Note on some observations of the signals from PSR electron detector

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1. Introduction. In this paper I present some analysis of the signals from the electron detectors (ED52x, y) installed in the PSR straight section N°5. The signals were recorded with stainless steel vacuum chamber installed for stable and unstable conditions, data files *103a and *103c respectively. As was proven by the subsequent experiments with TiN coated vacuum chamber, when the number of electrons detected in the section N5 decreased drastically but instability threshold did not changed, electron cloud in the section N5 is not the primary reason for instability. But observation of the signal from electron detector in this place can reveal some important features of the mechanism of electrons accumulation and its interaction with unstable beam. For this reason I used analysis on large time scale i.e. details of signals during one turn were not considered. Amplitude and position of the maximums of the pulses were found at each turn and this numbers attributed to each measurement point (i.e. turn).

2. Unstable beam. The trace of the signals from electron detectors ED52x, ED52y and wall current monitor WC41 are shown in figure 1 as it were recorded to files *103a. As one can see electron signal becomes detectable after about 2500 turns when stored beam current is near the maximum. After about 3500 turns electron signal is so large that it saturates amplifier. For further analysis electron signal is normalized on beam current (maximum of the electron detector signal is divided by the maximum of the wall current monitor signal). Normalized signal is shown in fig. 2. Note that signals from horizontal and vertical detectors are similar in shape but different in amplitude. It is most probably explained by not centered beam position, the beam can be closer to the detector in the horizontal plane than in the vertical one. By observing the same plot in logarithmic scale in fig. 3 we can easily observe step like behavior of the electrons accumulation. Number of collected electrons grows exponentially with turns up to point A where it saturates and stays on the same level up to point B. At this point exponential growth starts again with larger rate up point C where it saturates again and starts to growth at point D. The reason of the saturation (and even decreasing of the number of electrons in vertical detector) can be understood if we look at high frequency oscillations visible on the trace of the vertical signal. From the spectrum of these oscillations shown in fig. 4 we see that its frequency is equal to fractional vertical betatron tune of the beam. It turns out that electron detector is sensitive to distance to a beam therefore it works like BPM and proton beam movement is reflected in electron detector signal variation. The amplitude of betatron harmonic of the electron signal is shown in fig.5 together with average electron current. We see that the first saturation at point B occurs just at the moment when vertical oscillations start to growth. It looks like oscillating proton beam clears out accumulated electrons. But when amplitude of the vertical oscillations becomes larger some other mechanism increases rate of the electron accumulation. Fig. 6 provides clear indication that something changes in electron accumulation mechanism after 3500 turns. The distance between proton beam maximum and electron pulse maximum is shown in this figure and it suddenly decreased by about 25 ns (electron pulse moves from the gap closer to proton beam maximum) together with increasing the electron accumulation rate. The profiles of the signals from WCM and ED52y at one turn are shown in fig.7. Note that as I mentioned above electron cloud at the section N5 doesn't act on the proton beam motion but proton beam motion acts as external force on the electron cloud. It gives possibility to study an interaction of the electron cloud with the proton beam without analysis of self consisting problem of coupled oscillations.

3. Stable beam. The similar analysis was done for the case of a stable beam (data from files *103c were used) . Figures 8-12 show the results. As seen from fig. 9 the initial growth rate of the electron signal is the same as in the previous case and saturation occurs on the similar level. But it is hard to say definitely that saturation is connected to vertical oscillations while there is betatron amplitude increasing at the point of saturation. Just before extraction vertical instability develops and we can see from fig.10 that jump of the amplitude of betatron oscillations leads to sharp decreasing of the number of electrons. And again fig.11 shows that electron pulse maximum jumps closer to proton beam maximum just prior to instability.

4. Conclusion. The simple analysis of data from the electron detector at section N5 indicates that possibly two different mechanisms of electron accumulation (and/or production) exist in the ring. One has relatively slow accumulation rate and takes place before instability occurs. The second is connected with developed transverse proton beam oscillations. Proton beam oscillations cleans out electrons at the first moment. It may be useful to repeat "beam shaking" experiment while observing not only instability threshold but also signal from electron detector. Simultaneous recording of BPM signal (WM41) and electron detector signal can help to answer the question what is the first electron burst or vertical oscillations. And it is very interesting to make the comparative analysis of the electron signals at section N4 where they are much large.

5. Acknowledgements. I wish to thank Robert Macek who provided experimental data from PSR storage ring.

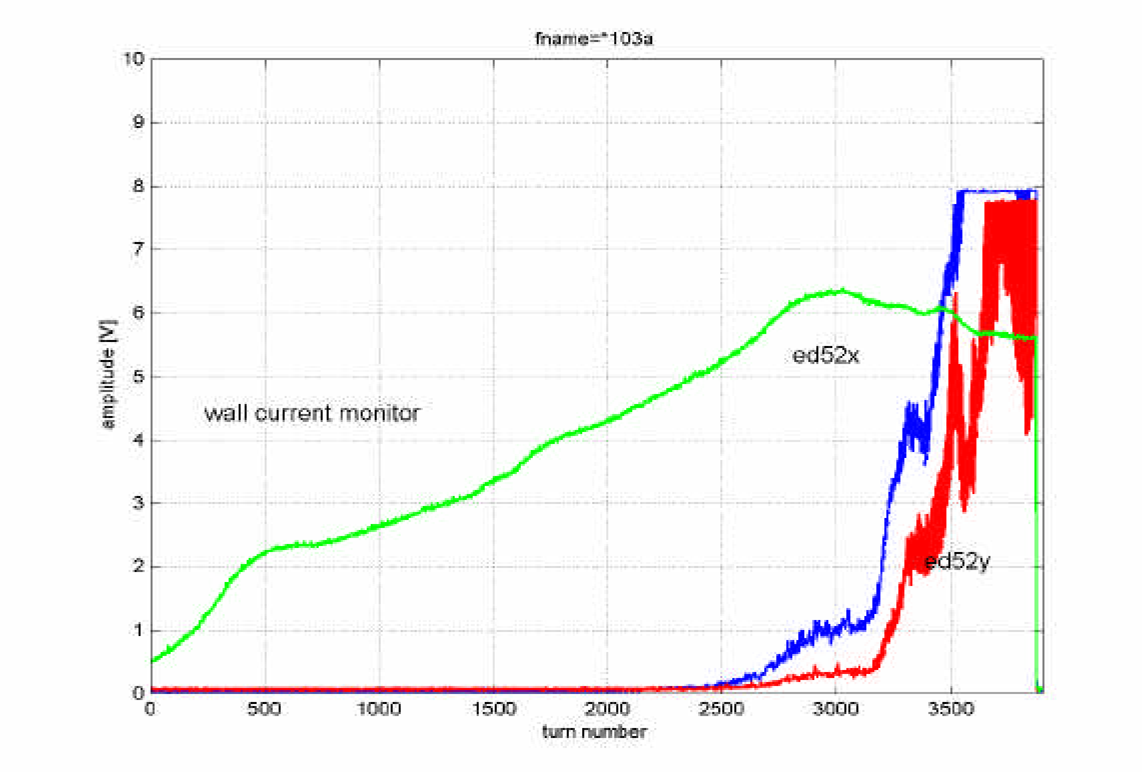

Figure 1 Trace of WC41, ED52x and ED52y. (unstable operation)

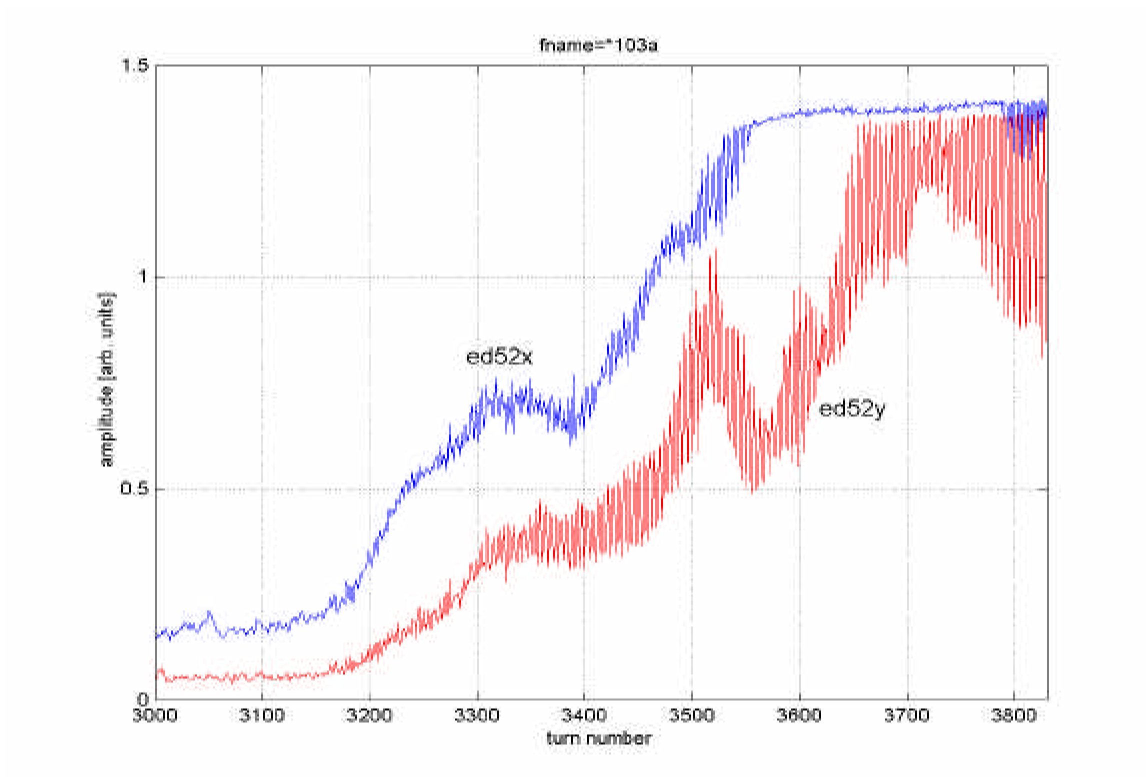

Figure 2 Normalized signal from the electron detector.

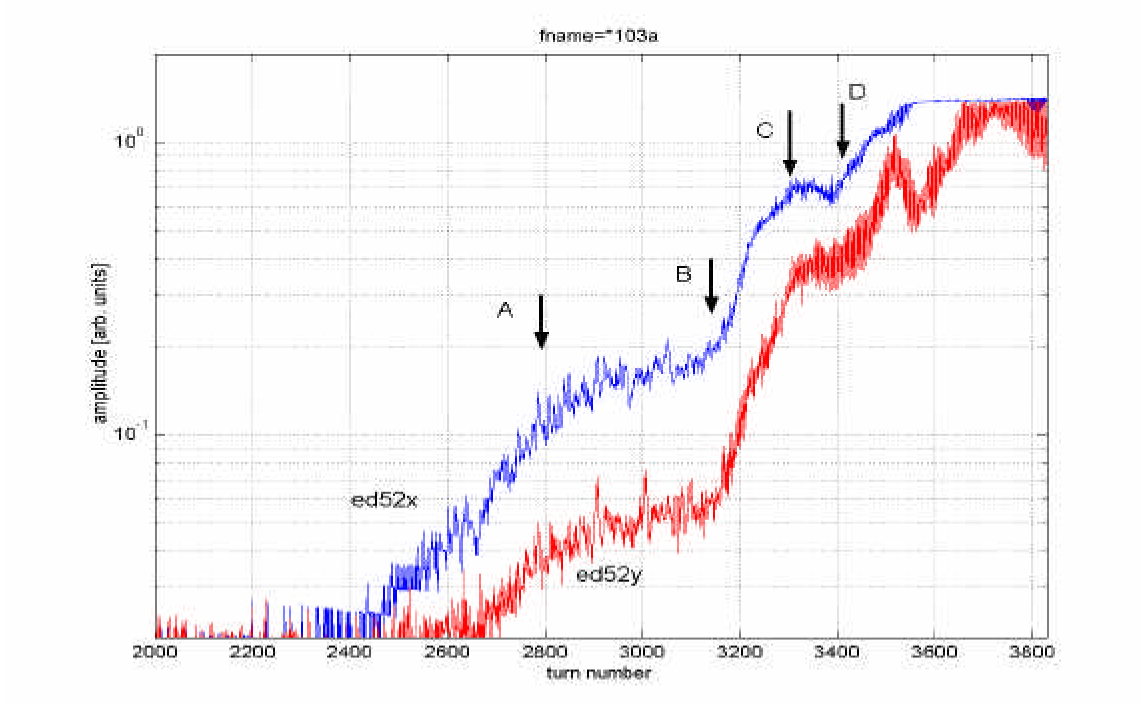

Figure 3 Normalized signal from the electron detector in logarithmic scale.

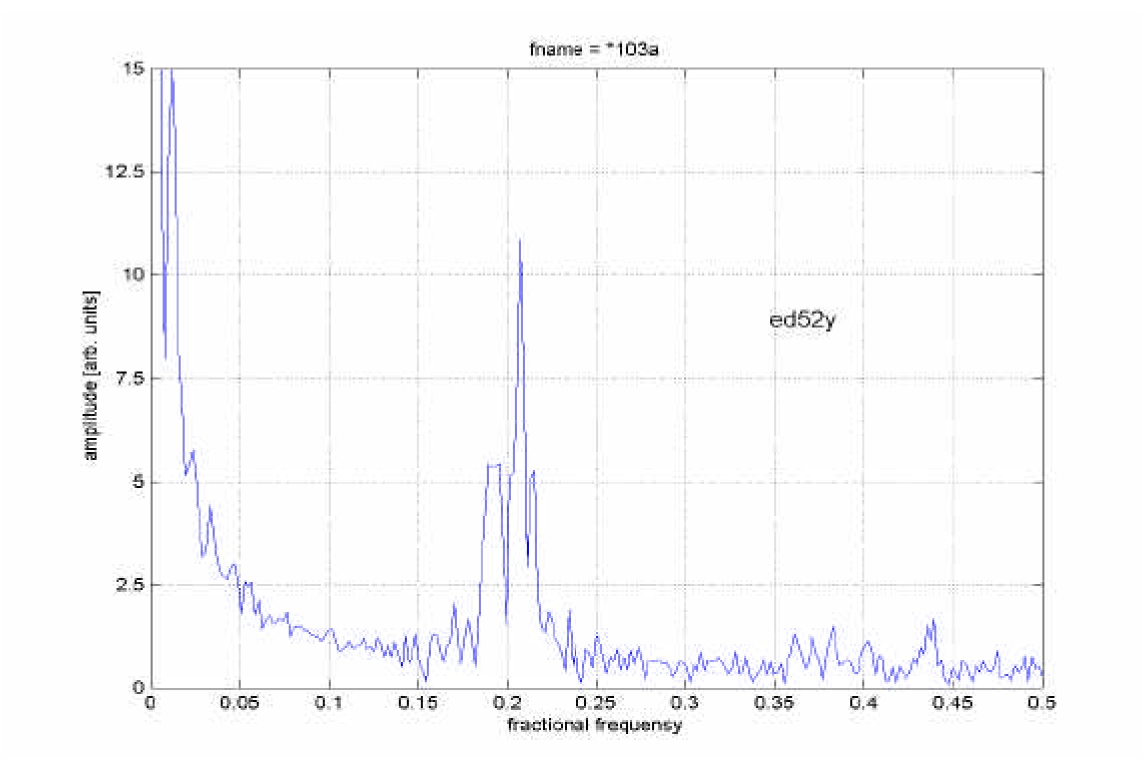

Figure 4 Spectrum of the signal from the vertical electron detector.

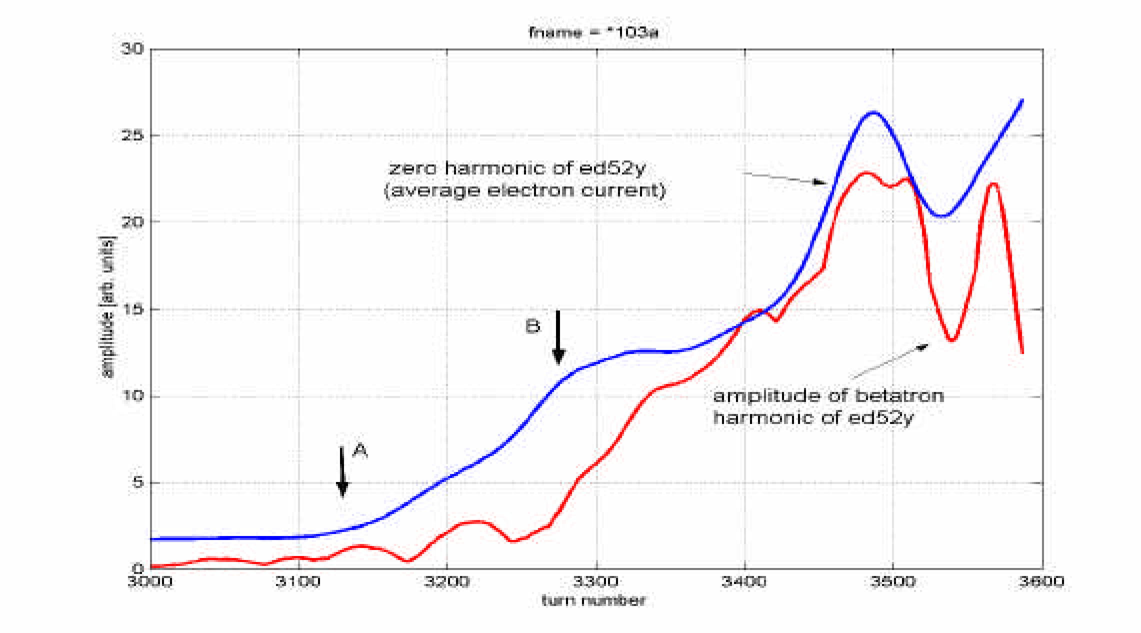

Figure 5 Amplitude of zero and betatron harmonics of the electron signal.

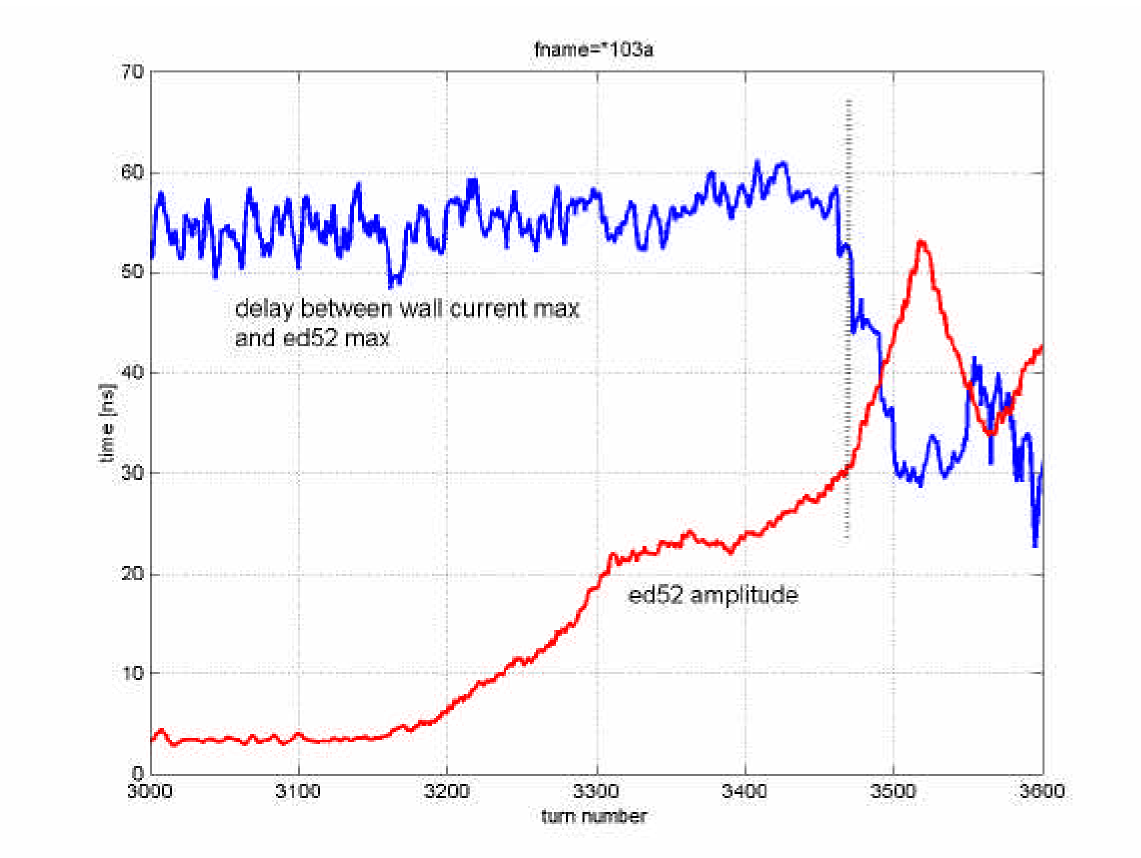

Figure 6 Time delay between electron pulse maximum and proton beam maximum.

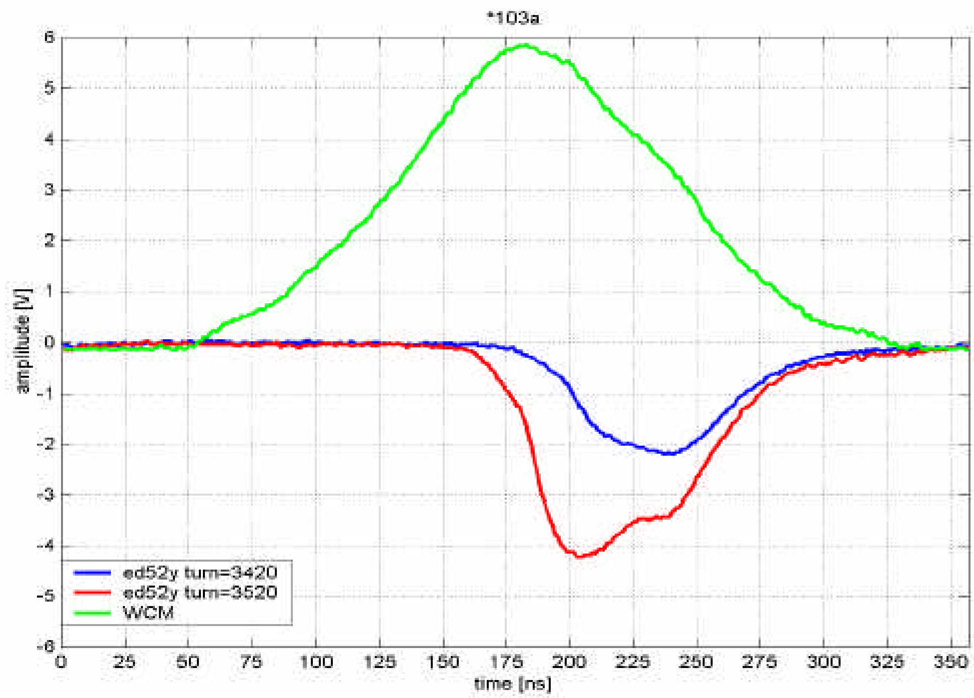

Figure 7. Signal from WCM and ed52y during one turn.

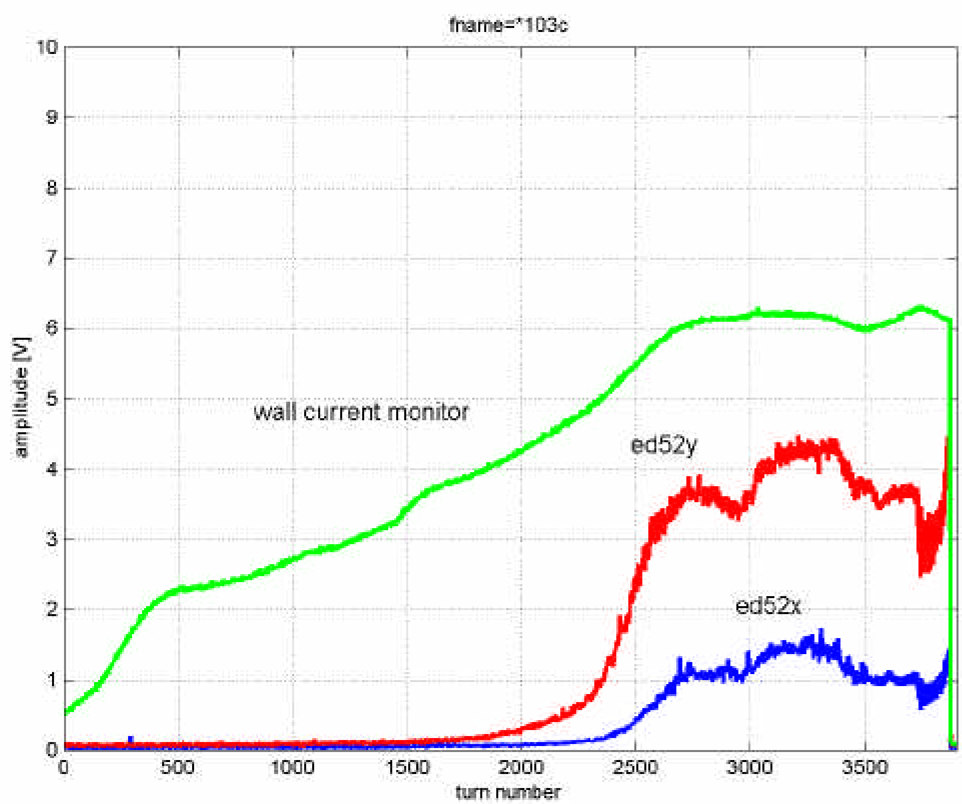

Figure 8. Trace of WC41, ED52x and ED52y as recorded by oscilloscope.(stable operation)

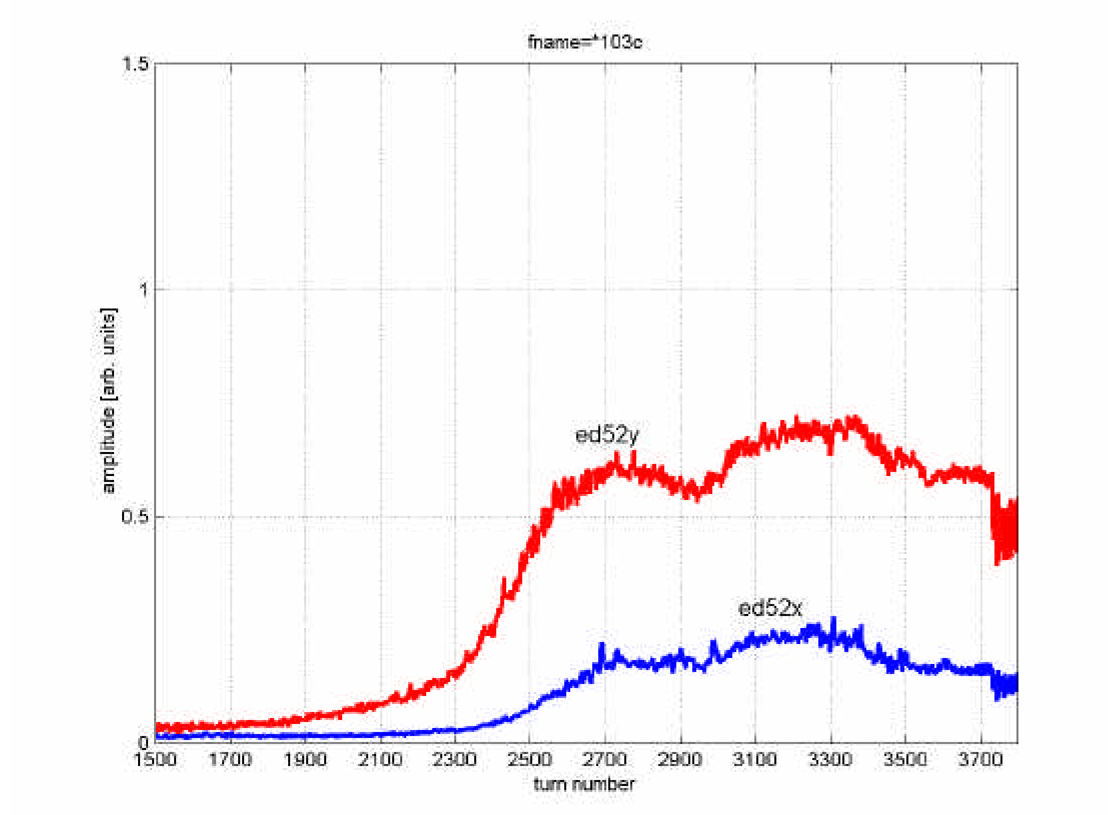

Figure 9 Normalized signal from the electron detector.

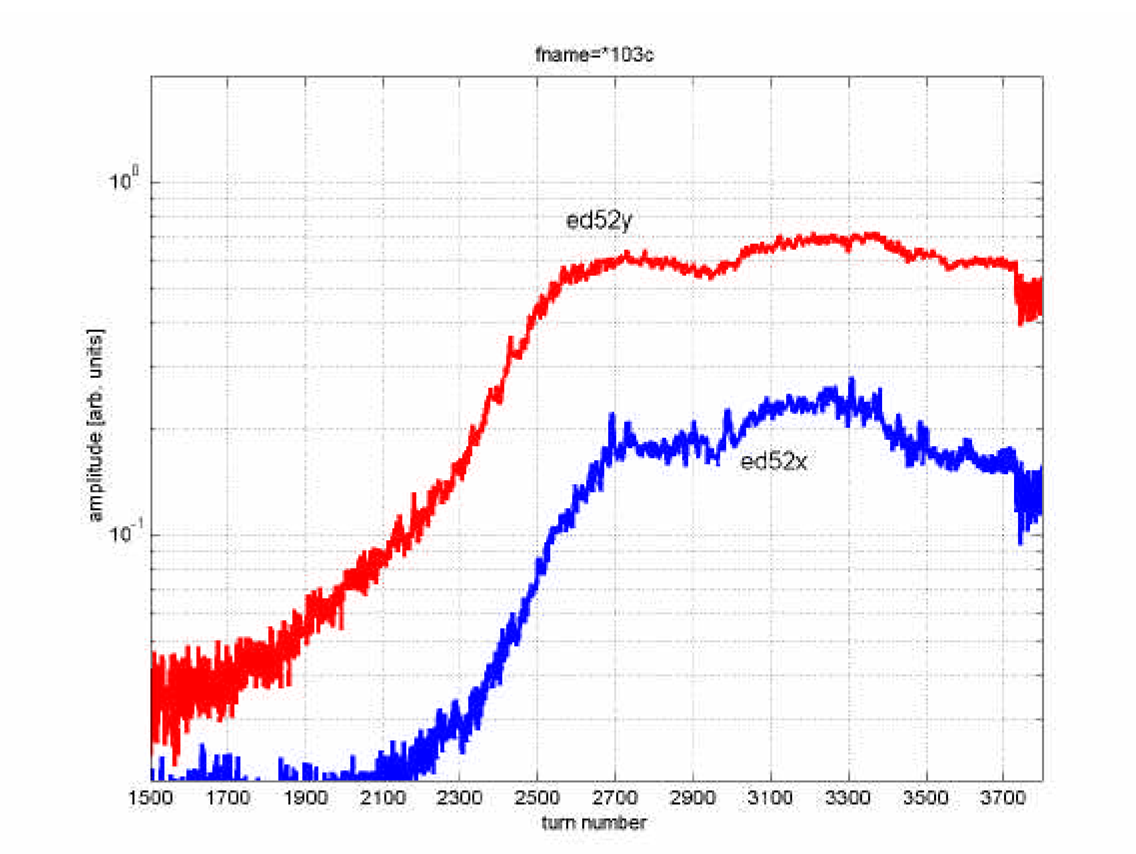

Figure 10 Normalized signal from the electron detector in logarithmic scale.

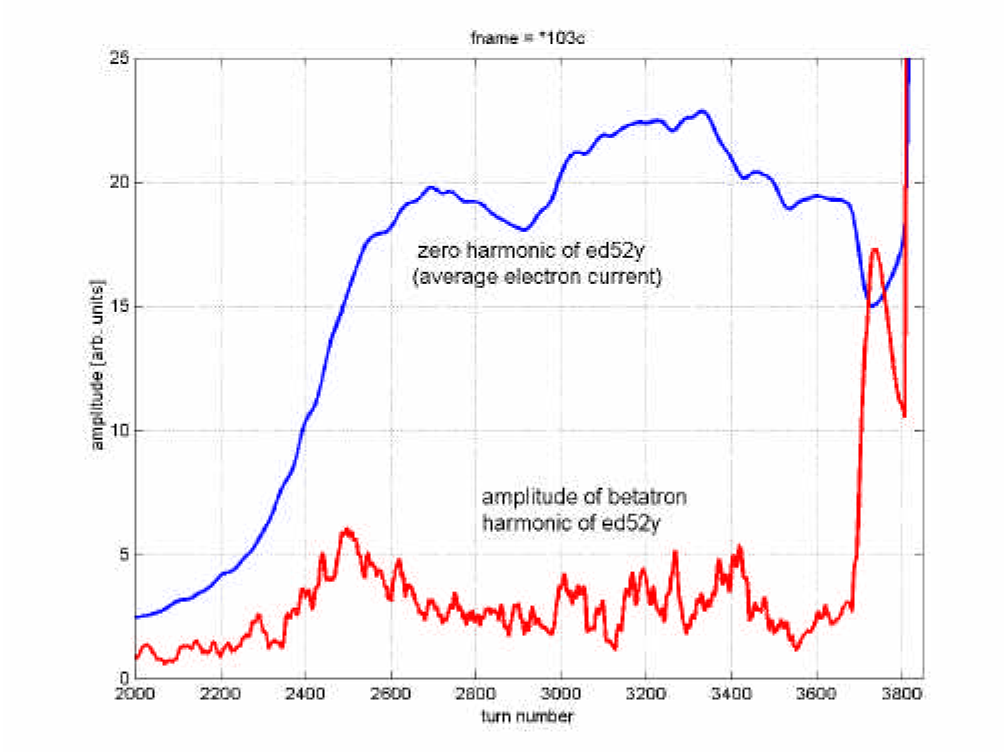

Figure 11. 5 Amplitude of zero and betatron harmonics of the electron signal.

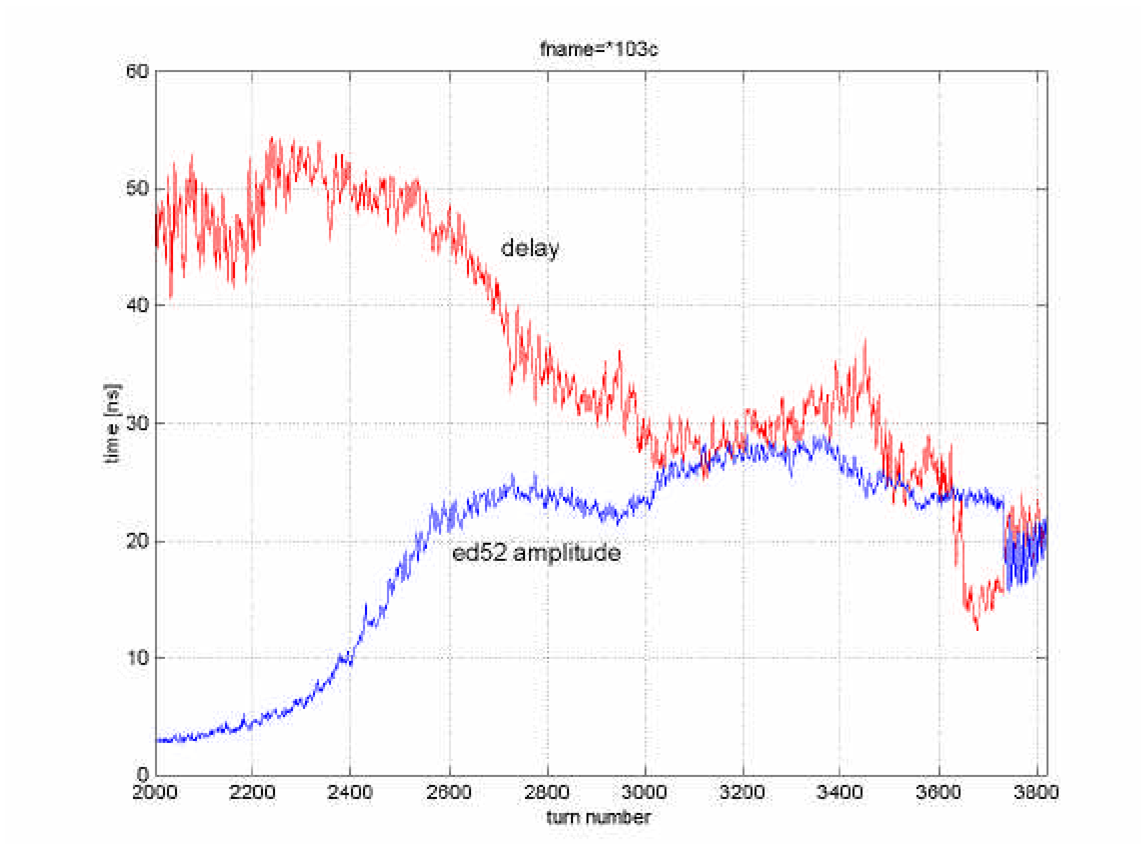

Figure 12. Time delay between electron pulse maximum and proton beam maximum.