Συνεργεια

# Advanced Accelerator Simulation Project

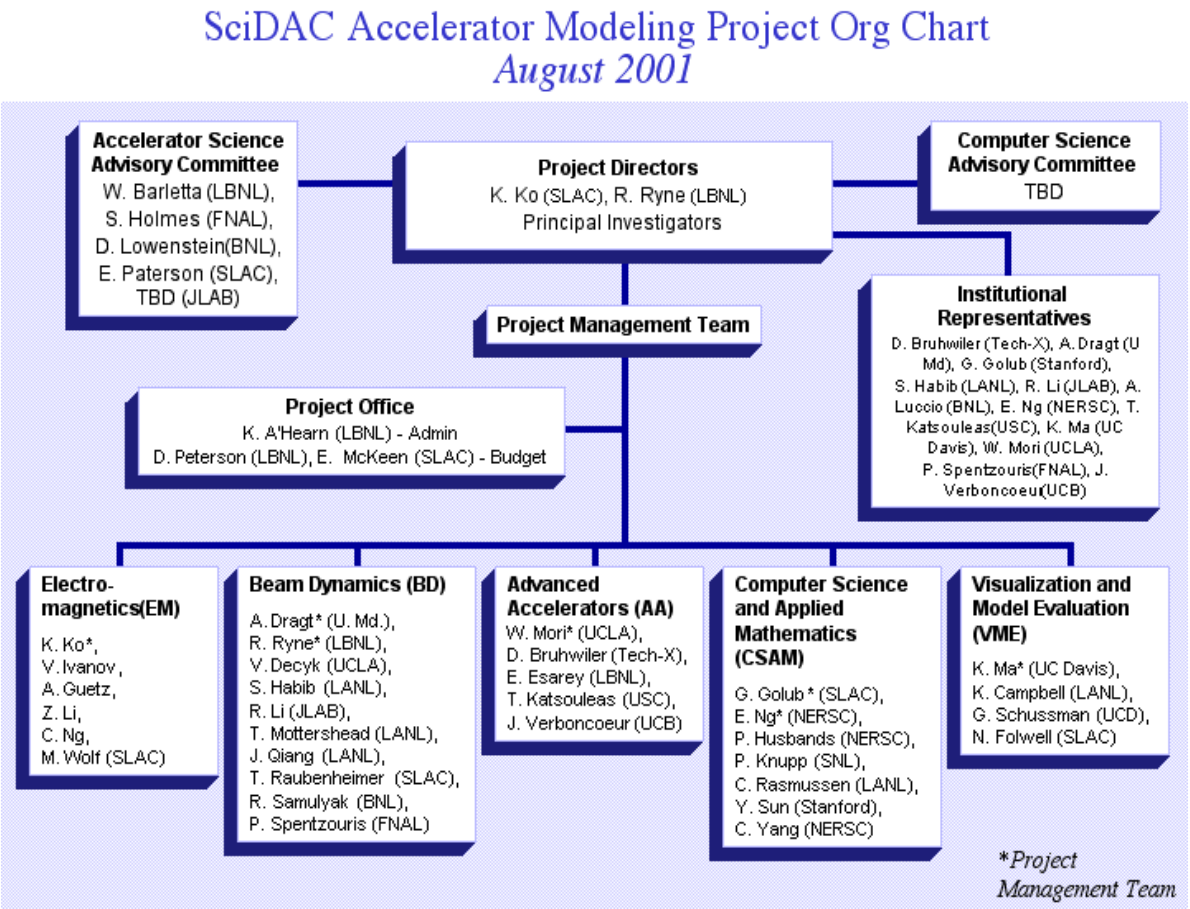
J. Amundson, P. Spentzouris

http://cepa.fnal.gov/psm/aas/Advanced_Accelerator_Simulation.html

- Overview of Project
  - history, scope, objectives, activity summary
- Code development
  - design, future plans
- Applications
  - current, future options

Συνεργεια

# Why the fancy name…




Members of a multi-Institution Collaboration. The charge : develop the next generation of parallel computing beam dynamics and accelerator modeling tools

Project funded by the SciDAC program:
$3M in years; FNAL $.32M

Συνεργεια

# Collaboration charge

From original charter:

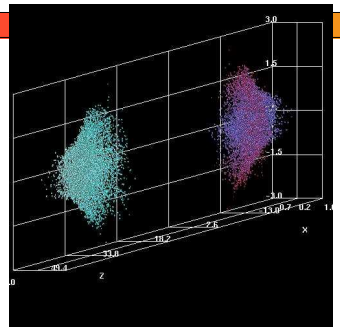
a) develop simulation tools for long term discovery

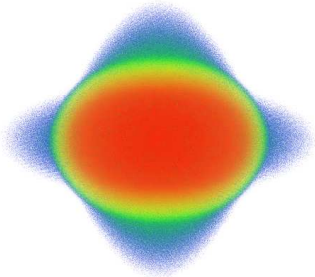
b) develop advanced design tools for next generation accelerator facilities

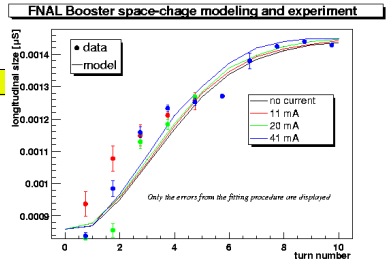
c) help optimize performance of present accelerators

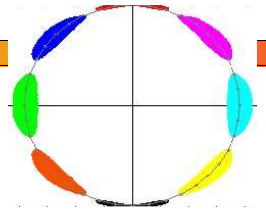
# Accelerator Modeling Collaboration

Συνεργεια







***LBNL***
**Beam-beam modeling, space charge in linacs & rings, parallel Poisson solvers, collisions**

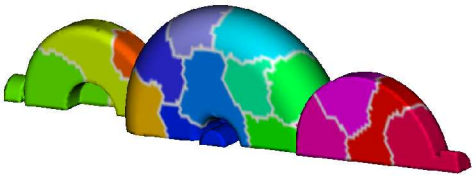
***UC Davis***
**Visualization, multi-resolution techniques**

***FNAL***
**Software Integration, Lie methods, space charge in rings, FNAL Booster sim/expt**

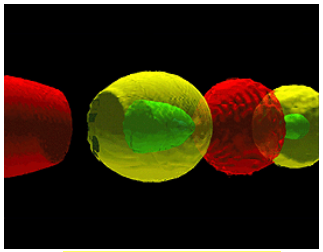
***BNL***
**Wakefield effects, Space charge in rings, BNL Booster simulation**

$$M = e^{:f_2:}\, e^{:f_3:}\, e^{:f_4:} \ldots$$
$$N = A^{-1}\, M\, A$$

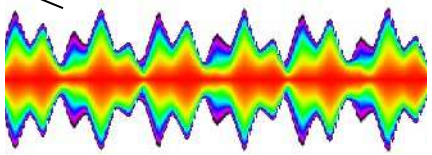
***U. Maryland***
**Lie Methods in Accelerator Physics, MaryLie**



***SLAC***
**Ellectromagnetic component modeling**



***UCLA***
**Parallel PIC Frameworks**

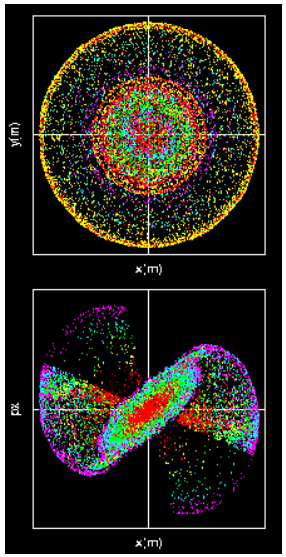


***LANL***
**High order optics, beam expts, collisions, multi-language support, statistical methods**

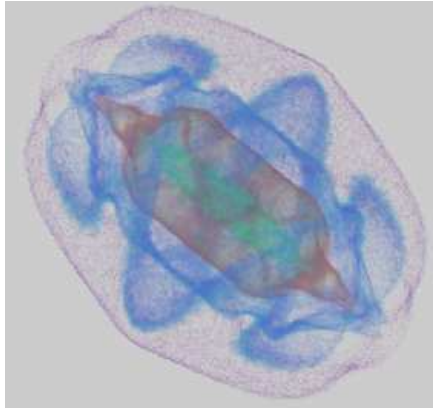
# Parallel Beam Dynamics Timeline

Συνεργεια

- Roots in 1980s: Lie methods
  and early 1990s: LANL-funded PIC code development
  - 2D parallel PIC
- Mid 1990s: DOE Grand Challenge
  - LANL/SLAC/Stanford/UCLA
  - developed Linac code (***IMPACT***)
    - 3D space charge, introduce particle manager concepts
- 1999: DOE/HENP bridge funding to SciDAC project
  - added LBNL, **FNAL** {space-charge in ionization cooling channels}, BNL and Jlab




➔ 2001: SciDAC Project
- Add modeling of high intensity beams in circular machines
- Additional physics (beam-beam, wakes, collisions,…)
- Extensible framework, integrated components



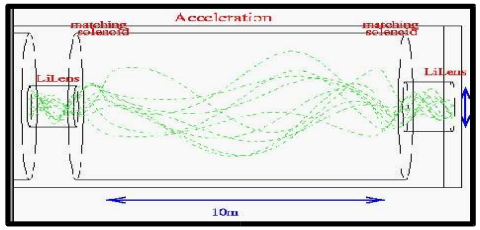
Συνεργεια

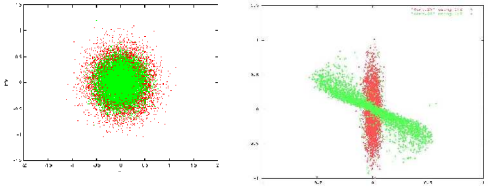
# FNAL participation timeline

- End of 1999 proposal writing for new initiative (PGS)
  - targeting future technologies (muon collider)
- FY2000: $60k bridge funds -> 2 students for space charge in cooling channels
- End of 2001: SciDAC funding, JFA joins beginning of 2002. Focus on
  - Space charge effects in circular accelerators
  - code integration, framework development, etc

    ⇒ introduced modern software techniques

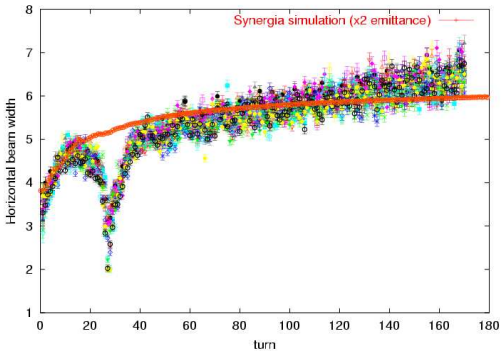
  ⇒ Synergia package
  - Machine data/Model comparisons



1PE: 500 particles, 460 sec

128 PE: 500,000 particles, 4400 sec



Συνεργεια

# Projects software development guidelines

- Develop a set of interoperable software modules to describe necessary beam dynamics effects ☺
- Integrate these components in an extensible framework to compose accelerator physics applications ☺
- Develop portable, parallel, scalable algorithms to maximize the performance and flexibility of the physics modules
- Reuse existing beam dynamics packages wherever possible, develop new capabilities as needed ☺
- Provide build system and code distribution tools, test suites and documentation; human interface and standard lattice description ☺

☺ ≡ Synergia emphasis

Συνεργεια

# Synergia team objectives

- Acquire expertise in parallel beam dynamics codes
  - both for design and operational issues
- Create Beam Dynamics package with the ability to model collective beam effects in 3D
  - Utilize power of parallel computing
- The code should
  - Integrate/utilize existing packages
  - Be easily distributable & portable
- Compare code predictions to machine data

Συνεργεια

# Achievements To Date

- First fully 3D parallel space-charge code for circular accelerators with multi-turn injection capabilities.
  - Re-use existing beam dynamics packages, mxyzptlk & Impact. Utilize split operator technique and include particle manager module
  - Provide build system and code distribution tools
  - Human(e) interface & standard accelerator lattice description (MAD)
  - Model FNAL Booster
    - Develop analysis software for both machine and simulated data. Perform machine studies and study/calibrate instrumentation

Συνεργεια

# Synergia model for rings

- Long beams in circular accelerators problematic for 3D modeling:
  - complicate calculation (curvilinear coordinates)
  - don't allow use of ballistic approximation in space charge kick application

⇒ Synergia solution: model a 3D slice of the total PhS volume using periodic boundary conditions. This approach maintains PhS density of full problem and allows for self-constistent modeling of space charge.

no need for projections to 2D surfaces and interpolation!

Συνεργεια

# Status/Plans

- 3 year SciDAC funding (~$350k) cycle ends at FY04
  - Finish development of space-charge package, with emphasis on code modularization. SBIR will provide help of 1FTE $\times 6$ months.
  - Compare Synergia against other codes (ML/Impact, ORBIT)
  - Have conclusive results on Booster space charge effects @ injection
  - documentation, distribute code (already have candidate users)
  - proposal writing for next initiative (work starts this summer)

Would like to include other physics modules (beam-beam, etc)

  - prerequisite code modularization, framework development

⇒ Would like to strengthen data/model comparison effort

Συνεργεια

# Plans/Issues

- Available manpower NOT sufficient for code development plus expansion of physics capabilities AND a coherent experimental program. Support is needed for
  - taking data (machine studies) at regular basis and storing and analyzing data using our analysis tools
  - running simulations and participate in data/model comparisons
- Why do we need to expand physics capabilities?
  - we need local expertise on any simulation tools needed for either new designs or present machine operation
    - Tevatron
    - LHC relevant modeling

faster turnaround and control of the studies

Συνεργεια

# Plans/issues

- Implementation will maintain current Synergia philosophy
  - re-use existing physics modules (beam-beam module developed at LBNL for example)
  - user friendly interface and MAD lattice description
  - portability to different platforms
- Will need to couple such development to additional machine studies (Tevatron). If so, will need support to perform these studies and do data & simulation analysis.
  - ➔ A BD post-doc working with us on beam studies and running simulations to compare
  - ➔ One (or more) grad students from the BD PhD program (same objective, slower time scale).