Momentum Mining in the Recycler

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All Experimenters Meeting
November 22, 2004

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Basics of an RF Bucket

Bunched Beam with Energy $E_0 \pm \Delta E$

RF Cavity

Rectangular Barrier

Sinusoidal

$V_{rf}$

AC

Potential Diagram

$U(t) = \frac{1}{T_0} \int_0^{T_0} V_{rf}(t) dt$

Barrier Bucket

Phase-space Area is Longitudinal Emittance Measured in $\text{eVs}$

Beam Pipe & the Beam

$\omega_{rf} = h \omega_{rev}$

$\omega_{r}$ harmonic number $h=1$

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Is it possible to isolate the cold beam from the high momentum tail of a beam distribution without emittance growth and use only the cold beam and use the leftover hot beam after further cooling?
Longitudinal Momentum Mining in a Synchrotron

New Technique


Physics

RF Voltage & Beam Boundary

Potential $U = \int V(t)dt$ & Beam Particle

(a)

(b)

(c)

Technique is applicable to any storage ring for beam mining

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Momentum Mining for Tevatron Collider Shots

We have successfully implemented longitudinal momentum mining in the Recycler to inject equal emittance, equal intensity pbars bunches for Tevatron shots.

The Longitudinal Momentum Mining scheme is ~2x more efficient than the “beam slicing scheme”
Mining of ~50 eVs (95%) beam for 9-transfers

200E10 protons with ~50 eVs
Before Mining

After Mining
6 eVs/bunch
**2.5MHz Bunches From RR**

Recycler pbars

Store # 3597

\[ \text{<Total Intensity/transfer>} \approx 20 \text{ E10} \]

\[ \text{<LE (95%)} \approx 2.3 \text{ eVs / bunch (±15%)} \]

\[ \text{Dp/p=} \pm 0.065 \%

\[ \text{<Transverse Emit.>} = 3.7 \pm 0.4 \text{ π-mm-mr} \]

Store # 3564

\[ \text{<Total Intensity/transfer>} = 11.7 \text{ E10} \]

\[ \text{<LE (95%)} = 2.2 \text{ eVs / bunch} \]

\[ \text{Dp/p=} \pm 0.065 \%

\[ \text{<Transverse Emit.>} = 4.1 \pm 0.3 \text{ π-mm-mr} \]

Yellow is 1st tranf.
Contribution of the Recycler to higher peak ppbar Luminosity

Use both Accumulator as well as Recycler pbars for the Tevatron shots → Mixed pbar Source Operation

Current Luminosity Record of $107.0 \times 10^3$ cm$^{-2}$s$^{-1}$

So far, we had 8 Mixed Pbar Source Shot Setups
- 3 shots to the Tevatron supplying 3 of the the 9 transfers
  - Average stash that we shot from .........................$85.5 \times 10^9$
  - Average intensity per transfer ................................$23.0 \times 10^9$
  - Percentage of beam captured for extraction ......83%
- 5 shots to the Tevatron supplying 2 of the 9 transfers
  - Average stash that we shot from .........................$55.0 \times 10^9$
  - Average intensity per transfer ................................$23.3 \times 10^9$
  - Percentage of beam captured for extraction ......80%

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Recent Improvements

- **RF Upgrades: Baseline corrections**
  - Replaced cables \( \rightarrow \) Reduces the RF waveform distortion
  - Vrf calibration
  - Dampers
  - Emittance monitor

- **We can mine 1-9 transfers on demand**
  - LLRF states development
  - Modification of the shot sequencer

- **Smooth recovery from Mining**
  - After beam transfer to the Tevatron
  - After mining but before transfer to the Tevatron if needed