





Perspectives for cancer  
tumour research and  
therapy with ions



# Building a Greek community for Accelerator Physics and Technology

**Dr. Yannis PAPAPHILIPPOU**

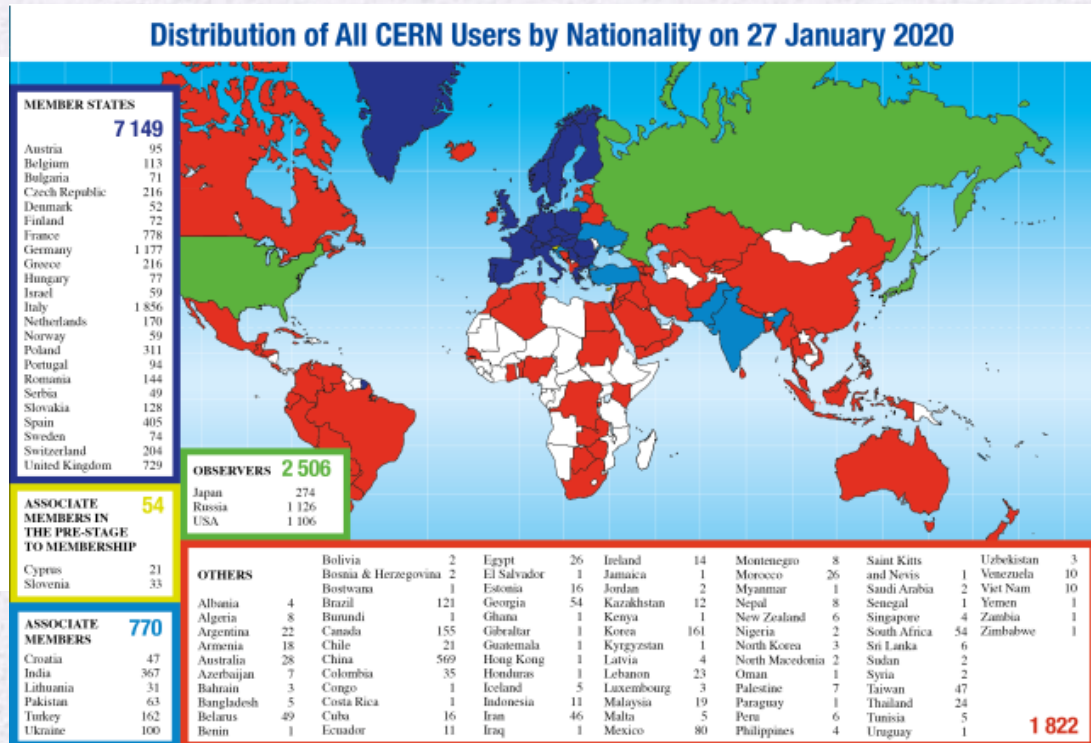
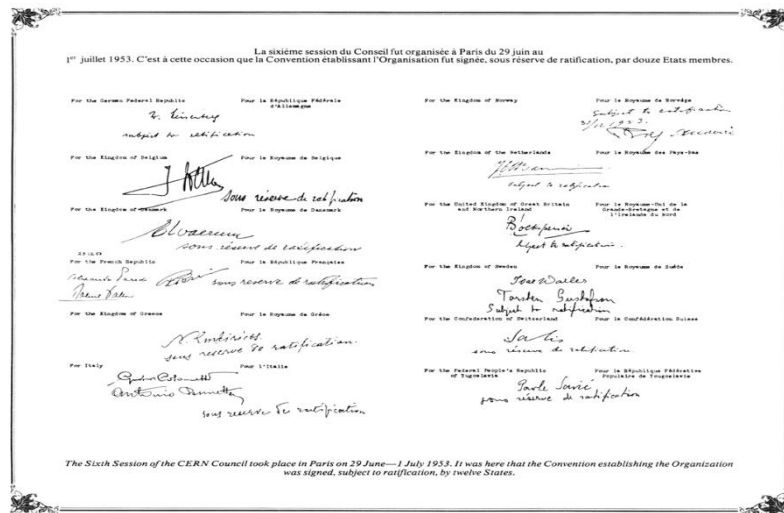
Accelerator and Beam Physics Group Leader  
Beams Department, CERN

Visiting Professor, Lab. of Nuclear and Particle Physics,  
Aristotle University of Thessaloniki

# 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.



# 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 Crete**), 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 Crete**), 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 Crete**), 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

LHC injector upgrade, LHC performance, HL-LHC, CLIC, FCC,...

# Examples of Accelerator physics studies



- CERN injector operation and LHC injector upgrade (LIU)

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

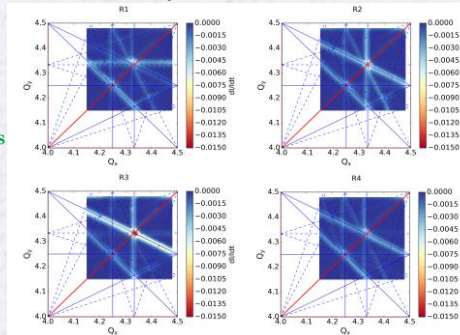
$$B = \frac{N_b}{0.5(\epsilon_x + \epsilon_y)}$$

Beam intensity  
(number of particles per bunch)

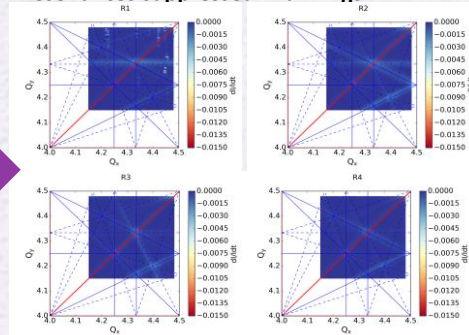
Beam transverse emittances  
(particle density in the phase space)

## Resonance Identification & Compensation

Loss maps measurements:  
Resonances up to 4<sup>th</sup> order revealed

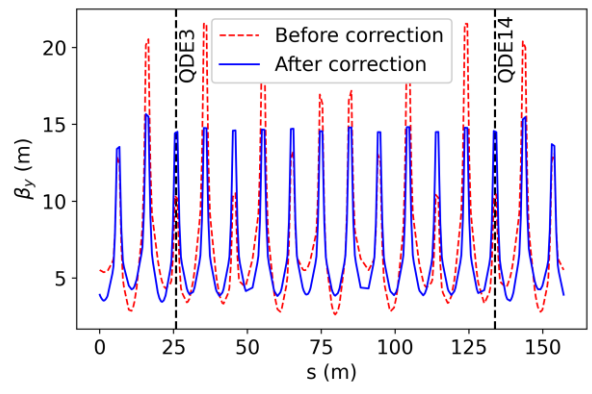


Experimental & analytical & optimizer  
Resonances suppressed in all rings



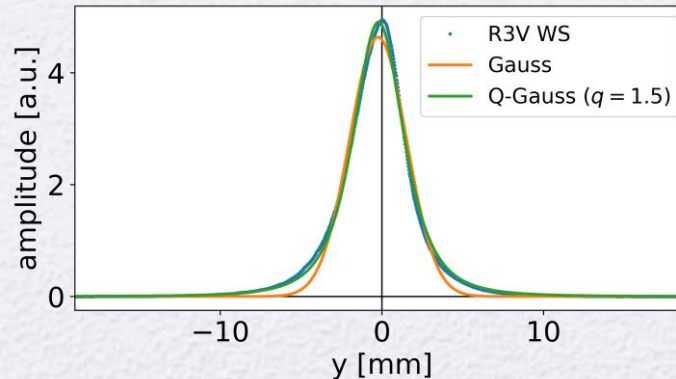
F. Asvesta

Correction of the optics perturbations



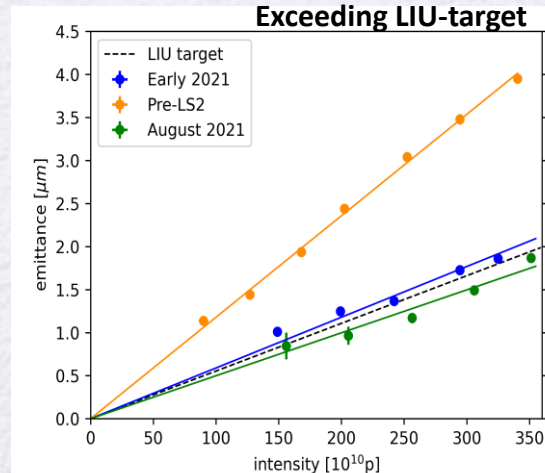
PhD of T. Prebibaj

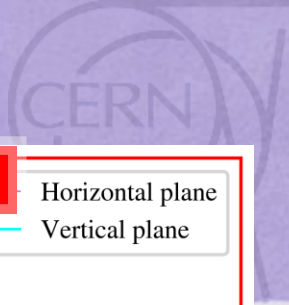
Improvements of the beam transverse particle distributions



F. Antoniou et al.

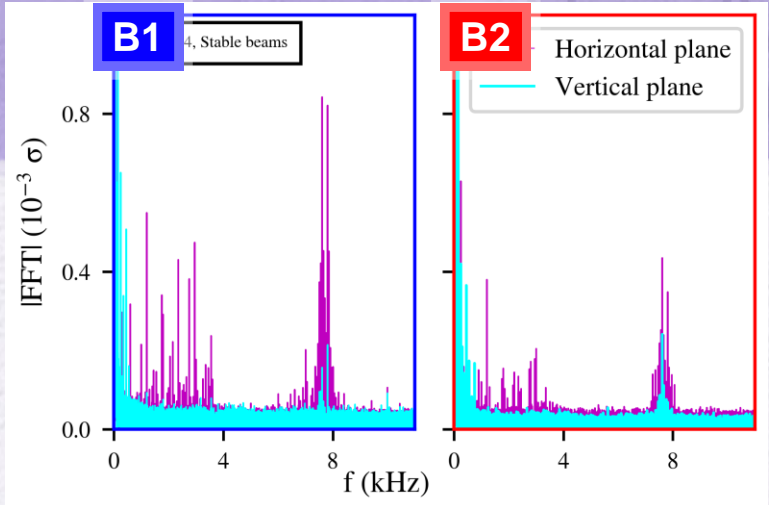
LHC Brightness:  
Exceeding LIU-target



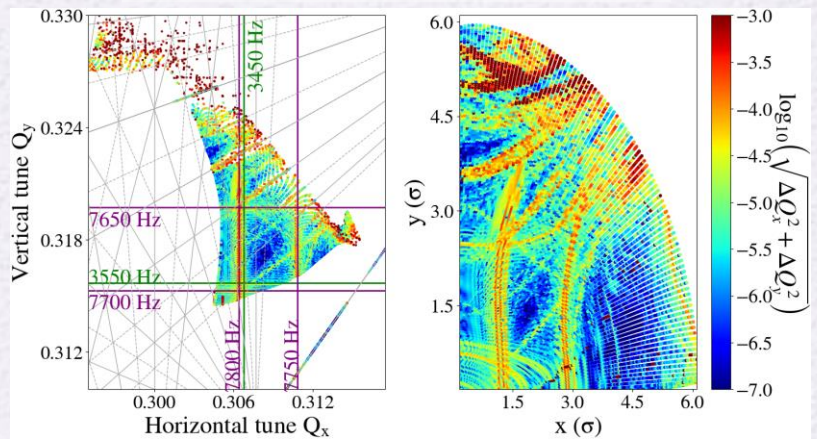
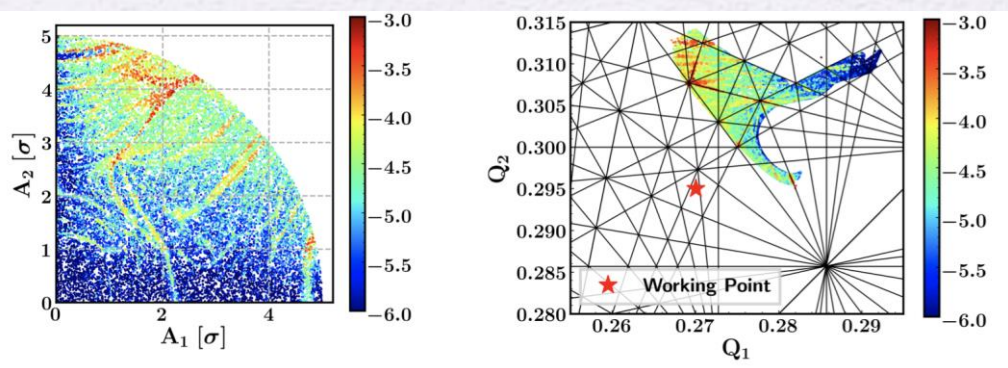


# Examples of Accelerator physics studies

- LHC design and operation
  - E-cloud and noise impact on lifetime
- Develop **simulation framework for e-cloud effect** over the required long timescales (10M turns), including **Theoretical framework, Tracking code and Software infrastructure**



Impact on beam lifetime



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

PhD of K. Paraschou

PhD of S. Kostoglou

# 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 Crete
  - Aristotelian University of Thessaloniki



National Technical  
University of Athens



UNIVERSITY  
OF CRETE



ARISTOTLE  
UNIVERSITY  
OF THESSALONIKI

# Areas of expertise beyond accelerator 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**



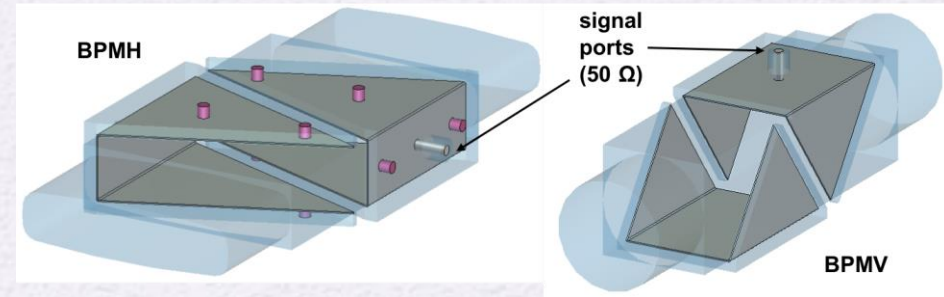
# Example: Beam Instrumentation



## Beam Loss monitors



## SPS BPMs (ALPS)



- Critical protection systems with high reliability and availability
- Realtime data acquisition and processing
- Ionisation chambers, secondary emission monitors, diamonds, silicon, Cherenkov fibres,...

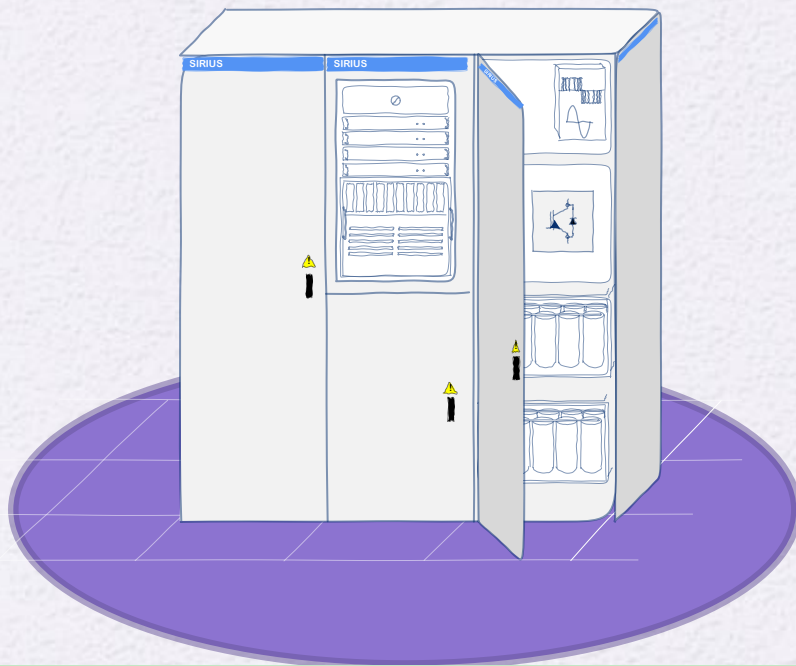
- Low level control for beam instrumentation, such as BPM at SPS (ALPS), BCTs (ns measurements)
- Machine timing with applications on real-time measurements
- Design multi-cycle/user/destination environment
- Frameworks (e.g. FESA) & system expert GUIs (Java, C++/Qt, Python ktl)
- Project management and commissioning

# Example: Electrical Power converters



## Electrical power converters

<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<sup>10</sup>

# Example: Secondary beam lines for fixed target experiments



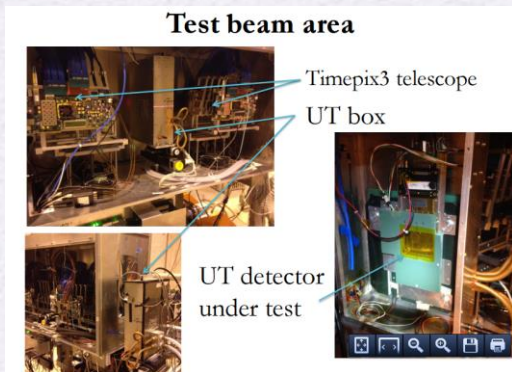
N. Charitonidis

- 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

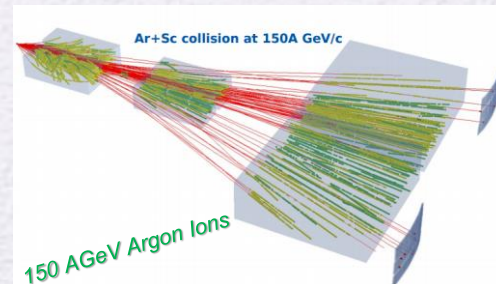


LHCb telescopes being tested in H8

180 GeV positive hadrons



CALICE calorimeter @ H2

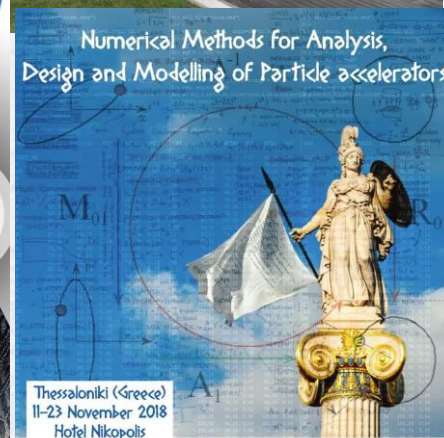


Ar+Sc @ 150A GeV @ H2 @ NA61 run

# Education in Accelerator Physics and technology



- **Undergraduate courses on Accelerators**
  - NTUA, AUTH, UoC
- **MSc course in Accelerators @ AUTH**
- **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

# Acknowledgements



F. Antoniou, F. Asvesta, N. Charitonidis, D. Delikaris, S. Kostoglou, E. Hatziangeli, R. Jones, K. Papastergiou, K. Paraschou, T. Prebibaj, A. Topaloudis, N. Triantafyllou, E. Tsesmelis, M. Vretenar, C. Zamantzas, M. Zampetakis (CERN), Y. Foka (GSI), K. Kordas, C. Petridou, D. Samsonidis, S. Tzamarias (AUTH)