Pulses to Accomplish Mission

Response to E3

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http://fire.pppl.gov

FIRE *Lighting the Way to Fusion*

FIRE would Produce Enough Data to Accomplish it's Mission

- FIRE's mission is to attain, explore, understand and optimize magnetically confined fusion dominated plasmas. It needs to provide a variety of magnetic fields, pulse lengths and power levels – not all of them at full field, full pulse length and full fusion power.

- The number of shots specified is that same as BPX

3,000	full field	High Performance H-Mode
30, 000	2/3 field	High Performance AT-Mode
~6 TJ	fusion energy	(Compare with NIF)

- Limits imposed by: mechanical fatigue, TF cool down, TF insulator radiation damage, divertor erosion and tritium inventory.

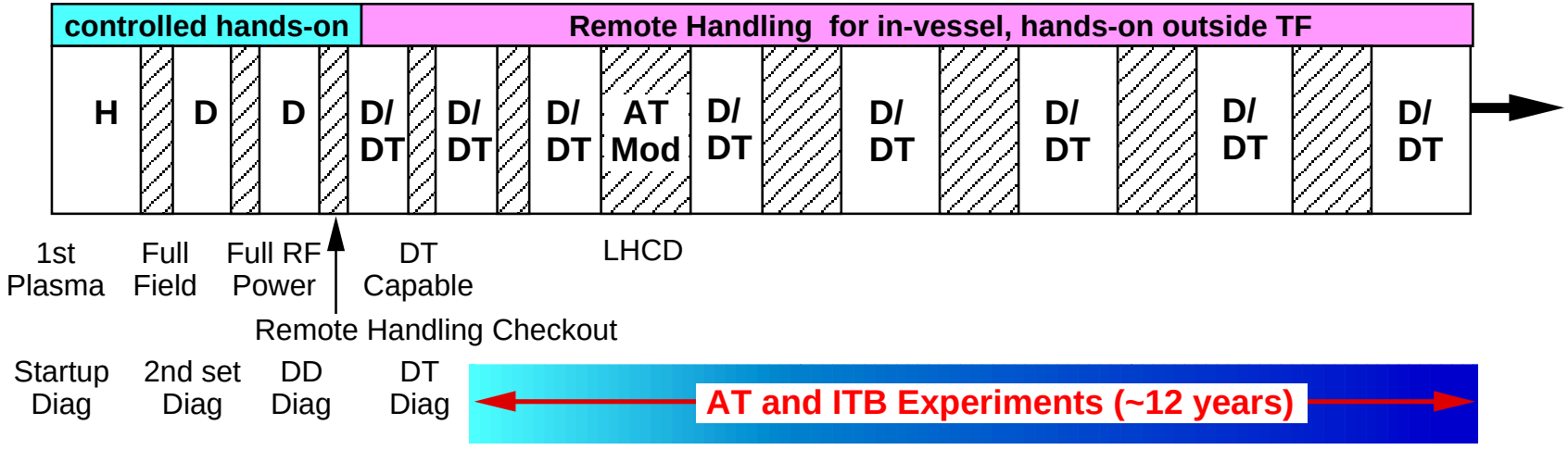
- The shot rate is limited but the number of shots/year is with in a factor of two of present large experiments.

- Similar to questions raised when we started planning for D-T operation in TFTR, and actions were taken to provide sufficient shots and data.

FIRE Experimental Plan

Years from 1st plasma	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	Original* Limits
Shots/ 2yr	4000	4000	4000	4000	3500	3500	3500	3500	**30,000**
Full B Shots/ 2yr	250	500	600	500	300	300	300	300	**3,000**
DT Energy(GJ)/ 2yr			1000	1000	1000	1000	1500	1000	**6,500**
Tritium Burnup(g)/2yr			2	2	2	2	3	2	

Q~ 5 -10 (short pulse initially, extend to full power and pulse length)



Startup Diag | 2nd set Diag | DD Diag | DT Diag

AT and ITB Experiments (~12 years)

H-Mode (~7 yrs)

- Control
- Cleanup
- Fueling
- Diagnostics
- Operations
- RF tests

- InitialRF Heating
- Plasma Power Handling
- Initial Physics studies

- Alpha heating
- Energy transport
- Fast particle
- Particle and ash removal

- Global Burn control
- Transient Profile control
- Transient Adv Tok

- Optimization of AT modes
- Non Inductive Profile control
- Improve Divertor and FW power handling
- Extend pulse length

H/D Operation Illustration

H/D Discharge	Q/Q(JET)	Dur	/hour	/day	/week	/month	months	/year
5T, 3.8MA, 5s	2	5tE	2.5	36	180	540	1.5	810
6.6T,5.1MA, 5 s	7.5		1.35	19.9	99.5	298.5	2	597
10T,7.7MA, 5 s	50		0.86	13.04	65.2	195.6	2	391
10T,7.7MA, 10 s	50	1tCR	0.63	9.82	49.1	147.3	1	147
10T,7.7MA, 20 s	50	2tCR	0.37	6.18	30.9	92.7	1.5	139
Total							**8**	**2085**

14 hrs/day
5 days/week
3 weeks/month
8 months/yr

Full Field Shots **678**

- Not all shots in present experiments are at full full, pulse length, power
- 2000 shots per year is comparable to annual shots from present day devices
- > 600 full B shots is comparable to present operating machines

D-T Operations Illustration

All DT with emphasis on High Field Shot sequences

D-T Discharge	Pfus(MW)	Dur(s)	Dur	/hour	/day	/week	/month	months	/year
5.0T, 3.8MA	10	2	$2\tau E$	3	43	215	645	0.9	581
5.0T, 3.8MA	10	5	$5\tau E$	2	29	145	435	0.7	305
6.6T,5.1MA	30	2	$2\tau E$	1.4	20.6	103	309	0.25	77
6.6T,5.1MA	30	5	$5\tau E$	1.29	19.06	95.3	285.9	0.25	71
6.6T,5.1MA	150	10	$1\tau CR$	1.05	15.7	78.5	235.5	0.5	118
6.6T,5.1MA	150	20	$2\tau CR$	0.76	11.64	58.2	174.6	0.6	105
6.6T,5.1MA	150	35	$3\tau CR$	0.33	5.62	28.1	84.3	0.65	55
10T,7.7MA	150	2	$2\tau E$	1	15	75	225	0.7	158
10T,7.7MA	150	5	$5\tau E$	0.83	12.62	63.1	189.3	1.2	227
10T,7.7MA	150	10	$1\tau CR$	0.5	8	40	120	1.2	144
10T,7.7MA	150	20	$2\tau CR$	0.33	5.62	28.1	84.3	1	84
Total								**8.0**	**1924**

14 hrs/day
5 days/week
3 weeks/month
8 months/yr

Full B Shots	**613**
AT (6.6T) Shots	**426**
Setup Shots	**885**

Fusion energy 1.5 GJ

- 1000 DT shots per year could be run, as many as TFTR 's total number of shots in three years(JET?)

- long term run plan would be ~ 2/3 DD shots to 1/3 DT to meet long term TF insulator limit of ~6TJ

We Need to be Proactive to Ensure Sufficient Data Rate to Satisfy Mission

- Comprehensive diagnostic set to provide complete characterization of plasma properties in one shot.
- Provide online data analysis coupled with real-time plasma simulations to enhance planning for next pulse.
- Increase the fraction and depth of analyzed shots above that of present experiments.
- Attain operational availability > 80%, TFTR was near 90% during the final year of D-T operation.

Additional Items are Being Pursued to Exploit the New AT Opportunities on FIRE.

1. An insulation R&D program is being proposed, and different insulator configurations are being evaluated that might allow an increase of >10 in total fusion energy.

2. The fatigue limits will be reviewed to determine if additional high field shots could be provided. With some optimization, there is potentially a factor two increase in the number of shots.

3. Additional cooling for shorter cool down could be provided. Adding a cooling line on the front of the TF plate would shorten cool down time by ~ 4 at a cost of ≈ 1 cm.