

Opportunities for Research on DIII-D

by
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Presented at the
NSTX Research Forum
Princeton Plasma
Physics Laboratory

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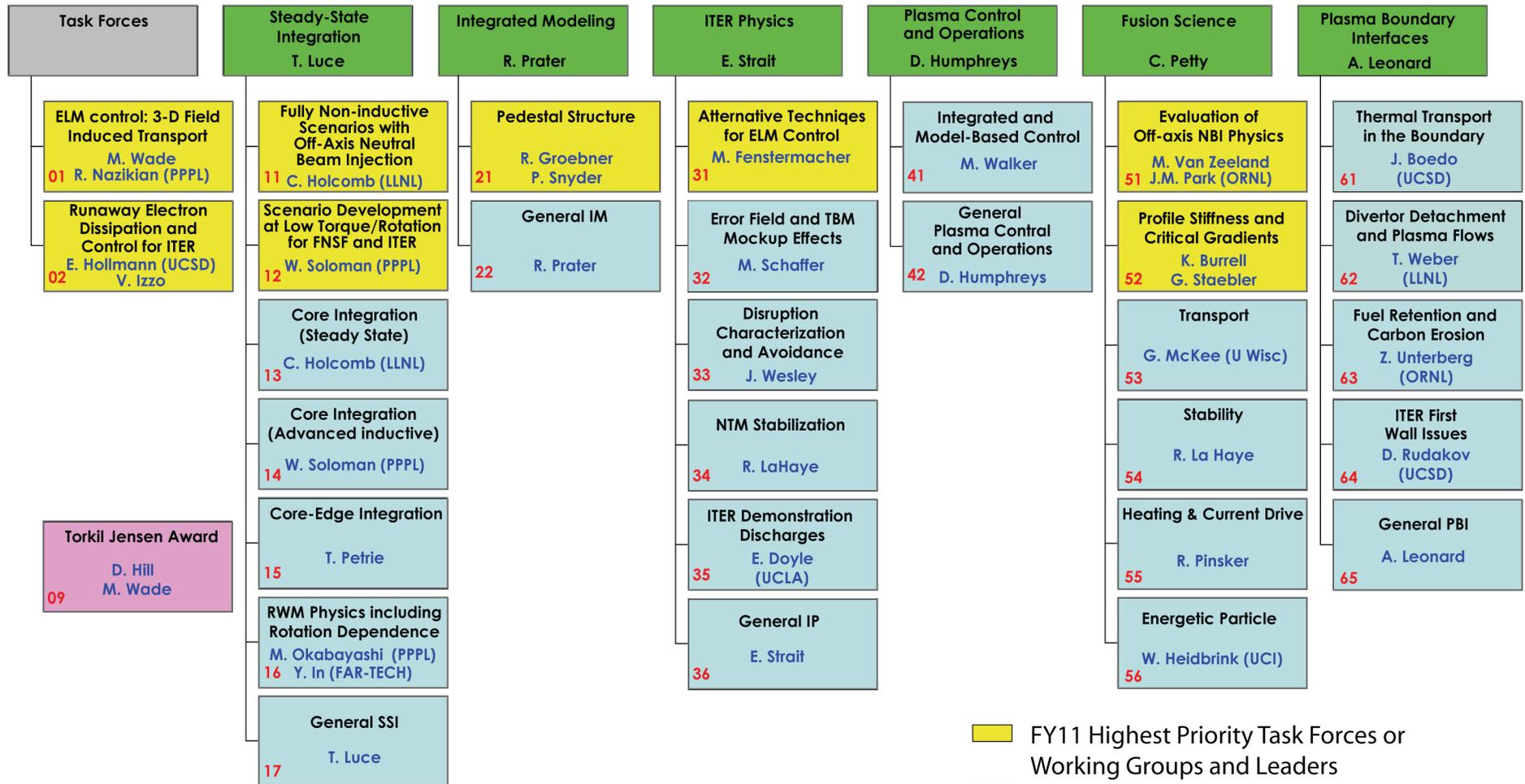


Key Research Areas Would Benefit from Enhanced NSTX Collaboration with DIII-D in Next Few Years

- Impact on ITER in near term
 - ★ ELM control, EF correction, disruption mitigation, for example
 - ... NSTX/PPPL strong on ELM pacing, 3D fields, EFC
- Research providing information for NSTX Upgrade
 - ★ Off-axis CD, “long pulse”, fully non-inductive ops
 - ... increased electron heating
- Leveraging NSTX and DIII-D common strengths
 - ★ EF, RWM, fast ion physics, for example
 - ... pedestal structure – **2011 JRT**
 - ... electron particle transport – **2012 JRT**

Flow Diagram of Experimental Research Areas for 2011 (Contact Persons Noted)

Physics Groups within the Experimental Science Division



- FY11 Highest Priority Task Forces or Working Groups and Leaders
- Other Working Groups and Leaders
- Physics Groups and Leaders
- (****) Collaborator Affiliations as noted

14 Weeks Physics Operation Planned in FY2011, 13 Weeks in FY2012, 5 Year Plan to October 2013

PROPOSED DIII-D FY2011 OPERATIONS SCHEDULE

Oct							Nov							Dec							Jan						
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■ Plasma physics
 ■ Startup
 ■ Option
 ■ Vent

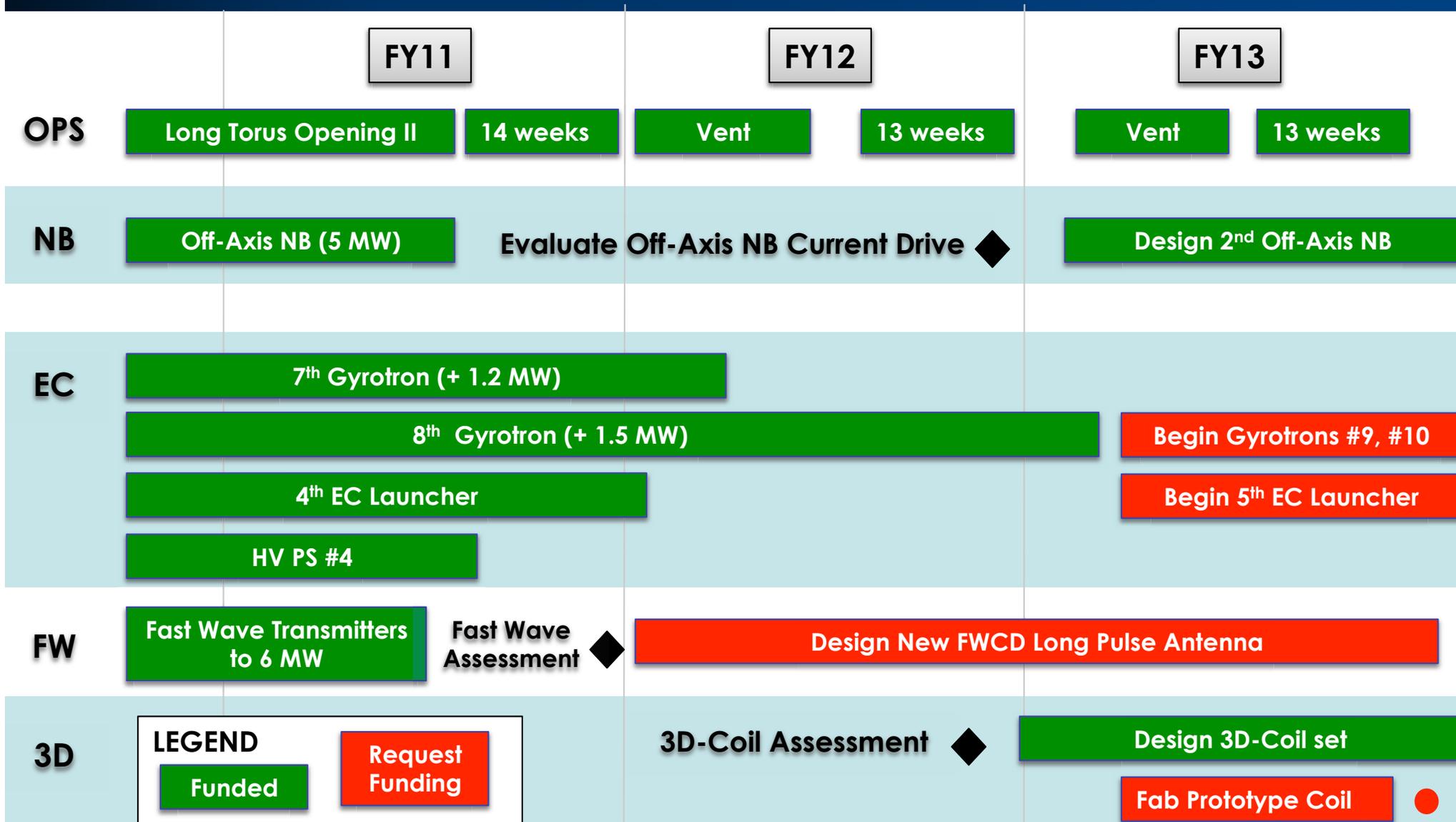
PROPOSED DIII-D FY2012 OPERATIONS SCHEDULE

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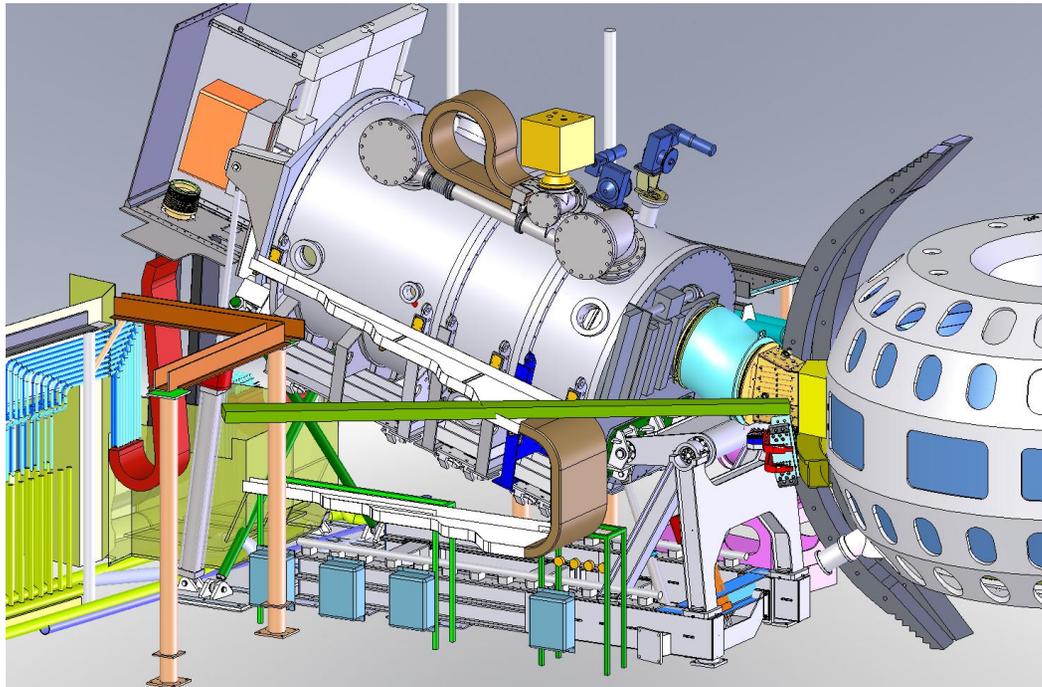
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 October 2013



New, Planned, and Proposed Hardware Upgrades Will Position DIII-D to Address Critical Science Issues



First Upgraded Beamline Will Provide 5 MW of Off-Axis Injection for Current Drive



- Off-axis beam provides valuable tool to modify current, rotation, and heating profiles
 - avoid driving $q(0)$ below 1

- Continuous adjustment of injection angle (0-16.5°)
 - Neutralization peak 40 cm below midplane
- Modified ion sources with stronger focusing successfully tested (June '10, Feb '11)
- Available for start of FY11 research campaign
- **Decision to proceed with 2nd OANB (to 10 MW) will be made after evaluation in FY12**
 - FY14-15 installation (LTO III)

System #7: 1.2 MW Depressed Collector Gyrotron and All Subsystems Should Be Ready by Early FY12



- **New tube updates existing design**
 - CuCrZr replaces OFHC Cu for longer collector life
 - Improved mode convertor - higher Gaussian content
- **Vault expansion completed for gyrotrons #7 and #8**
- **New HV supply with 2 mod/regs for independent control of gyrotrons**
- **Dual launcher from PPPL for #7 and #8 will be installed in early FY12 (PPPL currently major collaborator on EC)**



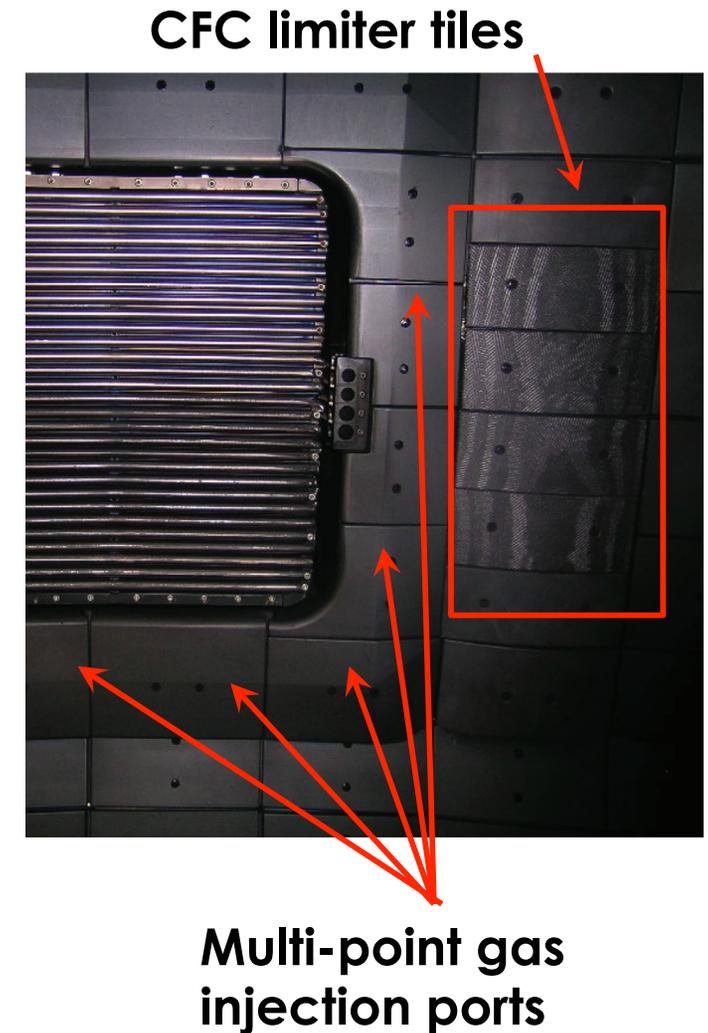
New HV Supply



ELECTRON CYCLOTRON

New Fast Wave Hardware Enables Increased Coupling to H-mode Plasma

- In FY10, smaller outer gaps yielded ~20% increase in coupling/cm
- **Antennas closer to plasma (FY11)**
 - 0° & 180° antenna – radial position adjustable 1 cm under vacuum
 - 285°/300° antenna – moved 1 cm closer
- **New gas injection points adjacent to antennas added for improved plasma/antenna coupling**
 - 5-point distributed injectors at 285° (FY11)
 - Single point injectors at 0° & 180°
- **Improved fault detector will allow ELM-resilient operation of FW systems (FY11)**



Welcoming Help in Fast Wave Systems

- Supporting antenna conditioning and tuning
 - ★ Operation and physics (strong PPPL collaboration already exists)
- Analysis and modeling high harmonic fast wave absorption cases

Assessment of fast wave coupling in H-mode to get additional electron heating (complementary to ECH) by October 2012

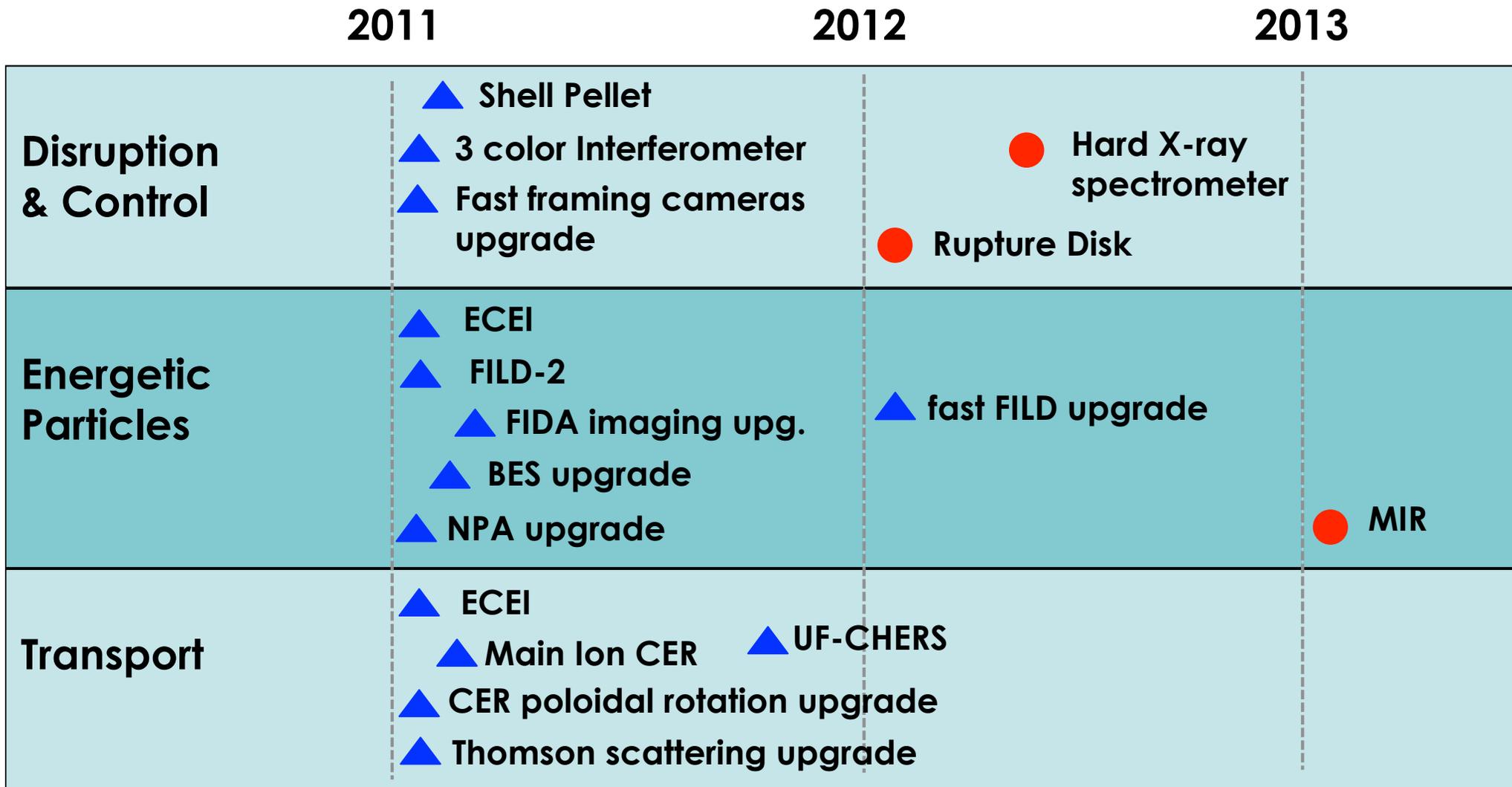
Many New and Upgraded Systems are Planned in Support of the Scientific Program

	2011	2012	2013
Pedestal	<ul style="list-style-type: none"> ▲ Edge Thomson Upgrade ▲ X-pt SXR ▲ Pellet Pacing (30Hz) ▲ Lithium beam Upgrade 	<ul style="list-style-type: none"> ● Line Ratio (n_e & T_e) 	<ul style="list-style-type: none"> ▲ Neutrals /TALIF
3D fields	<ul style="list-style-type: none"> ▲ X-pt SXR ▲ Main Ion CER 	<ul style="list-style-type: none"> ▲ IR/visible periscope ● New technique 	<ul style="list-style-type: none"> ▲ 3D magnetics (first phase)
Boundary	<ul style="list-style-type: none"> ▲ Divertor Thomson Upg. ▲ 2D flows (upper and lower divertor) ▲ Fixed Langmuir probes upgrade 	<ul style="list-style-type: none"> ▲ IR/visible periscope ▲ CP Langmuir swing probe ● Line Ratio (n_e & T_e) 	<ul style="list-style-type: none"> ▲ Neutrals /TALIF ● Divertor T_i

▲ : Planned

● : Under evaluation

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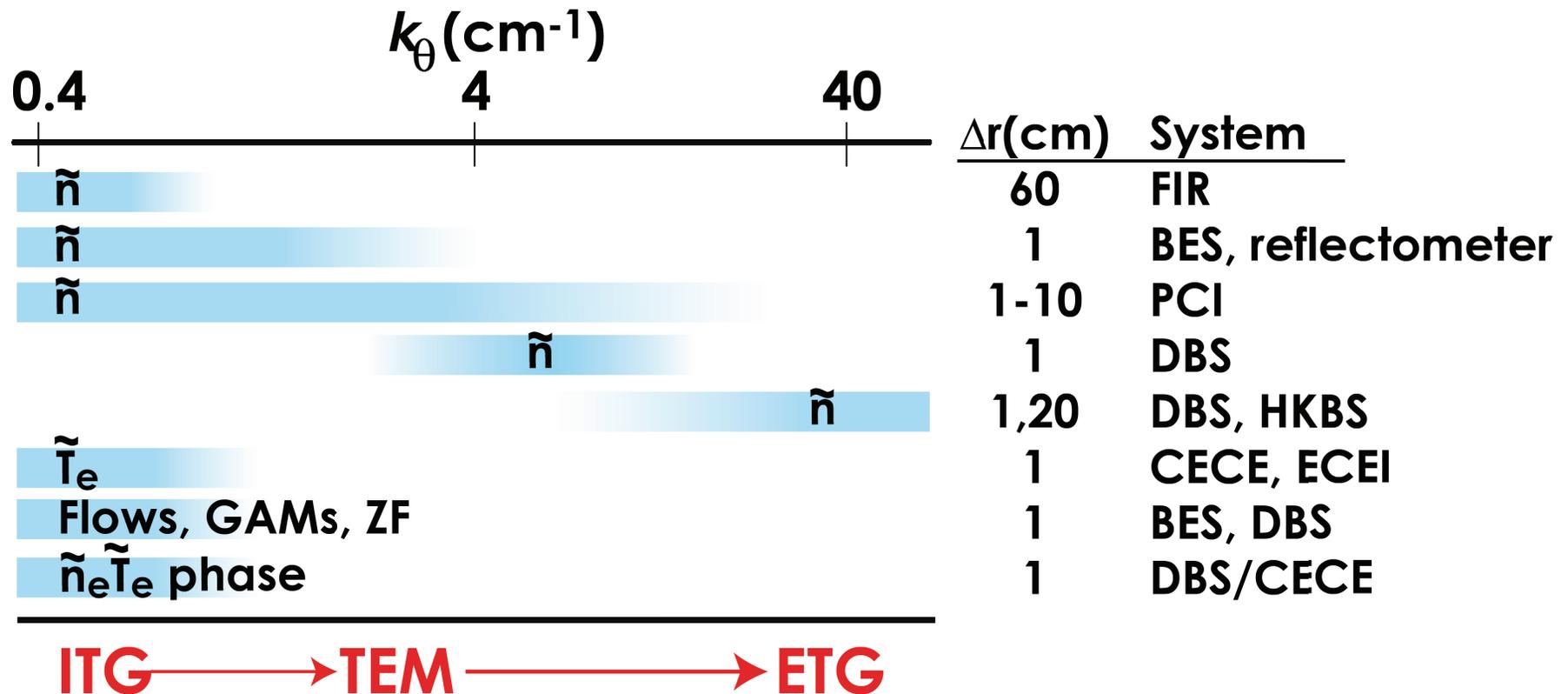
▲ : Planned

● : Under evaluation

Welcoming Help in Diagnostic Areas

- **Imaging diagnostics (relocating NSTX cameras to DIII-D?)**
 - ★ IR cameras for divertors, visible light cameras for deuterium (FIDA) or lithium beams (BES)
 - ★ SXR imaging of magnetic structures due to 3D
- **Li beam and Motional Stark Effect**
 - ★ Equipment for narrow wavelength filtering of polarized light
- Thomson Scattering support
- EFIT development
 - ★ 3D (PPPL strong here)
 - ★ Runaway electron equilibria

Broad Range of Fluctuation Diagnostics used in Validation Studies of Turbulence and Transport Simulations

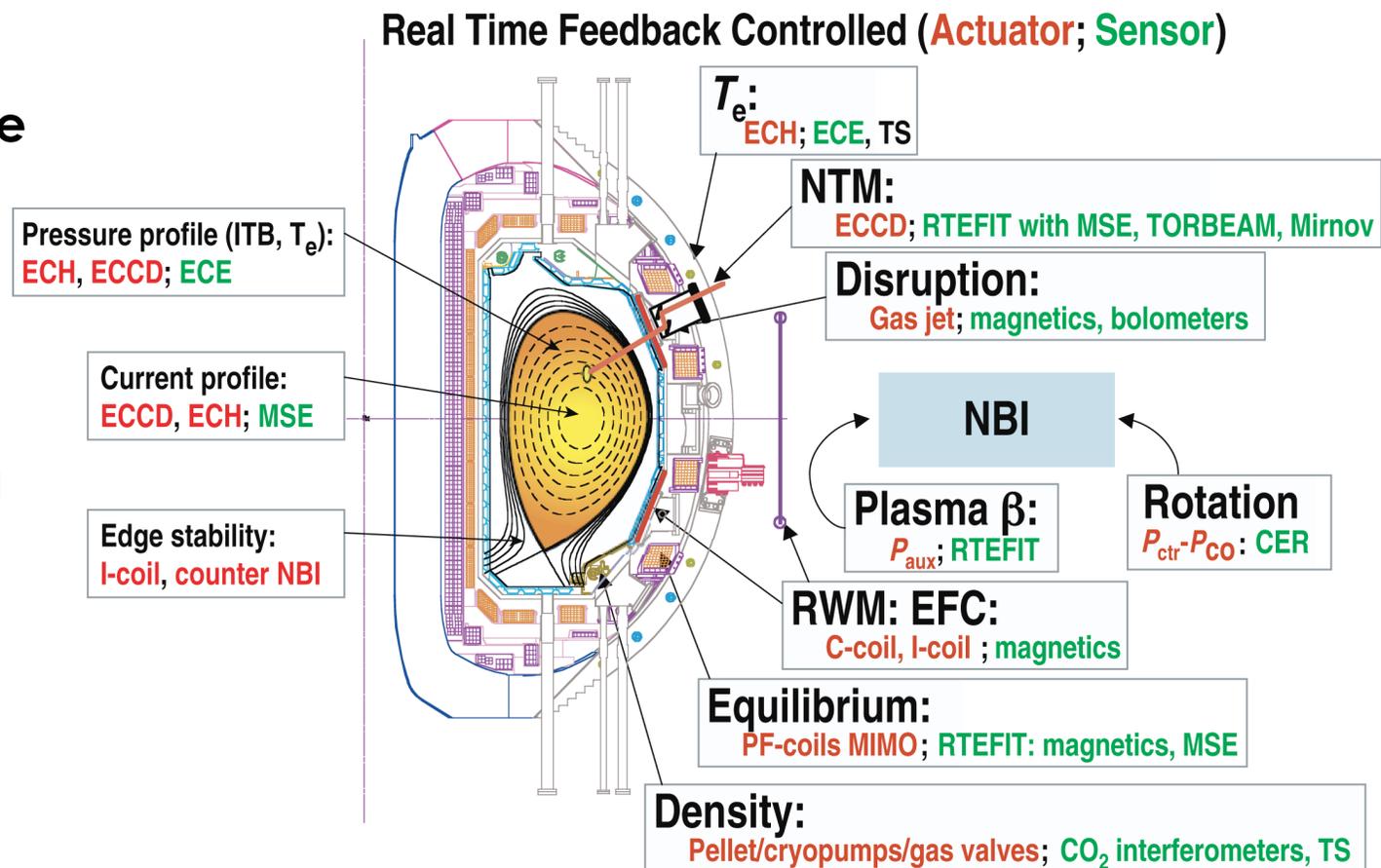


Welcoming Help in Transport

- Investigations of core energy and particle transport
 - ★ Extend work on energy transport to electron-scale modes (TEM and ETG)
 - ... begun for **2012 Joint Research Target**
 - ★ Validate transport models (e.g. TGLF) and simulations (e.g. GYRO)
 - ... participate in new experiments and analyze data
- Transport of fast ions during MHD events energetic particle instabilities (particularly with off-axis NBI)
 - ★ **Strong PPPL collaboration already exists**

Real-Time Control of Key Plasma Properties Enabled by Extensive Set of Control Tools

- Real-time q-profile
- Real-time boundary display
- Real-time plasma rotation control



Welcoming Help in Control/Stability/Scenario/ Boundary (Including Divertor 3D Footprints)

- Plasma control system (PCS)
 - ★ MIMO evaluation, profile control implementation, programming
 - ★ Off-normal/fault response algorithm development, disruption physics
 - ★ Participation in physics operations team (10 ~12 now)
- Steady state integration (SSI)
 - ★ Kinetic effects on RWM, error correction/RWM feedback, IPEC modeling
 - ... power system development, upgrades
 - ★ Advanced inductive and steady-state scenario development
- Boundary (including divertor footprints and features)
 - ★ Pedestal exps, data reduction, modeling and analysis (2011 JRT)
 - ★ Optimization of detached divertor operation
 - ... Snow flake, Super-X control
 - ... Maintenance of high pressure pedestal
 - ... Scaling of detachment onset

Scientific Milestones Seek to Take Advantage of New Capabilities to Support ITER and Steady State

	2011	2012	2013
Base	14 weeks 176: Pedestal model validation (JRT) 177: First experiments with 2MW off-axis NBI 178: ELM suppression and 3-D field induced transport	13 weeks 179: High performance with OANB and increased EC 180: Alternate ELM control techniques 181: Core transport model validation (JRT)	10 weeks 184: Quantify plasma response to 3-D fields 185: Techniques for reliable operation near limits 186: Impact of ITER-like conditions on high performance plasma
Incremental		+2 weeks 182: Runaway electron controlled-dissipation methods for ITER 183: Advanced scenarios with divertor heat flux solutions	+3 weeks 187: Radiative stability of partially-detached divertor discharges 188: Non-nuclear ITER operating scenarios

Summary: Opportunities for Research on DIII-D

- Upgrades to our Heating and Current Drive Systems (NB, EC, FW) will provide increased power and enhanced current profile control
 - ★ in conjunction with upgraded systems for diagnostics and control
- Assessments of fast wave effectiveness, off-axis NB current drive, and 3D-field physics will drive critical hardware upgrade decisions in FY11 and FY12 (FY13 begins October 2012)
 - ★ pointing to new 5-year plan beyond September 2013
- Collaboration is actively encouraged and welcomed
 - ★ Opportunities to make significant advances by leveraging DIII-D and NSTX distinctive strengths and unique capabilities