OPERATION STATUS OF THE BEIJING ELECTRON- POSITRON COLLIDER

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Abstract

The paper reports the operation status of the Beijing Electron Positron Collider(BEPC), which serves for both high energy physics experiment and synchrotron radiation application in the year 2002 to 2003. Besides, machine study is also described which is essential for the operation improvement and the BEPCII construction. As one progress, the so called "parasitic mode" with one wiggler for SR utility during HEP experiment was realized which is of great significance for BEPC's goal of "one machine with two dual purpose".

GENERAL DESCRIPTION

The Beijing Electron-Positron Collider serving for both high energy physics experiments and synchrotron radiation application has been well operating for more than 13 years since May 1989. Since the BES luminosity upgrading program in 1999, the performance and stability of the operation were greatly improved. The peak luminosity of BEPC has reached 5.8×10^{30} $cm^{-2}s^{-1}$ at J/ψ energy of 1.55GeV and 1.258×10^{31} $cm^{-2}s^{-1}$ at ψ(2S) energy of 1.84GeV respectively. Over 50 million J/ψ events were accumulated in two years from Sept. 1999 and 14 million (2S) events have been collected in the last run from Sept. 2001 to June 2002.[1] In all, the leading results for BES physics experiment are as follows:

- Precision Measurement of m_τ
- R measurement at 2 -5 GeV
- Theoretical study of τ and Charm physics
- A new resonance at the threshold of $p\bar{p}$ [3]

Meantime, for dedicated synchrotron radiation operation, many users coming from the universities and institutes all over the country carried out their experiments every year. The maximum beam current is around 120mA with lifetime over 20~30 hours. In addition, two insertion devices as well as new beamlines were installed in 2002. Besides, experimental studies for the machine development and BEPCII are being carried out. Improvement on the machine operation system and the database are still under way. BSRF users had finished about 300 experiment subjects which many achievements were attained. The operation and performance of BEPC in year 2002-2003 will be described in detail.

Comparing with the operation of 1999/2000 and 2000/2001 operation year, BEPC has made great progress both for BES and BSRF experiments. It can be seen from Table 2, the collision beam current was increased, and the fault time was reduced, so more and more integrated luminosity and events were gained in these years [1].

Table 3 is the comparison of the operation status among these years.

Table 1: General parameters

Parameters	Unit	Collision
Operation energy (*E*)	GeV	1.0-2.8
Injection energy (E_{inj})	GeV	1.3
Circumference	M	240.4
B-function at IP (B_x*/B_y*)	M	1.3/0.1
Tune ($\nu_x/\nu_y/\nu_z$)		5.8/6.7/0.2
Hor. emittance (ε_{x0})	mm·	0.39*
RF Frequency (f_{rf})	MHz	199.526
Harmonic number (*h*)		160
RF voltage (V_{rf})	MV	0.6-1.6
Bunch number (N_b)		1×1
Max. single beam current	mA	22*
Beam lifetime	hrs	6-8
Peak luminosity	$cm^{-2}s^{-1}$	5.8×10^{30}*

*-@1.55Gev

Table 2: Comparison between operating

Year		2000-2001 operation	2001-2002 operation	2002-2003 operation
Average rate of positron injection (mA/min)		3~4	3-4	2-3
Minimum injection time (minutes)		12	12	15
Maximum beam current (mA)	J/ψ	52.5	48.58	53.7
	ψ(2S)	72.3	91.78	96.14
Maximum luminosity ($10^{30}cm^{-2}s^{-1}$)	J/ψ	4.8	4.8	5.31
	ψ(2S)	10.1	12.54	11.82
Maximum integrated luminosity per shift (nb^{-1})	J/ψ	118.4	240	149
	ψ(2S)	212	288	242.8

Table 3: Operation time distribution

Year	Total (hrs)	BES	BSRF	MD	Injec-tion	Commis-sion	Fault	Others
2000-2001	6581	2574.4	1708.2	750.2	664.7	490.4	345.2	47.8
2001-2002	6372	2472.3	1888.1	556.9	837.4	173.0	402.9	41.4
2002-2003	5904	2324.3	992.3	656.1	803.8	923.0	312.8	17.7

2000-2001	100 (%)	39.1	26.0	11.4	10.1	7.5	5.2	0.7
2001-2002	100 (%)	38.8	29.6	8.7	13.1	2.7	6.3	0.6
2002-2003	100 (%)	38.5	16.5	10.9	13.3	15.3	5.2	0.3

OPERATION FOR BES EXPERIMENT

In the 2002-2003 operation, the total time for BES experiment was 2324.3 hrs. the colliding beam operation for the high energy physics experiment was at energy of ψ(2S). The colliding beam current had been increased steadily since the operation started. The maximum current achieved was 96mA, with the lifetime more than 10 hours. The Fig. 1 is the colliding current very week.

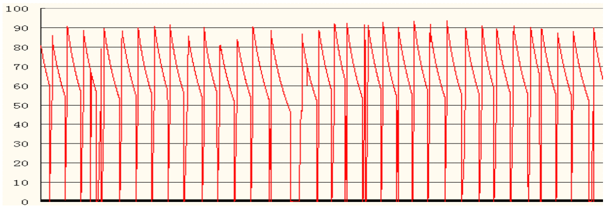

Figure 1: Beam current of every week.

The peak luminosity was 11.82 nb^{-1}, the maximum integrated luminosity per shift was 242.8 nb^{-1} in the period for ψ(2S) data taking. The integral luminosity reached to 35500nb^{-1}, the total ψ(2S) events data taken were 2450 nb^{-1} as illustrated in Fig.2 Furthermore, Linac also provided electron or positron beam with energy of 1.3Gev to the 10^{th} experiment hall between injection period for the BESIII TOF experiment and slow positron experiment with 1450 hrs [1], that is to say, Linac has realized one machine with multiple purpose.

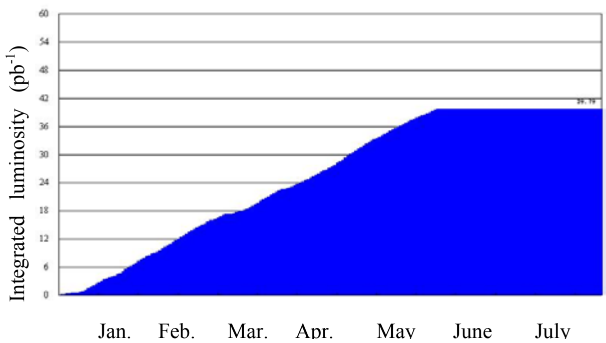

Figure 2: Integral luminosity in 2002-2003 year.

OPERATION FOR BSRF APPLICATION

Up to now, BSRF has become an important experimental platform in China. The users come from 46 Universities, 30 institutes of CAS, 18 institutes of Ministries and commissions and 6 others. About 800 subjects were carried out during the dedicated beam times last two years. The distribution of scientific area of users is shown in Fig. 3.

Since February 2001, for the first time we achieved to inject beam at fixed time of 7:00 am and 7:00 pm everyday during the synchrotron radiation experiment. Between two injections, the beam current was kept around 65-120 mA and the beam lifetime was about 20-30 hours. This has greatly improved the efficiency of SR experiments.

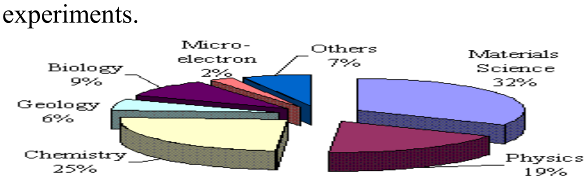

Figure 3: Scientific area of BSRF users.

In 2002-3003 year operation, the total time for the dedicated synchrotron operation was 992.3 hrs which was provided in two runs. The typical parameters of the synchrotron radiation operation were 2.2Gev and 80-130mA, and the lifetime was over 20 hours. The planned task was 110, the completed task was 168, so the experiment tasks were completed by 52.7% ahead of schedule.[3] Especially, the sars virus protein macro-molecule structure experiment was made on the macro-molecular crystallography beam-line with better result which was of greatly significance for sars virus study.

The completion of the installation and commissioning of the wiggler 3W1 made it is possible to realize the parasitic mode for both high energy physics and synchrotron radiation, which was of great significance to BEPC's goal of "one machine with two dual purpose". This work was done by carefully studying the perturbation on the lattice due to the wigglers and the corresponding compensation scheme. Thus, the lattice functions such as the beta at IP, the working point was matched to the same value as the normal collision mode, so the high luminosity at same level can be achieved with the parasitic mode.

The 4W2 wiggler is an In-Vacuum wiggler, which has larger magnetic poles as well as the transverse dimensions of the vacuum tank comparing to other IDs in the world. For the first time of commissioning, the beam lifetime decreased drastically to several tens of minutes when the gap was closed to 25mm, while the design value is 15mm. After heavily machine study by adjusting the COD, the working point, the coupling and the chromaticitiy, the beam lifetime was recovered to about 15 hours for single bunch at 5mA when the gap is 15mm, while for 130mA with multi-bunches, it's about 8 hours when the gap is 20mm. So far, for routine operation, the gap is set at 20mm, which can meet most users' requirement. We guess that the low beam lifetime at high current may due to vacuum degradation and the coupled bunch oscillations. Further study is still under way.[4]

Since all of above mentioned goals have been achieved, the front-end will increase from 4 to 7, the beamlines will reach from 9 up to 12, and the experiment stations will be expanded from 11 up to 13. The performances of the beamlines and experiment stations will be further enhanced. So research fields will be more extended.

In conclusion, in spite of the effect of sars, both for high energy physics experiment and synchrotron radiation application, the operation efficiency of BEPC is comparatively higher.

MACHINE STUDY

There are two objectives for BEPC machine study, One is to fix and resolve the problems in time during the operation. This includes optimization of operation mode, examination and repair of hardware system, experiment on the better and more stable mode for future operation.

Another objective is to do some experimental research on beam dynamics study for both BEPC and BEPCII.

Beam Based Alignment (BBA)

A Beam Based measurement system for BPM offset has established, with additional windings applied to the 32 quadruple magnets [see Dr. Hucl's thesis]. Based on the measured offsets of BPMs, the rms COD can be corrected to less than 1mm. This may help to improve the future performance of BEPC. Also, the system made it possible and convenient to precisely measure the beta functions around the ring. Further study on BBA as well as response matrix is being carried on which will be one of the basic systems of BEPCII.

Experiments on Photoelectron Instability (PEI)

A special-constructed detector was manufactured and installed at the BEPC storage ring for the electron cloud measurement. Joint experiments with experts from KEK and APS had been done to obtain more information on the photoelectron and secondary electron yields as well as the energy spectrum of the electron cloud through the direct measurements of the properties of the PEI cloud for both stable and unstable beams, which is also helpful to BEPCII. More experiments will be done soon.

Commission of parasitic mode

The parasitic mode with 3W1 wigglers for SR during the high energy physics was commissioned in 2002-2003 operation. Although the luminosity and emittance was affected in the parasitic mode, some measurements were taken to compensate the working point and βfunction at the colliding point.[4]

IMPROVEMENTS AND OTHERS

Besides machine study, the following measurements were taken to ensure the operation.

Operation with golden orbit and optimal working points: we found the golden orbit and the optimal working points for collision mode, with which the peak collision beam current is increased stably. Before switching off the separator, the working points was measured and adjusted carefully until the optimal values are got.

Some improvements of the storage ring

(1) The precision of magnet alignment was improved. During the summer shutdown, re-survey and alignment of the magnets of the storage ring are carried on, which can reduce error effectively.

(2) Stability of the power supply for magnets was much improved. All the power supplies of the correction magnets in the storage ring (including the transport lines) were upgraded during summer shutdown. All the power supplies of the dipoles and the quadrupoles in the storage ring were calibrated before starting. The database of the beam diagnostics system was improved and we can find out the unstable power supply in time by checking the history data.

(3) A distributed beam loss monitor system based on the CAN bus which can detect slight beam losses along the storage ring had been constructed. This helped us to understand the beam loss mechanism and find the corresponding problem.

(4) The control procedure of the beam orbit was set up in order to display and record the position of positron and electron beam in the storage ring vacuum chamber, the closed orbit can also be observed through the procedure, whose details can be displayed on the computer which is very convenient for the operator to observe beam orbit and adjust its track.

The improvement of linac

As for the linac, in order to stabilize the beam energy and optimize the spread which was helpful to improve the injecting rate. PSK and TWT timing experiment, buncher and prebuncher phase and power experiment were done to optimize the beam. Electron gun and positron pulse power supply were changed, Thales klystron were modified in order to adapted the higher power klystron on the future. On account of the aging of the vidicon camera, the CCD camera was modified at the AM3 analysis magnet, which has high sensitivity and resolution, However, its anti-radiation quality is not very good comparatively.

Besides the operation, many experiment was done for BEPCII construction, Large quadrople was equipped to test its function to increase beam, 3 energy doubler detune was also tested during its work, some studies such klystron modulator is also done to improve the quality of linac.

SUMMARY

After the luminosity upgrade program were finished, more success have been taken such as 50 million J/ψ events and 14 million ψ(2S) events taking; BSRF has become an important experimental platform, two insertion devices as well as new beamlines and the experiment stations such as the biology macro-molecular crystallography beamline and experiment station were constructed, the research fields will be extended. one machine with two dual was realized due to the completion of the 3W1 magnet which is essential for BEPC to improve its operation efficiency. Besides, experimental studies for machine development and BEPCII are being carried out. It is expected that BEPC will continue to run stably till the installation of BEPCII.

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