
Summary of DIII-D Diagnostic Mini-Workshop

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Enthusiasm for Moving Forward

- **Diagnostics are at the heart of what we do, providing a scientific basis for design of fusion power. A lot of interest in improving our measurements.**
- **A constrained budget creates tension between optimization of existing diagnostics and construction of new diagnostics.**
- **Each topical area has significant needs. A programmatic prioritization will be required.**
- **For significant new measurements an organized effort for additional resources will be required.**

TRANSPORT AND TURBULENCE DIAGNOSTICS DISCUSSION SUMMARY

Goal: Establish a quantitative understanding of turbulent transport in tokamaks that will allow a scientifically-sound predictive capability

High priority physics issues to be addressed:

- Identification of zonal flows: key to nonlinear saturation and transport levels ⇒
Proposed methods:
 - density turbulence time-varying flow-field (BES)
 - $S(k_r)$ spectra vs. collisionality
 - poloidally and toroidally separated correlation reflectometers observing same flux surface
- Measurements of high-wavenumber fluctuations believed to be associated with electron transport
 - High-wavenumber FIR scattering ($2 \leq k_{\perp} \leq 200 \text{ cm}^{-1}$) is only proposed method discussed: DIII-D system could be more highly optimized
- Quantitative comparison between transport simulations and experimental turbulence data
 - Filter modules/transfer functions applied to simulation output
 - Direct comparisons with present and future diagnostics

SCIENTIFIC ISSUES IN TRANSPORT & TURBULENCE

- Experimental identification of Zonal Flows
- Observation of Electron Temperature Gradient (ETG) modes
- Marginality condition and stiffness of models (χ vs R / L_{Ti})
- Edge turbulence measurements and comparison to theory
 - Complex: resistive/collisional effects, neutrals, CX, electromagnetic...
- Avalanche, streamer, heat pulse measurements
- Turbulent flux measurements in core
- Transport channels: particle, electron, momentum transport
- Validation of ion heat transport
 - Ion temperature gradient/Trapped Electron Mode physics
 - ExB shear suppression model
 - Neoclassical transport (near core)

DIAGNOSTICS FOR TURBULENCE AND TRANSPORT PHYSICS STUDIES

Physics issue	Physical Quantity	Possible Diagnostics
Identify Zonal Flows	Poloidal/toroidal velocity correlations, $S(k_r)$	2D BES, correlation reflectometers
ETG modes	High-k fluctuations	FIR
Role of ITG vs. TEM driven drift wave turbulence	Ion temperature fluctuations	High-Frequency CER (demonstrated, but difficult)
Fast ion transport (Turbulence & MHD)	Beam ion density	Relocated CX analyzer, neutron profiles
Nonlinear energy cascades	2D turbulence imaging, wave-wave coupling	BES ($L_{y,\alpha}$ for core), 2D reflectometry (\tilde{n} , T_e), Probes
Turbulence flow shear vs. growth rates	“	“
Main ion transport	T_i , v_ϕ , v_θ , n of H, D	CER (big modelling effort)
Electron heat transport	Low-k T_e fluctuations	Upgraded ECE
Turbulent flux	$\langle \tilde{n} \tilde{\phi} \rangle$, $\langle \tilde{n} \tilde{\phi} \tilde{T} \rangle$, \tilde{B}	HIBP (core), Probes (edge)

UTILIZATION OF EXISTING DIAGNOSTICS/TECHNIQUES

- Analysis technique development:
 - Temporal behavior: Wavelets
 - Higher order spectral analysis: bicoherence
 - Spatial eigenmodes: biorthogonal decomposition
- Transfer functions: simulation/experiment comparison
- Upgrading systems: cost effective route to enhanced scientific productivity

Divertor Measurements Needs

Unresolved issues in edge/divertor research which need new measurements can be grouped into three main topics.

- **Radial energy and particle transport**
 - Need poloidal and toroidal variations in transport.
 - No understanding or scaling of transport mechanisms
- **Neutral and impurity sources**
 - Uncertainty arises from transport and wall conditions.
 - Impurity sources tied directly to neutral spatial and energy distribution.
- **Role of drifts in edge/divertor solution**
 - Drift terms complicate modeling. Need to benchmark codes.

New Divertor Diagnostic Identified

- **Transport**
 - Imaging of edge turbulence; BES, Fast Cameras
 - Spatial variation of transport; wide view fast camera, distributed probes and enhanced probe techniques
- **Neutrals and Impurity Sources**
 - Distributed wall fluxes; wide camera views, fixed probes, pressure gauges, distributed spectroscopy, neutral energy analyzers
 - Plasma wall interactions; distributed samples, in situ measurements, omegatron for molecules

Divertor Diagnostics (Cont.)

- **Drifts**
 - 2D potential; enhanced probes, flow measurements
- **Improved Plasma Profiles**
 - Ti; Collective Thomson Scattering
 - Ne,Te; expanded Thomson, Helium puff or diagnostic beam
 - Flow velocity; 2D tangential spectroscopy, LIF, impurity puff

Stability Measurement Needs

- **Current Profile**
 - Edge current for pedestal stability
 - Central current profile for tearing or global mode stability
- **Mode Identification**
 - ELMs; High mode number
 - RWM; Slowly rotating low amplitude modes
 - Fast particle modes; high frequency, ejected particles

Stability Measurement Opportunities

- **Current Profile**

- Edge current; Li beam, Zeeman polarimetry, reciprocating probes
- Tearing mode stability; required resolution?

- **Mode Identification**

- ELMs; Tangential X-ray imaging, BES, Tile currents
- RWM; Saddle loops, Improved X-ray measurements, Improved magnetic analysis
- Fast particle modes; RF antennas for MHD spectroscopy, fast ion detectors, high frequency X-rays
- 3D modes; multiple imaging

Current Drive, ECCD, Diagnostics

- **Spatial & energy distribution of fast electrons**
 - Distribution function; Bremsstrahlung camera, oblique ECE
 - Heating profile; Improved ECE and Soft X-rays
- **Improved equilibrium construction**
 - Improved profiles; MSE, ECE
 - Separatrix location; probe separatrix locator