OPERATION AND PERFORMANCE OF THE BEIJING ELECTRON-POSITRON COLLIDER

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Abstract

The Beijing Electron-Positron Collider (BEPC) serving for both high energy physics experiments and synchrotron radiation application has been well operated for more than 13 years since May 1989. After the luminosity upgrade program from 1999, the performance and stability of the operation were much improved in recent years. The peak luminosity of the BEPC has reached 5×10^{30} $cm^{-2}s^{-1}$ at J/ψ energy of 1.55GeV and 1×10^{31} $cm^{-2}s^{-1}$ at ψ(2S) energy of 1.84GeV respectively. For dedicated synchrotron radiation operation, the maximum beam current is around 120mA with lifetime over 20~30 hours. The operation and performance of BEPC will be described in this paper in details.

1 GENERAL DESCRIPTION

The luminosity upgrade program of BEPC were finished in the spring of 1999. We had gained primary success of 25 million J/ψ events taking from 1999 to 2000 operation year. The last BEPC run began in September 2000, shuted down at the end of June 2001 according to schedule. In the period, BES (Beijing Spectrometer) team had finished the task for 50 million J/ψ events taking. Since April 1, 2001, BES team have also carried on the peak scan for ψ(2S), ψ(3770) and the data taking later. Machine study for BEPC and BSRF (Beijing Synchrotron Radiation Facility) experiments was executed at long intervals. For dedicated synchrotron radiation operation, BEPC provide maximum beam current is around 120mA with lifetime over 20~30 hours.

The latest round operation of BEPC started in September 2001, shuted down in the middle of June 2002 are planned. Up to now, BEPC have operated 2 months for dedicated synchrotron radiation, BSRF team had finished over 220 experiment subjects. Untill March 2002, BES team had been working continuously over 4 months, and over 14 million ψ(2S) events were accumulated.

The later BEPC operation plan is machine study and the data taking for ψ(3770) as well as the third time dedicated BSRF experiment. Up to May 17 2002, about 280000 ψ(3770) events were accumulated.

2 PERFORMANCE

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 1 that the collision beam current is increased, and the injection time is reduced, so more integrated luminosity and events are gained in 2000/2001 operation.[1]

In the operation year of 2001/2002, BEPC will hold and exceed these record. For example, the peak luminosity is reached 12.58×10^{30} $cm^{-2}s^{-1}$, and the maximum integrated luminosity per shift is 288 nb^{-1} in the period for ψ(2S) data taking.

Table 1: Comparison between 00/01and 99/00 operation

		1999/2000 operation	2000/2001 operation
Average rate of positron injection (mA/min)		1~2	3~4
Minimum injection time (minutes)		30	12
Maximum beam Current (mA)	J/ ψ	43.4	52.5
	ψ(2S)	67.8	72.3
Maximum luminosity ($\times10^{30}cm^{-2}s^{-1}$)	J/ ψ	4.5	4.8
	ψ(2S)	7.9	10.1
Maximum integrated luminosity per shift (nb^{-1})	J/ ψ	104.7	118.4
	ψ(2S)	152.9	212

The BEPC runs 9.5 months per year in average including 5 months for high energy physics, 3 months for dedicated synchrotron radiation running with more than 300 user, 1.5 months for start-up and machine study (MD). The operation time distribution is shown as Table 2 and Figure 1. Some results of the operation for BES and BSRF are as follows.

Table 2: Operation time distribution

Year	Total (hrs)	BES	BSRF	MD	Injec-tion	Commis-sion	Fault	Other
1999-2000	6504	2412	1481	760	950	260	628	14
2000-2001	6581	2574.4	1708.2	750.2	664.7	490.4	345.2	47.8
1999-2000	100 (%)	37.1	22.8	11.7	14.6	4.0	9.7	0.2
2000-2001	100 (%)	39.1	26.0	11.4	10.1	7.5	5.2	0.7

It can be seen from Table 2 that the operation time for BES and BSRF are increased, and the injection and the fault time are reduced, but the commissioning and recover time are increased.

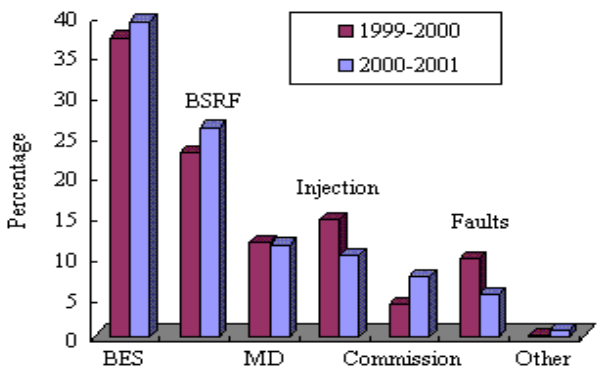


Figure 1: Operation time percentage.

2.1 BEPC Operation for BES

Due to significant improvement in machine performance, the integrated luminosity per day increased by factor of 3 – 4 in recent two years operation than before.

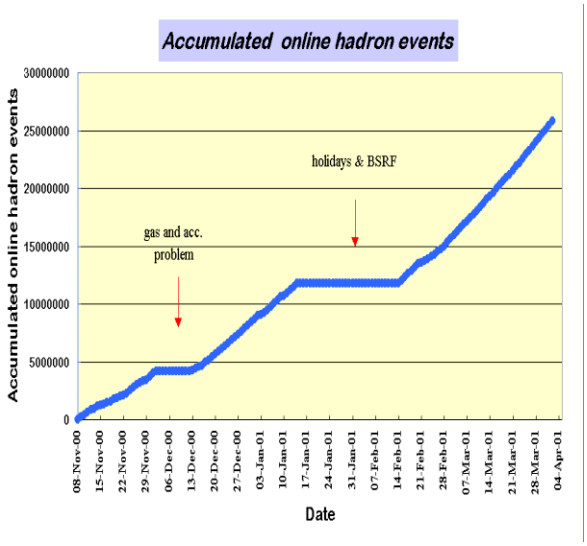
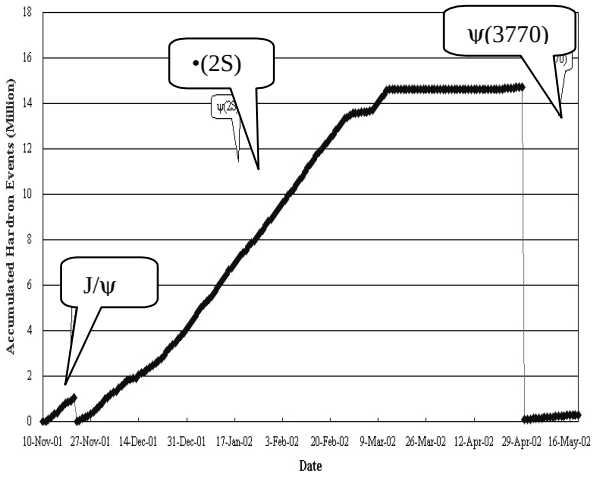


Figure 2: Accumulated online hadron events in 2000-2001 operation year



The BESII had collected over 50 million J/ ψ events in the past two years (compared with the BESI 8 million J/ψ events in about two years), and collected 14 million ψ(2S) events in 4.6 months (compared with the BESI 3.8 million ψ(2S) events in 3 months). So more •(2S) events are planned in 2002/2003 running and the great physical results are expected. Figure 2 and Figure 3 shows the BES data taking timetable in recent two years.

2.2 BEPC Operation for BSRF Experiment

Since February 2001, during the synchrotron radiation experiment, for the first time we achieved to inject beam at fixed time of 7:00 am and 7:00 pm everyday. Between two injections, the beam current was kept around 120-65 mA and the beam lifetime was about 20-30 hours. After injection on time, the integrated beam current was averagely increased from 1.7Ah to 2.0Ah per shift.

Up to now, BSRF has become an important experimental flat. The users come from many units at home and abroad. They come from 46 Universities, 30 Institutes of CAS, 18 Institutes of Ministries and Commissions and 6 Others. More than 400 subjects carried out their experiments during the dedicated beam times last year. The distribution of scientific area of users is shown as Figure 4.

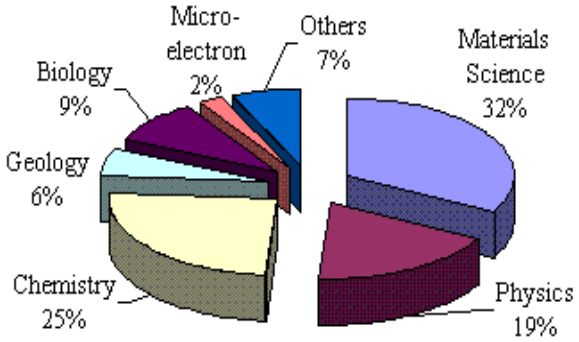


Figure 4: Scientific area of BSRF users

BSRF will construct next year two multi-cell wigglers and three beamlines: macro-molecular crystallography beamline , XAFS beamline and medium energy x-ray beamline (1.5-6KeV); Reconstruction 3B1B beamline, Monochromators of 4W1C and 4B9A.

After all of above mentioned goals have been achieved, the front-end will be increased from 4 to 7, the beamlines will be reached from 9 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. The research fields will be more extended.

2.3 BEPC Machine Study

There are two objectives for BEPC machine development study. One is to find out and resolve the problems as well as some faults 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 both for BEPC and its upgrade project as BEPCII.

(1) Beam Based Alignment (BBA)

Depending on beam itself, Beam Based Alignment system aligns the difference between the magnetic center of magnets and the electric center of BPM. Precise measurement of the offsets will greatly improve the performance of BEPC, and the BBA system will be one of the basic systems of BEPCII. As the first step to apply BBA on BEPC, additional windings were added to the 32 quadrupoles during the summer shutdown in 2000 so that the strength of each quadrupole can be individually adjusted within ±3% of its normal setting value. Then experiments as well as software development were carried out in recent two years to measure the offset of BPMs. With the preliminary data the quadrupole offset on BEPC can be calibrated to less than 0.2mm. Further study to reduce the excursion of the closed orbit is underway.

(2) Experiment on Photoelectron Instability (PEI) [2]

A specially-constructed detector was manufactured and installed at the BEPC storage ring for the electron cloud measurement. Joint experiments with experts from KEK and APS have 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 PE cloud for both stable and unstable beams. 4 more detectors are to be installed on the BEPC during this summer shutdown to do further studies. The experiment of PEI will be benefit to BEPCII.

(3) Dust effect and beam lifetime study

In the routine operation of the synchrotron radiation mode with multi-bunches, sudden reduction of the beam lifetime was observed. It was conjectured that this may be due to the dust effect which comes from the vacuum pumps. Experiment shows that with distributed ion pumps (DIP) in one half of the storage ring were switched off while the vacuum did not drop significantly, the rate on the sudden beam lifetime decrease reduced clearly.

(4) Commission of parasitic mode

As the increased demand from BSRF users, The parasitic mode with wigglers on for SR during the high energy physics was commissioned recently.

Other machine study includes: commissioning of large emittance mode, single interaction point experiment and vacuum measurement with high beam current.

3 IMPROVEMENTS

To make so much a progresses, besides the hard work of BEPC people, following improvements were taken:

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 higher and higher. Before switching off the separator, we measure and adjust the working points carefully until the optimal values are got. The precision of spectrum analyzer is less than 1 kHz, the working points are less than 0.001.

The improvement of linac includes:

1. All the power supplies of klystron were improved, which stabilize the beam energy at the exit of linac, and are helpful to the increase of injection rate.

2. About twenty vacuum gauges have been replaced, and the system of the interlock for the vacuum system was setup. The linac vacuum leakages occured in both 1999/2000 and 2000/2001 operation years.

The improvement of storage ring is:

1. The precision of magnet alignment was improved. During the summer shutdown, re-survey and alignment of magnet the storage ring are carried on. We use Laser Tracker firstly to survey the storage ring, which can reduce error effectively.

2. Stability of the power supply for magnets was much more 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. The temperature of the cooling water for the RF cavity gets more stable. By modifying the control software, updating one faster computer and a more sensitive magnetic valve, now the change of water temperature is controlled within $\pm 0.2^{o}$ C, while which was $\pm 1^{o}$ C before.

4. The BEPC storage ring magnet temperature protection system was upgraded during the summer shutdown, more than 700 thermal relays were installed.

5. The time of the magnet standardization was reduced from 6 to 4 minutes, by modifying the control software.

6. A distributed beam loss monitor system based on the CAN bus which can detect slight beam losses along the storage ring has been constructed. This helps us to understand the beam loss mechanism and find the corresponding problem. [3]

4 SUMMARY

After the luminosity upgrade program were finished, BEPC has been well operated for more than 3 years, and have taken enormous success such as 50 million J/ψ events taking; BSRF has become an important experimental flat, two insertion devices as well as new beamlines are under construction, and the research fields will be extended. Besides, experimental studies for machine development and BEPCII R&D are being carried out. It is planed that BEPC will continue to run stably till the installation of BEPCII starts.

5 REFERENCES

[1] X.M. Yu et al, "The Operation Status of BEPC in 2000/2001 Year", 6th BEPC Annual Meeting proceedings, p.8-13.

[2] Z.Y. Guo, "Studies on the Photoelectron Cloud at the BEPC", APAC01 proceedings, p. 377-379.

[3] J. Cao et al, "BEPC Storage Ring Beam Loss Monitor System Design", APAC01 proceedings, p.621-623