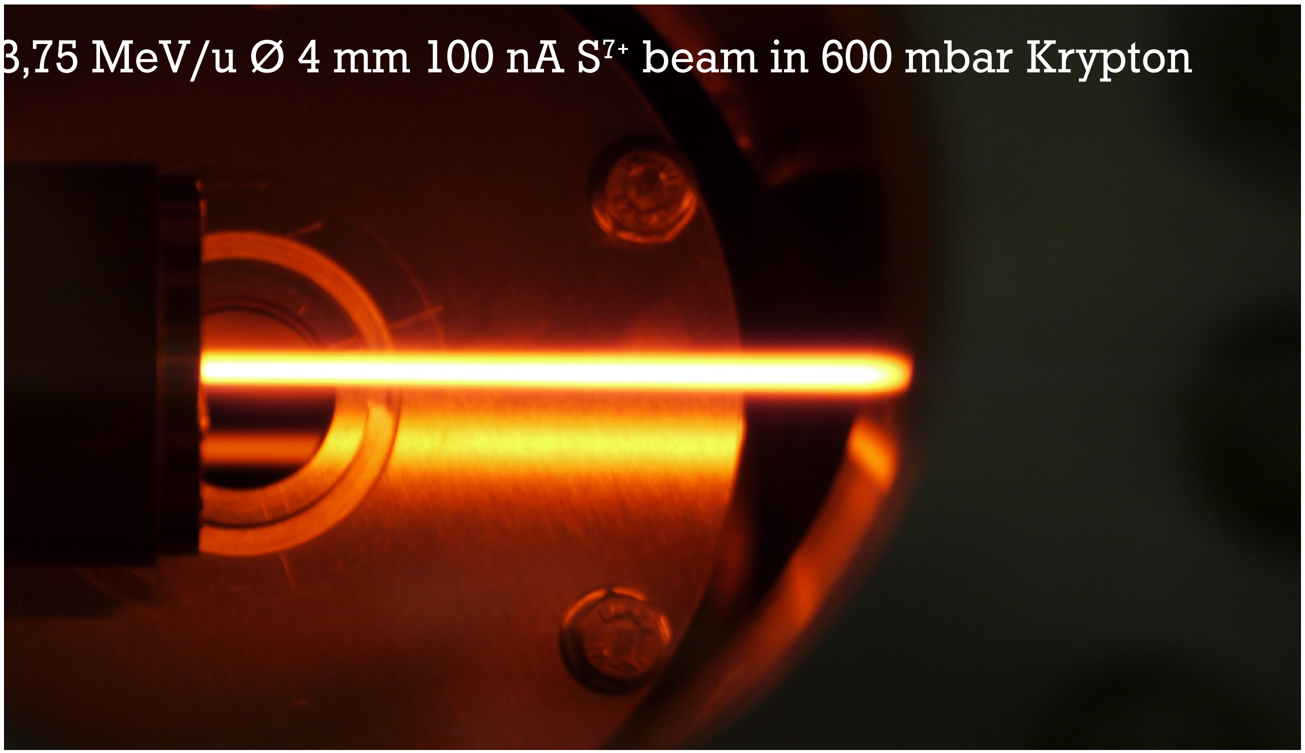
Aktuelles zum BIF-Monitor

BIF-Monitor – Current Research

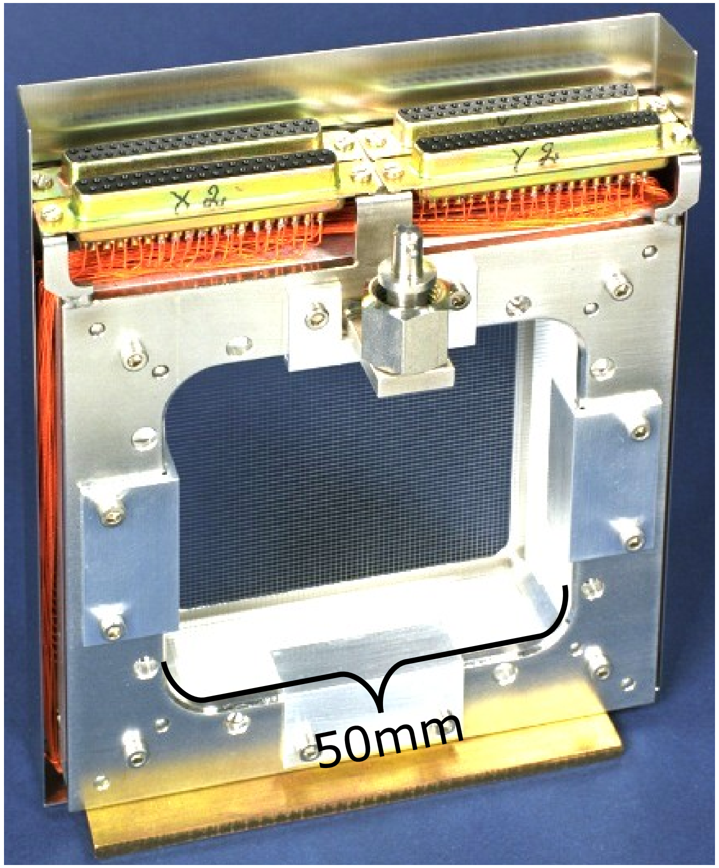


Group Seminar Beam Diagnostics Department
April 22nd 2010 – Frank Becker

Outline

- Motivation – Beam Profile Measurement
  - Benefit of non-intercepting profile measurement
- Introduction of the BIF-monitor
  - General idea, functionality and components
- Results of Research
  - Estimation of the photon yield
  - Variation of gas-pressure and particle-energy
  - Radiation induced background & shielding concept
  - Investigation of alternative working gases
- Technical Improvements
  - Visit at TANDEM-acellerator TU-Munich
- Conclusion

Conventional Wire-Based Systems

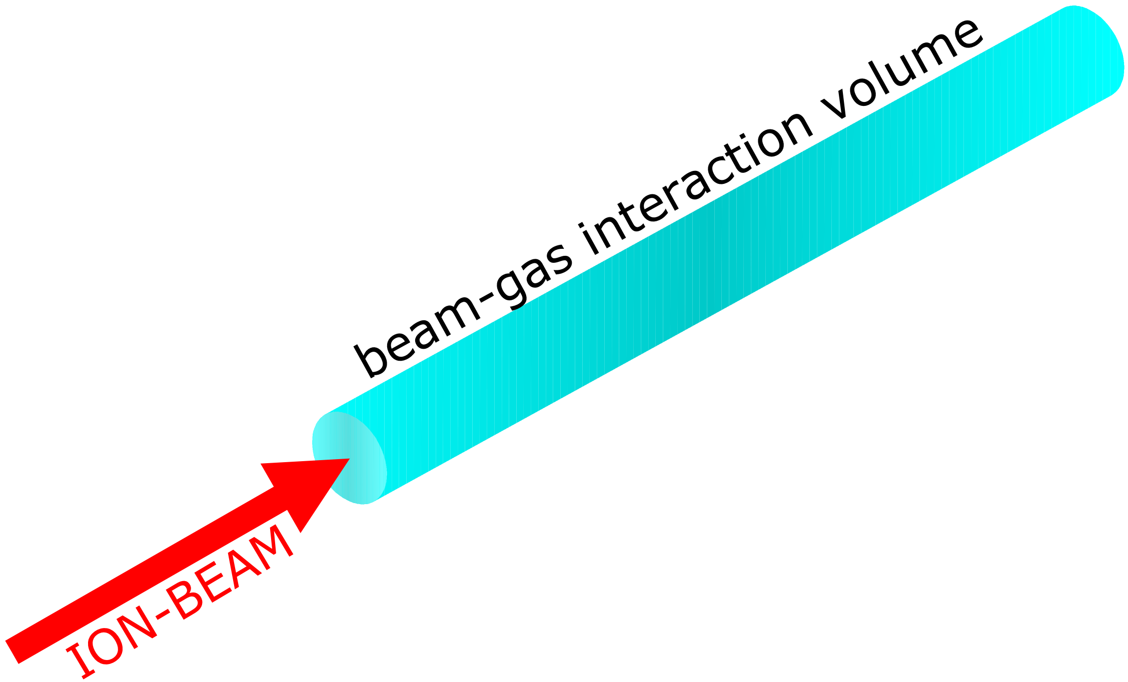


Secondary Electron Monitor (SEM)-Grid of 48 Tungsten wires Ø 100 μm in x-y-plane with 1 mm wire-spacing.

- Secondary Electron Monitor Grid
  - Sufficient signal strength
  - Limited spacial resolution (wire-spacing)
- Impact on the beam
  - Energy-loss in the wire, scattering (x´) momentum distr. (Δp/p), stripping…
  - Emittance „blow-up", beam-loss!
- Impact on the monitor
  - Heating the wires → melting!

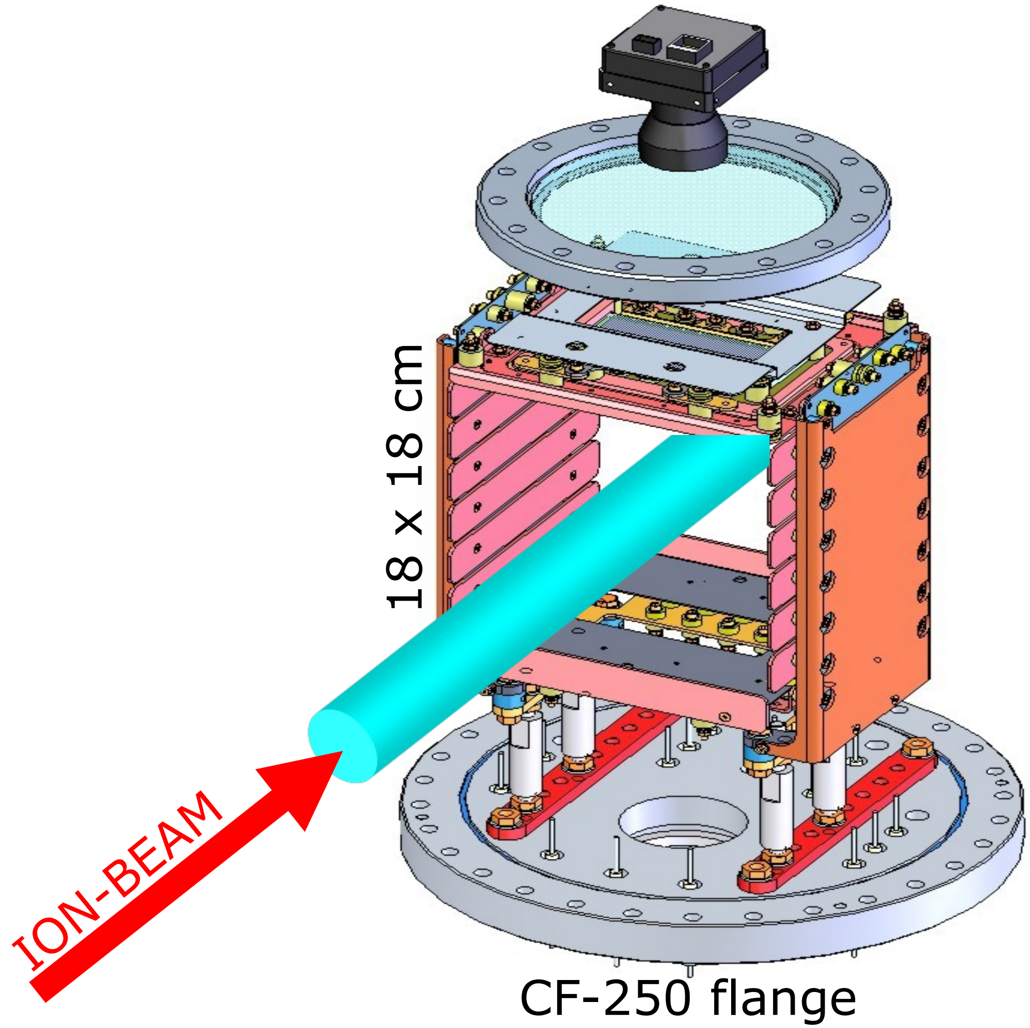
Non-intercepting beam diagnostics is mandatory!

Gas-Based Detectors



- For p ≥ 10^{-8} mbar residual gas N_2-dominated, UHV → H_2
- Atomic collisions driven by electronic stopping -dE/dx
- Excitation, ionization and fluorescence were observed

Ionization Profile Monitor

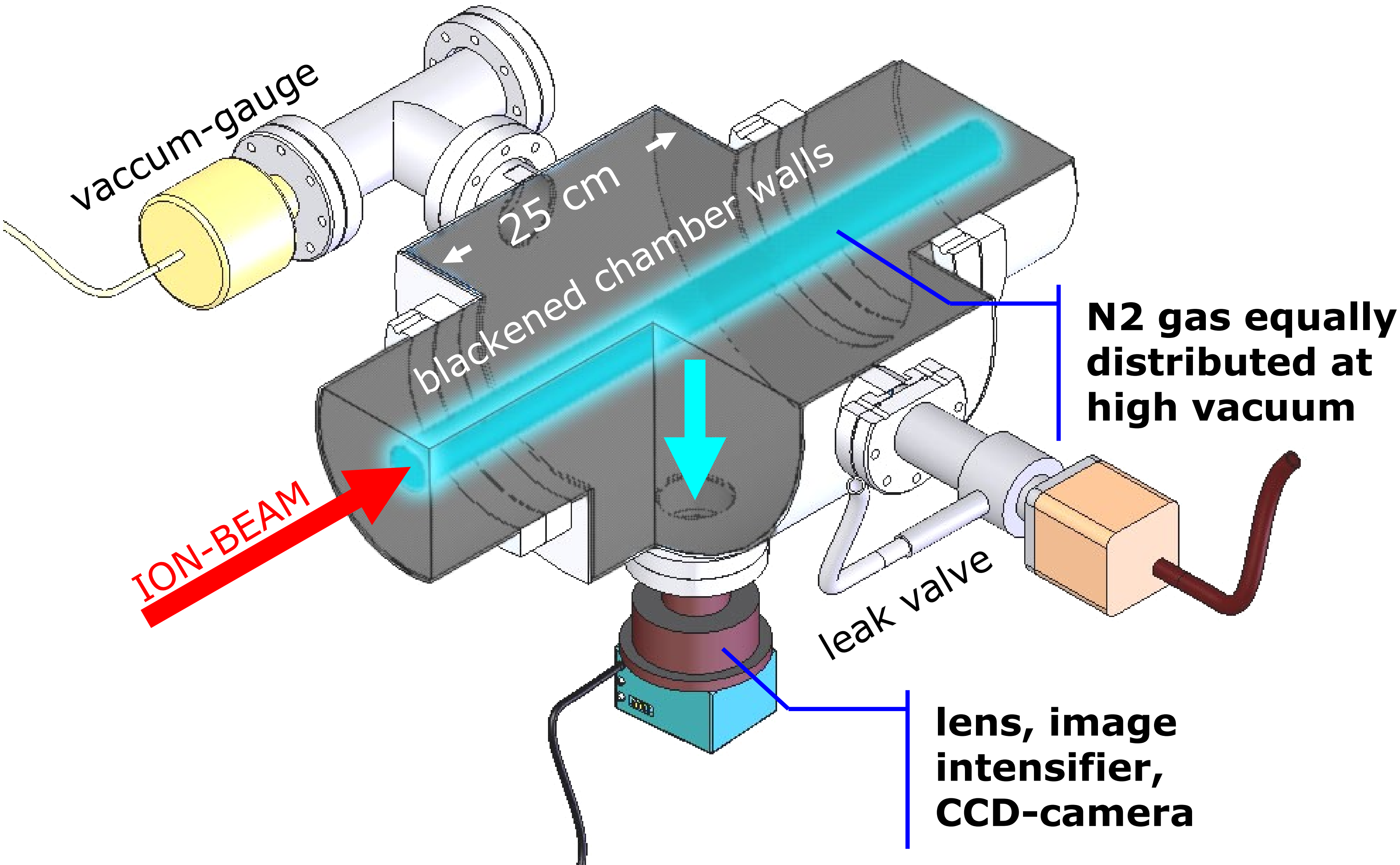


- Gas-ions accelerated in homogeneous E-field vs. spatially resolving sensor
- 10 kV accelerating HV → E = 55 kV/m
- Time of flight ~ 100 ns
- 4π-acceptance → all ions
- MCP-amplification ~10^6

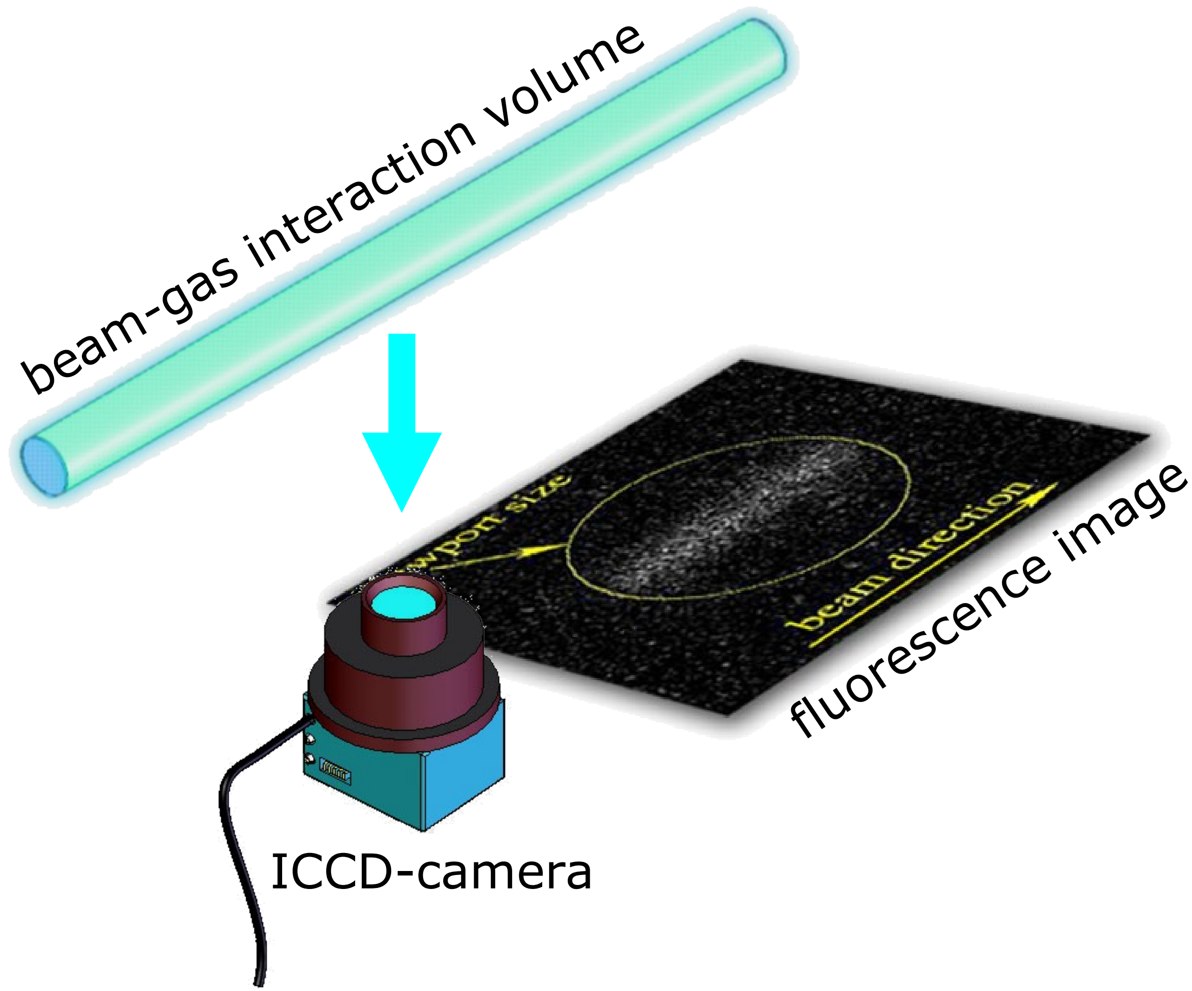
Sensitive profile monitor suitable for synchrotrons

[T. Giacomini et al. (2009)]

Beam Induced Fluorescence

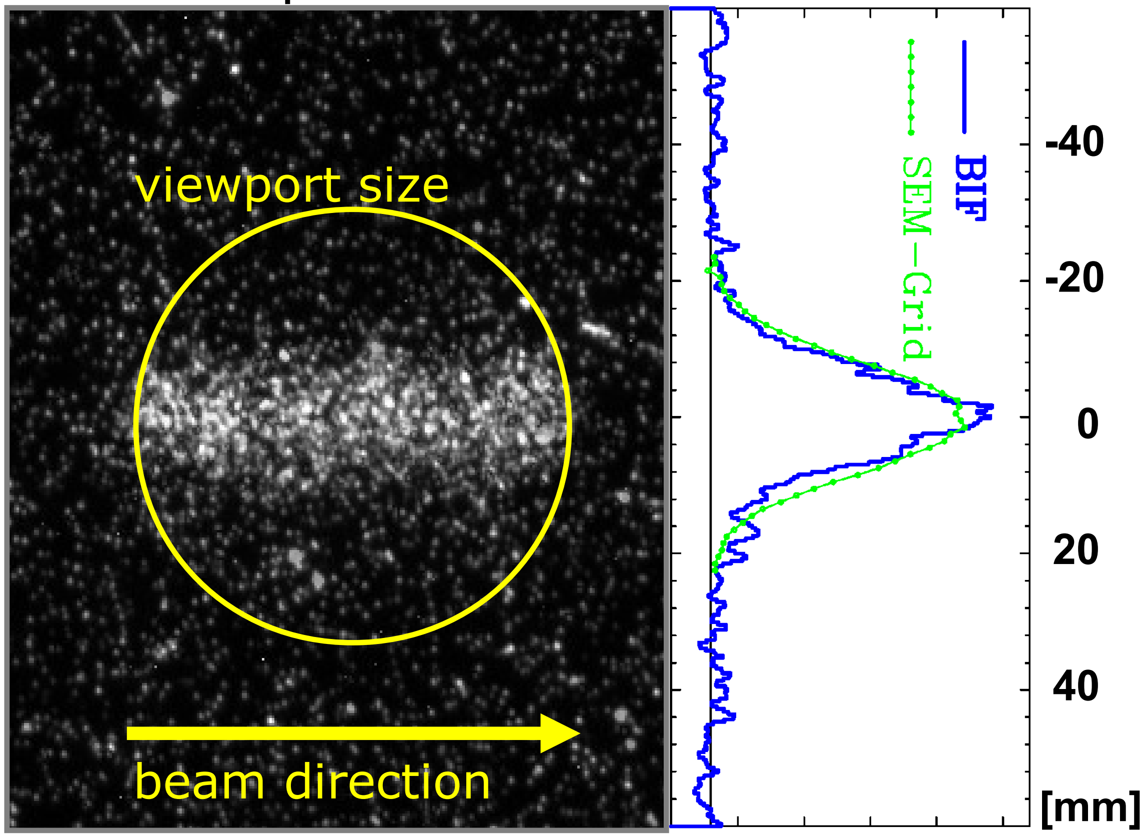


How a Beam Profile is Obtained



How a Beam Profile is Obtained

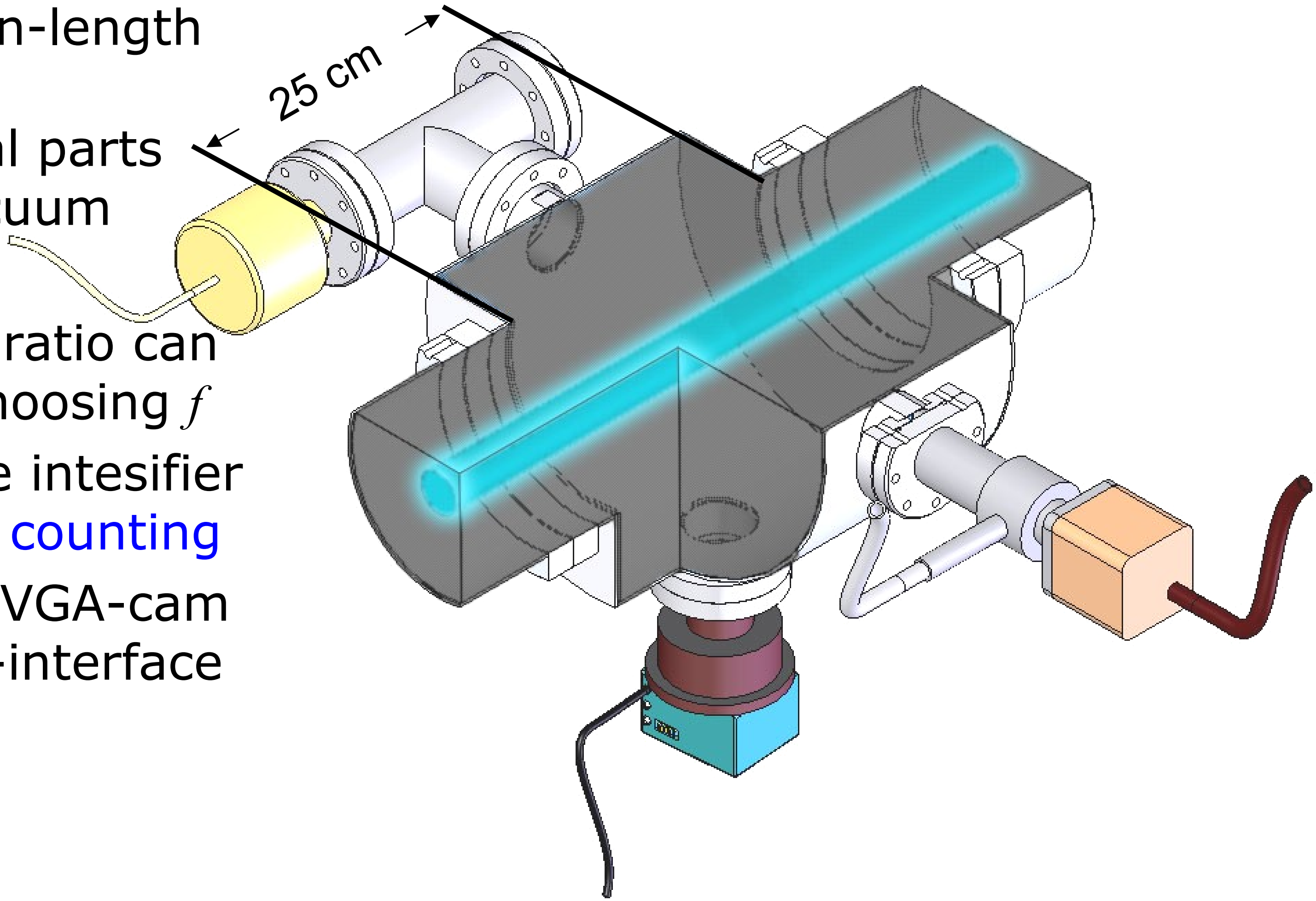
200 *A*MeV Xe^{48+} 20 pulses of 10^9 Ions in $5 \cdot 10^{-4}$ mbar N_2



BIF- and SEM-profiles in accordance with each other, $\Delta\sigma/\sigma \leq 10\%$

Benefit of the BIF-monitor

- Short insertion-length
- No mechanical parts inside the vacuum
- Magnification ratio can be adapted choosing f
- V-stack image intesifier single photon counting
- Digital 12-bit VGA-cam with FireWire-interface



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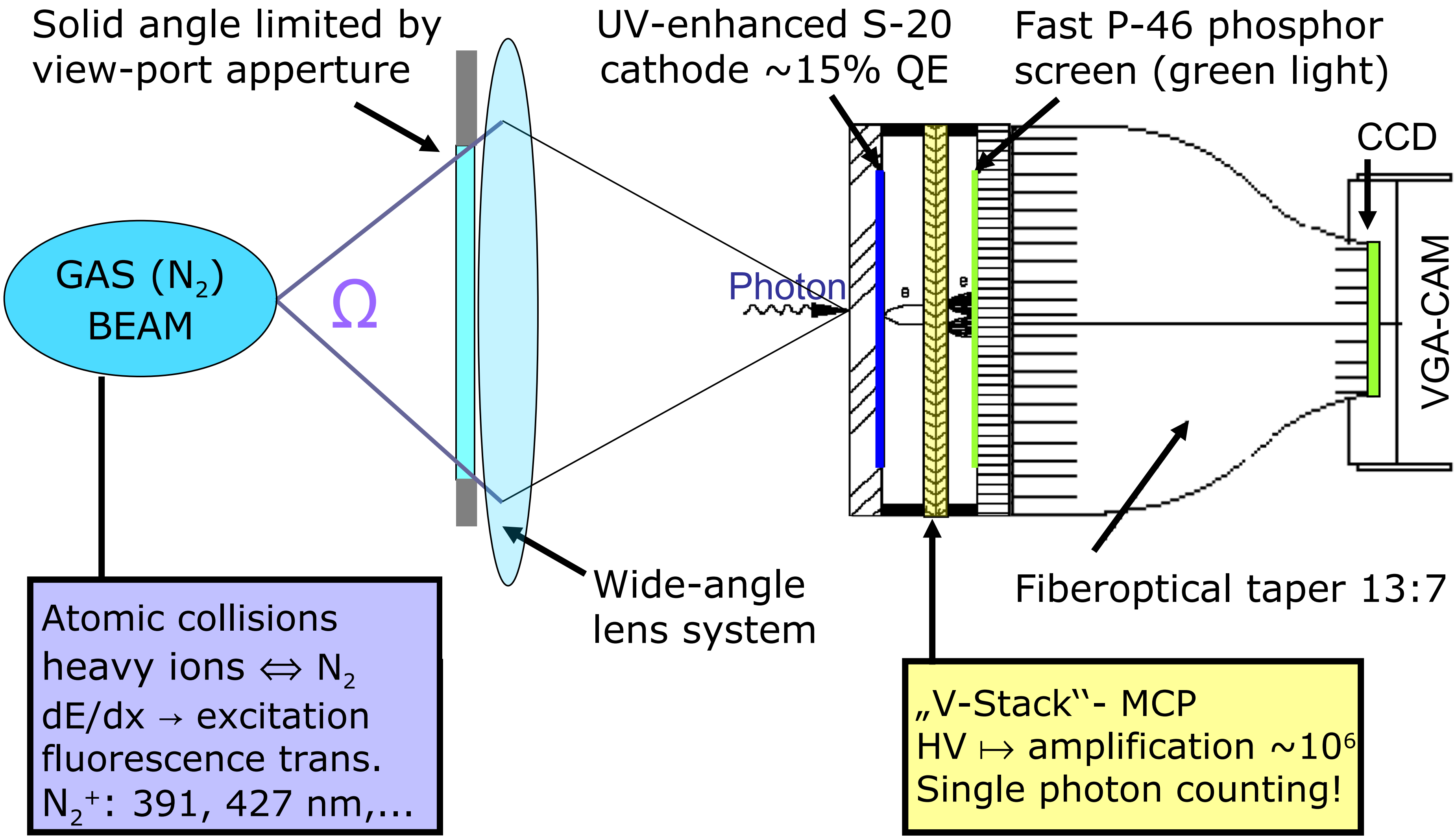
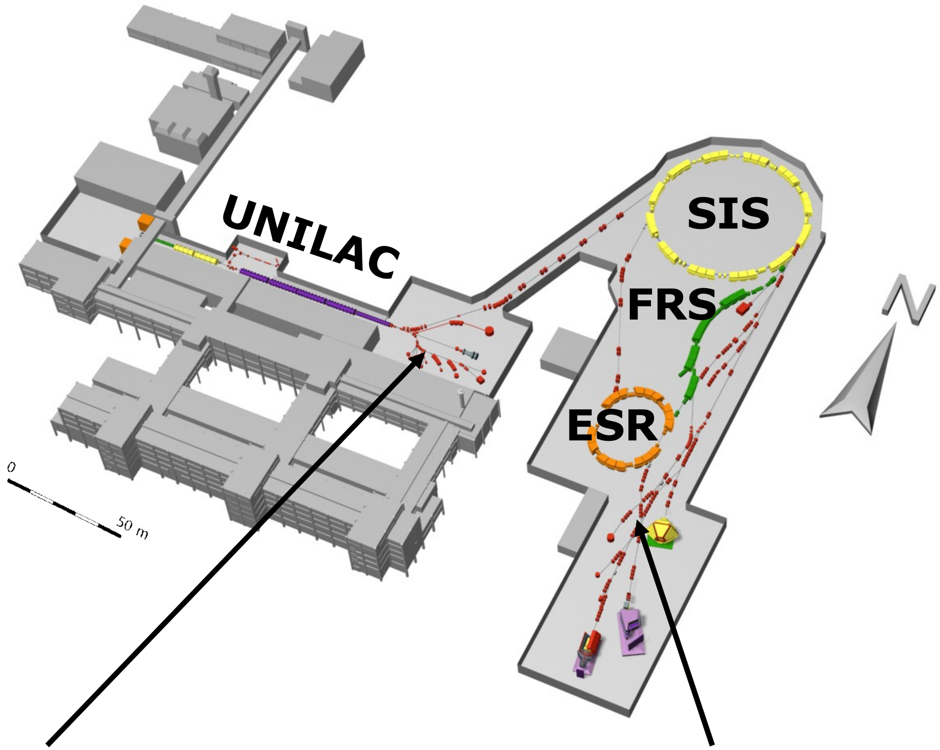
- Components of the shelf

Detection Principle



Non-intercepting Profile Monitors @ GSI



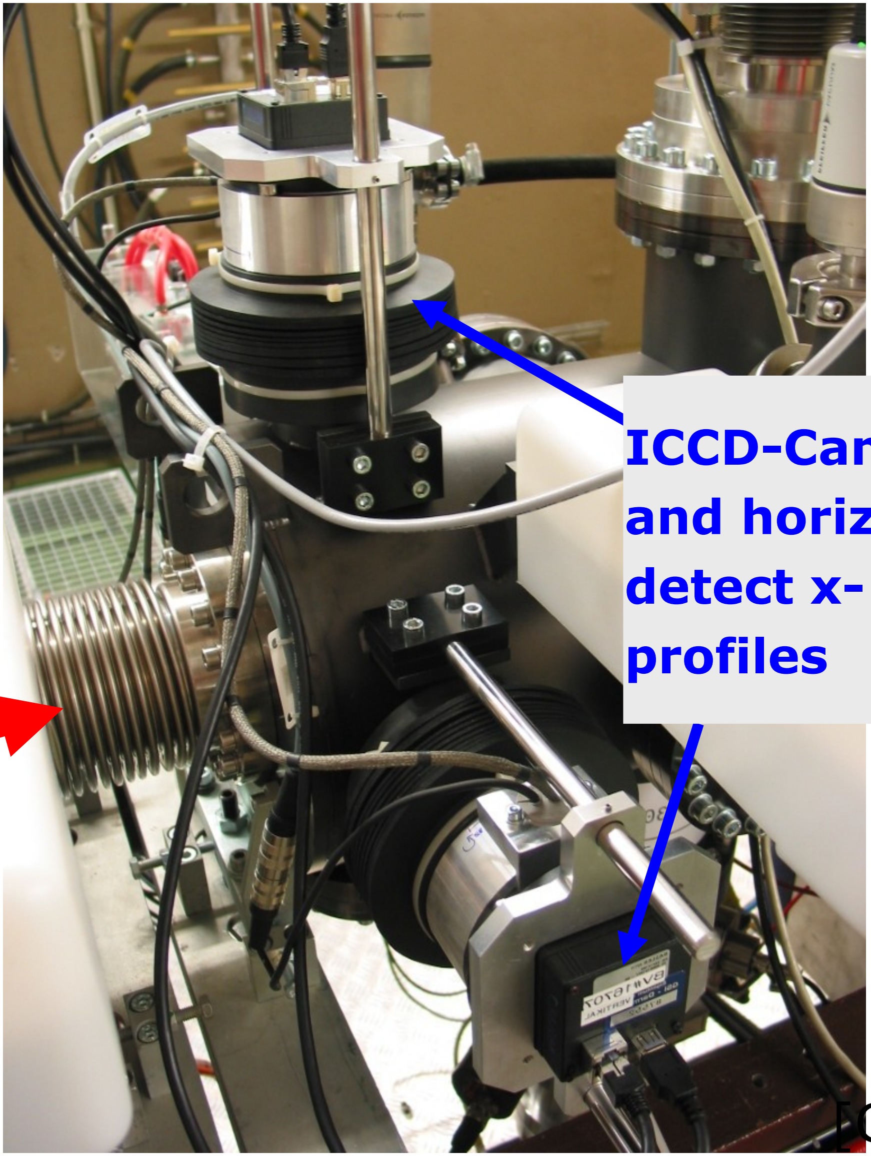
X2 experimental area (UNILAC) addressing beam energies (3,5 – 12 AMeV) and HTP Experimental area (SIS) with energies (50 – 750 AMeV).

NDCX injector Berkeley (7,5 AkeV)

- IPM's at SIS-18 and currently setup for ESR
- BIF-monitors along the UNILAC at 7 locations
- FAIR requires 2 IPM's and 14 additional BIF-stations
- 3 experimental areas for different beam energies 7,5 *A*keV – 750 *A*MeV

Non-intercepting profile diagnostics is mandatory!

BIF Setup at GSI-UNILAC



BEAM

ICCD-Cameras in vertical and horizontal plane to detect x- and y- beam profiles

[C. Andre, C. Dorn]

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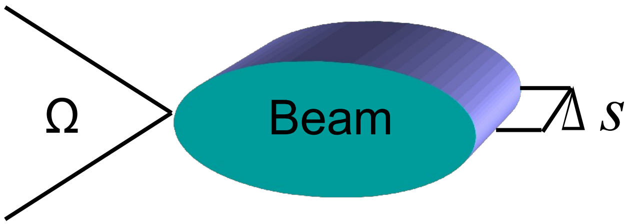
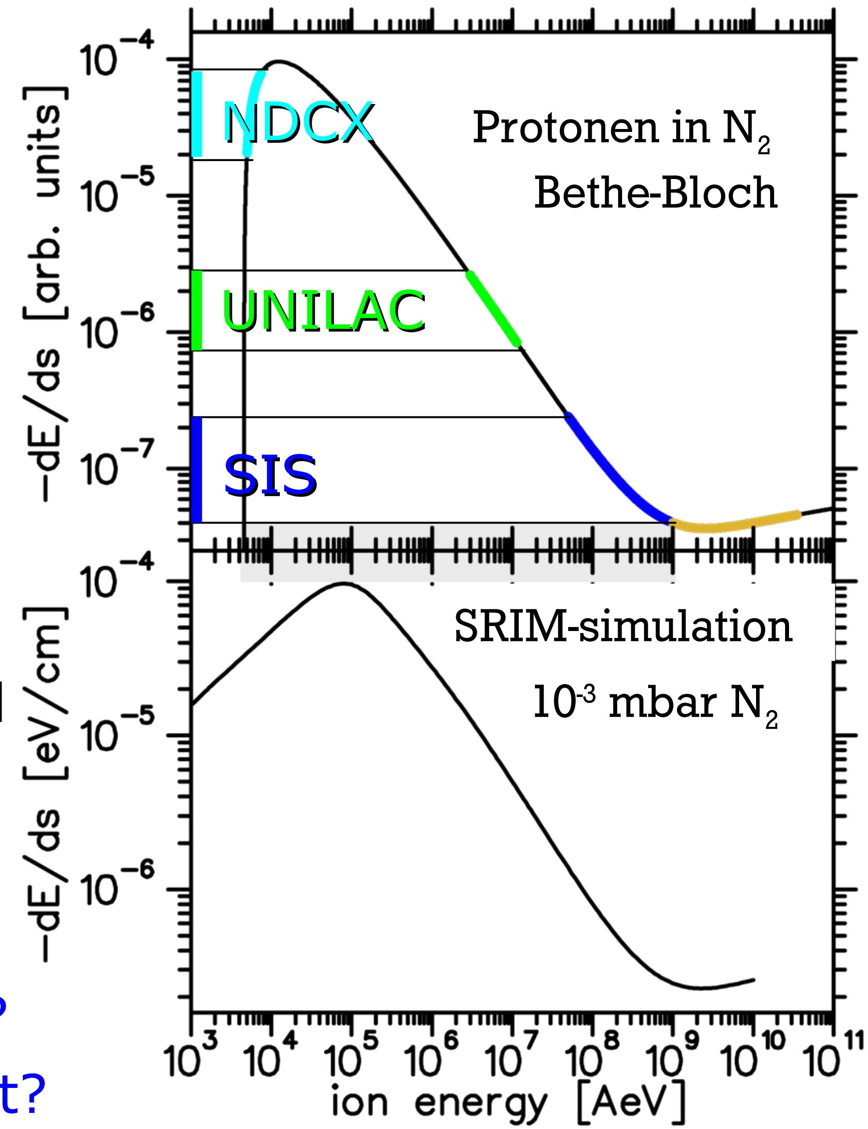
Expected Photon Yield



$$n_{photon} = p \frac{dE(\overline{q}^2_{Ion}, E)}{ds} \Delta s \frac{f}{h\nu} \Omega \, \varepsilon_{Detect.} \, n_{Ion}$$

$$f \equiv \frac{E_{photon}}{\Delta E_{Ion}} \approx 1\% \; ; \; \sigma_{photon,p,11AMeV} \approx 10^{-19} cm^2$$

- Yield determined by geometry and beam parameters (I,E,q)
- Energyloss scales like: NDCX/UNILAC/SIS → 500/10/1

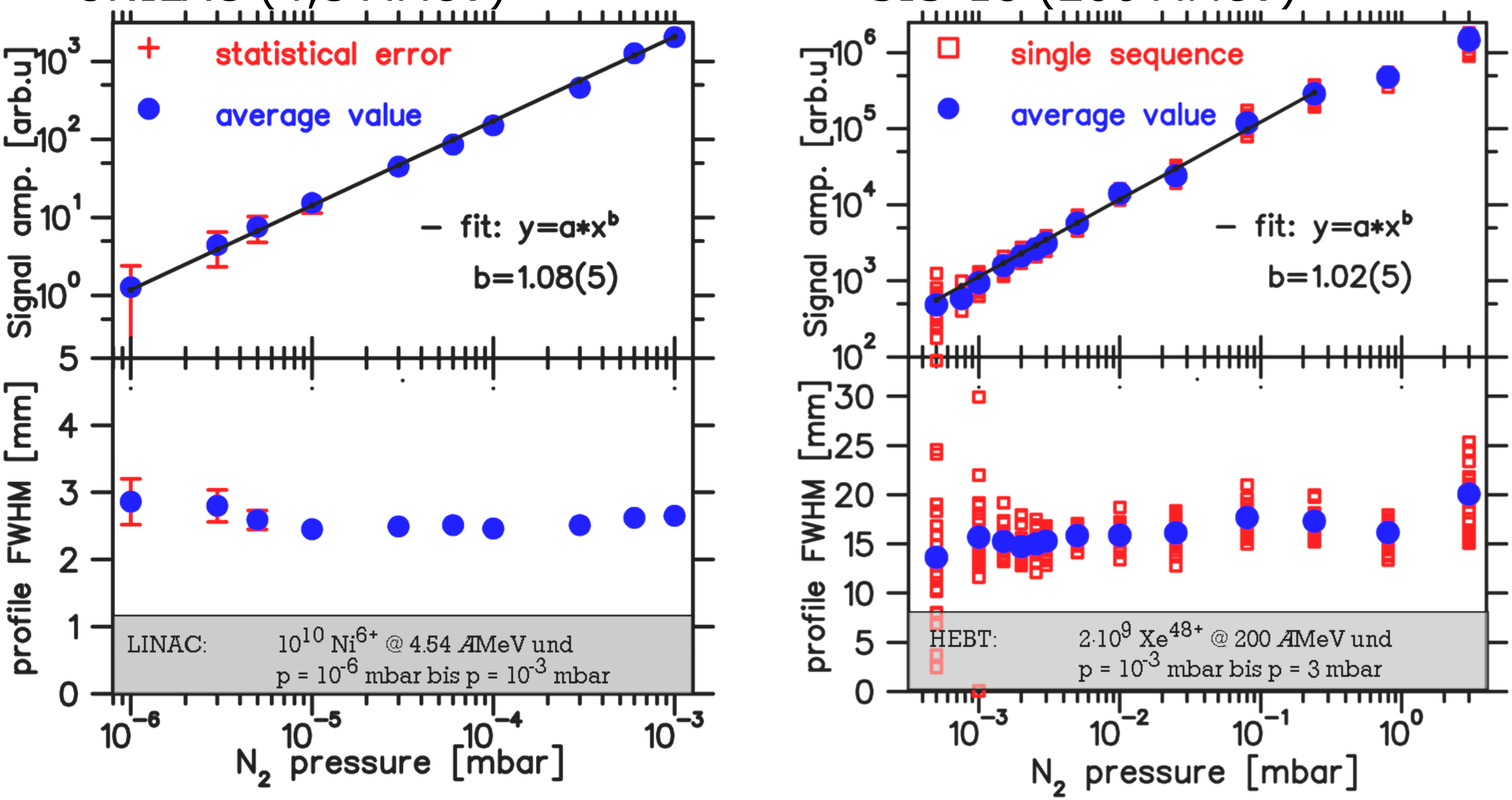


Is p free parameter to compensate?

Remains conversionfactor f constant?

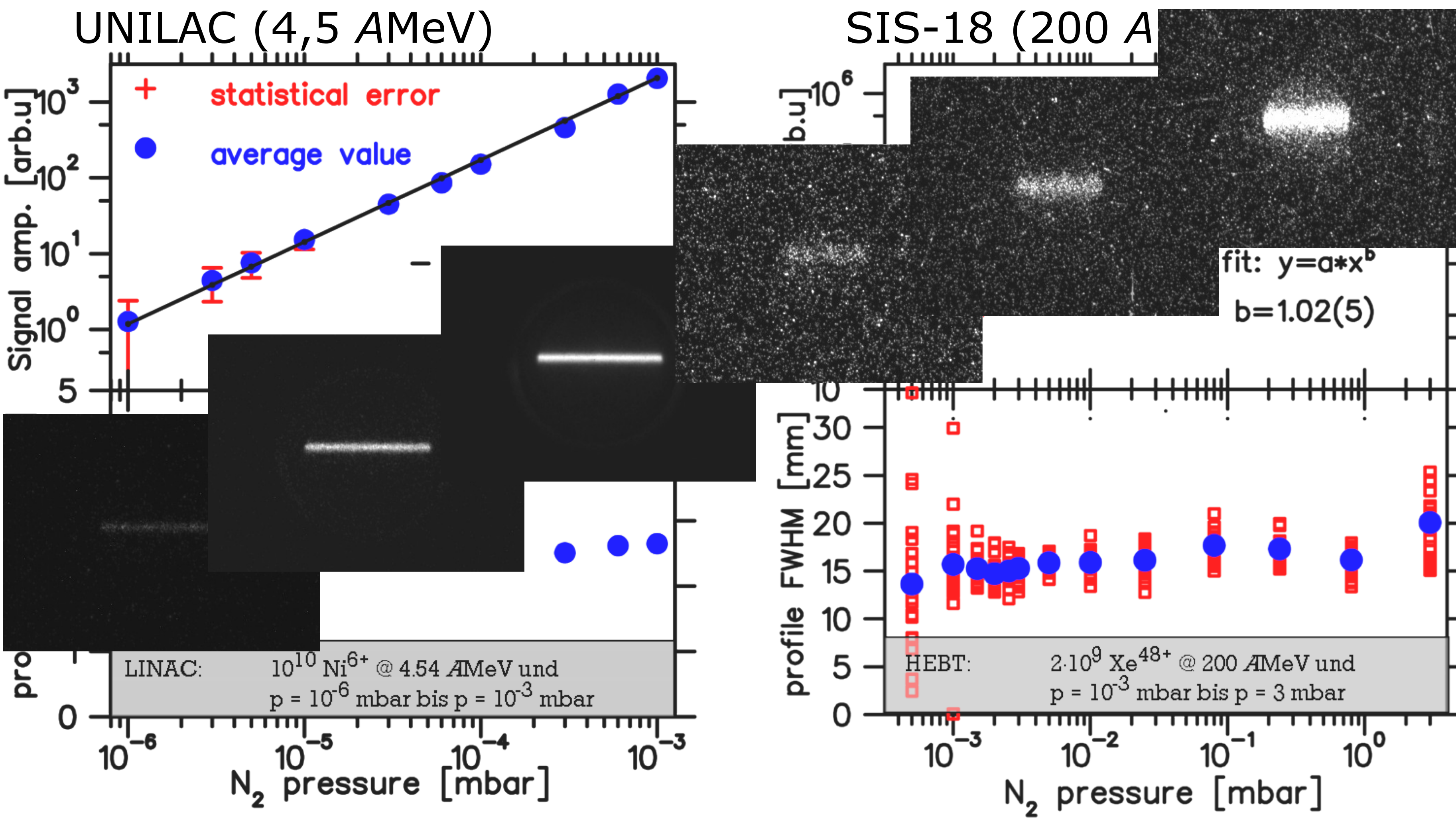
Pressure-Variation by 6 OM

UNILAC (4,5 *A*MeV) SIS-18 (200 *A*MeV)



Amplitude ~ p and σ = constant → p is a free parameter

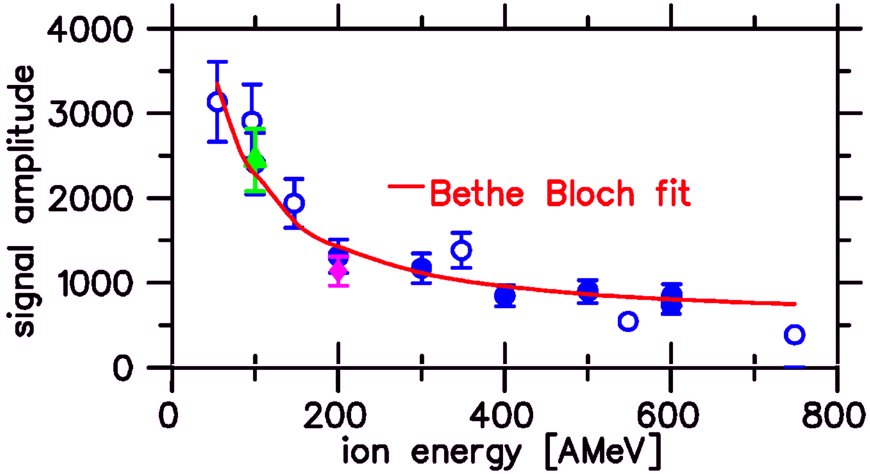
Pressure-Variation by 6 OM



Amplitude ~ p and σ = constant → p is a free parameter

Energy-Variation from 50 to 750 *A*MeV

- Integral signal-amplitude scales according to Bethe-Bloch formula
- Consistent results for Tantalum and Krypton ions, when normalized with respect to m and q of $^{238}U^{73+}$



Conversionfactor f does not depend on energy or ion-species → constant

Energy-Variation from 50 to 750 *A*MeV

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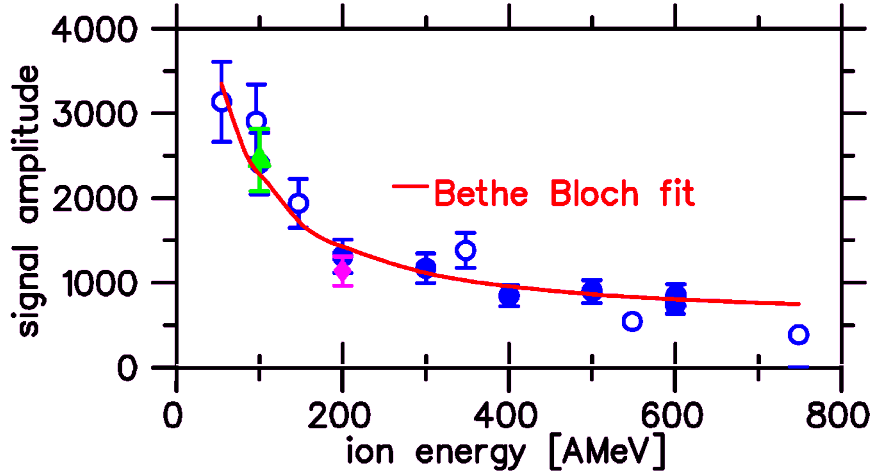
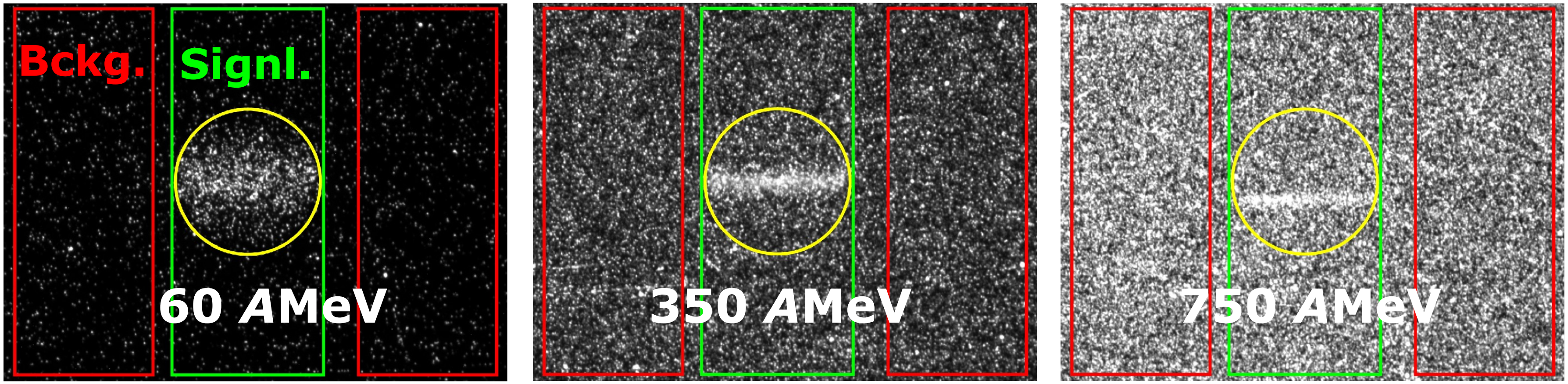
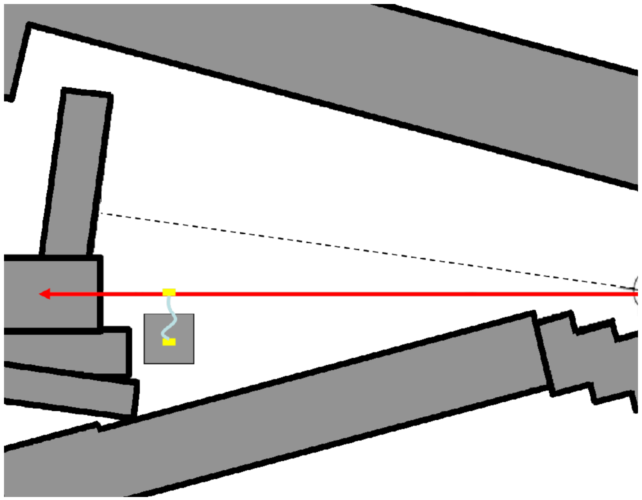
- Consistent results for Tantalum and Krypton ions, when normalized with respect to m and q of $^{238}U^{73+}$



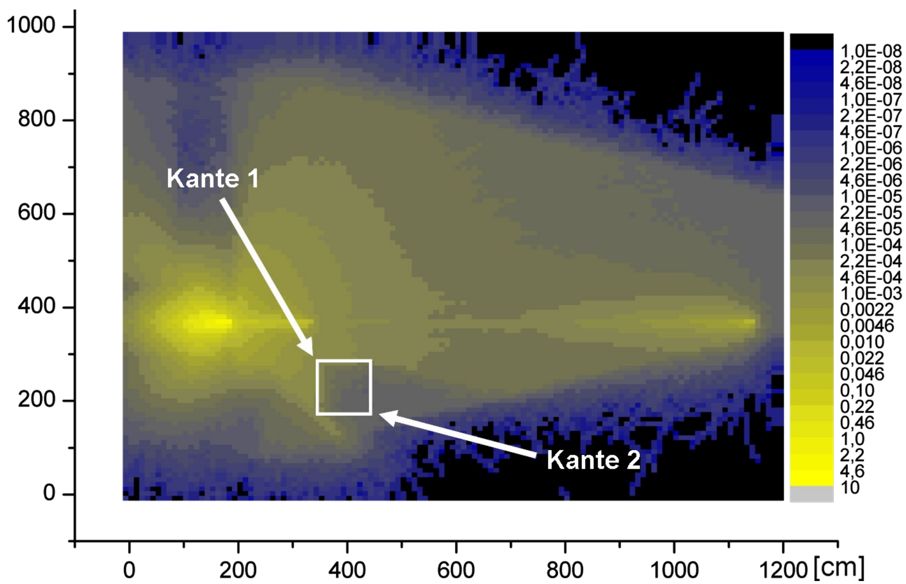


For increasing ion energy → Background increases and signal decreases!

Simulation of the Neutron Flux



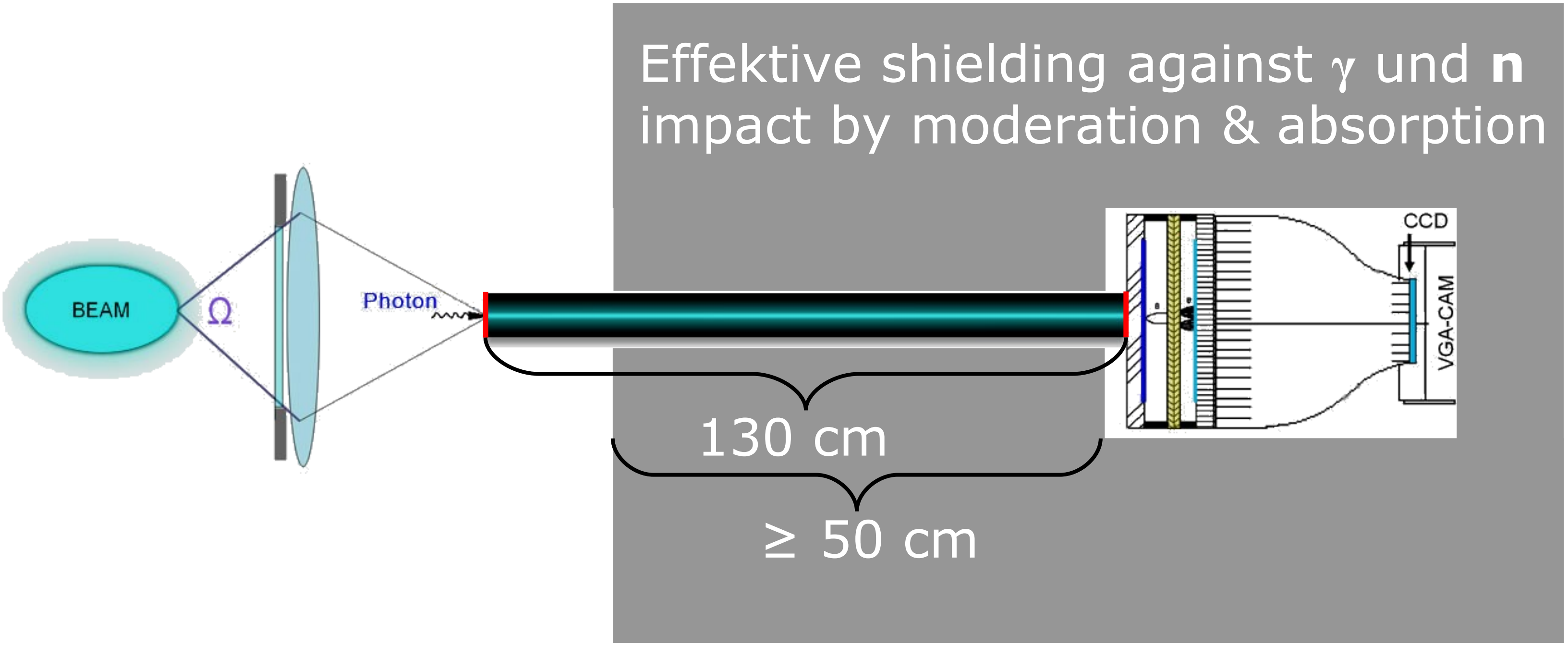
- HTP-caves topview with walls (grey), beamline (red) and 1 m³ concrete shielding
- ICCD-camera (yellow) is placed in the center of the block ~50 cm wall-thickness



- FLUKA-simulation n-flux for 900 *A*MeV $^{40}Ar^{18+}$ ions [A. Plotnikov (2009)]
- n-flux suppressed by 94 % and γ-flux by 96%!

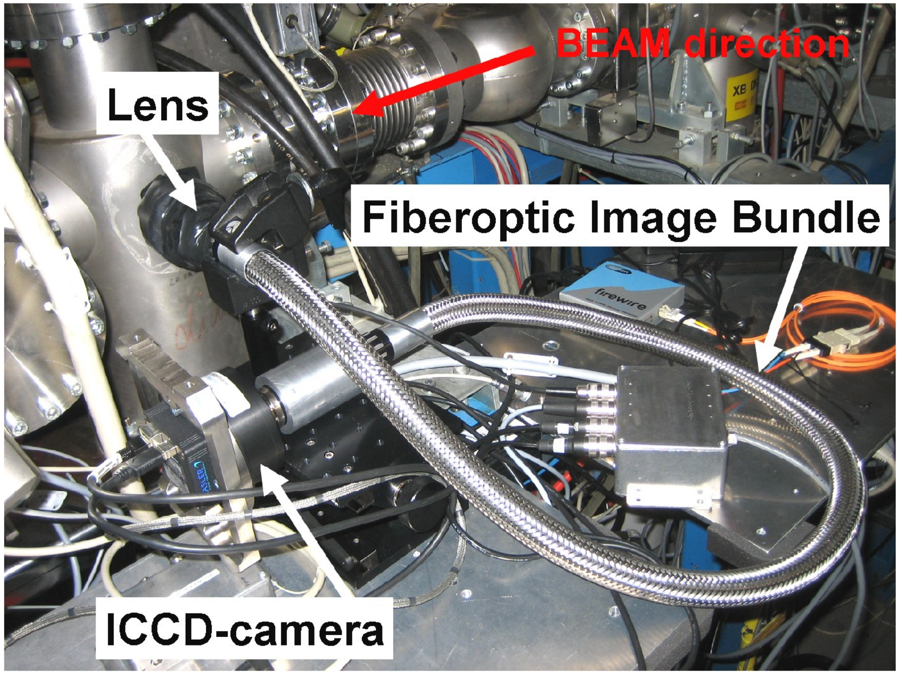
How can fluorescence images be transported into the shielded volume?

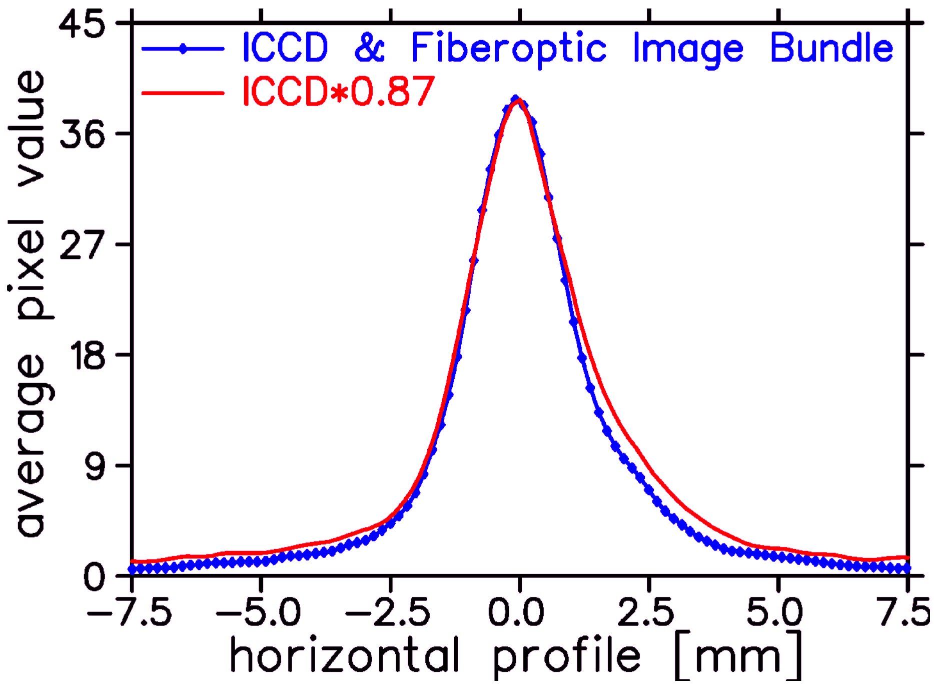
Shielding-Concept with Image-Guide



- Fiberoptic image guide with ~10^6 sorted optical fibers and $(15mm)^2$ transported active image area
- 65 % total optical losses (coupl. & transm.) 1,3 m length

Shielding-Concept with Image-Guide

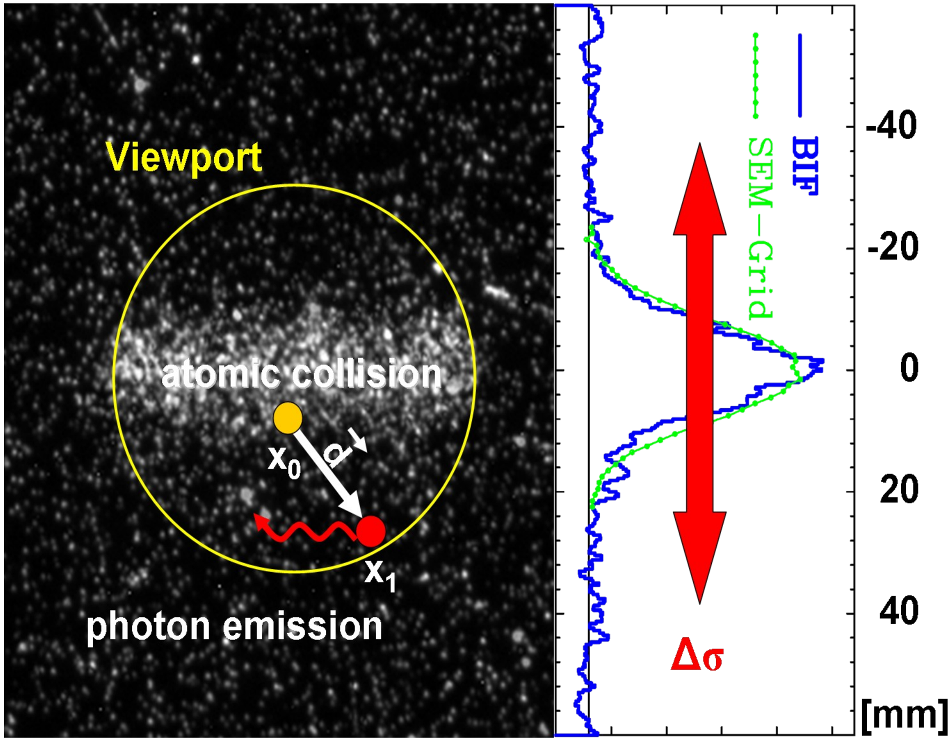




- Fiberoptic image guide with ~10^6 sorted optical fibers and $(15mm)^2$ transported active image area
- 65 % total optical losses (coupl. & transm.) 1,3 m length

Image guide and ICCD-camera resoulution have been matched
→ Imaging properties preserved, comparison profiles agree well

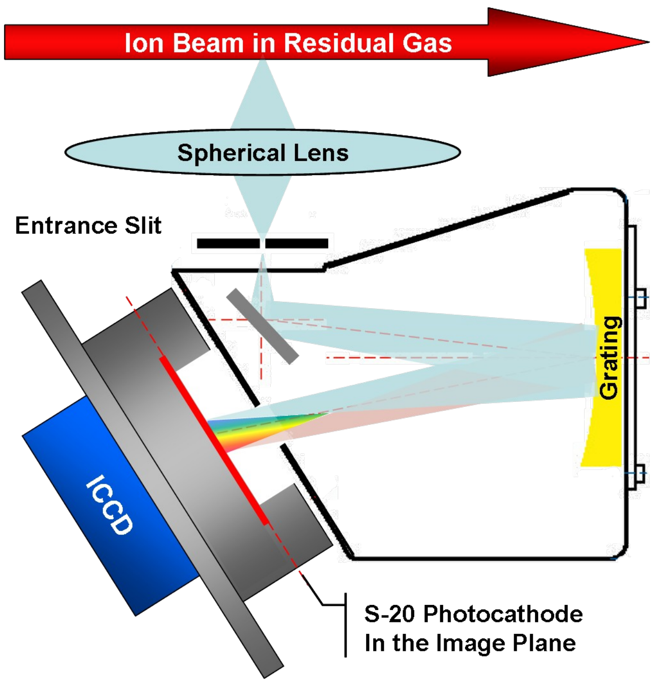
Systematic Errors – Alternative Gases

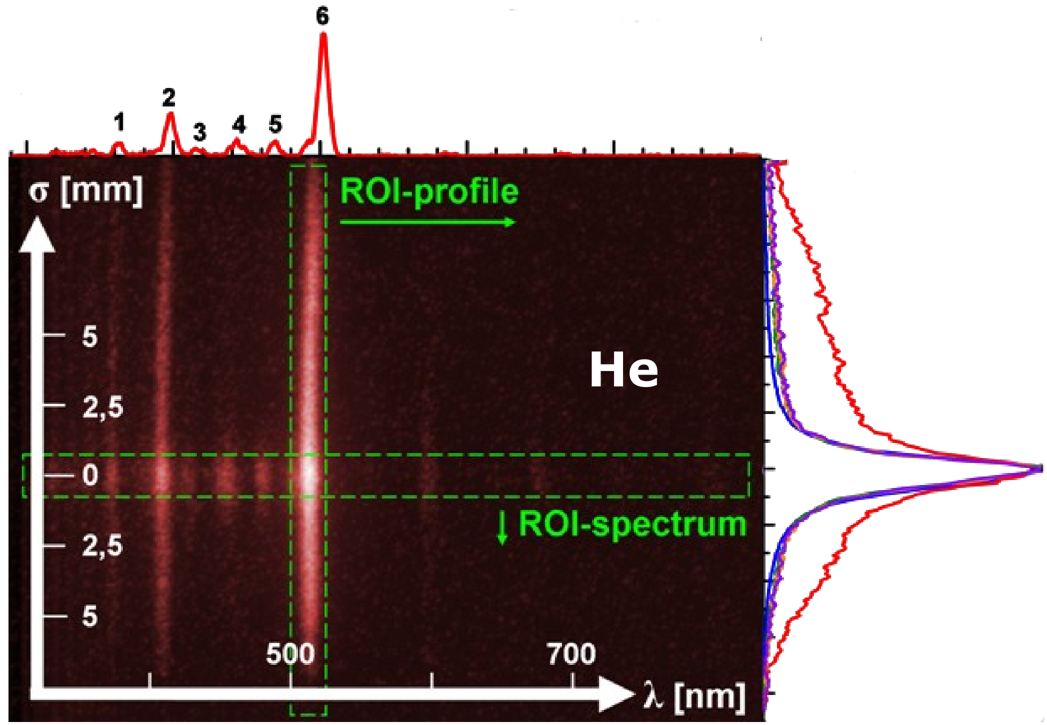


- BIF-profiles represent x_1 the location of photon-emission
- Gas-dynamics and lifetime of excited fluoresecence states influence profile errors
- Gas-dynamics defined by:
  - Temperature
  - Dissociation-kinetics
  - For ions E-field of the beam
  - Mass, charge…

Searching for alternative gases with larger mass and shorter optical lifetimes with respect to N_2 → Spectroscopy!

Imaging Spectrograph with ICCD

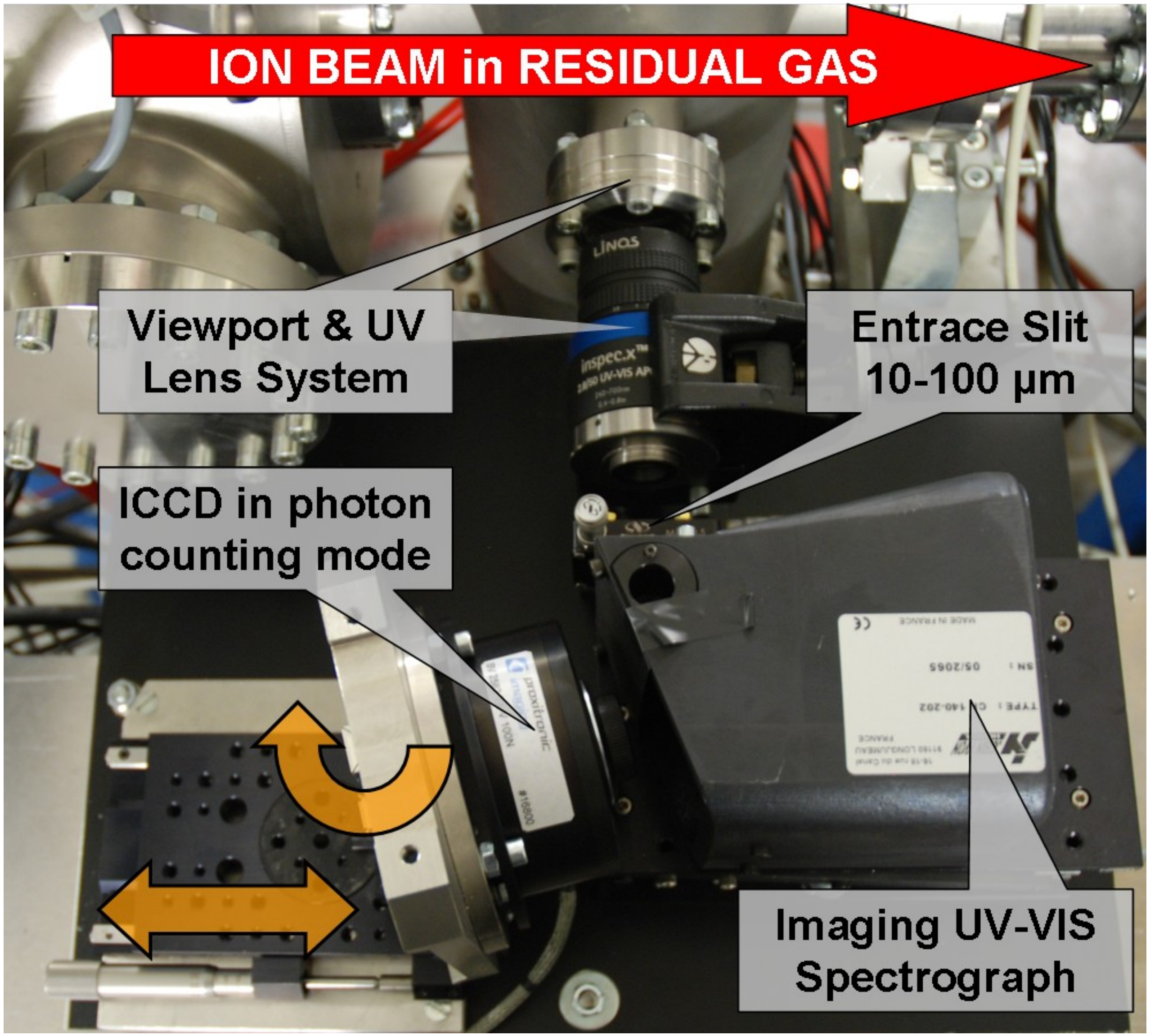




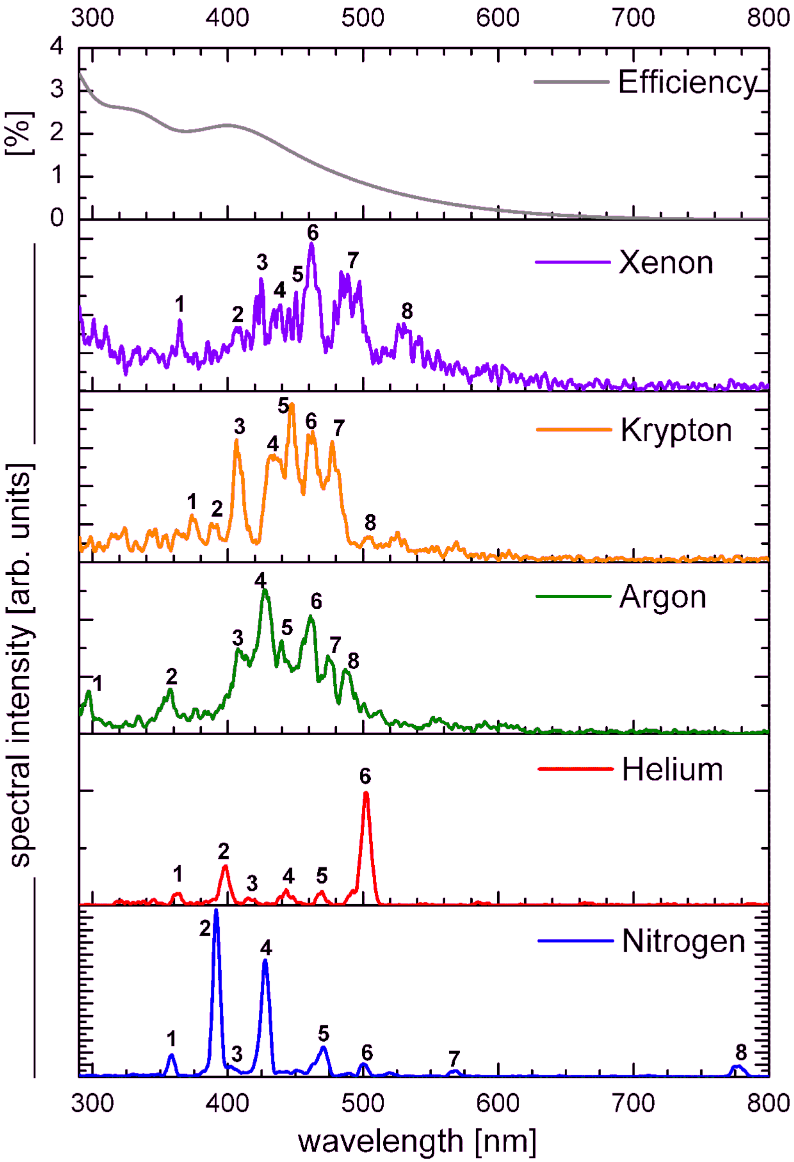
- Technique allows to record fluorescence-images with spectral and spatial information → spectra & beam-profiles
- Chromatically corrected quartz-optics → 300 – 800 nm

Intensity & spectral position of transitions → profile-width

And How it Looks Like in Reality...



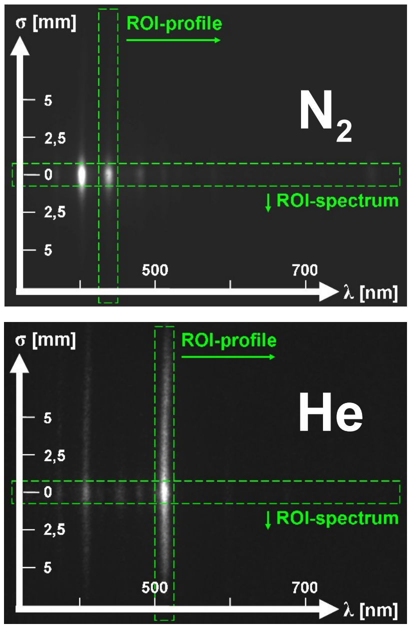
Results - Spectroscopy

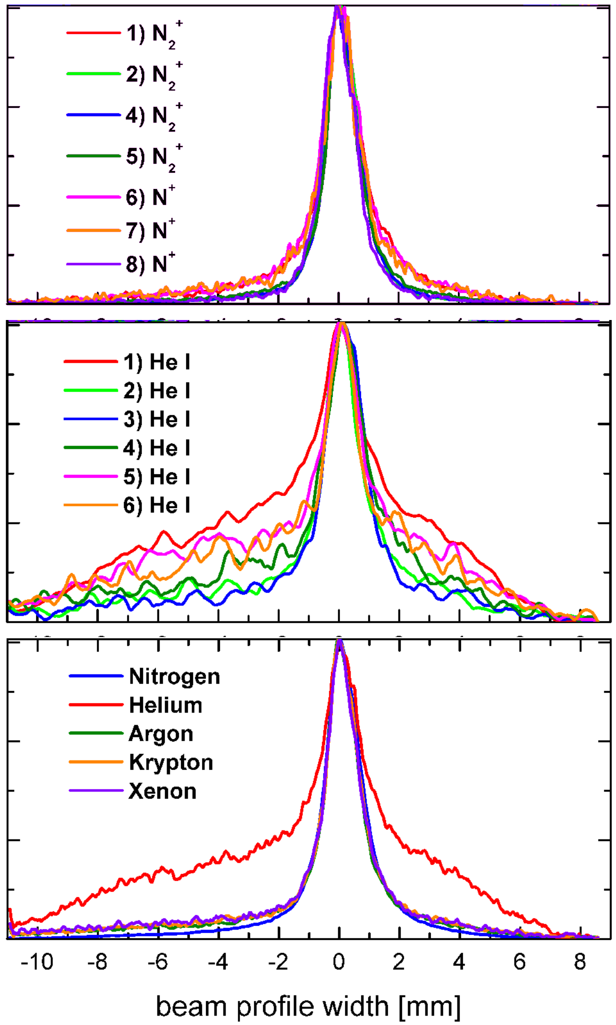


S^{6+} Ions @ 5 *A*MeV in 10^{-3} mbar gas:

- Efficiency → S-20 cathode (blue)
- All investigated gases show fluorescence-transitions in the visible range → blue-dominated
- Light gases N_2/He show less lines than heavy species → Possibility of monochromatic profile analysis!
- He shows neutral lines (He-I) in sensitive spectral range, all other gases show ionic lines (X-II)

Results Profile Analysis





Comparison:

N_2, He, Ar, Kr, Xe

- Transition-selective profile-projections of all nitrogen lines N_2^+ und N^+ with similar shapes
- Beam-profiles by He-I transitions variably broadened, lifetime-independent
- Integral profiles of heavy rare gases and N_2 agree very well
- He profile ist broadened and of different shape

Which Gas Works Best?

- Profiles in all rare gases but Helium agree with profiles in N_2
- Thermal drift $d_{thermal}$ for heavy gases (A_{Kr}=84, A_{Xe}=131, τ<10ns) vs. N_2 ($2A_N$=28, τ=60ns) → drops like 1 µm vs. 30 µm
- Rare gases occur as atoms → no dissociation-dynamics
- Chart compares light intensities $\mathbf{I_{mess}}$ and $\mathbf{I_{eff}} = I_{mess}/Z_{gas}$ normalized with respect to -dE/dx ~ Z_{gas}:

Gas	N_2	He	Ar	Kr	Xe
$\mathbf{I_{mess}}$	258	9	98	163	222
$\mathbf{I_{eff}}$	**100**	26	30	25	22

For most applications N_2 is the best compromise, due to its four times higher fluorescence-efficiency

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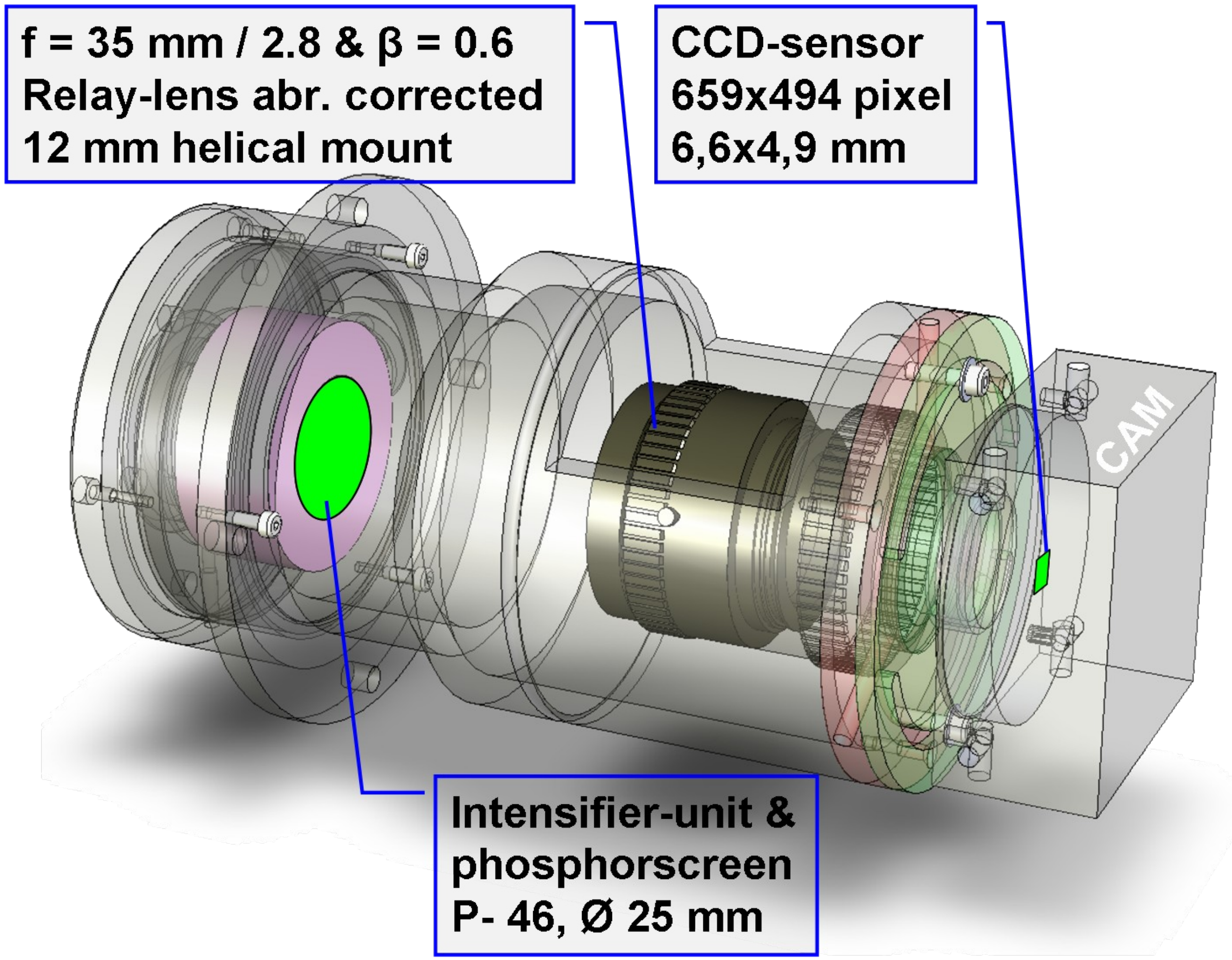
Reliability of Intensified Cameras

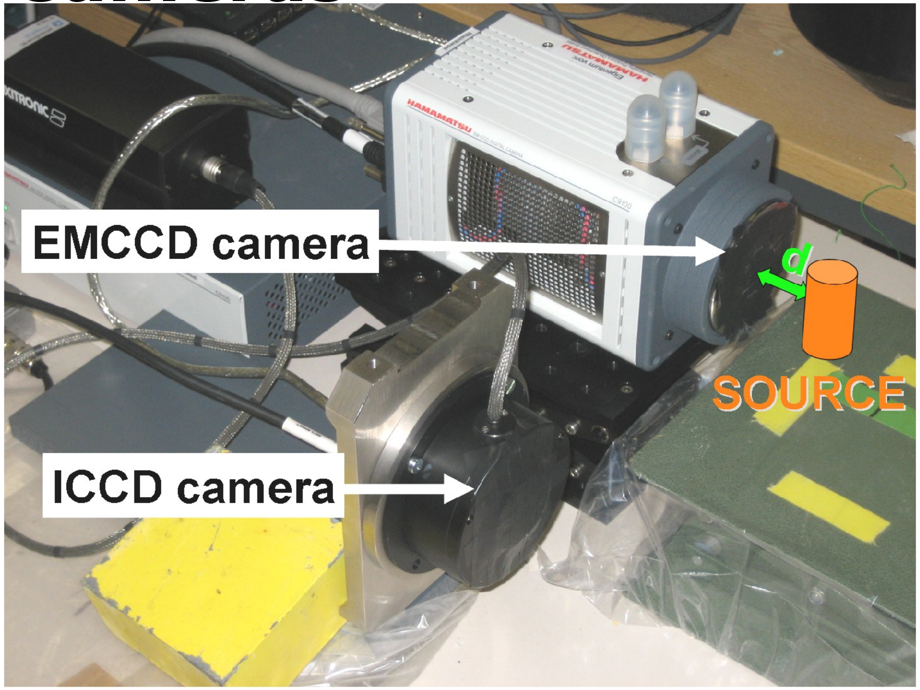


- Radiation-induced Background
- Aging of cathode, MCP and phosphor
- Radiation damage of CCD's (hot-pixel)

Modular design for easy replacement is mandatory

Radiation-hard components required

Testing Alternative Intensified Cameras

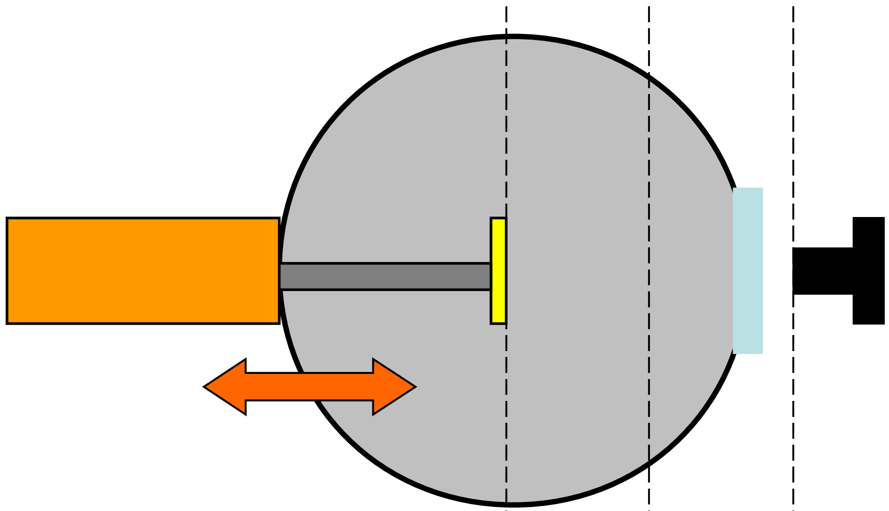


- EMCCD-Cameras integrate all sensitive components on 1 chip!
- In-vaccum design for easy sensor replacement

Replacing the sensor -> installing a new ICCD system

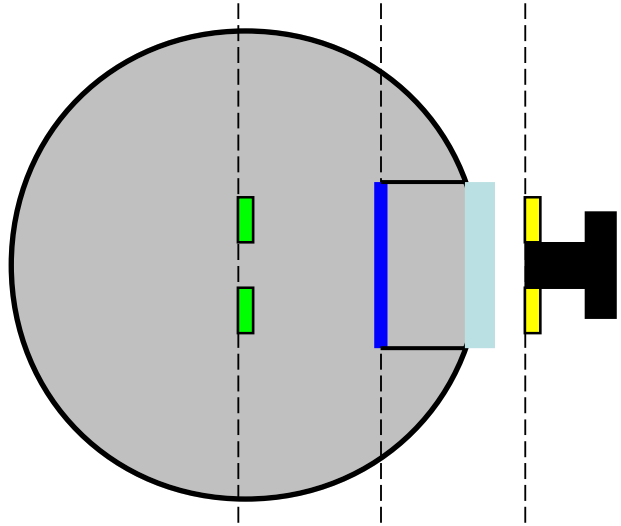
Can the Monitor be Simplified?

A)



- Conventional LED-drive with a vacuum feedthrough for spatial calibration

B)



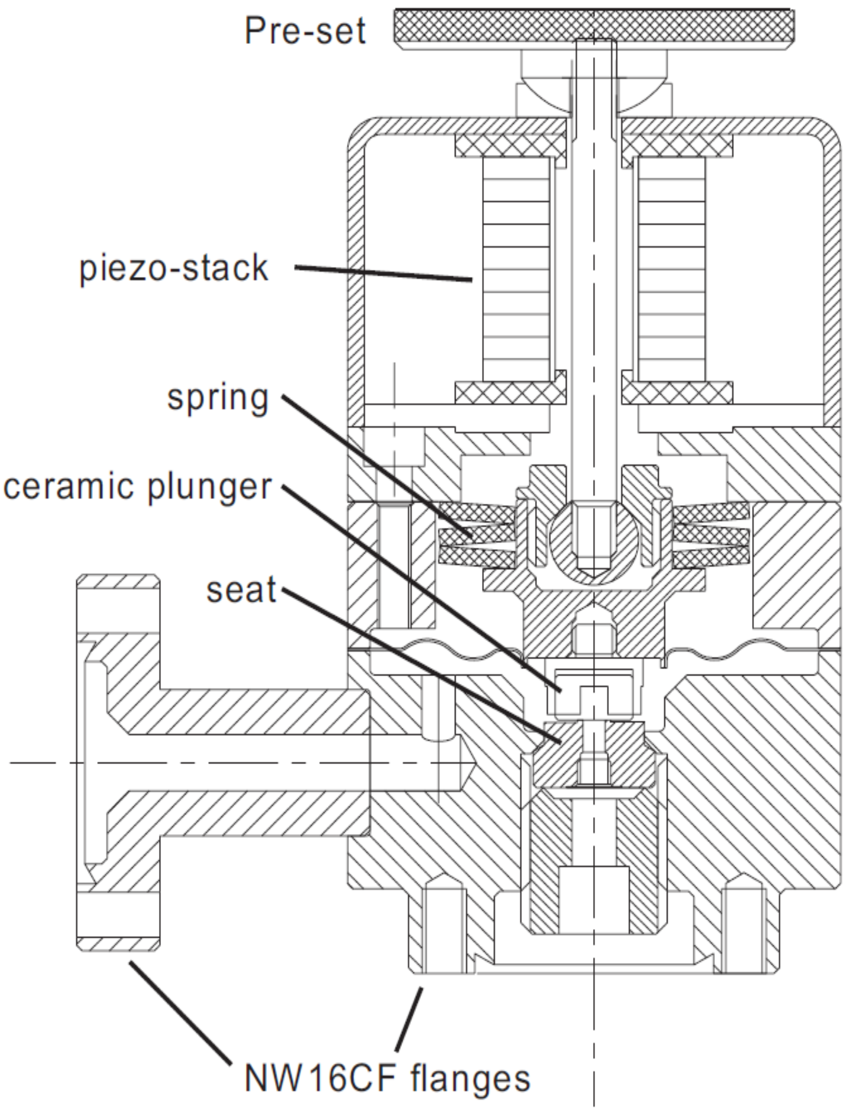
- Mirror of 95% transmission produces an LED-reflection on axis

-> No feedthrough

Advantages of Pulsed Gas Valves

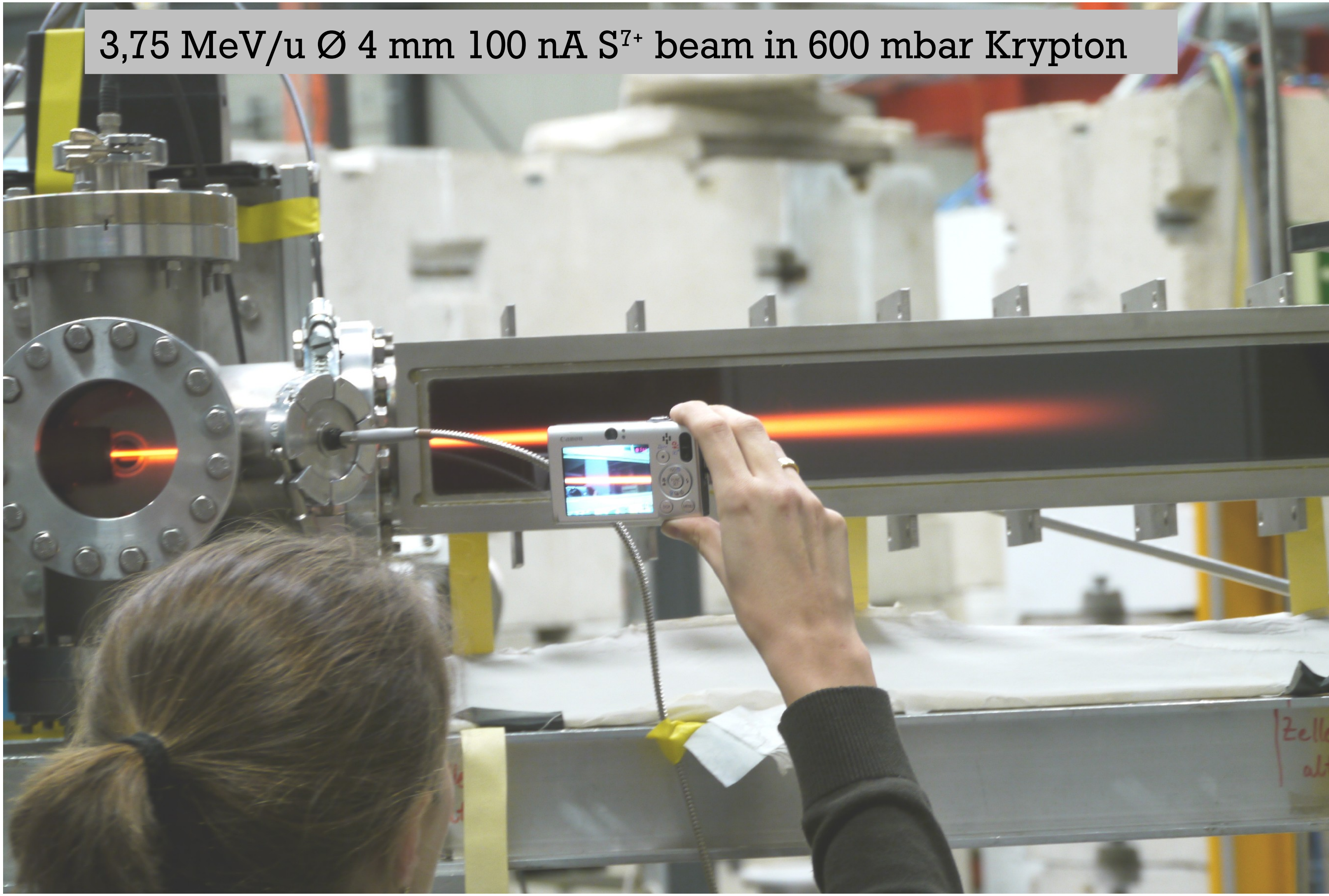
- Minimal pulse duration typical 0.1 - 20 ms
- Leak rates can be increased to match short pulse durations

Mean gas load is reduced while peak gas pressure is increased!

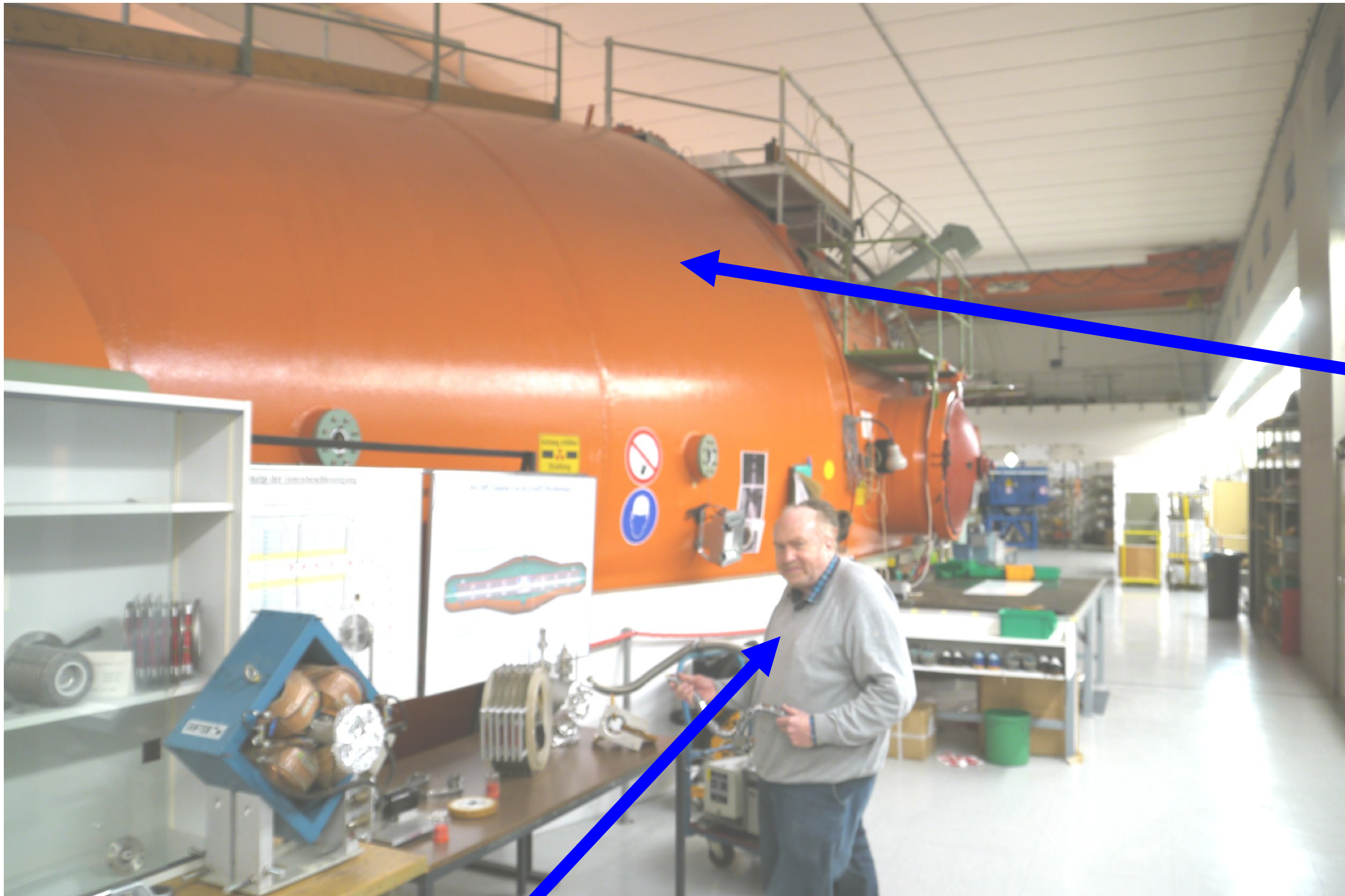


High Pressure -> easy Diagnostics :-)

3,75 MeV/u Ø 4 mm 100 nA S^{7+} beam in 600 mbar Krypton



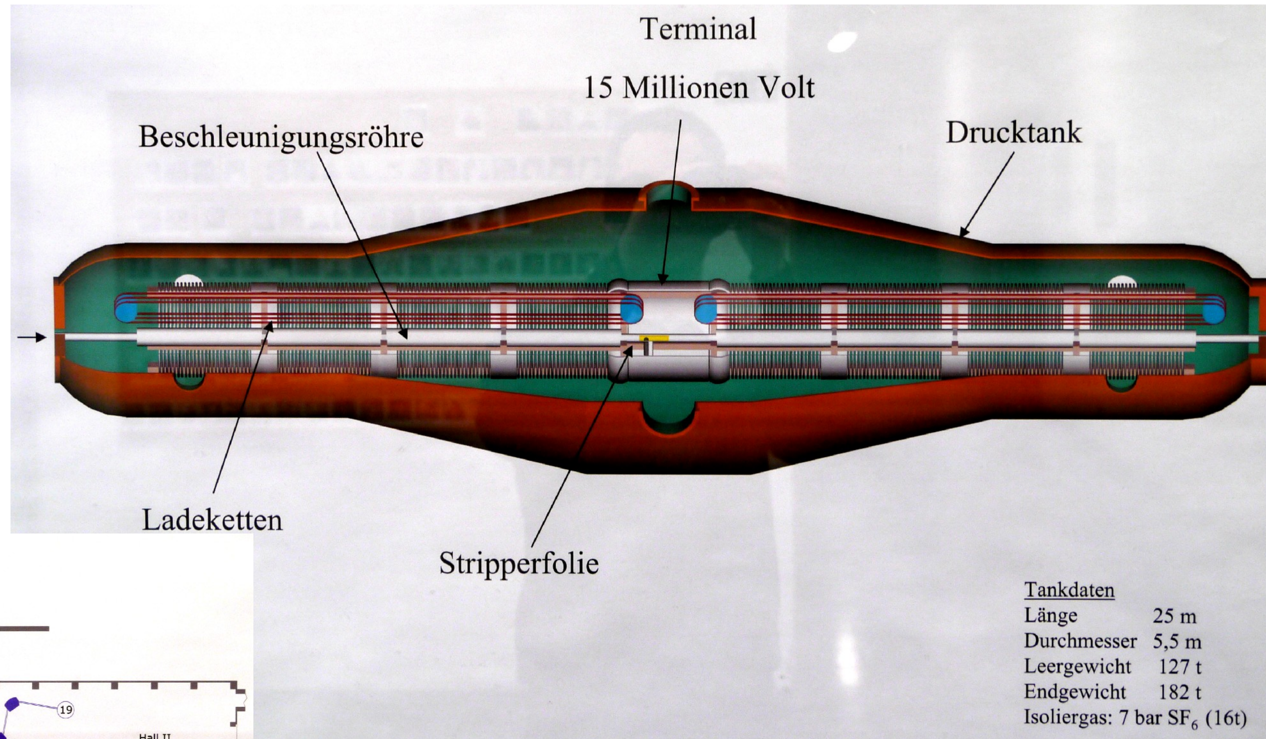
Our Visit at TANDEM-Munich

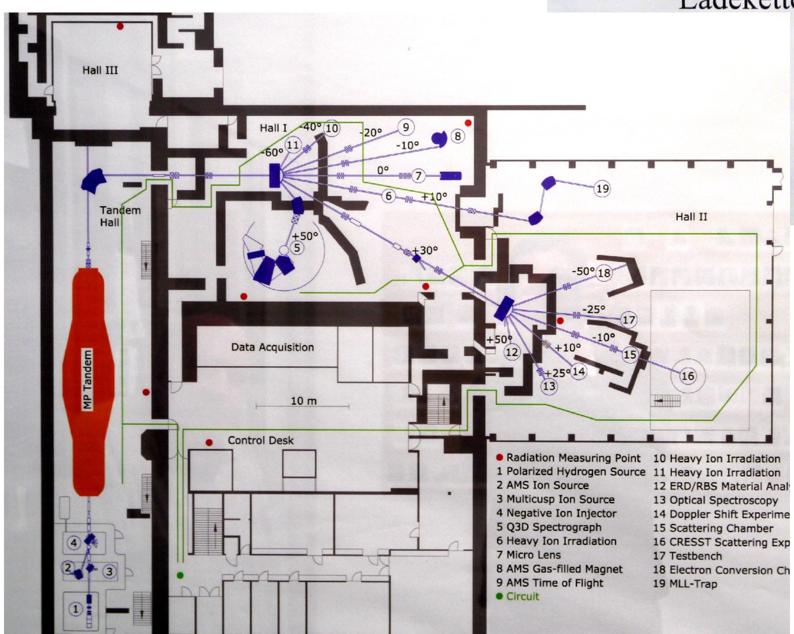


Tandem

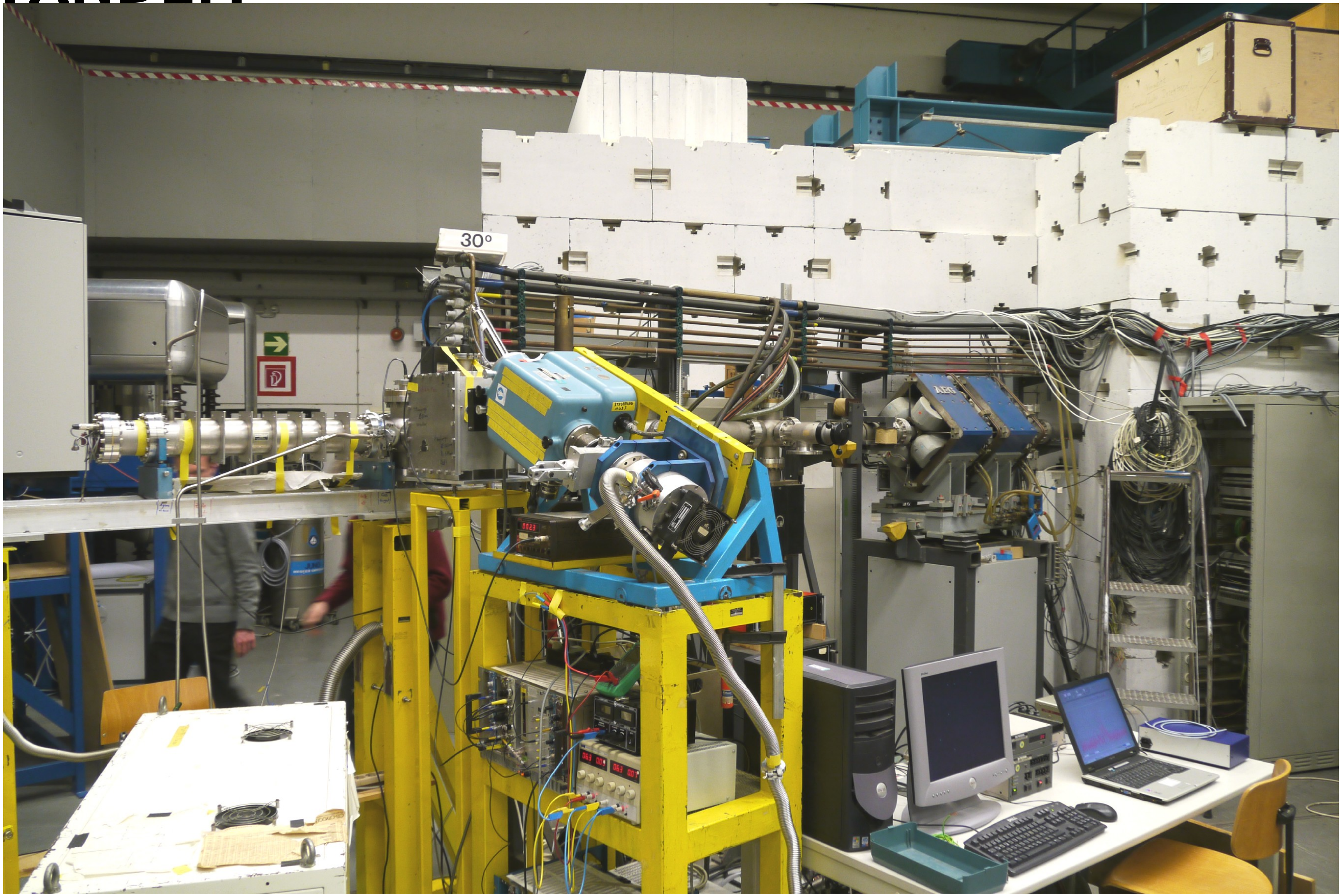
Professor Andreas Ulrich – Atomic Phyisics TUM

The TANDEM-Principle





Vacuum-UV Spectrometer at TANDEM



Decreasing Kr-Press. 1000 – 1mbar

3,75 MeV/u Ø 4 mm 100 nA S^{7+} beam in 1000 - 1 mbar Krypton

Conclusion

- Non-intercepting profile measurement is important for:
  - Beam transport & to characterize intensive ion beams
  - Best focusing upon experimental targets (WDM, FRS, ...)
- Successful application of the BIF-monitor was shown:
  - In the energy-range of 7,5 AkeV – 750 AMeV
- Results of research:
  - Signal-amplitude → linear with p, dE/dx with E → f = const.
  - Profile-width → does not depend on p → p free parameter
  - Radiation-background → $\sim E^2$ → Shielding is mandatory
  - Rare gases (Kr, Xe) can replace N_2 → reduced profile-errors
  - N_2 has highest fluorescence-efficiency per energy-loss
- Outlook – Technical improvement
  - Construction of a shielded BIF-monitor with an image-guide
  - Reliable design and rad-hard components for int. cameras
  - Pulsed piezo-driven gas-valves for lower average gas load
  - Further investigation of the high pressure regime > 1 mbar

Thank‘s to...

C.Andre [1], P. Forck [1], T. Giacomini [1], R. Haseitl [1], A. Hug [1], T. Milosic [1], H. Reeg [1], B. Walasek-Hoehne [1], F.M. Bieniosek [2], P.A. Ni [2] , A. Ulrich [3] , D.H.H. Hoffmann [4]

1) GSI, Helmholtzzentrum für Schwerionenforschung GmbH
2) LBNL, Berkeley, California
3) Department E-13, Technische Universität München
4) Institut für Kernphysik, Technische Universität Darmstadt

Thank you for your attention :-)