Extraction of antiprotons from the Recycler without a “hot bucket”

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MI departmental meeting

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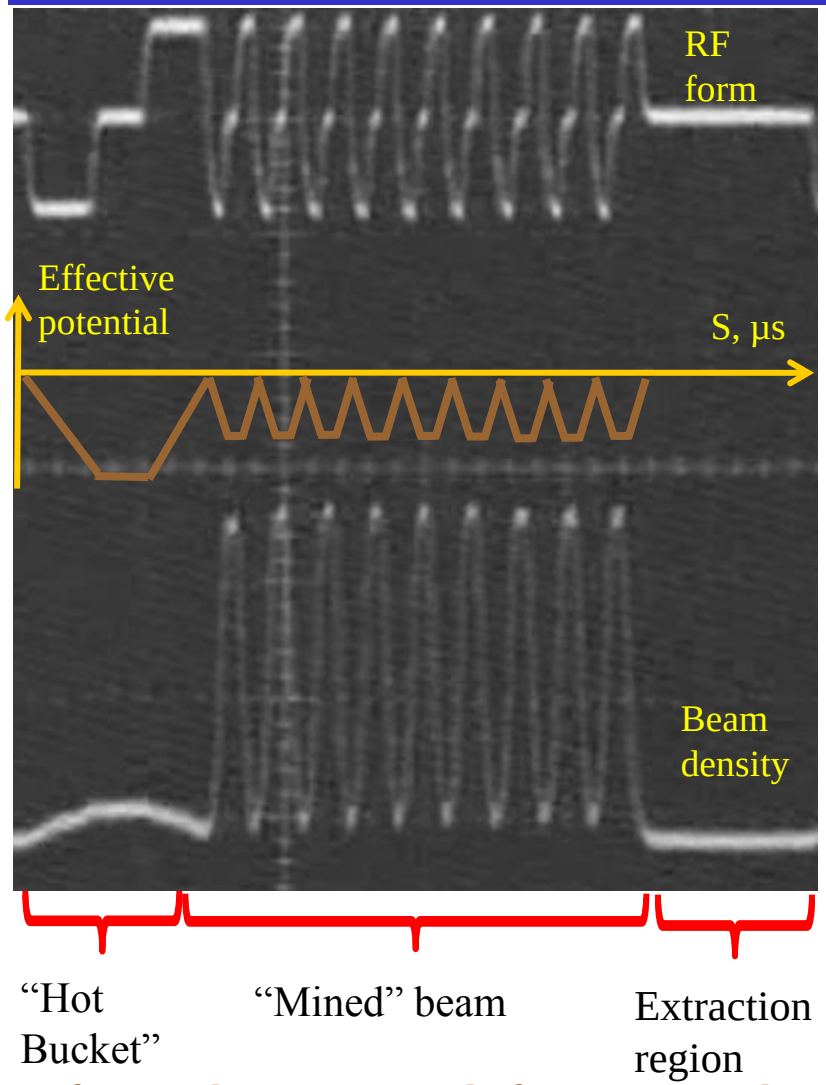
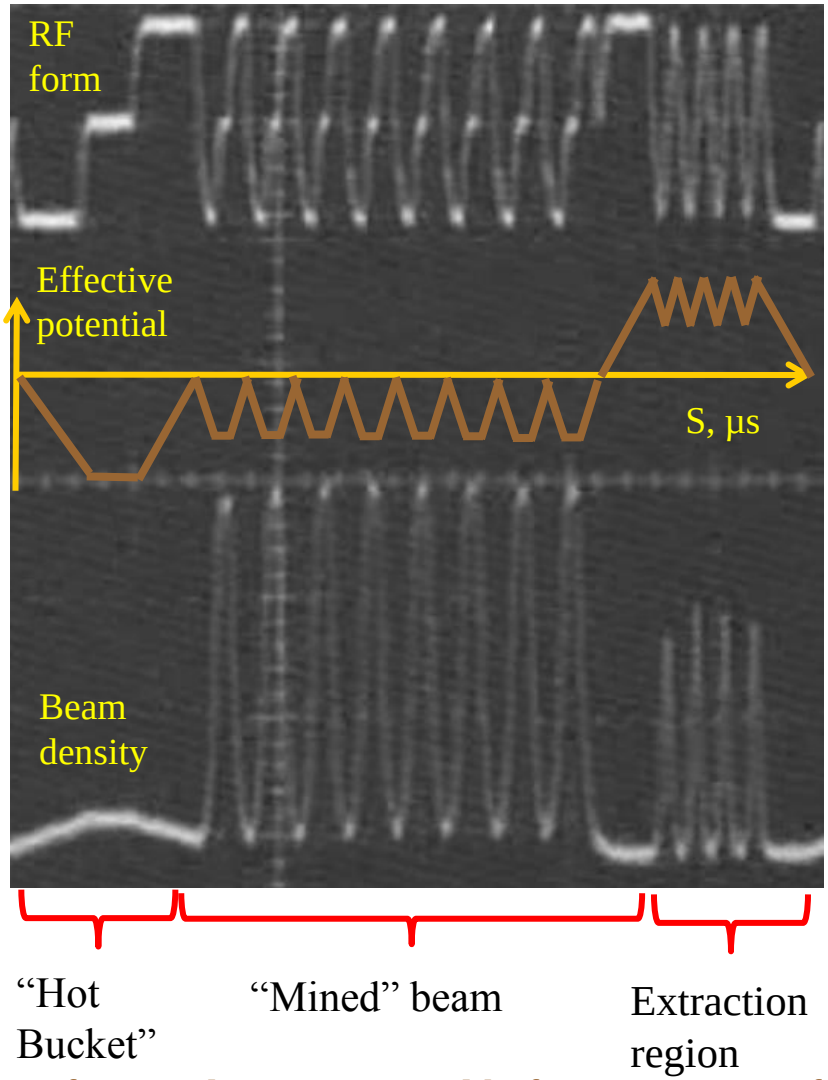
"Hot bucket"



RF form and RWCM signal after mining and growing the "hot" bucket. 17-Jun-2007, C. Bhat.

- "Hot bucket" was proposed and implemented (C. Bhat) to avoid sending "hot" pbars to MI
  - Separating pbars with high longitudinal actions and moving into a separate "hot bucket" by special RF manipulations
- Was decreasing the amount of DC beam in the machine
  - In absence of a damper, DC beam resulted in a transverse emittance growth because of ions

What has changed since implementation



RF form and RWCM signal before extraction of the first bunch. 17-Jun-2007, C. Bhat.

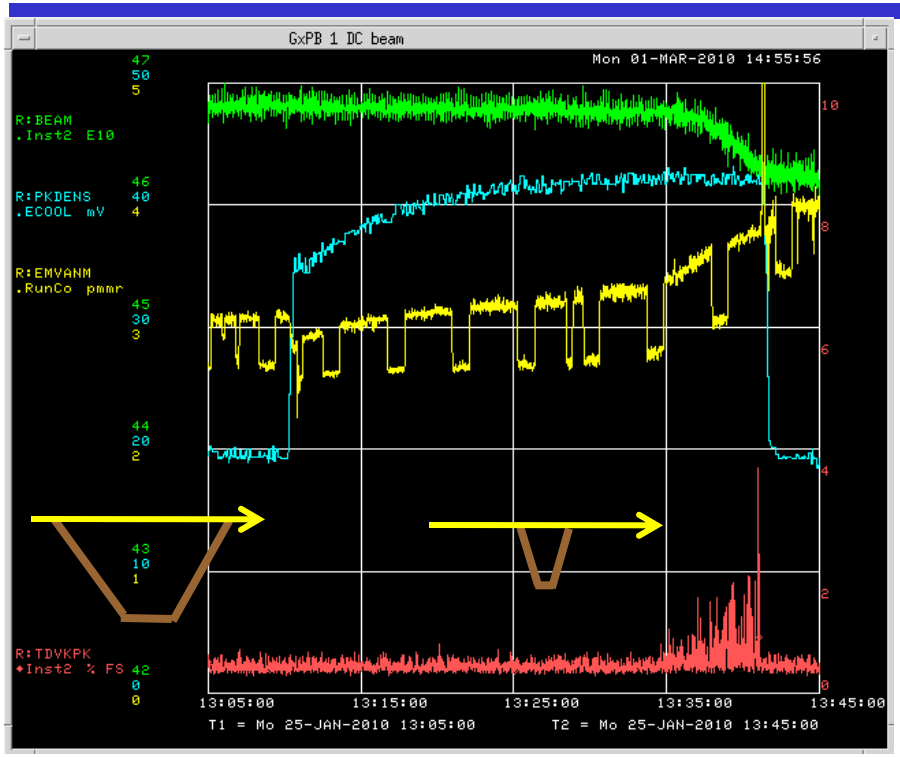
- "Anti-bucket" around pbars to be extracted (C.Bhat)
  - Pushed hot particles away from the extraction region
- Much smaller number of pbars leaving in "hot bucket"
  - Because of a more effective electron cooling
- Transverse dampers
  - A large DC beam doesn't cause a fast emittance growth
- Pbar beam is normally at the boundary of instability at extraction
  - Allows to send the brightest bunches to MI
- Do we need "hot bucket"?

Instabilities during extraction

Date	Np, E10	After extrac-tion of bunch #	Ecool status	Final cooling time. hrs	Changes
7-Dec-08	400	5, 6	After EC tuning	8	E-beam offset at extraction changed from 0 to 0.5 mm
27-Sep-09	420	5	After CS alignment	24	E-beam offset at extraction changed from 0.5 to 0.8 mm
7-Jan-10	410	6	300mA study	3	Adjusted e-beam offset for 0.3A
22-Feb-10	390	5	300mA study	1.3	?

- Developing of the instability depends on quality of e-cooling and details of pbar beam tails
  - Eliminating the "hot bucket" should help with the beam stability

Instability during "mining emulation" study



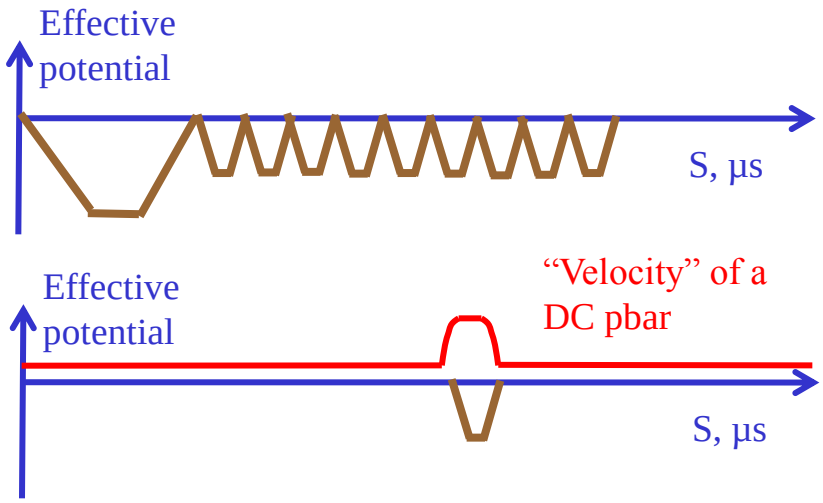
Instability while cooling a single bunch. January 25, 2010.

Green – number of pbars, (42 – 47)E10; Blue – longitudinal density, a.u.; Yellow – Fast emittance, 1pi/box; Red – damper kick, % of full scale.

E-beam was moved to 0.8 mm after right growing "soft" mini-barriers (two full-height, 12-bckt, opposite sign barriers separated by 12 bckts).

- 25-Jan-10: study with a single bunch to emulate mining with "soft" and "hard" buckets
  - The goal was to compare the resulting longitudinal emittance of the bunch
  - The results were not convincing
- The main effect happened to be an instability during emulating the "soft" mining
- Why instability?
  - E-cooling was not good
    - Before CS alignment
  - E-beam was kept at usual 0.8 mm
  - Instability stopped immediately after growing the "normal" bucket

Possible explanation: different RF structure for DC beam

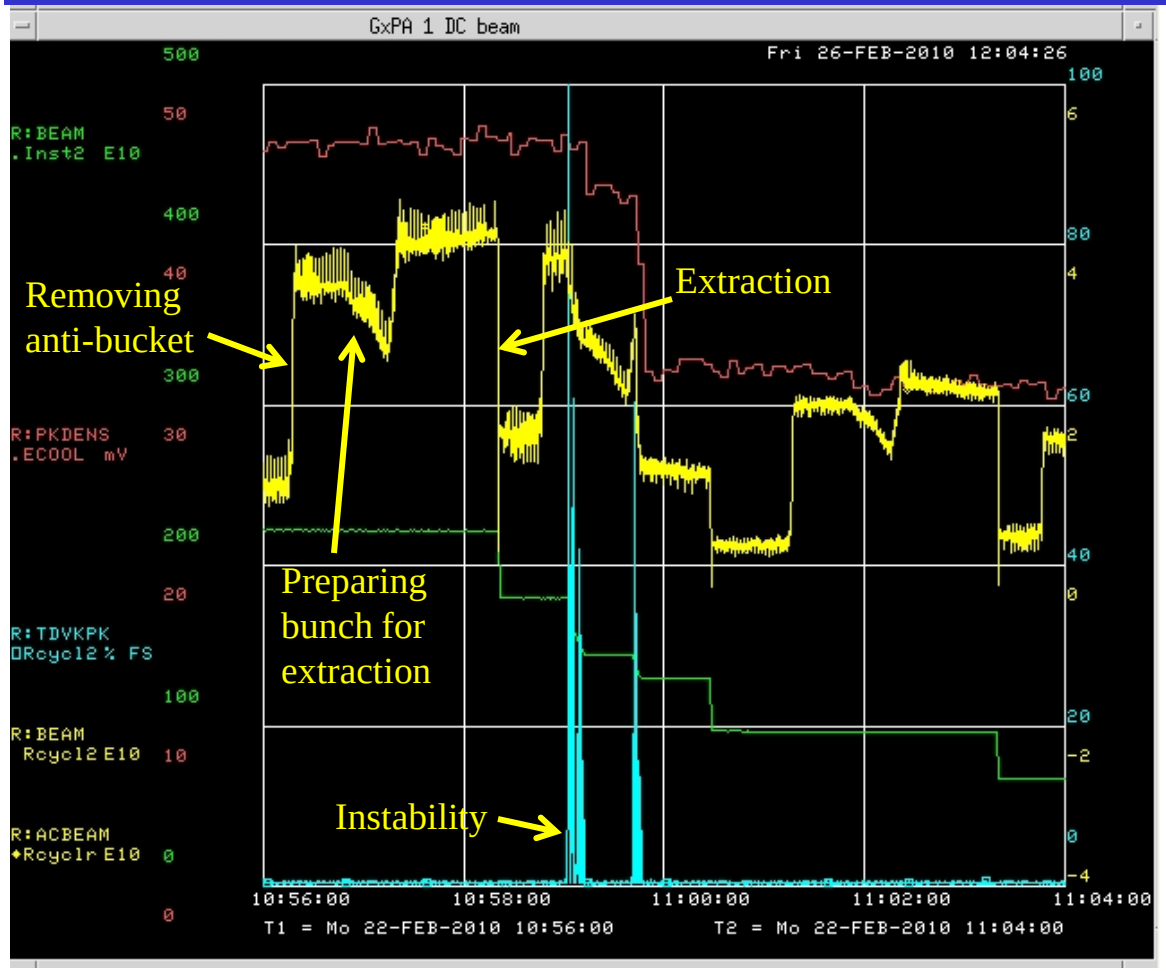


Comparison of effective RF potentials for cases of mined buckets (top) and the "soft-mining" emulation study (middle). The red line represents "velocity" dS/dt of a pbar not captured into the bucket. Numerically for RR:

	dS/dt [μs/s]≈dE[MeV]
Depth of the standard bucket	17 MeV
Depth of the mini-bucket	8.5 MeV
One turn	11 μs

- When most of the revolution period is free of RF, tail (DC) pbars spend most of their time outside of the bucket
  - Interaction with the core decreases, and efficiency of Landau damping drops

Pattern of when instabilities occur



Instability during extraction for shot #7629. 22-Feb-2010.

Green – number of pbars, 100E10/box;

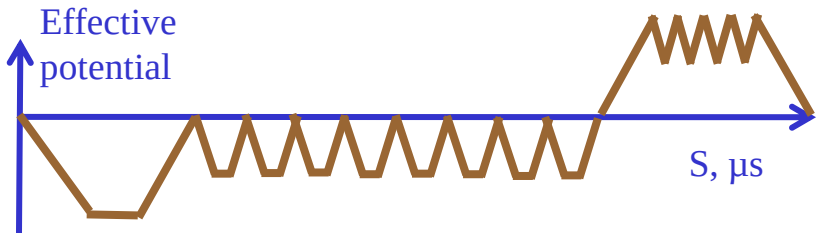
Blue – damper kick, % of full;

Yellow – DC beam, 2E10/box;

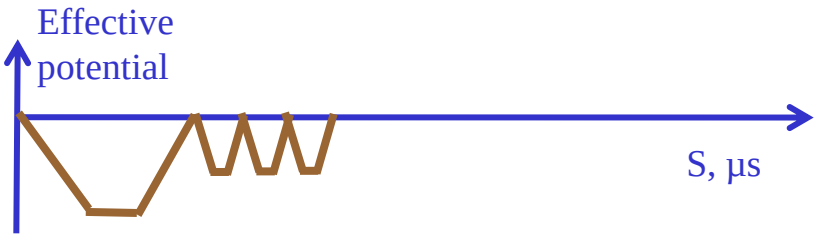
Red – longitudinal density, a.u.

- All instabilities during extractions occurred
  - After 5th or 6th bunch having been transferred
  - In the extraction cycle, after dropping the "anti-bucket"

Possible correlation with tail distribution



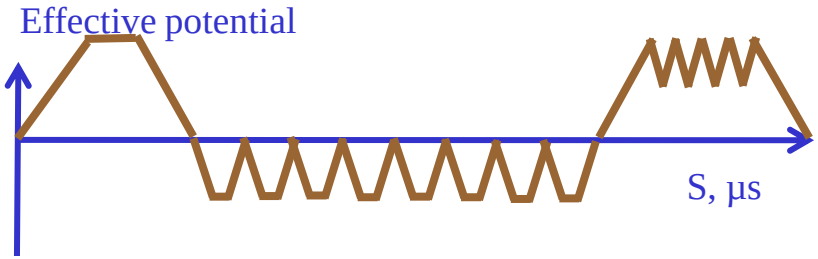
State before 1st extraction: tail particles stay primarily near the core.



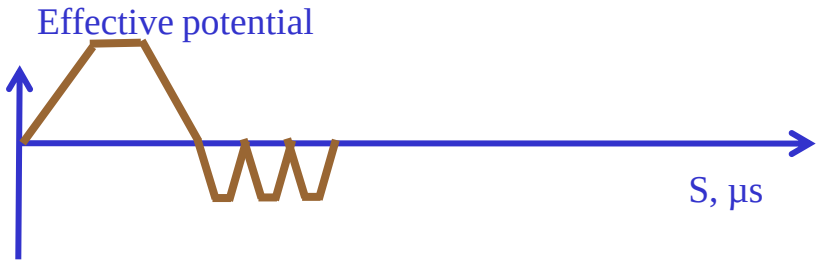
State after 6th extraction and dropping the "anti-bucket": tail particles are primarily far from the core.

- The larger portion of the turn being free of RF makes the beam more susceptible for an instability

Proposal: replace the "hot bucket" by "anti-bucket"



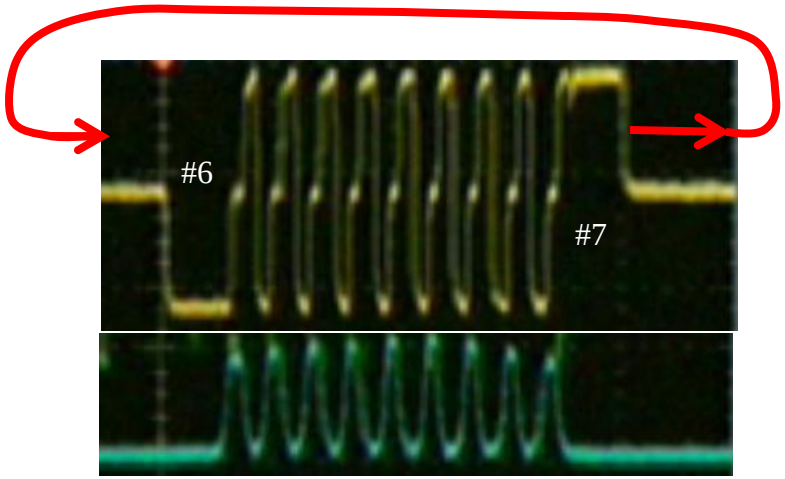
Con:
In the extraction configuration, the phase space for hot particles is lower . The beam loss during extraction may increase.



Pro:
In the configuration between extractions (the most dangerous one for instabilities), the number of tail particles effectively interacting with the core is significantly higher.

- Eliminating the "hot bucket" should significantly improve the beam stability.
- Possible side benefits:
  - No pbars in the area of kicker tail; mining efficiency should increase
- If the amount of DC beam in RR stays as low as now, an increase of the loss during extraction may be negligible.

Possible mechanics



- After mining, stay for 2 min for e-cooling at 0.8 mm
- Instead of moving #6, move barrier #7 to the right until it is side-by-side with #6
  - Because it is in a beam-free region, it shouldn't affect pbars
- Move the first bunch into the extraction position and proceed as usual
- After extraction, compress the bunch to the standard 308 bckts and continue as usual
- Chandra thinks it's doable

Summary

- Recycler operates at the stability boundary to provide the brightest beams to MI
  - Improves MI efficiency (coalescing)
  - Keeping the best possible conditions for stability is important
- Elimination of the "hot bucket" may improve the pbar beam stability without affecting significantly the transfer efficiency
  - Some side benefits are possible
- Chandra is looking at an implementation of this configuration
  - First, as a test
- We need to try it
  - A success would be to have the same transfer and coalescing efficiency
    - With a hope that the stability would improve
  - In this case, practical implications should be discussed
    - How to deal with partial mining?
    - Are the height and width of mining barriers optimal?