LA-UR- 11-05322

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Title:	Using a light gas gun for dynamic experimentation at the Advanced Photon Source
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Intended for:	Presentation at the 62nd AEROBALLISTIC RANGE ASSOCIATION Meeting

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Form 836 (7/06)

Using a light gas gun for dynamic experimentation at the Advanced Photon Source

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A small-bore light-gas gun was developed for dynamic experiments at the Advanced Photon Source (Argonne National Laboratory). This gun system will be used to obtain dynamic Laue diffraction and Phase Contrast Imaging (PCI) data for a variety samples (single/polycrystals, composites, etc.) impacted at velocities up to 1 km/s. The 12.7-mm bore gun system was designed to be portable for quick insertion into the experimental hutch while allowing the target chamber to rotate for sample alignment with the beam. The target chamber is equipped with auto-vent valves and flanges to prevent pressurization during the experiment. A detailed description of the gun system along with experiment results obtained from recent qualification tests will be presented.

Using a light gas gun for dynamic experimentation at the Advanced Photon Source

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Los Alamos National Laboratory

Presented at the

62nd Aeroballistic Range Association Meeting

September 19-23, 2011

Los Alamos NATIONAL LABORATORY EST 1943

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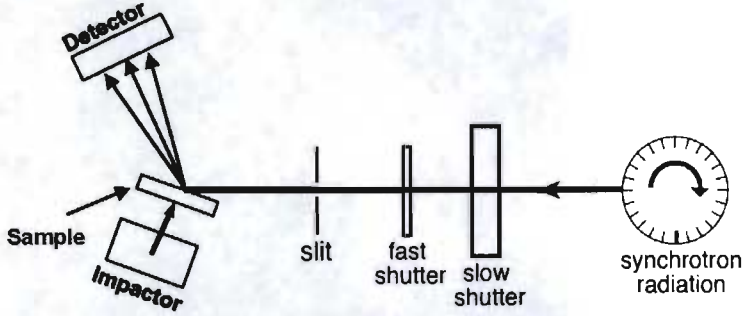
Outline

- Motivation
- IMPULSE gas gun system description
- Engineering analysis complete on breech, barrel, and target chamber
- Qualification of launcher system (underway/complete)
- Summary/Conclusions

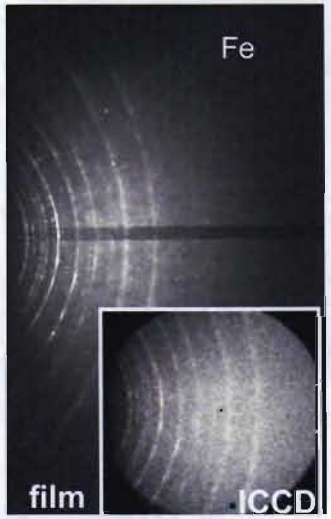
Motivation

- Synchrotron sources provide well-characterized, high-intensity radiation for experiments – mostly used for static experiments such as the diamond anvil cell
- Dynamic or impact experiments are needed to examine material properties in extreme conditions (high temperatures, pressures, etc.)
- Impact experiments can be performed if:
  - The dynamic event can be synchronized with beam
  - There are enough photons for nanosecond events
  - A fast detector is available
- Recent detector feasibility test have shown that it is possible to obtain sufficient x-ray intensity in 150 ns making dynamic Laue diffraction possible
- **Goal: develop a mobile plate impact facility for use at synchrotron sources such as the Advanced Photon Source (Argonne, IL)**

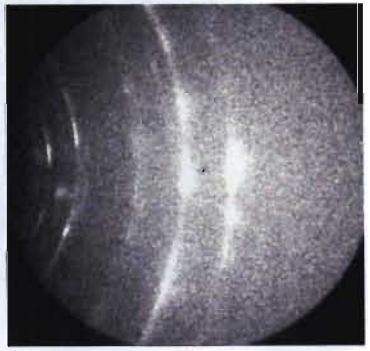
Dynamic Laue X-ray Diffraction Configuration



Iron (Film & ICCD)



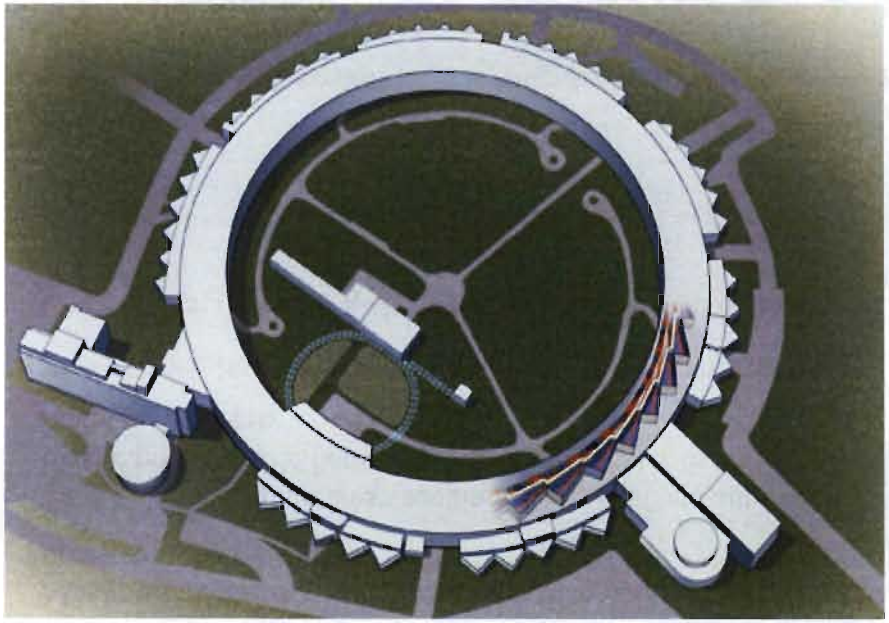
Polycrystal Cu



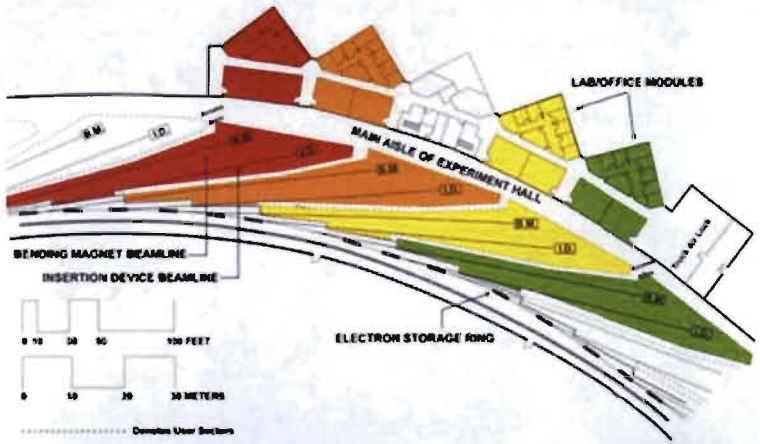
(Sheng, Jensen, Hooks, Ramos, Yeager, and Fezza)

Dynamic Experiments at the Advanced Photon Source (Argonne National Laboratory)

Experiments conducted around the ring of the Advanced Photon Source (Argonne) in experimental "Hutches" which protect people from the intense X-ray beam



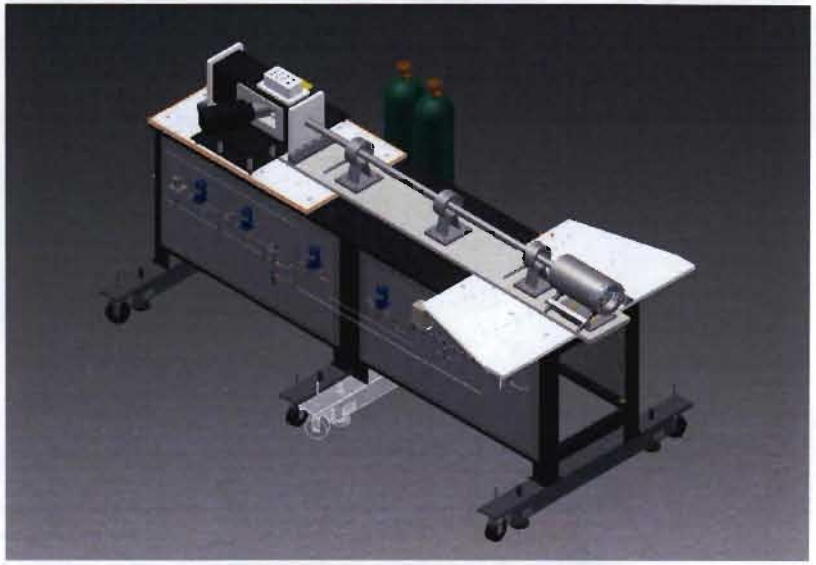
TYPICAL APS EXPERIMENT HALL & LAB/OFFICE MODULE CONFIGURATION

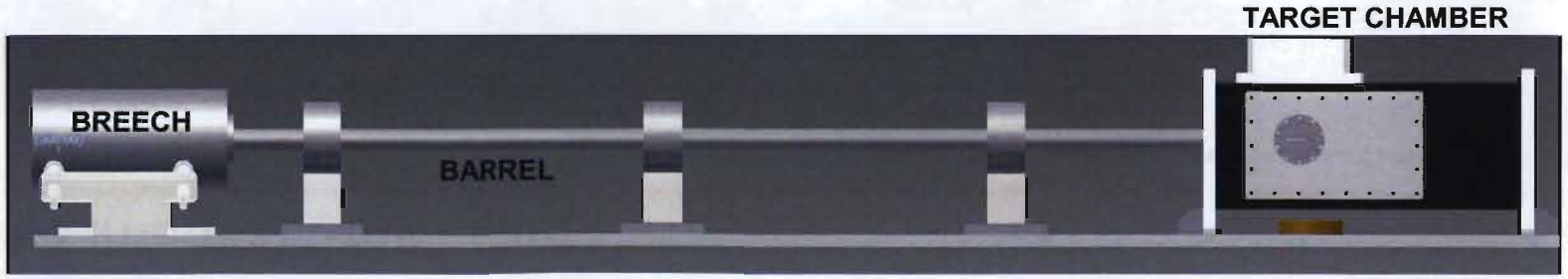


- Safety officers at ANL are involved with this experimental effort and will review our engineering report (IWD, drawings, operating procedure, engineering calculations/analysis, and pressure safety)

A 12-mm Launcher System has been prepared for use at APS
IMPULSE = IMPact system for ULtrafast Synchrotron Experiments

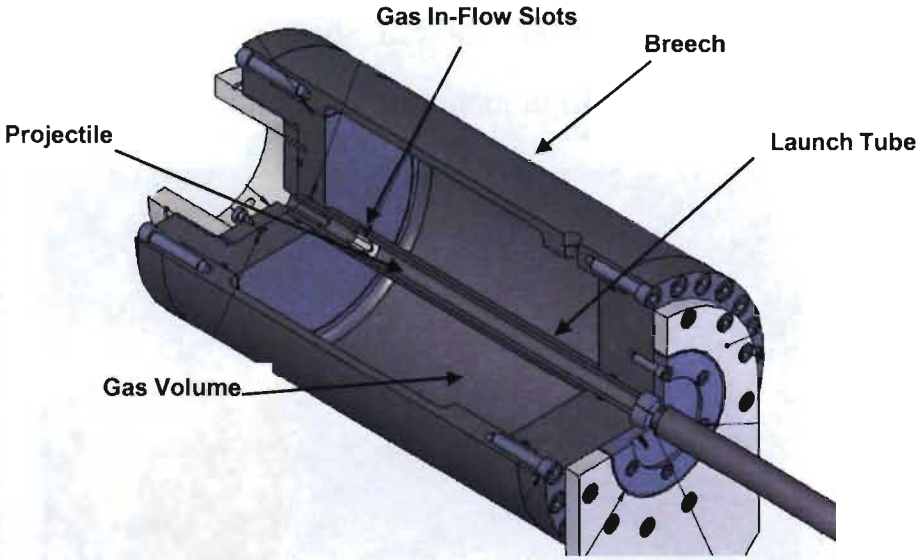
- Standard wrap-around breech design similar to current guns located at CH9 and Point-56 (pop-gun)
- 12-mm diameter projectile (50 caliber) with a velocity up to 1 km/s
- Maximum pressure within breech less than 2000 psi (standard bottle pressure) – NO PROPELLANT
- Target chamber maintains vacuum prior to shot and auto vents; thin plastic ports on side flanges allow x-rays to enter/exit and DO NOT maintain pressure
- Pressure manifold similar to current system at LANL and SNL
- Complete engineering analysis performed by R. Valdiviez (LANL)



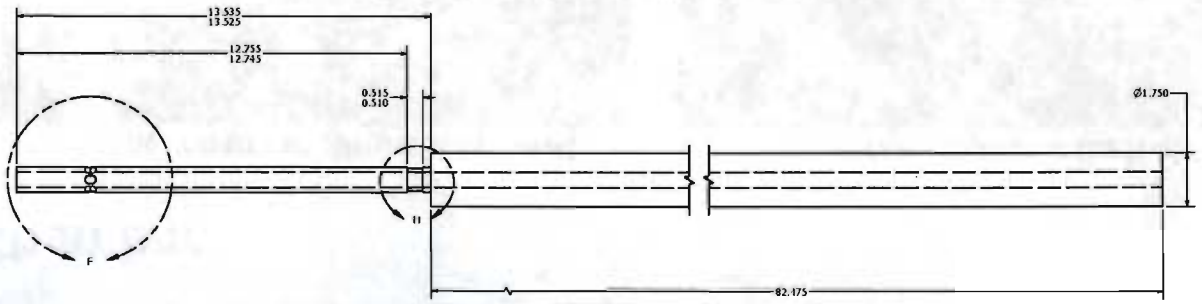


Launcher system based on Sandia Design

- Breech and barrel design based on Sandia launcher system
- Standard wrap-around breech design
  - Breech volume surrounds launch tube
  - Air inlet ports sealed by projectile
  - Volume behind projectile pressurized to launch
- New barrel designed (LANL) and fabricated by a New Lenox Ordnance (Gardner, IL)

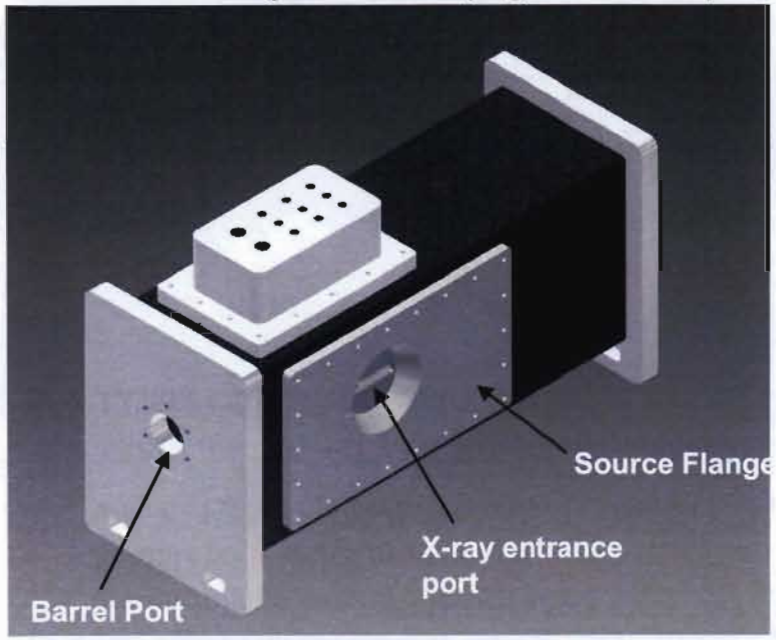


New barrel design – 12.5-mm smooth bore

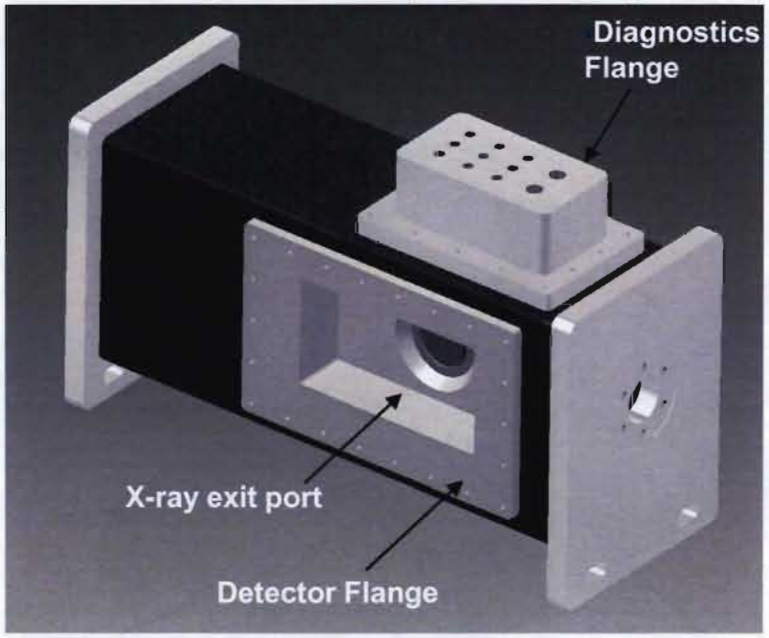


Target Chamber

Target chamber (Right side view)



Target chamber (Left side view)

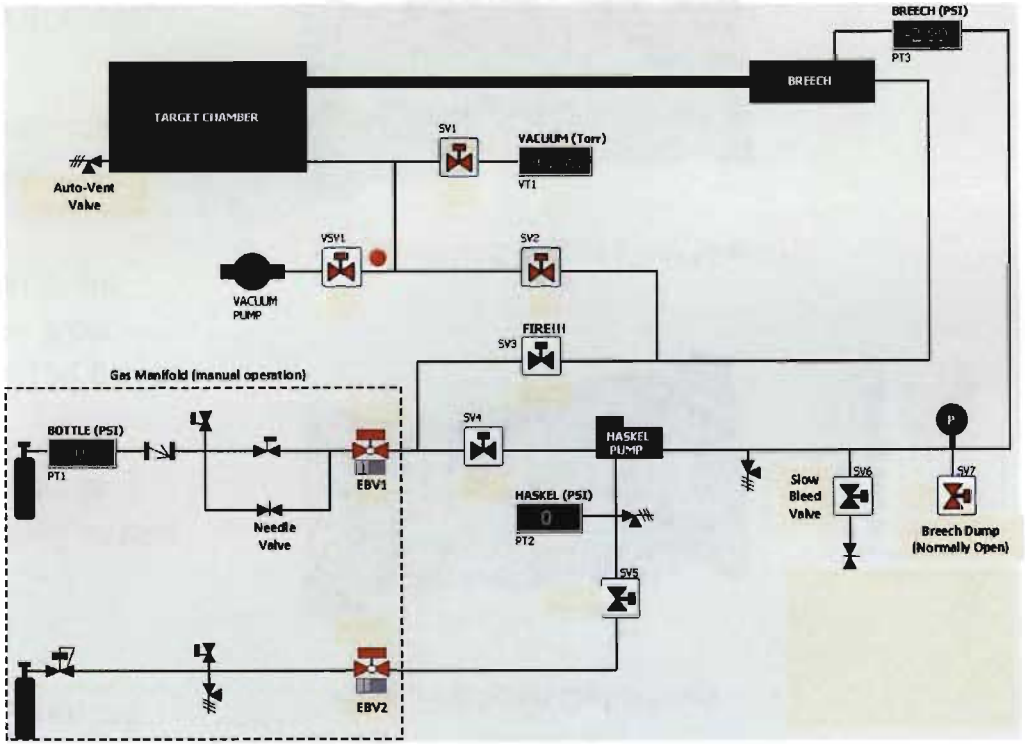


- Chamber requirements: hold vacuum, x-rays enter/exit, auto vent, fragment mitigation
- Diagnostics box equipped with velocimetry, coax cables, VISAR, pressure gauge
- Side ports allow close positioning of detector; input/exit of x-ray beam
- Chamber equipped with auto-vent features (back of chamber and side flange)

Vacuum Pressure manifold

- Pressure manifold initially based on existing gun system designs
- Vacuum capability incorporated into system to allow for evacuation of target chamber/barrel
- Haskel pump (intensifier) included to maximize gas bottle efficiency
- Labview based control system developed to operate pressure/vacuum manifold including projectile launch
- Components in dashed box are approved per pressure safety requirements for manual operation
- Remaining pressure system is remotely operated

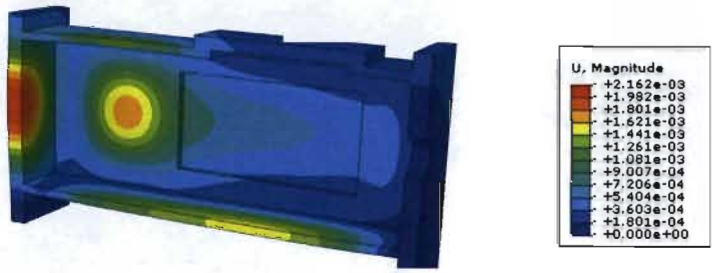
LABVIEW Control Graphic



Summary of Engineering analysis (R. Valdiviez, W-14 LANL)

- Robert Valdiviez (W-14 LANL) performed detailed analysis of IMPULSE system
- Predictions include:
  - Target chamber peak deflection (and peak stress) shown to occur in the rear target plate and is approximately 0.002-in in magnitude
  - Peak predicted stress (Von Mises – 11,150 psi) to occur 7 ms after start of pressurization. Rear plate determined to have lower yield strength (safety factor 3.2)
- Weakest component is the barrel section inside the breech (1.3 safety factor) – external barrel boundary has a safety factor of 16.
- Fatigue/Fracture analysis shows a lifetime of 400,000 cycles (or launches) prior to the next inspection – based on weakest component lifetime.

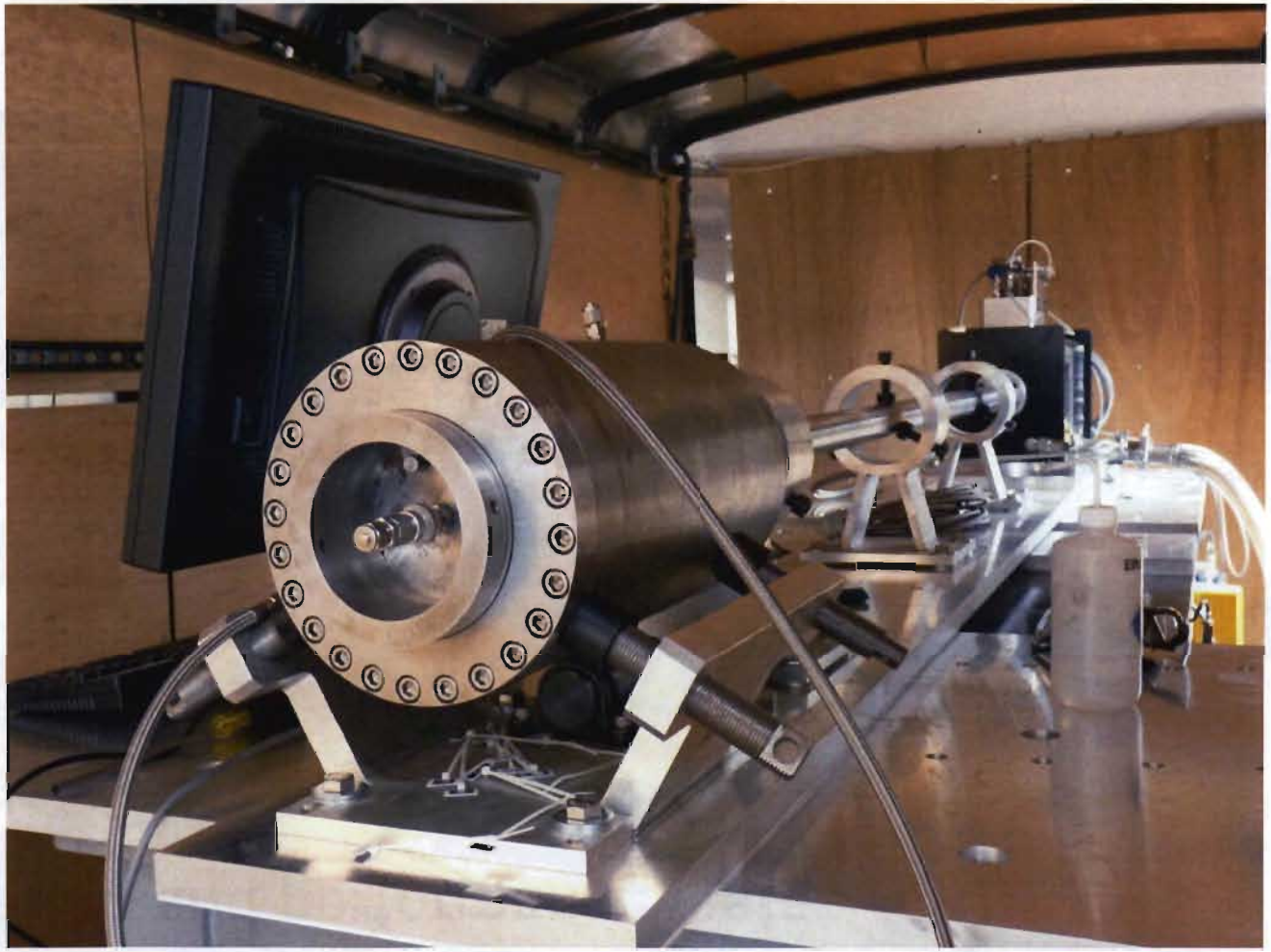
Peak Predicted Deflections



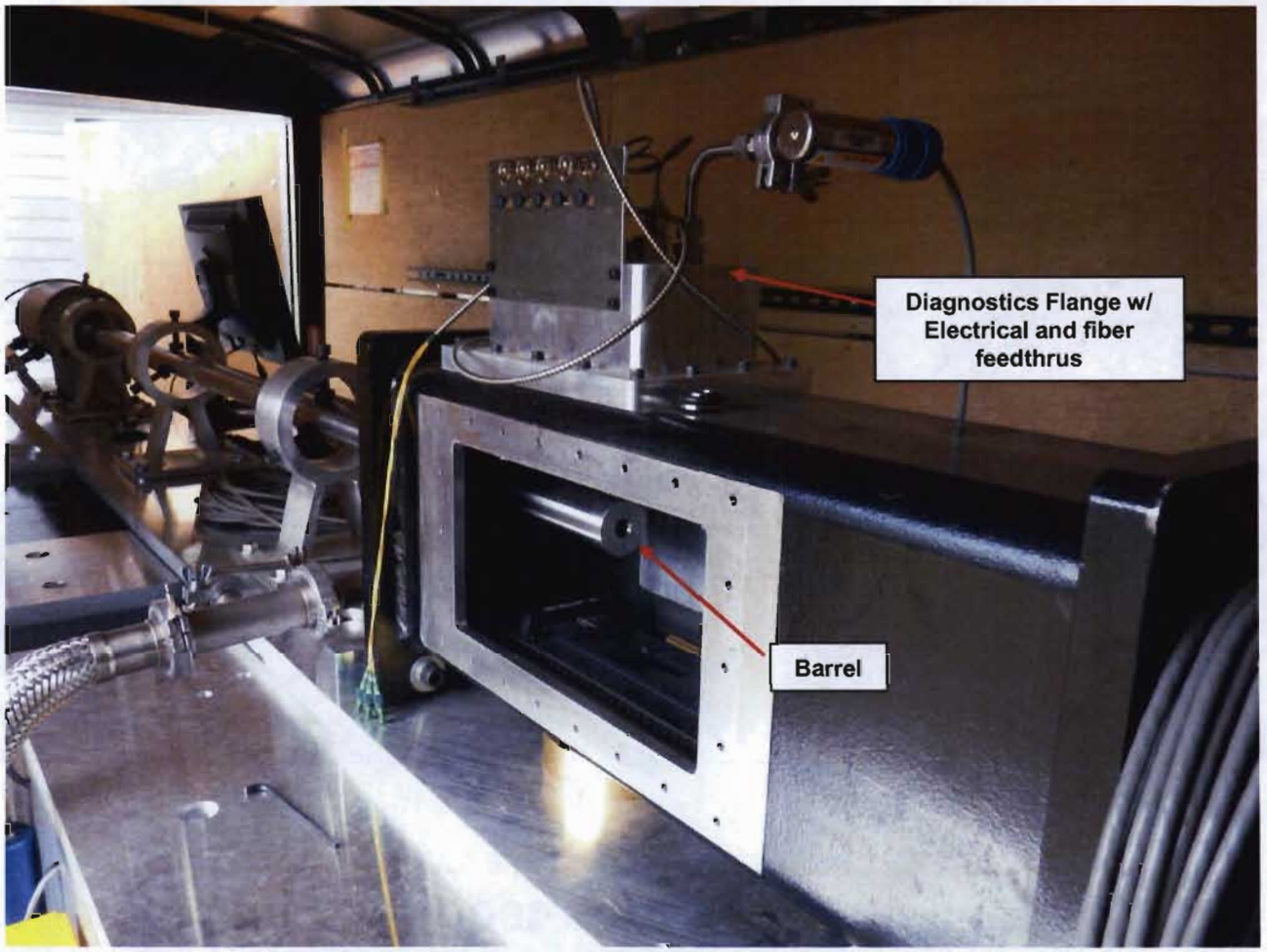
Peak Predicted Stress (Von Mises)

Gun system located inside trailer at firing site for qualification and performance tests

Gun system inside trailer at firing site

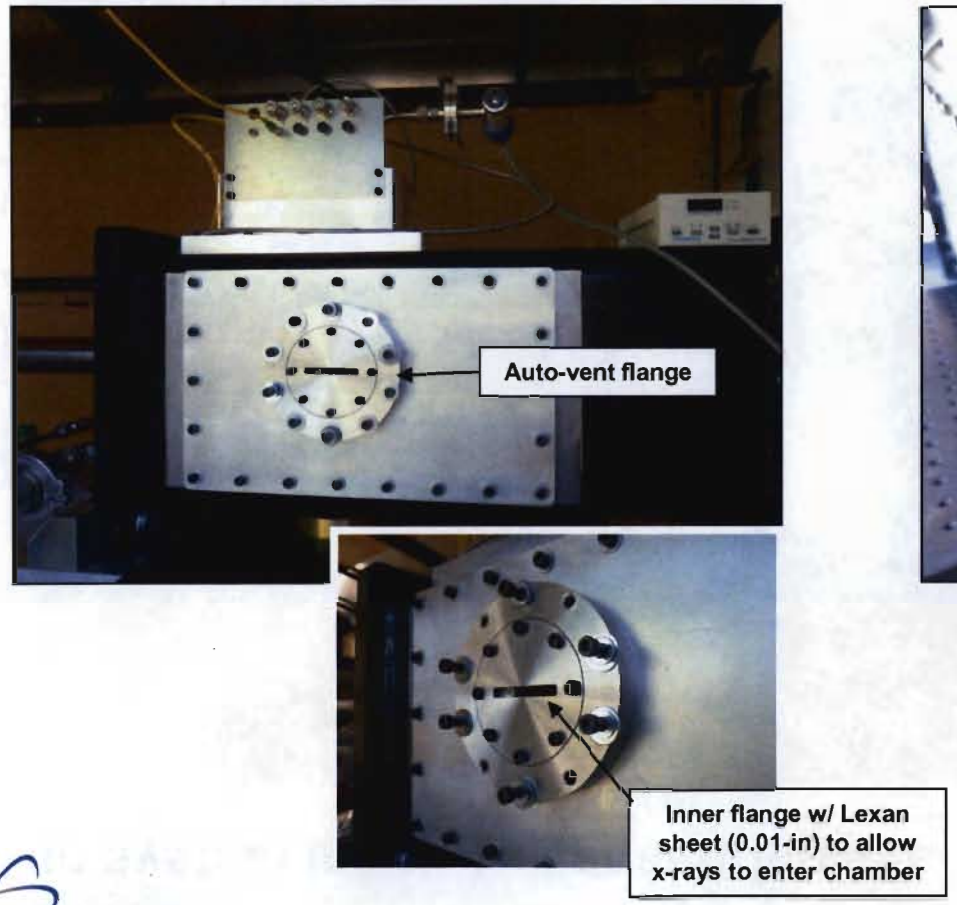


Gun system inside trailer at firing site



Target Chamber is equipped with two auto-vent flanges to prevent pressurization of chamber post-shot

Target Chamber (Side)

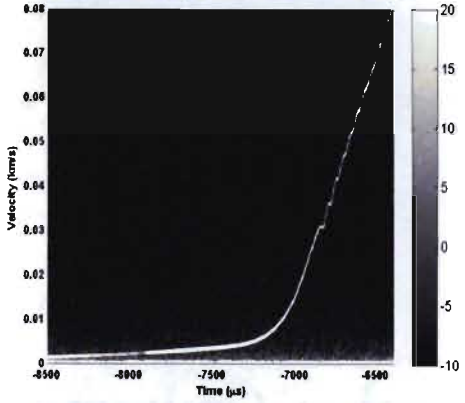


Target Chamber (Rear)

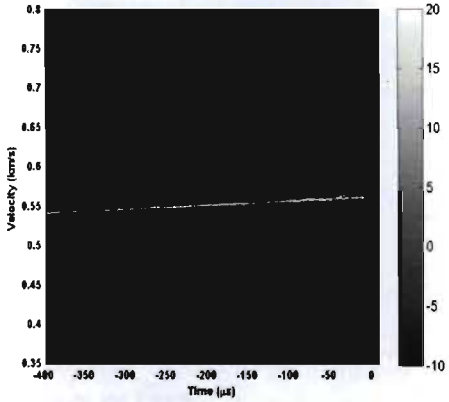
Gun qualification and performance tests

- A series of test shots were performed on gun system to qualify it for use at APS
- Gun performance curve (velocity vs. CM ratio) developed to predict velocity for physics experiemnts
- Three different projectile mass used to obtain a range of velocities
- Auto-vent valve testing

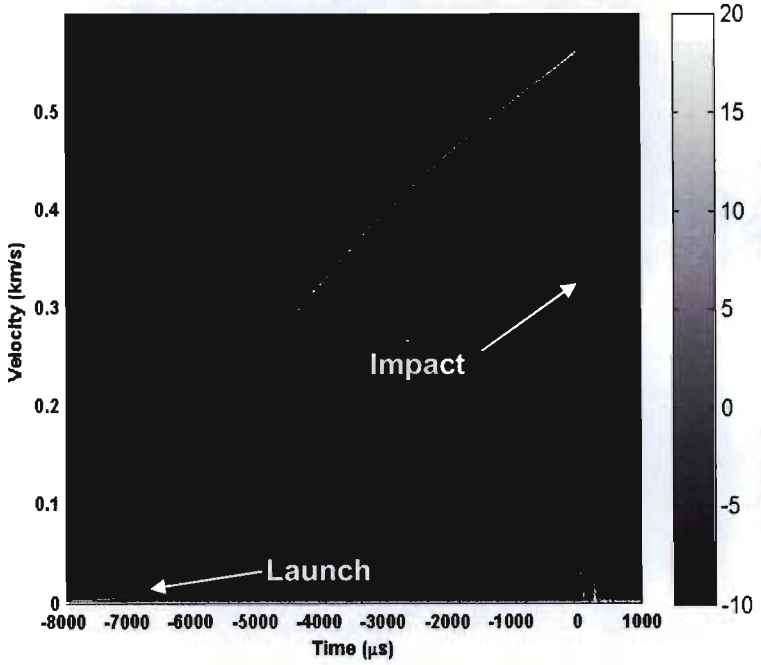
Initial Projectile Launch



Impact

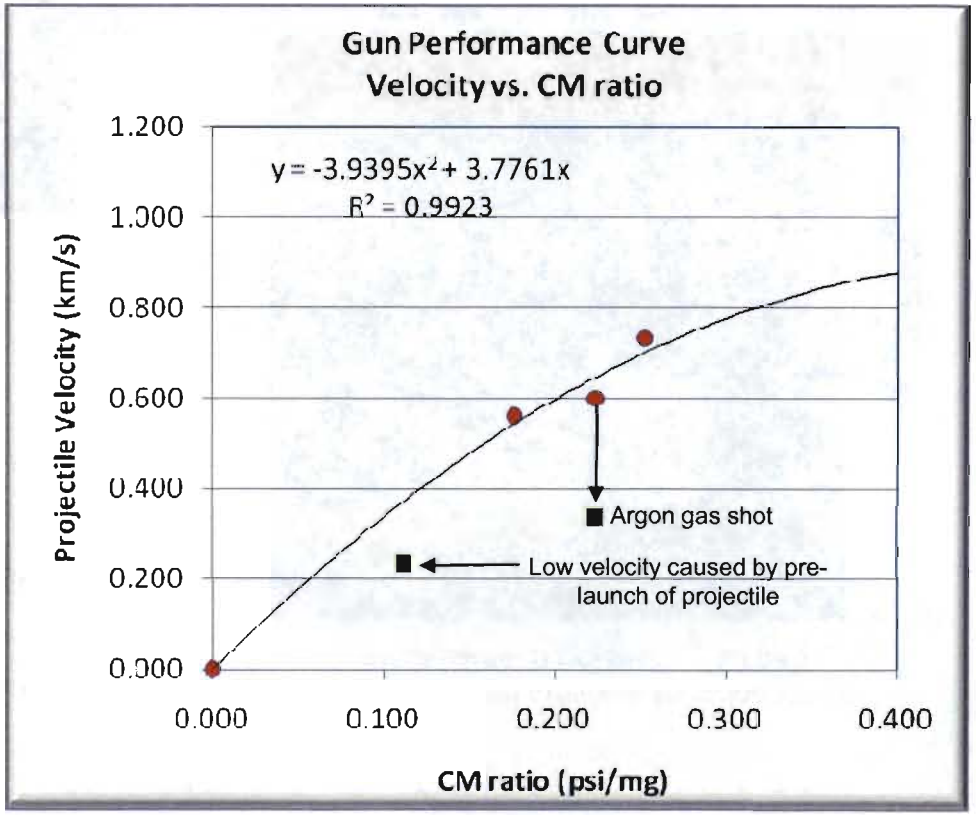


Projectile velocity history from launch to impact (Breech pressure 750 psi)



Summary of testing results

- Gun performance curve well-defined following several experiments
- Three projectile types used for low, moderate, and high velocity
- Pre-launch of the projectile was observed when the launch tube pressure was comparable to the breech pressure
- Pre-launch problem solved by including a small orifice in the launch tube line
- Auto-vent flanges functioned properly preventing pressurization of the target chamber post-shot



Summary and Conclusions

- Fabrication of system complete (table, goniometer, etc.)
- System installed inside an enclosed Hallmark Trailer for testing at the firing site
- Engineering analysis of launcher system (breech, barrel, target chamber, etc.) complete
- Detector feasibility tests complete
- First gun qualification shots complete to:
- Develop performance curve (Projectile velocity vs. Breech-pressure/projectile-mass ratio)
- Auto-vent feature of the system successful
- System qualified and ready for shipping to Argonne lab in IL