



Proton Radiography for Density Movies of Dynamic Exploding Events

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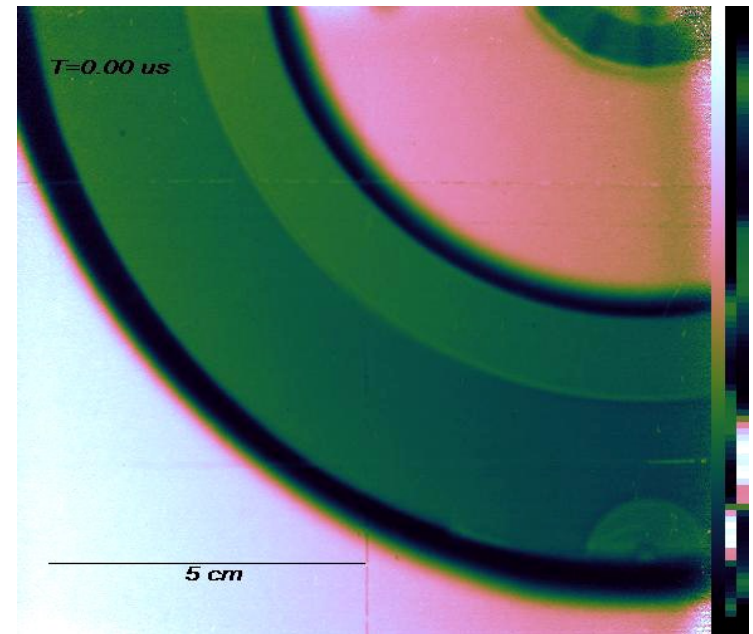
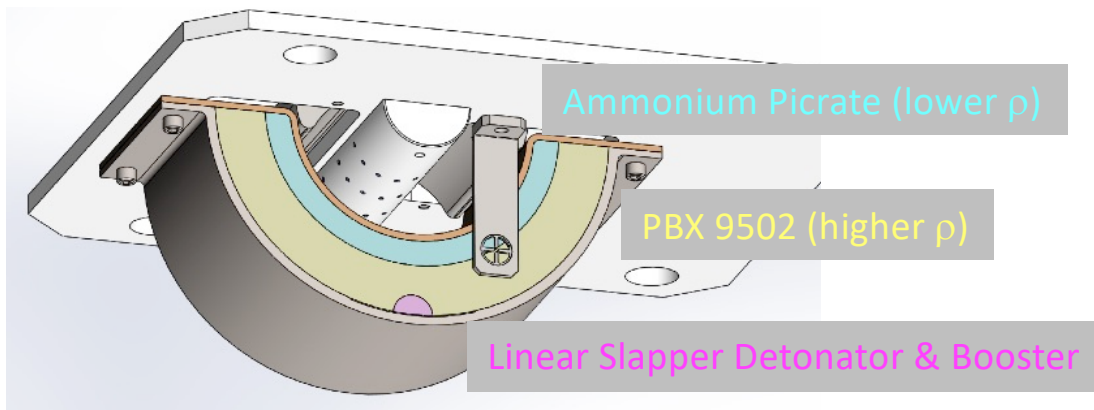
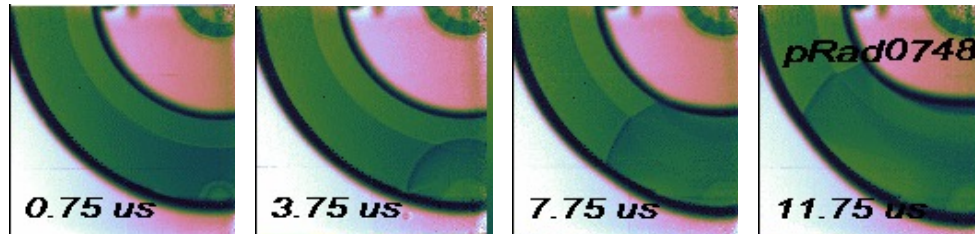


pRad

PROTON RADIOGRAPHY

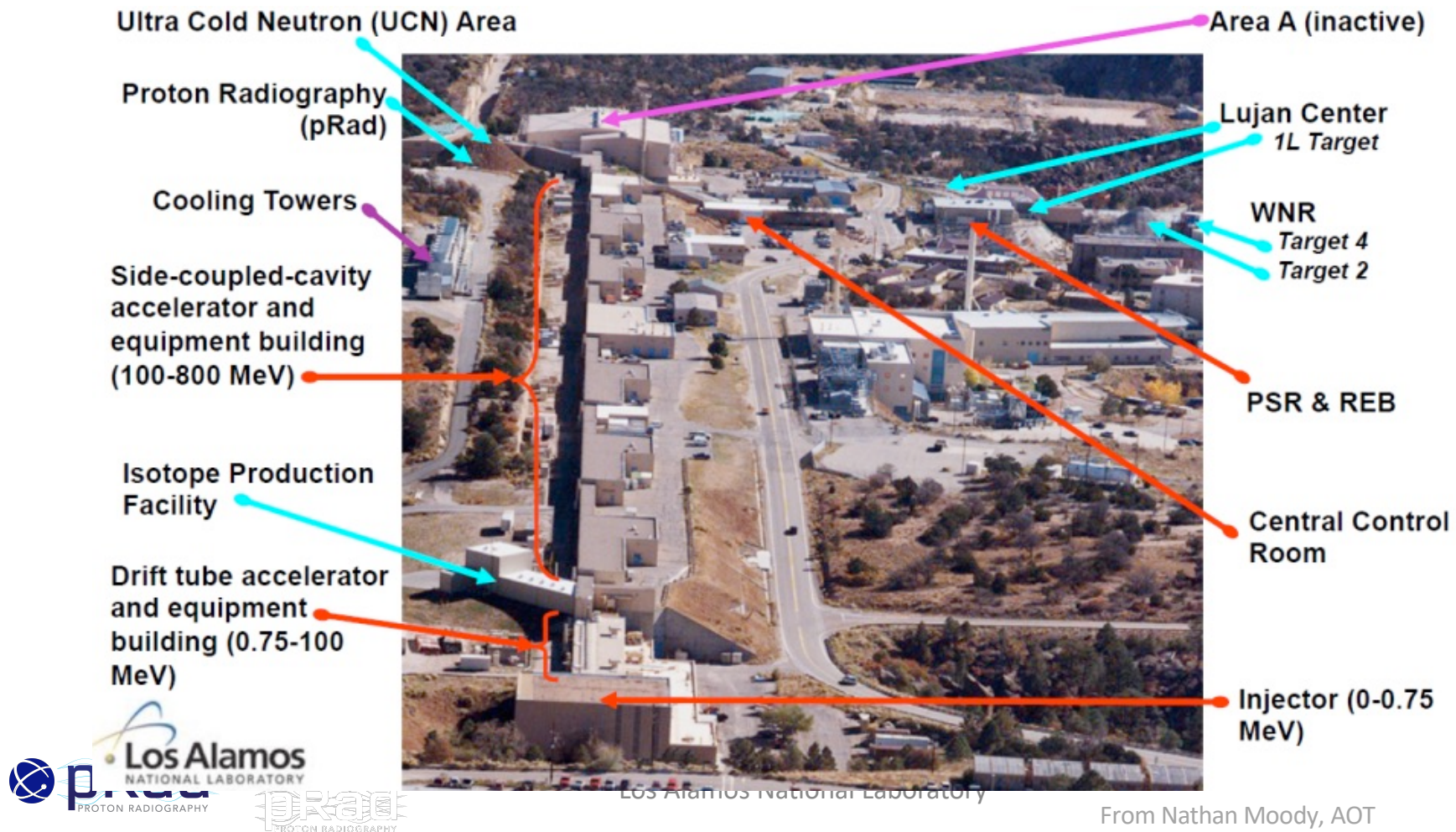
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Proton radiography allows us to see material deformation & explosive detonation front positions and speeds

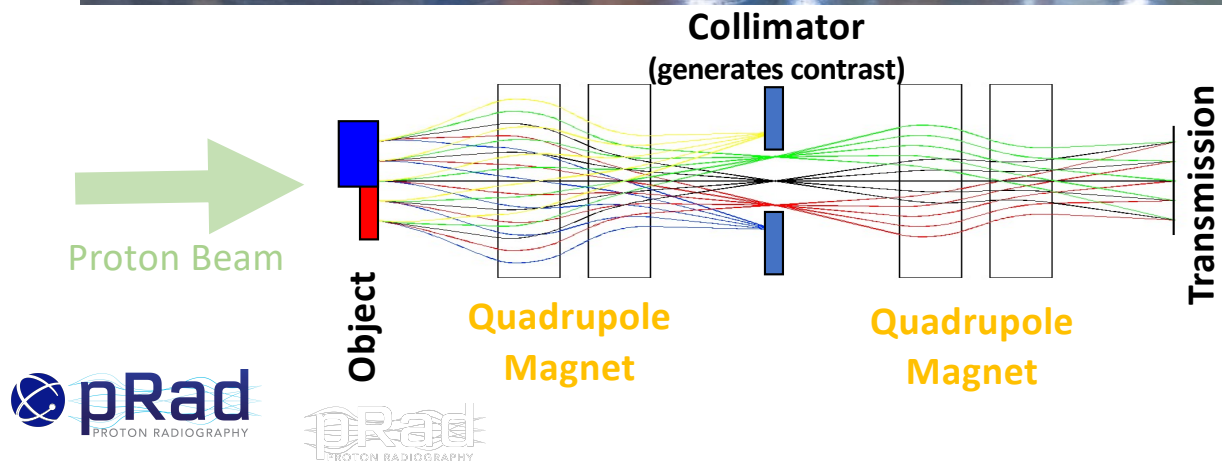


A density movie of the explosion can be directly compared to simulations to see if we are modeling materials correctly

pRad takes place at the Los Alamos Neutron Science Center (LANSCE, TA 53)



The Line C Dome is where all of the dynamic experiments occur



Object thicknesses and densities can be discerned from the multiple coulomb scattering observed at the transmission plane

Explosive experiments take place in a vessel



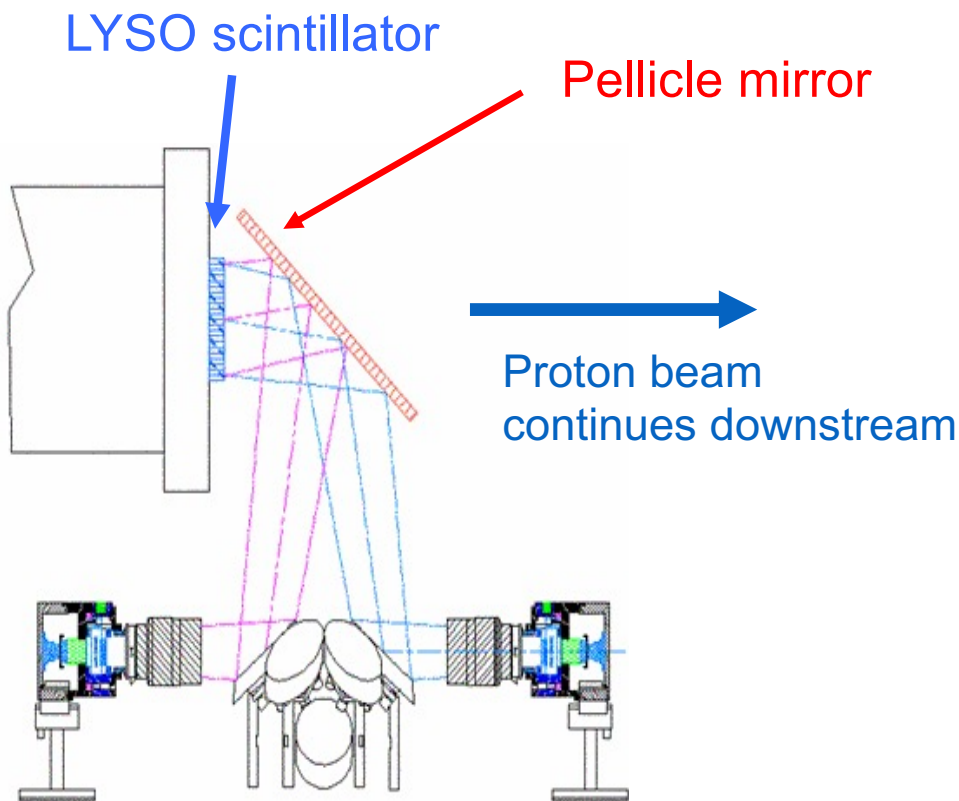
Vessel

Image Location

x3 quadrupole
electromagnets



pRad images are acquired with fast scintillators and high speed framing cameras

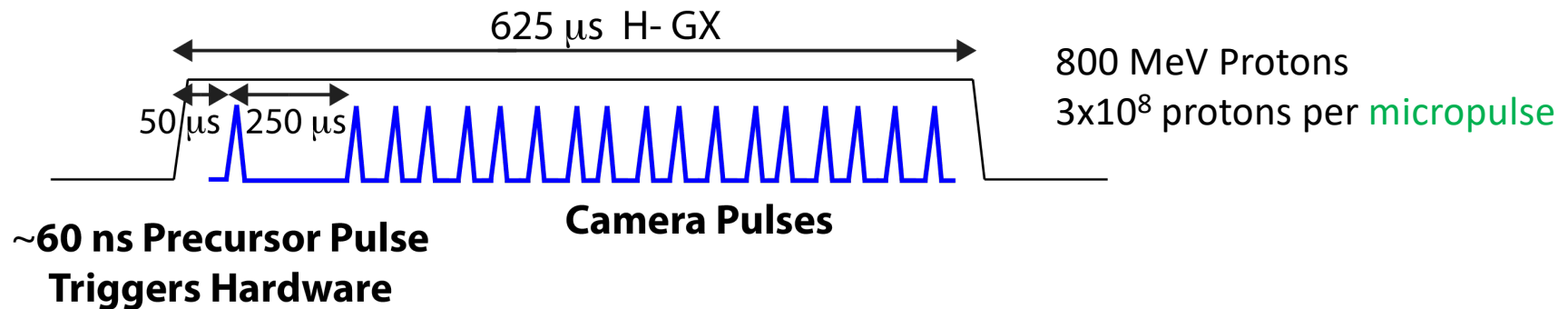


LYSO scintillator panel generates visible light with ~ 50 ns lifetime.

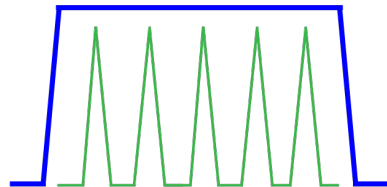
Fast cameras gated on different proton pulses take individual frames that are then stacked to make a movie.

Camera	10-frame	3-frame
Min integration time	50 ns	150 ns
Min inter-frame time	150 ns	358 ns
Dynamic Range	3430	1330
Read Noise (e^-)	79	216
Pixel array	1100 x 1100	720 x 726
Pixel pitch	40 μm	26 μm
Sensitivity ($e^-/\text{J}/\text{cm}^2$)	3.0×10^{12}	1.9×10^{13}
Sensor size	44 x 44 mm	21 x 22 mm
Well Depth	272	180

Temporal resolution allows capture of shock waves and detonation fronts in objects



Single Pulse Composition



Micropulses
 $f=201.25 \text{ MHz} \sim 5\text{ns}$
width=100 ps

Camera Pulse Structure

Minimum frame spacing: 200 ns

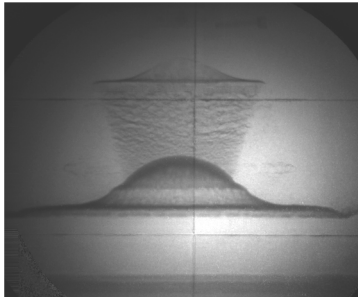
Exposure time: 50-100 ns

Number of frames: 22 (10-frame + 4 3-frames)

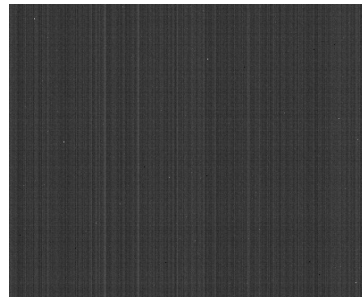
The pRad imaging pulse structure and timing is customizable, depending upon the experiment needs.

Going from raw radiograph to areal density

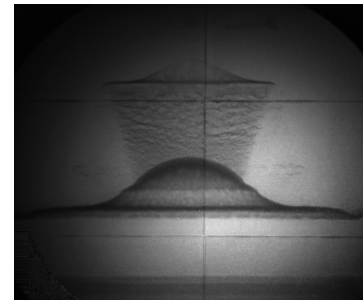
"Raw" Radiograph



Dark Field

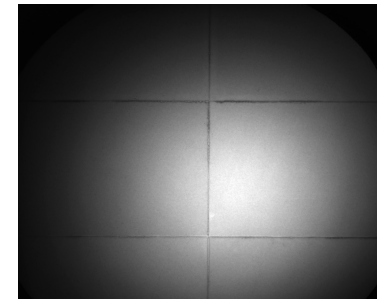


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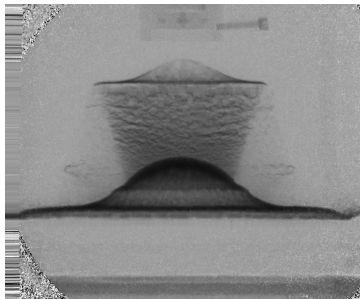


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Beam Picture



Transmission



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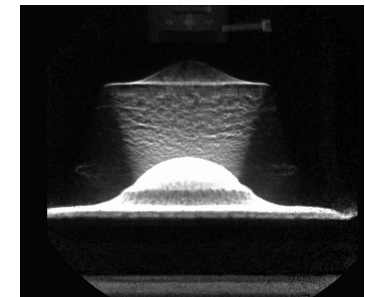
$$T = e^{-\frac{x}{\lambda}} \left(1 - e^{-\left(\frac{\theta_c p \beta}{14.1 \text{ MeV}} \right)^2 \frac{x_0}{2x}} \right)$$

Nuclear attenuation

Multiple Coulomb Scattering



Areal Density (g/cm²)

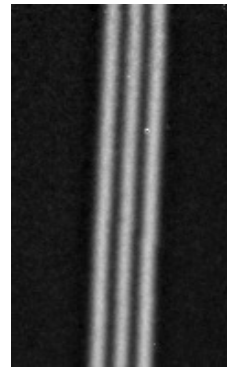


Several magnification systems are available for changing spatial resolution and FOV

Identity Lens –I
120 mm FOV



X3 Lens
44 mm FOV



2.5 lp/mm

X7 Lens
17 mm FOV



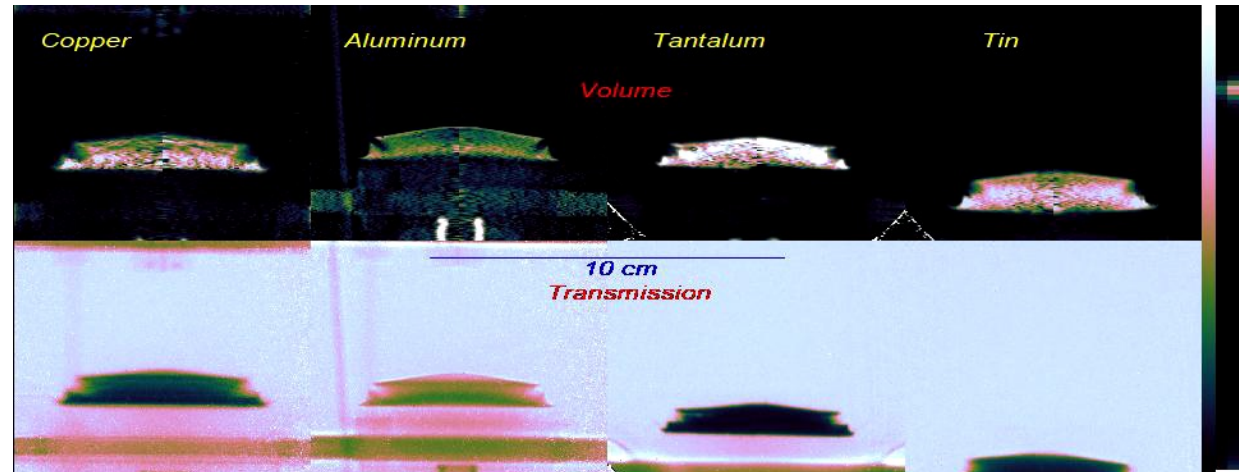
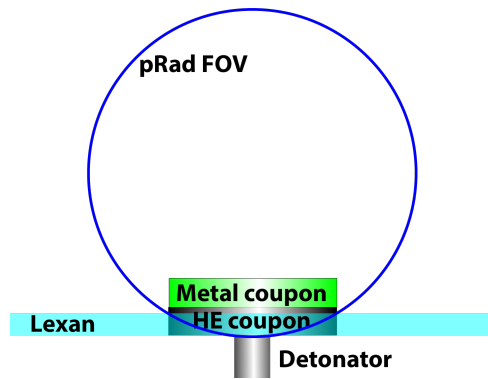
Ideal Spatial Resolution

178 μm

45 μm

25 μm

Dynamic material strength experiments show the structure in material failure



pRad 84 (copper)

pRad 85 (aluminum)

pRad 89 (tantalum)

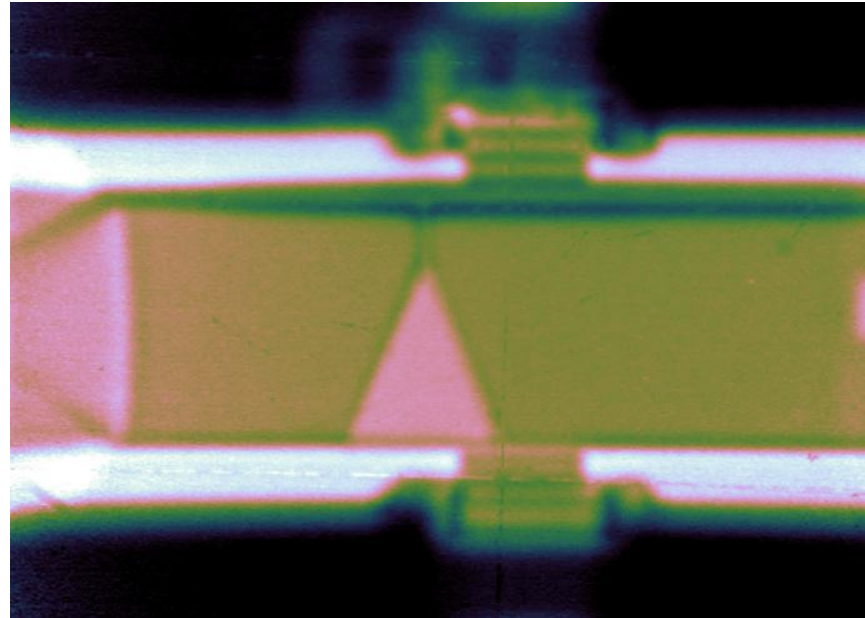
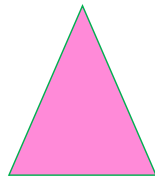
pRad 90 (tin)



WRX experiments study how inert materials can disrupt a detonation front

Detonation front moves left to right through HE slab

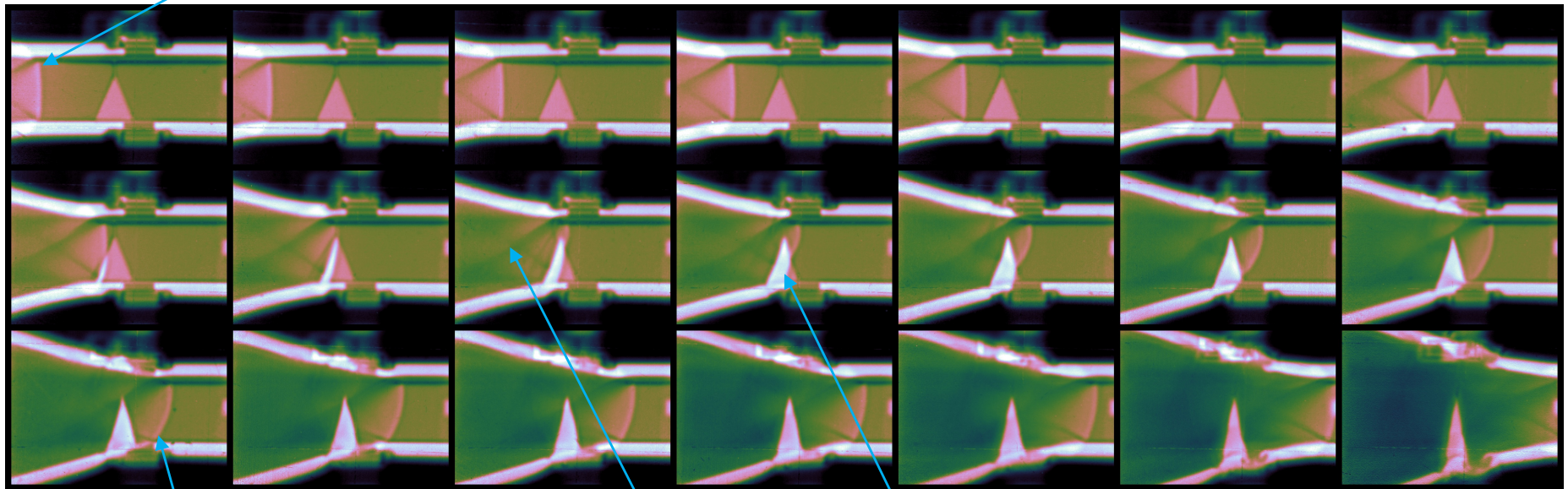
Polycarbonate wedge (starting proportions)



pRad images the **speed and shape** of the detonation shock waves through the HE and the det products, plus **pre- and post-shock densities**, giving strong constraints to equations of state

WRX experiments study how inert materials can disrupt a detonation front

Flat detonation front



Curved det front

Reflected shocks in
det products

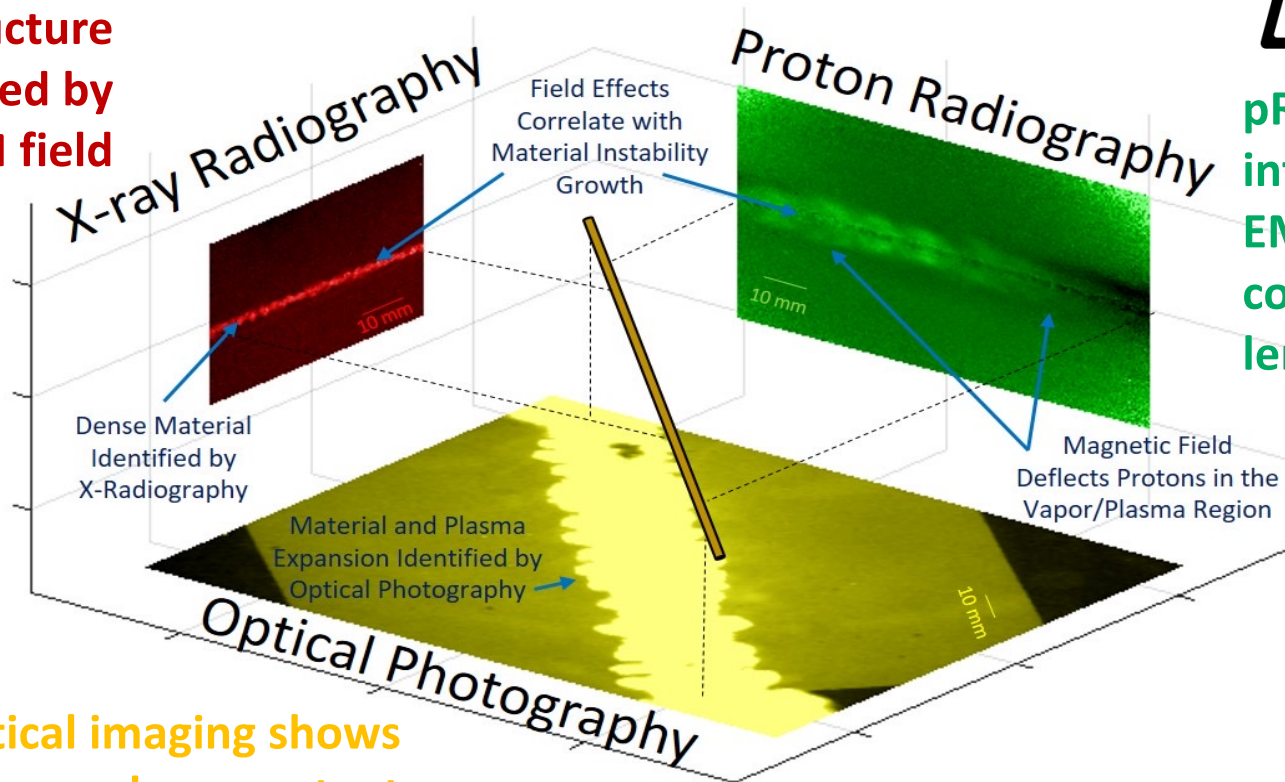
Shock speed/position through
polycarbonate wedge

ARL shots demonstrated a new way to use pRad to look at magnetic field effects in plasmas

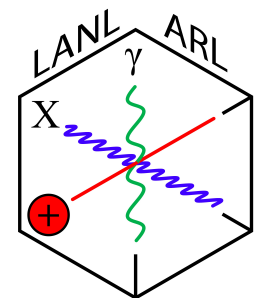
**X-ray structure
not influenced by
local EM field**



**pRad structure
influenced by
EM fields
collimators +
lenses**

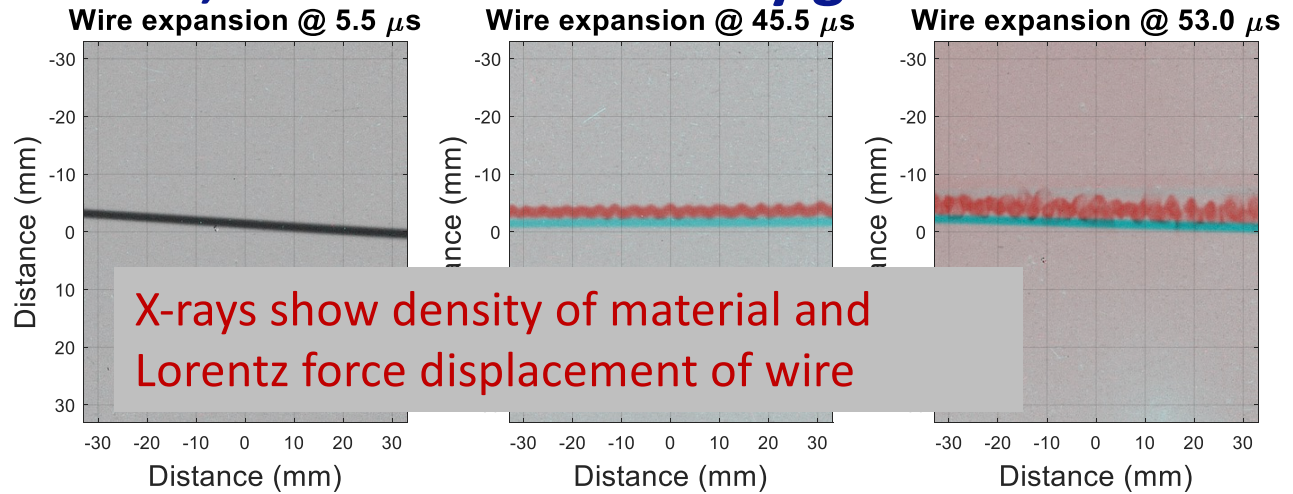
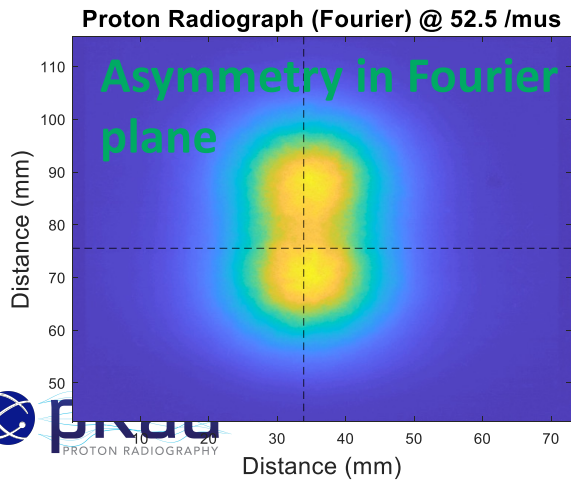
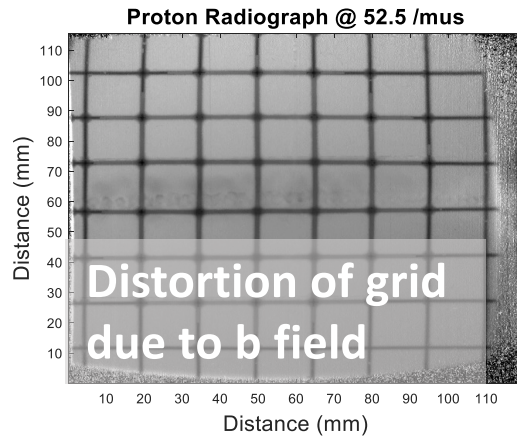


**Optical imaging shows
plasma extent**

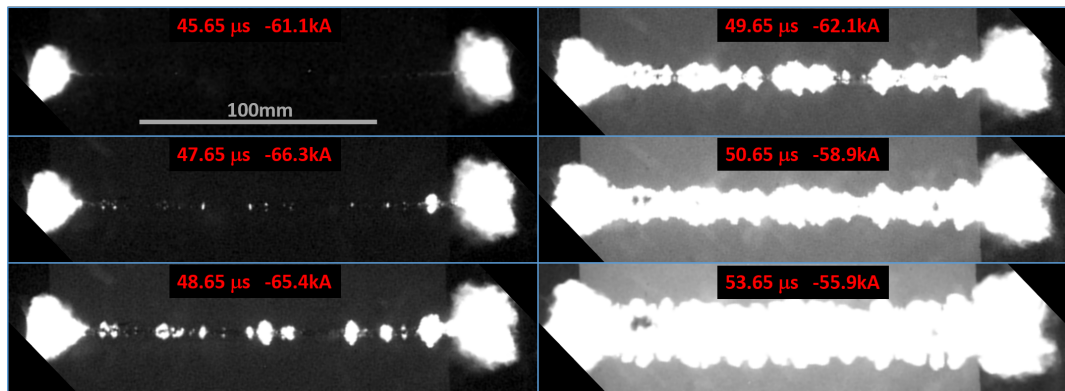


Contacts: Mike Zellner, ARL; Neukirch + Freeman ¹³

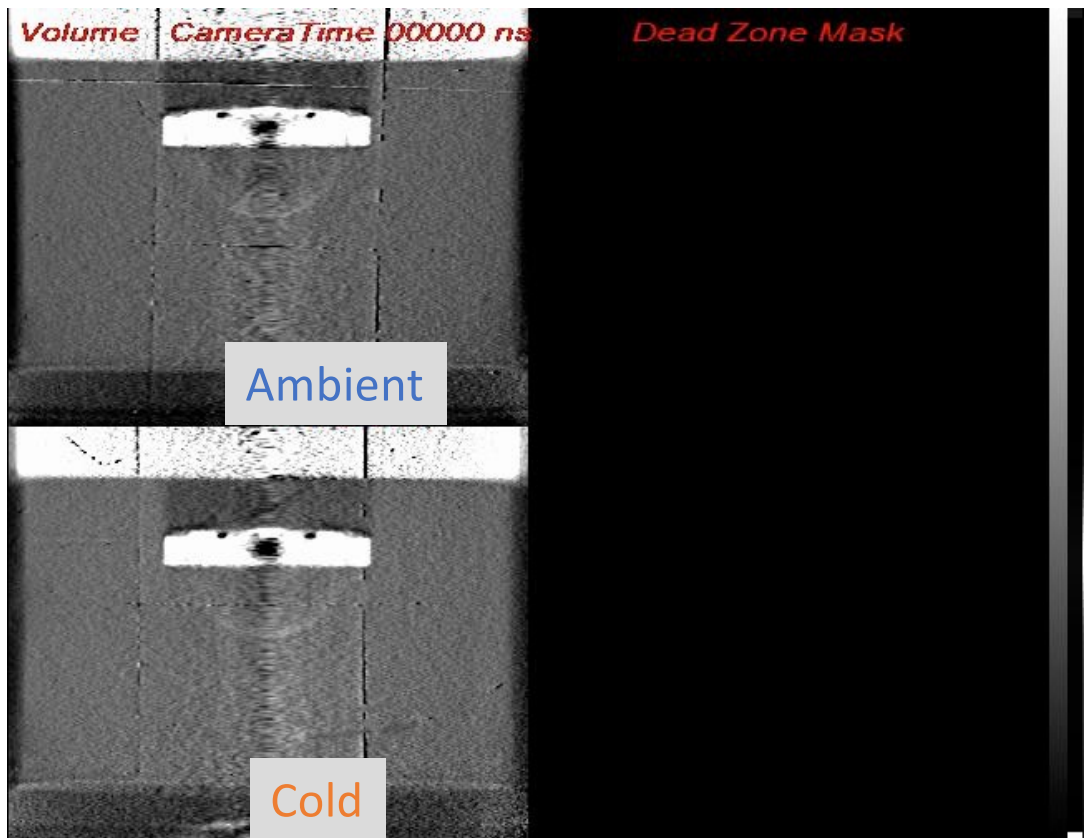
ARL experiments studying plasma behavior, conduction pathways in material mixtures, and MHD instability growth



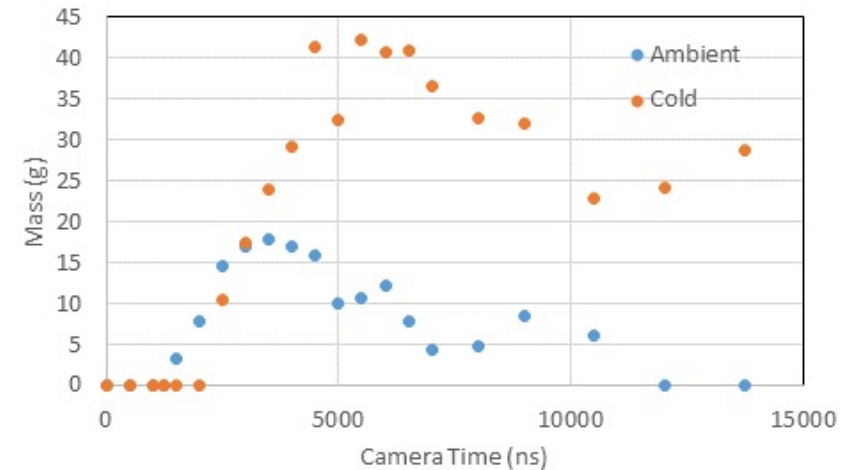
Development and extent of plasma



Explosives exhibit different dead zone behavior depending upon temperature

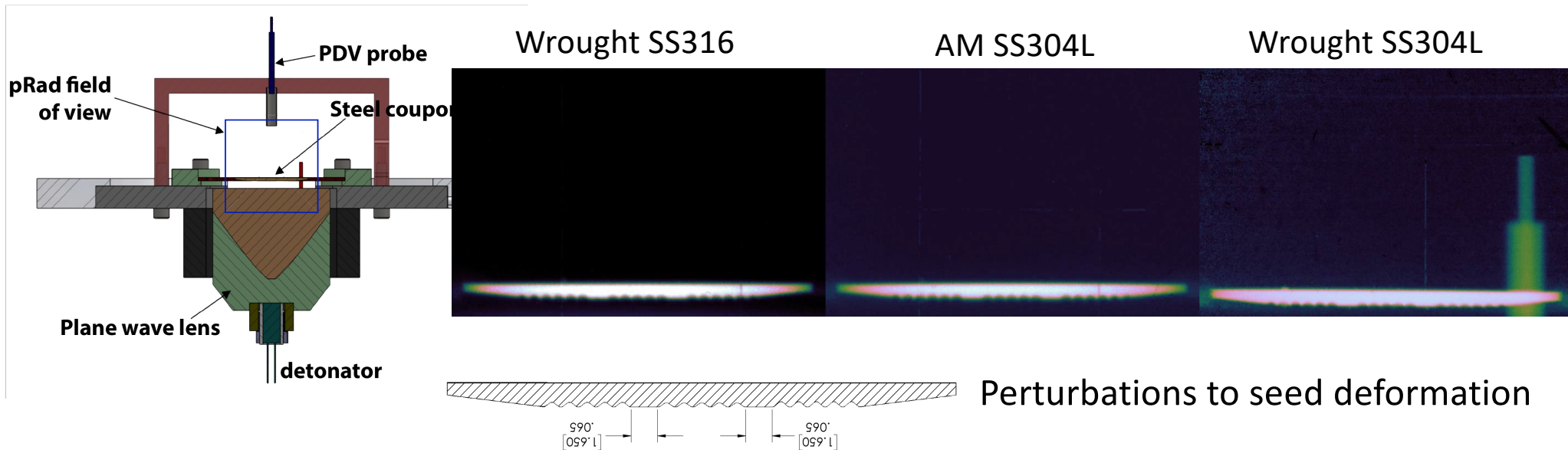


Dead zone masses are estimated from pRad density images and compared to pre-shot calculations



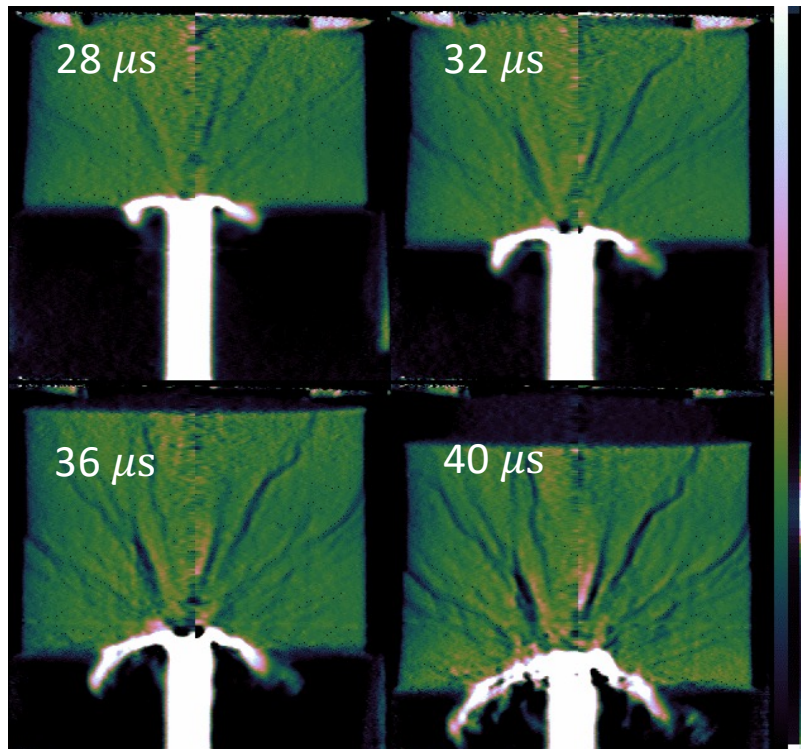
Contacts: Clif Mortensen, LLNL; Chris Morris

High strain rate drive (~225 kbar) shows how manufacturing processes affect strength



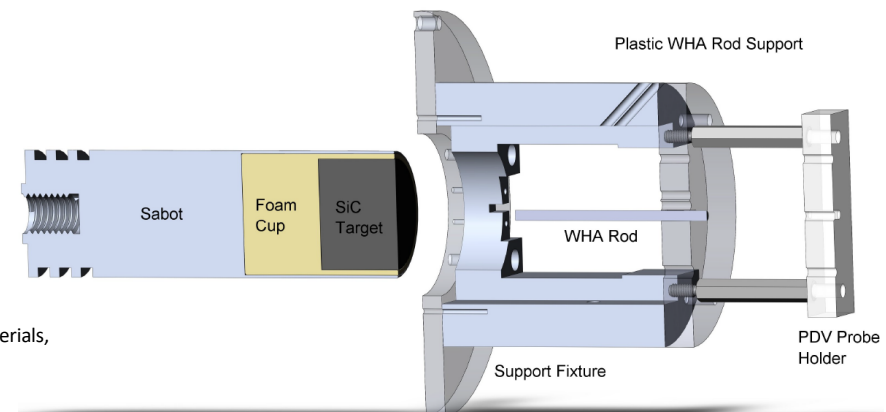
Manufacturing method (wrought vs AM) affects material strength

Army Research Lab reverse flyer series to examine armor failure using the pRad powder gun



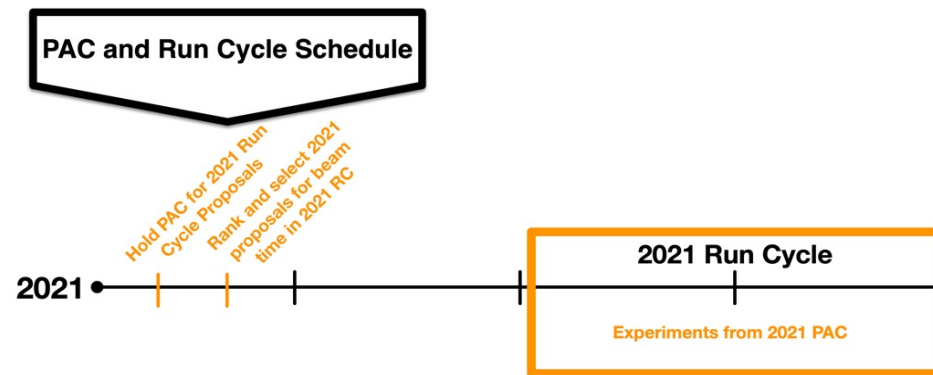
Density reconstruction of SiC fracture

Aydelotte B. et al. (2019) Proton Radiography of Reverse Ballistic Impacts. In: Dynamic Behavior of Materials, Volume 1. Conference Proceedings of the Society for Experimental Mechanics Series.



Contact: Brady Aydelotte

All experiments for pRad must be approved by a Proposal Advisory Committee



Submitted proposals should address these ranking criteria:

1. Quality of the science being proposed (What is the problem, and why are experiments needed?)
2. Impact to programs (How will the data be used?)
3. Appropriateness of the use of the pRad diagnostic for the experiments (Why can't this be done somewhere else?)
4. Readiness of the experiments, feasibility with stated resources, and requested time (Has other work been done informing the pRad experiments?)

What are the characteristics of highly-ranked experiments?

- Time and density resolution are needed
 - Justify time-resolved areal density measurements
- Thickness/transmission is optimized for pRad
 - Is this an experiment that will image well with 800 MeV protons?
- Facilities/Drivers
 - Are you using an existing capability, such as the powder gun or 6' vessel?
 - Will the proposal require significant investment?
- Materials
 - Are the proposed materials allowed? How will you know?

The best practice is to talk to a pRad team member.
Your proposal should address the above concerns.

More info about pRad is online

- The call for proposals for the 2022 Run Cycle comes out in December
- The LANSCE Website has the **User Manual** <https://lansce.lanl.gov/facilities/pRad/index.php>
- I will put you in contact with someone whose expertise can best assist you with experiment planning.



The screenshot shows the LANSCE (Los Alamos Neutron Science Center) website. The header includes the LANSCE logo and navigation links: ABOUT LANSCE, FOR USERS, SUBMIT A PROPOSAL, FACILITIES, and NEWS & EVENTS. The main content area is titled "Proton Radiography" and describes the facility's use of high energy protons for flash radiography. It includes a "Proton Radiography Capability Overview" section with a large image of the facility's interior. On the right side, there are social media links and a "PRAD RESOURCES" section with links to the "pRad User Manual" and a "Highlight Physics Focus on pRad.pdf".

Los Alamos National Laboratory Beam Status (login required) search site

LANSCE Los Alamos Neutron Science Center

ABOUT LANSCE FOR USERS SUBMIT A PROPOSAL FACILITIES NEWS & EVENTS

Facilities » Proton Radiography

Proton Radiography

Los Alamos National Laboratory has used high energy protons as a probe in flash radiography for a decade.

CONTACT

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pRad User Office
[Email](#)

Proton Radiography Capability Overview

pRad
PROTON RADIOGRAPHY

The proton radiography project uses 800 MeV protons from the LANSCE accelerator facility to diagnose dynamic experiments, such as explosive and powder gun experiments, and pulsed-power implosions. Dynamic experiments occur in the Line C Dome.

PROTON RADIOGRAPHY

[About](#)

[pRad Team](#)

PRAD RESOURCES

[pRad User Manual](#)

[Highlight Physics Focus on pRad.pdf](#)

