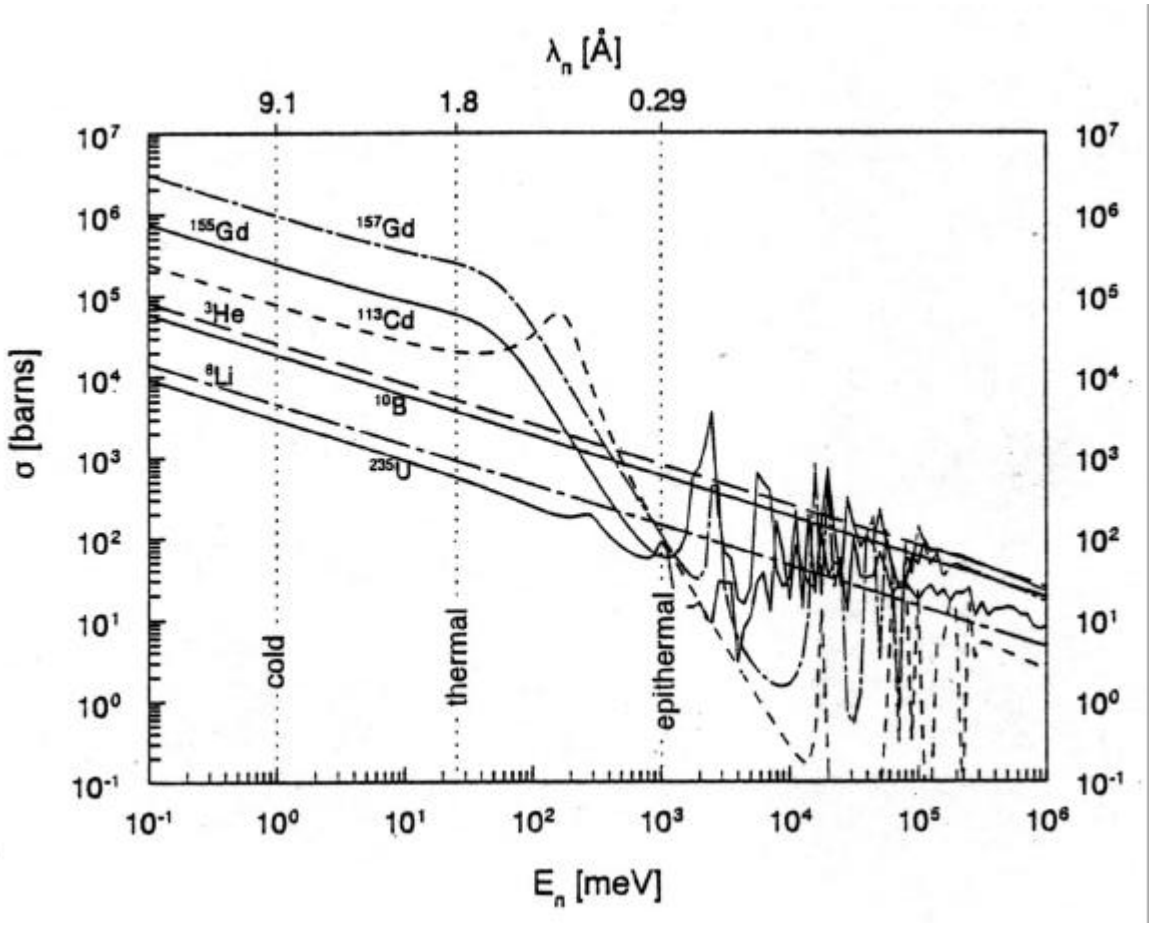
DESIGN, CONSTRUCTION AND COMMISSIONING OF AN ADVANCED 2D NEUTRON DETECTOR FOR PROTEIN CRYSTALLOGRAPHY

Graham Smith

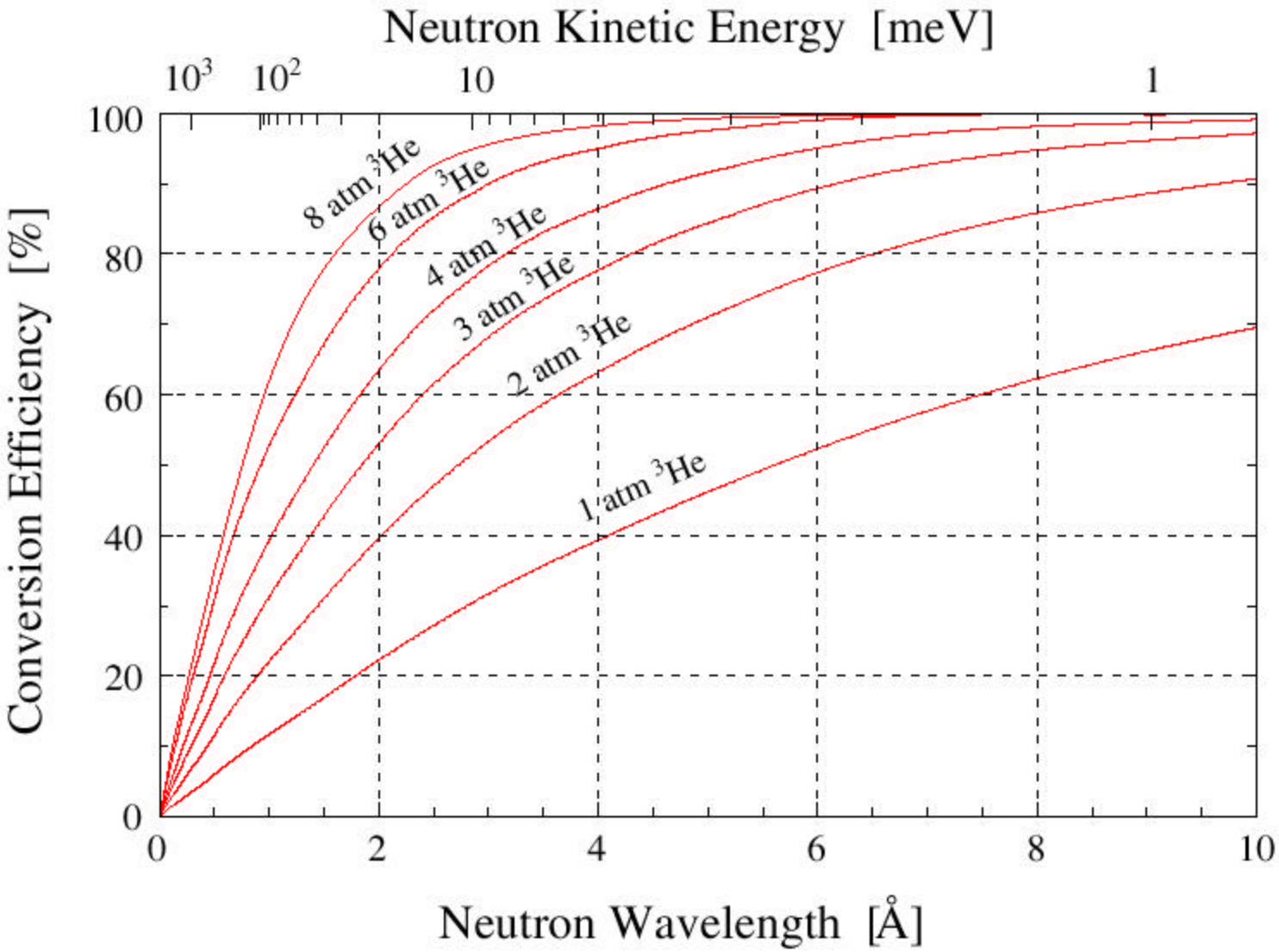
Gas Detector Group

Neutron Absorption Cross Sections



Conversion Efficiency of ^{3}He Filled Detectors

^{3}He (n, p) ^{3}H, Detector Gas Depth = 1.5 cm

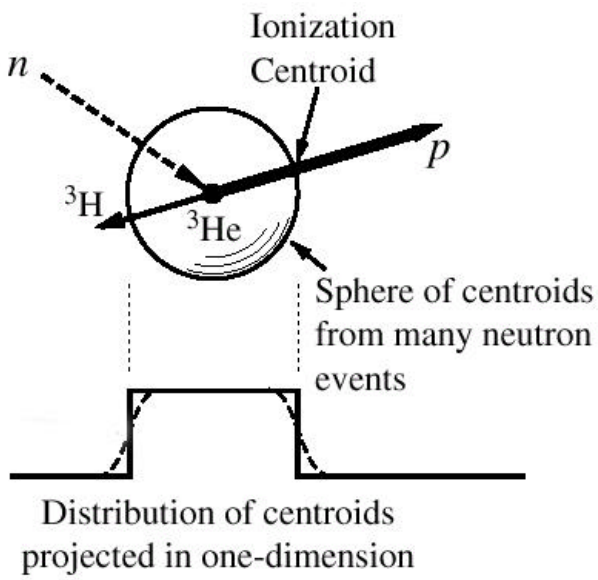


Proton/Triton Range and Position Resolution

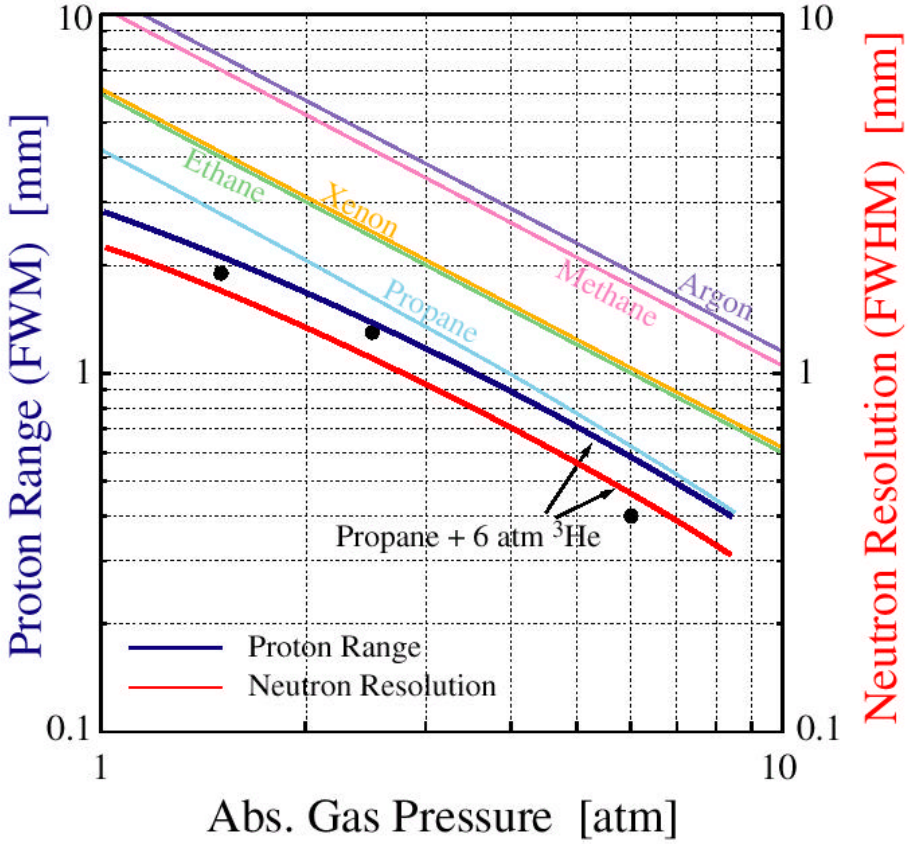
$n + {}^3He \rightarrow p + {}^3H + 764\ keV$

$\downarrow$

$\sim 3\times10^4$ ion pairs

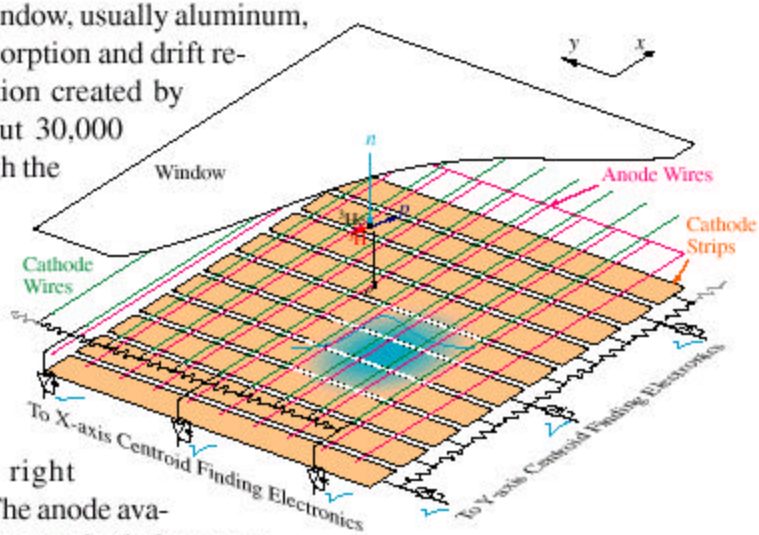


FWHM ~ 0.8 × Proton Range
(~4.2mm in atm. Propane)

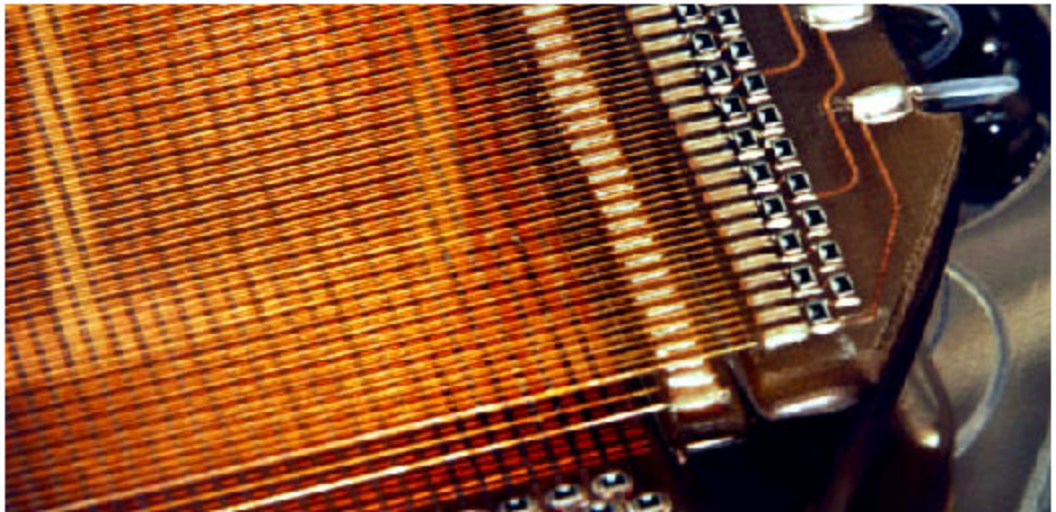


Thermal Neutron Detection

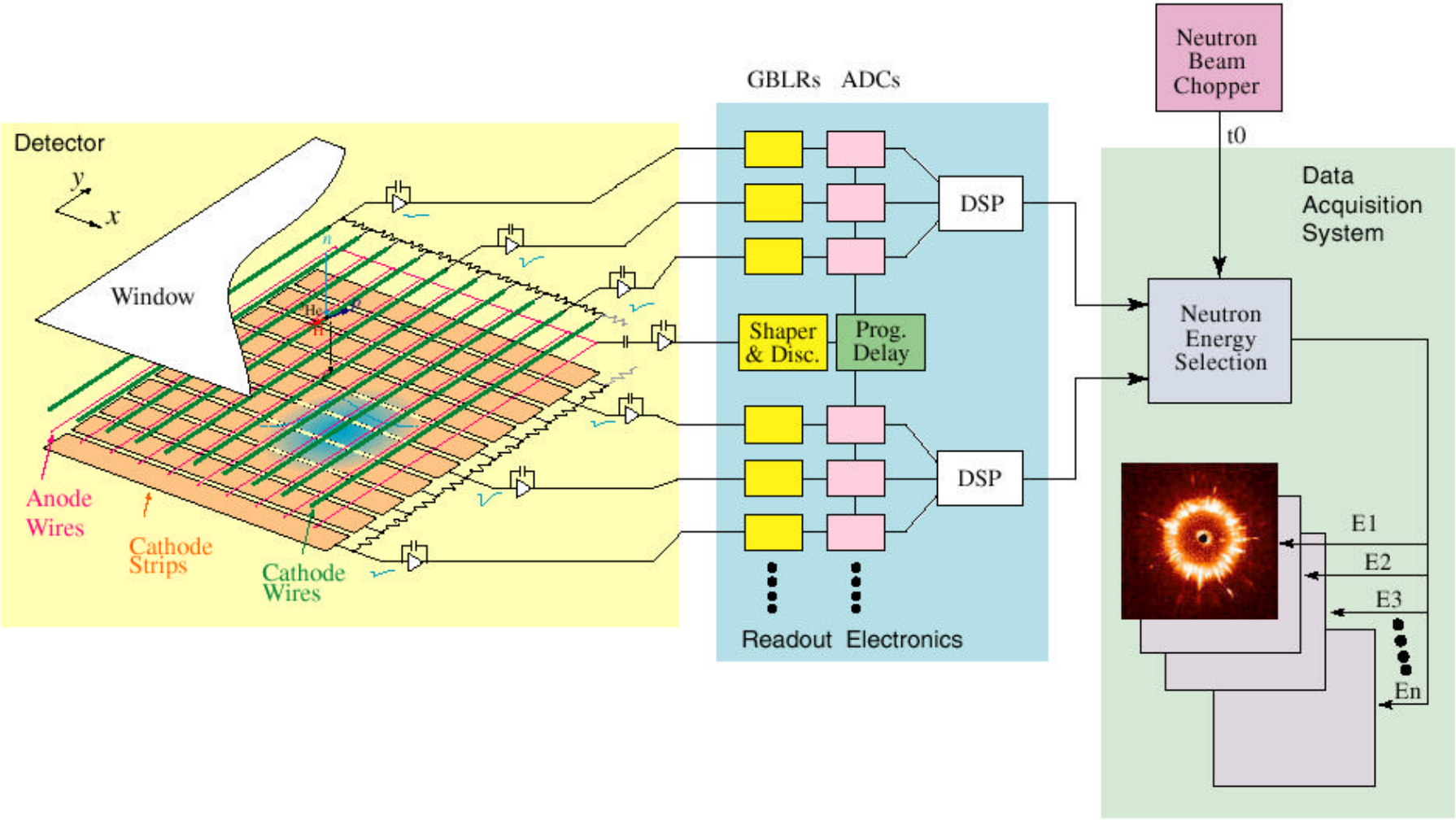
— Position Sensing



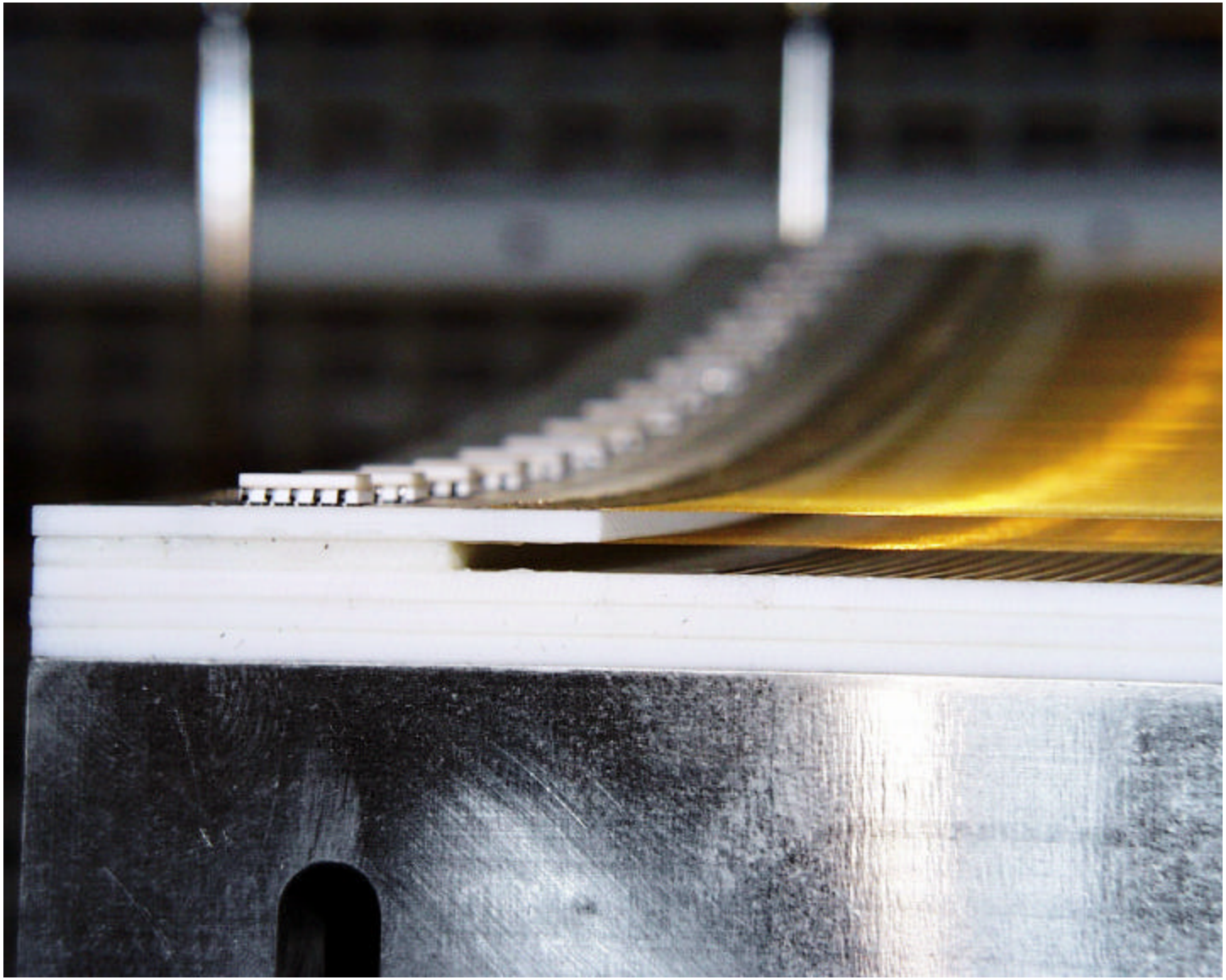
Neutrons enter through a window, usually aluminum, and most convert in the absorption and drift region. The primary ionization created by the proton and triton, about 30,000 electrons, then drifts through the upper wire cathode and an avalanche takes place on the nearest anode wire, or wires. The upper cathode wires and anode wires normally run in the same direction. The lower cathode has metal strips, running at right angles to the anode wires. The anode avalanche induces positive charge on both the upper and lower cathodes. The sampling of induced charge with cathode wires or strips yields the center of gravity of the anode avalanche with high precision when appropriate design criteria are followed. The numerous readout nodes along both axes are fixed in space. They act as fiducial marks, ensuring a high level of position stability.



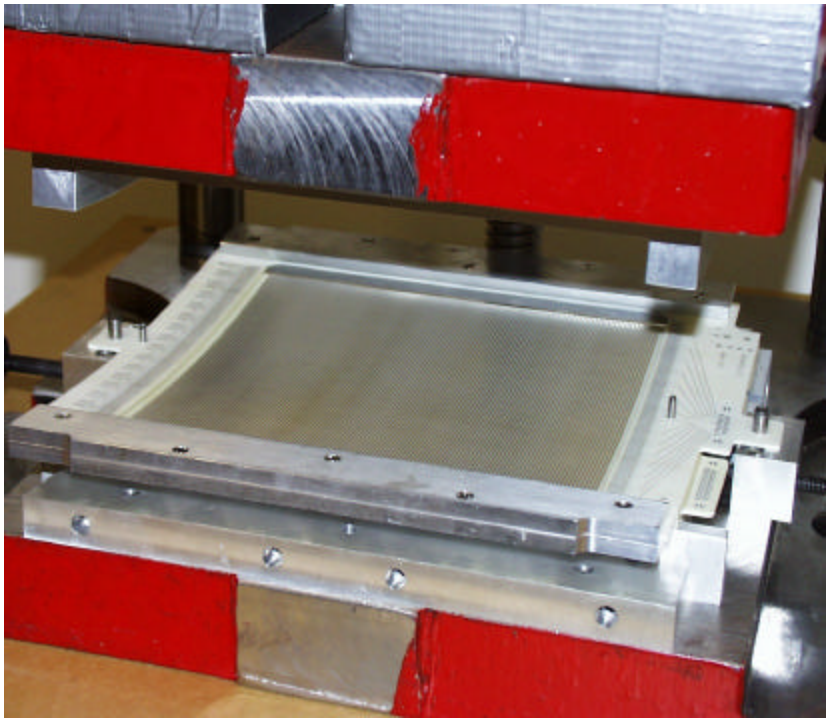
Detector for a Spallation Source
Electronic Block Diagram



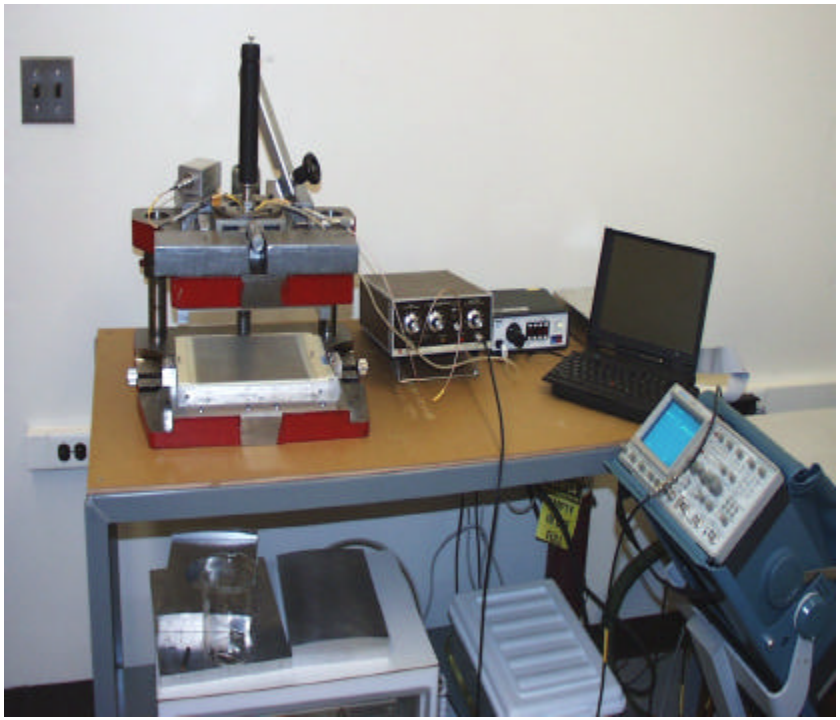
Edge view of one segment



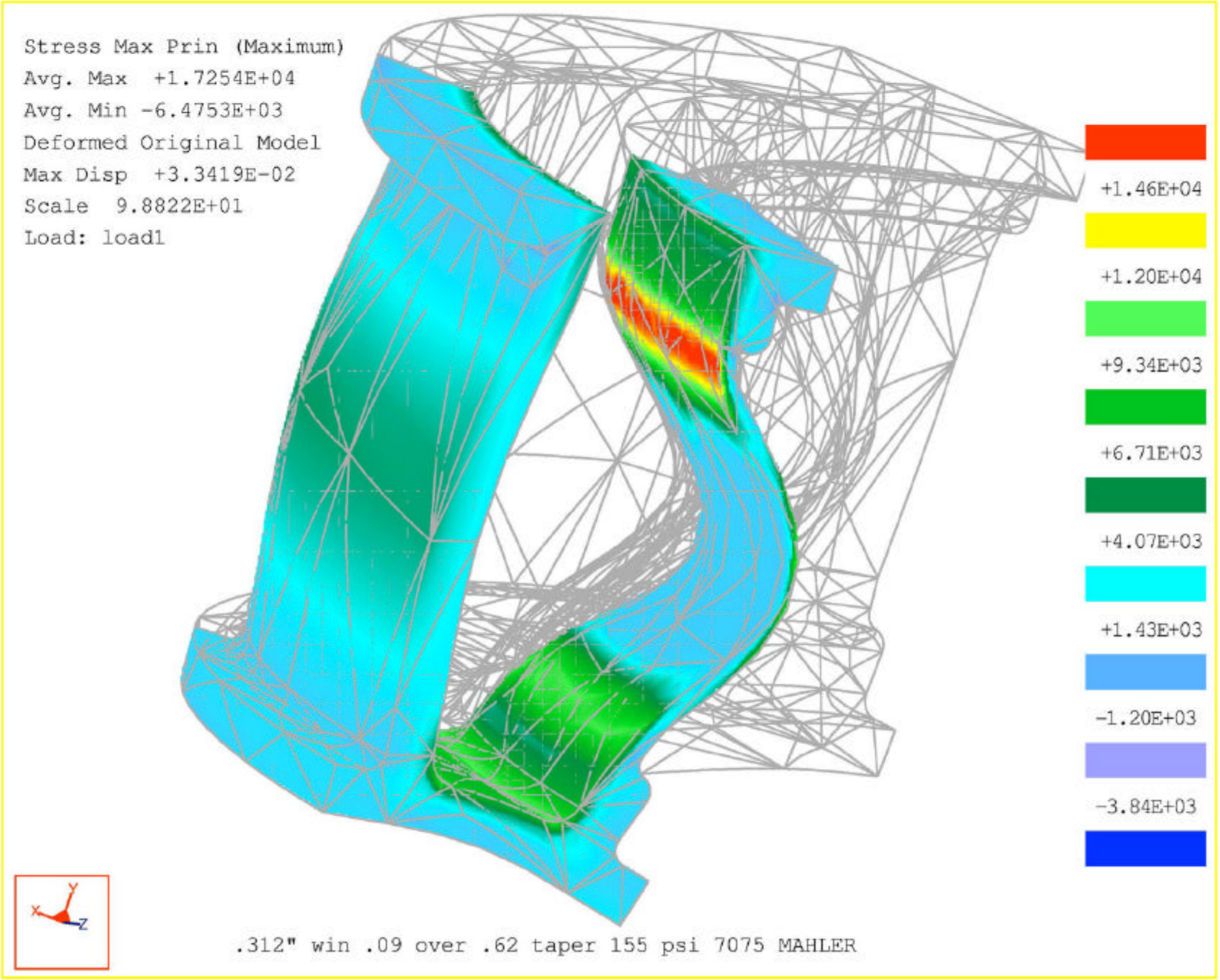
Lamination of Electrodes onto the Aluminum Back Plate



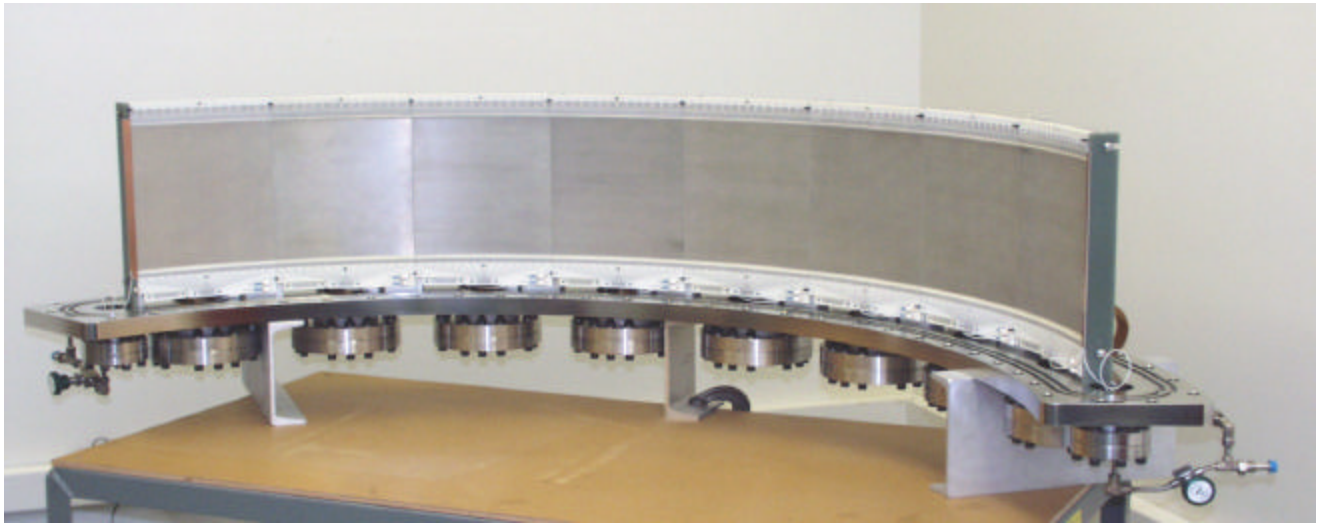
Last step of lamination process showing the wire grids pressed into place



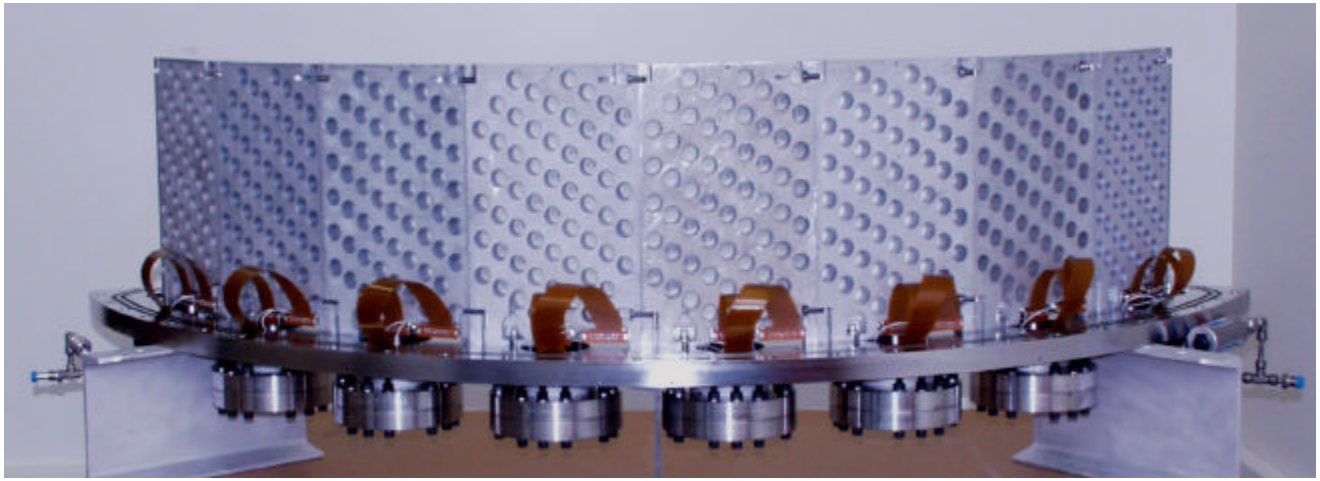
Lamination press with computerized wire tension measurement and adjustment


Stress Max Prin (Maximum)
Avg. Max +1.7254E+04
Avg. Min -6.4753E+03
Deformed Original Model
Max Disp +3.3419E-02
Scale 9.8822E+01
Load: load1
+1.46E+04
+1.20E+04
+9.34E+03
+6.71E+03
+4.07E+03
+1.43E+03
-1.20E+03
-3.84E+03
Y
X
Z
.312" win .09 over .62 taper 155 psi 7075 MAHLER

Front View

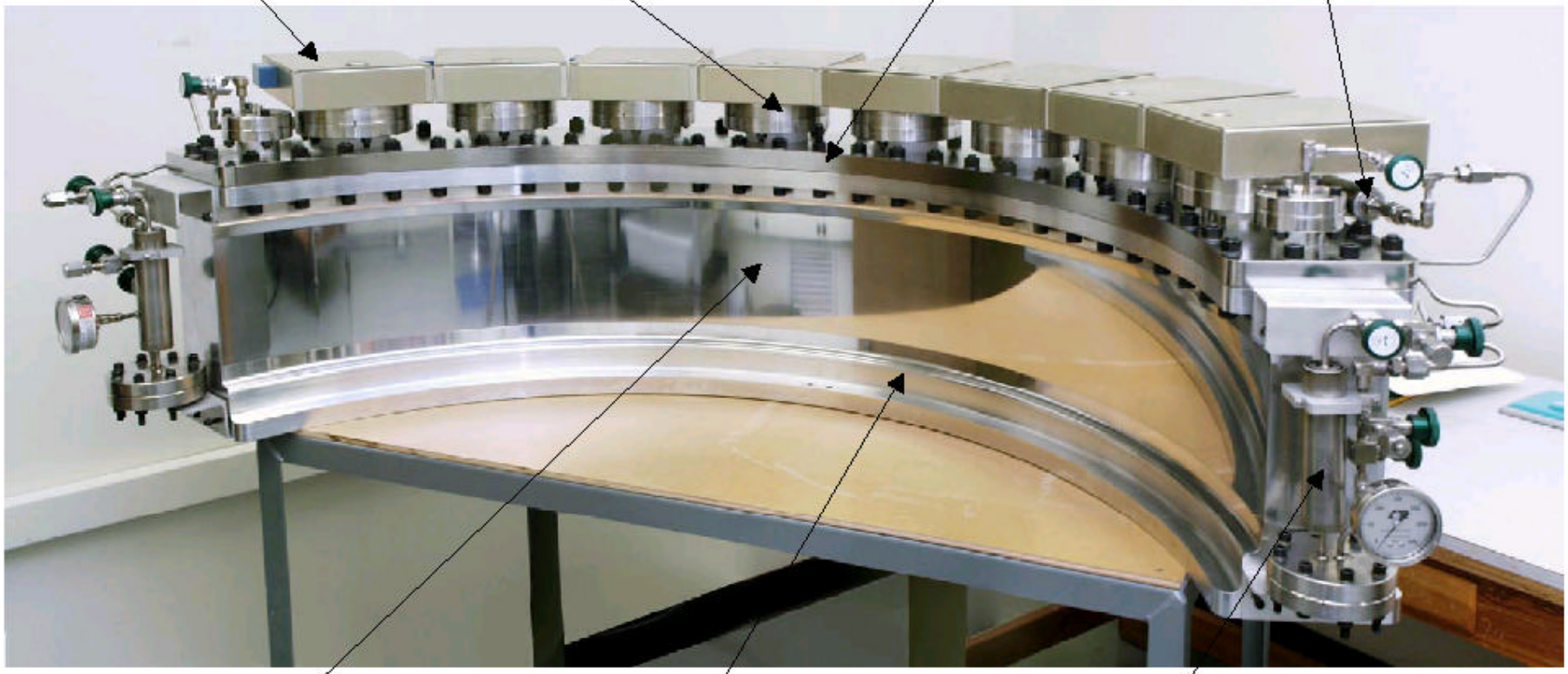


Back View

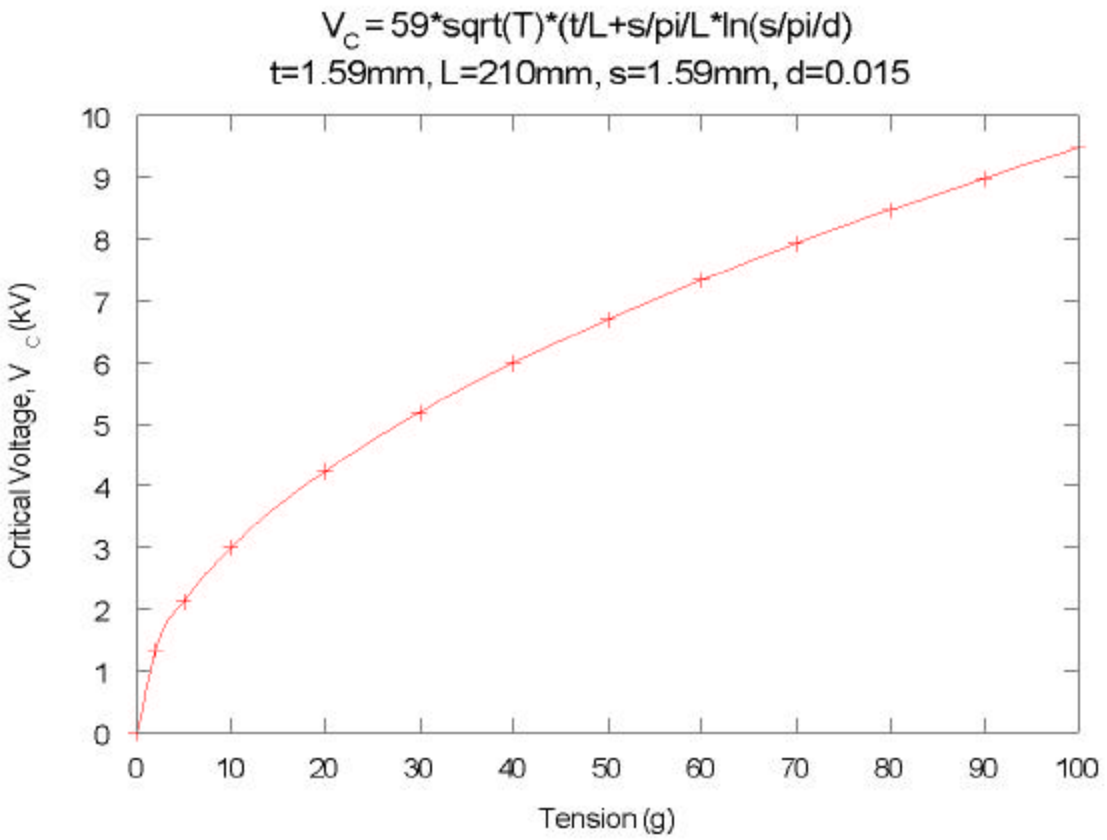


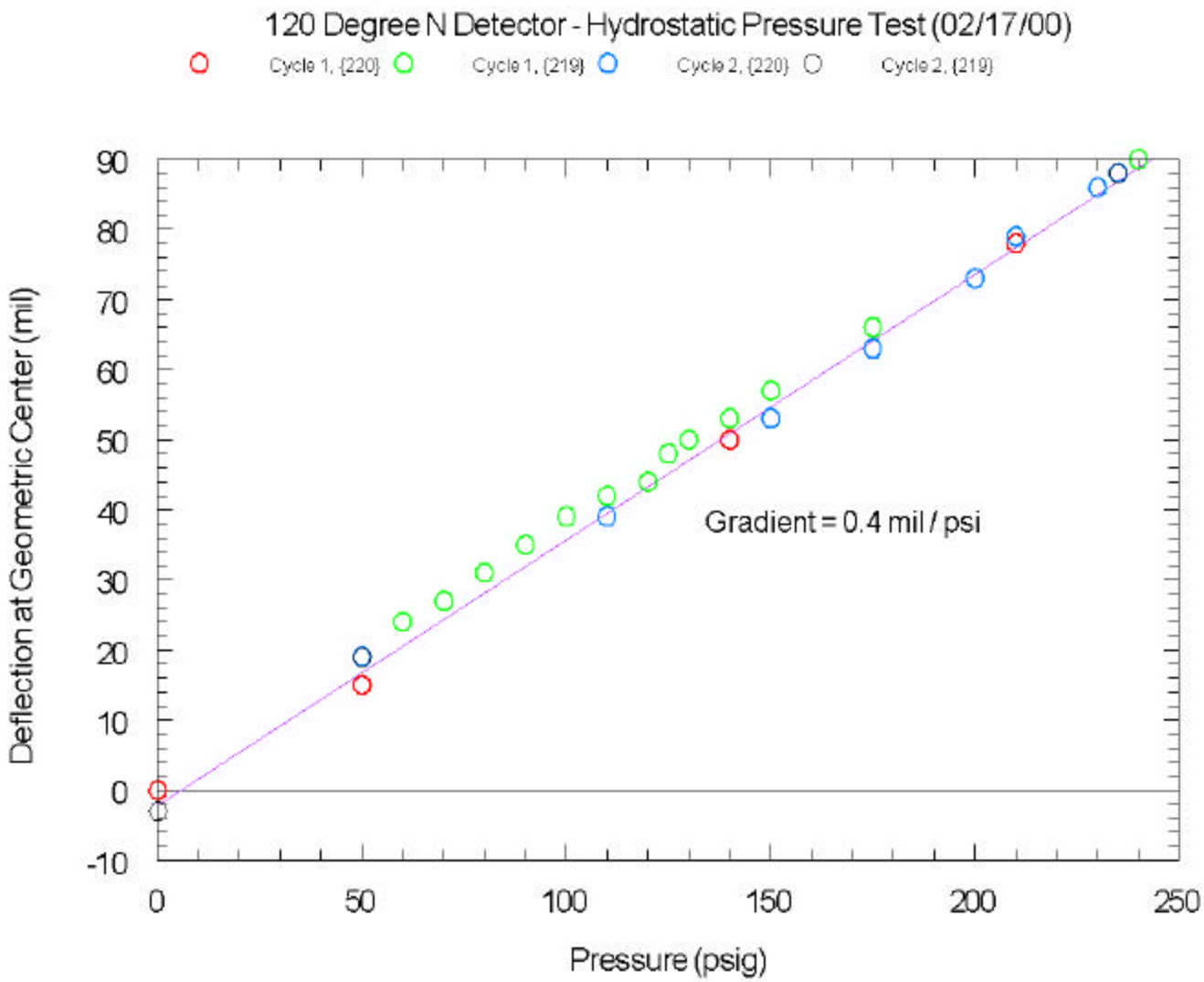
120º Two-Dimensional Thermal Neutron Detector for Protein Crystallography

- 0.3 m^2 area, $>10^5$ resolution elements, 1.3 mm FWHM
- Single gas volume, continuously sensitive readout
- Timing resolution → 0.15Å wavelength bandwidth
- 8 independent. wire segments → modularity, high count rate, $> 10^6\ s^{-1}$
- Encoding electronics optimized for high throughput, low noise
- Decoding with high performance digital signal processing



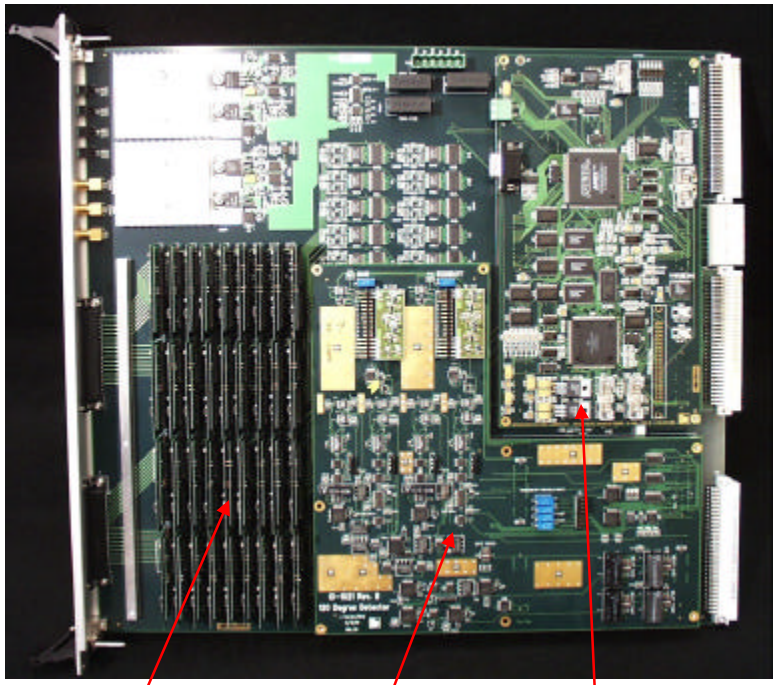
Critical Voltage vs Wire Tension




120 Degree N Detector - Hydrostatic Pressure Test (02/17/00)
Cycle 1, (220)
Cycle 1, (219)
Cycle 2, (220)
Cycle 2, (219)
Gradient = 0.4 mil / psi
Deflection at Geometric Center (mil)
Pressure (psig)
90
80
70
60
50
40
30
20
10
0
-10
0
50
100
150
200
250

Digital Encoding System

Complete VME Motherboard

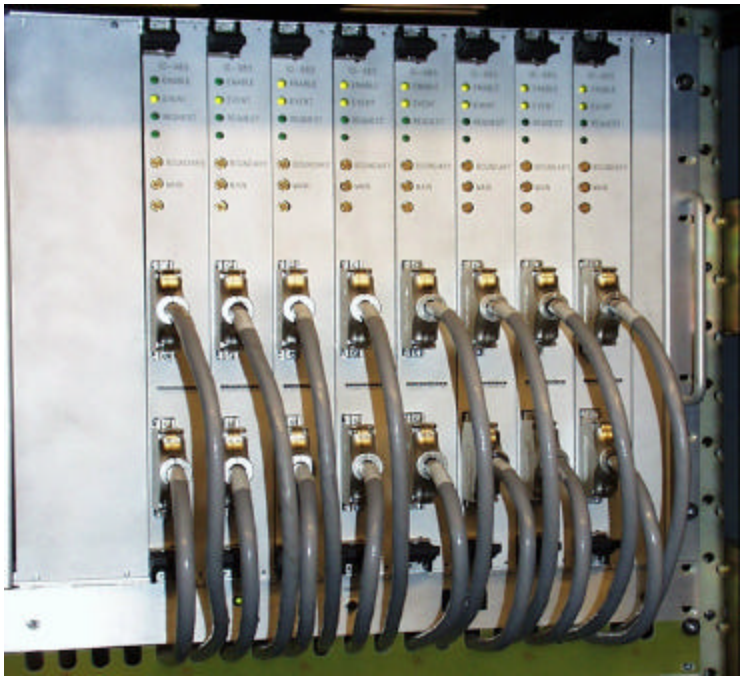


Gated Baseline Restorers

Anode Timing Daughter Card

Digital Daughter Card

Set Of Eight VME Cards In Crate



Shipping Day – BNL to LANL. July 27, 2001

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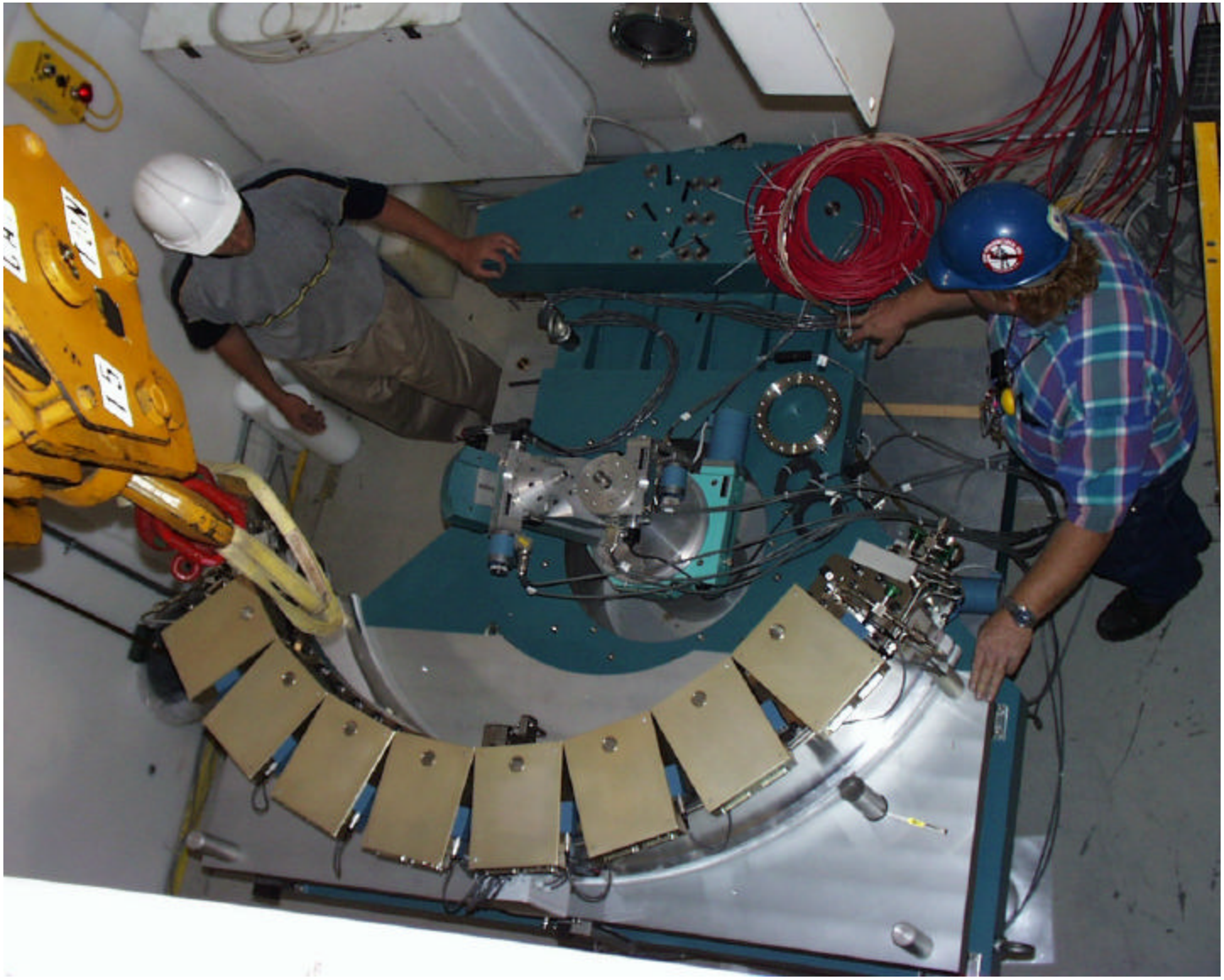
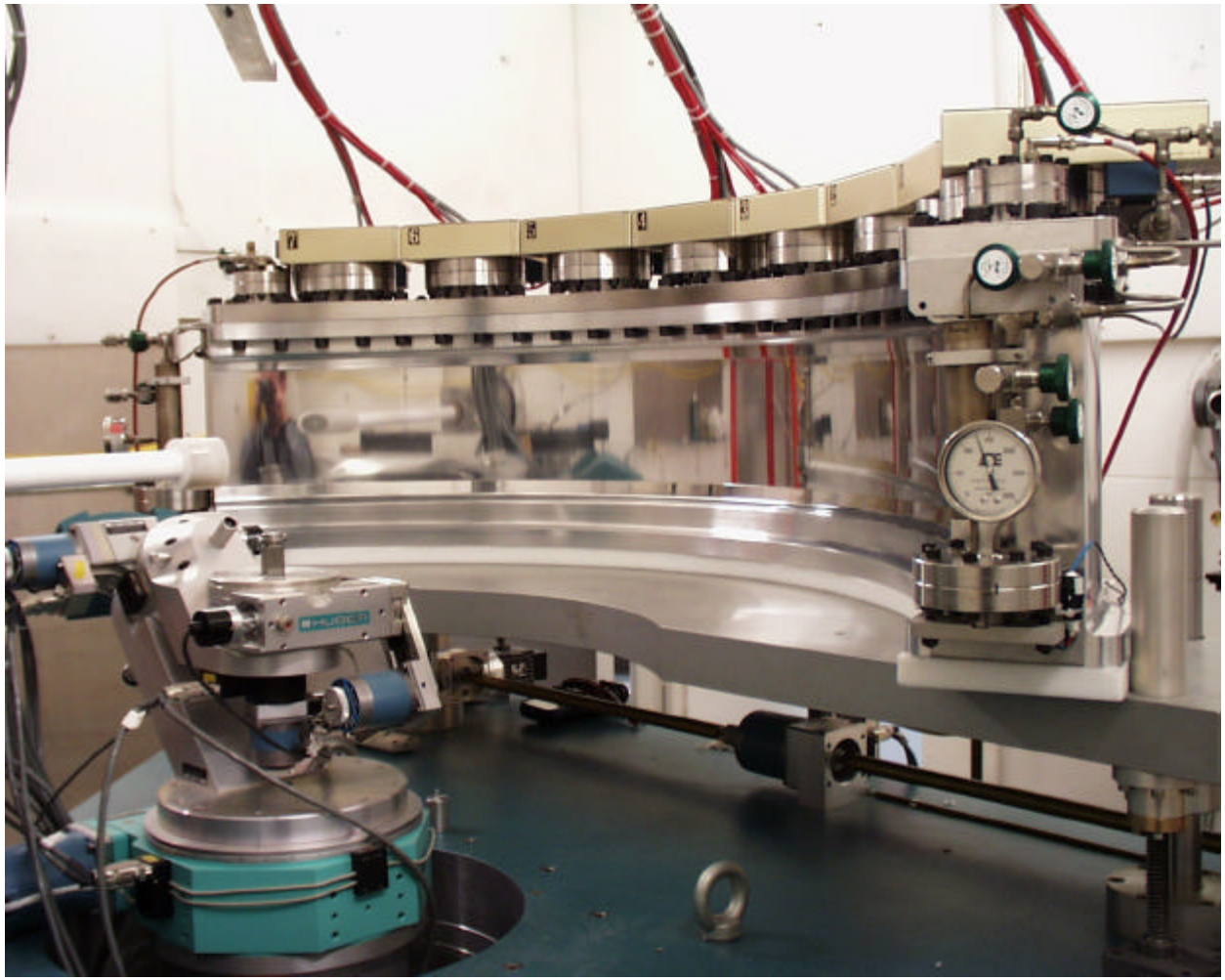
Detector on goniometer at LANSCE – top view



Detector on goniometer at LANSCE – side view



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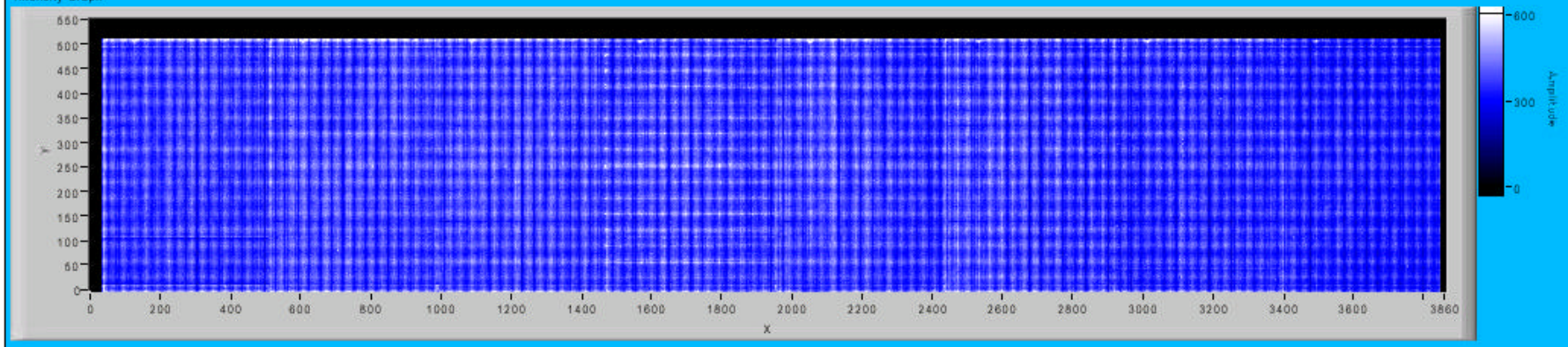
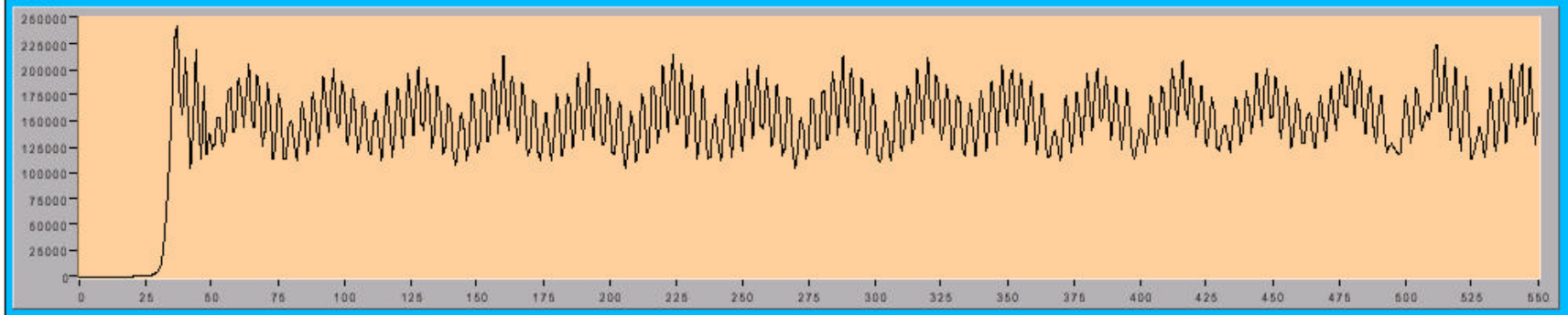
ND120: 8 Segment Read Data File

Intensity Graph

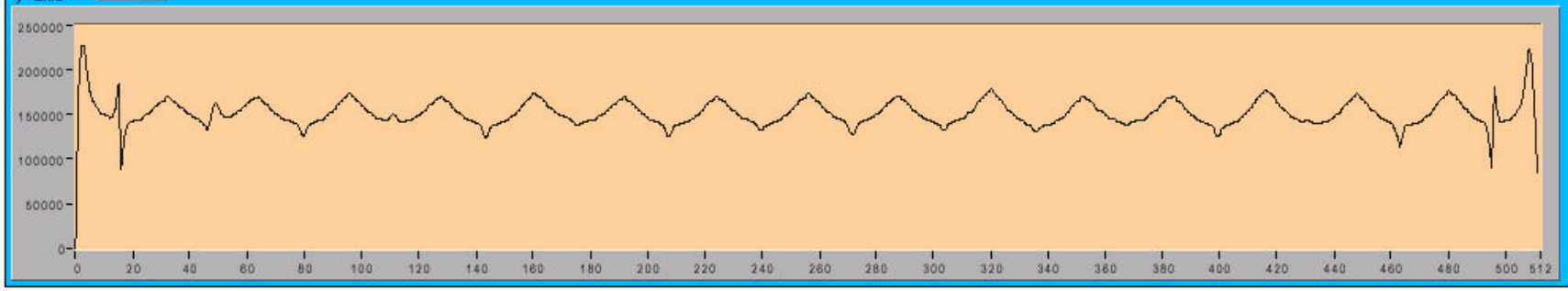


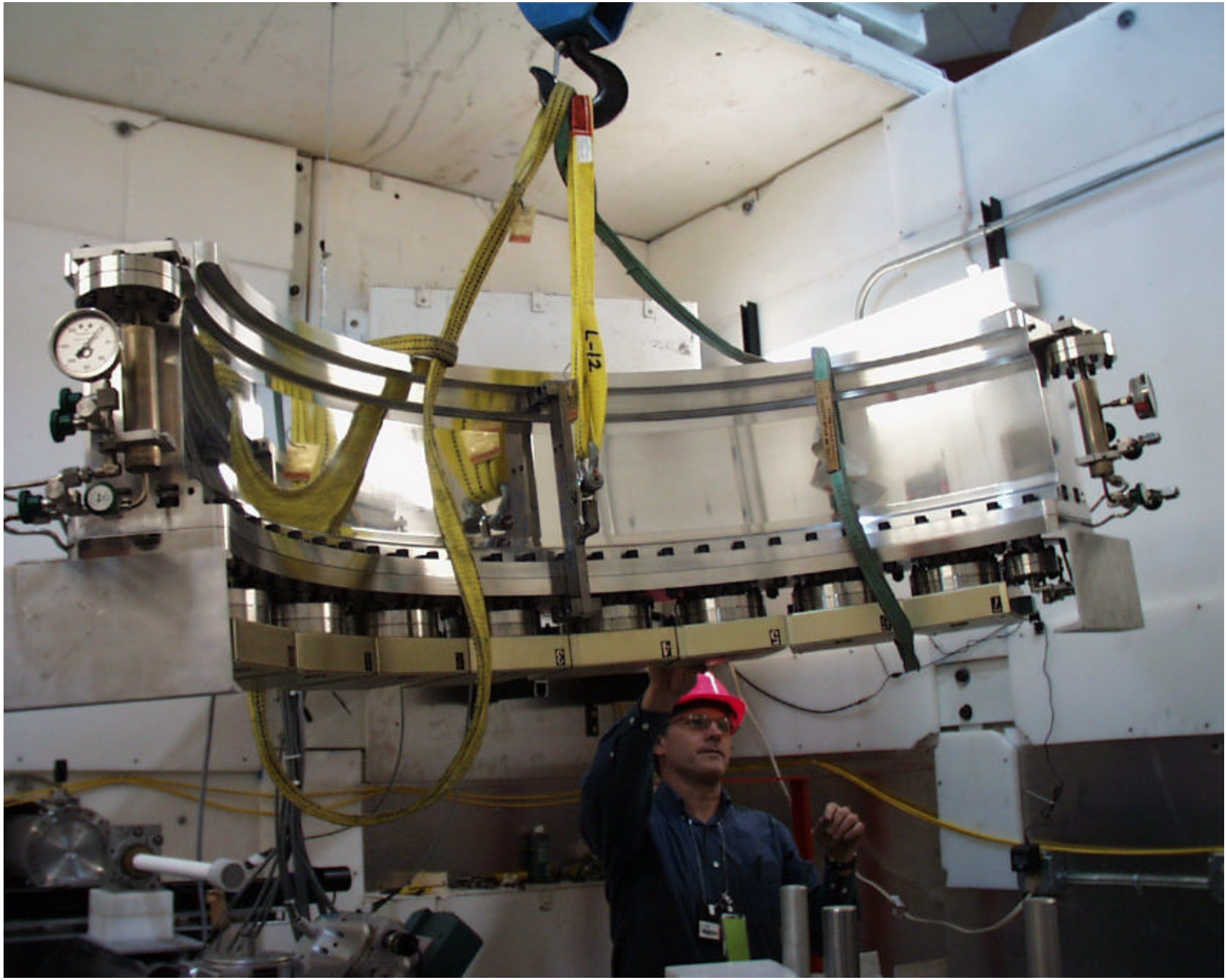
x -axis



y -axis

6 Display Segments



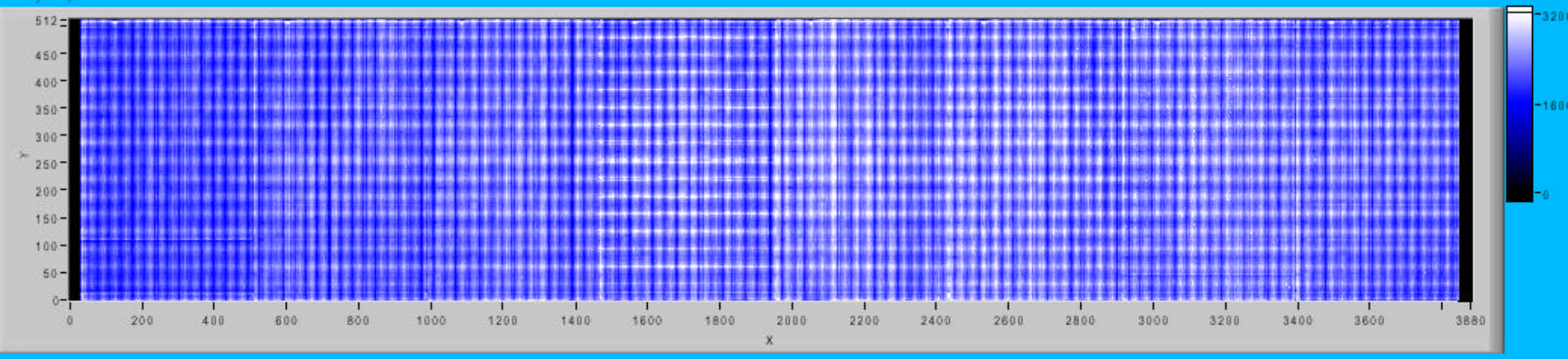

L-12

Disassembling

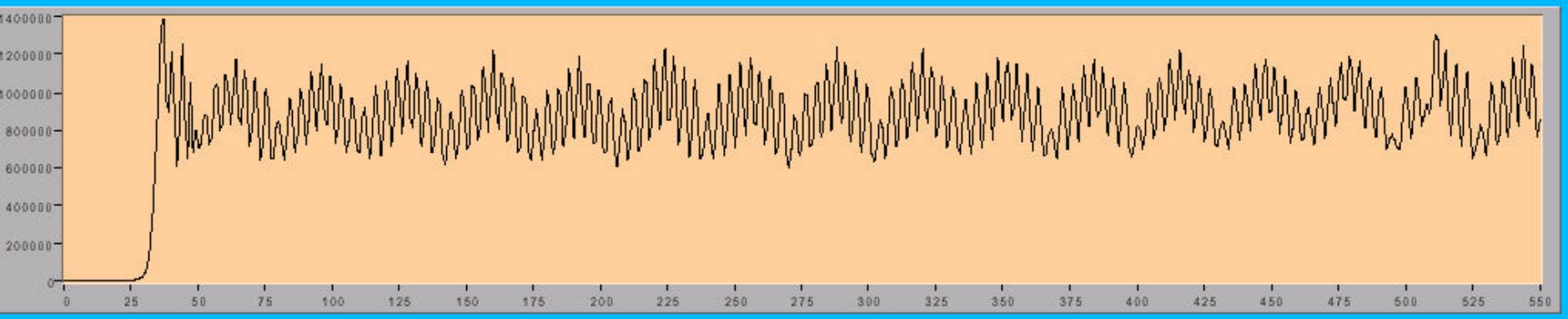
stuff\neutron\nd120\labview\latest\Read 8 segment data file v10.vi
nodified on 12/6/01 at 2:43 PM
d on 1/23/02 at 11:33 AM

ND120: 8 Segment Read Data File

tensity Graph

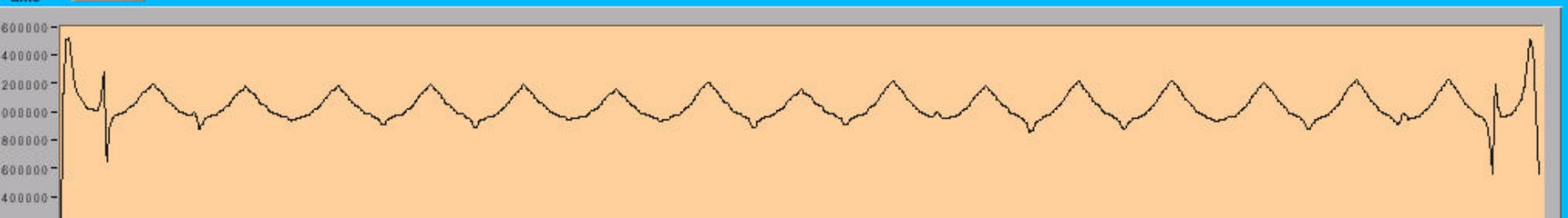


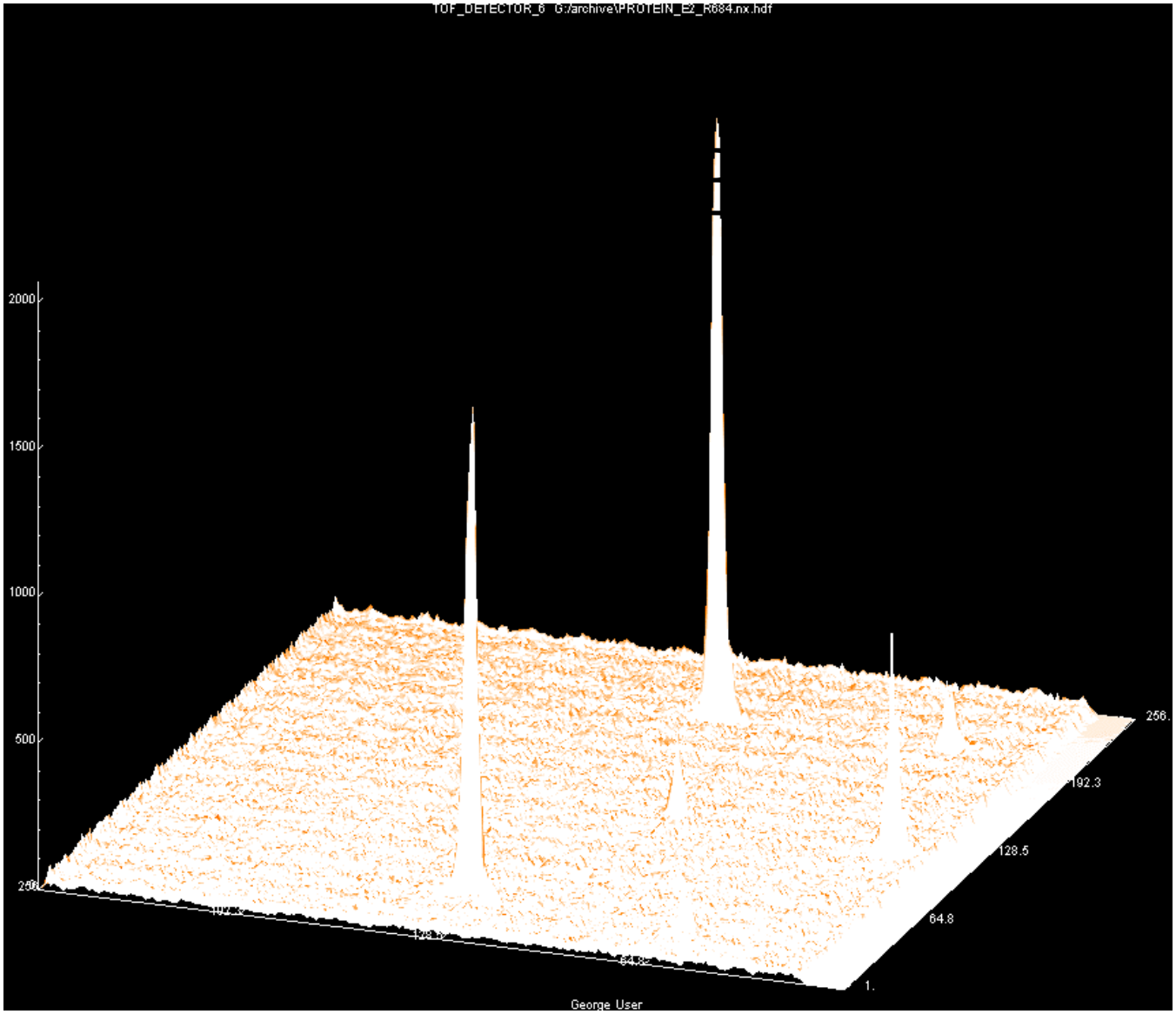
-axis



-axis

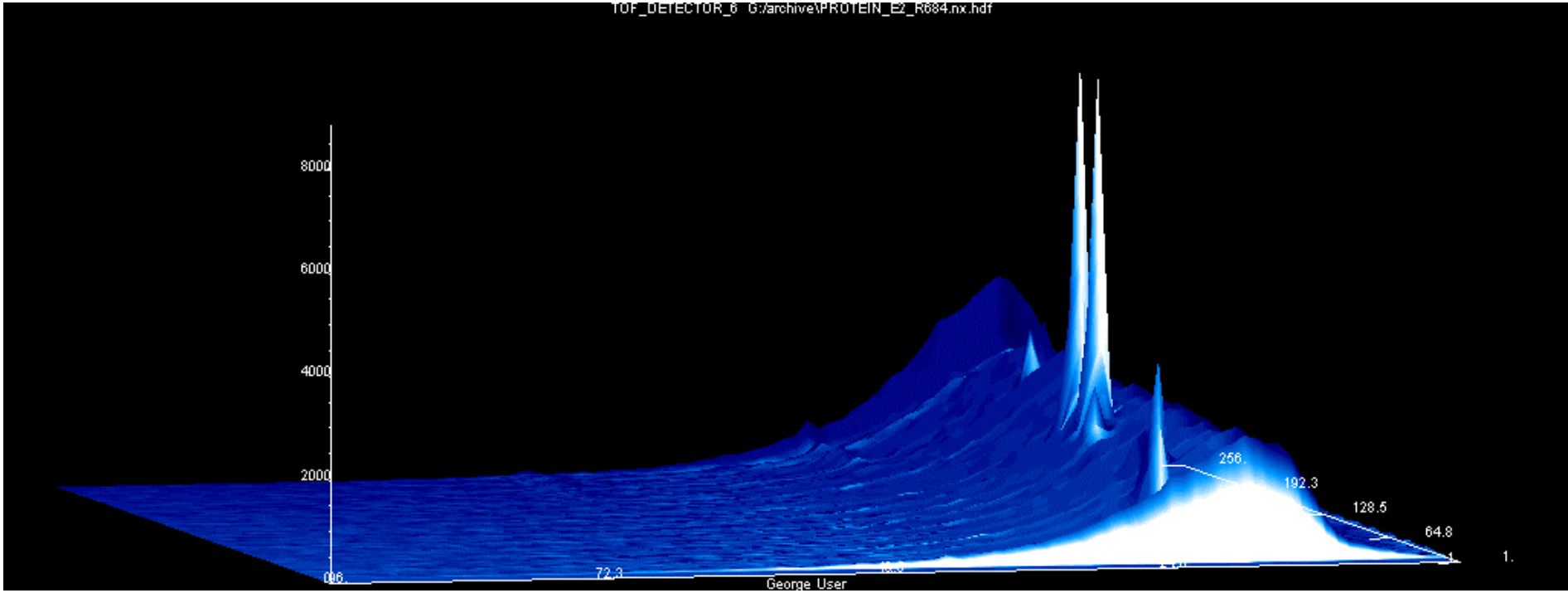
5 Display Segments





Diffraction studies of coenzyme of vitamin B12

This figure shows an isometric view one of the eight detector segments, summed over all 96 time channels. The detector segment subtends ~15ºx17º, has 250x250 spatial pixels.



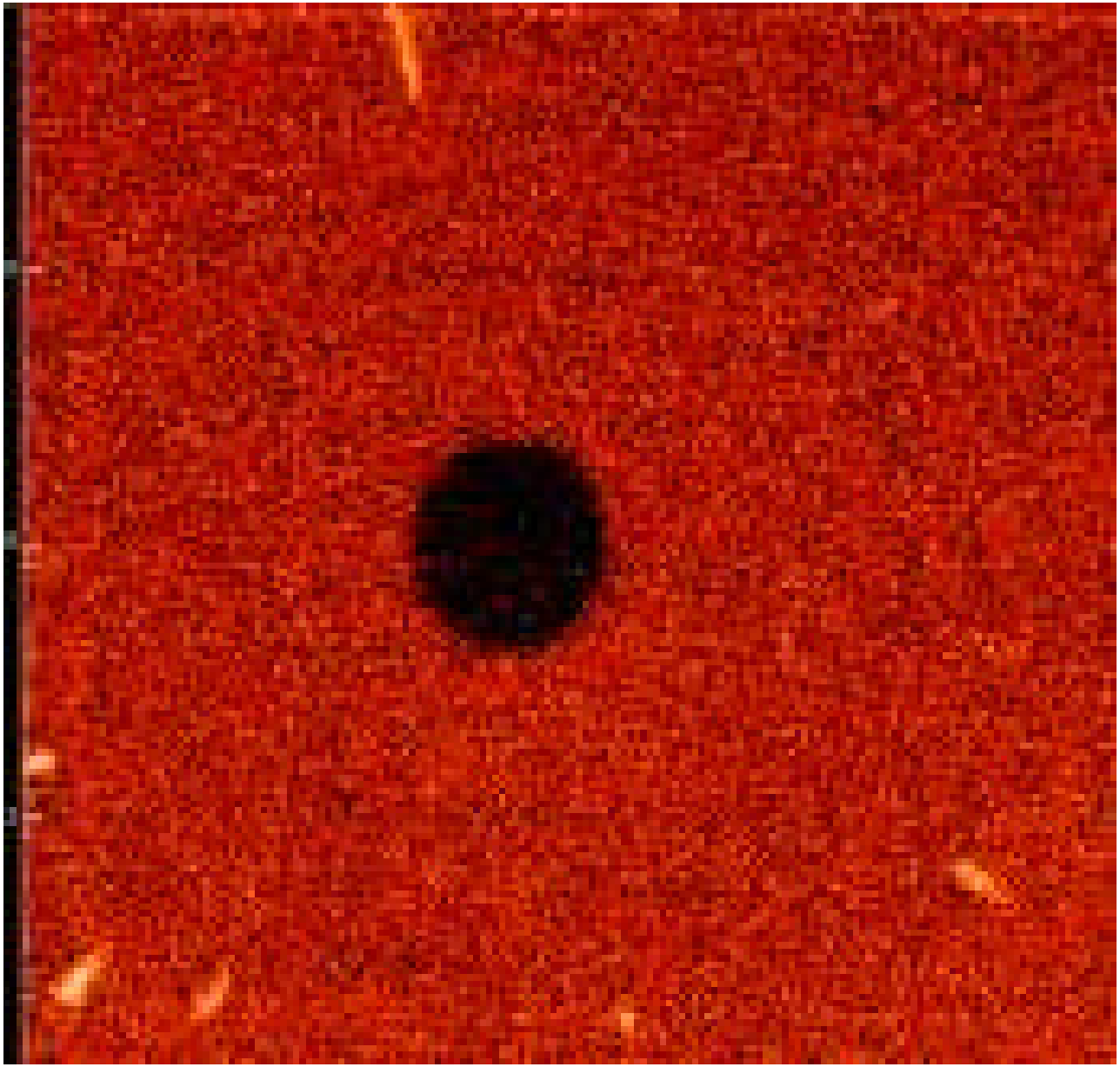
Diffraction studies of coenzyme of vitamin B12

This figure shows an isometric view of one of the detector segments projected down one of the spatial dimensions. The profile of the background scattering in the time dimension (horizontal), due mostly to incoherent scattering from hydrogen in the crystal, reflects the distribution of neutron wavelengths in the incident beam spectrum.

Detector Characteristics

PARAMETER	VALUE
Pressure Vessel	**Aluminum alloy, 7075-T6**
Yield Strength	**73,000 psi**
Design Strength	**18,250 psi**
Max Operating Press.	**141 psig**
Max Allowable Working Press.	**155 psig (1.1 MOP) Burst disc**
Actual Working Pressure	**125 psig**
Main Flange	**Stainless Steel, with 8 ´ 6” and 2 ´ 3 3/8” flanges**
Flatness	**£ 50 mm**
Seal	**Double “O” ring and copper gaskets**
Complete Vessel	
Mass	**250 kg**
Internal Volume	**30 liters**
Gas Composition	**6 atm ^{3}He, 2.5 atm propane (» $20k ^{3}He)**
Number of wire segments	**8**
Position Resolution	**1.3 mm FWHM**
Counting Rate	**³ 10^6 s $^{-1}$**
Radius of Curvature	**70 cm**
Angular coverage	**120° ´ 15°**
No. of 15 mm wires (anodes)	**960**
No. of 50 mm wires (cathodes)	**960**
No. of resistors (charge division)	**1918**
No. of pixels	**¼ million**
Center of Gravity	**About 10 cm outside center of window**

BNL's Thermal Neutron Detectors Performance Summary*

Position Resolution (FWHM)	**< 0.4 - 2 mm**
Number of Resolution Elements from	**128´128 to 4096´512**
Active Area	**from 5cm´5cm to 150 cm ´ 20cm**
Wavelength Range	**1 - 20 Å**
Detection Efficiency	**50 - 80 %**
Counting Rate (total)	**10^5 - 10^6 sec^{-1}**
Counting Rate (single peak)	**5 ´ 10^4 sec^{-1}**
Integral Non-linearity	**2 ´ 10^{-4} to 10^{-3}**
Absolute Position Accuracy	**30-100 µm**
Stability of Origin	**<50 µm**
Stability of Response (efficiency)	**<1%**
Differential Non-linearity	**±3%**
Dynamic Range	**Single Neutron Detection**
Timing Resolution	**~1 µs**

* Not all properties listed can necessarily be achieved in one detector.