Fermilab

Studies of the Chromaticity, Tune, and Coupling Drift in the Tevatron

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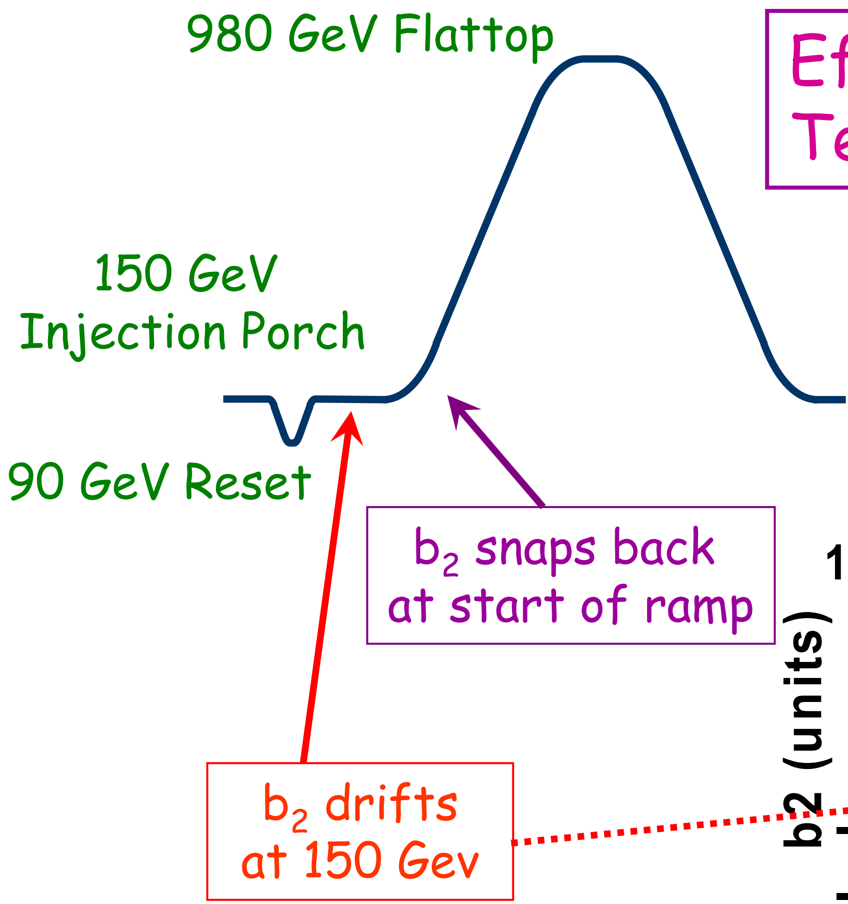
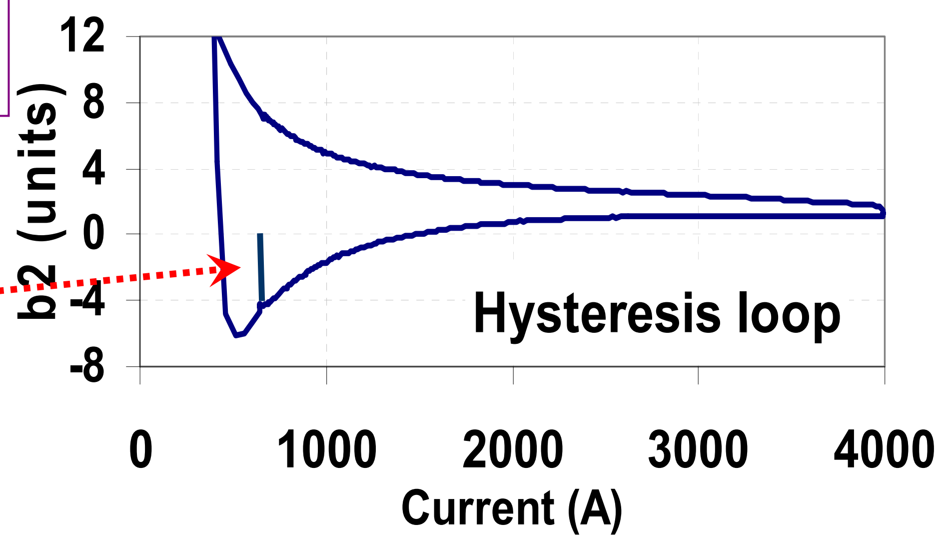
b_2 Drift & Snapback

Effects discovered during Tevatron commissioning

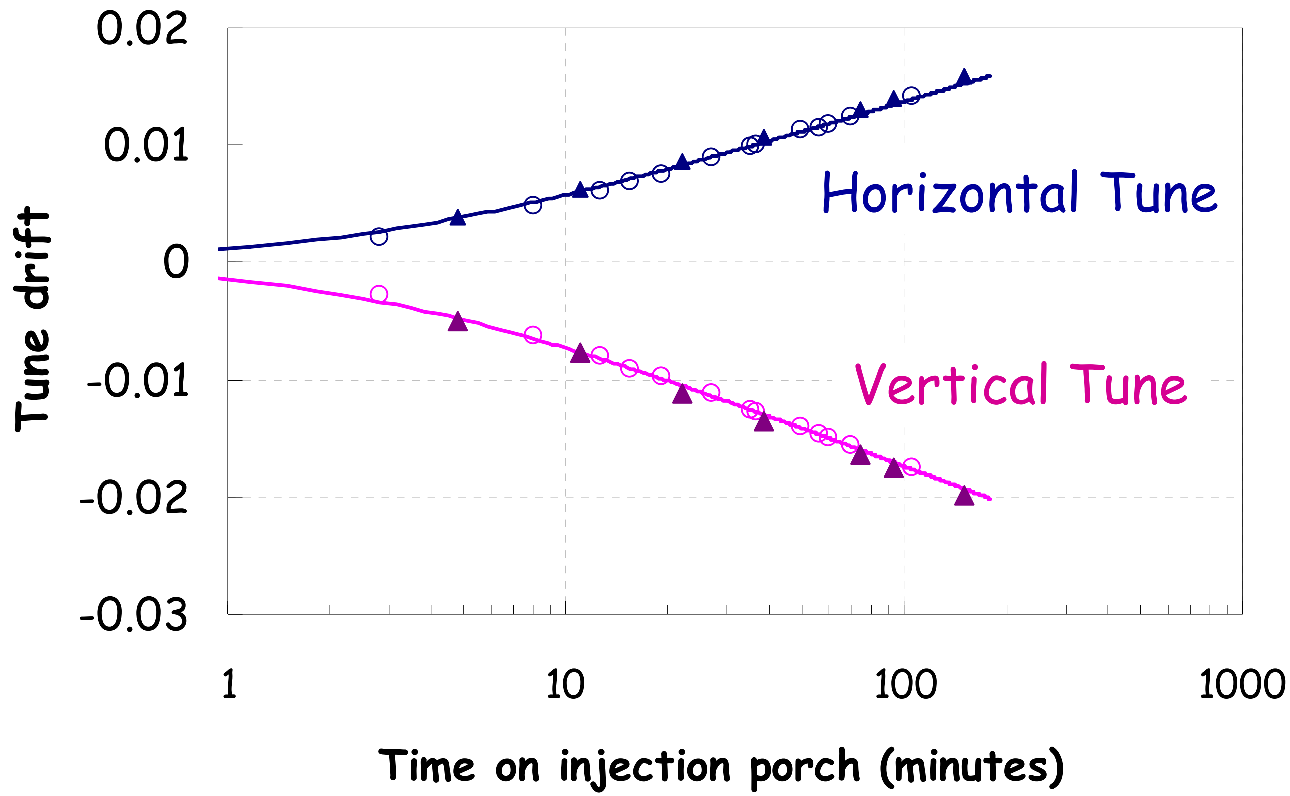




What's New

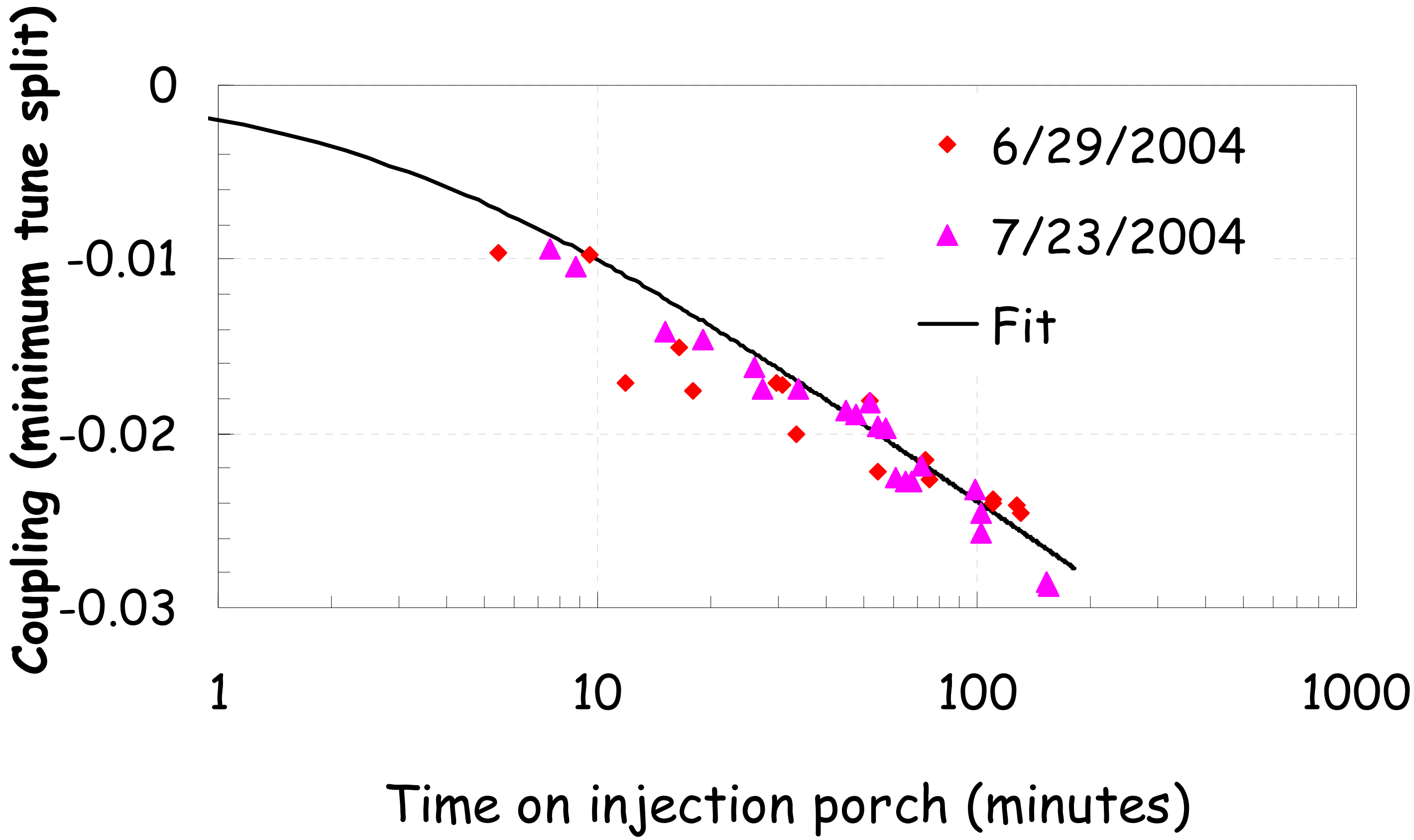
- "Discovery" of Tune and Coupling Drift
  - Documented and compensated for first time in Run II
- Challenge of Run II beam intensities
  - From 6×6 to 36×36
- Improved Magnet Measurements
  - P. Bauer (MOPA001), G. Velev (TPAP029)
- Beam Measurements
  - Focus of this talk
- Improved compensation algorithms
  - Better understanding of dynamic effects
  - Elimination of the "Dry Squeeze" Pre-cycle

Tune Drifts in the Tevatron



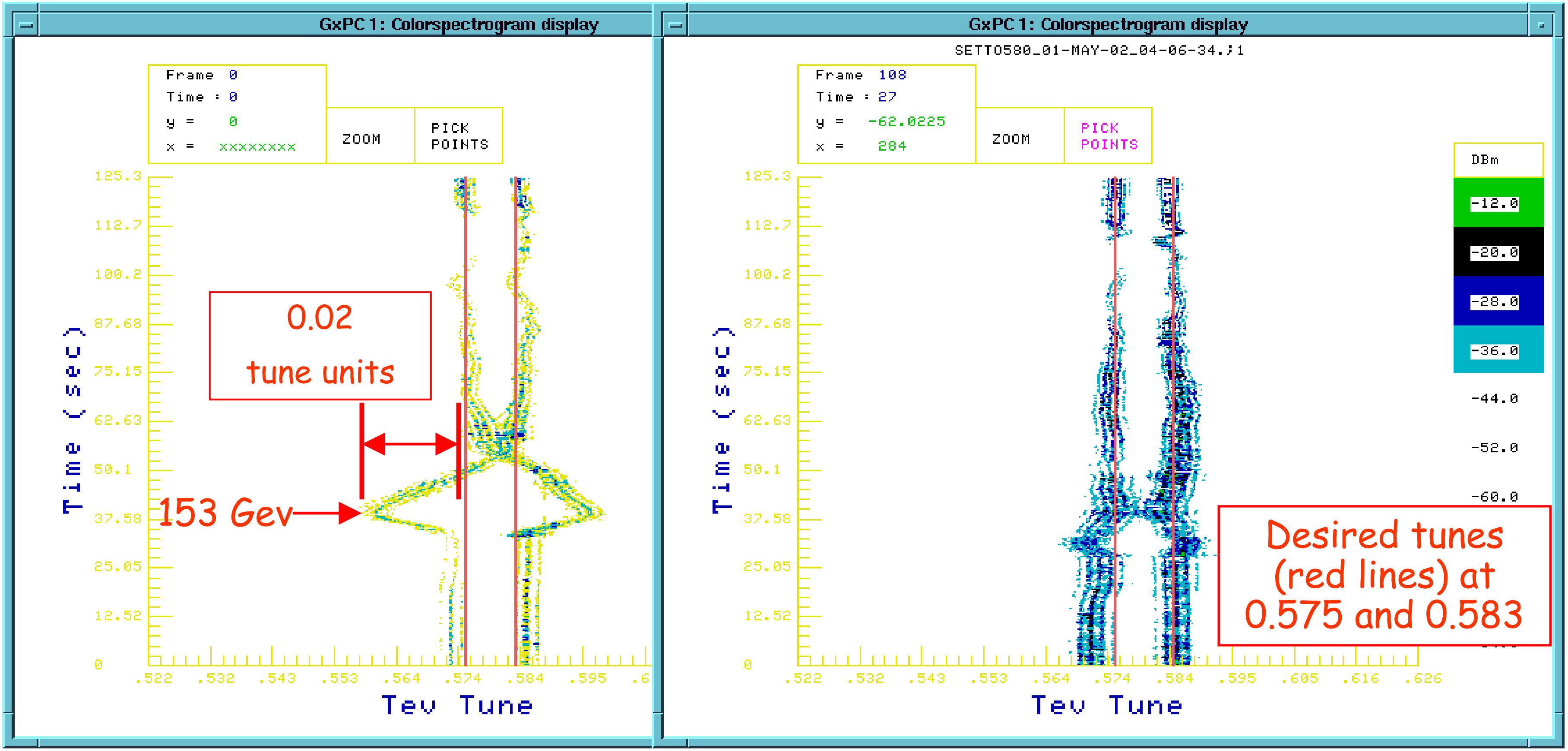
$$\nu^{\mathrm{fit}}_{\mathrm{x,drift}} = +0.003819 \times \ln\left(\frac{170\ \mathrm{s} + \mathrm{t}}{170\ \mathrm{s}}\right) \qquad \nu^{\mathrm{fit}}_{\mathrm{y,drift}} = -0.004840 \times \ln\left(\frac{170\ \mathrm{s} + \mathrm{t}}{170\ \mathrm{s}}\right)$$

Coupling Drifts in the Tevatron



$$\kappa_{SQ,drift}^{Tev-algo} = -0.00665 \times \ln\left(\frac{170\ s + t_{inj}}{170\ s}\right)$$

Tune Snapback on the Ramp



- Large tune/coupling excursions near start of ramp (150 → 153 Gev):
- Tune/coupling changes of (0.02 tune units, 0.02 minimum tune split)
- Variations fixed with **tune/coupling snapback correction** at start of ramp.

Magnitude of Drifts

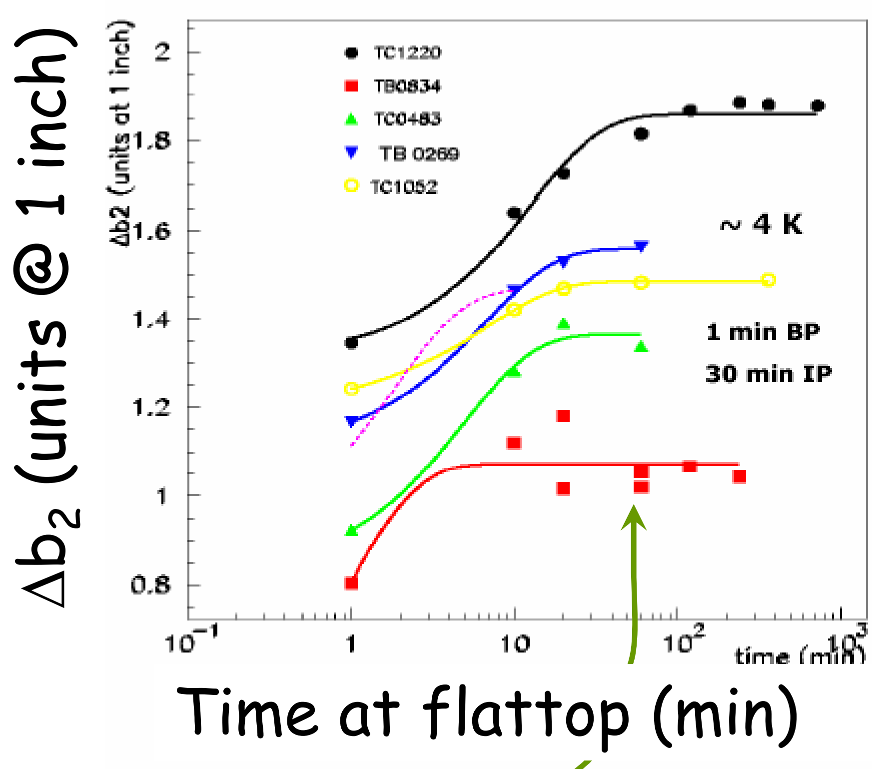
	Drift*	Tolerance
Chromaticity	40 units	~2 units
Tune	0.015 units	~0.002 units
Coupling	0.02 units of min. tune split	~0.003 units of min. tune split

Magnitude of drifts requires compensation using corrector magnets.

*After 1 hour on Injection Porch

Explore dependence of ramp history with offline magnet measurements.

Example:
Magnitude of drift depends on flattop time



Saturates after 1 hour at flattop.

Parameterization of Dynamic Effects

$$b_{2,drift}(t) = b_{2,fast} + b_{2,slope} \times \ln\left(\frac{t + t_s}{t_s}\right)$$

Fast drift for few secs, then log drift with t_s = ~300 sec

$$b_{2,snap}(t) = b_{2,drift}(t_{inj})\, e^{-\left(t / t_{SB} \right)^2}$$

Gaussian Snapback

$$t_{SB} = \sqrt{\frac{b_{2,drift}(t_{inj}) - 0.061}{0.0682}}$$

More drift means longer snapback time.

Chromaticity in the Tevatron

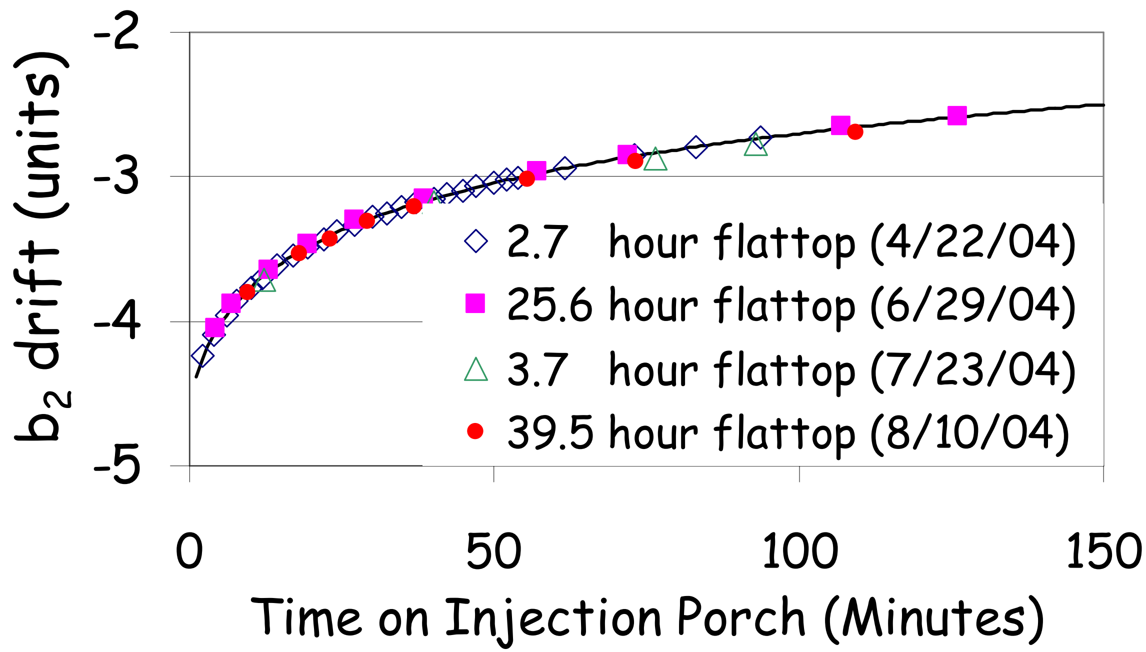
$$\xi_{\text{total}} = \xi_{b_2,\text{correctors}} + \xi_{b_2,\text{dipoles}} + \xi_{\text{natural}}$$

$$\begin{pmatrix} \xi_x \\ \xi_y \end{pmatrix} = \begin{pmatrix} 43.8 & 8.6 \\ -11.5 & -27.9 \end{pmatrix} \begin{pmatrix} I_{SF} \\ I_{SD} \end{pmatrix} + \begin{pmatrix} 26.38 \\ -24.12 \end{pmatrix} b_2 + \begin{pmatrix} -29.59 \\ -28.96 \end{pmatrix}$$

$\Uparrow$	$\Uparrow$	$\Uparrow$	$\Uparrow$	$\Uparrow$
Measure	Measure	Measure	Calculate	Calculate

Measure/estimate average b_2 in the Tevatron dipoles

Measured b_2 Drift in Tevatron



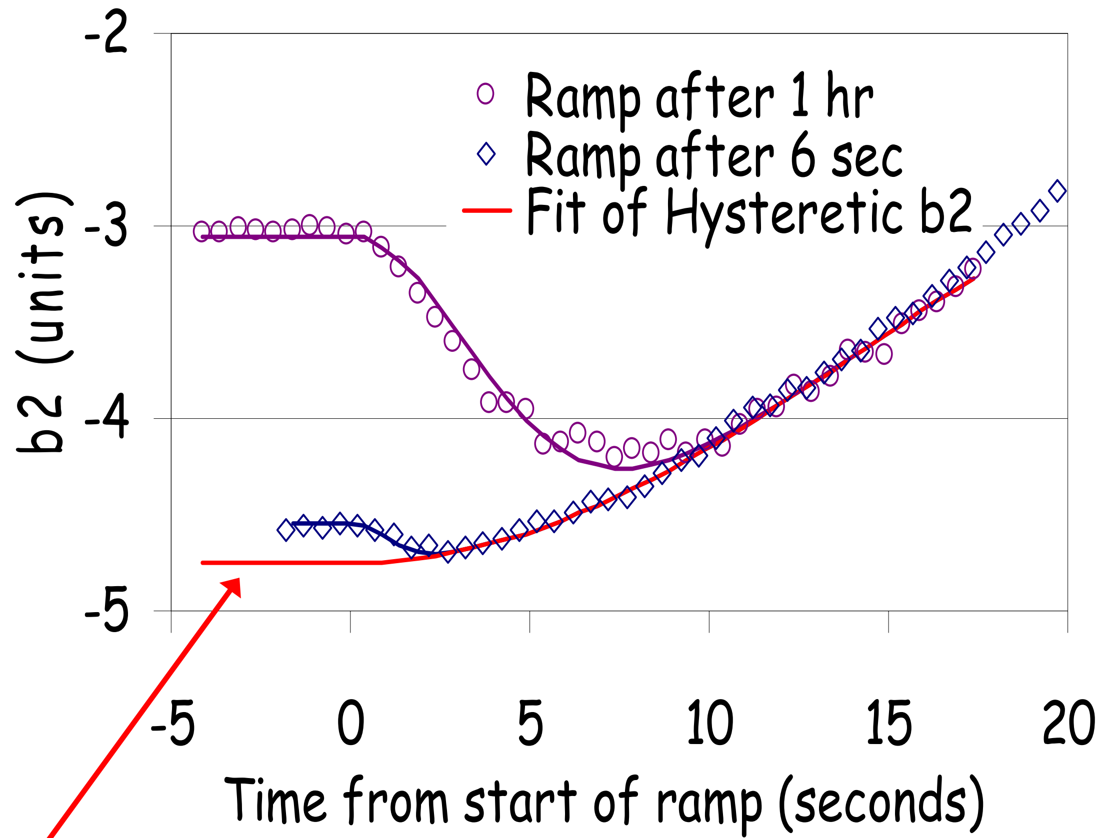
$$b_{2,\mathrm{total}}^{\mathrm{fit}}(t) = b_{2,\mathrm{hystertic}} + b_{2,\mathrm{fast}} + b_{2,\mathrm{slow}}$$

$$b_{2,\mathrm{total}}^{\mathrm{fit}}(t) = -4.75 + 0.21 + 0.512 \times \ln\left(\frac{t + 170\ \mathrm{s}}{170\ \mathrm{s}}\right)$$

Measurement of snapback at the start of Tevatron Ramp

1 hour front porch

6 sec. front porch



$$b_{2,hysteretic}(\Delta E) = -4.75 + 0.063 \times \Delta E + 0.00049 \times (\Delta E)^2$$

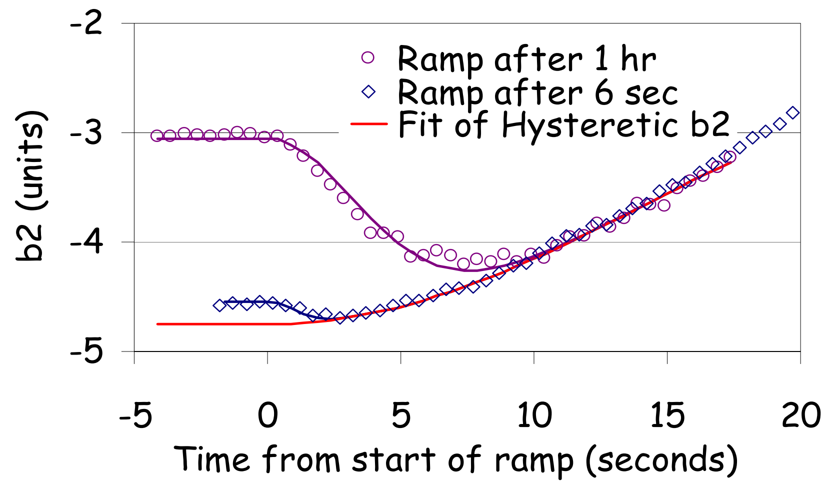
Measurement of snapback

6 sec front porch:

$b_2(t) = b_{2,hyst} + 0.21\times\exp(-(t/1.45)^2)$

1 hour front porch:

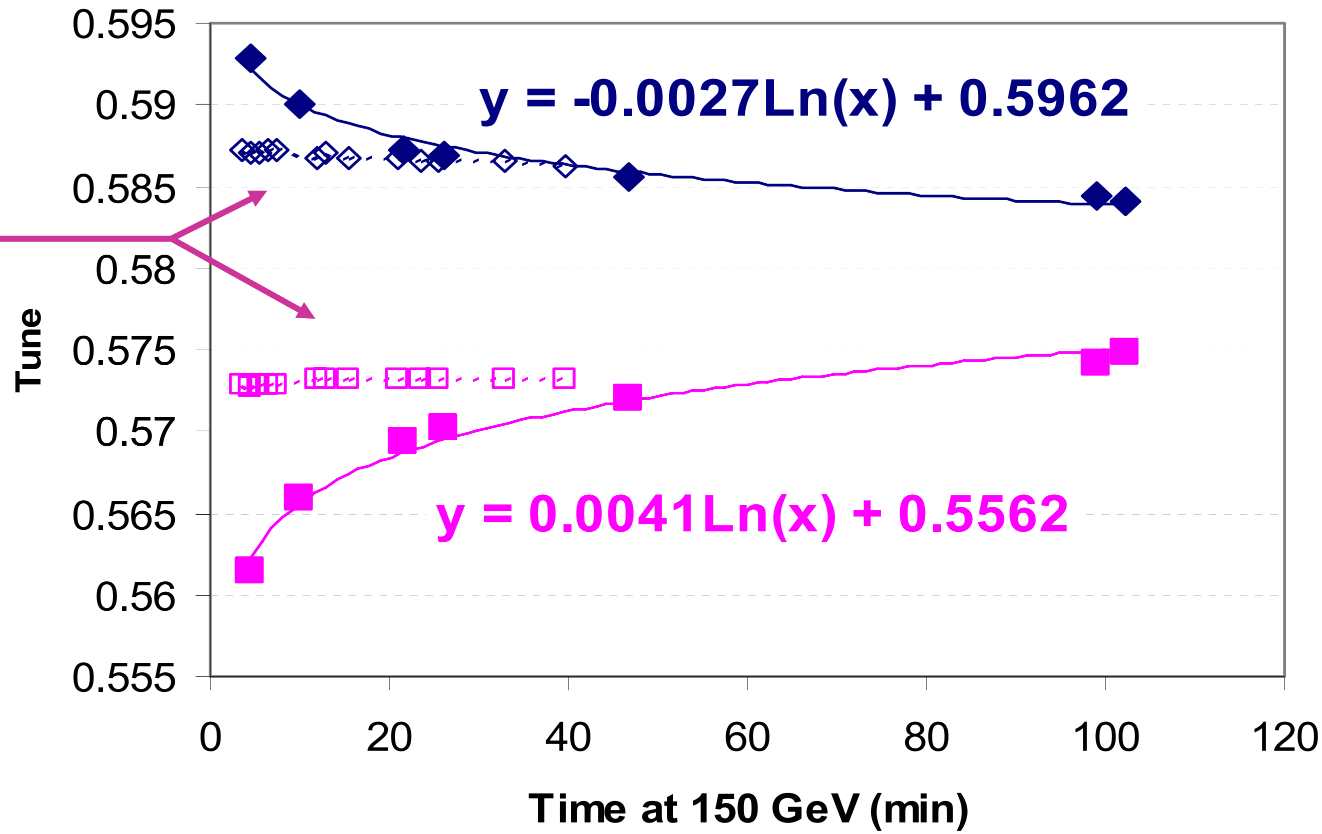
$b_2(t) = b_{2,hyst} + 1.69\times\exp(-(t/4.75)^2)$



	Magnitude	Measured time	Predicted time
6 second front porch	0.21	1.45 secs	1.42 secs
1 hour front porch	1.69	4.75 secs	4.88 secs

Tune Drift @ 150 Gev

After correction algorithm was implemented



We like $\Delta\upsilon(t) < 0.002$

Why does the tune drift?
Is it related to b_2 drift?

Conclusions

- Chromaticity, Tune, and Coupling Drift and Snapback have been measured in the Tevatron.
- Understanding has been improved and led to updated correction algorithms.
- Agreement between magnet measurements and Tevatron measurements