Lattice Development for an Energy Doubled LHC

Yunhai Cai and Yuri Nosochkov

SLAC National Accelerator Laboratory

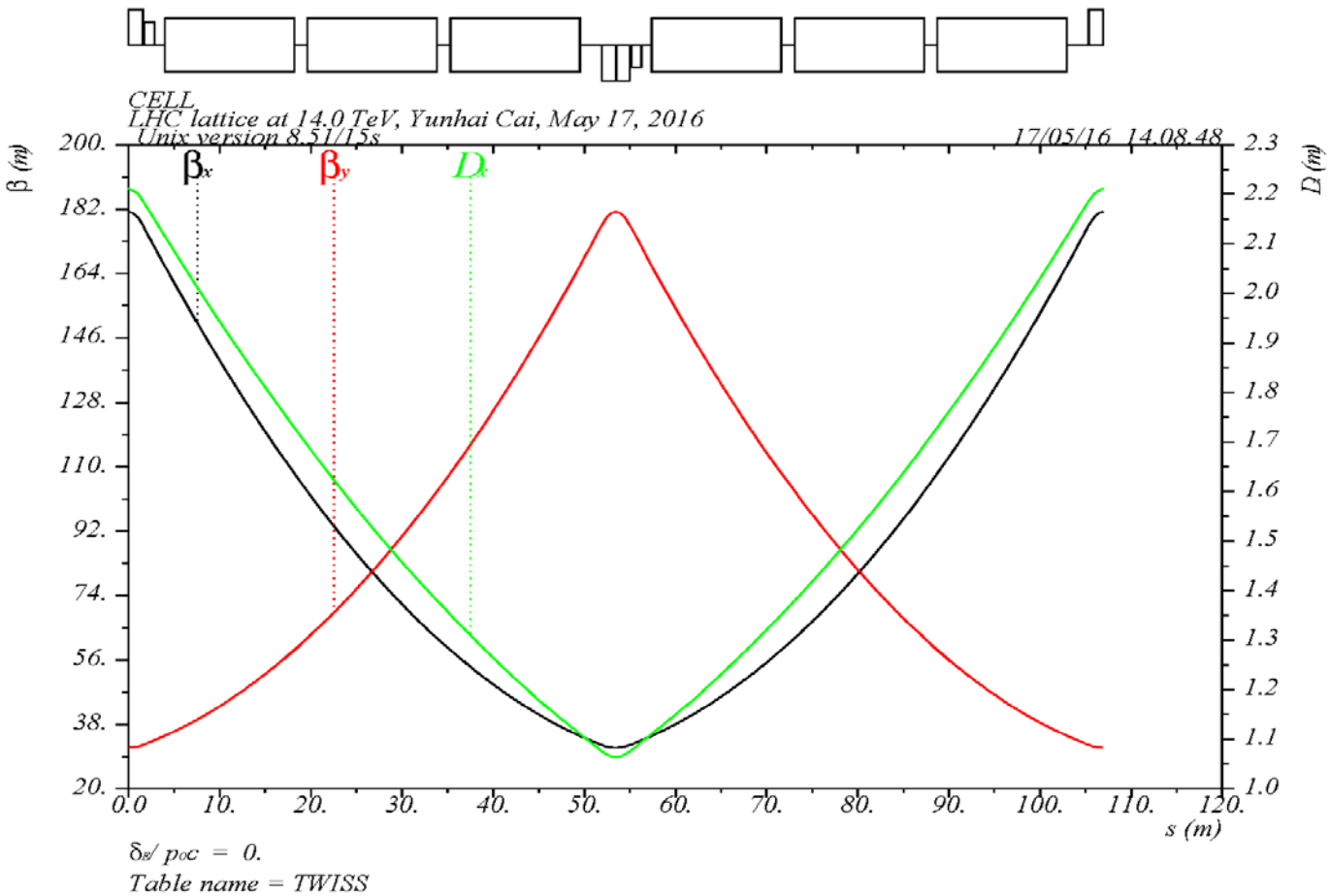
May 20, 2016

26th LARP/HiLumi Meeting, SLAC

U.S. DEPARTMENT OF ENERGY
Office of Science

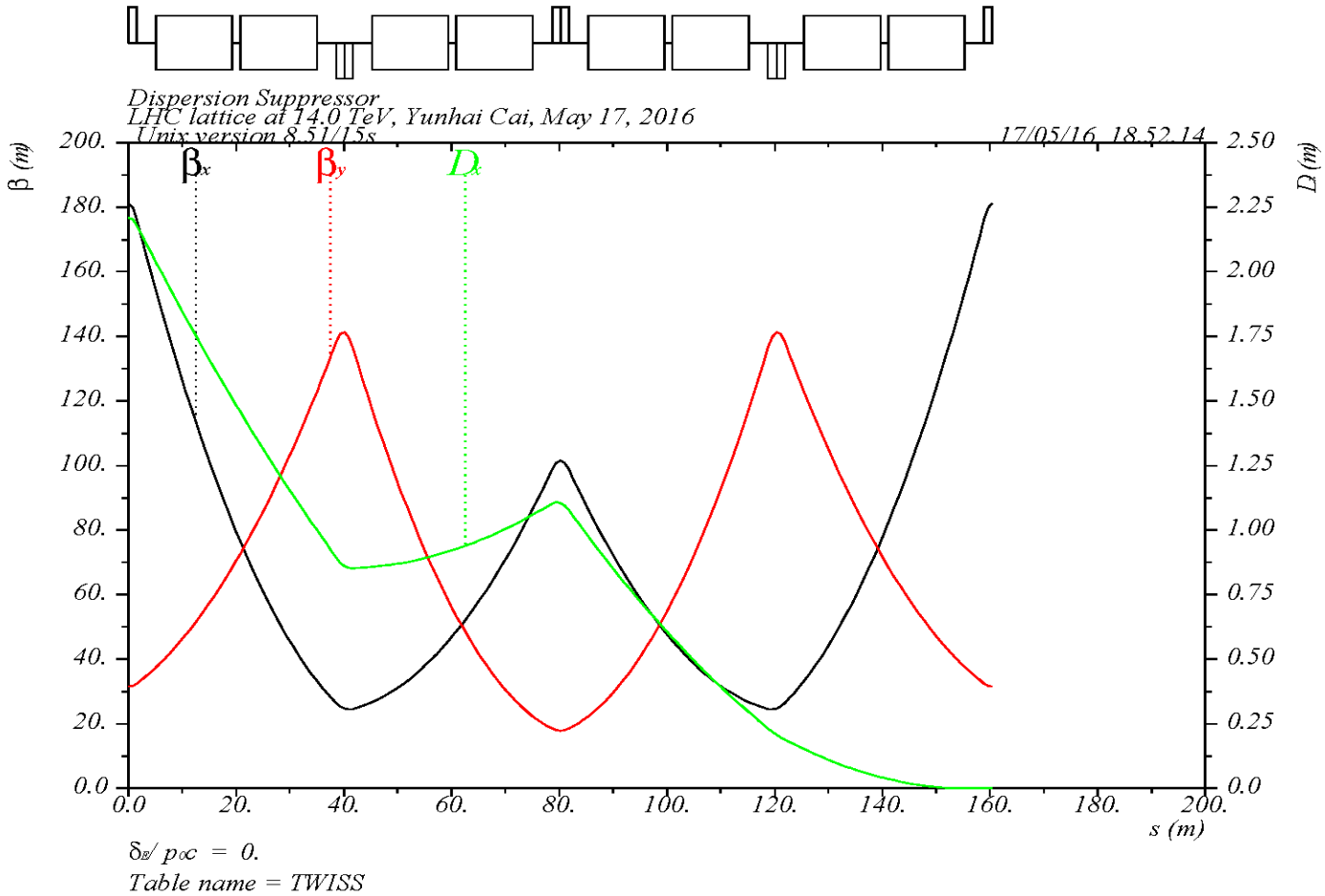
SLAC NATIONAL ACCELERATOR LABORATORY

LHC Cell

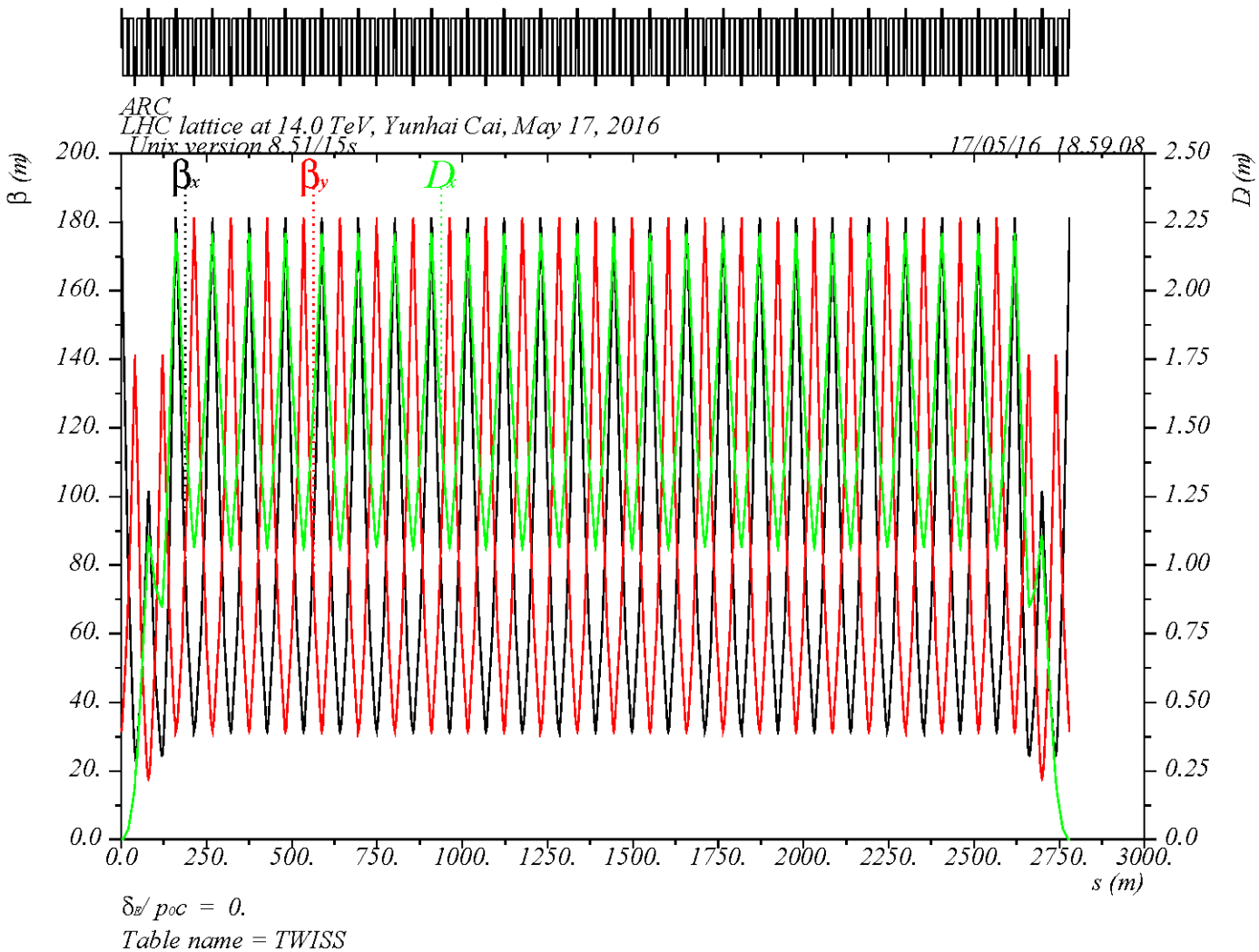


What are the optimal parameters?
Cell length? phase advance?

Dispersion Suppressor

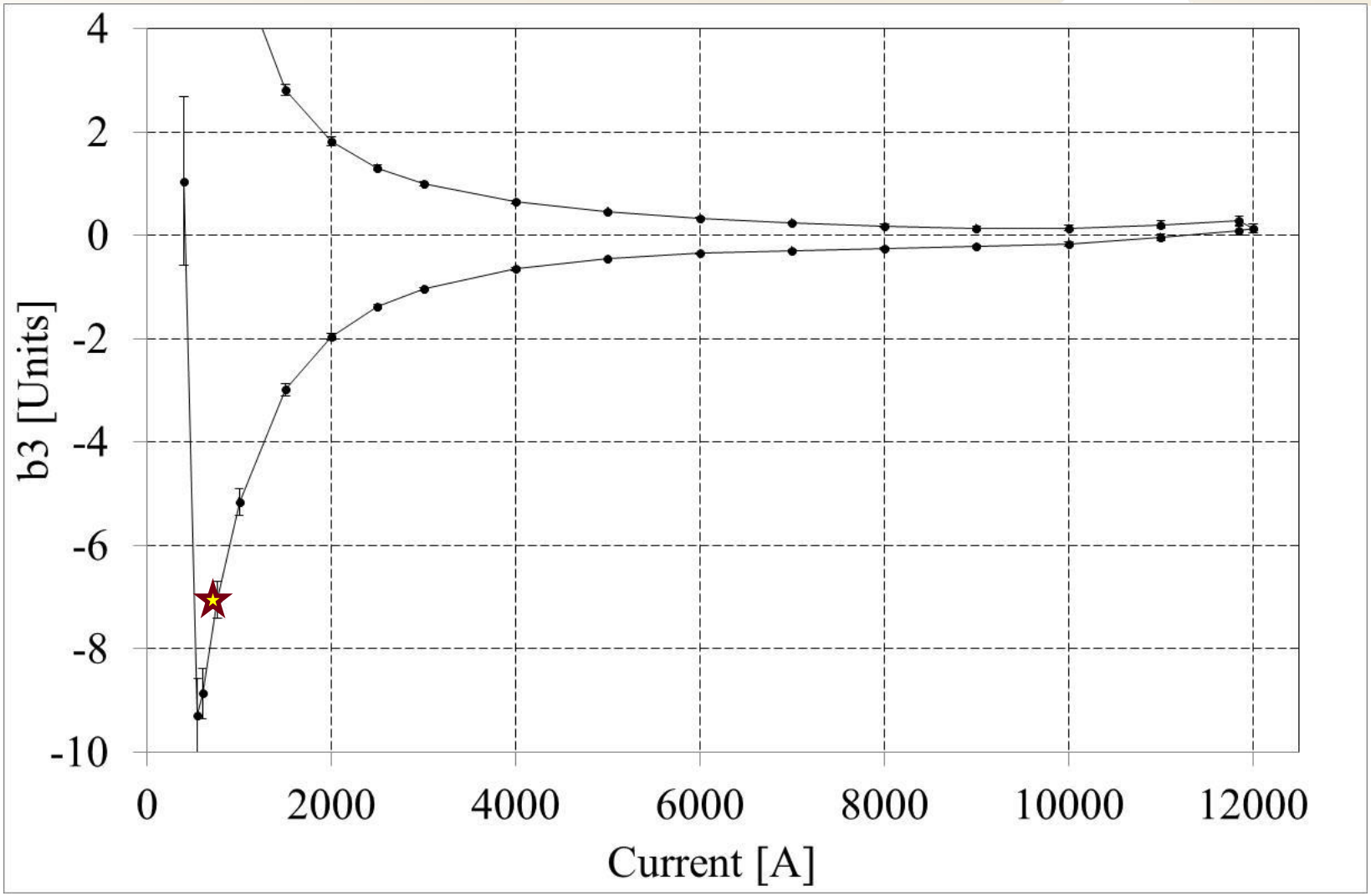


Arc (1/8 of Ring)



23 cells + 2 dispersion suppressors

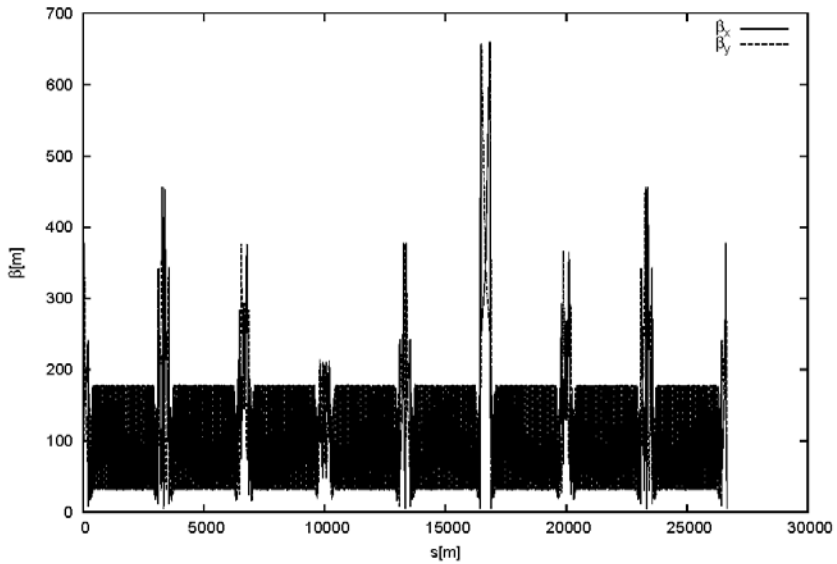
b_3 in the main LHC dipoles, and injection energy at 450 GeV



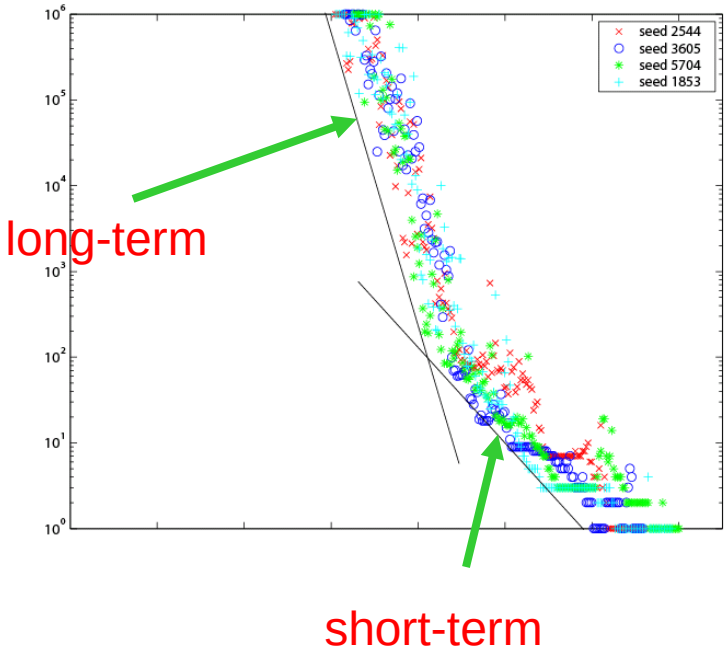
S. Izquierdo Bermudez, E. Todesco, D. Tommasini

Dynamic Aperture at Injection

LHC Lattice functions



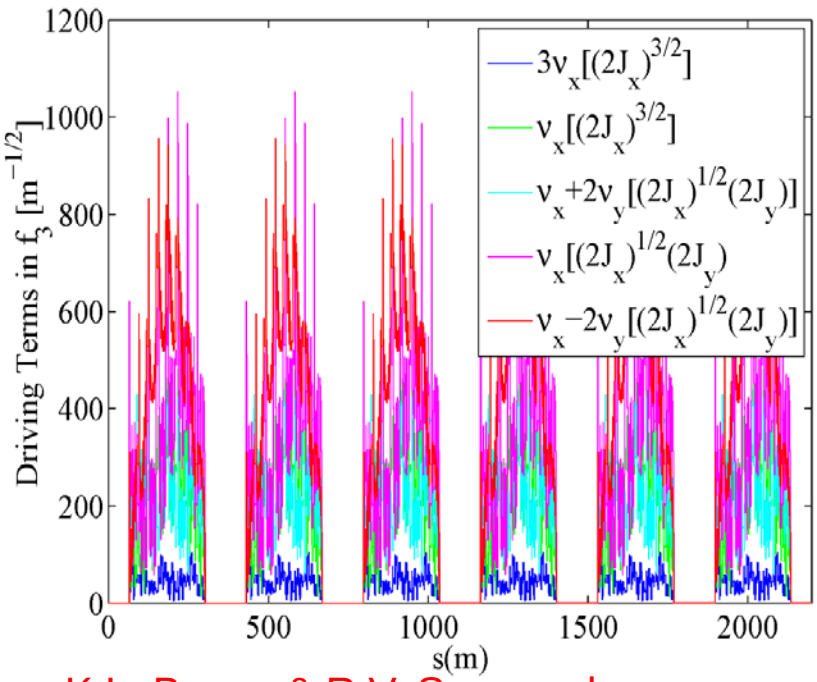
Dynamic Aperture



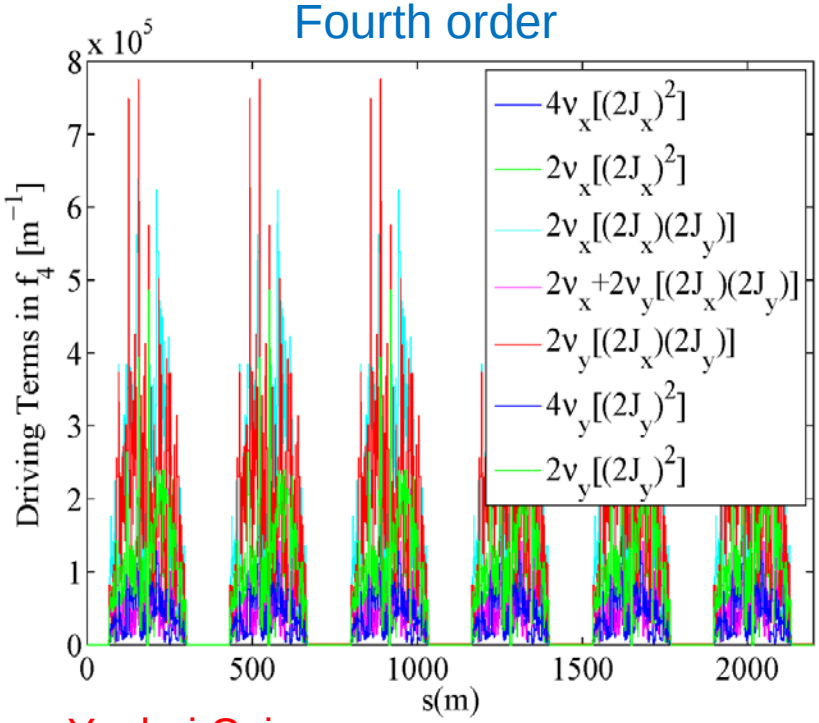
- What is the best injection energy?
- What is the necessary field quality?
- What kind of corrector package?

Cancellation of All Geometric 3rd and 4th Resonances Driven by Strong Sextupoles except $2\nu_x$-$2\nu_y$

Third order



Fourth order



K.L. Brown & R.V. Servranckx

Nucl. Instr. Meth., A258:480–502, 1987

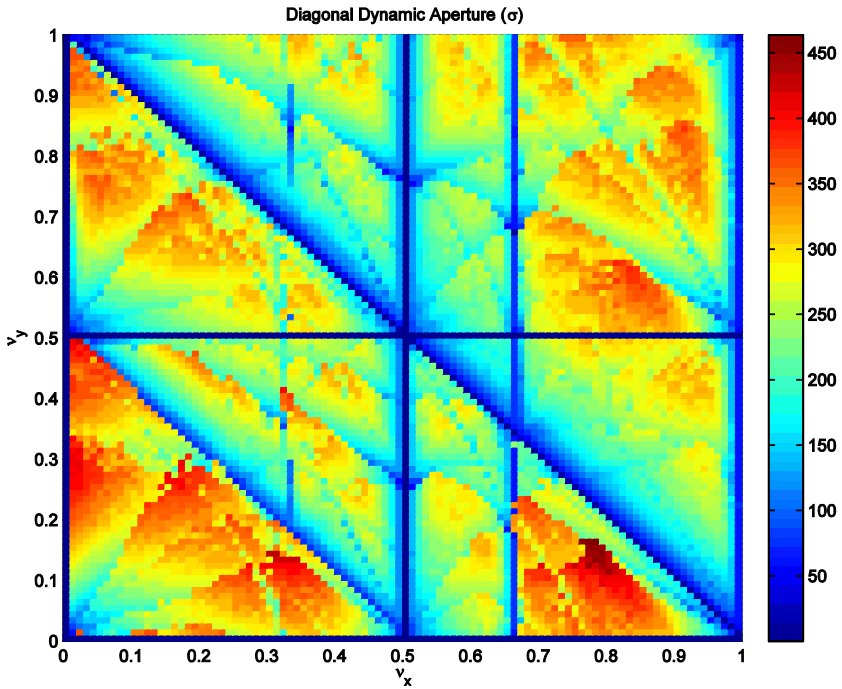
Yunhai Cai

Nucl. Instr. Meth., A645:168–174, 2011.

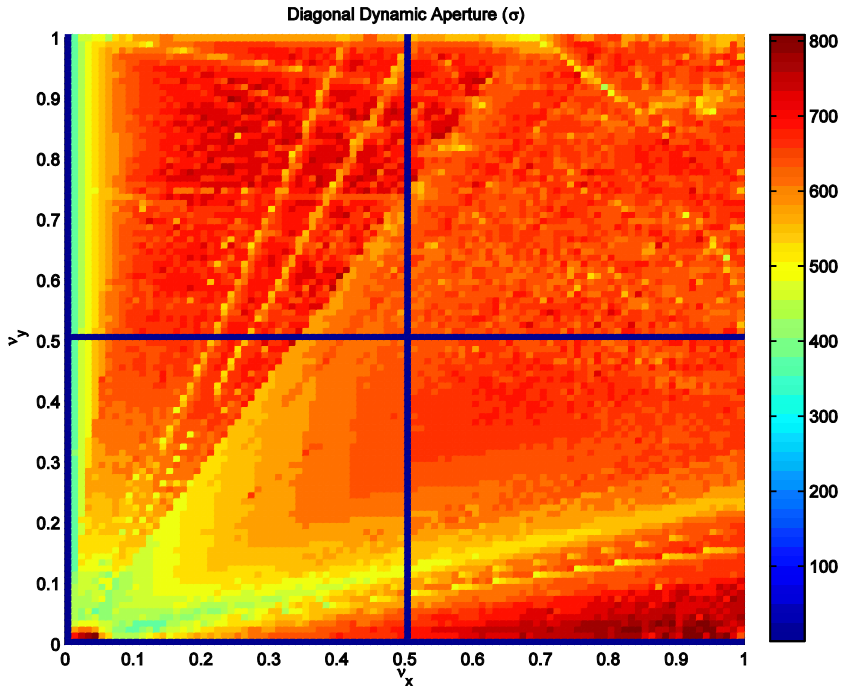
Three tune shift terms are canceled by specific settings of sextupoles.

Tune Scan of Dynamic Aperture

in a conventional ring

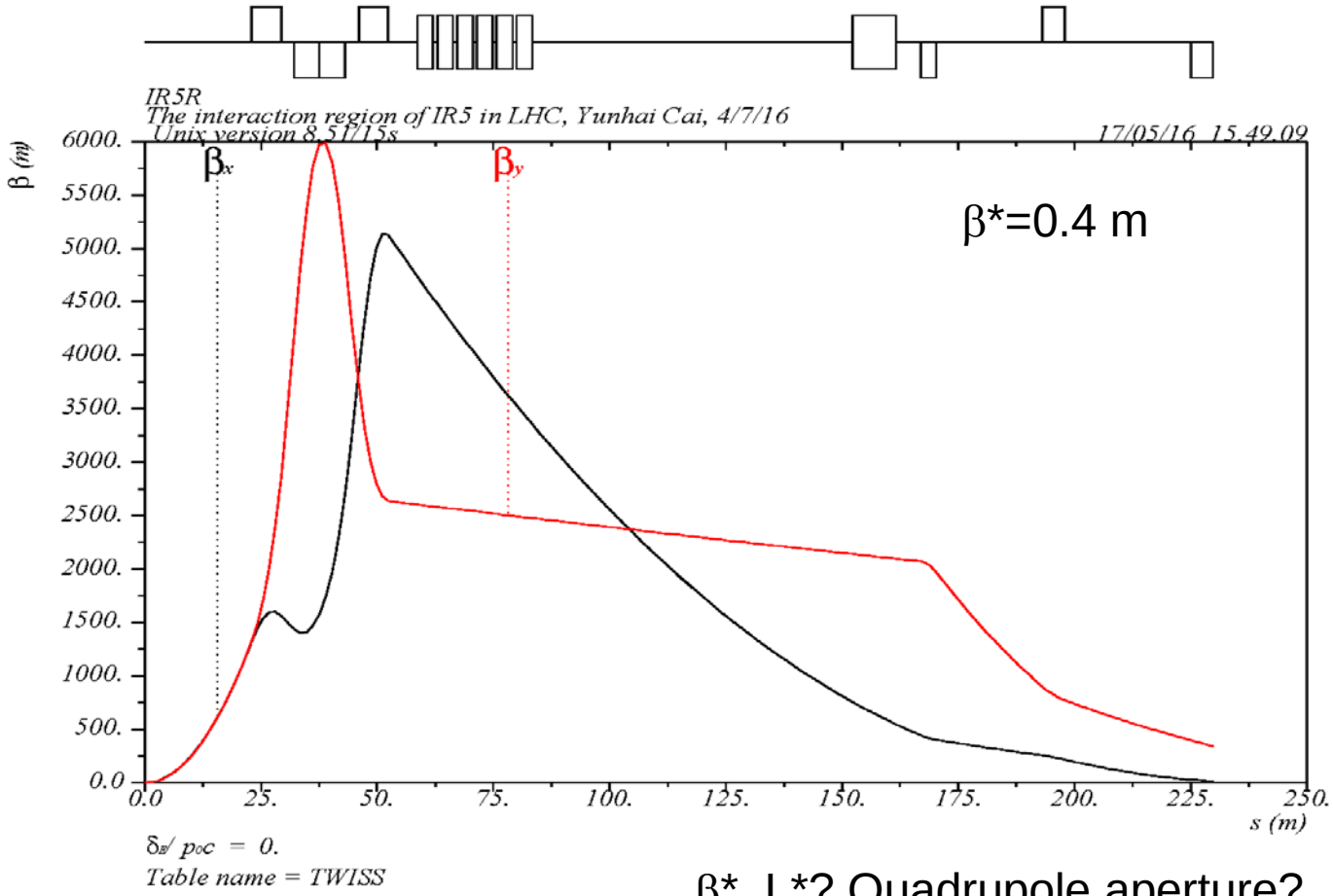


but with 4th order achromat



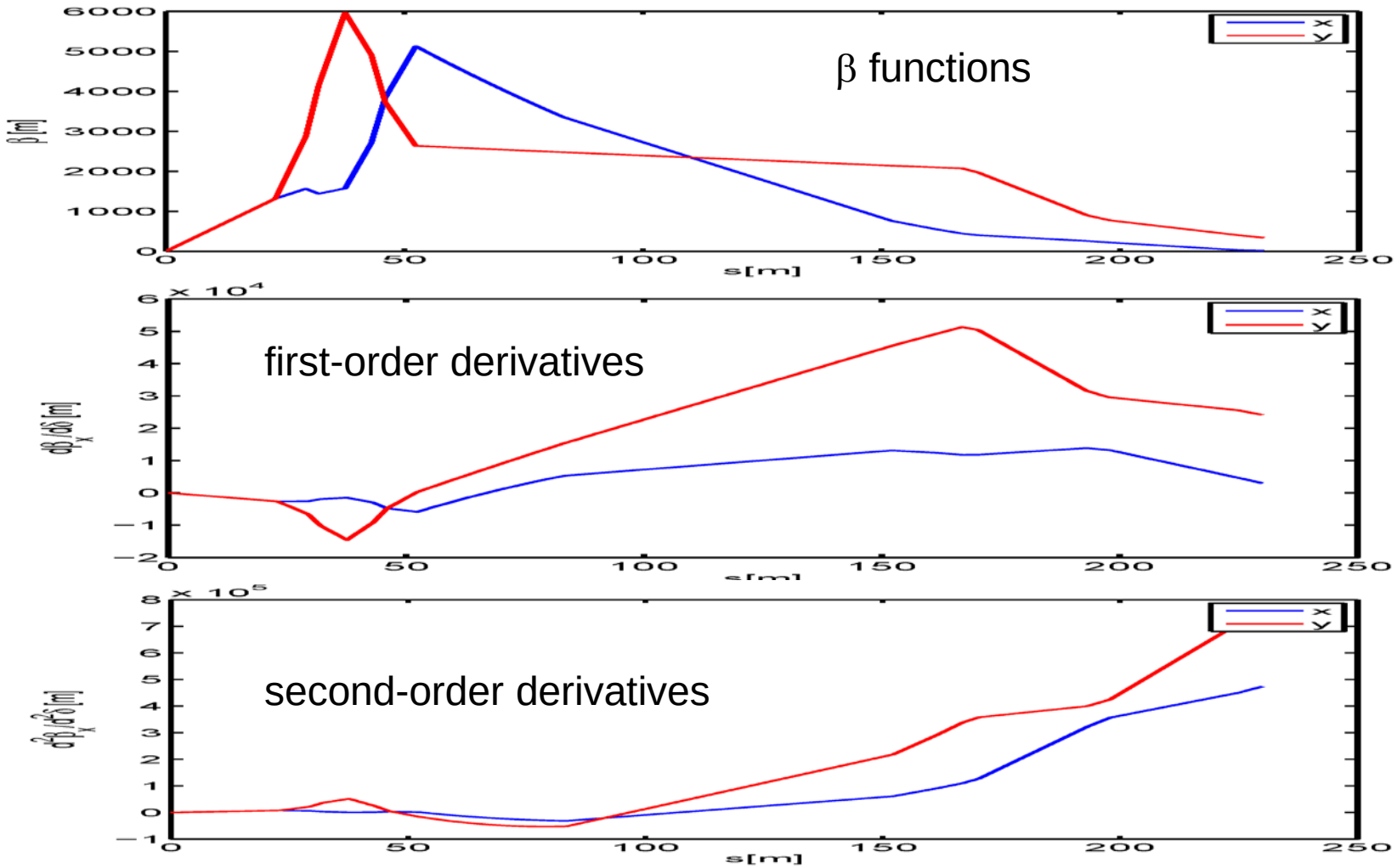
The dynamic aperture is in units of sigma of the equilibrium beam size. The USR design is built with 4th-order geometric achromats and therefore no 3rd and 4th order resonances driven by the sextupoles seen in the left plot.

Interaction Region



β*, L*? Quadrupole aperture?
Chromatic compensation?
Field quality in the triplet?

β Functions and their Chromatic Derivatives



They are useful for developing compensation scheme.

Luminosity

Bunch luminosity

$$L_b = f_{rev} \frac{N_b^2}{4\pi\sigma_x\sigma_y} R_g$$

where R_g is a geometrical reduction from the hourglass effect and crossing angle. It is also a good indicator for dynamical effects at high bunch charge.

Total luminosity: $$L = n_b L_b$$

Beam-Beam Limit

For round beams , the beam-beam parameter is given by

$$\xi = \frac{r_p N_b \beta^*}{4\pi\gamma\sigma^2}$$

And the luminosity can be re-written as

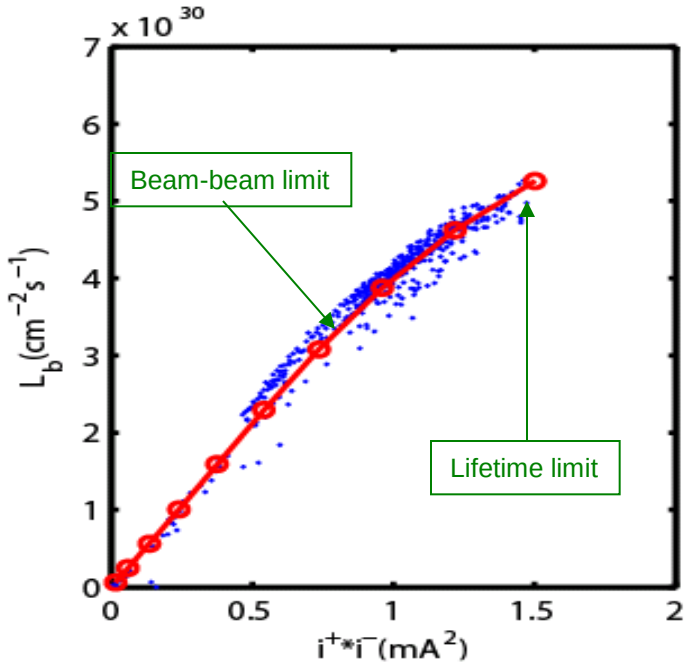
$$L = \frac{cI\gamma\xi}{r_e r_p I_A \beta^*} R_g$$

where I_A=17045 A. We should expect twice of the luminosity increase from an energy doubler. A smaller β^* and larger ξ is also helpful. Taking an example of the LHC running at E_0=4 TeV in June 2012, we have I=0.37A, ξ=0.0075, R_g=0.82, β^*=0.6 m and the luminosity is 6.59×10^{33} $cm^{-2}s^{-1}$.

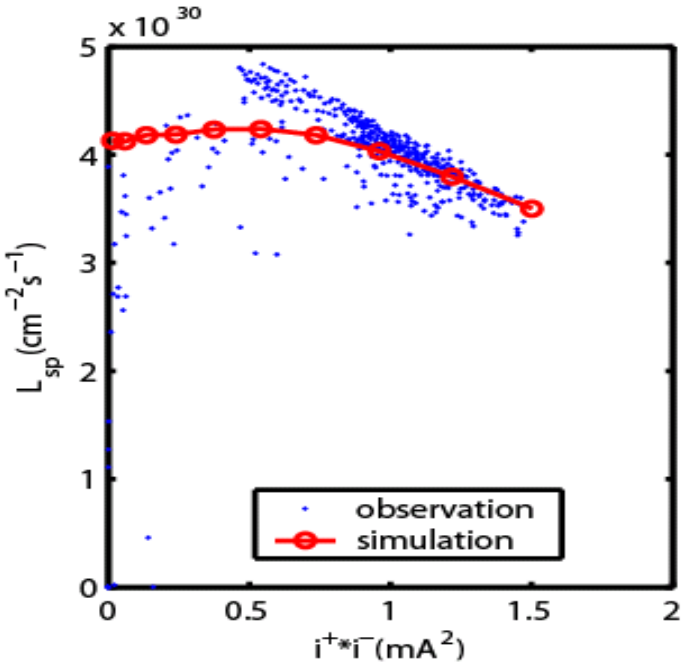
So what is the beam-beam parameter at 14 TeV of the beam energy?

Dependency of Beam Currents with Parasitic Collisions at PEP-II

Bunch Luminosity



Specific Luminosity



Data was taken in 24 hour period: between 21-NOV-2003 18:49:00 to 22-NOV-2003 18:49:00. The number of bunch was 1230 and bunch spacing was every two buckets. The ratio of currents in the measurement was not fixed as a constant but the agreements are surprisingly good.

Proposal

We plan to continue the close collaboration with CERN colleagues and magnet experts in LARP to

1) study the tradeoff of the major parameters at the injection: (1/2 FTE)

- injection energy,
- cell length and phase advance,
- field qualify and dipole aperture

and to investigate methods of mitigation for systematic magnetic errors.

2) to investigate the final focus system at the collision energy: (1/2 FTE)

- β^*, L*
- chromatic compensation,
- quadrupole aperture,
- and field quality in the triplet.

3) Finally, it is preferable if the work is extended to include the beam-beam effects, radiation damping and optimization of luminosity. (1/2 FTE)