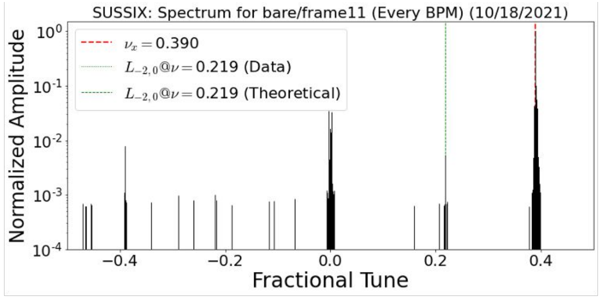
HB 2023

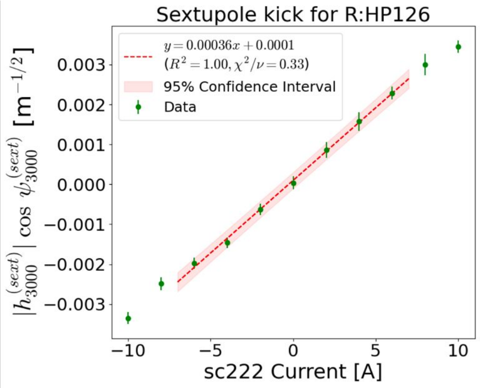
WGA: Beam Dynamics in Rings summary & highlights

H. Bartosik, G. Rumolo, J.L. Vay, N. Wang

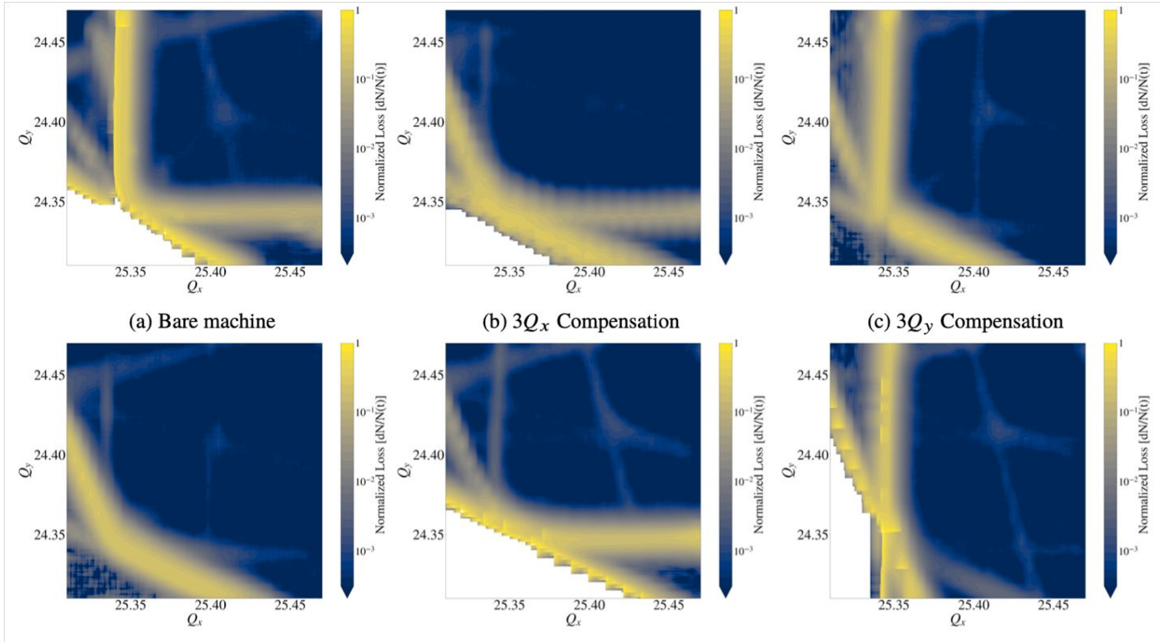
Minimizing losses from space charge & resonances

- **Compensation of resonances** driven by magnet errors is **standard practice**
  - Beam based measurements - in particular for existing machines without detailed error models





Christhian Gonzalez-Ortiz, FNAL



(a) Bare machine
(b) $3Q_x$ Compensation
(c) $3Q_y$ Compensation
(d) $3Q_x$ and $3Q_y$ Compensation
(e) $3Q_x$ and $2Q_x + Q_y$ Compensation
(f) $3Q_y$ and $Q_x + 2Q_y$ Compensation

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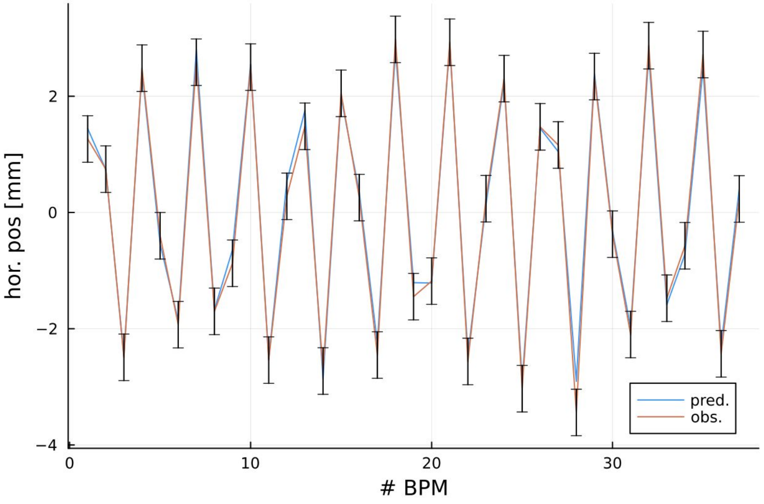
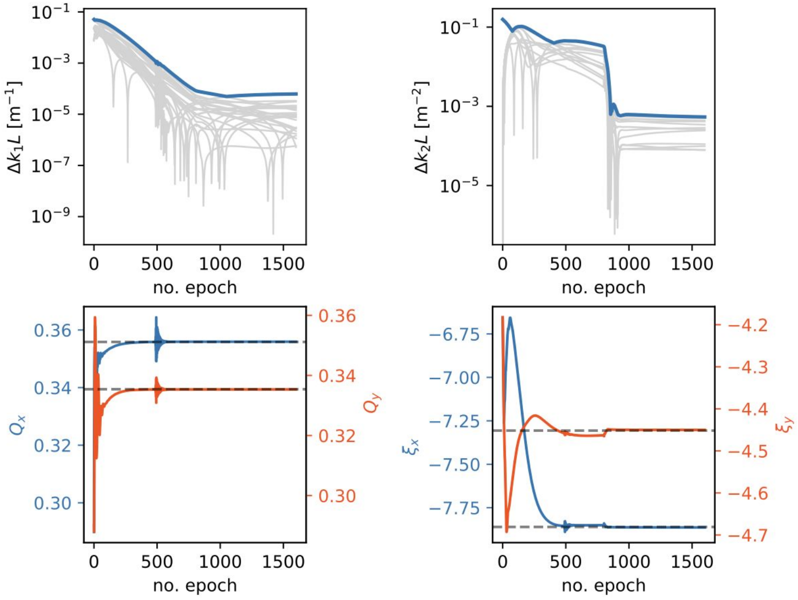
- **New method** for identifying magnetic field errors "**Deep Lie-Map Networks**"

Conrad Caliari, GSI





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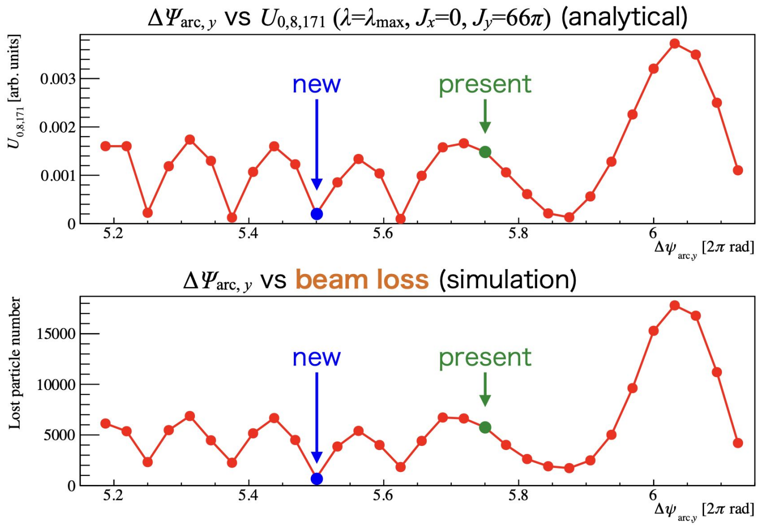
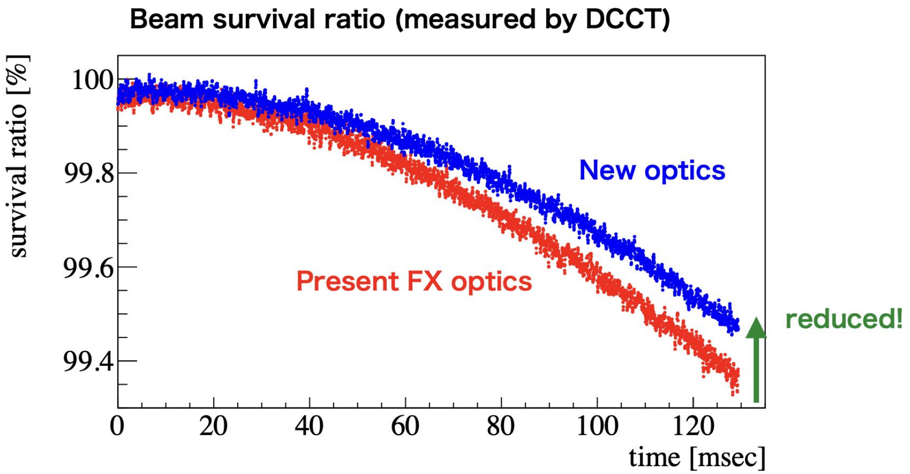


Takaaki Yasui, KEK



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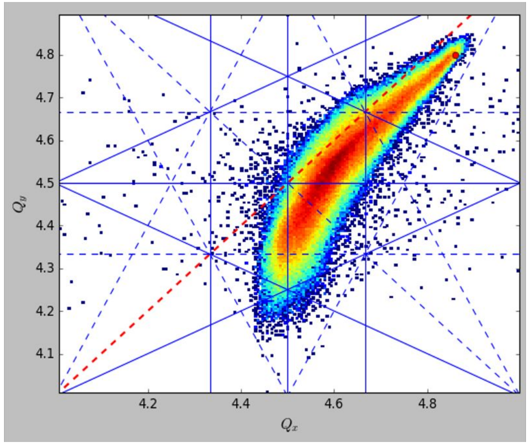
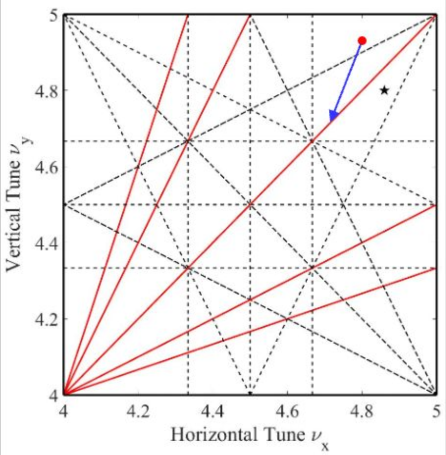
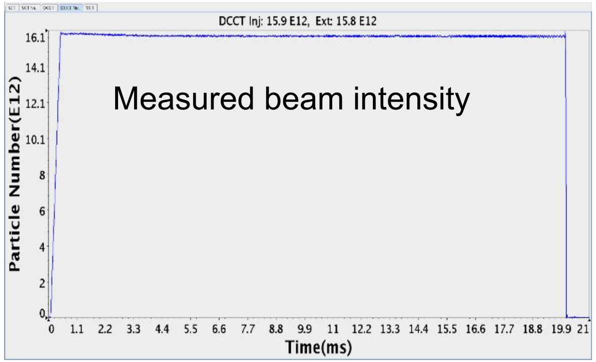




Shouyan Xu, IHEP



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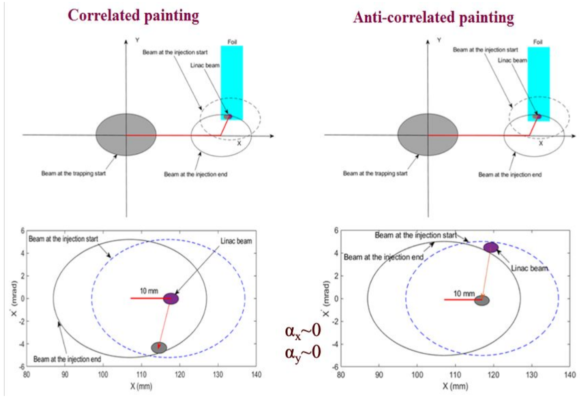
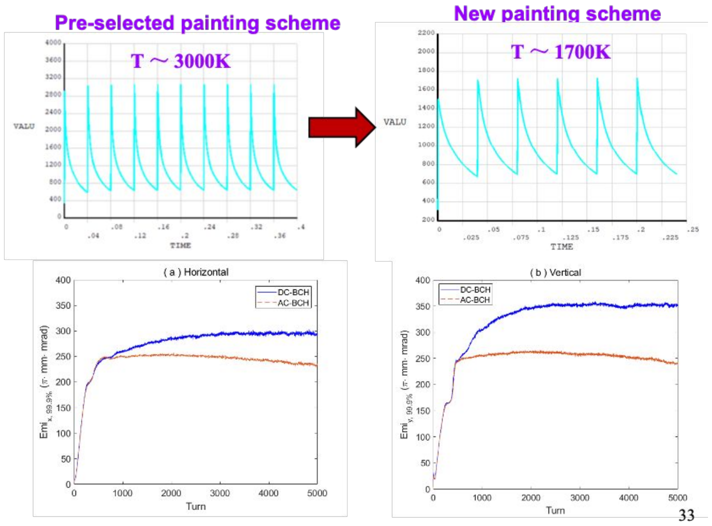
Ming-Yang Huang, IHEP





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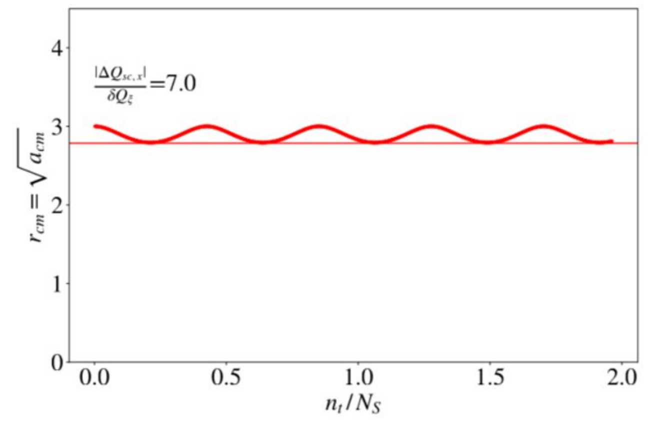
- Open question from V. Lebedev: what is the **maximum achievable space charge tune shift** in real machine with highly super-periodic lattice operating above half-integer?
- A. Oeftiger proposed to formulate the efficiency of resonance compensation as "**how much intensity could be gained by resonance compensation for a given amount of acceptable losses**"

Progress in understanding space charge effects

- **New 2 particle model with space charge and chromaticity for coasting beam**
  - Shows **coupling / exchange between coherent and incoherent motion**, also confirmed in multiparticle simulations as well as indications in measurements (CERN PSB)
  - Past studies from I. Karpov did not address this exchange
  - E. Metral suggested extension to include impedance

Giuliano Franchetti, GSI

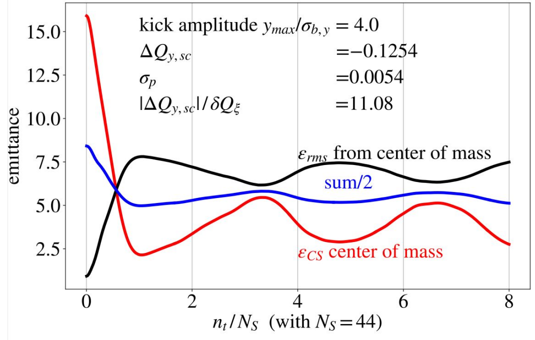


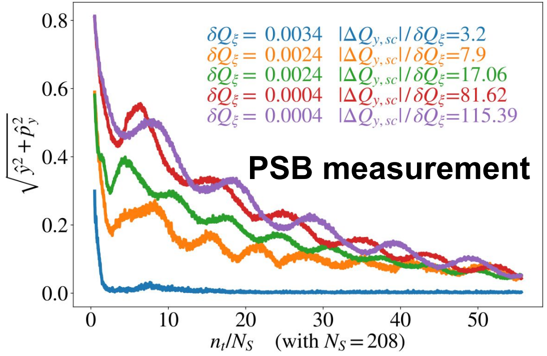
If the center of mass oscillates, it is a measurable quantity

The motion of the center of mass is of a "coherent" dynamics

The motion with respect to the center of mass "may be an incoherent dynamics"

PIC simulation





PSB measurement

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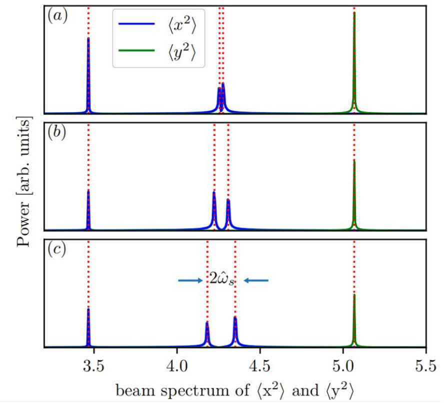
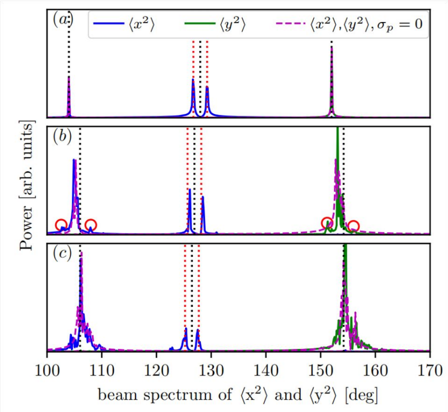
- **Coherent dispersion effect with space charge**
  - Coherent beam instabilities with dispersion (previously studied for 2D coasting beams)
  - **In the 3D case, sidebands appear around the envelope modes**





Yaoshuo Yuan, IHEP

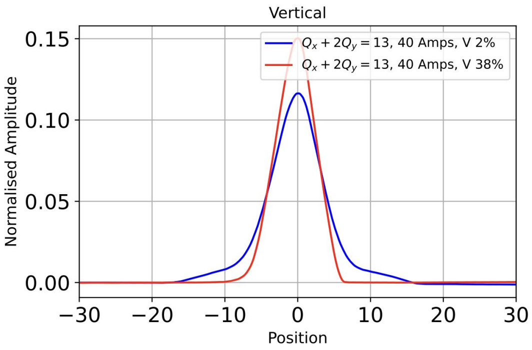
Sidebands appear around the envelope modes

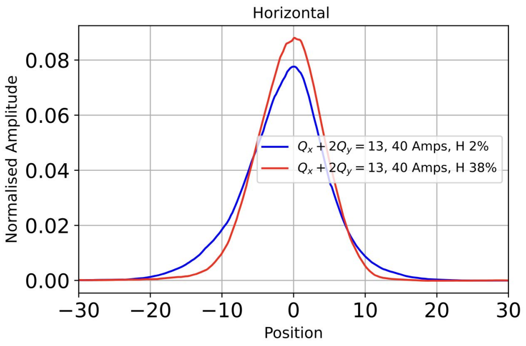
In the presence of space charge, the split of dispersion mode is coupled to envelope modes

Studies for characterizing luminosity

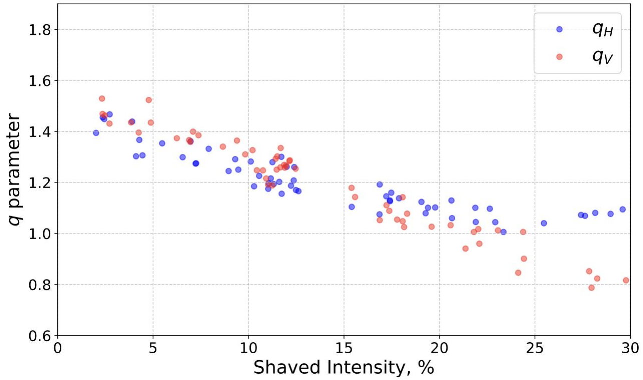
- **Non-factorizable distributions in LHC van der Meer scans** triggered space charge study
  - **Demonstrated experimentally** that **space charge induced periodic resonance crossing generates statistical dependence in transverse planes** (CERN PSB)
  - Evolution along CERN injector chain and impact on luminosity factorization in LHC to be studied

measured beam profiles before/after vertical scraping





tail population correlated between planes



Elleanor Lamb, CERN

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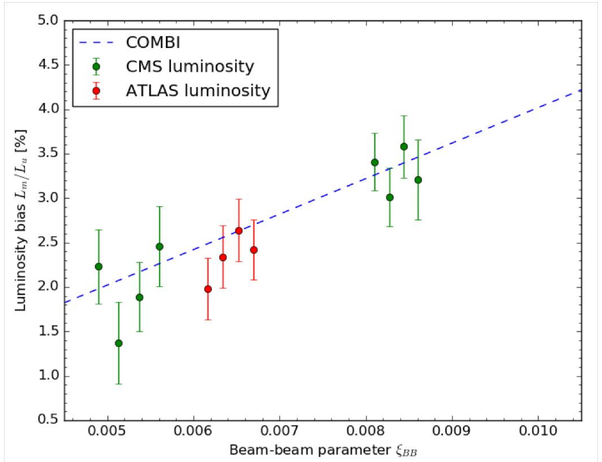
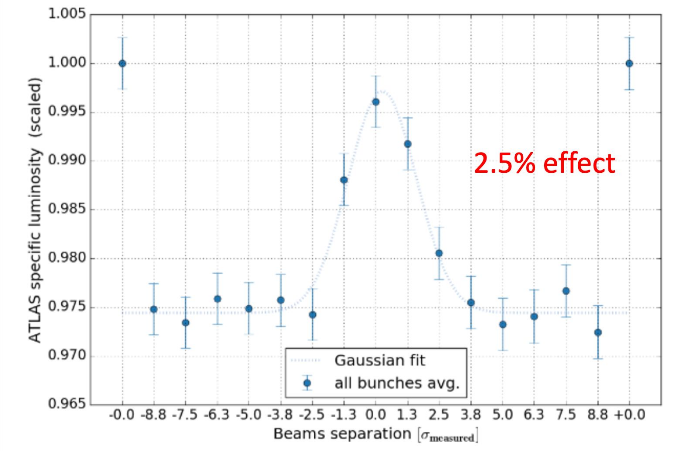
- **Detailed studies of beam beam effects on luminosity in LHC**
  - **BB experiment** at the **LHC** allowed to **validate** key aspects of the simulation model **at the % level**
  - **Numerical simulations are invaluable tools** to push precisions of LHC luminosity



ATLAS luminosity change as function of separation



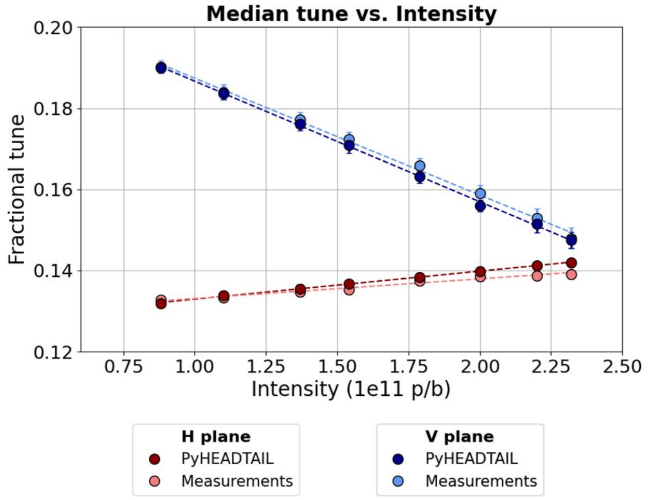
Tatiana Pieloni, EPFL

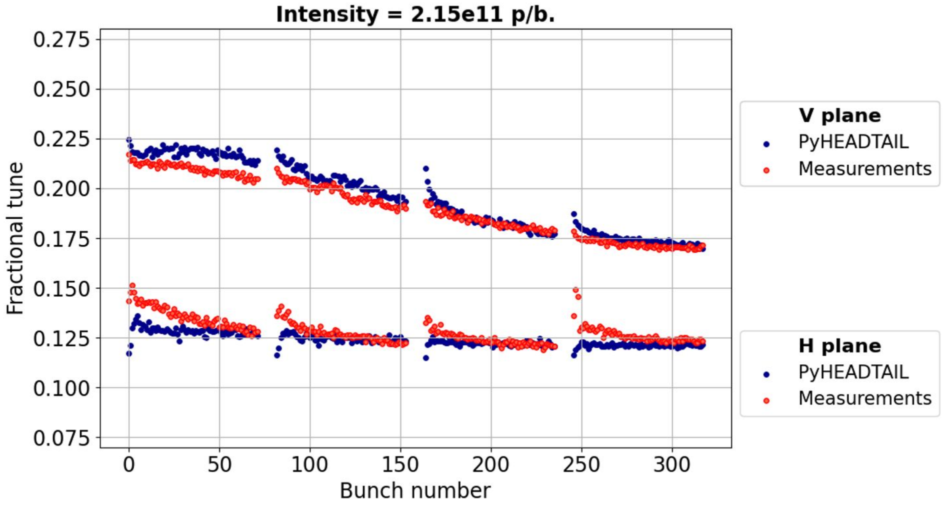
Measurements of the impact of BB effects on the luminosity in LHC

Controlling & mitigating impedance driven instabilities

- **Precise control of coherent tune shifts to ensure damper working efficiently in SPS**
  - Excellent agreement between model and measurement
  - So far no strong impact of tune shift on emittance blow-up - to be studied at brightness limit
  - **Question: Can we use a reactive damper to correct the bunch-by-bunch tune shifts?**

Ingrid Mases, CERN





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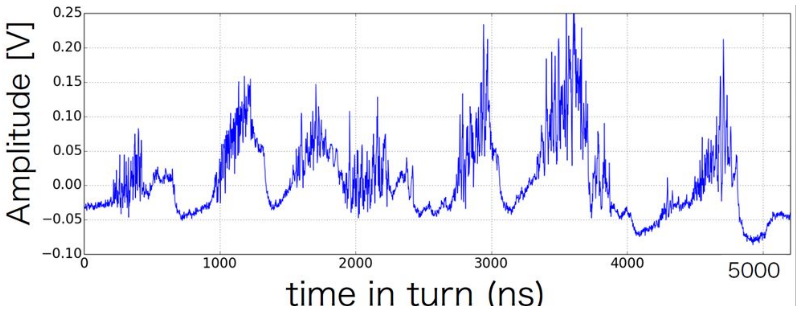
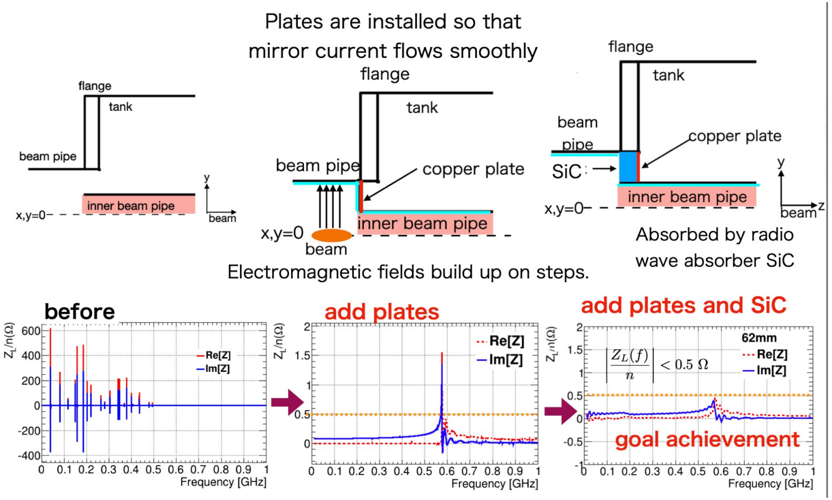
- **Nice example of curing longitudinal microbunch structure in J-PARC MR**
  - **Impedance reduction of eddy current septa confirmed by improved beam structure**

Aine Kobayashi, KEK

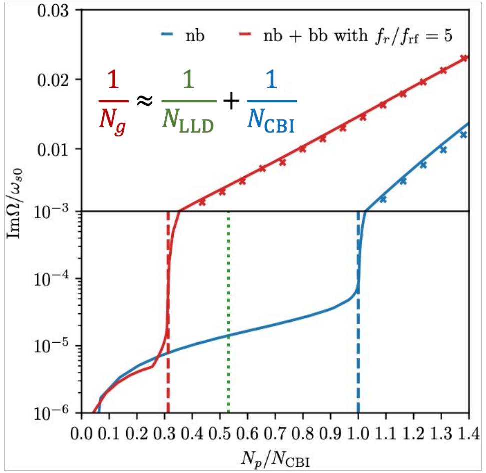




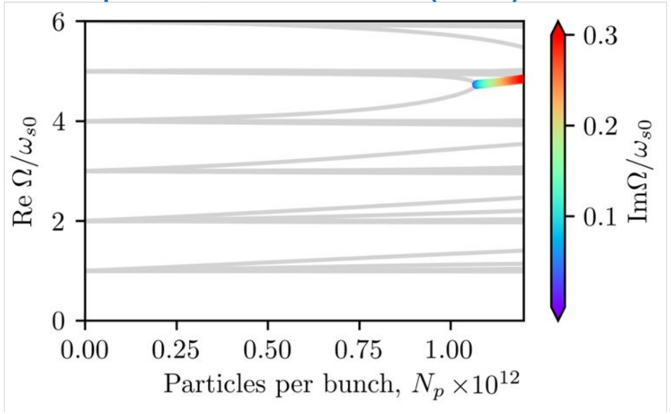
Understanding and characterization of instabilities

- **Significant progress in theoretical treatment of longitudinal instabilities**
  - Loss of Landau damping threshold (binomial distribution) is inversely proportional to cutoff frequency
  - Generalized threshold due to loss of Landau damping and coupled bunch instabilities
  - Important role of RF nonlinearity → radial mode-coupling instability

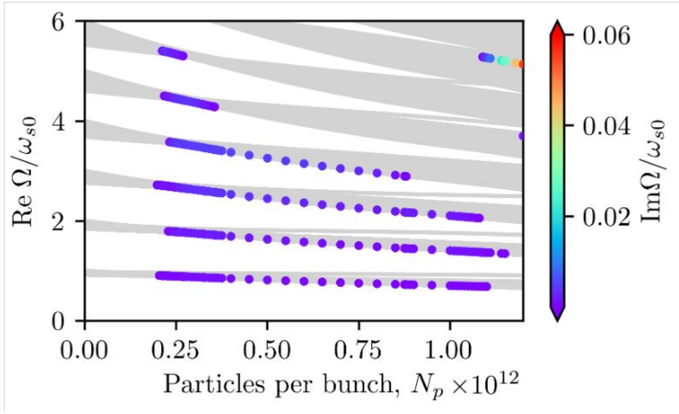
Ivan Karpov, CERN



van Kampen mode for linear rf without potential-well distortion (PWD)



van Kampen modes



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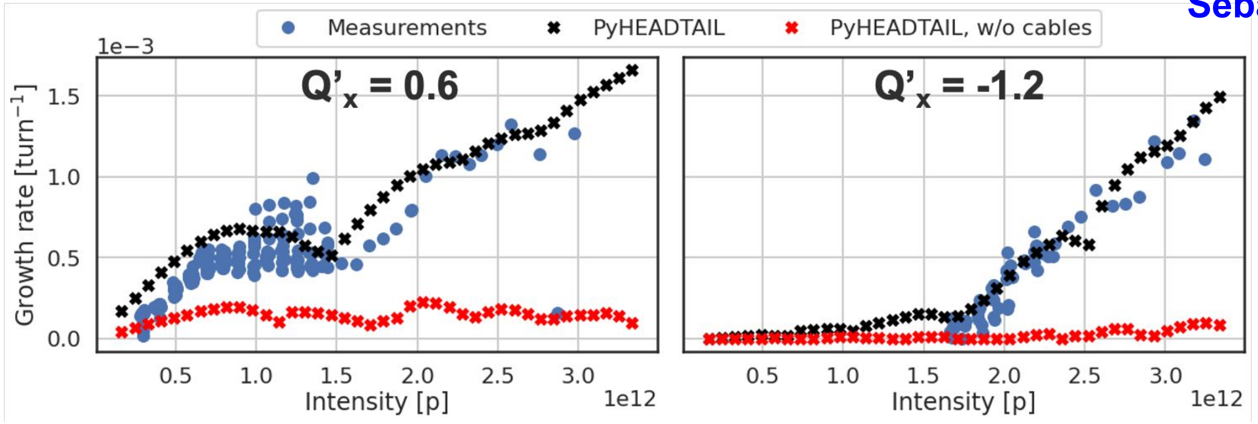
Sebastien Joly, CERN



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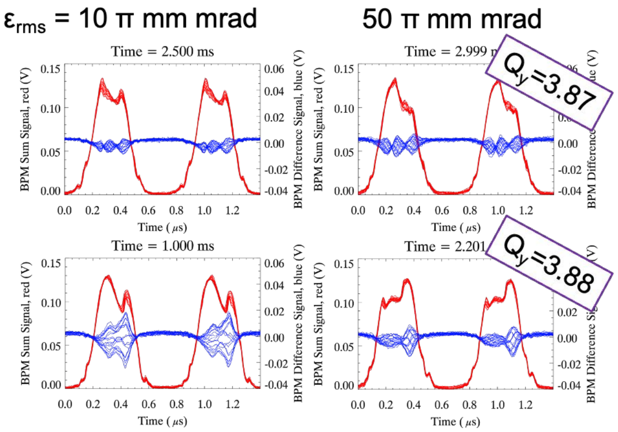
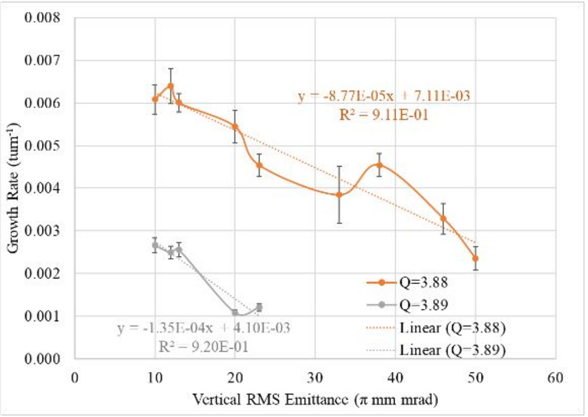
Robert Williamson, RAL





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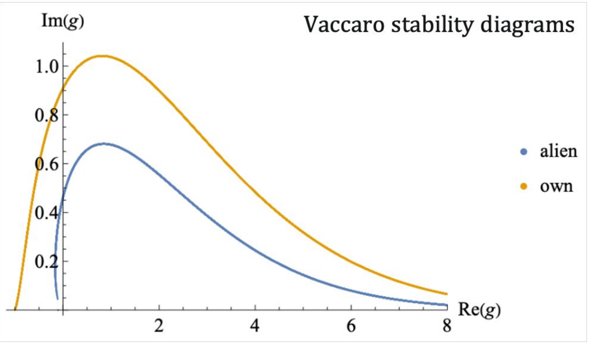
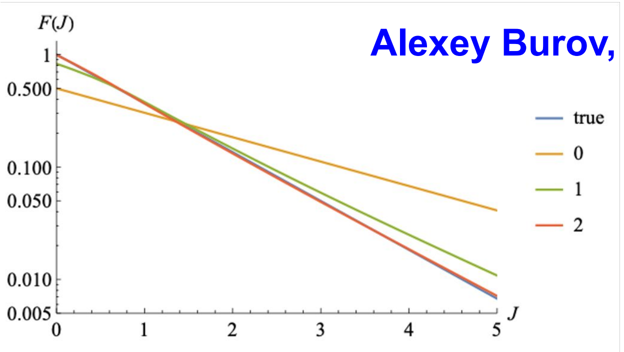
- **Proposal to solve the "inverse stability problem of beam dynamics"**
  - Determine distribution function from stability diagram → to be tested with measurements





Alexey Burov, FNAL

The pursuit for more powerful simulation tools

- **Powerful tools** needed for **accurate predictions** of high intensity-induced beam halo, losses, emittance growth and collective instabilities
- **Integration & modernization** of large body of **legacy codes** is a path toward **faster & more capable code suites**

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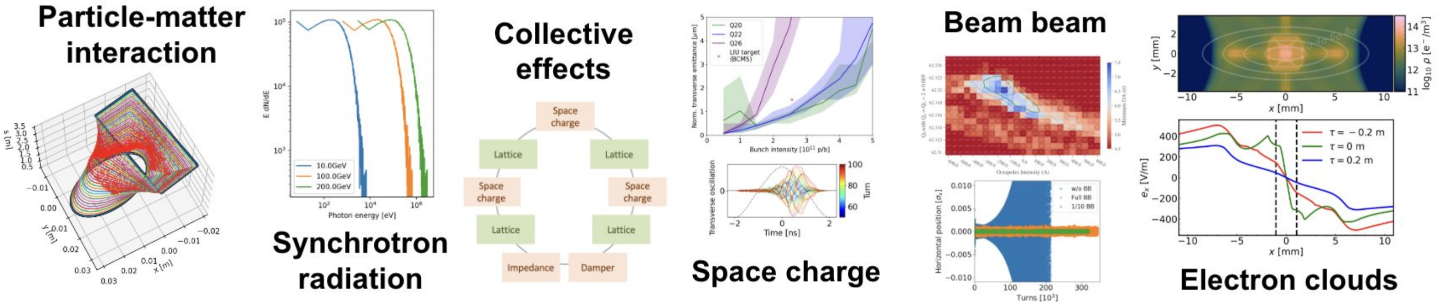
- CERN legacy codes **upgraded & combined** into **modern, integrated suite XSuite** (CERN)
  - Combining features of MAD, Sixtrack, COMBI, pyHEADTAIL, …, in modular & extensible suite with unified and flexible Python interface, CPU and GPU support
  - Already many users and applications

Giovanni Iadarola, CERN



Open source: https://xsuite.readthedocs.io/en/latest/

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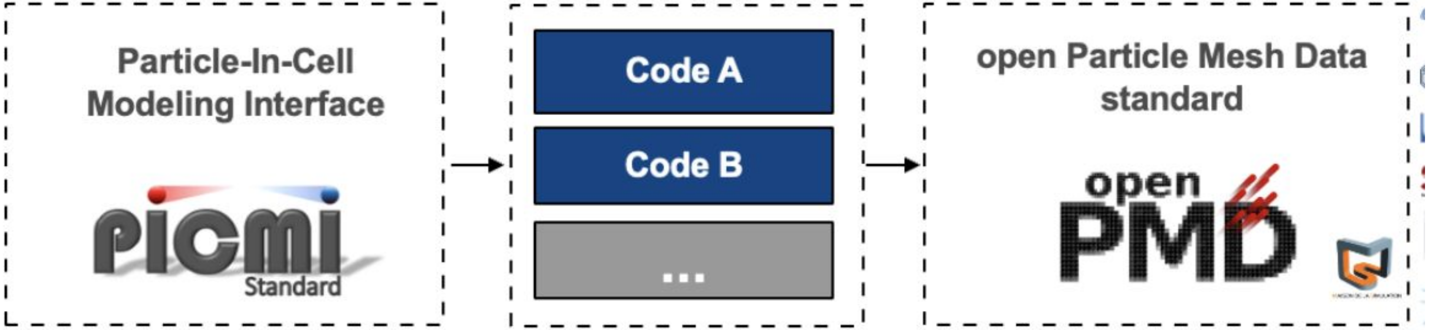
- Berkeley Lab codes **modernized & combined** into **integrated ecosystem BLAST** (LBNL)
  - triple acceleration approach (GPU, Mesh Refinement, AI/ML) with flexible Python frontend & part of larger **effort to develop Community Ecosystem based on standardized inputs/outputs**

Chad Mitchell, Berkeley Lab



BLAST
BEAM PLASMA & ACCELERATOR SIMULATION TOOLKIT

Open source: https://blast.lbl.gov/

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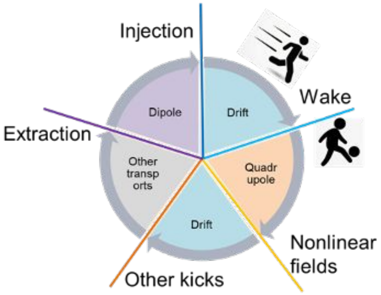
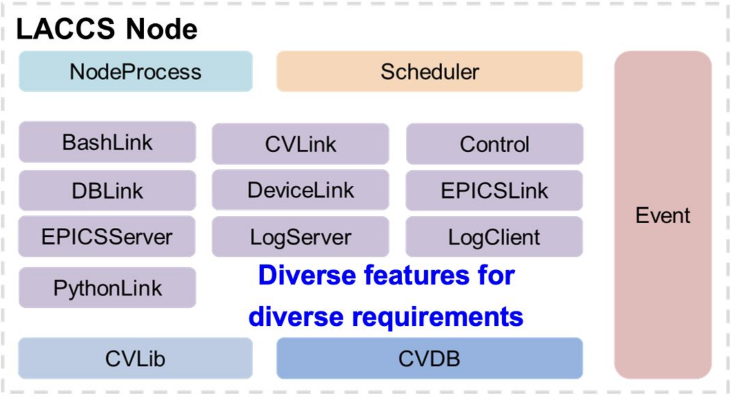
- New code **CISP-GPU** w/ many features for **end-to-end simulations** of HIAF/BRing (IMPCAS)
  - applied to nonlinear and space charge effects & mitigation; to be embedded into LACCS to provide high level features for commissioning and online dynamics research

Jie Liu, IMPCAS

CISP
强流效应模拟平台





Executable & doc: https://cisp.accsoftware.cn

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Trends:

- **Port to GPUs** ⇒ more particles, higher resolution, larger systems, longer integration time
- **Integration** ⇒ more efficient co-development & reuse; more physics at hand to explore all possible couplings, not “miss anything”, increase realism toward digital twins & open design capabilities beyond “what we can compute”; gateway to community ecosystems with standards
- **Programmable (Python) frontend** ⇒ user-friendliness with shorter learning curve & flexibility for extension, exploration & coupling with AI/ML tools; coupling w/ other codes & experiments

Challenges ahead

- **Loss control at <‰ level** to allow for **multi MW beam power** (e.g. ISIS II)

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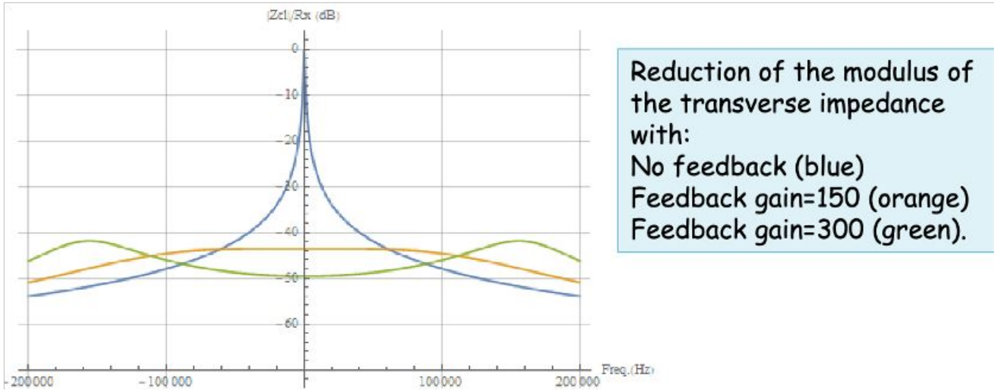
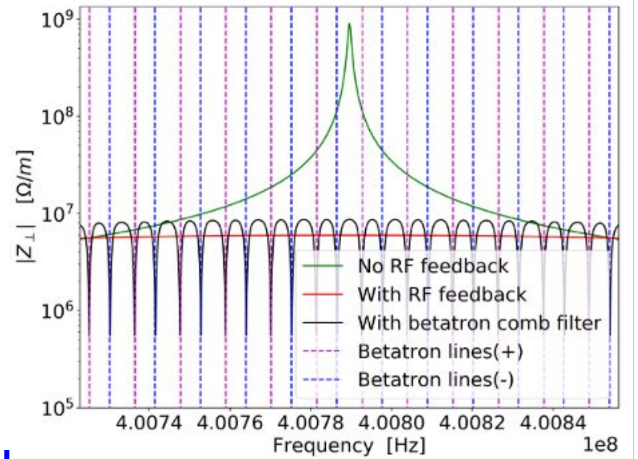
- **Crab cavities** (HL-LHC and EIC)
  - **Crab cavity noise and feedback requirements are beyond the state of art** → ongoing work

Gain of standard RF feedback cannot be increased further



comb filter can reduce impedance effects by acting at the right frequencies (betatron lines)



Nicolas Mounet, CERN

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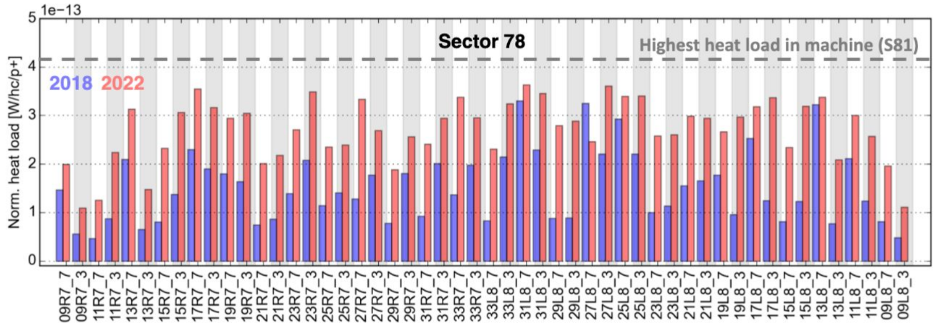
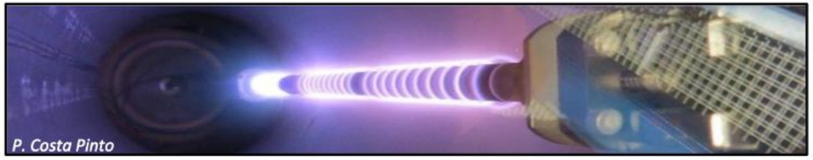
- **Mitigating e-cloud effects** in HL-LHC
  - Situation degraded after long shutdown, limiting the total number of bunches
  - Need to address the root cause → Plasma-assisted CuO reduction and carbon recovery (PE-CVD) OR carbon coating (10-20 nm) by sputtering

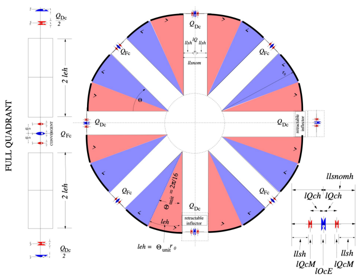


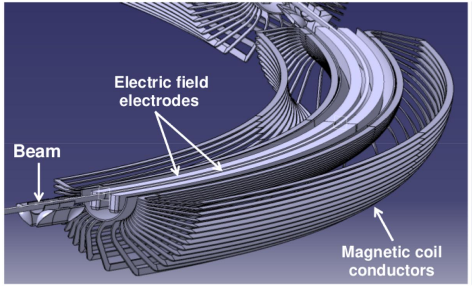


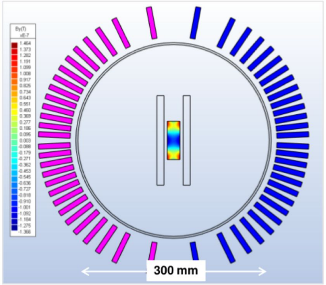
Nicolas Mounet, CERN

Challenges ahead

- **Loss control at <‰ level** to allow for **multi MW beam power** (e.g. ISIS II)
- Demonstrate **space charge compensation by pulsed e-lenses** (FAIR-SIS100)
- **Crab cavities** (HL-LHC and EIC)
  - **Crab cavity noise and feedback requirements are beyond the state of art** → ongoing work
- **Mitigating e-cloud effects** in HL-LHC
  - Situation degraded after long shutdown, limiting the total number of bunches
  - Need to address the root cause → Plasma-assisted CuO reduction and carbon recovery (PE-CVD) OR carbon coating (10-20 nm) by sputtering
- **Be creative for proposing new accelerator applications** for interesting physics cases
  - E.g. “Predominantly Electric “E&m” storage ring with nuclear spin control capability” to study “rear-end” d-p collisions







Richard Talman, Cornell University

BIG THANKS to all the speakers for the excellent and very interesting presentations, and to all participants for their active contribution and fruitful discussion !