

Theme I: Achieving and Understanding the Burning Plasma State in ITER

Understanding alpha particle effects

- Study alpha heating effects
- Understand instabilities driven by alpha particles

Extending confinement to reactor conditions

- Understand transport in the burning plasma regime
- Control how the ITER plasma spins
- Use transport barrier physics to achieve high gain
- Achieve a sufficient edge pedestal for high gain
- L-H transition and pedestal characterization
- Sawtooth activity
- Toroidal field ripple effects
- Transport and confinement in transient phases

Creating a self-heated plasma

- Startup, flat-top, and rampdown scenarios
- Achieve high gain in ITER
- Achieve modest gain steady-state capability
- Optimize gain in non-inductive plasmas
- Establish integrated simulation model
- Achieve 100% non-inductive operation of ITER
- Use RF systems to control ITER plasmas
- Provide central fueling in ITER
- Impacts of H-mode issues on operation and modifications
- Impacts of wall interaction issues on operation and modifications
- Error field correction
- Breakdown
- Ramp-Up
- Flat-top
- Termination
- Impacts of scenario development issues on operation and modifications
- Plasma facing materials - scenarios
- Refined set of ITER reference plasma scenarios
- Develop a comprehensive modeling capability
- Execute necessary R&D to prepare for upgrades to H&CD
- Handle unprecedented power exhaust challenge
- Operate with sufficiently low tritium inventory
- Tritium retention
- Dust
- PFC lifetime
- Plasma facing materials - PWI
- Assess the performance of power-plant-scale superconducting magnets

Theme I: Achieving and Understanding the Burning Plasma State in ITER

Controlling and sustaining a self-heated plasma

(Joint with Theme II Control panel)

- Control complex, burning plasmas
- Stability pressure-limiting instability
- Suppress confinement limiting instabilities in ITER
- Neoclassical tearing modes
- Resistive wall modes
- Error field effects
- Breakdown
- Define requirements for plasma control system
- Impacts of MHD stability control on operation and modifications

Mitigating transient events in a self-heated plasma

(Joint with Theme II Off-normal plasma events panel)

- Disruption/VDE/runaway mitigation
- Implement edge stability suppression in ITER
- ELM control/mitigation

Diagnosing a self-heated plasma

(Joint with Theme II Measurement panel)

- Deploy turbulence and alpha particle measurements
- Diagnostics

Theme II: Creating Predictable High-Performance Steady-State Plasmas

Plasma modification by auxiliary systems

Neutral Beam Injection

- Long pulse megavolt accelerator operation
- Long pulse megavolt power supply operation
- Long pulse negative ion source operation
- Long pulse positive ion source operation
- Neutron shielding of insulators
- Steady state neutral beam operation (lithium jet neutralizer)

Fuelling

- Steady state fueling technology
- Fueling efficiency and isotope mixture control
- Fueling method compatibility with ELMs

Theory

- Pellet fueling (including ablation and flows)
- Wave and wave particle interactions from antenna to separatrix
- How RF drives flows and currents
- Efficient RF current drive

ICRH

- Launchers; Steady state high power, large gaps
- Elm resilience with arc protection
- Impurity production and sheath formation
- Physics of breakdown and conditioning
- ICRF seed current drive in AT scenarios
- Antenna performance at high density

Lower Hybrid

- Steady state launchers
- AT scenario control; rotation, current profile, pedestal, NTM
- Edge fast electron production
- Density limit
- Optimal frequency in high density burning plasmas
- Penetration through high temperature pedestal

ECRH

- Effect of dominant electron heating and $T_e > T_i$ on confinement.
- Steady state high power gyrotrons with improved efficiency
- Frequency tuning of gyrotrons
- Multiple frequency transmission lines
- Steady state high power launchers and components

Additional issues for alternate configurations

- Heating in over dense plasmas

Theme II: Creating Predictable High-Performance Steady-State Plasmas

Control

(Joint with Theme I Controlling and sustaining a self-heated plasma panel)

- Operating Regime
- Plant Startup and Shutdown
- Kinetics
- Fusion plant
- Stability
- Off-normal control
- Reliability and Certification
- Modeling and Design
- Algorithms and Approaches
- Experimental demonstrations

Integration of high-performance steady-state plasmas

- Assessing ARIES/DEMO requirements
- Core performance requirements.
- SOL/divertor compatibility
- Heating and current drive
- Control needs
- Diagnostics
- Modeling requirements for DEMO era

Note: Above topics include assessment of integration issues for 3-D/stellarator devices

Validated predictive modeling

- Predictive tritium retention
- Pedestal and ELMs
- Prediction of core plasma pressure, current, flows
- Stability, including effects of intrinsic rotation
- Disruptions
- RF and fast particle physics (including interactions)
- Integrated modeling needs

Theme II: Creating Predictable High-Performance Steady-State Plasmas

Measurement

(Joint with Theme I Diagnosing a self-heated plasma panel)

- Measurement Capability for steady-state burning plasmas

- Measurement Compatibility with S-S BP conditions and Diagnostic Access concerns about radiation field, fluxes, fluences

- 1st-wall footprints for measurements

- Reliability and Calibration of Measurements under steady-state burning plasma conditions

- Interpretation and analysis of measurements

- Sensors for plasma control

Magnets

- Reliability

- Maintainability

- Demountability

- Alternate magnet geometries

- Materials-conductor, insulation, structural

Note: Panel is considering multiple magnet types and configurations.

Off-normal plasma events

(Joint with Theme I Mitigating transient events in a self-heated plasma panel)

- Disruptions

- Runaway electrons

- Large ELMs

- Energetic Alphas

Note: Above topics include assessment of issues for 3-D/stellarator devices

Theme III: Plasma-Material Interface

Plasma-wall interactions

- SOL and Divertor Plasma
 - Turbulent heat and particle transport
 - SOL particle flows
 - Impurity transport
 - Radiation transport
 - He pumping
- Erosion & Redeposition
 - Impurity generation
 - RF sheaths
 - Dust production
 - Morphology changes
 - Component lifetime
 - Energetic a effects
- ELMs & Disruptions
 - Off-normal heat flux
 - Energetic electrons
 - Impurity injection
- Tritium Retention
 - Safety
- Innovations
 - High radiation frac'n
 - Flux expansion
 - Stellarator edge
 - Material development
 - Liquid surfaces
 - Active coating

Plasma facing components

- Solid Surface PFC
 - Heat transfer development
 - Materials Development
 - Integrated PFC Development
 - Integrated Component Testing
 - Chamber Geometry Optimization
 - NDE technique development
- Liquid metal surface and design
 - Temperature limits
 - MHD Effects
 - Heat Removal
 - Materials Development (pipes, nozzles, etc.)
 - Diagnostics
 - Hydrogen and impurity retention, removal

Theme III: Plasma-Material Interface

- Integrated Testing
- PFC Maintenance
- Tools and Techniques Development
- Off-line Testing
- Integrated Testing

Internal components

- Measurement Systems
- RF Antennas (ICRF, LH)
- Microwave launchers
- Control Coils
- Innovation (materials, active coatings)

Theme IV: Harnessing Fusion Power

Fuel cycle

Needs for DEMO

- Need to adequately process fusion fuel
- Need to provide torus vacuum and fueling
- Need to adequately contain and handle tritium
- Need to adequately perform tritium accountability and nuclear facility operations
- Need to breed tritium
- Need to extract tritium from the breeding system
- Need to characterize, recover and handle in-vessel tritium

Power extraction

Operation of plasma chamber and divertor components at temperatures high enough for efficient power conversion

- Thermofluid/MHD, heat and mass transfer of reactor coolants and liquid breeders (He, liquid metals, water)
- Fabrication of complex plasma chamber structures and loop components from candidate materials
- Diagnosis, monitoring and control of blanket and primary cooling loop operation
- Effective radiation shielding of vacuum vessel, magnets, and personnel
- Development and validation of integrated plasma chamber system predictive capabilities
- Characterization of blanket system synergistic effects, failure modes and lifetime in fusion environment
- Integration, maintenance, and replacement methods for plasma chamber systems
- Efficient power conversion systems for electricity and hydrogen production including compatible heat exchangers
- Interaction of plasma chamber systems with plasma operation (high temperature walls, error fields, etc.)
- Interaction of plasma chamber system with tritium breeding functions and fuel cycle requirements

Theme IV: Harnessing Fusion Power

Materials science

- Alloy Development
- Chemical Compatibility
- Design Criteria
- Erosion
- Fabrication & Joining
- Plasma-Material Interactions
- Radiation Effects
- Safety, Licensing, RAMI
- Thermal Creep & Fatigue
- Tritium Inventory
- Tritium Permeation

Safety

- International Fusion Safety Standard Framework
- Integrated Management Strategy for Activated Material

RAMI

- Need for integrated design
- Component reliability and maintainability
- Component lifetimes
- Maintenance systems
- Disruptions and off-normal events

Theme V: Optimizing the Magnetic Configuration

Compact toroid

FRC

- Stability at large s (normalized ion gyroradius)
- Transport mechanisms and scaling
- Current drive and sustainment
- Fast particle effects on current drive, stability, confinement
- Heating methods

Spheromak

- Sustainment and confinement
- Efficient formation techniques
- Transport mechanisms and scaling
- Beta limiting mechanisms
- Particle balance and density control
- Fast particle effects on sustainment, stability, confinement
- Resistive wall mode control
- Technology for long pulse operation

Reversed-field pinch

- Transport mechanisms and confinement scaling
- Current sustainment
- Integration of current sustainment and improved confinement
- Plasma boundary interactions
- Energetic particle effects
- Beta limiting mechanisms
- Self-consistent reactor scenarios
- Optimized resistive wall mode control for a fusion environment

Spherical torus

- Start-up and ramp-up
- Plasma-material interface
- Electron energy transport
- Integration at high beta
- Magnets
- Stability and steady-state control
- Disruptions
- RF heating and current drive
- Ion scale transport
- Fast particle instabilities
- Neoclassical tearing modes
- Continuous neutral beam injection systems

Theme V: Optimizing the Magnetic Configuration

Stellarator

- Simpler coil systems
- Integrated high performance of Quasi-Symmetric optimized stellarators
- Confinement predictability
- Divertors
- Operational limits
- Impurity and fusion ash accumulation
- Reduction of anomalous transport
- Energetic particle instabilities
- Disruptions (limits on plasma current generated rotational transform)
- ELM-free high performance
- Profile sensitivity of operational limits
- Superconducting stellarator coils