PS2 space-charge simulations

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LARP Collaboration Meeting
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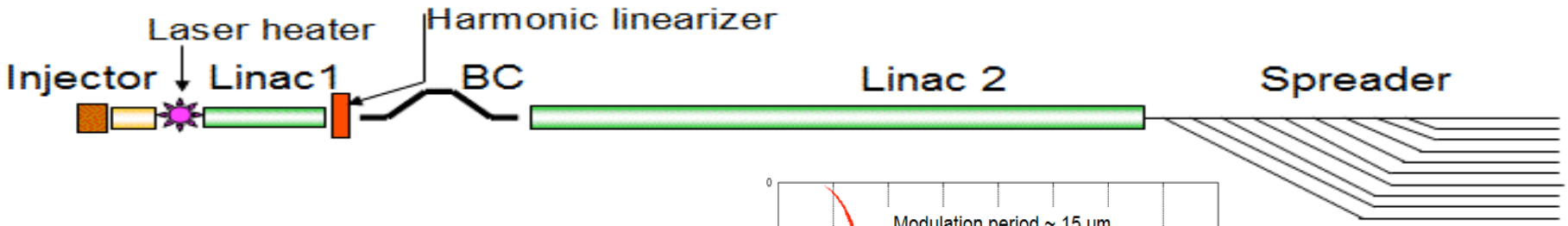
Background

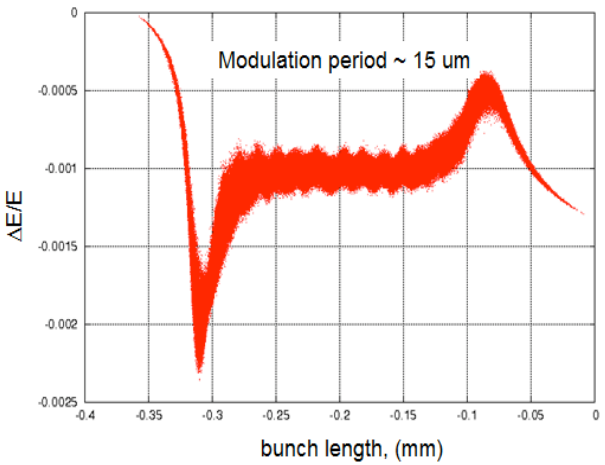
- Initial studies carried out under the SciDAC ComPASS project
  - —ComPASS=Community Petascale project for Accelerator Science and Simulation
- Using 3 codes:
  - —IMPACT-Z
  - —Synergia
  - —MaryLie/IMPACT
- Codes have much in common but also have individual strengths
  - —All are parallel particle-in-cell codes w/ 3D space charge

IMPACT code suite

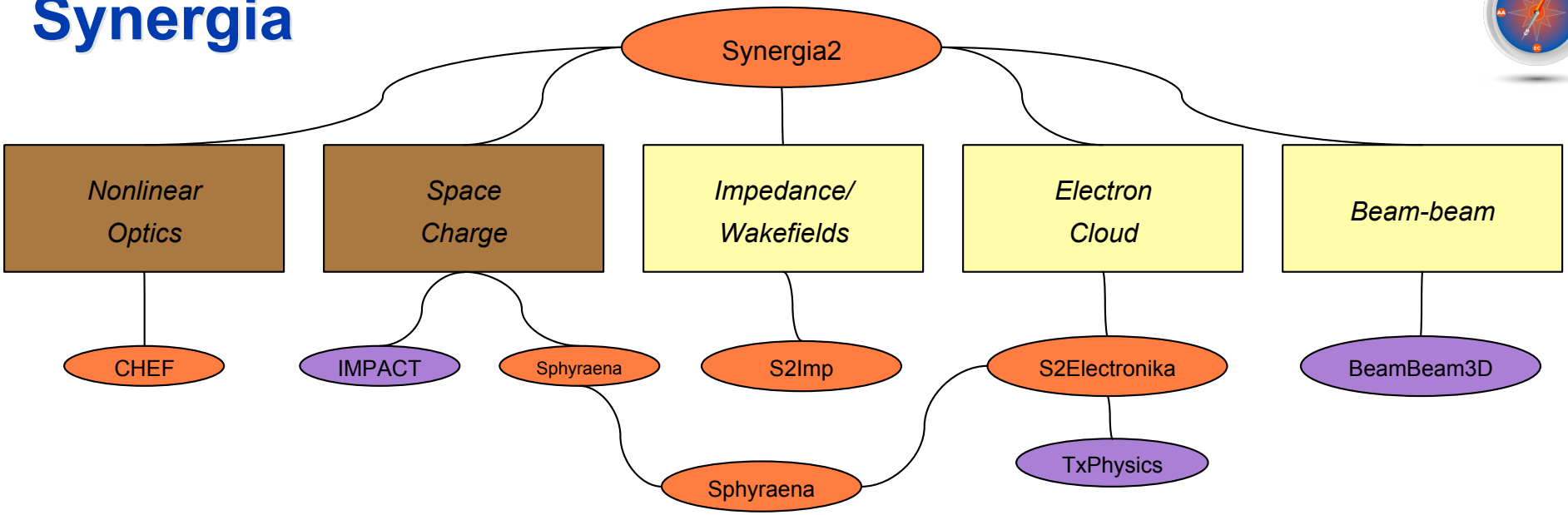
- IMPACT-Z: parallel PIC code (z-code)
- IMPACT-T: parallel PIC code (t-code)
- Envelope code, pre- and post-processors,…
- Optimized for parallel processing
- Applied to many projects: SNS, JPARC, RIA, FRIB, PS2, future light sources, advanced streak cameras,…
- Has been used to study photoinjectors for BNL e-cooling project, Cornell ERL, FNAL/A0, LBNL/APEX, ANL, JLAB, SLAC/LCLS



One Billion Macroparticle Simulation of an FEL Linac (~2 hrs on 512 processors)



Synergia



Scientific Computing Infrastructure

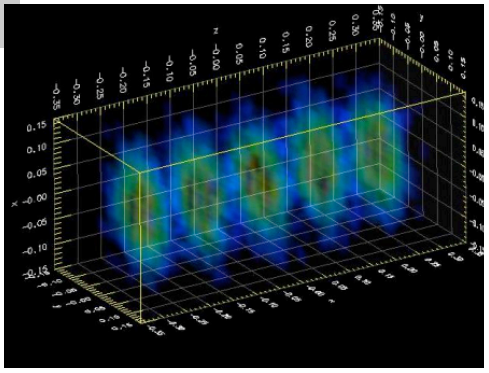
CCA PETSc Numpy Matplotlib PyTables

Numerical Computing Infrastructure

LAPACK FFTW HDF5 ATLAS GSL

Generic Computing Infrastructure

Python Boost Flex Bison



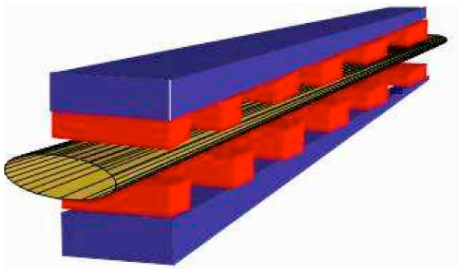
- Development aided by both internally and externally developed state-of-the-art packages. New physics modules are currently under development.
- Applied to FNAL booster, FNAL Mu2e experiment, CERN PS2

MaryLie/IMPACT (ML/I)

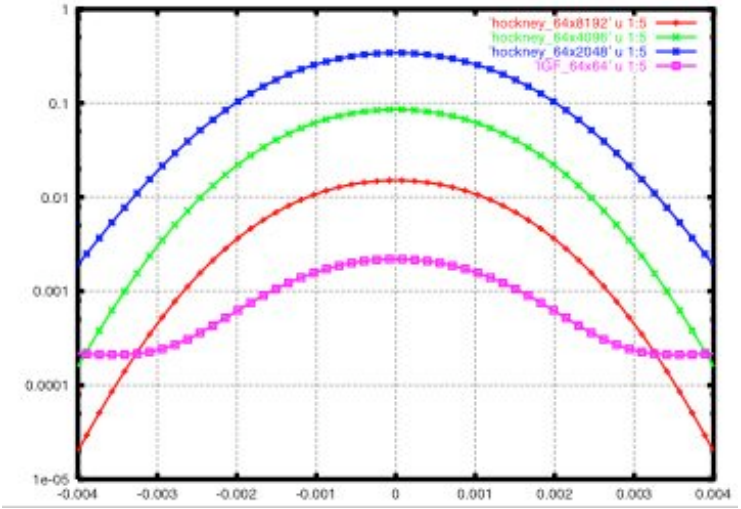
- Combines capabilities of MaryLie code (A. Dragt, U Md) with IMPACT code (J. Qiang, R. Ryne, LBNL) + new features
- Multiple capabilities in a single unified environment:
  - Map generation
  - Map analysis
  - Particle tracking w/ 3D space charge
  - Envelope tracking
  - Fitting and optimization
- Recent applications: ERL for e-cooling @ RHIC; CERN PS2

- Parallel
- 5th order optics
- 3D space charge
- 5th order rf cavity model
- 3D integrated Green func
- Photoinjector modeling
- "Automatic" commands
- MAD-style input
- Test suite
- Contributions from LBNL, UMd, Tech-X, LANL,…

Map computation from surface data

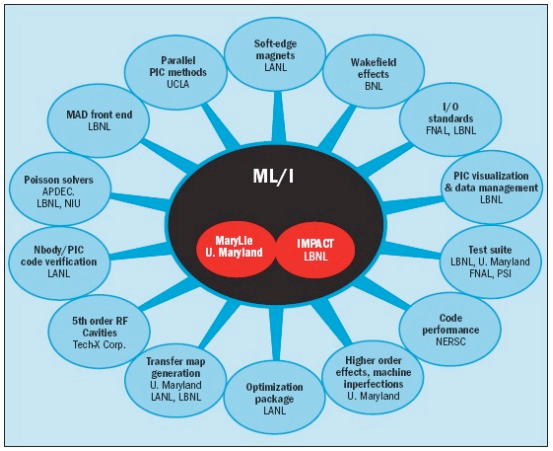


Alex Dragt, U. Md.



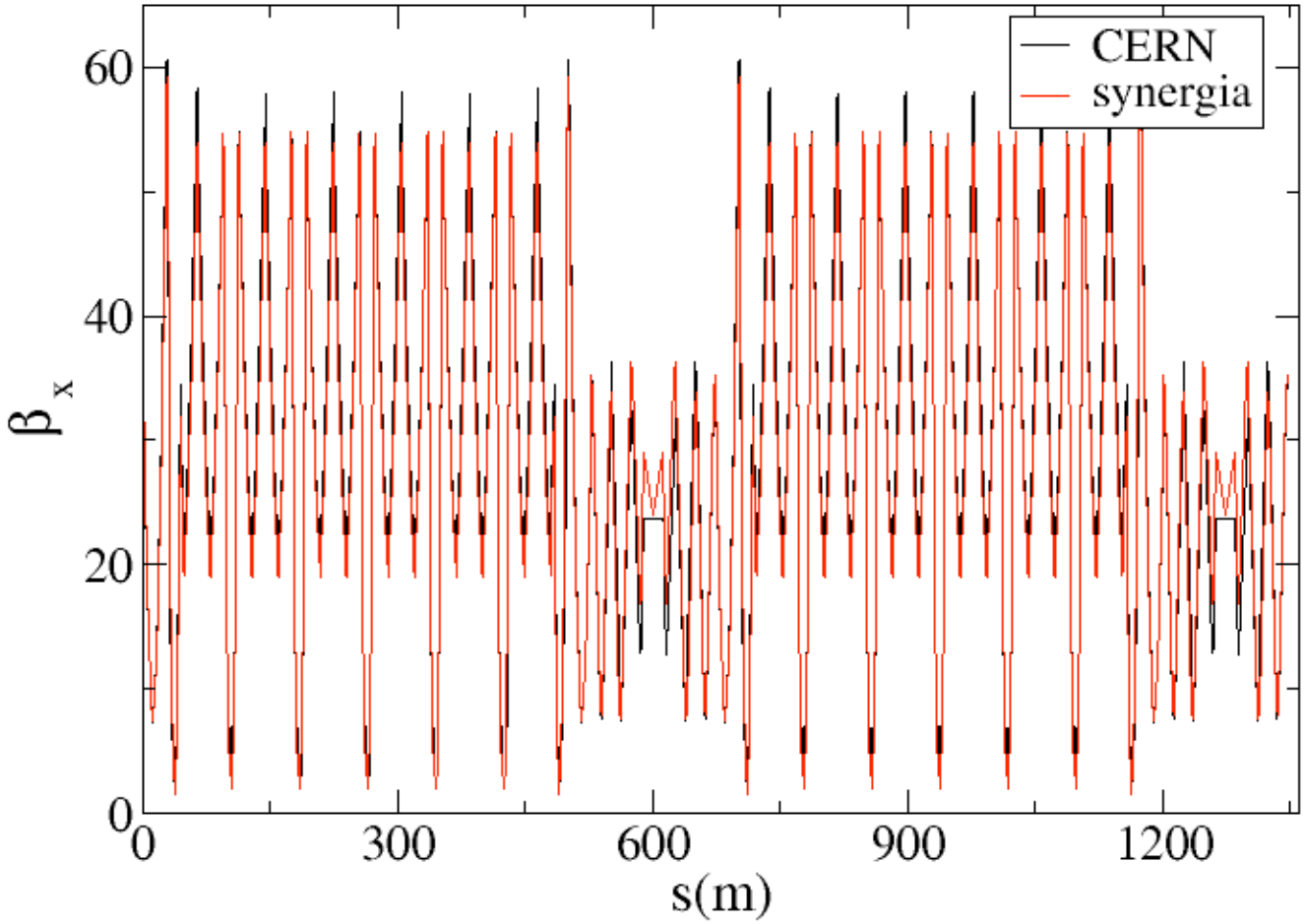
Error in E-field computed w/ different algorithms applied to a 2D Gaussian elliptical distribution w/ 500:1 aspect ratio

Integrated Green Function on 64x64 grid is more accurate than Hockney on 64x2048, 64x4096, 64x8192.

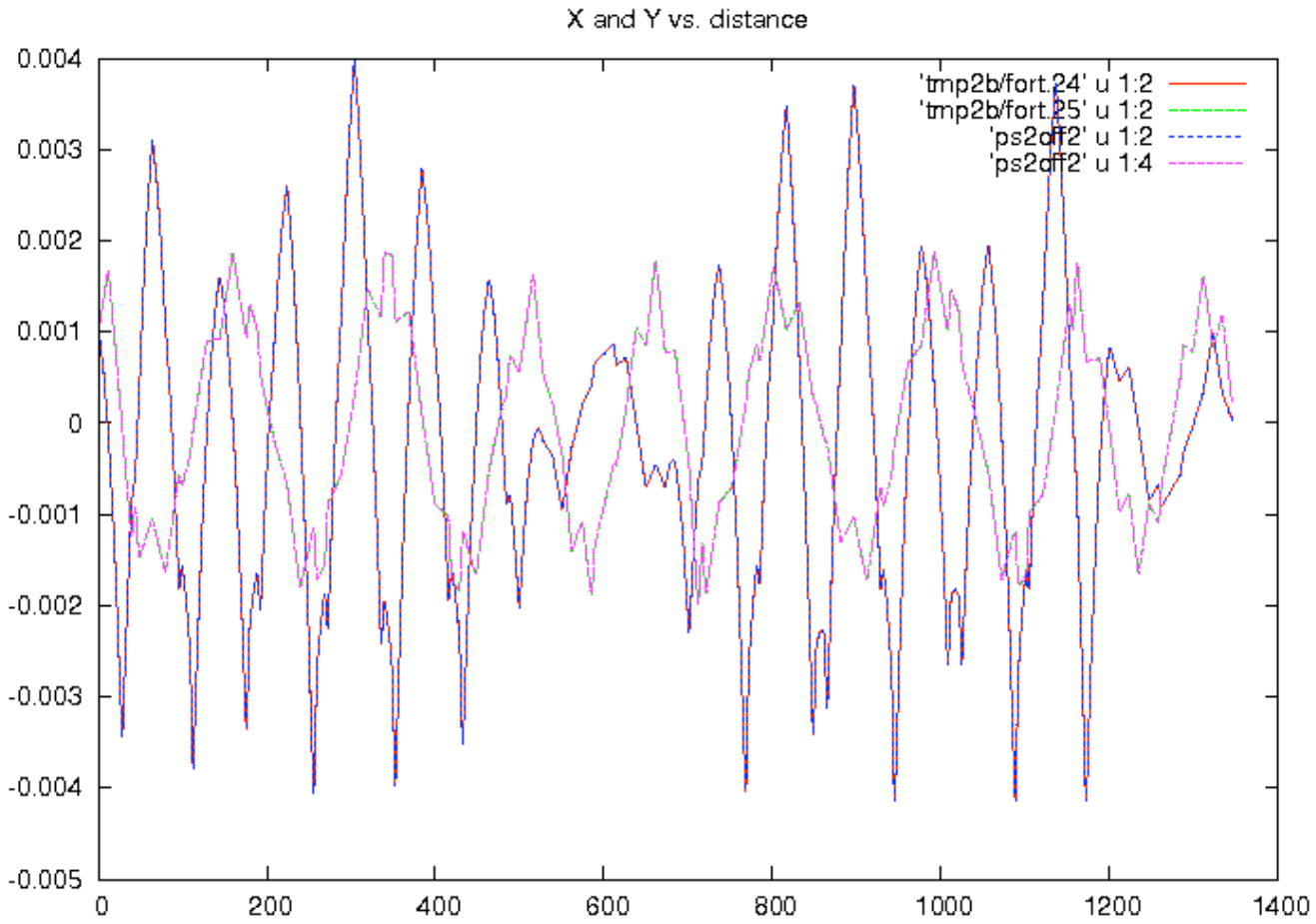


Initial studies

- **Able to read MAD description (except for SEQUENCE)**
- **ML/I and Synergia produced linear lattice functions in agreement w/ previous CERN results**



IMPACT and ML/I agreed on single-particle trajectories



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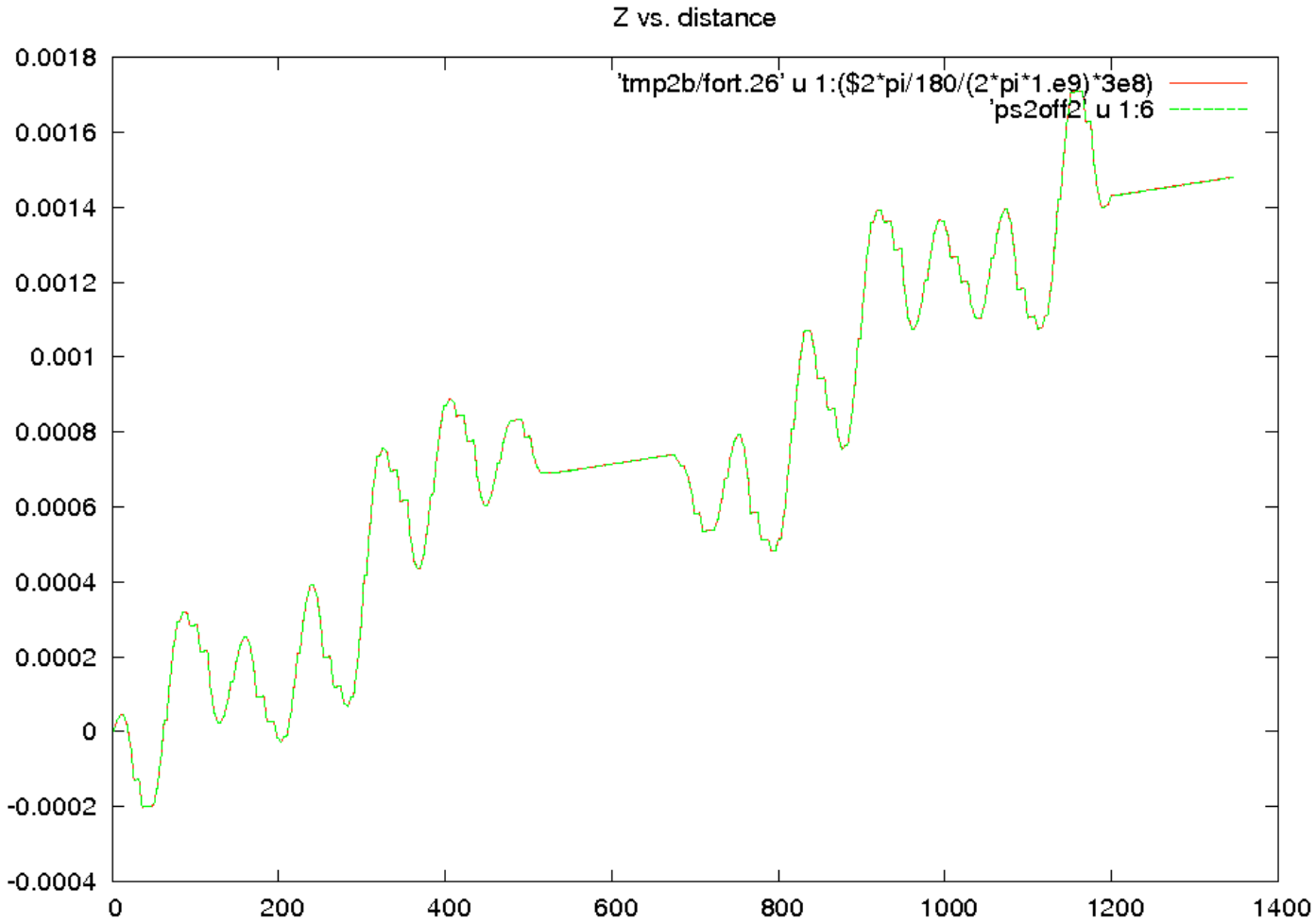
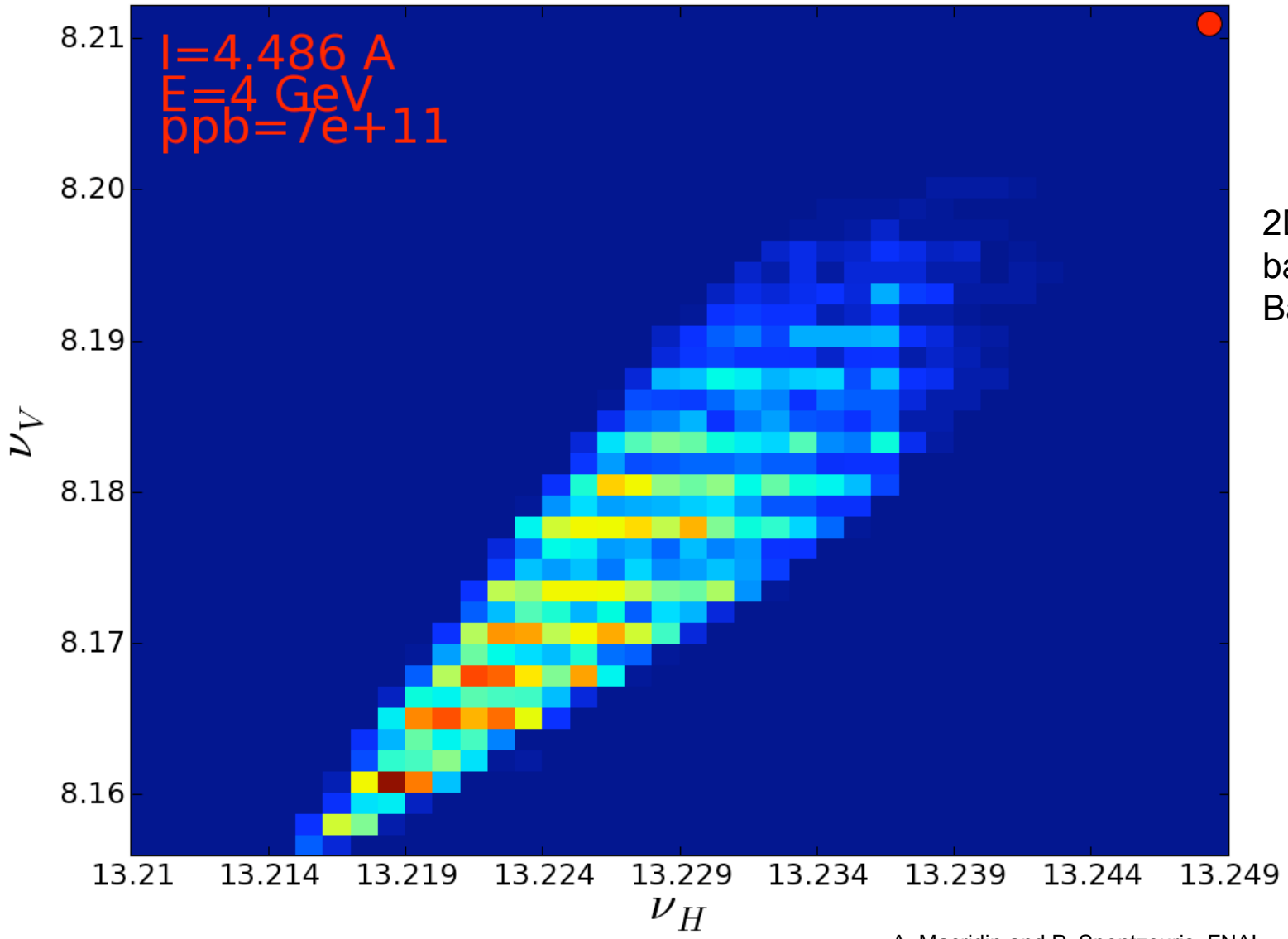


Tune spread due to space charge



2D simulation based on Basseti-Erskin

A. Macridin and P. Spentzouris, FNAL

Zero current matched beam

- **Zero current match found using MaryLie normal form capabilities:**
  - **Normalize 1-turn map: $M=A^{-1}NA$**

    A is the normalizing map

    N is the normal form which causes only rotations in phase space
  - **Consider a function $g((x^2+p_x^2),(y^2+p_y^2),(t^2+p_t^2))$**
  - **Then $f(\zeta)=g(A\,(x^2+p_x^2),(y^2+p_y^2),(t^2+p_t^2))$ is a matched beam.**

    Proof: The distribution after one turn is given by

    $f(M^{-1}\zeta)=g(AN\,A^{-1}.\,A\,(x^2+p_x^2),(y^2+p_y^2),(t^2+p_t^2))$ =

    $g(AN\,(x^2+p_x^2),(y^2+p_y^2),(t^2+p_t^2))$=

    $g(A\,(x^2+p_x^2),(y^2+p_y^2),(t^2+p_t^2))$

- **We generated a distribution of 1M particles using this approach; then performed element-by-element tracking for ~few hundred turns**

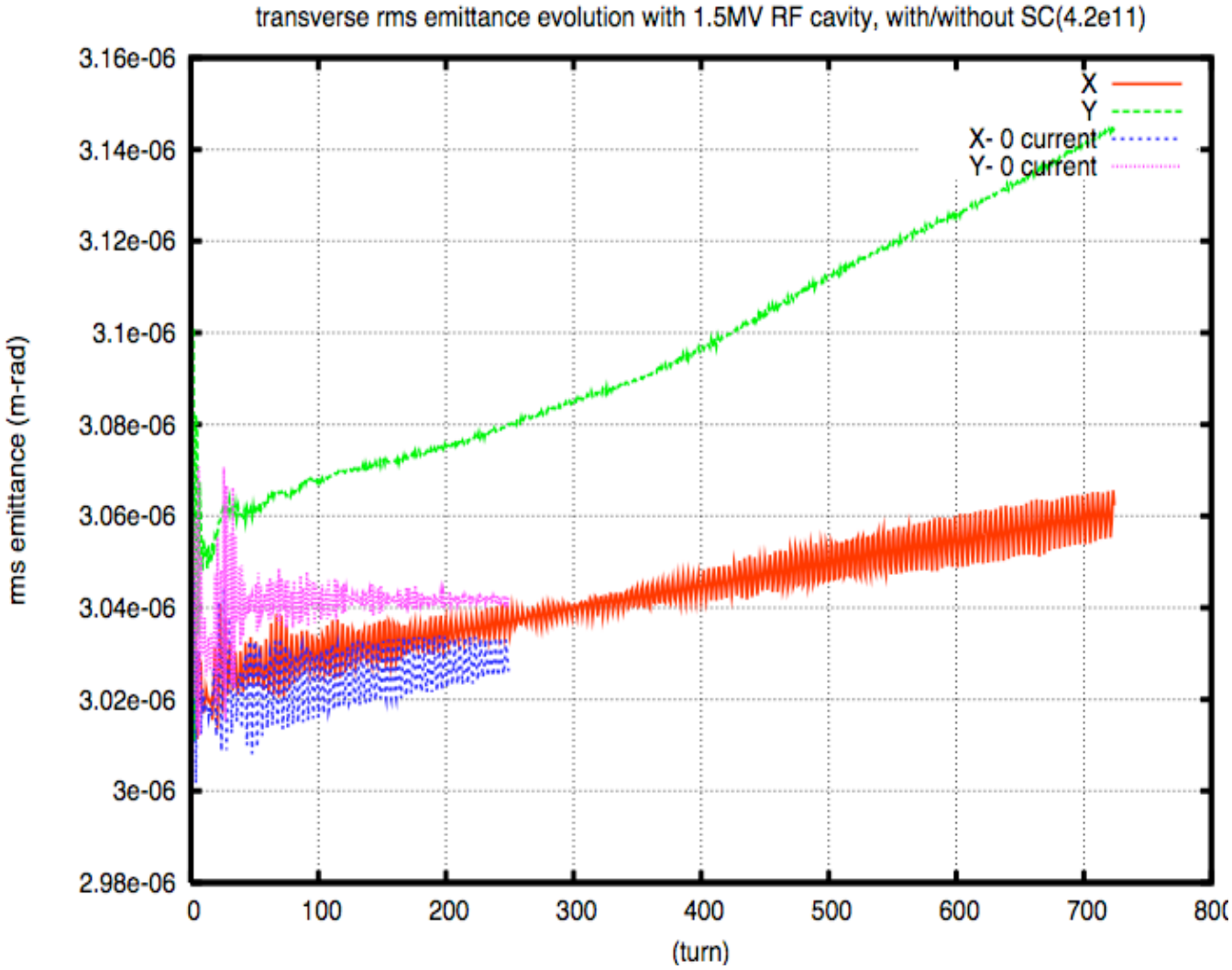
Parameters using for IMPACT simulations

RF voltage: 1.5 MV
RF frequency: 40 MHz
Initial Parameters:
- kinetic energy = 4 GeV
- rms x = 1.4 mm
- rms y = 0.93 mm
- rms emittance x = 3.0 mm-mrad
- rms emittance y = 3.0 mm-mrad
- rms z = 1 ns
- rms energy spread = 9.4 MeV
- 6D Waterbag distribution

Space Charge Model:
- 60 SC kicks per turn

Aperture size:
- round pipe with 8 cm radius

Preliminary IMPACT-Z results with/without space charge



Future plans

- Finish zero current studies including nonlinear effects
- Make code modifications, as needed, to model 3D space charge effects in rings
- Perform space-charge studies w/out acceleration
- Turn on ramping, perform space-charge studies
- More detailed modeling of injection into PS2