Space Charge Simulations

16/12/2020

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Introduction

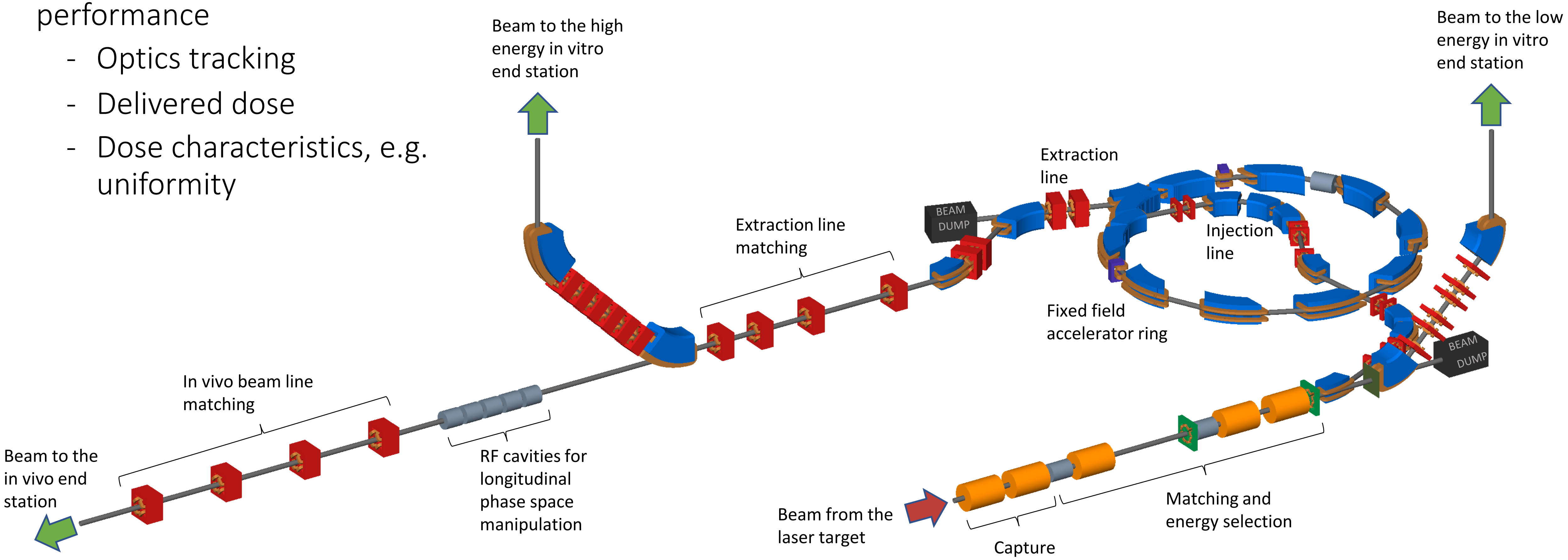
- Recap of beam line optics & performance

- Recent progress - model development

- Simulation & development plans

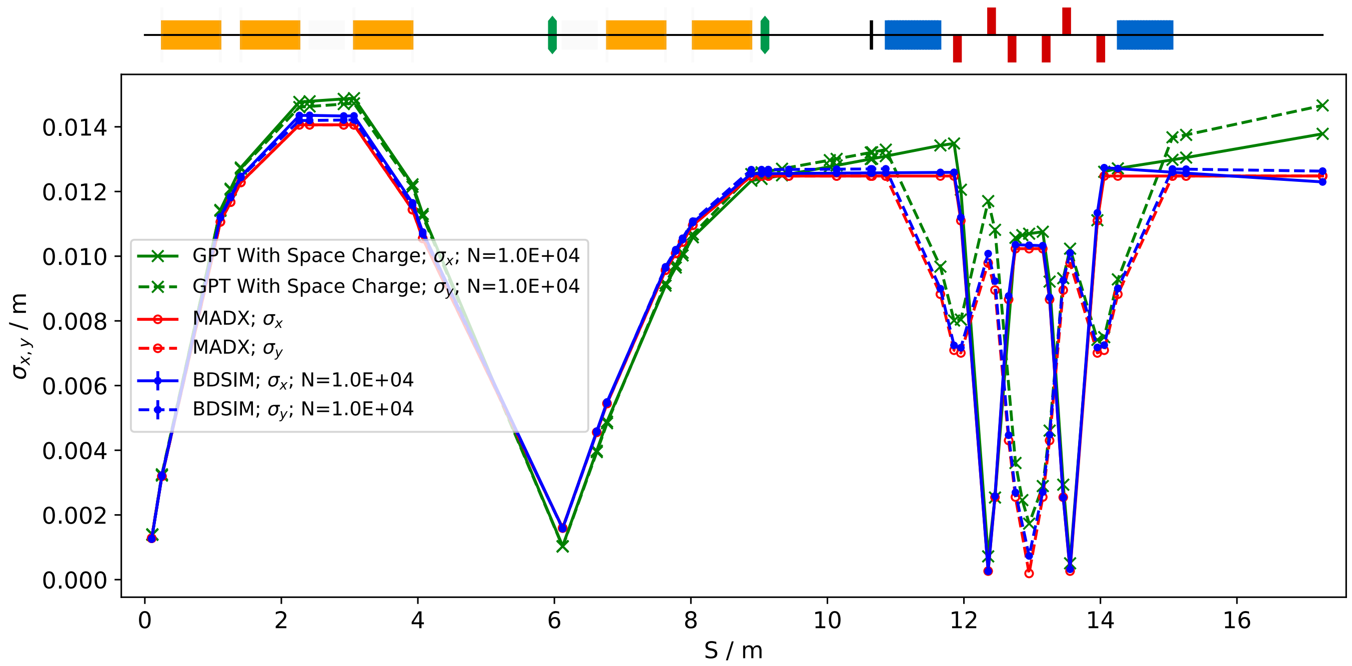
LhARA Beamline

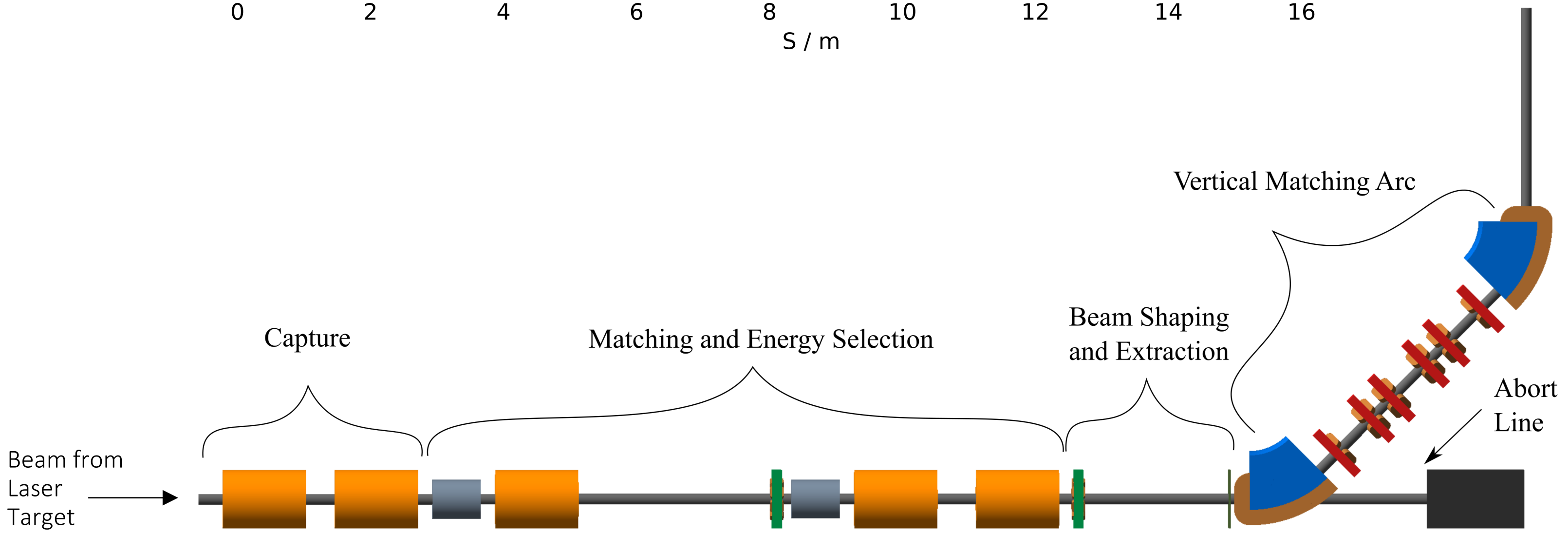
- Start-to-end simulations to evaluate machine performance
  - Optics tracking
  - Delivered dose
  - Dose characteristics, e.g. uniformity



Stage 1 - Recap

- Original model :
  - Gabor lenses simulated as solenoids
  - No RF fields simulated
- Improvements since (see Titus' and HT's talks)
  - Gabor lenses & collimation
- Excellent agreement between MADX and BDSIM
- Reasonable agreement seen between BDSIM and GPT with space charge
- Optimisation still required
  - Improved beam description
  - Octupole positions & strengths
  - RF parameters





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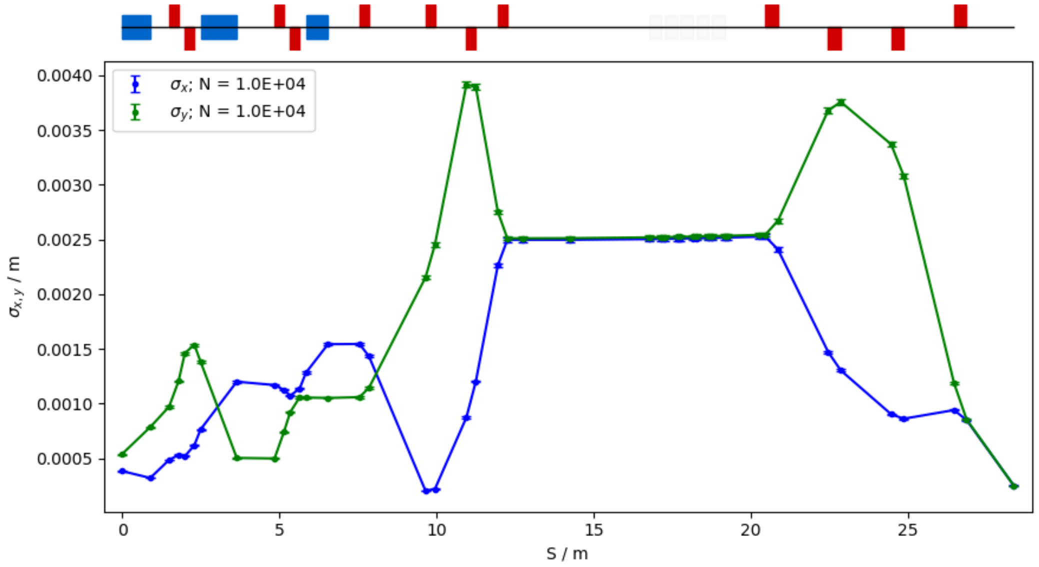
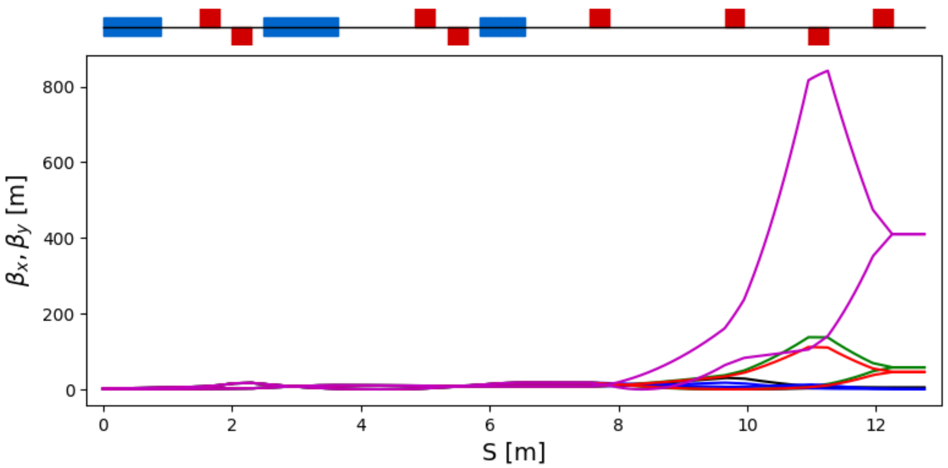
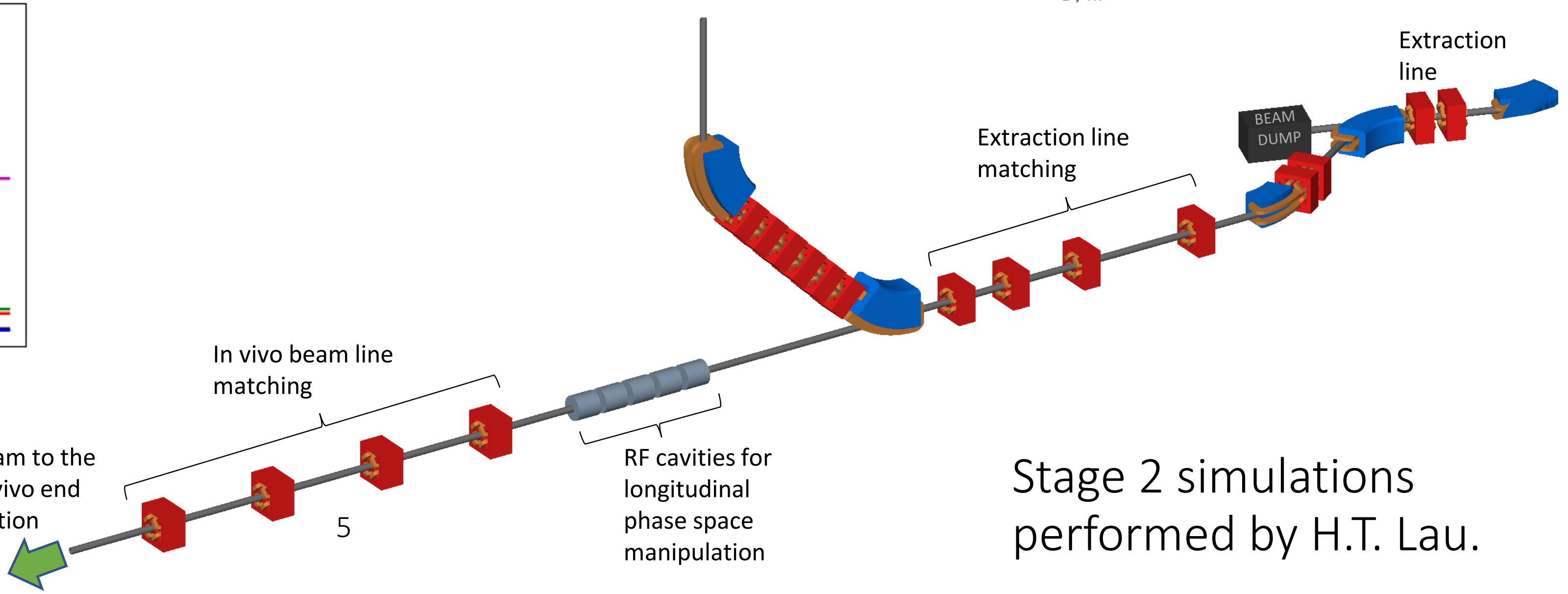
Stage 2 Recap

- Optics configurations to deliver beam between 1 and 30 mm
- Uncertainty in beam delivered by FFA– potential factor 10 variation in emittance
- Flexible optics configuration
  - Extraction line matching & in vivo beam line matching
- Space charge impacts in vivo beam delivery
  - Affects all energies







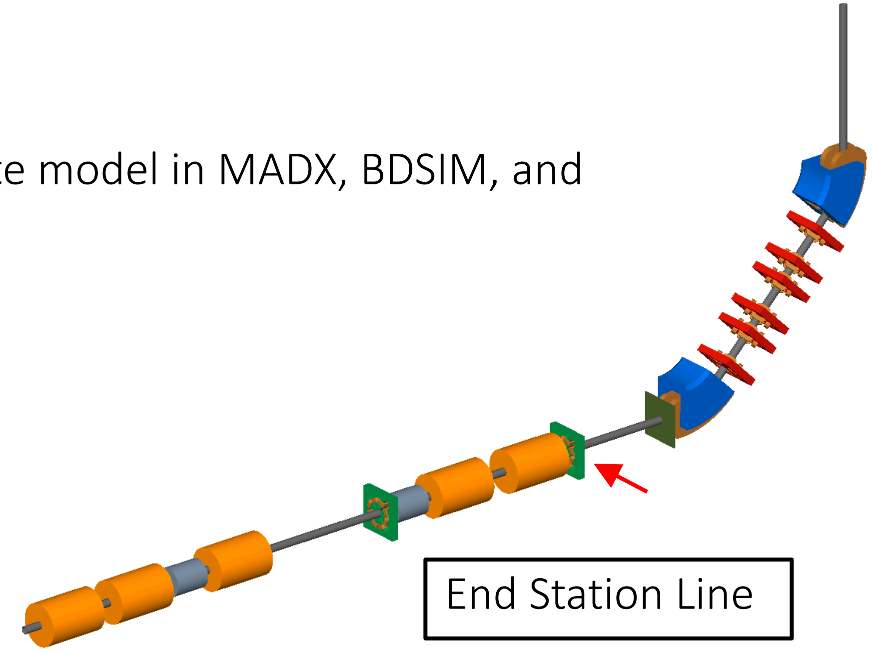
Stage 2 simulations performed by H.T. Lau.

Stage 1 Models

- Two complementary stage 1 models – injection line & end station line

- Common section – source to extraction section
  - But different Gabor Lens strengths

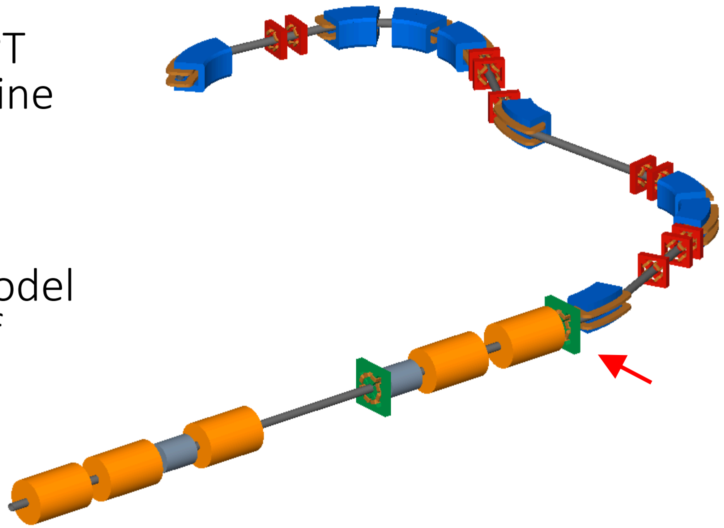
- Complete model in MADX, BDSIM, and GPT



End Station Line

- BDSIM, MADX & GPT model of injection line only

- Missing updated model of source to start of extraction line



Injection line

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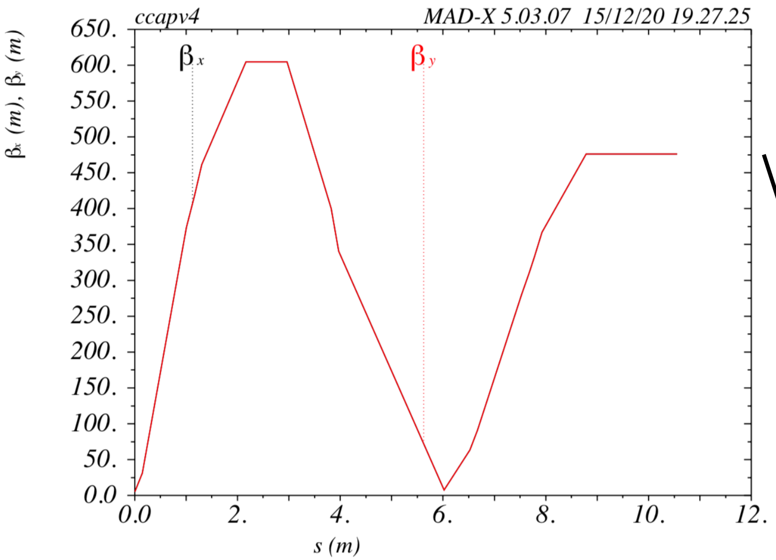
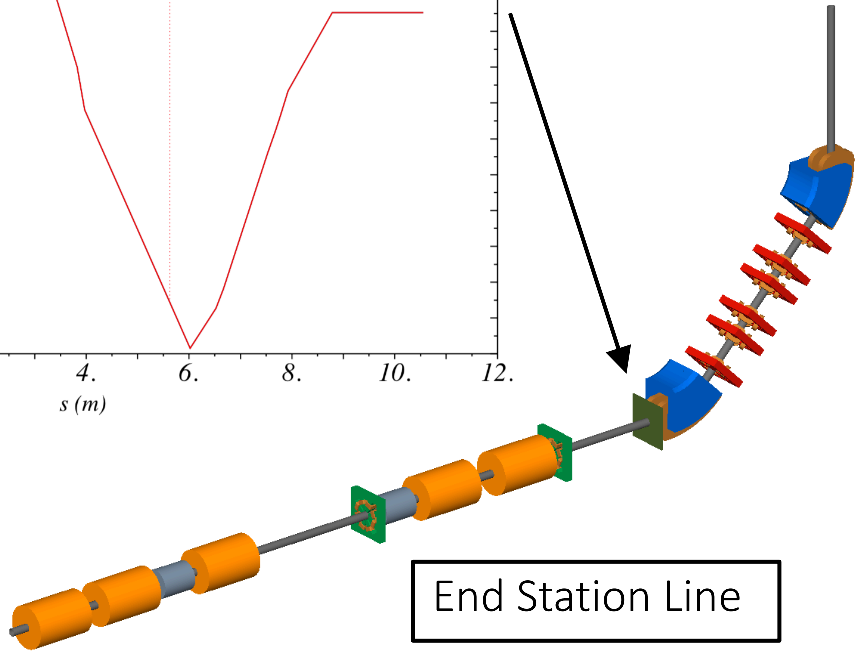
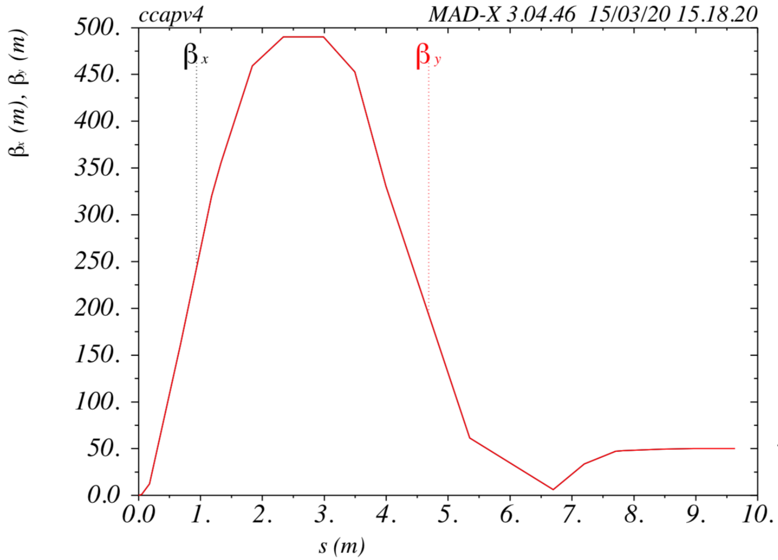
Stage 1 Model Optics

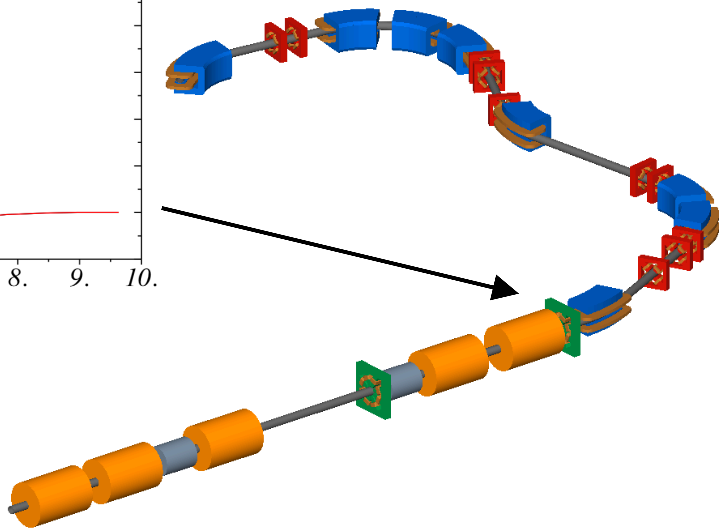
- Two complementary stage 1 models – injection line & end station line





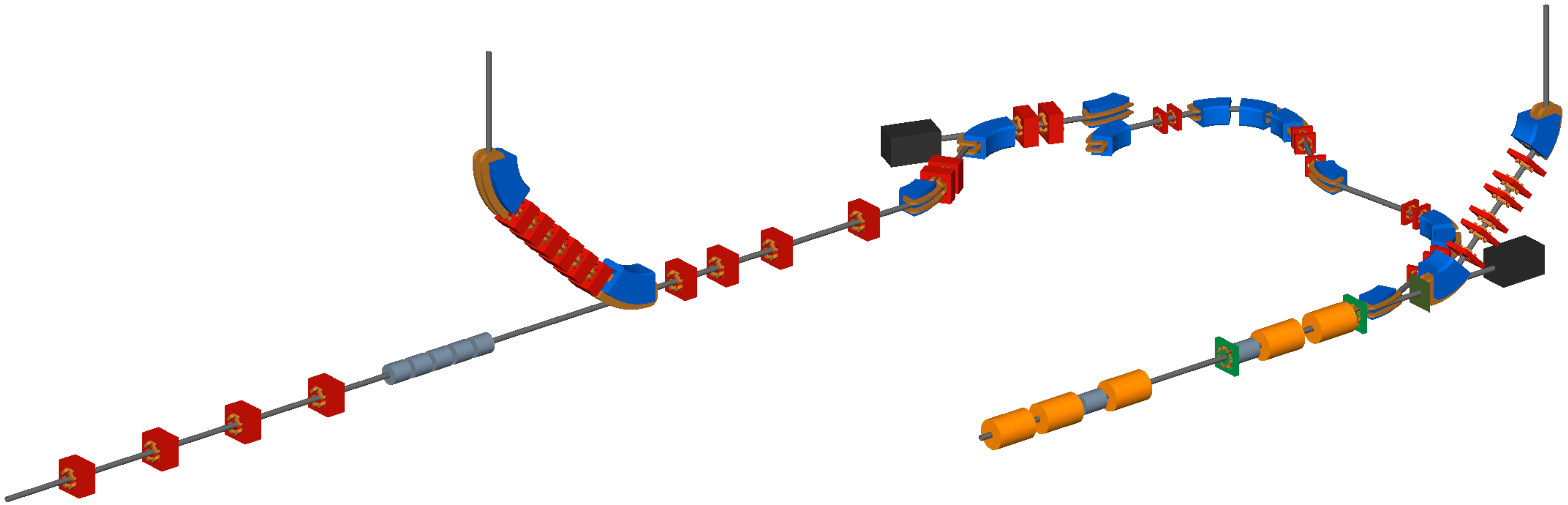
End Station Line



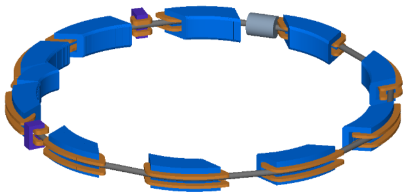


Injection line

Current Modelling Capabilities



- Can model:
    - Stage 1 in full
    - FFA injection line
    - FFA extraction line
    - Stage 2 in vitro and in vivo lines



- Missing:
    - FFA!

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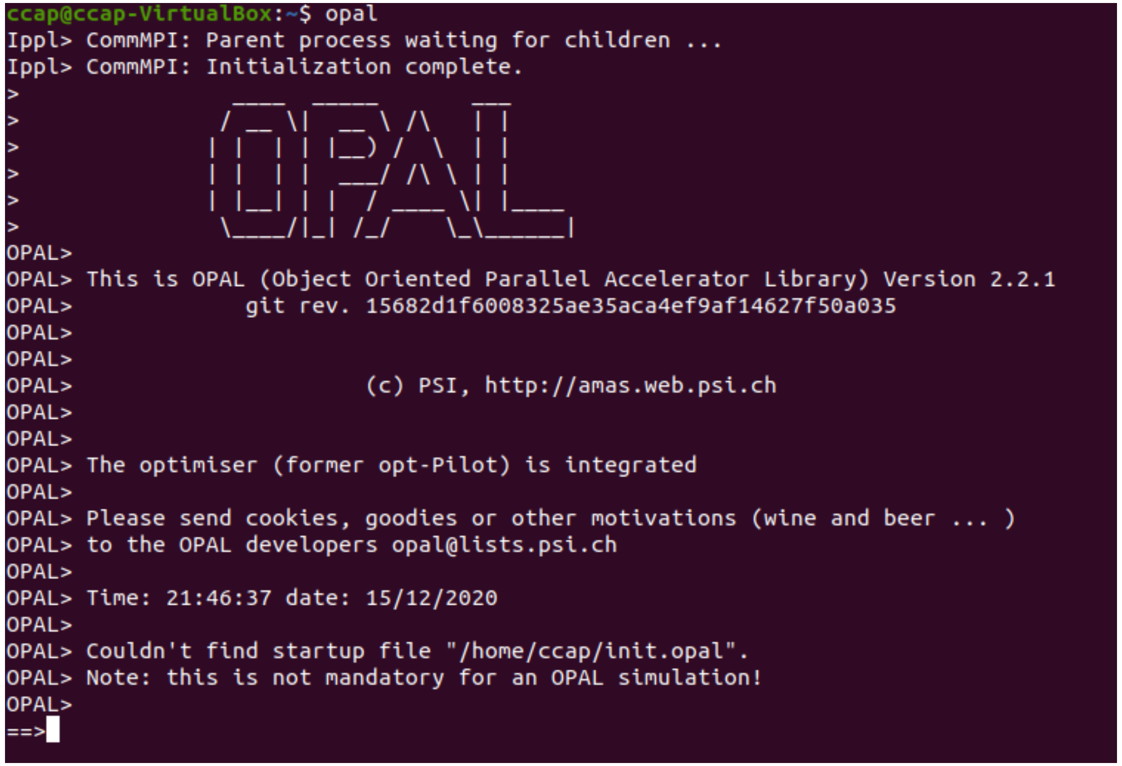
FFA Modelling – OPAL

- OPAL - charged particle optics in linear accelerators & rings
  - Includes 3D space charge effects

- Two main 'flavours':
  - OPAL-cycl – multi-turn modelling in FFAs
  - OPAL-t – beam lines

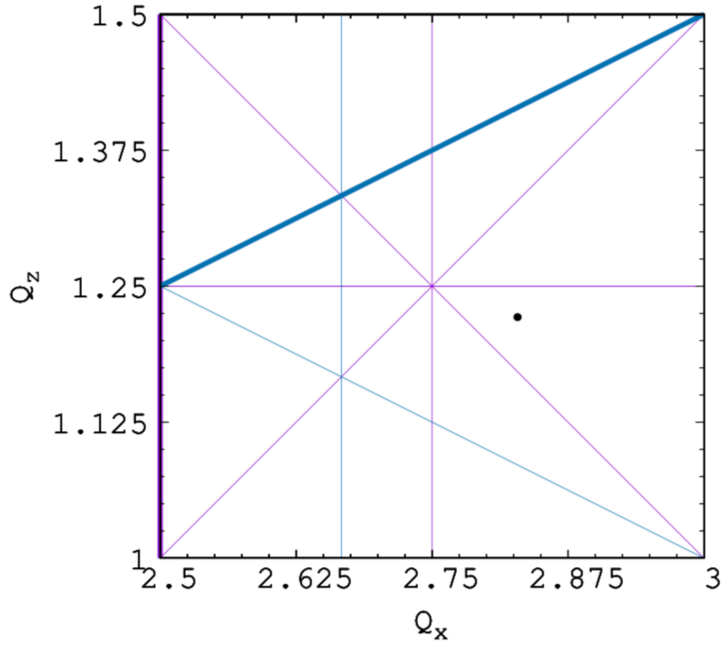
- Simple Ascii model description
  - No model visualisation

- Installed on Ubuntu virtual machine on IC Windows Server
  - Resource limited
  - Host data sharing



FFA Modelling – OPAL-cycl

- Model Validation:
  - Single particle tracking for calculating basic parameters (e.g. reference orbit)
  - Tune calculation mode (2 particles, reference & off-reference)
- Multi-particle tracking
  - Space charge effects
- Standard & specialised accelerator elements
  - Dipole, quad, solenoids, collimators – possible validation of stage 1 GPT model
  - FFA magnet (radial scaling or vertical scaling) & kickers for FFA
- Model development & verification is ongoing – need previous FFA model
  - Unnamed code in pre-CDR (PyZgoubi).



FFA Modelling – OPAL-cycl Continued

- Space Charge:
  - Solves 3D Poisson equations - particle mesh
    - Similar to GPT
  - Long bunch length - conductive boundaries required (transverse aperture info)
    - Dependent on stage 1 energy selection & longitudinal phase space manipulation

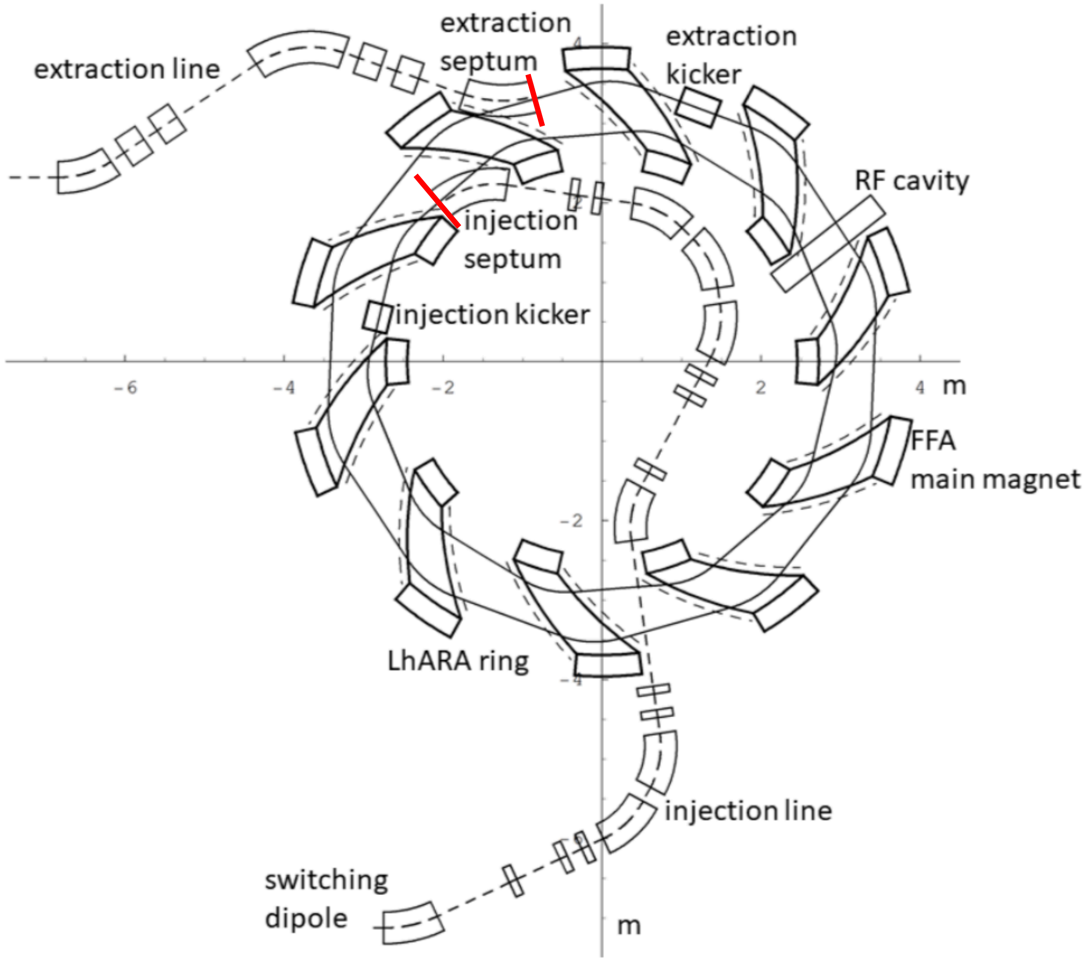
- Losses:
  - Some particle-matter physics available:
    - Energy loss (Bethe-Bloch), Coulamb scattering
    - Limited materials, no secondaries.
  - Aperture dependent

OPAL, BDSIM & GPT Toolchain

- (BDSIM,GPT) & OPAL on separate machines
  - No single self-contained code

BDSIM – Stage 1 & Stage 2 Injection → OPAL FFA Ring → BDSIM – Stage 2 Extraction

- Defined interface planes between codes & exchange particle coordinates

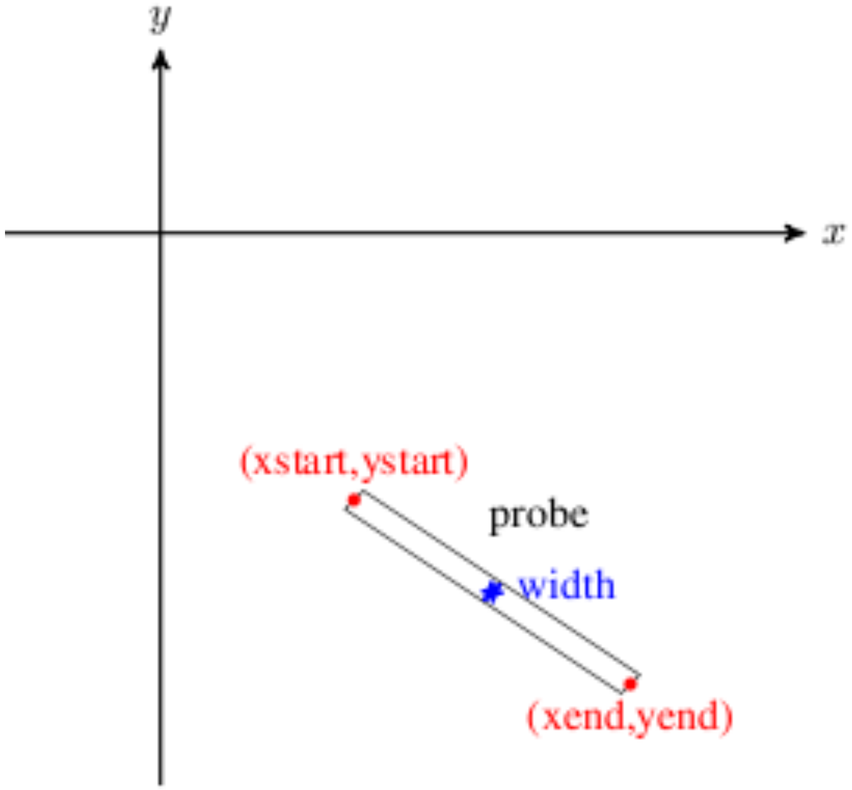


OPAL, BDSIM & GPT Toolchain

- OPAL probes akin to BDSIM samplers
  - Thin lattice element, 6D particle coordinates

- Python code (pyopal) to convert particle coordinates
  - In development. Working but not thoroughly tested
  - Dependent on pyOpalTools and pybdsim

- Developing test of simple linear model
  - Compare to BDSIM tracking – no space charge



Future work: Modelling

- FFA model development & verification
  - Need existing model

- GPT space charge self-consistency
  - Multiple space charge algorithms

- Model stage 1 in OPAL
  - Relatively simple model – further space charge verification

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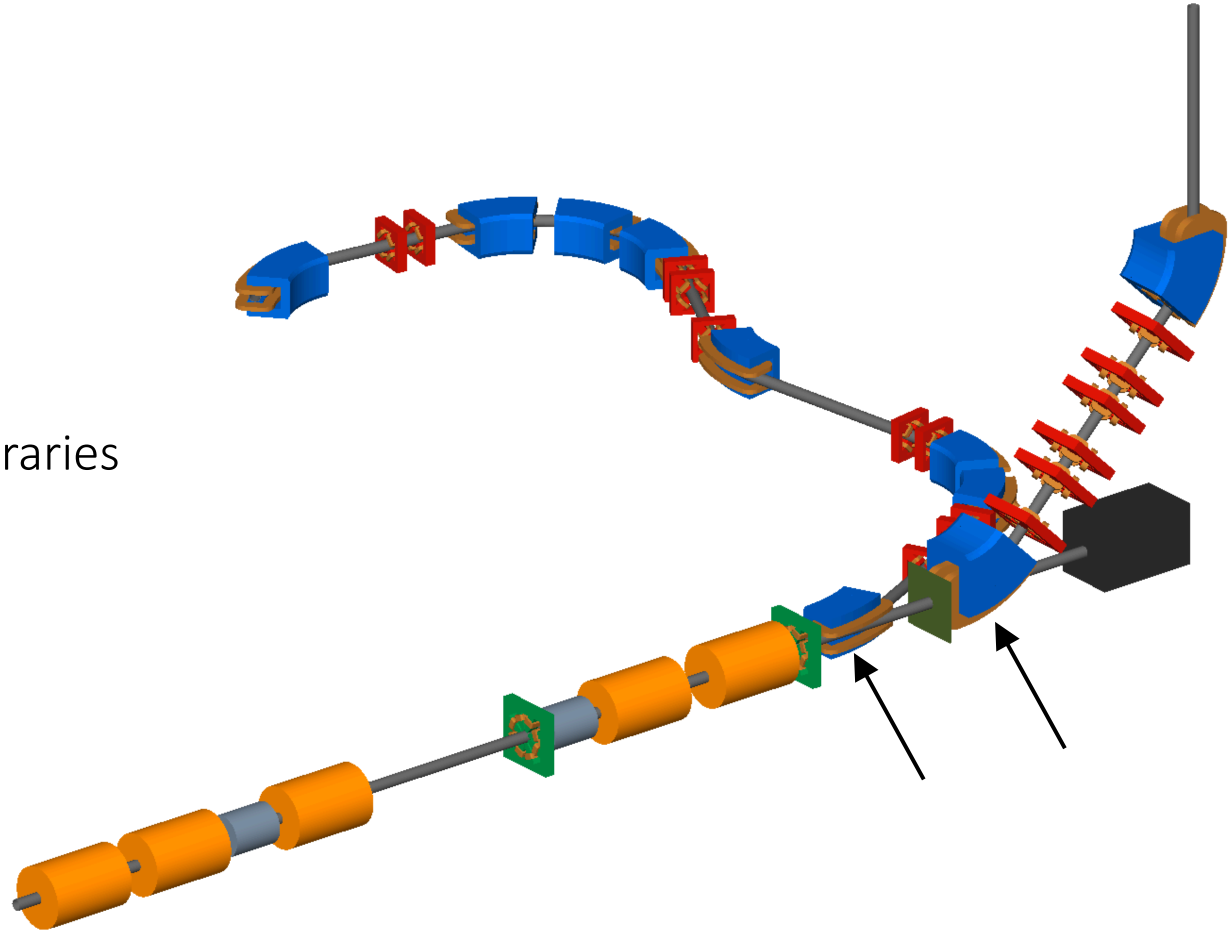
Future work: BDSIM Developments

- BDSIM space charge via external tracker
  - Spare couple of months?

- BDSIM interface to sixtrack
  - Generalised interface to external tracking libraries

- Split beam pipe apertures
  - No overlap of beam lines

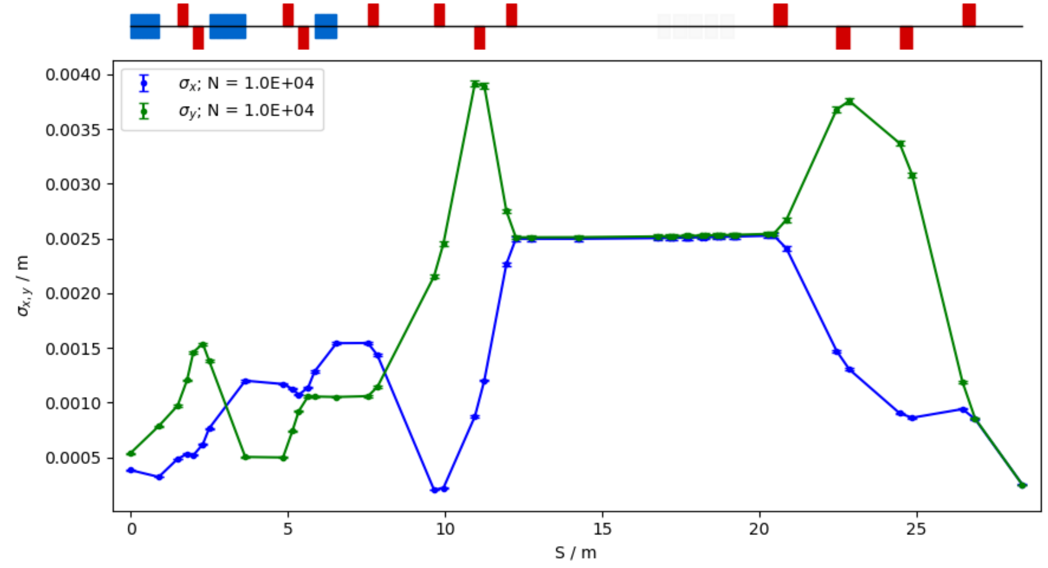


Future work: Machine - End Station Interface

- Simulation of machine & end station interface
  - Beam shaping nozzle
  - Dependent on Radiobiology program

- Limited nozzle capabilities in BDSIM
  - TOPAS interface (particle exchange / direct interface)
  - Planned development – CCAP motivation?

- No space charge simulation capabilities
  - Potentially affect dose profile of small spot sizes



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Summary

- Capability to simulate whole LhARA beam line
  - Three separate simulations – particle coordinate exchange

- Stage 1 optimization ongoing
  - Comparison of GPT space charge routines next year

- FFA Model in development
  - Need previous FFA model/data for validation + updated stage 1 lattice
  - Particle exchange working

Thank You!

Any questions?

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