“ m=0 tearing modes play a major rule in many physical processes such as the ion heating, momentum transport, and magnetic relaxation of the RFP* ”

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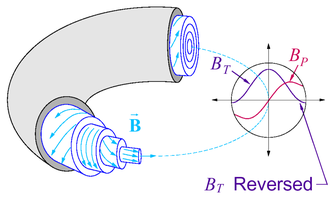
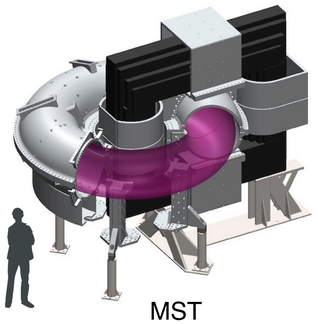
The reversed field pinch and MST





MST parameters:

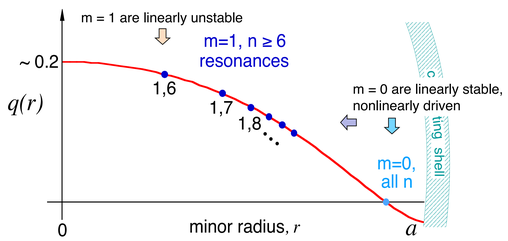
- R/a = 1.5 m/0.5 m
- n ~ 10^{13} cm^{-3}
- T_e < 2 keV
- T_{ion} ~ T_e
- B < 0.5 T
- τ_A ~ 1 μs
- ρ_{ion} ~ 1 cm
- β < 25%
- S = 5 ×$10^{5\text{-}6}$

Tearing instability and nonlinear coupling results in multiple magnetic reconnection sites

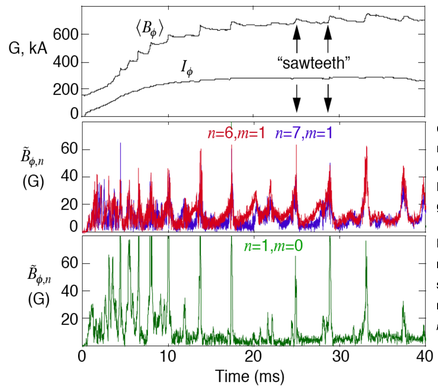
Tearing resonance:

$$0 = \mathbf{k}\cdot\mathbf{B} = \frac{m}{r}B_\theta + \frac{n}{R}B_\phi \Longrightarrow q(r) = \frac{rB_\phi}{RB_\theta} = \frac{m}{n}$$

m = poloidal mode number
n = toroidal mode number



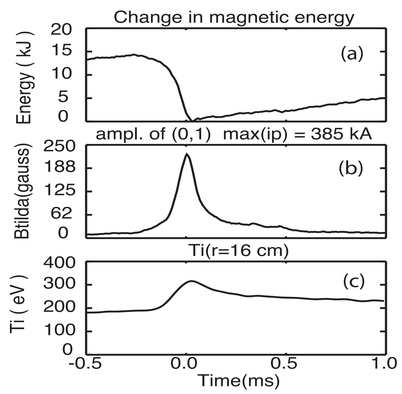
Sawteeth are quasi-periodic impulsive reconnection events



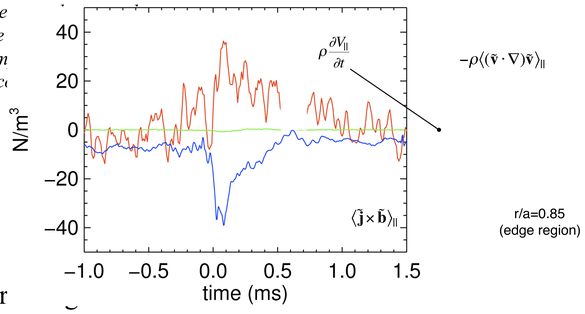
Core-resonant m=1 modes are largest, calculated to be linearly unstable from gradient $\nabla_r(J_\parallel/B)$

Edge-resonant m=0 modes are linearly stable, excited by nonlinear coupling to m=1 spectrum

Majority ions, Deuterium, are strongly heated at a sawtooth crash

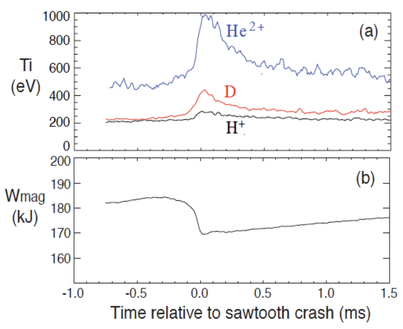


Large (0,1) mode is required for the release of magnetic ene the tem rec



r/a=0.85
(edge region)

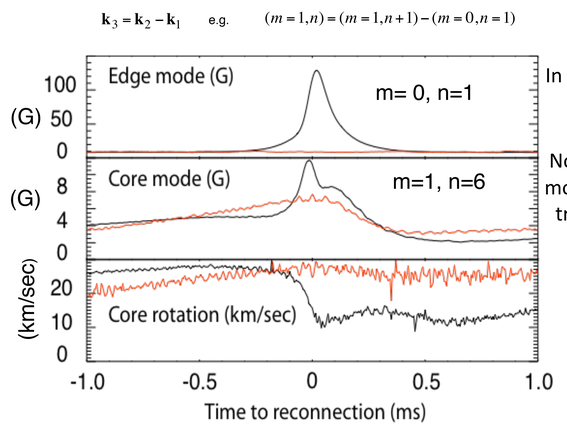
Non-collisional ion heating increases with incr



Majority ion temperature for H, D, and He plasmas increases with ion mass for similar magnetic energy release during reconnection event

Momentum relaxation and stresses are strongest when nonlinear coupling of tearing modes occurs.

$\mathbf{k}_3 = \mathbf{k}_2 - \mathbf{k}_1$ e.g. $(m=1,n) = (m=1,n+1) - (m=0,n=1)$



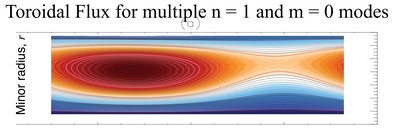
In red small m=0
⇓
No sudden momentum transport

The Reynolds and Maxwell stresses burst to large amplitudes during sawteeth.

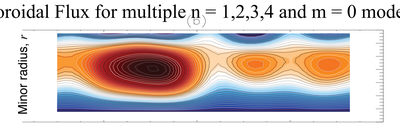
$$\rho\frac{\partial V_\parallel}{\partial t} \overset{?}{=} \langle\tilde{\mathbf{j}}\times\tilde{\mathbf{b}}\rangle_\parallel - \rho\langle(\tilde{\mathbf{v}}\cdot\nabla)\tilde{\mathbf{v}}\rangle_\parallel - \overset{0}{\cancel{\nabla_\parallel \tilde{p}}}^{\text{small}} + \nu\rho\nabla^2 V_\parallel$$

Complex island structure occurs for tearing modes in the RFP

Toroidal Flux for multiple n = 1 and m = 0 modes

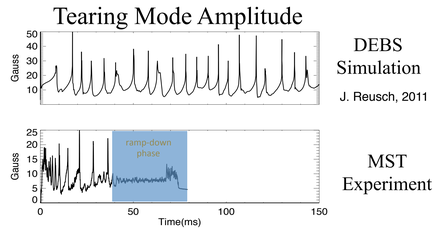


Toroidal Flux for multiple n = 1,2,3,4 and m = 0 modes



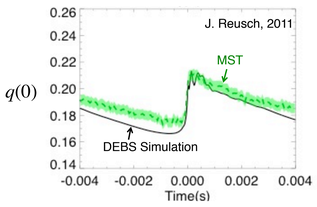
Tharp et al, PoP 2010

Computation produces sawtooth cycle with features very much like MST observations

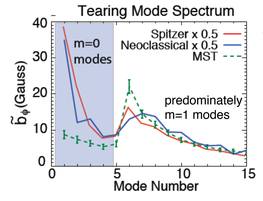


Evolution of the magnetic equilibrium in experiment and computation isnearly identical

On-axis Safety Factor



Tearing mode spectrum similar to MST, but amplitudes in DEBS are systematically 2X or so larger



J. Reusch, 2011

Multi-harmonic yields fine structure in the m=0 layer

Profile of the m=0 magnetic field components made with an insertable probe
Note: flux plot is not for whole B, only the mean-field and m=0 harmonics