

ORBIT-ESME Space Charge Simulation for the FNAL-Booster

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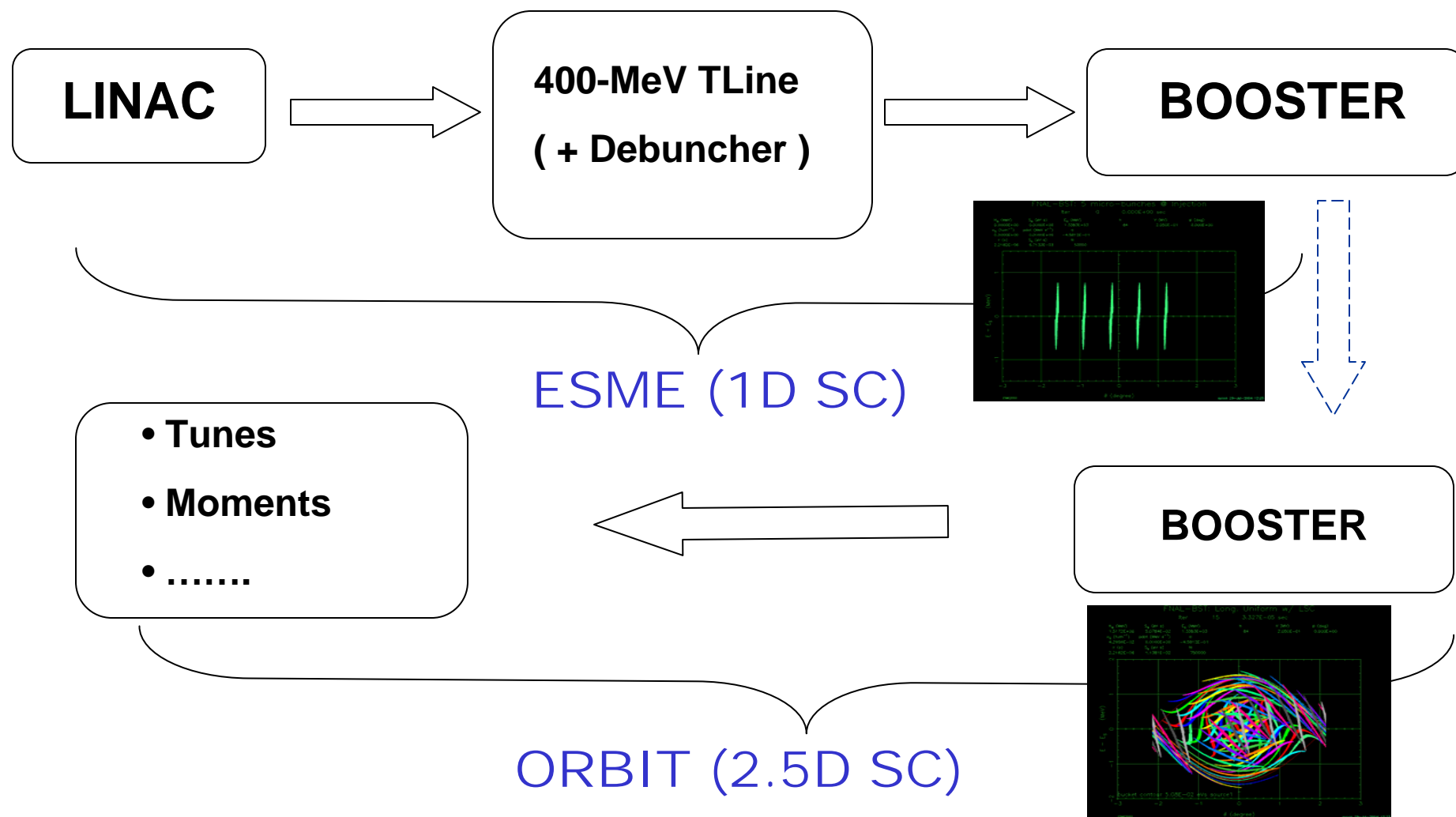
University of Rochester / FNAL / AD

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Booster Study Meeting



Simulation Block Diagram

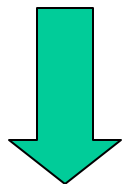
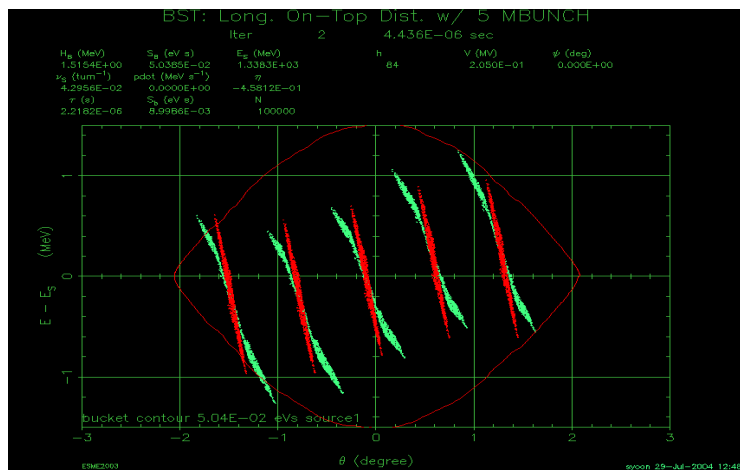




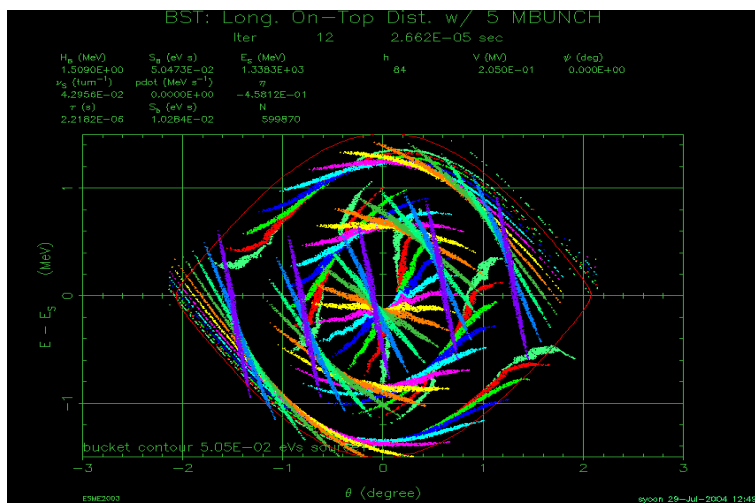
FNAL-BST SIM Parameter List

- MAD Lattice: FNAL-BST Lattice
- Ring Circumference: 474.204810 (m)
- Beam Kinetic Energy: 400 (MeV)
- β_R at Injection: 0.7131
- γ_R at Injection: 1.4263
- τ_{REV} at Injection: 2.2 (μ sec)
- γ_{TR} : 5.4696
- $|\eta|$ at Injection: 0.458
- β_x / β_y at Injection: 7.303 / 20.0232 (m)
- α_x / α_y at Injection: 0.214 / -0.180 (m)
- Φ_{min} / Φ_{max} at Injection: -180.0/180.0 (deg.)
- RF Voltage: 205.0 KV/Turn
- Transverse Distribution: bi-Gaussian
- Longitudinal Distribution:
Uniform/On-Top Distribution
- Max. No. of MacroParticle: 110K
- Injection Turns: 11
- Total Proton Intensity: 6.00e10 (ppb)
- RF Harmonics: 1
- FNAL-BST Harmonic No.: 84
- RF Phase = 0.0 (deg.)
- Tracking Turns after Injection: 50
- v_x / v_y (nominal tunes): 6.7/6.8
- v_S : 2.484e-3
- $\Delta E/E$: 1.346e-2
- Space Charge: 2.5 D
- No. of Longitudinal Bins: 32
- No. of Transverse Bins: 64
- Beam Pipe Radius, \varnothing : 2.54e-2 (m)

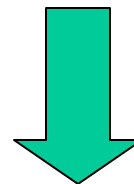
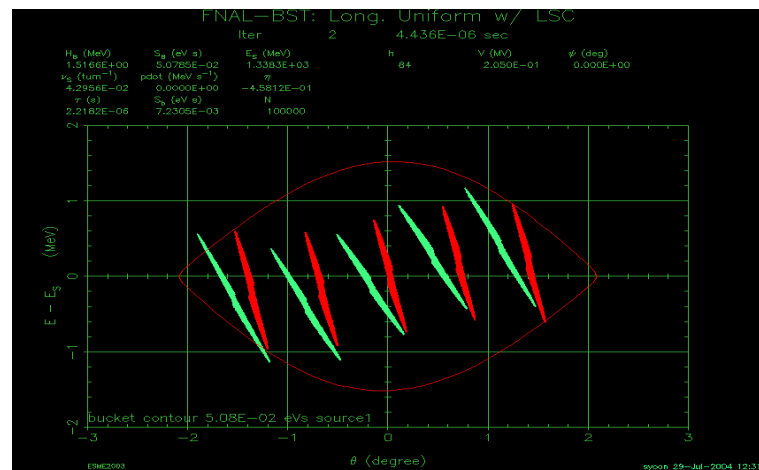
5 μ -bunch On-Top Injection



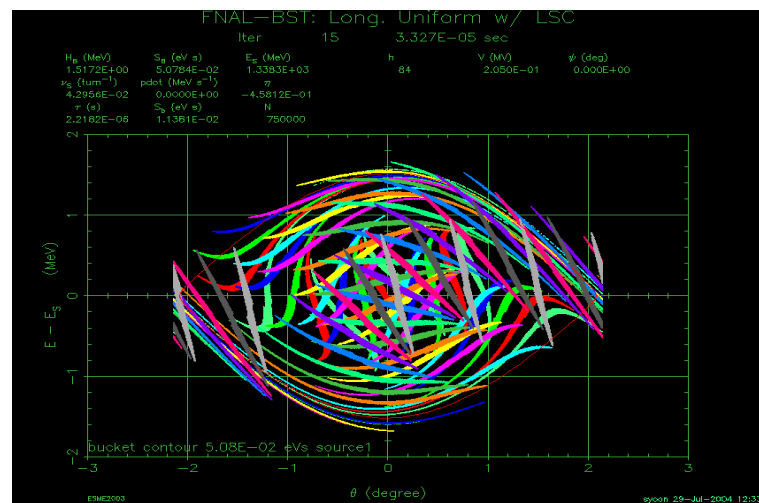
iteration

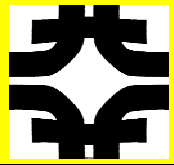


Uniform Injection



iteration



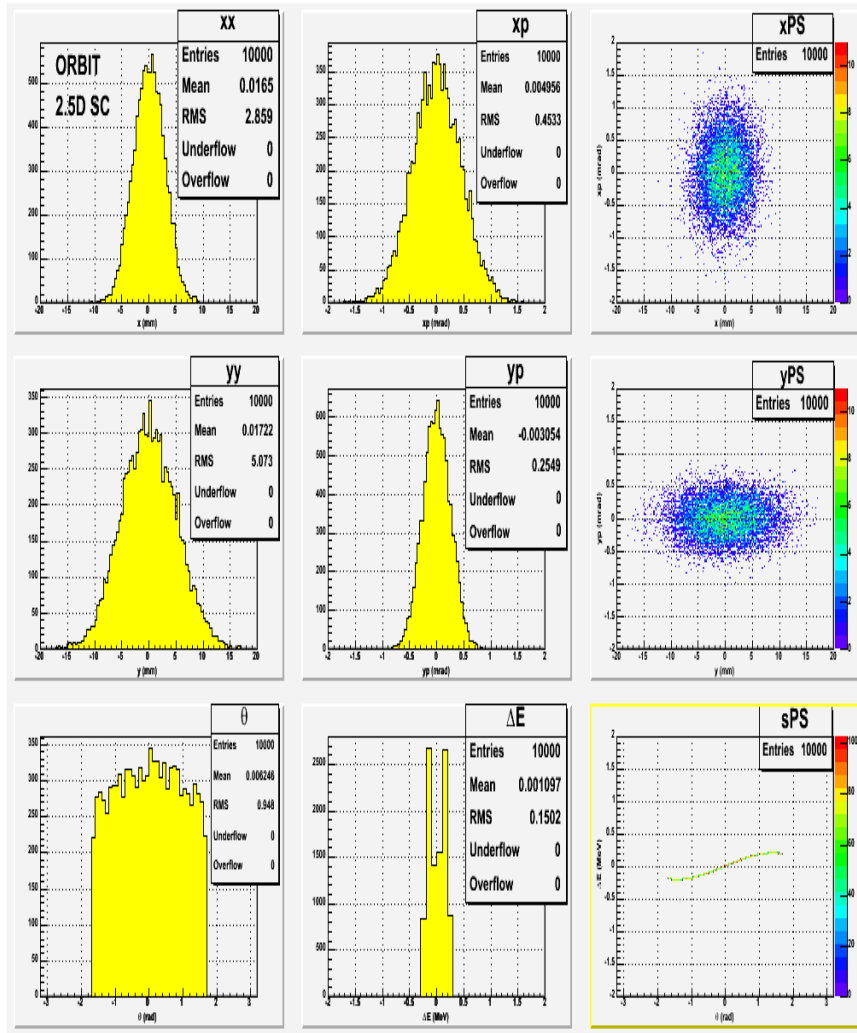


Motivation for ESME-ORBIT SIM

- The ESME is armed with a variety of features for synchrotron motion.
- The ORBIT-FNAL can simulate full space-charge effects both for synchrotron motion and betatron motion in high-intensity proton machines.
- As they were not born to be run together, it is right thing to check with what is feeding into ORBIT from ESME.
- To do so, I have set up several check-points for validation throughout the combined simulation runs.



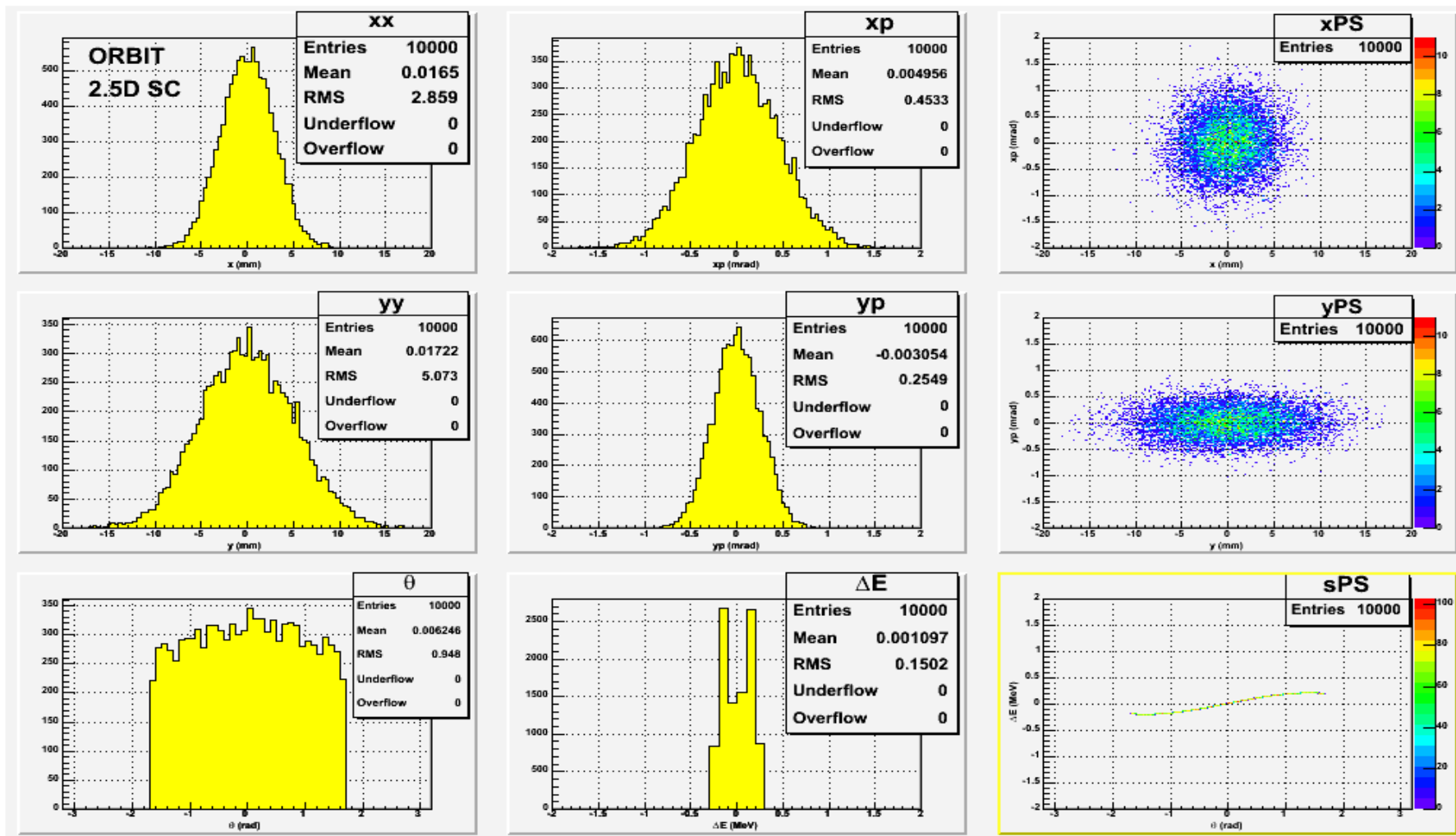
ESME-ORBIT SIM Validation



- 9 plots on the left display ORBIT input of 6-dimensional phase space coordinates from ESME simulation.
- 1st and 2nd columns from the left are for x, xp, y, yp, θ , ΔE in units of mm, mrad, mm, mrad, rad, MeV, respectively.
- 3rd column is for 3 phase-space maps (2 transverse and 1 longitudinal maps) Color indicator column on the far right shows population or density on the phase-space map.
- This validation was done at the interface of the combined simulation runs.

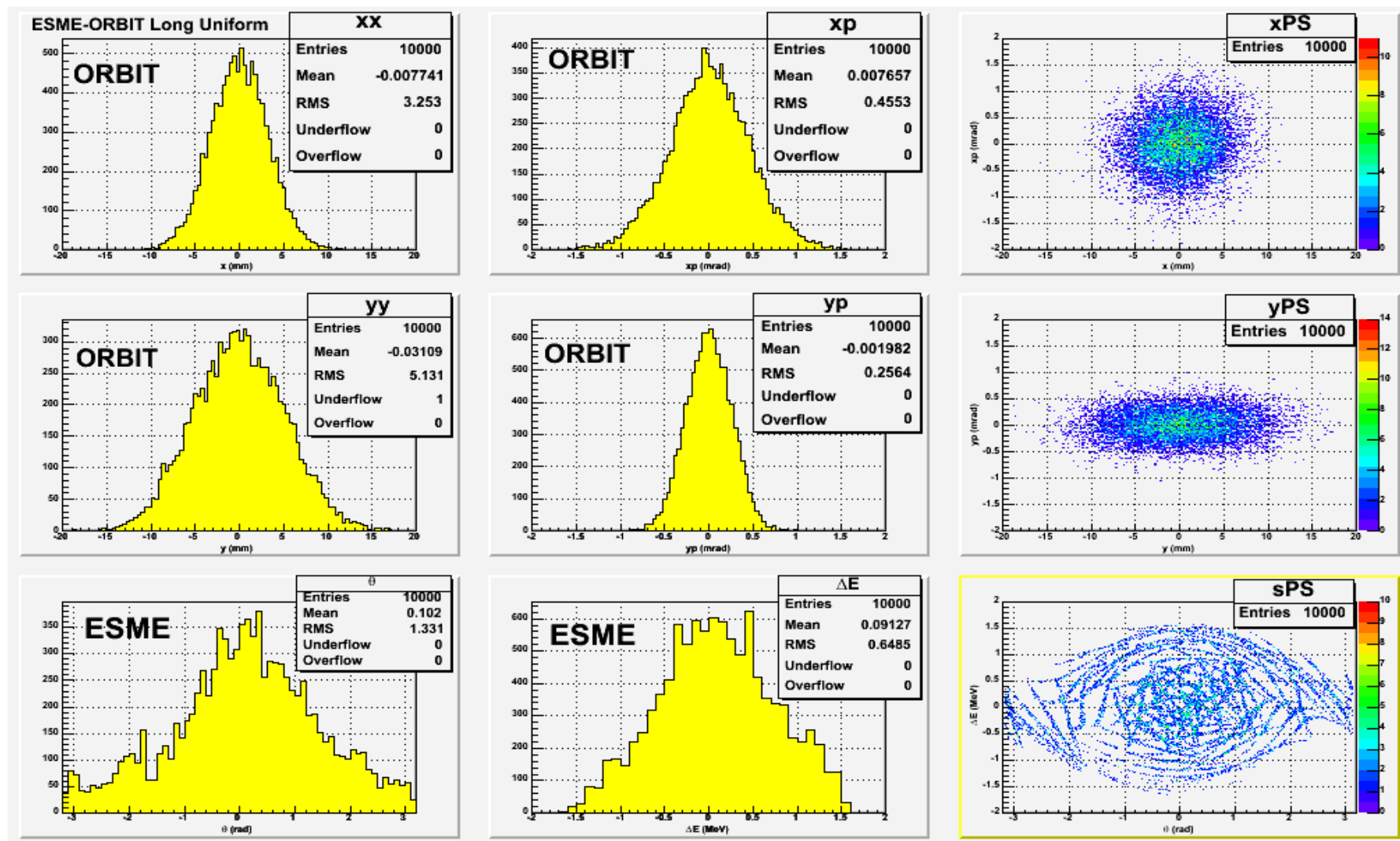


ORBIT Long. Uniform Injection



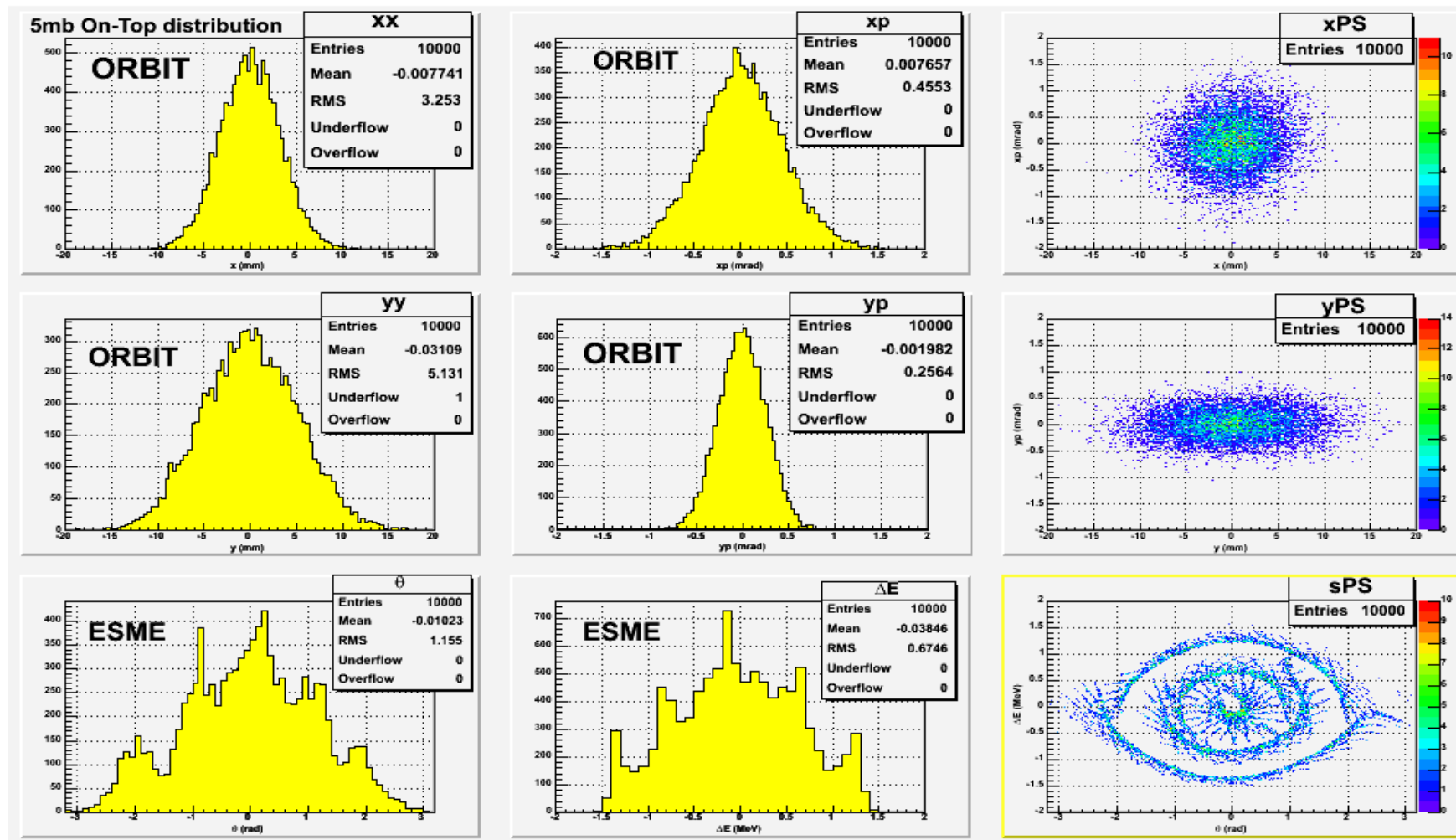


ESME Long. Uniform Injection



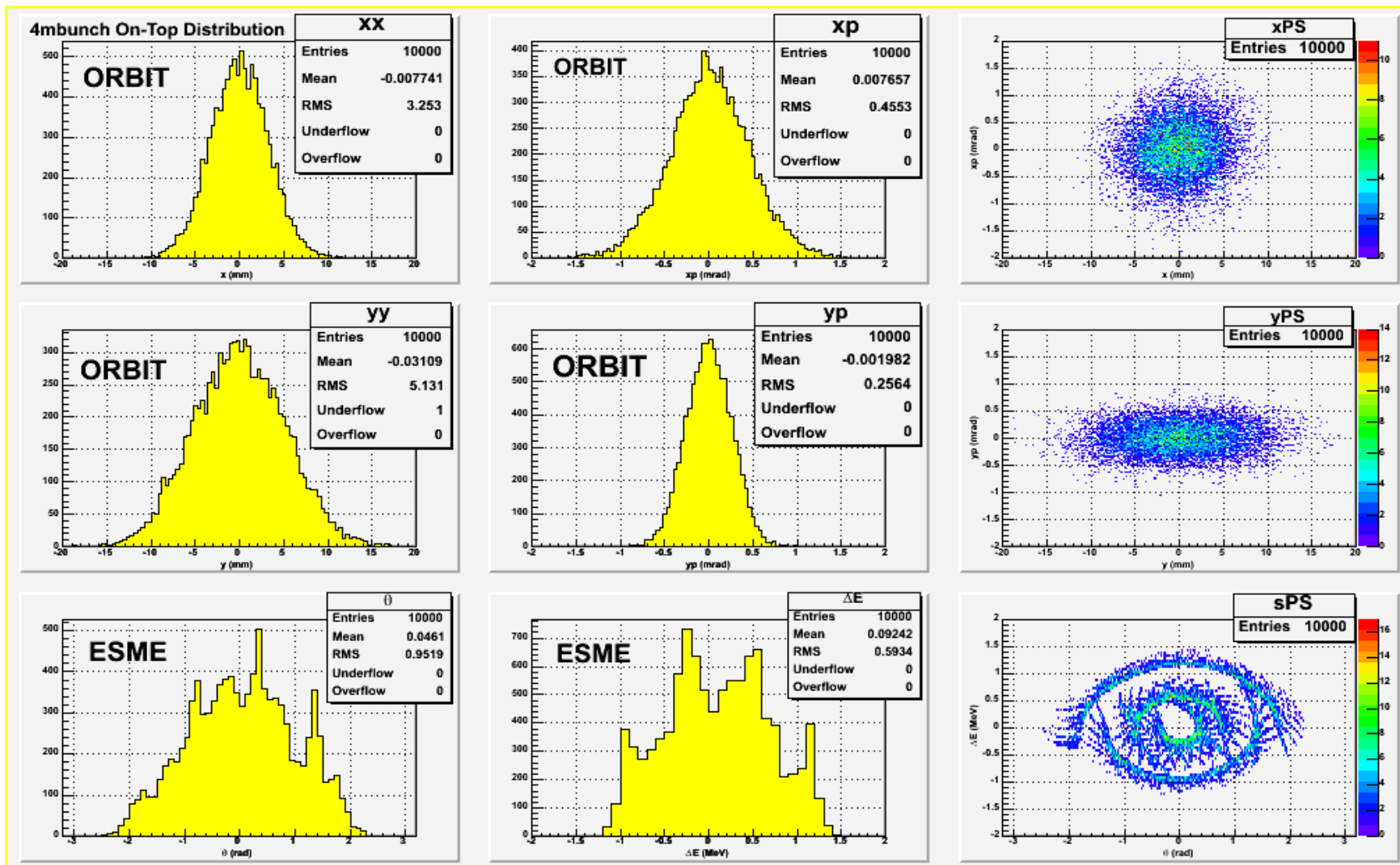


5 μ -bunch On-Top Injection



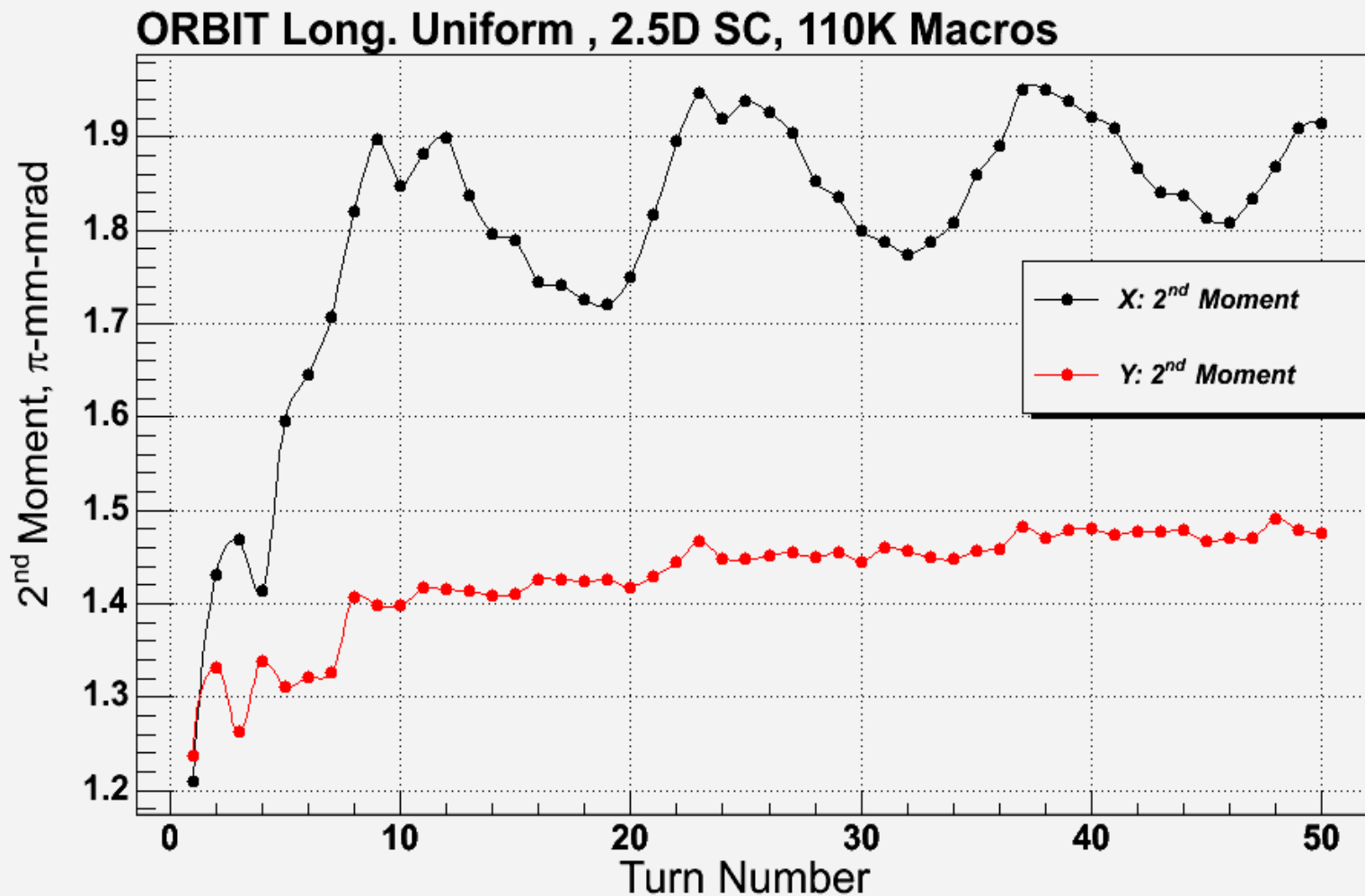


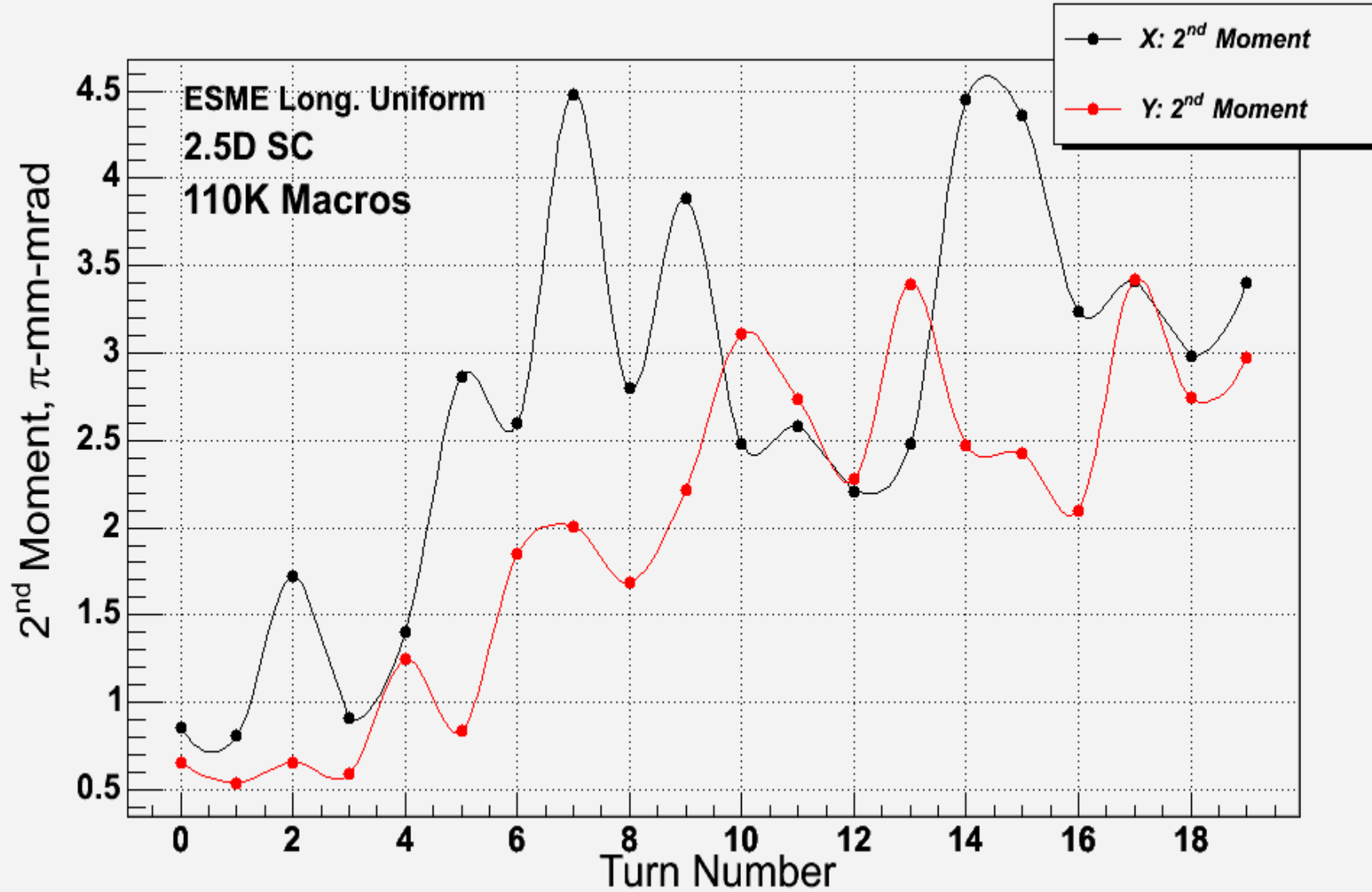
4 μ -bunch On-Top Injection



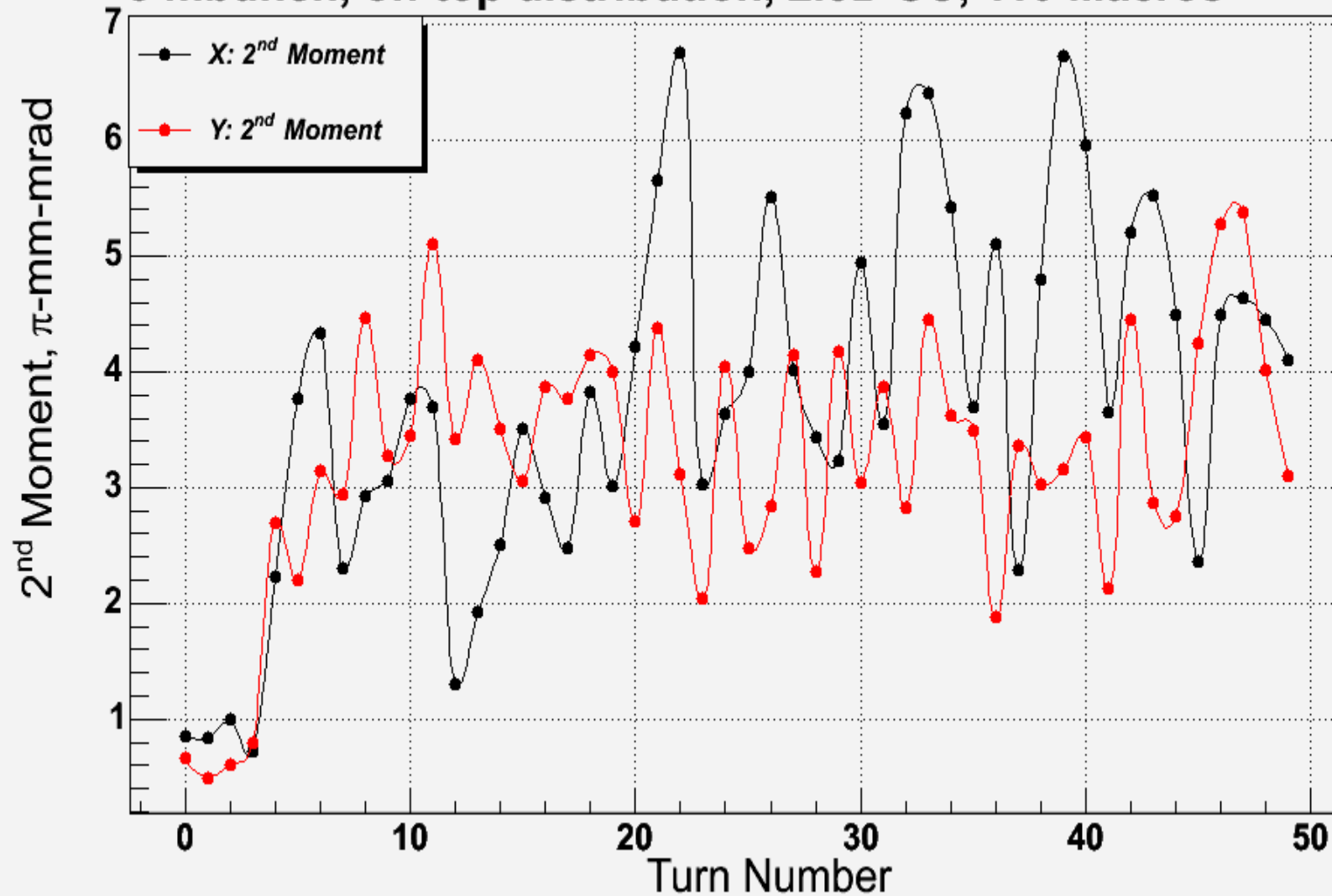


Transverse Emittance Growth

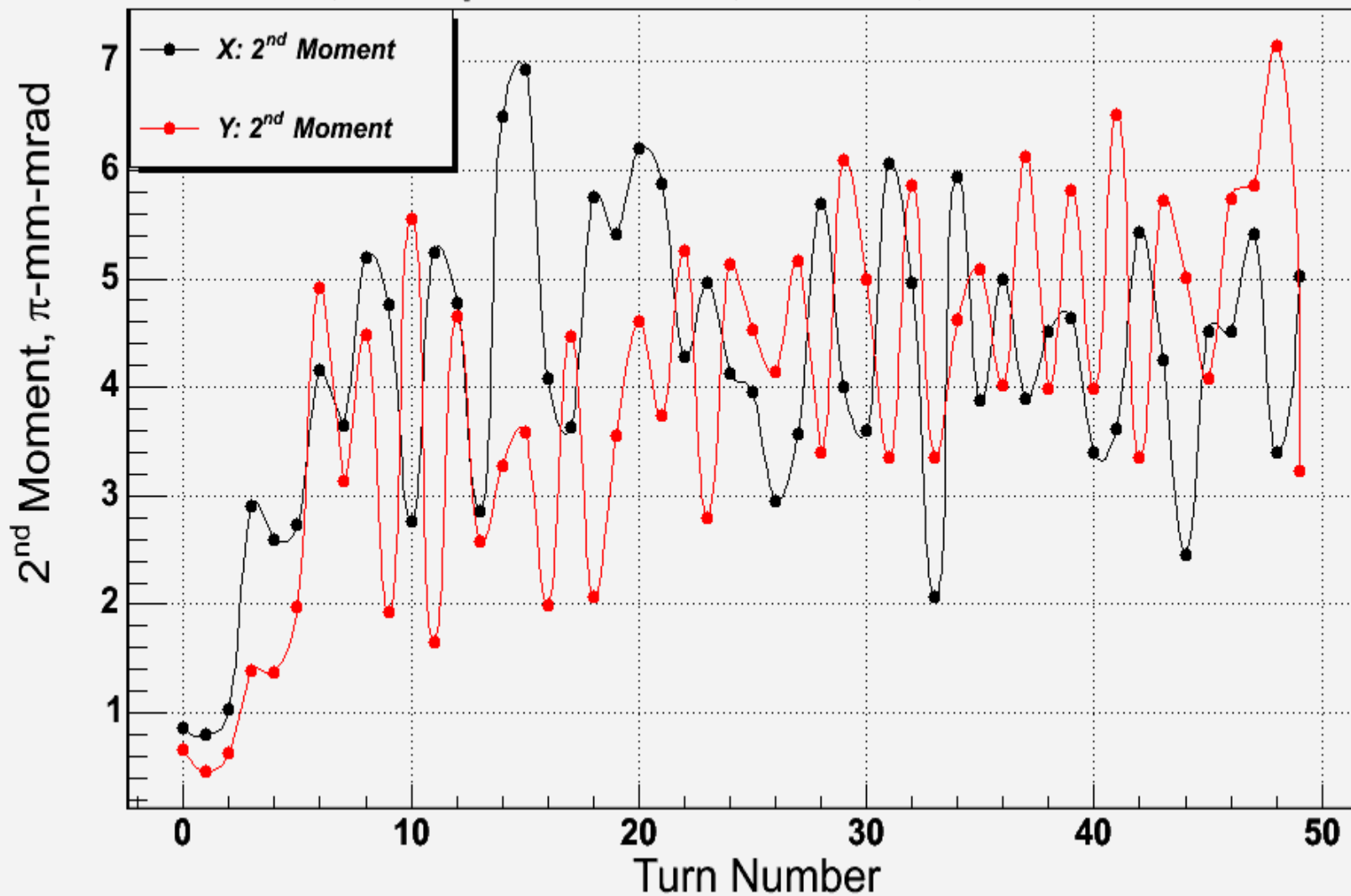




5 mbunch, on-top distribution, 2.5D SC, 110 Macros



4 mbunch, on-top distribution, 2.5D SC, 110K Macros





Concluding Remarks

- This is the first effort to run ESME and ORBIT-FNAL together, which makes it possible to simulate the Booster operation **more realistic than ever**.
- Simulation starting from LINAC, 400-MeV Transfer Line (+ Debuncher Process) through Booster
 - RF Node incorporated.
 - 2.5 D Full Space Charge Effects included.
- Compared to the ORBIT-only simulation with uniform longitudinal injection, the combined SIM demonstrates larger emittance growth.
 - The downside of this combined SIM is that it takes a dozen of small processing work. More efforts are currently underway to make this combinative SIM more **simplified**, **automated**, and **realistic**.