Συνεργεια

Advanced Accelerator Simulation Project Briefing

P.Spentzouris 04/05/05

Agenda

- Overview
  - → project status & plans, resources } Spentzouris
- Applications
- Synergia software project status & plans } Amundson
- "Next generation" Synergia Dechow
- Computational Accelerator Physics @ TechX } Stoltz

Συνεργεια

Objectives

- Develop accelerator simulation framework capable of 3D collective beam effect modeling, with realistic model parameters, in a time scale relevant for current operations.
  - tightly coupled parallel computing
  - flexible interface & analysis tools
  - re-use/integrate existing physics modules
- Maximize utilization of external funds
  - SciDAC, SBIR, university NSF/DOE collaboration

Συνεργεια

Justification

Our project adds accelerator physics modeling expertise at Fermilab, well matched to our specific skills and to existing CD infrastructure

- Experience developing "user oriented" software
- Combining theoretical, experimental, and computational background
- Great wealth of experience in running efficiently parallel clusters (lQCD group)

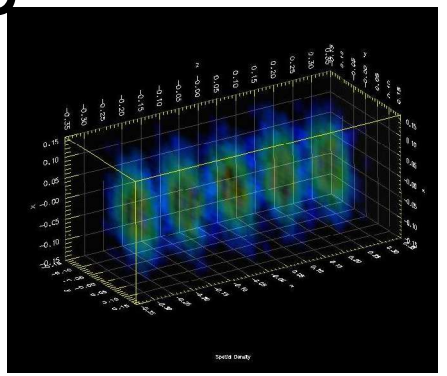
Συνεργεια

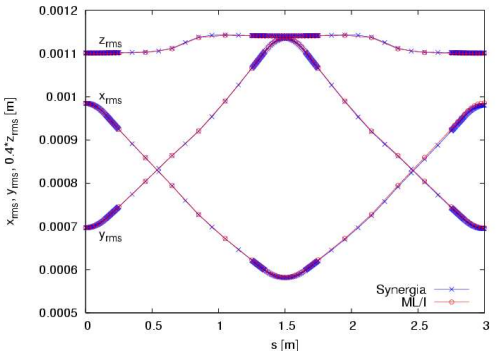
Successes

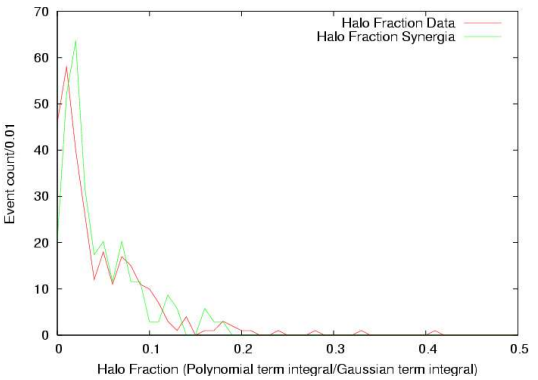
Συνεργεια

Physics

- Fully functional & tested space charge module
  - First multi-bunch 3D code for circular machines
  - Applied to Fermilab Booster modeling
  - Tested against other codes and theory



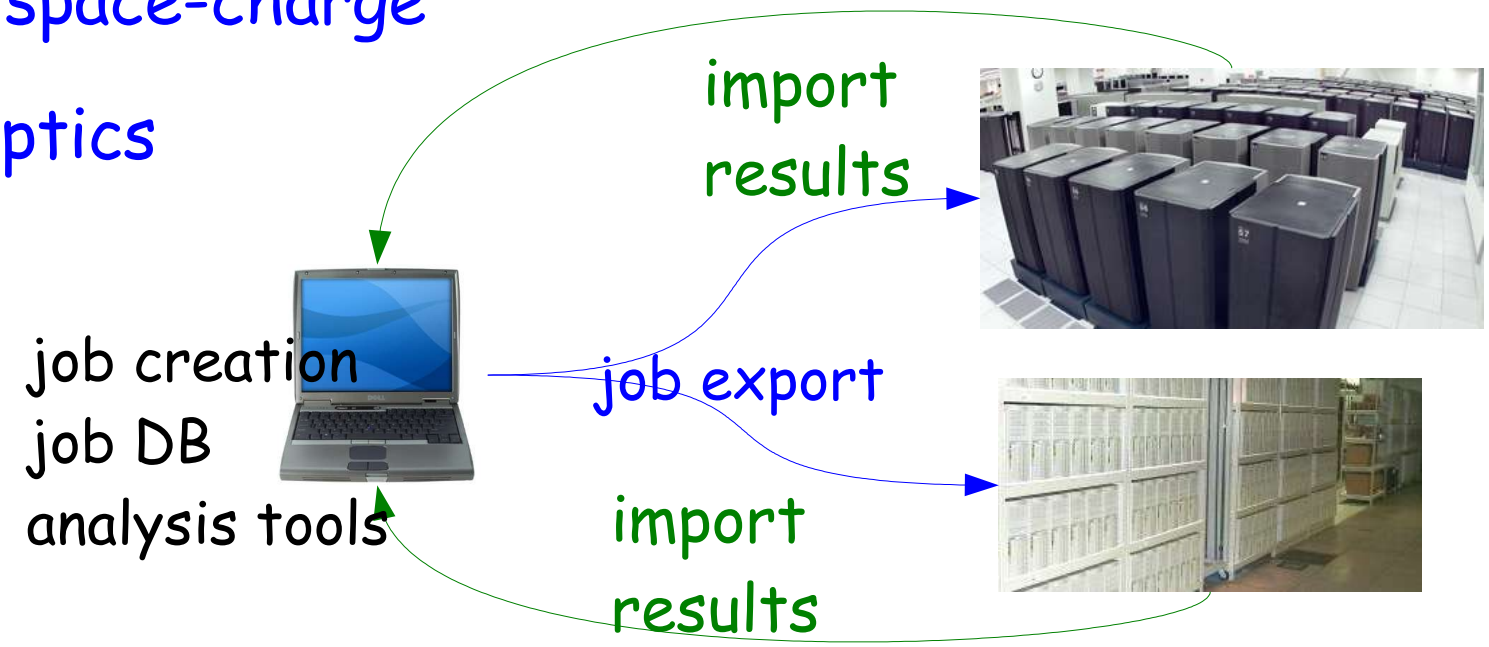




Συνεργεια

Synergia framework

- Humane user interface & flexible "model building" tools
- Complete job management & portable build systems
- Analysis tools & diagnostics
- Re-use LBNL space-charge and FNAL AD optics libraries



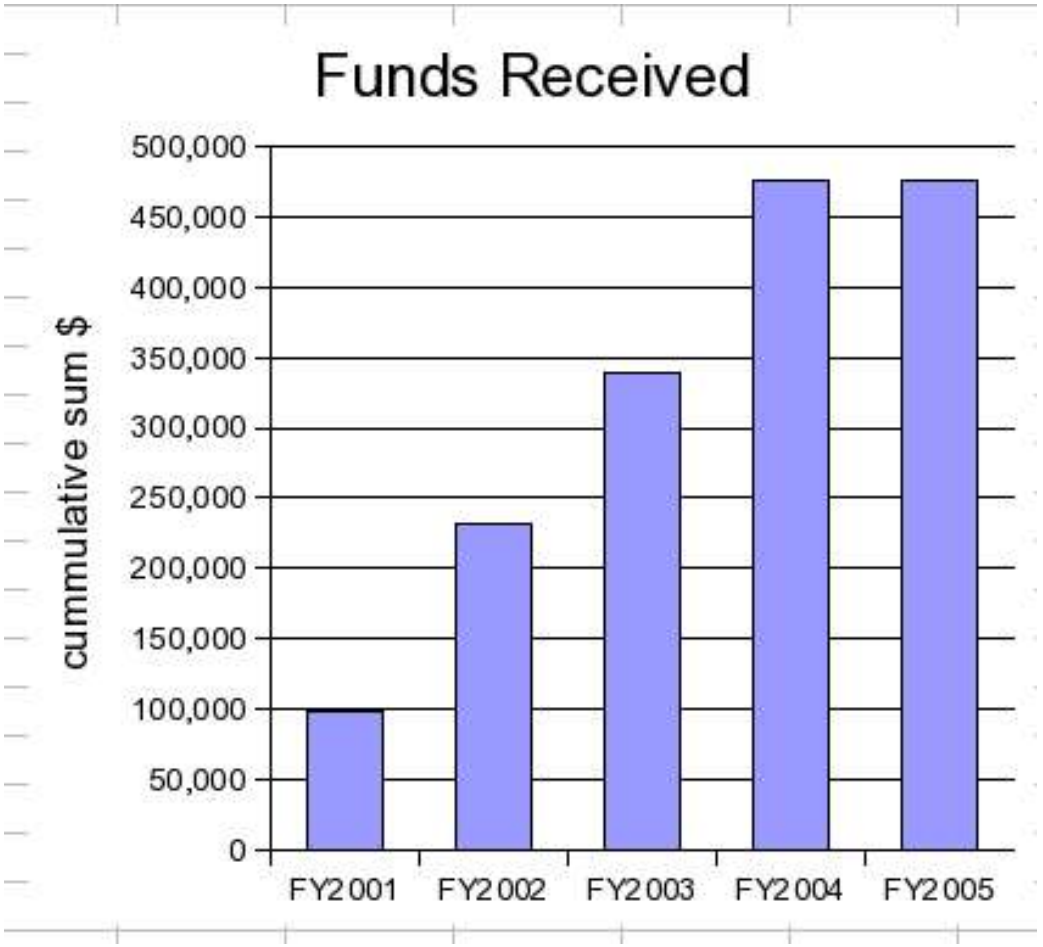
Συνεργεια

Current resources: direct and indirect non-CD funding

- ✔ SciDAC – up to summer 2006
- ✔ TechX SBIR phase II – up to fall 2006
- ✔ Collaboration with IIT (grad student) 4-5 years
- ✔ Collaboration with AD (Integration Dept., Booster group)
- ? TechX SBIR phase I (pending)
- ? DOE CS IIT career proposal (pending)
  - ✗ NSF proposals with IIT and DePaul rejected

Συνεργεια

External funding details



- One more year of SciDAC expected ~$150k (June '05)
- TechX SBIR
  - phase II $750K (current)
  - phase I ($100K)

Συνεργεια

Future external funding

- SciDAC (or daughter of SciDAC) past 2006
  - already asked to participate
- Opportunistic collaboration with universities
- Other initiatives
  - computer science
  - accelerator physics

➔ need CD support to identify opportunities

Συνεργεια

Resources: current manpower

- Fermilab CD
  - Amundson, Spentzouris: framework development & space-charge modeling
  - new Applic. Physicist (welcome Eric Stern): Tev beam-beam modeling & code development
- TechX: framework restructuring/modularization
  - D. Dechow (developer, full time), P. Stoltz (manager/developer), S. Kruger (consultant)
- IIT
  - D. McCarron (student, Booster measurements)

Συνεργεια

Friends (manpower in kind)

- Fermilab AD:
  - L. Michelotti, F. Ostiguy (single particle optics libraries development/maintenance; beam physics)
  - V. Lebedev (beam-beam contact), SDA analysis team: Tev modeling & measurements
  - Booster group (B. Pellico, contact): beam studies & measurements
- IIT: L. Spentzouris (Booster measurements)
- SciDAC: Ryne, Qiang, Samulyak (beam physics)

Multi-particle effects modeling effort

Συνεργεια

Management: 15% P. Spentzouris

Code development

J. Amundson
D.Dechow, 30% E. Stern, 20% P. Spentzouris
(TechX personel, Michelotti, Ostiguy)

Applications

P.Spentzouris
50% E. Stern, D.McCarron, other students
(AD contacts, L. Spentzouris)

Code modularization, optimization, new physics module implementation

Booster space-charge
New driver?
Tev strong-strong beam-beam effects,
electron cloud (MI)?
electron cooling?

Συνεργεια

Computing resources

- Given the number of physics projects and the "medium size" job unfriendliness of NERSC it is desirable to have dedicated cluster (previous briefing presentation, see appendix)
  - use Infiniband lQCD test cluster (Jim's talk)
    - so far sufficient
    - resources will be stretched when beam-beam & other applications ramp up

Συνεργεια

Physics applications

- **(NOT)** wrapping-up space-charge modeling (thought so last briefing). Recent developments emphasize proton source (neutrinos) and ILC. Interested in (offered to):
  - Model proton source upgrades/new proton source designs
  - ILC damping ring (started)

Infrastructure & physics capabilities already in place, although damping ring posses algorithmic (performance) challenges with its asymmetric parameters.

Συνεργεια

Physics Applications

- Strong-strong beam-beam effects [Tevatron, LHC]: started (just)
  - Requires studies, validation, realistic parameters (AD collaboration V. Lebedev)
  - ✔ Re-use LBNL code

➔ Finalize (finally) physics studies of the past 3 years: publish!

- see applications (next section of talk)

Συνεργεια

Other possibilities

- Impedance effects (general purpose)
  - Re-use R. Samulyaks code (SciDAC, BNL)
  - Multi-physics code development
- Electron cooling, electron cloud
  - Run II, neutrino program (MI) and LHC
  - SBIR phase I with TechX

➔ Code re-factoring (TechX) important for easy incorporation of new modules

Συνεργεια

Plans/expectations (~6 months)

- Implement Tev beam-beam model in LBNL module (minimal wrapping)
  - Use both experimentally determined optics and model; lifetime measurements, begin using SDA
- Study importance of space-charge in ILC damping ring with semi-realistic parameters
- Study options for electron cloud, electron cooling physics
  - Get feeling for potential impact on MI

Συνεργεια

Plans

- Detailed Booster studies
  - Quantify/characterize non-linear effects in machine operations with realistic parameters
  - Experimentally test interesting model expectations (see next section)

  ➔ Publish, including older studies!
- Begin studies of new proton driver designs
  - Which design? Will need input. This could be a long term project.

Συνεργεια

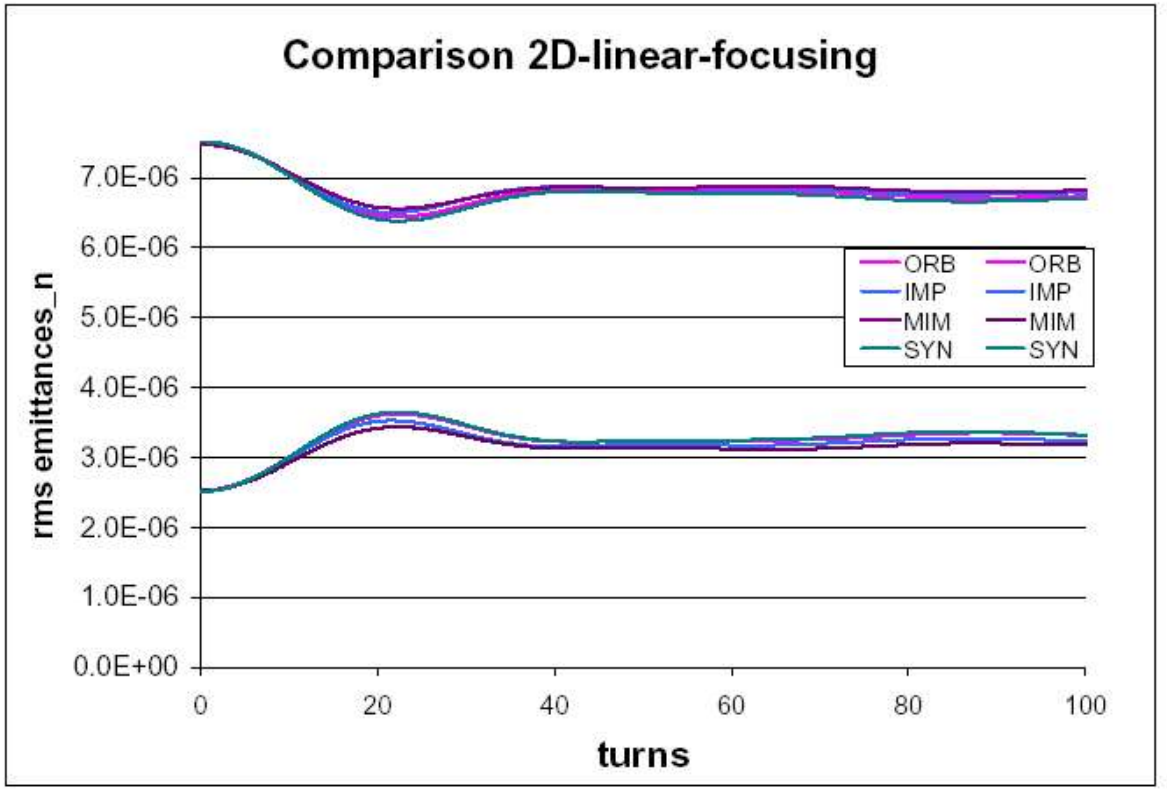
Synergia Applications

Two categories of applications: abstract physics modeling (generic machine representation); targeting operational parameter optimization (detailed machine modeling)

CERN PS modeling & benchmarks

Συνεργεια

Model Montague resonance at the CERN PS (standard simulation candle)
Compare with other codes (participation from accelerator modelers from 6 different labs)

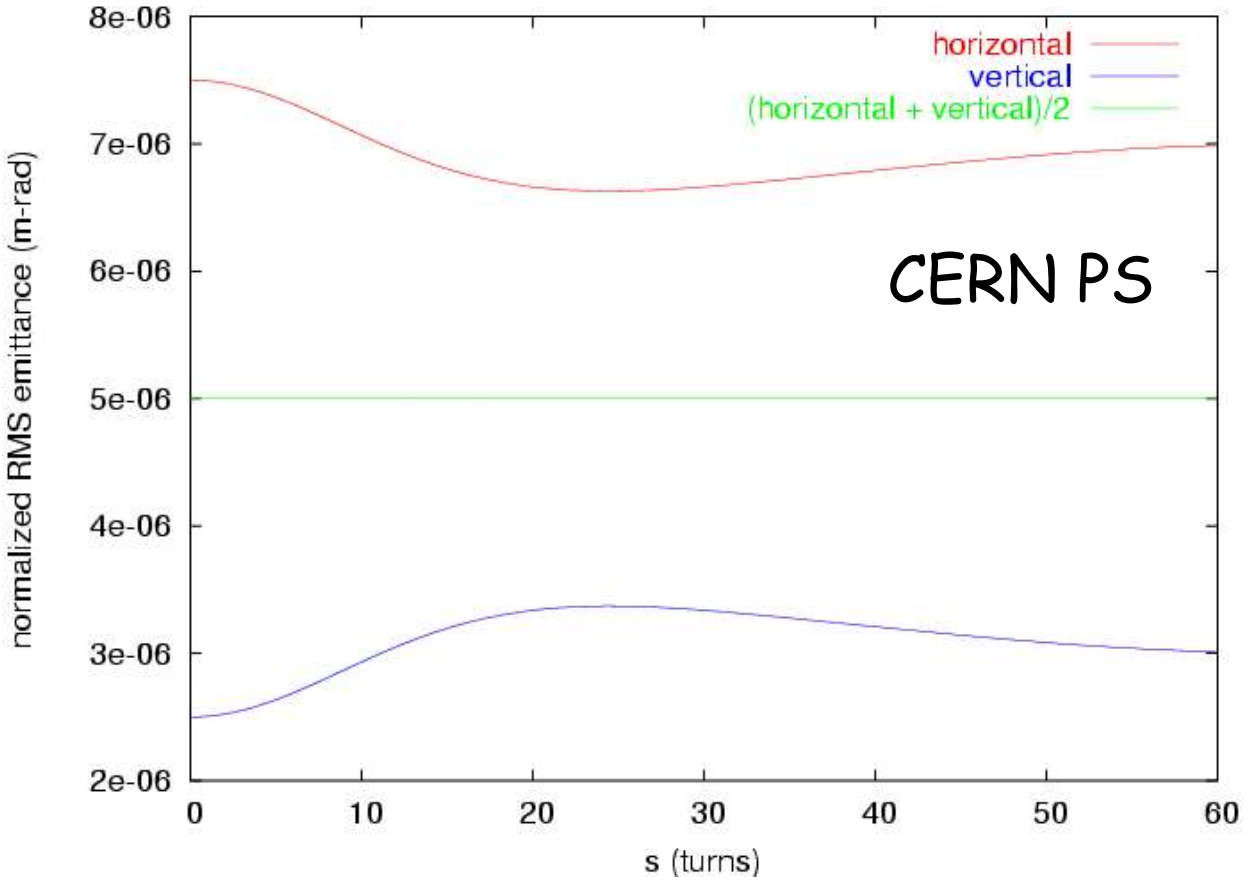


Συνεργεια

Numerical stability

Coupling resonance preserves sum of longitudinal and vertical emittance

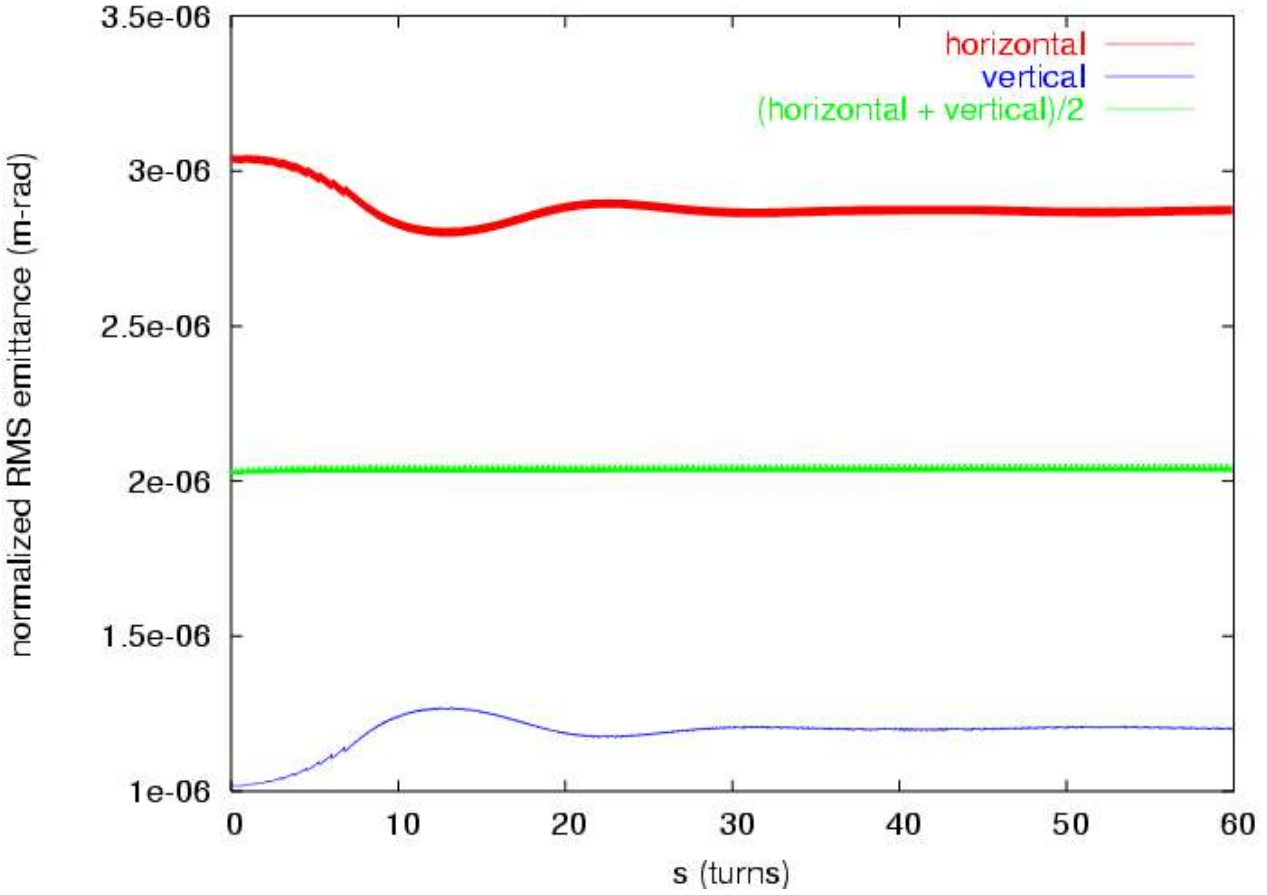
Most accurate implementation in benchmarks!



Συνεργεια

Booster "physics only"

Montague resonance

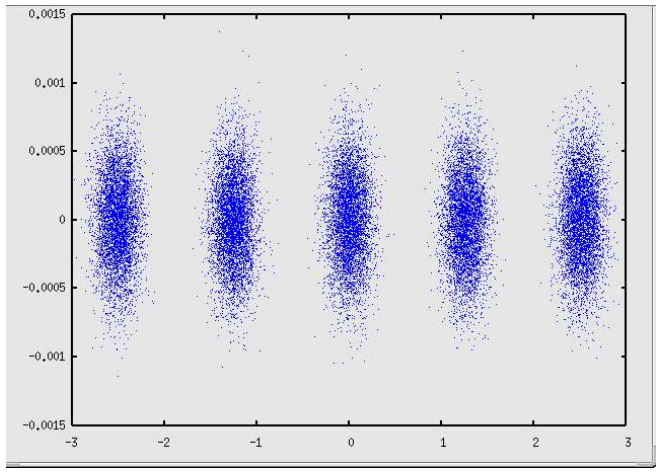


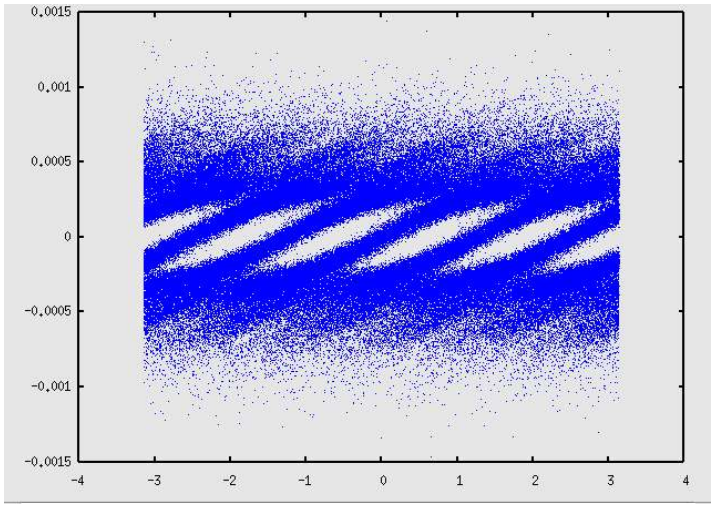
Συνεργεια

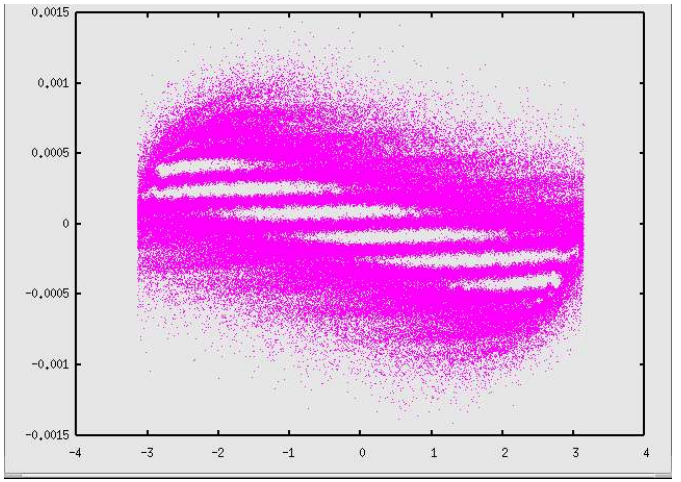
Booster 3D modeling

Realistic Booster a very complex model: ramping magnets, rf, large momentum spread, nonlinearities (space-charge, chromatic, ...), potential coupling between transverse and longitudinal planes.

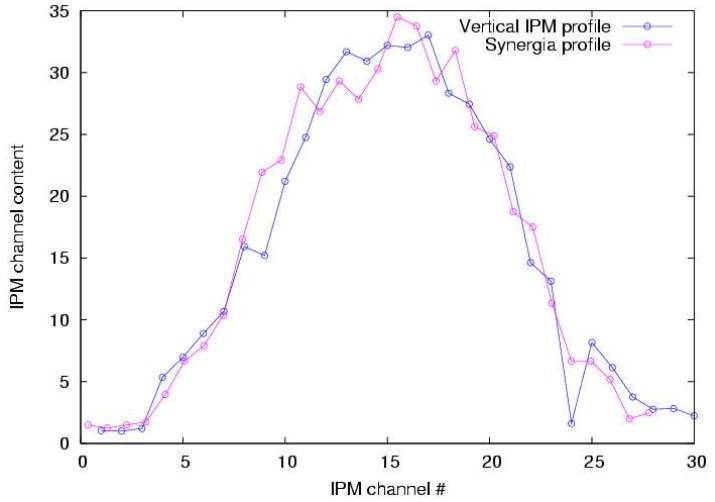
Longitudinal phase-space: injection, before bunching, begin bunching







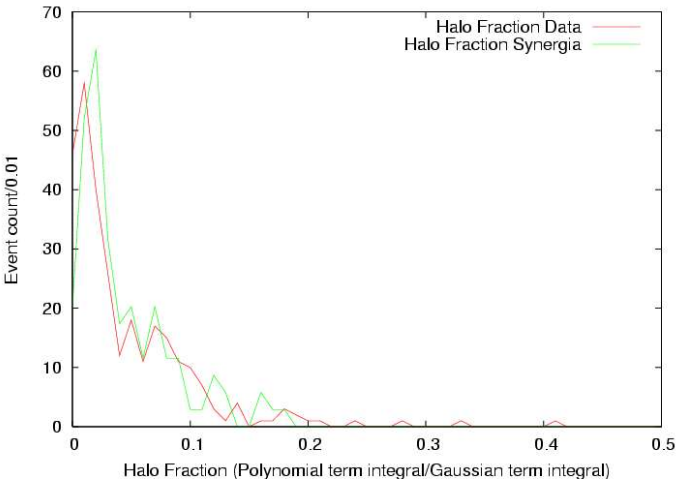
Model experimental data



Smeared Synergia vs data profiles

Model Booster beam during injection and capture phase. Measure beam profiles using IPM (our calibration & analysis). Model IPM response. Apply smearing to simulation.

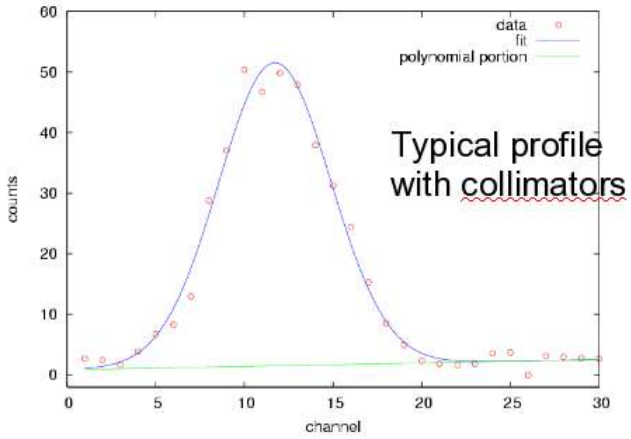
Try to understand tails in beam distribution using shape analysis. Try to quantify contribution of non-linearities necessary to fit data.



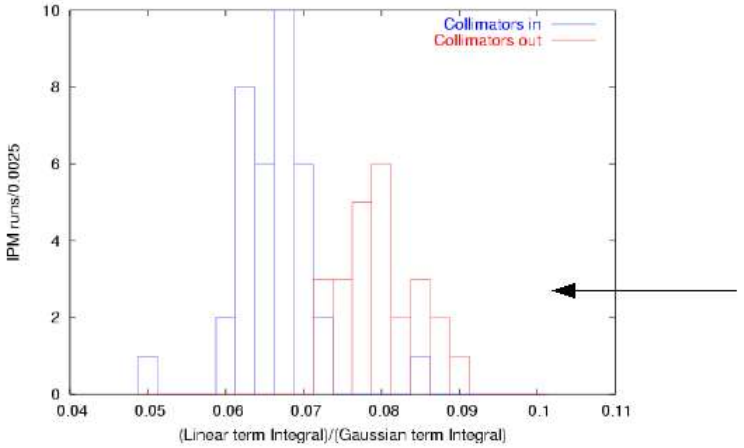
Συνεργεια

Booster measurements (side effect)

We fit the turn-by-turn IPM profiles to a Gaussian+linear function



Typical profile with collimators in.



$$G \equiv \int (Gaussian\ term)$$
$$L \equiv \int (Linear\ term)$$

L/G measures non-gaussian tails (halo)

We collect IPM data for many cycles with and without the collimators.

Average L/G for the last 500 turns in each data set.

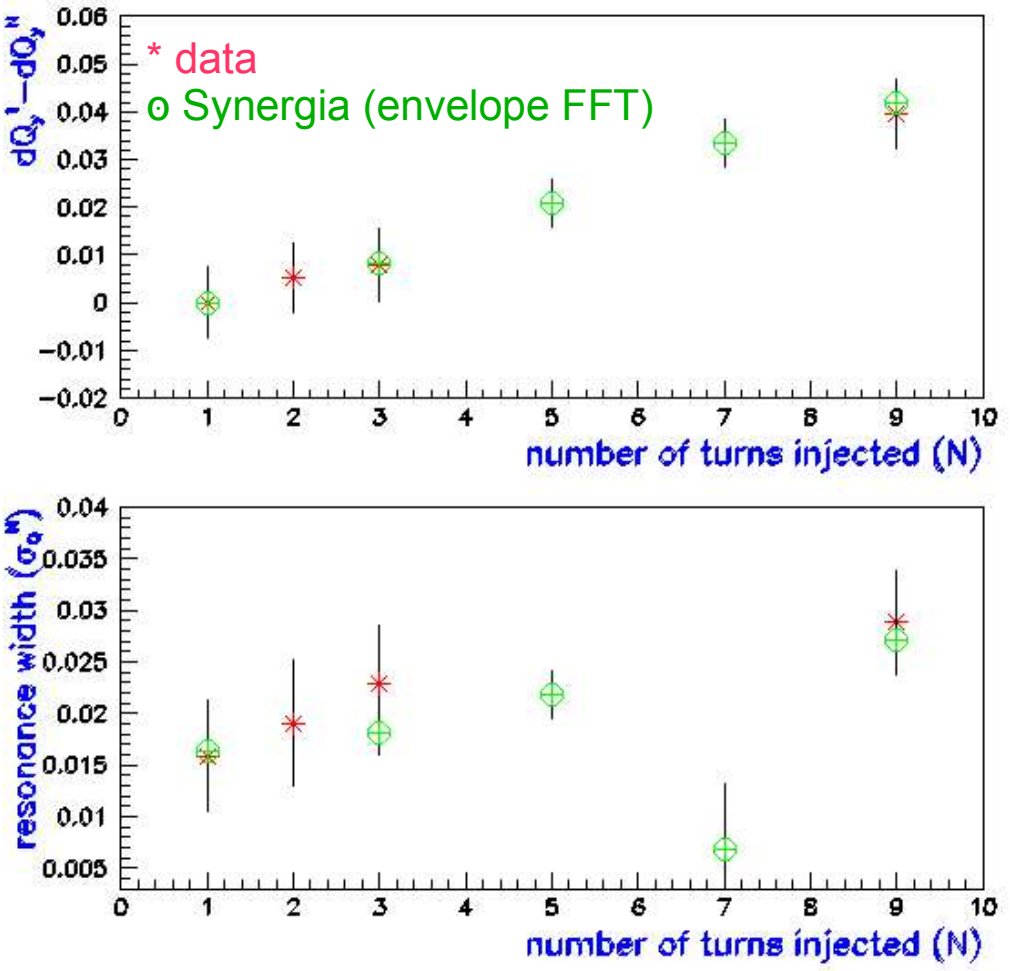
L/G without collimators is significantly larger than L/G with collimators.

J. Amundson, P. Spentzouris, CD/CEPA

Συνεργεια

Coherent Space-charge effects

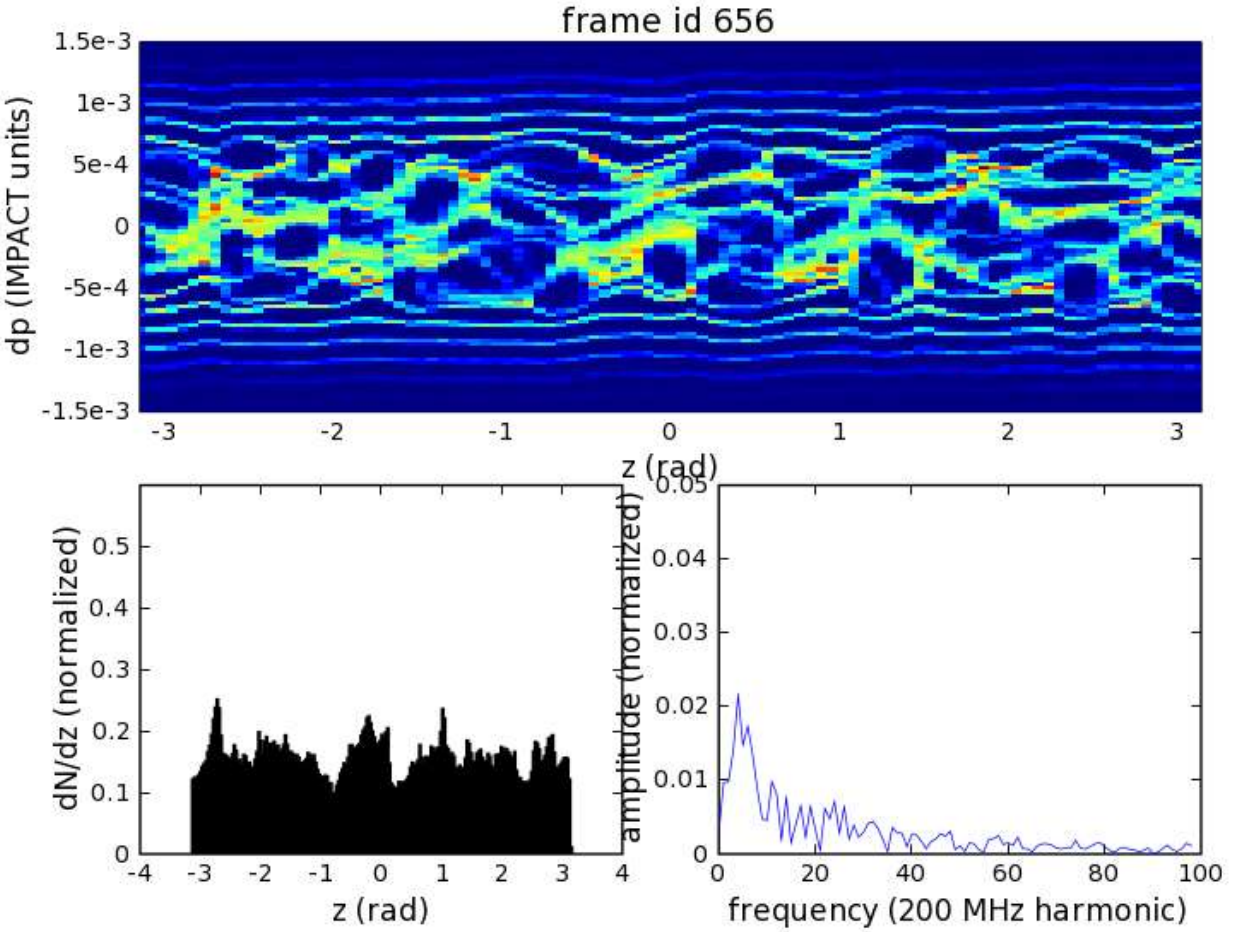
Stop-band measurements ~2 years overdue for publication!



Συνεργεια

Coherent noise due to space-charge

Simulation prediction agrees with analytic prediction of 1989 (Hofmann). Still need data (dedicated study); should be a nice physics publication



Συνεργεια

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

Συνεργεια

Appendix

(slides from previous briefing, 11/02/04)

Συνεργεια

Advanced Accelerator Simulation Project Briefing

J. Amundson & P. Spentzouris 11/2/04

Outline

- Project status
  - development, applications, resources
- Plans
  - Applications
- Synergia code development status & plans

} PGS

} JFA

Συνεργεια

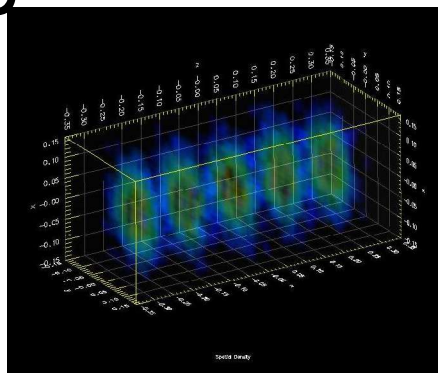
Status

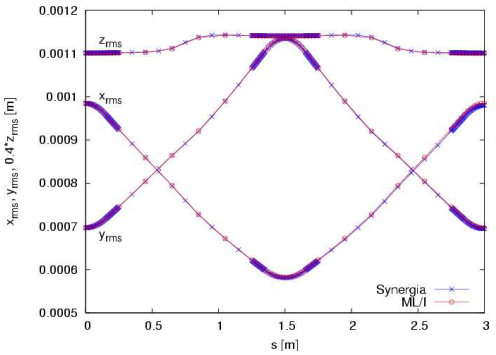
(last briefing March '04 & discussion in accelerator activity coordination meeting Aug '04)

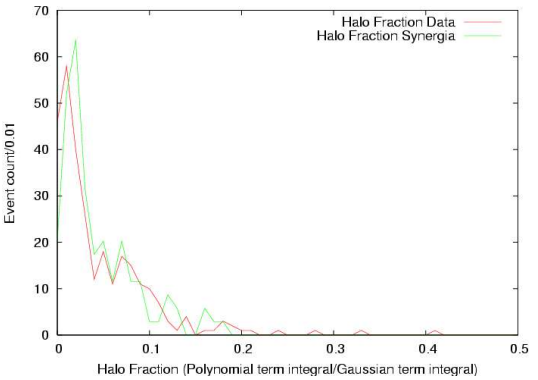
Συνεργεια

Physics

- Fully functional & tested space charge module
  - First multi-bunch 3D code for circular machines
  - Applied to Fermilab Booster modeling
  - Tested against other codes and theory







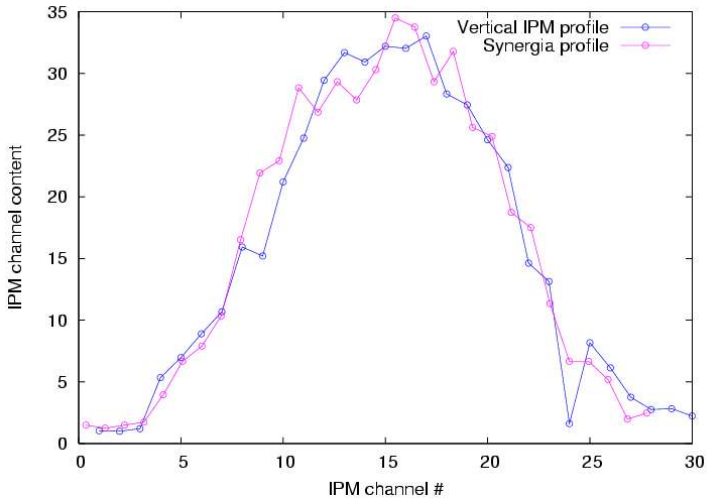
Συνεργεια

Booster Application

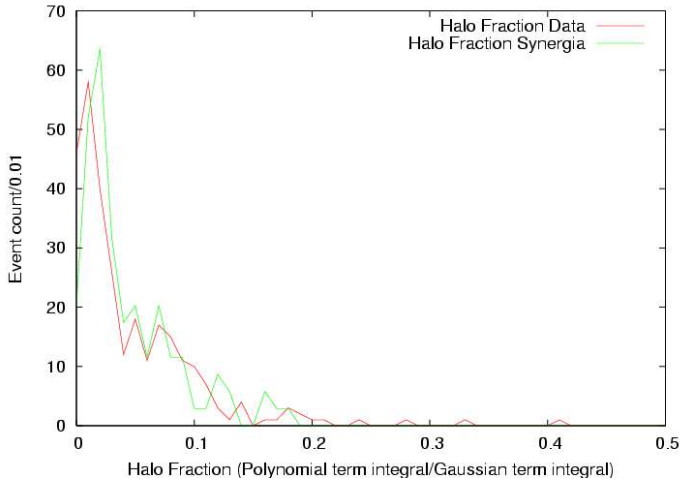
- Emphasis on use of realistic parameters & impact on operations
  - Beam studies & measurements
  - Calibration of beam detectors
  - Development of analysis tools
  - Work closely with AD machine & operations personnel

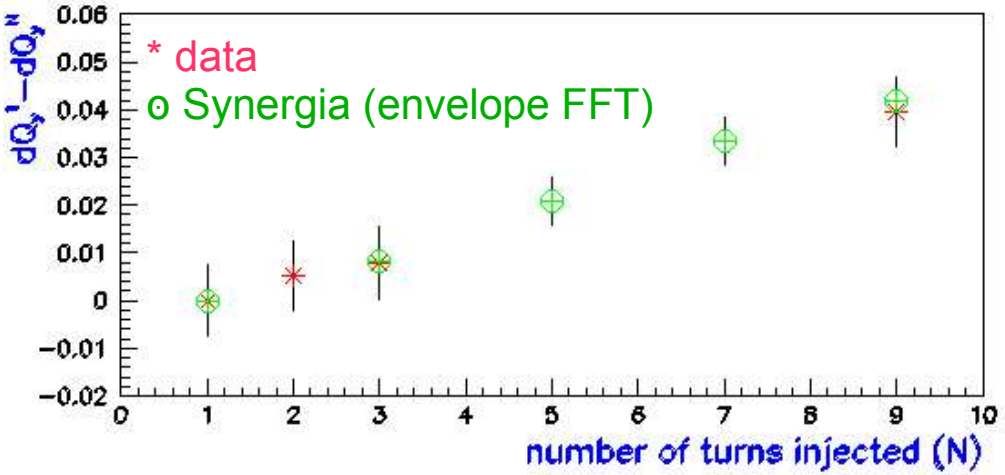
Application Examples

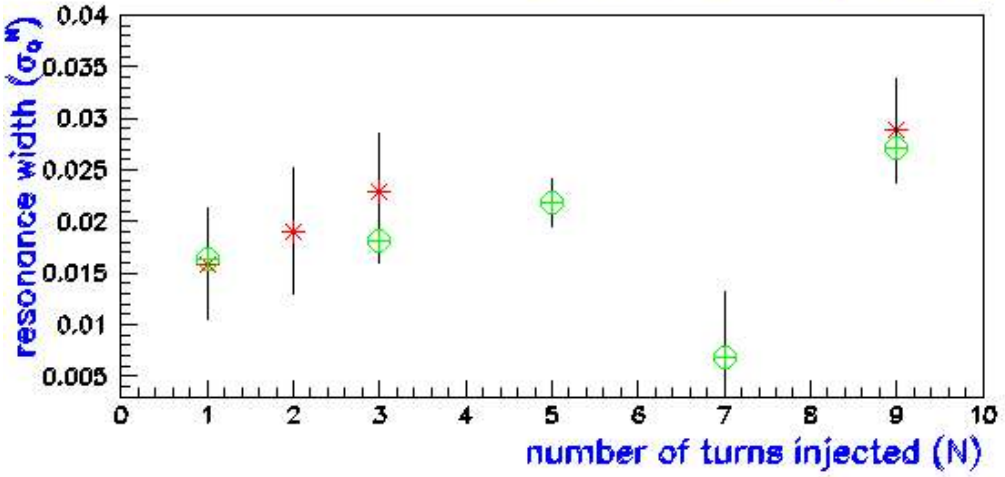
Συνεργεια



Smeared Synergia vs data profiles







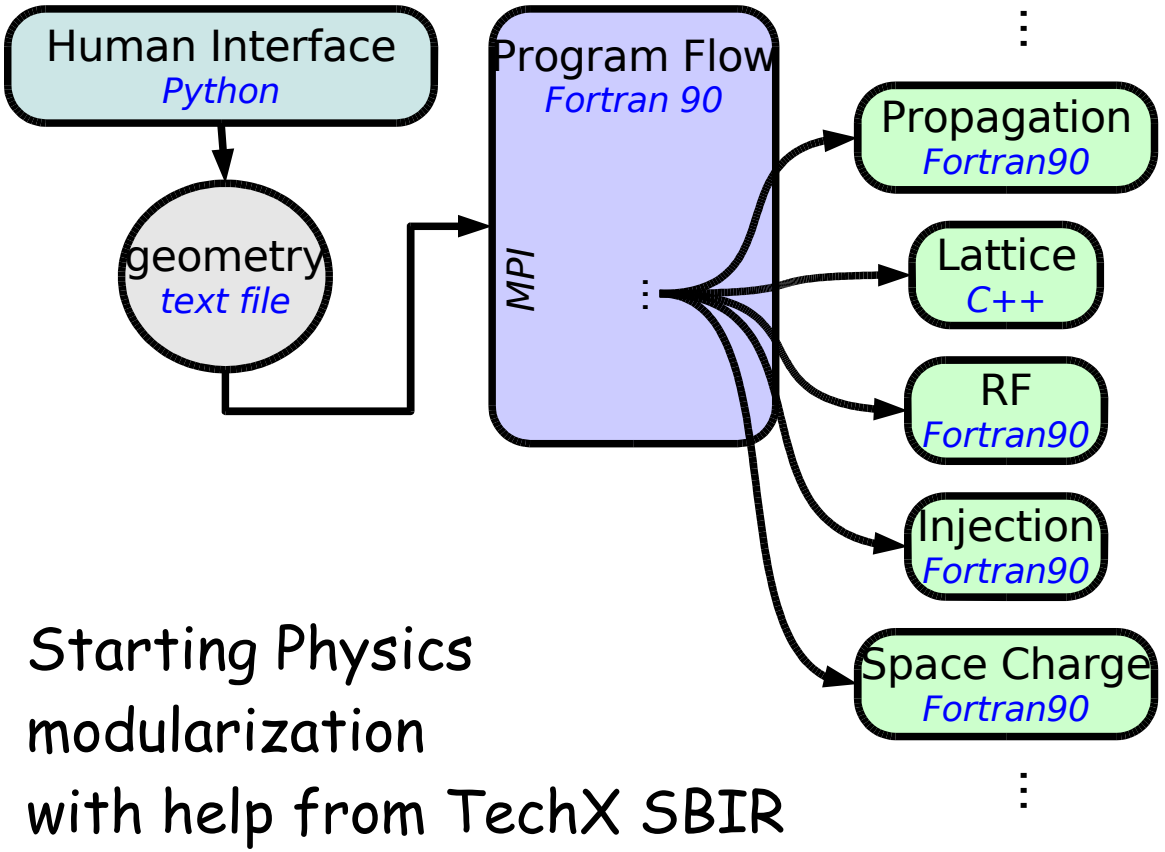
Συνεργεια

Impact (subjective metric)

- Substantial beam physics conference participation (including invited talks)
- Publications (2 plus one submitted)
  - also, conference proceedings & FNAL memos
- Specific requests for modeling (Booster, Tev, A0, CERN PSR)

Συνεργεια

Framework Status



Starting Physics modularization with help from TechX SBIR

- User interface: flexible geometry and program flow
- Internal geometry representation constrained by F90 program flow module

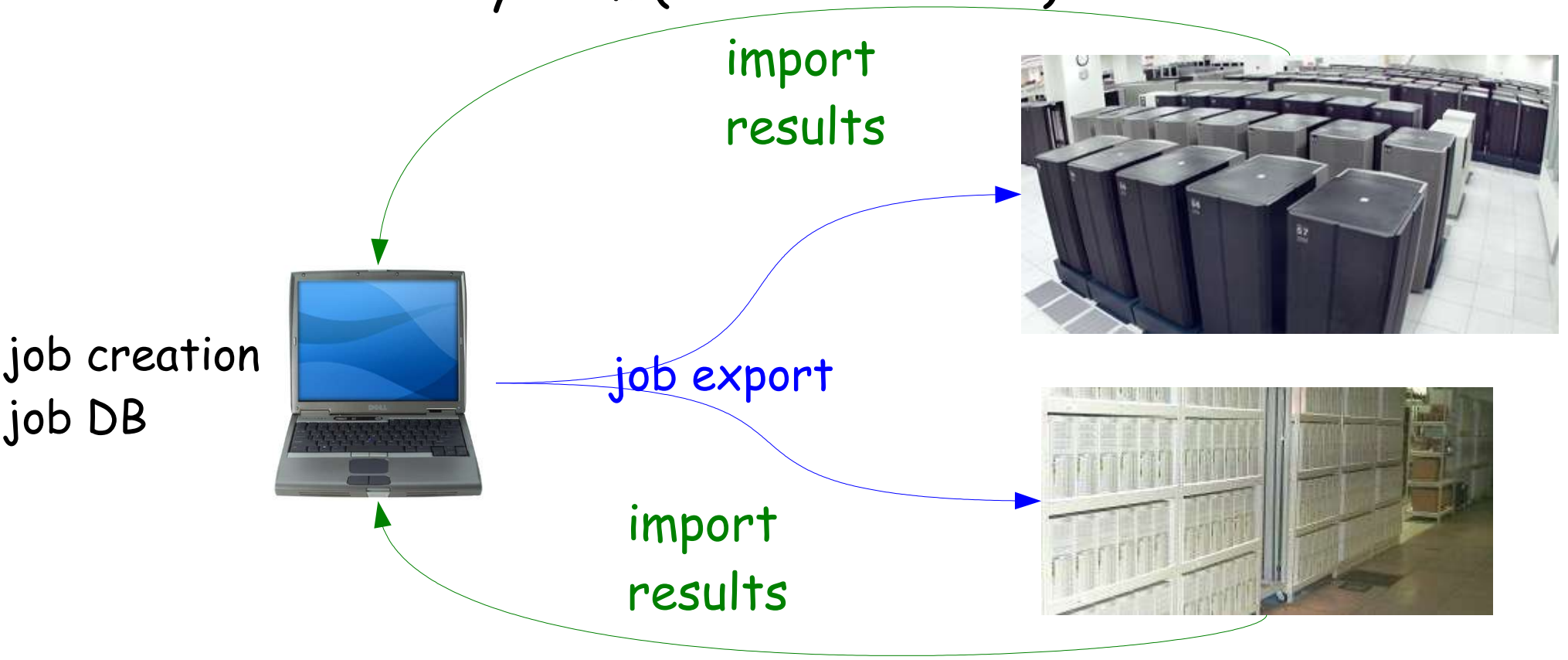
➔ complicates addition of new physics modules

➔ Jim's talk

Συνεργεια

Synergia framework

- Fully functional job management system (Python)
- Portable build system (GNU Autotools)



Συνεργεια

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

- ➔ Updated web pages but still a lot of work on documentation
- ➔ Test suite but need expansion

Συνεργεια

Resources: funding direct and indirect

- ✔ SciDAC -- 2 more years (funding increase)
- ✔ TechX SBIR phase II – 2 years
- ✗ NSF proposal with DePaul -- rejected
  - → will try again
- ? Support NSF CS IIT career proposal (pending)
- ✔ Collaboration with IIT (grad student) 4-5 years
- ✔ Collaboration with AD (Leo, Francois, Booster group, TeV???)

Συνεργεια

Resources: manpower

- So far it's been JFA (100%) & PGS (60%)
  - and leveraging AD (Booster group) and SciDAC (Ryne, Qiang) resources

➔ limited our ability to respond to new application needs/requests

➔ limited physics output

☺ **but things are changing!**

Συνεργεια

Resources: current manpower

- Fermilab CD
  - old guard: JFA, PGS
  - application physicist (position posted)
- TechX - possible new CP/mentorship
  - 1 FTE for 2 years (welcome Dr. Dechow)
  - P. Stoltz (manager), S. Kruger (consultant)
- IIT
  - D. McCarron (thesis on Booster space charge)
- IMSA (Matt Drake, student)

Συνεργεια

Friends (manpower in kind)

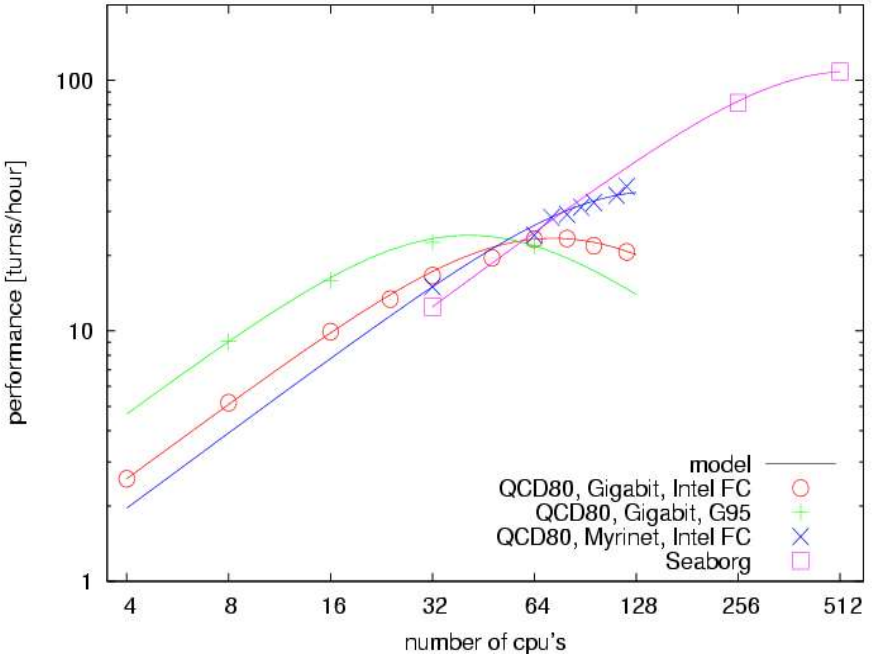
- Fermilab AD:
  - Leo, Francois (single particle optics libraries maintenance)
  - Tev liaison (TBA), V. Lebedev (contact)
  - Booster group (B. Pellico, contact)
- IIT
  - L. Spentzouris
- SciDAC: Ryne, Qiang, Samulyak

Συνεργεια

Resources (computing)

- So far we have used the old lqcd cluster and NERSC
- with additional manpower enhanced needs: "multi-tasking" and production modes

➔ need more resources



"multi-tasking" == more than one physics projects

production == more than one application per project

Συνεργεια

Options

- NERSC: not mid-size job friendly
- lQCD (any flavours) cluster:
  - cannot survive in parasitic mode

➔ Dedicated cluster at FNAL (FY05 budget)

- leverage lQCD expertise
- maximize physics output & code development

➢ Create Fermilab's multi-particle beam dynamics modeling "center"

Multi-particle effects modeling group

Συνεργεια

Management: 15% P. Spentzouris

Code development

J. Amundson
D.Dechow, 30% Apl. Physicist, CP(?), 20% PGS (Leo, Francois)

Code modularization, optimization, new physics implementation (TechX, SciDAC, DePaul (?), IIT(?))

Applications

P.Spentzouris
50% Apl. Physicist, D.McCarron, other students (AD contacts)

Booster space-charge (Dan's thesis)
Tev strong-strong beam-beam effects (Apl.P.), other (electron cooling?) TechX (?)

Συνεργεια

Plans & possible opportunities

Συνεργεια

New Physics & applications

- First step: implement strong-strong beam-beam effects [FNAL relevance: Tevatron]
  - Important to apply beam-beam @ Tevatron using the same approach as with space charge @ Booster: studies, validation, realistic parameters
  - Requires AD collaboration (V. Lebedev)

➔ Code development: multi-species simulation

➔ Re-use LBNL code

Συνεργεια

New physics & applications, cont

- Impedance effects (general purpose)
  - Re-use R. Samulyaks code (SciDAC, BNL)
  - Multi-physics code development
- Next step: electron cooling, electron cloud
  - relevance for Fermilab and LHC
  - Potential SBIR with TechX

Συνεργεια

Funding opportunities (future)

- Next SciDAC-like cycle (in 2 years)
  - Already asked to prepare to participate
    - White paper in '05, proposal '06
- SBIR with TechX (additional physics)
- NSF (with DePaul, IIT)
  - Optimization, algorithm development
- Grid (???)
- Astrophysics (not so crazy)

Συνεργεια

Issues

- CP/mentorship hire (replacing hire lost to AD gymnastics)
- Office space, especially for our "permanent" visitors

Συνεργεια

Summary: target objective

- Establish Fermilab's "collective beam effects" modeling effort
  - Unique expertise high performance accelerator modeling
  - Leveraging lQCD experience
  - Partnership with AD
  - Attract more funding and possibly expand to other physics if necessary or desirable