SR Improvements and Trade-Offs

L. Emery
(based on past presentations of M. Borland, G. Decker)
May15, 2002

Outline

- Discussion of general design limits
- List of enhancements
  - Global, local, injection
  - Costs and other issues

Design Limits

- The impossible
  - Fundamental accelerator optics limits
- The possible but with undesirable consequences
  - Mostly low lifetime (therefore need more frequent injections or need more bunches)
  - Lower charge per bunch
  - Injection losses, meaning ID radiation damage

Design Limits

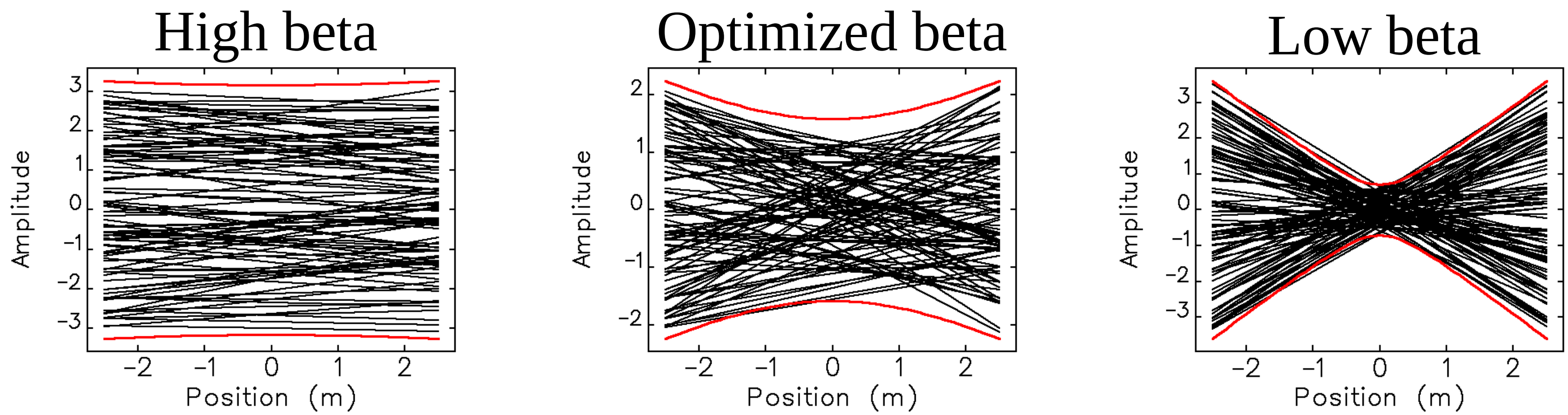
- The possible and easy: Already done!
  - Top-up, low emittance, and low betay for small aperture of narrow gap ID

The Impossible

- Arbitrarily low emittance.
  - Accelerator optics (new magnets) and sextupoles so strong that stable phase space is too small for accumulation.
  - Focusing $\Rightarrow$ chromatic correction (sextupoles) $\Rightarrow$ nonlinearity $\Rightarrow$ instability of oscillations

The Impossible

- Arbitrarily small or large beta functions in center of straight sections ($\beta_x = \sigma_x / \sigma_{x'}$)



  - Injection requires β close to L/2.
  - Very small β at center implies large β at ends.
  - Injection with accumulation impossible for very large β, around 100 m.

The Impossible

- Arbitrarily long straight sections (removing quadrupoles or moving them together)
  - Not compatible with small apertures. Need to keep the quadrupoles and some space between them for flexible accelerator optics matching.
- Arbitrarily high bunch current even with feedback.
  - Limited by beam's own field scattered by small apertures

Fundamental Trade-offs for the Possible

- Bunch density vs lifetime
  - $\tau \sim \sigma_x \sigma_y \sigma_z / Q$
- Stronger focusing vs injection beam loss
  - Nonlinearity of the stronger sextupoles.
- Customized beta functions (σ_x, $\sigma_{x'}$) vs injection beam loss
  - Larger σ_x at ends of VC + small apertures.
- Smaller gap or longer ID chambers vs injection beam loss + lower bunch charge

Global Enhancements

- Further reduction in emittance to <3nm lattice
- Reduction in coupling
- Increased beam current
- Higher bunch current
- 6-7 GeV configuration (most users benefit)
- Enhanced beam stability
- Regulate beam size

Local Enhancements

- Converging beta function
- Other customized beta functions

Injection Enhancements

- Center beam in ID VC aperture
- Bunch purity
- Transparent top-up
- Reduce booster emittance

Reduction in Emittance to < 3nm

- Increases brightness by a good fraction (10%'s)
- Shorter lifetime
  - May require higher booster charge, more frequent topup injection, more bunches
- Requirements: Stronger sextupoles, corrector magnets, one or more strong wiggler (option), which uses up one straight section

Reduction in Coupling

- I.e., lower vertical emittance (typically, 0.5% of ε_x)
- Reduces injection losses
- Shorter lifetime
  - May require higher booster charge, more frequent topup injection, more bunches

Increased Beam Current

- Increases the photon flux simply
- Shorter lifetime
  - May require higher booster charge, more frequent topup injection, more bunches

Increased Bunch Current

- For single bunch used in hybrid bunch pattern,
  - Presently use 5 mA
- Shorter lifetime for bunches
- Need feedback and/or stronger sextupoles to prevent instability.

6-7 GeV Optimization

- Vary energy while maximizing beam current to keep thermal load constant.
- Benefits: higher brightness for most users if right IDs are available
- Costs: very bad for high-energy x-ray experiments and (probably) timing experiments

Enhanced Beam Stability

- Supports higher brightness, i.e., stability requirement is relative to beamsize.
- Upgrades to diagnostics systems.
- How good is good enough?

Regulate Beam Size

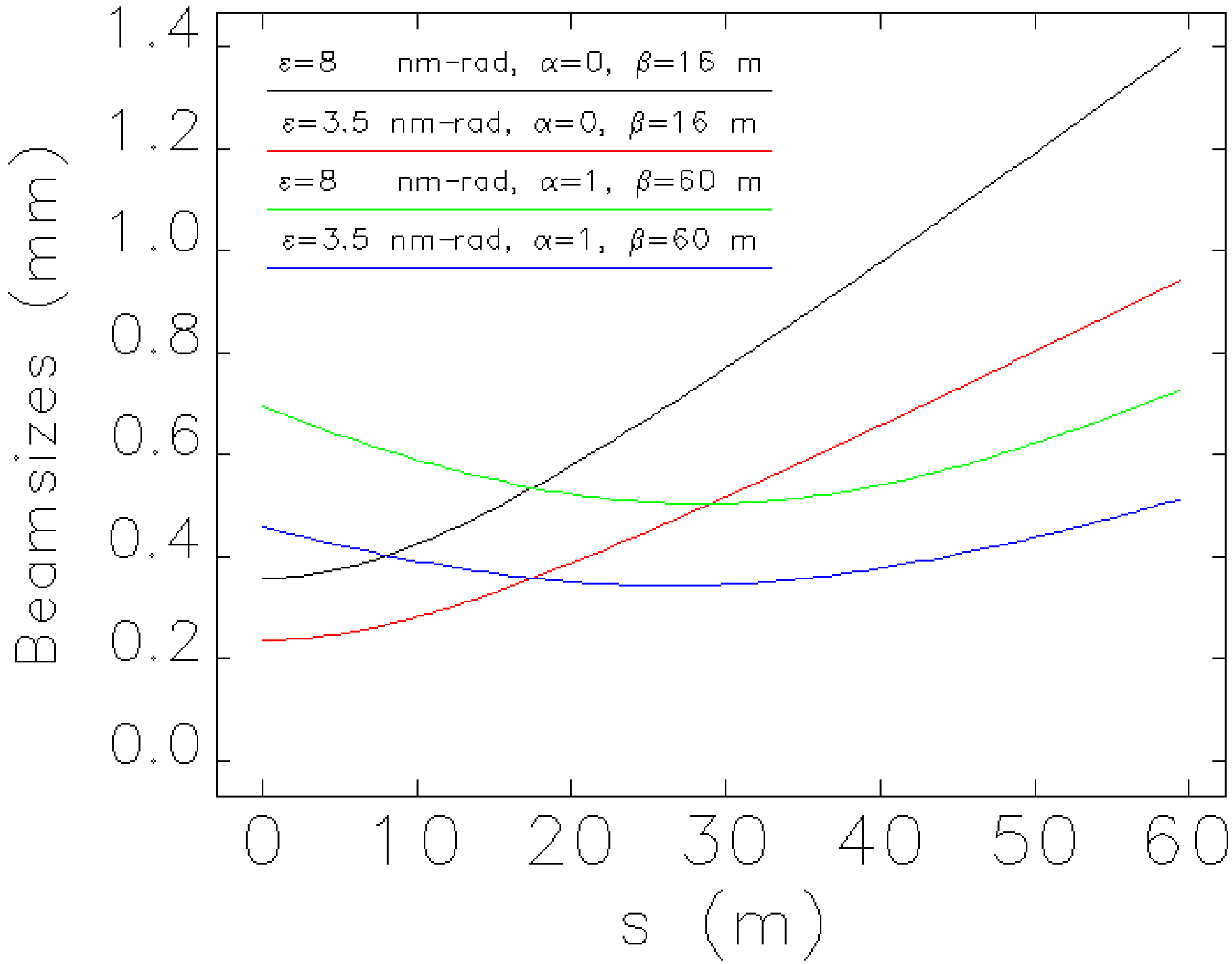
- Eliminate gap-dependent beam size changes
  - Vertical beamsize varies by at most ±5%, horizontal, by ±3%.
- New skew quad magnets near IDs
  - Small magnet such as in ID4-CPU
- Compensating horizontal wiggler (option) for horizontal beam size change

Converging Beta Function

- Aids x-ray optics by about x2 by prefocusing the photon beam
- Poor lifetime
- Distortion of lattice in two sectors, stronger sextupoles, possible emittance degradation
- Poor injection, ID damage possible

Converging Beta Function

- Beamsizes for converging betax



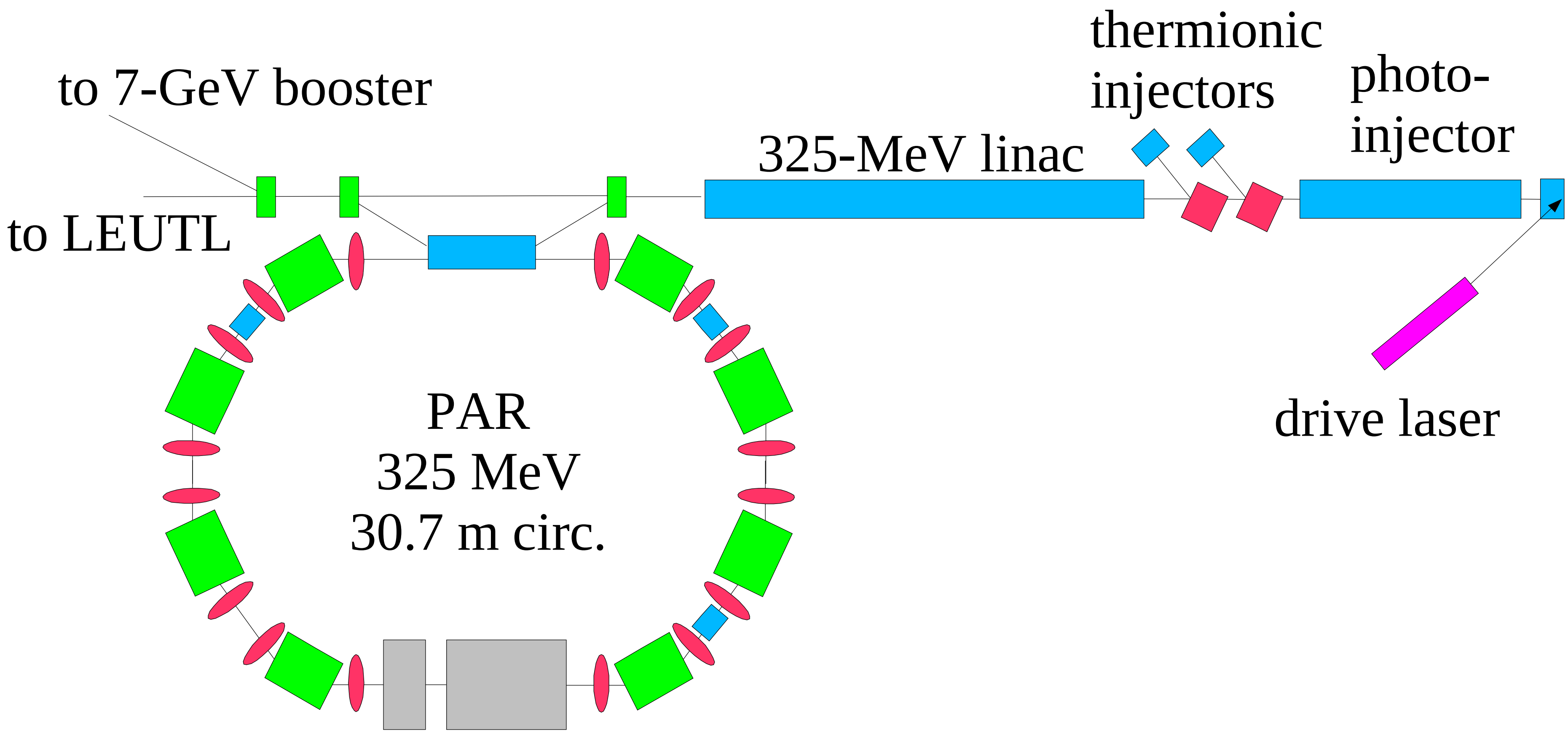
Long Straight Sections

- Very flexible, higher flux, multiple undulators
- Costs: new magnets, new chambers, ring distortion, ...
- Requirement: preserve SR acceptance by increasing aperture
- Easy for large gap undulator
- More difficult for small gaps: need in-vacuum ID

Center the Beam in Apertures and Magnets

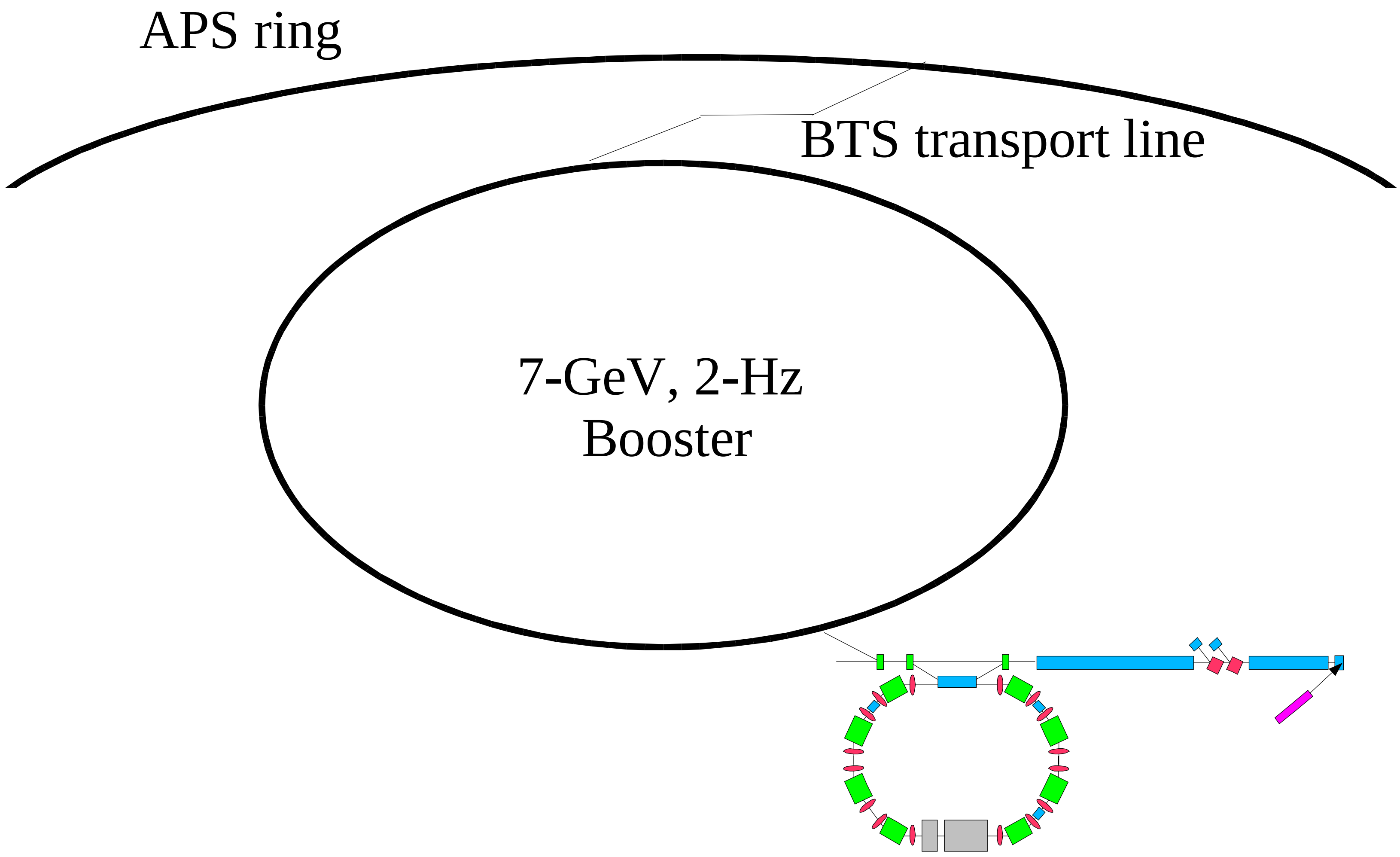
- Benefits:
  - fewer trips
  - easier accelerator optics correction
  - better injection efficiency
- Costs: need to realign beamline

Injector Description
Low-Energy Injector Schematic



(M. Borland)

Injector Description
High-Energy Injector Diagram



Bunch Purity

- Costs: operational complexity
- Current method of cleaning (using scrapers and global beam excitation) not compatible with top-up
- Need new idea or bunch-by-bunch feedback system

Transparent Top-Up

- Benefits: do top-up at shorter interval $\Rightarrow$ operate at lower lifetime
- Costs: unknown
- Other requirements:
  - New ideas (e.g., bunch-by-bunch feedback)
  - New kicker chambers
  - Redo septum FF compensation

Low-Emittance Booster Lattice

- Emittance reduced from 130 nm-rad to 100 nm-rad.
- Improved SR injection for reduced radiation damage to IDs
- Costs: small, need injector studies time during non-topup User run.

Beam Loss Control

- Benefits: reduced radiation damage to IDs, fewer rad monitor trips, which cause beam dumps, faster filling
- Costs: none
- Other requirements: perhaps new scrapers and BTS optics