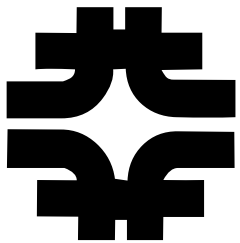
On Pbar Losses up the TeV Ramp



Paul Lebrun

Aug 20 2003

About 15 % of the pbar are lost up the ramp..

Worth studying!

(i) These losses are not constant, there seems to be a transition at 500 GeV where the losses start to increase (what Vladimir called the "400 GeV knee"

(ii) What is it correlated to ? Emittance? Beam positions ? Tunes ?

  (i) Is bunch dependent, (diff. Between bunch 0 and 1 within a train)

What we knew thus far..

Pbar losses up the ramp do depend on

(i) bunch number within a train, most likely because the emittance is not constant over bunch number.

(ii) vertical emittance (small emittance, high efficiency, as expected.)

(iii) the proton current, if the vertical emittance is large enough (> 15 pi),

(i) And such losses do not seem to be correlated with pbar bunch length (a surprise).

What we learned in this study

(i) The loss rate over the ~90 sec ramp is far from constant. It peaks right at the beginning of the ramp (~153 GeV) , but may have other extrema at 600 GeV (V.S. 400 GeV knee) and 900 GeV.

(ii) The pbar and the proton loss rate do not always track each other for E> 160 GeV.. Different mechanism are at play.

(iii) The 600 high losses started to appear around store ~2805 (July 21, Fete Nationale, Belgium) and are still (mostly!) with us. This loss rate fluctuate store to store by as much as ~ factor 5

(iv) These pbar losses at 600 GeV seem to be correlated with higher horizontal tunes for 3 store 2824, 2826, 2828, however this result has not been reproduced for recent stores (2898)

What we learned in this study, II

(i) Again, vertical emittance matter. Pbar Loss at 600 GeV during store 2847 were anomalously high probably because of high vertical emittance, despite good orbits, good tunes

(ii) The Pbar losses at 900 GeV seems to be correlated with the vertical position at B49 & A11.

(iii) The proton losses have not been studied as much as the pbar losses. However, it seems clear that the losses at the beginning of the ramp are also substantial. A prominent peak appears around 365 GeV, when the synchrotron frequency is ~ 60 Hz.

Agreed upon for our action plan makes sense!

1. Reduce emittances by improving optics at injection (TeV + transfer lines)

2. Better helix with more separation at high energy

Meanwhile, we need a lot more data!

(i) Why not producing FBI/FTP for all bunches during the ramp (and squeeze ?)

(ii) BPM data, FTP, for all BPM's, not just three of them (and one seemingly dead ! (VF49)

(iii) New Shottky bunch by bunch tunes, for all bunches, all the time!.

(iv) Faster SBD (times 3) (3x time CPU power..)

(v) ….

Data Sources

(i) SDA data per-se : little or no data during the ramp.

(ii) D44 data: 1Hz for FBI, 3 Hz for SBD, not quite enough…

  (i) Note: the node Backup failed to collect FBIANG data since August 10.. Revert to normal datalogger, however, some older stores are missing.

(iii) FTP : ~5 to 10 times more data, but only for the sum over all bunches.. No SBD data.

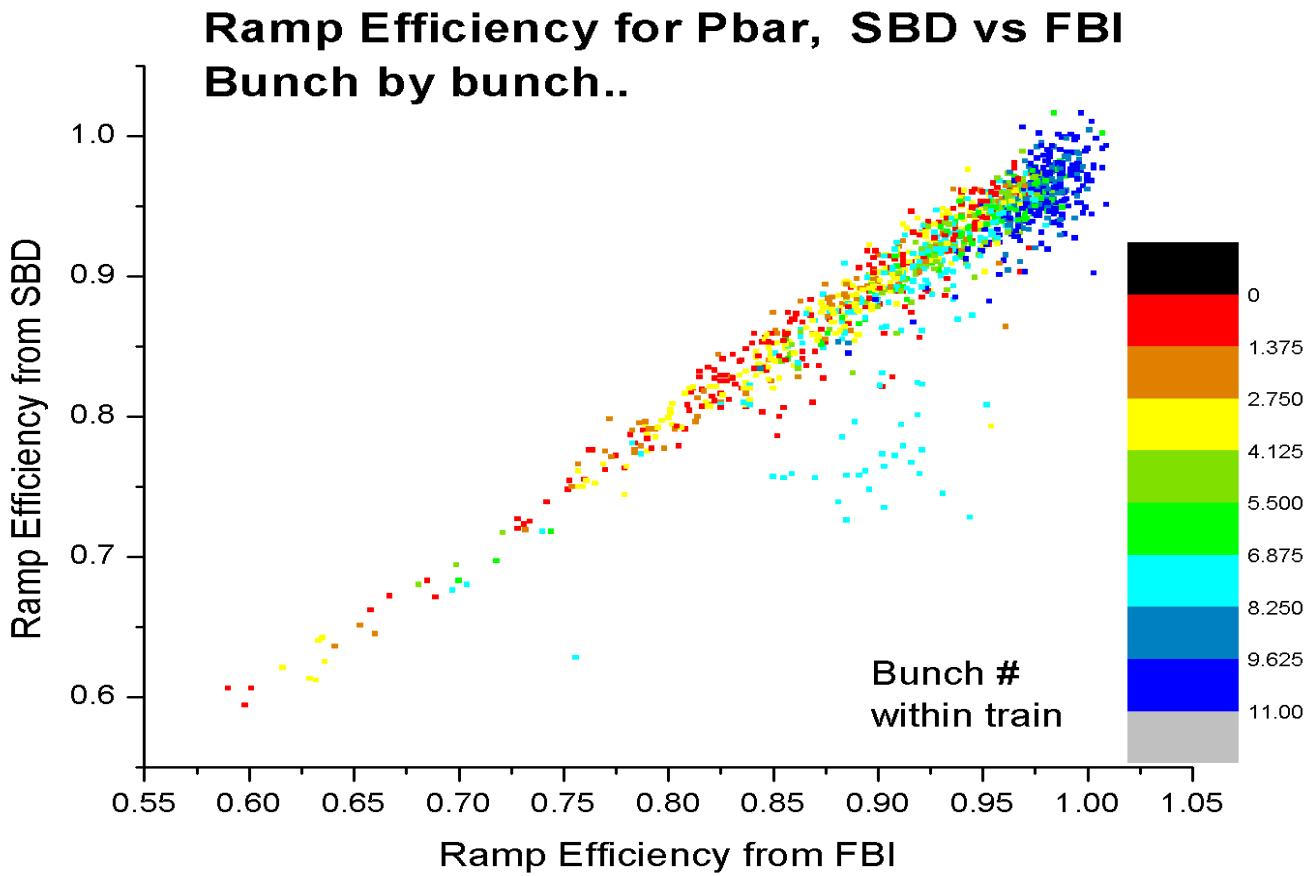
(iv) No correction on FBI or SBD intensity ratios. Such corrections factor are not expected to remain constant during the ramp, because the bunch length changes. Small effect, probably. However, due to sparseness of SBD data during the ramp, and related possible mistiming, some efficiency deduced from SBD data are a bit suspicious.

Data Sources, II

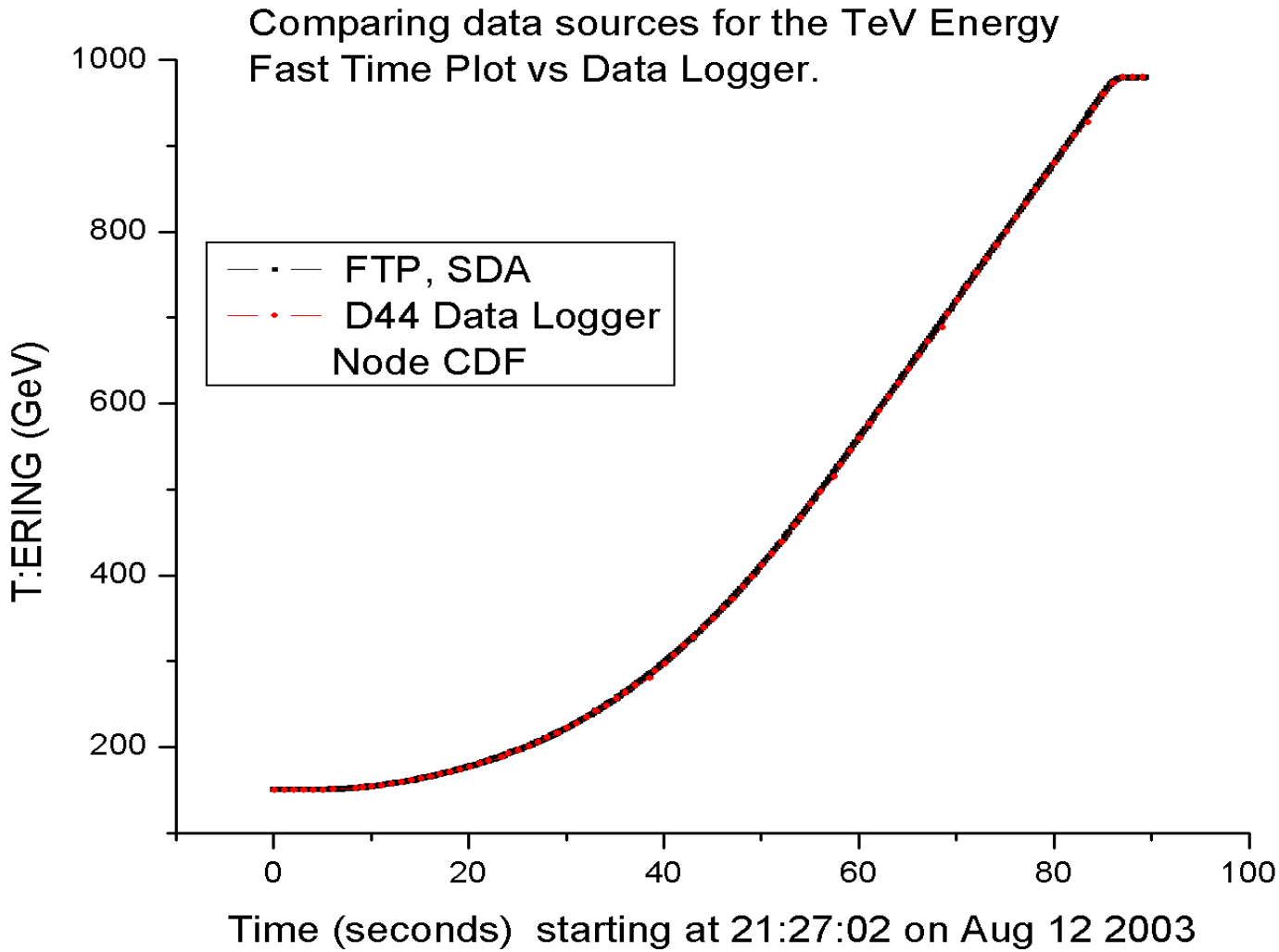
The following stores were studied:

2910, 2908, 2904, 2898, 2889, 2887, 2883, 2879, 2868,
2864, 2859, 2857, 2847, 2830, 2828, 2826,
2824, 2821, 2817, 2815, 2813, 2810,
2805, 2803, 2801, 2800, 2795, 2792,
2786, 2783, 2780, 2774, 2772, 2770

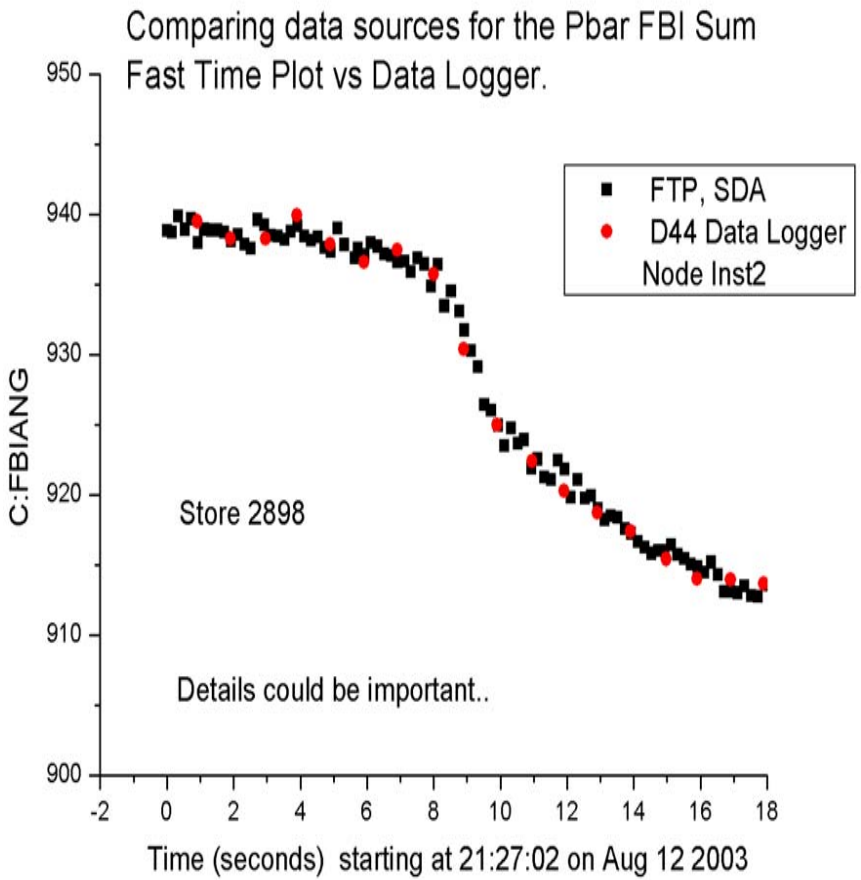
As usual, consider only ~ the last 2 months of data…

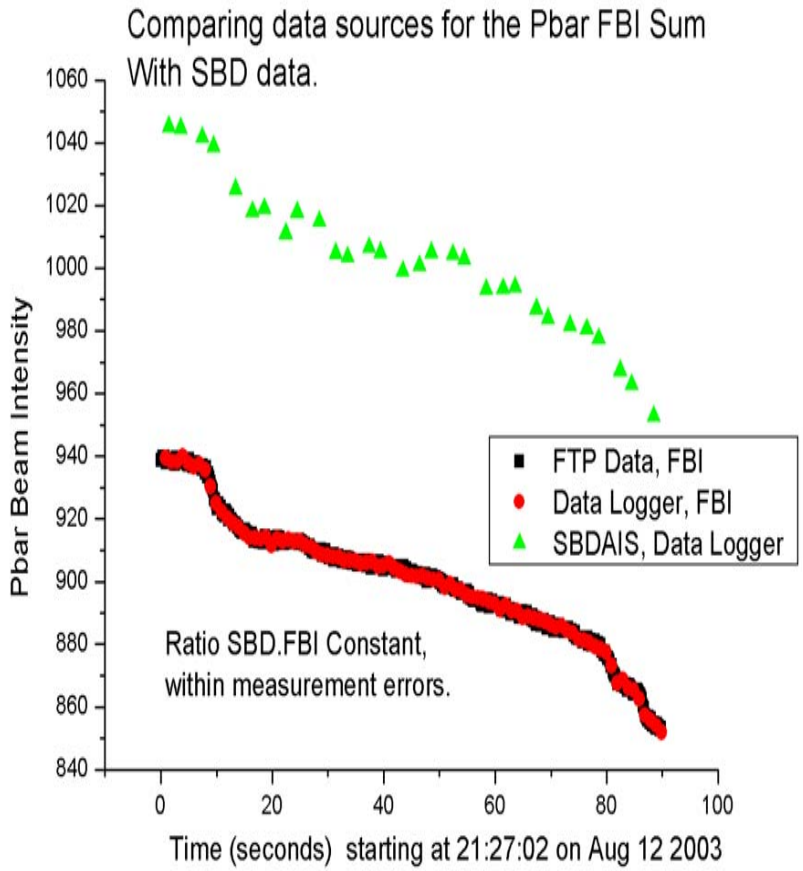


Ramp efficiency from SDA, defined as intensity ratios “Flattop”/”Before Ramp”. The bunch dependence, due to emittance, has been documented before (BD Doc # 746). Bunch number 7 is a mystery…



This is to show that we can synchronize FTP data and D44 data with beautiful (?) Java/osda software..



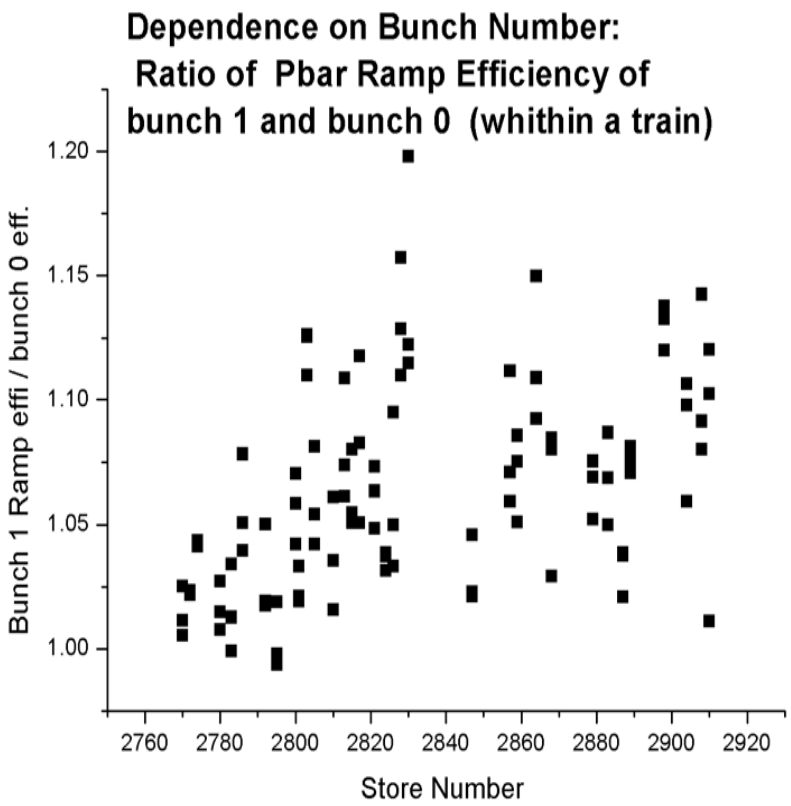


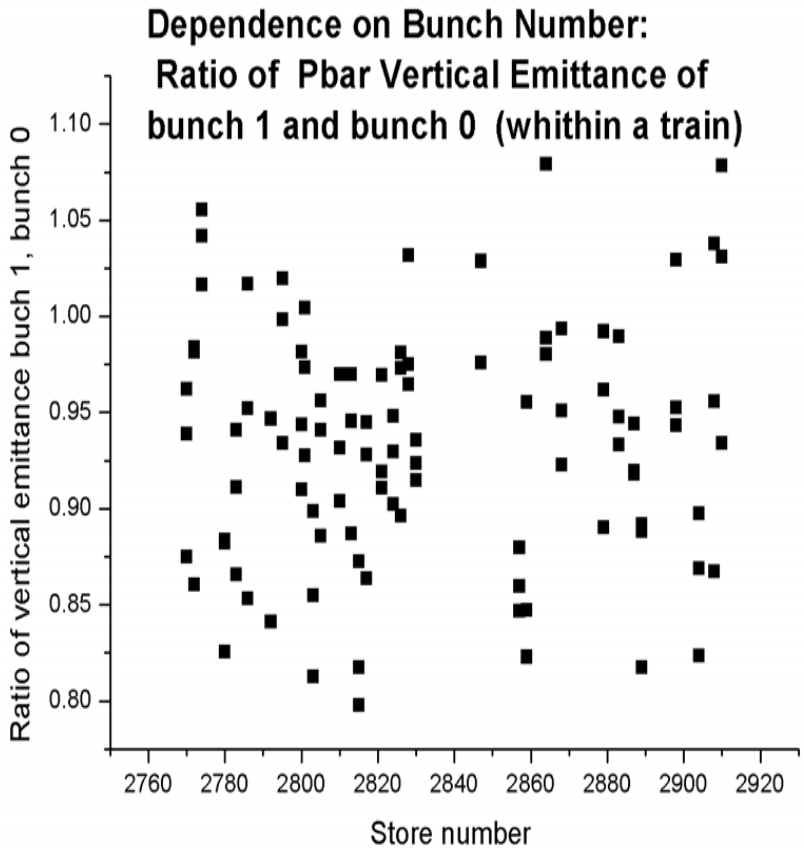
Definitely not enough SBD data points to compute loss rates between ramp slots.. => We will use the FBI to compute relative efficiency during the ramp. We are more interested in relative changes of these efficiencies, less in their absolute values.

Digression: Erratum on Doc 746

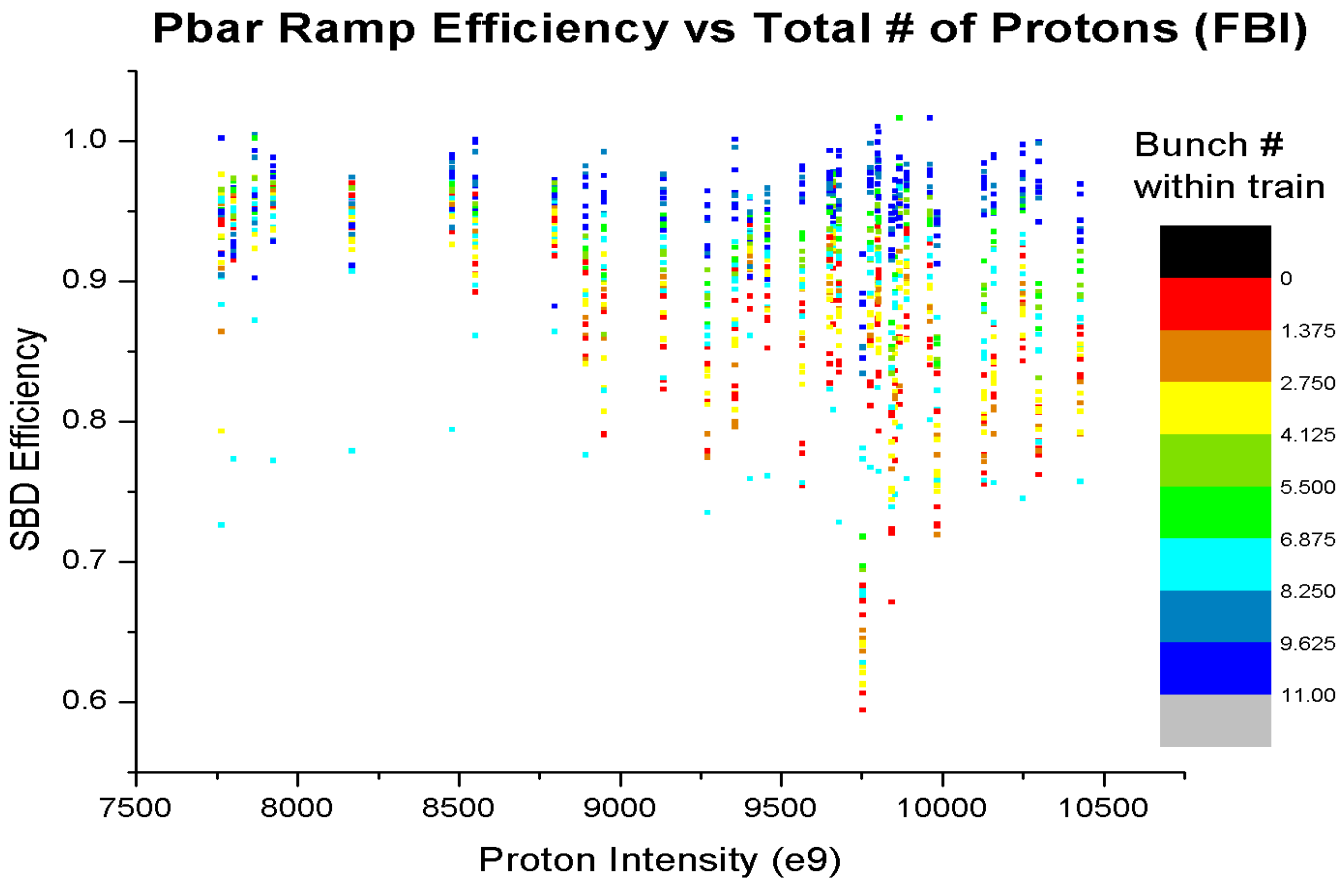
About three weeks ago, I stated that the Pbar Ramp efficiency was bunch number dependent, not only because of vertical emittance variation within the trains, but because of suspected parasitic longe range beam – beam effect. This observation was based on a statistical evidence of the difference of the ramp efficiency between the first two bunches in the trains, implicitly assuming that the vertical emittance for these two bunch are identical (same transfer in this 3-ring circus game!)

This statistical evidence has been confirmed using a bit more data, and using the SBD data, which is more reliable. ***However, the vertical emittances do differ between these two bunches! (***and I don't understand why, it must come from the pbar source..)

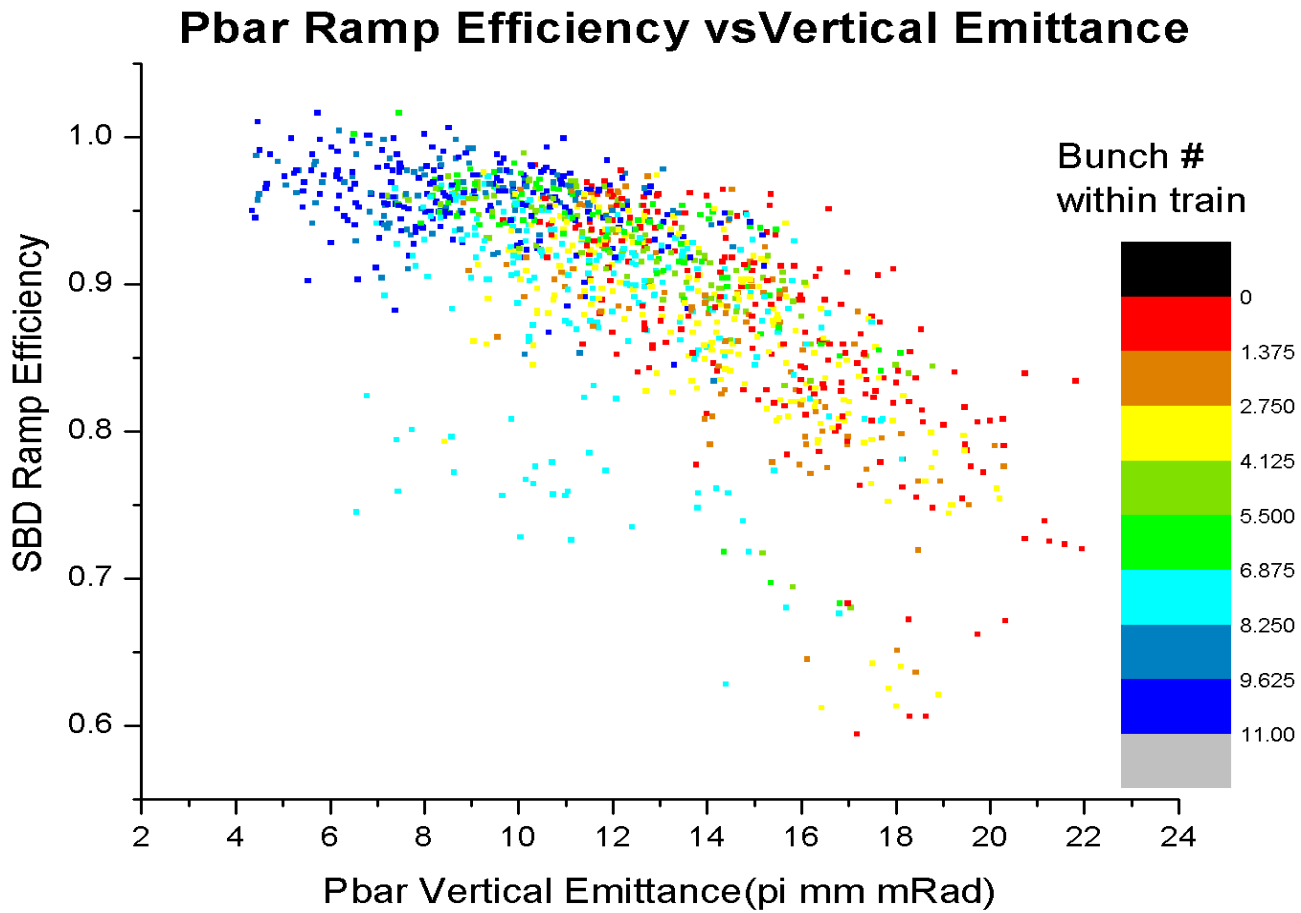




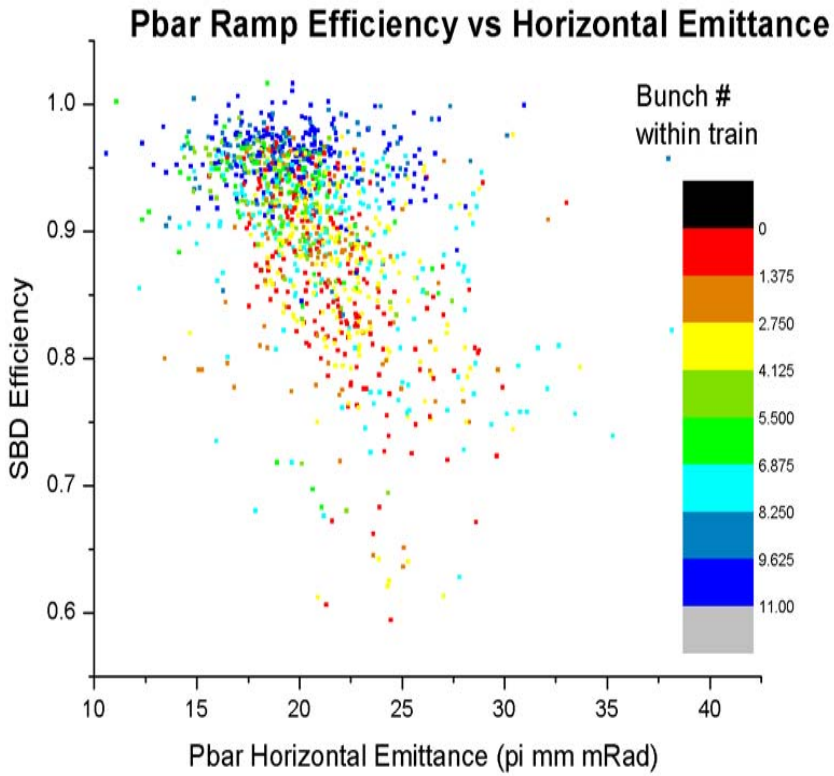
The average ratio of the SBD pbar ramp efficiency (SDA data) between bunch 1 and bunch 0 is 1.064 +- 0.004, over these ~33 stores (3 entries per store, 3 trains..) However, the vertical emittance ratio bunch 1/ bunch 0 is 0.934 +- 0.006. So it the difference in transmission efficiency can be attributed to emittance, not bunch position…

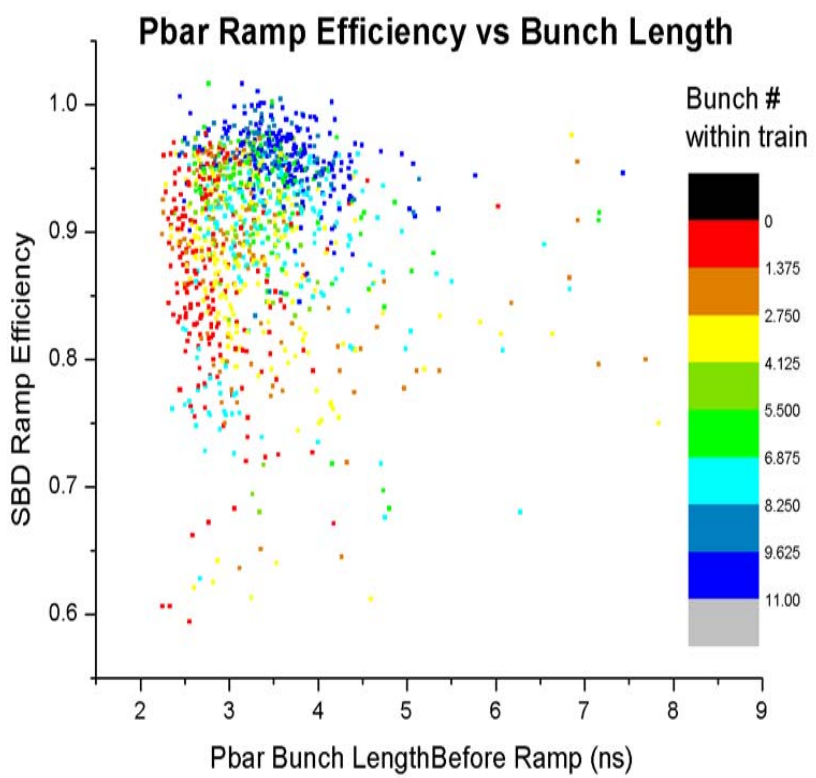


However, for large vertical emittance, (first few transfer from M.I.), the correlation with the proton intensity seems to be confirmed…
(based on SBD data, not FBI!)



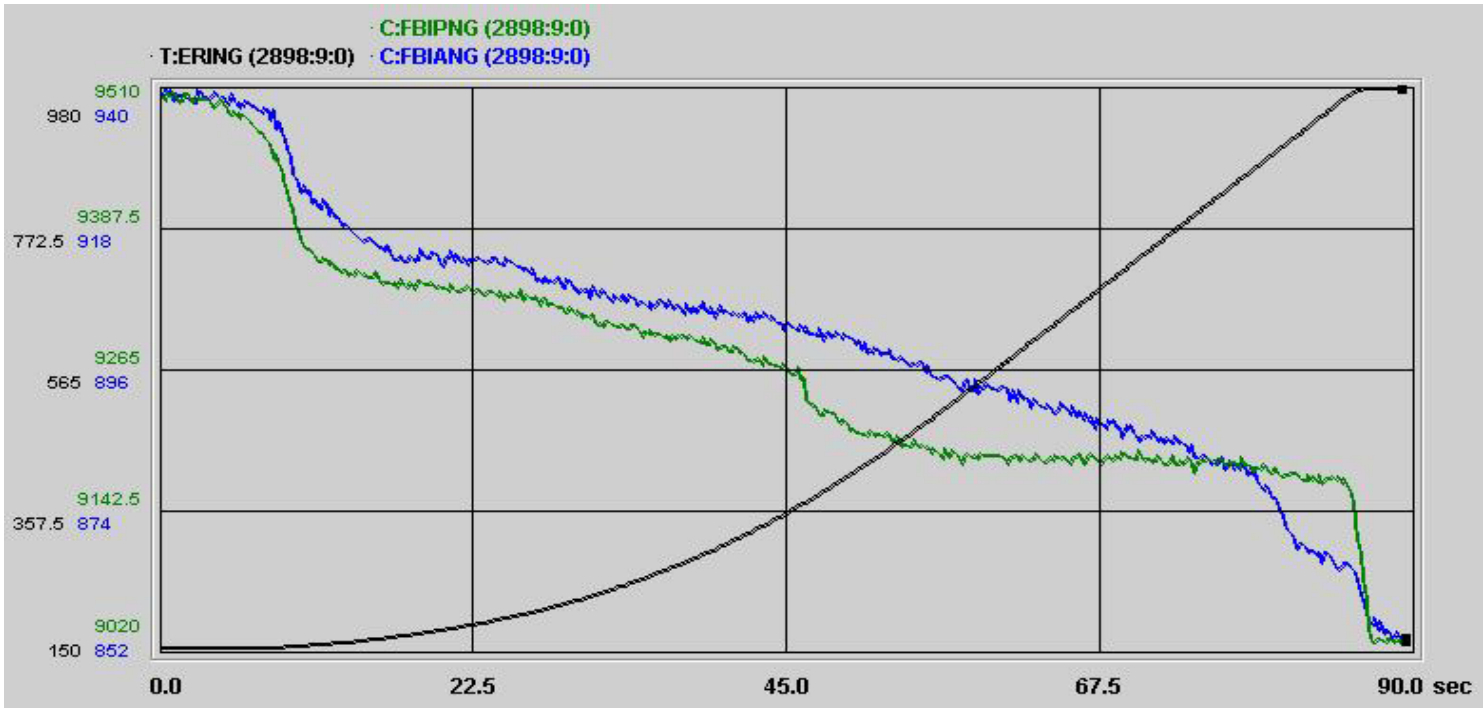
The correlation between ramp efficiency and the vertical emittance at 150 (measured seconds before we ramp), is also confirmed using the SBD data. ***However….***



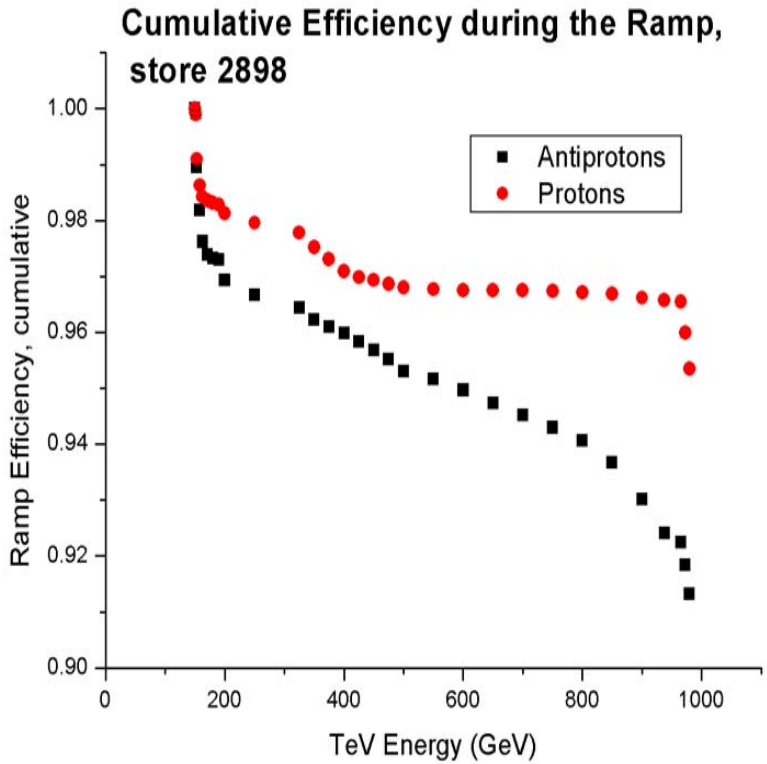


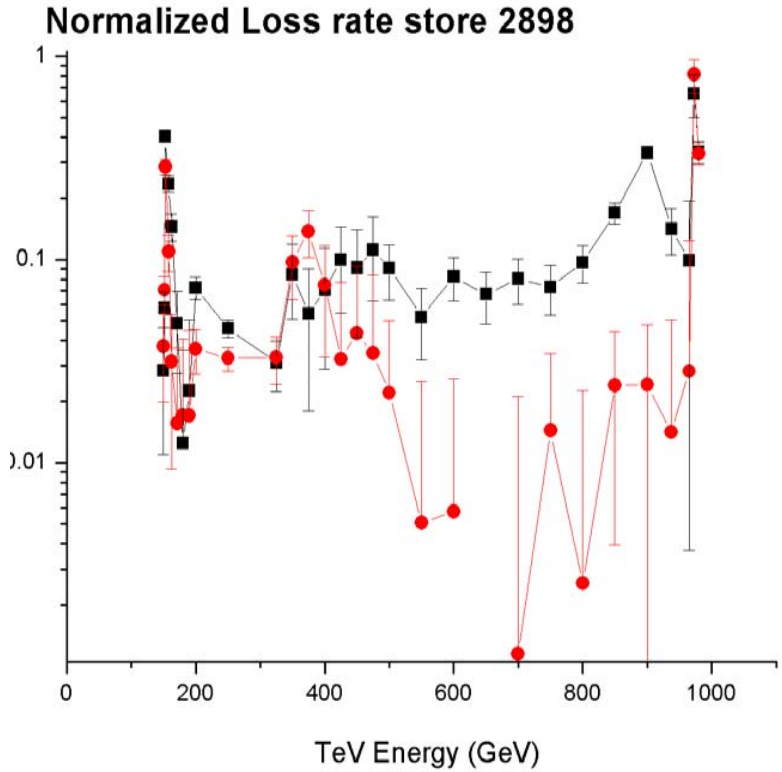
No clear correlation between ramp efficiency and the horizontal emittance, nor the bunch length ? Why are we so sensitive to the physical vertical size of the beam, and not it's horizontal width ? May we do not measure the horizontal emittance well enough ?

Onto the efficiency during the ramp. FTP data..



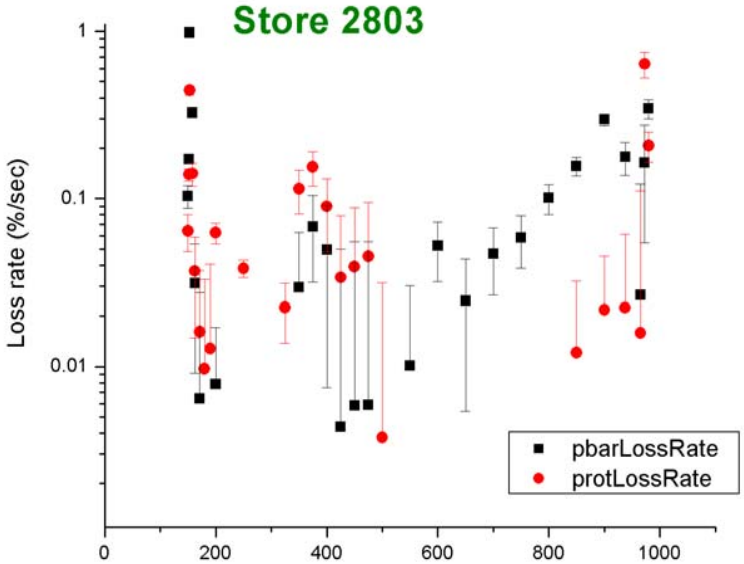
We take the FTP data, FBI, sum over all bunches, and hope that the correction factor are not too dependent on bunch length or the proton current. The data is transferred from the SDA database to the Java Virtual Machine via the osda package. We then compute the efficiency and the normalized loss rate (1.0/I) dI/dt versus energy. We also take the D44 data and compute the SBD efficiency during the early part of the ramp (E< 200) and the late part of the ramp (E > 200) .

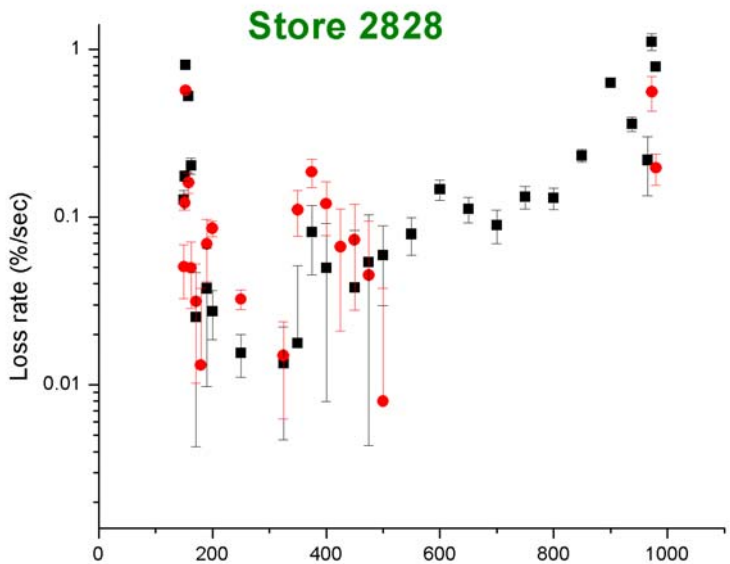


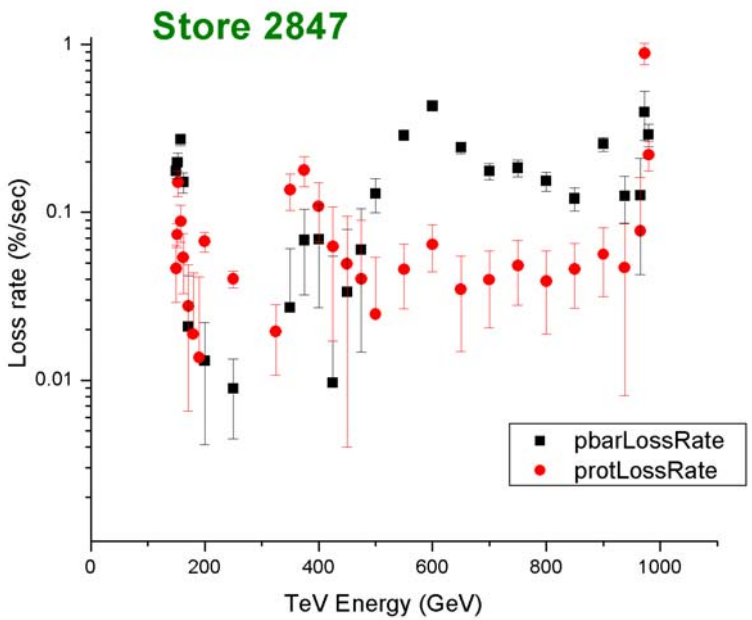


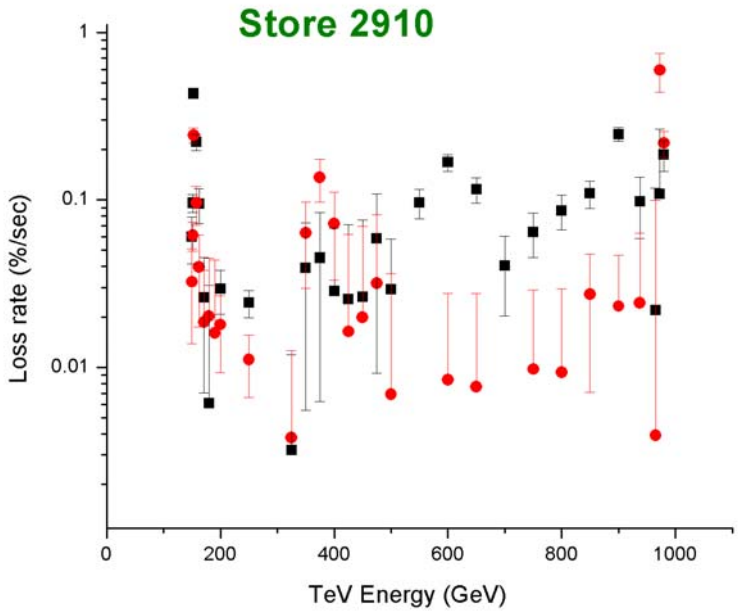
The Normalized loss rate is obtained with simple linear fits, assuming that the relative measurement error on the FBI readings is ¼ % (I am aware that the error on the absolute intensity is much higher!)

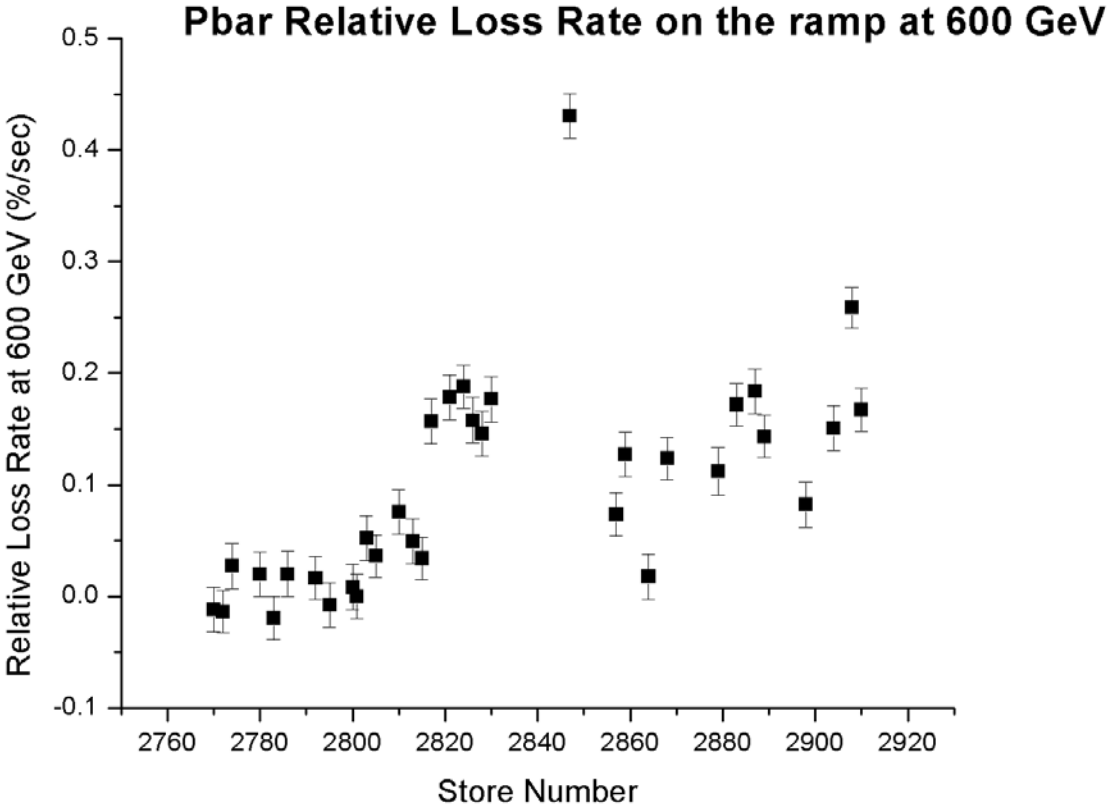
Note that, in this store, for the pbar, there are no very signficant " 400 GeV knee" .. Or bump at 600 GeV.. Not the case for other stores, …


Store 2803
Loss rate (%/sec)
1
0.1
0.01
0
200
400
600
800
1000
pbarLossRate
protLossRate

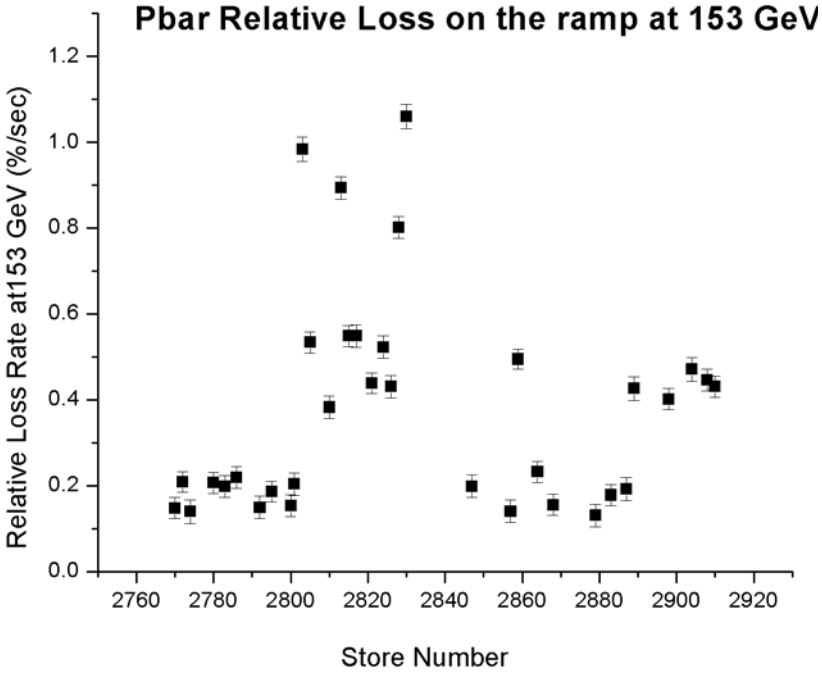

Store 2828
Loss rate (%/sec)
1
0.1
0.01
0
200
400
600
800
1000

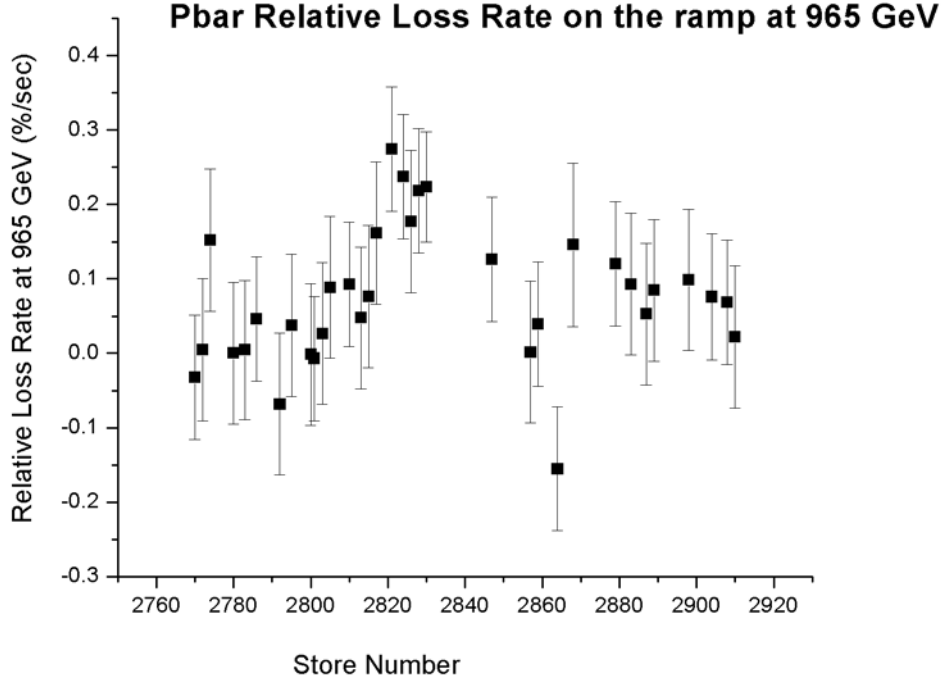

Store 2847
Loss rate (%/sec)
1
0.1
0.01
0
200
400
600
800
1000
TeV Energy (GeV)
pbarLossRate
protLossRate


Store 2910
Loss rate (%/sec)
1
0.1
0.01
0
200
400
600
800
1000
TeV Energy (GeV)

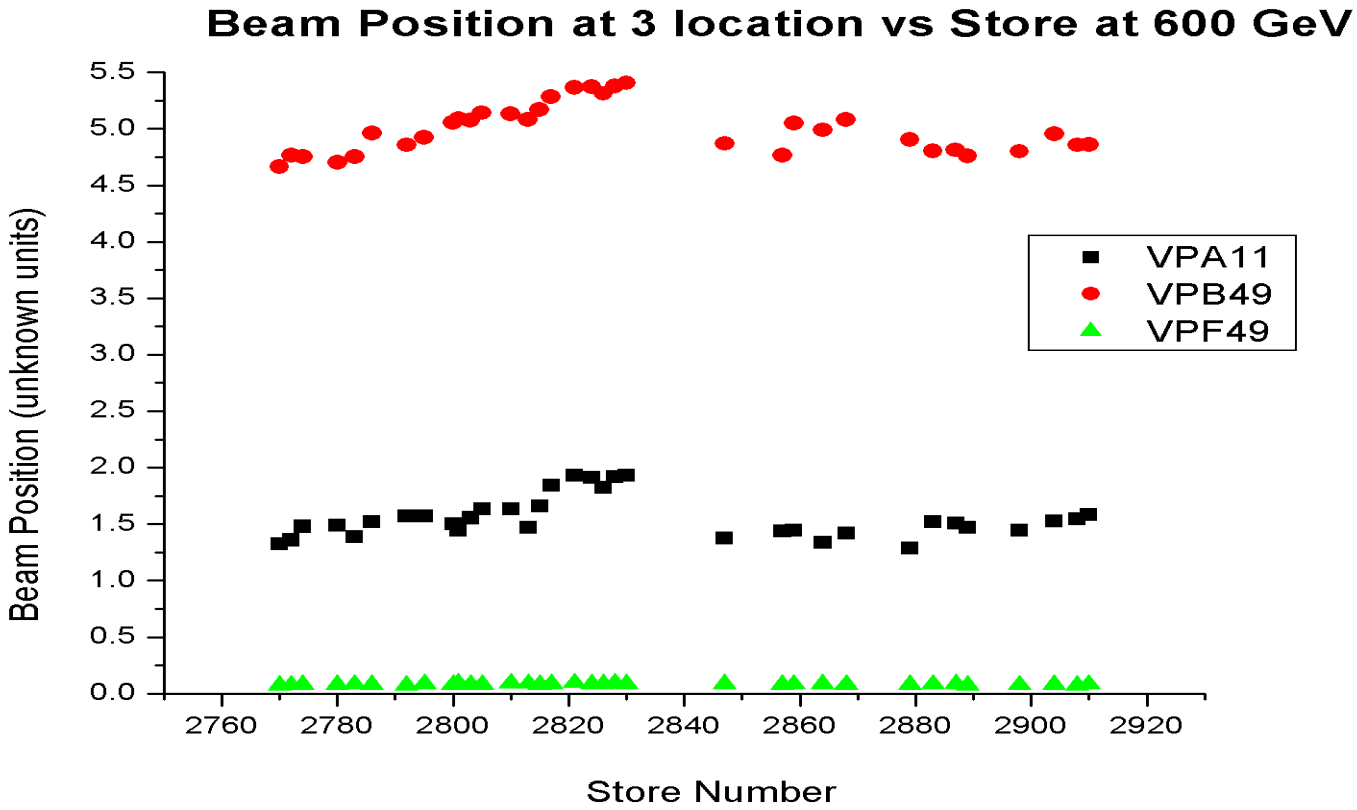


The 600 GeV bump in the loss rate started to appear end of July, gradually.. Store 2847 was exceptionally bad, due to large vertical emittances.

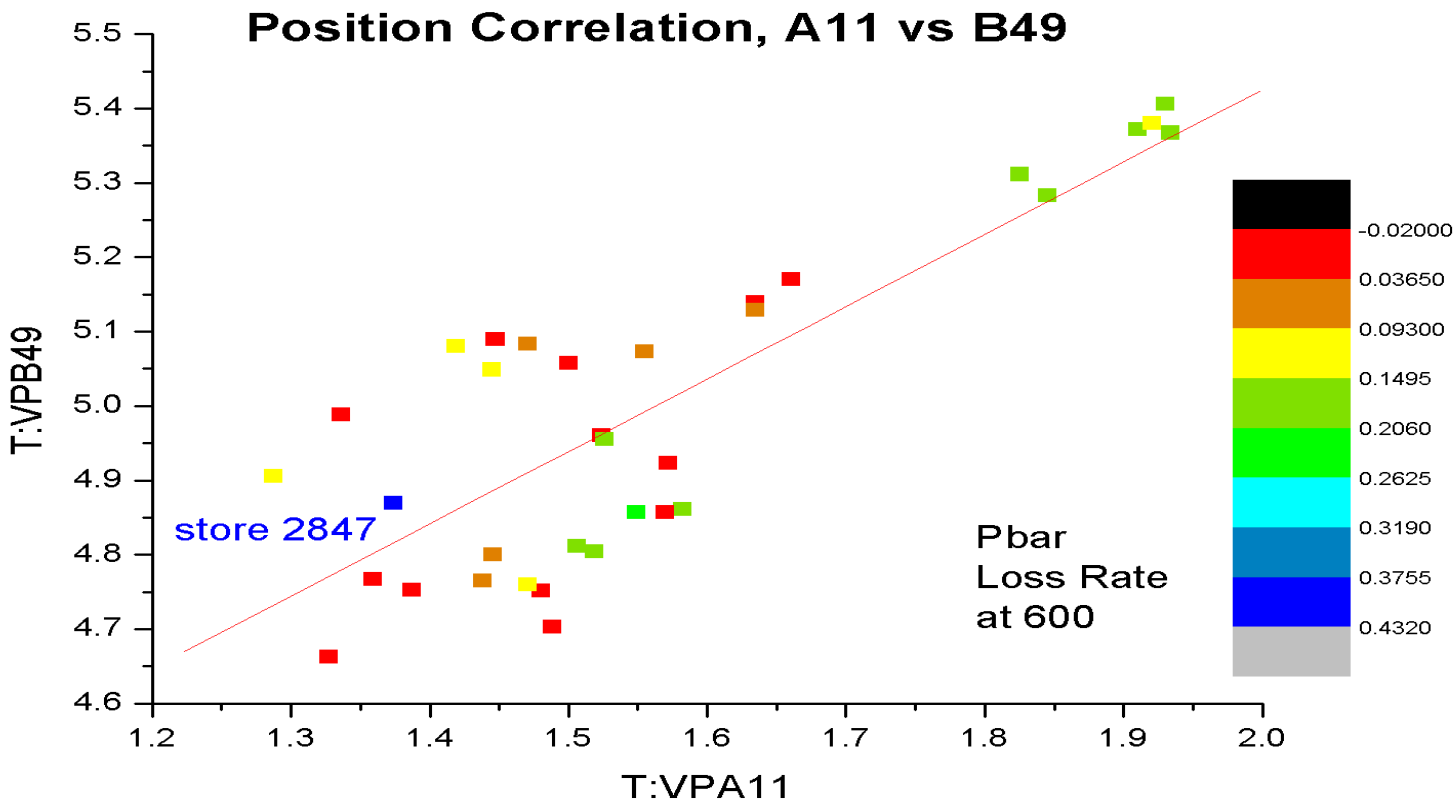




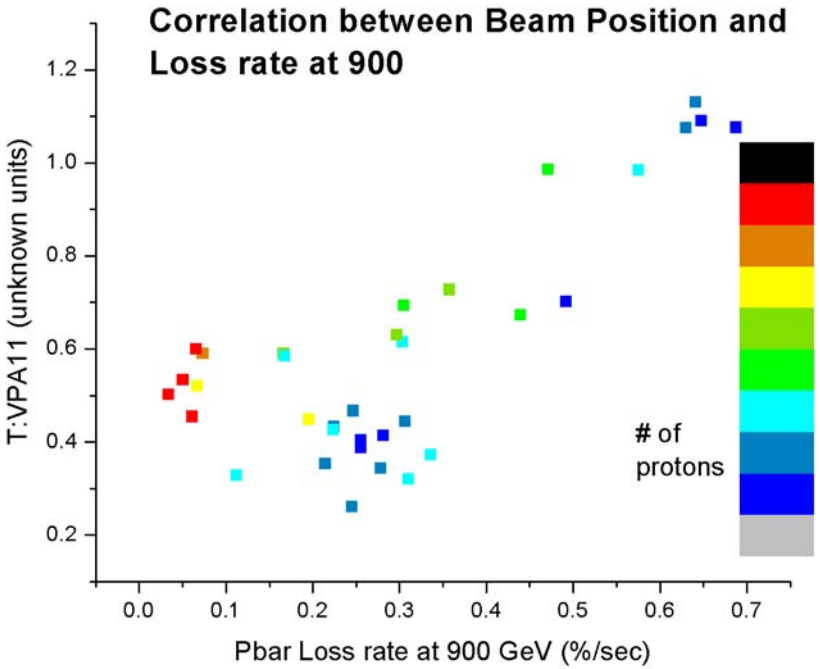
Note that the bump in the Pbar loss rate started to appear end of July, gradually.. Store 2847 was exceptionally bad, due to large vertical emittances. Also, store 2760 to ~2803 had smaller losses at all energies. Finally, the loss rates at the end of the ramp are higher then at 600 GeV. Since they do not last for a long time, they tend to be overlooked…

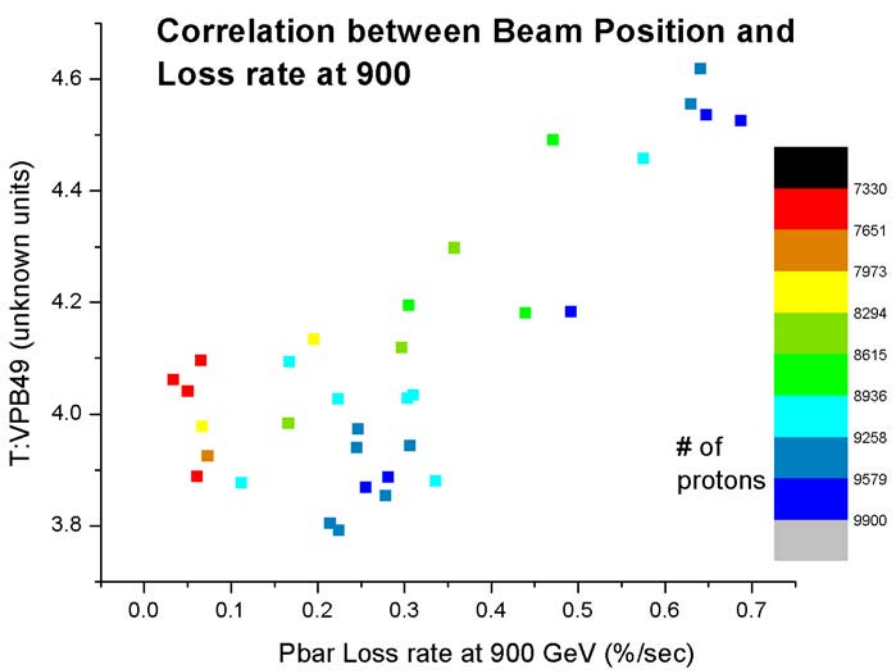


We FTP data for three Vertical BPM (A11, B49, F49) Note that these are "uncalibrated" data. F49 seems to be "dead", or not very interesting..
The positions at A11 and B49 are correlated, which is not too surprising..



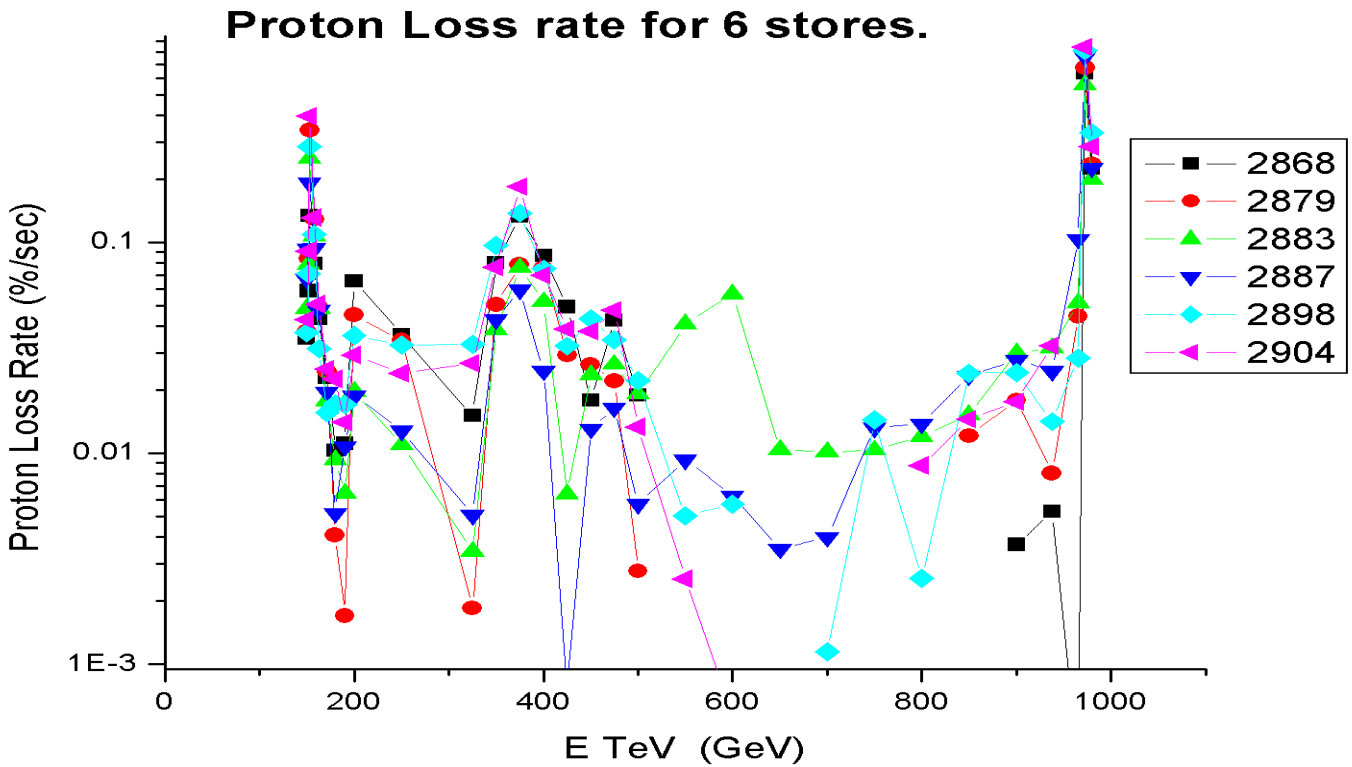
This correlation between these two BPM are shown here. Note that the correlation between the loss rate at 600 GeV and these position is far from established..





However, the correlation between the loss rate at 900 GeV and these positions is established in a the naive statistical sense. The correlation with the proton intensity is also clearly visible.

Proton Losses at 365 GeV..



Bump at 365 fairly reproducible… Also the losses at the end of the ramp..

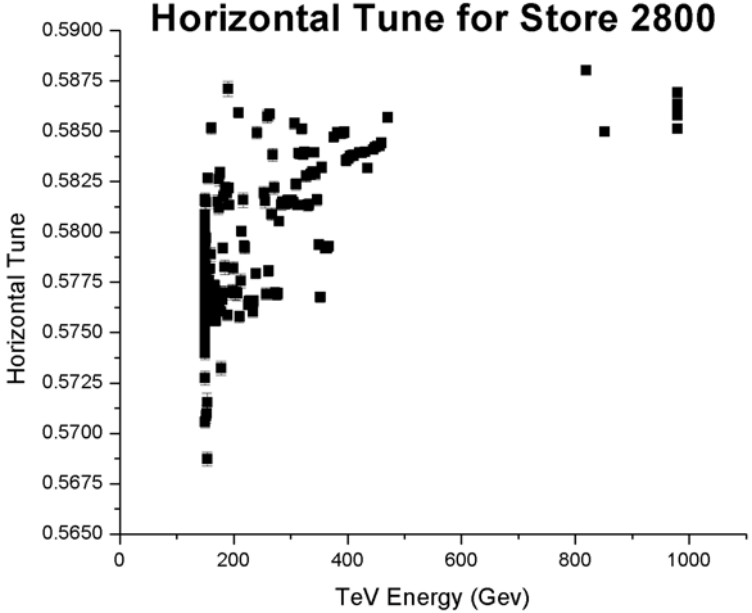
Tunes: hard to interpret.

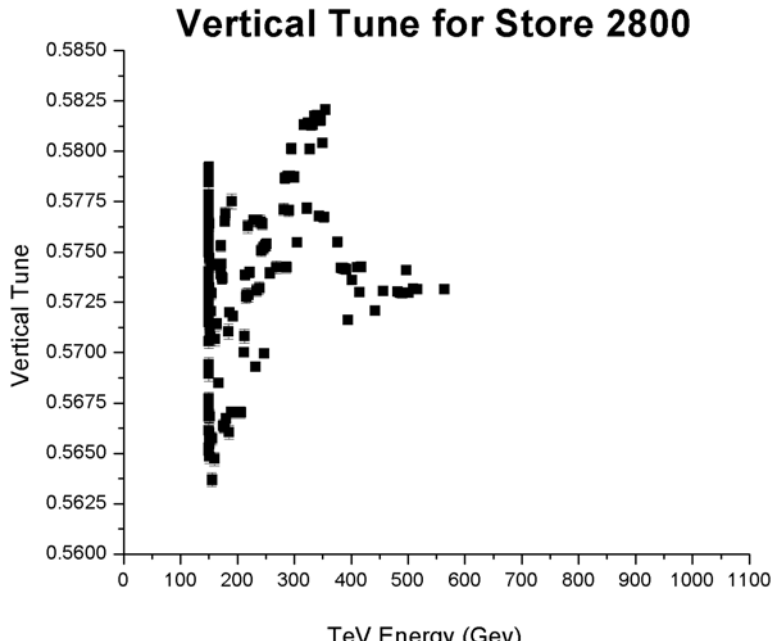
(i) The tune fitter on coalesced data is not 100 % reliable. Indeed, when the Shottky power is low, and no synchrotron satellite lines are visible, no result are reported.

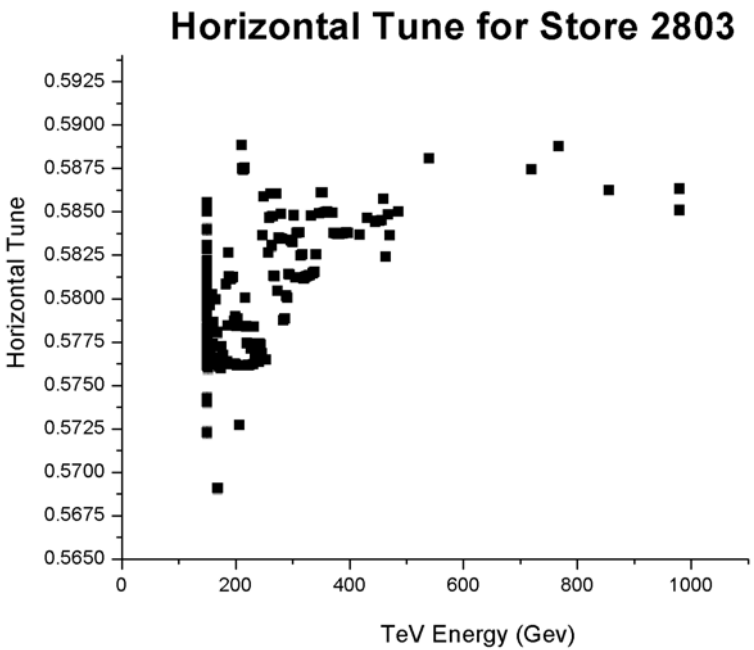
(ii) However, using the same algorithm, based on the 4 Hz data from the `vsamcr' data files, we can get consistent and fair comparison of data, store to store.

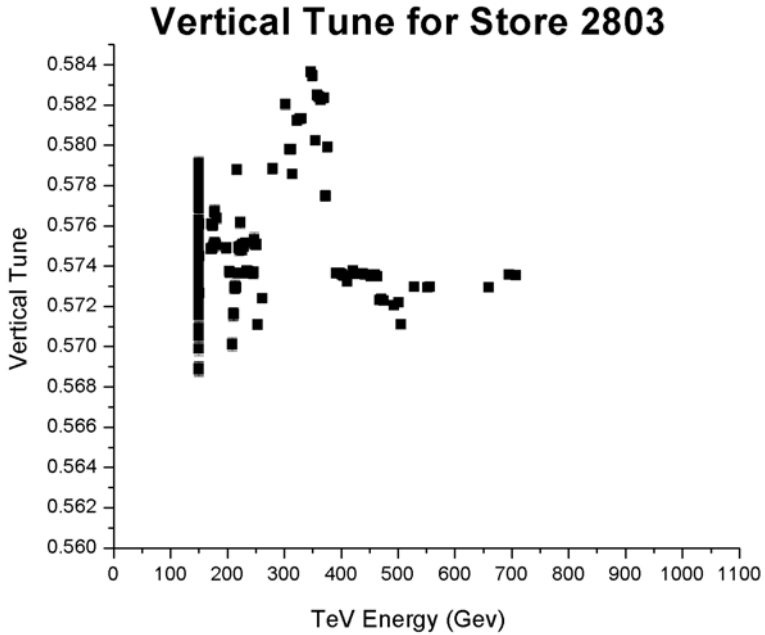
(iii) So, no tune detection might be a good knew (low level of betratron oscillation), seeing a tune misplaced with at a higher power level is most likely bad news.

(iv) We now give a sample of result from this tune fitter, for good stores (low pbar losses at 600 GeV), and for bad stores.

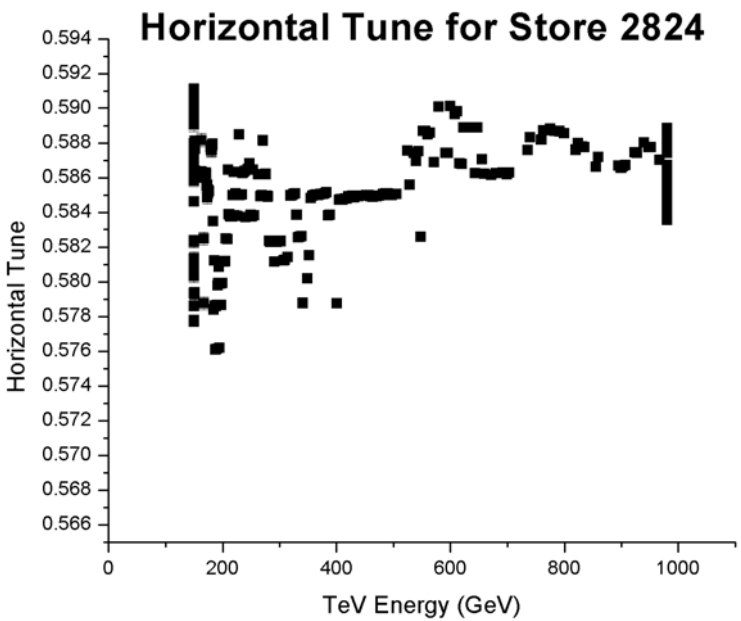

Horizontal Tune for Store 2800
Horizontal Tune
TeV Energy (Gev)

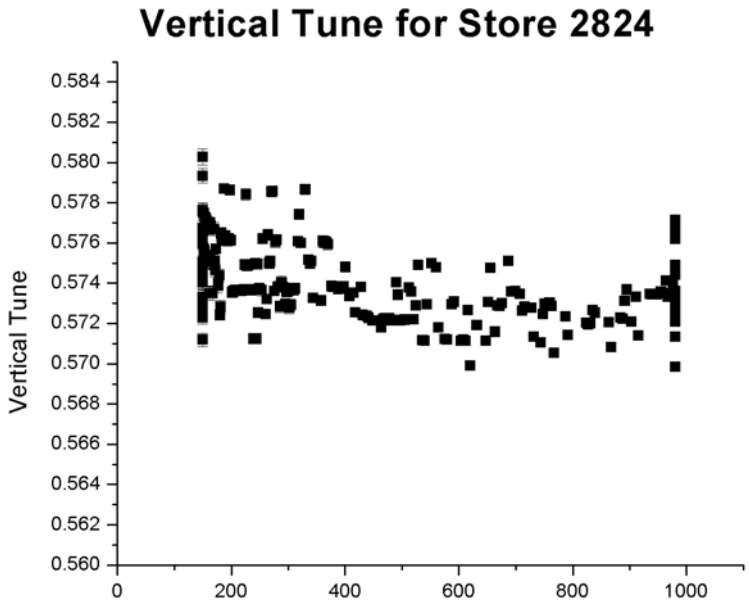

Vertical Tune for Store 2800
Vertical Tune
TeV Energy (Gev)

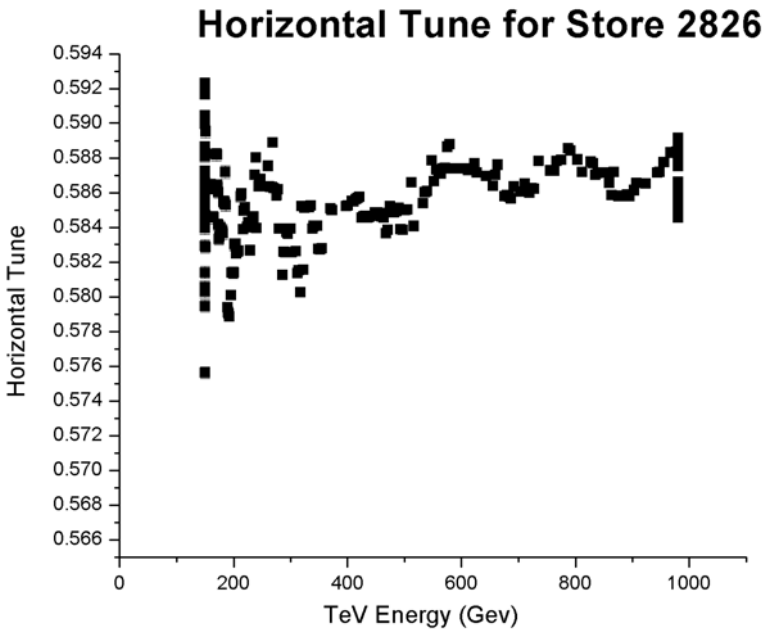

Horizontal Tune for Store 2803
Horizontal Tune
TeV Energy (Gev)

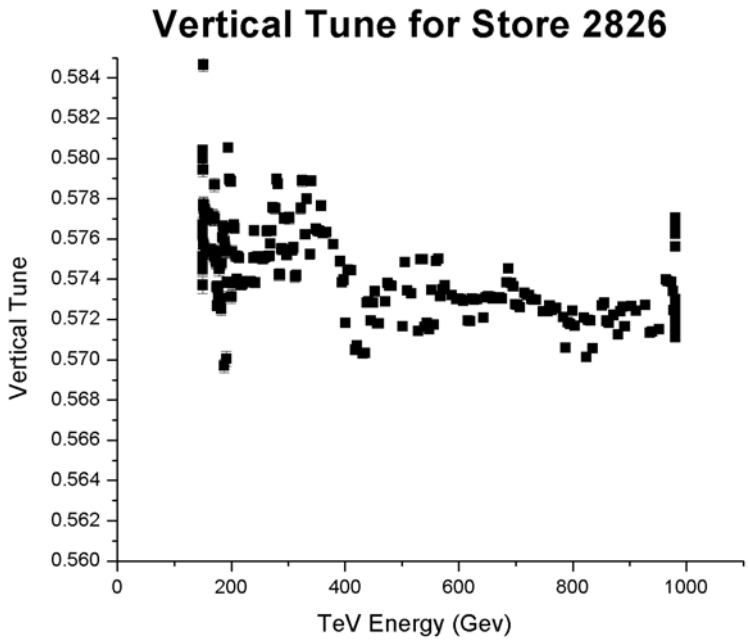

Vertical Tune for Store 2803
Vertical Tune
TeV Energy (Gev)

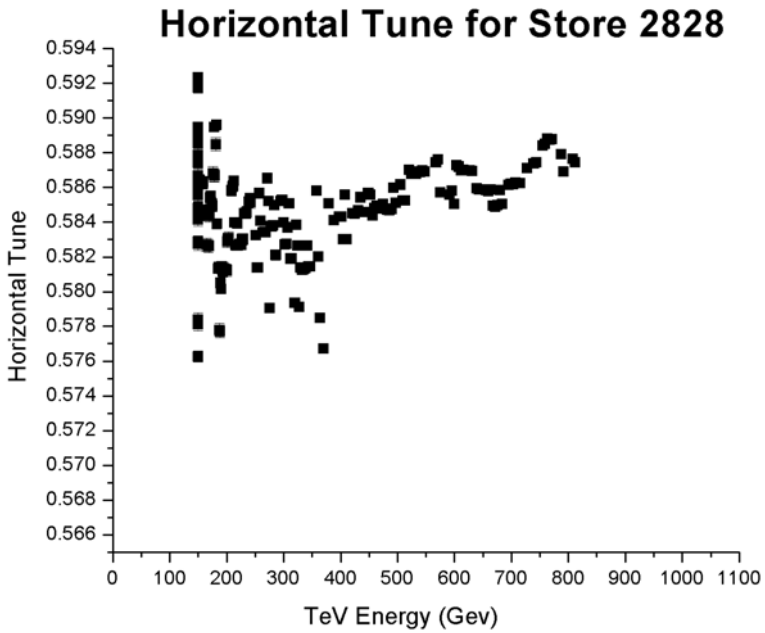
osses -

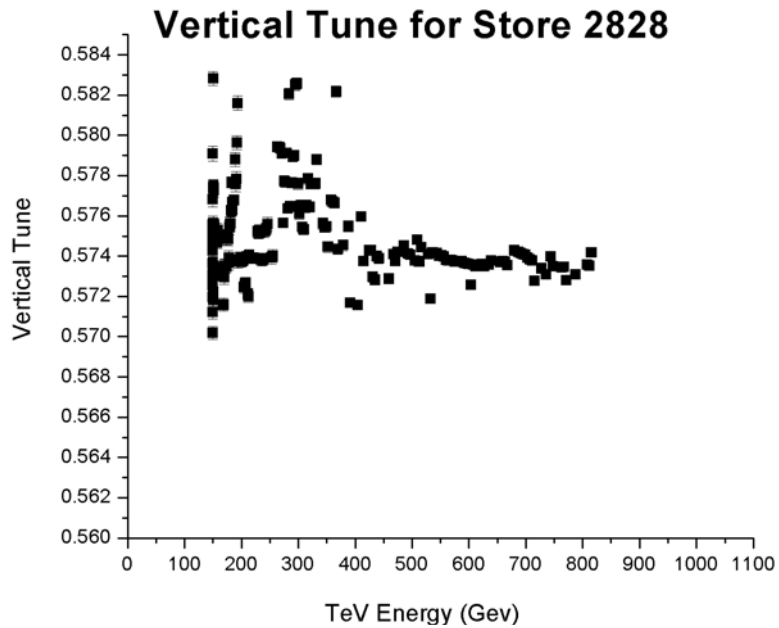

Horizontal Tune for Store 2824
Horizontal Tune
TeV Energy (GeV)

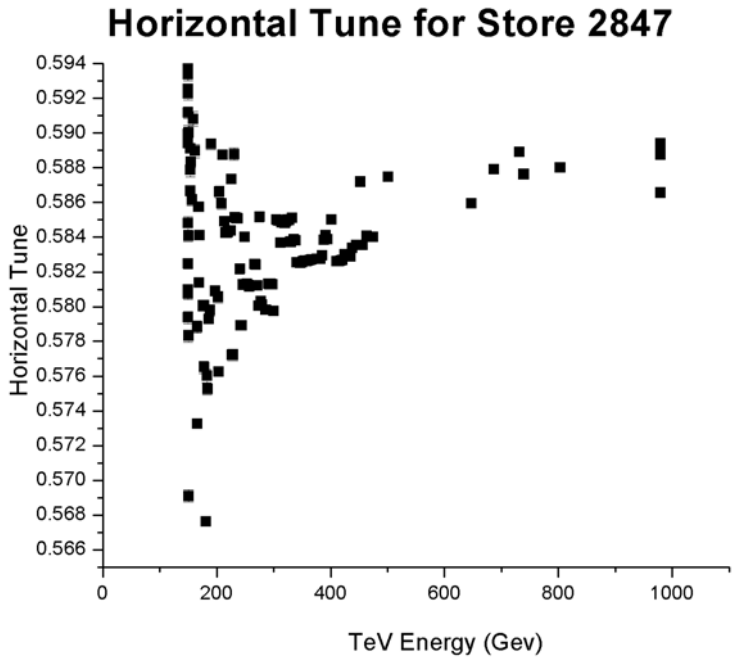

Vertical Tune for Store 2824
Vertical Tune

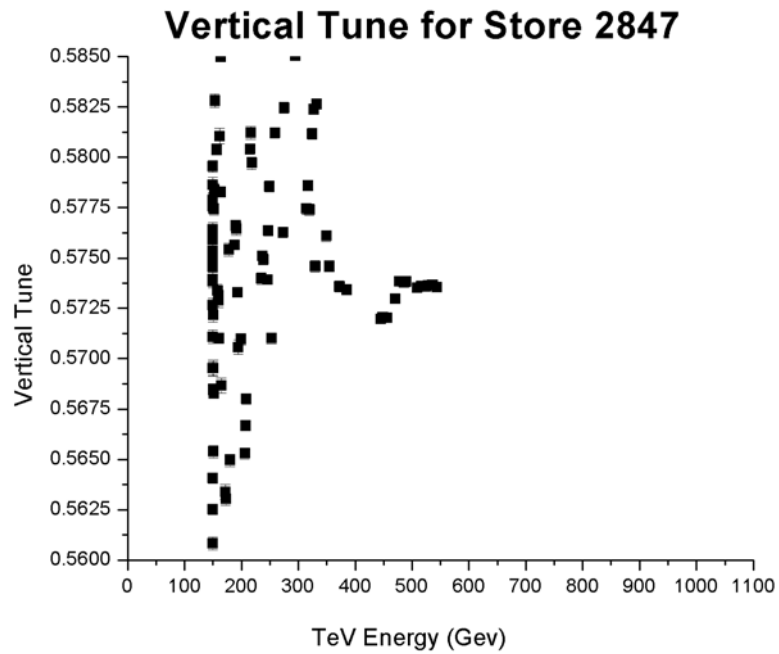

Horizontal Tune for Store 2826
Horizontal Tune
TeV Energy (Gev)


Vertical Tune for Store 2826
Vertical Tune
TeV Energy (Gev)

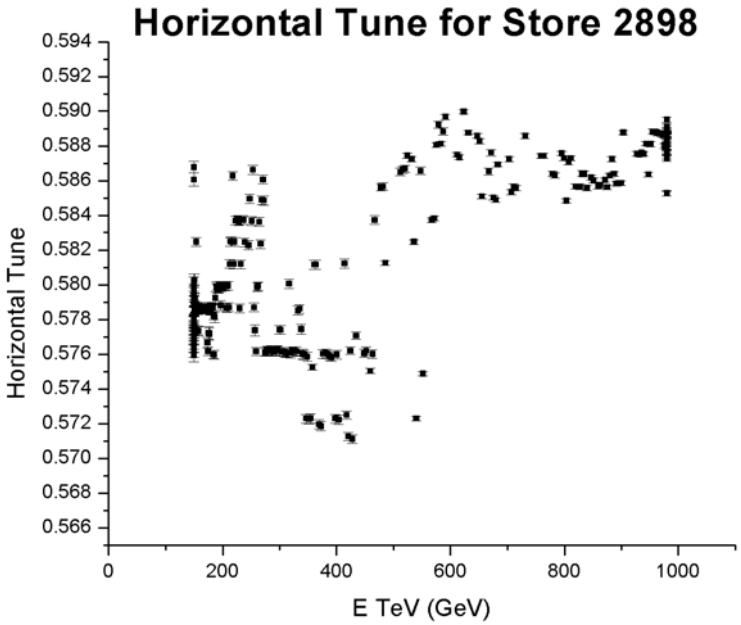

Horizontal Tune for Store 2828
Horizontal Tune
TeV Energy (Gev)

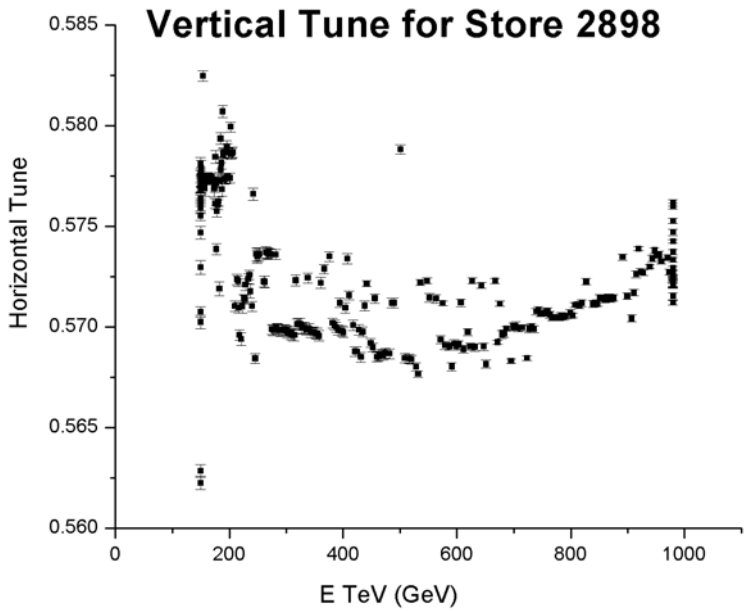

Vertical Tune for Store 2828
Vertical Tune
TeV Energy (Gev)

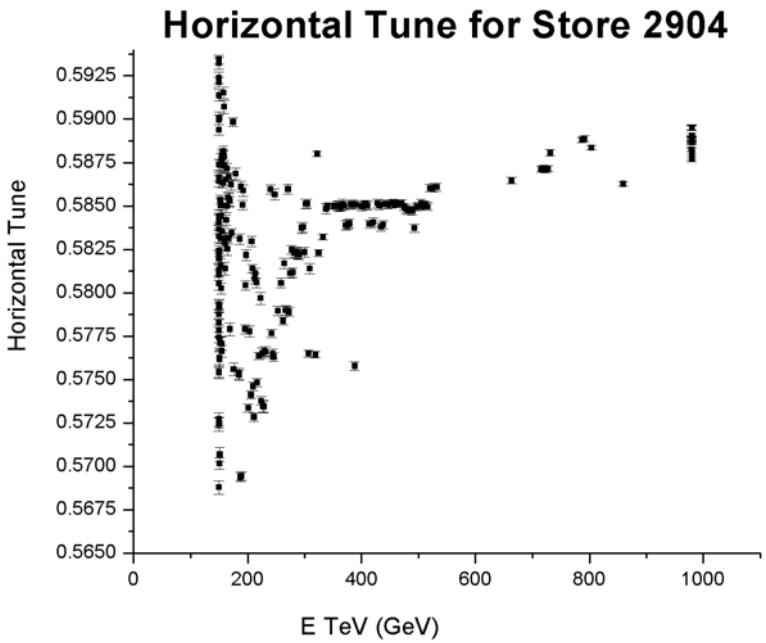

Horizontal Tune for Store 2847
Horizontal Tune
TeV Energy (Gev)

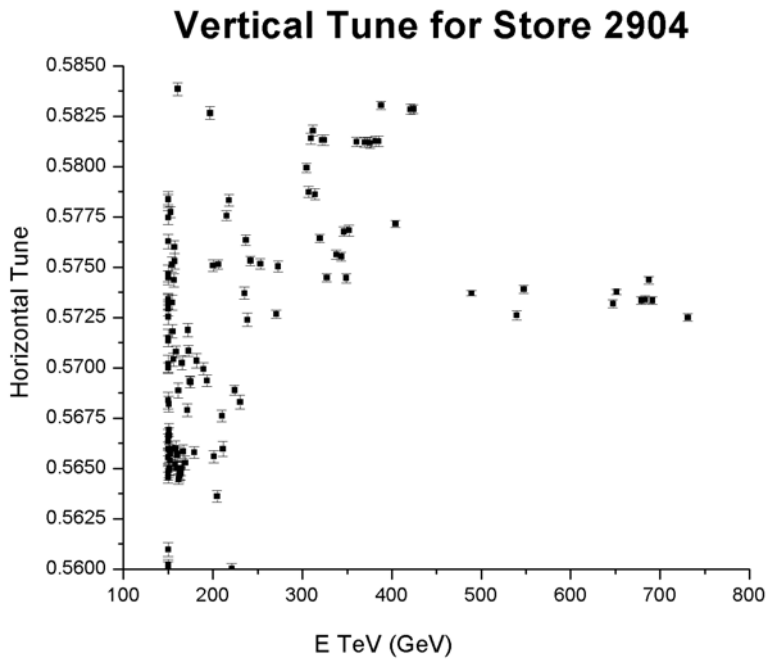

Vertical Tune for Store 2847
Vertical Tune
TeV Energy (Gev)

osses -


Horizontal Tune for Store 2898
Horizontal Tune
E TeV (GeV)


Vertical Tune for Store 2898
Horizontal Tune
E TeV (GeV)


Horizontal Tune for Store 2904
Horizontal Tune
E TeV (GeV)


Vertical Tune for Store 2904
Horizontal Tune
E TeV (GeV)

osses -

Tunes: not necessarily a smoking gun..

At 600 GeV, for at least two store after July 21, the horizontal tunes were close to a bit higher than the nominal values (0.583) by ~ 0.004

However, for store 2898, where the 600 GeV pbar losses were low, the bump in this horizontal tune at 600 GeV is also visible.

Need accurate bunch by bunch tune measurement, so that we can correlate with bunch by bunch loss rate.