ENERGETIC PARTICLE TRANSPORT CALCULATIONS FOR NCSX CONFIGURATION QAS3C10

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OUTLINE

1) Benchmarking and simulation method

2) QAS3C10 results and B scaling

3) Collisionality scaling

4) Injection position

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1) AXISYMMETRIC BENCHMARKING

AND METHOD

*** Both ORBITMN and TRANSP used:**

- Only n=0 components of QAS3C10 magnetic geometry,
- QAS3C10 iota profile, B_axis = 1T, Zeff = 1.8
- Full energy beam ions only: 40keV, co-parallel injection
- No charge exchange
- Beam deposition profiles from PBX-M high beta shot 53944
- Energy loss calculated at last closed flux surface

*** Collision models**

- TRANSP collision rate profiles similar to ORBIT
- ORBIT used $\nu = \nu(0)(1-r^2/a^2)$, $\nu_\varepsilon(r) = \nu_\varepsilon = 35/s = \nu(0)$

  The ORBIT collision rates correspond to TRANSP line averaged densities and temperatures

*** Results**

- TRANSP: when ions have slowed to 2-3 keV, thermal energies, power losses 29±3%
- ORBITMN: after $2\tau_\varepsilon$, ions have slowed to 5 keV power losses: 16% at τ_ε, 28±3% at $2\tau_\varepsilon$

2) RESULTS AND B SCALING

*** ORBITMN predicts ~50% power loss of co-parallel injected neutral beam ions**

- QAS3C10 power losses: 41±4% at τ_ε , 49±4% at $2\tau_\varepsilon$

- Fraction of particle lost versus time shows ~10% prompt losses from non-axisymmetry: ripple trapping

- Previous calculations showed that in QAS configurations counter and perpendicular injection not practical

*** Increased poloidal flux does not improve confinement**

- B= 1.0 T Energy losses in τ_ε: 41±4%, 2 τ_ε 49±4%

- B = 1.26 T 37±4%

- B = 1.4 T 39±4%, 2 τ_ε 48±4%

- Ripple losses moderate any confinement improvement expected with increased B

- Similar results found with broader, low edge deposition profile:

- Axisymmetric losses improve neoclassically ~$1/B^2$
  For 2 τ_ε at 1.4T energy losses were 33%, at 1T =>17%

3) COLLISIONALITY SCALING

*** ORBIT runs show little effect of varying collisionality: ν / ν_ε**

- Vary line averaged temperature and density
- Neutral beam ion loss with Zeff= 1.8, $\nu = \nu(0)(1-r^2/a^2)$, $\nu_\varepsilon(r) = \nu_\varepsilon$

<Ne >	<Te>	ν (0)	ν_ε	< ν / ν_ε >	E loss τ_ε	E loss $2\tau_\varepsilon$
*4 e19/m^3	1.3 keV	35/s	35/s	0.7	41x%	49%
**6 e19	1.3	53	50	0.7	41	50
3 e19	2.65	26	18	1.0	48	
5 e19	2.42	44	23	1.3	53	
5 e19	1.9	44	26	1.2	51	
7 e19	1.75	62	40	1.1	47	
9 e19	1.55	79	56	1.0	46	

* Plasma parameters PBX-M 53944, Zeff reduced from 2.7 to 1.8
** ISS95 scaling of density and temperature

*** TRANSP scan of density and temperatures**

- At higher densities and lower τ_ε
  lead to axisymmetric losses ~20%
  also show little effect of collisionality on loss (20-24%)

4) INJECTION POSITION

*** Injection at best angles $0 < \varphi < \pi$ may reduce losses**

Results with same deposition profile after τ_ε:

- Injection at random toroidal angles: 41±4%
  7% prompt losses

- Injection at $\varphi = 0$ (crescent cross section): 41±4%
  12% prompt losses

- Injection at $\varphi = \pi$ (square cross section): 37±4%
  0% prompt losses
  Prompt losses suppressed.

Further work: better statistics needed

SUMMARY

*** ORBITMN predicts ~50% power loss of co-parallel injected neutral beam ions**

* Benchmarked against TRANSP for axisymmetric losses

* ~10% prompt losses from non-axisymmetry due to ripple trapping

* Injection at angles $\varphi \sim \pi$ may reduce losses by 10% due to suppression of prompt losses

* Low temperature, Zeff reduce ν / ν_ε and τ_ε and energetic particle losses

* Effect of varying collisionality ν / ν_ε is ~ 20% for both axisymmetric and non-axisymmetric scans

* Increasing poloidal flux did not change QAS3C10 confinement

*** Reduced ripple wells of high priority for energetic ion confinement**

The following pages are from earlier related work and may not be discussed today at all.

PREVIOUS RESULTS

* ORBITMN used to predict particle transport

- QAS stellarators of PBX-M size, already ballooning stable

- Benchmarked against GC3 (Mynick code) for QAS2_20

- Diffusion coefficients and loss fractions
  depend strongly on presence of local ripple wells.

-Pitch angle scattering into ripple wells causes large diffusion
  coefficients and energetic particle loss fractions

- Ψ(edge) of less value for particle confinement than tokamaks

- Difficult to make MHD stable with good particle confinemen:
  release PBX-M size constraint, reduce field line ripple

PARALLEL COINJECTED NEUTRAL BEAM ION LOSS DURING τ_{SL} FOR TOROIDAL CONFINEMENT DESIGNS OF PBX-M SIZE

	Energy Loss (%)	Particle Loss (%)
QAS stellarators		
QAS2_20	7	12
QAS2_40	27	49
QAS3_30	14	27
QAS3_50	26	48
QAS4_40	25	45
tokamaks		
TOKQAS2_20	10	18
TOKQAS2_20q	0	0
TOKQAS3_53q	16	32

NEUTRAL BEAM ION LOSS DURING τ_{SL} QAS3_50 (1T),
(ν /ν_ε= 1, ν = 35/SEC, ν_ε= 37/SEC, τ = 0.03 SEC)

R_{inj} (cm)	Co/Counter	Parallel/Perp	Energy Loss (%)	Particle Loss (%)
130	co	parallel	28	51
34	co	perpendicular	76	91
-34	counter	perpendicular	100	100
-130	counter	parallel	79	91