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# Spatially-resolved $T_{ion}$ for NIF

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# The neutron imaging system is operating at NIF and has been providing hot-spot and cold fuel shape information since 2011.

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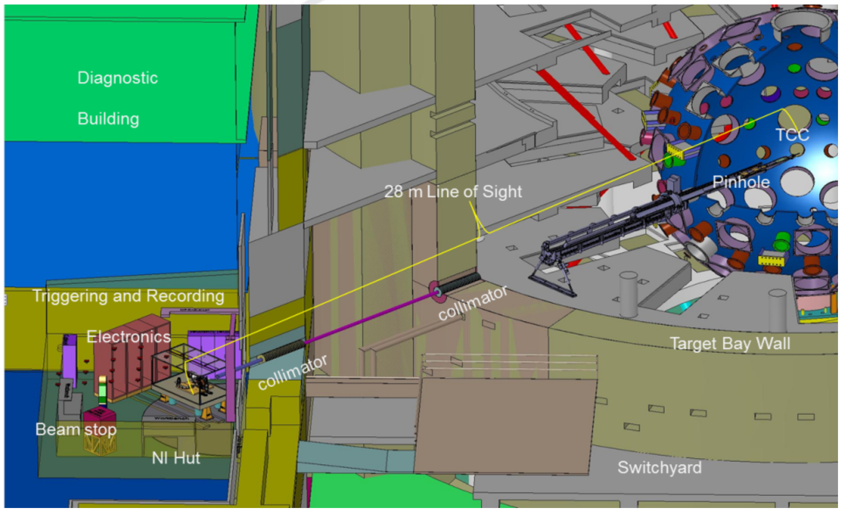
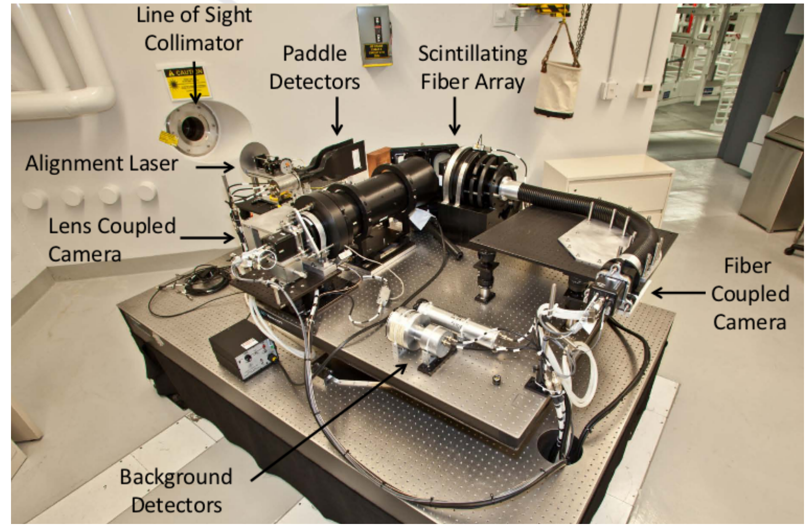
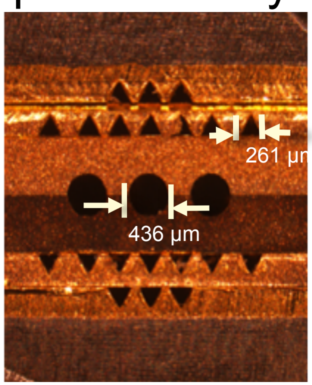
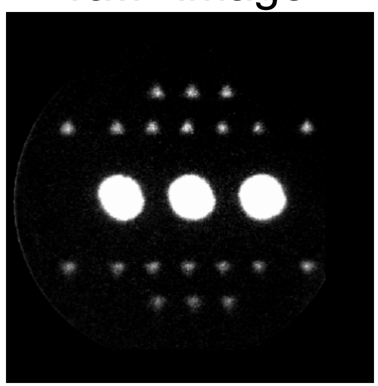


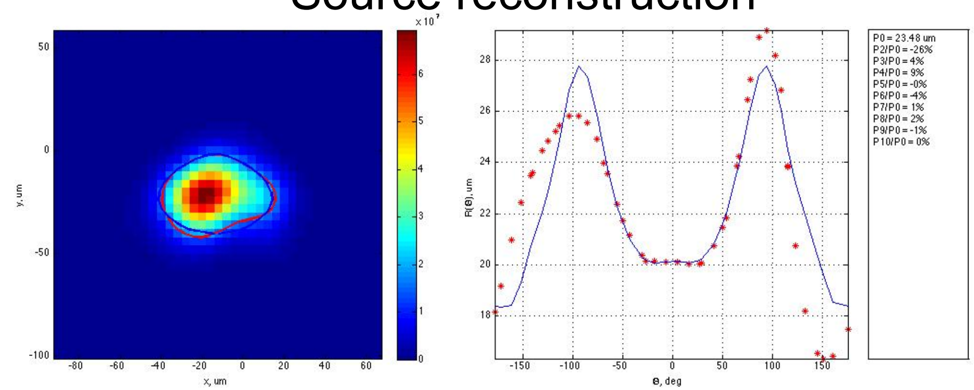

pinhole array




"raw" image

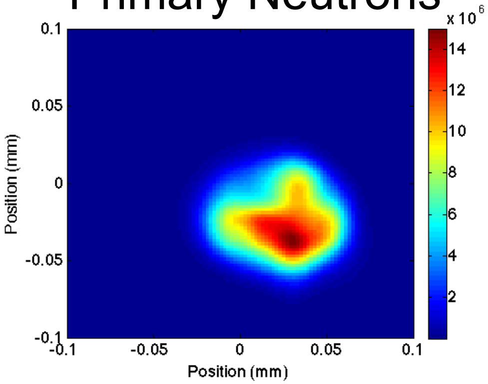


Source reconstruction

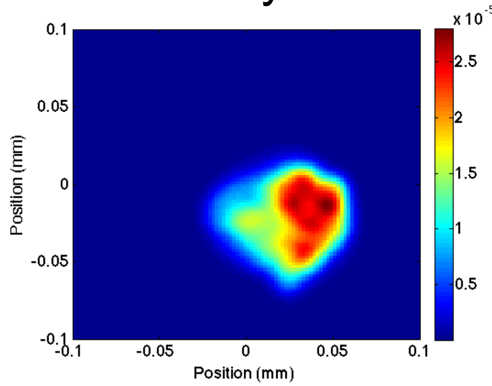


# NIC experience shows us that neutron and x-ray imaging are not the same. Recent 3D simulations have provided insight into this difference.

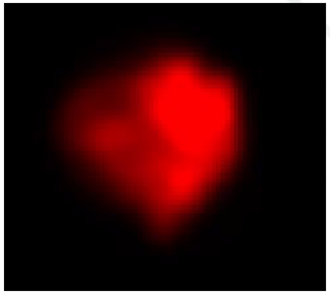
Primary Neutrons




X-rays

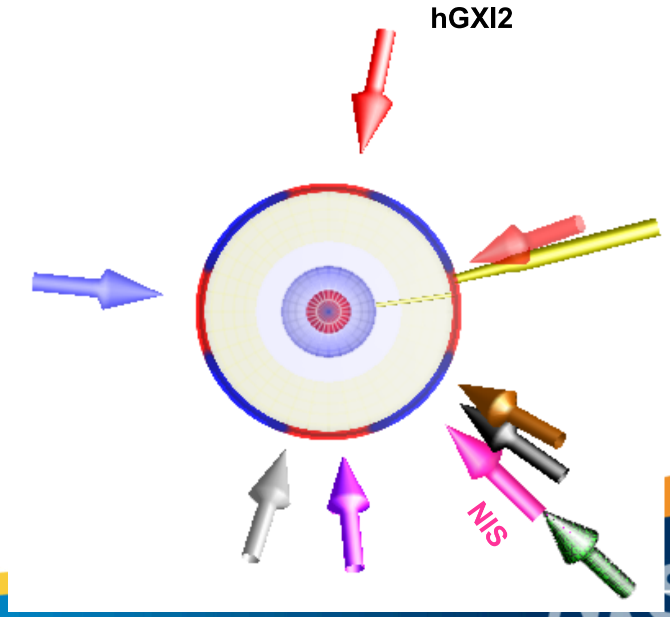



X-rays: red
Neutrons: cyan



A comparison of neutron images to x-ray images shows significant differences due to uneven distribution of mix in the simulations.

Currently there is no x-ray imager with the same view of the target as NIS, so we can't compare directly for asymmetric (3D) sources

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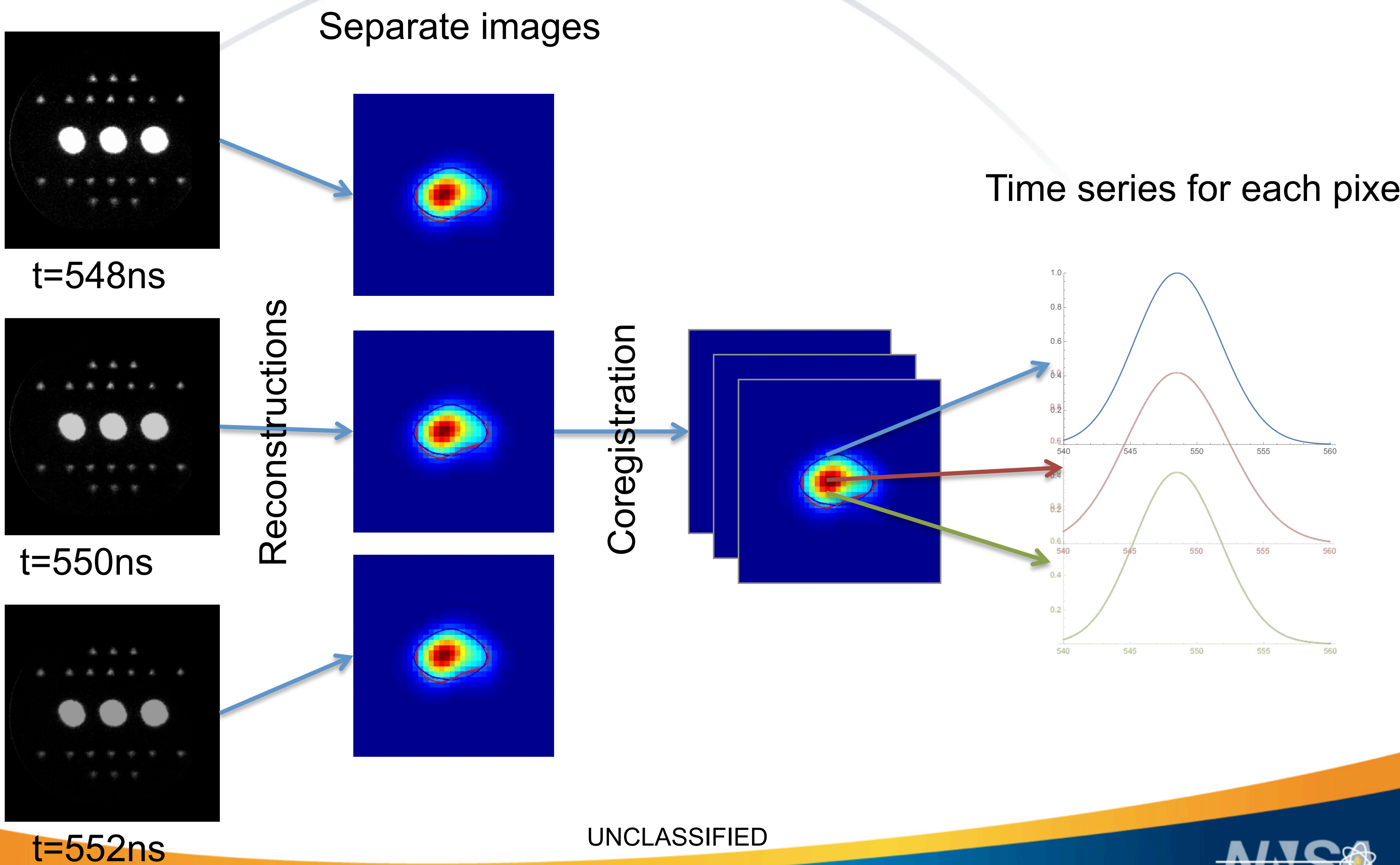
# Multi-frame neutron imaging

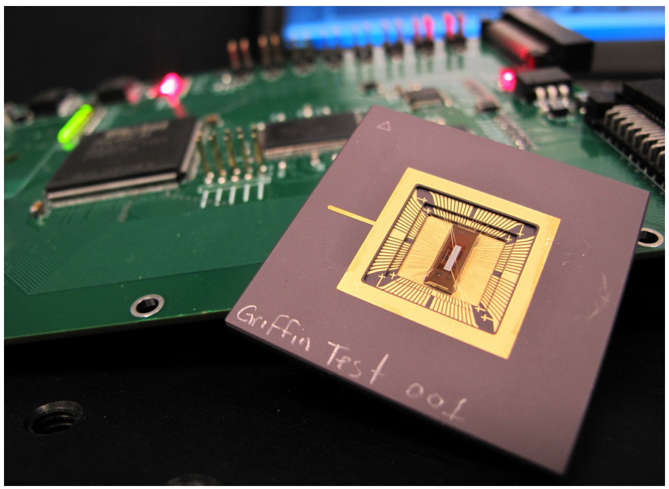
- Burn width is short compared to time of flight spread due to neutron energy variation
- Current NIS records images of two energy bins: 14-17 MeV (primary) and 6-12 MeV (downscattered)
- Neutron imaging with multiple frames could provide images with finer energy resolution and allow determination of ion temperature profile at bangtime
- This is not a new concept, but it was not previously considered feasible. Higher yields, faster cameras, and better analysis may have changed that

# Measurement concept



# Notional recording system

Replacing one of the 1-frame cameras on the NIS with a 1 GHz multiframe camera could provide the required data - cameras are or soon will be available



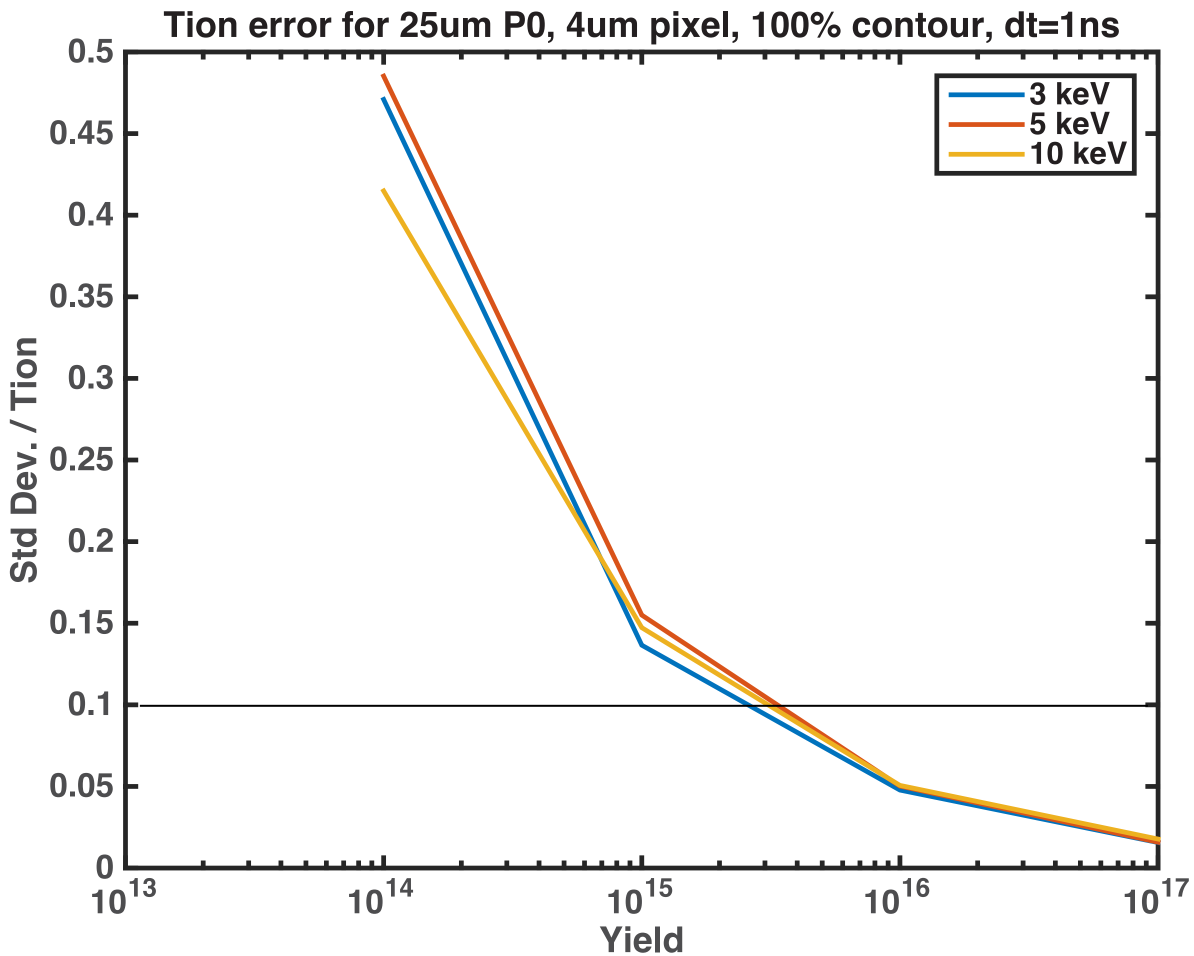

Sandia Hybrid multiframe sensor

Specialised Imaging 1 GHz framing camera

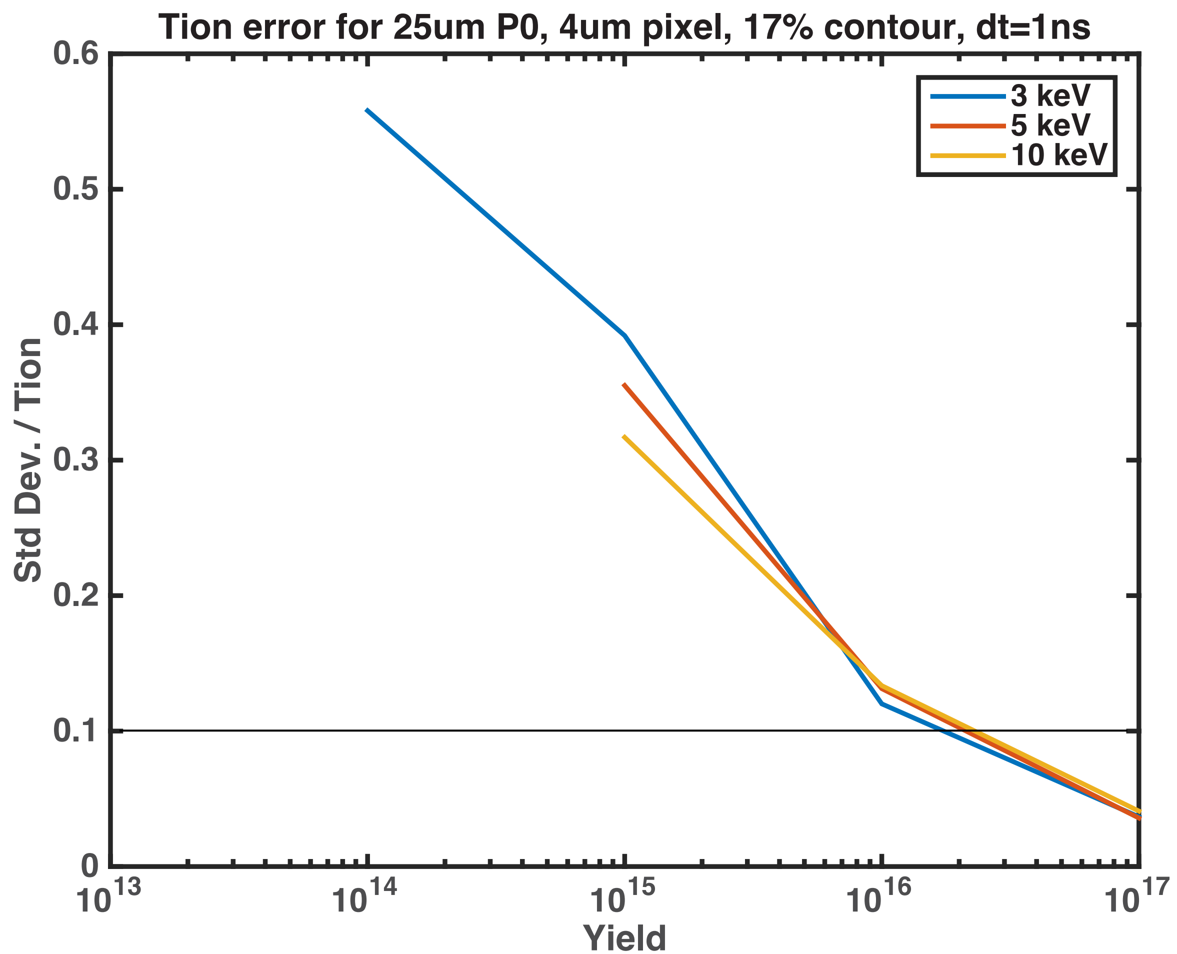
# Modeling – Information content

- Modeling with an ideal pinhole shows that the information exists to reconstruct ion temperature profile
- Reconstruction depends on pixel size, time resolution, and signal level
- Model uses neutron counting statistics

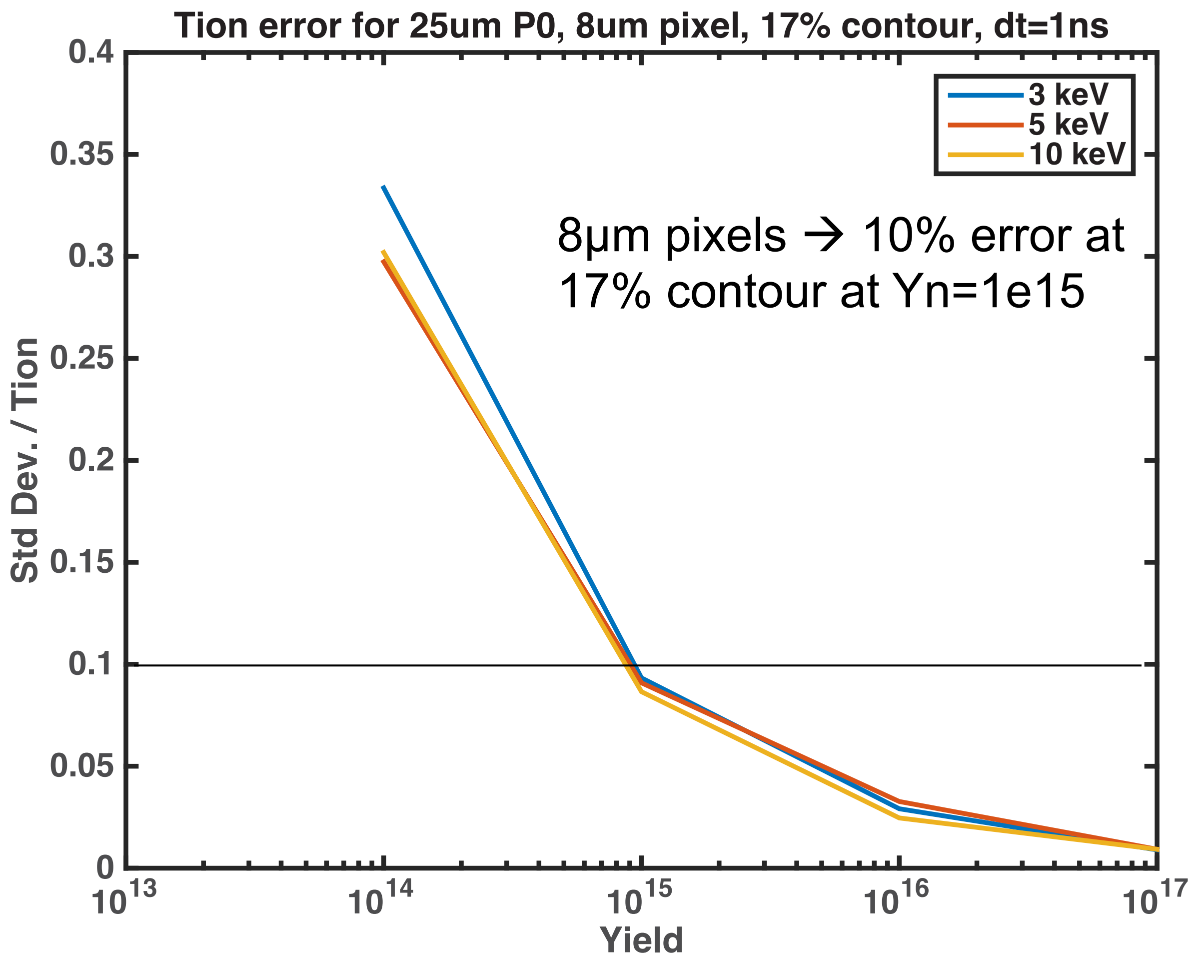
# At Yn=3e15, 10% error in Tion at brightest pixel



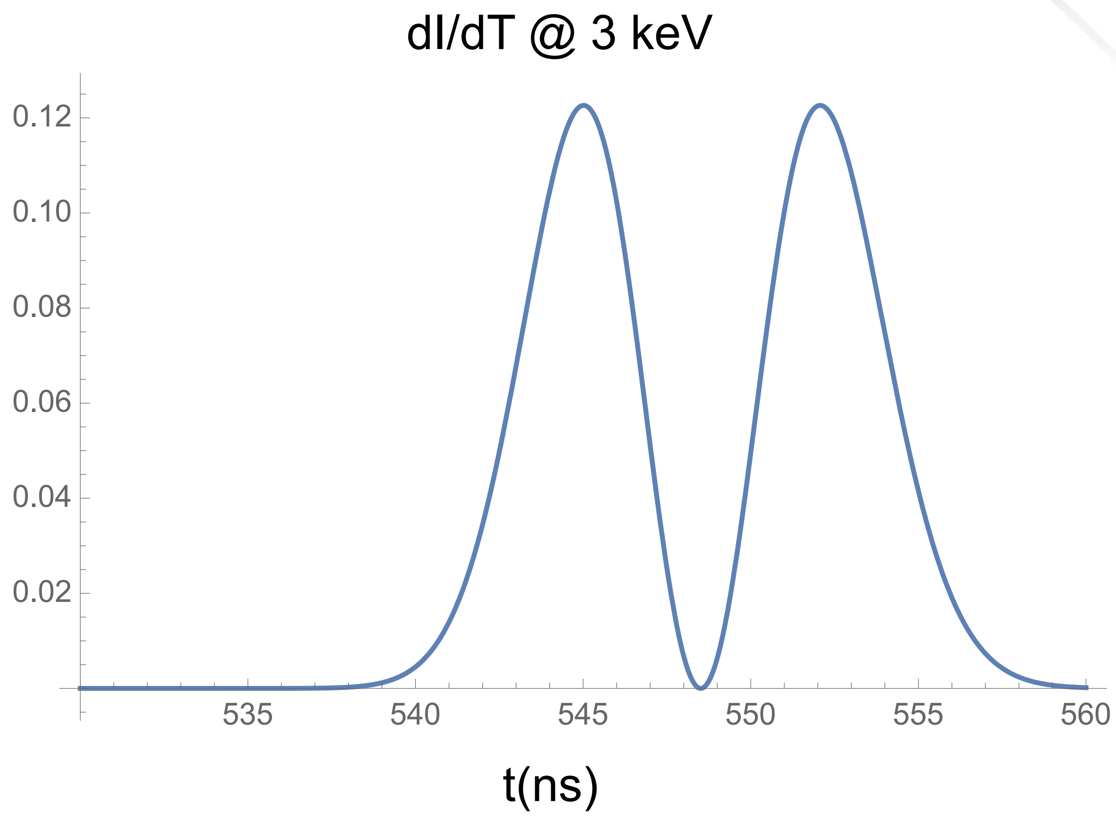
# At Yn=2e16, 10% error in Tion at a 4µm pixel on the 17% contour



# Larger pixels (worse spatial resolution) allow more accuracy at lower yield



# Some information can be obtained with fewer frames

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# Challenges

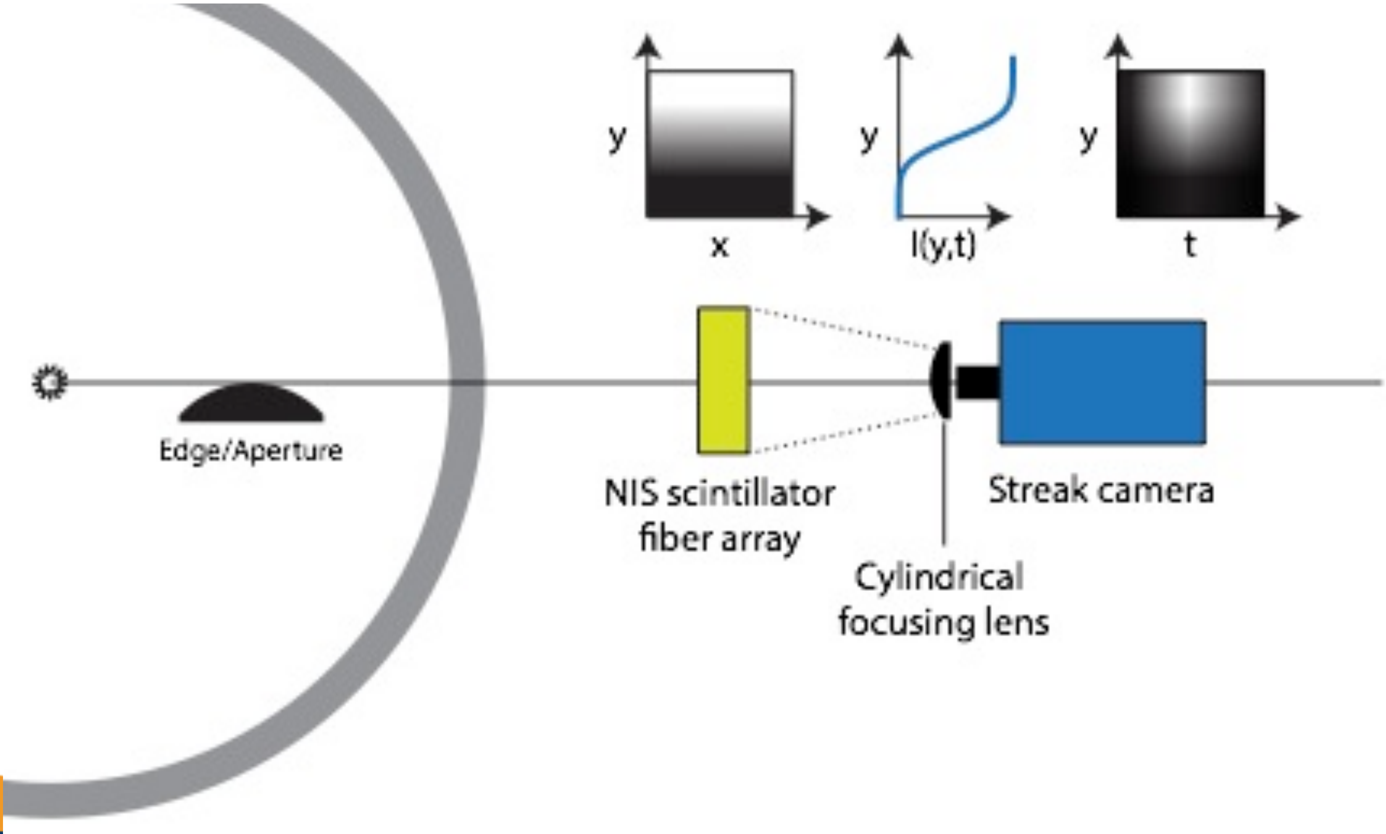
- Current reconstruction algorithms are optimized for shape, not pixel accuracy
- QE of split-intensified framing cameras is poor
- 1 GHz hybrid CMOS camera not yet available to field
- 3D to 2D spatial averaging – each pixel in an image averages ion temperature along a line integral through the source, reducing the signature
- Coregistration and cross-calibration challenging

# Path forward for 2D imaging

- Work underway to determine yield required for Tion reconstruction with a real system
- New aperture may be needed to capture lower-signal outer time bins
- Reconstruction algorithms could be adjusted

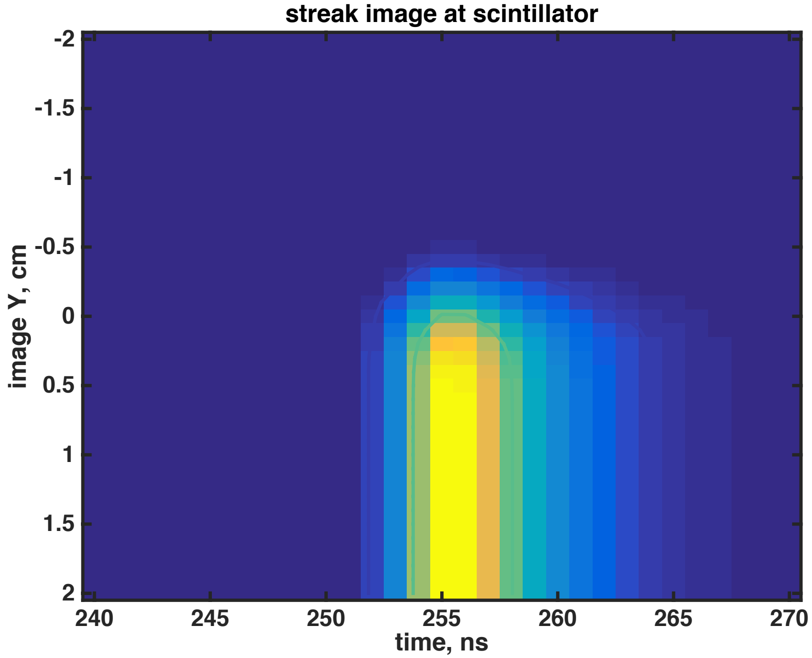
# Potential alternative: 1D imaging

- Spatially integrating along one dimension increases signal to noise ratio, and allows use of more sensitive streak cameras



# 1D imaging

- Forward model has been developed, studying signal levels
- Downside: spatial averaging problem is significantly worsened
- Localized hotspot may only change diagnostic signature a few %




Simulated streak image for 200x magnification rolled edge, 1D simulated source plasma with Tion = 4 keV (avg)

# Combining with other data

- Temperature profile can be combined with neutron image to extract DT ion density
- Ion density and temperature can be used to calculate expected x-ray emission (from DT alone)
- This can be combined with measured x-ray emission to determine amount of carbon mix
- 3D time (energy)-integrated neutron imaging may be combined with a Tion measurement to better understand 3D structure of hotspots, etc