Longitudinal emittance* in AGS (Au only)

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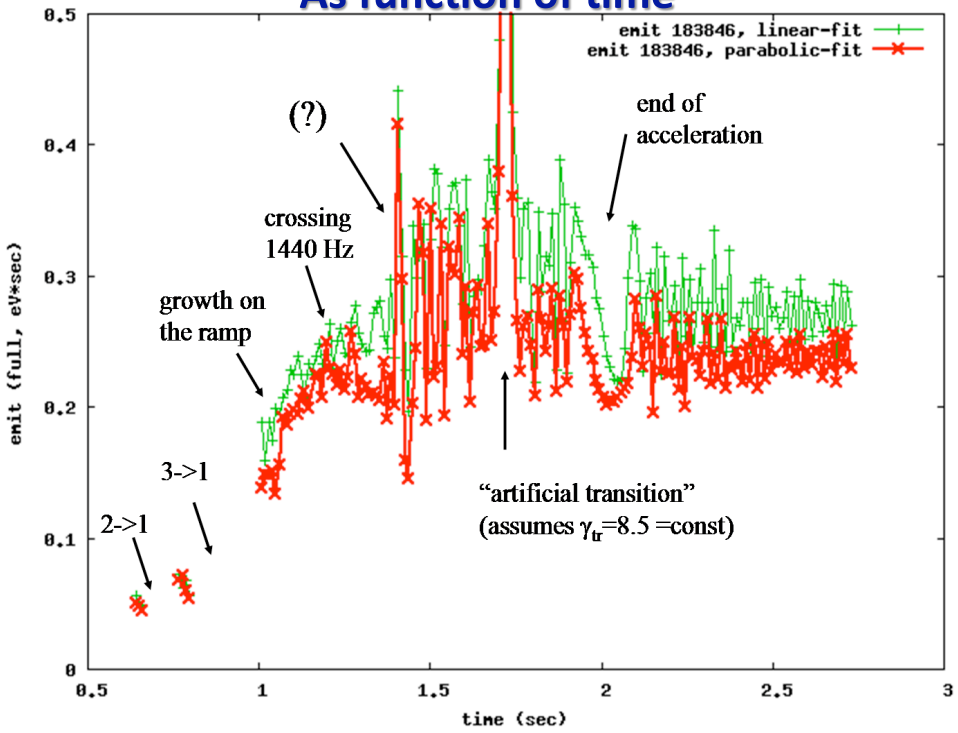
* - emittance = longitudinal emittance

Emittance growth in AGS

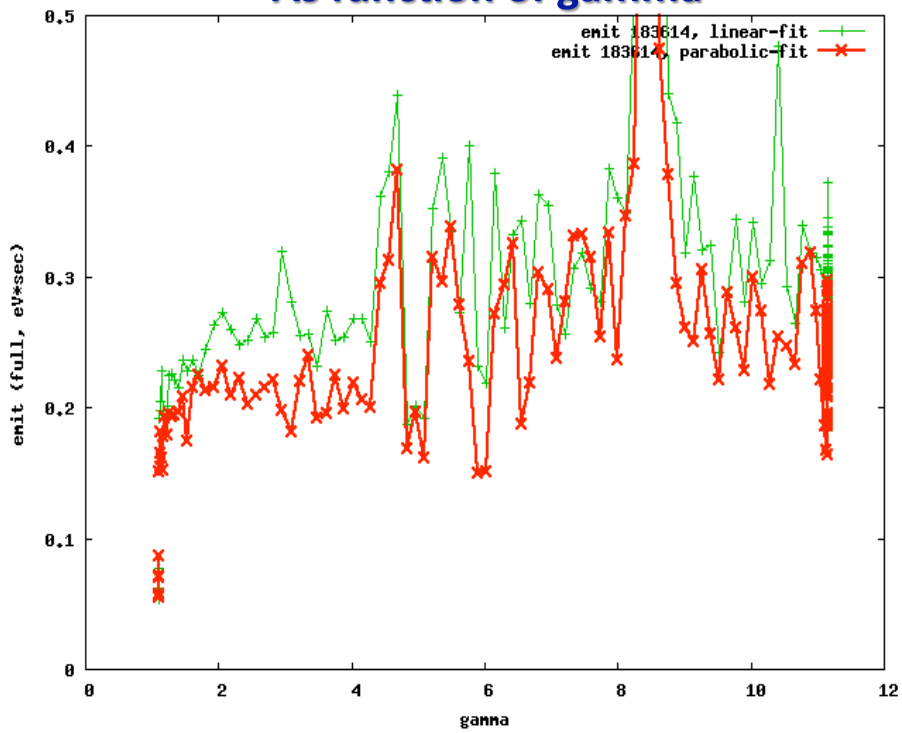
- Originally, I was asked to look at possibility to use low energy e-cooling (γ=1.1) to decrease long emittance in AGS (at inj.)
- Problem for low energy run: √9 GeV: 0.25, √5 GeV: 0.1 (eV·sec/u)
- Stochastic cooling in RHIC also needs smaller emittance, but not so small

Long. emittance before merge correction (Dec. 2007)

As function of time



As function of gamma



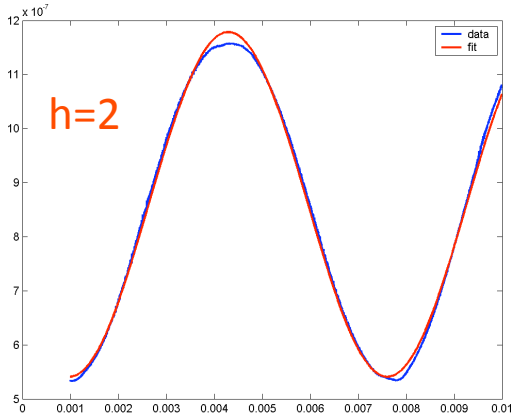
Fixing 3->1 merge

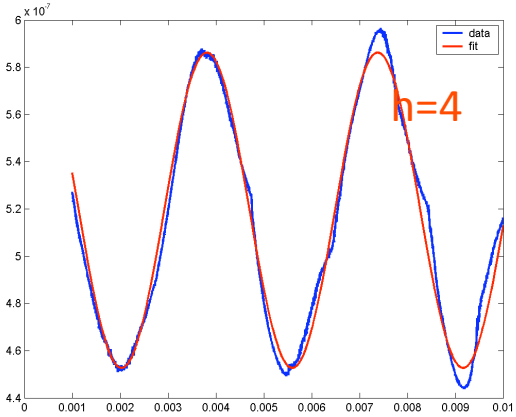
- Simulations showed that the merge had to work much better than observed.
  - Injection residual oscillations could not explain emittance growth
  - Wrong Voltages? Sure.
- Voltages were re-calibrated using dipole synchrotron oscillations of the deutron beam (one bunch injection)
- Voltages were completely off:
  - L10 cavity voltage was approximately “per cavity” not “per gap”.
  - Calibration of 4^{th} and 8^{th} harmonics were up to 50% off from expected
- After voltage amplitudes were fixed, the emittance growth at 3->1 merge almost disappeared. There is still some small growth, possibly caused by a small phase or/and amplitude error.
- Requirements on Voltage phase and amplitude (for given voltage profiles):
  - phase ±3°, amplitude (4h) ±5%

Voltage calibration and profiles

Direct injection of one single deuteron h4 or h8 (L10) was (relatively) easy.

Au f_4=0.63375 MHz, f_8=1.2675 MHz, **d** f_2=0.56481 MHz, f_4=1.12962 MHz



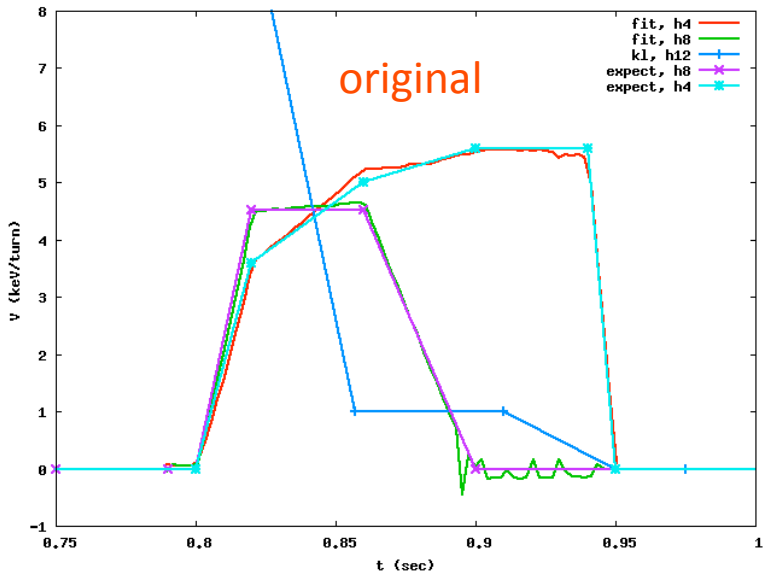


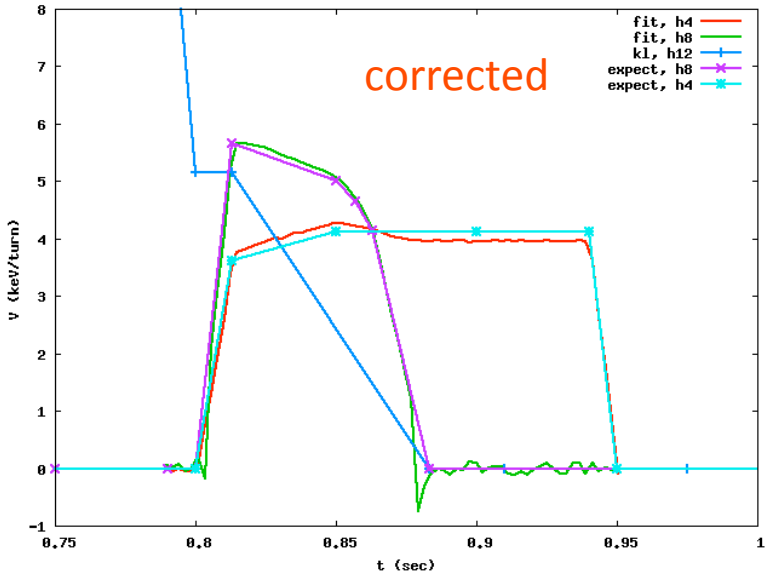
Function 24 kV!

ν_s=164 Hz, V_2=4.31 kV

ν_s=284 Hz, V_4=6.47 kV

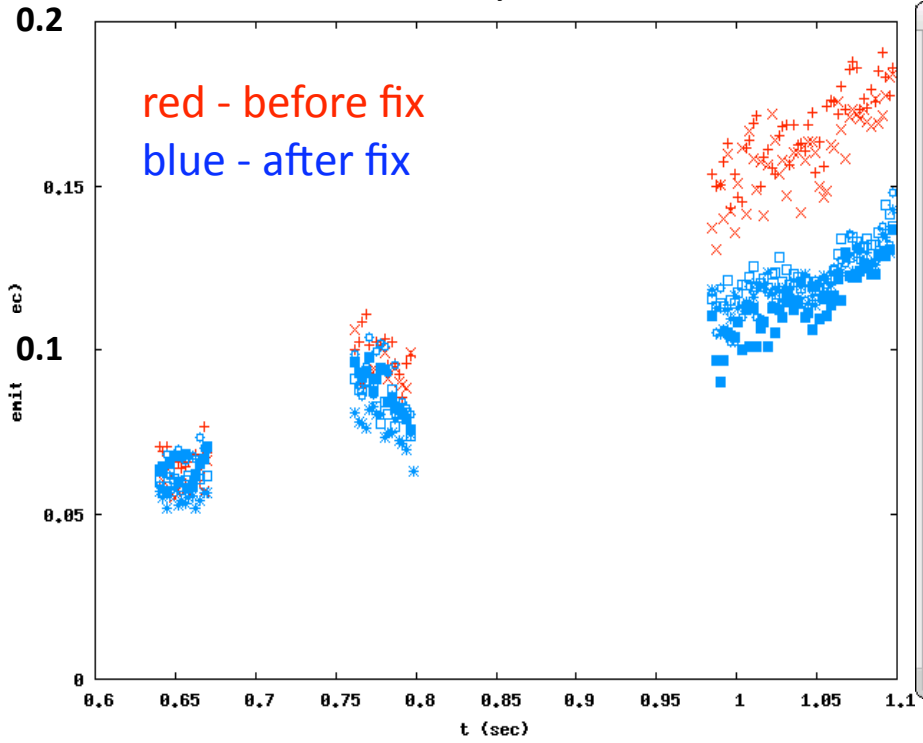
Calibration: 33.5 kV/gap/V
was 50 kV/gap/V



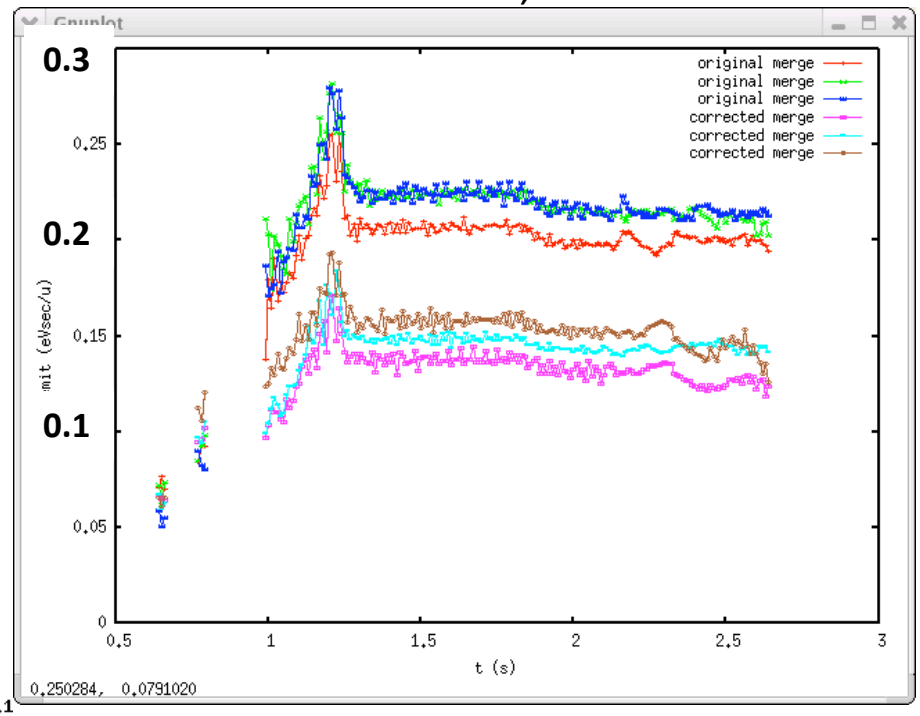


Fixing 3->1 merge

January, 2008

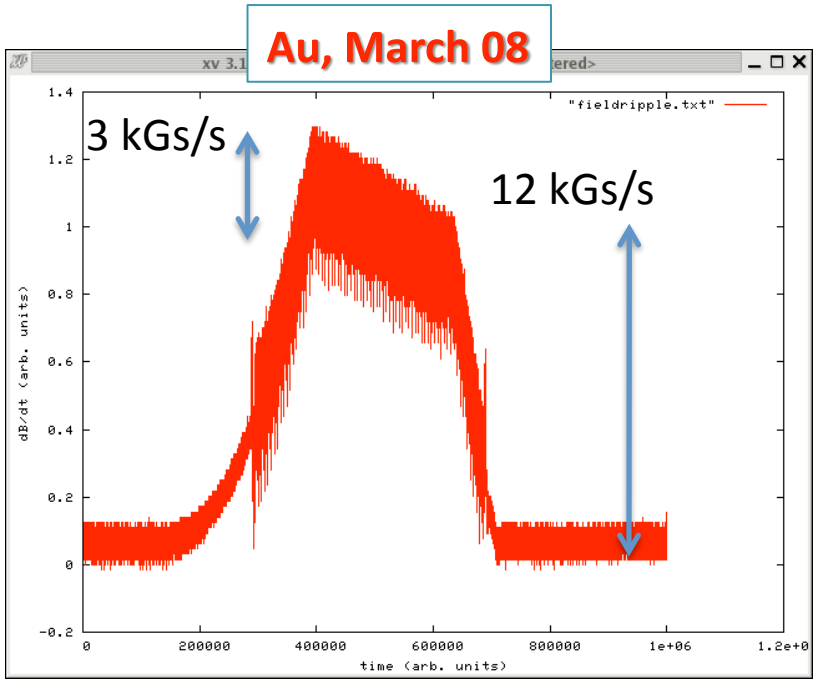


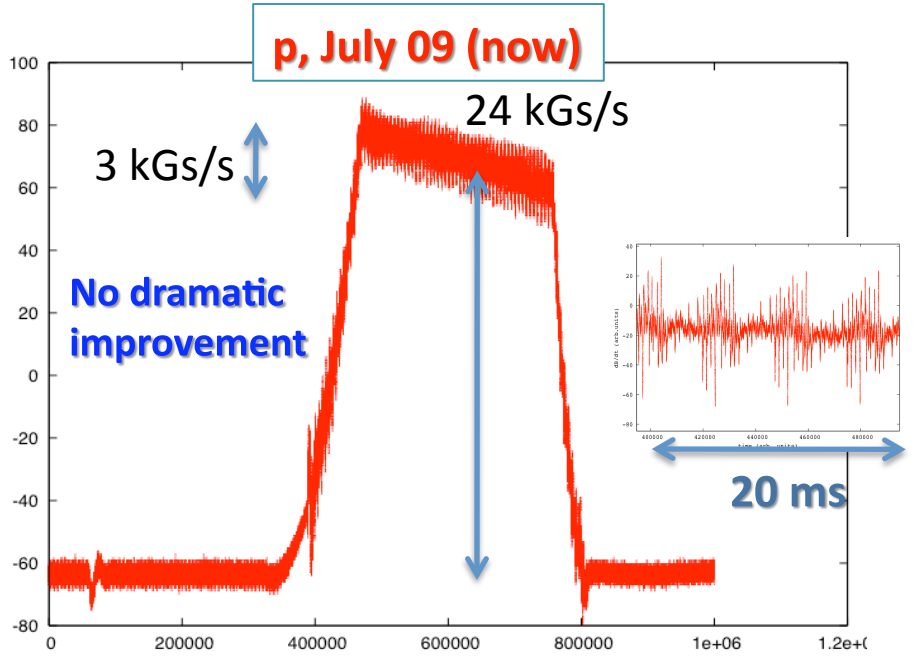
March, 2008

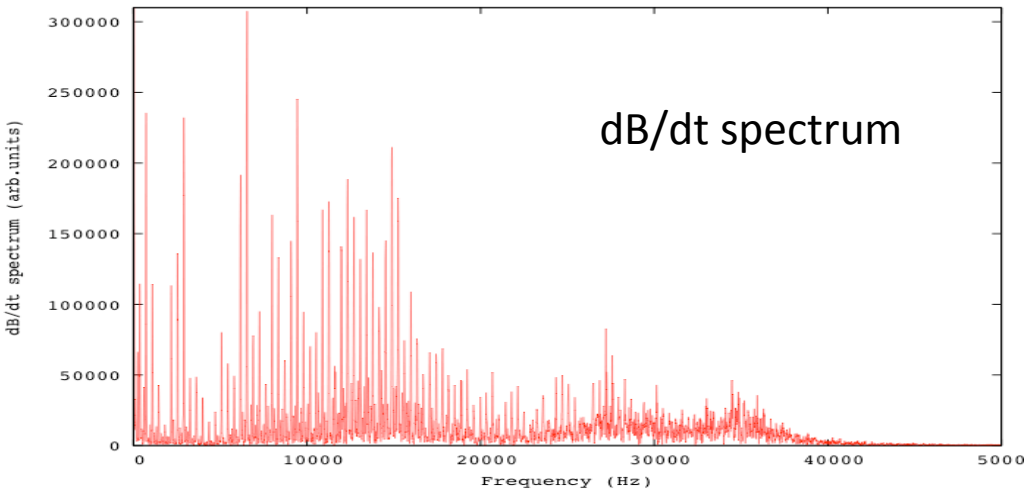


1. 0.1 eV·sec/u is achievable at injection
2. No need for low energy electron cooling in AGS (unless emittance < 0.1 needed)
3. Longitudinal emittance still grows during energy ramp

Emittance still grows on the ramp. Magnetic field ripple? Maybe.



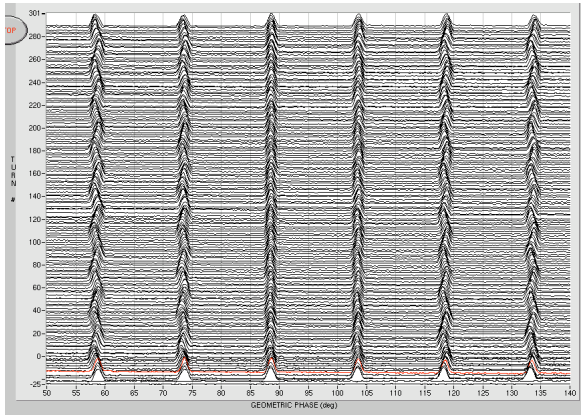




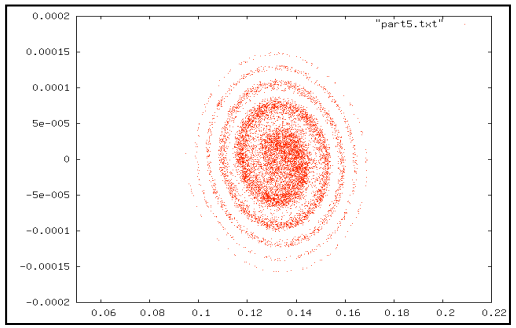
dB/dt spectrum has very high frequencies
B spectrum has to be divided by frequency
To be continued…

De-coherence suppression by space charge

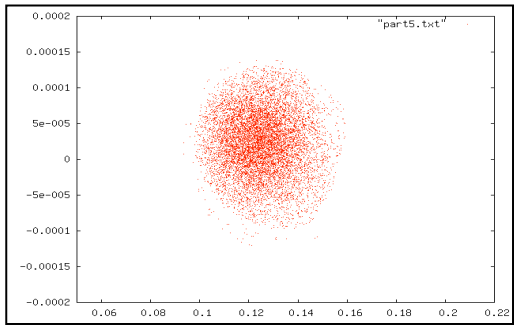
- **Space charge eliminates de-coherence caused by the cubic nonlinearity of the RF wave**



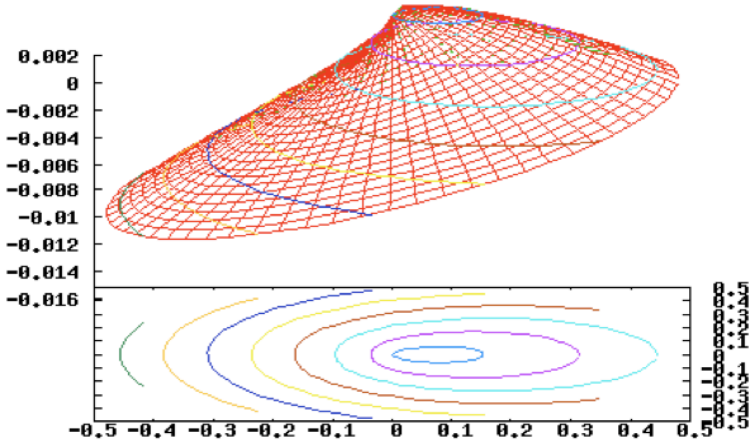
No SC



With SC



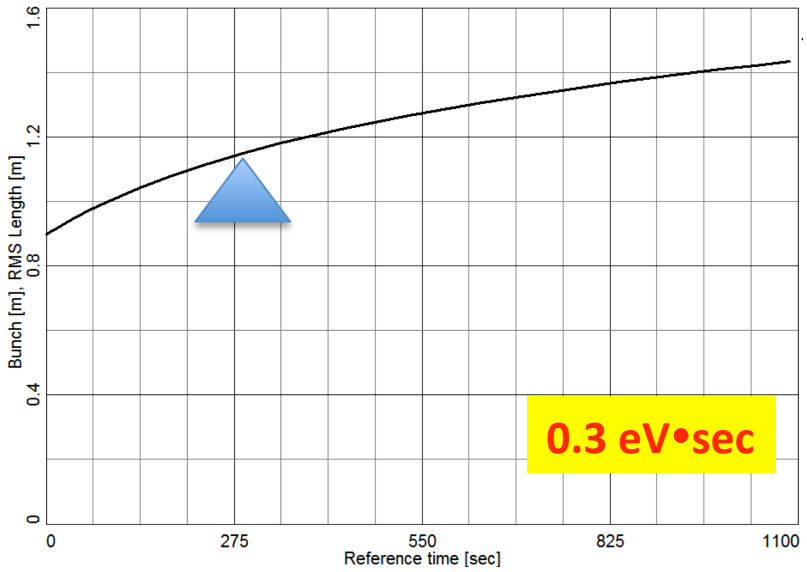
Hamiltonian

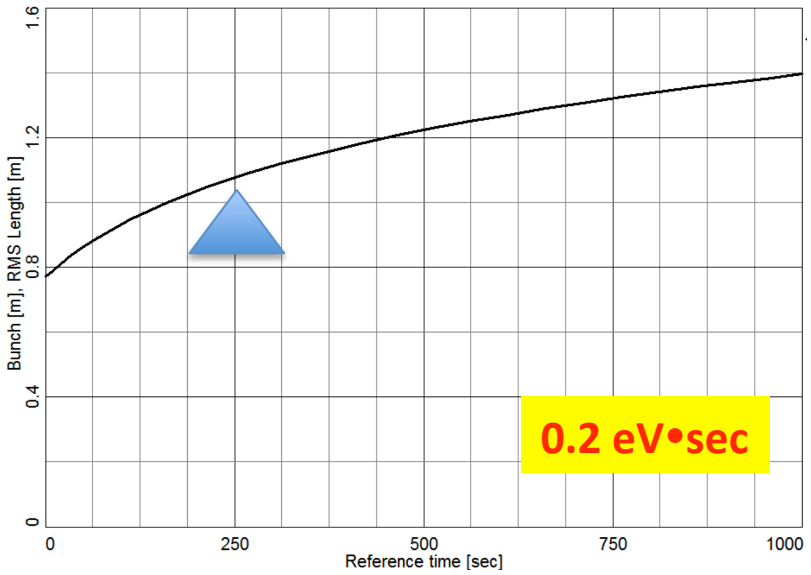


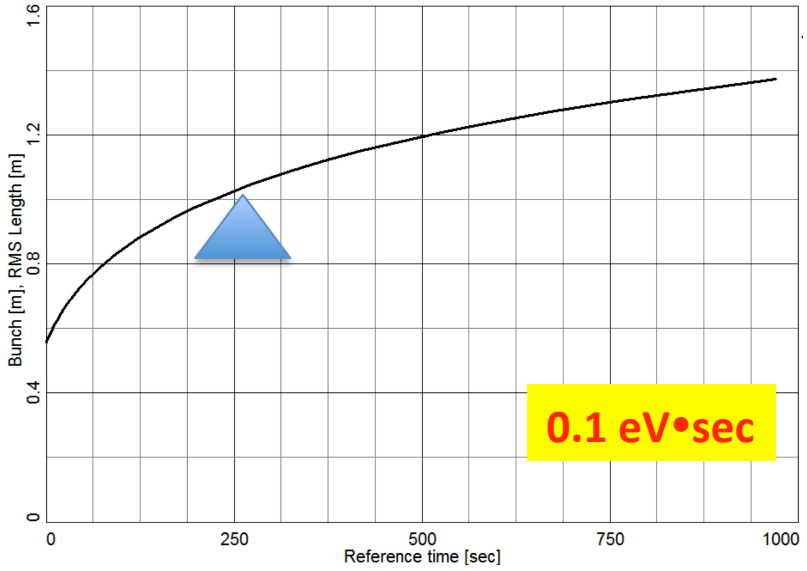
$$H = -\frac{3\beta I^2}{16\omega_0} + \left(\delta\omega - \frac{k_1}{2\omega_0}\right) I + k_1 \frac{\sqrt{I_c I}}{\omega_0}\cos(\Phi)$$

1) Space charge shifts stable point and keeps beam coherent
2) Gives opportunity to reduce effect of mismatch using a damper with feedback/feedforward
3) Needed only if emittance < 0.1 eV*sec needed

Emittance growth at injection caused by IBS







After 250 sec the longitudinal emittance differs by 20% (between 0.1 nd 0.3 eV*sec)

I am not sure why this is interesting for regular RHIC operations. 0.3 eV*sec should be sufficient.

There is also substantial emittance growth on the ramp.

Conclusions

- 3->1 Merge has been fixed. Emittance of 0.1 eV, sufficient for low energy running, is achievable at injection
- Emittance still grows on the ramp. Magnetic field?
- To be continued…