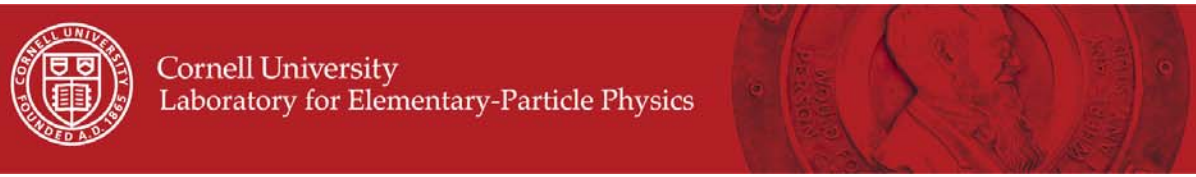
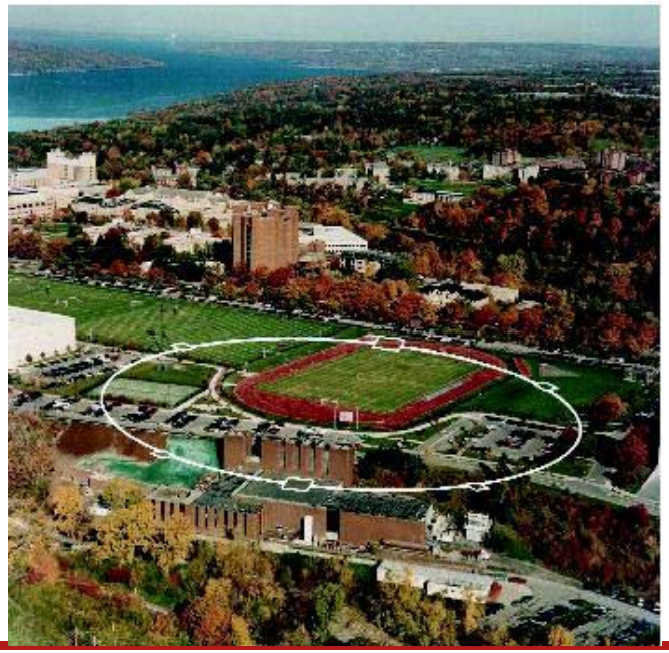


Optics Modeling of CesrTA

David Sagan

Cornell University



Outline

1. The Simulation Toolkit: Bmad
   - What it is.
   - Features.
   - Track record.
   - What it can do.
2. The Simulation Program: Tao
   - What it is.
   - Features
   - Examples
3. Tao Customized for CesrTA: Tao_Cesr
4. Conclusion

Simulation Toolkit: Bmad

Bmad is a software library for simulating relativistic charged particle dynamics
[Similar to Merlin (Nick Walker) or AT]

- In development at Cornell since 1996.
- Bmad was developed to:
  - Cut down on the time needed to develop programs.
  - Cut down on programming errors.
  - Provide a mechanism for lattice function calculations from within control system programs.
  - Provide a standardized lattice input format.
- Written in Fortran95 in a modular object oriented fashion.
- Runs on a variety of platforms:
  Linux, VMS, Windows, {OS-X}

Bmad Features

- MAD-like lattice file format.
- Full set of element types:
  - Custom, ElSeparator, Girder, Lcavity, Patch, Quadrupole, Sbend, Sextupole, Sol_Quad, Taylor, Wiggler, etc…
- Has routines for calculating:
  - Transfer matrices, Twiss parameters, Taylor maps to arbitrary order (Etienne's PTC code), radiation integrals, closed orbit, lattice layout ("floor" coordinates), intra beam scattering (IBS), space charge, coherent space charge (CSR), BPM error simulation, etc…
- Can track either particles or macroparticles (with 6x6 sigma matrix).
- Misalignment errors can be individually assigned to each element.
- Easy simulation of "control room knobs":

```
H12W: overlay = {B12W /0.5, B13W /0.5}, HKICK
```

- Has routines for nonlinear optimization.
- Documented.

Tracking in Bmad

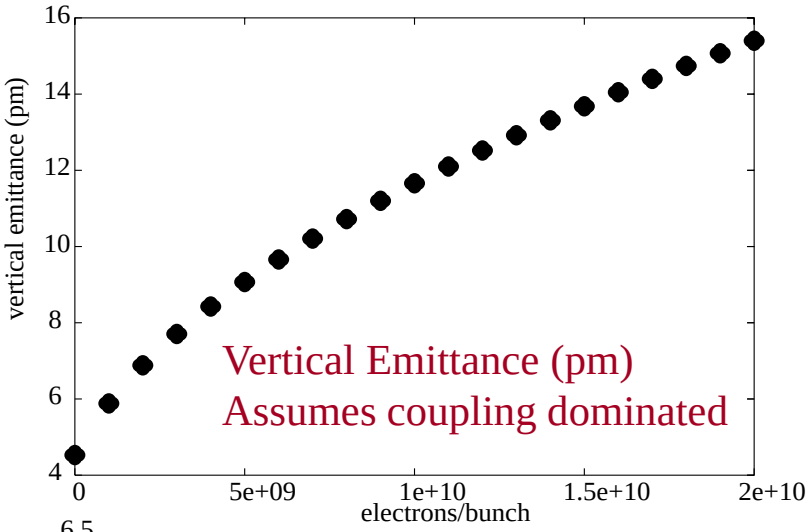
- Various tracking routines available:
  - Runge-Kutta integration.
  - Lie algebraic symplectic integration.
  - Taylor maps.
  - etc…
- The tracking method used for tracking can be set individually for each element.
- Short-range and long-range wakefields can be simulated.
- Radiation dampling and excitation can be included.

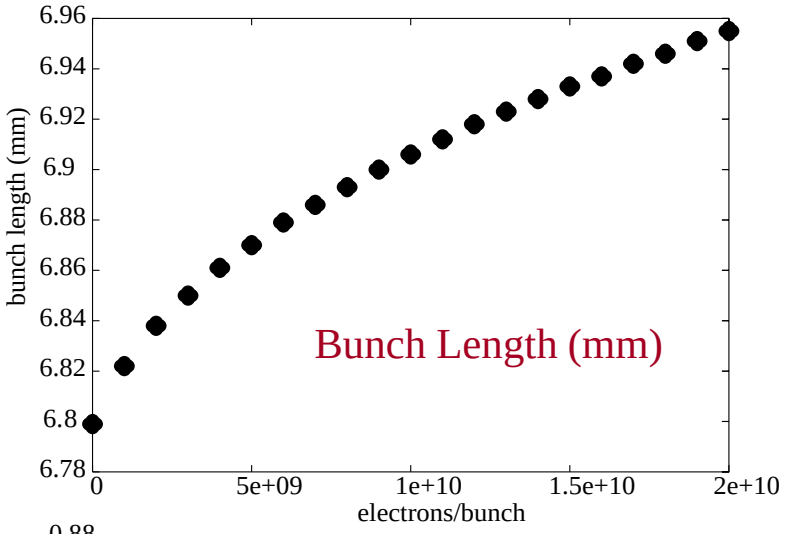
Bmad Track Record

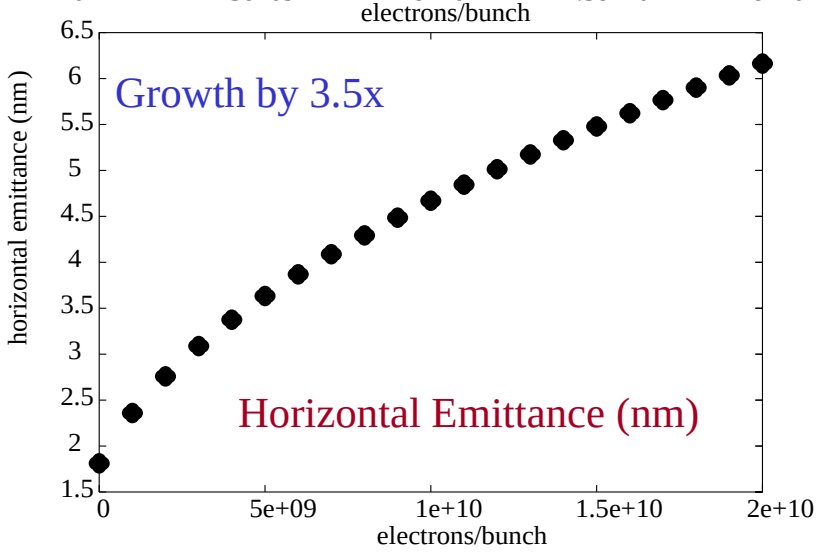
- Over the years Bmad has accumulated a strong track record for accurately and reliably simulating the Cornell CESR storage ring.
- Bmad is routinely used in the measurement, analysis and correction of closed orbits, coupling, betatron phase, and dispersion.
- In Linear Collider simulations, Bmad agrees well with LIAR, Merlin, Placet, and MAD.
- Programs have been built using bmad for:
  - Long term tracking (lifetime) studies.
  - Tune scan simulations.
  - Lattice design.
  - Lattice correction.
  - Beam-beam simulations.
  - Dynamic aperture
  - Synchrotron radiation heating calculations.
  - Frequency map analysis.
  - Etc…

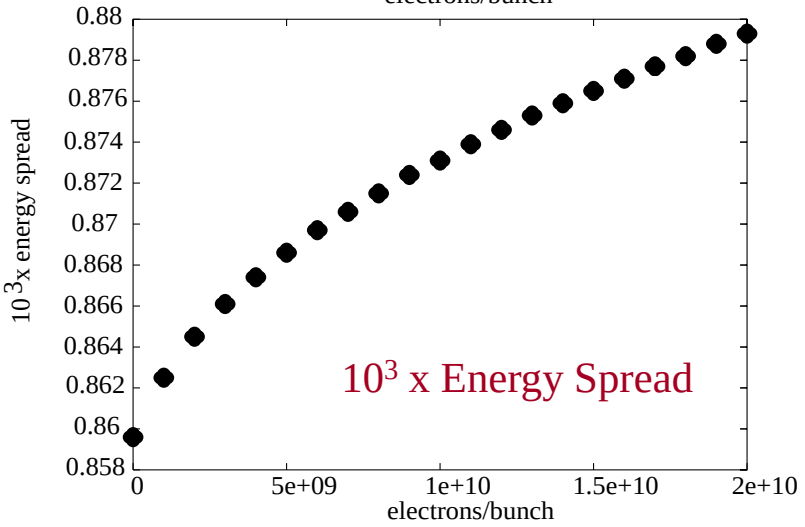
Example Bmad Application

IBS Evaluation (2 GeV Lattice)







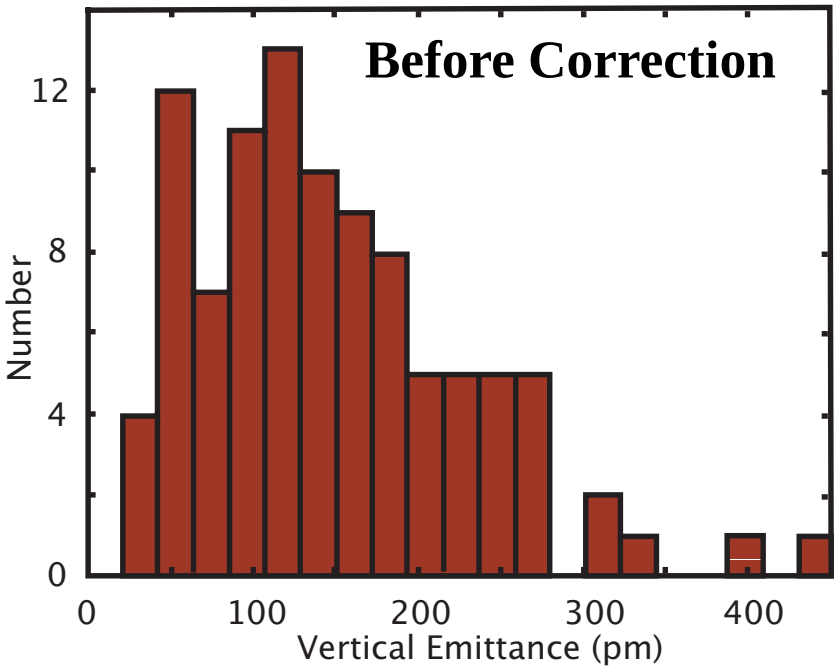


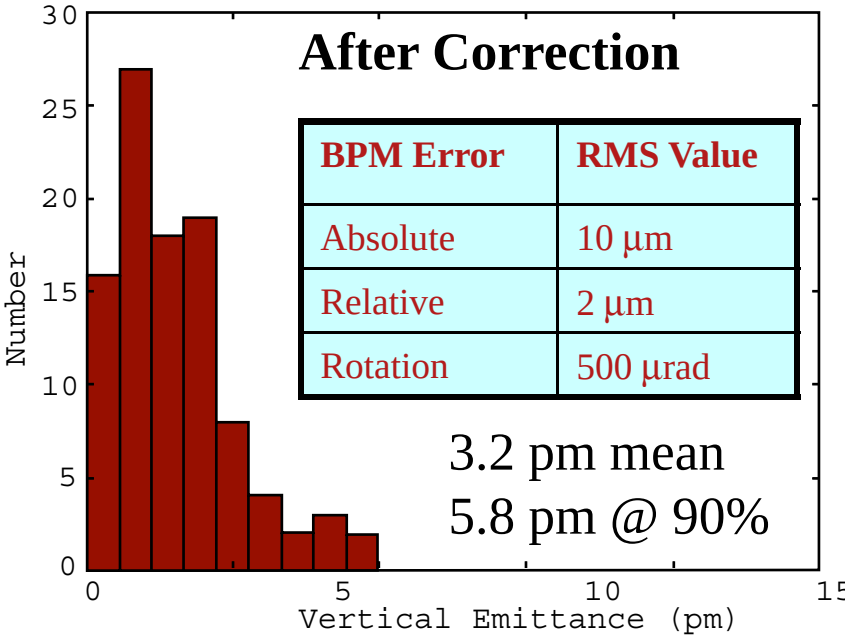
Another Example Application

Vertical Emittance Correction

CesrTA Simulation:

- Correcting the vertical dispersion and coupling using steerings, and skew quads, the vertical emittance can be corrected to a factor of ~3 of the ILC DR.
- Correcting the vertical dispersion with steerings gives the greatest benefit.





CesrV

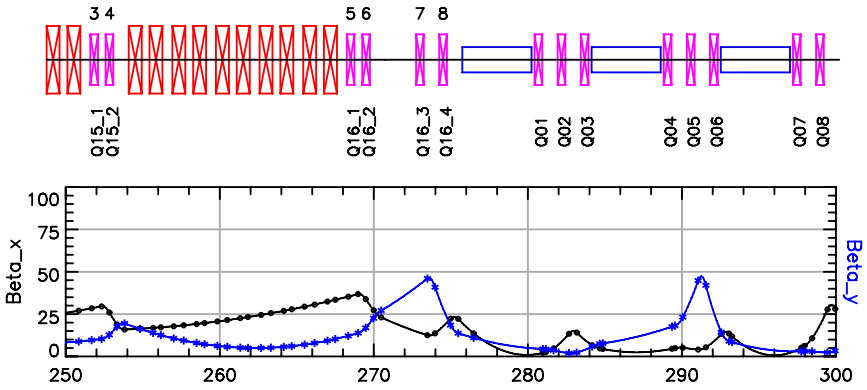
- Bmad is a software library. It is *not* a program.
- The first program to to use Bmad as its computational engine was a program named CesrV.
- CesrV has proved very successful in modeling Cesr and in its ability to measure and correct orbits, betatron phase, coupling, and dispersion. [See next talk.]
- However: The code in CesrV has been tailored for Cesr and is not flexible to evolve to our changing needs.

Tao

- When Cornell got involved in the ILC project, it was recognized that we needed a general purpose lattice design and modeling program.
- Thus was born Tao ("Tool for Accelerator Optics")
  - Tao uses Bmad as its simulation engine.
  - Tao's design is modular. The aim is to make Tao easily extensible to handle custom calculations. Example: An extension of Tao, called Tao_Cesr, has been created which has the ability to read-in data files created when orbit, phase/coupling, and dispersion measurements at Cesr are made.
  - Has built-in graphics plotting.
  - Initialization input files define the lattice being used, variable families, how to plot data, etc.
  - Has nonlinear optimizer for lattice design and modeling: Any set of parameters in the model lattice (eg: quad k's, steerings, element offsets, BPM tilts, etc.) can be chosen to fit any number of measurements (phase/coupling, dispersion, orbit, etc.)
  - Tao can handle multiple linked machines both storage rings and linacs.

Tao: Example Plots

Beta Plot

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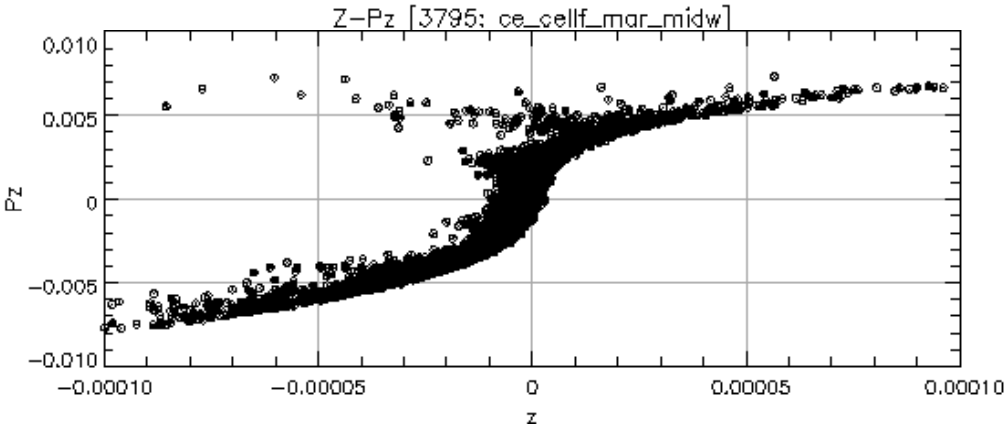
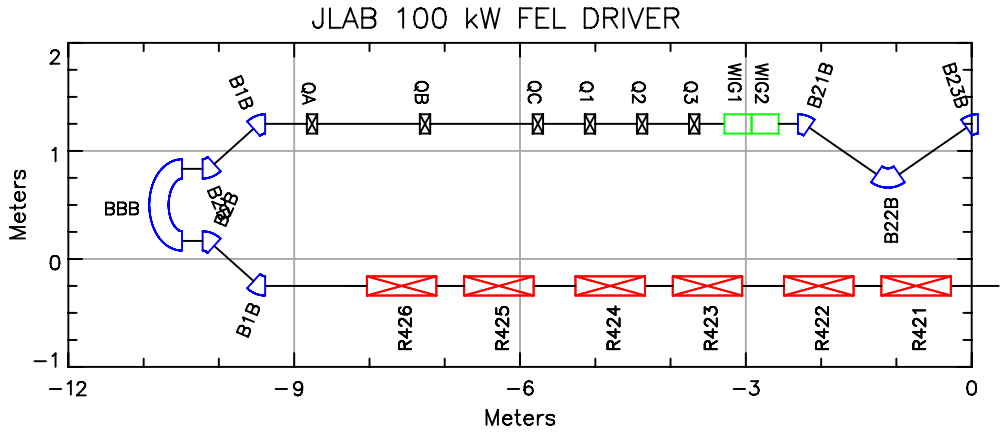
    2   Q14_2   B1_GRADIENT     -4.8743     -4.8743     0.1000  All    F
    3   Q15_1   B1_GRADIENT      5.5820      5.5820     0.1000  All    F
    4   Q15_2   B1_GRADIENT     -6.6929     -6.6929     0.1000  All    F
    5   Q16_1   B1_GRADIENT      3.8954      3.8954     0.1000  All    F
    6   Q16_2   B1_GRADIENT     -2.5332     -2.5332     0.1000  All    F
    7   Q16_3   B1_GRADIENT     -6.5396     -6.5396     0.1000  All    F
    8   Q16_4   B1_GRADIENT      7.1184      7.1184     0.1000  All    F
    9
    0
```

Phase Space Plot



Floor Layout Plot



Conclusion

- Bmad - a subroutine library for relativistic charged-particle simulations - has proved to be extremely useful in the construction of simulation programs.

- Tao is a flexible general purpose simulation and design program that uses Bmad as its simulation engine.
  - Tao is designed to be extensible so that custom code can be linked with Tao to create customized programs.
  - Tao allows simultaneous fitting of any combination of measurements (orbit, phase/coupling, dispersion, etc.) using any combination of steerings, quadrupoles, element offsets BPM gains, etc.