Experiences with, and Enhancements of BeamBeam3d for the Tevatron

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for the FNAL CPA group

BeamBeam3d is a great program...

- Parallel Green's function solver
- Multiple bunches
- Flexible maps and optics
- Stuff I haven't used: synchrotron radiation damping, etc.

For the Tevatron, I needed additional features*

*I started with an older version.

Enhancements to BeamBeam3d

Decouple tracking from the beam-beam solve

Introduce and track azimuthal coordinate and path length by bunch

Introduce the possibility of differing lengths of arcs in the accelerator

Allow different beam offsets (x and y) for each interaction point

Add resistive wall impedance

Add chromaticity that preserves symplecticity in the presence of coupled maps

External auxiliary programs for BeamBeam3d

Produce maps using externally determined lattice functions

Mais-Ripken coupled maps formalism:

$$\alpha_{1x}, \beta_{1x}, \alpha_{2x}, \beta_{2x}, \alpha_{1y}, \beta_{1y}, \alpha_{2y}, \beta_{2y}, u, \nu_{1,} \nu_{2,} \mu_{1,} \mu_{2} \Rightarrow V_1$$

V_x transforms uncoupled representation of particle coordinates into physical coupled coordinates at point *x* using Twiss parameters

$$M_{12} = -V_2 P U V_1^T U$$

$$P = \begin{pmatrix} \cos\mu_1 & \sin\mu_1 & 0 & 0 \\ -\sin\mu_1 & \cos\mu_1 & 0 & 0 \\ 0 & 0 & \cos\mu_2 & \sin\mu_2 \\ 0 & 0 & -\sin\mu_2 & \cos\mu_2 \end{pmatrix}$$

Map including chromaticity is

$$M_\xi = -V_2 P_\xi U V_1^T U$$

P_ξ calculated with phase advance $\mu_{1,2} = \mu_{x,y}(1 + \delta\xi_{x,y})$

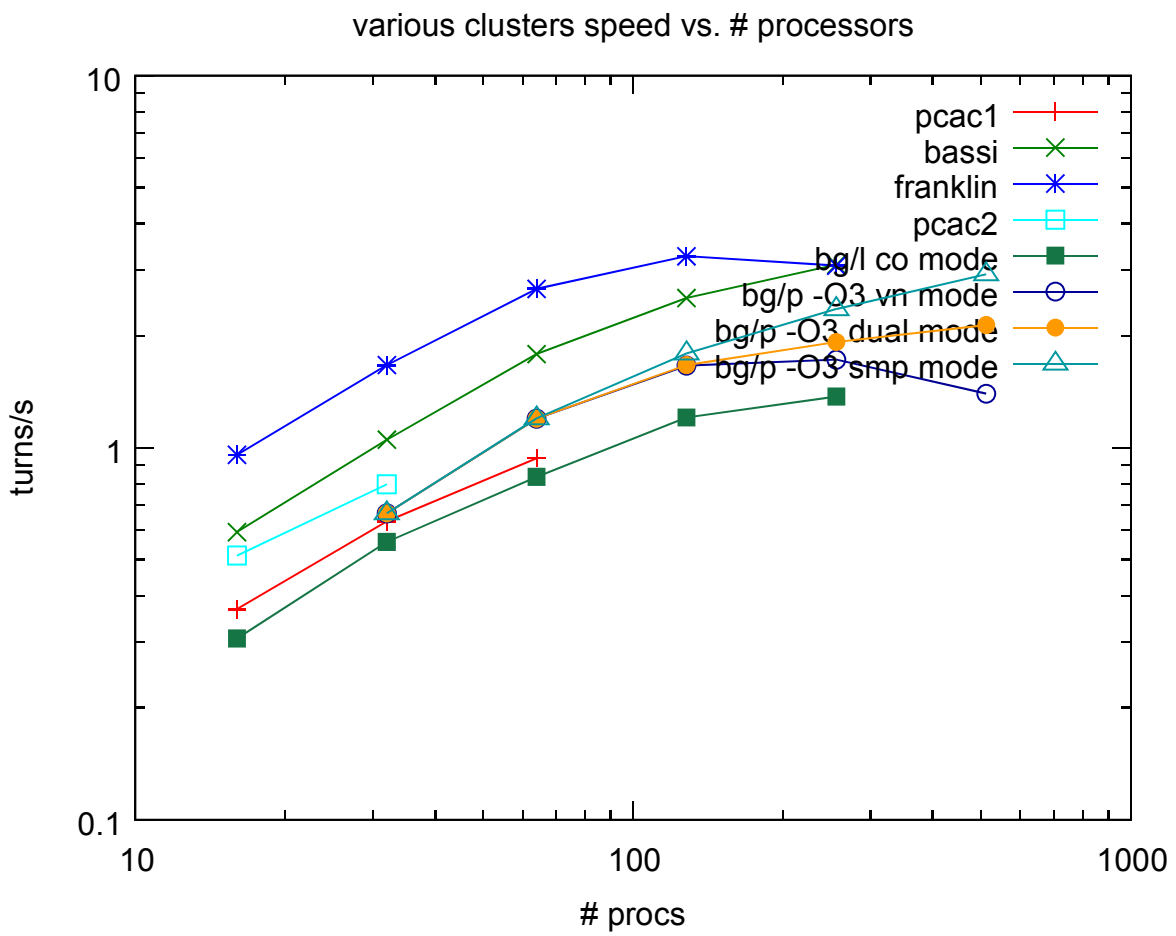
External auxiliary programs for BeamBeam3d (cont.)

Python scripts to generate bunch collision pattern input files and multi-bunch map files.

n on n bunches with head-on and 2n-1 long-range collisions

36 on 36 bunches at two head-on and four long-range interaction points

Running BeamBeam3d on BlueGene/P



BlueGene's are not very fast.

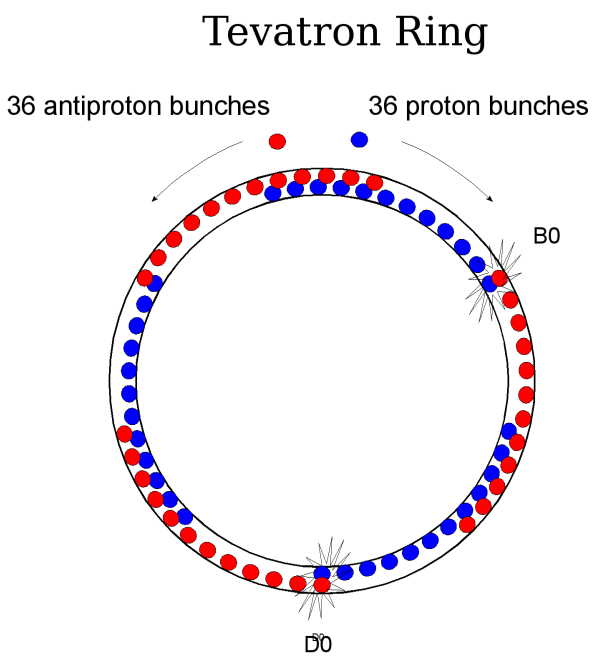
BGP has 4 CPUs/node.

With larger node/job network contention in the nodes requires running 1 task/4cpu node.

Performance is rolling off after 512 nodes.

Profiling on BG/P showed that 20% of the time was spent in ATAN. Most of the remaining time is spent in MPI communications. Using IBM optimized math libraries increased performance by 20%.

Running BeamBeam3d on franklin (NERSC)



Two head-on plus the four closest long-range interaction points with 36-on-36 bunches requires 75 steps/turn

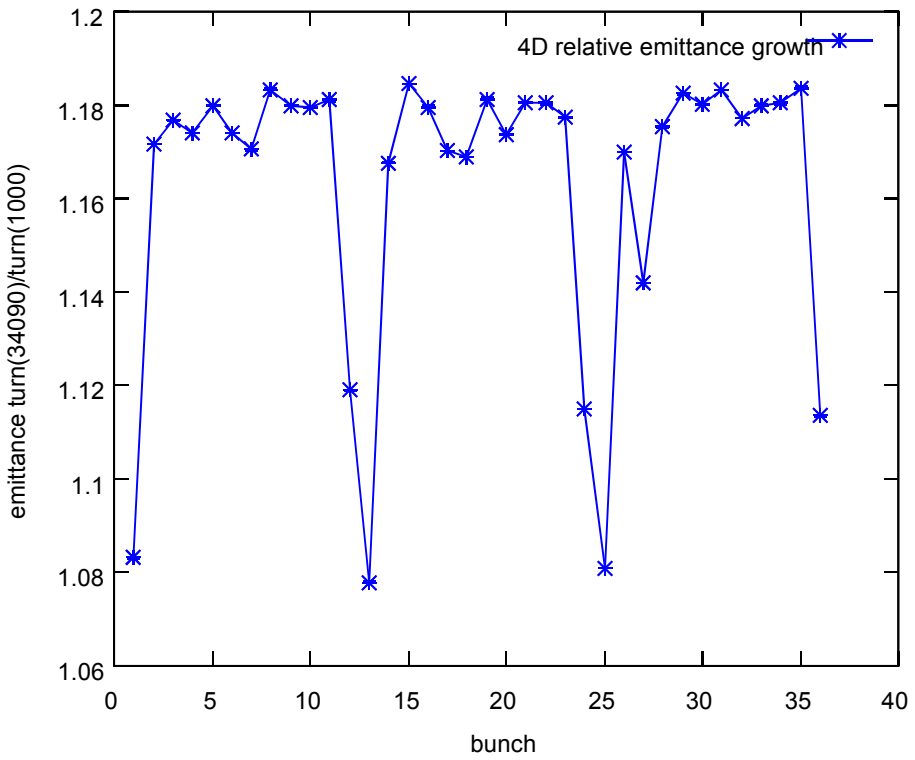
One slice beam-beam interactions performance is 1.9 s/turn with 64 CPUs

Six slices beam-beam interactions plus impedance performance is 42.7 s/turn with 96 CPUs.

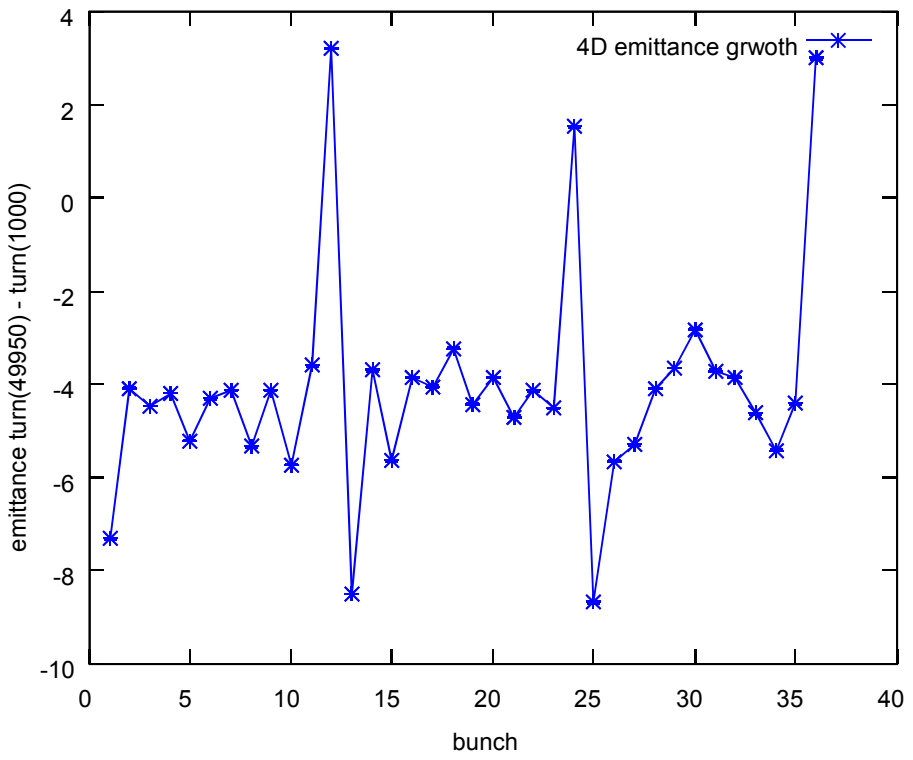
To run jobs on franklin, I have to run 2500 turn jobs, checkpoint and restart in a new job (2500 turns runs for 30 hours)

Details of emittance growth are sensitive to initial conditions

Equal emittance

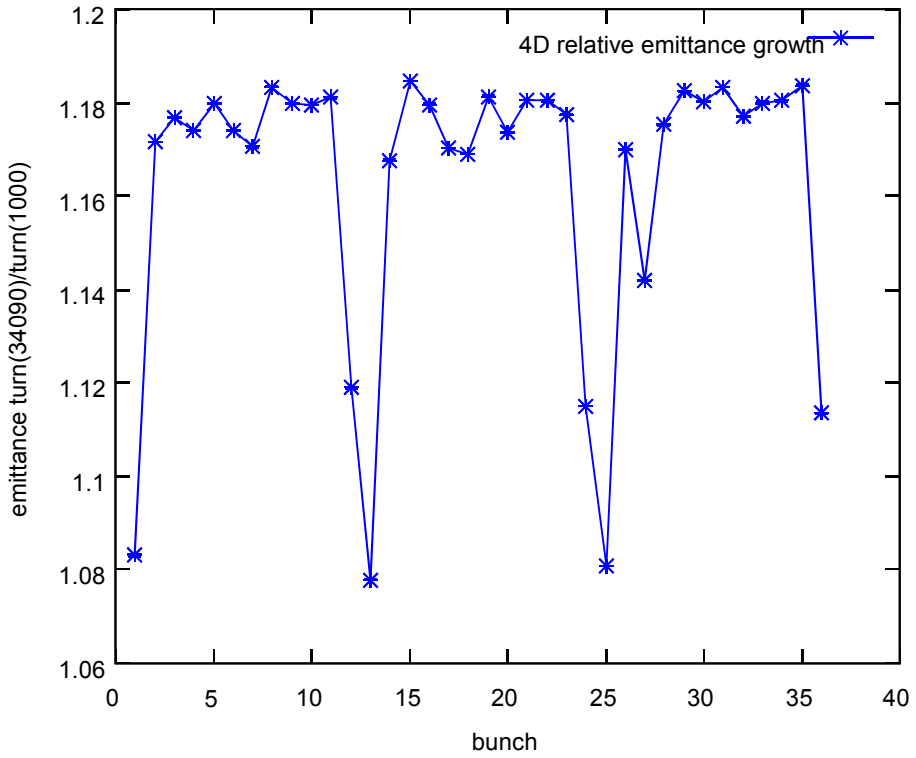


Unequal emittance

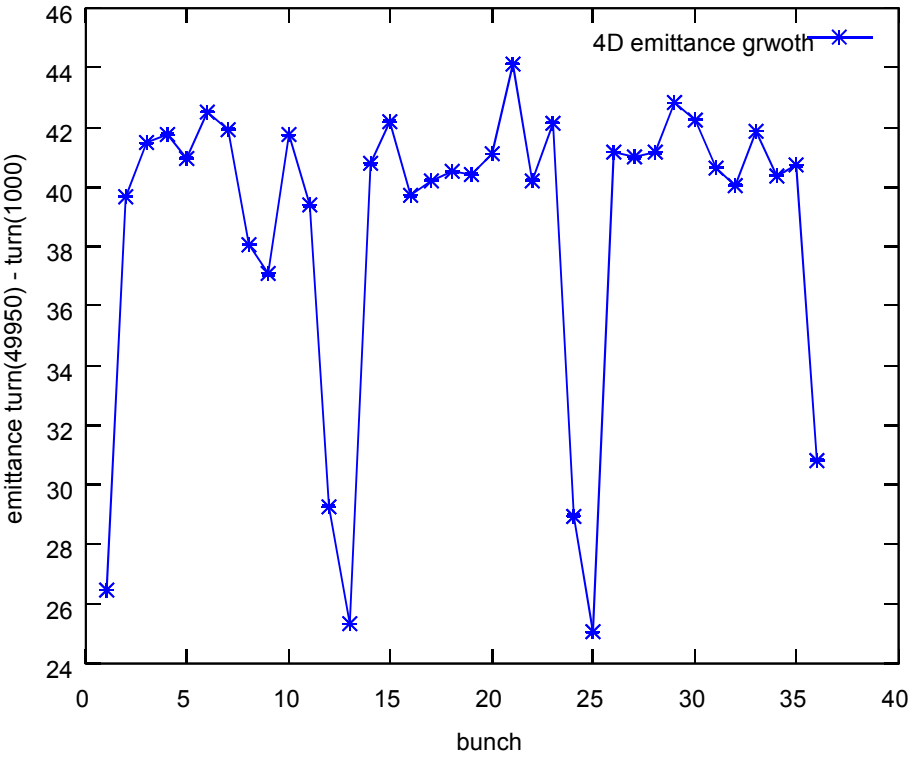


Tevatron results (cont.)

Nominal tunes

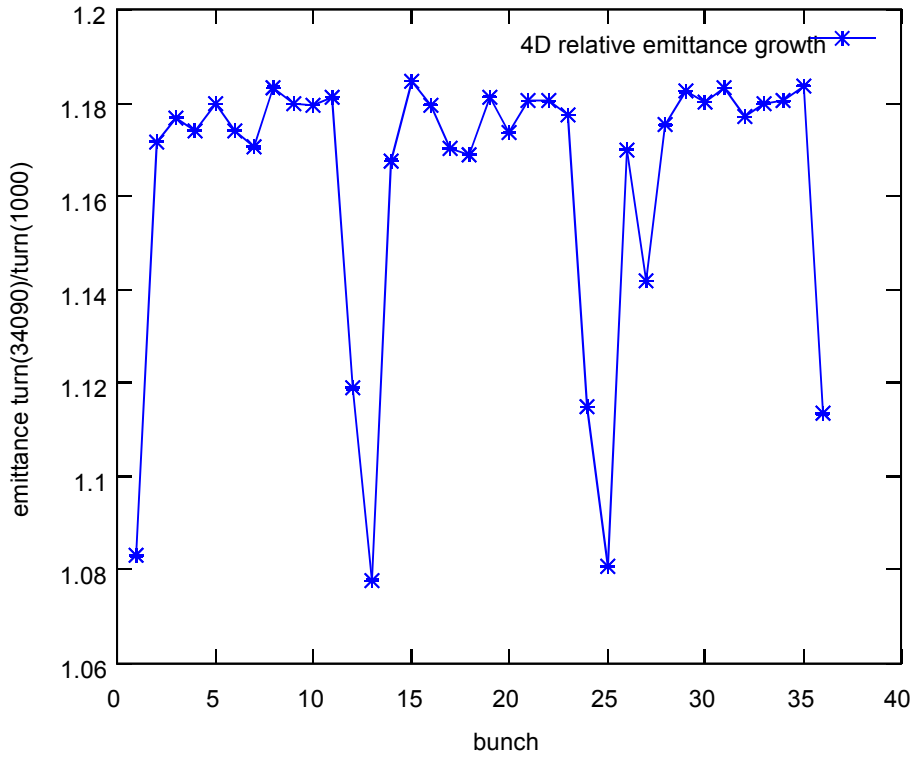


Tunes reduce by 0.002

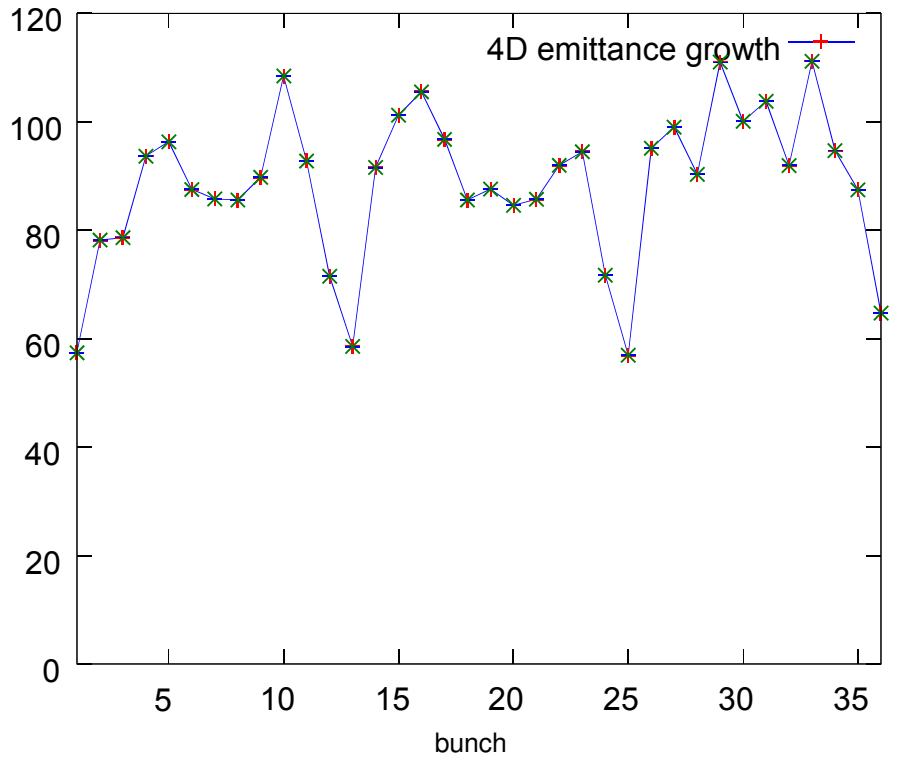


Tevatron results (cont.)

Single slice

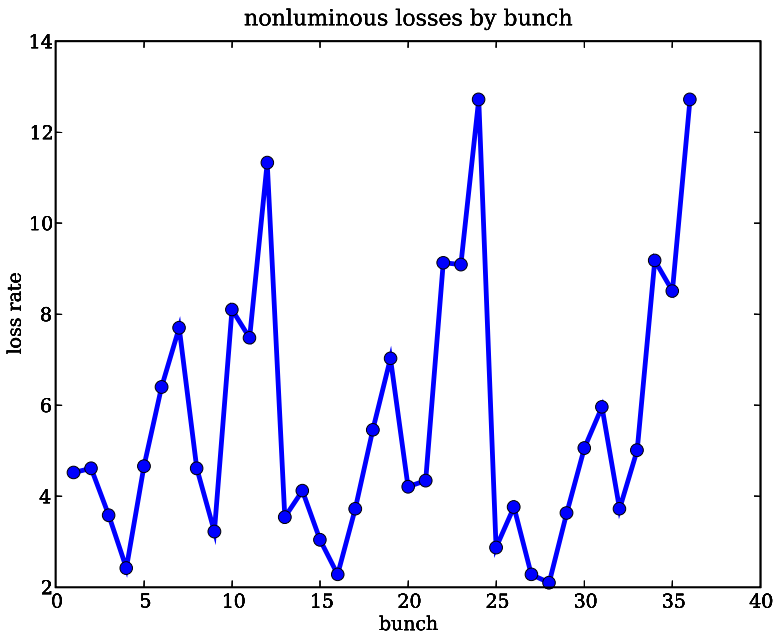


Six slices and impedance

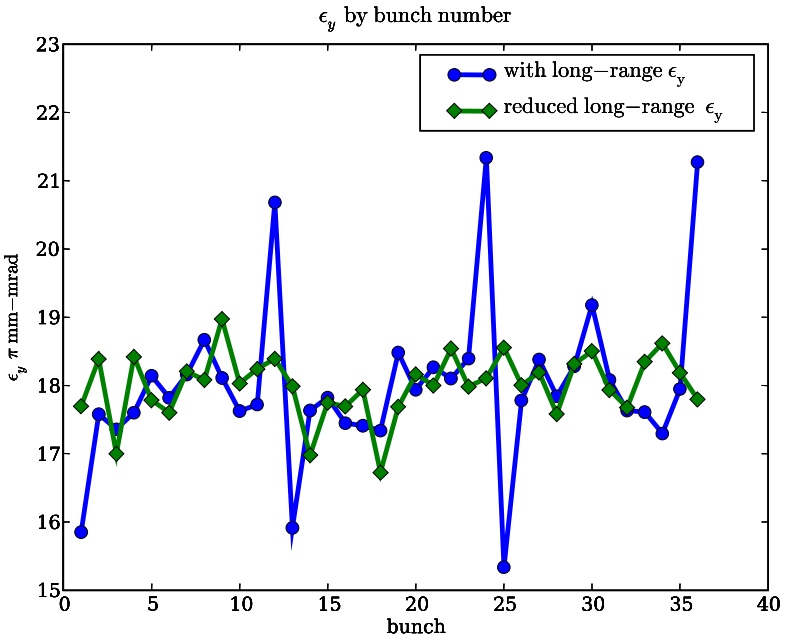


Tevatron results (cont.)

Measured losses



Simulated emittance growth



Summary

I've had a good run with BeamBeam3d

I've reached the limit on how far I can push it