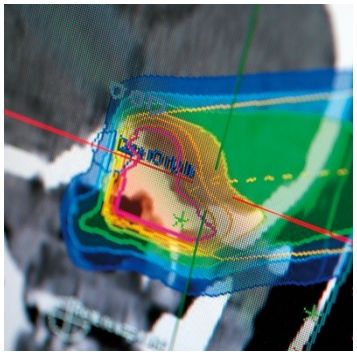
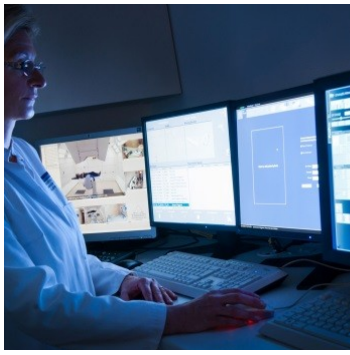
HEIDELBERG UNIVERSITY HOSPITAL

HIT Heidelberger Ionenstrahl-Therapiezentrum





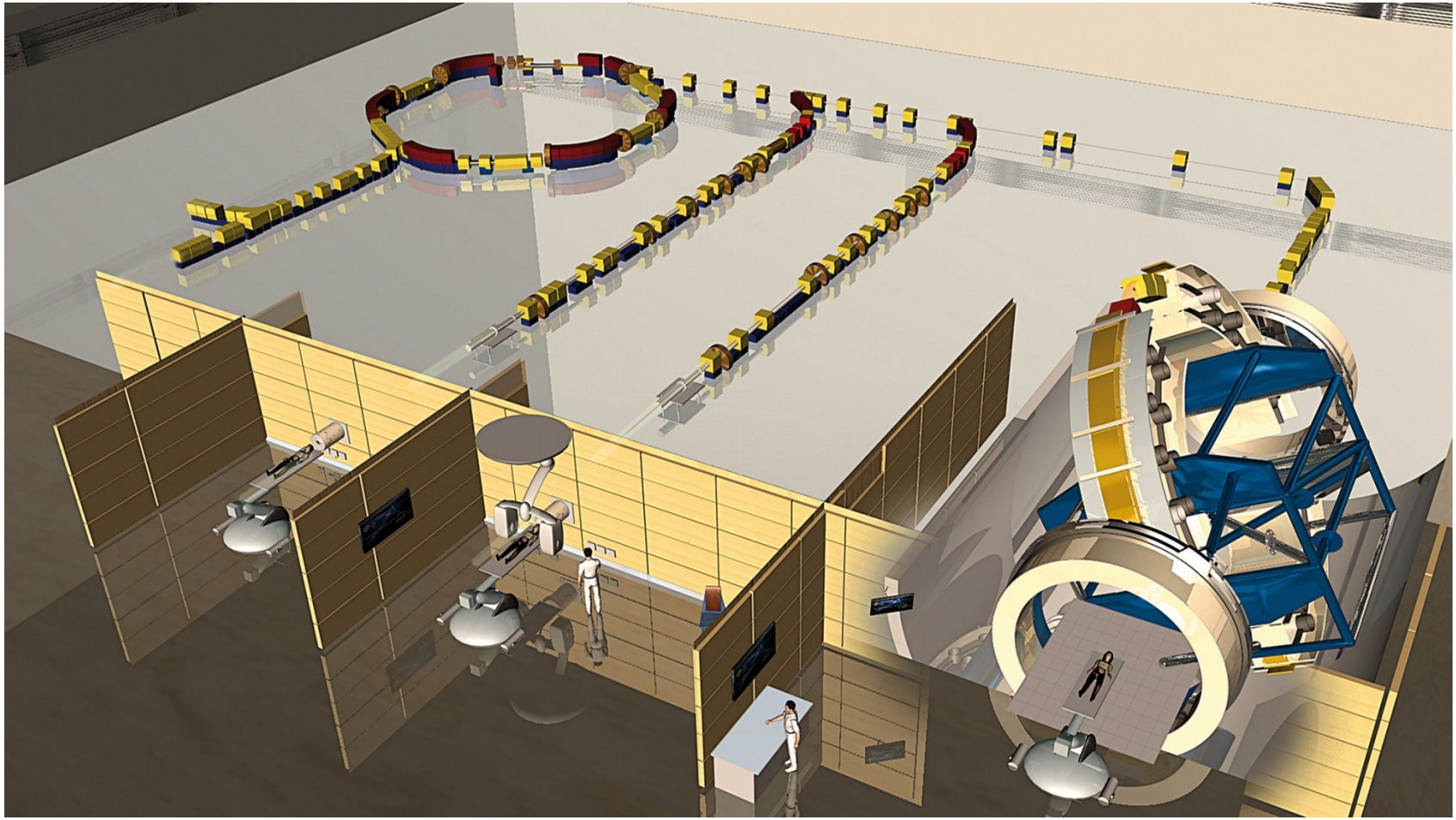
Usage of Scintillation Screens at the Medical Facility HIT

2nd April 2019,
ARIES-ADA topical Workshop on
Scintillation Screens and Optical Technology for transverse Profile Measurements

Harald Latzel
S. Brons, B. Hasch, J. Schreiner, J. Naumann, A. Peters, T. Haberer

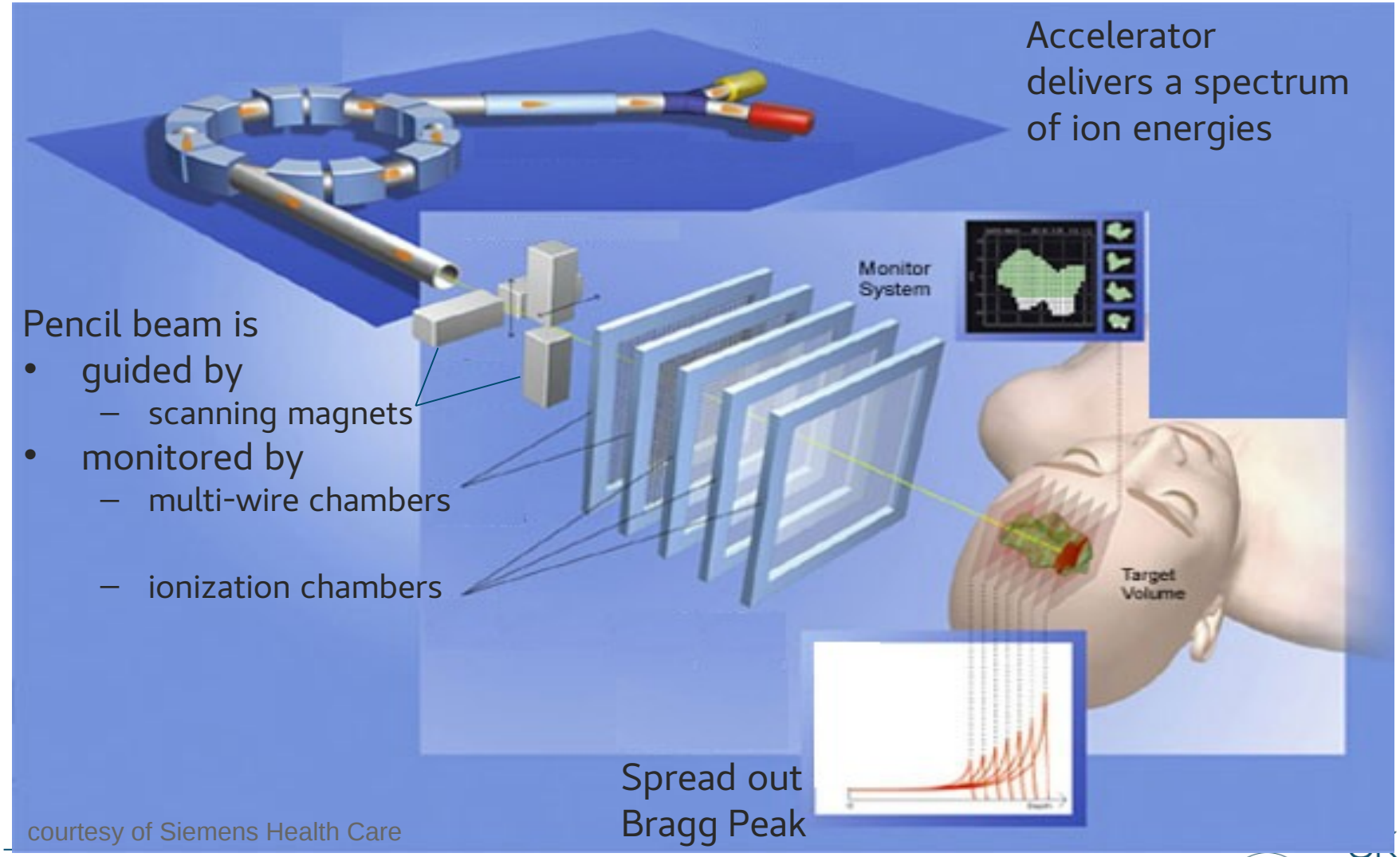
Overview of HIT Facility

Layout



How We Do Therapy

State of the art: pencil beam scanning



Pencil beam is

- guided by
  - scanning magnets
- monitored by
  - multi-wire chambers
  - ionization chambers

courtesy of Siemens Health Care

Beam Parameters at HIT

Precise dose delivery requires:

- Large variety of beam parameters
  - 4 ion types (**H, C**, He, O)
  - 255 energies (48 – 430 MeV/u)
  - 4 spot sizes(4 – 13 mm)
  - Intensity spectra (10^7 – 10^{10} part./ spill)
  - 36 gantry angles (0° – 360°)

- A control system, that makes any combination available cycle-by-cycle

What Are the Fields of Work in Medical Physics?

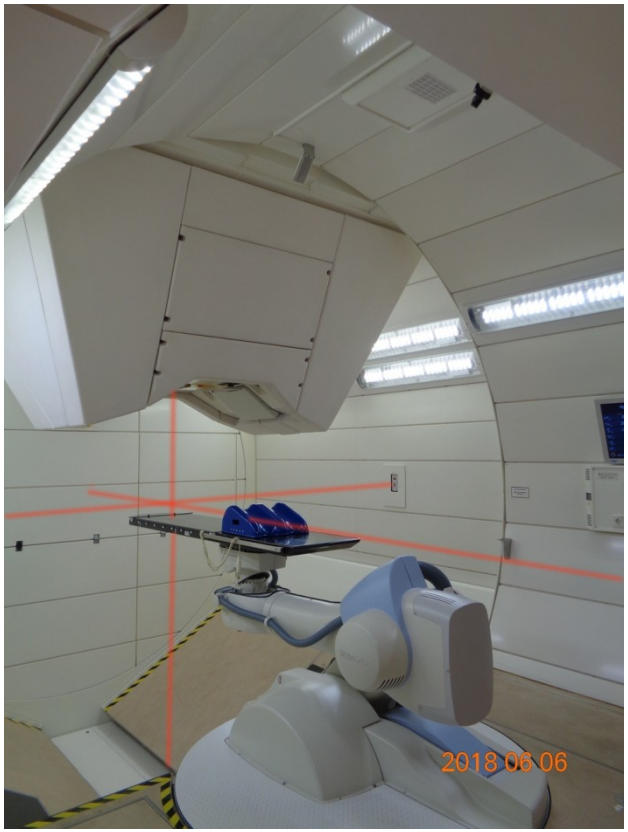
Quality assurance (QA)

- Safety checks (treatment rooms)
- Beam parameters
- Dosimetry
- Patient positioning
- Therapy planning
- Patient specific QA (Planverification etc.)

    - Ion species
    - Intensity
    - Energy (Range)
    - **Beam Position (allowed abs. deviation < 1 mm)**
    - **Beam Width (allowed deviation < +25%, > -15%)**

Concept of Isocenter

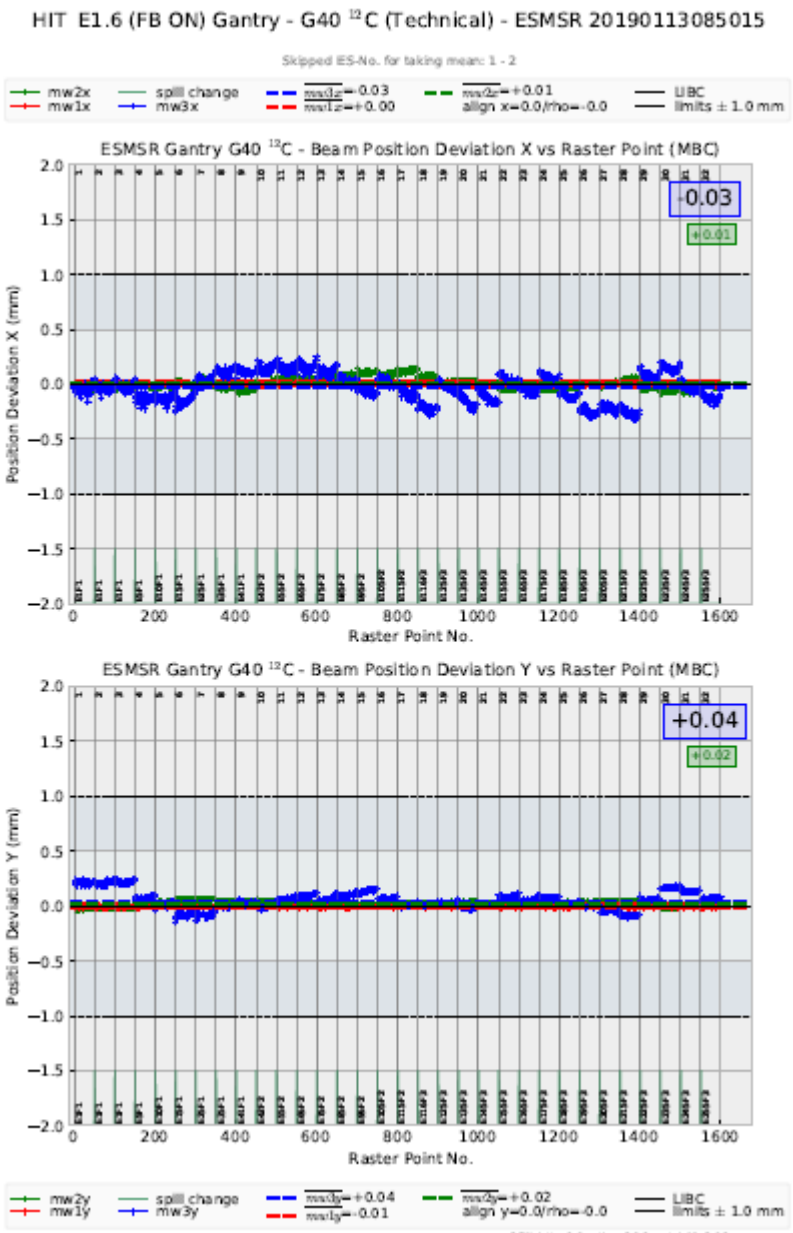
- defined by the crossing of the (virtual) vertical rotation axis of the treatment table and ideal beam axis
- marked by a positioning laser system
- target volumes normally located at or very close to the isocenter (as well as most detectors)



How We Measure Beam Position & Spot Size

Standard Tool

- Isocenter MWPC (Iso-MWPC)
  - spatial resolution: 0.1 mm
  - Integration time: 250 µs
  - Fully integrated in therapy control system
  - Easy handling /workflow except at Gantry



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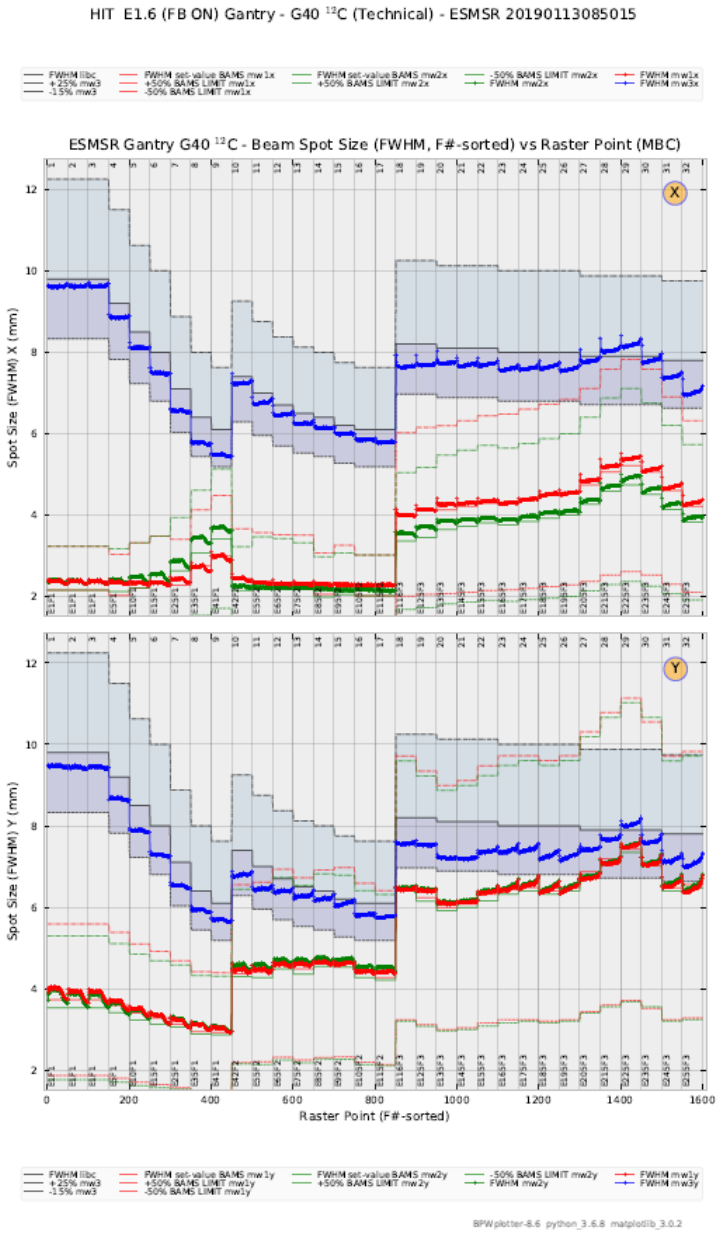
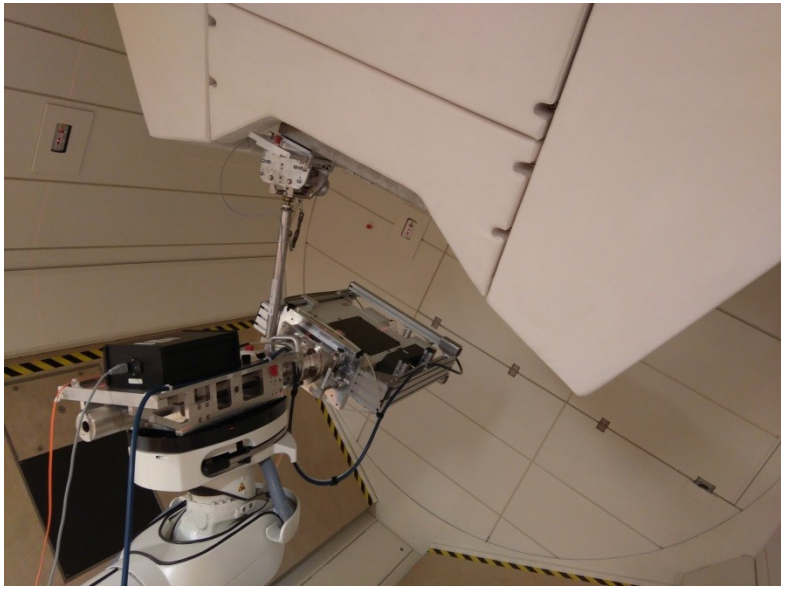


Measuring Beam Position & Spot Size with Iso-MWPC at the Gantry

- complex an time-consuming set-up
- Isocenter is not absolute – depends on gantry angle
  ➡ exact positioning not possible for all angles
- Better detector on treatment table
  ➡behaves like the patient
  ➡more accurate beam position measurement



Detector with Axial Symmetry

- Conical shape has axial symmetry
  - cone axis parallel to gantry axis
  - Open side is optical accessible
  - Scintillators could be made flexible

Conical Scintillation Screen

- Commercial product (Logos-Systems) available – does not match all HIT-requierements

Prototype Conical Scintillation Screen

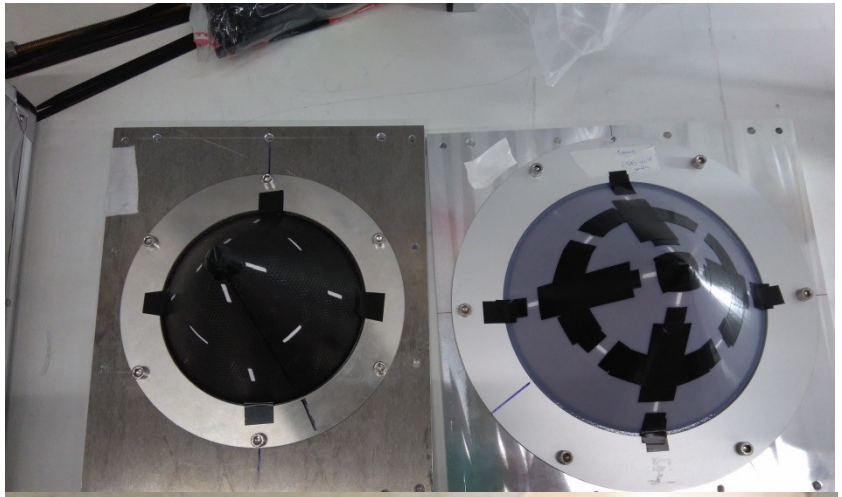
Study Design – what is important?

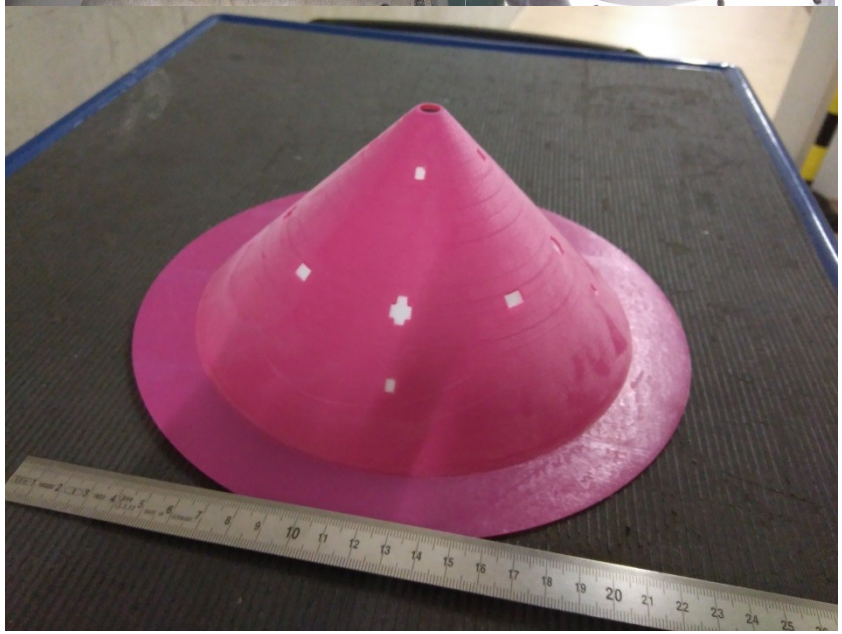
- Cone angle and size
- Positioning apertures for positioning lasers
- Cone material
- Scintillator material
- Camera and optics

Prototype Conical Scintillation Screen

Study Design – what was tested?

- Cone material
  - 3D prinited, composite material
- Cone angle
  - 30° and 45°
- Apertures for positioning lasers
  - Now very close to final design





Prototype Conical Scintillation Screen

Study Design – what was tested?

- Scintillator material
  - Carestream LANEX – green (phosphor: rare-earth compound)
  - Dr. Goos (AGFA) LGG 400 – green (phosphor: Gd2O2S:Tb)
  - Dr. Goos (AGFA) LGY 400 – blue (phosphor: rare-earth compound with Ytterbium)
  - Proxivision P43 (phosphor: Gd2O2S:Tb) – not yet tested

Prototype Conical Scintillation Screen

Study Design – what was tested?

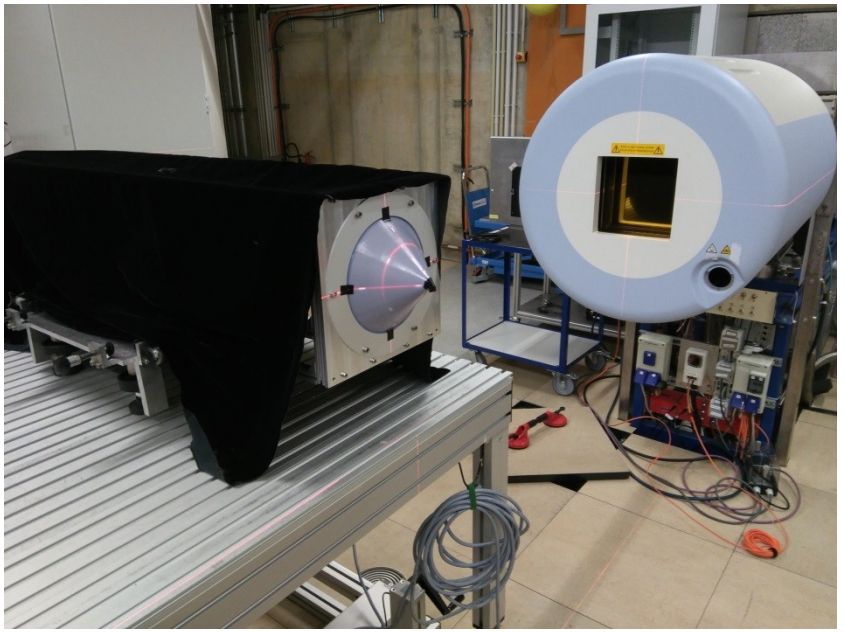
- Camera and optics

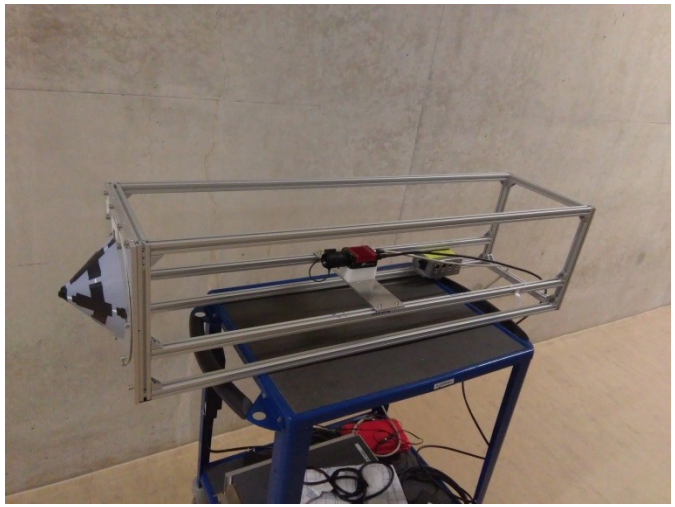
	Hama. Orca	AV GT-2450	AV GT-2460
Resolution (pixel)	1344 x 1024	2448 x 2050	2464 x 2056
Pixel size (µm)	6.45	3.45	3.45
Sensor type	CCD	CCD	CMOS
Sensor Dimension (mm^2)	8.67 x 6.60	8.45 x 7.07	8.50 x 7.09
Bit Depth	16	14	12
Objective (focal length, mm)	25	16	16
Distance Obj.– Isoz. (30° / 45°) (mm)	~730 / ~ 850	~525 / ~ 542	522 / ~ 540
Depth of field (theor., k-dep., lower Limit, mm)	~75	~ 65	~ 65
Optical resolution (30° / 45°) (theor., mm)	0.15 / 0.2 mm	0.07 / 0.1	0.07 / 0.1

Prototype Conical Scintillation Screen

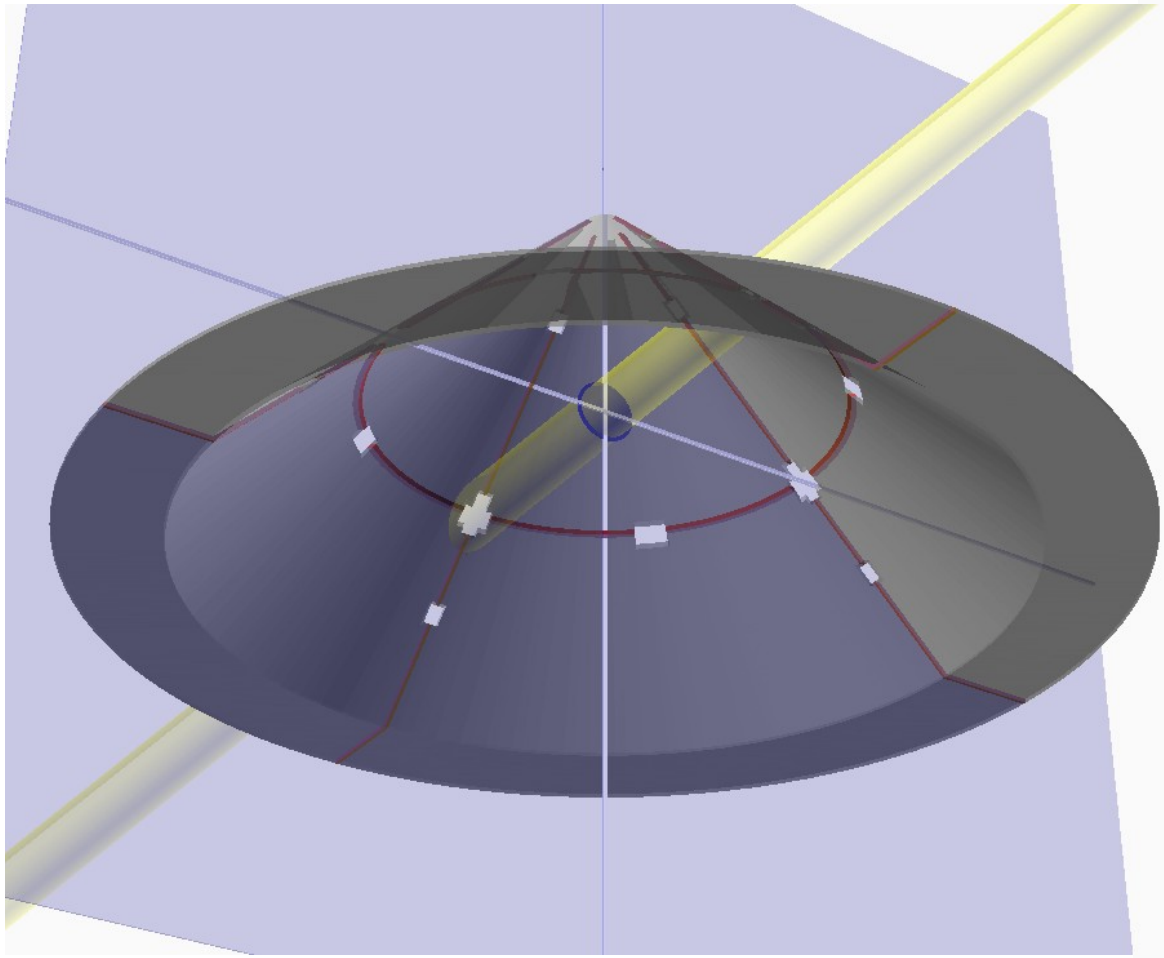
Study Design

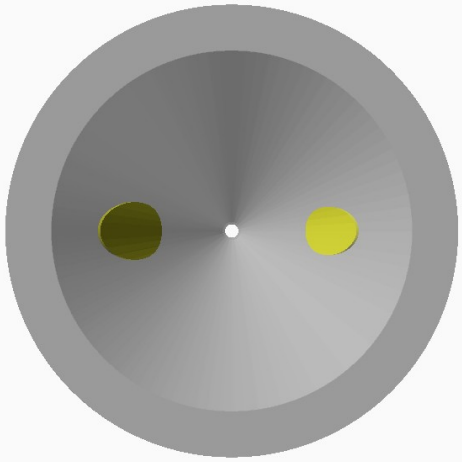
- Construction of a prototype

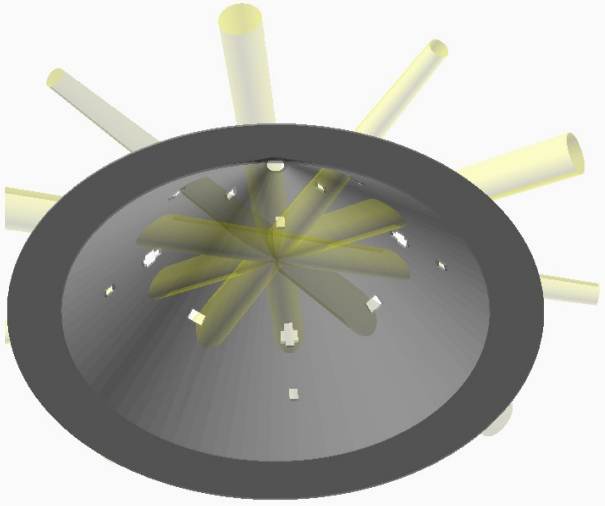




Mathematical Model







Mathematical Model

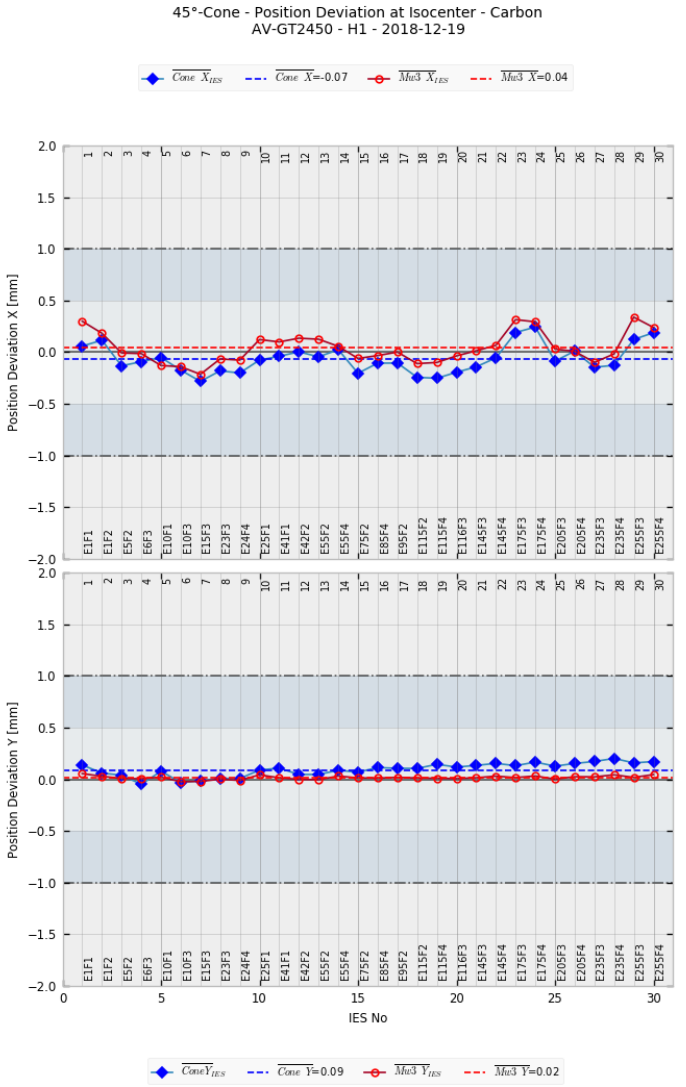
- Model parameters
  - Corrections
    - Background
    - hot / dead pixel (random, during irradiation)
  - Setup of detector
    - Treatment room
    - Camera
    - Objective
    - Sensor
    - Distance sensor – cone
    - Cone geometry

Mathematical Model

- Model parameters
  - Registration of cone – crucial point
    - Picture of laser marks to construct / define isocenter (planes)
  - Reconstruction of beam spots
    - Projection of the 2 spots onto iso-plane (mapping 3D → 2D)
    - Position
      - Raw data (2D-pixel distribution)
      - center of gravity, pixelwise, ray optics
    - Spot size
      - Profiles from 2D distribution on iso-plane (each spot seperated)
      - Double Gaussian fitting, initial values from statistics
      - Resulting spot size averaged from both spots

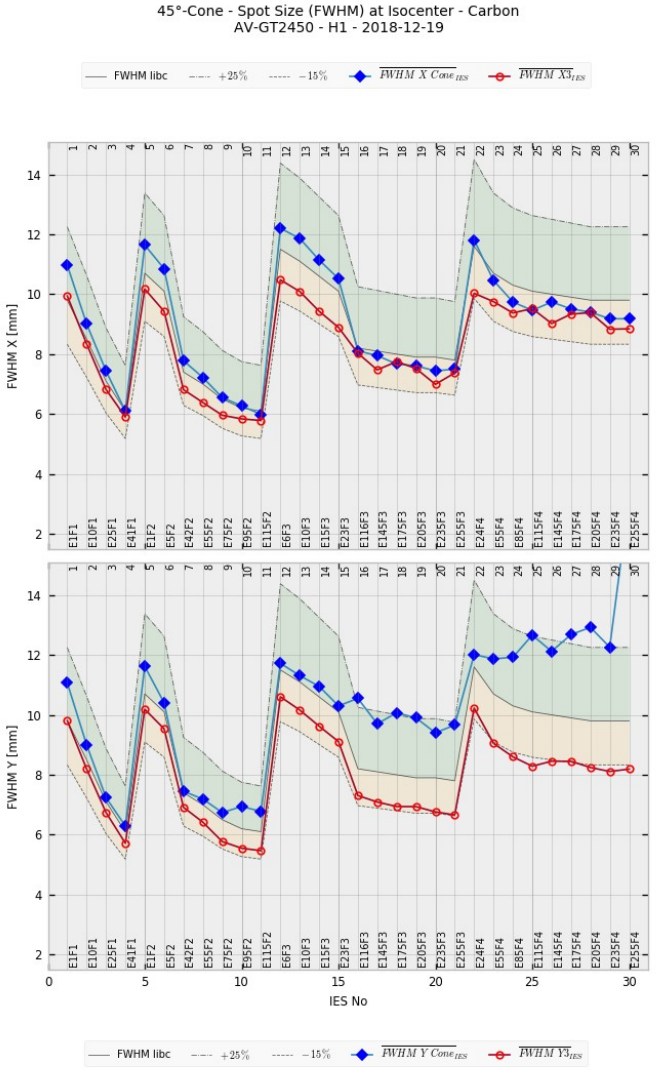
Measurements & Results

- Carbon ions at horizontal room 1
  - Position deviation at isocenter



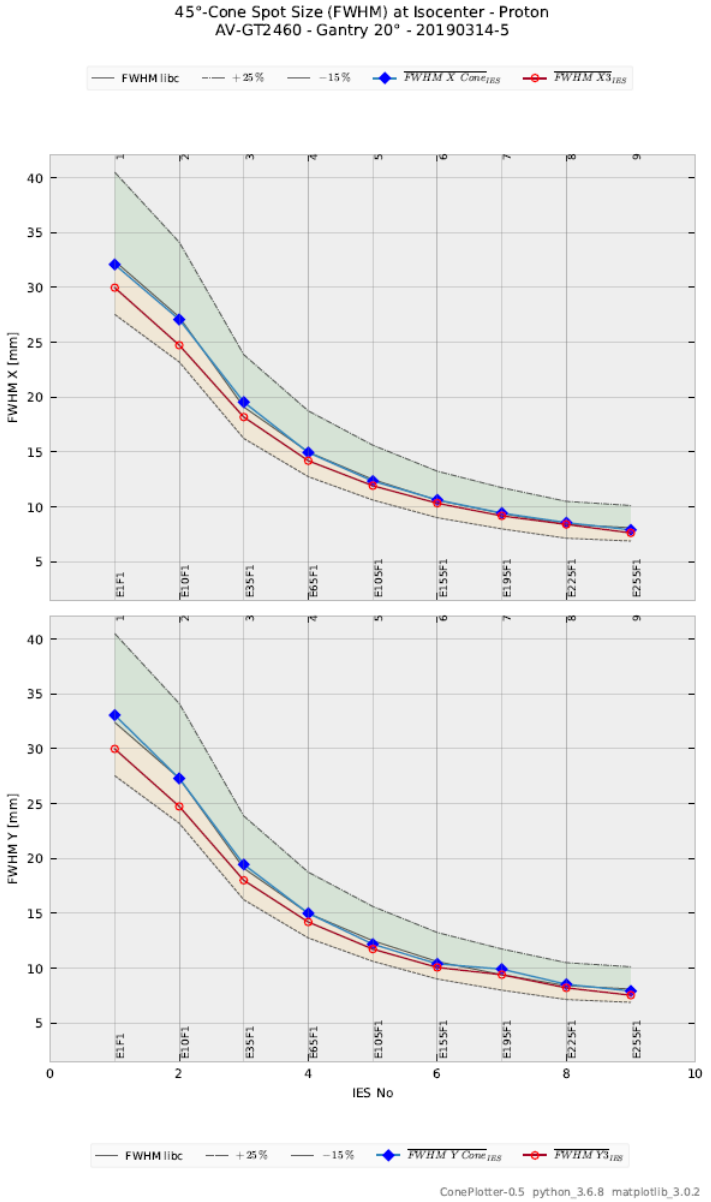
Measurements & Results

- Carbon ions at horizontal room 1
  - Position deviation at isocenter
  - Spot Size (FWHM) at isocenter



Measurements & Results

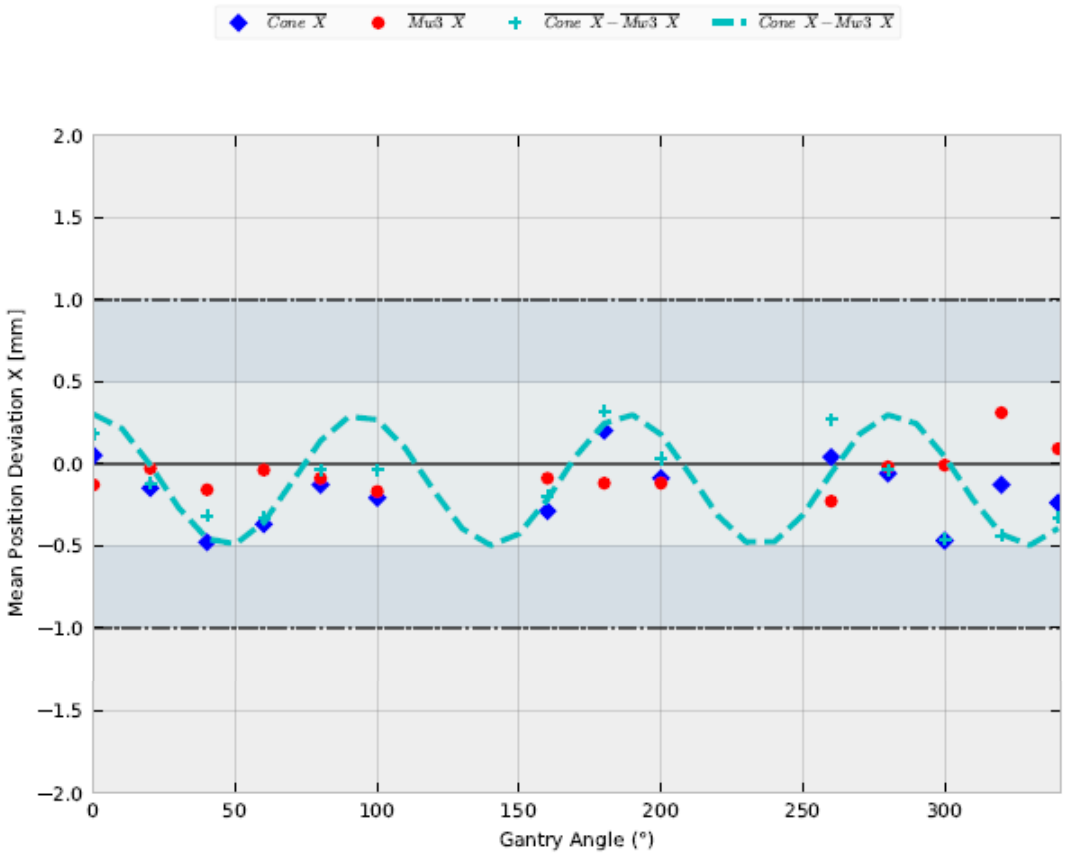
- Protons at gantry
  - Position deviation at isocenter
  - Spot Size (FWHM) at isocenter



Measurements & Results

- Protons at gantry - comparison of Iso-MWPC vs cone

- 1st attempt of an interpretation concerning the relative movement between Iso-MWPC and cone on treatment table (it‘s not a fit)



Conclusion & Outlook

- Measuring position works quite good
  - Accuracy around 0.1 mm
  - Good correlation to standard detector
  - Problems with 12C spot sizes of higher energies
  - Robustness of repeatability still to be tested

- Still to improve / optimize
  - Mechanics
    - Housing
    - Camera mounting, calibration & positioning tools
  - Cone made of composite
  - Scintilator material
    - Inclusive inserting an positioning in cone
  - Camera
  - Software for aquiering, analyzing & archiving
  - Workflow

Thank you!

And the entire HIT team, especially:
S. Brons, B. Hasch, J. Schreiner, J. Naumann, A. Peters, T. Haberer