SAND2011-4183 C

Experimental Validation of the First 1-MA Water Insulated Mykonos LTD Voltage Adder

SAND2011-4183C

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LTD Technology is a New Paradigm in Accelerator Physics.

- As you heard in the previous presentations, Sandia, the High Current Electronics Institute at Tomsk (HCEI), Russia, the International Technologies for High Pulsed Power (ITHPP), France, the C.E. Gramat, France, are the leaders toward the development of a new class of very compact, high current, high voltage, very fast (70-100-ns) pulse generators based on the LTD (Linear Transformer Driver) technology.

- The salient feature of the new technology is switching and inductively adding the pulses at low voltage straight out of the capacitors through low inductance transfer and ferromagnetic core isolation (basic unit = stage or LTD cavity).

- We can inductively add stages (cavities) in series in a voltage adder configuration (like the radiographic LTD accelerator, HERMES III, RITS-6 e.t.c) to get Multi-Megavolt outputs.

- We can add in parallel many voltage adders to get both Multi-Megavolts and Multi-Mega-amps.

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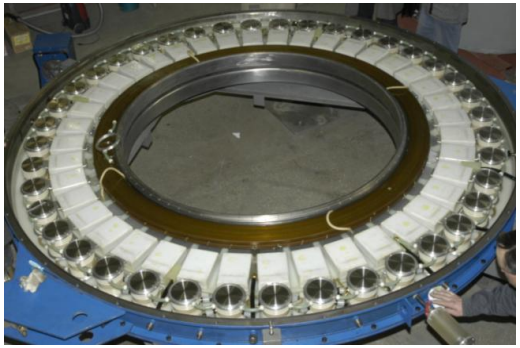
Presentation Outline.

- Introduction
  - The LTD cavity.
  - Induction accelerator with LTD cavities.

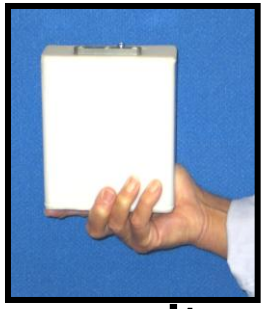
- Experiments with 1-MA LTD cavities
  - Single cavity.
  - Five cavity vacuum insulated voltage adder.
  - Why to use voltage adders with water insulation.
  - Two cavity, MYKONOS II, water insulated voltage adder.
  - Conceptual high current LTD driver designs for future consideration.
- Summary
- Future plans



The 1-MA LTD Cavity

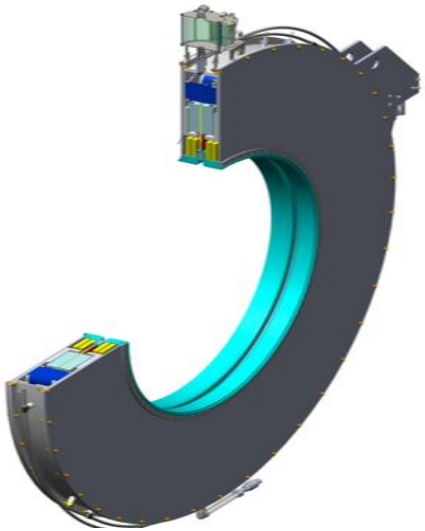
Only 3 basic components

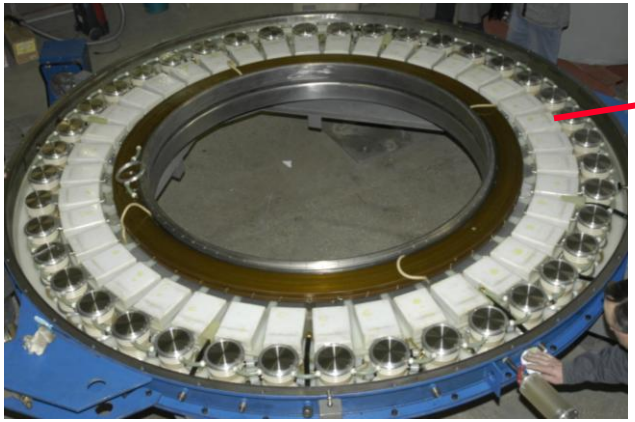
switch



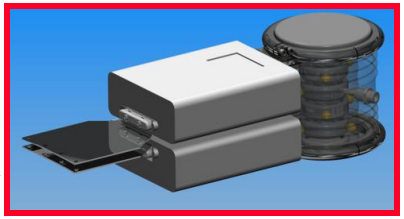
capacitor

ferromagnetic core





brick



40 bricks
40 nF caps
L= 6 nH
C= 800 nF
Ropt. Load = 0.108 Ω

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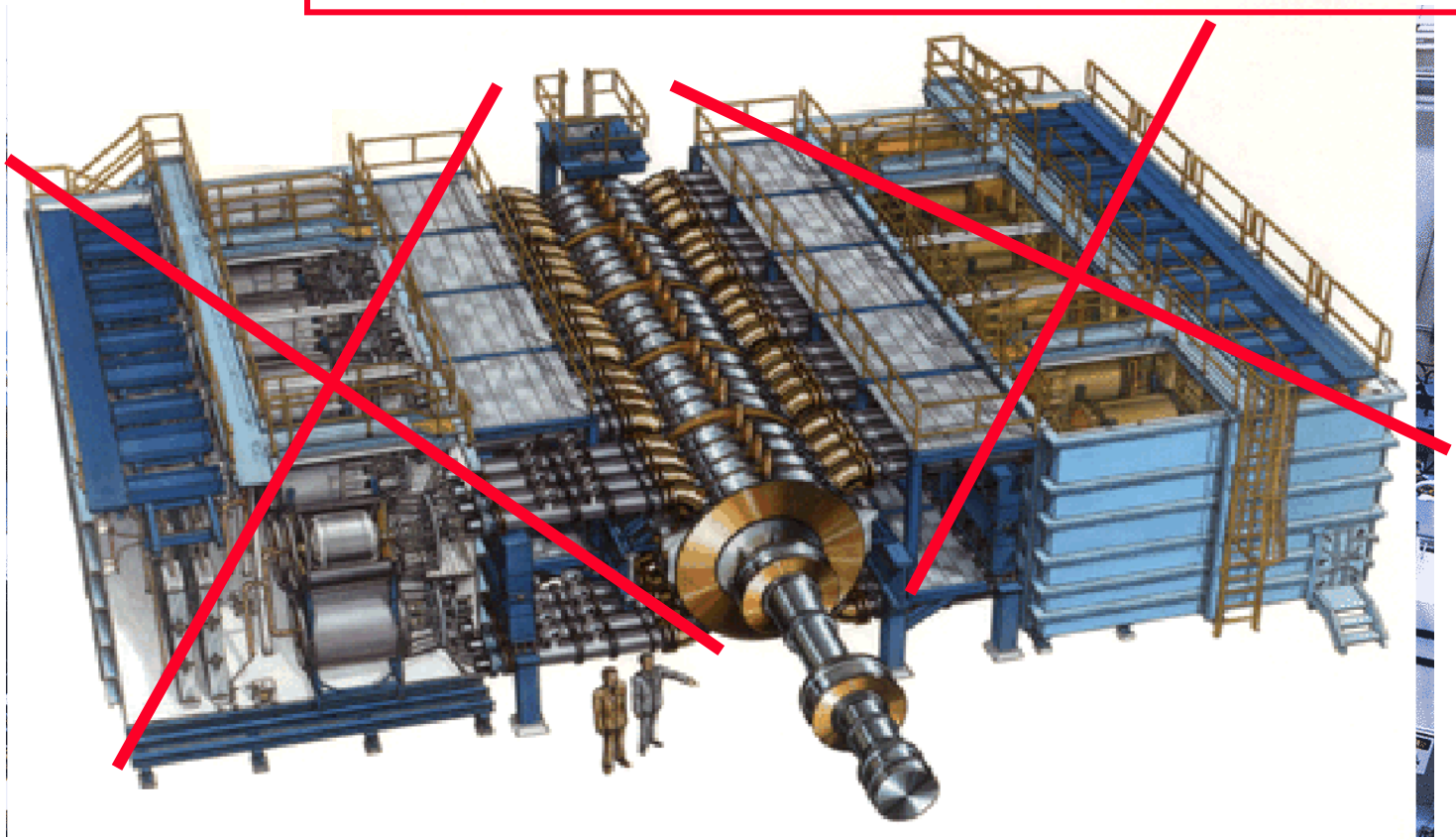
A 1-MA, 20-MV LTD voltage adder will look like the HERMES-III center section but with smaller diameter.

LTD drivers are very compact.
No need for multistage pulse compression.
No need for multimegavolt switches (6MV for Z).



HERMES III

An LTD Voltage Adder is an adder that connects in series a number of inductively isolated LTD cavities.

LTD five 1-MA cavity Voltage Adder Vacuum Insulated

A. A. Kim, M. G. Mazarakis, *et. al.*,
Phys. Rev.ST Accelerators and Beams 12, 050402 (2009)

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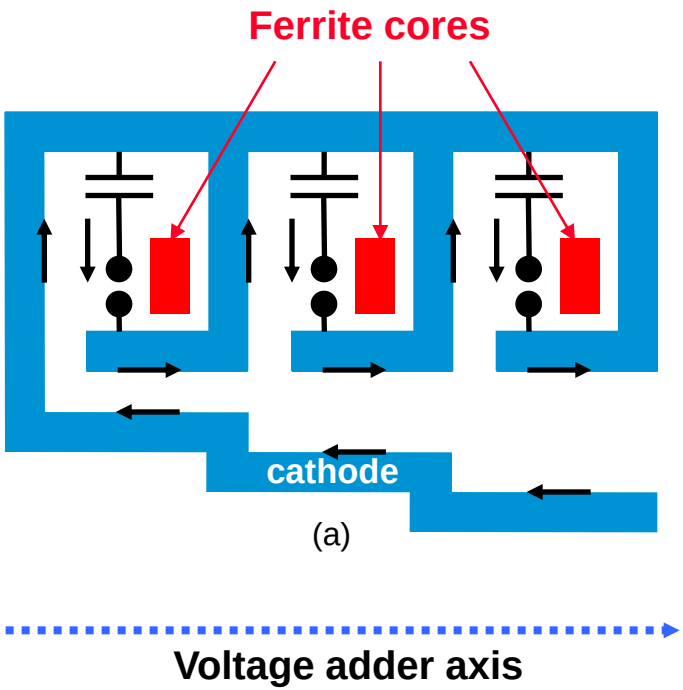
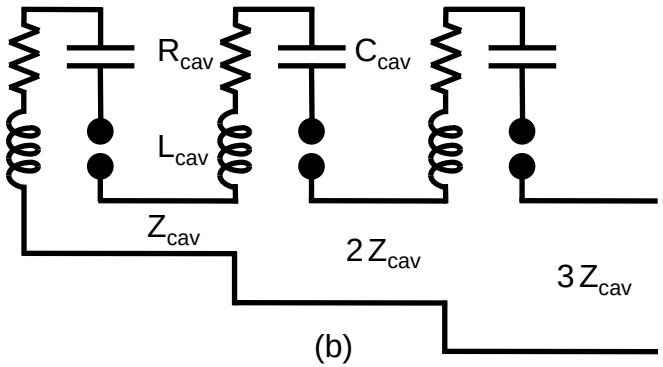
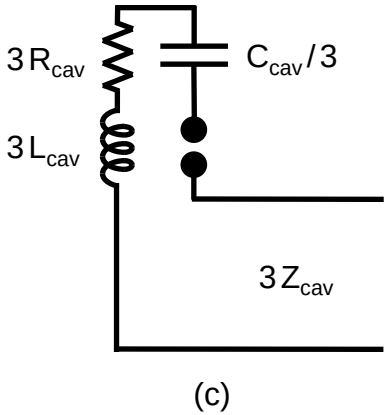
To first order, an n-cavity LTD voltage adder can be modeled as a simple RLC.

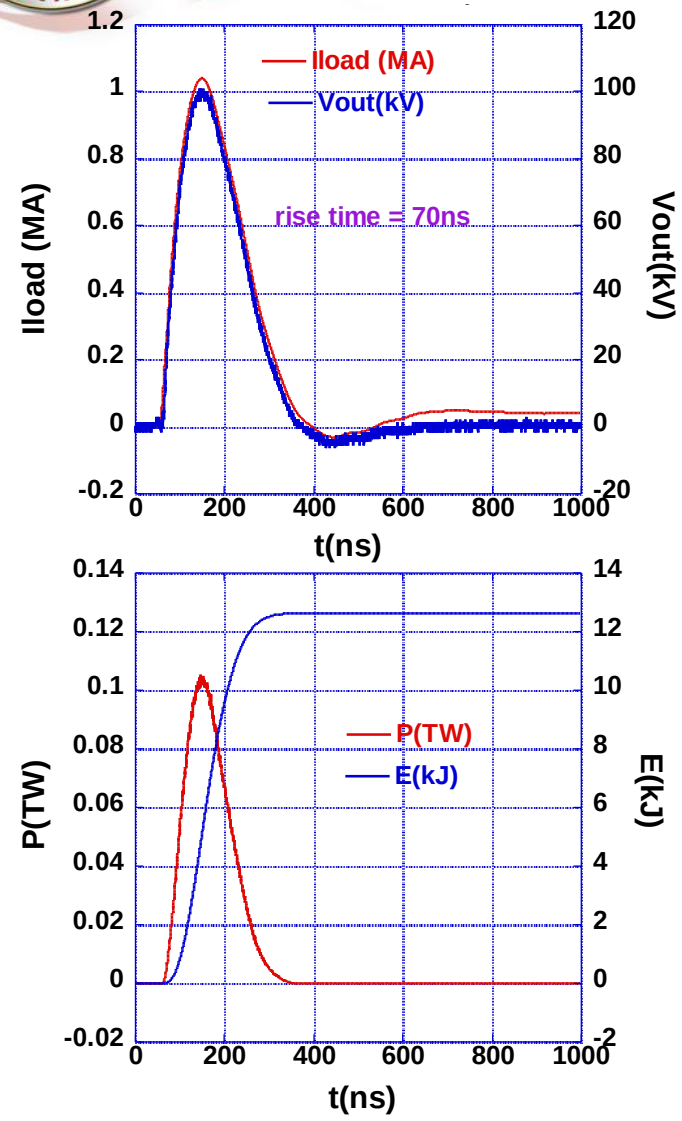


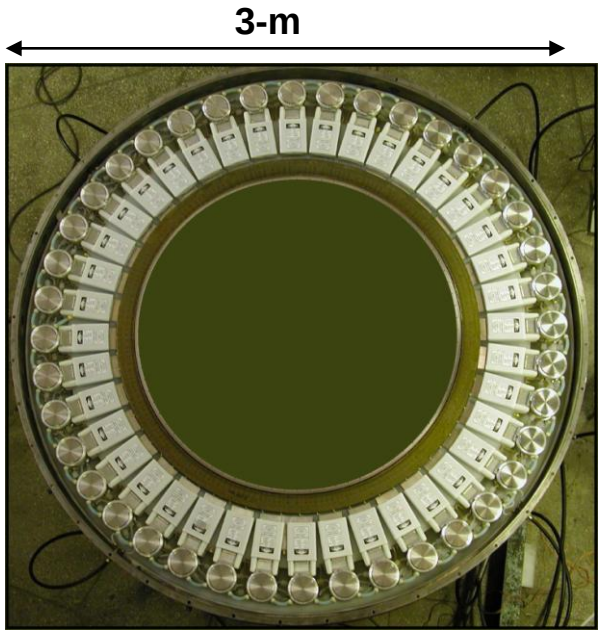




M. G. Mazarakis *et al*. "A Compact, High-Voltage E-Beam Pulser," 12th IEEE Pulsed Power Conference, Monterey, California, July 1999.
Pulsed Power Conference Proceedings p. 412

The 1-MA, 100-GW, LTD cavity performed as predicted by simulations and analytical calculations.





1-MA, 100-GW, 70ns LTD cavity (top flange removed)

80, 40-nF caps ,

40 switches, 200 kV

0.1 Ohm load **0.1TW**

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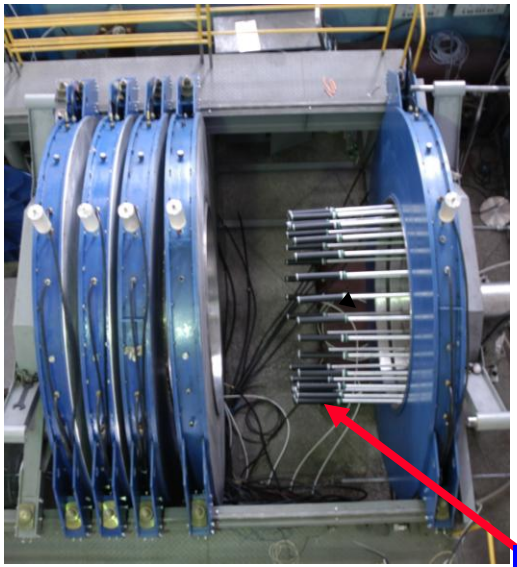
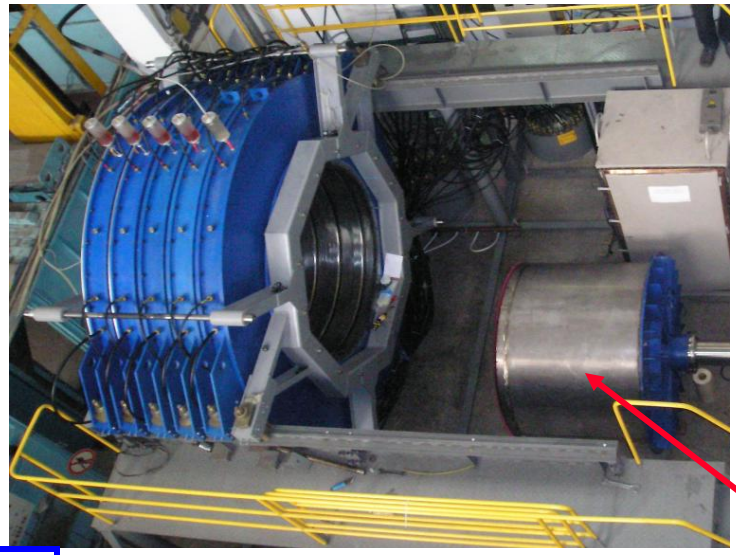
A five cavity 1-MA LTD voltage adder was tested with resistive and vacuum diode loads.



resistors

Resistive load Experiments.



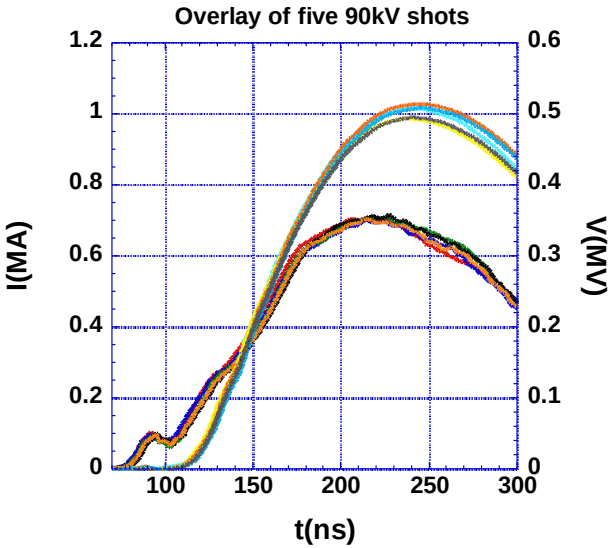
cathode electrode

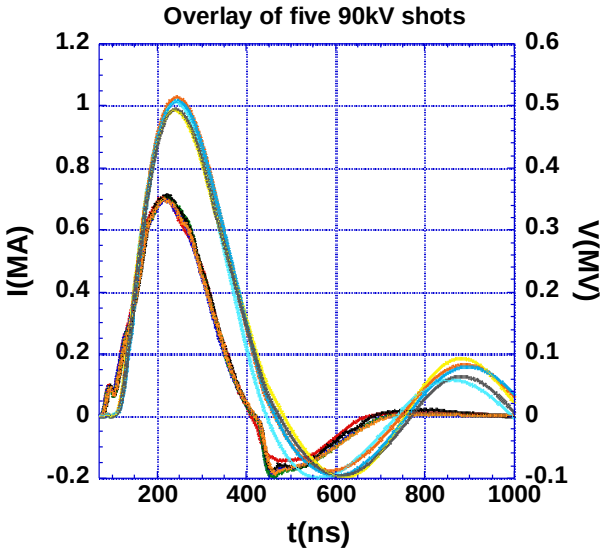
Vacuum diode load experiments.

A. A. Kim, M. G. Mazarakis *et al*., Phys. Rev.ST Accelerators and Beams 12, 050402 (2009)

M. G. Mazarakis, A. A. Kim *et al*., IEEE Trans. Plasma Sci. Vol. 38, NO. 4 2010

We have conducted 5-cavity LTD vacuum insulated voltage adder experiments.





A. A. Kim, M. G. Mazarakis, *et al*., Phys. Rev. ST Accelerators and Beams 12, 050402 (2009)

Work performed at the HCEI

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Why water insulation.

Advantages of water insulated voltage adders

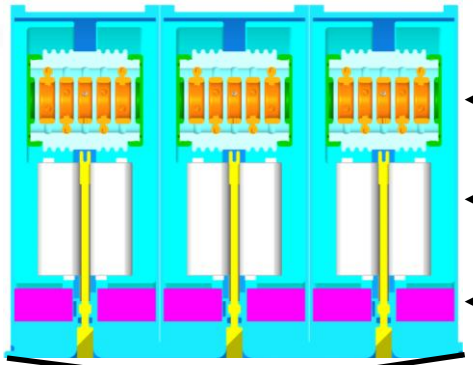
- Current flows on the surface of the conductors.
- No sheath current erosion and resulting pulse shortening.
- Can be terminated with high impedance loads without losing ~1/3 of the total current on the walls.
- No wall erosion.
- Lengthen transit time from cavity to cavity by a factor of 9.
- The later is very important for output pulse shaping by staggering cavity trigger.
- Connect many voltage adders in parallel to a comon transmission line without suffering magnetic nulls.

Disadvantages

- High voltage water vacuum interfaces.
- Air bubbles in an enclosed system.
- Metal corrosion.
- Extremely high forces to compress cavities water and oil tight.
- Larger weight.

We feel that the advantages outweigh the disadvantages.
Our goal is to test this assumption.

Each LTD module consists of a large number of annular LTD cavities connected in series.



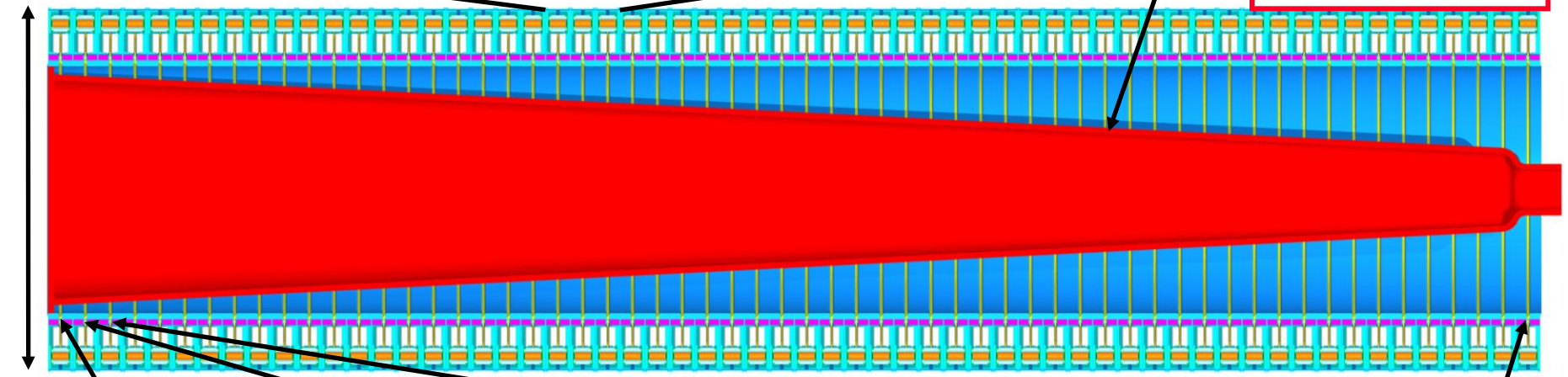
expanded view of 3, 1-MA LTD cavities

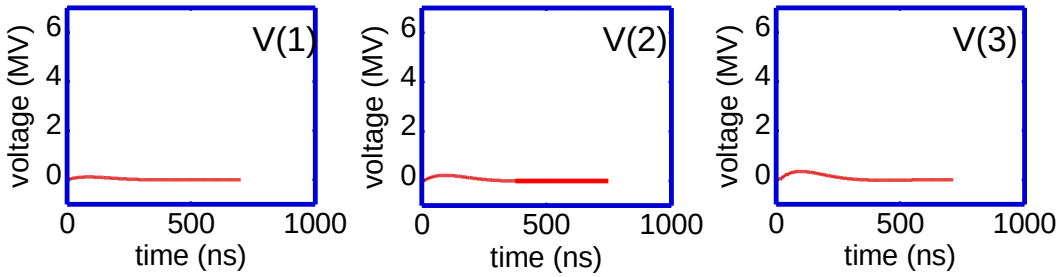
60-cavity annular LTD module

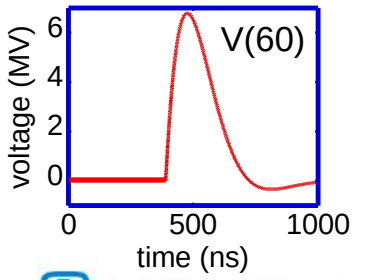
central conical conductor

$\eta_{energy} = 70\%$

3 m







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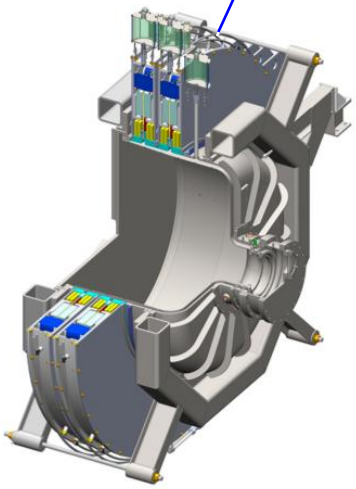
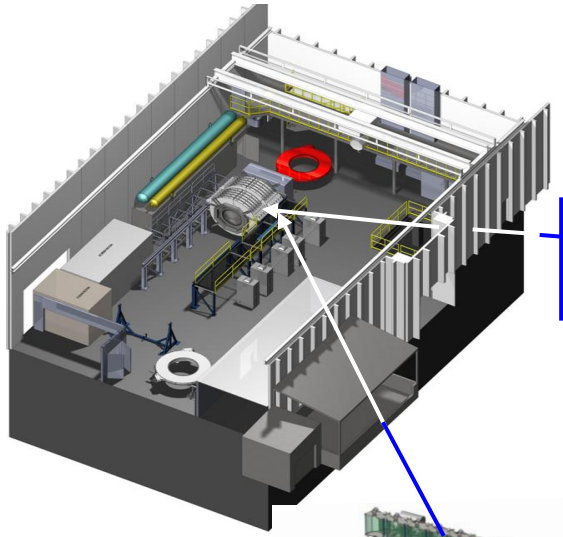
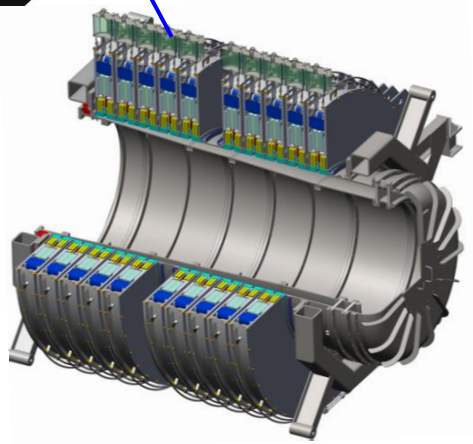
The MYKONOS laboratory is complete and the first two LTD cavity voltage adder is undergoing testing with water.

Sandia MYKONOS II, June 2011



MYKONOS X Laboratory, Dec. 2011 (?)





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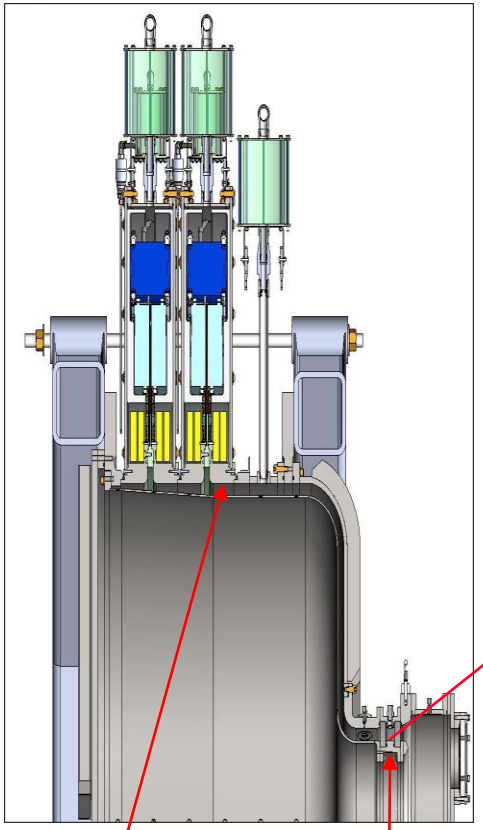
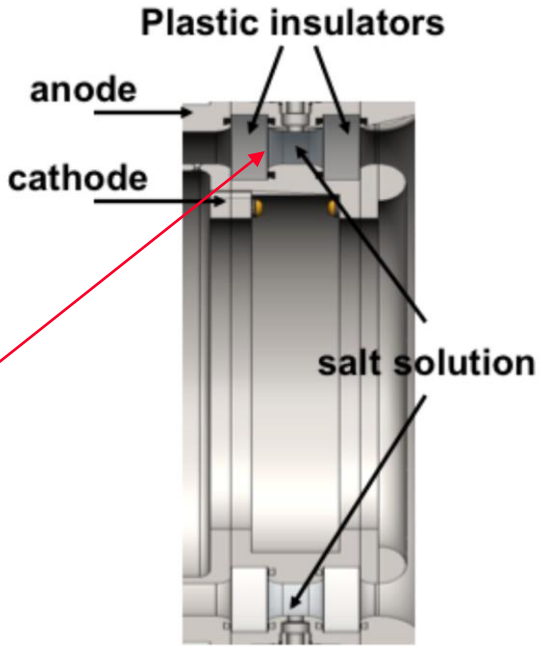
The two LTD cavity 1-MA 200-kV voltage adder

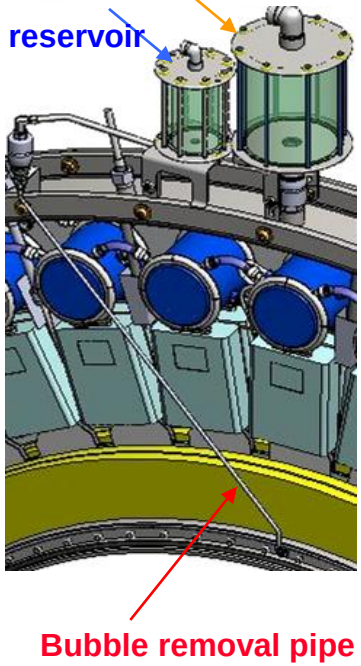


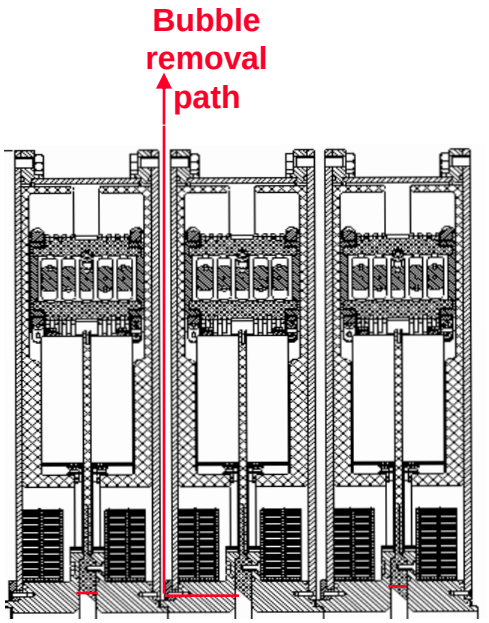
Two LTD cavity voltage adder



radial liquid resistive load

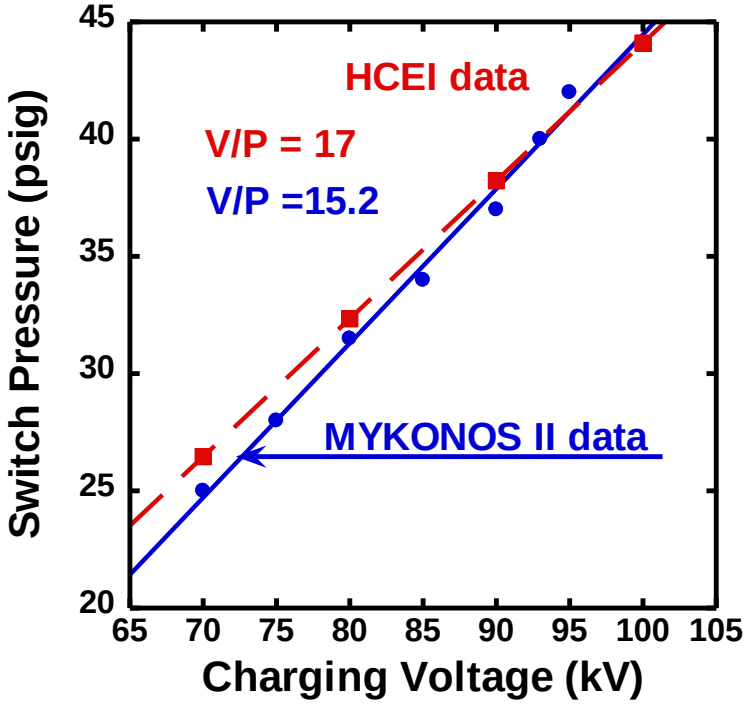
The LTD cavities were modified to operate in a de-ionized water environment

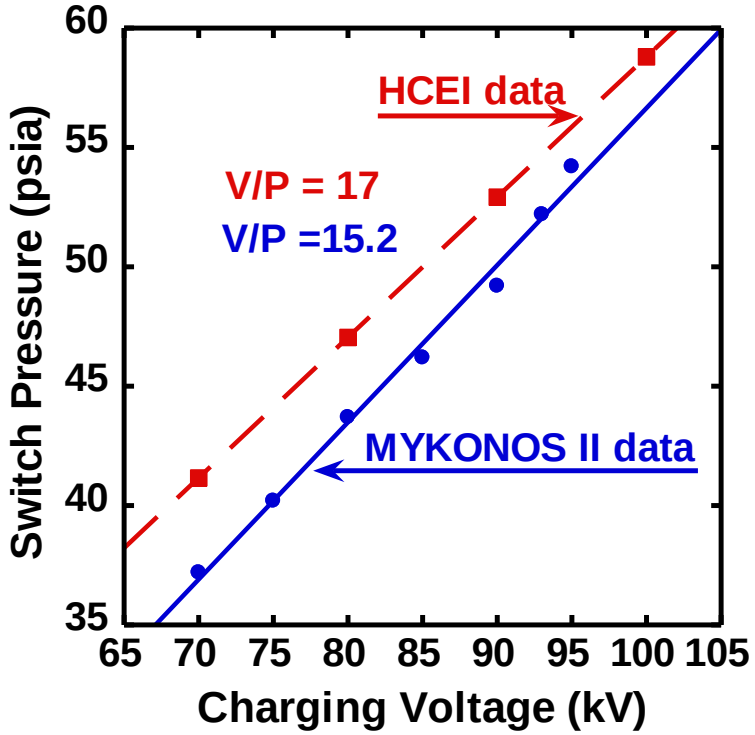




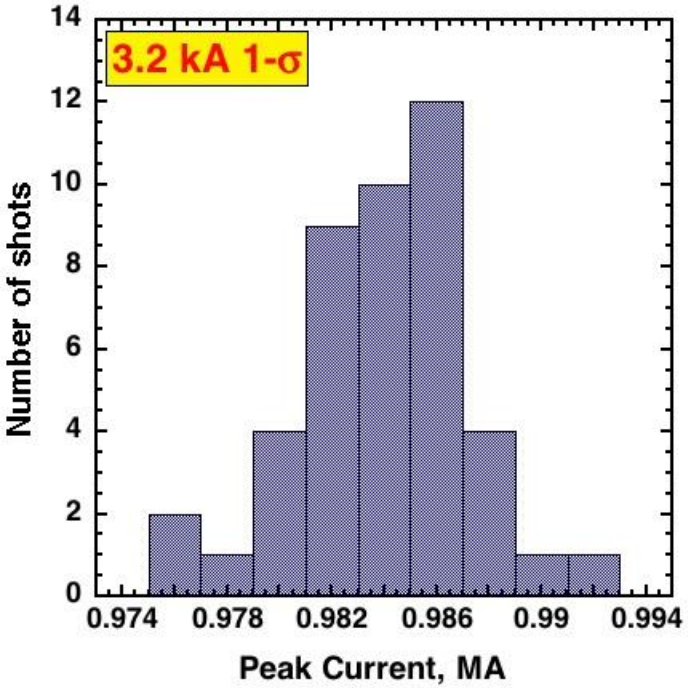
1. Change water interface angle to 94^0
2. Passivate stainless steel surfaces
3. Provide bubble removal paths from the voltage adder interior
4. Install water and oil reservoirs connected to vacuum pumps
5. Install deaeration and deionization systems
6. Modify O ring groves for water

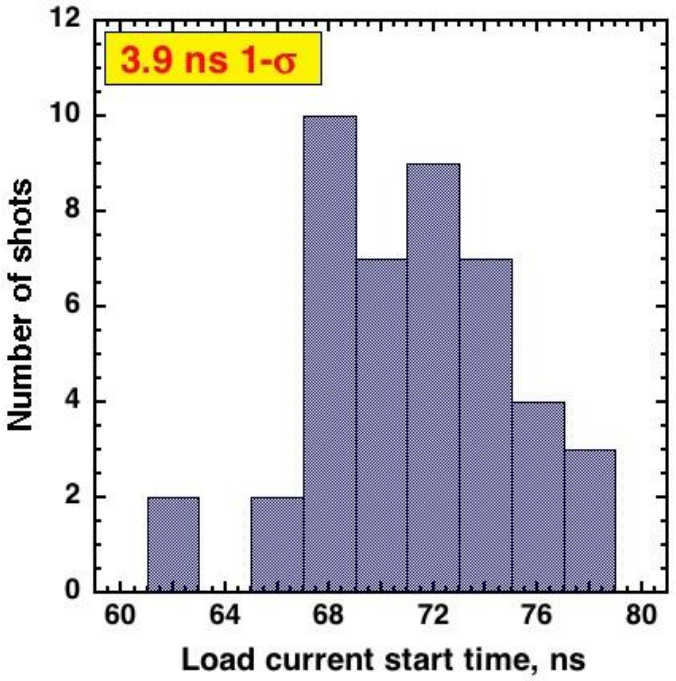
MYKONOS II Switch Conditioning Results Close to those of HCEI





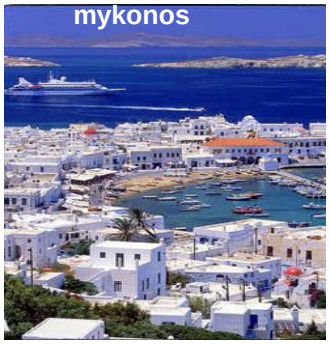
At 95 kV the switch pressure is not yet optimized, however the run time and pick current variation is reasonable.





Summary of the 1-MA, Fast (100-ns), LTD experimental test results and future plans.

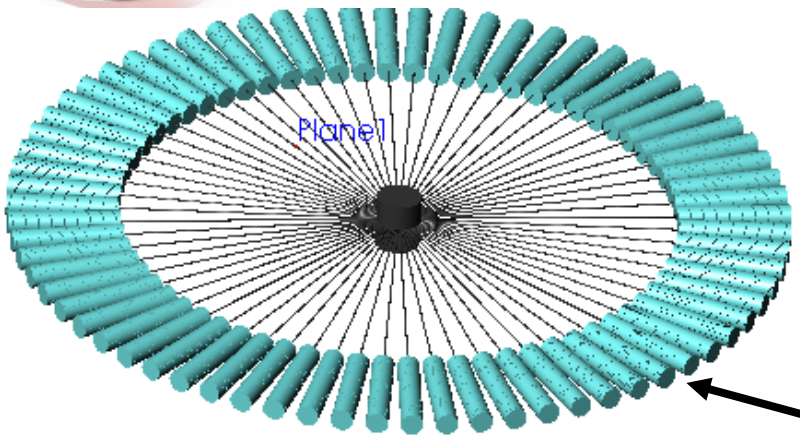
- **1-MA, 100-kV LTD stage individually tested met 0.1 TW output design specs.**
- **First tests of a five stage vacuum insulated voltage adder with resistive and diode loads demonstrated successful energy, power addition and transmission to the load. [M. G. Mazarakis *et al.*, *IEEE Trans. Plasma Sci., vol. 38, No. 4, 2010*]**
- **A water insulated 2-cavity (MYKONOS II) voltage adder is in the process of commissioning.**
- **We have already successfully demonstrated the pulse shaping capabilities of MYKONOS II by staggering the firing of each cavity and of each cavity four quadrants. [M. E. Savage *et al.*, paper 2P-46 this afternoon]**
- **We have fired in rep-rate mode 1,800 shots conditioning the switches between 50 and 95kV.**
- **Work under progress to reach the 100-kV design charge voltage.**
- **We plan to do life time measurements by firing 10,000 shots at 100-kV charging.**
- **Work in progress to modify the remaining 8 cavities for the MYKONOS X 1-MA, 1-MV, 1-TW voltage adder.**



Back up slides

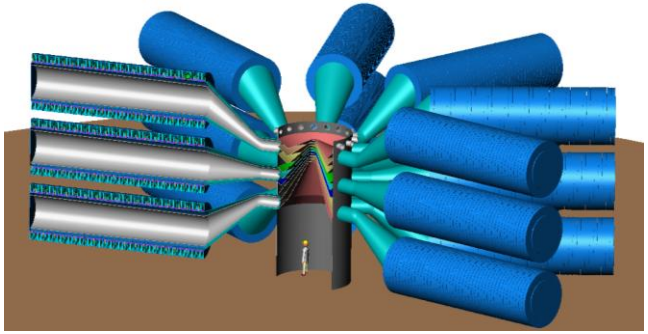
Conceptual designs of z-pinch drivers with multiple 1-MV, 100-ns LTD voltage adders connected in parallel.

With future very low inductance switches and high density capacitors the designs could shrink dramatically.

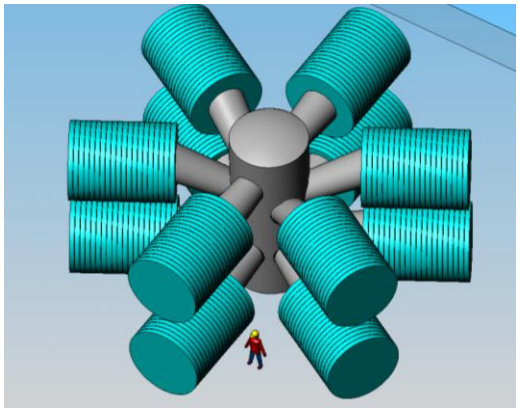


0.5 Petawatt driver

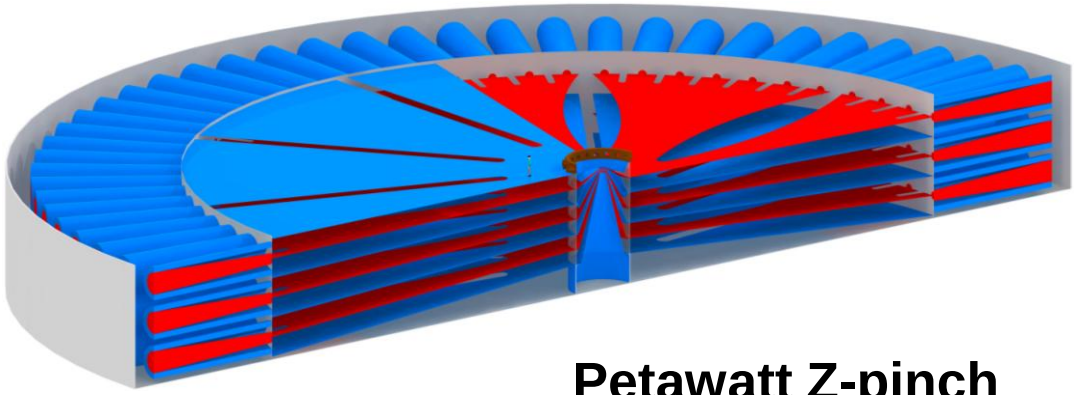
1-MA, 7-MV voltage adder



ZR equivalent



Saturn equivalent



Petawatt Z-pinch driver

W. A. Stygar *et al.*, Phys.Rev. ST Accelerators& Beams, 10, 030401 (2007)

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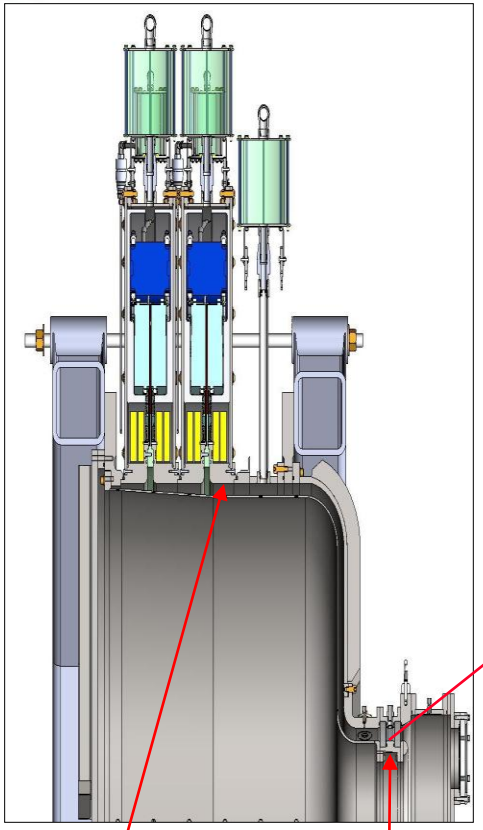
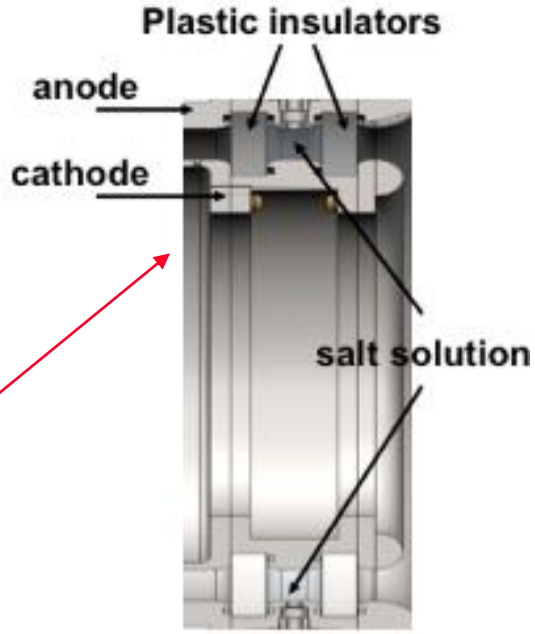
The two LTD cavity 1-MA 200-kV voltage adder

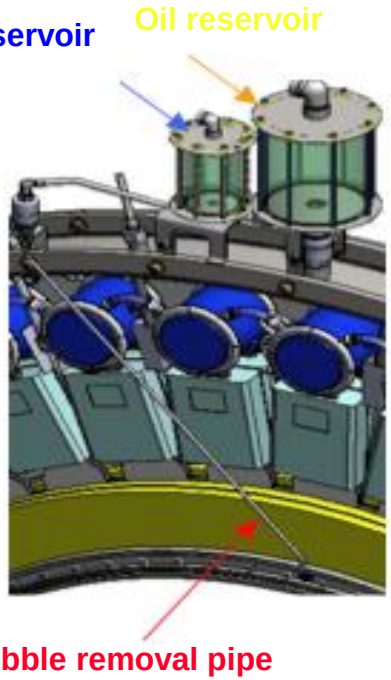


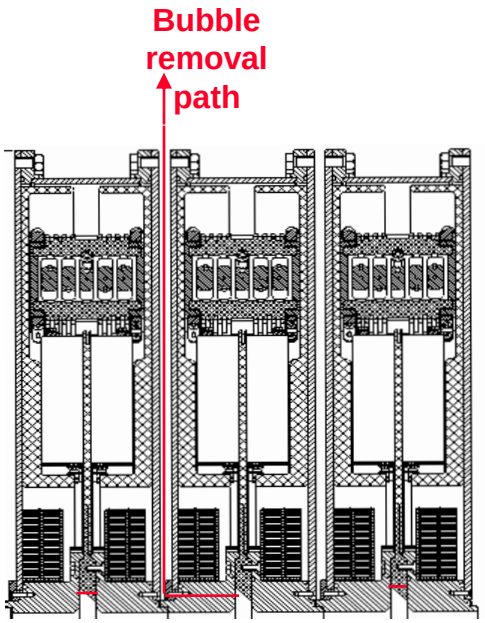
Two LTD cavity voltage adder



radial liquid resistive load

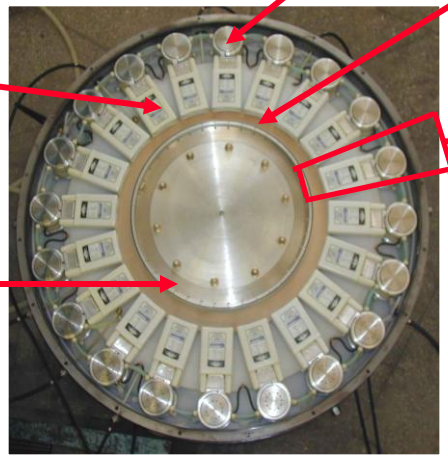
The LTD cavities were modified to operate in a de-ionized water environment



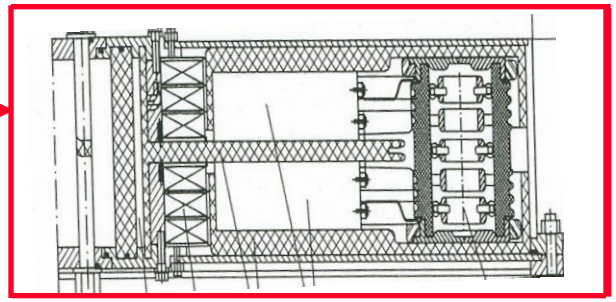


1. Change water interface angle to 94^0
2. Passivate stainless steel surfaces
3. Provide bubble removal paths from the voltage adder interior
4. Install water and oil reservoirs connected to vacuum pumps

The fast LTD cavity is an induction accelerator cavity which encloses the pulse producing circuits ("bricks").



0.5-MA prototype cavity



Brick side section