SUMMARY AND CONCLUSION FROM CERN-GSI WORKSHOP (18-19/02/2009, GSI)

E. Métral, E. Benedetto, C. Carli,
D. Quatraro, G. Rumolo and B. Salvant

- **Web page: http://www-linux.gsi.de/~boine/CERN-GSI-2009/CERN-GSI-2009.htm**
- **Summary**
- **Appendix: Previous CERN-GSI bi-lateral working meeting in 2006 ➔ http://care-hhh.web.cern.ch/care-hhh/Collective%20Effects-GSI-March-2006/default.html**

AGENDA (1/2)

CERN/GSI beam dynamics and collective effects collaboration meeting

Feb. 18/19, 2009, GSI, C27 seminar room (downstairs)

Participants: Elena Benedetto, Giovanni Rumolo, Christian Carli, Benoit Salvant, Elias Metral, Diego Quatraro, Heiko Damerau (all CERN), A. Burov (FNAL), V. Kapin (ITEP), L. Hänichen, W. Müller (all TUD), G. Franchetti, V. Kornilov, A. Parfenova, S. Paret, S. Appel, S. Sorge, I. Hofmann, A. Plotnikov, O. Chorniy, E. Mustafin, W.Daqa, P. Spiller, O. Boine-F. (all GSI)

Agenda:

Feb. 18

13:45 Welcome

14:00 High-intensity operation in the PSB, C. Carli

14:30 Beam loss studies with space charge for SIS-18/100, G. Franchetti

15:00 Recent HEADTAIL upgrades, G. Rumolo

15:30 Simulation studies with HEADTAIL and PATRIC for SIS-100, V. Kornilov

16:00 Coffee break

16:30 Measurement of nonlinear field components in SIS-18, A. Parfenova

17:00 Measurements of adiabatic rf capture in dual rf buckets , O. Chorniy

17:30 Measurement of flat bunches in a dual harmonic rf system in the PS, H. Damerau

19:00 Dinner at ‘Weisser Schwan’

AGENDA (2/2)

Feb. 19

9:30 Instability rise-time far above the TMCI threshold: Comparison between simple theory, MOSES and HEADTAIL, E. Benedetto

10:00 Head-tail modes for strong space charge, A. Burov

10:30 Coffee break

11:00 Transverse Schottky signals and decoherence with space charge, O. Boine-F

11:30 News on the transverse wall impedance at low frequencies, E. Metral

12.45 Lunch

14:00 Wake-fields for non-relativistic bunches, D. Quatraro

14:30 Simulation of impedances with Particle Studio, L. Hänichen

15:00 Wake-field simulations of asymmetric structures with Particle Studio, B. Salvant

(Particle Studio simulations of the resistive wall impedance, C. Zannini)

15:30-17.00 Discussion (e.g. MADX/space charge talk by V. Kapin)

SUMMARY (1/18)

- **High-intensity operation in the PSB (Christian)**
  - Main ingredients for high-intensity operation in PSB
  - Plans for the PSB with LINAC4
  - Comment from A. Burov: In the FermilabBooster they saw a very fast instability which could be explained only by coherent synchrotron-betatron resonance. He wondered if this could be the source of our recently observed instability. It seems not due to the very low Qs…
  - Question from I. Hofmann: What about skew quads at injection (are they still used… they plan to use them)? Answer from Christian: The skew quads are still used in practice for the injection process (they are on all the time, otherwise the losses increase)

➔ Possible collaborations: Run MICROMAP code for PSB and PS2

SUMMARY (2/18)

- **Beam loss studies with space charge for SIS-18/100 (G. Franchetti)**
  - Space charge provides a strong amplitude dependent detuning which "helps" the particle trapping (2 resonance crossing / half synchrotron oscillation)
  - Chromaticity provides a tune modulation but does not create an amplitude dependent detuning: it acts like the bare tune is modulated. It does not help any trapping into resonances but it creates a periodic resonance crossing too (2 resonance crossing / one synchrotron oscillation)
  - When both space charge and chromaticity are present space charge helps trapping and chromaticity helps to shift the bare tune against the resonance
  - S317 experiment confirms the understanding of the long term space charge driven mechanisms. It nicely extends what started at CERN in 2002 and we add new experimental information: here for a different resonance (3rd order)

SUMMARY (3/18)

- Reminder: Simulations of the beam losses are optimistic!

→ Possible collaborations:

1) MDs planned in the PS to try and correct the chromaticities for the nominal LHC beam, as the transverse feedback should work

2) Ecloud? (question from Giovanni)

Reminder on Comparison of SC and EC incoherent effect: "We compared SC & EC incoherent effects in terms of beam emittance growth for structure resonances. We find that the beam response for EC incoherent effects is understandable in terms of periodic resonance crossing as for SC incoherent effects" (Giuliano, ECM'08, CERN)

SUMMARY (4/18)

- **Recent HEADTAIL upgrades (Giovanni)**
  - HEADTAIL has been improved
    - is interfaced with MAD-X and Z-BASE to track a single bunch in a real lattice with localized impedance sources
    - can track a single bunch in a double harmonic rf system and in an accelerating bucket (also across transition)
  - Near future upgrade plans:
    - A robust model for longitudinal space charge
    - Correctly include wake fields in the low energy range
    - Extension to multi-bunch simulations
  - Comment from A. Burov: He encourages us to include the 2nd order of alphap + 2nd order of chromaticity as they also contribute to Landau damping ➔ Both are already included

➔ Possible collaborations: Benchmark HEADTAIL with PATRIC (TMCI etc.)

SUMMARY (5/18)

- **Simulation studies with HEADTAIL and PATRIC for SIS-100 (V. Kornilov)**
  - Talk he should have given at CERN
  - I could not access it this morning
  - HT modes can limit SIS100 during the 1 s accumulation time at injection
  - In PATRIC, at the beginning they used impedances as input. Now they have also the possibility to use wake fields

→ Possible collaborations

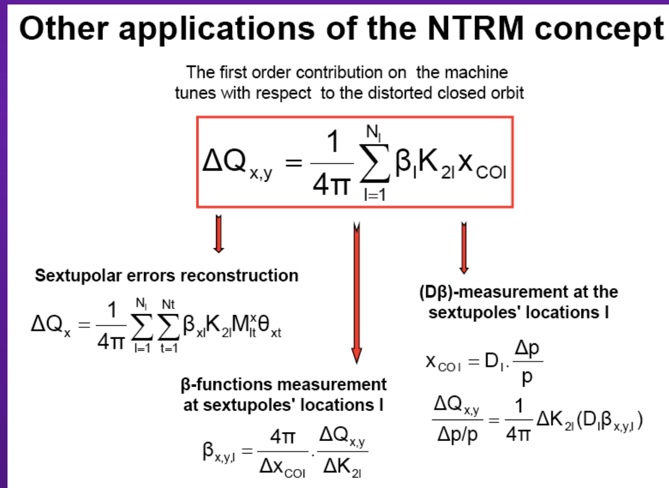
1) Benchmark HEADTAIL with PATRIC for coasting and/or very long bunches. Discussions ongoing, in particular on the modeling of the betatron phase advance

2) MDs planned in the PS with the nominal LHC beam (See A. Burov's part)

Comment: As already discussed, one should implement the multi-turn wake in HEADTAIL

SUMMARY (6/18)

- **Measurement of nonlinear field components in SIS-18 (A. Parfenova)**
  - Tune measurements are preferable than orbit measurements due to errors etc.
  - Experimental validating in the SIS18 of a new technique (NTRM = Nonlinear Tune Response Matrix) to diagnose nonlinear field errors in circular accelerators, their strength and polarities
  - Other applications



➔ **Possible collaborations: Already planned MDs in the SPS with Rogelio (Test of reconstruction of localized sextupolar and octupolar errors)**

SUMMARY (7/18)

- **Measurements of adiabatic rf capture in dual rf buckets (O. Chorniy)**
  - Conservation of the longitudinal emittance is a concern for them and they have to be fast so the rf capture is a delicate process

- **Measurement of flat bunches in a dual harmonic rf system in the PS (H. Damerau)**
  - As expected, stable flat bunches have been observed during ~140 ms on the flat-top, batch of 18 bunches in h= 21/42
  - Large synchrotron frequency spread stabilizes coupled bunch oscillations visible with h1= 21 only
  - Small phase errors (~ 2º) lead to significant asymmetry of bunches →need transient beam loading compensation
  - Plan for 2009: Transient beam loading during 10→20MHz splitting (The first splitting on the flat-top for LHC25 exhibits differences along the batch. Differences in relative phasing from the head to the tail of the bunch train are suspected)

SUMMARY (8/18)

- **Instability rise-time far above the TMCI threshold: Comparison between simple theory, MOSES and HEADTAIL (Elena)**
  - **Good agreement between the 3 for the case of a SPS "short" bunch**
  - **Next step for Elena: What happens for "long" bunches (PS, *v*-factory proton driver, …)?**

SUMMARY (9/18)

- **Head-tail modes for strong space charge (A. Burov)**
  - Assumption: the space charge tune shift dominates (much bigger!) over the lattice tune spread, the synchrotron tune and the wake-driven tune shif
  - The paper is accepted by Phys. Rev. ST-AB; it can be found at http://arxiv.org/abs/0812.3914
  - D. Möhl and H. Schönauer (1974) ➔ "rigid beam approximation (rigid slice, frozen space charge). According to him, for the strong space charge, the rigid-beam approximation is justified for the bunched beam as well
  - TMCI is shown to have high threshold due to a specific structure of the coherent spectrum of the space charge modes (the most affected lowest mode has no neighbor from below…)
  - Comment: I can understand this for coupling between modes 0 and -1 but I expect small effect of space charge for higher order mode coupling as it is the case in the SPS (and similarly for the effect of a flat chamber) ➔ To be seen

SUMMARY (10/18)

➔ **Possible collaborations:**

1) Re-do the SUSSIX analysis of the HEADTAIL simulations (a la Benoit) in the case of the SPS TMCI with SC ➔ Diego. We expect to see the same shifts of the coherent modes a low intensity and then a possible change when intensity increases. However, it will not be the strong space charge regime of A. Burov
2) Planned MDs in the SPS (TMCI at injection) with larger transverse emittances (if controlled transverse emittance blow-up works in the PSB!)
3) Planned MDs in the PS (head-tail on the long injection flat bottom) with larger transverse emittances (if controlled transverse emittance blow-up works in the PSB!)

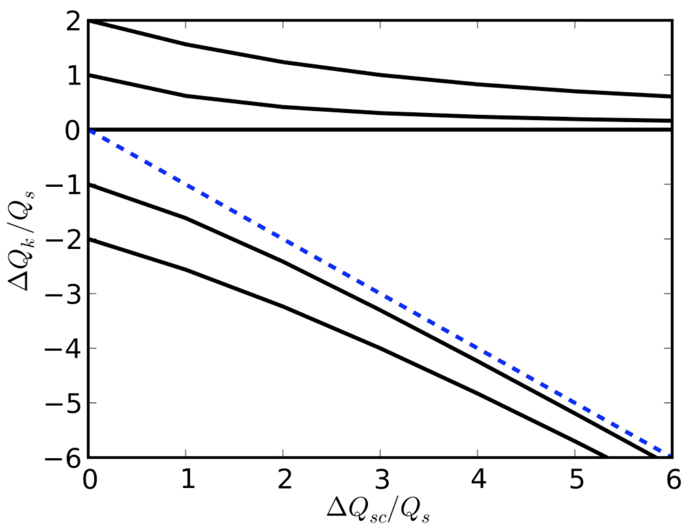
SUMMARY (11/18)

- **Transverse Schottky signals and decoherence with space charge (O. Boine-Frankenheim)**
  - **Schottky spectra of coasting beams with space charge**
  - **Transverse Schottky spectrum from bunched beams**
  - ➔ **Head-tail modes with space charge**
  - **Transverse decoherence of kicked bunches with space charge**

Shift of head-tail modes with space charge

M. Blaskiewicz, Phys. Rev. ST Accel. Beams 1, 044201 (1998)

for a barrier air-bag distribution.



For k≠0: $\Delta Q_k = -\frac{\Delta Q_{sc}}{2} \pm \sqrt{(\Delta Q_{sc}/2)^2 + (kQ_s)^2}$

Weak space charge:

$\Delta Q_{sc} \ll Q_s$ $\qquad \Delta Q_k = -\frac{\Delta Q_{sc}}{2} \pm kQ_s$

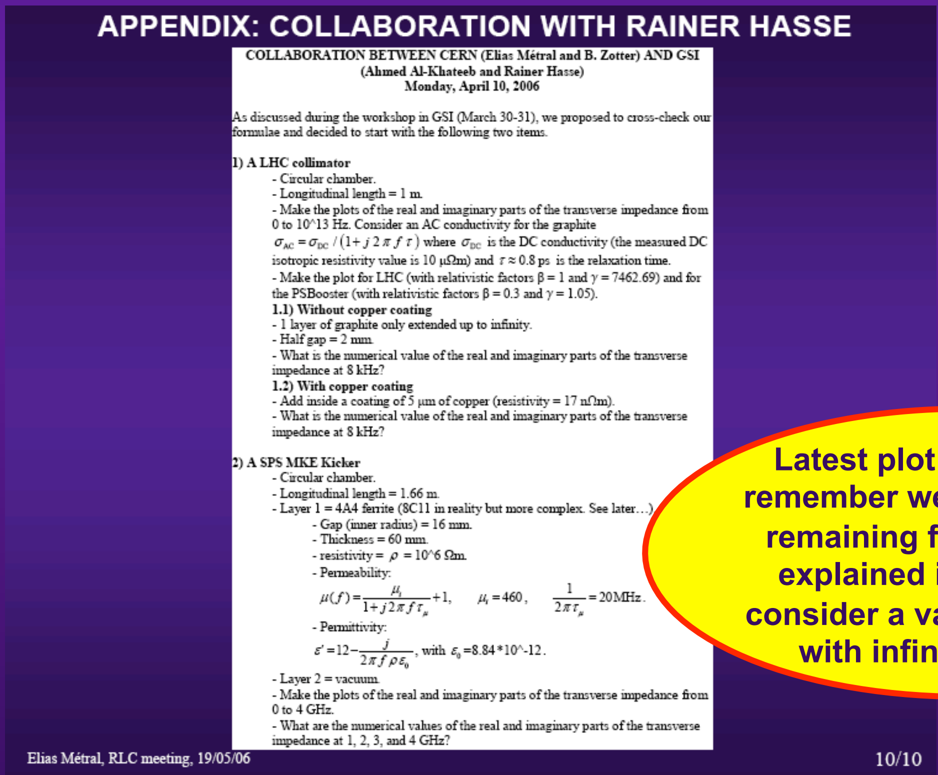
Strong space charge:

$\Delta Q_{sc} \gg Q_s$ $\qquad \Delta Q_k = \frac{(kQ_s)^2}{\Delta Q_{sc}} \approx 0, \quad \text{for} \quad k > 1$

$\Delta Q_k = -\Delta Q_{sc}, \quad \text{for} \quad k < 1$

SUMMARY (12/18)

- **News on the transverse wall impedance at low frequencies (Elias)**
  - **"Wall" impedance instead of "resistive-wall" impedance**
  - **Question from R. Hasse: Do we know where the difference observed in the past comes from? Answer: No follow-up**
  - **Reminder: Collaboration planned in 2006 after the GSI-CERN workshop**



APPENDIX: COLLABORATION WITH RAINER HASSE

COLLABORATION BETWEEN CERN (Elias Métral and B. Zotter) AND GSI (Ahmed Al-Khateeb and Rainer Hasse) Monday, April 10, 2006

As discussed during the workshop in GSI (March 30-31), we proposed to cross-check our formulae and decided to start with the following two items.

1) A LHC collimator

- Circular chamber.
- Longitudinal length = 1 m.
- Make the plots of the real and imaginary parts of the transverse impedance from 0 to 10^13 Hz. Consider an AC conductivity for the graphite $\sigma_{AC} = \sigma_{DC} / (1 + j\, 2\pi f \tau)$ where σ_{DC} is the DC conductivity (the measured DC isotropic resistivity value is 10 μΩm) and $\tau \approx 0.8$ ps is the relaxation time.
- Make the plot for LHC (with relativistic factors β = 1 and γ = 7462.69) and for the PSBooster (with relativistic factors β = 0.3 and γ = 1.05).

1.1) Without copper coating

- 1 layer of graphite only extended up to infinity.
- Half gap = 2 mm.
- What is the numerical value of the real and imaginary parts of the transverse impedance at 8 kHz?

1.2) With copper coating

- Add inside a coating of 5 μm of copper (resistivity = 17 nΩm).
- What is the numerical value of the real and imaginary parts of the transverse impedance at 8 kHz?

2) A SPS MKE Kicker

- Circular chamber.
- Longitudinal length = 1.66 m.
- Layer 1 = 4A4 ferrite (8C11 in reality but more complex. See later…).
  - Gap (inner radius) = 16 mm.
  - Thickness = 60 mm.
  - resistivity = ρ = 10^6 Ωm.
  - Permeability:

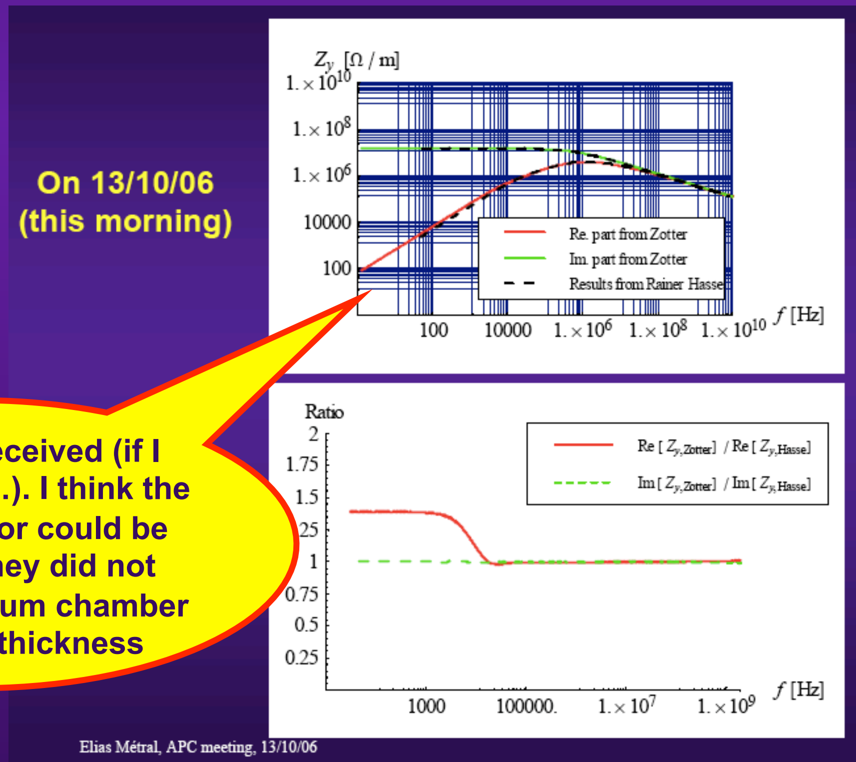
$$\mu(f) = \frac{\mu_i}{1 + j 2\pi f \tau_\mu} + 1, \qquad \mu_i = 460, \qquad \frac{1}{2\pi \tau_\mu} = 20\,\text{MHz}.$$

  - Permittivity:

$$\varepsilon' = 12 - \frac{j}{2\pi f \rho \varepsilon_0}, \text{ with } \varepsilon_0 = 8.84*10\text{^-}12.$$

- Layer 2 = vacuum.
- Make the plots of the real and imaginary parts of the transverse impedance from 0 to 4 GHz.
- What are the numerical values of the real and imaginary parts of the transverse impedance at 1, 2, 3, and 4 GHz?

Elias Métral, RLC meeting, 19/05/06 10/10



Latest plot I received (if I remember well…). I think the remaining factor could be explained if they did not consider a vacuum chamber with infinite thickness

SUMMARY (13/18)

- **Wake-fields for non-relativistic bunches (D. Quatraro)**
  - Longitudinal non ultra-relativistic wake has been calculated (still some problems with traversal one)
  - A new model for the non ultra-relativistic wake BB has been introduced
  - Beam dynamics studies

→ Possible collaboration: Benchmark of Diego's formulae with CST Particle Studio with $\beta \neq 1$, when available

SUMMARY (14/18)

- **Simulation of impedances with Particle Studio (L. Hänichen)**
  - Comparison between simulations and analytical estimates from Al. Khateeb et al.
  - Was devoted mainly to longitudinal impedance (smooth and corrugated pipes)
  - Christian reminded us that there are corrugated beam pipes in the bending magnets of the PSB

→ Possible collaboration: It started already with Benoit and Carlo

Comment: We believe it could be a good idea to organise a workshop at some point (~ end of the year or beginning of next year) on impedances and wake-fields: theory, measurements and simulations (procedures in time and frequency domain to disentangle dipolar and quadrupolar impedances…)

SUMMARY (15/18)

- **1) Simulations and RF Measurements of SPS Beam Position Monitors and 2) Particle Studio simulations of the resistive wall impedance of copper cylindrical and rectangular beam pipes (Benoit)**
  - **1)**
    - **Very good agreement between time domain, frequency domain, eigenmode, and bench RF measurements**
    - **Next: Obtain dipolar and quadrupolar impedances and re-launch HEADTAIL simulations for the SPS bunch**

SUMMARY (16/18)

- 2)
  - A factor 4.4 is observed between the amplitude of simulated wakes and theoretical wakes
  - This amplitude factor aside, we have separated the dipolar and quadrupolar terms in the rectangular shape, and they agree with the theory
  - The simulated wakes obtained for several rectangular shape form factors also agree with the theoretical curve
  - Issues with cylindrical shape
  - Coupling and non linear terms vs. transverse offsets

SUMMARY (17/18)

- **Discussions → Talk by V. Kapin: Status of Space-Charge Simulations with MADX**
  - **Question from G. Franchetti: How many people use PTC at CERN?. After discussion with Gianluigi (after the workshop), it seems that not only "many" people are using it but in addition it has been decided to use it for machines with energies smaller than the one of the PS**
  - **Comment from Oliver: He mentioned that there were some discussions about MAD, which could be given to a professional company**
  - **Initial plans for S.C. in 2006**

From "V.Kapin: Plans for PTC modules in 2006"[1] .
(MADX meeting 20 March 2006, CERN, Geneva)

Two options are discussed – "inserting BB-kicks" & with PTC-library:
I.a) usage a "linear" kick-matrix for Twiss parameters (b);
I.b) a space-charge kicks from "frozen beam" during tracking;

II) Model using a new PTC elements (many "Beam-Beam")

For the option II:

- Beam-beam element for PTC (coding by E.Forest)
- MADX PTC tracking with a space-charge kicks inside thick elements (even with fill-turn maps)

SUMMARY (18/18)

Present Status

With the option I -> for FAIR SIS100:

"Benchmarking of sp.-charge induced loss in SIS100 ring"

"DA with Octupoles (for Landau damping) in SIS100"

- **BB in MADX-PTC** (option II)
  => non-linear maps including s.c. (inside "thick elements")
  => non-linear maps of a whole ring.
  => all the map formalism & Normal Forms.
  Status: 1) BB are in PTC-library (done by E.Forest)
  2) interfacing with MADX -> ??? (manpower required)

- **Other possible collaborations**
  - **Montague in a machine where one can have both split and unsplit tunes (PSB or SPS?)**