Fermilab

Measurement and Correction of Tune and Chromaticity Drifts in the Tev

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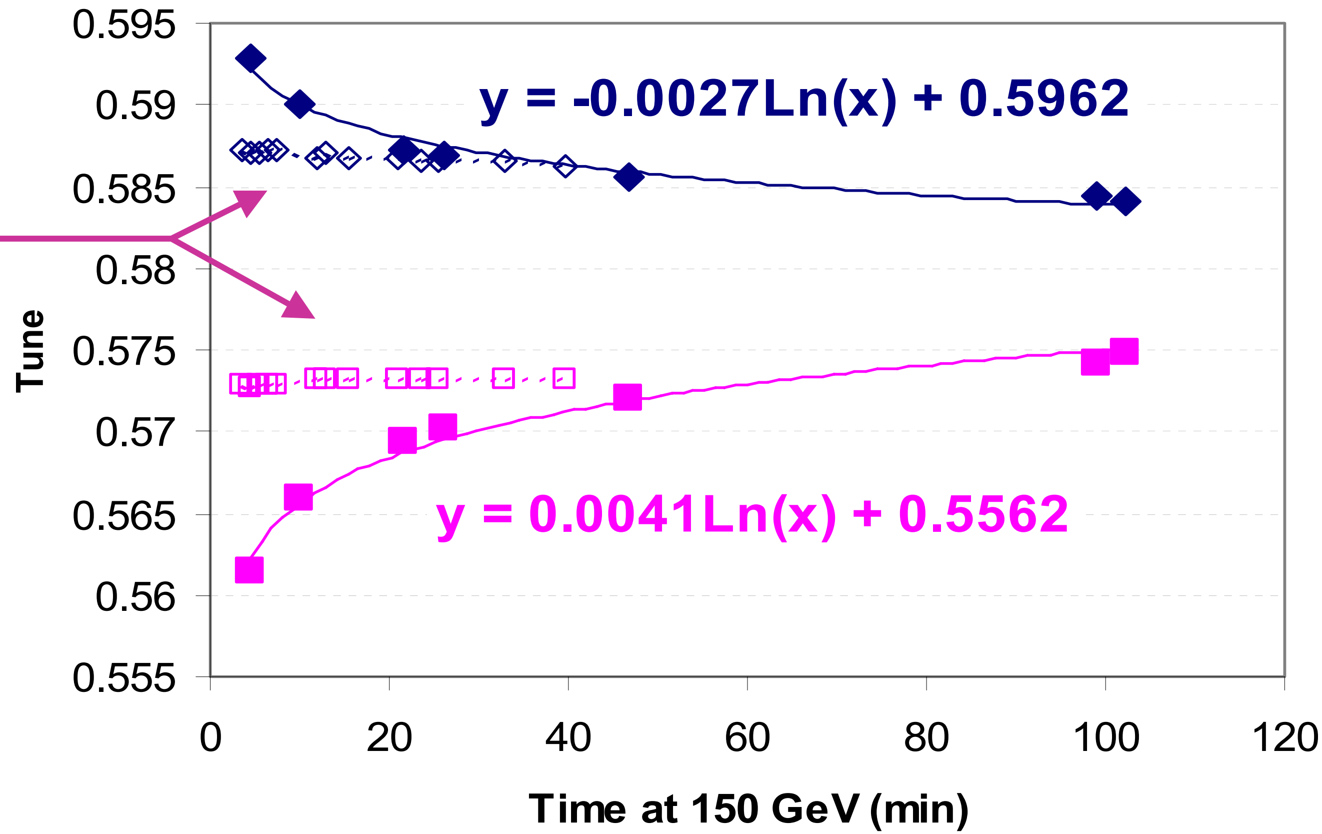
Tune Drift @ 150 Gev

After correction algorithm was implemented

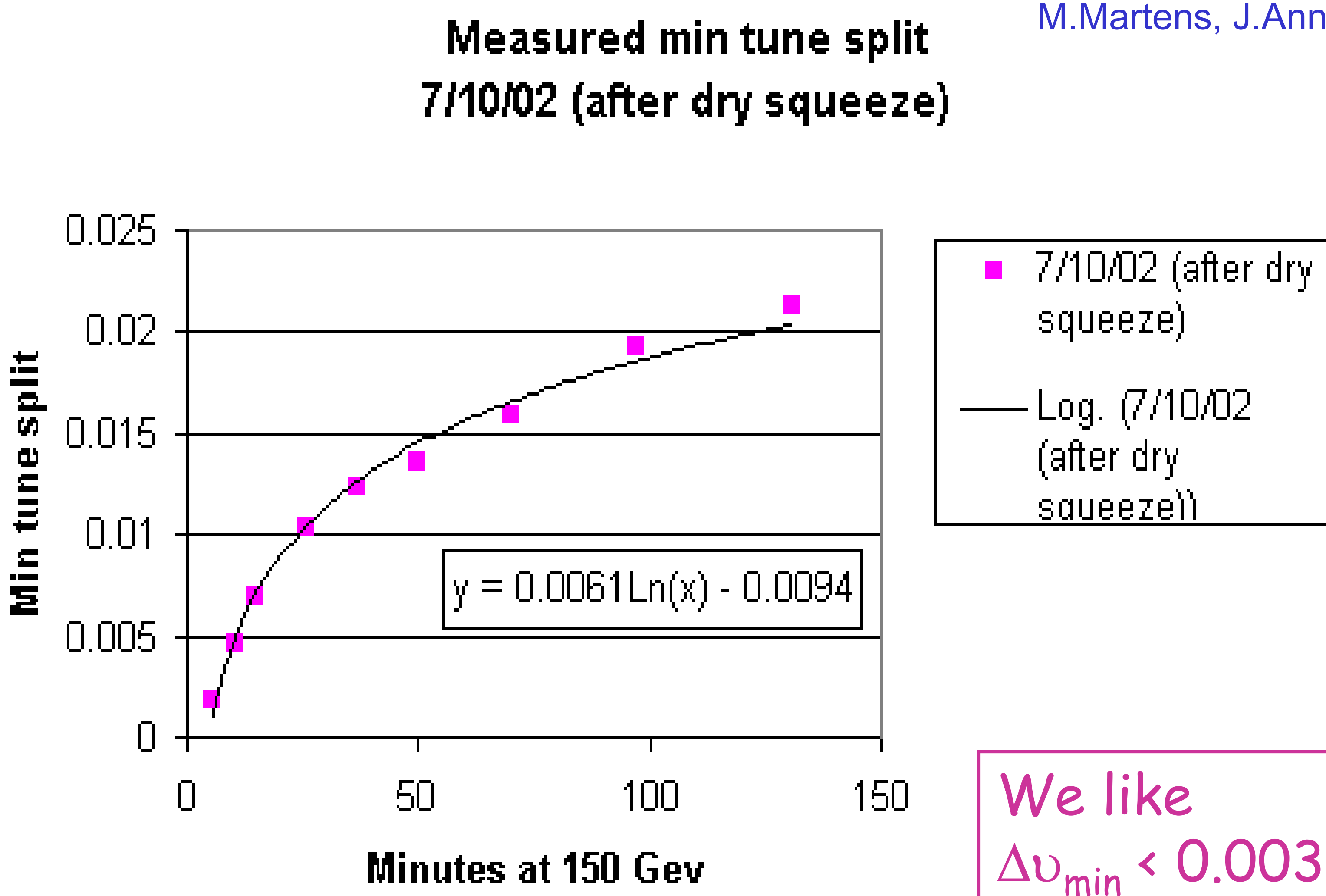
We like $\Delta\upsilon(t) < 0.002$



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

Coupling Drift @ 150 Gev

M.Martens, J.Annala

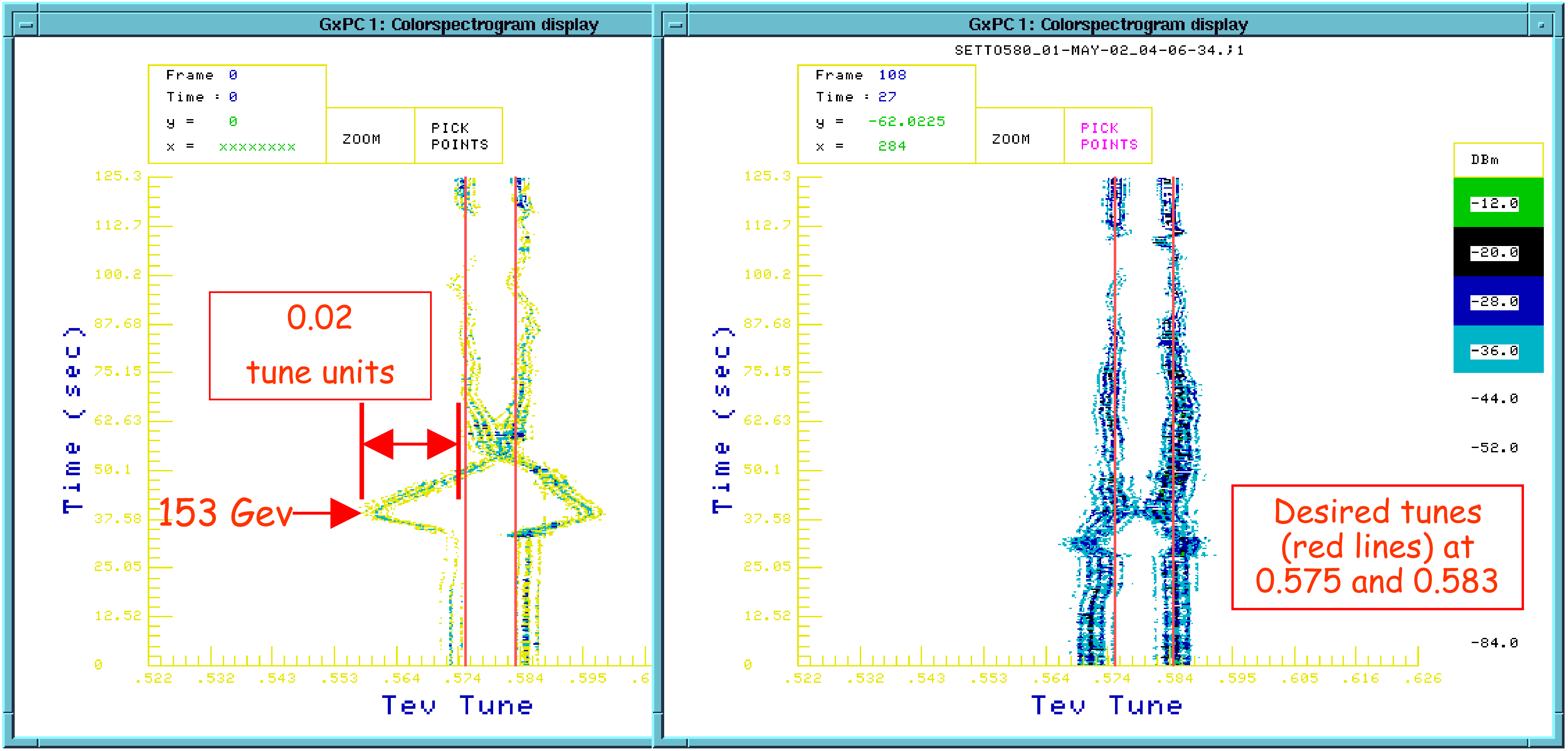


We like $\Delta\upsilon_{min}$ < 0.003

The “fine print” for this talk

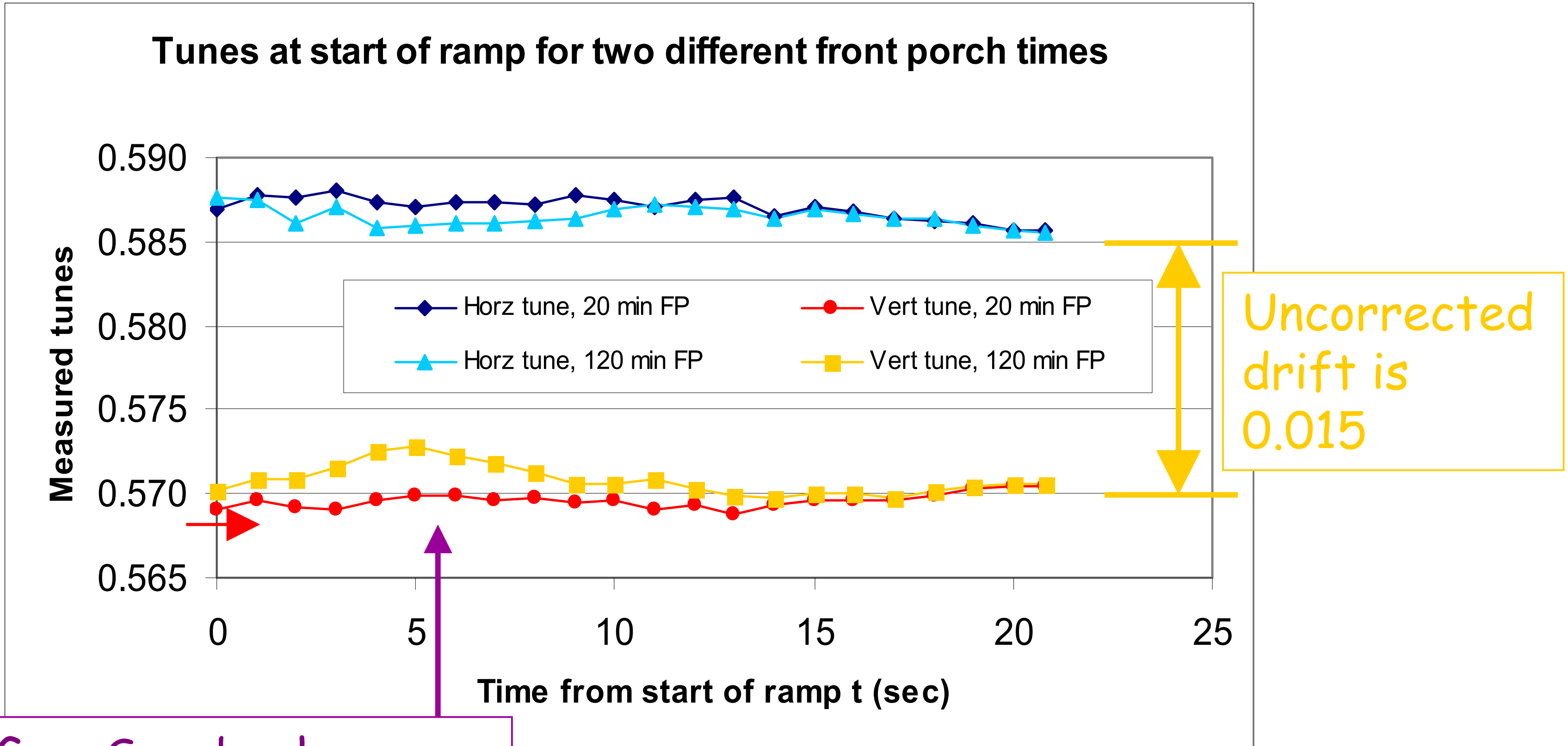
- Design Tevatron lattice (MAD) for most calculations.
- All measurements on the central orbit (i.e. no helix)
- Consider only the typical shot setup scenario
  - 15 minute dry squeeze between stores.
  - ~1 minute back porch
  - Results not applicable to “no dry squeeze” situation
- Do not consider
  - Coupling in MAD model
  - Rolled dipoles or quads in MAD model
  - Higher order multipoles in MAD model
  - Distribution of b_2 along a dipole magnet

Tune Variations on Ramp/squeeze



- Near start of ramp (150 → 153 Gev): large tune/coupling excursions
- Tune/coupling changes of (0.02 tune units, 0.02 minimum tune split)
- Variations fixed with <u>additional breakpoint at 153 Gev</u> and <u>tune/coupling snapback correction</u> at start of ramp.

Tune Variations on Ramp/squeeze



153 Gev. Snapback corrections are done.

Snapback algorithm:

$\Delta\upsilon_x = \upsilon_{x,0}\,[1-2(t/T)^2+(t/T)^4\,]$ T=6sec

$\Delta\upsilon_y = \upsilon_{y,0}\,[1-2(t/T)^2+(t/T)^4\,]$ T=6sec

$\Delta Sq = Sq_0\,[1-2(t/T)^2+(t/T)^4\,]$ T=6sec

Summary: Tune Compensation

Run II is first time for tune drift and snapback compensation.

Tune and coupling drift at 150 Gev well compensated.

Tune snapback much better. Maybe could be fine tuned? Maybe longer that 6 seconds?

Coupling snapback has not been measured. (Time consuming to do so.)

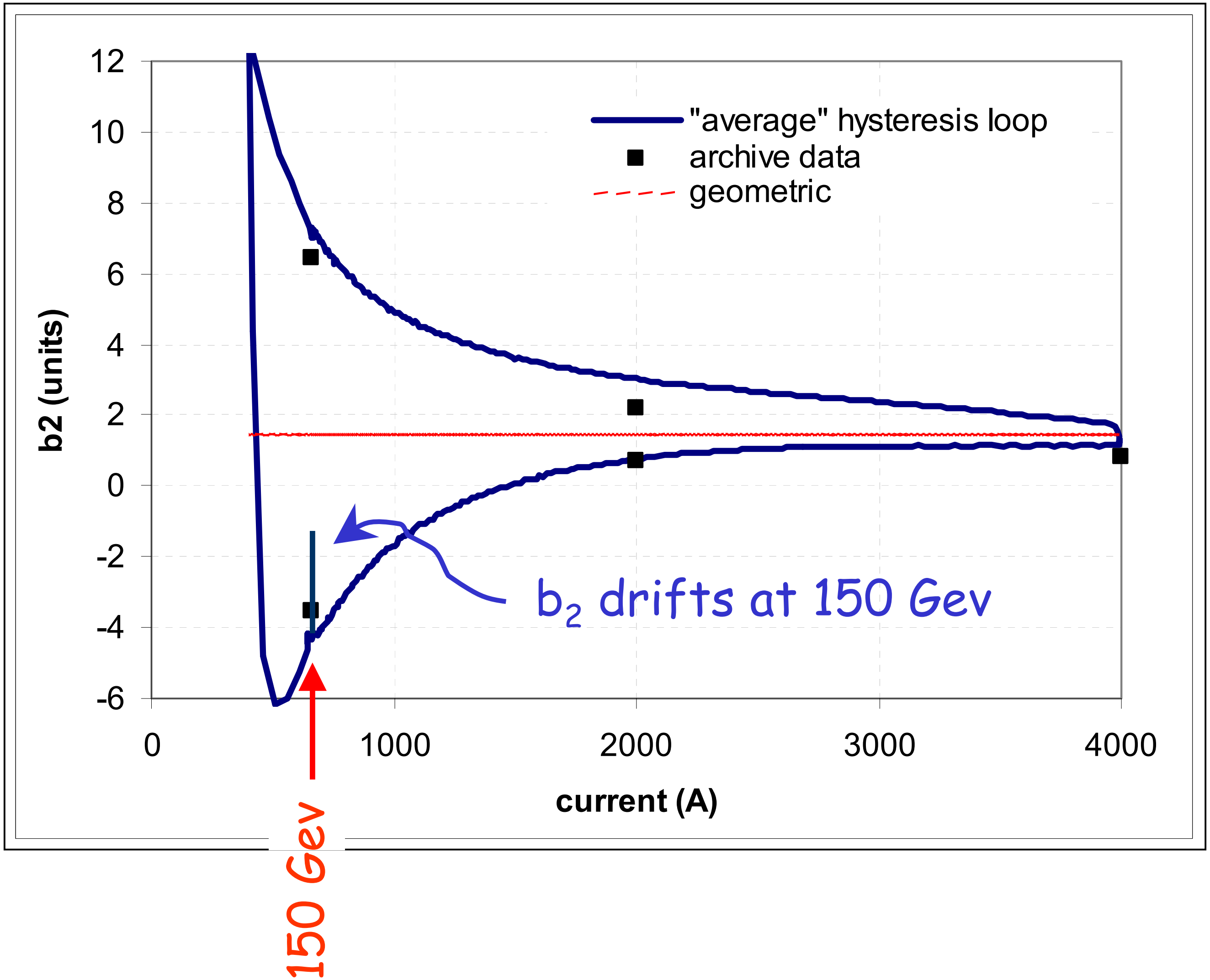
Drifts not yet completely explained.

Is the tune drift related to feeddown effects?

- Orbit offsets in sextupole field feeddown to quadrupole field ⇒ changes the tune.
- Similar time behavior for both b_2 and tune drift.
- Tune excursions at ramp start are in first ~6 secs, which is length of b_2 snapback.
- Definitely have orbit offsets
  - Scallop effect from rolled dipoles.
  - Radial position offset in Tev orbit.

So, lets digress and understand b_2 in Tev first, then ask if feeddown hypothesis is correct

Chromaticity Hysteresis



Chromaticity in the Tevatron

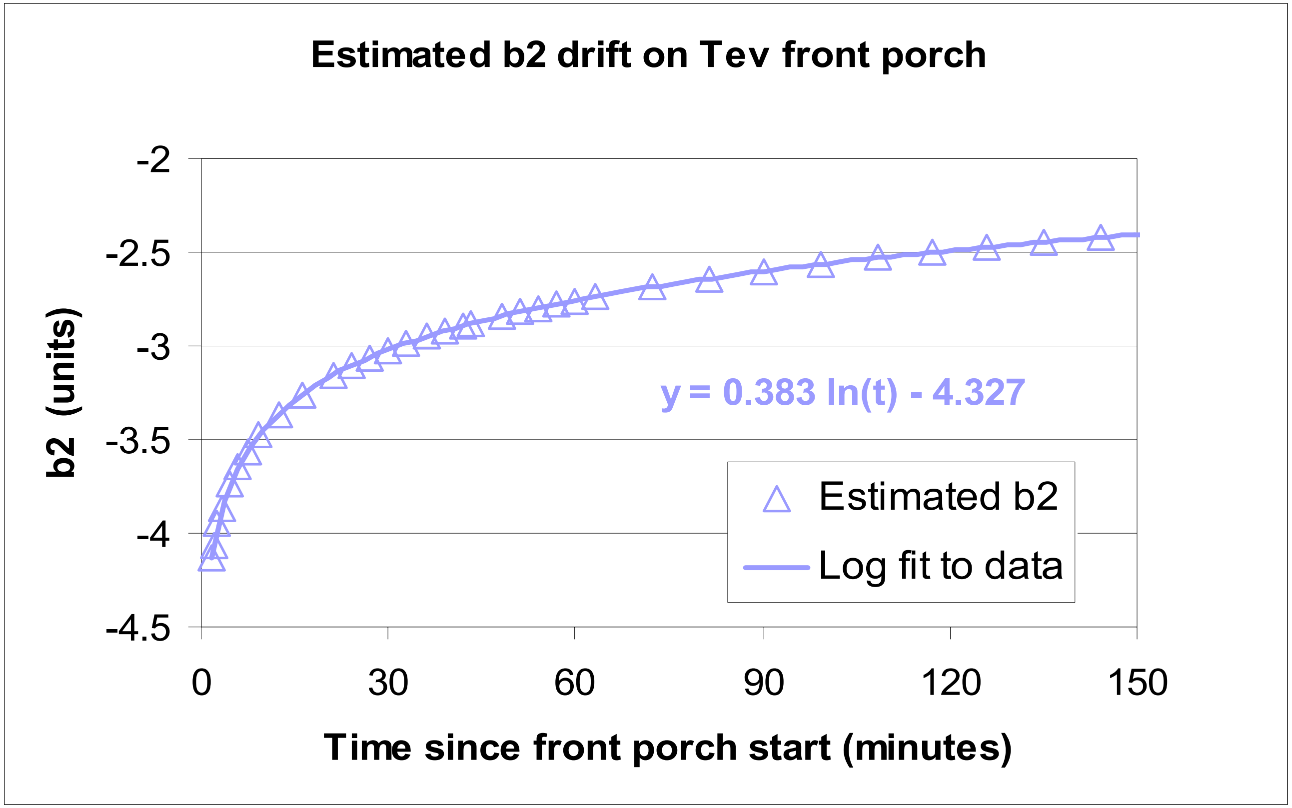
Total = Chrom. correctors + Dipole b_2 + Natural

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

⇑ Measure ⇑ Measure ⇑ Measure ⇑ Calculate ⇑ Calculate

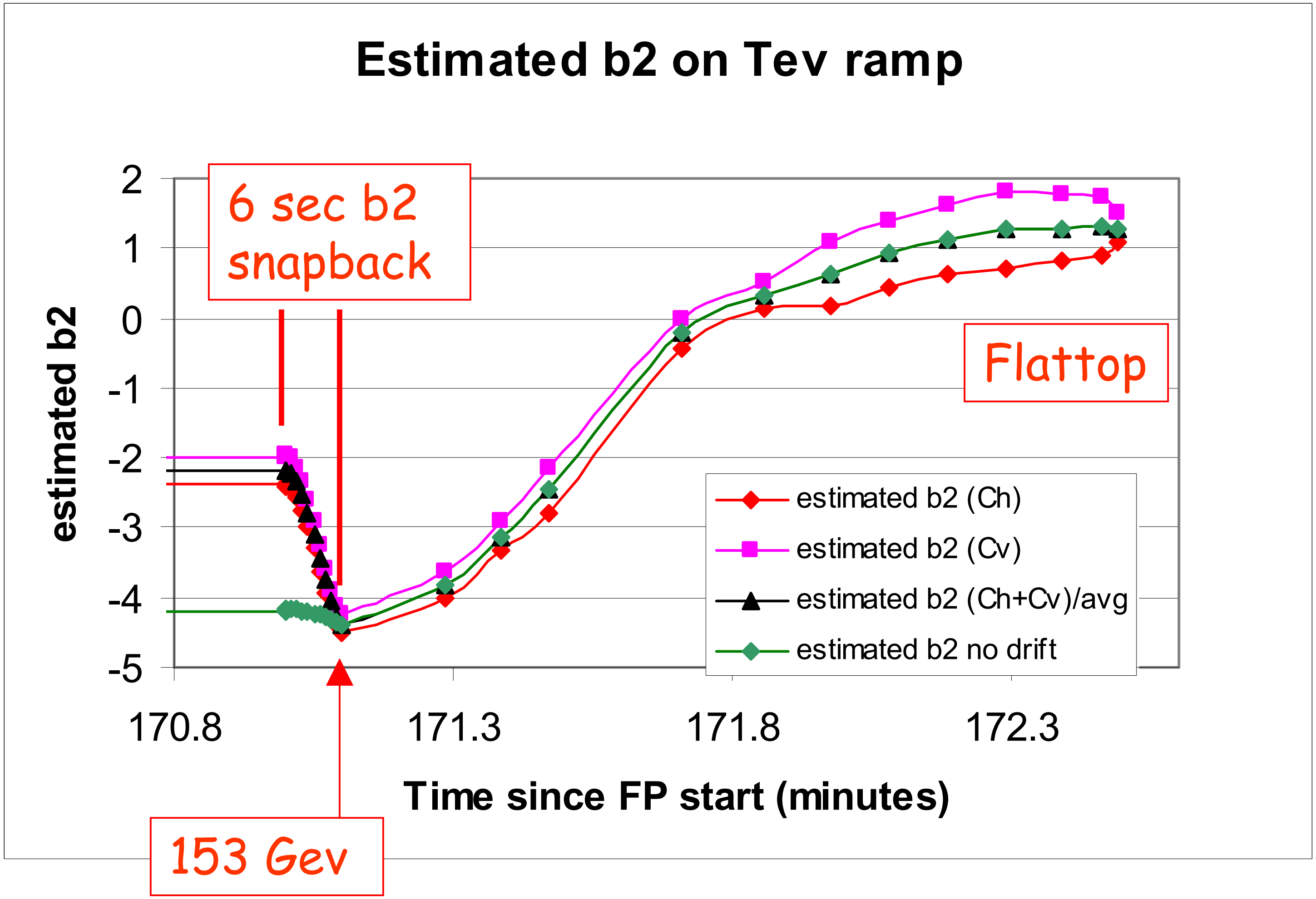
Measure/estimate average b_2 in the Tevatron dipoles

b2 drift at 150 Gev

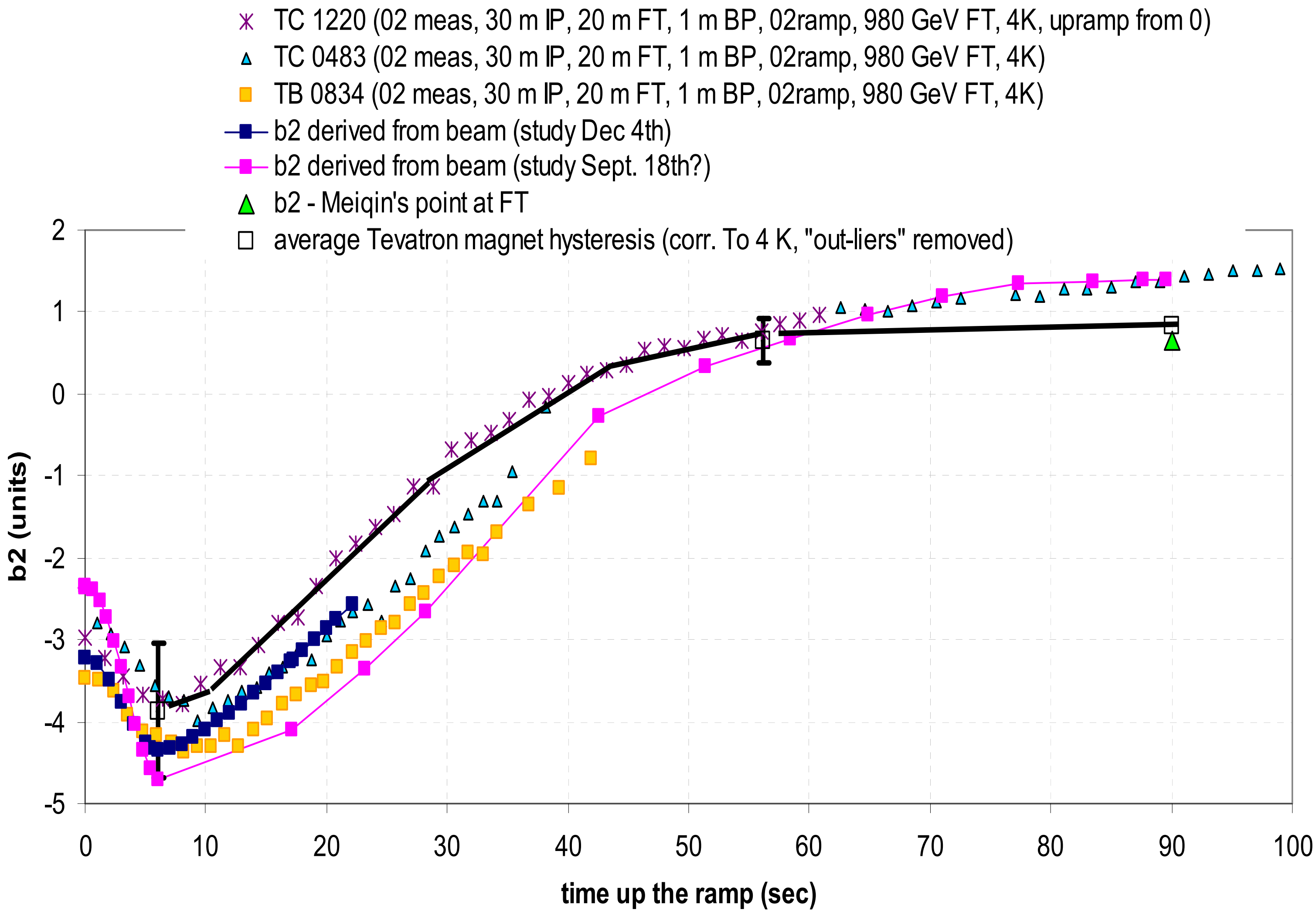


- ξ would drift by ~50 units, but controlled to ~2 units.
- Compensated with sextupole corrector time ramp.
- Algorithm is based on '96 magnet meas. and beam meas. (Annala)

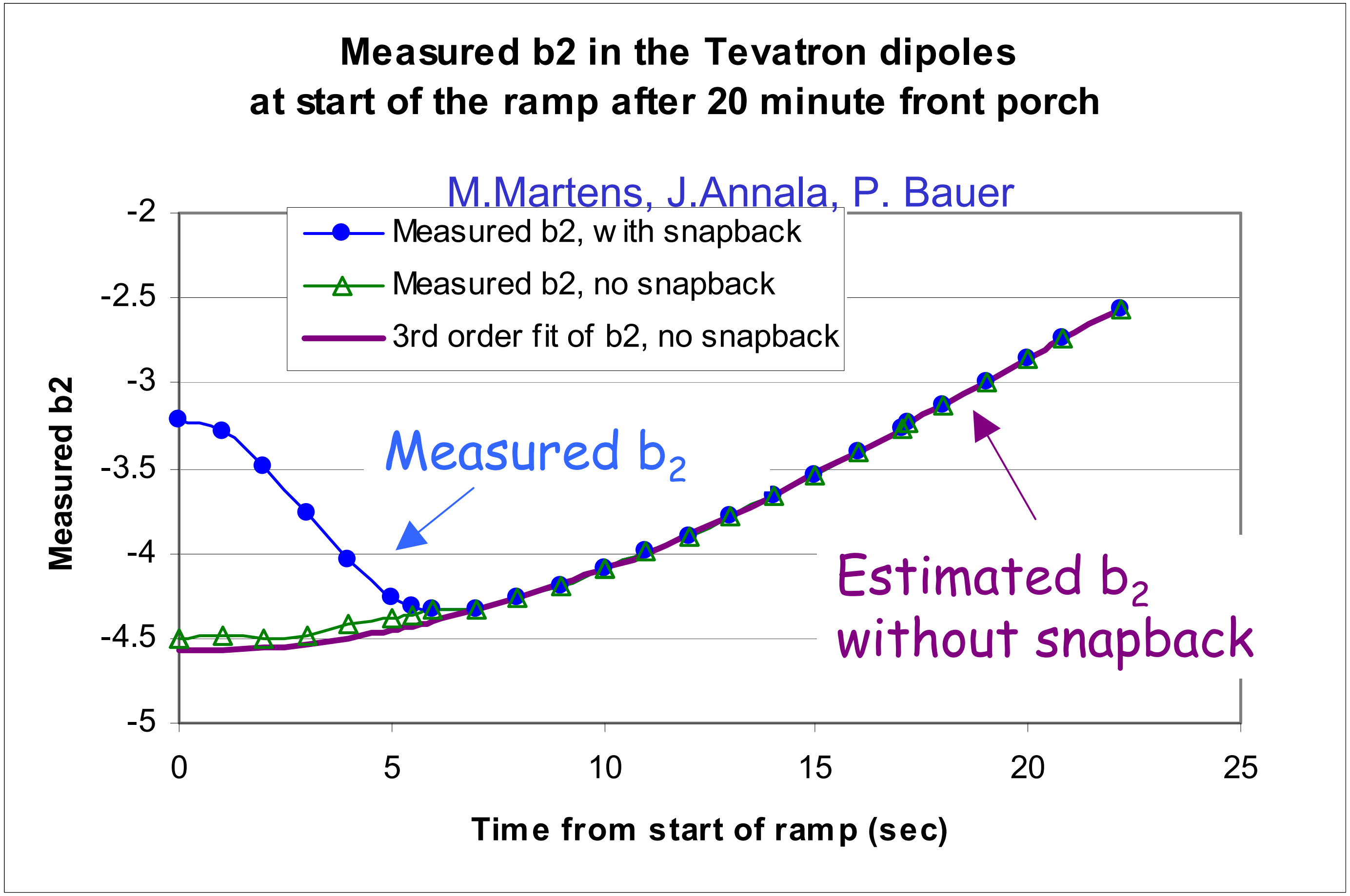
b2 on the ramp (including snapback)



b2 measurements compared to magnets



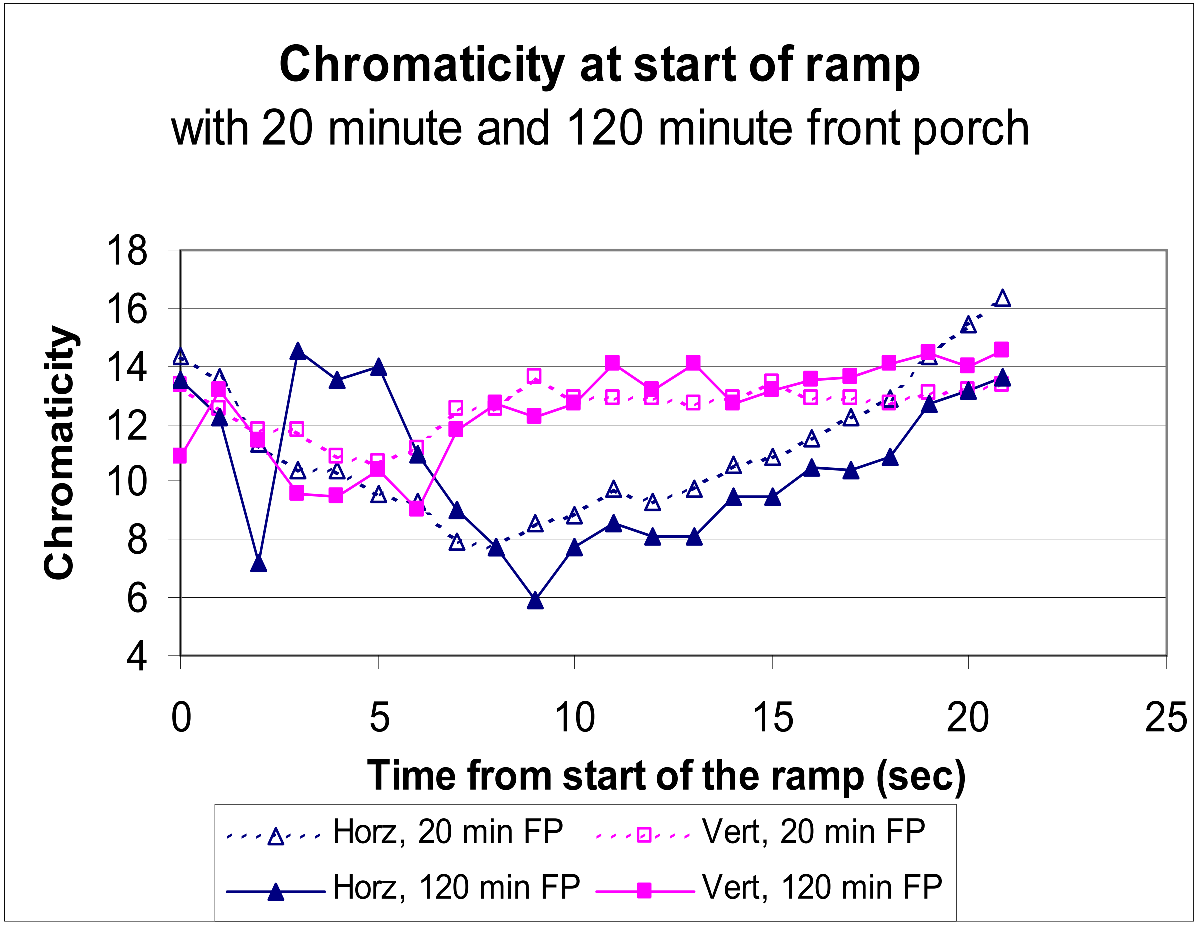
b2 Snapback Measurements



b2 snapback algorithm:

b2 comp. $= \Delta b2\ [1-2(t/T)^2+(t/T)^4\ ]$ T=6sec

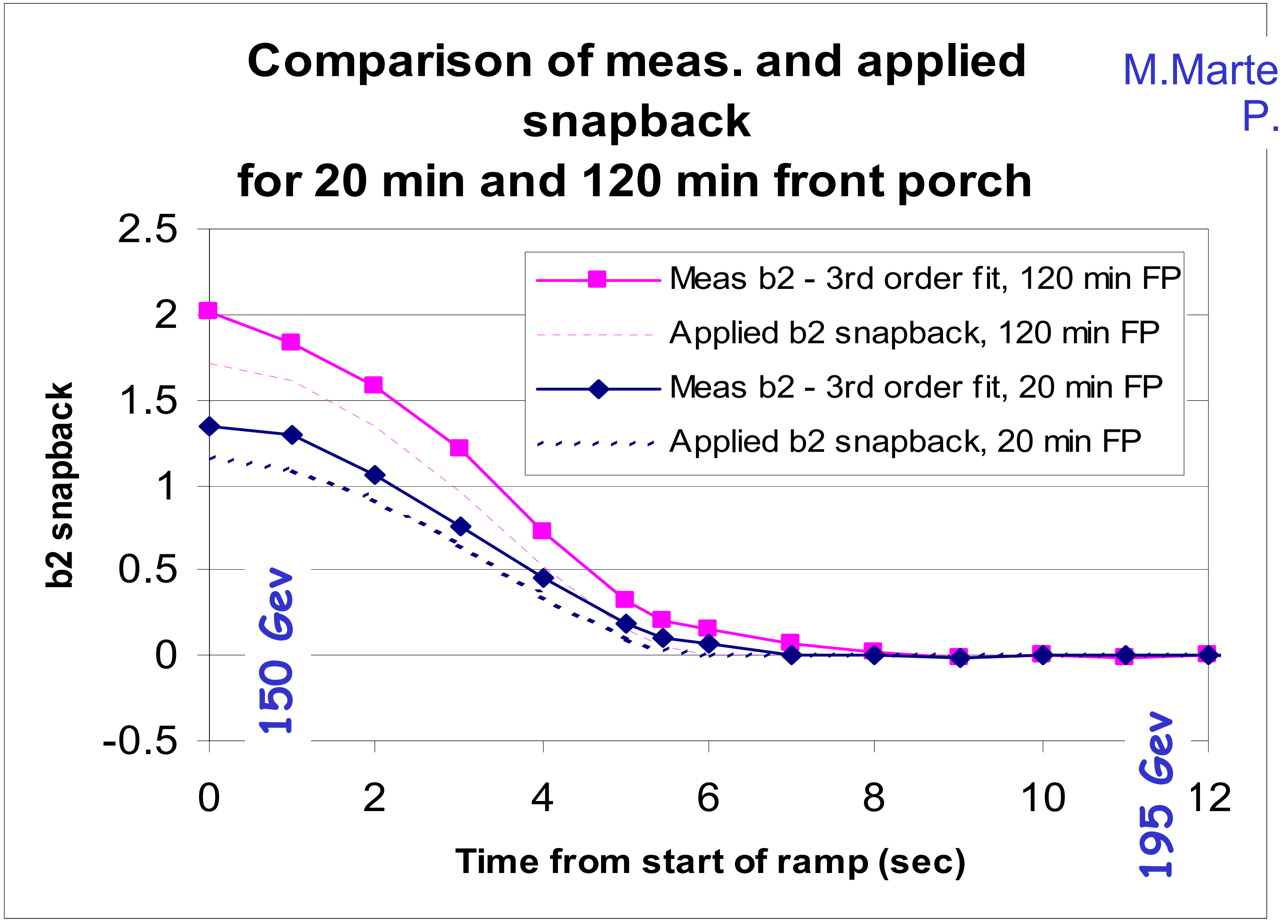
Chromaticity Measurements



ξ at start of ramp

- Time capture mode
- Tunes split and adjusted at start of ramp
- Tunes every 1 sec
- 2 ramps with ΔRF

Chromaticity Snapback Compensation



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Summary: b2 Snapback Measurements

First time in RunII for precise b2 snapback measurement. (Having tune drift compensation helped)

Algorithm,

$\Delta b2\ [1-2(t/T)^2+(t/T)^4\ ]\quad T=6sec,$

works well for 20-minute and 120-minute front porch (with "standard shot setup" preparations)

Maybe snapback takes ~8 seconds instead of ~6 seconds? Maybe underestimate amount of correction needed.

Tune drift from feeddown

$$\Delta \nu_x = \frac{1}{4\pi} \sum \beta_x \, (\Delta K_1 L) = \frac{1}{4\pi} \sum \beta_x \, (\Delta K_2 L) \, \Delta x$$

Quad field   Sextupole field

Orbit offset

Three sources of time varying sextupole fields

$$\Delta \nu_x = C_{Dip} \langle \Delta b_2 \rangle \langle \beta_x x_0 \rangle_{Dip} + C_{SF} \Delta I_{SF} \langle \beta_x x_0 \rangle_{SF} + C_{SD} \Delta I_{SD} \langle \beta_x x_0 \rangle_{SD}$$

Tune drift from feeddown?

$\Delta \nu_x = -0.0027 \ln(t)$ ⇐ Measured tune drift

$\Delta b_2 = +0.358 \ln(t)$ ⇐ Meas/est b2 drift

$\Delta I_{SF} = -0.19 \ln(t)$ ⇐ b2 compensations

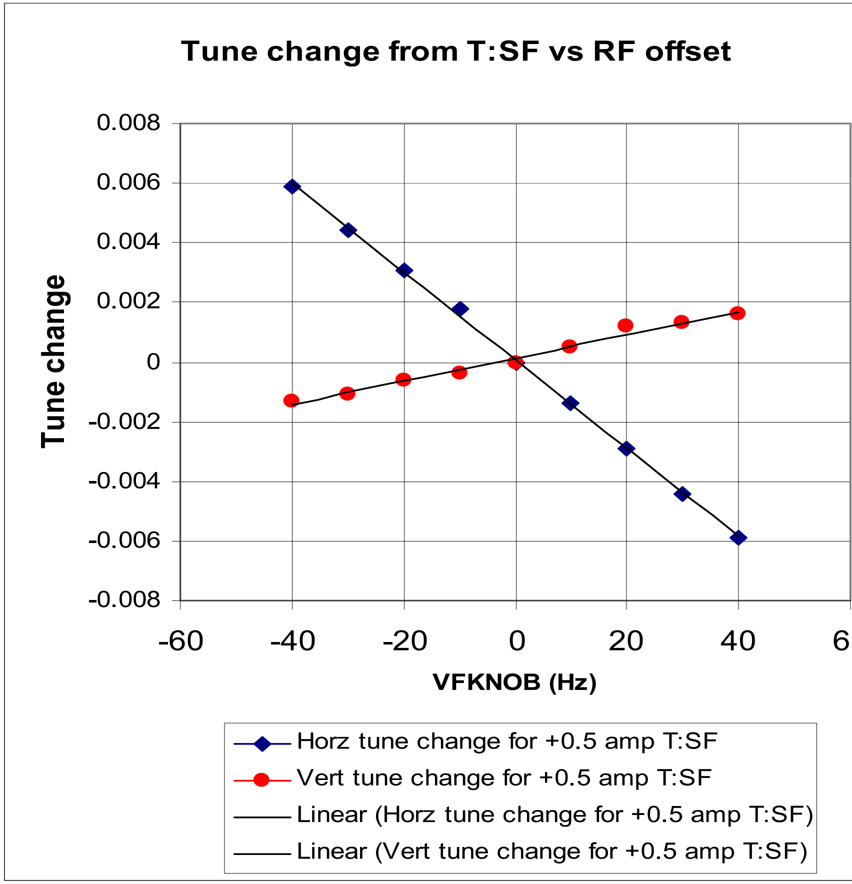
$\Delta I_{SD} = -0.293 \ln(t)$ ⇐ b2 compensations

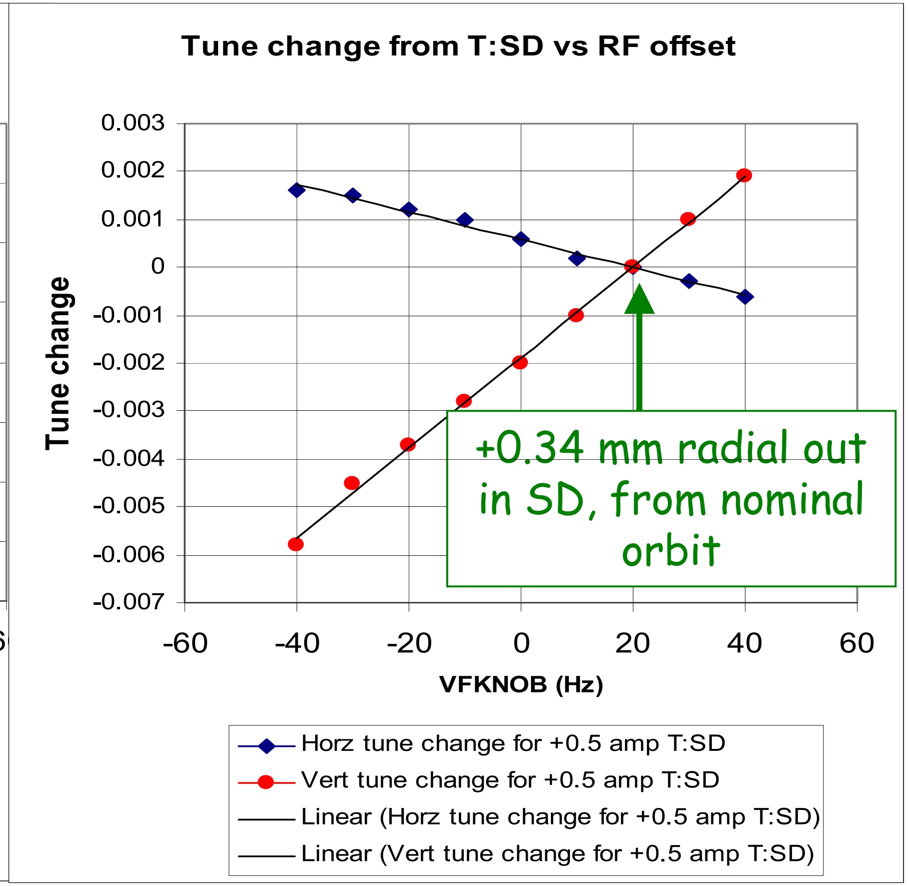
This gives (where x in mm) ⇒

$$-2.7 = 3.44\langle x \rangle_{\text{Dipole}} - 2.04\langle x \rangle_{\text{SF}} - 1.02\langle x \rangle_{\text{SD}}$$

What are orbit offsets?

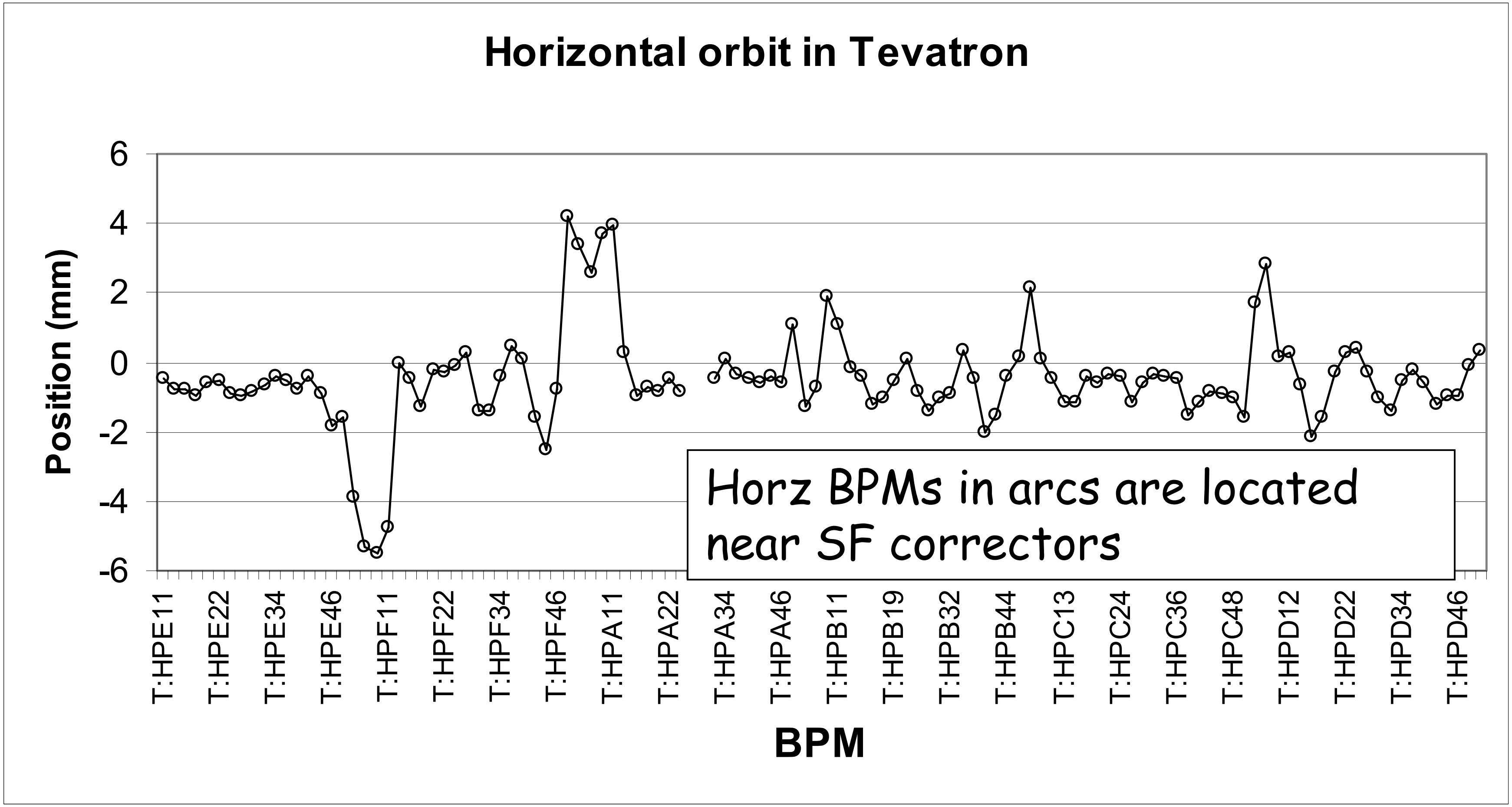
Where is beam in T:SF and T:SD?





Horz orbit is centered (on average) in T:SF magnets
Horz orbit is +0.34 mm (on average) in T:SD magnets
Measurement also provides calibration of T:SF and T:SD

Orbit in Tev from BPMs



$$\text{From BPMs} \quad \langle x \rangle_{SF} = -0.71\,\text{mm}$$

Horizontal orbit offset needed (1)

<u>Scenario #1: Believe SF and SD center meas.</u>

$$-2.7 = 3.44\langle x\rangle_{Dip} - 2.04\langle x{=}0\rangle_{SF} - 1.02\langle x{=}{+}0.34\rangle_{SD}$$

$$\Rightarrow \langle x\rangle_{Dipole} = -.68 \text{ mm}$$

(Using vertical tune drift $\langle x\rangle_{Dipole} = -.95$ mm)

How can we be off –0.68 mm horizontally in dipoles, but not in SF and SD?

Horizontal orbit offset needed (2)

Scenario #2: Believe BPMs at SF

$-2.7 = 3.44\langle x\rangle_{Dip} - 2.04\langle x=-.71\rangle_{SF} - 1.02\langle x=0?\rangle_{SD}$

$\Rightarrow \langle x\rangle_{Dipole} = -1.13$ mm

(Using vertical tune drift $\langle x\rangle_{Dipole} = -1.4$ mm)

Coupling drift from feeddown

$$\Delta \nu_{\min} = \frac{1}{2\pi} \sum \mathrm{sqrt}(\beta_x\ \beta_y)(\Delta \mathrm{K}_2 \mathrm{L})\ \Delta \mathrm{y}$$

$$\Delta \nu_{\min}(t) = 0.006 \ln(t)$$

$$(\Delta K2L)(t) = 9.78 \times 10^{-4} \ln(t)\ \mathrm{m}^{-2}$$

$$\langle\ \mathrm{sqrt}(\ \beta_x \beta_y)\rangle = 53\ \text{meters}$$

$\langle y \rangle_{Dipole} = +0.94$ mm

Summary: b2 feeddown hypothesis

Still seems plausible, but some mysteries remain.

Why do BPMs and SF scans give different orbit offsets?

Do we really have ~1mm horizontal offsets in dipoles. Seems likely from BPM orbit.

How does alignment and coupling change things?