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magnetic steering scaling in ISAC TRI-BN-24-14

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Intro

This short note is to derive a scaling for steerers in MEBT and HEBT. The idea is to ‘teach’ the Bayesian steering optimizer a ‘reasonable’ adjustment in steering to avoid either many too small steps and tuning on noise, or a very large step that would lose all the beam.

It is base upon using 2 mrad as a reasonable adjustment. This is admittedly arbitrary, but loosely based upon believable unknown misalignments in the beamline.

If the beam was always the same species at the same energy, this would be trivial: simply based it upon some fraction of the power supplies’ ranges. But in fact beams are more or less sensitive to the steerers according to their rigidity.

Beam rigidity

This is basically given by the product of magnetic field B and radius of curvature ρ: $mv^2/\rho = qvB$, or,

$$B\rho = \gamma mv/q = \beta\gamma \frac{mc^2}{qc} = \beta \frac{A}{Q}\, 3.1\,\mathrm{Tm} \qquad (1)$$

We dropped γ since $\beta \ll 1$. A is the mass number: $mc^2 = 931 A\,\mathrm{MeV}$ and $q = Qe$.

Now we need β. Realizing that energy E per unit mass is $\frac{1}{2}v^2$, we can write:

$$\beta = \sqrt{\frac{2E}{931\,A\,\mathrm{MeV}}} = 0.046\sqrt{\tilde{E}}, \qquad (2)$$

where $\tilde{E}$ =energy per units mass in MeV per amu. For example, in MEBT, $\tilde{E} = 0.15$ so $\beta = 0.018$, and $B\rho = 0.056\,\frac{A}{Q}$ Tm.

Deflection angle

If small, the deflection angle in a dipole is $\theta = L/\rho$ where L is the length over which the B field is applied. But B varies and so ρ varies but $B\rho$, being momentum per charge stays constant. Thus,

$$\theta = \frac{\int B dl}{B\rho} = \frac{\int B dl}{(0.144\,\mathrm{Tm})(A/Q)\sqrt{\tilde{E}}} \tag{3}$$

MEBT

In MEBT, steerers were designed to have maximum $\int Bdl$ of (click to access reference) 7000 G-cm, or 0.007 Tesla-metres. This applies to the steerers with power supplies of max current 100 A (these were designed by G. Stinson) and and those with 3 A (these were inherited from Chalk River lab and referred to as AECL steerers; see last slide). For largest $A/Q = 6$, this is a deflection of 20 mrad, which is rather large. So if we think in terms of what is a steerer current change that results in a deflection of 2 mrad, it is $1.7A/Q$ Amps for the (-100 to +100) Amp steerers, and $0.05A/Q$ Amps for the (-3 to +3) Amp steerers. More compactly,

$$\Delta I = 0.017\,\frac{A}{Q}\,I_{\rm max} \qquad (4)$$

where $I_{\rm max}$ is the max installed power supply current.

HEBT

HEBT differs from MEBT in that its energy is variable; between 0.15 and 1.5 MeV/u.

HEBT steerers were apparently designed to a requirement of (clicky) $\int Bdl = 6400$ G-cm, or 0.0064 Tm.

Applying eq. 3 to the most rigid beam of $A/Q = 6$, $\tilde{E} = 1.5$, we get: 6 mrad. Let's again use 2 mrad as an allowable steering step. This corresponds to a current step of

$$\Delta I = 0.044 \frac{A}{Q} \sqrt{\tilde{E}}\, I_{\mathrm{max}} \tag{5}$$

the steerers

Table 1

Section	Name	Type	Max current/A	
MEBT	X,YCB1	AECL	3	
	X,YCB3	Stinson	100	
	X,YCB5	AECL	3	
	YCB7A	Stinson	100	
	YCB7B	Stinson	100	
	X,YCB9	Stinson	100	
	YCB11	in Q11; Characteristics not known	3	
	XCB12	in Q12; Characteristics not known	3	
DTL	XYCB2	dtl triplet; not functional; built into Q2; min current is zero?	200	
	XYCB5	dtl triplet; not functional; built into Q2; min current is zero?	200	
	XYCB8	dtl triplet; not functional; built into Q2; min current is zero?	200	
	XYCB11	dtl triplet; not functional; built into Q2; min current is zero?	200	
HEBT	XYCB0	Stinson	100	
	XYCB2	Stinson	100	
	XYCB5	AECL	3	
	XYCB8	Stinson	100	
	XYCB10	Stinson	100	
	XYCB12	AECL	3	
	XYCB14	AECL	3	
	XYCB16	AECL	3	
HEBT2	XYCB2	AECL	3	
	XYCB4	Stinson	100	
	XYCB6	Stinson	100	
DSB	YCB2	AECL	3	
	XYCB4	AECL	3	
	XYCB6	AECL	3	
	XYCB8	Stinson	100	
	XYCB10	Stinson	100	
	XYCB12	AECL	3	
	YCB14	AECL	3	