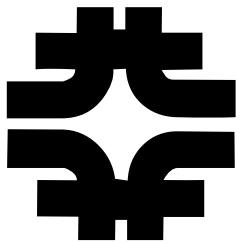
On Tevatron Proton Lifetime at 150 December 3 Study vs Store data.



Paul Lebrun

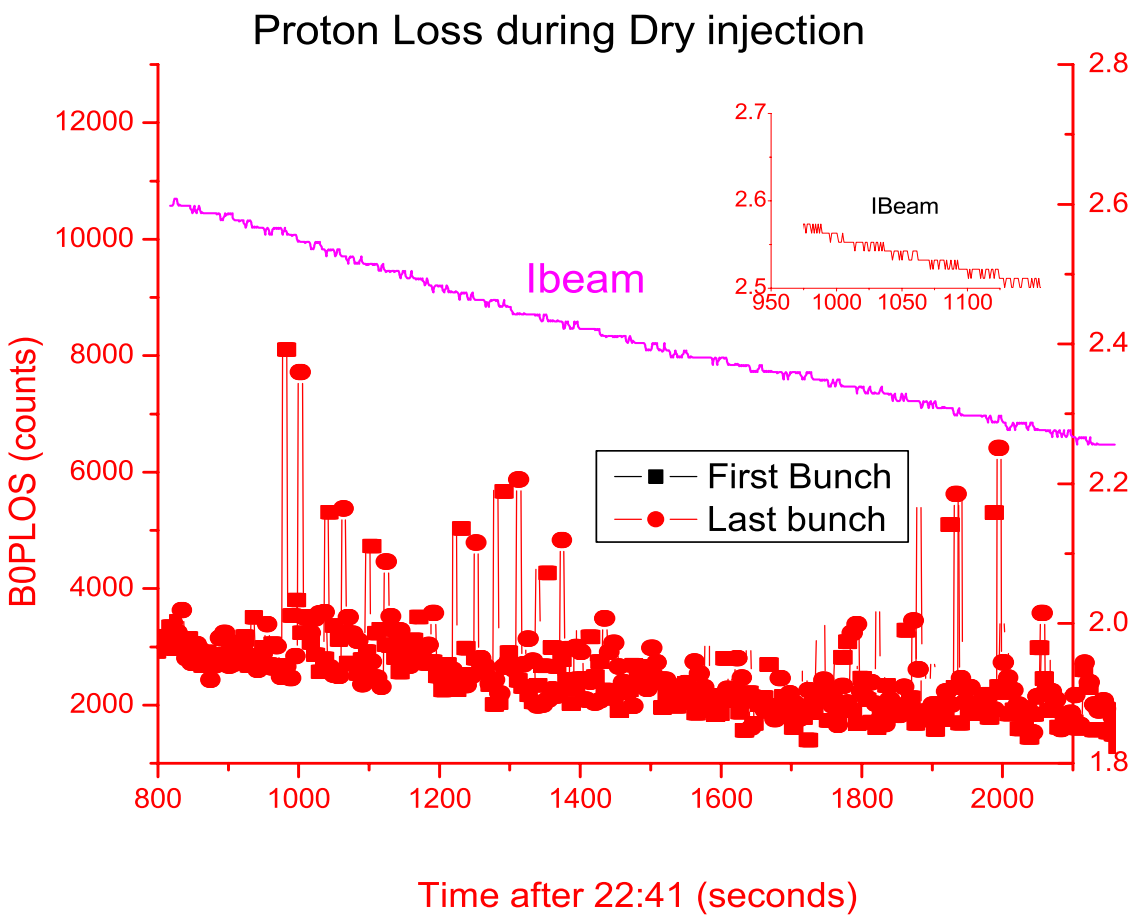
Fermilab

January-December 2002

December 3 Beam Study: Addendum

- Frank Zimmerman already wrote a report on this study (doc # 303). This document provide further detail on the motivation, context and results on the first part of the study:
  - Motivation:
    - Does the pbar beam influence the proton life time at 150 ?
    - Does the firing of the pbar kicker influence the proton beam ?
    - How do we fit such lifetimes?
    - Is this proton lifetime correlated with anything else?
- Results:
  - The "dry firing" of the pbar kicker does not affect the bunched proton beam (Good)
  - Lifetime is always well describe by a "non-linear" exponential decay.
  - No strong evidence that pbar affect the proton lifetime.
  - Correlated with the bunch length decrease rate, not much else.

Discussion: “dry-firing” experiment.



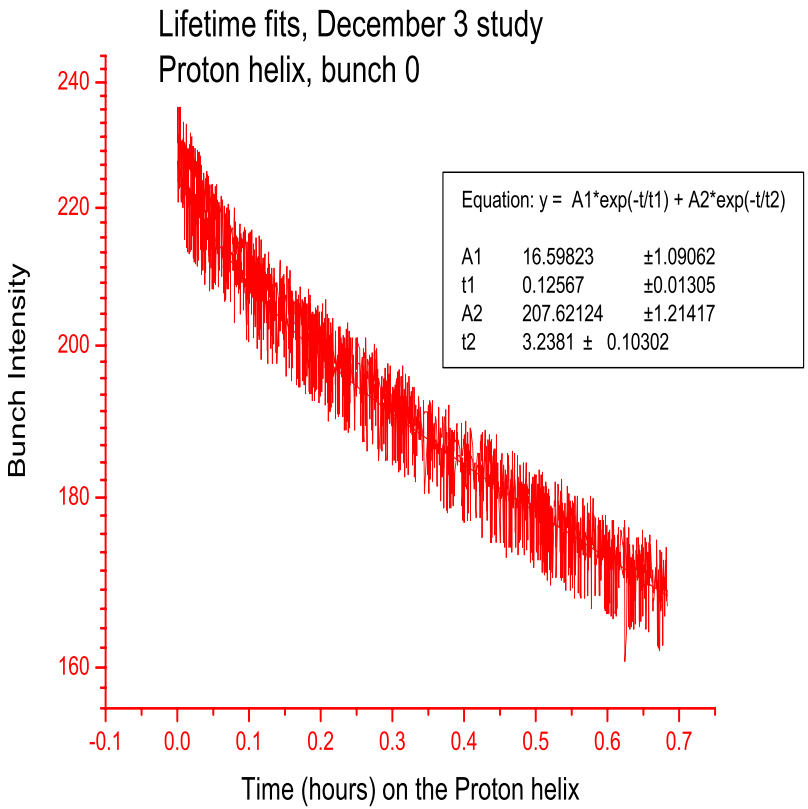
Clear correlation of sudden burst of lost protons with the “dry firing” of the pbar kicker was observed. See fig 14 of Frank Z., and this plot (produced on January 7 2003, from archived D44 data). Frank Z. noted in his log book that the first dry firing started at 22:55, the D44 clocks placed at 22:48 P.M. (977 seconds after 22:41) .Oh well…

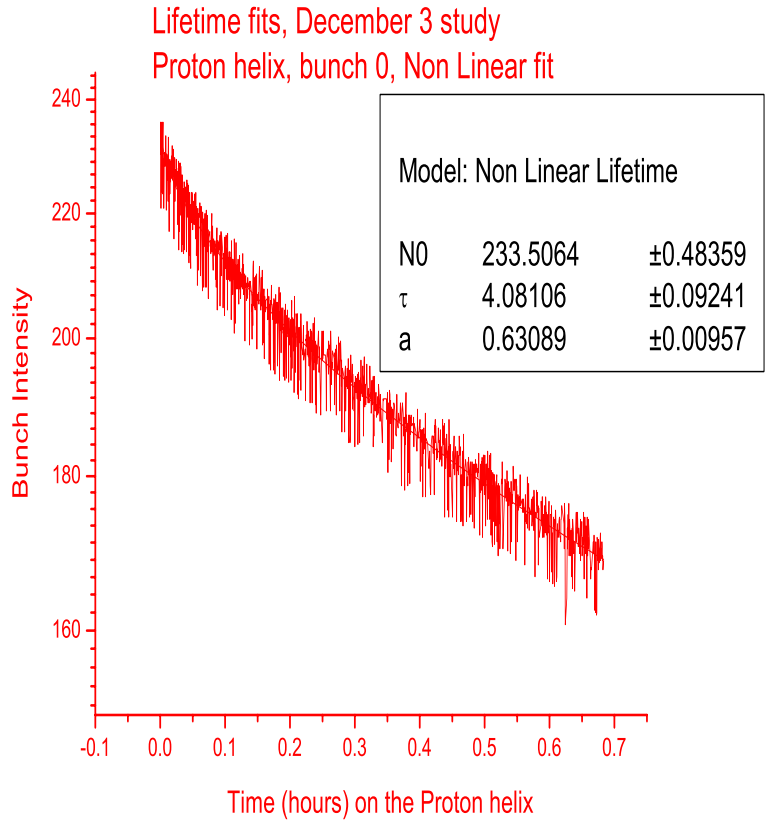
Note : No discernal change in Ibeam < .0.4 %

Lifetime fits.

- On figure 16, various fits are presented. The "sqrt(t)" lifetime seems to fit better. Hovewer, a more general phenomenological fit could be of the form:
  - $N(t) = N0 \exp(-(t/\tau)^a)$
  - This is the form that fits "best". The exponent is typically between 0.4 and 1.0
- Within the context of a simple diffusion model (for instance, see Mike Syphers lecture note, October-November 2002, or short talk presented by V. Lebedev, Tevatron meeting, January 3 2003), one expect the bunch intensity to follow:
  - $F(Z,t) = \text{Sum } (c_n \,.\, J0(\lambda_n.\text{Sqrt}(Z)) \exp((-\lambda_n^2)*t/4)$
  - Where Z is a normalized "radius" in one of the two transverse planes, J0 are Bessel functions
  - => Sum of exponentials. Note: typically, in 1D model, the lifetime decreases versus time.
- This topic has been previously studied, see talk presented at the RunII Commissioning meeting, P.Lebrun, "On Tevatron Lifetime, Beam and Luminosity", November 7 2002.

Non-linear lifetime, I~ e $^{-sqrt(t/\tau),}$ vs multiple lifetime.





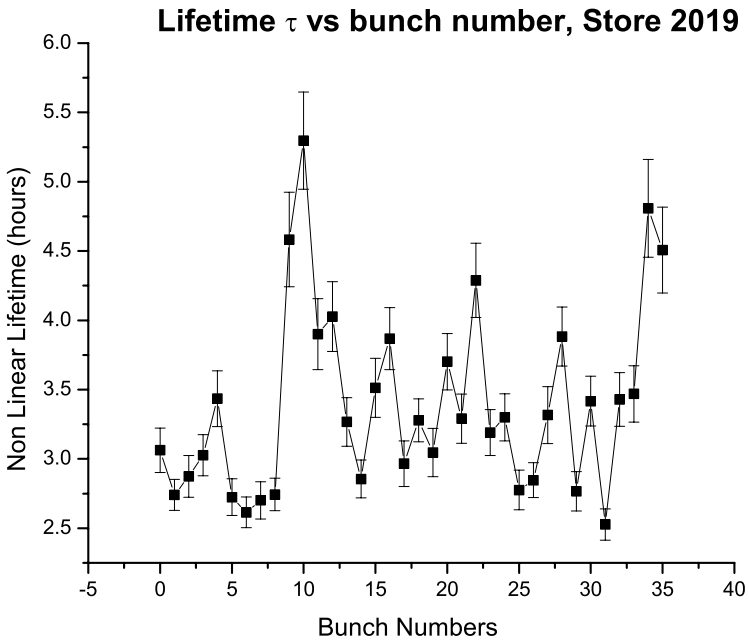
Non-linear lifetime, vs multiple lifetime, II

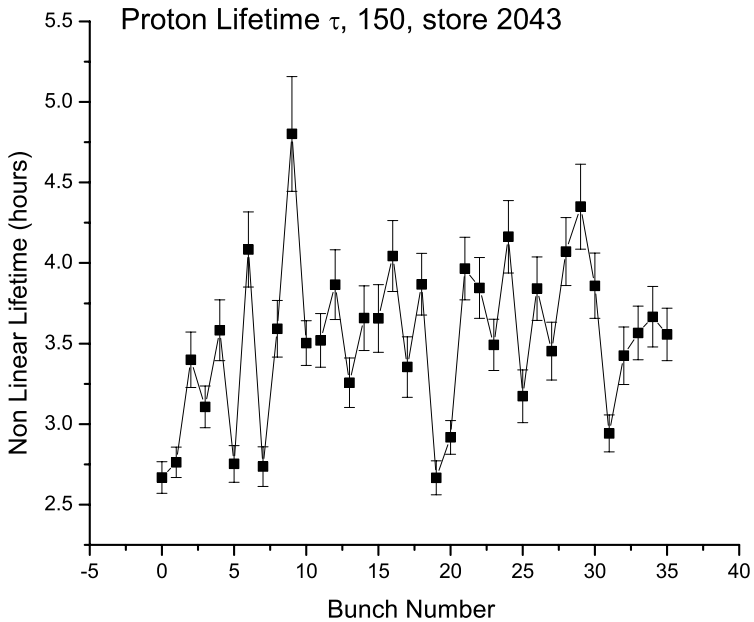
- Both fits look god, but multiple lifetime fits has one additional parameter. At short times, 2-lifetime fits not were not always successful (see previous talk, November 7.)
- The lifetime typically increases vs time…This goes against a very simple 1D diffusion model, where at t=0, there are no losses. A more complete model in 6D, with multiple sources of diffusion and multiple apertures could probably explain a lifetime increasing with time… (more thinking is needed!)
- Conversely, using the multiple lifetime model, "a small beam component disappear fast at early time.. ". The trouble with this analysis approach is:
  - The ratio between the these two beam intensities is strongly correlated with the two lifetime (one additional parameter.)
  - No clear-cut between these two distinct population..

  However, this model will have a physical interpretation: the small population with a short lifetime probably corresponds to the tail of Δp distribution.

  For sake of fitting reliability and simplicity, use the non-linear fit from now on..(one less parameter to worry about).

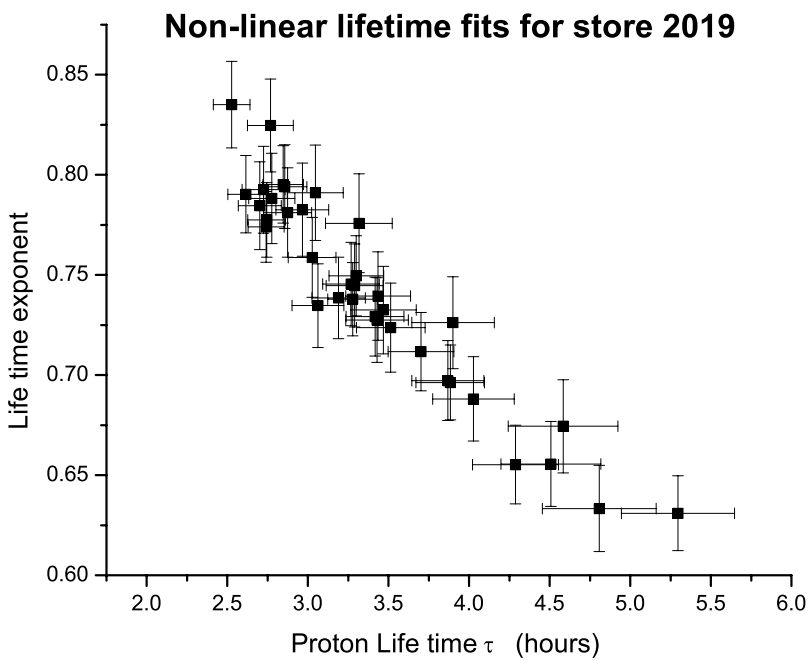
Are these Non-Linear lifetime values dependent on the presence of the pbar beam?

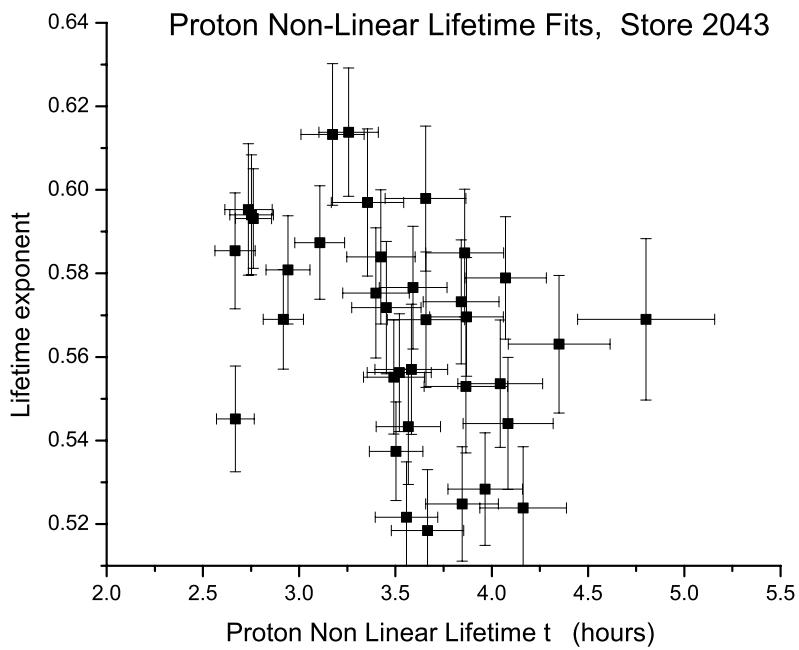




- Perform these non-linear fits for two stores, before and after the dedicated study. Compare these lifetimes to those measured on December 3 2002 at ~22:50

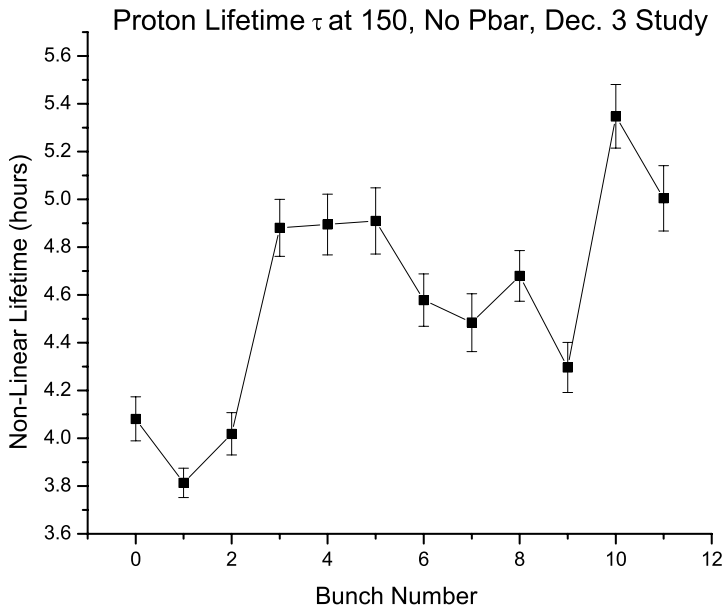
Non-Linear lifetime fit for store 2019/2043

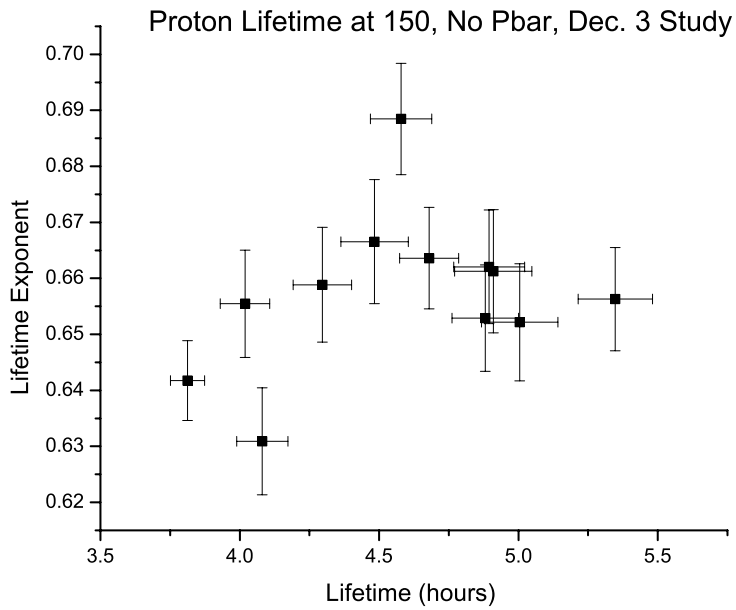




- **The exponent "a"seems to be correlated (sometimes) with this non-linear lifetime value τ**

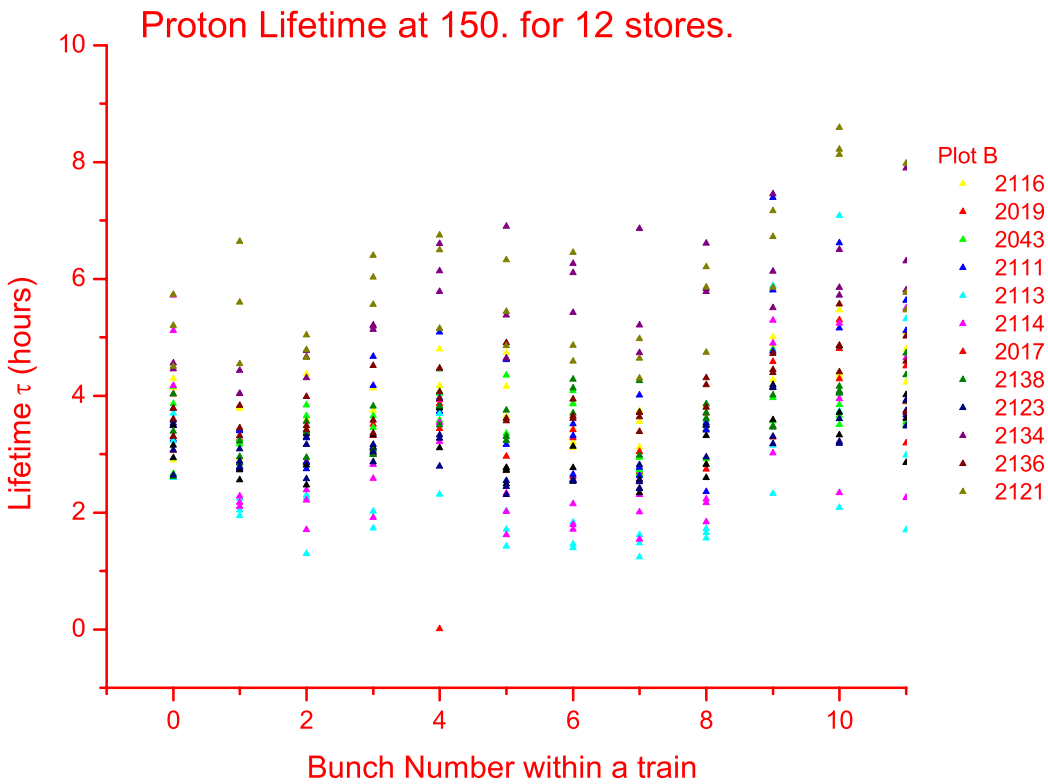
Non-Linear lifetime fit Without Pbars

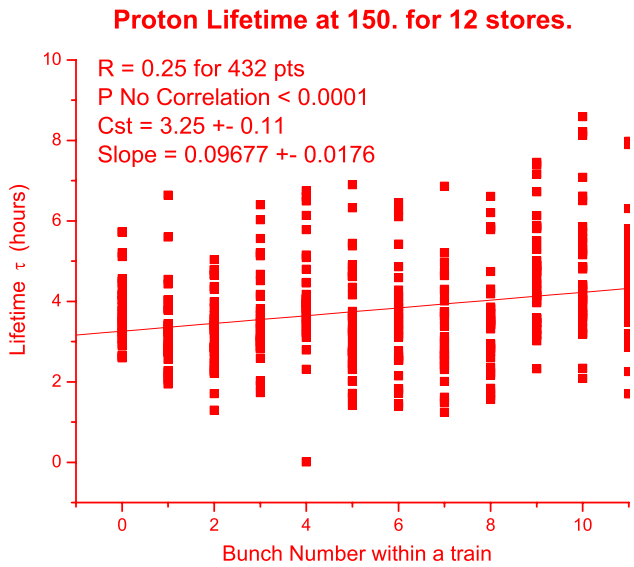




- As much bunch to bunch variation.
- No significant difference! Pbar are not affecting significantly the proton lifetime at 150

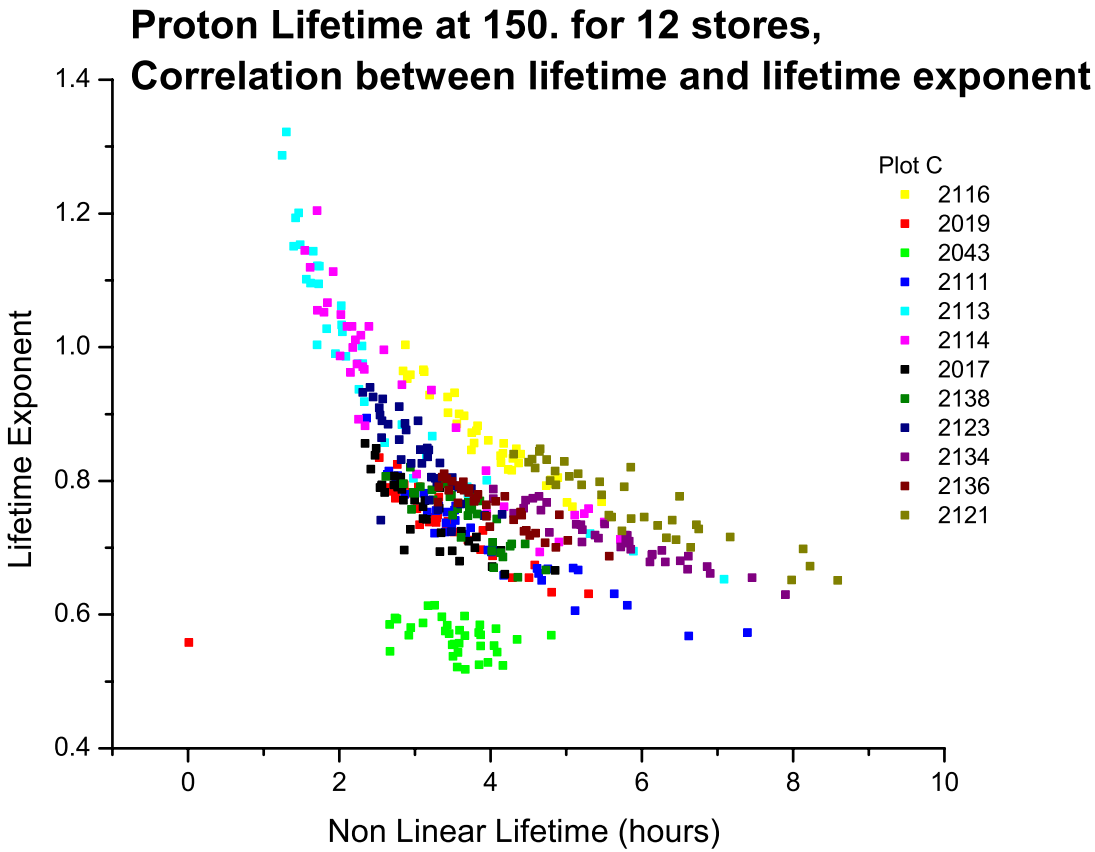
Correlation between τ and other variables.. Based on 12 stores, some fairly recent..





Weak, but statistically Correlation between Bunch number within a train and lifetime!

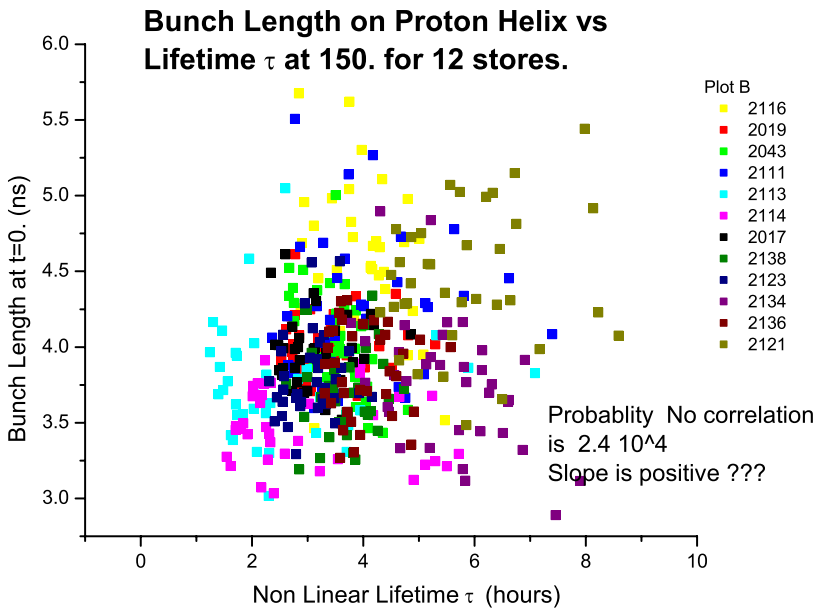
Correlation between τ and Exponent

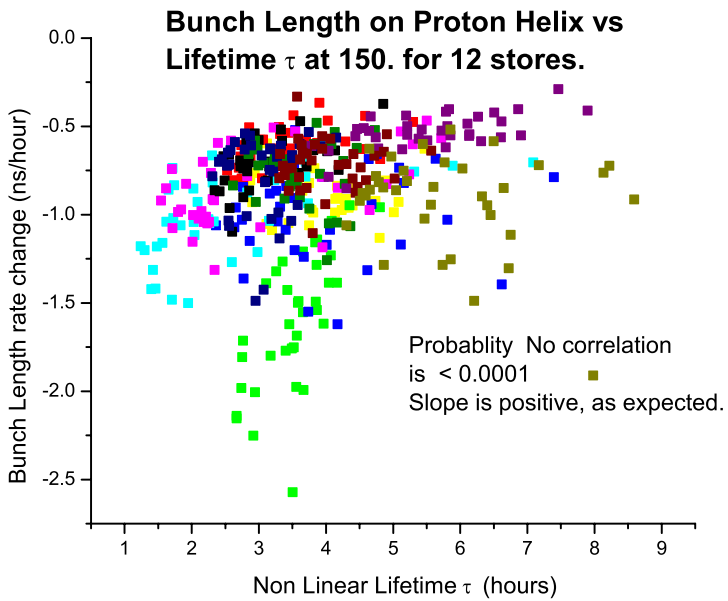


Store 2043
Was the exception...

We also have quite a
Bit of store to store
variation

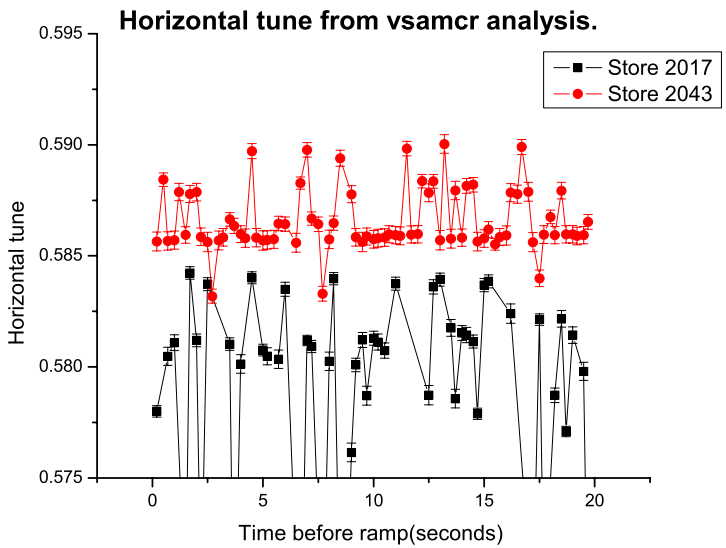
Correlation between τ and bunch length

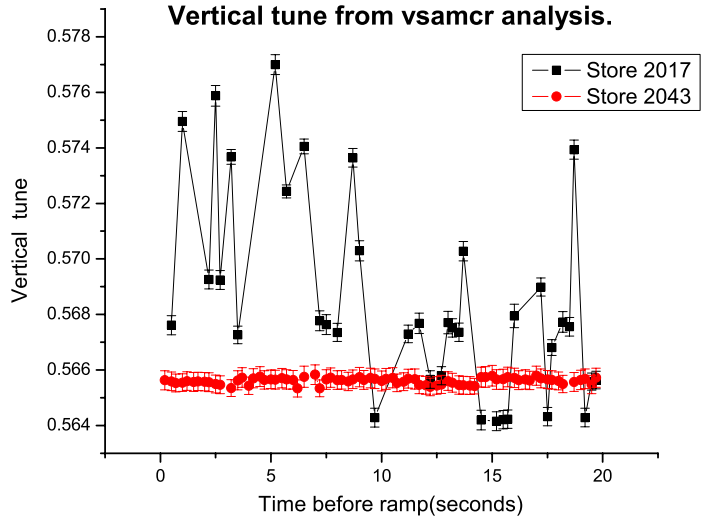




These correlations are weak. Note that the "bunch length" are the one reported by SBD, I.e., based on Gaussian fit. The correlation are weak, once again probably statistically significant (definitely for the bunch length rate change).

Store 2043 vs 2019.. Tunes?





The betatron tunes extracted from vsamcr files, before we ramp, are shown here for these stores (the tunes were not "measured" via the new TeVTuneTracker software during pbar injection, we have to rely on the ramp data). For store 2043, the "ghostline" at 0.565 must have very prominent, and could have excited the beam, leading to a shorter lifetime. Perhaps… Other thing could have happened!.

Status…

The pbar kickers do not affect much the proton beam.

The pbar beam does affect (much!) the proton lifetime. If we want to look for such an effect, we first mist control the store-to-store and bunch-to-bunch variation better.

Mostly un-explained fluctuation store to store, worse, bunch to bunch in what the lifetime really is or should be. A correlation between longitudinal scraping rate and lifetime is definitely established.

Other hidden variables are at play:

- Tunes
- Shottky power.. Beam excitation due to "ghostline"
- Detailed longitudinal bunch shape (tails!) ➔ need access to "TeV Mountain Range data"
- Transverse emittances (corrected with proper momentum spread)

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