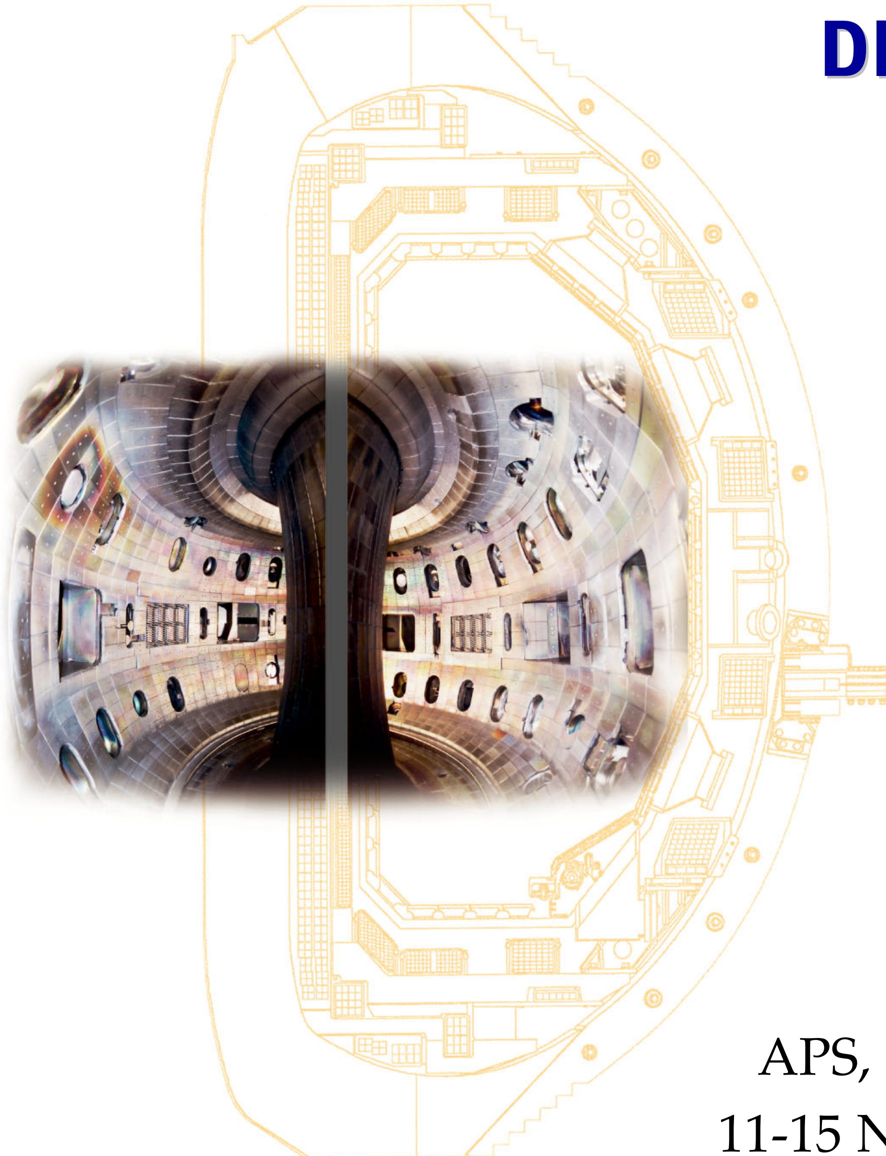
Modeling stochastic effects in the DIII-D boundary



T. E. EVANS,

General Atomics, San Diego, CA

R. A. MOYER,

UCSD, La Jolla, CA

D. REITER,

Forschungszentrum Jülich, Germany

S. V. KASILOV,

Kharkov Institute of Physics, Kharkov, Ukraine

and

A. M. RUNOV,

MPI, Greifswald, Germany

APS, DPP Meeting

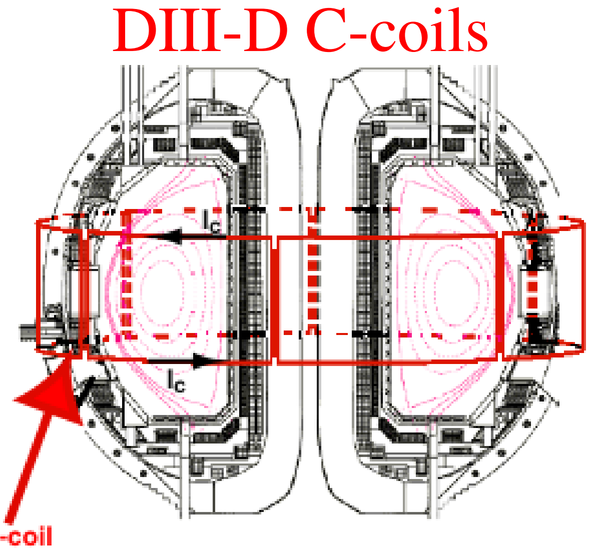
11-15 November 2002,

Orlando. Florida

Overview and motivation

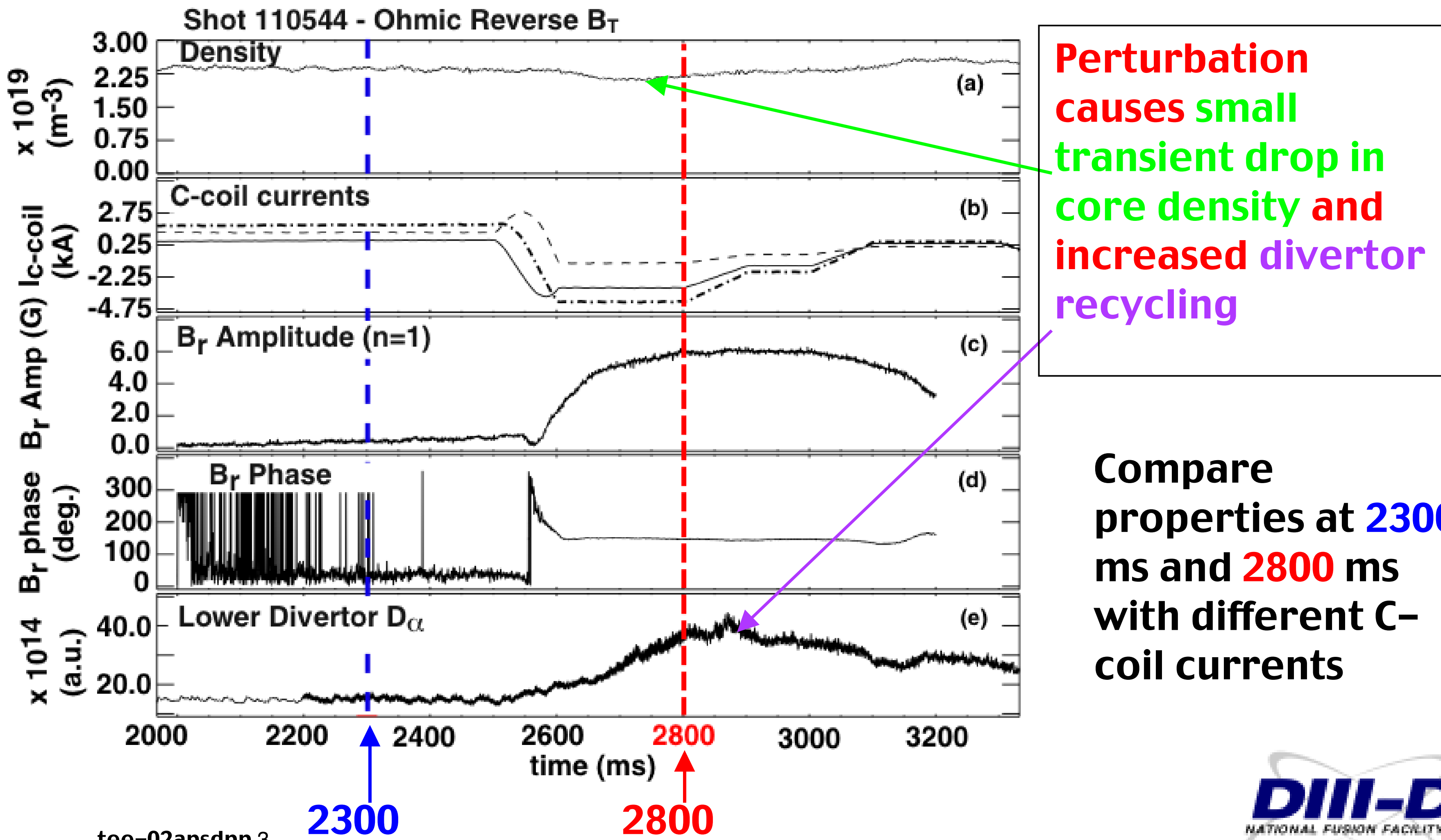
- **Advanced Tokamaks use non-axisymmetric magnetic perturbation coils to control MHD modes that limit performance (locked, neoclassical tearing, and resistive wall modes).**
  - > C-coils in DIII-D(see Jackson, QP1.080 and Schaffer QP1.076 for additional details)
- **Experiments in diverted Ohmic plasmas demonstrate that the C-coils produce edge properties similar to those found in circular plasmas with stochastic boundaries**
  - > Increased recycling (in the divertor)
  - > Broadened recycling profiles indicating spreading of particle/heat fluxes at plates
  - > Reduce edge n_e and T_e gradients consistent with stochastic field regions predicted by field line integration
- **A key question is the nature of the plasma response in the high power, high rotation, and high confinement regimes of interest to the AT program.**
- **Developing an understanding of the plasma response to stochastic layers can provide a tool for control of the edge pedestal region, including:**
  - > Dynamically limit the edge pressure gradient,
  - > alter ELM behavior, and
  - > Regulate core performance due to coupling of core transport to pedestal height.

DIII-D C-coils



Changes in C-coil currents are used to actively perturb DIII-D boundary

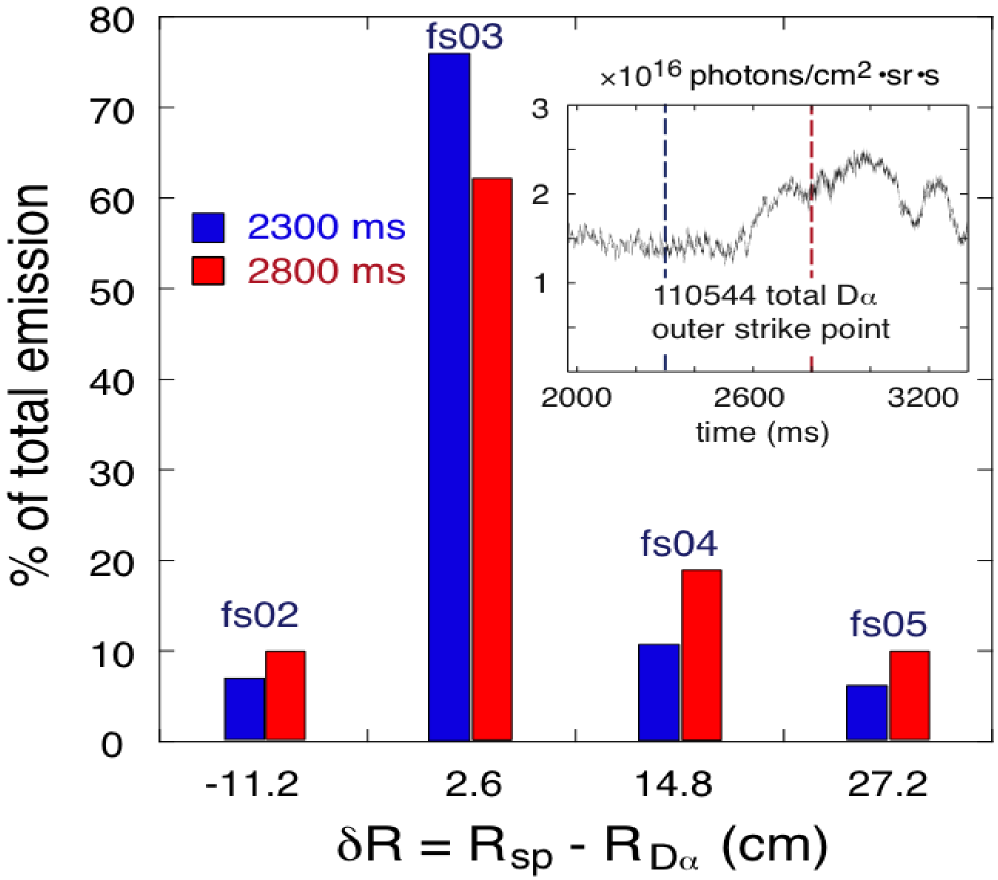
- Diverted Ohmic discharges have been used in DIII-D to compare with stochastic boundary results from non-diverted Ohmic tokamaks.

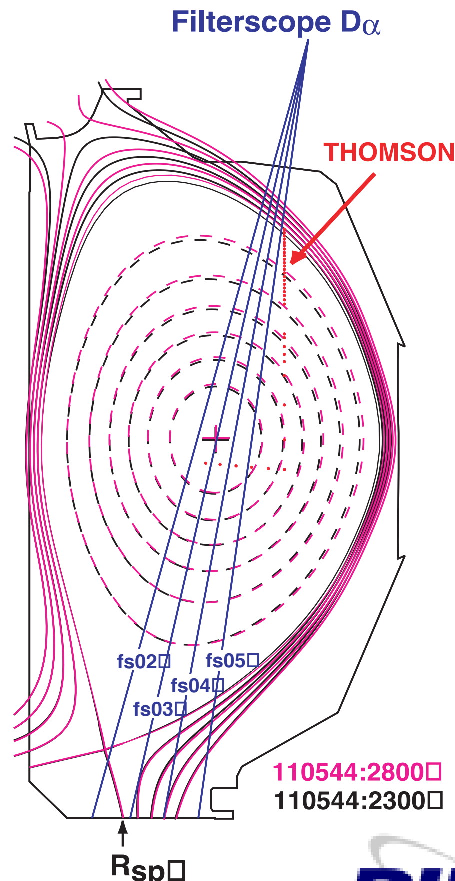


Compare properties at 2300 ms and 2800 ms with different C-coil currents

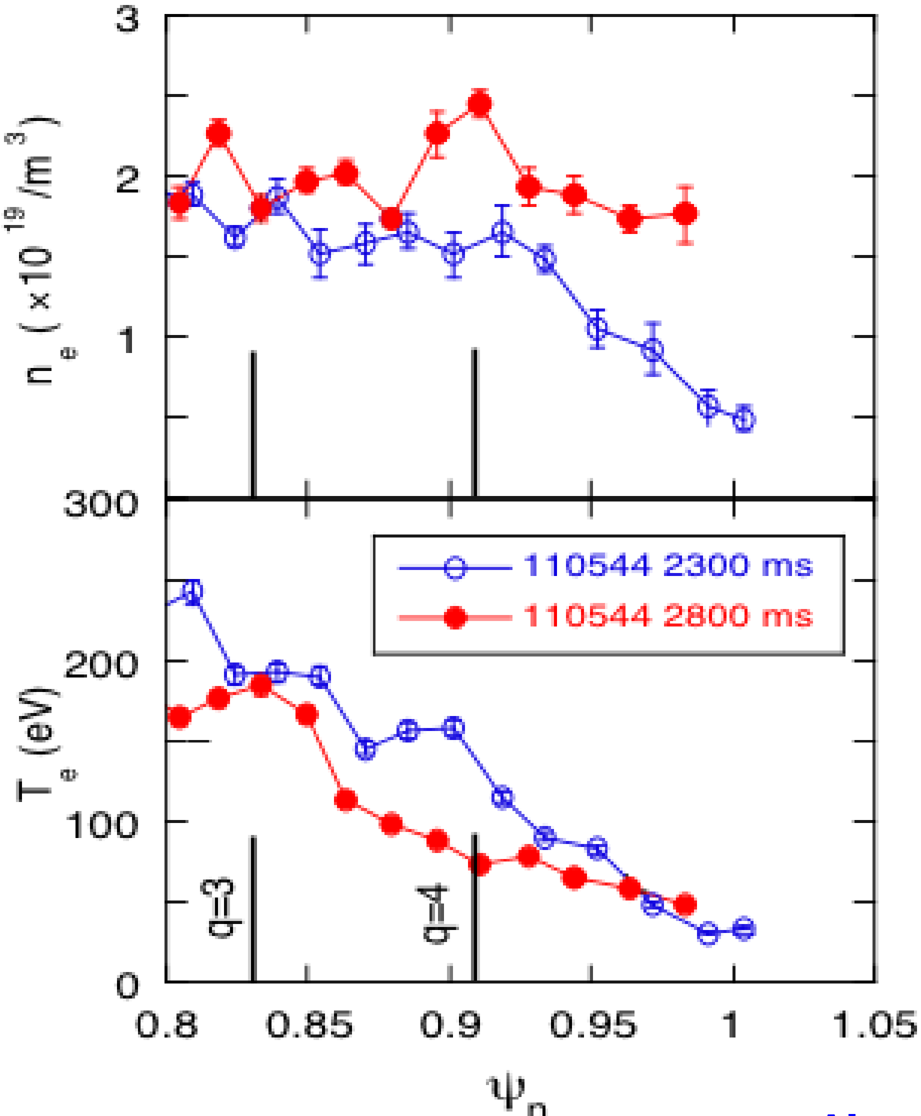
Total divertor D_α increases and broadens when C–coil current is changed

- Increase in total recycling consistent with connecting previously closed field lines to divertor target plates
- Broadening of recycling profile consistent with spreading of (and presumably heat) fluxes particle





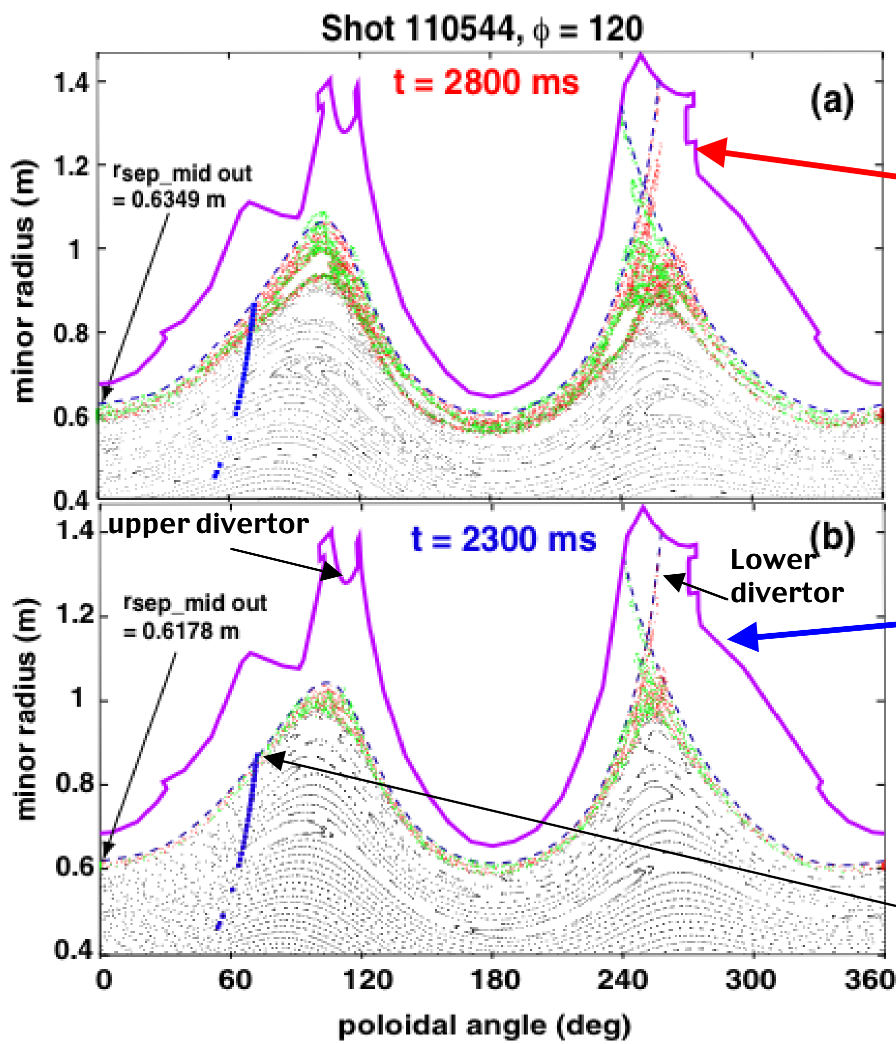
Edge profiles flatten and edge T_e decreases when C-coil current is changed.



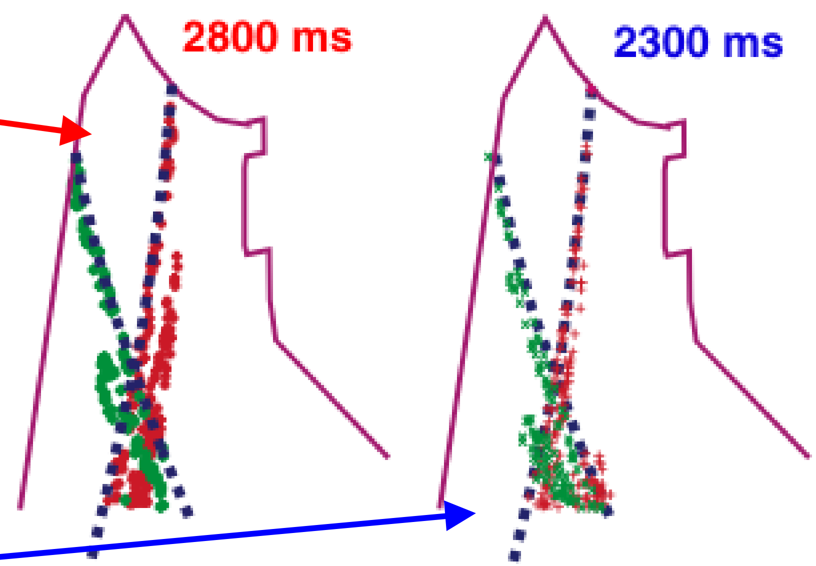
- **Thomson profiles averaged over 6 Thomson pulses.**
- **The edge n_e and T_e profiles flatten across the outer 8-9 Thomson points (outside q=3) in discharge 110544**
  - > **Response similar to that in previous ergodic boundary experiments on TEXT, Tore Supra, JIPP-T IIU**
  - > **Width is consistent with TRIP3D field line integration code results of the stochastic boundary layer**
- ***No change in core profiles ψ_N < 0.8 observed between 2300 and 2800 ms***

Also see Moyer, RP1.046

TRIP3D field line modeling shows an increase in the stochastic layer width with the change in the C-coil current at 2800 ms



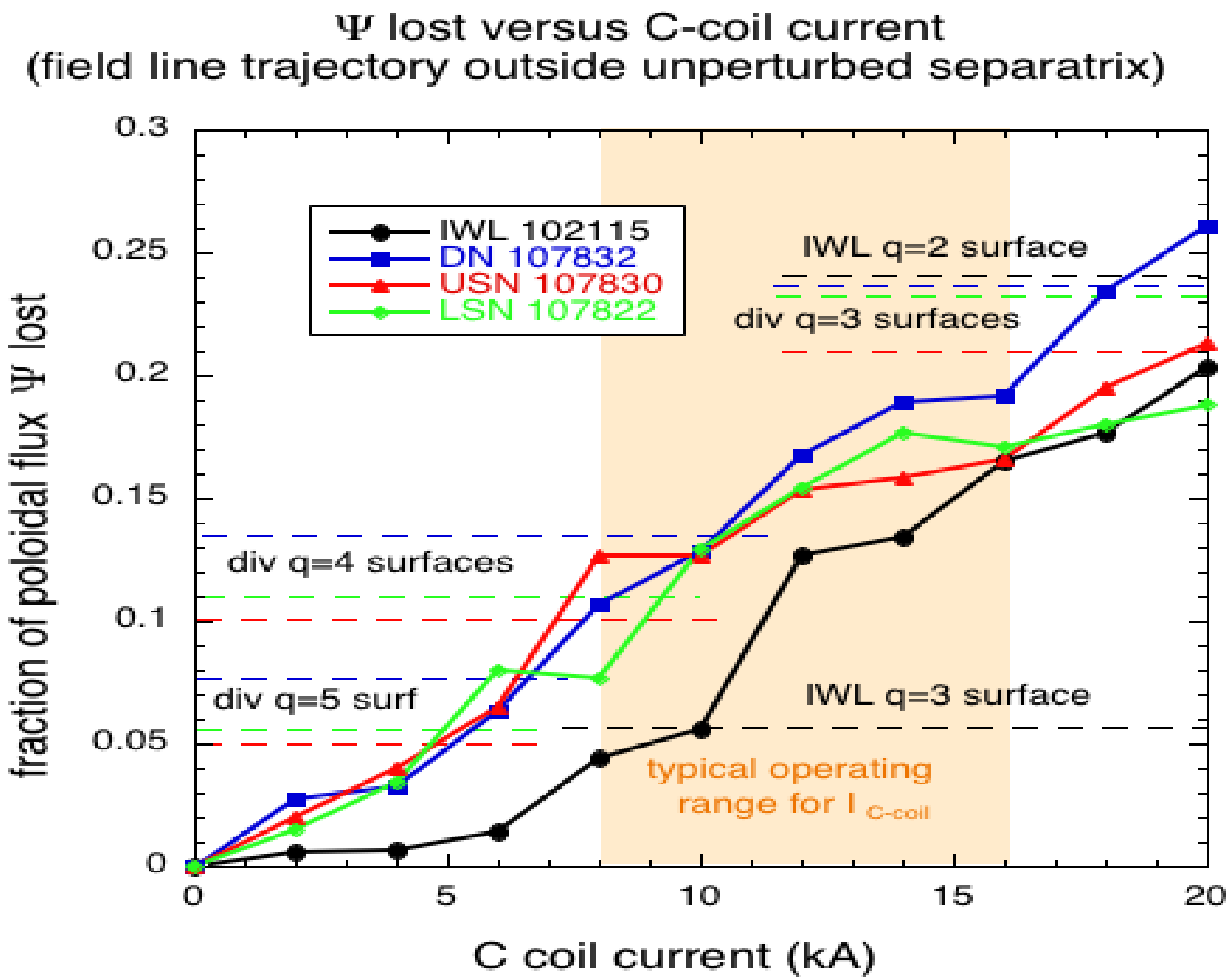
Open field lines indicated with red (Bϕ direction) and green (opposite Bϕ) dots.



- Use measured C-coil currents at 2300 and 2800 ms in TRIP3D.
- The stochastic layer width increases by a factor of 2.5 at 2800 ms versus 2300 ms.
  - > 9 Thomson points versus 3

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

C-coil current scaling studies show diverted plasmas are more sensitive to perturbations



The width of the stochastic layer (edge magnetic flux loss) is larger in diverted Lower and Upper Single Null (LSN and USN) plasmas for C-coil currents below 16 kA than in non-diverted Inner Wall Limited (IWL) plasmas and for Double Null (DN) plasmas at all currents.

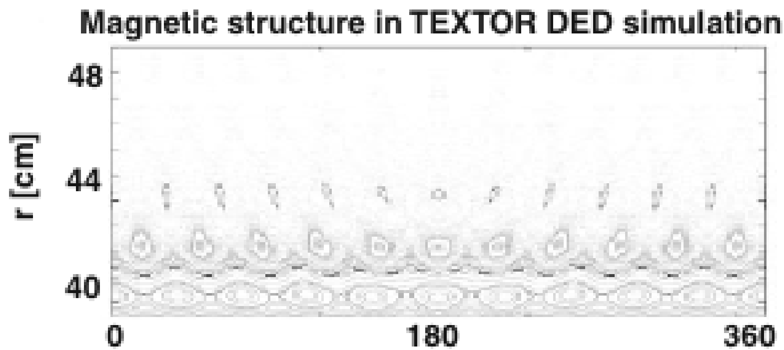
See T. E. Evans, R. Moyer, P. Monat, Phys. of Plasmas, 9 (2002) for additional deatils

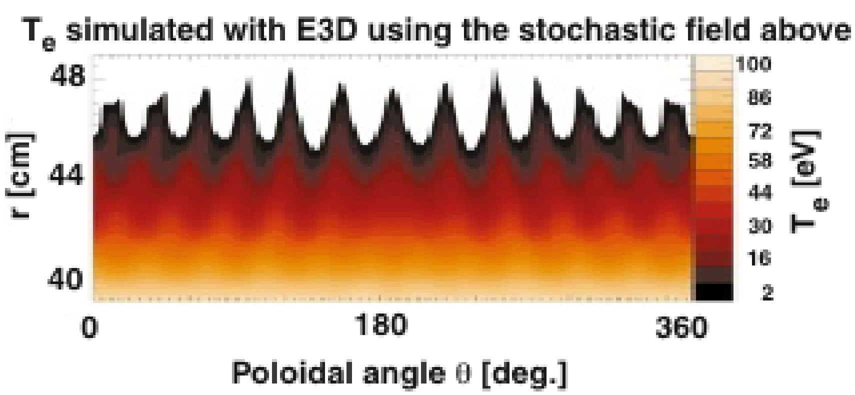
DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Quantify calculated stochastic layer effects on the plasma boundary with a 3-D heat transport model

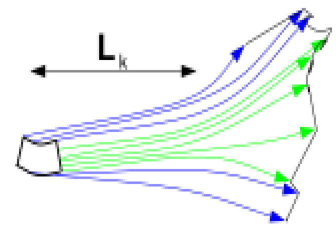
- **Couple the E3D Monte Carlo heat transport code to TRIP3D**
  - > E3D solves the heat balance equation for edge plasma conditions with stochastic magnetic field structures using a “multiple local magnetic coordinate system approach” (MCSA)
  - > Calculate the plasma temperature and the profiles of the radial heat flux due to the classical parallel and anomalous perpendicular diffusion

Expample of E3D results

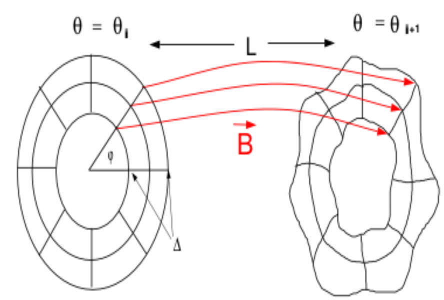




Stochastic flux tubes are mapped along distorted paths in E3D that are defined by the TRIP3D field line code.



Grids are interpolated along toroidal cuts of length L_i such that $L_i < 2 L_k$ ($L_k \equiv$ Kolmogorov length) to approximate stochastic diffusion effects in the model.



Summary and future goals

- Experiments in diverted Ohmic plasmas demonstrate that the DIII-D C-coils produce edge properties similar to those found in circular plasmas with stochastic boundaries
  - Increased recycling (in the divertor)
  - Broadened recycling profiles indicating spreading of particle/heat fluxes at plates
  - Reduce edge n_e and T_e gradients consistent with stochastic field regions predicted by field line integration
- Diverted tokamaks plasmas are more sensitive to resonant perturbation (the formation of stochastic boundary layer) than non-diverted tokamaks.
- Future goals:
  - Develop self-consistent stochastic boundary plasma models
    - Model heat transport in DIII-D stochastic layer with coupled TRIP3D (field line integration code) and E3D Monte Carlo heat transport code
  - Explore options for using stochastic boundaries to improve edge plasma performance and stability (e.g., ELM control, etc.)
    - High power DIII-D stochastic boundary experiments combined with stochastic plasma models (i.e., TRIP3D/E3D)
      - Pedestal pressure and current profile control
      - Impurity screening and radiation control
- For additional information see posters by: Jackson, QP1.080 and Schaffer QP1.076 (Thursday morning) and Moyer, RP1.046 (Thursday afternoon)