Pbar Acceleration in MI using 2.5 MHz (h=28) and 53 MHz (h=588) rf Systems

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BD Review

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Summary and Conclusions

- Have investigated a pbar acceleration scheme in the MI for collider operation. This scheme is expected to give **$\Delta\varepsilon_l$ <50%** from **8-150GeV.** Whereas the coalescing scheme in use gives rise to $\Delta\varepsilon_l \approx$100-140% growth including the beam-loading effects.

  The present scheme involves the use of
  - 2.5MHz rf system for 8-27 GeV acceleration
  - Bunch rotation in 2.5MHz rf bucket
  - 53MHz rf system for the 27-150GeV acceleration
- We have carried out
  - Beam dynamics simulations: ESME, for ε_l =0.8-2.8eVs, beam intensities = 60-170E9pbars/bunch ♣
  - Beam studies: ε_l=0.8-2eVs, beam intensities = 20-60E9pbars/bunch for one and four bunch bunches acceleration cases.

♣ Initial intensity goal was **60E9pbar/bunch** with 397 nsec bunch spacing . The new goal is **170E9 pbar/bunch**. For the new intensity we have only the simulation results.

Summary and Conclusions (cont.)

There are no showstopper!

- Simulations done with beam loading compensation and Vrf(53MHz)~600V predict
  - up to about 20% longitudinal emittance growth for bunches with ε_l=0.8-2.8eVs and 170E9 pbars/bunch for the case of four bunch acceleration from 8-150 GeV.
- **Beam Studies with Protons:**
  - **Single Bunch Acceleration (intensity up to 60E9p and ε_l=1-1.6eVs) with minimum beam loading effect: about 30% emittance growth of which**
    - **"No noticeable" emittance growth during bunch compression at 8GeV**
    - **≈ 25% emittance growth during transition crossing**
    - **No noticeable emittance growth during bunch rotation**
    - **≈ 95% beam in central bunch and ≈ 5% in satellite**
  - **Four bunch Acceleration (intensity of 20-60E9p/bunch and ε_l=0.8-2.0 eVs) some beam loading effects: about 45% emittance growth of which**
    - **"No noticeable" emittance growth during bunch compression at 8GeV**
    - **Average of ≈ 30% emittance growth during transition crossing**
    - **Average of ≈ 15% emittance growth during bunch rotation**
    - **≈ 90% beam in central bunch and ≈ 10% in satellite**

Our thanks are due to

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- Dave Johnson
- Dave Wildman
- Ioanis Kourbanis
- Shekhar Mishra
- John Marriner
- Many Individuals in the MI/RF Group
- Operation group

Milestones: Beam Studies

Studies with Protons:

1	**2.5MHz acceleration from 8- 27 GeV and capture in 53MHz buckets** (cycle time ≈ 10 sec)	2.5MHz bunches prepared at 8 GeV 20-60E9p/bunch εl = 0.8-2 eVs	**Done** Slow acceleration with 2.5MHz RPOS loop closed & Phase-feedback **LLRF – Brian will talk** **HLRF – Joe will talk**
2	**53MHz acceleration from 27 GeV to 150 GeV** (cycle time ≈ 5 sec)	2.5MHz bunches prepared at 27GeV	**Done** (A preliminary study is made)

Future Plans

3	**Combine step-1 and 2** (cycle time ≈ 13 sec)	2.5MHz bunches prepared at 8 GeV	After the Sept-Nov 2003 shut-down

Studies with pbars:

4	**2.5MHz pbar acceleration from 8- 150 GeV** (cycle time ≈ 13 sec)	Use the 2.5MHz pbars bunches from Accumulator	2.5MHz bunch transfer to MI is Done. This study will be done after completion of step 3

Requirements

- **Beam Loading Compensation**
  - 2.5MHz Feed-back factor of 5
  - 2.5MHz Feed-forward factor of 10
  - 53MHz Feed-back factor of 5
  - 53MHz Feed-forward factor of 10
- 53MHz rf voltage less than 400V or less during the 2.5MHz acceleration from 8-27 GeV and bunch rotation
- 2.5MHz BPM (soft)

Future Plans

Shift ≈2 hours, One study cycle/120~180 sec, Cycle time ≈13sec

- Tune for four-rotation case (1-2 shifts)
- Address beam loading issues (1-2 shifts)
- Accelerate from 8 to 150 GeV (5-6 shifts). This involves
  - *Ramp development, Re-configuring I6 page, Orbit studies, Transverse tune and Chromaticity setting and 53MHz rf curve setting to preserve the long. emit.*
- Accelerate pbars (1-2 shifts)
- High Intensity study (3 shifts)

Total of about 15 shifts

- Work on an application program to measure the long. emittance at various stages of acceleration. (SBD?)

With contingency we may need 19-20 shifts. This corresponds to about 50 hours of beam time with an impact of 7-10% on the time-line.

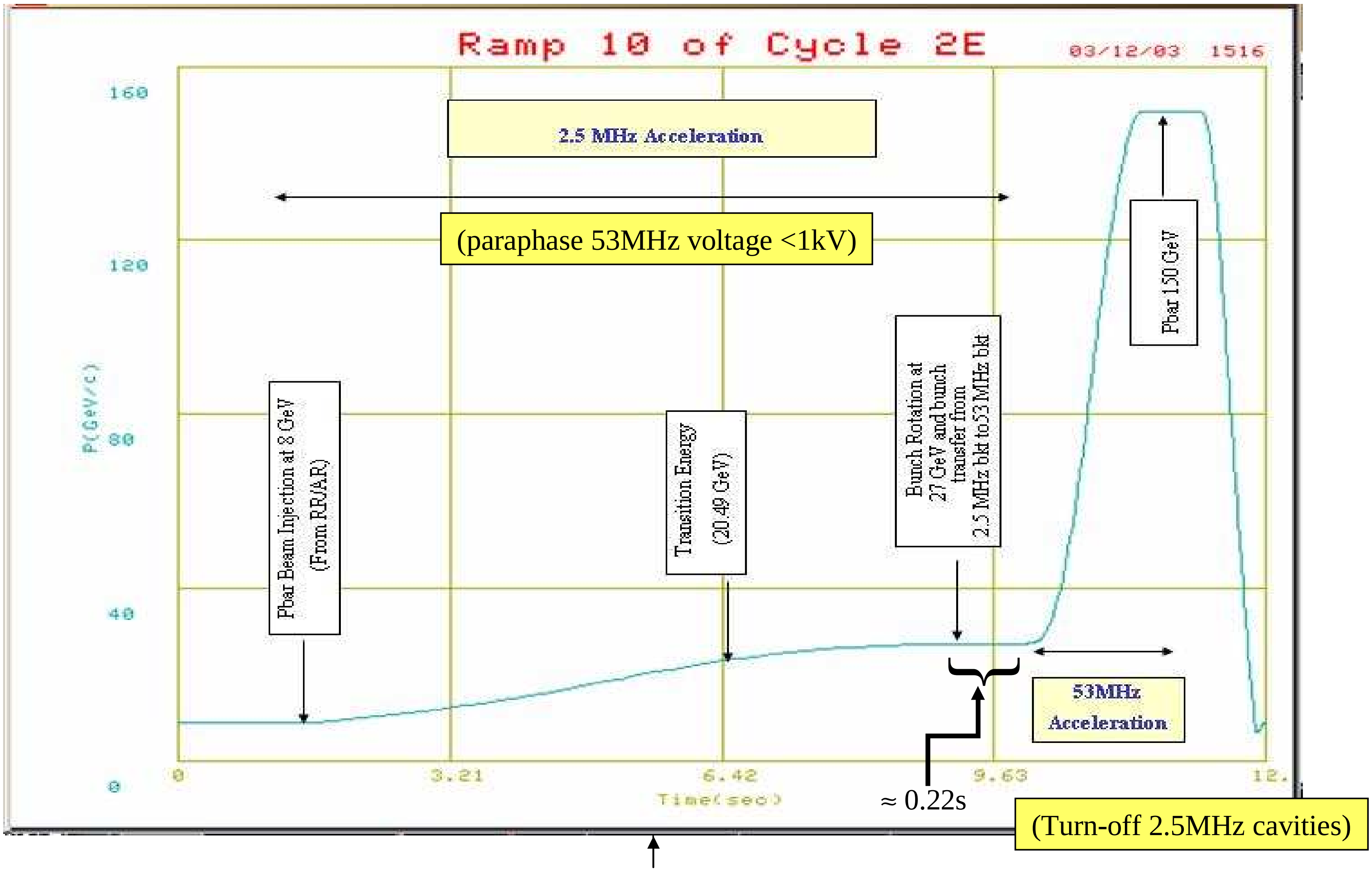
Issues

Reliability

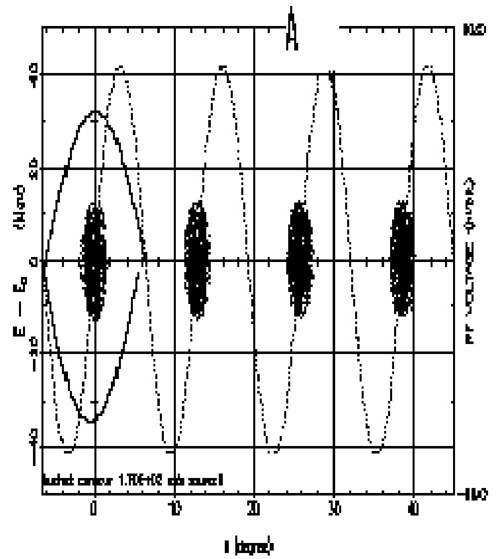
- Beam-loading compensation up the ramp
- Transition crossing:
  - There are some intensity dependent effect which arise from beam loading of 2.5MHz and 53MHz rf systems.
- How well do we keep Vrf(53MHz) low reliably during 8-27 GeV acceleration?
- 2.5MHz rf cavity heating:
  - Cavity performance has been closely monitored during our past study period. We find considerable voltage dropping and phase shift during an extended study. Precaution should be taken to limit the power we are dumping into the 2.5MHz cavities. This limits us to 2-3 hour shifts per study period.
  - During operation we need to turn it off if we are not transferring pbar beam to the Tevatron?

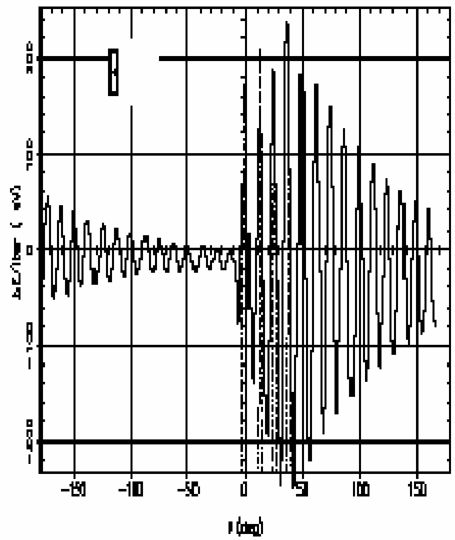
What is the Acceleration Scheme?

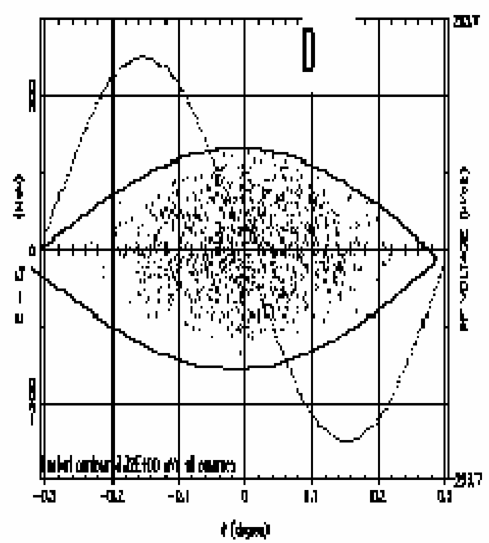
It is simple! Do harmonic transfer from h=28 → h=588 above MI transition energy.



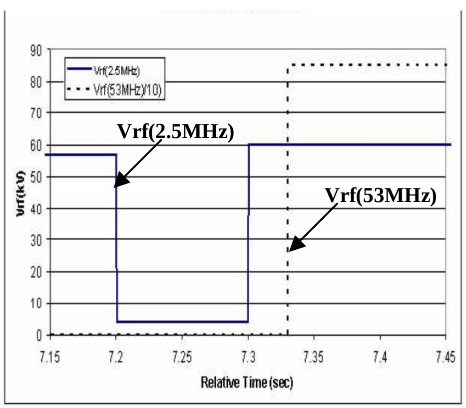
Simulation with 2.5MHz Beam-loading Compensation

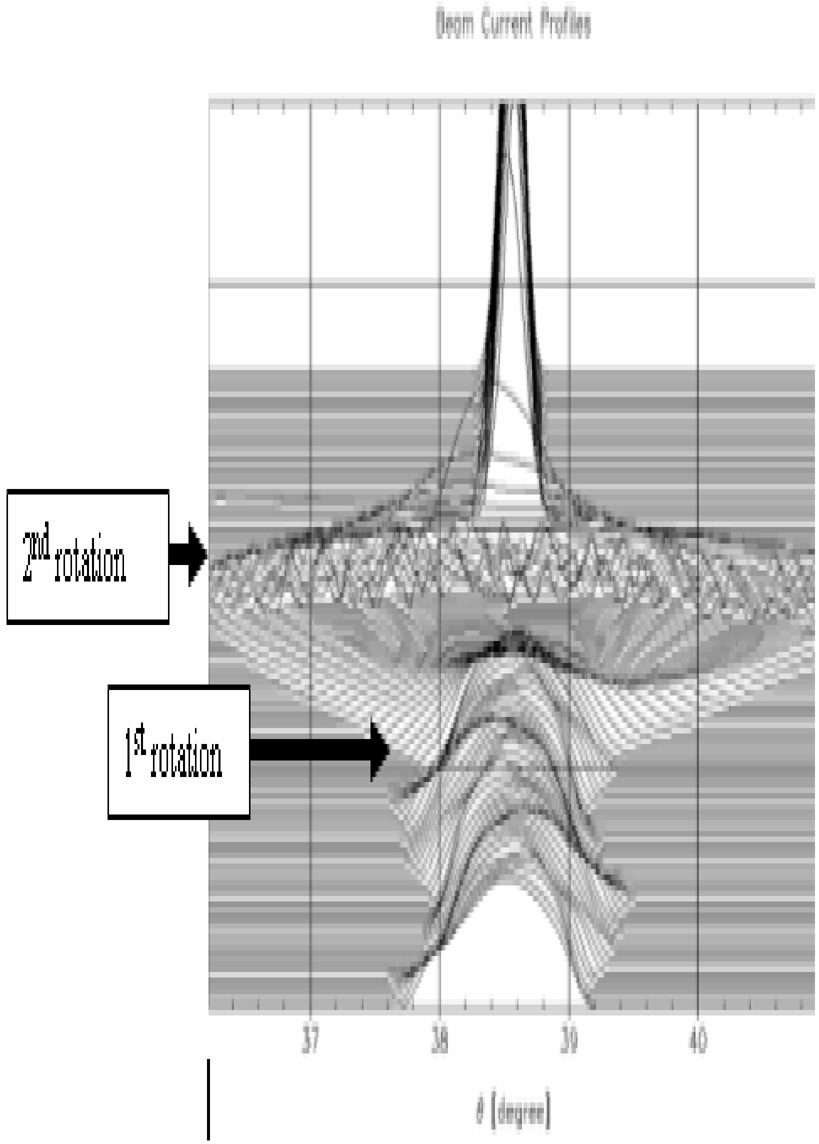






RF Manipulations at 27GeV:
Two rotation Scenario



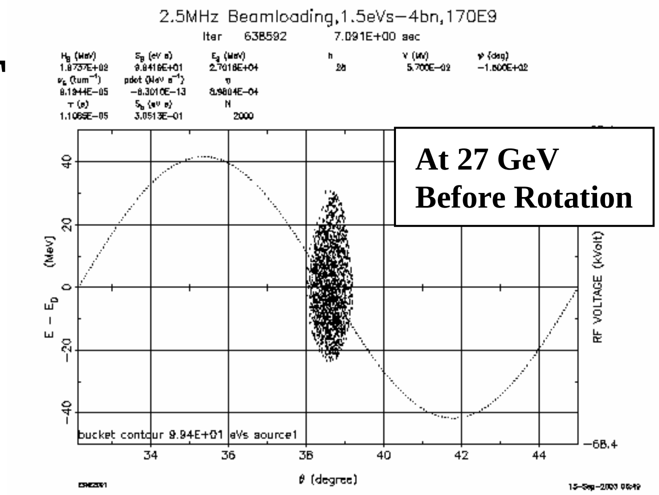


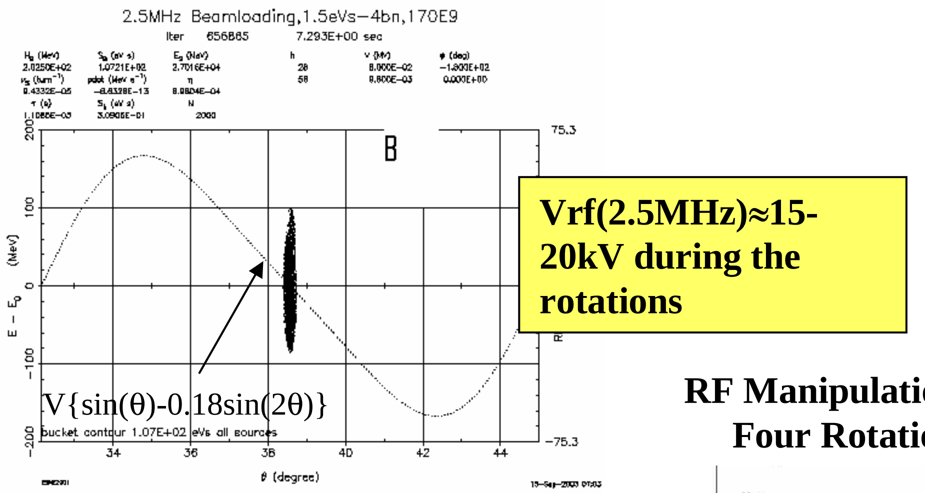
7% emittance dilution for 1.5eVs beam bunches

ESME: Four Rotation Scenario

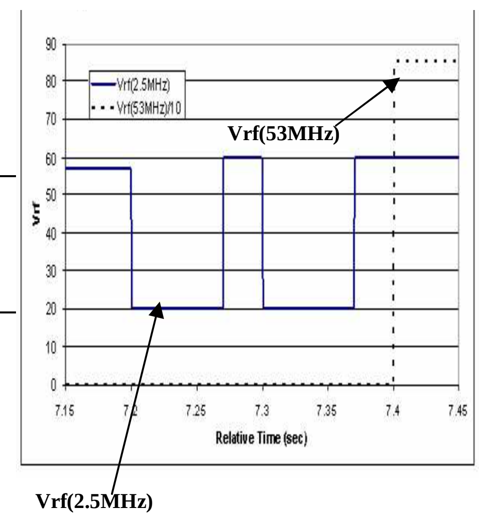
To minimize the effect of Vrf(53MHz) during harmonic transfer

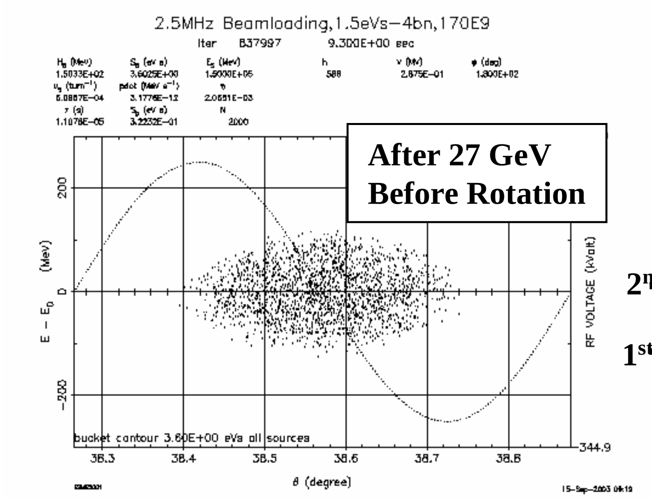
F

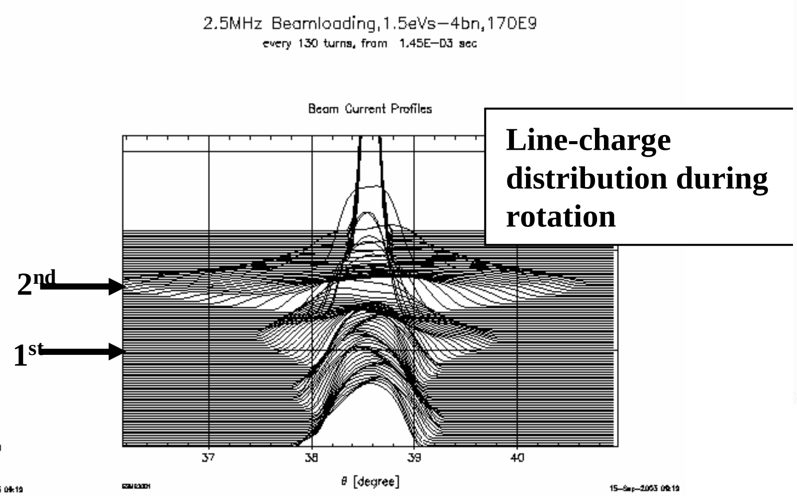




RF Manipulations at 27 GeV: Four Rotation Scenario

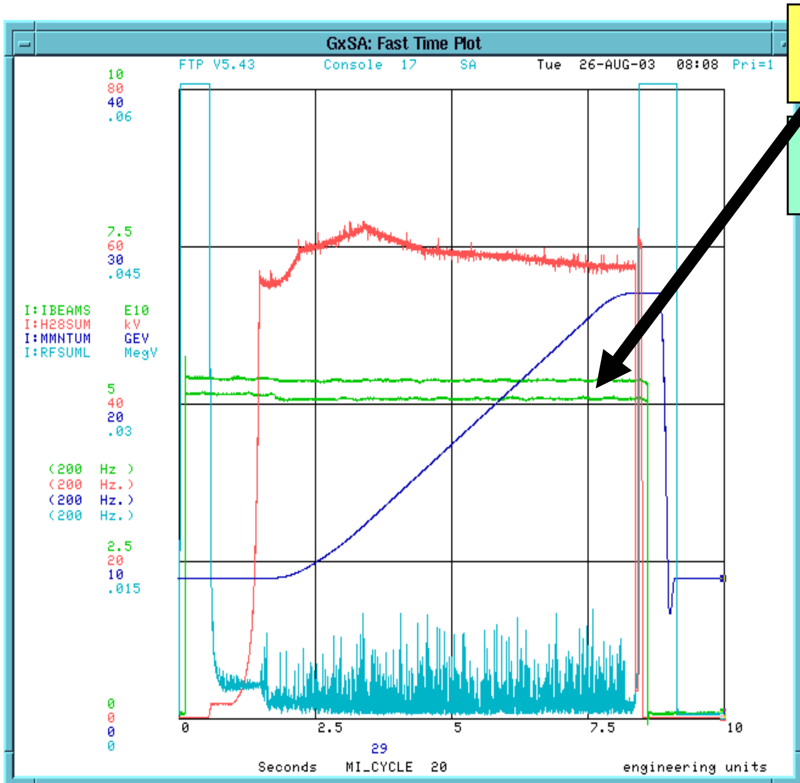




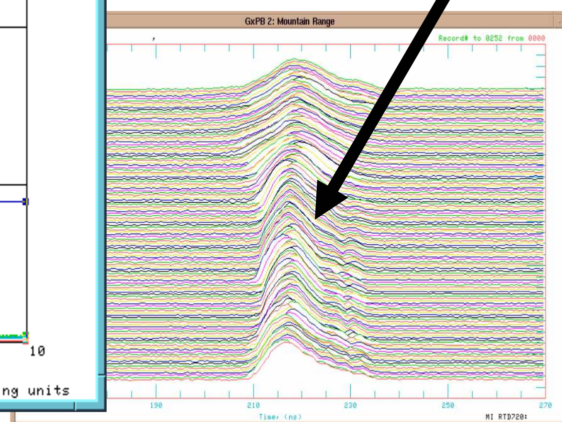


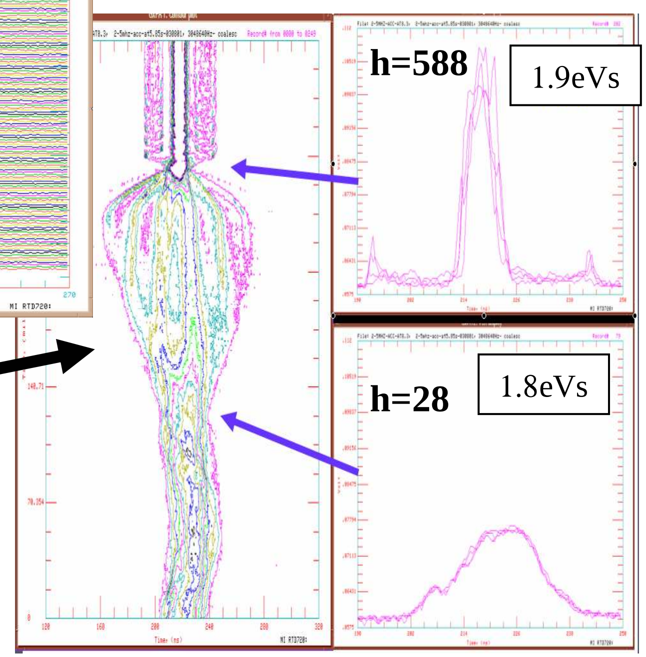
Conclusions: <10% emittance growth from 8 -150 GeV with no particle loss

One Bunch Acceleration



- 100% Transmission from 8 -27 GeV
- Reasonably good Transition crossing



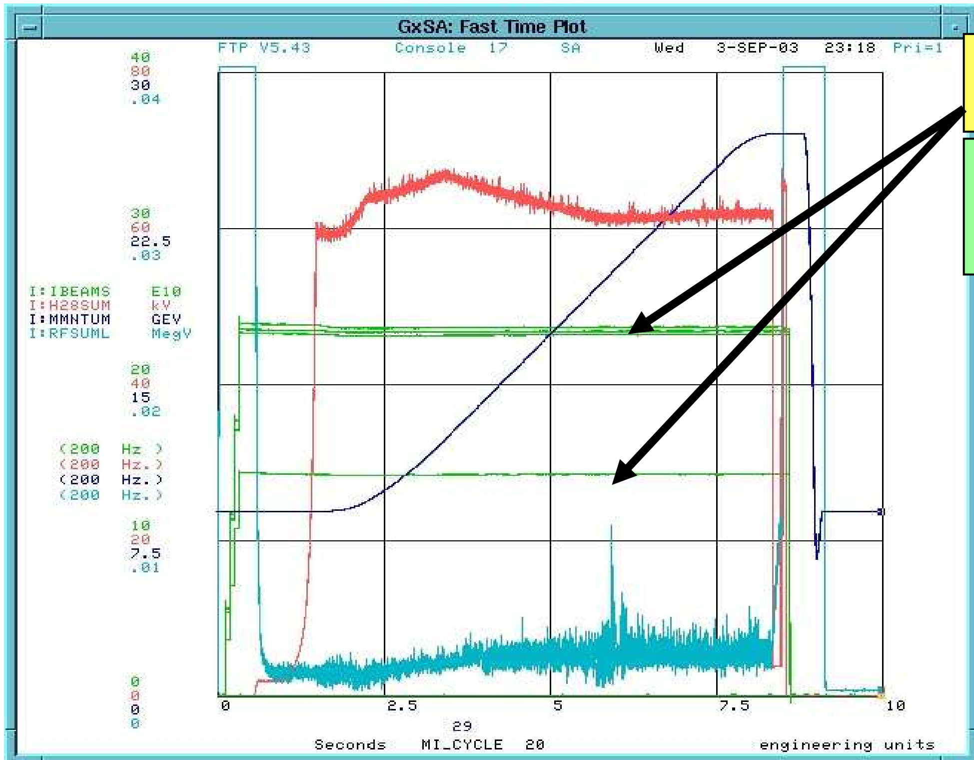


- Harmonic transfer

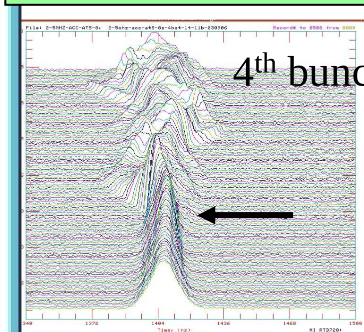
Conclusions:

≈30% emittance growth from 8-27 GeV with ≈5% beam in satellite

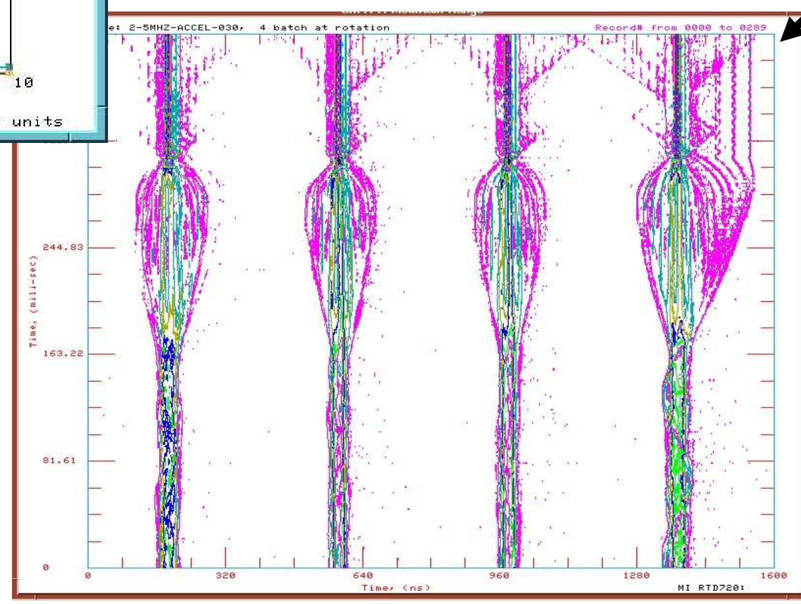
Multi-bunch Acceleration



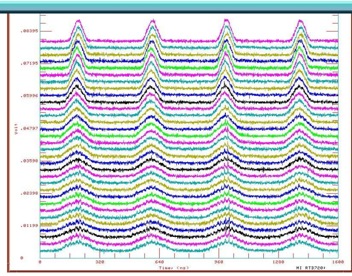
- 100% Transmission from 8 -27 GeV
- Reasonably good Transition crossing for the 2nd bunch, not good for 4th bunch

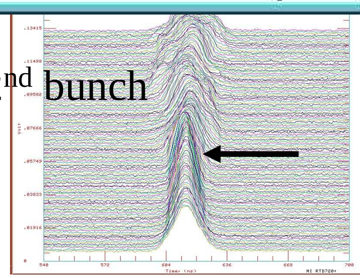


- Harmonic transfer



8GeV Beam





Conclusions:

≈45% emittance growth from 8 to 27GeV with ≈10% beam in satellite