

SUMMARY OF WORKING GROUP A: BEAM DYNAMICS IN HIGH-INTENSITY CIRCULAR MACHINES

G. Franchetti (GSI) and E. Métral (CERN)

- ◆ **22+1 (excellent) talks!**
 - **ASIA: 4 (1 IHEP Beijing, 1 J-PARC, 2 KEK)**
 - **EU: 10+1 (4+1 CERN&EPFL, 4 GSI, 1 FZJ, 1 RAL)**
 - **USA: 8 (1 BNL, 5 FNAL, 1 ORNL, 1 UMD)**
- ◆ **Overall program**
- ◆ **Summary by talks**
- ◆ **Discussion session**

Overview Program HB2010

Monday 27.09.10			Tuesday 28.09.10		Wednesday 29.09.10		Thursday 30.09.10		Friday 01.10.10
Saal 2			Saal 1	Saal 2	Saal 1	Saal 2	Saal 1	Saal 2	PSI Auditorium
8:45	Opening Remarks M. Seidel, PSI		Announcement		Announcement		Announcement		
8:55	Welcome, K. Clausen, PSI		V. Kain, CERN		V. Balbekov, Fermilab		J. Rodnizki, Soreq NRC		Transfer to PSI
9:10	R. Sheffield, LANL		J. Wenninger, CERN		V. Komilov, GSI		M. Ikegami, KEK		8.15 h departure
9:55	C.R. Prior, STFC/RAL/ASTeC		H. Hotchi, JAEA/J-PARC		S. Wang, IHEP Beijing		A.P. Shishlo, ORNL		
10:30			A.C. Menger, PSI		K. Ohmi, KEK		S.G. Yaramyshev, GSI		
10:45	Coffee								Summary Talks
11:00	J. Galambos, ORNL								
11:35	T. Koseki, KEK								Coffee
12:10	R.W. Assmann, CERN								
12:45									
13:00									
13:15									Summary Talks
13:30	Lunch								
13:45									
14:00									
14:30	P. Spiller, GSI								
15:05	J. Tang, IHEP Beijing								Lunch
15:40	W. Leemann, LBNL								
16:15	Poster Session	Discussion Laser Acceleration	14:15 Y.Shobuda, JAEA/J-PARC		E.B.Holzer, CERN		T. Baer, CERN		
16:45			N. Mounet, EPFL		C.Gabor, STFC/RAL/ASTeC		B.L. Beaudoin, UMD		
17:15			A.V. Burov, Fermilab		P. Forck, GSI		A.V. Fedotov, BNL		
17:30			E.N.Shapostnikova, CERN		J.M. Carmona, CIEMAT		K.Y. Ng, Fermilab		PSI Tour
17:45	Refreshments		15:35		Coffee		Coffee		
18:00			15:50						
18:15	Poster Session		16:05 S. Parek, GSI		K. Satou, J-PARC/KEK		V.A. Lebedev, Fermilab		Coffee
18:30			V.V. Danilov, ORNL		M. Wendt, Fermilab		Y. Senichev, FZJ		
18:45									
			Working Group B&D		Working Group D		Working Group A		Departure to Morschach or individual departure to Airport
			J.-B.Lallement, CERN		A.V. Aleksandrov, ORNL		S. Nagaitsev, Fermilab		
							S. Aumon, EPFL		
							O. Chorniy, GSI		
							+ H. Damerau, CERN		

17.30 - 19.20 h Bus transfer / to cable car station

19.00 h. Apéro

20.00 h Dinners

Working Groups

WG-A	Beam Dynamics in High-Intensity Circular Machines
WG-B	Beam Dynamics in High-Intensity Linacs
WG-C	Accelerator System Design, Injection, Extraction
WG-D	Commissioning, Operations and Performance
WG-E	Computational Challenges in High-Intensity Linacs, Rings including FFAGs and Cyclotrons
WG-F	Beam Diagnostics and Instrumentation for High-Intensity Beams
WG-G	Beam Material Interaction
	Discussion or Joint Discussion Session

PROGRAM

- 1) Yoshihiro Shobuda (J-PARC): shobuda@post.kek.jp => Coupling impedances of a short insert in the vacuum chamber
- 2) Nicolas Mounet (EPFL): Nicolas.Mounet@cern.ch => News on the 2D wall impedance theory
- 3) Alexey Burov (FNAL): burov@fnal.gov => Van Kampen modes for bunch longitudinal motion (notion of radical loss of Landau damping)
- 4) Elena Shaposhnikova (CERN): Elena.Chapochnikova@cern.ch => Longitudinal peak detected Schottky spectrum
- 5) Stefan Paret (GSI): S.Paret@gsi.de => Transverse Schottky and BTF measurements in space charge affected coasting ion beams
- 6) Slava Danilov (SNS): danilovs@ornl.gov => Studies of the effect of 2nd harmonic on the e-p instability and RF control on instabilities
- 7) Valeri Balbekov (FNAL): balbekov@fnal.gov => Effect of space charge on instabilities
- 8) Vladimir Kornilov (GSI): v.kornilov@gsi.de => Head-tail bunch dynamics with space charge
- 9) Sheng Wang (IHEP Beijing): wangs@ihep.ac.cn => The study of space charge effects for RCS/CSNS
- 10) Kazuhito Ohmi (KEK): ohmi@post.kek.jp => Simulation of space charge effects in JPARC
- 11) Alexander Molodozhentsev (KEK): alexander.molodozhentsev@kek.jp => Results from the commissioning of the JPARC Main Ring
- 12) Giuliano Franchetti (GSI): g.franchetti@gsi.de => Long term simulations of the space charge and beam loss in the SIS18 experiment
- 13) Christopher Warsop (RAL): chris.warsop@stfc.ac.uk => High intensity studies on the ISIS synchrotron, including key factors for upgrades and the effects of the $\frac{1}{2}$ integer resonance
- 14) Tobias Baer (CERN): Tobias.Baer@cern.ch => Tune resonance phenomena in the SPS and related machine protection
- 15) Brian Beaudoin (UMD): sabern@umd.edu => High intensity beam physics at UMER
- 16) Alexei Fedotov (BNL): fedotov@bnl.gov => Interplay of space charge and beam-beam in colliders
- 17) K.Y. Ng (FNAL) => Application of a localized chaos generated by RF-phase modulations in phase-space dilution
- 18) Valeri Lebedev (FNAL): val@fnal.gov => Optical stochastic cooling in Tevatron
- 19) Yuriy Senichev (FZJ): y.senichev@fz-juelich.de => Electron cooled beam losses phenomena in COSY
- 20) Sergei Nagaitsev (FNAL): nsergei@fnal.gov => Nonlinear optics as a path to high-intensity circular machines
- 21) Sandra Aumon (EPFL): Sandra.Aumon@cern.ch => Transverse mode coupling instability measurements at transition crossing in the CERN-PS
- 22) Oleksander Chorniy (GSI): O.Chorniy@gsi.de => Fast compression of intense heavy ion bunches in SIS18
- 23) Heiko Damerau (CERN): heiko.damerau@cern.ch => Longitudinal performance with high-intensity beams for LHC in the CERN PS

Coupling impedances of a short insert in the vacuum chamber (**Yoshihiro Shobuda**)

- ◆ **3D (finite length) theory of a “short” (wrt beam pipe radius) resistive insert, sandwiched by perfectly conducting chambers**
- ◆ Theory benchmarked against ABCI (upgraded to handle a resistive material inside a cavity)
- ◆ **Nature tries to minimize the beam energy loss! => Entire image current runs on the thin insert (i.e. still perfect shielding) except when the skin depth is more than several orders of magnitude larger than the pipe thickness**
- ◆ If the insert length $> \sim$ beam pipe radius => The 2D theory (e.g. Zotter2005, BurovLebedev2002...) should be a good approx.
- ◆ ***This could be applied for instance in the CERN SPS where all (~ 200) BPMs are electrically isolated by enamel flanges (one in each side)***
- ◆ ***Another 3D study was performed by Gluckstern-Zotter2008 (AB-Note-2008-045)***

News on the 2D wall impedance theory (**Nicolas Mounet**)

- ◆ **2D (infinite length) theory for both cylindrical and flat multi-layer chambers, long. and trans. (Zotter2005 formalism) => Assumptions:**
 - **Linearity, Isotropy and Homogeneity**
 - **Anomalous Skin Effect and Magneto-Resistance neglected**
- ◆ **Matrix formalism (as used already by others like Ivanyan2008 and Hahn2010) => Only need to multiply N-1 (relatively) simple 4x4 matrices and invert the final result, to get the constants => # of layers no longer an issue**
- ◆ **Comparison with other formalisms ongoing, codes available**

CYLINDRICAL

- **Notion of wall impedance (instead of resistive-wall impedance)**
- **New quadrupolar term (usually considered only for asymmetric chambers)**

FLAT

- **Transverse quadrupolar terms in general not opposite in sign**
- **Generalized Yokoya factors (material and frequency-dependent)**

Van Kampen modes for bunch longitudinal motion

(Alexey Burov)

- ◆ In 1955, N. G. Van Kampen found the eigen-system of Jeans-Vlasov equation for infinite plasma => Van Kampen modes are the numerical solutions: The spectrum consists of a continuous and discrete (which may not exist) parts
- ◆ Eigen-modes of Jeans-Vlasov equation for bunch longitudinal motion were first considered by A. N. Lebedev in 1968
- ◆ This method can be applied for an arbitrary impedance, RF shape and beam distribution function => It was applied here for the case of the resistive-wall impedance, considering only the dipole azimuthal mode $m = 1$. Stability areas (intensity - emittance) were found for 3 RF modes (single RF system, BS and BL modes)
- ◆ Loss of Landau damping (which results as phase mixing of Van Kampen modes of the continuous spectrum) => 2 possibilities:
 - Discrete mode inside bucket => Some tails can help
 - Discrete mode outside => Radical loss of Landau damping

Longitudinal peak detected Schottky spectrum (Elena Shaposhnikova)

- ◆ The “peak detected Schottky” is a diagnostics tool developed by D. Boussard and T. Linnecar and used in the SPS since the late 70s
- ◆ The quadrupole line was always believed to represent well the particle distribution in synchrotron frequencies
- ◆ A detailed analysis revealed that ideally (case corresponding to the detection of the bunch peak amplitude), it would be very close to the particle distribution in synchrotron frequencies, similar to the spectrum in revolution frequencies obtained for an unbunched beam
=> Much closer than that given by the traditional longitudinal bunched-beam Schottky spectrum
- ◆ In reality, the measured peak detected signal is proportional to an average over the bunch current around its peak value
- ◆ The difference mainly depends on the phases over which the bunch current averaging is performed

Transverse Schottky and BTF measurements and simulations in space-charge affected coasting ion beams (**Stefan Paret**)

- ◆ **Scan vs. intensity measured in SIS18 => Deformations of the Schottky spectra and of the BTFs were observed**
- ◆ **An analytic model with linear space charge (KV distribution, i.e. homogeneous beam profile) was employed to describe the deformed signals => Reminder: linear SC is different from impedance!**
 - **Very good agreement with Schottky data**
 - **Very good agreement with BTF data at low intensity. At high intensity deviations from the model are observed**
 - **The stability diagrams obtained from the BTFs are shifted and shaped by space charge as expected (noise at high intensity)**
- ◆ **The (small) differences observed between measurements and theory does not come from the linear space charge model as it was confirmed by PIC simulations**
- ◆ ***To be done with bunched beams but no solid theory...***

Studies of the effect of 2nd harmonic on the e-p instability and RF control on instabilities (**Slava Danilov**)

- ◆ **Reminder for e-p instability mitigation: Electron collection near stripper foil + coating of all pieces of VC with TiN + Solenoids near the regions with high loss + Clearing electrode near the stripper foil + Electron detectors for electron accumulation study**
- ◆ **1st obs. with $\sim 1\text{E}14$ p few years ago => Dominated by e-p instability**
- ◆ **Strong dependence on RF configuration => Possible explanation: e-accumulation dependence on long. distribution of the p bunch**
- ◆ **2 new parameters were introduced to study better the mechanism: Trailing edge steepness and Integrated SEY as a function of the trailing edge duration**
- ◆ **Most promising case for e-p mitigation: sharp edge, created by high-voltage barrier cavity => In this case the e- accelerated by the protons have a much higher energy (few keV) where the SEY is smaller than 1**

Effect of space charge on transverse instabilities

(Valeri Balbekov)

- ◆ **Assumptions: SC dominated regime (vs. impedance of the machine), below mode coupling**
- ◆ Cases of boxcar (Sacherer, 1972 => Bunch with constant linear density), parabolic and Gaussian distribution discussed
- ◆ **SC almost completely controls intra-bunch oscillations (head-tail modes): frequency, shape, and threshold of possible instability, but it cannot cause the beam instability itself**
- ◆ The wake field is directly responsible for this and even if it is relatively small, it controls the beam collective modes including the instability growth rate
- ◆ **There is a rigid mode which is not sensitive to SC and synchrotron oscillations for any distribution => No Landau damping (to be avoided by chromaticity)**
- ◆ Landau damping suppresses almost all intra-bunch modes if SC tune shift $< \sim$ synchrotron tune

Head-tail bunch dynamics with space charge

(Vladimir Kornilov)

- ◆ **Assumptions: Single-bunch, below mode coupling, case of SIS100 on the injection plateau with a SC tune shift of -0.25**
- ◆ **Non-realistic “airbag” bunch of Blaskiewicz1998 is a very useful model, as a very good agreement with PIC codes were found (PATRIC + HEADTAIL) using Gaussian bunch => Bunch form is not so important. *This is the case also without SC (e.g. Laclare1987)***
- ◆ **Predictions of Landau damping by SC (only!), by Burov2009 and Balbekov2009, are confirmed by simulations. The eigenfunctions from simulations and theories with Gaussian or water-bag bunches are very similar. *Seem to be the same as without SC (Sacherer)***
- ◆ **Above a certain SC, the instability growth rate saturates (to a value close to the case without SC) => Could explain why the mode $|m| = 6$ was observed in the past with a very large SC (~ -0.25)**
- ◆ **It is also seen from simulations that increasing SC, a head-tail instability can change its mode => See discussion session**

The study of space charge effects for RCS/CSNS

(Sheng Wang)

- ◆ **Circumf = 228 m, 4 superperiods, max. SC tune shift = -0.28**
- ◆ Injection performed within a long drift space => Anti-correlated painting is adopted. *It was mentioned that correlated painting is sometimes better with SC to end up with a constant density (as a significant beam halo could be produced)*
- ◆ **Design benefits from the commissioning of exiting spallation neutron sources: Trim Q design, chromaticity correction, transverse collimation, momentum collimation...**
- ◆ Several space charge effects were studied (including the Montague resonance) with ORBIT and SIMPSONS. *It was reminded to be careful when using KV distributions as some artifacts could be introduced*
- ◆ **The combined effects of space charge and sextupoles were in particular studied, as the conclusion is important for the chromaticity correction design**

Simulation of space charge effects in JPARC (**Kazuhito Ohmi**)

- ◆ **Target for J-PARC: 1 MW in RCS and 750 kW in MR**
- ◆ **KO developed a new code (SCTR) for that**
- ◆ **Long term simulation => 20ms for RCS and 1s for MR**
- ◆ **Main results for RCS:**
 - **KV distribution is broken an early stage of the simulation**
 - **The realistic painting process will be done in the simulation**
- ◆ **Main results for MR:**
 - **750 kW is very hard already with the ideal lattice**
 - **Higher probability for 0.75Hz (instead of 0.45 Hz) RepRate**

Results from the commissioning of the JPARC Main Ring (Alexander Molodozhentsev)

- ◆ **Studies of resonance-induced beam losses for the Main Ring (maximum power lost 450W)**
- ◆ **Computational model as realistic as possible: all magnet nonlinear components and field leakage from injection septum + 6D beam distribution => 2 studies:**
 - **MR at low power (single particle) => Experimental and numerical tune scans to identify the main resonances (most critical is sum $Q_x + Q_y = 43$)**
 - **Origin: CO distortion on sextupoles**
 - **Exercise: Controlled deformation of CO orbit in sextupoles to create linear coupling + compensation scheme => Works!**
 - **MR with moderate power => Try and find the best working point and there is a good agreement between simulations and measurements**

Long term simulations of the space charge and beam loss in the SIS18 experiment (**Giuliano Franchetti**)

- ◆ Detailed simulations of emittance evolution and beam survival of several beam conditions present a reasonable agreement with the correspondent measurement
- ◆ These measurements are consistent with previous findings in the CERN PS
- ◆ It is worth mentioning that in the CERN PS the $\frac{1}{4}$ order resonance was studied while in SIS18 the $\frac{1}{3}$ order was analyzed
- ◆ Numerical analyses of the resonance crossing regime suggest that a scattering is most likely the process taking place, which is consistent with the experimental data, although the latter do not give a direct evidence of the mechanism
- ◆ *Could such mechanisms play an important role in beam-beam?*

High intensity studies on the ISIS synchrotron, including key factors for upgrades and the effects of the $\frac{1}{2}$ integer resonance (**Christopher Warsop**)

- ◆ **Ring high intensity issues for an ISIS Injector Upgrade => Measurements and experiments on the ISIS Ring**
- ◆ **Transverse dynamics: Working Points + Simulation studies of space charge limit**
- ◆ **Study of the $\frac{1}{2}$ integer in vertical plane, 3rd order structure resonance, maybe due to the image charge**
- ◆ **Longitudinal dynamics: Simulation of the evolution of the Hofmann-Pedersen distribution**
- ◆ **Measurement in ISIS: Instabilities => Lifetime decreases with the intensity**
- ◆ **Storage ring mode experiments: $\frac{1}{2}$ integer studies. For a fixed tune the intensity was increased and beam loss have been measured**

Tune resonance phenomena in the SPS and related machine protection (**Tobias Baer**)

- ◆ **SPS incident on June 27th, 2008 => Hole made after beam impact of high-intensity beam ($\sim 3E13$ p @ 400 GeV/c = 2 MJ)**
- ◆ **Tune resonance phenomena were then studied in detail**
 - **By a linear decrease of Q, a complete beam loss can be achieved in 3 turns (i.e. ~ 70 micros) => Diverging CO. Note that the intensity is measured with BPM, as BCT is too slow**
 - **Going faster it is possible to cross $Q = 26$ with almost no loss, but huge oscillations**
 - **With the fastest speed we could in fact reach the super-periodic resonance $Q = 24$, which is much larger than the others**
- ◆ **For the machine protection => New Fast Position Interlock: 6 BPMs with new HW using logarithmic amplifiers (large dynamic range), turn-by-turn interlock processing via FPGA, in commissioning...**



High intensity beam physics at UMER (**Brian Beaudoin**)

- ◆ **Increase of the performance from ~100 turns to ~1000 turns, since last HB**
- ◆ **Status report**
 - **Systematic study of the transverse resonances and beam survival => Scan vs. intensity (space charge)**
 - **Studies of longitudinal dynamics and the need for confinement (otherwise the beam structure disappears after ~ 100 turns)**
- ◆ **Next steps: Optimize the longitudinal confinement to continue other studies, such as improvement of the injection matching etc.**

Interplay of space charge and beam-beam in colliders

(Alexei Fedotov)

- ◆ **Low-Energy RHIC (to search for QCD phase transition critical point) requires the use of e- cooling for luminosity upgrade => Space charge and beam-beam simultaneously present for a long time (high order resonance are very important in colliders!). Issue: Interplay between the 2, which is largely unexplored?**
- ◆ **What is the acceptable space-charge tune shift for a long beam lifetime with collision?**
- ◆ **APEX campaigns in 2009-2010: Several combinations of space charge and beam-beam strength => First observations which need to be interpreted on numerical and theoretical bases**
- ◆ **=> This is a new field which involves 2 different areas**

Application of a localized chaos generated by RF-phase modulations in phase-space dilution (**K.Y. Ng**)

- ◆ **Motivation: Very small bunch at ALPHA (20 m e- storage ring, under construction at Indiana University) is to be extended to 40 ns, and a RF barrier bucket is too costly**
- ◆ **An alternative method is proposed: Create an RF phase modulation to generate a large chaotic region at the center of the RF bucket**
- ◆ **The tiny bunch is immersed into a stochastic layer. The method require a large modulation amplitude so to form a large chaotic area, and that the initial position of the tiny bunch is inside part of this chaotic region**
- ◆ **This is obtained by offsetting the relative phases of the 2 RF systems**
- ◆ **The method allows to find all the parameters to reach a uniform density bounded in phase space**

Optical stochastic cooling in Tevatron (**Valeri Lebedev**)

- ◆ **Average luminosity is limited by the IBS => Larger beam brightness results in a faster luminosity decay**
- ◆ It is impossible to make a significant improvement (~2 times) without beam cooling in Tevatron. 10-20% is still possible (new tunes, larger intensity beams)
- ◆ **Optical stochastic cooling proposed**
 - Suggested by Zolotorev, Zholents and Mikhailichenko (1994) but never tested experimentally
 - Same as normal stochastic cooling except the much larger BW (~ 200 GHz) => Undulators replace PU and Kicker
- ◆ **VL extended the theory => Sum of the cooling rates is proportional to the kicker-to-pickup M56 coeff.**
- ◆ OSC cannot be introduced in 2-3 years, but looks feasible in 5-6 years. For the moment an extension of Tevatron to 2014 is discussed
- ◆ **Could not be useful in the LHC as it is not IBS driven (SR already)**

Electron cooled beam losses phenomena in COSY

(Yurij Senichev)

- ◆ The COSY ring is operating for medium energy experiments in the energy range 45-2500 MeV
- ◆ 2 different methods to measure the acceptance of the COSY => Either the machine acceptance was overestimated in the beam lifetime calculation, and the actual machine acceptance for a cooled beam is significantly lower or the e- beam affect the p-beam stability => This has been investigated in detail
- ◆ Reminder: An e- beam can not only cool an ion beam, but also heat it up (Reistad1993)
- ◆ Nonlinear e- lenses of a polynominal approximation of the e- force
- ◆ With this modelization => Systematic study of the DA for the p beam:
(1) Monochromatic p beam, (2) p beam with momentum spread and
(3) e- beam off centre
- ◆ => The e- beam is the main reason of decreased DA in COSY

Nonlinear optics as a path to high-intensity circular machines

(Sergei Nagaitsev)

- ◆ Richter1965 => 1st mention of an octupole for Landau Damping (as a linear accel. has a “non steep” Hamiltonian, subject to instability)
- ◆ Presently, most accelerators rely on both LD and Feedbacks and there is always a trade-off between LD (nonlinearities) and DA
- ◆ However, another design using “steep” Hamiltonians (i.e. very stable system) can provide “infinite” LD (in transverse planes)
- ◆ 1st paper on the subject by Nikolay Nekhoroshev in 1971
- ◆ Non-linear 2-D “steep” Hamiltonians (i.e. very stable) that can be implemented in an accelerator have been found (1st examples of completely integrable non-linear optics!). Main issue is that in 2-D the fields of non-linear elements are coupled by the Laplace equation
- ◆ The potentials should satisfy Laplace equation in addition to Darboux1901’s one
- ◆ Current proposal to build a machine at Fermilab (POP experiment)

Transverse mode coupling instability measurements at transition crossing in the CERN-PS (**Sandra Aumon**)

- ◆ **Motivations:** Understand the dynamics of the fast instability at transition (\sim no synchrotron motion) with/without gamma jump. Improve stability of high intensity beams with gamma jump without compromising the longitudinal density (which is done at the moment). Predict also transverse stability of the ultimate LHC beam
- ◆ Measurements without gammat-jump \Rightarrow Vertical instability appears 2 ms after transition, TW with high-frequency (~ 700 MHz)
- ◆ **HEADTAIL** simulations revealed a good agreement with a Broad-Band model with a transverse shunt impedance of ~ 1.4 M Ω /m. Note that in 1989 coherent tune shifts measurements revealed an impedance of ~ 3 M Ω /m (but it was dipolar + quadrupolar!) \Rightarrow Next step: improve the impedance model
- ◆ Measurements with gammat-jump \Rightarrow Instability appears after, why?
- ◆ **Next step: Implement the gammat-jump in HEADTAIL**

Fast compression of intense heavy ion bunches in SIS18

(Oleksander Chorniy)

- ◆ Simulations have been recently benchmarked with measurements
 - ◆ Bunch compression (performed at top energy with 2 new ferrite cavities) and phase space reconstruction by tomography => It revealed that the bunch compression could be improved
 - ◆ RF capture at injection energy => Space charge does not produce longitudinal emittance growth during RF capture

Longitudinal performance with high-density beams for LHC in the CERN PS (**Heiko Damerau**)

- ◆ **Motivations: Intensity and beam quality limitations not fully understood yet. Improvements required for ultimate beam for LHC**
- ◆ 24 RF cavities from 2.8 to 200 MHz => Many potential impedance sources
- ◆ **The following machine (SPS) imposes to accelerate with a fixed longitudinal density**
- ◆ Coupled-bunch mode spectra during acceleration remains the same
- ◆ **However, at top energy it becomes very different => Time dependent driving impedance sources: The 10 MHz RF cavities**
- ◆ Cures: detuning of unused cavities, add a second gap relay to close both cavity gaps of 10 MHz cavities and feedbacks
- ◆ **New coupled-bunch instabilities with the new beam (150 ns bunch spacing) currently used to fill the LHC => 40/80 MHz RF cavities**

DISCUSSION SESSION (1/2)

- ◆ **How can we extract the Van Kampen modes from Schottky measurements?**
- ◆ In coasting-beams one can have clear Schottky signals, as in simulations for both coasting and bunched beams. However, in machines with bunched beams, it is almost always impossible (always some coherence)
- ◆ **Why/how does a head-tail mode change with intensity (space charge)? => Some recent simulations by V. Kornilov revealed this and recent measurements in the CERN PSB by G. Rumolo&Co also => To be further investigated**
- ◆ Some analytical formulae exist to predict instability thresholds for particular types of impedances (narrow-band or wide-band resonators for instance), but a theory is missing when both are taken into account. The new (semi-analytical) approach from A. Burov seems to be the best way to go

DISCUSSION SESSION (2/2)

- ◆ **Instabilities should be also discussed with associated electronic feedbacks => There is a need to discuss more closely with the feedback experts (noise issues etc. responsible for emittance growth). Including a realistic model for the different feedbacks in simulation codes is an interesting and challenging subject**

**MANY THANKS TO ALL THE PARTICIPANTS
FOR ALL THE VERY INTERESTING DISCUSSIONS!**