Laboratoire d'Annecy de Physique des Particules

Modelling process for vibrations estimation of the MDI

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FUTURE CIRCULAR COLLIDER

UNIVERSITÉ SAVOIE MONT BLANC

MDI Work packages

Task 0. Coordination

Task 1. 3D engineering design of IR and MDI mechanical layout with integration
1.1 Beam pipe design
1.2 Cryogenic Magnets integration
1.3 Shielding against hard SR & collision debris
1.4 IP detectors integration, i.e. lumical, VXD, support & alignment & maintenance & cabling
1.5 Vacuum sys. integration
1.6 Supporting structures design
1.7 Thermal simulations
1.8 Management of electrical and hydraulic connections/routing
1.9 Mechanical IR assembly, disassembly & repair procedures
1.10 Project Design Management

Key deliverables: 3D CAD model of whole IR ; Preliminary structure design; Thermal and mechanical simulations; Civil engineering requirements (CERN); Prototypes (IR vacuum chamber INFN), alignment devices (CERN))

Task 2. Beam backgrounds, beam loss & radiation
2.1 Top-up injection backgr. incl. beam-beam and dedicated collimation, masking and shielding; comparing backgr. situation for different injection schemes
2.2 SR bkg with masking & shielding optim
2.3 Other single-beam BG(res.gas, Touschek, thermal γ)
2.4 Beam losses and backgr. from collisions processes: beamstrahlung, $\gamma\gamma$ collisions, bhabha, luminosity, including spent beam tracking and shielding optimization
2.5 Software tool development, link MDI codes and FCCSW
2.6 Simulation evaluation of backgrounds in detectors and mitigation
2.7 Tail collimation & machine protection strategy
2.8 Collimation scheme and strategy incl. IR collimators
2.9 Shielding of IR magnets against collision debris
2.10 Handling of incident beamstrahlung (diagnostics?)
2.11 Beam abort system: requirements, abort gaps, signal processing, etc.
2.12 Protection against rare devastating events e.g. dust
2.13 Mask + collimation hardware design
2.14 Geant4 model +/- m from IP
2.15 Neutron radiation in IR area, Fluka

Key deliverables: Masking, shielding, collimation systems; Injection scheme(s), Background sustainability by detectors; Machine protection strategy

Task 3. Conceptual design of IR elements/systems
3.1 IR Magnets design w. field map (solenoid compensation), supports, spatial tolerance, el.-magn. forces, OP conditions
3.2 Cryostat design, dimensioning cooling systems
3.3 Luminosity calorimeter & lumi. meas. including alignment
3.4 Vertex detector & possibly other IP detectors
3.5 IR beam abort sensors
3.6 Remote vacuum connection
3.7 IR vacuum system, coatings & possible HOM absorbers
3.8 IR beam diagnostic devices, Beamstrahlung monitor
3.9 Shielding experimental environment?

Key deliverables:
Prototypes (FF magnets, remote vacuum connection)

Task 4. Alignment tolerances & vibration control
4.1 Alignment specifications
4.2 Alignment/survey strategy & results
4.3 Vibration study, stabilization strategy, etc.
4.4 Feedback systems for beam collision adjustment ; feedback to maintain luminosity with top-up injection

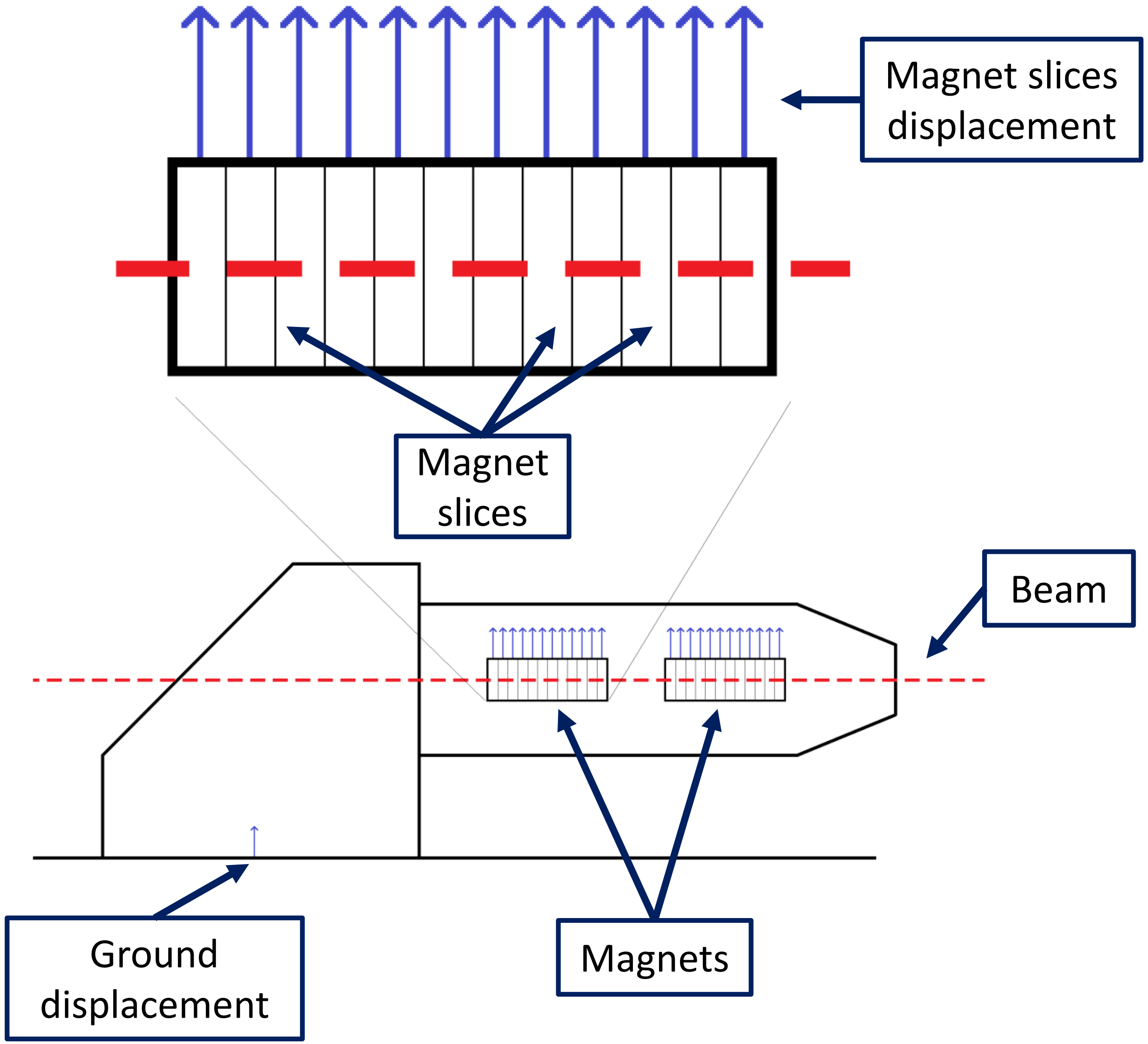
Key deliverables: Alignment/survey strategy; Stabilization strategy; IP Feedback design

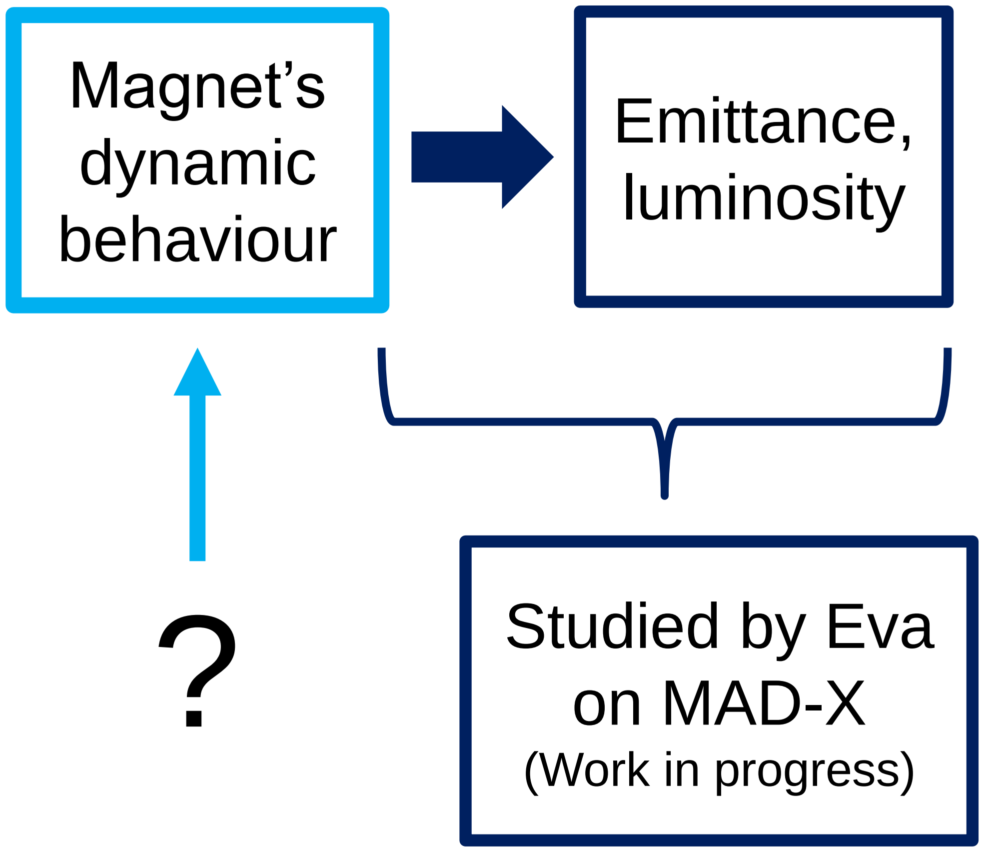
Task 5. Heat Load Assessment
5.1 Resistive wall
5.2 Geometric impedance, HOM heat load, HOM absorbers
5.3 Heat load from SR, Beamstrahlung, radiative Bhabhas
5.4 Electron clouds 5.5 Cooling of detector elements
Key deliverable: Thermal power budget

Presentation overview

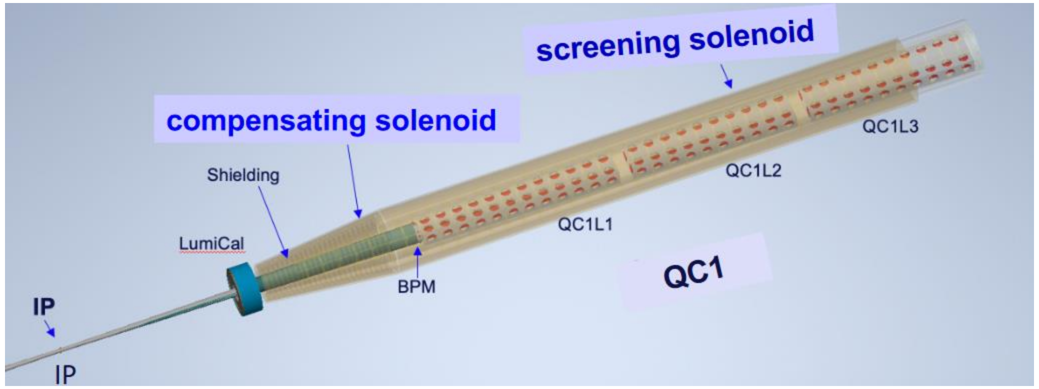
- Goal
- Current situation
- Overview of the process
- Modelling
- Modal analysis
- State space model
- State space model’s processing
- First results
- Conclusion
- Perspectives

Goal

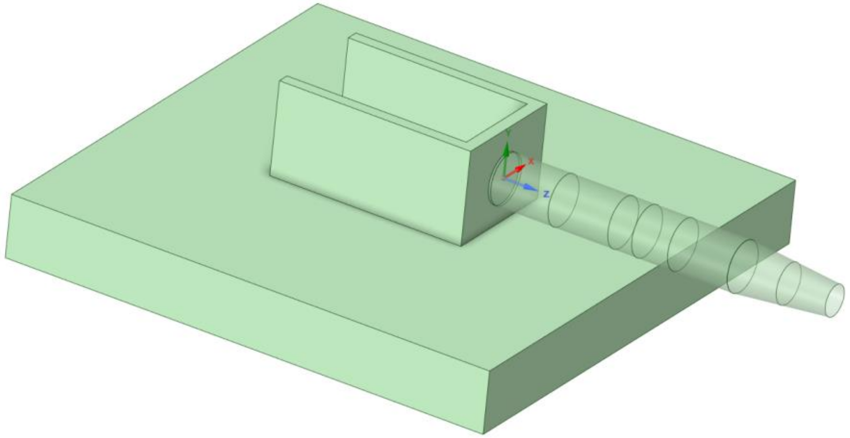

Magnet slices
displacement
Magnet
slices
Beam
Ground
displacement
Magnets


Magnet's dynamic behaviour
Emittance, luminosity
?
Studied by Eva on MAD-X
(Work in progress)

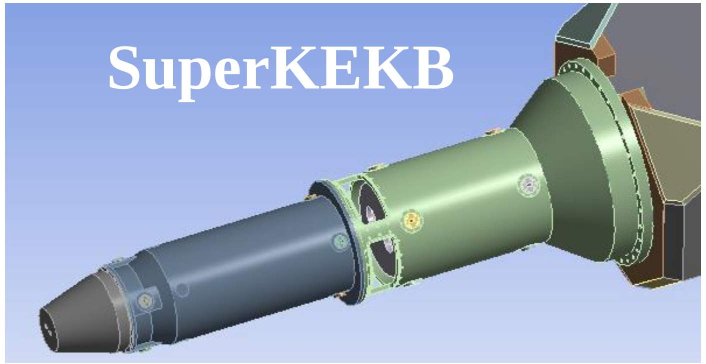
Current situation



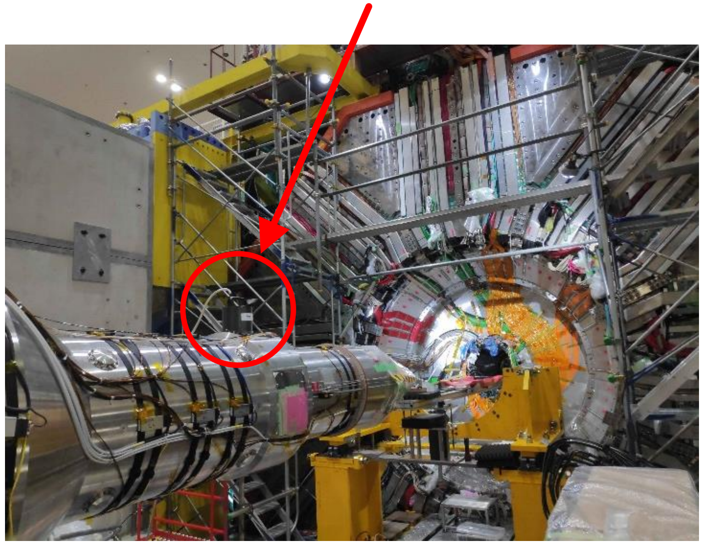
The design of the MDI is still in progress.



Development of the process using a simplified 3D model



accelerometer

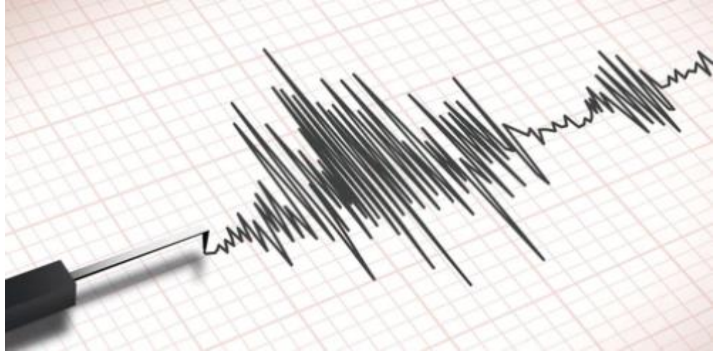


Similarities:

Similar beam, cryostat in cantilever

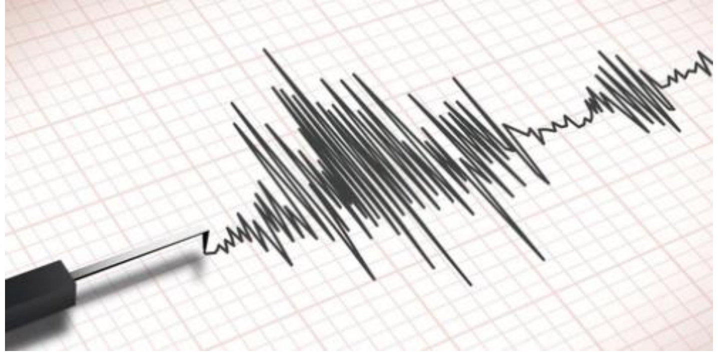
Difference:

The HER and LER final focus magnets are not symmetrical inside the cryostat

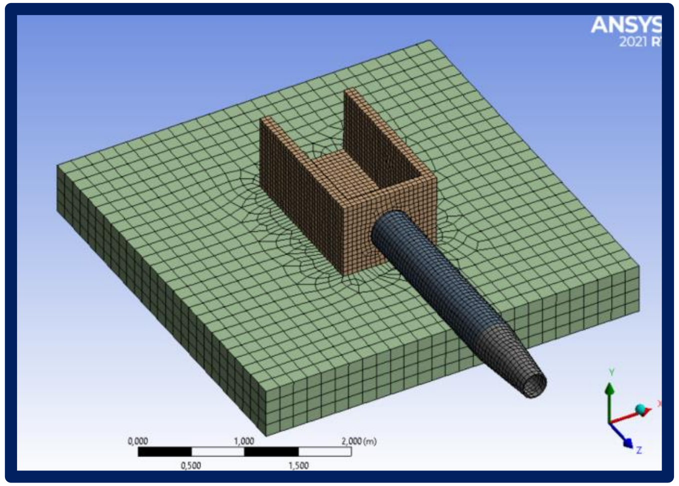


Input displacements

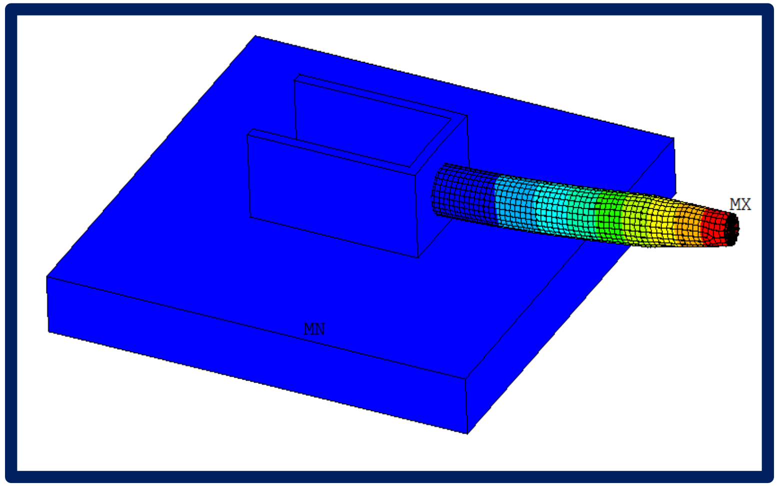
Simple mathematical model



Output displacements



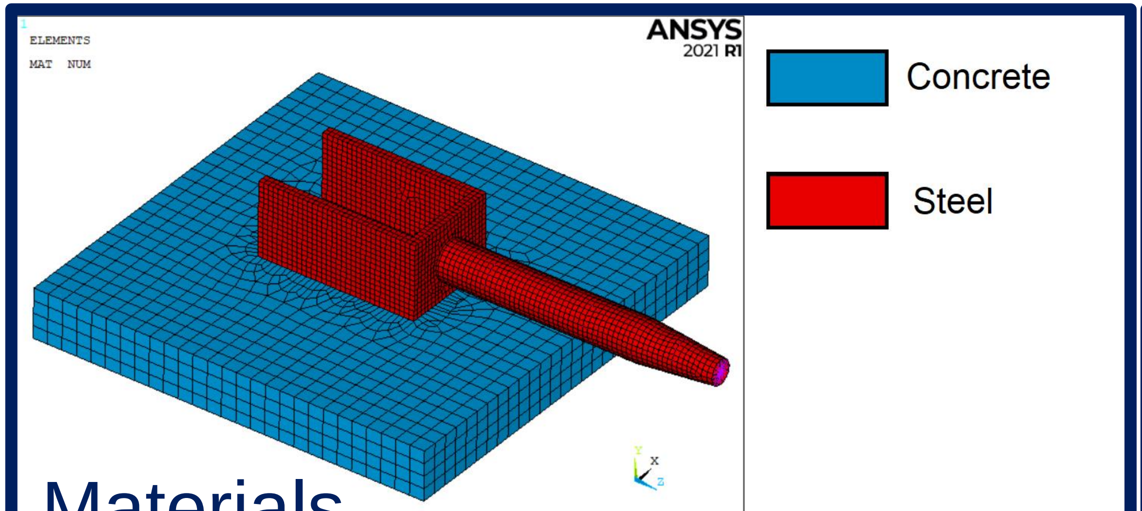
① Modelling



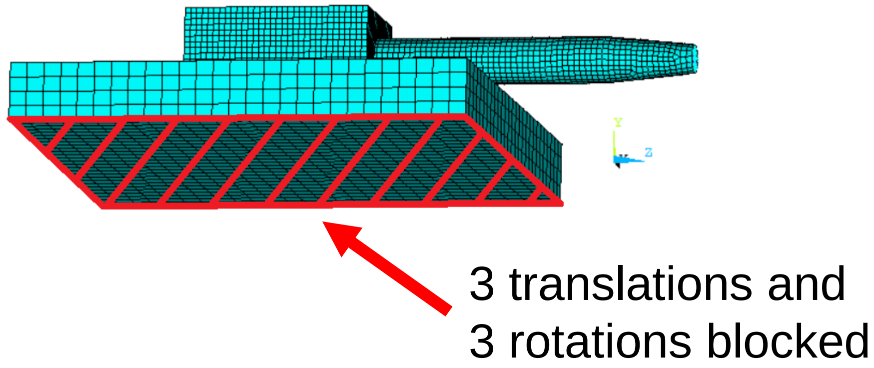
② Modal Analysis

③ State space model

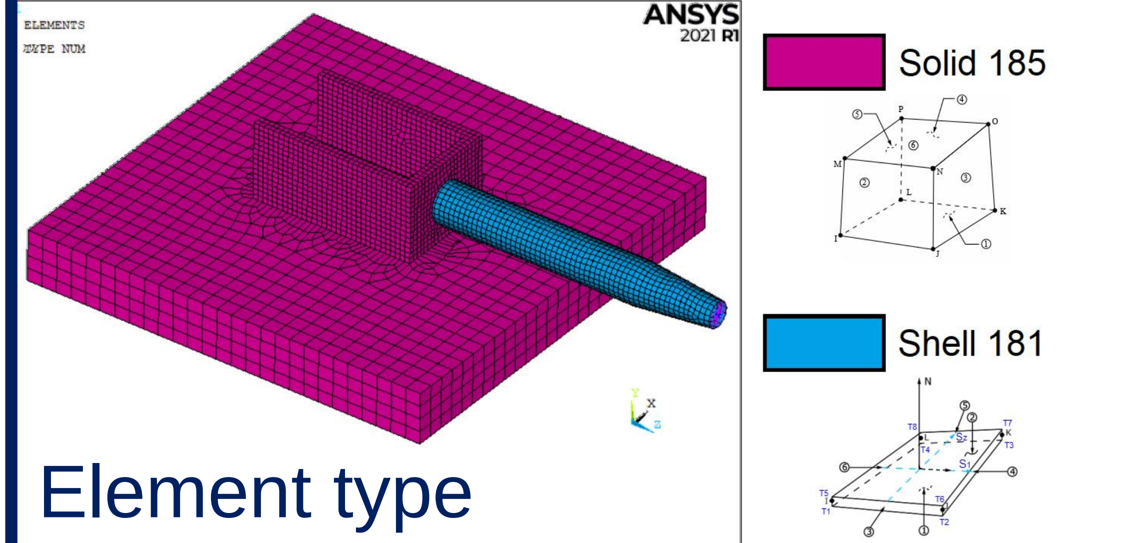
① Modelling



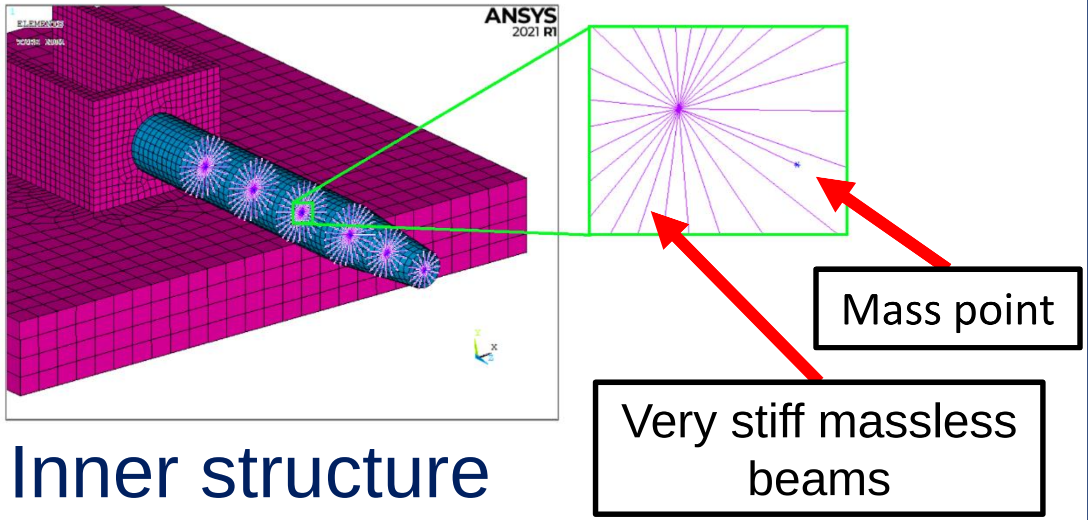
Materials



Boundary conditions

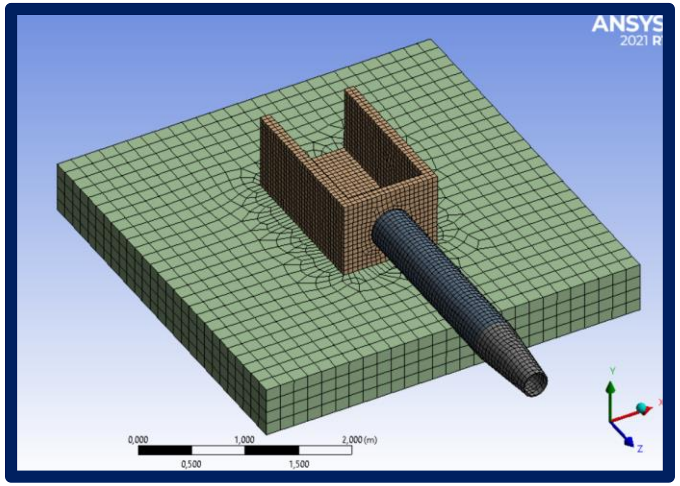


Element type



Inner structure

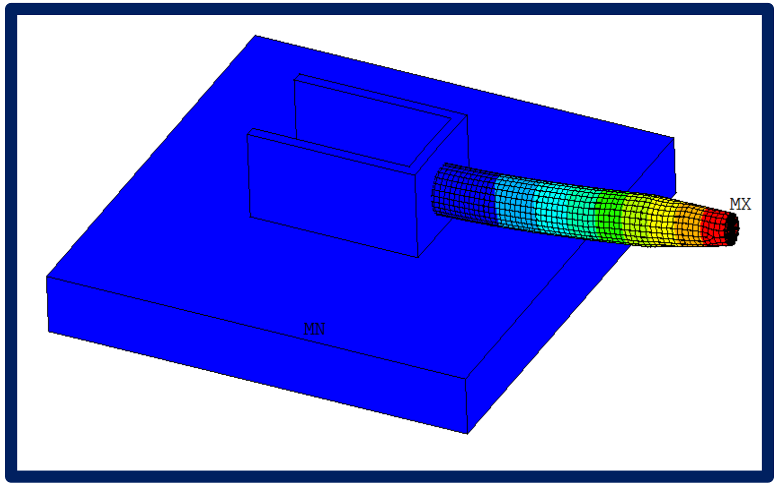
② Modal analysis



Linear model:
(no plasticity, no contacts, etc…)

modal analysis

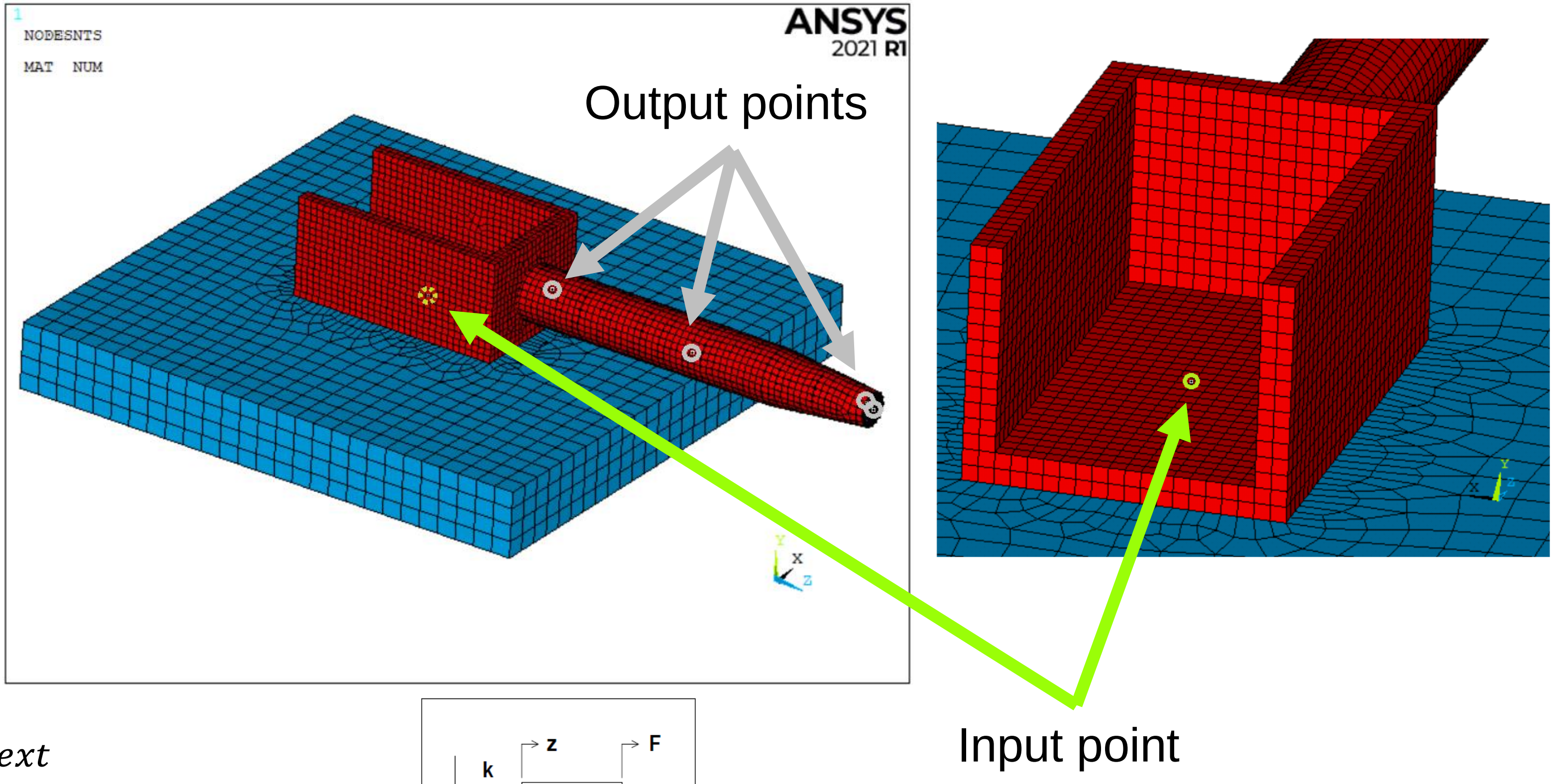
Mode-extraction method:
Block Lanczos



natural frequencies and mode shapes

③ State space model

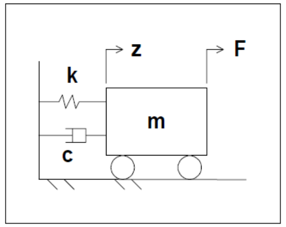
Calculation of the state-space matrices



General formula: $\sum \vec{F} = m \cdot \vec{a}$

For one point: $m \cdot \vec{a} + c\vec{v} + kz = \vec{F}_{ext}$

Matrix form: $[M] \cdot [\ddot{z}] + [C] \cdot [\dot{z}] + [K] \cdot [z] = [F]$



Variable change:

$x_1 = z_1$ Position of Mass 1
$x_2 = \dot{z}_1$ Velocity of Mass 1
$x_3 = z_2$ Position of Mass 2
$x_4 = \dot{z}_2$ Velocity of Mass 2
…

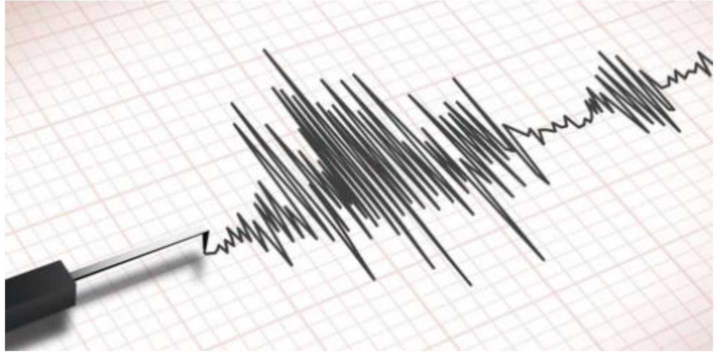
$$[\dot{x}] = [A] \cdot [x] + [B] \cdot [u]$$

$$[y] = [C] \cdot [x] + [D] \cdot [u]$$

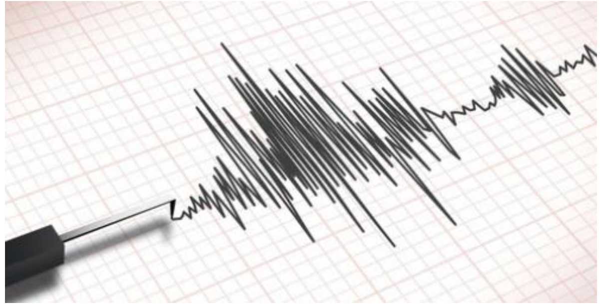
x, u and y represent the states, inputs and outputs respectively, while A, B, C and D are the state-space matrices.

State space model's treatment

Calculation of the state-space matrices

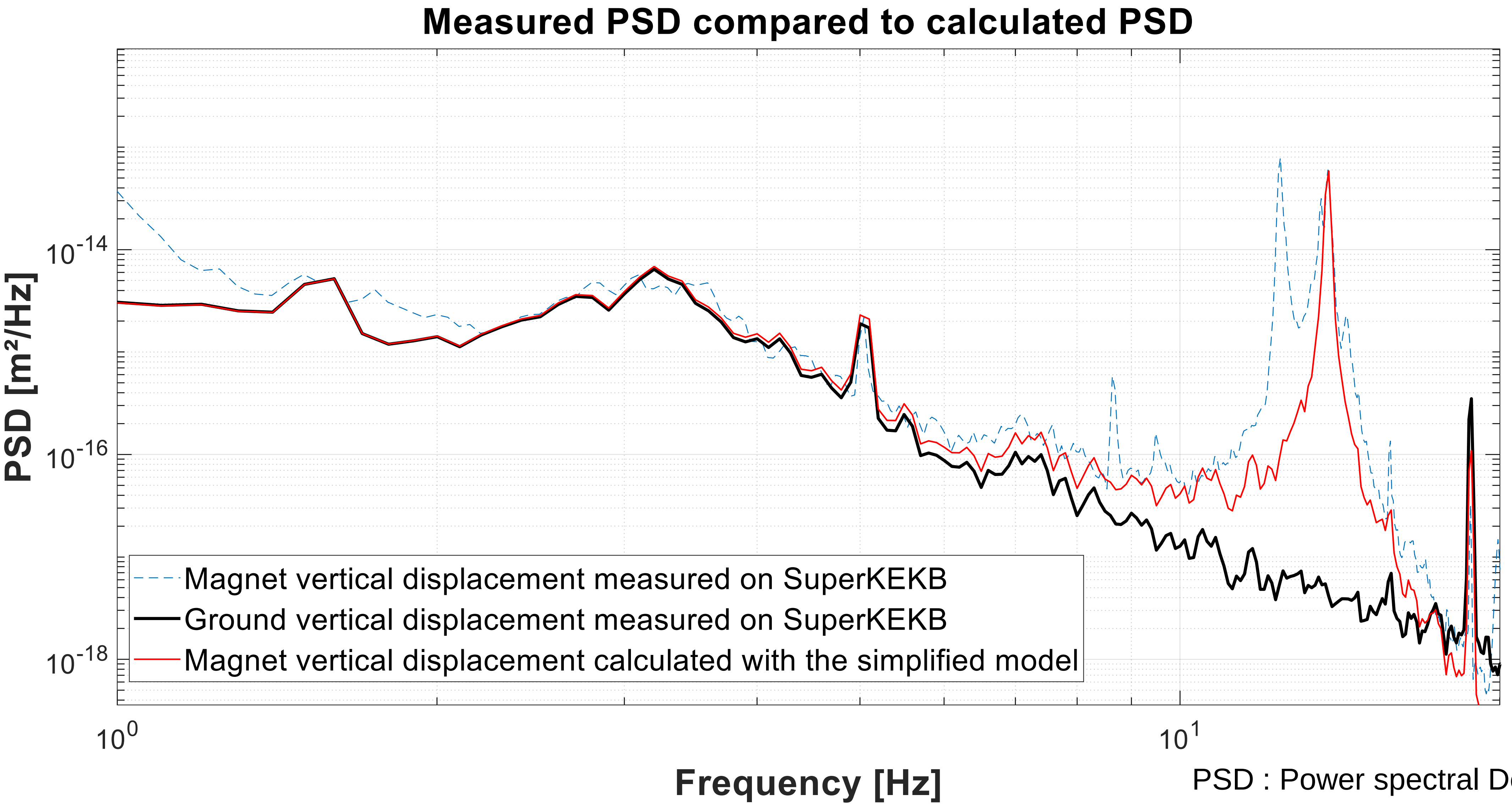


Input displacements



Output displacements

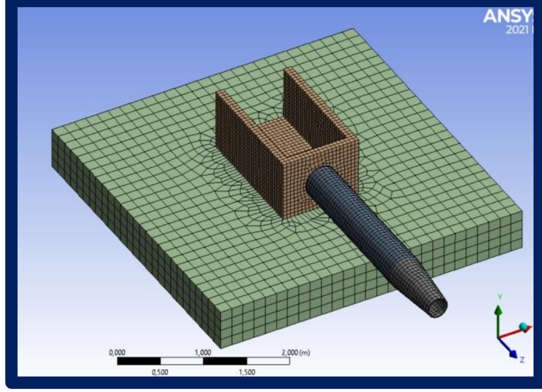
First results

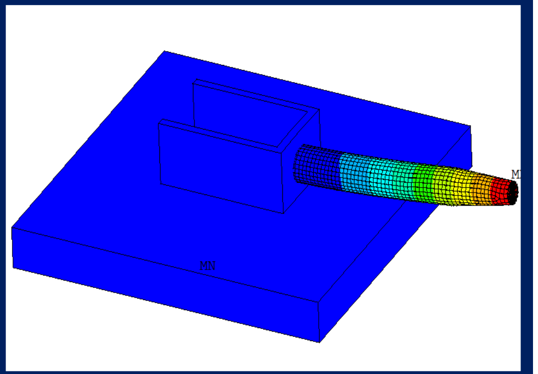


PSD : Power spectral Density

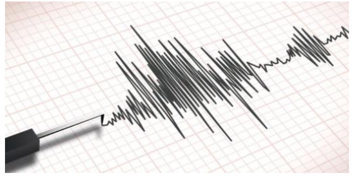
Conclusion

Ansys



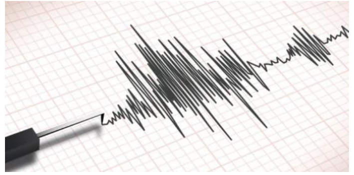


State space matrices



Input displacements

MATLAB



Output displacements

MAD-X

- very light model
- very fast calculation
- modal calculation independent of input displacements: only one FE calculation
- can’t take into account non linearities

Perspectives

Build an instrumented prototype to test the process:

Simple cantilever beam

During the development of the MDI, we will need different prototypes to characterize the dynamic behavior of the structure and estimate the impact on future emittance and luminosity.

FCC reduced model

Small cryostat section

Test on different parts

Test on the connecting parts

1
4

Thank you
for your attention!