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)

Potential Diagram

After Stacking

Potential Diagram

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Sequences of Longitudinal Phase Space Coating

Voltage Waveforms & Phase-space distributions

\[
\int Vdt
\]

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 WCM data

Simulated Energy spectrum

Synchronous energy

Time (μs)

E-E₀ (MeV)
Experimental Demonstration of Longitudinal Phase-space Coating

(Video)

Recycler Period (11µs)

New Beam

Cold Beam

RF Fanback signals

Wall Current Monitor Signals

Work in progress

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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

Parameters:
Barrier Pulse = \(\pm 2\) kV,
Ramp Voltage = \(\pm 1\) kV
Beam Intensity \(\sim 1.5E12\) p
LE (initial) \(\sim 16\) eVs,
LE (final) = LE = 18 eVs
\(\Delta\)LE \(\sim 12\%\)
Experimental Results from studies in MI

1.59 µsec

0.8 µsec

Test Device in MI

Peak RF Voltage: 500V
Type of Ferrite: Not Known
Shunt Impedance: 50Ω
Bandwidth: ~50kHz-100MHz
Dimension: 1.5 meter
Cost: not known
Fast Bunch Compression: Non-symmetric Compression

Experimental Demonstration

Schematic View

2nd Rotation

1st Rotation

Injection

Experiment: Mountain Range

Preliminary
Fast Bunch Cogging

Schematic View

(a) Injection

(b) Cogged Bunch

Experiment: Mountain Range

Injected Bunch from Main Injector

Preliminary

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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 $\rightarrow$ more compression
    $\rightarrow$ 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 eV
Vrf (init.) = 350 kV
Vrf (rotation) = 90 kV (h=84) + 40 kV (h=168)

T = 0 msec
dE = 15 MeV

T = 0.3 msec
dE = ±6 MeV
Booster Beam
Present Status (from Kiyomi)

Bunch Rotation off

Bunch Rotation on

Vrf ~ 450kV

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.....