



# Status of the DARHT 2<sup>nd</sup> Axis Accelerator at Los Alamos National Laboratory

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## The Dual Axis Radiographic Hydro Test Facility is Located at the Los Alamos National Laboratory



DARHT was conceived in the early 80's as a critical tool for nuclear weapons development and stewardship



*DARHT consists of two induction linear accelerators oriented orthogonal to one and other.*



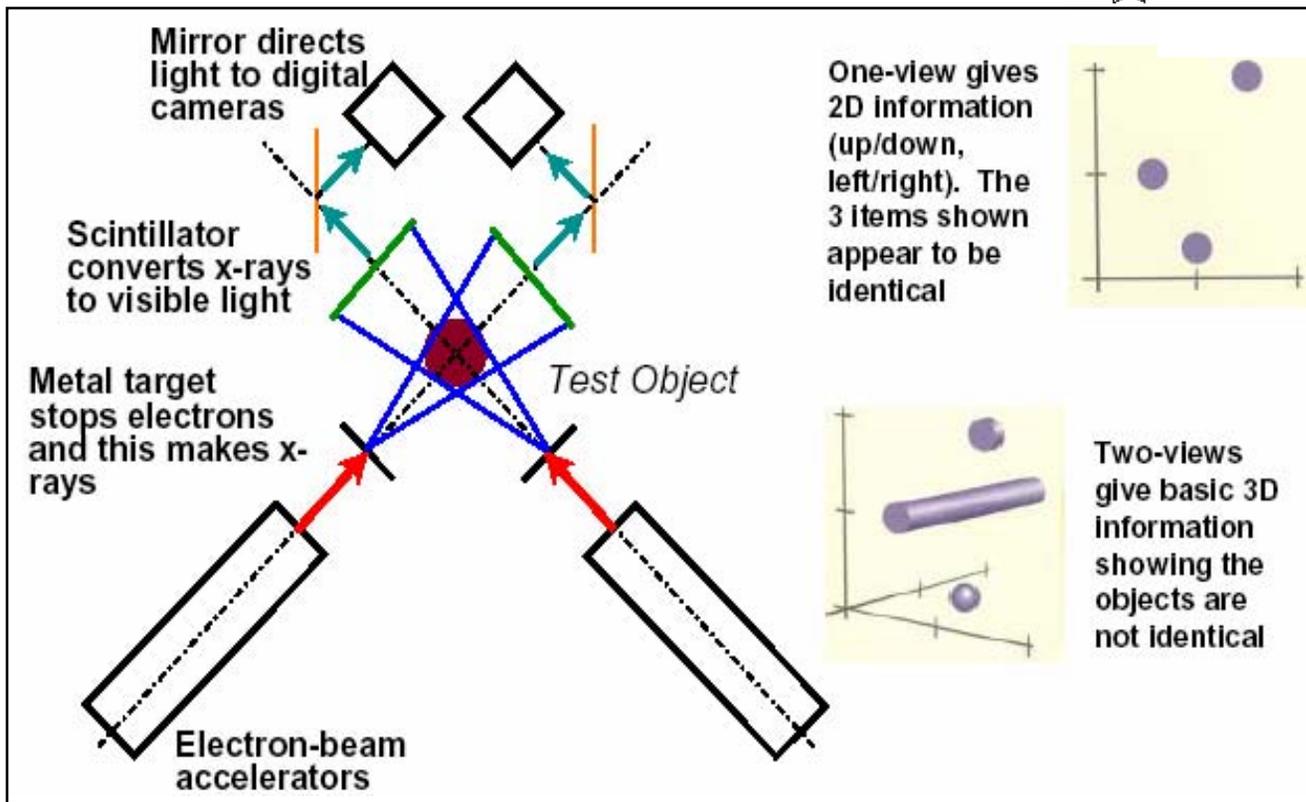
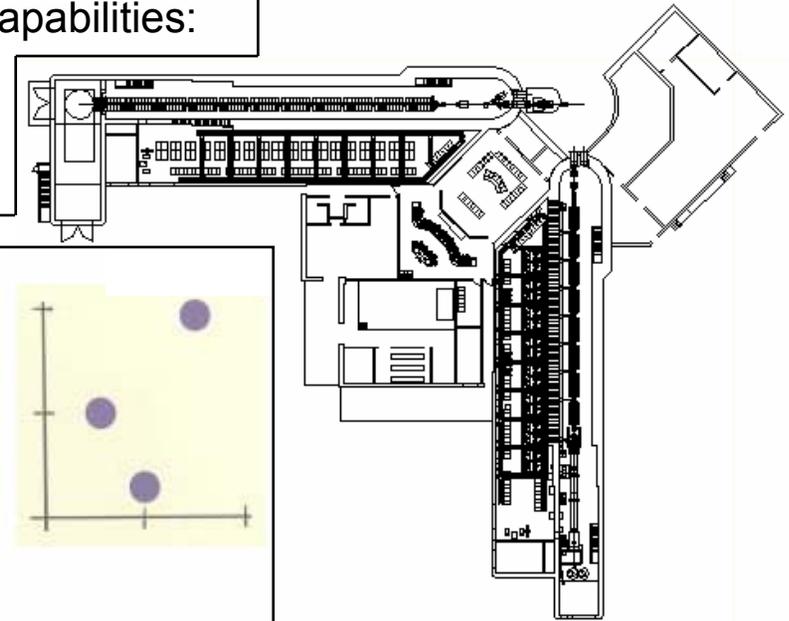
# DARHT's Dual Axis Design Concept is Based on Generating "quasi-3D" Images

Flash radiography measurements require 3 essential capabilities:

*High resolution - image with fine detail and minimal noise*

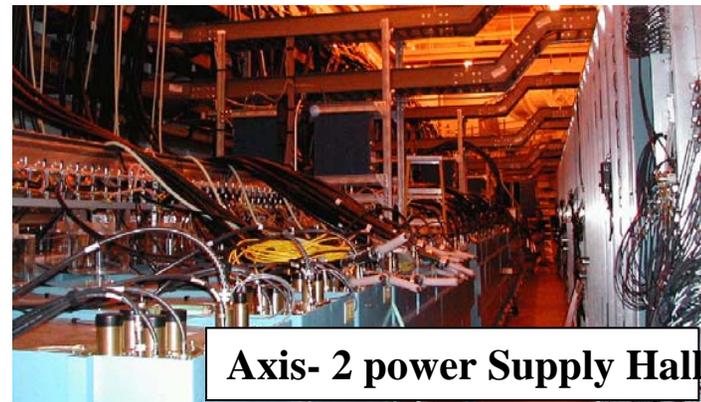
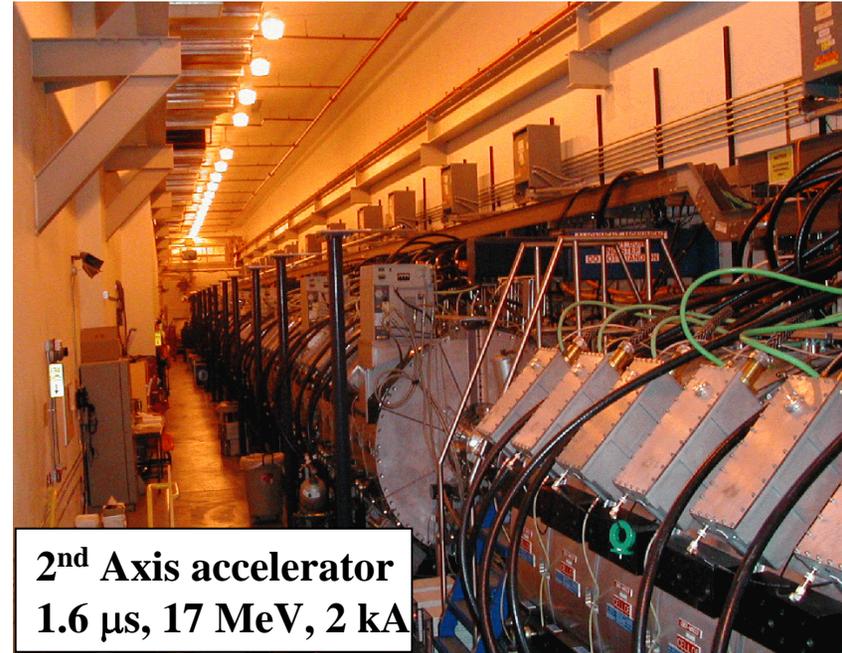
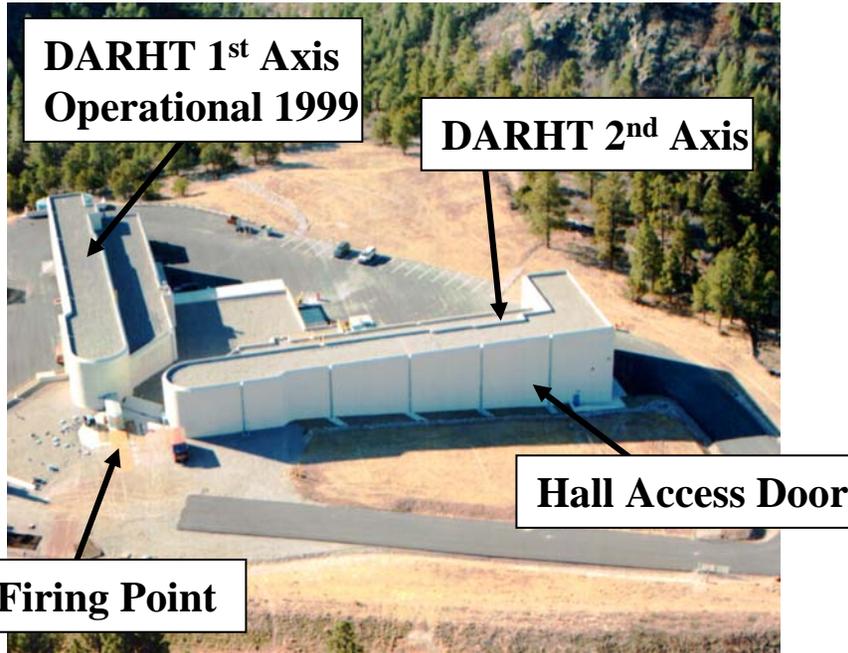
*Multiple views ("quasi-3D" reconstruction)*

*Multiple times (dynamic code benchmarking)*



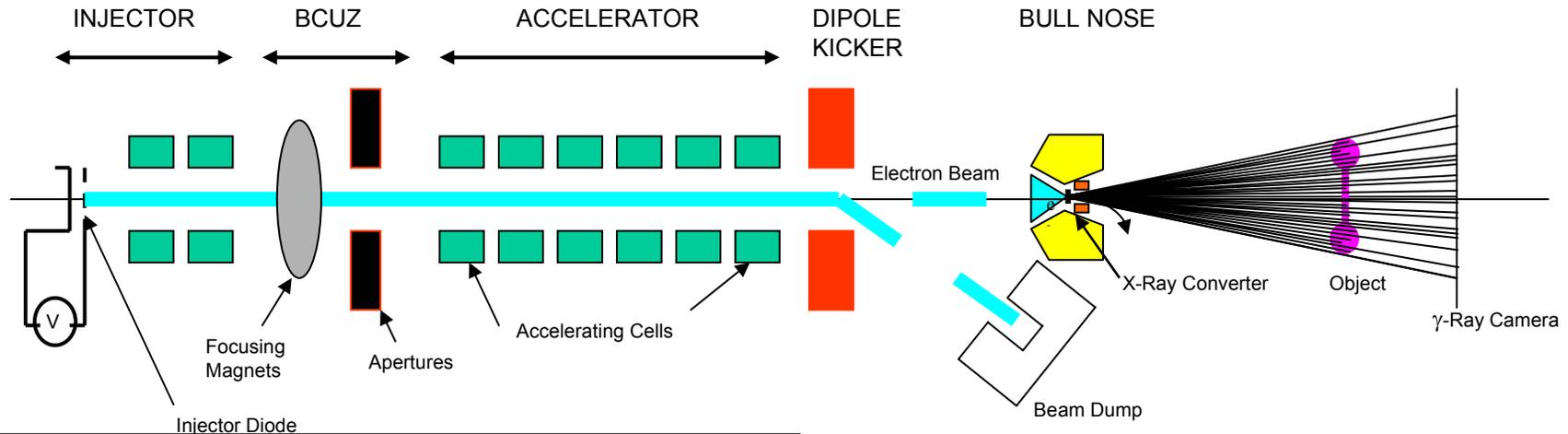


# When the DARHT 2nd Axis is Completed, the DARHT Facility Will Provide Orthogonal, Multi-frame Images



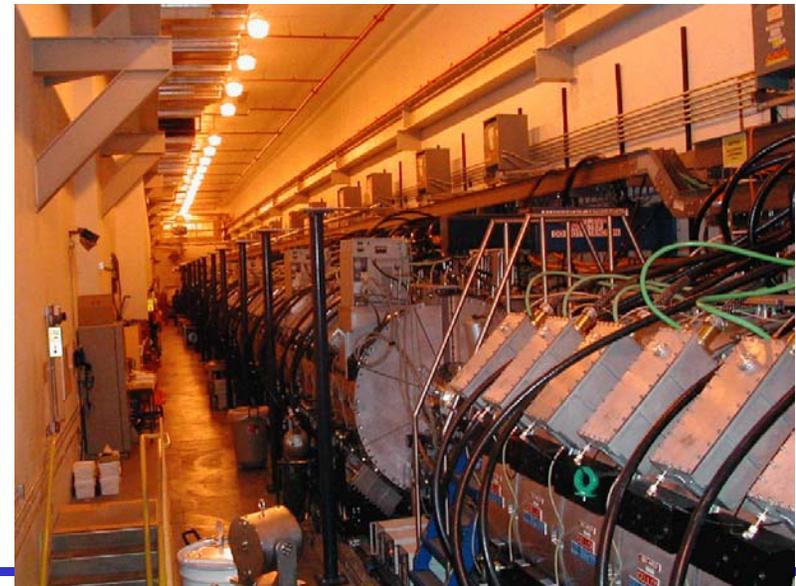


## The DARHT 2<sup>nd</sup> Axis Represents a Considerable Advancement in Induction Linac Technology (1.6 $\mu$ -sec Beam, Four Pulses)



2.5 MeV, 2 kA, 2  $\mu$ -sec injector  
74 accelerator cells operating at 200 kV/cell  
Total beam energy of 17-18 MeV  
Four pulses over 1.6  $\mu$ -sec duration  
Multi-pulse kicker (variable,  $\geq 4$  pulses)  
Multi-pulse (up to 4 pulses) x-ray converter target

***The DARHT 1<sup>st</sup> axis produces a single 60 ns electron beam (and one radiograph)***





## At DARHT 2<sup>nd</sup> Axis Project Completion, the DARHT Facility will have Dual Axis, Multi-Pulse Radiography Capability

	Energy (MeV)	Current (kA)	Length ( $\mu$ sec)	Size* (mm)	Pulse (#)
Requirement	16.5	2	1.5	1.6	4
Goal	18	2	1.6	1.6	4

\* FWHM

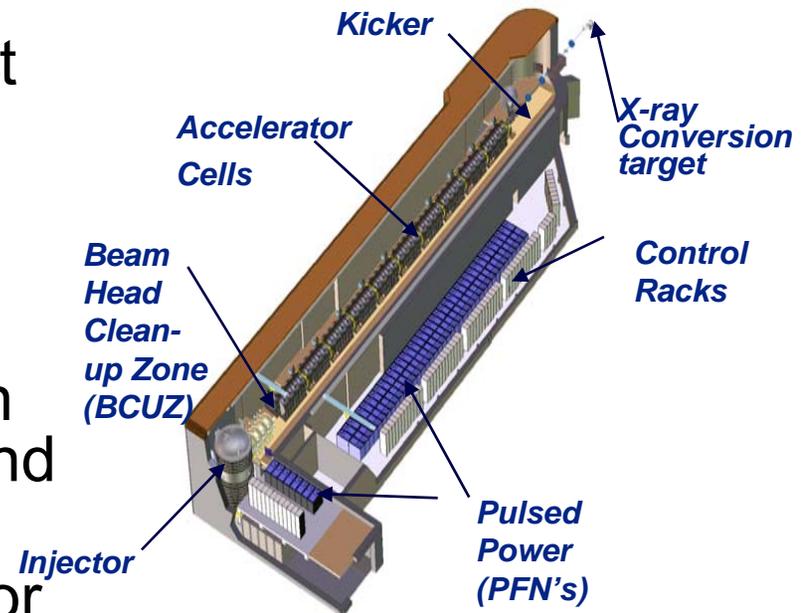
The goal for the x-ray dose format is 100 Rad, 100 Rad, 100 Rad & 300 Rad for the four pulses.

*The x-ray output dose is consistent with the needs of the National Hydrotest Program.*



## DARHT 2nd-Axis Refurbishment and Commissioning Project Began in 2003

- The DARHT Construction Project was completed in March 2003.
- High-voltage breakdown in the accelerator cells was later observed.
- The project identified the solution to the high-voltage breakdown and implemented the solution.
- Commissioning of the accelerator and downstream kicker and four-pulse target will be completed in March 2008.



Costs	
Axis 1	\$105M
Axis 2	\$155M
Current Proj	<u>\$ 90M</u>
Total	\$350M



## Cell Refurbishment Began in June 2005 after a Rigorous Acceptance Testing on Six Prototype Cells

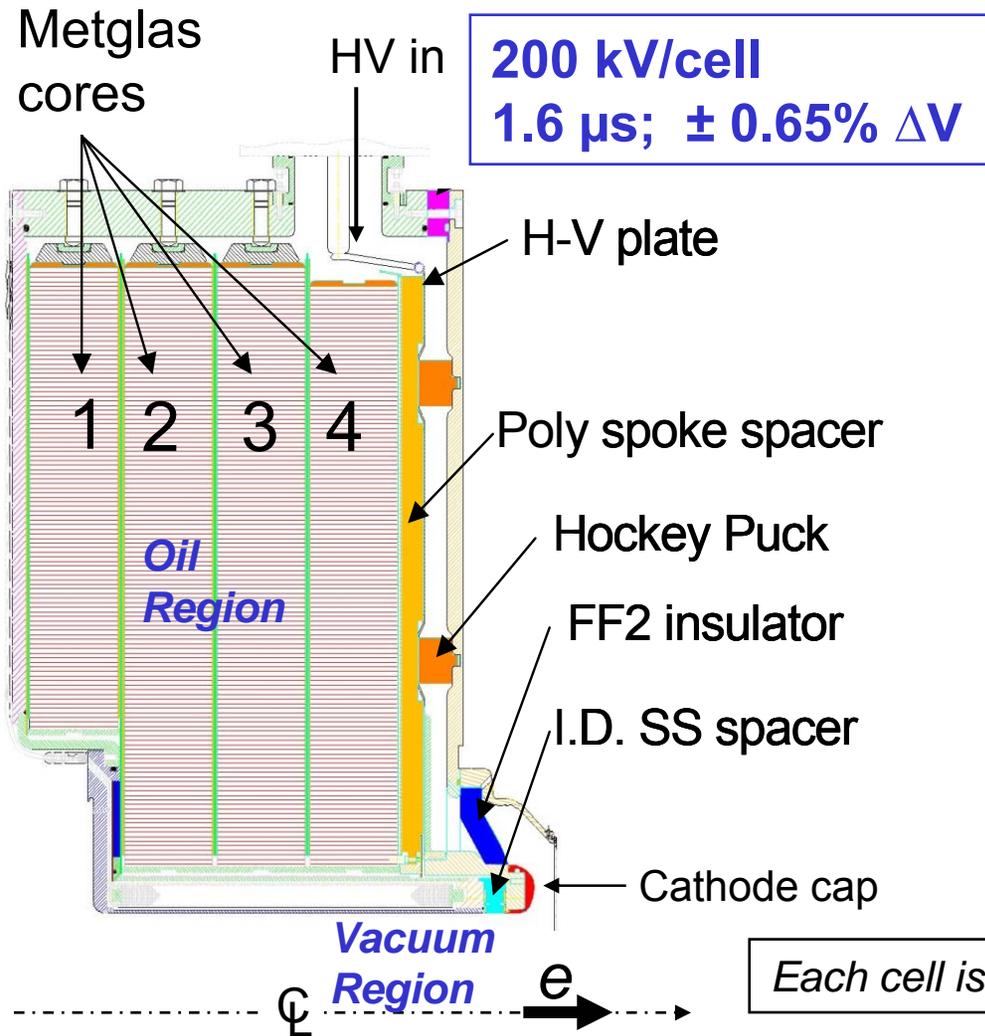
Prototype Cell	Voltage Test Level	# Shots Specified	# Shots Taken
#1	200 kV	50,000	50,069
	250 kV		8,700
#2	220 kV	25,000	26,510
	250 kV	8,700	12,698
#3	250 kV	8,700	8,772
#4	250 kV	8,700	8,700
#5	220 kV	25,000	25,114
	250 kV	8,700	12,288
#6	220 kV	25,000	25,038
	250 kV	8700	12,364
<b>Total #</b>		<b>168,500</b>	<b>190,253</b>



*No voltage breakdowns occurred during acceptance testing*



# The Accelerator Consists of a Series of 74 Cylindrically Symmetric Accelerator Cells



The cell accepts HV pulse from driver and delivers this pulse to annular gap in inner cylindrical surface (beam line)

Inner conductor is surrounded by annular ferromagnetic cores to reduce leakage current from HV plate to ground

The large radial cross sectional area of cores (A) multiplied by the flux density swing ( $\Delta B$ ) without saturation, must be greater than the volt-second product (VT) of the pulse flattop

Each cell is 1.85-m in diameter and weighs 7,300 kg



# The Refurbishment of the 74 Accelerator Cells has been Completed

Cell removal at DARHT



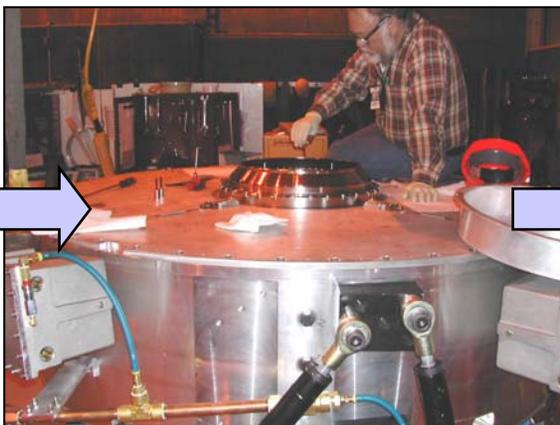
Cells staged in TA 35-125



Cell disassembly and cleaning



Mechanical assembly



High voltage acceptance testing

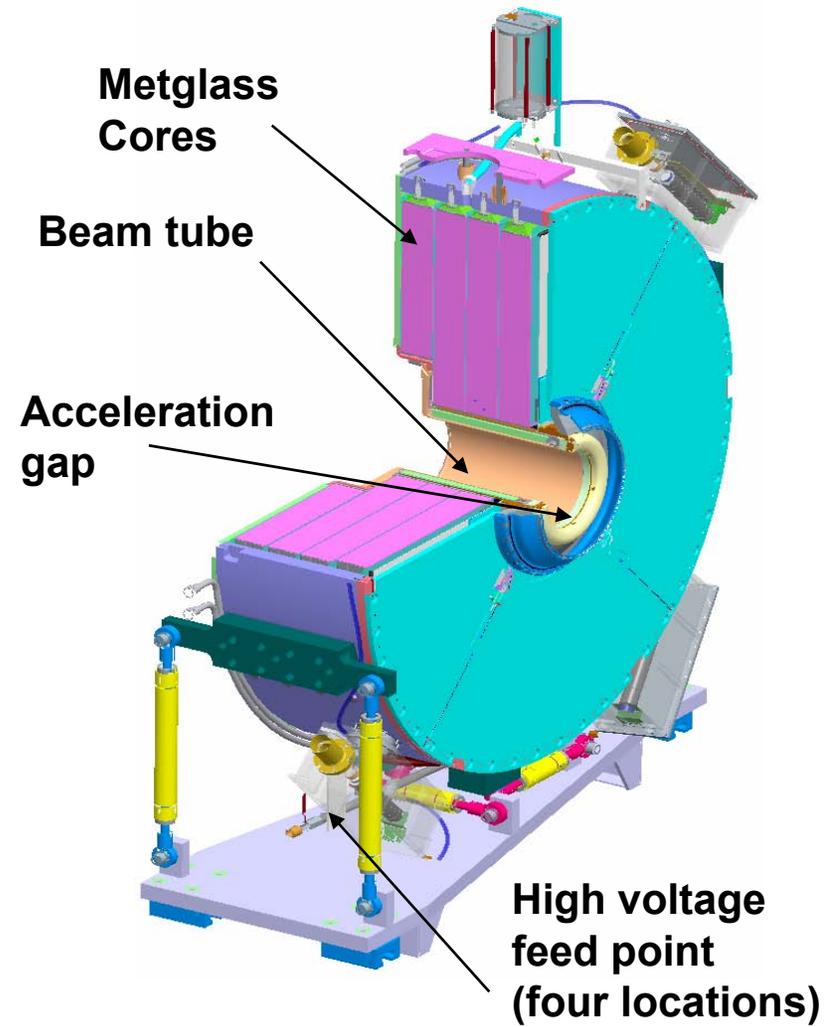
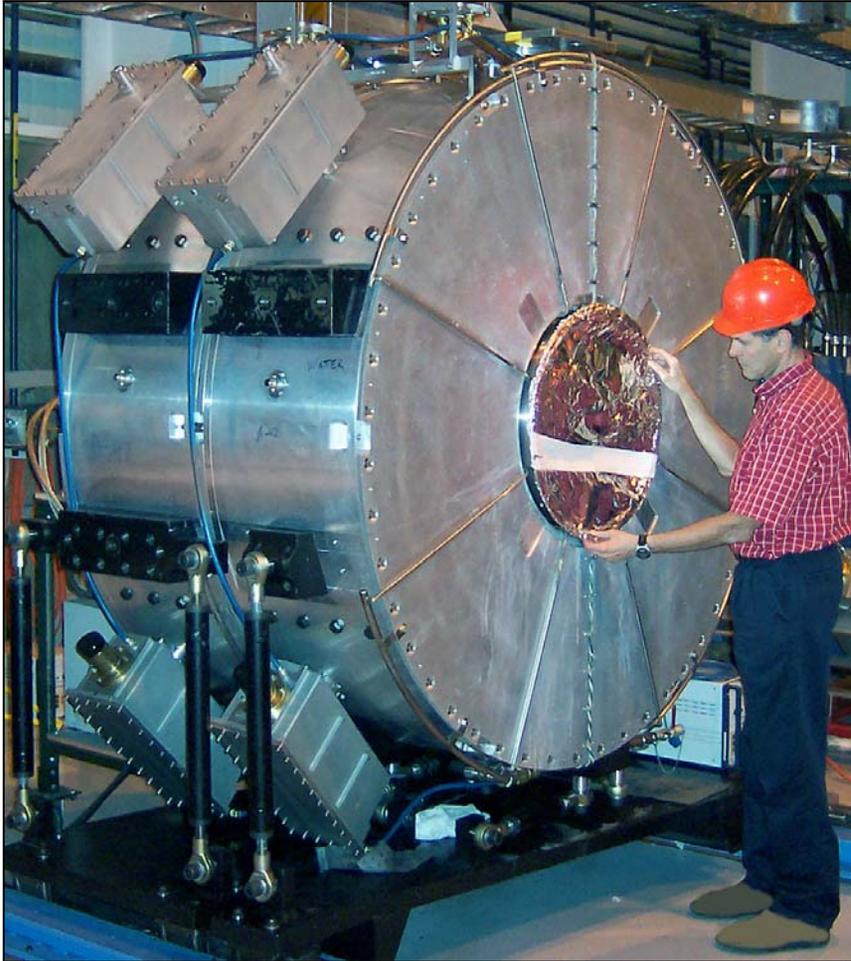


Cells installed in the DARHT accelerator hallway



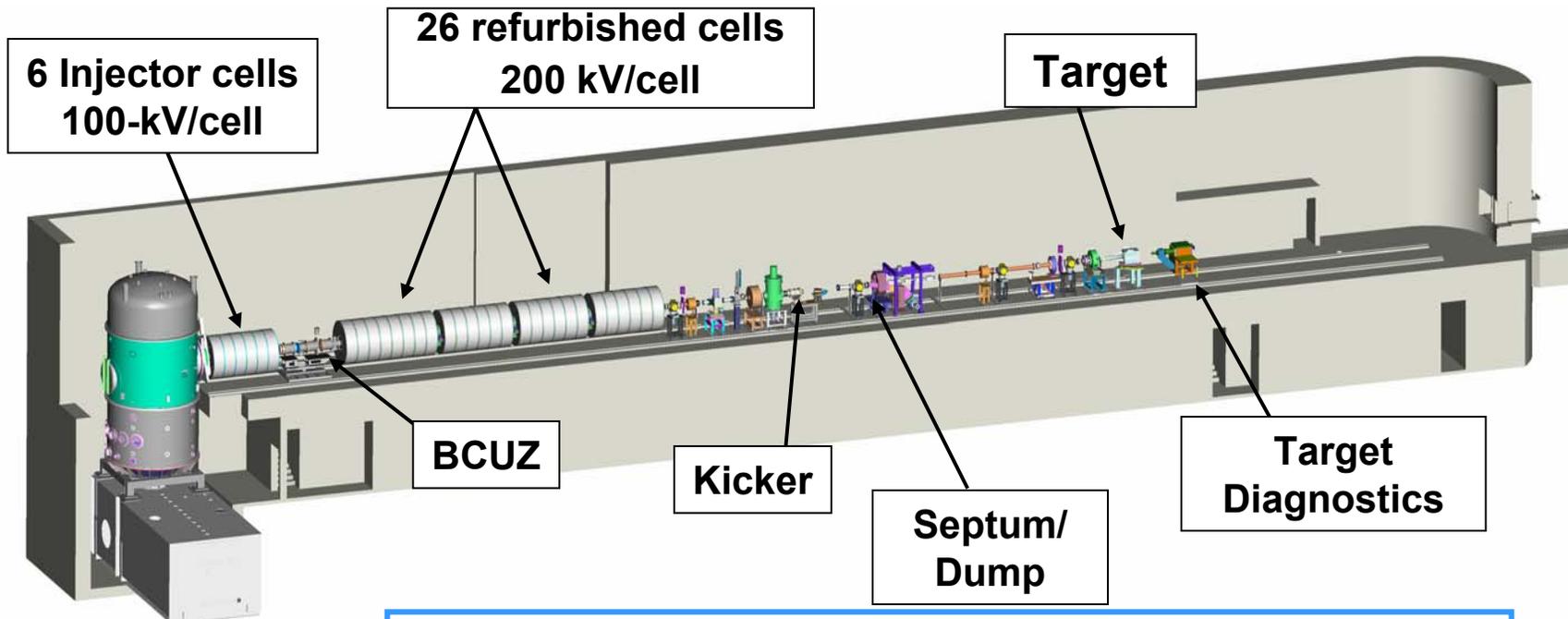


# All Cells have been Refurbished and Tested at LANL





## The Scaled Accelerator Provided a Test Bed for Multi-Pulse Kicker & Target Performance Evaluation



- 26 refurb cells
- 7.8 MeV
- 1.0 kA beam
- 1.6- $\mu$ s pulse

- **Beam Transport Tests at the 1.6- $\mu$ s pulse length**
  - Refurbished accelerator cells
  - Kicker and Septum
  - Dump
- **Multi-pulse target tests - Four pulses in 1.6 $\mu$ sec**
- **Operational Experience**



## 8 MeV Operation on the Scaled Accelerator Extrapolates to 18 MeV for the Full-up Accelerator

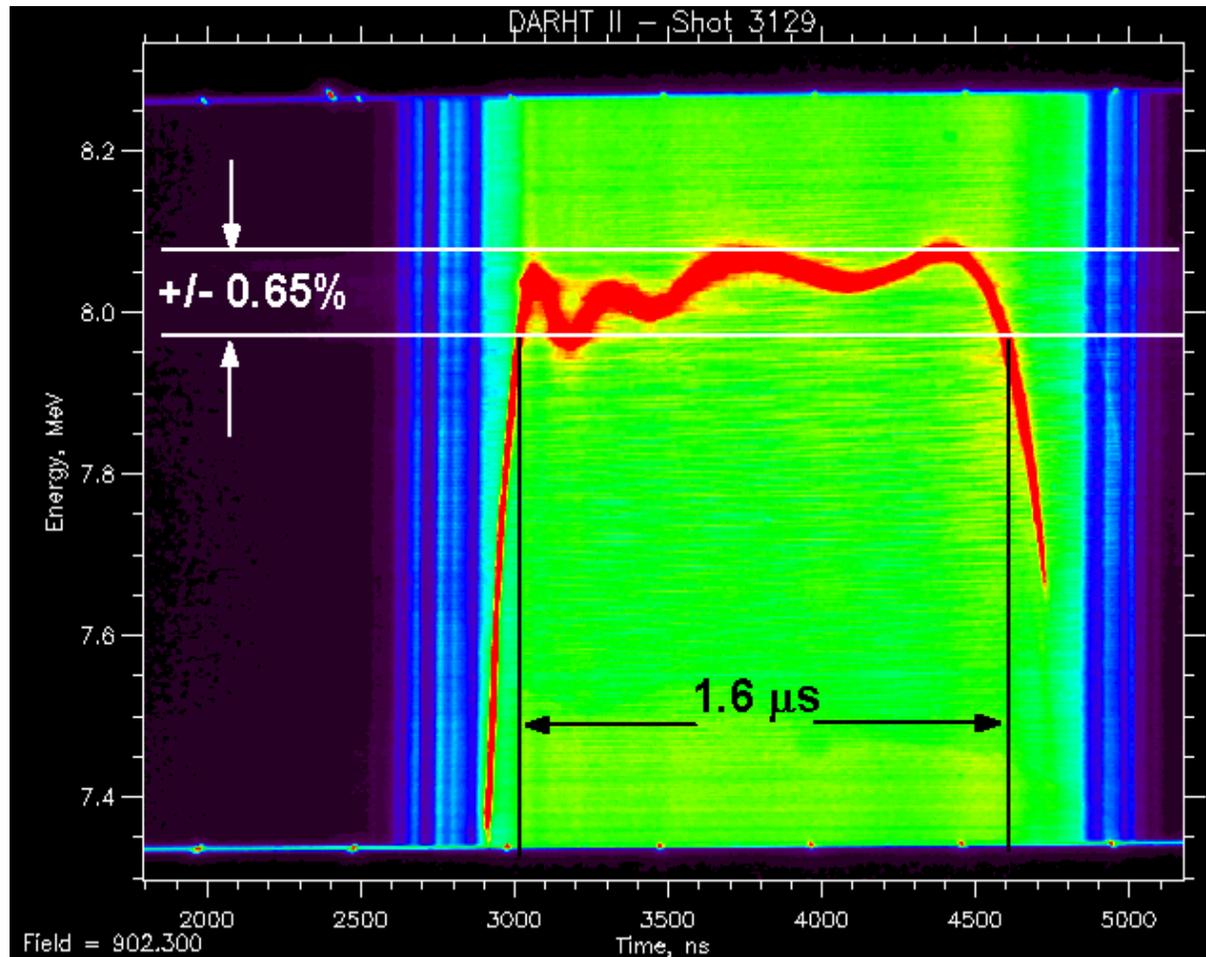
	Scaled Accelerator	Full Energy Accelerator
Injector	2.0 MeV	2.5 MeV
Injector Cells	0.6 MeV	1.4 MeV
Accelerator Cells	<u>5.4 MeV</u>	<u>14.2 MeV</u>
Total	8.0 MeV	18.1 MeV

Project Requirement is	16.5 MeV
Project Goal is	18.0 MeV



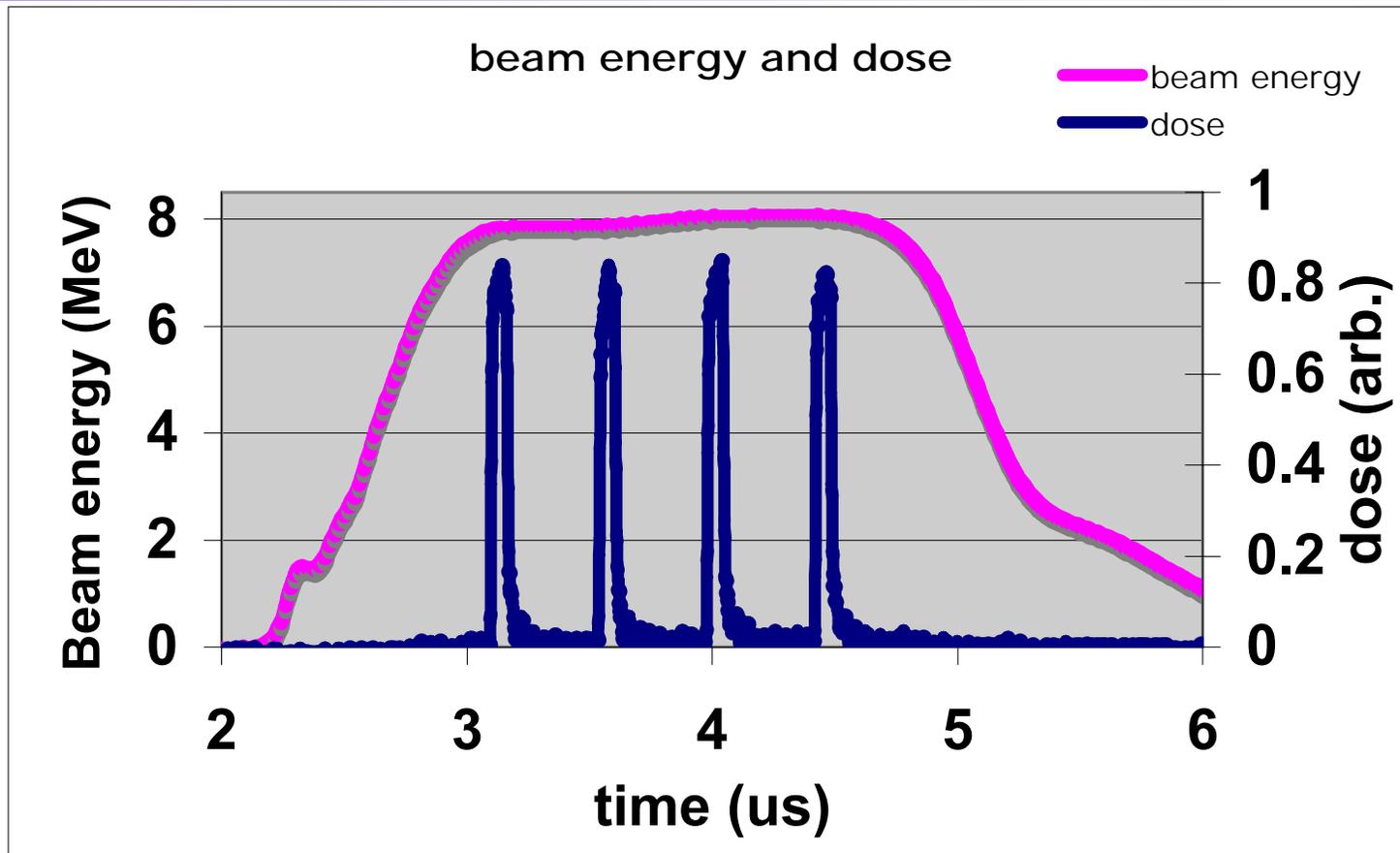
# The Kinetic Energy Measured with a Magnetic Spectrometer at the Scaled Accelerator Exit was within $\pm 0.65\%$ over $1.6 \mu\text{sec}$

Shot 3129





# The X-Ray Dose Rate for all Four Pulses Remains Approximately Constant

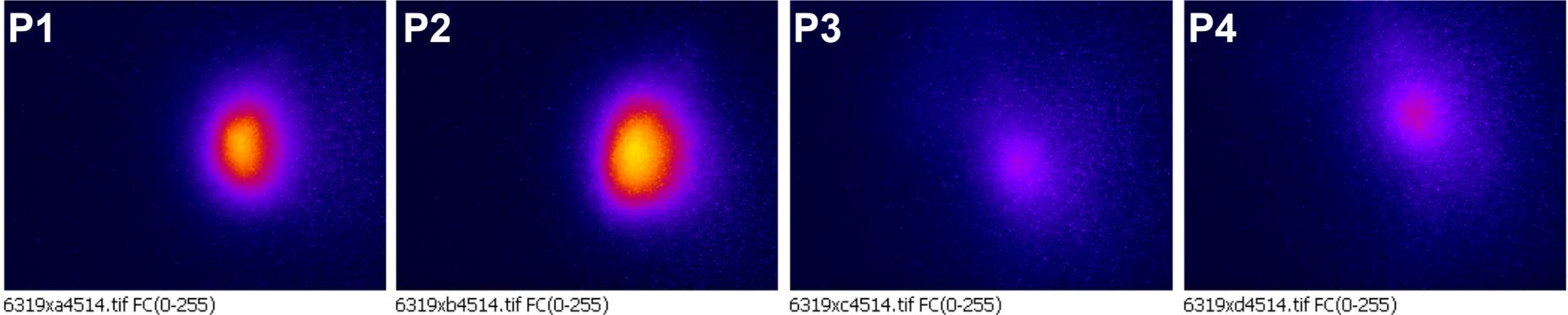


Scaled Accelerator Test Data

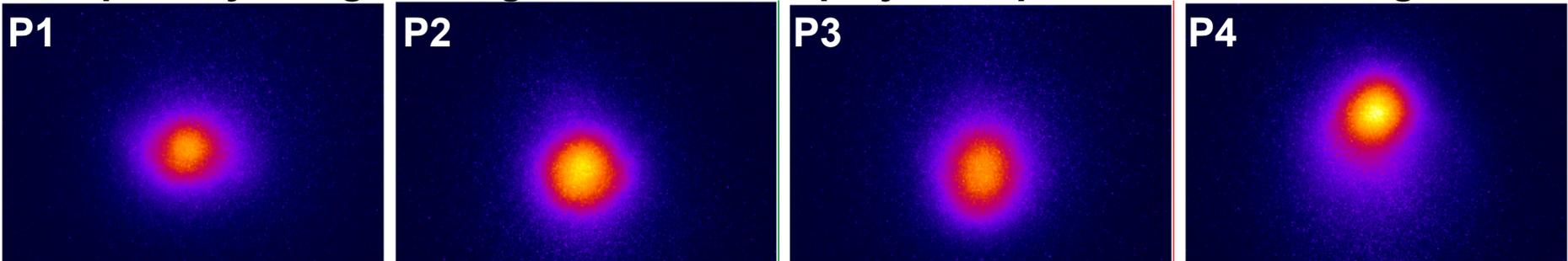


# DARHT 2<sup>nd</sup> Axis is on Track to Provide Unprecedented Hydro Test Data

Conventional target will not support the generation of 4 X-ray pulses



Specially designed target should meet project requirements\* & dose goals

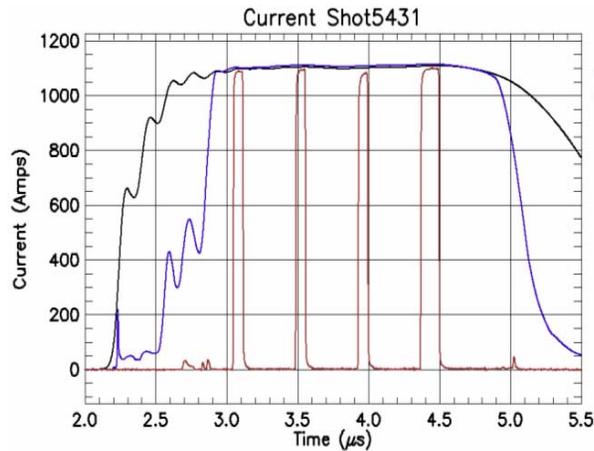


Measured beam spot sizes are ~1 mm FWHM for all 4 pulses

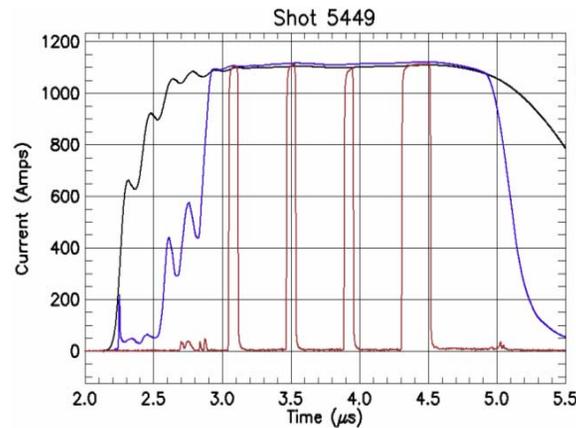
**\*DARHT-II requirement: 4 pulse with FWHM <1.6 mm**



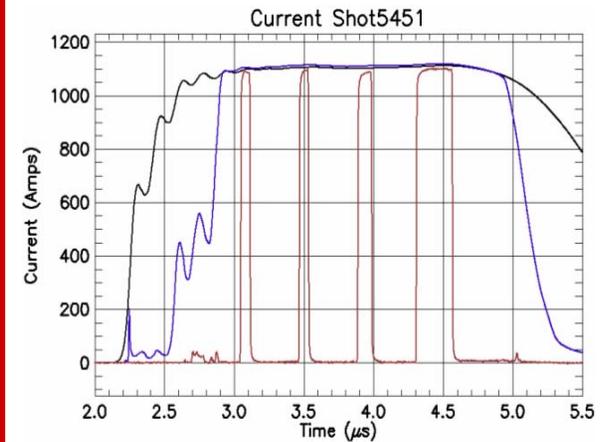
# Kicker Pulse Formats Exceed the Pulse Lengths Needed to Achieve the X-ray Dose Goals



**Four pulses**  
**60 ns**  
**60ns**  
**60 ns**  
**120ns**



**Four pulses**  
**60 ns**  
**60ns**  
**60 ns**  
**200ns**  
Format expected to meet  
the x-ray dose goals of  
**100R, 100R, 100R, 300R.**

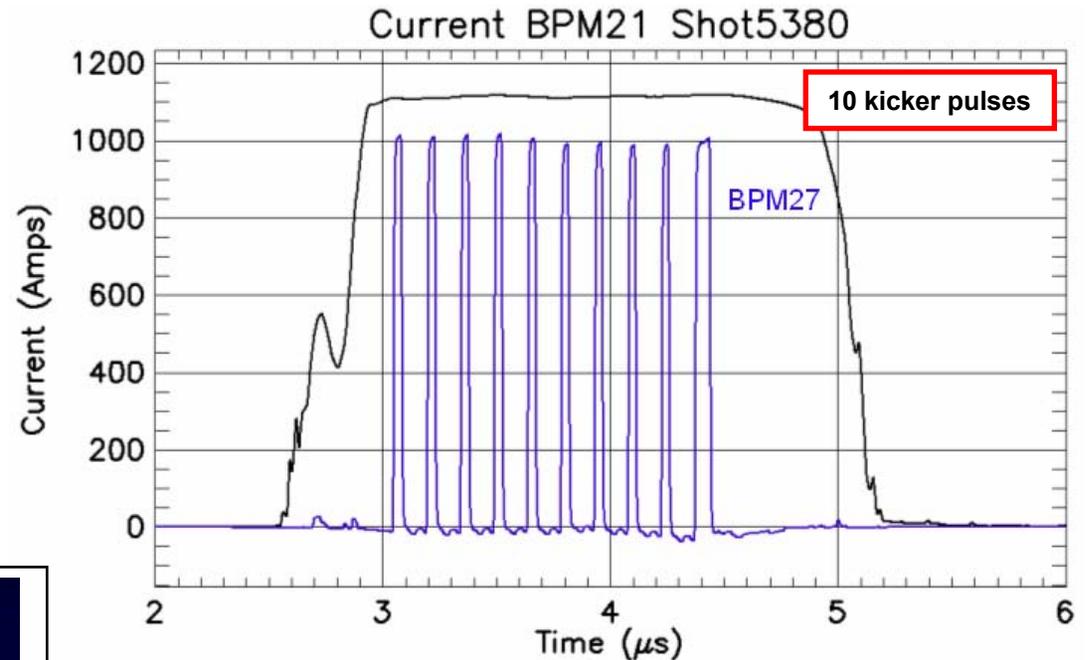
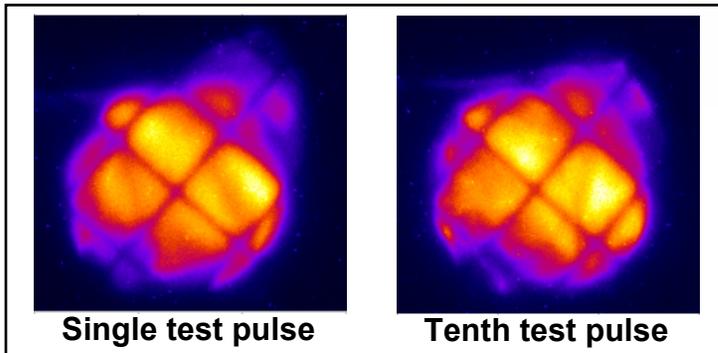
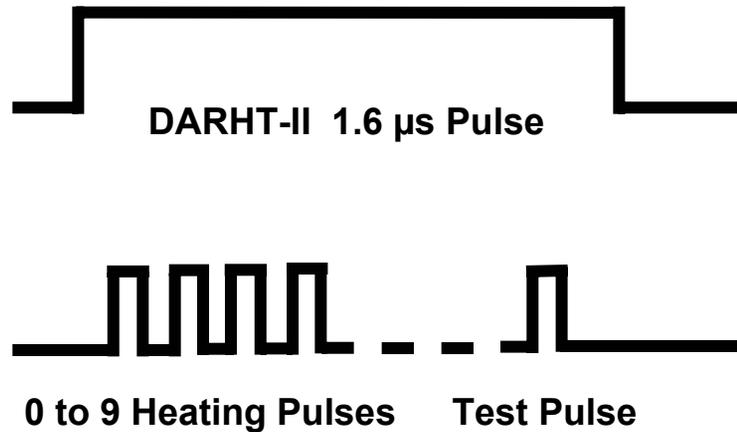


**Four pulses**  
**60 ns**  
**60ns**  
**90 ns**  
**250ns**

**Ability to tune pulse formats offers flexibility.**



# The Septum Edge Heating by the Beam was Studied and no Effect on the Beam was Observed



***No Effect on Beam Observed, even when Tested to 150% of Nominal Septum Heating at Full Energy***

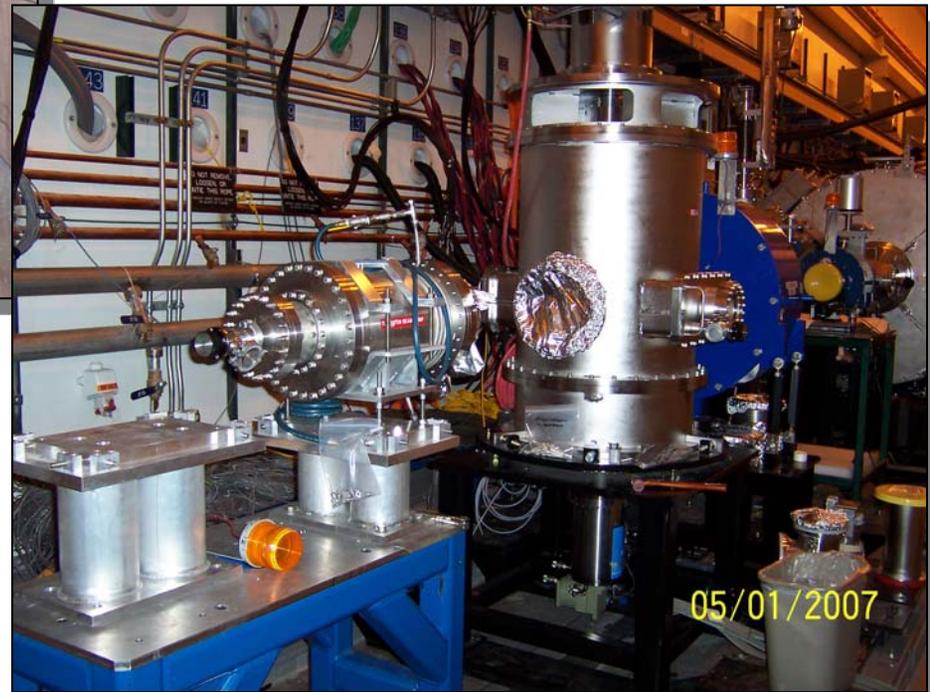


## Installation of the Full Energy Accelerator Began in February after Completion of the Scaled Accelerator Tests



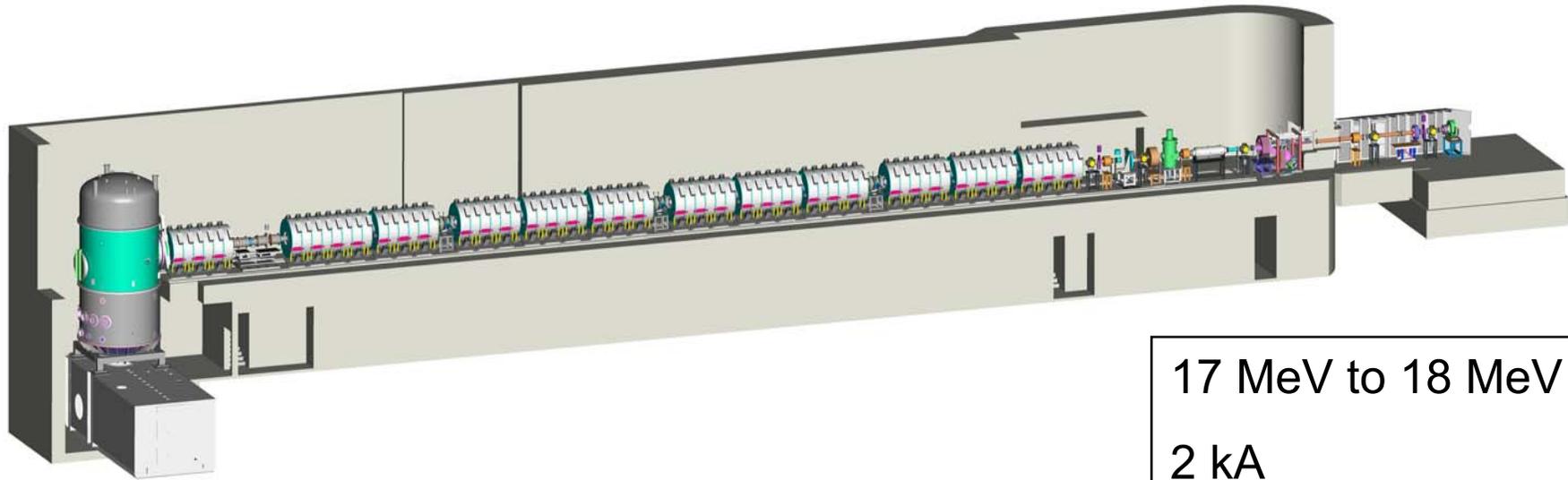
Accelerator cells  
installed and ready for  
integration

The commissioning  
diagnostics station being  
assembled at the exit of  
the accelerator





## Commissioning of the Full Energy Accelerator Began in June 2007



17 MeV to 18 MeV

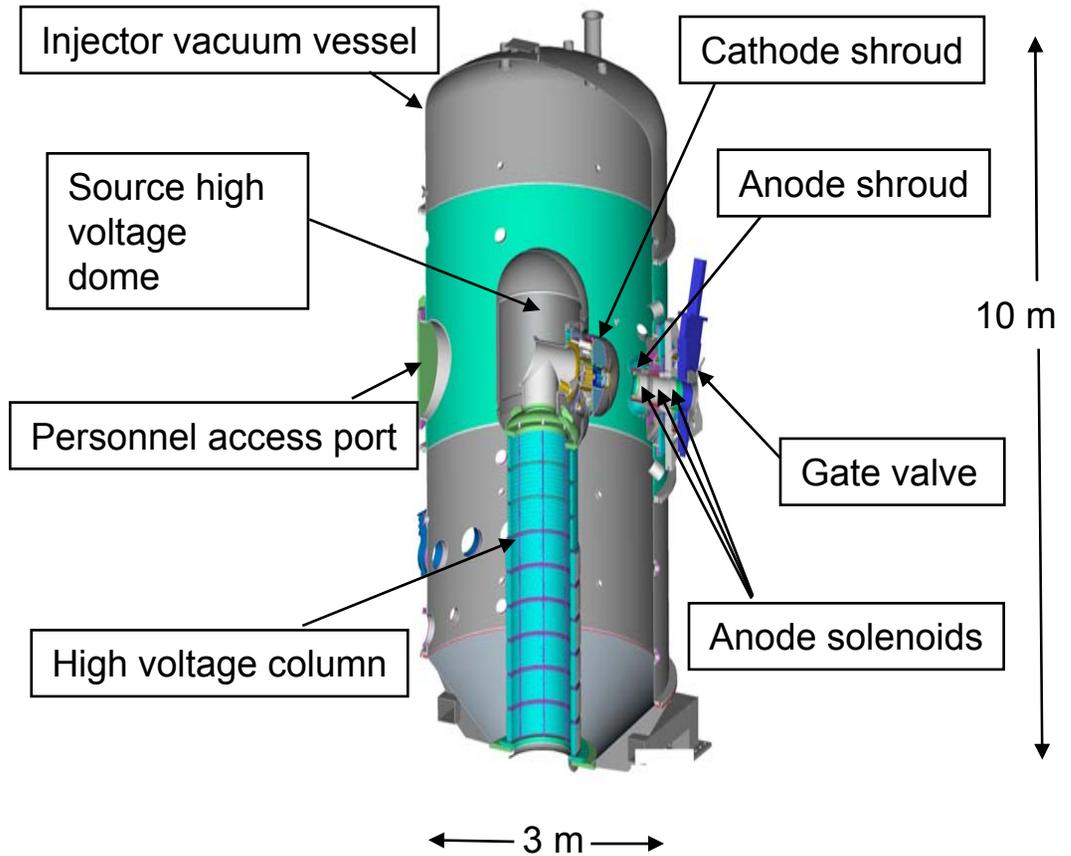
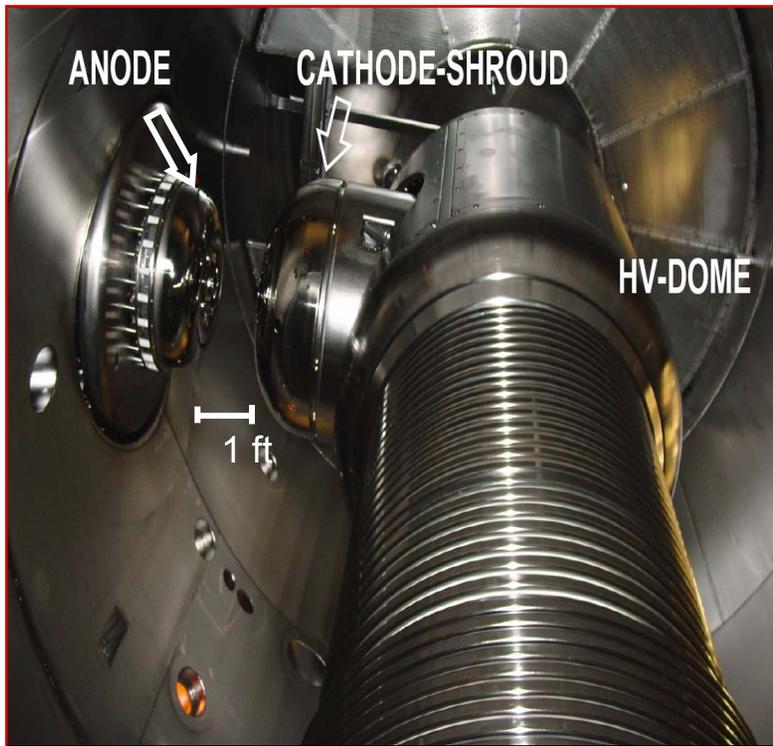
2 kA

1.6  $\mu$ s

- Multi-pulse X-ray performance to be demonstrated by April 2008
- Integration of the 2nd axis into the DARHT Facility will then begin
- First dual axis hydro test will occur as early as May 2008

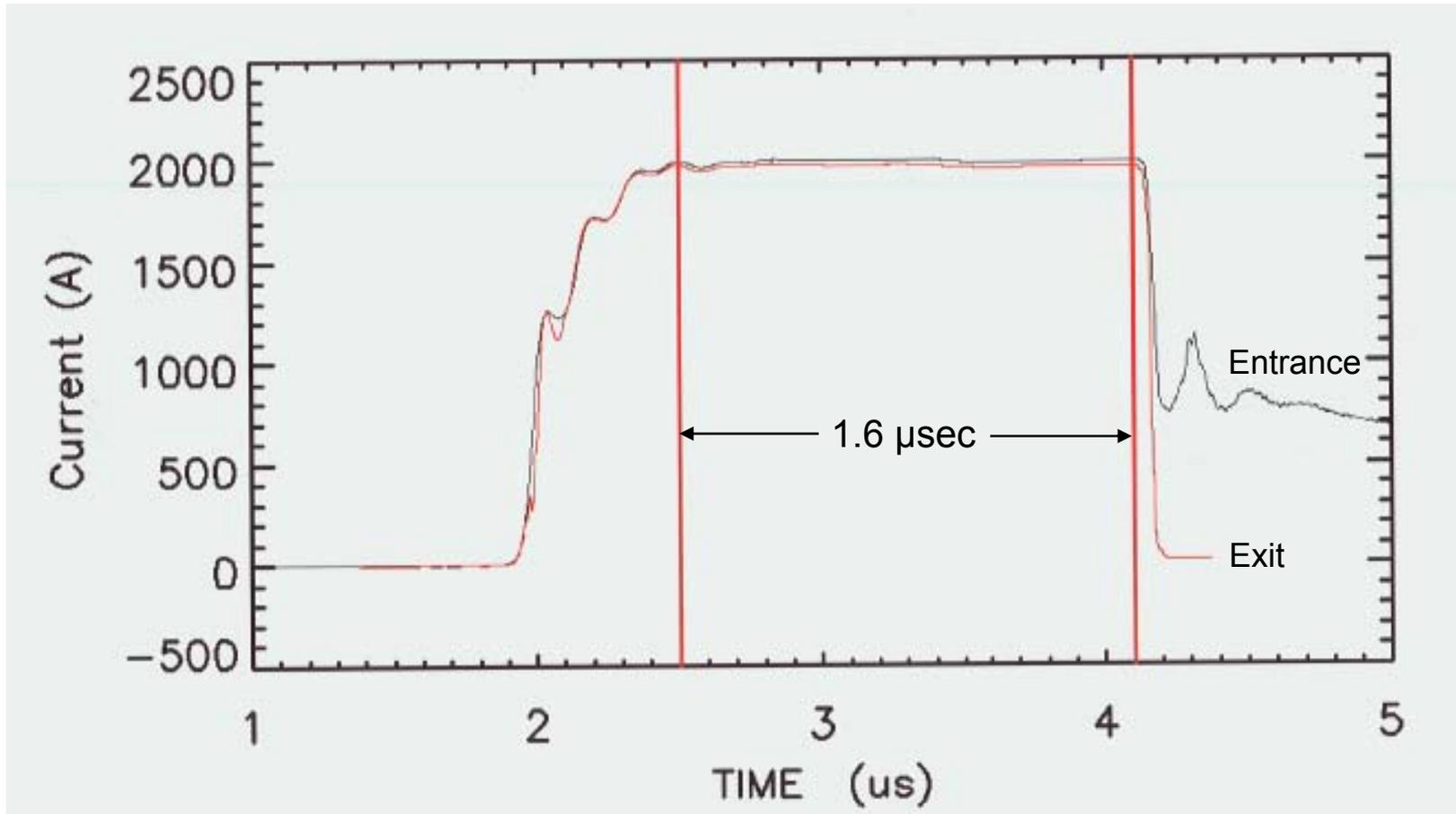


# The Injector has Successfully Operated at 2.5 MV, 2 kA with a Pulse Length of $\sim 2 \mu\text{sec}$ FWHM



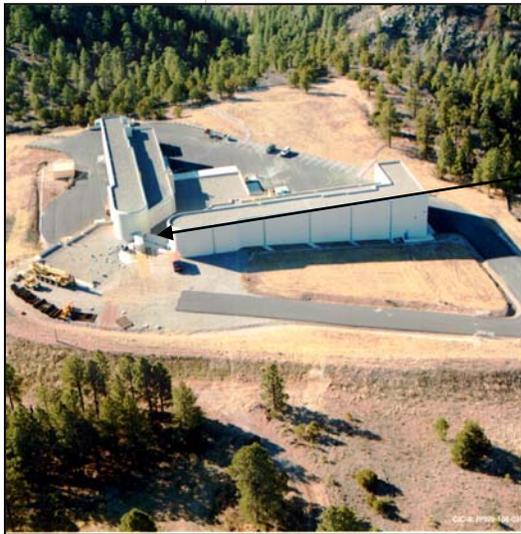


# A 2 kA, 1.6 $\mu$ sec Flat-top Beam has been Transported Through the Accelerator to an Energy of 17 MeV

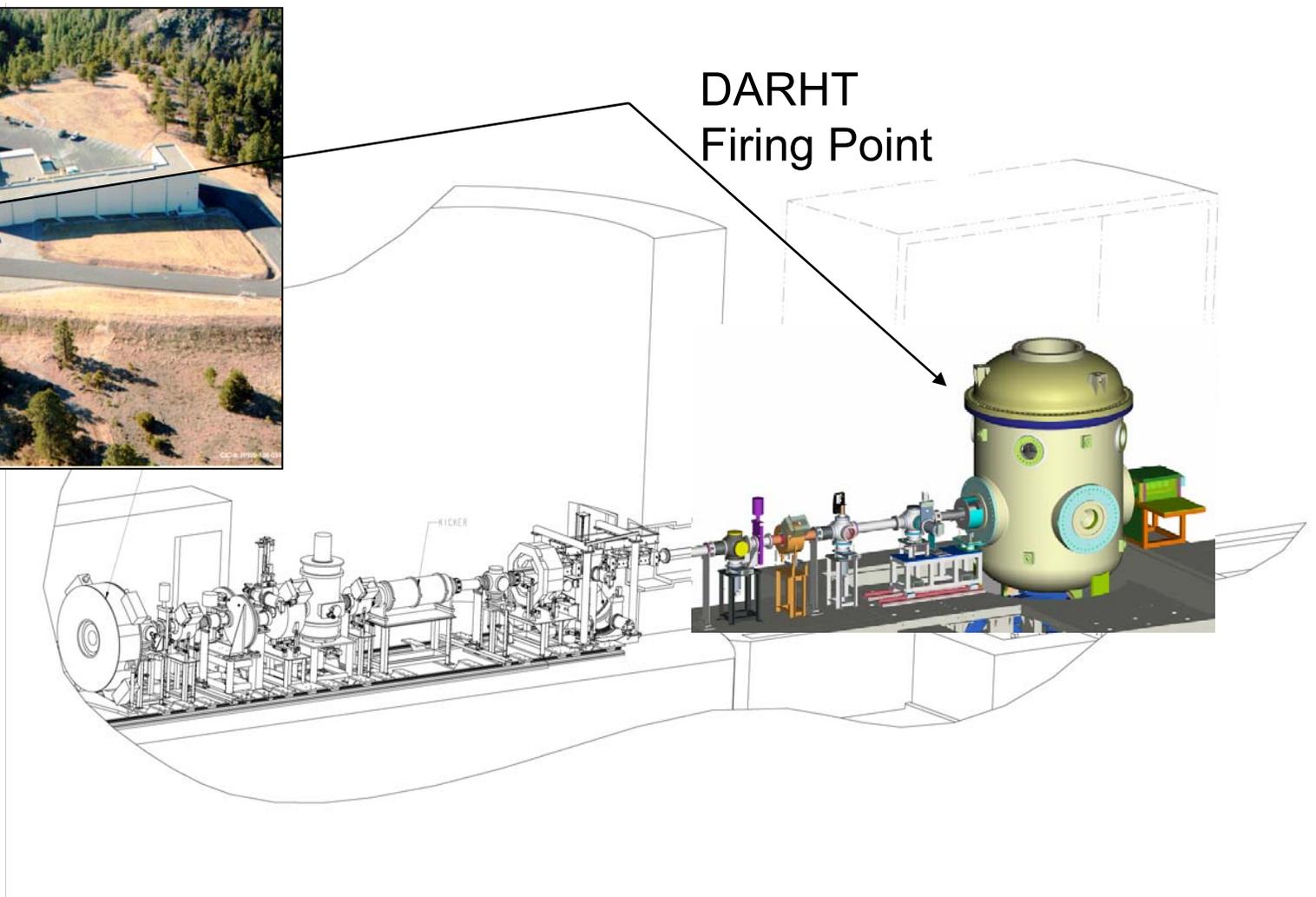




# The DARHT Project will Provide Four Radiographic Pulses into a Containment Vessel.

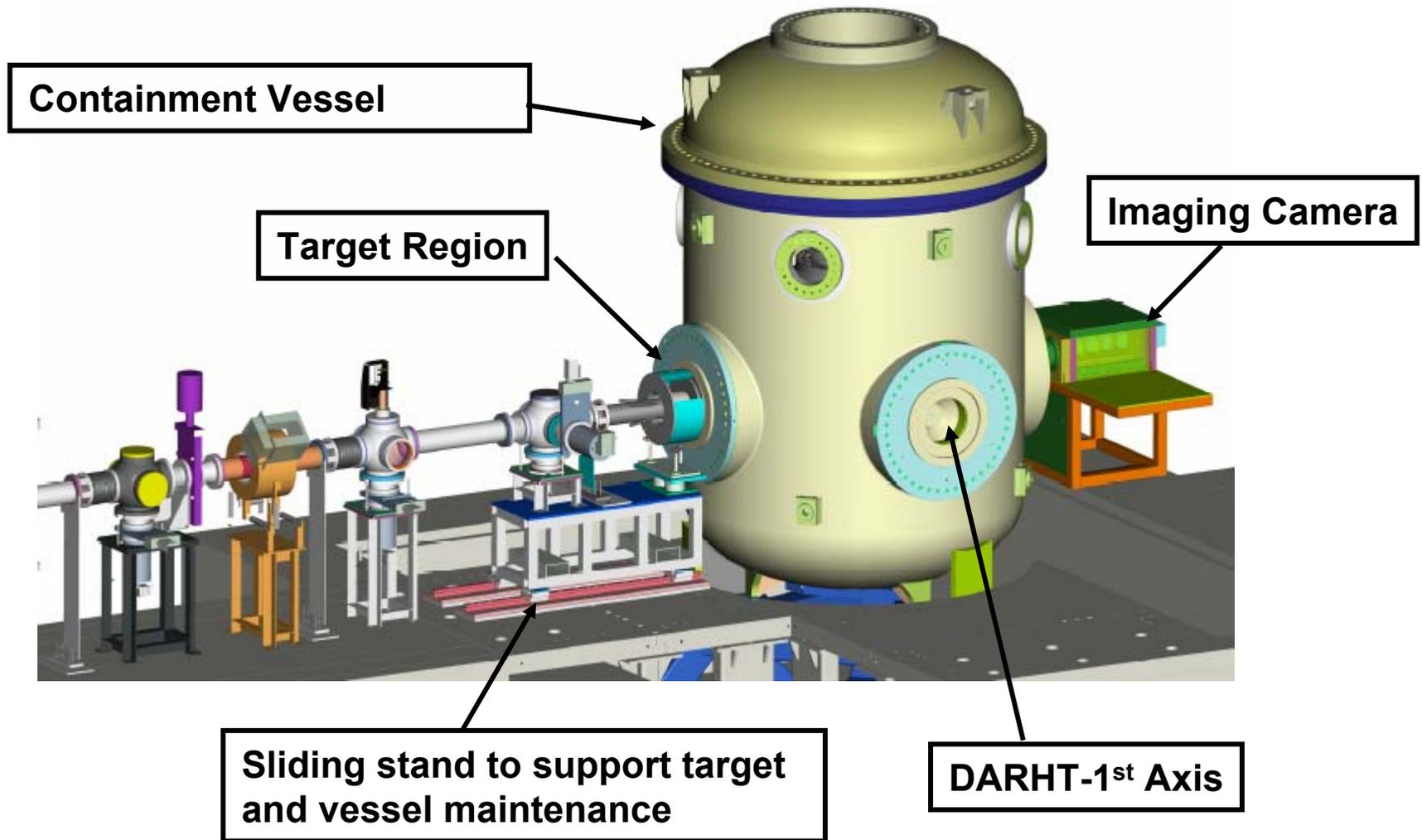


DARHT  
Firing Point





# The X-ray Conversion Target Configuration has been Integrated with the New Safety/Containment Vessel





## Remaining Major Project Milestones

<b>Milestones Name</b>	<b>Baseline / Planned Date</b>
<b>Start Full Energy Commissioning</b>	<b>June 2007</b>
<b>Commissioning to Beam Dump Complete</b>	<b>July 2007</b>
<b>Full Energy, Multi-Pulse X-ray Delivery</b>	<b>Feb 2008</b>
<b>Accelerator ready for Hydro-testing</b>	<b>May 2008</b>



# Early in 2008, the DARHT Facility will have Dual-axis, Multi-pulse Radiography Capability

