trip report to PEP-II MAC

with visit to LBNL HIF VNL

Frank Zimmermann

RLC meeting

14.01.2005

PEP-II Machine Advisory Committee met at SLAC from December 13—15,2004

In only three months of operation since the last meeting PEP-II peak luminosity was increased by 10% and the monthly luminosity by 40%.

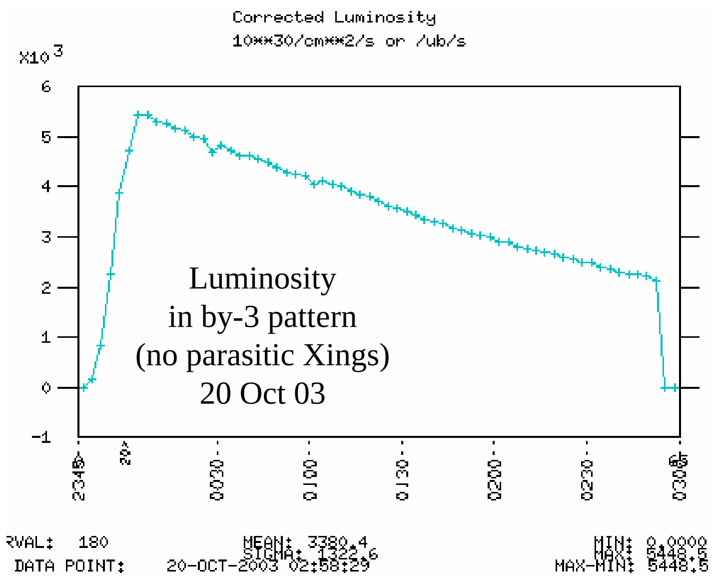
Large increase in monthly luminosity was primarily due to successful "trickle charging" mode of filling and reduction of beam aborts.

An impressive 116 fb^{-1} was delivered during Run 4.

A few slides from beam-beam presentations and from my summary on beam dynamics follow.

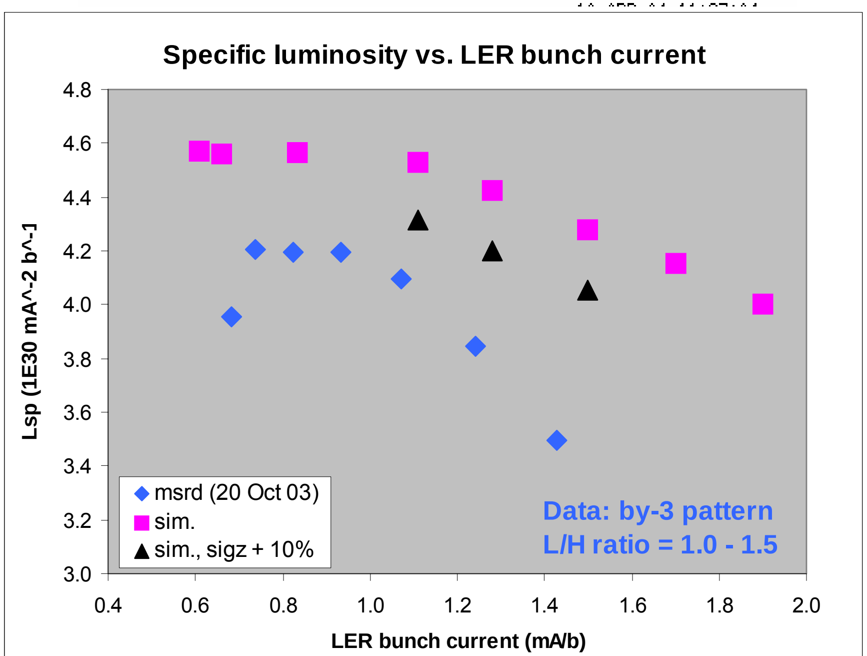
Comparison of measured luminosity with b-b simulations

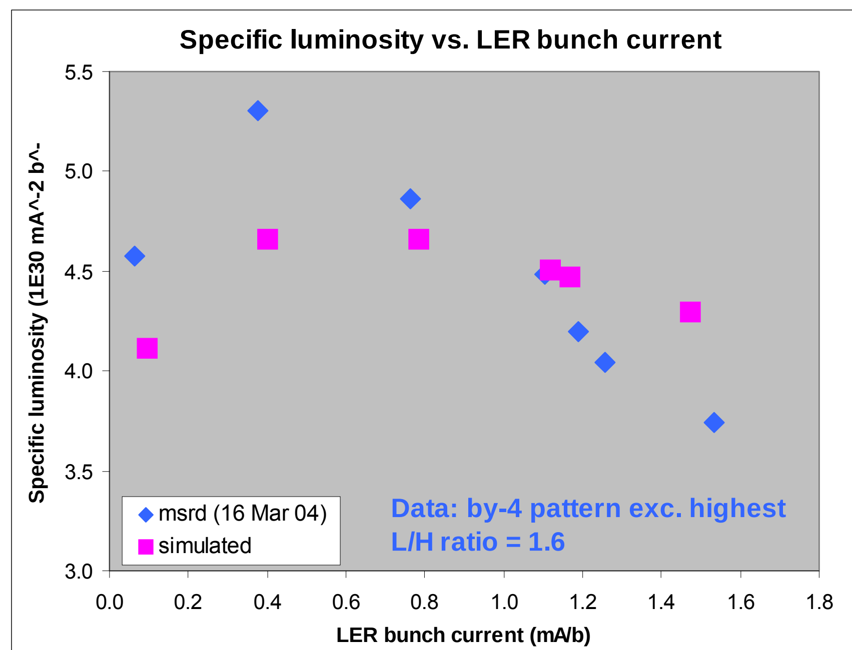
Simulations:
Y. Cai / I. Narsky



Beam-current dependence of L_{sp}

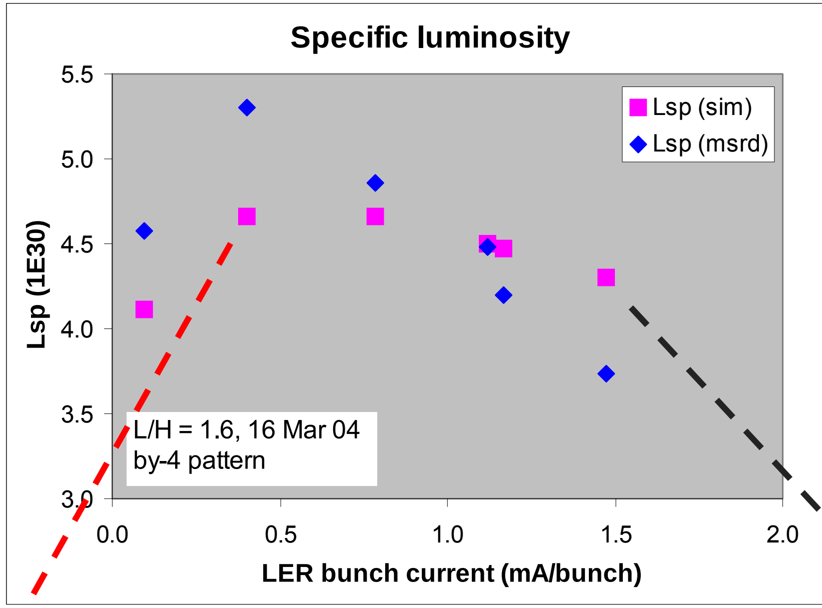
- **Absolute scale: 15-20 % agreement**
- **Current-dependence steeper in data**
- **Uncertainties:**
  - **assumed values of β, ε, σ_z**
  - **lattice non-linearities (not incl'd)**





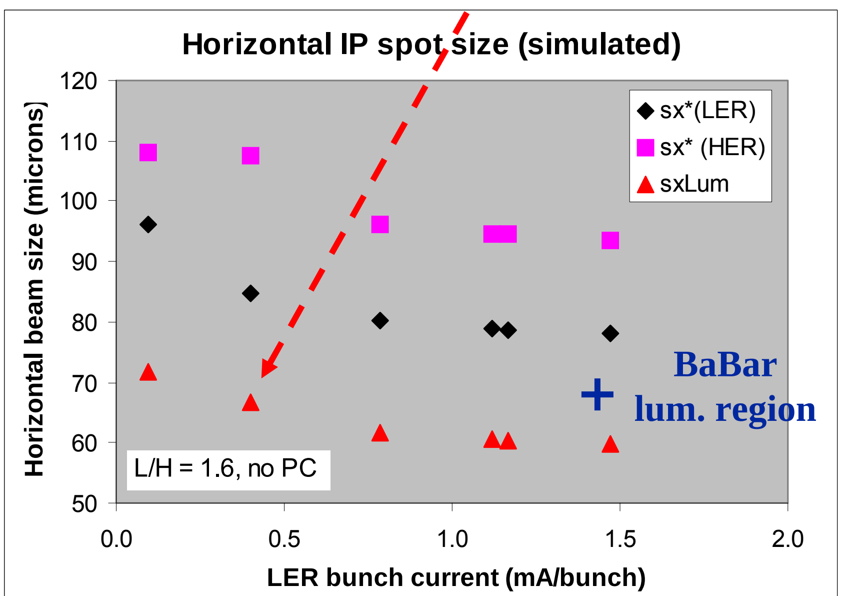
Beam-beam simulations: L_{sp} & IP spot sizes

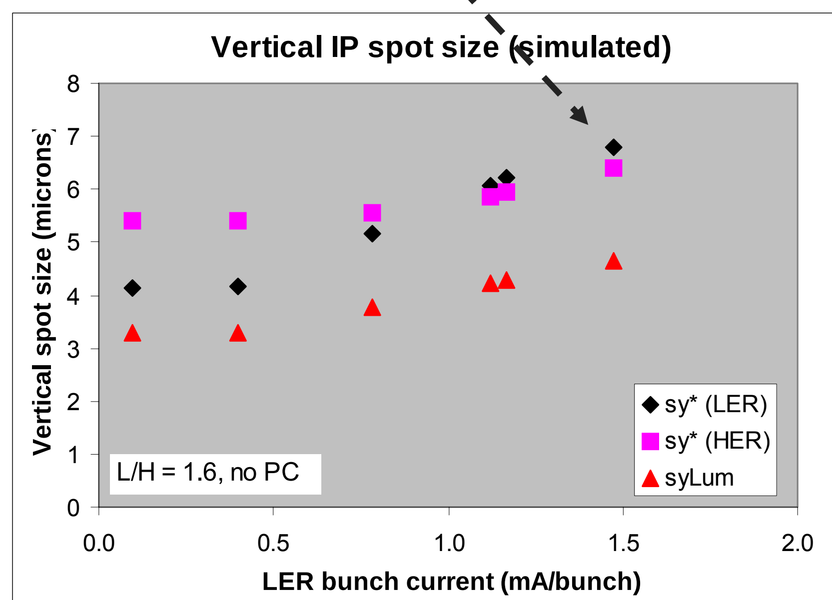
Simulations: I. Narsky
Parameter set: 2003



Dynamic β

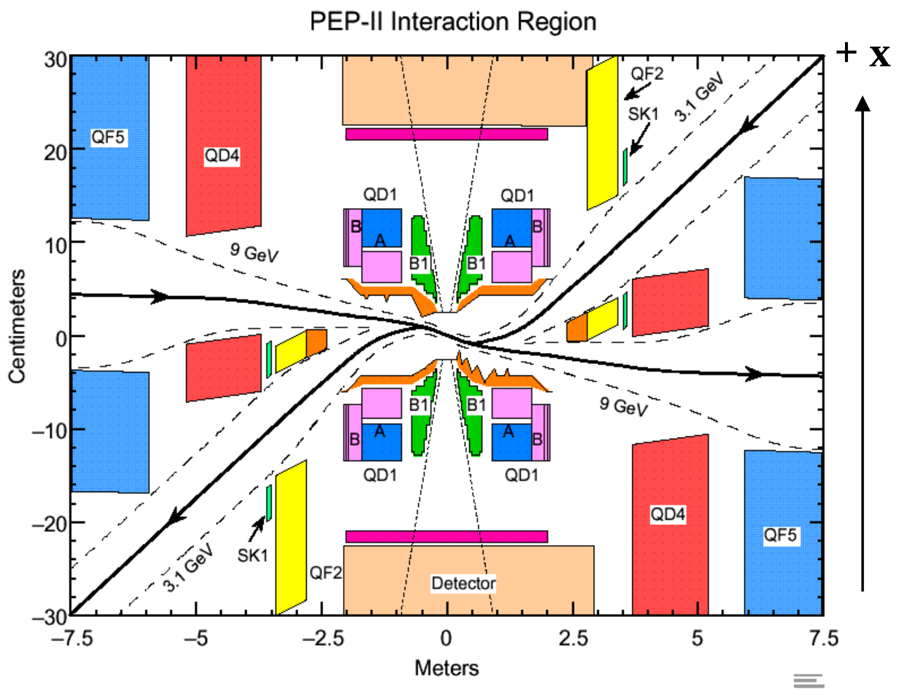
Vertical blowup (LER ??)





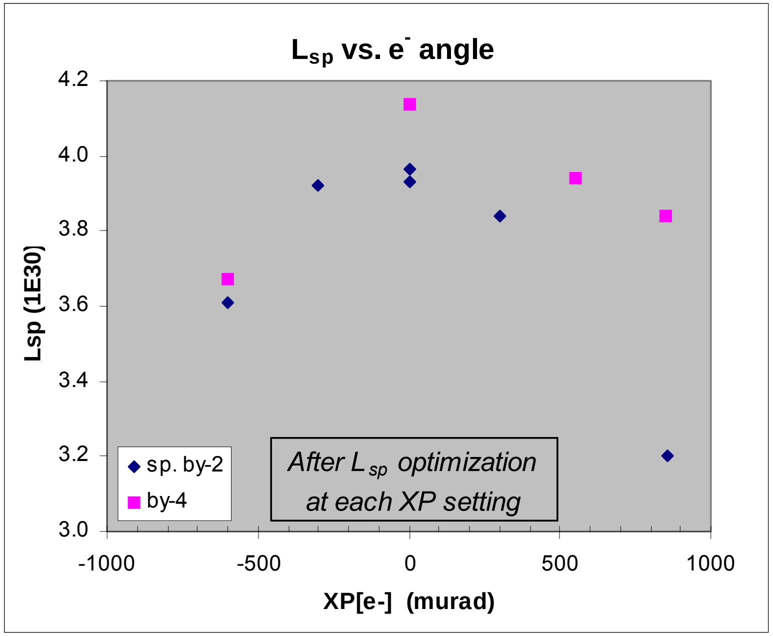
Beam-beam sensitivity to parasitic crossings & Xing angle

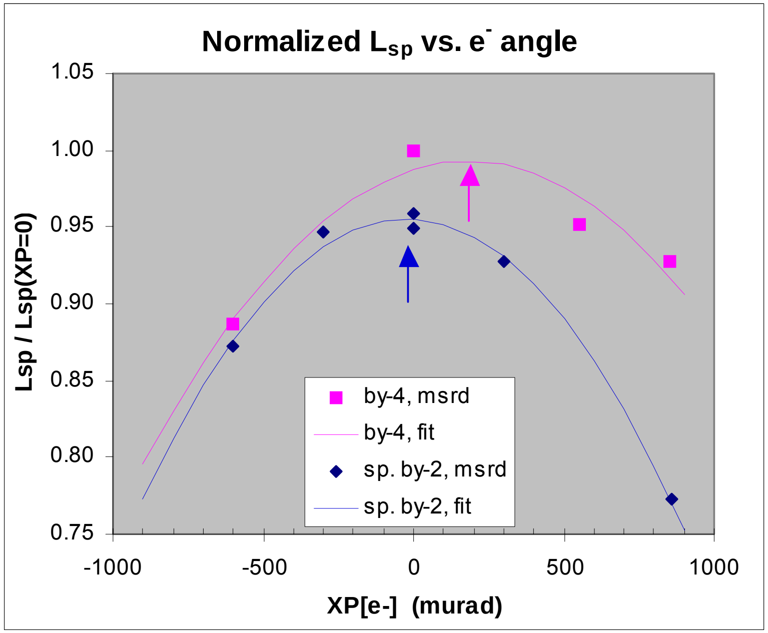
- **Goal: measure the luminosity degradation associated with**
  - **parasitic crossings**
  - **horizontal crossing angle**
- **Principle**
  - **by-2 pattern: compare L_{sp} at minimum, nominal & maximum parasitic-xing separation (= e$^-$ x-angle) <u>with full L optimization</u> at each setting**
    ➔ sensitivity to Xing angle + parasitic crossings
  - **by-4 pattern: compare L_{sp} at minimum, 0, & maximum (achievable) Xing angles (= e$^-$ x-angle) <u>with full L optimization</u> at each setting**
    ➔ sensitivity to Xing angle only
  - **HEB only: measure impact (if any) of e$^-$ x-angle on e$^-$ beam properties**



- **ΔX @ parasitic crossings**
  - **XP(e-) more +ve ⇔ ΔX (PC) ↓**
    - **nominal:**
      ΔX(PC) = 3.22 mm @ z = +/- 63 cm
    - **XP_{max}(e$^-$) = - 0.60 (+ 0.85) mrad**
      ⇔ ΔX → 3.6 (2.7) mm

L_{sp} dependence on Xing angle & PC separation: experimental summary



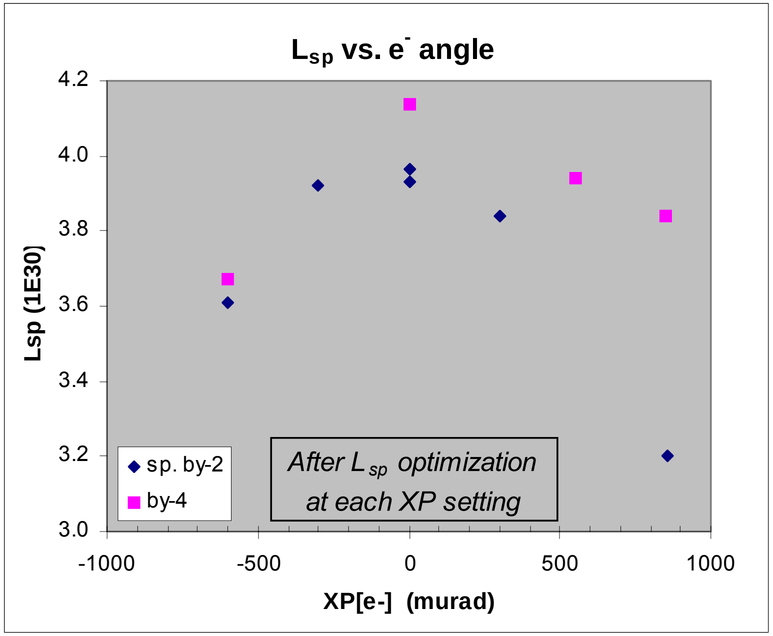


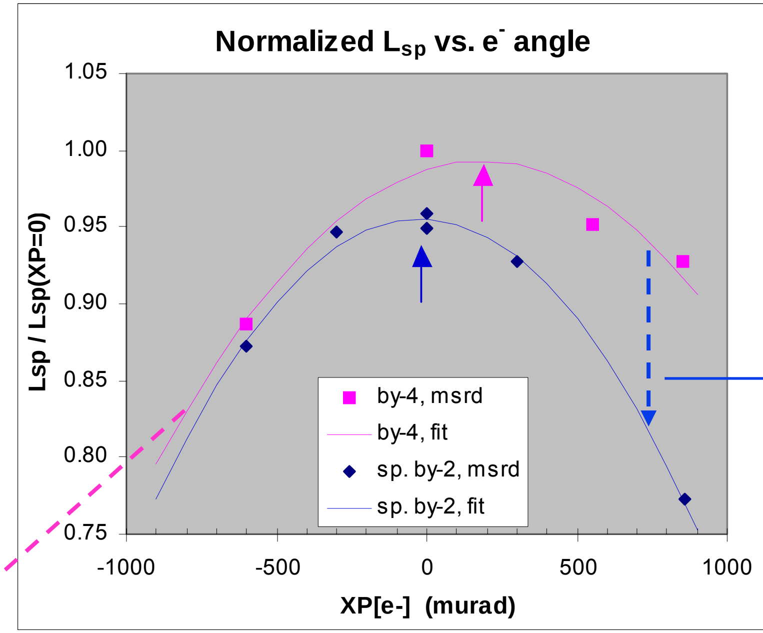
- **Without parasitic Xings (by-4) L_{sp} exhibits a parabolic dependence on XP(e-)**
- **With parasitic Xings (by-2)**
  - **the peak L_{sp} is ~ 5% lower (@ nominal PC separation) than in the by-4 pattern**
  - **the larger XP(e-), the steeper the L_{sp} degradation**

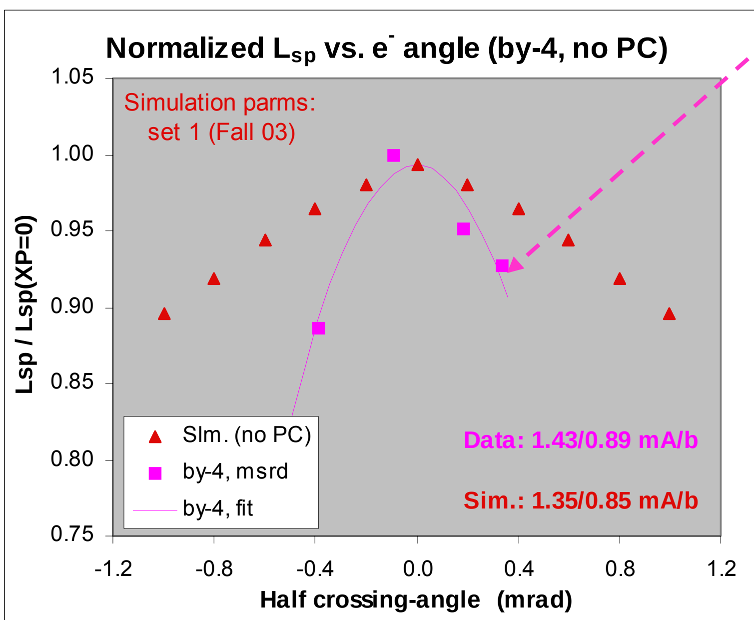
- **The optimum e^- x angle is ~ 0.2 mrad more -ve in the by-2 pattern (→ weaker PC effects)**
- **This suggests that in the presence of parasitic Xings, the optimum e^- angle is a compromise between Xing-angle & PC-induced luminosity degradation**

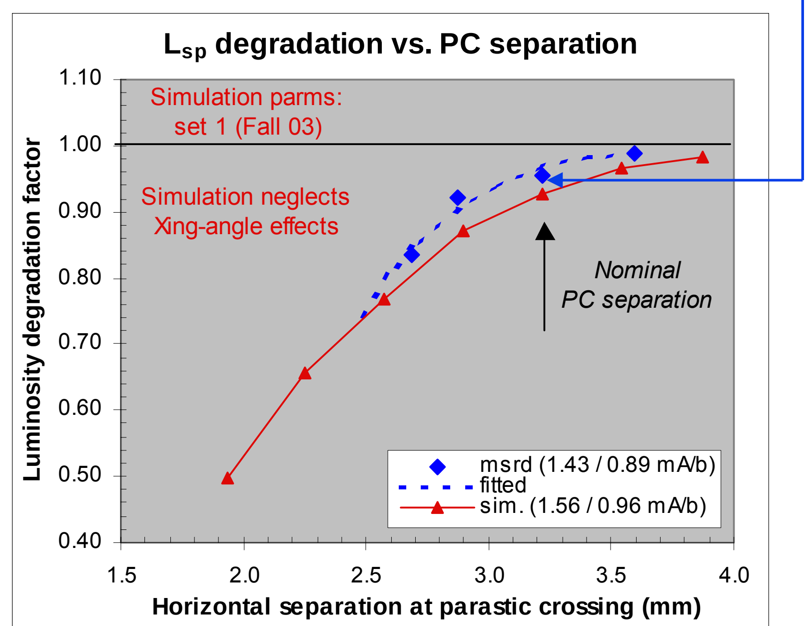
L_{sp} dependence on Xing angle & ΔX_{PC}: data vs. simulations

Simulations: Y. Cai
Parm. set: 2003



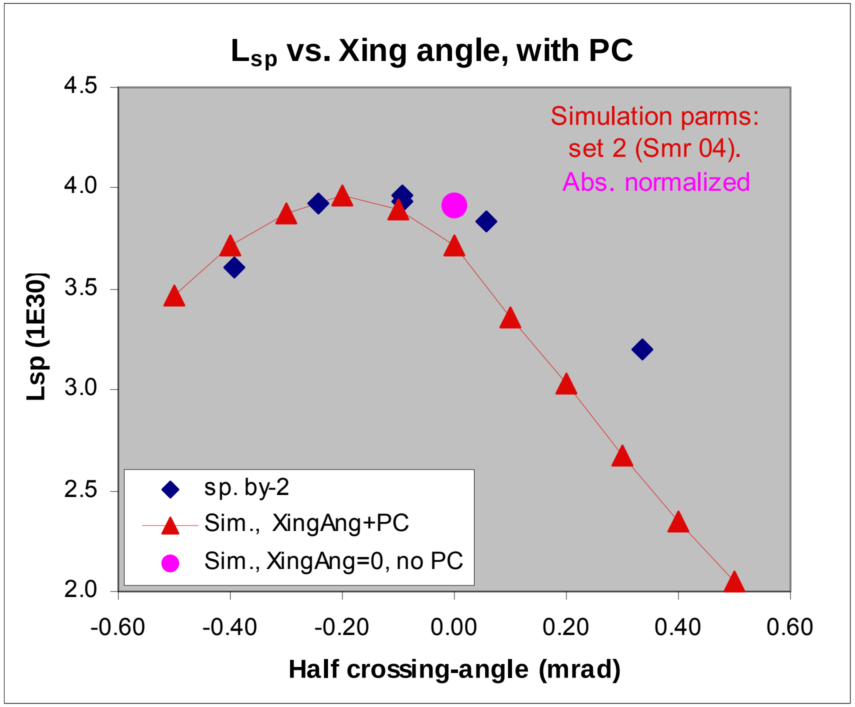


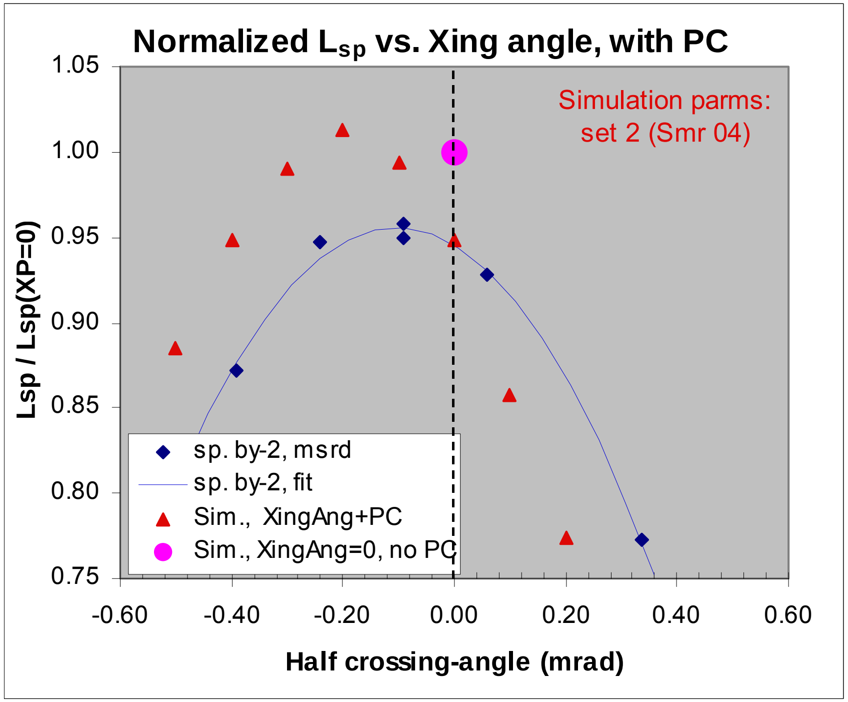




Y. Cai
Parm. set: 2004

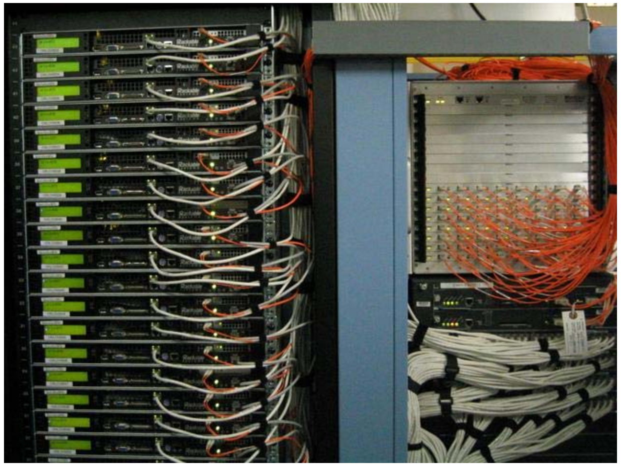
Combined effect of Xing angle & parasitic crossings





- **The simulation confirms that in the presence of parasitic crossings, introducing a small –ve Xing angle improves the luminosity**
  - **The optimum Xing angle is slightly larger in the simulation (-0.2 mrad) than in the data (-0.1 mrad) – consistent with the (previously) simulated Xing-angle dependence without PC's**
  - **In the simulation, the best L_{sp} achieved with parasitic Xings is 3% larger than without PC's; in the data, it is 4% smaller with PC's.**

SLAC PC FARM



- Linux cluster interconnected with 64-bit PCI-X (PCIXD, Lanai X) Myrinet 2000.
- All nodes are 2.6GHz dual-Xeon Pentium IV Rackable systems running RHEL 3.0.
- These are 128 of our 384 node Linux cluster.
- 20% faster than seaborg at NERSC for beam-beam simulation using 32 processors.
- We own 25% of the cluster.

PEP-II Parasitic Collisions
May 21, 2004

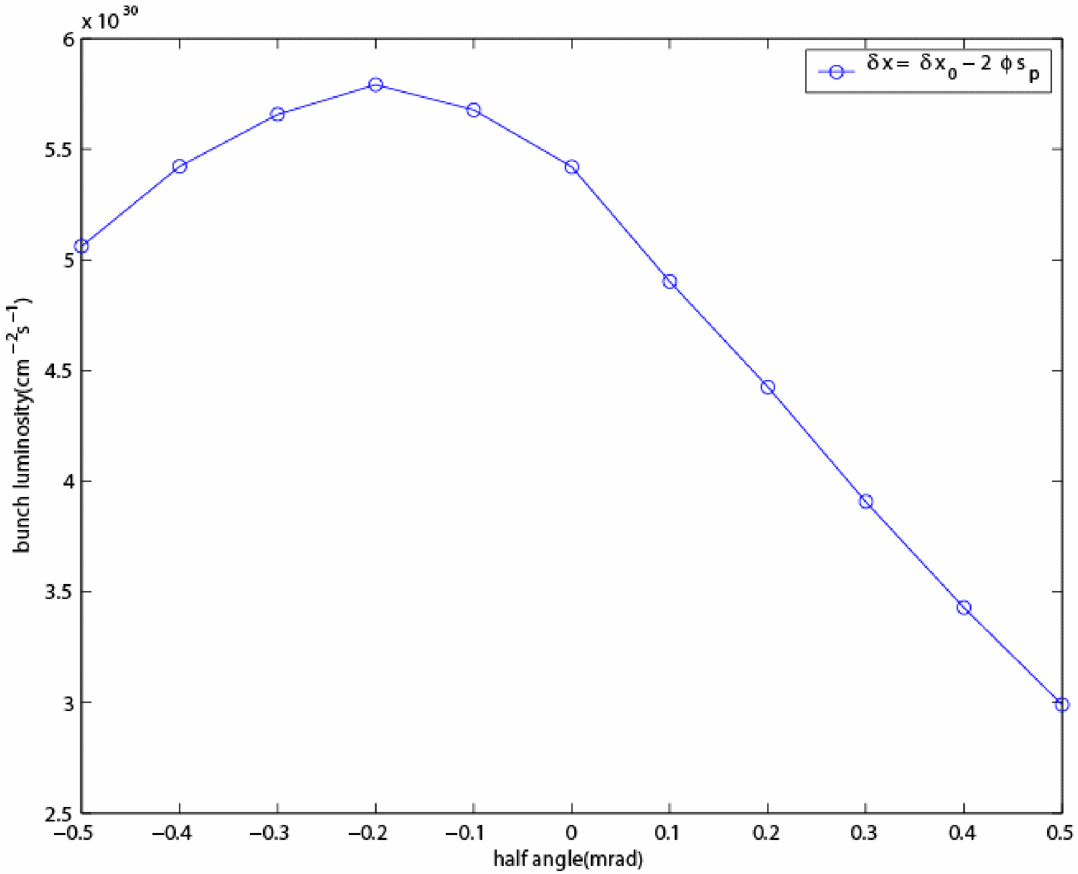
crossing[m]	δx[mm]	# of σ(e+)	# of σ(e-)
0.32	0.1	0.84	0.51
0.63	3.22	17.38	10.61
0.95	9.69	36.87	22.51
1.26	17.78	52.16	31.85
1.58	28.86	68.28	41.69
1.89	43.6	86.75	52.97
2.21	60.53	103.38	63.13
2.52	77.61	116.52	71.15
2.84	94.73	126.41	77.19
3.15	112.31	135.28	82.61

Tune Shift Due to Parasitic Crossings

	LER(e+)	HER(e-)
Horizontal	-0.000958	-0.000523
Vertical	0.0233(0.026)	0.0123(0.014)

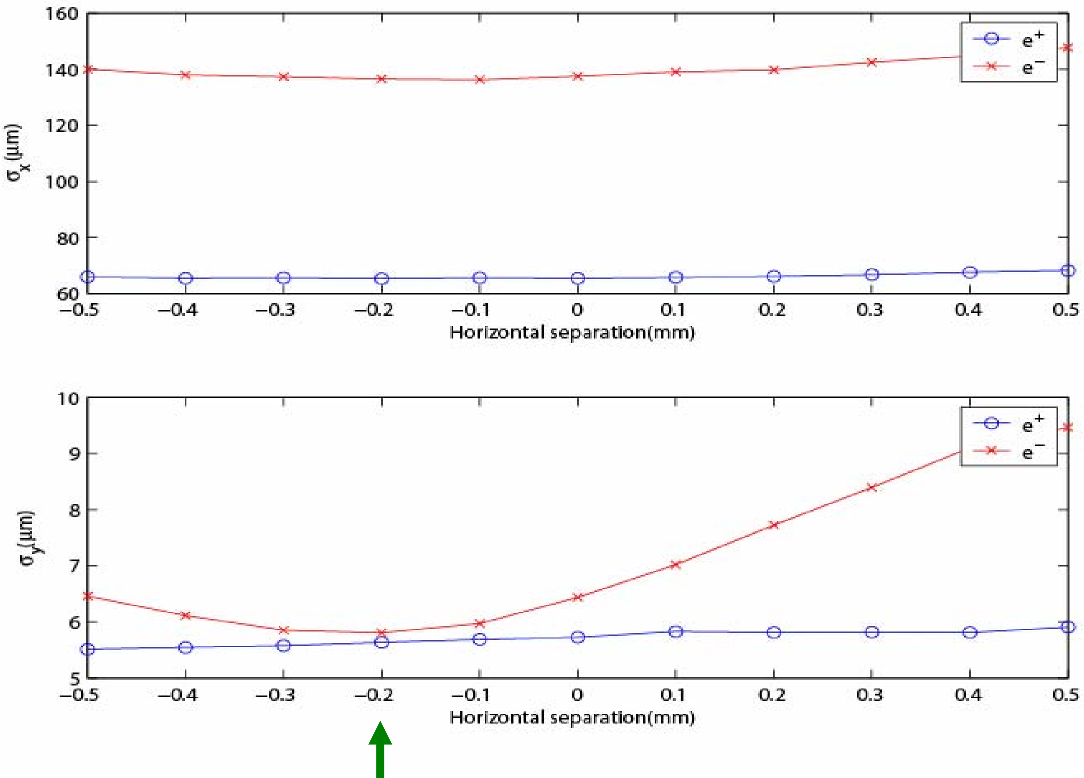
Two nearest parasitic collisions are included in the calculation. Single parasitic collision contributes half of the value.

Parasitic Collisions and Crossing Angle at PEP-II



Compared with the measured luminosity: 5.61 10^{30} $cm^{-2}s^{-1}$, the simulation result with -0.2mrad is closer.

Trade off between Parasitic Collisions and Crossing Angle



Best luminosity achieved when the vertical beam sizes are small and matched.

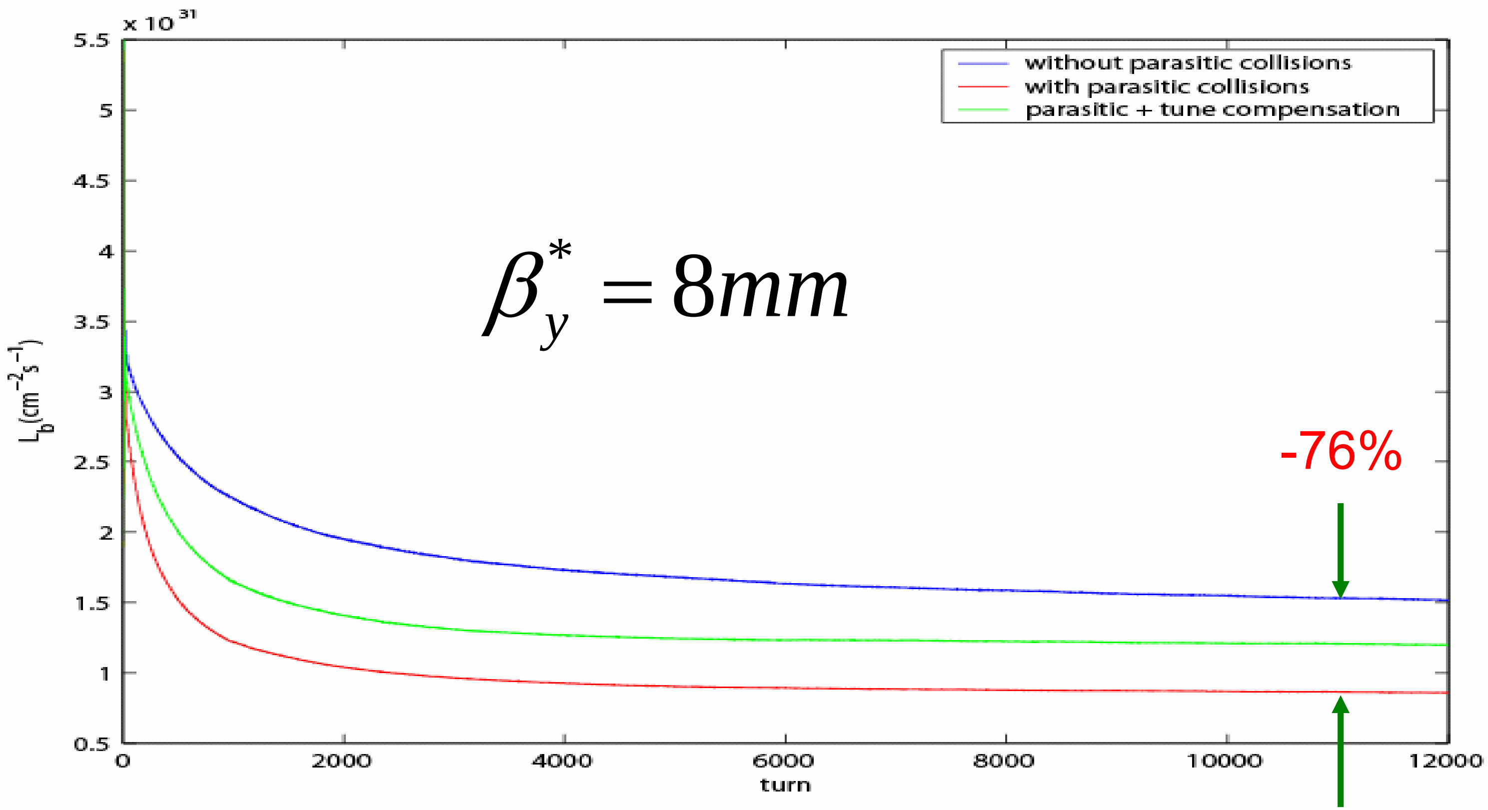
Parameters	Description(2007, Seeman)	LER(e^+)	HER(e^-)
E(Gev)	beam energy	3.1	9.0
N	bunch population	12.03×10^{10} (2.62mA)	5.88×10^{10} (1.28mA)
β_x^*(cm)	beta x at the IP	28	28.0
β_y^*(cm)	beta y at the IP	0.8	0.8
ε_x(nm-rad)	emittance x	60.0	60.0
ε_y(nm-rad)	emittance y	1.0	1.0
ν_x	x tune	0.5162	0.5203
ν_y	y tune	0.5639	0.6223
ν_s	synchrotron tune	0.032	0.055
σ_z(cm)	bunch length	0.9	0.9
σ_p	energy spread	6.5×10^{-4}	6.1×10^{-4}
τ_t(turn)	transverse damping time	9800	5030
τ_l(turn)	longitudinal damping time	4800	2573

Tune Shift Due to Parasitic Crossings Year of 2007

	LER(e+)	HER(e-)
Horizontal	-0.00139	-0.00098
Vertical	0.0406	0.0286

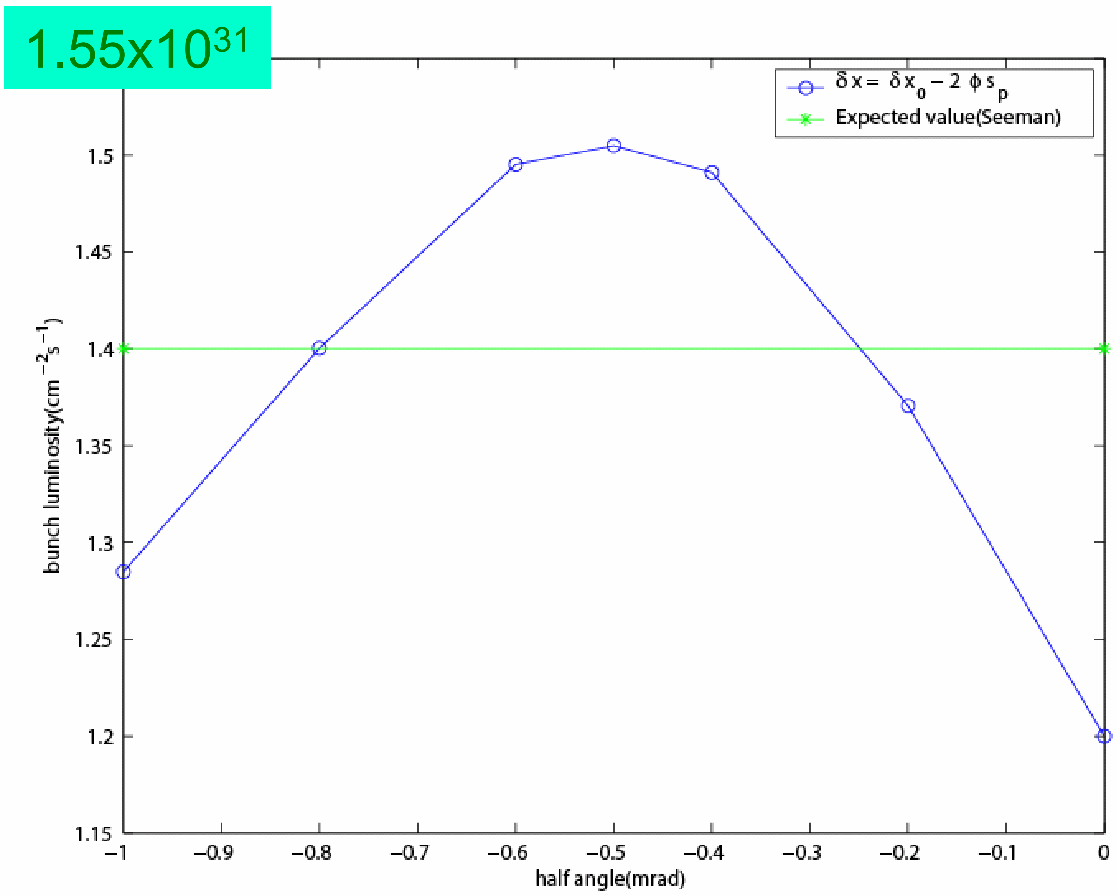
Two nearest parasitic collisions are included in the calculation. Single parasitic collision contributes half of the value. Values are nearly doubled compared to ones in 2004.

Luminosity Degradation due to Parasitic Collisions (Year of 2007)



Without parasitic collisions, the total luminosity = 1715x1.51x10^{31} cm^{-2}s^{-1} = 2.59x10^{34}cm^{-2}s^{-1} compared to Seeman's expected value: 2.4x10^{34}cm^{-2}s^{-1}.

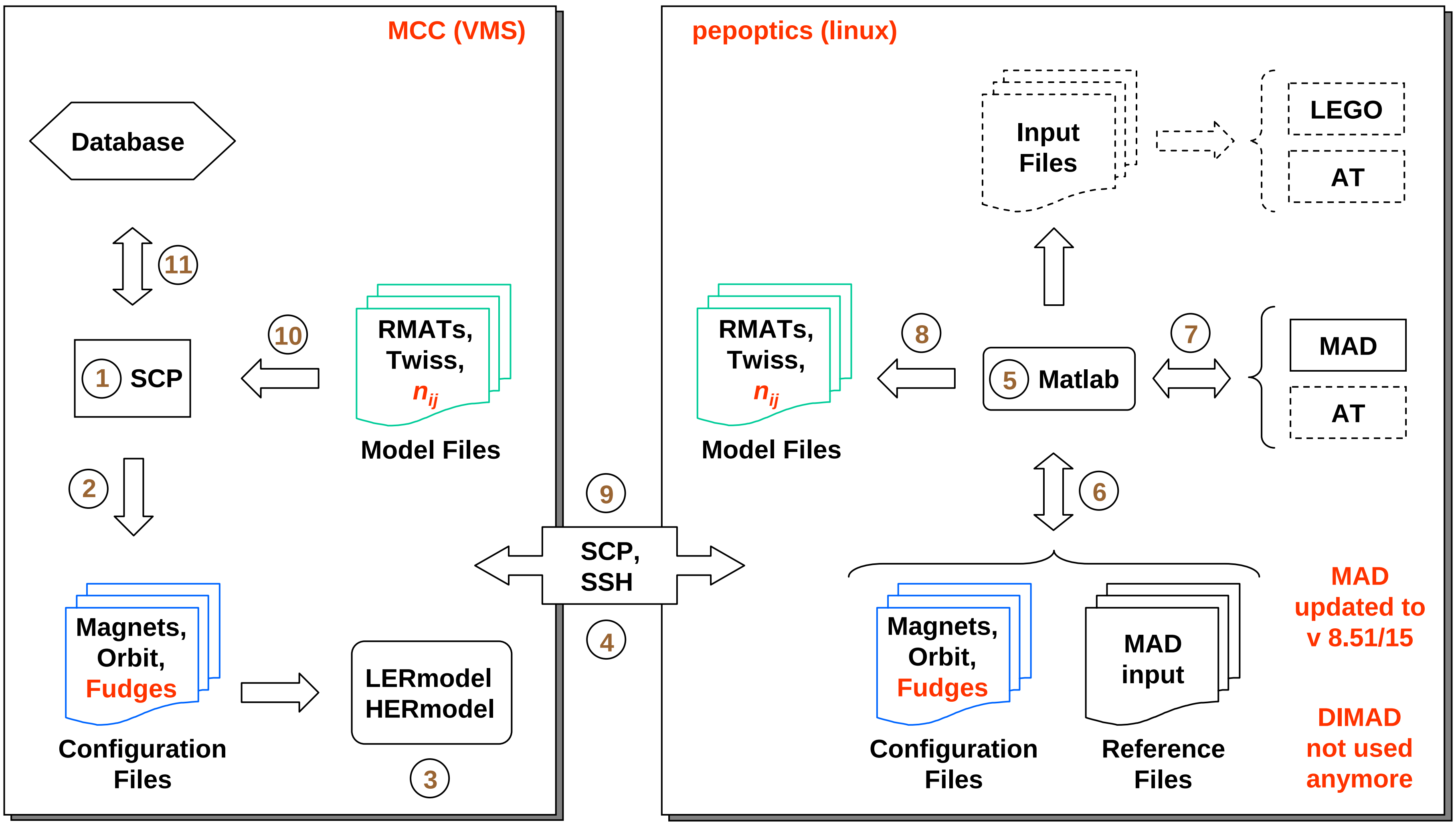
Tune and Crossing Angle Compensation for Parasitic Collisions



Expected luminosity can be achieved with tune compensation and small crossing angle (-2x0.5mrad).

δx = 3.85 mm at ϕ = -0.5mrad (3.22mm at ϕ =0) which is about 12 σ_x separation.

PEP Online Modeling: Process



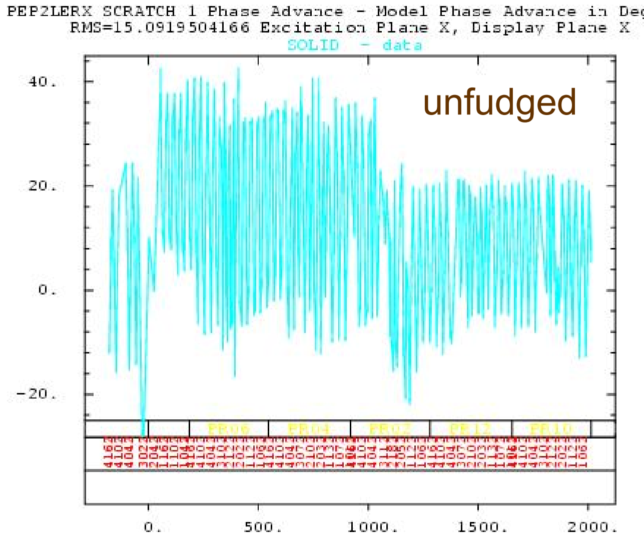
Lattice parameters in highly coupled systems

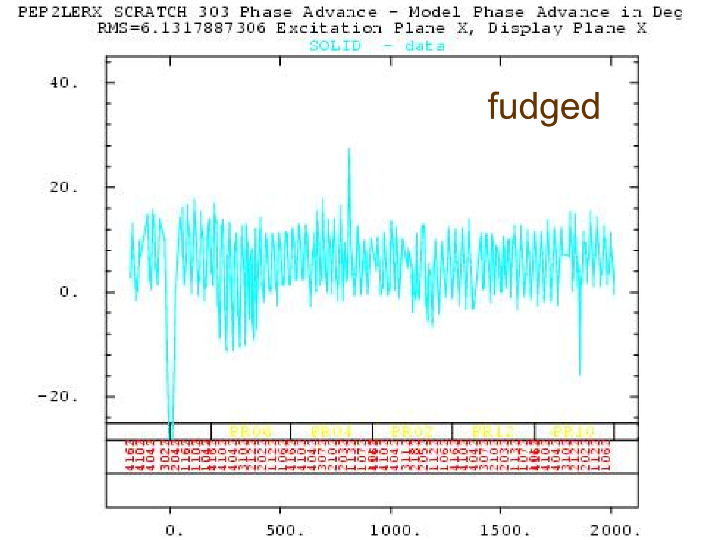
- MAD (v 8.51/15-SLAC) has been modified to output “effective” transfer matrices (first order expansion about the closed orbit; includes “feed down” effects from sextupoles)
- Andy Wolski’s normal form analysis[1] is used to extract coupled lattice parameters from the transfer matrices
- 10 coupled lattice parameters (μ, β, α, η, η' for modes 1 & 2) and 8 elements of the normalizing transformation (n_{13}, n_{14}, n_{23}, n_{24}, n_{31}, n_{32}, n_{41}, n_{42}) at each element are returned to be loaded into the MCC database

[1]See http://www-library.lbl.gov/docs/LBNL/547/74/PDF/LBNL-54774.pdf

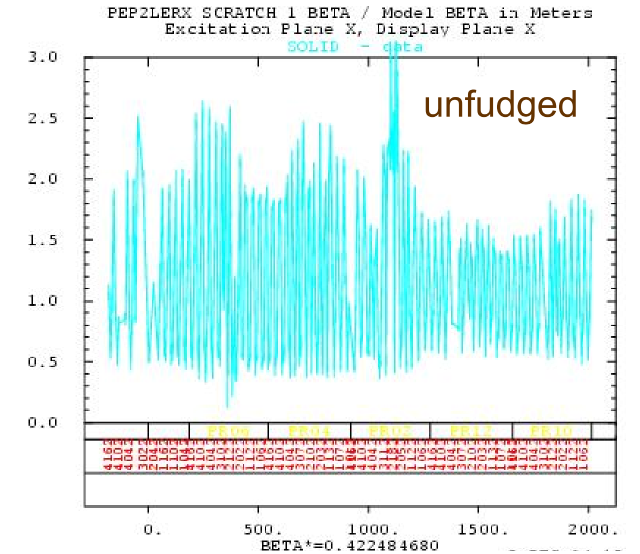
ORM-derived fudge factors: LER (2)

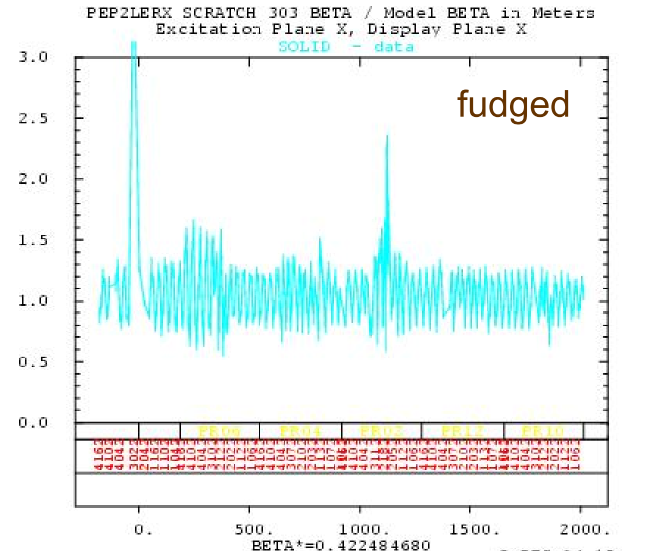
$\phi_X(meas) - \phi_X(model)$





$$\frac{\beta_X(calc)}{\beta_X(model)}$$

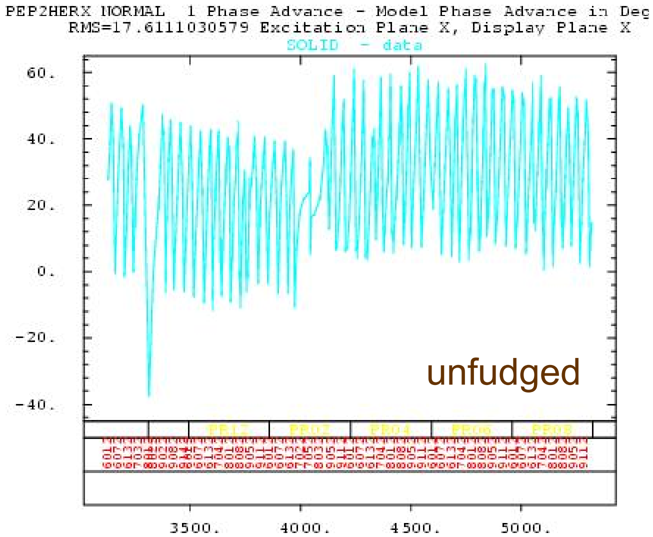


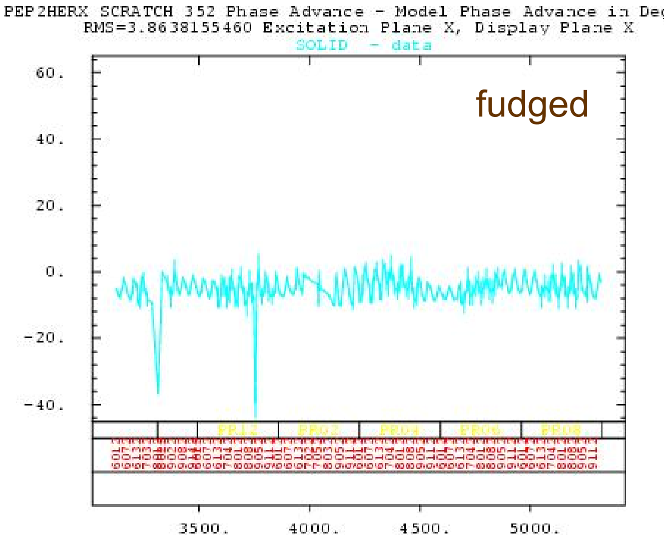


M. Woodley

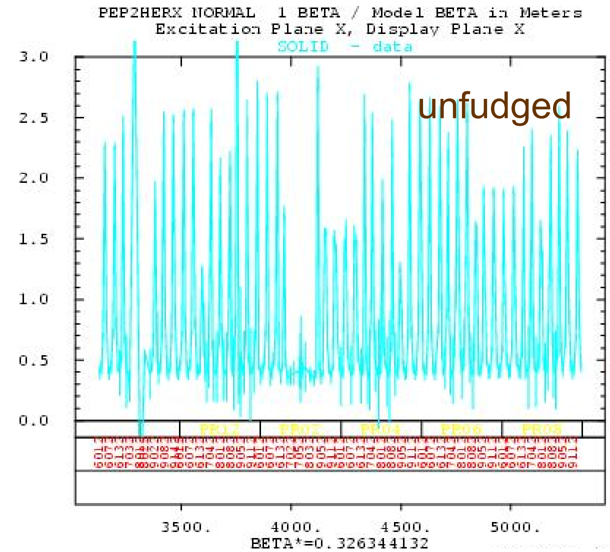
ORM-derived fudge factors: HER (2)

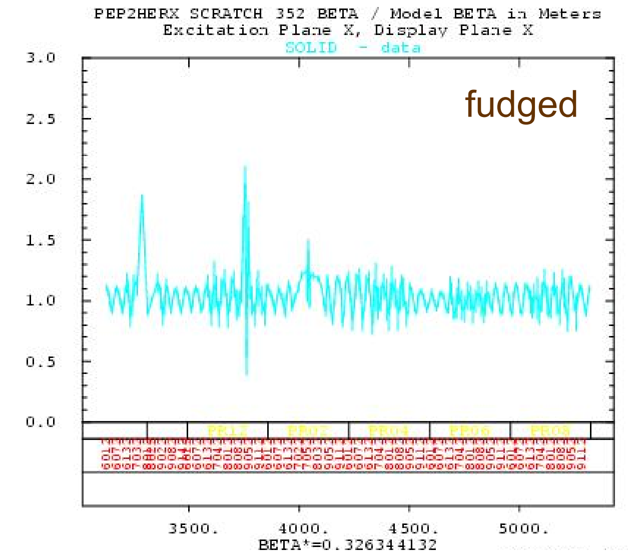
$\phi_x(meas) - \phi_x(model)$





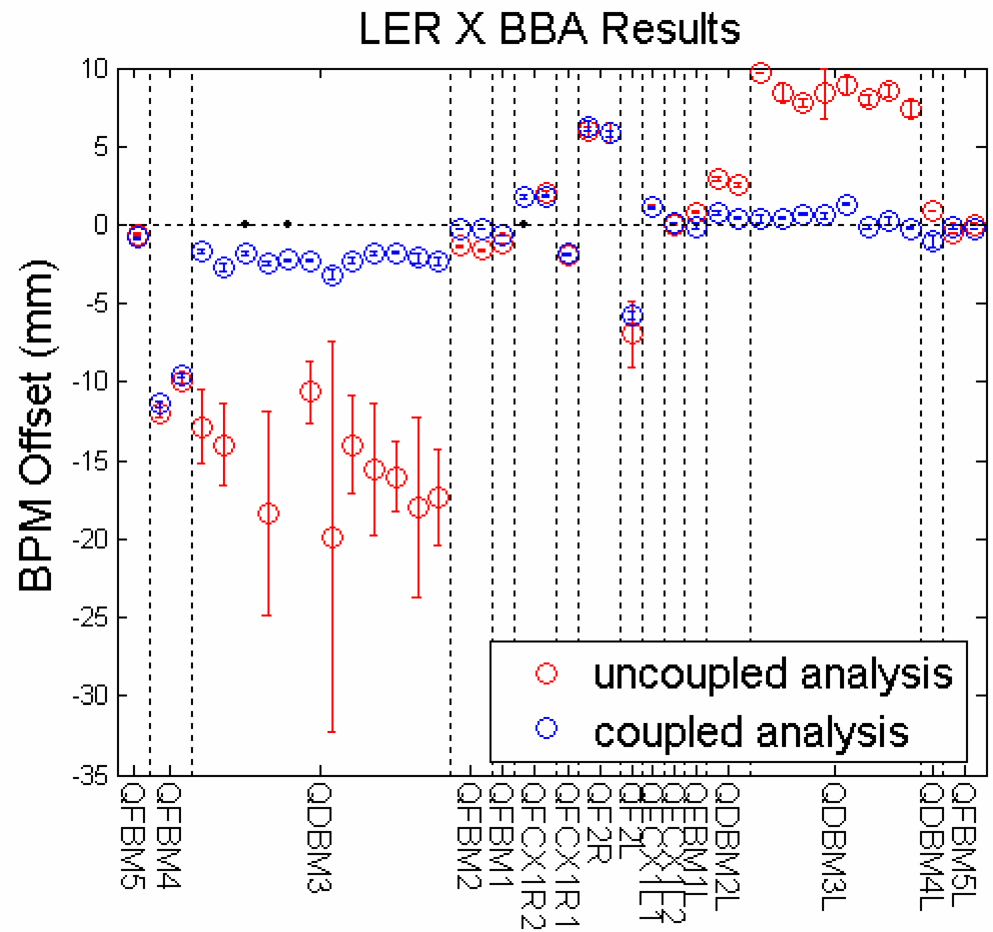
$\dfrac{\beta_x(calc)}{\beta_x(model)}$





M. Woodley

LER BPM X Offsets: Then and Now



specific luminosity

- unchanged over the last year
- measured luminosity reproduced within +/-10% in beam-beam simulations taking low-current emittances as input
- orthogonal optics tuning knobs for luminosity optimization may gain ~10% in luminosity, making use of improved optics model
- with better optics correction, more optimal region in tune space may become accessible (e.g., closer to half integer)
- simulations suggest lowering ε_y is another key to increasing $\xi_{x,y}$

reducing vertical emittance

- likely side-benefit of correcting large beta beating using fudge factors from ORM
- try to apply *dispersion-free steering* (extremely successful in SLC & LEP)
- confirm ultimate limits from vertical bends, solenoid, skew quadrupoles, opening angle,…
- study possibility to *weaken vertical bends*

beam-beam simulations

- closely reproduce present observations
- recommend intensive simulation campaign exploiting enhanced computing power
- simulate & compare luminosity performance for different IR upgrade scenarios
- tune survey, optimization of emittances and β_x^*'s, dependence on bunch length
- include nonlinear map for ring with wiggler
- brute-force simulation of beam tails & determine scaling of beam-beam background with ξ
- could *octupoles* control tails, as at DAFNE?
- study possible benefit of *actively compensating parasitic collisions (e.g., wire)*, as for LHC

beam-beam experiments

- beam studies revealed sensitivity to θ_c & d_{sep}
- parasitic collisions presently reduce luminosity by ~5%, for 20% less separation it is ~20%, close to an edge
- ~10% luminosity loss for θ_c=0.5 mrad (2x more sensitive than simulation)
- what are minimum required separation and maximum allowed θ_c for 2007 parameters (2x higher charge, larger emittance)?
- explore effect of parasitic collisions & θ_c for 2007, e.g., with wiggler on and increased bunch charge in mini-train

optics model, ORM & BBA

- unification made good progress; MAD now used for most applications
- ORM analysis should include dispersion
- compare model dispersion with measurement
- compare MIA & ORM results
- large fudge factors in some cases (artifact?)
- fit ORM data for orbit offsets at sextupoles; possibly realign magnets with large offsets
- ORM analysis could be speeded up, e.g., by exciting few correctors per plane, as KEKB (faster data acquisition & analysis)
- check that nonlinear terms (from sextupoles) do not affect quality of BBA analysis

HIGH-ENERGY PHYSICS

Report Slams SLAC's Safety Practices

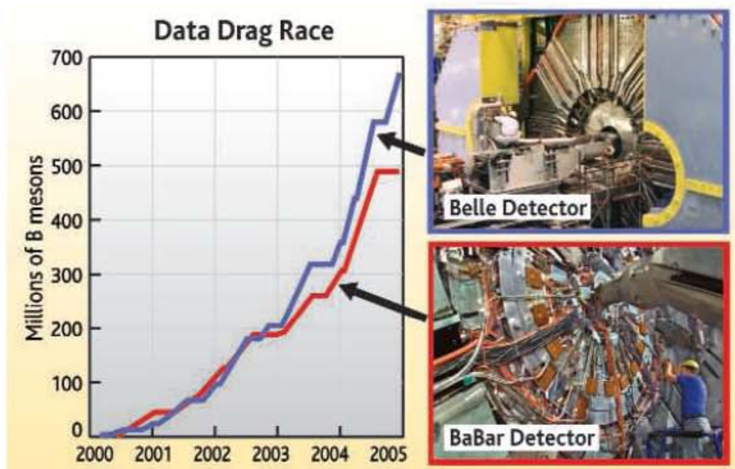
Management at the Stanford Linear Accelerator Center (SLAC) routinely disregarded safety regulations in order to keep the scientific results coming. That's the conclusion of a Department of Energy (DOE) investigation into a serious electrical accident this fall at DOE's high-energy physics facility in Menlo Park, California (*Science*, 29 October, p. 788). The accident has led to the indefinite shutdown of the lab's accelerators, causing SLAC to lose ground to a Japanese laboratory engaged in the same type of research.

Released on 15 December, the DOE accident report blasts SLAC management for fostering a culture in which "unsafe conditions have become a part of the everyday way of doing business." SLAC spokesperson Neil Calder says the lab will take its comeuppance and do what's needed to fix the problems. "The report is the report," says Calder. "We respect that, and now we can use [the report] as a means of going ahead" to improve safety.

The 11 October accident occurred when an electrician tried to install a circuit breaker in a 480-volt power panel without shutting off the electricity, a practice known as hot work. The action presumably was a timesaving step. A short caused an explosion that set the electrician's clothes on fire. He suffered severe burns over 50% of his body and was hospitalized for several weeks. The accident automatically triggered the inquiry by DOE's Office of Environment, Safety, and Health. The lab's flagship PEP-II particle collider and other accelerators had been taken down for repairs and improvements in July but were scheduled to resume operations in mid-October.

Investigators found plenty of blame to go around. There was no justification for installing the breaker with the power on, they concluded, and the SLAC field supervisor who ordered the work had not obtained the required hot work permit. The electrician, a contractor, lacked the face shield, hood, fire-resistant clothing, and insulated tools that would have protected him. Moreover, according to the report, local DOE officials had not been pressing the lab to follow its own safety regulations.

But investigators directed their harshest criticism at laboratory management. "It appears that SLAC has consistently placed operations ahead of safety," the report says. Investigators found that hot work was routinely performed without permits, and that management allowed such breaches of protocol in order to keep the lab's accelerators running and the data flowing. "SLAC's emphasis on the scientific mission as a means to secure funding from the [DOE] Office of Science and compete with other laboratories reached [the field supervisor's] level as direction to 'just get the job done,' " the report states.



Busy as Bs. SLAC's BaBar detector is falling behind its Japanese counterpart in spotting B mesons.

SLAC's main competitor is the Japanese particle physics laboratory KEK in Tsukuba. Like SLAC, KEK has a collider designed to produce fleeting particles called B mesons, which may hold the key to understanding the subtle differences between matter and antimatter. In recent years KEK's collider has pumped out significantly more B mesons than SLAC's (see graph). SLAC researchers are still competitive, says Sheldon Stone, a physicist at Syracuse University in New York, but "it certainly doesn't help that they're shut down."

SLAC and local DOE officials must draw up a corrective action plan, to be submitted to DOE by early February. The lab's accelerators won't start up until DOE is sure that the lab can operate safely, says Milton Johnson, chief operating officer for DOE's Office of Science. "We'll take whatever time is necessary to assure that the employees and workers are safe," he says. In the meantime, Stanford University, which runs the lab for DOE, has convened its own panel of experts to examine lab safety.

–ADRIAN CHO

CREDITS: PHOTOS (TOP TO BOTTOM) COURTESY OF KEK; COURTESY OF LAWRENCE BERKELEY NATIONAL LABORATORY; GRAPH SOURCE: SLAC AND KEK

Published by AAAS

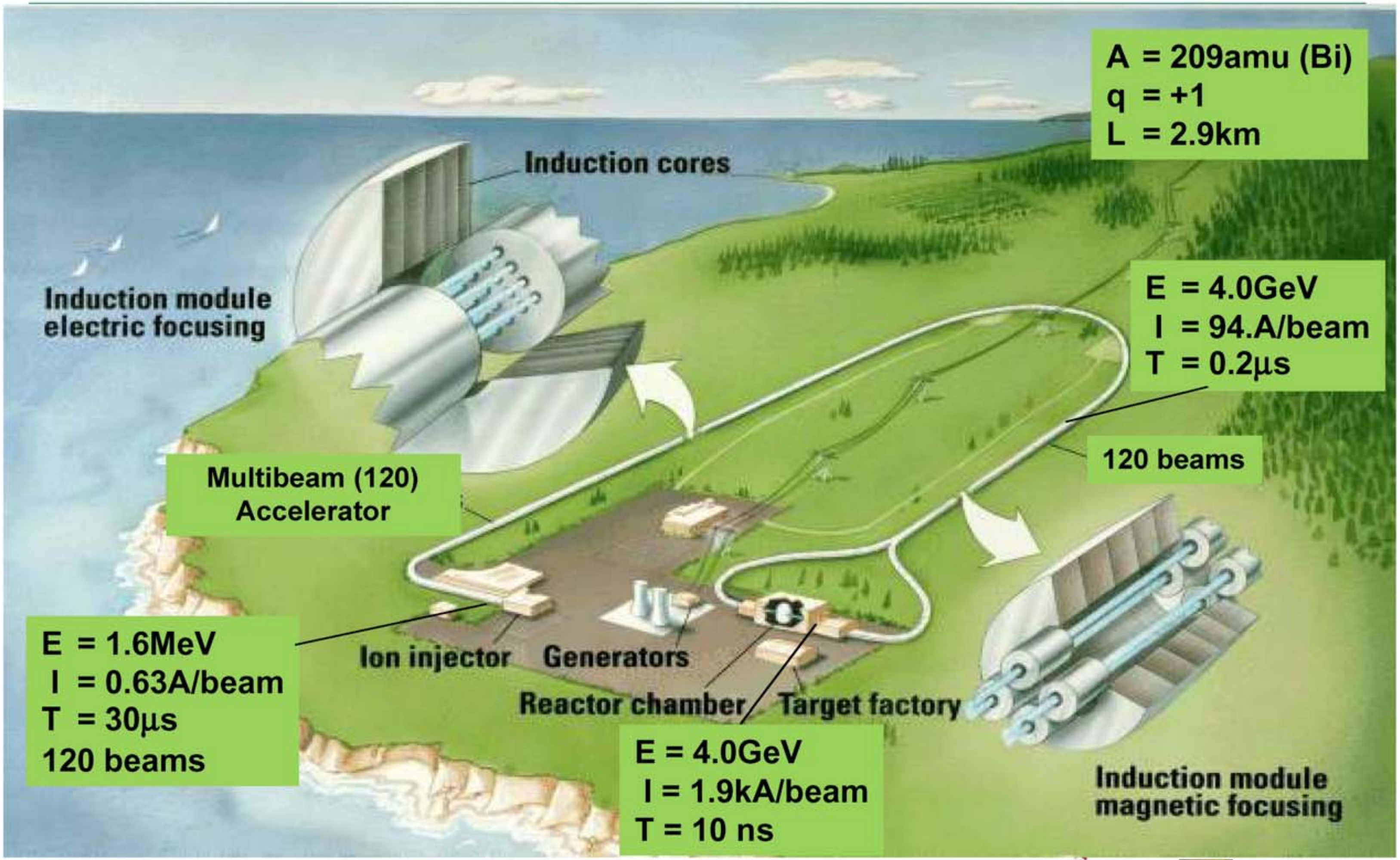
HIF

Heavy Ion Fusion

Virtual National Laboratory

The US Heavy-Ion Fusion program has the long-term goal of developing inertial-confinement fusion as an affordable and environmentally attractive source of electrical power. Toward this goal, the near-term HIF research at US National Laboratories uses **reduced-scale experiments and state-of-the-art numerical simulations to understand the injection, transport, and focusing of the high-current beams** needed for this approach to fusion energy. Since 1998, this research has been co-ordinated in the US by the Heavy-Ion Fusion Virtual National Laboratory.

HIF Power Plant Driver – Many high-current beams needed to deliver several Mjoules to target with GeV ions



VNL Research Activities

Current and Planned Experiments

High-Current Experiment (HCX)

investigating the transport of a high-current ion beam through electric and magnetic quadrupoles

Neutralized-Transport Experiment (NTX)

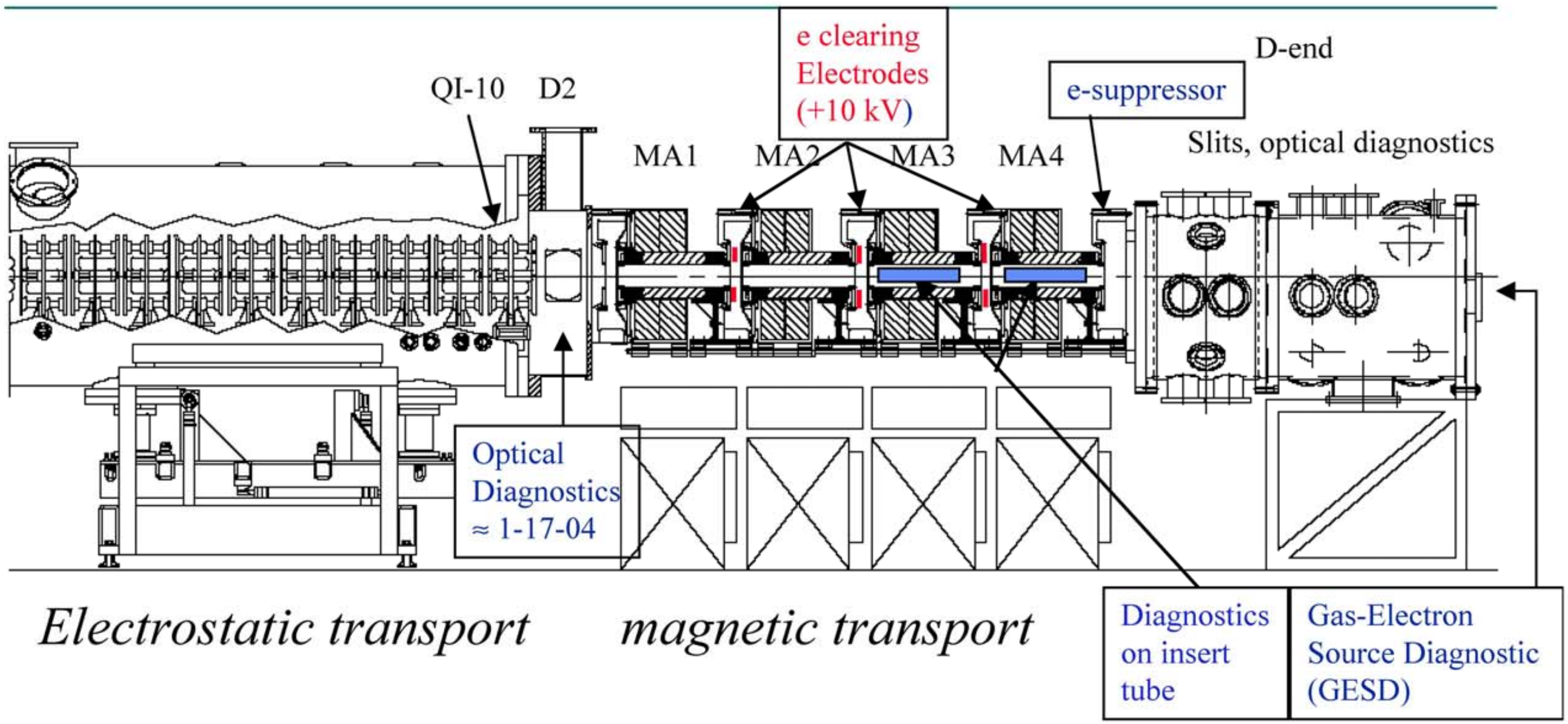
modeling aspects of the transport of a space-charge-dominated ion beam in a fusion chamber

HIF Computer Codes

The Virtual National Laboratory for Heavy Ion Fusion has developed a suite of computer codes for modeling beam injection, acceleration, transport, and focusing in induction accelerators and transport in fusion chamber. These codes can describe beams at differing levels of detail, from zero-dimensional systems equations to 3-D electromagnetic particle-in-cell (PIC) models.
Goal is an ***integrated, detailed, and benchmarked source-to target beam simulation capability.***

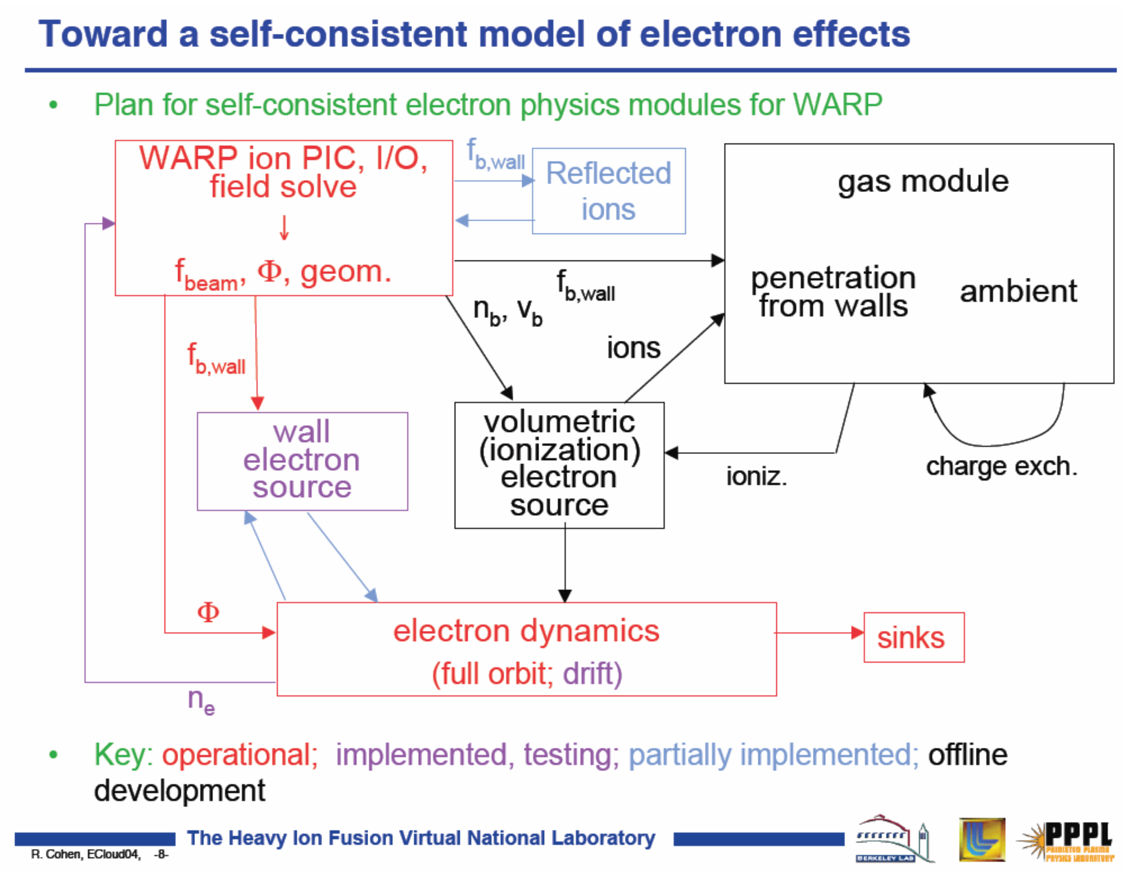
IBEAM MathCad systems program to study accelerator-design trade-offs and economics.
WARP Electrostatic code w envelope, PIC, and Vlasov models to examine injection and transport.
BEST Nonlinear perturbative PIC code for studying beam stability and halo formation.
LSP Implicit electromagnetic PIC code, particle-fluid electron model for modeling high-density plasmas.
BPIC A modern 2-D / 3-D electromagetic PIC code for chamber transport.
BICrz A 2-D electromagnetic PIC code for chamber transport.

HCX layout for ECE studies in magnetic quads



- ECE experiments began with diagnostics mounted on insert tubes within magnetic quads MA3 & MA4.
- Later experiments removed insert tubes, added electron-suppressor after MA4 and clearing electrodes between magnets.

Self-consistency plan



roadmap for WARP+POSINST

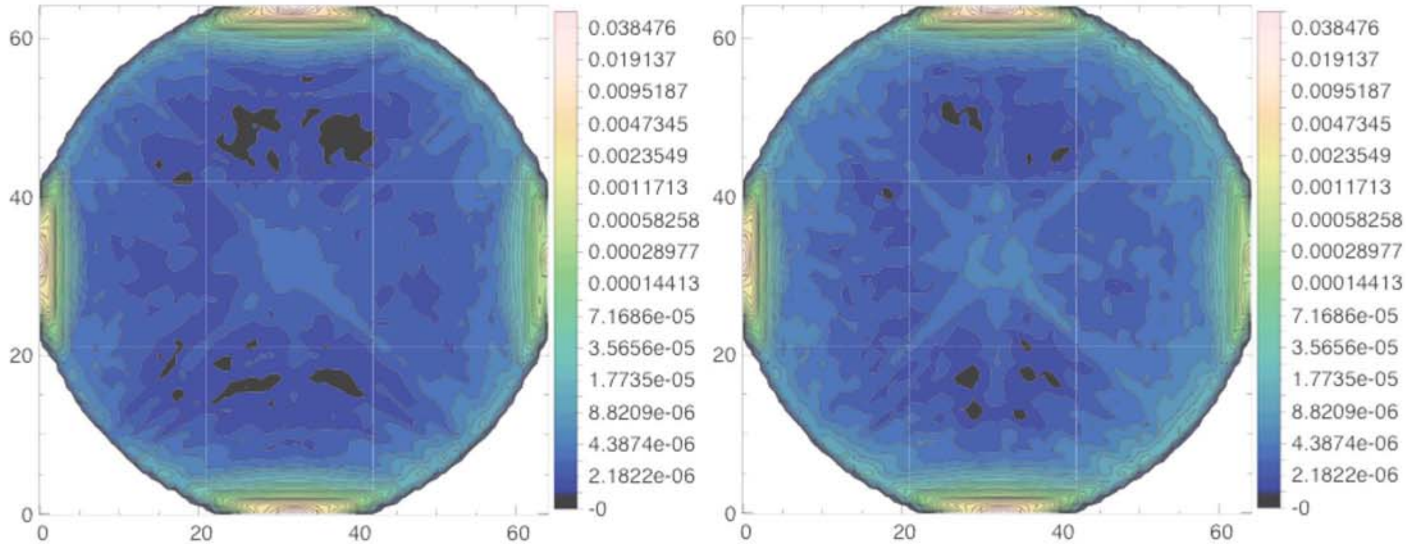
R. Cohen, ECLOUD’04

Self-consistent e-i simulation requires technique to bridge timescales

- Need to follow electrons through strongly magnetized and unmagnetized regions ⇒ need to deal with electron cyclotron timescale, ~ 10^{-11} sec.
- Ion timescales > 10^{-8} sec.
- Algorithm to bridge: interpolation between full-electron dynamics (Boris mover) and drift kinetics (motion along B plus drifts).
- Properly chosen interpolation allows stepping electrons on bounce timescale (~10^{-9} sec) yet preserves:
  - Drift velocity
  - Parallel dynamics
  - Physical gyroradius

Interpolated model reproduces the e-cloud calculation in < 1/25 time

- Compare full-orbit model, $\Delta t=.25/f_{ce}$, with interpolated model with Δt 25 times longer



Full-orbit

Large-timestep interpolated

the end