Preliminary simulations of e-cloud feedback in the SPS with Warp-Posinst

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LARP E-cloud mini-workshop
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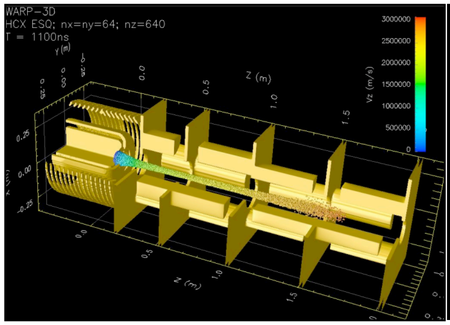
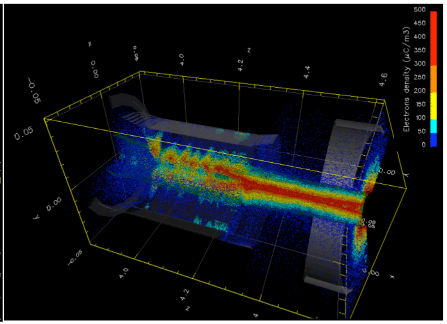
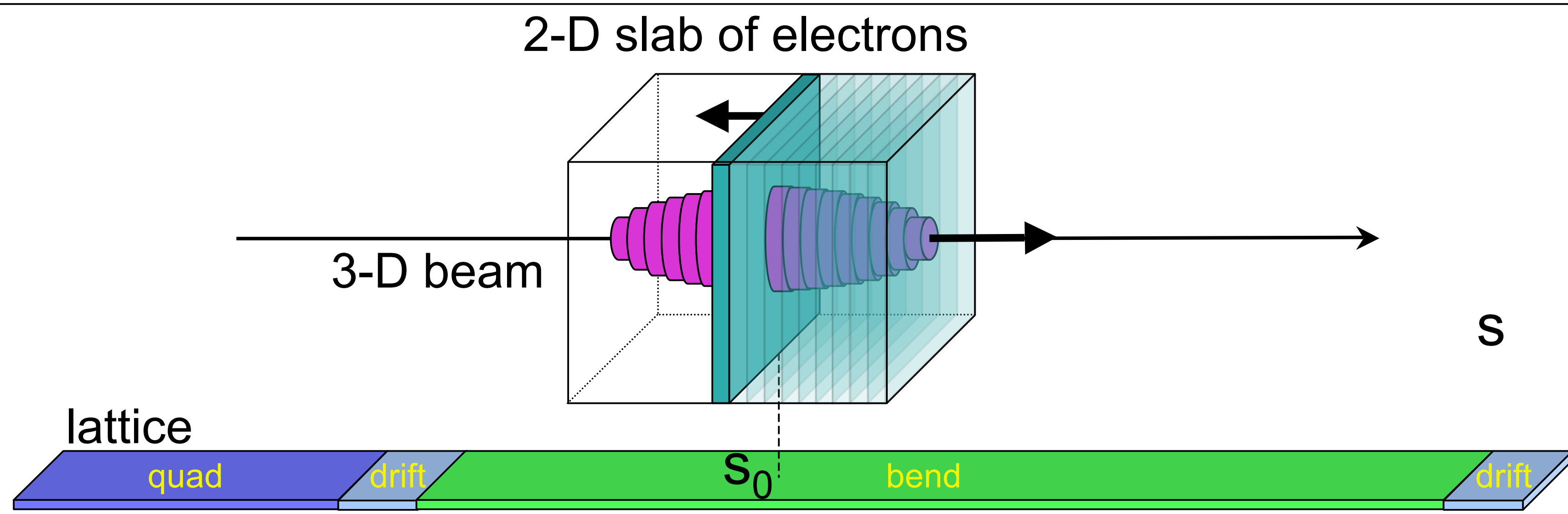
Warp - 3-D accelerator PIC code

- **Geometry:** 3D, (x,y), (x,z) or (r,z)
- **Field solvers:** electrostatic - FFT, capacity matrix, multigrid, AMR
  electromagnetic - Yee mesh, PML bc, AMR
- **Particle movers:** Boris, “drift-kinetic”, new leapfrog
- **Boundaries:** “cut-cell” --- no restriction to “Legos” (not in EM yet)
- **Lattice:** general; takes MAD input
  - solenoids, dipoles, quads, sextupoles, …
  - arbitrary fields, acceleration
- **Bends:** “warped” coordinates; no “reference orbit”
- **Diagnostics:** Extensive snapshots and histories
- **Python and Fortran:** “steerable,” input decks are programs
- **Parallel:** MPI
- **Misc.:** tracing, quasistatic modes,
  support for boosted frame



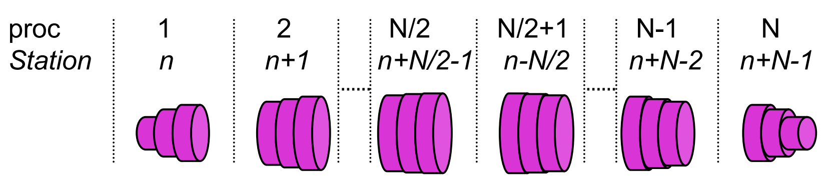


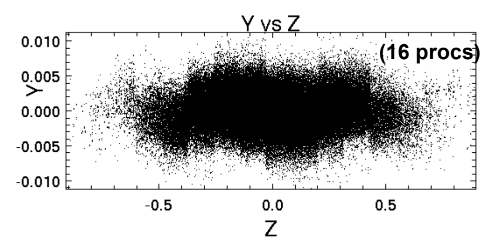
Warp - quasi-static mode ("QSM")



1. 2-D slab of electrons (macroparticles) is stepped backward (with small time steps) through the <u>frozen</u> beam field
   - 2-D electron fields are stacked in a 3-D array,
2. push 3-D proton beam (with large time steps) using
   - maps - "WARP-QSM" - as in HEADTAIL (CERN) <u>or</u>
   - Leap-Frog - "WARP-QSL" - as in QUICKPIC (UCLA/USC).

On parallel computers:





Feedback model 1

- record centroid offset $y_0(t)$ at station *n* for 1 beam passage

- *apply low-pass FFT filter (sharp cutoff at 800MHz): $y_0(t) \Rightarrow \hat{y}_0(t)$

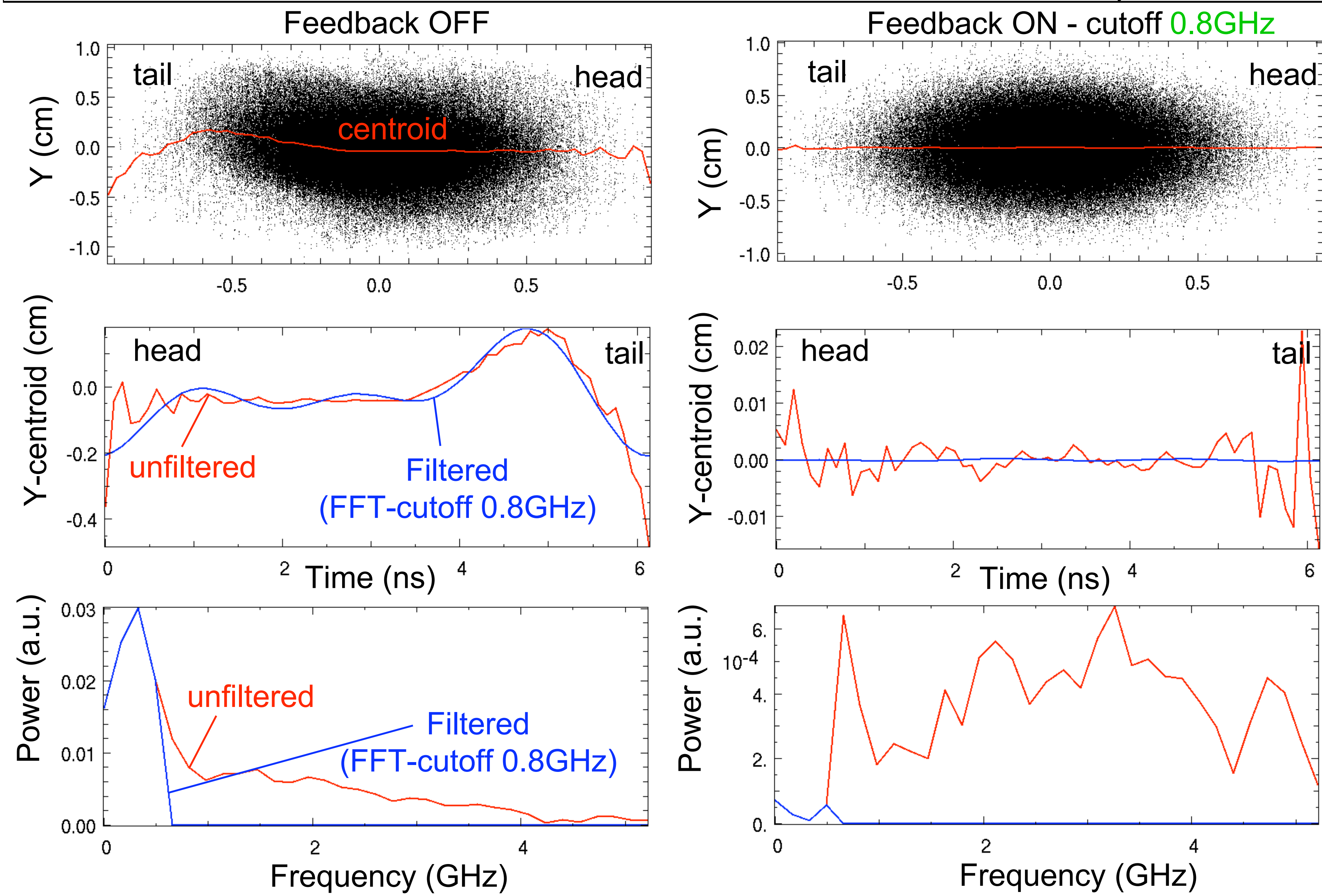
- scale transverse position $y \Rightarrow y - g \cdot \hat{y}_0$ (g=0.1 used in all runs)

*optional stage

Preliminary simul. study of SPS EC feedback*

Model 1 - beam distribution after 300 turns

*CM10, talk by furman

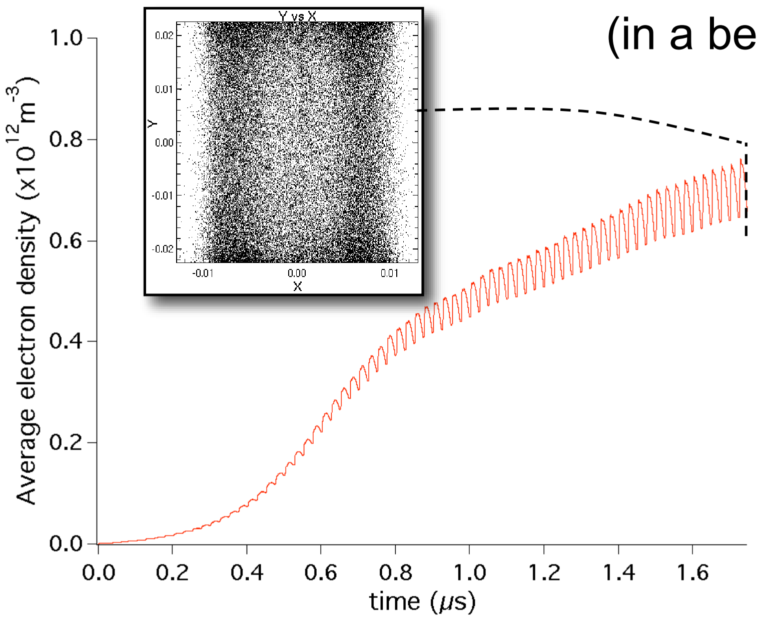


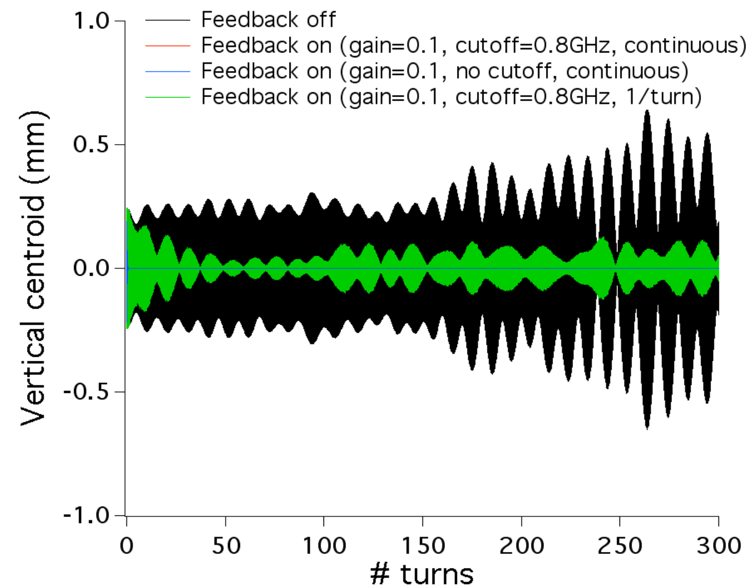
Preliminary simul. study of SPS EC feedback

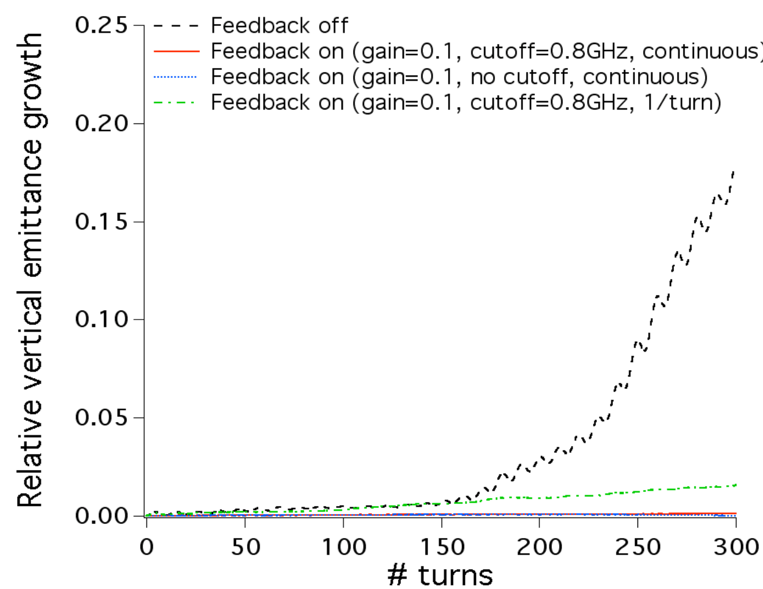
(disclaimer: all simulations done with same resolutions but no guarantee that this is converged)

- SPS at injection (E_b=26 GeV)
  - γ=27.729
  - $N_p=1.1\times10^{11}$
  - continuous focusing
    - $\beta_{x,y}$= 33.85, 71.87
    - $\nu_{x,y}$= 26.12, 26.185
    - ν_z= 0.0059
  - N_{stn} ecloud station/turn=100

Initial e-cloud distribution From Posinst (in a bend)







Feedback model 2 - prediction at n turns

- record centroid offset $y_0(t)$ and $y_1(t)$ at station *n* for 1 beam passage for two consecutive turns

- predicts $y_n(t)$ from $y_1(t)$ and $y_0(t)$ using linear maps, ignoring longitudinal motion and effects from electrons (n=2 in all runs)

- *scale according to line charge density λ: $y_2(t) \Rightarrow y_2(t) \cdot w_\lambda$

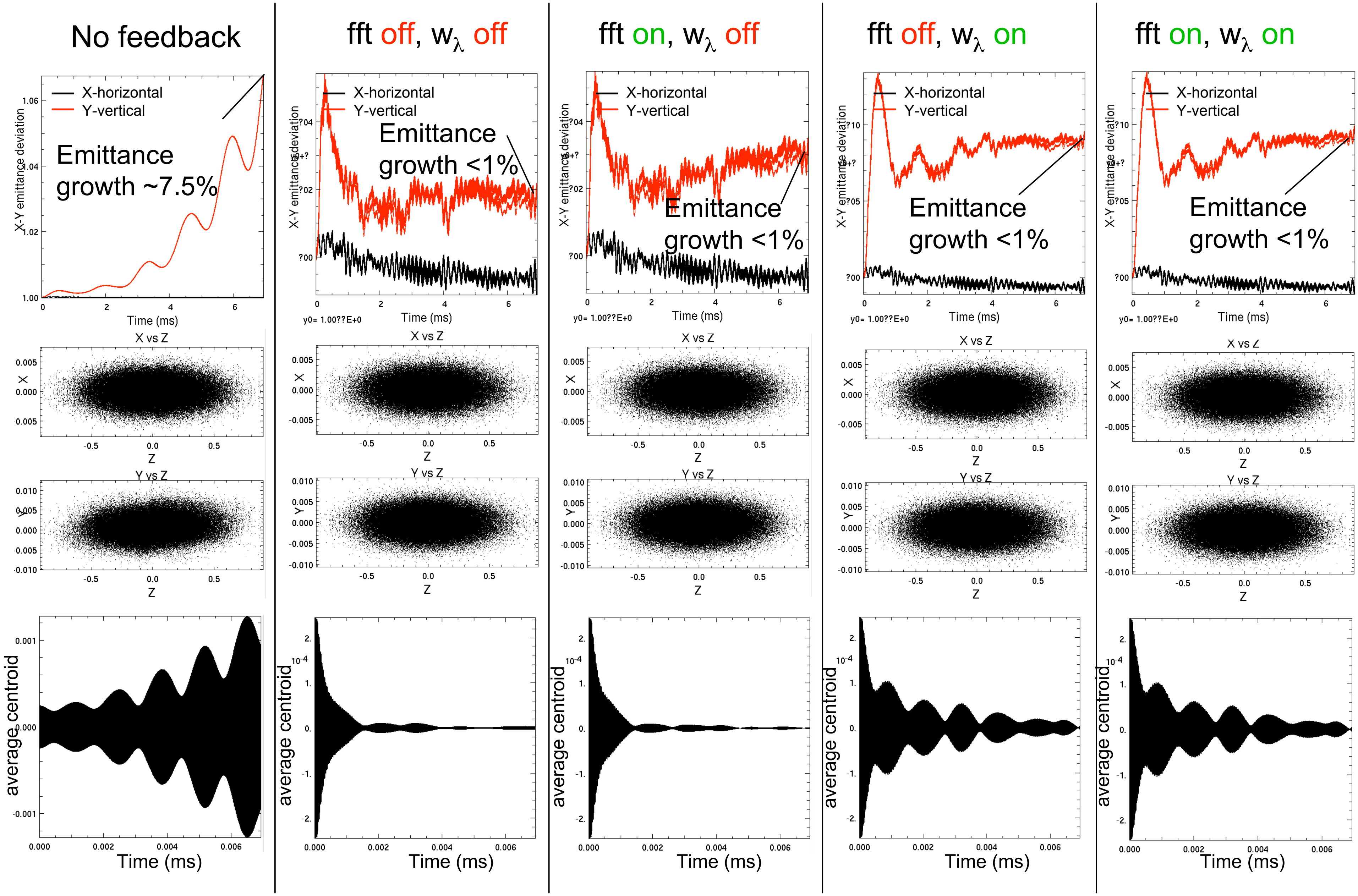
- *apply low-pass FFT filter (sharp cutoff at 800MHz): $y_2(t) \Rightarrow \hat{y}_2(t)$

- one turn later, scale transverse position $y \Rightarrow y - g \cdot \hat{y}_2$ (g=0.1)

*optional stage

Preliminary simul. study of SPS EC feedback

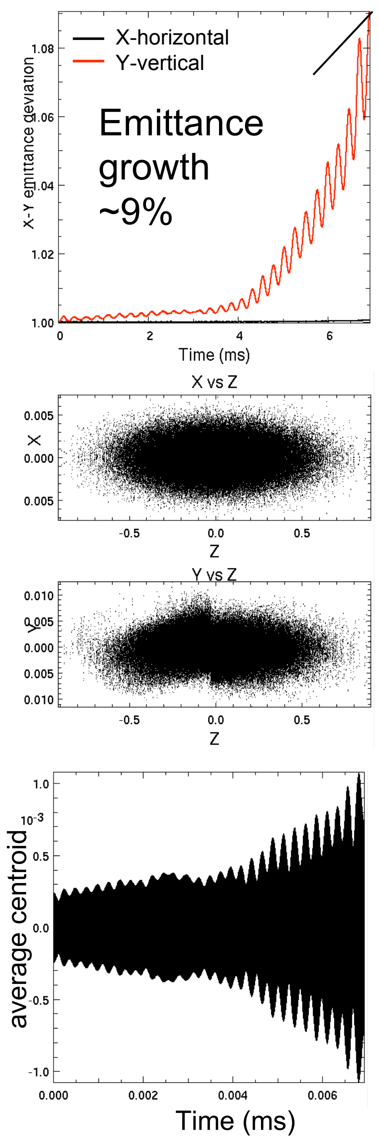
Model 2 - n_e~1.5×10^{12} m^{-3}



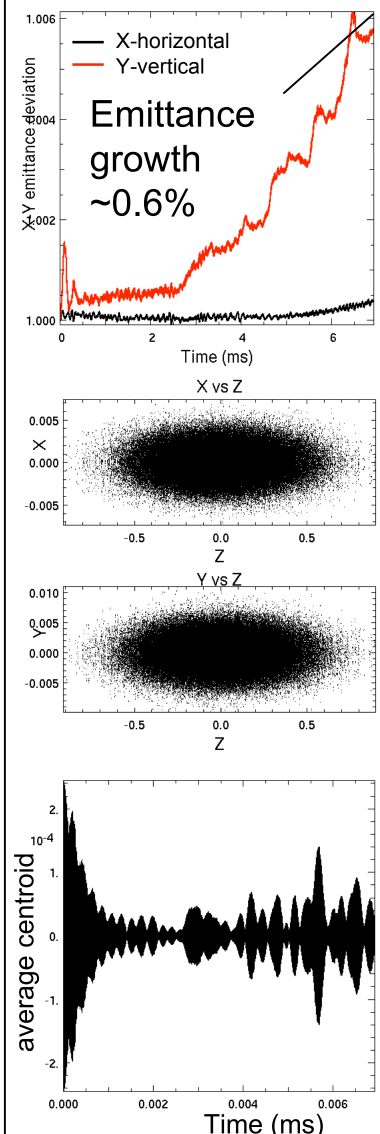
Preliminary simul. study of SPS EC feedback

Model 2 - $n_e \sim 6\times10^{12}$ m^{-3}

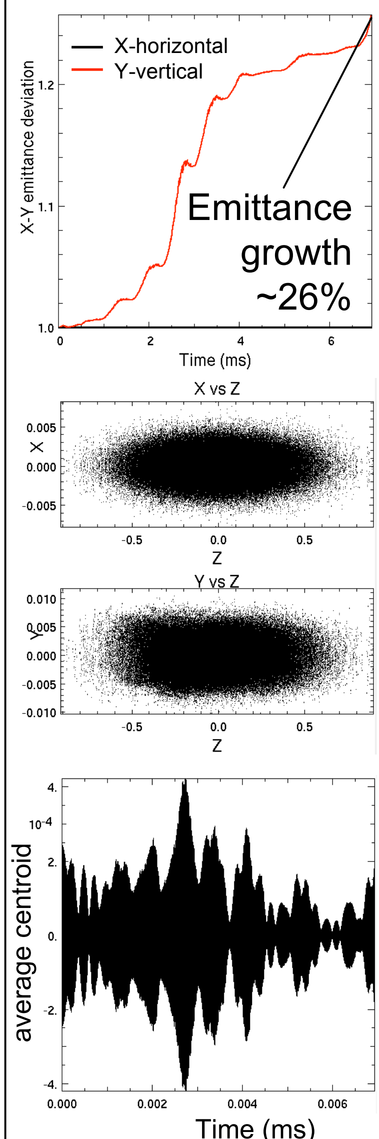
No feedback



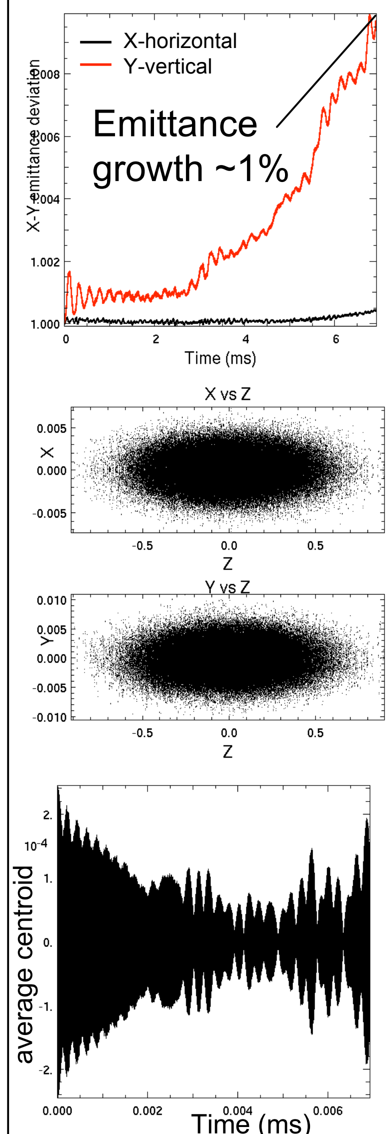
fft off, w_λ off



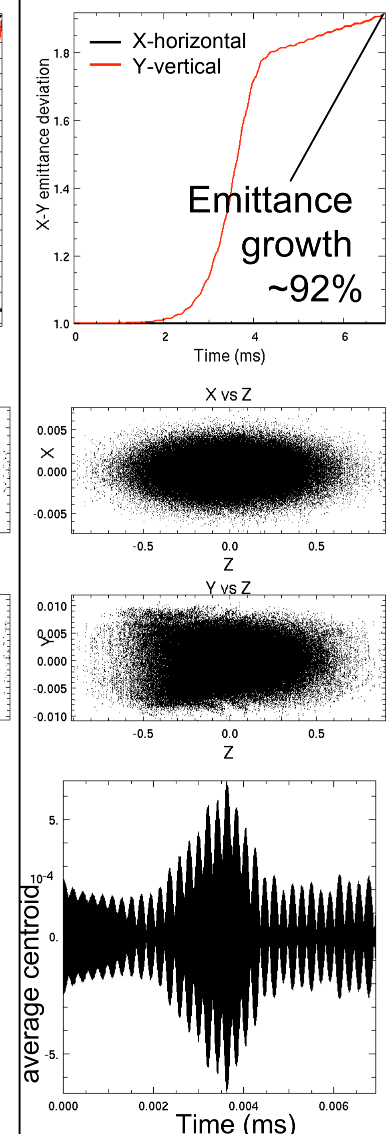
fft on, w_λ off



fft off, w_λ on



fft on, w_λ on



Preliminary simul. study of SPS EC feedback
tentative conclusions

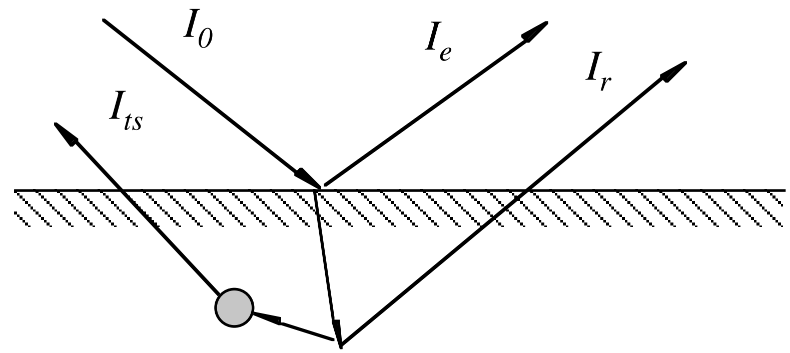
- Idea seems, in principle, to work well with some restrictions
  - damping the coherent vertical motion has beneficial impact on emittance growth if the correction signal has the right modes and phases, which may be compromised by:
    - frequency response cutoff,
    - quality of prediction from pickup to kicker,
    - …

- What next:
  - better modeling of the feedback system (bandwidth, gain, noise,…): ideally setup algorithm reproducing future experimental feedback system as closely as possible,
  - longer runs,
  - freq. Cutoff: higher cutoff (1 GHz?); smoother,
  - …

BACKUPS

POSINST provides advanced SEY model.

Monte-Carlo generation of electrons with energy and angular dependence.
Three components of emitted electrons:



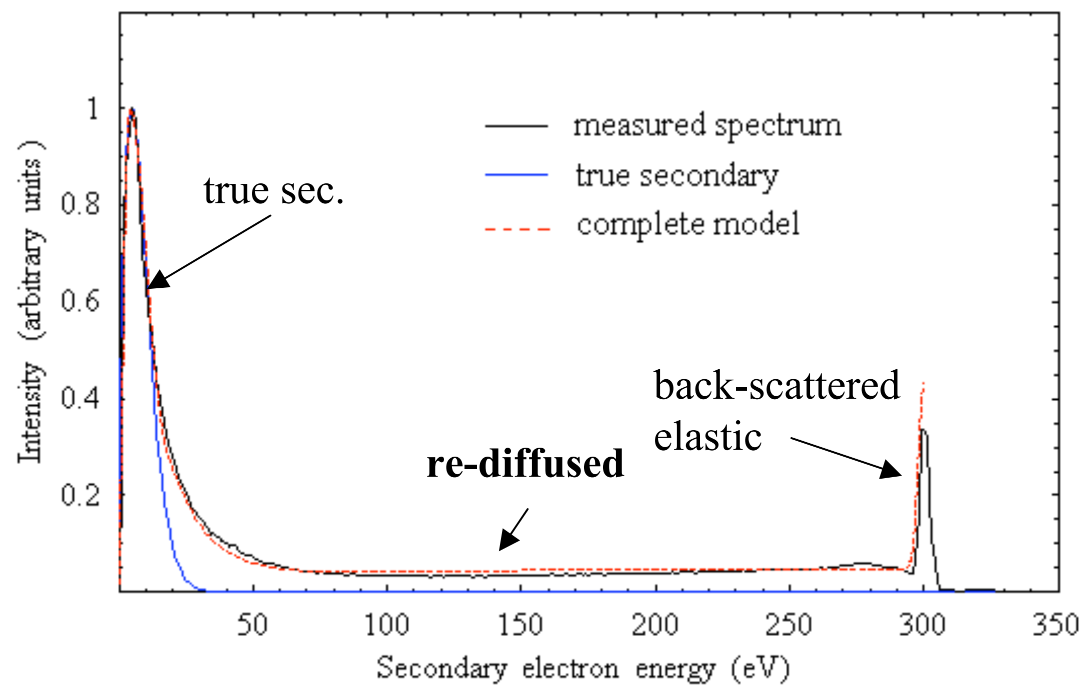
backscattered: $\delta_e = \frac{I_e}{I_0}$,

rediffused: $\delta_r = \frac{I_r}{I_0}$,

true secondaries: $\delta_{ts} = \frac{I_{ts}}{I_0}$

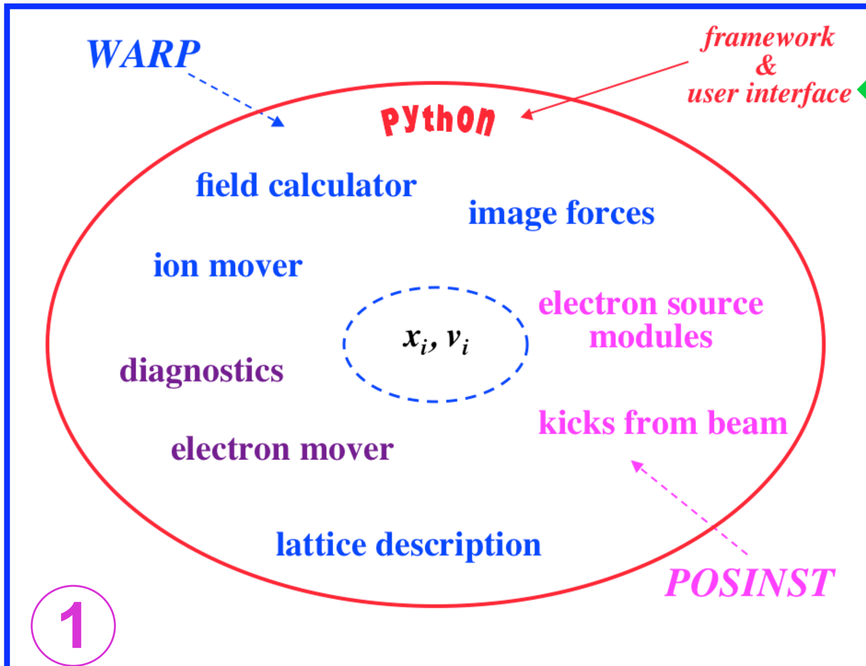
Phenomenological model:

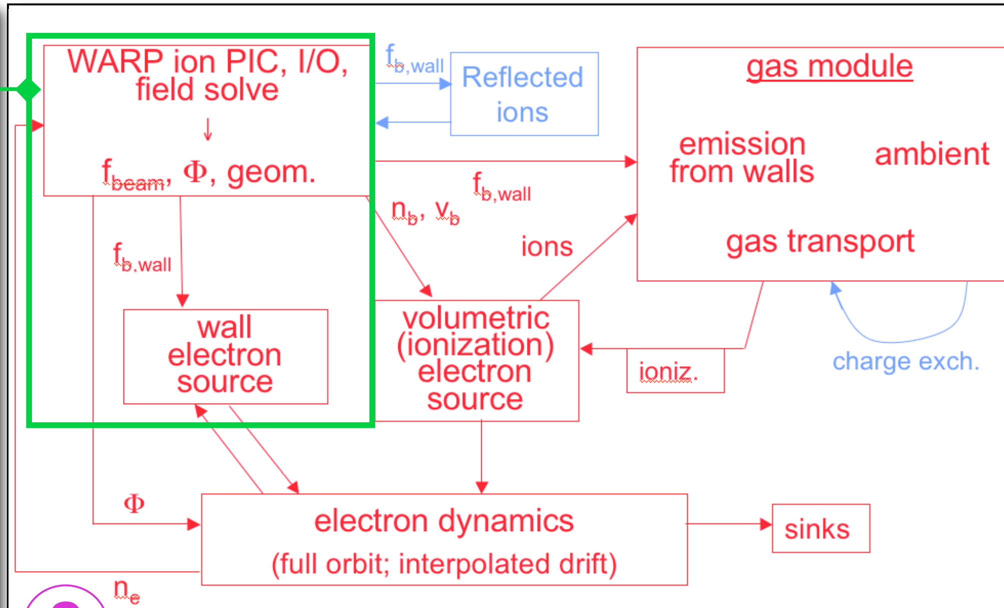
- based as much as possible on data for δ and $d\delta/dE$
- not unique (use simplest assumptions whenever data is not available)
- many adjustable parameters, fixed by fitting δ and $d\delta/dE$ to data



WARP-POSINST unique features

LARP merge of WARP & POSINST + new e⁻/gas modules





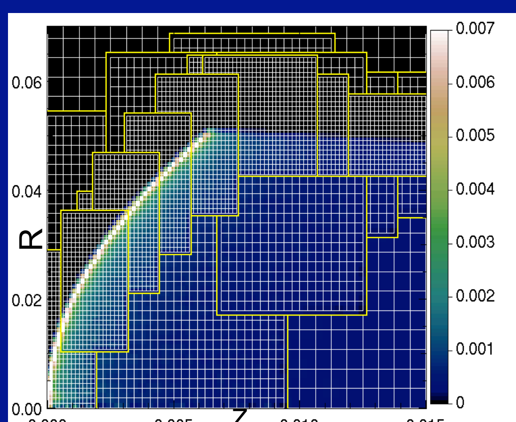
Key: operational; partially implemented (4/28/06)

+ Adaptive Mesh Refinement

concentrates resolution only where it is needed

Speed-up

3 x10-10⁴



+ Novel e⁻ mover

Allows large time step greater than cyclotron period with smooth transition from magnetized to non-magnetized regions

4 Speed-up x10-100