Mechanical dynamic load of the LHC Arc cryo-magnets during the installation

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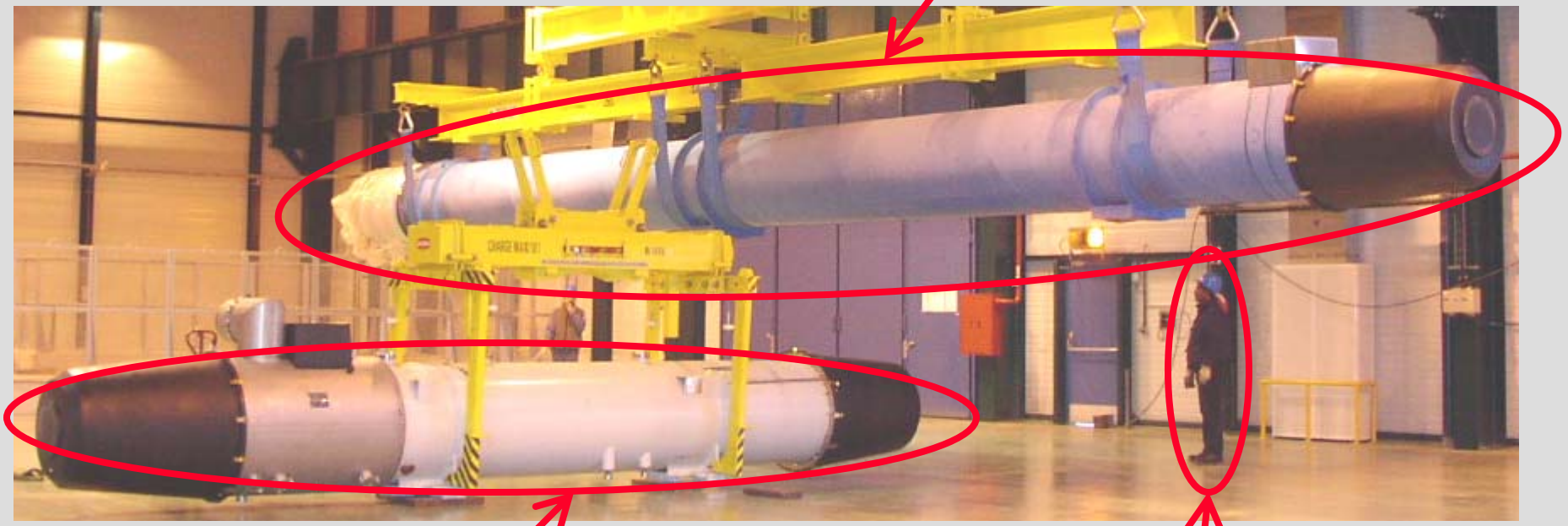
Technical Support 2004 Workshop

Overview

- Introduction
- Analysis
  - Calculations
  - Tests
  - Specifications
- Results serial transport
- Conclusions

Introduction

- **LHC Arc cryo-magnets**



- Long
- Heavy
- Contain fragile components
- Geometry integrity to be ensured during transport

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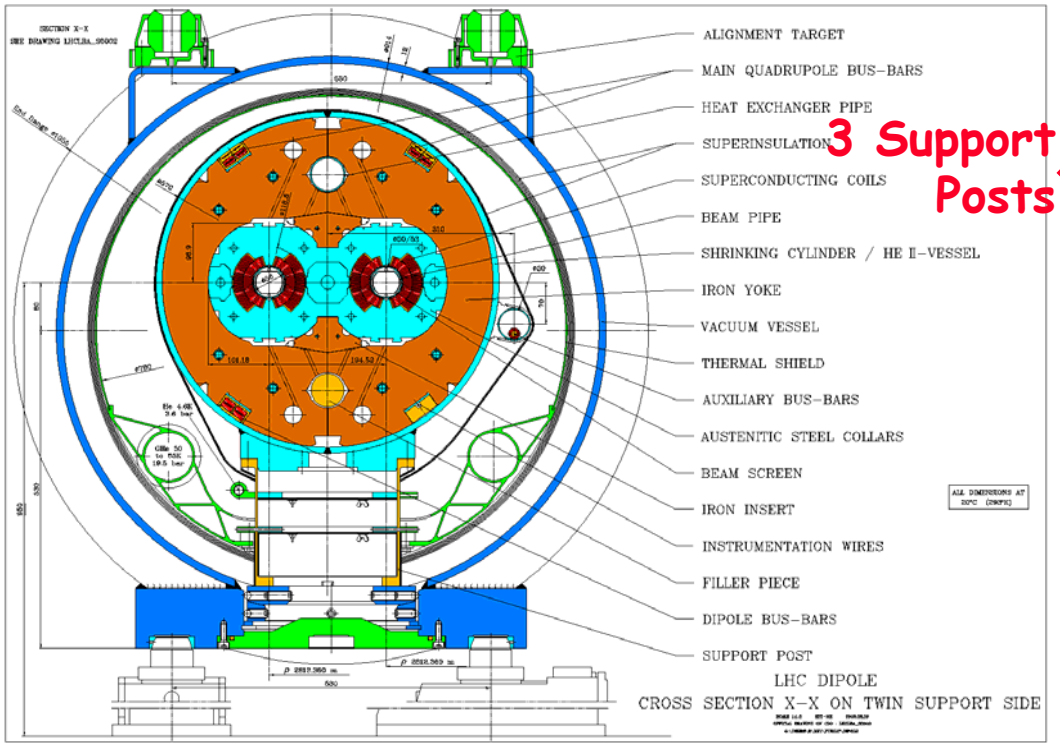
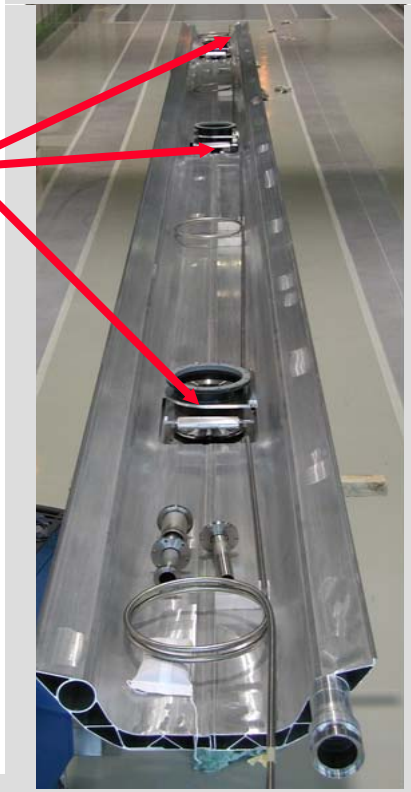
- Difficult to handle and transport
- Understanding their dynamic behavior is compulsory to avoid damages

Introduction

Cryo-dipole





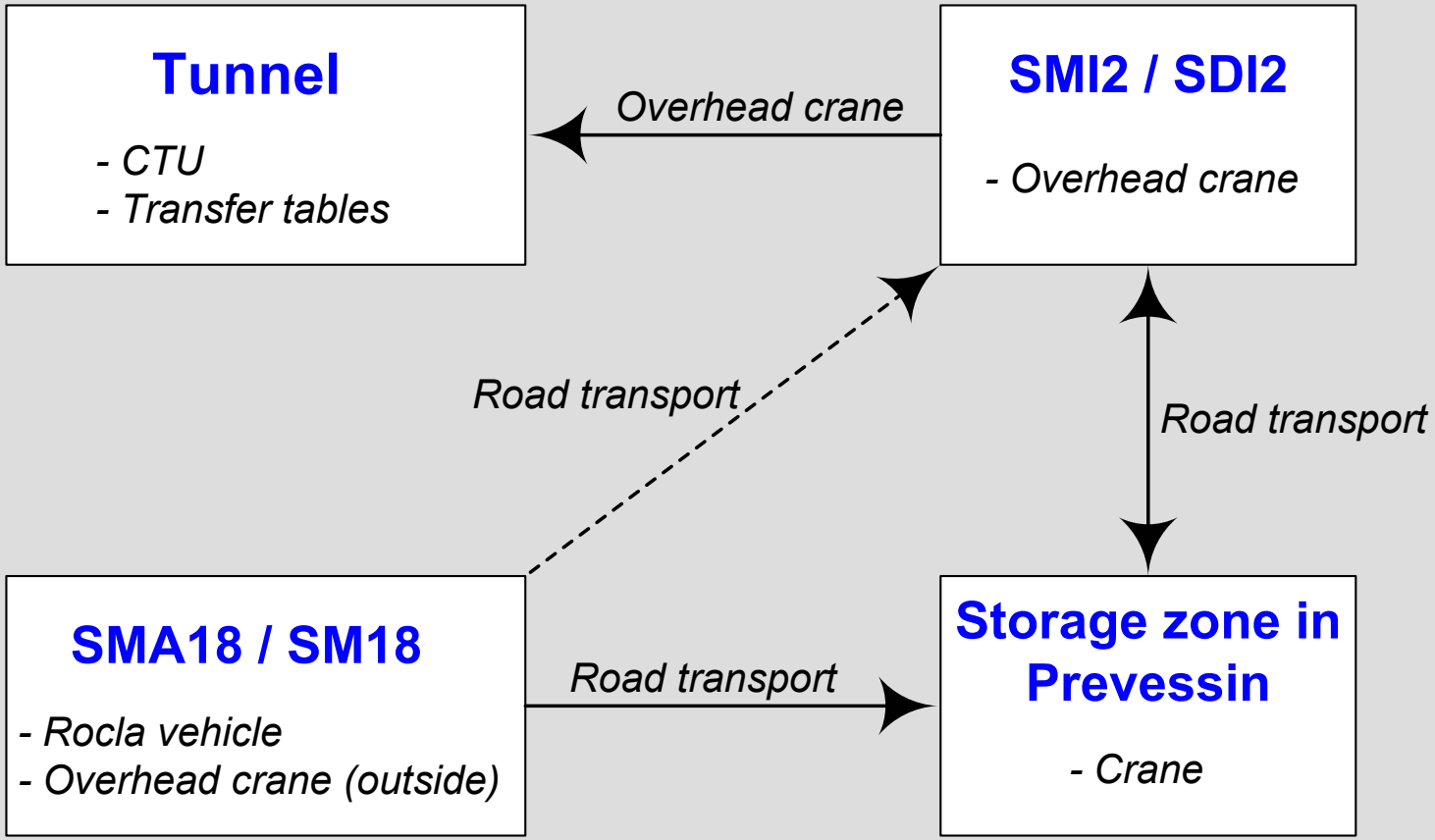
- **Constraints (specifications):**
  - Cold mass maximum stress: 40 MPa
  - Vacuum Vessel maximum stress: 87.5 MPa
  - Maximum Δcoaxial between CM and VV axes at the extremity: 2 mm

- Support posts

	Maximum load (specification)	Displacement (equivalent)
Compression (nominal)	125 kN	0.4 mm
Compression (exceptional)	175 kN	0.56 mm
Shear (nominal)	0	0
Shear (exceptional)	37.5 kN	0.95 mm

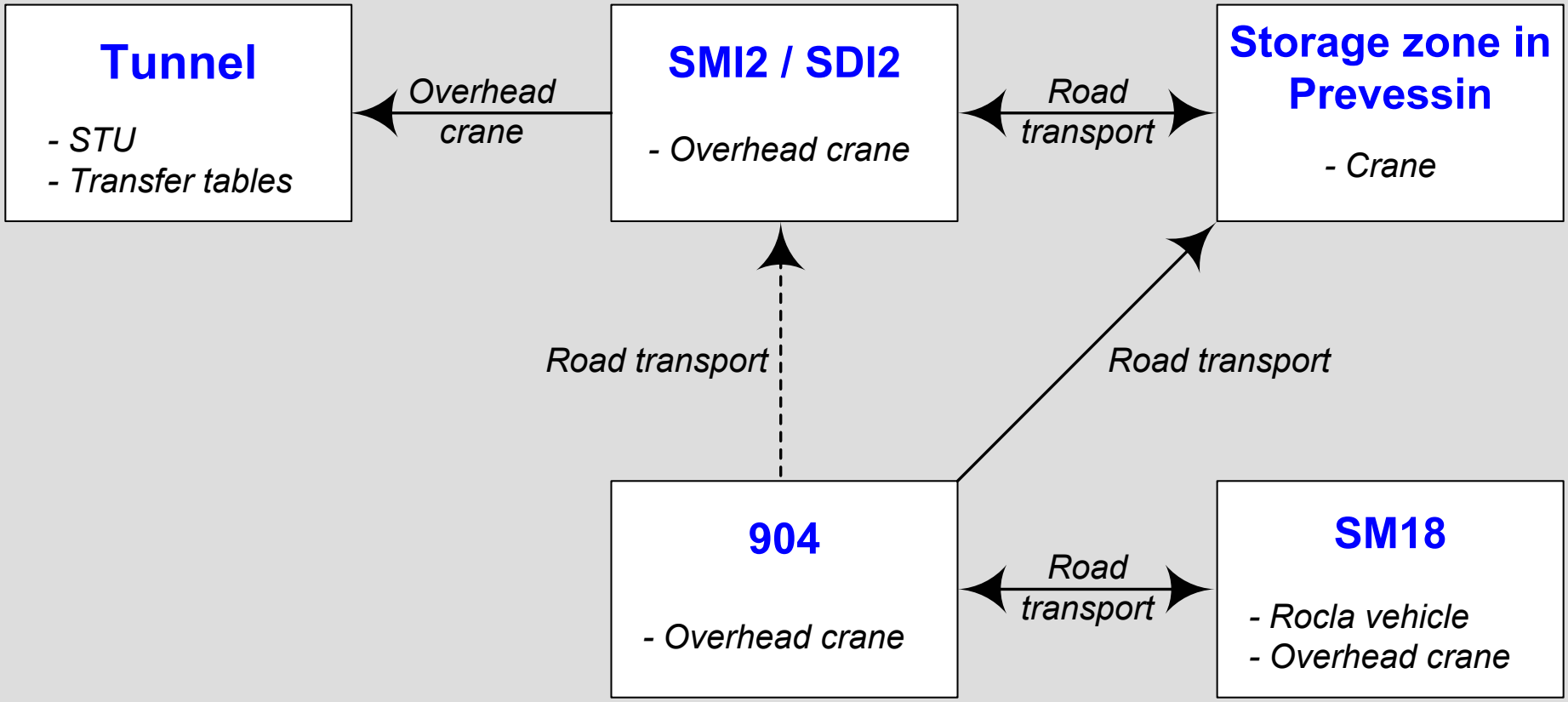
Introduction

- Several transport and handling sequences for each cryo-magnet
  - Cryo-dipole



Introduction

- Several transport and handling sequences for each cryo-magnet
  - Short Straight Section



Introduction

- Several transport and handling sequences for each cryo-magnet

- The dynamic behavior of each type of cryo-magnet has to be studied for each type of handling and transport

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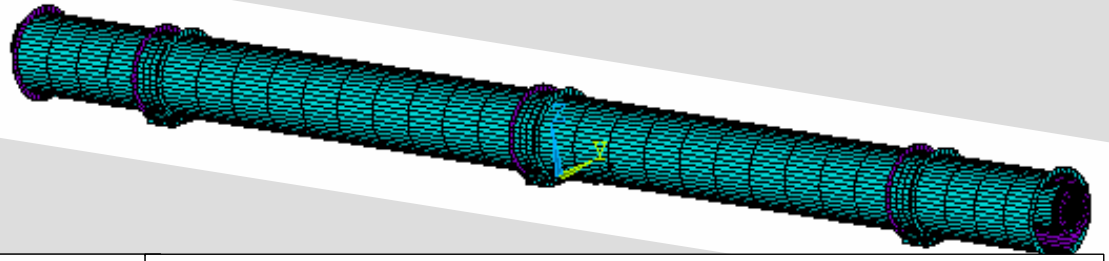
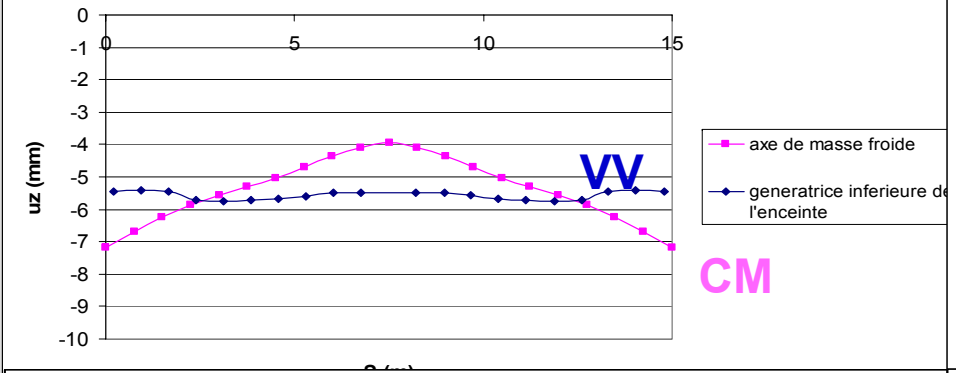
Analysis - Calculations

Cryo-dipole finite elements model with ANSYS

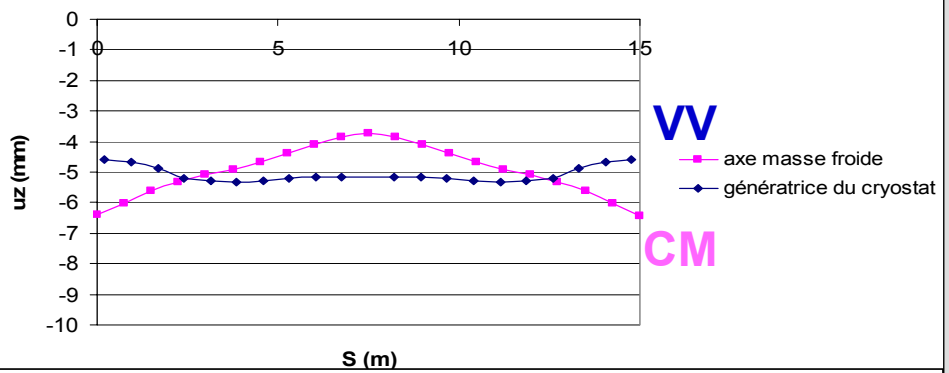
- Static calculations – deflection of cryo-dipole on different vehicles:



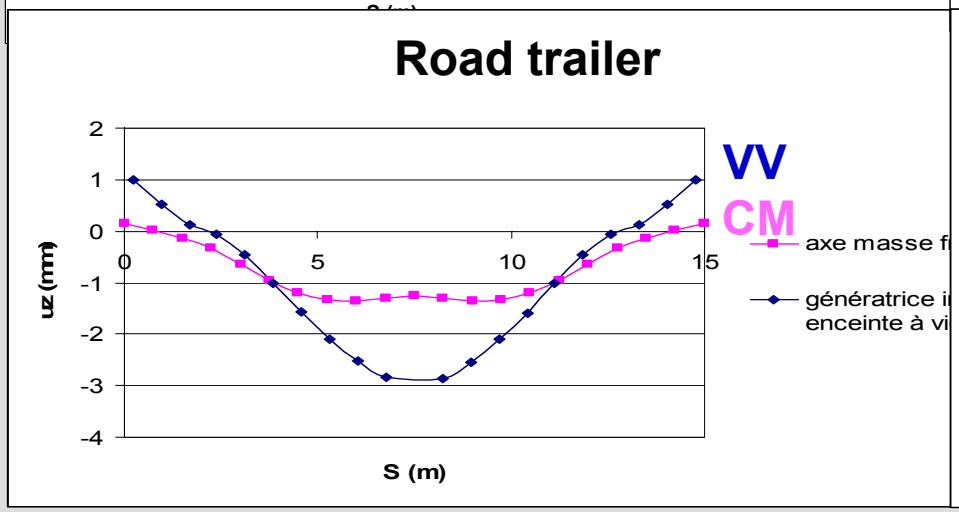
ROCLA



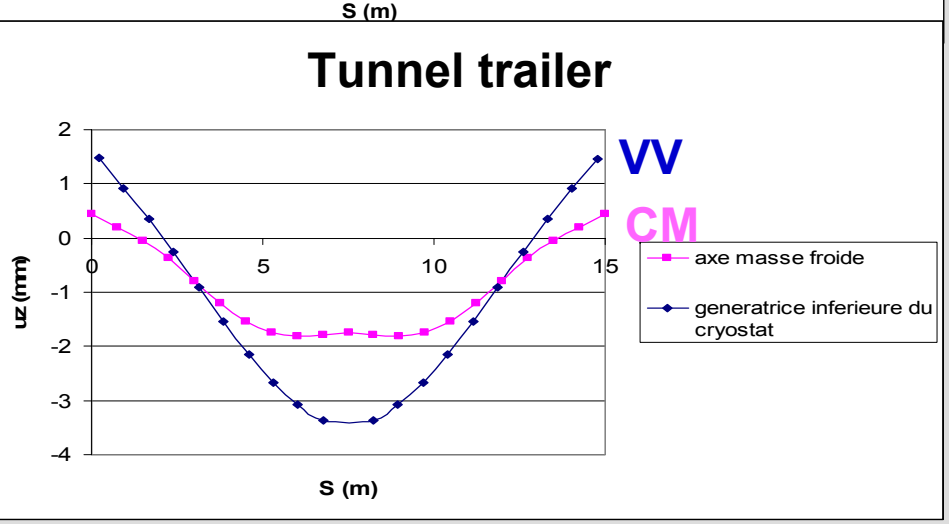
Crane



Road trailer

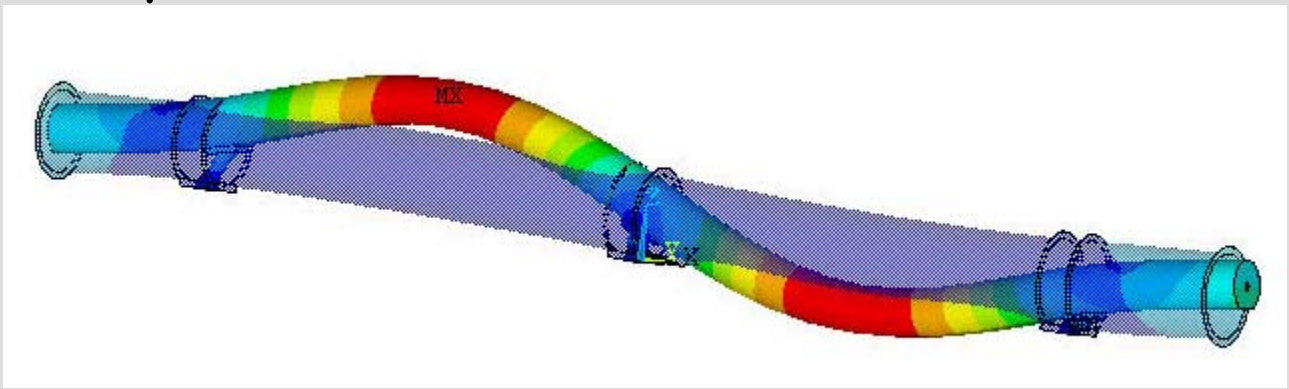


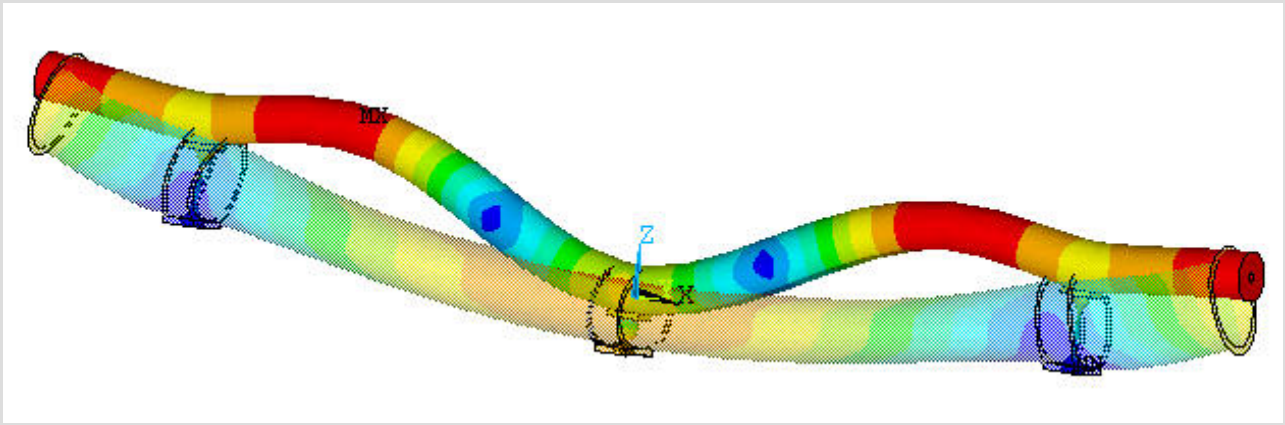
Tunnel trailer



Analysis - Calculations

- Modal analysis



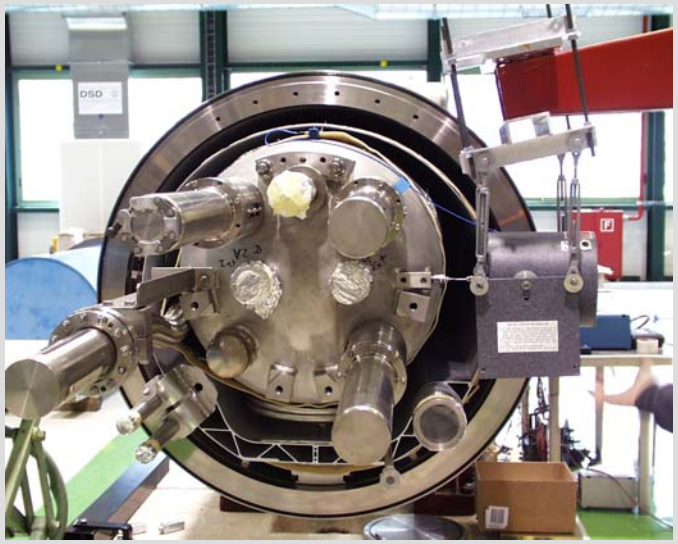


- Natural frequencies up to 50 Hz
- Modal shapes

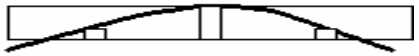
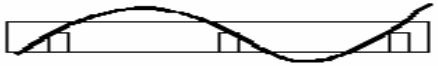
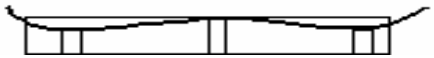
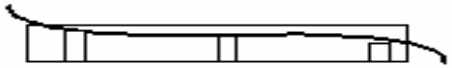
calculated for different types of boundary conditions corresponding to different handling and transport conditions

Analysis - Tests

- Experimental modal analysis validated the theoretical model

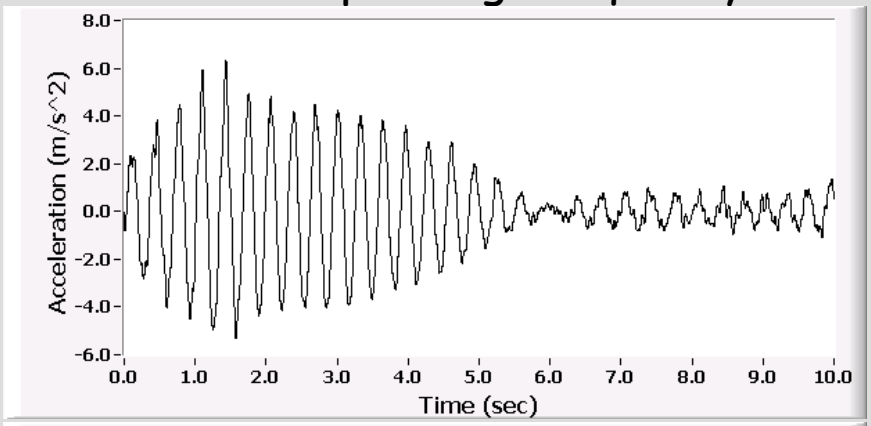


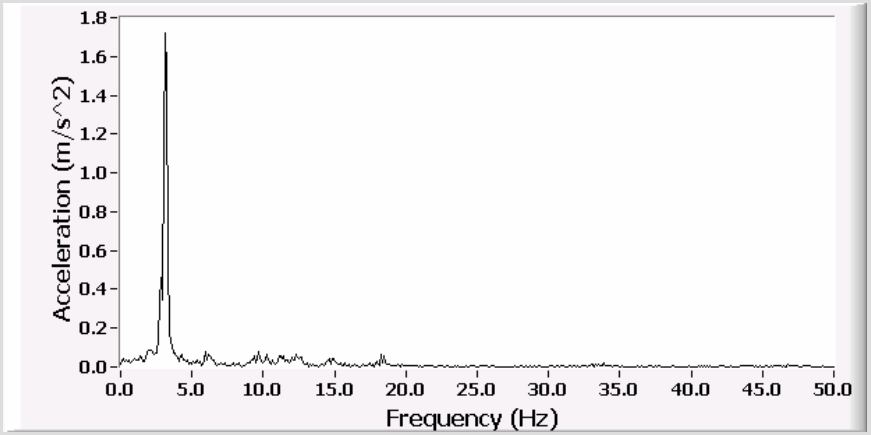
- Example of modal analysis results (comparison tests/calculations):

Vertical modes (cryo-dipoles on concrete blocks)	Test	Calculation
	8 Hz	10 Hz
	16 Hz	17 Hz
	36 Hz	34.6 Hz
	28 Hz	32 Hz

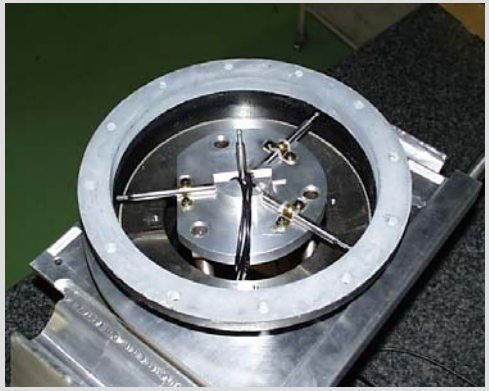
Analysis - Tests

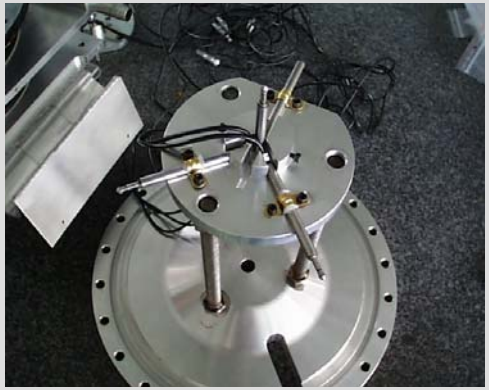
- **Cryo-magnet dynamic behaviour tested under several real transport conditions**
  - Accelerations measured:
    - Amplitudes
    - Corresponding frequency





  - Support posts dynamic deformation measured





Analysis - Specifications

- Calculations allowed to determine the modal scheme of the cryo-magnets under different transport conditions
- Theoretical model validated by tests
- Tests allowed to determine which modes are excited during each type of transport

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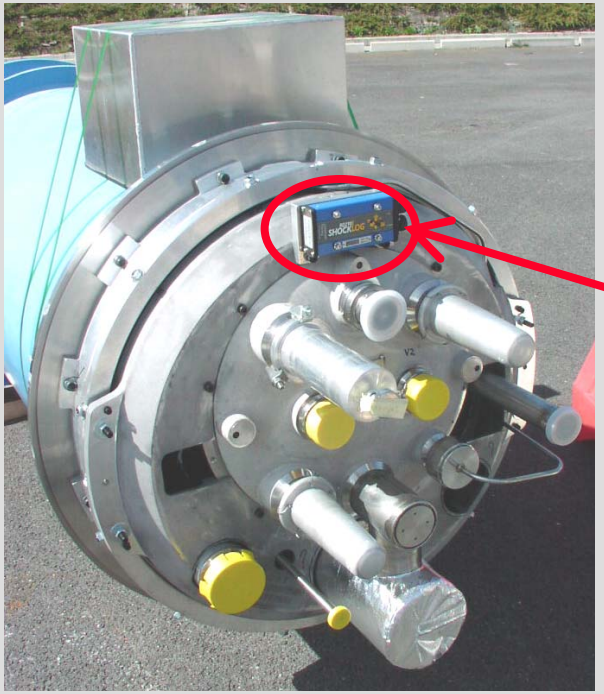
- Maximum accelerations specified for each type of transport
  - Example: accelerations limits for road transport

Cryo-magnet	Lateral	Vertical	Axial
Cryo-dipole	5 m/s²	7 m/s²	4 m/s²
SSS	2.9 m/s²	2.9 m/s²	2.9 m/s²



Shocklog

- A tri-axial acceleration-monitoring device has to be installed on each handled and transported cryo-dipole and SSS

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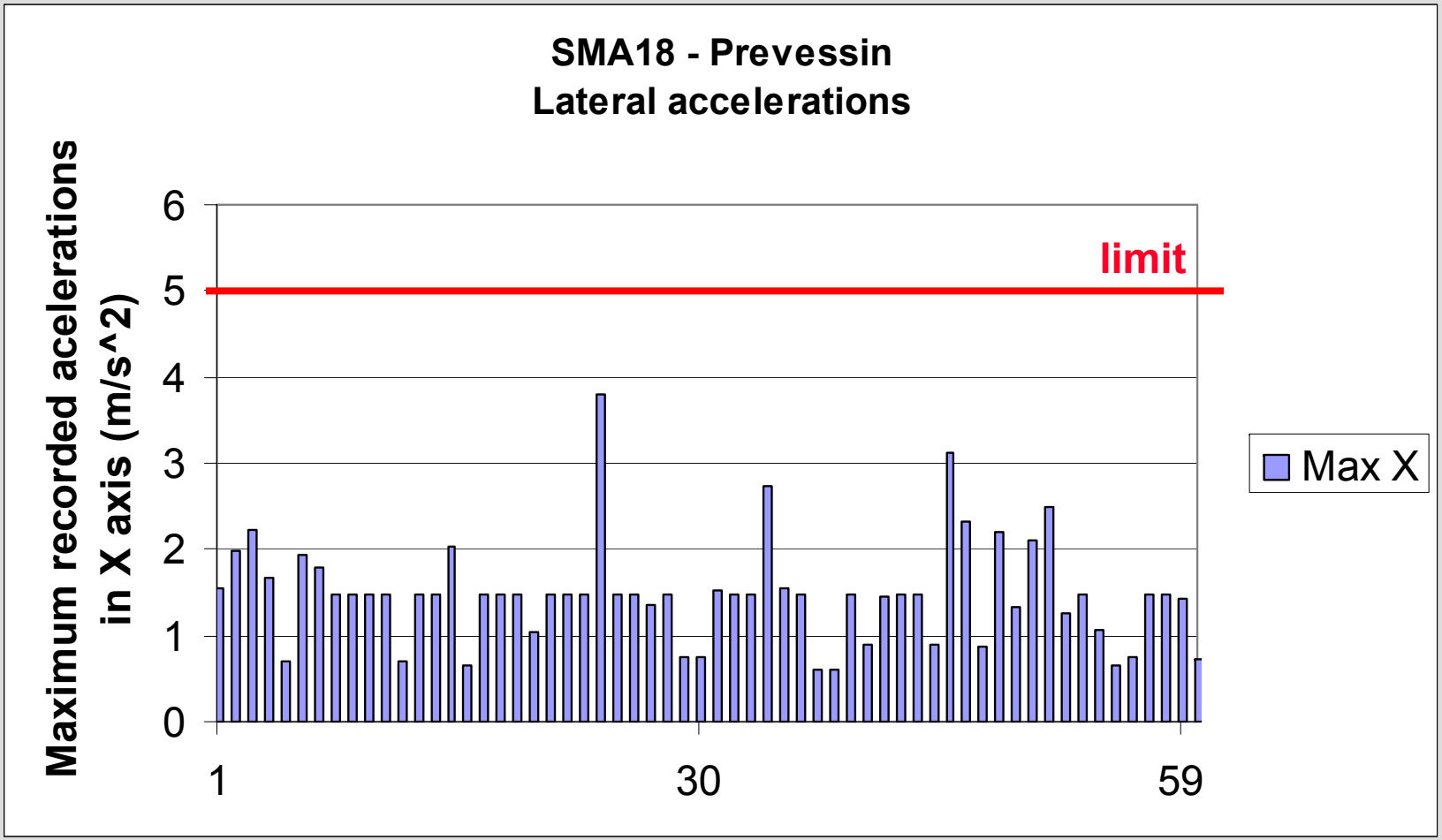
Results serial transport

Conclusions

Results serial transport

- Examples of measured maximum accelerations during cryo-dipole road transport:
  - SMA18 - > Prevessin storage zone



Results serial transport

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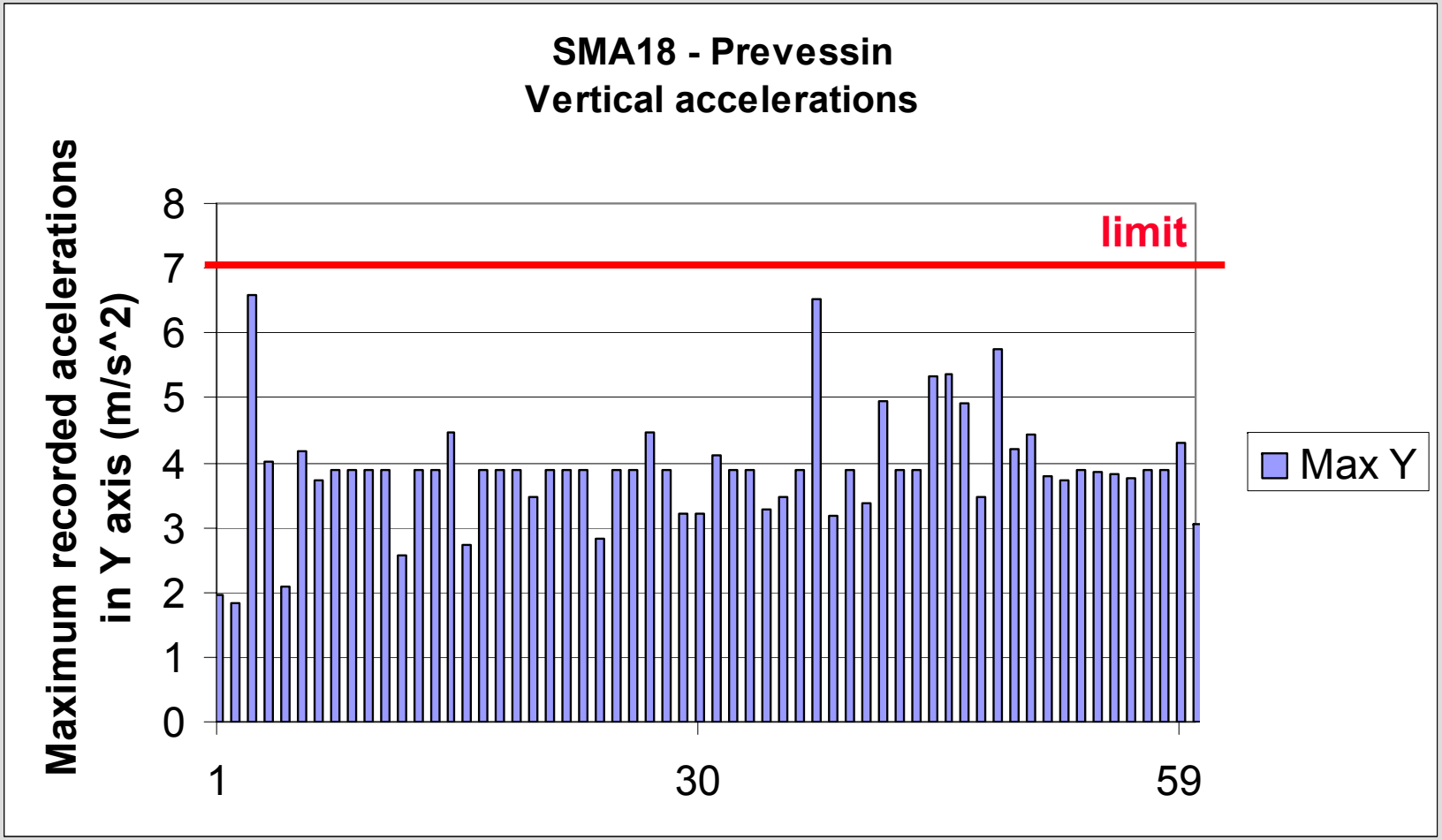

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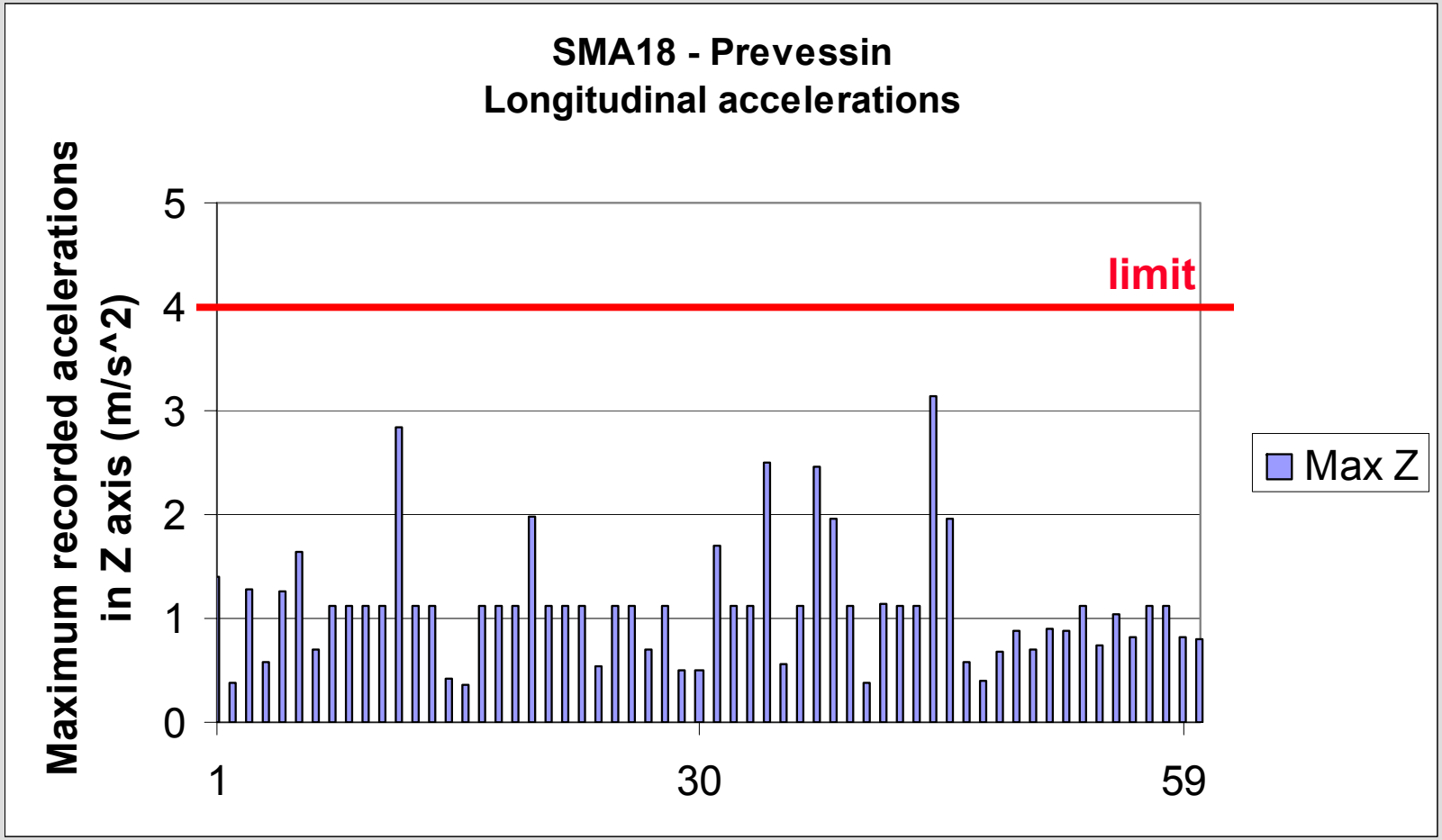
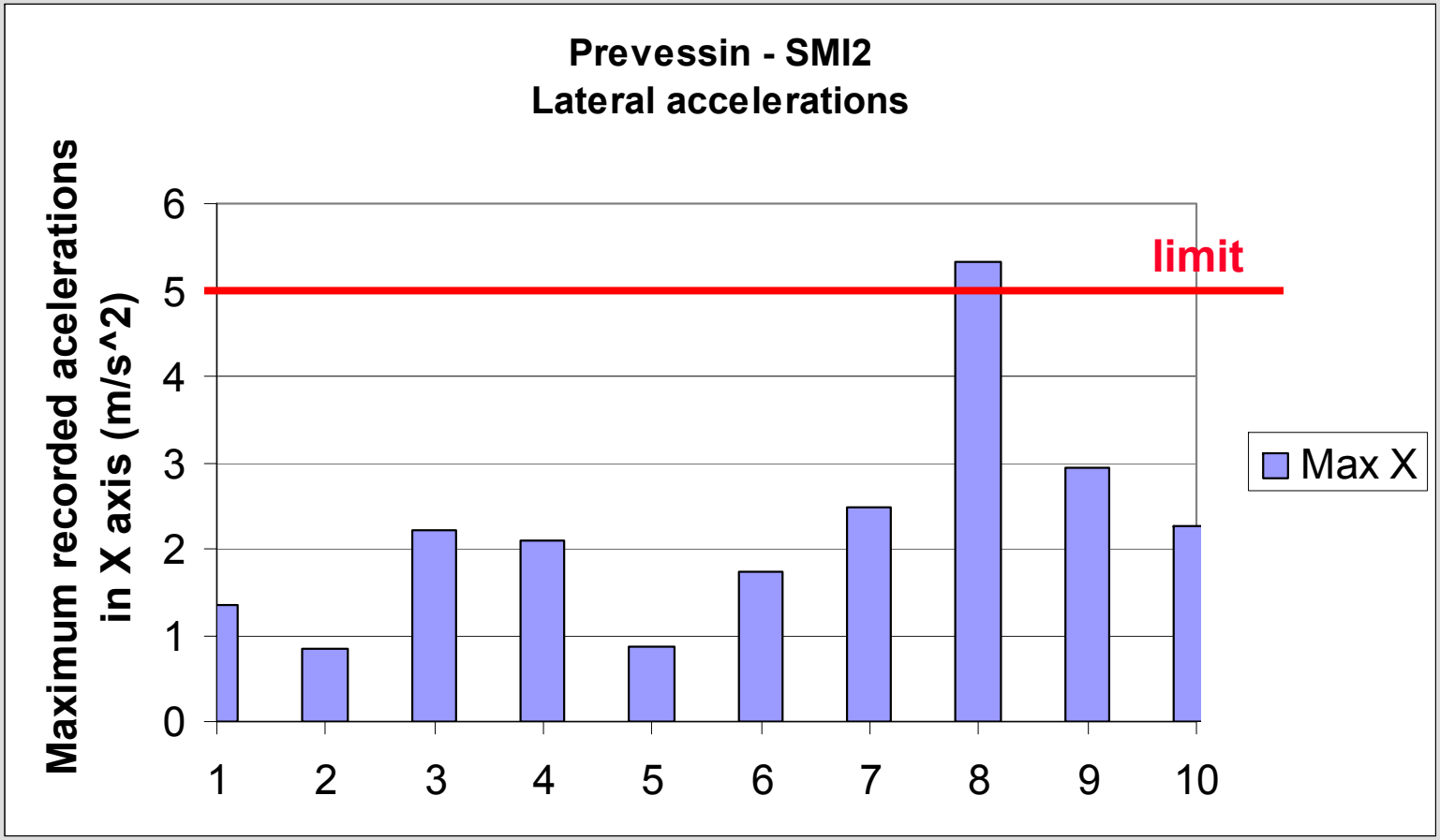


Results serial transport

- Examples of measured maximum accelerations during cryo-dipole road transport:
  - Prevessin storage zone -> SMI2



Results serial transport

- Examples of measured maximum accelerations during cryo-dipole road transport:
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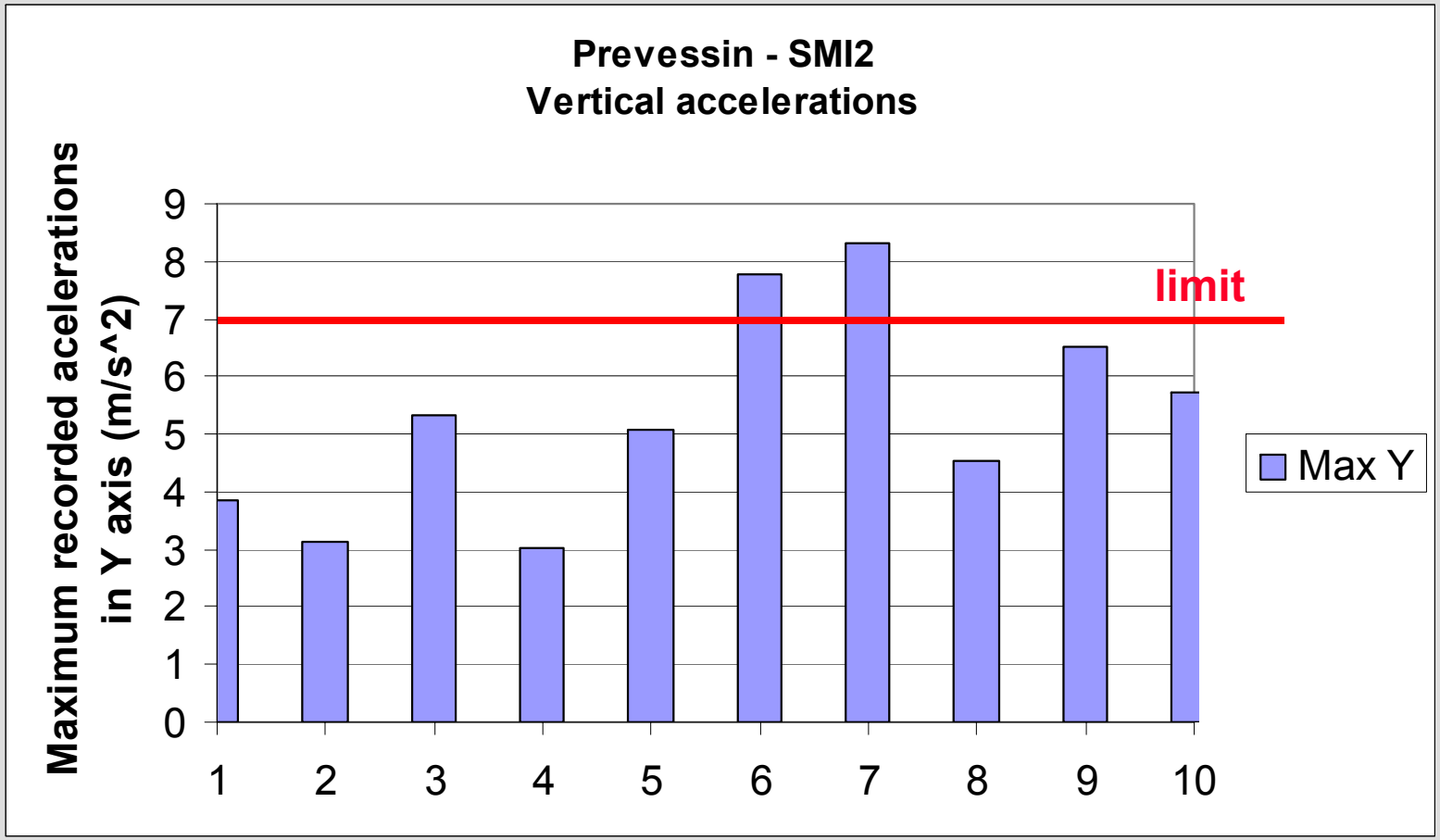
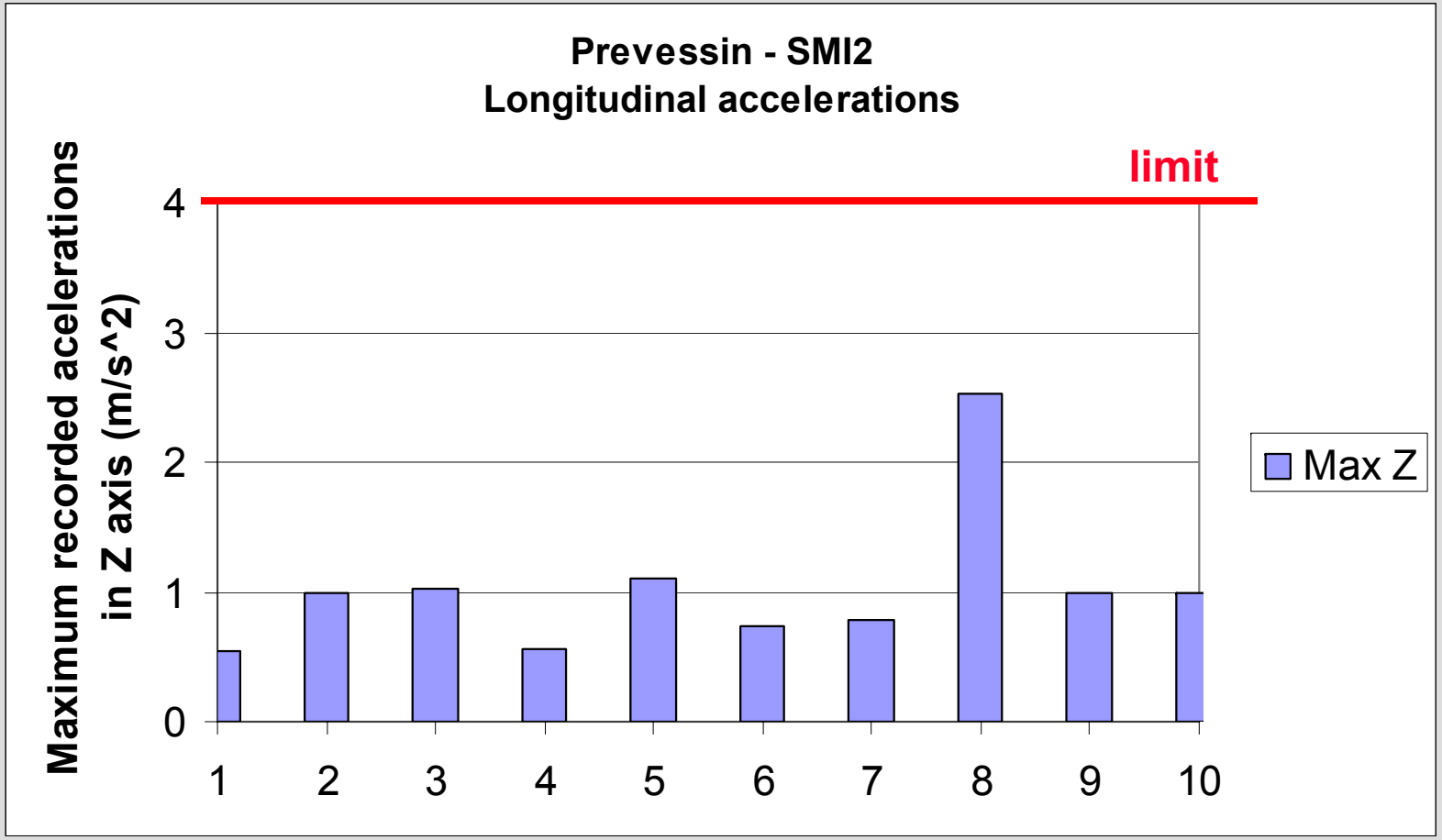


Results serial transport

- Examples of measured maximum accelerations during cryo-dipole road transport:
  - Prevessin storage zone -> SMI2



Results serial transport

- The transport results show that, generally, the monitored accelerations are below the limits but with limited margin left;

- Results from acceleration monitoring are used to detect details such as out-of-specification accelerations that need improvement (e.g. overhead crane movement adjustment, additional tooling) :
  - Operation of cryo-dipole positioning on jacks in SMI2 building;
  - Short Straight Section positioning on jacks in 904 building;
  - Holes in the asphalt ... etc...

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Conclusions

- The Arc cryo-magnets behaviour under different handling and transportation conditions has been studied;
- Maximum admissible accelerations have been specified;
- A tri-axial acceleration-monitoring device is installed on each handled and transported Arc cryo-magnet;
- The transport results up to now show that, generally, the monitored accelerations are below the limits but with limited margin left;
- Results from acceleration monitoring are used to detect details such as out-of-specification accelerations that need improvement.

References

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