OPERATION STATUS 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 5.8×10^{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. Over 50 million J/ψ events were accumulated in two years from Sept. 1999 and 14 million ψ(2S) events have been taken in the last run from Sept. 2001 to June 2002. For dedicated synchrotron radiation operation, 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 the last summer(2002). Besides, experimental studies for the machine development and BEPCII R&D are being carried out. Improvement on the machine operation system and the database is still under way. It's expected that BEPC will continue to run stably till the mounting of BEPCII starts. The operation and performance of BEPC will be described in this paper in details, and also the presentation will be offered about the operation team, organization system etc.

1 GENERAL DESCRIPTION

The Main Parameters of the BEPC

Parameters	Unit	Collision/ SR
Operation energy (E)	GeV	1.0-2.8/ 2.2
Injection energy (E_{inj})	GeV	1.3
Circumference	m	240.4
B-function at IP (B_x*/B_y*)	m	1.3/0.1//18/18
Tune (ν_x/ ν_y/ ν_z)		5.8/6.7/0.02//
Hor. emittance (ε_{x0})	mm	0.39*/0.08
RF Frequency (f_{rf})	MHz	199.526
Harmonic number (h)		160
RF voltage (V_{rf})	MV	0.6-1.6/0.8
Bunch number (N_b)		1×1/60-80
Max. single beam current	mA	22*/137
Beam lifetime	hrs	6-8/20-30
Peak luminosity	$cm^{-2}s^{-1}$	2.9×10^{30}*

*-@1.55Gev

BEPC has been well operated nearly 14 years since May 1989, and have obtained many important fruits both in high energy physics experiments and synchrotron radiation application. The leading results are as follows:

* Precision Measurement of m_τ
* Study of ξ(2230)& q(1720)
* ψ' *VP,VT*
* measurement of f_{Ds}
* R measurement at 2 -5 GeV
* Theoretical study of τ and Charm physics etc.

In synchrotron radiation application , many users come from the universities and the institutes all over the country carried out their experiments during the dedicated beam times every year.

The luminosity upgrade program of BEPC were finished in the spring of 1999. We had gained primary success, over 50 million J/ψ events taking from 1999 to 2001. Since April 1, 2001, BES(Beijing Spectrometer) 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 were executed. For dedicated synchrotron radiation operation, BEPC provide maximum beam current is around 120mA with lifetime over 20~30 hours.

The last round operation of BEPC started in September 2001, shut down in the middle of June 2002 was planned. Untill March 2002, BES team had been working continuously over 4 months, and over 14 million ψ(2S) events were accumulated. Up to May 17 2002, about 285,800 ψ(3770) events(the integrated luminosity reached 8.15 pb^{-1}) were accumulated. For dedicated synchrotron radiation run, BEPC had operated nearly 3 months (alternation of 3 times). BSRF team with there users had finished about 300 experiment subjects.

The latest BEPC operation began in Nov. 2002, and the plan is still the data taking for ψ(3770) as well as 3 times dedicated BSRF experiment.

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 held and exceeded these record, for example, the peak luminosity is reached $12.58\times10^{30}cm^{-2}s^{-1}$, 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
	$\psi(2S)$	67.8	72.3
Maximum luminosity ($\times 10^{30} cm^{-2} s^{-1}$)	J/ψ	4.5	4.8
	$\psi(2S)$	7.9	10.1
Maximum integrated luminosity per shift (nb^{-1})	J/ψ	104.7	118.4
	$\psi(2S)$	152.9	212

The BEPC runs about 9 months per year in average including 5 months for high energy physics experiments, 3 months for dedicated synchrotron radiation running, about one months for start-up and machine study (MD). The operation time distribution is shown as Table 2. 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.

2.1 BEPC Operation for BES

Due to significant improvement in machine performance(β function at IP was reduced from 8.5cm to 5cm etc.), the integrated luminosity per day increased by factor of 3 – 4 in recent three years operation than before.

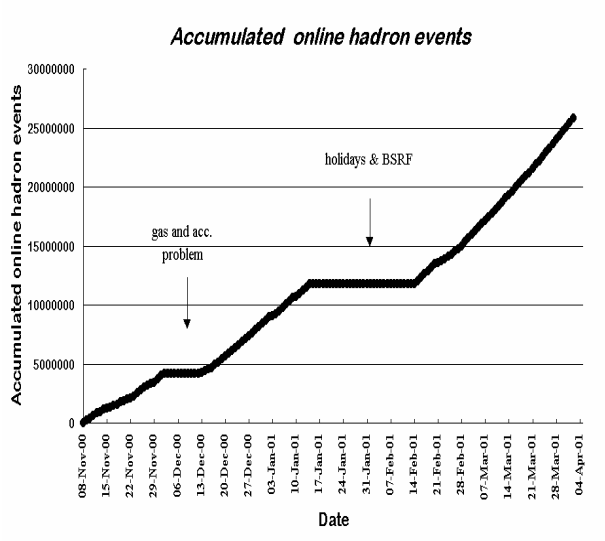

Figure 1: Accumulated online hadron events in 2000-2001 operation year

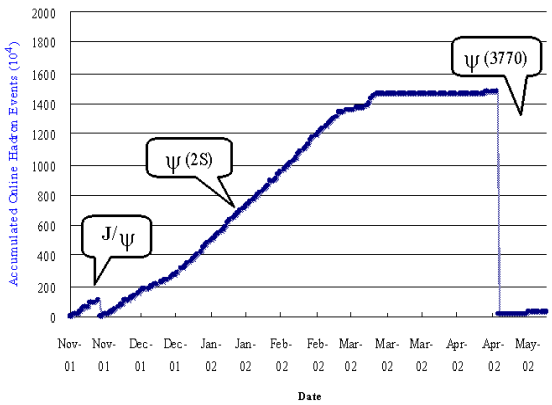

Figure 2: BES data taking status in 2001-2002 year.

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). For ψ(3770) data taking in last May, the integrated luminosity is reached 8.15 pb^{-1}; The integrated luminosity of 45 pb^{-1}(on line) are planned in 2002/2003 running and the great physical results are expected. Figure 1 and Figure 2 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 platform. 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. About 700 subjects carried out their experiments during the dedicated beam times last two years. The distribution of scientific area of users is shown as Figure 3.

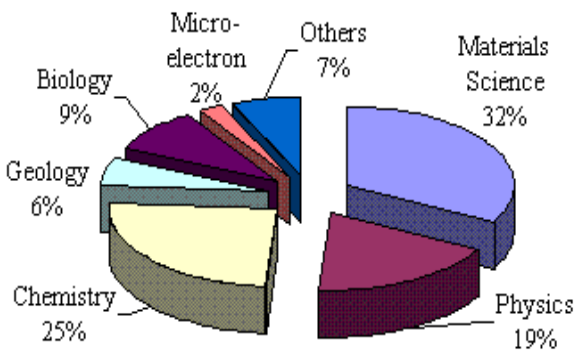

Figure 3: Scientific area of BSRF users

BSRF will construct two multi-cell wigglers(last year) and three beamlines: macro-molecular crystallography beam-line , XAFS beamline and medium energy x-ray beamline (1.5-6KeV); Reconstruction 3B1B beamline, Monochro-mators 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 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 AND OTHER

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:

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, and otherwise.

Some improvements of the storage ring are:

(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. 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 ±0.2°C, while which was ±1°C before.

(4) 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].

The Control system

The current control system of the BEPC was built in 1987, which was transferred from SLAC New Spear system and upgraded in 1994. A VAX4500 computer with the CAMAC hardware controls most of the

equipment on the storage ring. Some devices are controlled by PCs including the beam instruments, injection power supplies and linac equipment. Two VAX workstations serve as the console and all of the machines are connected with 100Mbps Ethernet. Since 1994 the current system runs well.

According to the design of the BEPCII, a double ring schema will be adopted and a number of new devices will be added in the system, such as the super-conducting RF cavities, and beam feedback system. So the current system has to be upgraded and it will be developed with EPICS. VME IOCs will be added in the system with field-bus, PLCs to control equipment. And we will keep some CAMAC hardware in use and merge it into the EPICS system. Recently the development of prototype system is in progress.

4 ORGANIZATION OF THE OPERATION TEAM

We established the full time operation team in 2001 for poolling the strength to jump in the design and the construction of BEPCII(the upgrade project of BEPC), the organization system chart is as follows:

Deputy Director of IHEP
↓ …
Deputy Director of Accelerator Center
↓ …
Head of Linac — Head of the Storage Ring
↓ — ↓
10 operators — 10 operators

Number of operators per shift are 4 persons, 2 persons work at the central control room, and other 2 work at the Linac control room. The type of shift is 5-shift rotation, and the work time is 12 hrs per shift, i.e. after working on duty 12 hrs, the operators have a rest for 48 hours.

Most of the operators are young people, the mean and median years of experience are less than 2 years(only as an operator since Sep 2001), they come from the different professional groups of the Accelerator Center such as AP, RF, Control groups and so on. They have been working at each group for several years(from 1 year to 10 many years). In general, the new hires also come from above groups and they graduated from the different universities. They take charge of the operator or the chief operator by training 3-4 months.

The type of maintenance program of BEPC is prevention each other the combination with random during the summer downtime and in the running time. Almost all of the maintenance works of the machine be done by our staff. The correlation personnel of every system(group) undertake each responsibility, by way of coordinating promptly solving the problem or fixes a breakdown. The downtime of the machine yearly average is about 25%(3 months).

Moreover, our logbook is recording paper special made(printed) by ourselves. The control room area is about 85 and 100 square meter (for Linac and the central control room) and the number of display screens are about 15 to 20 respectively. The control system description is as above third section.

The special challenges for our operation group are as follows: The ageing phenomenon of the equipments and components and parts are becoming seriously increasingly, for the operators and the maintenance personnel, they work very hard, but the fault rate is still move upward to some extent year after year. The second problem is: The personnel are young and are short of experience, including the operators and the maintenance personnel.

5 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 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 the experiment station were constructed, the research fields will be extended. Besides, experimental studies for machine development and BEPCII R&D are being carried out. It is expected that BEPC will continue to run stably till the installation of BEPCII starts.

6 REFERENCES

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

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