High Aspect Ratio Hole Characterization in Tantalum foils for use in Pinhole Based Diagnostics

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General Atomics

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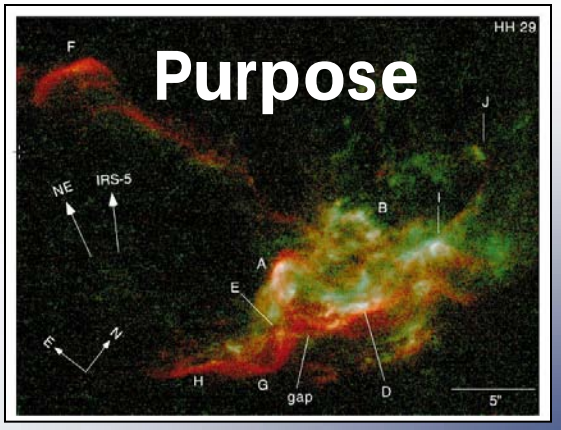
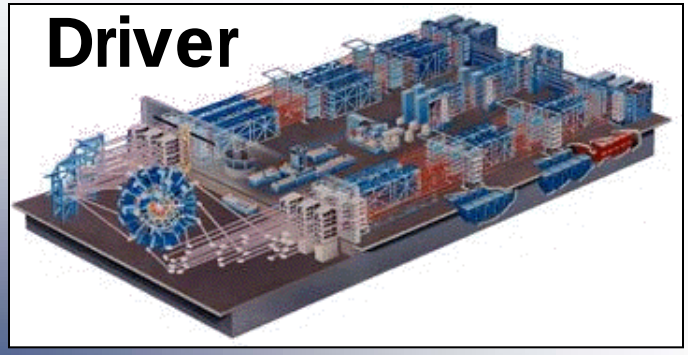
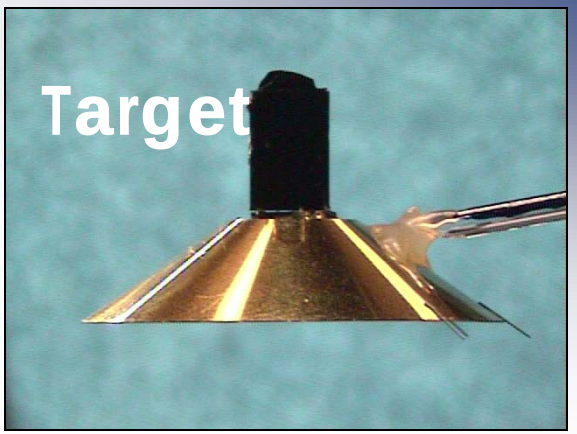
4 key aspects of a successful experiment



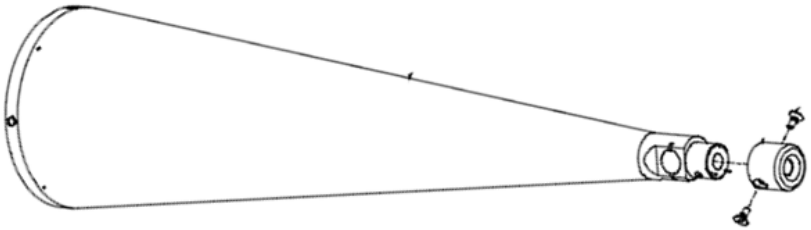


Results

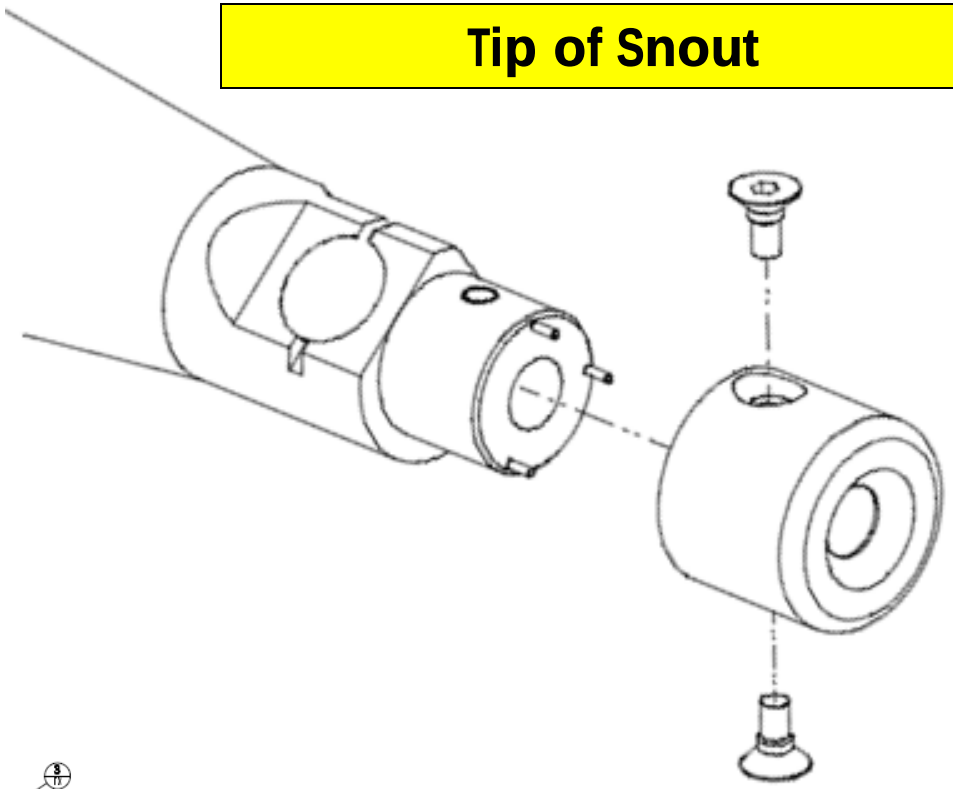


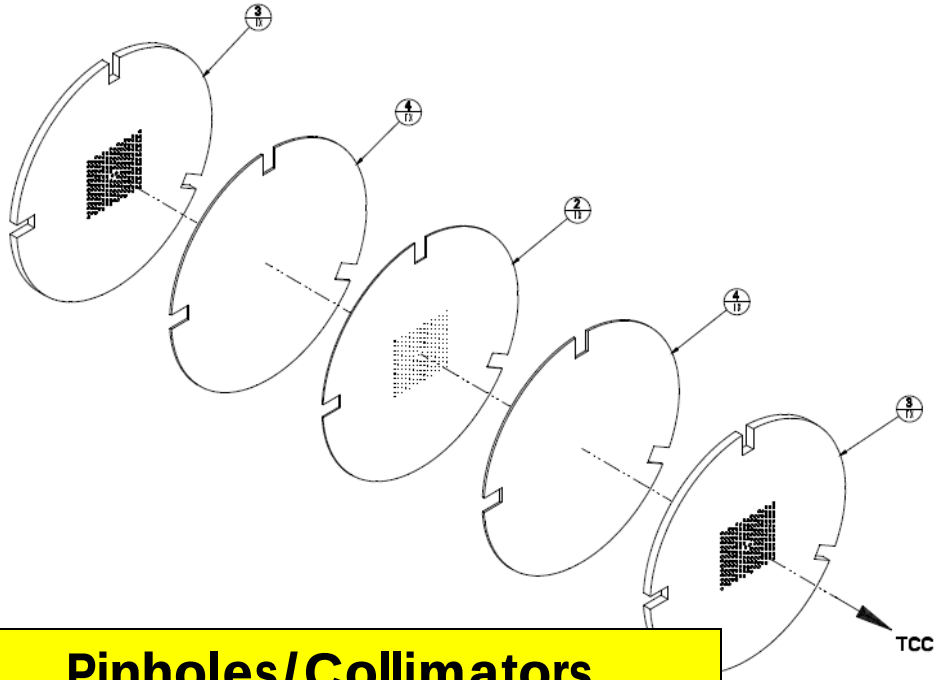
LLNL Pinhole Assembly

Snout



Tip of Snout

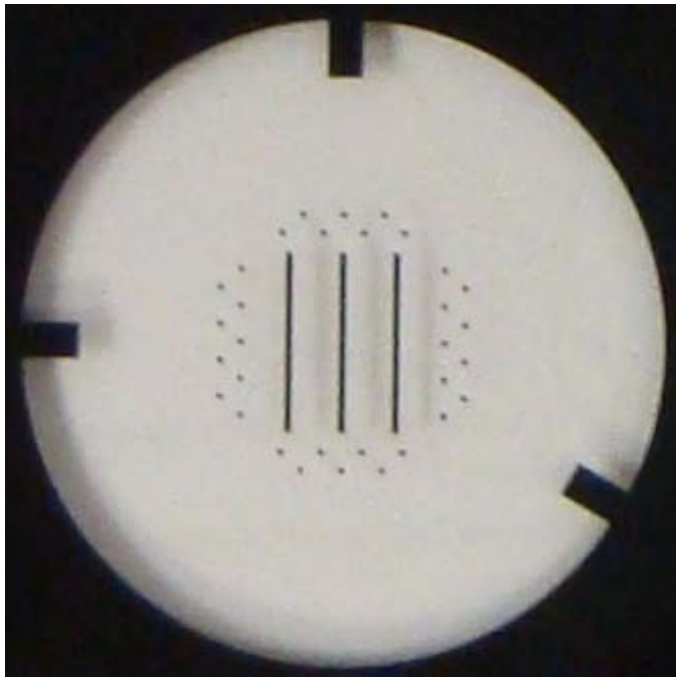




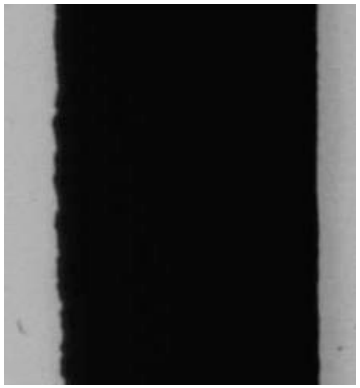
Pinholes/Collimators

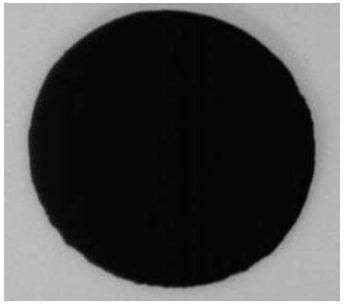
GA radiographs PH components for historical record and for analysis of features

- **Initially, Contact Radiography (CR) data used to correct each PH's diameter (intensity profile)**
  - Over 400 components from other vendors have been analyzed in 2011

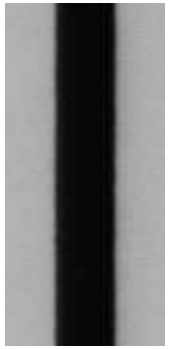


150μm





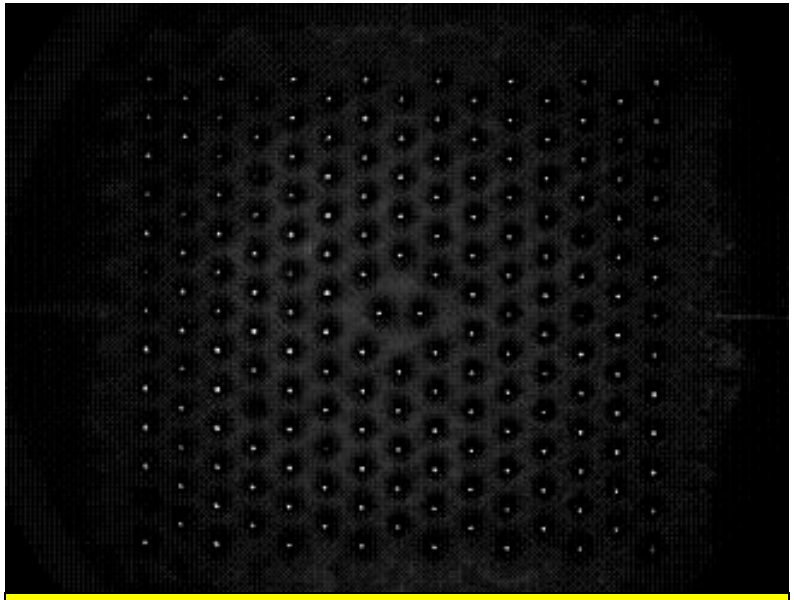
25μm



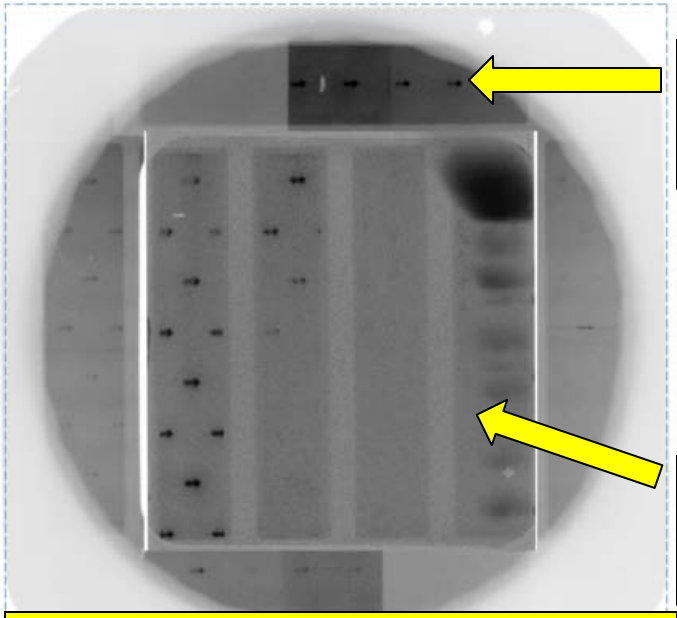
10μm

PH fabrication have resulted in lost data from NIF experiments

- Several shots did not return full data in FY10 & FY11
- Attributed to PH fabrication
- Optically inspection did not prevent failures



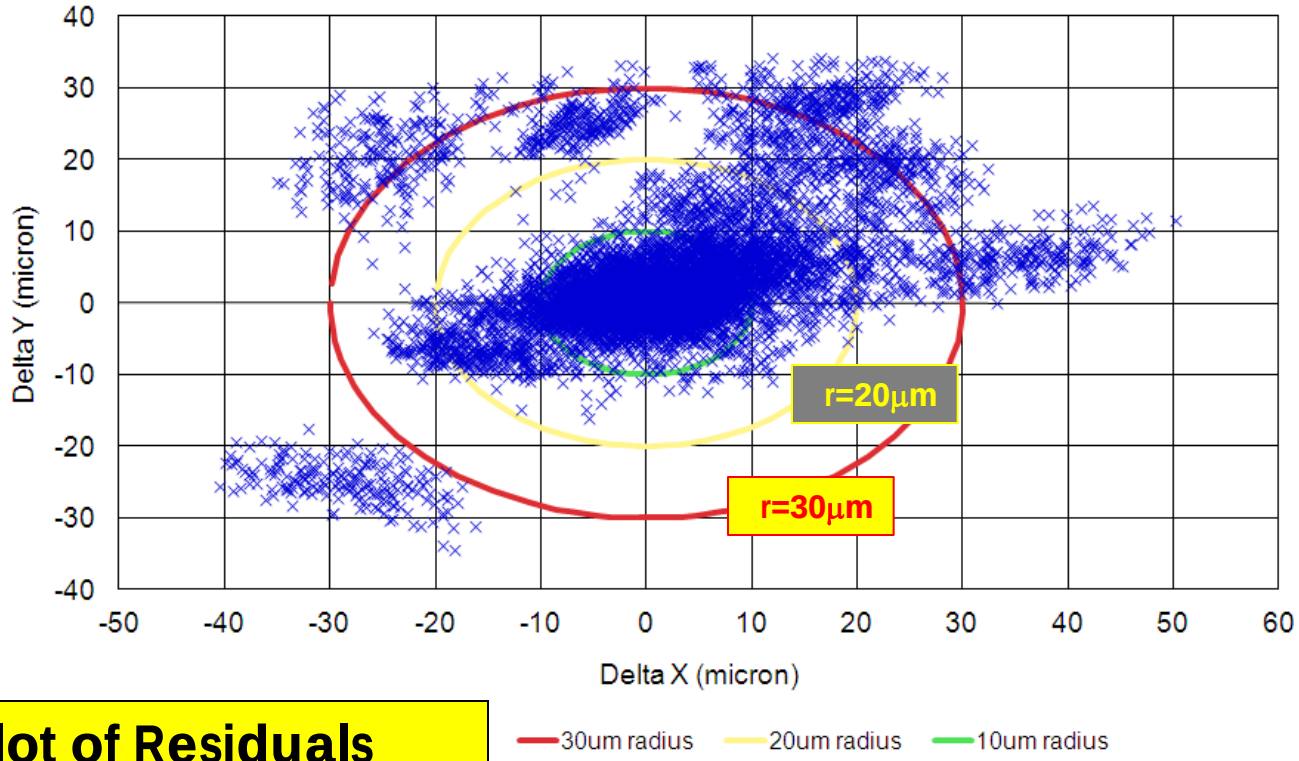
Optical inspection



Missing data

Pinhole suppliers were not holding tolerances

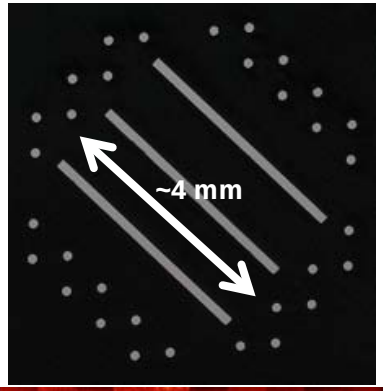
- **GA used NEXIV system to generate an x-ray based dimensional map of the PHs and COLs**

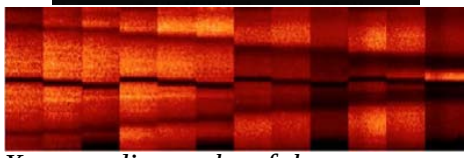


Plot of Residuals design - measured

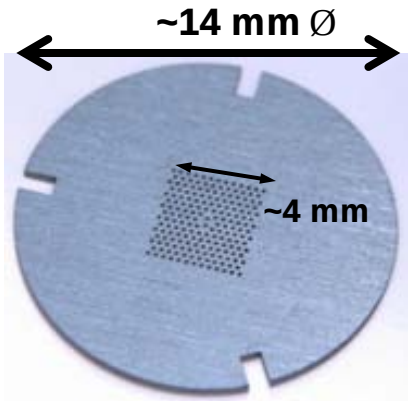
PH are complex and enable several functions

Convergent Ablator

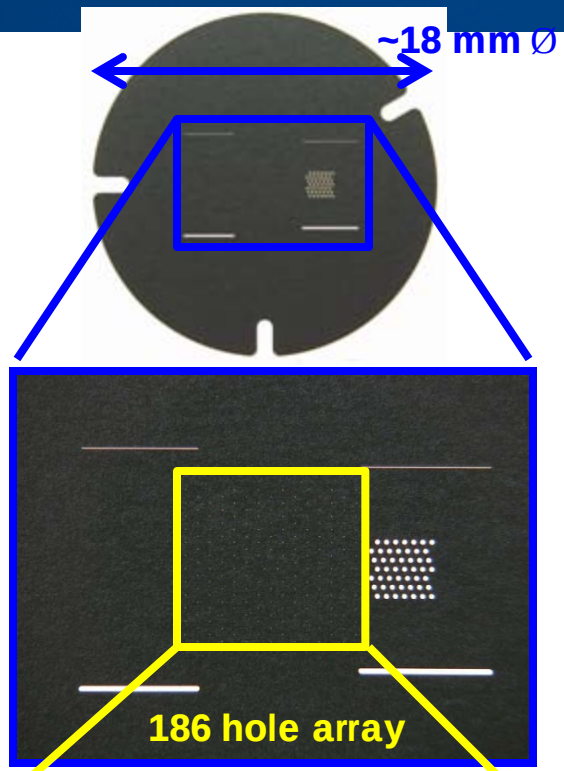


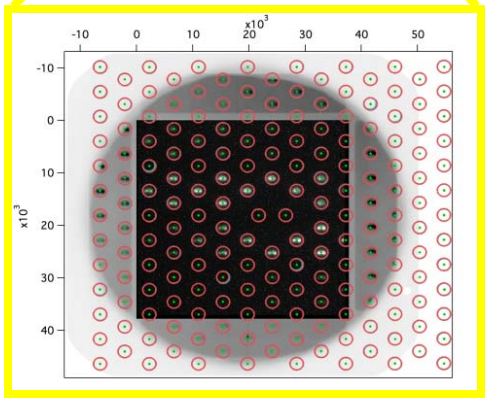


X-ray radiographs of the convergent ablator capsule during implosion.



GXD: 186 hole array





Typical pinhole design:

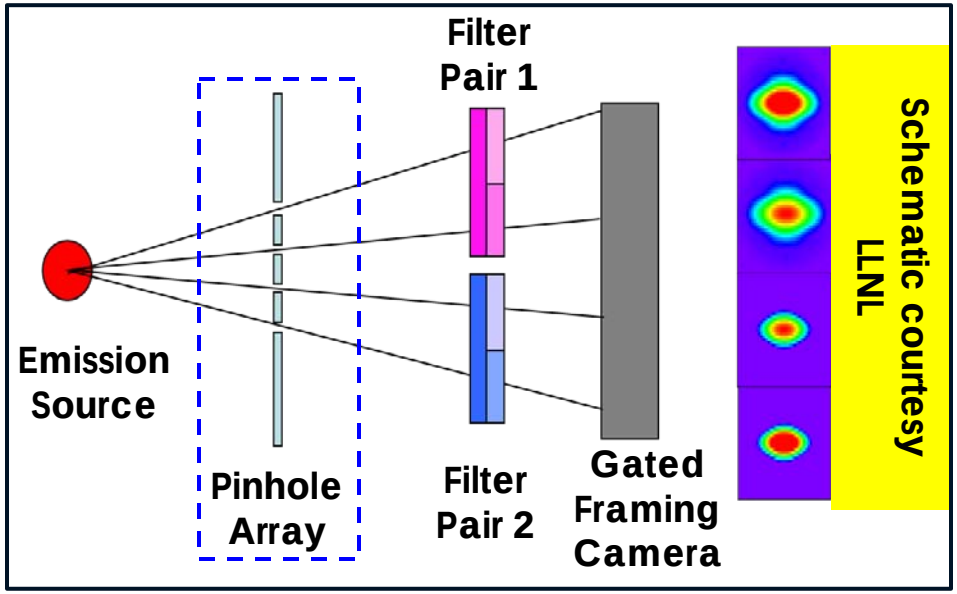
PH: 10 μm Ø, 75 μm thick Ta

COL: 150 μm Ø, 300-500 μm thick Ta

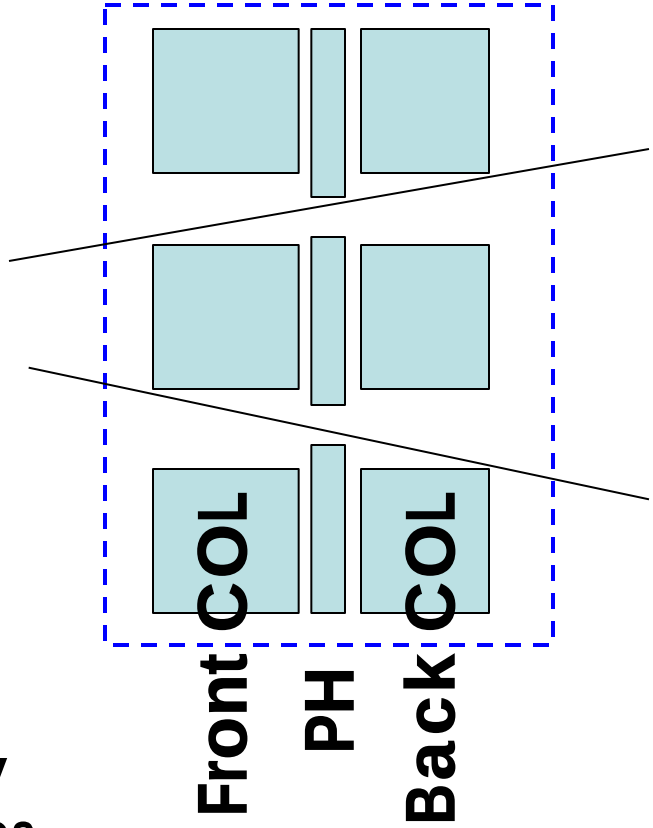
- **12-250 holes/features per plate**

Registration difficulty comes from designs that enable data redundancy & time dilation

Generic Diagnostic Design

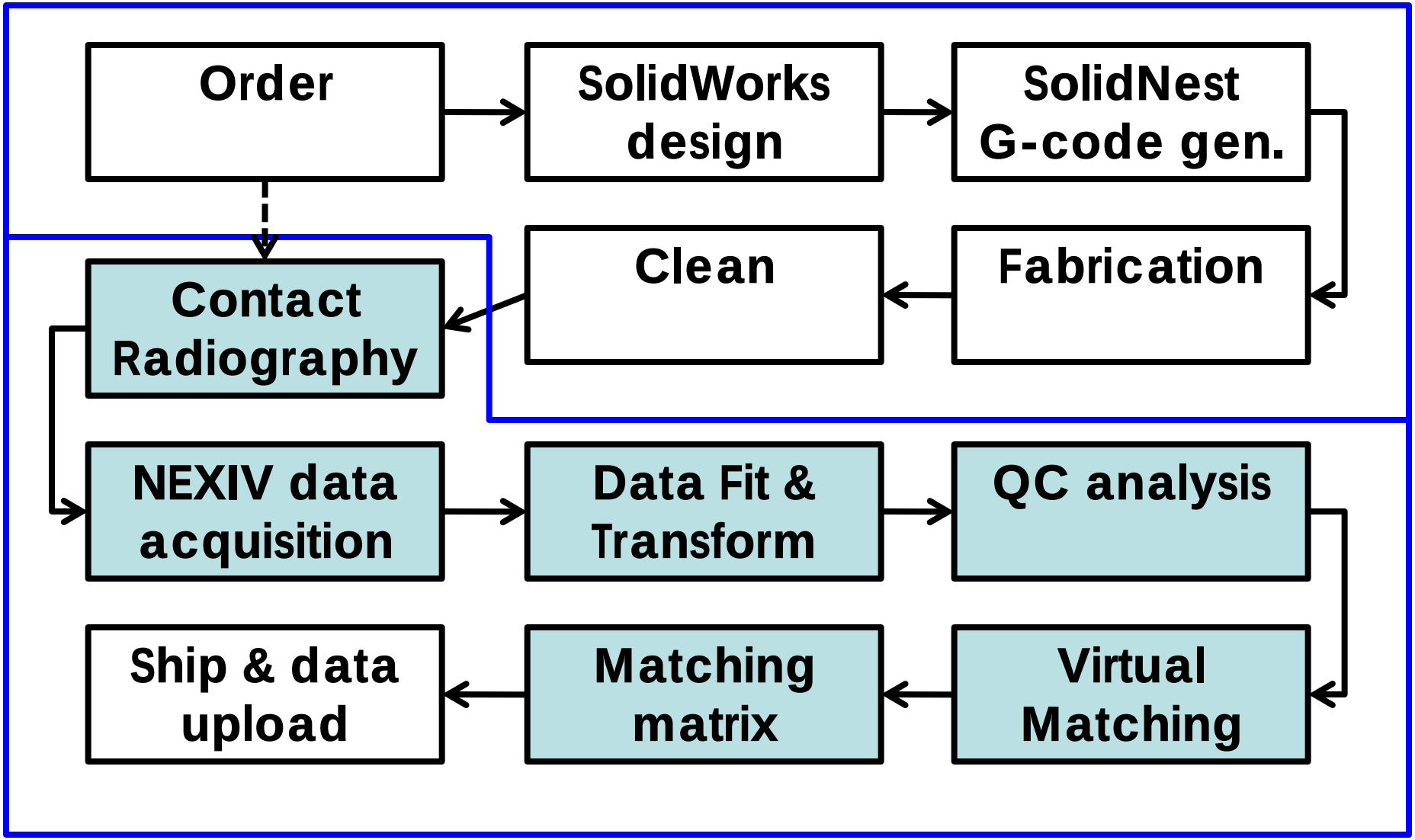


PH assembly cross section



- Complexity arises from alignment of many Collimators (COL) and Pinhole (PH) features

GA proposed a process that provides more information about the components



Example design: 186 hole array for GXD

186 GXD PH/COL design

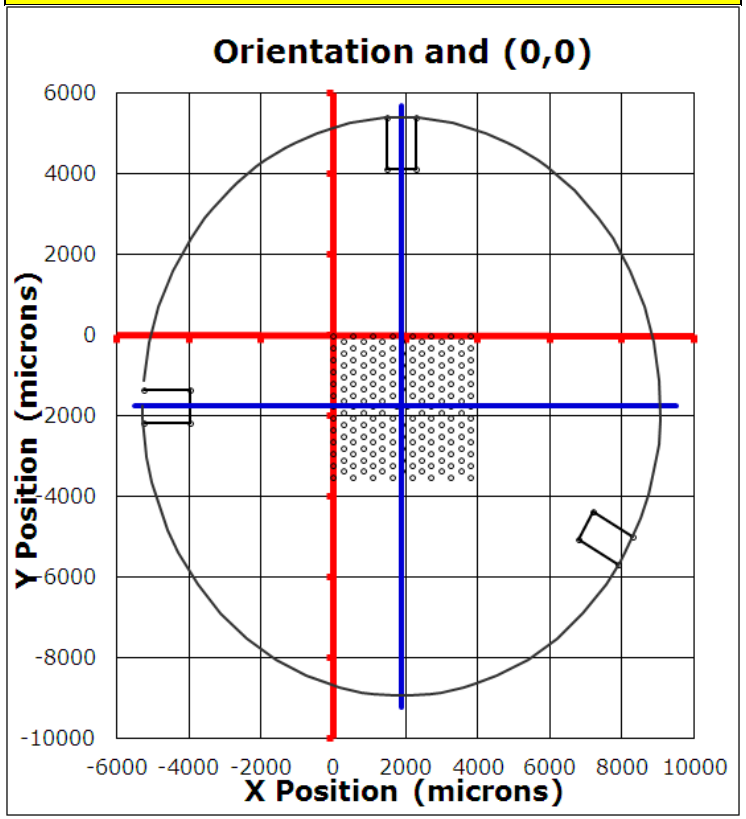


Photo of 186 hole COL

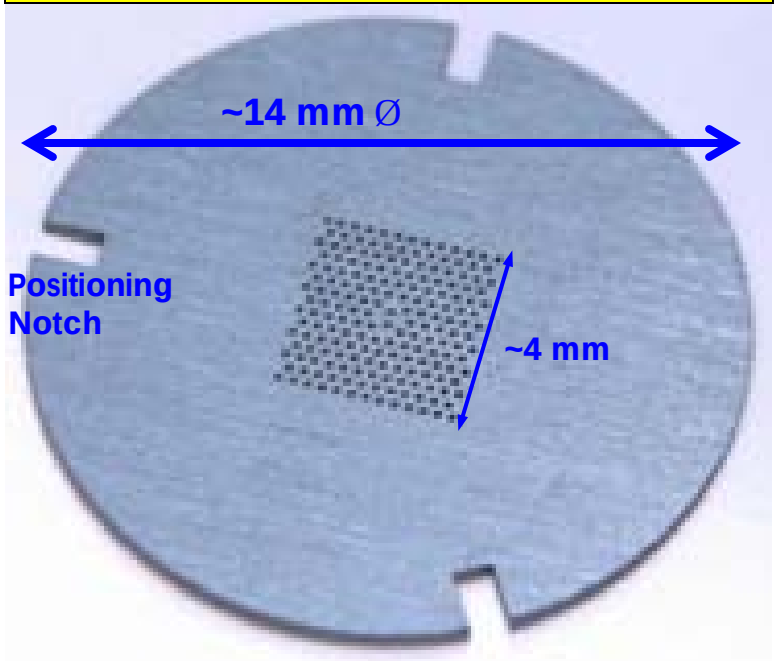


Plate is ~14 mm in diameter, notches are 0.8 x.1.2 mm
Hole position tolerance is +/- 5 μm
Hole diameter tolerance is +/- 2 μm

Traditional capsule characterization tools (CR + NEXIV) provide data

Contact Radiography

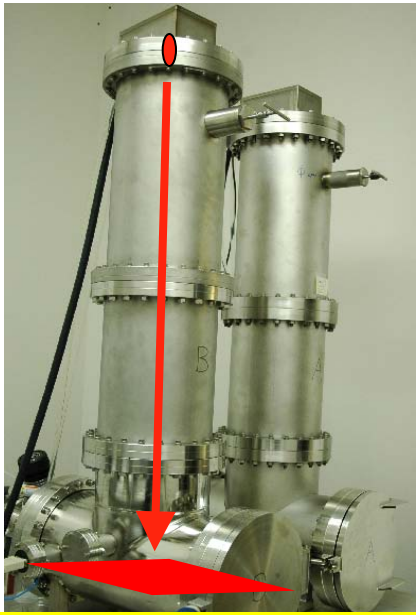
NEXIV data acquisition

- X-ray CR performed at 9 keV on individual PH & COL components
- NEXIV (video measurement system): automated image capture and measurements

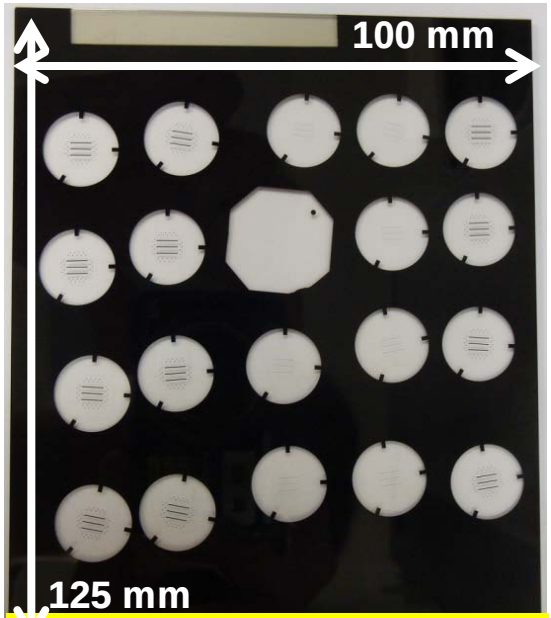
X-ray source

~960 mm

Film plate



CR System

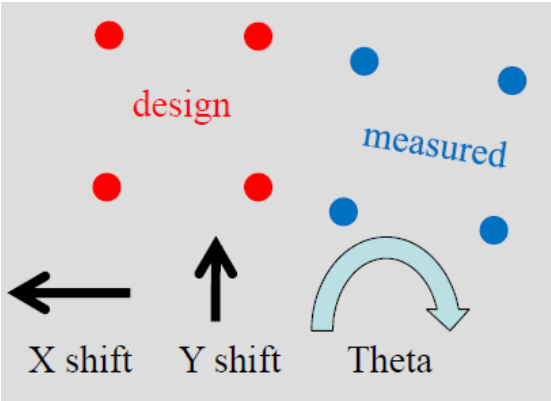


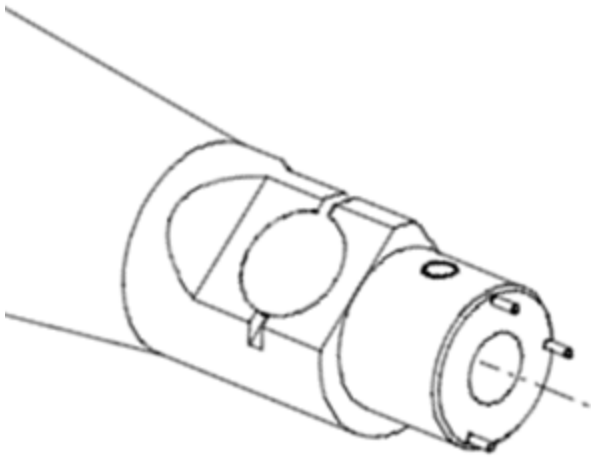
Film Plate

NEXIV

Fitting algorithm compares data sets

- A least square analysis finds the coordinate transformation based on the array only
- Apply coordinate transformation to the notch measurements
- Examine the notch position with respect to a design snout

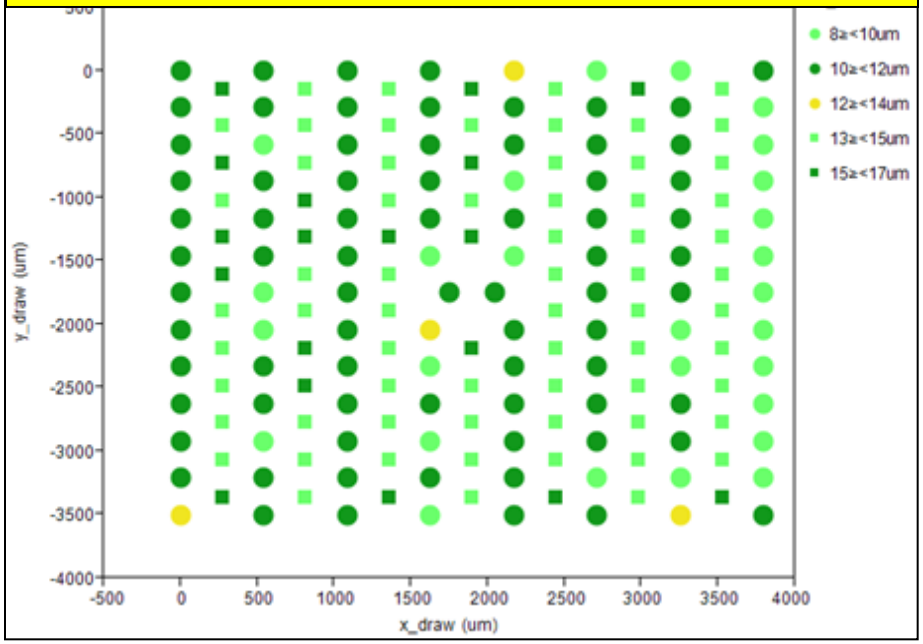




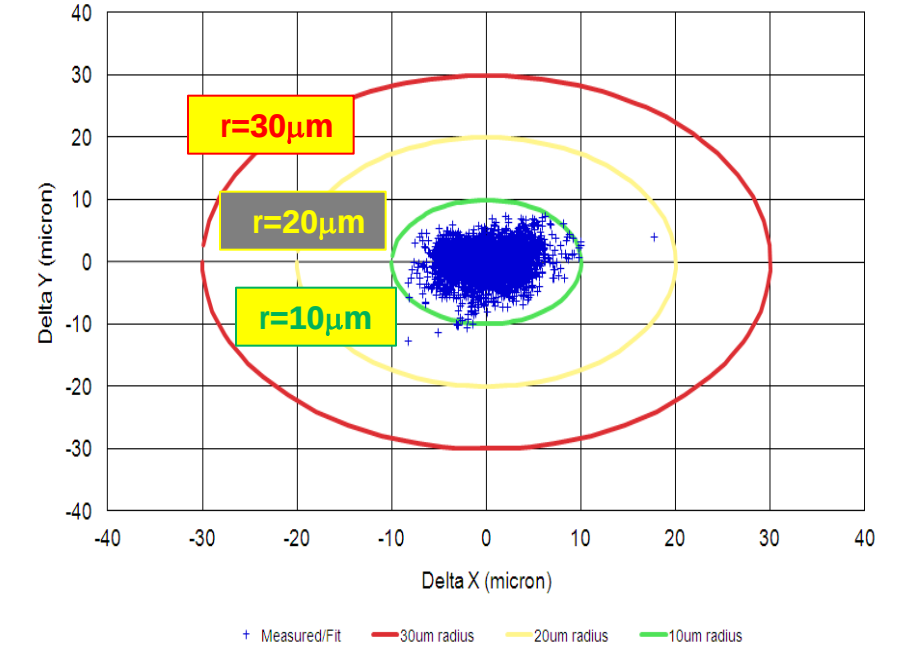
Evaluation of the Array data demonstrates self consistency

QC analysis

PH Diameter Plot



PH Residuals Plot (Array only)



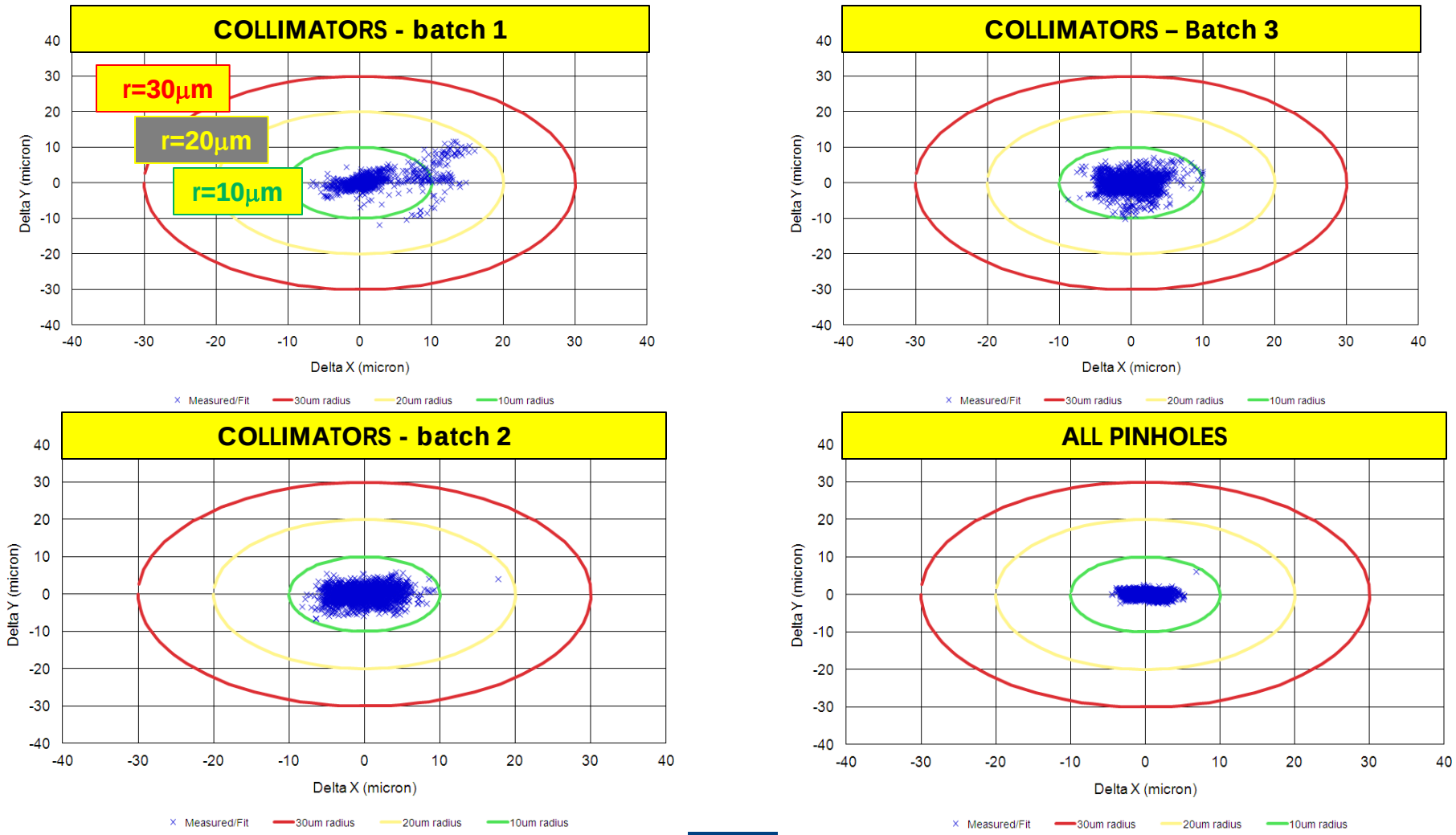
NIF

GENERAL ATOMICS

Validate fabrication by plotting Position Residuals

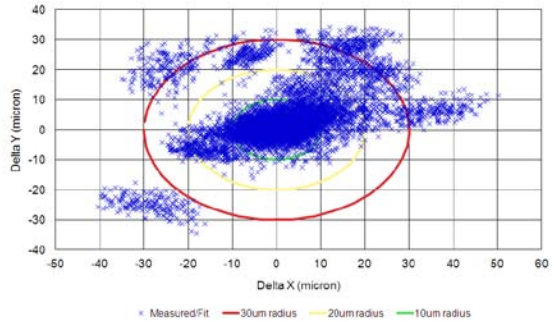
QC analysis

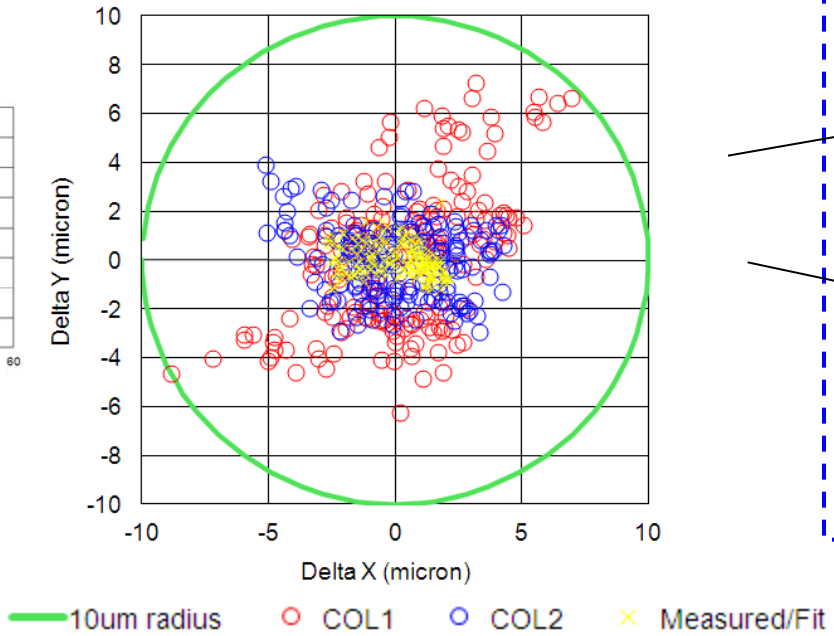
ARRAY with respect to NOTCH

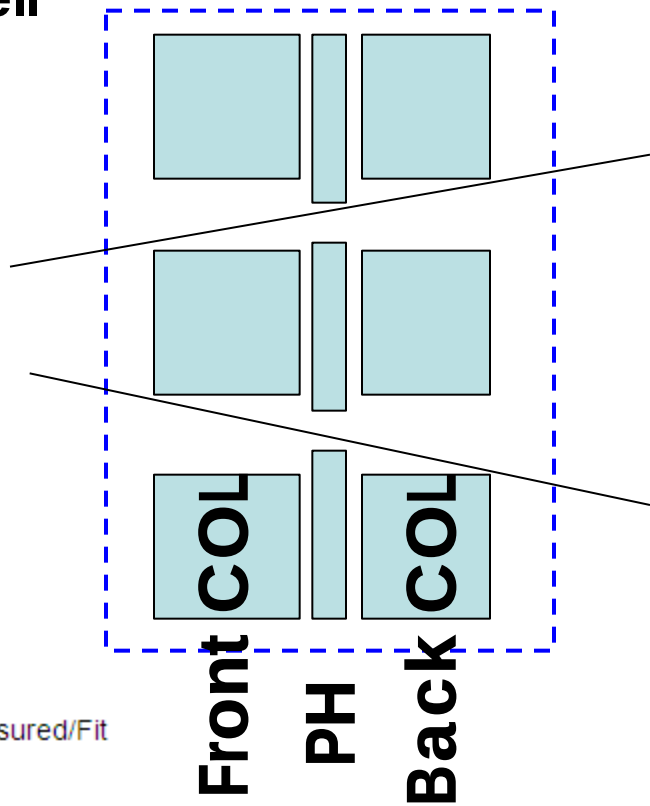


Virtual fitting of three components together allow component matching

- **Simply plotting the same data does not provide a quantitative assessment of how well the parts will work together**



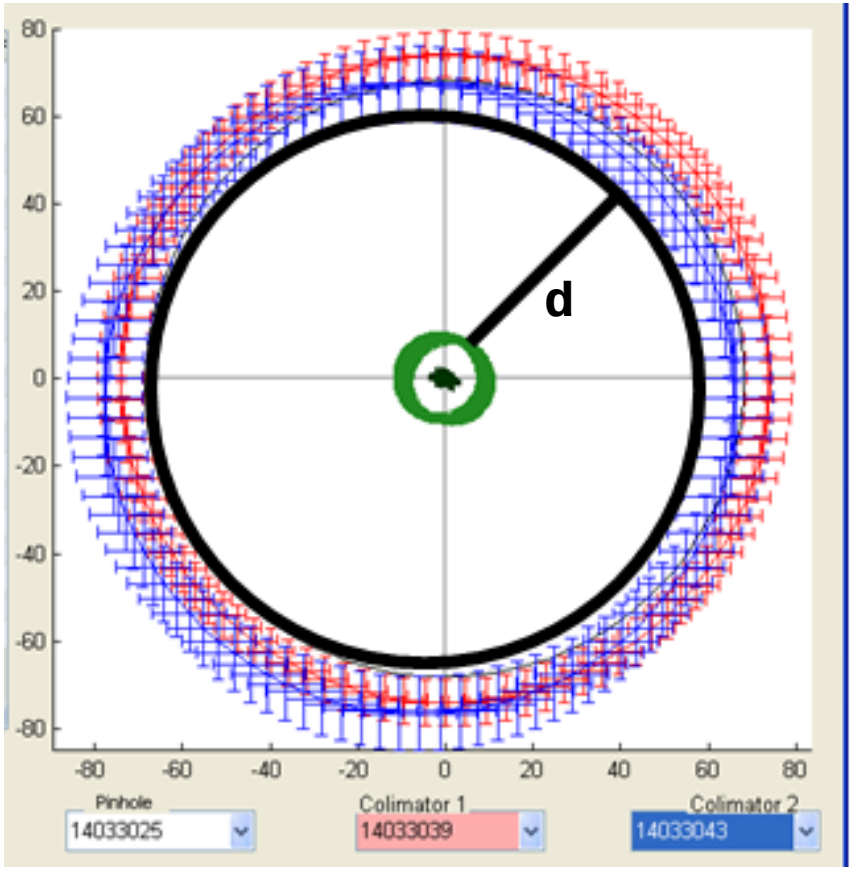




“fit-for-use” indicates acceptability, and allows selection and assessment

Virtual Matching

- Plot PH centers & diameters
- Represent each COL plate by <u>smallest</u> COL hole with ± 3σ positional error (x & y) centered on the array’s centroid
- <u>non interference region is defined</u>
- Maximize the minimum distance “d” for all components in the analysis



Matching algorithm considers full matrix of parts identifying acceptability

Matching matrix

Deliverable is a Matrix of matched parts

				(AAA10-101429-AB-01)						
				PINHOLES						
		Order		P123	P123	P123	P123	P123		
			SN	14033099	14033100	14033101	14033102	14033103	COL Fits	Col pins
(AAA10-101429-AB-03)	COLLIMATORS	P124	14033114	YES	YES	YES	YES	YES	1423	787
		P124	14033115	YES	YES	YES	YES	YES	4958	787
		P124	14033116	YES	YES	YES	YES	YES	7616	787
		P124	14033117	YES	YES	YES	YES	YES	3482	787
		P124	14033118	YES	YES	YES	YES	YES	3585	787
		P124	14033119	MAYBE	YES	YES	MAYBE	MAYBE	478	787
		P124	14033120	YES	YES	YES	YES	YES	1022	787
		P124	14033121	YES	YES	YES	YES	YES	2154	787
		P124	14033122	YES	YES	YES	YES	YES	2279	787
		P124	14033123	YES	YES	YES	YES	YES	1728	787
			Ph Fits	3620	3563	3098	3786	3011		
			PH pins	787	787	787	787	787		

Components are manual evaluated and matches are identified

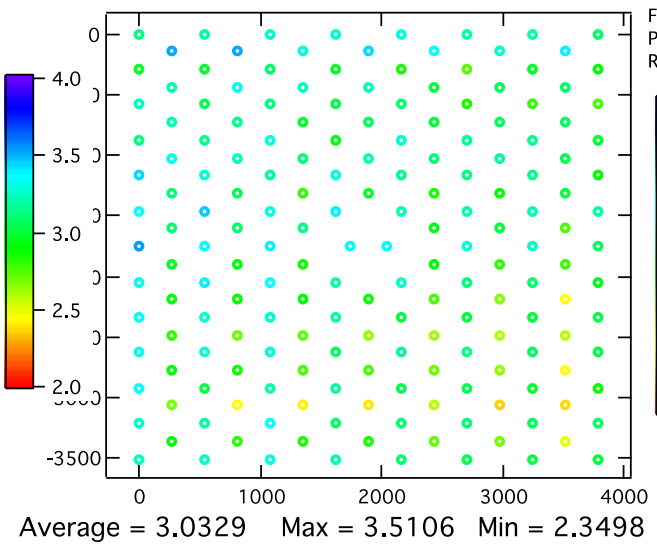
Advantage: identify sets in advance, reduce reject rate after assembly

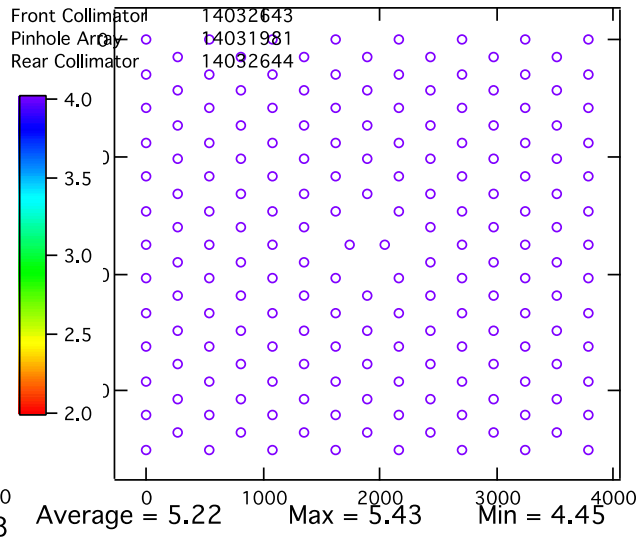
- **Determine if sets will work together ahead of diagnostic build and inspect process**
- **Identify and "kit" sets of parts ahead of build**
- **Allow alternate verification methods or simulation to be conducted ahead of build**
- **Increases confidence of success!**

Robin Benedetti (LLNL Scientist)

Considers part thicknesses, assembly configuration, magnification, location to implosion

Poor set **vs.** **Good set**





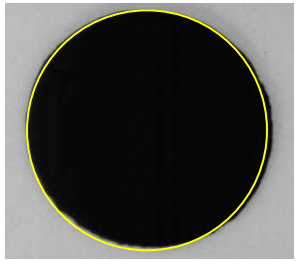
Summary

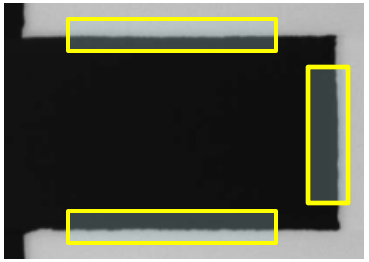
- Insufficient fabrication / metrology resulted in lost data from experiments on the NIF
- Pinhole (PH) Design complexity introduces registration issues
- Target Metrology tools were used to evaluate pinholes and collimators
- Data fitting & transformation evaluates “fit-for-use”
- Virtual matching of sets improved assembly yield and minimizes last minute issues
- Data allows responsible scientists to confirm acceptability ahead of build

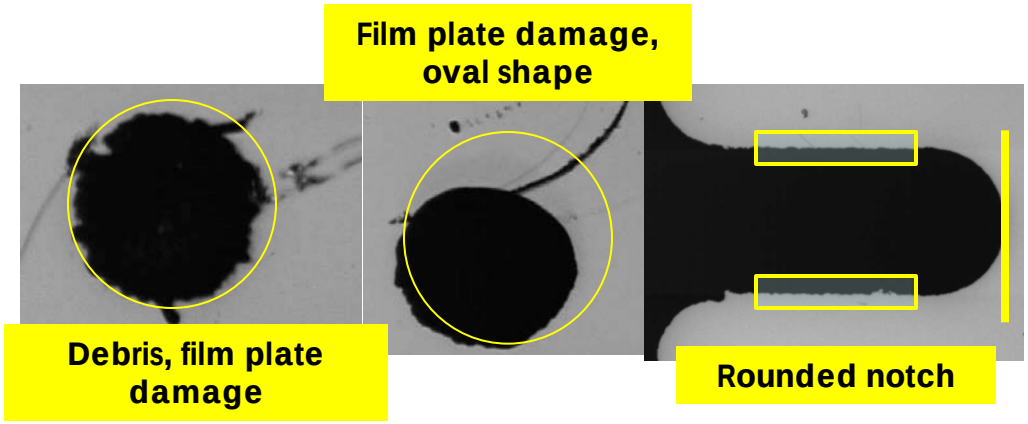
Questions

Is hasn't been smooth sailing: we encountered many characterization challenges along the way

- NEXIV camera is resolution limited (8 μm minimum feature size)
- CR film plate emulsions are easily damaged
- Mis-leading NEXIV analysis: gray scale, lighting, circular fits, ovals, or debris or damage to film plate
- Multiple features in one design: various size holes, ovals, slots
- Treatment of rounded notches
- 2 notches vs 3 notches or hole positioning locators.

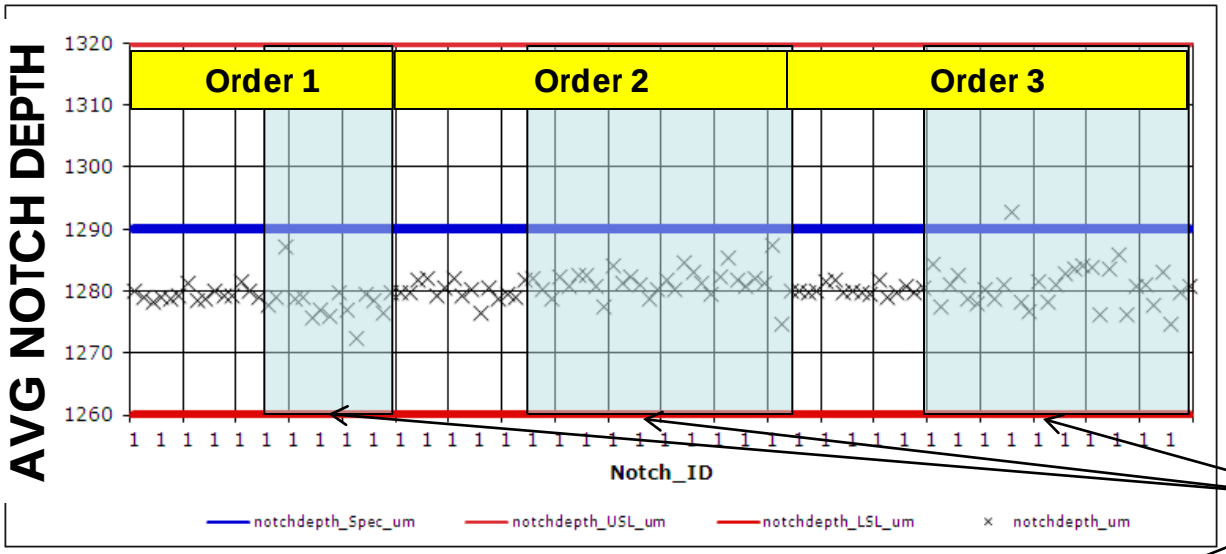


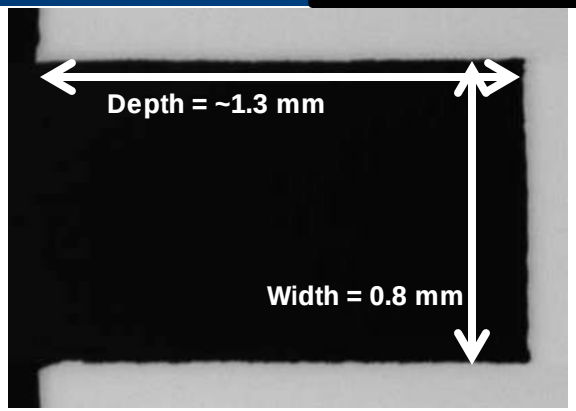


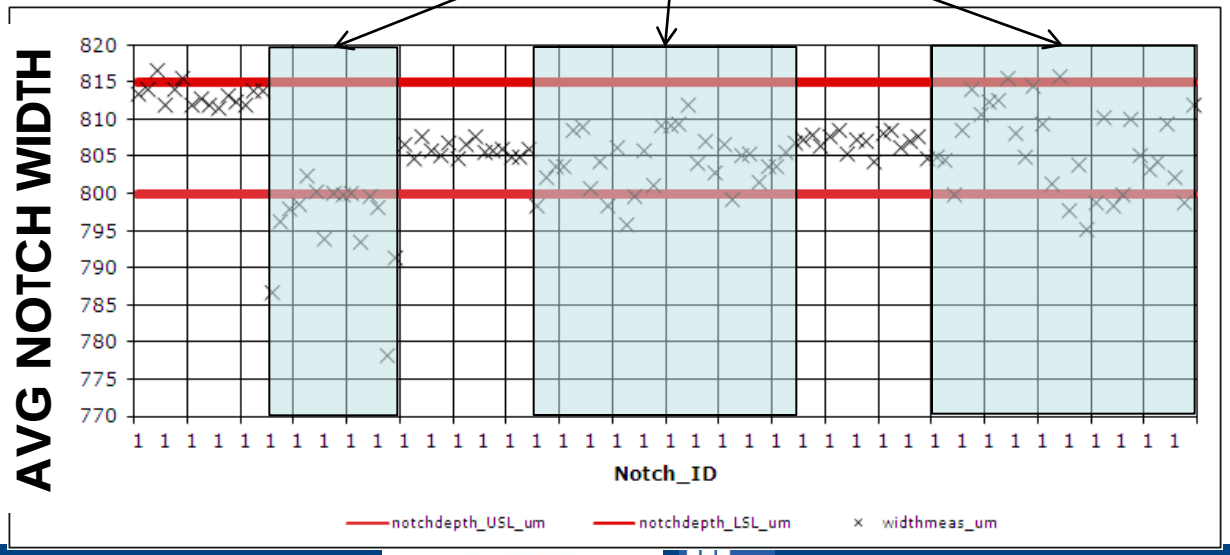


Trend charts highlight variability

QC analysis





COLLIMATORS

- COLs have higher variability vs PHs
- re-examine measurement process