3D Energy Deposition Measurements in Hadron Therapy with GEMPix

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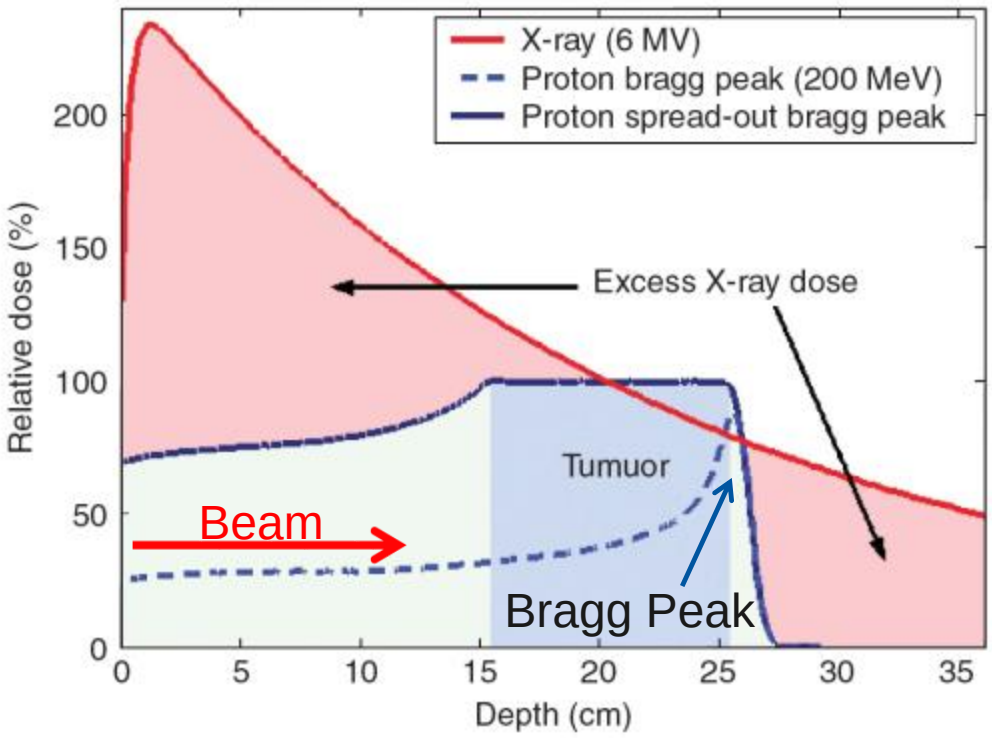
Introduction: Radiation Therapy

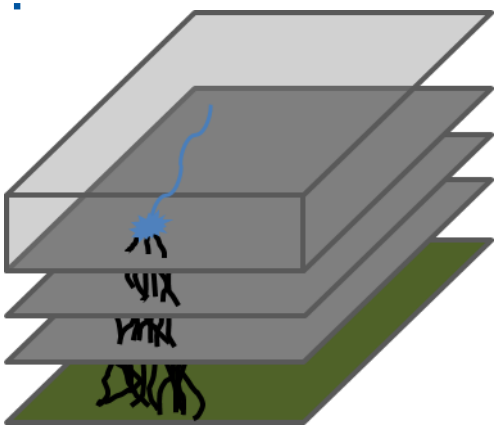
- Cancer therapy:
  - Surgery
  - Chemotherapy
  - Radiation therapy
    - X-rays
    - Proton- / Hadrontherapy
- Need for quality assurance tools, beam monitors, …
- Typical system: water phantom + ion chamber
- New detectors needed for Proton- / Hadrontherapy!

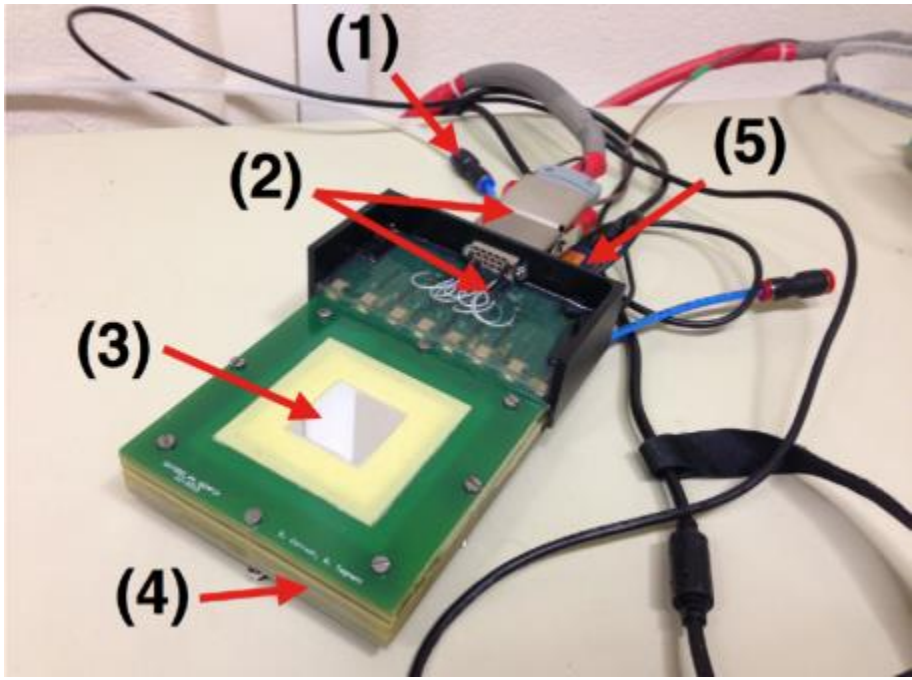


→ GEMPix in water phantom

The GEMPix Detector

- GEMPix: 3 GEMs + Timepix
- 9 cm^3 Ar:CO_2:CF_4
- Several applications of the GEMPix: Hadrontherapy, Microdosimetry, Radiotherapy, Radioactive waste, …





1) Gas supply
2) HV supply
3) Mylar entrance window
4) GEM foils
5) FITPix readout

GEMPix: GEMs + Timepix

3 GEMs:

- Kapton foil with thin copper layers
- Gas amplification in holes (large field)
- Total gain of max 10^5

4 Timepix chips:

- 512 x 512 pixels
- each 55µm x 55 µm
- detection threshold per pixel of 1000 electrons

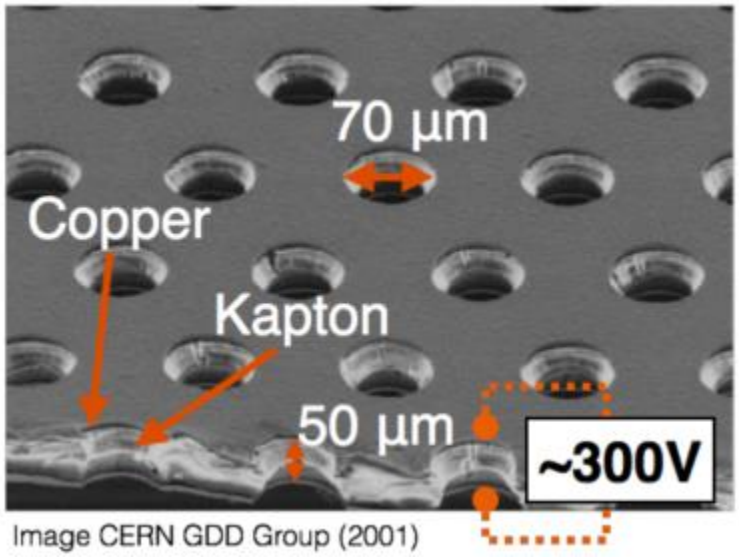
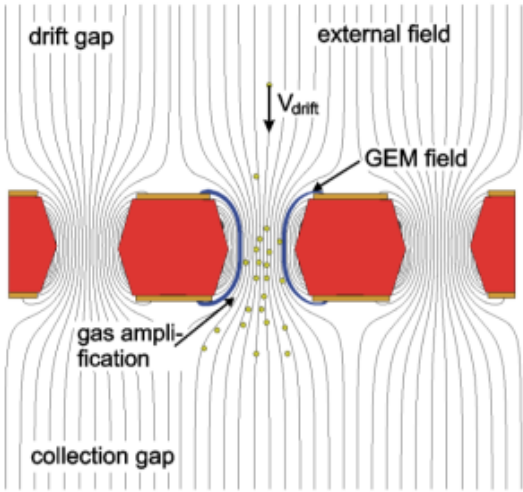
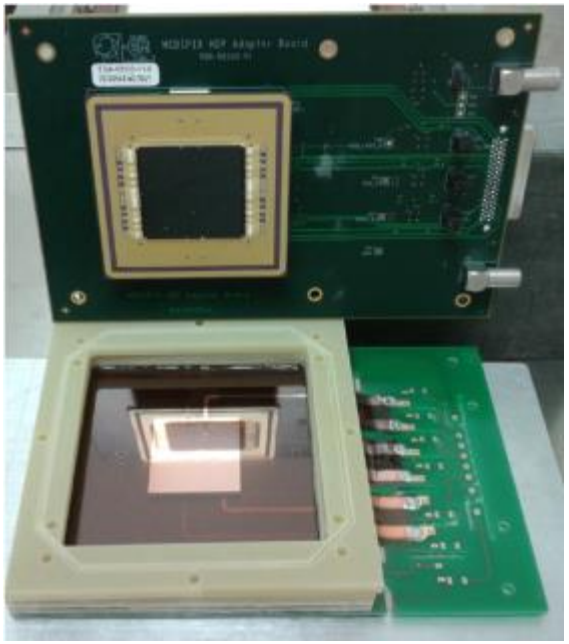
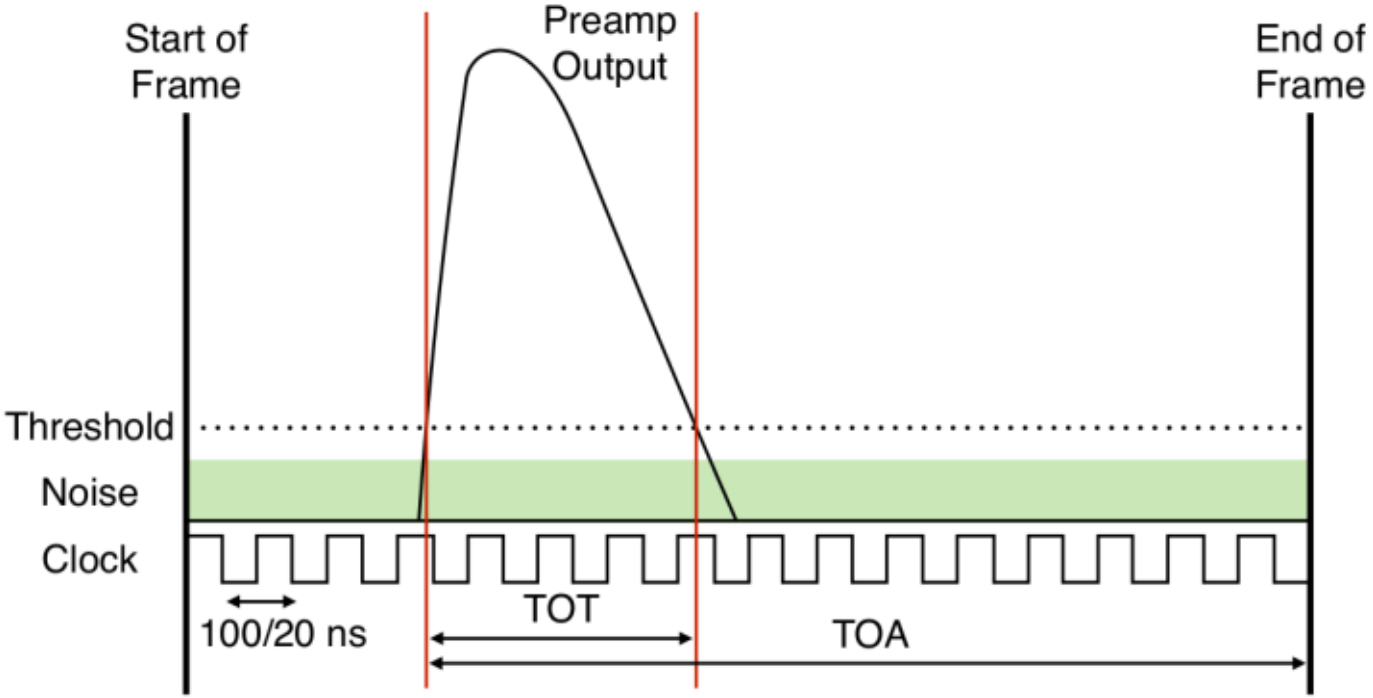


Image CERN GDD Group (2001)





Timepix: Time and Charge Measurements



Different modes possible:

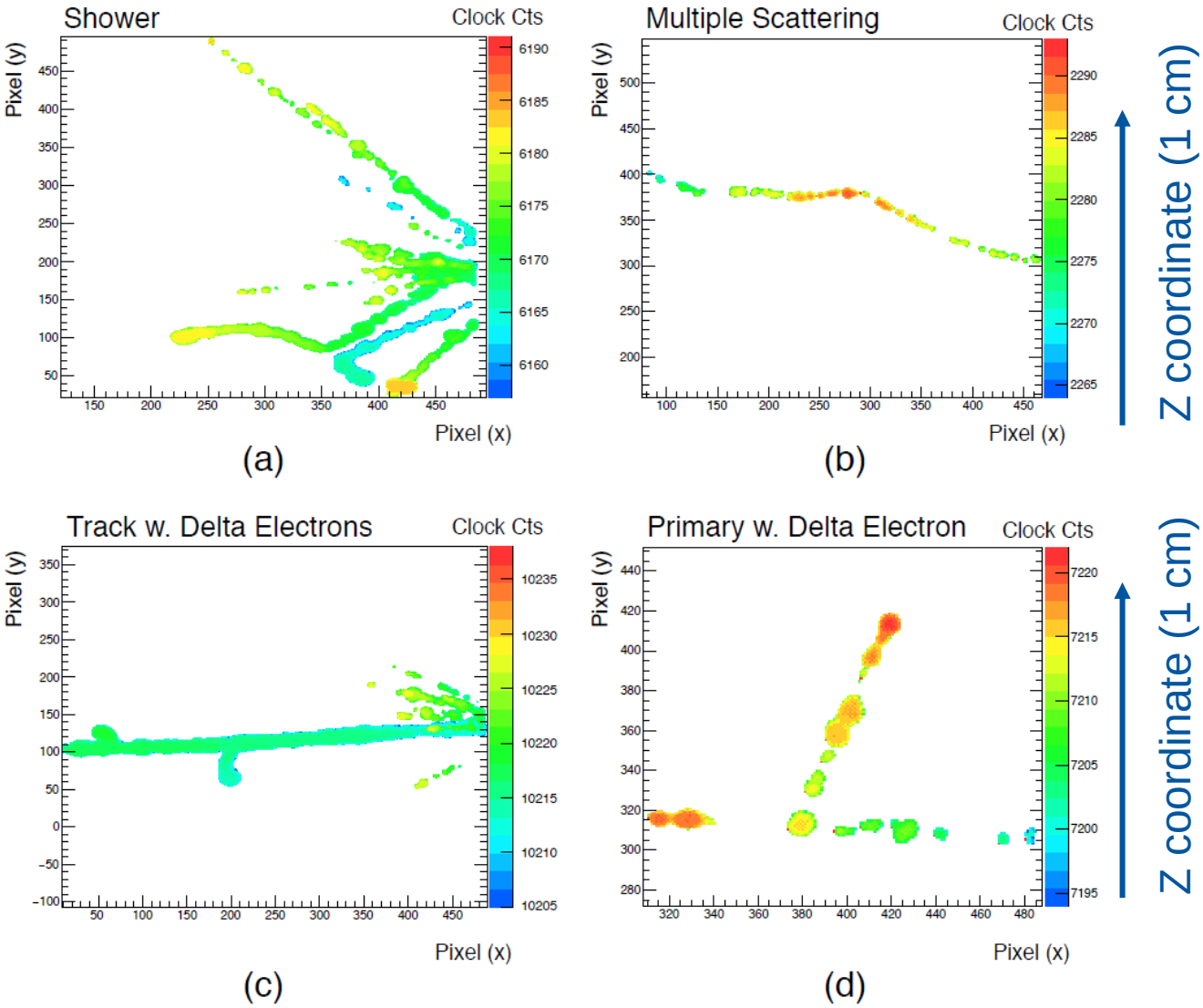
- Pulse counting
- Time of Arrival (TOA) → 3D track reconstruction
- Time over Threshold (TOT) → Charge and dE/dx

Timepix 3 will e.g. provide TOA+TOT simultaneously

3D Track Reconstruction (TOA)

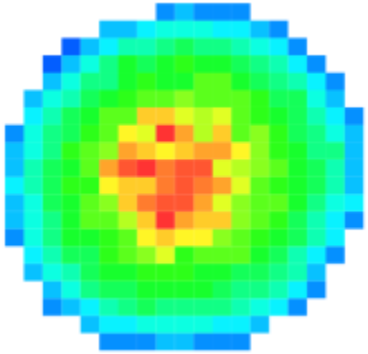
3x3 cm^2

Possibility to study single particles
→ lateral measurements
→ secondaries

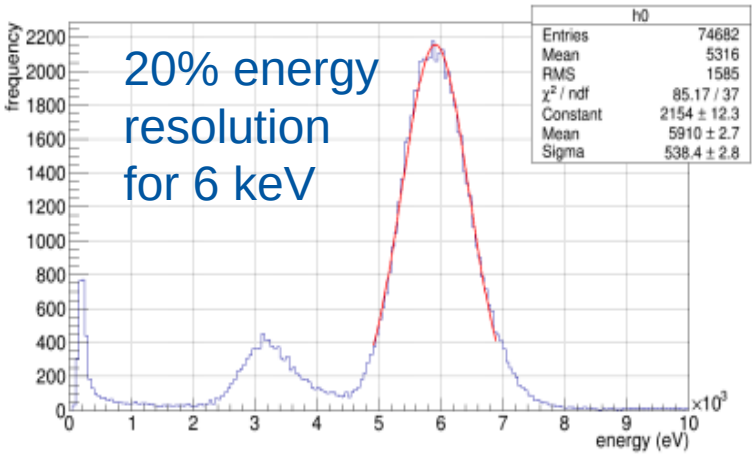


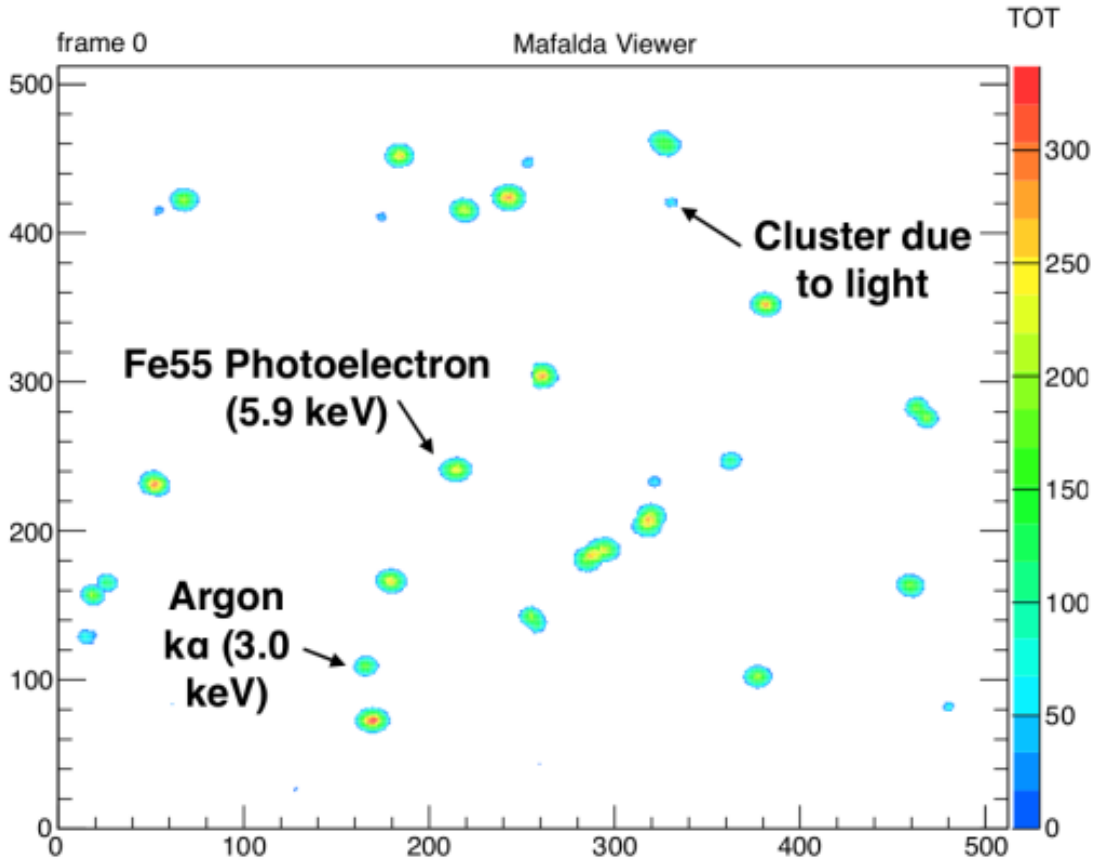
Charge Measurement (TOT)

X-ray detection: 6 keV from ^{55}Fe (1s frame)

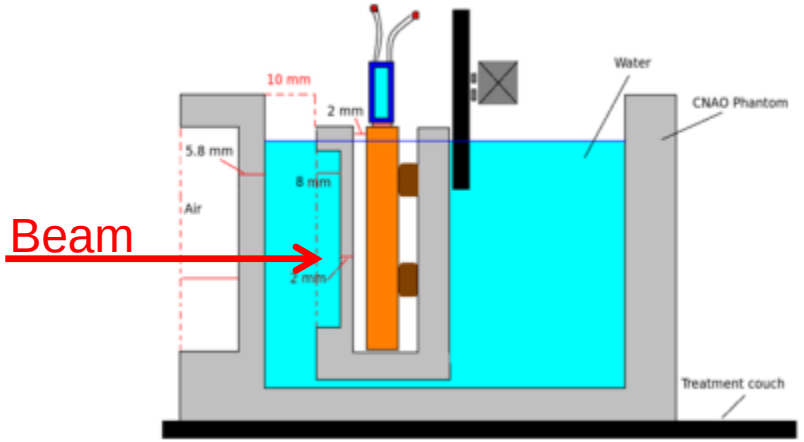


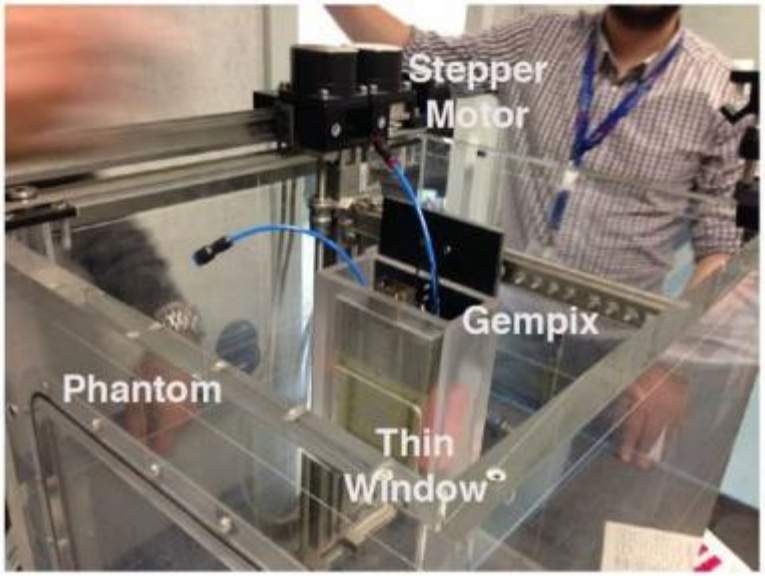
Single
6 keV
X-Ray





Setup at CNAO



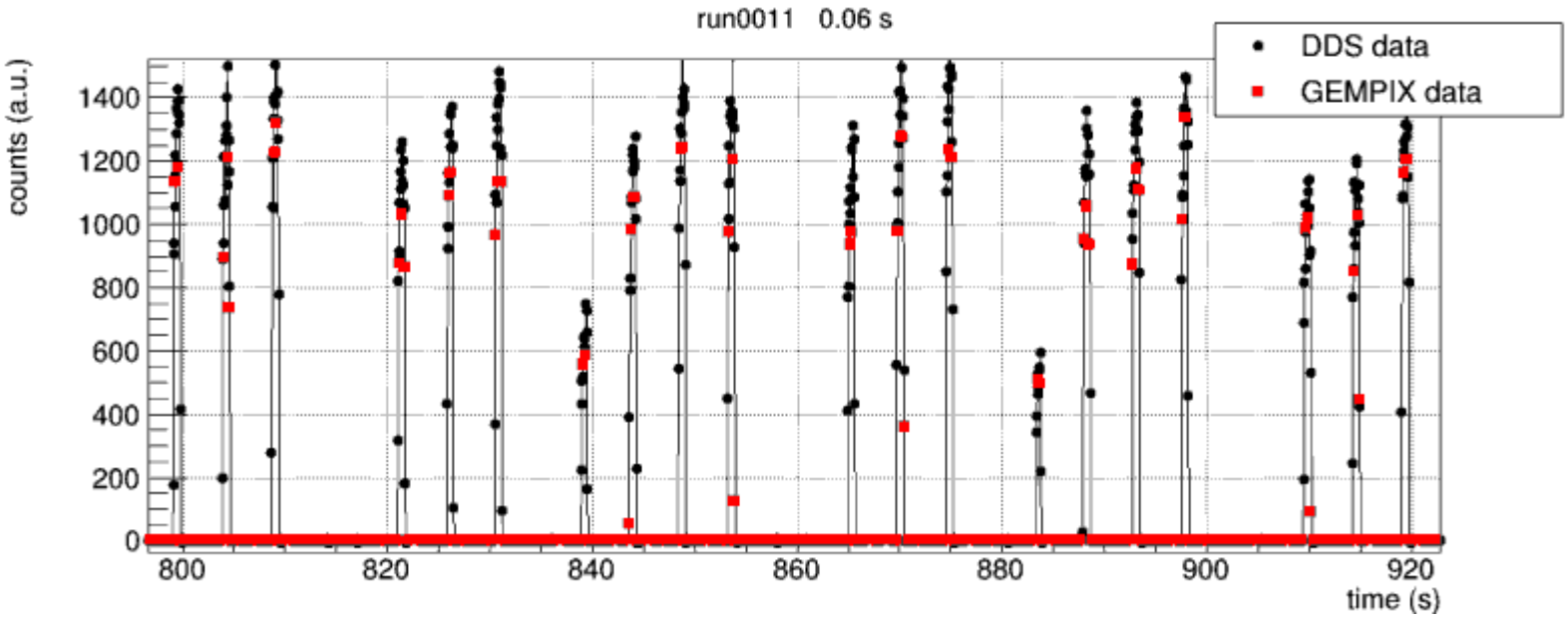


GEMPix inserted in a water phantom

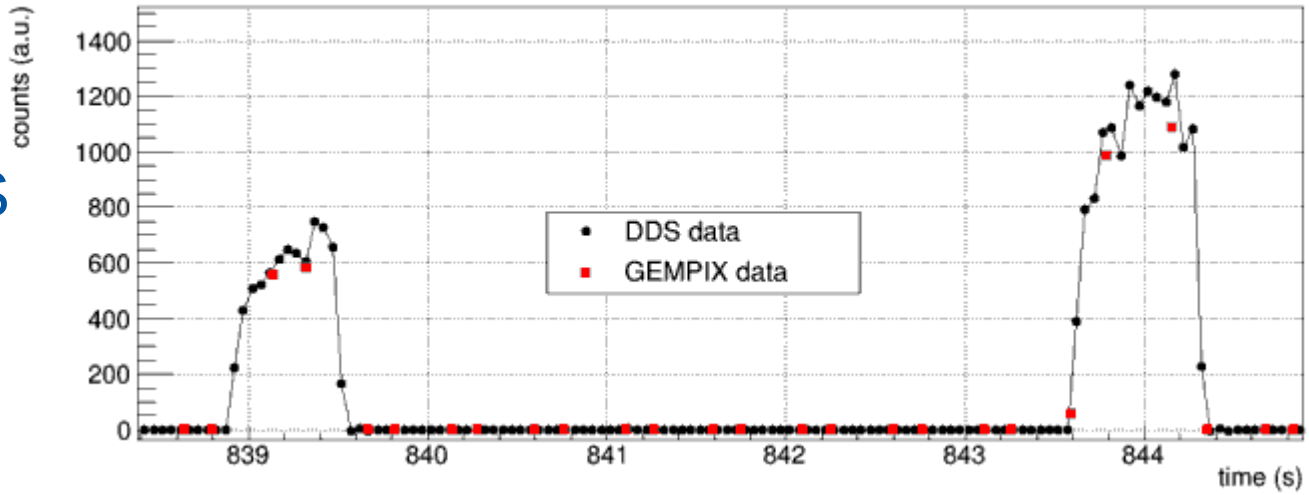
Measurements at CNAO

- Carbon ions
- Energy: 280 or 332 MeV/n
- Scan along beam axis, ~30 positions
- Frames (pictures) of 20 ms taken, 5-10 frames per position
- TOT mode
- Total: 20 min per scan
  - → Frames provide beam monitoring
  - → Integrated TOT counts per position provide Bragg Curve
  - → 3D reconstruction of energy deposition

Comparison DDS and GEMPix

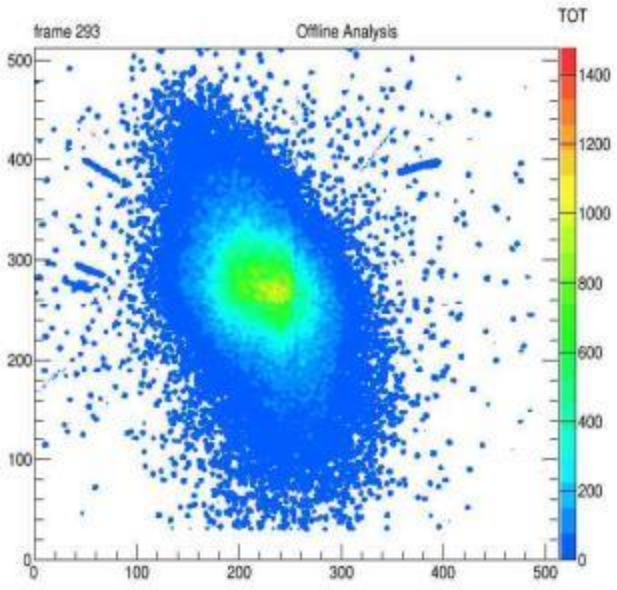


Good agreement between DDS and GEMPix

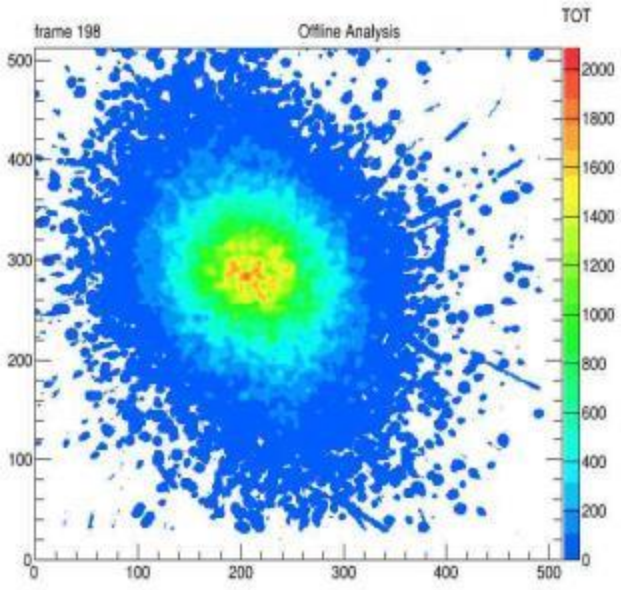


Beam Monitor

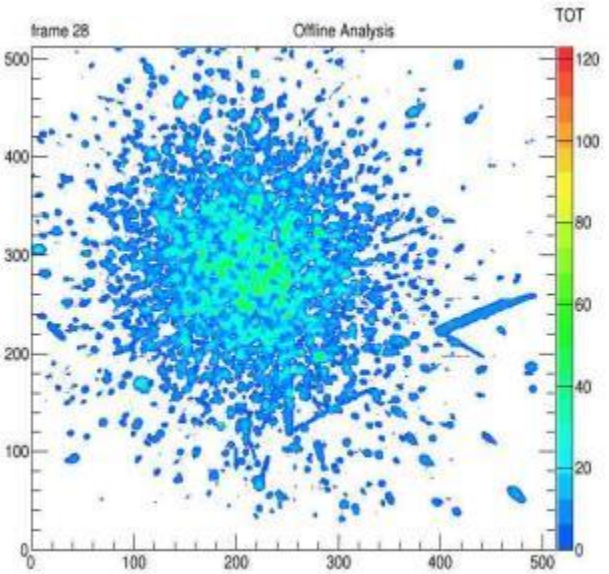
Plateau



Peak



Tail

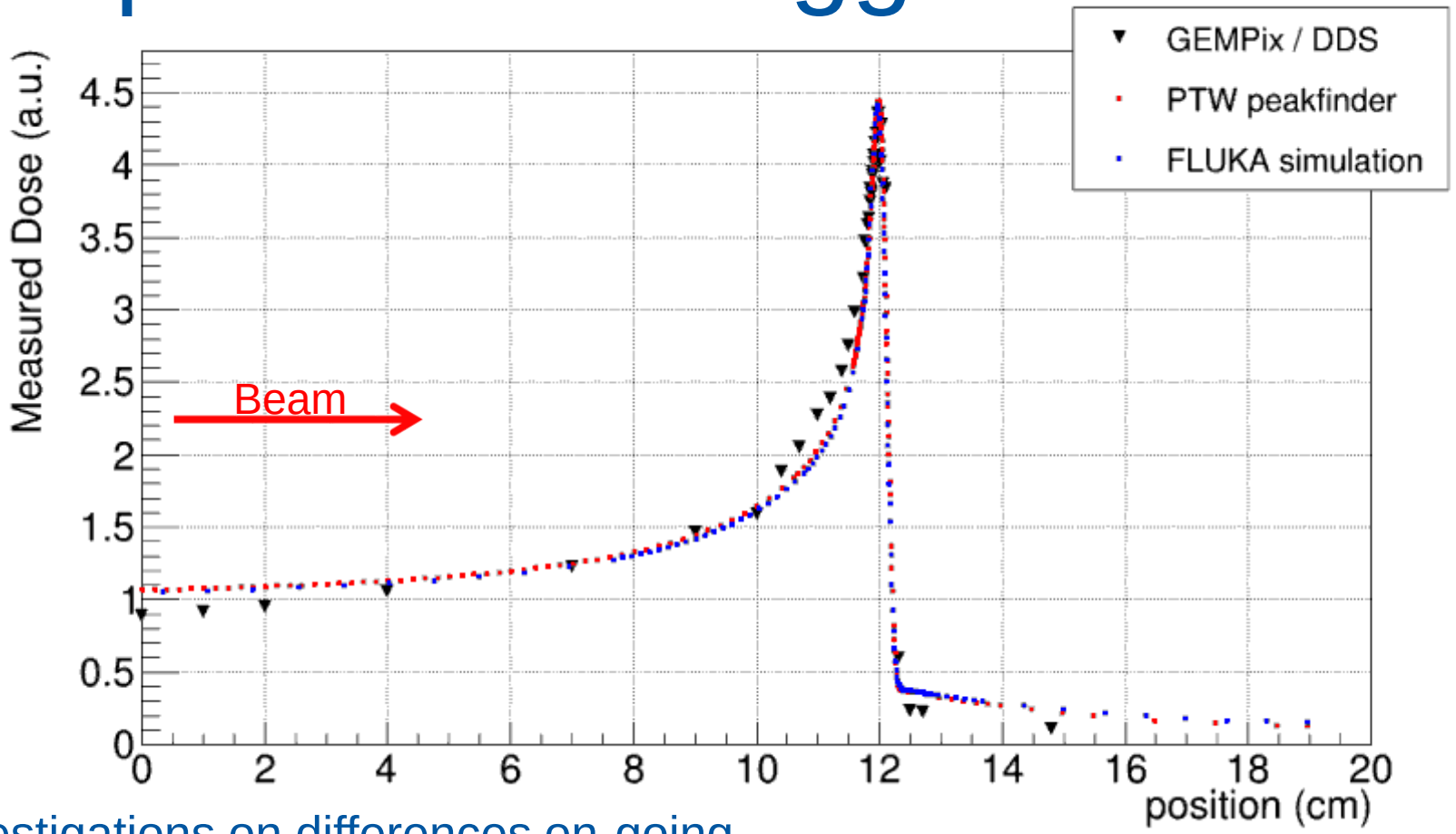


Beam spot taken on Plateau, Bragg Peak and Tail

Frame length: 20 ms / 100 ms (before / after the Bragg Peak)

Beam halo: single particle reconstruction

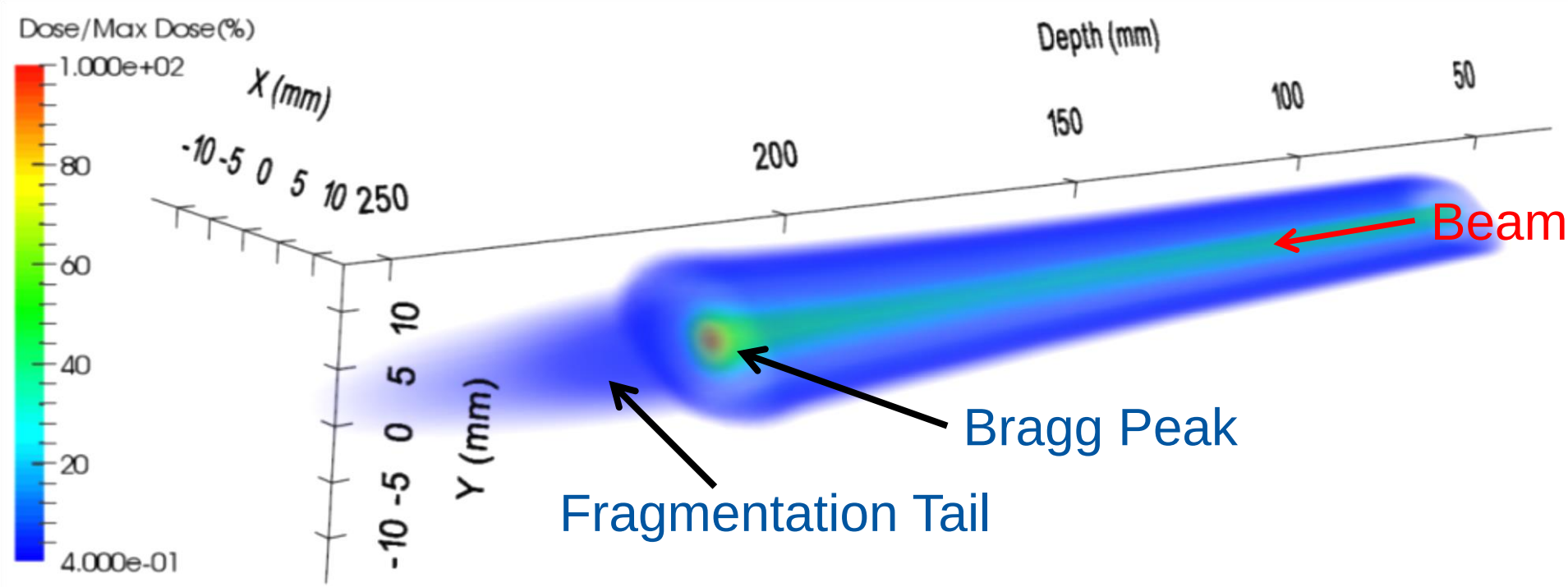
Depth Scan: Bragg Curve



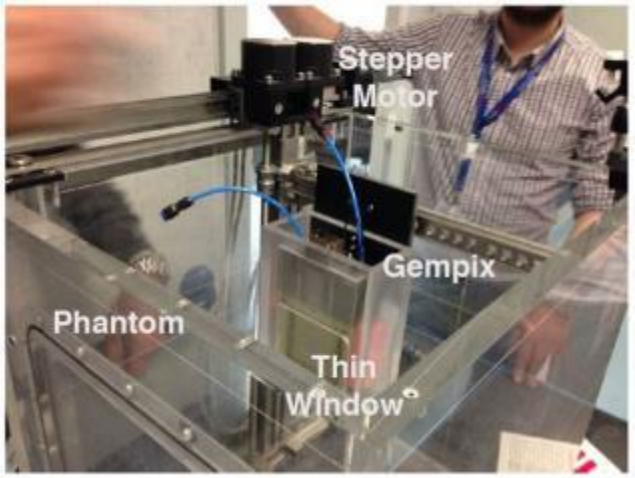
Investigations on differences on-going

In general: good agreement between reference measurements / simulation and GEMPix

3D Reconstruction



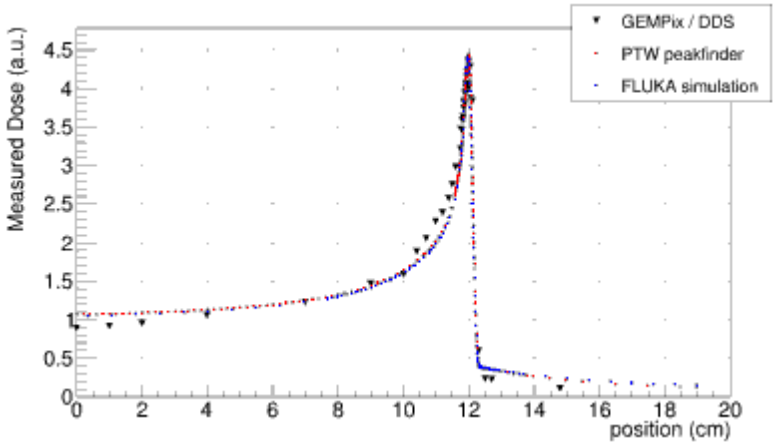
Old Setup

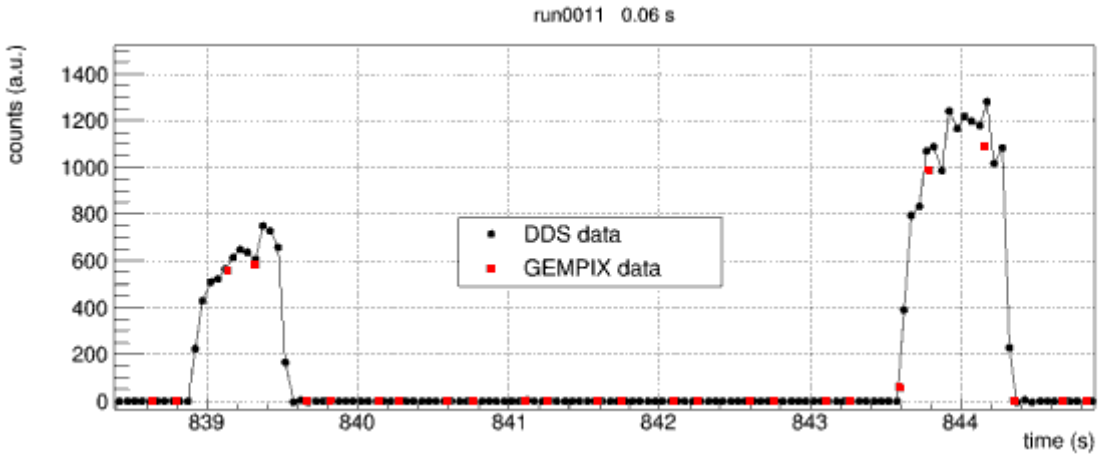


GEMPix
+ CNAO water phantom
+ CNAO Dose Delivery System

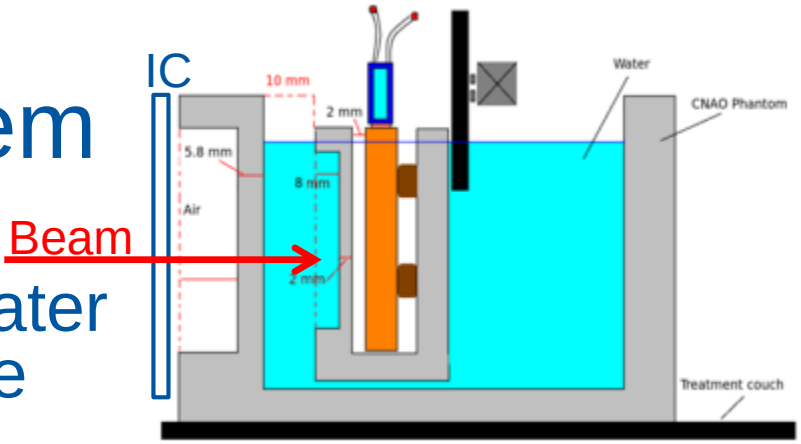
→ GEMPix must be dismounted after each shift
→ Timing issues with reference system
→ Study of differences in Bragg curve with more reliable setup
→ New issues when going to other beam facility?

→ Development of an integrated system!



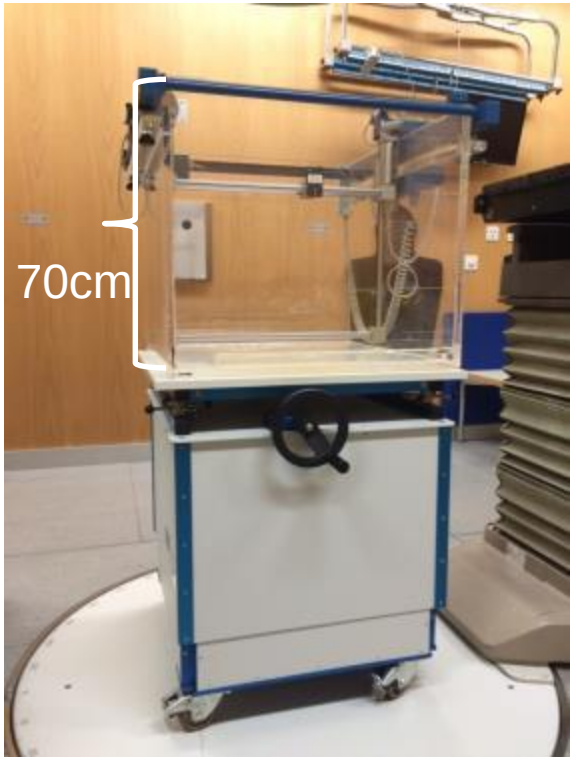


Outlook: Integrated System



Integrated system with GEMPix, water phantom, ion chamber as reference

- Water phantom was donated by Luzern hospital
- Ion chamber (PTW 34080) acquired
- Funded by MAPF
- Integration HW/SW at CERN Idea^S
- Tests at Linac4 (160 MeV)
- Measurements at clinical facilities
- Independent of local beam delivery system



Wellhoefer Blue Phantom

Thank you for your attention!