NSTX-U JOHNS HOPKINS UNIVERSITY Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Investigation of CAE/GAE-induced electron thermal transport on NSTX

presented by:

Kevin Tritz

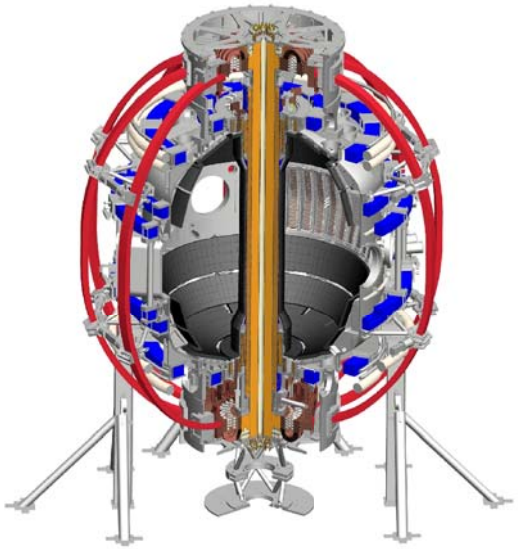
Johns Hopkins University

N.N. Gorelenkov, R. White (*PPPL*), N.A. Crocker (*UCLA*),
E. Belova, E. Fredrickson, S. Kaye (*PPPL*), D. Stutmam (*JHU*) & the NSTX-U team

54th Annual Meeting APS Division of Plasma Physics
Providence, RI
10/30/2012

Coll of Wm & Mary
Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Lehigh U
Nova Photonics
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Tennessee
U Tulsa
U Washington
U Wisconsin
X Science LLC

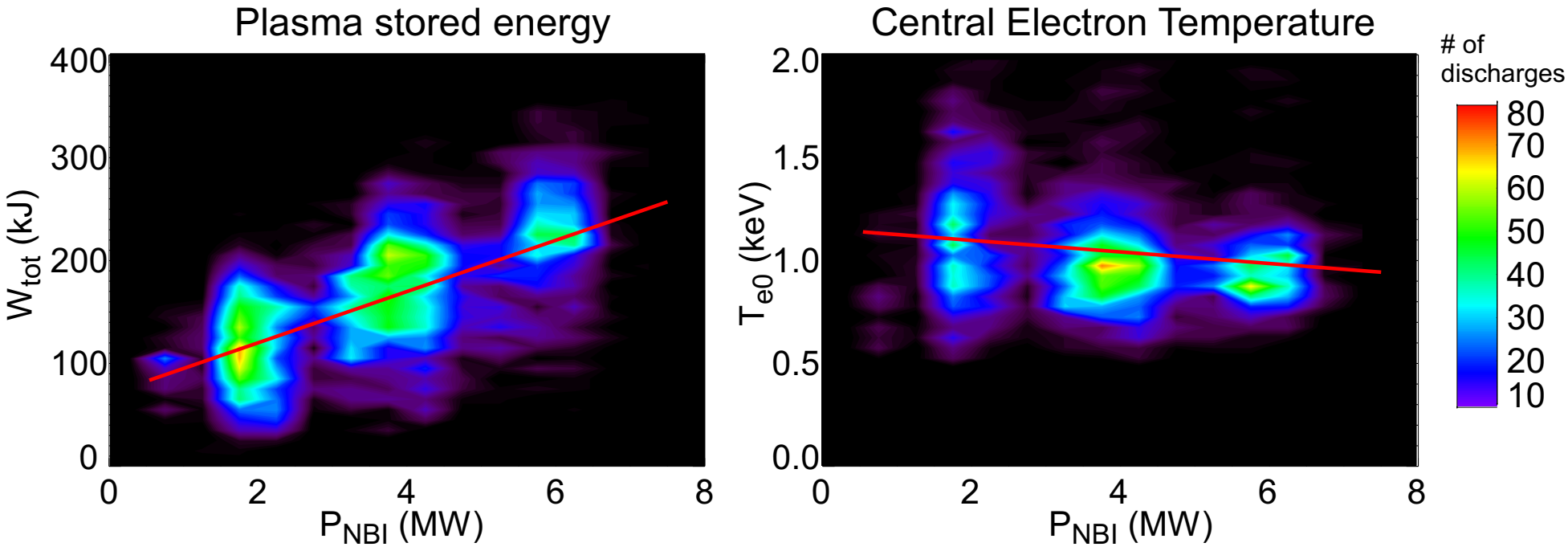
Culham Sci Ctr
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Inst for Nucl Res, Kiev
Ioffe Inst
TRINITI
Chonbuk Natl U
NFRI
KAIST
POSTECH
Seoul Natl U
ASIPP
CIEMAT
FOM Inst DIFFE
ENEA, Frascati
CAE, Cadarache
IPP, Julich
IPP, Garching
ASCR, Czech Rep



Fast ion-induced CAEs and GAEs could explain the unusually high levels of electron thermal transport in the core of high power NBI heated H-mode NSTX plasmas.

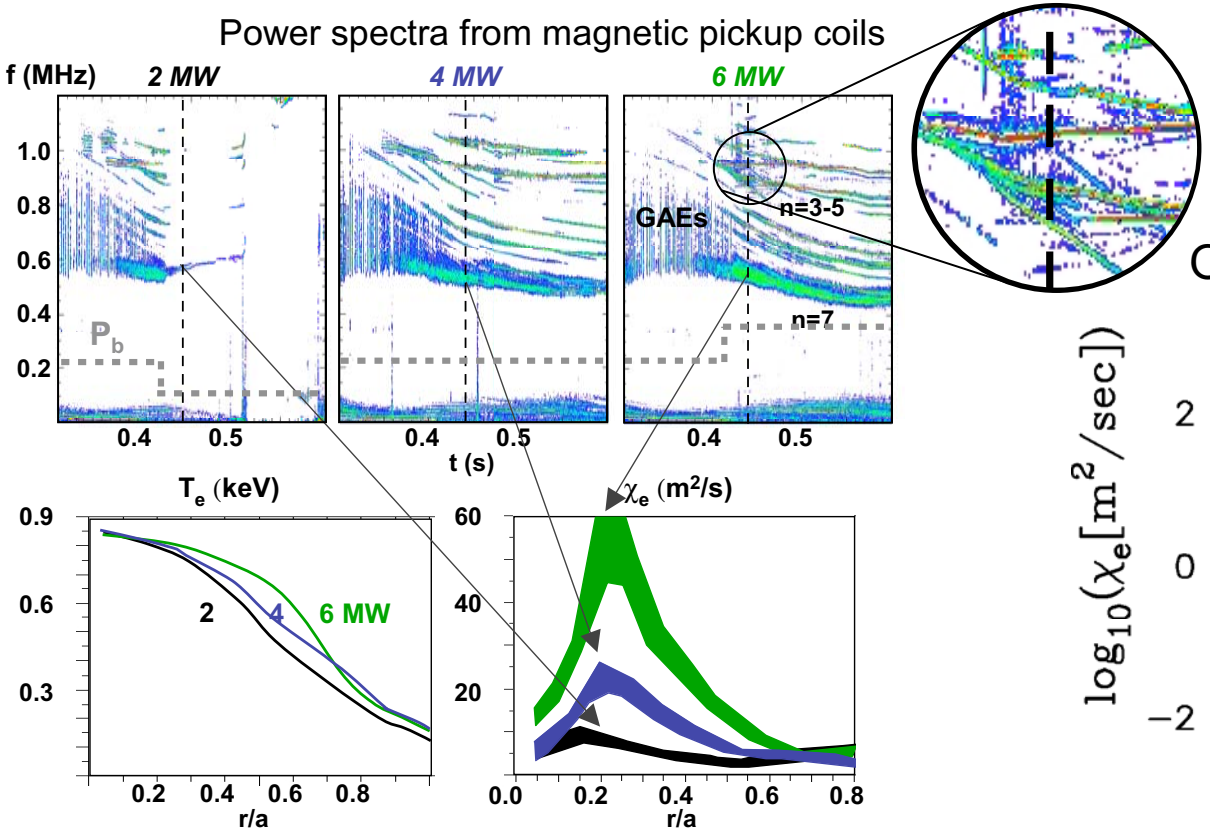
NB power has little effect on T_{e0}

Plasma Discharge Histograms



- Database scan of >4000 NBI plasma discharges on NSTX
  - Identify central electron temperature at maximum stored energy
- Large scatter observed, wide range of plasma discharges
- Small but noticeable decrease in T_{e0} vs. P_{NBI}
  - Overall plasma stored energy increases with P_{NBI} (T_e profile broadening)

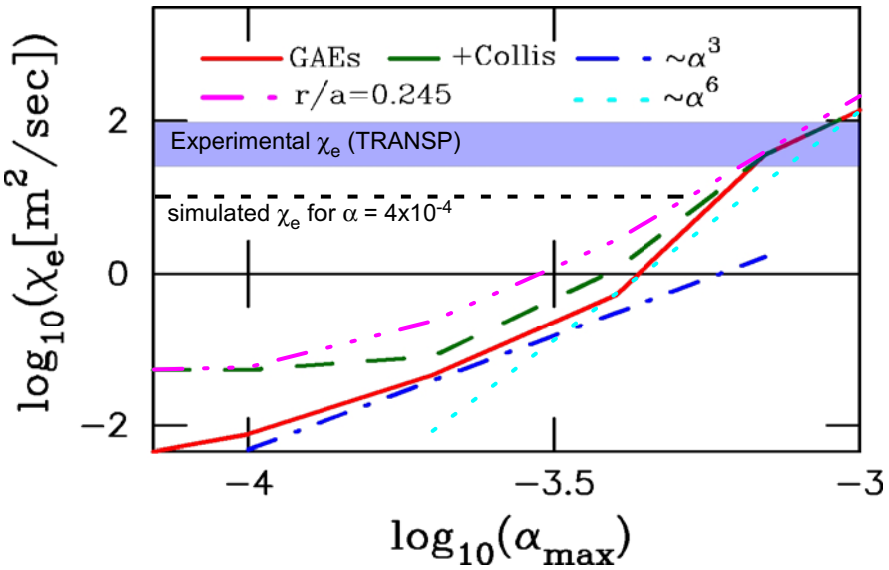
High frequency AE modes proposed as possible mechanism for rapid electron thermal transport in plasma core



D. Stutman, PRL 2009

Convergence/divergence of mode frequencies evidence of GAEs $\omega_j = v_A k_{\|j} \approx v_A \frac{m_j - n_j q}{q R_0}$

ORBIT simulated electron transport

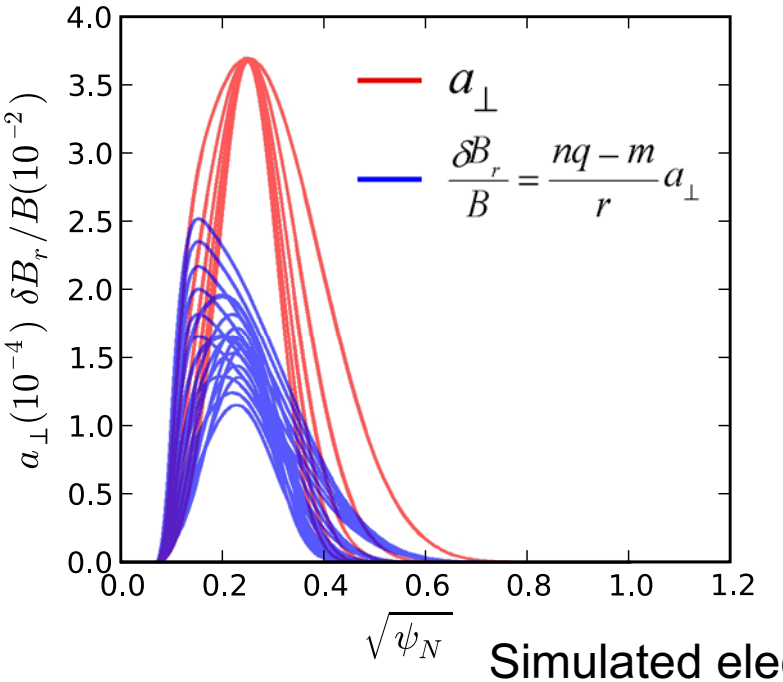


N.N. Gorelenkov Nucl. Fus. 2010

- AE activity correlates strongly with P_{NBI} steps and enhanced core electron thermal transport
- ORBIT guiding center code used to simulate GAE-induced electron transport, scales as amplitude, α^{3-6}

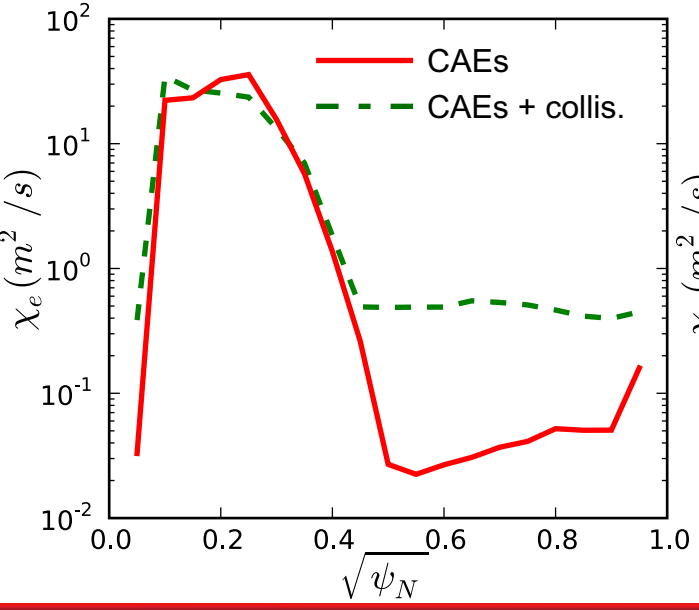
ORBIT recently modified to study effects of Compressional AEs on electron transport

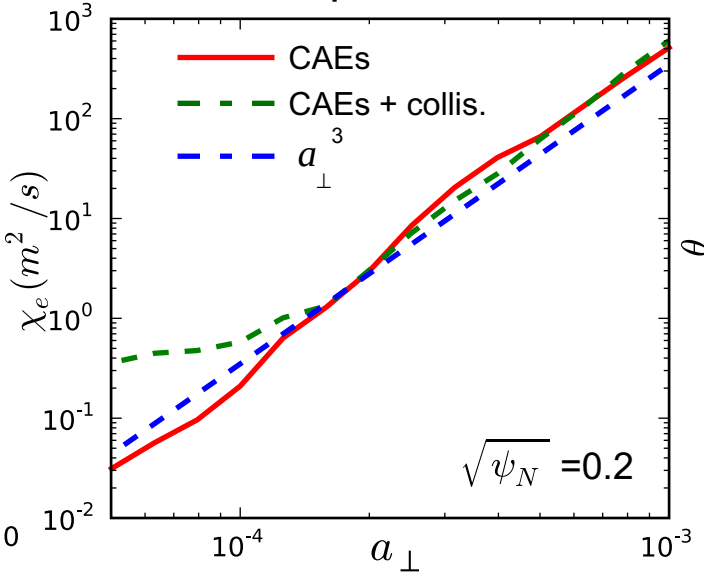
CAE model used for ORBIT simulations



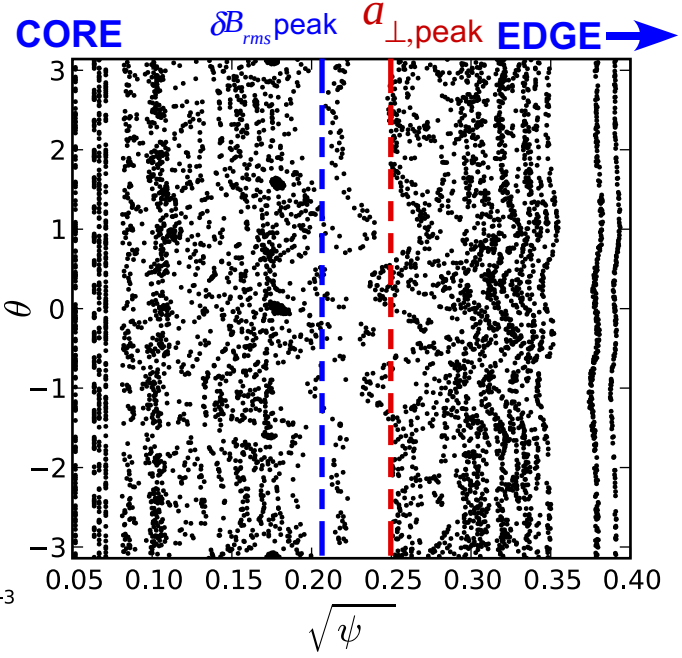
- Data/dispersion analysis identifies core GAEs & CAEs (*N.A. Crocker PPCF 2011*)
- ORBIT used to scan effects of number of CAEs and amplitude, $a_\perp$
- ORBIT shows similar strong e⁻ transport, scaling for CAEs (~$a_\perp^{3\text{-}4}$)

Simulated electron transport

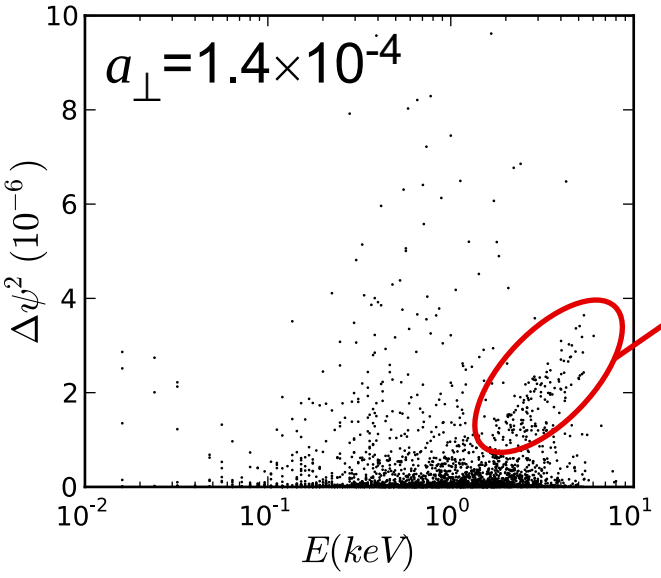


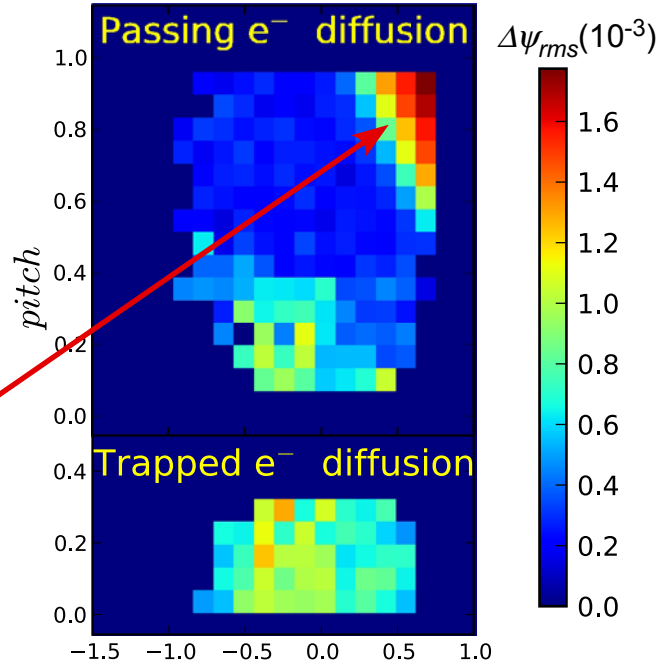


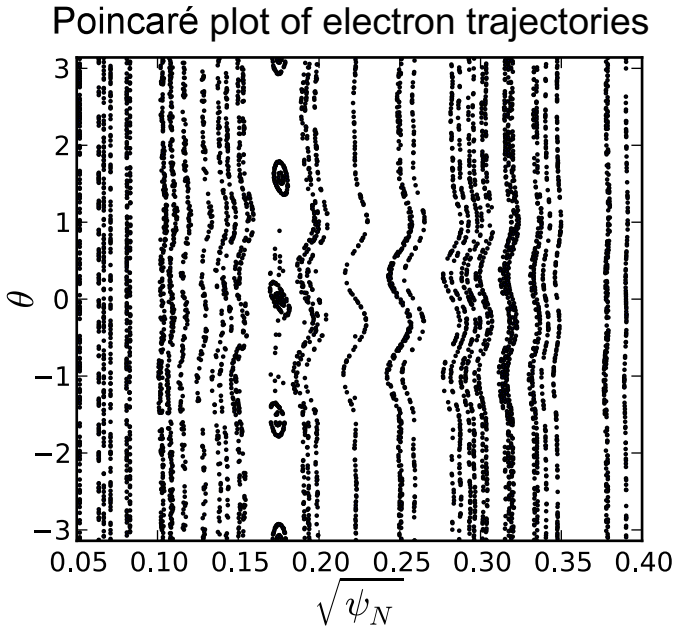
Poincaré plot of electron trajectories

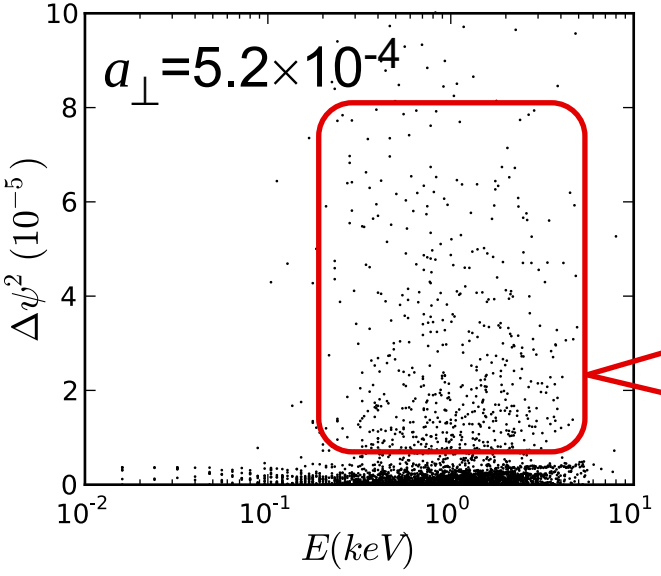


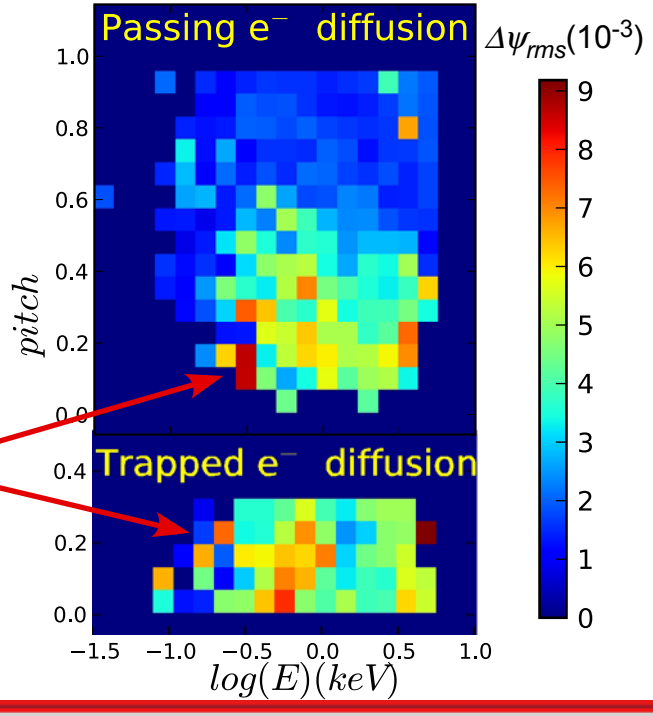
Electron transport at higher $a_\perp$ amplitudes shifts to lower energy particles with higher $v_\perp/v_\parallel$

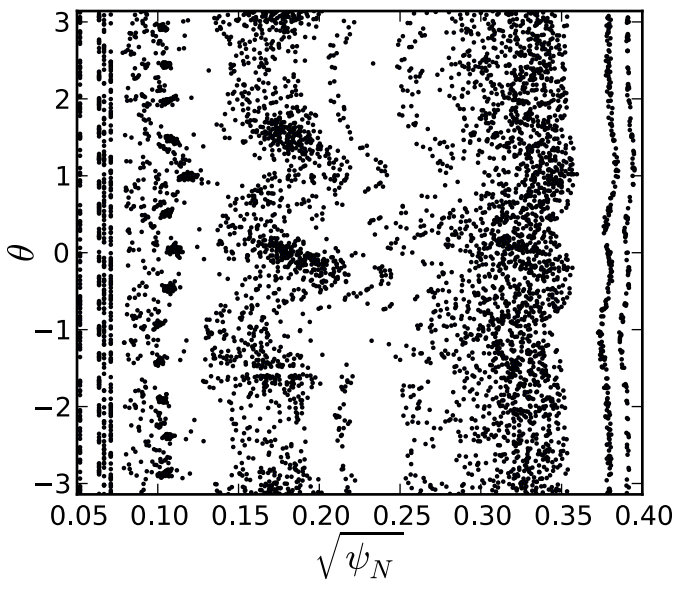






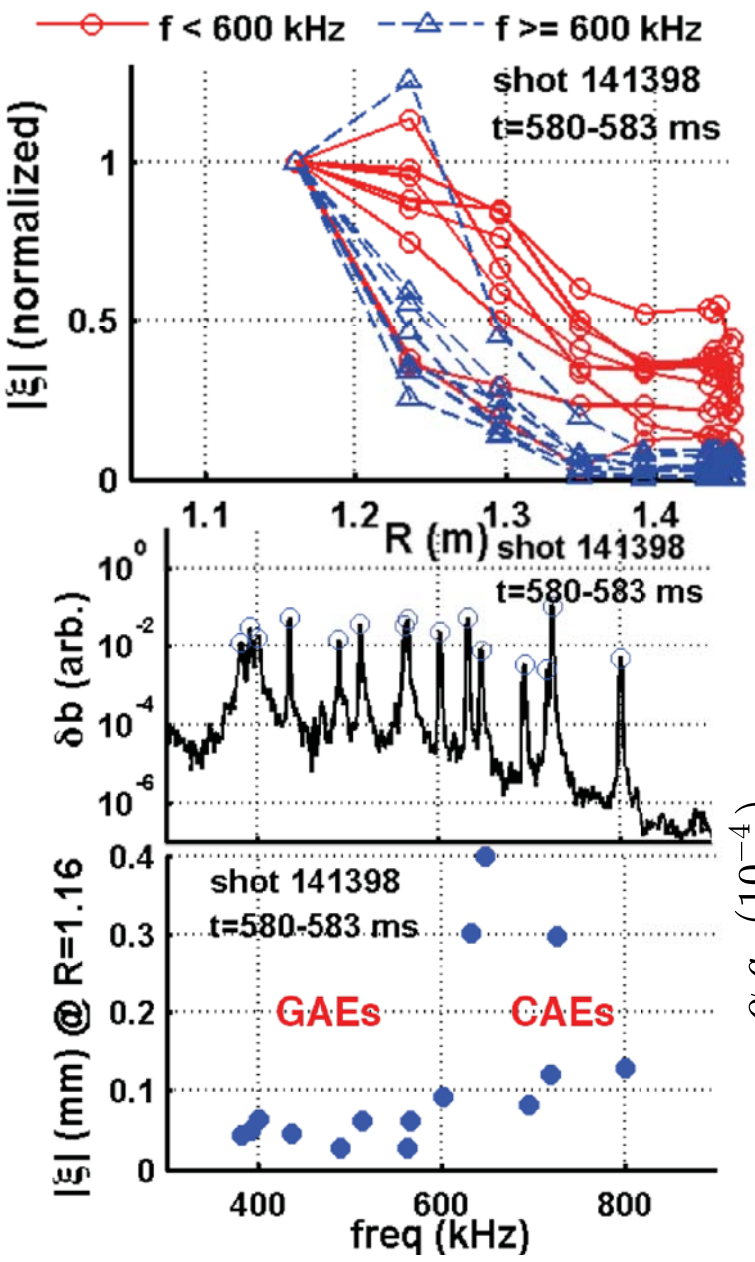






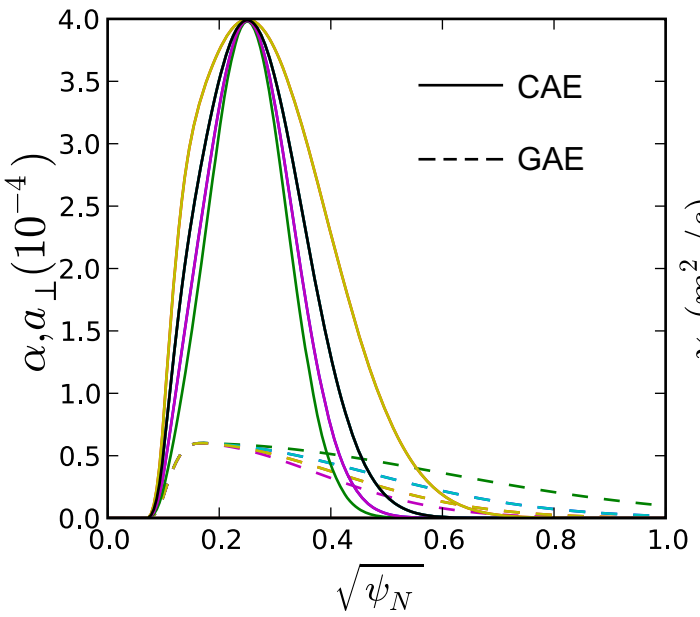
ORBIT simulation of χ_e using modes based on reflectometer measurements consistent with TRANSP χ_e

N.A. Crocker, GO6.03

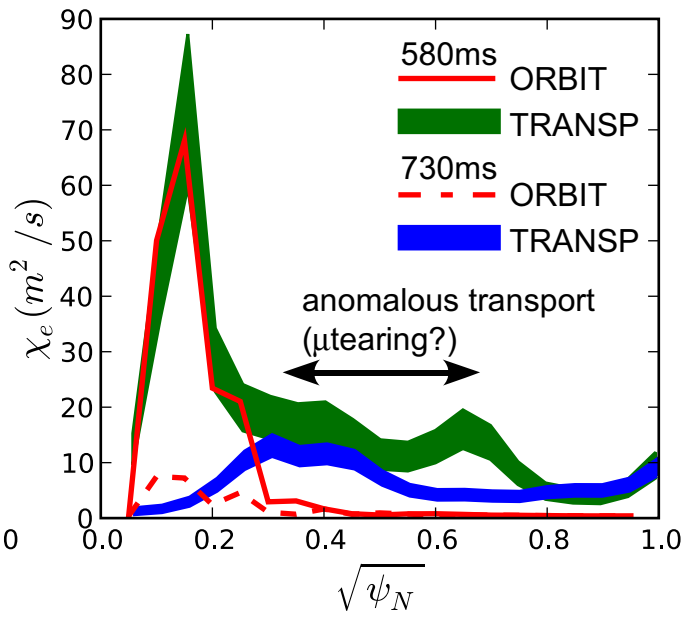


- location, width, n-number, frequency range, and amplitude guided by reflectometer measurements
- χ_e matches TRANSP amplitude/profile
- challenging core measurements (<1.15m), ORBIT forces α, $a_\perp(r_{axis}) \rightarrow 0$

Model used for ORBIT simulations

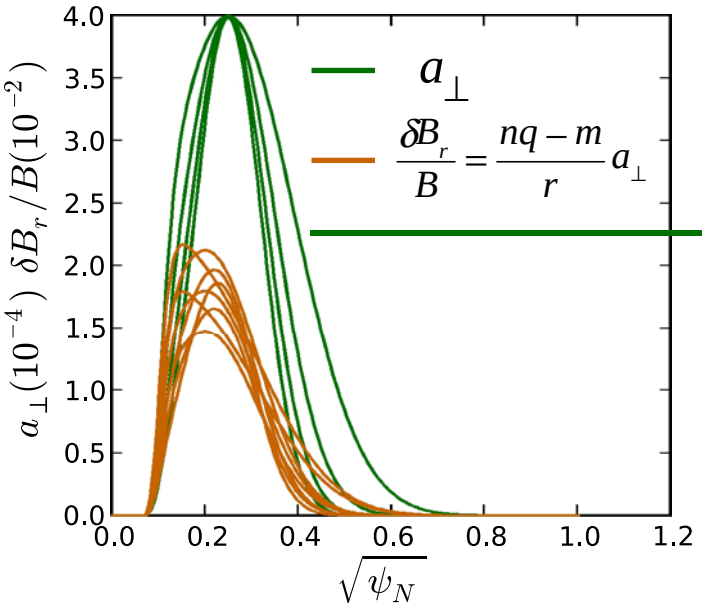


Comparison of ORBIT/TRANSP χ_e

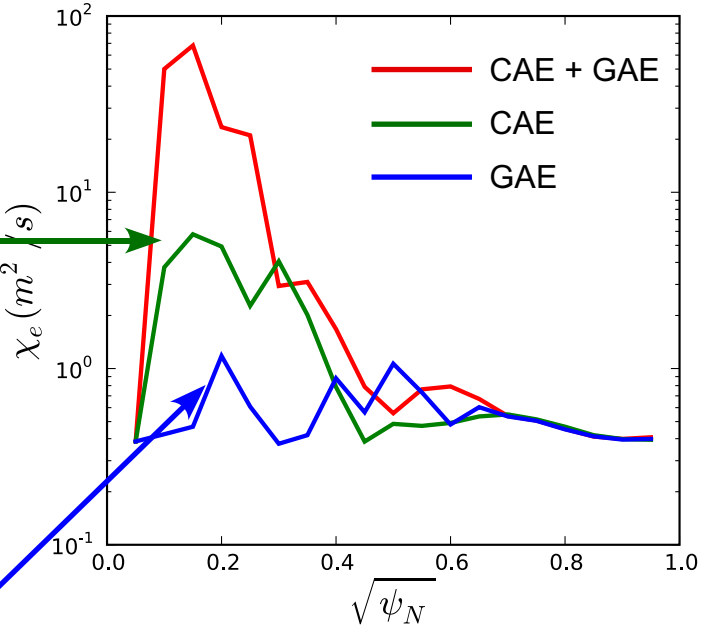


CAE/GAE core modes interact non-linearly to enhance electron transport

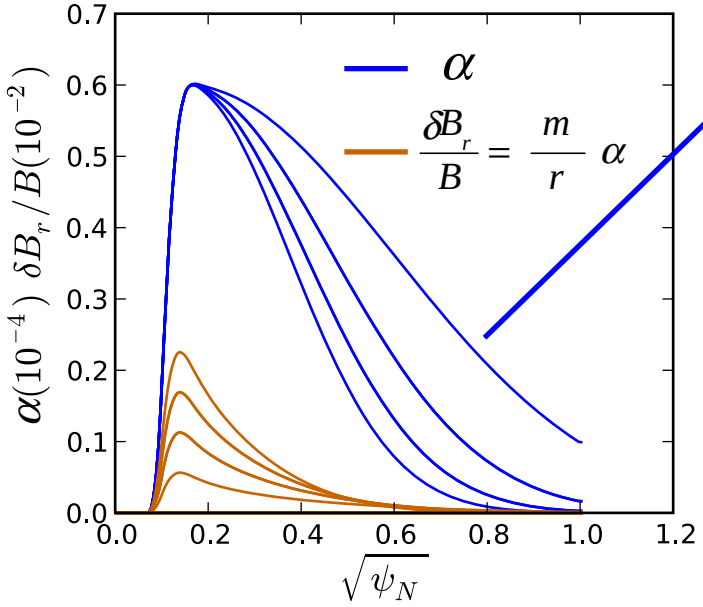
ORBIT CAE modes



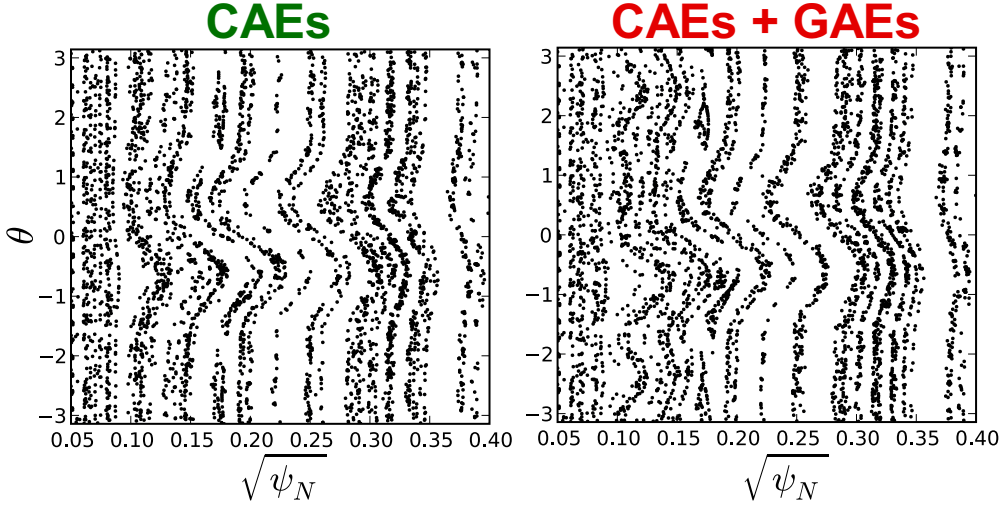
ORBIT simulated e- transport



ORBIT GAE modes



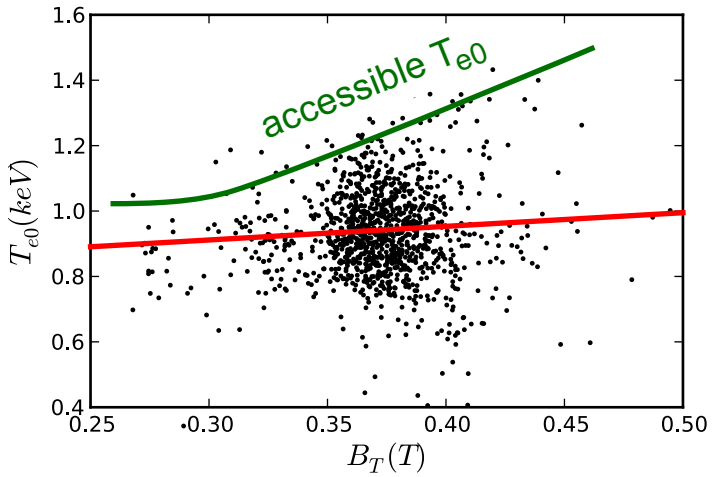
Poincaré plot of electron trajectories

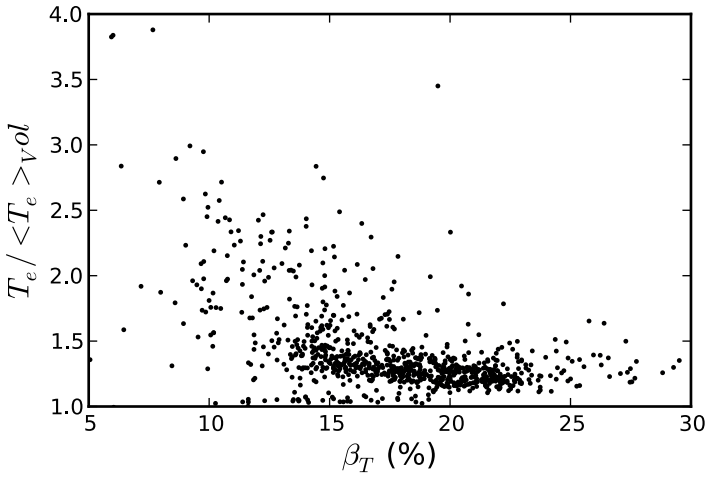


B_{T0} trend in high power H-modes suggests CAE/GAE transport may be mitigated for NSTX-U

- CAE/GAE modes appear more virulent at low B_T, hypothesis:
  - higher B_T reduces drive (lower v_{FI}/v_A)
  - higher B_T reduces mode amplitude (lower $\delta B_r/B$)
- NSTX-U will access higher B_T: 0.45 → 1.0 T, reduce v_{FI}/v_A ~ ×2

High power H-modes (P_{NBI} > 5.5MW)





- Trends not fully understood, further investigation for CAE/GAE effect
- 'Flattening' of T_e profile may be advantageous for improved stability

Summary

- New results from modified ORBIT code demonstrate CAE induced core e^- transport with strong amplitude scaling
- Simulations using mode parameters guided by measurements predict e^- transport that compares well to TRANSP χ_e

Future Work

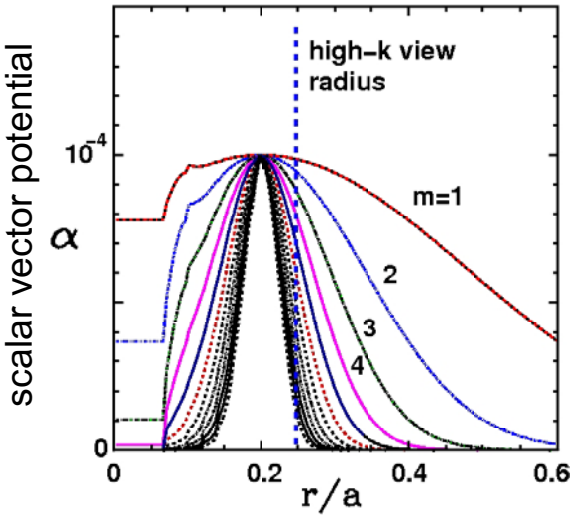
- Modify ORBIT to accept direct GAE/CAE radial mode structures from measurements
- Use HYM code to predict GAE/CAEs for NSTX-U and future devices for simulation of expected core e^- transport
- Favorable T_{e0} scaling with B_T suggest AE-induced e^- transport could be mitigated on NSTX-U
- Investigate the use of CAE/GAE antenna for active mode mitigation/excitation and localized χ_e control

Backup Slides

ORBIT guiding center code used to simulate GAE effects on electron thermal transport

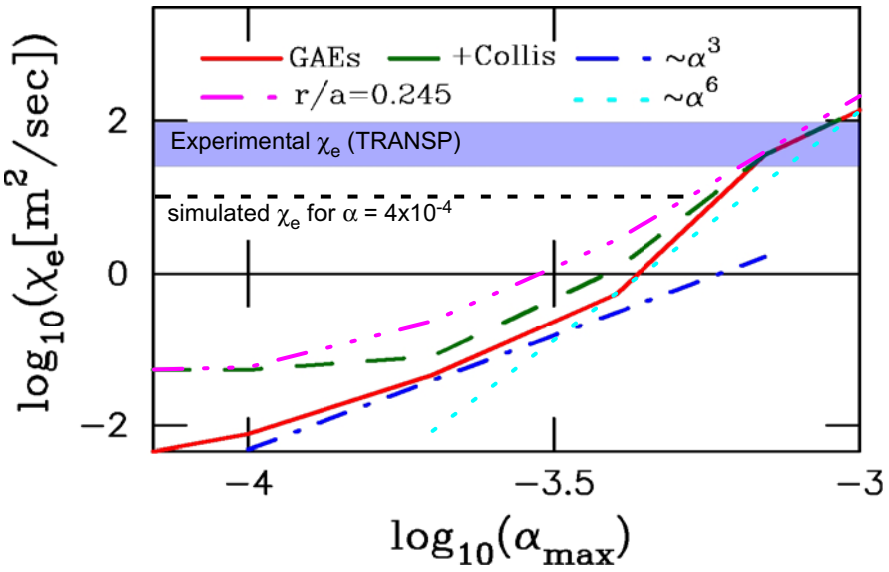
N.N. Gorelenkov Nucl. Fus. 2010

GAE Model used in ORBIT calculations

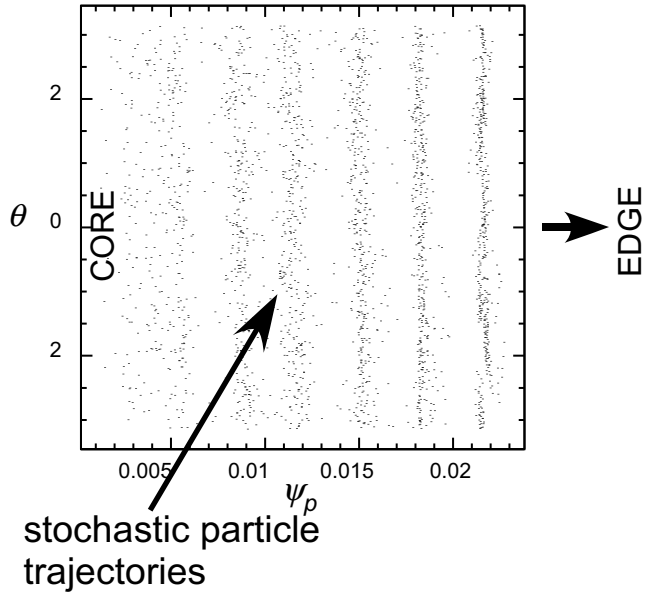


- Ad-hoc model used to study transport vs. mode amplitude and number
- $\chi_e > 10 m^2/s$ for GAE mode amplitude: $\alpha > 4x10^{-4}$, number: N > 16
- 'stochastic' transport sensitive to mode structure and amplitude ($\sim\alpha^{3\text{-}6}$)

Simulated electron transport

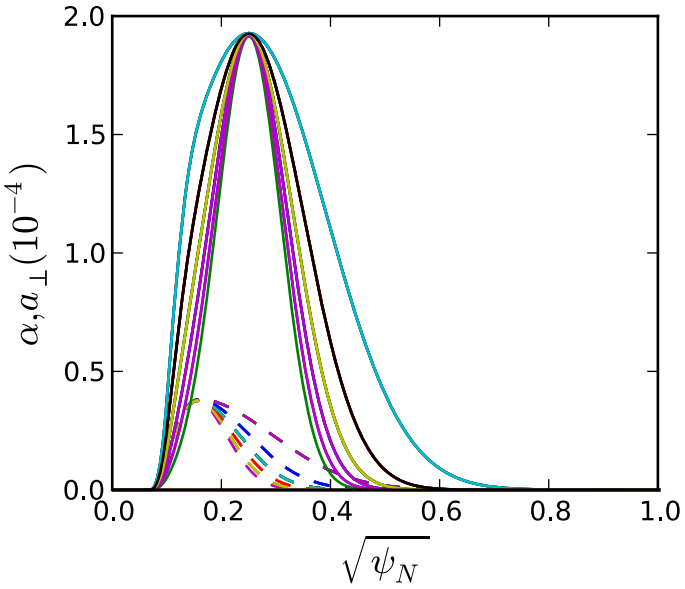


Poincaré plot of electron trajectories



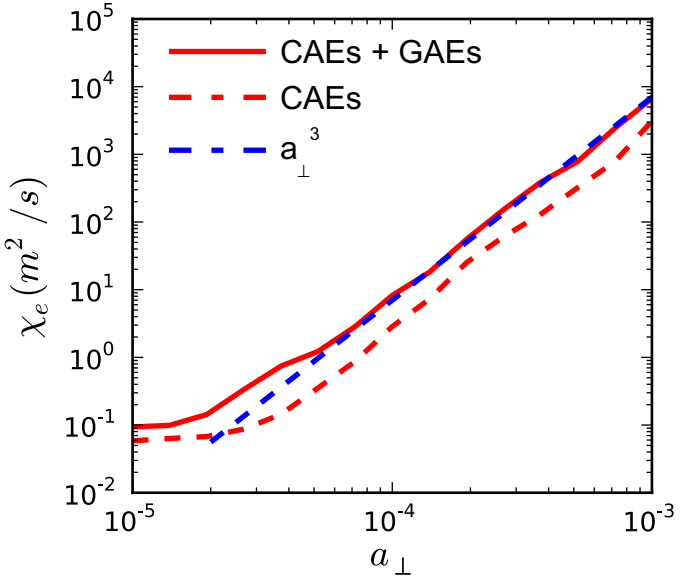
CAEs/GAEs at multiple locations enhances simulated electron transport in plasma core

Model used for ORBIT simulations



- ORBIT simulations with both shear and compressional modes in plasma core
- guided by measurements, GAE amplitude chosen $\alpha \sim 0.2 \times a_\perp$
- χ_e increased by factor of $\times 3$, shows similar scaling with amplitude

Simulated electron transport



Poincaré plot of electron trajectories