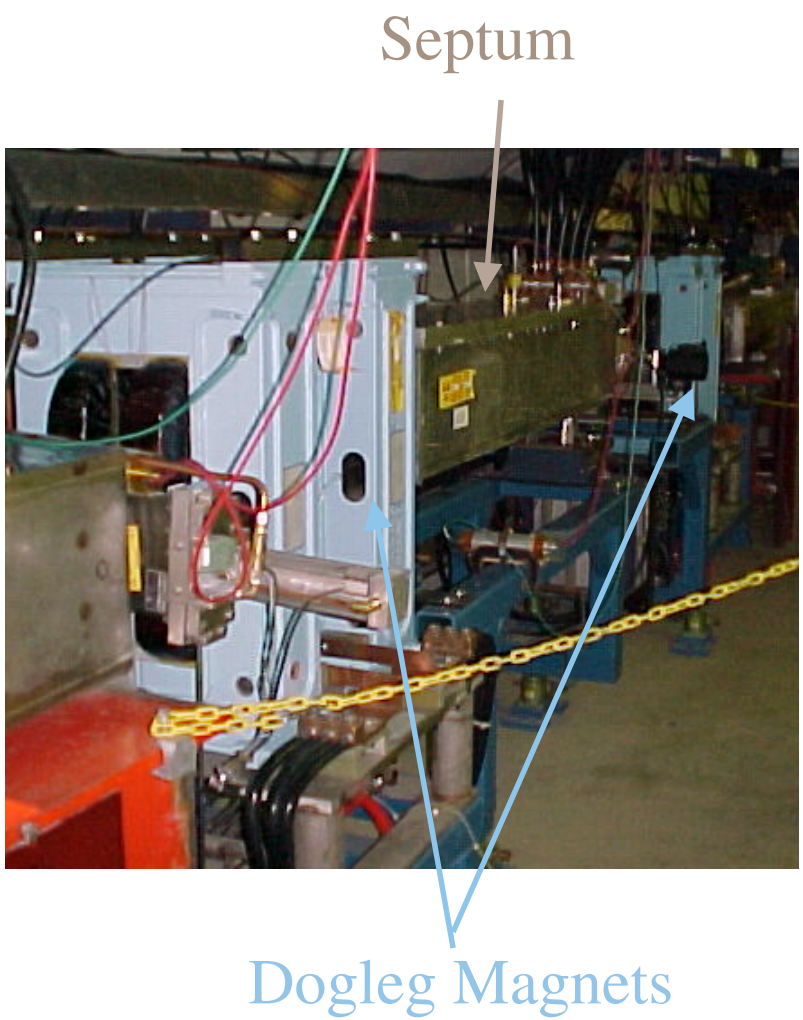
Dog(leg)s of War

Eric Prebys

Run II Meeting

March 13, 2003

Dogleg Problem



- Each of the two Booster extraction septa has a set of *vertical* dogleg magnets to steer the beam around it during acceleration.

- More powerful doglegs were installed in 1998 to reduce losses early in the cycle.

- These magnets have an edge focusing effect which distorts the *horizontal* injection lattice:
  - 50% increase in maximum β
  - 100% increase in maximum dispersion.
  - Harmonic contributions.

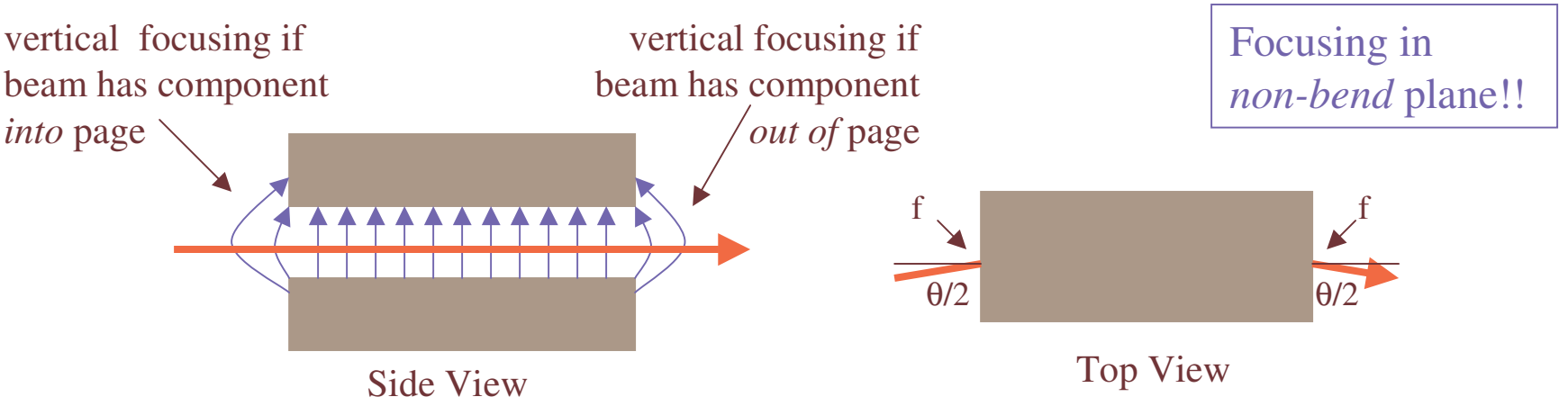
- Effect goes like I^2. Now tune to minimize.

- Recently got an unusual opportunity to explore potential improvements from fixing the problem.

- Working on schemes to reduce or remove problem.

Parasitic Focusing

Rectangular (RBEND) magnet:



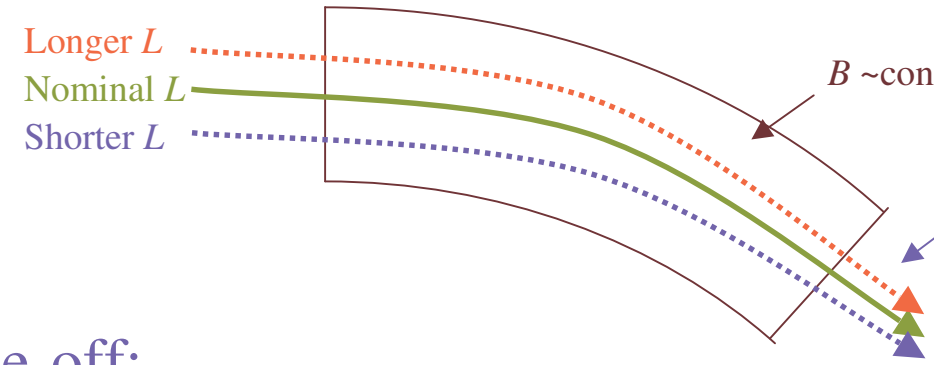
Focusing in *non-bend* plane!!

Always focusing!!

$$\frac{1}{f} = \frac{1}{\rho}\tan\frac{\theta}{2} \cong \frac{\theta^2}{2L} \quad \text{(per edge)}$$

Parasitic Focusing (cont'd)

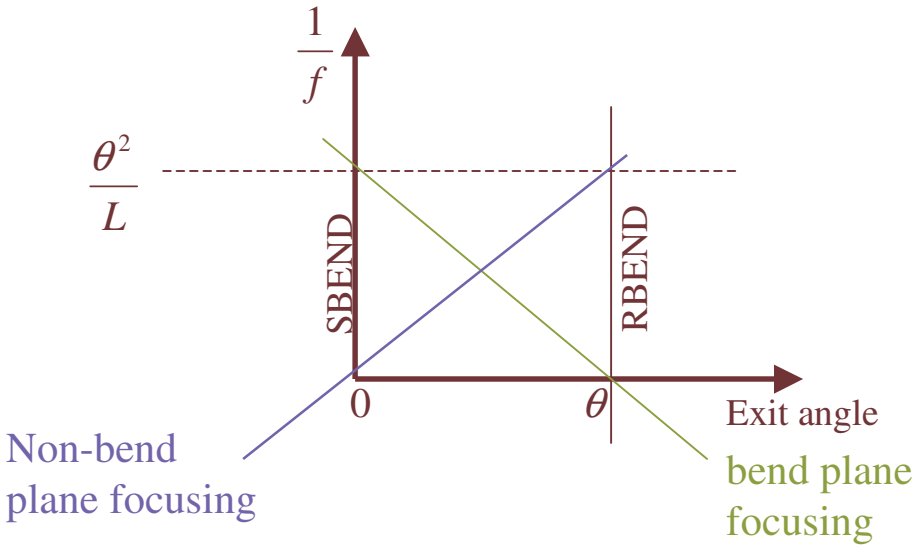
Sector (SBEND) magnet:



Focusing in *bend* plane!!

$$\frac{1}{f} \cong \frac{\theta^2}{L}$$

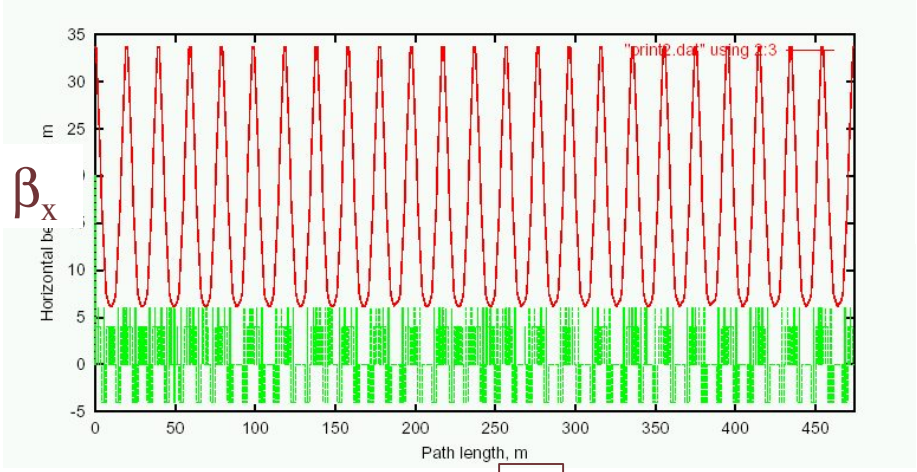
Trade-off:



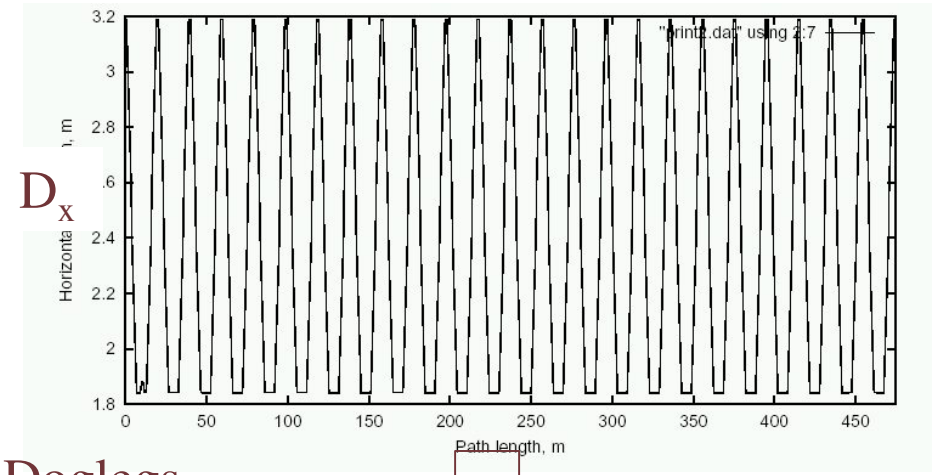
Predicted Effect of Doglegs

Ideal Lattice

β_x

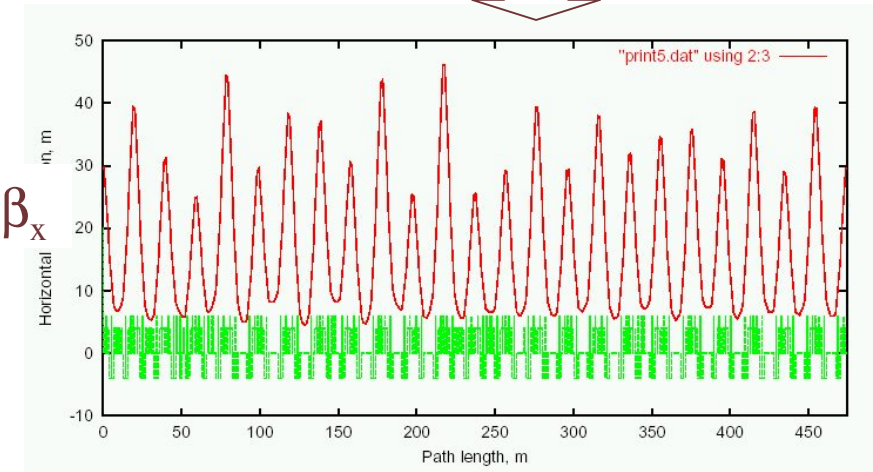


D_x

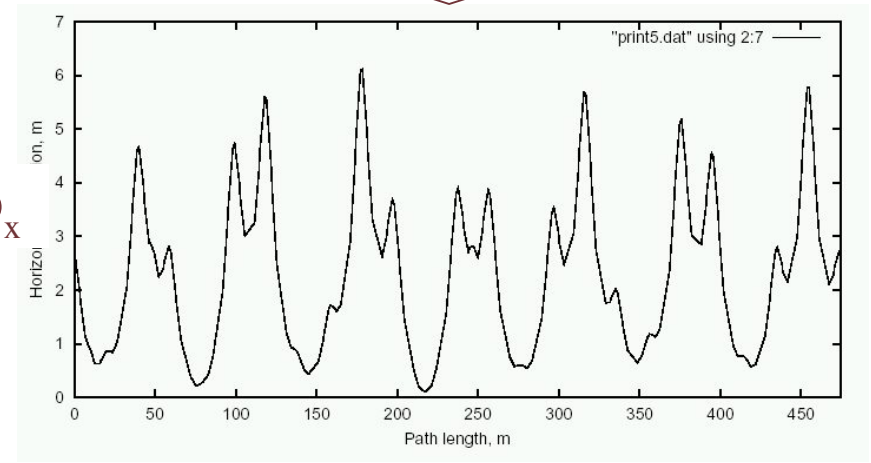


Add Doglegs

β_x

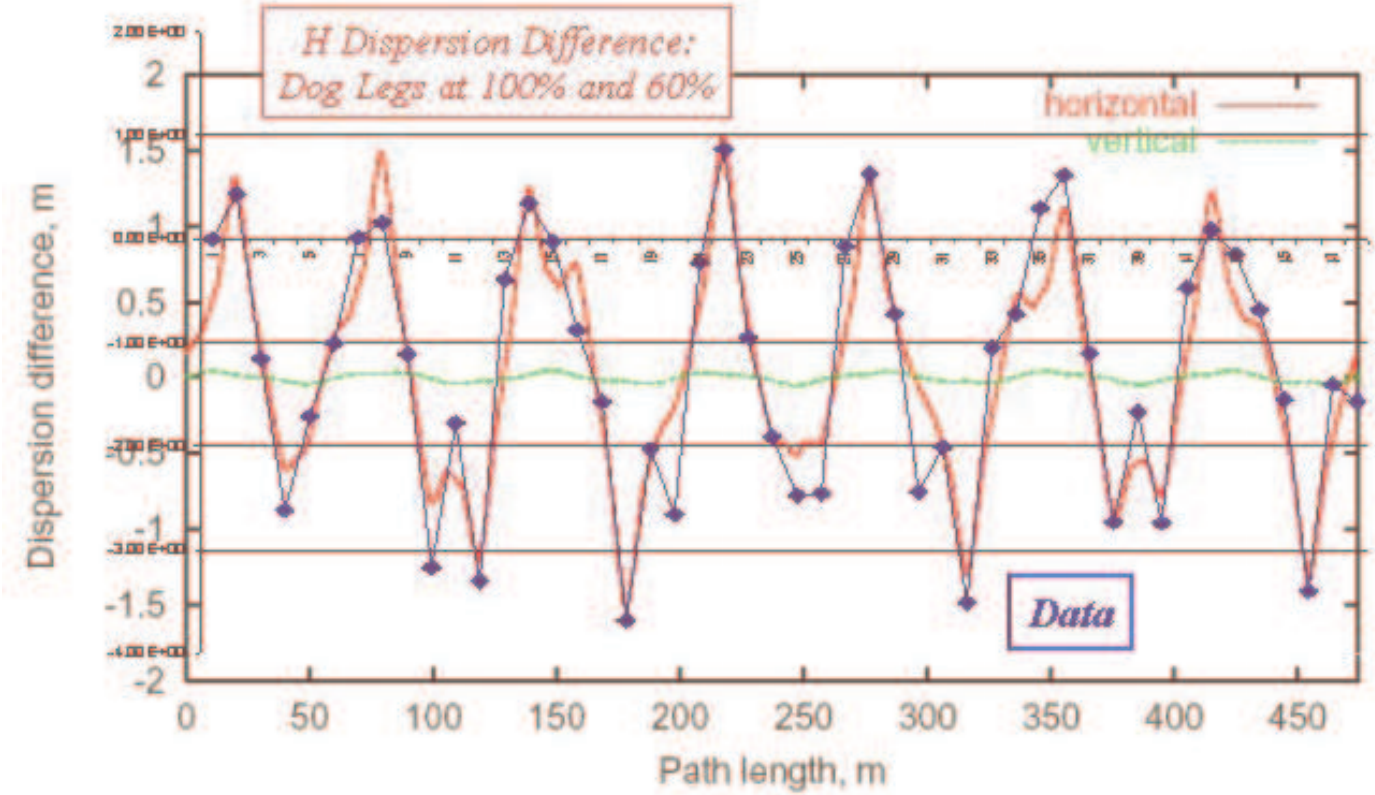


D_x



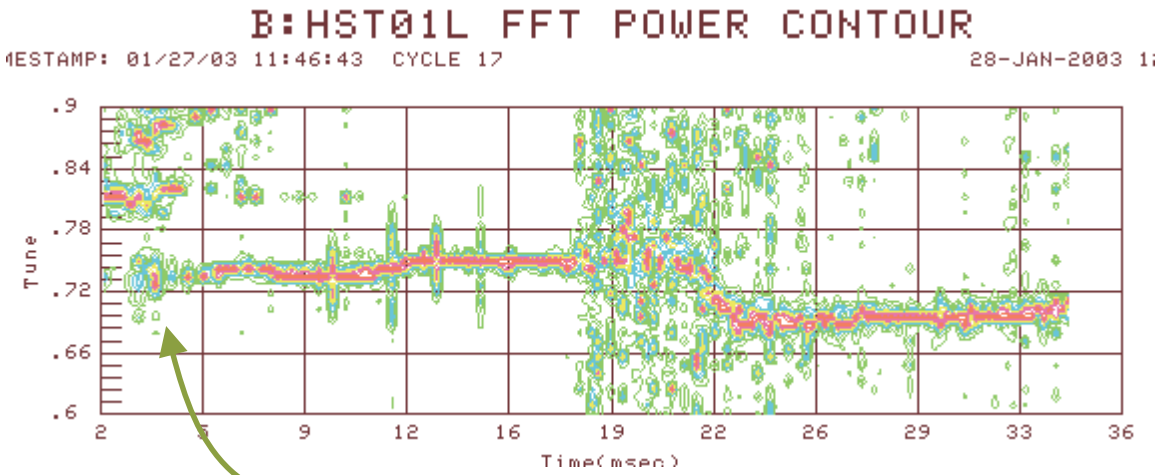
Preliminary Study: Dispersion

Measured dispersion for different dogleg currents:



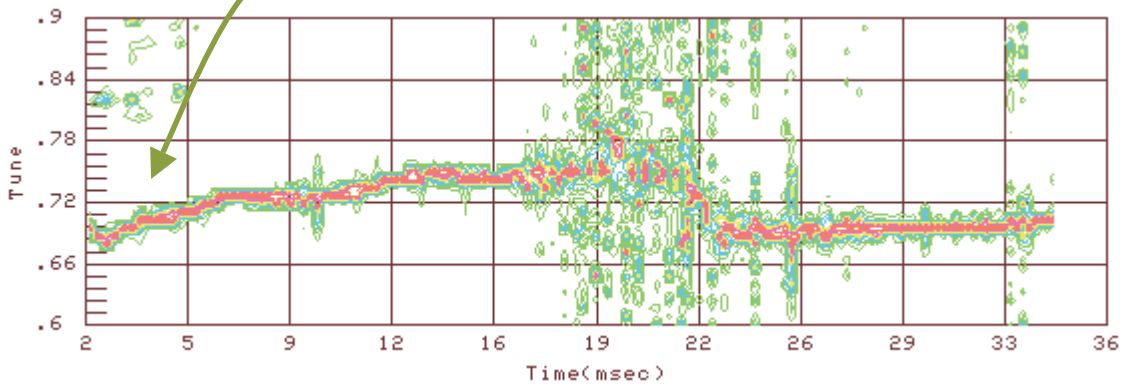
Preliminary Study: Tune

100% Dogleg Current



Tuneshift ~ prediction

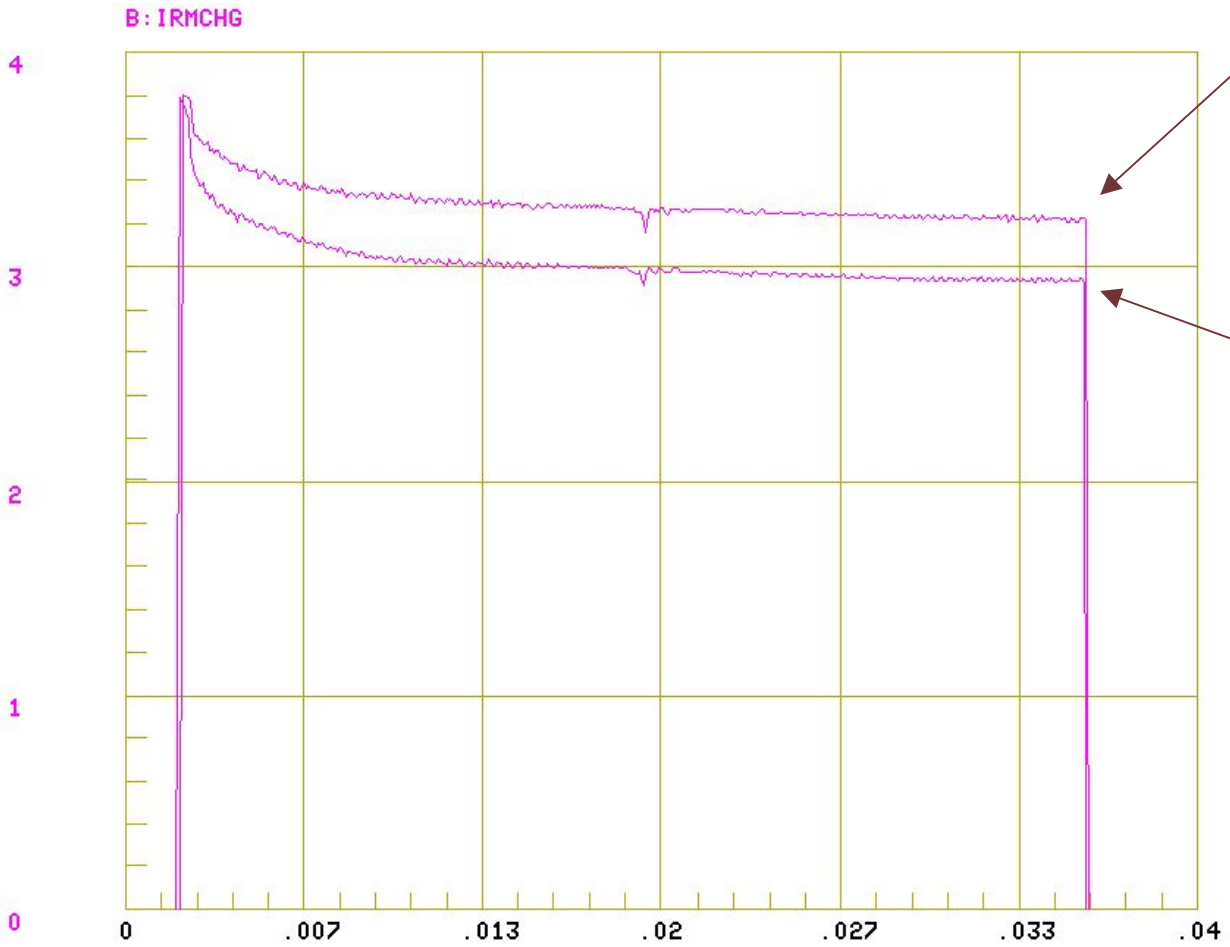
60% Dogleg Current



Dead Dog Studies

- Took advantage of recent TeV Magnet failure to raise the Long 13 (dump) septum and turn off the associated dogleg.
- Doglegs almost exactly add, so this should reduce the effect by almost half.
- The mode of operation prevents short batching, booster study cycles and RDF operation.
- Had about 36 hours of study in this mode.
- Bottom Line: **major improvement**.

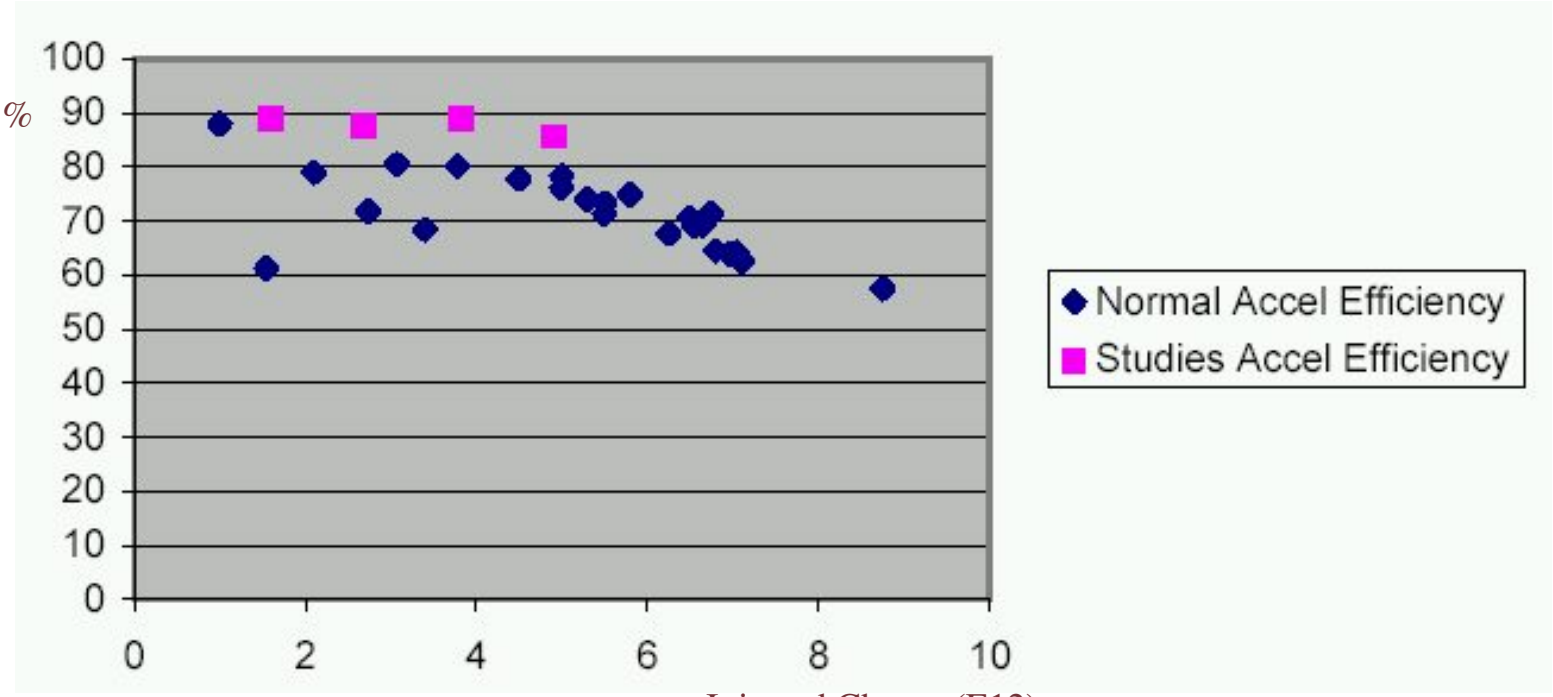
Transmission After Tuning



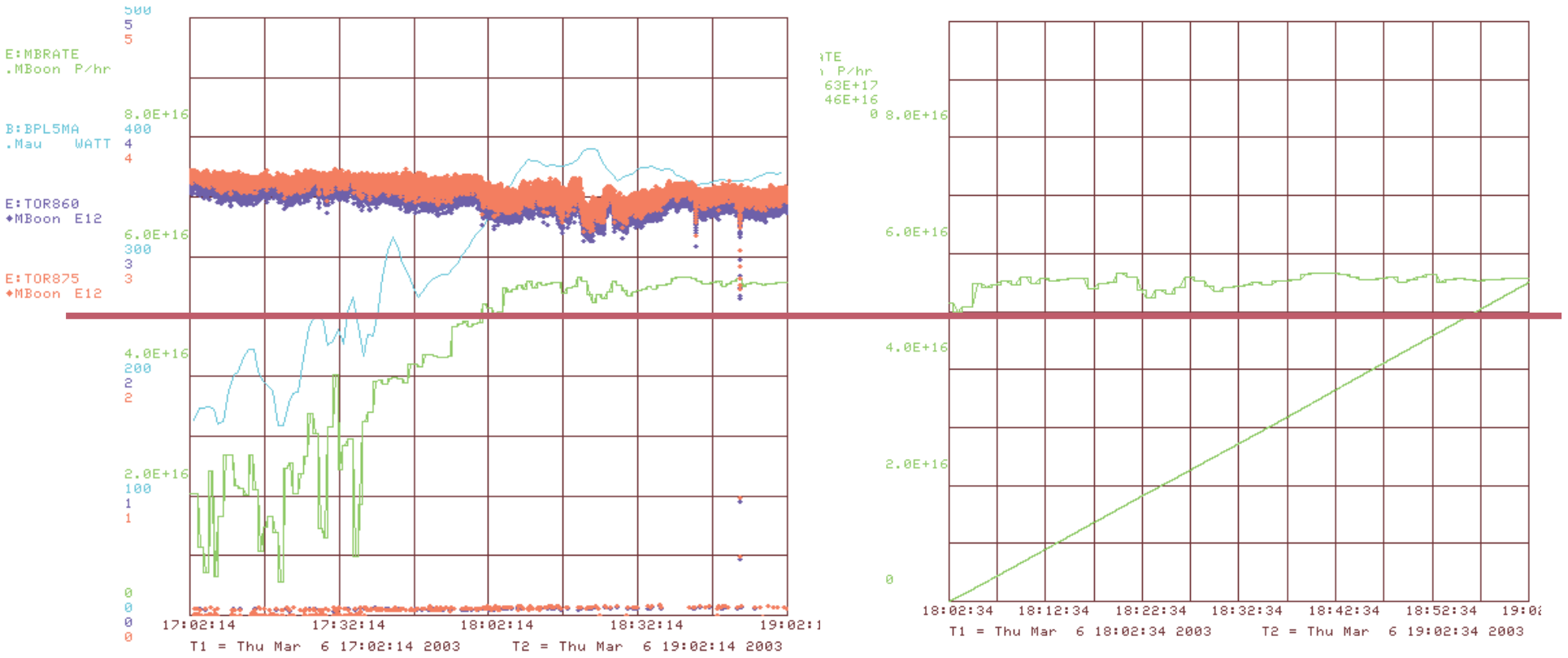
March 6, 7 turns, 1 dog

March 3, 7 turns, both dogs

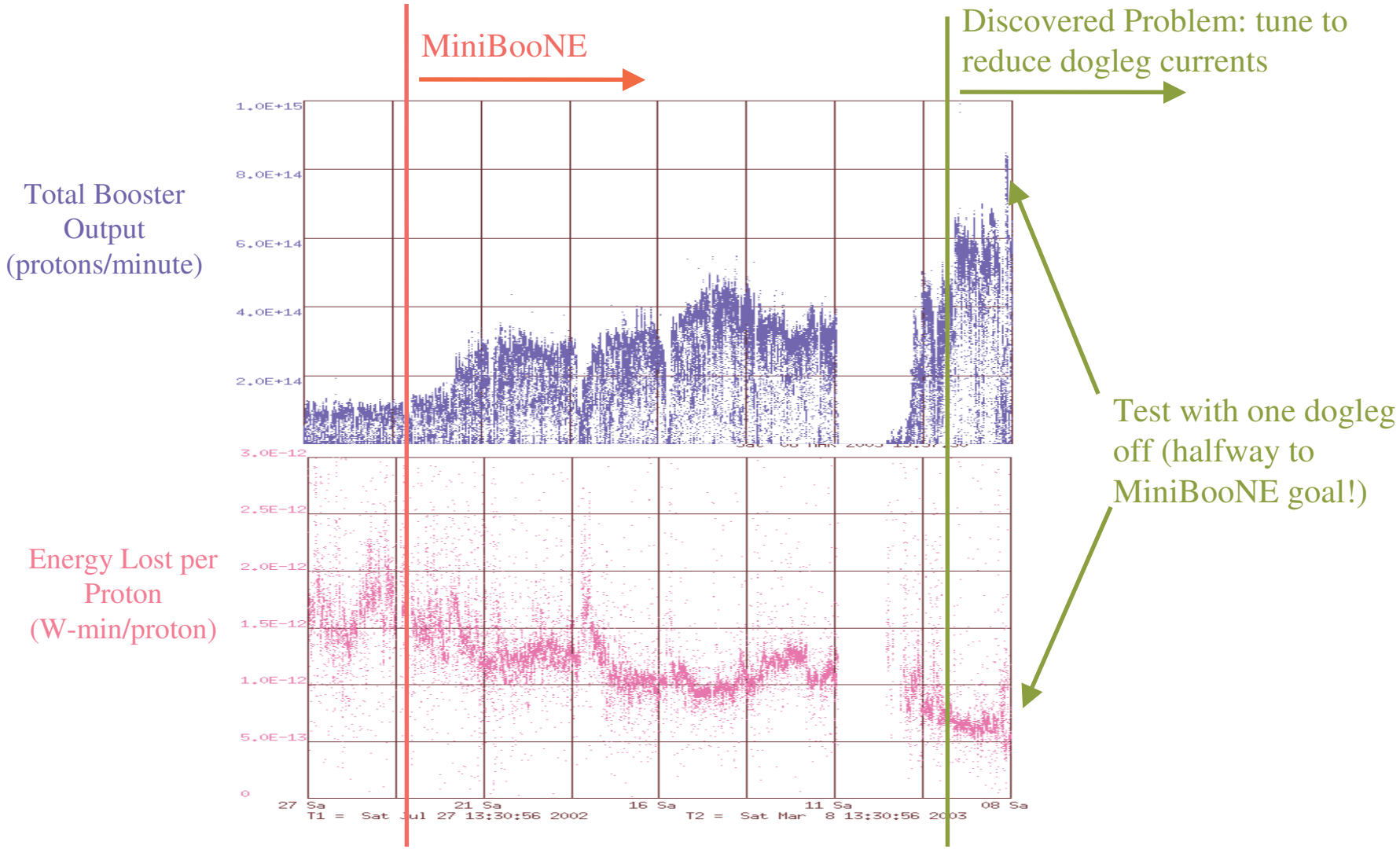
Transmission with One Dogleg



Record Running w/o Dogleg



Booster Performance Over Time

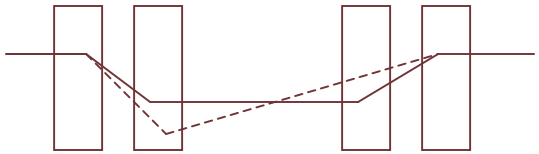


Comments

- We have verified the dogleg effect and that it is a problem.
- We've tuned in our present configuration for 5 years, and were able to achieve record performance with only 36 hours of tuning in the one dog configuration. Almost certainly more room for improvement.
- **Remember, only one dogleg was removed!**
- Now, how fix the problem:
  - Short term: ameliorate problem ASAP
  - Long term (~2005): eliminate problem.

Short Term Solutions

- Tune to minimize current?
  - helped so far, but near limit.
  - Maybe raise L13 septum a bit?
- Motorize L13 septum to switch modes quickly?
  - Operational nightmare
- Eliminate L13?
  - Find another way to short-batch
  - Make a dump in MI-8 for Booster study cycles?
- Correctors?:
  - These don't look like quads, so can't find a fix – yet.
- Spread out doglegs (effect goes down with square of separation):
  - Not a lot of room. Maybe separate downstream magnets?
- Three-legged dog?
  - Turn of the third of the four magnets.
  - Need to increase first two reduces net improvement.



Long Term Solutions

- Large Aperture Lattice Magnets?
  - Obviously the “right” idea.
  - Must match lattice AND (preferrably work with existing resonant circuit).
  - Potential for big screw-up.
- Pulsed extraction bump (Lackey)?
- New ideas welcome
  - **Brainstorming session tomorrow at 10:30**

Final Comments

- After several false starts, Beam Physics began to get seriously involved with Booster matters in late 2002.
- This problem was almost immediately found.
- What other surprises await?