BELFEM Code Validation and Benchmarking

Simon-Mathieu B. Hartman[1,2], Christian Messe[2], Gregory Giard[1,2], Yufan Yan[2], Lucas Brouwer[2], Frédéric Sirois[1], and Giorgio Vallone[2]

Internship presentation - December 9th, 2025

1. Polytechnique Montréal
2. Lawrence Berkeley National Laboratory

Outline

- **Introduction**
- Code validation
- Magnet geometry generation
- Functionality testing and benchmarking
- Conclusion

Introduction

BELFEM: FEM code exploiting the H-φ formulation

- Automatic φ potential "cut" generation

- Thin shells

- Optimised solvers (e.g., Strumpack)

Internship objectives

- Validation against analytical solutions

- Benchmarking

- Providing feedback as a "pure" user

Outline

- Code validation
- **Magnet geometry generation**
    - **Code Structure**
    - **CTT**
    - **Block with flared ends**
    - **Block with flared ends assembly**
- Functionality testing and benchmarking
- Conclusion

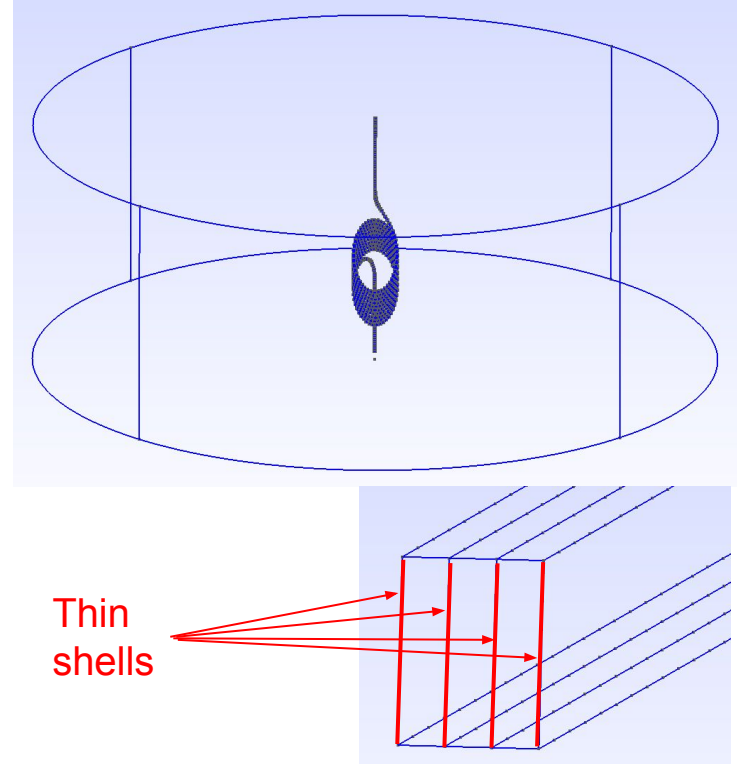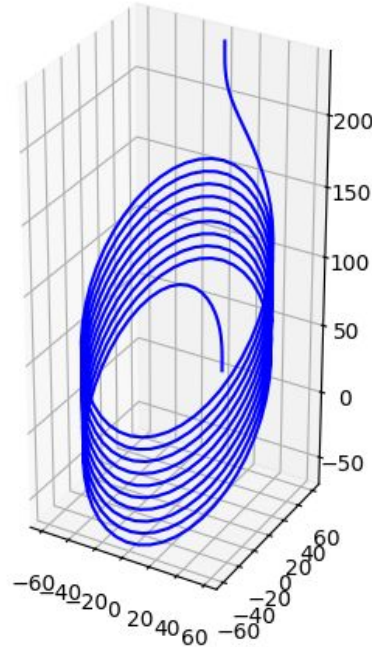# Magnet Geometry Generation - Code Structure

- Python tool writes .geo file and generates .msh mesh file
- Geometry construction
    1. Coil base curve creation
    2. Cross-section creation
    3. Cross-section "extrusion" along base curve
    4. Air domain creation
- Tape stack cross-section
- Available magnet types
    - CCT magnets
    - General block with flared ends dipole magnets

GMSH →*.msh→ BELFEM →*.exo→ ParaView

Magnet Geometry Generation - CCT
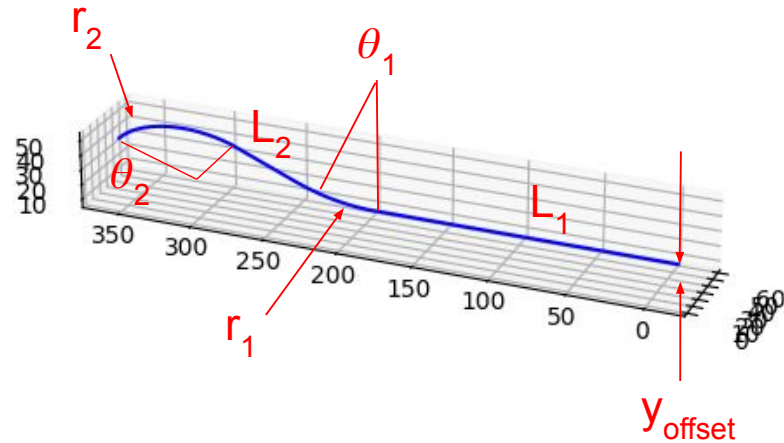
Available parameters

- r_1
- r_2
- pitch
- angle
- number of turns
- number of tapes
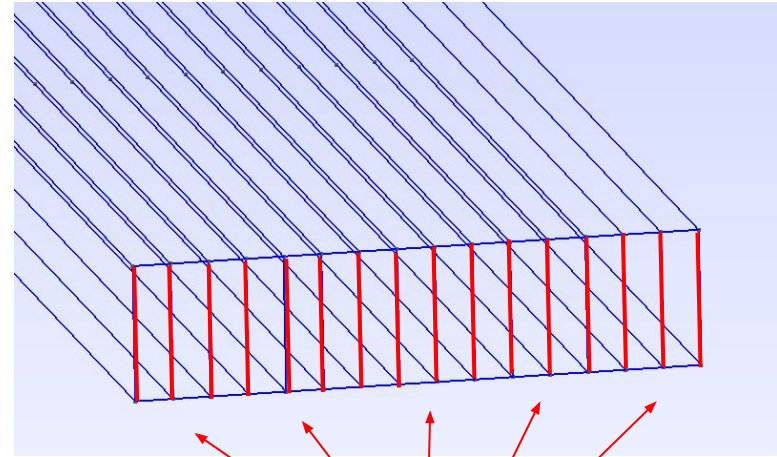- mesh size in tapes
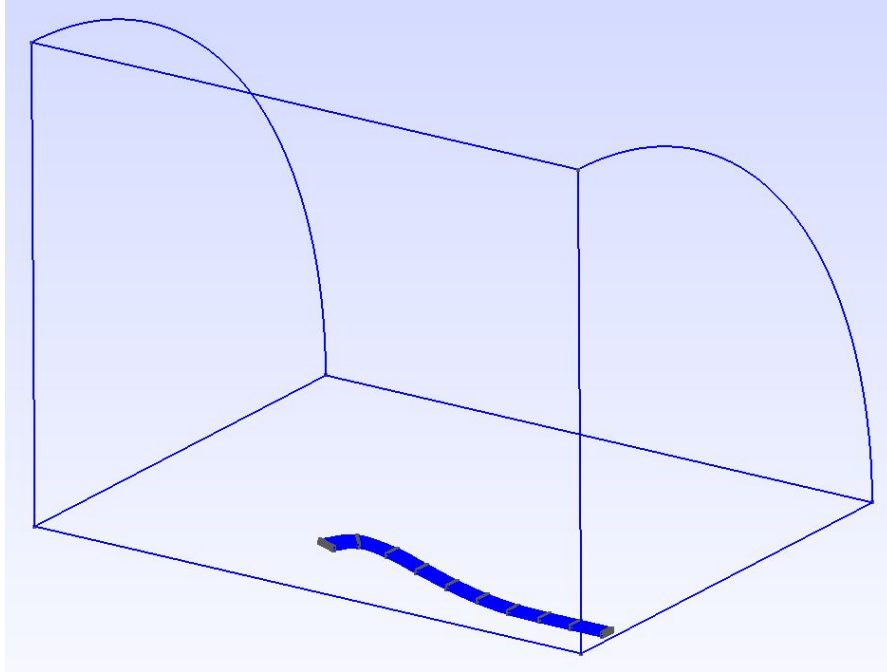- mesh size in air

Thin shells

Magnet Geometry Generation - Block With Flared Ends

- Geometry generation assumes symmetry BC on the xy, xz, and yz planes (i.e. the simulation takes into account the full coil and a full mirrored coil in z<0 octants)
- Available parameters
    - r_1
    - r_2
    - L_1
    - L_2
    - z_{offset}
    - θ_1
    - number of tapes
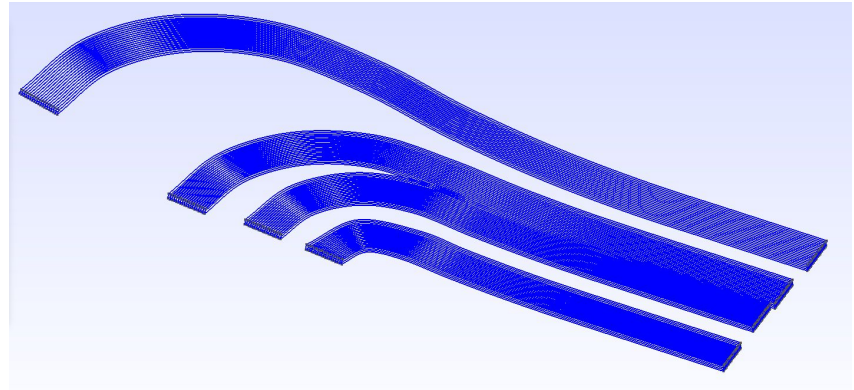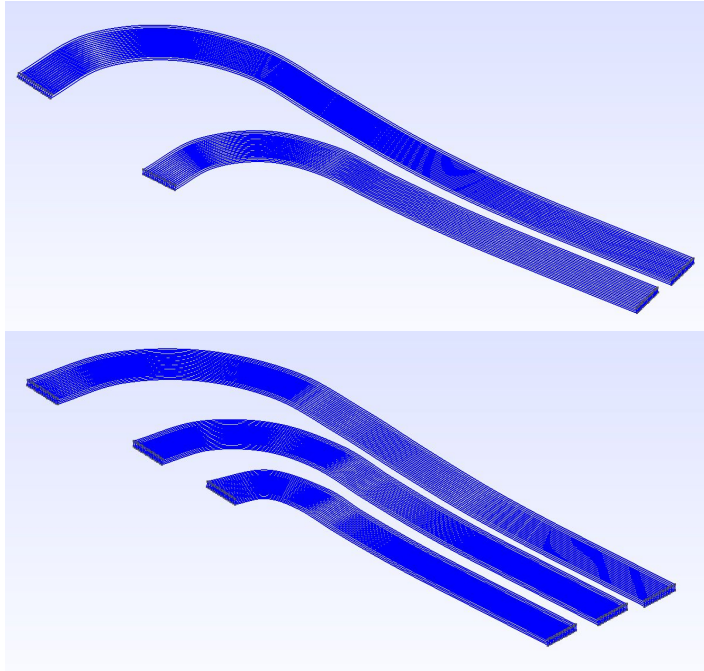   - mesh size in tapes
    - Mesh sizes in air

Magnet Geometry Generation - Block With Flared Ends

Thin shells

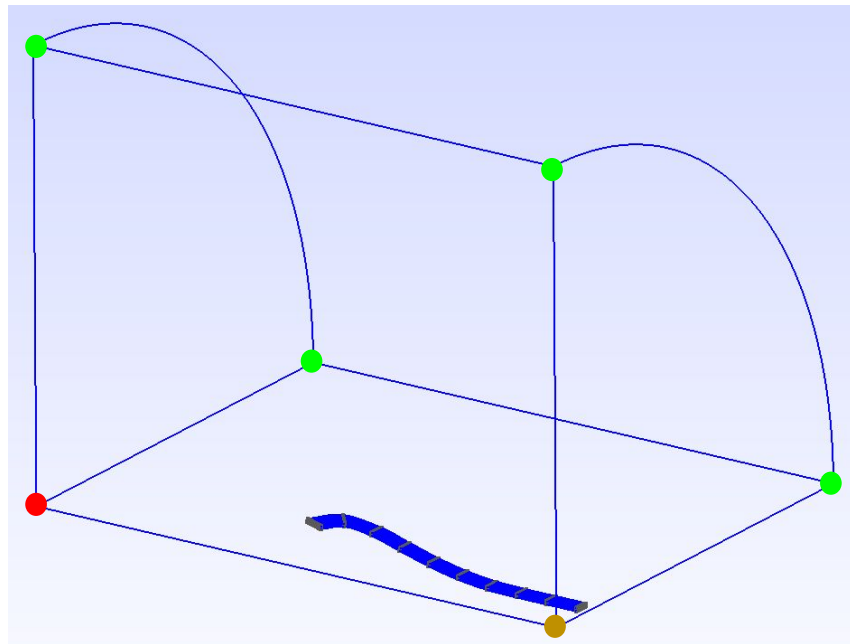# Magnet Geometry Generation - Block With Flared Ends Assemblies

Magnet Geometry Generation - Block With Flared Ends

The mesh size inside tapes can be specified.

Mesh size 1

Mesh size 2

Mesh size 3

Magnet Geometry Generation - Block With Flared Ends