SYNCHROTRON RADIATION @ SUPERB COMPARED TO DEDICATED FACILITIES

First Results

SuperB Meeting Frascati

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2010-09-29

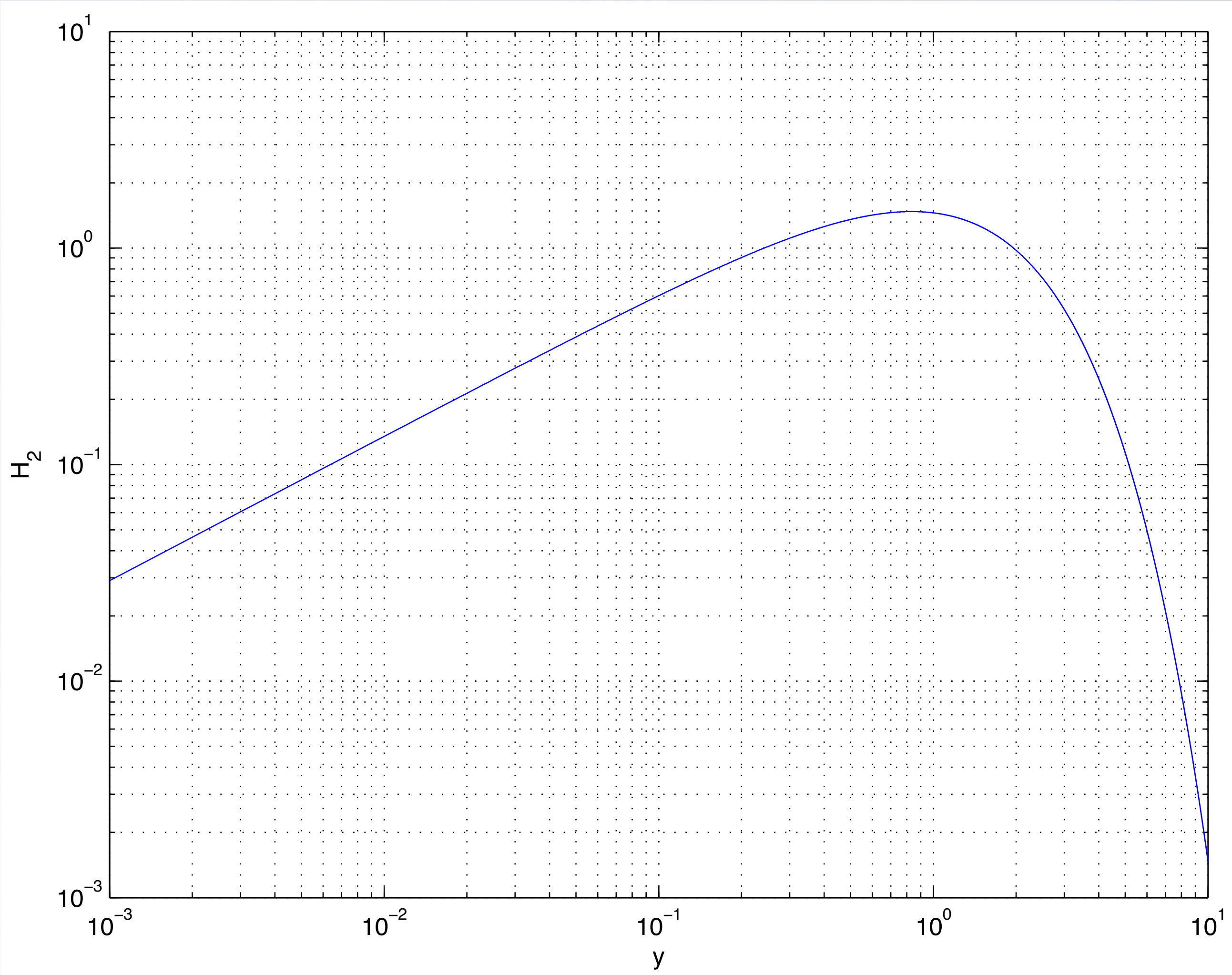
COMMENTS

- First cut to compare bend magnet and undulator synchrotron radiation from SuperB HER and LER to other dedicated sources: NSLS II, PEP X, ESRF, ...

- The calculation is done analytically using the formalism described in the standard literature (Wiedemann, ...)

- Source point data for SuperB for bend calculation extrapolated and same as NSLS-II for undulator calculation.

SPECTRAL CENTRAL INTENSITY BEND MAGNET CALCULATION



$$\left.\frac{d^2F}{d\theta\cdot d\psi}\right|_{\psi=0} = \frac{3\alpha}{4\pi^2}\gamma^2\frac{\Delta\omega}{\omega_C}\frac{I}{e}H_2(y)$$

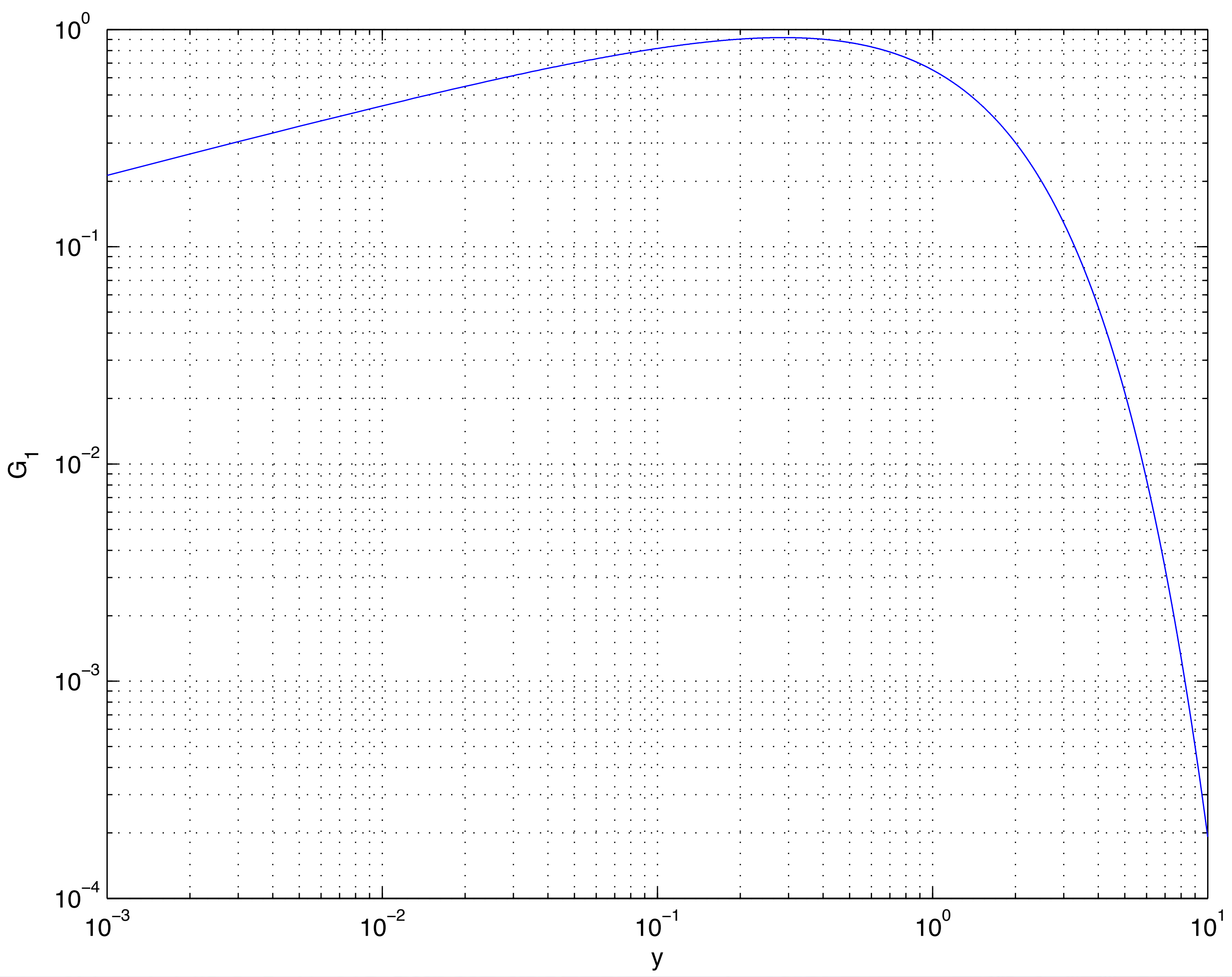
$$H_2(y) = y^2K^2_{2/3}\left(\frac{y}{2}\right)$$

$$\left.\frac{d^2F}{d\theta\cdot d\psi}\right|_{\psi=0} = 1.327\times 10^{13}\,E^2[GeV]\;I[A]\;H_2(y)$$

SPECTRAL FLUX BEND MAGNET CALCULATION

$$\frac{dF_{bm}(y)}{d\theta} = \frac{\sqrt{3}}{2\pi}\alpha\gamma\frac{\Delta\omega}{\omega}\frac{I}{e}G_1(y)$$

$$G_1(y) = y\int_y^\infty K_{5/3}(y')\,dy'$$



$$\frac{dF_{bm}(y)}{d\theta} = 2.457\times10^{13}\,E[GeV]\;I[A]\;G_1(y)$$

SPECTRAL BRIGHTNESS BEND MAGNET CALCULATION

$$B_{bm} = \frac{\left.\dfrac{d^2F(y)}{d\theta \cdot d\psi}\right|_{\psi=0}}{2\pi\,\Sigma_x(y)\,\Sigma_y(y)}$$

$$\Sigma_x(y) = \left[\varepsilon_x\beta_x + \eta_x^2\delta_E^2 + \sigma_r^2(y)\right]^{\frac{1}{2}}$$

$$\sigma_r(y) = \frac{\lambda}{4\pi\sigma_\psi(y)}$$

$$\Sigma_y(y) = \left[\varepsilon_y\beta_y + \sigma_r^2(y) + \frac{\varepsilon_y^2 + \varepsilon_y\gamma_y\sigma_r^2(y)}{\sigma_\psi^2(y)}\right]^{\frac{1}{2}}$$

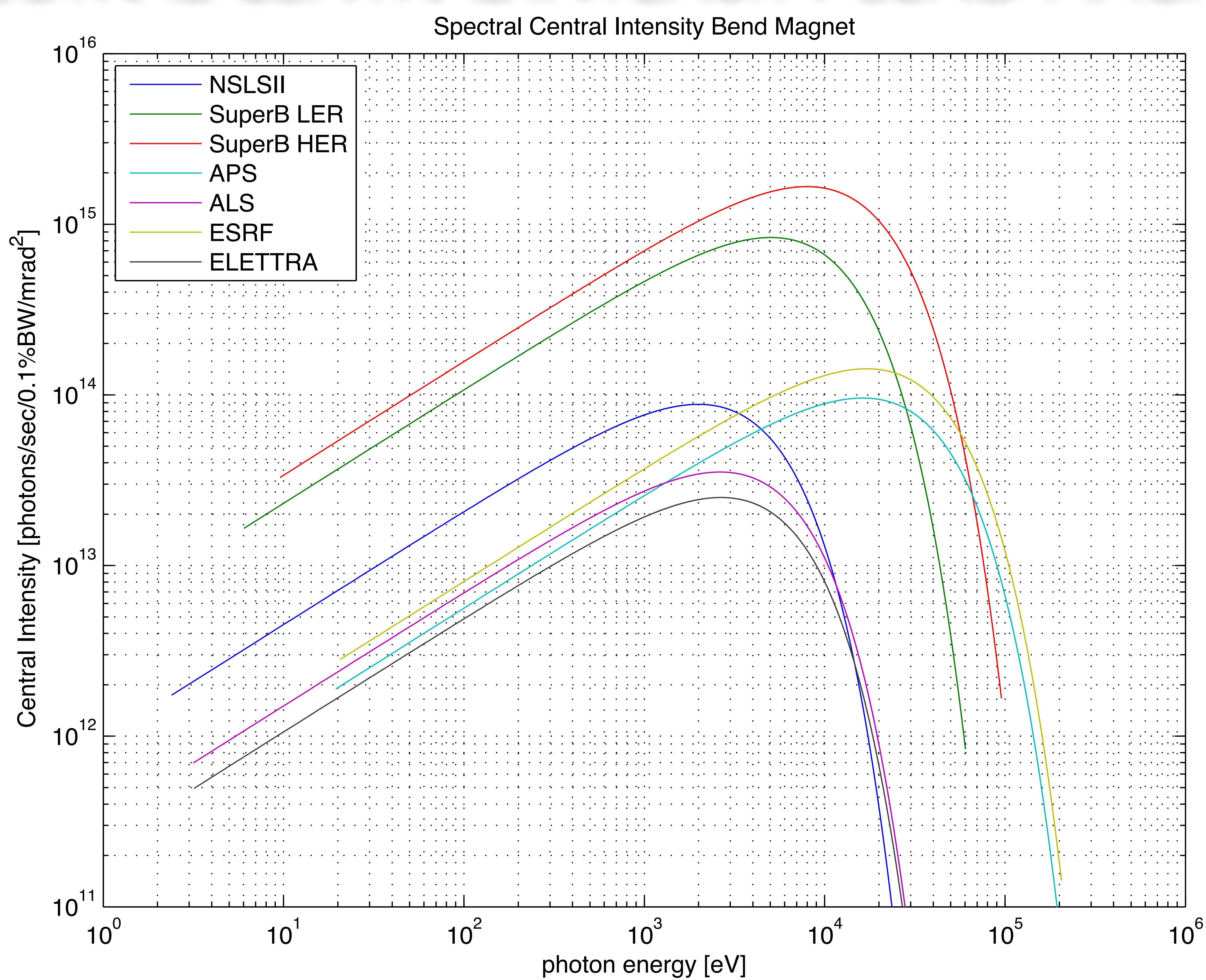
$$\sigma_\psi^2(y) = \frac{1}{\sqrt{2\pi}}\frac{\dfrac{dF_{bm}(y)}{d\theta}}{\left.\dfrac{d^2F_{bm}(y)}{d\theta\,d\psi}\right|_{\psi=0}}$$

PARAMETER TABLE BEND MAGNET

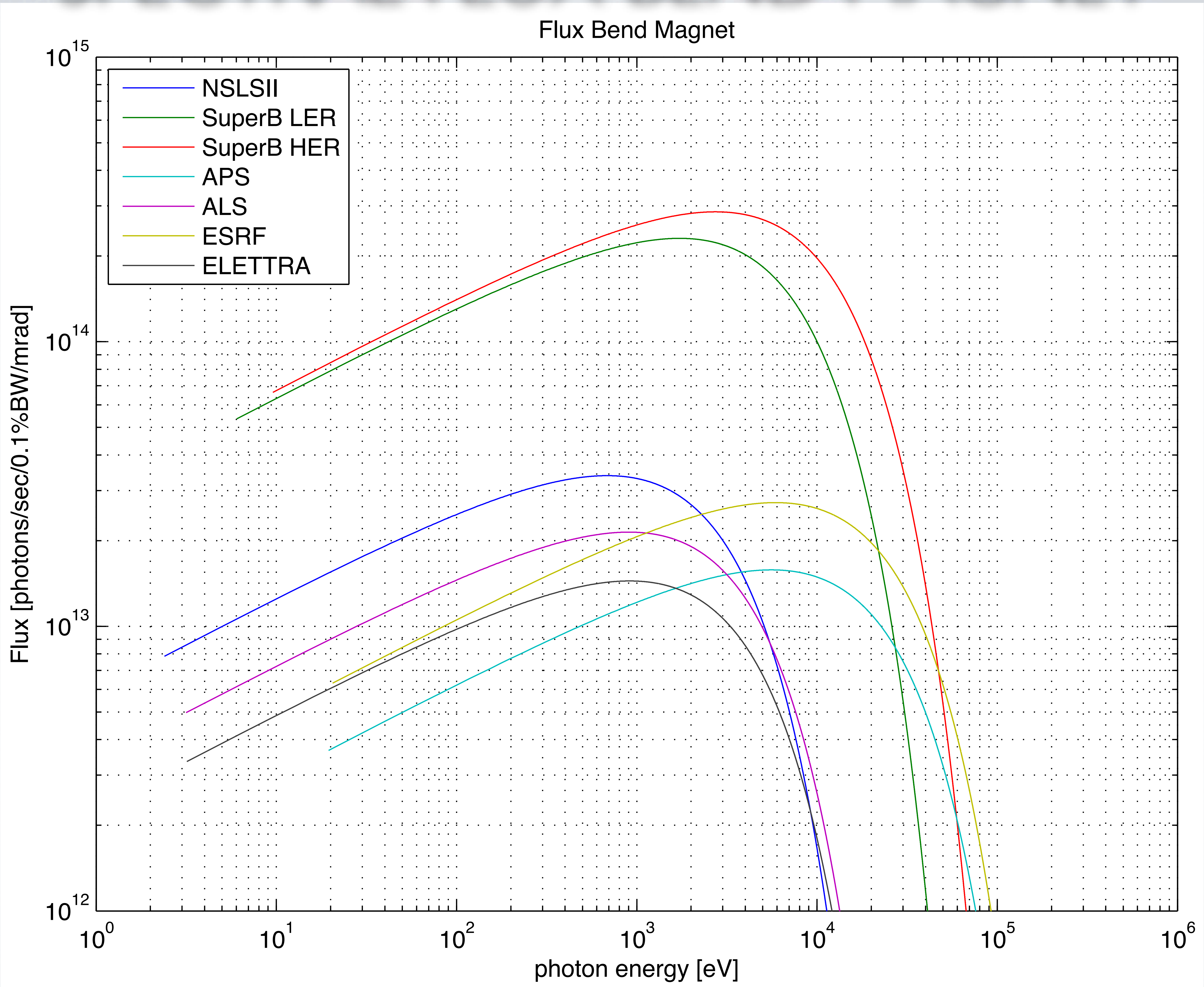
Parameters *	SuperB HER	SuperB LER	NSLS II	APS	ESRF	ELETTRA	ALS
E [GeV]	6.7	4.18	3	7.0	6.03	2.0	1.9
I [mA]	1892	2447	500	100	200	320	500
ρ [m]	69.64	26.8	24.975	38.961	23.623	5.55	4.81
B [T]	0.32	0.52	0.4	0.599	0.85	1.2	-
εx [m rad]	2.0 E-9	2.46 E-9	0.55 E-9	2.514 E-9	4.0 E-9	7.0 E-9	6.3 E-9
βx [m]	2.5	2.5	-	1.7	0.99	-	0.87
σE [1]	6.43 E-4	7.34 E-4	10.0 E-4	9.6 E-4	11.0 E-4	8.0 E-4	9.7 E-4
ηx [m]	0.065	0.066	0.0	0.05	0.045	-	0.072
εy [m rad]	5.0 E-12	6.15 E-12	8.0 E-12	22.6 E-12	25.0 E-12	70.0 E-12	50 E-12
βy [m]	15.0	13.5	-	24.1	34.9	-	1.36
αy [1]	-2.0	-2.5	-	0.614		-	-0.069
γy [m^-1]	0.334	0.537	0.05	0.101	0.10	0.5	0.740
σx [mm]	82.1 E-3	92.1 E-3	125.0 E-3	81.7 E-3	77.0 E-3	139.0 E-3	101.8 E-3
σy [mm]	8.66 E-3	9.11 E-3	13.4 E-3	27.0 E-3	29.5 E-3	28.0 E-3	8.2 E-3

* Source of data different web pages and presentations

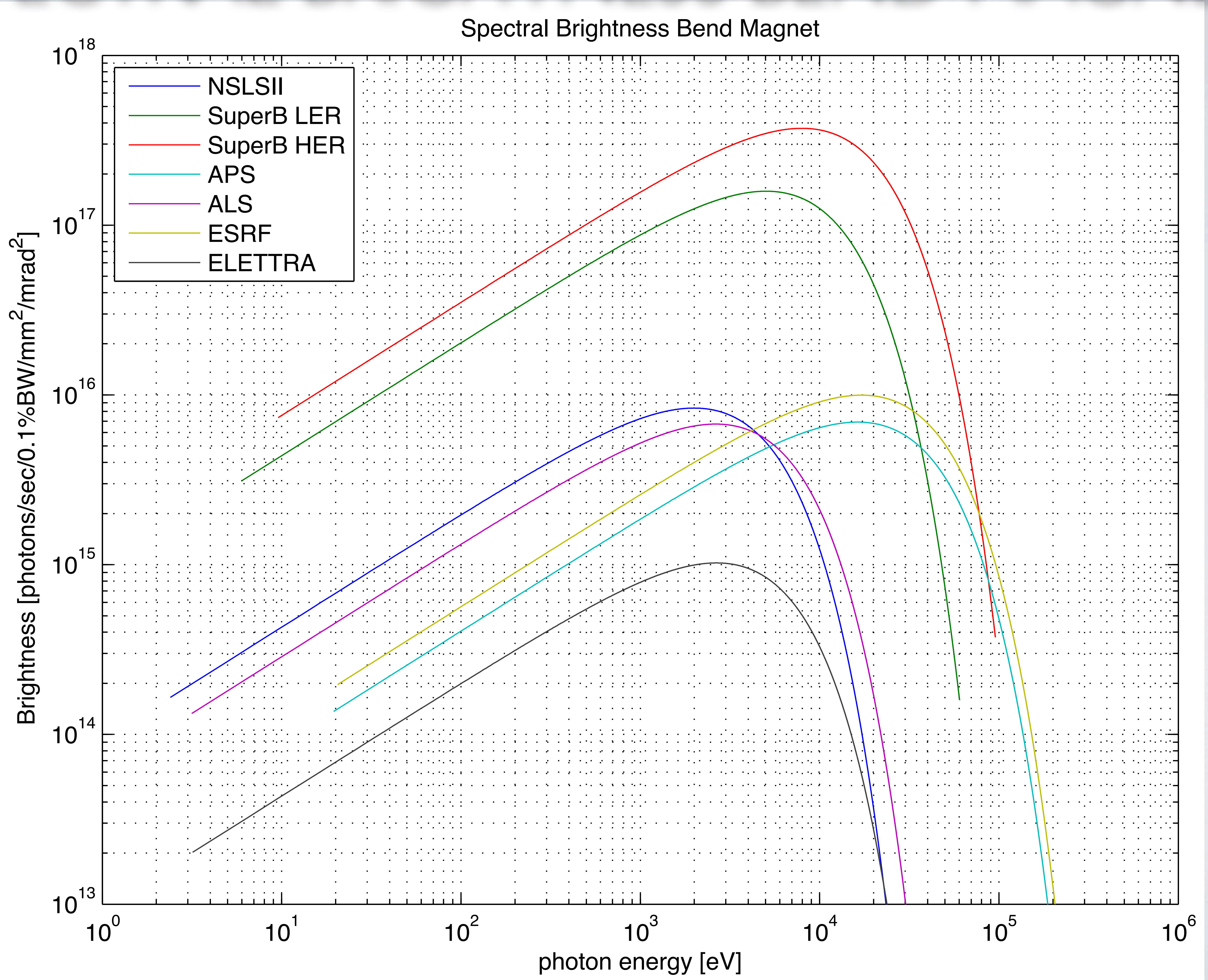
SPECTRAL CENTRAL INTENSITY BEND MAGNET



SPECTRAL FLUX BEND MAGNET



SPECTRAL BRIGHTNESS BEND MAGNET

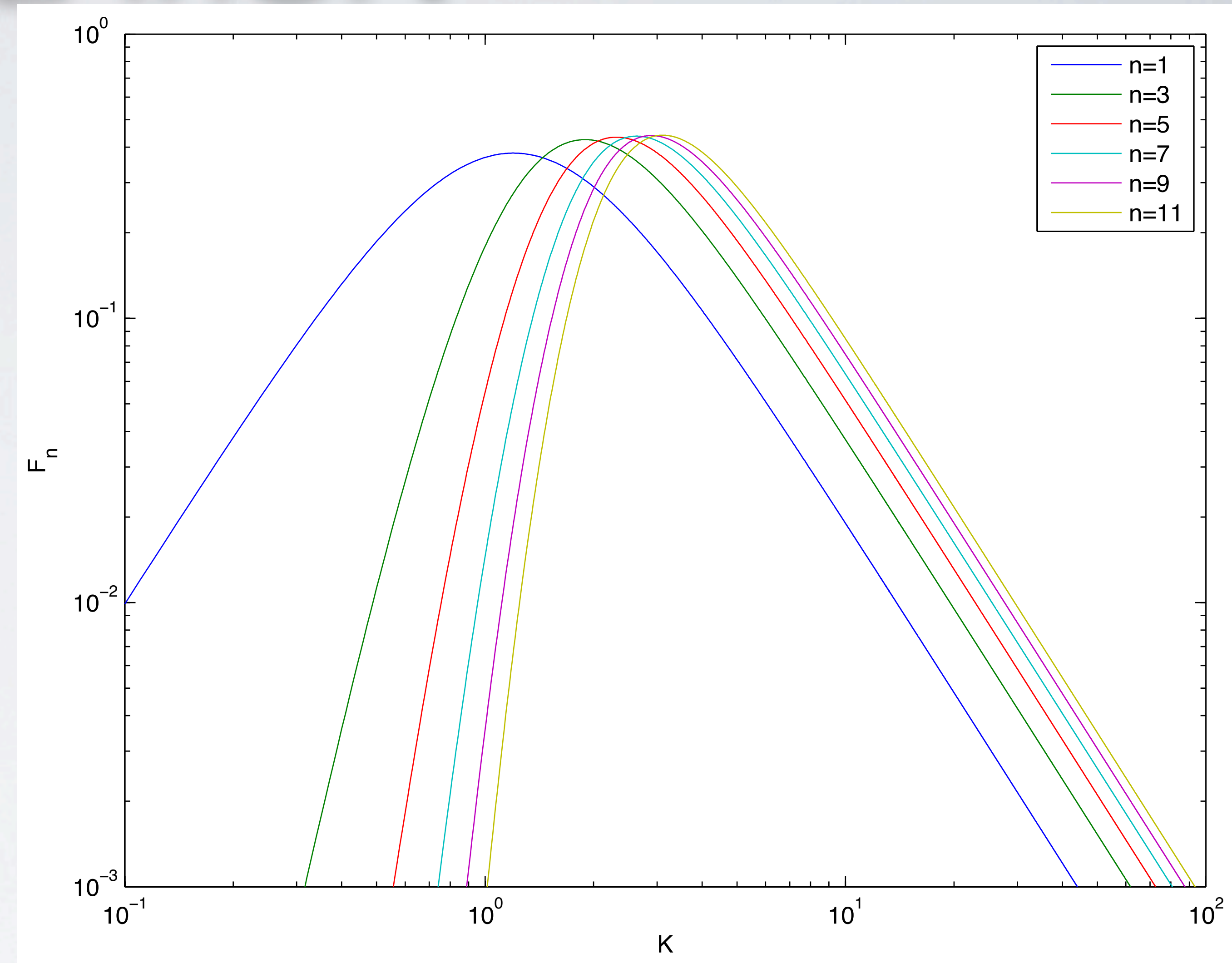


SPECTRAL FLUX UNDULATOR CALCULATION

$$F_u(K,\omega) = \pi\alpha N \frac{\Delta\omega}{\omega}\frac{I}{e} Q_n(K) \ , \quad n = 1,3,5,\ldots$$

$$Q_n(K) = \left(1 + \frac{K^2}{2}\right)\frac{F_n(K)}{n} \ , \quad n = 1,3,5,\ldots$$

$$F_n(K) = \frac{K^2 n^2}{(1+K^2/2)^2}\left[J_{\frac{n-1}{2}}\left(\frac{nK^2}{4\left(1+\frac{K^2}{2}\right)}\right) - J_{\frac{n+1}{2}}\left(\frac{nK^2}{4\left(1+\frac{K^2}{2}\right)}\right)\right]^2$$



$$F_u(K,\omega) = 1.431 \times 10^{14} N Q_n(K) \ I[A] \ , \quad n = 1,3,5,\ldots$$

$$\lambda = \frac{\lambda_u}{2\gamma^2 n}\left(1 + \frac{K^2}{2}\right) \ , \quad n = 1,3,5,\ldots$$

n	harmonic number
N	number of periods
λ_u	period length
K	strength parameter
λ	undulator radiation wave length

$$K = \frac{eB_0\lambda_u}{2\pi mc} = 0.934\lambda_u[cm] \ B_0$$

$$\varepsilon = \frac{ch}{\lambda}$$

SPECTRAL CENTRAL INTENSITY UNDULATOR CALCULATION

$$\left.\frac{d^2 F_u}{d\theta \cdot d\psi}\right|_{\psi=\theta=0} = \frac{F_u}{2\pi\, \Sigma'_x \Sigma'_y}$$

$$\Sigma'_x = \sqrt{\sigma'^2_x + \sigma'^2_r}$$

$$\Sigma'_y = \sqrt{\sigma'^2_y + \sigma'^2_r}$$

$$\sigma'_r = \sqrt{\frac{\lambda}{N\lambda_u}}$$

SPECTRAL BRIGHTNESS UNDULATOR CALCULATION

$$B_u = \frac{F_u}{(2\pi)^2 \Sigma_x \Sigma_y \Sigma'_x \Sigma'_y}$$

$$\Sigma_x = \sqrt{\sigma_x^2 + \sigma_r^2}$$

$$\Sigma_y = \sqrt{\sigma_y^2 + \sigma_r^2}$$

$$\sigma_r = \frac{1}{2\pi}\sqrt{\lambda N \lambda_u}$$

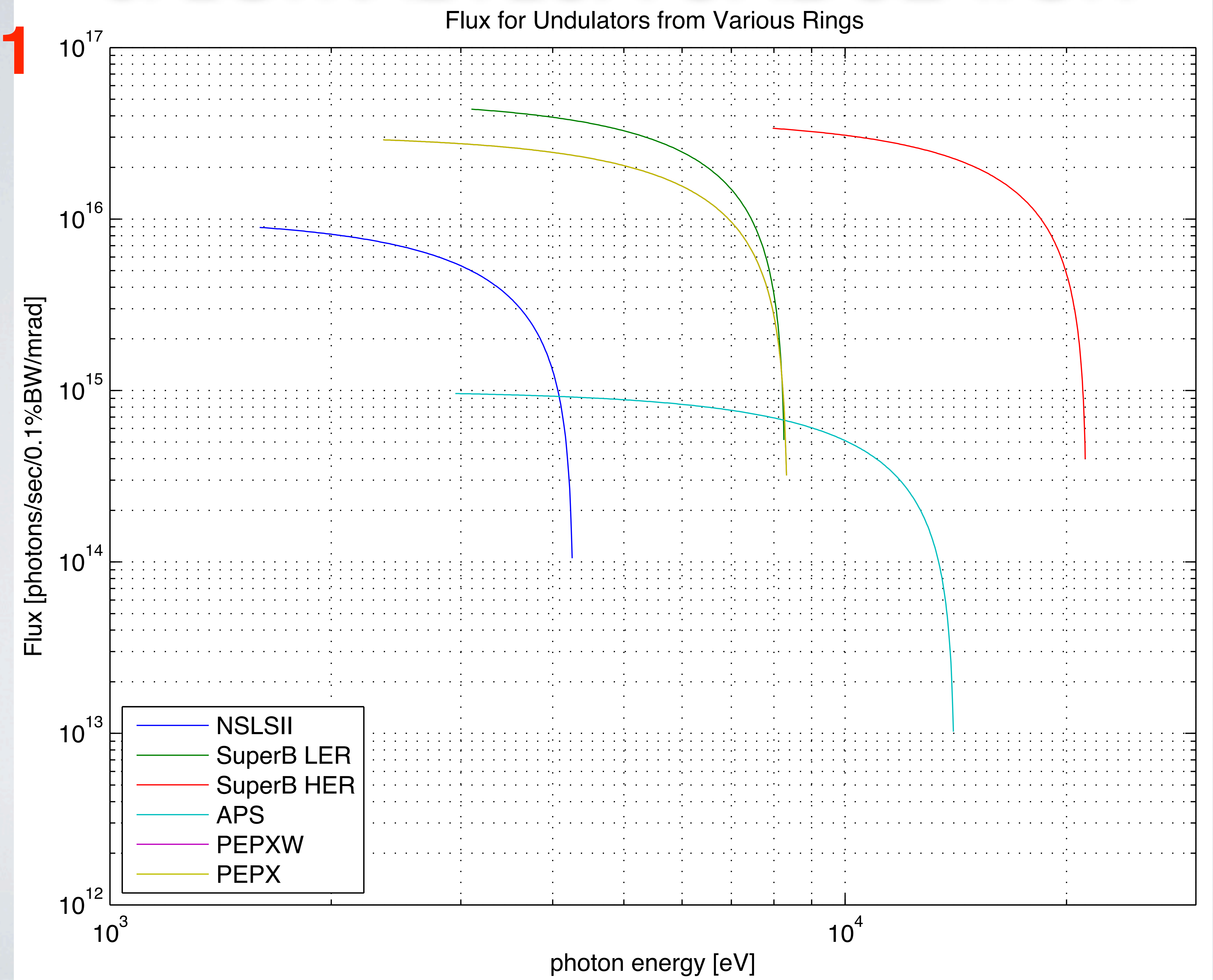
PARAMETER TABLE UNDULATOR

Parameters *	SuperB HER	SuperB LER	NSLS II	APS	PEPX W	PEPX
	IVU20	IVU20	IVU20	U33	IVU23	IVU23
E [GeV]	6.7	4.18	3	7.0	4.5	4.5
I [mA]	1892	2447	500	100	1500	1500
σE [1]	6.43 E-4	7.34 E-4	10.0 E-4	9.6 E-4	1.14 E-3	1.14 E-3
εx [m rad]	2.0 E-9	2.46 E-9	0.55 E-9	2.514 E-9	85.7 E-12	379 E-12
βx [m]	1.8	1.8	1.8	1.7	16.04	16.04
εy [m rad]	5.0 E-12	6.15 E-12	8.0 E-12	22.6 E-12	215 E-15	948 E-15
βy [m]	1.1	1.1	1.1	24.1	6.27	6.27
σx [mm]	60.0 E-3	66.5 E-3	33.3 E-3	278 E-3	37.0 E-3	78.0 E-3
σy [mm]	2.4 E-3	2.6 E-3	2.9 E-3	8.9 E-3	1.16 E-3	2.44 E-3
$\sigma x'$ [mrad]	33.3 E-3	37.0 E-3	16.5 E-3	11.8 E-3	2.32 E-3	4.86 E-3
$\sigma y'$ [mrad]	2.1 E-3	2.7 E-3	2.7 E-3	3.3 E-3	0.190 E-3	0.390 E-3
N [1]	148	148	148	72	150	150
λu [mm]	20	20	20	33	23	23
Kmax [1]	1.83	1.83	1.83	2.75	2.26	2.26
Kmin [1]	0.1	0.1	0.1	0.1	0.1	0.1

* Source of data different web pages and presentations

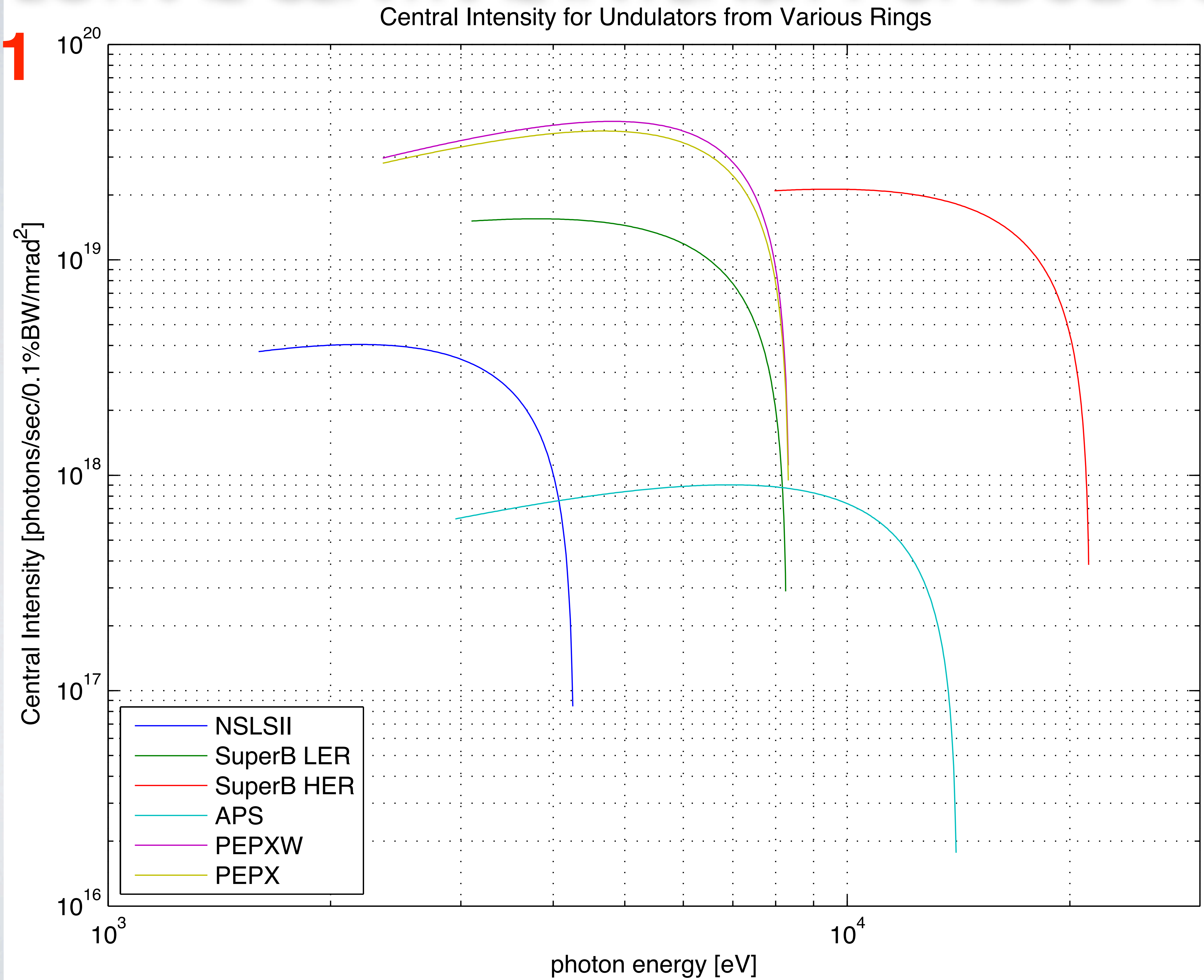
SPECTRAL FLUX UNDULATOR

n=1

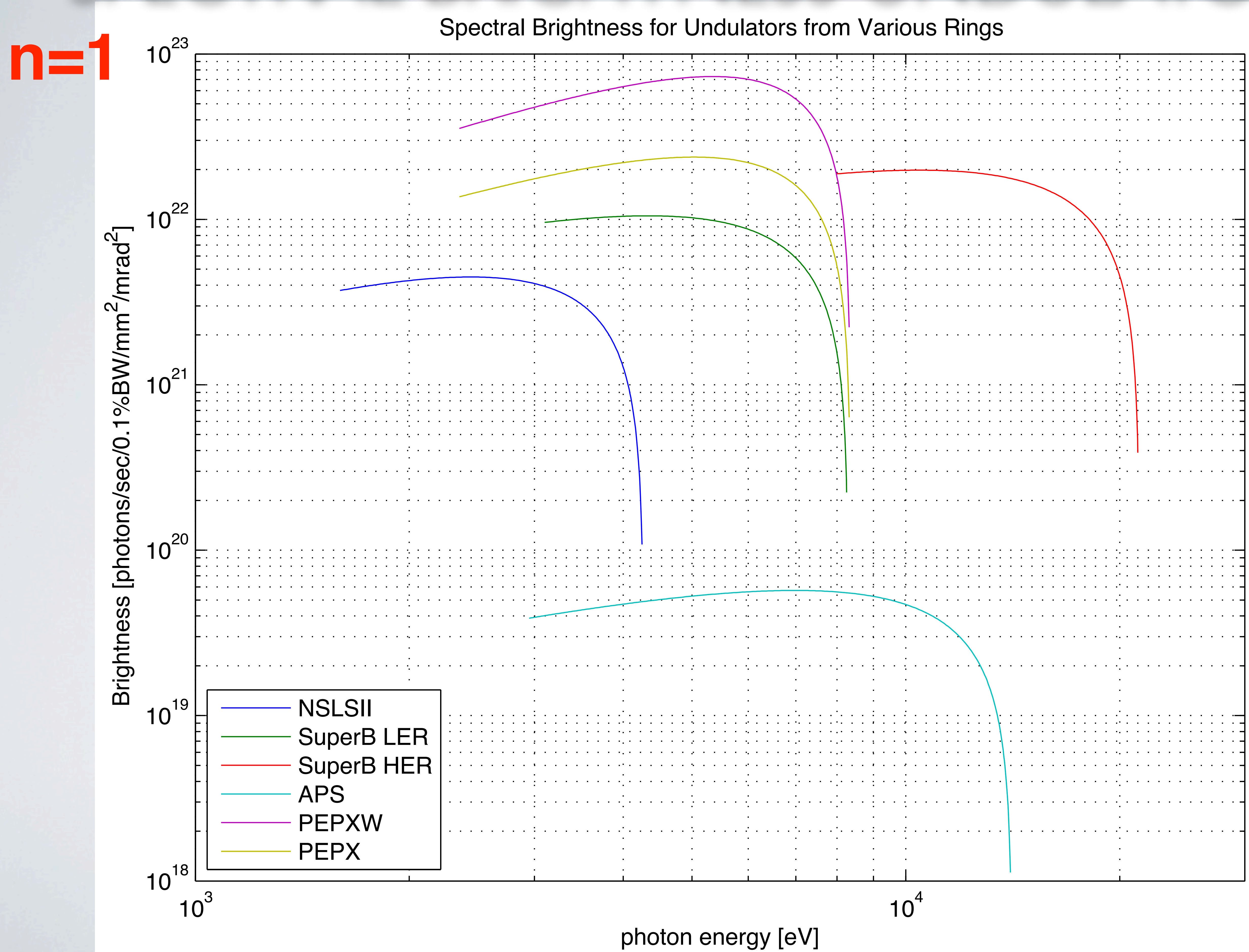


SPECTRAL CENTRAL INTENSITY UNDULATOR

n=1

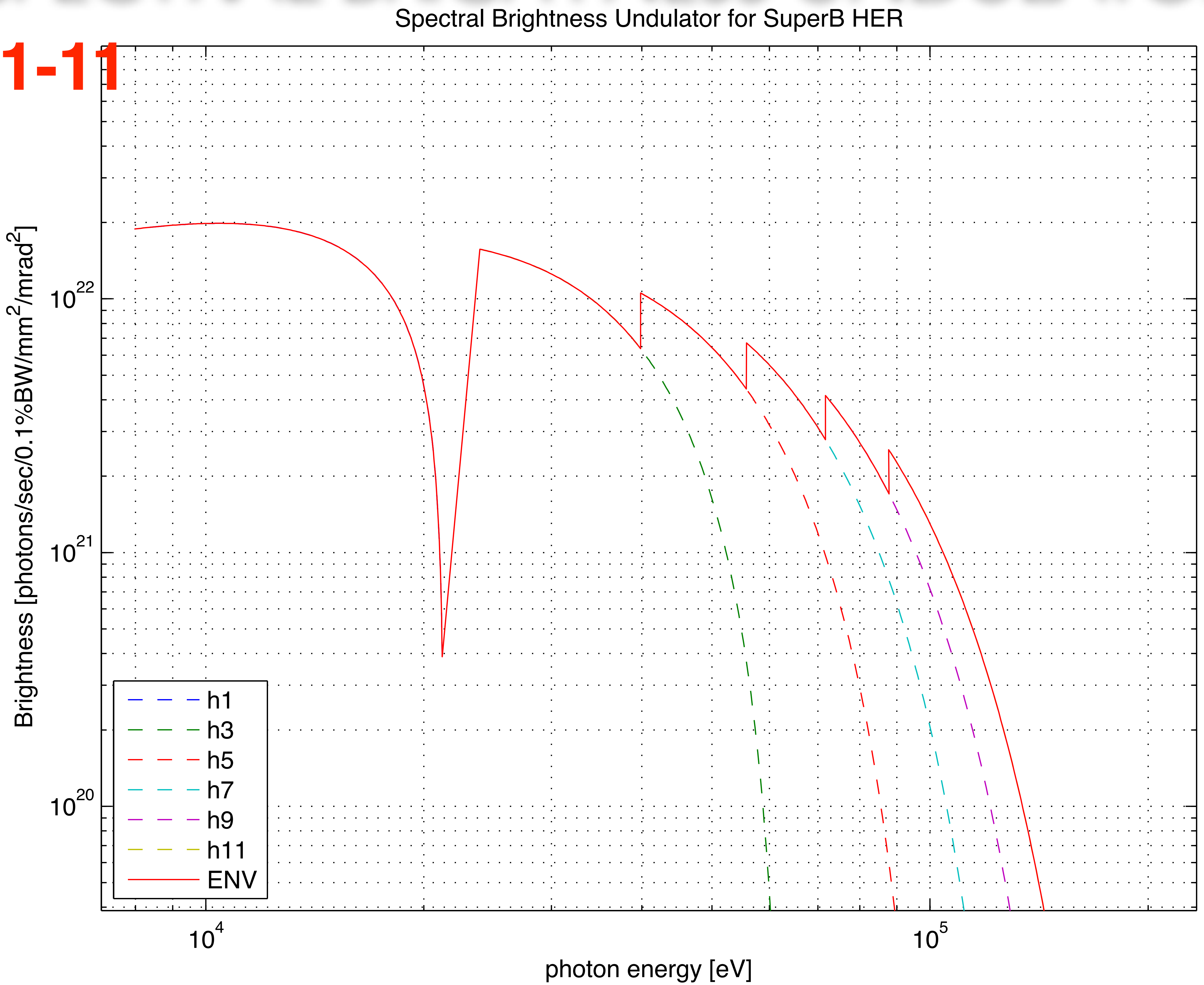


SPECTRAL BRIGHTNESS UNDULATOR

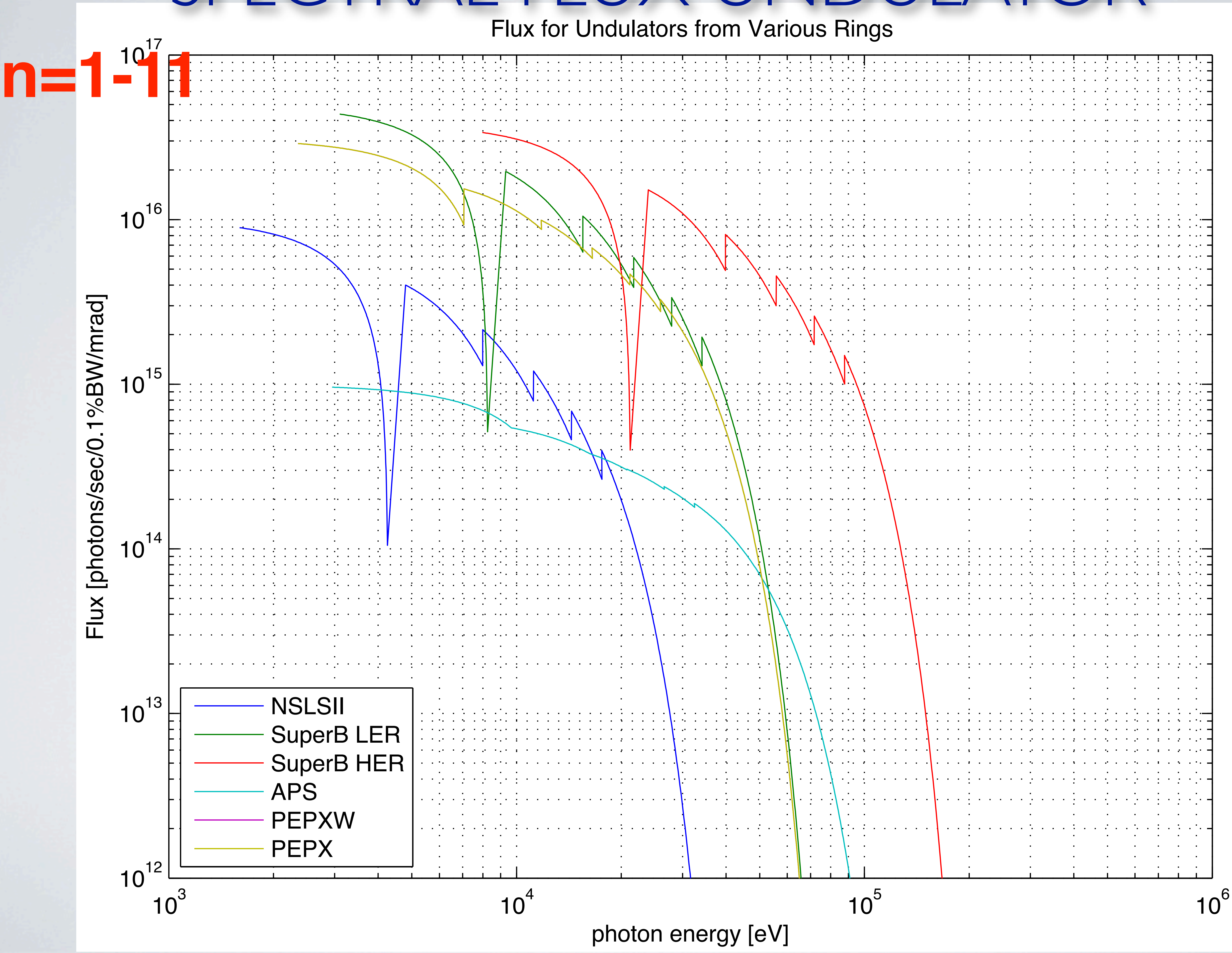


SPECTRAL BRIGHTNESS UNDULATOR

n=1-11

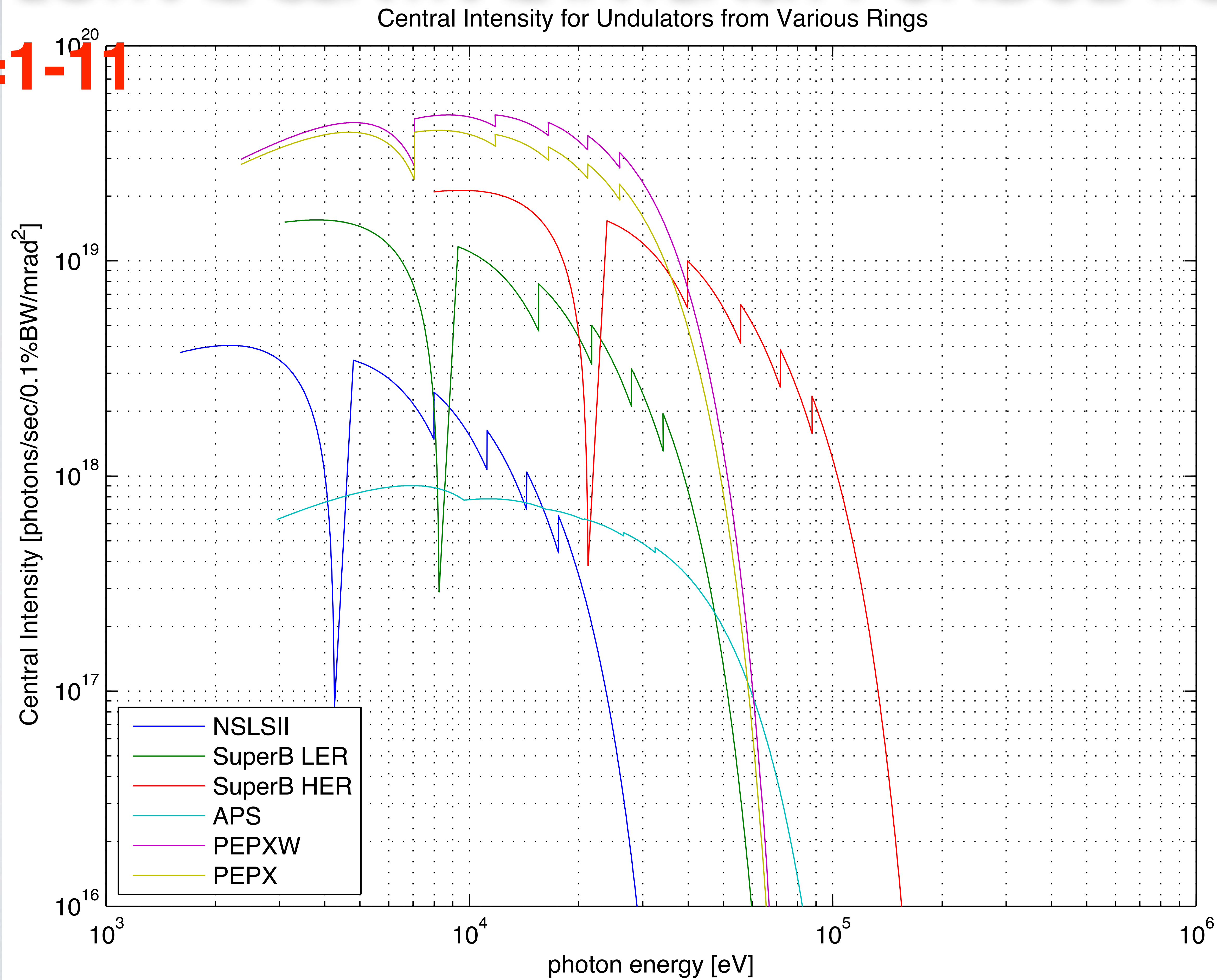


SPECTRAL FLUX UNDULATOR



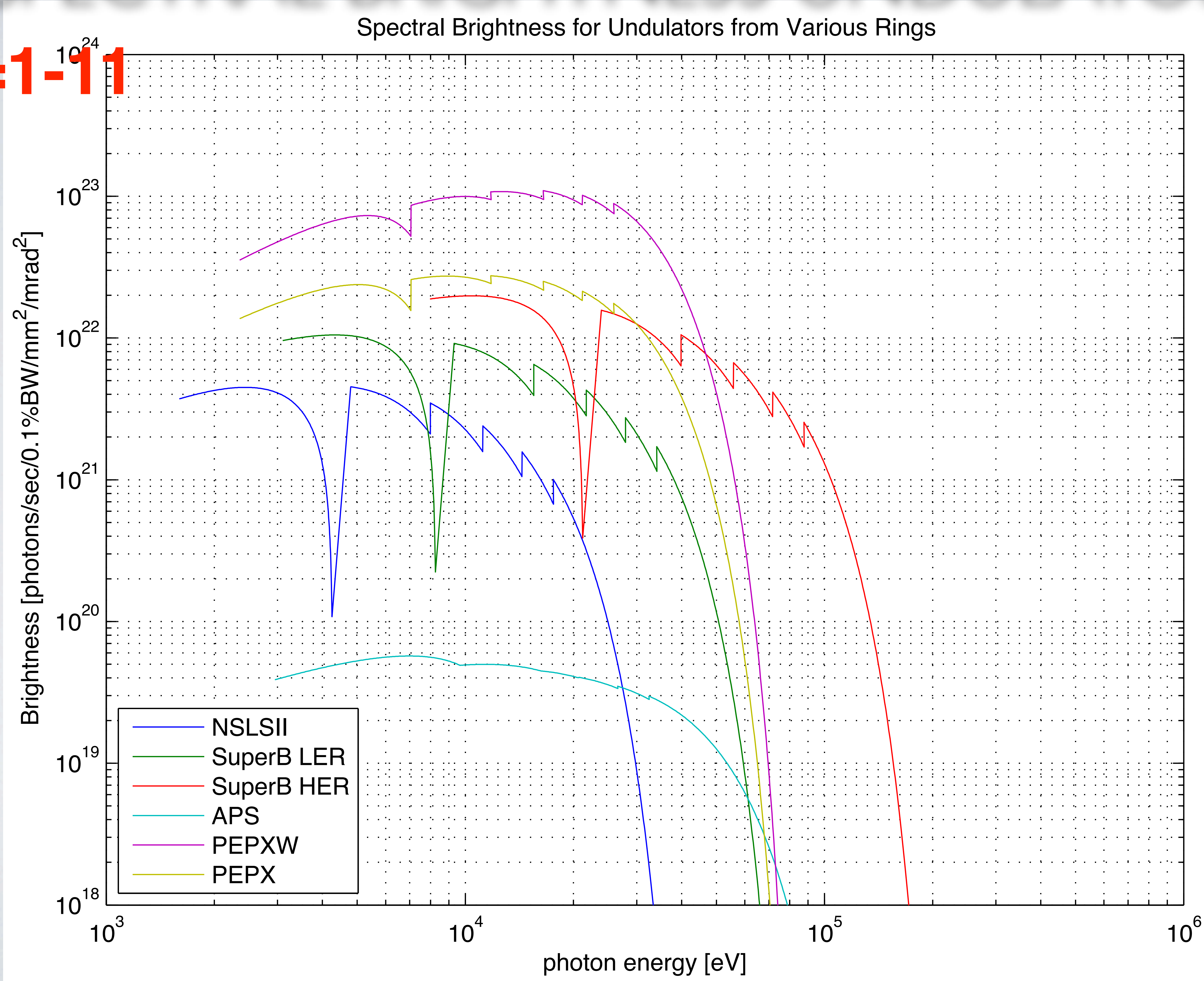
SPECTRAL CENTRAL INTENSITY UNDULATOR

n=1-11

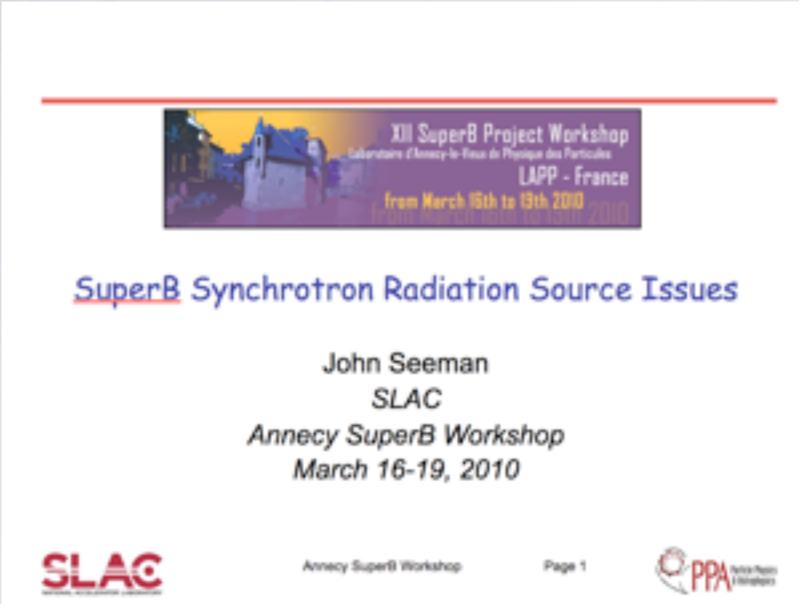


SPECTRAL BRIGHTNESS UNDULATOR

n=1-11



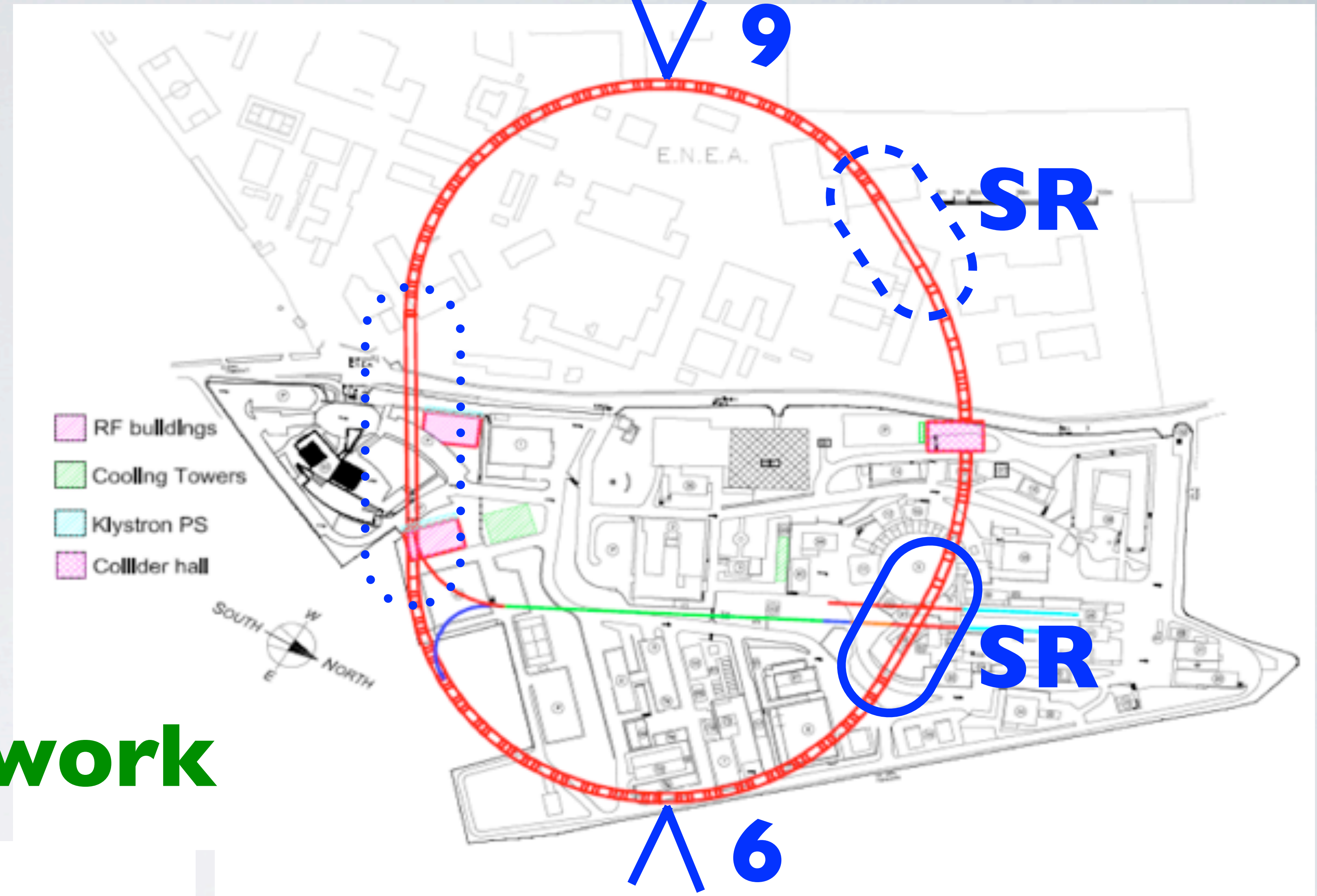
LOCATIONS


SuperB Synchrotron Radiation Source Issues

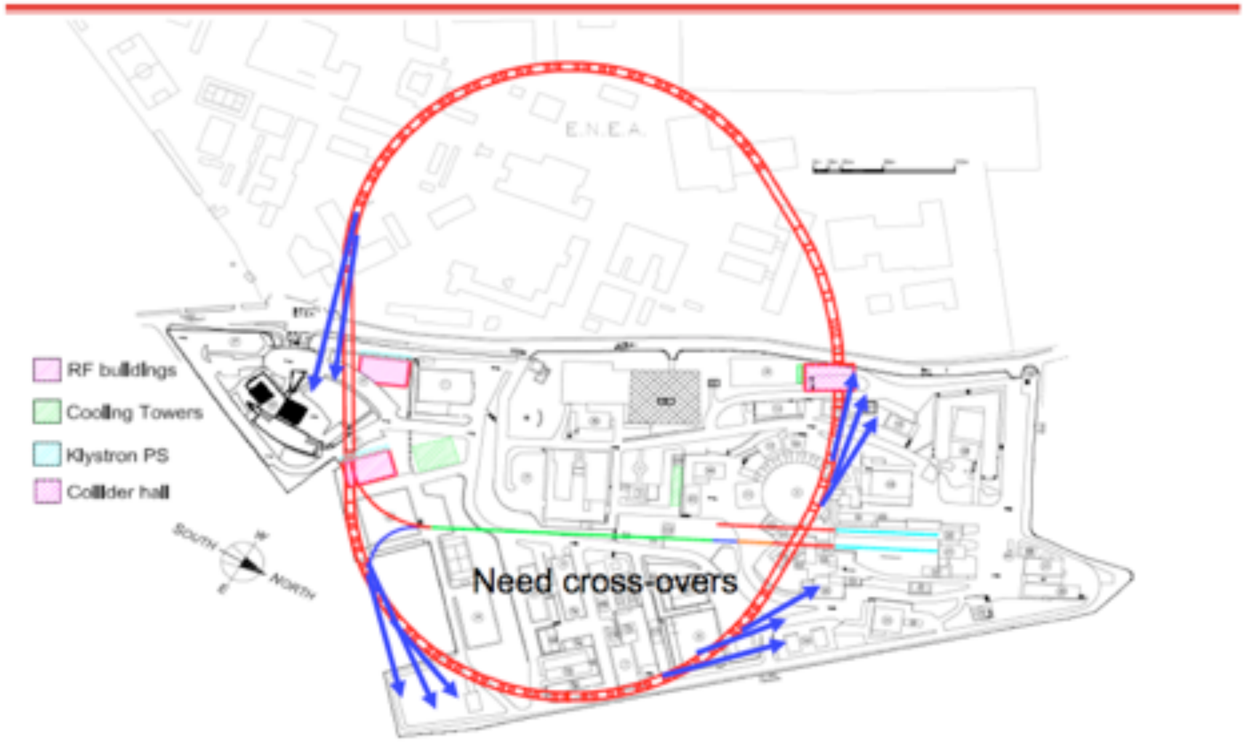
John Seeman
SLAC
Annecy SuperB Workshop
March 16-19, 2010

SLAC · Annecy SuperB Workshop · Page 1 · PPA

Needs much more work



Frascati Site: Potential LER SR Beam Lines



Frascati Site: Potential HER SR Beam Lines

BACKUP SLIDES

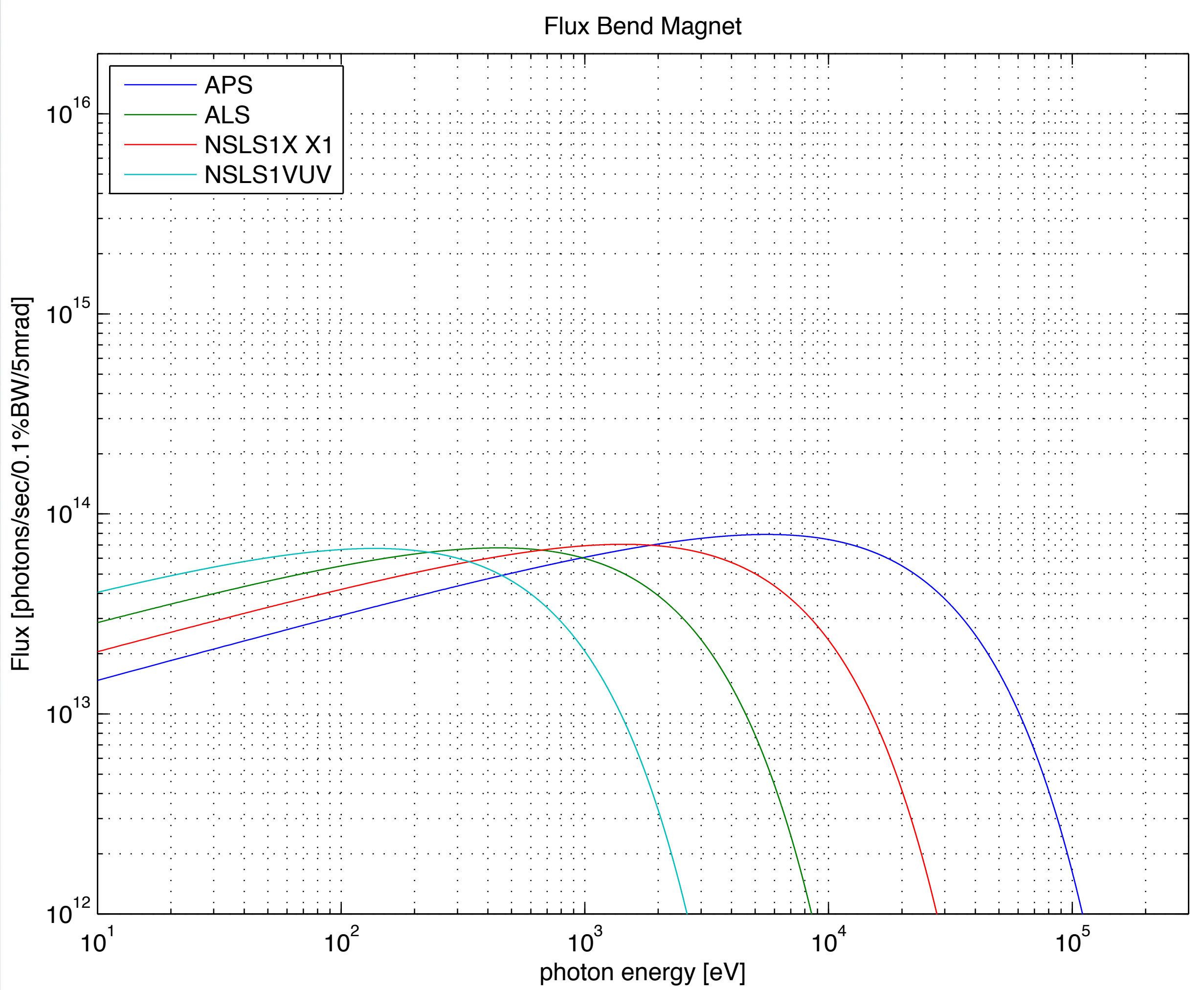
- Sources for information
- Benchmark test results for code used
- Basic relation used for calculating synchrotron radiation (Schwinger)

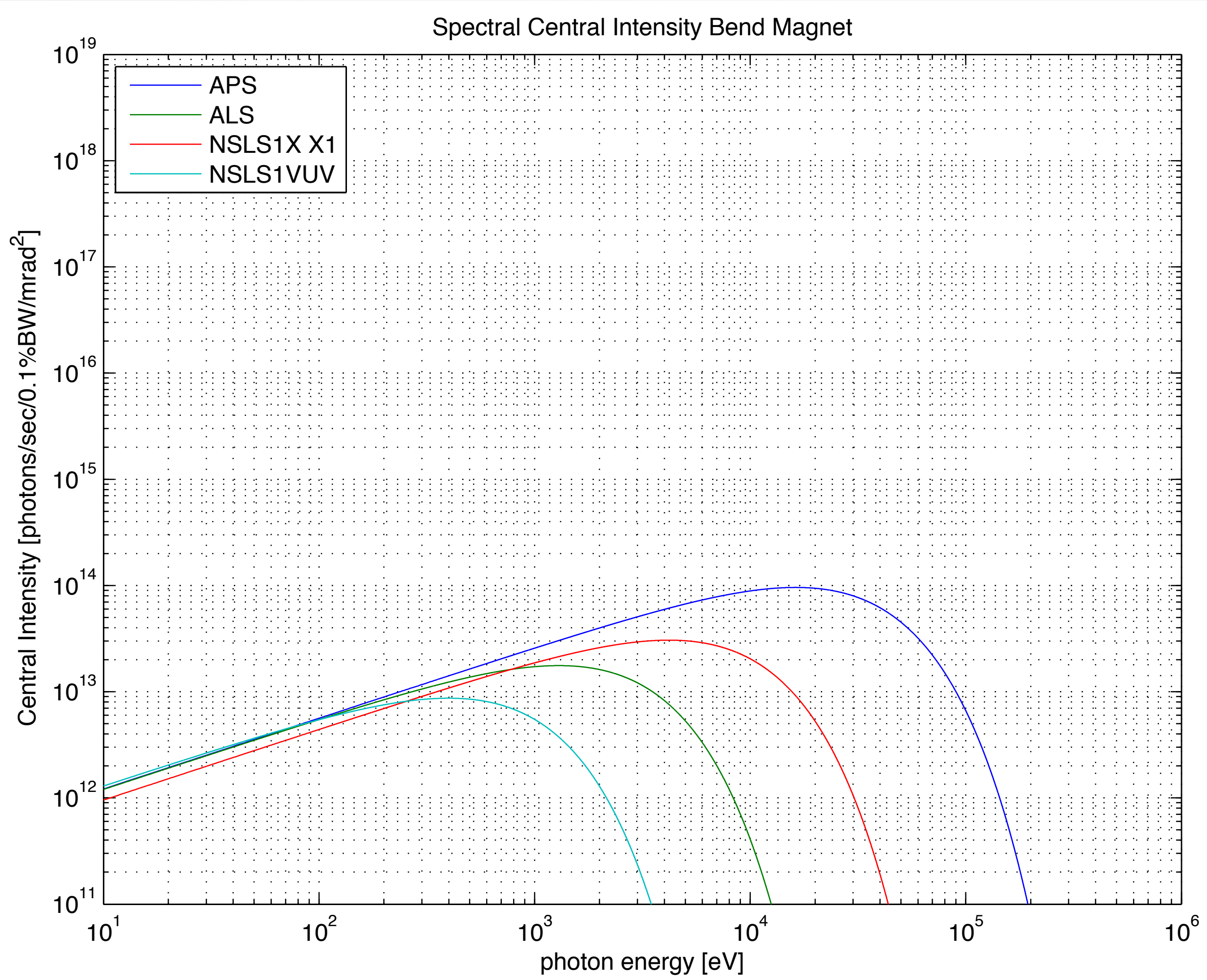
SOME SOURCES

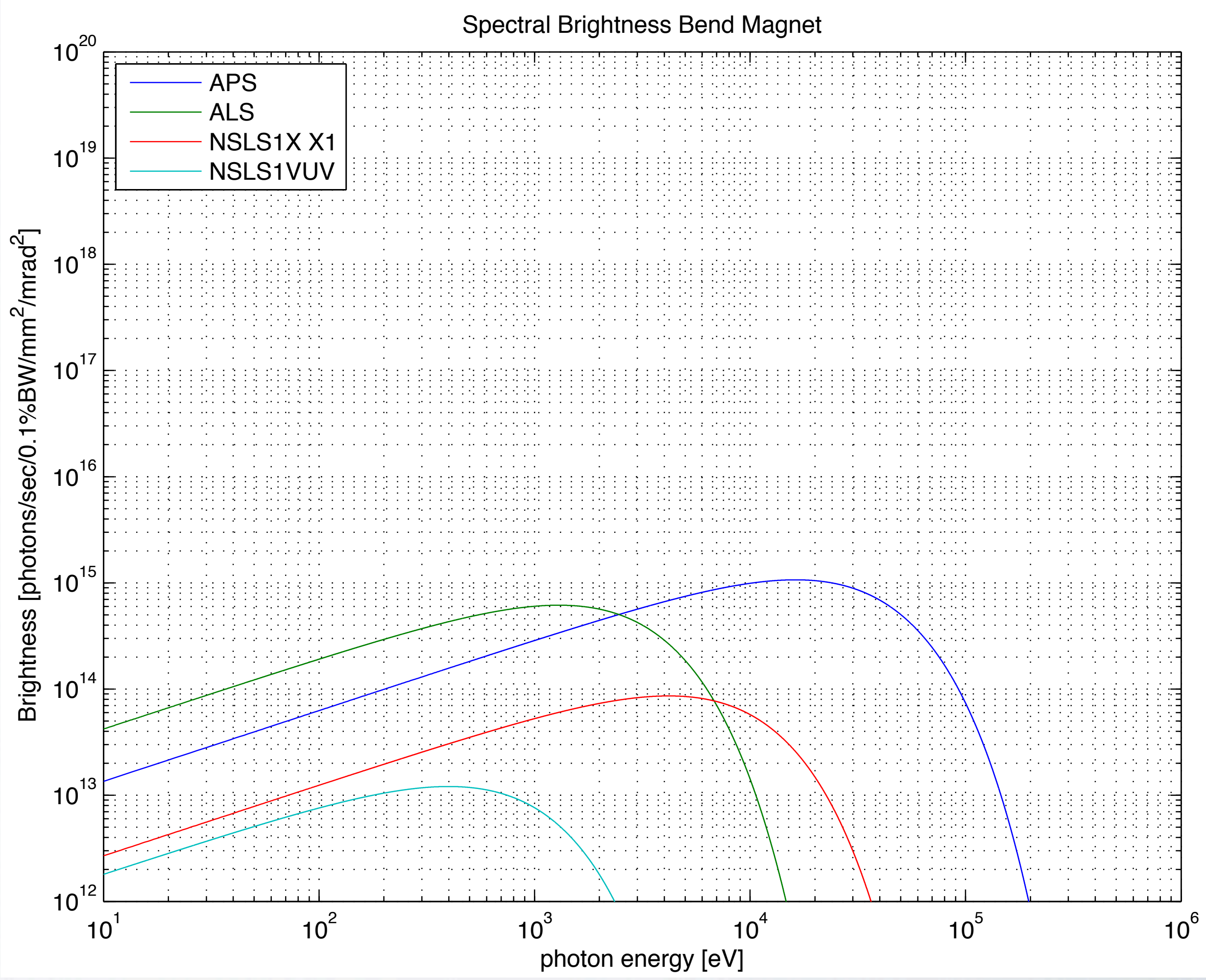
- Hulbert and Weber: "Flux and brightness calculations for various synchrotron radiation sources."
- Wiedemann: "Synchrotron Radiation"
- Kwang-Je Kim: "Characteristics of Synchrotron Radiation"
- NSLS II web page: NSLS-II Source Properties and Floor Layout.
- Seemann: "SuperB Synchrotron Radiation Source Issues."
- Cai: "Choice of Parameters for PEP-X."
- Various Web pages: ALS, ELETTRA, APS, ESRF.

BENCHMARK TEST OF CODE USED FOR BEND MAGNET CALCULATIONS

Compare to: Hulbert and Weber: "Flux and brightness calculations for various synchrotron radiation sources."

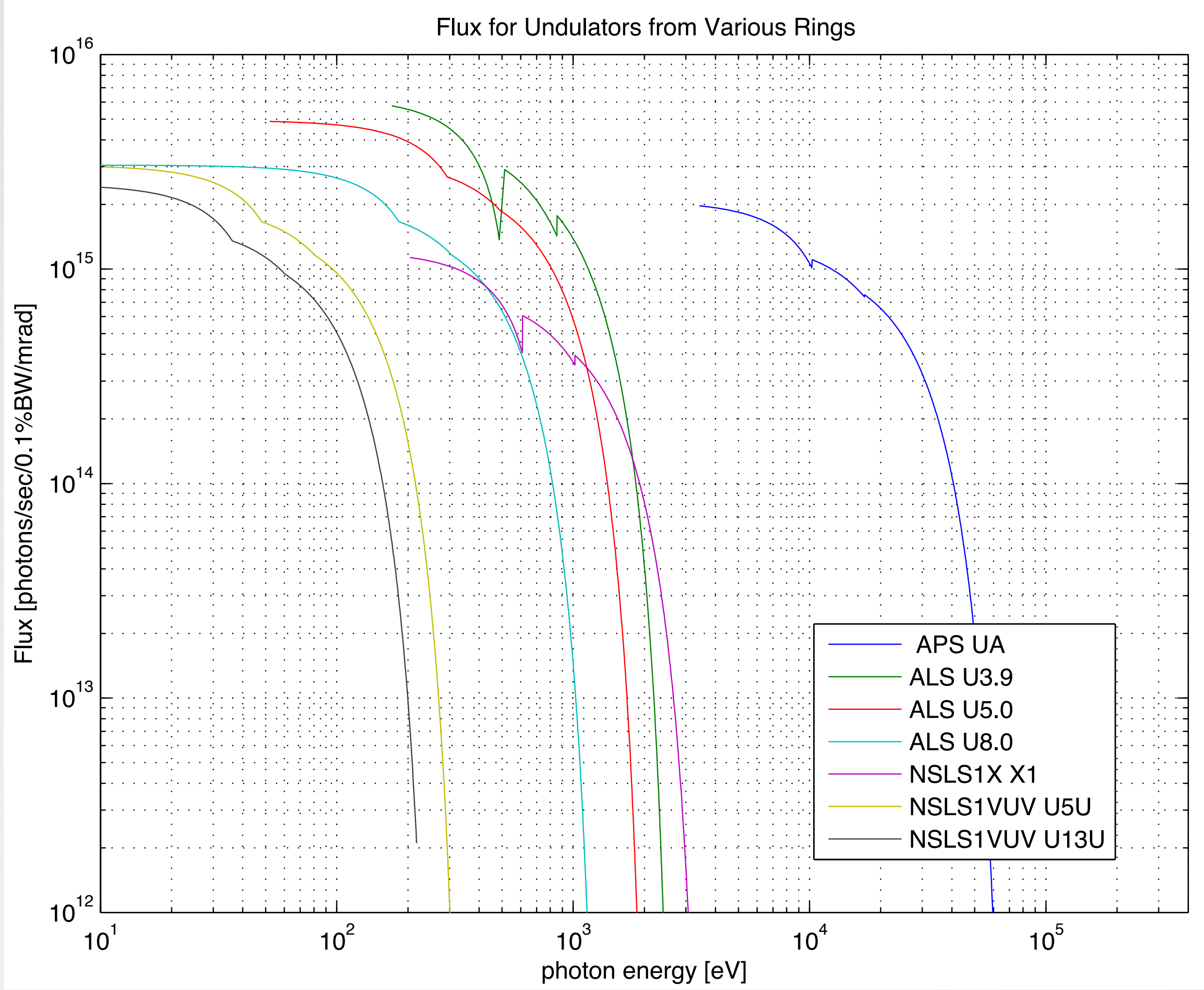


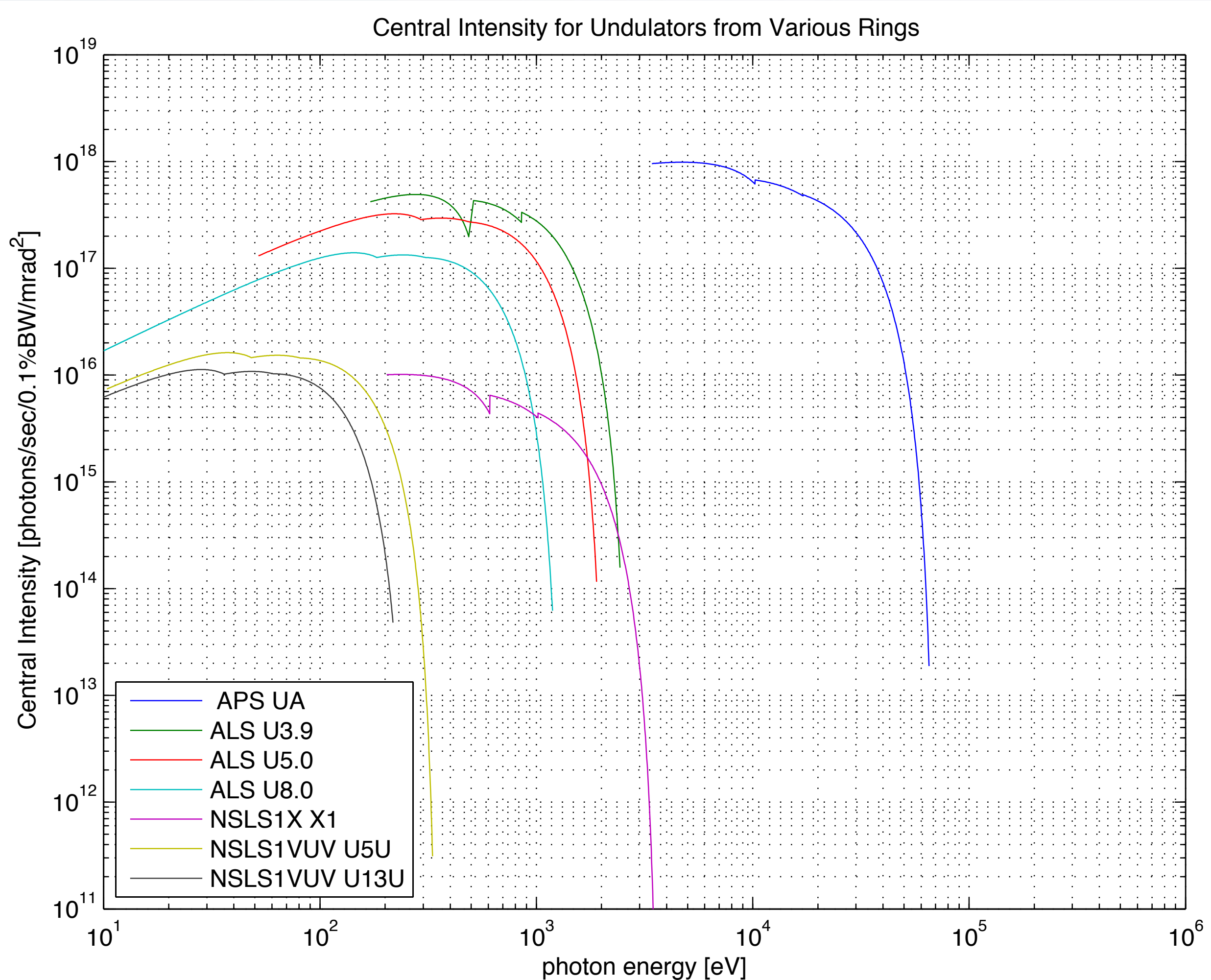


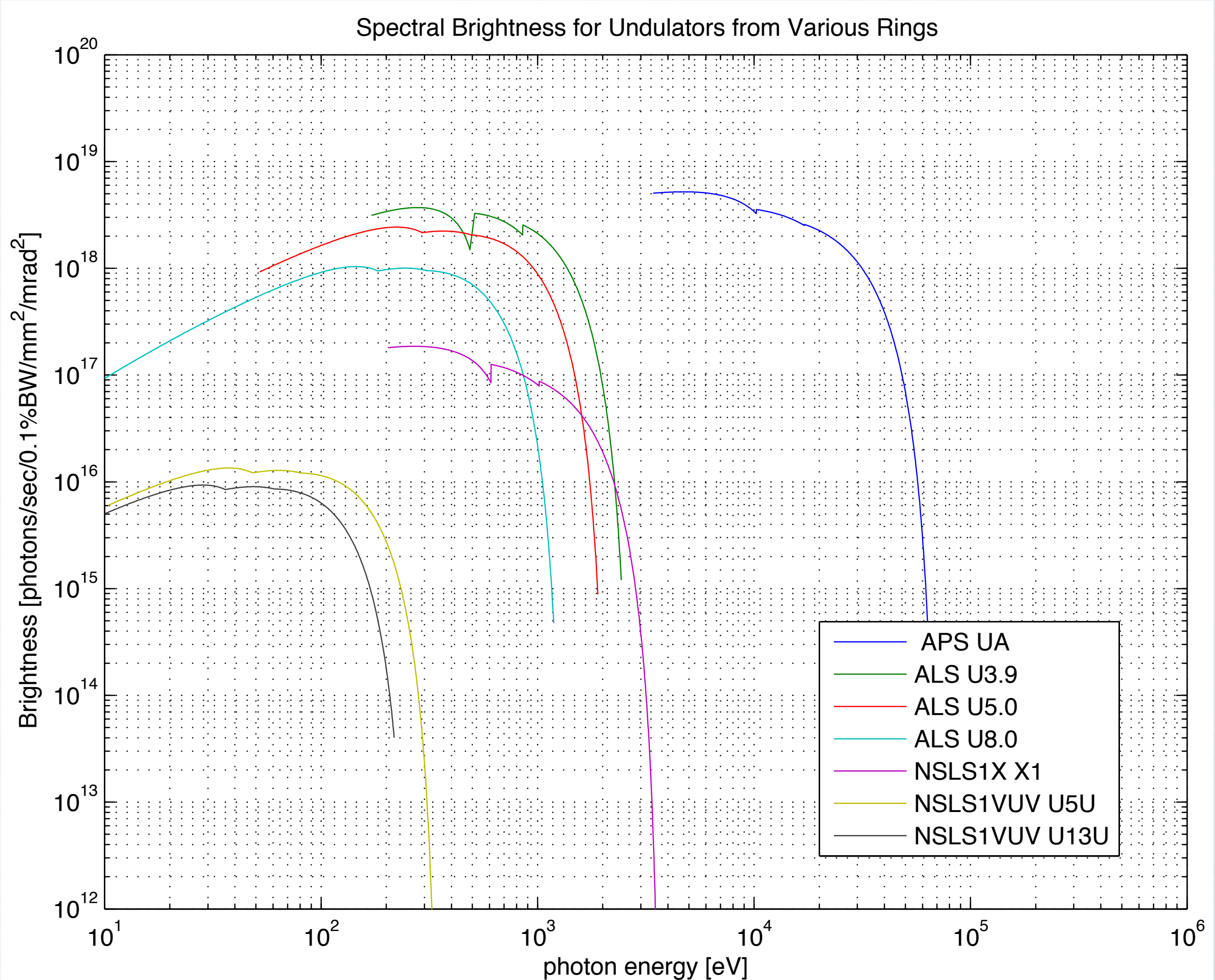


BENCHMARK TEST OF CODE USED FOR UNDULATOR CALCULATIONS

Compare to: Hulbert and Weber: "Flux and brightness calculations for various synchrotron radiation sources."







ANGULAR DISTRIBUTION OF RADIATION EMITTED BY ELECTRONS MOVING THROUGH A BEND MAGNET WITH A CIRCULAR TRAJECTORY IN THE HORIZONTAL PLANE

$$\frac{d^2 F_{bm}(\omega)}{d\theta \cdot d\psi} = \frac{3\alpha}{4\pi^2}\gamma^2 \frac{\Delta\omega}{\omega}\frac{I}{e} y^2 \left(1+X^2\right)^2 \times \left[K_{2/3}^2(\xi) + \frac{X^2}{1+X^2} K_{1/3}^2(\xi)\right]$$

F_{bm}	photon flux (number of photons per second)
θ	observation angle in the horizontal plane
ψ	observation angle in the vertical plane
α	fine stricture constant
γ	electron energy
ω	angular frequency of photons
ω_C	critical angular frequency of photon distribution
ε	photon energy
ε_C	critical photon energy
I	beam beam current
e	electron charge
c	speed of light
B	magnetic field strength
E	electron beam energy
ρ	radius of instantaneous curvature of the electron bean trajectory

$$\rho = \frac{E}{ecB}$$

$$\rho[m] = 3.33 \frac{E[GeV]}{B[T]}$$

$$\omega_C = \frac{3\gamma^2 c}{2\rho}$$

$$\varepsilon_C = \hbar\omega_C$$

$$\varepsilon_C[keV] = 0.665\ E^2[GeV]\ B[T]$$

$$\xi = \frac{y\left(1+X^2\right)^{3/2}}{2} \qquad X = \gamma\psi$$