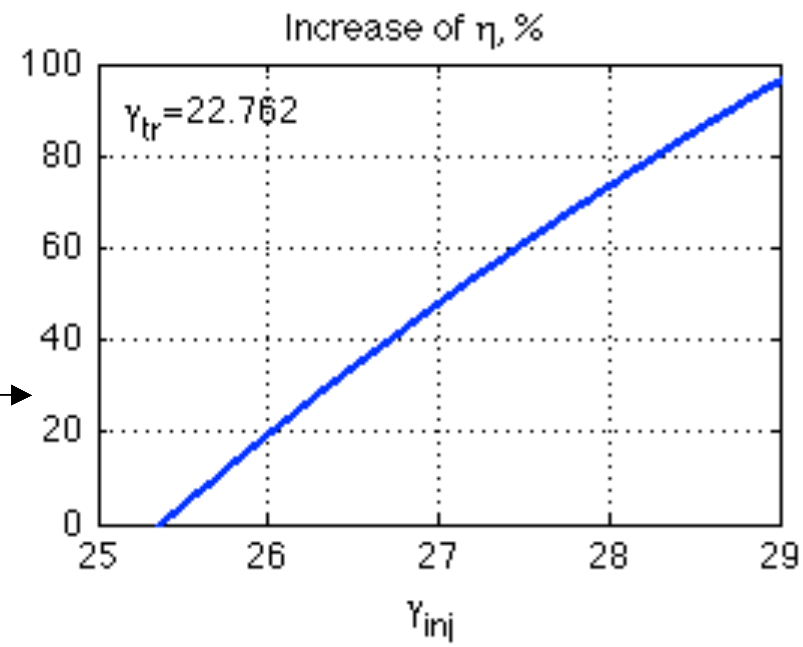
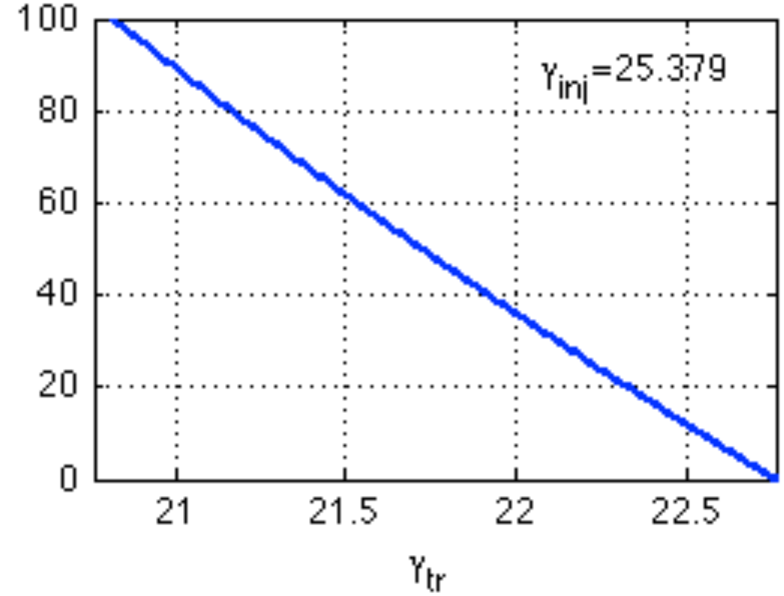
# RHIC Injection Energy: Quantify the Benefit

S.Y. Zhang 10-18-2010

## 1. RHIC injection energy

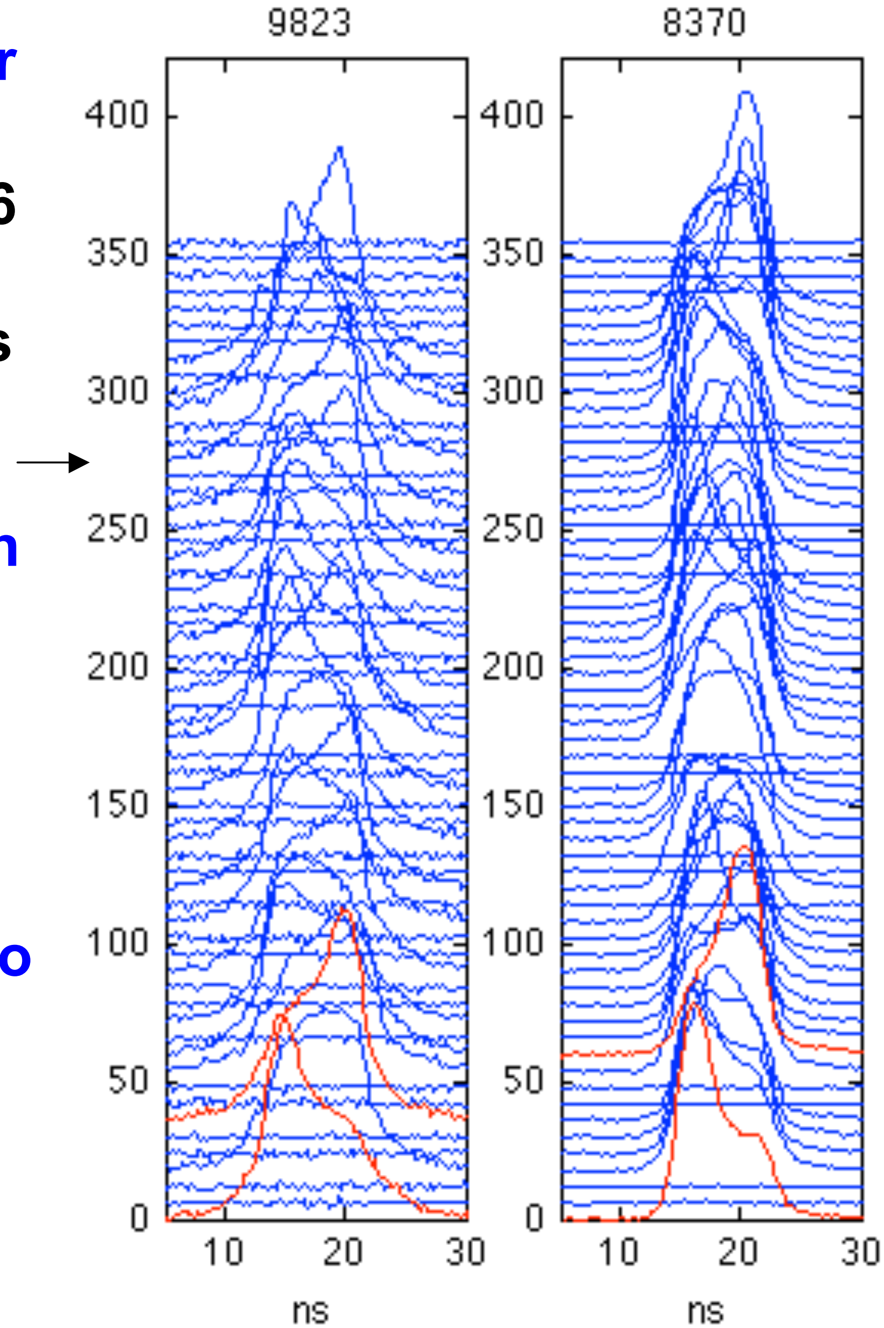
- **RHIC proton injection is close to the transition. A relatively small increase of the injection energy and/or a small decrease of the transition can result in large increase of the slippage factor $\eta$.** →
- **Larger slippage $\eta$ help on longitudinal beam instabilities.**
  - **High order mode and coupled bunch mode instabilities. The relevant impedance is narrow-band, e.g., from the RF cavities. The damping forces include $\eta$ dp/p.**
  - **Microwave instability. The relevant impedance is broad-band, e.g., from the beam chamber steps, ports, and bellows. The damping forces include $\eta(dp/p)^2$.**



## 2. 28 MHz

- With the 28 MHz cavity, the high order mode instability is clearly presented.
  - Fill 9823 for proton injection, with 36 bunches, $10^{11}$ protons per bunch.
  - Fill 8370 is gold beam at 30 seconds above the transition, 48 bunches, with $10^{9}$ ions per bunch.
- Sextupole mode instability has shown in both, see red lines. It may be from RF cavity impedance, the form factor shows 80 to 100 MHz is relevant.
- The damping of 8370 later in the ramping shows the effect of $\eta$ dp/p.
- The microwave instability is difficult to directly observe. However, the strong dependence of the beam longitudinal emittance on intensity in past proton runs suggests that it might be taking an effect.

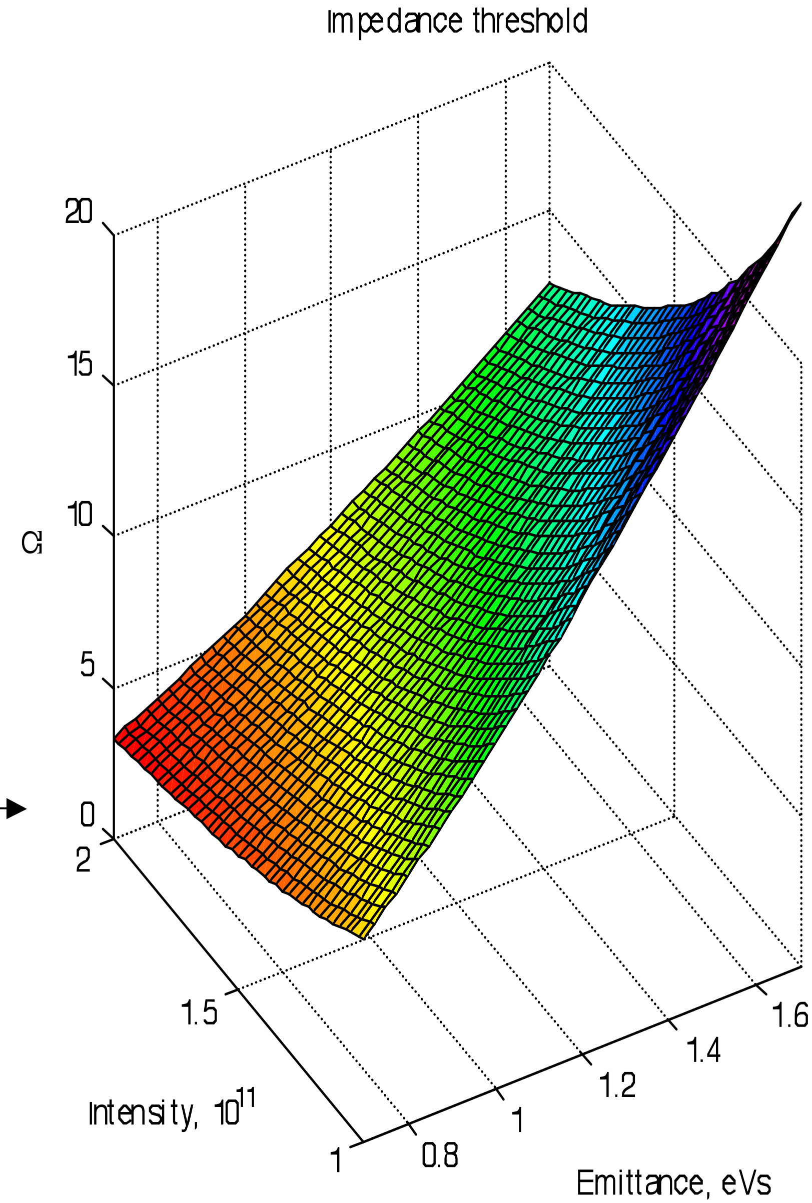


## 3. 9 MHz

- **The high order mode instabilities of 9 MHz depend on the new RF cavity. In Run11, dipole will be corrected.**
- **For microwave instability, the broad-band impedance is as same as for 28 MHz. The impedance threshold has strong dependence on bunch intensity, emittance, and slippage,**

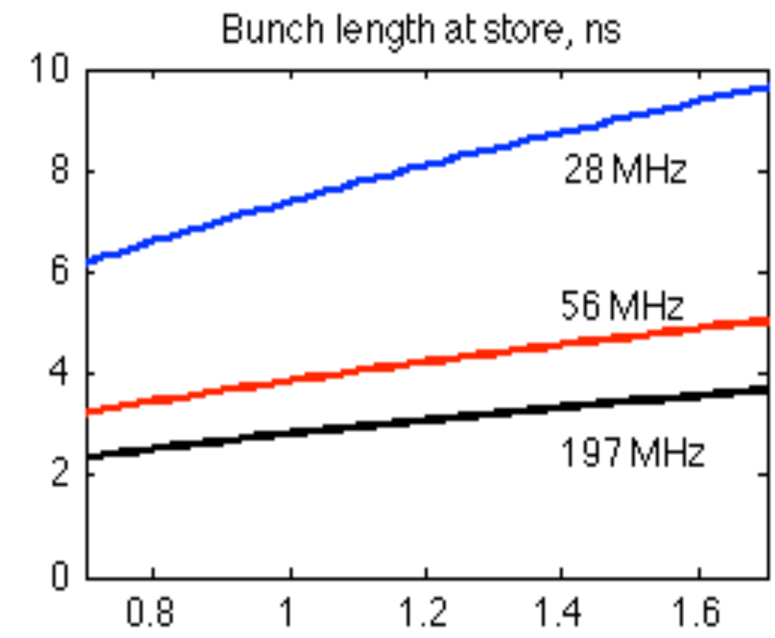
$$|Z/n|_{th} \propto \eta^{0.75}\varepsilon_{\ell}^{1.5}V_{rf}^{0.25}/N_{bunch}$$

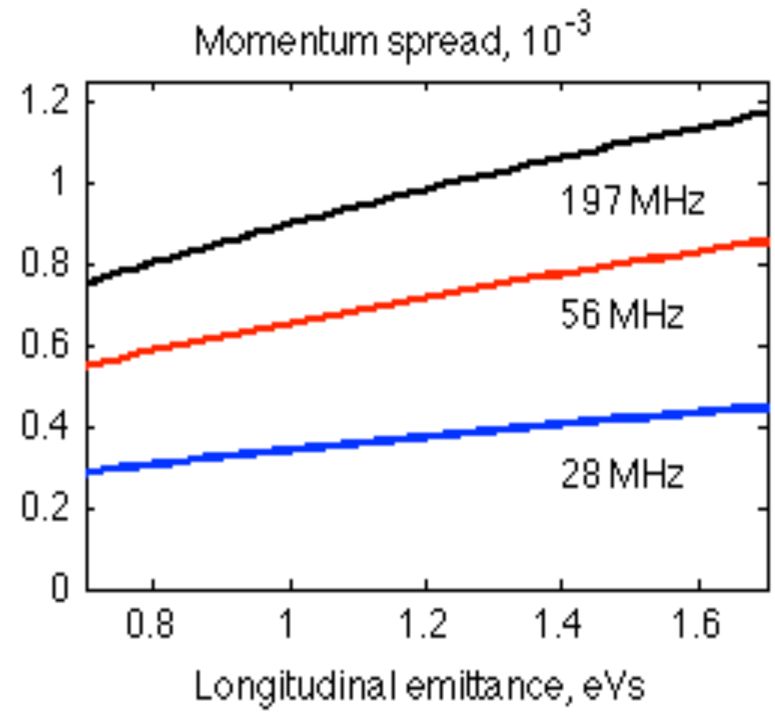
  - **For current injection with 9 MHz, impedance threshold vs. intensity and emittance is shown. Broad-band impedance needs to measure.** →
  - **With transition γ reduced by 1 unit, the slippage is increased by 49%, and $|Z/n|_{th}$ increased by ~ 2 Ω. This is a big change, considering 96 unshielded cold bellows in RHIC has an impedance of 0.2 Ω.**



# 4. Longitudinal emittance

- **With the ±30 cm vertex cut, there is a factor of 2 loss in luminosity, and in Run11 PHENIX vertex detector will be ±10 cm? Shorter bunch is needed.**
- **Bunch length ∝ square root of the longitudinal emittance for given RF voltage. For 28 MHz with 300 kV, and 56 and 197 MHz with 2 MV, the bunch length is shown for 250 GeV. In Run9, the bunch length is >10 ns, indicating the longitudinal emittance > 1.7 eVs.** →
- **The momentum spread also ∝ square root of the emittance. It is an important factor in the momentum aperture caused beam loss, and hence the luminosity lifetime. It may also pose a limit in reducing β*. The momentum spread vs. longitudinal emittance at 250 GeV is shown.** →



## 5. Some comments

- Currently, the longitudinal emittance is defined at the RHIC injection (very little growth in ramping to 100 GeV and 250 GeV). The emittance has a strong dependence on intensity. A larger slippage at the injection will help, especially for high intensity.
- A larger slippage also helps for instabilities at injection with 9 MHz.
- The microwave instability impedance threshold with 9 MHz is a half of 28 MHz for same emittance and same intensity. Furthermore, at 100 GeV it is the same as the injection, but at 250 GeV it is lowered by 40%.
- In Run9, Fill 10229 with the 9 MHz ramping, the longitudinal emittance has shown some 20% growth between 100 GeV to 250 GeV.