Radiation Environment for FIRE Diagnostic Ports

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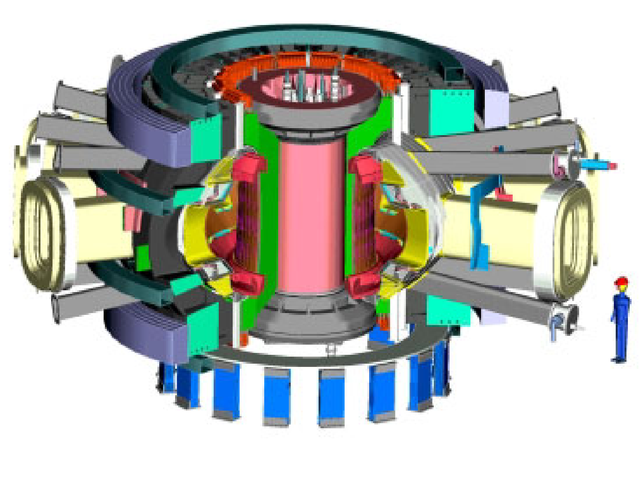
Fusion Ignition Research Experiment (FIRE)

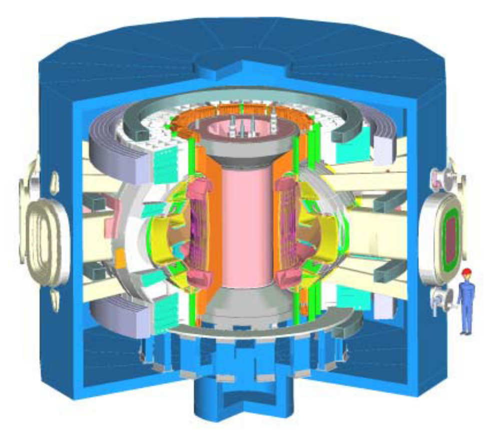
http://fire.pppl.gc

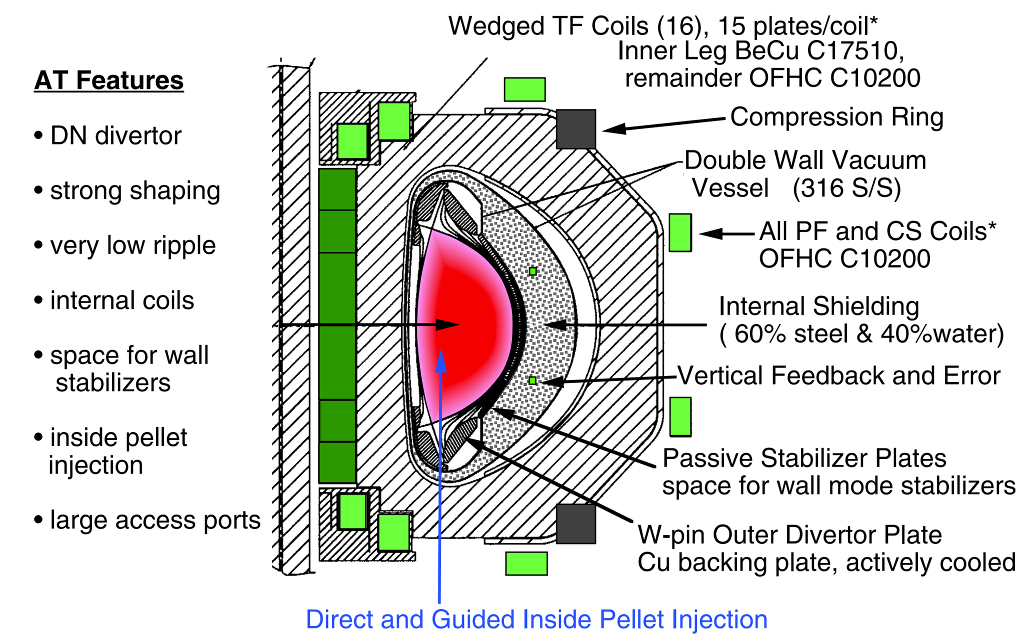


Design Features

- R = 2.14 m, a = 0.595 m
- B = 10 T
- W_{mag}= 5.2 GJ
- I_p = 7.7 MA
- $P_{aux} \leq 20$ MW
- Q ≈ 10, P_{fusion} ~ 150 MW
- Burn Time ≈ 20 s
- Tokamak Cost ≈ $375M (F
- Total Project Cost ≈ $1.2B at Green Field site.

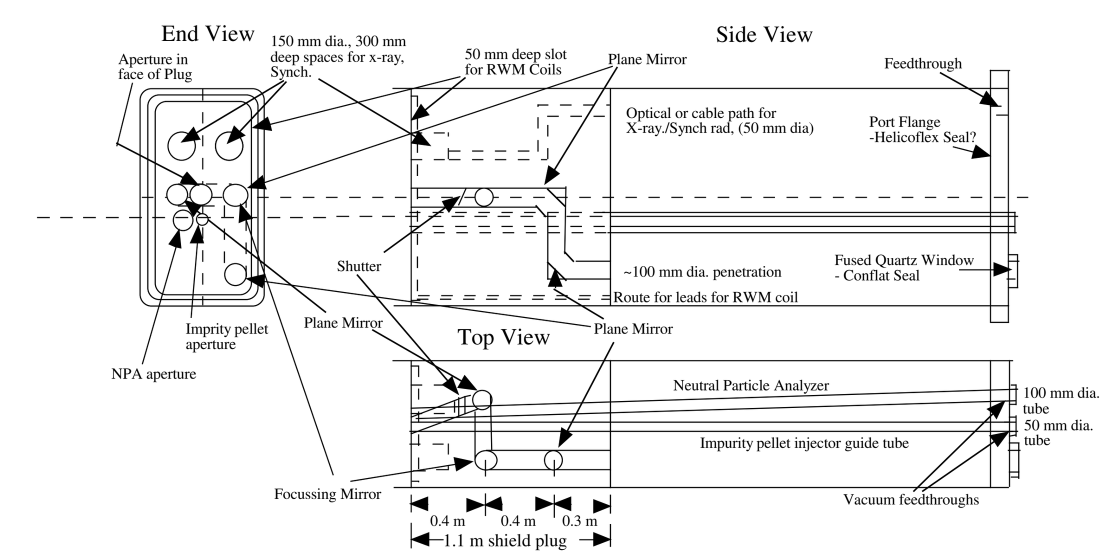
- **16 Wedged TF Coils**
- **Two Pairs of External Divertor Coils**
- **Two Pairs of External Ring Coils**
- **Free-standing, Segmented CS**
- **Vacuum Vessel Filled with Steel/Water for Shielding**
- **Plasma Facing Components:**
  - **-Be coated Cu 1st Wall**
  - **-W pin-type Inner Divertor, Baffle, & Outer Divertor**
- **2 Outboard Poloidal Limiters**
- **Internal Passive & Active Stabilization Coils**
- **Remote Maintenance**





*Coil systems cooled to 77 °K prior to pulse, rising to 373 °K by end of pulse.

FIRE Midplane Diagnostic Port J



FIRE Port Plug J

Radiation Environment at FIRE Midplane Diagnostic Port J

- Neutron and gamma fluxes affect plasma diagnostic performance
- Most serious streaming problem occurs in clear straight tubes for the Neutral Particle Analyzer (NPA) and Impurity Pellet Injector Guide tubes
- Other diagnostics (Thomson scattering) will make use of labyrinthine penetrations to curtail the streaming. It will include four bends with mirrors at corners
- Neutronics calculations performed to determine nuclear radiation environment at locations in the diagnostics penetrations and to assess the impact of streaming on flux and dose outside the port flange

Nuclear Parameters Calculated

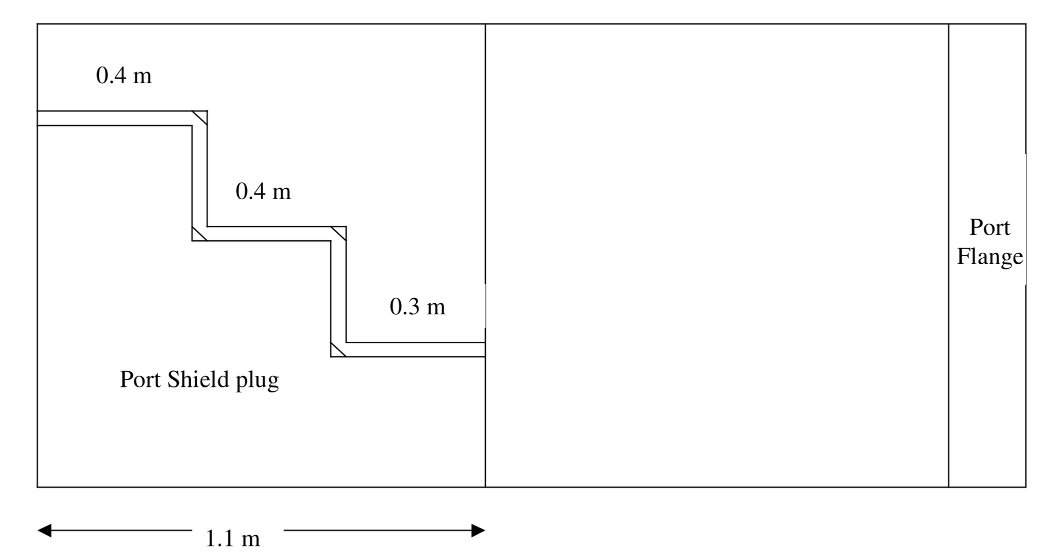
- The total neutron flux (integrated over all energies), the fast neutron flux (E > 0.1 MeV) and the total gamma flux were calculated at the front of the plug, along the penetrations, at the back of the plug and at the back of the port flange
- The absorbed dose rates in silica (SiO_2) and alumina (Al_2O_3) were calculated. The gamma contribution to the dose varies from ~30% at the front of the port plug to ~80% at the back of the port flange

Calculation Models

Three different models were used in the calculations

1. The first one assumes no penetrations in the plug and flange
2. The second case is for the worst case streaming with a 10 cm straight penetration through the plug and flange
3. The third case represents the Thomson scattering penetration with four bends

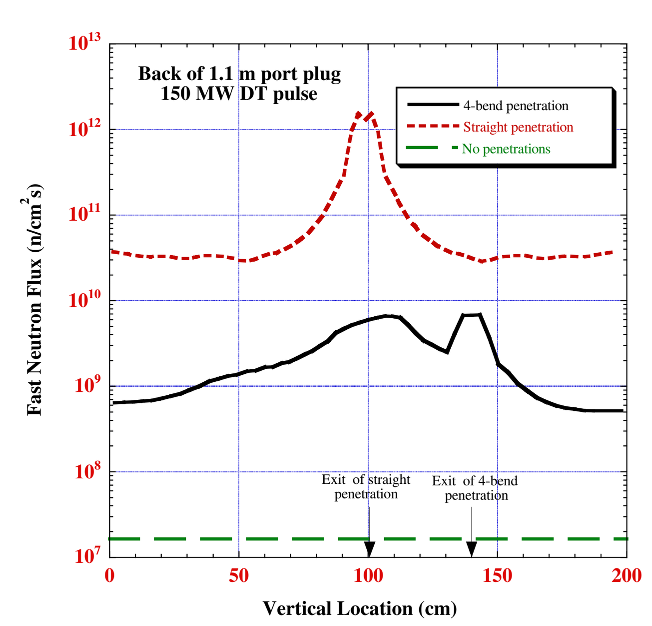
Calculation Model for the Thomson Scattering Penetration



Absorbed Dose Rates in Silica and Alumina along the Thomson Scattering Penetration

	Dose Rate During 150 MW DT Pulses (Rad/s)	
	Silica	Alumina
Front of port plug	7.90x10^5	8.48x10^5
First bend	7.69x10^4	9.85x10^4
Second bend	1.01x10^4	1.76x10^4
Third bend	1.24x10^3	2.25x10^3
Fourth bend	1.41x10^2	2.67x10^2
Back of port plug	1.65x10^1	3.14x10^1
Back of port flange	3.80	7.07

Fast Neutron Flux at Back of Port Plug



Flux at Back of Port Flange

	Total Neutron Flux (n/cm^2s)		Fast Neutron Flux (E>0.1 MeV) (n/cm^2s)		Total Gamma Flux (γ/cm^2s)	
	Peak	Average	Peak	Average	Peak	Average
1.1 m plug without penetrations	1.04x10^7	1.04x10^7	6.23x10^6	6.23x10^6	1.04x10^7	1.04x10^7
1.1 m plug with 10 cm straight penetration	5.14x10^{11}	1.27x10^{11}	2.75x10^{11}	6.38x10^{10}	3.96x10^{11}	1.03x10^{11}
3.4 m plug with 10 cm straight penetration	4.18x10^7	2.64x10^6	1.08x10^7	7.51x10^5	4.28x10^7	2.96x10^6
1.1 m plug with 10 cm 4-bend penetration	5.00x10^9	1.99x10^9	1.50x10^9	8.84x10^8	5.00x10^9	2.10x10^9
3.4 m plug with 10 cm 4-bend penetration	9.64x10^4	7.04x10^3	1.97x10^4	1.63x10^3	1.59x10^5	1.33x10^4

Additional Shielding Requirement

- Acceptable biological dose rates behind port flange were obtained for a 1.1 m port plug without any penetrations (~3 mrem/hr after 1 hr, ~0.1 mrem/hr after 1 day)
- These acceptable dose rates can be maintained with penetrations by increasing the plug thickness
- For straight 10 cm penetration the plug thickness needs to be increased to ~3.1 m
- For 4-bend penetration the plug thickness should be increased to ~2.1 m
- Since both penetrations exist in diagnostic plug J, the port plug should be increased to 3.4 m, the location of the cryostat interface