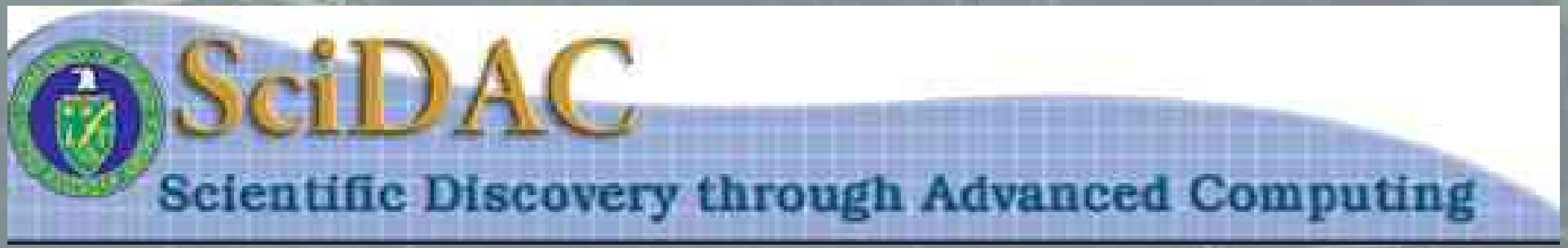
Συνεργεια

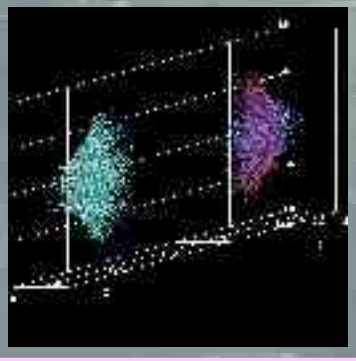
Advanced Accelerator Modeling at FNAL

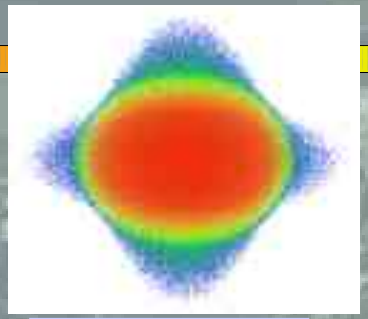
Synergia, a fully 3D beam dynamics framework, capable of modelingspace charge effects in circular accelerators!



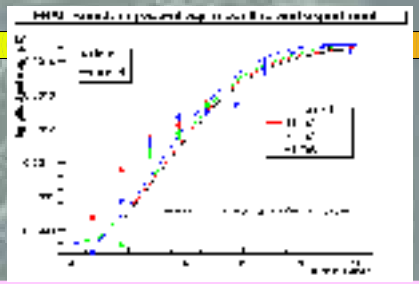
Accelerator Modeling Collaboration

Συνεργεια

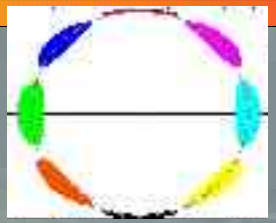




UC Davis
Visualization, multi-resolution techniques



FNAL
Software Integration, Lie methods, space charge in rings, Booster simulation& experiment



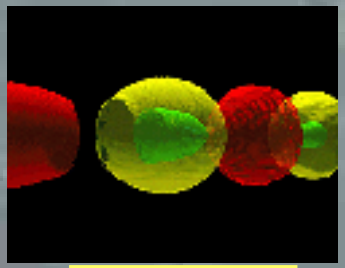
BNL
Wakefield effects, Space charge in rings, BNL Booster simulation

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

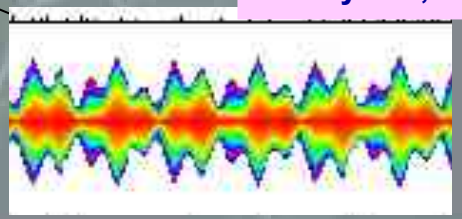
$$M = e^{:f_2:}\, e^{:f_3:}\, e^{:f_4:} \ldots$$
$$N = A^{-1} M A$$

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

Συνεργεια

The Synergia project at FNAL

- First fully 3D space-charge code for circular accelerators
  - Re-use existing beam dynamics packages
  - Provide build system and code distribution tools
  - Human interface & standard accelerator lattice description
  - Model and compare with data from existing accelerators

Συνεργεια

Synergia Framework

import
results

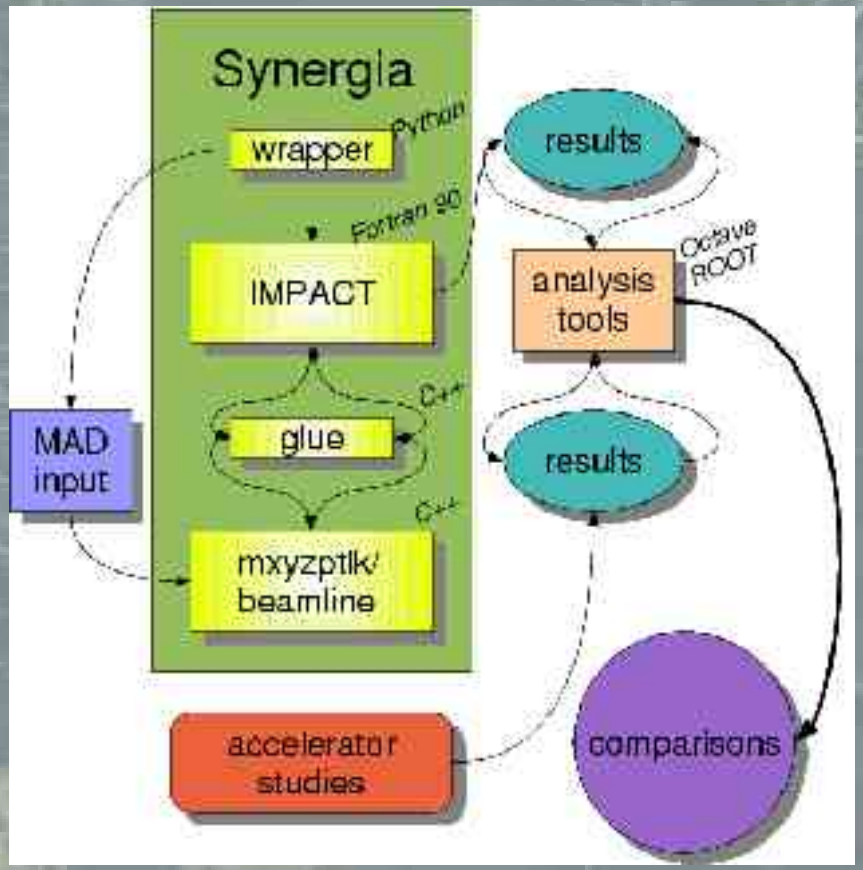
job creation
job DB

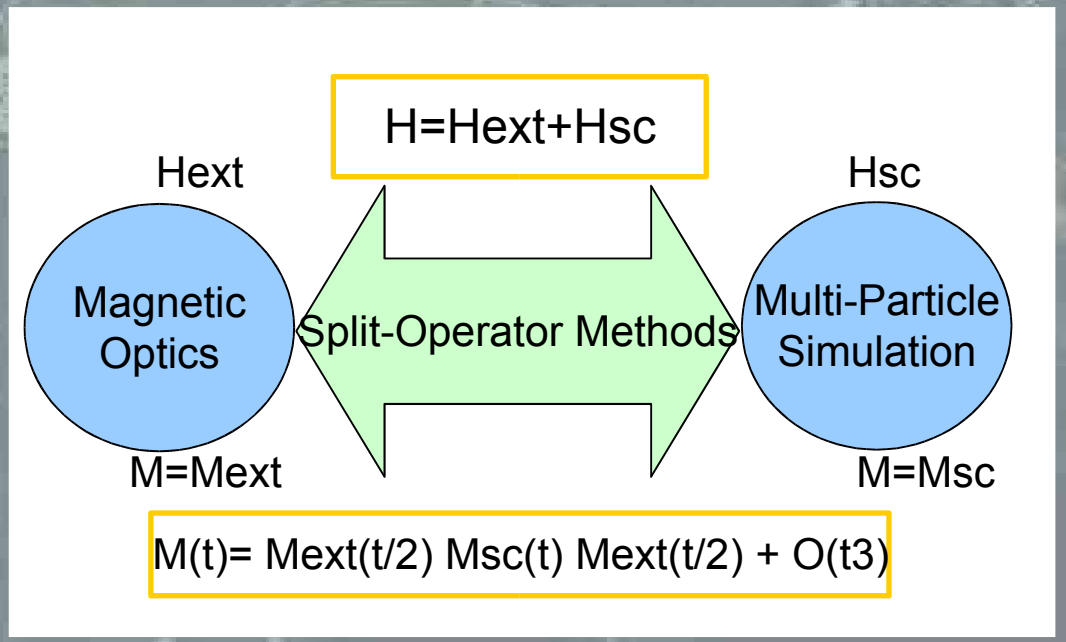
job export

import
results

Synergia Framework

Synergia uses modern software design principles and relies on the Split-Operator Methods for performance





High intensity proton driver modeling

Συνεργεια

- Problem: optimize accelerator performance
- Problem size (FNAL Booster example):
  - 6×10^{12} protons circulating for 20,000 turns
  - ~100 electromagnetic elements in accelerator
- Need to model the beam's self-interaction
- Need to understand observed beam characteristics and losses

  ➔ *requires 10^6 to 10^7 macro-particles*

The FNAL Booster

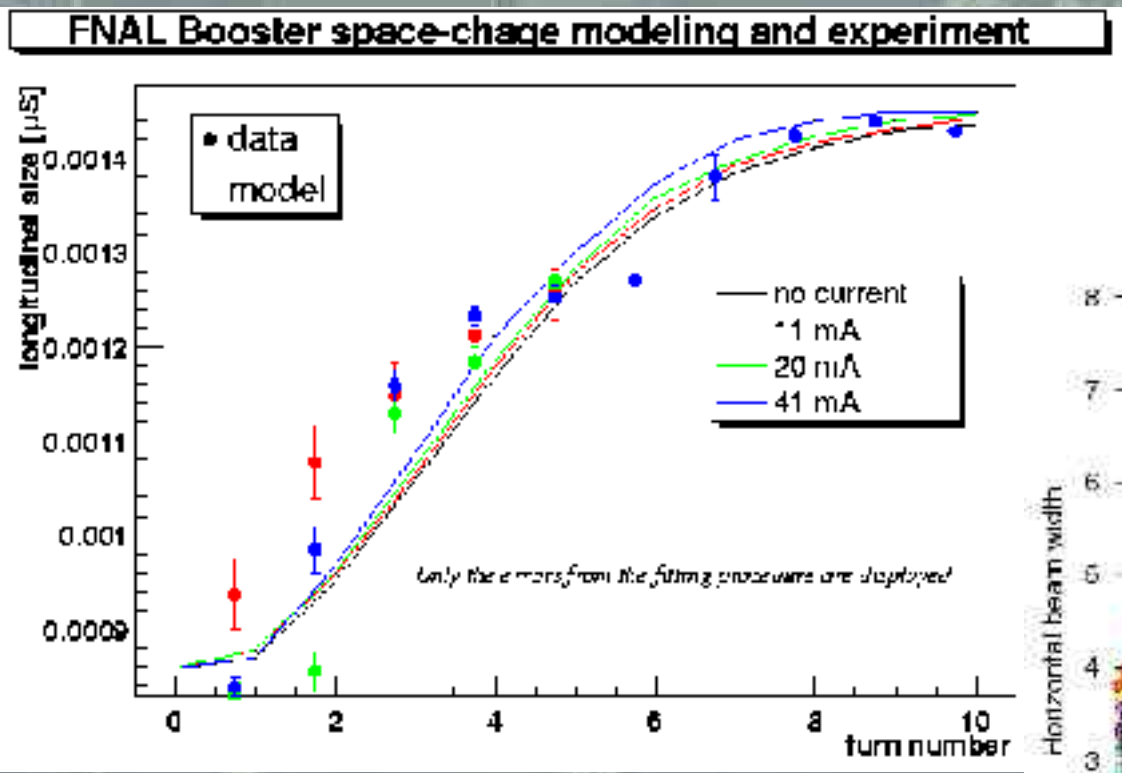
The Booster is a rapid cycling machine (66 ms cycle), accelerating protons from 400 MeV to 8 GeV

The success of the FNAL neutrino program, the quest to understand the nature and properties of neutrino masses, depends on the Booster.

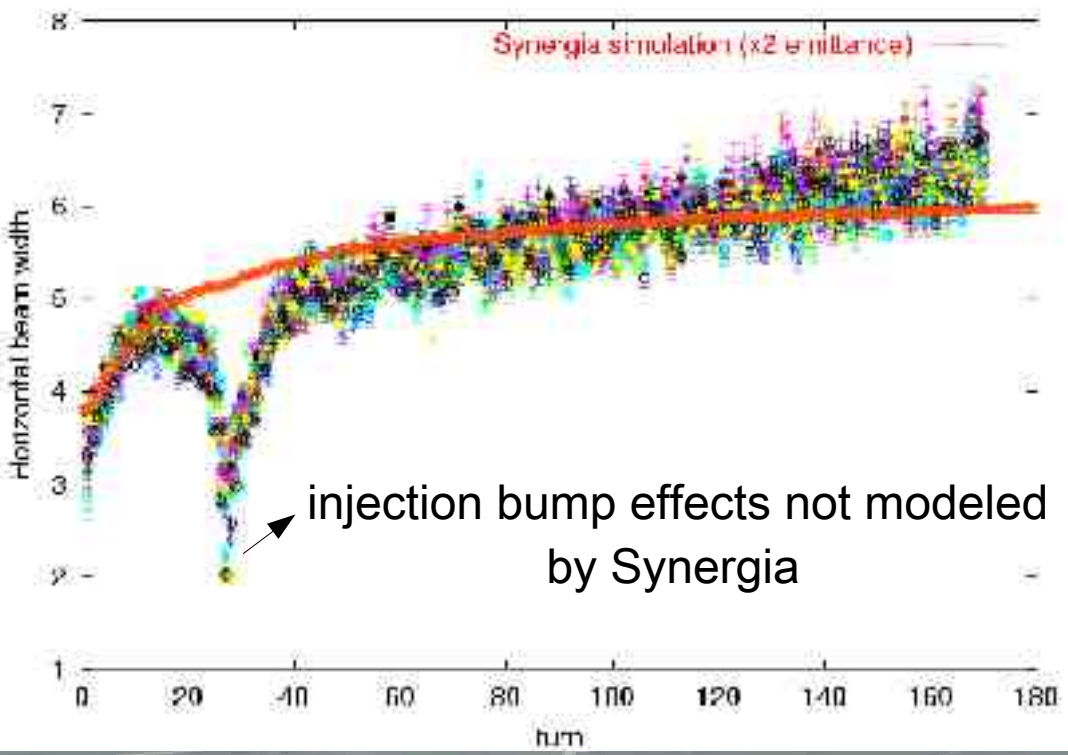
Multi-particle dynamics effects, such us space charge are responsible for machine losses which limit intensity

Data versus model comparisons

Συνεργεια



Data/MC comparison, a rare phenomenon in Beams Physics!

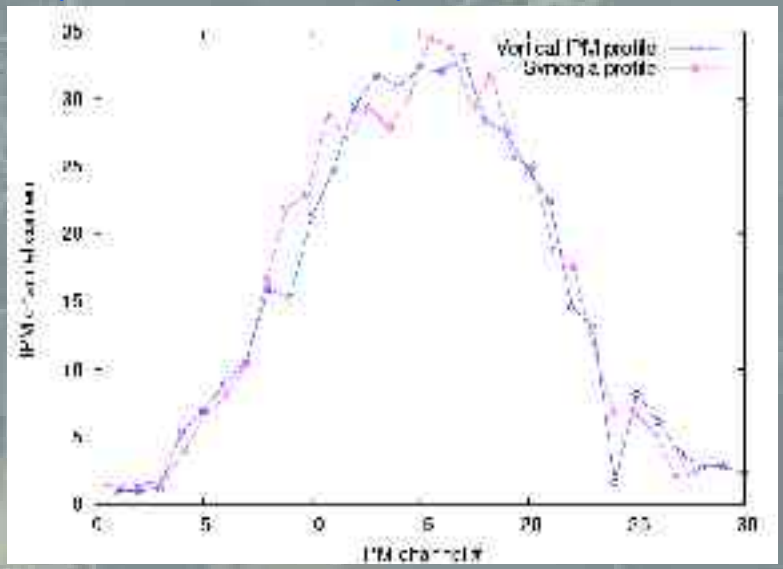


Model describes data well!

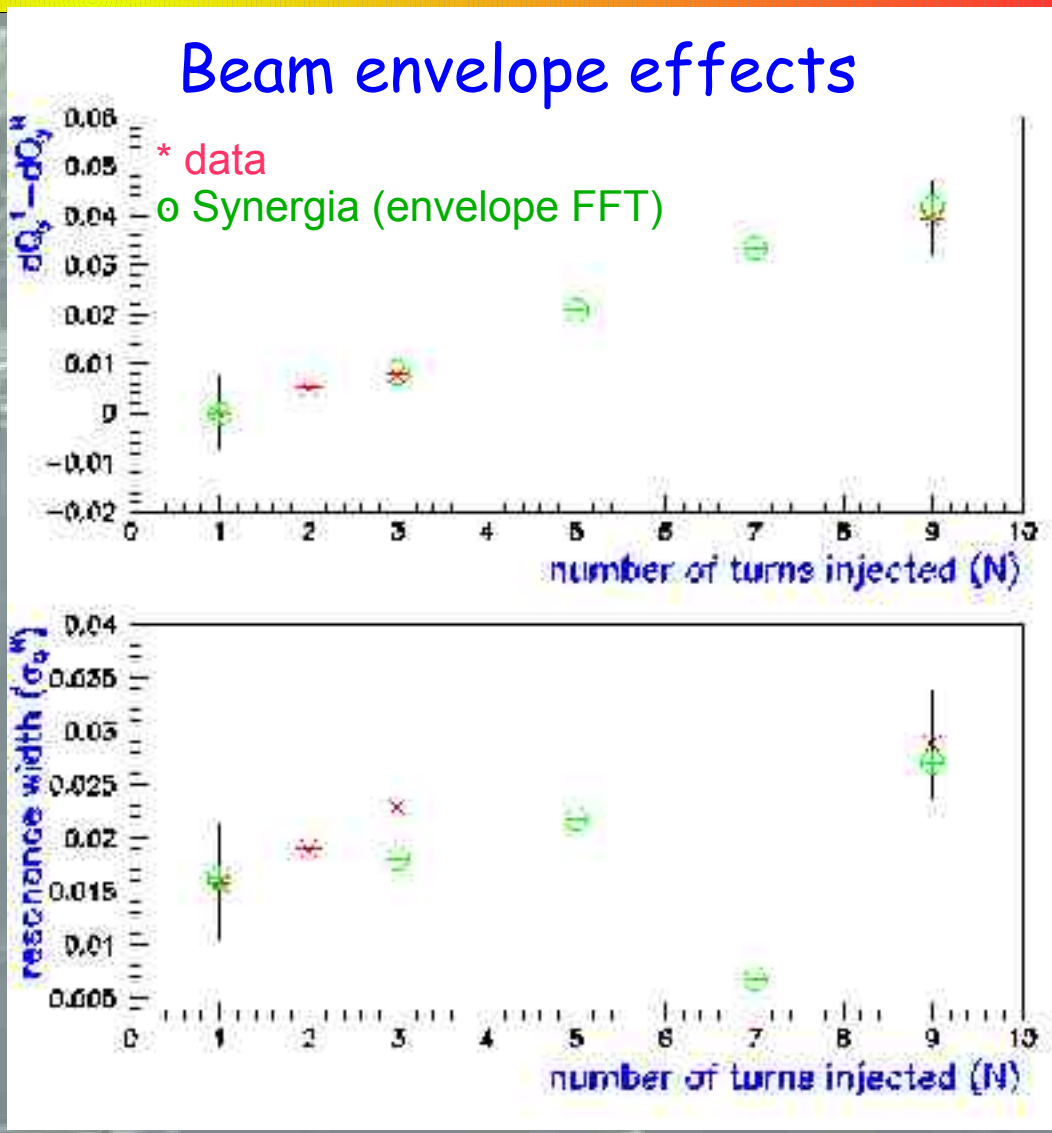
Συνεργεια

Data versus model comparisons

Measured & simulated profile comparison

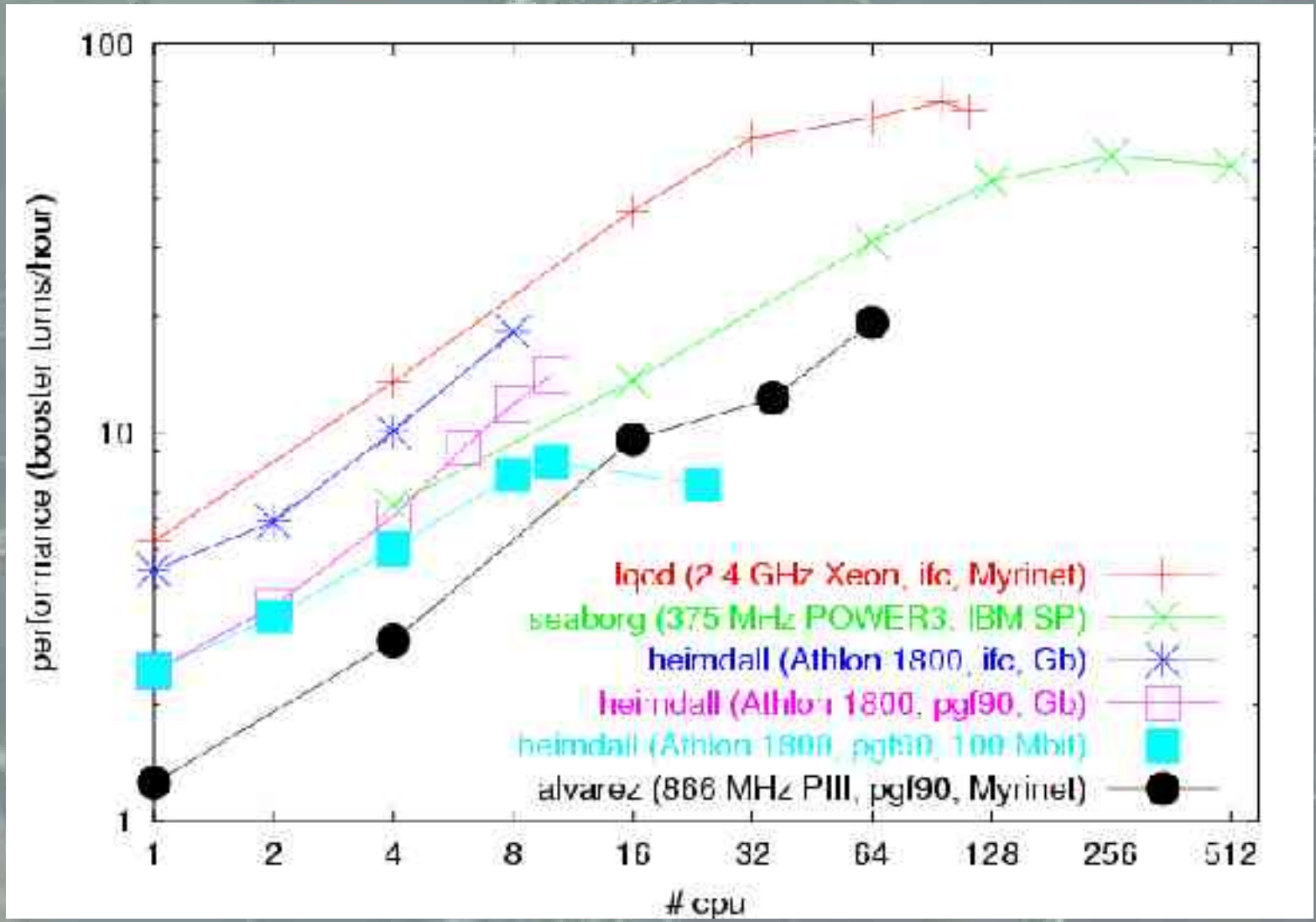


Beam envelope effects



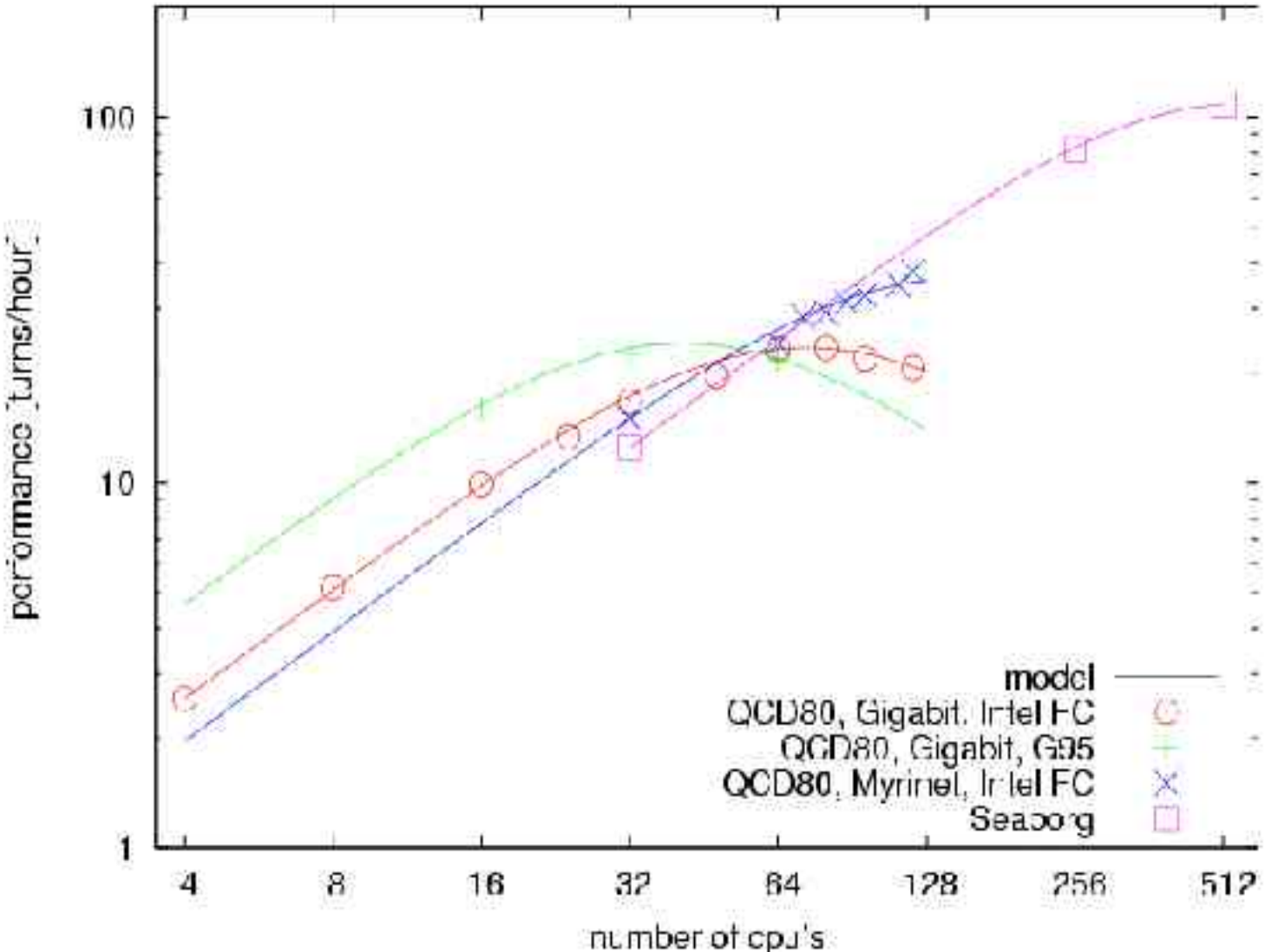
Συνεργεια

Code Performance



Συνεργεια

Code Performance



Requirements for end to end accelerator simulation

Συνεργεια

- Computational effort:

  $\sim N_{turns} \times N_{bunches} \times N_{kicks} \times \{parameters\}$

  - for 20,000 turns $\rightarrow$ 20 days
  - for multi-bunch simulation with smoothing, effective $N_{bunches}$ ~10

$\Rightarrow$ need ~100$\times$ current capability and improved scalability

☞ continuation of program for both hardware and software development!