Beam Dynamics and Theory

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Core Competencies (Tevatron complex)

- Optics and optics measurements
  - Building precision optics models with LOCO (differential orbits)
    - Tevatron, Pbar source, Recycler
      - Booster – is happening now
    - Transfer lines
  - Turn-by-turn
    - Significant progress in understanding
    - Did not go as easy as we expected
    - Successful application for decoupling at Tevatron ramp
  - Automated steering (all rings, almost all lines)
- Instabilities and impedances
  - Effect of space charge on beam stability
  - Impedances: laminated magnets, multi-layer vacuum chamber …
    - μ-measurements @ high frequency (up to 1 GHz)
  - Operation of feedback systems
    - Effect of x-y coupling in Tevatron
  - ep-instability

Core Competencies (continue)

- Luminosity evolution model
  - Diffusion due to RF noise
  - Single and multiple IBS
  - Residual gas scattering (transverse and longitudinal)
- Stochastic cooling
  - Theory
  - Measurements and their analysis
  - Equalizers
- Beam-beam effects in hadron colliders
  - Beam-beam simulations
  - Effect of IBS and other diffusion mechanisms
  - Second order chromaticity
  - Coherent beam-beam effects
  - Helix and cogging optimization
- High energy electron cooling
  - coupled optics
  - IBS in electron beam

Core Competencies (continue)

- Beam collimation, beam dumps, radiation shielding and their simulations
  - Tevatron, MI, NUMI
    - We are working on Booster collimation now
- Instrumentation: turn-by-turn BPMs, quadrupole BPM, …

Core Competencies (lost opportunities @ Run II)

- Coherent beam-beam effects
  - Hardware was not ready in time
- Anomalous Schottky noise in Accumulator
  - Did not get enough priority

Core Competencies (Ongoing)

- Ionization cooling and its simulation
- Muon collider optics
- Slow extraction in the presence of strong space charge (μ-to-e)
- Integrable optics
- Beam dynamics in Project X linac

Future needs in theory (general statement)

- Theory work is mainly driven by needs of real projects
  - It was like this before and hardly will be changed in the future
  - There were a few exceptions outside Fermilab
    - It can happen here
- It does not look prudent to plan theoretical advances

Future needs in theory and simulations

- PIP
  - Optics, instabilities, radiation shielding, realistic BD simulations
- MI
  - Transition crossing at Project X intensity
  - Instabilities at Project X intensity (including ep)
  - Laser stripping simulations
- g-2 & μ-to-e & LBNE
  - More work to be done. It does not require significant developments in theory or simulation software
  - Targets and radiation shielding
  - New ideas can be helpful
- Project X (without MI & Recycler)
  - Logical continuation of present effort
    - Does not require significant effort in theory or software development
  - Beam part of physics experiments
    - Muons – started; Kaons – should follow; other – straight forward

Future needs in theory and simulations (continue)

- IOTA
  - Simulations of integrable optics
  - Optical stochastic cooling
- Muon collider and Neutrino factory
  - RF breakdown in magnetic field
    - both pressurized and vacuum cavities
  - Logical continuation of present effort
    - ionization cooling, optics, instabilities in proton driver rings
- LARP – orthogonal to the rest of FNAL program
  - Collimation with hollow e-beam and bent crystal
  - Crab cavity simulations
  - Beam-beam simulations
  - Participation in Injector upgrade
- ILC – we are still doing this
  - Lattice optimization, emittance preservation studies
  - Dark current modeling and simulations
    - It can be helpful to Project X

New technologies

- RF
- SC magnets
- Collimation with hollow e-beam

Accelerator theory

- Nonlinear beam dynamics (endless!)
- Coherent instabilities and methods of their suppression
- advanced cooling methods (?)

New concepts

- e- acceleration by proton beam wake-field
- Nonlinear Integrable optics
- Emittance exchange

2012 plans

Based on information from:

Solyak, Valishev, Nagaitsev, Nagaslaev, Thangaraj, Piot

project	D&S FTEs in FY12	D&S FTEs needed in FY12	students
PIP		2	2 Ph.D.
mu2e & g-2		3	
Project-X	7	8	4 grad
ILC		2	
MC & NF	3.5	4	
LARP		1.5	1 grad
ASTA	2	3	
IOTA		2	3 grad
Proton wakefield accelerator		2.5	
Computational Accelerator Physics			
Total		**28**	**2+8**

- this makes ~40 real persons (students not counted!)

(personal opinion by YA)

Do we need a special Beam Dynamics Department (Group)?

Of course we can live without it since people participate in the projects across department lines.

Still, theorists must have an opportunity to work on ideas beyond the frames of officially approved projects and programs, and an Accelerator Theory department is a natural haven for that.

There is a small Theory & Simulations department at APC (5 FTE, 2 GS, 1PD) which is making important (in my view) contributions to:

- MAP
  - new 6D and final cooling schemes
  - new lattice designs for MC wih small β^*
  - new lattice for p-driver accumulation ring
- Project-X
  - Injection painting in RR with 6D space charge
  - LEBT design
- Mu2e, ILC