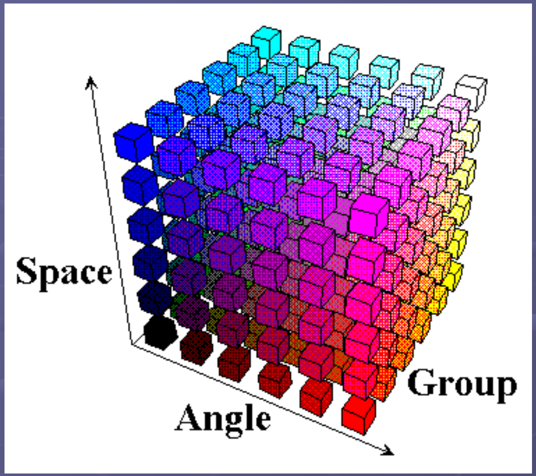
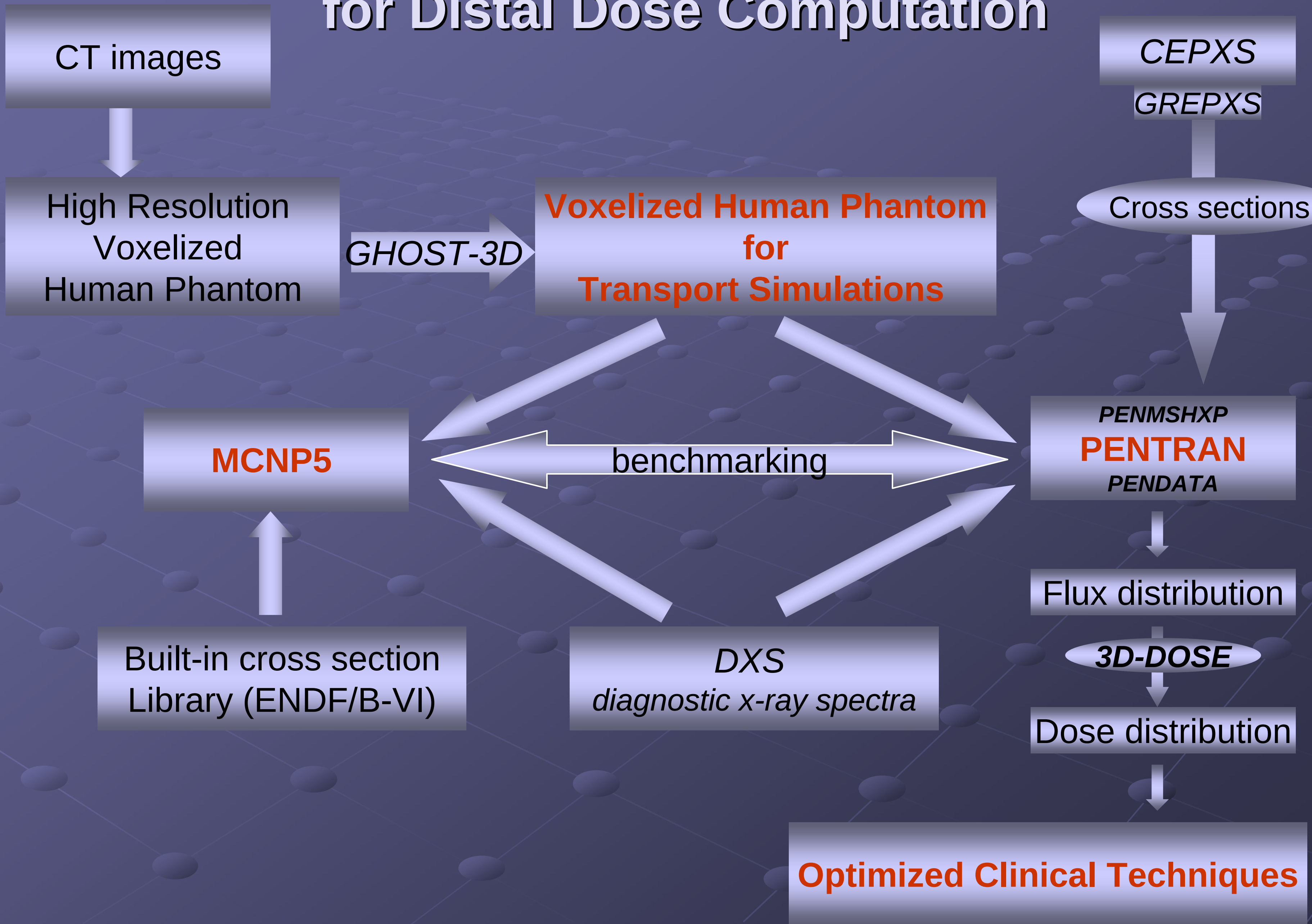


PENTRAN Code Workshop

Presented by Glenn E. Sjoden,
Monica Ghita, and Ahmad Al-Basheer

Nuclear and Radiological Engineering

Simulation Methodology for Distal Dose Computation



Diagnostic X-Ray Energy Spectrum

-Experimentally measured - less convenient due to

- special procedures to prevent saturation of the detector
- difficulties regarding stripping the spectrum from the measured pulse height spectrum
  - corrections for – K-escape
    - Compton scattering
    - inefficient photon absorption

-Theoretically generated by computational methods

- very convenient for research studies
- readily provided according to diverse operational settings
- needs to be validated

Diagnostic X-Ray Energy Spectrum

- Birch & Marshal – BM model (*Phys. Med. Biol.,* 1979, 24(3), 505-517)
  - theoretical model to generate x-ray spectra for tungsten target in the 30-150 kVp energy range
  - accounts for target attenuation, inherent and added filtration, air attenuation
  - theoretical spectra are compared to measured spectra

- Tucker *et al.* - TBC model (*Med. Phys*.,18(2), Mar/Apr 1991, 211-218)
  - improves BM model by assuming both bremsstrahlung and characteristic x-ray production take place at varying depths within the target

- Comparative studies of the two models (*Med. Phys.,*19(3), May/June 1992, 579-582) and of the two models and measurements (*Med. Phys.,* 25(1), Jan 1998,114-120)

DXS: A Diagnostic X-Ray Spectra Generator for X-Ray Transport Simulations

- Bremsstrahlung production

$$N(E)dE = \frac{\alpha r_e^2 Z^2}{A} \frac{dE}{E} \int_E^{T_0} \frac{B(T + m_0 c^2)}{T} \left(\frac{1}{\rho} \frac{dT}{dx} \right)^{-1} e^{\frac{-\mu(E)\left(T_0^2 - T^2\right)}{\rho C \sin\theta}} dT$$

$$B(T) = (A_0 + A_1 T_0)[1 + B_1\left(\frac{E}{T}\right) + B_2\left(\frac{E}{T}\right)^2 + B_3\left(\frac{E}{T}\right)^3 + B_4\left(\frac{E}{T}\right)^4], E \le T$$

- Characteristic x-ray production

$$N(E_i) = A_k \left(\frac{T_0}{E_k} - 1 \right)^{n_k} f(E_i) \int_0^R P\left(\frac{x}{R}\right) e^{-\frac{\mu(E_i)x}{\sin\theta}} dx$$

$$P\left(\frac{x}{R}\right) = \frac{3}{2}\left[1 - \left(\frac{x}{R}\right)^2\right], x \le R$$

Thomson-Whiddington relation

$$\rho C x = T_0^2 - T^2$$

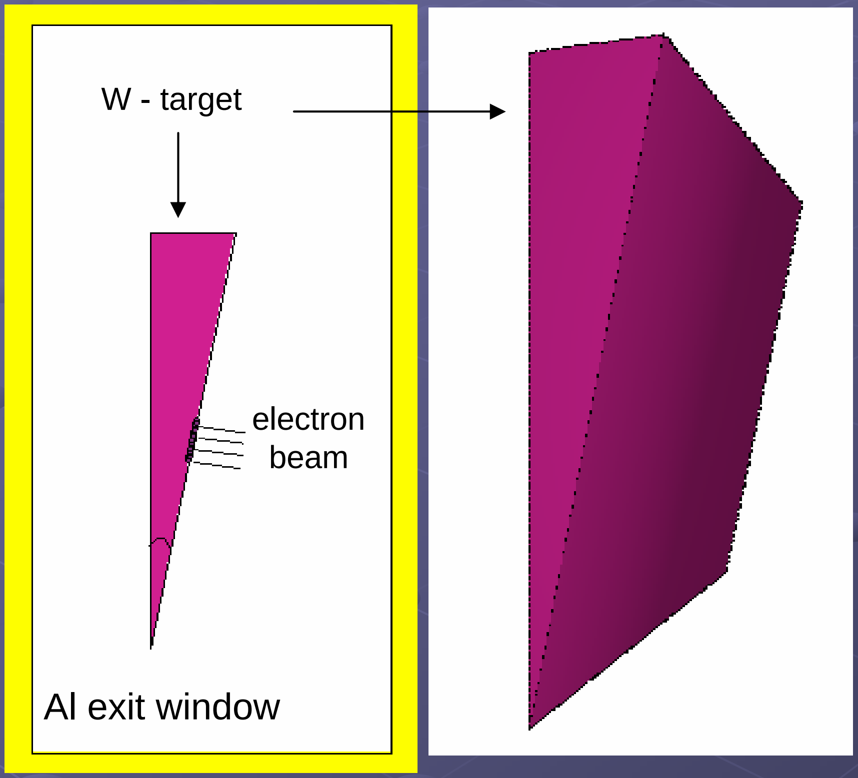
DXS: A Diagnostic X-Ray Spectra Generator for X-Ray Transport Simulations

- analytical fitting functions for:
  - Thomson-Whiddington constant $C(T_0) = c_1 + c_2 T_0$
  - Mass attenuation coefficients $\frac{\mu(E)}{\rho} = a_1 + a_2 E^{-1.6} + a_3 E^{-2.7} + a_4 E^{-3.5} + a_5 E^{-4.5}$
  - Mass stopping power $\frac{1}{\rho}\frac{dT}{dx} = a_m + b_m e^{-c_m T}$
- Tungsten K-absorption edge $E_k = 69.5 keV$
- Tungsten characteristic lines

$$K_{\alpha 1} \rightarrow 59.32 keV$$
$$K_{\alpha 2} \rightarrow 57.98 keV$$
$$K_{\beta 1} \rightarrow 67.2 keV$$
$$K_{\beta 2} \rightarrow 69.1 keV$$

DXS: A Diagnostic X-Ray Spectra Generator for X-Ray Transport Simulations

MCNP5 simulation – tungsten anode x-ray tube



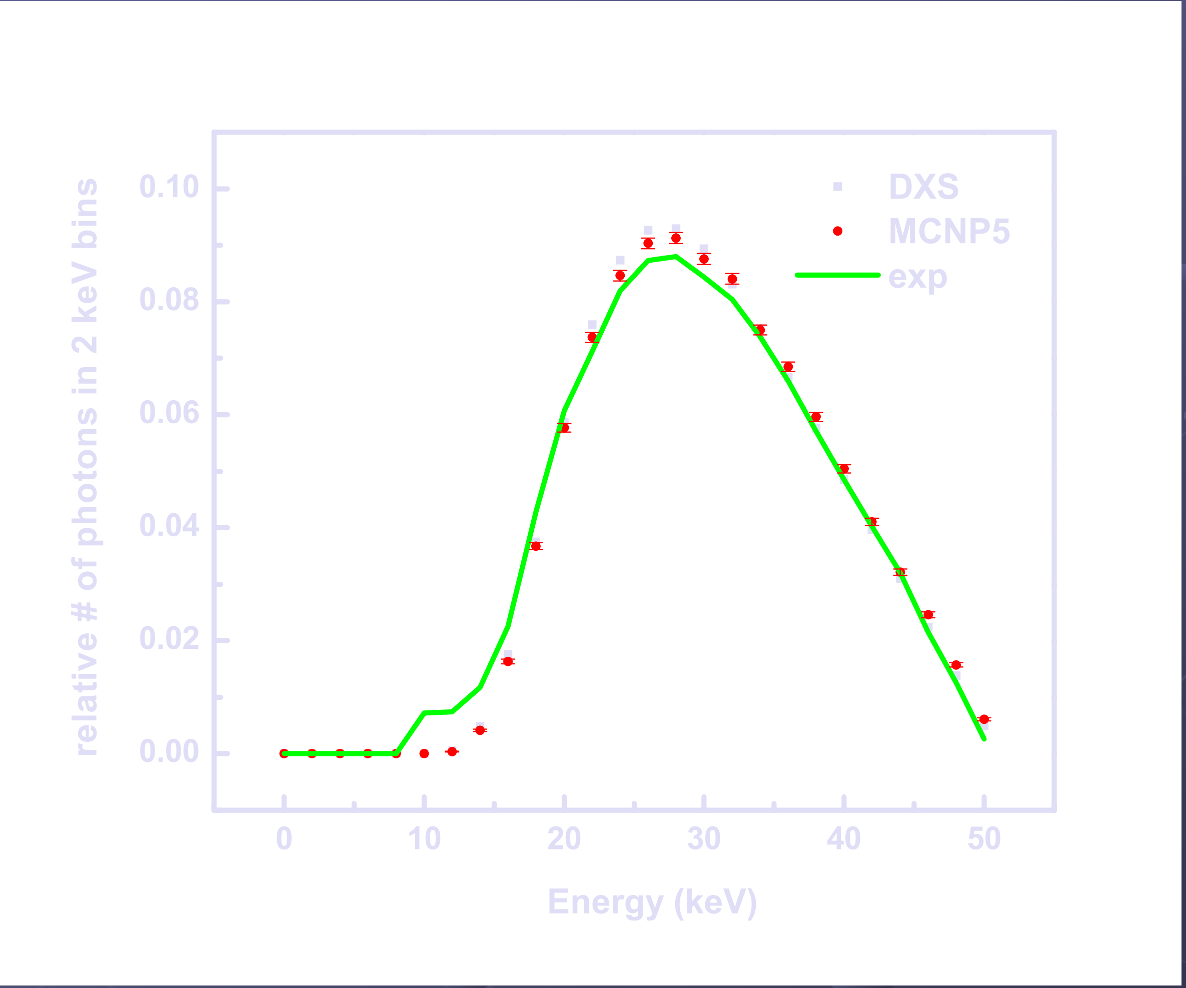
Tungsten anode – 12 degrees angle
Inherent filtration – 1.2 mm Al equivalent

Monoenergetic electron beam

-uniformly distributed on the focal spot
-normally impinging on the target

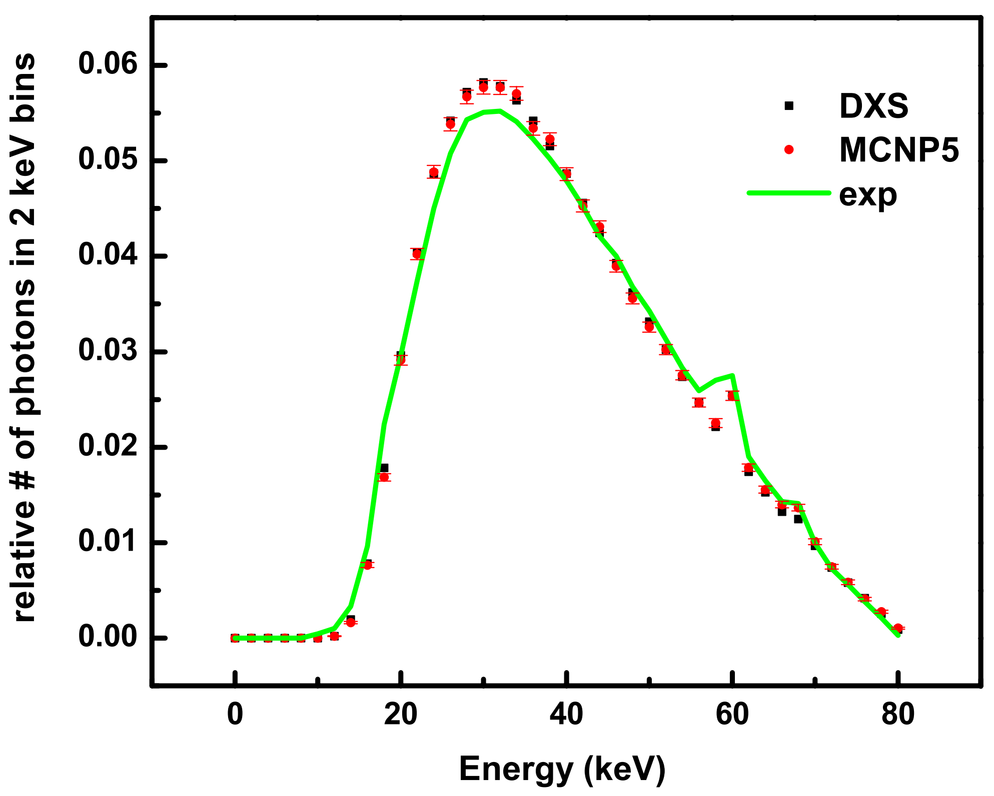
F1 current tally at exit window

DXS: A Diagnostic X-Ray Spectra Generator for X-Ray Transport Simulations



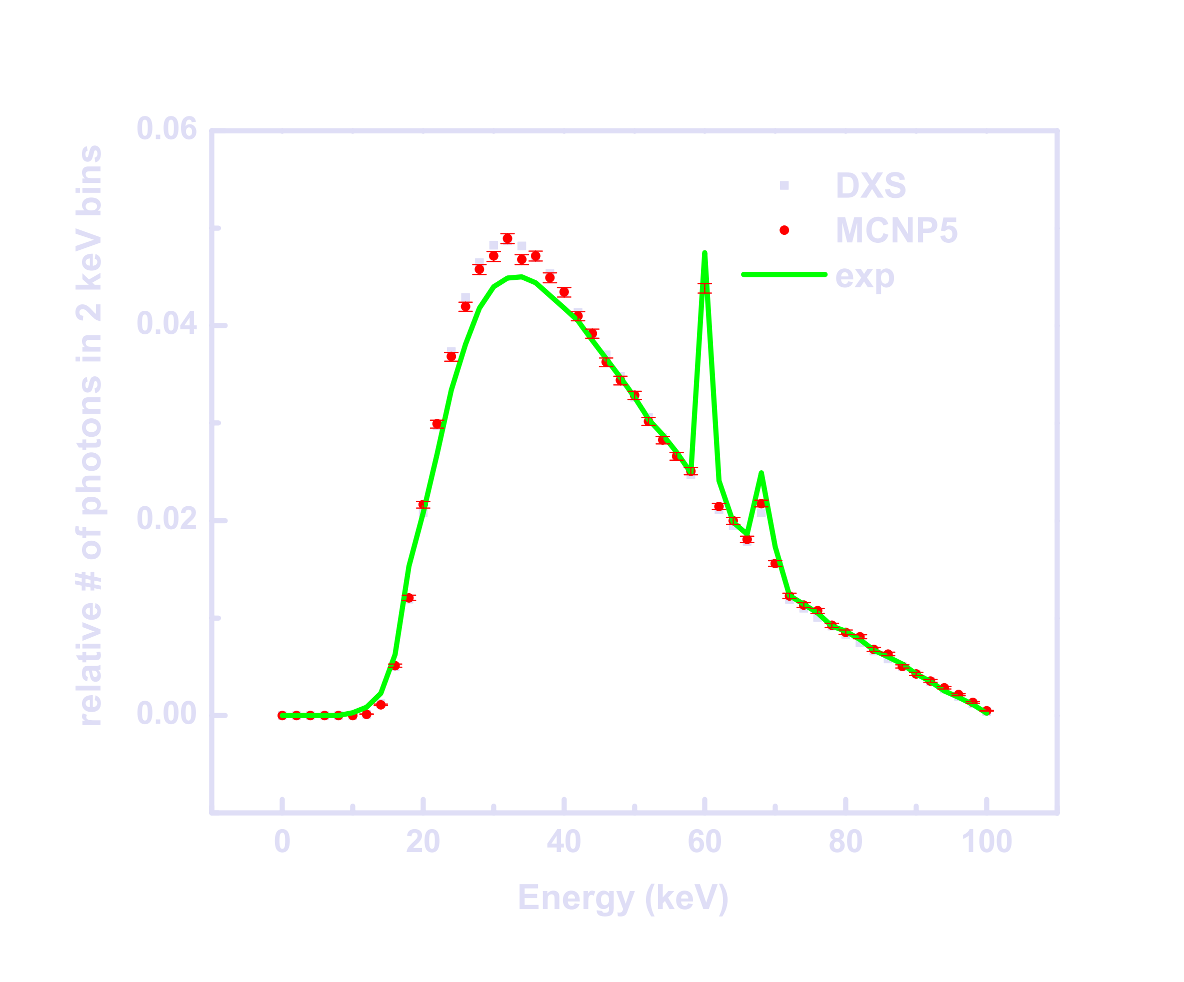
50 kVp

DXS: A Diagnostic X-Ray Spectra Generator for X-Ray Transport Simulations



80 kVp

DXS: A Diagnostic X-Ray Spectra Generator for X-Ray Transport Simulations



100 kVp

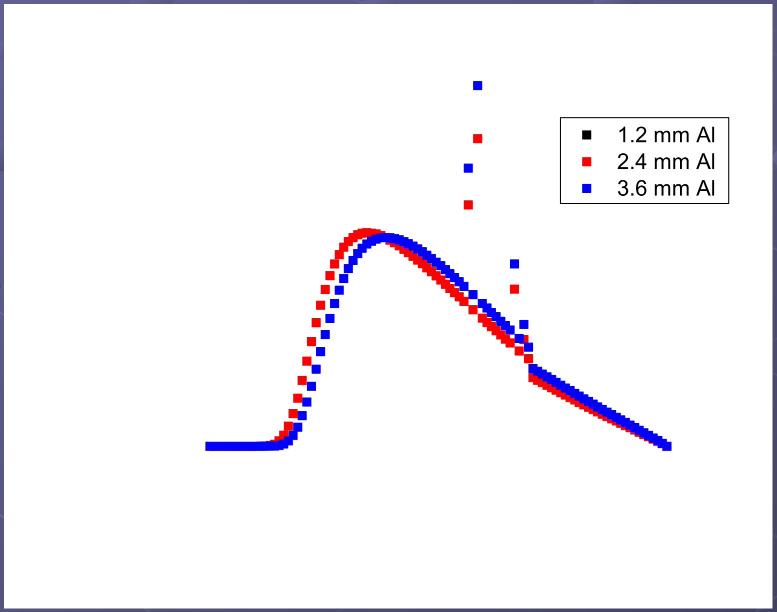
DXS: A Diagnostic X-Ray Source Generator for X-ray Transport Simulations

INPUT PARAMETERS

- kVp
- target angle
- aluminum filtration
- other filtration (Be,Cu,Ta)
- air path
- energy group structure

OUTPUT OPTIONS

-Spectrum normalized to unit area
-Spectrum normalized to maximum bin
-Spectrum adapted to energy group structure
-Input file for CEPXS-the cross-sections generator code



12º W anode

100 kVp