Report on ECLOUD'07 – Emittance Growth

S.Y. Zhang, April 27, 2007

I. RHIC proton beam emittance growth

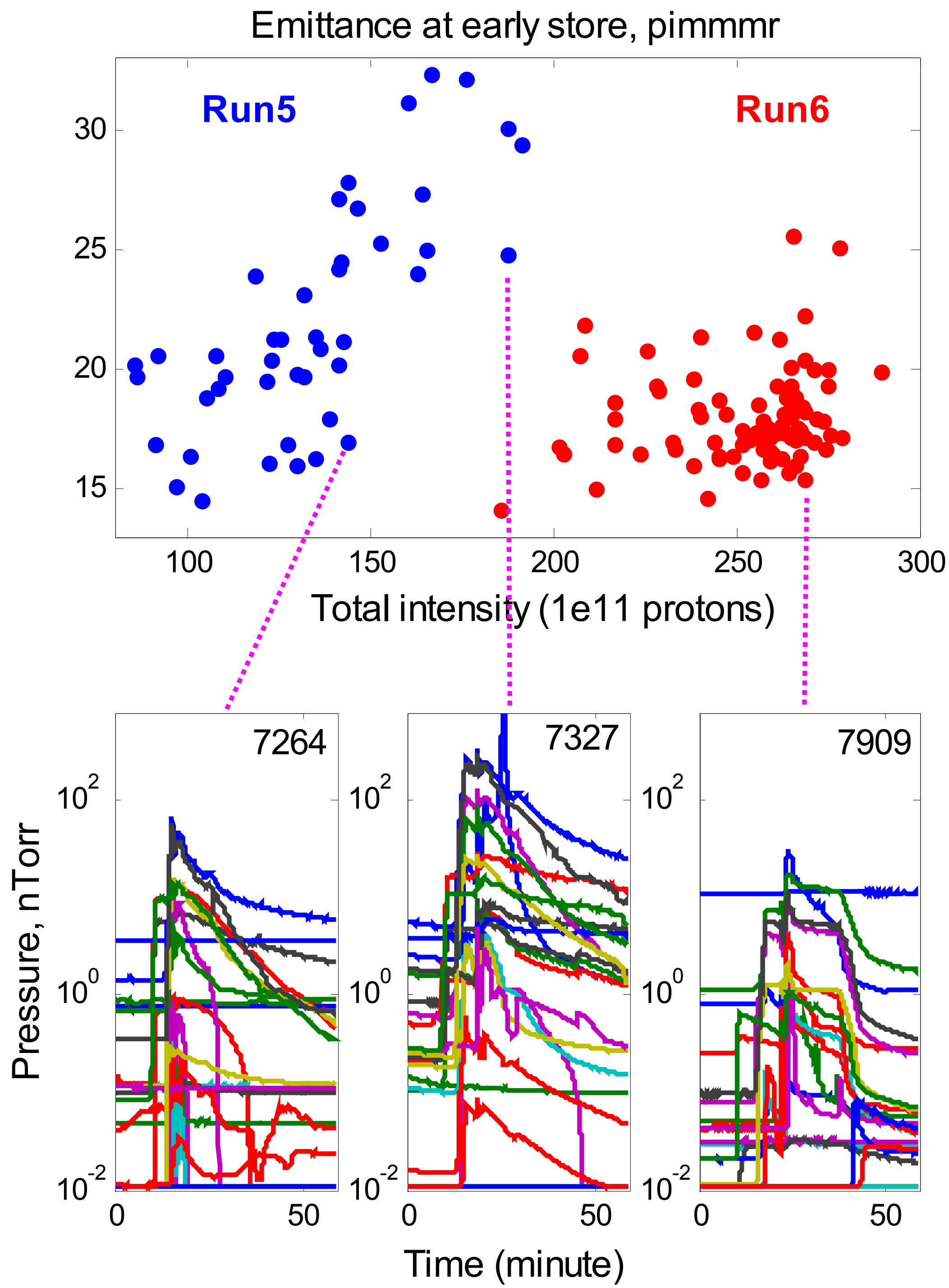
II. Observation in other machines

III. Electron cloud induced emittance growth - Simulations

I. RHIC proton beam emittance growth

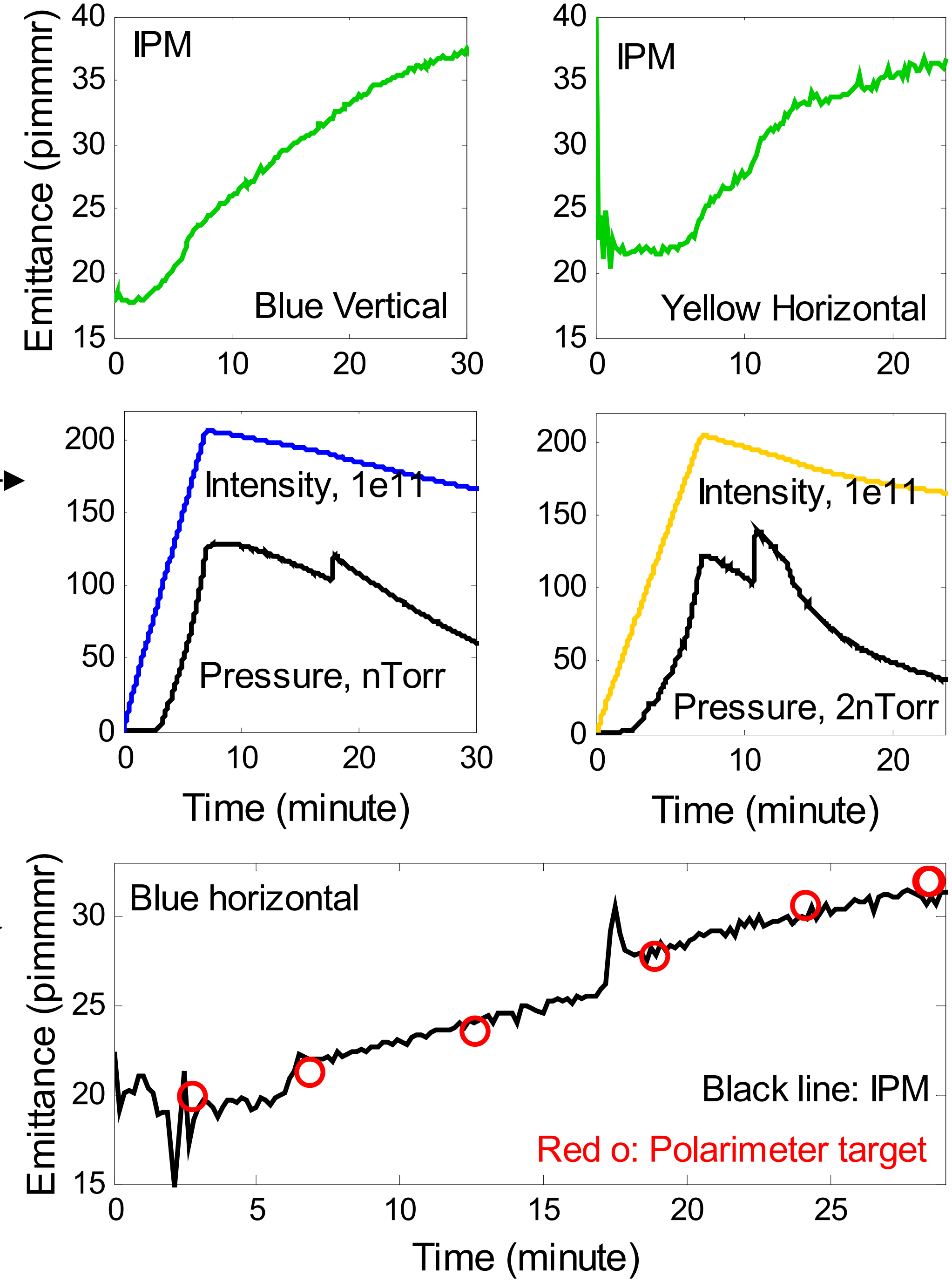
1. Dependence on pressure rise – electron cloud

- In 2005, the beam emittance growth was observed for fills with high pressure rise.
- In 2006, with improved chambers, the pressure rise was reduced, so for the emittance growth.
- Dynamic pressure rise at RHIC is mainly caused by electron cloud.



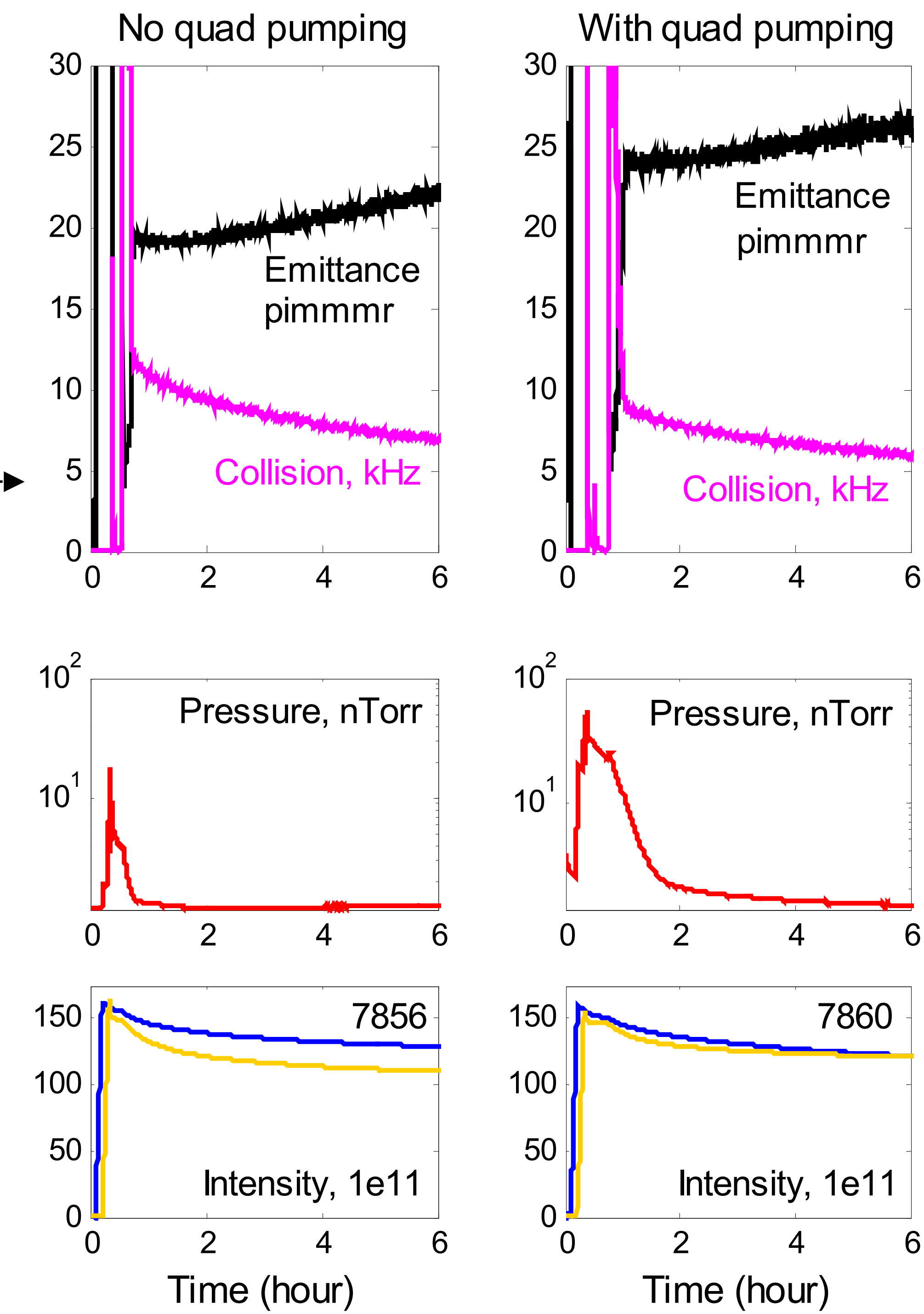
2. Beam study case

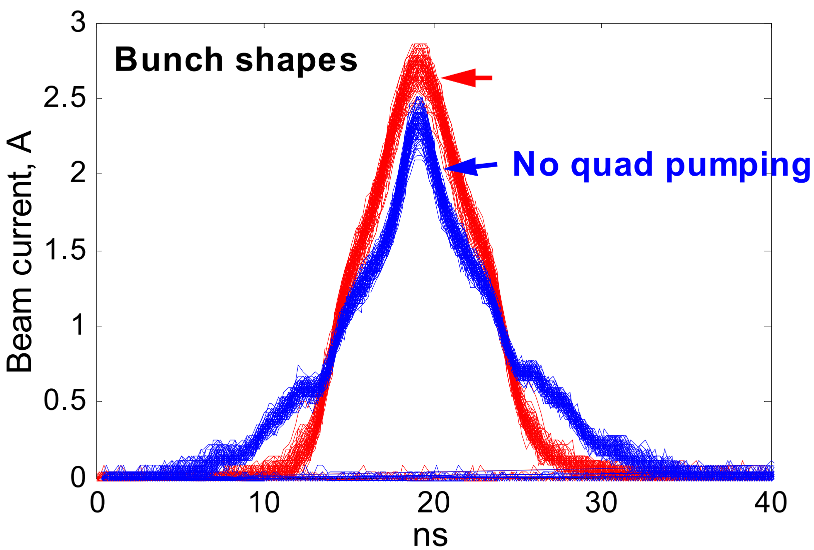
- **110 bunches with 1.9e11 per bunch injected, then the RF voltage raised from 100 kV to 300 kV.**
- **There are correlations of emittance growth and the pressure rise for both blue and yellow beams.**
- **Blue horizontal emittance also measured using polarimeter target, which agrees with the IPM emittance.**



3. Bunch length effect

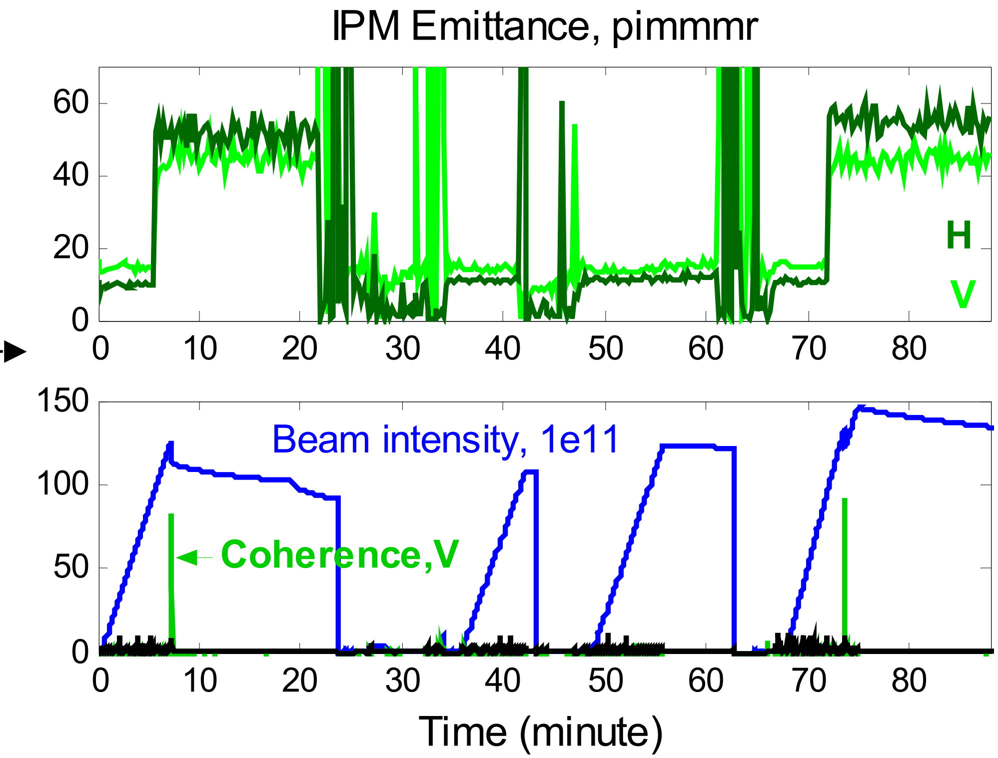
- **Shorter bunches injected into RHIC, using quad pumping at the AGS extraction.**
- **With higher peak current, the dynamic pressure rise is higher. Larger emittance growth causes about 15% luminosity reduction.**

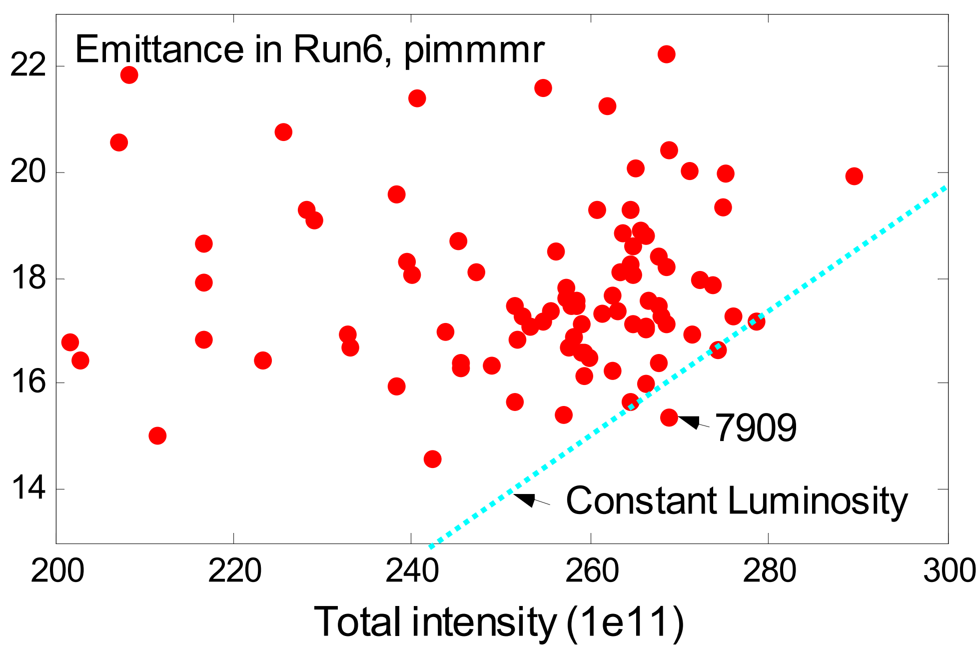




4. Emittance growth rate

- Fast emittance growth due to instability often observed at RHIC. Tap chromaticity usually cures the problem.
- Much slower and smaller emittance growth is relevant in operations. Machine tuning in later Run6 of 6 weeks was focused on ~2 $\pi\mu$m/hour of the growth.
- 7909 is the ‘Golden Fill’ in entire Run6 – 0.4 $\pi\mu$m better.
- This emittance growth is observed from ZDC, it is too small and slow to identify by instruments.

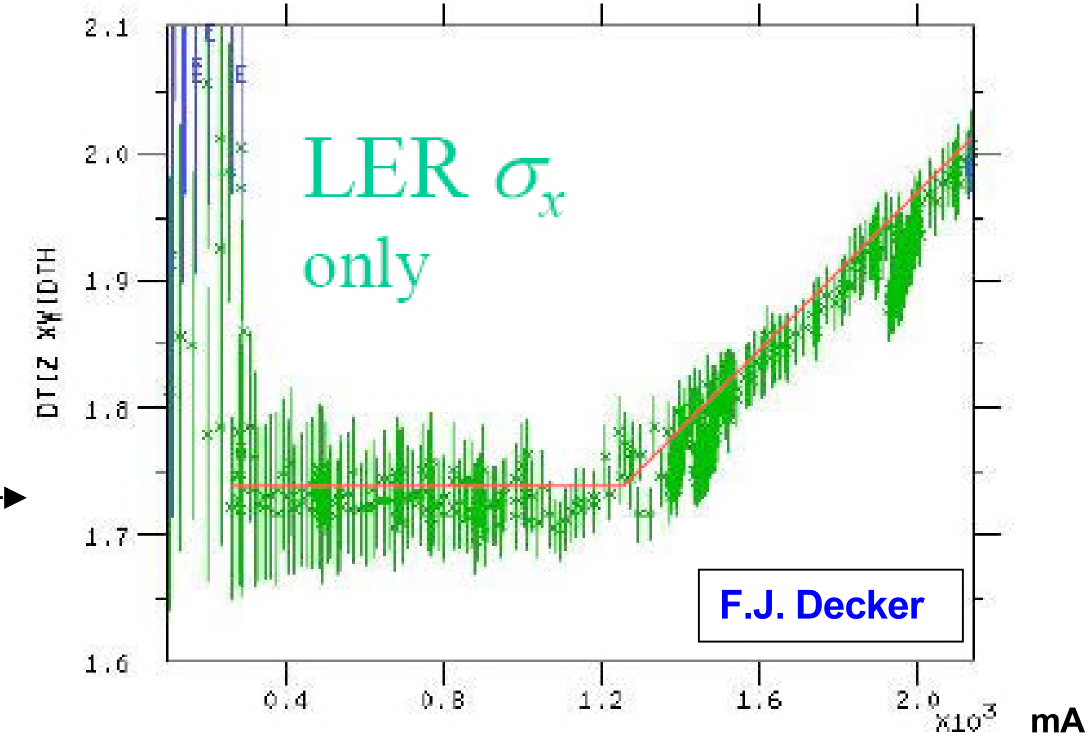




II. Observation in other machines

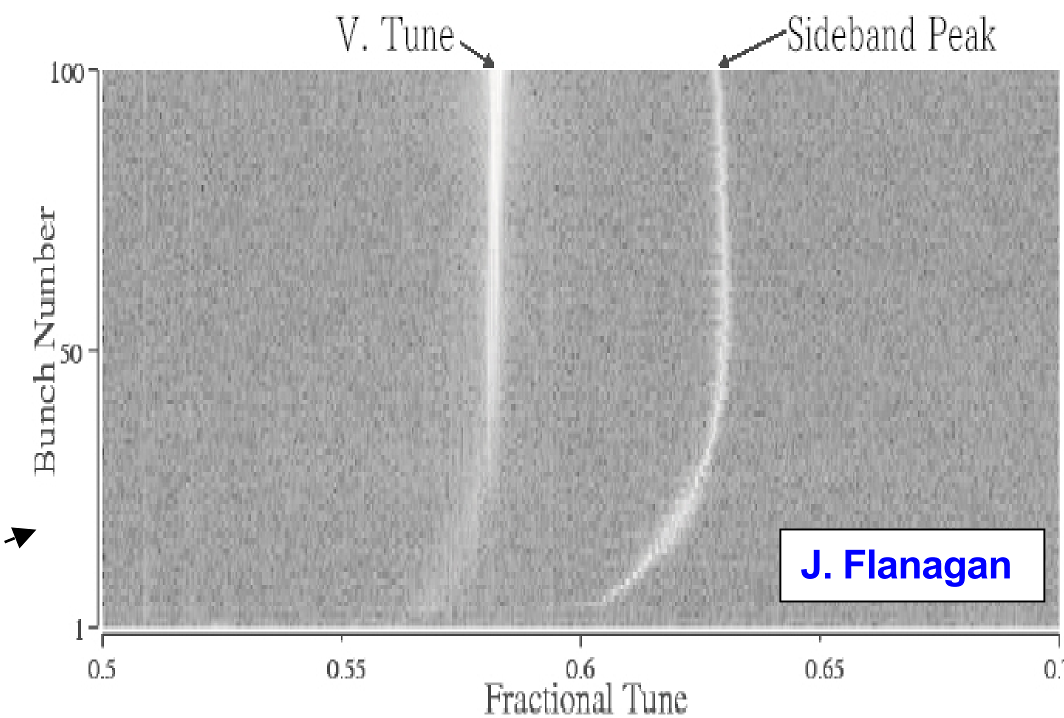
1. PEP-II

- Beam emittance growth identified due to EC.
- The growth threshold was 3e10 e+ per bunch and bunch spacing of 8.4 ns.
- Solenoids applied for improvement.



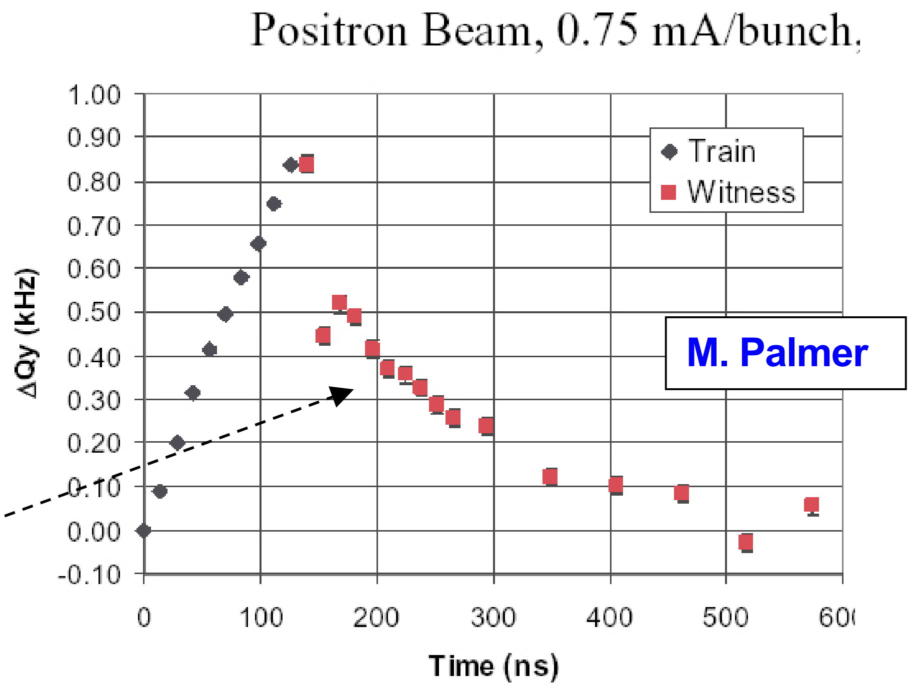
2. KEKB

- Threshold was 2.2e10 e+ per bunch, and bunch spacing of 8 ns.
- Currently the {e+ e-} collision is a more serious limit than EC.
- A sideband of Qv+Qs exits above the threshold. One sideband ~ nonlinearity?



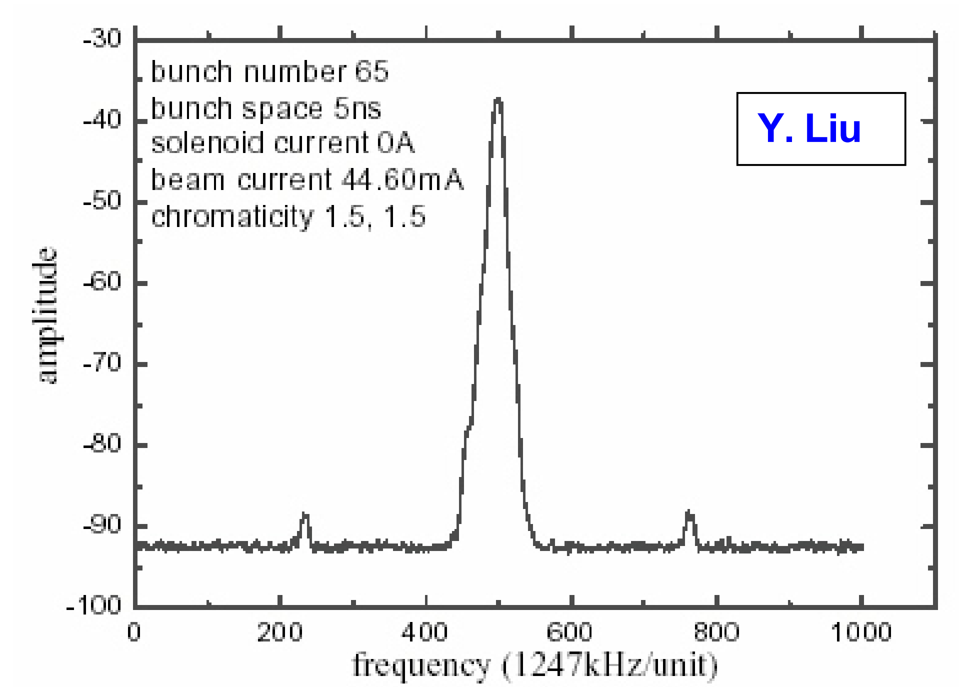
3. CESR

- **Threshold is 1.2e10 e+ per bunch and bunch spacing of 14 ns.**
- **Machine luminosity limited by long range beam-beam.**
- **Witness bunch tune shows ~170 ns time constant of secondary e- reduction.**



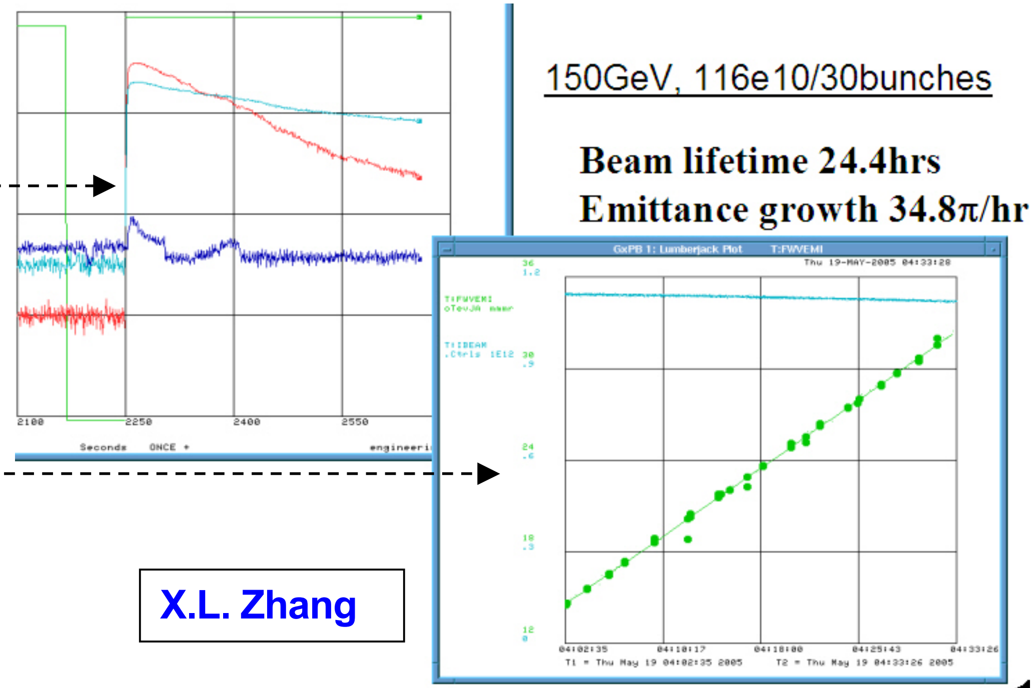
4. BEPC

- **Threshold is 0.4e10 e+ per bunch and bunch spacing of 12 ns.**
- **Betatron sideband (two-sided) disappeared when solenoids turned on.**
- **Clearing electrods, chromaticity and octupolar magnets all have effects.**



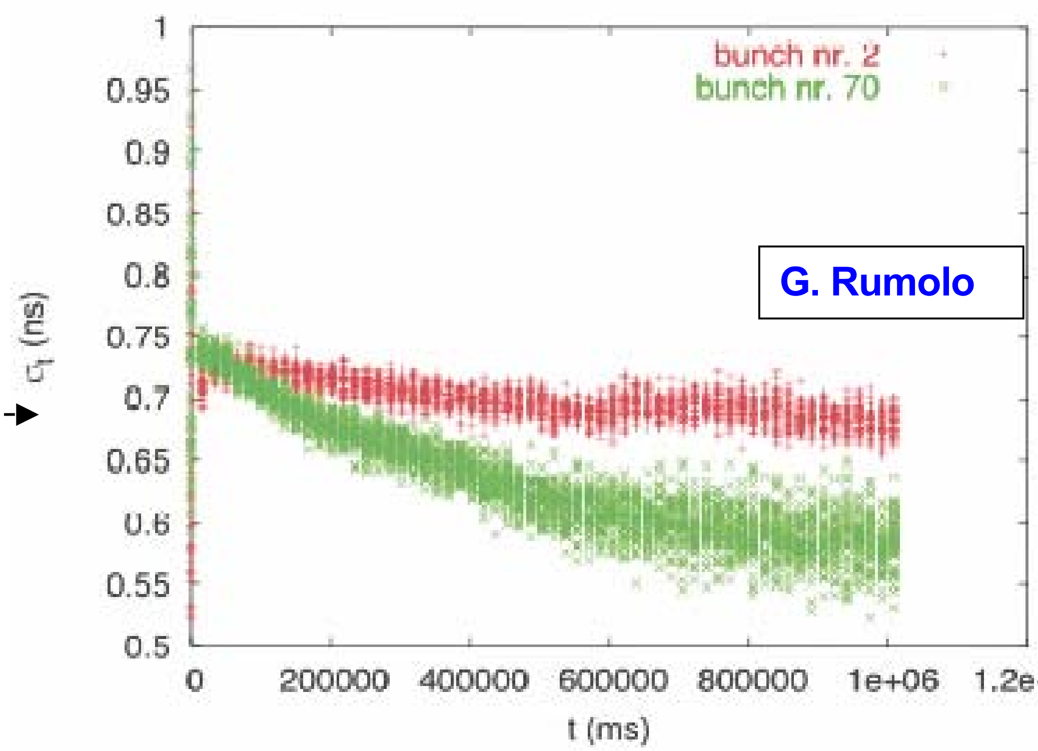
5. Tevatron - MI

- Dynamic pressure rise with 4e10 protons per bunch, 19 ns bunch spacing, and 30 bunches total.
- Emittance growth of 35 $\pi\mu$m per hour measured using flying wires.
- EC concern of main injector (MI) for neutrino programs.



6. SPS - LHC

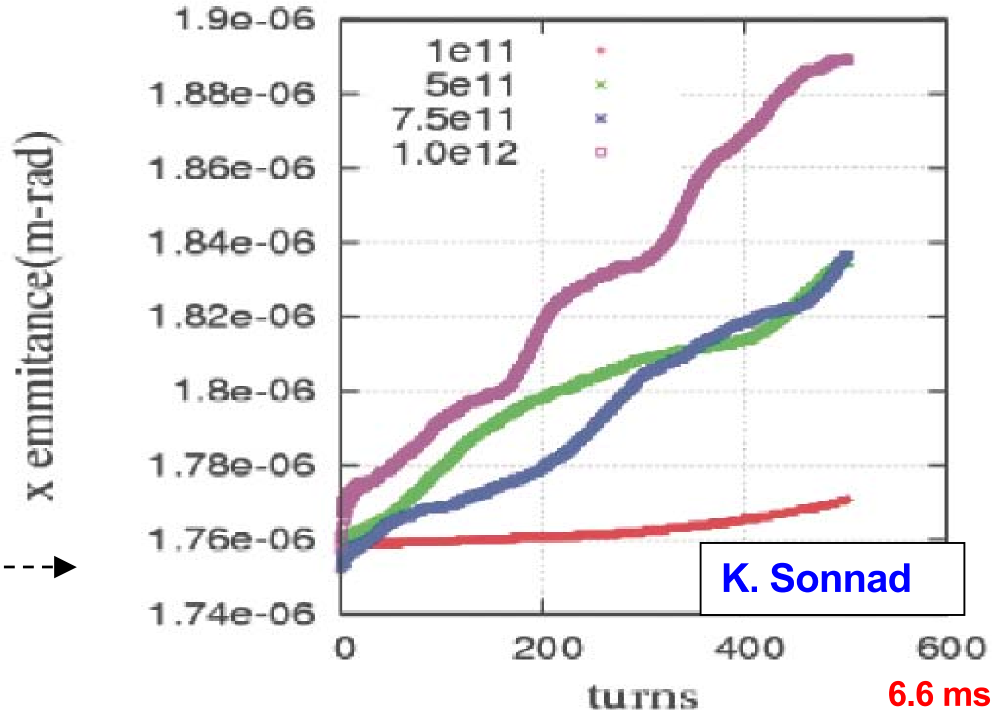
- Beam emittance growth at SPS after beam scrubbing, for LHC beam 1e11/bunch, 25 ns bunch spacing.
- Trailing bunch intensity reduced more, bunch length also shortened more.
- LHC heat load & instability are less concerned than the slow emittance growth in planned 24 hour store.



III. EC induced emittance growth - simulations

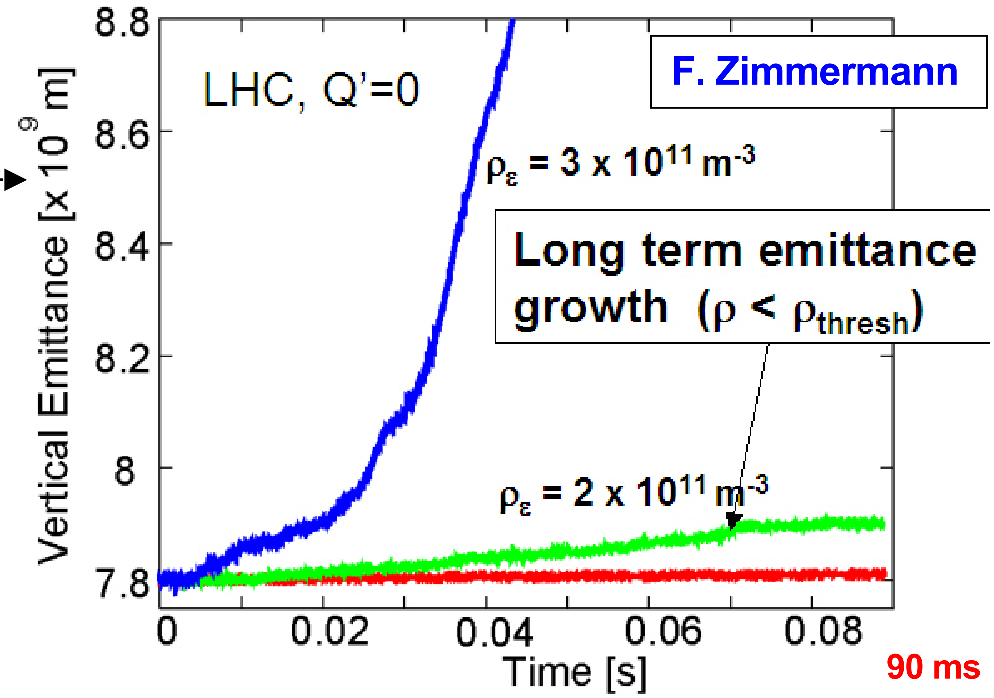
1. Due to head - tail instability

- EC induced head-tail instability can cause fast and large emittance growth.
- Well simulated, usually a few ms time period is sufficient.
- Not of big concern for RHIC.



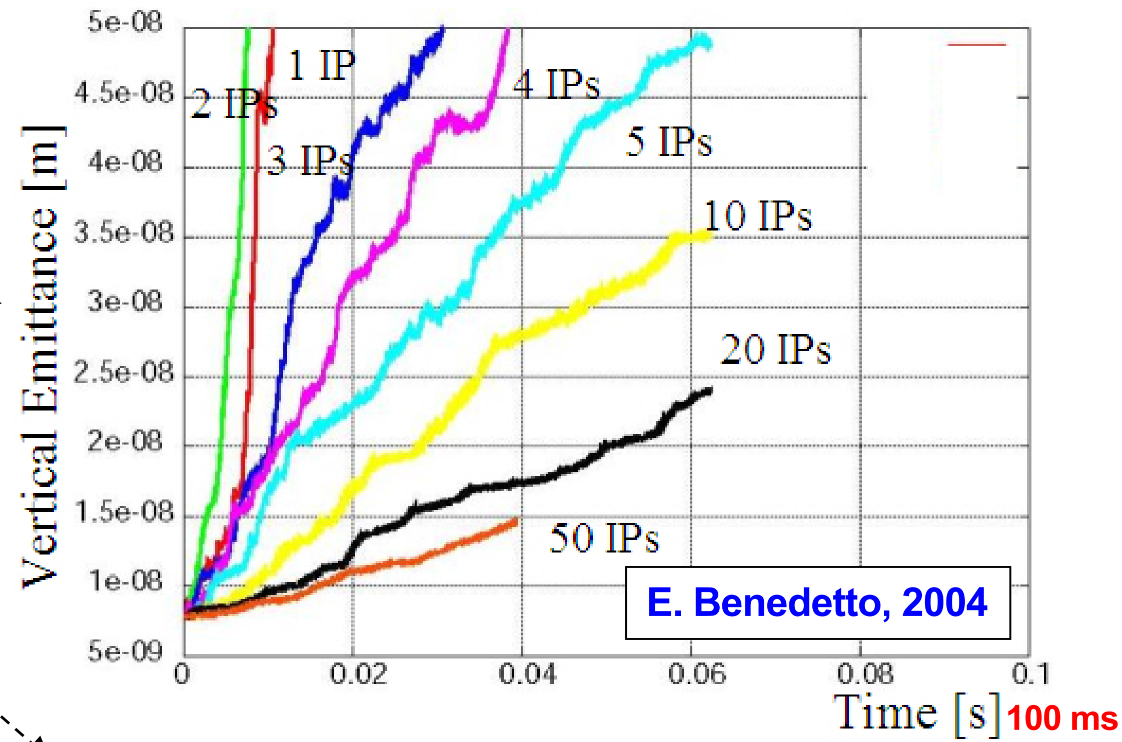
2. Below the threshold

- It was found the emittance may grow slowly below the head-tail threshold.
- Resonance crossing and even trapping might be the cause.
- Lot of progress in recent couple of years, but there are a few questions to be answered.



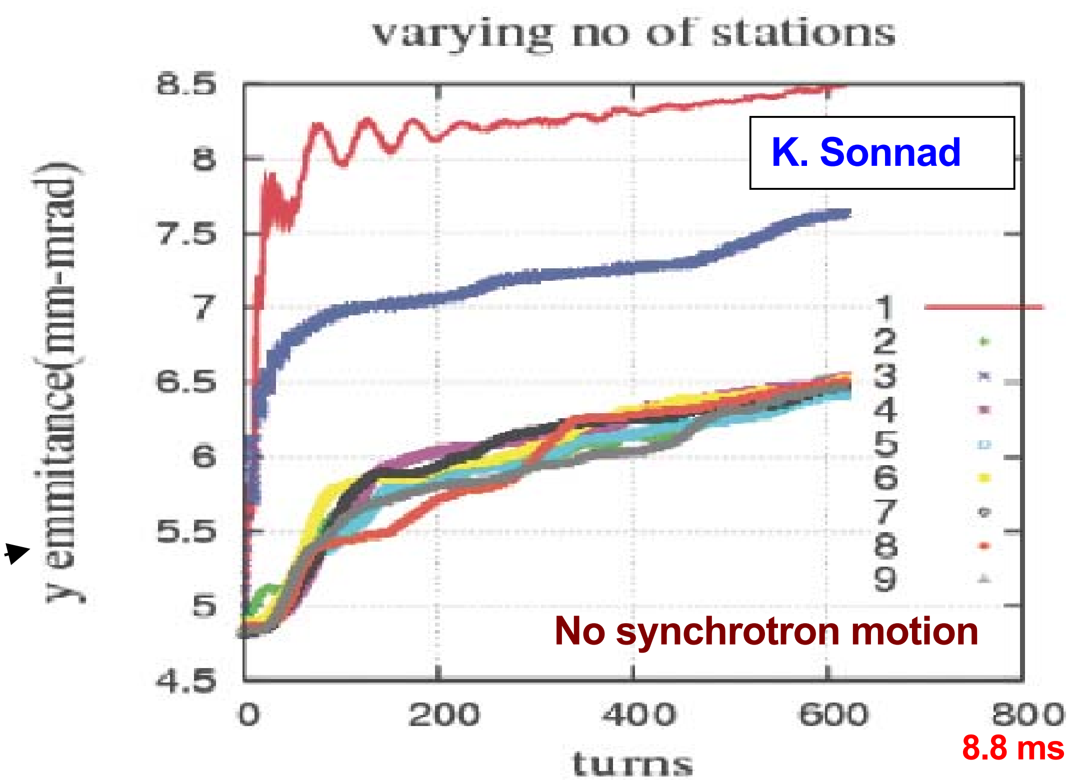
3. No. of IP and convergence

- More interaction points (IP) produce slower growth, with no convergence (CERN). The difference can be very large.
- Simulations by LBNL team for MI see convergence at a few IPs.
- 2 or 4 IPs / betatron cycle is enough (M. Furman)?



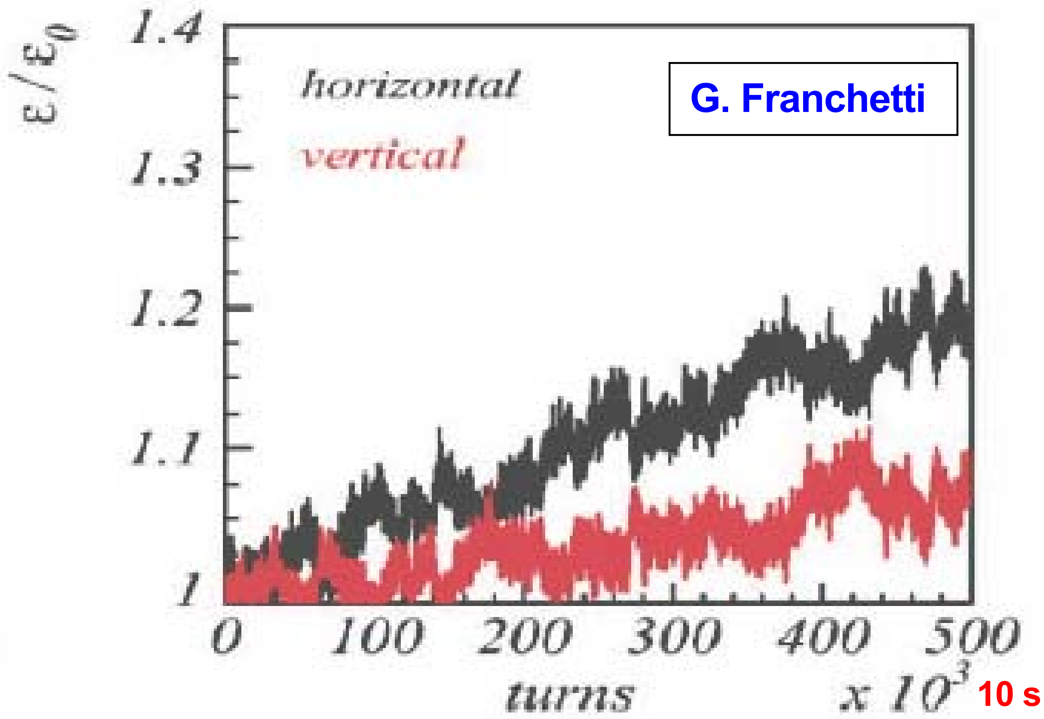
4. Synchrotron motion

- CERN simulation shows no real emittance growth when RF is off, suggesting that the synchrotron motion is essential.
- LBNL simulation has emittance growth when the RF turned off.



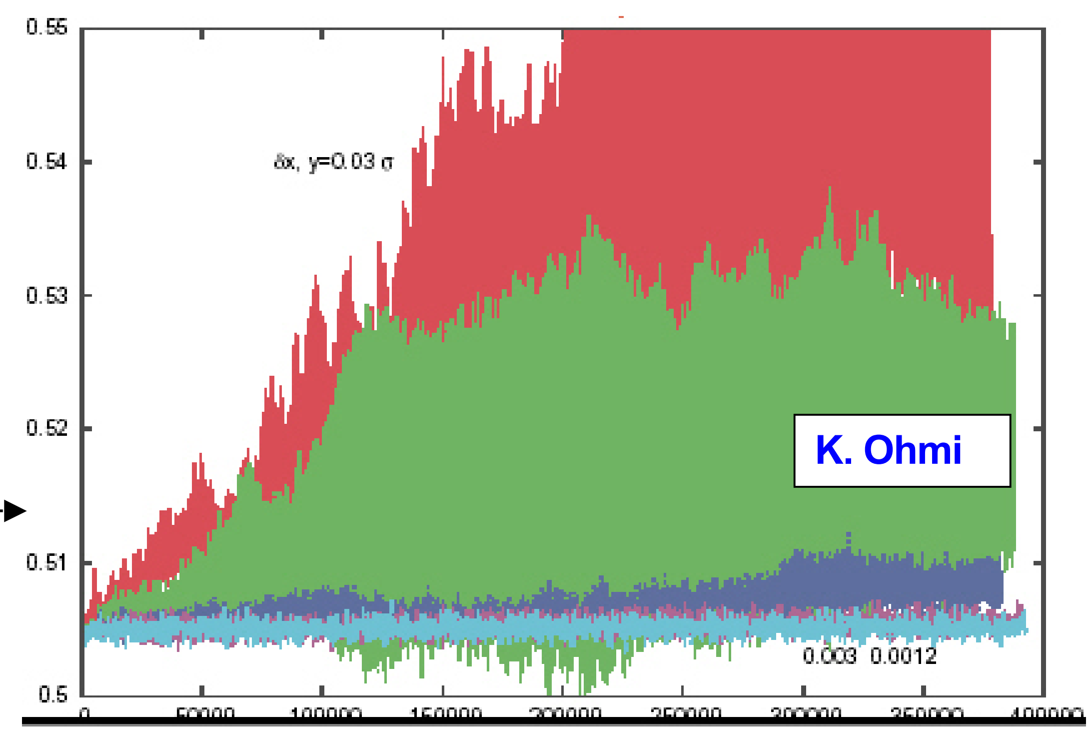
5. Slowest growth rate so far

- Early simulations of the emittance growth below the threshold showed that the emittance doubled in < a few seconds.
- CERN and GSI used 744 IPs (dipoles) for SPS, vertical emittance doubled in 4 minutes – still too fast.



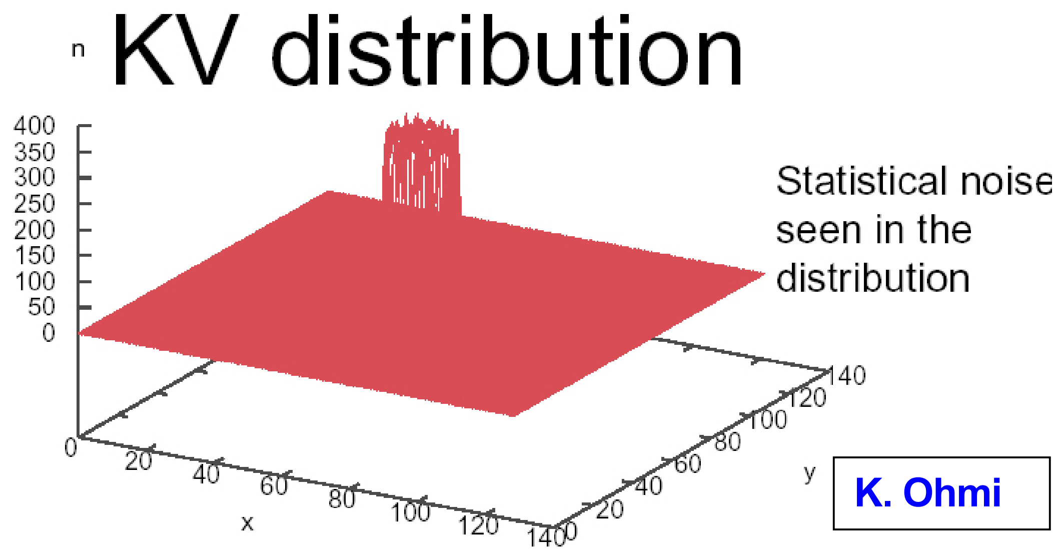
6. Chance of improvement

- Number of macro-particles is limited by computing power, ≤ 1e6.
- With digital noise, it is very difficult to simulate slow growth, e.g. ~2 πμm/h.
- With 1e6 macro-particles, luminosity lifetime of 24 h was simulated for beam-beam at LHC.



7. Physical and artificial noise

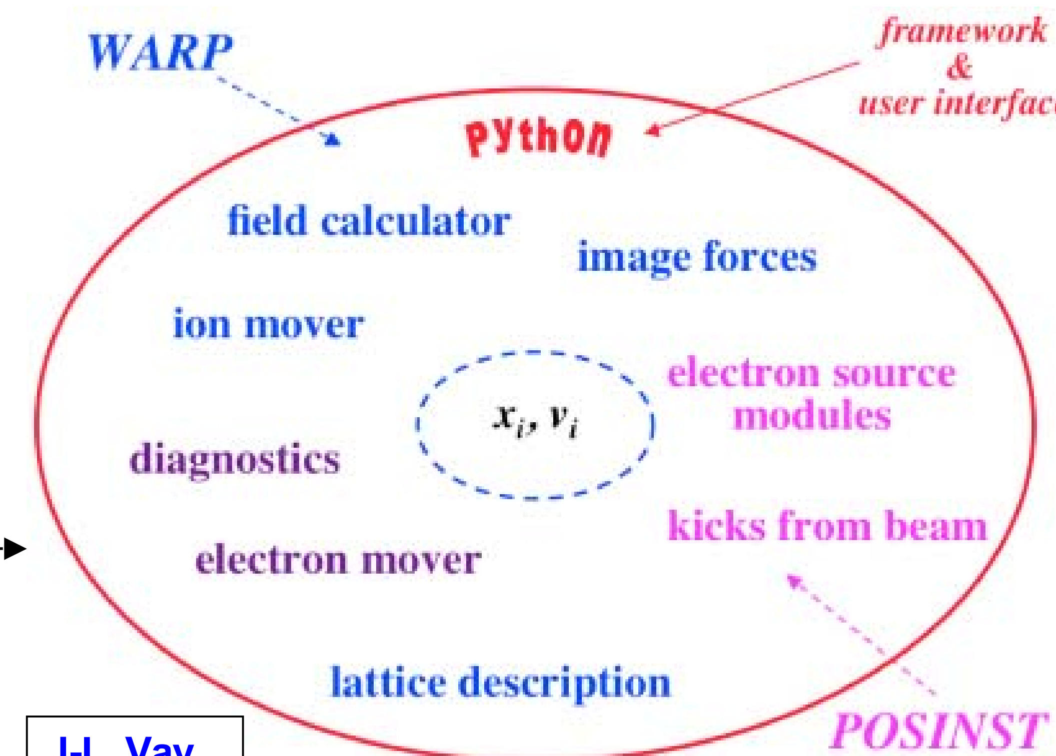
- Statistical noise can be seen in the distribution.
- The weak-strong model is better than strong-strong if this noise is larger than the physical ones.
- Non-periodic potential is more serious than periodic ones.



K. Ohmi

8. Code development

- Beam to electron code was relatively well developed.
- Electron cloud effect on the beam can be coupled with beam-beam and space charge.
- CERN: HEADTAIL
- GSI: e-MICROMAP
- LBNL: WARP (e- to beam) on POSINST (beam to e-)
- KEK: PEHTS
- SNS: ORBIT
- ILC: CMAD



J-L. Vay