Development of a Scintillation Fibre Transverse Profile Monitor for Low-Intensity Ion Beams at HIT

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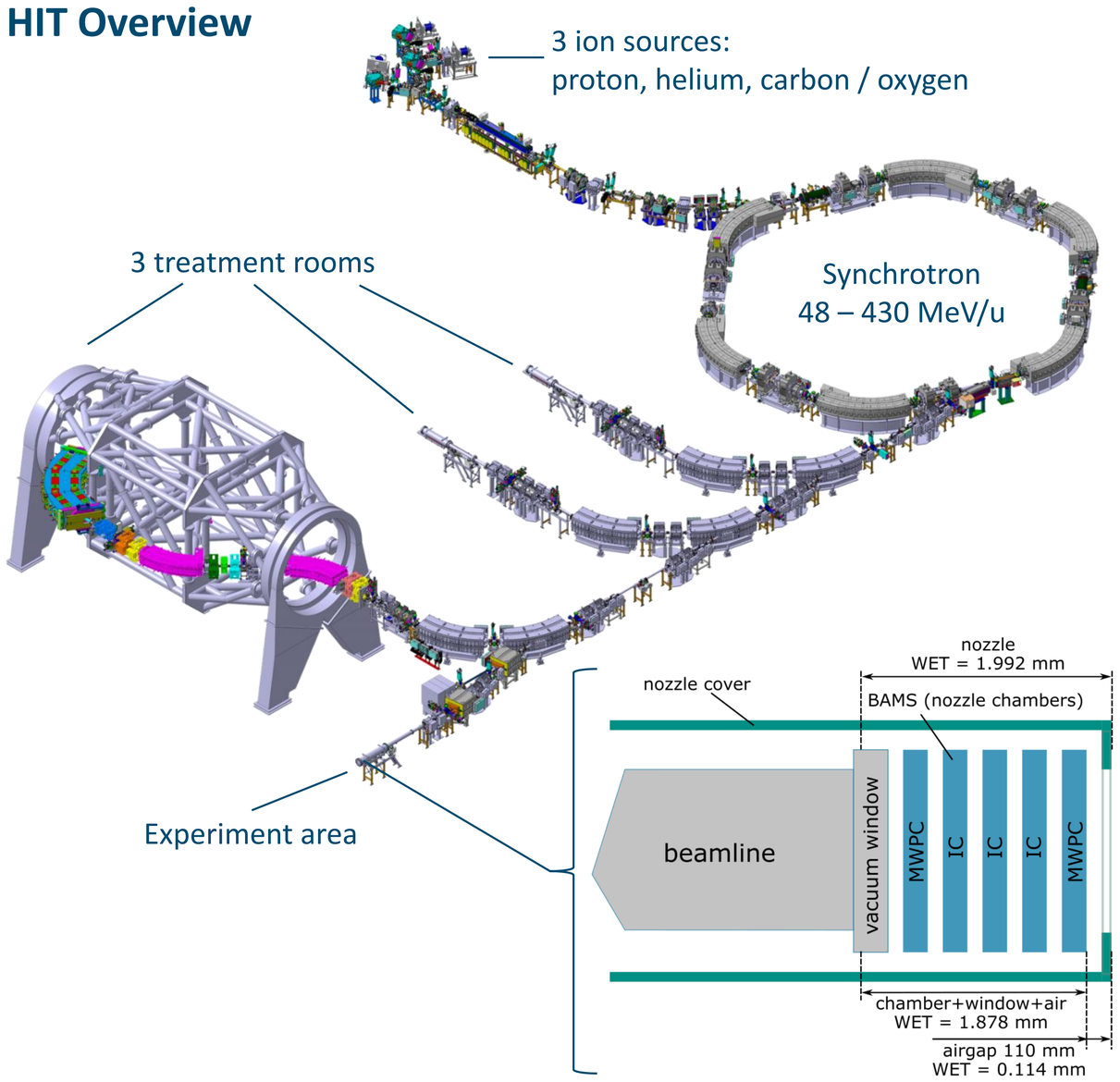
Objective

The non-therapeutically used low-intensity ion beams (< 1E5 ions/s) at HIT are not currently monitored. This work shall close this gap. It will allow for new forms of tumour diagnostics (ion radiography) and several experiments based on a controlled, low-intensity ion beam. The beam is to be measured for position, width, and intensity.

HIT Overview

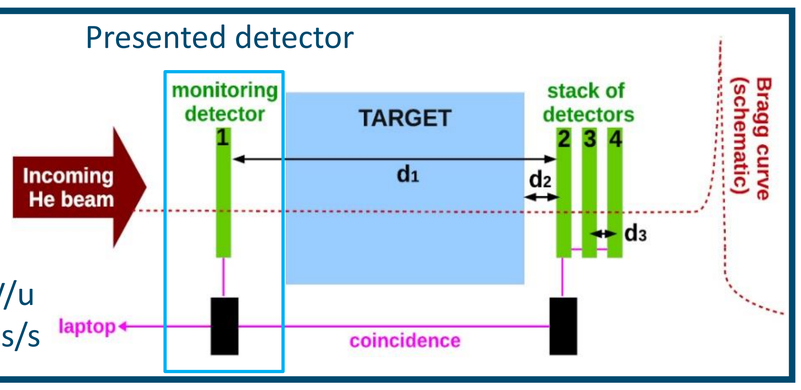


DFG Project

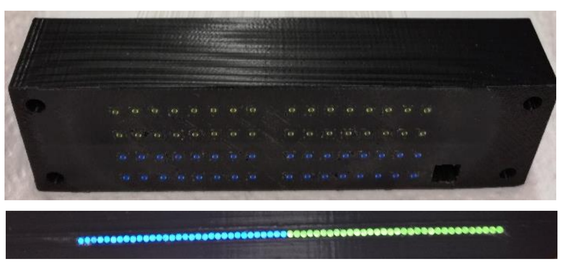
Helium Beam Radiography

- TimePix detectors
- Single ion tracking, with energy information
- High energy beam: > 240 MeV/u
- Low intensity beam: < 1E5 ions/s

Presented detector



Materials



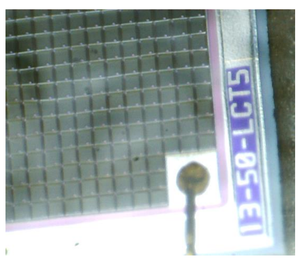
1) Scintillating Fibres (SciFi)

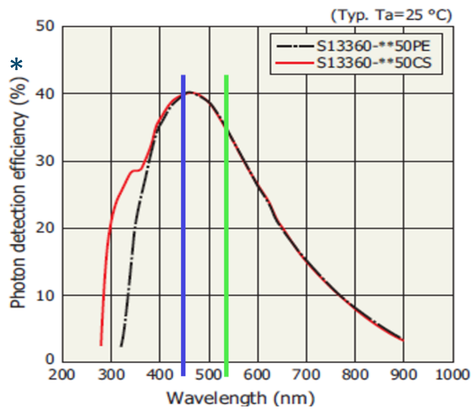
Kuraray SCSF-78 multiclad
- "Standard", 2.8ns decay, 450nm

Kuraray SCSF-3HF multiclad
- Radiation harder, 7ns decay, 530nm

2) Silicon Photomultiplier (SiPM/MPPC)

Hamamatsu
S13360-1350PE
- 1.3 x 1.3 mm²
- 50µm pixels
- 667 APDs
- V_{BR} = 53V ± 5V
- V_{OP} = V_{BR} + 3V
- Gain: 1.7E6





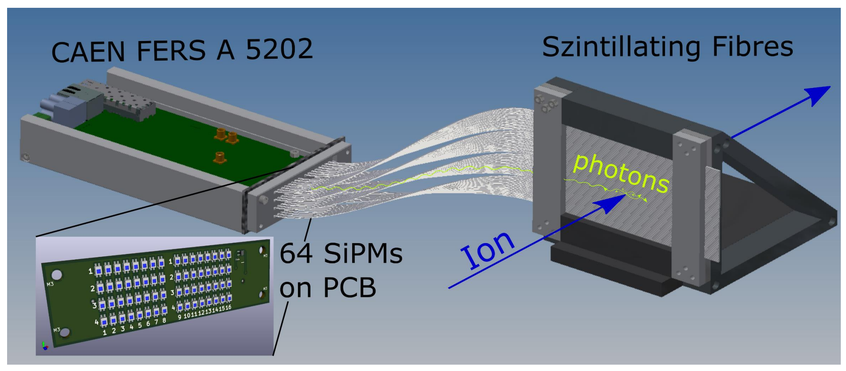
* PDE

3) Front-End Readout System (FERS)

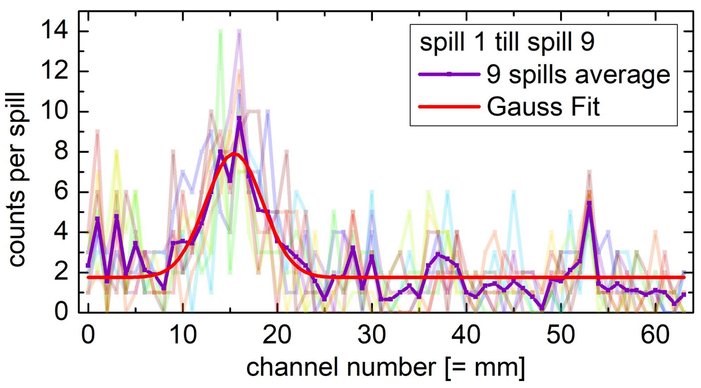
CAEN FERS A5202
- 64 channels (standalone)
- Counting Mode: 1E2 - 1E7 ions/s
- Timing Mode (ToA): < 5E4 ions/s
  ToT optional
- Citiroc (ASIC), FPGA, SiPM supply

Prototype Setup

- Ion hits SciFi
- Deposited energy emitted as photons
- Photons guided to SiPM
- Gain for 1 phot.: 1.7E6
- FERS readout & process signals from SiPMs



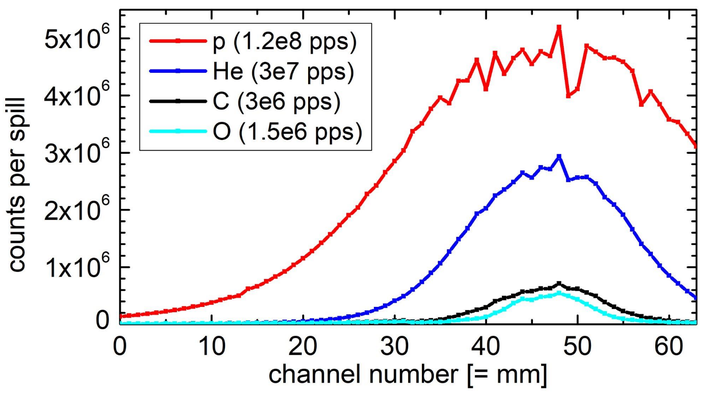
Experiment Results



1) Minimal Intensity

- Intensity varies remarkably
- TimePix: ~ 8 ions/s (averaged)
- Single spill (5 s): ~ 40 ions/s
- Position accuracy uncertainty below 1E2 ions/s: > 1mm

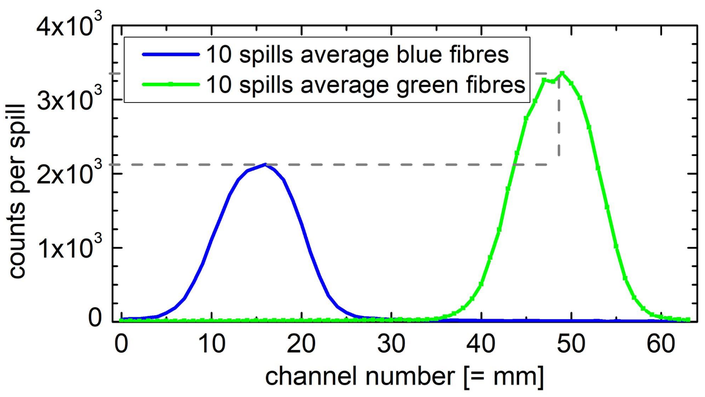
→ Data evaluation limited due to marginal incidents.



2) Maximal Intensity (SiPM limit)

- SiPM recharge time = 50ns
  → theoretical limit 2E7 ions/s
- Practical limit at 1E7 ions/s, as non-equal ion distance
- If several hits within recharge, counts are lost (see proton)

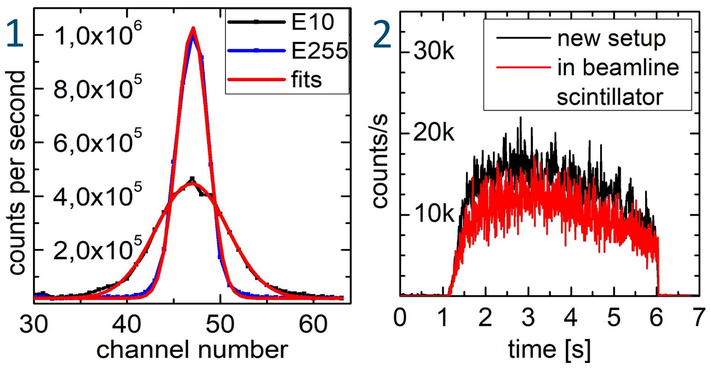
→ Limit due to speed of electronics.



3) Comparison of Fibres (SNR)

- Even with smaller PDE* of the SiPM, the rad. hard SCSF-3HF show 50% higher signal.
- Noise when no beam: < 20 Hz
- SNR within beam: ~ 100
  here noise due to fibre crosstalk

→ SNR already sufficient



4) Comparison of Intensity

1. Intensity (=integrated area) show only 1 % difference for the two different energies, but same intensity settings (DIC controlled)
2. Spill shape (=intensity) same for adjusted integrated scintillator and the prototype

Conclusion

The scintillating fibre profile monitor was tested successfully with the proton, helium, carbon, and oxygen ion beams, provided at the HIT facility, with energies that varied from 50 – 430 MeV/u and intensities from 1E2 to 1E7 pps. The described setup is capable of functionally and reliably measuring the beam position, width, and intensity of the yet unmonitored, only experimentally used, low-intensity ion beams at HIT.

Outlook

- Setup second plane: x & y measurement.
- Prototype stackable. Area aim: 25 x 25 cm².
- Integration in dynamic intensity control system: Intensity feedback loop for low intensities.
- Combination with replacement for MWPCs: Also scintillating fibre mats, but for treatment intensities (1E6 – 1E10 ions/s)
- Front tracker to ion radiography setup (single ion tracking)