2.5 MHz Acceleration in the Main Injector

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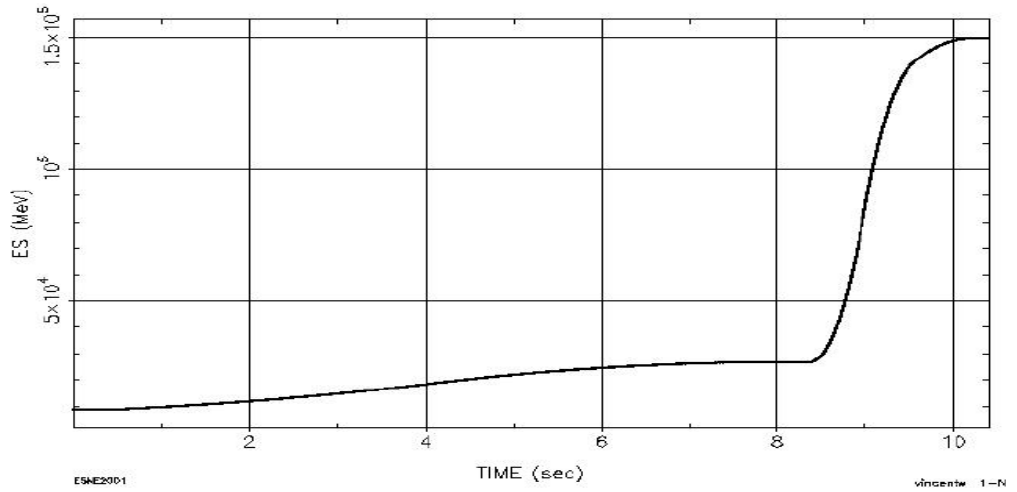
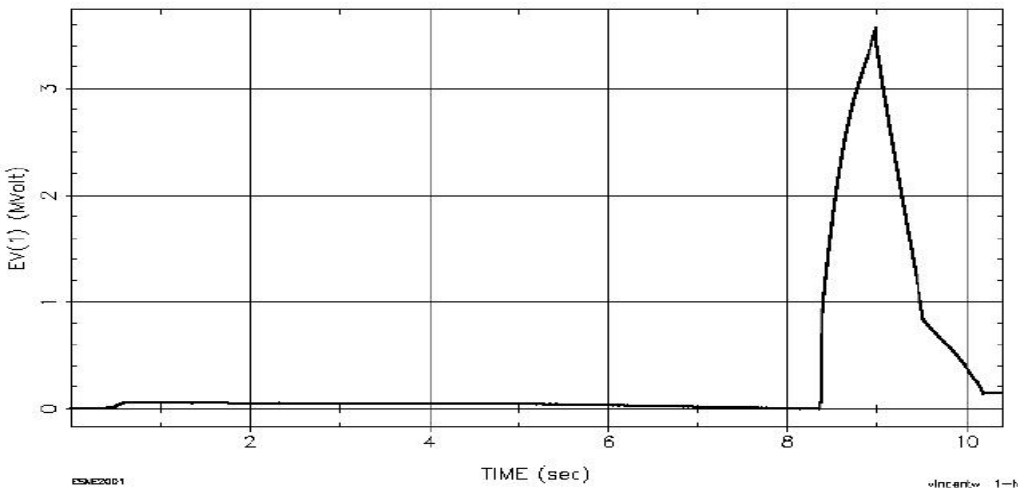
Simulation of 2.5 MHz Acceleration

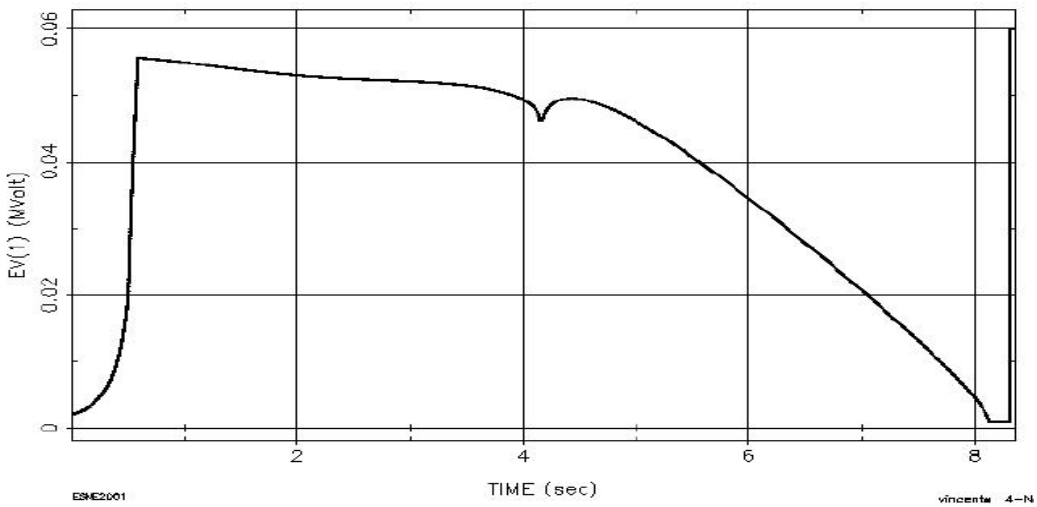
Initial beam and rf parameters:

- total beam energy (GeV): 8.938
- momentum compaction factor: -0.008683
- rf frequency (MHz): 2.5
- rf voltage for 2.5 MHz rf system (kV): 2
- invariant 95% longitudinal emittance (eVs): 1.5 per bunch
- number of particles per bunch: 6E10

Ramp and rf Programs



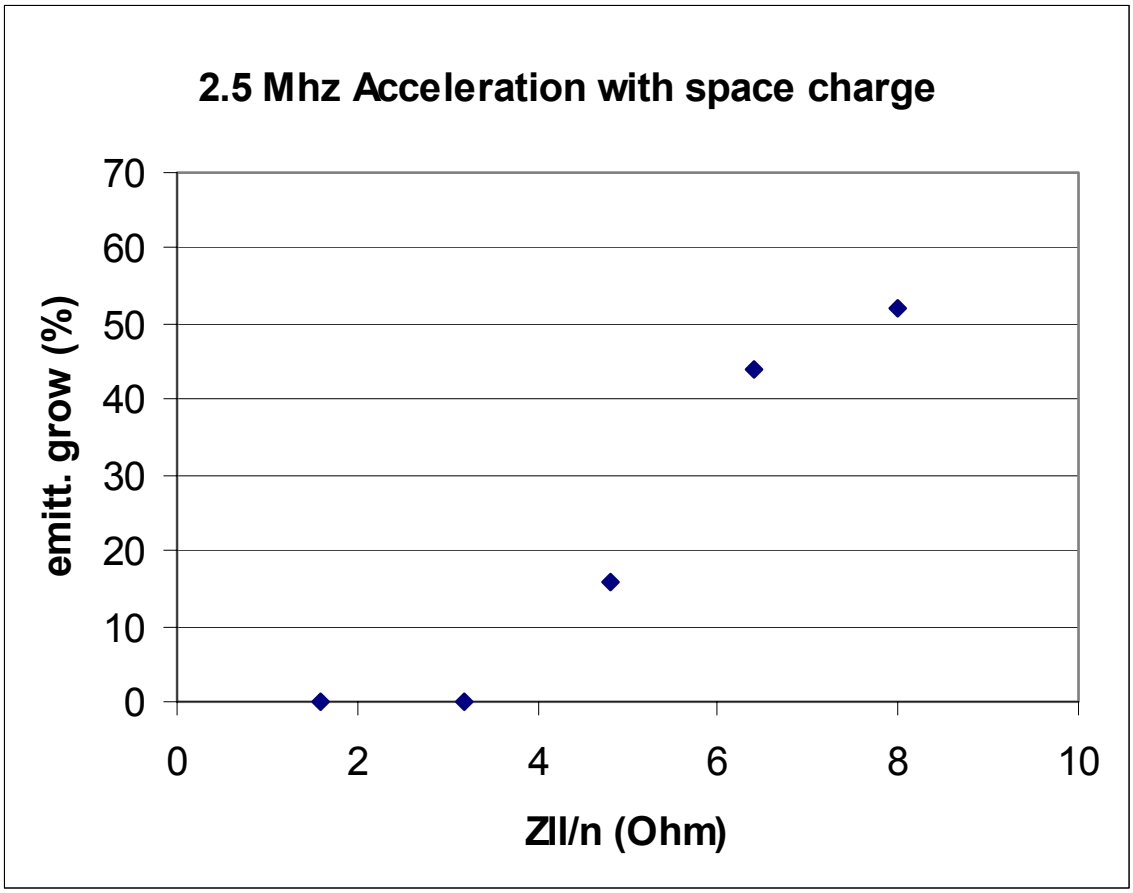




Simulation with Space Charge and Wall Impedance

Input parameters:

- assume circular beam pipe with 10.5 cm diameter
- Z_{11}/n: 1.6, 3.2, 4.8, 6.4, 8
- 1.6 is the "measured" MI longitudinal impedance per harmonic
- number of macroparticle: 200000
- single bunch (6E10)



Simulation with 2.5 MHz Beam Loading

- 4 bunches and 1 cavity
- Cavity Q=112.5 and R_{sh}=45000 Ohm
- To simulate 5 cavity beam loading, the shunt impedance is increased by a factor of 5.

Results

- Peak beam loading voltage: 1.9 kV
- At beginning of 27 GeV rotation, beam loading voltage is 1.4 kV and cavity voltage is 1 kV.
- Overall emittance grow is problematic.
- Conclusion: need 2.5 MHz beam loading compensation.

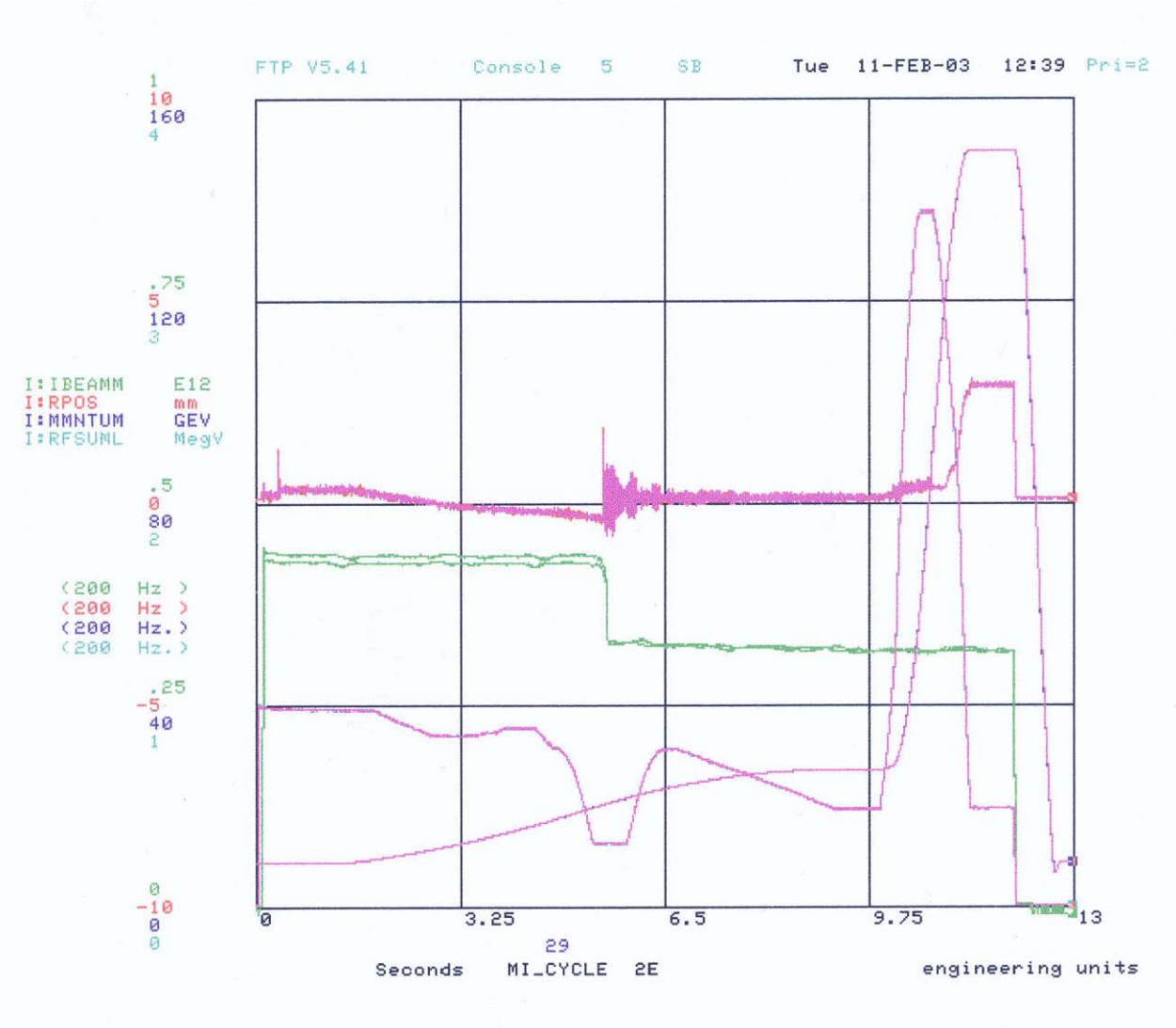
2.5 MHz Acceleration

- Tune transverse motion using 53 MHz bunches, i.e., fine tune chromaticity and tune programs to obtain good transmission.
- Try open loop 2.5 MHz acceleration while the radial and phase feedbacks are being worked on.

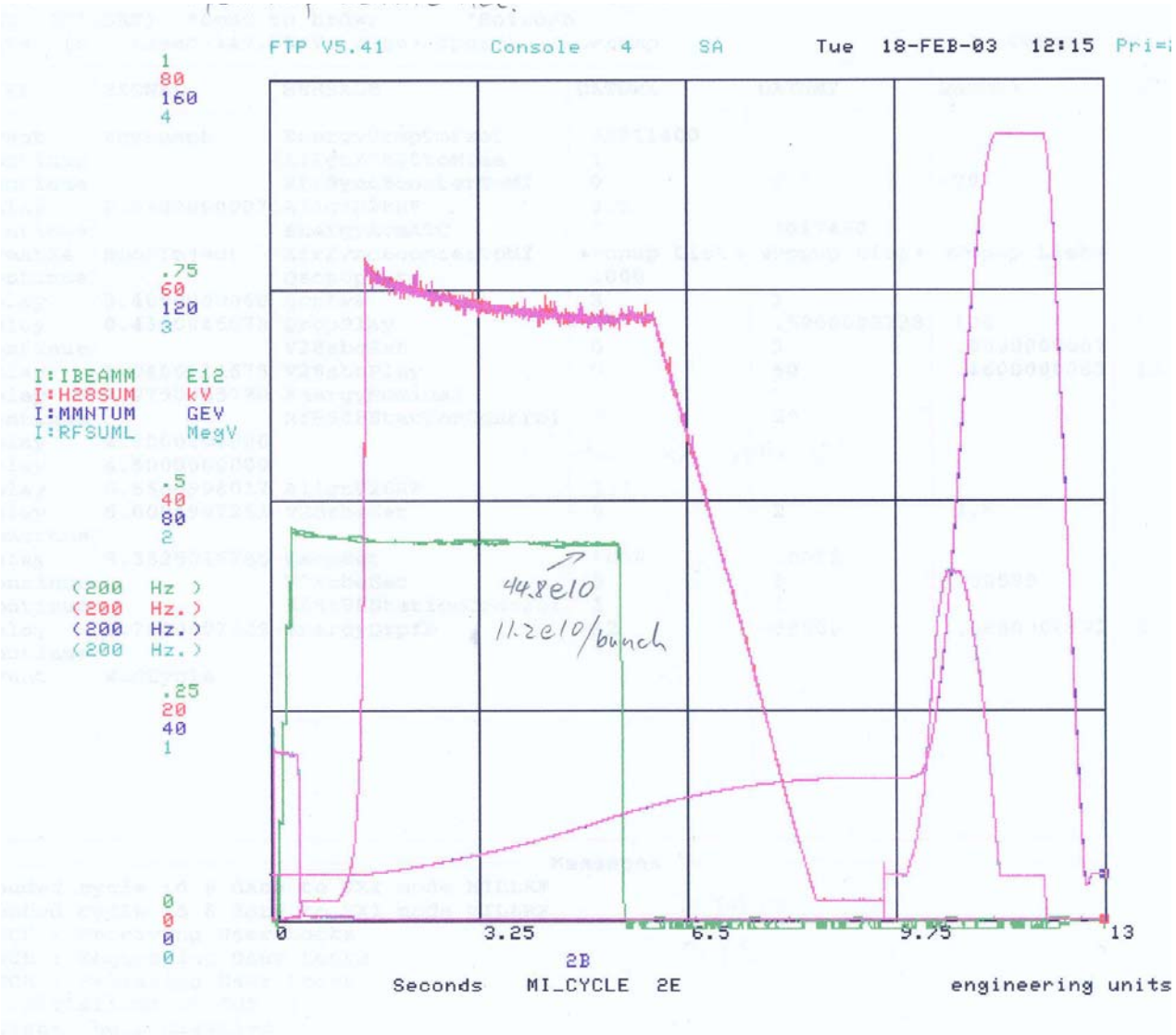
-- 4 Booster batches injection with 7 bunches per batch.

-- 53 MHz bunches are adiabatically debunched into 2.5 MHz buckets.

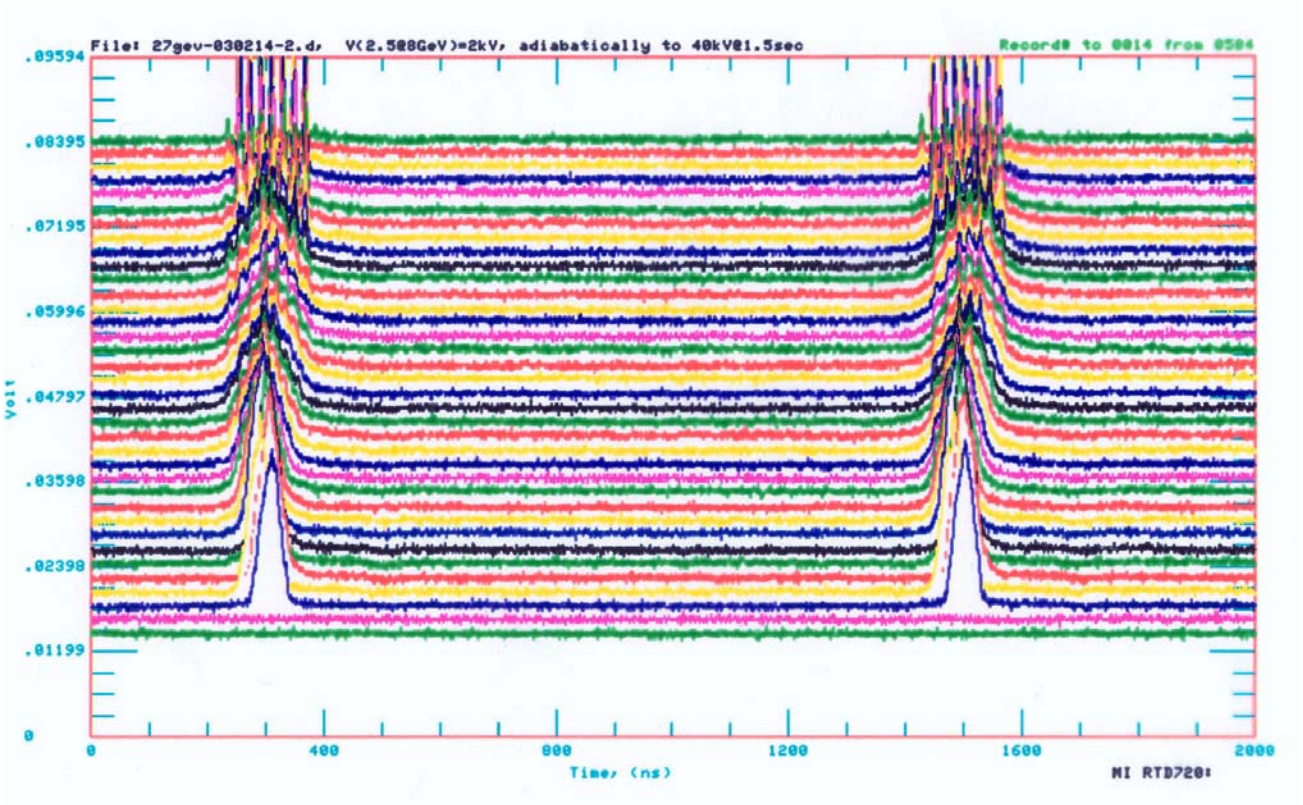
53 MHz Acceleration: Tuning of Transverse Loss



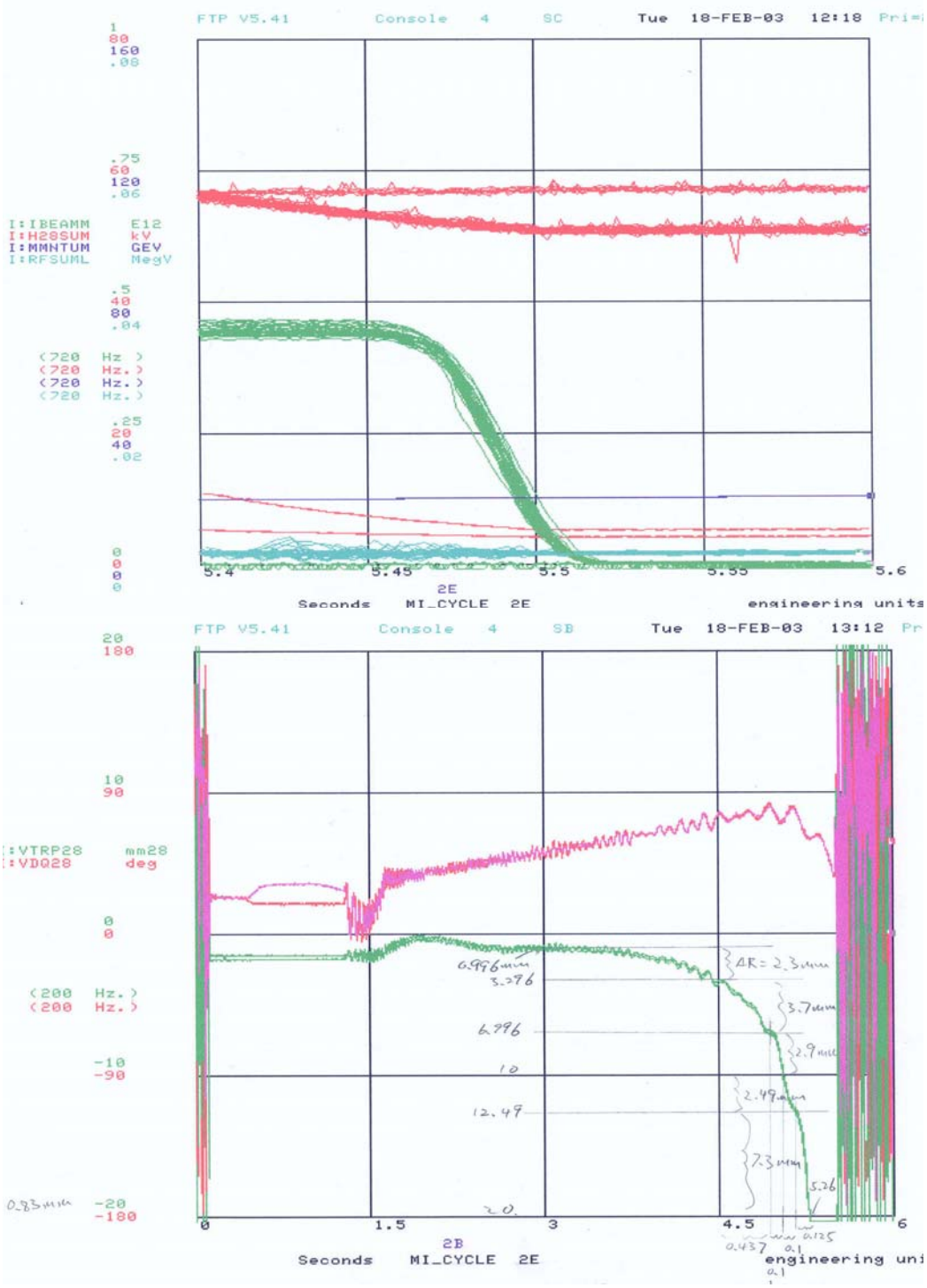
2.5 MHz Open Loop Acceleration



Mountain Range

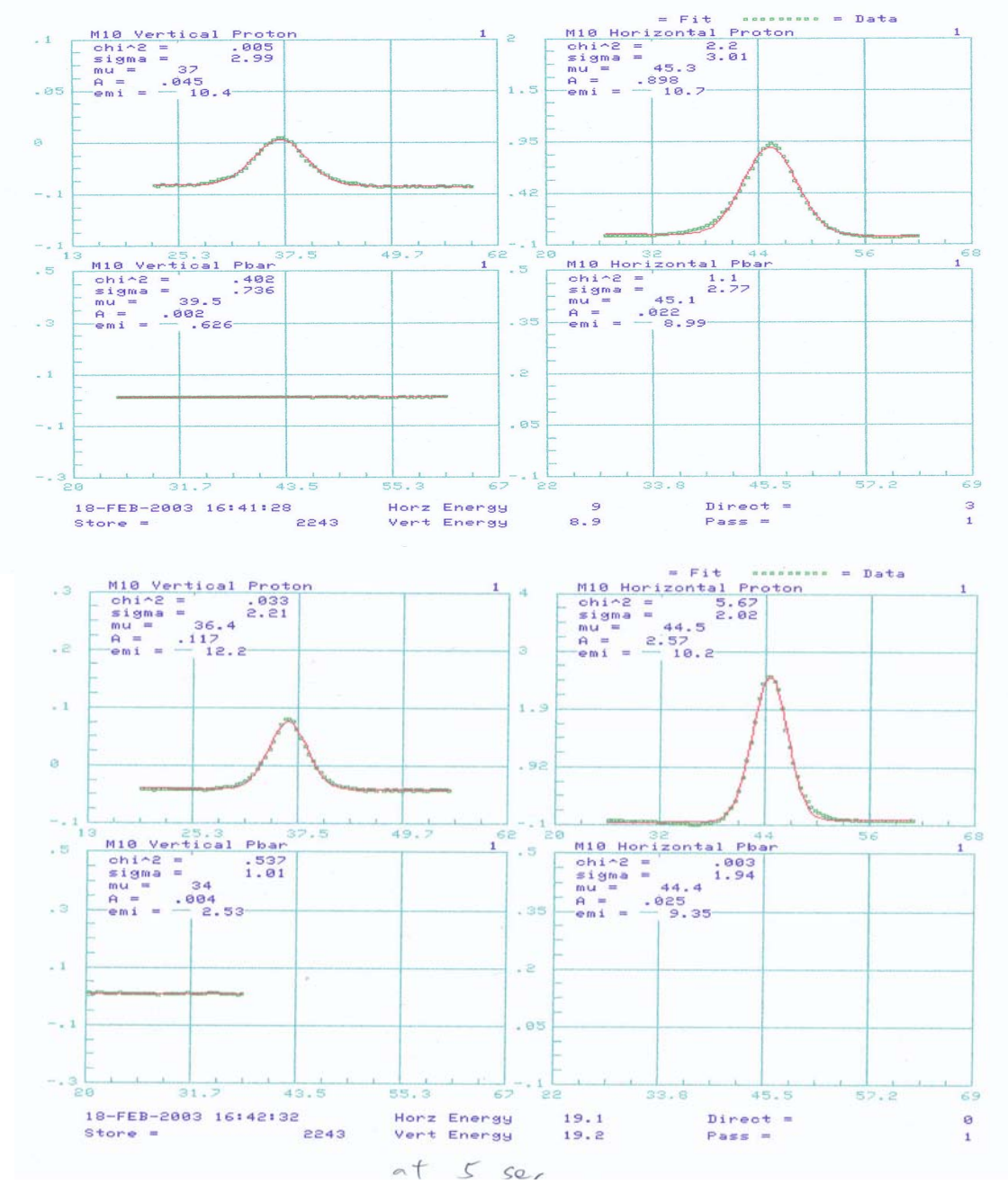


Beam Loss



Bottom plot: Radial position of 2.5 MHz beam (bottom curve) and phase of the beam (upper curve).

Transverse Emittance During 2.5 MHz Acceleration

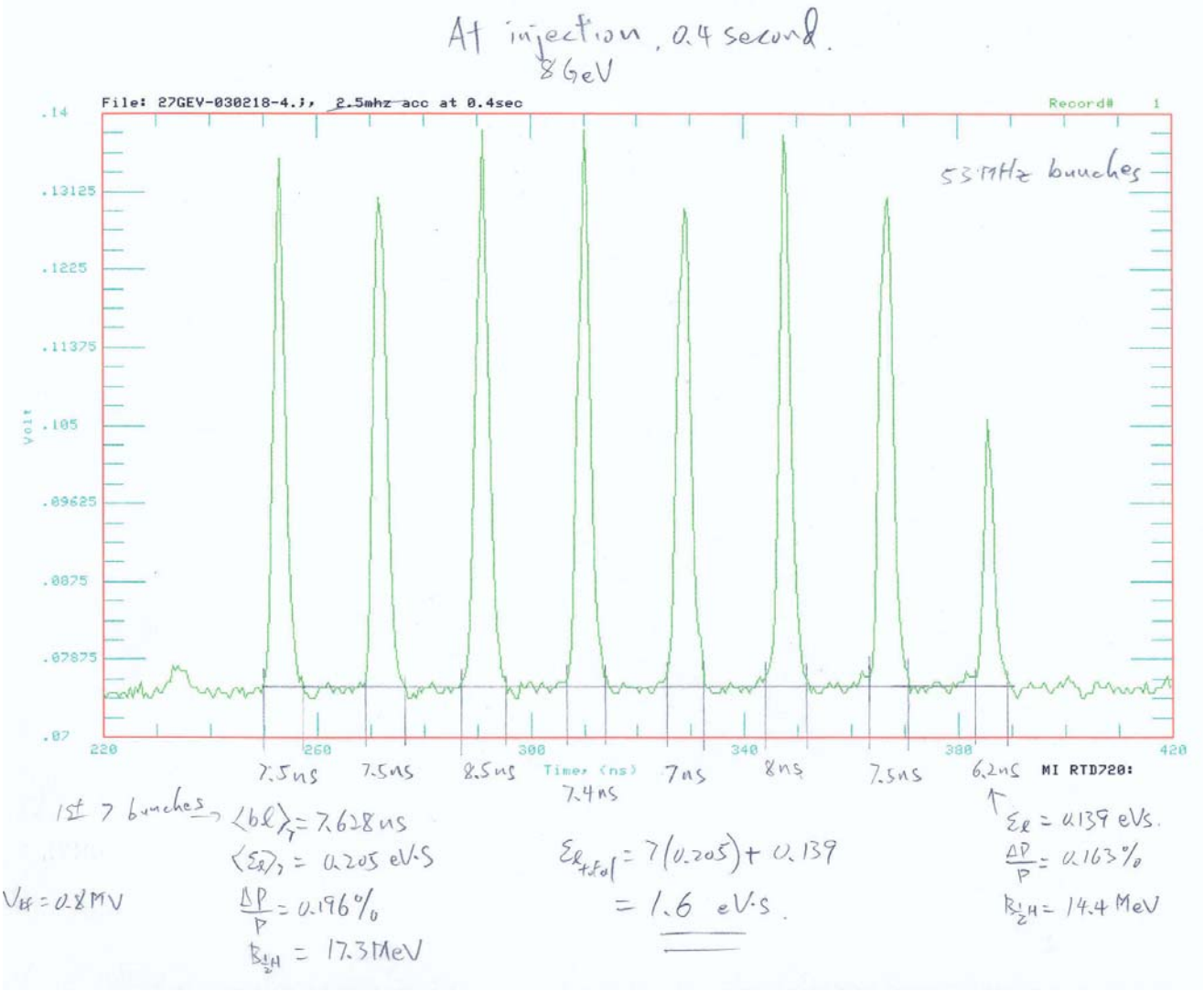


At 9 GeV: vert.emit=10.4, hor.emit=10.7

At 19 GeV: vert.emit=12.2, hor.emit=10.3

Longitudinal Emittance

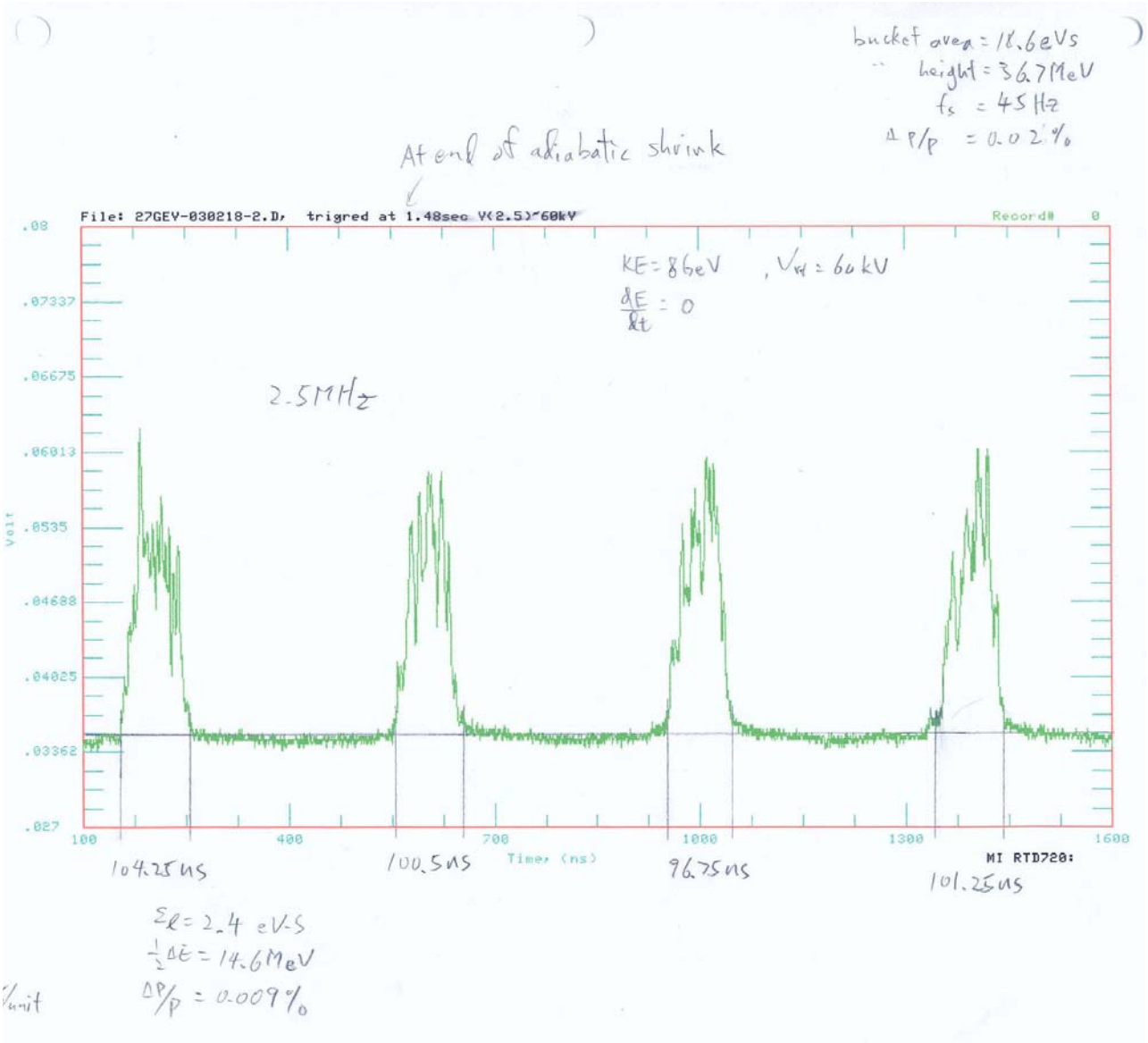
53 MHz bunches at injection, first batch



Average emit. per bunch=0.19 eVs

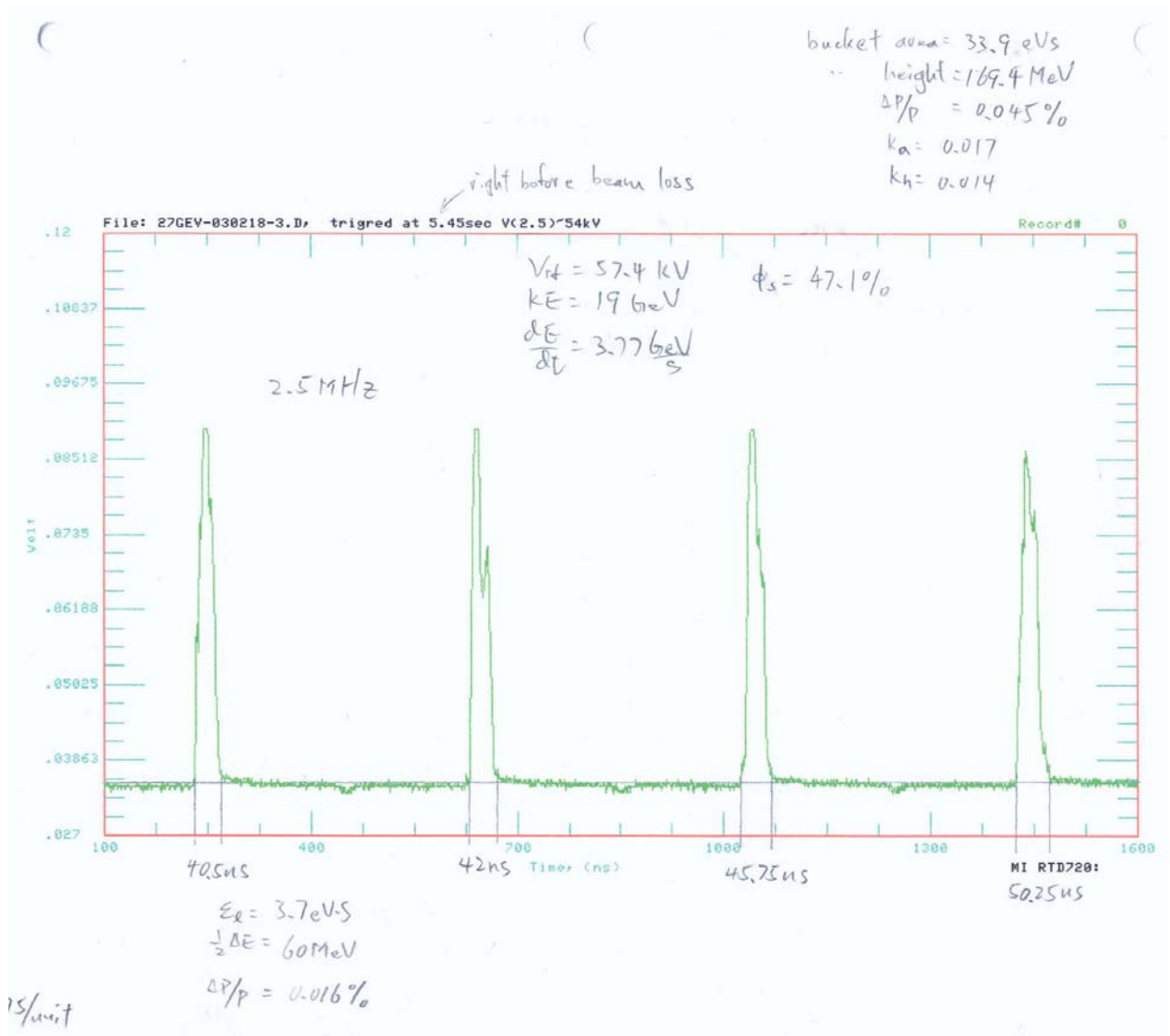
Total emit. = 1.6 eVs

2.5 Mhz bunches at 8 GeV before acceleration



Emit. for first bunch = 2.4 eVs

2.5 MHz bunches at 19 GeV before transition



Emittance of first bunch = 3.7 eVs gives about 50 percent emittance grow (for 8 GeV to 19 GeV acceleration).

ESME simulation with beam loading shows a 30 % rms emittance grow.

Future Work

- Radial and phase feedback.
- Study 2.5 MHz beam loading and compensation.
- Study transition loss.
- Study emittance grow.

References:
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7. John Marriner, Main Injector Beam Loading in the 2.5 MHz System, March 2001.
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