

# 3D coil design using splines

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- One of the main challenges for stellarators is the fabrication of non-planar coils. FOCUS is a code created to address this challenge and allow simpler coil designs.
- Both physical and engineering constraints
- Coils as arbitrary curves in 3D
- Fourier and Spline representation now available



- Described by Control Points ( $p_i$ ) 
$$\mathbf{f}(t) = \sum_{i=0}^{\infty} p_i \mathbf{B}_i(t)$$
- Basis functions obtained by Cox-De Boor algorithm

$$B_{0,i}(t) = 1 \quad (t \in [t_i : t_i + 1])$$

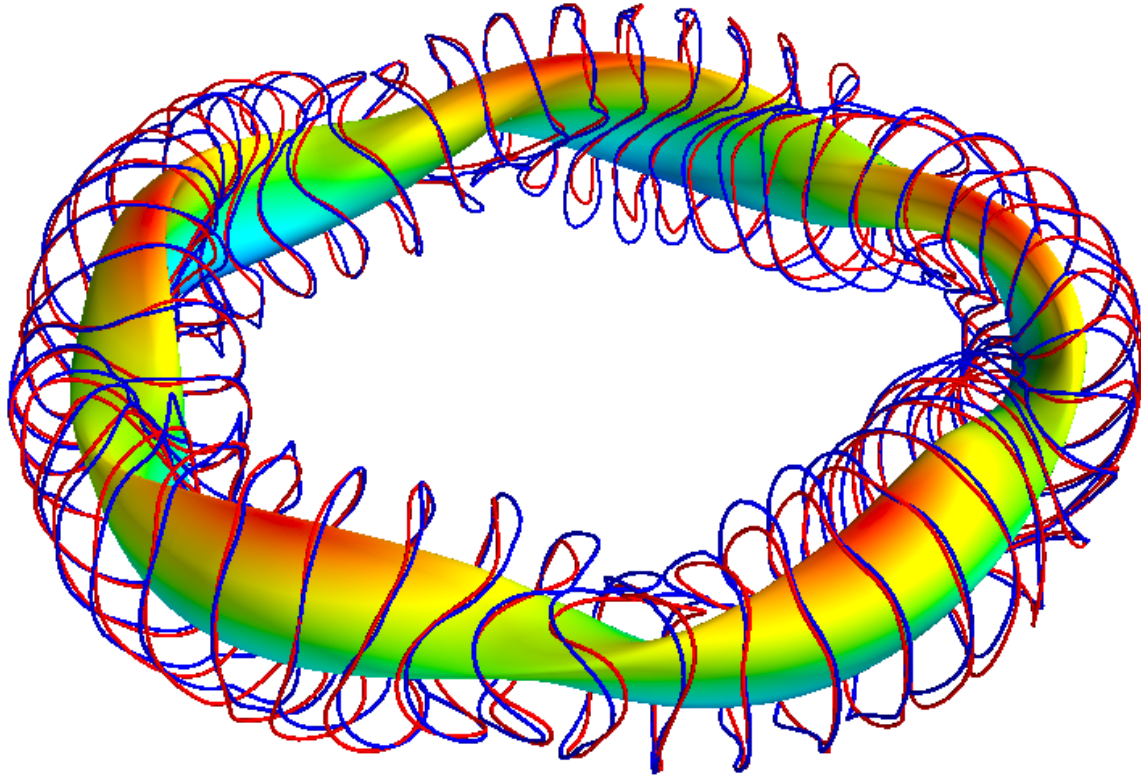
$$B_{k,i}(t) = \frac{t-t_i}{t_{i+k}-t_i} B_{k-1,i}(t) + \frac{t_{i+k+1}-t}{t_{i+k+1}-t_{i+1}} B_{k-1,i+1}(t)$$

- Derivatives calculated analytically

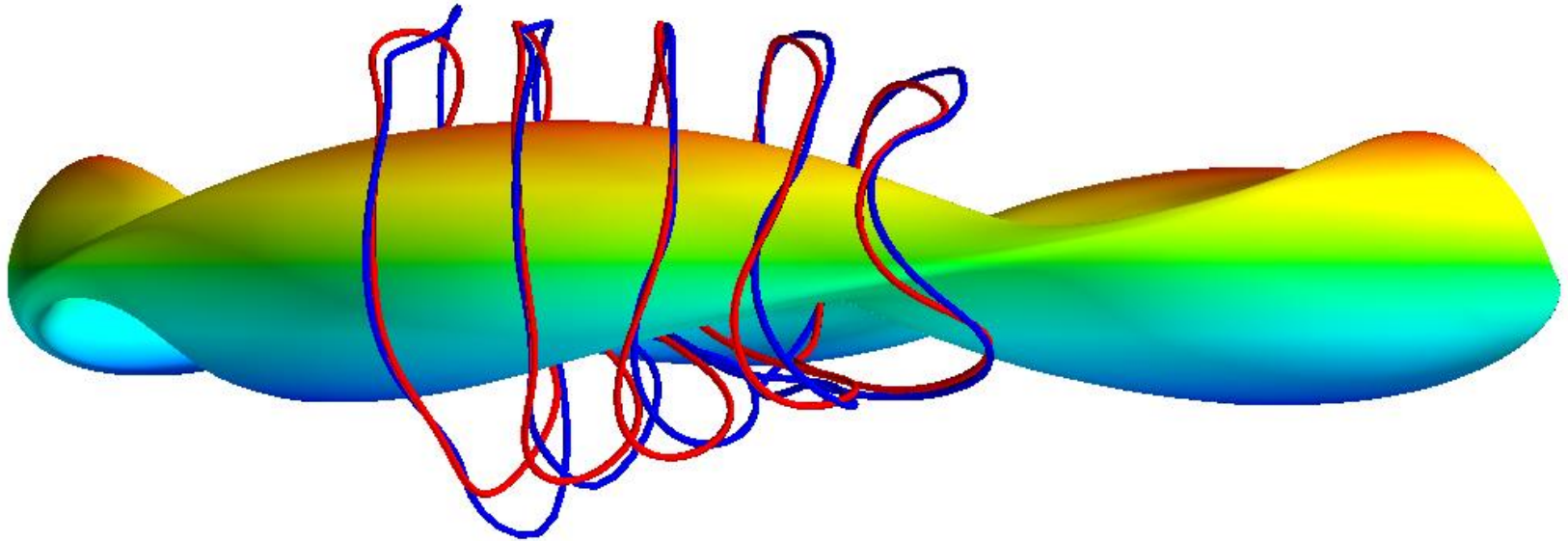


- Constraint : Making the outer part of the coils straighter to improve accessibility and simplify maintenance
- Reduce curvature of the coil computed at the points with the greatest distance from the origin

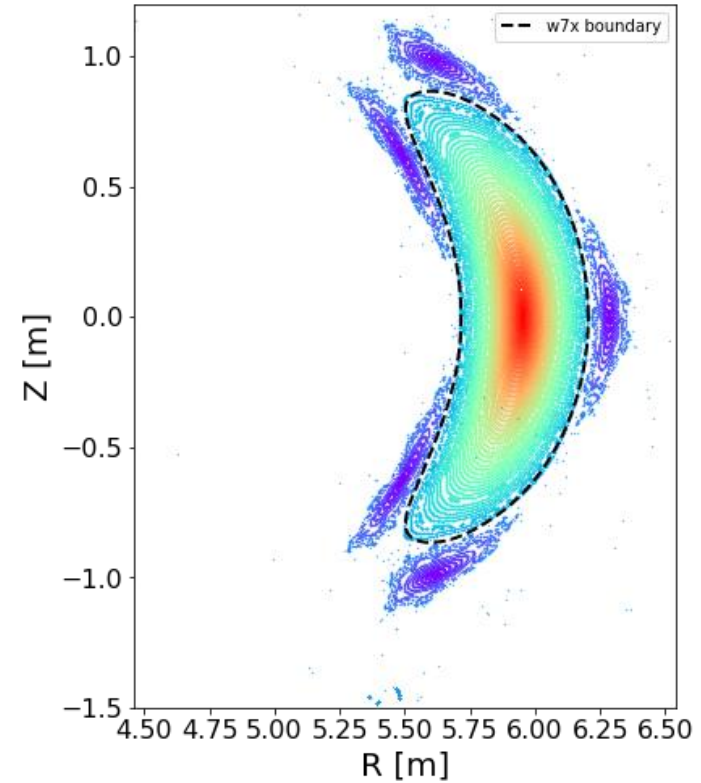
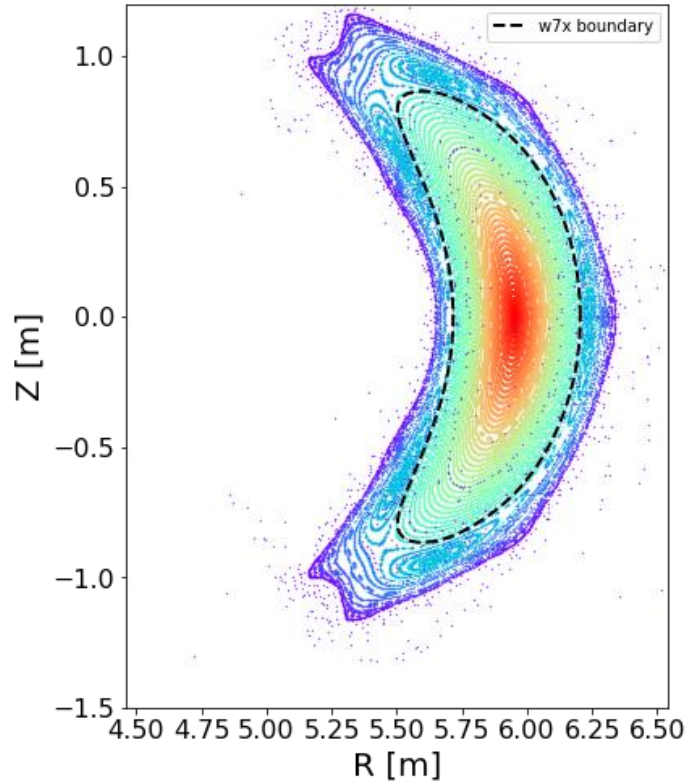
$$f_{straight} = \frac{1}{N_c} \sum_{i=1}^{N_c} \int_0^{2\pi} W(t) H_{\kappa_{s,0}}(\kappa_{s,i}) (\kappa_{s,i} - \kappa_{s,0})_s^\alpha dt$$



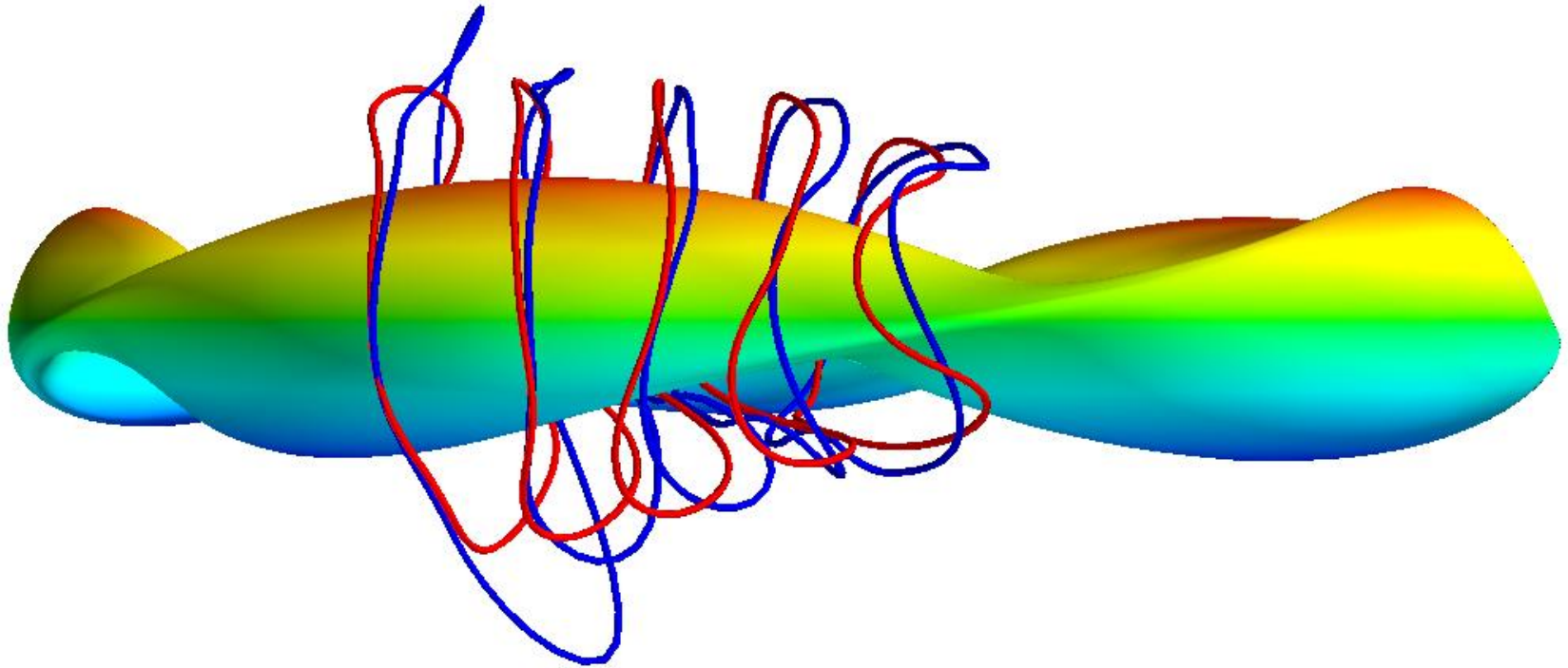
*Comparison of benchmark (red) and improved design (blue) on w7x plasma surface*



*Comparison of benchmark (red) and improved design (blue) on w7x plasma surface*



- Comparison of benchmark (left) and improved design (right) on w7x plasma surface



*Comparison of benchmark (red) and improved design (blue) on w7x plasma surface*





- A Spline representation has been added to FOCUS to enable the design of coils with a straighter outer section
- By varying the corresponding weight it is possible to balance this requirement with the need for a suitable magnetic field
- In the future it will be possible to use this feature to design reactors that are easier to build and maintain