
CERN

Experts' support for capacity building

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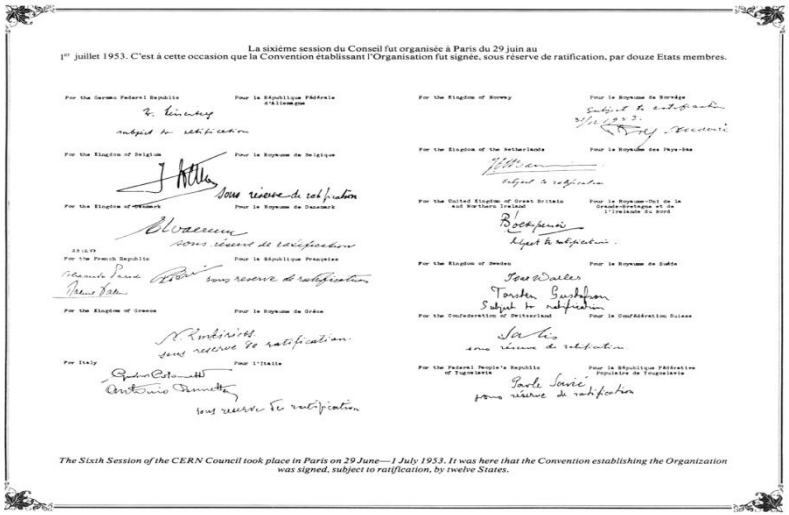
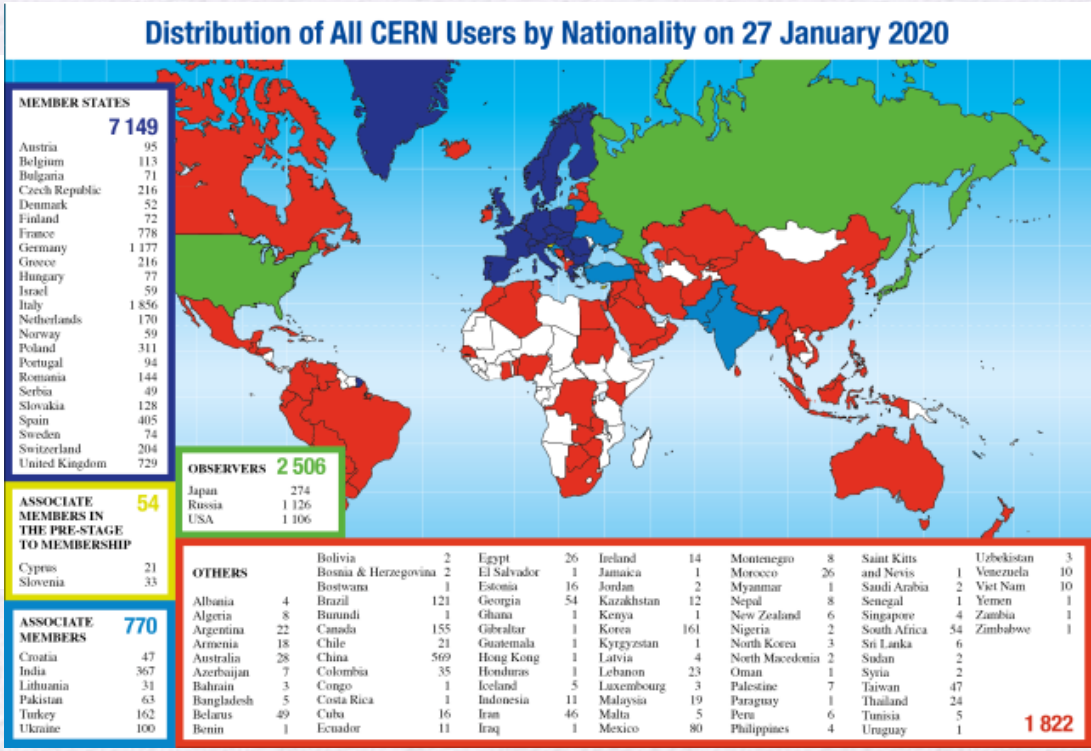
Some history

- Greece among the 12 **founding member states** of **CERN** (1954), with large **particle physics community** (**216 users @ CERN experiments** in **2020**)
- Since last two decades, continuous effort to build a community in **Accelerator Physics and technology** for **Greece.**



La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.

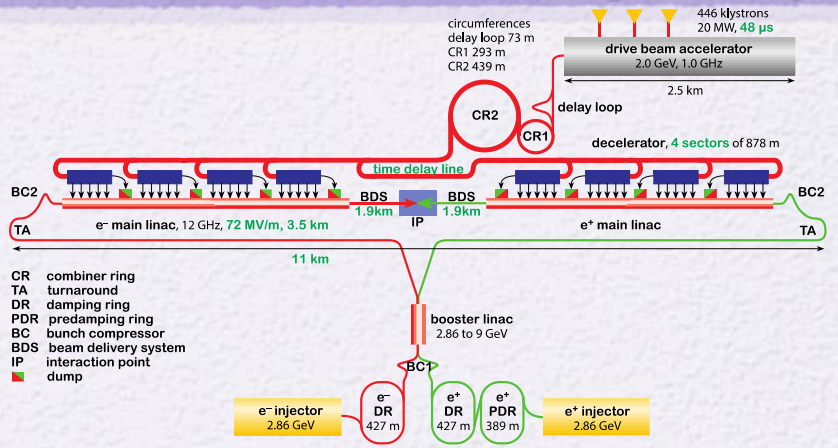


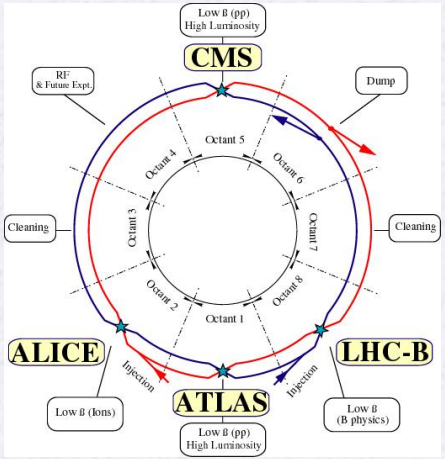
Greek Students in Accelerator fields

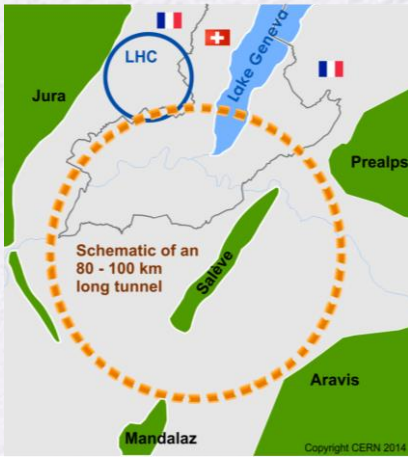
- Several **technical** (MSc level) and **doctoral studentships** @ CERN, some partially supported by public grants (e.g. IKY), in beam physics, accelerator operation and technology. A **non-exhaustive list**
  - Michalis Zampetakis (**Un. of Creta**), 2018-2022, IBS and space-charge combined with cooling in hadron and lepton rings.
  - Kostas Paraschou (**Un. of Thessaloniki**), 2018-2022, Impact of incoherent e-cloud effects in LHC
  - Natalia Triantafyllou (Un. of Liverpool), 2018-2022, Emittance growth due to crab-cavity noise
  - Tirsi Prebibaj (Un. of Frankfurt), 2020 – 2023, Optics and resonance correction for high brightness beams
  - Dr. Sophia Kostoglou (**National Technical University of Athens**), 2017-2020, Noise effects and their impact on the performance of LHC and HL-LHC.
  - Dr. Kyriacos Skoufaris (**Un. of Creta**), 2016-2020 Symplectic integration schemes, beam-beam effects in LHC and HL-LHC.
  - Dr. Foteini Asvesta (**National Technical University of Athens**), 2015 - 2020, Space-charge effects in the LHC injectors.
  - Dr. Stephania Papadopoulou (**University of Creta**), Lattice design for low emittance rings, halo formation in high-brightness lepton and hadron beams.
  - Dr. Theodoros Argyropoulos (**National Technical University of Athens**), 2010 - 2014, Longitudinal dynamics of harmonic RF cavities
  - Dr. Eirini Koukovini Platia, (EPFL), 2011 – 2015, Coherent effects and instabilities in low emittance rings
  - Dr. Fanouria Antoniou (**National Technical University of Athens**), 2009 – 2015, Intrabeam Scattering dominated ultra-low emittance rings
- Most of them continued as **post-doctoral fellows** at CERN and elsewhere
- Five hired as **staff applied physicists** at CERN

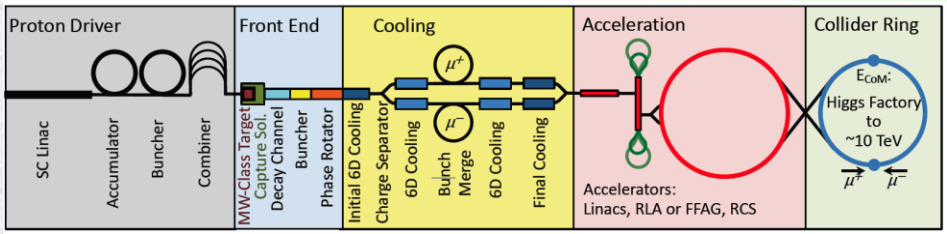
Accelerator studies and projects

- CERN injector operation and LHC injector upgrade (LIU)
- LHC design and operation
- High-luminosity LHC
- Compact Linear Collider (CTF3)
- Low Emittance Rings (Synchrotron Light Sources,…)
- Future Circular Collider
- Muon Collider









Brightness studies in the PS Booster

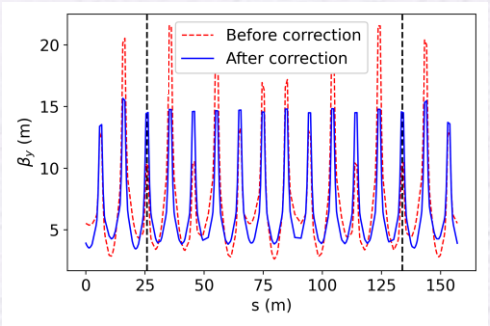
Optimization of the **beam brightness** for low energy machines (PSB).

$$B = \frac{N_b}{0.5(\epsilon_x + \epsilon_y)}$$

Beam intensity (number of particles per bunch)

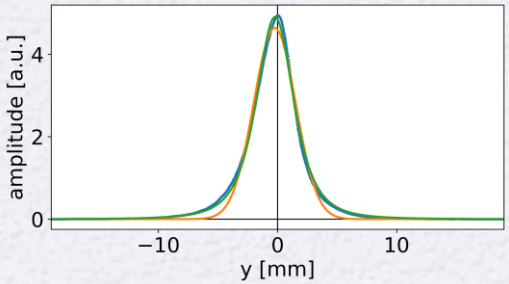
Beam transverse emittances (particle density in the phase space)

Correction of the optics perturbations



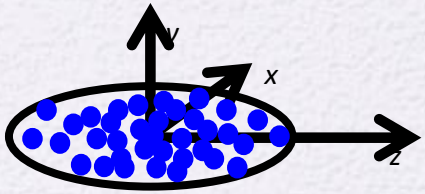
- Particles **oscillate** around the accelerator (machine optics).
- Errors in the magnetic fields can enhance these oscillations → **beam losses**.
- Goal is to bring oscillations back to acceptable levels (**optics correction**).

Improvements of the beam transverse particle distributions



- The shape of the particle distributions is important for the emittances.
- Many factors degrade the particle profiles (**beam tails**) → **emittance growth**.
- Goal is to optimize and accurately reconstruct the beam profiles.

Mitigation of the effects caused by the self-interaction of the charged particles of the beam (space charge effects)



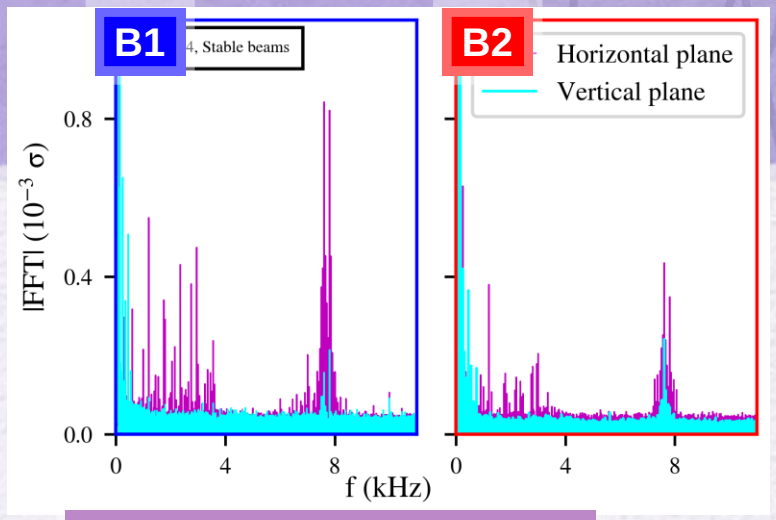
- Space charge effects can lead to many undesired effects (tune spread, resonance excitation, etc.).
- Combined with errors in the magnetic field errors can greatly limit the brightness (**emittance growth** and **beam losses**).

PhD of T. Prebibaj

LHC & HL-LHC noise studies

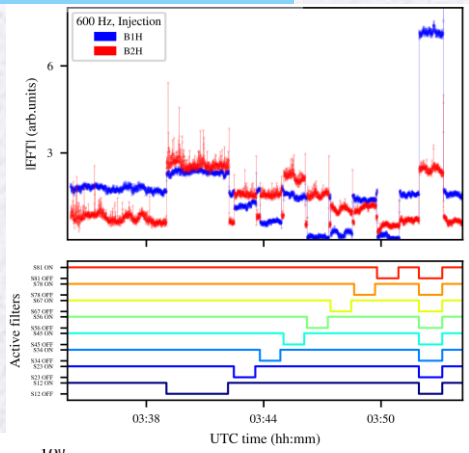
CHALLENGE: chasing the source of the 10^{-3} σ beam oscillations and its impact on beam lifetime.

- 50 Hz harmonics on transverse beam spectrum.
- Harmonics of Beam 1 x2 larger amplitudes than Beam 2.

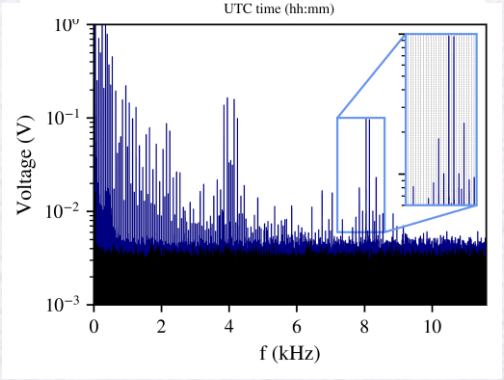


Perturbation source

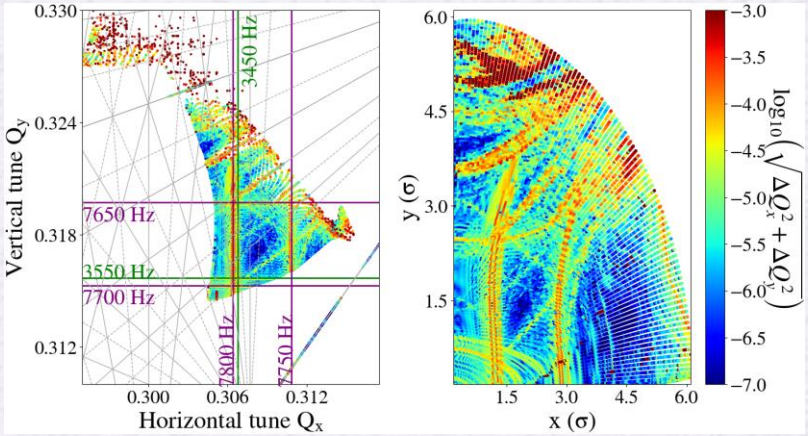
Power converters of main dipoles: tests with active filters



UPS voltage measurements, additional studies in Run 3



Impact on beam lifetime



Single-particle tracking simulations:
22h beam lifetime for Beam 1
and **27h** for Beam 2

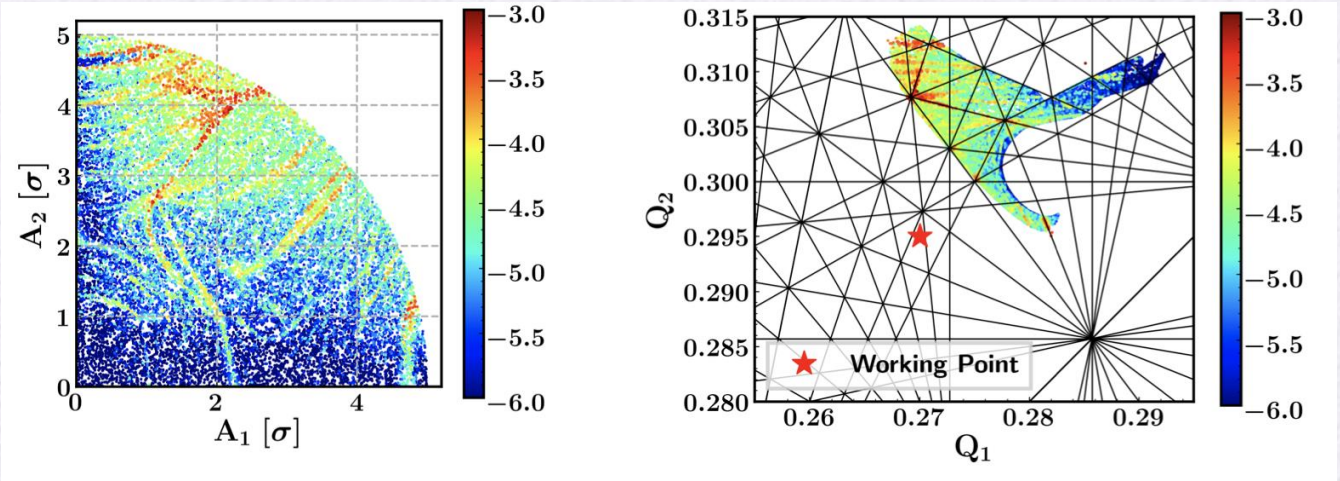
PhD of S. Kostoglou

e-cloud at LHC and HL-LHC: incoherent effects

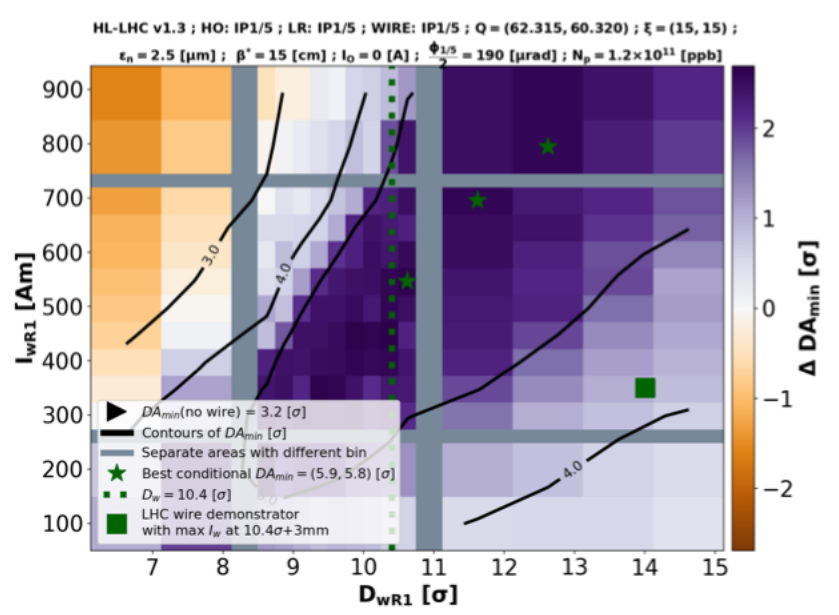
- **LHC data shows slow beam degradation due to e-cloud at injection and collisions**
- Develop **simulation framework for e-cloud effect** over the required long timescales (10M turns), including
  - **Theoretical framework**
  - **Tracking code**
  - **Software infrastructure to simulate and condition the electron pinches** and setup the simulation from the MAD-X description of the machine

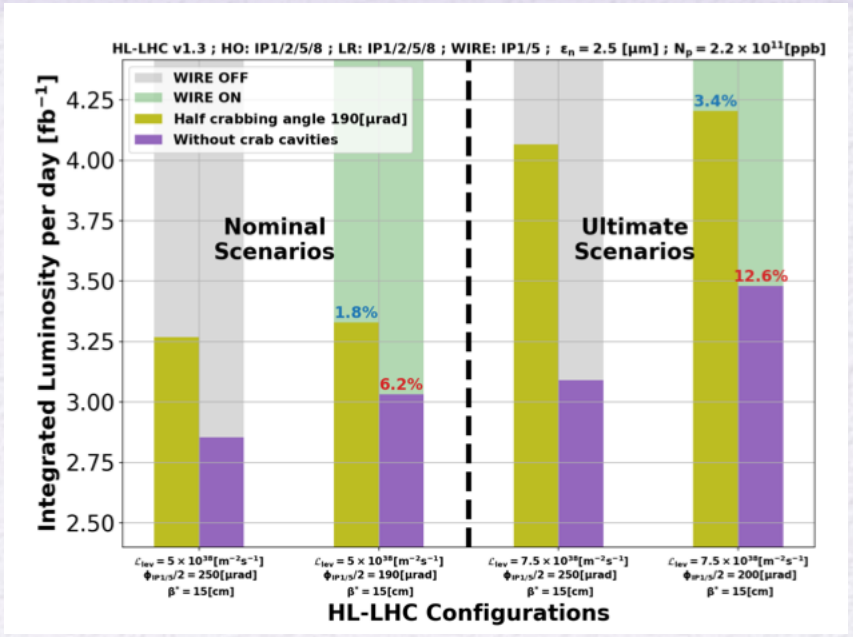
PhD of K. Paraschou

- Presently capable of **simulating 10 M turns** (15 minutes of beam time) by exploiting computational power of GPUs



HL-LHC beam-beam wire compensation





CHALLENGE: Predict and optimize the future (HL-LHC) by

- taking into account Machine Protection constraints and
- minimizing complexity, saving commissioning time and maximize machine availability.

PhD of K. Skoufaris

Collaboration agreements with Greek institutions for Accelerators

- Collaboration agreements signed for broad range of subjects of accelerator physics and technology
  - National Technical University of Athens
  - University of Creta
  - Aristotelian University of Thessaloniki

National Technical University of Athens

UNIVERSITY OF CRETE

ARISTOTLE UNIVERSITY OF THESSALONIKI

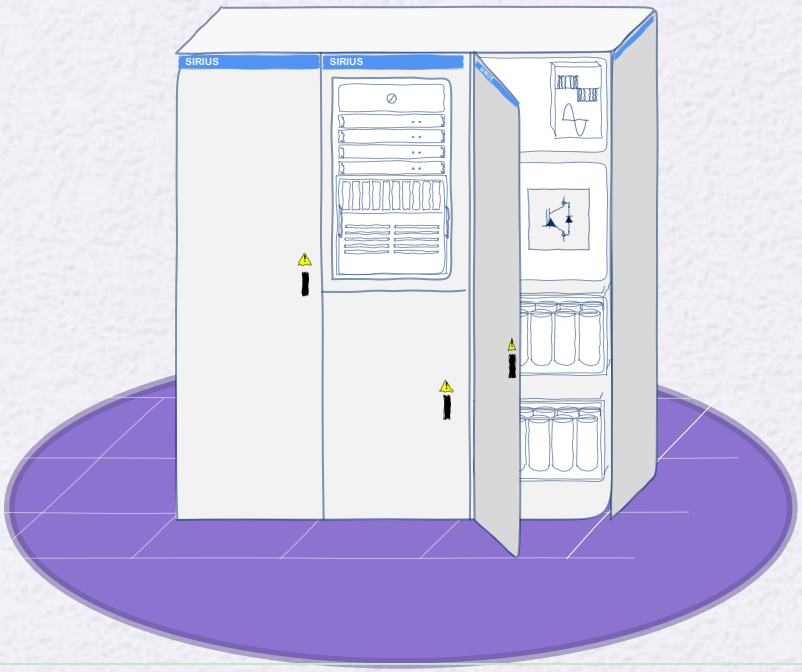
Areas of accelerator expertise

- Accelerator and beam physics
- Accelerator operation
- Experimental areas – secondary beam lines
- Radio-Frequency systems design, including LLRF
- Accelerator controls
- Beam instrumentation and diagnostics
- Magnet design
- Cryogenics
- Power convertors and electronics

Electrical Power convertors

Electrical power converters group

https://videos.cern.ch/record/2688929



- Electronic devices that **control the parameters of electrical current** (amplitude, frequency) to perform reproducible experiments
- At CERN the **precision** that is expected is in the order of 1 part per million.
- Approximately **5000 power converters** from 1kW to 60MW are operated across the complex

Precision of a power converter

It is equivalent to scoring an Ace (golf ball entering a hole with a single hit) from 20km far

K. Papastergiou

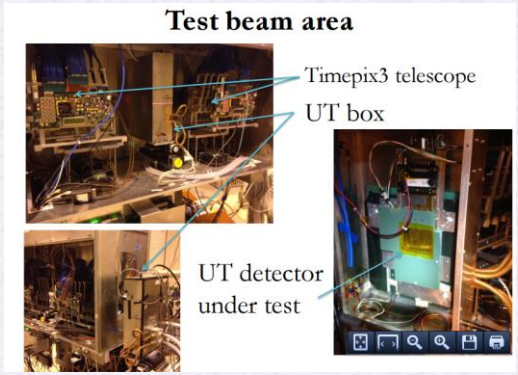
Secondary beam lines for fixed target experiments

N. Charitonidis

- Fixed target experiments with secondary beams, e.g. NA48/COMPASS, NA61/SHINE, NA62, NA64, NA65 ....

part of ATLAS detector waiting for beam in H8

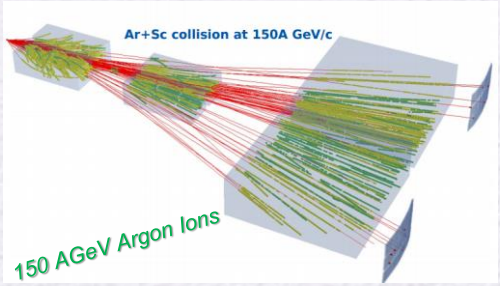
Hadron + Electron beams, all Energies from 50 – 300 GeV



LHCb telescopes being tested in H8

180 GeV positive hadrons

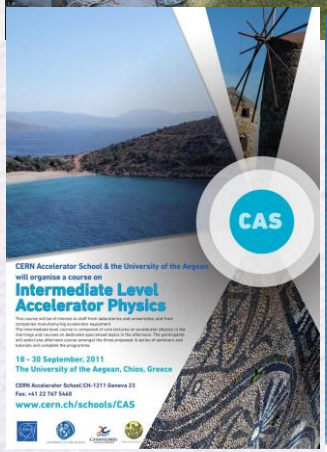
CALICE calorimeter @ H2

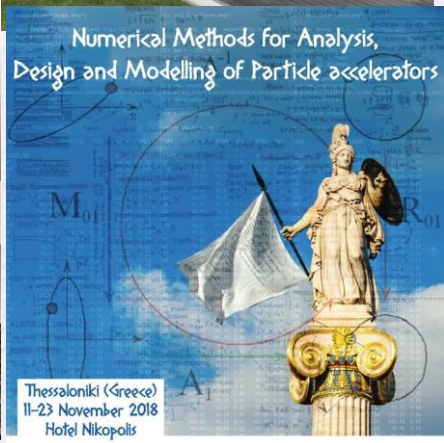


Ar+Sc @ 150AGeV @ H2 @ NA61 run

Education in Accelerator Physics and technology

- **Undergraduate courses** on Accelerators
  - NTUA, AUTH, UoC
- **MSc course** in Accelerators @ AUTH (since 2020)
- **Intermediate CERN Accelerator School (CAS)** in **Chios** (2011)
- **Advanced CAS** in **Thessaloniki** (2018)
- Several students attended **specialised accelerator schools** (USPAS, LC school, JUAS)





Summary

- Over last ~20 years **critical mass** of Greek accelerators scientists has been developed with a **large spectrum** of expertise in beam physics, accelerator design and technology
- Forms **solid base** which could be further enhanced with **targeted studies** in order to support design and operation of an **accelerator** for **Hadron Cancer Therapy** and Biomedical Research with Protons and Heavy Ions