WGA Summary

Yong Ho Chin, Wolfram Fisher,
Giuliano Franchetti

WGA - Structure

1. Collective effects (4 talks)
2. Space charge – beam-beam (4 talks)
3. Code development and benchmarking (4 talks)
4. New machines / New Concepts (4 talks)
5. Theory (4 talks)
6. Emerging talents (6 talks)

WGA - Talks

1

- A Two Particle Model for Study of Effects of Space-Charge Force on Strong Head-Tail Instabilities.; Yong Ho Chin
- Measurement and interpretation of transverse beam instabilities in the CERN Large Hadron Collider (LHC) and extrapolations to HL-LHC; Elias Métral
- Identification and Reduction of the CERN SPS Impedance; Elena Shaposhnikova
- Electron Cloud Effects in the CERN Accelerator Complex; Giovanni Rumolo

2

- Space Charge Driven Beam Loss for Cooled Beams and Possible Mitigation Measures in the CERN Low Energy Ion Ring; Hannes Bartosik
- Space Charge Effects on the Third Order Coupled Resonance; Giuliano Franchetti
- Intensity Effects in the Formation of Stable Islands in Phase Space During the Multi-Turn Extraction Process at the CERN Ps; Shinji Machida
- Beam-Beam Effects in the Large Hadron Collider; Tatiana Pieloni

3

- Code Benchmarking for Long-Term Tracking and Adaptive Algorithms; Frank Schmidt
- PIC Solvers for Intense Beams: Status and Future Prospects; Oliver Boine-Frankenheim
- Code Development for Collective Effects; Kevin Shing Bruce Li
- Numerical Modeling of Fast Beam Ion Instabilities; Lotta Mether

4

- Beam-dynamics Issues in the FCC; Frank Zimmermann
- Studies of High Intensity Proton FFAGs at RAL; Christopher Prior
- Nonlinear Focusing in IOTA for Space-Charge Compensation and Landau Damping; Sergei Nagaitsev
- Two-plane Painting Injection in BRing of HIAF Project; Weiping Chai

5

- Typology of space charge resonances; Ingo Hofmann
- Head-Tail Modes With Strong Space Charge: Theory and Simulations; Alexey Burov
- Head-Tail Instability and Landau Damping in Bunches with Space Charge; Vladimir Kornilov
- Resonances and envelope instability in high intensity linear accelerators; Dong-O Jeon

6

- Using an Electron Cooler for Space Charge Compensation in the GSI Synchrotron SIS18; William Stem
- Space charge effects in FFAG; Malek Haj Tahar
- Use of RF Quadrupole Structures to Enhance Stability in Accelerator Rings; Michael Schenk
- Nonlinear Optics Experiments at the University of Maryland Electron Ring; Kiersten Ruisard
- Space Charge effects and mitigation in the CERN PS Booster, in view of the upgrade.; Elena Benedetto
- Stripline Beam Position Monitors with Improved Frequency Response and their Coupling Impedances; Yoshihiro Shobuda

Disclaimer

This summary is highly subject to the limits of the conveners, and does not represent a judgment of the contents of the presentations or of the activity that took place in the working group A.

Collective Effects

CONCLUSION

- **In a machine like the LHC, not only all the mechanisms have to be understood separately, but (ALL) the possible interplays between the different phenomena need to be analyzed in detail, including the**
  - **Beam-coupling impedance (with in particular all the necessary collimators to protect the machine but also new equipment such as crab cavities at large β-function)**
  - **Linear and nonlinear chromaticity**
  - **Landau octupoles (and other intrinsic nonlinearities)**
  - **Transverse damper**
  - **Space charge**
  - **Beam-beam: BBLR and BBHO**
  - **Electron cloud**
  - **Linear coupling strength**
  - **Tune separation between the transverse planes (bunch by bunch)**
  - **Tune split between the two beams (bunch by bunch)**
  - **Transverse beam separation between the two beams**
  - **Noise**

Elias Métral, HB2016 workshop, Malmö, Sweden, 05/07/2016

Elias Metral /CERN

Collective Effects

Concluding remarks

⇒ Thanks to intensive measurements and highly empowered simulation tools, we have reached a deep knowledge of the electron cloud in the different CERN accelerators

- For the present beam parameters (25 ns beams)
  - PS and SPS can deliver the required beams well within original specs
  - LHC still suffers from electron cloud, but is now operating thanks to scrubbing with physics. The question is still open, up to which point?
- For future beam parameters (double intensity, double brightness)
  - PS is expected to deal with possible e-cloud instabilities at 26 GeV thanks to the transverse feedback system
  - SPS will rely on scrubbing and will prepare to full a-C coating of the most e-cloud prone chambers if that will not be enough during Run 3
  - HL-LHC will depend on the scrubbing evolution, experimental dependence of e-cloud on bunch intensity, a-C coating of the new triplet chambers – and may use e-cloud free filling patterns, if needed
  - Future projects should include anti-ecloud coatings in their baselines!

Giovanni Rumolo / CERN – electron clouds

Space charge / beam-beam

Experimental characterization of the LEIR intensity limitation

- Beam loss during and after RF capture
- Identified interplay of betatron resonances and large direct space charge detuning as driving mechanism
- Excessive vertical emittance growth after RF capture

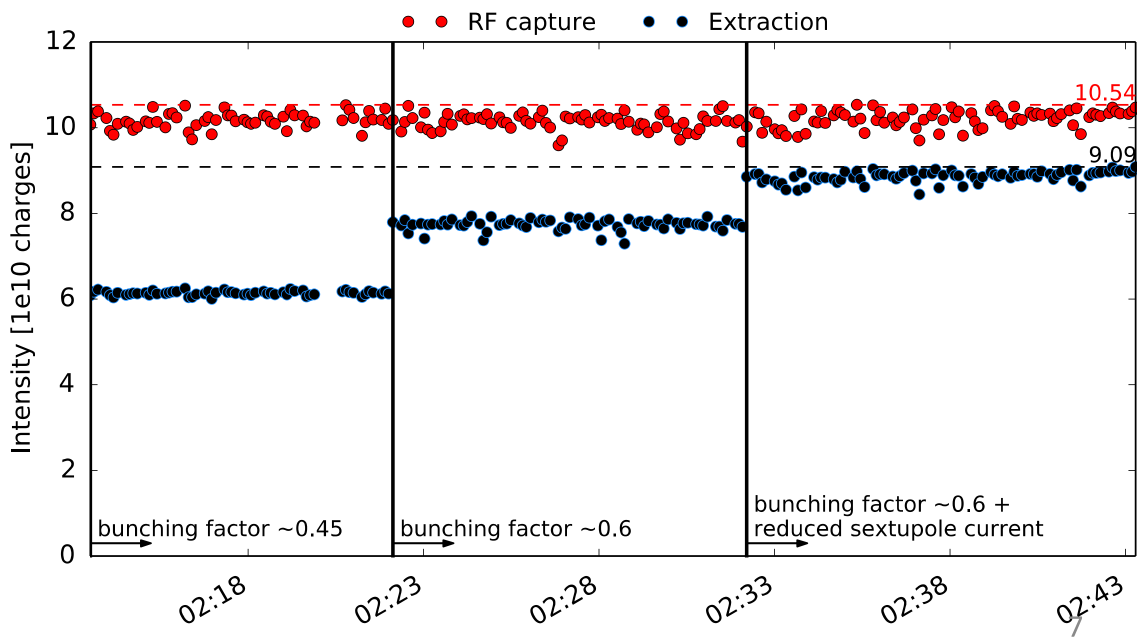
Clear loss reduction after implementation of mitigation measures

- Maximized bunching factor
- Reduced excitation of chromatic sextupoles

Future steps

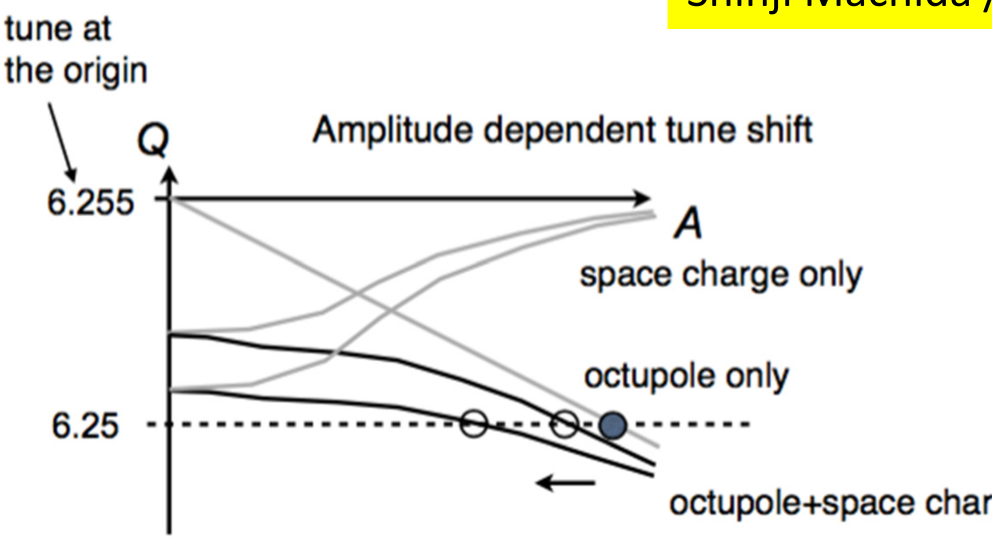
- Maximize accumulated intensity with 10 Hz injection rate
- Develop new machine optics to avoid low order resonances
- Detailed studies of resonances (including driving term measurements) and possibly compensation
- Simulation studies (magnetic model, space charge, impedance, …)

Hannes Bartosik / CERN
Low Energy Ion Ring

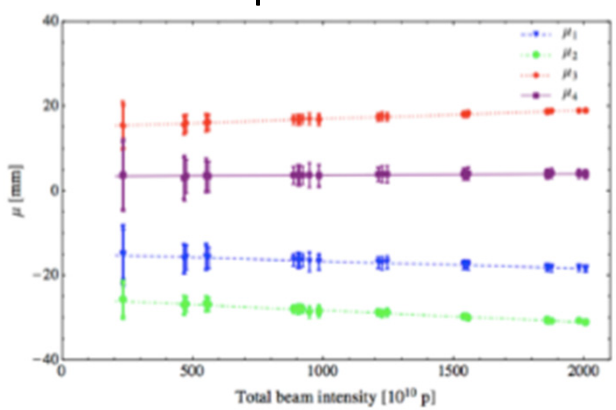


Space charge / beam-beam

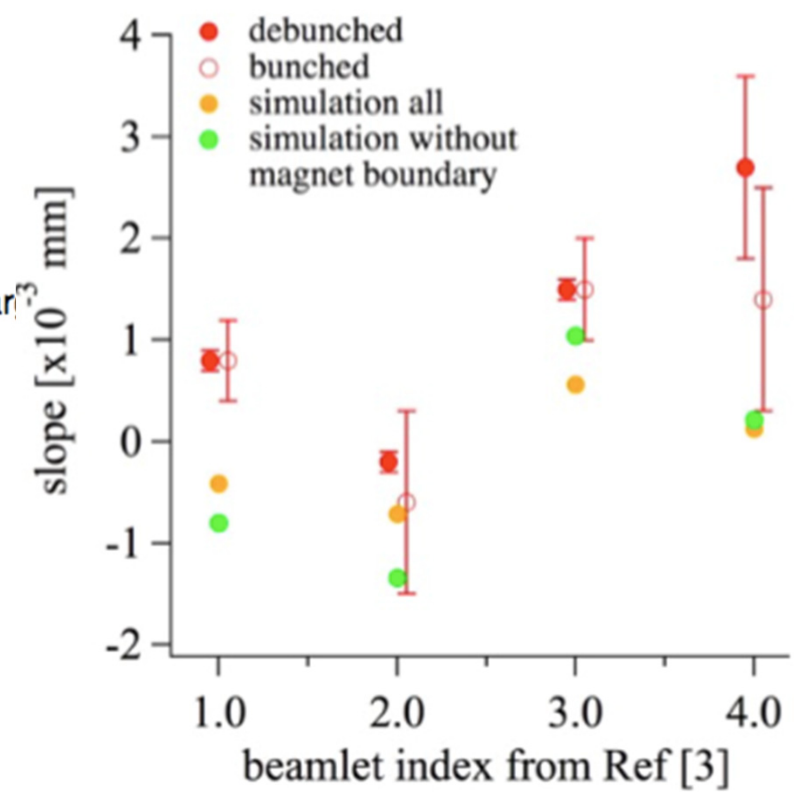
Shinji Machida / STFC



Experiment



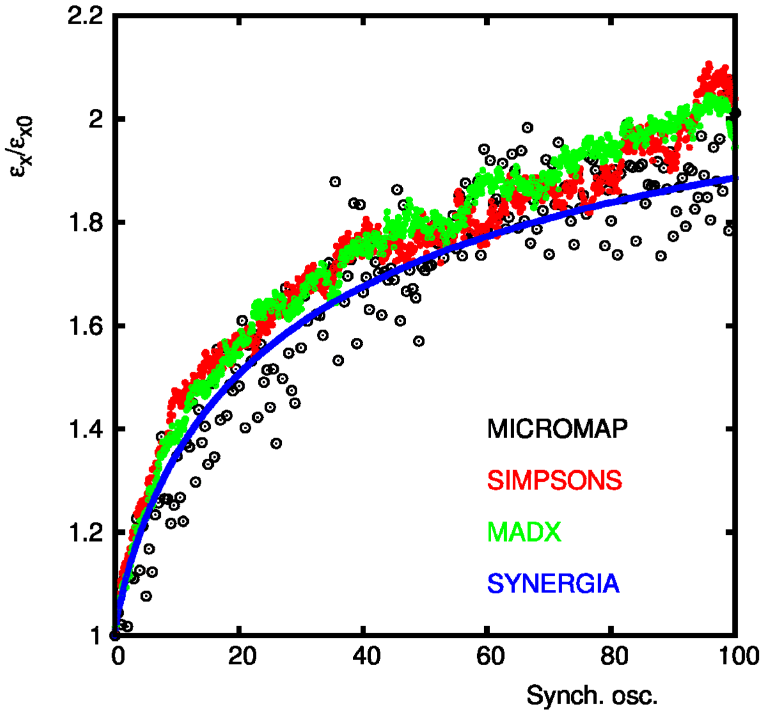
Including boundary



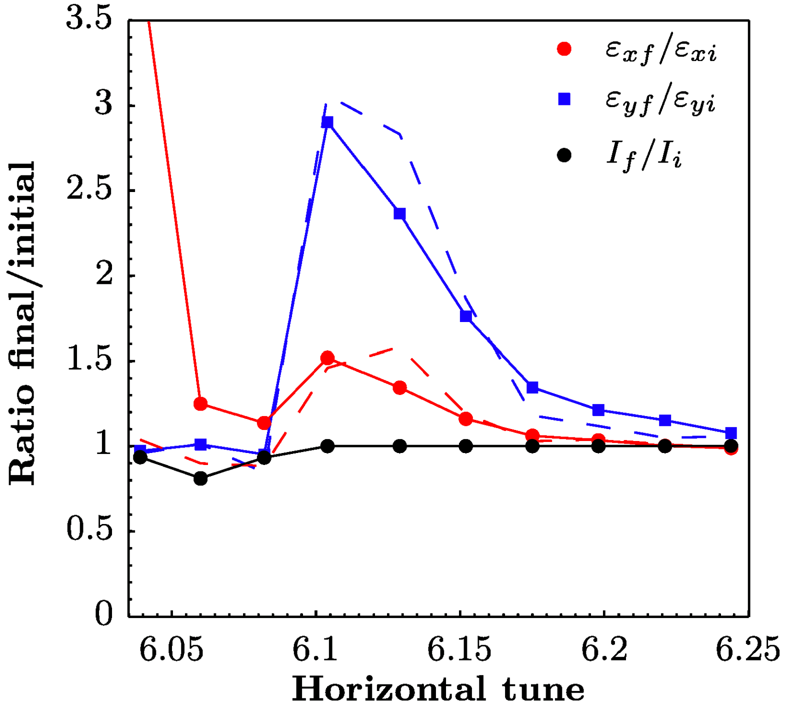
Codes, and benchmarking

F. Schmidt /CERN

periodic crossing of the
3rd order resonance



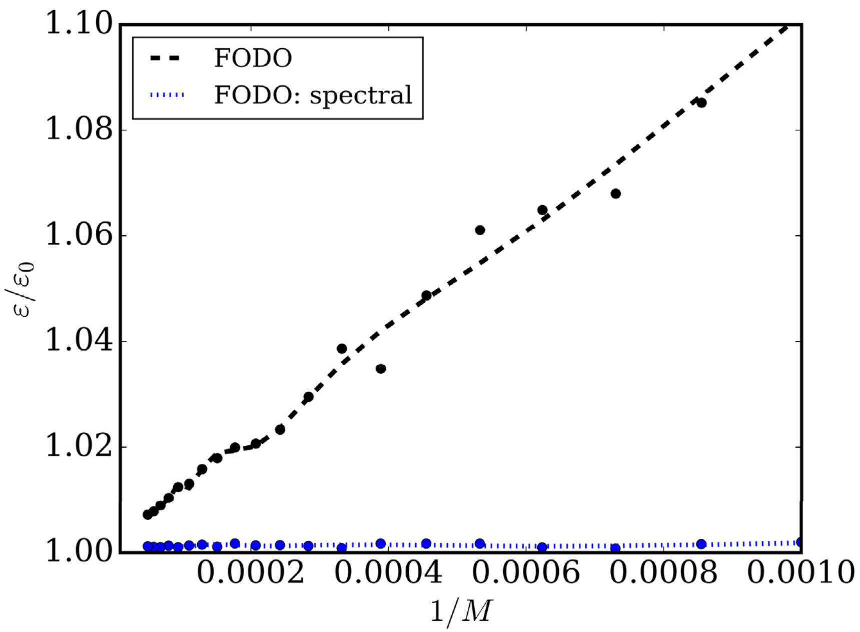
code / experiment benchmarking

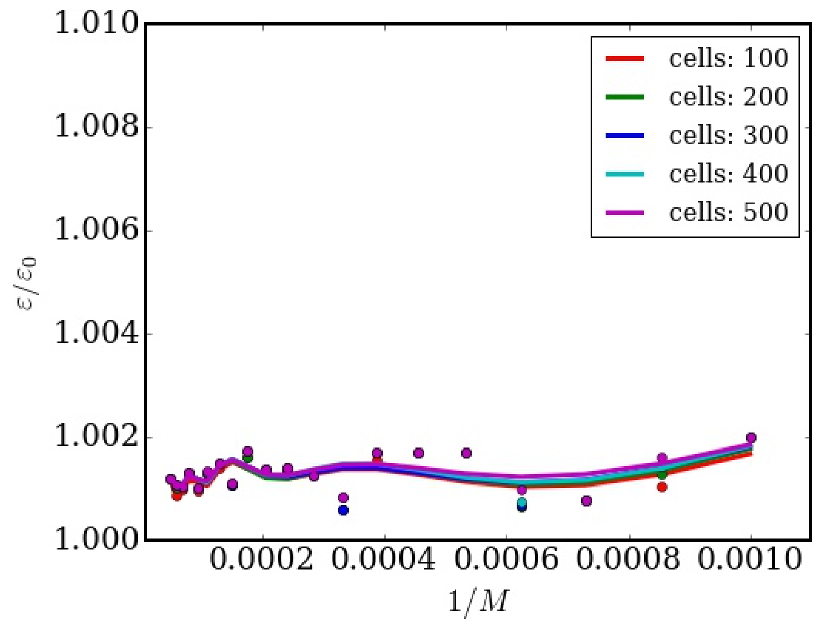


Codes, and benchmarking

O. Boine-Frankenheim / TUD / GSI

Noise free PIC → Spectral solver





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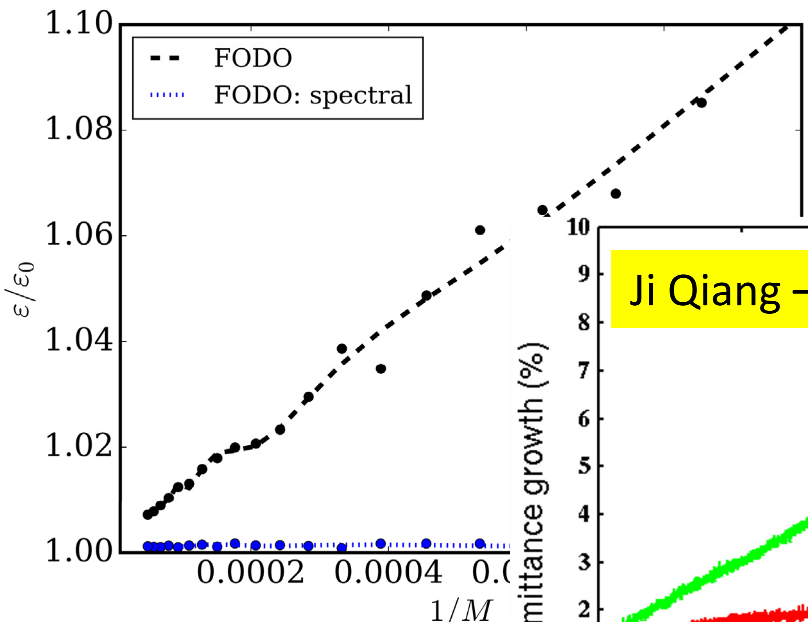
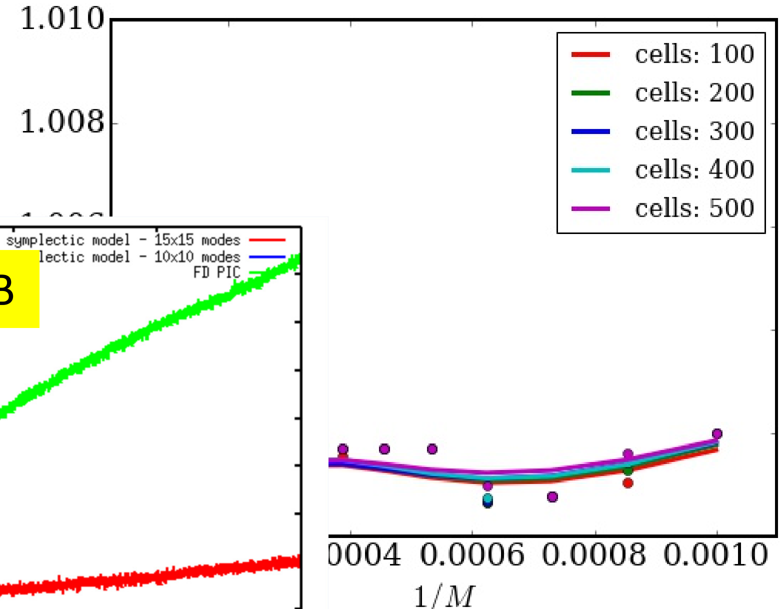
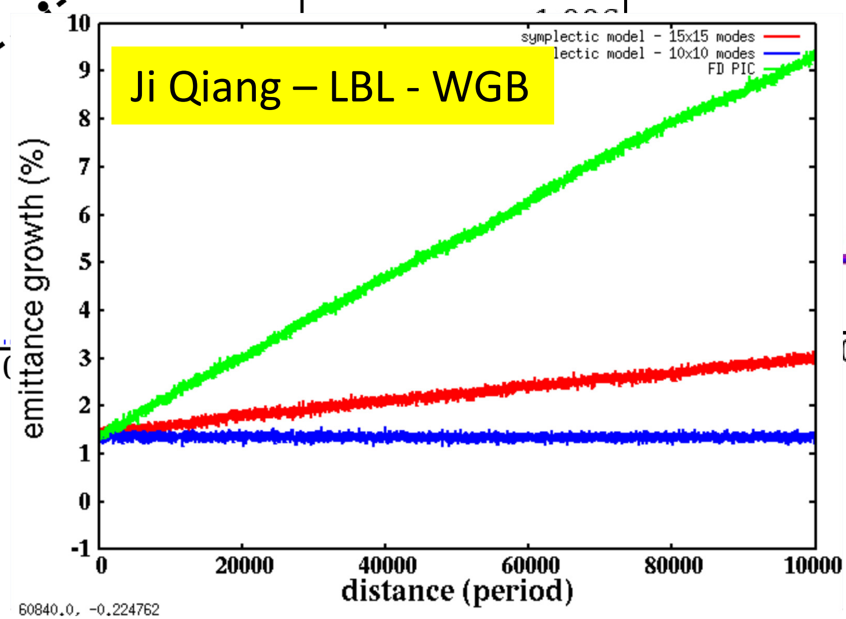
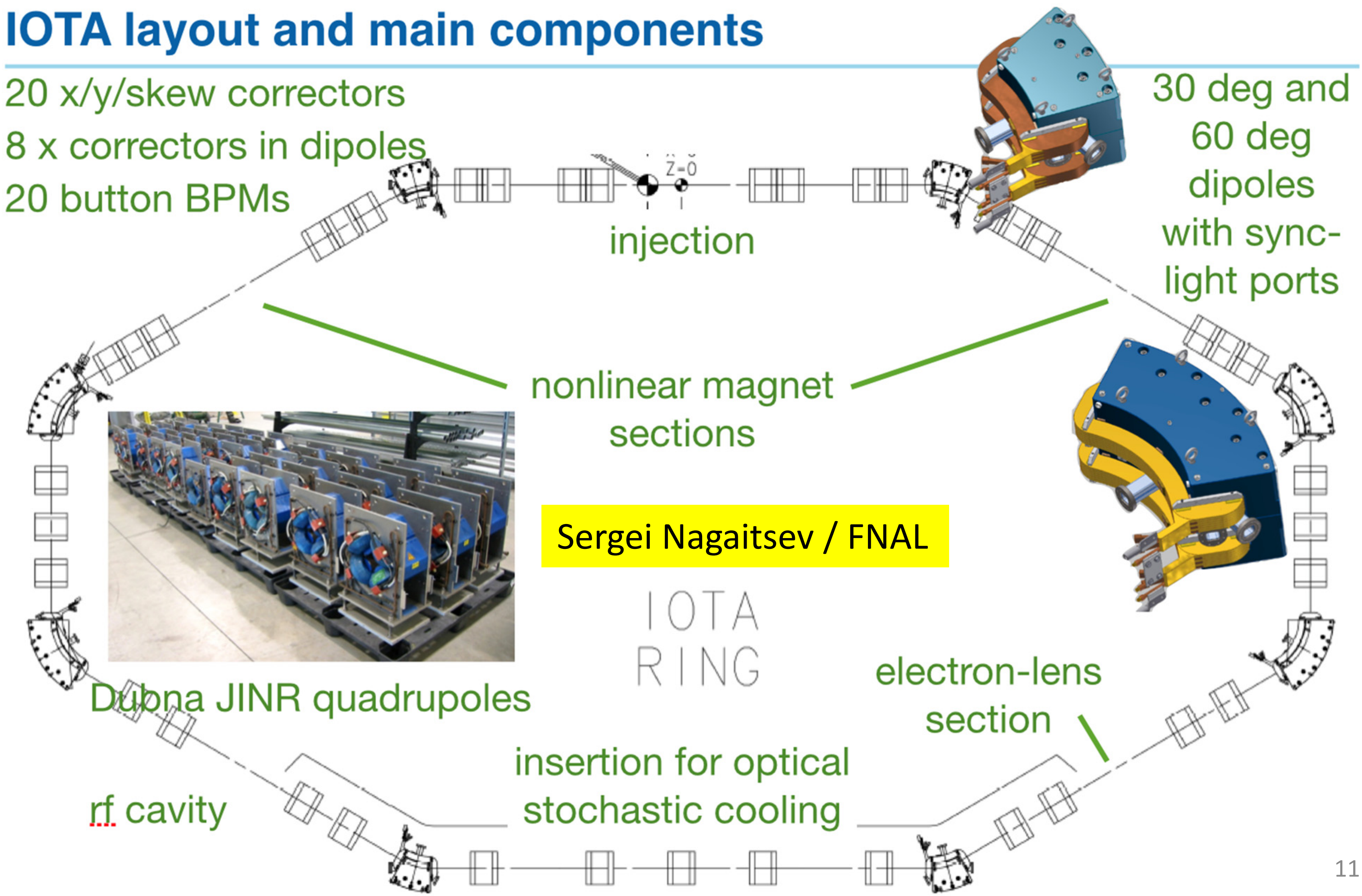




Ji Qiang – LBL - WGB



New machines / New Concepts



New Machines / New Concepts

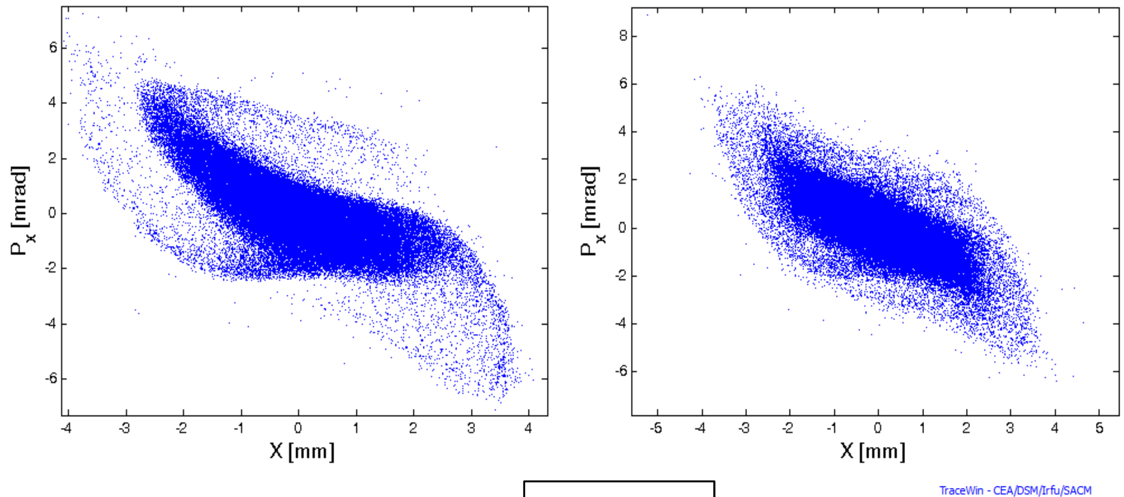
Christopher Prior / ASTeC

- An encouraging start to the study of FFAGs as a driver of a next-generation neutron source
  - several different designs created for both main ring and small test ring
- Depending on the results of simulation with space-charge, and with suitable technological advances, the proposal to use H^+ rather than H^- could well be viable.
- Note the implications for ESS
  - neutrino proposals could avoid the need for H^- ions in the linac
- Study assisted through experimental opportunities in Japan and the new Paul Trap set-up at RAL

Theory

I. Hofmann

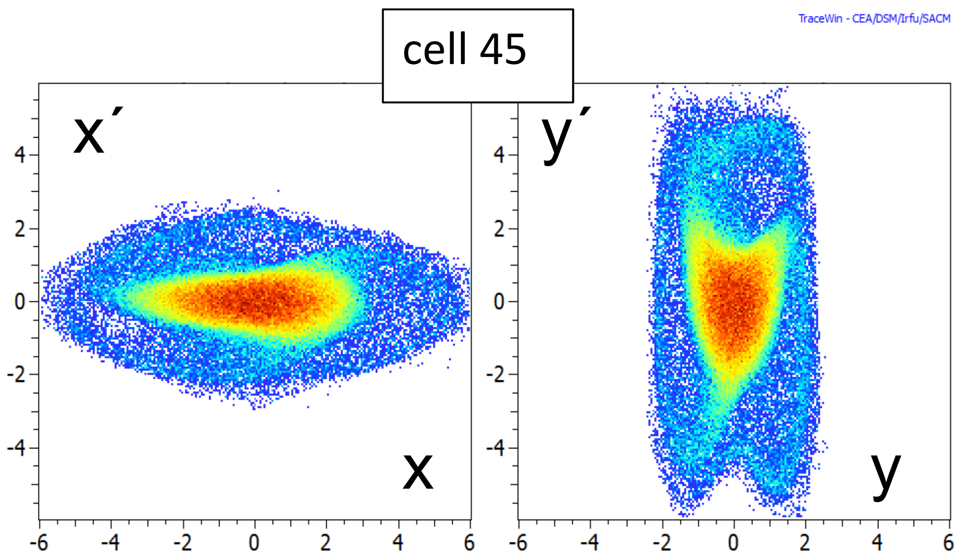
- ✓ **Two main groups** of resonant space charge effects
  - "Single particle" resonances with **driving term in initial space charge** profile – "usual" resonance diagram
  - Parametric **"half-integer"** resonances = instabilities with **driving term pumped from initial noise** – "stability diagram"
- ✓ Parametric resonances characterized by coherence in density - frozen space charge simulation fails!
- ✓ Stimulate **more experiments** to further advance our understanding and come to a more **complete picture** (synchrotron motion?)
- ✓ Analogous discussion on emittance transfer – where also **resonances <u>and</u> instabilities** matter (driven by anisotropy rather than parametrically)



The 3rd order instability for high intensity linear accelerators

Dong-O Jeon

Very sensitive to the initial distributions and not always observed.



3rd order parametric resonance (60 deg stopband) again half-integer 2:1 type = instability

I. Hofmann


ess
EUROPEAN
SPALLATION
SOURCE

Theory

Head-Tail Modes With Strong Space Charge: Theory and Simulations. A. Burov

M. Blaskiewicz
Fast head-tail instability with SC

A. Burov
Head-tail modes for strong space charge

A. Burov
Coupled-Beam and
Coupled-Bunch Instabilities

V. Kornilov & O. Boine-Frankenheim
Head-tail instability and Landau damping
in bunches with space charge

V. Kornilov et al.
Threshold of head-tail instabilities in
bunches with space charge

A. Macridin et al.
Simulation of transverse modes with their
intrinsic Landau damping for bunched beams
in the presence of space charge

Theory

V. Kornilov /GSI

- Landau damping is the essential part of the beam stability
- We are now able to predict the instability thresholds: accurate $Re(\Delta Q_{coh})$ and incoherent (inter. & exter.) spectrum needed
- The airbag theory for head-tail shifts due to space-charge, due to coherent effect, and the combinations, is verified by simulations and by the experiment
- The model of the effective Landau damping with the modulated coherent frequency gives correct predictions, and adequate physical understanding

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- The model of the effective Landau damping with the modulated coherent frequency gives correct predictions, and adequate physical understanding

Extra Discussion today 8:00-8:45!

Emerging studies from young researchers

Space charge effects in FFAG; Malek Haj Tahar

Using an Electron Cooler for Space Charge Compensation in the GSI Synchrotron SIS18; William Stem

Stripline Beam Position Monitors with Improved Frequency Response and their Coupling Impedances; Yoshihiro Shobuda

Nonlinear Optics Experiments at the University of Maryland Electron Ring; Kiersten Ruisard

Use of RF Quadrupole Structures to Enhance Stability in Accelerator Rings; Michael Schenk

Space charge history timeline

Incoherent

Incoherent tuneshift
KV
Laslett

coherent/ core stability

Emittance preservation
multiparticle simulations
Sacherer's theory

few % beam loss

Particle core models
simulations codes

return of the incoherent

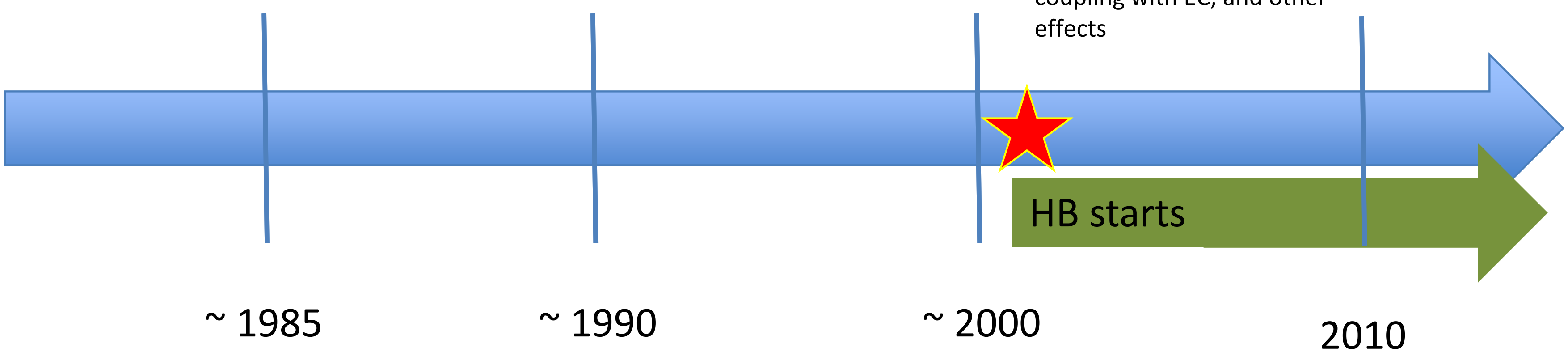
Machines studies
CERN,GSI, J-PARC, SNS

machine modeling in codes

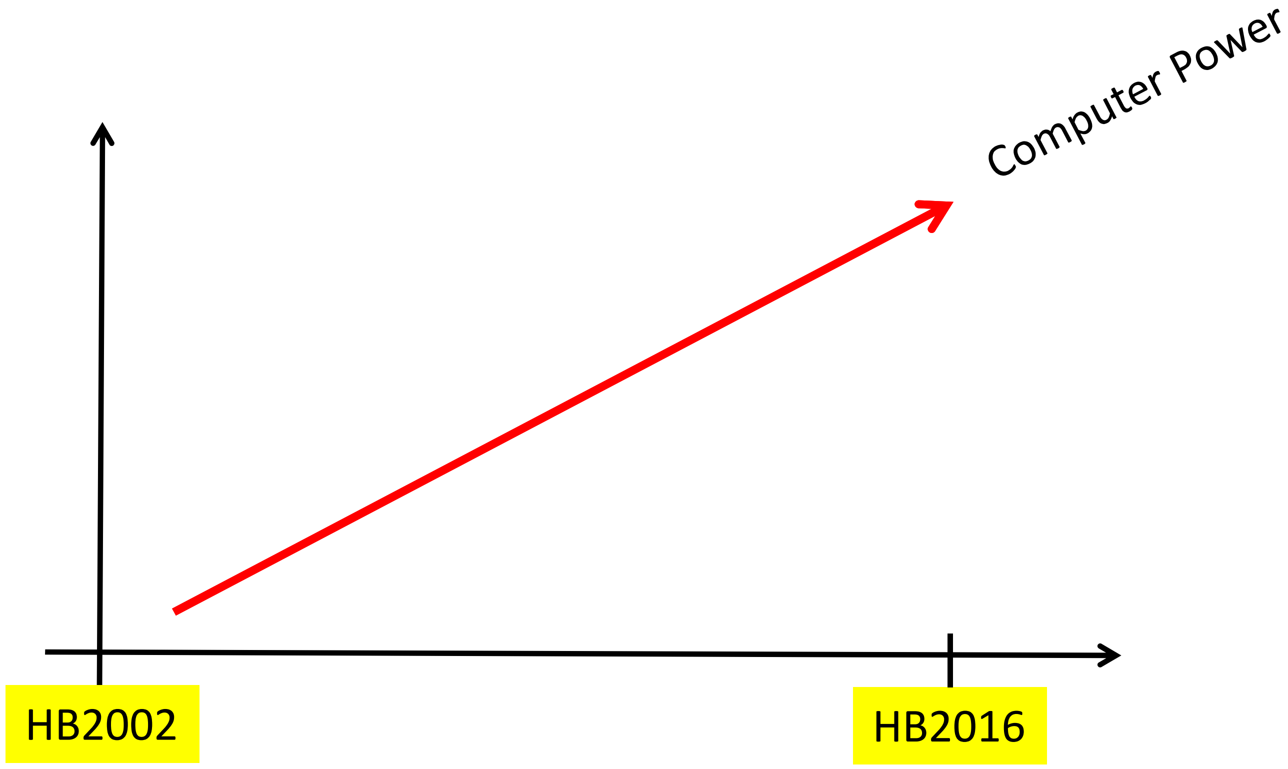
long term tracking (frozen)

coupling with EC, and other effects

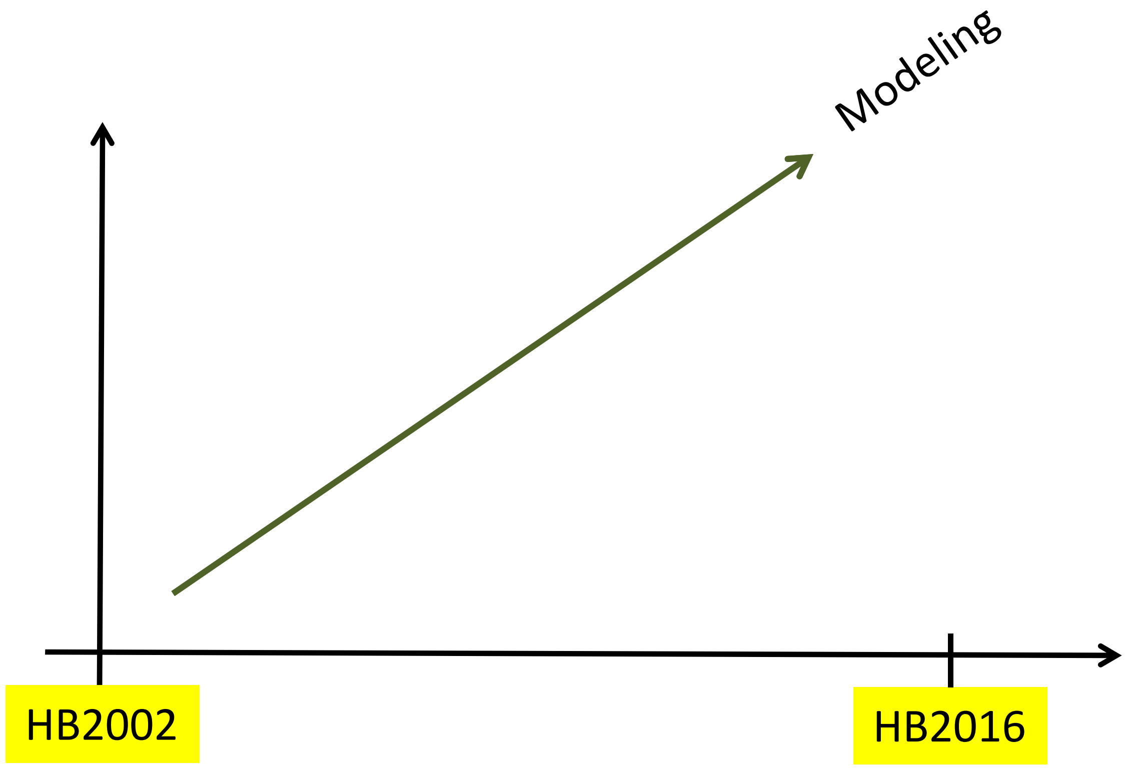
New trends / new challenges ??



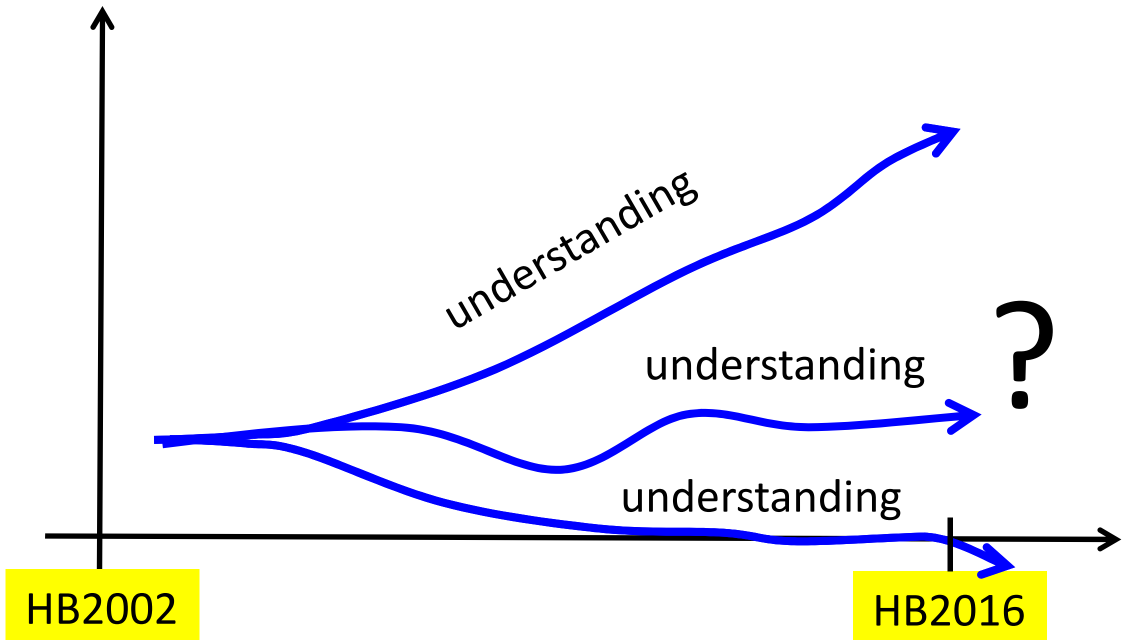
Trends



Trends



Trends


understanding
understanding
?
understanding
HB2002
HB2016

Coherent effects

Incoherent effects

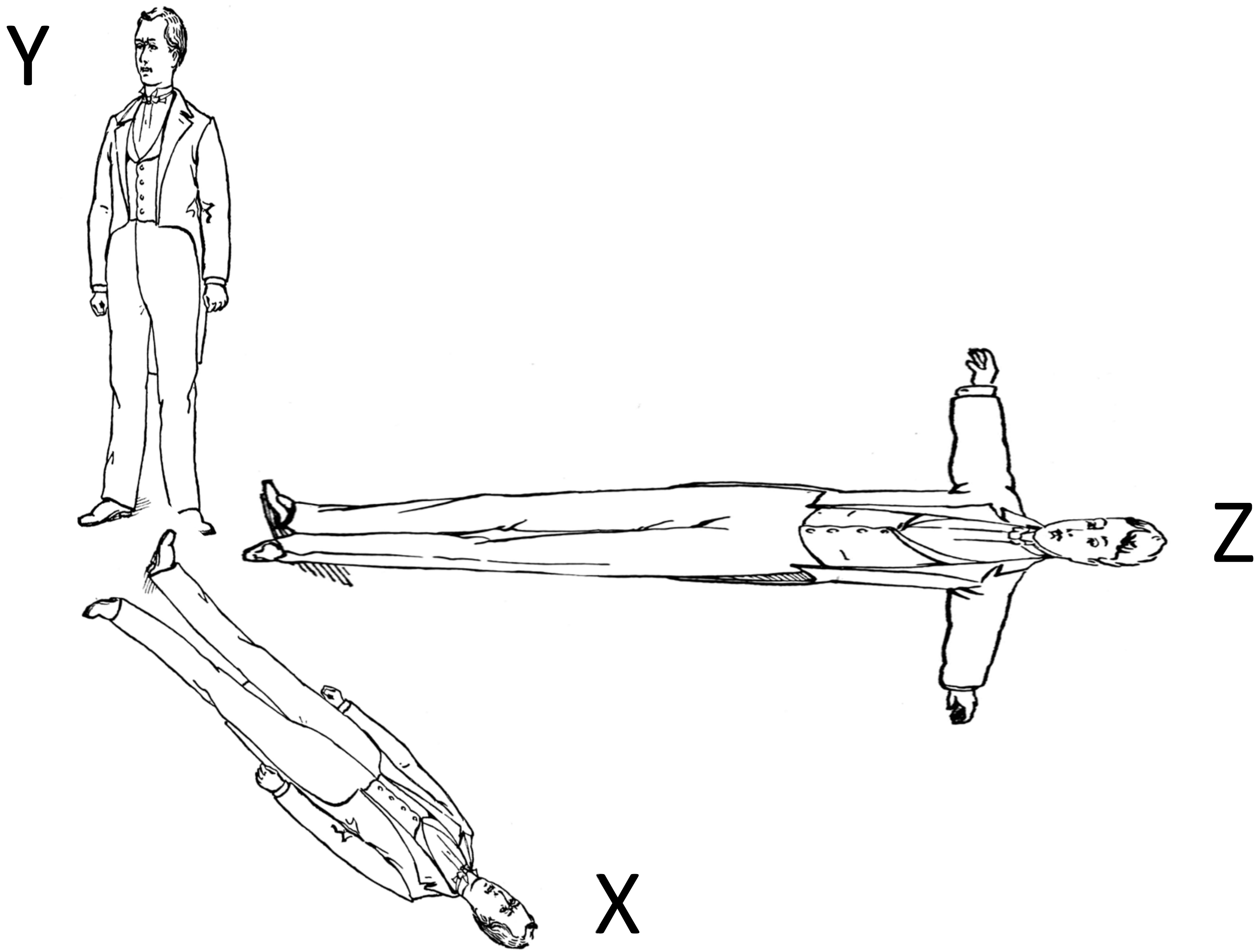
Coherent effects

Incoherent effects

Coherent effects

Incoherent effects

Transverse/Longitudinal marriage ?



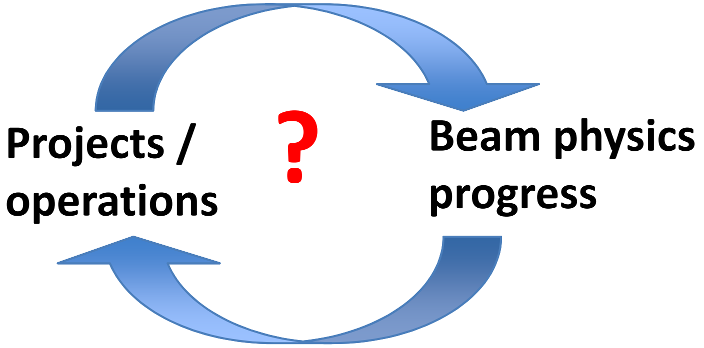
Machine experiments, and beam dynamics in rings

A: Useful machine experiments ?

B: Interesting machine experiments ?

Do we need better machine experiments ?

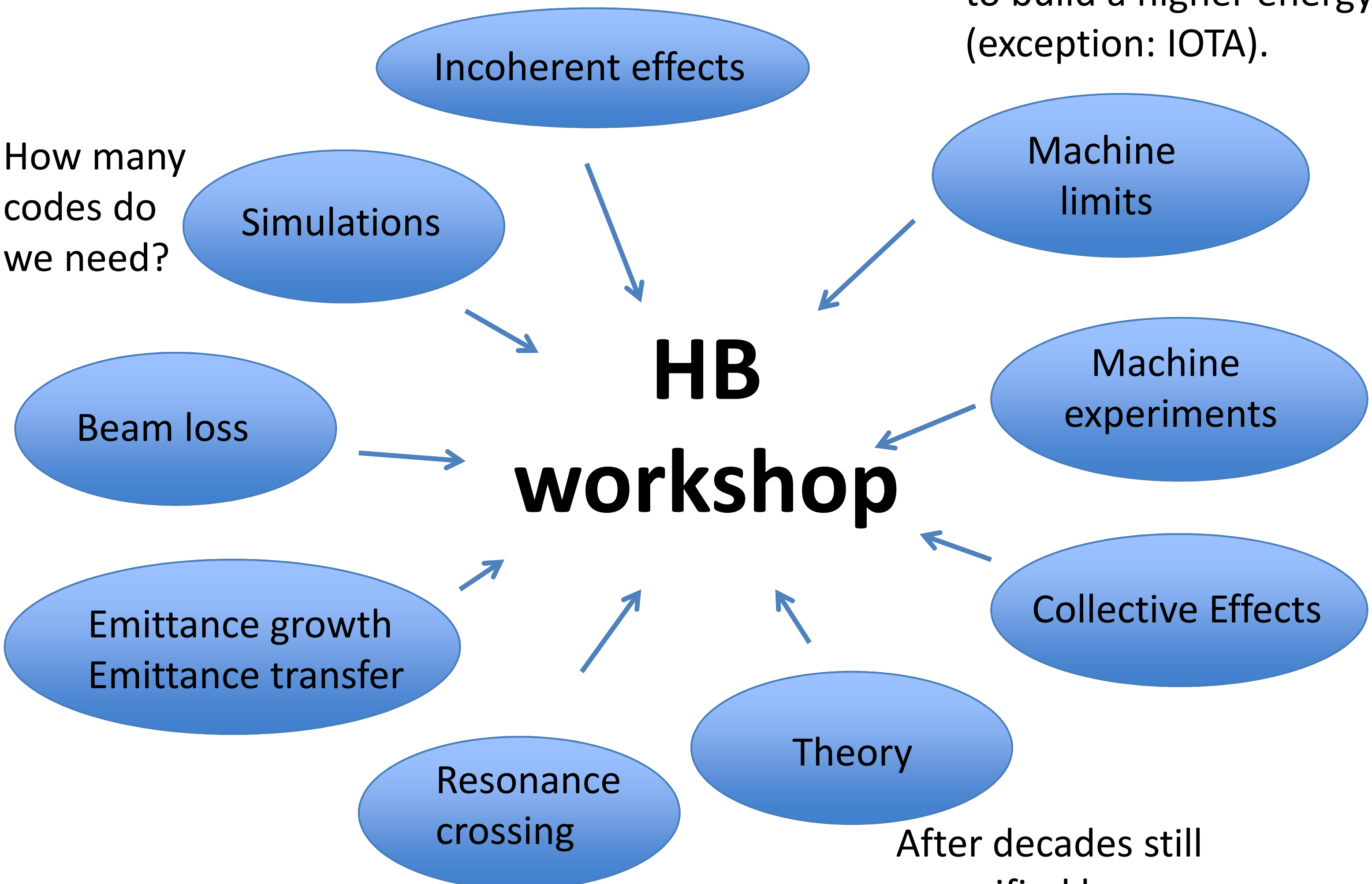
- For what new beam physics?
- Do we need more machine-code-theory benchmarking?



Outlook

Standard response to space charge limited ring is still to build a higher energy Linac (exception: IOTA).

How many codes do we need?



After decades still no unified language to describe space charge phenomena?

See you in the next HB workshop!