SYNCHROTRON LIGHT OPTIONS AT SUPER-B*

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Abstract

Super-B is a planned asymmetric high luminosity e^+e^- collider at the $\Upsilon(4S)$ resonance as PEP-II and KEKB, to be built in Italy. The Super-B High (HER, 7 GeV) and Low (LER, 4 GeV) Energy beams characteristics are comparable to NSLS-II and other state of the art synchrotron light sources. This suggests the use of this facility, either parasitically or in dedicated runs, as light source. In this paper we compare the characteristics of the synchrotron light generated at Super-B with existing, in construction and proposed facilities. We investigate different schemes to incorporate the generation of synchrotron radiation in the collider lattice design and look at different beam line layouts for users.

INTRODUCTION

In the past high energy particle colliders were designed to collide as many particle as possible. This was done by maximizing the beam current, using relative large emittances and squeezing the beam at the interaction point. During the operation of PEP II the limits of both raising the beam currents and squeezing the beam were experienced. Therefore the optics was modified to lower emittance. The successful test of the "large Piwinski angle" and crab waist scheme, with extremely low design emittances, at the DAPHNE collider at Frascati [1] made it the design choice for Super-B. Both HER and LER have been designed to meet these requirements and the design parameters relevant to our study, are shown in Table 1.As comparison the design parameters from NSLS II [2] and other state of the art synchrotron light sources have been added to this table. From these parameters it is obvious that synchrotron radiation generated from both HER and LER is comparable to this last generation sources.

BENCHMARK RESULTS

To quantify the statement above the synchrotron radiation generated from both rings using bend magnets and standard undulators have been analytically calculated using the formalism described in [3]. A MATLAB script was used to calculate the bessel functions and calculate flux, and brightness. To verify this setup a benchmark test was performed with a set of parameters and results calculated with an alternative code. As comparison the same calculations have been performed for other light sources to benchmark both HER and LER. For the comparison state of the art facilities in operation, construction and design are used.

Bend Magnet

Bend magnet radiation is parasitically generated in any collider and no change to the optics needs to be implemented. Although most third generation light sources are optimized for undulator and wiggler beam lines bend magnet sources are part of future designs and their performance optimized. The brightness for the different facilities is shown in Figure 1. The parameters used for the calculations are those in Table 1. The data were extracted from the facilities web pages, CDR's and presentations. Future facilities like PEPX are not included here as no data was available for it. For bend magnets the HER and LER have the brightest photon beam. However the offset to the other sources is smaller as the source parameters (beam emittance and divergence) are less optimized. The results for photon flux is not shown here, since it is dominated by beam current and the HER and LER will have the highest.

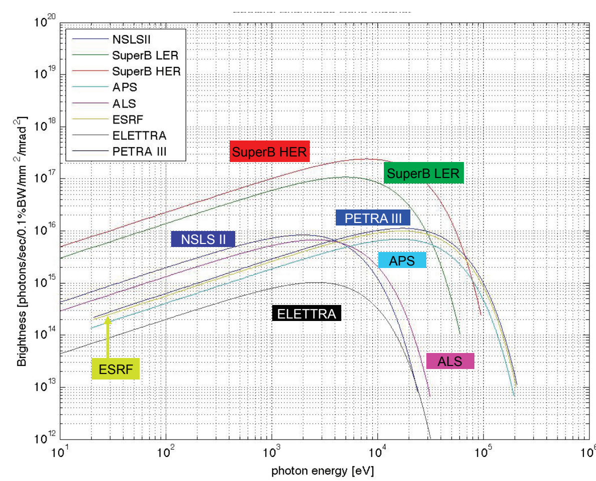

Figure 1: Brightness generated from bend magnets as a function of photon energy.

Undulators

The figure of merit for third generation light sources is the radiation generated from insertion devices. For this purpose the undulator radiation as documented on the same

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Table 1: Parameter Table for Bend Magnet Radiation Calculation

Param.	HER	LER	NSLS II	APS	ESRF	ELETTRA	ALS
E[GeV]	6.7	4.18	3.0	7.0	6.03	2.0	1.9
I[mA]	1892	2447	500	100	200	320	500
ρ[m]	69.6	26.8	24.98	38.96	23.62	5.55	4.81
ϵ_x[nm]	2.0	2.46	0.55	2.51	4.0	7.0	6.3
ϵ_y[pm]	5.0	6.15	8.0	22.6	25.0	70.0	50.0
γ_y[m^{-1}]	0.33	0.54	0.05	0.101	0.10	0.50	0.74
σ_x[mm]	82.1	92.1	125	81.7	77.0	139	102
σ_y[mm]	8.66	9.11	13.4	27.0	29.5	28.0	8.20

Table 2: Parameter Table for Undulator Radiation Calculation

Param. Undulator	HER IVU20	LER IVU20	NSLS II IVU20	APS U33	PEPX IVU23	Soleil U20	Spring8 U24	Petra III U29
E[GeV]	6.7	4.18	3.0	7.0	4.5	2.75	8.0	6.0
I[mA]	1892	2447	500	100	1500	500	100	100
σ_x[μm]	82.1	92.1	125	81.7	22.2	3880	286	140
σ_y[μm]	8.66	9.11	13.4	27.0	7.00	8.08	6.00	5.60
σ'_x[mrad]	33.3	37.0	16.5	11.8	7.40	14.5	11.0	7.9
σ'_y[mrad]	2.1	2.7	2.7	3.3	1.2	4.6	1.0	4.1
N[1]	148	148	148	72	150	90	186	172
λ_u[mm]	20	20	20	33	23	20	24	29
K$_{max}$[1]	1.83	1.83	1.83	2.75	2.26	1.0	2.21	2.2
K$_{min}$[1]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

sources quoted above have been used for facilities in operation and construction. For better comparison the same device type as at NSLS II was chosen for the Super-B HER and LER. Source point and device parameters are summarized in Table 2. The brightness for the undulator radiation is depicted in Figure 2. PEPX generates the highest brightness followed by HER and LER. This is a result of the high beam currents in these rings. A detailed study of the difference of source point parameter and its effect on the brightness between PEPX and the Super-B rings by considering the photon beam diffraction limit showed that the higher brightness in PEPX is generated by its lower horizontal emittance.

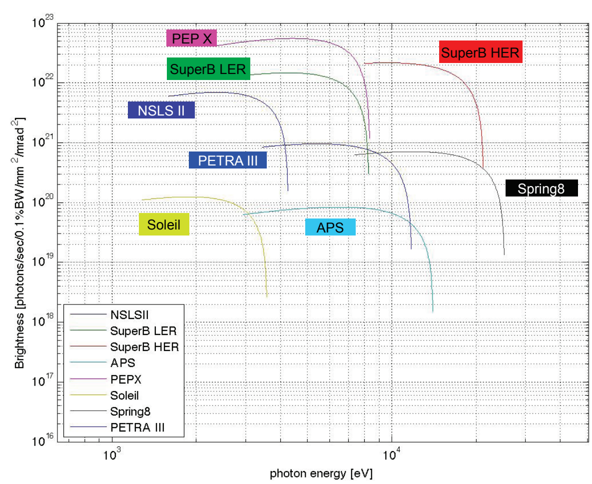

Figure 2: Brightness as a function of photon energy for different reference undulator radiation calculated for benchmarking different facilities.

Source Parameter Optimization

A brief study to optimize the brightness in the HER was conducted, the result is plotted in Figure 3. By reducing the HER energy and beam coupling (from design 0.25% to 0.1%) the beam emittance is reduced. This gain is unfortunately mostly canceled by the change of the diffraction limit as the calculation show, since to achieve the same level of brightness as in PEPX the horizontal emittance would have to be significantly reduced.

BEAM LINE LAYOUT

When using the Super-B rings as a synchrotron light source one has to plan for additional space for the photon

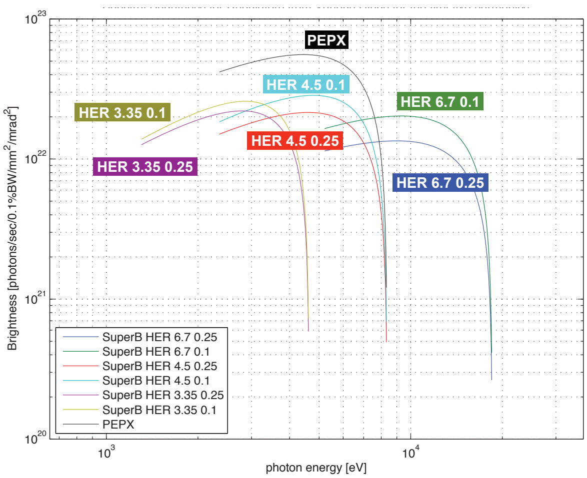

Figure 3: Brightness as a function of photon energy for different energies and coupling values of the HER in comparison to PEPX baseline design.

Figure 4: All possible bend magnet photon beam line location with different contour lines showing the distance to the source point.

beam lines and user space. This is significant as collider facilities are usually located underground for radiation protection purposes whereas third generation light sources are surface installations.

LNF Site at Frascati Rome

During the study the LNF site near Rome was the primary choice. This site demands an underground installation as the surface area is already mostly occupied. In addition the ring dimensions partially exceed the LNF boundaries. This investigation was aimed to understand where and with what length photon beam lines could be placed within the LNF boundary. An overview is shown in Figure 4. It shows the planned Super-B tunnels with injector. Added to these are the contour lines with distances from the source point in 25 meter steps to a maximum of 150 meters. Only bend magnet source points from the outer ring were used. the upper portion of beam lines originate from the LER the lower from the HER. Figure 5 is a magnification of the lower left area. As the picture indicates a set of HER beam lines with different length could be located there completely within LNF boundaries. The same contour line legend of Fig.4 applies.

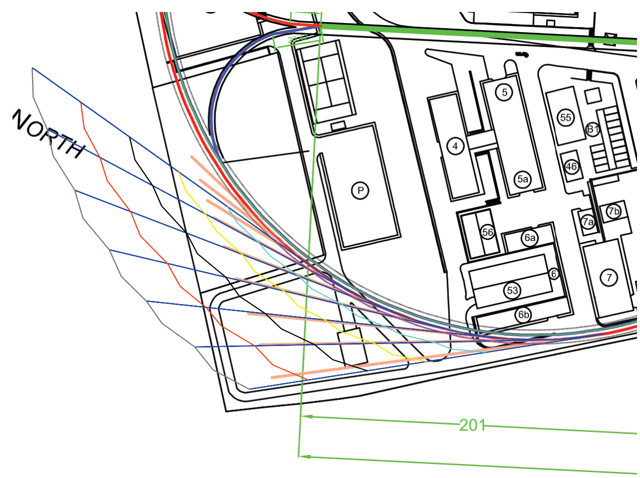

Figure 5: Area of possible HER beam lines which would be located within LNF boundaries. The contour line legend of fig.4 applies.

CONCLUSIONS

The calculations show that both Super-B LER and HER can be utilized as state of the art third generation light sources. This applies for both bend magnet and undulator generated radiation. One factor for the site choice will be if the rings will be located underground or on the surface. Also the needed length and number of photon beam lines will have to be taken into consideration when making this choice.

REFERENCES

[1] M. Zobov et. al., "Test of Crab-Waist Collisions at the DAΦNE Phi-Factory" Phys. Rev. Lett. 104, 174801 (2010) 30 April 2010.

[2] "NSLS-II Proposal for Approval of Conceptual Design (CD-0)", `http://www.bnl.gov/nsls2/`.

[3] Center for X-ray Optics and Advanced Light Source, "X-RAY DATA BOOKLET", `http://xdb.lbl.gov/`.