Alternative Optics

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Introduction

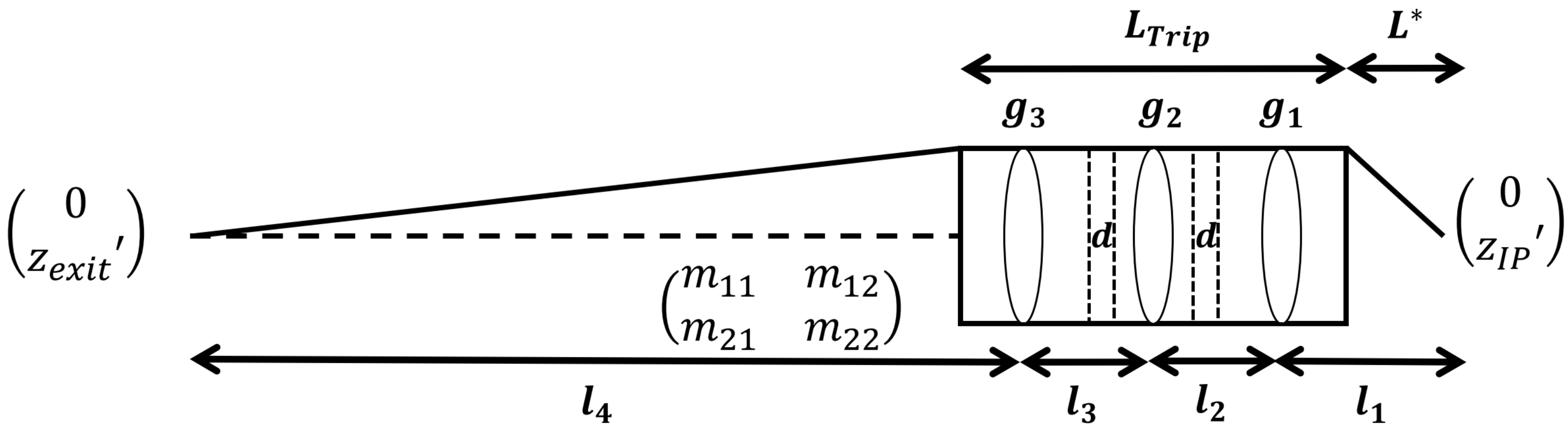
- **FCC-hh**
  - Unprecedented high energy – 100 TeV CoM
  - High luminosity requirement – $30 \times 10^{34}\ \mathrm{cm^{-2}s^{-1}}$ peak luminosity
- **Experimental Interaction Regions**
  - Two straight sections in tunnel
  - Match arc optics to low β^* in IP
- **Final Focus Triplet**
  - Exposed to large amounts of collision debris
  - Large aperture to accommodate both beams with large β
  - Novel Nb_3Sn technology
- **Baseline Design**
  - Based on scaling LHC Triplet
  - Presented by R Martin
- **Find Alternative Triplet using Method Independent from Baseline**

Goals

- Achieve a β^* of 0.3 m
  - Ideally also slightly lower
- Matched with $15.5\,\sigma$ crossing angle
- Sufficient shielding
  - Protect over one lifetime of ~ 30 ab^{-1}
  - Dose limit ~ 30-100 MGy
- Allow for $15.5\,\sigma$ beam stay clear in triplet
  - Both beams in one aperture, separated by $15.5\,\sigma$
- Achieve this with the shortest possible triplet

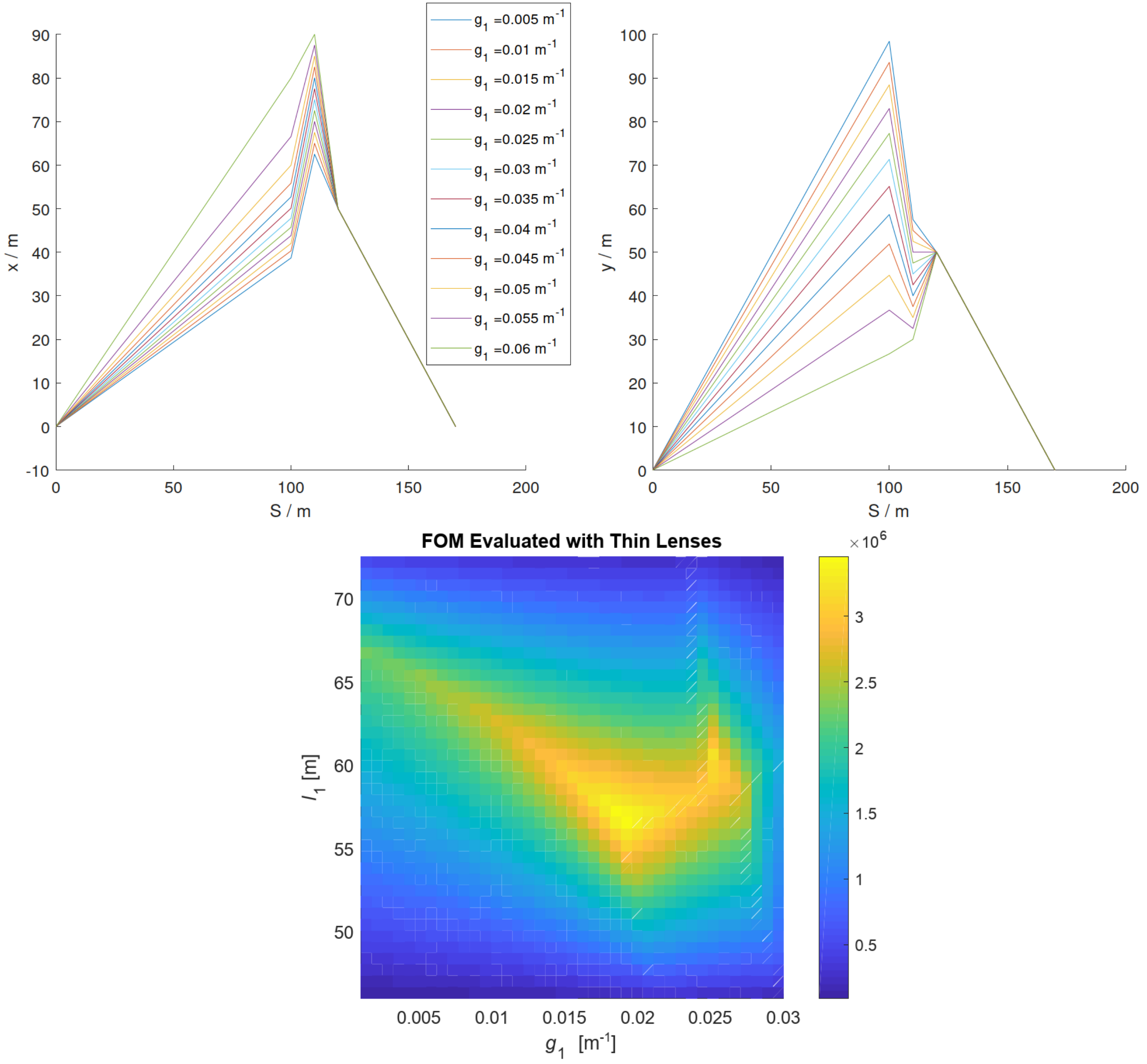
Thin Lens Approximation

- **Can be solved analytically**
  - **Represent quadrupoles as thin lenses at centre**
  - **Enforce focusing condition**
- **Used as a first approximation**
- **Sample large design parameter space**
- **Initial condition for finite length matching**

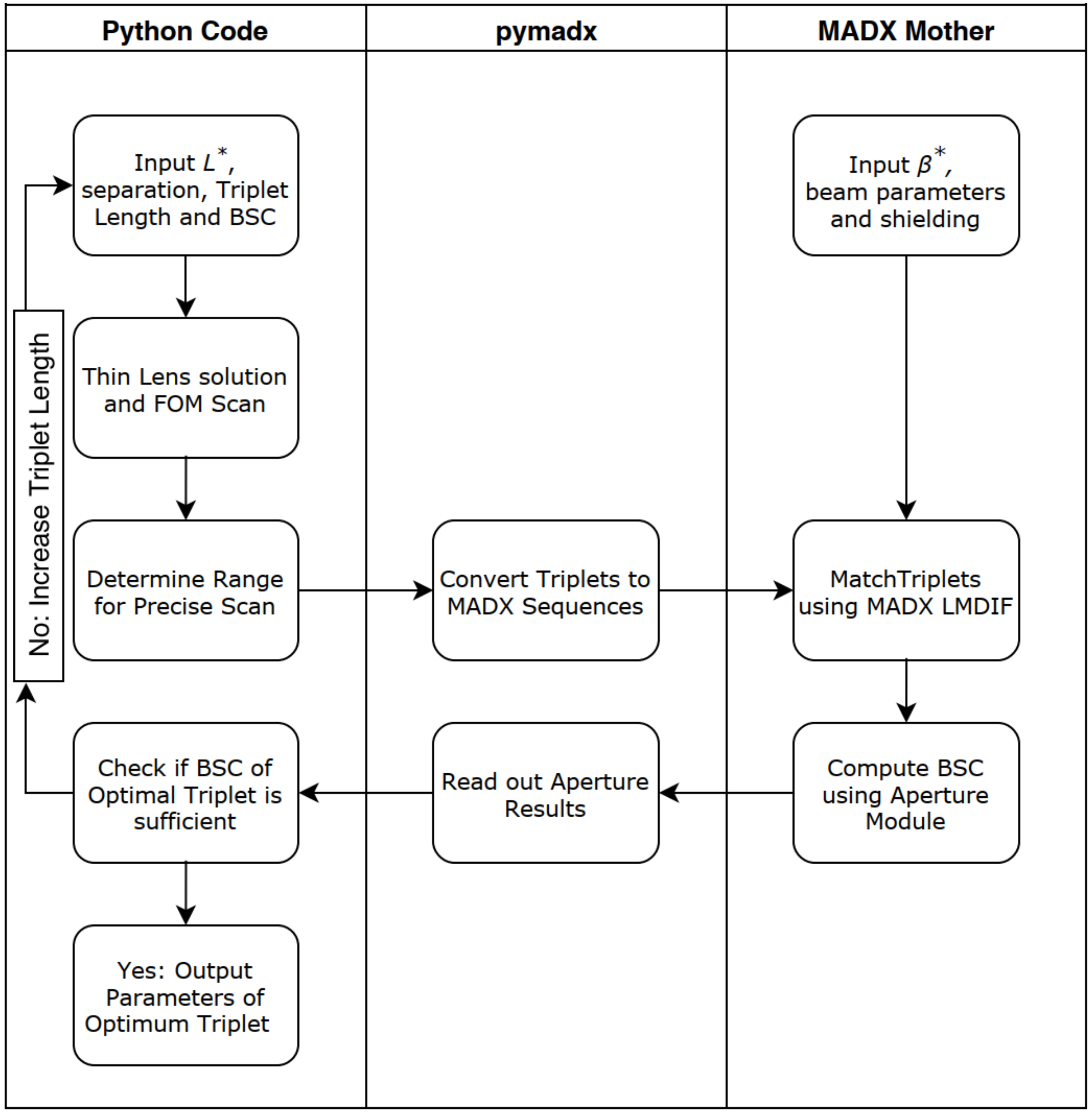


Thin Lens Figure of Merit

- **Track 1 σ particle through all lenses in x and y plane**
- **Estimate required aperture**
  - Assumes quadrupole gradient $\sim \frac{B_{max}}{r}$
  - $r \approx \frac{B_{max} L_Q}{g \times B\rho}$
- **Estimate BSC**
  - $\frac{r}{max(x,y)}$
- **Compute thin lens FOM**

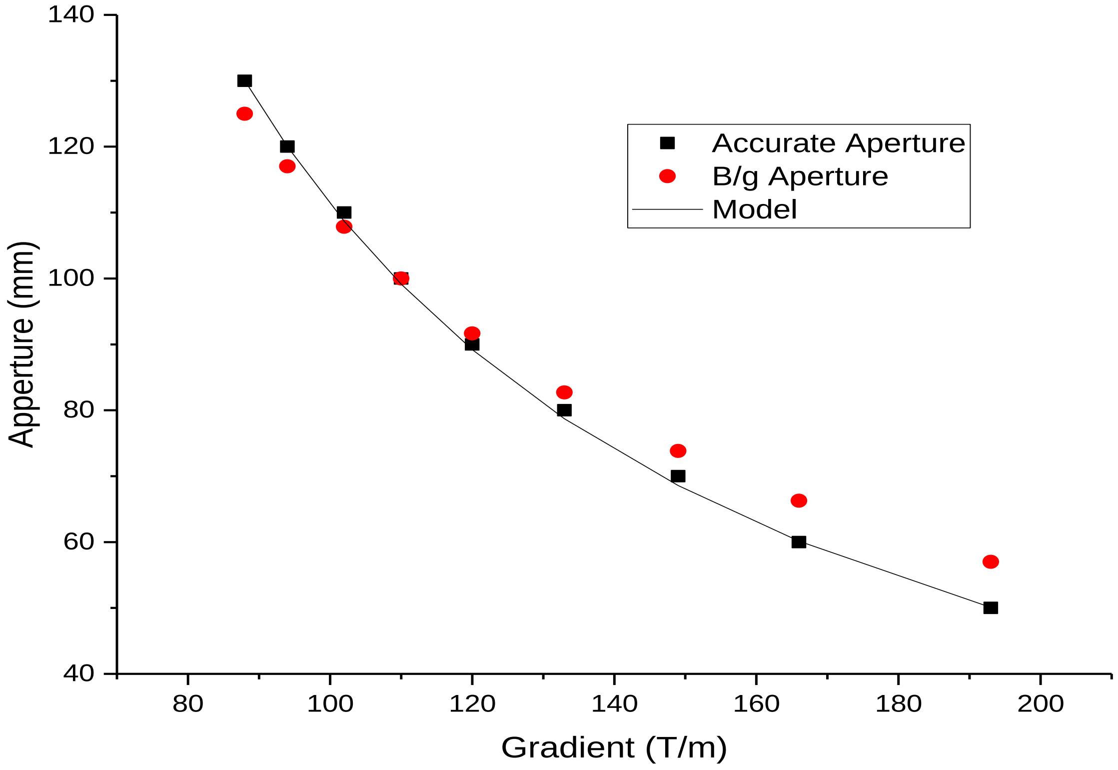


Optimisation Process



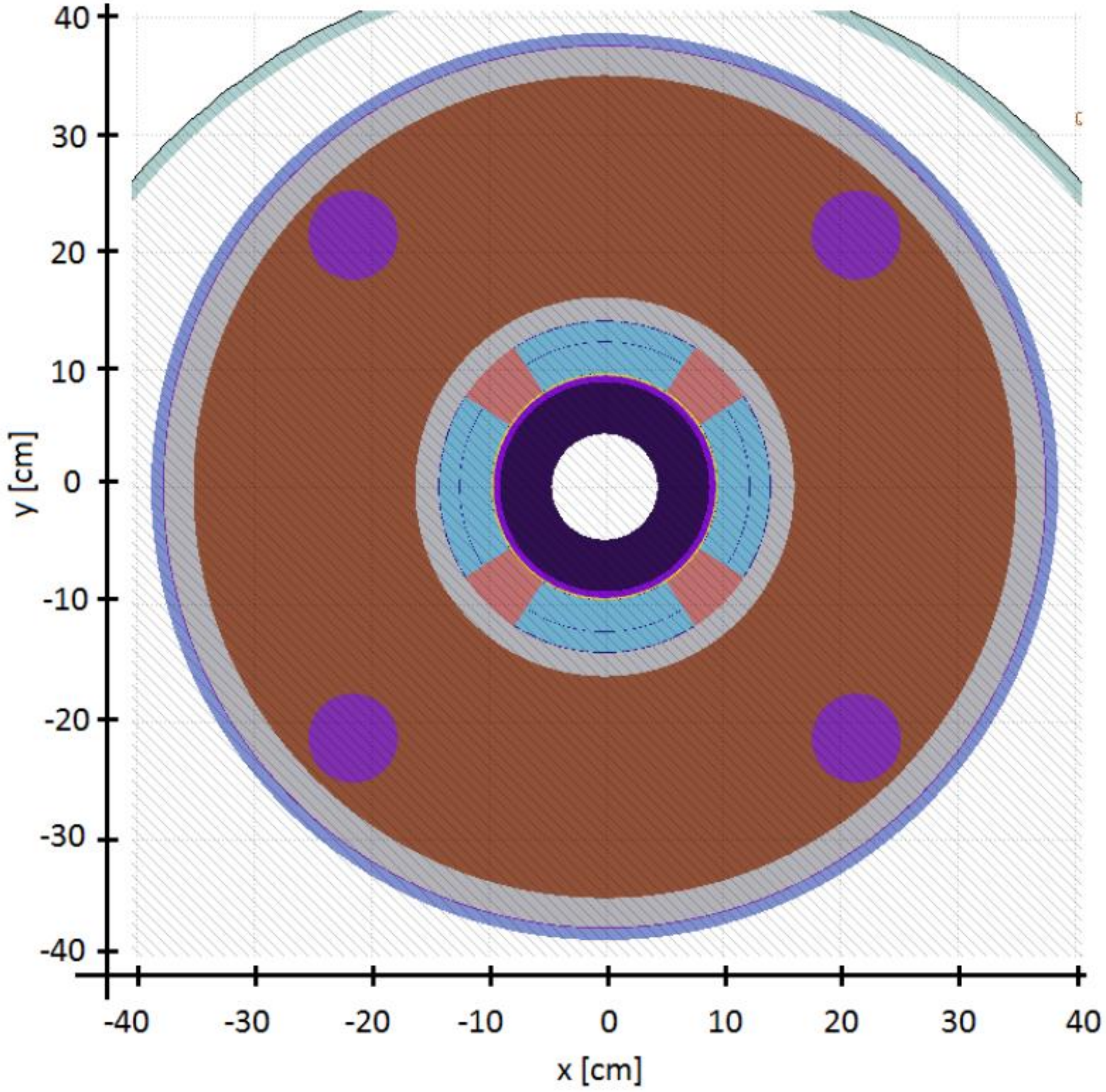
Actual Magnet Model

- **Exponential fit**
  - Based on actual estimates
  - More accurate than gradient $\sim \frac{B_{max}}{r}$ estimate
- **In aperture calculation also account for**
  - Cold bore (5.4% of radius)
  - Cooling channel (1.5 mm)
  - Kapton insulation (0.5 mm)
  - Beam Screen (2.05 mm)
  - BS insulation (2 mm)

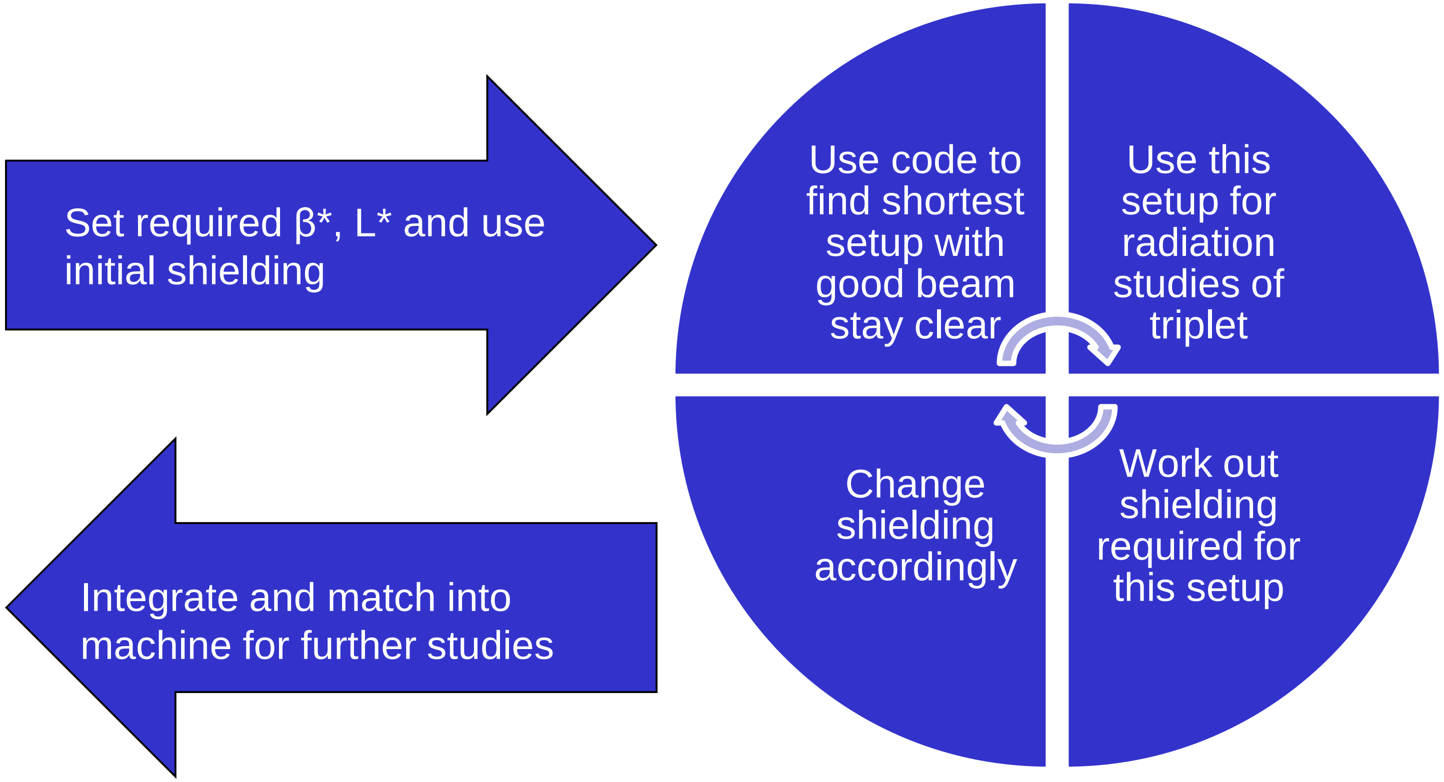


Energy Deposition Studies

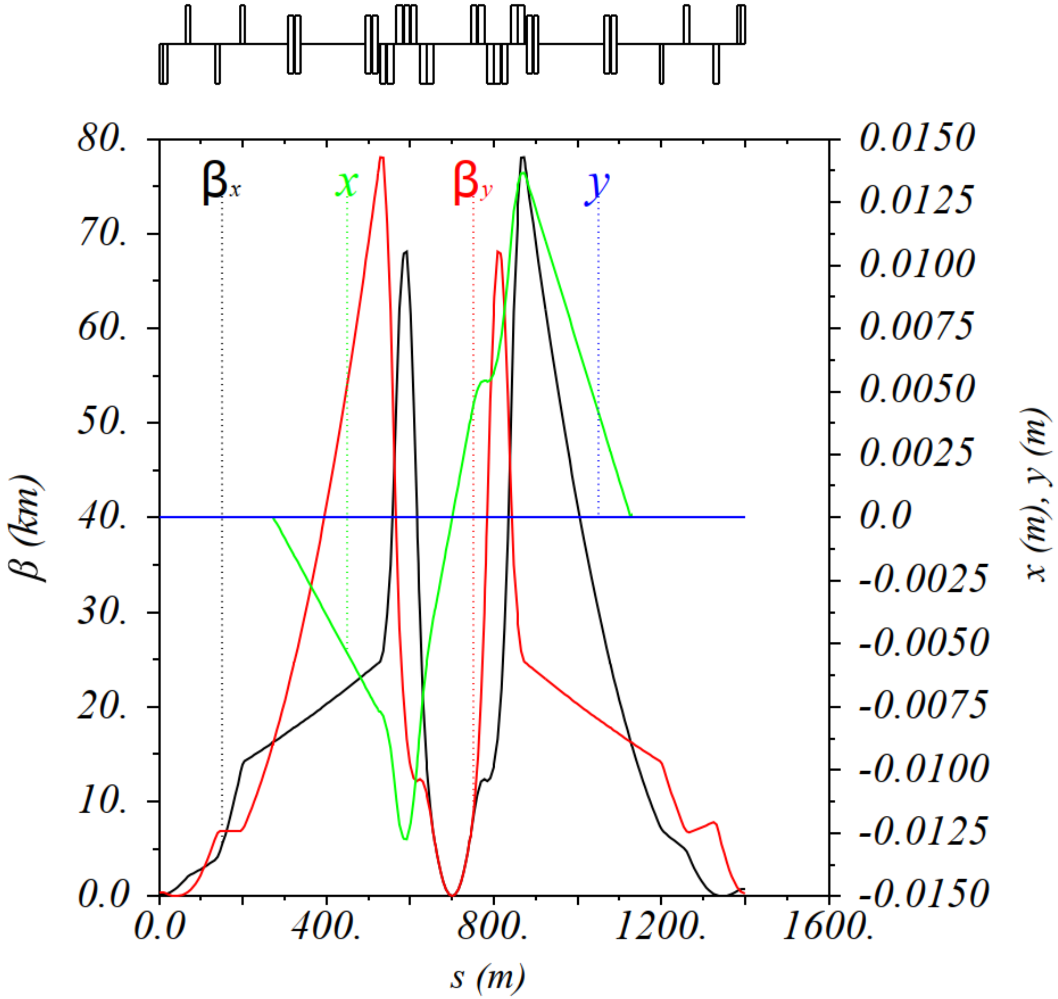
- **Jose Abelleira (Oxford)**
- **FLUKA model**
- **Parameterised to be altered easily**
- **Test final triplet designed after optics optimisation**



Work Together



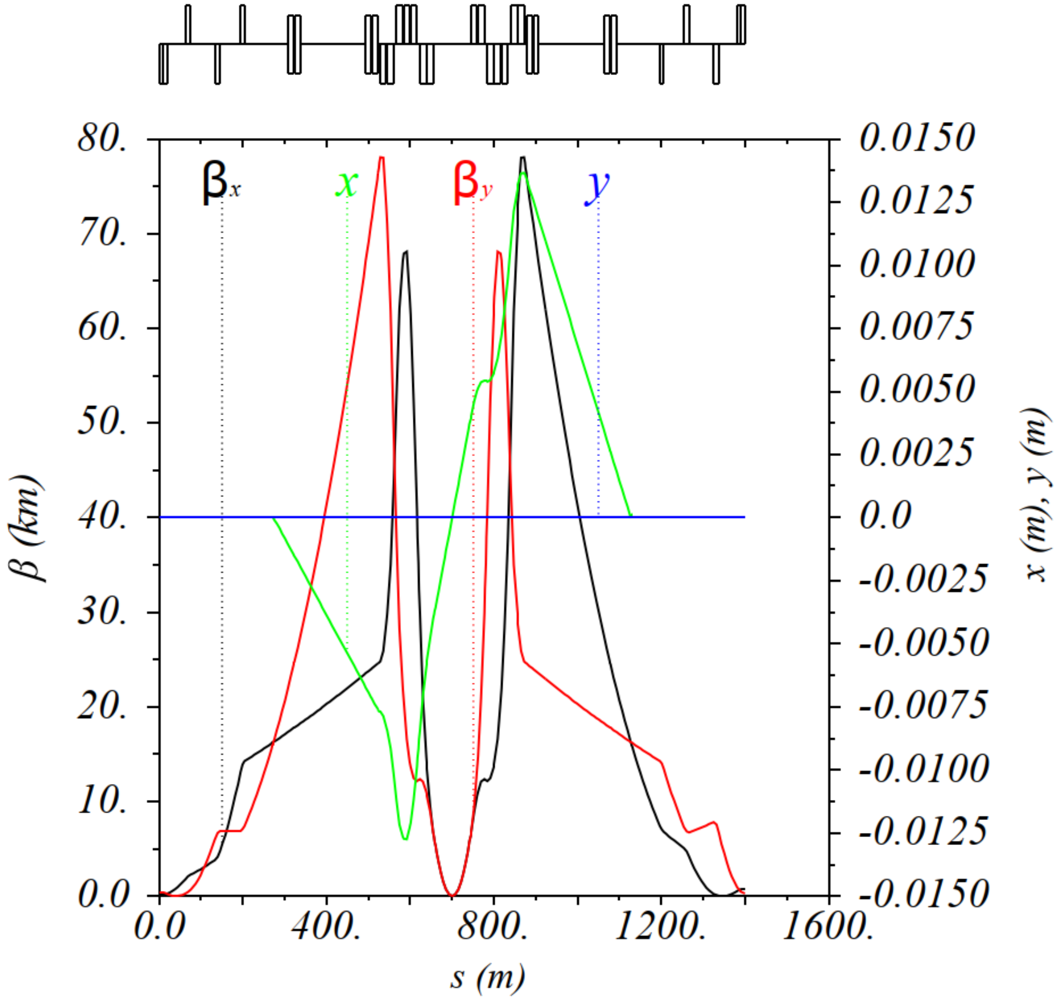
Results for 45 m L*



Parameter	Q1	Quadrupole Q2	Q3
Sub-magnets	2	3	2
Sub-magnet Length (m)	15	15	15
Coil Radius (mm)	98.3	98.3	98.3
Gradient (Tm^{-1})	106	110	97
Shielding (mm)	44.2	33.2	24.2

- **Triplet made of 7 identical magnets**
  - **Uniform aperture benefits deposition**
  - **Easier to design**
  - **Smaller pool of backups**
- **Shielding in magnets increases towards IP**

Results for 45 m L*



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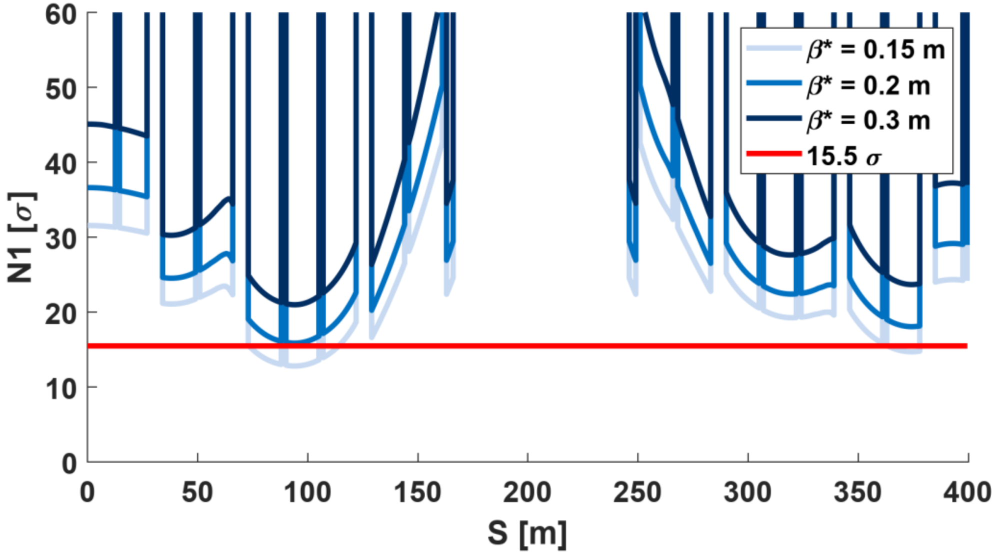
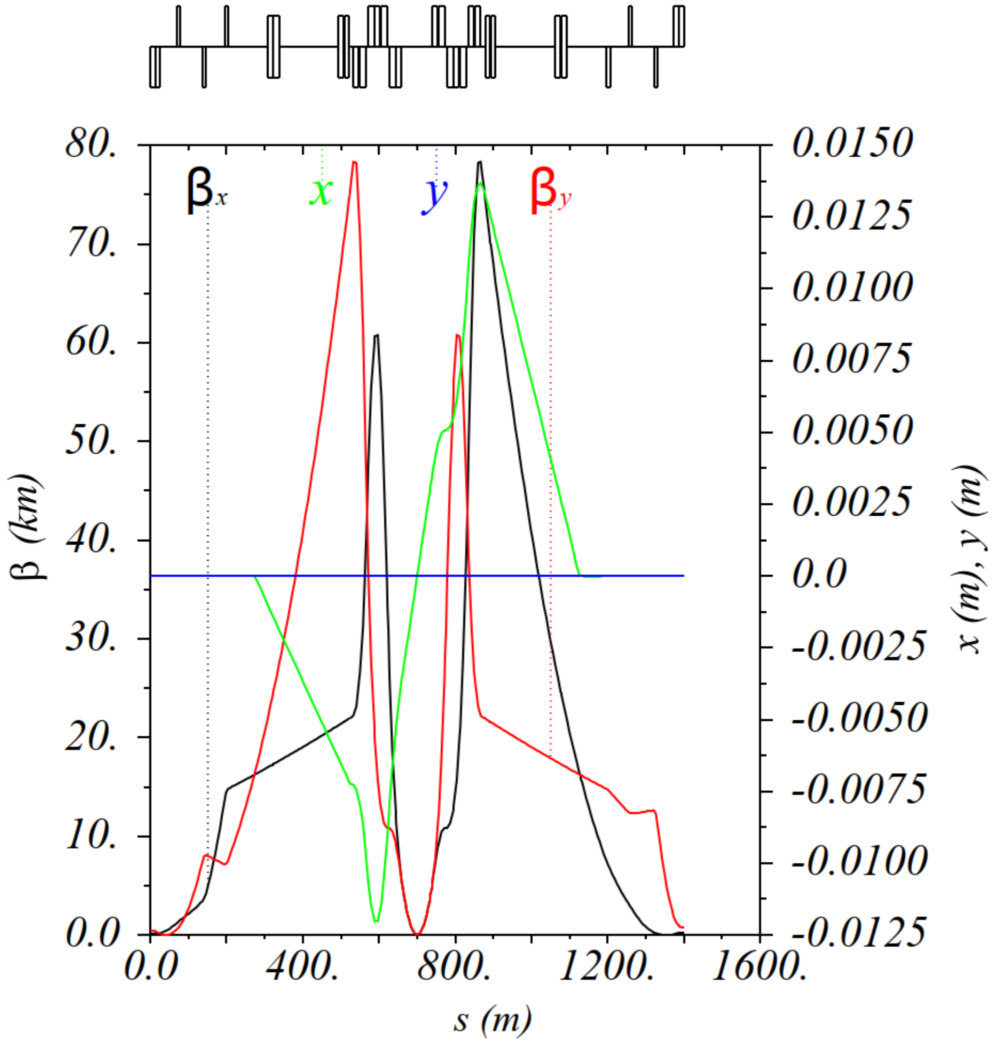


Move towards 40 m L*



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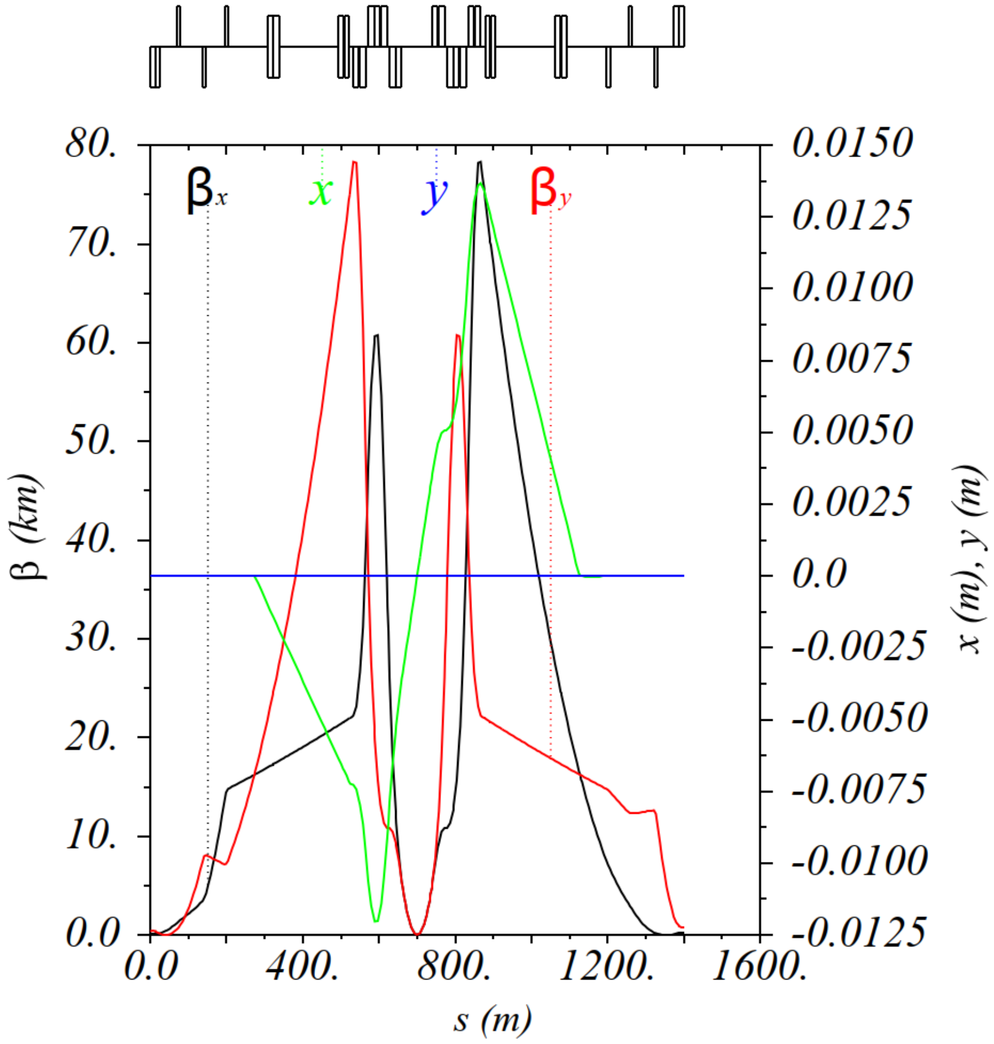
Sub-magnets	2	3	2
Sub-magnet Length (m)	15	15	15
Coil Radius (mm)	96.5	96.5	96.5
Gradient (Tm^{-1})	106	112	99
Shielding (mm)	44.2	33.2	24.2

- **Moved triplet 5 m closer to IP**
  - **Due to change in experimental hall layout**
- **Re-matched triplet**
  - **Slightly increased strength**
  - **Slightly smaller β**
- **Reduced Chromaticity**

Move towards 40 m L*



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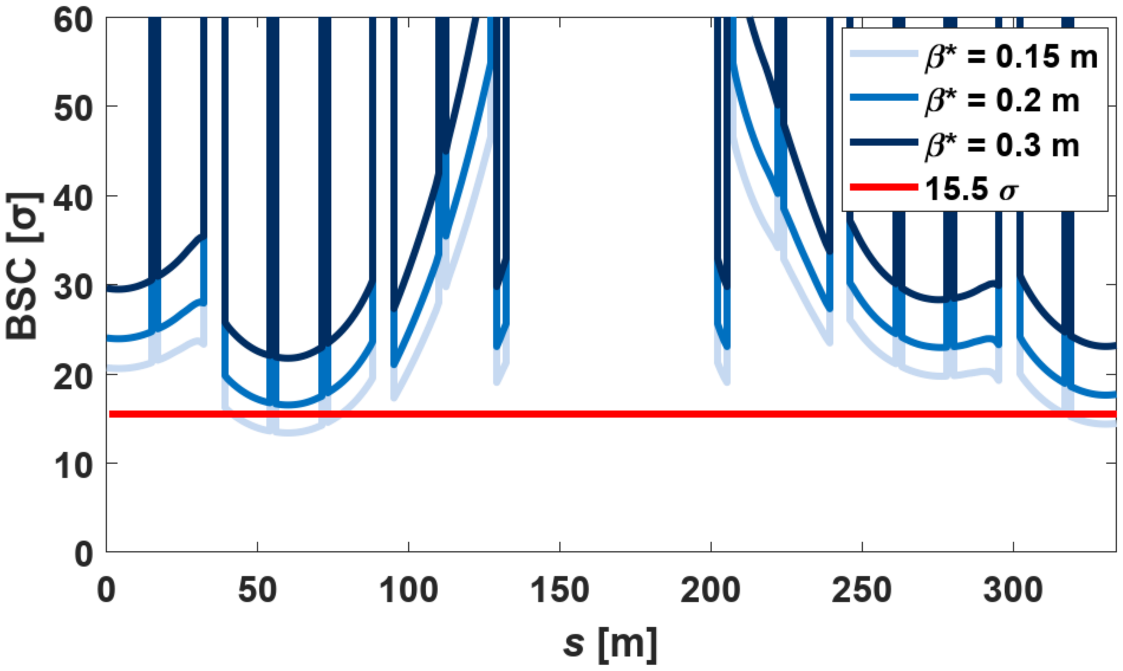
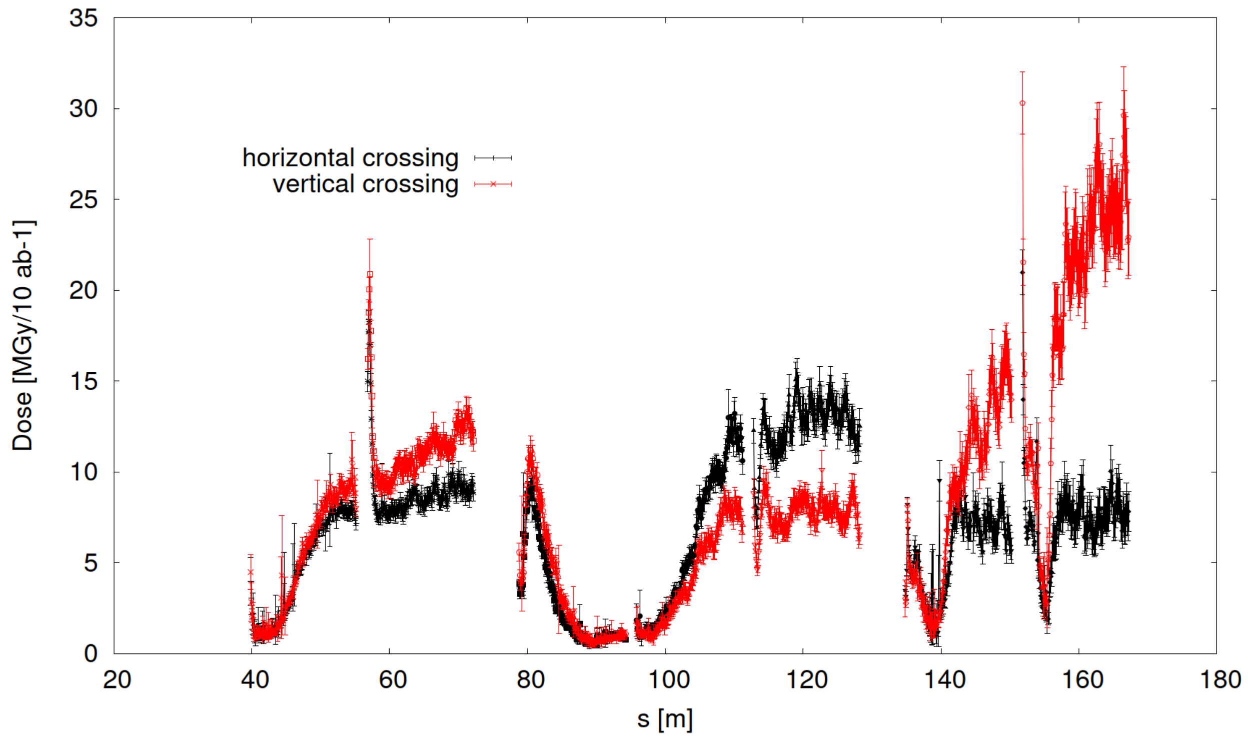


Energy Deposition

- **Largest deposition in Q3**
- **Can be reduced by switching crossing planes**
  - < 15 MGy/ 10 ab^{-1}
- **For 30 ab^{-1} lifetime**
  - < 45 MGy
- **At lower end of 30 MGy – 100 MGy limit**
- **Comparable to baseline**



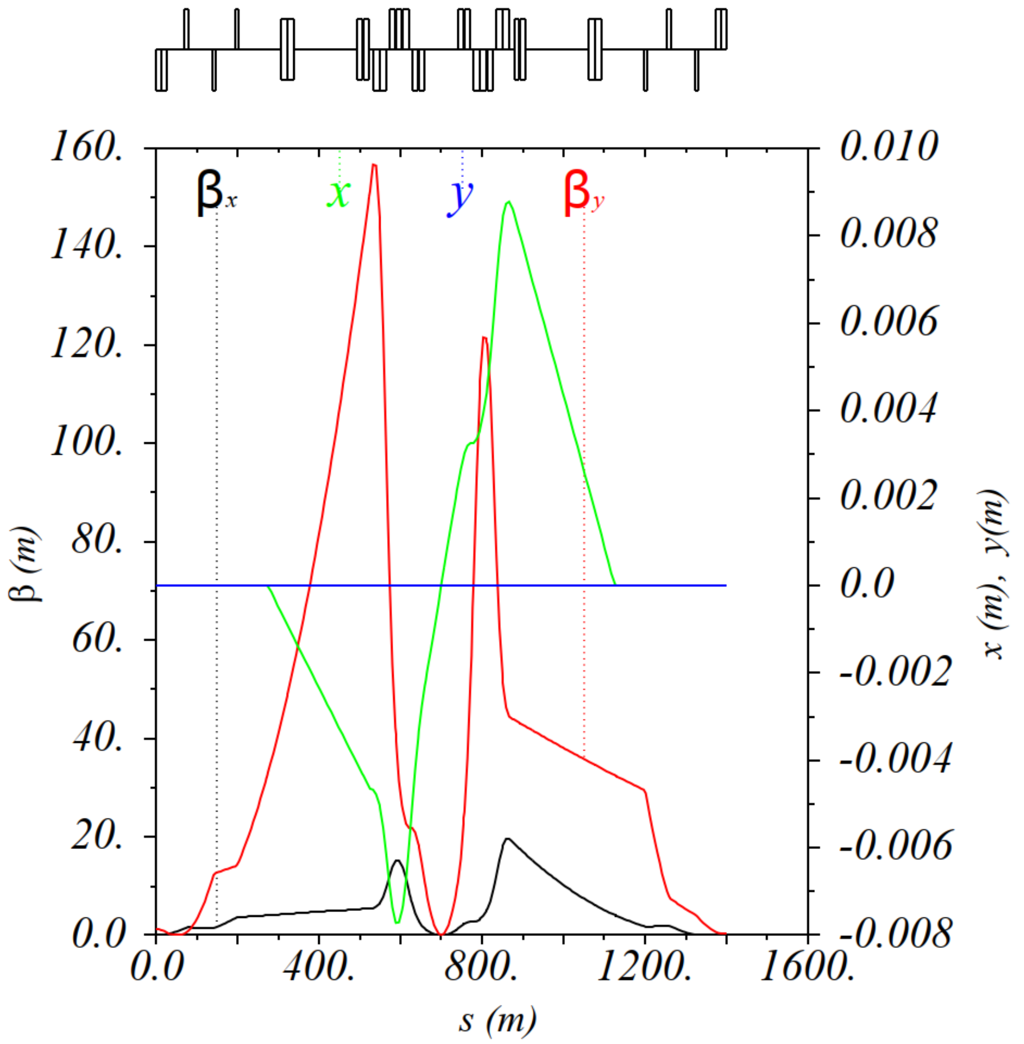
Jose Abelleira

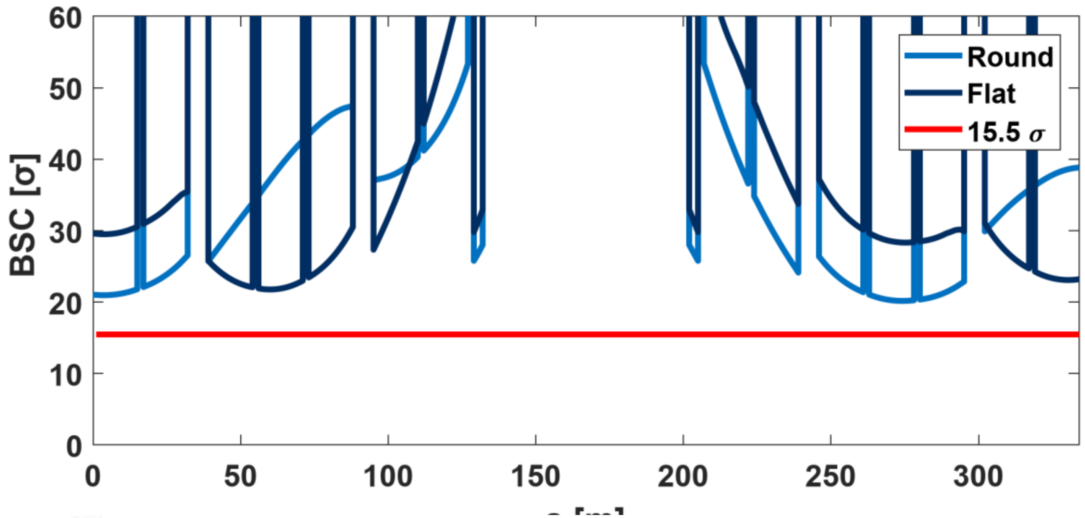
EuroCirCol
A key to New Physics

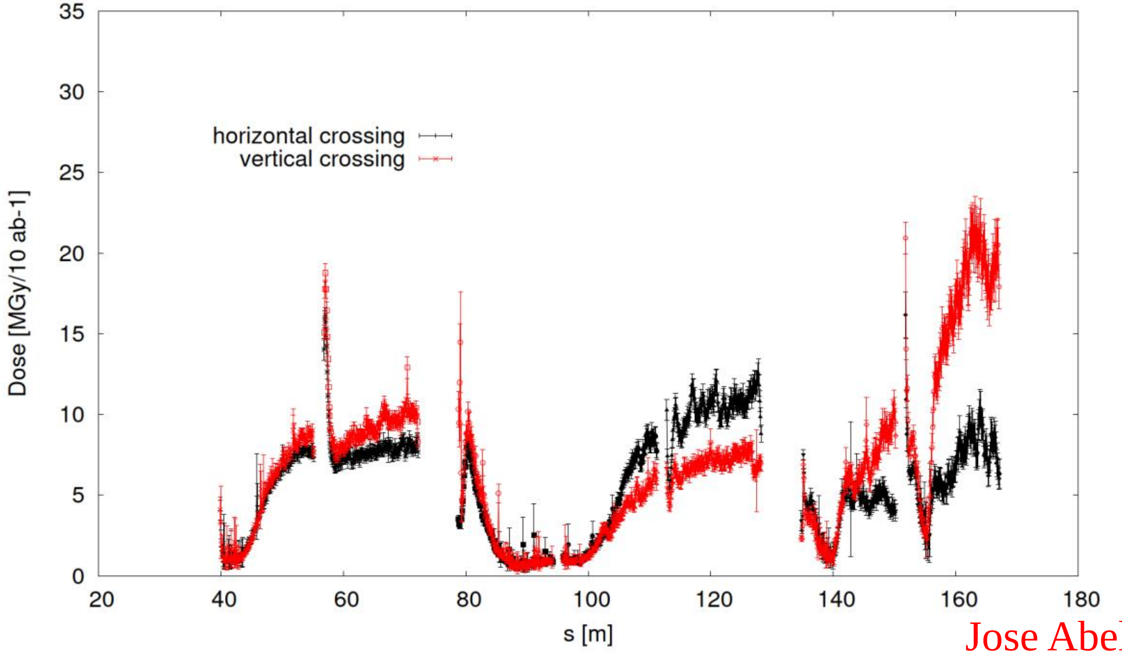
Flat Optics

- Motivation
  - Compensation if crab cavities aren't available
  - Large β^* in crossing plane
  - Allows smaller crossing angle
- Study to find best flat optics choice performed by Jose Abelleira
- 1.2×0.15 m optics
- Achieved with same triplet and matched with matching section

Flat Optics Results







Jose Abelleira

Comparison to Baseline

- **Several Similarities**
  - Alternative Triplet 2.5% shorter magnetic length (R. Martin)
  - Radiation dose comparable to "High Shielding" baseline optics (B. Humann)
  - Same 0.2 m β^* reach in this case
  - Both options satisfy DA requirements (E. Cruz-Alaniz)
- **Largely confirms baseline approach**
- **Differences**
  - All sub-magnets identical
    - One design, less backup
  - Unequal β functions
  - Varying shielding

Summary

- **Design of Alternative Triplet**
  - Triplet optimisation code
  - Optics and energy deposition studies
- **Full Optics Set**
  - Injection
  - Collision (various β^*)
  - Flat-optics
- **Comparable to Baseline Triplet**
- **Made of 7 Identical Magnets**