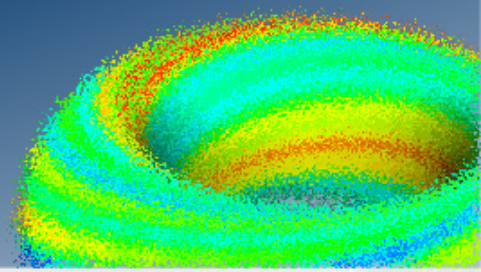
Fusion Group

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA



Structural Analyses of DEMO Magnets

José Lorenzo

12/02/2020

EUROfusion Engineering Grant - 2020/02

Outline

1. **Introduction**
2. Background
3. Engineering Grant
4. Summary

Introduction

- MSc in **Industrial Engineering** (Universidad de Sevilla, 2014).
- 2 years in the **Magnets, Superconductors and Cryostats (MSC) Group at CERN** in collaboration with CIEMAT.
- Currently working in the **Fusion Group** at **Barcelona Supercomputing Center (BSC)**.
- Awarded with **EUROfusion Engineering Grant** *"Structural Analyses of DEMO Magnets"*.

Barcelona Supercomputing Center (BSC)

- Spanish National Supercomputing Center and Public R&D Institute.
- **3rd party of CIEMAT in EUROfusion** Consortium Agreement.
- Partnership for Advanced Computing in Europe (PRACE): Hosting Member; Host of EuroHPC pre-exascale machine.
- Multidisciplinary team of ~640 people from ~45 countries.

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

EUROfusion

PRACE

MareNostrum 4

Total peak performance: **13.7** Pflops	
General Purpose Cluster:	11.15 Pflops (1.07.2017)
CTE1-P9+Volta:	1.57 Pflops (1.03.2018)
CTE2-AMD:	0.52 Pflops (1.11.2019)
CTE3-Arm V8:	0.5 Pflops

PRACE

Access: prace-ri.eu/hpc_acces

RES
RED ESPAÑOLA DE SUPERCOMPUTACIÓN

Access: bsc.es/res-intranet

BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación

MareNostrum 1
2004 – 42,3 Tflops
1st Europe / 4th World
New technologies

MareNostrum 2
2006 – 94,2 Tflops
1st Europe / 5th World
New technologies

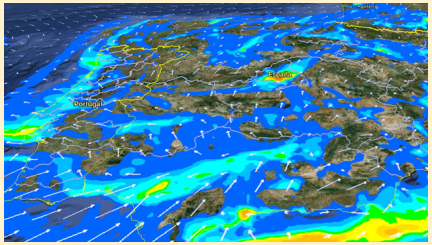
MareNostrum 3
2012 – 1,1 Pflops
12th Europe / 36th World

MareNostrum 4
2017 – 11,1 Pflops
2nd Europe / 13th World
New technologies

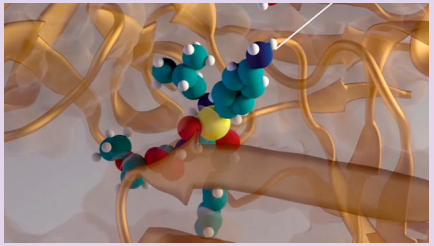
BSC Research Departments

Computer Sciences

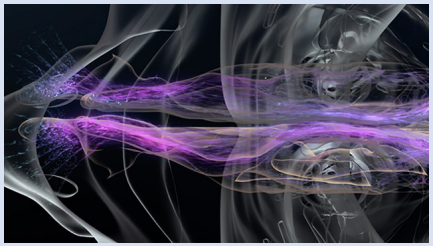
Earth Sciences



Life Sciences



Engineering (CASE)



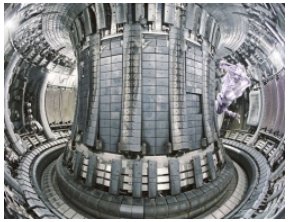
Computational Social Sciences
Data Analytics & Visualization
Environmental Simulations
Fusion
Geophysical Applications
HPC Software Engineering
Physical & Numerical Modelling
Quantic
Smart Cities

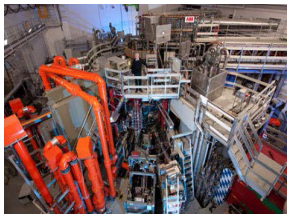
- Develop computational tools to simulate highly complex problems exploiting supercomputing capabilities.
- In-house HPC code Alya to simulate **coupled multiphysics problems on large meshes**.
- Expertise in **Computational Mechanics, Electromagnetism, Finite Element Analysis (FEA).**

Fusion Group at BSC

- Focus in numerical modelling and code development.
- Combine world-class HPC expertise with fusion physics and technology.
- Participation in various EUROfusion work packages.
- Participation in fusion experiments.
- Leading the FusionCAT project (2019-2022).

JET





ASDEX upgrade

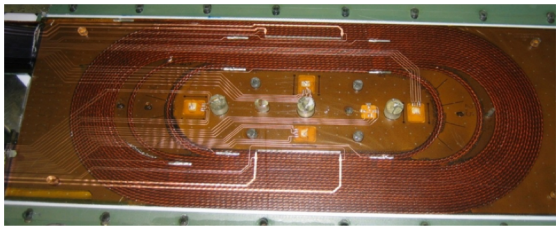
Outline

1. Introduction
2. **Background**
3. Engineering Grant
4. Summary

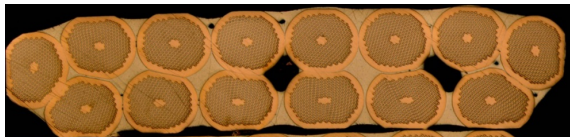
Background: MSC Group at CERN

- TE (Technology) – MSC (Magnets, Superconductors and Cryostats) – TF (Test Facilities):
  Superconducting Magnet Test Facilities SM18

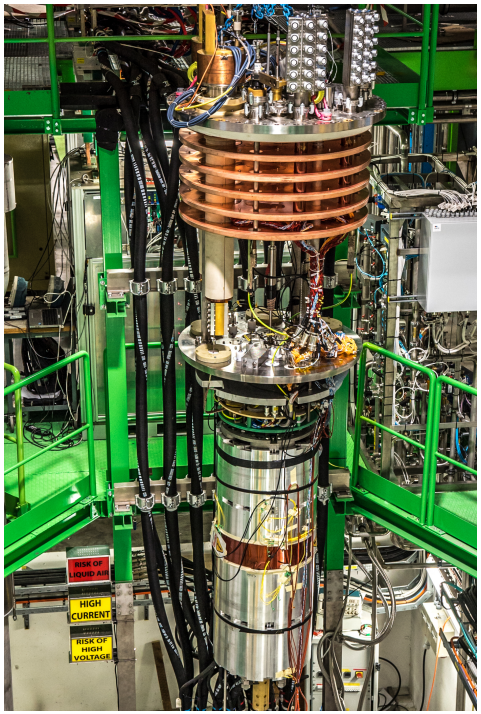
- Test of epoxy impregnated Nb_3Sn Racetrack Coils to validate the impregnated Nb_3Sn-based coil technology.



Impregnated racetrack coil



14-strand Rutherford cable



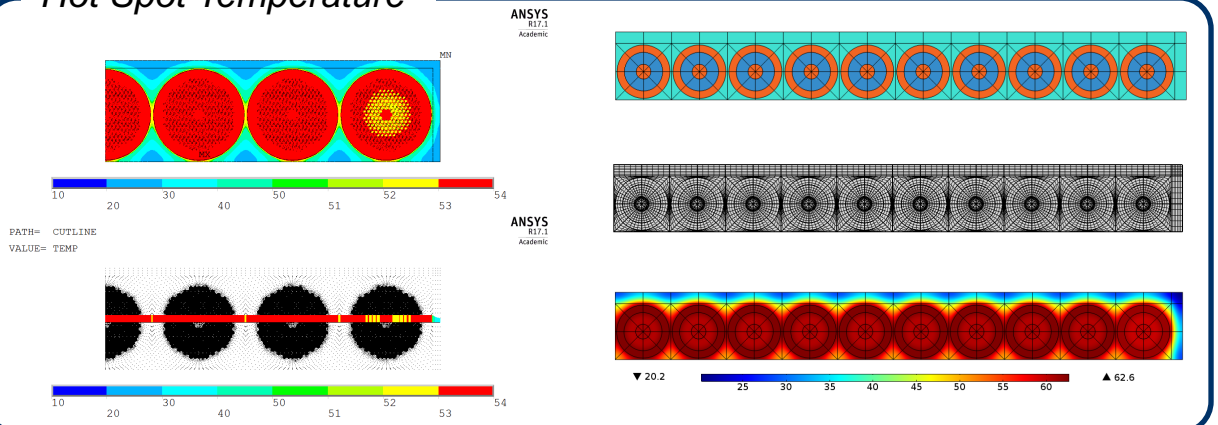
Vertical cryostat at CERN SM18

- **Study of the behaviour during quench** of Short Model Coils tested at SM18:
  - Hot Spot Temperature.
  - Longitudinal and turn-to-turn Quench Propagation Velocity.

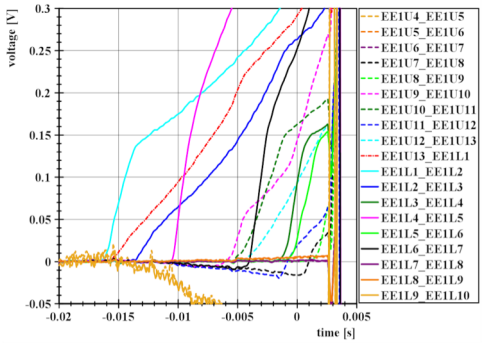
Background: MSC Group at CERN

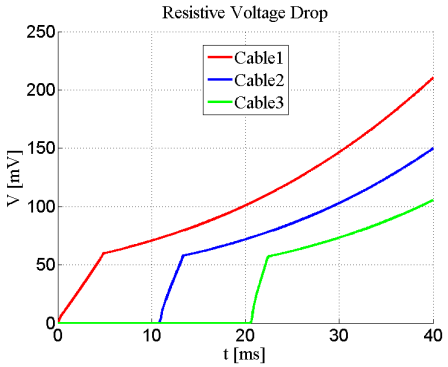
- Development of analytical and numerical models of quench in Nb_3Sn racetrack coils.

Hot Spot Temperature

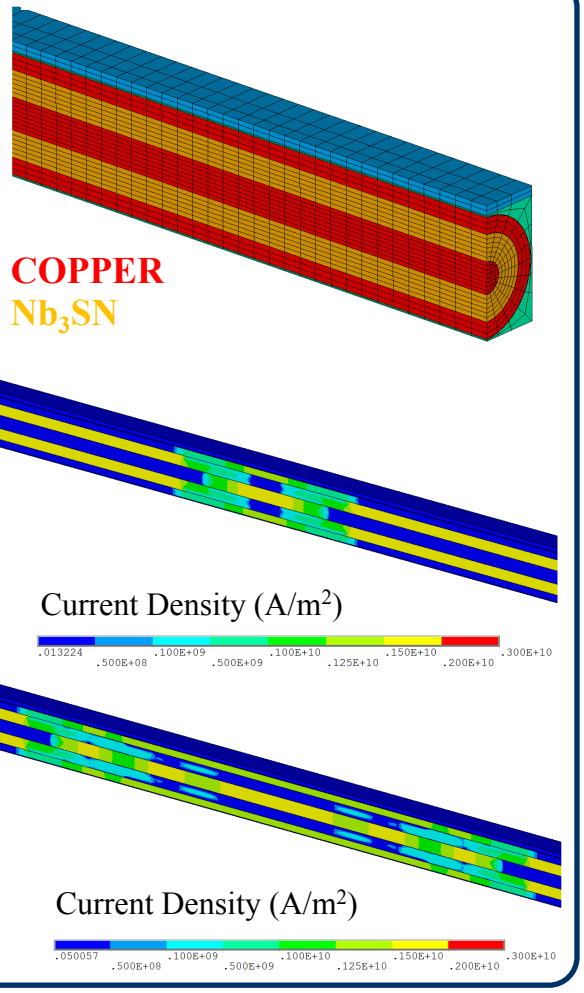


Turn-to-turn Propagation





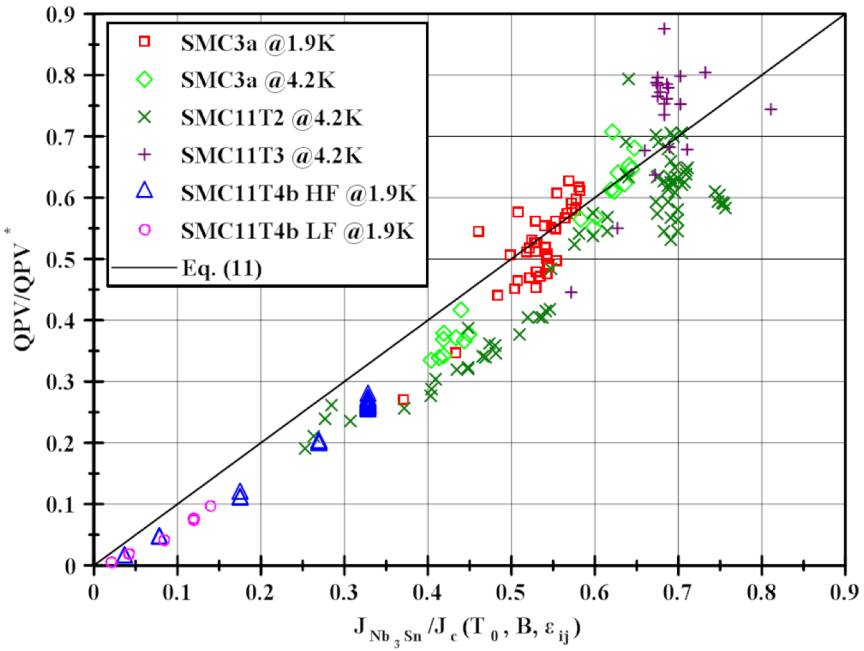
Longitudinal Propagation

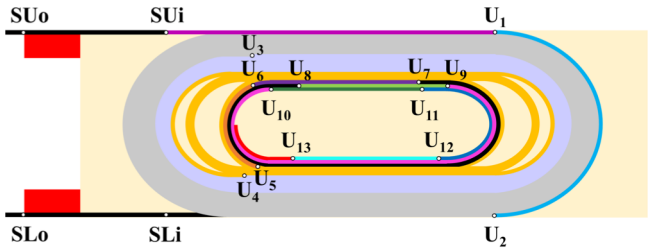


Source: J. Lorenzo et al., *"Quench Study in Nb_3Sn Racetrack Coils".*
https://indico.cern.ch/event/652634/contributions/2656324/attachments/1491764/2319127/Seminar_QuenchStudy.pptx

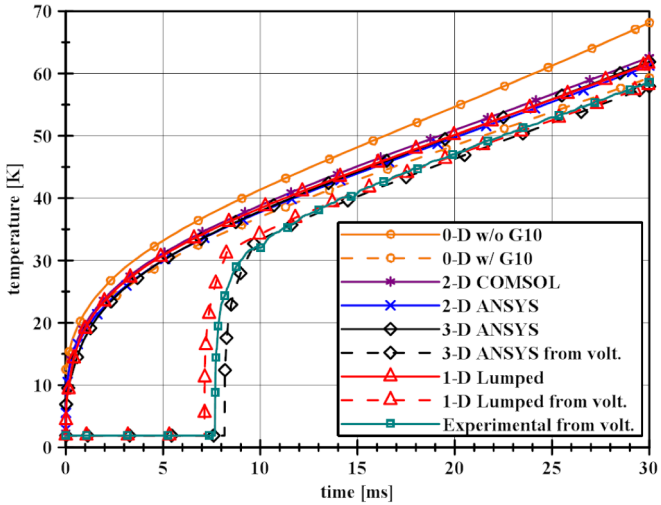
Background: MSC Group at CERN

- Analysis of experimental data sets collected throughout the magnet training at SM18.





Schematic of voltage taps in Short Model Coil to measure the voltage drop along coil sections

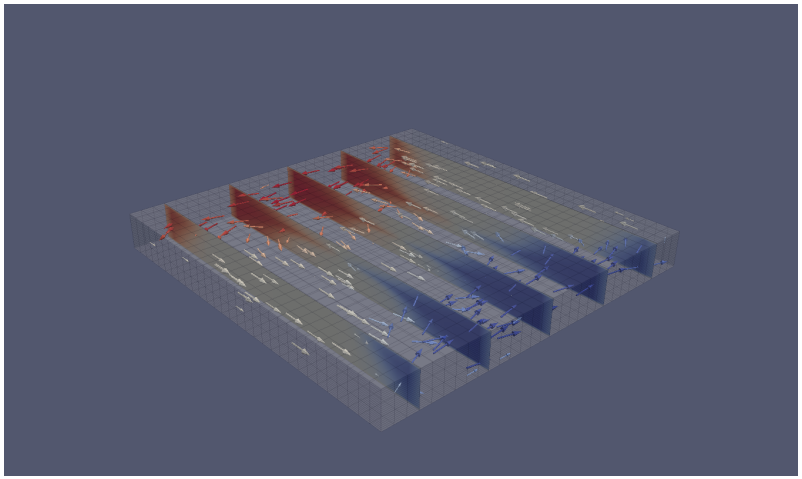


- Experimental validation of numerical models.

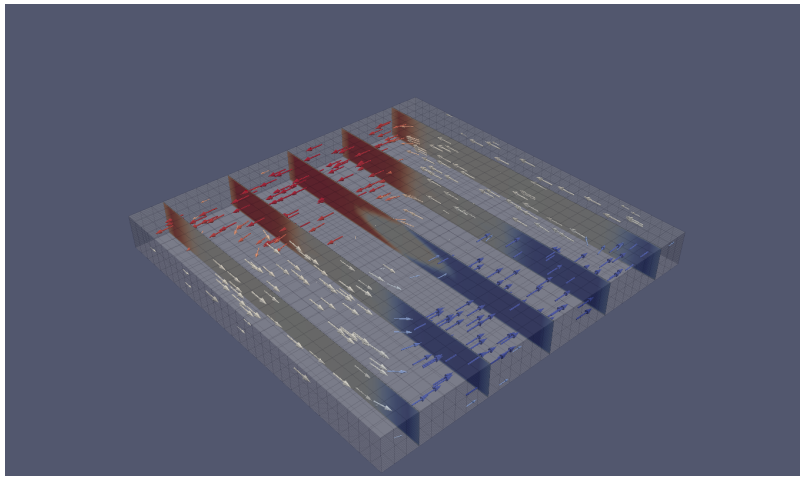
Source: J. Lorenzo et al., *"Quench Propagation Velocity and Hot Spot Temperature Models in Nb_3Sn Racetrack Coils".*

Background: Fusion Group at BSC

- HPC framework for the **multiphysics simulation of High-Temperature Superconductors** (HTS) to investigate cable layouts for fusion.
- Electromagnetic module solving the **H-formulation** of Maxwell's equations implemented in the **Alya code** and tested using up to 2400 processors in MN4.
- **Collaboration with ICMAB** for the experimental validation of the code.



Current density distribution in bulk superconductor.



Current density distribution in stacked superconductor.

3-D benchmark with Alya Magnet module: 5.5 million DoFs using 920 processors in MN4.

Outline

1. Introduction
2. Background
3. **Engineering Grant**
4. Summary

EEG: Project Objectives

- **Parametric structural assessment**:
  - Alternative Magnetic Configurations of DEMO magnet system.
  - DEMO magnets supports and intercoil structures.
- **Parametric electromagnetic modelling** of DEMO magnet system.
- Training in **manufacturing technologies** for Fusion magnets.
- Use of **HPC techniques** for the mechanical analysis of DEMO structural elements.

EEG: Work Programme

- **3-year programme** divided in 5 Work Packages (WPs):
  - Review of literature on Fusion Magnets (WP1).
  - Parametric Electromagnetic and Mechanical analyses (WP2 & WP3).
  - Expertise in manufacturing technologies (WP4).
  - HPC in numerical modelling of Fusion Magnets (WP5).

FUSION FOR ENERGY

- **Missions** for training and collaboration: F4E, SPC, PMU Garching.
- **Collaboration with industry** involved in Fusion: Elytt Energy, Tratos Cavi, Criotec.

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE | SWISS PLASMA CENTER

ELYTT ENERGY

- **Dissemination** in international conferences.

EEG: First Year

- **WP1: Literature Review.**
  - Tokamaks, Basic electromagnetic & mechanical models of fusion magnets, design parameters and PROCESS code.
  - DEMO magnet system, pre-conceptual designs.
  - ITER magnet system.
- **WP2: Electromagnetic Modelling of DEMO magnet system.**
- **WP3: Mechanical Assessment.**
  - Assessment of Alternative Magnetic Configurations: Double Null (DND), Snowflake (SND), X (XD), Super-X (SXD) divertors.

EEG: Experienced Mentor

Dr Mantsinen

- PhD in Engineering Physics (1999, Finland).
- More than 20 years of international experience in **nuclear fusion** and **plasma physics** research.
- **Fusion Group Leader** at BSC.
- Collaboration with **magnetically confined fusion experiments**.
- Coordination, analysis, and modelling of experiments on several fusion facilities (JET, AUG, DIII-D and TJ-II).

Outline

1. Introduction
2. Background
3. Engineering Grant
4. **Summary**

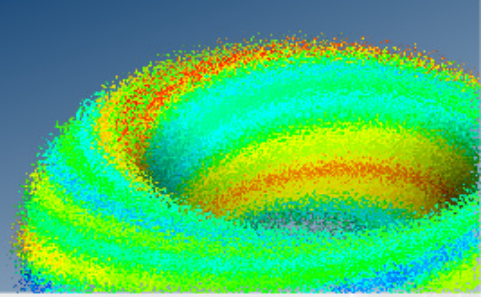
Summary

- Training in DEMO magnet system (electromagnetic modelling, structural analyses, manufacture).
- Background in superconductivity, magnets and numerical modelling.
- At BSC, I will work with experts in FEA and have access to outstanding resources provided by current MN4 and MN5 upgrade by the end of 2020.
- Collaboration with F4E, SPC and PMU Garching.
- Involve industry in DEMO activities.

Fusion Group

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA



Thank you

fusion.bsc.es

@Fusion_BSC

fusion@bsc.es

jose.lorenzo@bsc.es