Proton Stacking in the Recycler

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Tuesday SNuMI Meeting
High Intensity Protons
April 4, 2006

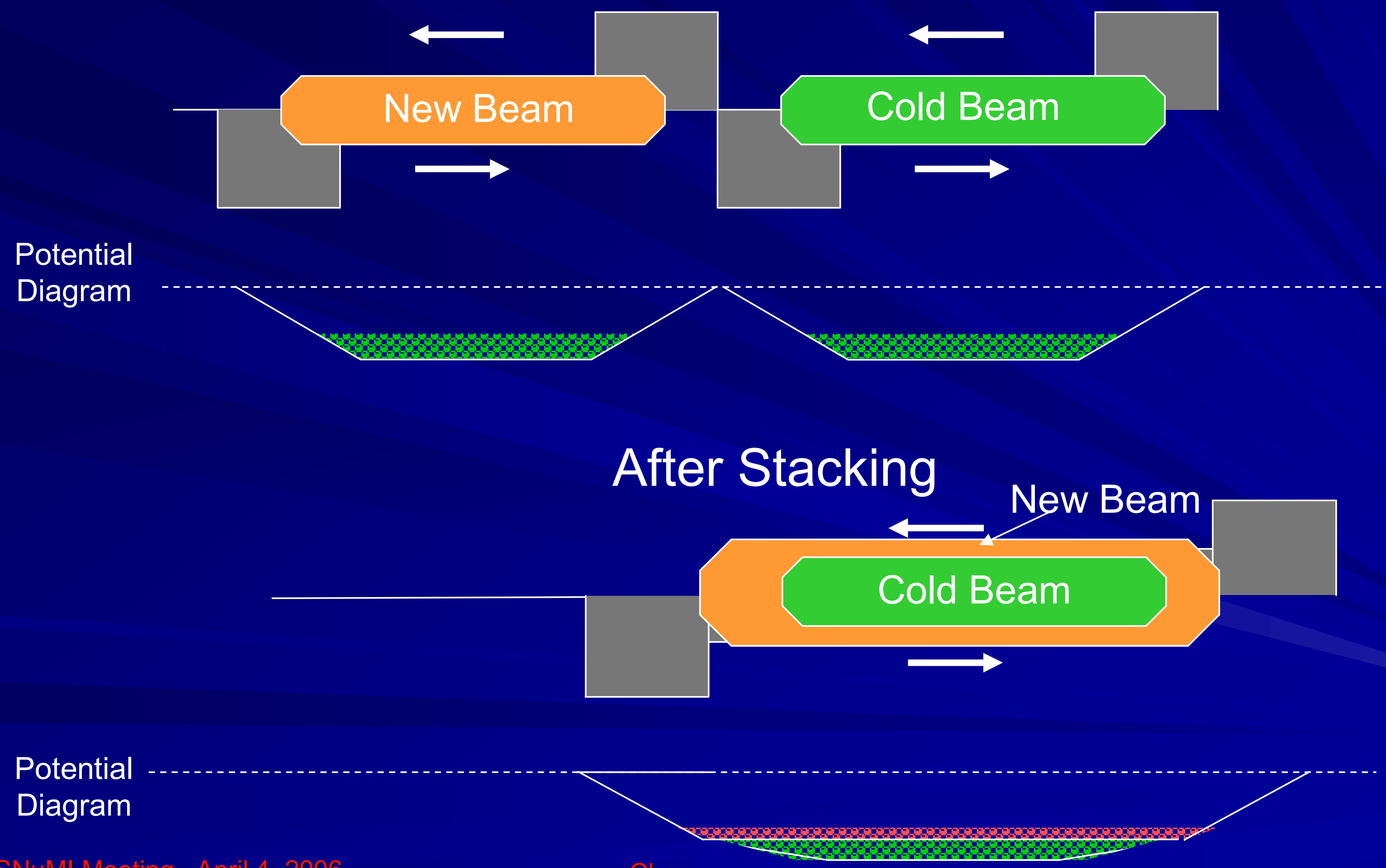
Contents

- Barrier bucket proton stacking schemes
  - Longitudinal Phase-space coating
  - Fast barrier compression technique
  - Momentum stacking (Griffin's scheme)

Longitudinal Phase-space Coating

Scheme developed for Recycler pbar stacking during e-cool era

C. M. Bhat, Beams-doc-2057-v1 (Dec. 2005)

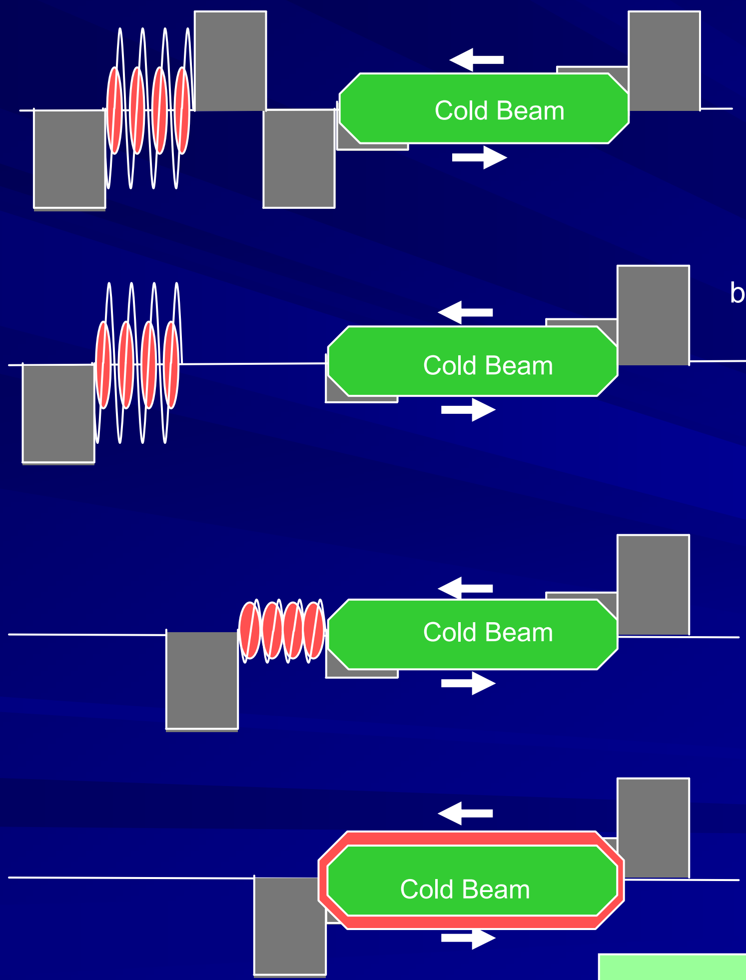


Sequences of Longitudinal Phase Space Coating

Voltage Waveforms & Phase-space distributions

$\int V dt$

Potential diagram

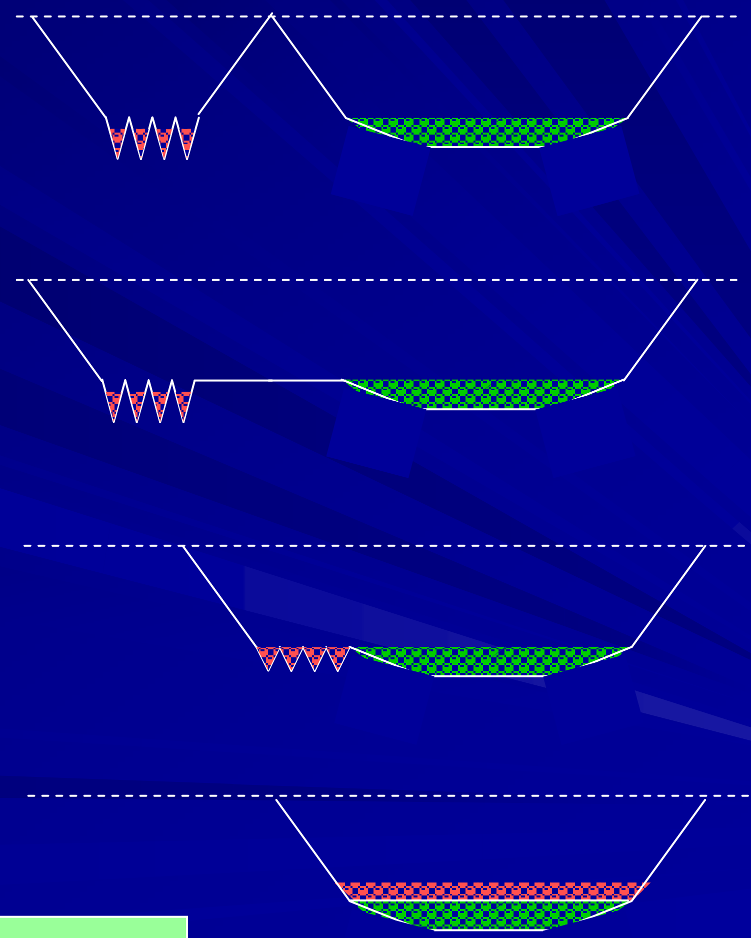


Injection

Bring the injected beam to the level of cold beam

Bring the injected beam closer to cold beam

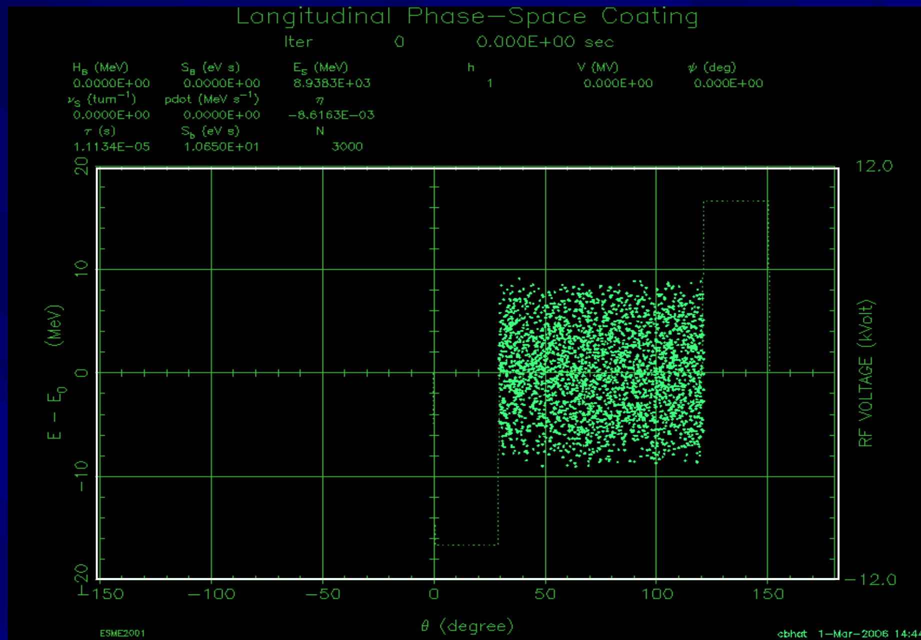
After painting the new beam on cold beam



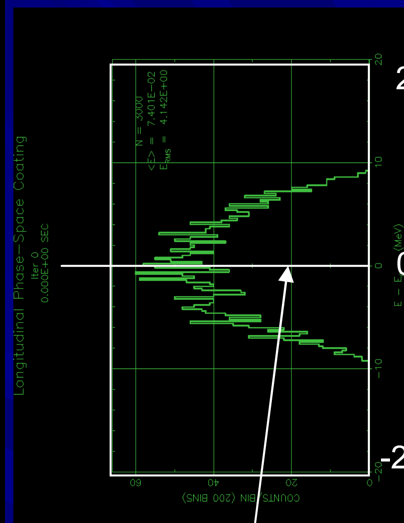
or variations of this ….

Simulations of Phase-space Coating

Phase-space distribution

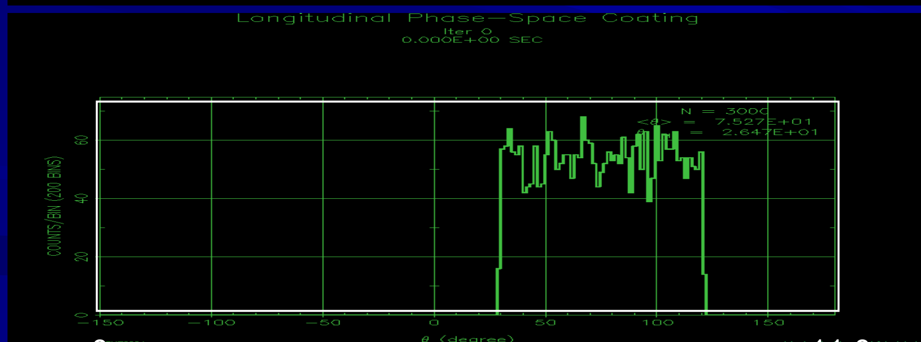


Simulated Energy spectrum



Synchronous energy

Simulated WCM data

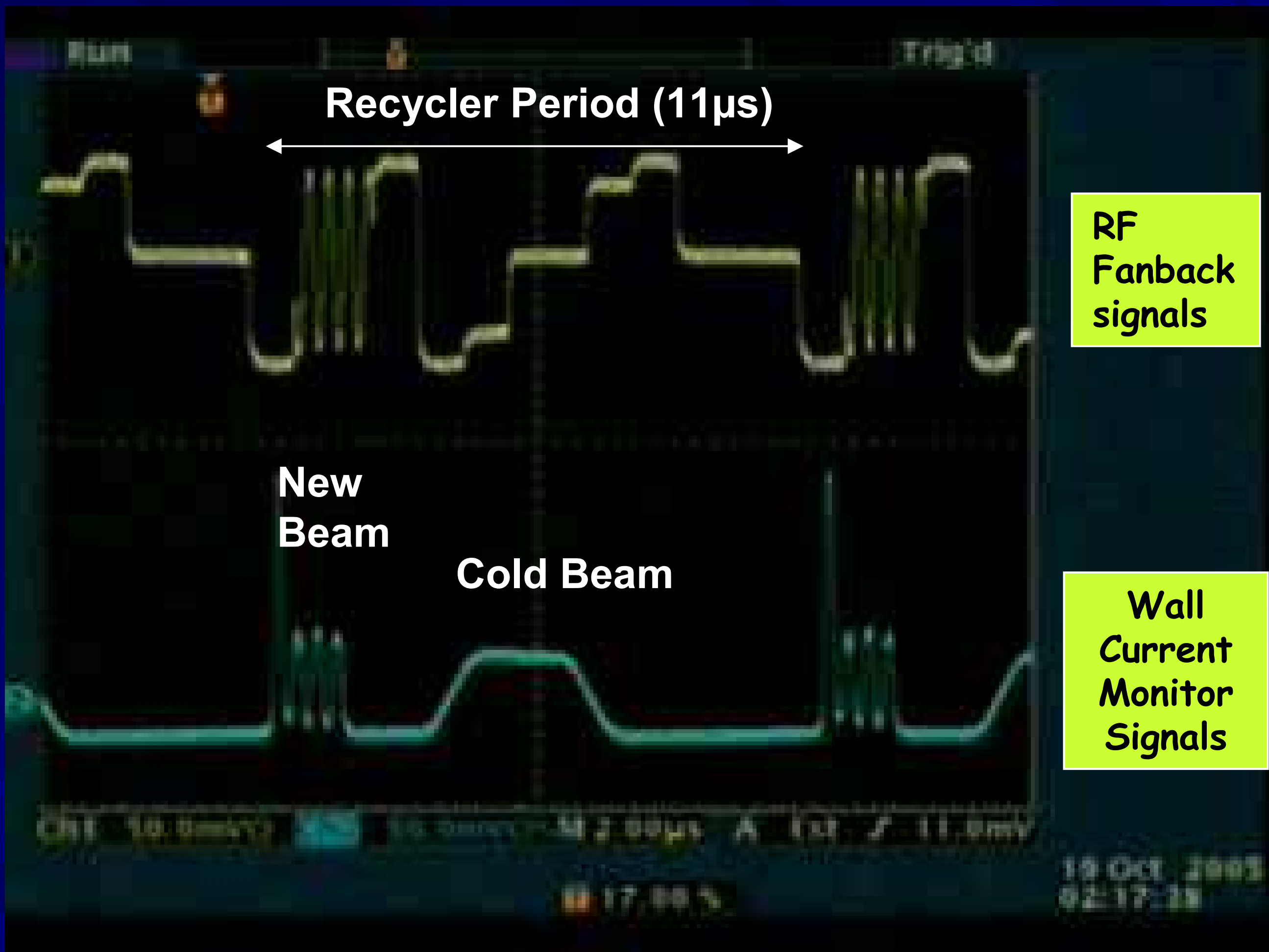


0 5.5 11.0

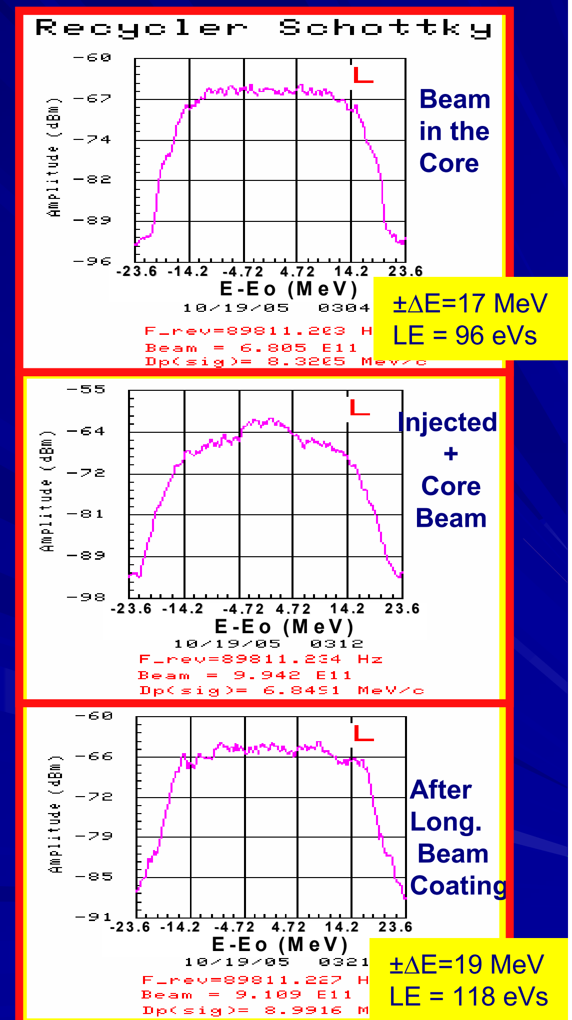
Time (μs)

Experimental Demonstration of Longitudinal Phase-space Coating

(Video)



Schottky Spectrum



Work in progress

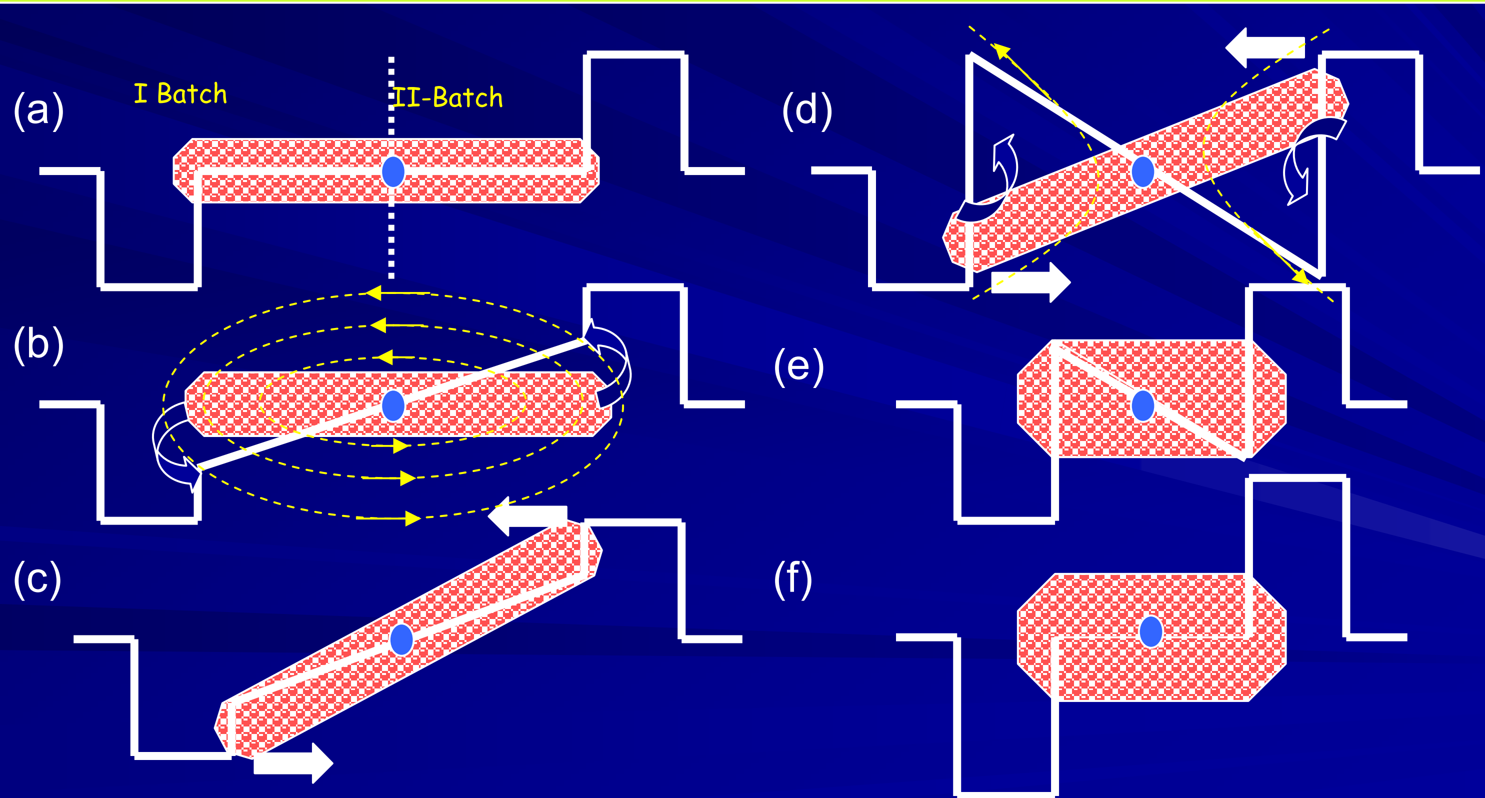
Fast Bunch Compression

(EPAC2004, page 1479)

Chandra Bhat*, Bill Foster*, Brian Chase, Jim MacLachlan*,Kiyomi Seiya, Phillip Varghese, Dave Wildman

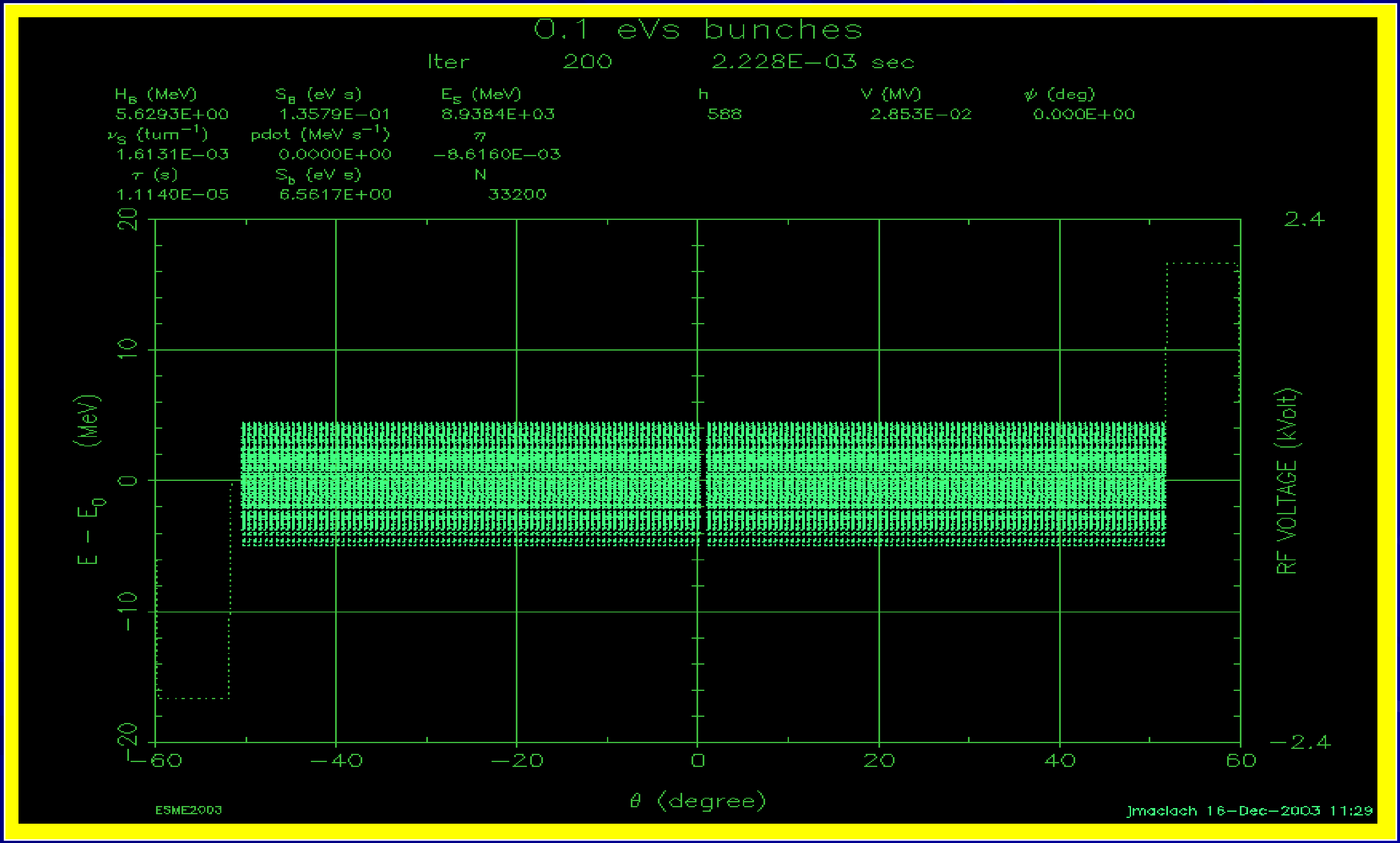
Physics of Fast Bunch Compression:

Rotation of a bunch about rf stable and unstable point within a Barrier bucket



Fast Bunch Compression:

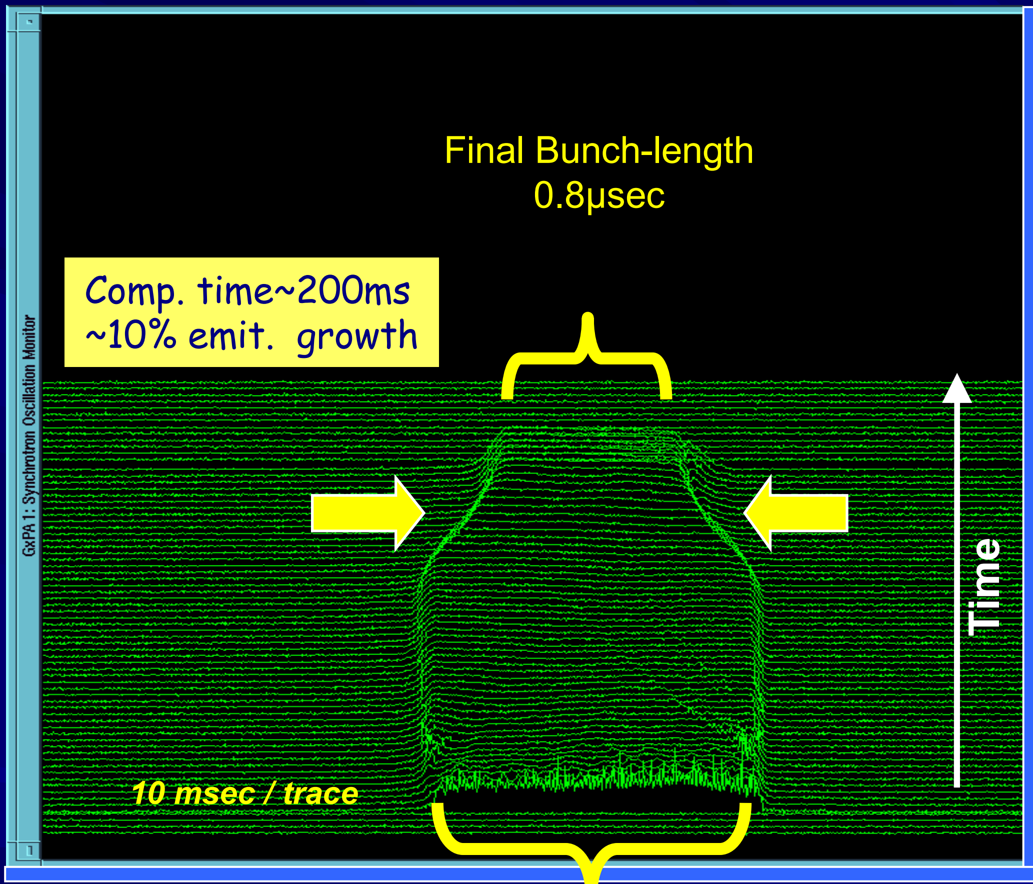
Symmetric Compression ESME Simulations



Simulations: J. MacLachlan

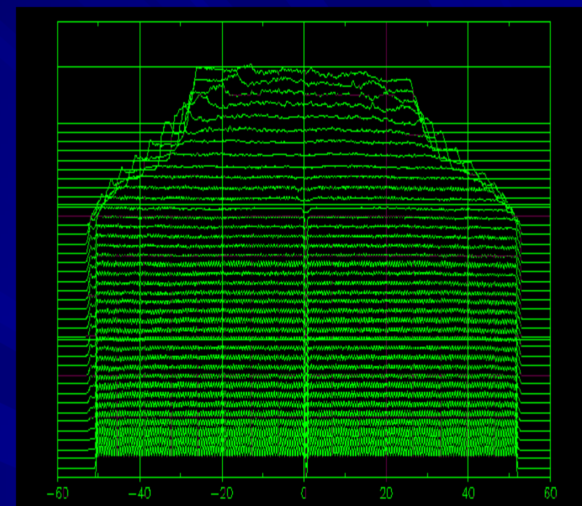
Symmetric Compression

Experimental Results: One Booster Batch Compression in the Recycler



Injected Batch from Main Injector,
Bunch Length=1.59 μsec

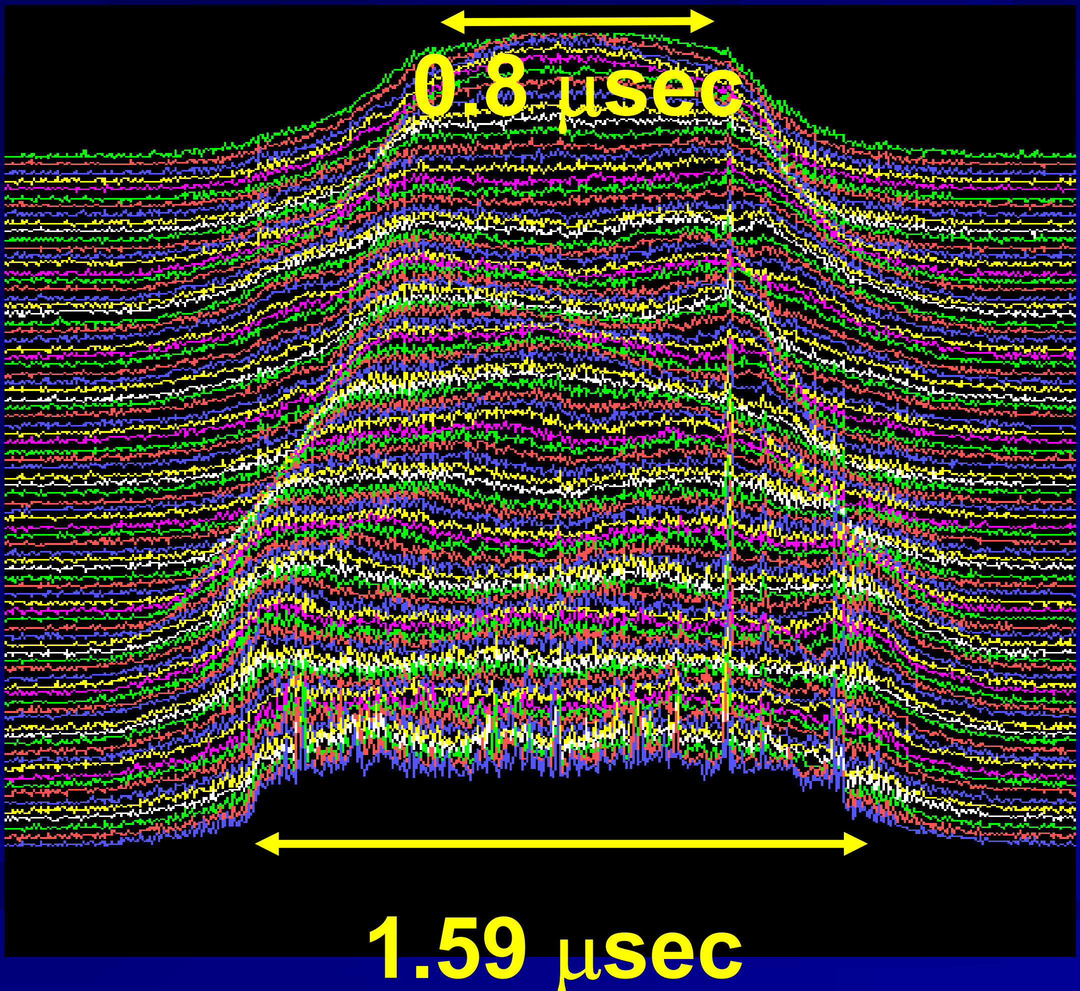
ESME Predictions



Parameters:

Barrier Pulse = ±2kV,
Ramp Voltage = ± 1kV
Beam Intensity ~1.5E12p
LE (initial) ~16 eVs,
LE (final)= LE= 18 eVs
ΔLE ~ 12%

Experimental Results from studies in MI

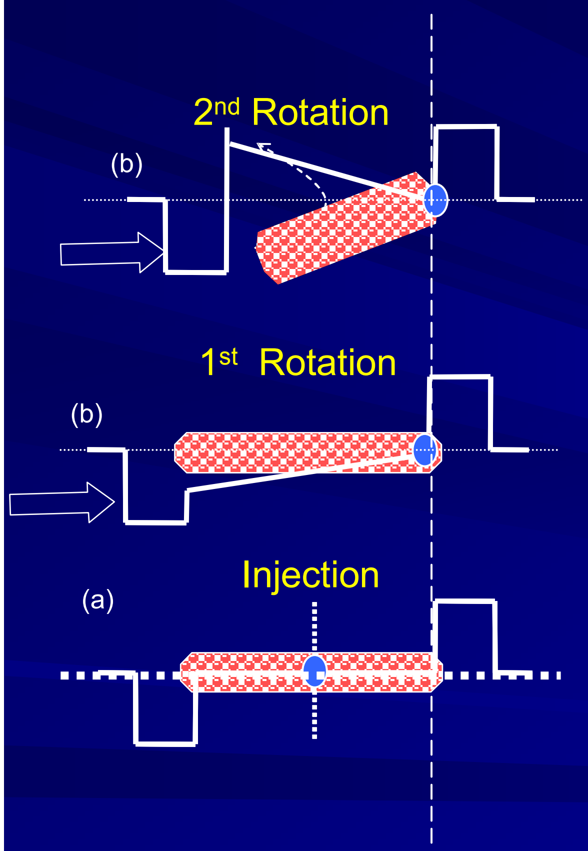


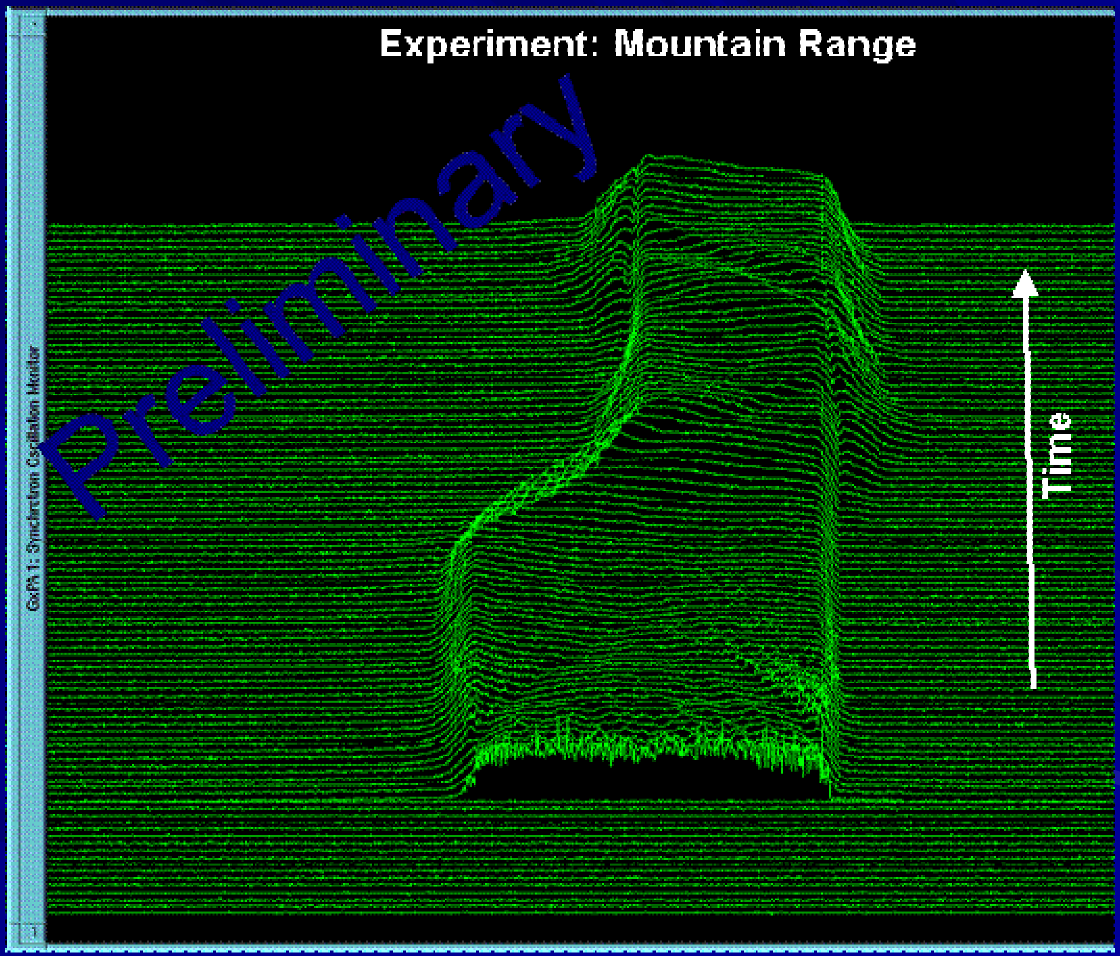
Peak RF Voltage: 500V
Type of Ferrite: Not Known
Shunt Impedancd: 50Ω
Bandwidth ~50kHz-100MHz
Dimension= 1.5meter
Cost = not known

Fast Bunch Compression:

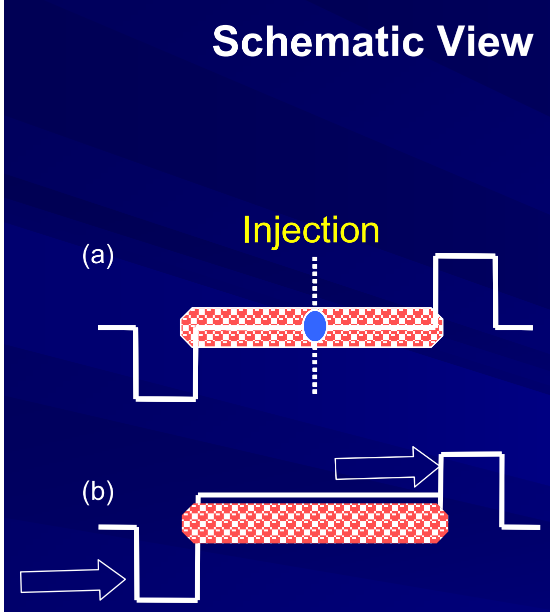
Non--symmetric Compression

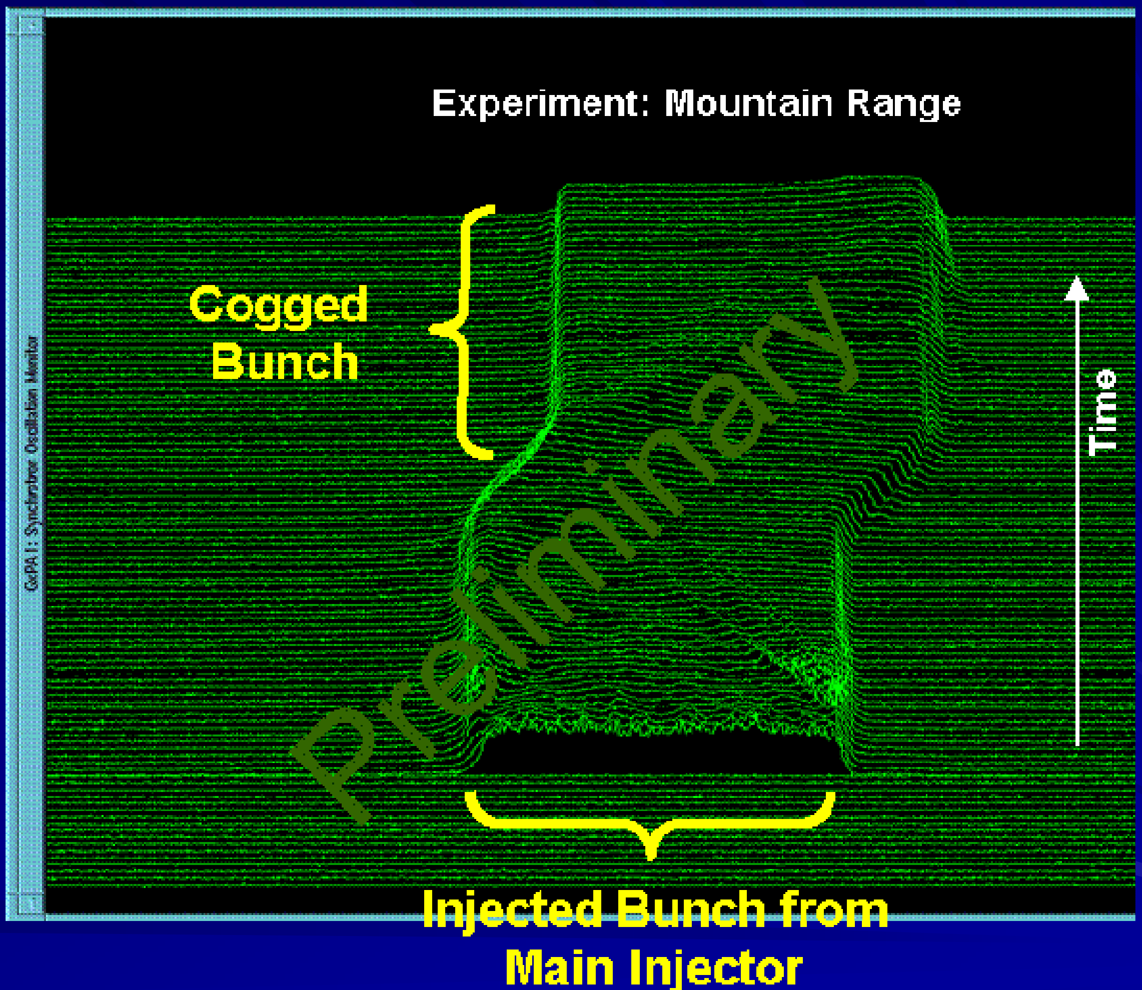
Experimental Demonstration





Fast Bunch Cogging





Advantages

- May not need any MAJOR rf upgrades in the Recycler.
- However, higher barrier rf voltage from ±2 kV to ±4 kV (±6 kV ?) is beneficial. ($1M+)
  - Higher rf voltage ← more compression
    ← Faster cogging

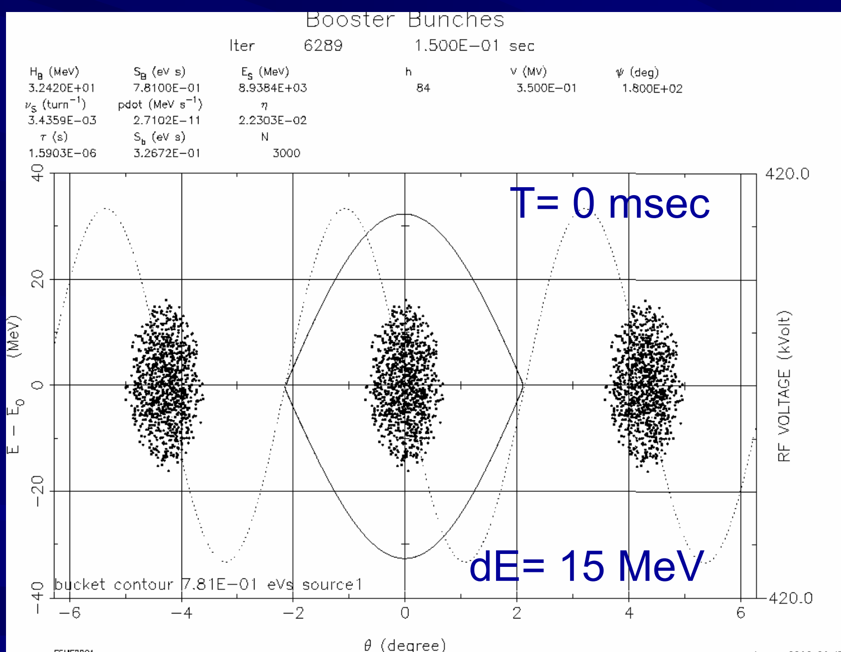
Issues

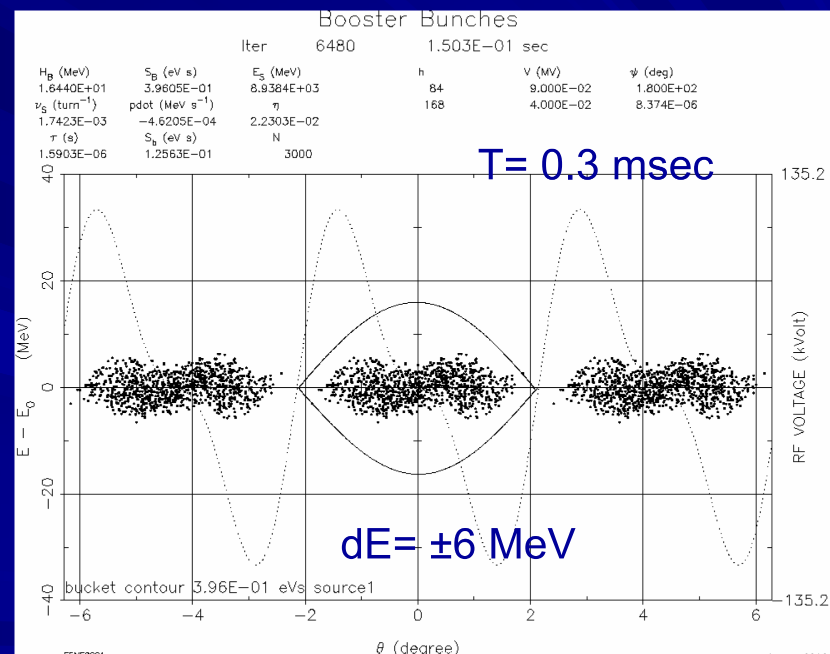
- How to produce low energy spread beam in the Booster? - ideally speaking we need rectangular bunch from the booster (this should be produced without any emittance growth). Later I have given a possible scheme, which needs further work.
- Recycler LLRF is capable of doing this sort of rf gymnastics.
- Beam-loading – is this a problem?
- How do we adiabatically capture in 53 MHz buckets in the MI before acceleration

Booster Beam

De-bunching (Bunch Rotation)

LE= 0.16 eVs
Vrf(init.) = 350 kV
Vrf (rotation) = 90kV (h=84)+40 kV(h= 168)

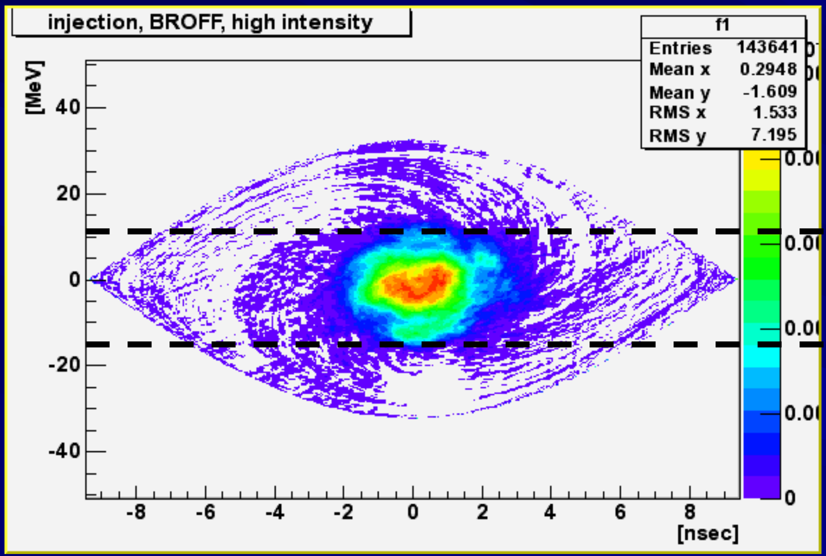




Booster Beam

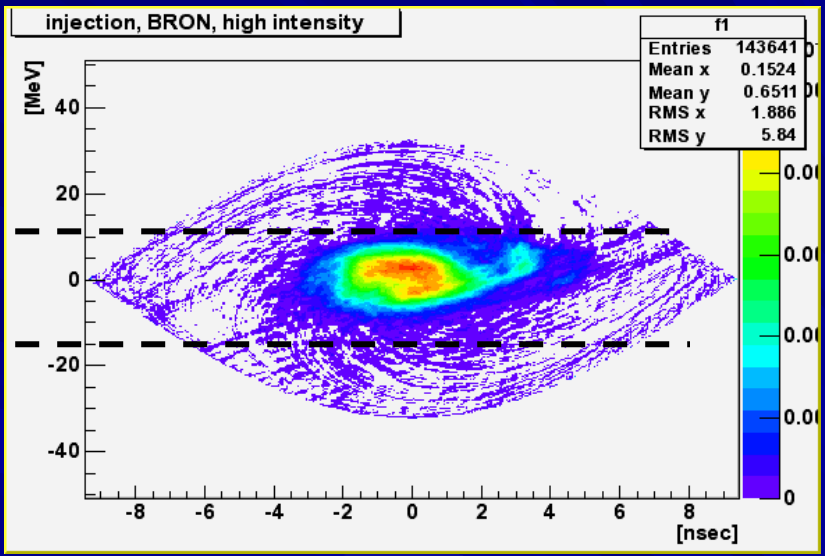
Present Status (from Kiyomi)

Bunch Rotation off



Vrf ~ 450kV

Bunch Rotation on



Vrf ~ 200kV

Future Plans

- If any of these techniques can be used for high intensity proton stacking in the Recycler then perform detailed simulations with beam-loading effects,
- Figure out the stacking scheme – this is like solving a “magic cube puzzle”.
  - For example, we know that Recycler is about 11us long. Inject the three successive Booster batches 1,2 and 3 at bucket number 1, 168 and 336 of Recycler. Compress the batch-1 to the right and batch-2 to left to their half size (these are non-symmetric compressions). Start compression of the 3rd batch to the left so that we can inject 4th batch can be injected in between 1st and 3rd. And so on. In the meanwhile, one can merge 1st and 2nd compressed batched start (fast) cogging towards the 3rd batch. And so on.
- Understand what are their limitations
- Conduct some further experiments in the Recycler to workout the mechanics. This
- So on…..