Vittorio Ferrentino

Optics and Magnetic Modelling of the CERN Proton Synchrotron

Tutor: Prof. Pasquale Arpaia

co-Tutor: Dr. Ewen Hamish Maclean (CERN)

Cycle: XXXVII

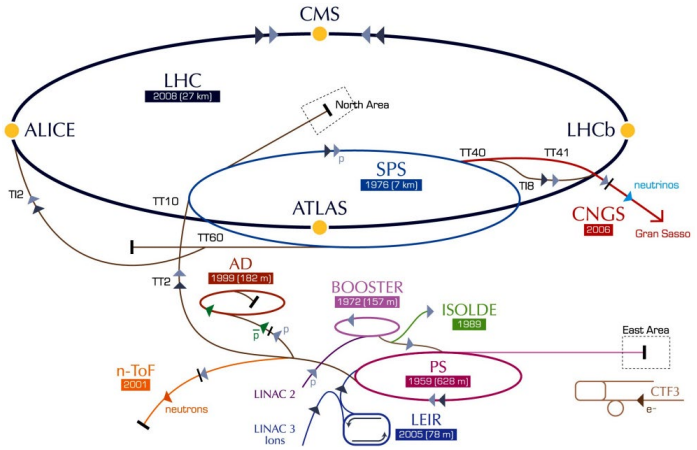
Year: First

My background

- **MSc degree in Electrical Engineering at the University of Naples Federico II, Naples, Italy on 09th December 2020**
  - Thesis title: Analysis of thermal transients in a superconducting combined-function magnets for hadron therapy gantry
  - Tutors: Prof. Pasquale Arpaia and Prof. Annalisa Liccardo
  - Collaboration with CERN, Switzerland, Geneva
- **PhD in Information Technology and Electrical Engineering (ITEE)**
  - Start date: 1 January 2022
  - Tutor: Prof. Pasquale Arpaia
- **Partner Organization:**
  - European Organization for Nuclear Research (CERN)
  - CERN supervisor: Dr. Ewen Hamish Maclean
- **Scholarship type:**
  - Enrolled supernumerary under the UNINA-CERN agreements and the CERN Doctoral Student Programme
- **Research group/laboratory:**
  - Instrumentation & Measurement for Particle Accelerator Lab (IMPALab)
  - CERN sections: BE-ABP-LNO and TE-MSC-NCM. Optics measurements and corrections team (OMC)

Research field of interest

- The main research area of interest is the modeling of particle accelerators and beam optics measurements
- The project is mostly focused on both the optics and magnetic modeling of CERN Proton Synchrotron (PS) accelerator Main Unit, which is one of the injectors of the LHC
- Time invested also for the beam optics measurement in the LHC for the 2022 LHC Commissioning and Run 3.



[1] https://home.cern/science/accelerators/proton-synchrotron

[2] https://cds.cern.ch/record/2423241

Summary of study activities (1)

- **Courses/PhD schools**:
  - Scientific writing
  - CERN Accelerator School (CAS): Introduction to Accelerator Physics; Kaunas, Lithuania
  - Metrology and Machine Learning for Brain Computer Interfaces
  - 5th Future-IoT PhD School: Iot meets Autonomy 2022; Berlin, Germany
  - My first steps in French

  <u>To be completed with the final exam</u>:
  - On the challenges and impact of Artificial Intelligence in the Insurance

- **Events attended:**
  - Training on Methodical Accelerator Design (MAD-X): Beginners
  - Training on Methodical Accelerator Design (MAD-X): Intermediate

Summary of study activities (2)

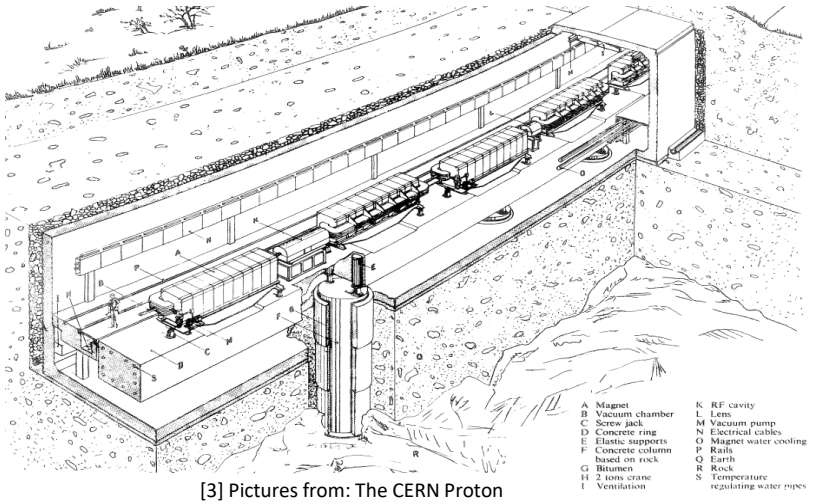
- **Seminars**:
  - Project Vac: Can a Text-to-speech Engine Generate Human Sentiments? (DIETI)
  - Global and cluster Synchronization in complex network and beyond (DIETI)
  - Computational single-cell biology – From one-to-many cells (DIETI)
  - From basic principles in spintronics to some recent developments toward spin-orbitronics (DIETI)
  - Living well within planetary Limits: is it possible? And what can physicists contribute? (CERN)
  - Design Thinking (Center for Advanced Internet Studies (CAIS))
  - Potential and challenges of next generation railway signaling systems: Moving Block and Virtual Coupling (DIETI)
  - Towards a political philosophy of AI (DIETI)
  - Towards AI-Driven Cancer Precision Medicine (DIETI)

Summary of study activities (3)

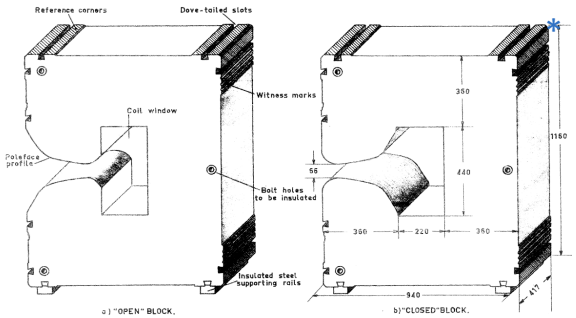
- **Seminars**:
  - Everything you always wanted to know about the Internet (but were afraid to ask) (CERN)
  - ITER, the magnets and the road to the first plasma (CERN)
  - 5G Academy: Fixed Wireless Access (DIETI)
  - 5 Academy: AR for remote use of measurement instrumentation (DIETI)
  - Vine robots: design challenges and unique opportunities (DIETI)
  - PhD4PhD: A student's speaking – Thermoacoustics for renewable energies (DIETI)
  - Probing and infusing biomedical knowledge for pre-trained language models (DIETI)
  - PhD4PhD: A student's speaking – Robotic assistance: pros and cons of a new technology (DIETI)
  - 5G Academy: Introduction to intellectual property management (DIETI)
  - Cybercrime and Information Warfare: National and International actors (DIETI)
  - Privacy and Data Protection (DIETI)

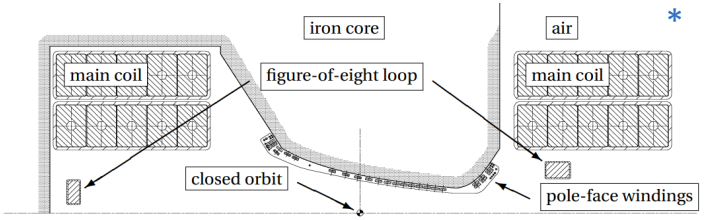
Research activities: Overview (1) - Problem

- **CERN Proton Synchrotron (PS): main features**
  - Circumference of 628 m
  - 277 room-temperature magnets (main unit dipoles, extraction magnets, injection magnets, and so on)
  - Accelerates protons and heavy ions beam from 2 GeV up to 26 GeV kinetic energy
- **PS Main Unit (MU):**
  - 100 Main Unit along the ring
  - Each of them with 3 coils: main coils and two additional circuits (F8L and PFW)
  - Pole shape designed to create a combined function magnetic field

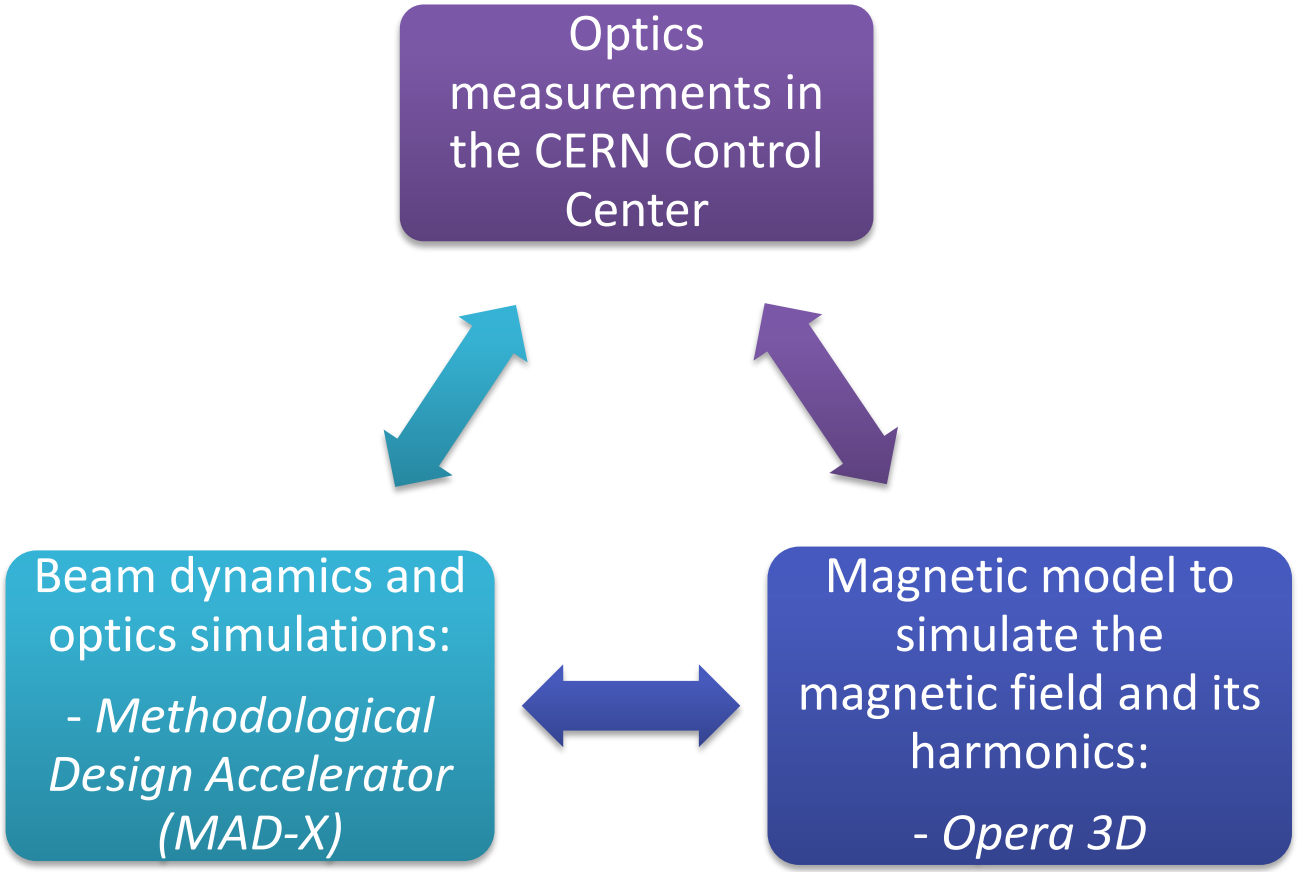


[3] Pictures from: The CERN Proton Synchrotron magnets – Report design





Research activities: Overview - Methodology (2)



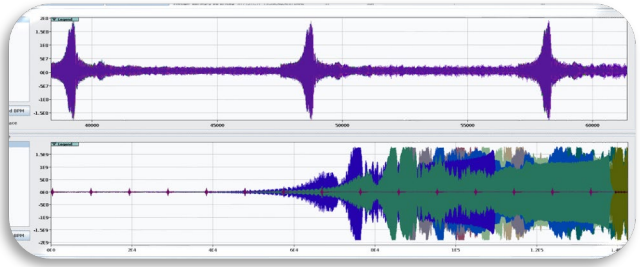
[4] https://mad.web.cern.ch/mad/

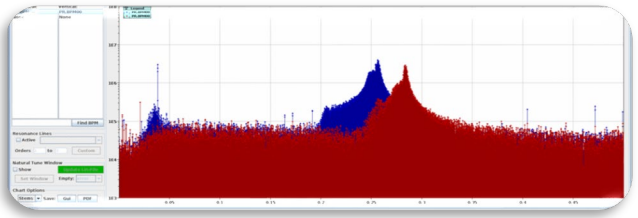
[5] http://www.rcnp.osaka-u.ac.jp/~sakemi/OPERA/ref-3d.pdf

Research activities:

Overview – Expected results and validation (3)

- **Optics measurements:**
- Allows acquiring beam orbit and from it measuring the spectrum and tunes through FFT

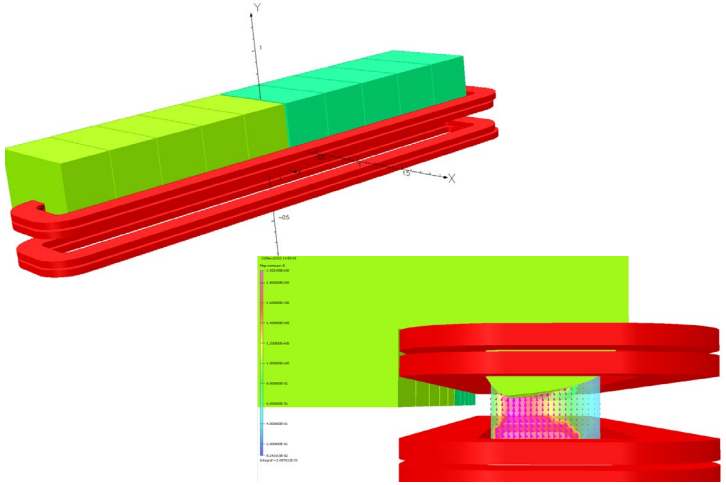


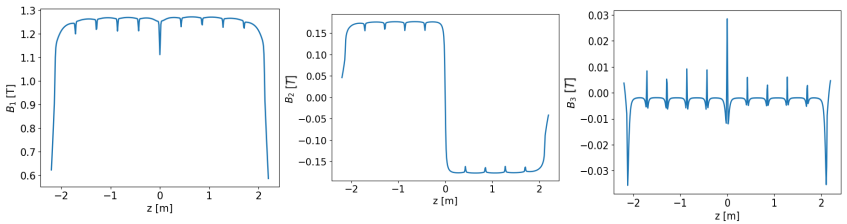


Methodical Accelerator Design MAD-X

Magnetic model:

- Allows simulating the magnetic field map in the magnet aperture and its multipolar components (dipole, quadrupole, sextupole, and so on)

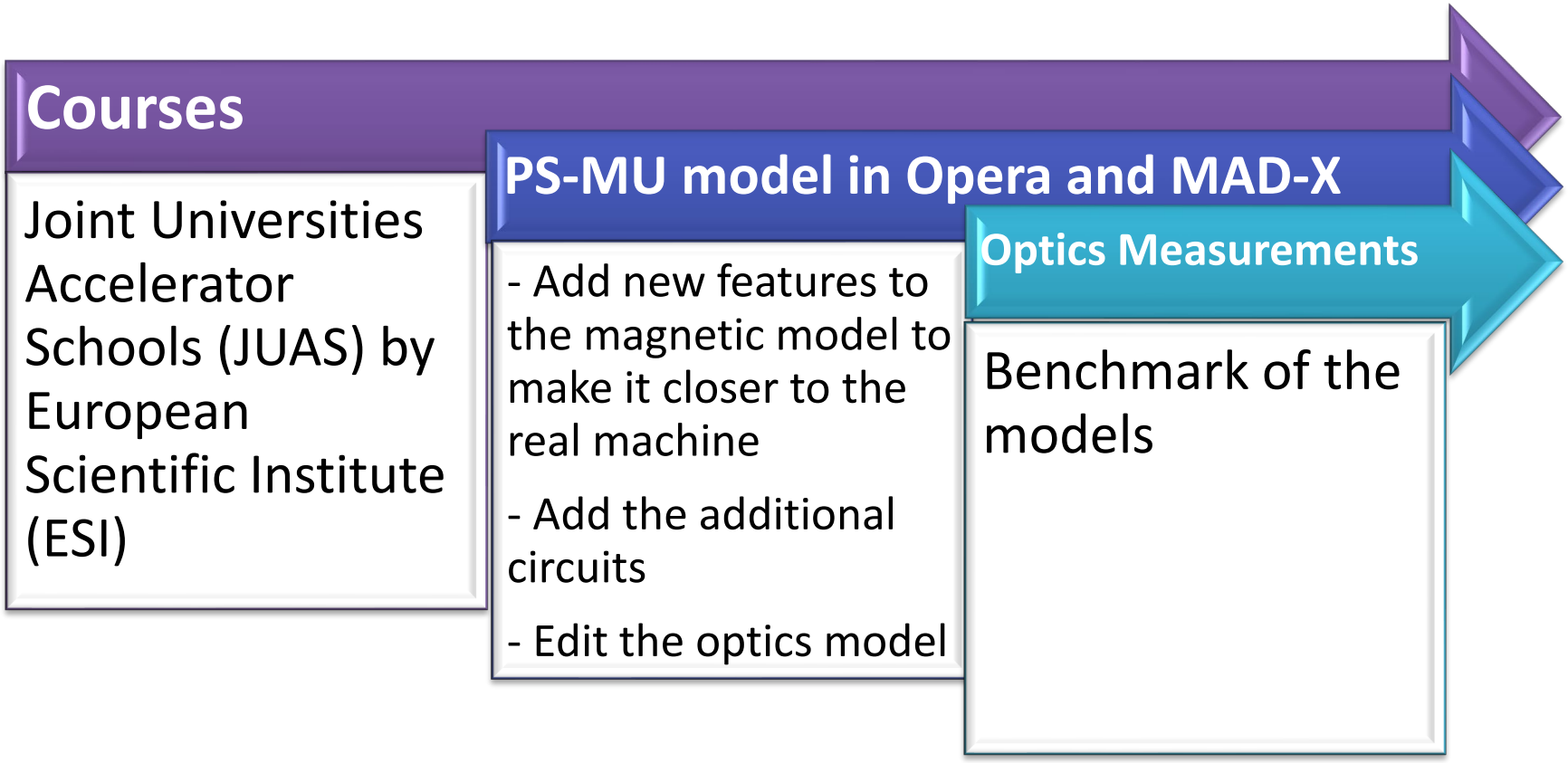




Products

[1]	**Title**: Analysis of thermal transients in superconducting combined-function magnet for hadron therapy gantry **Authors**: Vittorio Ferrentino, Pasquale Arpaia, Antonio Gilardi, Mikko Karppinen, Charilaos Kokkinos, Emmanuele Ravaioli **Current status**: Submitted **Journal**: IEEE Transactions on Applied Superconductivity

Next year


Courses
Joint Universities Accelerator Schools (JUAS) by European Scientific Institute (ESI)
PS-MU model in Opera and MAD-X
- Add new features to the magnetic model to make it closer to the real machine
- Add the additional circuits
- Edit the optics model
Optics Measurements
Benchmark of the models

Thank the ITEE Board, ITEE tutors and colleagues for your attention