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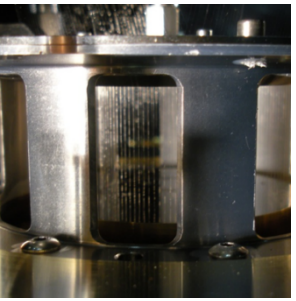
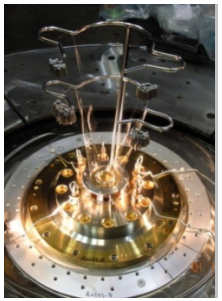
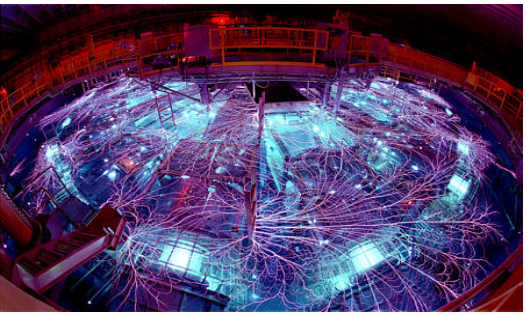
SAND2016-7169C

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT







SCALING OF Kα LINE EMISSION IN Z PINCHES FROM 2 – 60 keV

David J. Ampleford, Guillaume P. Loisel, Stephanie B. Hansen, Patrick F. Knapp, Christine A. Coverdale, Christopher A. Jennings, Gregory A. Rochau

Sandia National Laboratories, Albuquerque, NM 87185

ICOPS, Banff June 2016

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Overview: Non-thermal Kα is a promising route to higher photon energy sources on Z

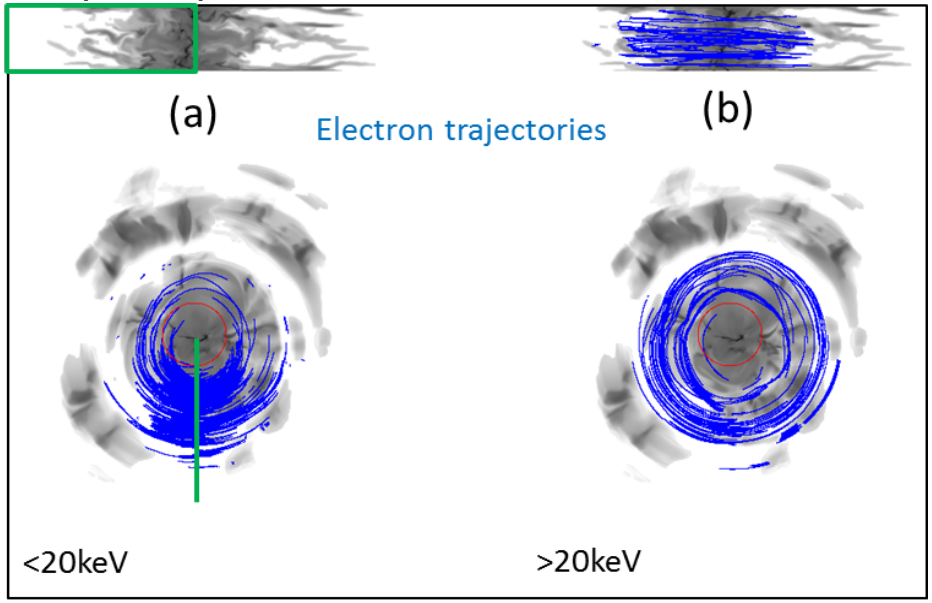
- Optimization of non-thermal Kα emission is more complicated than creating breaks in a plasma column
- We have studied dynamics responsible for Kα emission
  - New diagnostics have aided us in building this understanding
  - We've started to build a detailed picture of Kα emission
- We have investigated the scaling of K α emission to 59 keV
  - New diagnostics were needed to allow this assessment
  - Scaling looks similar to inferred at lower photon energies and would not be feasible with thermal emission (e.g. Heα)

Underlying physics is not as trivial as might be expected

- Large fields are required for electron runaway
  - Dreicer field

$$E > E_D = 5.8 \times 10^{-18} \ln \Lambda \frac{n_e}{T_e}$$

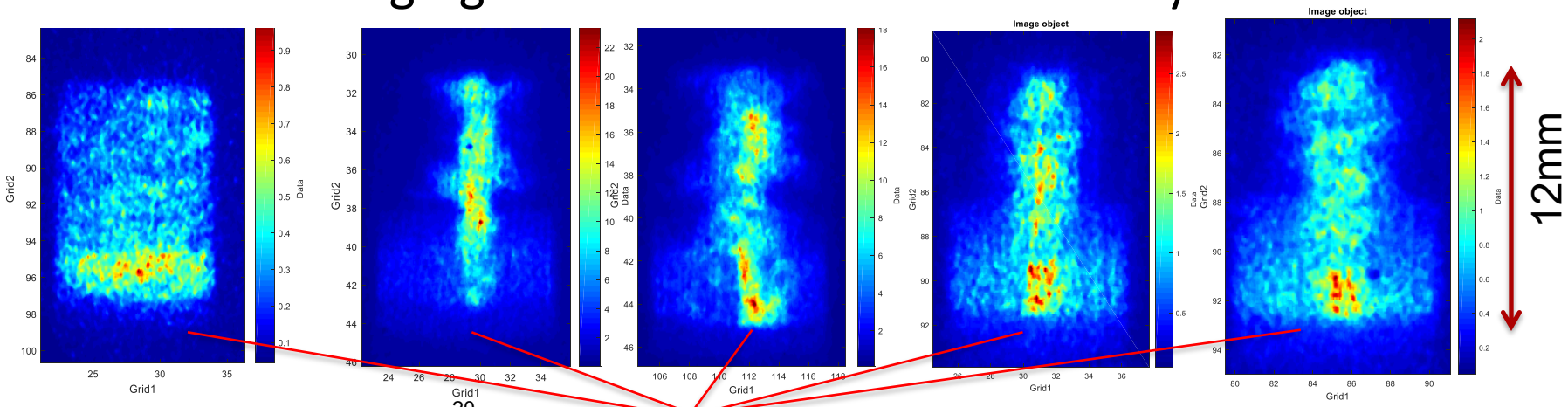
- Electrons are highly magnetized,
  - Aren't accelerated axially across gaps or radially into dense plasma
  - Trajectories post-processed from MHD simulations



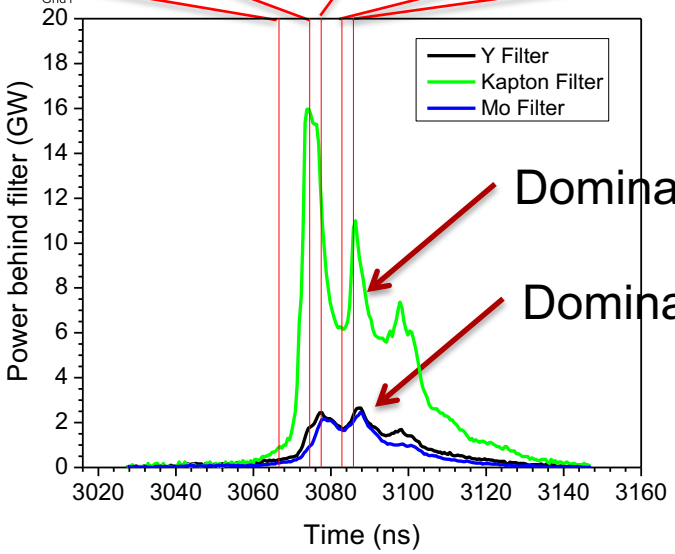
Simulation by
J.P Chittenden *et al*

Using 17 keV Mo Kα emission we have studied how Kα emission connects to array dynamics

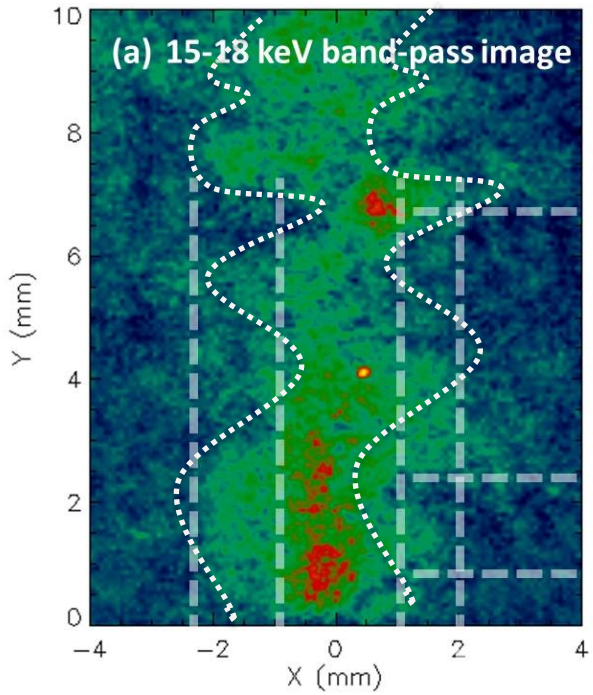
- Self emission imaging at 277 eV shows the overall dynamics

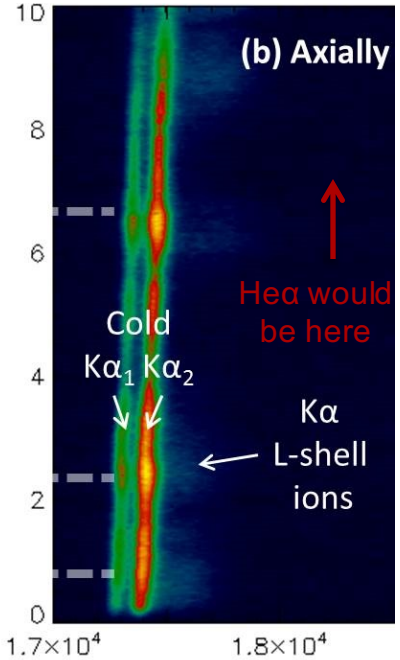


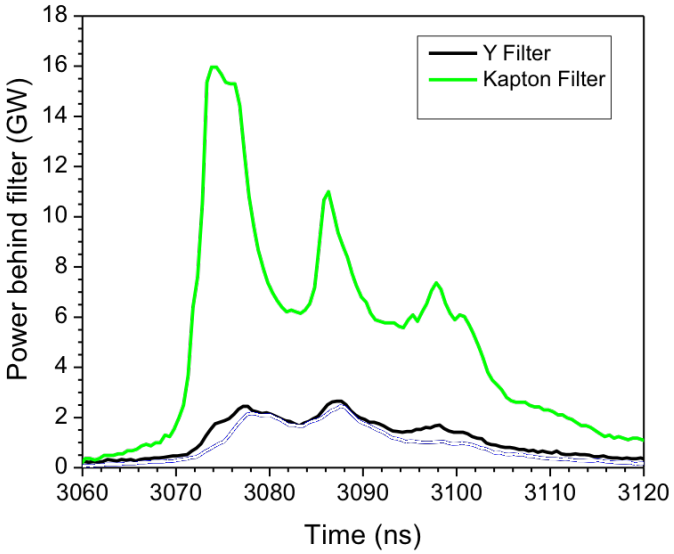
- Comparing with PCDs we see how Kα fits in evolution

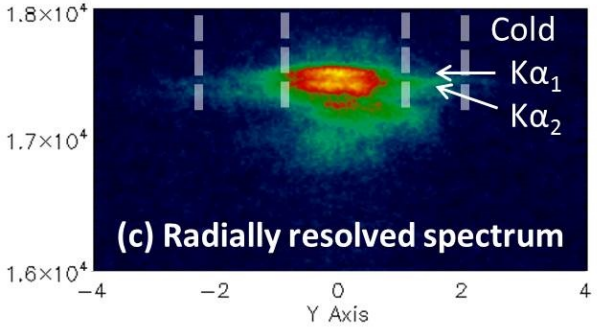


Spatially resolved spectra combined with high energy pinhole imaging provide insight into structure



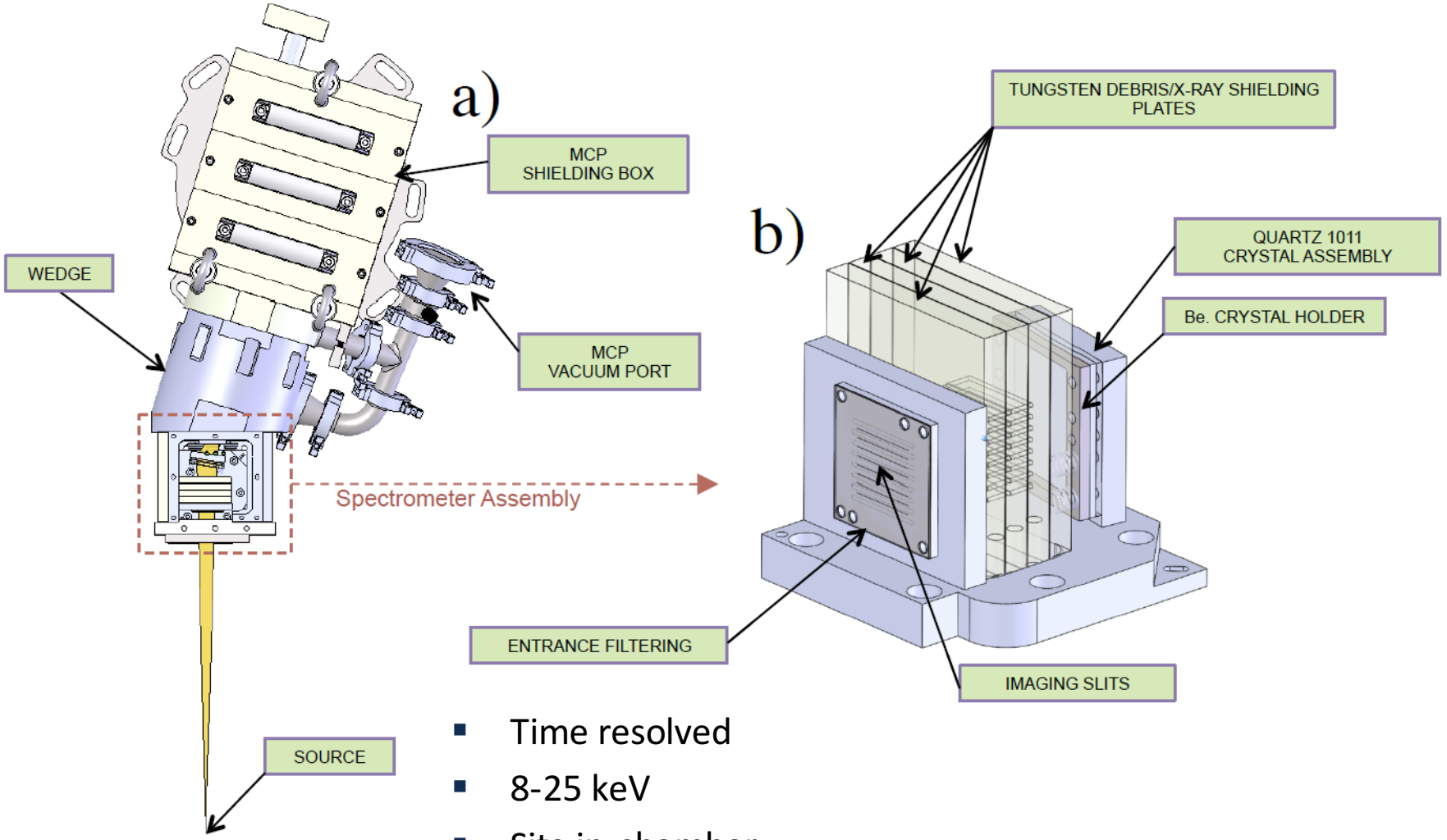






- Bright spots in 2D image and spectrum at
  - Warmer plasma in L-shell charge states
- Cold Kα emission from most of pinch height and few mm diameter (wavelength confirms this is cold Kα)
- Indications of quasi-helical (m=1) structure
  - Consistent with late time emission of Kα

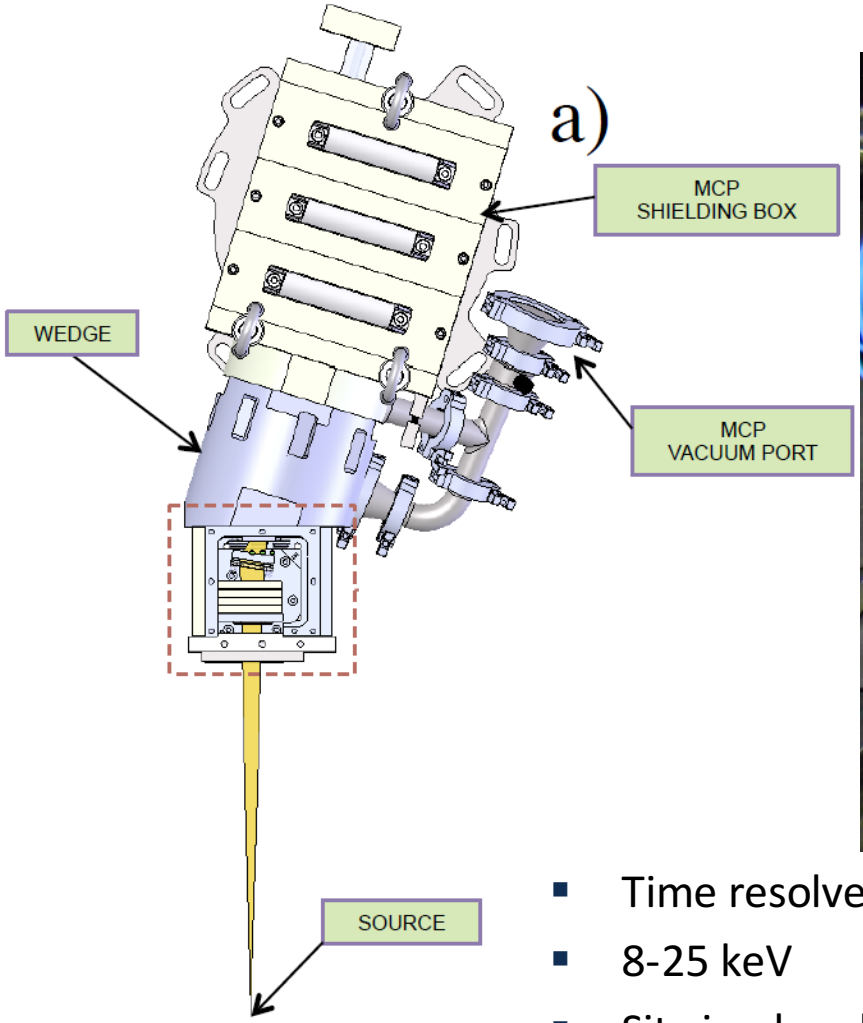
New time-resolved transmission spectrometer allows us to assess evolution of Kα

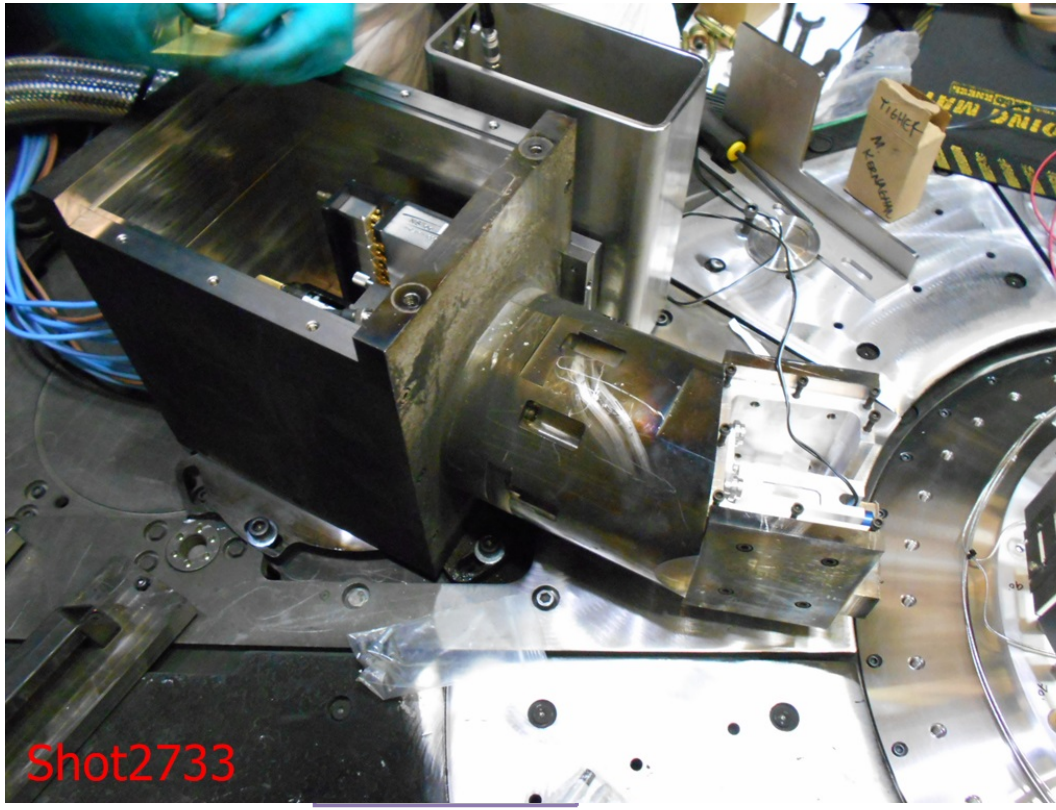


- Time resolved
- 8-25 keV
- Sits in-chamber
- $\lambda/\Delta\lambda \sim 500$

P.F. Knapp et al., In preparation for RSI

New time-resolved transmission spectrometer allows us to assess evolution of Kα





- Time resolved
- 8-25 keV
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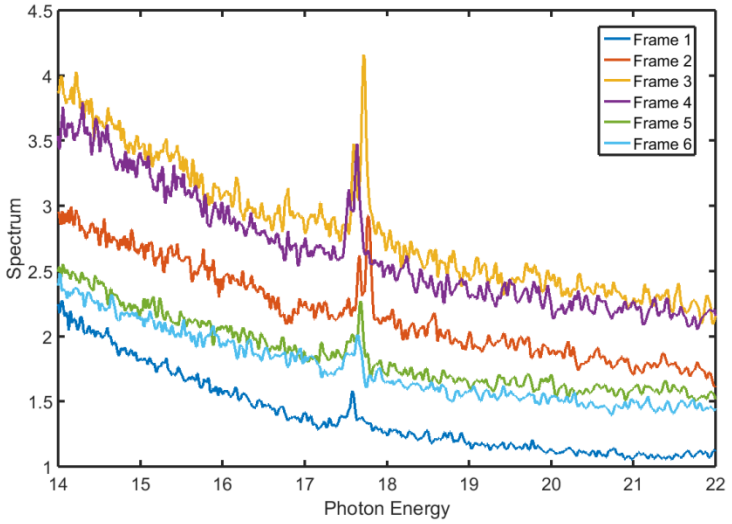
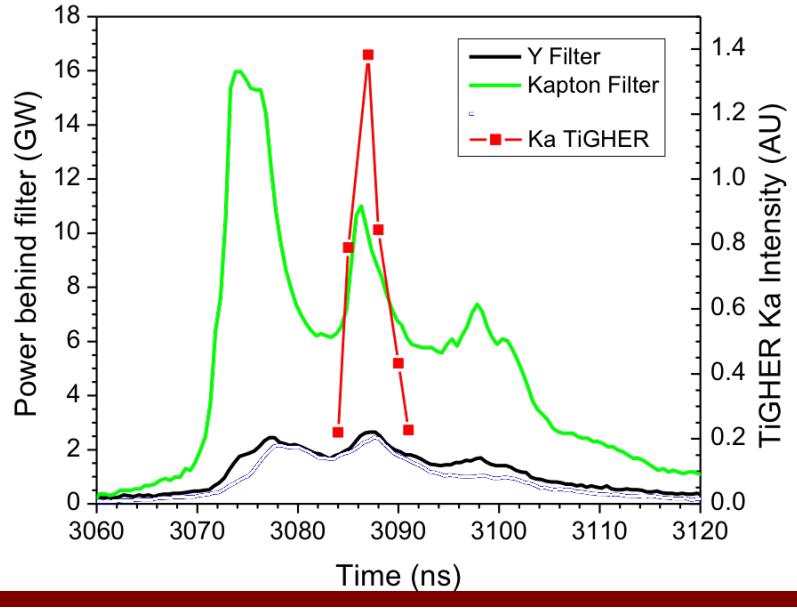
P.F. Knapp et al., In preparation for RSI

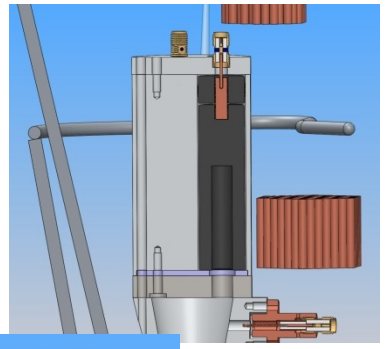
Time resolved spectra show fast rise and fall of Kα

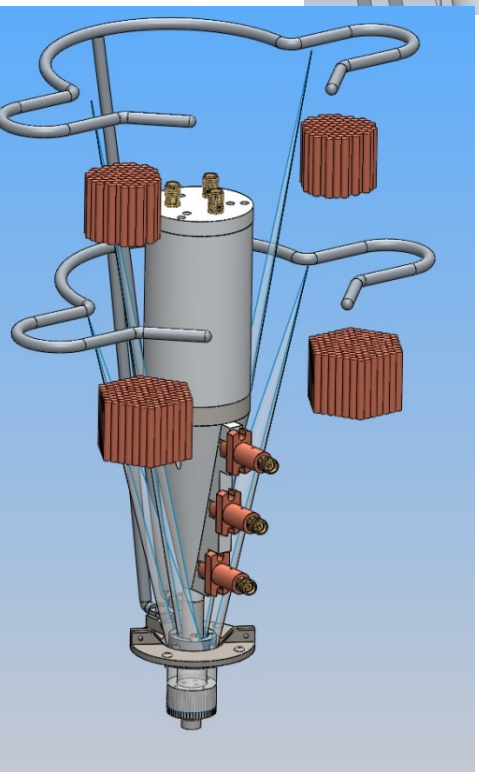


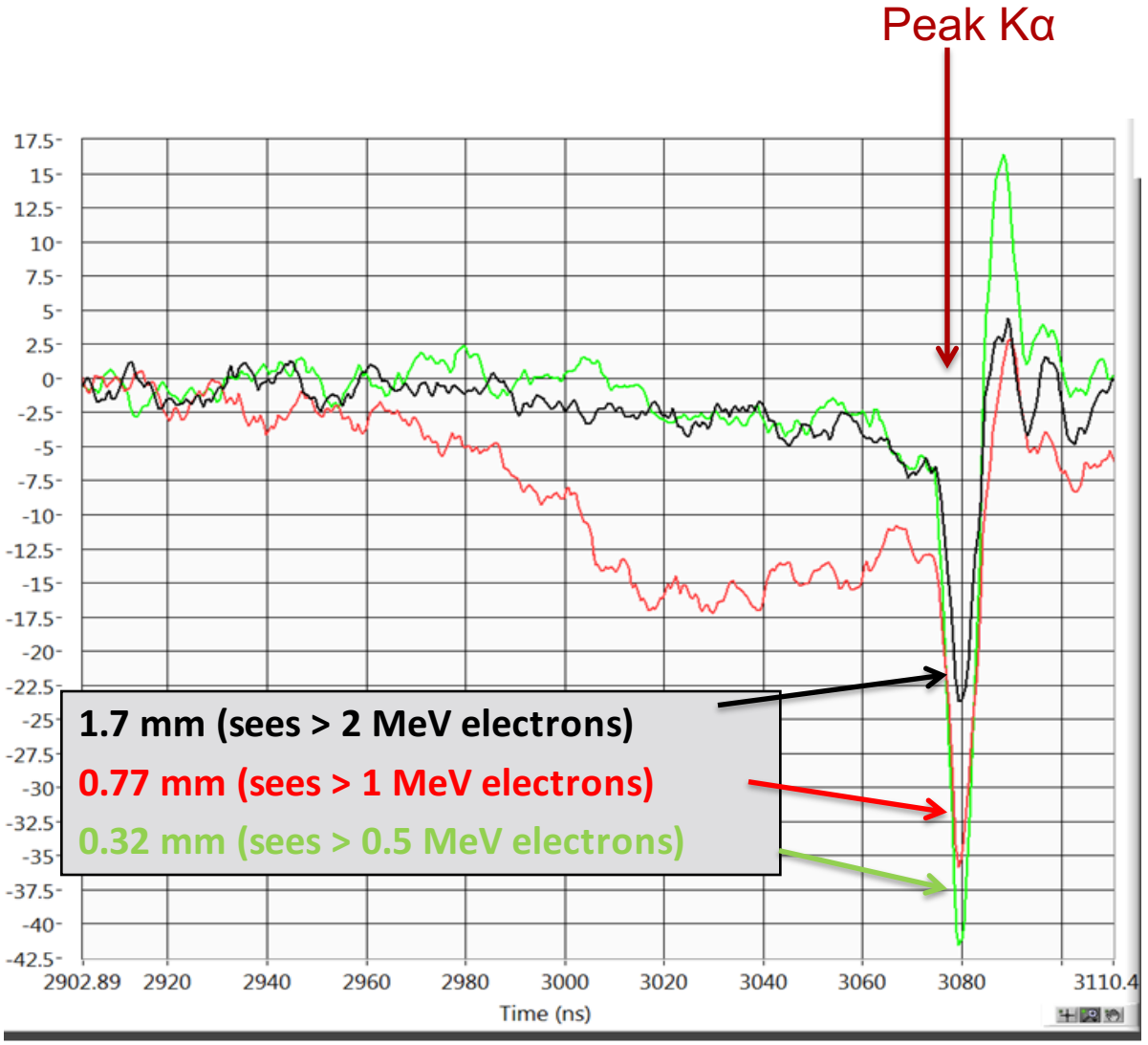


- Mo Kα seen on time resolved spectrometer
- Rises and falls rapidly
  - ~3ns FWHM
  - Faster varying than continuum
- May be other short bursts
  - TiGHER captured 10 ns window
- Kα pulse resembles shape of one pulse on the PCD trace
  - More work needed on checking cross timing of Kα pulse

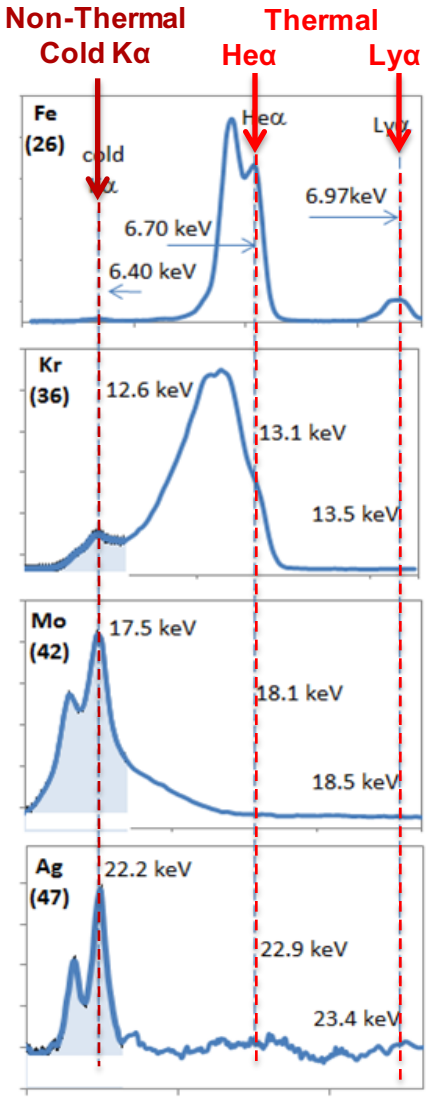
We have developed a Faraday Cup looking at energetic electrons that are present in Z pinches on Z



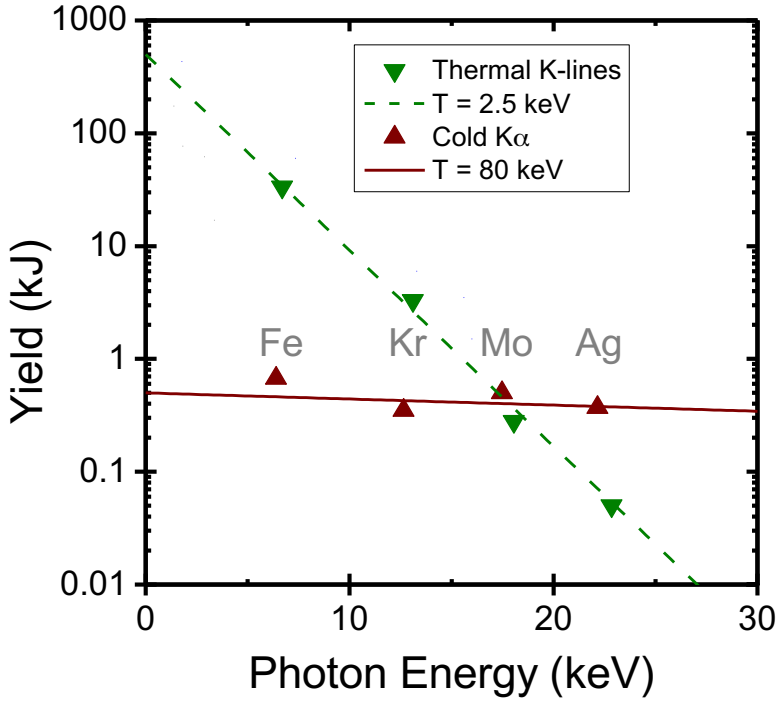




Spectra from Z experiments using different materials shows transition from thermal to non-thermal emission



- As atomic number increases see transition
  - from thermal K-shell (Fe almost entirely Heα)
  - to non-thermal K-shell (Ag entirely cold Kα)
- Scaling to higher energies is much better with cold Kα

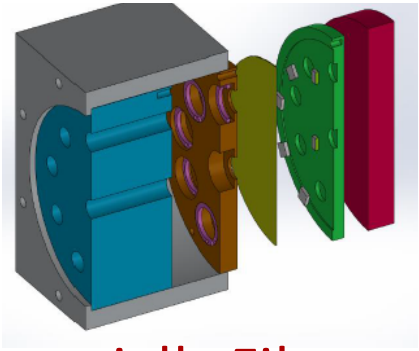


To assess higher photon energy Kα & Bremsstrahlung we have developed a number of diagnostics

Filtered TLD detectors

Absolute fluence measurement 10keV-20MeV

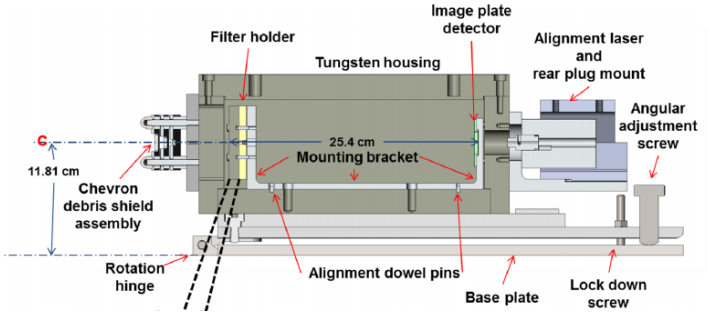
V. Harper-Slaboszewicz *et al. In prep.*



Time Integrated PHC

Spatial structure 15 keV-100 keV

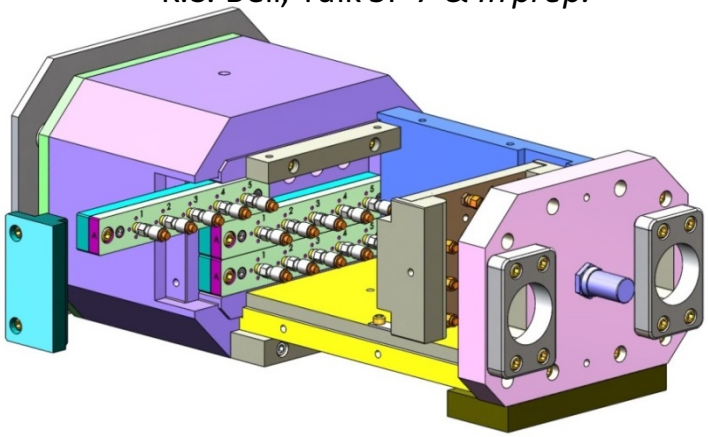
L.A. McPherson *et al.,* RSI **87**, 063502 (2016)



Differentially Filtered Diodes

Absolute fluence measurement 10keV-20MeV

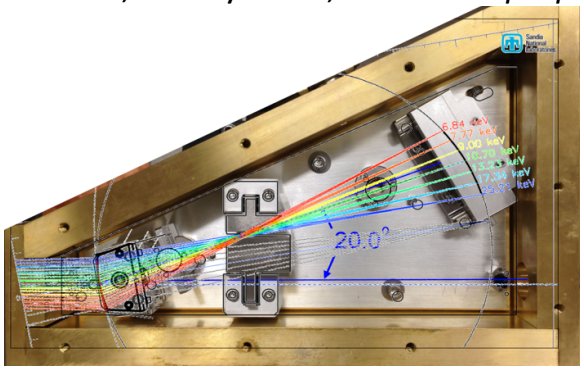
K.S. Bell, Talk 5F-7 & *In prep.*



Space resolved spectra

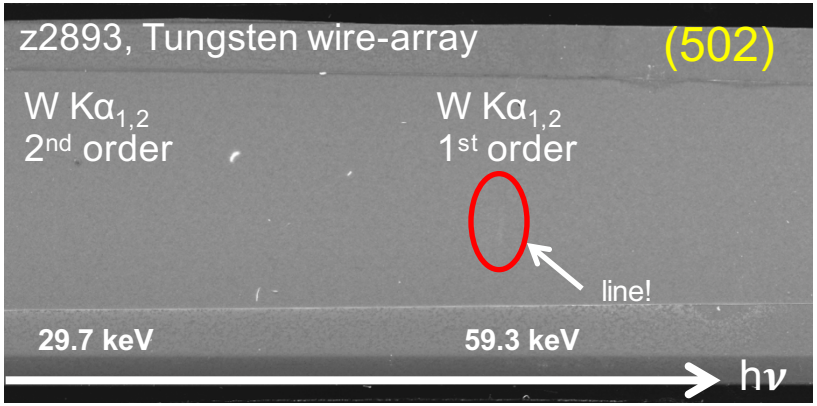
Spectra 7 keV-100 keV

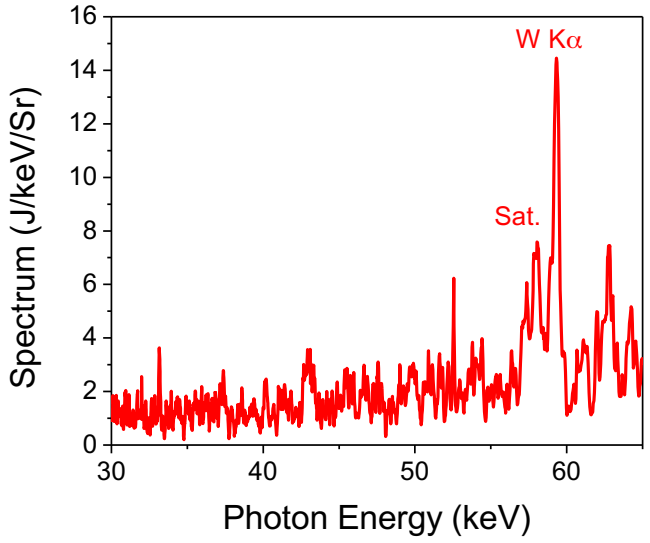
G. Loisel, J Seely et al., HTPD & *In prep.*



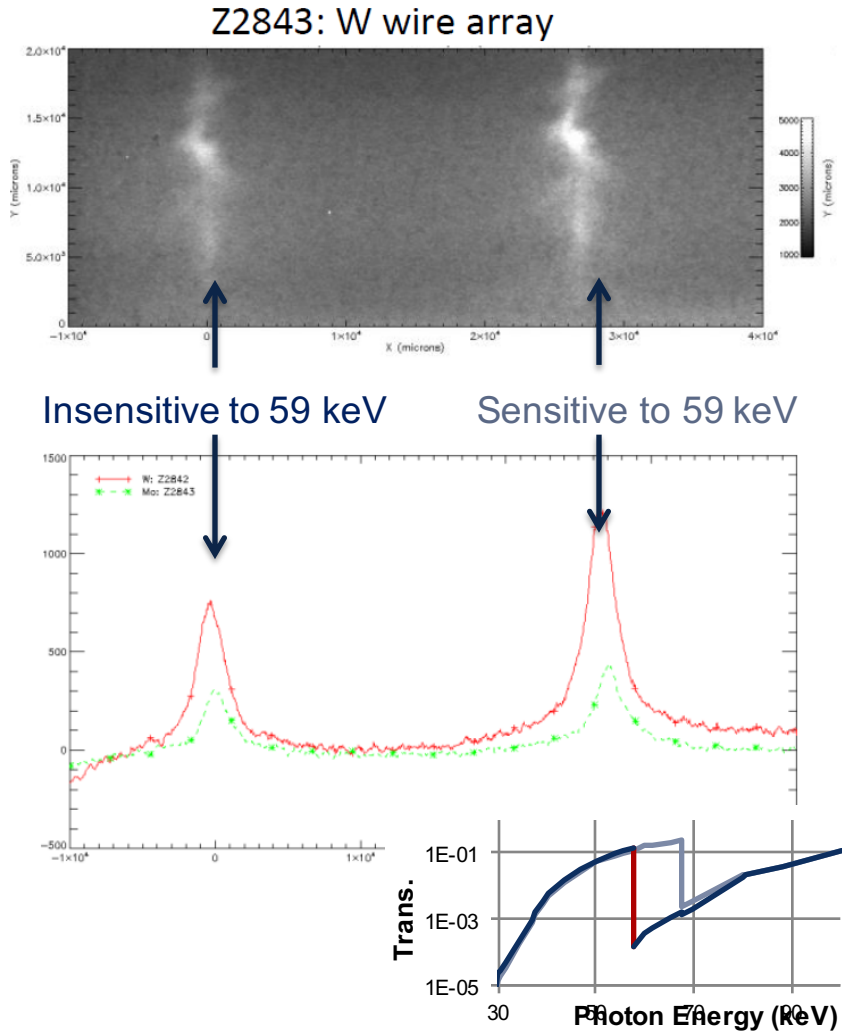
Recent data has shown first evidence of W Kα emission on Z

Spectra show evidence of line



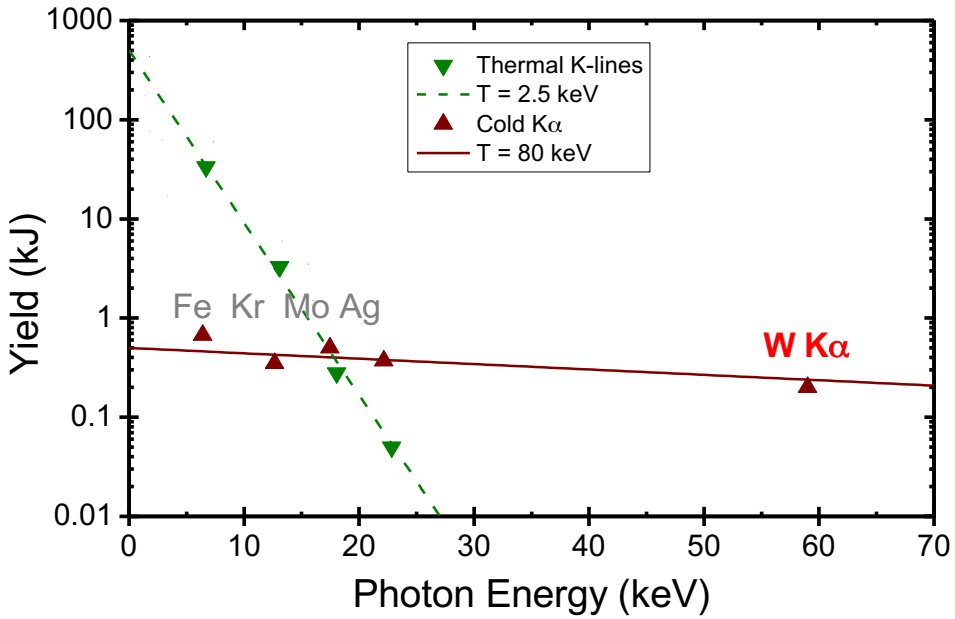


Ross paired for ~60keV gives image



Scaling to W Kα is consistent with lower energy data

- We have previously assumed an energetic electron population at energies ~80 keV to provide scaling through Kα data
  - Not tightly constrained, especially with small range in hv and small dependence on Te
- W data point fits well and provides first data point at >30 keV for wire arrays



Calibration of Quartz 502 CRITR-X setup by Loisel, Seely *et al.*
W yield unfold by G. Loisel

We are also taking steps to better measure Bremsstrahlung from wire arrays on Z

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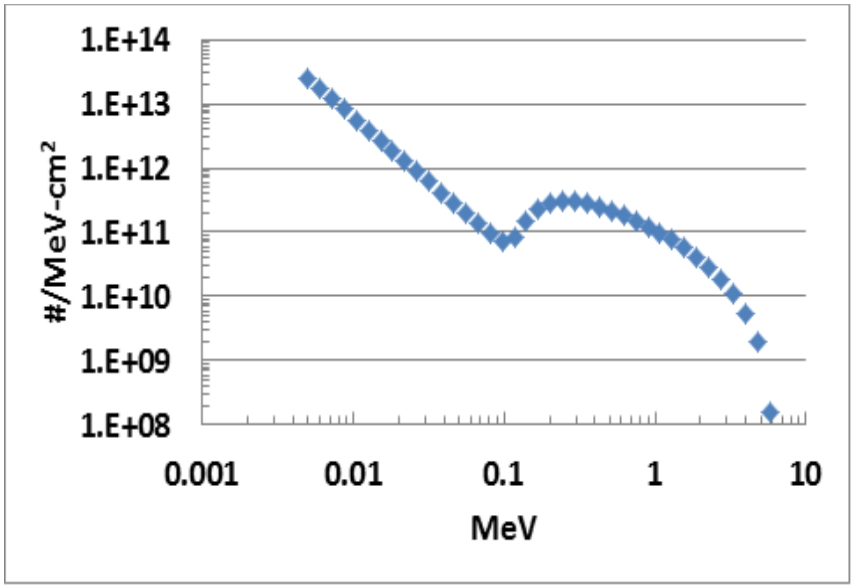
V. Harper-Slaboszewicz *et al. In prep.*



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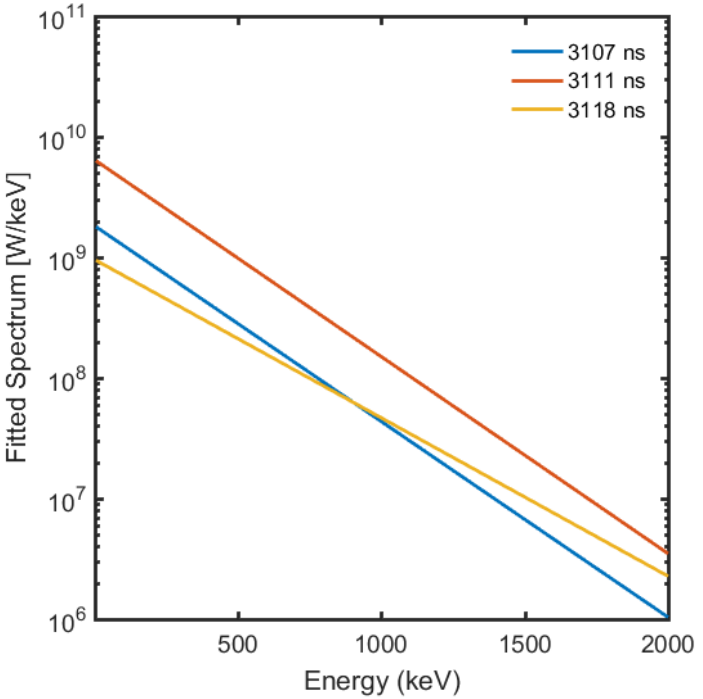

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