Short Bunches in RHIC

- Concerns
    - synchrotron tune shifts
    - peak currents (ECLOUD)
    - betatron tune shifts
    - IBS rates
- benefits
    - interaction diamond

dfs = difference between measured and low current tune,

low current tune is a fitted parameter so the vertical scale would be shifted for the green line.

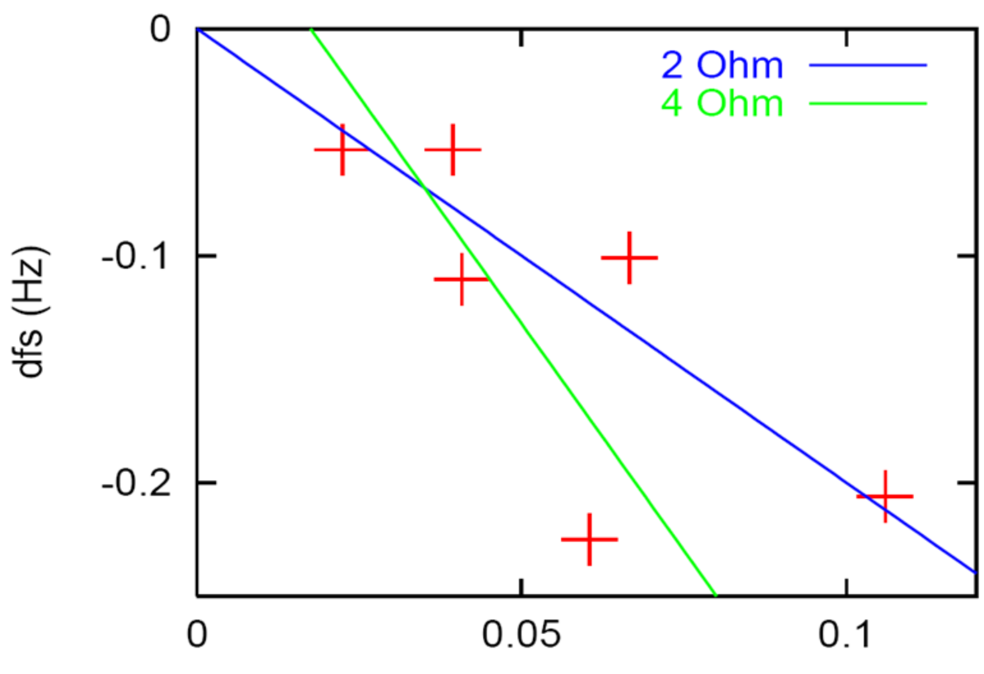
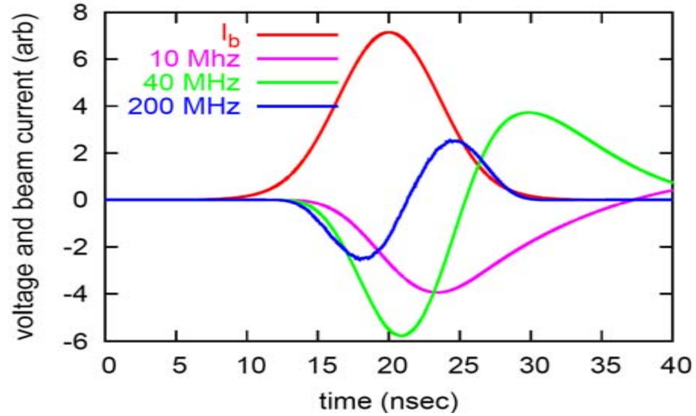


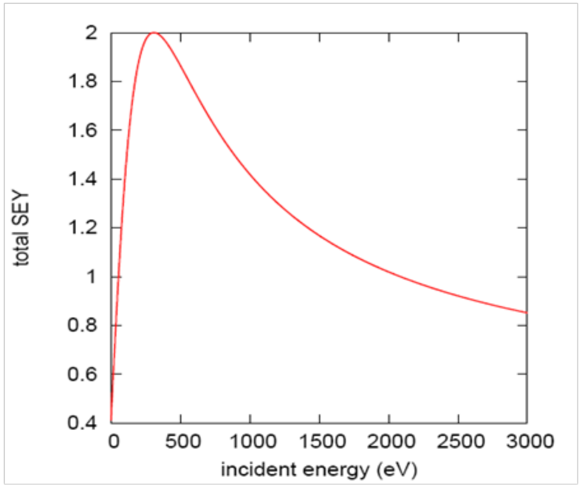
Figure 5: Synchrotron frequency shift versus N/w^3 at store. N is in units of 10^8 ions and w is in nanoseconds. Lines corresponding to $\omega_0 L = 2\Omega$ and $\omega_0 L = 4\Omega$ are shown for reference.

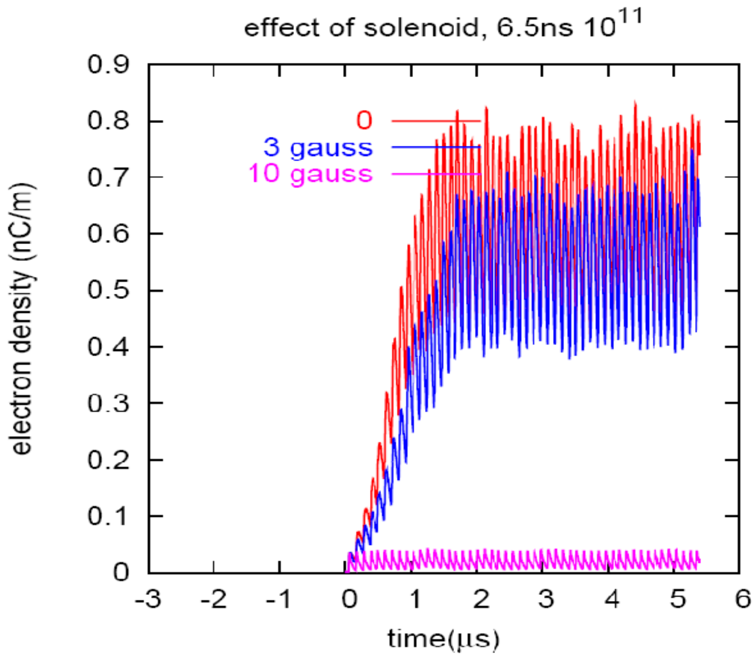
Abort kicker is low frequency, giving wrong sign for tune shift

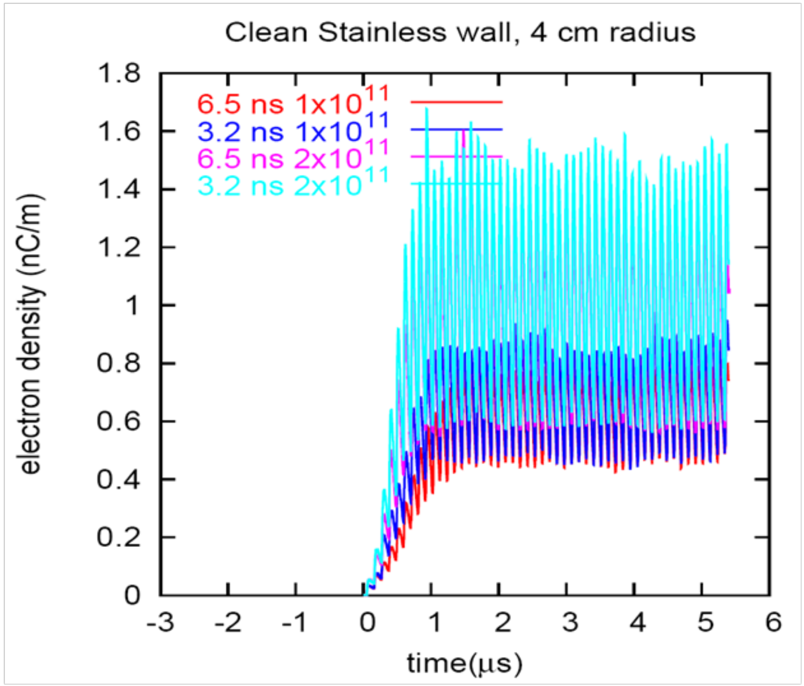


Electron clouds

In this regime bunch length looks unimportant, but SEY is a guess. Magnetic field looks important/useful (SY Zhang)







Impact of reduced longitudinal emittance

For a broad band impedance and parabolic bunch

$$V(\tau) \approx V_{rf}\,\omega_{rf}\,\tau + L\,\frac{3Q}{2\hat{\tau}^3}\,\tau \qquad \omega_0 L = \mathrm{Im}\,\frac{Z}{n}$$

Impedance threshold
$$\frac{\Delta\omega_s}{\delta\omega_s} = \frac{12LQ}{\hat{\tau}^5\,\omega_{rf}^3\,V_{rf}} \propto \hat{\tau}^{-5}$$

Reduced emittance could be a challenge.

Re-measure Z/n using stochastic cooling gear.

Ideally:

Gate the signal from a given bunch and measure *incoherent* synchrotron frequency so there are no collective dynamics.

There's a problem with *INCOHERENT*

Recent work on transverse Schottky shows that the transverse incoherent space charge tune shift does not show as naively expected in the Schottky signal, wrong sign

Broad band Z/n is similar to incoherent space charge in that both yield no net frequency shift for the rigid mode.

A little thought is needed.

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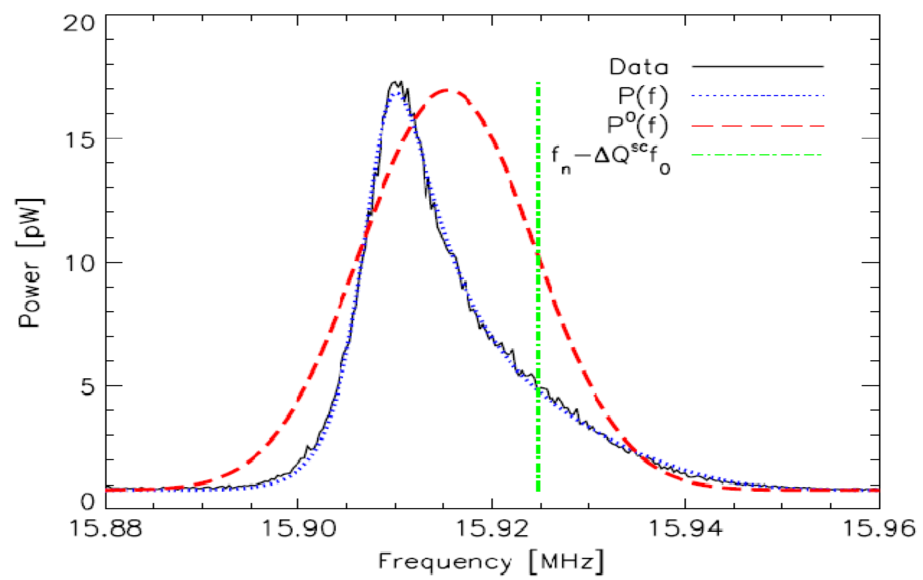

FIG. 8. (Color) Lower vertical sideband of the 75th harmonic measured in SIS-18. The measured data is plotted as a black curve. The dotted blue curve represents the analytic expression Eq. (17) with fitted parameters. The dashed red curve shows the expected Schottky spectrum for $U_{sc} = 0$ (maximum adjusted). The vertical green line indicates the incoherent frequency $f_{n,\pm} \pm \Delta Q^{sc} f_0$ shifted by space charge.

Betatron tune shifts and IBS

Rigid beam frequency shift

$$\Delta\Omega = i\frac{qcI_{avg}}{4\pi Q_\beta E_T}\sum_{n=-\infty}^{\infty}\exp(-n^2\omega_0^2\sigma_t^2)Z_\perp([n-Q_\beta]\omega_0)$$

$$\propto 1/\sigma_t$$

IBS from Alexei Fedotov RHIC/AP/168

$$\frac{d\sigma_p^2}{dt} \approx \frac{r_i^2 N\Lambda\sqrt{2/\pi}}{8\beta^4\gamma^3\varepsilon_x^{3/2}\left\langle\beta_x^{1/2}\right\rangle\sigma_t} \propto \frac{N}{\sigma_t}$$

$$\frac{d\varepsilon_x}{dt} \approx \left\langle\frac{D_x^2 + (D_x^{'}\beta_x + \alpha_x D_x)^2}{\beta_x}\right\rangle\frac{d\sigma_p^2}{dt}$$

Interaction diamond

interaction rate per unit volume per unit time for head on

$$\frac{events}{d^3xdt} = \sigma_c 2vn_+(x,t)n_-(x,t) = \sigma_c \frac{dL}{d^3xdt}$$

Gaussian round beams

$$n_\pm(x,t) = \frac{N}{(2\pi)^{3/2}\sigma_x^2(s)\sigma_s} \exp\left[-\frac{x^2+y^2}{2\sigma_x^2(s)} - \frac{(vt \pm s)^2}{2\sigma_s^2} \right]$$

Integrate luminosity density over x,y,t

$$\frac{dL}{ds} \propto \frac{N^2}{\sigma_x^2(s)\sigma_s} \exp(-s^2/\sigma_s^2)$$

Critical length $\sigma_x^2(s) = \varepsilon\left(\beta^* + s^2/\beta^*\right)$ $\sigma_s \approx \beta^*$