Overview of Electron Cooling Scenario, Commissioning Plan and Schedule

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Beam Cooling in the Recycler

The missions for cooling systems in the Recycler are (were):

- The multiple Coulomb scattering (IBS and residual gas) and other diffusion mechanisms need to be neutralized.
- The momentum spread of stacked antiprotons needs to be reduced between transfers from the Accumulator to the Recycler.
- Transverse and longitudinal emittances of the recycled antiprotons need to be reduced by roughly 1/e in the 8-10 hour store length. (Presently not part of the mission; May be in the future)
- Recently added: the effects of the Main Injector ramping need to be neutralized.

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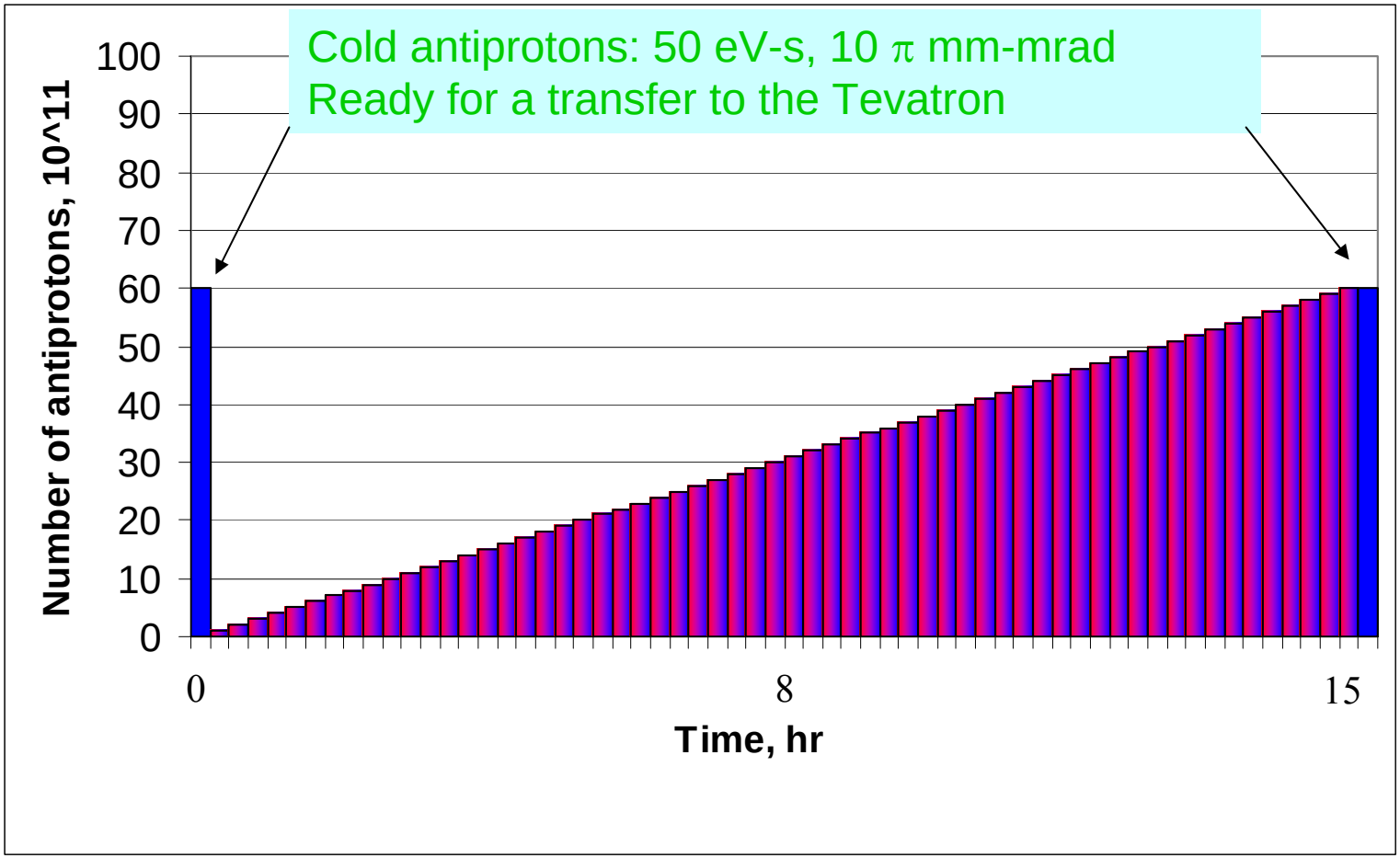
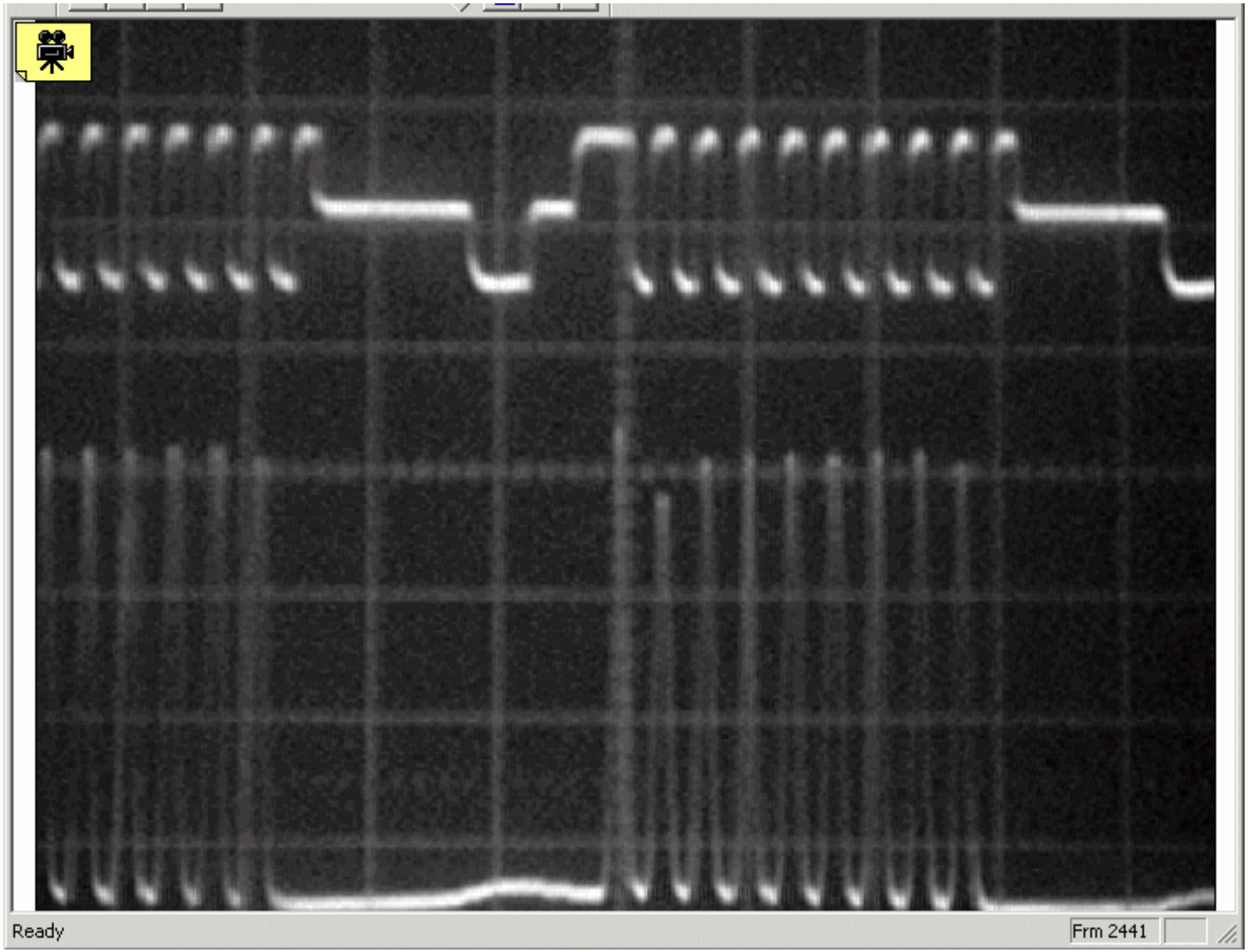
Recycler stack evolution



At present, the max. number of stored pbars is 15e11

Prepare 9 (6 eV-s each) bunches for extraction

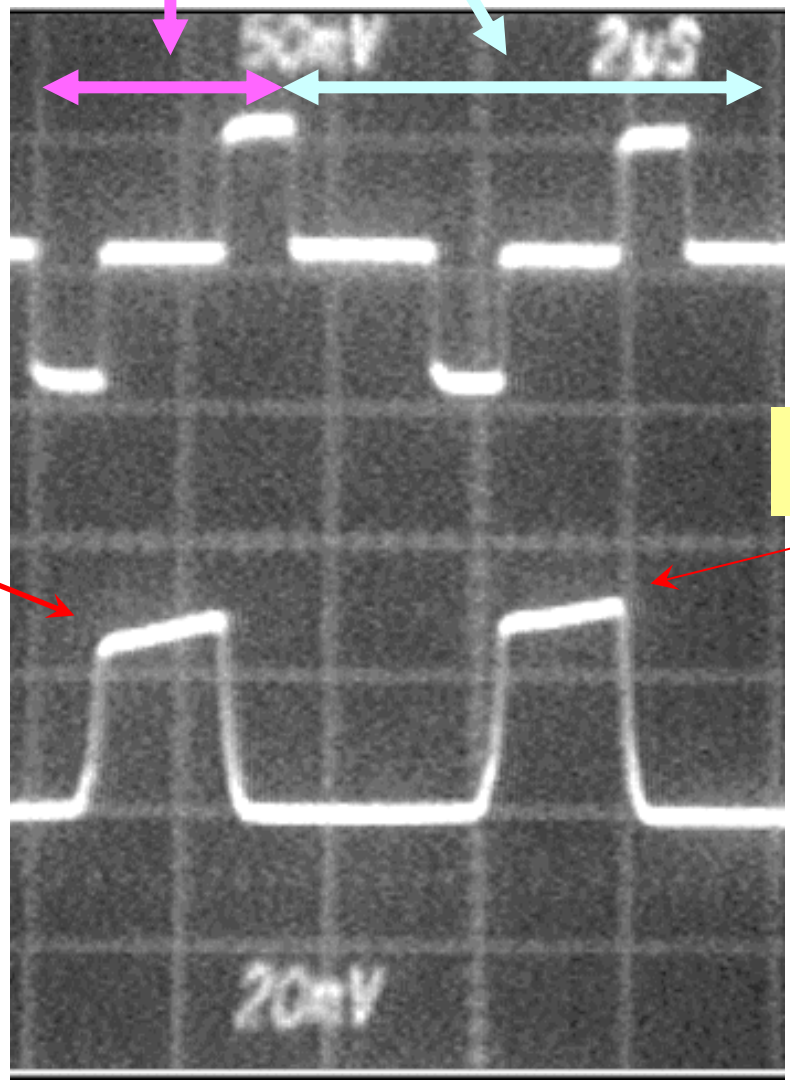


Recycler transfers with gated cooling

- Every 30 min, a new batch of 22E10 pbars (15-π mm-mrad, 15 eV-s) arrive from the Accumulator and is kept separately for 25 minutes.
- During 25 min, the batch is pre-cooled by gated ⊥ SC. The ⊥ emittances are cooled from 15 to below 10 π mm-mrad. The longitudinal emittance is kept unchanged.
- After that, the stack of 50 eV-s, 7-π mm mrad is merged with a 15-eVs, 10-π mm mrad batch. Now the electron cooling is applied. After 30 min, the || phase space is cooled from 65 to 50 eVs, making it ready for the next merge.

Recycler transfers with gated cooling

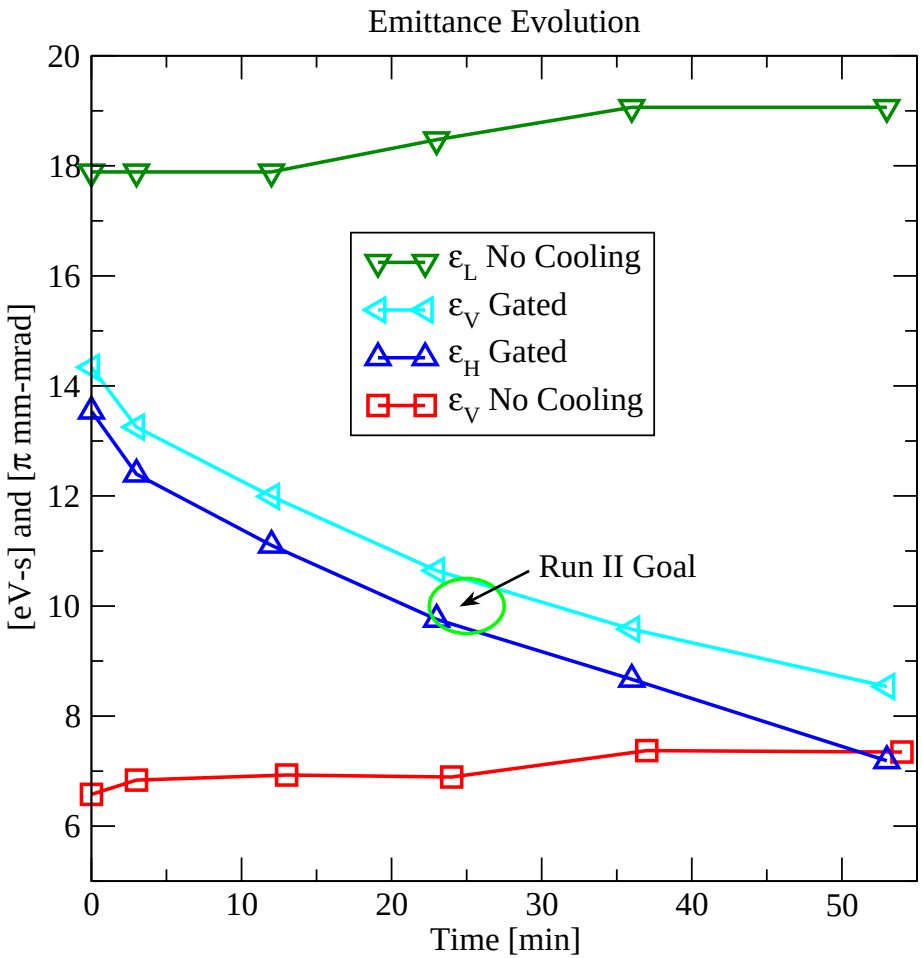
Gated cooling: ON OFF



New batch

Cold Stack

Gated Cooling

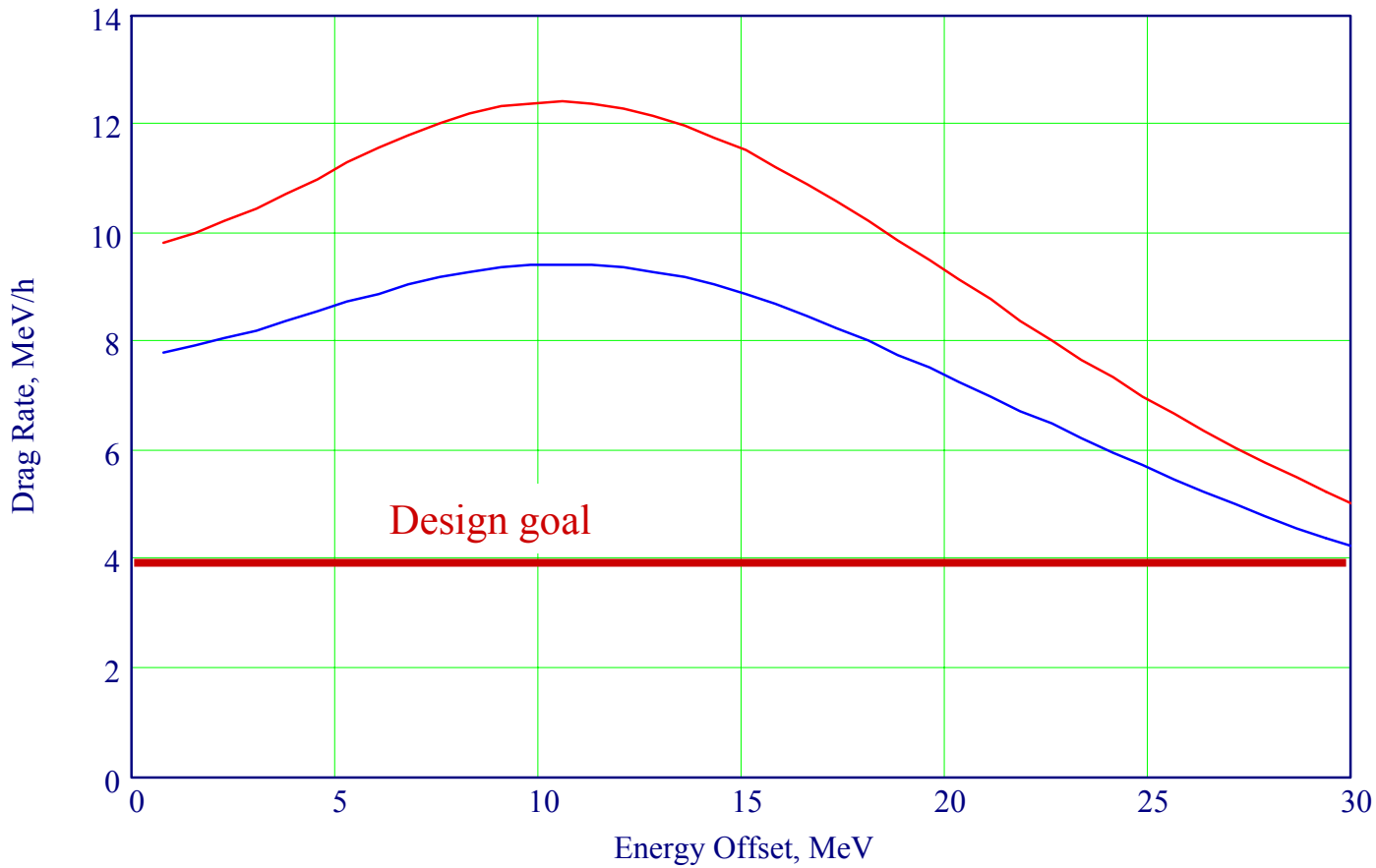


Two segments of beam (25e10 pbars each): one cooled/gated and one not. The uncooled bunch shows natural emittance growth due to IBS and coulomb scattering.

Electron Cooling: Long. Rate Design Goal

- Cooling needed: 30 eV-s per hour
- To minimize the IBS rate, a 65-eV-s stack will be kept in a 4-μs long bunch; 95% of particles will have its energy offset ≤8 MeV.
- For particles with $\Delta E \approx 8$ MeV the drag rate needs to be about 4 MeV/hr to cool 15 eV-s in 30 minutes.

Calculated long. drag rates

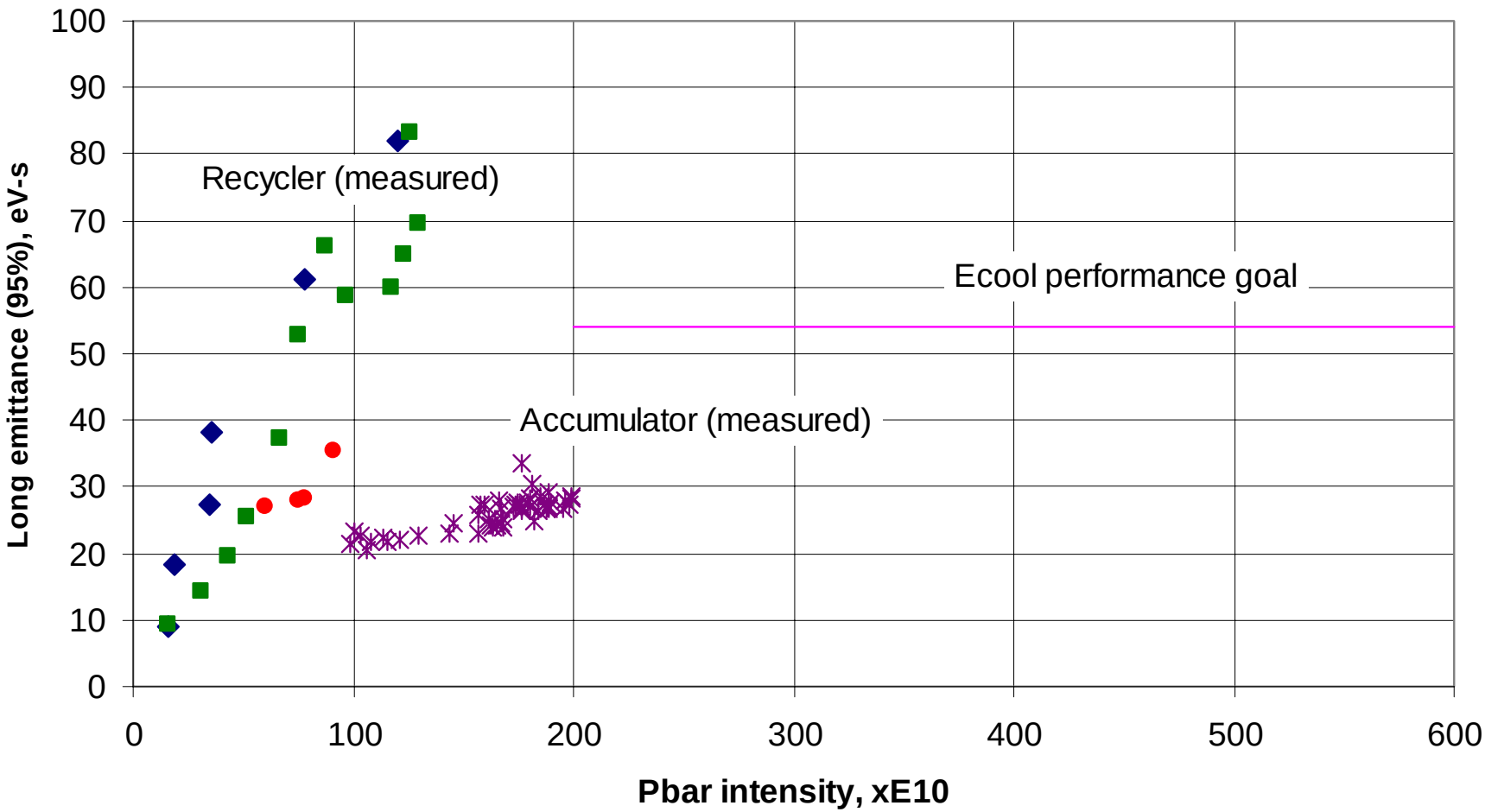


The electron beam current is 0.5 A, the effective electron 1-D angular spread is 0.2 mrad. The pbar emittance, used in these calculations, is 10 μm (95%, n). The curves correspond to a particle with both transverse actions having rms values (upper) and a particle with one action being rms and another action being twice the rms (lower).

Equilibrium long. emittance

- For a nearly constant drag rate $F_0 \approx 4$ MeV/hr the equilibrium energy distribution is not gaussian but exponential: $f(E) \sim \exp(-|E|/\sigma)$, where $\sigma = D/(2F_0)$ and D is the diffusion rate.
- The diffusion rate is mostly determined by the intra-beam scattering
- All our experience with the stochastic cooling system in Recycler to date is consistent with the IBS being the second (after new batch injection) largest longitudinal heating mechanism.

Summary of longitudinal emittances



Summary

- The performance goals for the electron cooling commissioning project are:
  - Drag rate: at least 4 MeV/hr for particles with an 8-MeV energy offset
  - Equilibrium pbar beam emittance: 54 eV-s, 7-π mm-mrad

Ecool and Recycler Design Parameters

Parameter	Design Value	Achieved (best)	Units
Electron Beam			
Terminal Voltage	4.34	3.5 (4.34)	MV
Beam Current	0.5	0.5 (0.7)	A
Terminal Voltage Ripple, rms	500	500	V
Electron Angular Spread, rms	0.2*	≤0.3	mrad
Duty Factor (averaged over 8 h)	95	99 {12-h run}	%
Recycler Ring			
Lifetime (zero-emittance beam)	150	500	hours
Emittance growth rate (n, 95%)	3	≤3	π mm-mrad
Gated cooling of 20e10 pbars, 15 to 10 π mm-mrad	25	25	minutes
Transfer efficiency, MI-RR	85	90	%

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- The Recycler is brought up to its present level through a known and well-documented process
- The Recycler never stops contributing to the HEP luminosity, it just becomes more efficient over about 10-months period.
- The electron cooling beam is commissioned through a series of well-defined incremental steps.
- We assume that there is no lab-wide shutdown until Sep 2005.
- We have no schedule contingency in our plan – everything has to work just right.

Milestones

- All e-cool systems are ready for commissioning 02/01/05
- U-bend commissioned 03/14/05
- Full beamline commissioned 04/04/05
- A 0.5 A DC beam 07/08/05
- Cooling of antiprotons 09/08/05