Some Notes on Sparse Correctors

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Look at having sparse corrector layout:

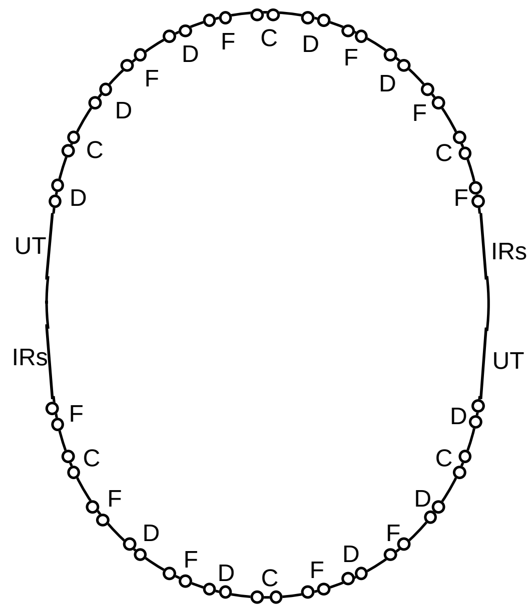
– Better packing fraction
– Shorter cable runs to correctors
– Fewer interfaces to power, cryo system

For now, study steering, tune, and chromaticity corrections …

Issues:

– Corrector strengths
– Lattice perturbations
– Allowable orbit distortions
– Dynamic Aperture (sextupoles)

- At SSC, had “missing magnets” to allow space for future devices
- Access shafts located about every 4 km
- Final spacing dictated by safety concerns (distance to egress points)
- Positions were massaged to match site conditions

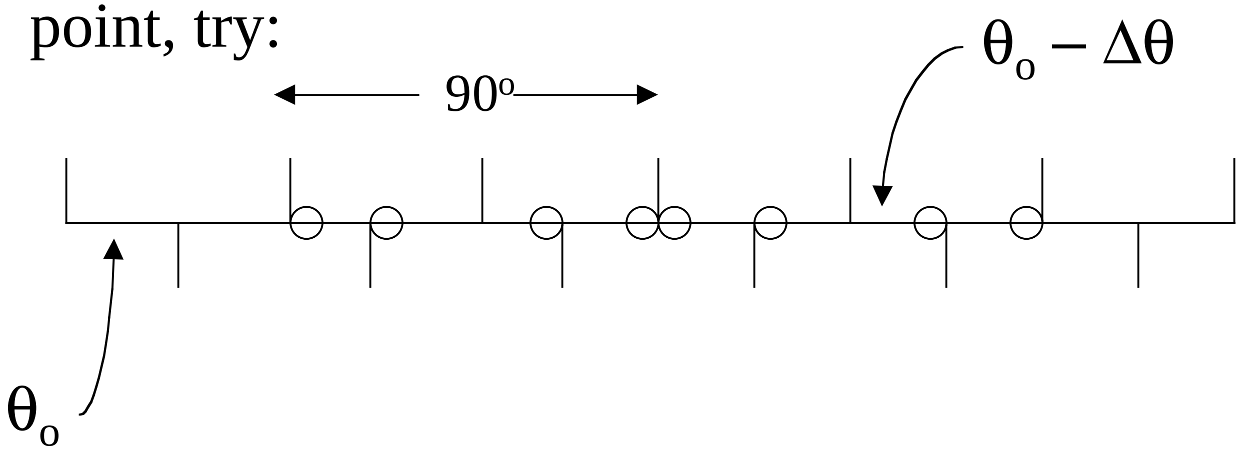


An example:

- Disrupt standard FODO structure every L_{sec} km
- Insert region with free space for correctors
- Try 90^{o} cells with missing magnets...

Correction Region

Near each access point, try:



○ = “short” or “missing” magnet

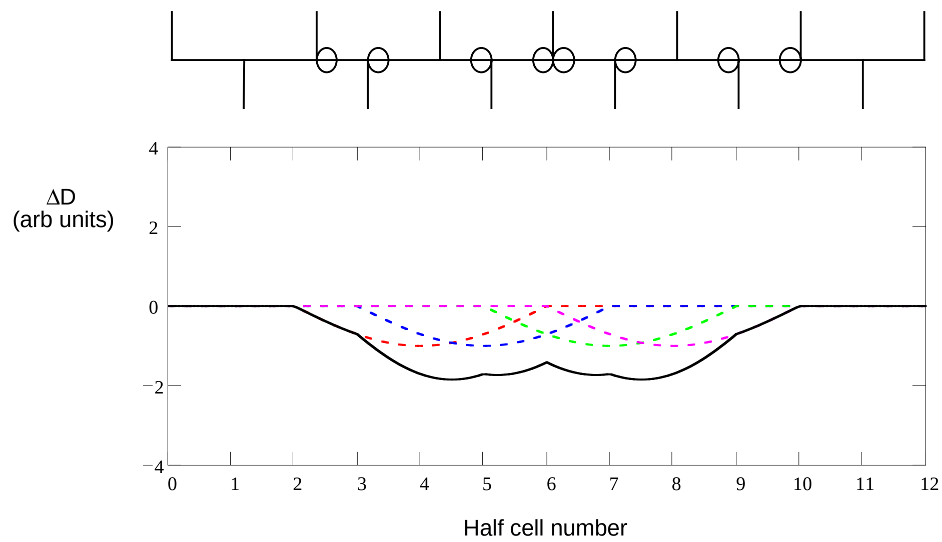
As a numerical example, take SSC numbers:

- $L_{sec} \approx 4$ km
- $L = 90$ m, $\mu = 90^o$
  - $D_{max} = (243\text{ m})\theta_o$
  - $D_{min} = (116\text{ m})\,\theta_o$
- Take $\Delta\theta/\theta_o = 1/5$

  (1/5 dipoles per half cell)

  $\Rightarrow$ *Then….*

Disturbance of Dispersion Function:



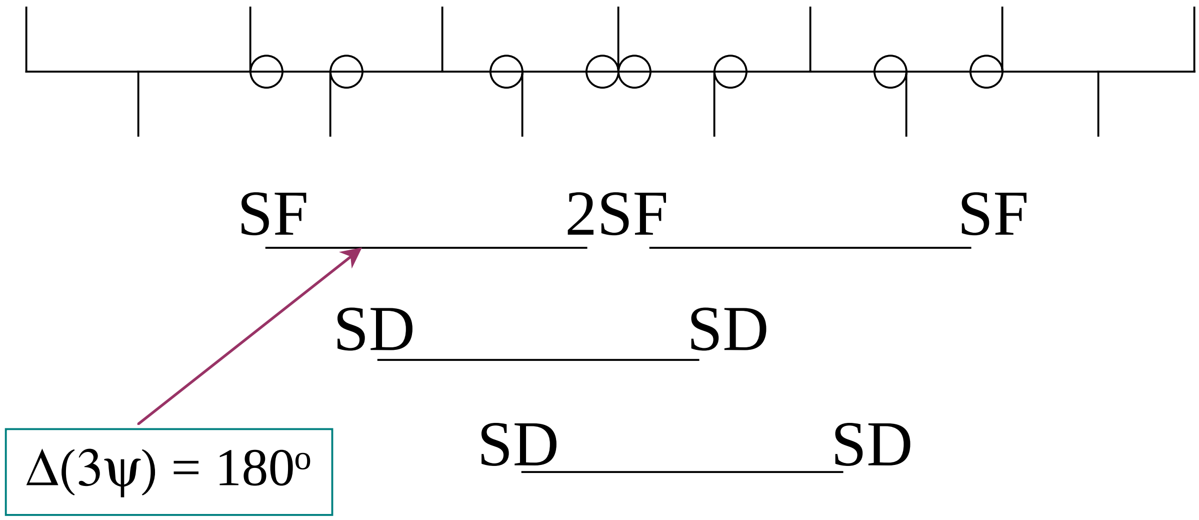
Location	$\Delta D/D_0$
2	0
3	-16
5	-25%
6	-15%
7	-25%
9	-16%
10	0

$$\boxed{\Delta\theta/\theta_o = 1/5}$$

(in SSC, 15 m)

So, chromaticity correctors will need to be stronger by appropriate amounts...

Chromaticity Correction



In one "sector" (SSC),

$\approx$ 44 half-cells

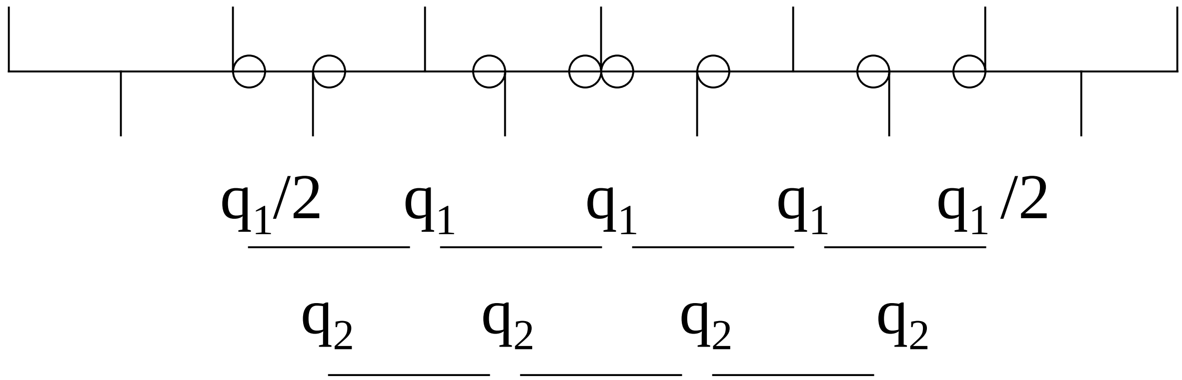
$\Rightarrow$ 22 β_{max} locations

$\therefore$ need (22/4)*1.15 = 6X stronger F sextupoles,
and (22/4)*1.25 = 7X stronger D sextupoles

SSC Specs: F sext: 0.15 T-m ($\approx$ 0.6 m)
(@1 cm) D sext: 0.25 T-m ($\approx$ 1 m)

Need about 6-7 m at D locations

Tune Adjustment



adjust strength of q @ β_1, disturbs β downstream ...

$$\frac{\Delta\beta}{\beta}(s) = -(q\beta_1)\sin(2\psi_0) + \frac{1}{2}(q\beta_1)^2(1-\cos(2\psi_0))$$

$\therefore$ with 90^o cells, $\Delta\beta/\beta$ remains $\approx$ local

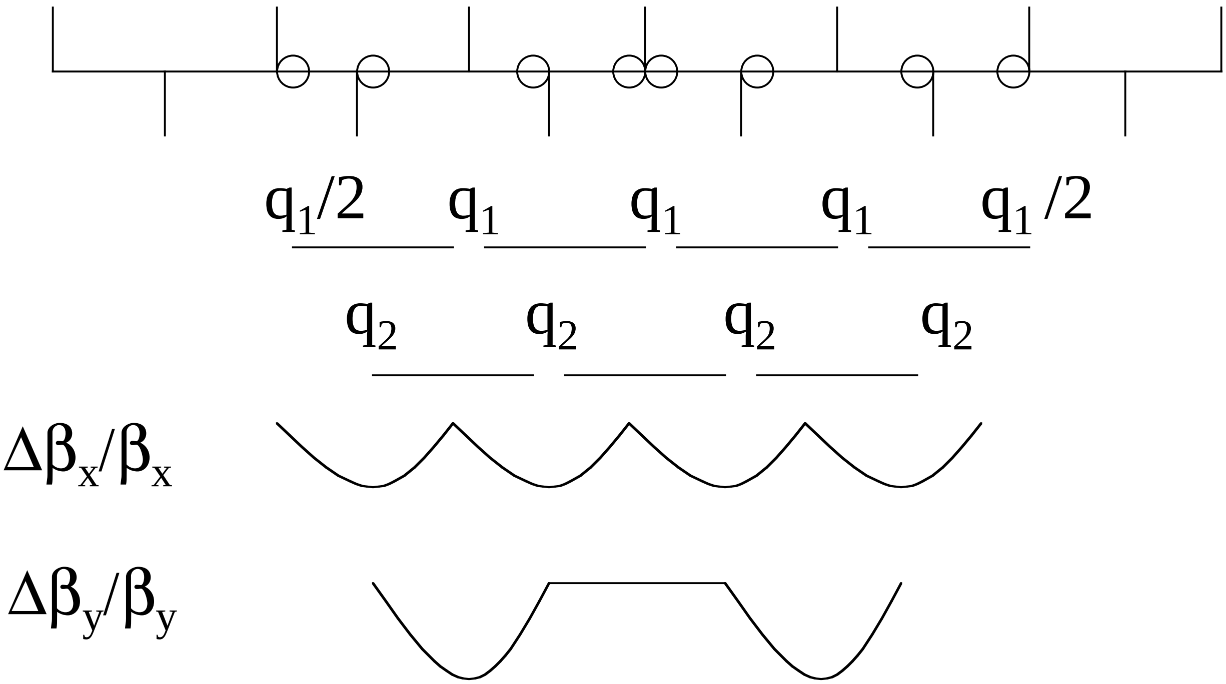
estimate: $\Delta\nu \approx (1/4\pi)(\beta/F)N\delta$

$2 \approx (1/4\pi)(350\text{m}/64\text{m})(20*4)\delta$

$\Rightarrow \delta = 0.06$ % of (1/F)

$\boxed{\therefore \text{ local } (\Delta\beta/\beta)_{max} \approx -(0.06/2)(350/64) = 15\%}$

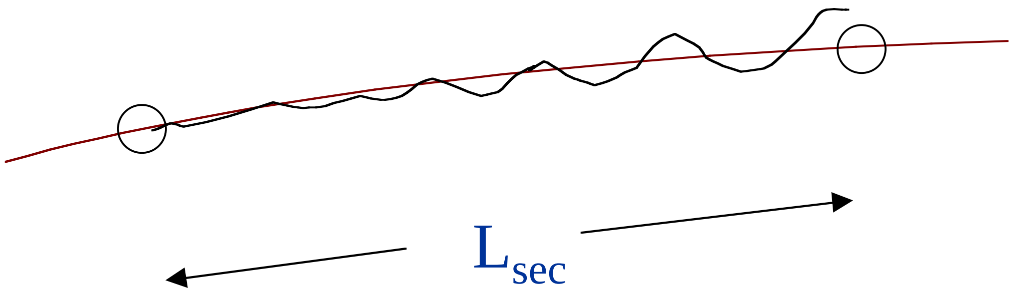
Tune Adjustment (cont'd)



$\therefore$ $(\Delta\beta_y/\beta_y)_{max} \approx$ 30%, with these maxima located at the F quads

- in reality, F/D corrections *interlaced*, $\therefore$ perturbations are coupled
- effects dispersion function
- above, used $\Delta\nu$ = 2 units; may not be this large
- note: at SSC, tune quads had δ = 0.06 (design)

Steering



for quad displacement d, $\Delta\theta = d/F$

so, at *n*-th quad,

$$\Delta x_n = \sum_i \theta_i \sqrt{\beta_i \beta_n} \sin \psi_{i\to n}$$

$$\langle \Delta x_n^2 \rangle = \theta_{rms}^2 \beta_n \langle \beta \sin^2 \psi_{i\to n} \rangle n$$

$$\Rightarrow \Delta x_n^{rms} = \theta_{rms} \sqrt{\langle \beta \rangle \beta_n} \sqrt{n/2}$$

So:

$$\boxed{\Delta x_n^{rms} = \frac{2d_{rms}}{L} \sin\frac{\mu}{2} \sqrt{\langle \beta \rangle \beta_n} \sqrt{n/2}}$$

Steering (cont'd)

note: $\beta \propto L$, so Δx_n^{rms} independent of L

BUT,

if $n = L_{sec} / L$, where L_{sec} is predetermined,

then $\Delta x_n^{rms} \propto 1/L^{1/2}$

note also: d_{rms} is likely a function of L
(quads further apart, harder to align)

SSC-type numbers:

$$\Delta x_n^{rms} = \frac{2\left(\frac{1}{4}mm\right)\frac{\sqrt{2}}{2}}{90\,m}\sqrt{(200\,m)(350\,m)}\sqrt{40/2}$$

$$= 4.6\ mm$$

$$\boxed{\therefore \text{ could expect } \Delta x_{max} \approx 15 \text{ mm}}$$

Steering (cont'd)

rms corrector strength $\approx \Delta x^{rms}/\beta_{max}$

$\approx$ (4.6 mm)/(350 m)

$\approx$ 13 μrad

$\therefore$ max strength $\approx$ 40 μrad

For SSC numbers,

$\Rightarrow$ B*L = (10/3)(20,000)(40 10^{-6}) T-m

= 2.7 T-m

(3 T over 1 m, say)

note: if "steer" @ each quad location, would have...

$\Delta\theta^{rms} \approx d_{rms}/F \approx$ (0.25 mm)/(64 m)

$\approx$ 4 μrad

$\boxed{\therefore\ \theta_{max} \approx 12\ \mu\text{rad},\ \ B{*}L \approx 1\text{T-m}}$

(for local correction)

Next Steps...

- Shorten / Optimize module
  * change half-cell length?
  * abandon FODO?
  * ???

- Practical range of tune adjustment
  * beta-beat
  * effect on chromaticity correction

- Range of steering corrections
  * use of various steering algorithms
  * tolerable residual orbits

- Dynamic Aperture with sparse chromaticity correction

- Effect on phases *between* modules