Detectors for Regular Beam Tuning and Daily Quality Assurance at the HIT Facility

Andreas Peters, HIT

Industry meets Academia: Beam Monitoring

GSI, 10th November 2011

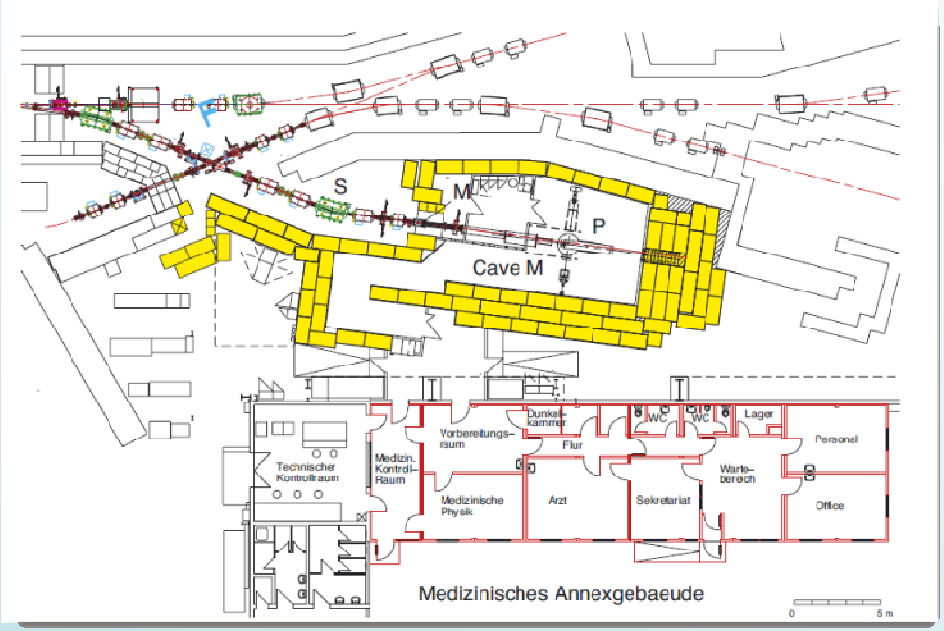
HIT Betriebs GmbH am
Universitätsklinikum Heidelberg

http://www.hit-centrum.de

Outline

- Introduction: Tumour therapy with particle beams (p, C) at GSI and HIT
- Used detector systems for accelerator beam diagnostics, beam tuning and Daily QA measurements:
  - ICs
  - MWPCs
  - Screens
- Conclusions and Acknowledgement

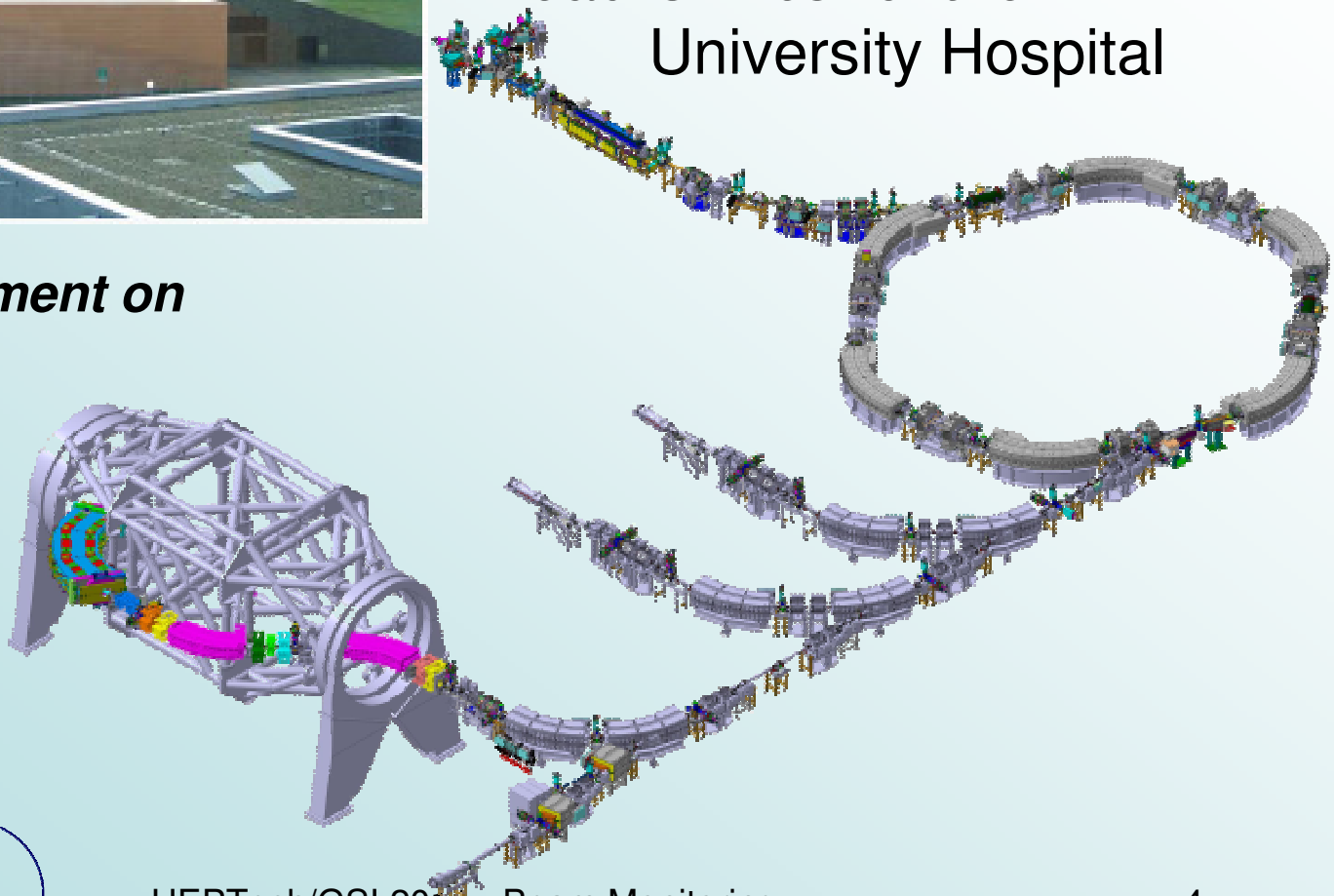
Particle Therapy Facility @ GSI



HIT concept and layout is based on experience from GSI; 448 patients were treated with carbon beams from 1997 – 2008 using raster scanning technique

Particle Therapy Facility – HIT/Heidelberg

Compact building (60 x 70 m², 3 levels), directly linked to the "Head Clinics" of the University Hospital



Start of patient treatment on 15th November 2009

At present two horizontal treatment rooms in operation, Gantry under commissioning

HIT Heidelberger Ionenstrahl-Therapiezentrum

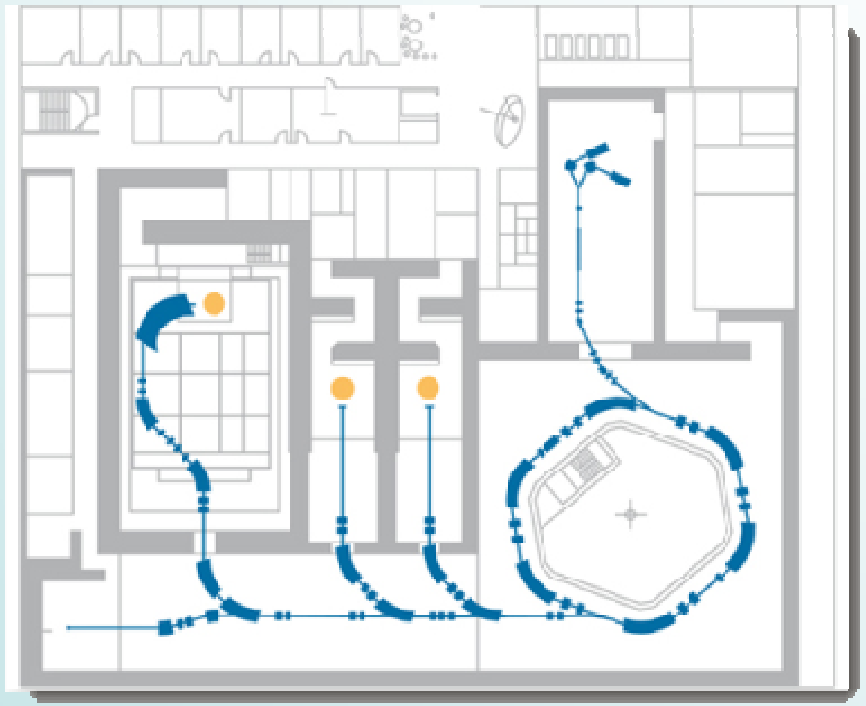
Particle Therapy Facility – HIT/Heidelberg

• Ions	:	p	$^{3}He^{2+}$	$^{12}C^{6+}$	$^{16}O^{8+}$
• Energies (MeV/u)	:	48	72	88	102
(255 steps)		-220	-330	-43	-430

- Beam spot size : 4 - 10 mm (2d-gaussian)
  (4 steps)
- Intensity: 10 steps

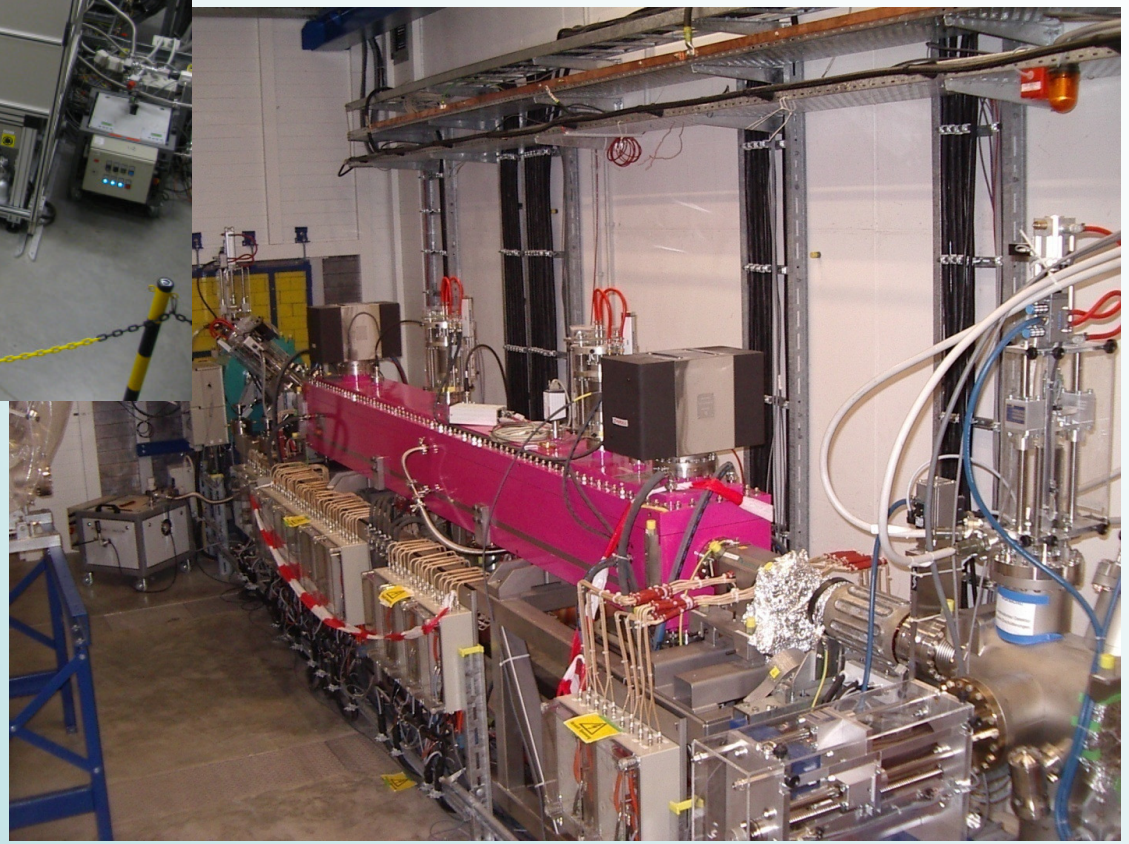
Change to $^{4}He^{2+}$

- Treatment caves: 3
  (2 horizontal, 1 iso-centric gantry)
- QA and Research: 1 (1 horizontal)



Particle Therapy Facility – HIT/Heidelberg

Injector: 2 ECR ion sources (8 keV/u) for proton and carbon ions…



… and following a RFQ and an IH-DTL linac → 7 MeV/u end energy

HIT Heidelberger Ionenstrahl-Therapiezentrum

Particle Therapy Facilities – HIT/Heidelberg

Synchrotron

High energy beam transport (HEBT)

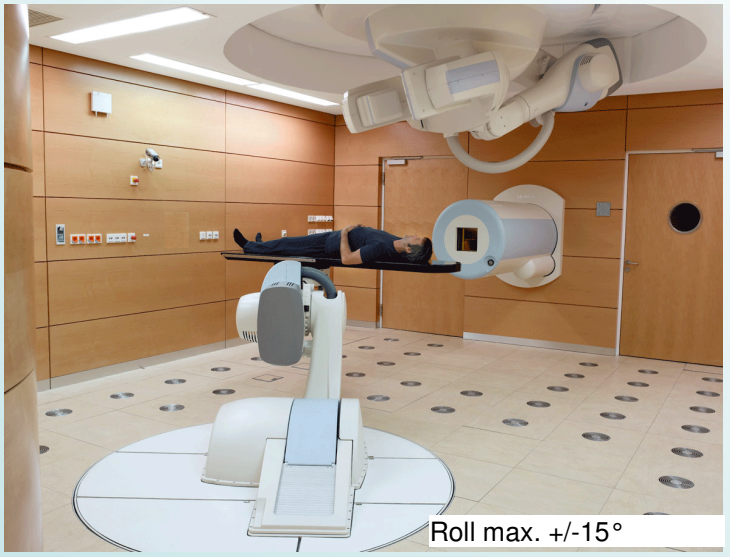
HIT Heidelberger Ionenstrahl-Therapiezentrum

Particle Therapy Facilities – HIT/Heidelberg


Isocentric Rotation +/-100°

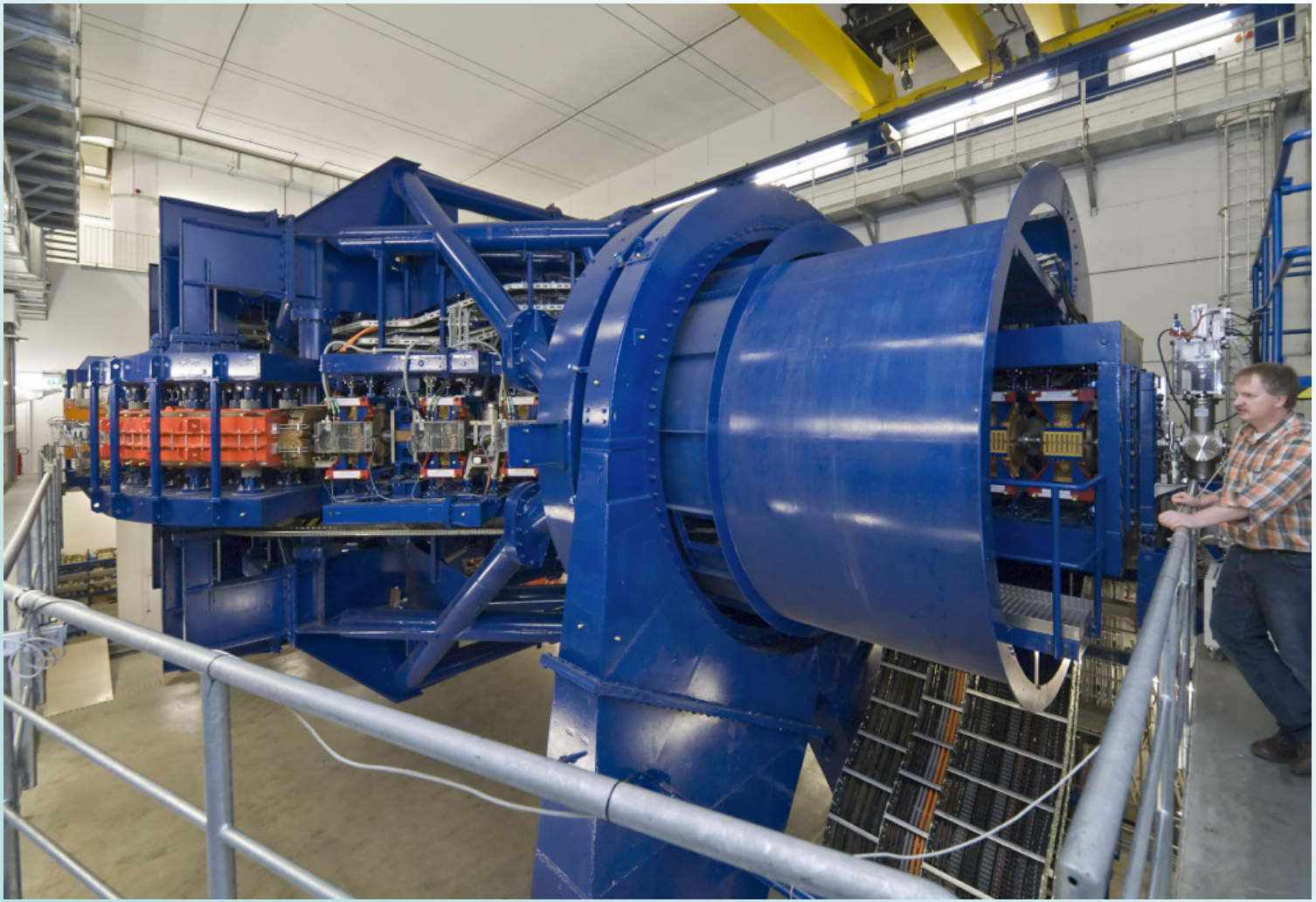

Pitch max. +/-15°


Step On Position 650 mm


Roll max. +/-15°

Horizontal Treatment Place

Particle Therapy Facilities – HIT/Heidelberg



Worldwide first isocentric ion gantry – including a scanning system:

Ø = 13m
25m long

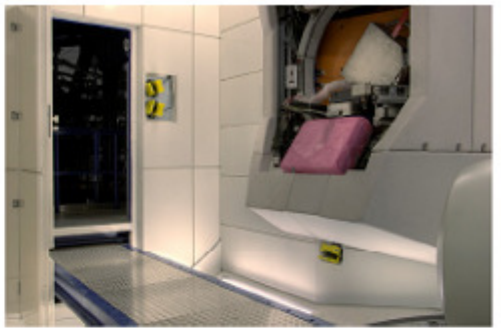
600 tons overall weight

0.5 mm max. deformation

HIT
Heidelberger Ionenstrahl-Therapiezentrum

Particle Therapy Facilities – HIT/Heidelberg

Patient Gantry Room



Tilt floor, pending on Gantry position

Nozzle

Bumber mats

Patienttable, Roboter

Used detector systems for accelerator beam diagnostics, beam tuning and Daily QA measurements:

- ICs
- MWPCs
- Screens

HIT Beam Diagnostics System

The different beam diagnostics systems can be classified in three groups:

- Non-destructive diagnostic systems that will work online during the patient treatment and in all other cases
- Destructive measurement devices that will be used for the daily checks of the machine and the beam stability, and in addition for beam tuning and solving simpler machine problems
- Special devices that will be necessary during the commissioning and in case of serious machine problems.

Detectors for Beam Monitoring

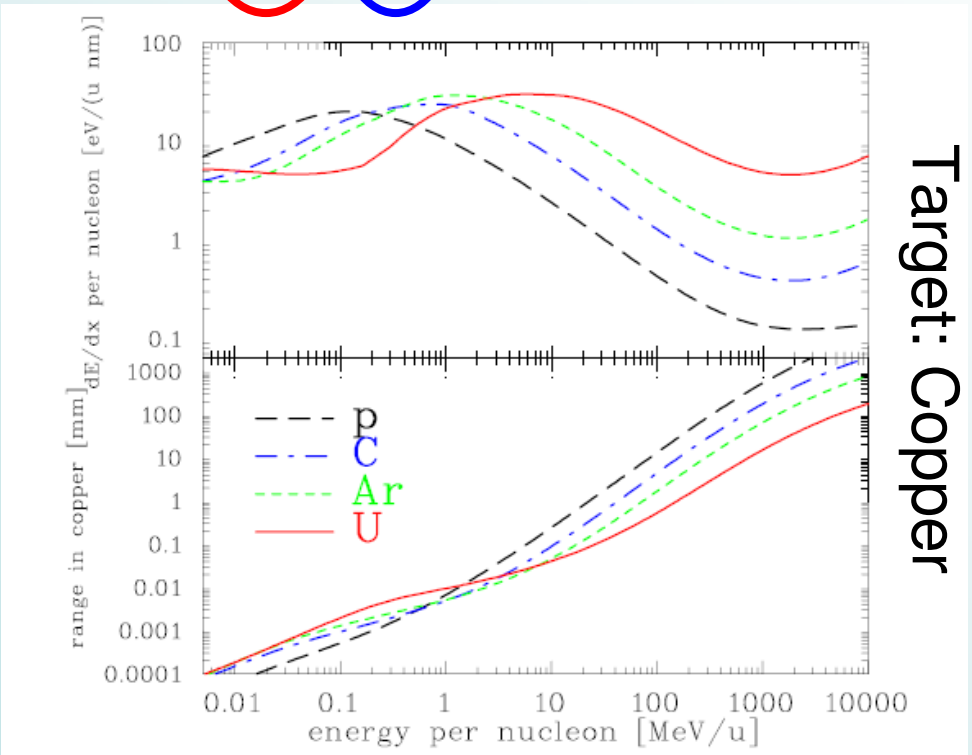
All beam diagnostics equipment used to monitor the beam intensity and position / profiles (HEBT!) is based on energy loss in matter (mainly gases) → electronic stopping:

Bethe Bloch-Equation:

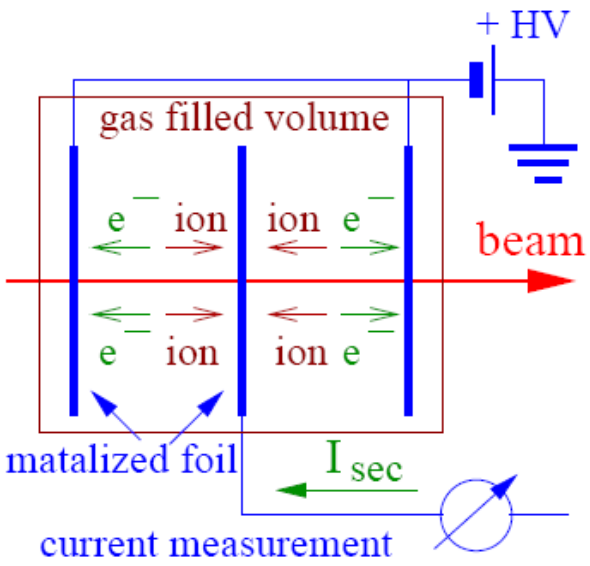
$$-\frac{dE}{dx} = 4\pi N_A r_e^2 m_e c^2 \cdot \frac{Z_t}{A_t}\rho \cdot \frac{Z_p^2}{\beta^2}\left[\ln\frac{2m_e c^2\gamma^2\beta^2}{I} - \beta^2\right]$$

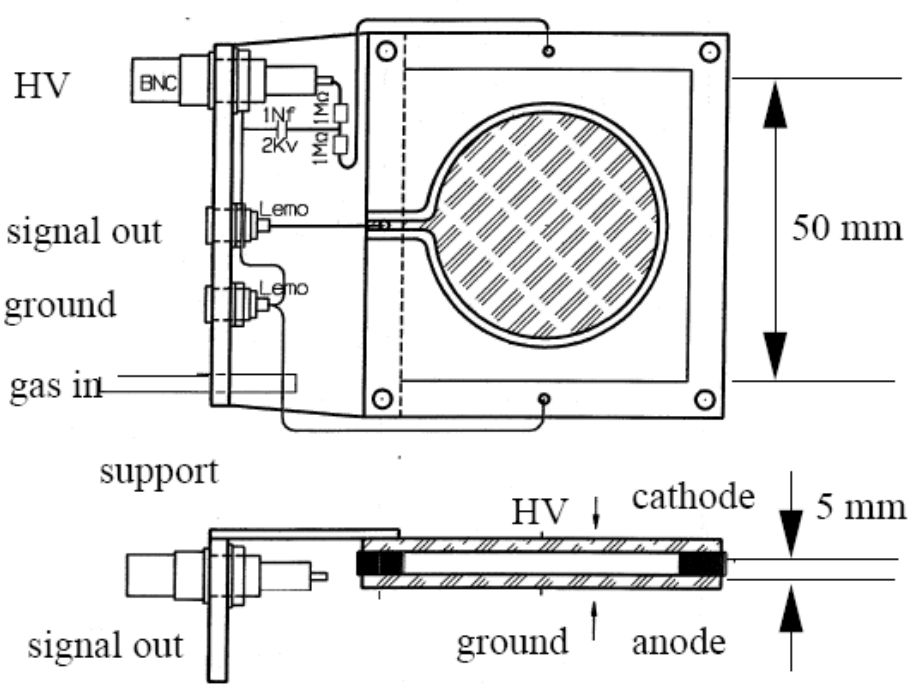
Target:
Charge & Mass (Z, A),
Density (ρ), Ionization Potential (I)

Projectile:
effective charge (Z_p),
Velocity (γ, β)



Detectors for Beam Monitoring - Intensity

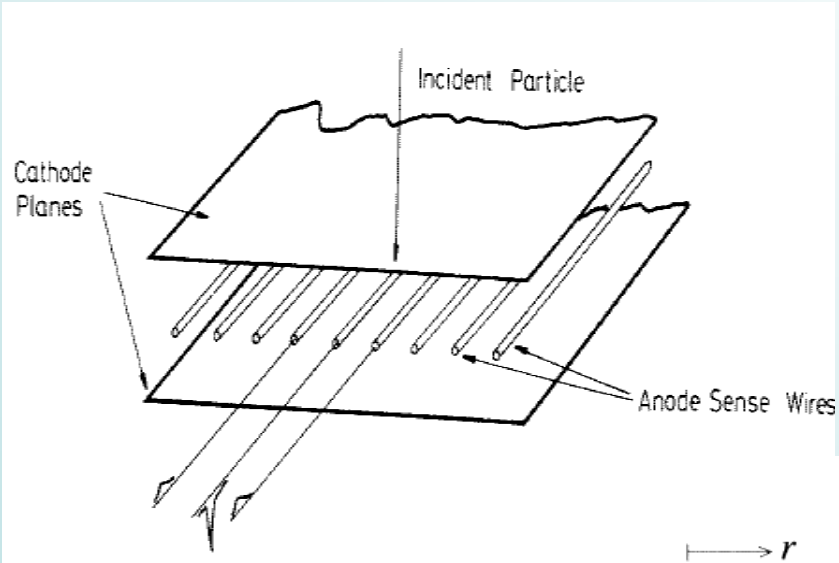




Principle layout (left figure) and example implementation (at GSI) with used parameters to work in the proportional regime

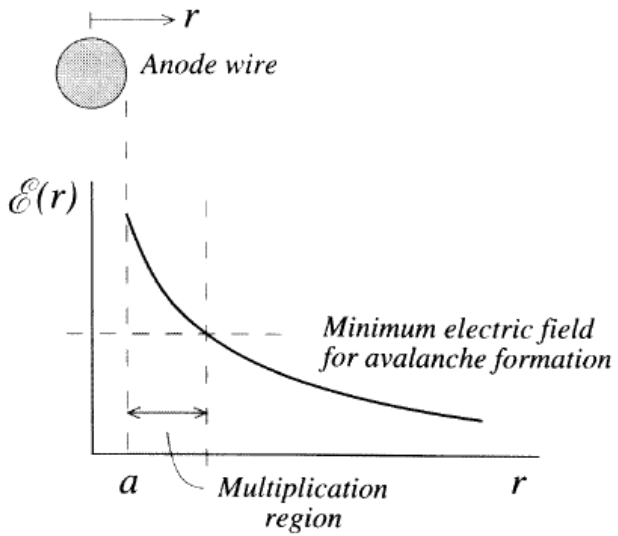
active surface	64×64 mm^2
active length	5 mm
electrode material	1.5 μm Mylar
coating	100 μg/cm^2 silver
gas (flowing)	80 % Ar + 20 %CO_2
pressure	1 bar
voltage	500 ... 2000 V

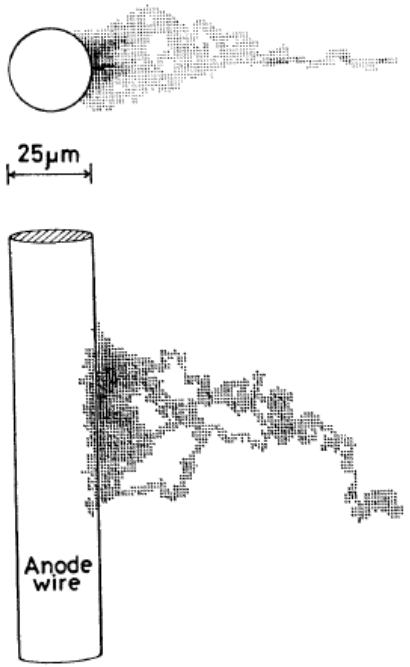
Detectors for Beam Monitoring - Profile



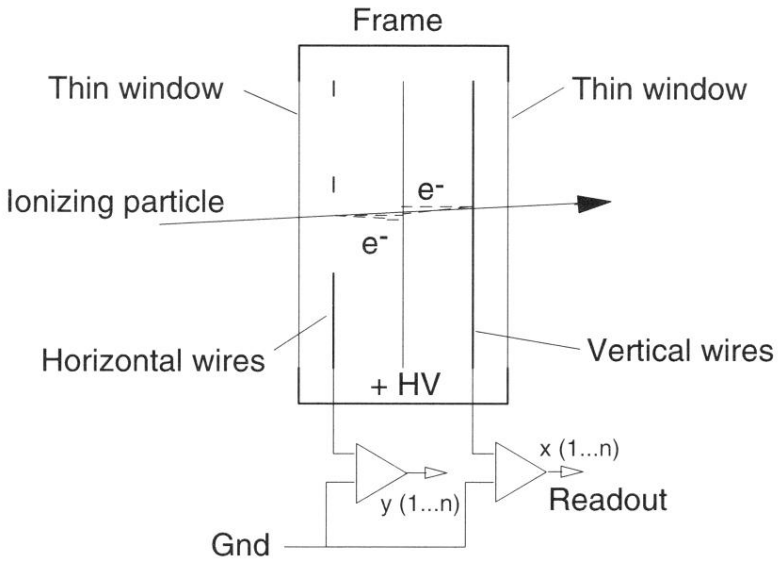
Principle layout of a Multi-wire proportional chamber (MWPC)

Electric field close to the anode wires with region of amplification (up to 10^4)

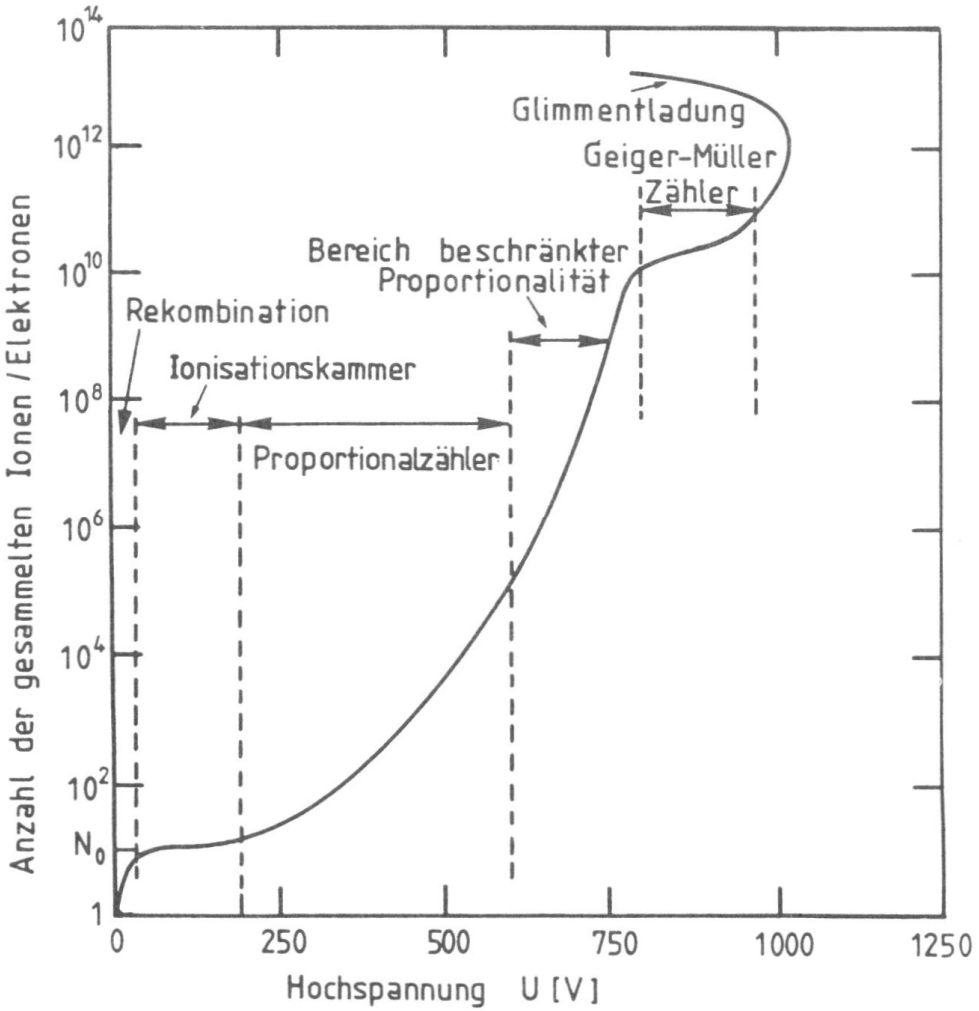




Detectors for Beam Monitoring - Profile

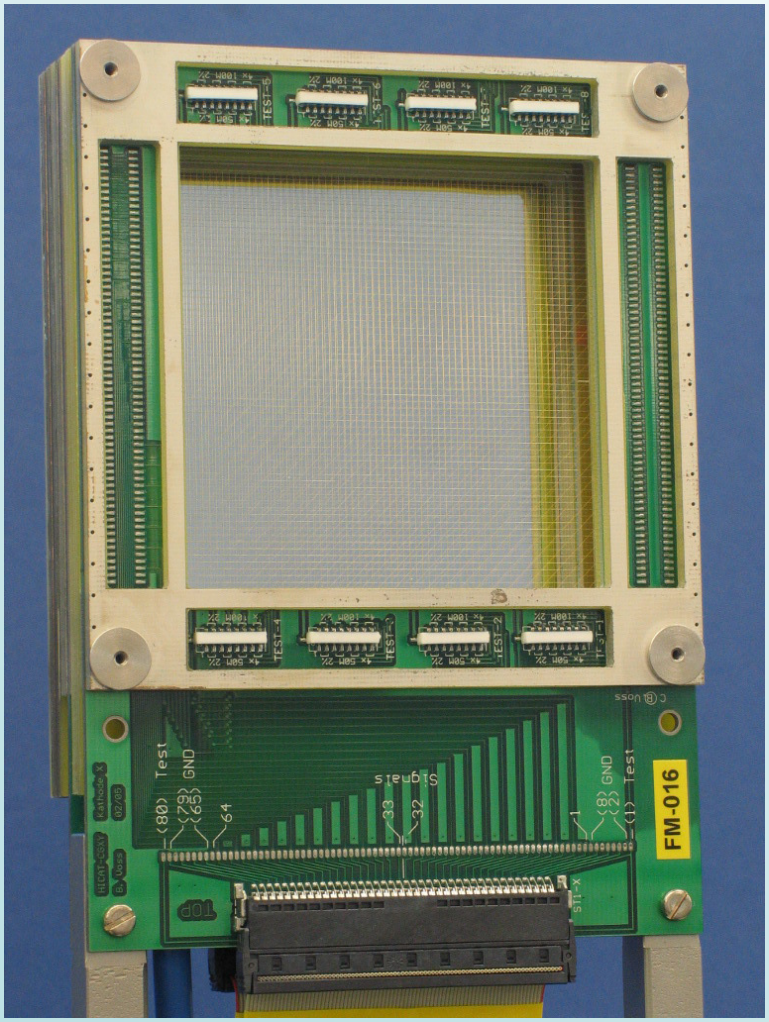


Scheme of a MWPC for beam profile measurement



Operating ranges of gas detectors

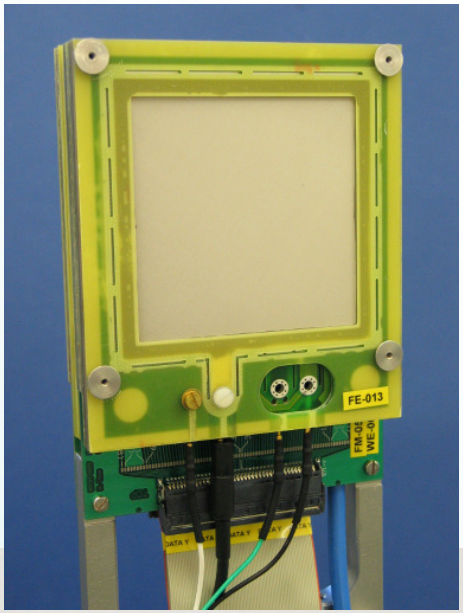
Detectors for Beam monitoring – MWPC/IC



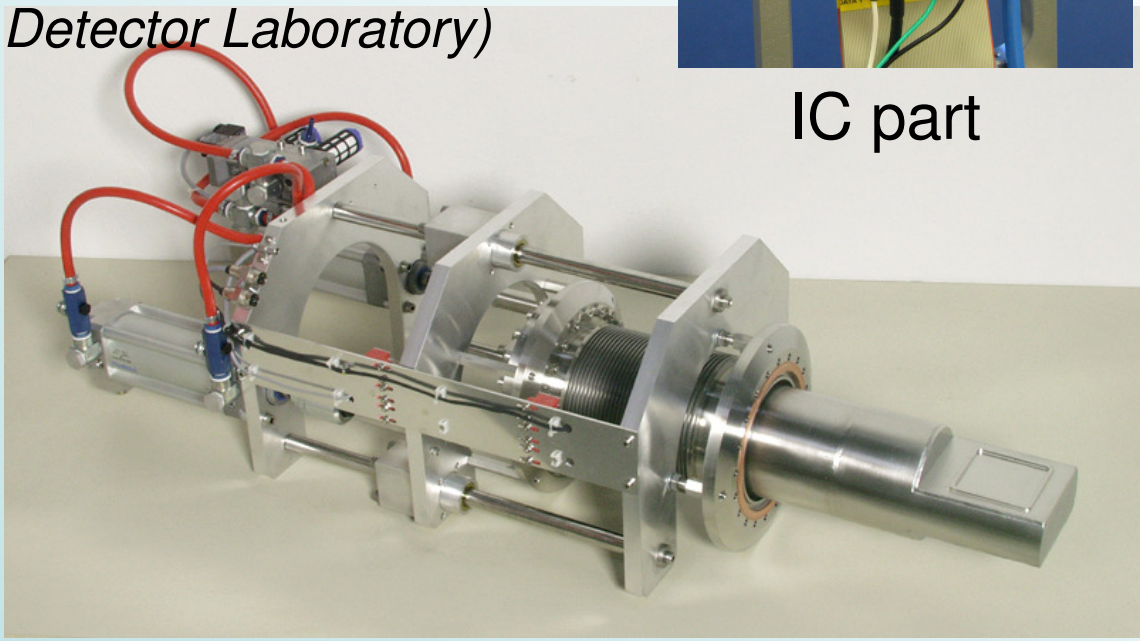
MWPC part

Compact combined detector system working at HIT in the HEBT; feed-through with detector bag – windows to vacuum consist of 50 µm stainless steel

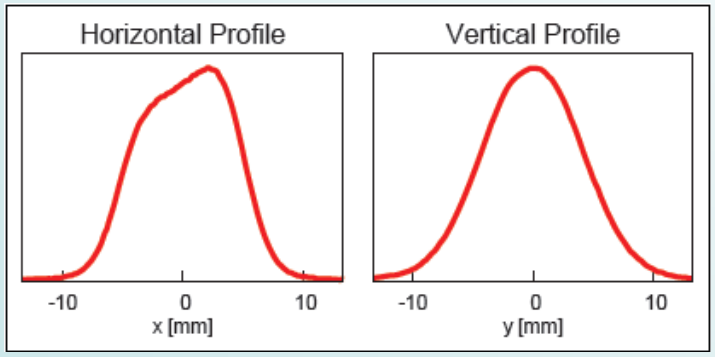
(MWPC/IC manufactured by B. Voss & team at GSI Detector Laboratory)



IC part

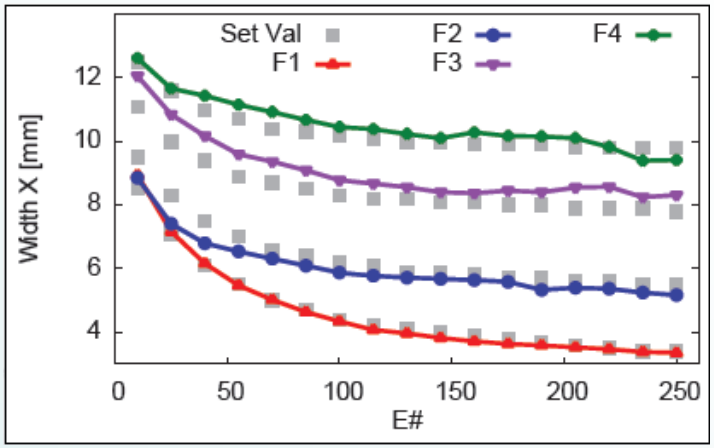


Detectors for Beam Monitoring - Measurements

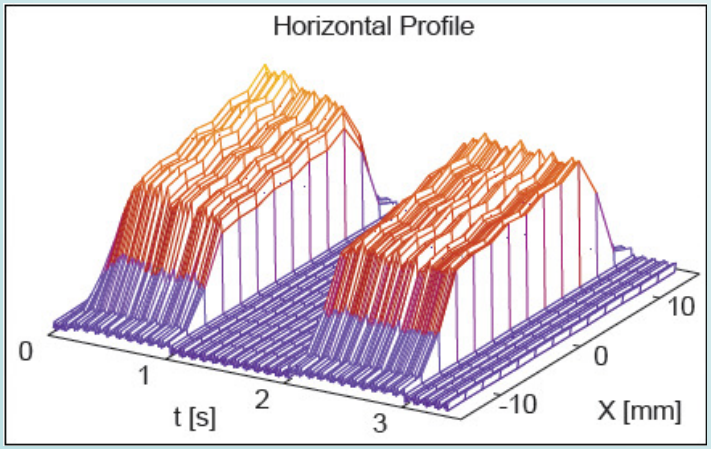


Profile measurements behind synchrotron ($^{12}C^{6+}$, 250 MeV/u, 10 mm FWHM)

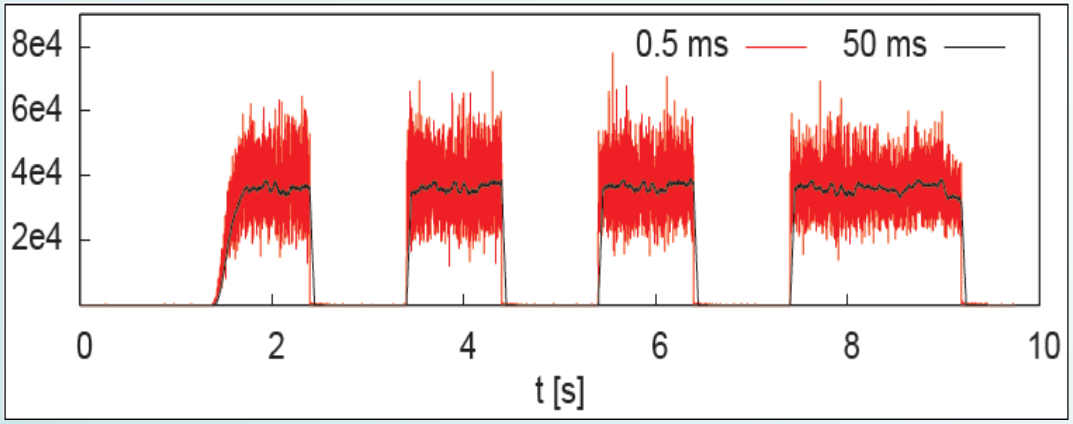
Measurements with MWPCs and ICs at HIT



Profile width of $^{12}C^{6+}$ near isocenter position



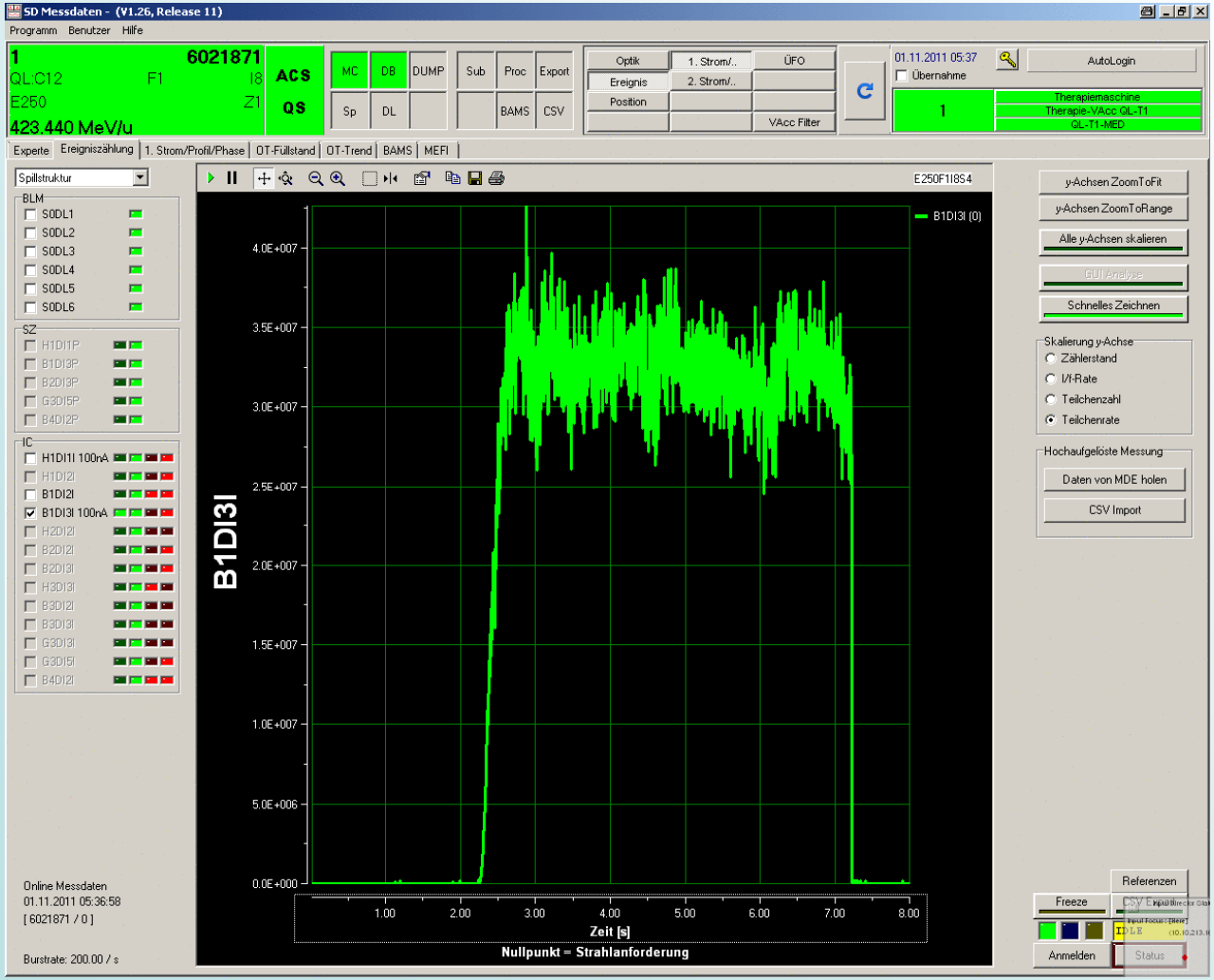
Profile measurements versus time ($^{12}C^{6+}$, 250 MeV/u, with spill pause)



Intensity of extracted beam from synchrotron („spill" with pauses)

Gas gain G(1200 V) ~15

Daily Beam Quality Checks - Spill

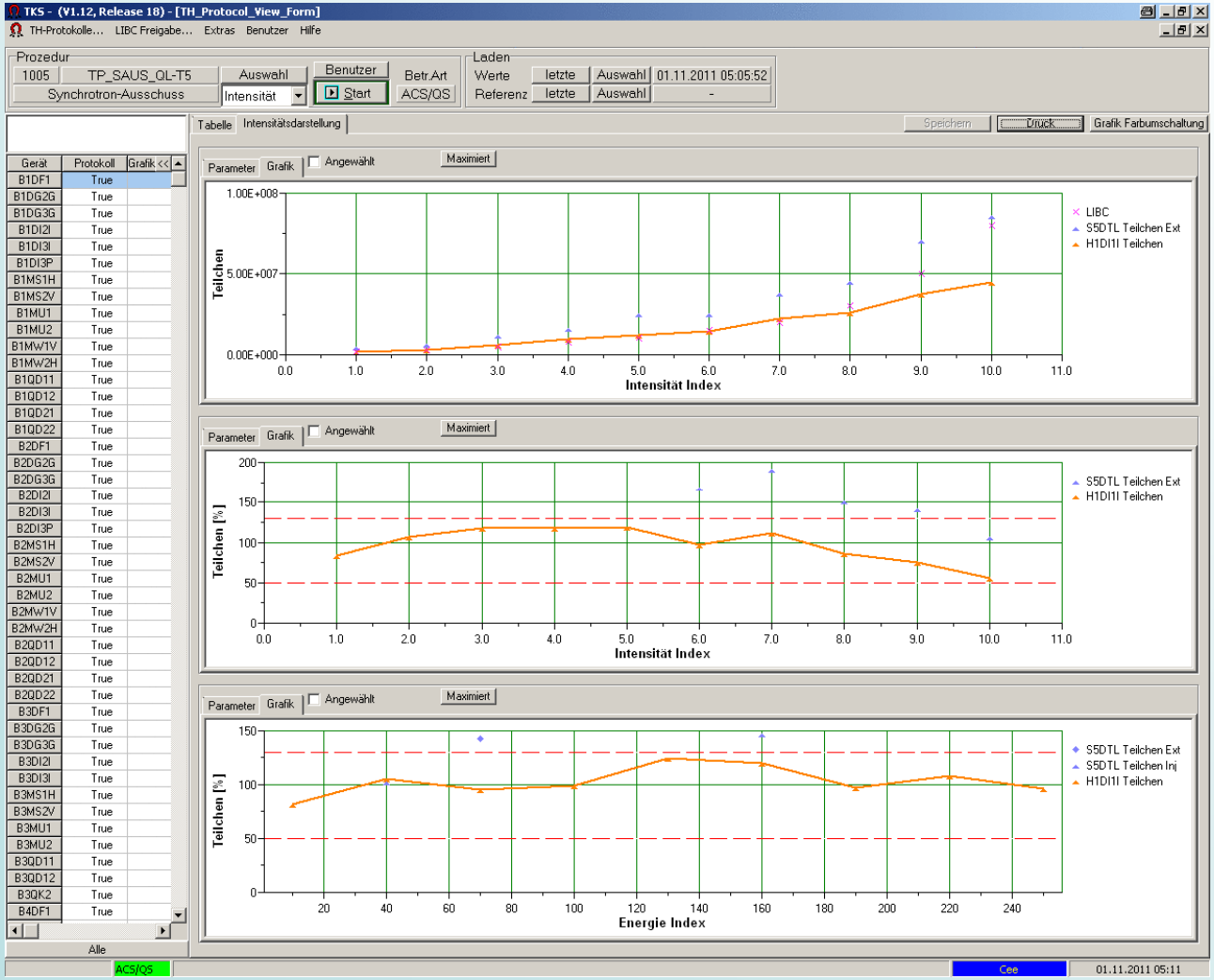


Intensity vs. Time (5 s extraction)

→*Control of intensity steps, spill shape including rise time, etc.*

[Starting in 2012 spill regulation will be introduced]

Daily Beam Quality Checks - Intensity

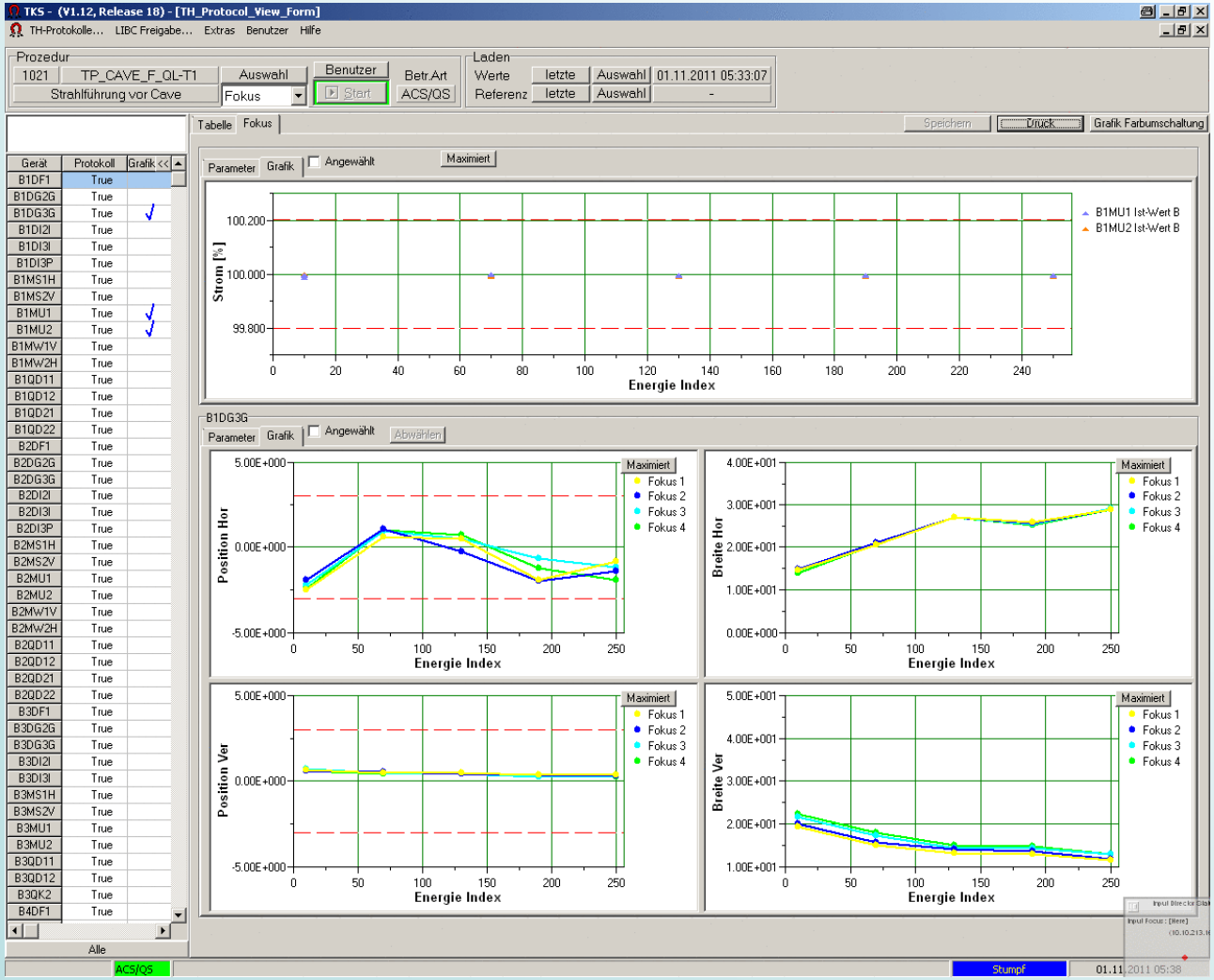


Intensity steps overall (at fixed energy)

Intensity steps standardized with limits

Fixed intensity step vs. energy

Daily Beam Quality Checks - Profile



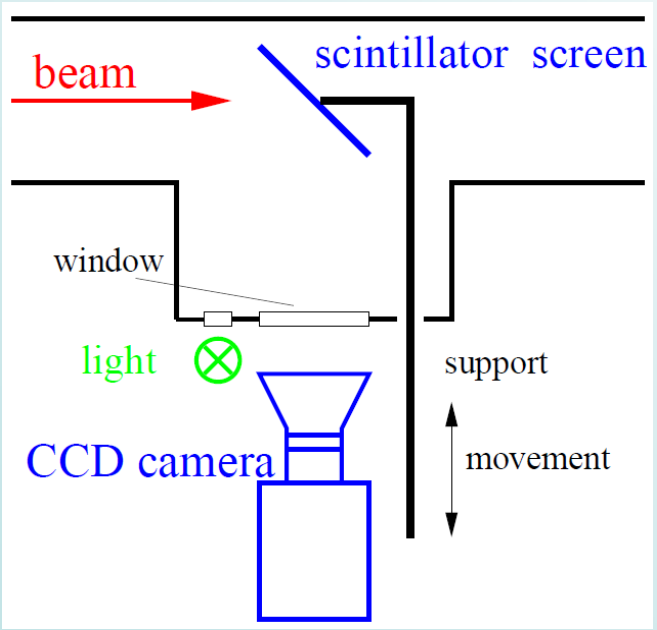
Dipole currents (Actual values)

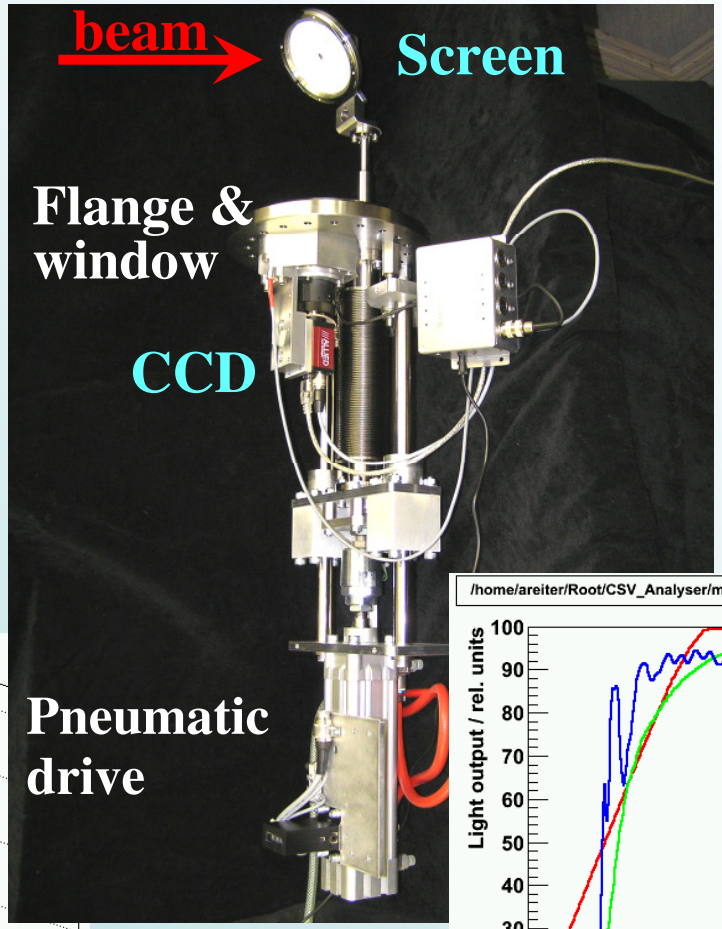
Horizont. and vertical beam positions and profile width in front of scanner magnet system

Daily Beam Quality Checks - Summary

- "Work horses" for daily checks of beam quality are ICs and MWPCs (combined detectors)
- Extremely reliable, only two installation errors have to be fixed, no problems since then (~ 5 years) – operators have deep trusts in the measurements
- Highly-developed layout with long history at GSI and conservative operating parameters
- Reserves in gain to go to lower intensities for experiments with demands in change of optics

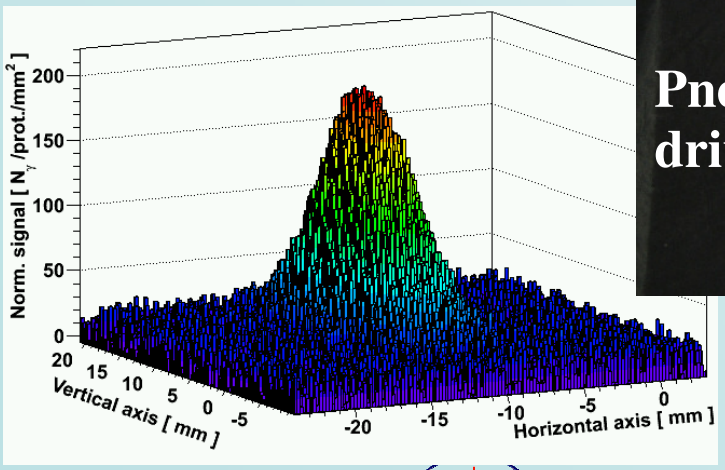
Detectors for Beam monitoring – Screens



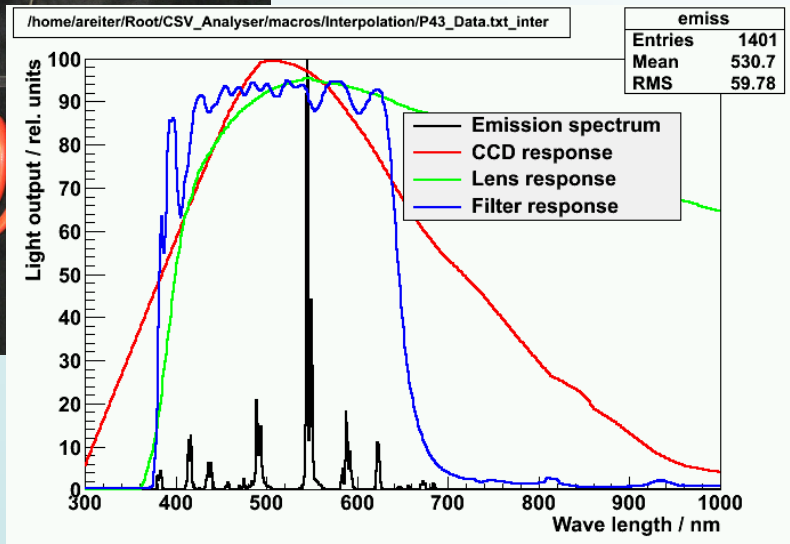


Redundant devices to MWPCs: Screens

Used material: P43

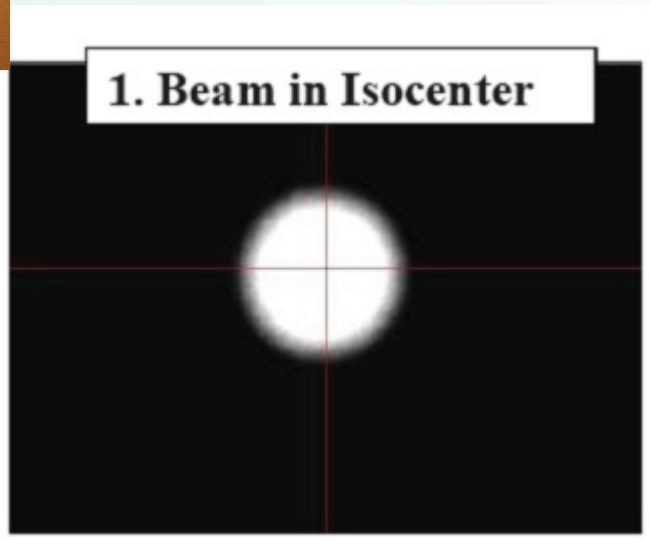


Beamline version



Detectors for Beam monitoring – Screens

Different versions for Isocenter Diagnostics – fixation on robot or at Gantry nozzle



Regular Beam Quality Checks at Isocenter

- Use of Screen Diagnostic Systems in air (mounted every time when needed)
- Large detector areas possible at reasonable costs
- Use of standard industrial components (optics, CCD camera, etc.)
- Until now only two 1-dimensonal projections of screen images are used for beam checks and tuning
- In future: 2D beam analysis and emittance measurements planned

Acknowledgement

Many thanks to

- *my colleagues of the HIT Accelerator Team, especially Jochen Schreiner and Klaus Höppner*
- *my ex-colleagues of the GSI BD Team, especially Andreas Reiter, Marcus Schwickert and Peter Forck*
- *Bernd Voss and his team at the GSI Detector Laboratory*

for providing material for this talk.

Detectors for Regular Beam Tuning and Daily Quality Assurance at the HIT Facility

Thank you for your attention !

Rasterscan@HIT/H1
Carbon 430 MeV/u