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Magnetic field modelling of the wire

WP2/WP13 HL-LHC Satellite Meeting, Long-Range Beam-Beam Wire

September 23, 2022 - Uppsala

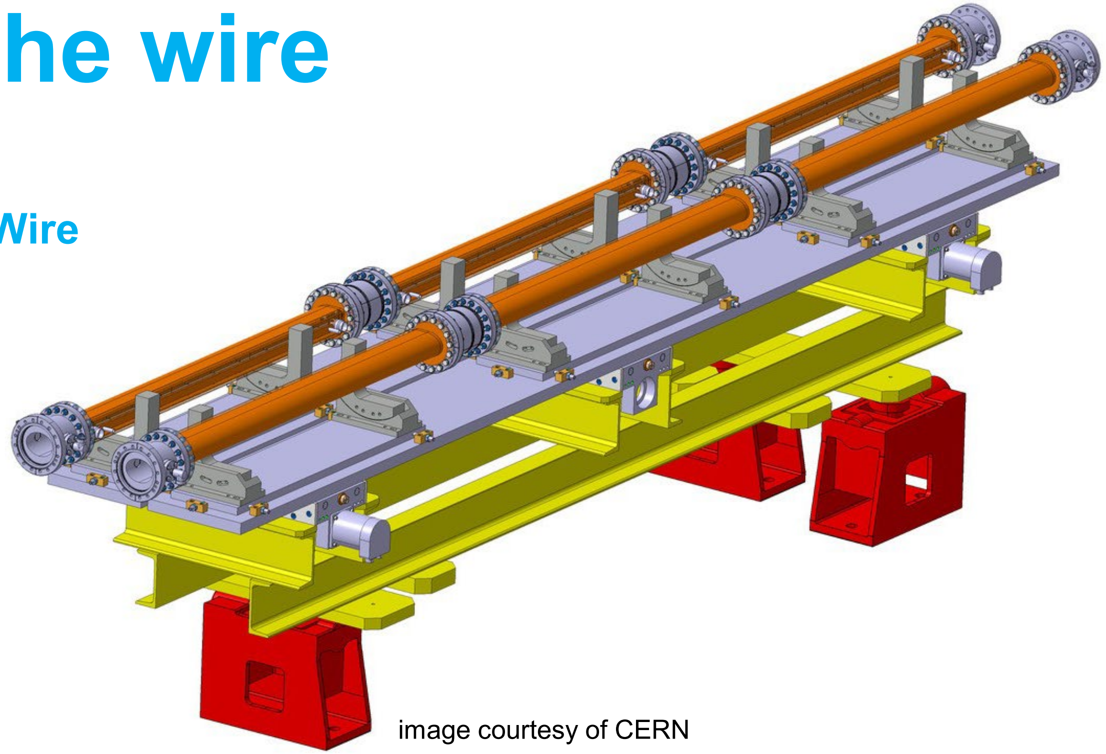


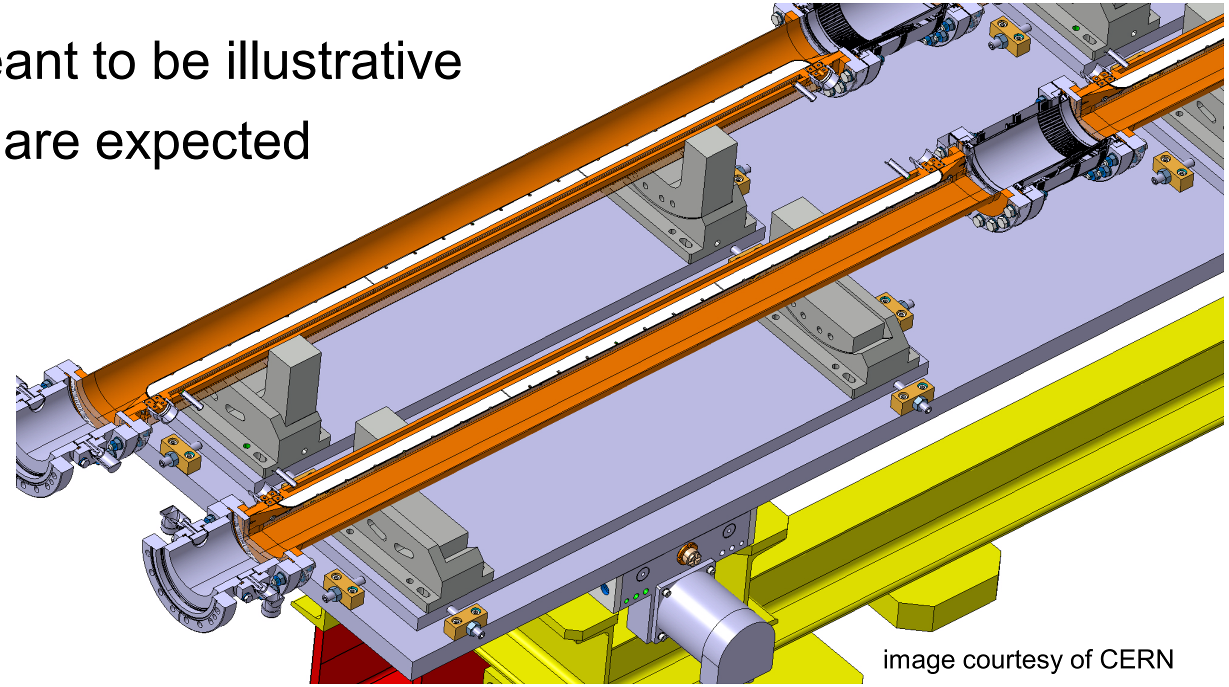
image courtesy of CERN

Marco Marchetto, TRIUMF

Discovery, accelerated

Initial remarks

- The assigned task is to produce a realistic model of the current wire proposal in order to extract magnetic fields for beam dynamics simulations
- The main goal of this presentation is to provide the status of the model
- The data (magnetic fields) presented are meant to be illustrative
- Improvements or modifications to the model are expected



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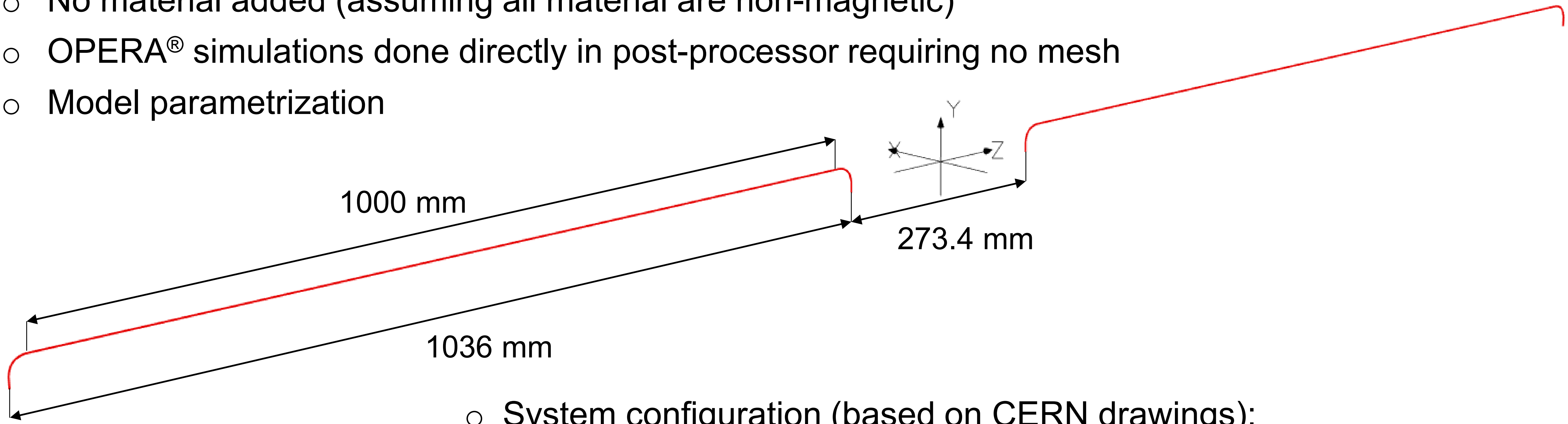
Baseline configuration

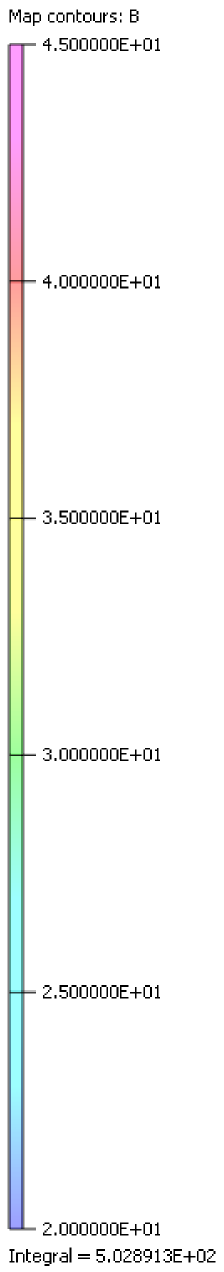
- Baseline configuration with two simple wires (no brazing)
- No material added (assuming all material are non-magnetic)
- OPERA® simulations done directly in post-processor requiring no mesh
- Model parametrization

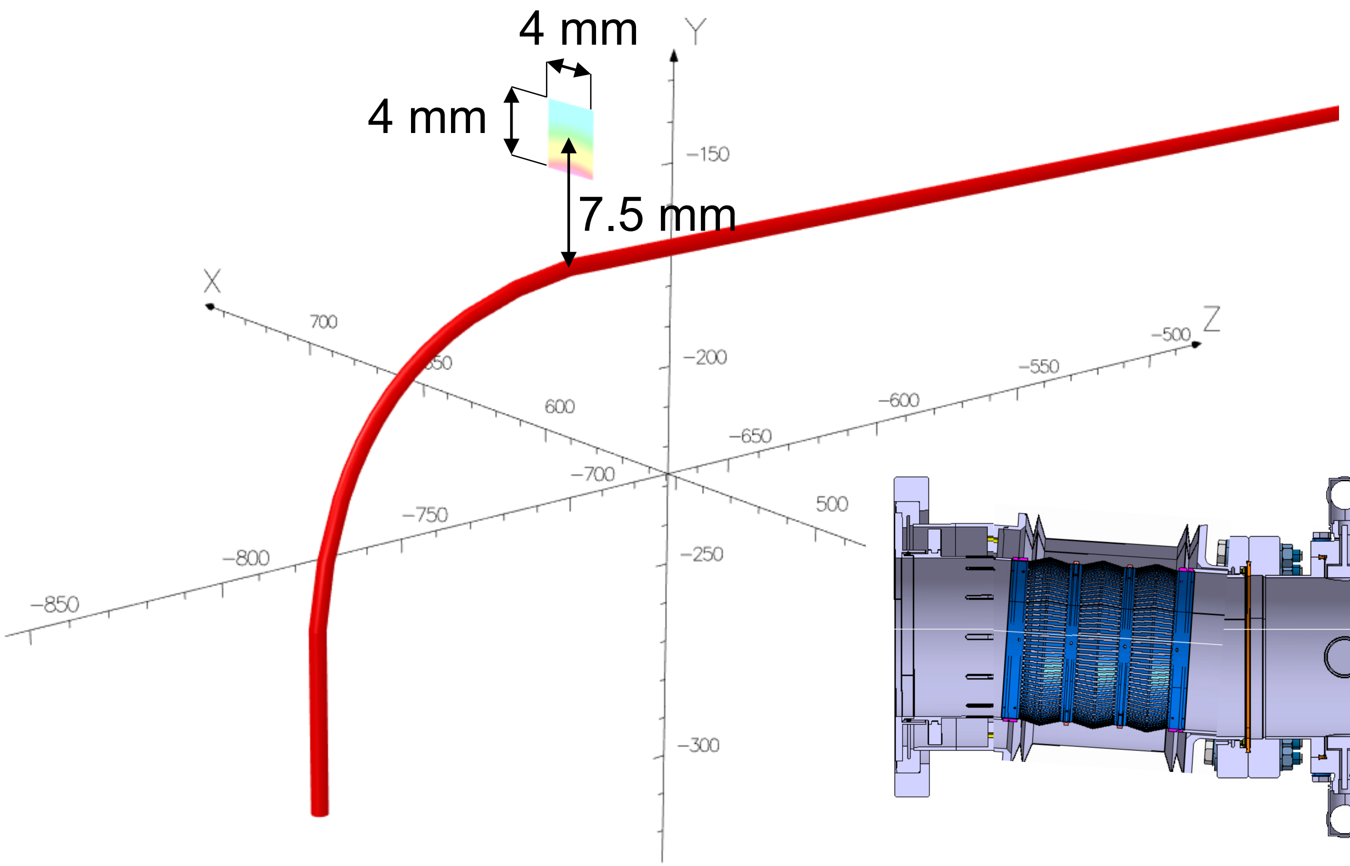


- System configuration (based on CERN drawings):
  - Total current: 150 A (OPERA current density 193.30 A/mm^2)
  - Current flow from -z to +z
  - Wire diameter: 1 mm
  - Wire length: 1000 mm (straight section)
  - Bend radius: 18 mm (wire axis)
  - Separation between wires: 273.4 mm (feedthrough to feedthrough)

Data window

- Simulation data extracted around the beam axis:
  - at 7.5 mm from the wire, and ± 2 mm in the transverse directions (x, y)
  - at entrance of single wire, and between two wires





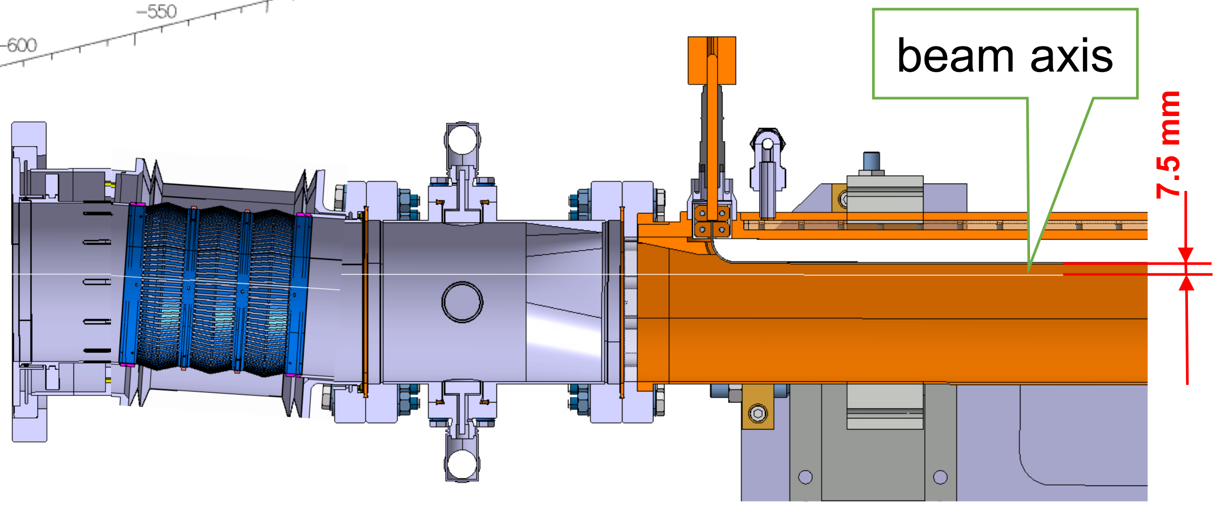
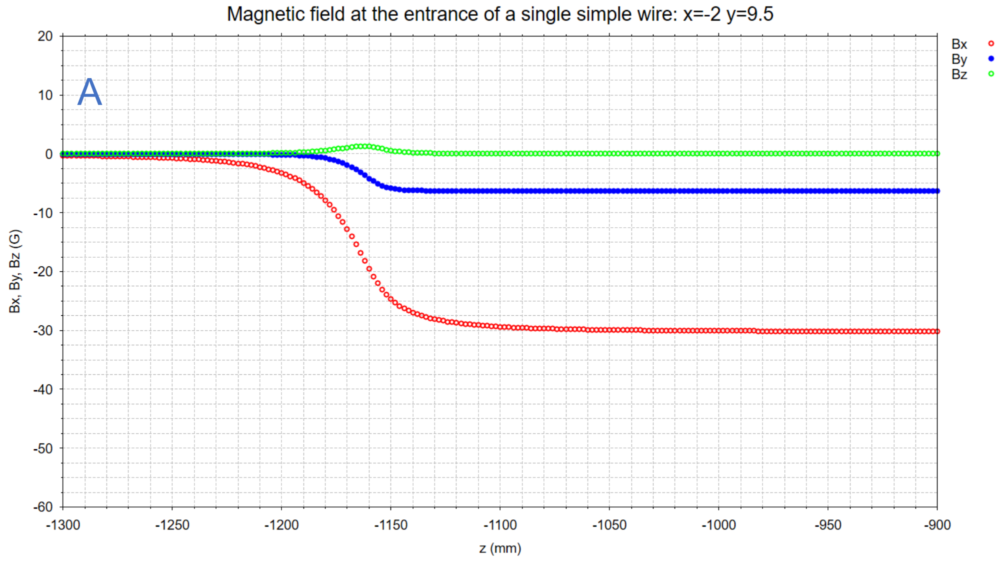
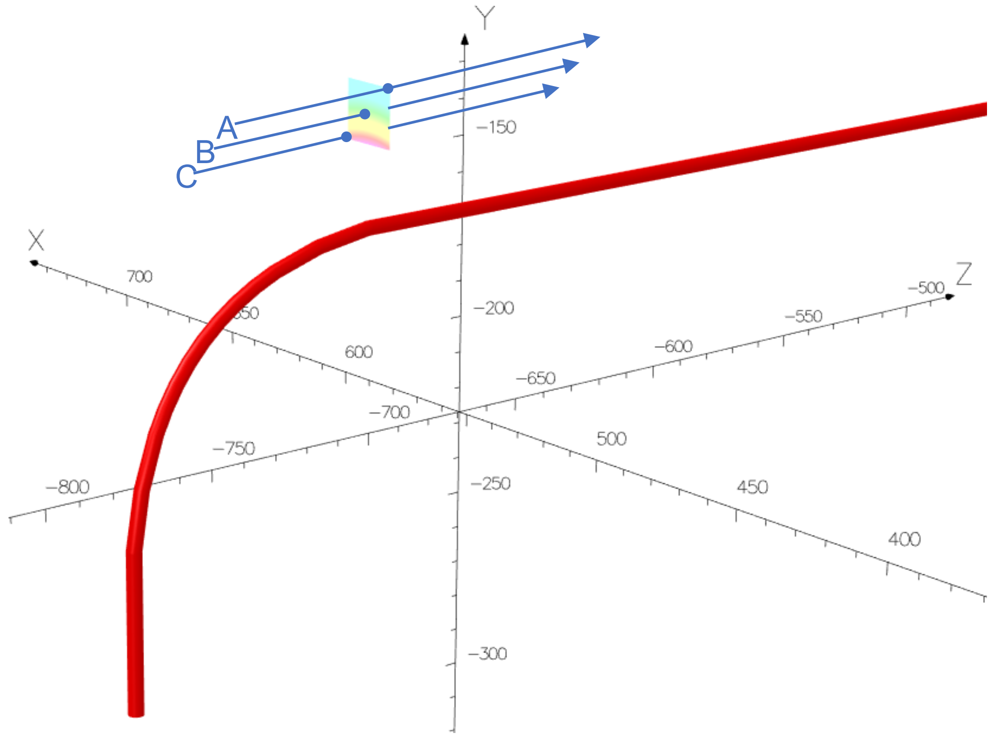


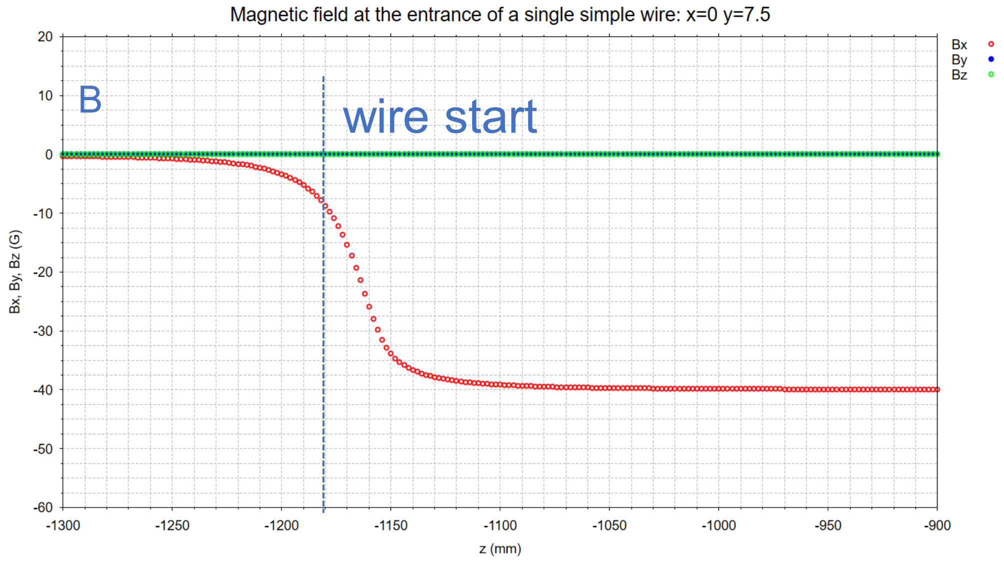
Image courtesy of L. Gentini

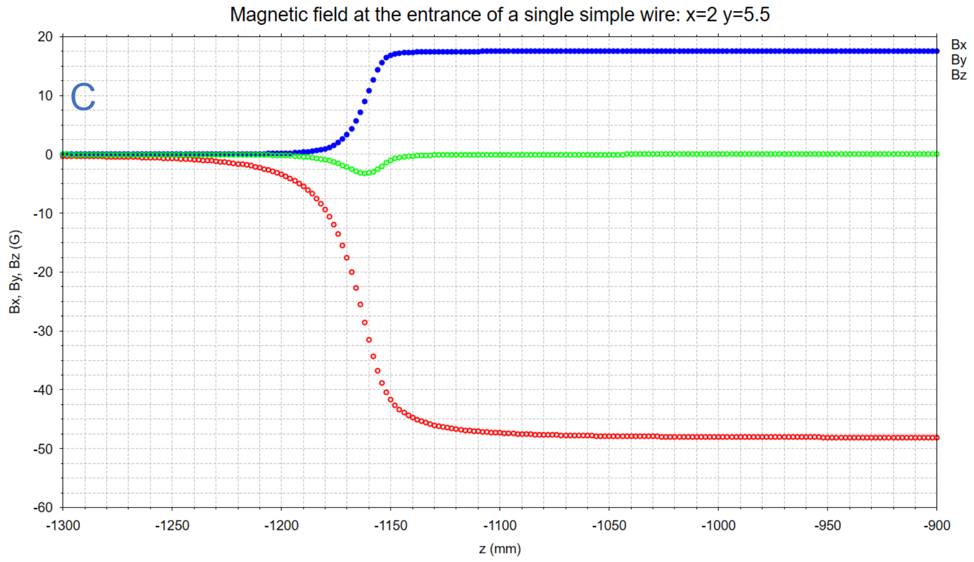
Entrance of a simple wire - longitudinal

- Simple wire has no braze features, just round
- Magnetic field components vs longitudinal direction (z)

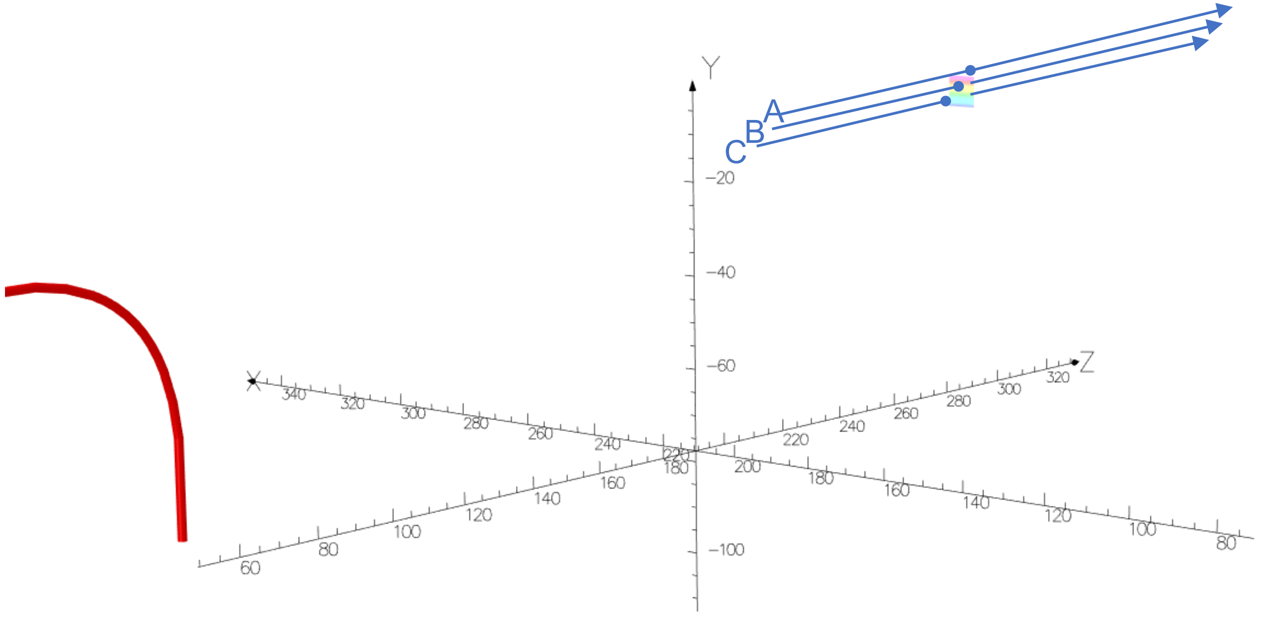


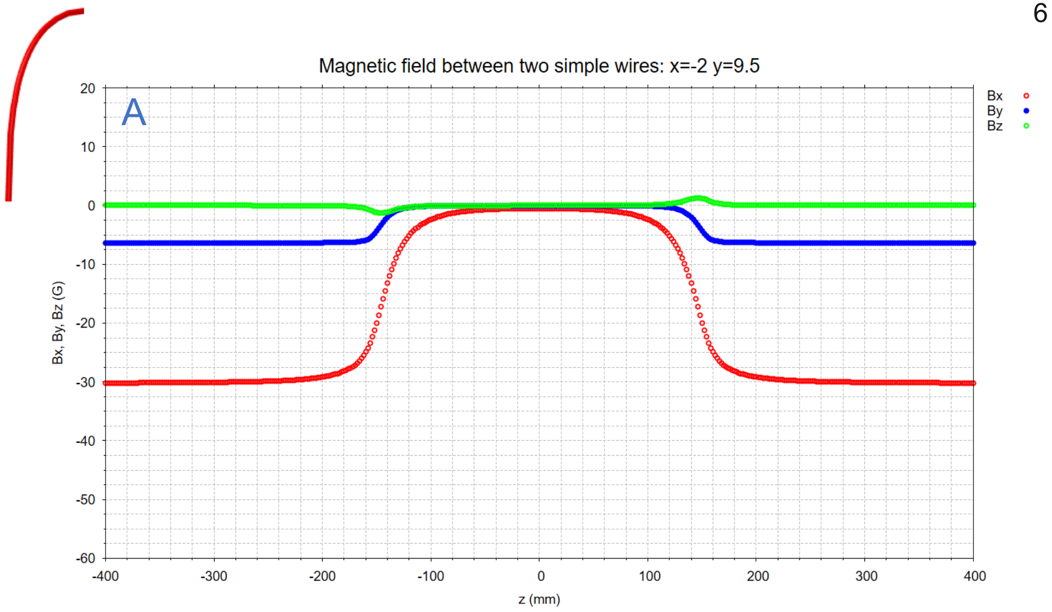


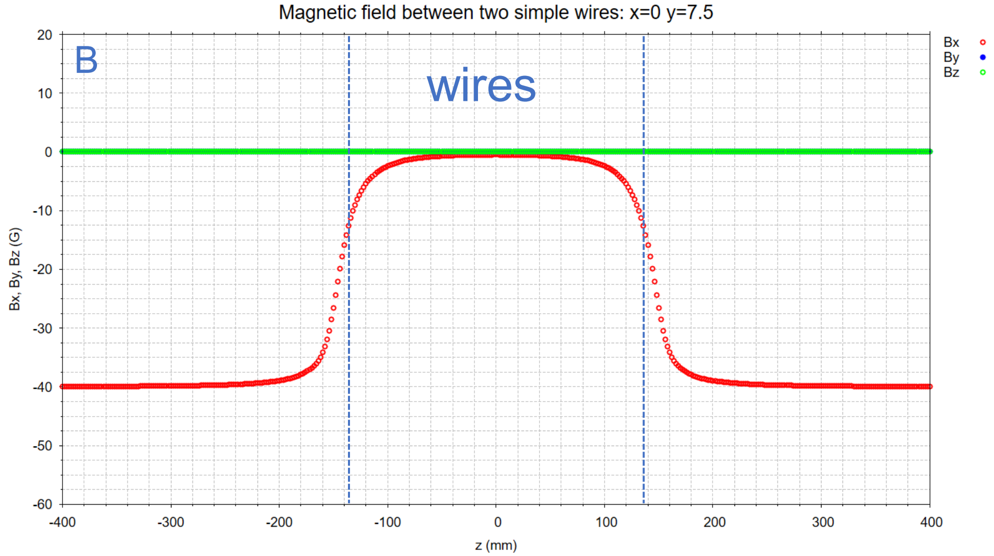


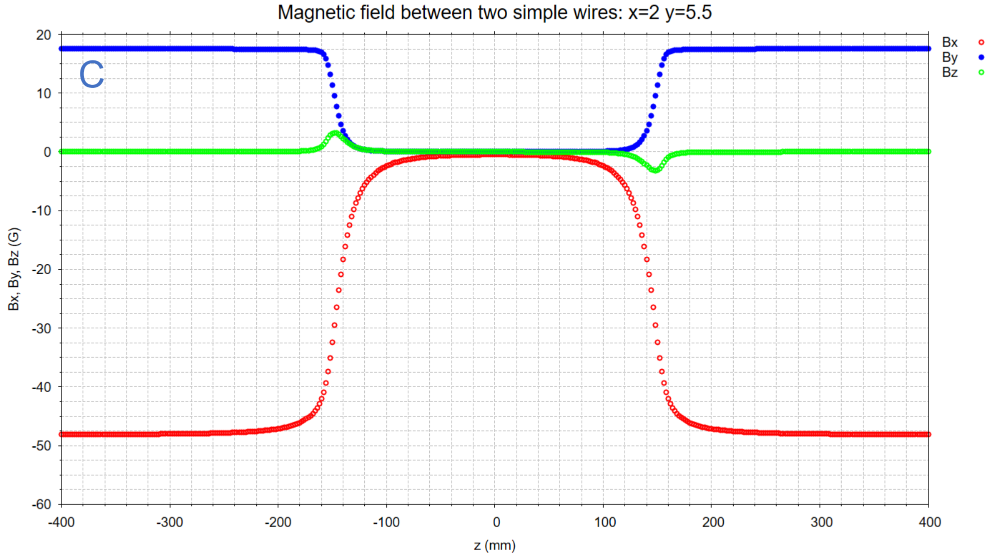


Between two simple wires - longitudinal

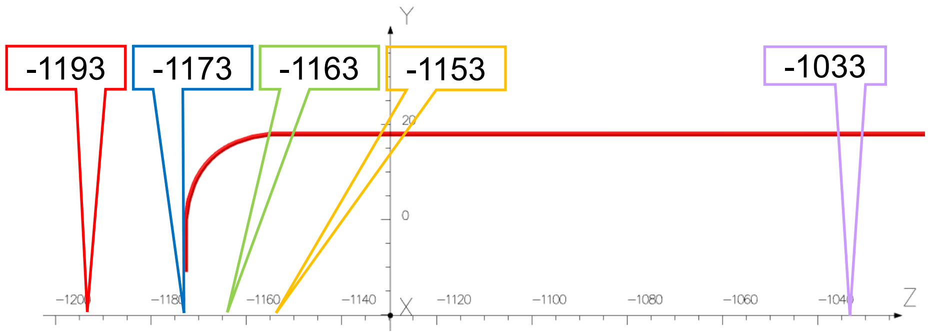




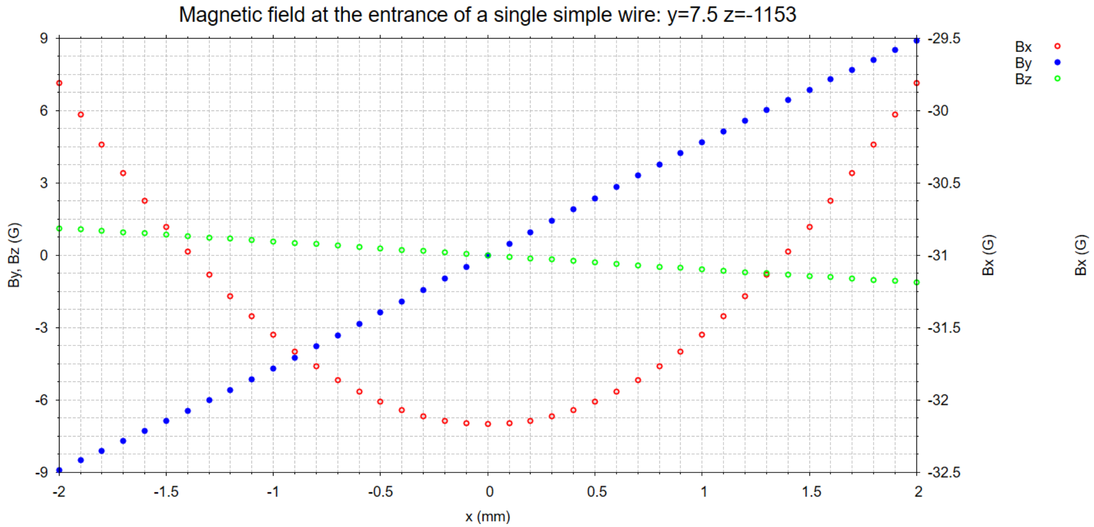


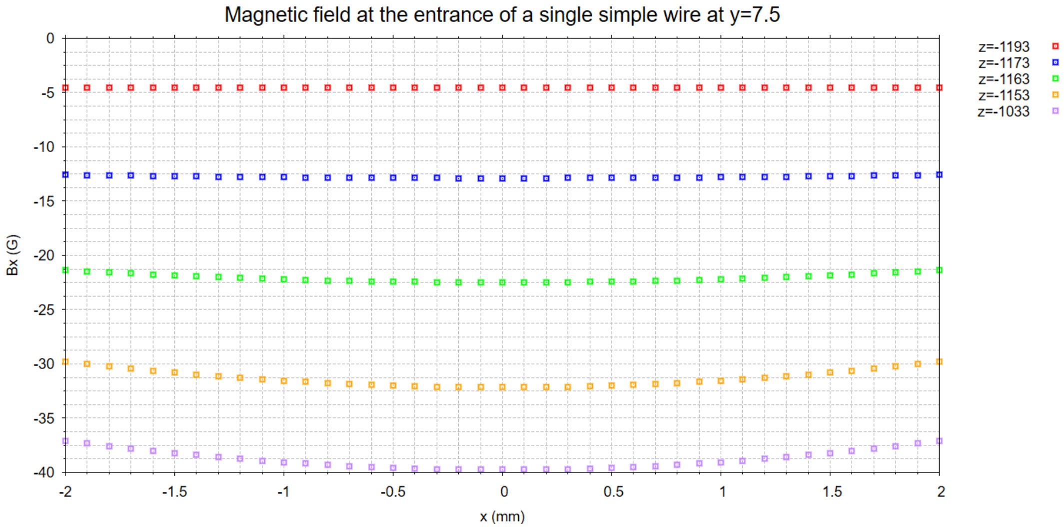


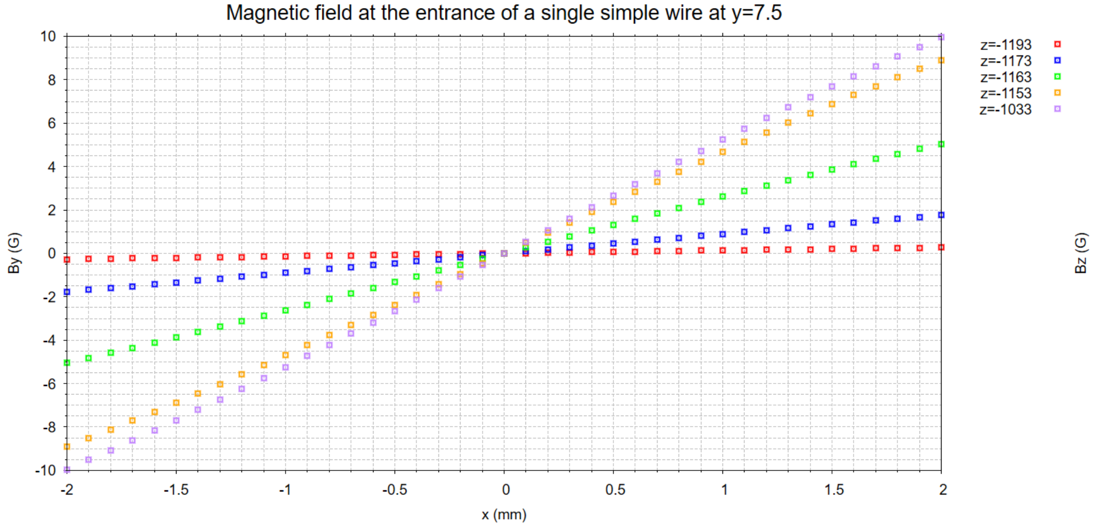
Entrance of a simple wire - transverse

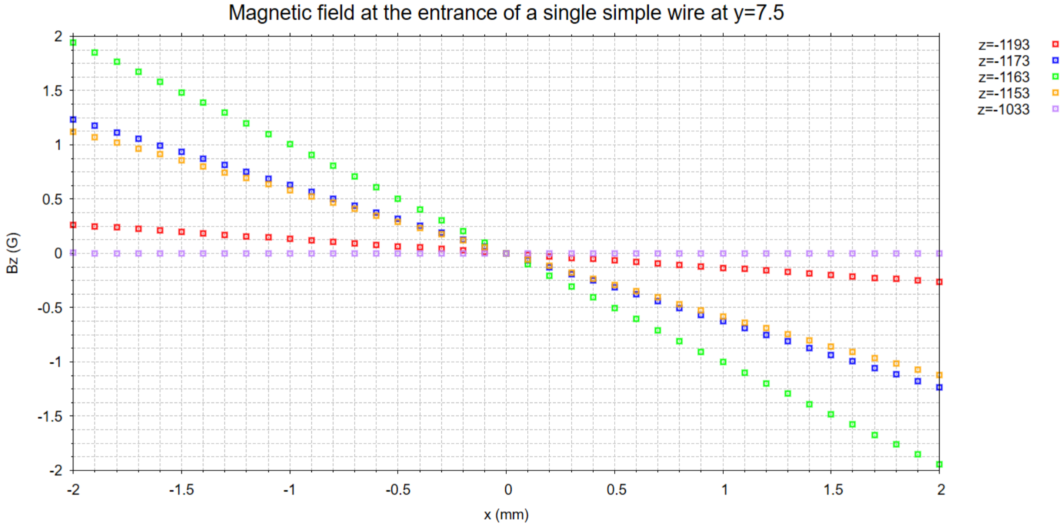


- Magnetic field components vs transverse direction (x)



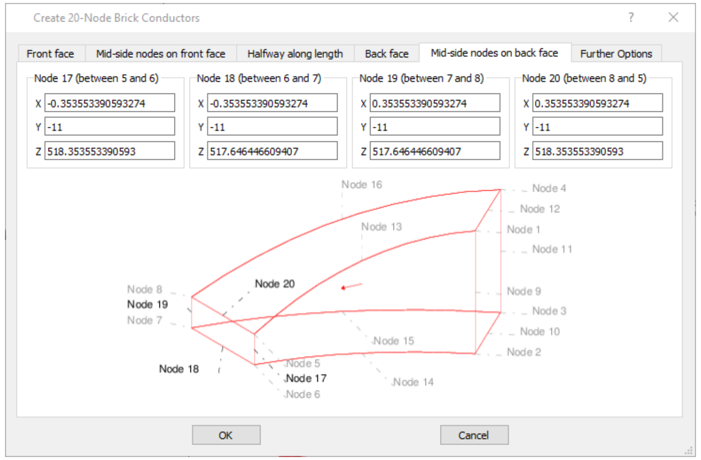


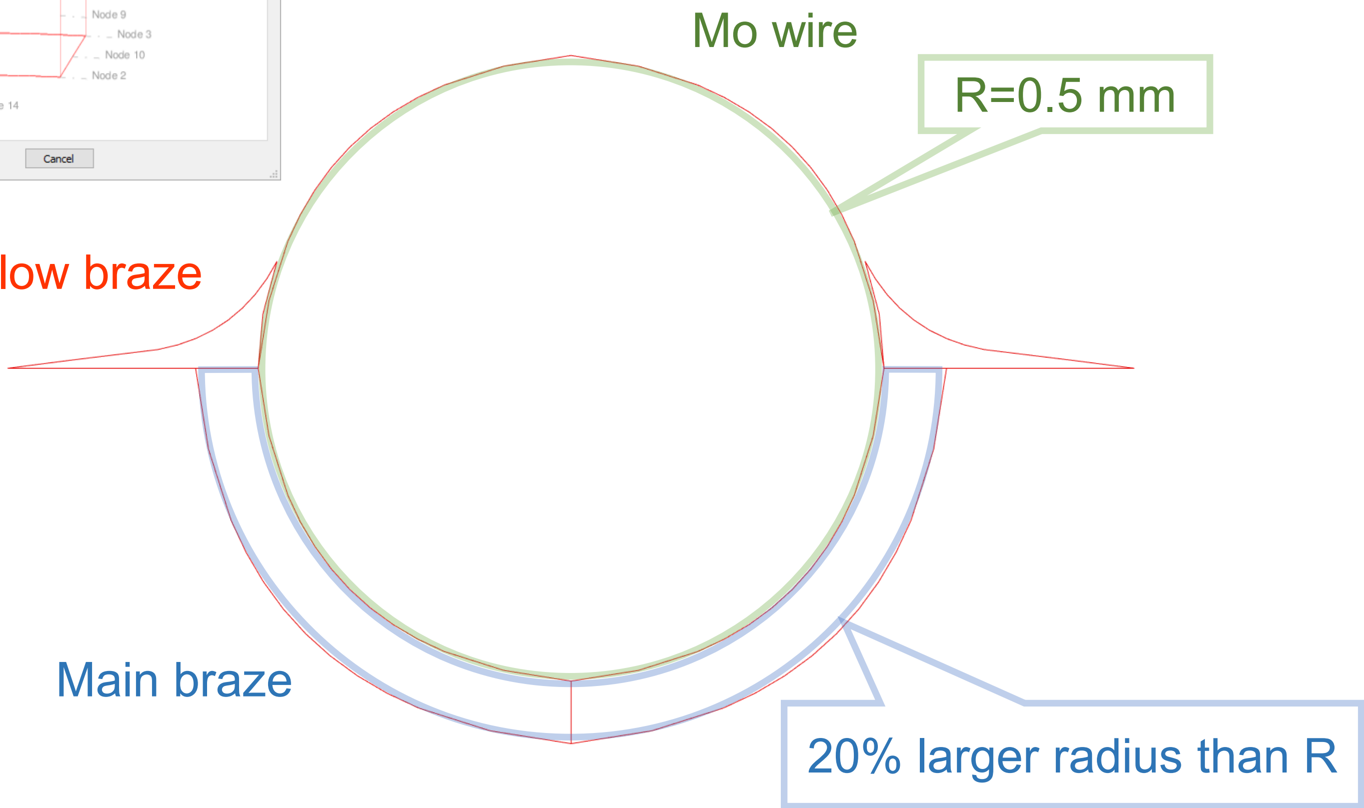


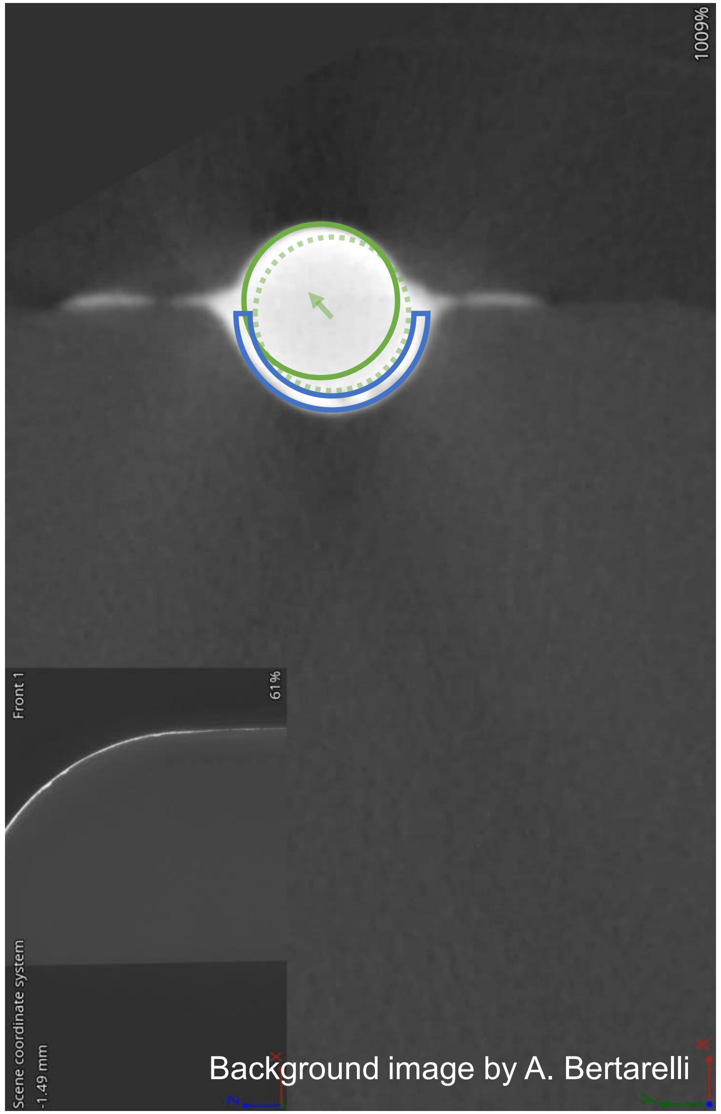


Modelling of the brazed wire

- Modelling based on the radiographic image of brazed wire
- Used OPERA 20-node brick to re-create the profile of the brazed wire in different sections

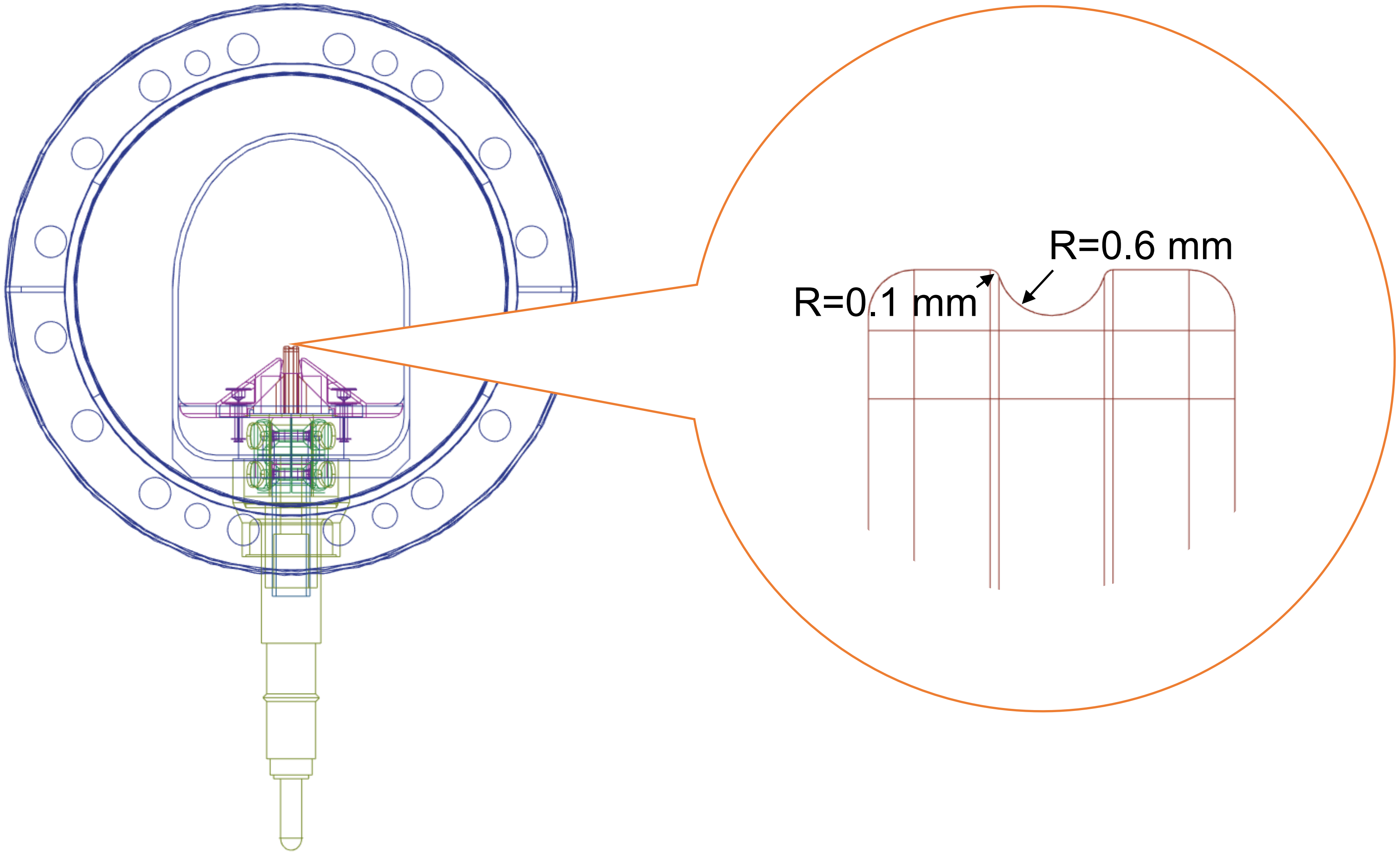






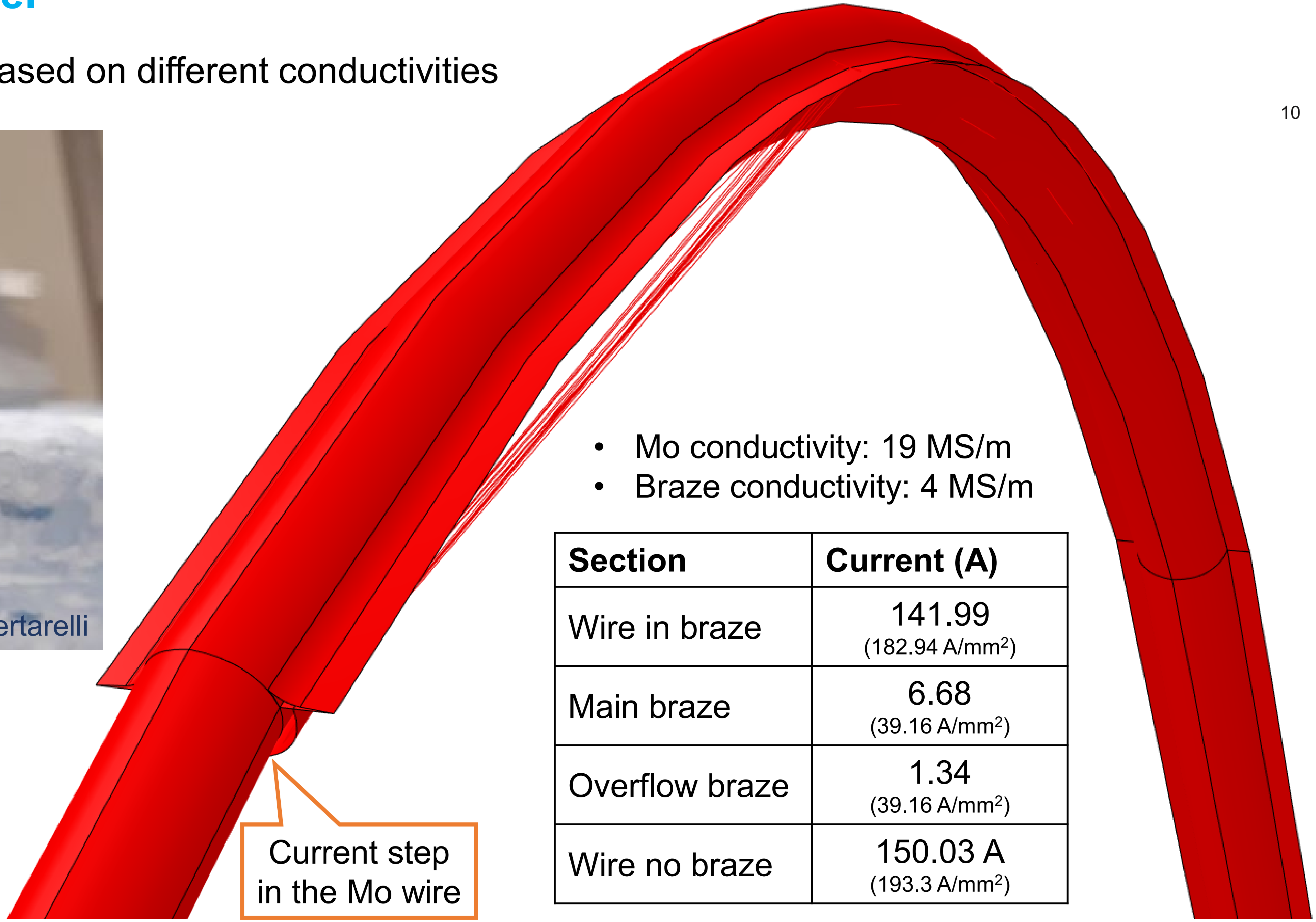
Modelling fidelity

- 20% larger (main) braze radius consistent with AlN geometry
- Small 0.1 mm radius not included in the model
- Overflow brazed modelled on “reasonable approximation”



Brazed wire 3D model

- Current distribution based on different conductivities

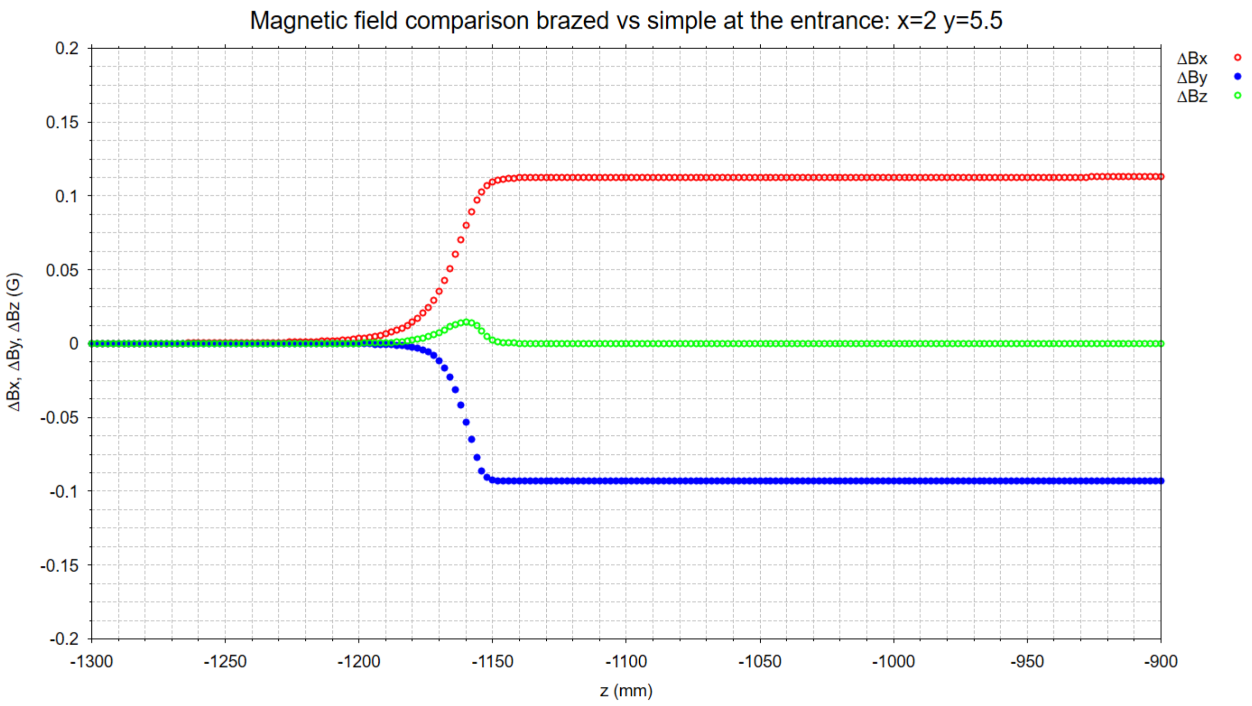


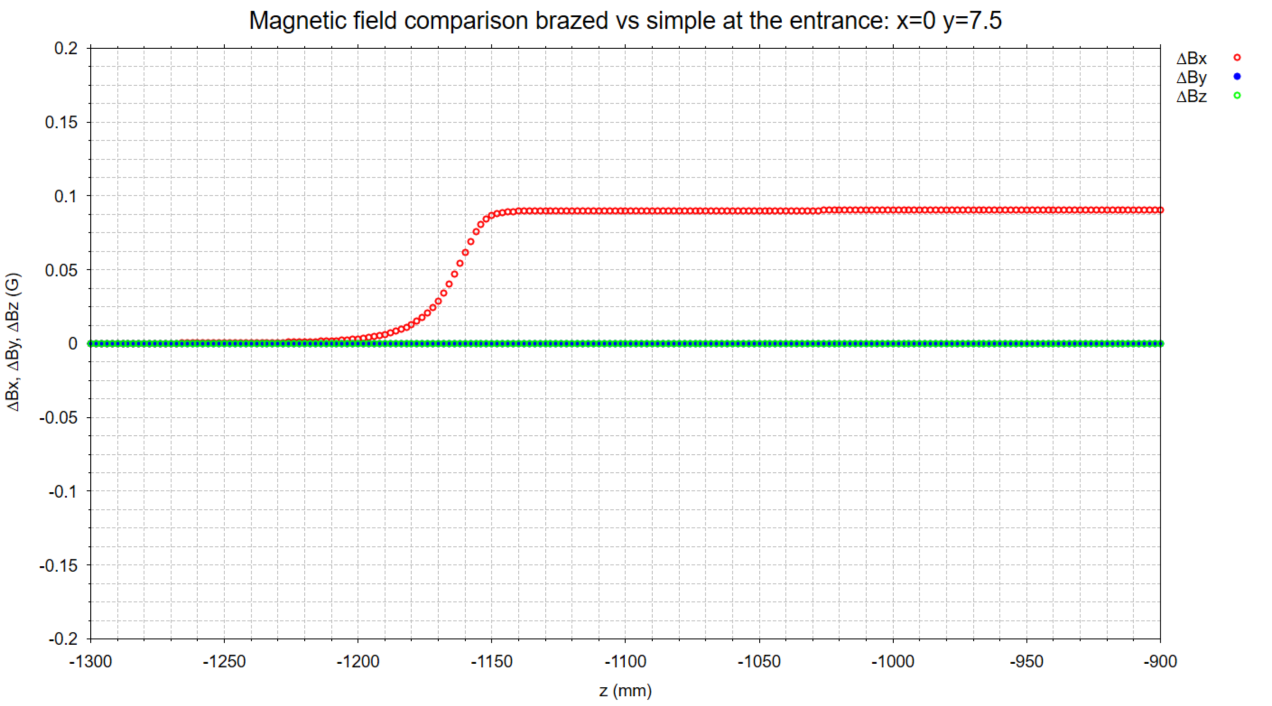
- Mo conductivity: 19 MS/m
- Braze conductivity: 4 MS/m

Section	Current (A)
Wire in braze	141.99 (182.94 A/mm^2)
Main braze	6.68 (39.16 A/mm^2)
Overflow braze	1.34 (39.16 A/mm^2)
Wire no braze	150.03 A (193.3 A/mm^2)

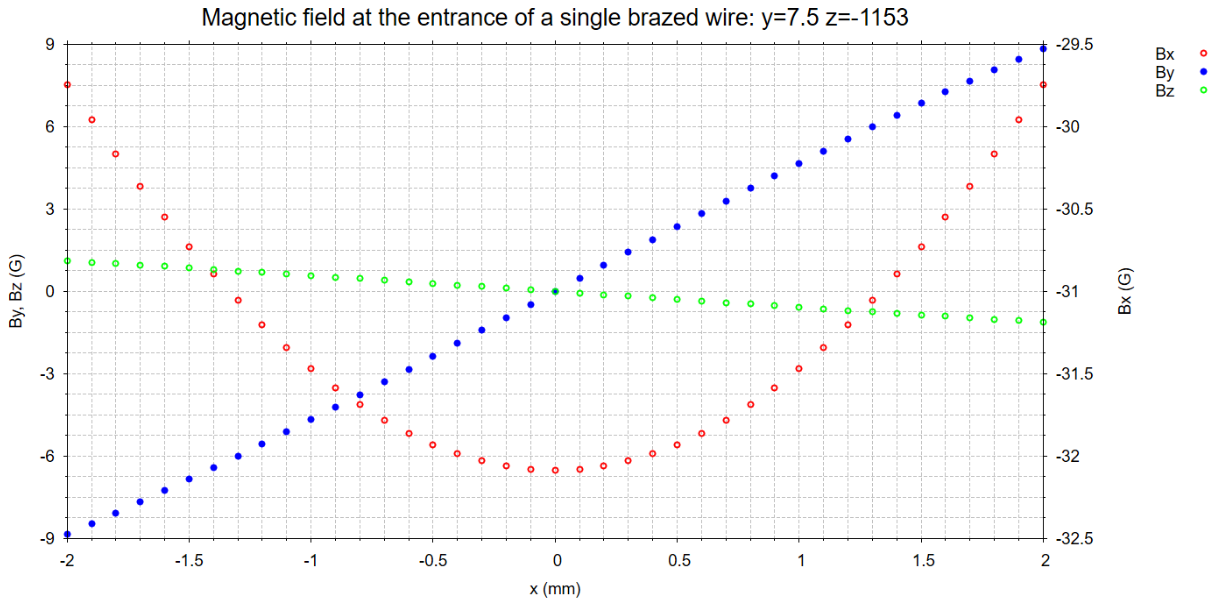
Comparing simple and brazed wire

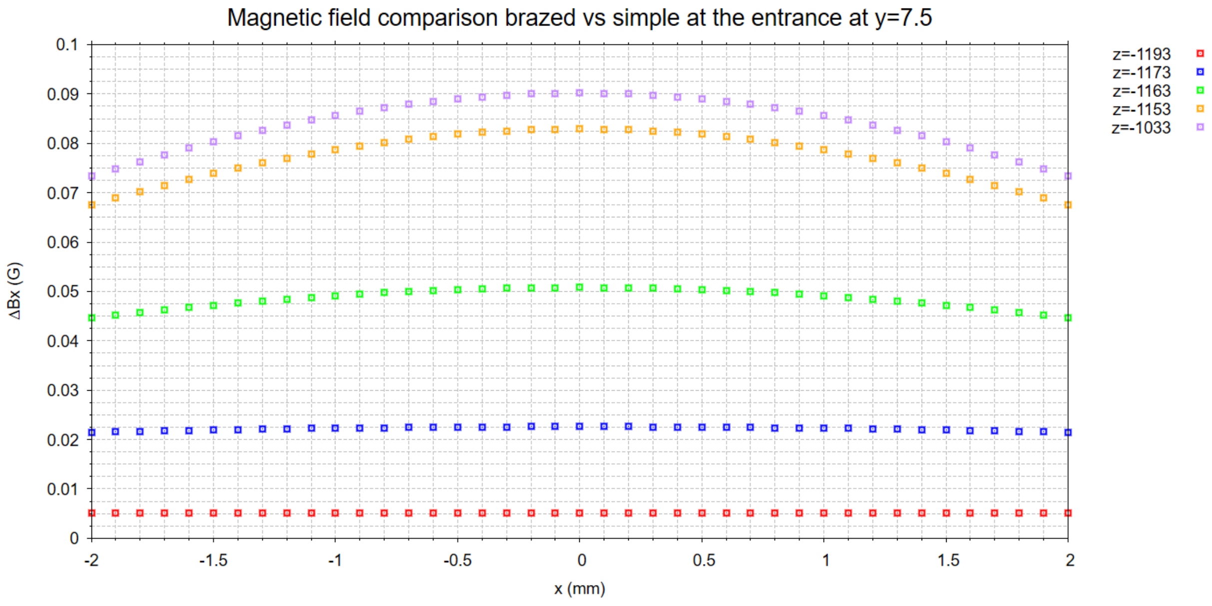
- Magnetic fields of the brazed model are very closed to the simple one
- Plotted the difference $\Delta B = B_{brazed} - B_{simple}$ for comparison
- Field variations: 0.2% (Bx), 0.6% (By)

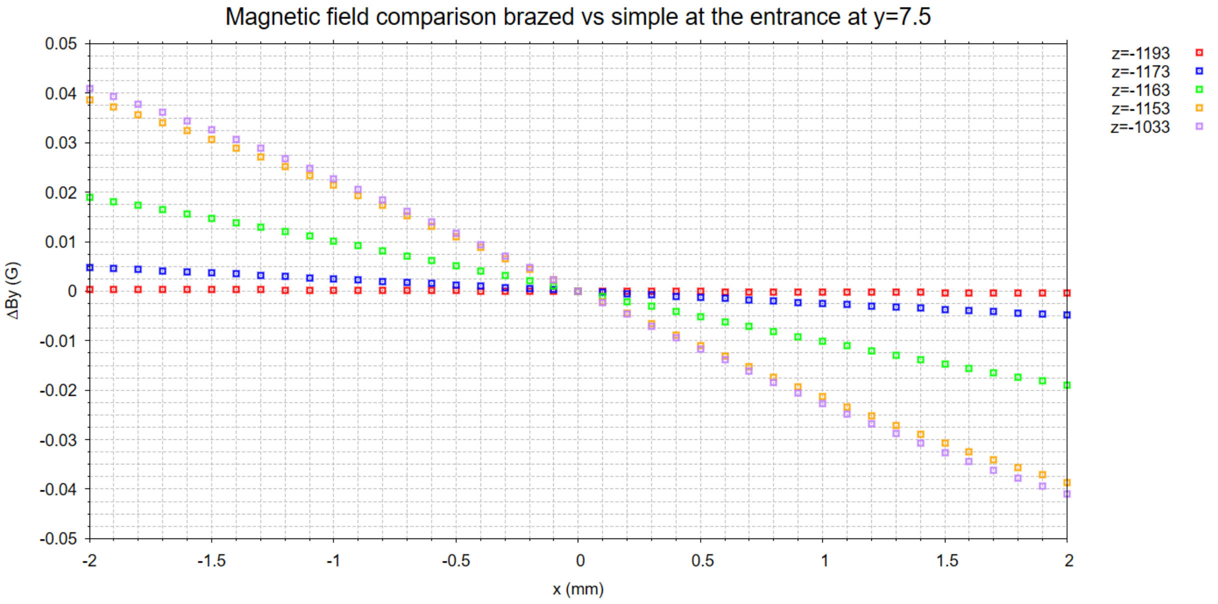


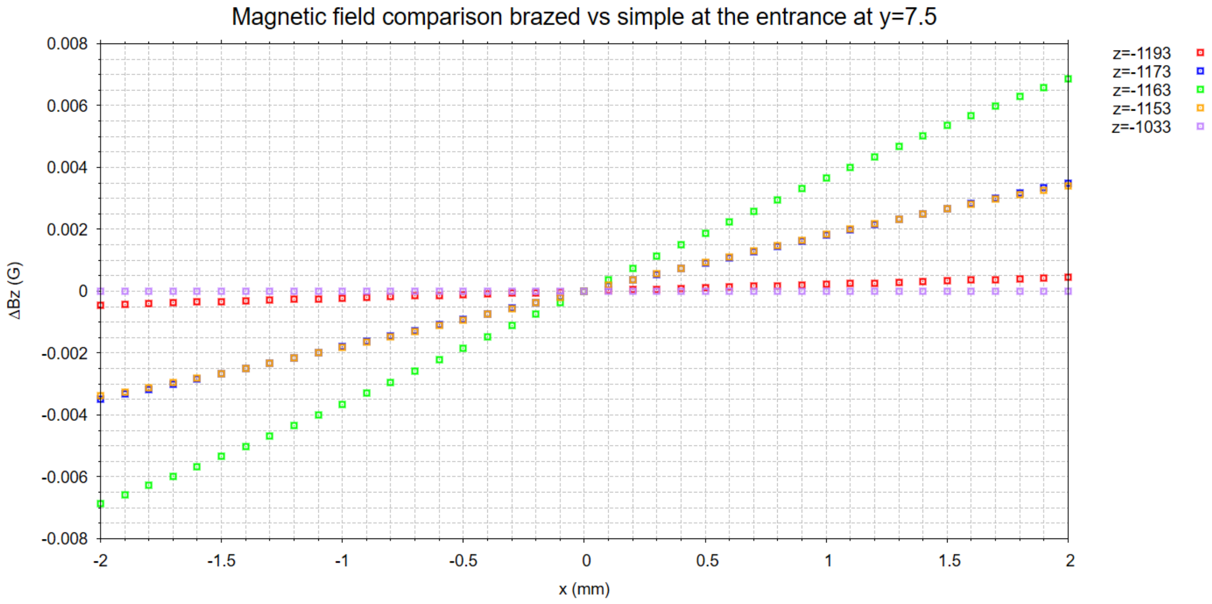


Comparing simple and brazed wire – transverse fields









Final remarks

- The current model can be easily modified by changing the parameters (wire diameter, length, bend radius, braze overflow shape, current distribution, etc.)
- Magnetic fields can be extracted on a convenient grid for beam dynamics simulations
- Alternative geometries (wire profile), or wire supports (to improve wire location if necessary) could be considered

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Thank you
Merci

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