SWISS FEL HARD X-RAY BACKGROUND CALCULATION

V. Khachatryan, V. Tsakanov

CANDLE

Yerevan

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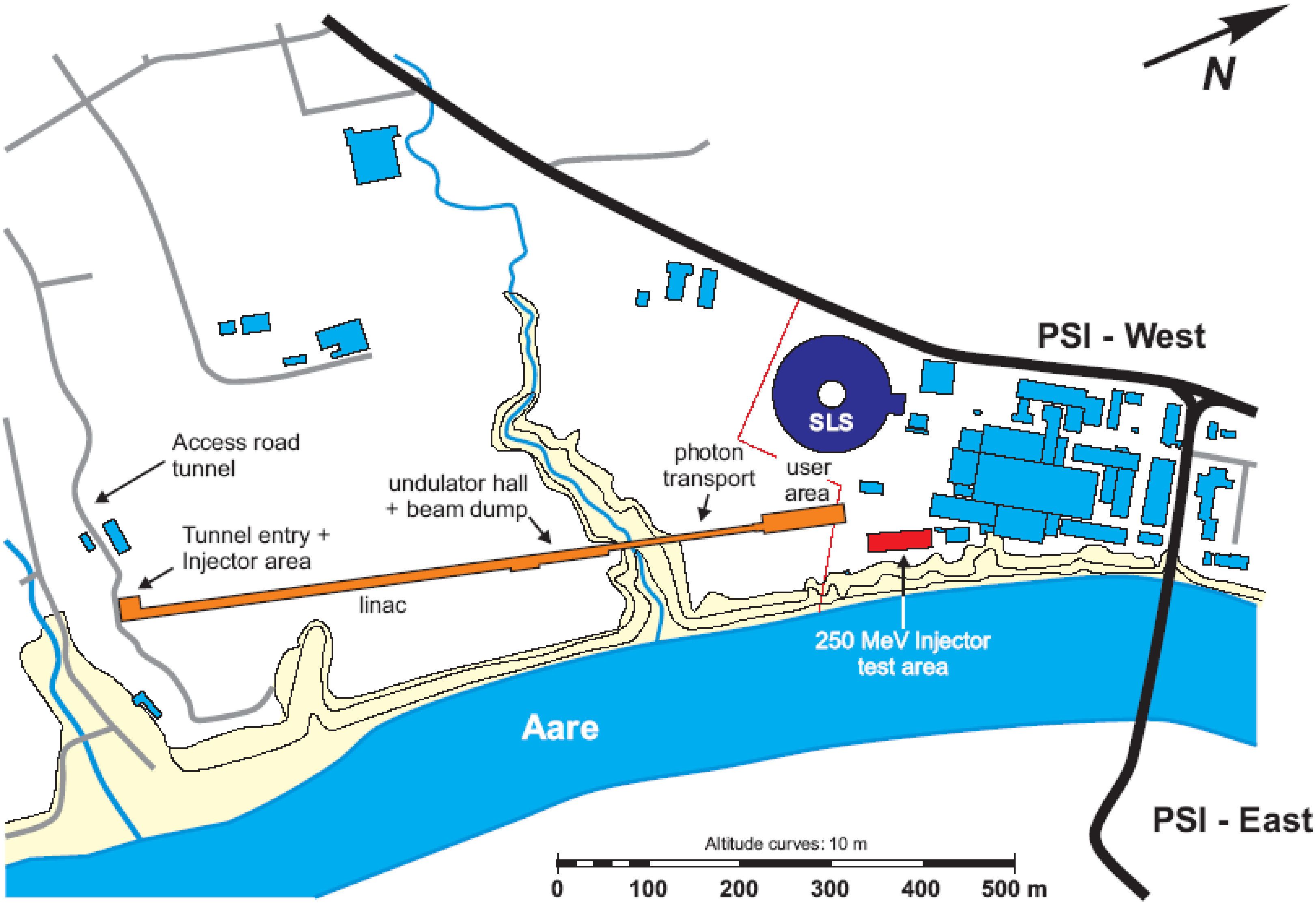
CANDLE - PSI collaboration

Work package L

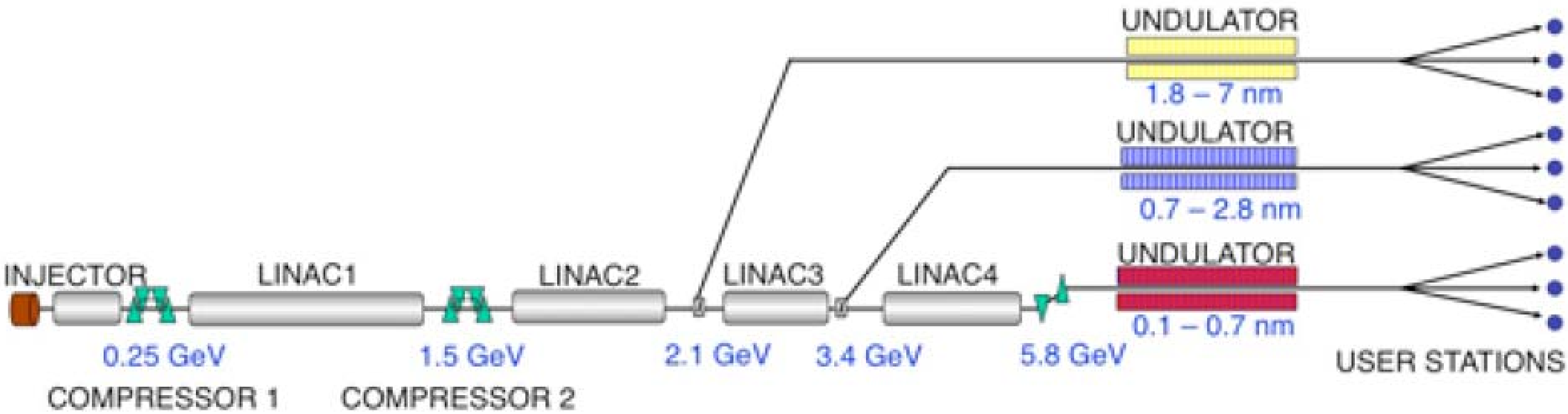
L-1 Beam parameters scan for the FEL performance

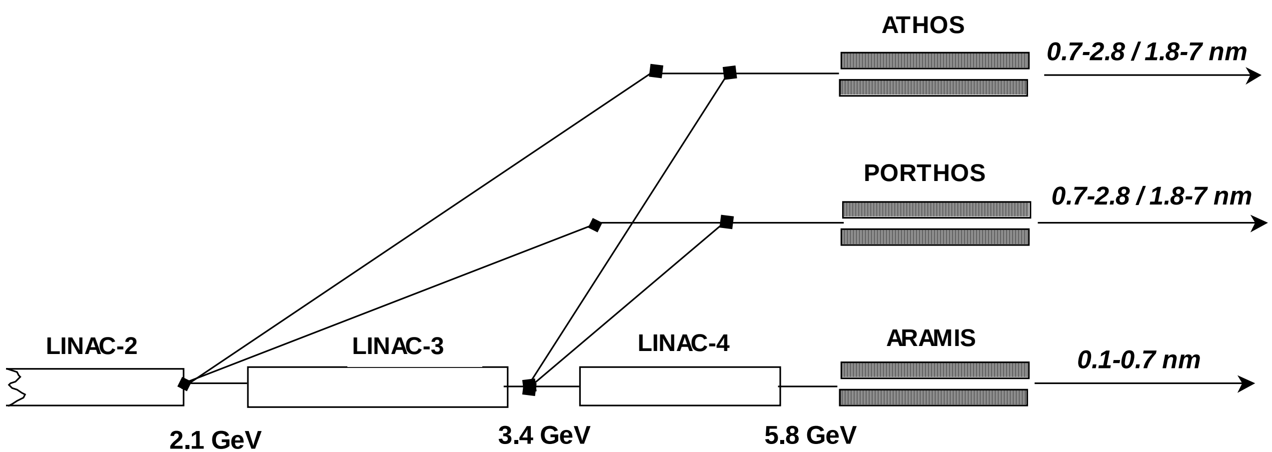
L-2 Startup of hard X-ray background calculation (bremsstrahlung)

L-3 The study of the spontaneous background radiation



SwissFEL chematic layout





SwissFEL chematic layout

	PSI-XFEL	PSI-XFEL	PSI-XFEL
Q (pC/bunch)	200	100	10
σ_r, laser (mm)	0.27	0.214	0.1
Laser rise and fall time (ps)	0.7	0.7	0.7
Max. umber of bunches / pulse	3	3	3
Minimum bunch spacing (ns)	50	50	50
Projected emittance(mm.mrad)	0.46	0.40	0.15
Slice emittance (mm.mrad)	0.4	0.28	0.1
Slice rms energy spread (keV)	300	230	200
Peak current (kA)	2.7	2.0	0.7
Beam energy for 0.1 nm (GeV)	5.8	5.8	5.8

Beam parameters scan for the FEL performance

SASE FEL simulation with SIMPLEX and GENESIS

Scan over:

• Emittance ε,

•Peak current Ip,

•Energy spread δE,

Current goal: to have low emittance, low bunch charge (but high bunch compression), low energy spread, low beam energy and compact design of FEL facility.

Bunch charge 200 pC/bunch and 10 pC/bunch alternatives

Spontaneous background radiation

- provides essential background to FEL radiation
- increases beam energy spread
- drives out the beam from the FEL resonant condition

The mean energy loss of each electron by incoherent radiation is given by:

$$dE/dz = 2r_e^2\gamma^2 H(z)^2/3$$

The spontaneous radiation in the long chain of the undulator can be simulated by SPECTRA code.

Hard X-ray background due to bremsstrahlung

Bremsstrahlung radiation is generated when electron beam is interacted with collimators, beam diagnostic devices (such as wire scanners) and residual gas.

Bremsstrahlung radiation overlaps with the FEL radiation.

Bremsstrahlung causes beam energy losses and widens beam energy spread.

Calculation methods

Particle tracking codes can be used. GEANT numerical tracking code allows to use complex geometries and materials. It uses internally EGS4 code for electromagnetic processes` simulations and FLUKA code for simulation of the processes involving hadrons.

Bremsstrahlung spectrum

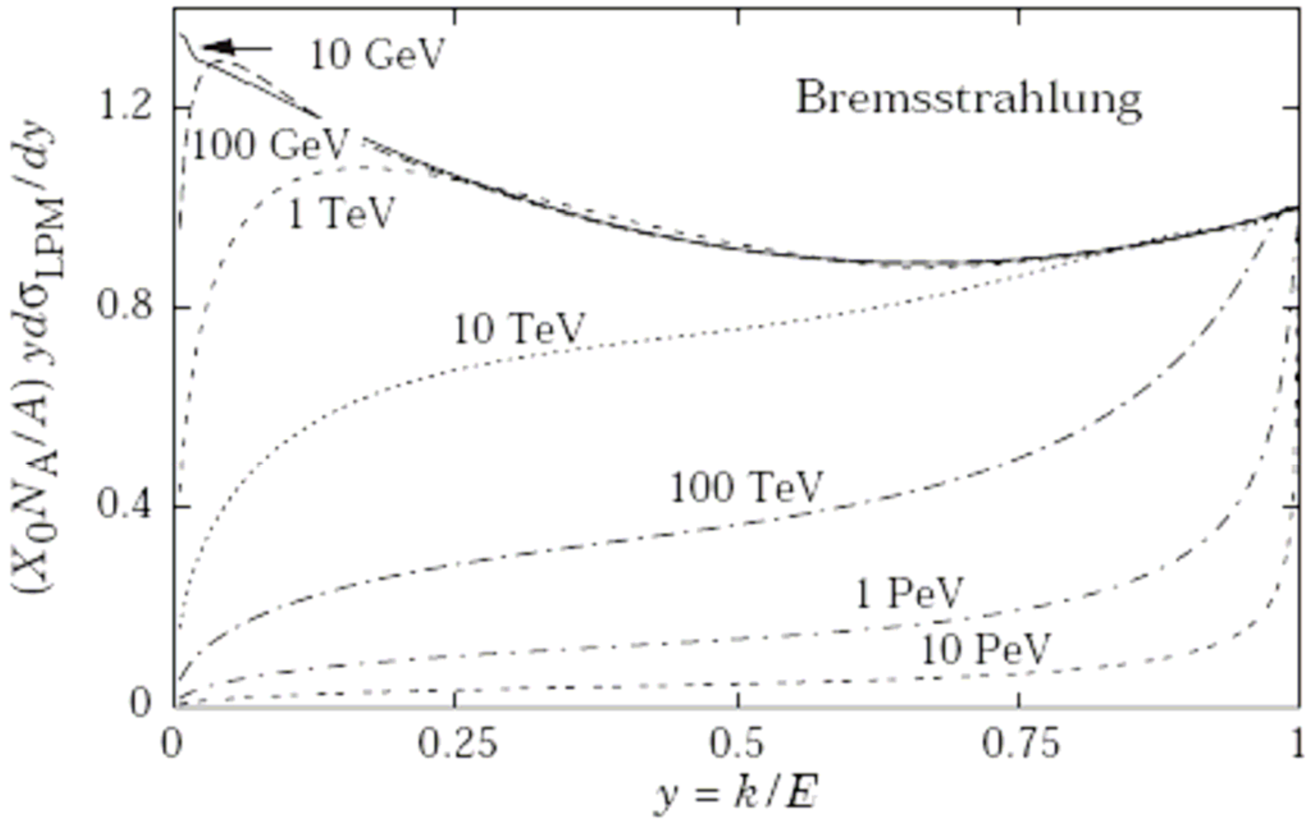


Figure 27.11(PDG report 2008): The normalized bremsstrahlung cross section k dσLPM/dk in leadversus the fractional photon energy y = k/E. The vertical axis has units of photons per radiation length.

Electron critical energy

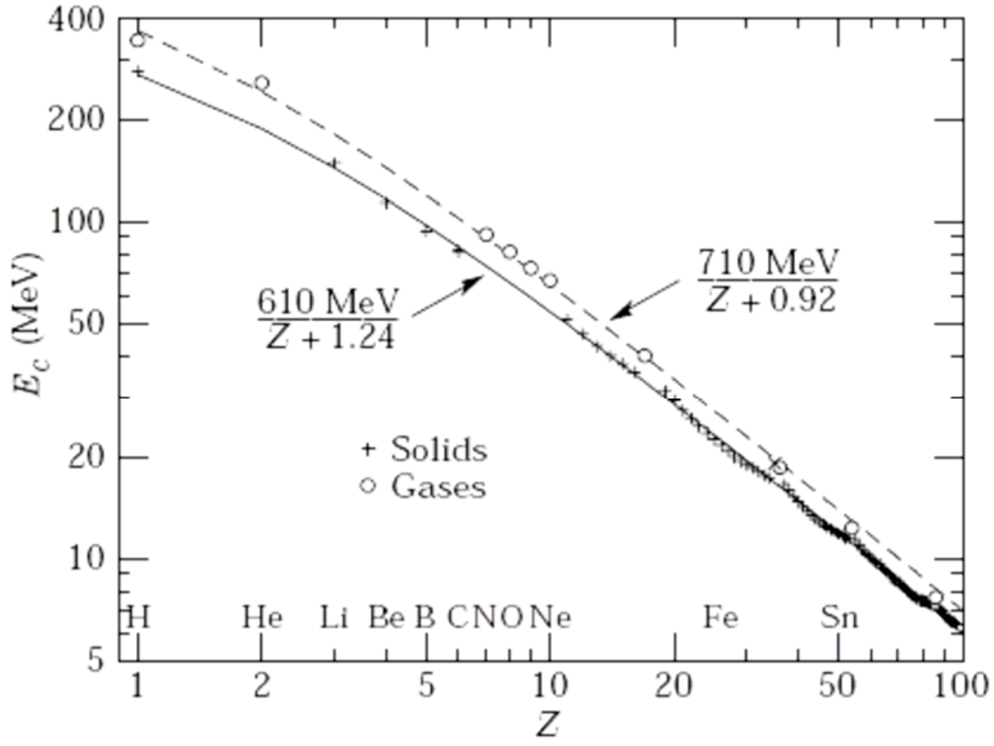


Figure 27.13(PDG report 2008): Electron critical energy for the chemical elements, using Rossi's definition [4]. The fits shown are for solids and liquids (solid line) and gases (dashed line).

Simple formulae

Radiation length

$$X_0 = \frac{716.4 \text{ g cm}^{-2} A}{Z(Z+1)\ln(287/\sqrt{Z})} .$$

Rad. Length for mixtures and compounds

$$1/X_0 = \sum w_j / X_j$$

Bremsstrahlung spectrum

$$\frac{d\sigma}{dk} = \frac{A}{X_0 N_A k}\left(\tfrac{4}{3} - \tfrac{4}{3}y + y^2\right) .$$

# of photons

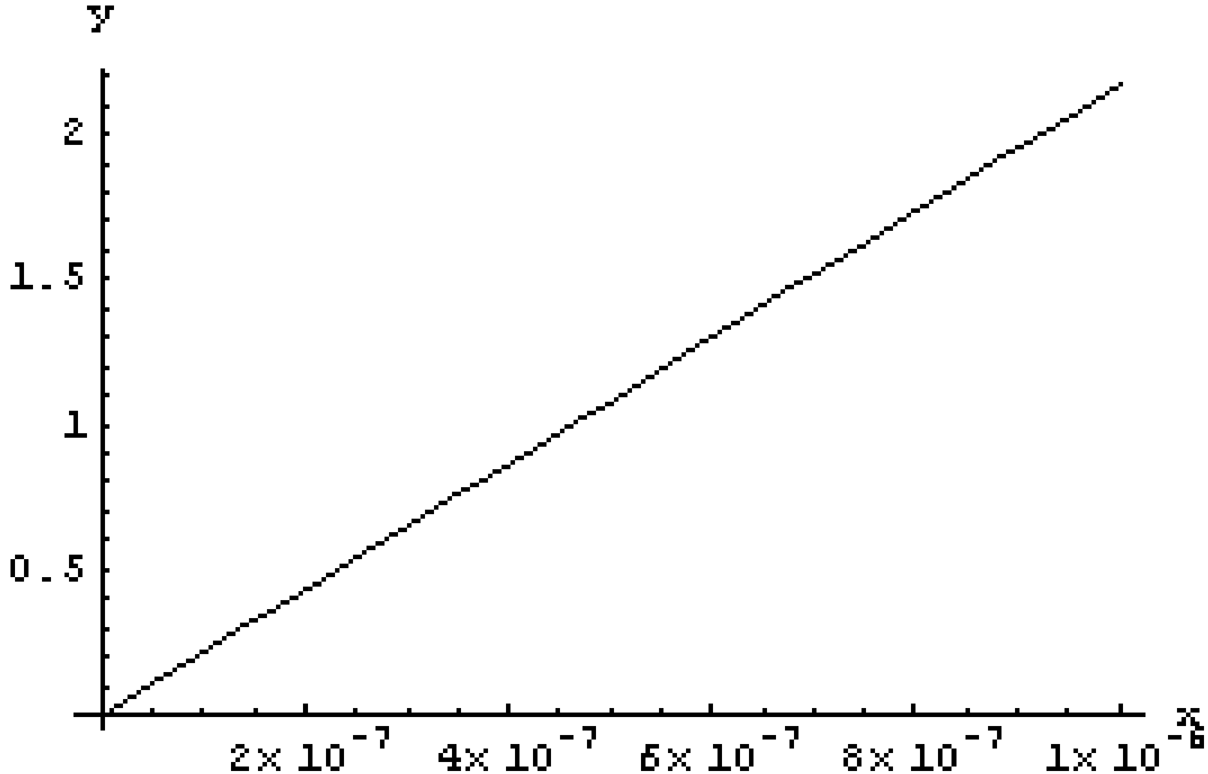
$$N_\gamma = \frac{d}{X_0}\left[\frac{4}{3}\ln\left(\frac{k_{\rm max}}{k_{\rm min}}\right) - \frac{4(k_{\rm max} - k_{\rm min})}{3E} + \frac{k_{\rm max}^2 - k_{\rm min}^2}{2E^2}\right]$$

Critical energy

$$E_c = \frac{610 \text{ MeV}}{Z + 1.24} \quad (\text{solids and liquids}) , \quad = \frac{710 \text{ MeV}}{Z + 0.92} \quad (\text{gases}) .$$

Bremsstrahlung on residual gas

Residual gas	CO
Atom. Weight	28
Effective Z	7.14
Density	1.25 10^-6 g/cm^3
Rad. Length	37.7 g/cm^2
Beam pipe length	100m



x→ Residual gas pressure [atmosphere];

Y→ Number of radiated photons/bunch with the energies 1- 50 keV