# Continuous Injection ("Trickle Charge") at PEP II

***U. Wienands, for many others…***

**Top up LER buckets as beam current dribbles out.**

**LER trickle first because of greater gain**

- shorter beam lifetime
- longer time to top up
- also less injection background

**BaBar state machine has separate state for trickle mode**

- BaBar is ramped up / down by PEP Ops in automatic mode.

# Trickle Controls

## Charge/pulse

typically inject "small quanta only"

## Maximum trickle (injection) rate

about 3/sec average when setup & trickling

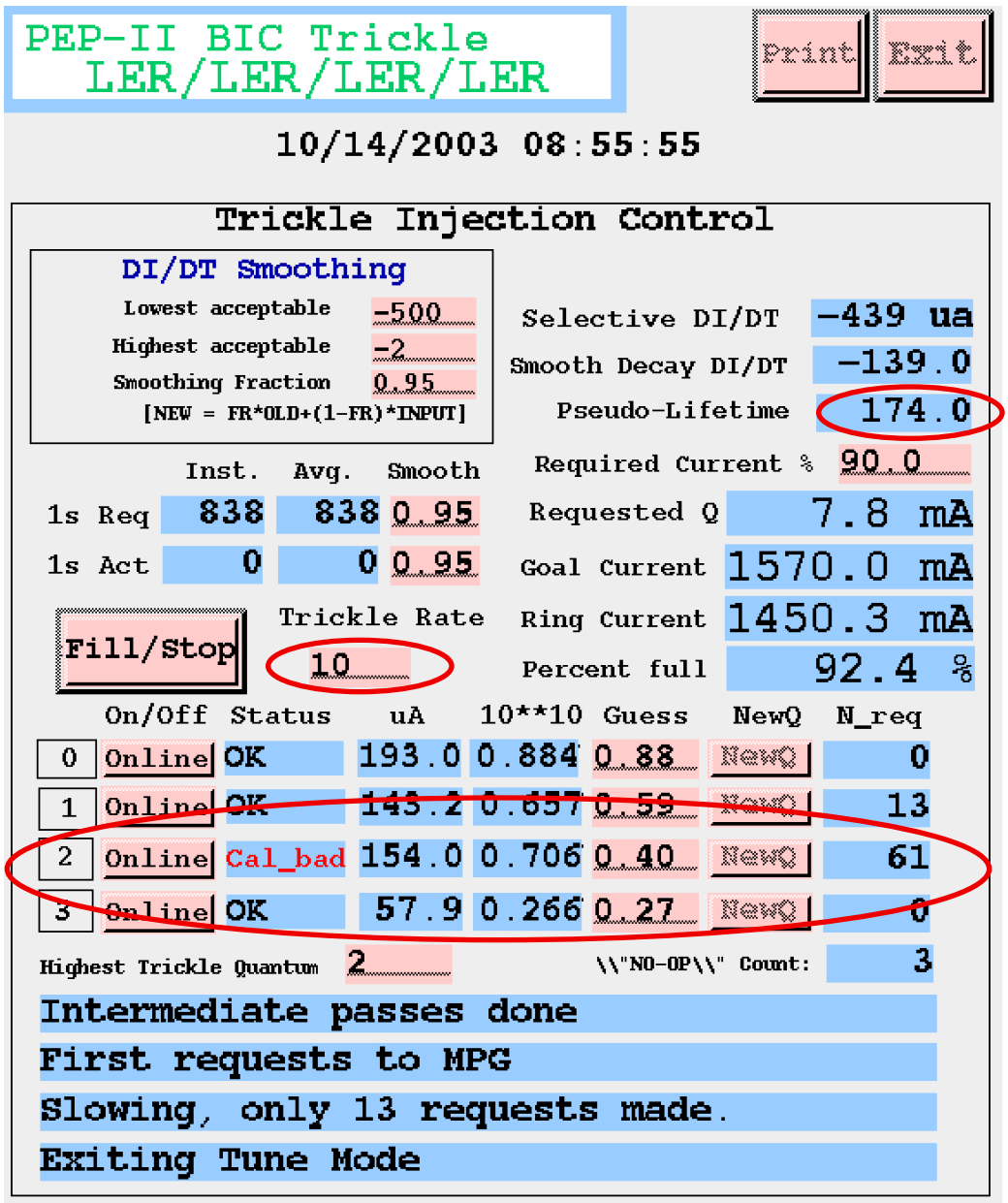
## "Pseudo lifetime"

Normal, DCCT-based beam-lifetime for LER unuseable
"Pseudo lifetime" calculated from bunch currents
avoiding those just injected.

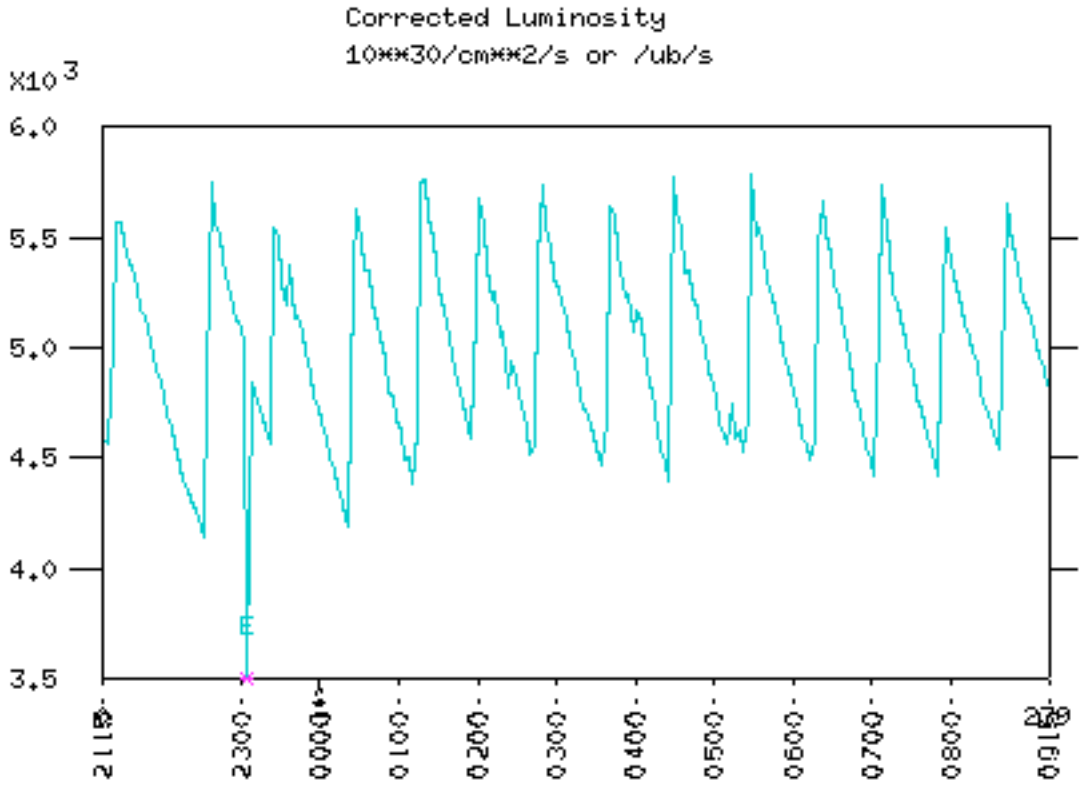
## Minimum beam current fraction

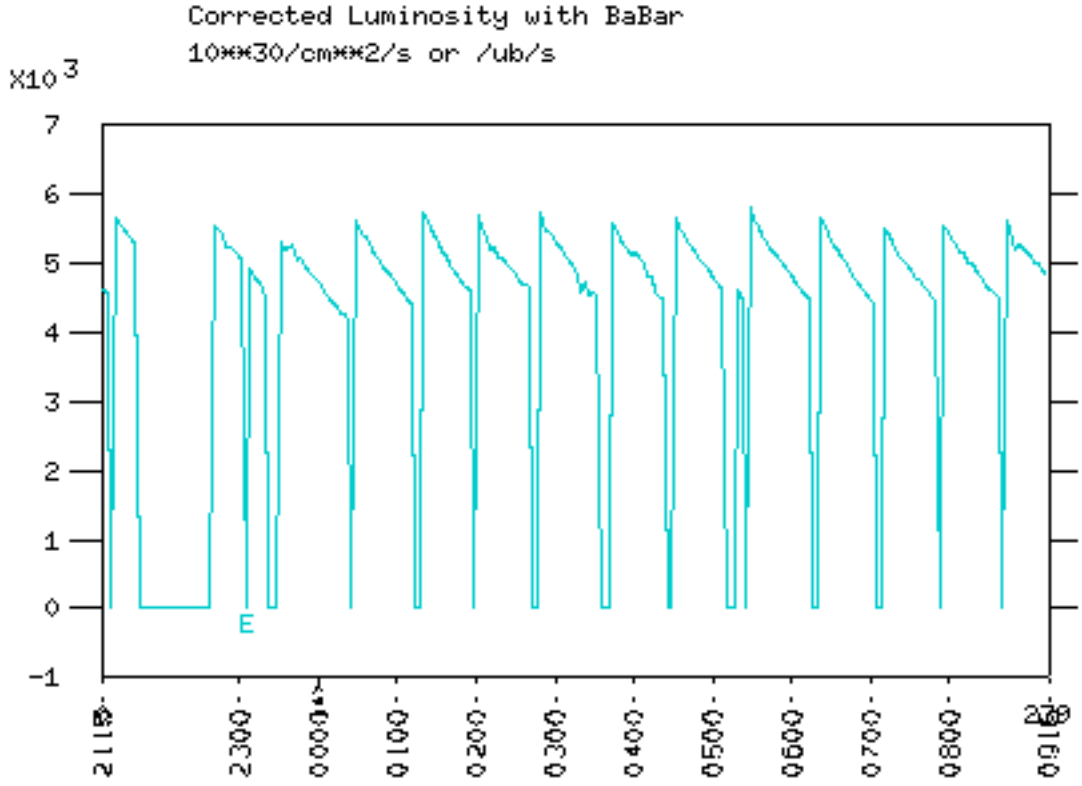
Avoid "trickling from scratch"

# Trickle-Charge Panel (BIC)



# Luminosity History (no trickle)



# Tuning Tools

## Radiation detectors (diodes, xtals, SVTRAD)

useable only when backgrounds are too high!

## Injection trigger counters

count EMC triggers after injection pulse
histogram of triggers *vs* time
EPICS variables with integral counts
FFT shows effect of beam-energy deviations.
normalized to injection rate
Implemented by O'Grady, Weaver, Fisher, Decker

## DCH current

quite useful for monitoring of average background
not fast, so not useful to assess injection spikes

## Trigger rate (L3)

similar behaviour as DCH current

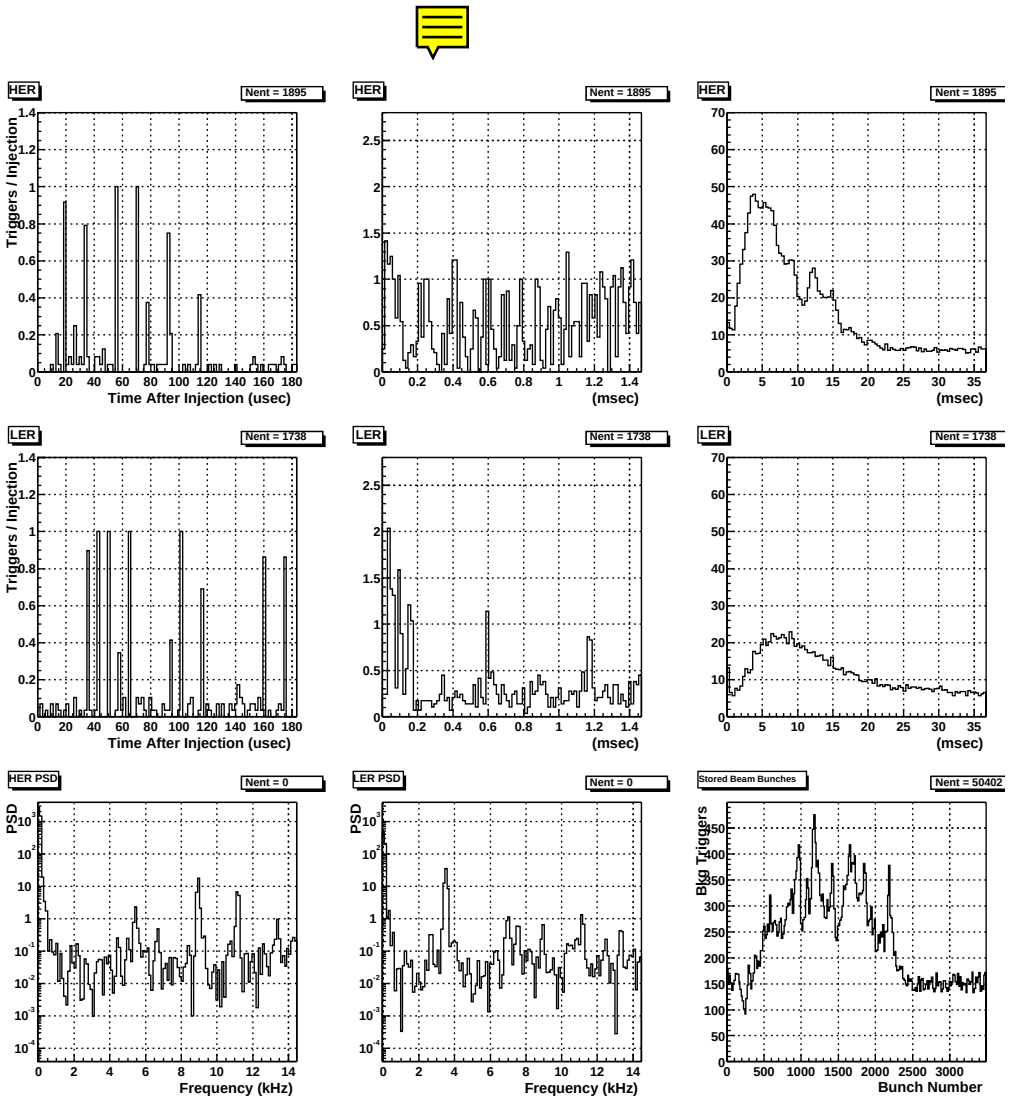
# Injection Background Monitoring

**Trigger Monitoring**

Times for each trigger generated
Current live display tool

Update at 1Hz
No deadtime
Capable for neutral and tracking triggers
Routinely archived

EPICs scalars summary
- Used for setup/tuning (correlation plots)
- Not archived

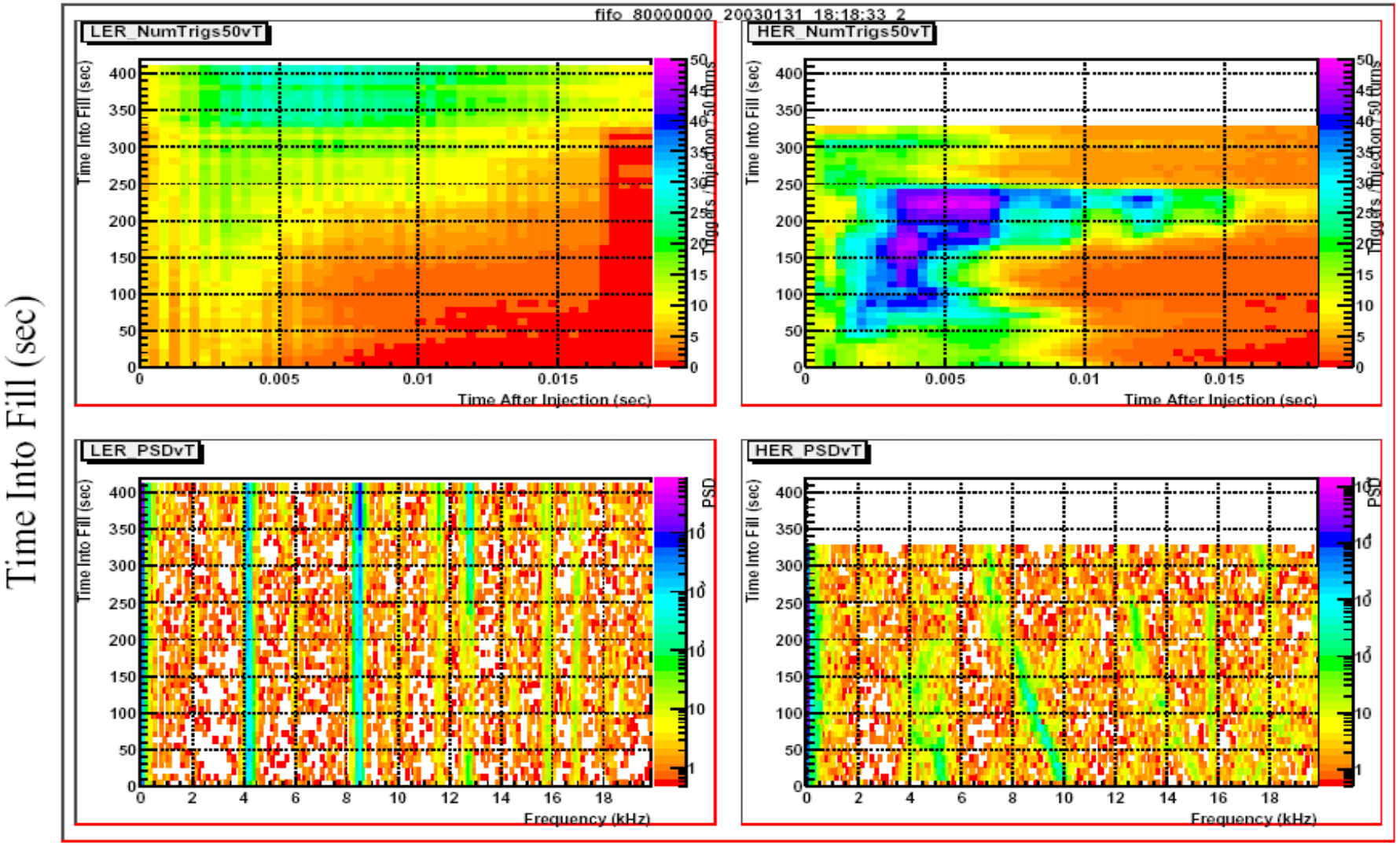


# Injection Background

LER HER

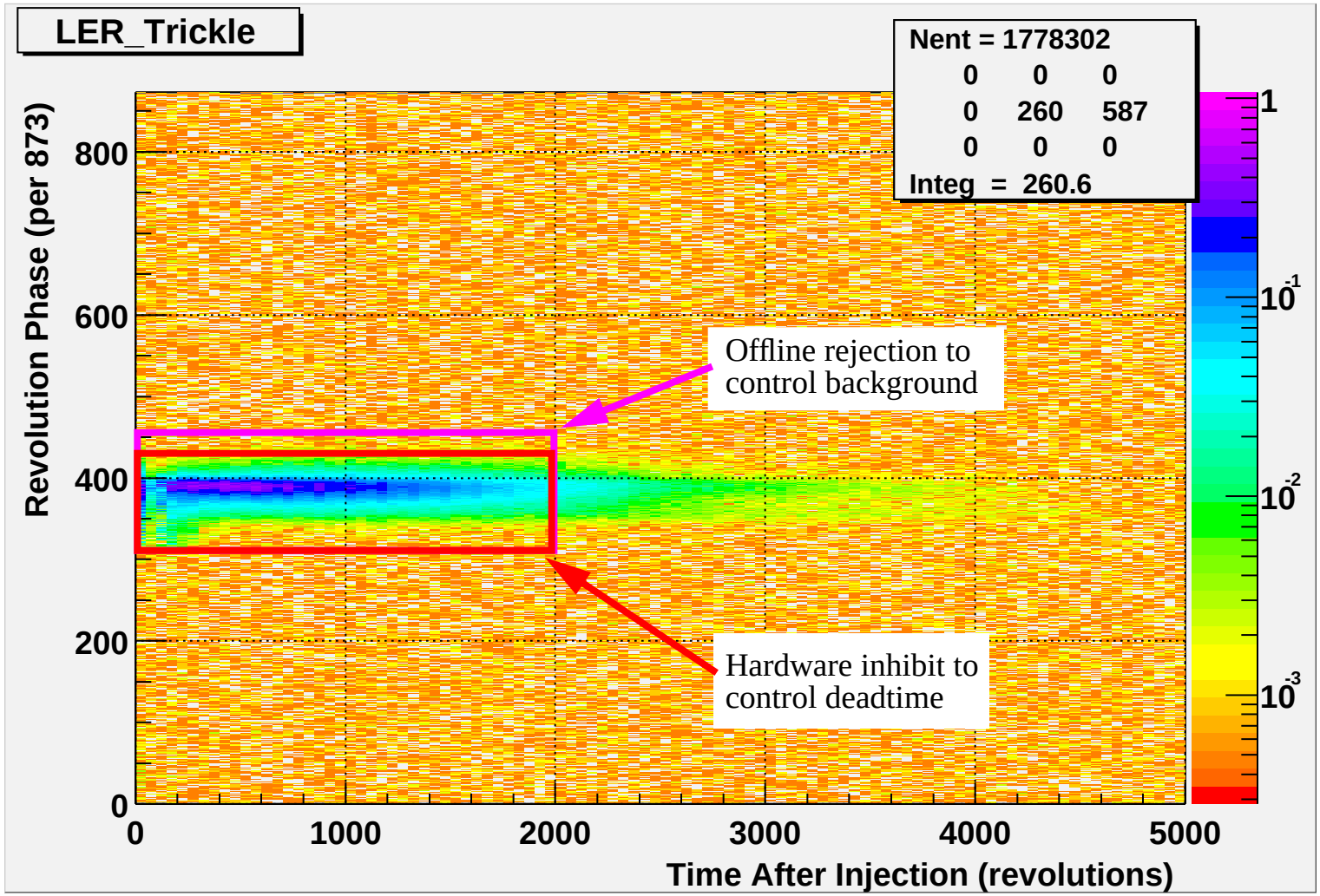
From:

M. Weaver




Time Into Fill (sec)

Injection backgrounds increase as a fill progresses. The period from 0 to 240 seconds consists of large charge quanta injection into the HER and LER at 15 Hz each. The period from 240 to 320 seconds uses small charge quanta injection into the HER. The period from 320 to 410 seconds includes 30 Hz injection into the LER.


LER_Trickle
Nent = 1778302
0 0 0
0 260 587
0 0 0
Integ = 260.6
Revolution Phase (per 873)
0
200
400
600
800
0
1000
2000
3000
4000
5000
Time After Injection (revolutions)
1
10-1
10-2
10-3
Offline rejection to control background
Hardware inhibit to control deadtime

# Trickle-Charge MD Summary (June 13, 2003)

**Chestnut, Decker, Fisher, Iverson, Kozanecki, Schuh, Stanek, Sullivan, Turner, Van Hoover**

**What have we gained (13-Jun, 8:00…16:00, ∫Ldt=137, *vs* 16-Jun, 0:00… 8:00, ∫Ldt=124):**

Average-to-peak Lumi ratio: 82% *vs* 72% (14% gain)

Fraction of time stable beam: 89% *vs* 80% (11% gain)

Luminosity lifetime: 426m *vs* 224m (90%gain)
(by itself, 5% gain in L if nothing else changes)

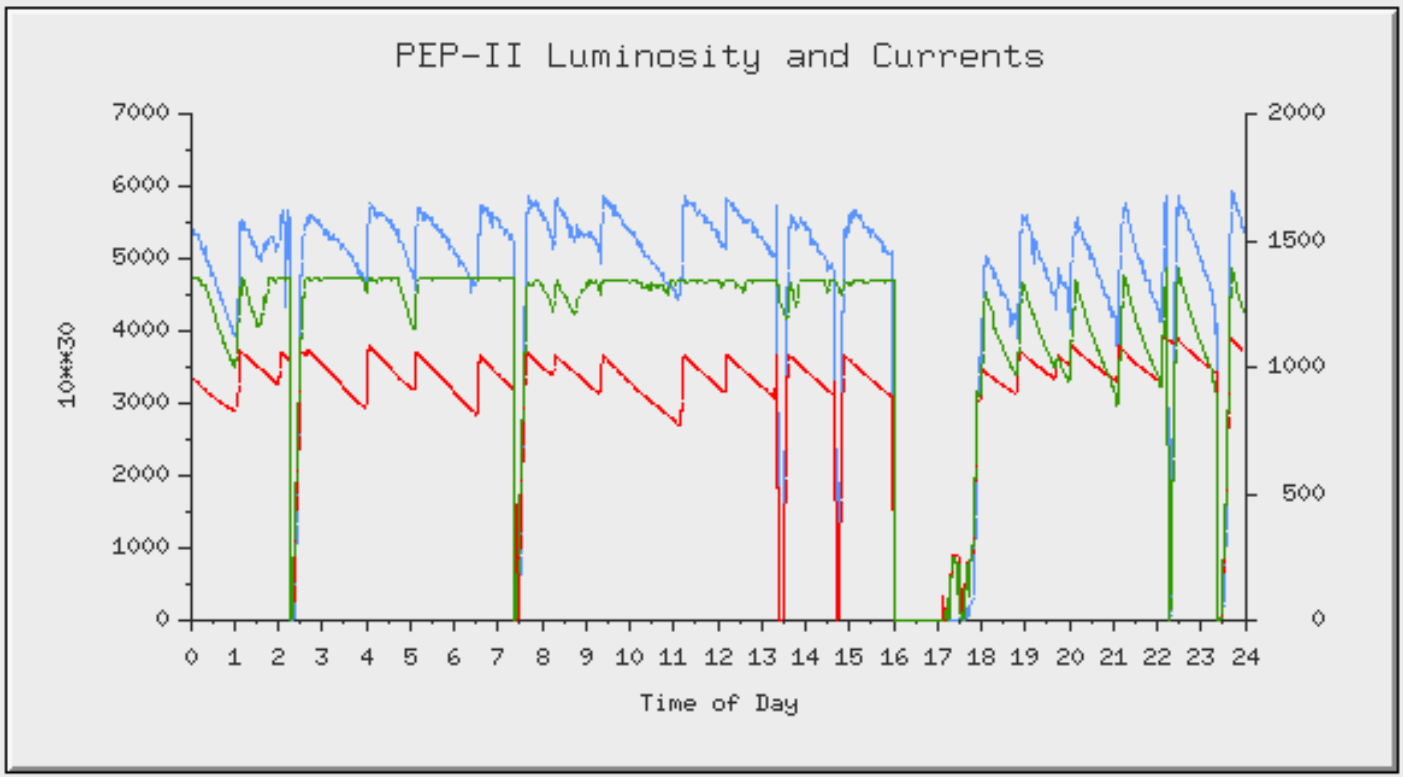
Average peak Luminosity 5787 *vs* 5914 ( 2% loss)

| I HER | I LER | Luminosity | Spec Lum | E HER | E LER | E CM |
|---|---|---|---|---|---|---|
| 1062.65 | 1200.79 | 5376 | 3.94 | 8988 | 3121 | 10592 |
| mA | mA | 10**30/Sec | N*10**30 / mA**2/Sec | MeV | MeV | MeV |

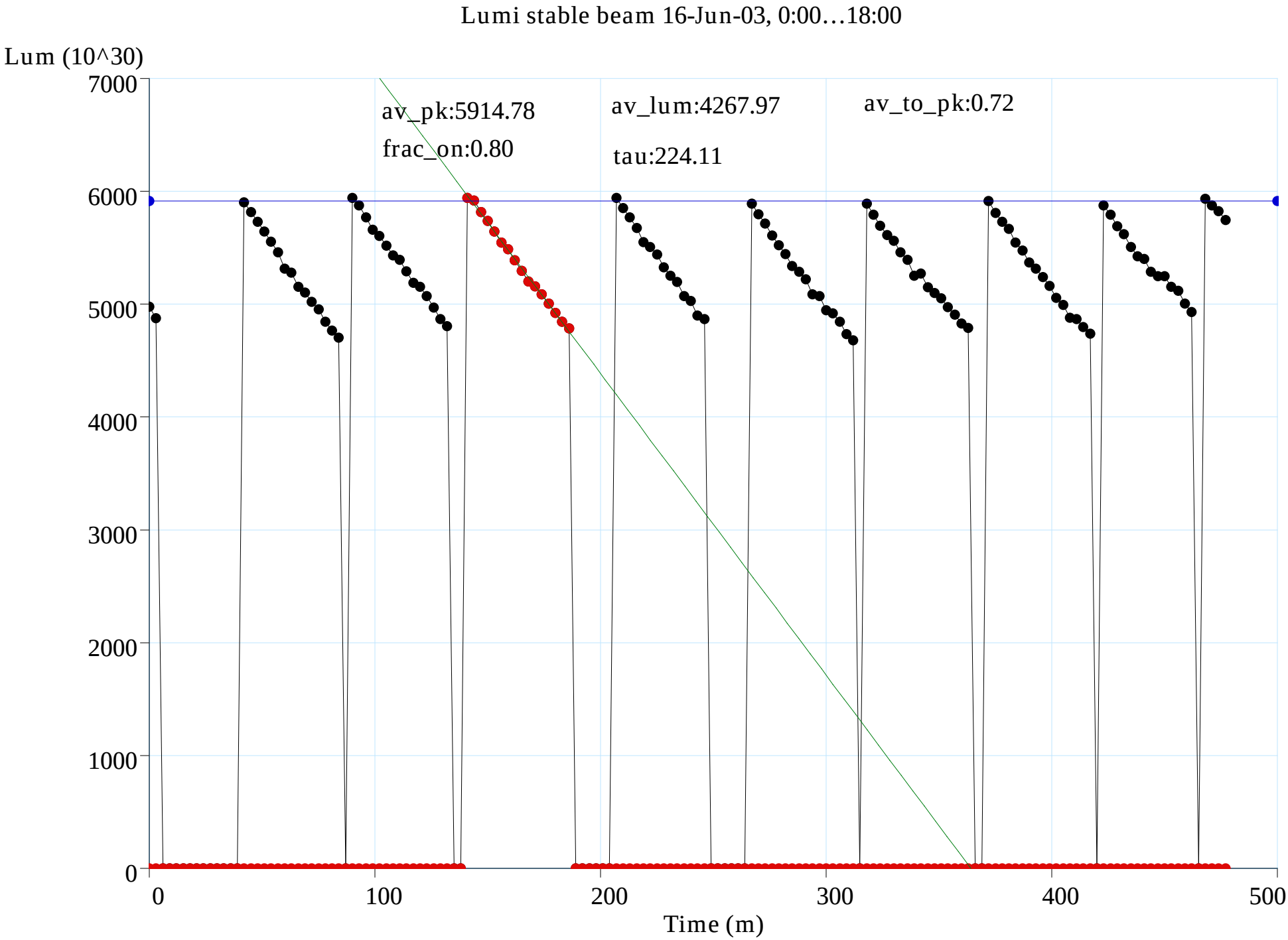
HER N Buckets / Pattern
938 by3_t10_fb1200_new

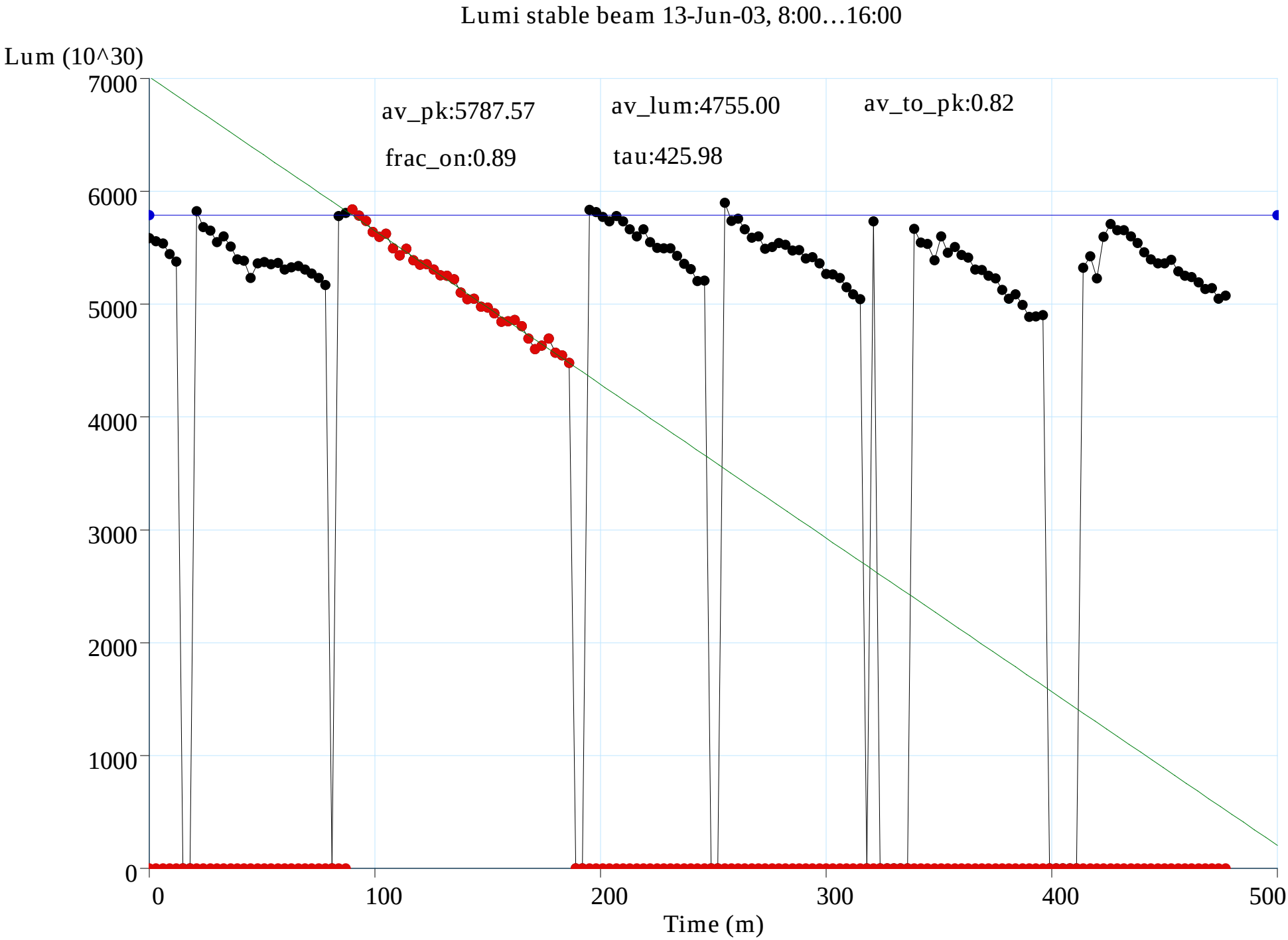
LER N Buckets / Pattern
938 by3_t10_fb1200_new

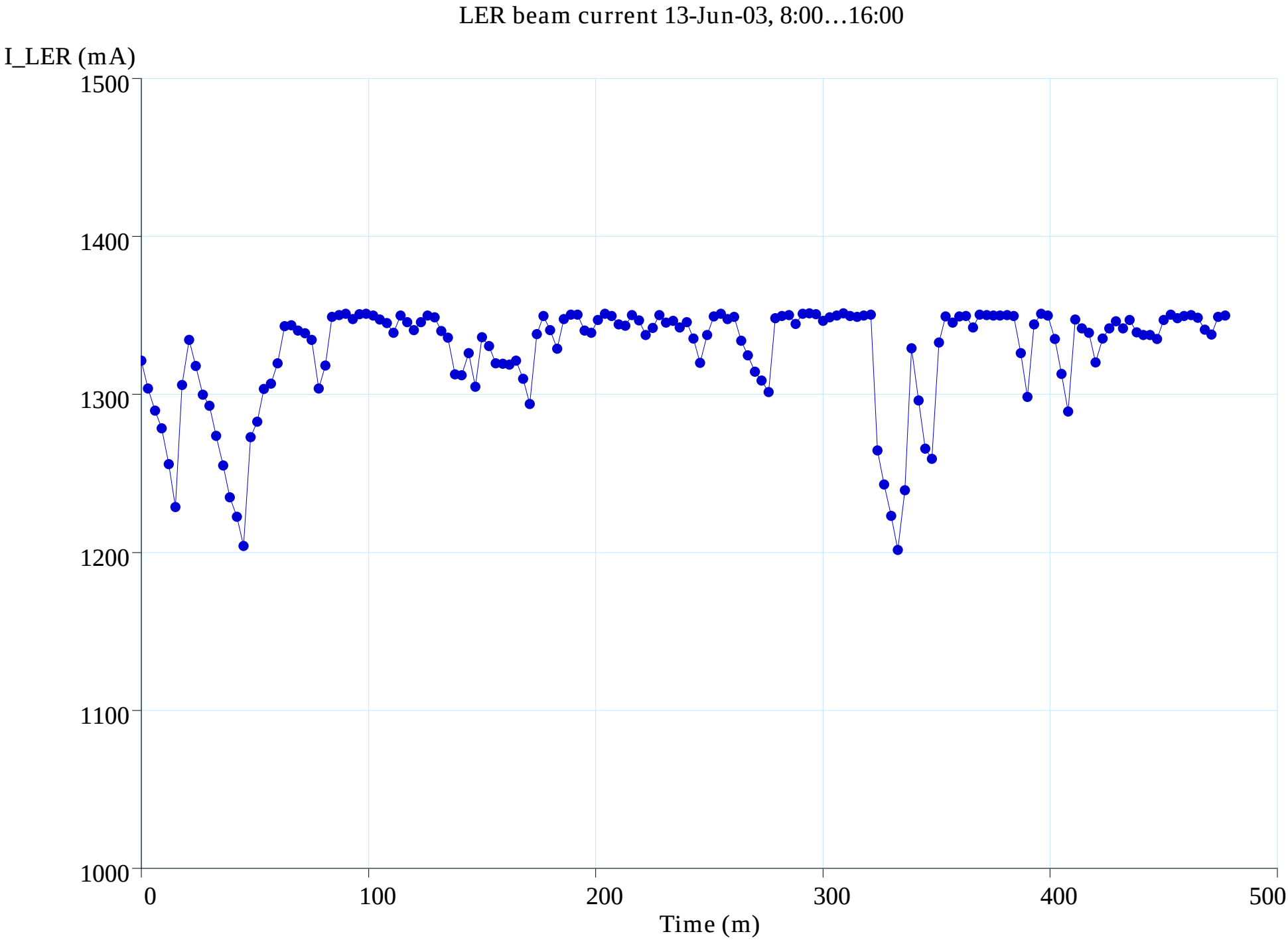
| | | | | | | |
|---|---|---|---|---|---|---|
| Last Owl/Day/Swing/24hr | 112.8 | 137.8 | 80.9 | 331.4 | Shift: | 0.32 /pb |
| Peak Luminosities | 5891 | 5946 | 5973 | | | 5397 |




06/14/2003 00:00:38


Lumi stable beam 16-Jun-03, 0:00…18:00
Lum (10^30)
av_pk:5914.78
frac_on:0.80
av_lum:4267.97
tau:224.11
av_to_pk:0.72
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
Time (m)


Lumi stable beam 13-Jun-03, 8:00…16:00
Lum (10^30)
av_pk:5787.57
av_lum:4755.00
av_to_pk:0.82
frac_on:0.89
tau:425.98
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
Time (m)


LER beam current 13-Jun-03, 8:00…16:00
I_LER (mA)
1500
1400
1300
1200
1100
1000
0
100
200
300
400
500
Time (m)

**What was the background situation:**

The injection-trigger counters for the LER showed a tendency to make a "bump" for ≈ 15 ms. Could be mostly tuned out by lowering the injection energy.

For the June-25, 2002 trickle run, no such bump is documented

The injection-trigger counter display (Weaver display) was instrumental in tuning up injection & diagnosing the energy offset.

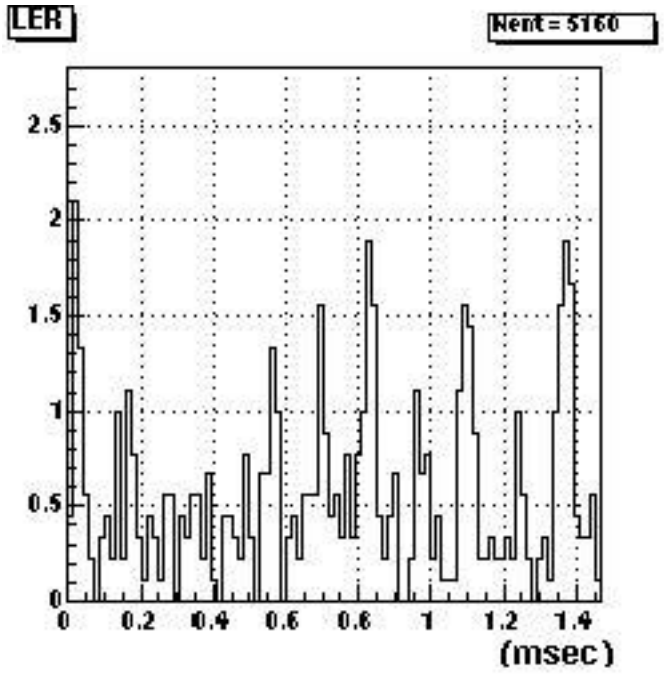
The DCH current was quite noisy, with average currents ≥1000 μA.

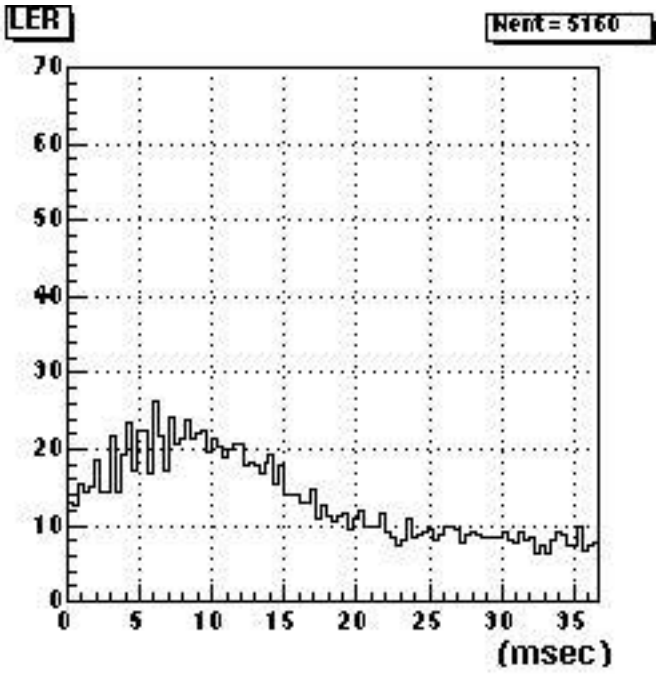
In june last year, significantly quieter and lower avg. current despite higher LER current, althout HER & Lumi were lower.

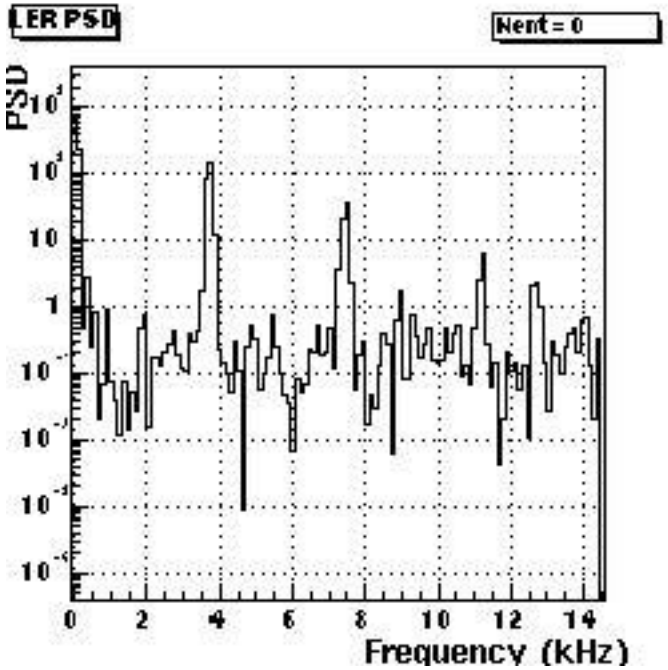
**In summary, the background situation was worse than last June.**

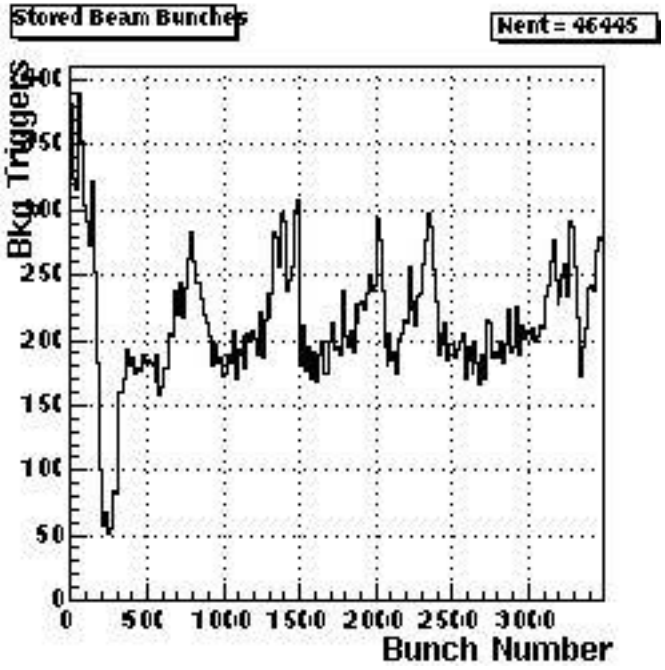
Just like then, transverse injection coordinate tuning did not help.

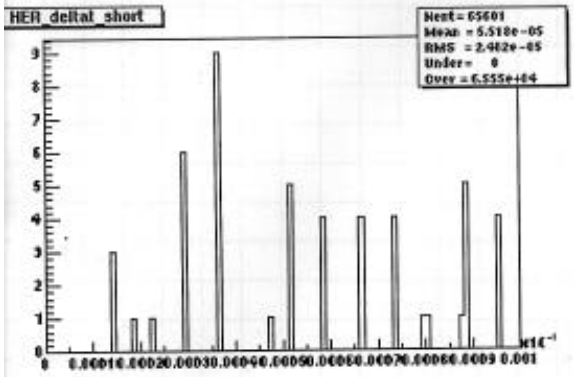
New tunes or insufficient tuning of the injection line?

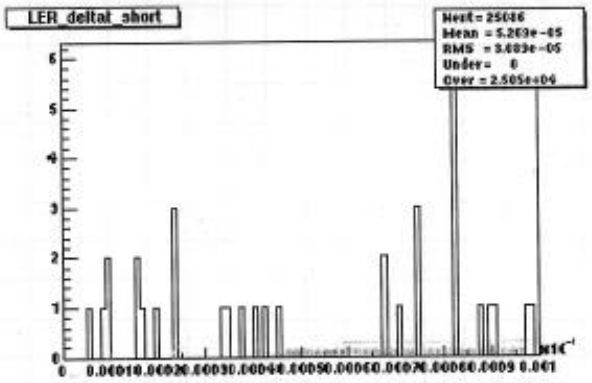

LER
Nent = 5160
2.5
2
1.5
1
0.5
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4
(msec)

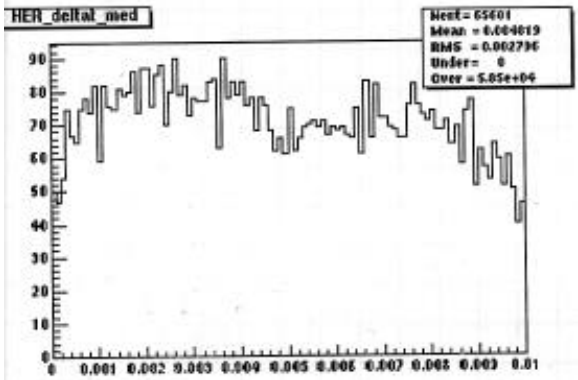

LER
Nent = 5160
70
60
50
40
30
20
10
0
0 5 10 15 20 25 30 35
(msec)

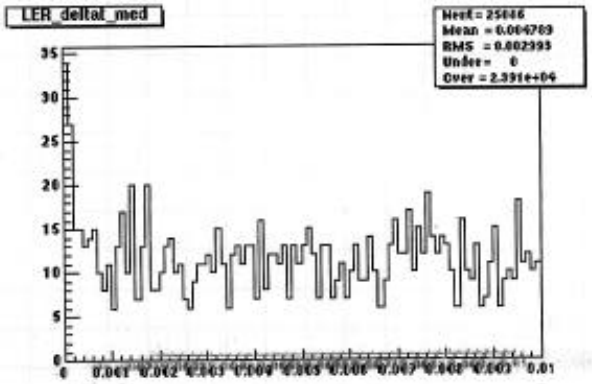

LER PSD
Nent = 0
PSD
0 2 4 6 8 10 12 14
Frequency (kHz)

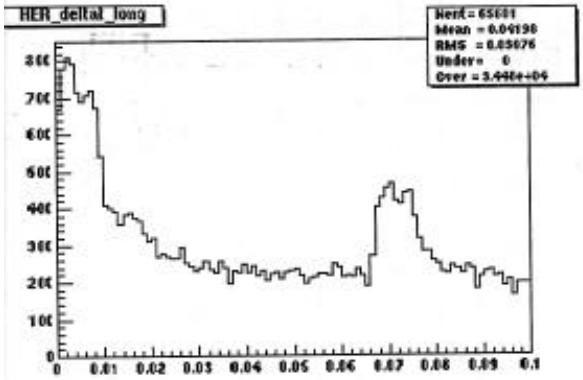

Stored Beam Bunches
Nent = 46445
Bkg Triggers
0 500 1000 1500 2000 2500 3000
Bunch Number

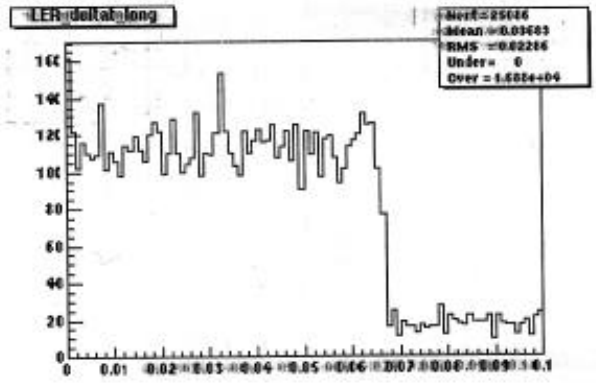



tracks @ 15 Hz / 7 sec bin

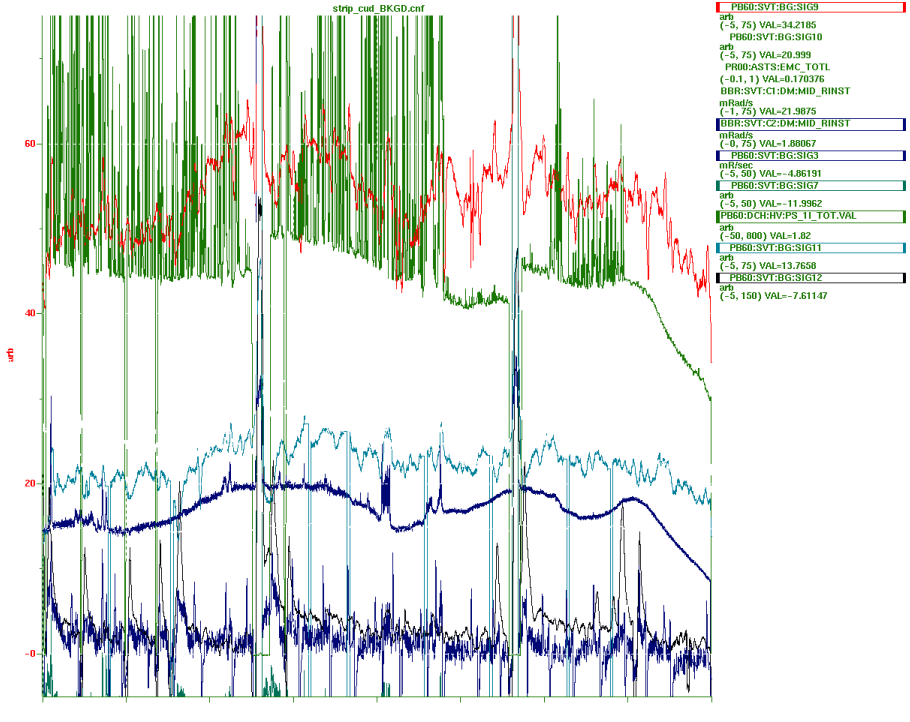
1700 ~ 950

**Oct. 03 Update:**

**Proper injection setup can almost get rid of the injection noise**

**With that setup & using collimators**
**DCH current reduced significantly, but**
**DCH has trouble staying on with all interlocks enabled**

**We keep scraping in the injection region**
**(do we need collimators there??)**

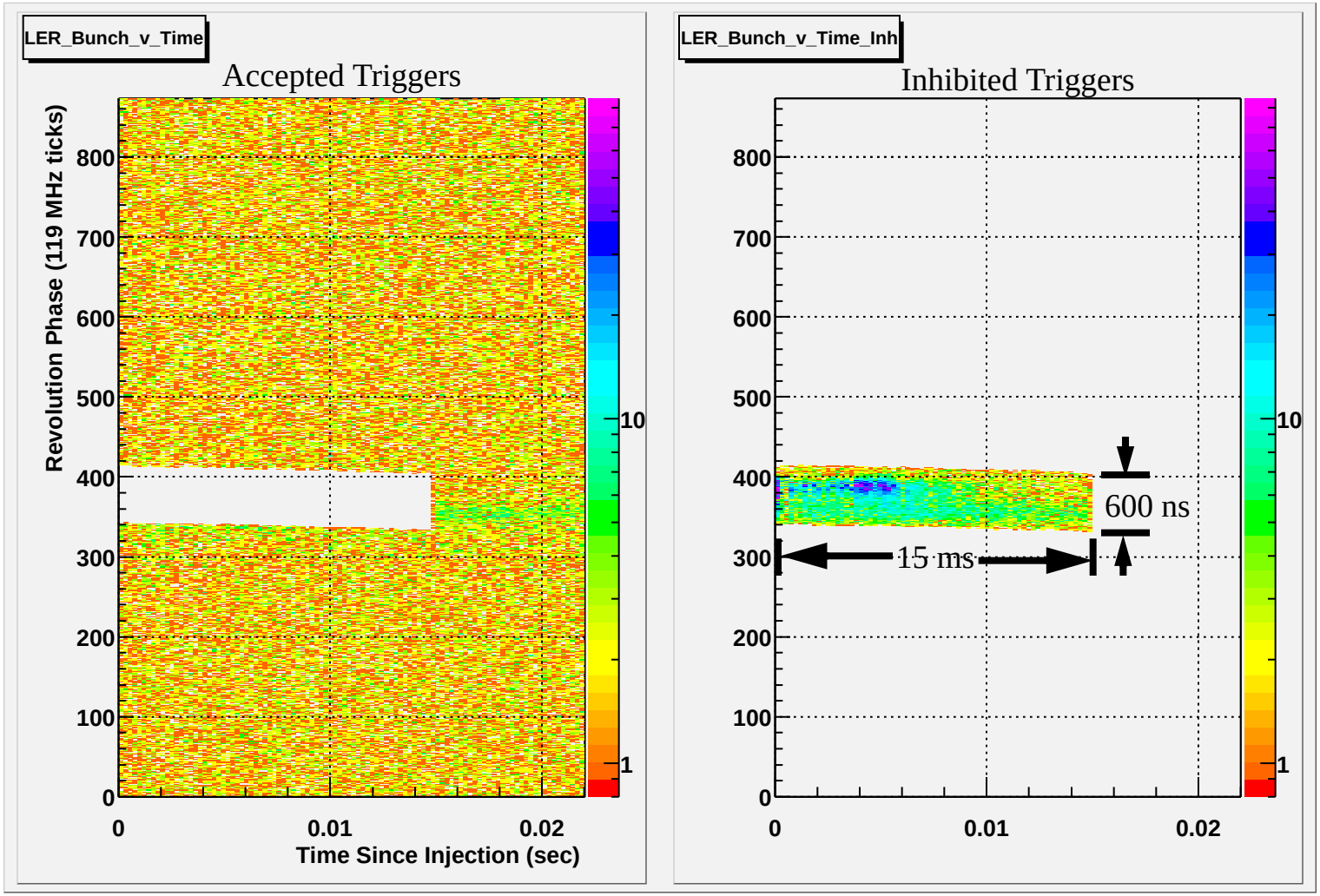

strip_cud_BKGD.cnf
PB60:SVT:BG:SIG9
arb
(-5, 75) VAL=34.2185
PB60:SVT:BG:SIG10
arb
(-5, 75) VAL=20.999
PR00:ASTS:EMC_TOTL
(-0.1, 1) VAL=0.170376
BBR:SVT:C1:DM:MID_RINST
mRad/s
(-1, 75) VAL=21.9875
BBR:SVT:C2:DM:MID_RINST
mRad/s
(-0, 75) VAL=1.88067
PB60:SVT:BG:SIG3
mR/sec
(-5, 50) VAL=-4.86191
PB60:SVT:BG:SIG7
arb
(-5, 50) VAL=-11.9962
PB60:DCH:HV:PS_TI_TOT.VAL
arb
(-50, 800) VAL=1.82
PB60:SVT:BG:SIG11
arb
(-5, 75) VAL=13.7658
PB60:SVT:BG:SIG12
arb
(-5, 150) VAL=-7.61147
arb
60
40
20
-0

# BaBar Data Acquistion

Deadtime ~ >10%  (June 2002,2003)
Due to small number of CPU intensive events in L3 Trigger processing
Solved by buffering upstream of the processing

Remaining Deadtime ~ 2-5% (June 2003)
Due (mostly) to DCH readout of rapid succession events with large DCH occupancies
- An anticipated bottleneck for future Lumi upgrade scenarios
- A proposal to fix is being drafted; 2 years to a solution

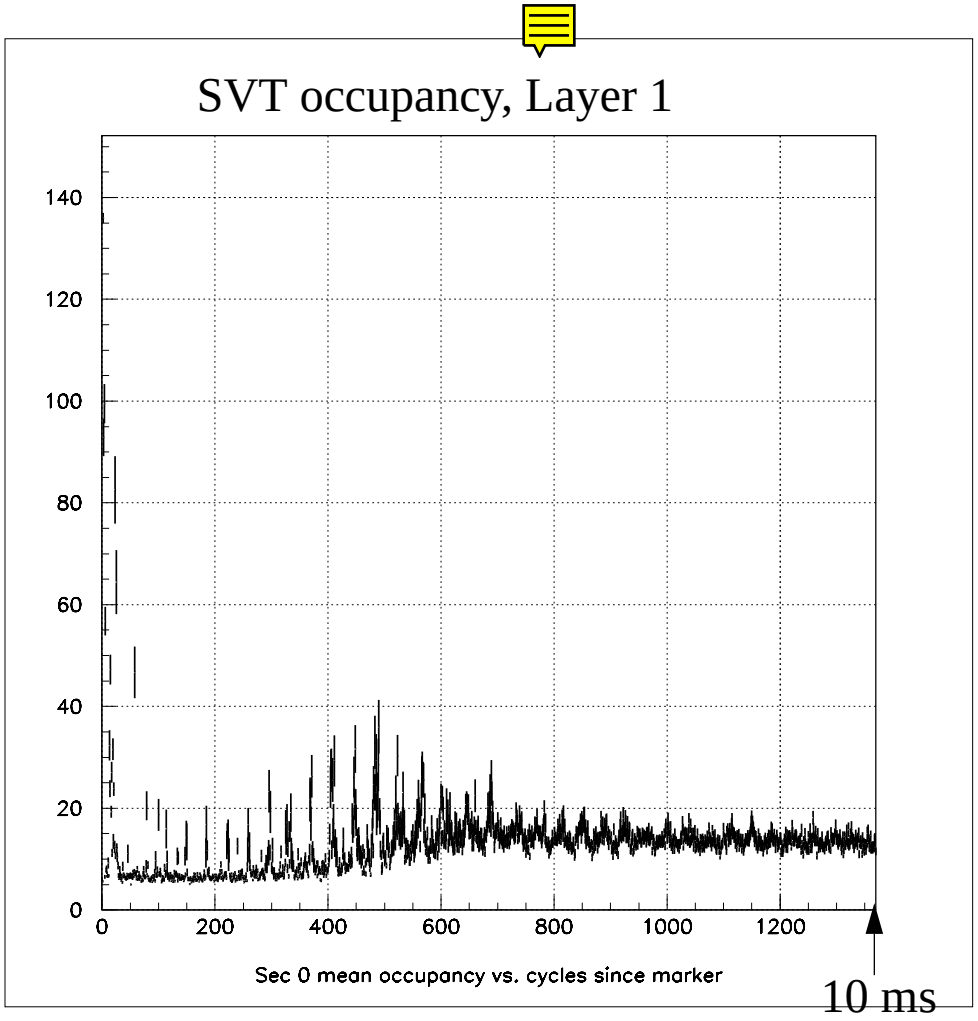
Mitigate deadtime by inhibiting detector readout during selected time intervals
- +-300 ns around passing of the injected bunch (determined by trigger time resolution)
  for the first 5-15 ms after injection.
- Choose as small a window as possible to remove the deadtime.




Inhibited time = 600ns x 10ms/7.336us x InjectionRate = 1% at 10 Hz injection rate
An interim implementation is ready, a stable long term solution is being developed.
The sampling triggers for detector readout of injection monitoring are tied to the implementation of the inhibit.

**Detector Monitoring**

BaBar readout and fast monitoring
Under development
Occupancies, Total Charge/Energy
Sample ~5 passes per injection
update at 20sec - 2min
Monitor detector exposure (protective)




Possible example
30 minutes of statistics
June 13, 2003

**What improvements do we need (incomplete list):**

Smooth out trickle-algorithm in BIC, avoid stoppage
(including cleaning up BIC-MPG communication).

Get EPICS bar-chart display showing rate of injection/bunch.
also want display of total injection rate

Get a hardware real-time injection indicator
(pulsed LED or counter).

Make sure LESIT feedbacks don't stop if too many small quanta.

Stabilize setup of quanta (intensity, energy).

BaBar need to update its interlocks (we bypassed too many).

Speed up refresh of injection-trigger histograms (Weaver-display).

# Summary

∫ Luminosity gain by trickle charge demonstrated

Setup for trickling ≈ 2 shifts,
probably faster with more experience

Backgrounds appear manageable
with proper tuning

BaBar has developed the gating
procedures needed to avoid dead time

Trickling will require the Linac to deliver
10 Hz all the time!

Expect to begin trickling within a few weeks

HER is next. Much tougher!