Simulation Updates

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WP6 Meeting

25th July 2023

Beam Data Sets

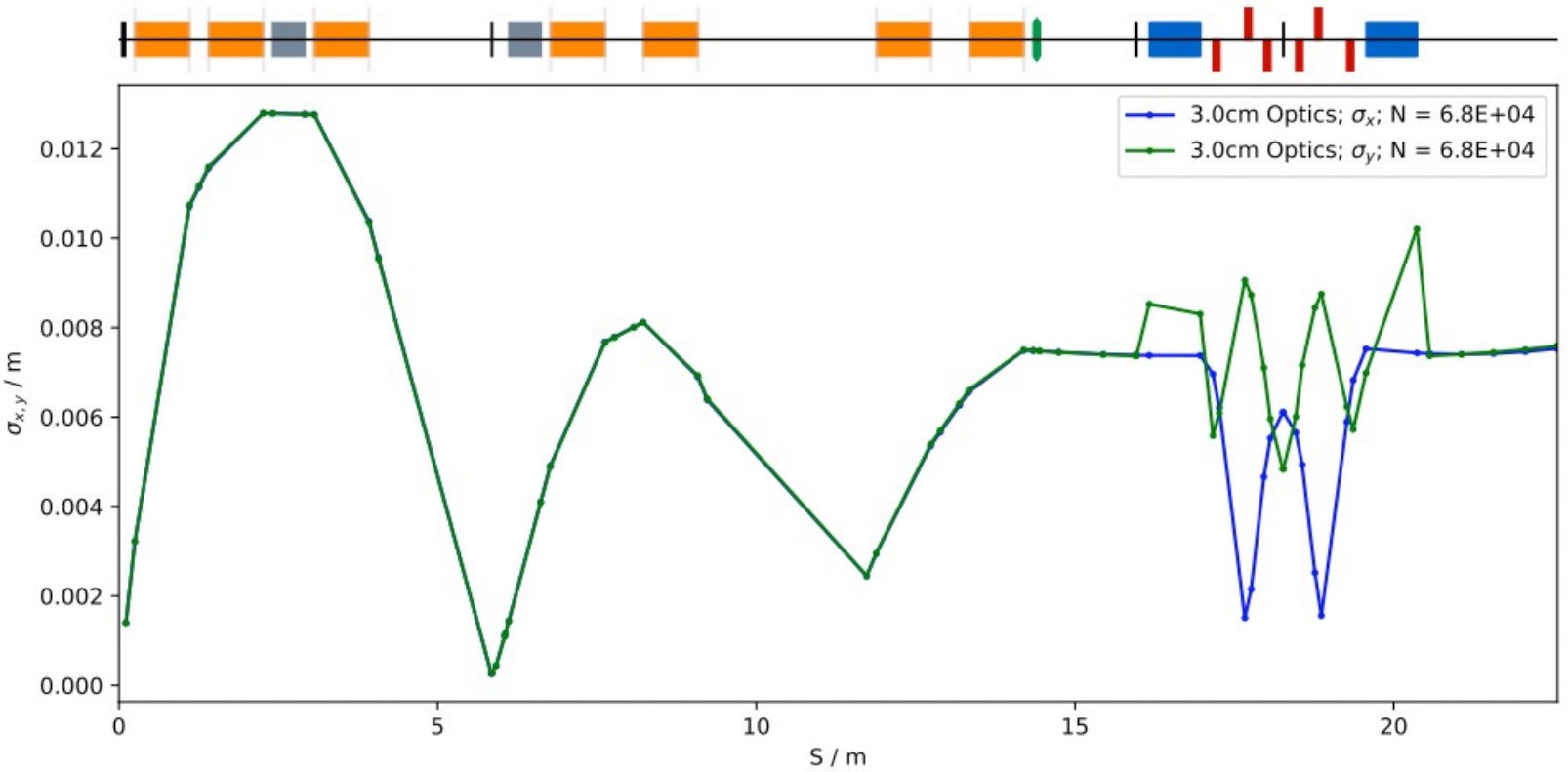
- Have beam data set at nozzle exit:
  - 15 MeV ± 2% - 10000 protons
  - 15 MeV ± 2% - 68044 protons
  - 15 MeV ± 5% - 10000 protons
  - 15 MeV ± 5% - 68162 protons

- Nozzle transmission: 68%
  - Comparable beam profiles
  - Little impact on transmitted spectrum

- Step-by-step guide on getting beam at nozzle exit:
  - Guide: ccap-sim/beam
  - Data: /home/hep/wshields/ccap/ccap-sim-data/beam/

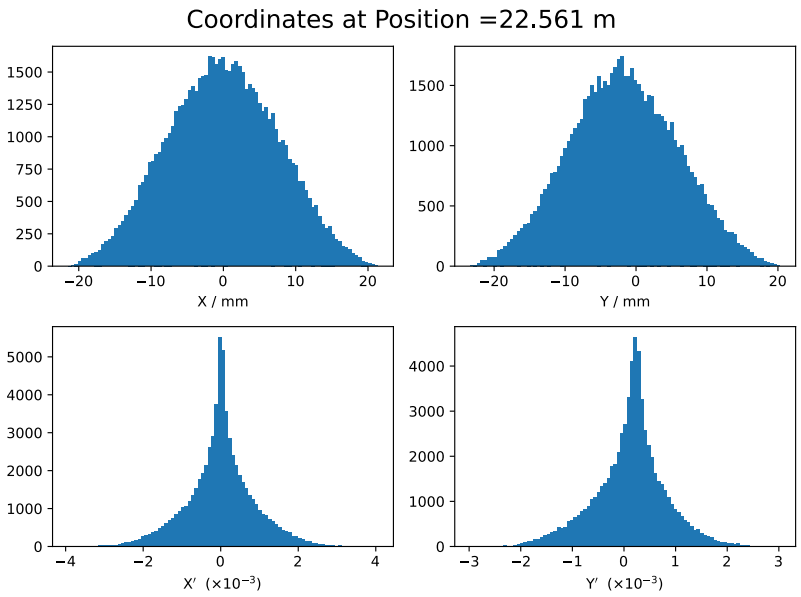
- 3 data sets:
  - Partial:
    - Initial simulations (03/23)
    - Re-check (06/23)
  - Full:
    - Second re-check (07/23)

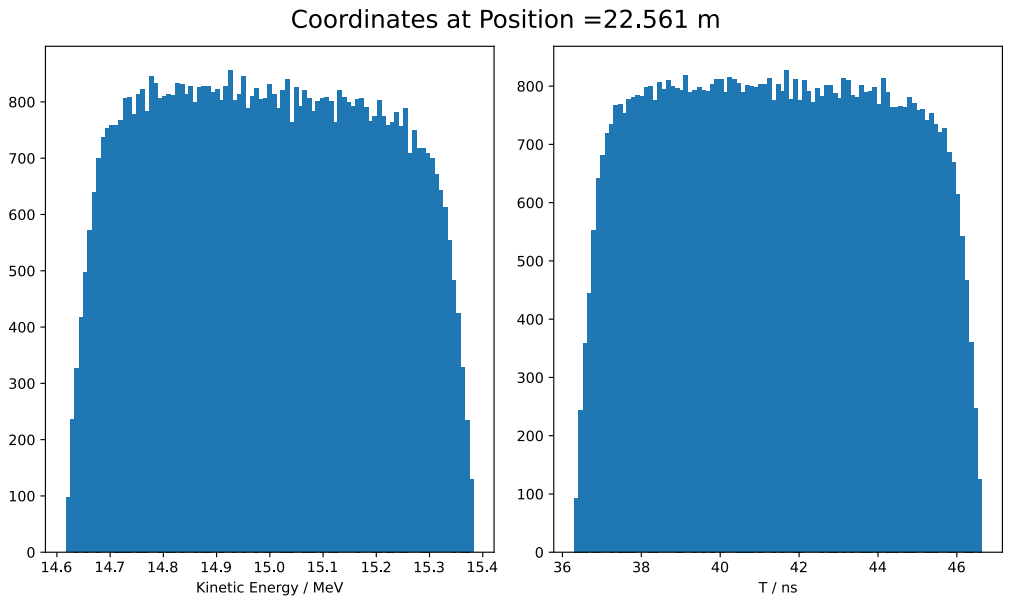
3.0cm Spot Size Config



- Full stage 1 beam line, 68044 protons, space charge, 15 MeV ± 2%
  - 100k target exit -> 68% nozzle transmission

3.0cm Spot Size End Station Beam Profile





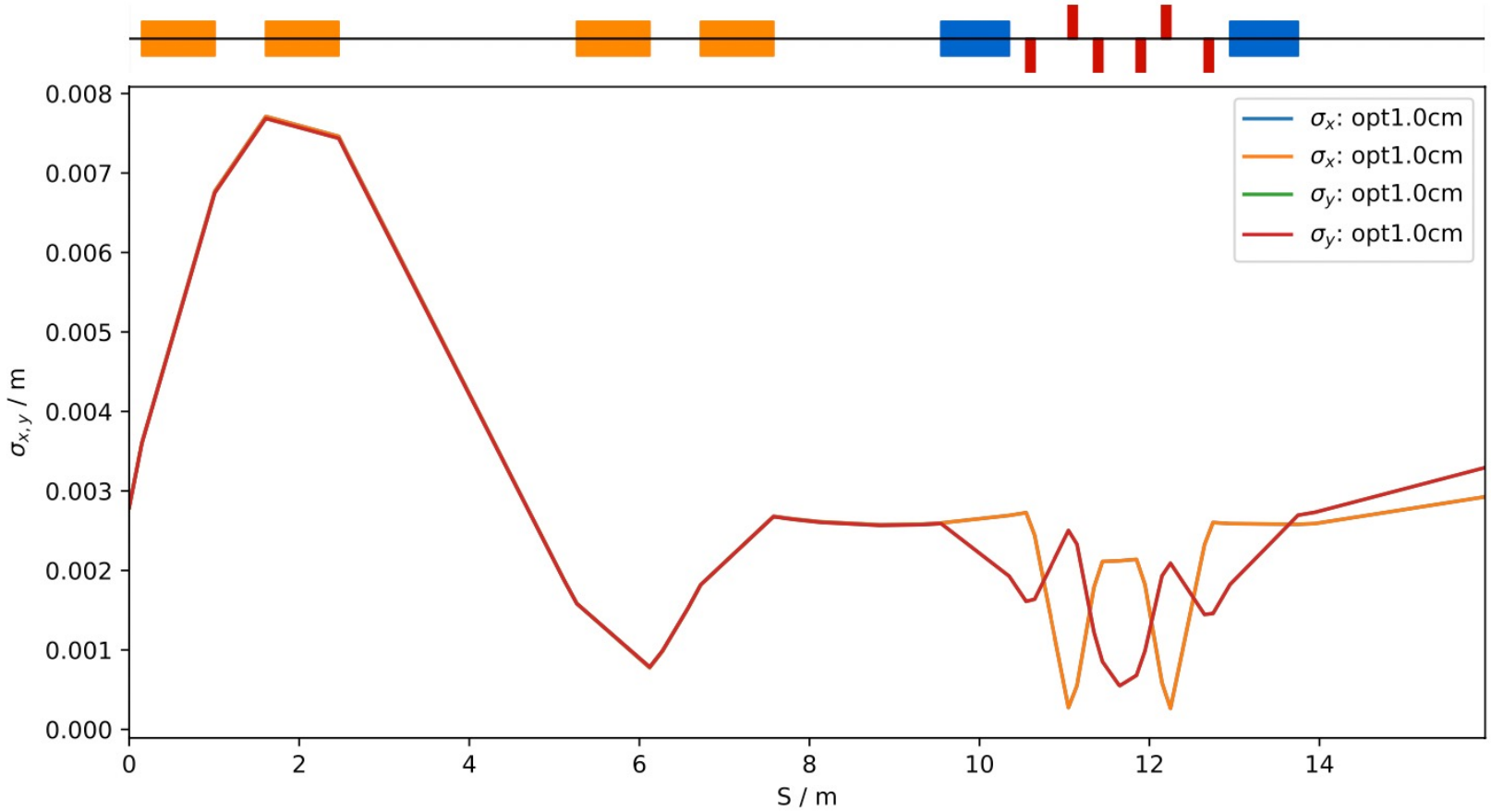
- Beam parameters:

```
S (m)       : 22.56
Npart       : 68044.00
Emitt X     : 6.66e-06
Emitt Y     : 5.20e-06
Beta X  (m): 8.66
Beta Y  (m): 11.26
Alpha X     : -0.19
Alpha Y     : -0.26
Sigma X (m): 0.00753
Sigma Y (m): 0.00759
Sigma Z (m): 0.14678
```

Target: 0.0075m

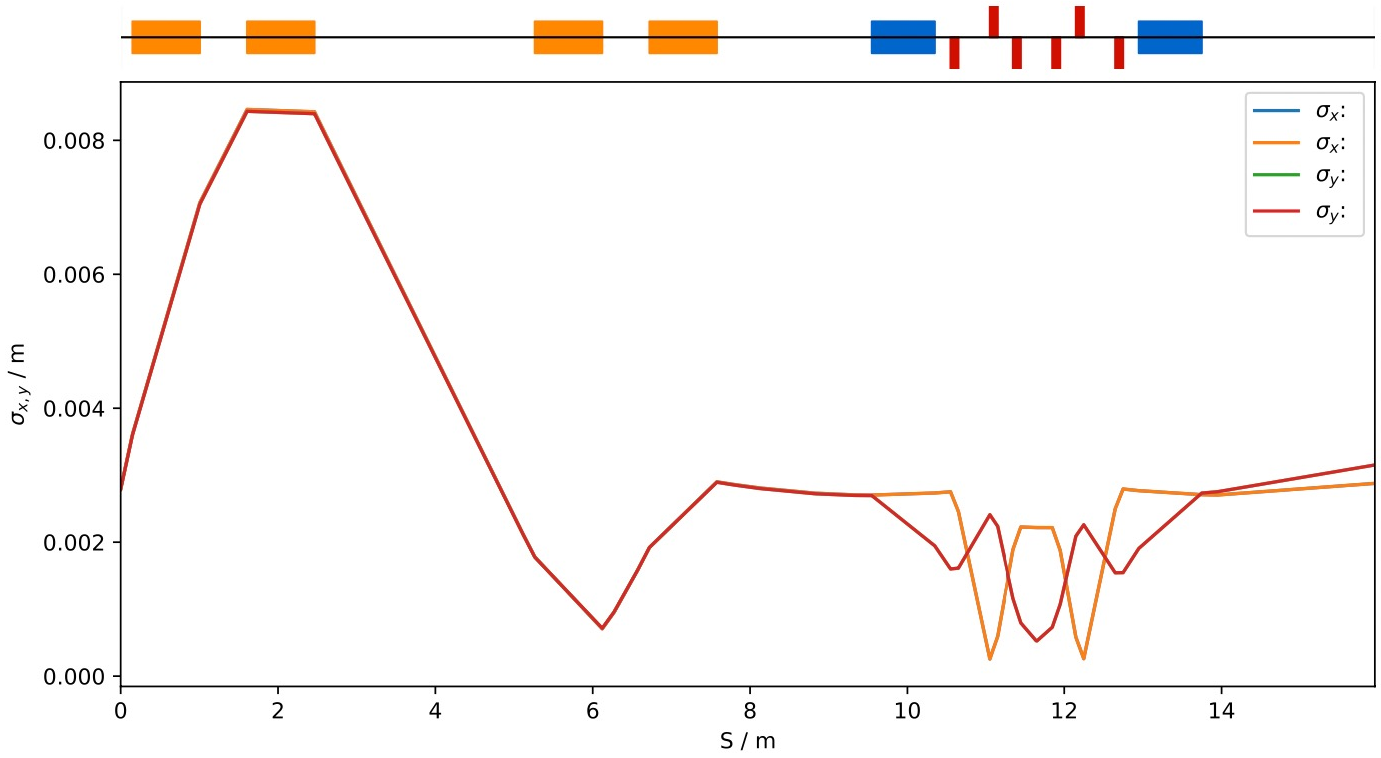
- Bunch length (T): 2.77 ns (1 sigma (z) * velocity)

Spot Size Optimisation



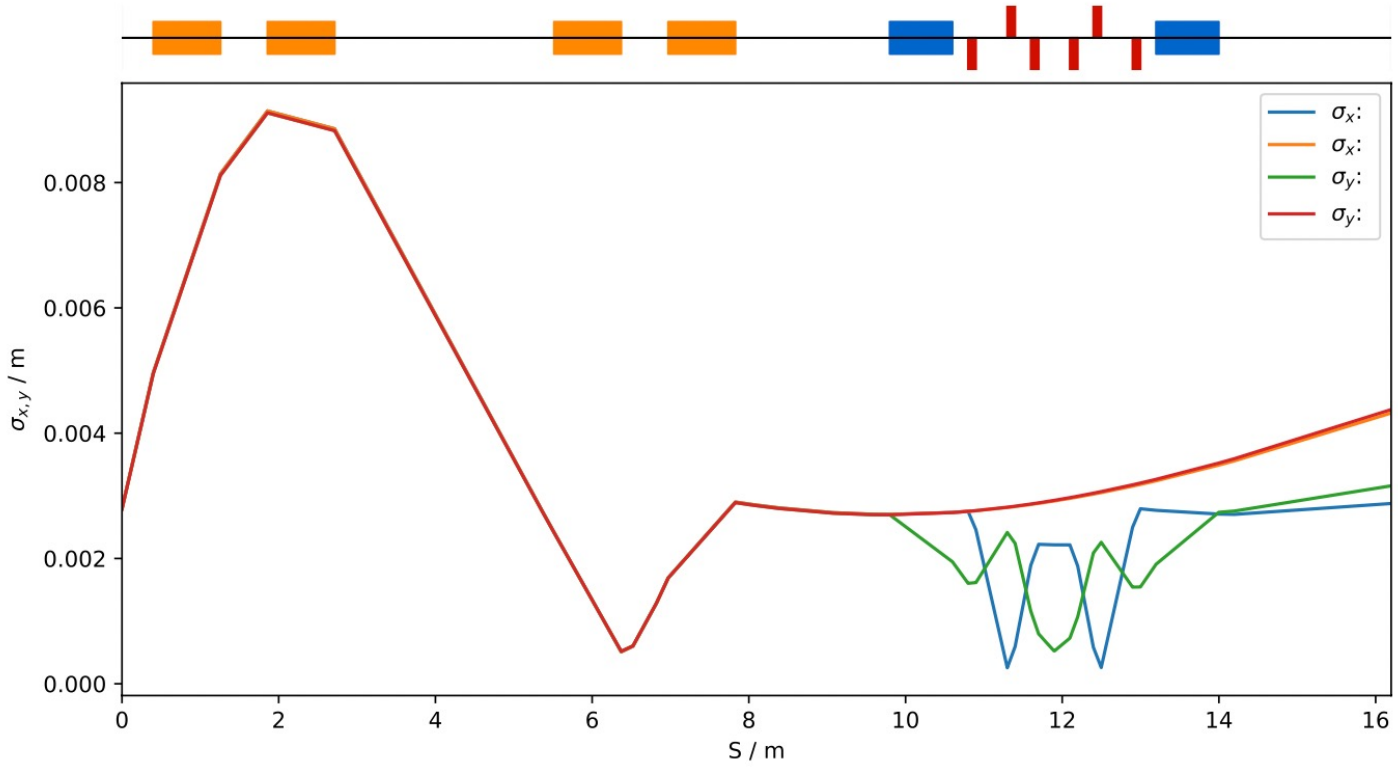
- MADX optimisation – beam at CAV02 mid-point (GL1, 2, & 3 optimised)
  - Similar optics behaviour to GPT optimisation (pre-arc parallel beam)
- MADX optimised solutions for 3.0, 2.5, 2.0, and 1.5cm spot sizes

Spot Size Optimisation



- 1cm (2 sigma diameter) spot size – "optimised", machine length unchanged.
  - End station**: σ_x: 1.151cm, σ_y: 1.261cm** (β_x : 5.796m, α_x : -0.365, β_y :6.869m, α_y : -0.607)
  - + beam constraints in end station drifts
- Acceptable?
  - Space charge simulations to be run
  - Asymmetry from beam production.
  - Dose profile sensitive to end station position

Spot Size Optimisation



- Arc crucial to small spot size beam transport
  - Equivalent drift length model – divergent beam
- Optimising the full stage 1 model in GPT with space charge is impractical:
  - Simple optics (no optimisation) without arc: ~ 10 minutes (10k protons)
  - Simple optics (no optimisation) simulation with arc : ~ **4 hrs** (10k protons)

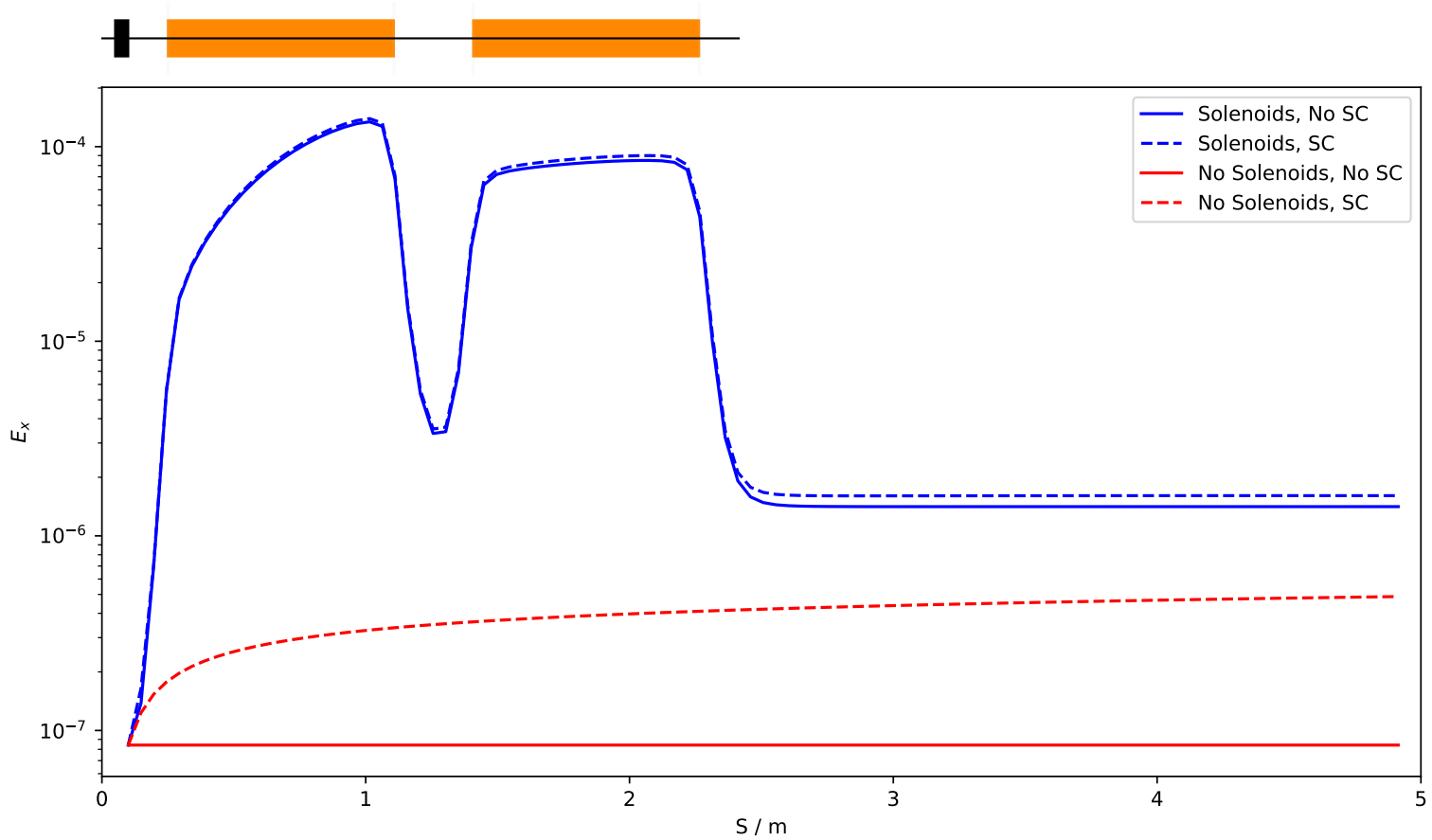
Further Optimisation

- Mini-beam-like optimisation for smaller spot sizes?
  - Vary arc quads +… ?

- Modifiable element lengths:
  - 0.3m between Gabor lens pairs
  - 2.5m drift between GL5 & GL6
  - 0.5m RF cavity drift length (after energy collimator) ???
    - Location sensitive?
  - Started investigating – no success yet

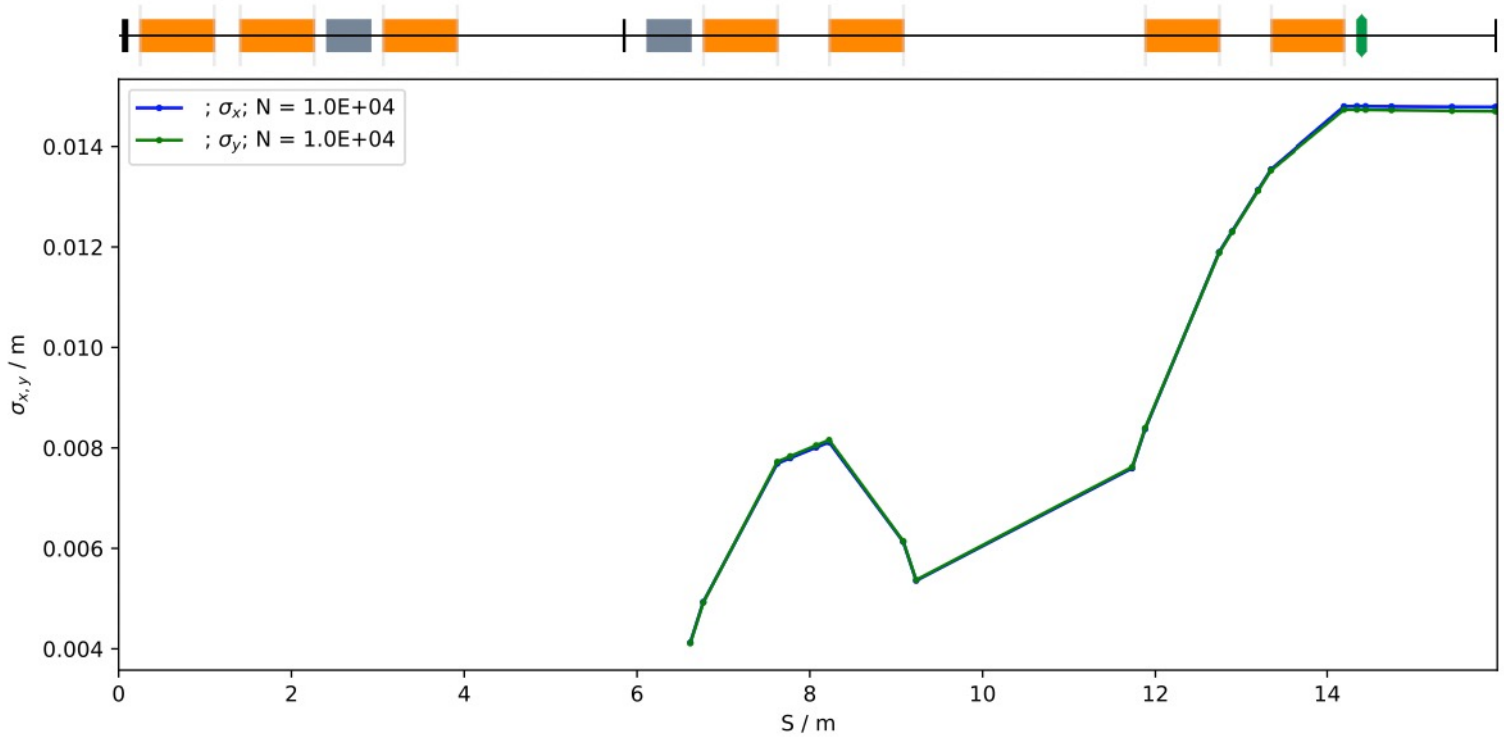
- Alternative code
  - RF-track, IMPACT-T, …

FFA Injection Conditions



- Reminder - known emittance growth from solenoids
- Most recent emittance at switching magnet (3cm spot size configuration):
  - 3.757e-06

Optimised Optics for FFA Injection 1

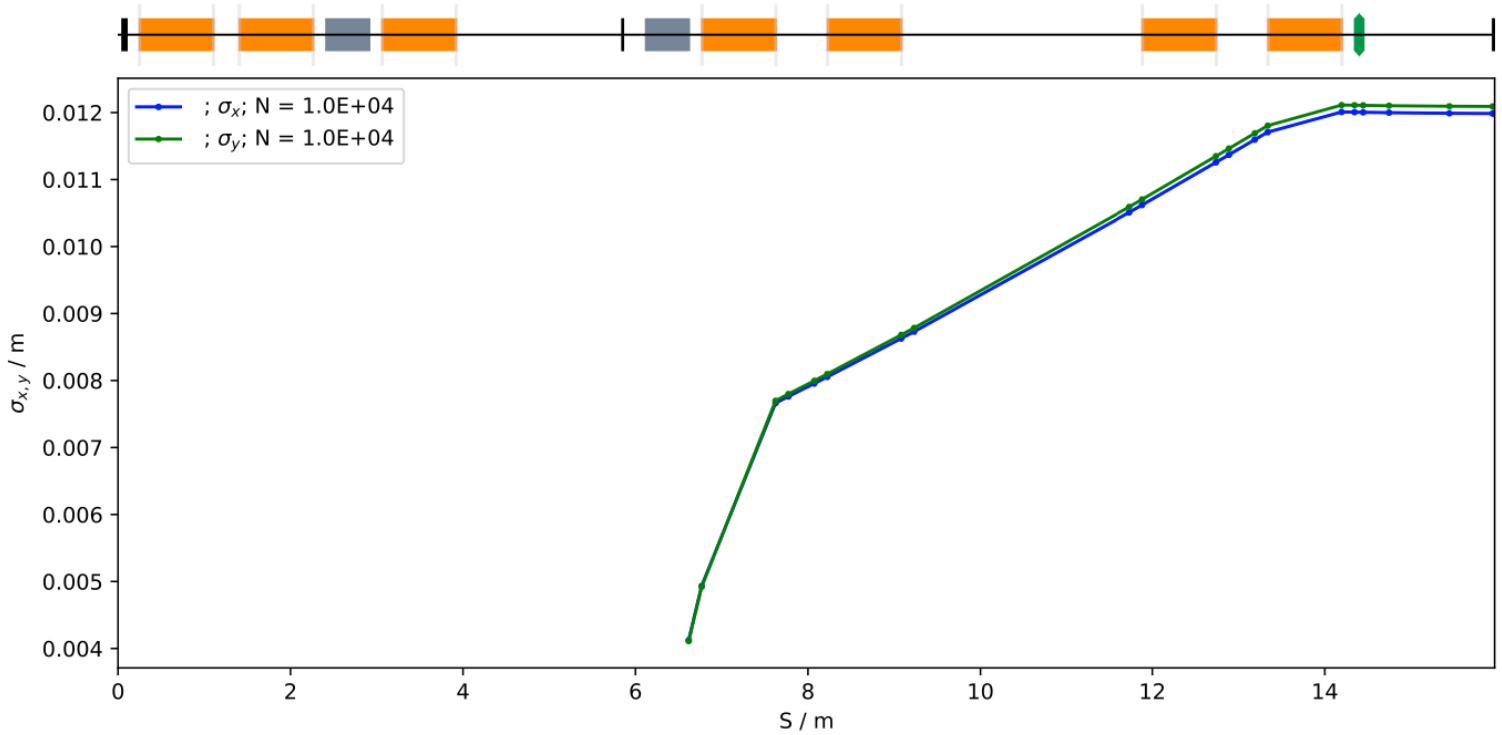


- Solution found

```
S (m)       : 17.96
Npart       : 10000.00
Emitt X     : 4.38e-06
Emitt Y     : 4.50e-06
Beta X  (m): 50.74
Beta Y  (m): 48.82
Alpha X     : -0.06
Alpha Y     : -0.03
Sigma X (m): 0.01480
Sigma Y (m): 0.01470
Sigma Z (m): 0.11061
```

- Large 1σ beam radius

Optimised Optics for FFA Injection 2



- Second solution found
  - GL5 & GL6 off
- Large 1σ beam radius
- Asymmetry mitigated by optimised injection line
  - Understanding of TNSA origin desired first

```
S (m)       : 17.96
Npart       : 10000.00
Emitt X     : 2.91e-06
Emitt Y     : 2.81e-06
Beta X  (m): 50.24
Beta Y  (m): 52.86
Alpha X     : -0.07
Alpha Y     : -0.07
Sigma X (m): 0.01200
Sigma Y (m): 0.01210
Sigma Z (m): 0.11050
```

- **Outstanding questions:**
  - Do we need the focus after GL5?
  - Is this acceptable by the FFA?
    - If not, how do we mitigate this?

End Station Dose Calculations

- Lilli & myself - cross-checked dose calculations
  - Cannot obtain pre-CDR dose values

- Pre-cdr dose calculations independent of LhARA beam transport performance
  - Exception: bunch length for instantaneous dose calculation

- Likely found HT's dose simulation files (BDSIM)
  - Model stored in the output - investigating
  - Copied on LX & to local machine

- Shelve end-station simulations – focus on Markus ion chamber modelling
  - Pre-CDR comparison / re-run

- Standardised set of doses at various energies & beam sizes
  - **Write up as technical note**
  - Scale dose as appropriate.

LhARA / CERN ABP Discussions

- Meeting 28/04/23:
- https://lhara-abp.notion.site/lhara-abp/1a32dbfe63cf4ffcba567f079b31d206?v=8fc266b2cc6c4d9aac52ebc7707ce700

Space charge/collective effects:	*Beam dynamics and simulation:*	*Plasma lenses, source and capture:*	*Conventional source:*
• Code-to-code validation • Code-to-data validation • Conceivable to develop collaborative code development.	• Electrostatic focusing/Stage I • FFA • Inclusion of space charge in linac and ring	• Consideration of discharge lens alongside electron plasma lens • Understanding source and capture	• Performance of conventional source • Protons and ion
- Code-code validation – yes (LhARA) - Code-data validation useful - yes (both) - Collab. development sought (both + BDSIM)	- ES focusing – definitely possible - FFA – to be investigated - Space charge modelling in linac – yes - Ring – to be investigated - Personal note – in contact with Chris Rogers – pyopal offers potential interface to FFA + SC modelling	- Discharge lens – not discussed - Source & capture understanding - yes	- Not discussed

RF-Track Discussions

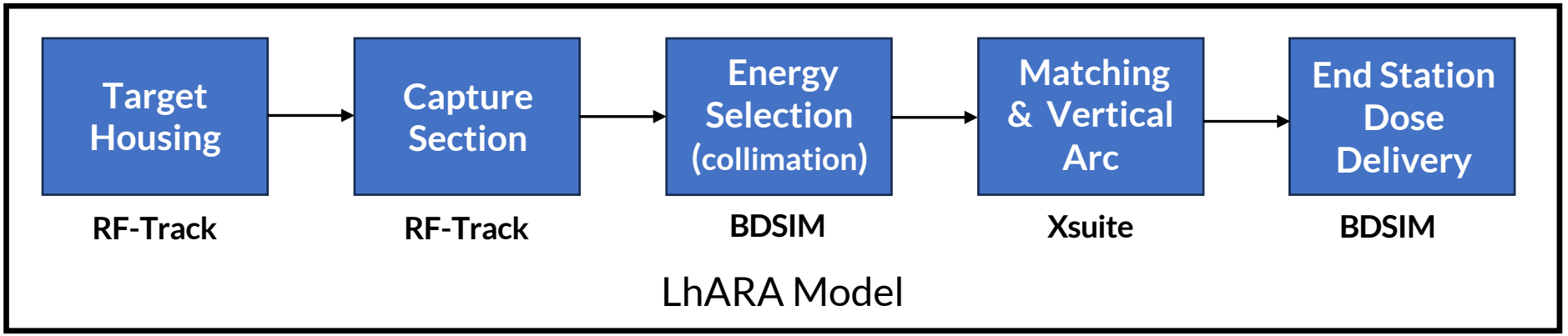
- Constructive discussions with Andrea Latina on RF-Track:
  - Composite (co-propagating) beams can be modelled
    - Only mono-species beam validated
  - Code obtained & working (mac)
    - Also to be installed on RHUL multi-core PC
  - Basic collimation (aperture cut-off)
    - Limited physics

- Plan:
  - Recreate first 10cm after nozzle with current methodology
    - SC validation
  - Input/output conversion tools
  - Set-up for co-propagating beams
    - Need electron phase space & spectrum data
  - Explore possible modelling of Gabor lens e- cloud & proton/ion beam
    - Effect on beam dynamics, transmission

RF-Track Discussions

- RF-Track & Xsuite interface in development
  - Xsuite: new multiparticle tracking code suite
    - Aim to eventually replace existing multiparticle tracking codes (MAD-X track, sixtrack, etc)
    - Interface with said codes provided
    - More here.

- Aim: Interface BDSIM with Xsuite (and RF-Track by extension)
  - Develop BDSIM interface
    - Pybind11 – ongoing
  - Reconvene in ~2 months.



Summary

- Done:
  - Installed & tested RF-track
  - Regenerated beam data set at nozzle exit (± 2% & ± 5%)
  - Sent updated survey of 7 Gabor lens model
  - Matched beam conditions for FFA injection*
  - Optics settings validated for 3.0cm beam
- Ongoing:
  - Optimisation routines for smaller spot sizes
  - Optimisation validation for smaller spot sizes
  - Reconstructing HTs end station simulations
  - Comparison to baseline design
- Todo:
  - Performance evaluation of ± 5% beams
    - No optimisation. Transport & transmission assessment.
  - Alternative space charge codes & model validation.
    - RF-track, OPAL, IMPACT-T, …?
  - Update models of alternative baseline design (v5.5)
  - Develop OPAL model of FFA