SAND2006-5577C

The Z Refurbishment (ZR) Project at Sandia National Laboratories*

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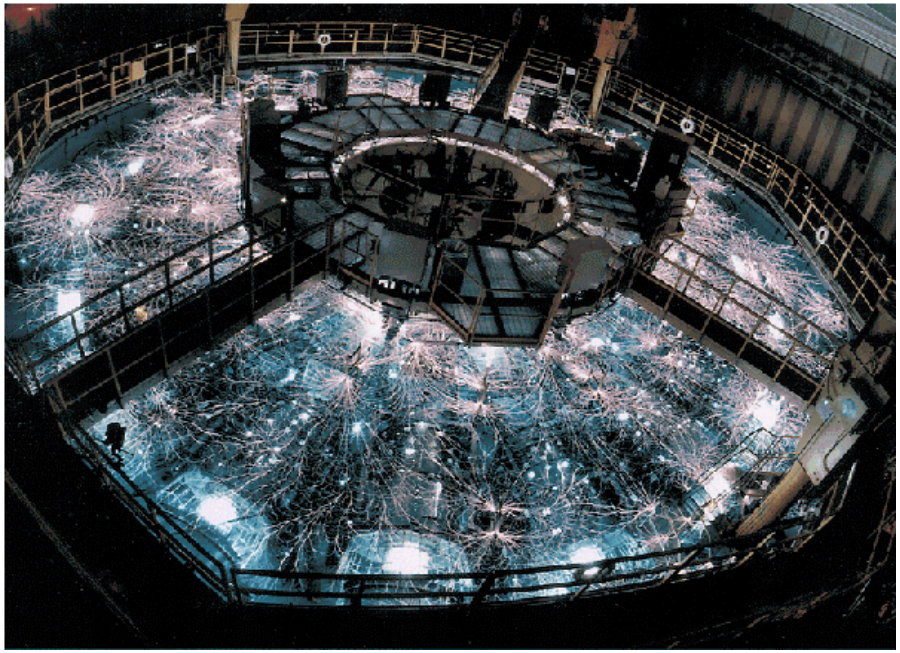
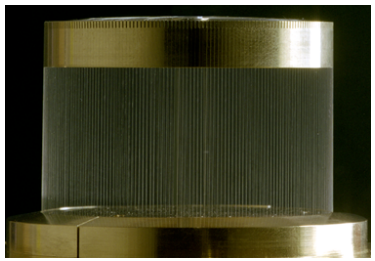
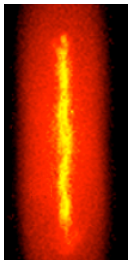
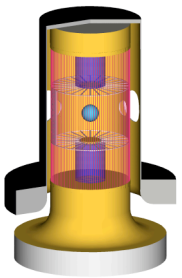
*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

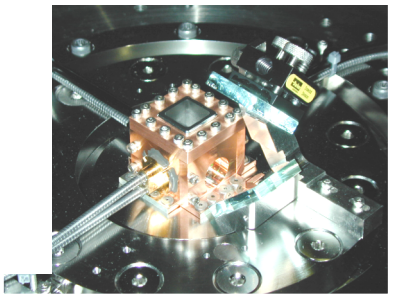
Z has been a very productive facility for Z-Pinch Physics, Radiation Science, ICF, and Equation of State in it's ten year life time



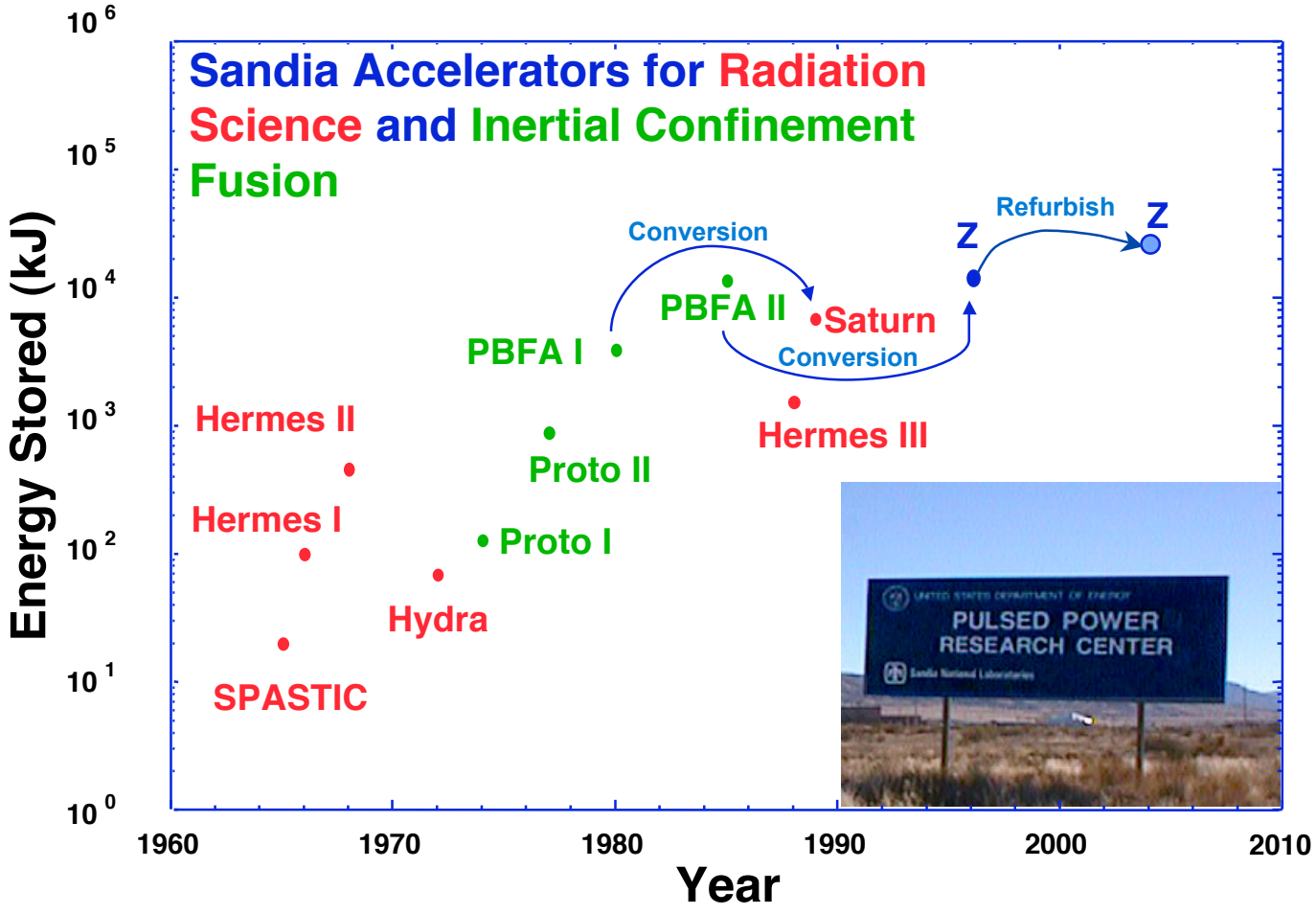








Sandia has a forty year history of successfully building and converting pulsed power facilities



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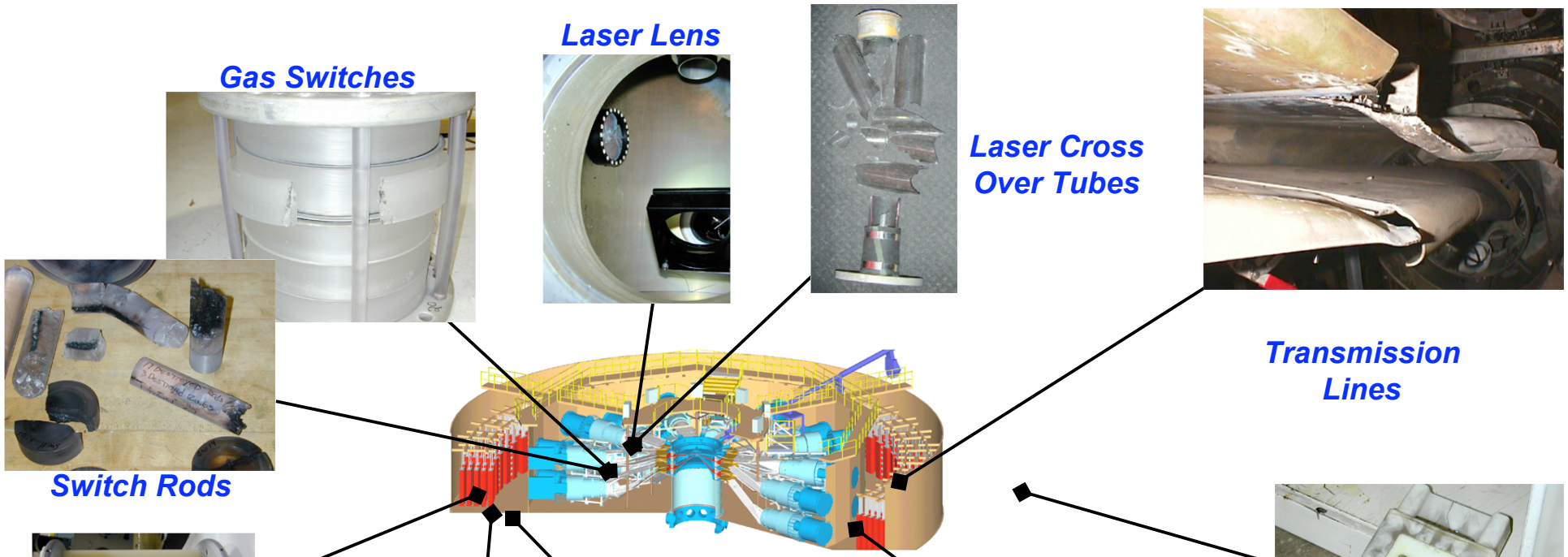
The Challenge for *ZR* is to Meet Diverse Requirements

- ✓ **Increased capacity needed to meet programmatic requirements**
  - ➢ ***ZR*** *operating double - shift will enable 400 shots per year (~ 240 limit today – 2 standard shifts)*
- ✓ **Increased precision/flexibility requested by users**
  - ➢ ***ZR*** *will improve yearly load current reproducibility (~5% now → 2% after)*
  - ➢ ***ZR*** *will improve short term z-pinch reproducibility (~3% now → 1% after)*
  - ➢ ***ZR*** *will provide tailored pulse shaping for materials property programs*
- ✓ **Enhanced capability will increase scientific scope**
  - ➢ ***ZR*** *will provide higher temperatures, x-ray power, x-ray energy, and magnetic pressures for the HEDP community via higher current (18 MA now → 26 MA after)*

Continued availability of ***Z*** is required for Sandia to meet its mission commitments.

ZR *will extend the useful life of* ***Z*** *to beyond 2010.*

Aging Z Required Constant Repair



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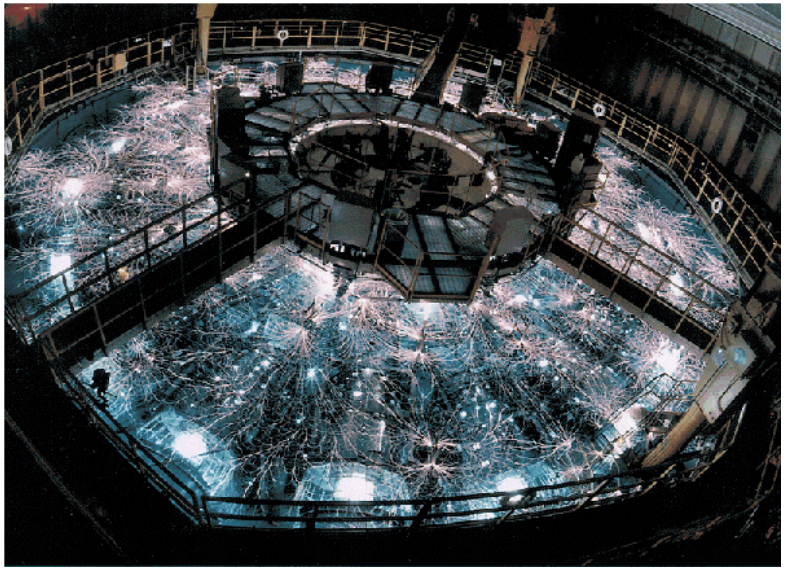
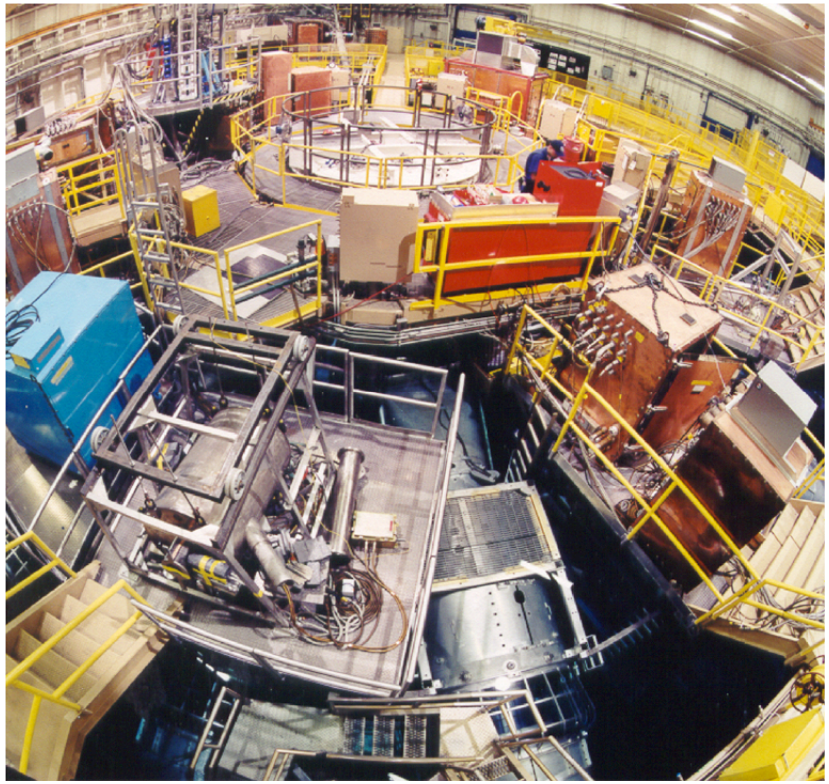
Diagnostics Infrastructure Has Become Congested

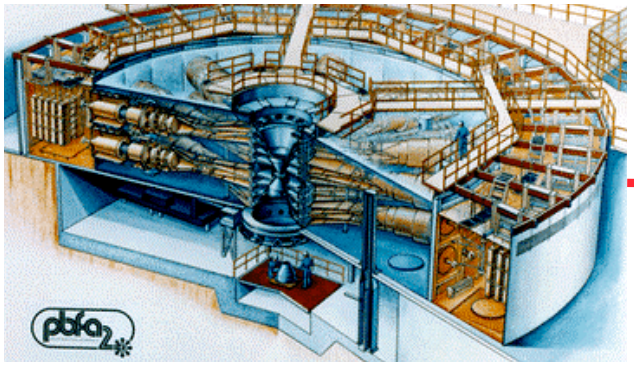
Unobstructed Top of PBFA II ~1985



Top of Z Cluttered Today

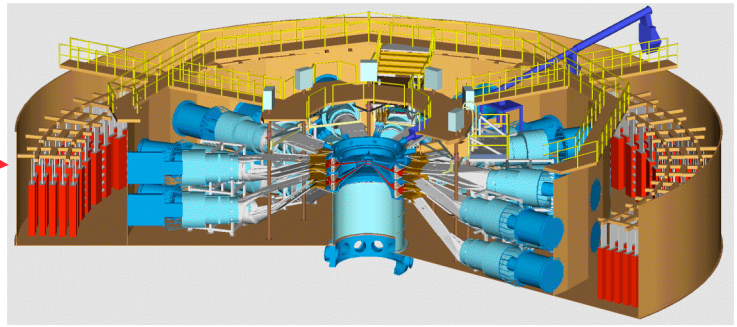


Z evolved from PBFA II. The components are twenty one years old in 2006



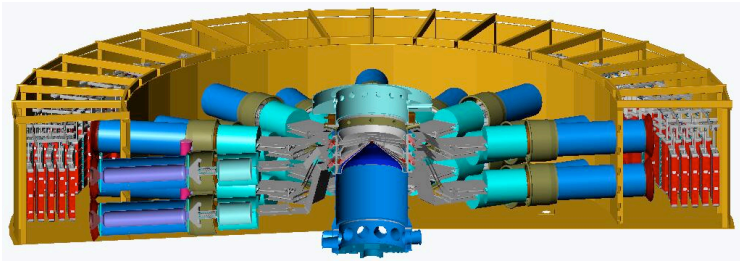
1985 - PBFA II

PBFA-Z Project



1996 - Center Conversion to Z

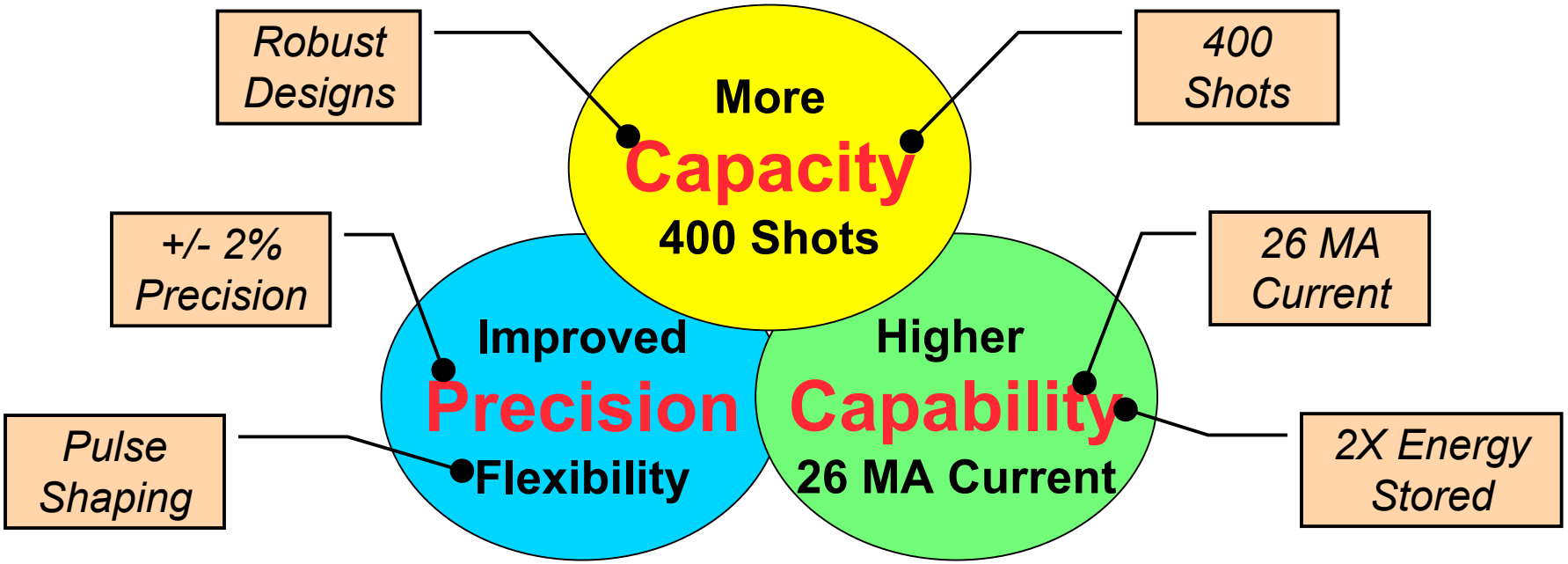
ZR Project



2006 - Z Refurbished

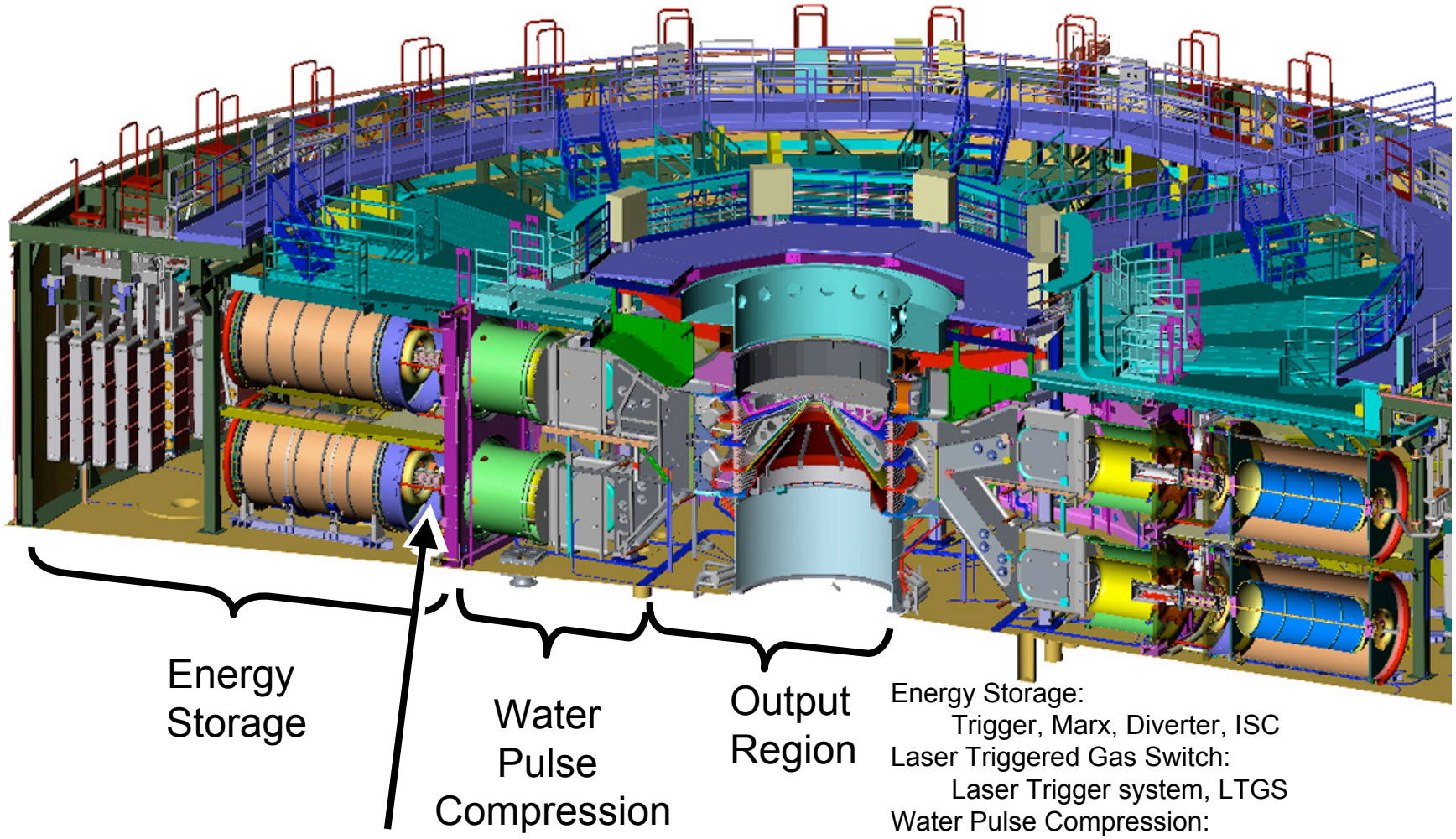
Sandia's approach to *ZR* is Balanced

Achieve a useful balance between



with minimum impact to ongoing experimental programs.

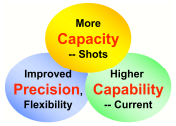
Z-Refurbishment Pulsed Power subsystems

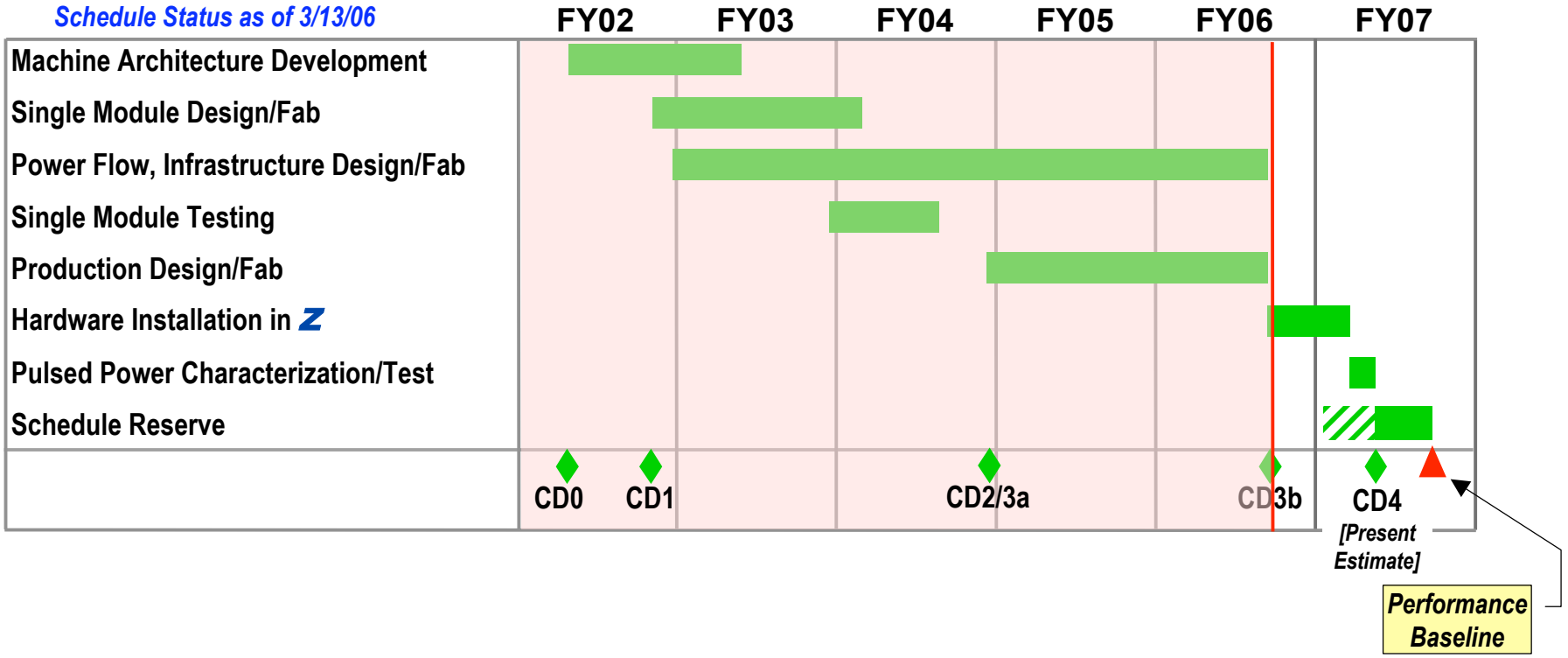


Energy Storage:
Trigger, Marx, Diverter, ISC
Laser Triggered Gas Switch:
Laser Trigger system, LTGS
Water Pulse Compression:
PFL, Main switches, OTL1, Peak switches, OTL2, merge
Output Region:
Water convolute, Vacuum Interface, MITLs

Project Summary

Project Description: Refurbish *Z*'s energy storage, pulse forming, and vacuum power flow systems, providing more shot capacity, improved precision and pulse shape flexibility, and higher current capability, with minimum interruption to *Z*'s experimental community.





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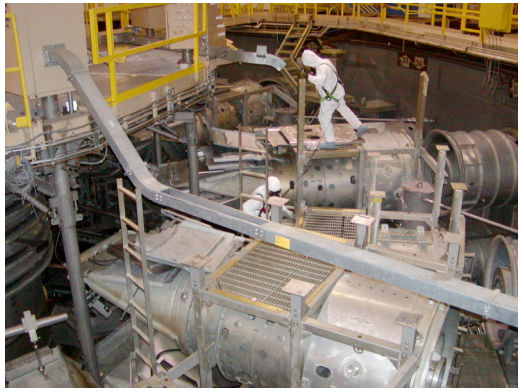
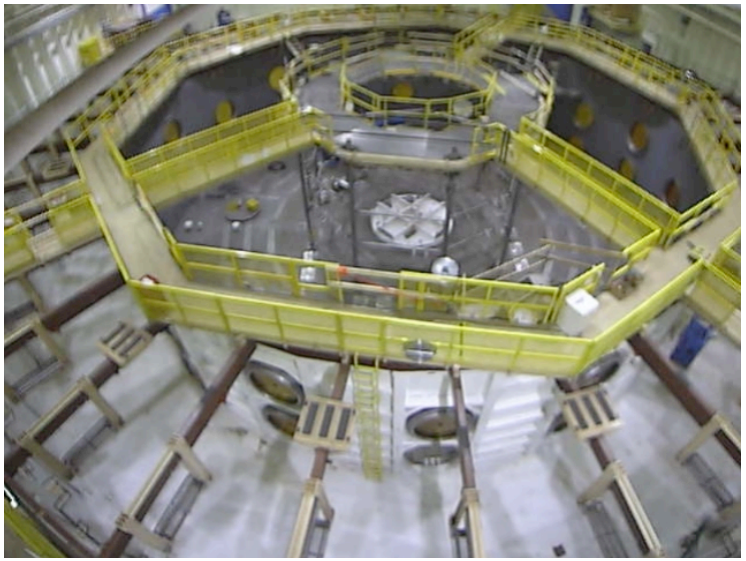
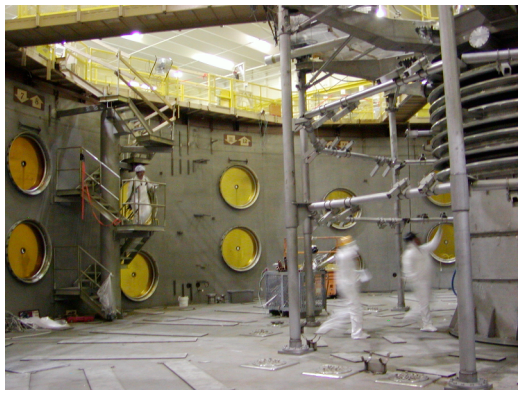
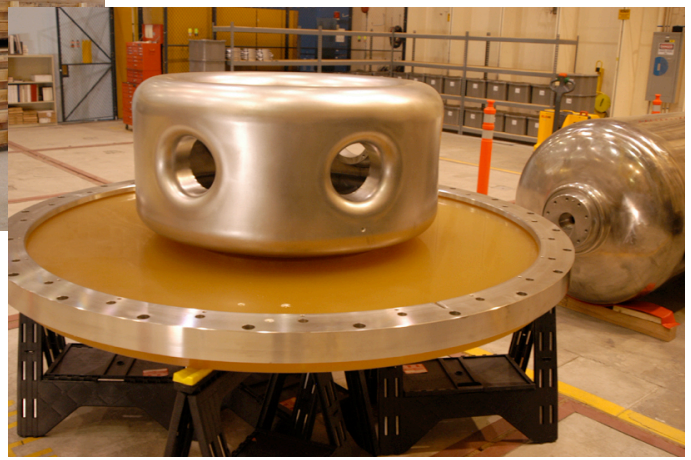
The Z facility has been disassembled



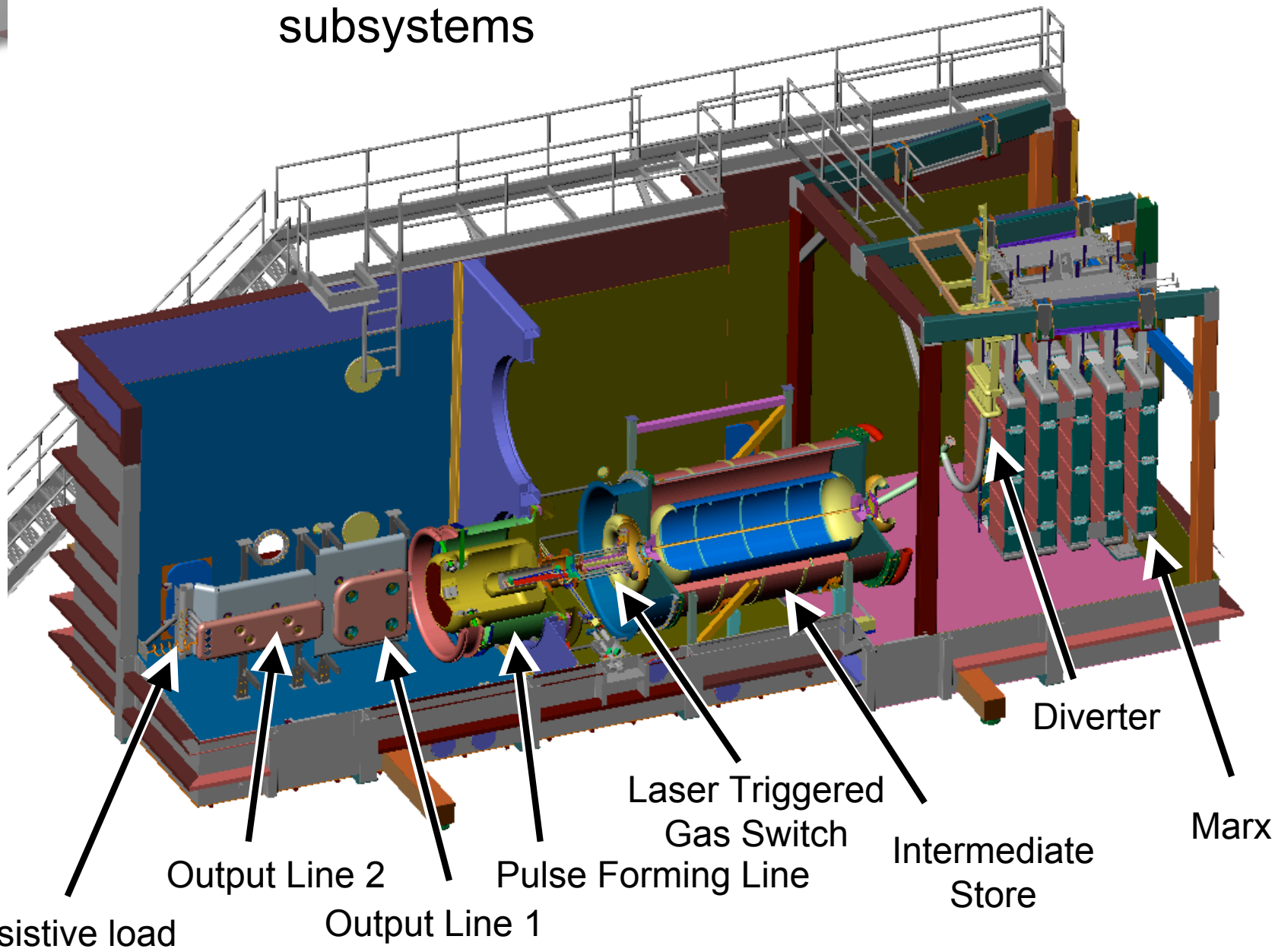




Construction of ZR components is underway



Z-20 demonstrates the core ZR Pulsed Power subsystems



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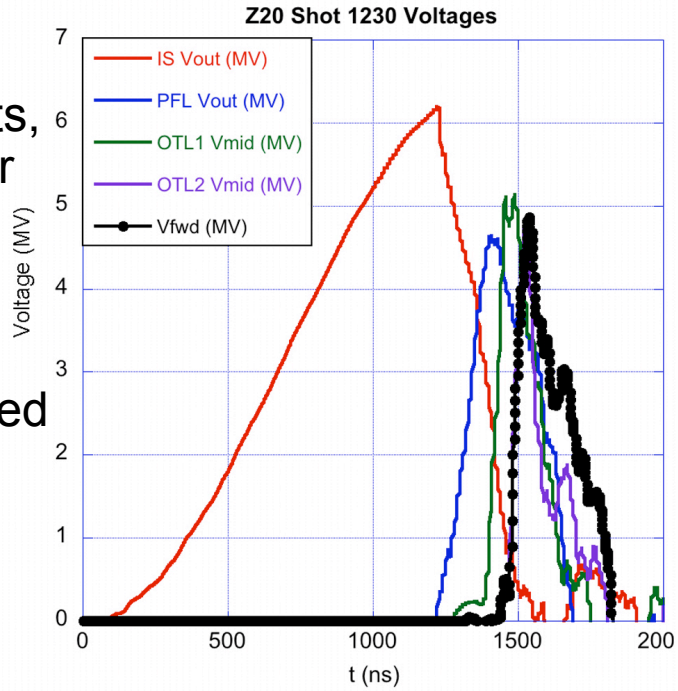
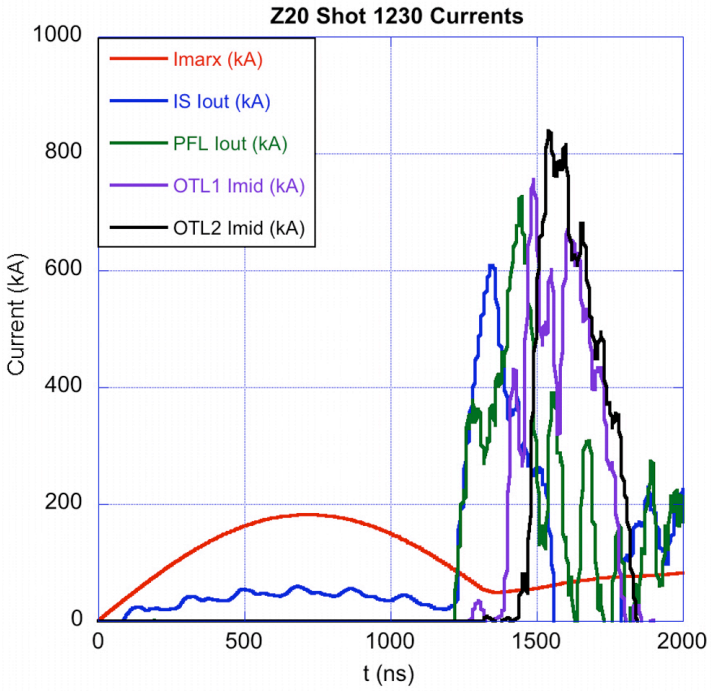
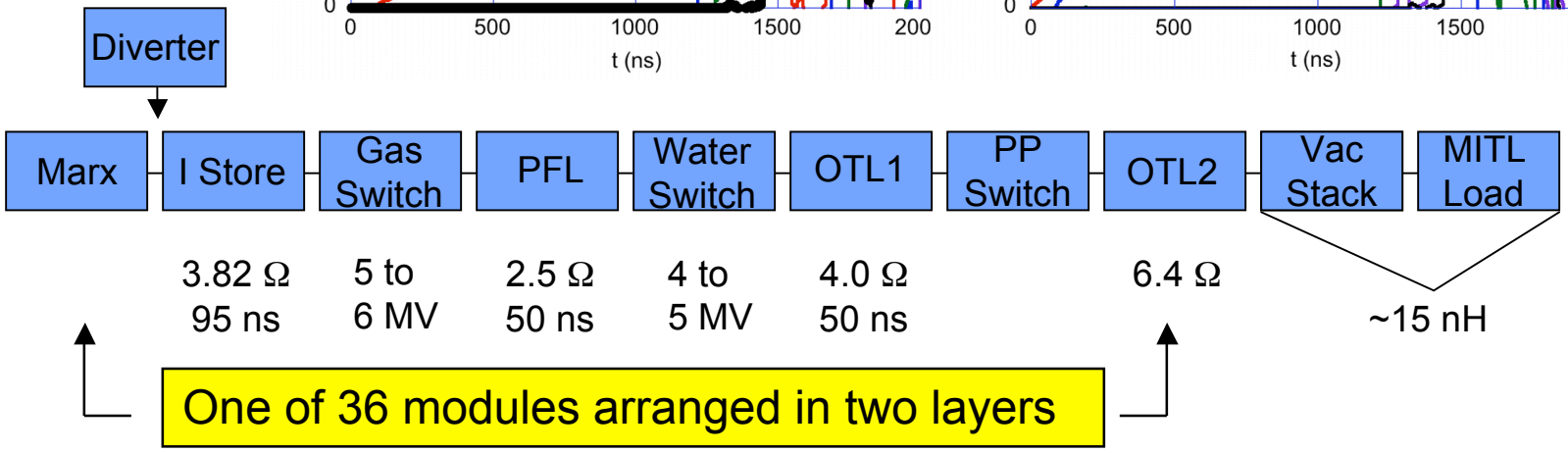
ZR power compression process is a four step process

- Standard pulsed power components, just used at higher levels
- Performance observed in Z_{20} matches anticipated waveforms







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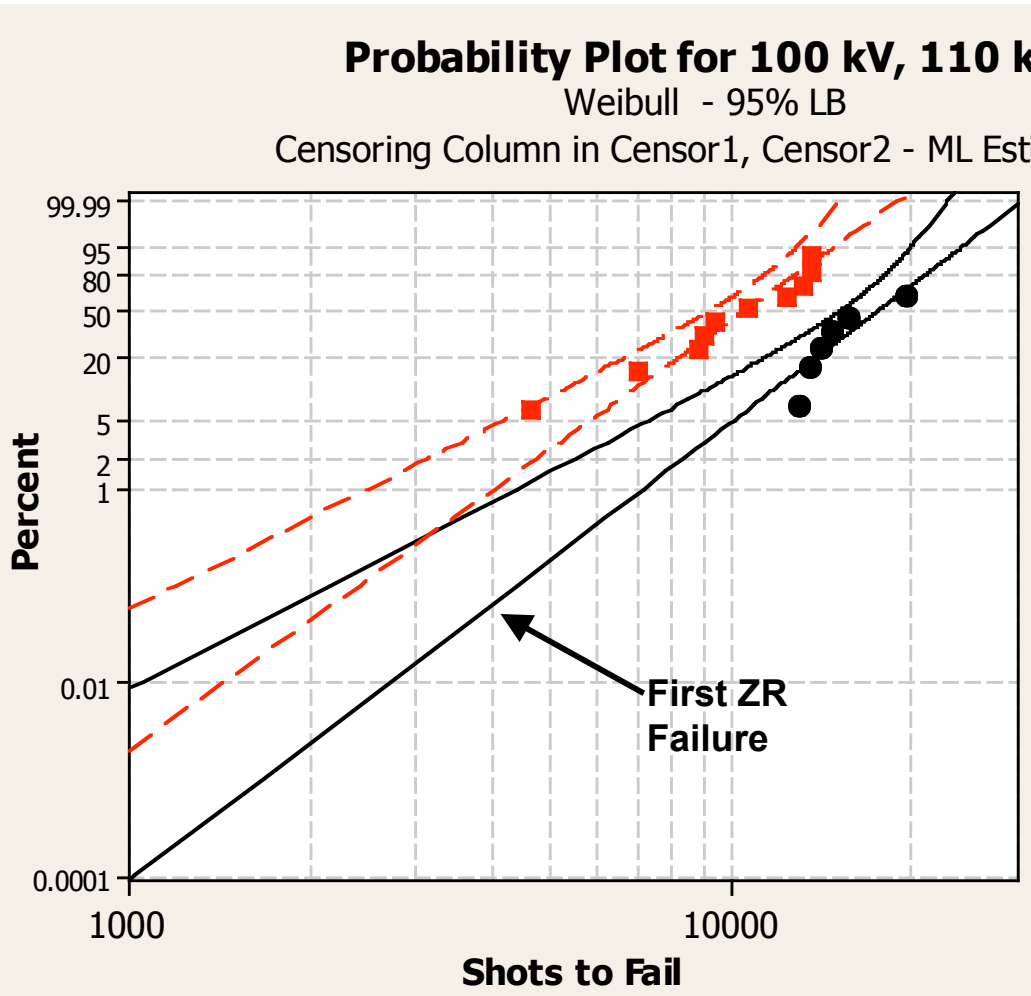
Comparison of 100-kV and 110-kV Capacitor lifetime data emphasizes the voltage dependence.



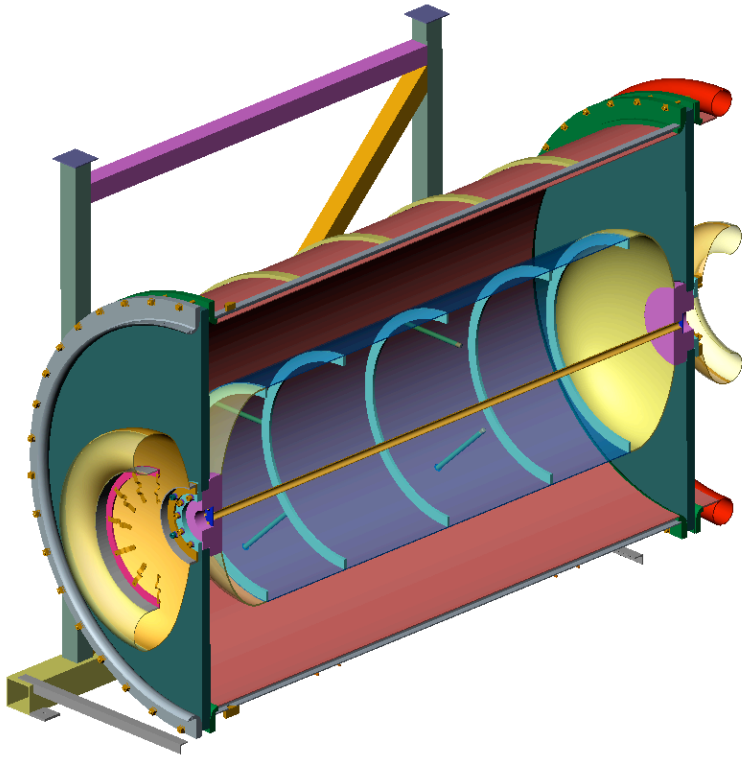
Selected Sorrento/GA over TPC/AVX, ICAR, Trench Ltd, and CSI Tech.

Projecting down the 100-kV fitted curve, the first lifetime dielectric failure for a ZR size population will occur at about 4,000 shots.

At a charge voltage of 90 kV and four hundred experiments/year we do not expect first capacitor failure for 21 years

Intermediate storage capacitor is very robust

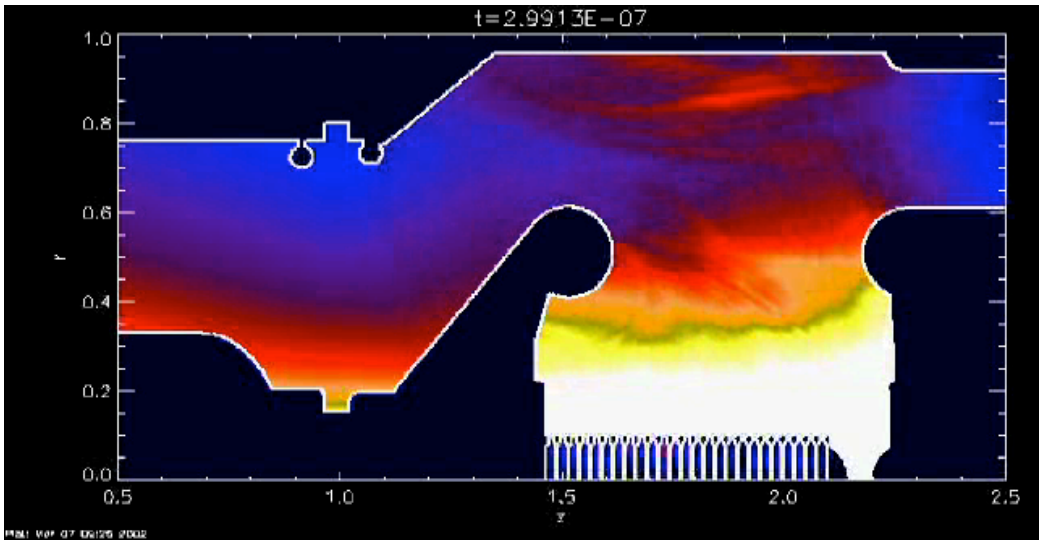
- Very robust design based on extensive experience with cousins
- Only observed failure was due to fabrication processes
- Tested internal arc response by spiking an earlier version - a 15” spike was needed - and no significant damage was observed
- Internal gas line to allow SF_6 flow through the LTGS



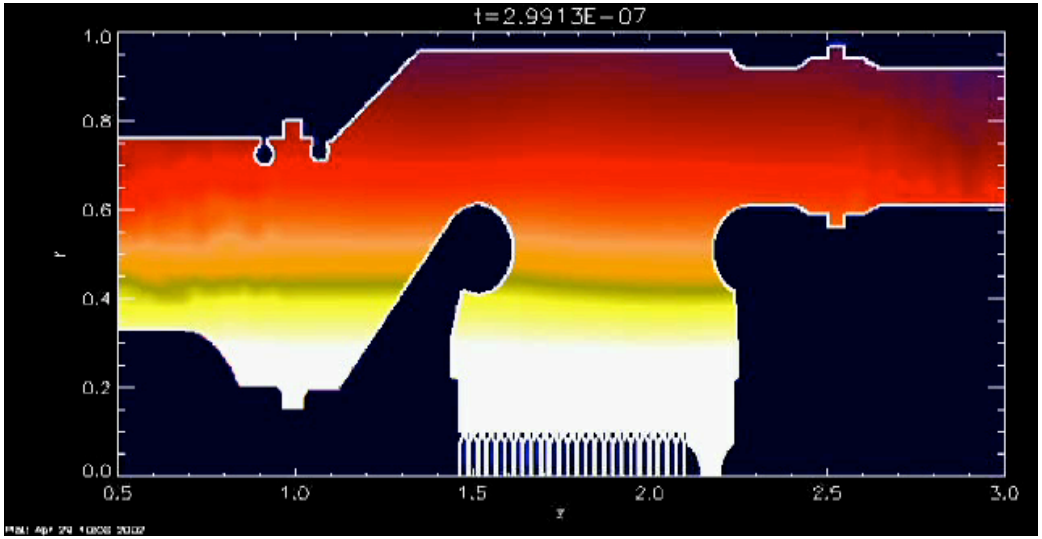
The IS has been charged to 6.5+MV without any breakdown

2-D QuickSliver code is being used to analyze the operation of the Intermediate Store Gas Switch

Plot of B_θ fields when 6 MV Intermediate Store Gas Switch under water dielectric fires



Plot of B_θ fields when 6 MV Intermediate Store Gas Switch under oil dielectric fires



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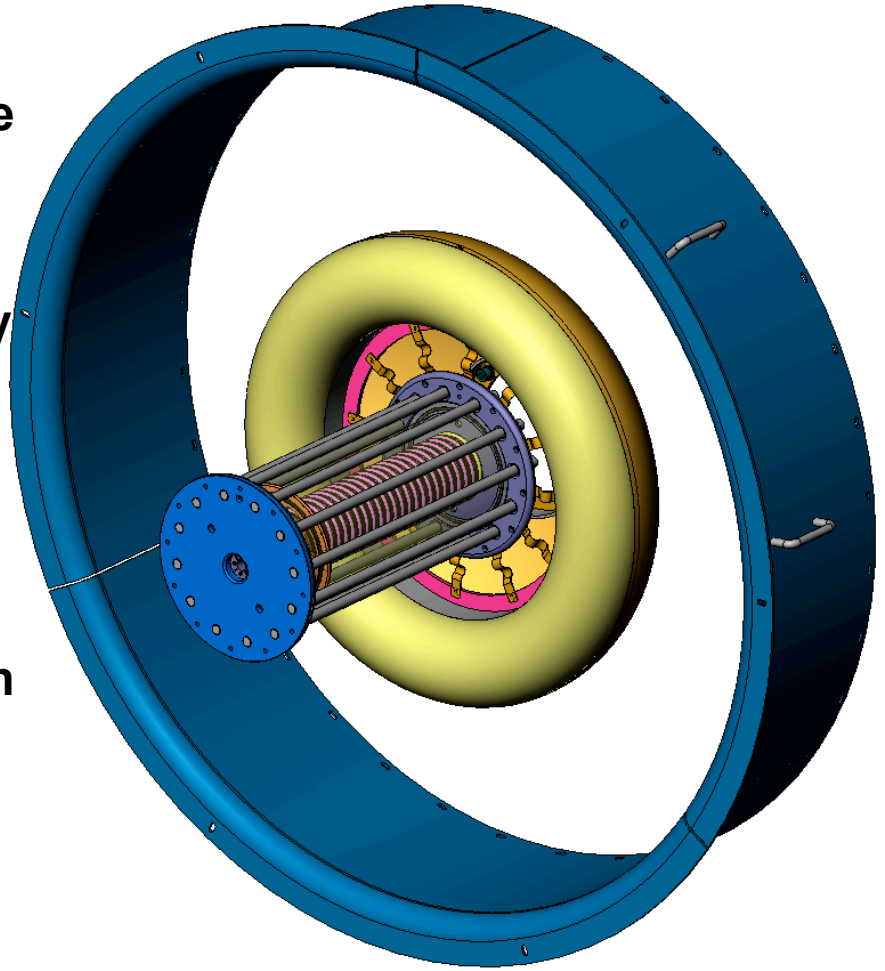
Laser Triggered Gas Switch

- 6-MV (or more) required for 26 MA
- Developing an understanding of the fault modes
- Do not expect the Initial Operating Condition version to meet reliability expectations
- Investigating alternative designs to provide desired performance and lifetimes
- Phased improvements to ZR remain reasonable extrapolations



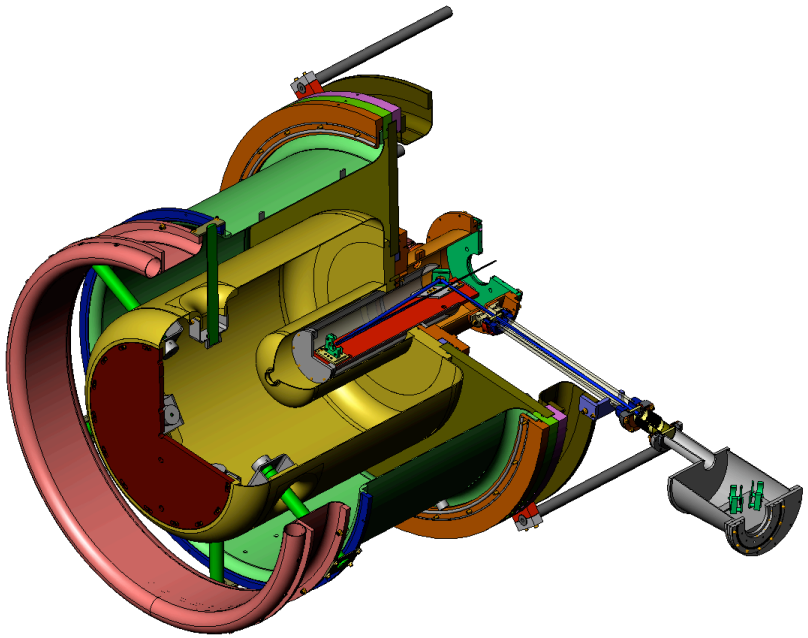
More information on LTGS

Progress in Laser Triggered Gas Switching
Presented by
John Maenchen

Wed-O 01

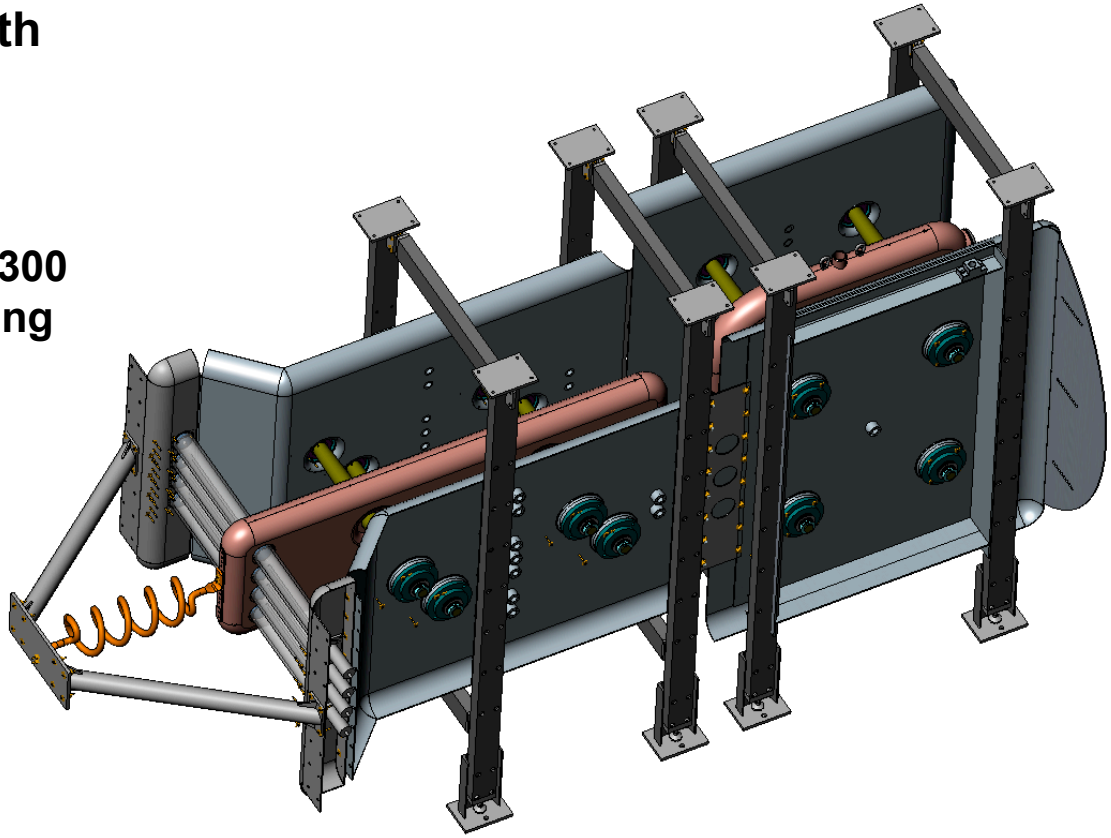
Pulse Forming Line

- ZR design has evolved beyond the version under test on Z-20
  - ZR will avoid the PFL support posts across the stressed water, instead using a 4” cantilever barrier and possibly supports across the oil
- Incorporates the laser trigger system
  - cross-over tube (and LTGS gas feeds)
  - cassegrainian telescope
- New abrupt transition: coax-to-linear triple water switch array
- Water switches were derived from extensive studies on a predecessor test bed

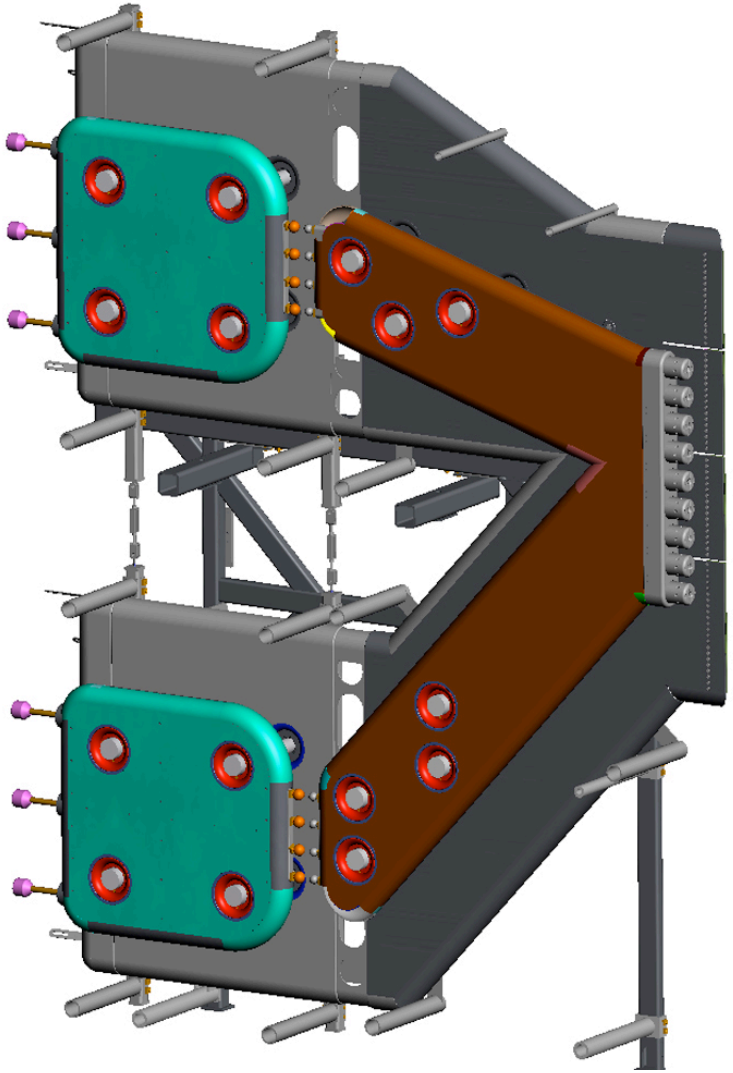


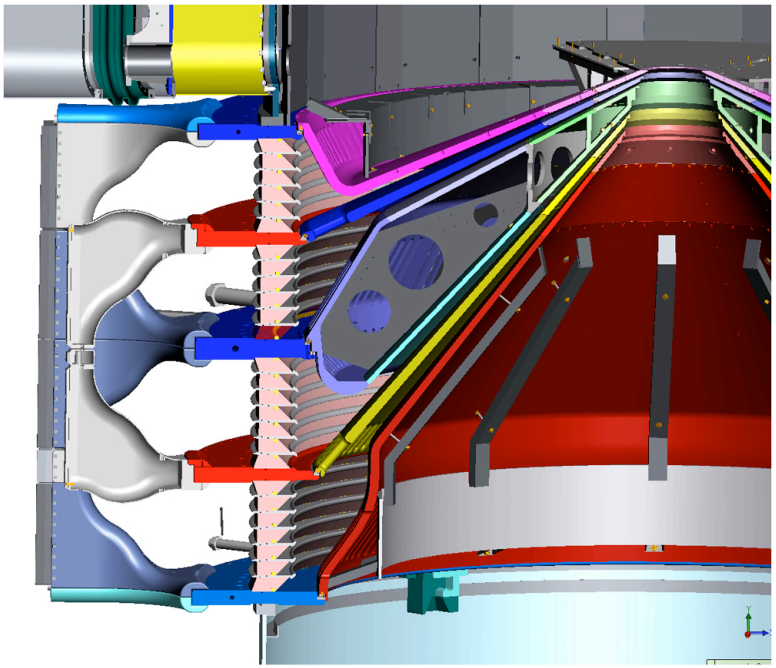
Output Lines are also a step transformer system

- Impedance transformers with pulse shaping
- Novel support post design
  - one support rod failure in 1300 shots, with fully open peaking gaps, generating 6-MV
- Z-20 is terminated in a resistive load.
  - Full voltage flashes the resistors, so typically undermatched, creating a significant reflected wave
- Performance matches prediction



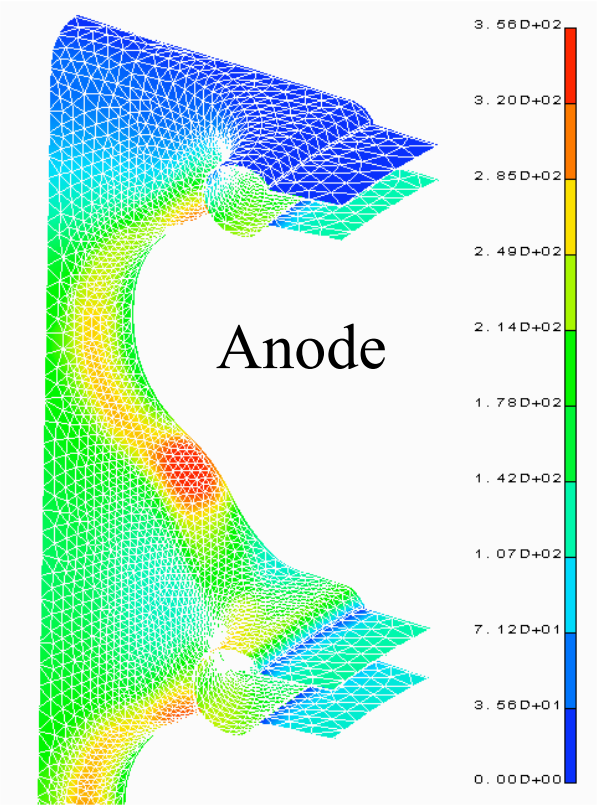
Untested components: OTL-2 junction, water convolute, vacuum stack, and MITLs



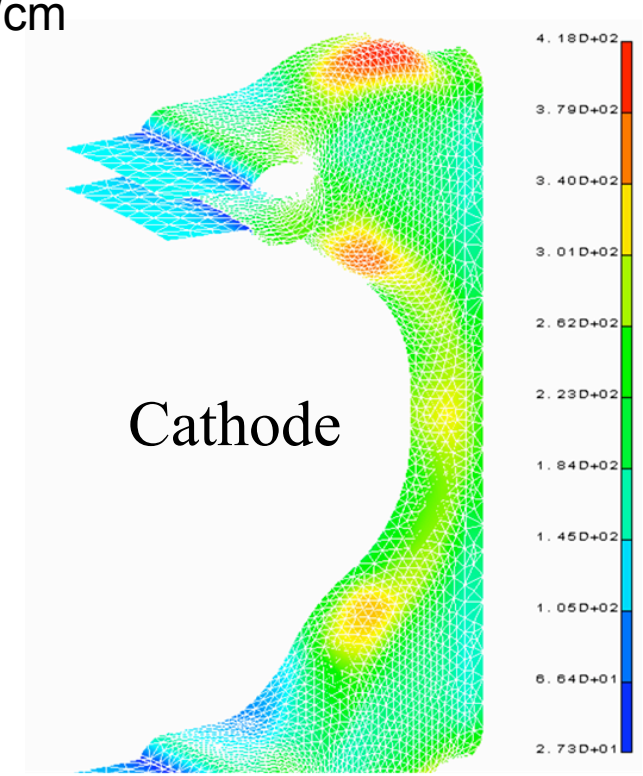


Fields have been calculated in the convolute

- **Fields with 6 MV applied voltage**



420 kV/cm



504 kV/cm

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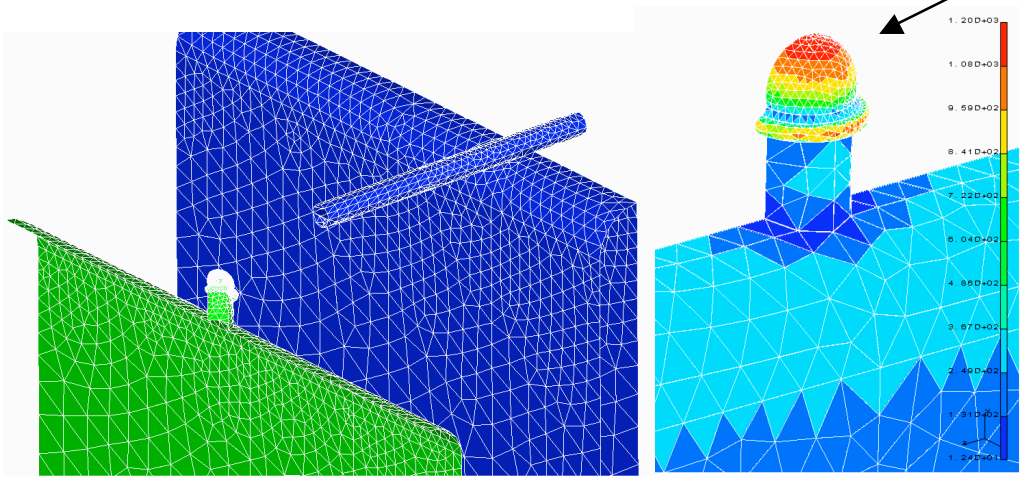
Tests were done on Z-20 to test breakdown at significantly higher fields than will be present in ZR

- **No effect on the output power, but some occasional late-time closure at high fields**

1.2 MV/cm



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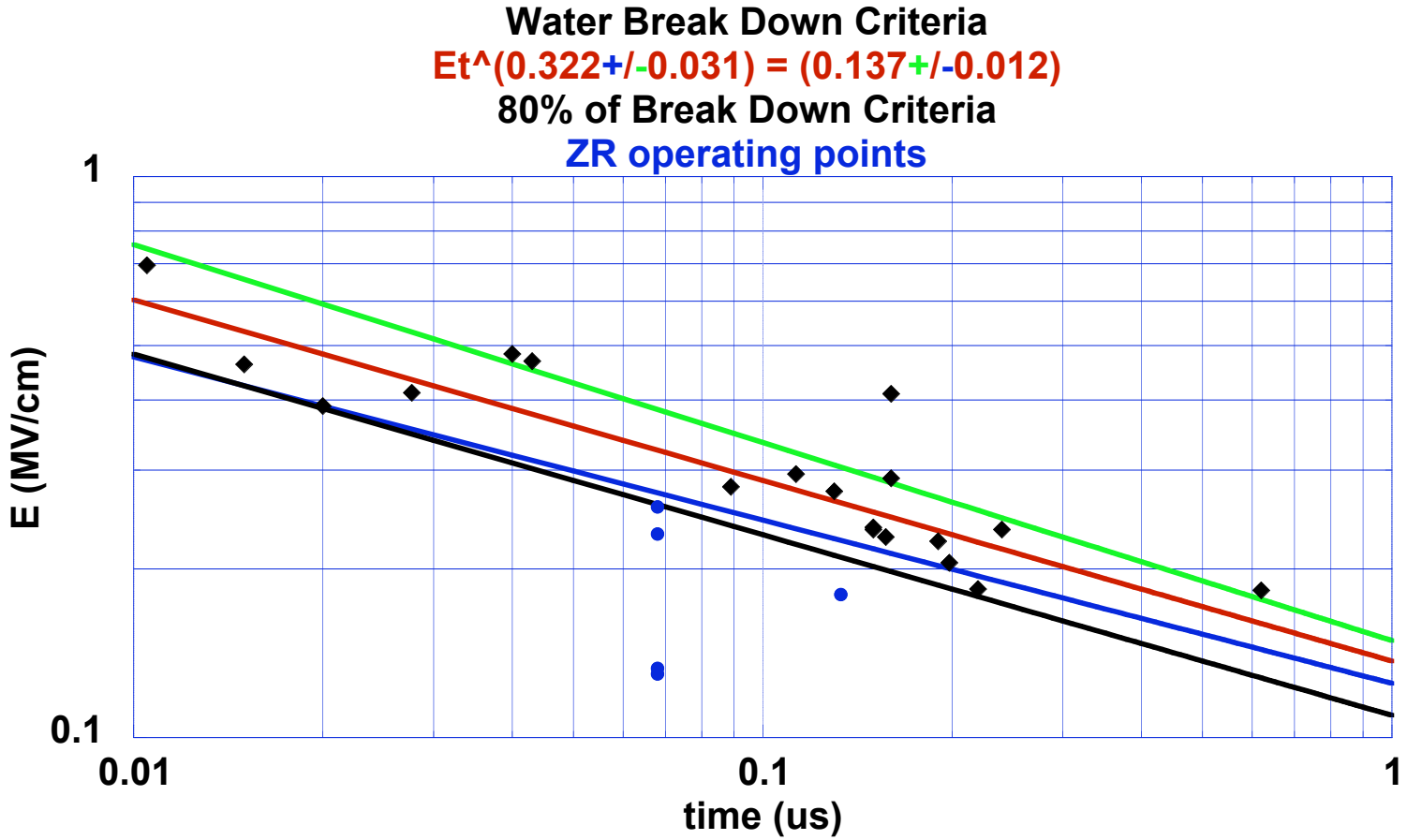
Point-plane breakdown describes large-area water breakdown

- **Bill Stygar's analysis shows no breakdowns below 80% for a wide range of times**

$$Et^{.322\pm.031} = 0.137 \pm 0.012$$



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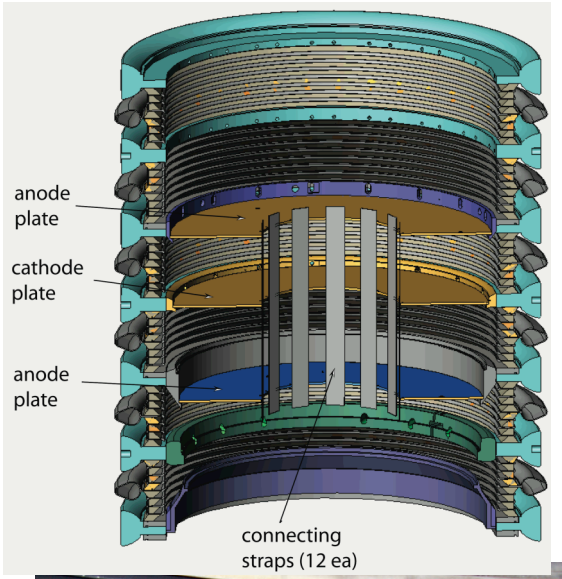
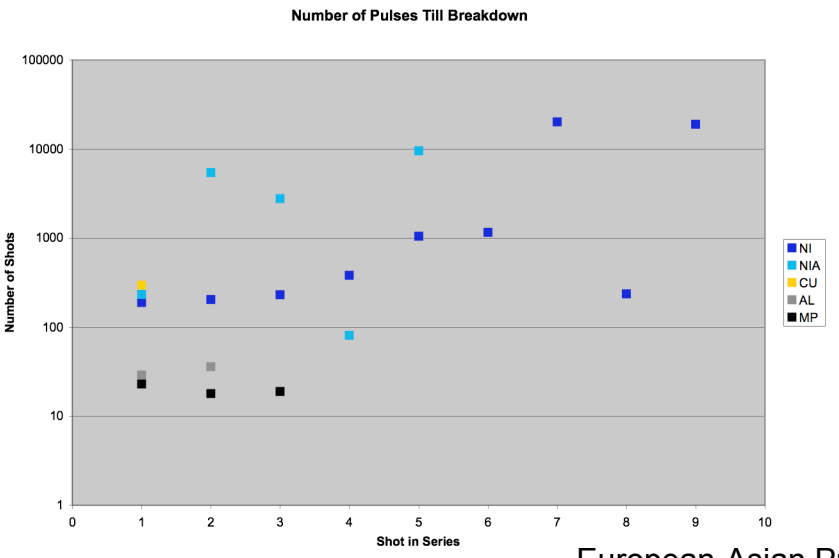
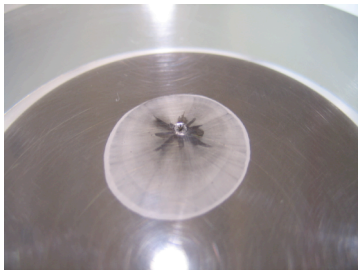
Flashover and bulk breakdown have been tested extensively

- **Flashover- *MiniZ* and *Saturn***
  - **Shown that the anode plug is robust and does not cause bulk breakdown**
  - **Anode plugs are still in Saturn**
- **Bulk breakdown- *Insulator tester***
  - **Shown that conductive polymer increases life compared to metal**







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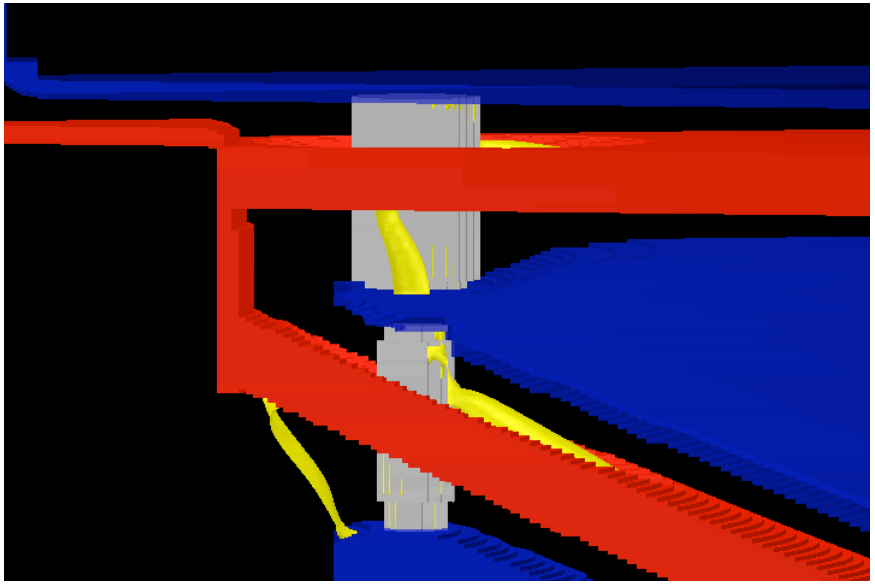
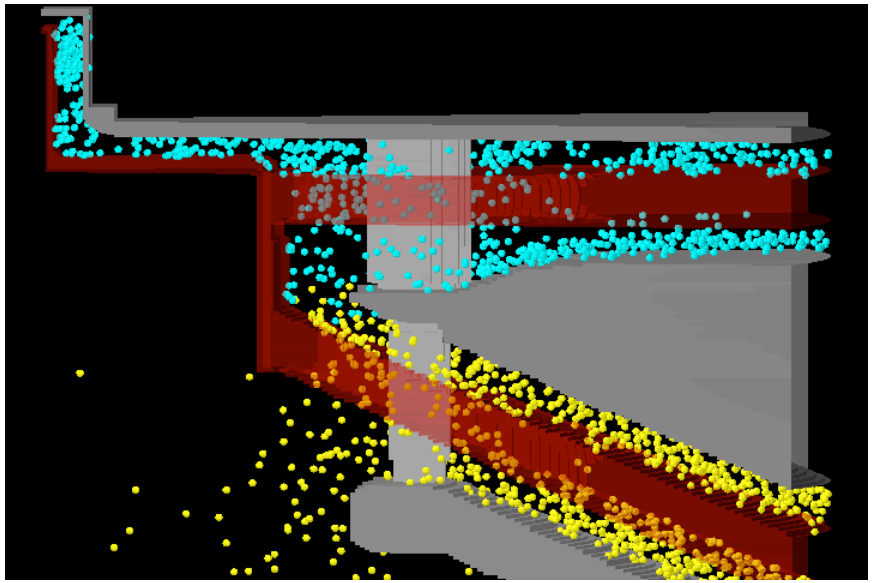
3-D QuickSliver PIC being used to model and design the double-post-hole-convolute

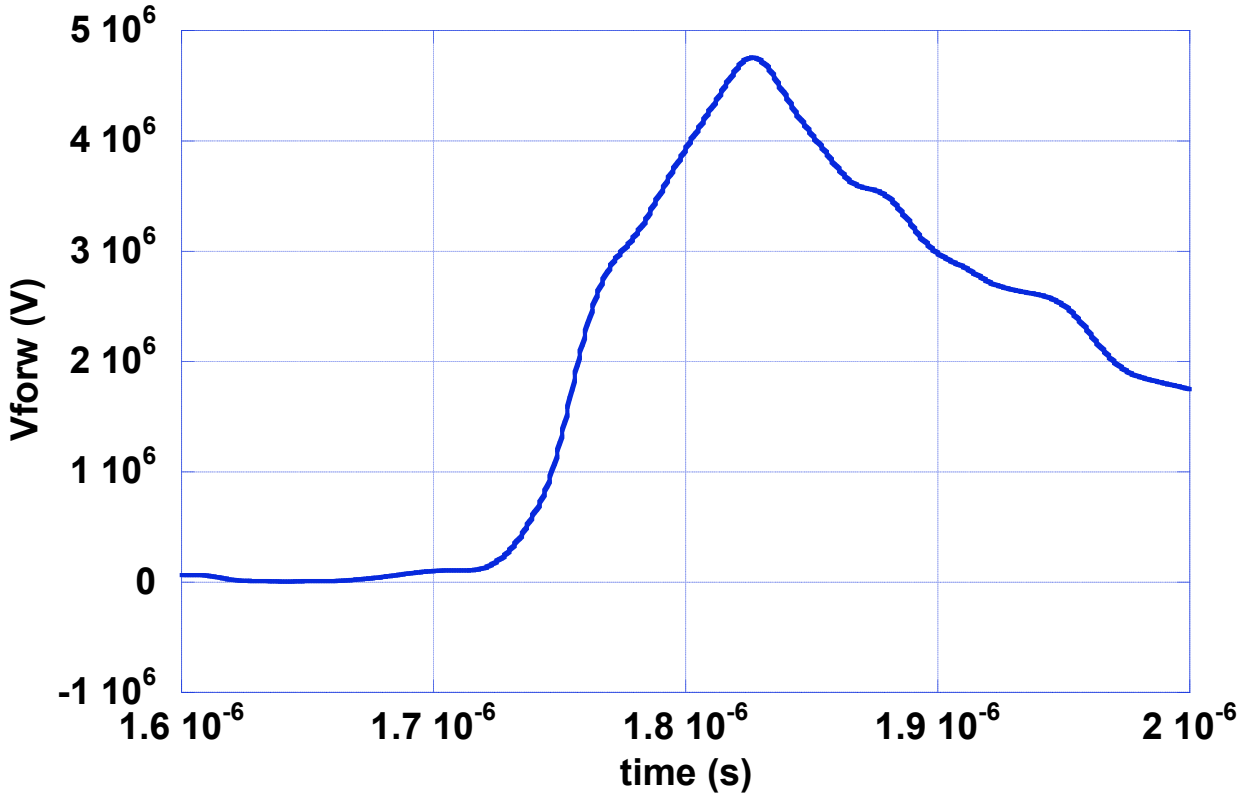
The double-post-hole-convolute is used to place four power flow feeds in parallel.

Each post has five magnetic nulls.





The ZR project will deliver a 4.8 MV forward going wave in a 0.18 ohm system



The peak electrical power is 127 TW and delivers 8.2 MJ in 100 ns and 14.7 MJ in 200 ns

Higher current will provide increased capability

Capability	Z today	After Refurbishment
Peak load current reproducibility	± 5 %	± 2 %
Pulse shaping flexibility	Minimal	Significant Variability
Peak Current	18 MA	~26 MA
Power Radiated (Nested Arrays)	230 TW	~350 TW
Energy Radiated (Single Array)	1.6 MJ	~2.7 MJ

Increased capability will be applied to:

- Hot spot Inertial Confinement Fusion
- Fast ignition
- Radiation hydrodynamics
- Opacity
- Material response to radiation fluence
- Dynamic material properties