



# **Operational Enhancements for the Los Alamos Neutron Science Center Isotope Production Facility**

*Martin Pieck for the Project Team*

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# Where are we Located?

Los Alamos, New Mexico,  
Southwest of the U.S.A.  
South End of Rocky Mountains

Rocky Mountains

Los Alamos Town Site  
& Residential Areas

Los Alamos  
National  
Laboratory  
(LANL)

Los Alamos Neutron  
Center (LANSCE)  
which hosts Isotope  
Production Facility

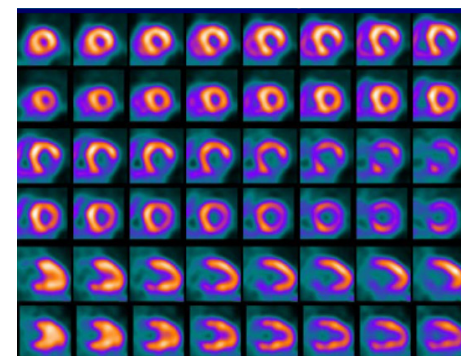


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# Isotope Production Facility (IPF) produces Isotopes for a variety of Applications



- **LANSCE** provides pulsed beams of protons and neutrons to five experimental facilities serving an international scientific community
- **IPF** focuses on the Supply of Domestic Isotopes
  - **Production of Medical Isotopes** for Positron Emission Tomography Scan; ~30k patients/month
  - **Global Security Applications** to improve physics codes and support cross section measurements
  - **R&D Efforts** including Environmental Science



Positron Emission Tomography Scan of a Heart

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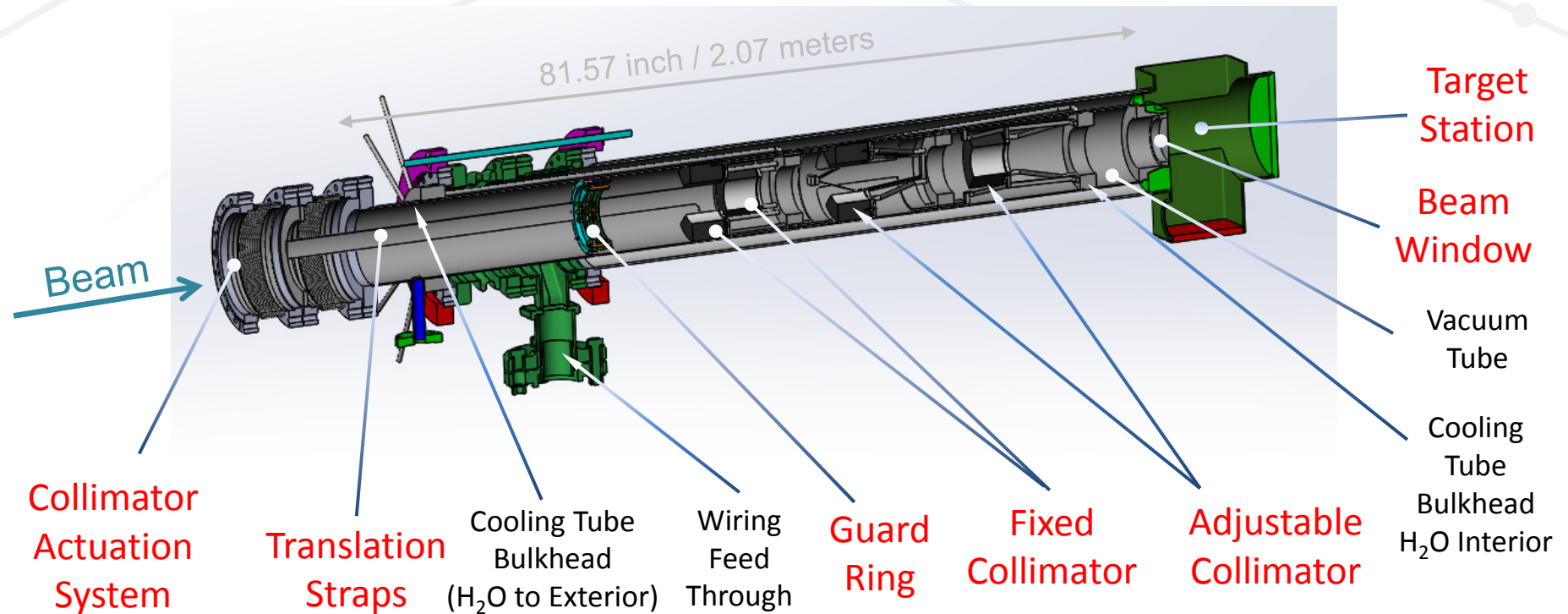
# IPF's Operational Enhancements were enabled through the Execution of an Upgrade Project

- Reduce Programmatic Risk with respect to anticipated Beam Window failure
- Enhance Isotope Production Capacity through a greater collimator aperture, improved beam rastering, and higher beam current
- Enhance Reliability with improved Diagnostic capabilities
- Project Scope included:
  - **Beam Window,**
  - Guard Ring,
  - **Active & Adjustable Collimator,**
  - **Beam Window Deflection Measurement,**
  - **Beam Raster System,**

*Beam Window Assembly*

  - Beam Diagnostics
    - Slit & Harp (Emittance),
    - Wire Scanner (profile)
    - **Beam Energy, Beam Position & Phase Monitor**
    - Low Intensity Beam Current,
  - Interlocks and Protection, and Controls.
- This 2 year, \$6.4M project was executed with an equivalent of ~12 Full Time Employees (6 a year), however, 64 different people participated
- The interdisciplinary capabilities were provided by **LANL's Accelerator Operations & Technology division** which is responsible for operating, maintaining and enhancing the LANSCE accelerator.

# Overview: Redesigned Beam Window Assembly hosts numerous Engineering Advancements



- Redesigned Beam Window better accommodates a range of beam sizes, energies & intensities
- New Adjustable Collimator provides variable aperture size which can be changed remotely
- The upstream fixed collimator protects the adjustable collimator mechanism from errant beam. Furthermore a guard ring provides additional protection.
- Each Collimator Segment is capable of incident beam current and nominal temperature measurements while simultaneously being water cooled

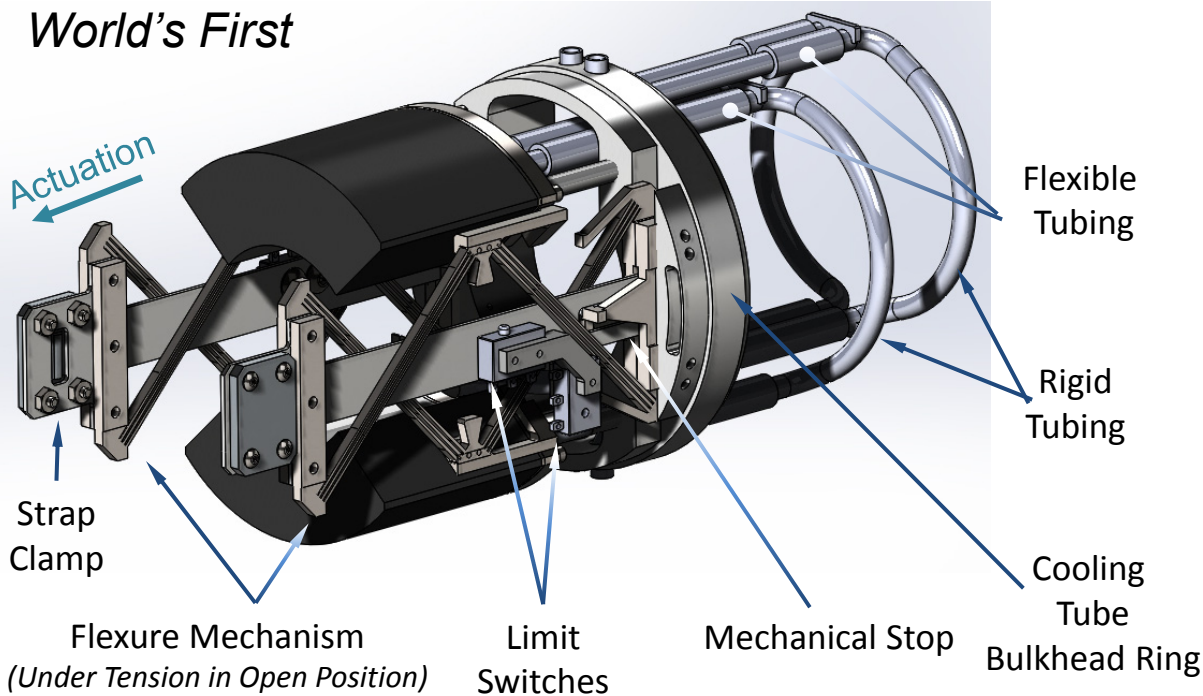
# Active & Adjustable Collimator Enables Variable Aperture Sizes



Titanium Flexure Mechanism

- Var. aperture: 1.4"-2.3" (~36-58mm)
- Second unit is rotated by 90 deg.
- Driven by a strap & protected by limit switches and mechanical stops
- Water tubing for thermal mgmt.

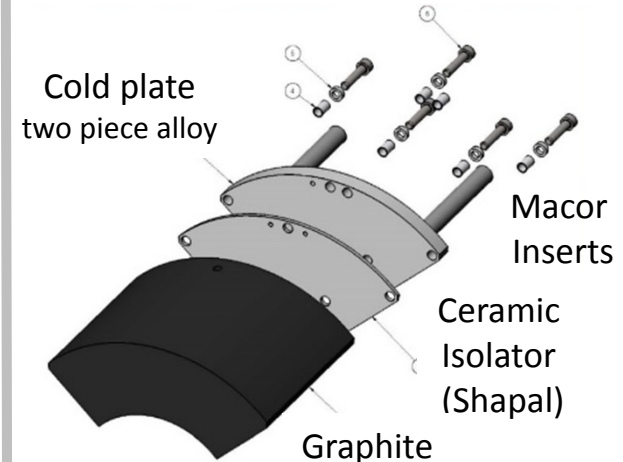
*World's First*



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## Collimator Segment Assm.

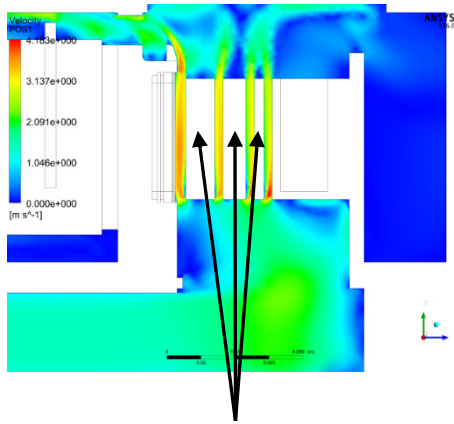
- Cold Plate electrically isolated but thermally coupled to the Graphite
- Machinable Ceramic – Shapal; elec. isolator but good therm. conductivity
- Set of screws isolated by Macor inserts + solder



# Beam Window Parametric Design Study for Survivability

included different: beam sizes, energies & intensities, in order to determine the sweet spot for the beam window thickness & shape

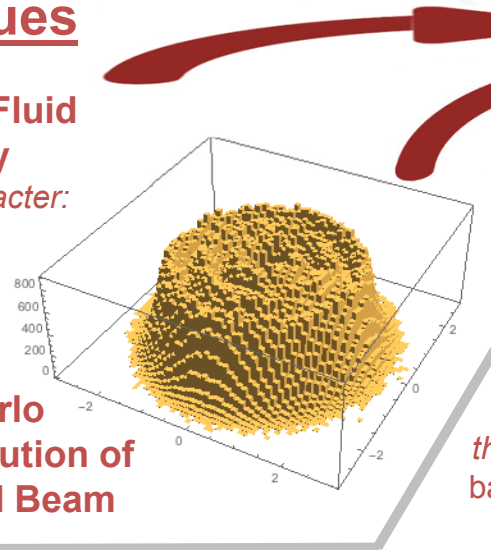
## Modeling & Simulation Techniques



Target Stack (3)

1a) **Computational Fluid Dynamic Study**  
cooling hydraulic character:  
i.e. pressure drop,  
velocity, etc.

1b) **Monte Carlo  
Generated Distribution of  
3-circle Rastered Beam**



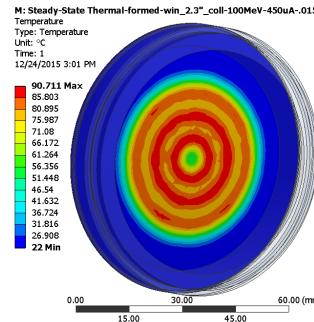
2 & 4) **Conjugate Heat Transfer (CHT) Model**  
thermal interaction  
between solids  
and fluids  
thermal hydraulic  
characteristics

3) **Finite Element Model  
using CHT solution**  
thermal mechanical stress & deformation  
based on the window temperature profile  
and applied structural loads

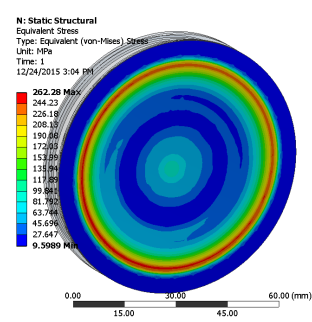
## Thermal-Mechanical Design Modeling resulted in a new Beam Window design

- Accepts Beam Currents in excess of 450  $\mu\text{A}$
- DTL Beam Energy 41, 72 & 100 MeV
- Pre-formed shape with a 1 mm deflection which is consistent with the 1.2 mm deflection on the previous window which was flat
- Thickness: 381  $\mu\text{m}$  (reduced from: 635  $\mu\text{m}$ )

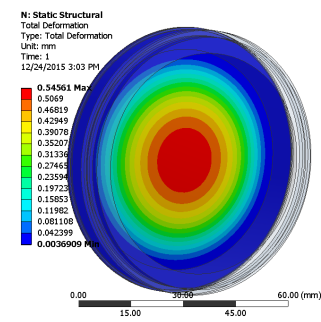
### Thermal Profile



### Thermal Stress



### Deformation



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# Beam Window Displacement Measurement

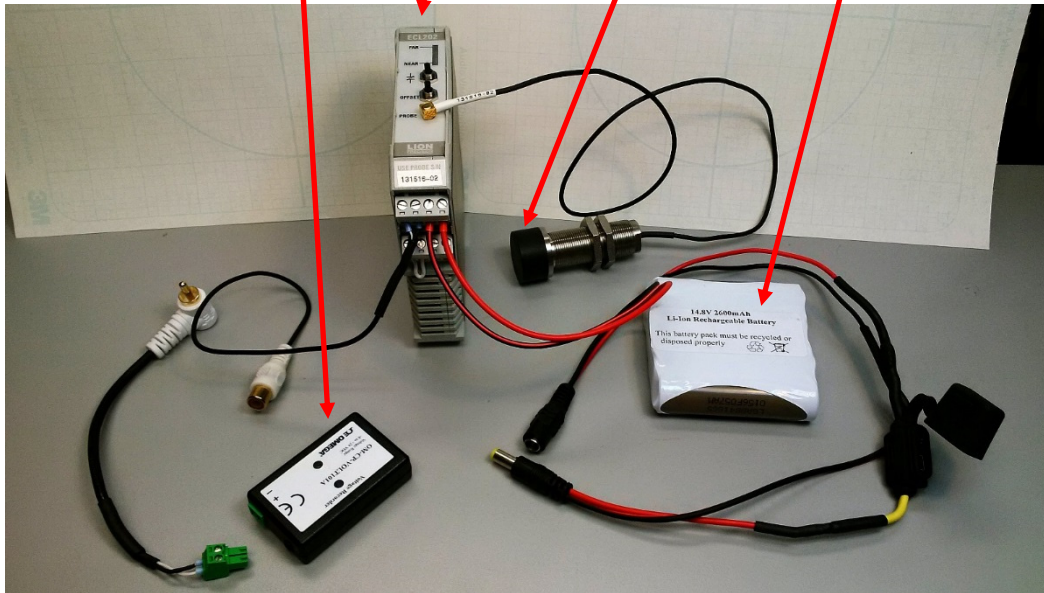
stand-alone data logger, using a eddy-current sensor, which provides high-resolution, noncontact displacement sensing over a small distance range

Data  
Logger

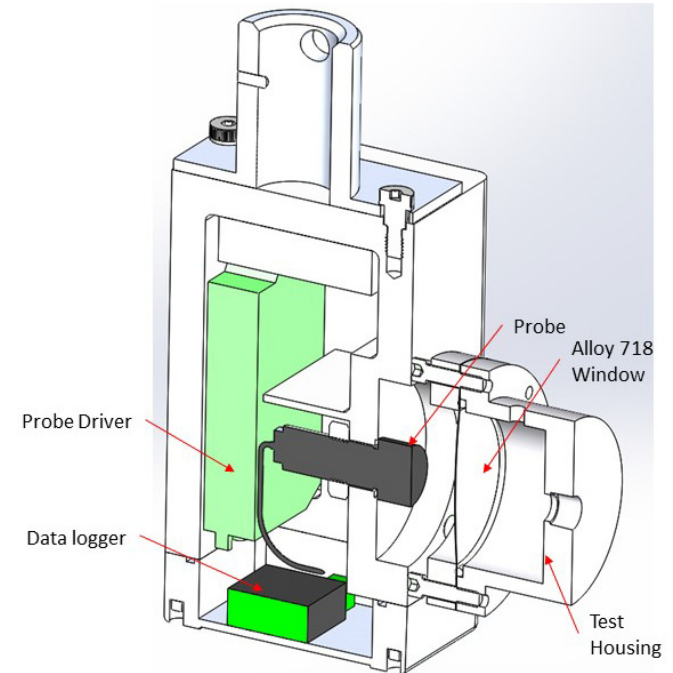
Probe  
Driver

Probe

Battery  
Pack



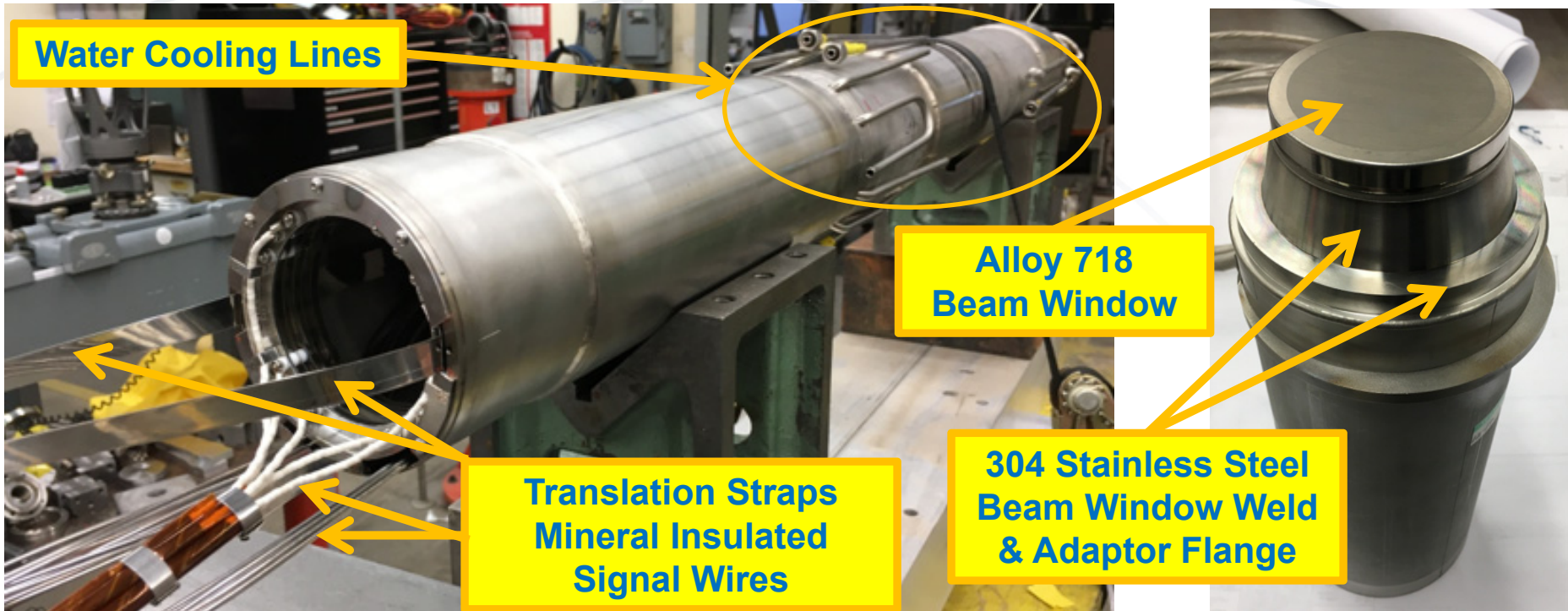
- Displacement Measurement Device Housing which can be attached to the target stack trolley and lowered to the beam window



- The system is capable of measuring the extent of beam window deflection with micrometer precision.

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# Beam Window Assembly Pictures



Top Left:

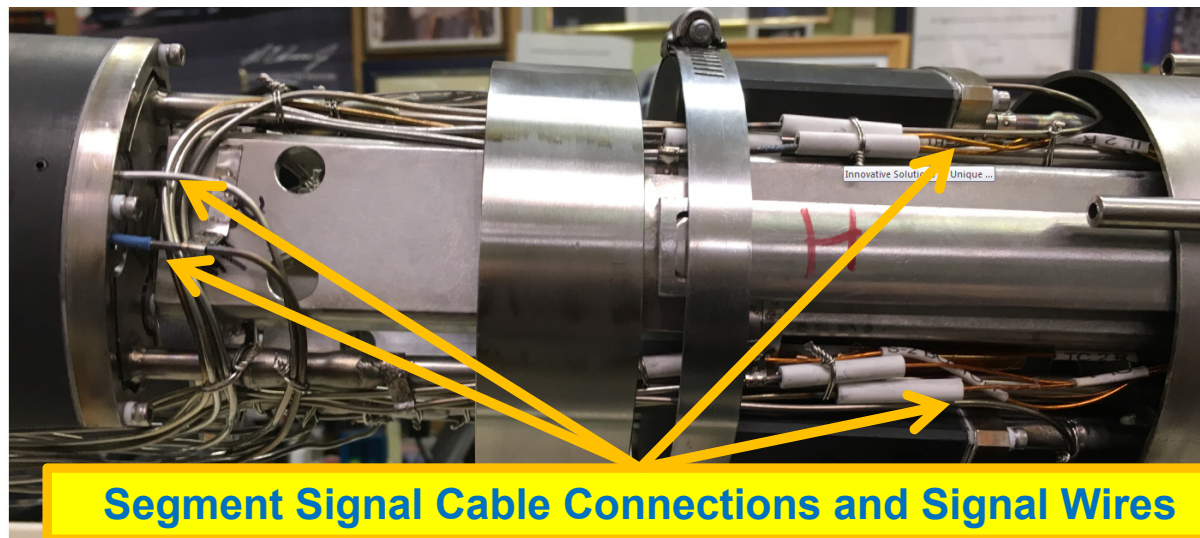
**Beam Window Assembly hosting Collimators and Guard Ring**

Top Right:

**Beam Window Assembly End Cap**

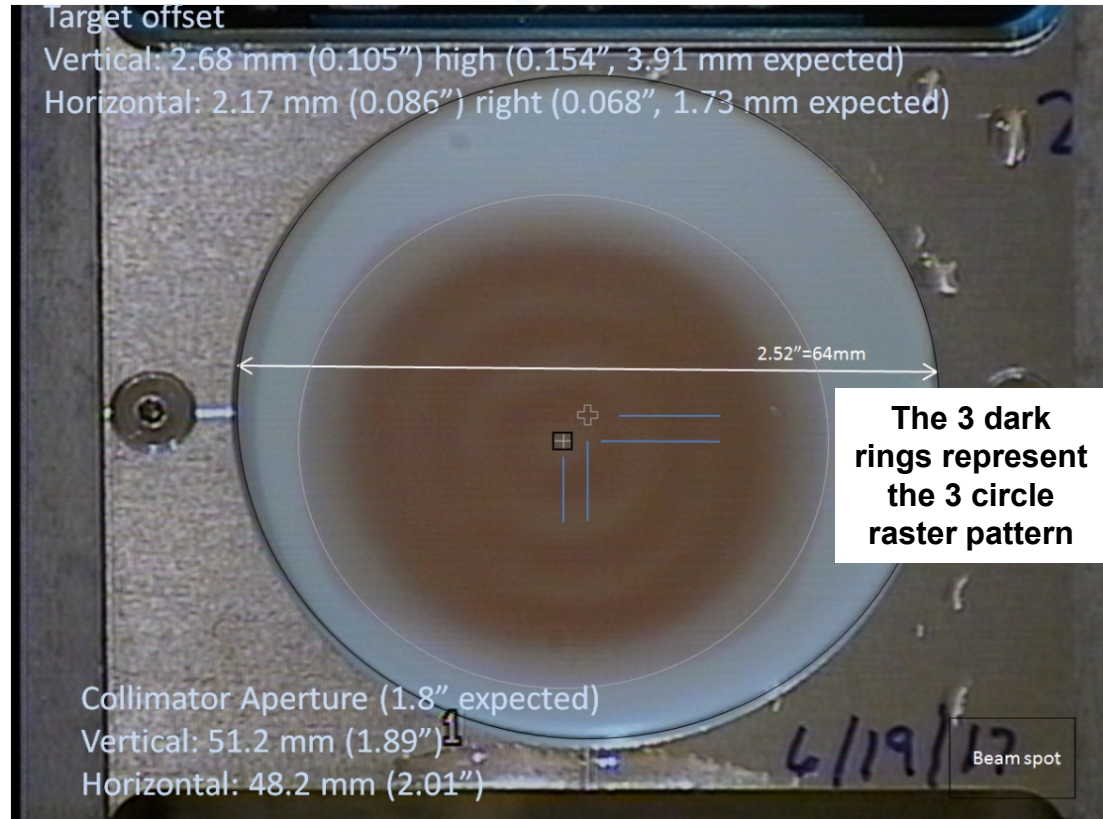
Bottom:

**Beam Window Assembly Fixed Collimator**



# Enhanced Beam Raster System enabling optimized Beam Power Distribution on Target

- A pair of power supplies are driven with sinusoids at 4.95 kHz to create a circular raster pattern of multiple predetermined diameters - up to 100 (World's First)
- During one IPF beam pulse of 625  $\mu$ s, 3+ circles of the same radii are delivered
- Predetermined ellipse axes can be adjusted on the fly  $\pm 10\%$  from the circle diameter
- As of today, one, three and five circle raster patterns have been tested and routinely used on different target sizes between 1.6"-2.5" (~41-64mm)

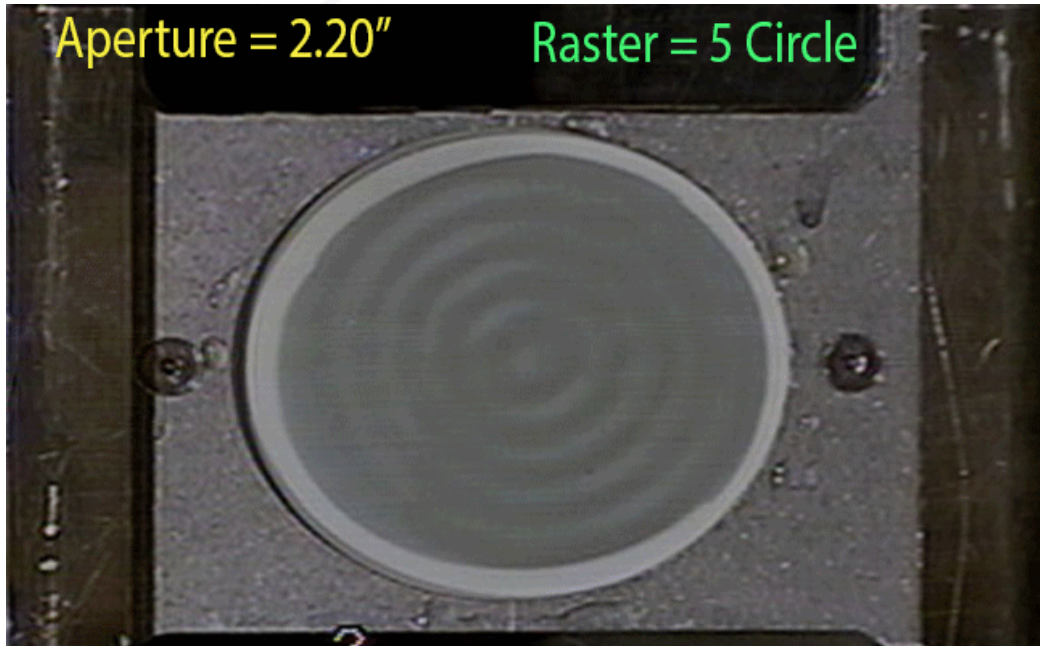


**3-Circle Raster Pattern on ~2 inch (~51mm) Target  
~42  $\mu$ A-min exposure**

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# Beam Raster System Protecting in Real Time against Errant Beam



## Test Runs:

From: 2.20" (~56mm) collimator aperture, 5-Circle, 100  $\mu$ A-min exposure

To: 1.47" (~37mm) collimator aperture, 3-Circle, 41.67  $\mu$ A-min exposure

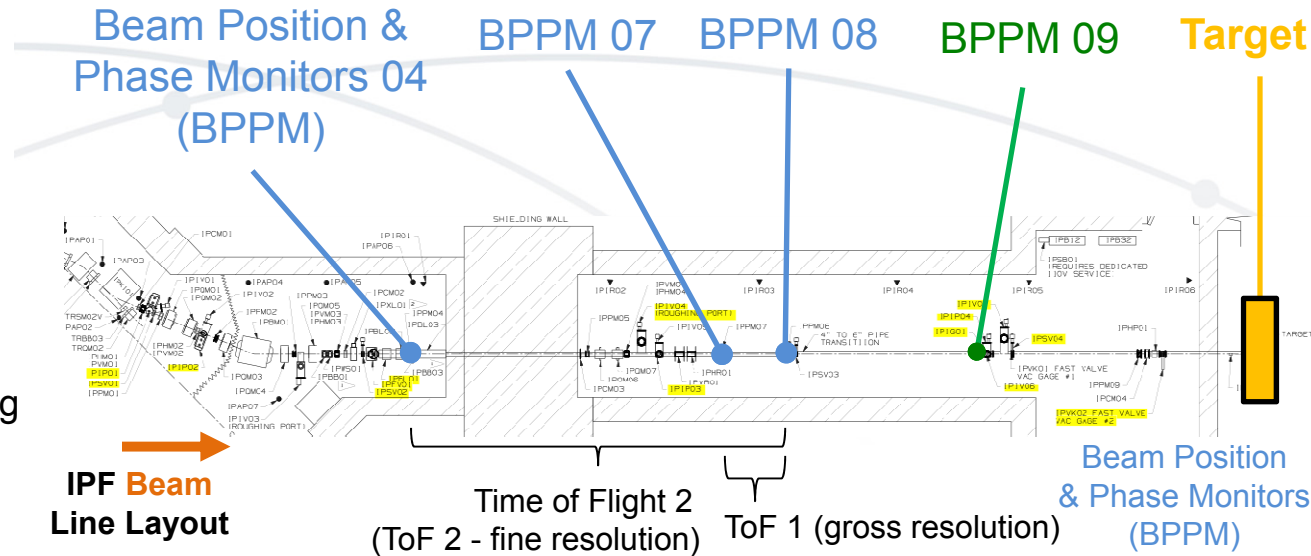
- Redundant protection system that checks raster pattern prior to & during beam delivery
- Beam delivery limits are set to protect the beam window not to exceed 200°C
- This translates to a worse case scenario where the beam needs to be turned off within 220  $\mu$ s or ~1/3 of the beam pulse
- Errant raster pattern is detected by comparing scheduled with measured raster magnets' voltages and currents

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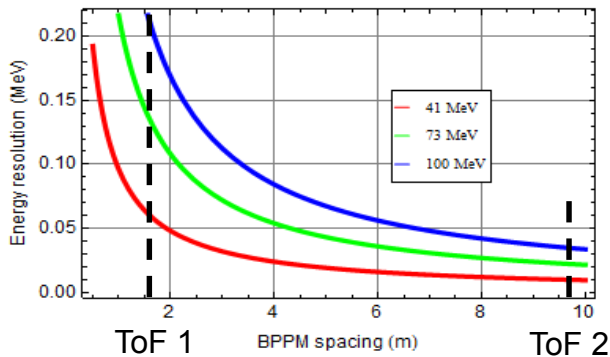
# Beam Energy Measurement Capabilities

- A new VPX/cPCI high speed data acquisition system utilizing existing Beam Position and Phase Monitors (BPPM).

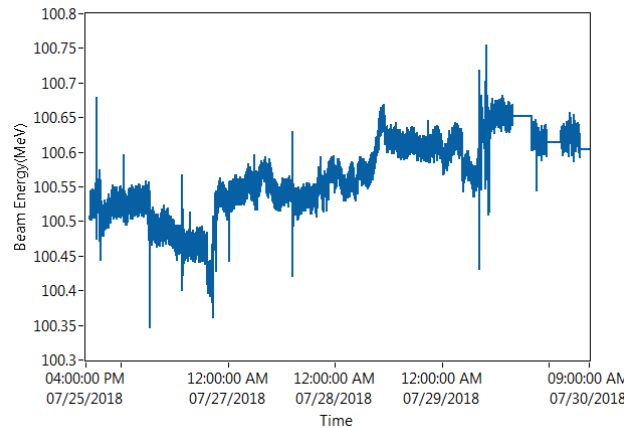


## Energy Resolution over BPPM Spacing

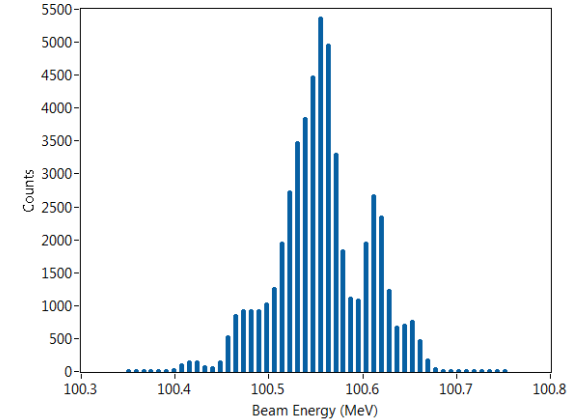
for 1° phase measurement precision



## Energy Timeline Measurement (5 days)



## Energy Histogram (5 days)

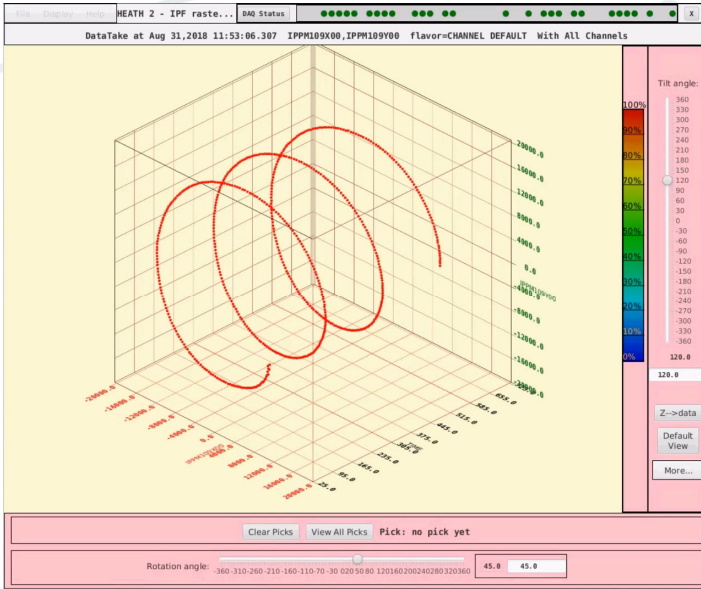


- The use of three BPPMs 04, 07 & 08 have the drift spacing between them that provides the gross and 50 keV fine resolution which was required for the IPF production.

- Energy measurements can be done at nominal drift tube linac operational energy levels of 41, 72 & 100 MeV
- Beam Phase Monitoring resolution of 0.25 ° or 3.45 ps at 201.25 MHz

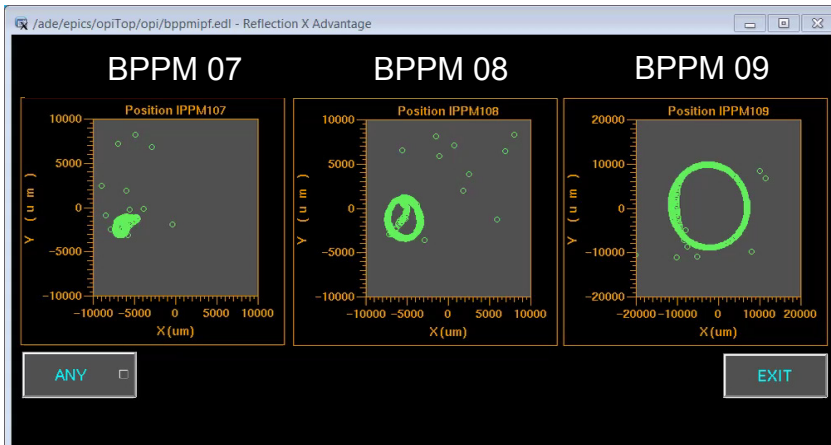
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# Enhanced BPPM Diagnostic Capabilities

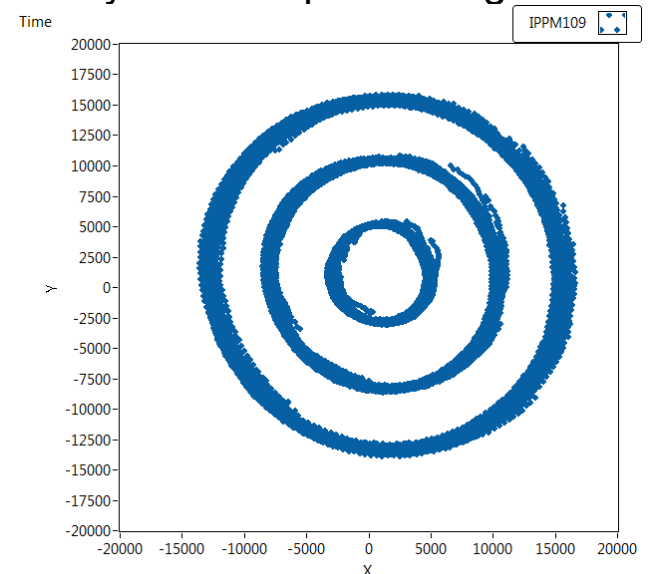


Circle Raster Pattern for 625  $\mu$ s Beam Pulse  
(Red & Green Axes: Position – Black Axis: Time)

- Circle Raster Pattern Pulse to Pulse analysis of the beam centroid with
  - Time Resolution: 1 microsecond
  - Position Resolution: 10 microns
- Multiple BPPM locations with expanding raster pattern as the beam approaches the IPF target.
- Time lapse measurement proves the repeatability of beam positioning near target.



Multiple Beam Position locations as the Raster Pattern expands toward the IPF Target



2 min Time Lapse Measurement of 3 circle raster pattern at BPPM 09

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# Selected Beam Window Assembly Fabrication Challenges

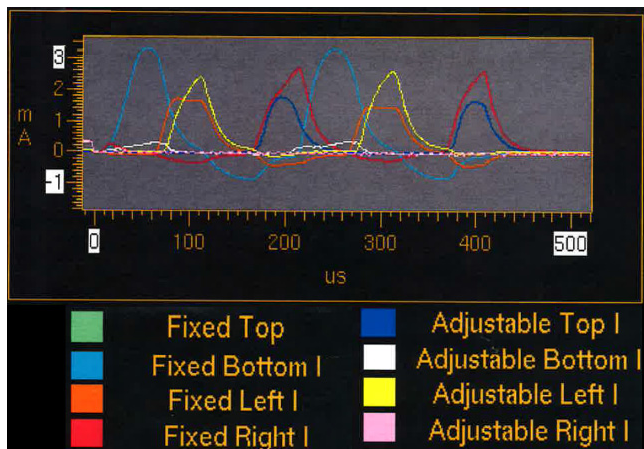
- The overall fabrication process was difficult, time consuming and provided challenges to make repairs after it was assembled – difficult to access
- The Mineral Insulated signal wires used did lose their insulating resistivity performance due to seal issues
- The connections of signal wires and thermocouples located in the collimator segment assemblies proved to be fragile
- The wire-routing, -strain relieve and -density put too much tension on the flexure mechanism (no spring back) such that it needed to be changed from pull to push-pull.
- *These Lessons Learned are being incorporated in the fabrication of the next beam window assembly – currently being assembled.*

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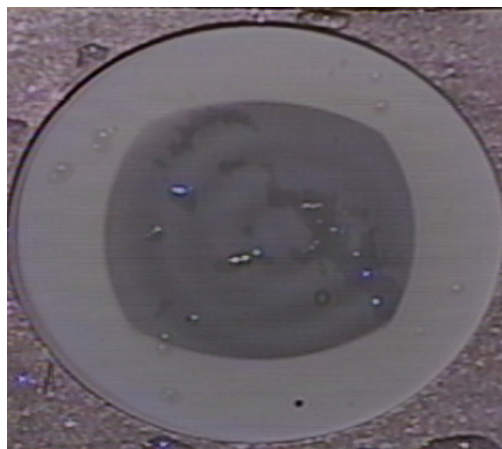
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# New Enhancements provide some Unique Operational Experiences

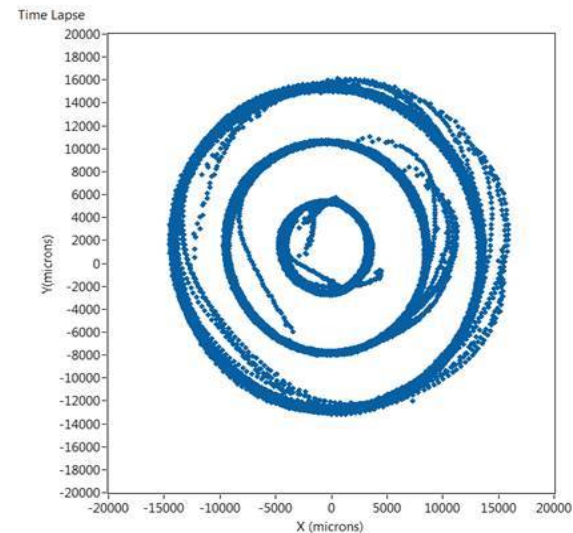
- Operators using active collimator signals for beam tuning
- At smaller collimator aperture the beam shadow is not exactly symmetric
- Previously unobserved changes in Beam Energy can now be visualized



**Fixed and Adjustable Collimator Segments Impingent beam signals based on a raster beam**



**3-Circle Raster Pattern  
1.47 inch (37 mm)  
collimator aperture  
14.67  $\mu$ A-min exposure**



**Erratic 3-Circle Raster Pattern**

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# Summary

- ***All the capability enhancements had a very positive effect on the operations & productivity of the Isotope Production Facility.***
  - ***The combination of***
    - world's first adjustable collimator with a larger aperture,
    - improved thermal-mechanical window design,
    - world's first multi circle raster pattern and
    - supported by improved beam diagnostics,
- => supports an increase of isotope production capacity by a factor 2.25***
- => the newly gained accuracy to which Incident Beam Energy is now known determines our ability to control the yield and purity of the isotopes we produce.***
- ***Given the improvements the Isotope Production Facility has recently set the world record for beam on a molten RbCl Target - 320  $\mu$ A (100 Hz)***

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# Thanks to the Project Team!



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