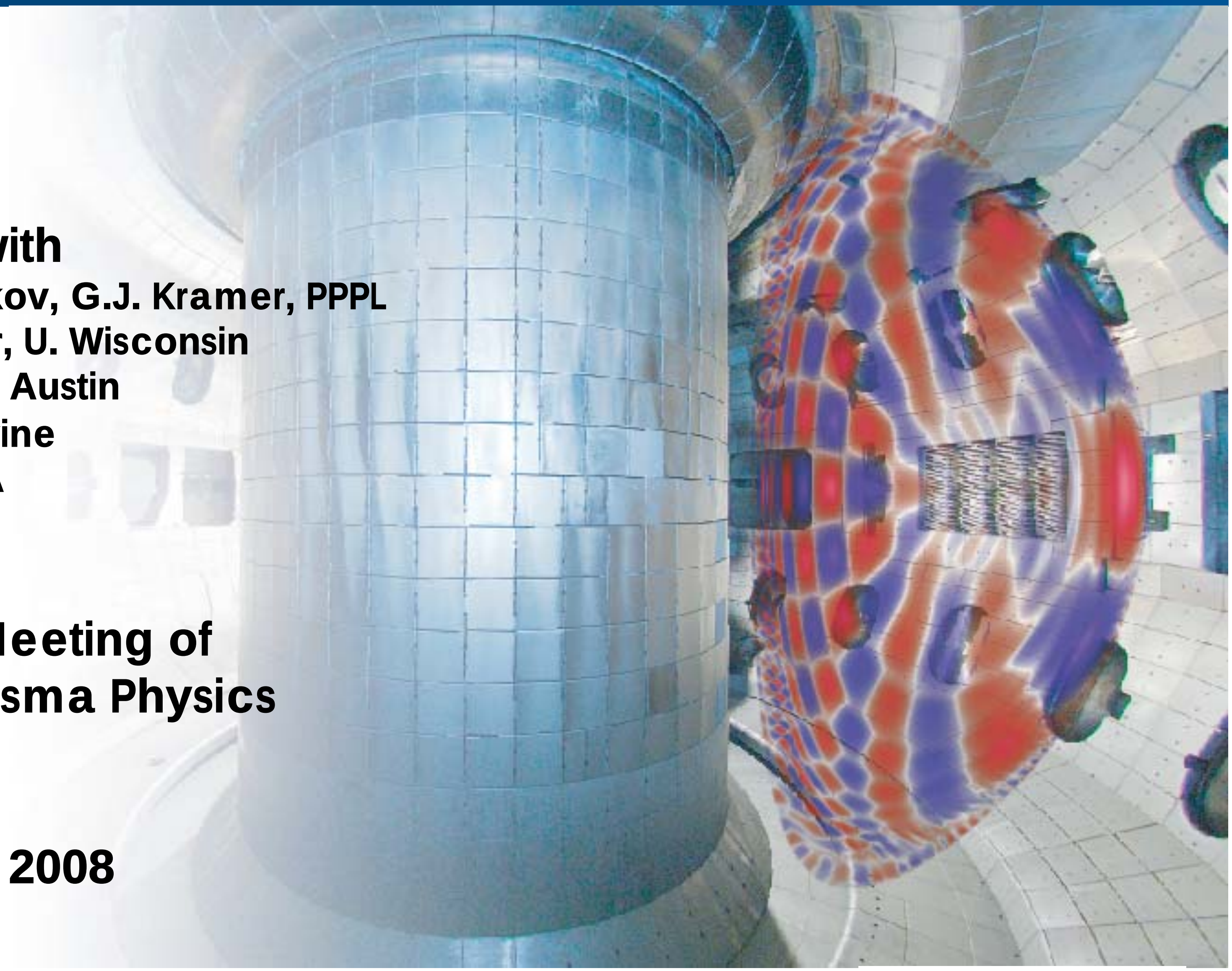
Intense Geodesic Acoustic Modes Driven by Counter Passing Beam Ions in DIII-D



by
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Large Radial Scale Geodesic Acoustic Modes (GAMs) Discovered on DIII-D

- **Background**
  - Geodesic Acoustic Modes (GAMs) are localized zonal flows:
    $w_{GAM} \approx 2C_s/R$ N. Winsor et al., Phys.Fluids (1968)
  - Weak damping allows high-n turbulent beat wave excitation – as with zonal flows, with implications for turbulence regulation

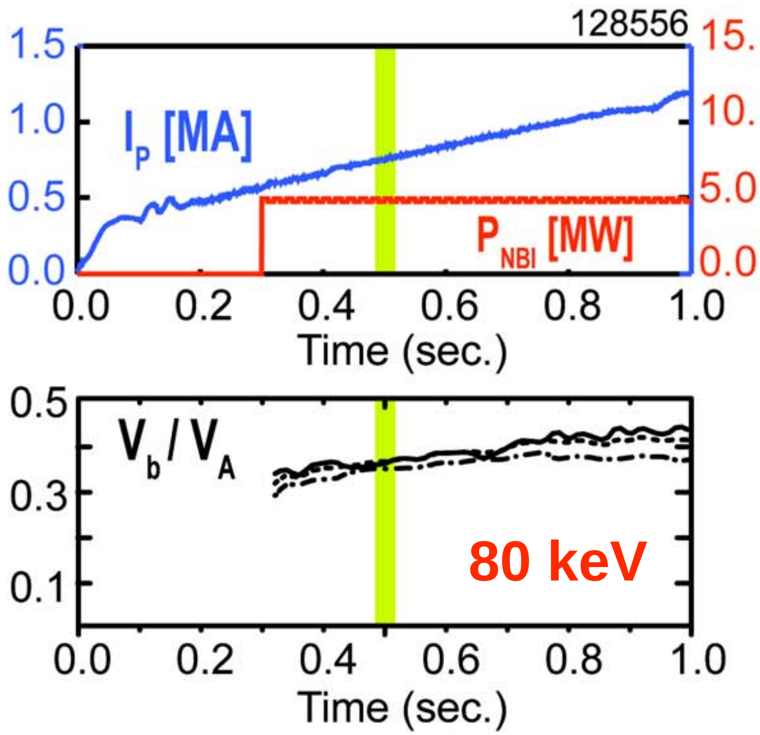
C.D. Conway et al., PPCF (2005)

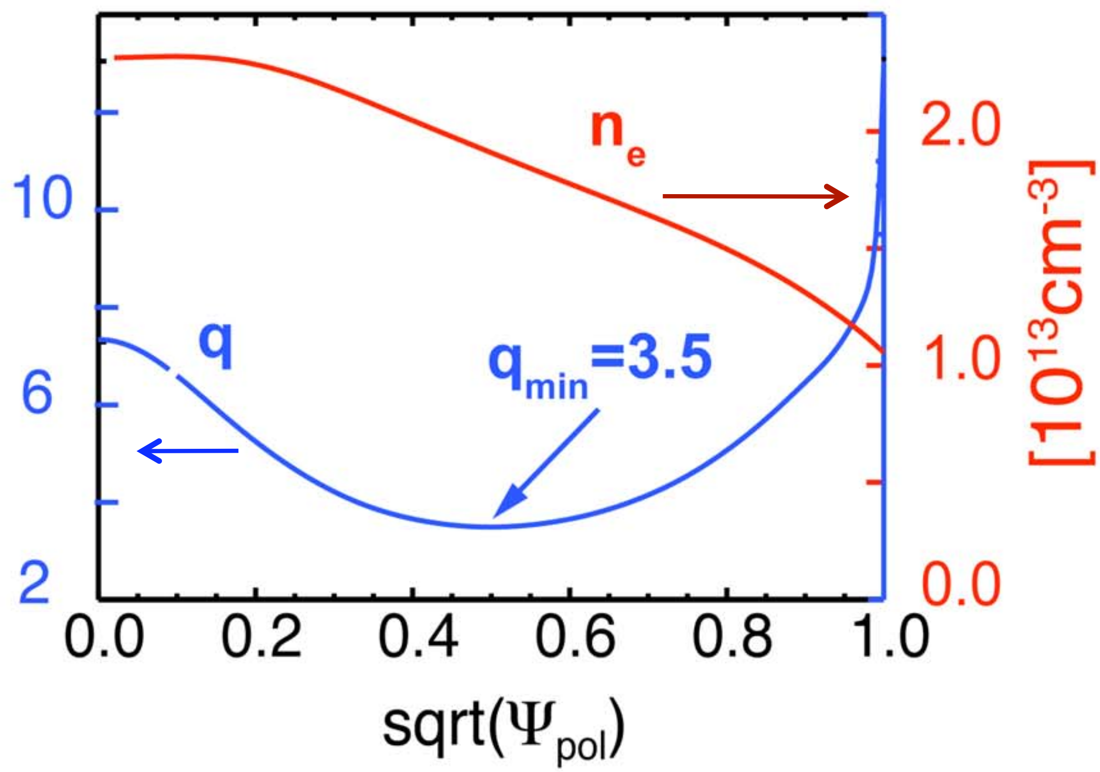
- **Radial localization (continuum of modes) means weak fast ion drive**

- **But, a surprising new result on DIII-D:**
  - Large scale GAMs are excited by counter going beam ions at high q_{min}
  - Strong bursting and neutron drops; intense beam ion interaction

R. Nazikian et al., PRL (2008)

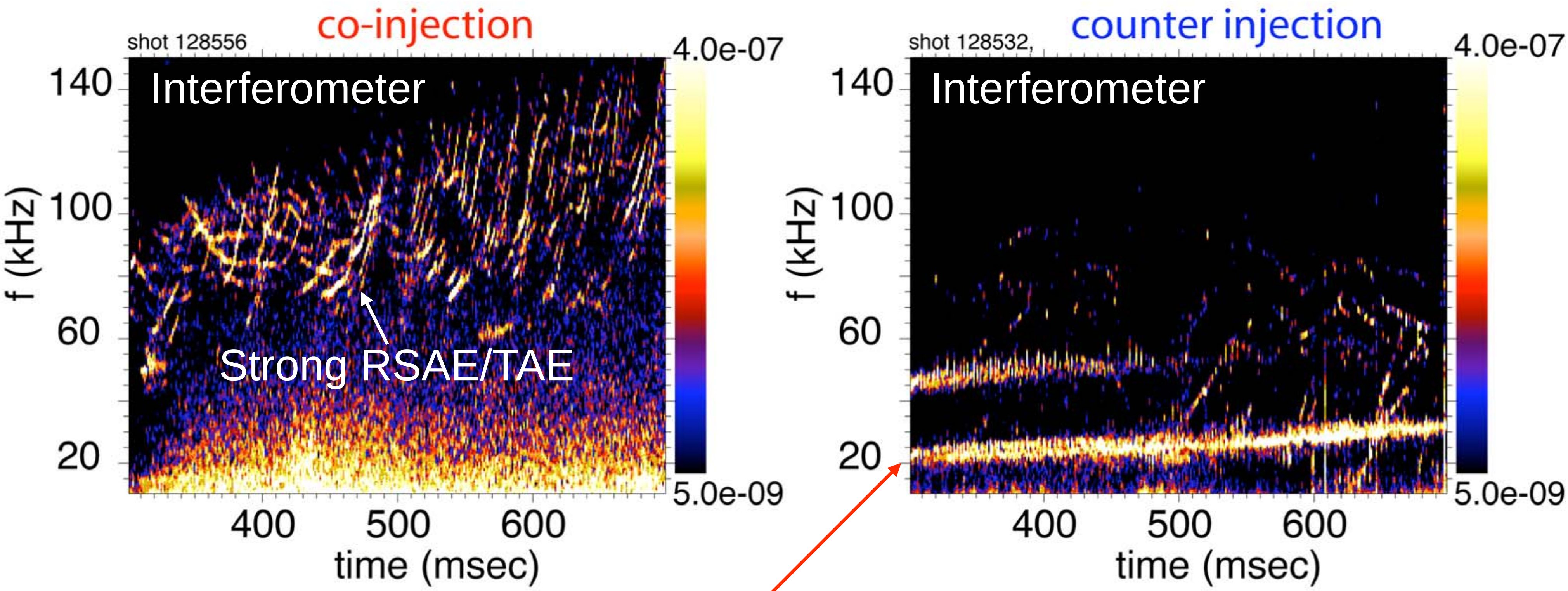
Recipe for n=0 GAM Excitation in DIII-D: Counter Tangential Beam Injection with High q_{min}





- 80 keV beam ions, β_{fast} ˜ $\beta_{thernal}$< 1%

Counter Beam Injection Drives Intense GAM Density Fluctuations in DIII-D

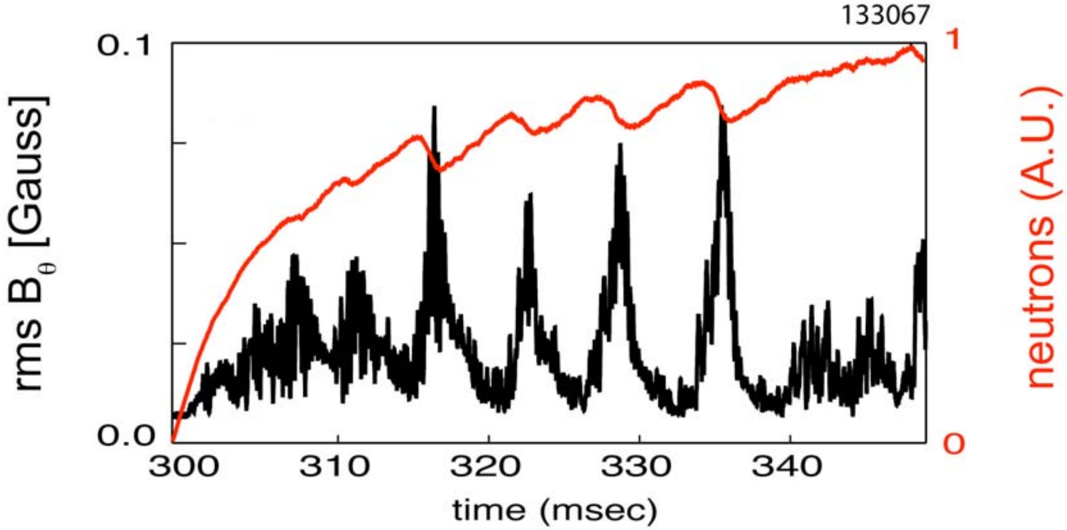


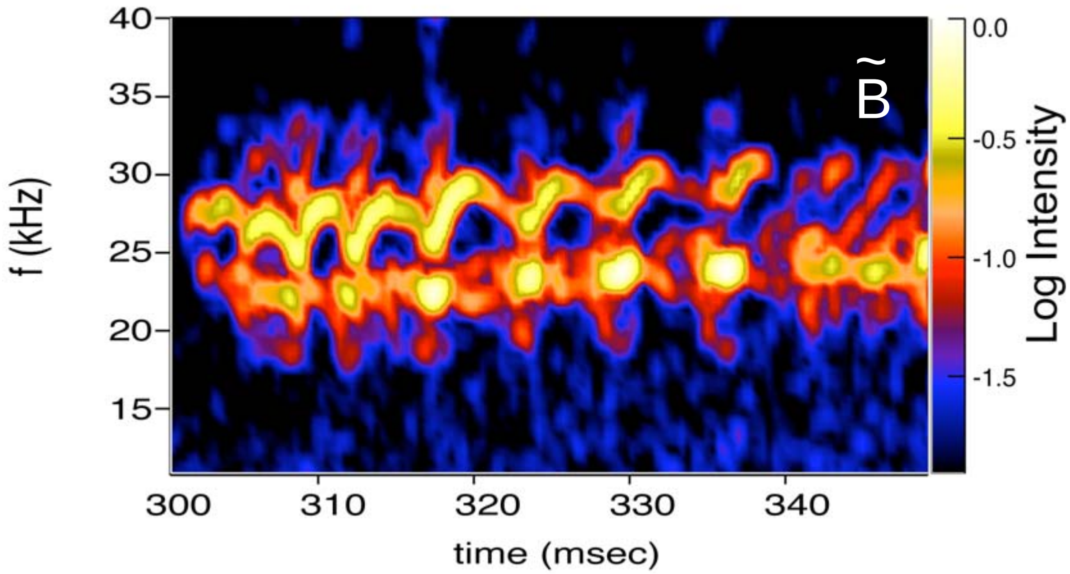
GAM: 1-2% density fluctuation near midplane

n=0 from toroidal array of magnetic probes

- **Note: RSAEs, TAEs with co-injection are Shear Alfvén waves**

GAM Interacts Strongly with Counter-going Beam Ions: Infer Loss and/or Redistribution from Neutron Signal

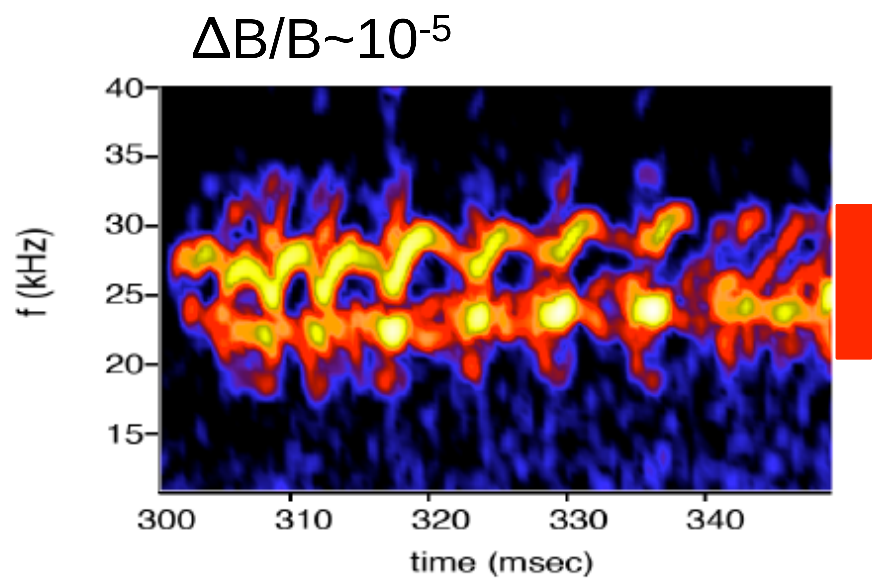


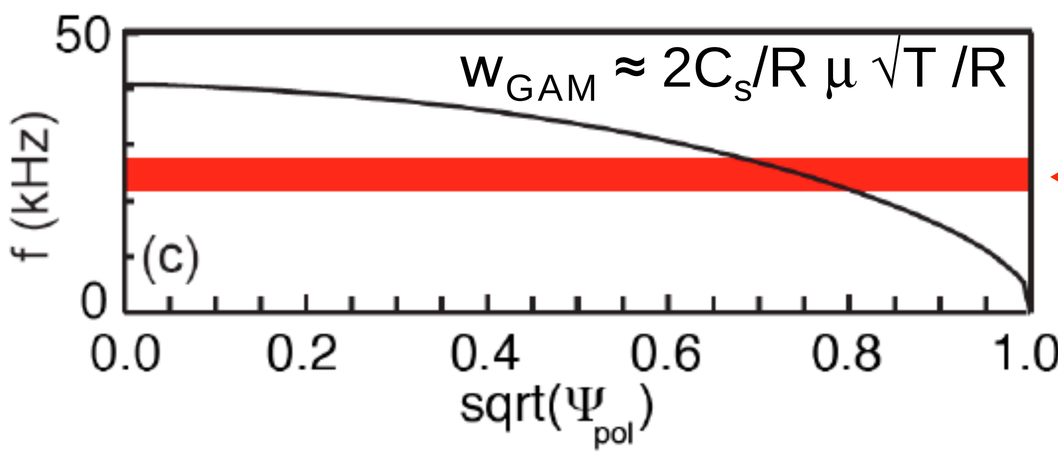


- 10-15 % neutron drops with each mode burst
- Mode bursting seen on magnetics: $\Delta B/B \sim 10^{-5}$
- frequency chirping, frequency splitting suggests hole-clump formation

H. L. Berk, B. N. Breizman, and N. V. Petvishvili, Phys. Lett. A 234, 213 (1997).

Mode Frequency in the Range for Geodesic Acoustic Modes: Intersects the GAM continuum



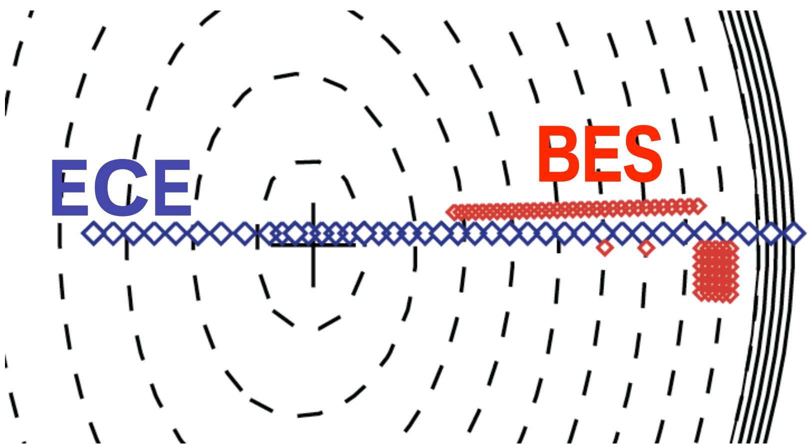


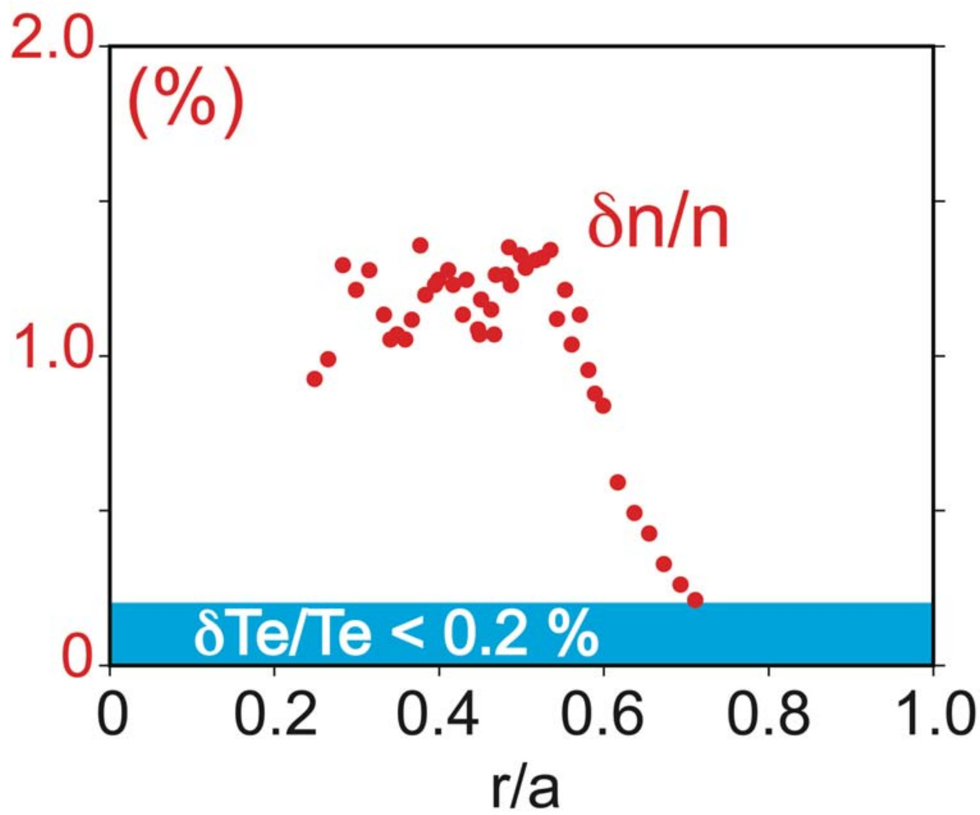
- **GAM continuum frequency decreases monotonic with radius**
- **Key Question: Is mode localized to the intersection with the continuum at ρ ≈ 0.75?**

Answer: Internal Measurements Reveal Global Eigenmode with GAM-like behavior

ECE array measures DT_e

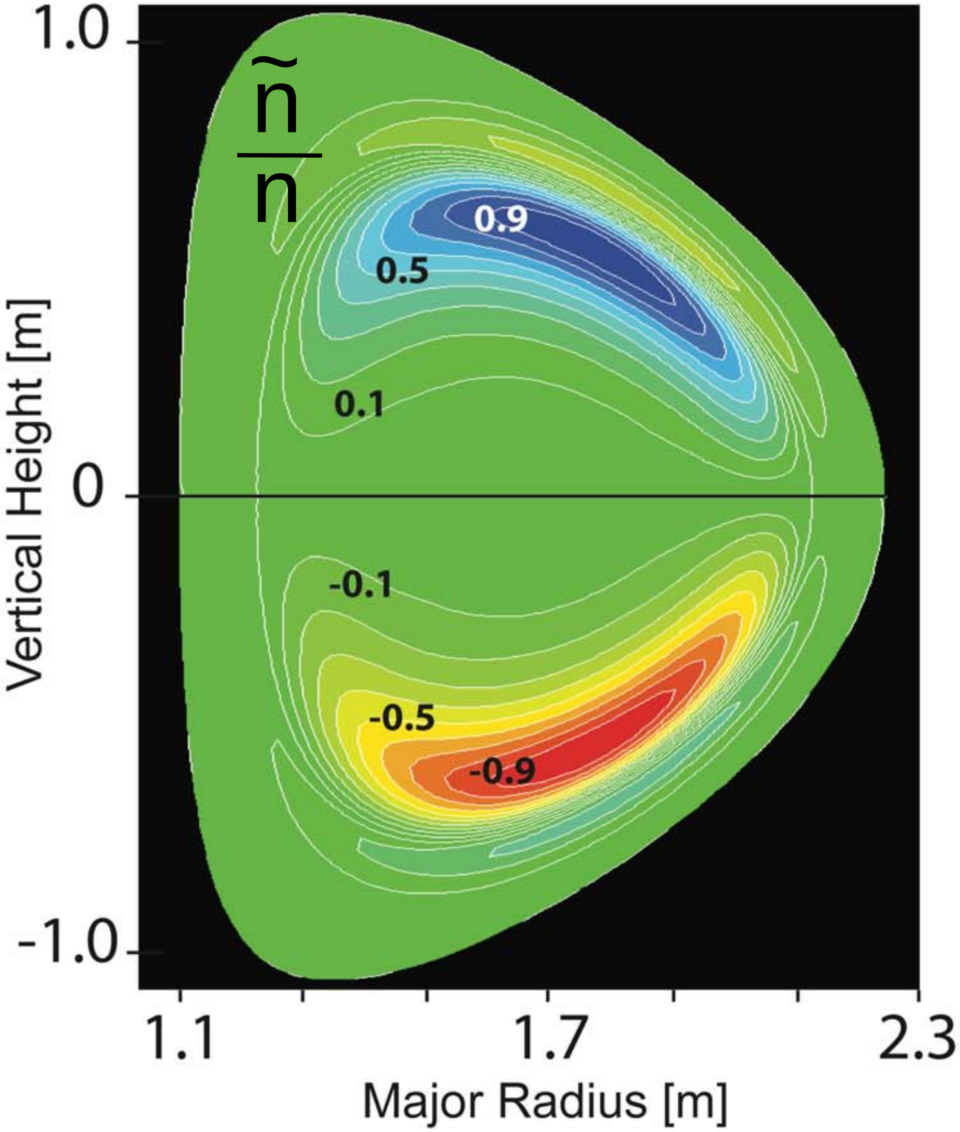
BES array measures Dn_e

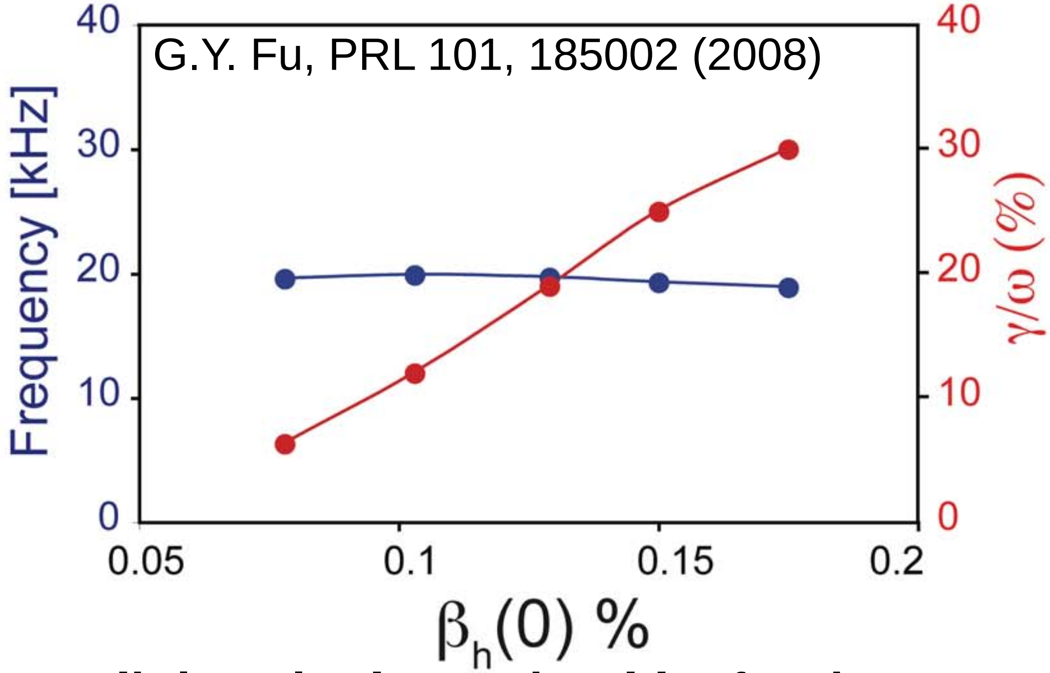




- **Mode not localized to intersection with continuum**
- **DT_e<<Dn_e indicates compressional mode, no radial displacement (GAM-like)**
- **But, Extended radial structure is inconsistent with standard GAM theory**

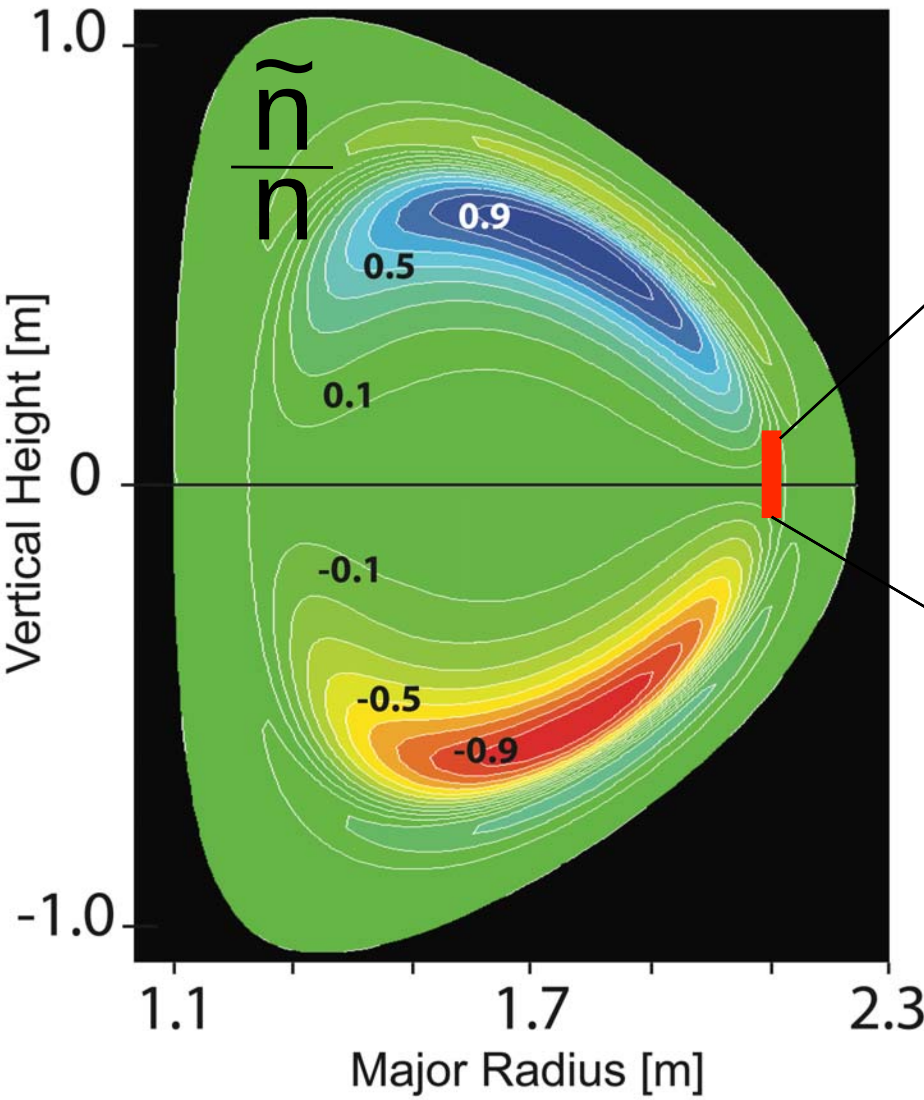
New Hybrid (MHD-kinetic fast ion) Simulation Reveals Global GAMs for Comparable Fast Ion/thermal Beta

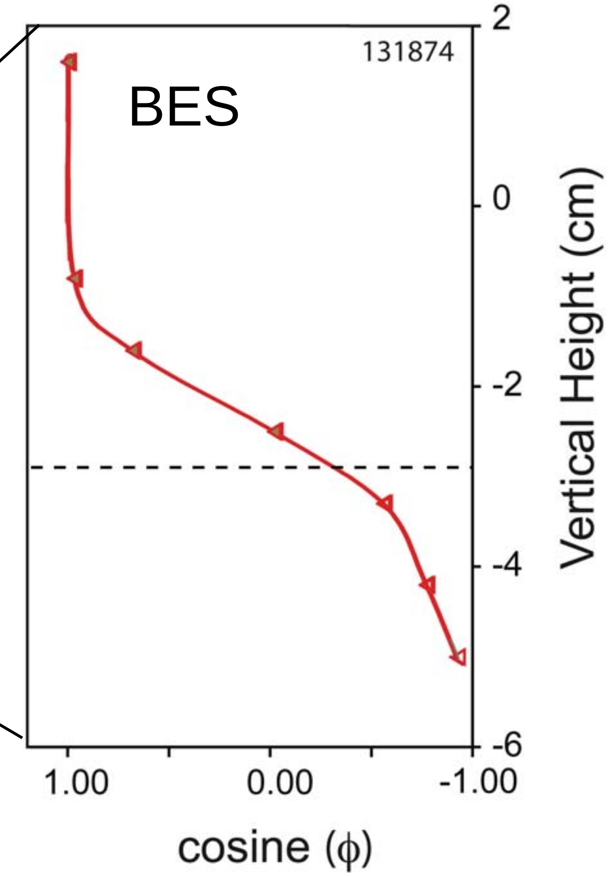




- **Radial scale determined by fast ion poloidal orbit width, not thermal ions !**
- **Large linear growth rate consistent with bursting/chirping/neutron drops**
- **Is up/down standing wave prediction consistent with experiment?**

Up/Down Standing Wave Prediction Confirmed Using Vertical BES Detector Array





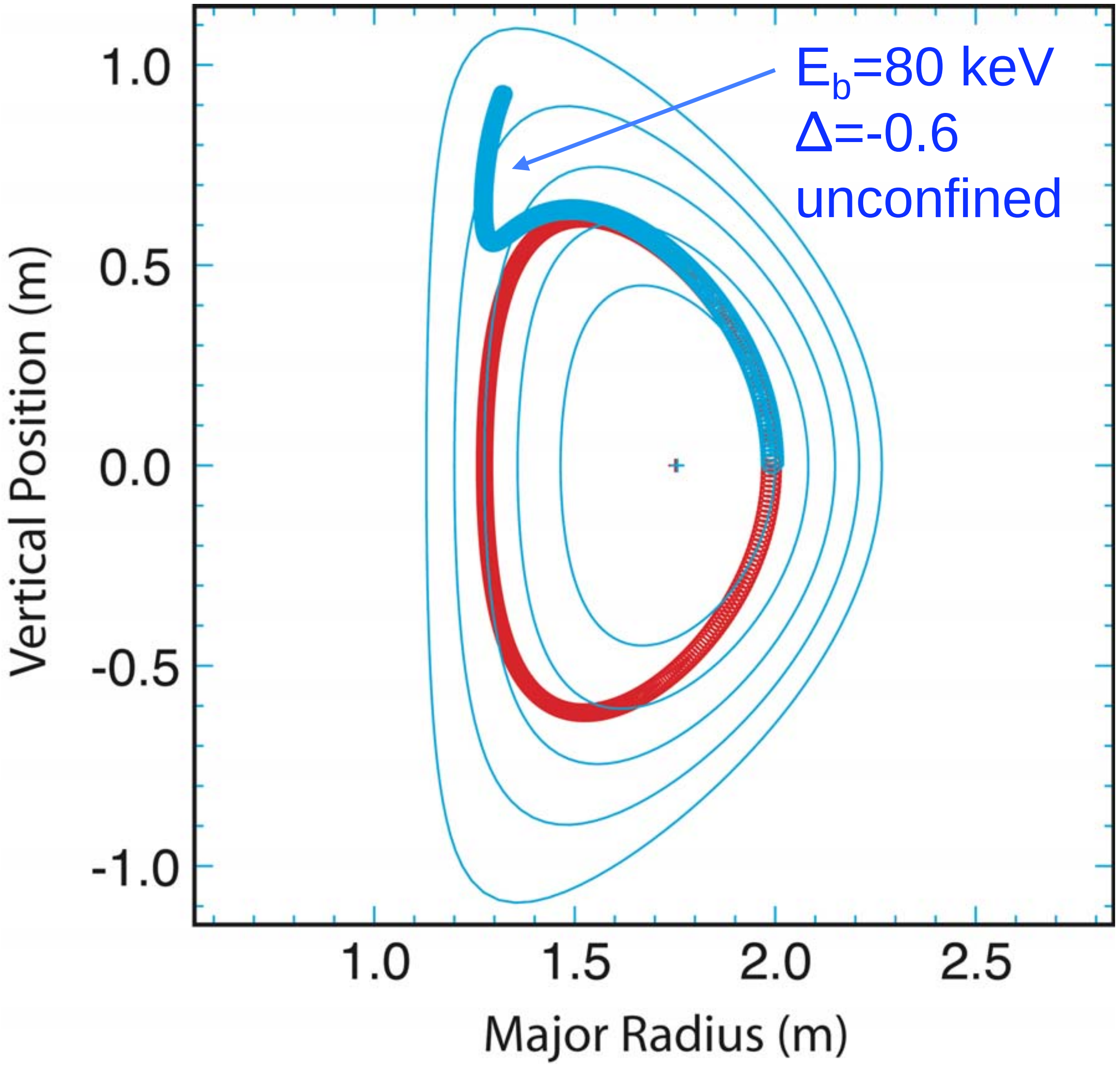
- **Dn_e/n_e≈1-2% near midplane**
  - extrapolates to peak Dn_e/n_e≈10-15% !

What drives the GAM? Strong Anisotropy Drive for Counter Beam Injection at High q_{min}

- **At high q_{min}, counter injected beam ions are close to loss boundary**

- **80 keV beam ions are on unconfined trapped orbits for R > 200 cm and q_{min} > 3.5**

- **no unconfined orbits for similar co-injection plasmas**



Summary/Outstanding Issues

- **Counter beam injection excited global n=0 GAMs in DIII-D**
  - Compressional density fluctuations, no radial displacement
  - Mode frequency inside GAM continuum
  - Strong bursting, frequency chirping, neutron drops
- **New theory with $\beta_{fast} \sim \beta_{thermal}$ reproduces main observations**
  - Large radial scale length determined by fast ion orbit width
  - Large linear growth rate, up to 30% !!
- **Issue: Particle should conserve toroidal angular momentum for n=0 mode, so why do we see losses and or redistribution?**
- **Next step: Need to measure pitch angle distribution of losses on outer wall with scintillator probe array**

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

PPPL PRINCETON PLASMA PHYSICS LABORATORY