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Horizontal beam line for therapy

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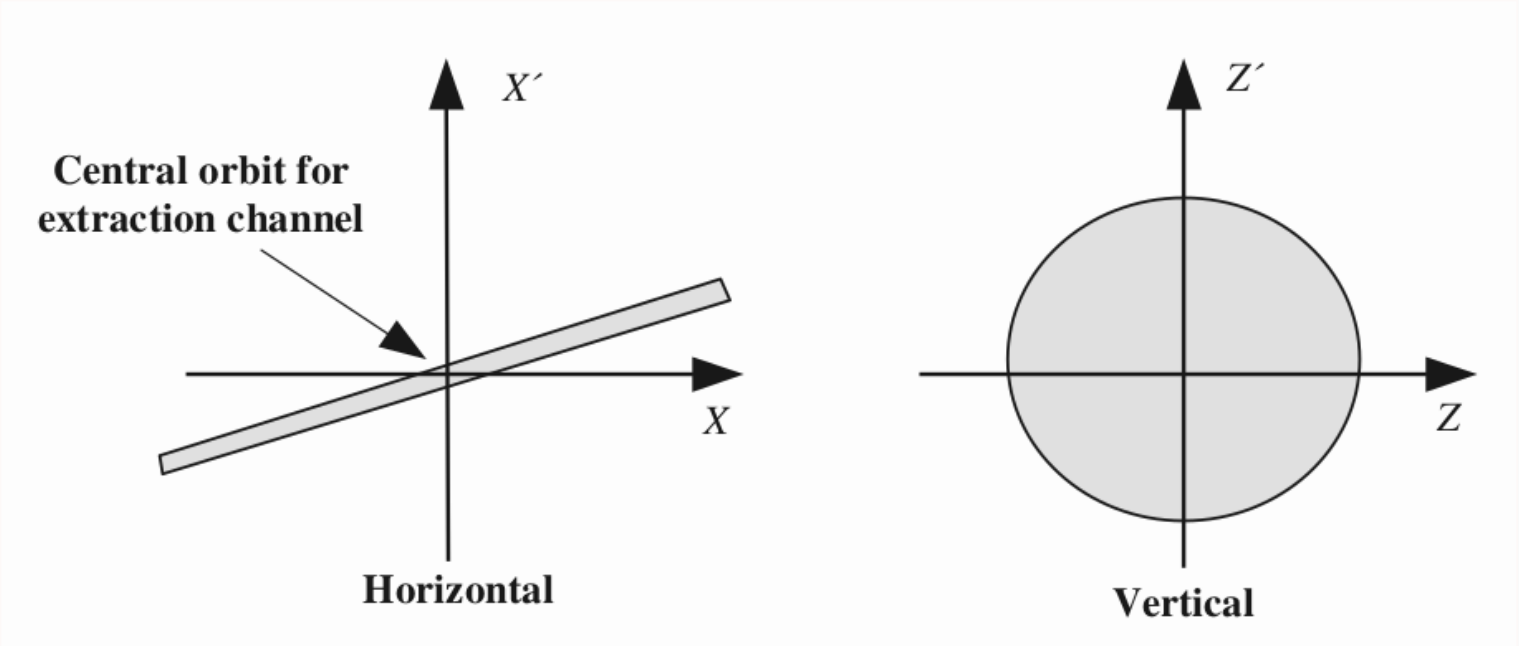
The role of beamline

- Transform extracted transverse beam shape and size to the shape and size required on the patient
- Scan the beam on patient (active scanning systems)
- Provide good transmission (minimize losses)
- Tolerant to quad errors (eg. due to temperature drifts) and variation of extraction parameters

The layout of the shortest is determined by the required beam size range on the patient. Longer beam lines have more degrees of freedom (they are not as limited as the shortest one). Gantry has special requirements.

The spill - slowly extracted beam

- All useful slow extraction processes generate beam with very small horizontal emittance in the shape of *bar of charge*
- The vertical emittance of extracted beam is a standard ellipse



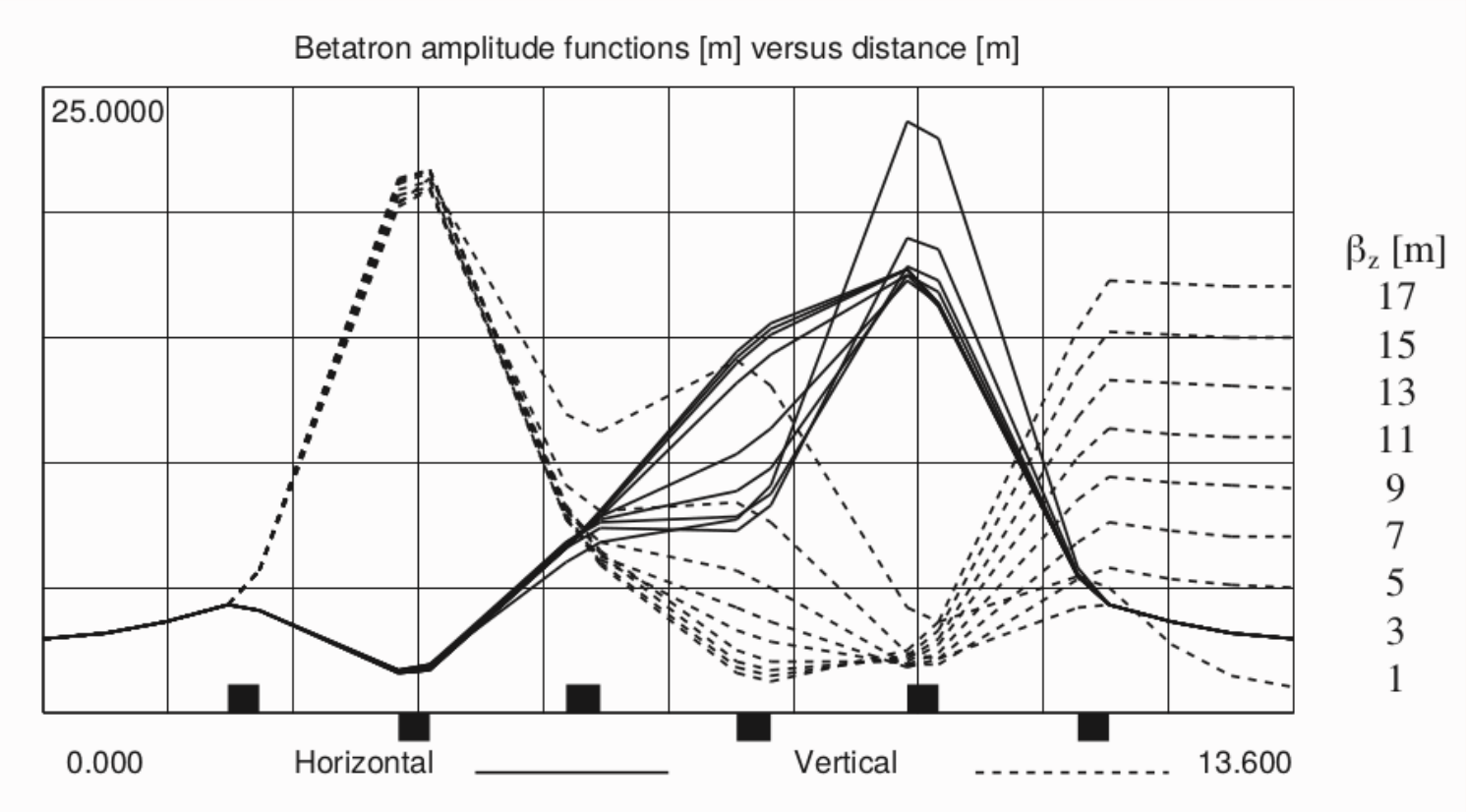
PIMMS modular approach

PIMMS report, Volume 1 Section 9 - modular beamline design.
Main ideas:

- Control horizontal beam size on the partient by rotating *bar of charge* - a group of quadrupoles dedicated to this task is called *phase shifter*
- Control vertical beam size by standard change of betatron amplitude - a group of quadrupoles dedicated to this task is called *stepper*
- *Phase shifter* and *stepper* are actually identical and can be combined together to make a *phase shifter-stepper* module
- MedAustron uses *phase shifter-stepper* module

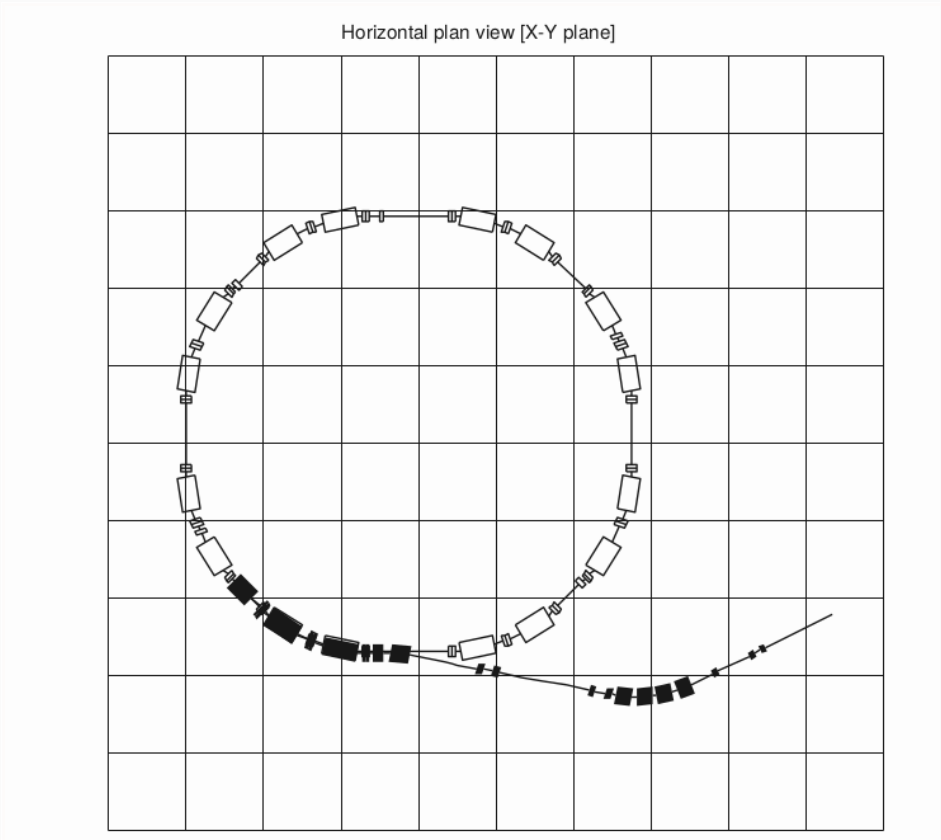
Phase shifter-stepper

- *Phase shifter-stepper* module is made of 6 quadrupoles
- It is 13.6 m long
- One *phase shifter-stepper* module is installed before the first switching dipole and used ot regulate beam sizes on all lines



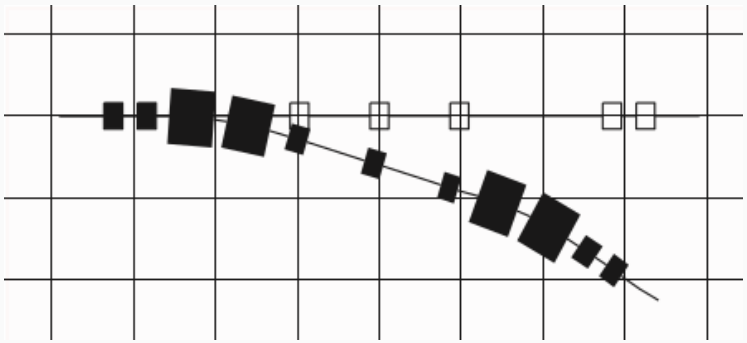
Matching section

- The *phase shifter-stepper* module accepts zero-dispersion beam as input
  (this is necessary if we want to keep the modular design)
- In order to do this there is a *matching section* before the *phase shifter-stepper* module



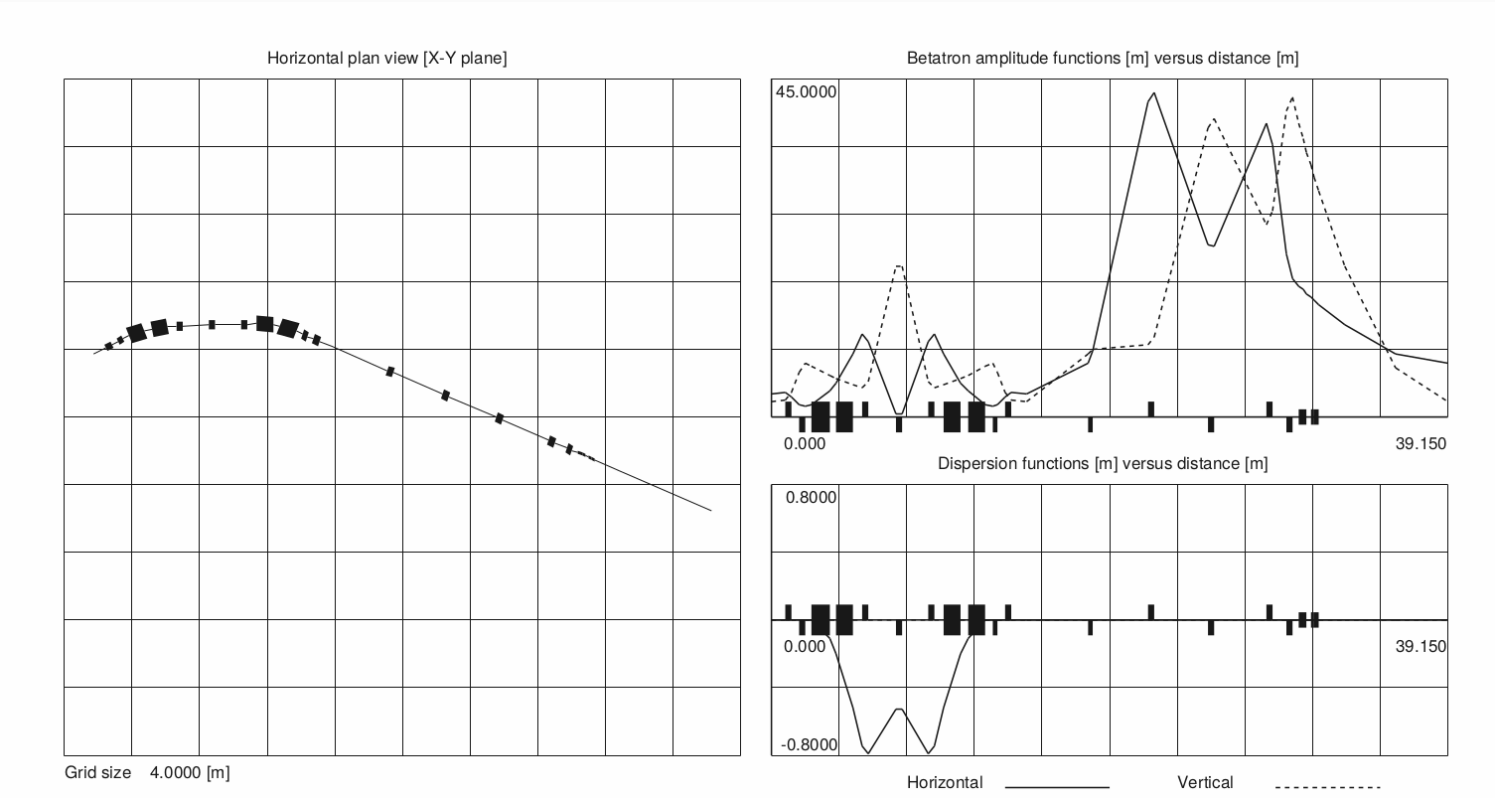
Extension modules

- After *phase shifter-stepper* module beam transport to the patient is done by telescopic extension modules
- In order to conserve beam shape, these modules have phase advance $n\pi$ and $\alpha_{out} = \alpha_{in}$
- They can provide beam size magnification (redundance: this is already done by *phase shifter-stepper*)
- They can contain close-dispersion bends



Scanning extension module

- The last module before the patient contains two scanning dipoles after the last quad
- Contraints on phase advance $n\pi$ and $\alpha_{out} = \alpha_{in}$
- The scanning magnets can be before the last quads - scanning is more parallel, but larger aperture is needed

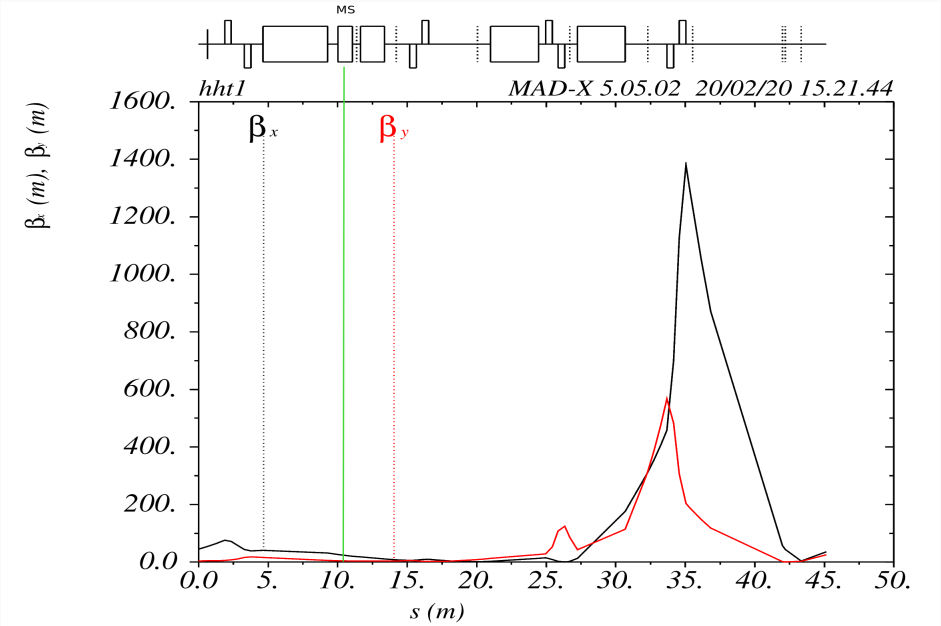


Summary of horizontal line

- Modules: matching + *phase shifter-stepper* + closed-dispersion bend + scanning
- Distance from magnetic septum to patient: 23.3m+13.6m+12m+27m = 75.9 m
- Number of magnets: 25 quadrupoles and 8 (small) dipoles
- What about chopper? Extra 5m
- PIMMS matching section and scanning section seem to be designed with wast space, even MedAustron looks more compact (investigating details)

Horizontal line in HIT

- Theoretically 6 parameters have to be matched on patient: β_H, β_V, α_H, α_V, D_H, D'_H. Only 6 quadrupoles are needed!
- Indeed HIT uses 6 quadrupoles on horizontal line
- HIT and PIMMS quadrupoles have similar length (0.5 m)
- Distance from magnetic septum is only about: 35 m
- There are only 3 (massive) dipoles after magnetic septum



Horizontal line in HIT

- Original PIMMS modular design of transfer line lattice is nice, buy way too large/expensive/complex
- We know from HIT that they have troubles to set the first beam line - missing quadrupoles
- Custom design is more difficult to set up and debug - more diagnostics is helpful
- Nevertheless I think we should go for custom design, but:
  - add 2-3 quads and a few meters of space to the common part of the beam line after extraction
  - keep zero dispersion along the main beamline
- In the last layout (Feb 12) the length of the first beamline is about 30 m