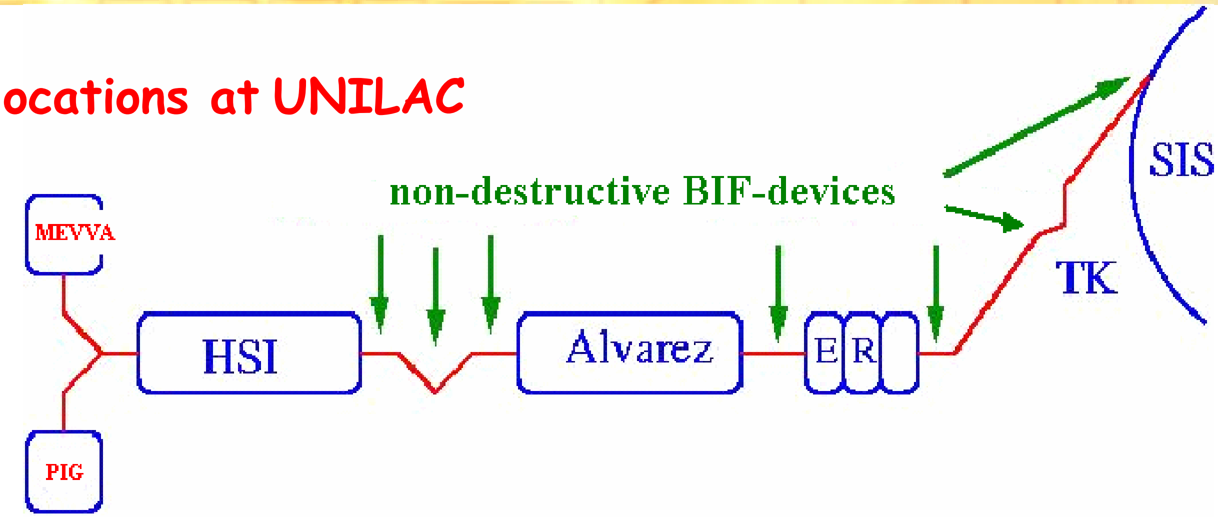
- CCD-camera: Basler A311f featuring 649x494 pixels, 12 resolution, 50 frames/s, IEEE1394
- Readout (in preparation): HUB → optical fiber → real-time controller on RT-LabVIEW (NI)
- Software (in perparation): RT-LabVIEW and data transfer to LINUX for data presentation

LabVIEW Software:



Application of BIF at FAIR (kürzen)

Planned locations at UNILAC



Planned for 7 locations at p-LINAC as standard device

Open questions: → Sufficient signal strength ?
→ Differences to ions ?
→ Optical transitions from beam ions ?
→ Applications at LEBT ?

Technical realization: → Optimal setting for optics
→ Data acquisition system and software

At HEBT (behind SIS18/100)

for fast extraction ?
(first tests performed at COSY)

Novel device for non-intersecting Bunch Shape Measurement

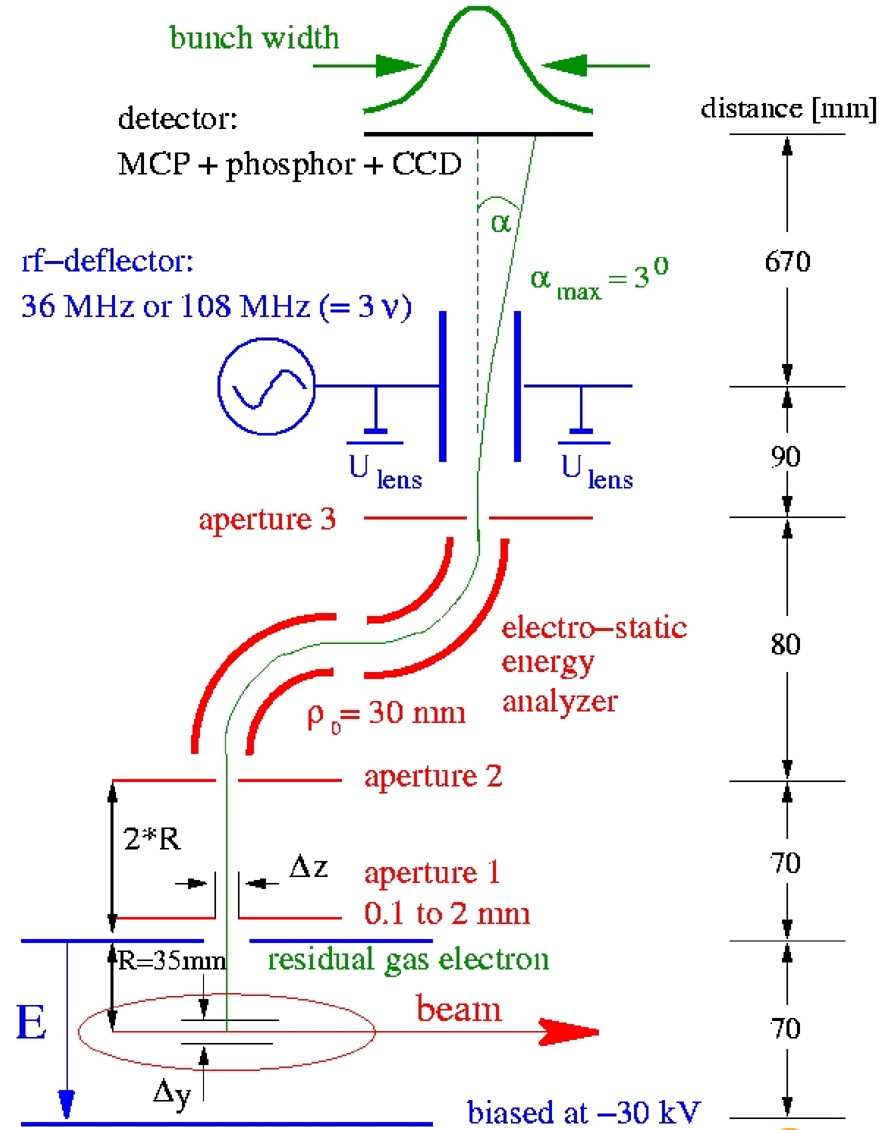
Idea for novel device

- Secondary electrons for residual gas
- Acceleration by electric field
- Target localization by apertures

  and electro-static analyzer

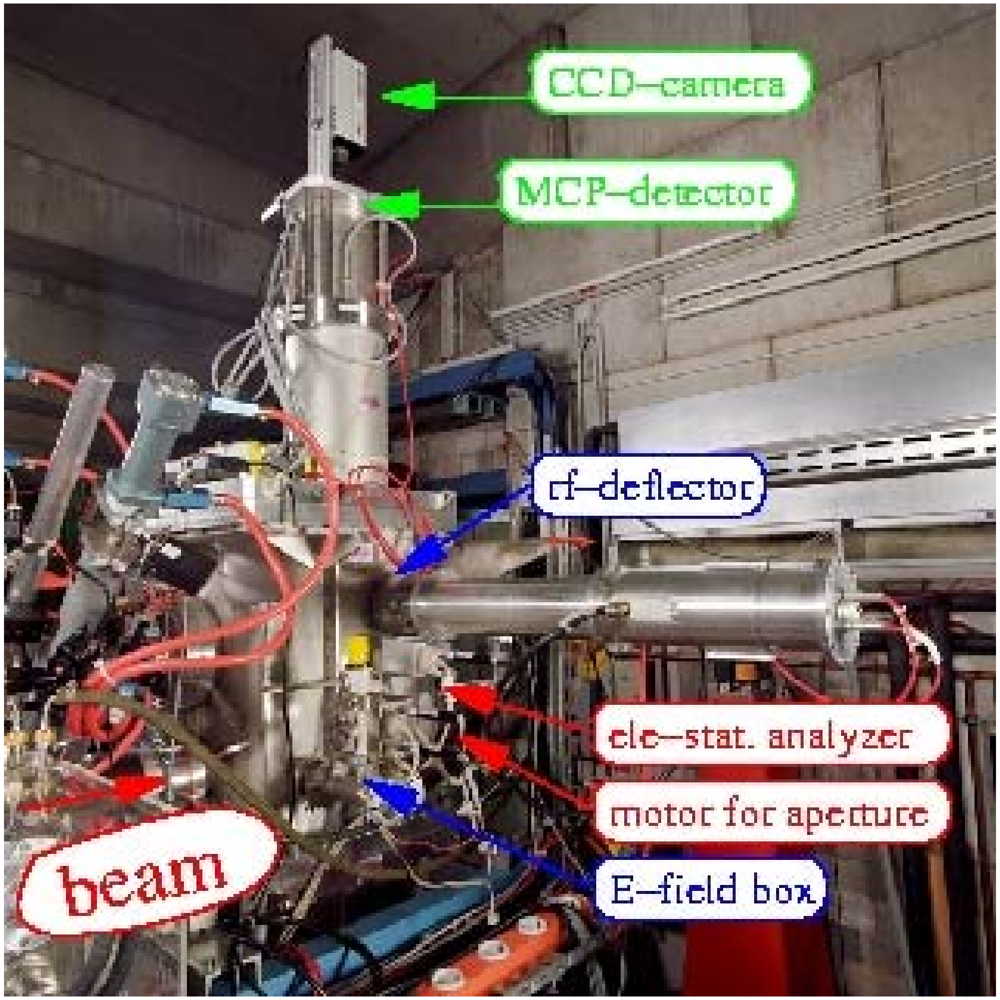
  (Δy = 0.2 to 2 mm, Δz=0.2 to 1 mm)
- Rf-resonator as 'time-to-space' converter
- Readout by MCP + Phosphor + CCD
- Measurement done within one macro-pulse

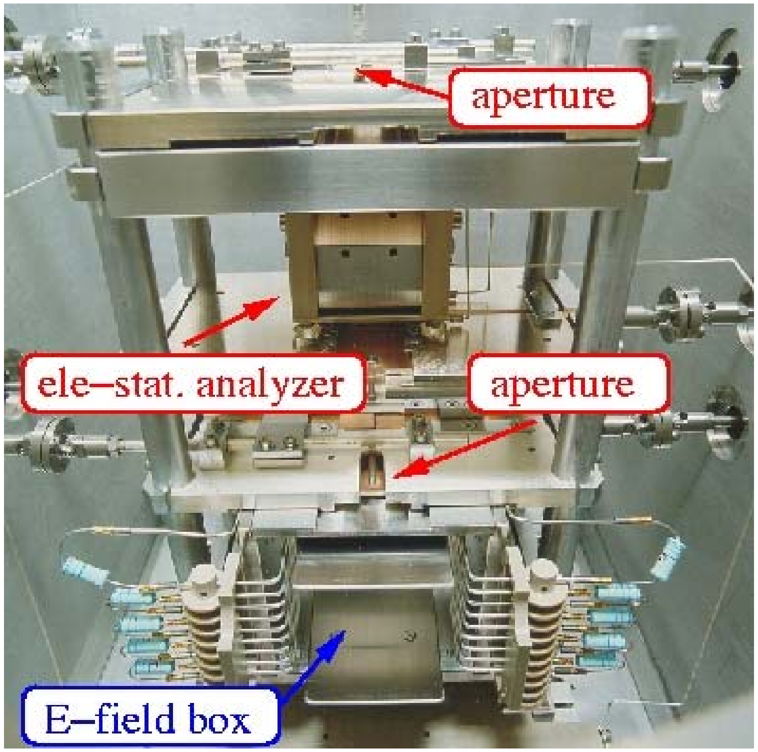
  (not yet achieved due to back-ground)

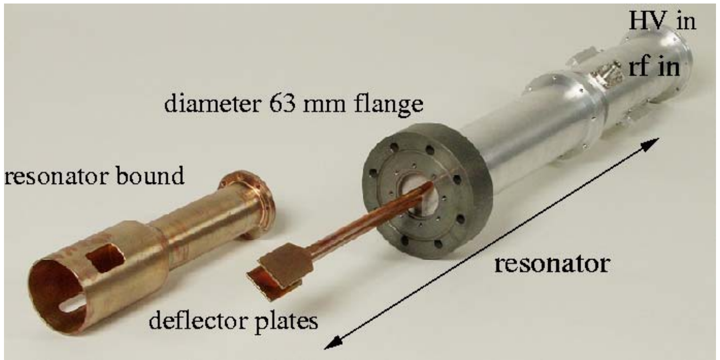


Realization for Bunch Shape Monitor

The installation for beam based tests:



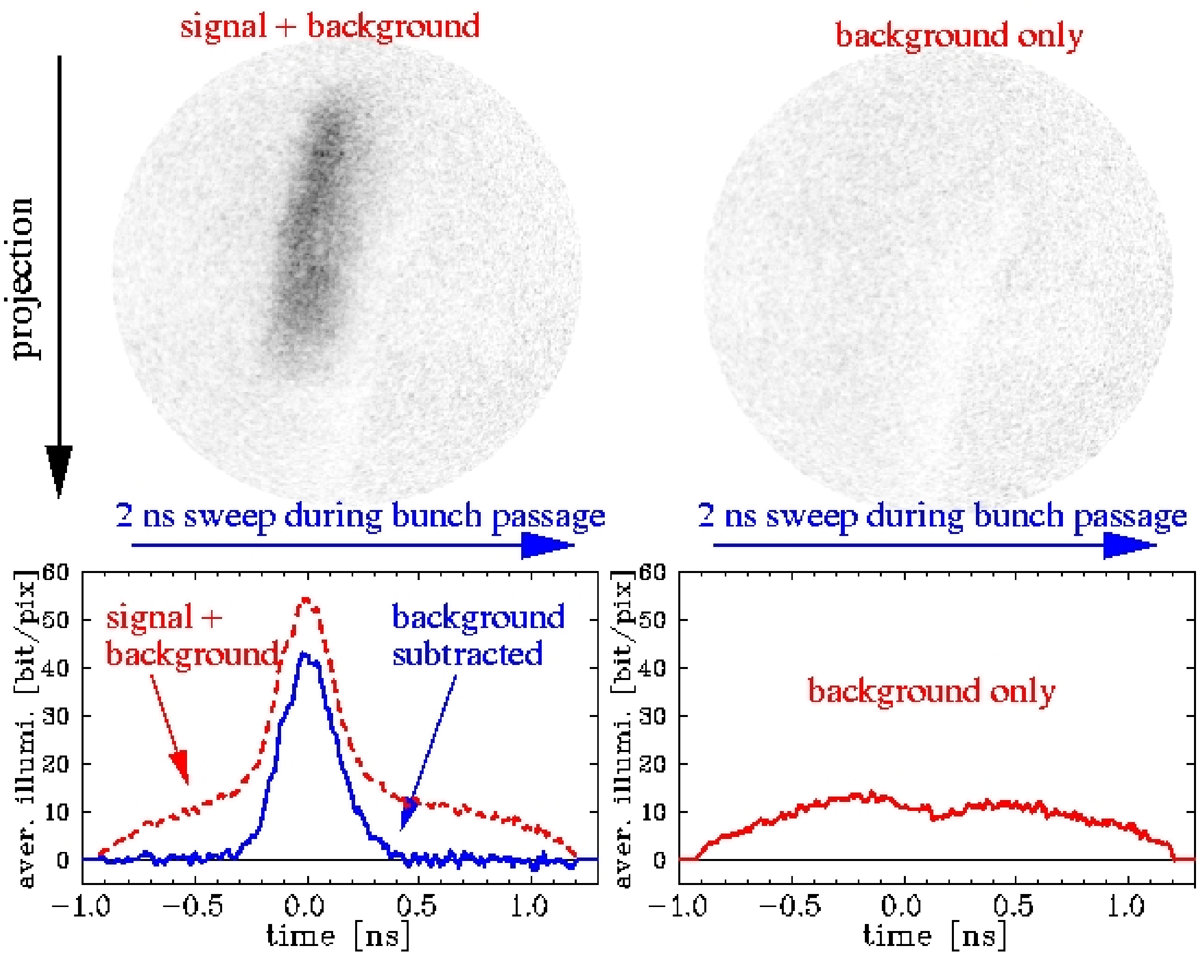




First results from Bunch Shape Measurement

Time information carried by the sec. e- is transferred to spatial differences

Image from MCP



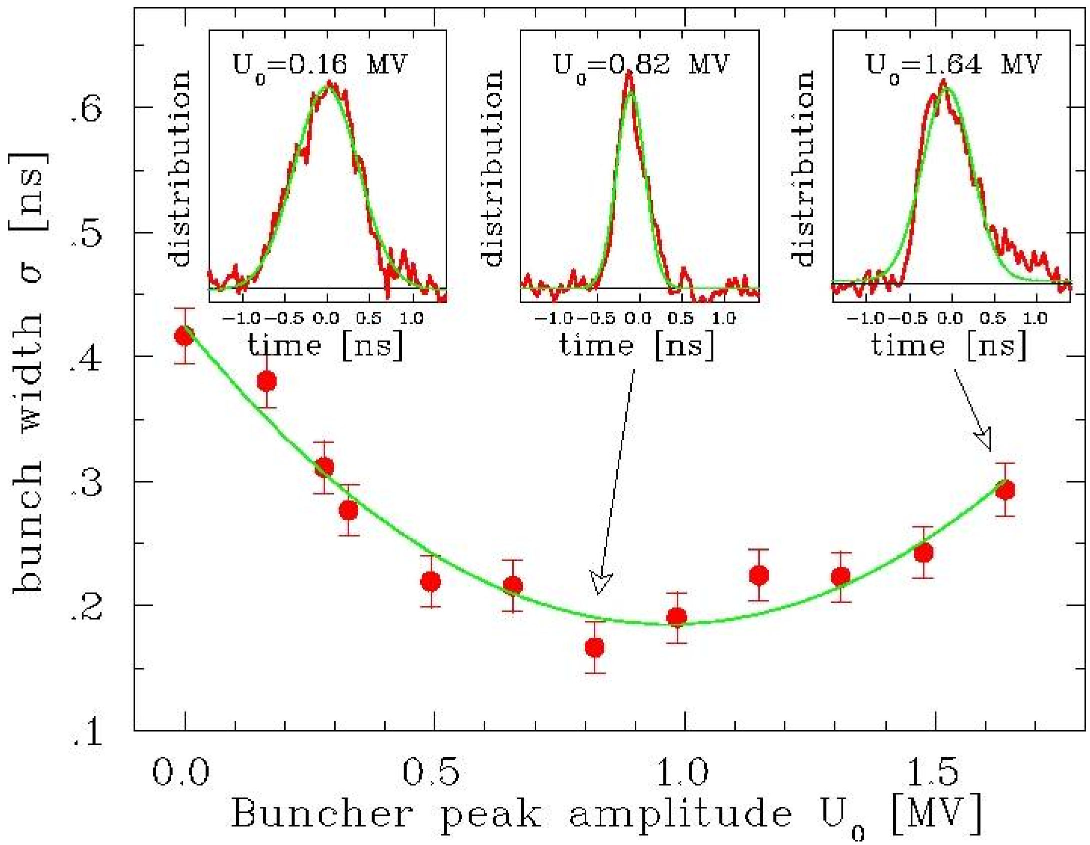
Features:

- single electron detection
- Recorded within few macro-pulses
- pressure bump required
- Back-ground should be suppressed

Beam parameters:

- Au^{25+} at 11.4 MeV/u
- I=60 eμA, 1 ms macro pulse
- Average: 16 macro pulses
- Pressure $p=10^{-5}$ mbar
- Deflector power P=8 W

First results from Bunch Shape Measurement



Variation of buncher:

- Bunch shape was determined, influeneced by buncher
- Pick-up: No measurable influ- ...ence
- Emittance determination ...possible

Beam parameters:

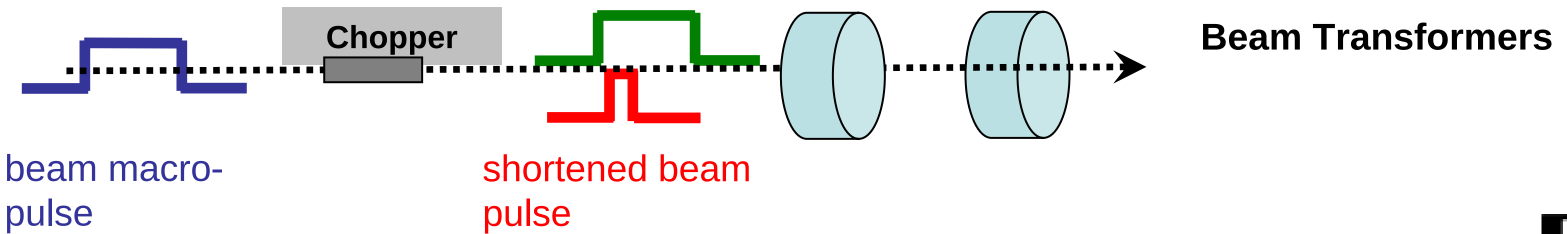
Ni^{14+} at 11.4 MeV/u, I=2 emA, 0.21 ms macro pulse, average: 4 macro pulses, pressure p=10-5 mbar

Conclusion

- BIF-method successfully tested (comparison with SEM, Res. gas monitor)
- BIF-prototype designed, constructed and mounted behind the GSI-DTL
- Proof of principle for the Bunch Shape Monitor on test bench
- Design of the Bunch Shape Monitor is done

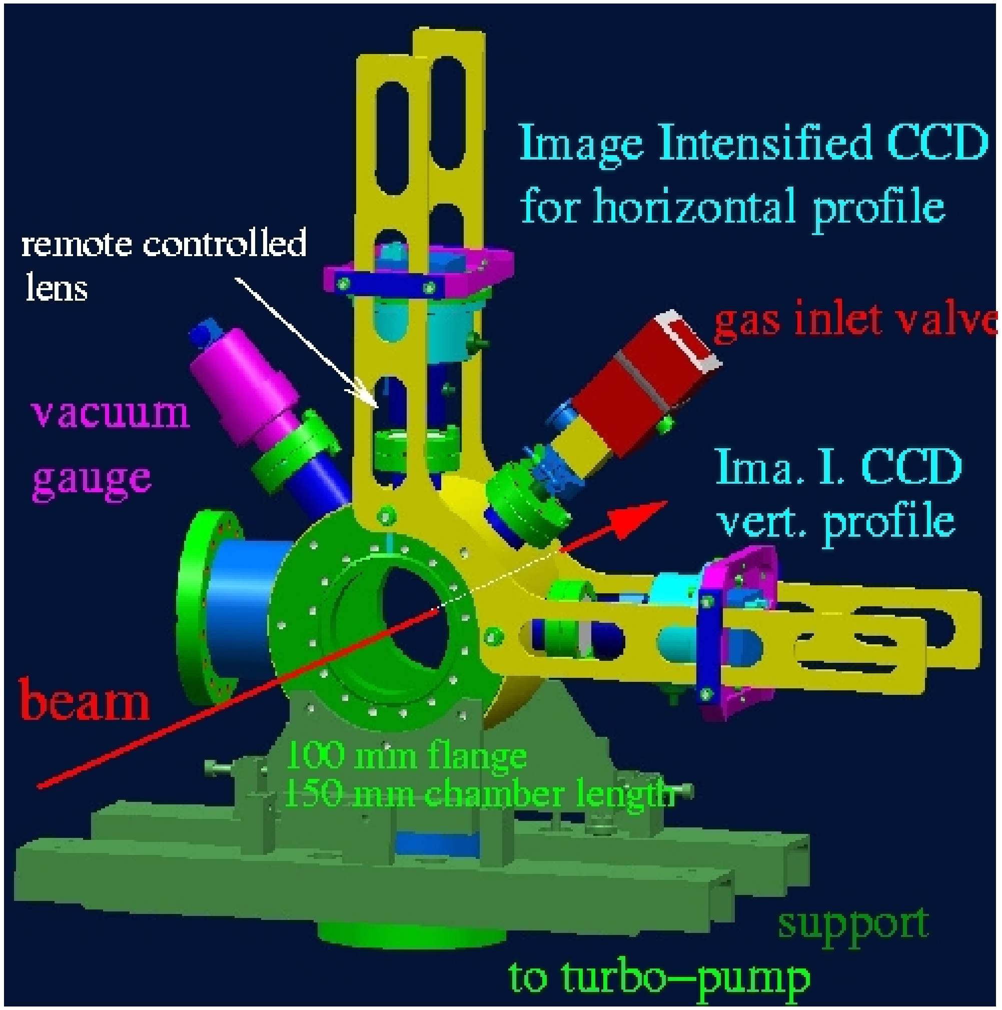
Further proceeding within HIPPI

- Testing of the BIF-prototype
- Finalization of the Bunch Shape Monitor-design
- Construction of the Bunch Shape Monitor-prototype
- Preparation of On-line Transmission Control-system
- Detailled reporting at HIPPI-05



New setup for Prototype

Planned installation (150 mm length)



- Image Intensifier: Proxitronics
- CCD camera: Basler A311f
- Lens: Pentax f=16 mm remote contr.
- (Distance –beam to II: 280 mm)
- Gas-inlet: Pfeiffer-system

Focal depth has to be match: