

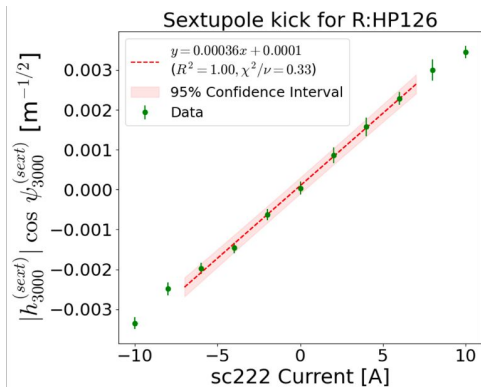
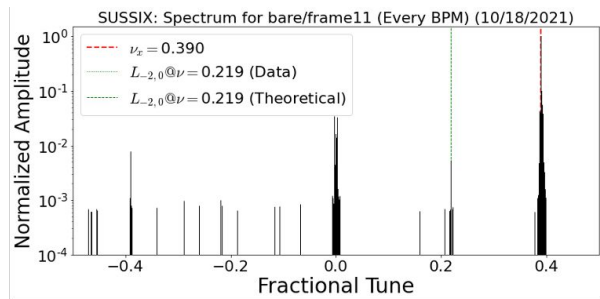


WGA: Beam Dynamics in Rings summary & highlights

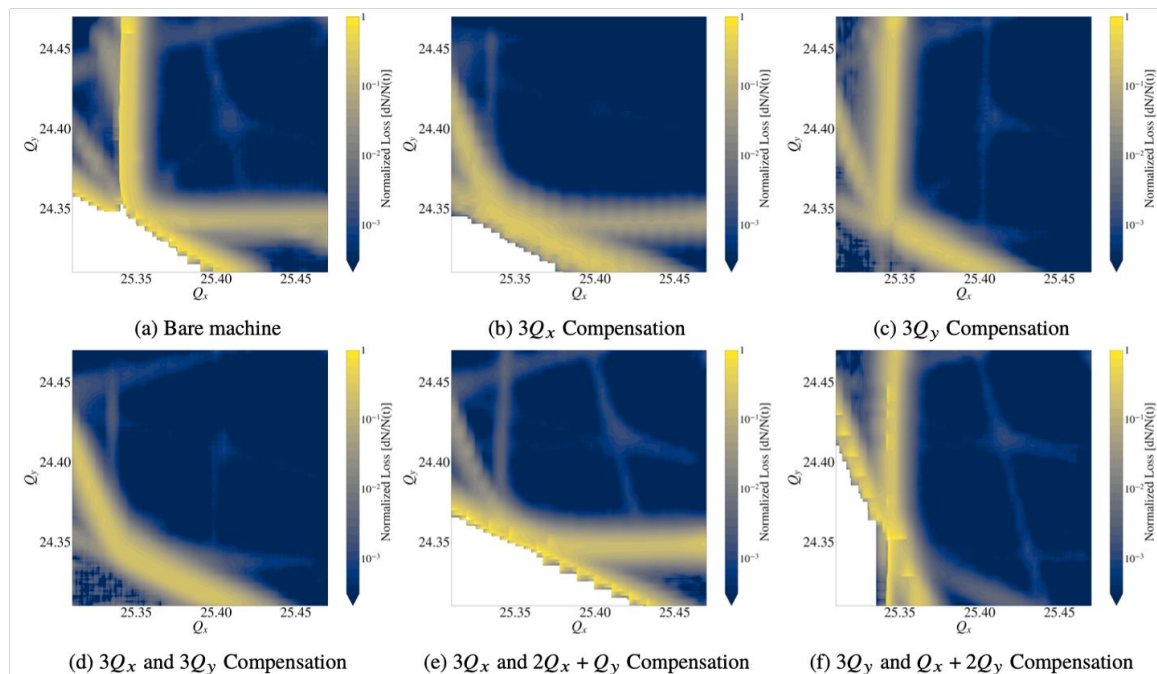
H. Bartosik, G. Rumolo, J.L. Vay, N. Wang

HB 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



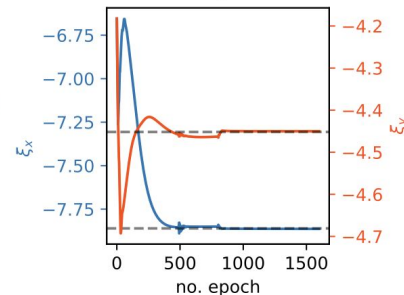
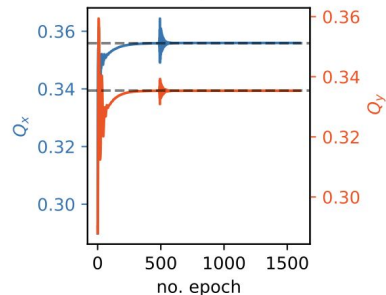
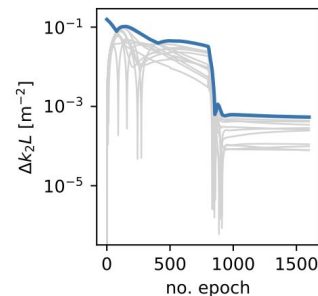
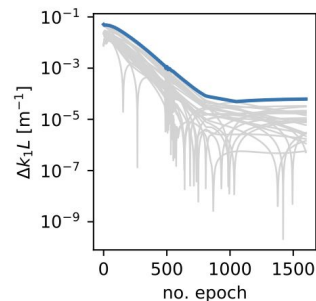
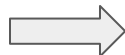
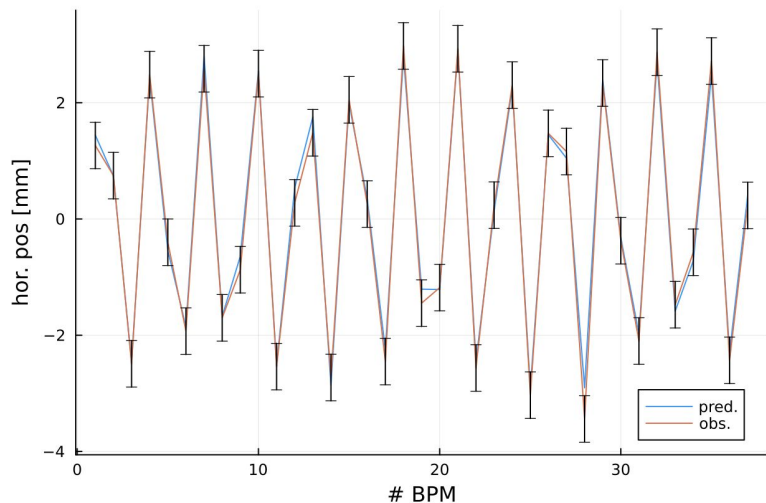
Christian Gonzalez-Ortiz, FNAL



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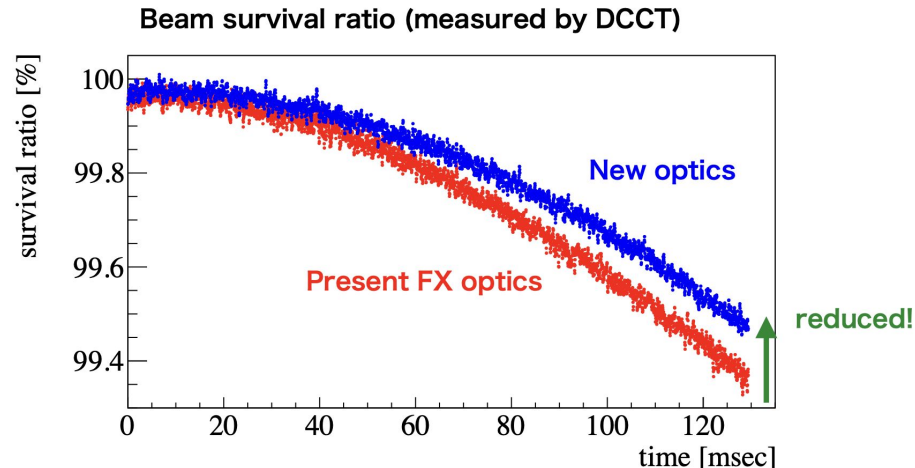
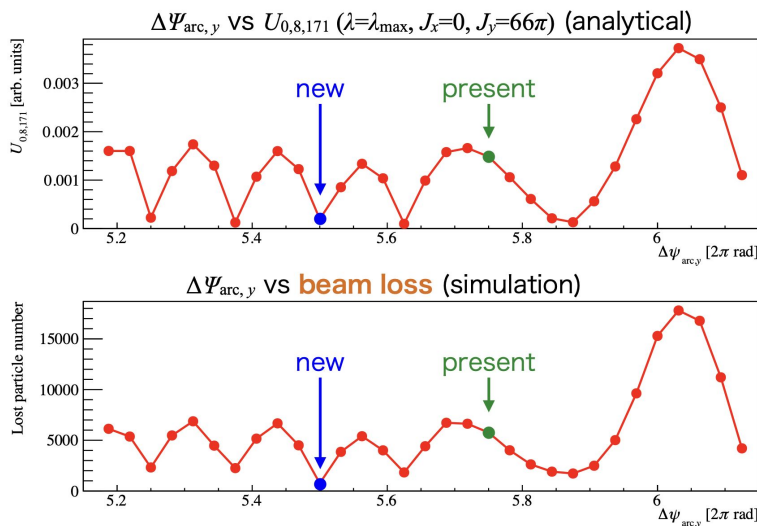
Conrad Caliari, GSI



Minimizing losses from space charge & resonances

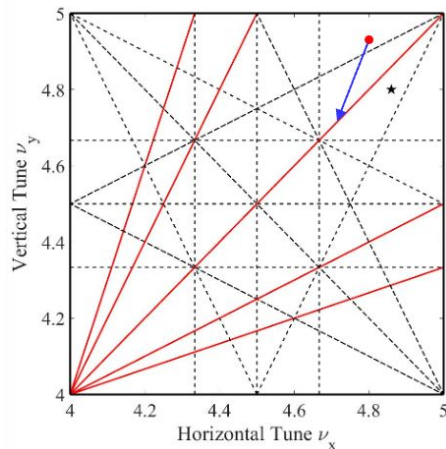
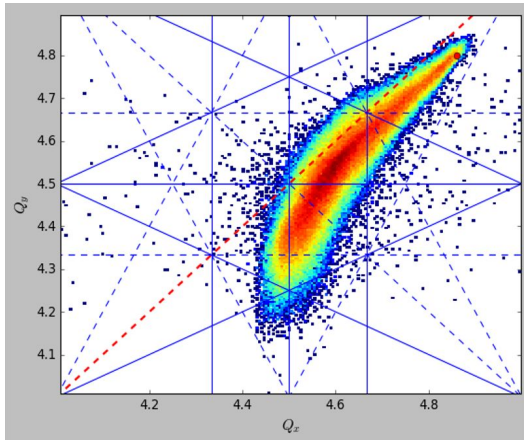
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Takaaki Yasui, KEK

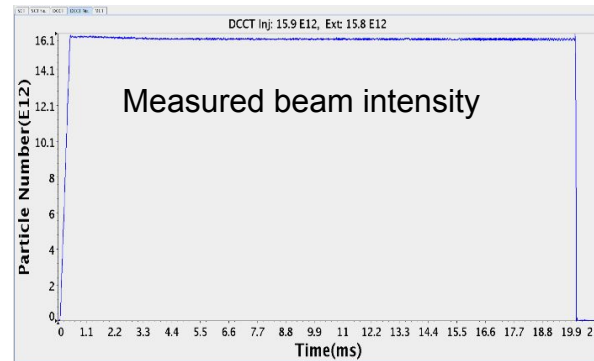


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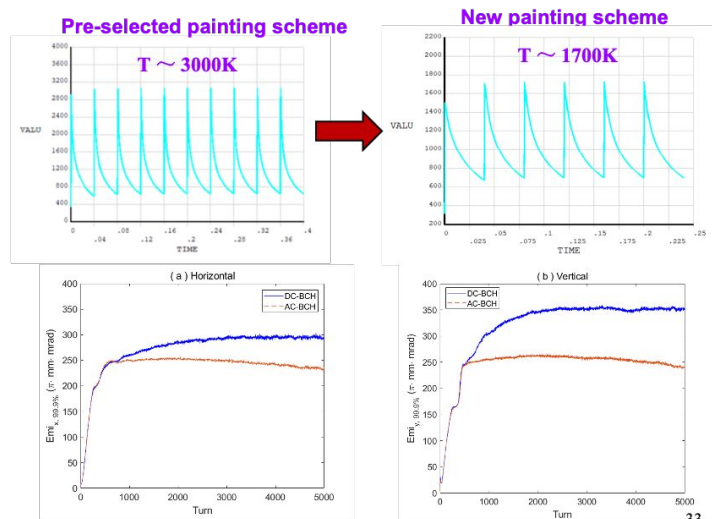
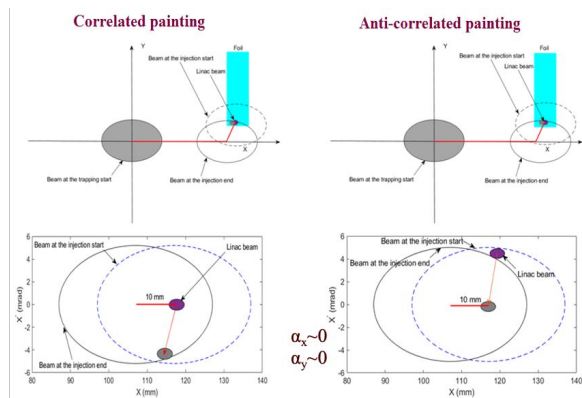
Shouyan Xu, IHEP



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Ming-Yang Huang, IHEP



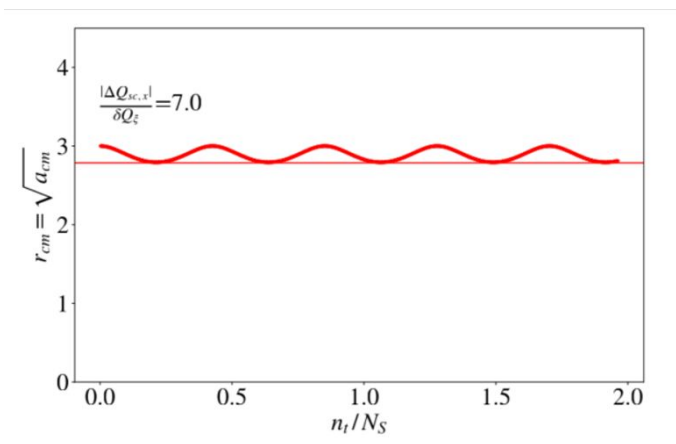
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- A. Oeftiger proposed to formulate the efficiency of resonance compensation as “**how much intensity could be gained by resonance compensation for a given amount of acceptable losses**”

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



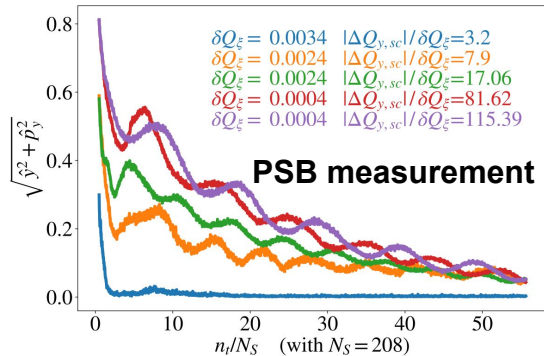
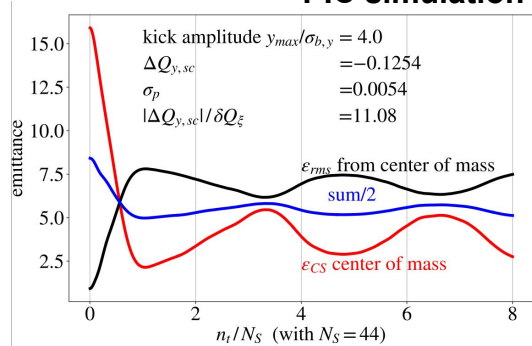
If the center of mass oscillates, it is a measurable quantity



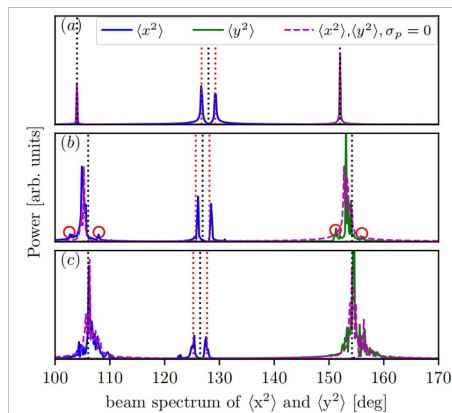
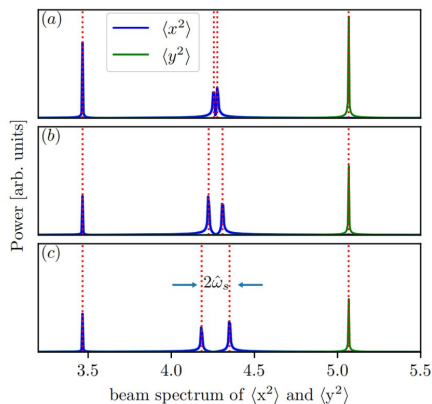
The motion of the center of mass is of a **“coherent”** dynamics

The motion with respect to the center of mass **“may be an incoherent dynamics”**

PIC simulation



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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**



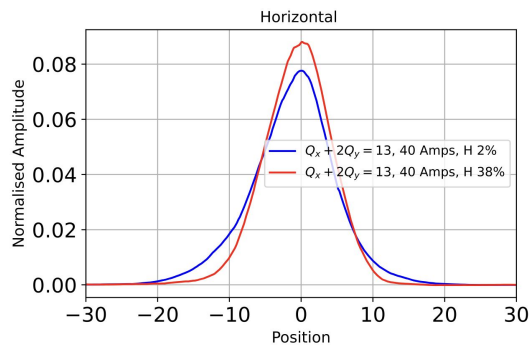
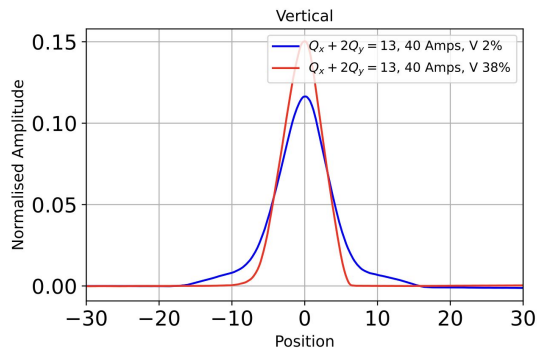
Yaoshuo Yuan, IHEP

Sidebands appear around the envelope modes

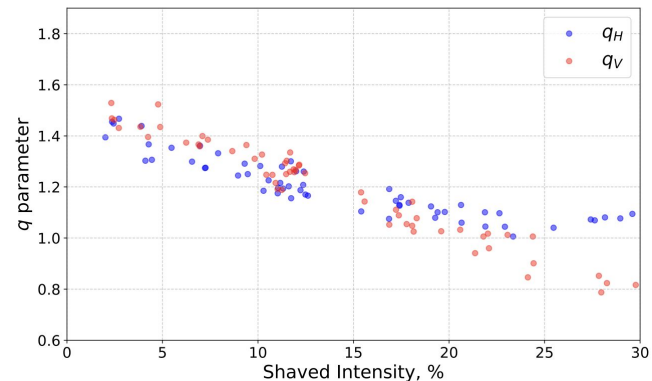
In the presence of space charge, the split of dispersion mode is coupled to envelope modes

- **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

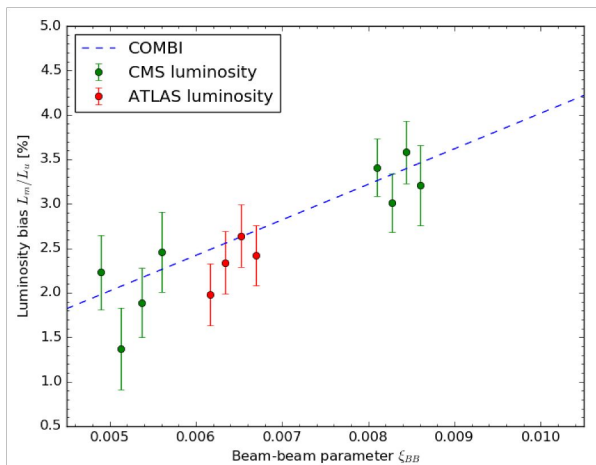
measured beam profiles before/after vertical scraping



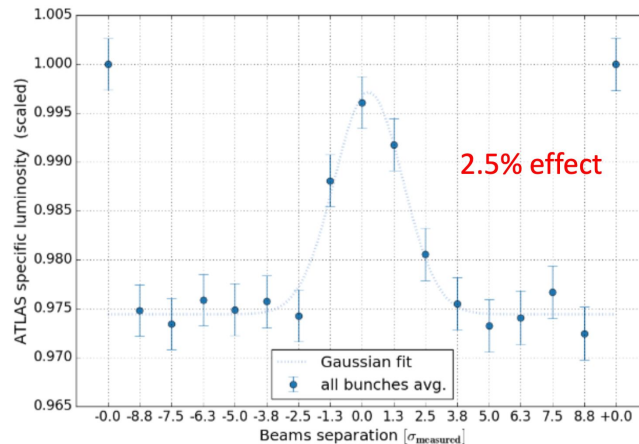
tail population correlated between planes



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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

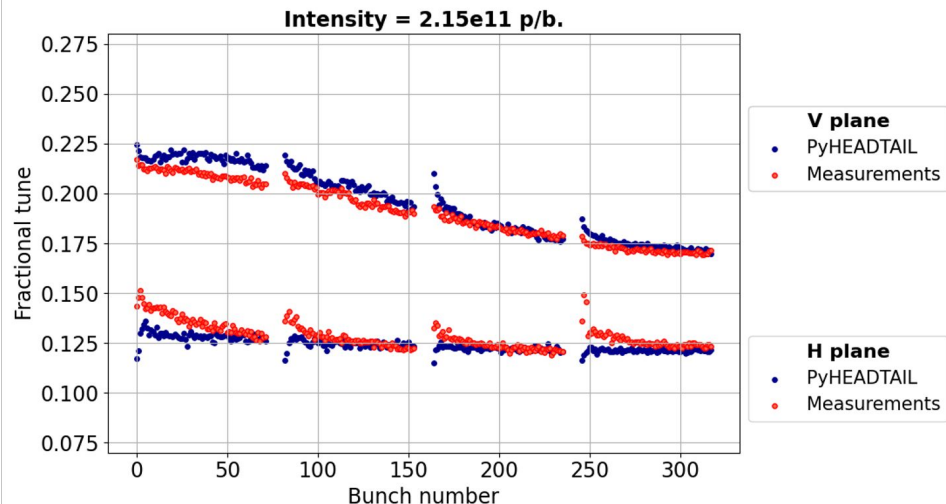
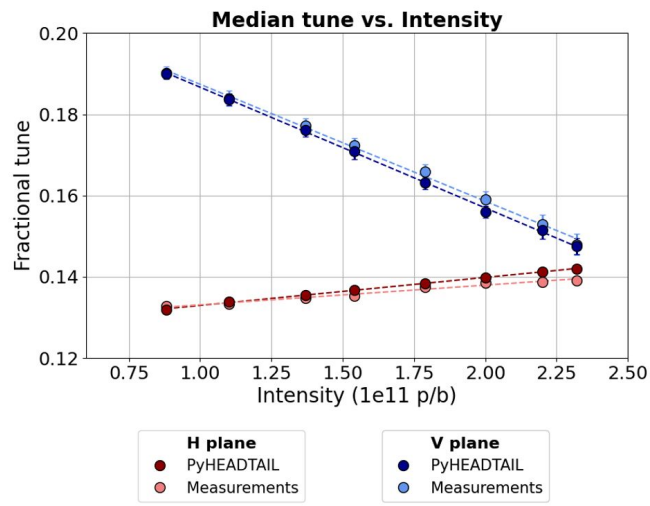


Tatiana Pieloni, EPFL

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

- **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?**

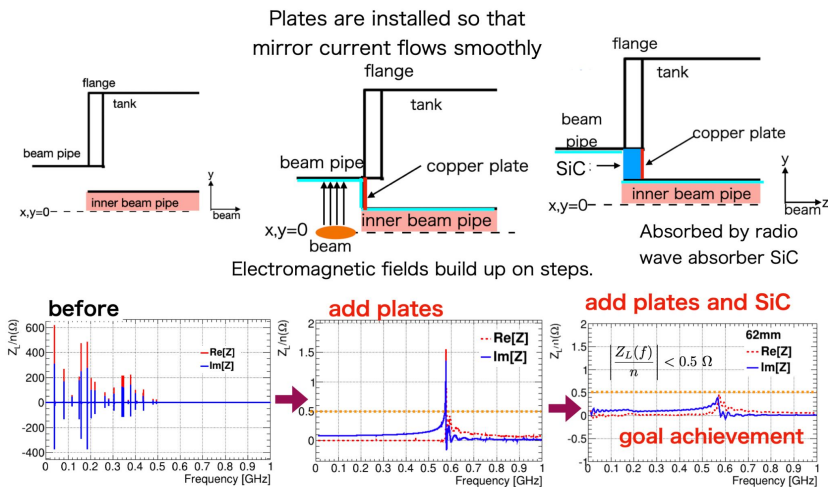
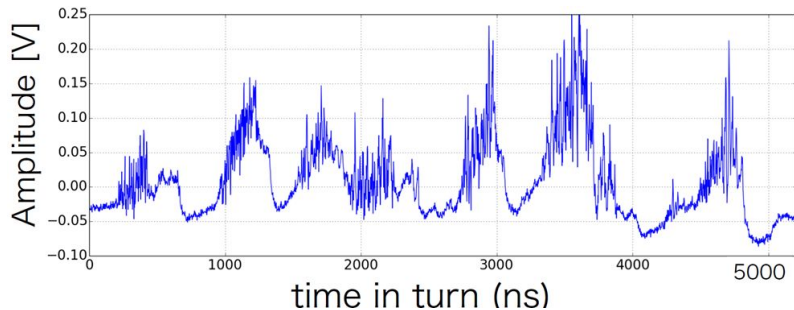
Ingrid Mases, CERN



HB Controlling & mitigating impedance driven instabilities

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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

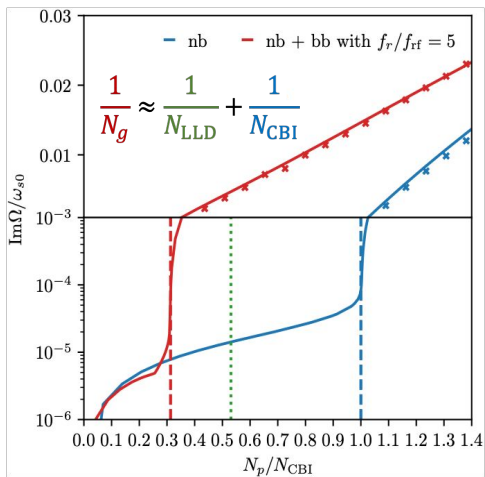
Aine Kobayashi, KEK



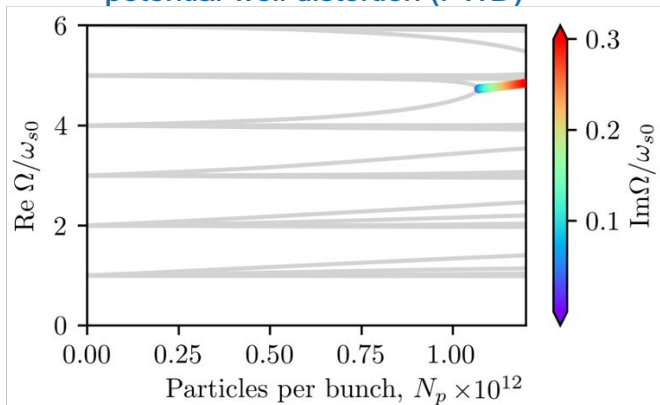
HB Understanding and characterization of instabilities

- 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

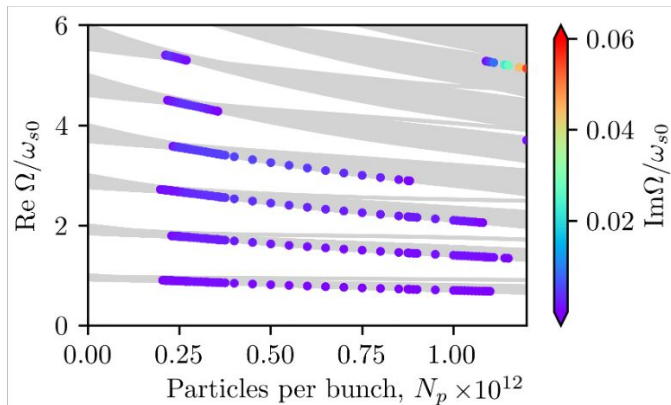
Ivan Karpov, CERN



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

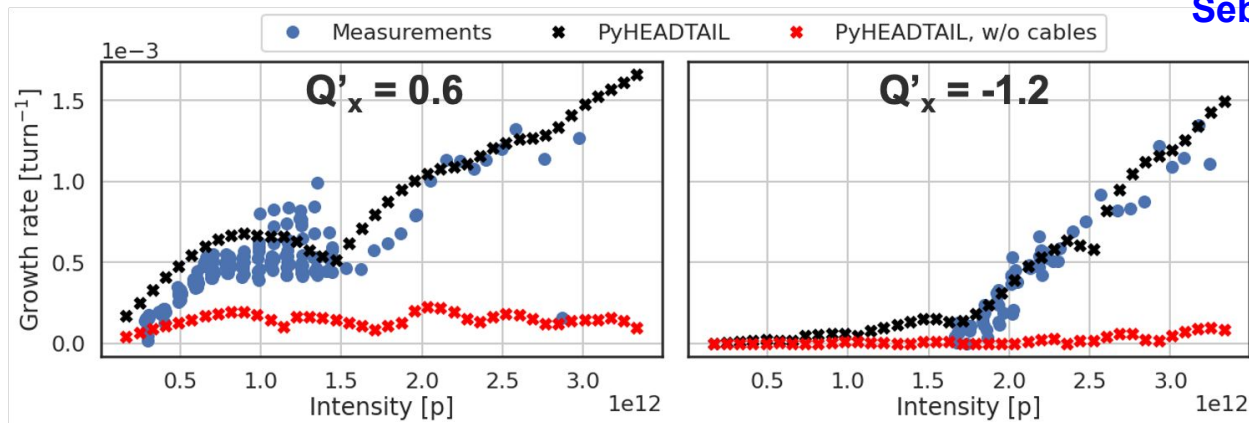


van Kampen modes



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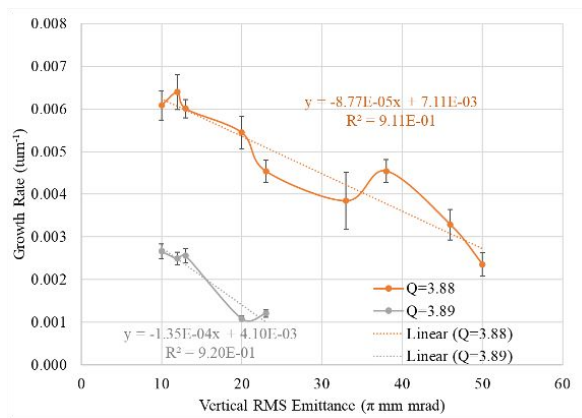
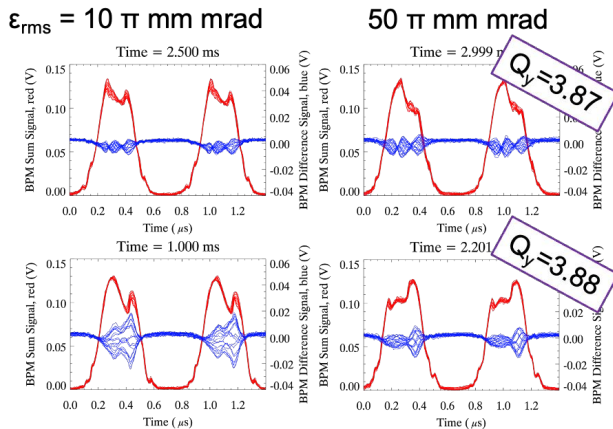


Sebastien Joly, CERN

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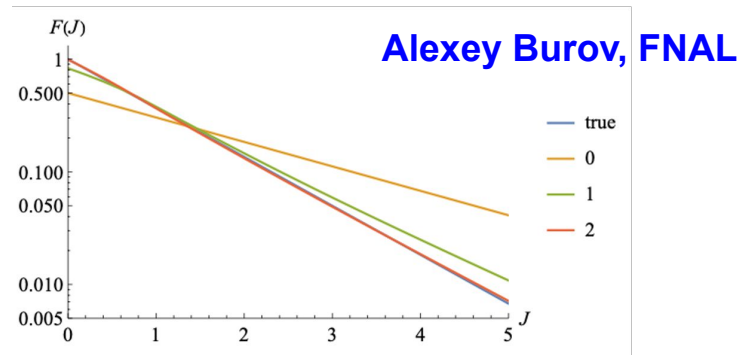
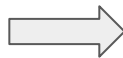
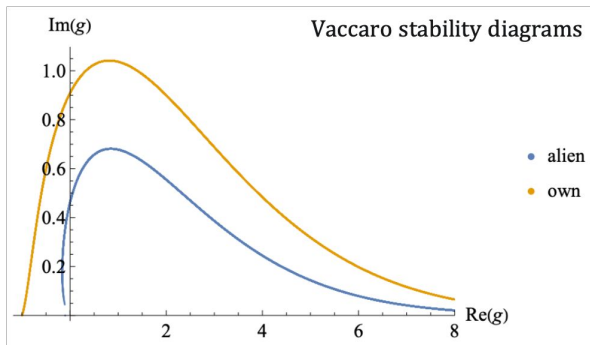
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Robert Williamson, RAL



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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





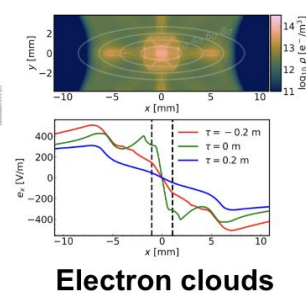
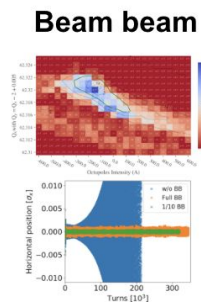
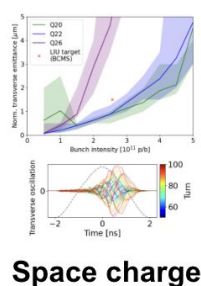
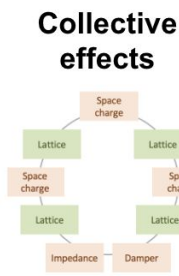
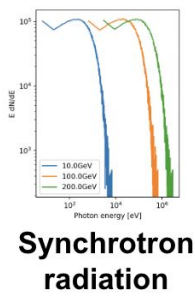
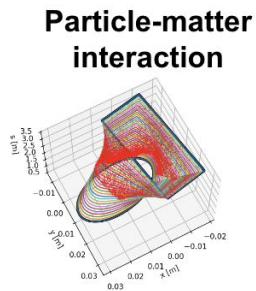
The pursuit for more powerful simulation tools

- **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

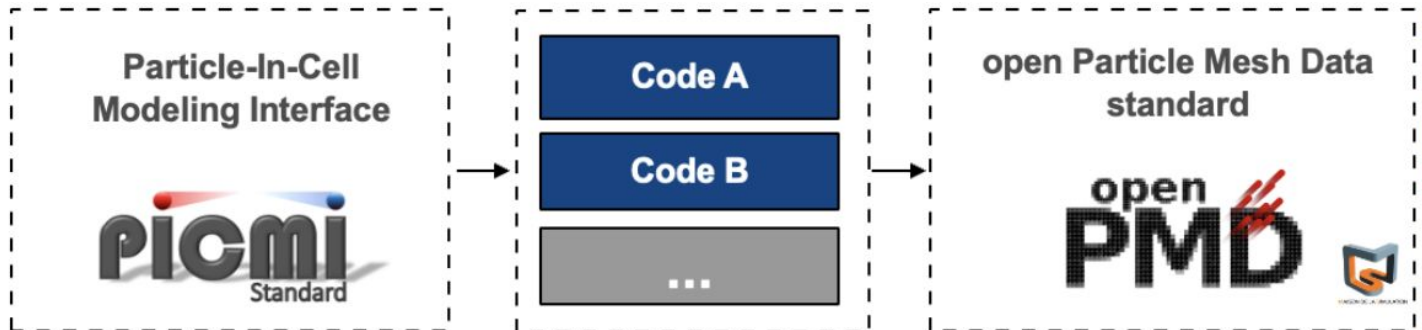
Giovanni Iadarola, CERN



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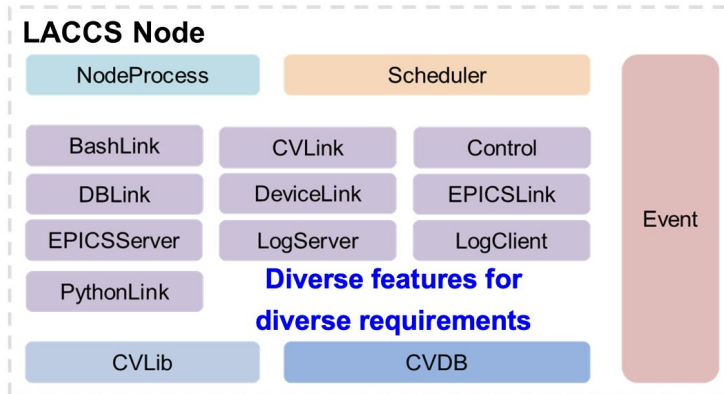
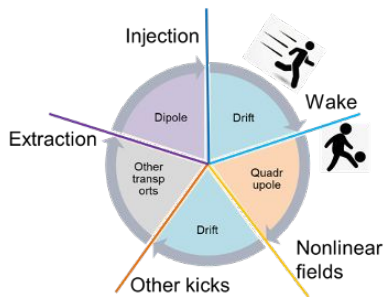
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- Berkeley Lab codes **modernized & combined** into **integrated ecosystem BLAST** (LBNL)
 - triple acceleration approach (GPU, Mesh Refinement, AI/ML) with flexible Python frontend & part of larger **effort to develop Community Ecosystem** based on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

Chad Mitchell, Berkeley Lab



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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



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Trends:

- **Port to GPUs** \Rightarrow more particles, higher resolution, larger systems, longer integration time
- **Integration** \Rightarrow 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** \Rightarrow user-friendliness with shorter learning curve & flexibility for extension, exploration & coupling with AI/ML tools; coupling w/ other codes & experiments

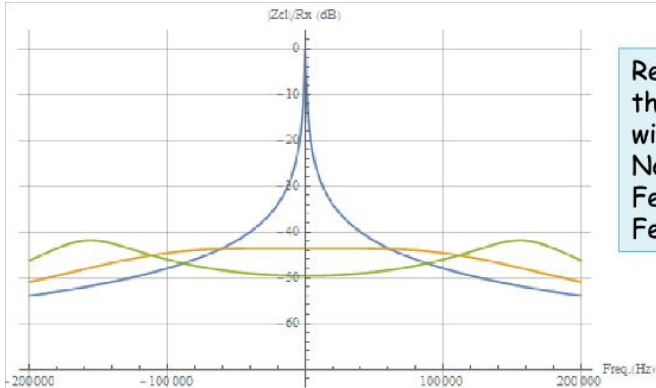
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- **Demonstrate space charge compensation by pulsed e-lenses (FAIR-SIS100)**

HB Challenges ahead

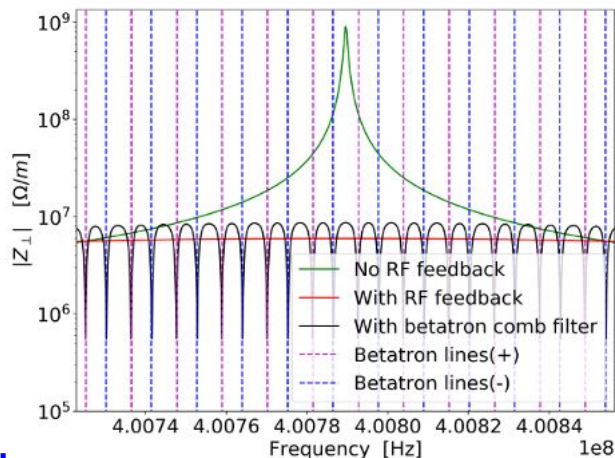
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- Crab cavities (HL-LHC and EIC)
 - Crab cavity noise and feedback requirements are beyond the state of art \rightarrow ongoing work

Gain of standard RF feedback cannot be increased further



Reduction of the modulus of the transverse impedance with:
No feedback (blue)
Feedback gain=150 (orange)
Feedback gain=300 (green).

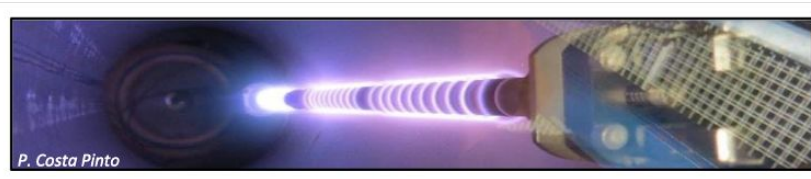
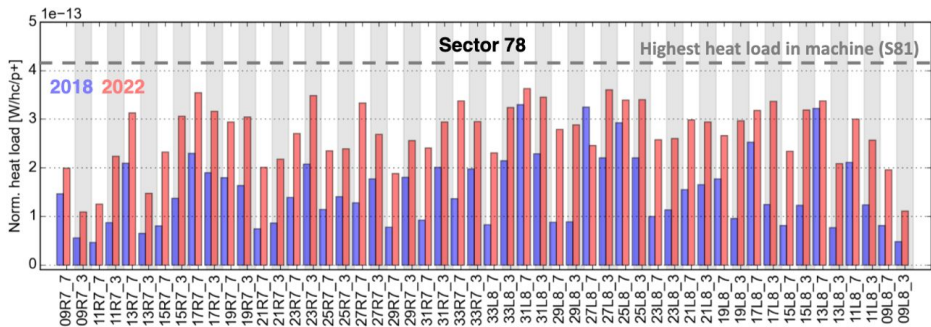
comb filter can reduce impedance effects by acting at the right frequencies (betatron lines)



Nicolas Mounet, CERN

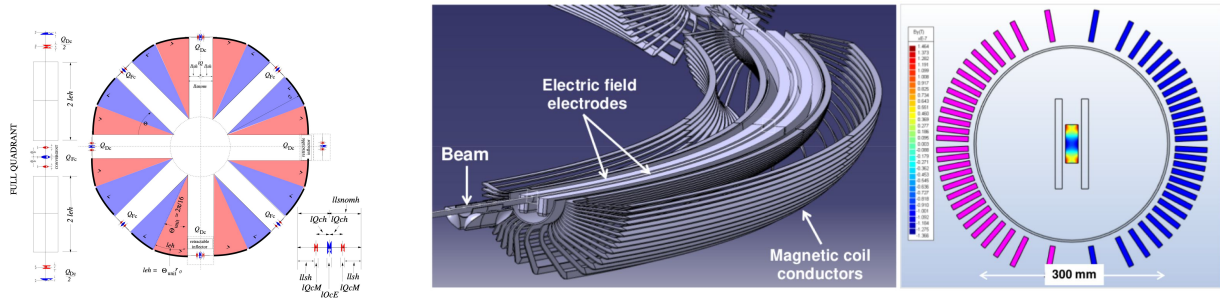
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 - **Crab cavity noise and feedback requirements are beyond the state of art** → ongoing work
- **Mitigating e-cloud effects in HL-LHC**
 - Situation degraded after long shutdown, limiting the total number of bunches
 - Need to address the root cause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



HB Challenges ahead

- **Loss control at $<1\%$ level** to allow for multi MW beam power (e.g. ISIS II)
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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
- **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



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