

# Recycling Tevatron Pbars: efficiency estimate update

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# Intro in History of R-ing

- **TM-1991 (1996) “Recycler TDR”**

Table 2.1.2: Parameters which describe the effect of recycling antiprotons on antiproton stacking and average luminosity during Run II. Comparisons are made with Run I operations (without both the Main Injector and the Recycler).

Parameter	Run I	MI only	Recycler
Store Duration $T_s$ (hr)	12	12	7
Injection Time $T_f$ (hr)	2.5	1	1
Antiprotons at End of Store	73%	65%	78%
Deceleration Efficiency	0%	0%	80%
Acceleration Efficiency	75%	90%	90%
Integrated Luminosity ( $\text{pb}^{-1}/\text{store}$ )	0.56	2.9	3.4
Required Usable Stack ( $10^{10}$ )	48	144	264
Antiprotons Recycled ( $10^{10}$ )	0	0	148
New Antiprotons Stacked ( $10^{10}$ )	48	144	116
Required Stacking Rate ( $10^{10}/\text{hr}$ )	4	12	17
Average Luminosity ( $\text{pb}^{-1}/\text{hr}$ )	0.04	0.21	0.43
Store Hours Needed to Achieve the Snowmass Criterion Between Integrated and Peak Luminosity	98 (typical)	101	93

– **logistics of recycling presented**

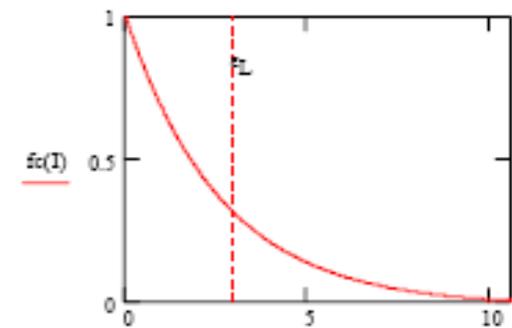
– **7hr stores, 10% stores lost, est effect ~2xL**

# Abandoning R-ing (2003)

- **AAC and DoE Reviews (V.Lebedev)**
  - based on detailed model, compared to 2002 experience

## Efficiency of the Antiproton Recycling

Transverse efficiency into 30 mm mrad acceptance, $\kappa_{tr}$	0.969
Longitudinal efficiency into 3 eV s acceptance, $\kappa_L$	0.727
Fraction of stores with successfully decelerated protons, $\kappa_{success}$	0.7
Fraction of antiprotons survived at the store end, $\kappa_{TeV}$	0.747
Total efficiency of pbar recycling, $\kappa_{TeV} \kappa_{success} \kappa_L \kappa_{tr}$	<b>0.368</b>



Dependence of the longitudinal distribution function on the action at the end of a store

- was considered to be “not worthy”:

The major technical obstacle to recycling is the removal of the protons prior to antiproton deceleration and extraction. This must be accomplished quickly (so as not to significantly add to shot setup time) and reliably, without risking Tevatron quenches or significant radiation dose for the experiment detectors. Initial studies have indicated that meeting these requirements is problematic, and would require substantial work and study time.

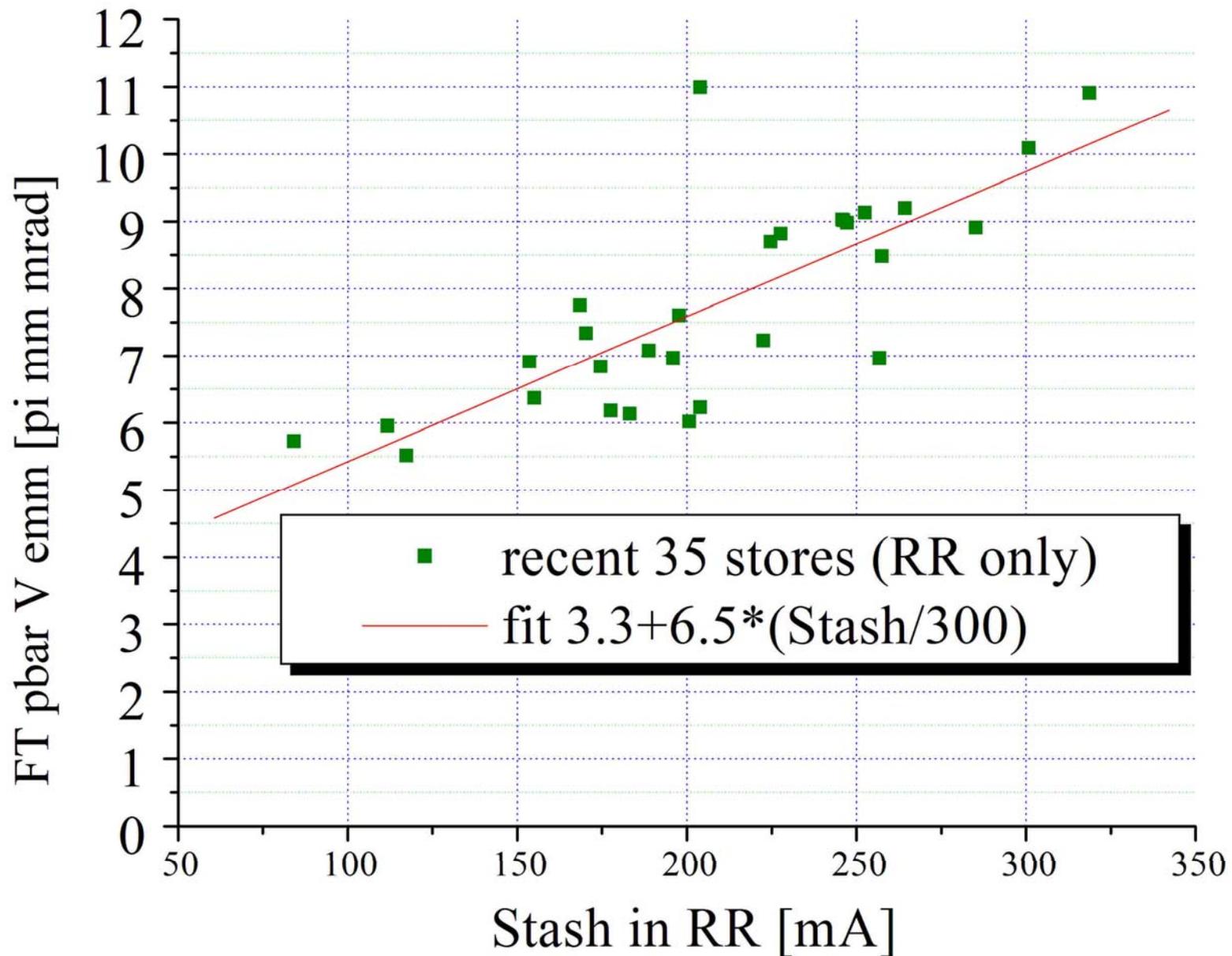
It has been decided that no work will be scheduled for recycling at this time. The

# Resurrecting R-ing (2005)

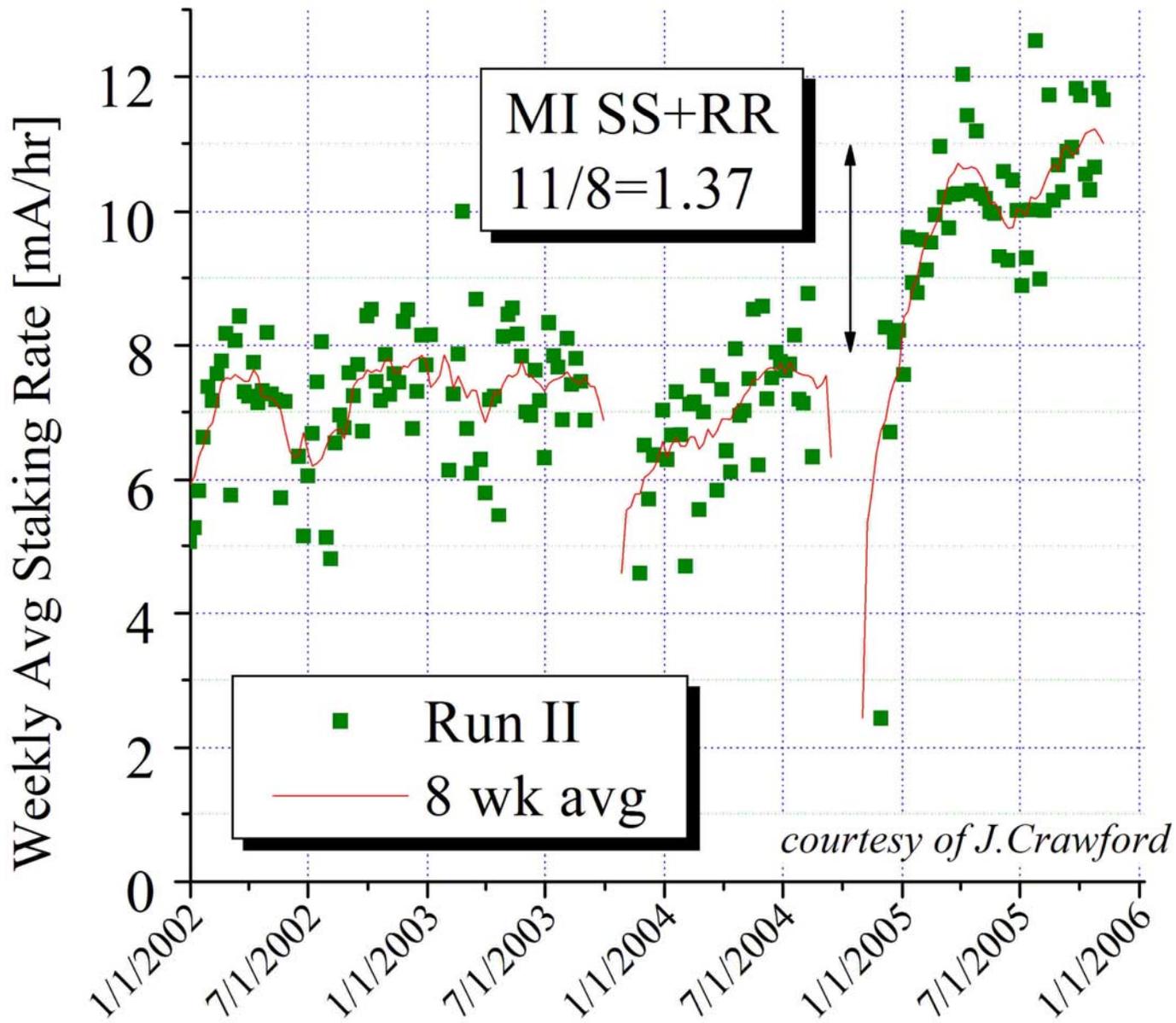
- **have things changed?**

- Valery's analysis redone by VS and ~confirmed
- reliability is up compared to 2002
- instead of beam dynamics models, data from HEP stores used (e.g no tails in  $f(l)$  found)
- **total r-ing efficiency ~30% is product of :**
  - **transverse acceptance**      **0.96 → 0.9**
  - **% stores survive**            **0.7 → 0.8**
  - **3eVs acceptance**            **0.73 → 0.85**
  - **fraction Na left**              **0.75 → 0.50**
- **gain of 15-25% is “worthy” nowadays:**
  - “pbar thirst” stronger: no 45mA/hr goal anymore
  - pbar production rate is in focus of Run II upgrades
  - progress is not as fast as expected

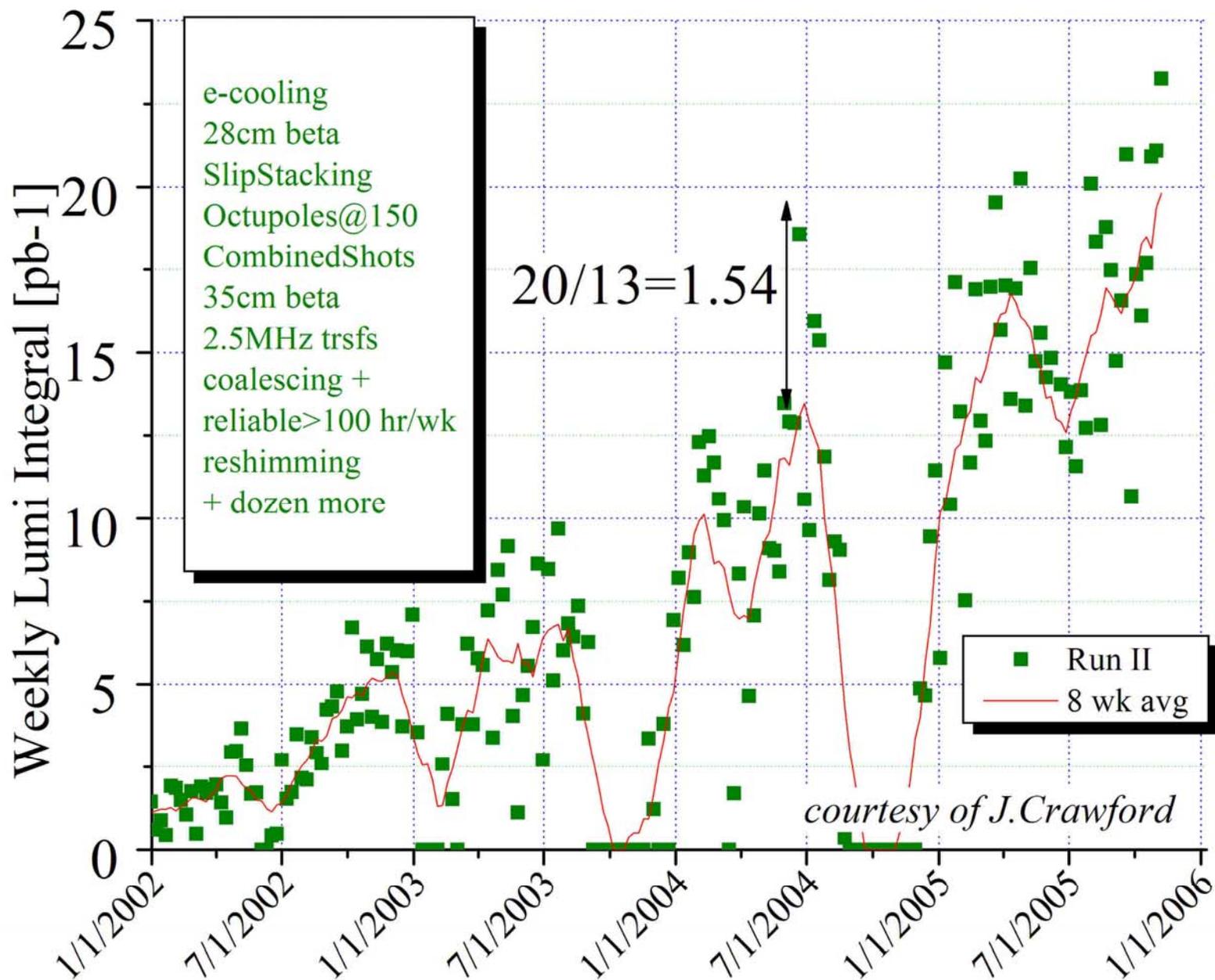
# Larger Emittances take some toll..



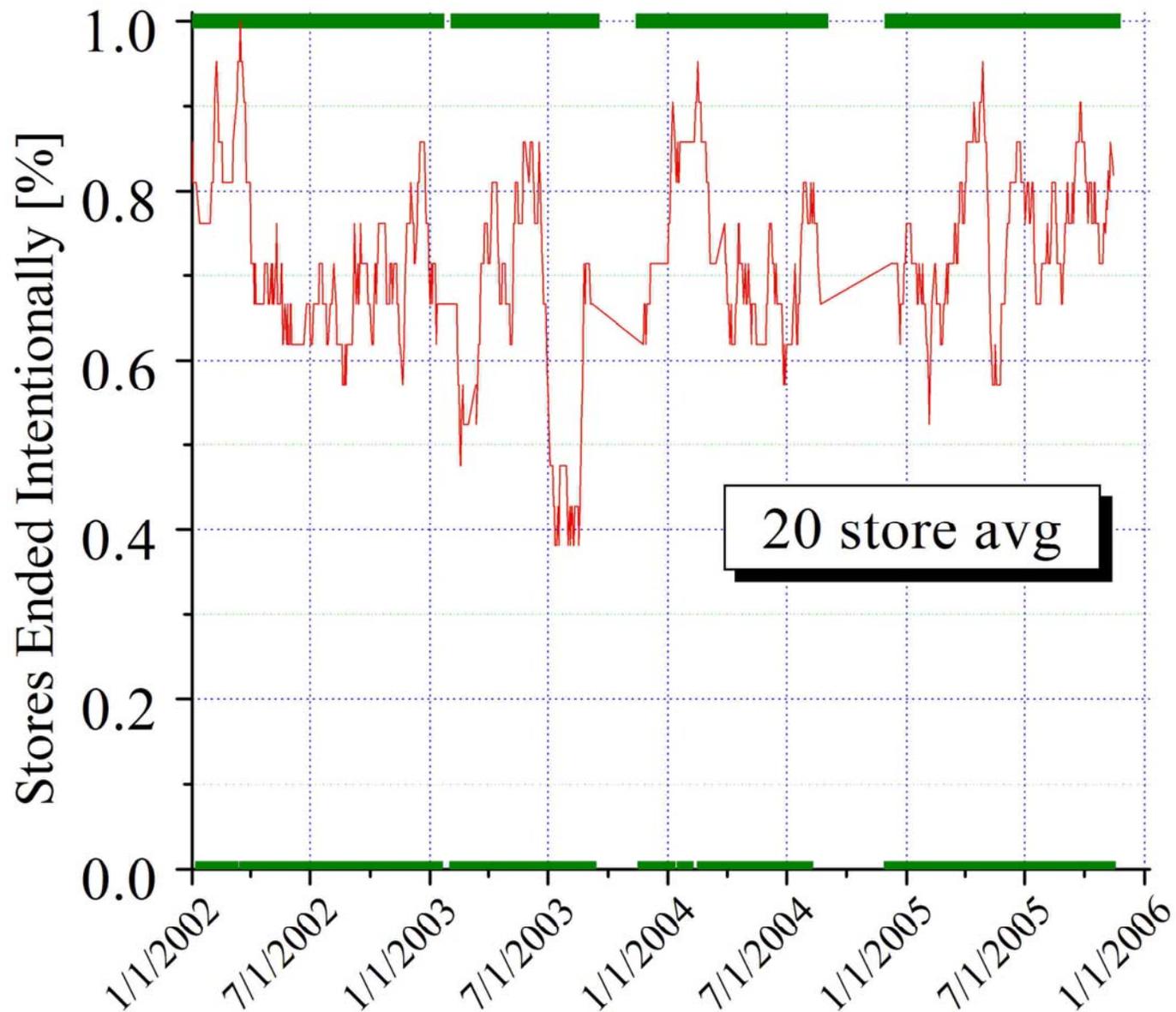
# Run II Pbar Production 2002-05



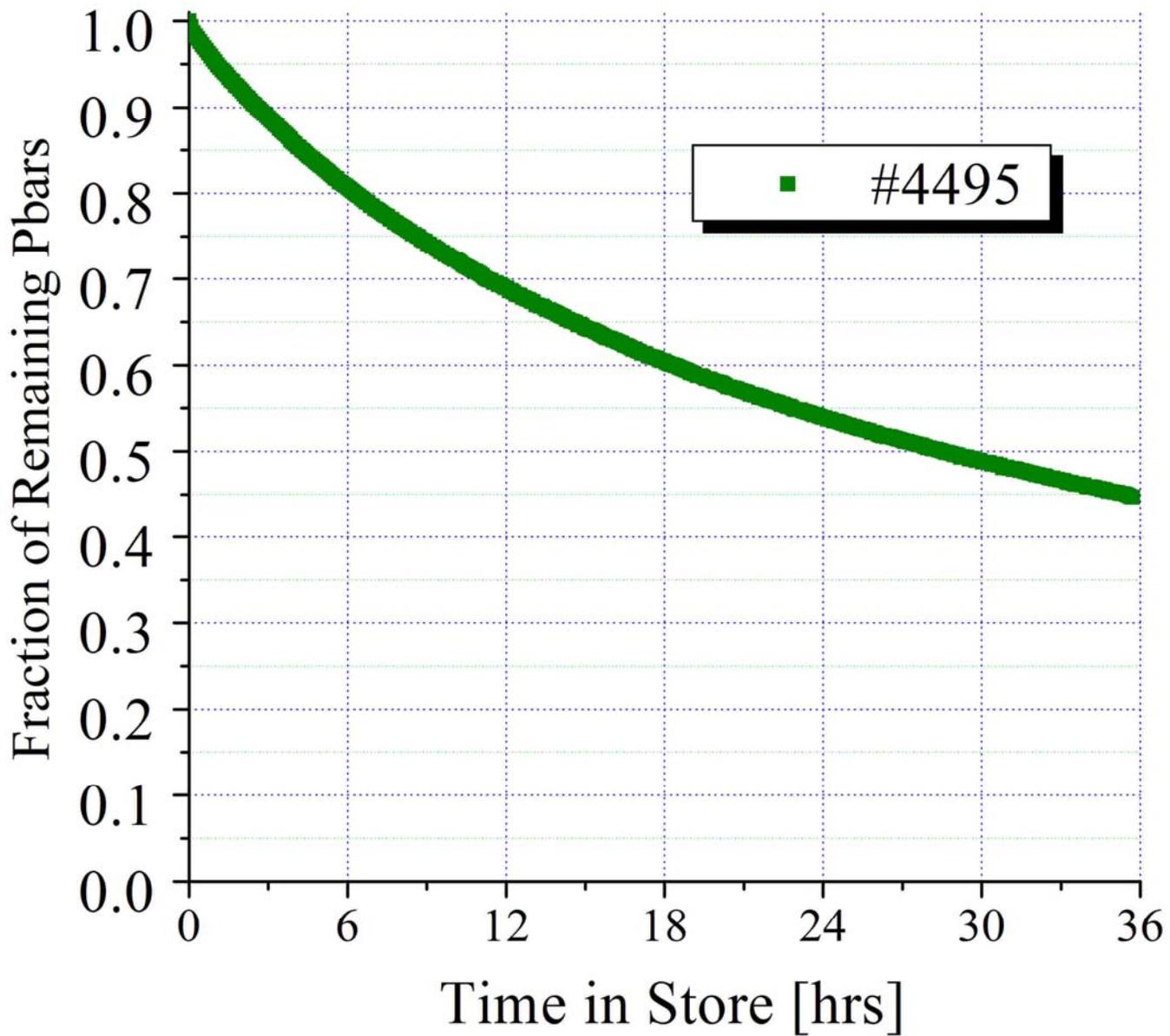
# ...and Integrated Luminosity



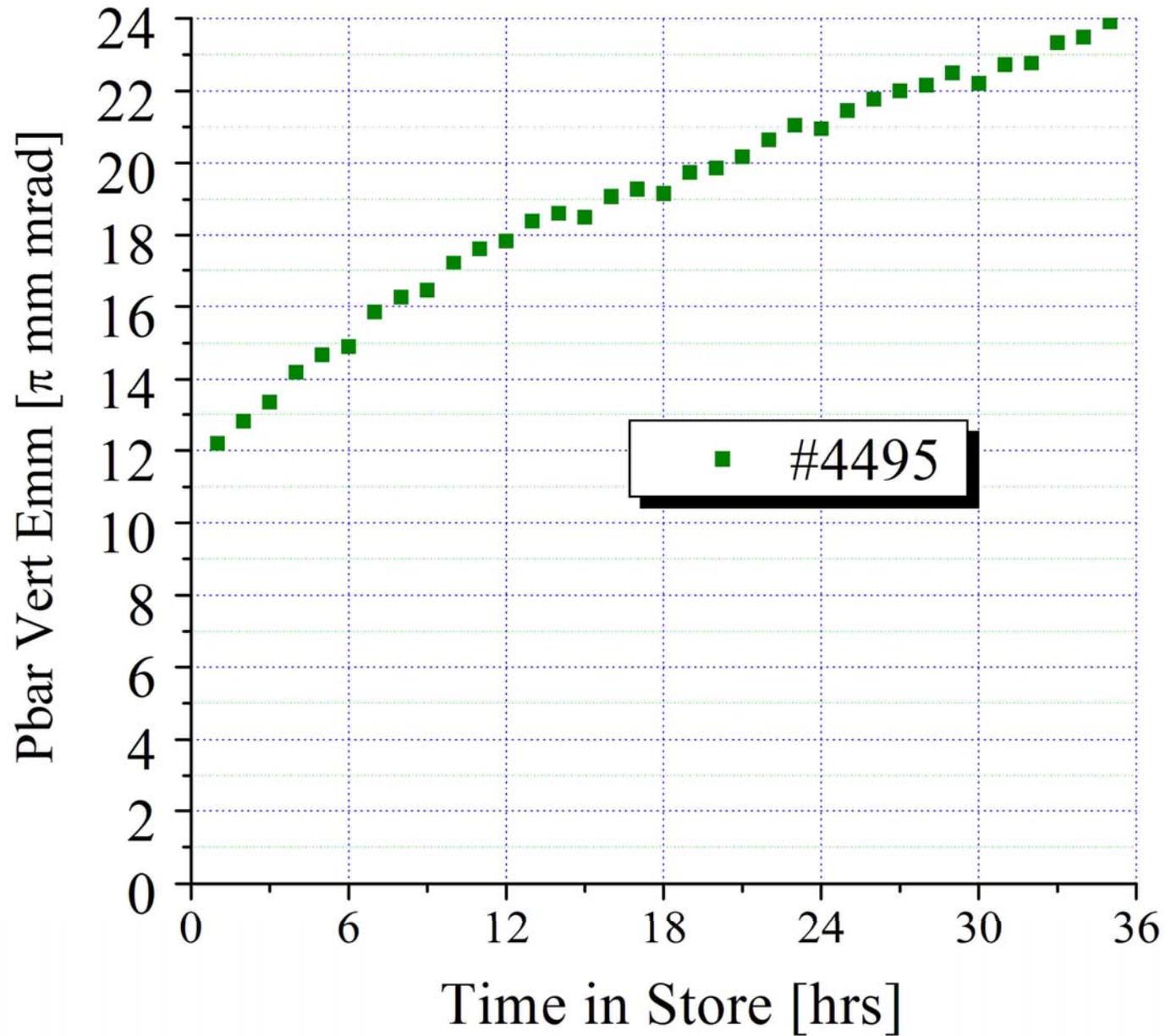
# Store Ending 2002-05



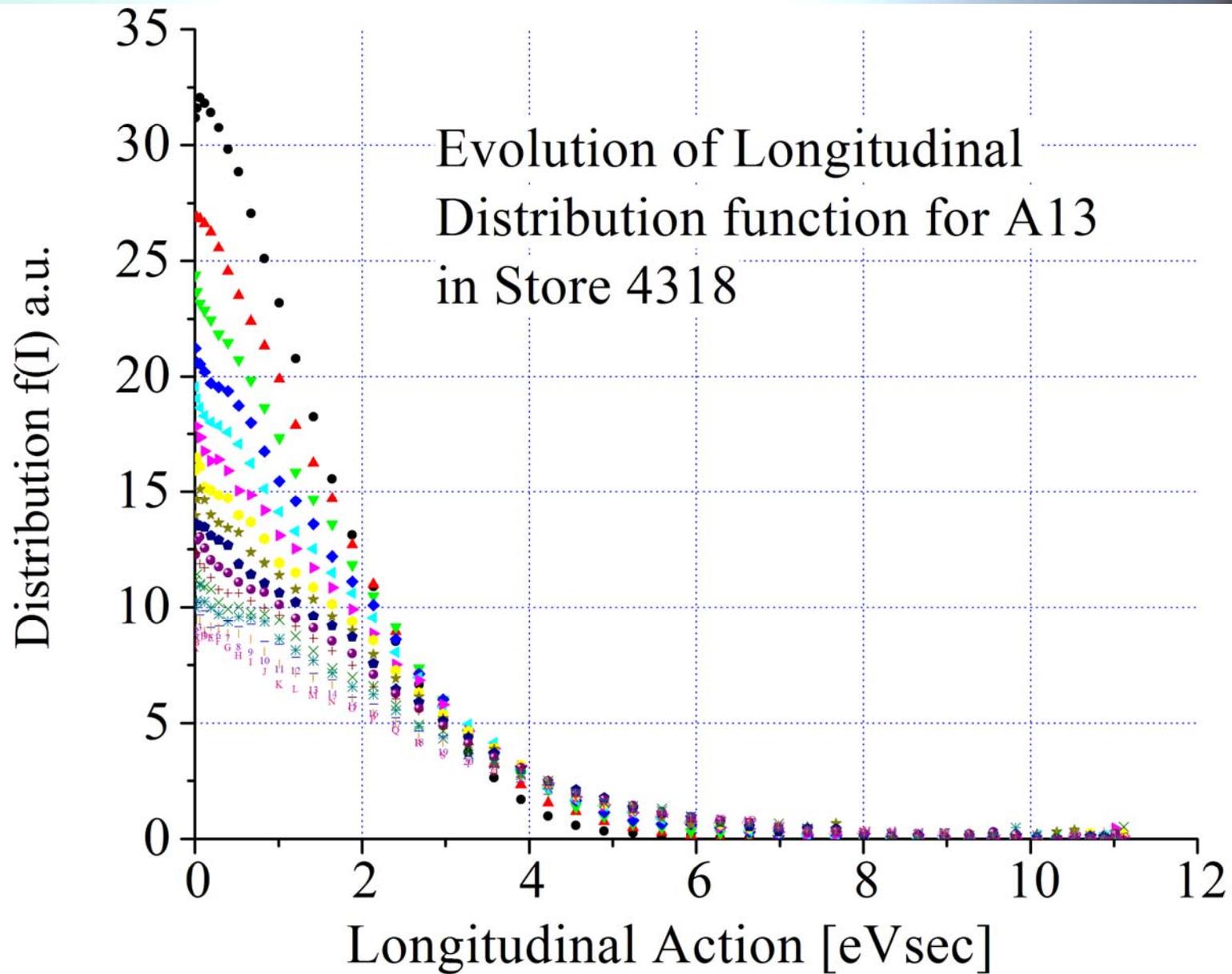
# Pbar Intensity in the Tevatron



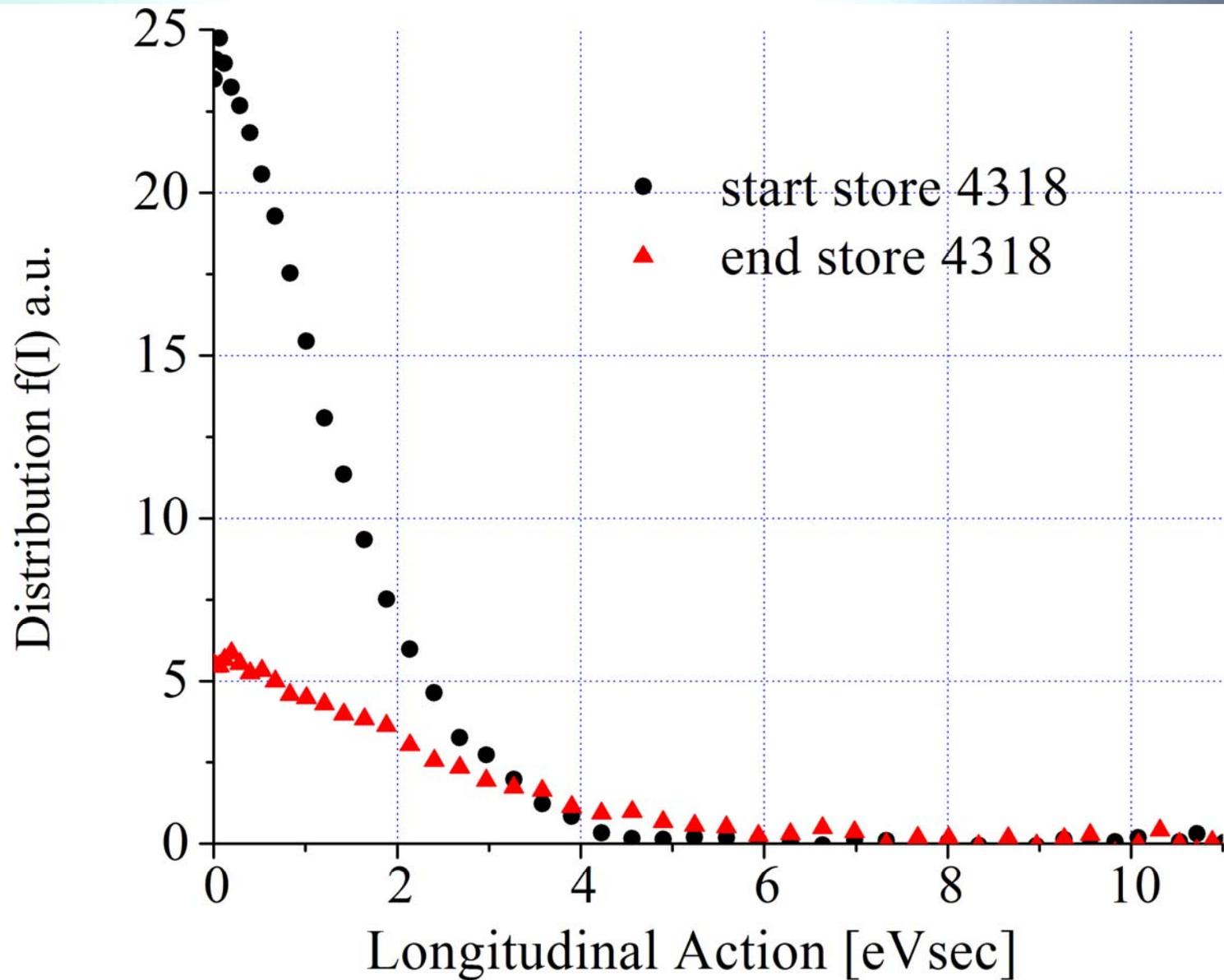
# Pbar Emittances in Store



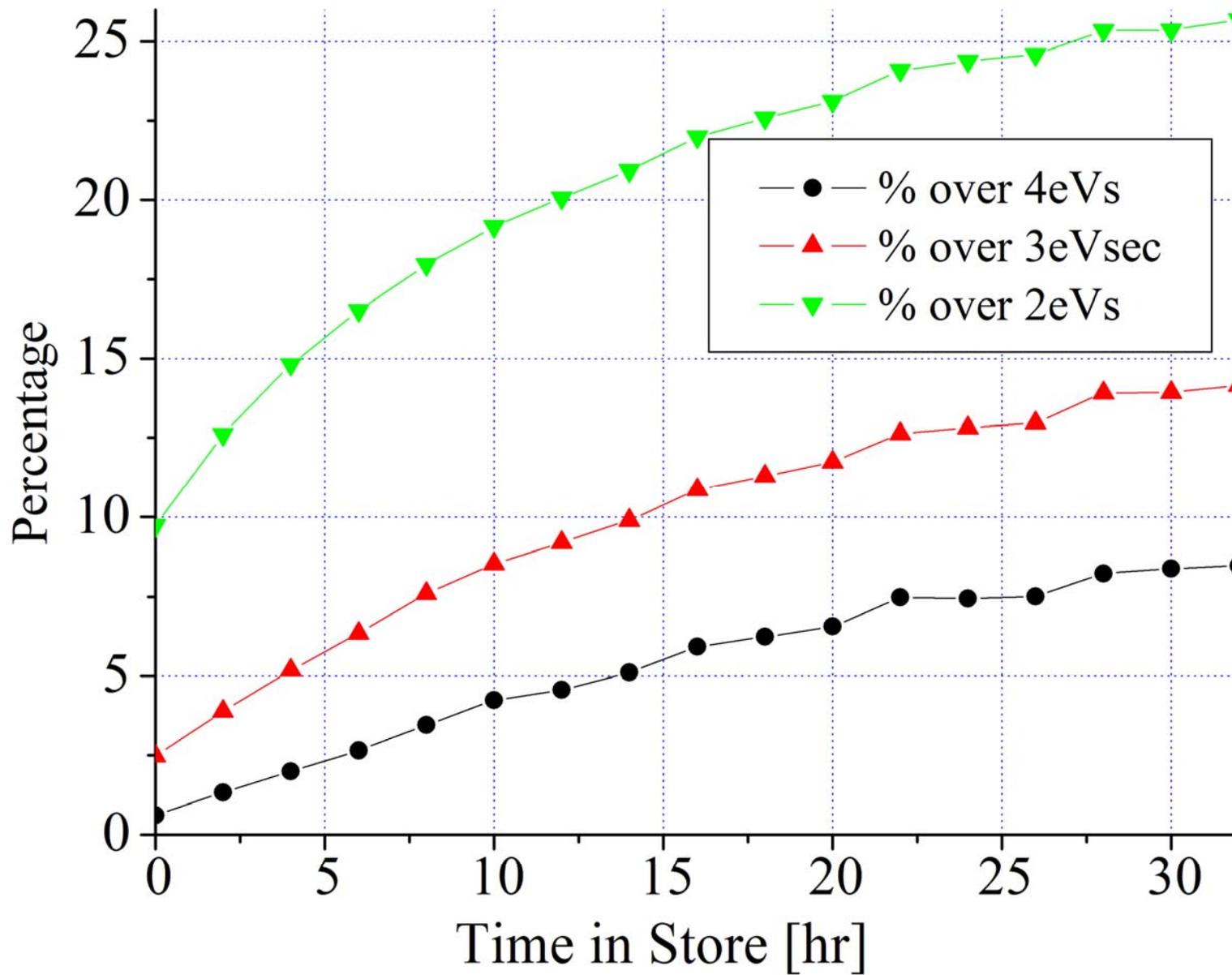
# Pbars in the Tevatron: Evolution



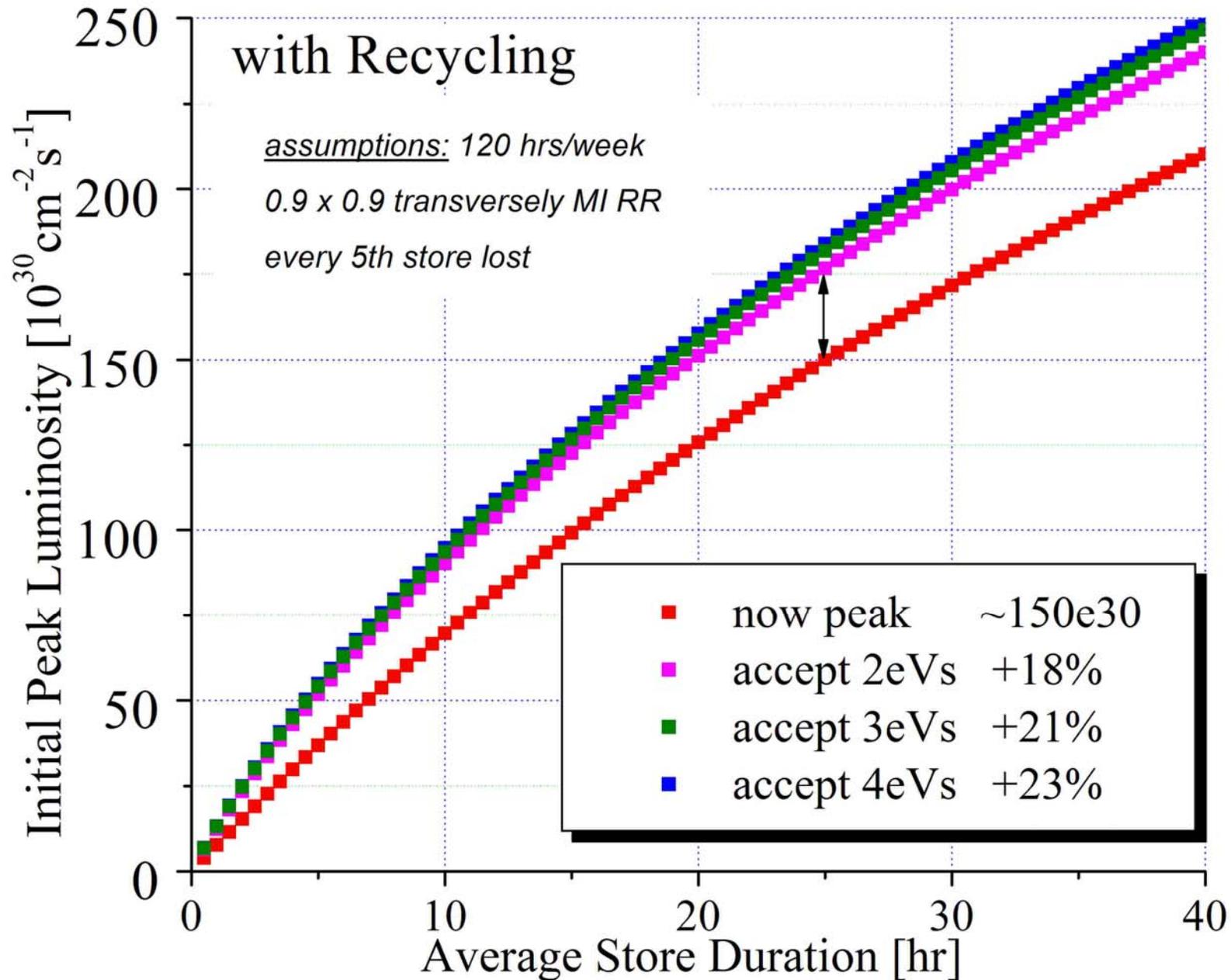
# Pbars in the Tevatron: EoS



# Pbars beyond acceptance in #4318



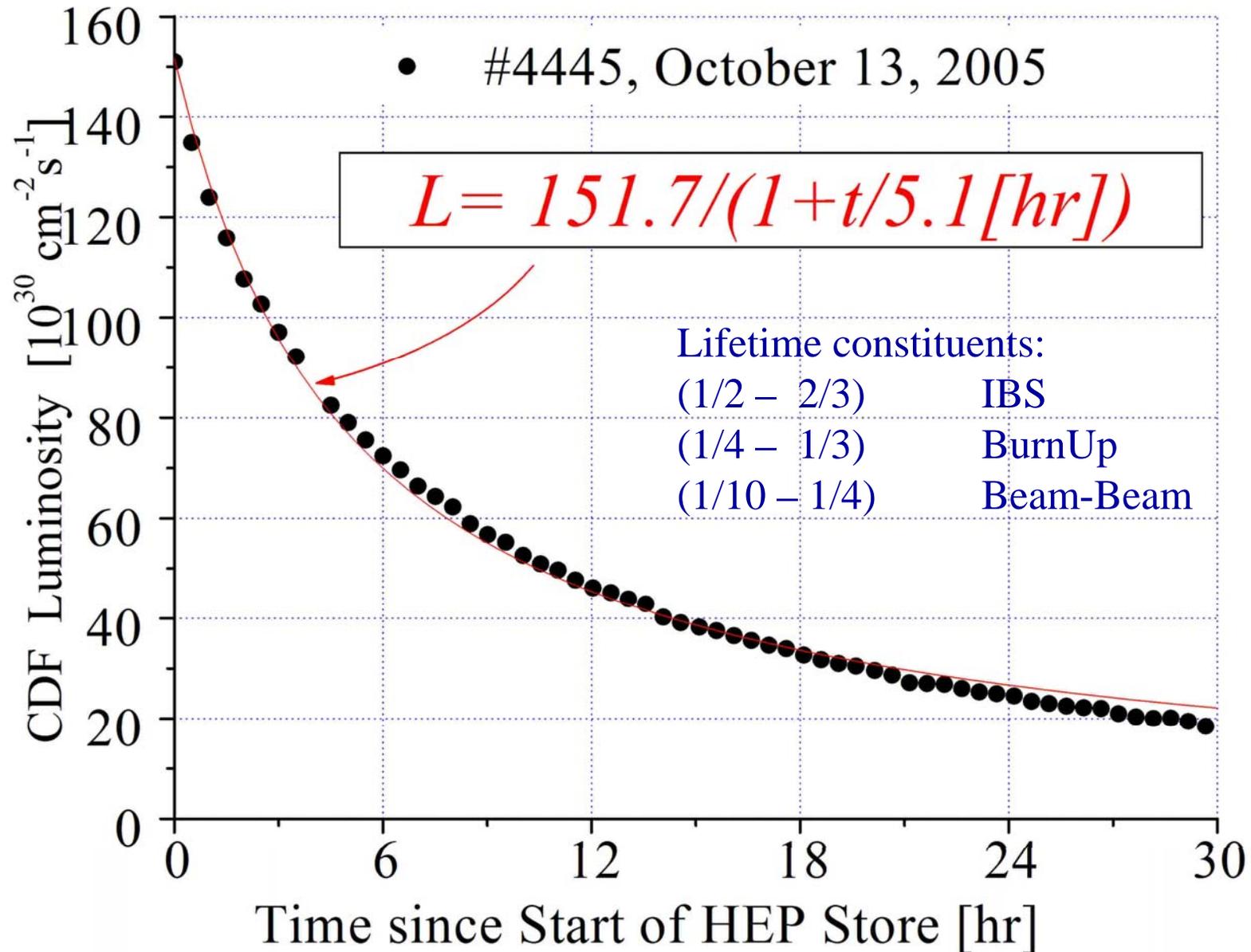
# Pbars beyond acceptance in #4318



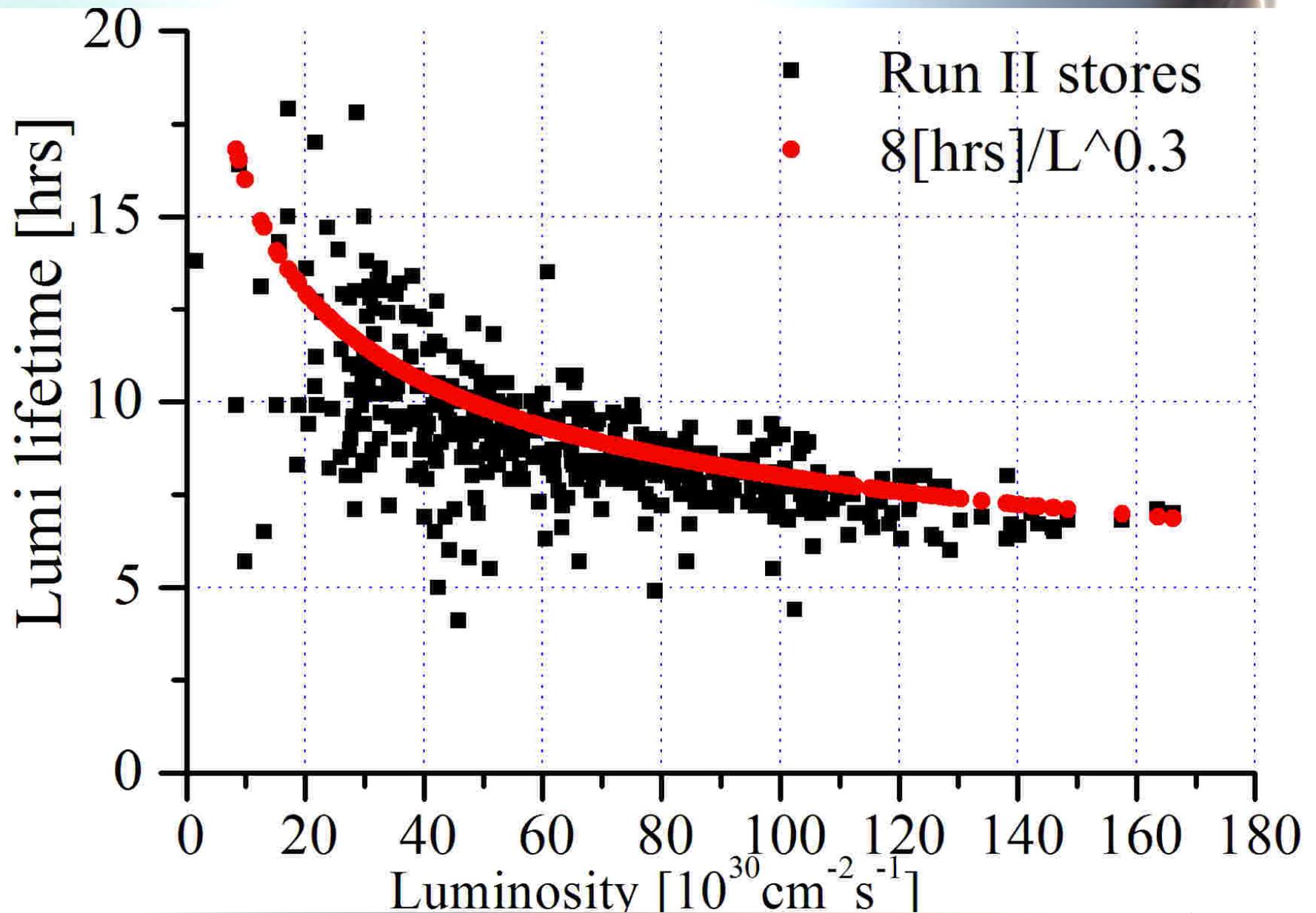
# Luminosity Integral

- **Integral depends on:**
  - **peak luminosity**
  - **store duration**
  - **luminosity lifetime**
  - **# hrs/week (reliability)**

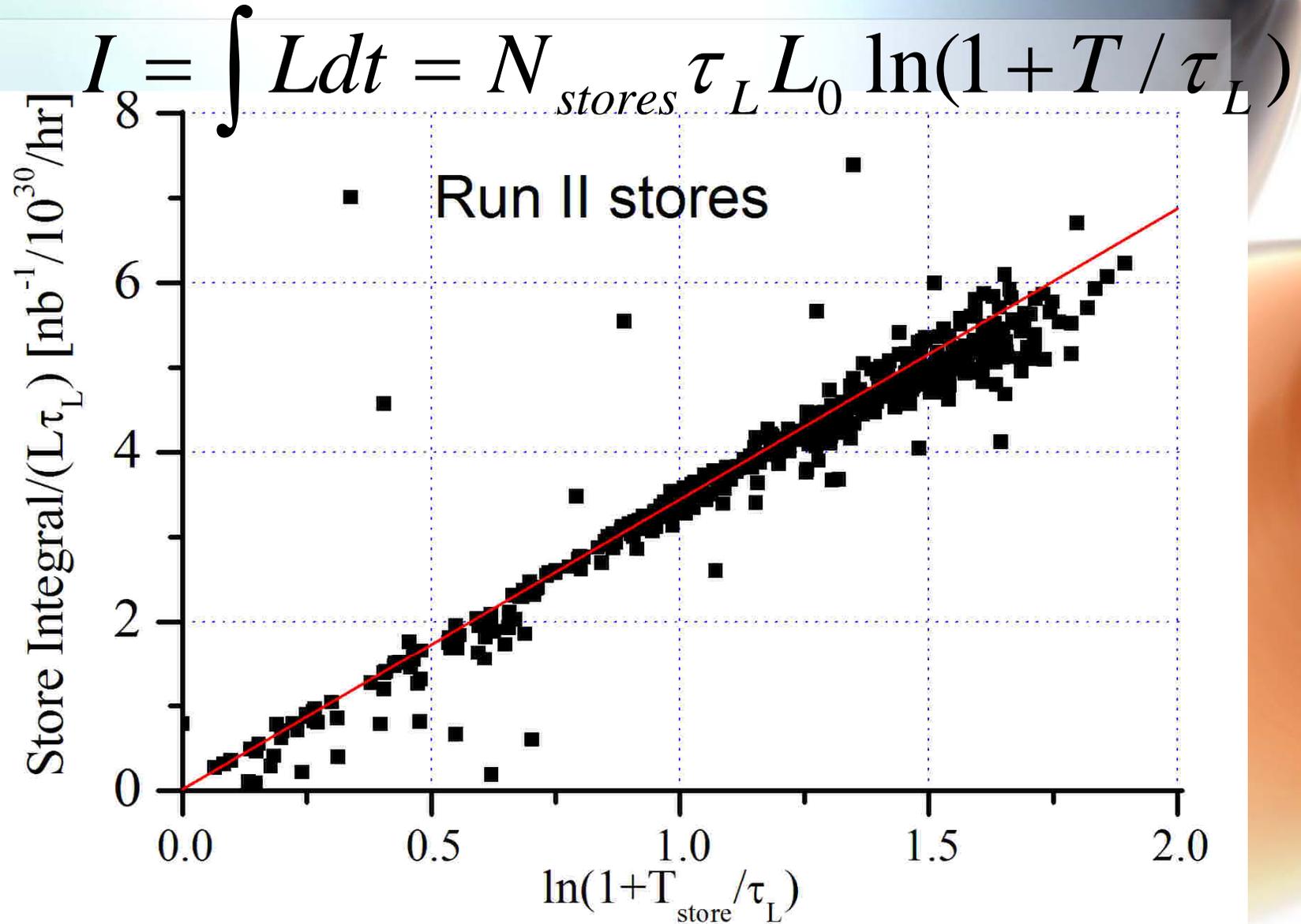
# Luminosity Decays $\sim 1/(1+Time/\tau)$



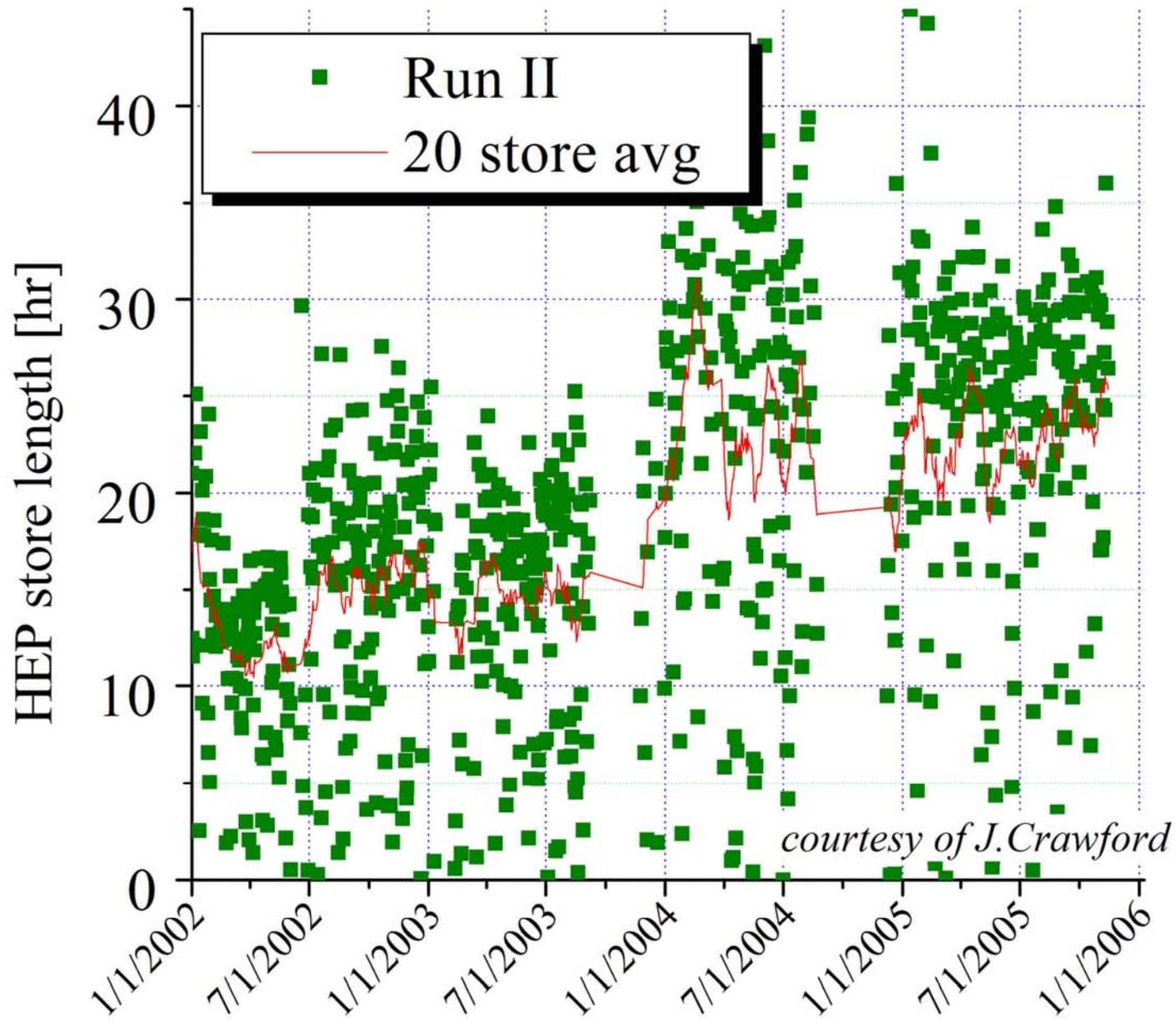
# Luminosity Lifetime vs Peak Lumi



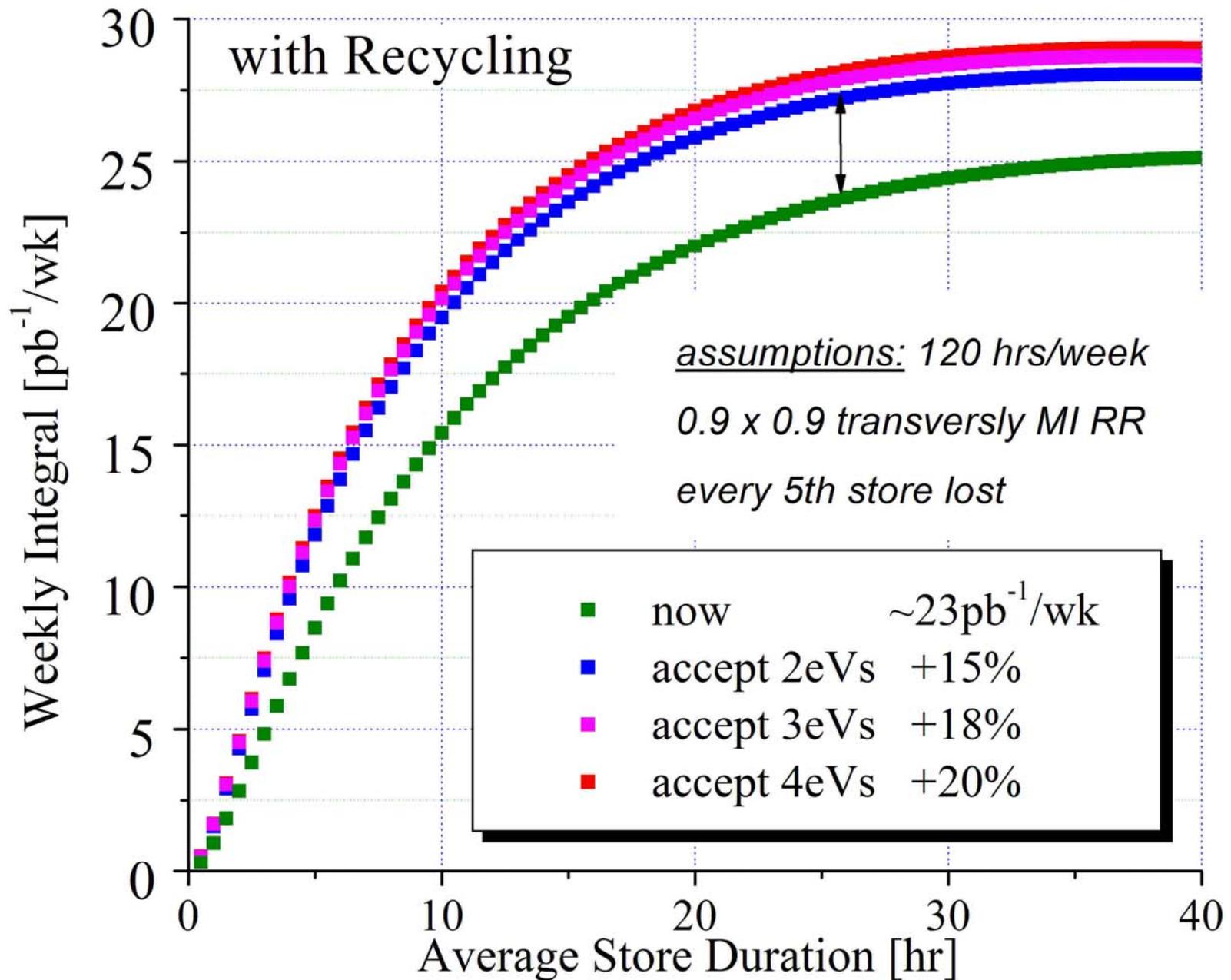
# Luminosity Integral Dependencies



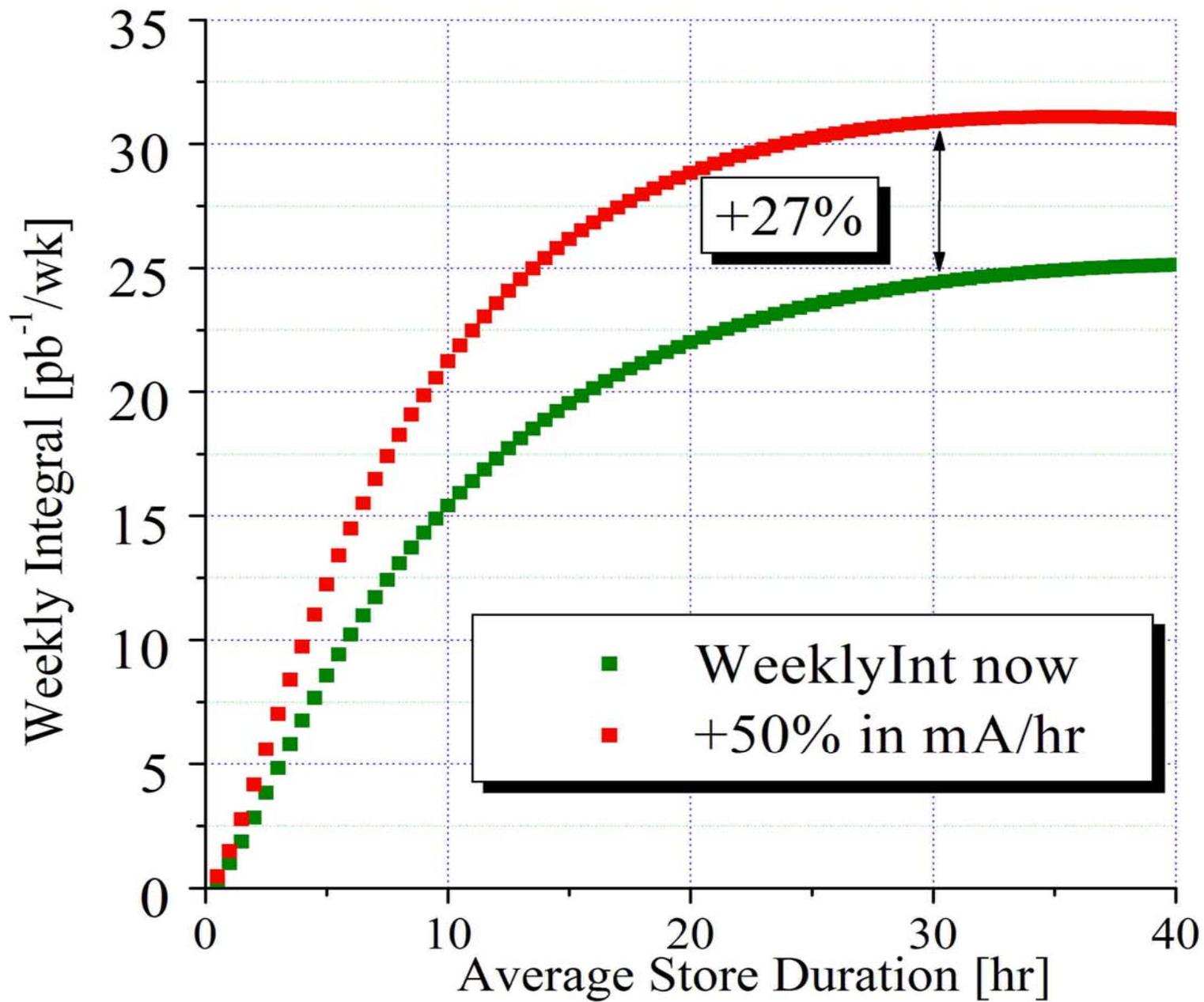
# Run II store lengths



# Recycling gives 15-20% in Integral



# Compare: 27% if Production's Up 50%



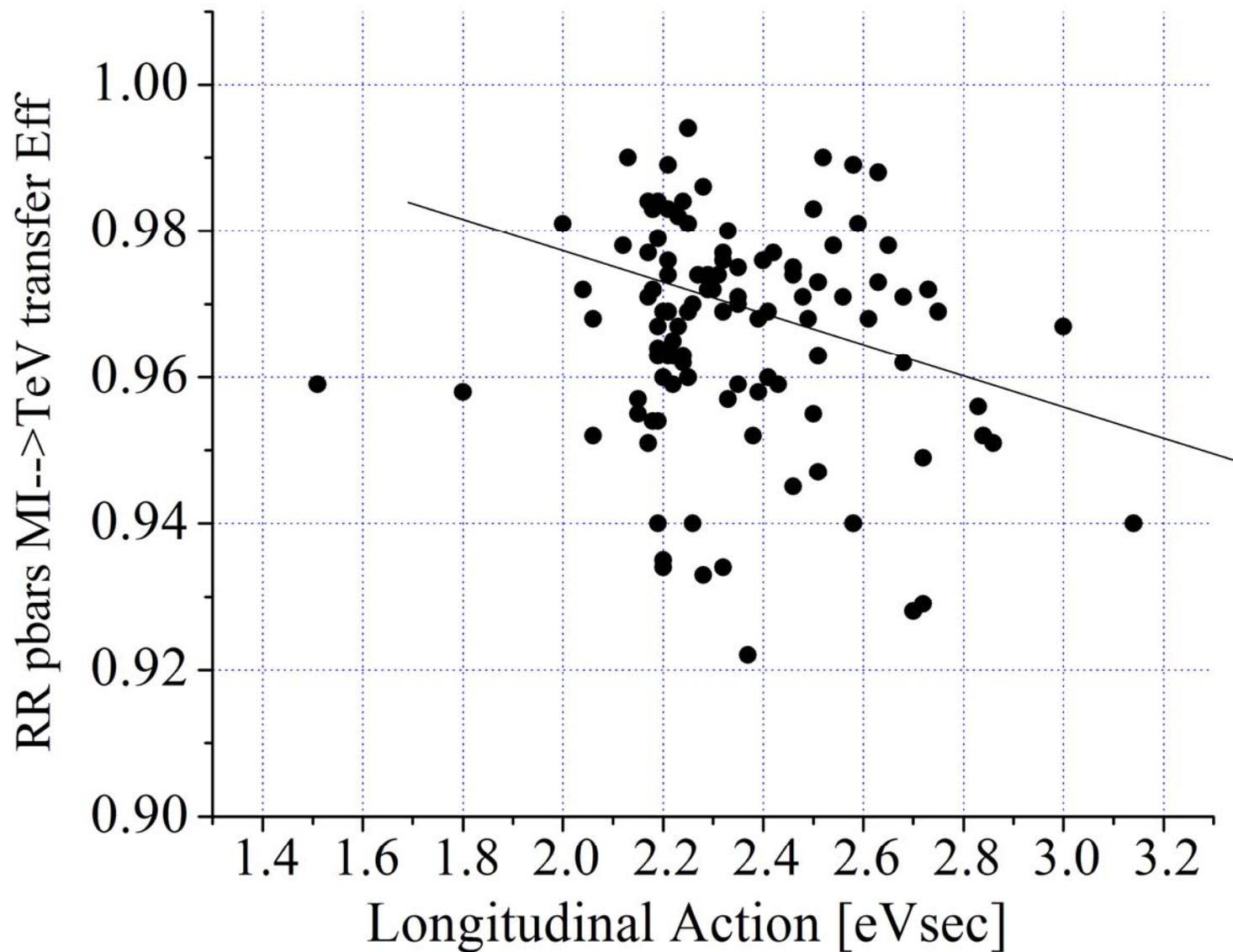
# Comments/Issues (1)

- **TM-1991 Recycling Efficiency estimates too optimistic:**
  - assumed very high production rates and short stores
- **Valery's estimates from 2002 confirmed by VS:**
  - 25-30% recycling efficiency possible for long stores
  - that gives 18-23% gain in peak luminosity
  - and 15-18%-25% gain in integrated luminosity
- **IBS in higher intensity pbar bunches will be about the same because of somewhat larger emittances**
- **Longitudinal emittance of 4..2eVs limits longitudinal efficiency to 0.90...0.73**
- **Transverse Emittances of about 20 pi limits transverse transfer efficiencies to 0.9x0.9 ~0.8**

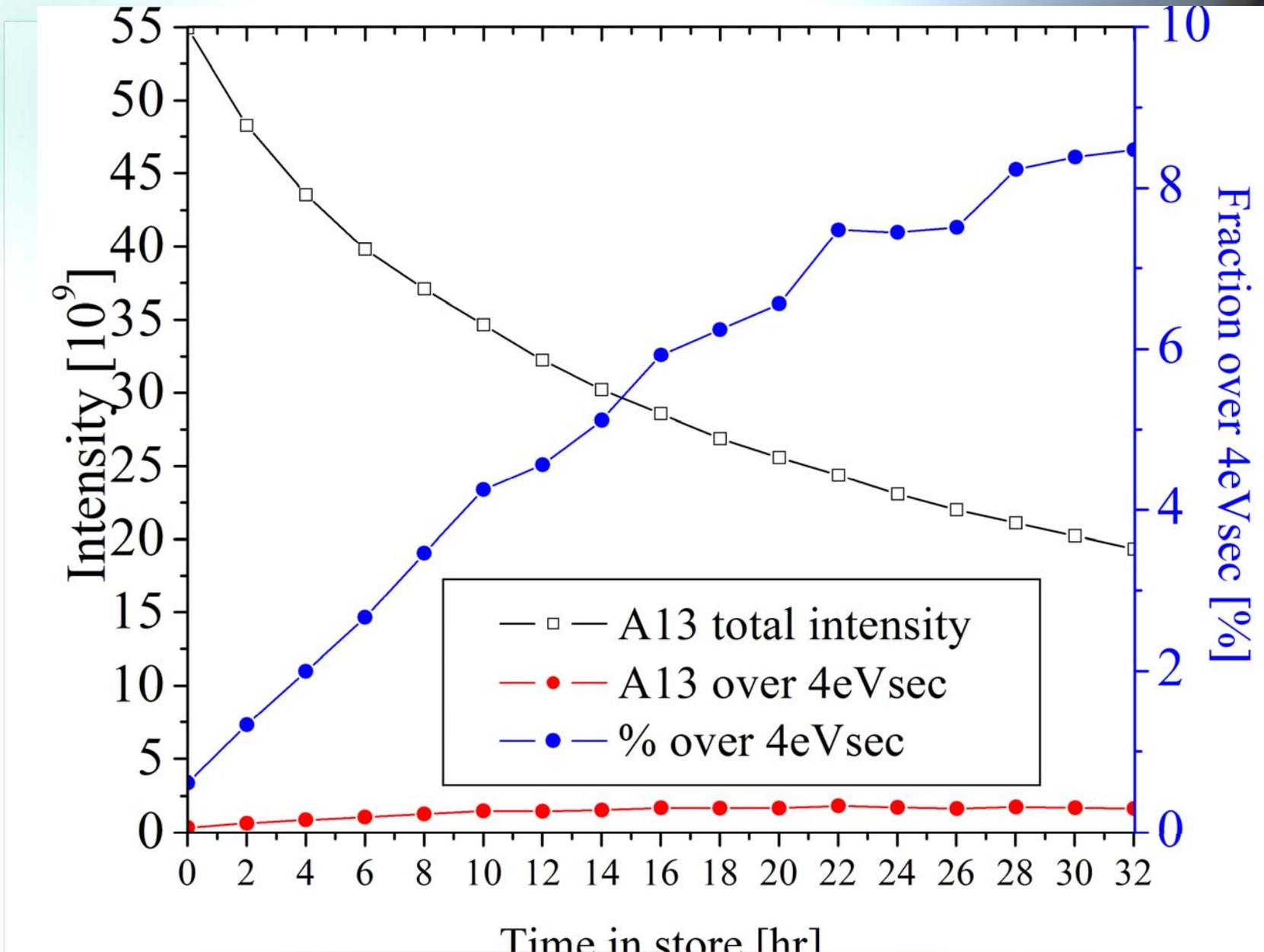
# Comments/Issues (2)

- **proton removal should be successful now (comp. to '02)**
  - 5-10 min OK , compared to 2 min before
  - better shielding at E0 and A48
  - much better control of scraper angle and position (smooth steps)
  - stabilized orbit vibrations
  - p-beam is much wider at the end of longer stores
- **B2 on the ramp down and backporch**
  - tested, works fine (Jerry)
- **MI ramp down**
  - no big problems? (Ioanis, C.Bhat)
  - 53MHz (150→25) 2.5MHz (25→8 GeV) in TM-1991
- **Long and Transv apertures in transfer lines**
  - no big surprizes expected, to be explored with SDA
- **Recycler was supposed to have no problem to accept 3eVs according to CDR – still true?**
- **Sequencer/Controls/Synchronization ... is needed**
- **TeV IPMs may suffer ... move to C0**

# SuperTable: MI→TeV loss on transfer



# Pbars in the Tevatron: store 4318



# Let's Do Some Math (old est's)

<b>Store Length</b>	<b>20 hrs</b>	<b>30 hrs</b>
<b>Left in Tev</b>	<b>46% x</b>	<b>37% x</b>
<b>Deceler Eff</b>	<b>-(5-8)%</b>	<b>-(7-10)%</b>
<b>Tev→MI Eff</b>	<b>-(4-6)%</b>	<b>-(4-6)%</b>
<b>MI Deceler Eff</b>	<b>-(5-10)%</b>	<b>-(5-10)%</b>
<b>MI→RR Eff</b>	<b>-(5-15)%</b>	<b>-(10-20)%</b>
<b>Trsf Time 2/3 hr</b>	<b>-(1-3)%</b>	<b>-(2-4)%</b>
<b>Gain in RR Na</b>	<b>+(30-37)%</b>	<b>+(22-27)%</b>
<b>Gain in L_peak</b>	<b>+(24-30)%</b>	<b>+(18-22)%</b>
<b>Gain in L_integr</b>	<b>+(19-24)%</b>	<b>+(14-18)%</b>