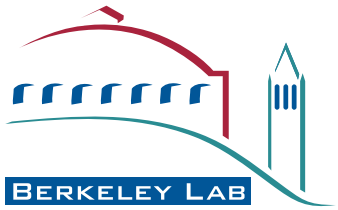
Simulation Results of SPS Feedback Control System of Electron Cloud Transverse Instabilities

LARP 15TH Collaboration Meeting, SLAC, USA



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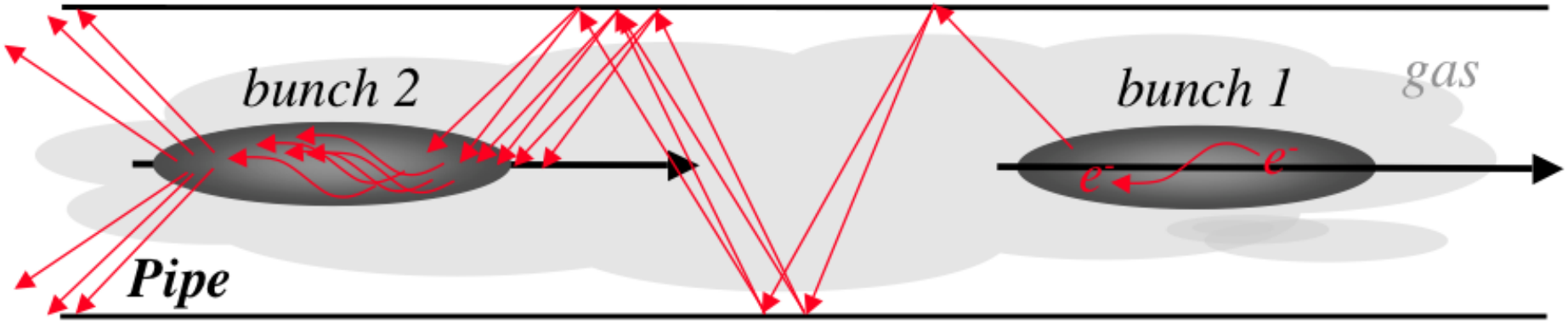
Outline

- Motivation
- Modeling
  - Feedback Scheme
  - WARP/POSINST framework
- Feedback System Simulation Results
  - Open Loop case
  - Closed Loop case
  - Kick Signal applied to bunch
- Future Plans
- Conclusions

Motivation

- Transverse Instabilities observed in SPS beams due to electron clouds

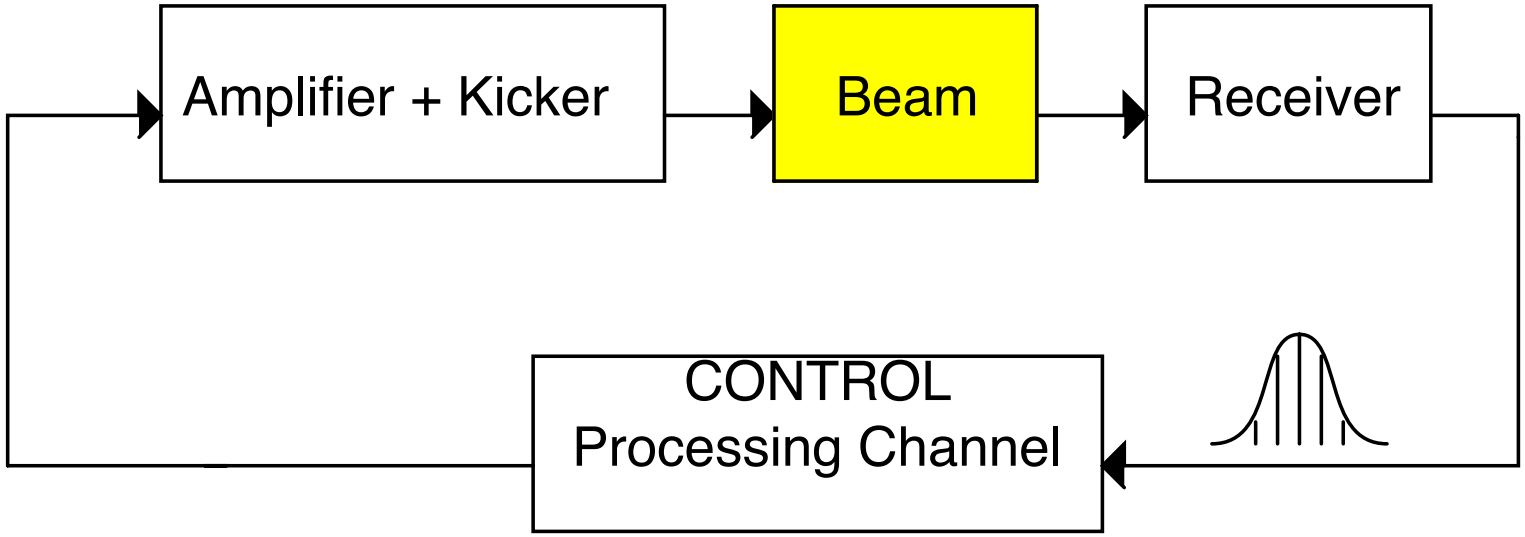


- Possible solution: **Feedback System** to control beam transverse motion, (see J.L.Vay et al. Proceedings of IPAC 2010, [1], J. Fox et al. Proceedings of IPAC 2010 [2]).

- Use of the Particle-In-Cell framework Warp-Posinst

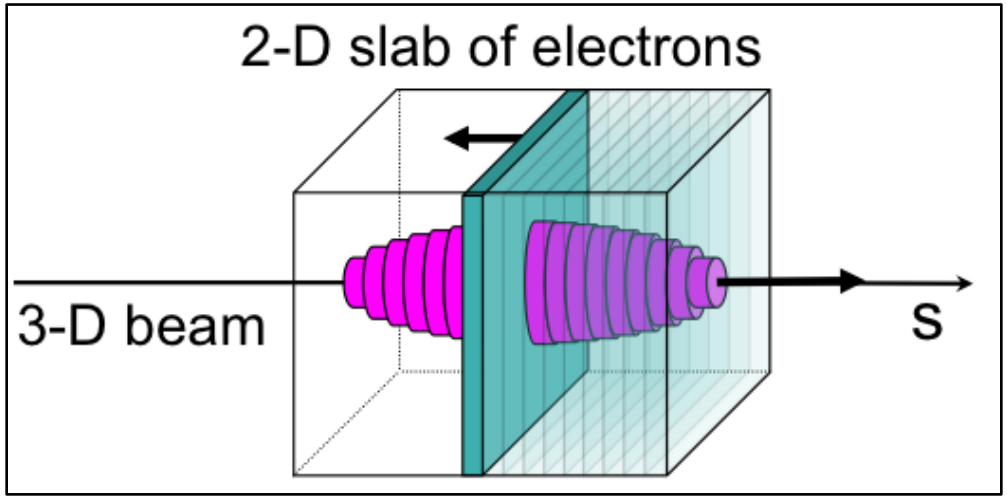
Feedback Model

Scheme of the overall system:



WARP/POSINST framework

- WARP quasistatic model similar to HEADTAIL, QuickPIC.

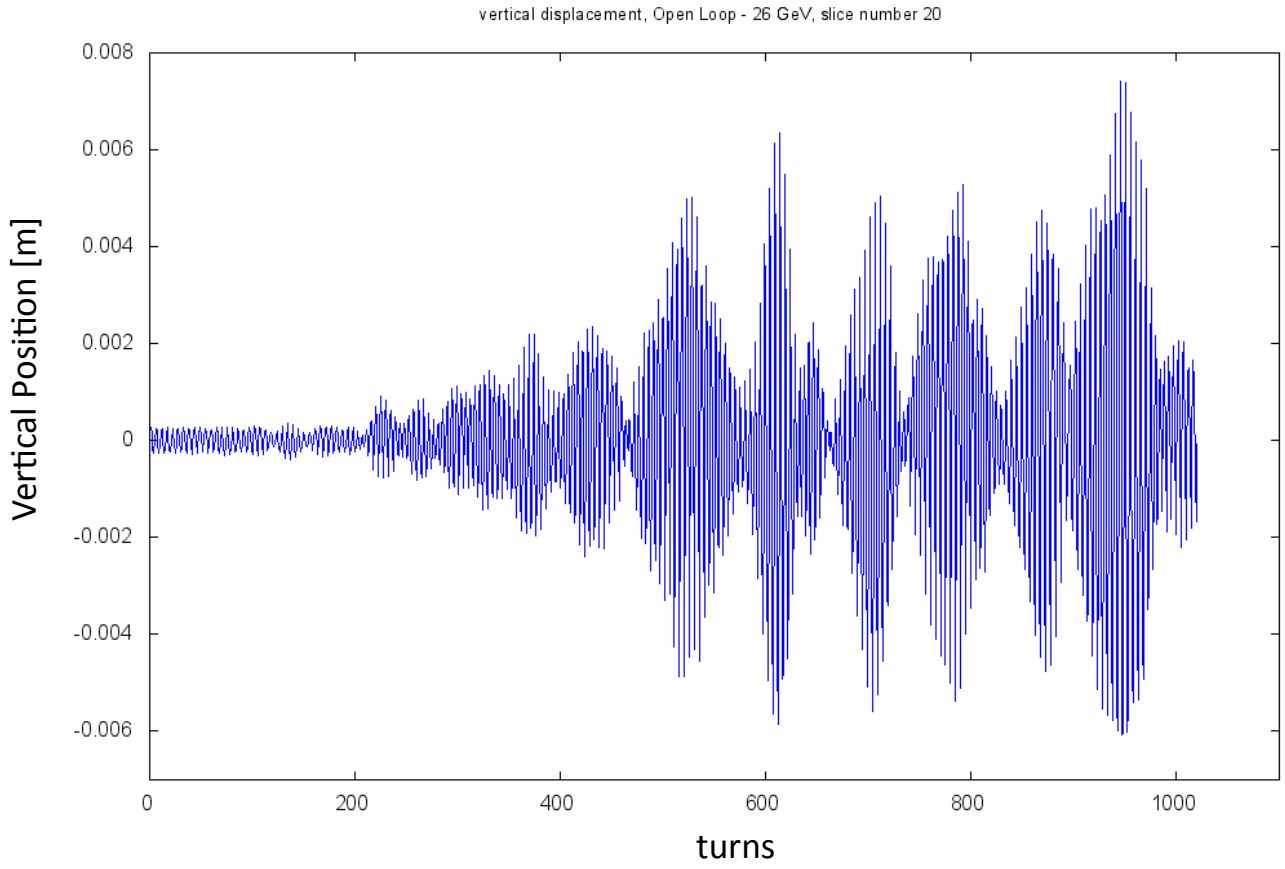


- Option of using POSINST to get secondary emission of electrons
- Uniform Ecloud density distribution used in our Single-Bunch runs.

Open Loop Simulation Results - I

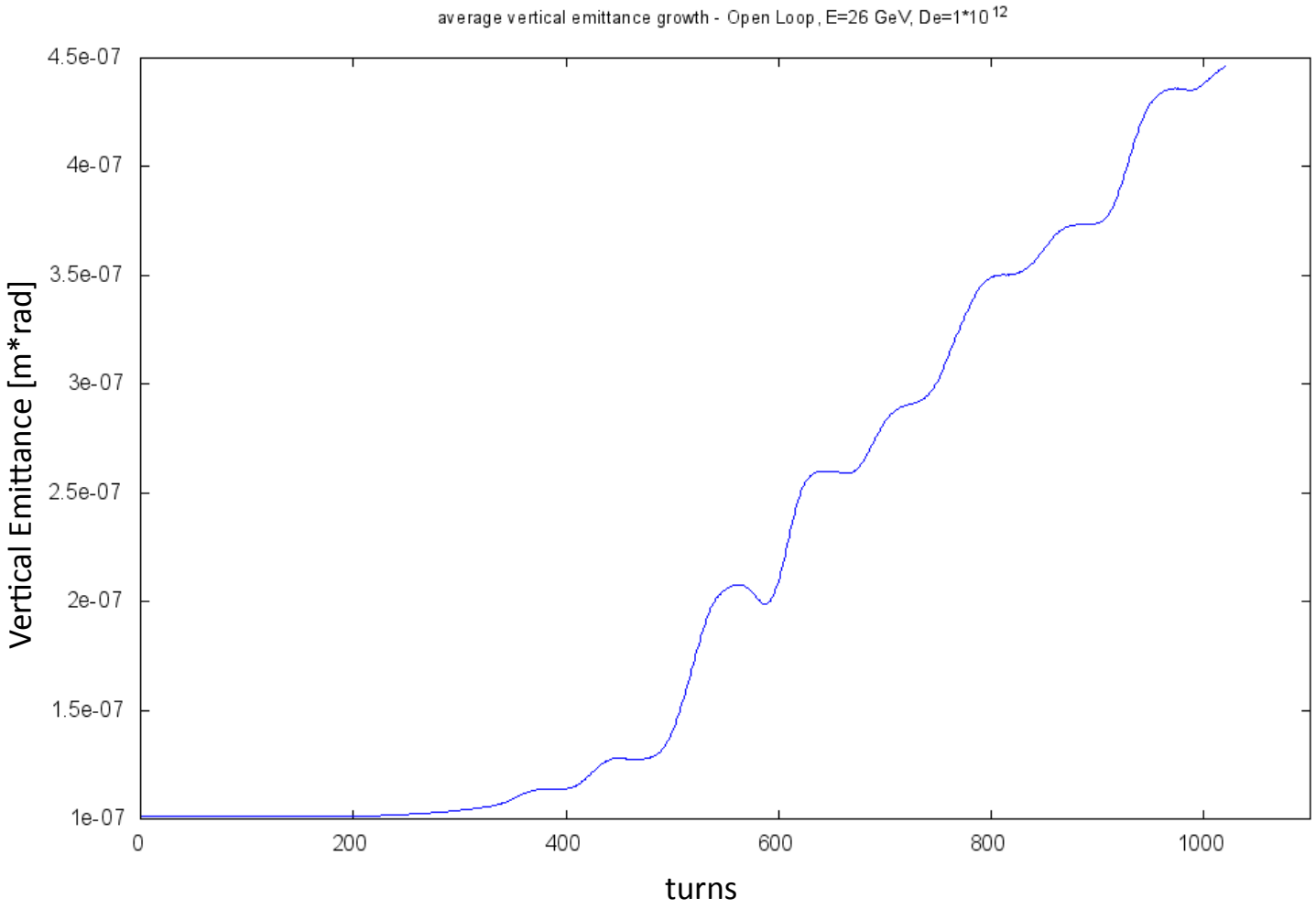
- Open loop simulations show large transverse oscillations. Data from 2009 MD show similar motion (see talks C. Rivetta et al. [3], R. Secondo et al. [4])

Vertical Position of a slice in the TAIL for an open loop run at 26 GeV with Electron Density of De = 10^{12}.



Open Loop Simulation Results - II

Bunch average Vertical emittance, E = 26 GeV with Electron Density of De = 10^{12}



Feedback System Considerations

- Feedback model still incomplete, though lot of progress has been done. The model has infinite Bandwidth, no noise, no interfering signals from horizontal motion or propagating beam pipe signals.

- Estimation of **kicker signal** necessary to control instabilities is essential.

- The control action is performed applying a kick from an ideal kicker, forcing the bunch vertical displacement to zero (y → 0)

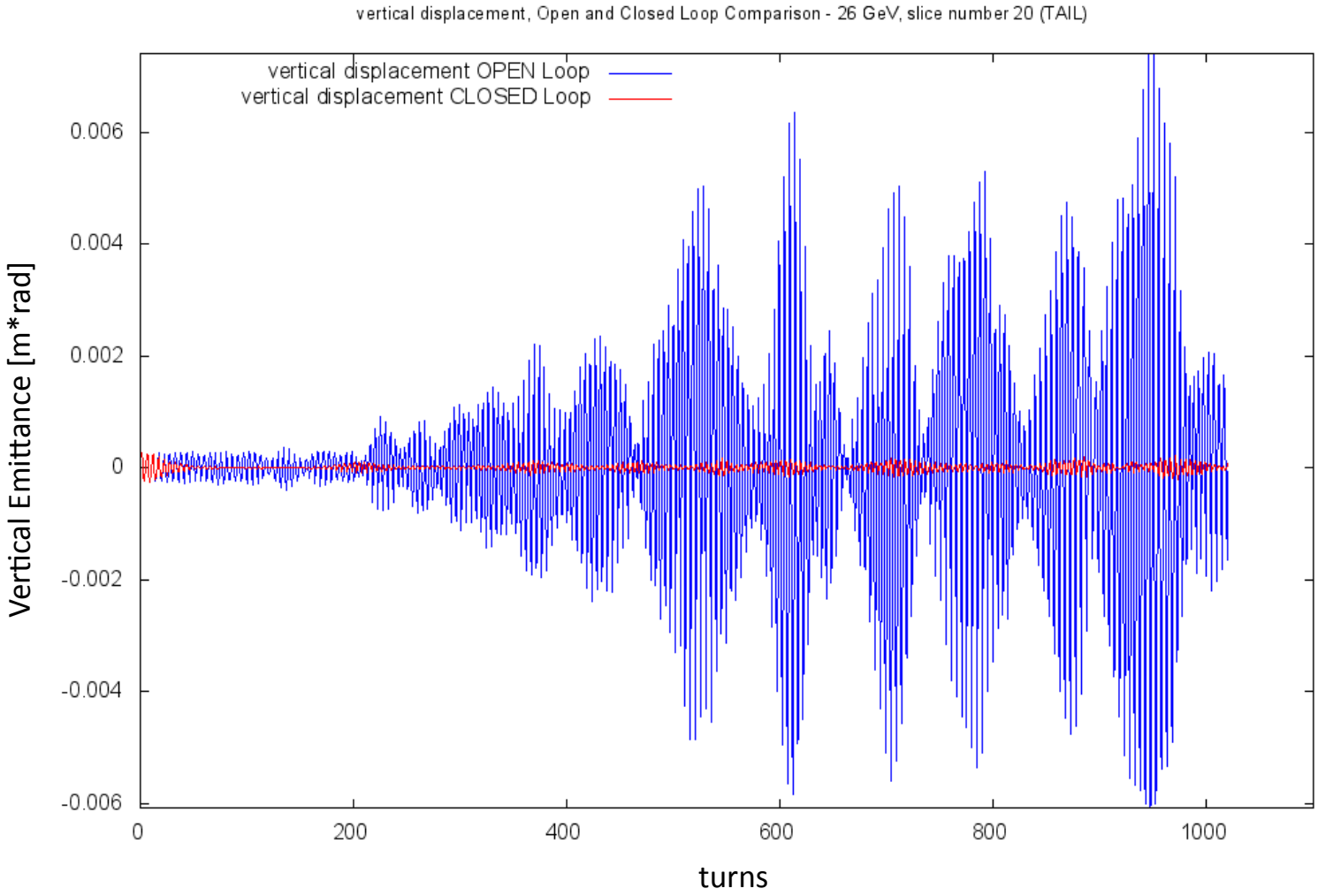
$$\ddot{y} + \omega^2 y = K(e - y) + \Delta p_{\perp}$$

Interaction Beam-Ecloud

Signal of the Ideal Kicker

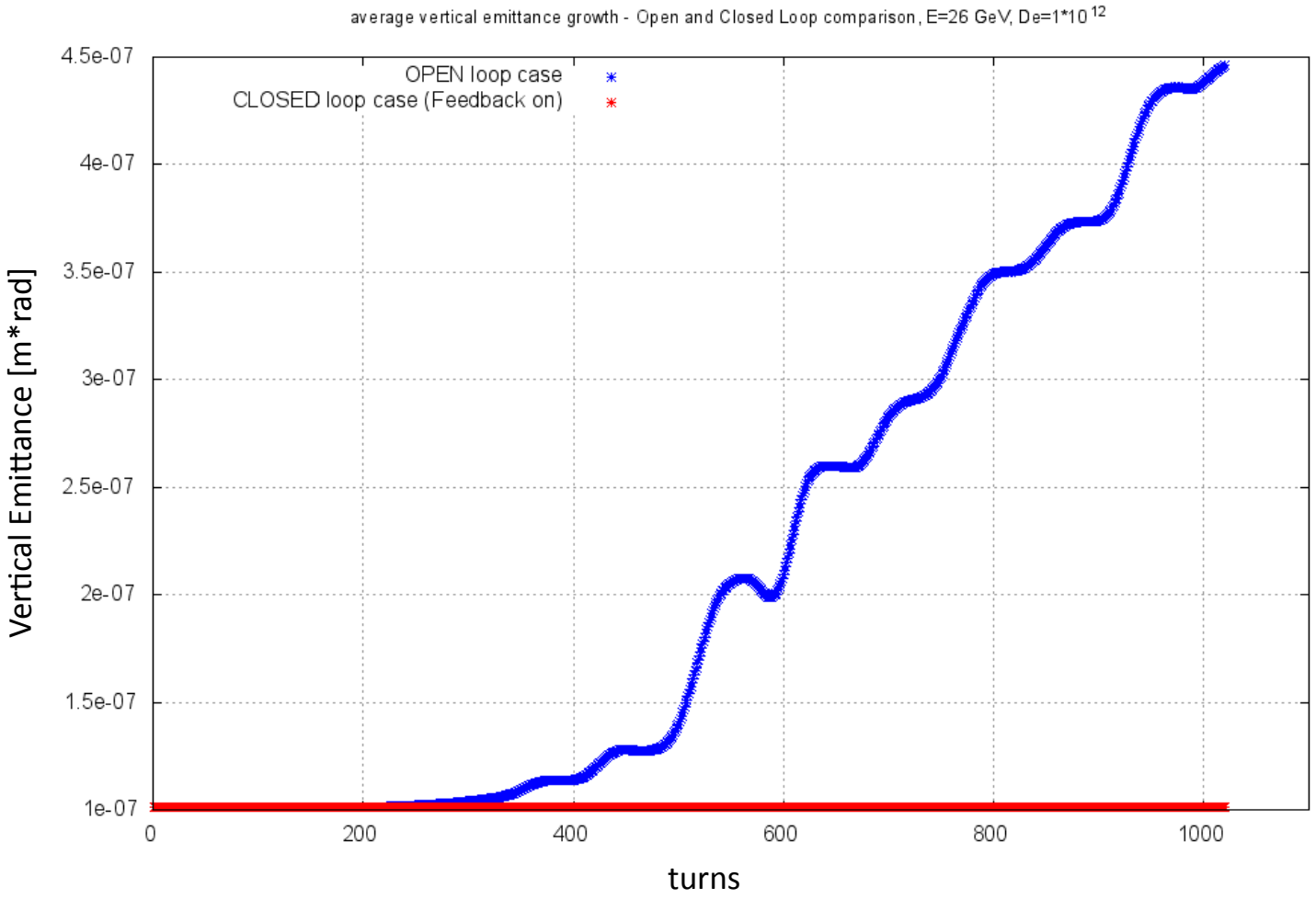
Feedback System – Closed Loop Performance I

Vertical displacement comparison between Open Loop and Closed Loop (Feedback on) cases of a single slice in the TAIL of the bunch. E = 26 GeV with Electron Density De =10^{12}



Feedback System – Closed Loop Performance II

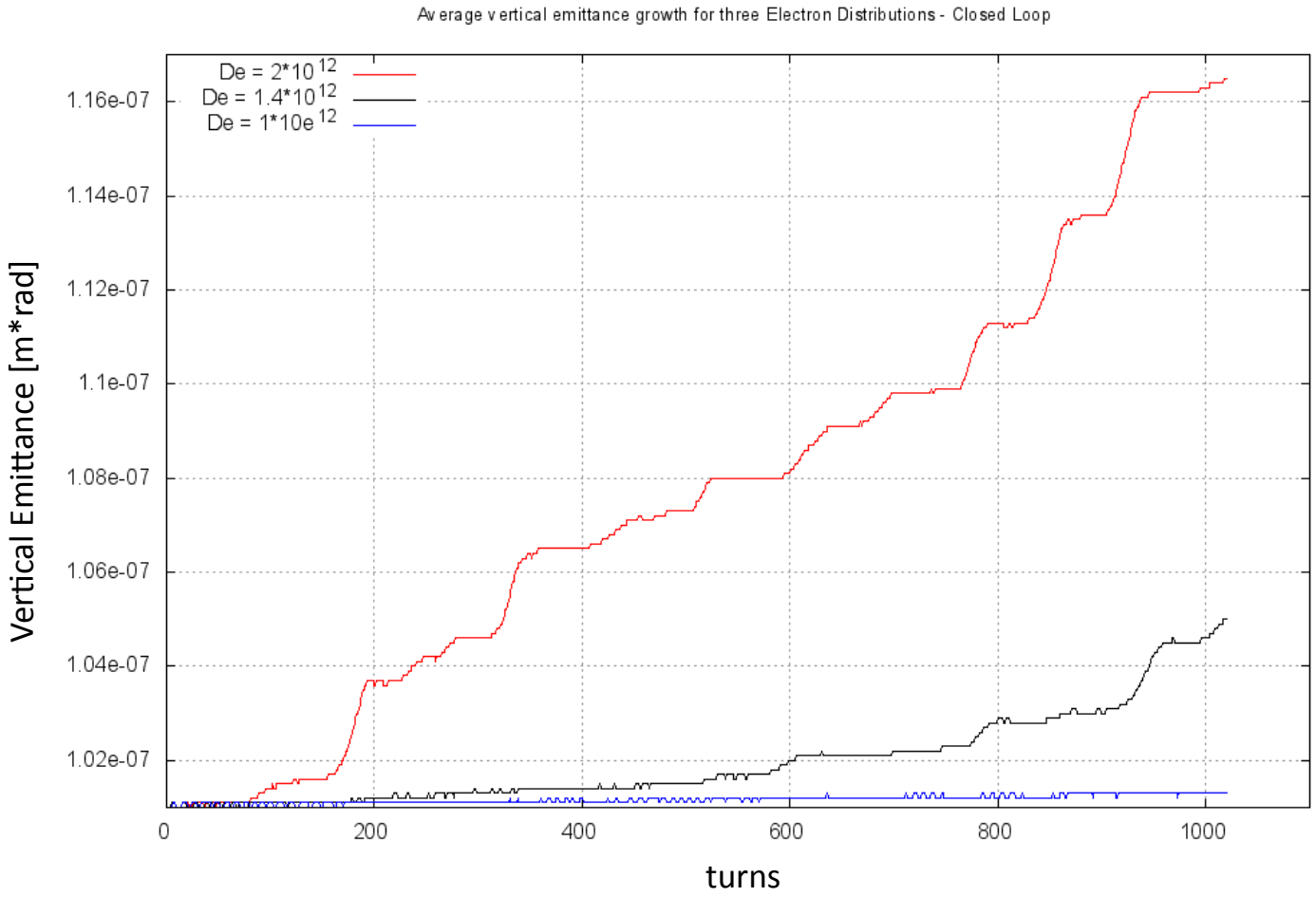
Bunch average vertical emittance Comparison between Open Loop and Closed Loop (Feedback on) cases. E = 26 GeV with Electron Density De = 10^{12}



Feedback System – Closed Loop Performance III

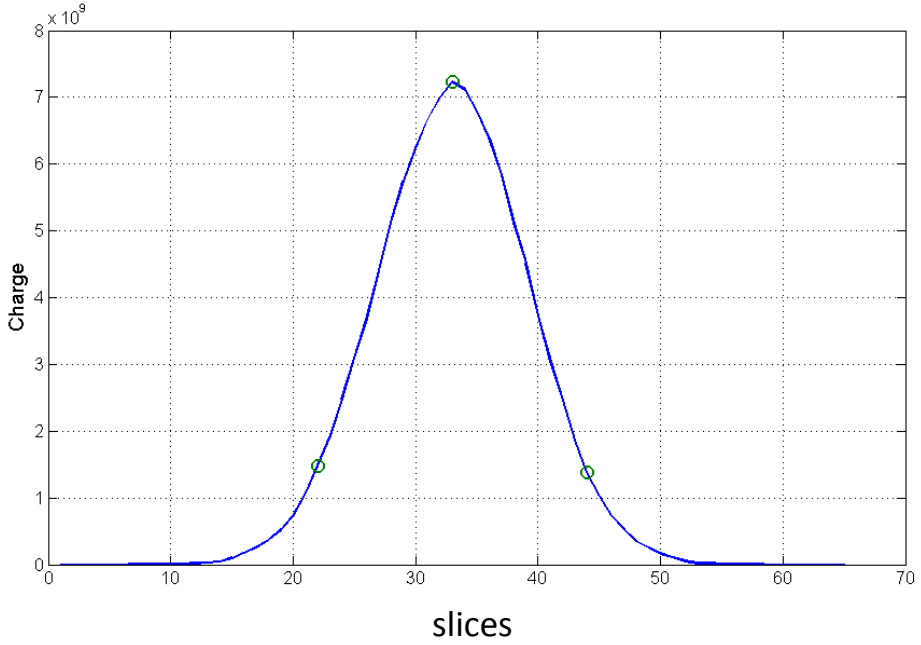
- Increasing the Electron Density leads to emittance growth.

Bunch average vertical emittance for three Closed Loop runs with De = $1*10^{12}$, De = $1.4*10^{12}$ and De = $2*10^{12}$

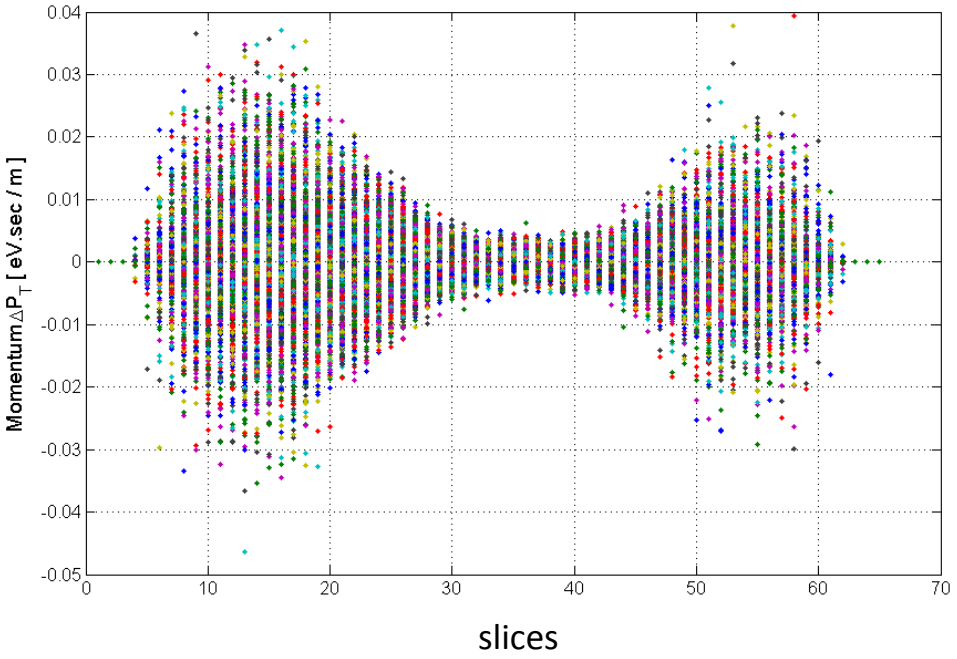


Kick Signal applied to bunch - I

Charge profile of the bunch

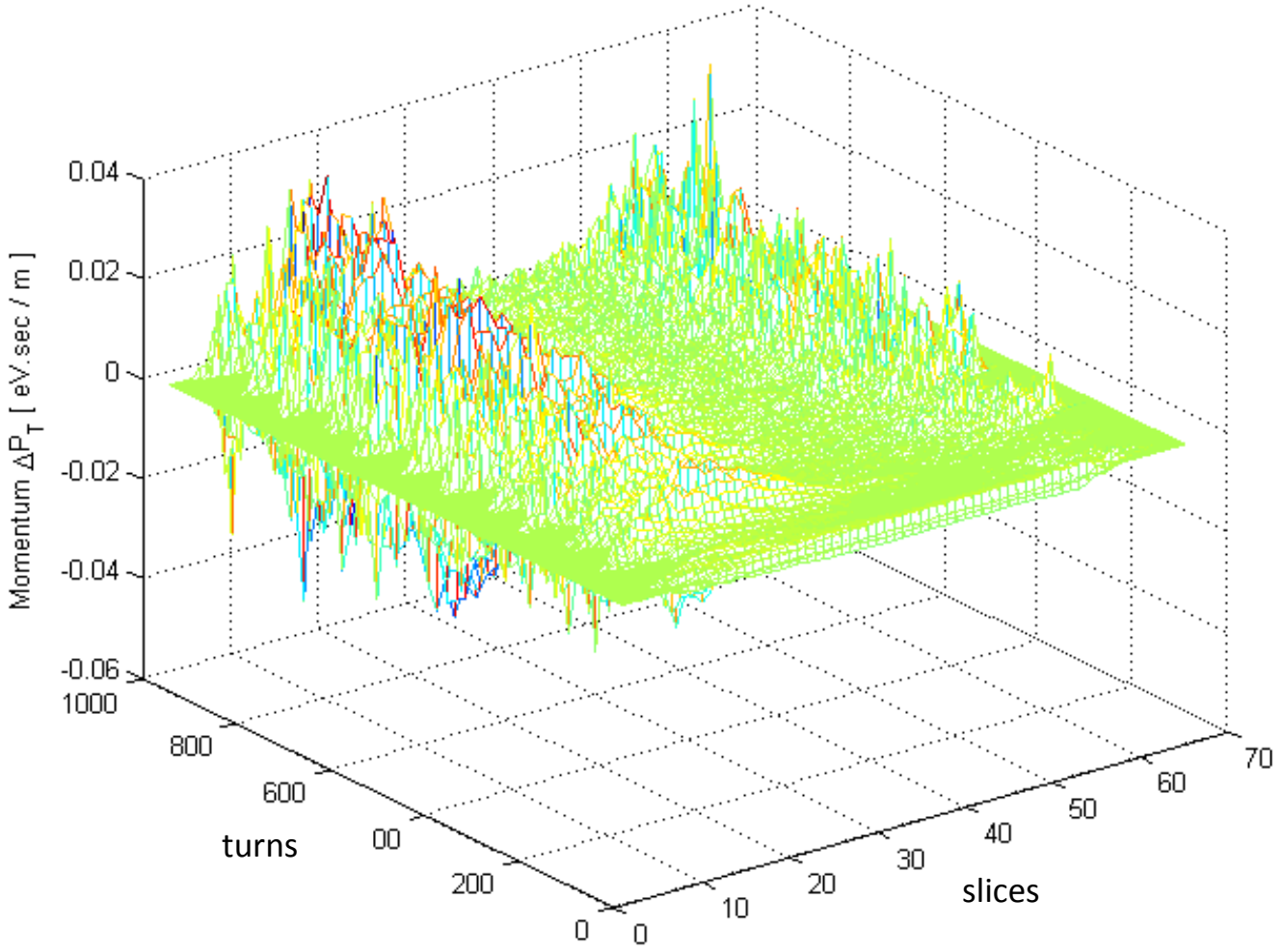


Kick signal with No Limitation and De=10^{12} - 2D view



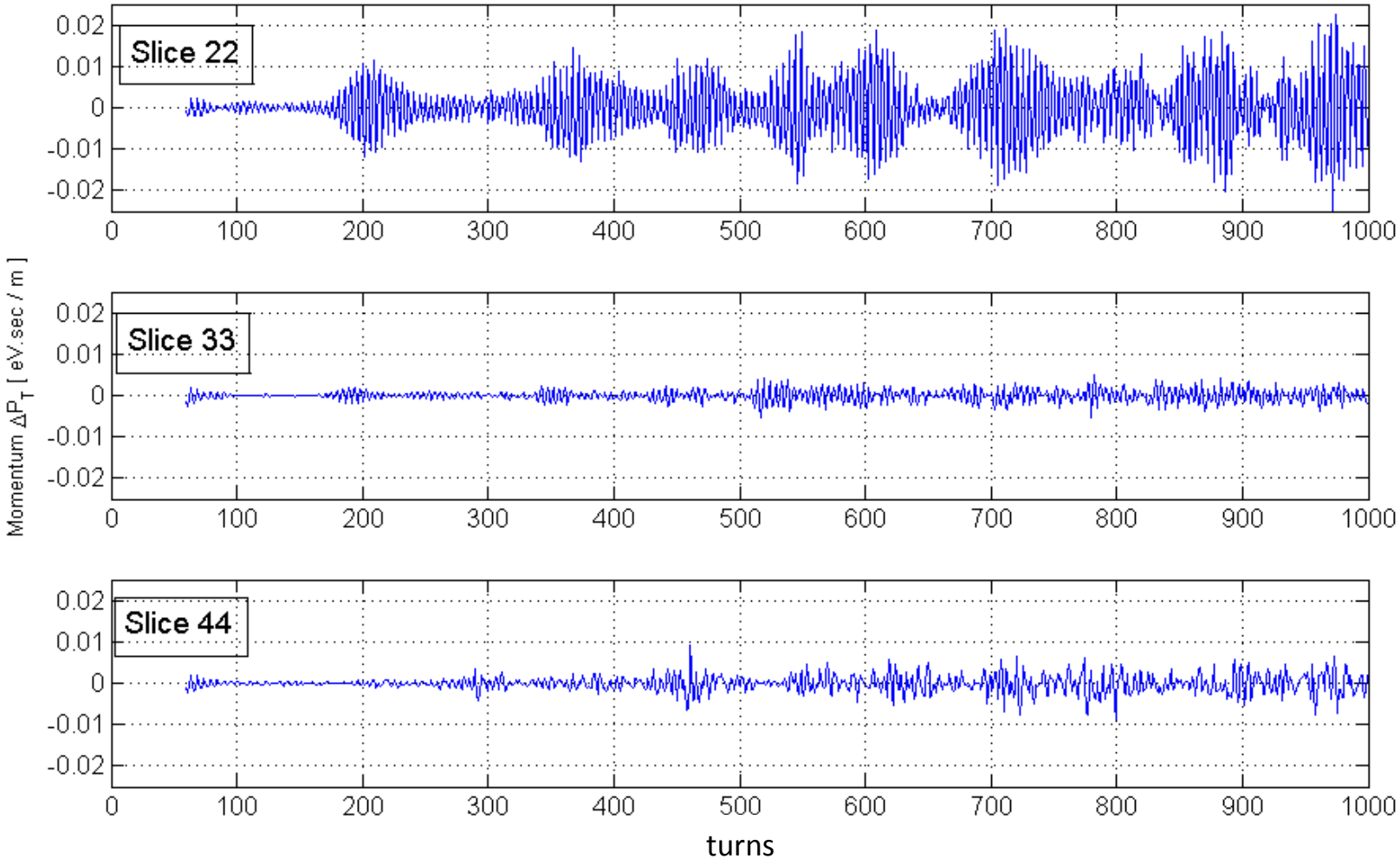
Kick Signal applied to bunch - II

- Kick signal with No Limitation and De = 10^{12}



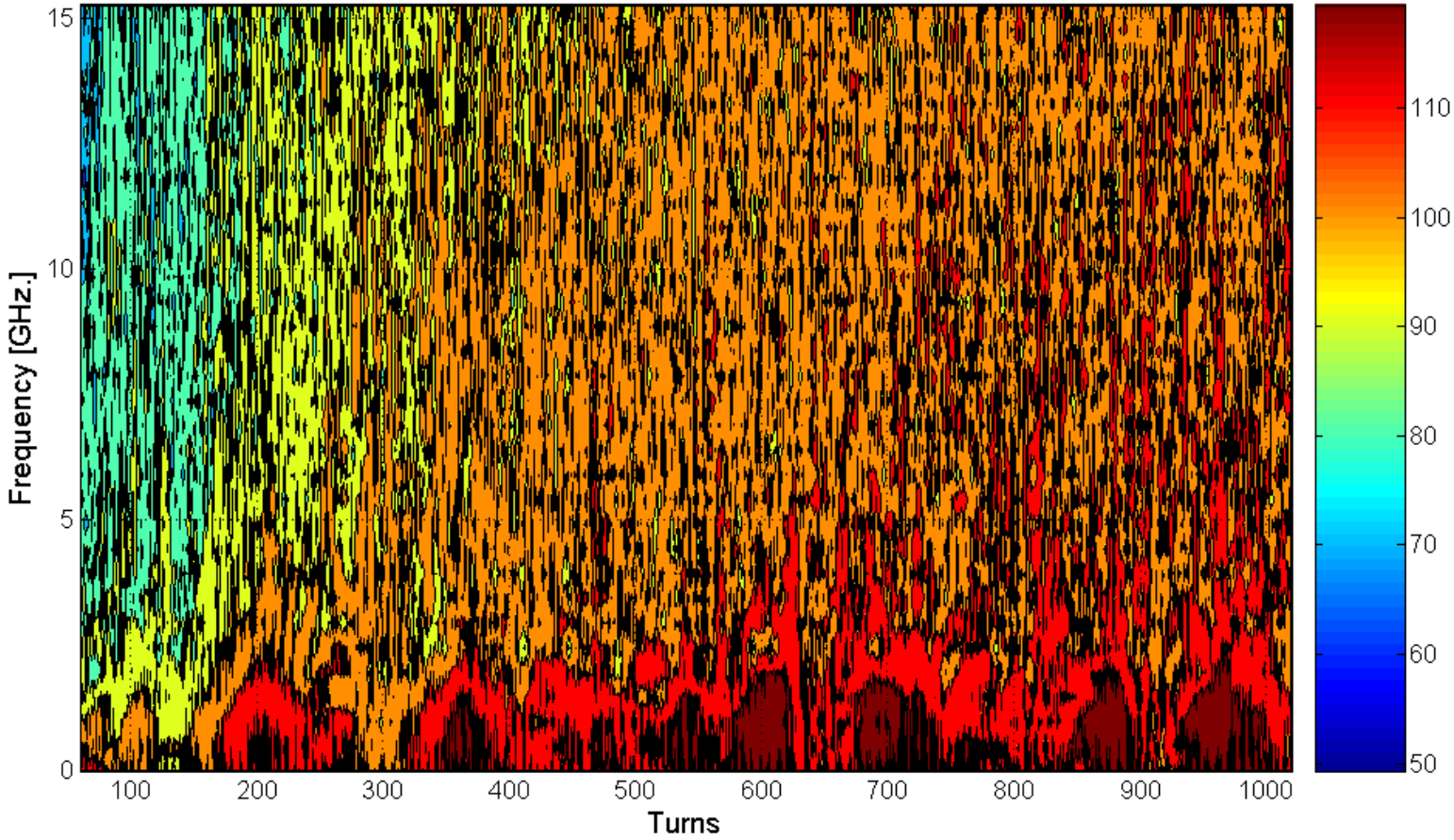
Kick Signal applied to bunch - III

- Time Domain evolution of the Kick signal for three slices with No Limitation for an Electron Density De = 10^{12}. Slice #22 is located in the tail of the bunch.



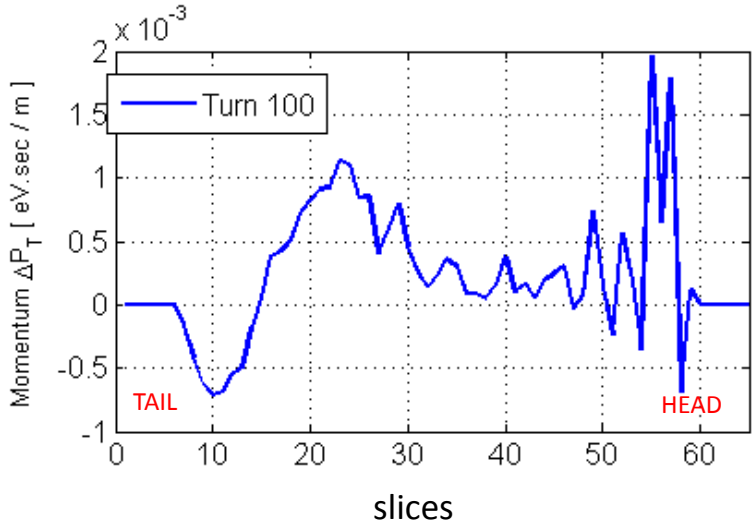
Closed Loop Frequency Spectrum

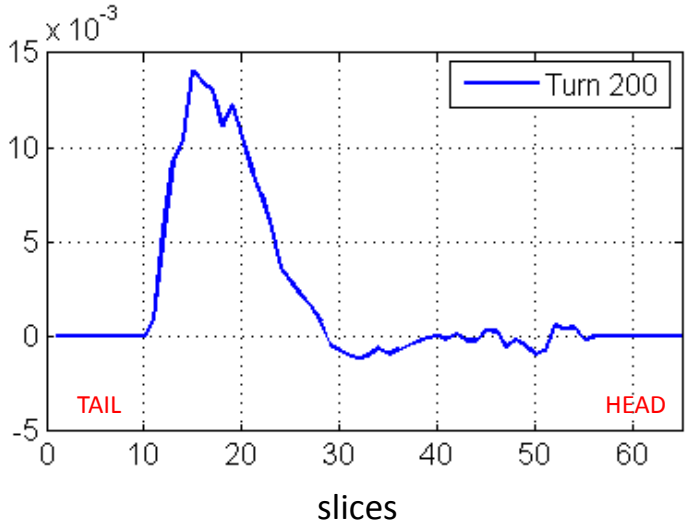
- Frequency Spectrum of the bunch in Closed Loop for an Electron Density De = 10^{12}.

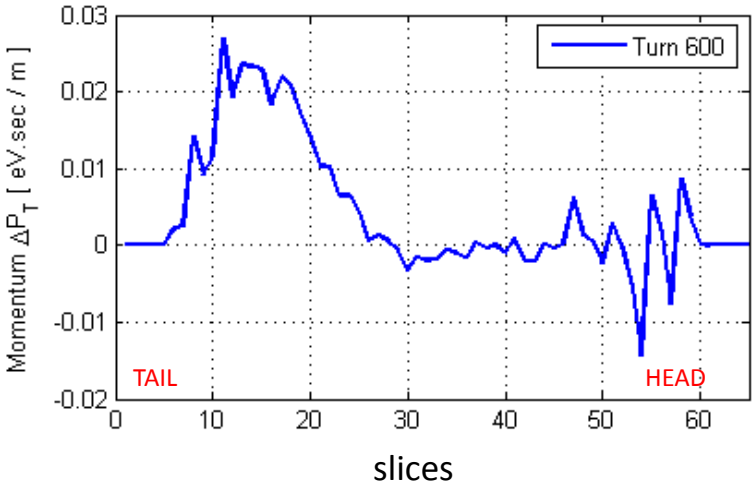


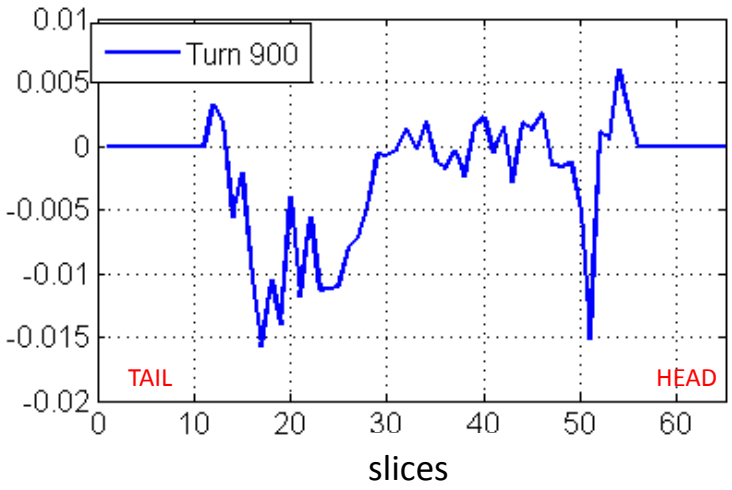
Kick Signal applied to bunch - IV

- Kick signal with No Limitation and De = 10^{12}









Future Plans

- Improve the Model of the Feedback making it more realistic
- Provide essential information to set the kicker design specifications
- Apply Feedback to multi-bunch simulations. See J. L. Vay et al., [5]
- Analyze data from 2009 and 2010 MDs and benchmark the model

Conclusions

- A Feedback Control System is a possible solution to damp single-bunch ecloud instabilities in the SPS

- WARP/POSINST framework used to simulate the e-cloud effect in the SPS and study the Requirements and Limits of the Feedback Design.

- Understanding the kicker signal level needed to efficiently control the beam is a key parameter.

- Frequency content in Closed Loop using an ideal kicker can raise up to higher frequencies than 1-2 GHz. This issue need to be studied more carefully

- Future developments will lead to a more realistic model of the system and a better understanding of the key parameters.

References

- [1] - “Simulation of Electron Cloud driven instability and its attenuation using a feedback system in the CERN SPS”. J. L. Vay, J. M. Byrd, M. A. Furman, R. Secondo, M. Venturini, (LBNL, USA); J. D. Fox, C. H. Rivetta, (SLAC, USA); W. Hofle, (CERN, Switzerland). Proceedings of IPAC 2010, Kyoto, Japan.

- [2] – “SPS Ecloud Instabilities - Analysis of machine studies and implications for Ecloud Feedback”. John Fox, Themis Mastorides, Georges Ndabashimiye, Claudio Hector Rivetta, Daniel Van Winkle (SLAC, Menlo Park, California), Riccardo de Maria (BNL, Upton, Long Island, New York), Wolfgang Höfle, Giovanni Rumolo (CERN, Geneva), John Byrd, Miguel Furman, Jean-Luc Vay (LBNL, Berkeley, California). Proceedings of IPAC 2010, Kyoto, Japan.

- [3] - “Feedback Control of SPS E-Cloud/TMCI Instabilities”. C. H. Rivetta, J. D. Fox, A. Bullitt, T. Mastorides, G. Ndabashimiye, M. Pivi, O. Turgut (SLAC, USA); W. Hofle, B. Savant (CERN, Switzerland); M. Furman, R. Secondo, J.-L. Vay (LBNL). ECLOUD10 Talk, Cornell, Ithaca, USA.

- [4] - “Simulated Performance of an FIR-Based Feedback System to Control the Electron Cloud Single-Bunch Transverse Instabilities in the CERN SPS”. R. Secondo, J.-L. Vay, J. M. Byrd, M. A. Furman, M. Venturini (LBNL, USA), J. D. Fox, C. H. Rivetta (SLAC, USA), W. Hofle (CERN, Switzerland). ECLOUD10 Talk, Cornell, Ithaca, USA.

- [5] – “Numerical Modeling of E-Cloud Driven Instability and its Mitigation using a Simulated Feedback System in the CERN SPS” J.-L. Vay, J. M. Byrd, M. A. Furman, R. Secondo, M. Venturini (LBNL, USA); J. D. Fox, C. H. Rivetta (SLAC, USA); W. Höfle (CERN, Switzerland). ECLOUD10 Talk, Cornell, Ithaca, USA.