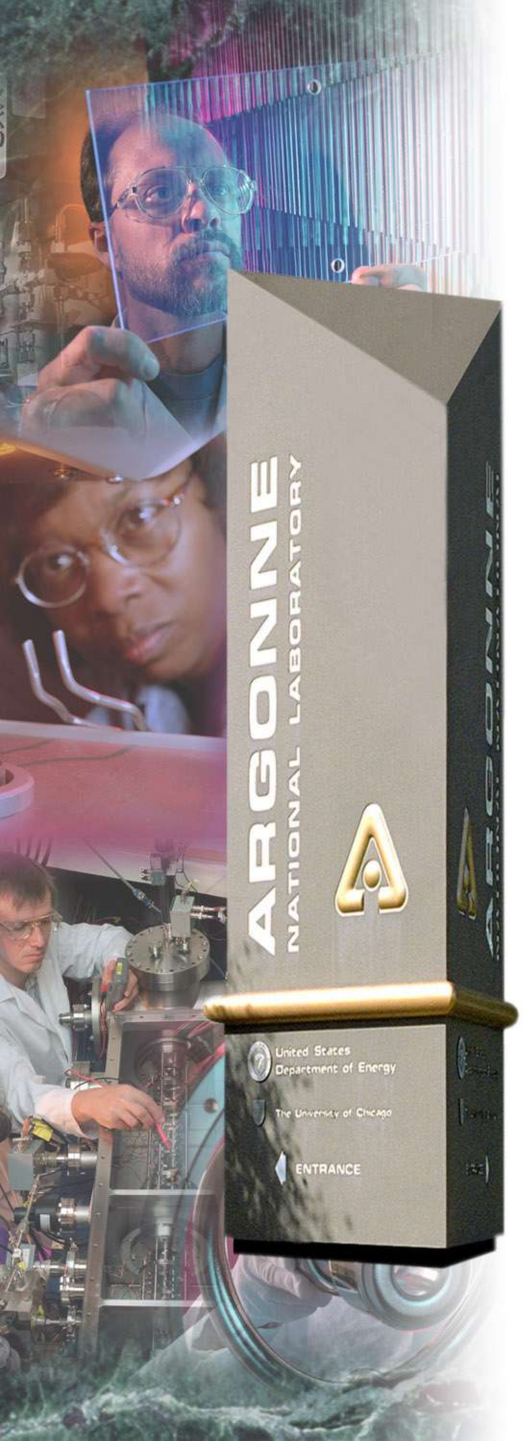

Super-Bright Storage Ring as an Alternative to an ERL

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Goals for New APS Ring Design

- Fit in existing tunnel
- Preserve existing ID beamlines
  - n*40 sectors
- Possibly preserve the bending magnet beamlines
- Provide ~1000-fold increase in average brightness
  - Lower emittance (factor ~50)
  - Longer undulators (factor ~2)
  - More current (factor ~10)

XPS7 Design

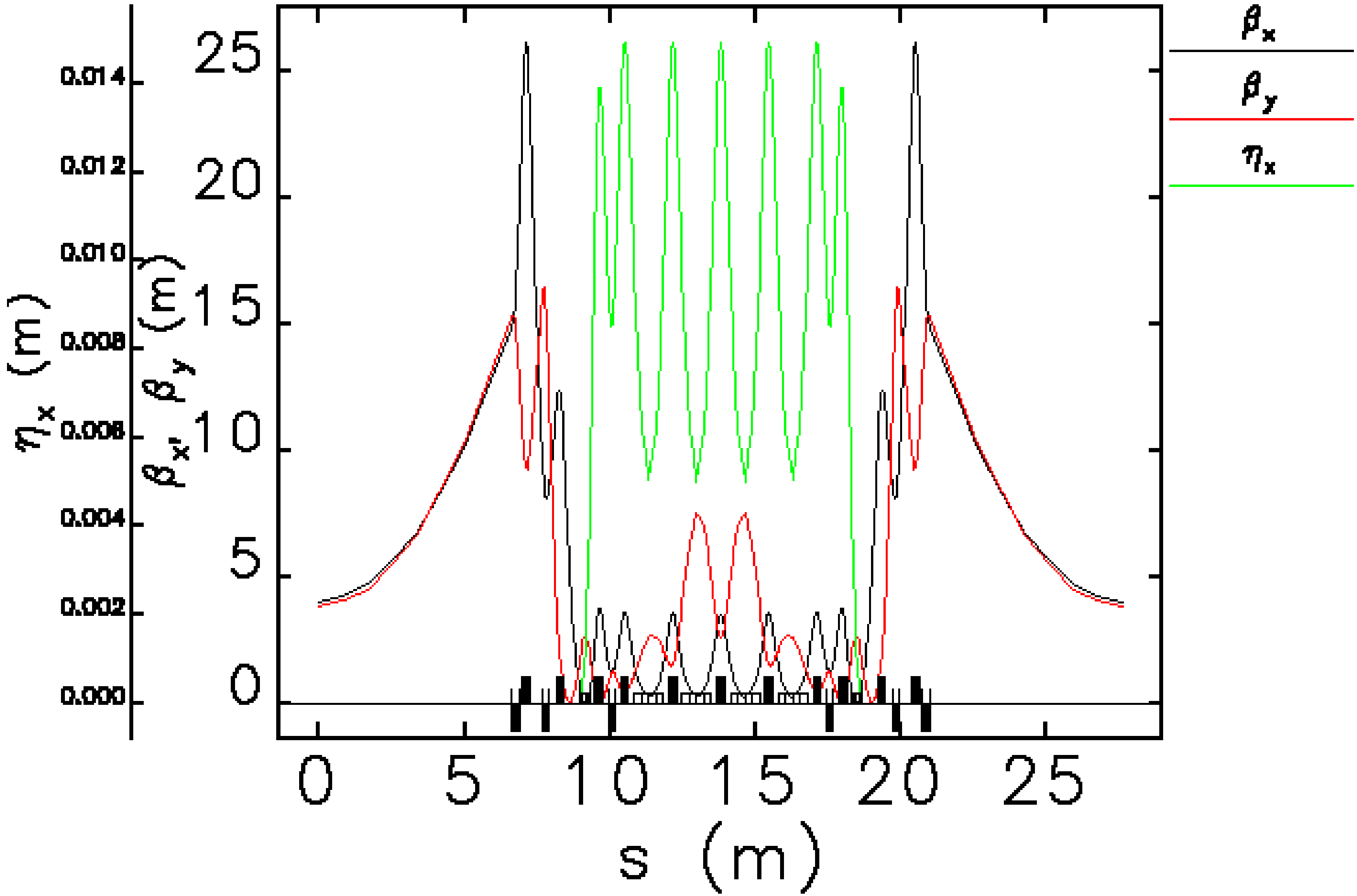
- Original XPS design[1] had an error.
- New design is based on similar concepts
- Use combined function magnets
  - Dipole with fixed gradient and sextupole
  - 12 pole magnets for combined quadrupoles, sextupoles, and correctors
- Use variable permanent magnets
  - Only way to get the strengths required
  - Need the stability for ultra-low emittance
  - Need electromagnetic trims for correctors

[1]L. Emery and M. Borland, PAC 2003, p 256.

XPS7 Design

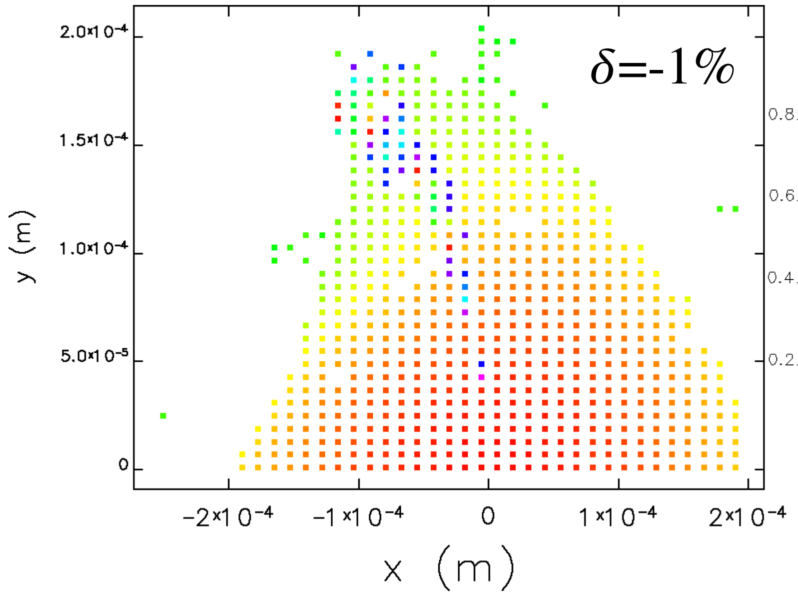
- At 7 GeV
  - Natural geometric emittance is 0.08 nm
  - With 100% coupling, normalized emittances are 0.6 μm
  - 0.18% rms energy spread
- Allows 12 m for straight sections
  - Could give up some to make easier design
  - Zero dispersion to avoid messing up emittance with undulators

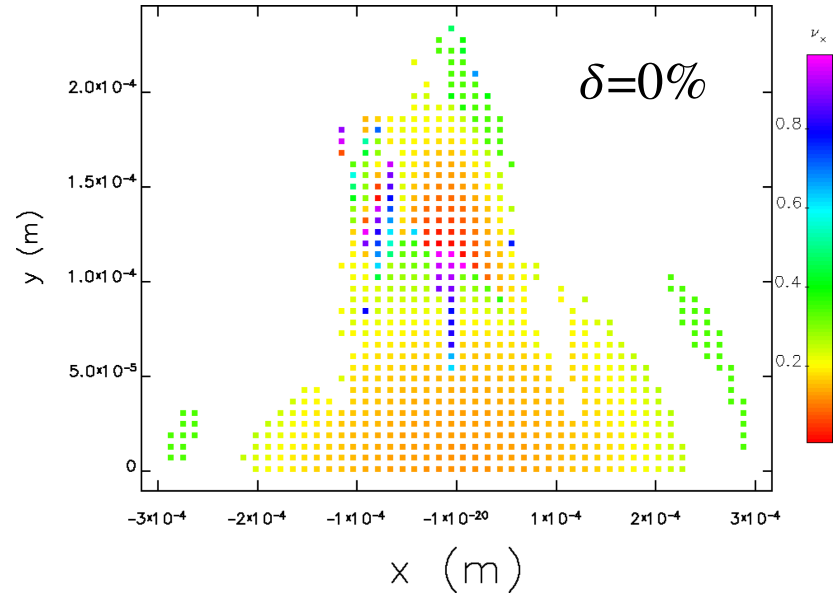
XPS7 Lattice

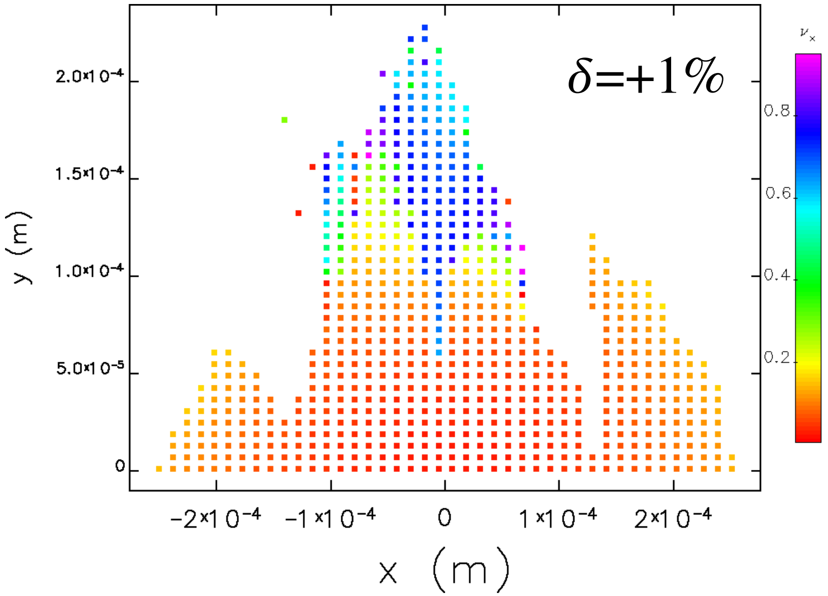


Designed with *elegant* (M. Borland)

Dynamic Aperture Needs Work!







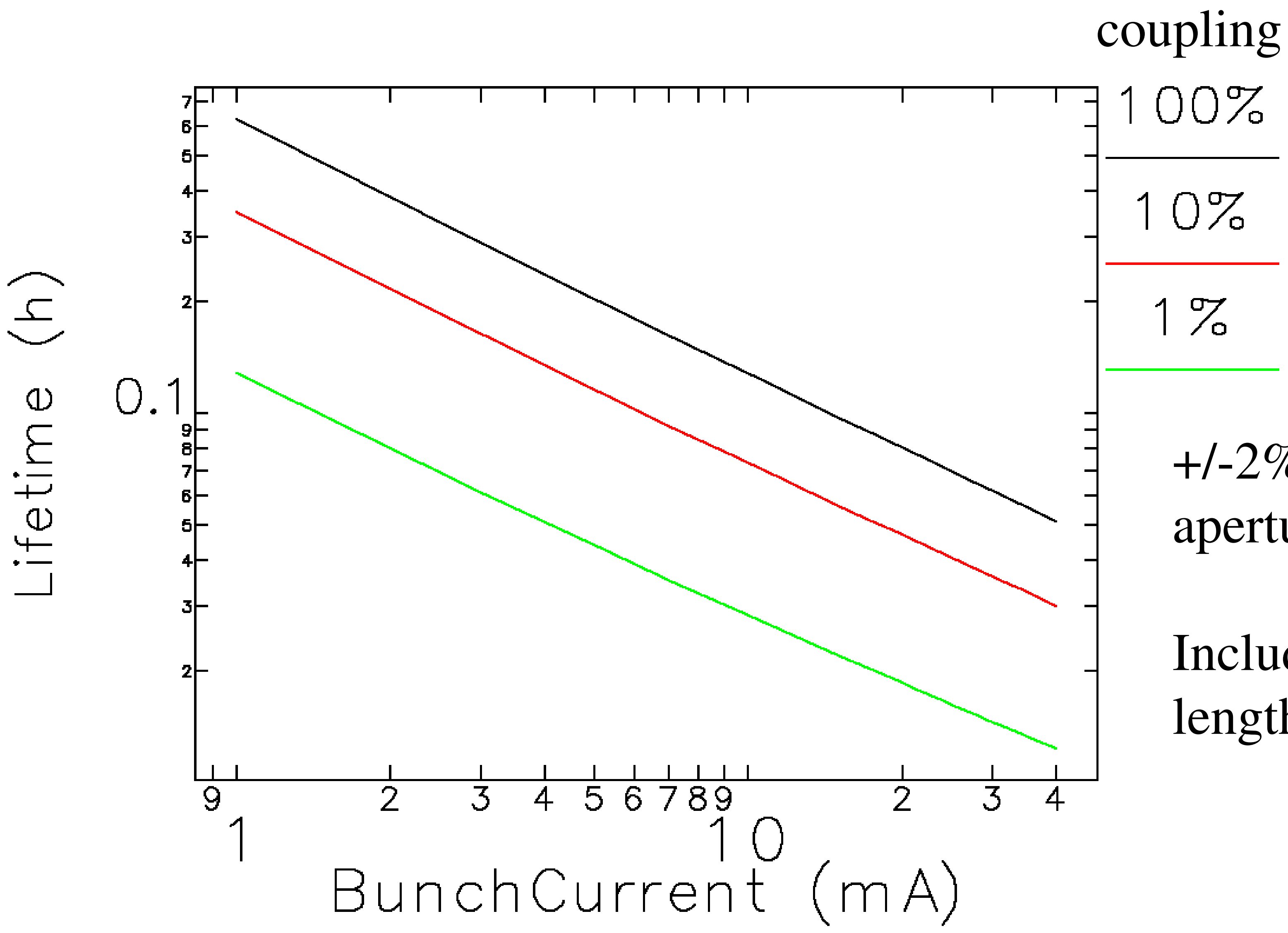
Color code shows horizontal tune.

Momentum aperture too small: +/- 1%

DA is much too small:
0.1mm x 0.05mm or 7σ x 3.5σ

Computed with *elegant* (M. Borland)

Beam Lifetime Predictions

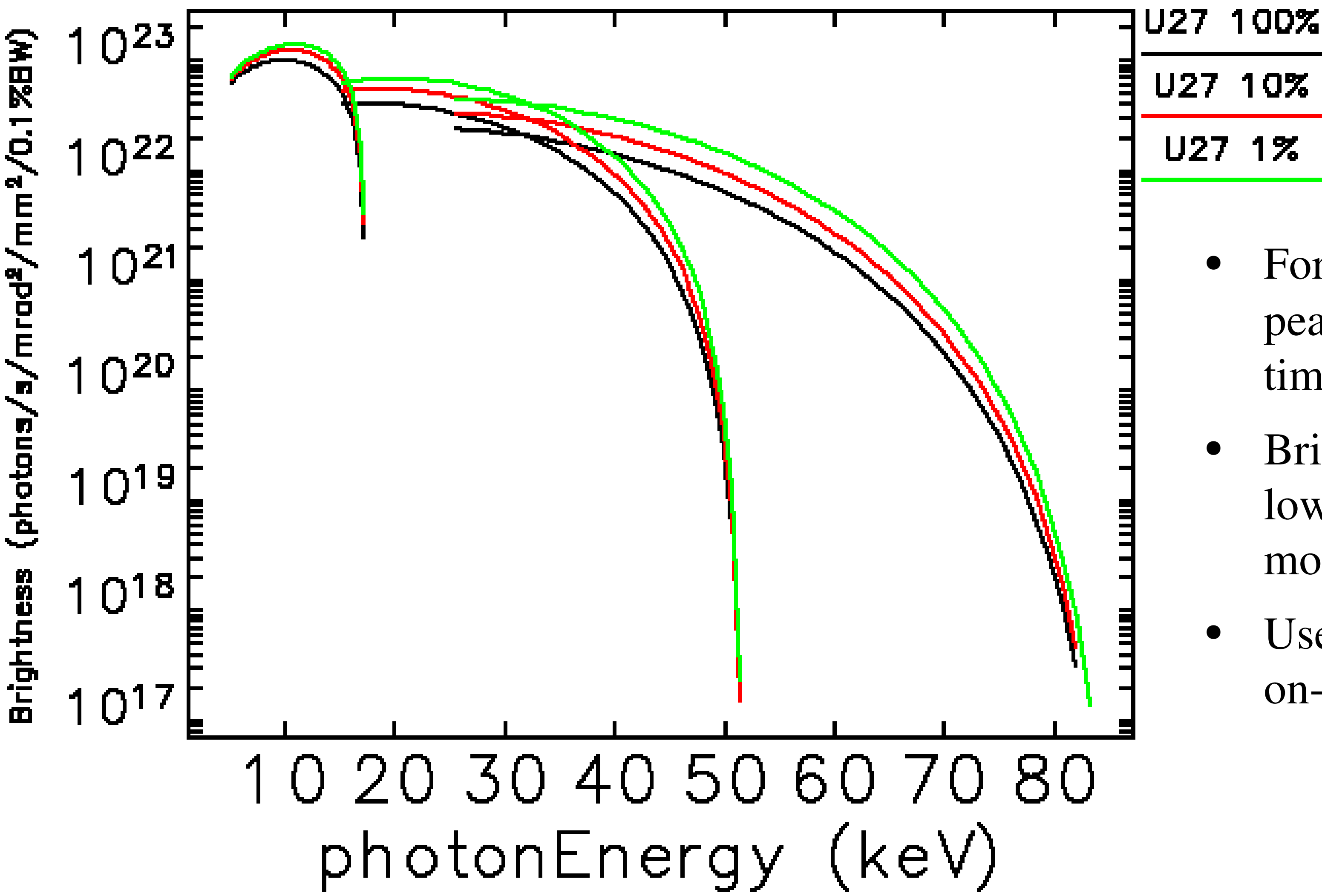


+/-2% momentum aperture *assumed*

Includes bunch lengthening and IBS

Using *haissinski* and *ibsEmittance* (L. Emery) and *beamLifetimeCalc* (M. Borland)

XPS7 Brightness at 1A in 1000 Bunches



- For 100% coupling, peak is 1×10^{23}, ~1500 times present
- Brightness gain from low coupling is modest
- Use 100% coupling, on-axis injection

Using *sddsbrightness* (H. Shang, R. Dejus)

Top-up Interval

- Top-up interval requirement set by regulation requirement

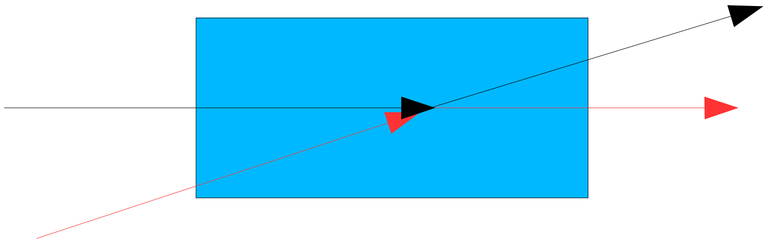
$$\Delta T_{inj} = \tau \frac{\Delta I}{I}$$

- Presently APS has ~1% regulation
  - 1 hour lifetime implies injection every 36s
  - 0.1 hour lifetime implies injection every 4s
- APS now tops-up every 120s
- “Most” APS users don't see any ill effects from top-up event

Conventional Injection

- In present rings, injection involves accumulation of multiple shots in each rf bucket
  - Modest charge/bunch requirement for injector
- Liouville's theorem requires that we inject off-axis in order to accumulate
  - New particles have residual betatron oscillation and must damp to closed orbit
  - Requires low coupling if vertical aperture<<horizontal
  - Need large dynamic aperture compared to the stored beam dimensions
    - APS DA is $25\sigma_x$

On-Axis Injection



- Don't accumulate:
  - New beam kicked in
  - Old beam kicked out and transported to dump
- Compatible with full coupling and poor DA
- Kicker technology is a prime consideration
  - Injecting into individual buckets requires very fast kickers
    - APS bucket spacing is 2.8 ns
    - Kicker rise/fall times better than 20ns are hard
  - Injecting long trains requires a long flat-top

Few-bucket filling with on-axis injection

- APS has a standard 24-bucket fill
  - 150 ns spacing
- At 1A, need ~40 mA/bunch
  - 0.05 hour lifetime (3 min)
- For 1% current stability
  - Replace a bunch every 1.8 s
  - Need 67 nA and 120 nC/bunch (!) from injector
- Each bunch is kept for 43 s
  - 80% left when dumped
  - Dump power is 470 W

On-axis One-Shot Filling

- Fill the whole ring at once with a complete pulse train
  - Previous fill is extracted at the same time and dumped
  - Only way to fill a large number of buckets
  - Could also support very flexible fill pattern
- For 1 A and 1000 bunches
  - 84 ns for kicker rise+fall
  - 0.6 hour lifetime
- For 1% regulation
  - Replace beam every 22 s
  - 1.2 kW dump power
  - 170 nA and 3.7 nC/bunch from injector

Conclusion

- XPS7 concept looks promising
  - For 1A beam current, 12m device gives 1500 times present APS brightness
- However, significant issues remain
  - Obtain adequate dynamic and momentum aperture
  - Evaluate magnet feasibility
  - May need to back off from minimum emittance
- Novel operating method utilizes rapid replacement of depleted bunches
- Few-bunch mode requires high charge/bunch injector