Progress on RHIC and LHC Beam-Beam Simulations at LBNL

Miguel Furman and Ji Qiang
LBNL

Workshop on Beam Experiments at RHIC
BNL, September 26-27, 2002

Beam-Beam Effect

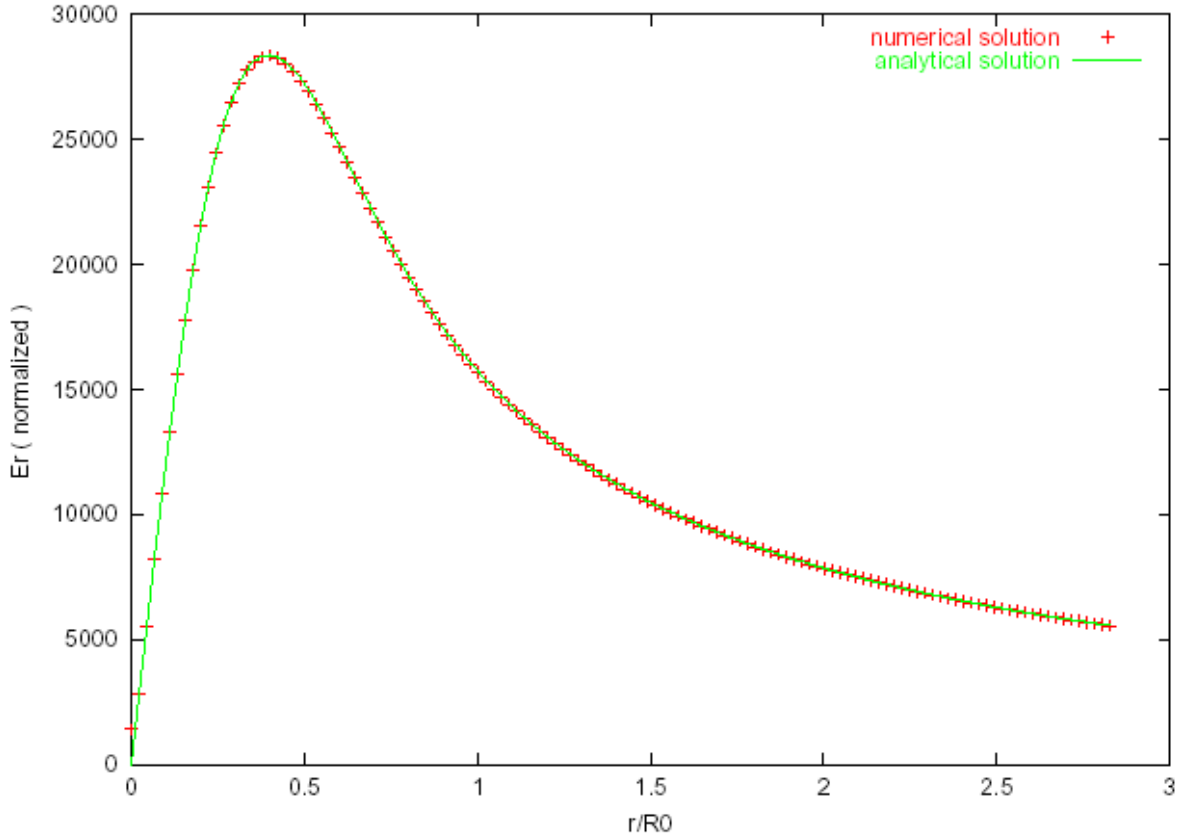
- Main current goal: evaluate LHC luminosity monitor
  - also: long-term luminosity performance of LHC
  - effect of parasitic collisions, B-T-B population fluctuations
  - close contact with LHC beam-beam team at CERN
  - collaboration with Accel. Modeling and Advanced Computation (AMAC) group at LBNL
    - One of SciDAC centers; R. Ryne, head.

PIC code features

- PIC simulation code "BEAMBEAM3D" (J. Qiang)
  - parallel computation; runs on NERSC MPP machine
  - fully 3D (including $\sigma_z \neq 0$)
  - independent beam parameters for the two beams
  - crossing angle (a la Hirata, transverse boost)
  - arbitrary closed-orbit separation (static or time dependent)
  - long-range collisions: "shifted Green's function" technique
  - linear lattice map (linear coupling and nonlinear elements coming soon)
  - weak-strong options (e.g.., multi-IP collisions, with varying phase advance)
  - arbitrary beam particle type
- Typical runs:
  - 10^6 macroparticles/bunch
  - 16 processors (up to 512)
  - ~several hours CPU time for ~10^5 turns with linear lattice map

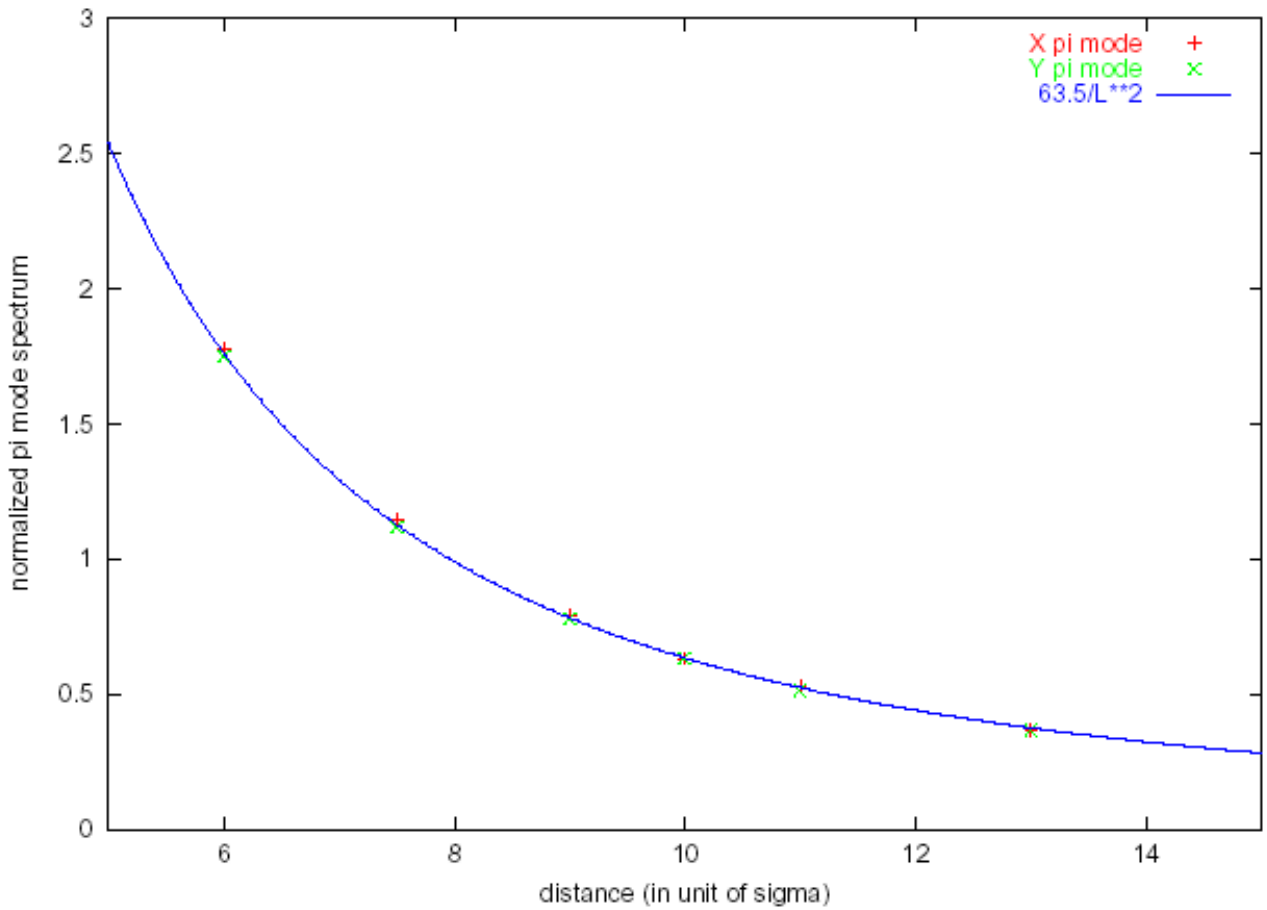
BEAMBEAM3D Simulations

- E-field vs. radius for Gaussian distribution
  - analytic and PIC computation



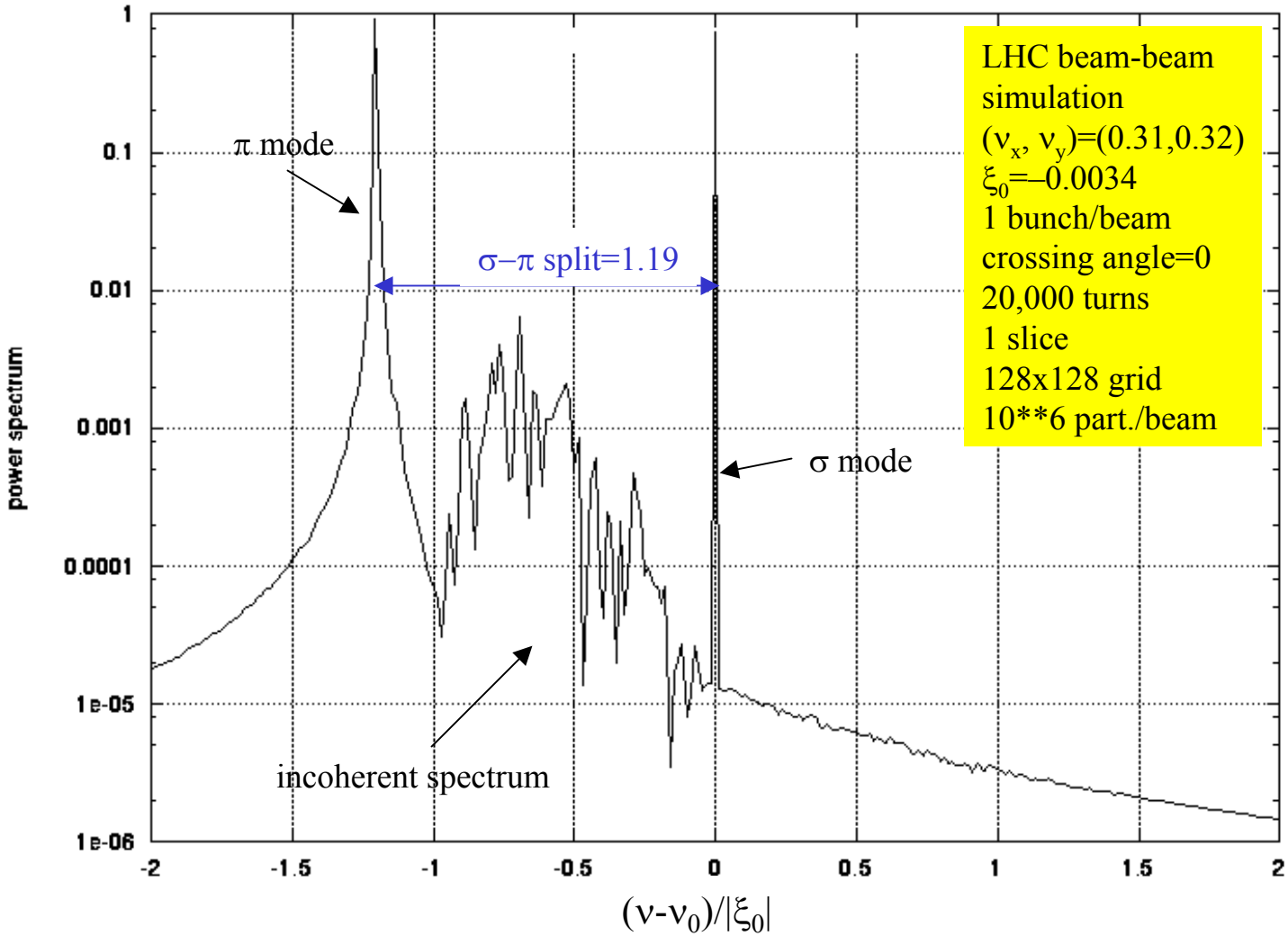
BEAMBEAM3D Simulations (contd.')

- π-mode tune shift vs. beam separation (parasitic collisions)
  - PIC computation and $1/L^2$ fit



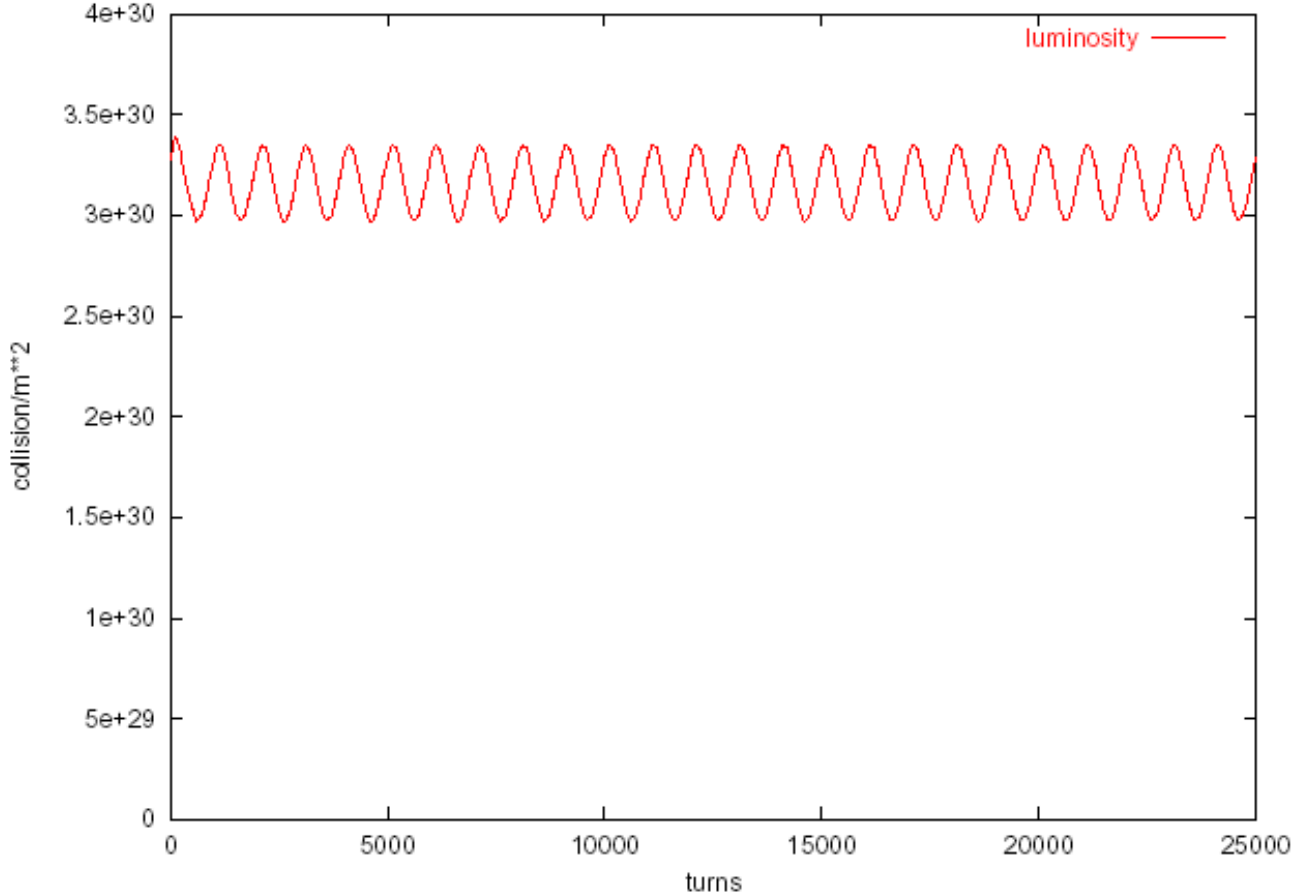
BEAMBEAM3D Simulations: LHC Beam-Beam spectrum

- Coherent beam-beam tune shift factor (MSYFKKUA)



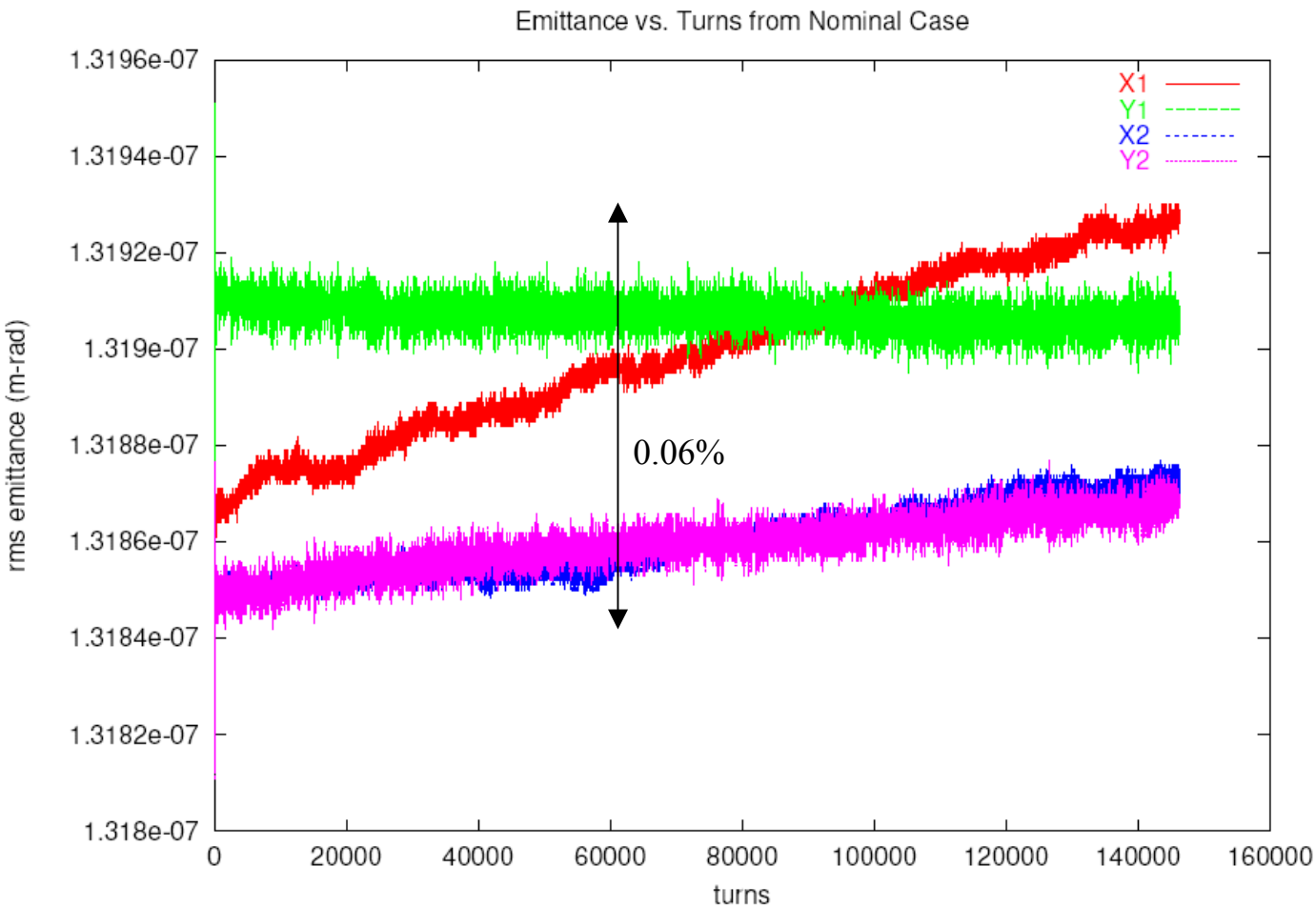
LHC: sweeping luminosity detector

- Simulated luminosity vs. time
  - period=1000 turns (artificially short)
  - modulation depth=(0.2/0.6 σ) (artificially large)



RHIC (proton) simulations

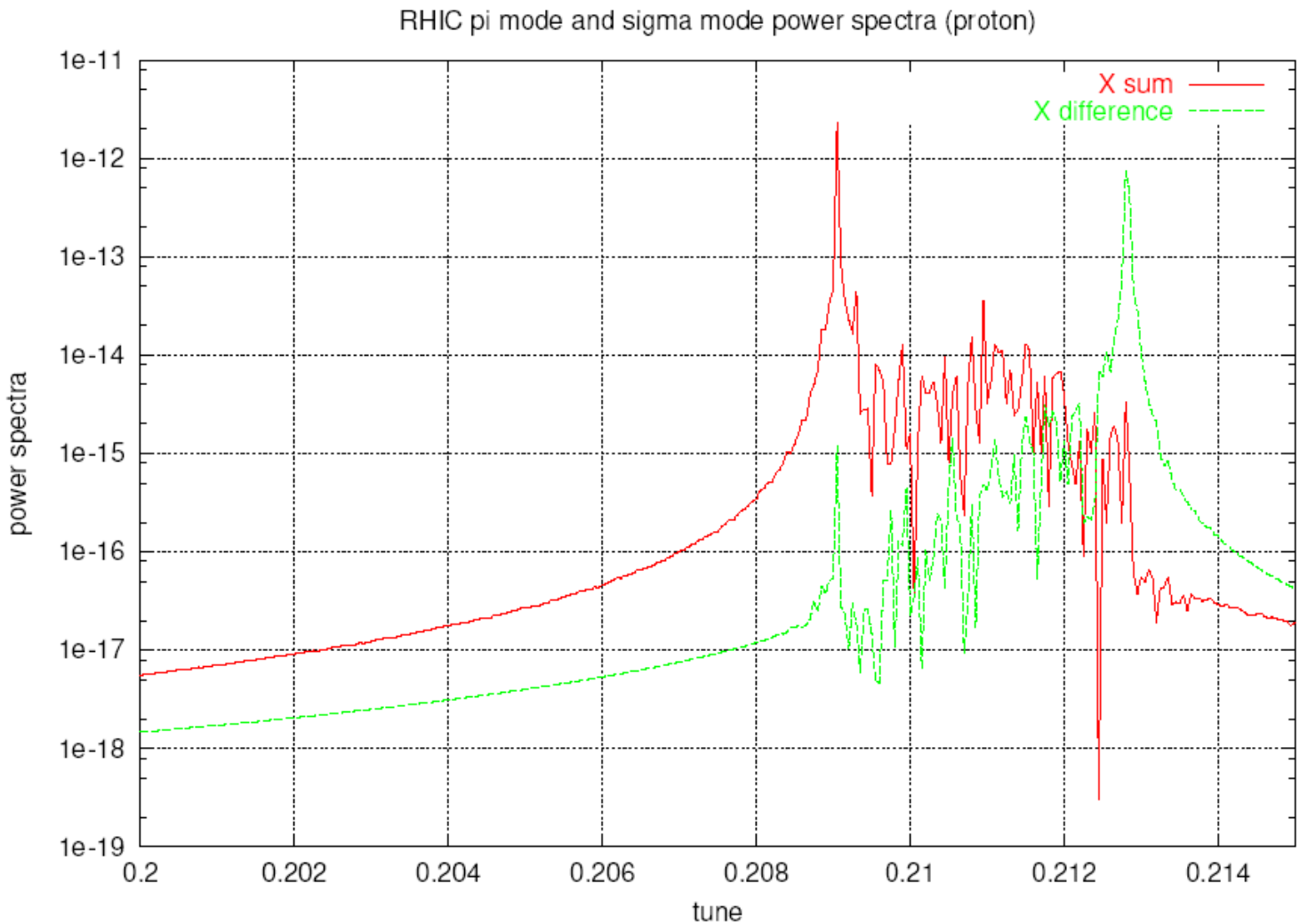
- Head-on collisions (crossing angle=0)
  - Similar to M. Vogt et. al. (EPAC02); also W. Fischer et. al., BNL C-AD/AP/7



1: $(\nu_x, \nu_y)=(0.2129,0.2412)$
2: $(\nu_x, \nu_y)=(0.2126,0.2392)$
1 bunch/beam
1 slice
$N/10^{11}=(0.84,0.88)$
$\xi_0=0.003$
10^6 macroparticles/bunch
128x128 grid
16 processors

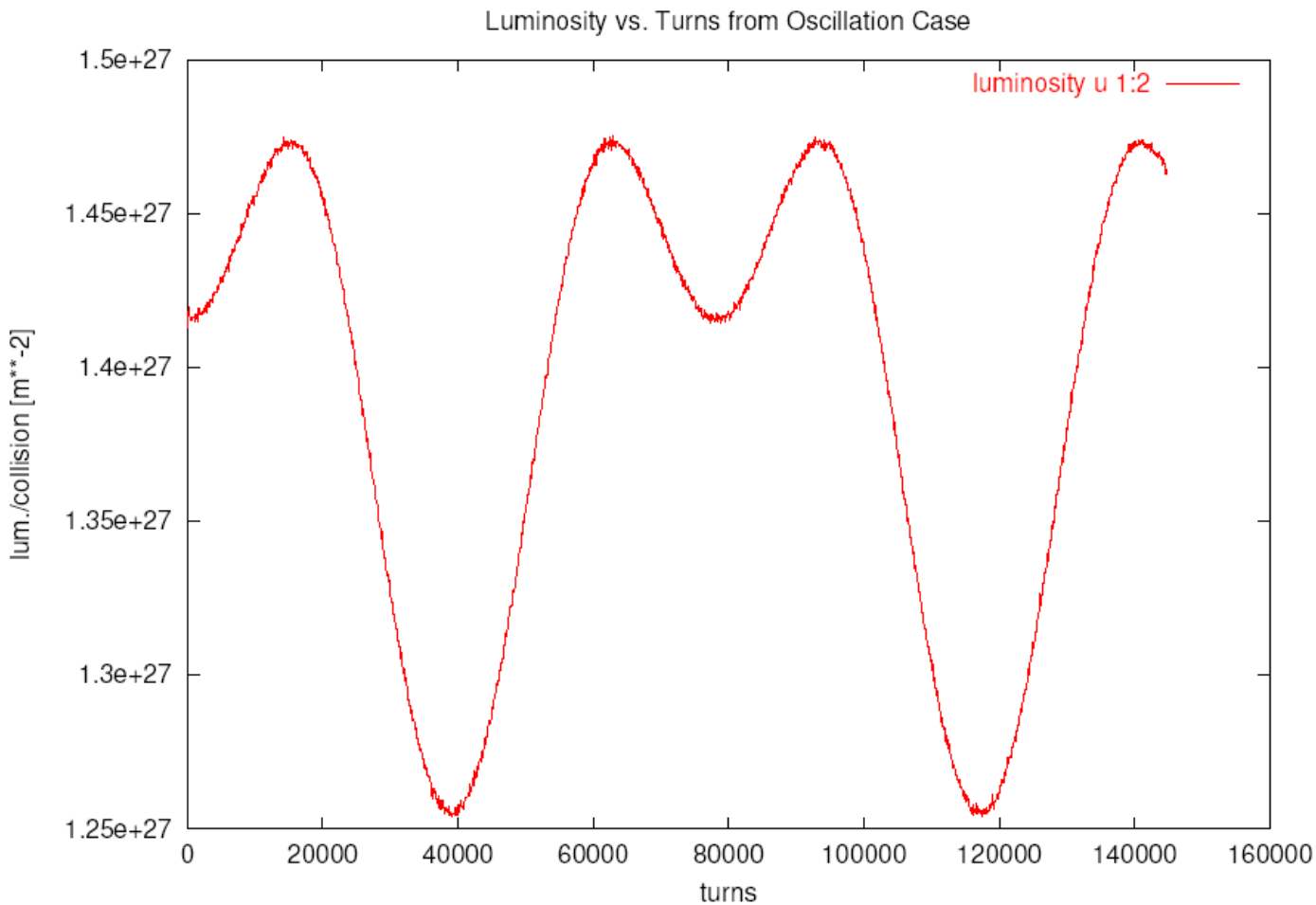
RHIC (proton) simulations: beam-beam spectrum

– in agreement with Vogt et. al.



RHIC (proton) simulations: luminosity

- Oscillation of one beam about the other:
  - f=10 Hz; depth= 0.2/0.6 σ (artificially large)



Oscillation:
f=10 Hz
T=84000 turns
depth: 0.2/0.6 σ

RHIC (proton) simulations: emittances

- Oscillation of one beam about the other

Oscillation:
f=10 Hz
T=84000 turns
depth: 0.2/0.6 σ

Conclusions

- We are developing a parallel PIC strong-strong beam-beam code
  - up and running on NERSC MPP machine
  - scalability ~linear up to 16 processors
  - passes basic tests
  - strong-strong mode: 1 bunch/beam, 1 IP (so far)
  - weak-strong mode: multibunch, multi-IP
  - fully 3D, but finite bunch length still needs to be exercised
  - nonzero crossing angle, but still needs to be exercised
  - ability to read 6x6 linear map and 6x6x6 nonlinear matrix, but still needs to be exercised (can use a symplectic map à la MARYLIE)
  - head-on or parasitic collisions
  - arbitrary closed-orbit separation at IPs or PCs (static or time-dependent)
  - have carried out simple applications to LHC and RHIC
  - we are eager to enhance the value of the SciDAC program with further applications to important problems such as RHIC, LHC and TEVATRON.