Schemes for Producing High Intensity Low- Longitudinal Emittance Proton Bunches for the Tevatron Collider Shots

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Motivation

The instantaneous luminosity at each experiment is given by

$$L = \frac{\gamma}{2\pi} f_0 B N_p N_{pbar} \frac{H}{\beta^* \varepsilon_p \left\{ 1 + \frac{\varepsilon_{pbar}}{\varepsilon_p} \right\}}$$

Design goal à 2.7×10^{32} $cm^{-2} sec^{-1}$ (~a factor 3 over current average)

Increasing N_p and N_{pbar} and,
decreasing ε s and longitudinal emittances { Produce higher instantaneous luminosity.

<u>Plans for Pbars:</u> "2.5MHz pbar Acceleration"-Combination of 2.5MHz and 53MHz Acceleration (2.5MHz Acceleration from 8GeV -27 GeV, harmonic transfer from h=28à h=588, 53MHz acceleration from 27GeV-150 GeV) being commissioned

Protons

The present 150 GeV coalescing scheme **has done SUPERB JOB** providing intense proton beam to the Tevatron Collider during Run I and Run II, till now.

Present Status:

- From MI: ~300E9 protons/coalesced bunch with
  <RMS bunch length ≈ 2.3 nsec ⇒ LE=2.5 eVs (MISBD)
- In Tevatron at Collision: ~250E9 protons/bunch with
  <LE> < 3 eVs (TevSBD). (beam losses MIà Tev, 150 GeV lifetime, Acceleration, low beta-squeeze)

This implies – about 20% lower luminosity because of beam loss and 2% from the Hourglass factor due to large LE at collision.

Tevatron study showed that if proton LE is reduced from 3 eVs to 2 eVs keeping the other beam properties then we can improve the peak luminosity by about 12-17%.

Can we improve the quality of the proton beam in the MI?

Yes!

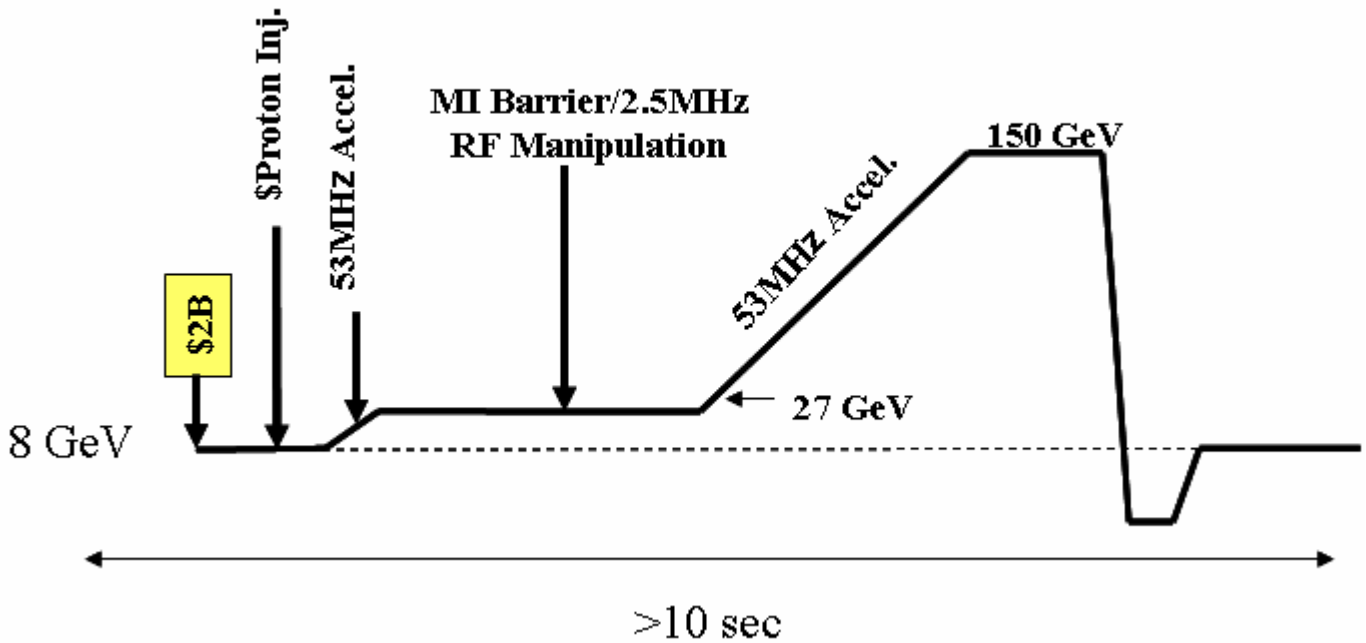
Schemes for Producing Bright Proton Bunches

These two schemes use MI Damper RF cavities

- Barrier Bucket Scheme-1
- Barrier Bucket Scheme-2
- Coalescing at 27 GeV ✗

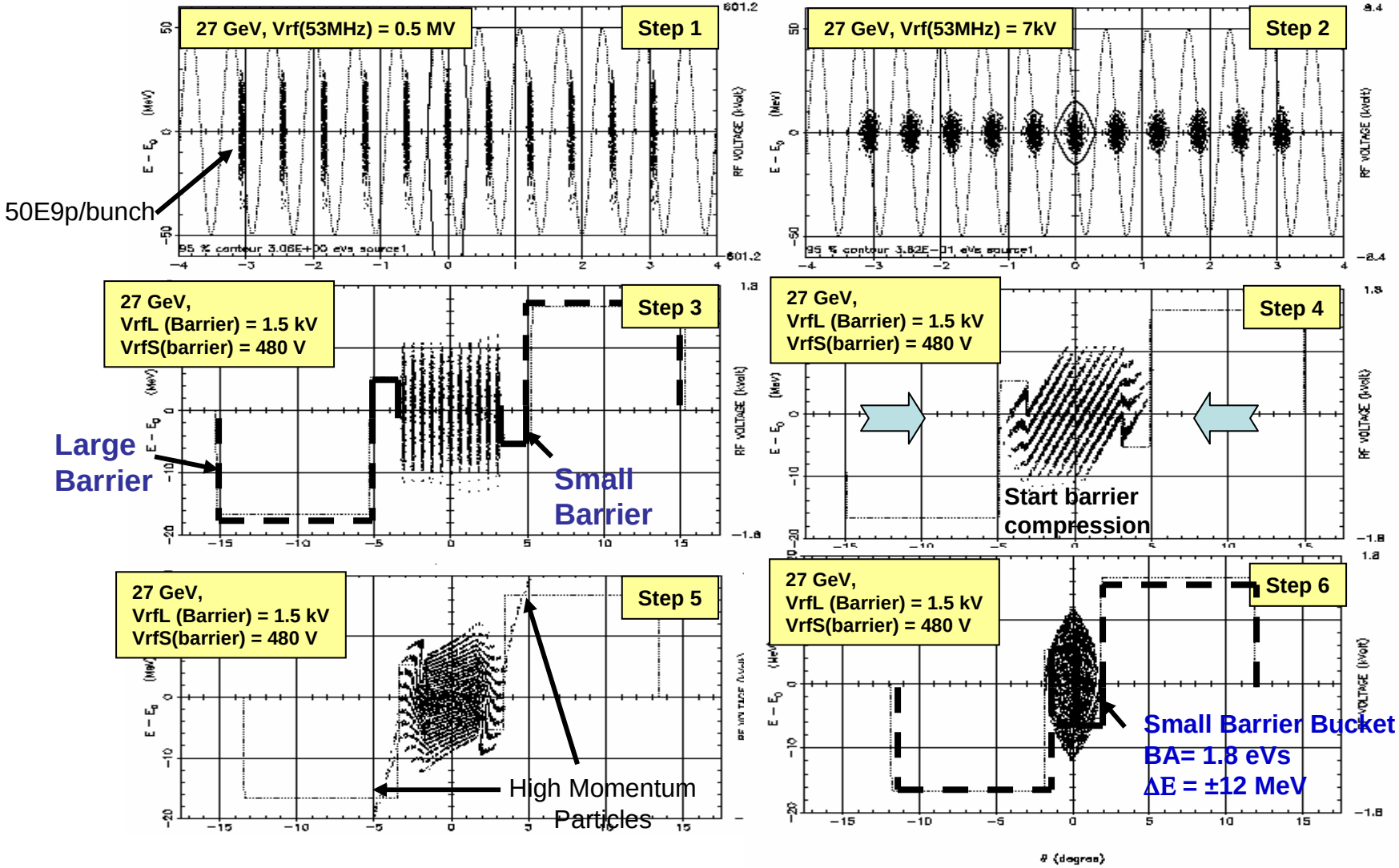
Based on Experience gained from

"Longitudinal Momentum Mining in RR"
C.M. Bhat PLA 330(2004) 481.
& Barrier Compression Studies in MI
D. Wildman et. al



Barrier Bucket Scheme -1

ESME simulations; (LE(inj) = 0.15 eVs)



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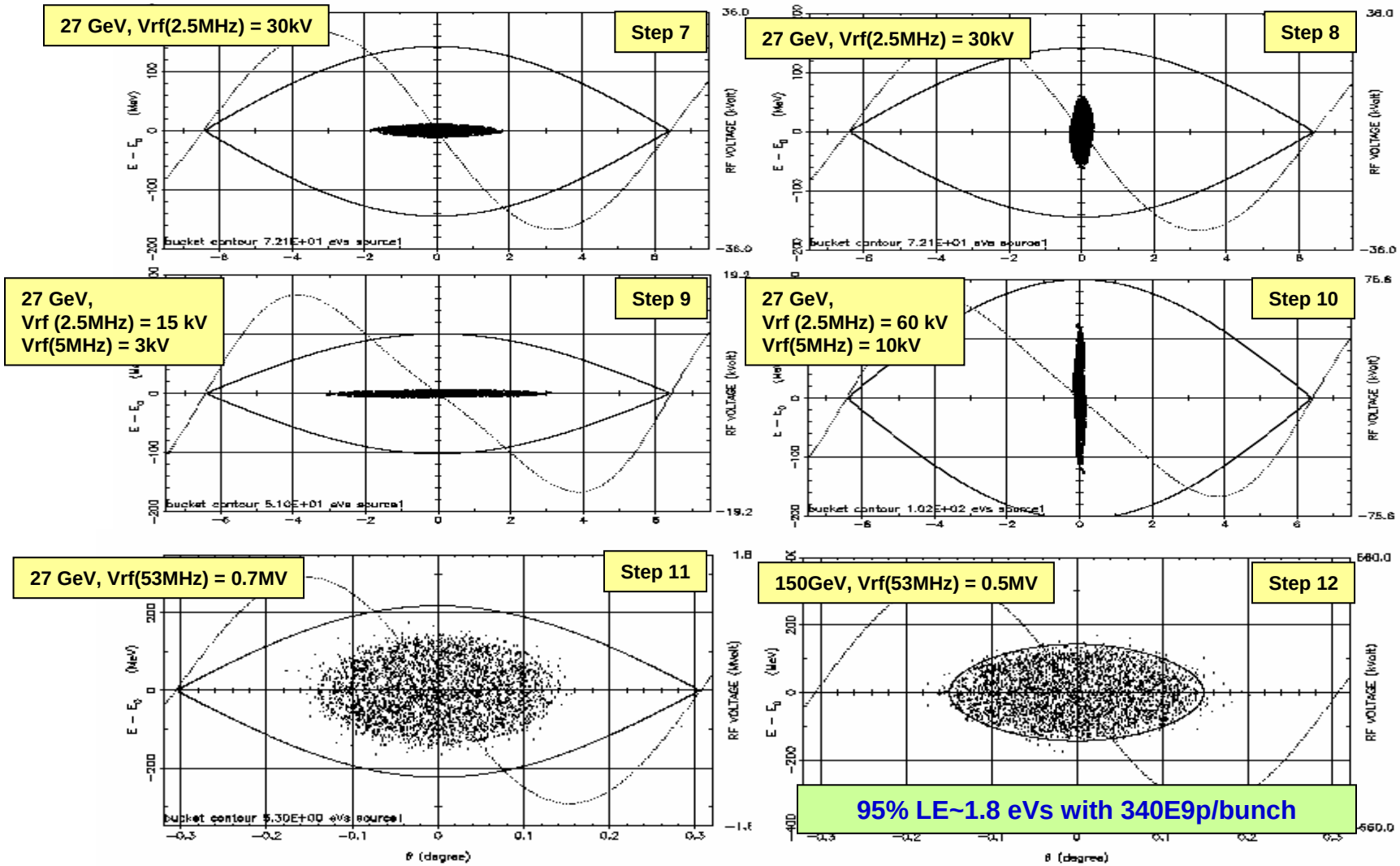
Barrier Bucket Scheme -1 (Cont.)

ESME simulations; (LE(inj) = 0.15 eVs)



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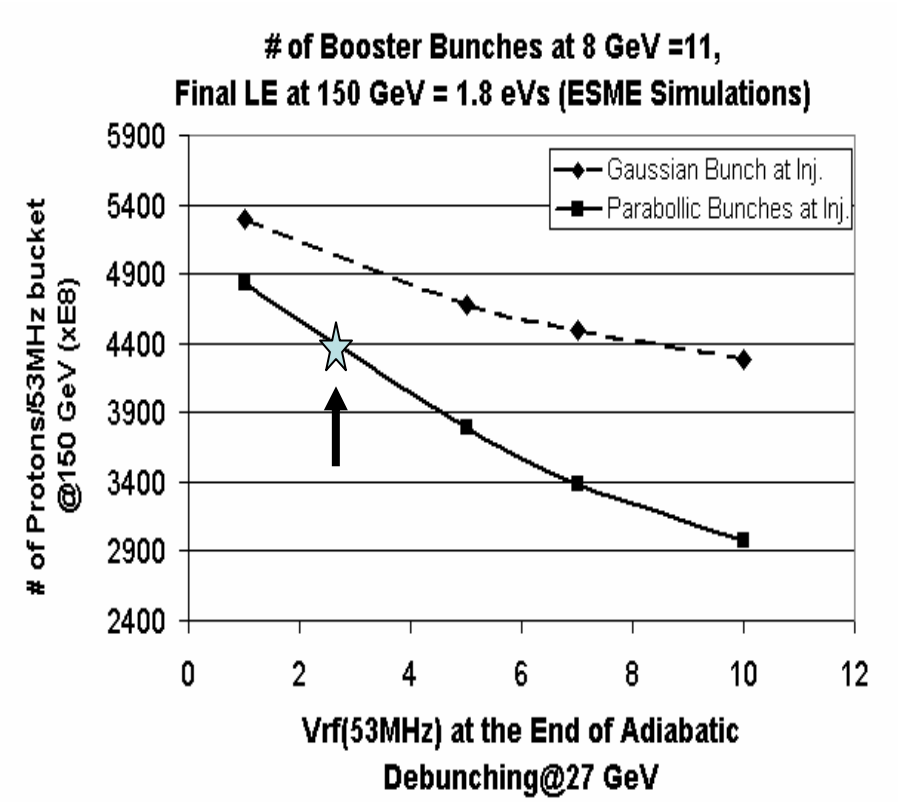
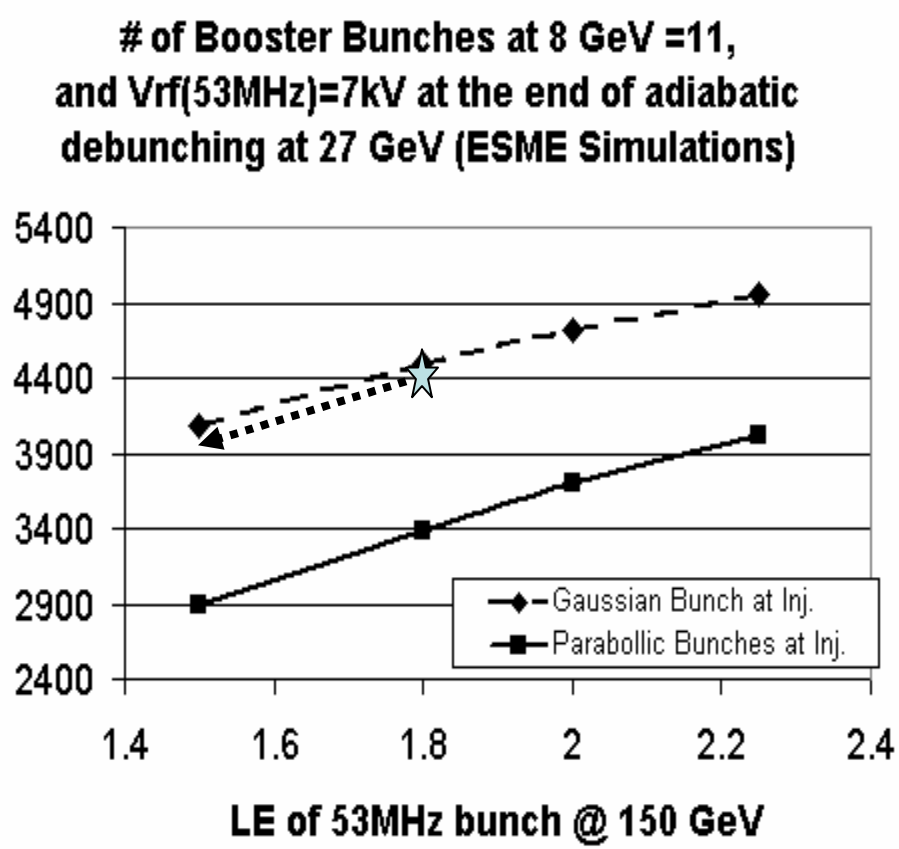
Simulations Continued

(Barrier Compression Method)

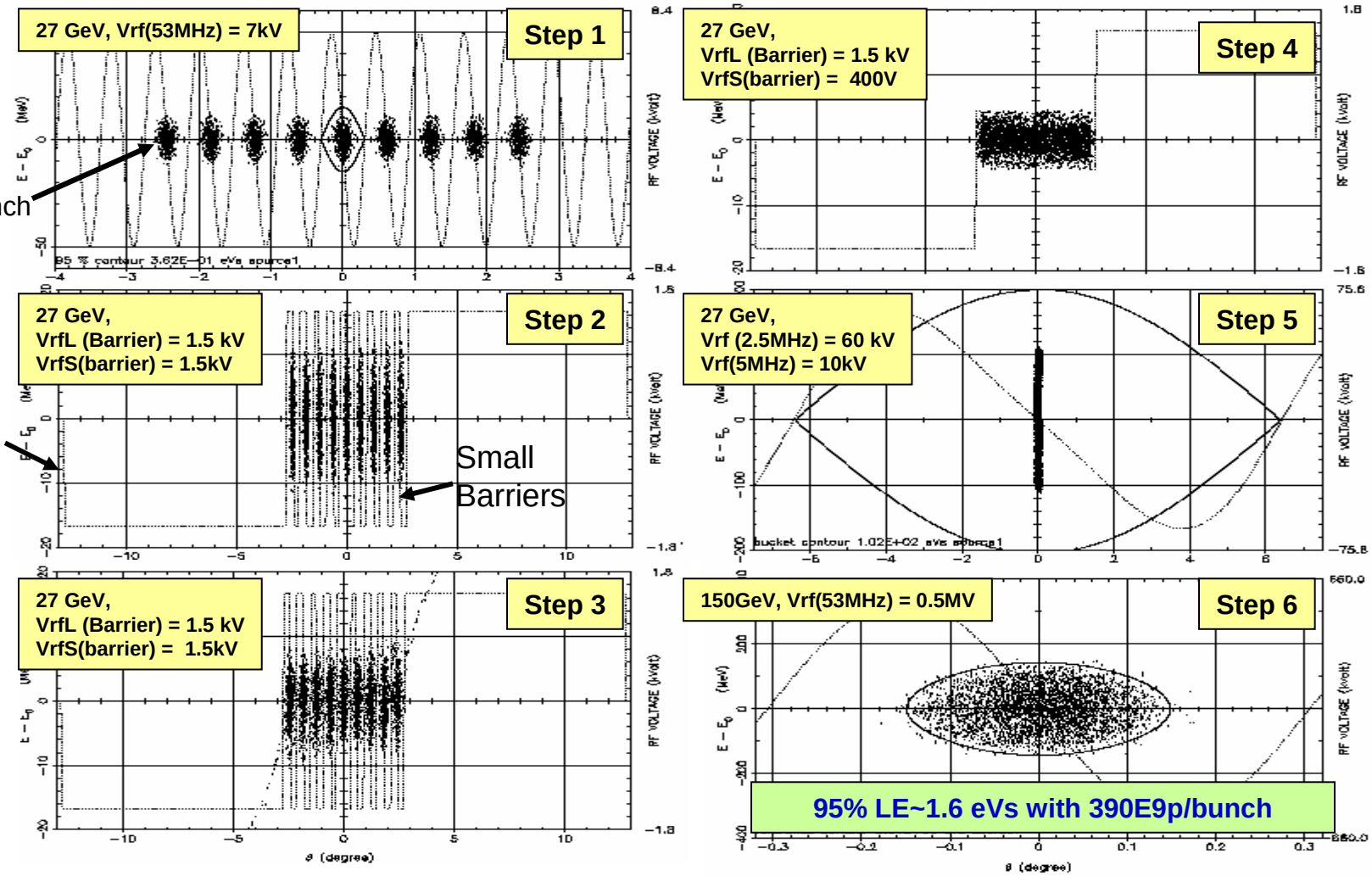




If number of Booster bunches is changed from 11 to 15 then bunch intensity went up by 7%

Barrier Bucket Scheme -2

ESME simulations; (LE(inj) = 0.15 eVs)



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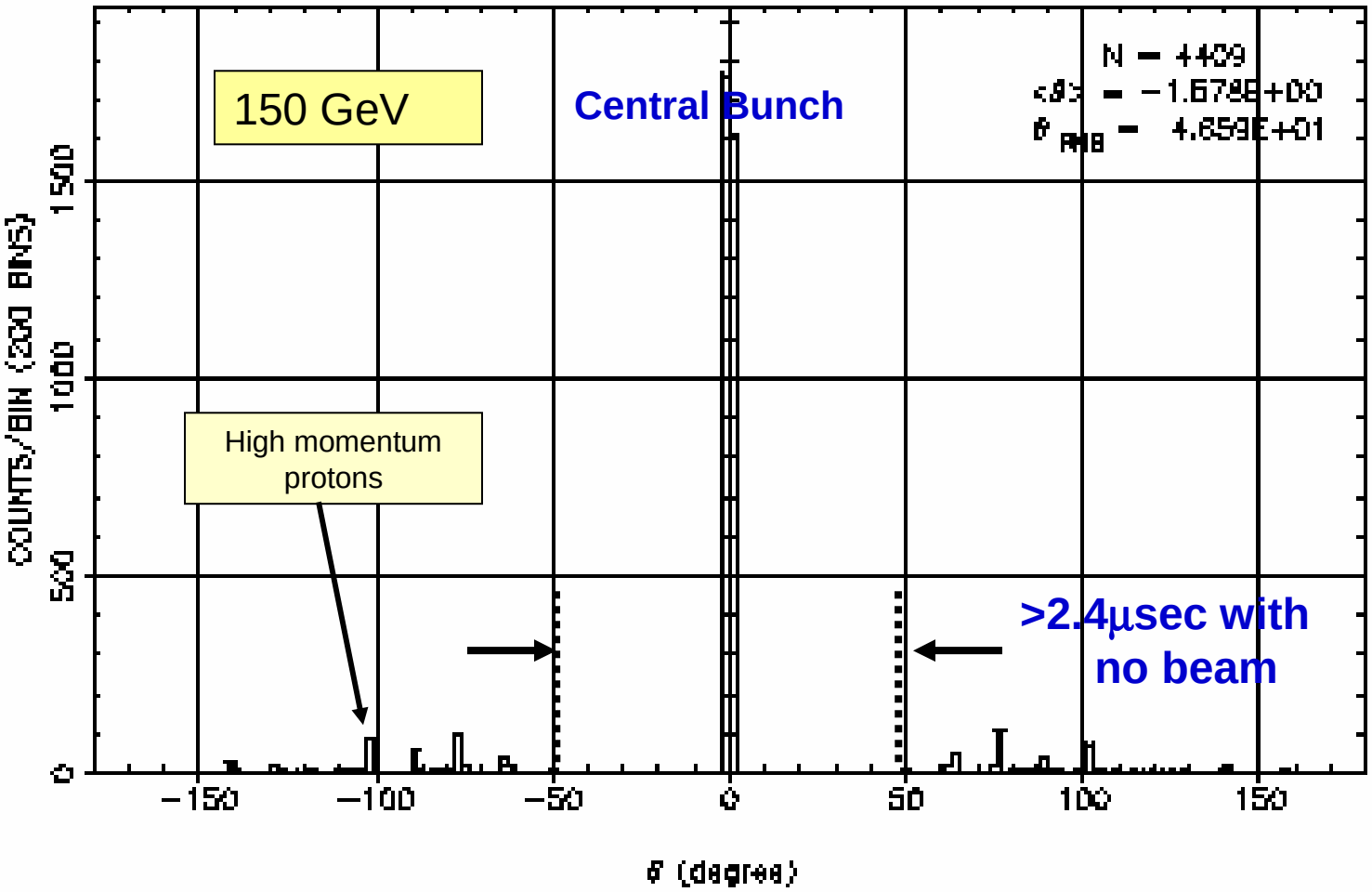
With 11 bunch injection ~80% beam survive in about 1.7 eVs

Central Bunch and the rest



Space-Charge and Wake Field Effects

- Space-charge: Space Charge density is about four times smaller than standard operation condition of MI à this is not a problem
- Longitudinal microwave instability: Keil-Schnell limit is evaluated for bunch with 600E9protons à this is not a problem
- Cavity Beam-loading effects from 2.5MHz and 53MHz rf system are evaluated for bunch intensity ~400E9protonà this is not a problem
- Barrier RF system: 50Ω x3 =150 Ω system gives about -1.2V potential distortion. This can be corrected à this is not a problem

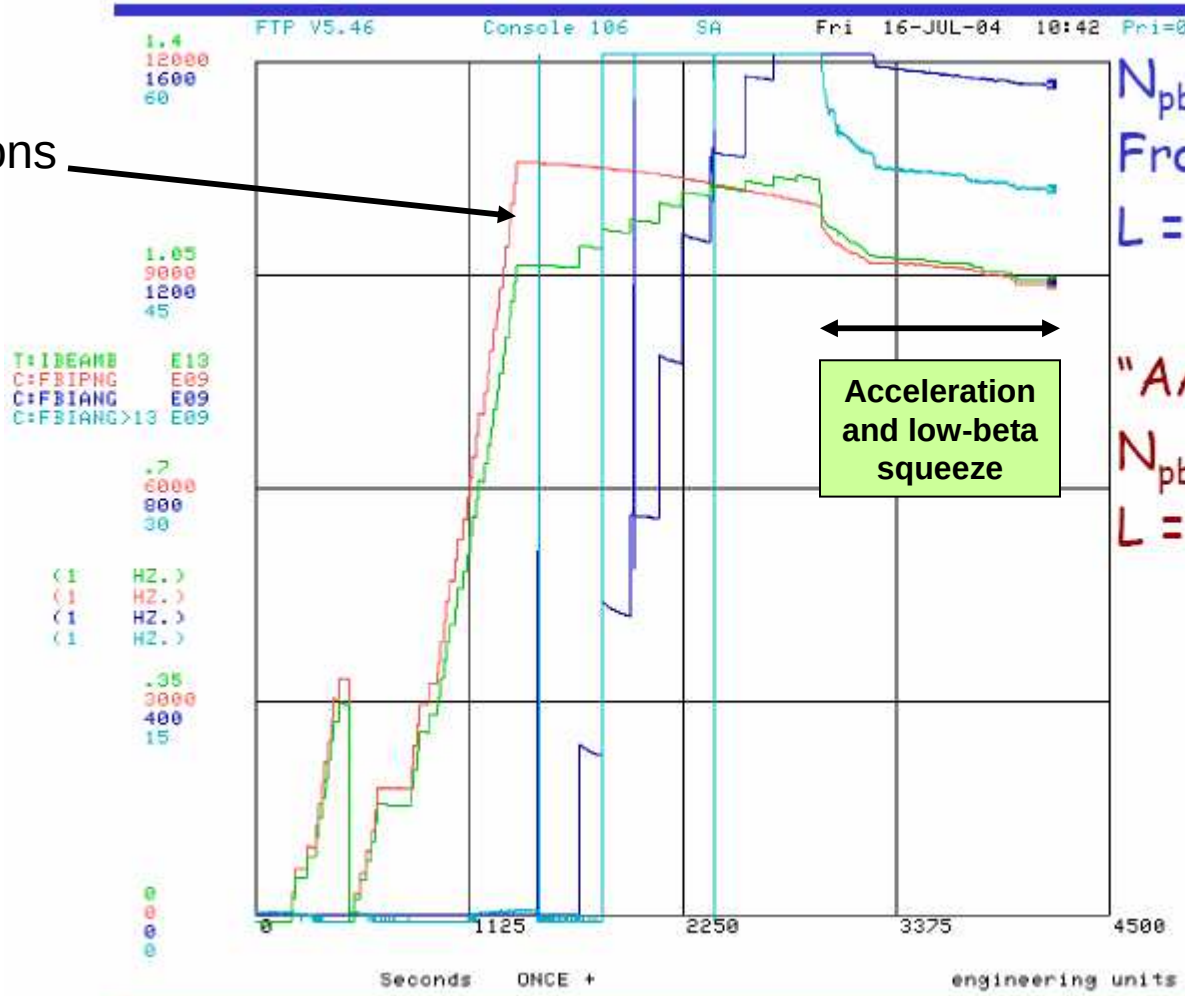
Detailed simulations are in progress

Summary

- It is evident that with bunch intensity ~300E9p/bunch and LE~2 eVs at collision the peak luminosity can be increased by about 20%.
- I propose two promising schemes to achieve proton bunch intensity in access of 300E9 with LE<1.8 eVs for Tevatron shots. These schemes use MI barrier rf systems.
- The Barrier bucket coalescing scheme -2 seems relatively simpler than the scheme -1

Example: Lots of Pbars in Store #3657

Protons



Acceleration and low-beta squeeze

N_{pbar}=1556 e9
From AA+RR
L = 103 e30

"AA only" record
N_{pbar}=1265 e9
L = 85 e30