Third ILC Damping Rings R&D Mini-Workshop

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Choosing the Baseline Lattice for the Engineering Design Phase

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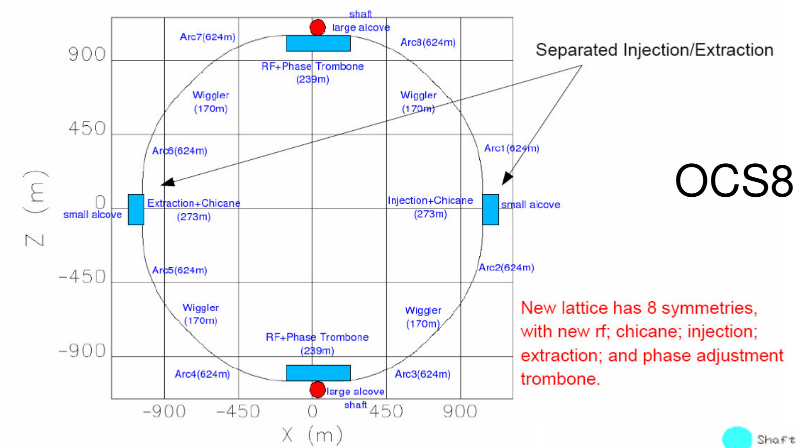
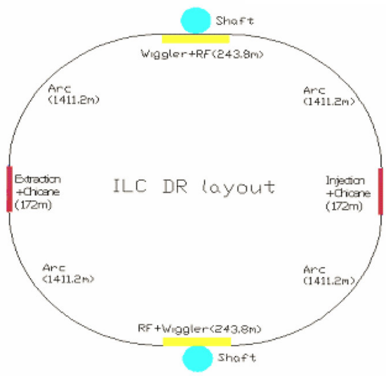
Damping rings lattice options



OCS8 (TME)

New lattice has 8 symmetries, with new rf; chicane; injection; extraction; and phase adjustment trombone.

FODO



4 arc sections.

4 straight sections, one for injection, one for extraction, and the other two for RF/wiggler.

Two shafts in all and no TL.

Beam is counter-rotating.

Why we need to make a choice…

Studies during the engineering design phase will explore in some detail issues related to cost and technical performance.

For these studies to proceed in a sensible manner, we need a "stable" lattice design setting fixed specifications for (e.g.):

- conventional facilities: circumference, layout, power, cooling…
- magnets
- vacuum
- rf

Some optimisation of the lattice is to be expected, but changes should happen for good reason, infrequently, and in a controlled manner.

Having an "alternative" lattice design to the baseline is allowed, and even desirable: but it is to be expected that the alternative will receive much less attention than the baseline.

Issues to consider in selecting a baseline

The selection of the baseline lattice should take into account issues related to:

- technical performance
- cost
- completeness and maturity

We don't have time for a complete, thorough evaluation…

… but we should have some discussion, and make the best decision that we can.

Both lattices have the same circumference: 6476.439 m

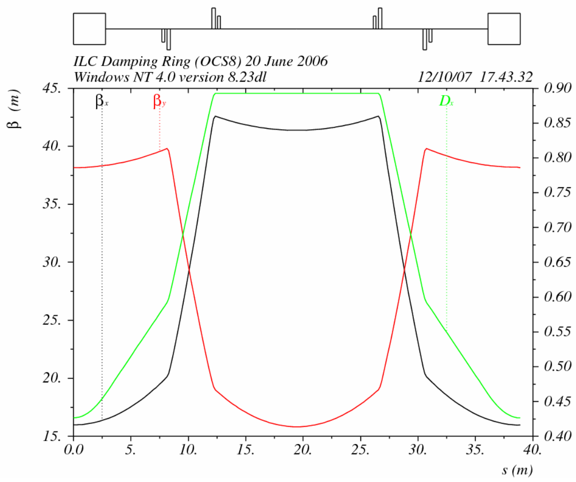
- Harmonic number 14042 set by need for timing flexibility.

Both lattices, it seems, can meet the specifications for:

- damping times (simply a question of wiggler…)
- equilibrium emittances (horizontal and longitudinal)
- "nominal" momentum compaction factor
- dynamic aperture

Arc cells

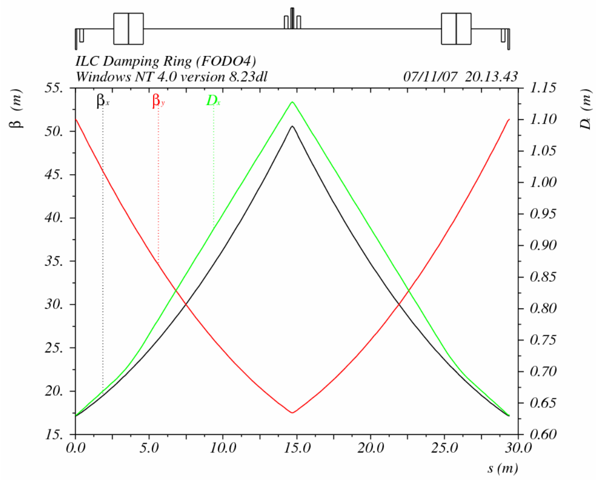
OCS8



120 arc cells with:

- 1 dipole (5.6 m, 0.16 T)
- 4 quadrupoles
- 4 sextupoles

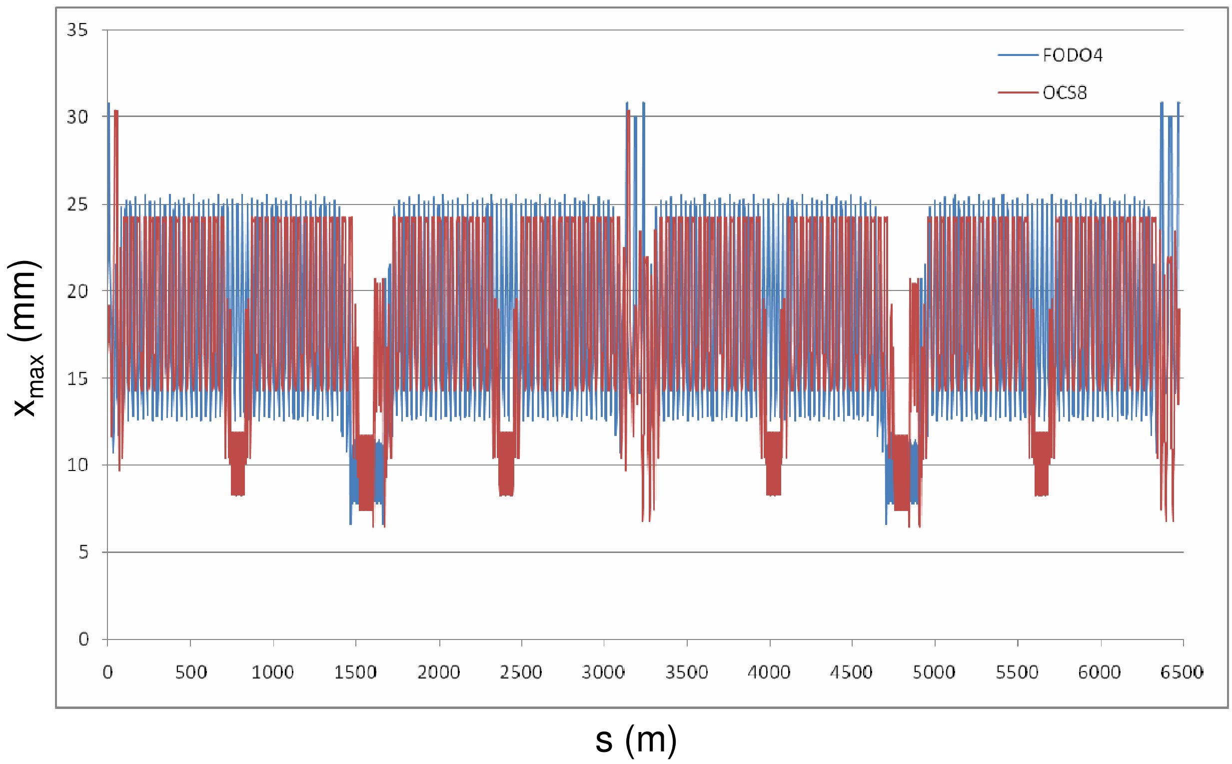
FODO4



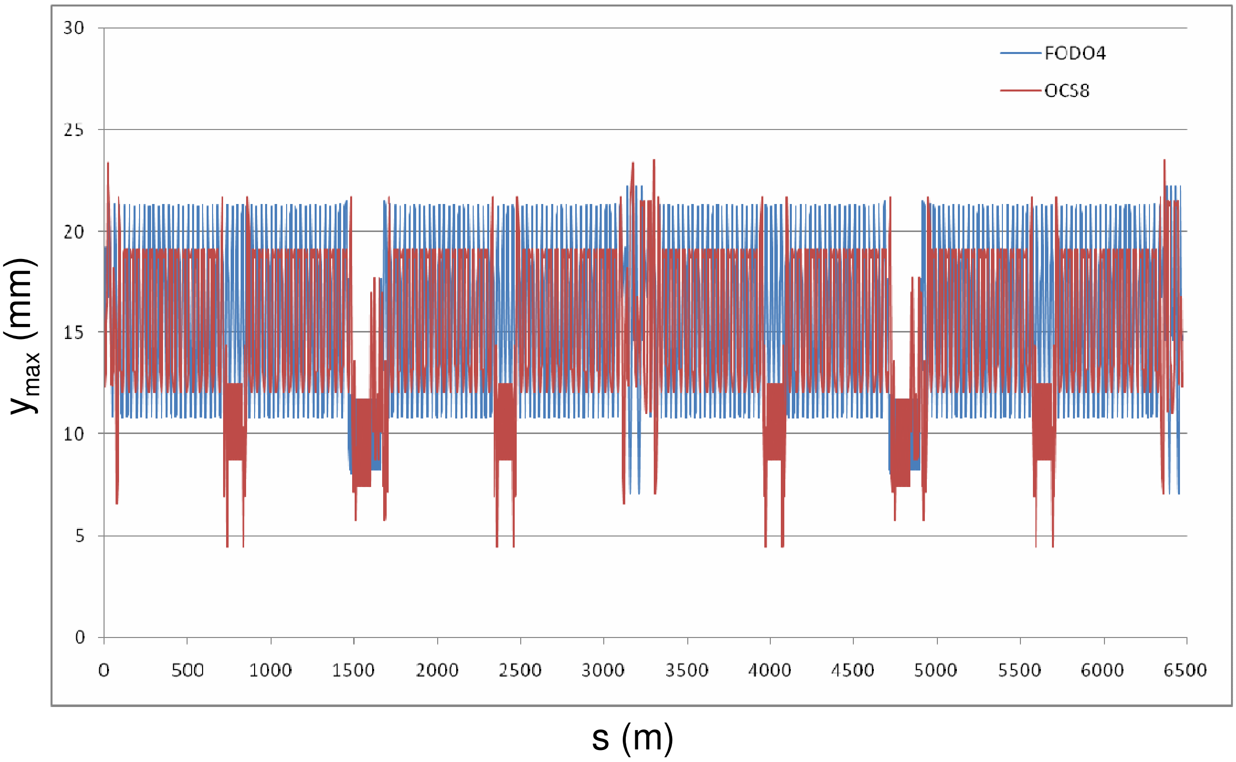
184 arc cells with:

- 2 dipole (2 m, 0.14 T)
- 2 quadrupoles
- 4 (or maybe 2) sextupoles

Horizontal aperture requirements



Vertical aperture requirements



Numbers of magnets

Magnet	OCS8	FODO4
dipoles	120×6 m + 16×3 m	368×2 m
arc quadrupoles	480	368
all quadrupoles	778 (0.3 m)	534 (0.1 m, 0.2 m and 0.3 m)
sextupoles	480	368 (can reduce to 184)

Momentum compaction factor

Specification is for a momentum compaction factor of 4×10^{-4}.

- Set by (crude) estimates of instability thresholds.

Tunability in momentum compaction factor is highly desirable.

- Reducing momentum compaction would allow reducing bunch length (beneficial for the bunch compressors) without additional rf – if instabilities permit.
- In case of difficulties with instabilities, momentum compaction factor could be increased to raise thresholds, albeit at cost of increased bunch length (compensated by additional rf?)

Tunability in momentum compaction factor is not so easy to achieve while meeting other constraints:

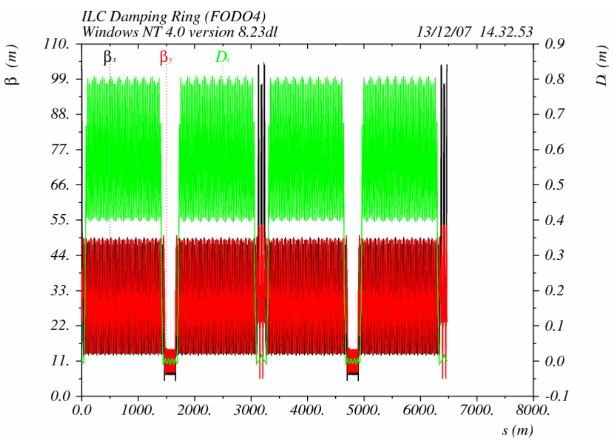
- Geometry must remain fixed, so no variation in dipole fields.
- Dispersion in the arcs must be varied, but the dispersion suppressors must still match the dispersion to zero in the straights (otherwise there will be large emittance blow-up from the wigglers).

FODO lattice has tunable momentum compaction factor, from 2×10^{-4} to 6×10^{-4}

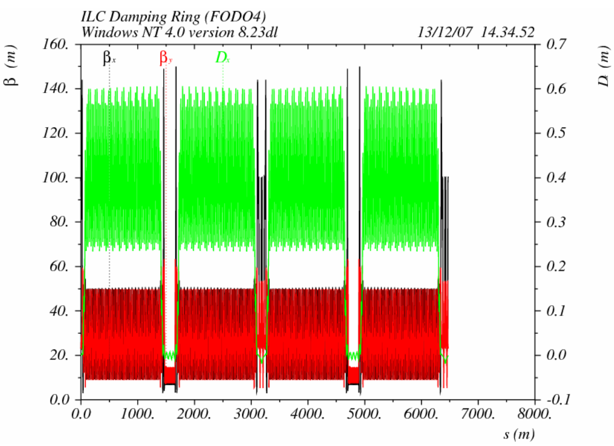
•but there is some adverse impact on the dynamics...

Tunability in FODO4 lattice (Yi-Peng Sun)

Phase advance/cell	α_p	ε_0	ν_x	ν_y	ξ_{x0}	ξ_{y0}
60°	6.6×10^{-4}	0.55 nm	41.3	41.2	-50.8	-47.7
72°	4.2×10^{-4}	0.42 nm	48.3	47.2	-56.5	-55.8
90°	2.7×10^{-4}	0.35 nm	58.3	57.3	-81.3	-74.9

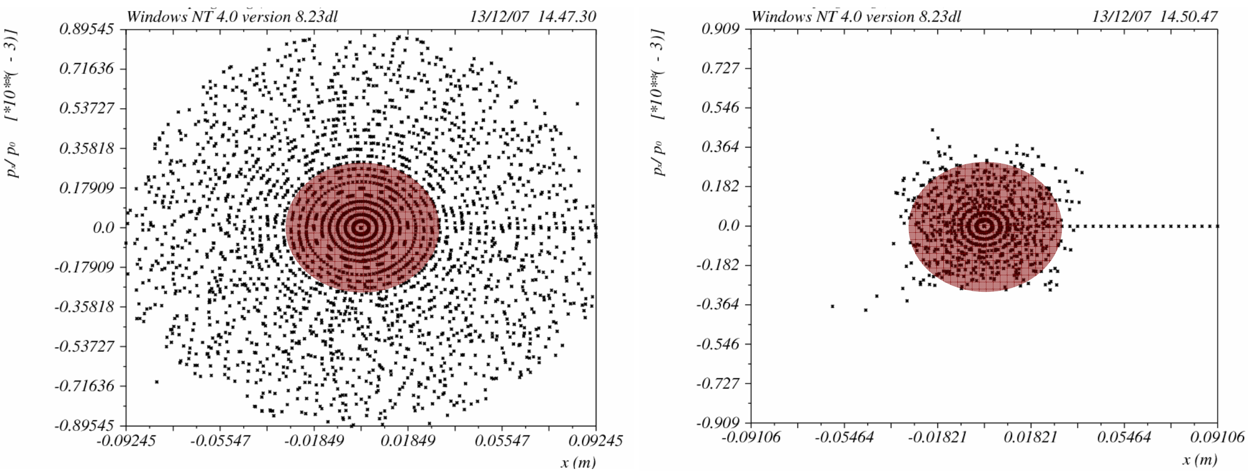


$72°, \beta_{max} \approx 100$ m



$90°, \beta_{max} \approx 150$ m

Reduced dynamic aperture at low momentum compaction factor



72°: Dynamic aperture > $3x_{max}$

90°: Dynamic aperture < x_{max}

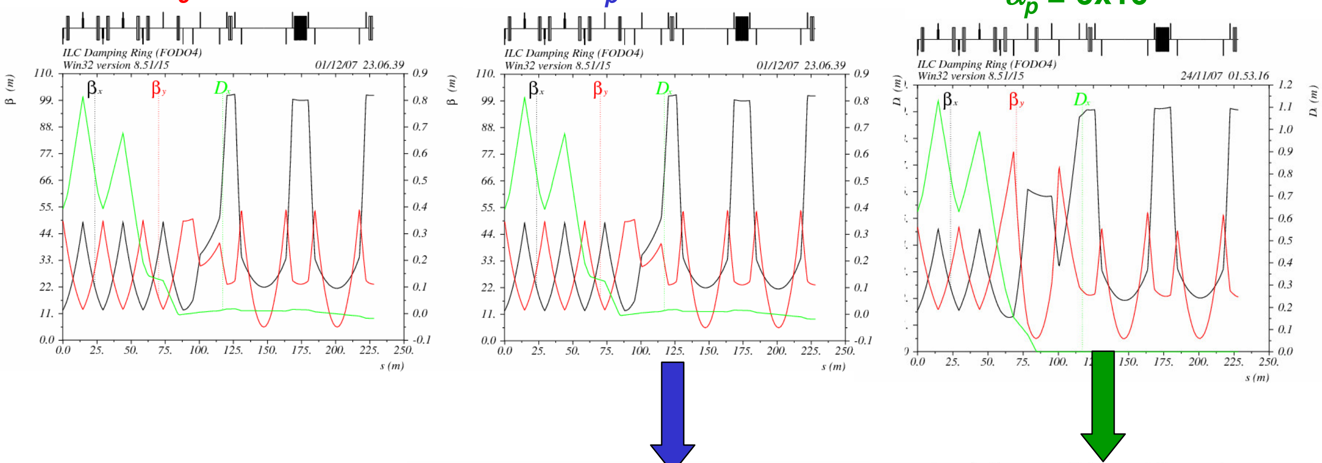
Tracking using LIE4 method in MAD;
chromaticity close to zero;
zero energy deviation;
linear (hard-edge dipole) wiggler model;
no magnet errors.

Tunability in FODO4 lattice (Marica Biagini)

α_c = 2x10^{-4}

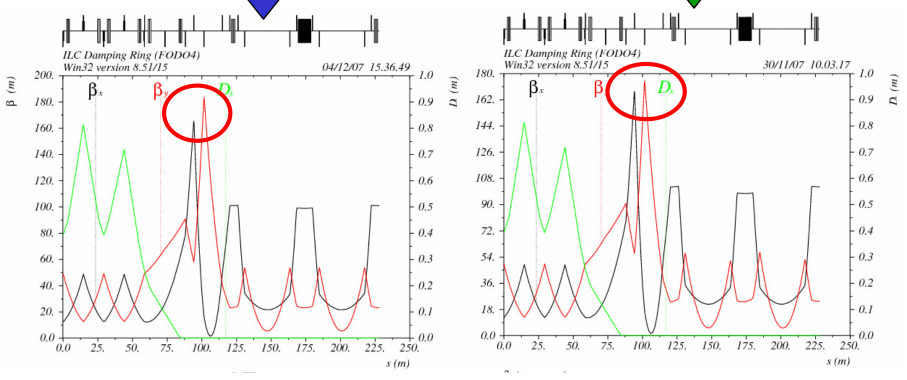
α_p = 4x10^{-4}

α_p = 6x10^{-4}



Same bending angle
and same layout
as 2x10^{-4}

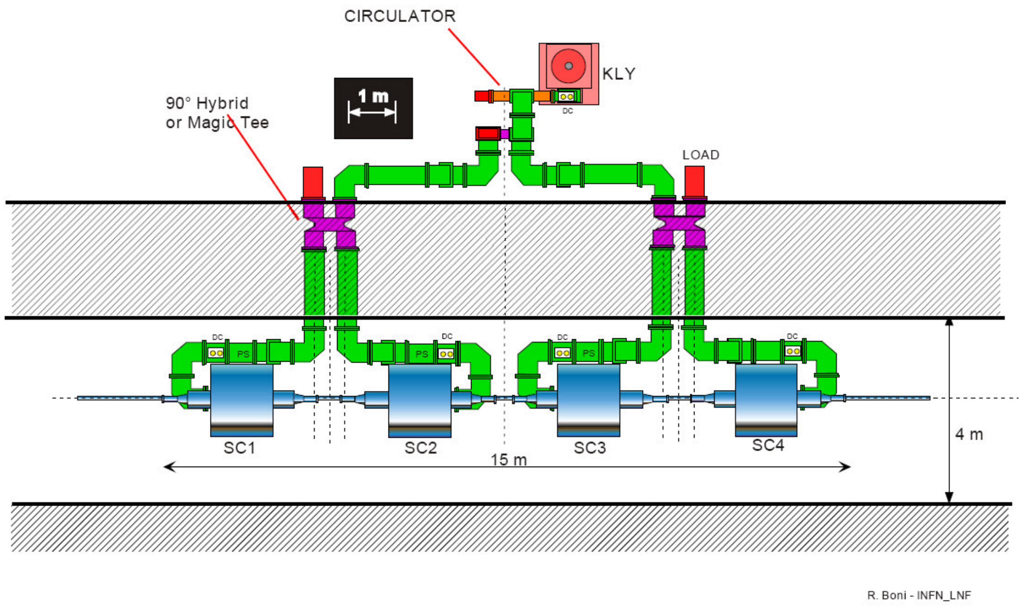
Higher beta peaks



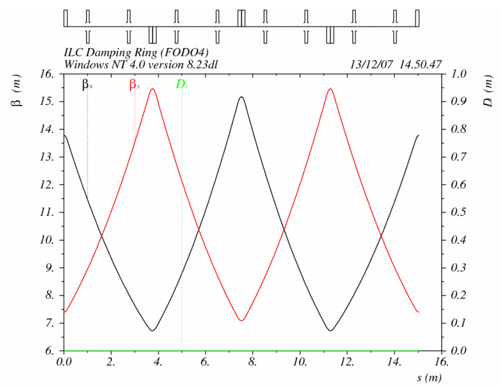
RF section layout

RF cryostats need ~ 3.5 m longitudinal space

FOOTPRINT VIEW
OF ONE RF STATION

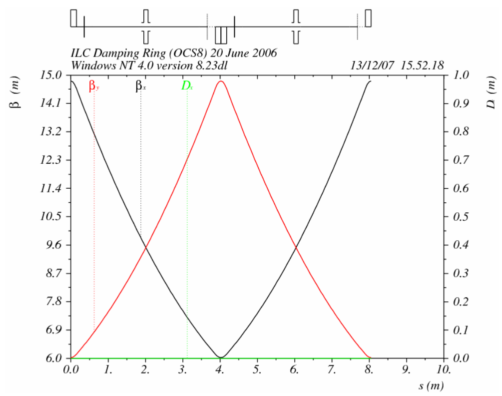


RF section layout



FODO4:

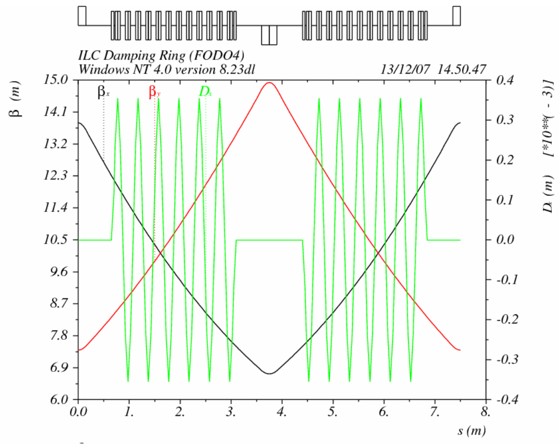
2 rf cavities in 3.46 m space between quadrupoles



OCS8:

1 rf cavity in 3.725 m space between quadrupoles

Magnet spacing: wiggler section



FODO4:

- 0.50 m drift between wiggler and quad
- 2 wiggler sections, each of 150 m length
- Shorter cryogenic lines, but more radiation power to handle

OCS8:

- 0.75 m drift between wiggler and quad
- 4 wiggler sections, each of 85 m length
- Longer cryogenic lines, but less radiation power to handle

Some “pros and cons”: OCS8

✓ The lattice is essentially complete:
- all principal specifications are met;
- ready for the studies planned for the engineering design phase.

✓ Design and layout have evolved through the configuration studies and reference design report.
- separation of systems (e.g. wiggler in four straights)
- spacing (e.g. for wiggler, rf...)

✘ Tunability of momentum compaction factor has not been demonstrated...
- ...but what is possible for one lattice ought to be possible for the other.

✘ Number of magnets is larger than in the present version of the alternative FODO4 lattice.

✓ Number of magnets is smaller than in OCS8.

✓ At least some tunability in momentum compaction factor has been demonstrated.

- Still concerns over dynamic aperture as the momentum compaction is adjusted.

✗ A number of modifications/optimisations are desirable before “fixing” the lattice for the engineering design report:

- Possible separation of wigglers into more straights? Involves a change in layout...
- Spacing for rf cavities
- Spacing for wigglers

- There is significant pressure to fix the lattice so that the studies for the engineering design phase can begin in earnest.
  - Extended delay “waiting for things to be ready” could be harmful to the collaboration.
- OCS8 is the more mature lattice at this stage; this lattice can be “fixed” to allow engineering design studies to begin immediately.
- FODO4 provides an alternative with some possibility of cost savings. Work to address some of the issues (some very minor, other more significant) should continue through the engineering design phase.