



## Abstract

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The Pegasus Facility is studying Extremely-Low-Aspect Ratio Tokamak (ELART) plasmas, accessing high- $\beta$  plasmas. A 60 Turn Toroidal Field bundle in the centerstack limited rod currents to  $<150\text{kA}$  and no ramp capability. An upgraded 12 Turn TF bundle is in house and will allow for improved performance with rod currents  $>300\text{kA}$  as well as added ramp capability. The ELART design requires a high stress ohmic solenoid, capable of operating at peak fields of  $>10\text{T}$  to achieve a flux swing of  $120\text{mV}\cdot\text{sec}$ . The ohmic power system utilizes 4 MJ of capacitance at 15kV impedance-matched through a 4:1 step down transformer to the solenoid. Operation parameters are limited due to the resistivity of the solenoid and power supply losses and limit operations to 50 to  $60\text{mV}\cdot\text{sec}$ . Added impedance matching as well as improved cooling capabilities will allow access to design parameters of  $>100\text{mV}\cdot\text{sec}$ . In the past year, the internal machine hardware was completely replaced, adding a complete set of magnetic diagnostics, segmented divertor plates, and a 2-strap, high power antenna.

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# Outline - Facility Upgrades at PEGASUS

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- **Internal Machine Hardware**
  - *Diverter Plates, Core Shielding, Magnetic Diagnostics, Rail Limiters, RF Antenna*
- **Machine Conditioning & Gas Control**
  - *Ti Getter System, Gas Valves, Gas Valve Controllers*
- **OH System Reconfiguration**
  - *High Current Toroidal Inductors, 4:1 High Current Transformer, Solutions to Capacitor Bank Charging/Switching Systems*
- **Data acquisition & Control**
  - *Upgrades to Data Hy way, New Control Room*
- **TF System Upgrades**
  - *New TF Bundle, New TF Power System, Preliminary Tests/Staged Upgrade using current bundle*
- **Proposed Future Upgrades**
  - *Divertor Coils, OH Future, EBW/ECH Systems*



# Internal Hardware Installed in PEGASUS Vacuum Chamber

(a) 0.11m Diameter Center Post and Shielding

(b) Upper and Lower Limiters

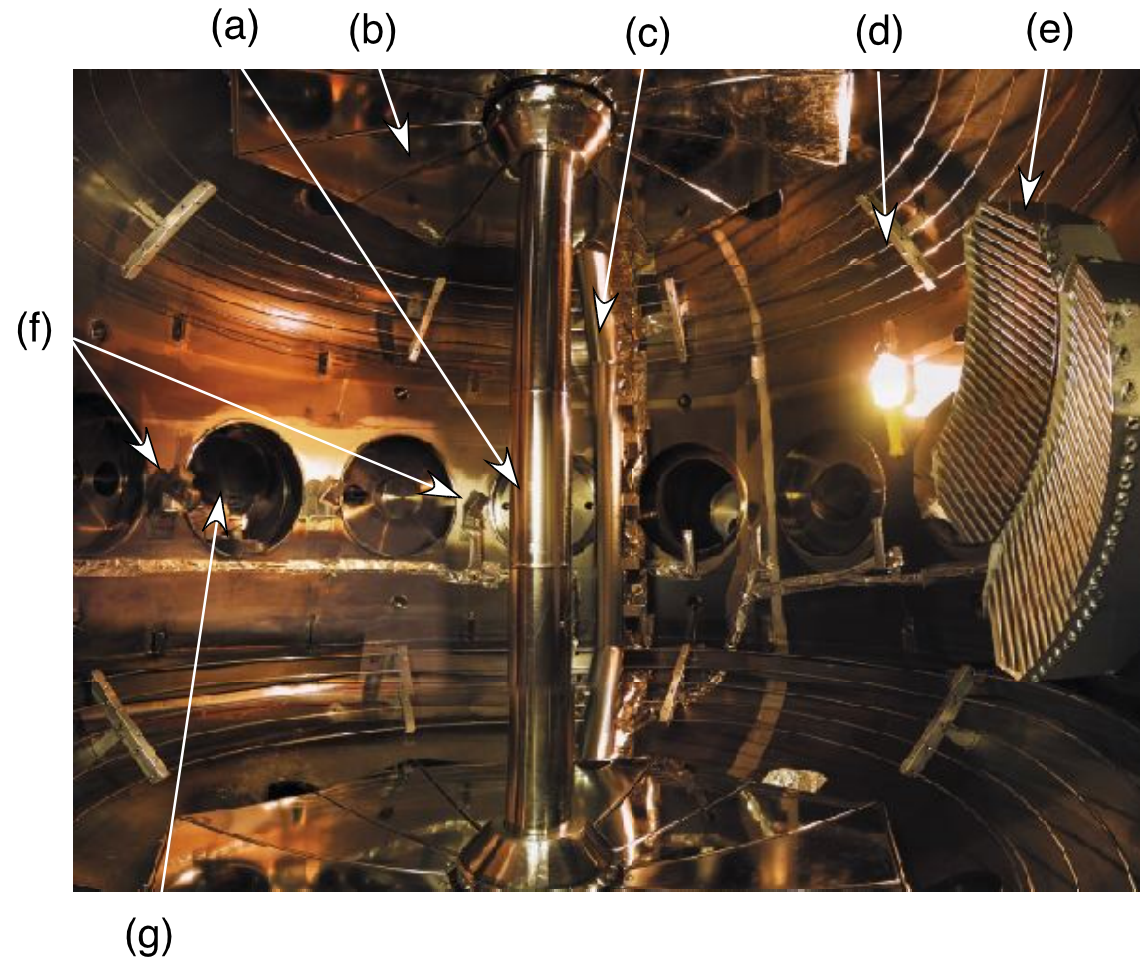
(c) Outer Rail Limiter

(d) Fluxloops

(e) HHFW Heating Antenna

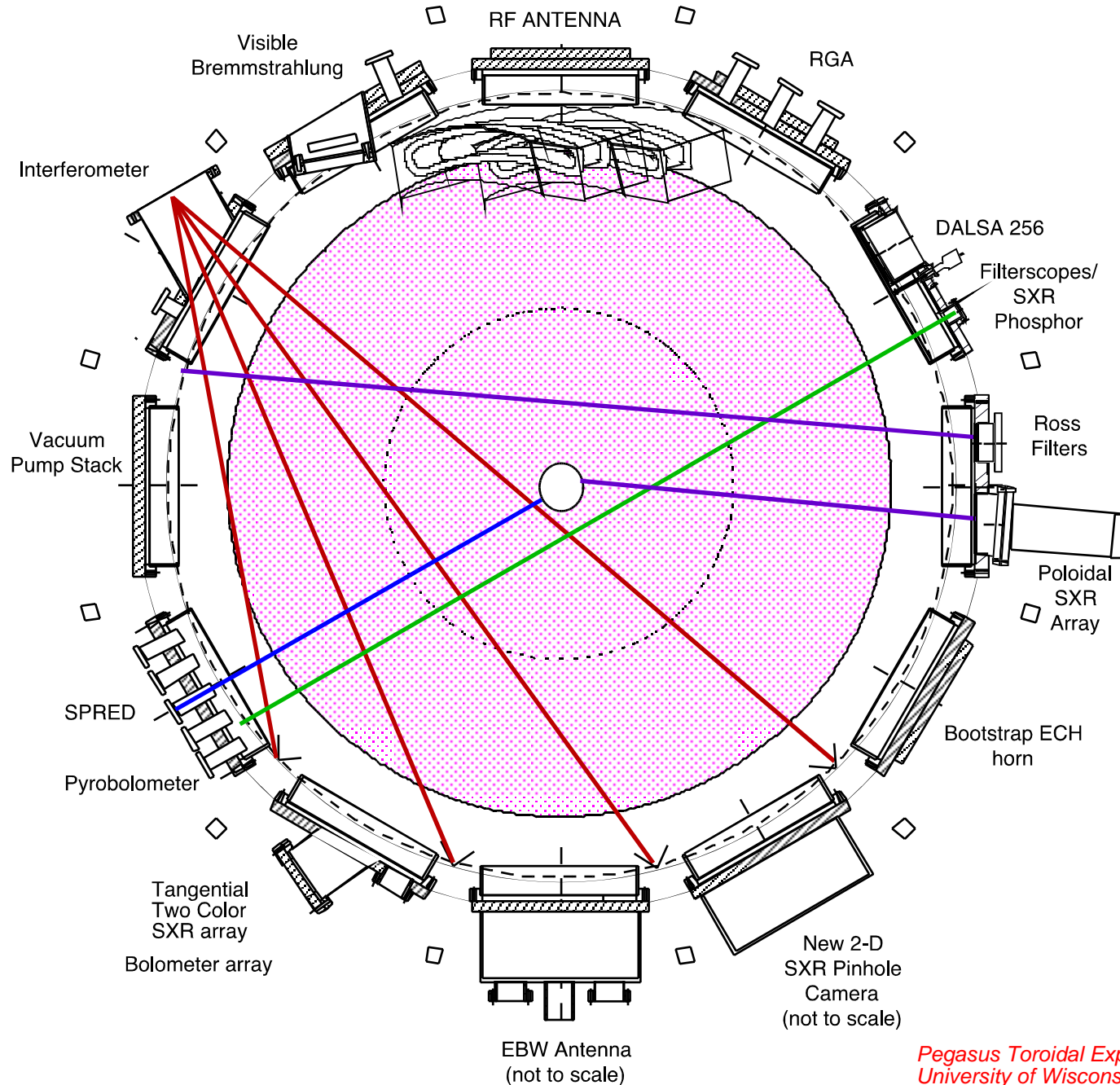
(f) Interferometer Retroreflectors

(g) Steerable EBW Antenna





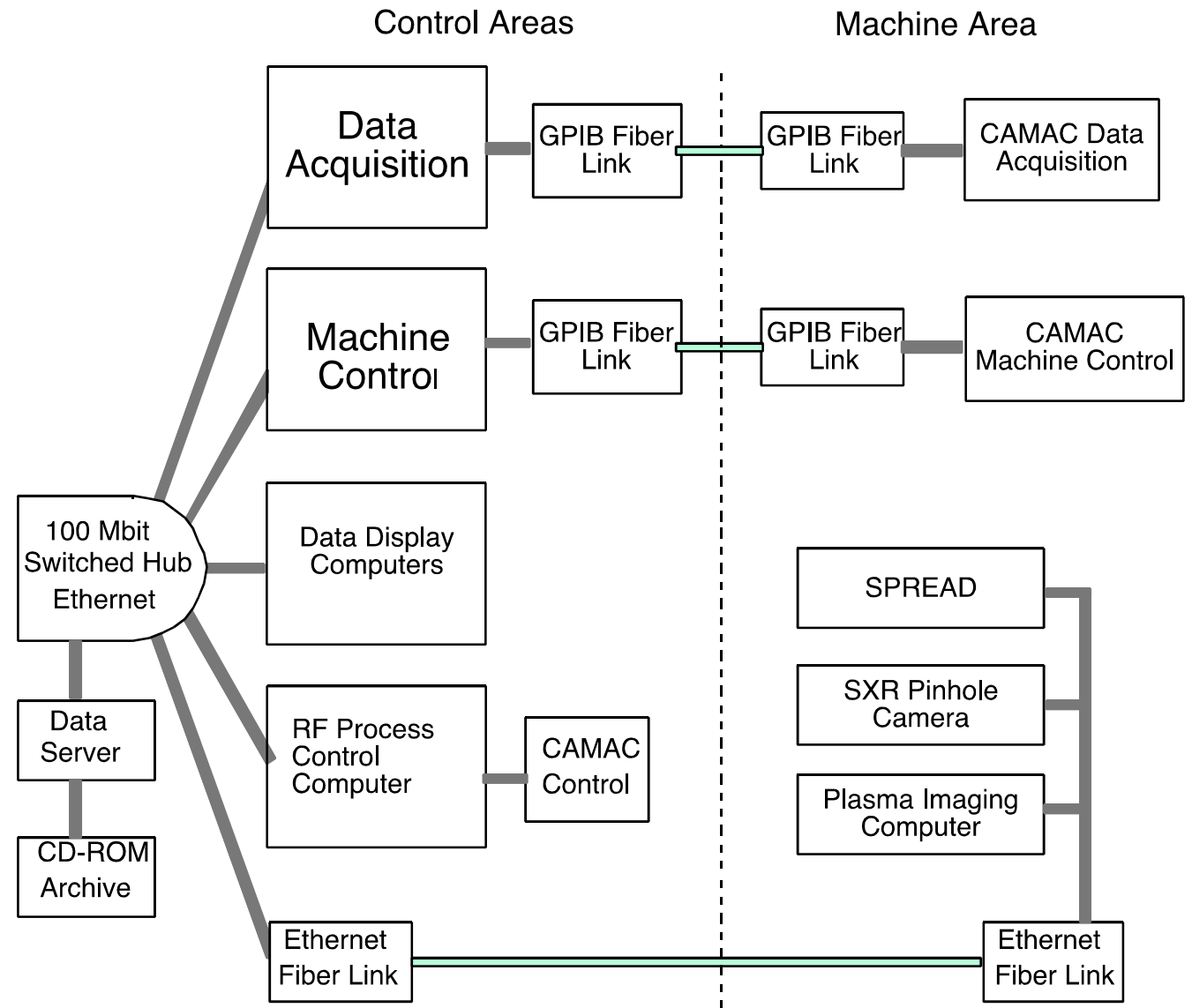
# Machine Vacuum Vessel Port Allocation





# Installed New Distributed GPIB Based Data Acquisition System

- *Modular design improves flexibility and reliability*
- *Improved throughput for fast turnaround of critical diagnostics*
- *Control room operation of remote machine-based computer-controlled diagnostics*







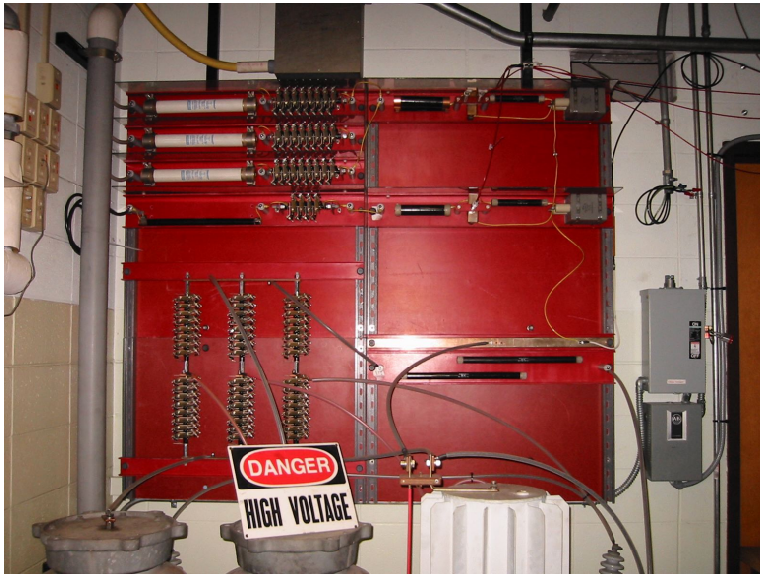
# NEW PEGASUS Control Room Built for Added Safety and Control



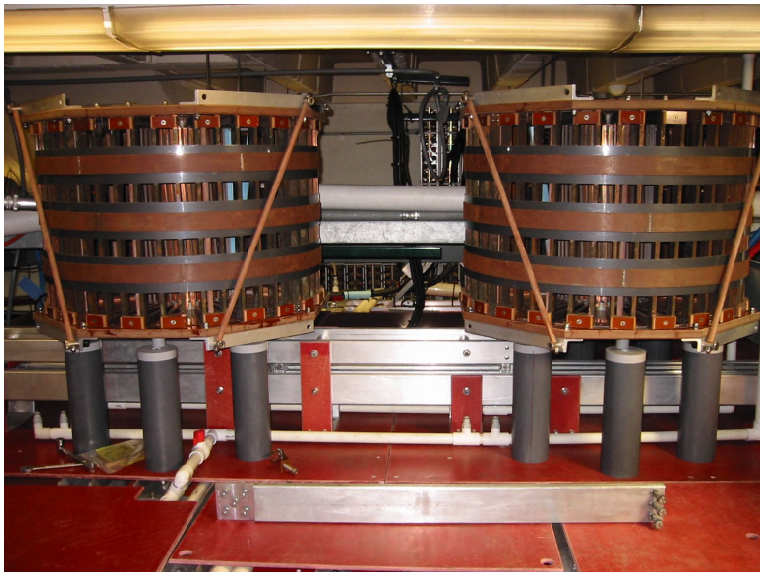




# Ohmic System Upgrades



100kW HV Charging System



High Current Ohmic Toroidal Inductors



Ohmic System Transformer



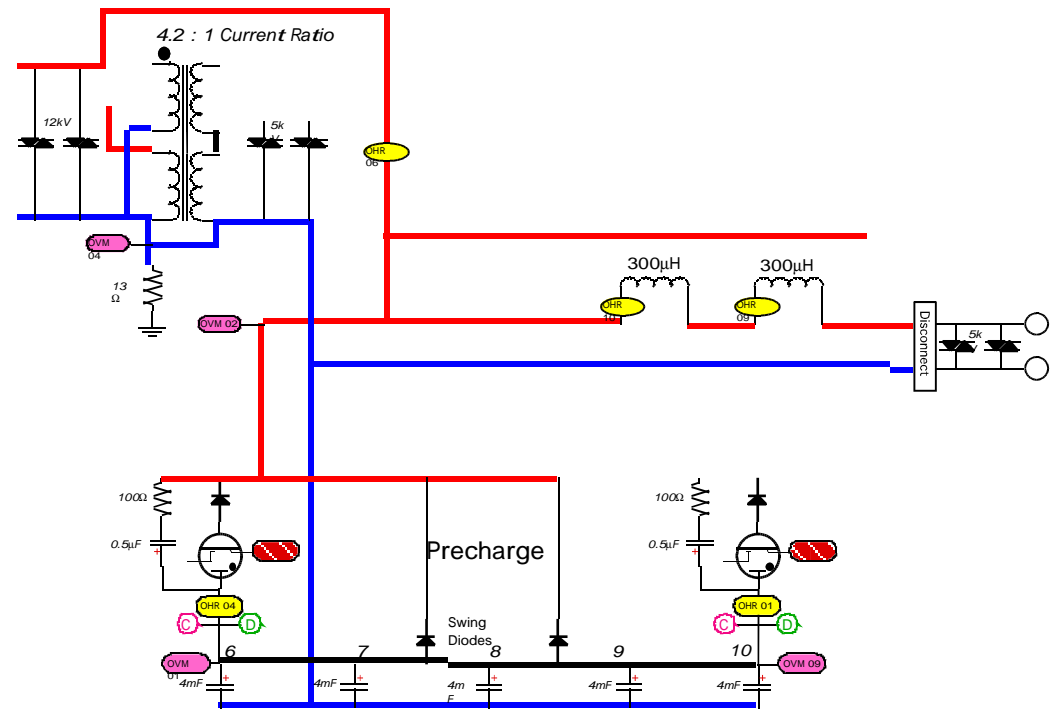
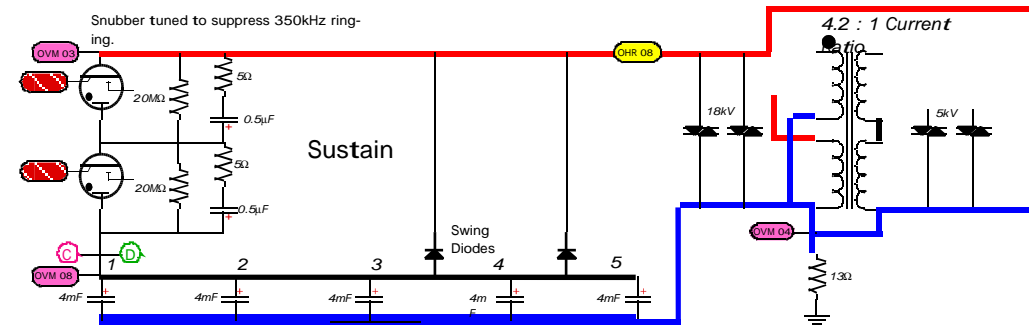
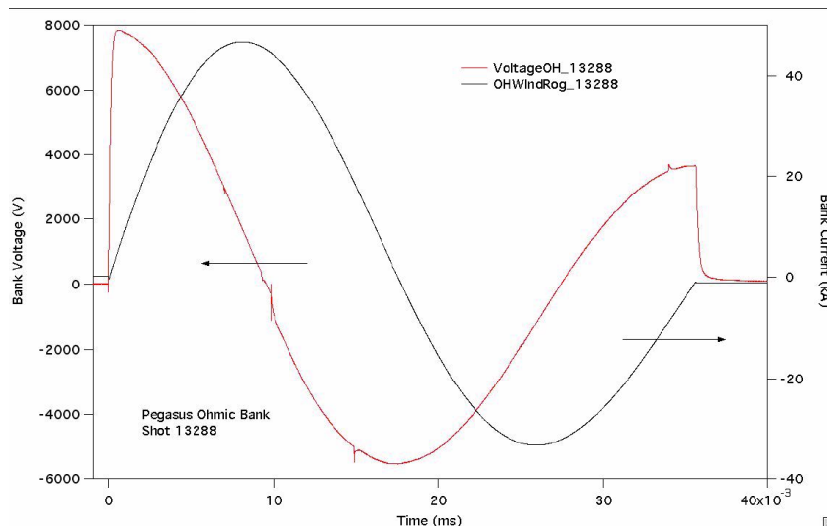
# Improved Ohmic Waveform Control Delivers More Volt-sec

## • Ohmic System Schematic

- *Parallel ignitron switching*
- *Swing through diodes*
- *Staggered ignitron firing provides reliable switching*

## • High Current System

- *300 $\mu$ H toroidal inductors operate up to 5kV-70kA*
- *Swing through diodes allow for a complete cycle.*







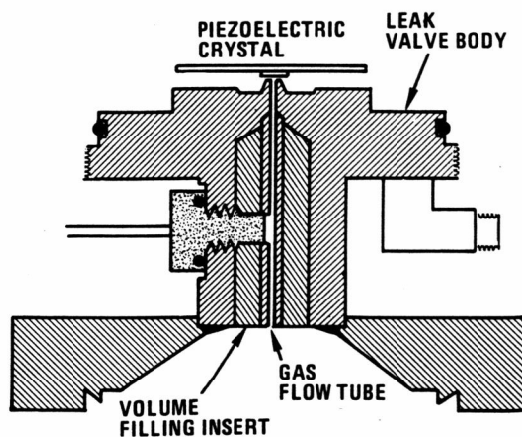
# New Machine Conditioning & Gas Control

- **Ti Getter System**

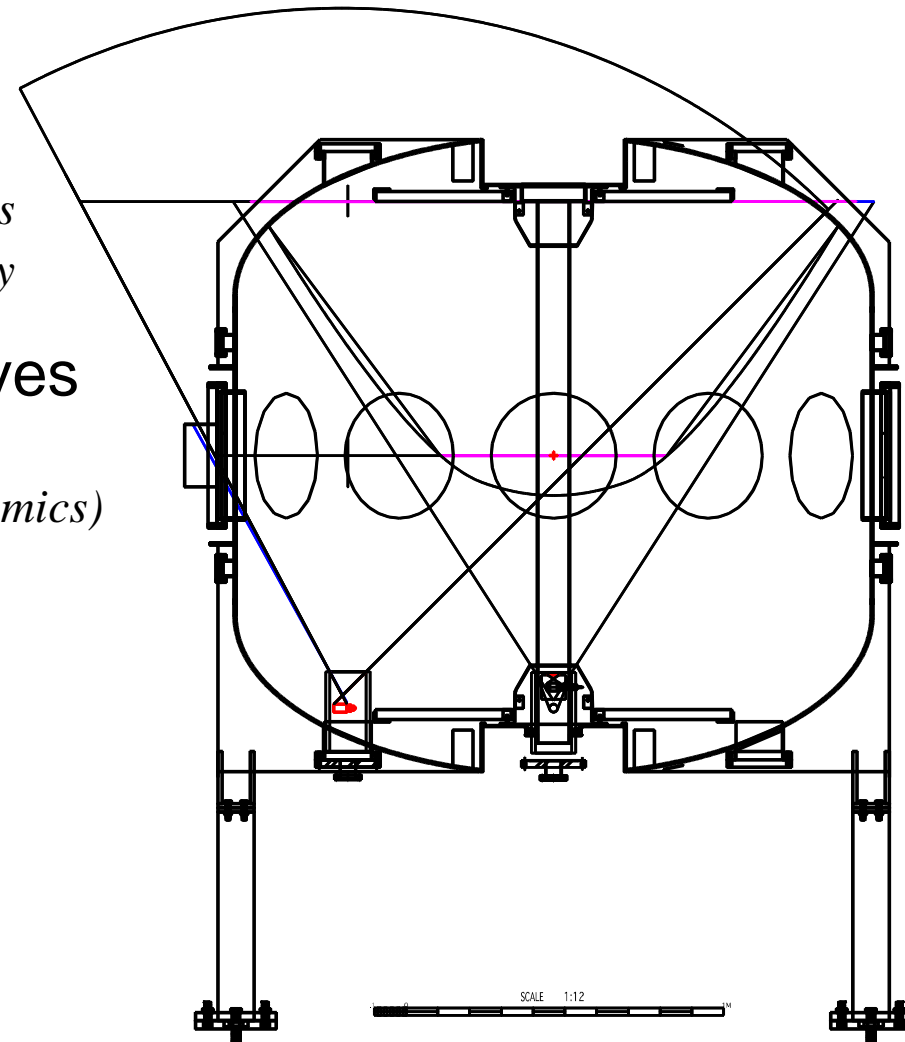
- *New multi-getter system in  $H_2O$  cooled jackets*
- *Getters plasma impact region without active shutters*
- *Allow between shot gettering for shot reproducibility*

- **Capillary Tube Piezo-Electric Gas Valves**

- *Significantly increased gas throughput (50X)*
- *Reference S.C. Bates and K.H. Burrell (General Atomics) Rev. Sci. Instrum. 55 (6), 934 (1984)*



Gas Valve Example



Getter Spot Lights



# TF System Upgrades

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- Design

- *Provide High-TF for improved plasma startup and MHD control*
- *Rapid TF ramp down during shot to provide access to High- $\beta$ , Low- $Q$  regime*

- New TF Bundle

- *12 turn high current low inductance potted bundle in house*
- *Installation without venting machine*
- *Will allow access to high current ( $>400\text{kA}$ ) rod current - increased from present  $150\text{kA}$*
- *Low inductance will allow  $\sim 2\text{msec}$  current ramp down during shot*

- New TF Power Supply System

- *Simple commutated electrolytic capacitor bank*
- *Passive resistive crowbar for rapid current ramp down*
- *Modular design will maximize drive flexibility*

- Preliminary Tests at High Field - No Ramp Down

- *Use 2 -  $3\text{MVA}$  AC/DC converters to double applied voltage/current*
- *Rewire 60 turn coil for 12 turn operation*



# TF Power Supply Systems



- Present 3MVA AC/DC Inverters

- Installed 60 Turn TF bundle utilizes one 3MVA inverter for ~140kA rod current at 600V - no ramp capability
- Test to use two inverters in a push-pull arrangement to double applied voltage and current for installed TF bundle - no ramp capability
- Inverters supplied from 10MVA 480V line



- TF Capacitor Bank Modules

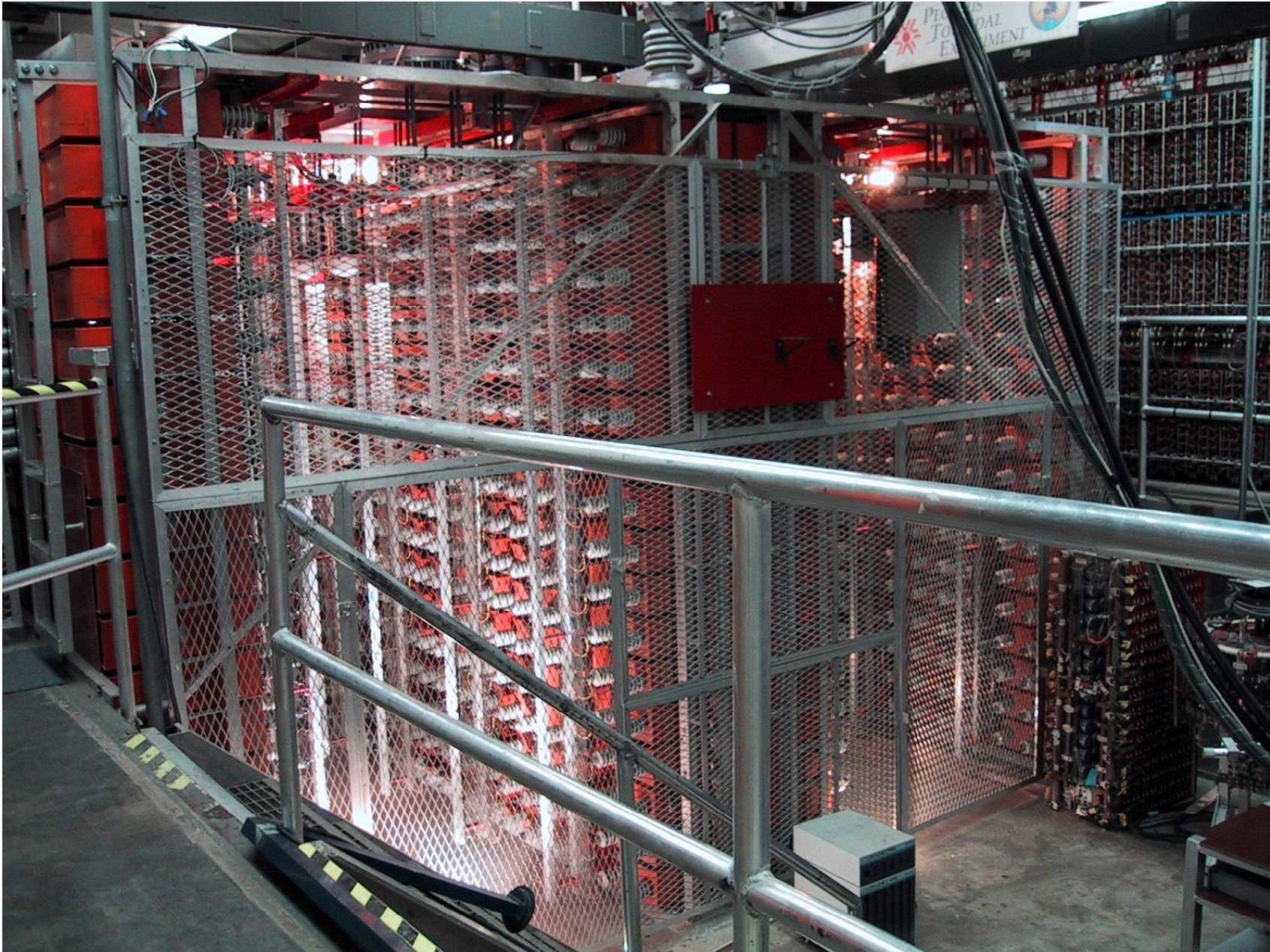
- 72 modules comprised of 40mF @ 450V
- Can be added in parallel/series to vary voltages and/or capacitance.
- Allow for rod currents of >400kA
- Simple SCR commutation and passive resistive crowbar for ramp down capability
- LLNL donated surplus capacitors for this power supply







# Ohmic Power Supply





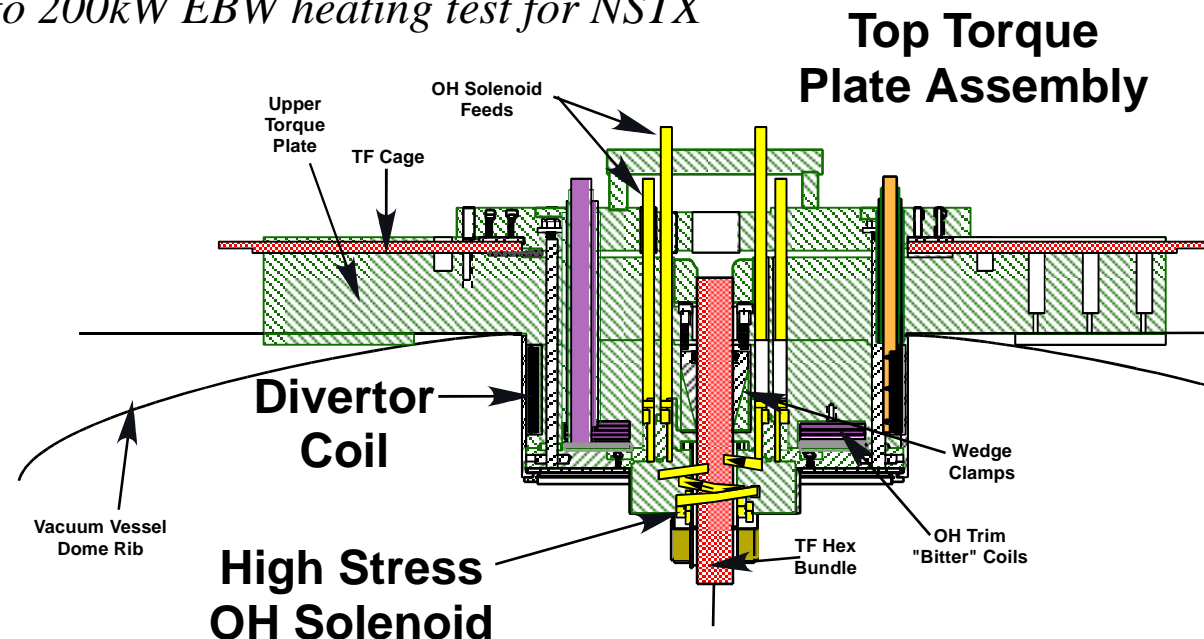


# Proposed Future Upgrades

- **Activate Divertor Coils**
  - *Control of edge MHD through sheer modification*
  - *Possible access to H-mode*
- **Increased Volt-sec from High Stress Solenoid**
  - *Install tappable shielded inductor(s) in OH system*
  - *Enhanced solinoid cooling capability with new TF bundle installation*
- **EBW/ECH Systems**
  - *10kW non-inductive startup experiment - installed*
  - *Proposed expansion to 200kW EBW heating test for NSTX*



10kW 2.45GHz RF Source





# Summary of PEGASUS Facility Activities

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- Upgrades to Machine and Facility

- *New internal armor and diagnostic hardware*
- *New data acquisition and control systems*
- *New PEGASUS control room for safety*
- *Improved conditioning with the use of Spot-Light getter system*
- *Increased gas feed throughput with capillary piezo-electric gas valves*

- Upgrades to Power Systems

- *Increased Ohmic heating capability with the use of high current toroidal inductors and an impedance matching 4:1 high current transformer*
- *Improved Ohmic waveform control with the use of high current swing-through diodes*
- *Preliminary testing of improved TF rod current with no ramp down capability.*

- Future and Proposed Upgrades

- *Future TF to allow for greatly increased rod current with added ramp down capability.*
- *ECH/EBW experiment to study non-inductive current drive/startup*
- *Activate divertor coils*





# Reprints - PEGASUS Facility

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# RF Power Supplies

