The MAX IV 3 GeV Storage Ring

Multibend Achromats for Ultralow Emittance

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Where is MAX-lab? What is MAX-lab?

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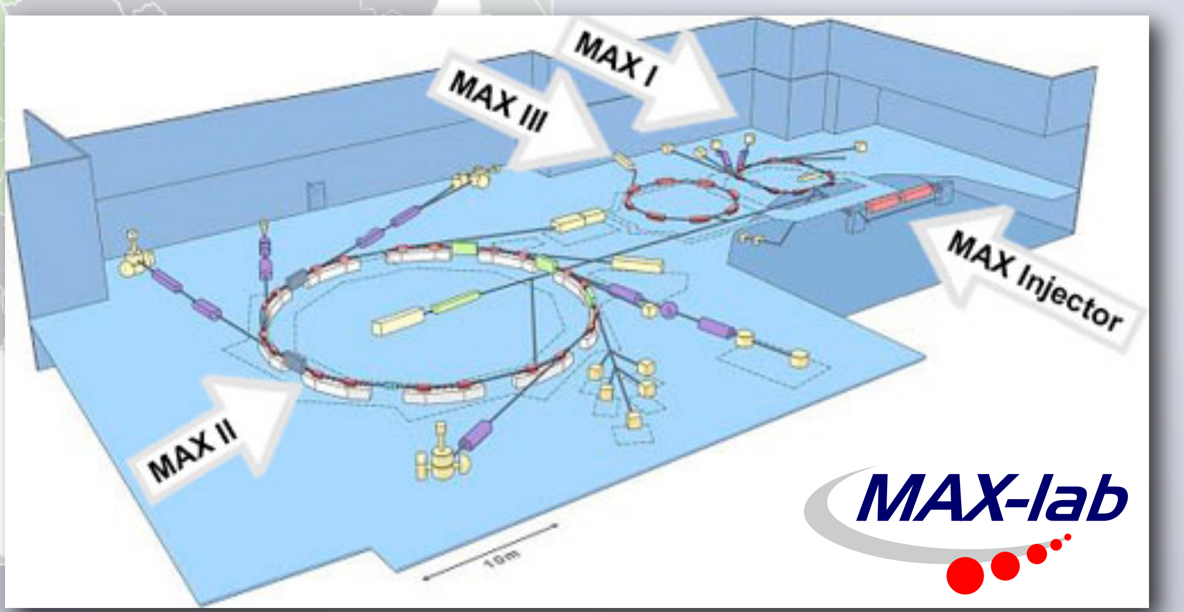
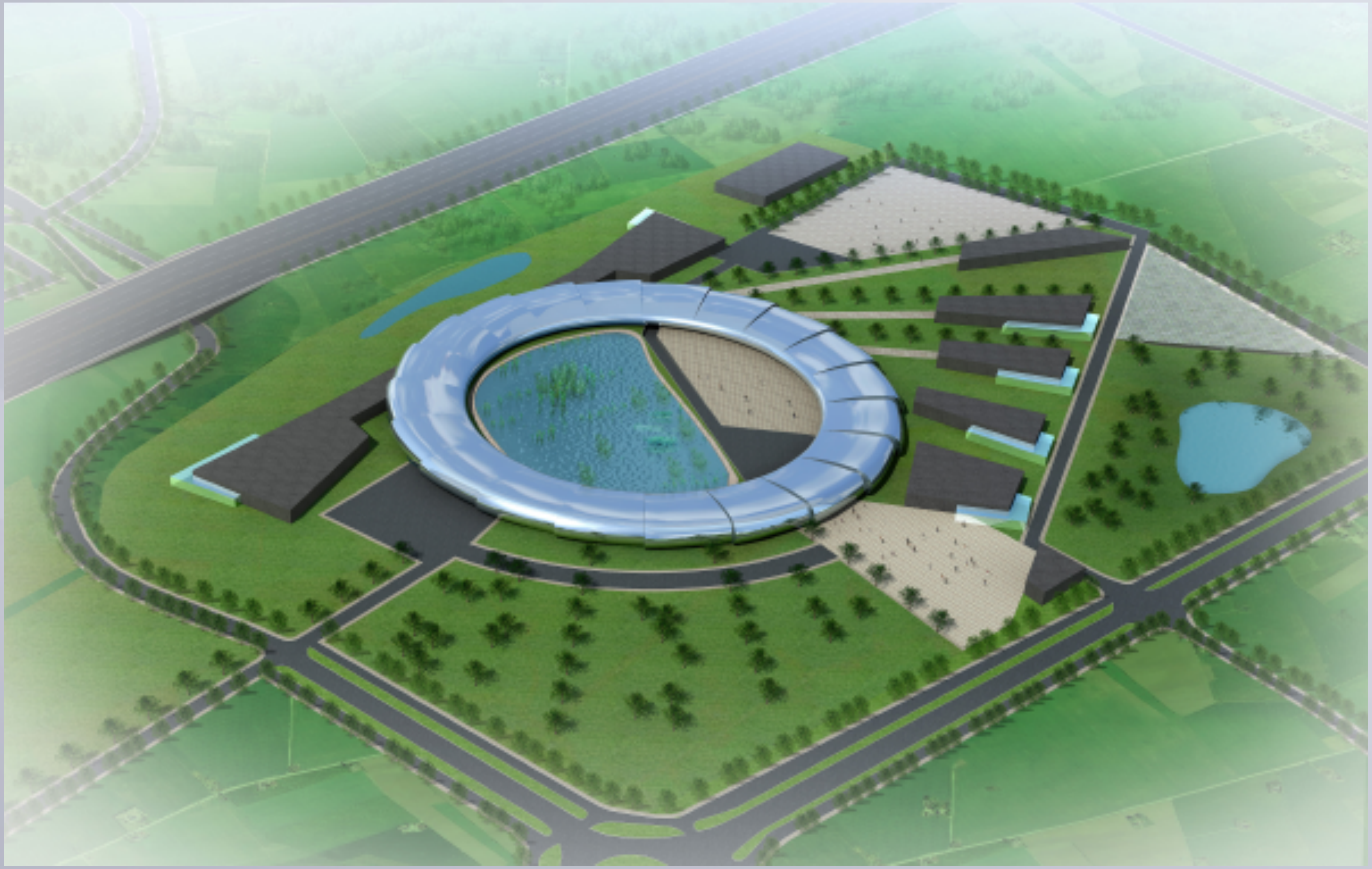
MAX I : 550 MeV, 1986
MAX II: 1.5 GeV, 1996
MAX III: 700 MeV, 2007
MAX-FEL: 133nm, 2009



MAX IV will become the new MAX-lab

- New site, replacement for present MAX-lab and MAX I, II, III rings
- Funding granted April 2009, construction starts mid 2010, commissioning of the 3 GeV storage ring in 2014, user operation 2015



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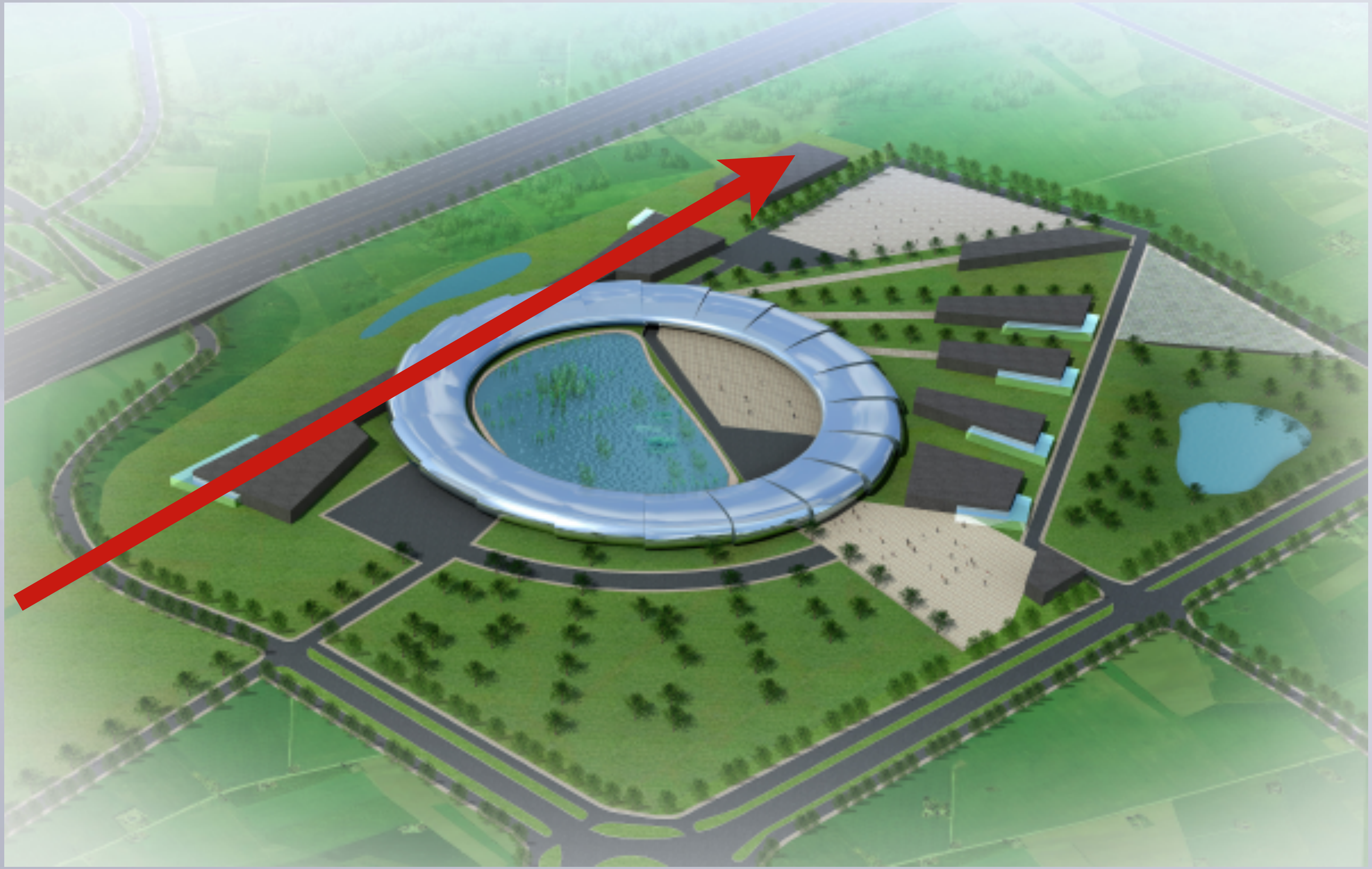

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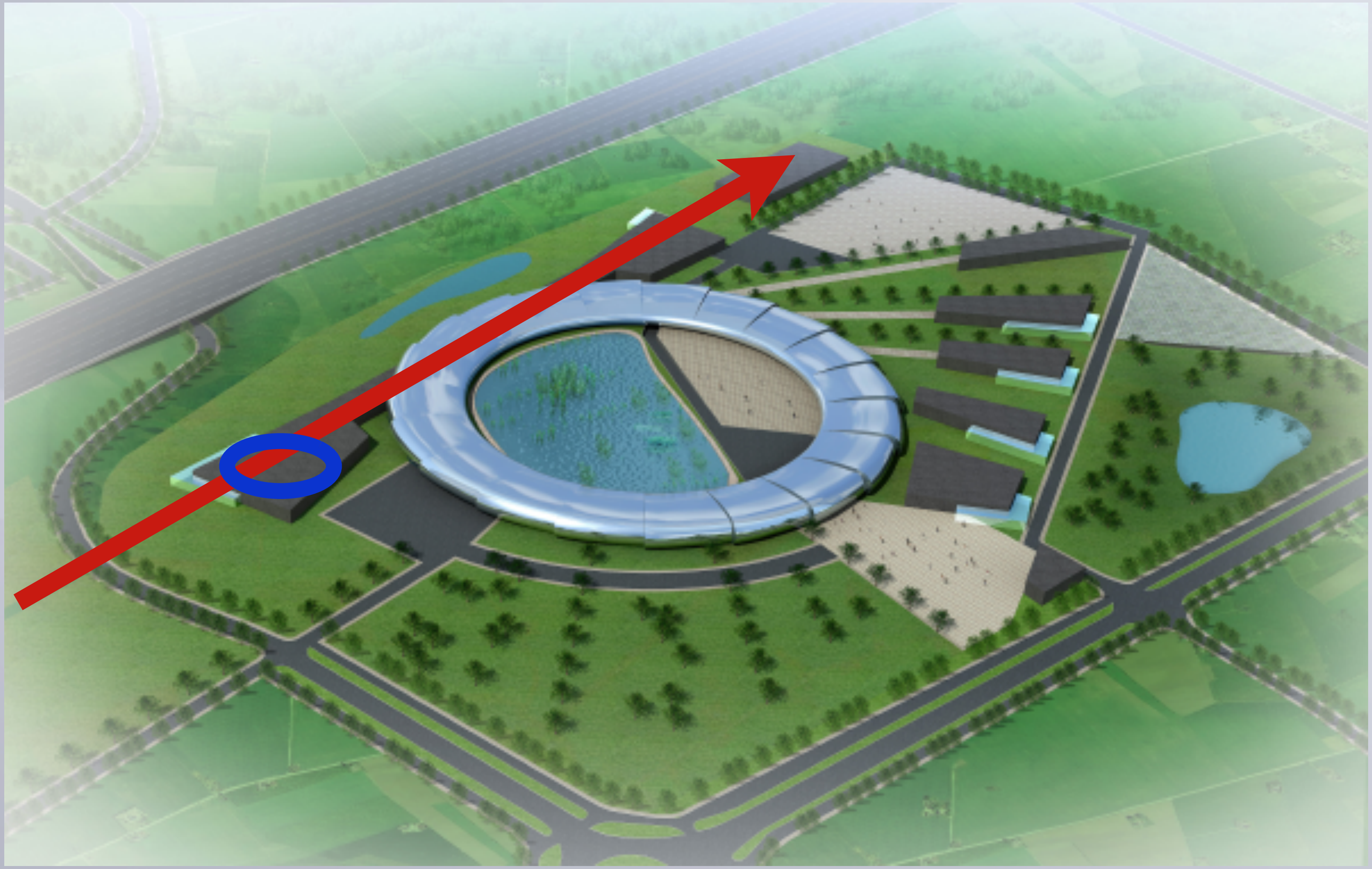
- 1.5 GeV SR
  (IR/UV)
  12 DBAs
  $\varepsilon_x = 6$ nm rad



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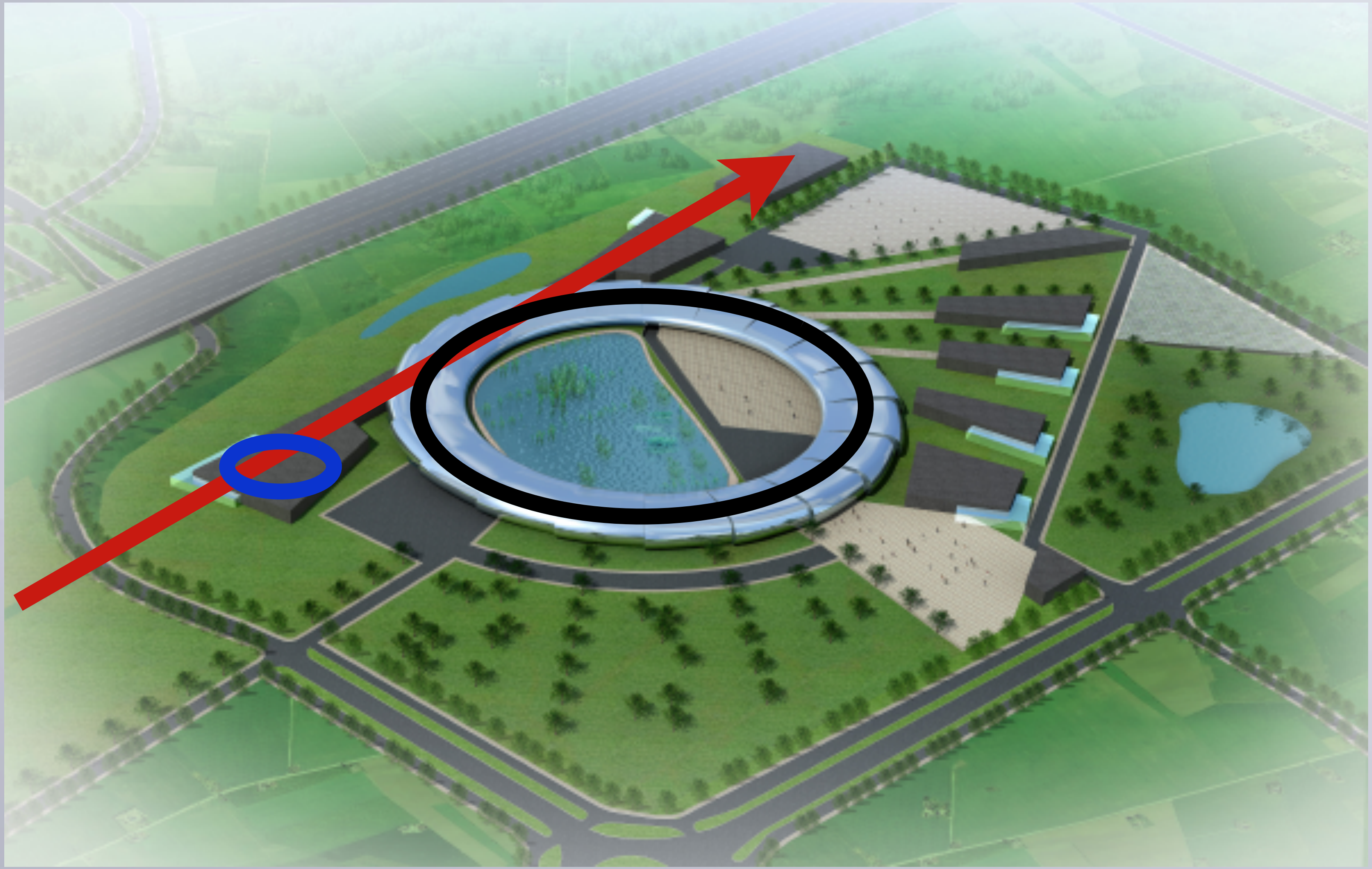
- 3 GeV SR
  (X-ray)
  20 MBAs
  $\varepsilon_x < 0.3$ nm rad



Multibend Achromats for Ultralow Emittance

- Originated in the damping ring community
  - → simple (many unit cells, high periodicity)
  - → robust (relaxed optics, error tolerance)

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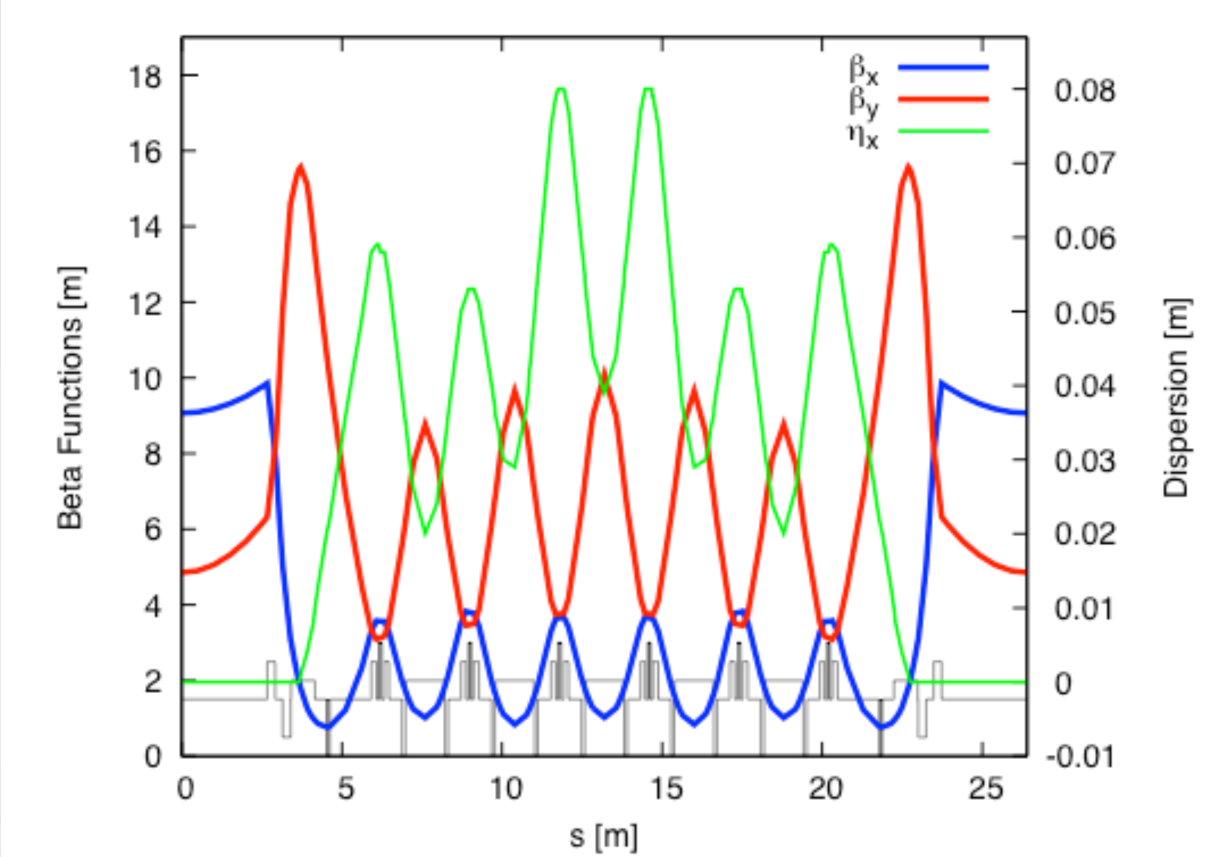
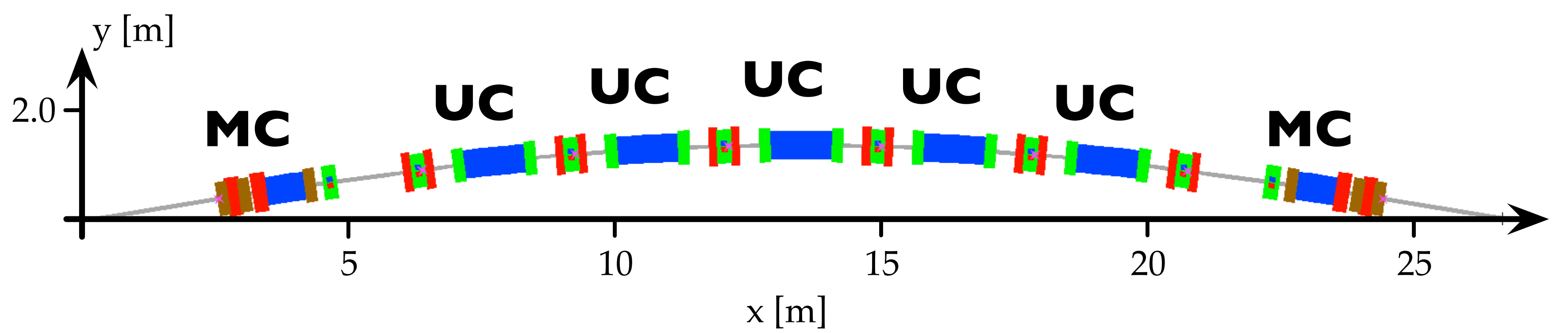
- Several iterations at MAX-lab
  - NIM A **508** (2003) 480 → 3 GeV (285 m), 12 MBAs, ε_x = 1.2 nm rad
    combined-function magnets, narrow apertures, integrated magnet design
  - PAC '07 → 3.0/1.5 GeV rings stacked, 2x12 MBAs, ε_x = 0.83 / 0.4 nm rad
    replace MAX II with new ring, stacking possible because of magnet integration → **CDR**
  - PRST-AB **12** 120701 (2009) → 3 GeV, 528 m, 20 MBAs, ε_x < 0.3 nm rad
    gradient dipoles, discrete sexts/octs, fully integrated magnet design, build new 1.5 GeV ring to replace MAX II and MAX III → **re-evaluated, approved, and funded**

MAX IV Multibend Achromat Lattice

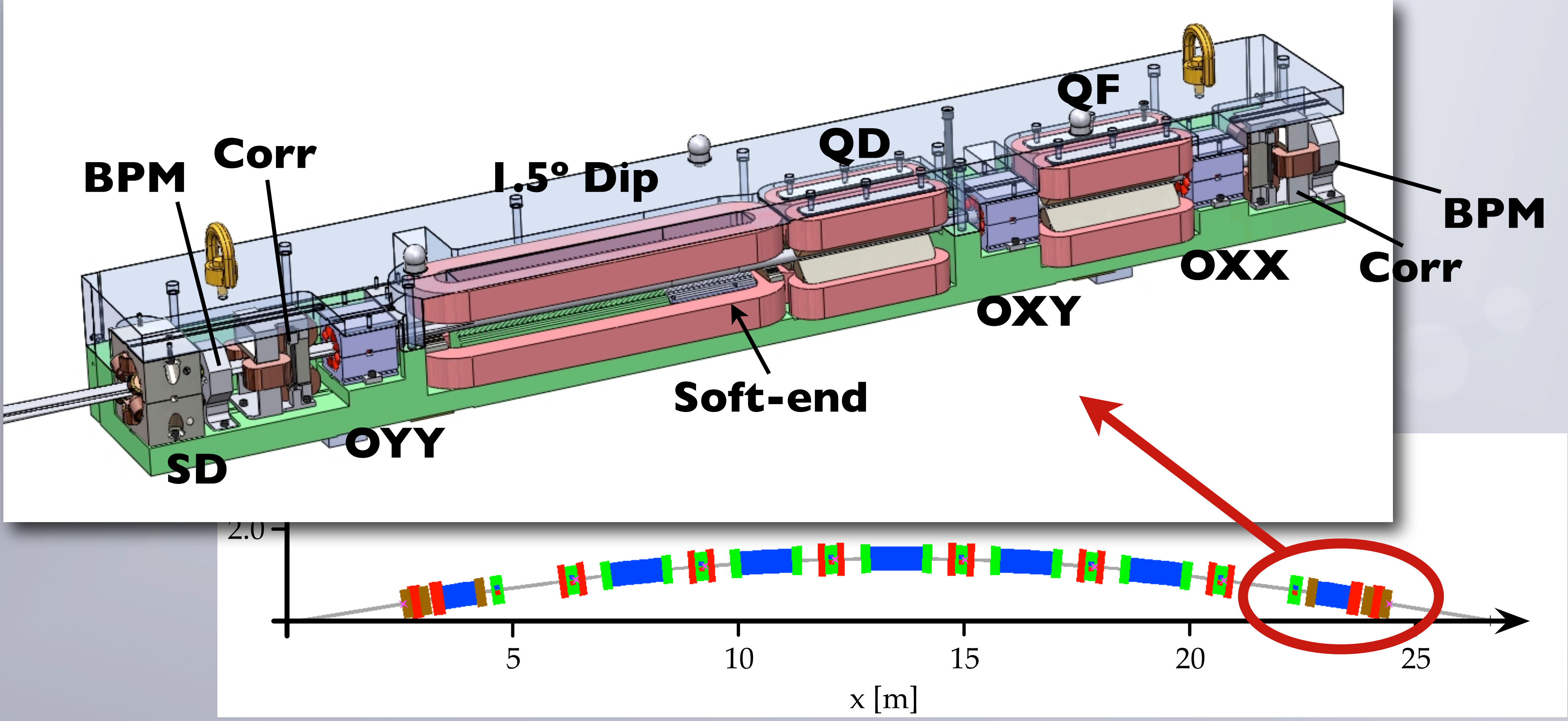
- 20 MBAs → 19 ID straights
- 5 unit cells, 2 matching cells
- 5 m long straight sections
- 1.3m short straights (→RF)
- Gradient dipoles
  - 3° bends in UCs (~ 0.5 T)
  - 1.5° soft-end bends in MCs
- Quads, sextupoles, octupoles
- η_{max} = 8 cm, $\sigma_y^* < 6$ µm
- ν_x = 42.20, ν_y = 14.28
- nat. ξ_x = – 50, ξ_y = – 44





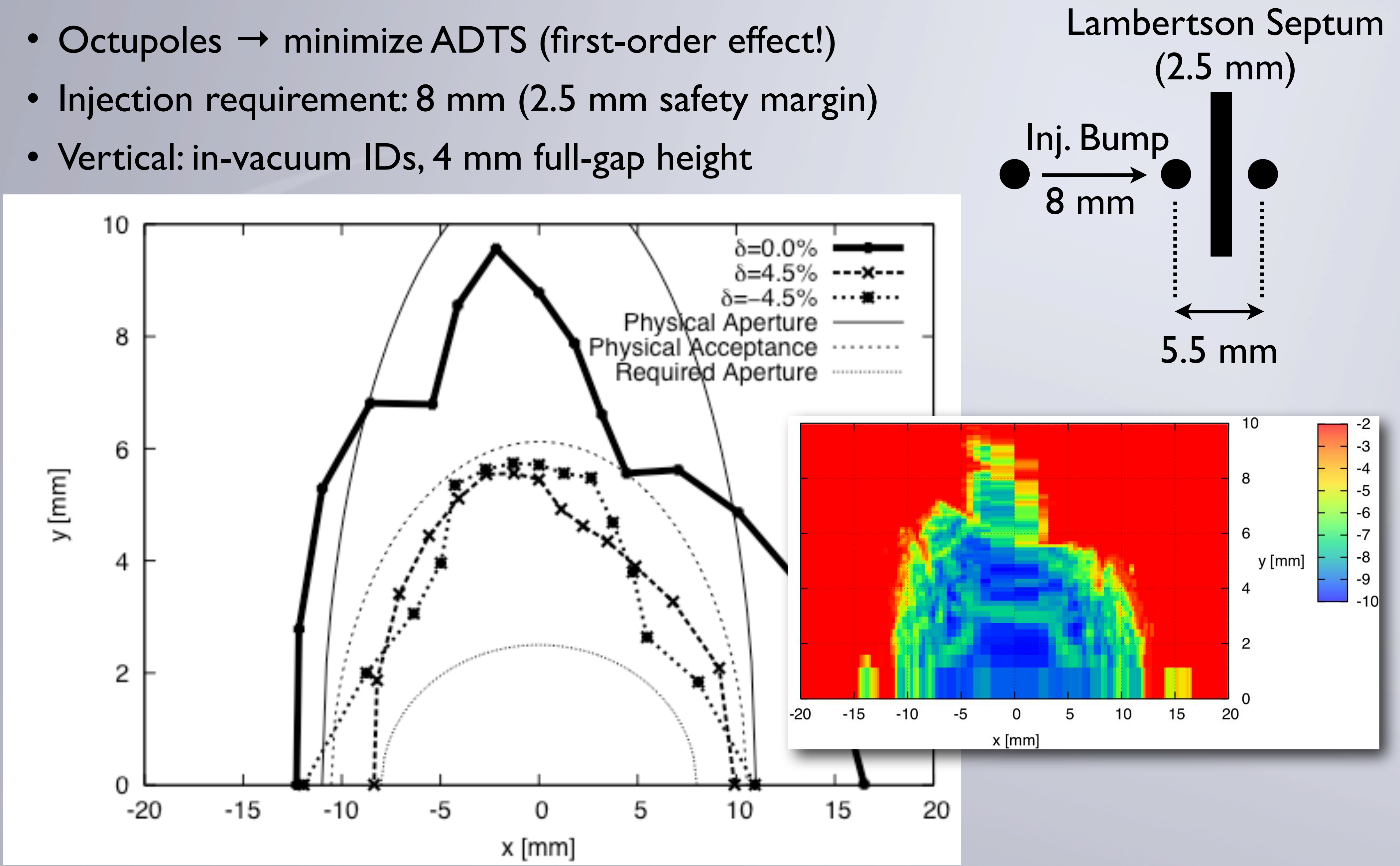
Integrated Magnet Design

- Compact MBA optics → highly-integrated magnet design
- Each unit cell and matching cell is machined from two solid blocks of iron (demonstrated at MAX III → NIM A **601** (2009) 229)
- Machining precision → excellent alignment (small beam size → tolerances!)



Dynamic Aperture

- Octupoles → minimize ADTS (first-order effect!)
- Injection requirement: 8 mm (2.5 mm safety margin)
- Vertical: in-vacuum IDs, 4 mm full-gap height



Lambertson Septum
(2.5 mm)

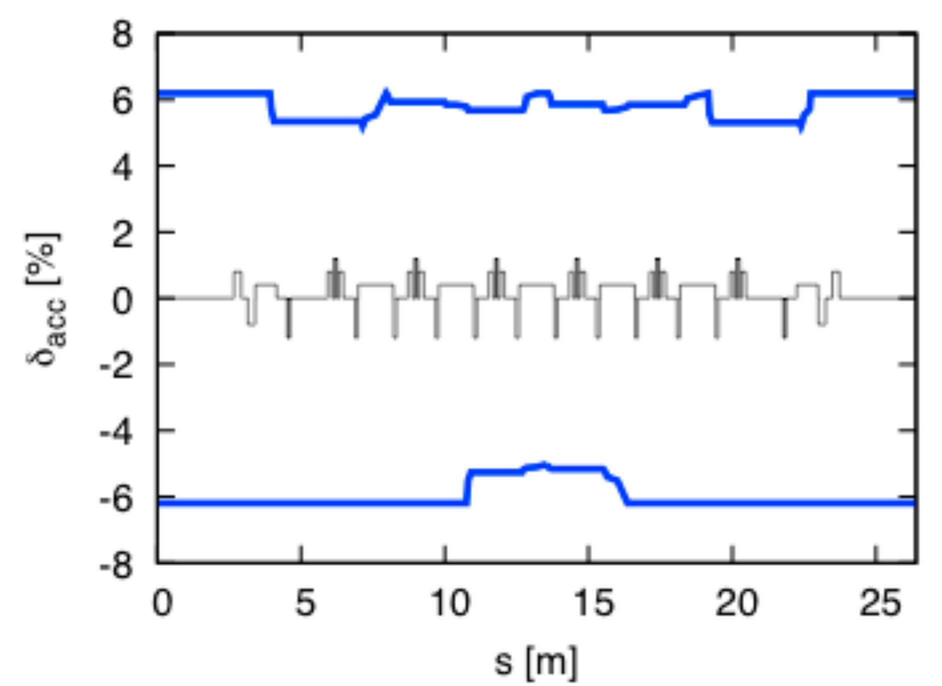
Inj. Bump

8 mm

5.5 mm

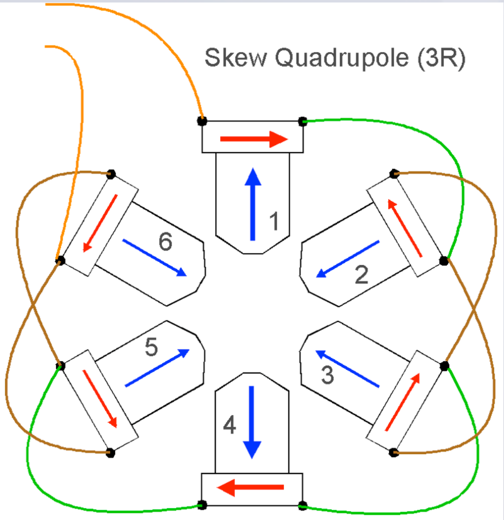
Momentum Acceptance and Lifetime

- Sextupole chromatic correction + 100 MHz RF system
  → Small chromatic tune footprint
  → FMA: stop bands > 6%
  → 6D tracking: lattice MA > 4.5%
  → Excellent overall MA



- "Worst case" scenario: assume RF MA at 4%
  → Touschek lifetime 26h (low ε!)
  → Total lifetime >10h

- Further improve lifetime? → coupling control
  - beam-based BPM calibration to sextupole centers
  - corrector-based realignment of magnet cells as demonstrated at MAX III (NIM A **597** (2008) 170)
  - secondary windings: aux. sextupoles, skew quadrupoles
  → drive vertical dispersion bumps



A. Streun (SLS)

Emittance and IBS

- MAX IV 3 GeV SR is IBS-limited!
- Damping wigglers reduce emittance (B = 2.22 T, λ = 80 mm, L = 2 m)
- DWs also increase energy spread → reduce IBS contribution to ε
- Landau Cavities → increase Touschek lifetime & reduce IBS contribution to ε

	ε_x [nm rad]	
	Without IBS	With IBS
Bare lattice	0.326	0.453
Bare lattice with LC	0.326	0.372
Lattice with four PMDWs and LC	0.263	0.297
Lattice with four PMDWs, ten IVUs, and LC	0.201	0.231