Poloidal Flux Requirements For NCSX

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In an axisymmetric field

A particle's drift orbit width is easily calculated by from conservation of

$$E = _ \, m \, v_{||}^2 + \mu B, \quad \text{and}$$

$$p_\phi = R \, m \, v_\phi + e \, \Psi_P / 2\pi$$

where Ψ_P is the poloidal flux and μ is the magnetic moment.

The minimum orbit width occurs for deeply passing particles with $\mu = 0$ fixed $v_{||} \sim v_\phi$

$$\delta\Psi_P = 2^{3/2} \pi \, 10^{-4} \, (M_{amu} \, E)^{1/2} \, \delta R$$

where δR is the variation in R as the particle orbits around the flux surface, E in eV.

Motion across poloidal flux is due to B drift as particle changes R due to parallel motion

Axisymmetric

$\delta\Psi_P = 2^{3/2} \pi 10^{-4} (M_{amu} E)^{1/2} \delta R$

Estimate the minimum required poloidal flux in the machine required to have, say, 4 beam-ion drift orbit widths across the profile, evaluated at the half-radius

orbit widths are larger for v > 0 particles

orbit widths are larger for larger r/a

So, for PBX-M, δR= 0.4m, M_{amu} E = 40keV

$\delta\Psi_P$ = 0.071 W

want Ψ_P = 0.28 W at least

high β shot had Ψ_P = 0.45 W, good beam capture.

In a QA stellarator

Will conserve quasi-momentum, the

$p_\phi = R\, m\, v_\phi + e\, \Psi_P / 2\pi$

of the equivalent axisymmetric device (same Boozer spectrum). Now the variation δR around the orbit must be understood as that giving the same $\delta|B|$ to generate the same B displacement

$\delta R = R\ \ \delta|B|\ \ / |B|$

So, taking R = 1.45m for the PBX-M vessel

At s=0.35 ~ half radius

Qas2(40%) $\delta|B|\ \ / |B| = 0.32$

$\delta R \sim 0.47$

want $\Psi_P \sim 0.33$

Qas3_c10 $\delta|B|\ \ / |B| = 0.23$

$\delta R \sim 0.33$

want $\Psi_P \sim 0.23$

Required ι

As Allen B. did, can calculate $\iota = \Psi_P / \Psi_T$ to get the required flux. For a = 0.4m and B = 1T, $\Psi_T = 0.5$ W want $\iota \sim 0.46$ at a minimum.

May be able to get away with less than 4 orbit widths if use only co- injection tangential to the magnetic axis and careful tailoring of density profile to encourage central deposition.

For comparison, high β PBX-M shot had $\iota = 0.8$.