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APSx3 Lattice Design

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U.S. DEPARTMENT OF ENERGY

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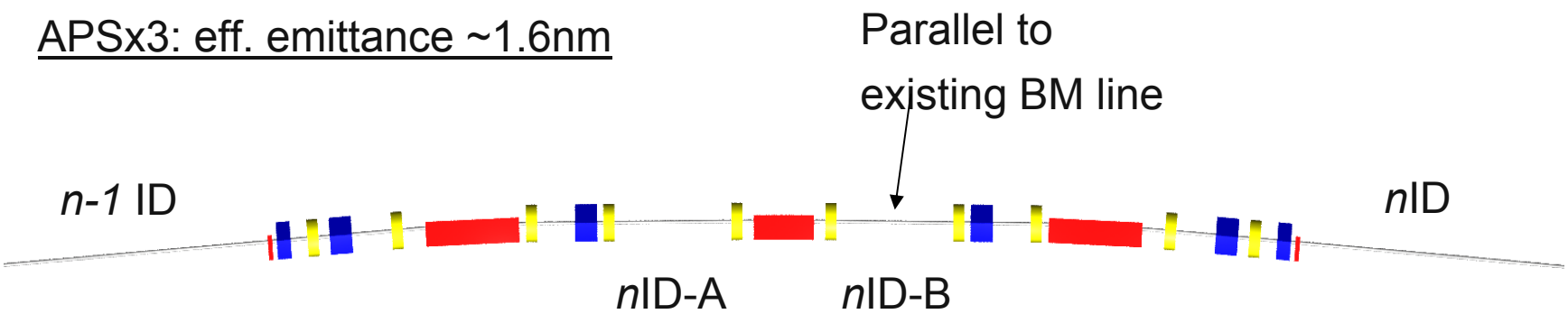
Sector layout

- Offers three times as many ID beamlines – one long and 2 short IDs per sector
  - Offers increased length for main ID straight section – 8 m available for ID (compared to 5 m presently)
  - Offers two 2.1-m long straight sections (about 1 m available for ID), one is parallel to present BM beamline
- Could provide a three-pole wiggler for beamlines that still want bending-magnet-like source

APSx3: eff. emittance ~1.6nm



2.1m magnet-to-magnet in new straight sections.

Figure is courtesy of L. Emery

Beta functions

- Lattice is triple-bend achromat, bending angles are chosen to make second short ID parallel to the present BM beamline
- Lattice has 6 quadrupoles and 10 sextupoles

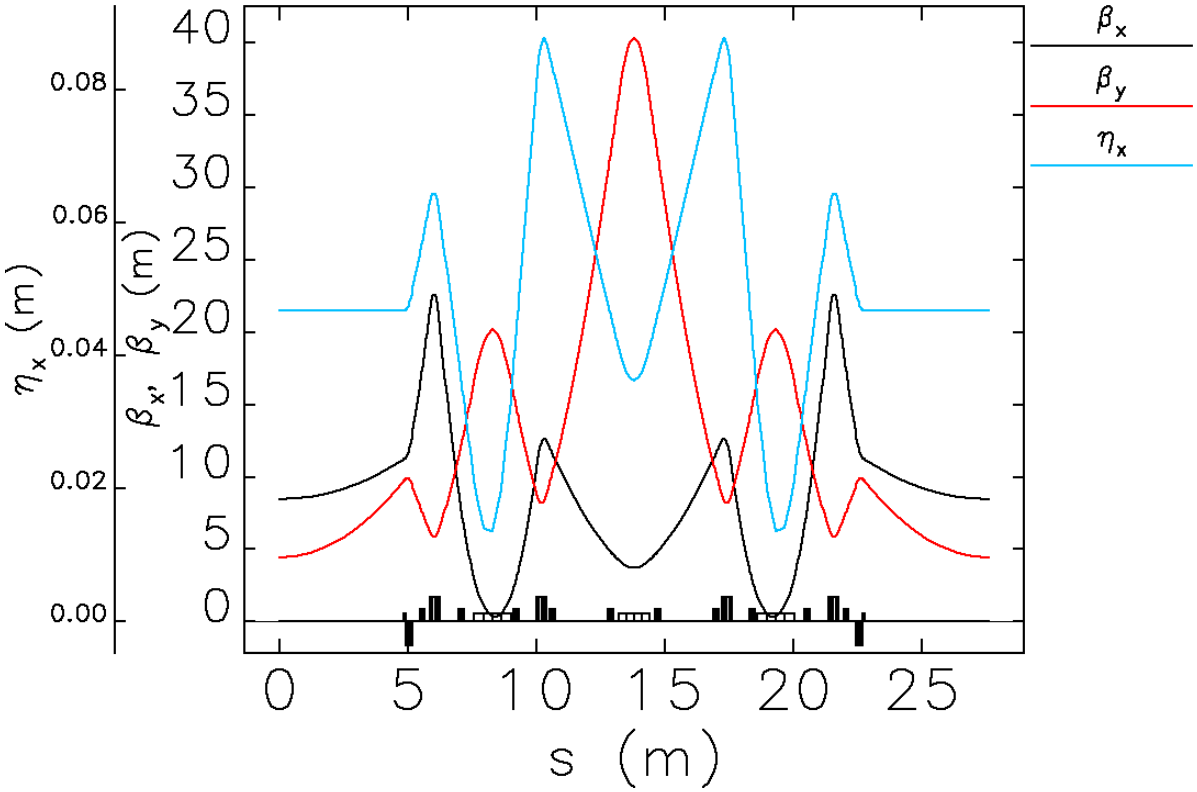


Table of parameters

	APSx3	APS
Energy (GeV)	7	7
Emittance (nm rad)	1.44	2.51
Effective emittance (nm rad)	1.67	3.1
Betatron tune X	50.11	36.20
Betatron tune Y	19.44	19.26
Chromaticity X	-129	-92
Chromaticity Y	-62	-45
Energy spread	1.41×10^{-3}	0.96×10^{-3}
Energy loss per turn (MeV)	9.1	5.4
Momentum compaction	1.19×10^{-4}	2.81×10^{-4}

Magnets

Bending magnets

	L (m)	Angle (mrad)	B (T)	K1 (1/m^2)	G (T/m)
B0	1.427	67.847	1.11	-0.370	-8.64
B1	1.225	19.385	0.37	-0.289	-6.75

Quadrupoles

	L (m)	K1 (1/m^2)	G (T/m)
QI1	0.25	-1.545	-36.1
QI2	0.40	1.942	45.3
QDF	0.40	1.860	43.4

Sextupoles

	L (m)	K2 (1/m^3)	G (T/m^2)
S1	0.2	57.4	1340
S2	0.2	-67.2	-1569
SE	0.2	-106.9	-2496
SF	0.2	89.3	2085
SD	0.2	-35.4	827

DA requirements

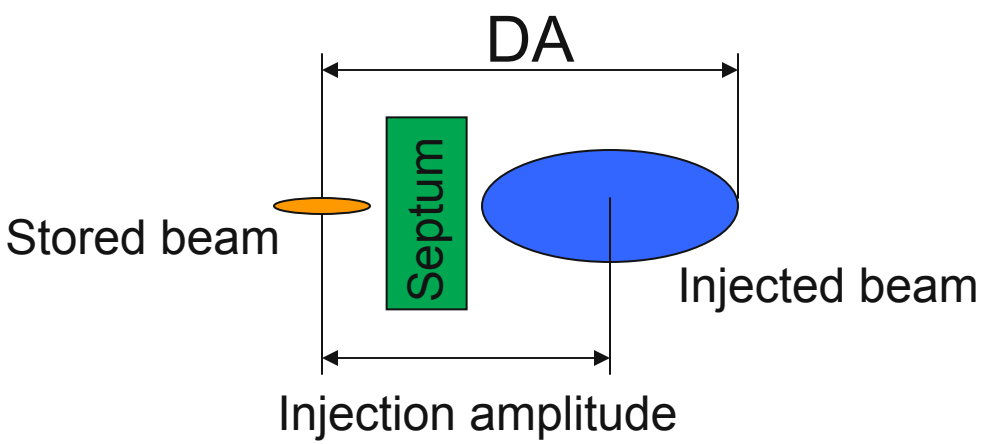
- Booster emittance is assumed to be 30 nm rad (about one half of the present value)

- Required dynamic aperture for injection:

$$6\ \sigma_{inj} + 5\ \sigma_{stored} + 2\ mm\ (\text{septum}) + 0.5\ mm\ (\text{margin}) = 7.7\ mm$$

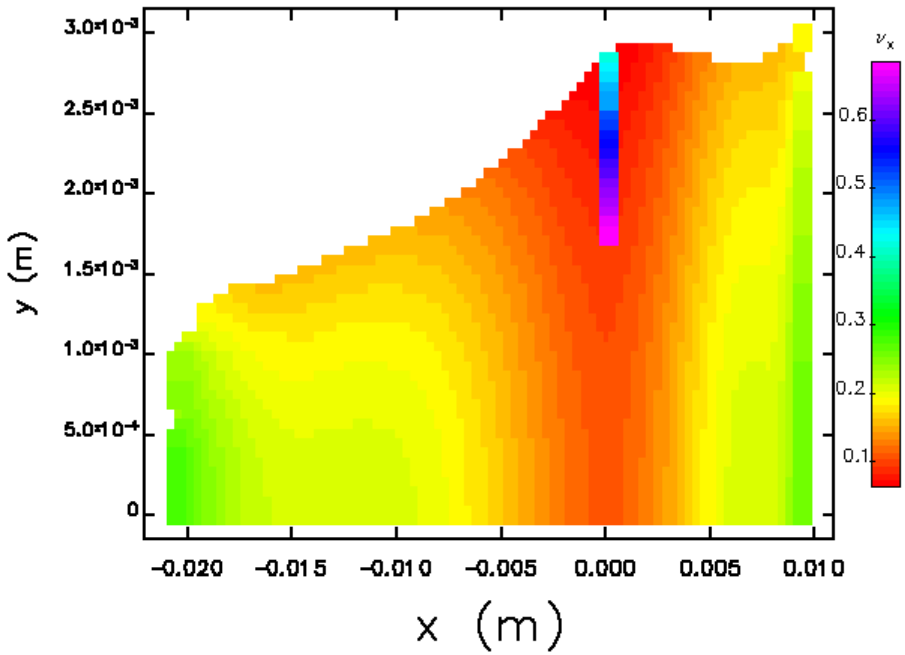
- Center of injected bunch – injection amplitude (for injection simulation):

$$3\ \sigma_{inj} + 5\ \sigma_{stored} + 2\ mm\ (\text{septum}) + 0.5\ mm\ (\text{margin}) = 5.4\ mm$$

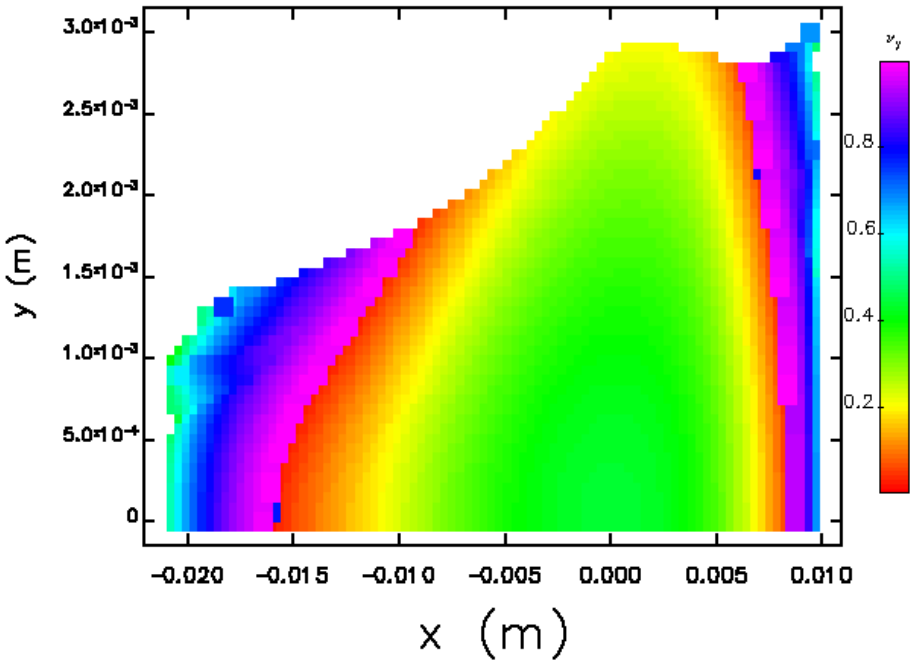


Dynamic aperture

- Due to very high sextupole strength, higher-order sextupole effects are important – simple minimization of main harmonics is not enough
- Due to very high symmetry, optimization of ideal lattice DA is pointless – errors are required to excite resonances (especially tilts)
- Three sextupole families are available for DA optimization; dynamic aperture was optimized using genetic optimization algorithm



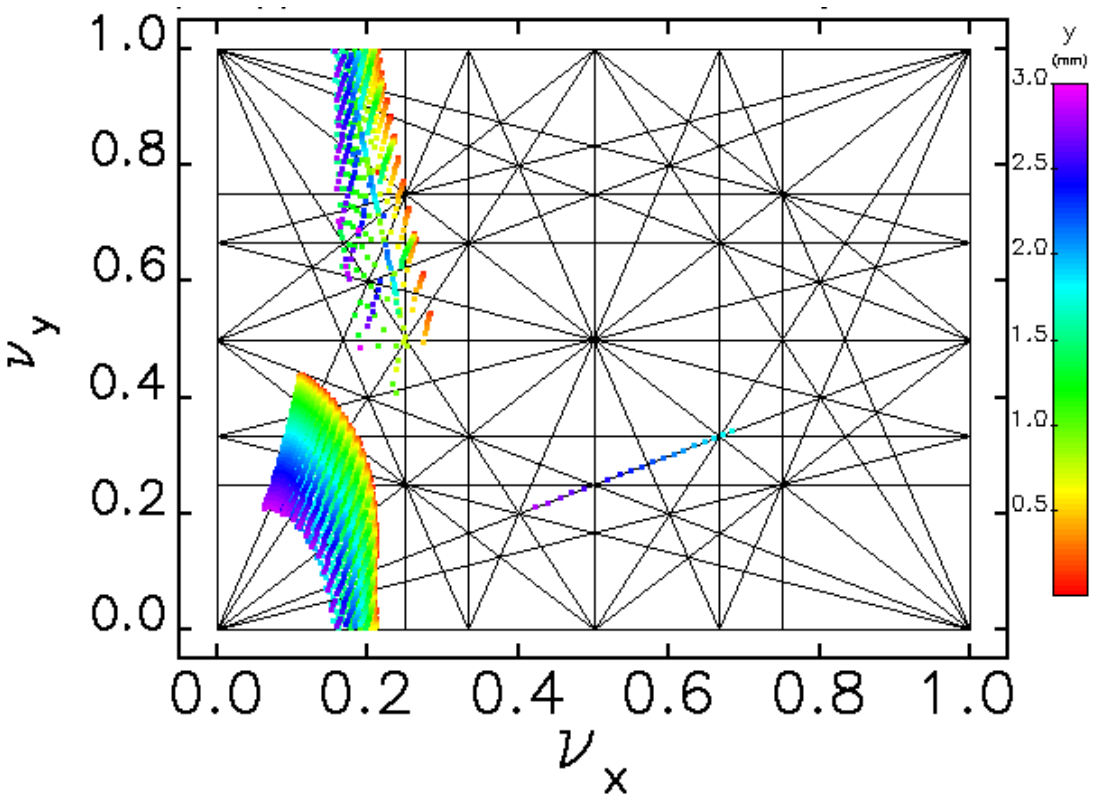
Color indicates x tune



Color indicates y tune

Tune shift with amplitude

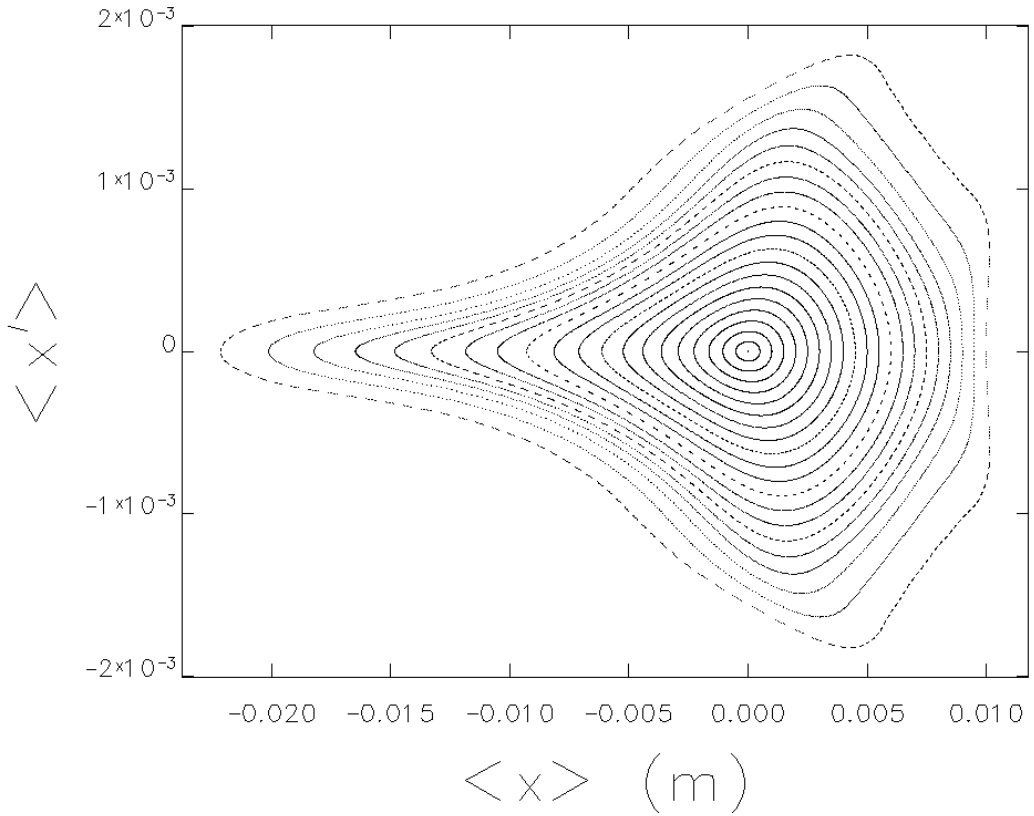
- Higher-order terms of tune shift with amplitude are large and impossible to suppress
- We don't expect particles beyond integer resonance to survive full-scale 6D tracking with synchrotron damping



Color indicates initial y amplitude

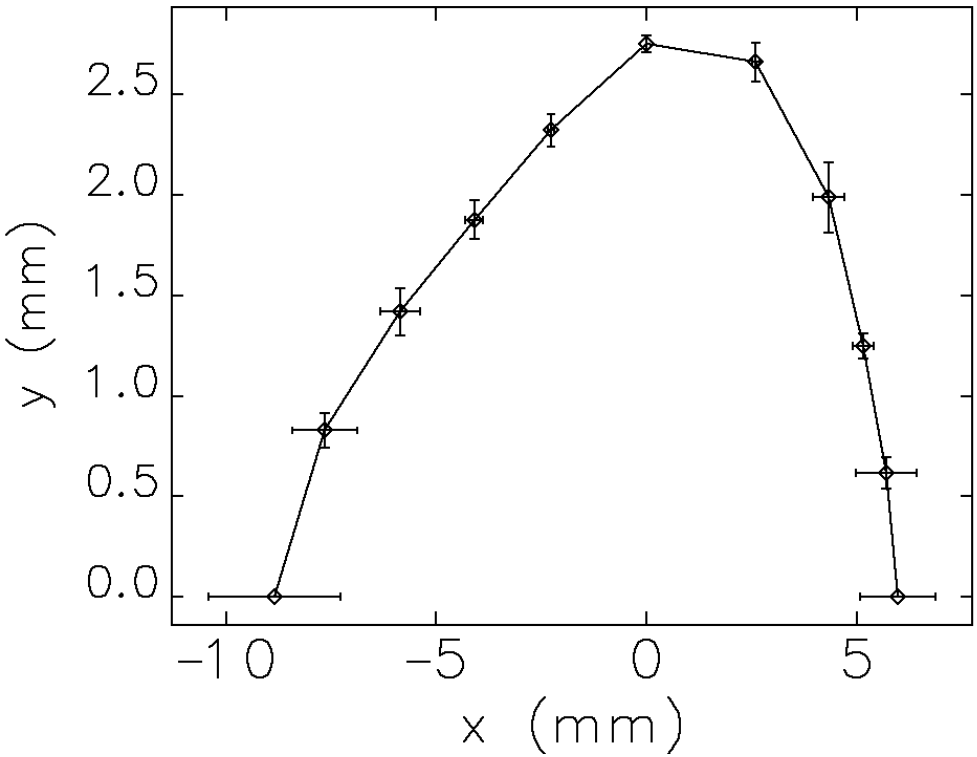
Horizontal phase space

- Phase space shape emphasizes strength of higher-order sextupole resonances



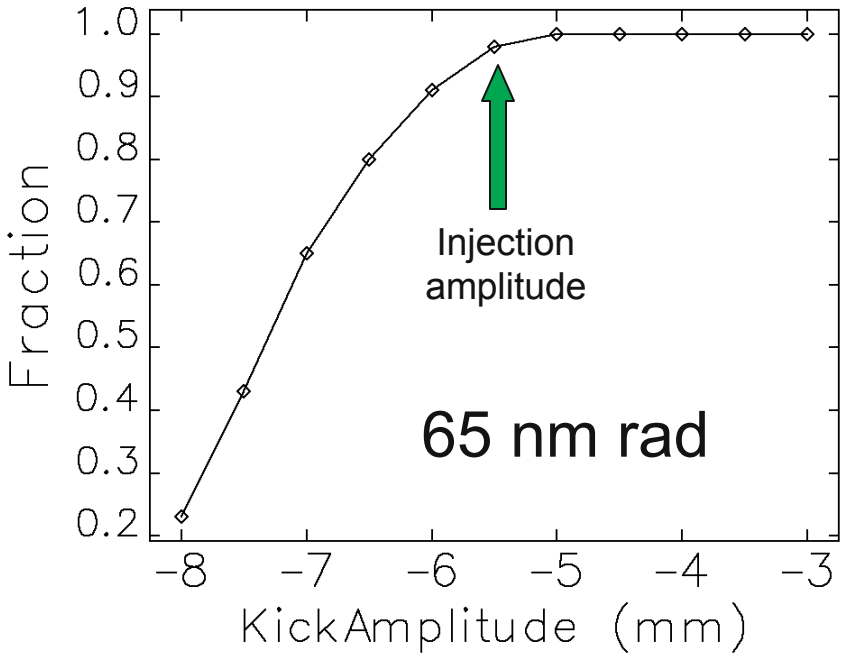
DA with errors

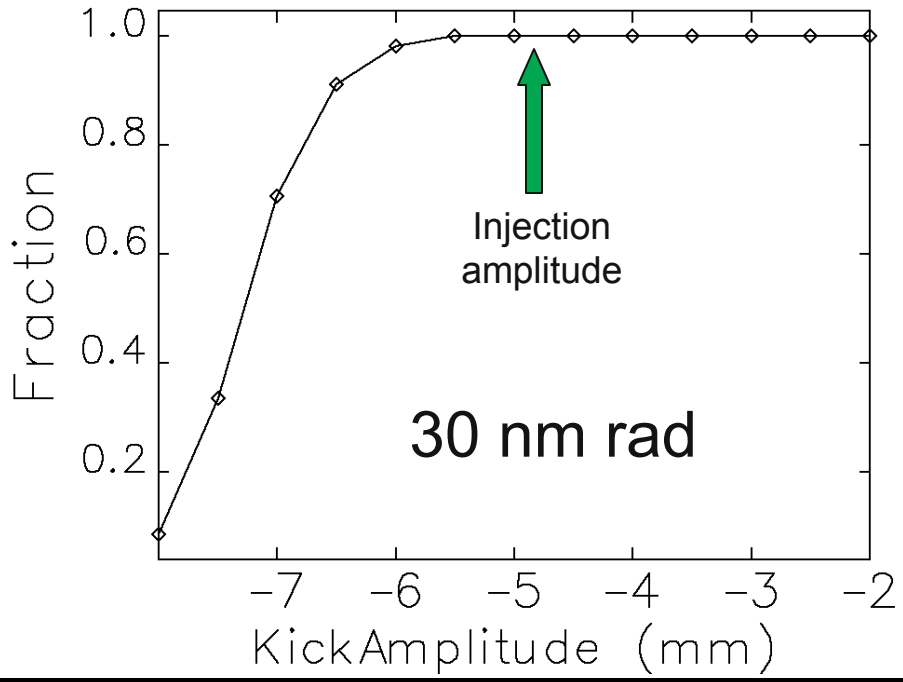
- Quadrupole fractional errors of 5×10^{-4} and tilts of 5×10^{-4} rad were used. This set of errors represents the level of symmetry breaking that is routinely achieved at APS after lattice and coupling correction (5% beta function beating)
- 50 different seeds were calculated



Injection simulation

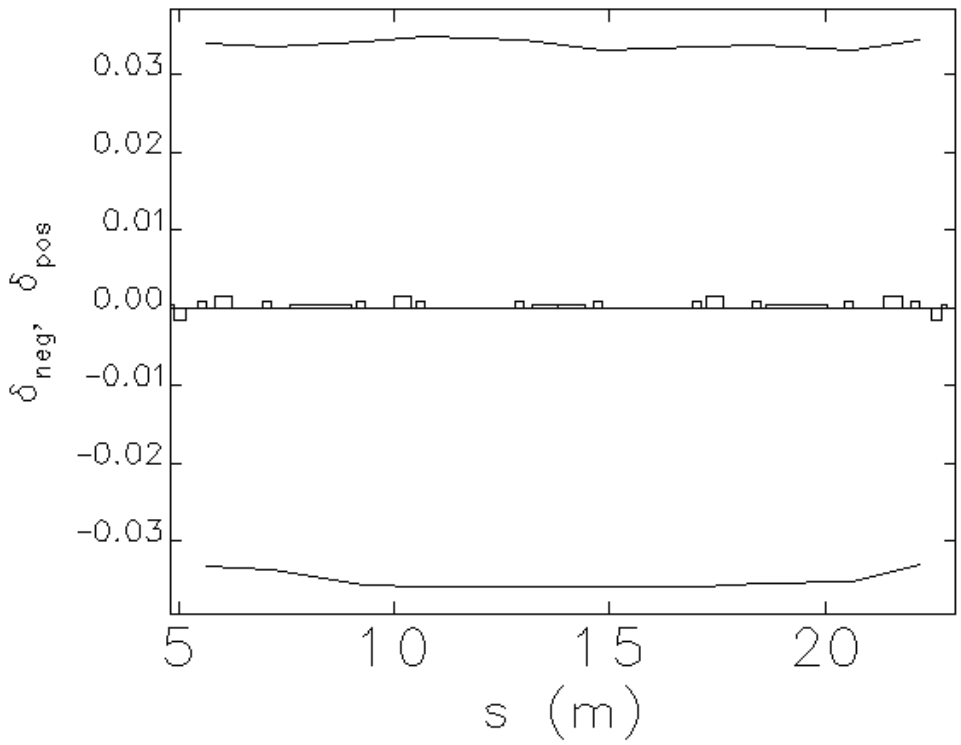
- Realistic 3-D gaussian bunch with 65 and 30 nm rad emittance and matched beta functions is used for tracking (1000 particles, 1000 turns)
- Injection is simulated as just initial deviation of the bunch – no kickers
- Lattice with errors is used (one seed only)
- No synchrotron radiation





Momentum DA

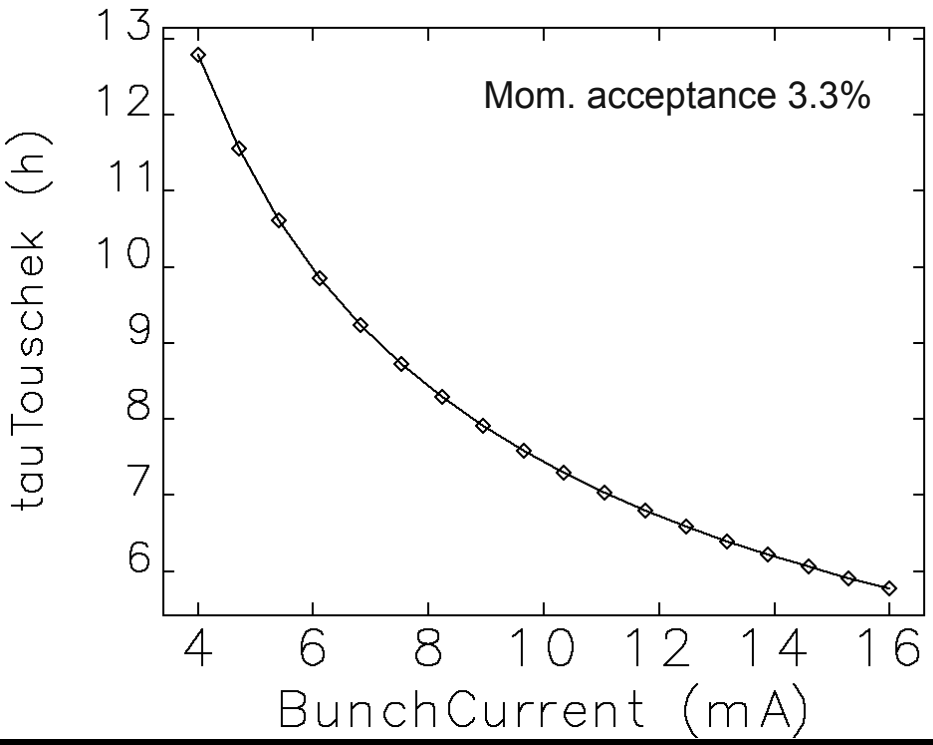
- Single particle tracking, momentum deviation only
- With RF cavity, without synchrotron radiation for simplicity
- Tracking starts from different locations along the lattice, momentum deviation is increased until the limit is found

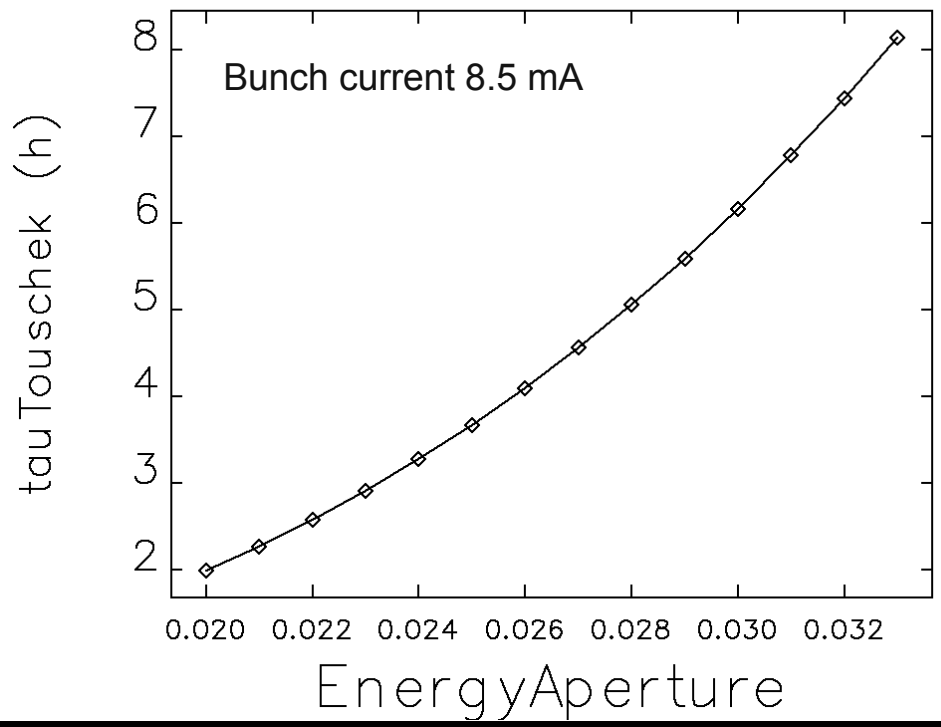


Momentum aperture search

Lifetime

- Lifetime is calculated using Haissinski equation
- Assumed coupling is 1%, RF voltage is 13 MV
- Bunch length is comparable to the present APS





Conclusions

- APSx3 lattice provides increased length for ID straight sections – from 5 m to 8 m
- APSx3 provides additional two 2-m long straight sections (for approx. 1-m long ID), one located at present BM beamline
- Improves beam emittance by a factor of 2

- Dynamic aperture suitable for injection can be achieved, however injection efficiency with the present booster might not be 100%
- Lifetime that is enough for topup can be achieved with low chromaticity