FFAG Lattice Costs

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Modified Palmer Cost Model

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\begin{aligned}
B_{i\pm} &= B_0 \pm B_1 f_R R \\
R_{o\pm} &= f_R R + t_C \left| B_{i\pm} \right| \\
B_{o\pm} &= B_0 \pm B_1 R_{o\pm} \\
B_{e\pm} &= \begin{cases} B_{i\pm} & |B_{i\pm}| \geqslant |B_{o\pm}| \\ B_{o\pm} & |B_{i\pm}| < |B_{o\pm}| \end{cases} \\
C_{\pm} &= C_{m0} B_{e\pm}^{1.5} R_{o\pm} (L + f_E f_R R) \\
f_Q &= \frac{|B_{e+} + B_{e-}|}{|B_{e+}| + |B_{e-}|} k_D + \frac{|B_{e+} - B_{e-}|}{|B_{e+}| + |B_{e-}|} k_Q \\
C_{\text{mag}} &= \frac{1}{2}(C_+ + C_-) \left(\frac{n_0}{n} \right)^{1/3} f_A f_Q \\
C_{\text{rf}} &= \frac{k_C V G_0}{G} + \frac{k_P V G}{G_0} \\
C_{\text{lin}} &= C_L L_R
\end{aligned}
$$

- Costs C_{mag} (magnets), C_{rf} (RF), and C_{lin} (linear)
- Central field is B_0, gradient is B_1
- n magnets, magnet radius is $f_R R$, magnet length is L
- Total installed voltage is V, RF gradient is G
- Ring length is L_R

Modified Palmer Cost Model (cont.)

f_R	1.3	t_C	2 mm
C_{m0}	22.5 mPB/T$^{1.5}$/m^2	f_E	20
k_D	1	k_Q	1.5
n_0	300	f_A	1.5
k_C	30 PB/GV	k_P	26.8 PB/GV
G_0	16 MV/m	C_L	25 mPB/m

- PB is our cost unit the “Palmer Buck”

FFAG Lattice Design

- Non-Scaling FFAG lattices optimized to same design parameters

Minimum energy	10 GeV
Maximum energy	20 GeV
RF frequency	201.25 MHz
Voltage per cavity	7.5 MV
RF drift length	2 m
Short drift length	0.5 m
Minimum energy tunes	0.35
ΔT per cell	7.12 ps
Normalized acceptance	30 mm
Pole tip fields	7 T

- Compare different lattice types: triplet, doublet, FODO
- Not optimized for cost

FFAG Lattices

Type	FDF	FD	FODO 1 RF	FODO 2 RF
Cells	93	101	113	82
D Length (cm)	128	101	81	99
D Radius (cm)	8.4	6.9	8.0	8.3
F Length (cm)	45	81	60	74
F Radius (cm)	9.5	12.4	14.2	17.8
RF Voltage (MV)	698	758	848	1230
Circumference (m)	481	436	612	470
Magnet cost (PB)	76	69	90	98
RF cost (PB)	45	49	55	80
Linear cost (PB)	12	11	15	12
Total cost (PB)	134	129	161	189

- Magnet costs generally high: re-optimize for cost, probably lower fields