Lifetrac Introduction

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10 November 2013

Lifetrac history

- Author – Dmitry Shatilov (BINP)
- Development started in ~1995
  - D. Shatilov, Beam-beam simulations at large amplitudes and lifetime determination, Part. Accel. 52 (1996) p. 65.
  - Since then used for design and performance improvements at
    - VEPP-4 (BINP), DAFNE (INFN/LNF), VEPP-2000 (BINP), KEKB (KEK)
- Initial design for electron-positron colliders
  - Key feature: determine the equilibrium distribution with radiation damping, quantum excitation and beam-beam

Lifetrac history II

- Tevatron Run II (2001-2011) – beam-beam major performance limiting factor
- Code modification started in 2003 to accommodate non-equilibrium distributions
  - Emphasis made on usefulness of simulations for real machine tuning and improvements
    - About a dozen real applications of the simulations for explanation of problems and planning upgrades. In each case the simulation predictions worked well.
  - As such, the easily measurable observables were determined
    - Intensity lifetime (better than 1% measured in real machine)
    - Emittance blowup (~10% resolution from SR, bunch-by-bunch)
    - Luminosity degradation (~1% bunch-by-bunch)

Lifetrac design

- Core of the code - single-particle tracking
- Normal mode of operation – macroparticle beam (typically 10,000 particles) tracked for 10^6-10^7 turns
  - Aperture restrictions (collimators) register particle losses and give beam lifetme
  - Emittances computed for the ensemble with averaging over ~10,000 turns (better statistics)
  - Luminosity calculated numerically as a convolution of the macroparticle ensemble with analytical bb of strong beam
- Results can be compared directly with operations

Lifetrac design

- Treatment of the machine lattice
  - Initially 6D linear maps between IPs and other devices
    - Sufficient for most needs, especially Tevatron where dynamics was beam-beam dominated. Chromaticity was treated through ‘tricks’ but was symplectic and well agreed with observations
  - Since 2012 – full element-by-element thin lens
- Many physics devices implemented
  - Electron Lenses of various types
  - Crab Cavities (tested by DS at KEKB)
  - Wire Compensators
  - Collimators (in principle, can model loss maps)
  - Special magnets (for Integrable Optics)
  - etc.

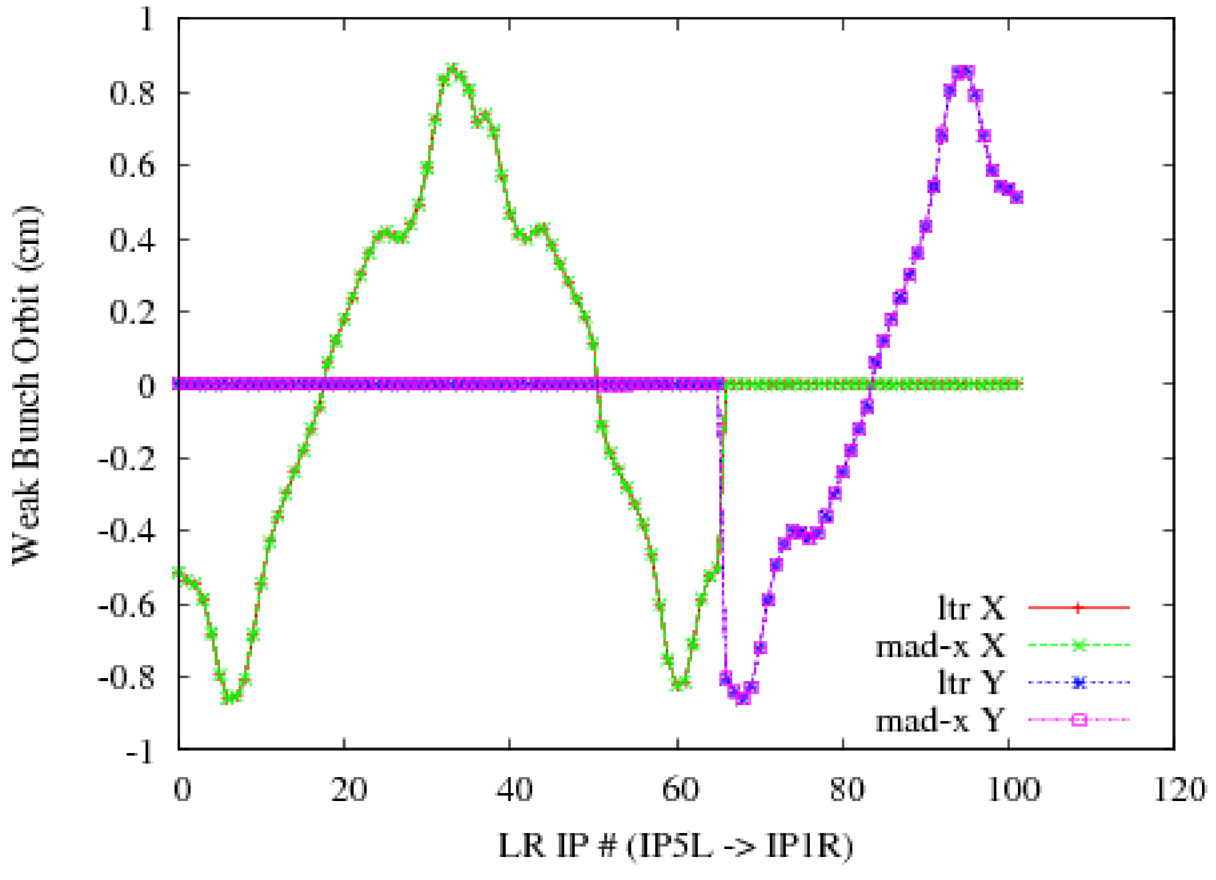
Lifetrac design

- Recently added features
  - FMA (2007)
  - Dynamic Aperture (2011)
  - mad-x –to– lifetrac lattice conversion (2012-2013)

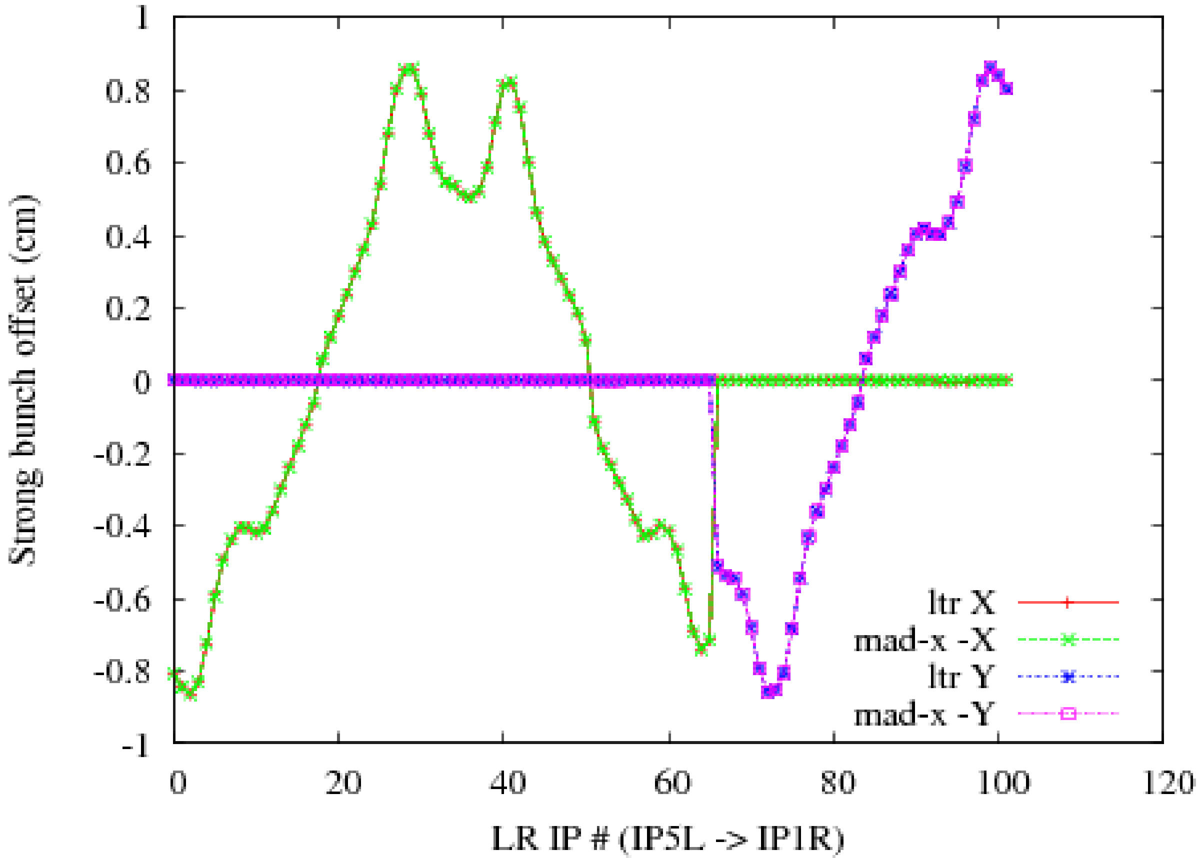
MAD-X to Lifetrac

- Begin with the thin-lens mask file
- Use `twiss` with default format to dump the full lattice for weak beam
  - this prints all relevant element information (L for drifts, KNL, KSL for multipoles, KICKs for correctors, VOLT for cavities, KS for solenoids, etc.
  - also put markers at locations of IPs
- For strong beam, use mylhcbeam=2 and dump lattice data (betax, betay, dx, dy, offsets) at IPs
  - parameters of IPs are then calculated from these

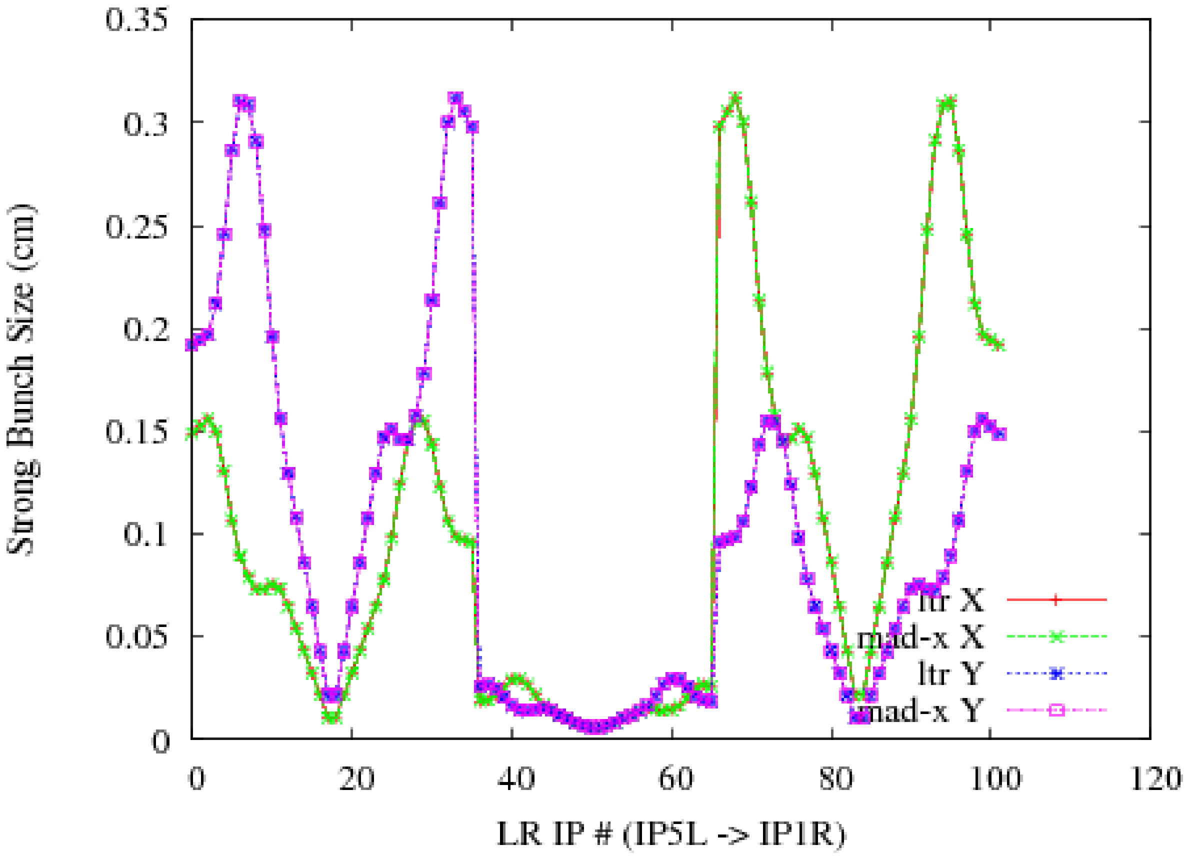
Verification with mad-x



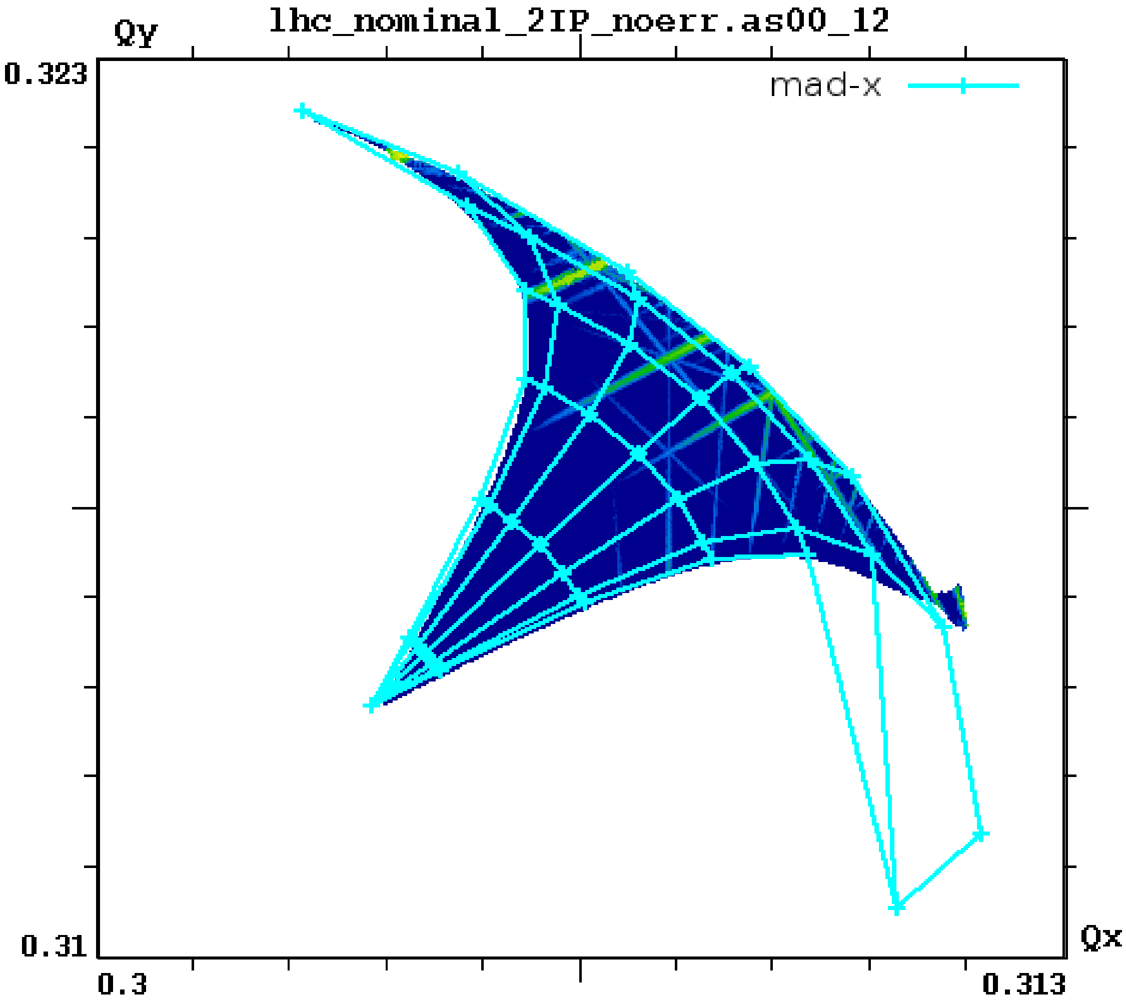
Verification with mad-x



Verification with mad-x



mad-x footprint and FMA LHC Nominal



Known differences with SixTrack

- Different definition of beam sigma
  - SixTrack uses analytical maps to find normal mode matrix
  - Beam-beam is included into normal mode (in Lifetrac – not!)
    - Hence, the sigma may be different if dynamic beta is significant
    - Not obvious how one implements analytical linear maps for 6D beam-beam
- Different definition of DA
  - Action in sixtrack is determined through averaging
  - Initial value in Lifetrac

What we should look at?

- Footprints
  - easy computed, can benchmark with mad-x
- Details of single-particle motion in physical coordinates
  - This will eliminate the problems of defining sigma and DA