Recent PPPL/DIII-D Activities and Plans

by

B.A. Grierson

Princeton Plasma Physics Laboratory

Presented at the NSTX-U/Magnetic Fusion Science Weekly Physics Meeting

B318, PPPL

August 20, 2018

PPPL is the Largest Collaborating Institution on DIII-D

Raffi Nazikian

Brian Grierson

Alessandro Bortolon

Nikolas Logan

Shaun Haskey

Arash Ashourvan

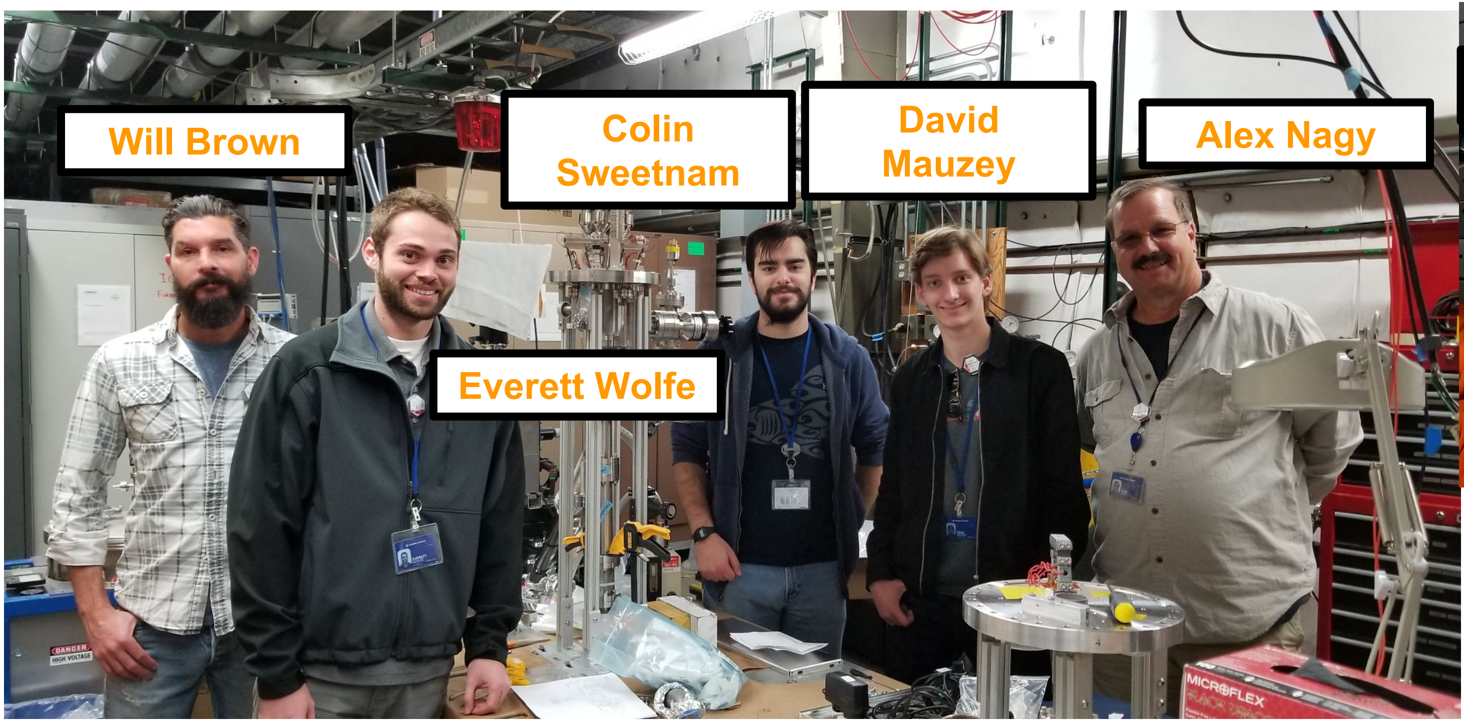
Qiming Hu

Matthias Knolker

- Seven Ph.D. Physicists*
- One graduate student*

* Permanent off-site

PPPL Leads and Manages Major Engineering and Operations Elements of the DIII-D Program



Taylor Raines (new Jr. Engineer)

Off-Site Staff Maintain Close Connection to the Lab Through the Physics Topical Areas

3D Fields & Stability

- ELM control with RMPs
- Entrain MHD modes and RT stability
- NTV and plasma rotation

Integrated Modeling & Scenarios

- Thermal transport, heating and current drive
- EP transport
- Scenario design and model validation
- Extrapolation to ITER

Core-Edge Integration

- Impurity delivery and control
- Pellet pacing
- Pedestal structure and transport
- Heat flux mitigation

Off-Site Staff Maintain Close Connection to the Lab Through the Physics Topical Areas

3D Fields & Stability

- J-K Park, N. Ferraro, M.D. Boyer, M. Okabayashi K. Erickson, W. Tang, Z.R. Wang
- M3D-C1
- IPEC
- GPEC
- DCON

Integrated Modeling & Scenarios

- F. Poli, S. Kaye, W. Guttenfelder, W.X. Wang, M. Podesta, N. Gorelenkov, G. Kramer
- TRANSP
- RBQ
- GTS

Core-Edge Integration

- R. Maingi, A. Diallo, R. Lunsford, R. Hager, W. Guttenfelder, C.S. Chang
- Impurity technology
- XGC, CGYRO

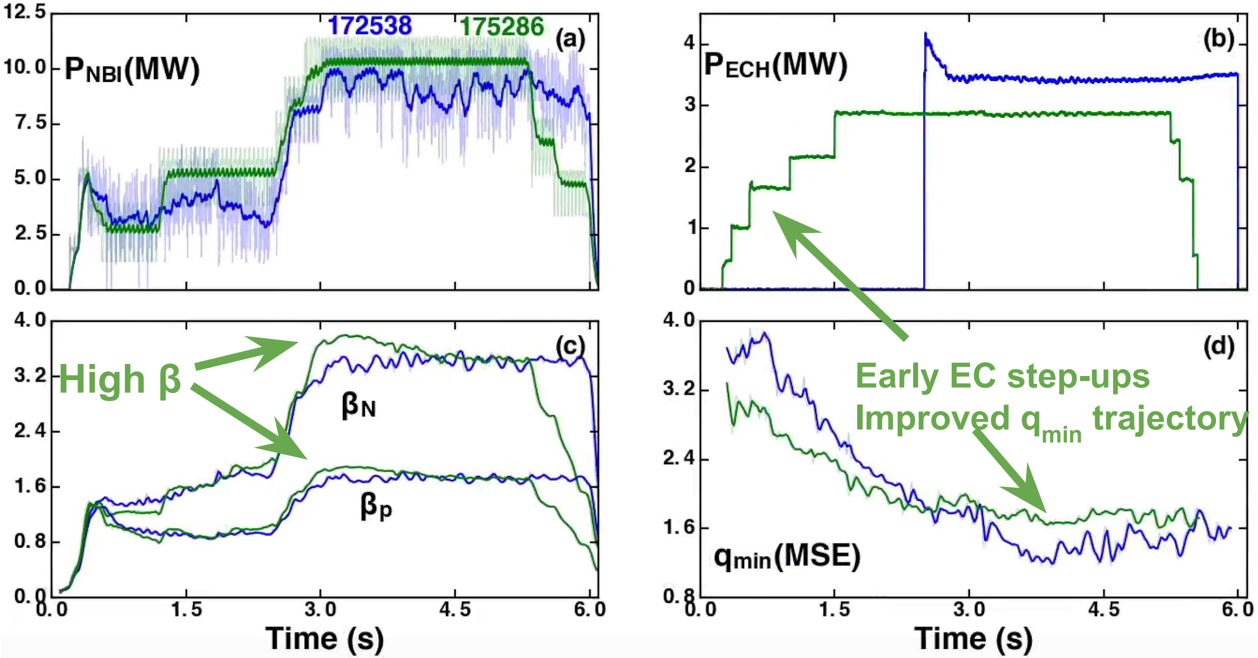
Select Recent Physics Results*

* Too many to cover in short time, apologies

DIII-D NATIONAL FUSION FACILITY

"Predict First" EC and NBI Trajectory Achieved High Beta Access with Smooth, Elevated and Sustained qmin

- Challenge to achieve operating point in high-β steady-state AT
  - Operational space limited by onset of TMs and degraded confinement
  - Empirical "recipe" developed in control room
  - #1 Goal: Test predictive TRANSP simulations



F.M. Poli, TTF Plenary (2018) *EPS* (2018)

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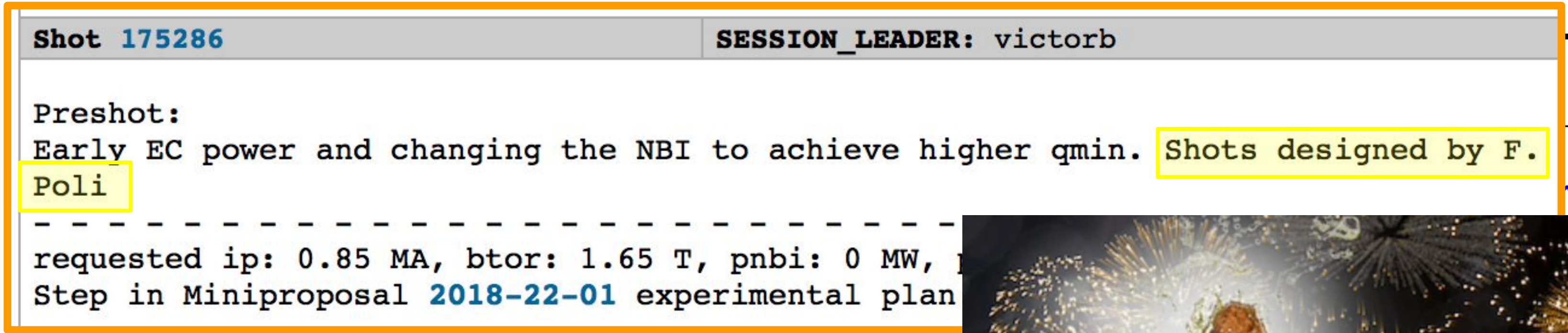

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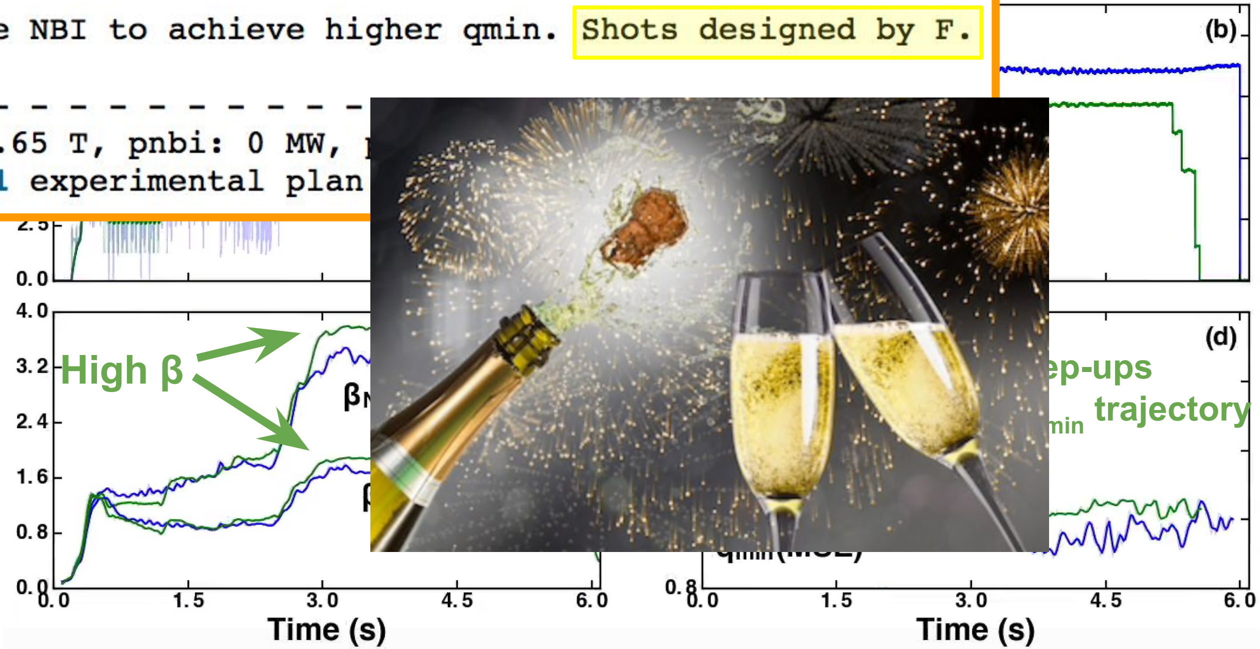


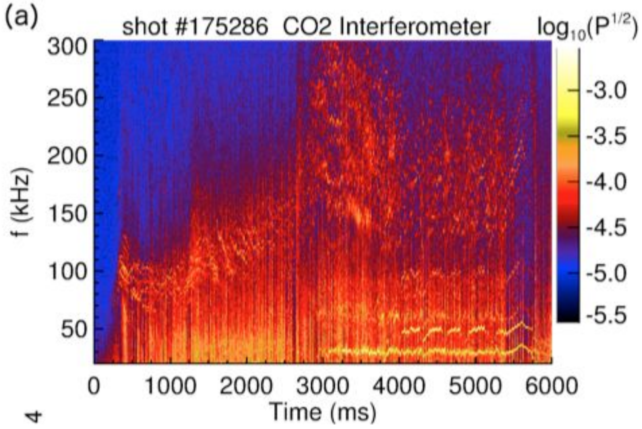
F.M. Poli, TTF Plenary (2018) *EPS* (2018)

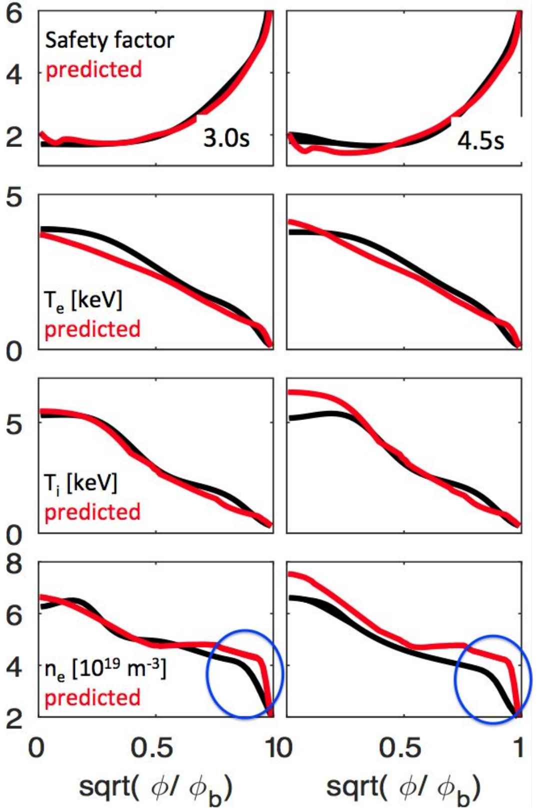
Validation of Predictions Against Achieved High qmin Scenario Identifies Key Areas Where Model Improvements are Required

- **Investigation beyond global agreement with predictions reveals**
  - Edge density pedestal needs improved particle transport model
  - Neutron discrepancy requires AE transport

➢ **Integrate reduced AE transport models**

➢ **Improve pedestal density predictions**

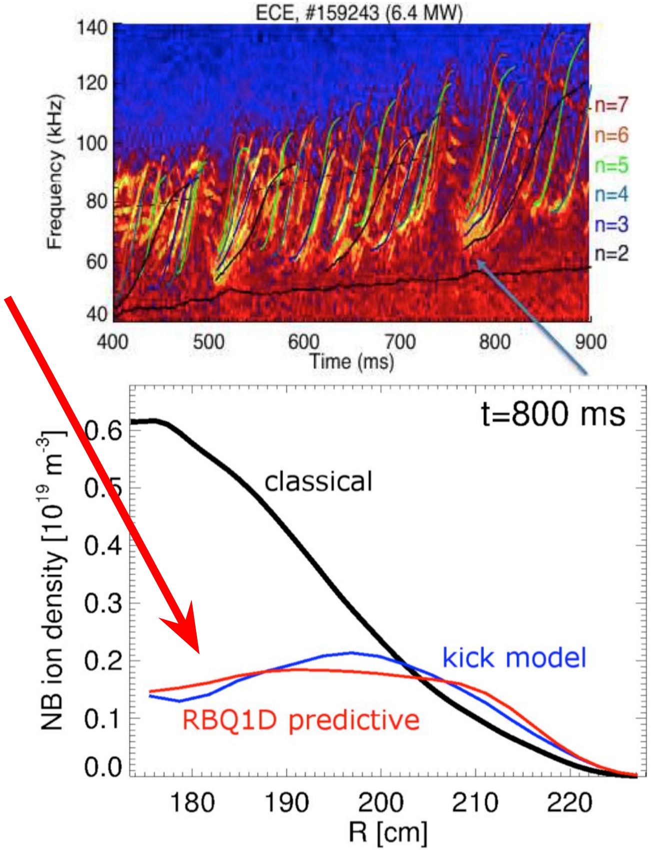




F.M. Poli, *EPS* (2018)

Reduced Models of AE-Induced Transport are Showing Promising Performance for Use in Scenario Design

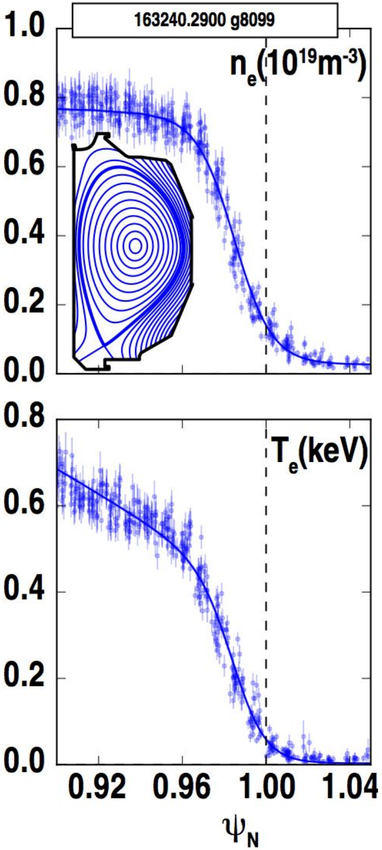
- **RSAEs cause transport by perturbing the fast-particle distribution function**
- **RBQ-1D provides diffusion in canonical angular momentum space and captures *profile shape***
- **Mostly passing particles near injection energy of 60-70 keV**
  - Depletes NBCD
- **Perturbed distribution function available for validation with FIDA**

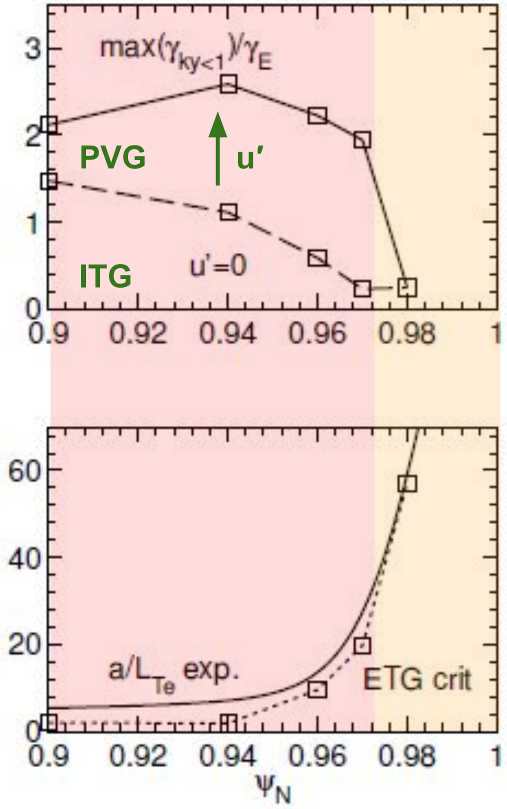


N.N. Gorolenkov AAPPS-DPP Invited (2017)

CGYRO Simulations Indicate Electrostatic Instabilities Dominant From Top of Pedestal into Steep Gradient

- Goal for FY19 JRT is quantifying *particle transport*
- Linear simulations show transition from ITG/PVG → ETG modes radially
  - Rotation shear drives PVG
  - γ(ITG/PVG) > γ(ExB) inside 0.96
- Pedestal a/L_{Te} tracks critical gradient for ETG ($\eta_e$crit~1.2)
- Nonlinear simulations in progress to quantify energy and particle fluxes



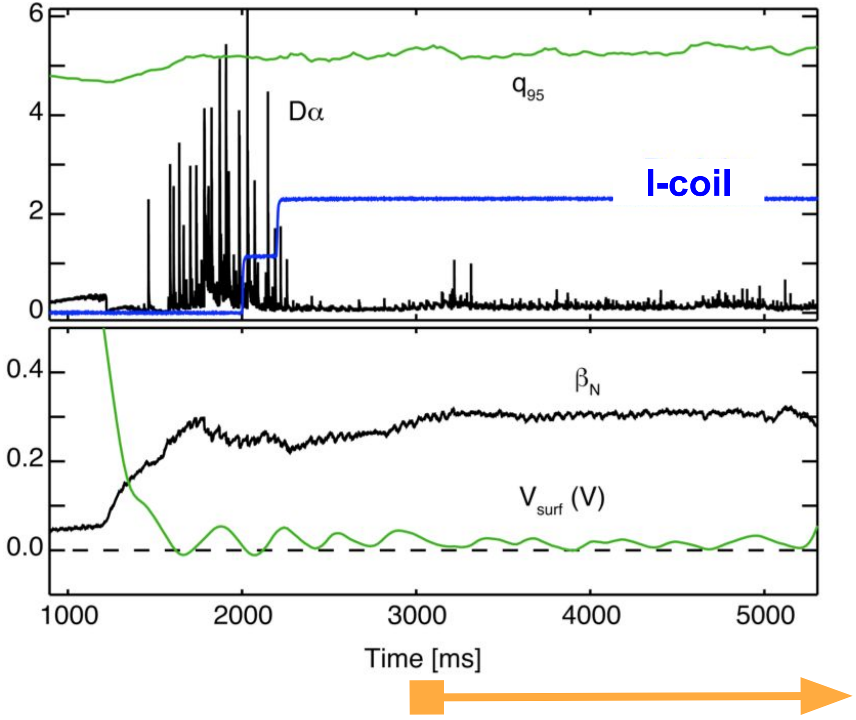


W. Guttenfelder, *APS* (2018)

ITER Q=5 Steady State Target with ELM Suppression Extended to q95=5.2; Enters Oscillating Two-State Pedestal

- Pedestal "pulsations" driven by cyclic variations in the resonant field strength at top of pedestal
- Bifurcations between ELM suppression and Grassy-ELM regime moderates divertor heat flux
- Dramatic change in pedestal structure
  - Density flattens, zero of ExB shear widens
  - Pedestal grows wider, higher
  - Drives need to understand edge rotation and radial electric field Er

R. Nazikian NF (2018), Press Release



Ohmic transformer turned off

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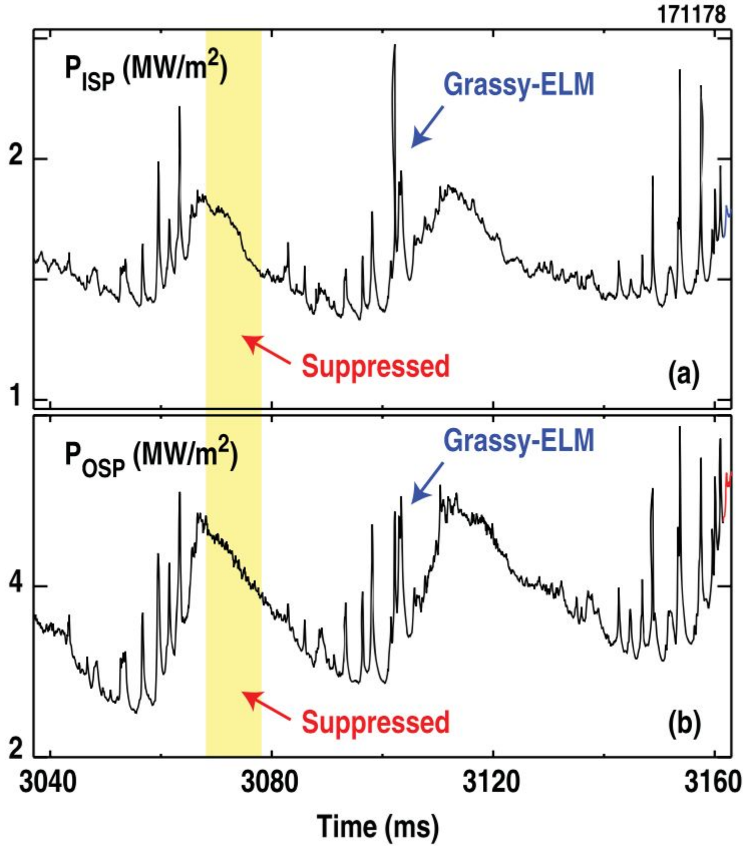
R. Nazikian NF (2018), Press Release



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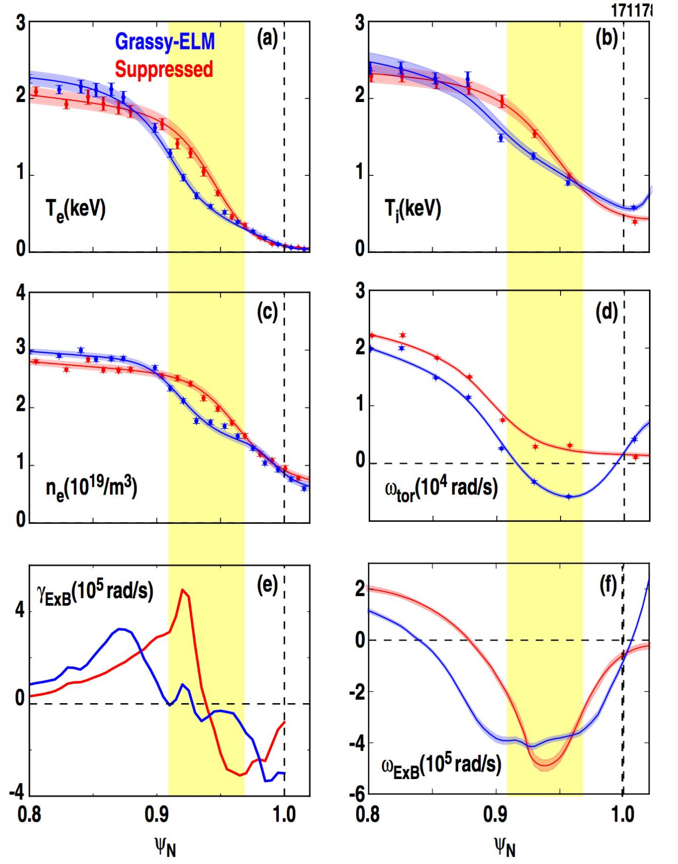
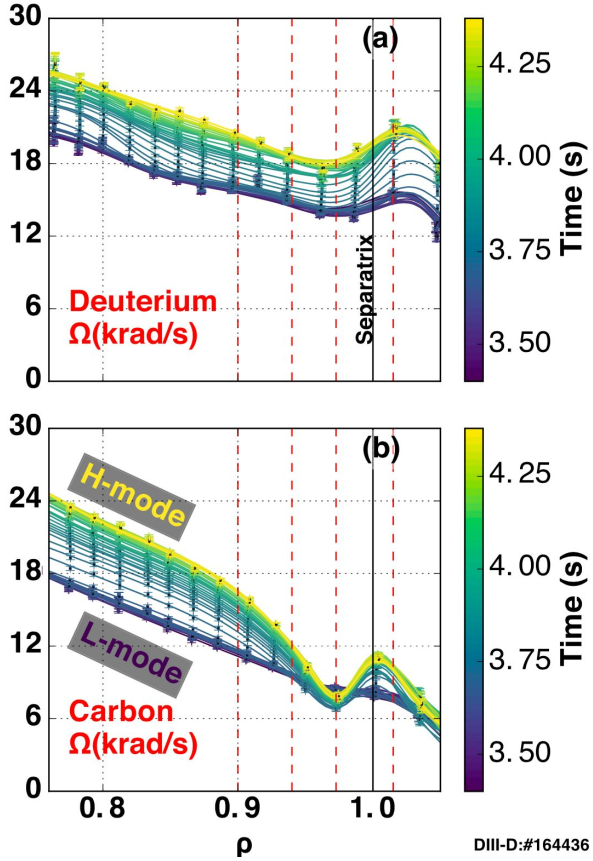
R. Nazikian NF (2018), Press Release
A. Ashourvan (NSTX-U MFS July 19 2018)

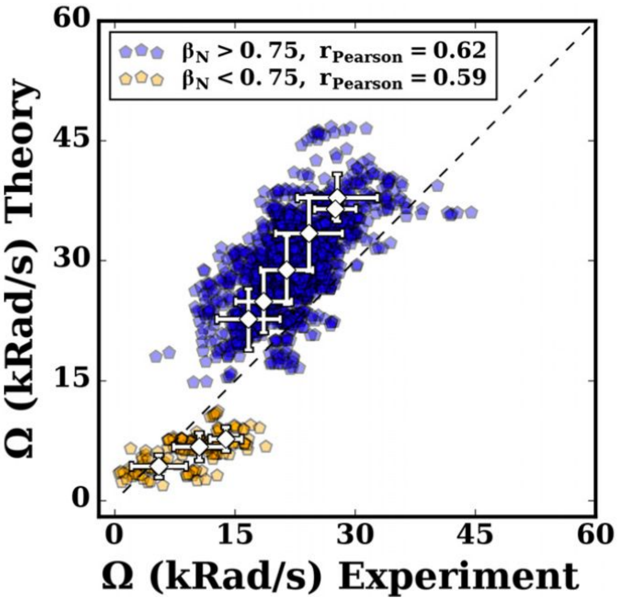


New Deuterium Measurements Have Improved our Understanding of Main-ion Properties of the Pedestal

- First ever capability
- Reveals dramatic differences with impurity rotation
- Used to validate intrinsic rotation model[TSD]
- Revealing lower main-ion temperature in pedestal
  - Implications for model validation

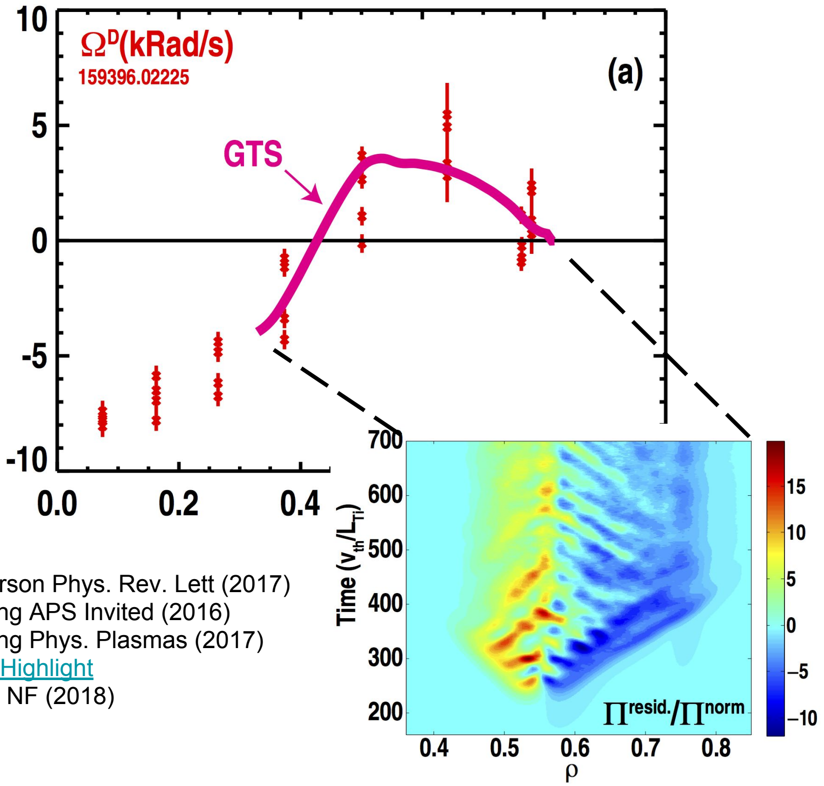
B.A. Grierson, RSI (2016)
S.R. Haskey, RSI (2016)
S.R. Haskey, RSI (2018)
Ashourvan APS Invited (2017)
Ashourvan Phys. Plasmas (2018)
S.R. Haskey HTPD Invited (2018)
S.R. Haskey PPCF (2018)





Global Nonlinear Gyrokinetic Simulations Capture the Core Main-ion Intrinsic Rotation Profile Structure

- **Well known "rotation reversal" in ohmic L-mode plasmas a challenge to simulate**
  - $\Pi_{resid} \equiv 0$ in local limit
- **GTS global simulations show *intensity gradient* and *ZF ExB shearing* dominate $k_{\parallel}$ symmetry breaking**
  - Momentum pinch weak
  - Balance of $\Pi_{resid} \equiv 0$ and χ_{φ}
  - Recently confirmed on ASDEX*

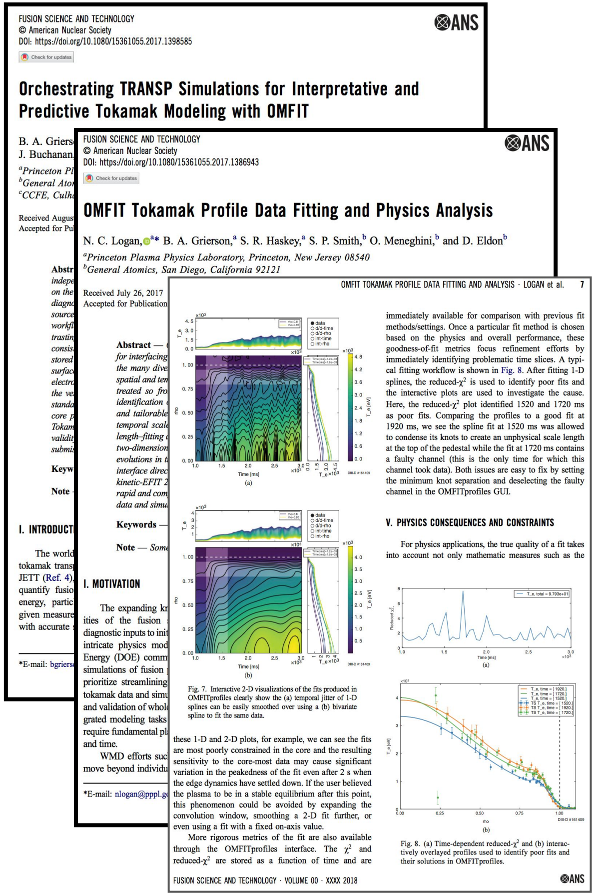


B.A. Grierson Phys. Rev. Lett (2017)
W.X. Wang APS Invited (2016)
W.X. Wang Phys. Plasmas (2017)
DOE SC Highlight
*Hornsby NF (2018)

DIII-D NATIONAL FUSION FACILITY

PPPL Staff at DIII-D Have Led Community-Based Analysis Capability Supporting Domestic and International Cooperation

- **Through GA's OMFIT PPPL and collaborating institutions have expanding the usage of TRANSP***
  - Now >65 registered TRANSP users at DIII-D
- **Streamlined and standardizing profile analysis with advanced fitting methods**
- **OMFIT + TRANSP integration continues to grow incorporating the world's tokamaks**
  - ASDEX-Upgrade, C-Mod, COMPAS, DIII-D, JET, MAST, NSTX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DOI: https://doi.org/10.1080/15361055.2017.1398585

Orchestrating TRANSP Simulations for Interpretative and Predictive Tokamak Modeling with OMFIT

FUSION SCIENCE AND TECHNOLOGY
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DOI: https://doi.org/10.1080/15361055.2017.1386943

OMFIT Tokamak Profile Data Fitting and Physics Analysis

N. C. Logan,[a*] B. A. Grierson,[a] S. R. Haskey,[a] S. P. Smith,[b] O. Meneghini,[b] and D. Eldon[b]

[a]Princeton Plasma Physics Laboratory, Princeton, New Jersey 08540
[b]General Atomics, San Diego, California 92121

Received July 26, 2017
Accepted for Publication

OMFIT TOKAMAK PROFILE DATA FITTING AND ANALYSIS · LOGAN et al. 7

immediately available for comparison with previous fit methods/settings. Once a particular fit method is chosen based on the physics and overall performance, these goodness-of-fit metrics focus refinement efforts by immediately identifying problematic time slices. A typical fitting workflow is shown in Fig. 8. After fitting 1-D splines, the reduced-χ^2 is used to identify poor fits and the interactive plots are used to investigate the cause. Here, the reduced-χ^2 plot identified 1520 and 1720 ms as poor fits. Comparing the profiles to a good fit at 1920 ms, we see the spline fit at 1520 ms was allowed to condense its knots to create an unphysical scale length at the top of the pedestal while the fit at 1720 ms contains a faulty channel (this is the only time for which this channel took data). Both issues are easy to fix by setting the minimum knot separation and deselecting the faulty channel in the OMFITprofiles GUI.

V. PHYSICS CONSEQUENCES AND CONSTRAINTS

For physics applications, the true quality of a fit takes into account not only mathematic measures such as the

Fig. 7. Interactive 2-D visualizations of the fits produced in OMFITprofiles clearly show the (a) temporal jitter of 1-D splines can be easily smoothed over using a (b) bivariate spline to fit the same data.

these 1-D and 2-D plots, for example, we can see the fits are most poorly constrained in the core and the resulting sensitivity to the core-most data may cause significant variation in the peakedness of the fit even after 2 s when the edge dynamics have settled down. If the user believed the plasma to be in a stable equilibrium after this point, this phenomenon could be avoided by expanding the convolution window, smoothing a 2-D fit further, or even using a fit with a fixed on-axis value.

More rigorous metrics of the fit are also available through the OMFITprofiles interface. The χ^2 and reduced-χ^2 are stored as a function of time and are

Fig. 8. (a) Time-dependent reduced-χ^2 and (b) interactively overlayed profiles used to identify poor fits and their solutions in OMFITprofiles.

FUSION SCIENCE AND TECHNOLOGY · VOLUME 00 · XXXX 2018

N.C. Logan Fus. Sci. & Tech (2018)
B.A. Grierson Fus. Sci. & Tech (2018)
F. Poli NSTX-U MFS July 30 2018

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PPPL Staff in DIII-D Program Communicate High Impact Scientific Results Through Publications and Press Releases

DOE Web Highlight

Fusion Energy Sciences (FES)

Facilities
Science Highlights
Benefits of FES
Funding Opportunities
Fusion Energy Sciences Advisory Committee (FESAC)

04.27.17

Plasma Turbulence Generates Flow in Fusion Reactors

Heating the core of fusion reactors causes them to develop sheared rotation that can improve plasma performance.

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The Science

Improved stability and confinement in fusion reactors comes through generation of sheared flow. High-energy particle beams commonly drive the flow. Researchers ran new simulations that are showing how the plasma can self-organize to generate its own sheared flow even when

Enlarge Photo

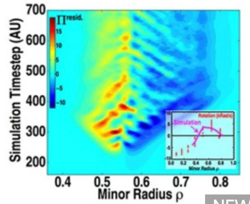

Image courtesy of W.X. Wang

Simulation of plasma turbulence generat… positive (red) and negative (blue) residua… that drives rotation shear. Comparison b… measured and simulated rotation profile

AIP Physics of Plasmas

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Featured

Multi-scale transport in the DIII-D ITER baseline scenario with direct electron heating and projection to ITER

B. A. Grierson, G. M. Staebler, W. M. S…

Featured Article

(Photo by Shaun Haskey)

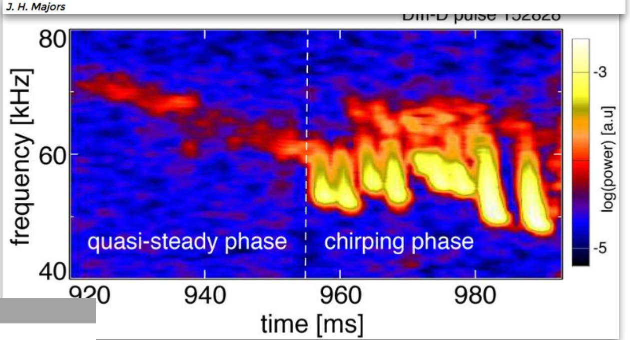
Physicists Brian Grierson of PPPL, left, and Gary Staebler of General Atomics

AIP Scilight

DECEMBER 2017 • https://doi.org/10.1063/1.5018736

A close look at fast ion microturbulence in tokamaks builds predictive capability for fusion

J. H. Majors



NEWS

PPPL and General Atomics scientists make breakthrough in understanding how to control intense heat bursts in fusion experiments

By Raphael Rosen
March 13, 2015

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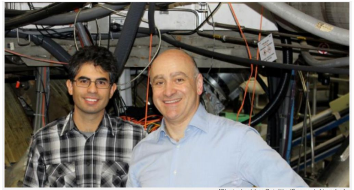


(Photo by Lisa Petrillo/General Atomics)

Carlos Paz-Soldan, left, and Raffi Nazikian at the DIII-D tokamak.

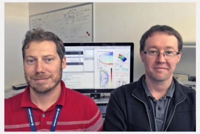
Press Releases

PPPL and General Atomics team up to make TRANSP code widely available

DOE/PRINCETON PLASMA PHYSICS LABORATORY

SHARE PRINT E-MAIL

Plasma transport analysis, the study of how plasma particles, heat and momentum drift across magnetic field lines, is a necessary first step for understanding how well fusion reactors are performing. Teams of scientists from the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and General Atomics (GA) have joined forces to bring PPPL's premier transport code, TRANSP, to beginning users and experts alike.

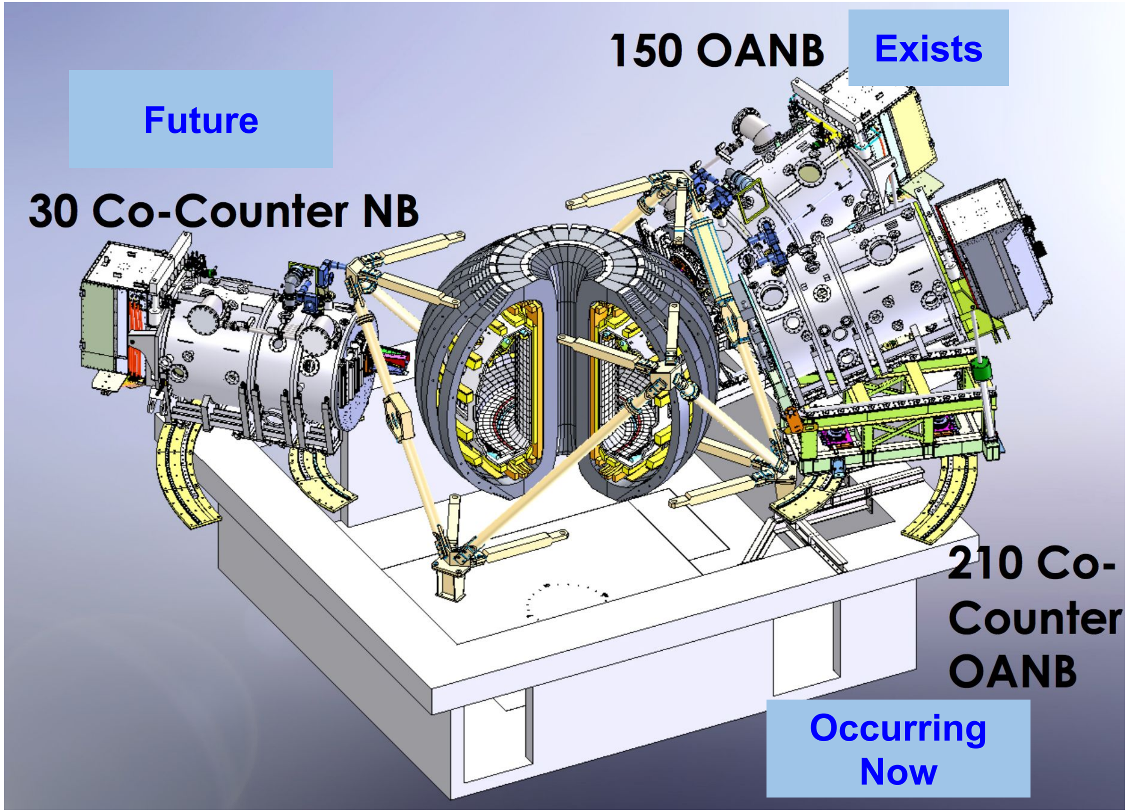


DIII-D NATIONAL FUSION FACILITY

Recent Engineering and Operations Activities

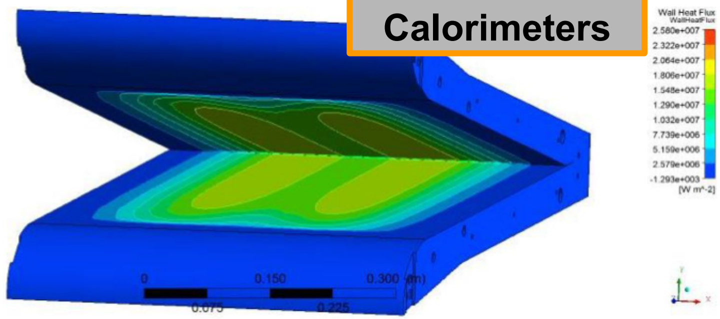
During the Current Long Torus Opening (LTO) DIII-D is Making NB 210 Co/Ctr Steerable and Off-Axis

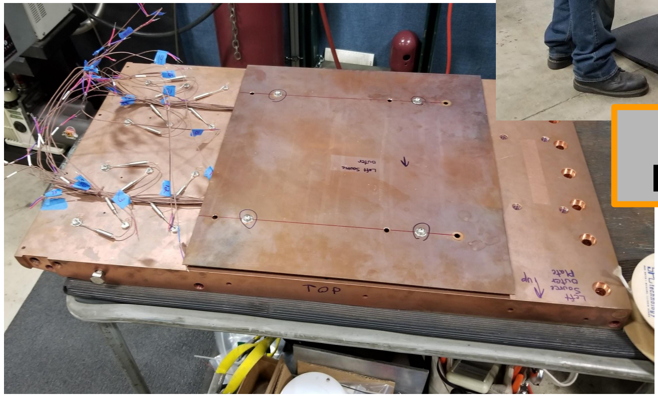
- Primary goal for CCOANB is achieving β_N~5 with broad pressure and current profile
- Target completion March 22nd
- Alex Nagy: Deputy Proj. Manager



PPPL Supplying Calorimeters and Pole Shields for Existing 150 OANB and New 210 CCOANB

NB150 Calorimeters





NB210 Pole Shields

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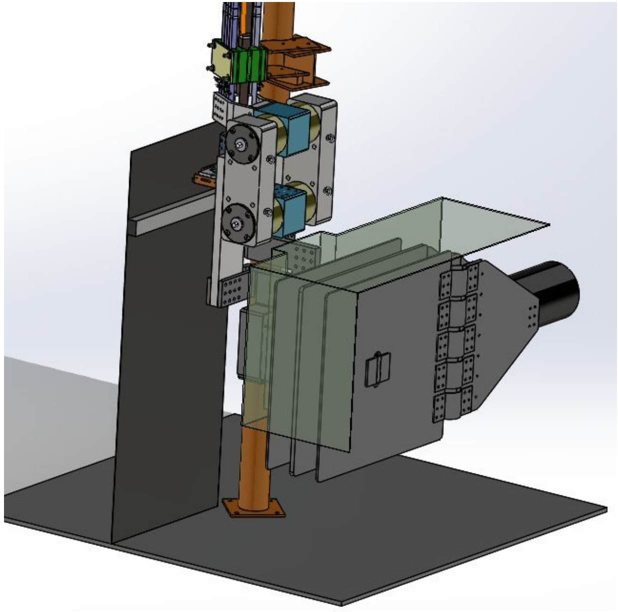
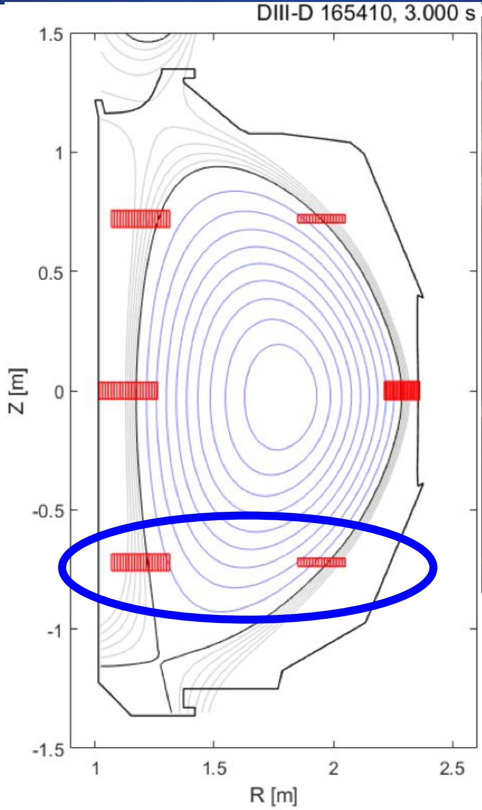
New Toroidal Field Reversing Switch and Ly-alpha Diagnostic Enhance Divertor and Core/Edge Studies



TF Switch enables day-to-day (shot-to-shot?) reversing of toroidal field for divertor drifts and 3D field studies



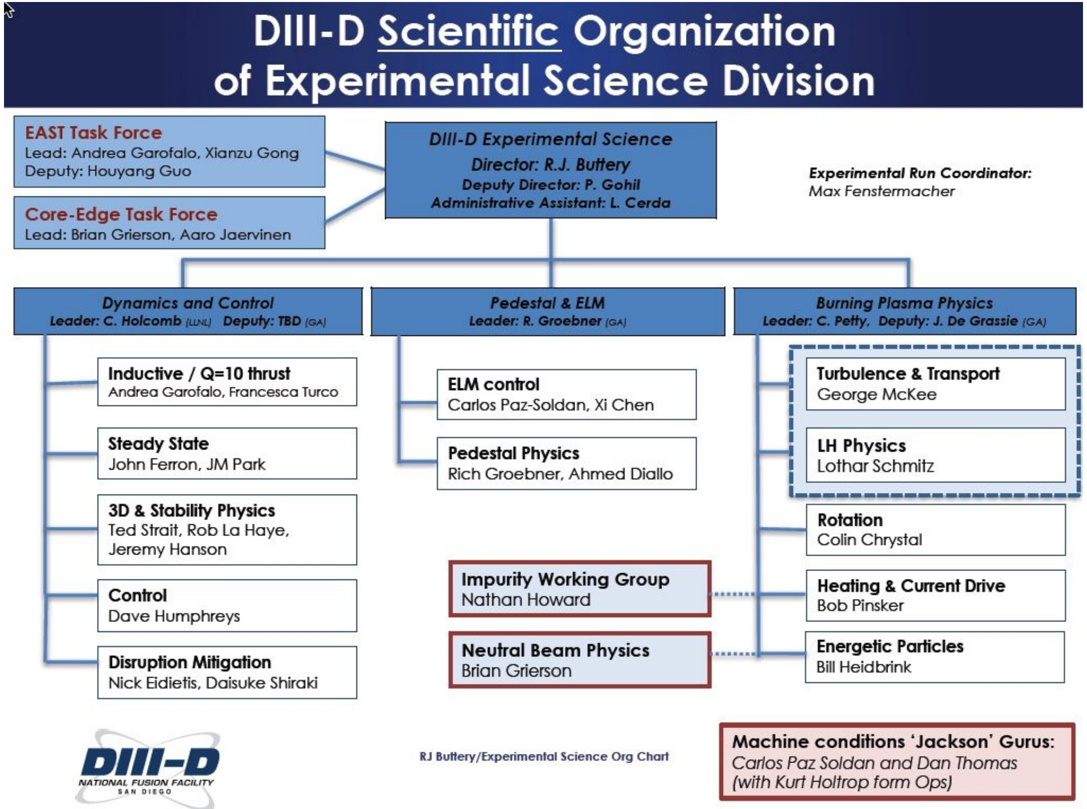
First pair of HFS/LFS Ly-alpha arrays installed during LTO for neutral density and radiation
A. Bortolon, A. Rosenthal (MIT)

DIII-D NATIONAL FUSION FACILITY

Near Term Activities and Long Term Goals

Get (Stay) Involved Through DIII-D's Research Opportunities Forum and Topical Research Groups

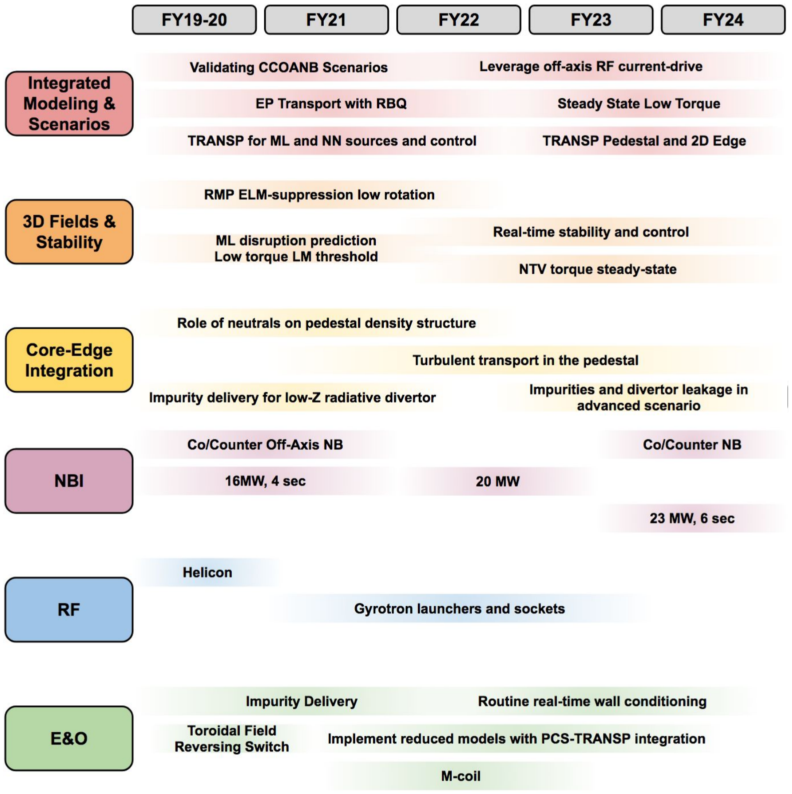
- **Core-Edge Integration**
  - Brian, Alessandro
- **3D Fields and Stability**
  - Nik, Raffi
- **Dynamics and Control**
  - Brian, Francesca, Arash
- **Pedestal and ELM**
  - Raffi, Ahmed, Brian
- **Burning Plasma**
  - Brian, Mario, Shaun, Arash
- **Research Forum late Dec '18 or Jan '19**



Come See Us at Major Meetings and Discuss PPPL Plans for DIII-D Over the Next Five Years

- IAEA FEC
  - **Mario Podesta(oral)**, Brian Grierson, Ahmed Diallo, Dan Boyer, Florian Laggner, Michio Okabayashi, Robert Hagar
- APS-DPP (Invited)
  - Nik Logan, Zhirui Wang, Egemen Kolemen, Brian Grierson
- **PPPL companion to the DIII-D Five Year Proposal**
  - https://diii-d.gat.com/diii-d/Home
- **Reach out, visit and stay involved**

It's an exciting program!



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