

Preliminary Simulation Results of Separation of the X-Rays Emitted by Femtosecond Electron Beam Slices at Synchrotron SOLEIL

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on behalf of the SOLEIL
“FS Slicing” Working Group

Calculation Methods

Generation of E-Beam Slices in a Storage Ring Using a Femtosecond Pulse Laser

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R.W. Schoenlein et. al.
G. Ingold et. al.

Separation of X-Ray Emission by Femtosecond E-Beam Slices from the Core E-Beam Emission

Analytical Estimation for Electron Energy Modulation:

$$\Delta\gamma_{\max} \approx 2mc^2 (A_L A_U \eta_{emit} N_U / (\xi N_L))^{1/2}$$

OR: Numerical Calculation of the Energy Transfer:

$$\dot{\gamma} = \frac{e}{mc} \vec{\beta}_{\perp} \cdot \vec{E}_{L\perp} \Rightarrow \Delta\gamma(x_e, x'_e, y_e, y'_e, \phi_e, \gamma_e)$$

OR: SASE-Type Simulation

$$\frac{d\gamma}{dz} = -k_r \frac{a_r a_u}{\gamma} \sin(\theta + \phi_r)$$

$$\frac{d\theta}{dz} = k_u - k_r \frac{1 + p_{\perp}^2 + a_u^2 - 2a_r a_u \cos(\theta + \phi_r)}{2\gamma^2}$$

$$\frac{dp_{\perp}}{dz} = -\frac{1}{2\gamma} \frac{\partial a_u^2}{\partial r_{\perp}} + k_{foc} r_{\perp}$$

$$\frac{dr_{\perp}}{dz} = \frac{p_{\perp}}{\gamma}$$

$$\left[2ik_r \frac{\partial}{\partial z} + \nabla_{\perp}^2 \right] a_r \exp(i\phi_r) = -\frac{e\varepsilon_0 I}{mc} \left\langle \frac{a_u \exp(-i\theta)}{\gamma} \right\rangle$$

Phase-Space Distribution of Electrons after Modulator:

$$f_{sat\ m} = \frac{dN_e}{dxdx'dydy'd\phi d\gamma} \Big|_{\substack{\gamma_{\min} < \gamma < \gamma_{\max} \\ S=S_{\text{mod}}}}, f_{core\ m} = \frac{dN_e}{dxdx'dydy'd\phi d\gamma} \Big|_{S=S_{\text{mod}}}$$

⇓ Machine Lattice

Phase-Space Distribution of Electrons at Radiator:

$$f_{core\ r}(x_e, x'_e, y_e, y'_e, \phi_e, \gamma_e), f_{sat\ r}(x_e, x'_e, y_e, y'_e, \phi_e, \gamma_e)$$

Electric Field Emitted by One Electron in Radiator and Propagated through Beamline Optics (Retarded Potentials + Fresnel Propagator):

$$\vec{E}_{\omega\perp 1} = iec^{-1} \omega \int_{-\infty}^{+\infty} R^{-1} [\vec{\beta}_{\perp} - [1 + ic/(\omega R)] \cdot \vec{n}_{\perp}] \cdot \exp[i\omega(\tau + R/c)] d\tau$$

$$\vec{E}_{\omega\perp 2} \approx \frac{k}{2\pi i L} \iint \vec{E}_{\omega\perp 1} \exp[ikS_{12}] d\Sigma, \quad \vec{E}_{\omega\perp 2} = \vec{E}_{\omega\perp 1} T_{12} \quad (\text{Beamline})$$

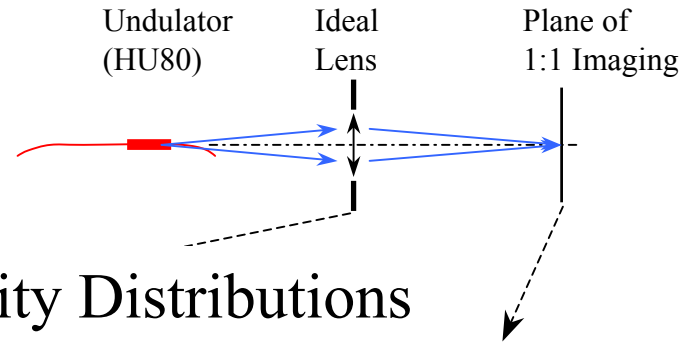
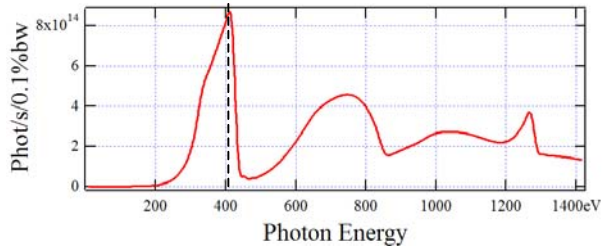
Scattering to add !

Intensity Distributions of the “Core” and “Satellite” Emission:

$$I_{core(sat)}(x, y) = \int |\vec{E}_{\omega\perp 2}(x, y, x_e, x'_e, y_e, y'_e, \gamma_e)|^2 f_{core(sat)}(x_e, y_e, x'_e, y'_e, \gamma_e) dx_e dy_e dx'_e dy'_e d\gamma_e$$

Undulator Radiation

in the Range of Intensities Covering Several Orders of Magnitude

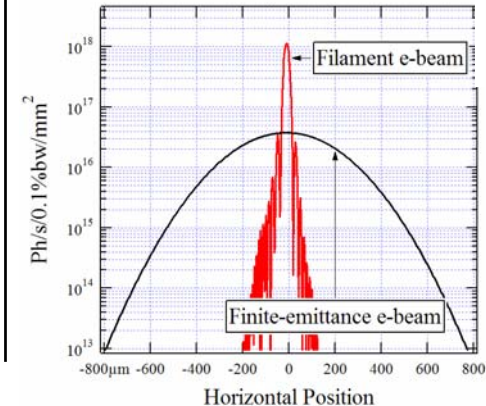
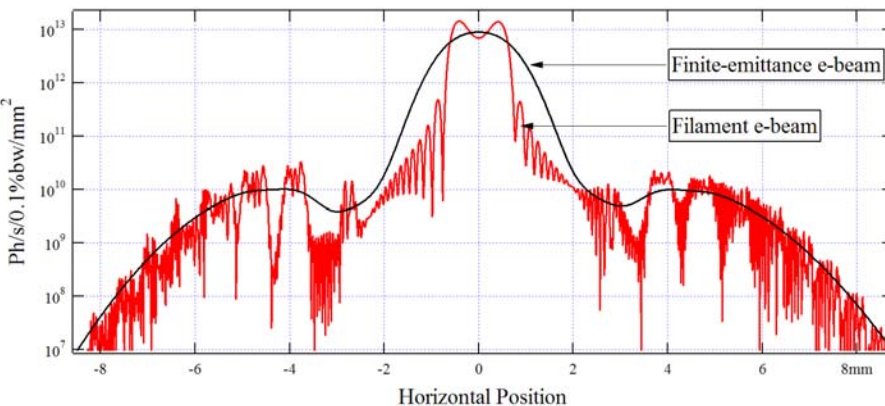
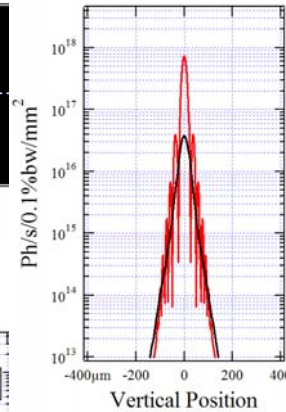
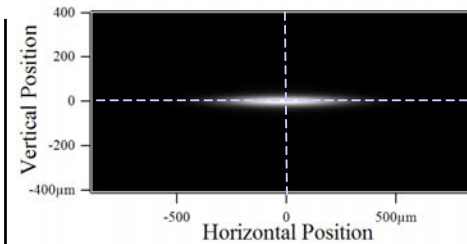
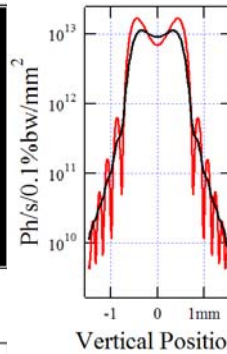
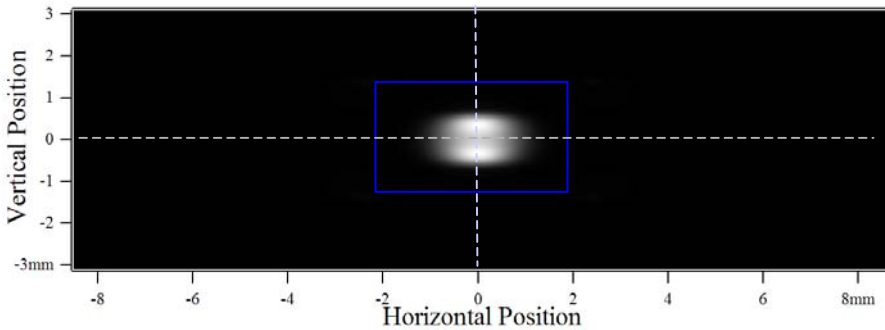


SOLEIL Medim-Size Straight Section
 Undulator: $\lambda_u = 80$ mm, $N_p = 19$
 Photon Energy: $\varepsilon = 415$ eV

Intensity Distributions

At 10 m from Undulator

In the Plane of 1:1 Imaging



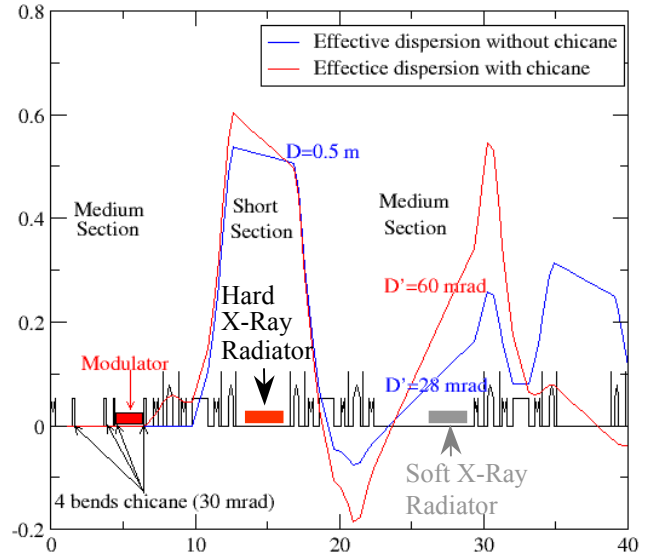
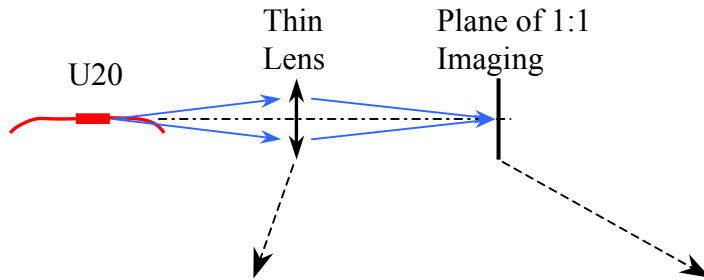
Separation of Emission from FS E-Beam Slices Using SOLEIL Natural Dispersion: General Spatial Horizontal Scheme for Hard X-Rays

E-Beam, Modulation:

$E_0 = 2.75 \text{ GeV}$ $\Delta E_{\text{max}} \approx 14 \text{ MeV} (?)$
 $I_{\text{s.b.}} = 10 \text{ mA}$ $f_L = 10 \text{ kHz}$
 $\sigma_b = 24 \text{ ps}$ $\sigma_L = 50 \text{ fs}$

Hard X-Ray Radiator:

Undulator U20
 (in-vacuum)

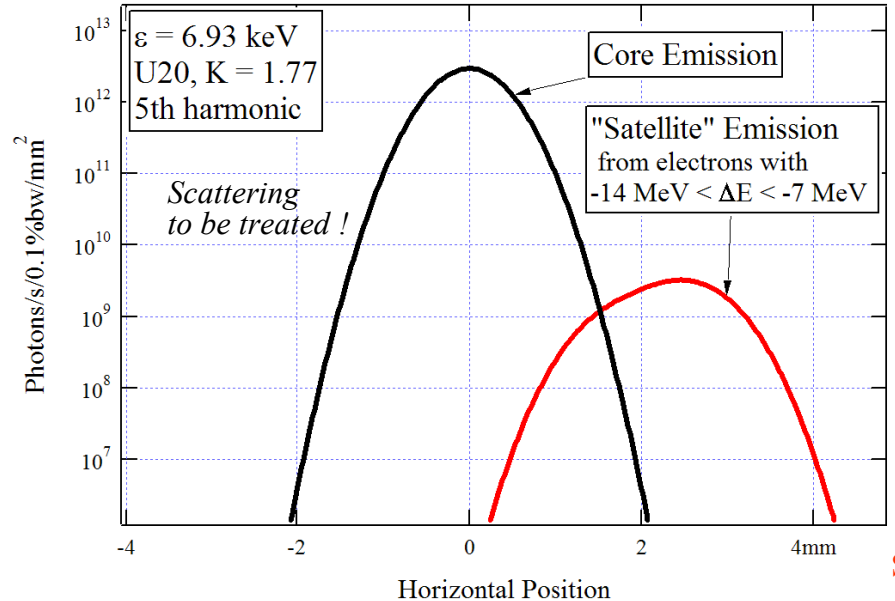
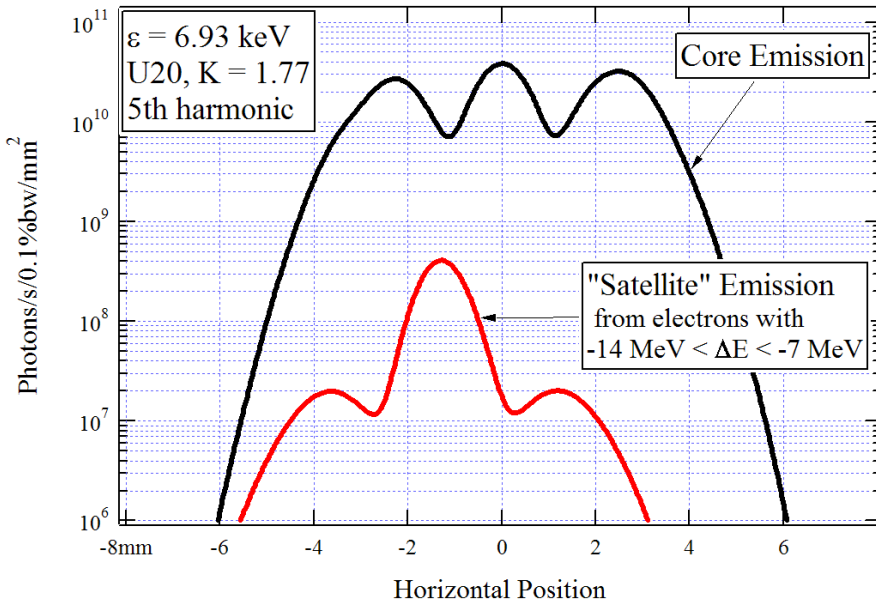


A. Loulergue
 A. Nadjj
 L. Nadolski
 M.-P. Level

Intensity in Transverse Plane Before Mirror

Intensity in the Plane of 1:1 Imaging

Cuts by Median Plane



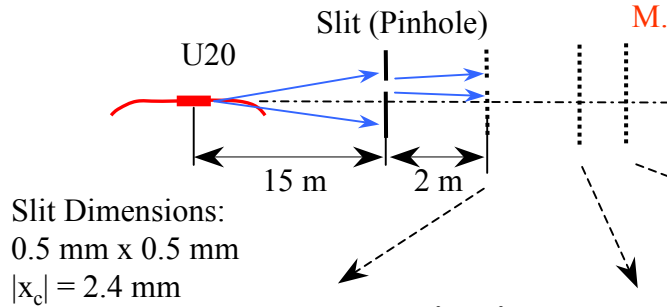
Separation of Emission from FS E-Beam Slices Using SOLEIL Natural Dispersion: Pinhole-Based Spatial Horizontal Scheme for Hard X-Rays

E-Beam, Modulation:

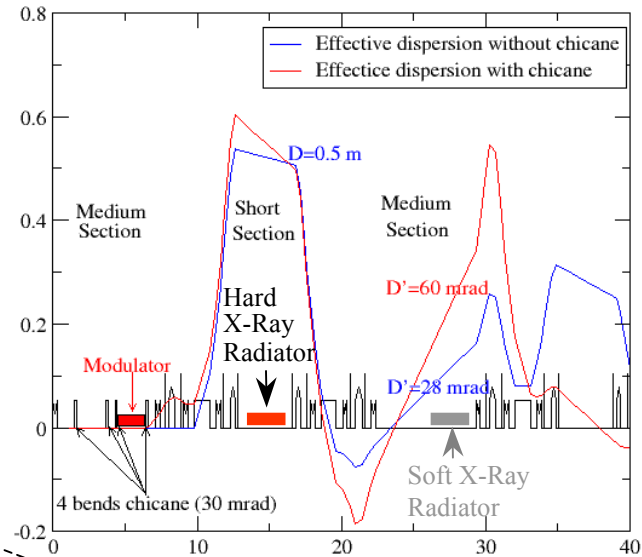
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Hard X-Ray Radiator:

Undulator U20
 (in-vacuum)



T. Moreno
 M. Idir

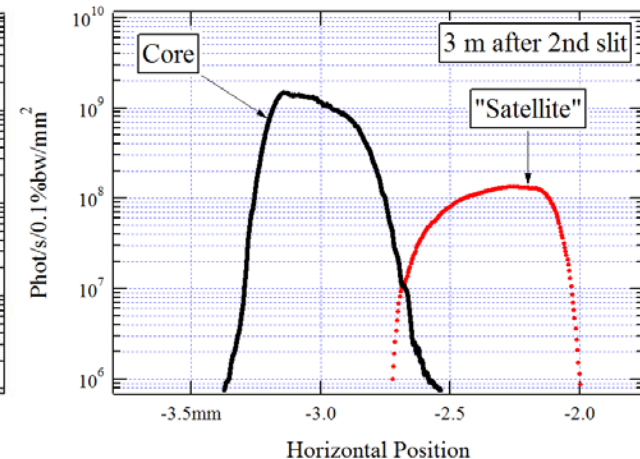
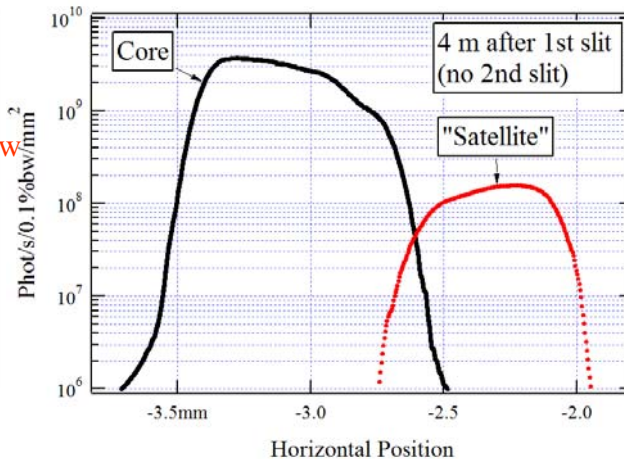
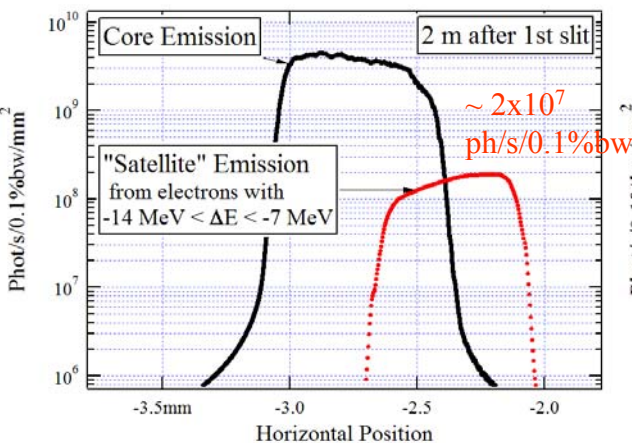


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Intensity in Transverse Planes After Slit(s)

Results of Propagation of Partially-Coherent Wavefront (Cuts by Median Plane)

$\varepsilon = 6.93 \text{ keV}$



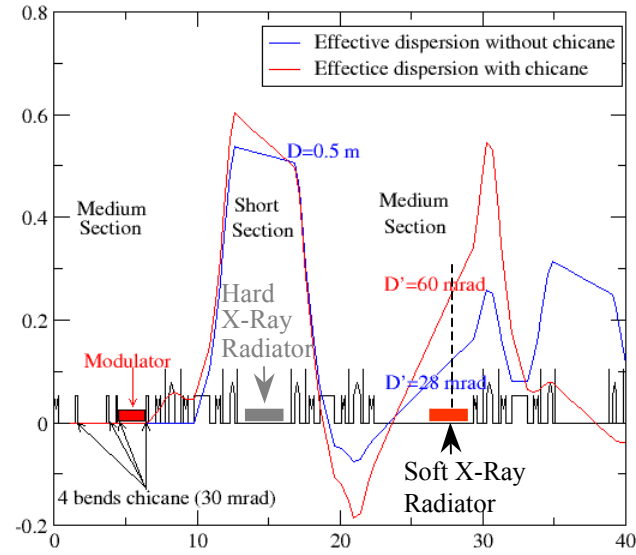
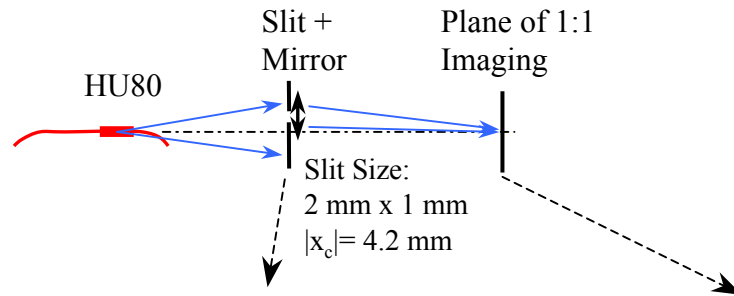
Separation of Emission from FS E-Beam Slices Using SOLEIL Natural Dispersion and a Chicane: Spatial-Angular Horizontal Scheme for Soft X-Rays

E-Beam, Modulation:

$E_0 = 2.75 \text{ GeV}$ $\Delta E_{\text{max}} \approx 14 \text{ MeV}$ (?)
 $I_{\text{s.b.}} = 10 \text{ mA}$ $f_L = 10 \text{ kHz}$
 $\sigma_b = 24 \text{ ps}$ $\sigma_L = 50 \text{ fs}$

Soft X-Ray Radiator:

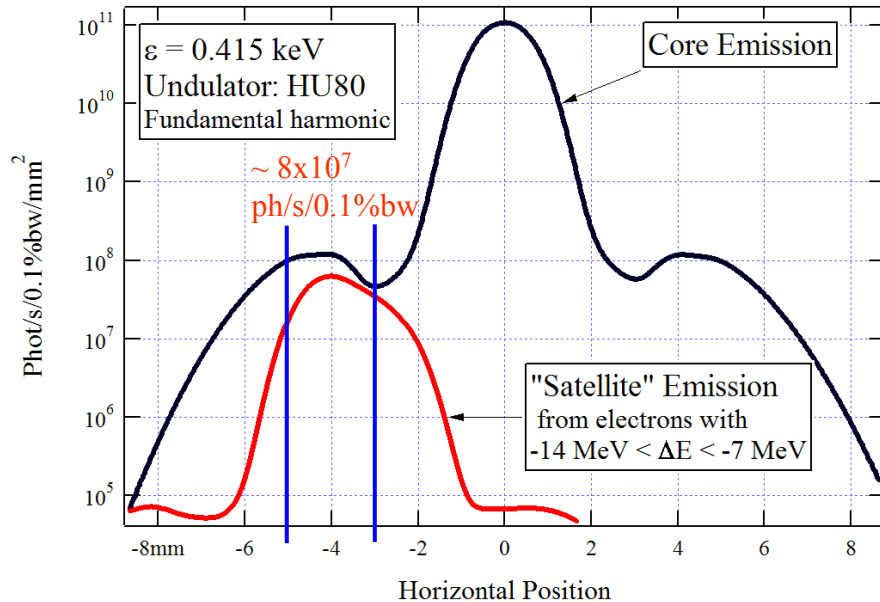
Undulator HU80
 (Apple-II)



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Intensity in Transverse Plane Before Mirror
 10 m from Undulator

Cuts by Median Plane



Intensity in the Plane of 1:1 Imaging

