ALPHA PARTICLE CONFINEMENT IN TFTR D-T PLASMAS WITH REVERSED AND MONOTONIC MAGNETIC SHEAR

Martha H. Redi

Princeton Plasma Physics Laboratory, Princeton University, Princeton, NJ USA

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OUTLINE

*** Introduction: Guiding center code simulations**

- Monotonic and Reversed Shear

*** Global losses**

- Comparison with lost alpha detector data

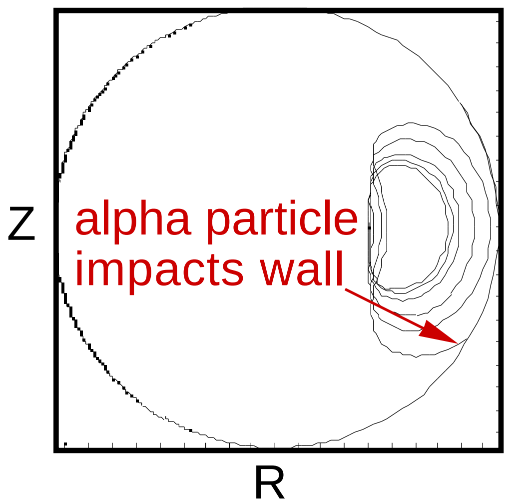
*** Confined alpha profiles**

- Comparison with PCX confined alpha data

Stochastic Ripple diffusion by Toroidal Field Ripple

*** Trapped ion banana orbits "walk" out of the plasma.**

- Lose alpha heating of fusion plasmas. Cause intense local heating of vessel wall θ=0.



Guiding Center Code alpha orbit in TFTR, Ip/R = 0.9MA/2.6m

*** Stochastic Ripple Threshold: simple model of Goldston, White, Boozer**

- $\delta_S = (\varepsilon/(N\pi q))^{1.5} (1/\rho q')$ at trapped ion bounce point
- Toroidal field ripple: $\delta = (B_{MAX}-B_{MIN})/(B_{MAX}+B_{MIN})$
- If $\delta/\delta_S > 1$, the ion undergoes stochastic ripple diffusion

SIMULATION OF ALPHA ORBIT LOSS

*** ORBIT guiding center code calculates alpha guiding center orbits**

- in flux coordinates for real magnetic geometry

- with pitch angle scattering and slowing down

*** New threshold for stochastic ripple diffusion, $\delta/\delta_S > 1$**

- δ_{WGRB}, White, Goldston, Redi, Budny, Phys. Plas. 1996

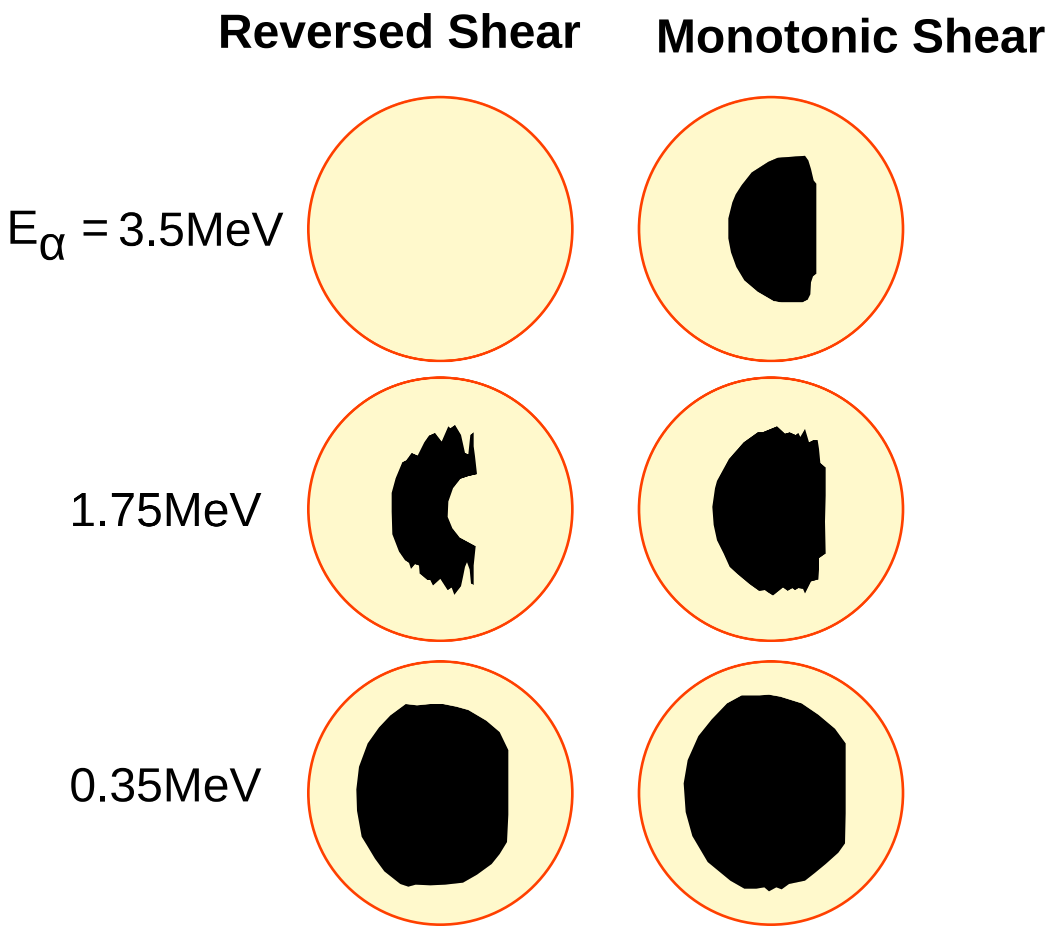
- Universal theory, first principles, no renormalization factors, unlike δ_{GWB}

- Explicit construction of primary resonances and route to chaos

- Includes poloidal dependence, non-circular confinement domain

- Includes toroidal precession, important for fast ions

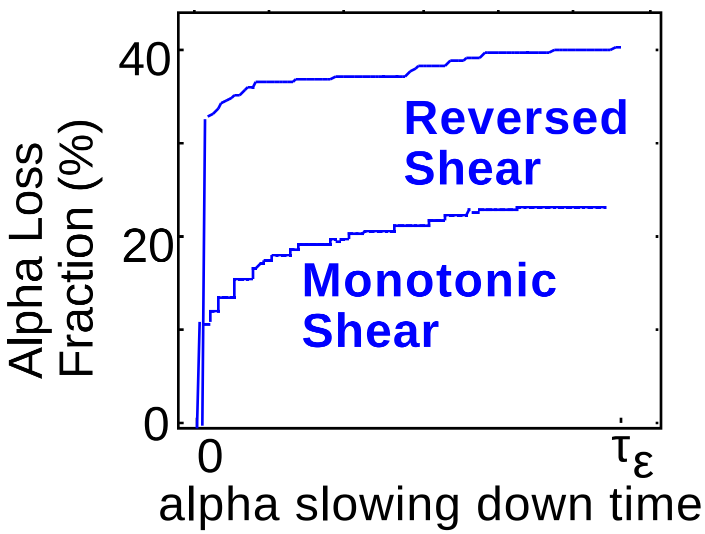
ALPHA BANANA TIP CONFINEMENT DOMAIN REDUCED IN REVERSED SHEAR



PRINCETON PLASMA PHYSICS LABORATORY

GUIDING CENTER CODE ALPHA PARTICLE LOSSES FOR TFTR (%)

	Reversed Shear (1.6MA)	Monotonic Shear (1.8MA)
First Orbit	18	6
Delayed Particle Loss	22	17
Total Particle Loss	40	23
Total Energy Loss	38	19



*** Loss occurs earlier in slowing down process for reversed shear.**

*** Effect of collisional ripple loss smaller in reversed shear**

Comparison with Lost Alpha Detector Data

*** First orbit and ripple losses have different poloidal angle footprints**

- First orbit loss distribution peaked at ~- 60^{o} with $0^{o} > \theta > -180^{o}$

- Ripple loss distribution peaked just below $\theta = 0^{o}$

*** Measurements of alpha loss per DT neutron at θ=-90^{o}**

- Reversed shear loss ~ 3x monotonic shear loss (1.6 MA RS/ERS, supershots)

- Agrees with expected reversed shear first orbit loss increase due to higher q(0)

*** Measurements of alpha loss per DT Neutron near midplane (-20^{o})**

- No good comparison shots for reversed shear vs supershot losses

- Measurements near midplane are difficult to interpret in detail due to shadowing effect of outer limiters

III. Comparison with Pellet Charge Exchange Diagnostic

*** Pellet charge exchange diagnostic (PCX) detects only $v_{//}/v$=-0.05 at midplane.**

- Simulated data: select ions after τ_S or $2\tau_S$, in $v_{//}/v$ = -0.15 to +.05 and $|\theta| \leq 0.1$

- Reduced phase space: Must simulate 200x orbits as for global loss

*** Reversed shear: all trapped alphas lost initially**

- Pitch angle scattering refills trapped distribution

- Statistics: must follow 100x orbits as for monotonic shear

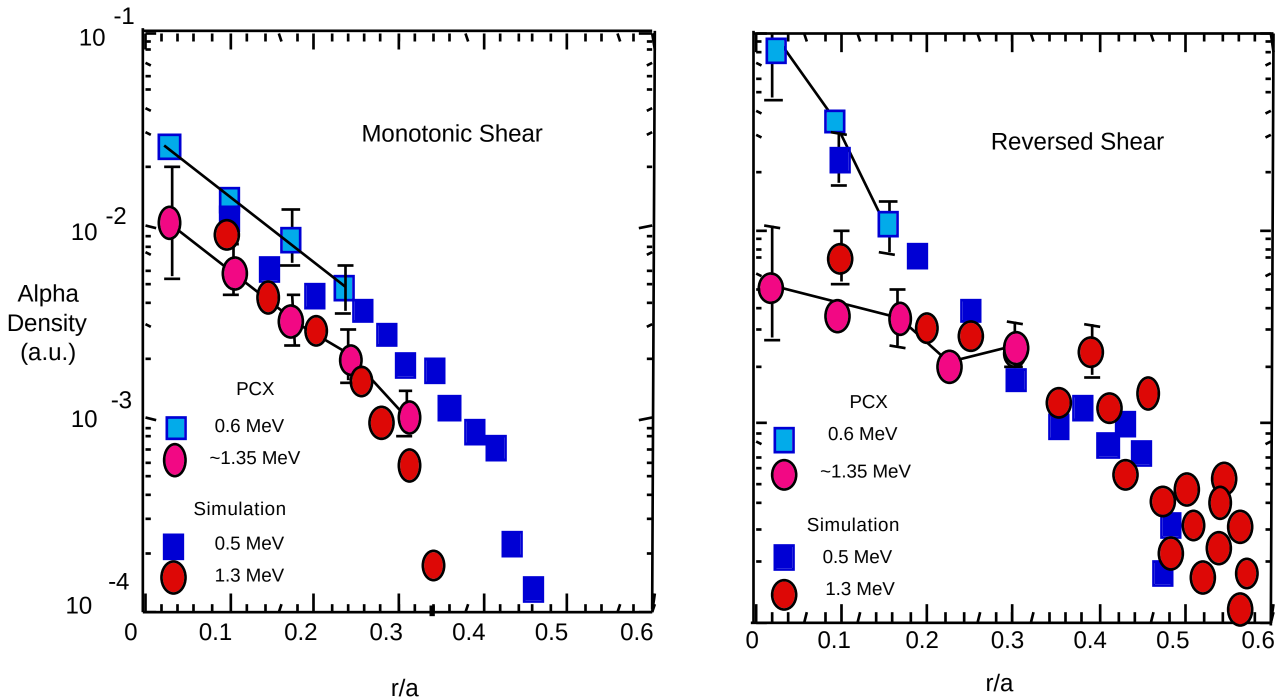
*** To minimize computational run time**

-WGRB loss algorithm and accelerated collision rates, ν_{PA} and ν_S.

- Gives good global loss estimates even for reversed shear equilibria.

-Conservation laws for E, μ to project the final orbits to θ=0 to improve statistics.

Good Agreement of PCX and Neoclassical Transport Simulations with Collisions and Ripple Loss



CONCLUSIONS

*** Simulations of neoclassical transport of alphas with ripple and collisions in good agreement with measured TFTR DT data**

- Entire plasma above threshold for 3.5 MeV alpha particles in reversed shear

- All trapped alphas are lost at birth from stochastic ripple and first orbit losses

- Pitch angle scattering of passing ions continues alpha loss during slowing down

- Simulations of reversed shear: 40% alphas lost, 1/2 from stochastic ripple diffusion; 2x loss of comparable monotonic shear

*** Can a viable reversed shear ITER be designed with minimal δ_{TF} and Z_{eff} to maximize alpha heating?**