Results and Future Plans from BES

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The values of $R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$ for 85 center-of-mass energies between 2 and 5 GeV are reported. Preliminary results using partial wave analysis for J/ψ decays to $\gamma\pi^+\pi^-$, γK^+K^-, $\phi\pi^+\pi^-$ and ϕK^+K^- are presented. The BESIII/BEPCII, a project for the future of BES, is introduced.

1. PRESENT STATUS OF BESII/BEPC

The Beijing Spectrometer (BES) at Beijing Electron Positron Collider (BEPC), so far the only e^+e^- machine operating in the center-of-mass (cm) energy from 2–5 GeV and directly producing charmonium and charmed mesons, has been running for 12 years. Both BEPC and BES were upgraded between 1995 and 1997, and the upgraded BES is called BESII [1]. Currently the BES experiment is benefiting from the upgraded machine and detector, though some of the detector and machine parts are suffering aging problems seriously. Table I lists some major parameters of the detector performance.

Table I Comparison of the major parameters with BESI and BESII

System	Parameter	BESI	BESII
VC	$\sigma_{xy}(\mu)$	250 (CDC)	90
	planes	4	12
MDC	$\sigma_{xy}(\mu)$	200-250	190-210
	$\Delta p/p$	$1.76\sqrt{(1+p^2)}$	$1.78\sqrt{(1+p^2)}$
TOF	σ_t(ps)	370	180
	$L_{attenuation}$(m)	1-1.2	3.5-5.5
BSC	$\Delta E/E(\%)$	25	21
ESC	$\Delta E/E(\%)$	23	22
DAQ	dead time/event(ms)	20	10

Figure 1 shows the history of the integrated hadronic events accumulated with BESII since November 1999 at the J/ψ resonance. With this 50×10^6 J/ψ event sample, which is about 6 times as high as the previous world's largest J/ψ sample, BES can systematically study J/ψ decays to excited baryonic states and search for glueballs and hybrids.

2. VALUES OF R IN 2–5 GEV

In precision tests of the Standard Model (SM) [2], the quantities $\alpha(M_Z^2)$, the QED running coupling constant evaluated at the Z pole, and $a_\mu = (g-2)/2$, the anomalous magnetic moment of the muon, are of fundamental importance.

The dominant uncertainties in both $\alpha(M_Z^2)$ and a_μ^{SM} are due to the effects of hadronic vacuum polarization, which cannot be reliably calculated in the low energy region. Instead, with the application of dispersion relations, experimentally measured R values are used to determine the vacuum polarization, where R is the lowest order cross section for $e^+e^- \to \gamma^* \to$ hadrons in units of the lowest-order QED cross section for $e^+e^- \to \mu^+\mu^-$, namely $R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$, where $\sigma(e^+e^- \to \mu^+\mu^-) = \sigma^0_{\mu\mu} = 4\pi\alpha^2(0)/3s$.

The values of R measured with BESII in 2–5 GeV are displayed in Figure 2, together with BESII values from [3] and those measured by MarkI, $\gamma\gamma 2$, and Pluto [4–6]. The R values from BESII have an average uncertainty of about 6.6%, which represents a factor of two to three improvement in precision in the 2 to 5 GeV energy region. Of this error, 4.3% is common to all points. These improved measurements have a significant impact on the global fit to the electroweak data and the determination of the SM prediction for the mass of the Higgs particle [7]. In addition, they are expected to provide an improvement in the precision of the calculated value of a_μ^{SM} [8, 9], and test the QCD sum rules down to 2 GeV [10, 11].

As pointed out by F.A. Harris [12], even after using the new BESII R value, the error on $\alpha(M_Z^2)$ is still dominated by the energy region from 1 to 5 GeV. Roughly 50% of the error in $\alpha(M_Z^2)$ is from 1–3 GeV. Therefore, PEP-N will make a great contribution to reduce this crucial uncertainty.

Using R data below 3 GeV, we are also measuring the the cross section of $e^+e^- \to p\bar{p}$, the π form factor, and testing pQCD by studying hadronic event shape, energy dependence of inclusive spectra, and some of the exclusive spectra (for example, $e^+e^- \to \pi^+\pi^-X$, K^+K^-X) in e^+e^- annihilation.

3. RESONANCE PARAMETERS OF $\psi(2S)$ AND $\psi(3770)$

To improve the measurement of the $\psi(2S)$ resonance parameters and leptonic decay branching fraction, we did a de-

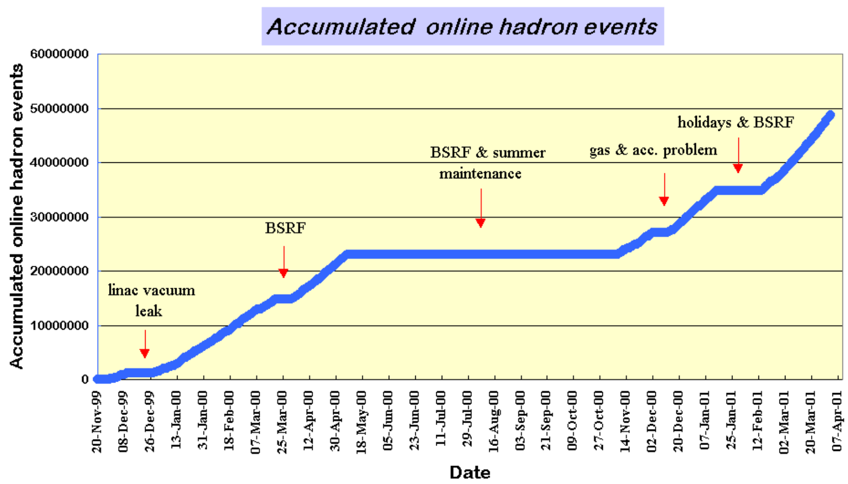

Figure 1: Integraded hadronic events accumulated with BESII since November 1999.

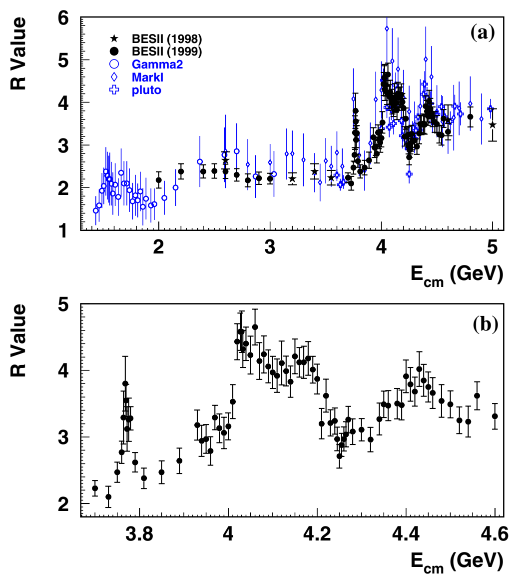

Figure 2: (a) A compilation of measurements of R in the cm energy range from 1.4 to 5 GeV. (b) R values from this experiment in the resonance region between 3.75 and 4.6 GeV.

tailed scan in the 3.67–3.71 GeV region during the R scan. Figure 3 shows the production cross section of $\psi(2S) \rightarrow$ hadrons, $\pi^+\pi^- J/\psi$, and $\mu^+\mu^-$.

A detailed scan was also done this year over the J/ψ, $\psi(2S)$ and $\psi(3770)$ to improve the measurement of the resonance parameters and total production cross section of $\psi(3770)$. The J/ψ and $\psi(2S)$ resonances are used for mass calibration. Figure 4 plots the preliminary R-values in the 3.66–3.83 GeV energy range.

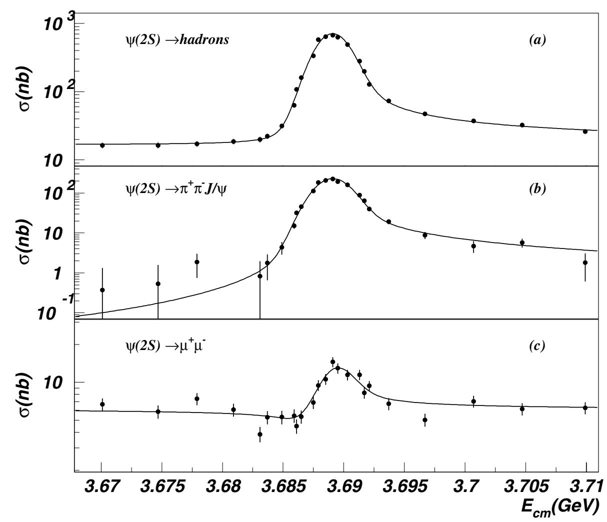

Figure 3: Measured cross section of $\psi(2S) \rightarrow hadron, \pi^+\pi^- J/\psi$ and $\mu^+\mu^-$.

4. J/ψ DECAYS

The $f_0(1710)$, first observed by the Crystal Ball Collaboration in $J/\psi \rightarrow \gamma\eta\eta$, has been considered as the possible lightest 0^{++} glueball candidate because of its large production rate in gluon rich processes, such as J/ψ radiative decays, pp central production, etc., and because of the lattice QCD calculation of the lightest 0^{++} mass. However, the spin-parity of $f_0(1710)$ is still not clear in different channels after many years' efforts. Based on BESII 24×10^6 J/ψ data, the partial wave analysis (PWA) is applied to the 1.7 GeV mass region in J/ψ radiative decays to K^+K^- and $\pi^+\pi^-$. In K^+K^- mass spectrum, the PWA analysis shows a strong 2^{++} component, which is consistent with the well known $f_2'(1525)$ with the mass and width being in good agreement with PDG values,

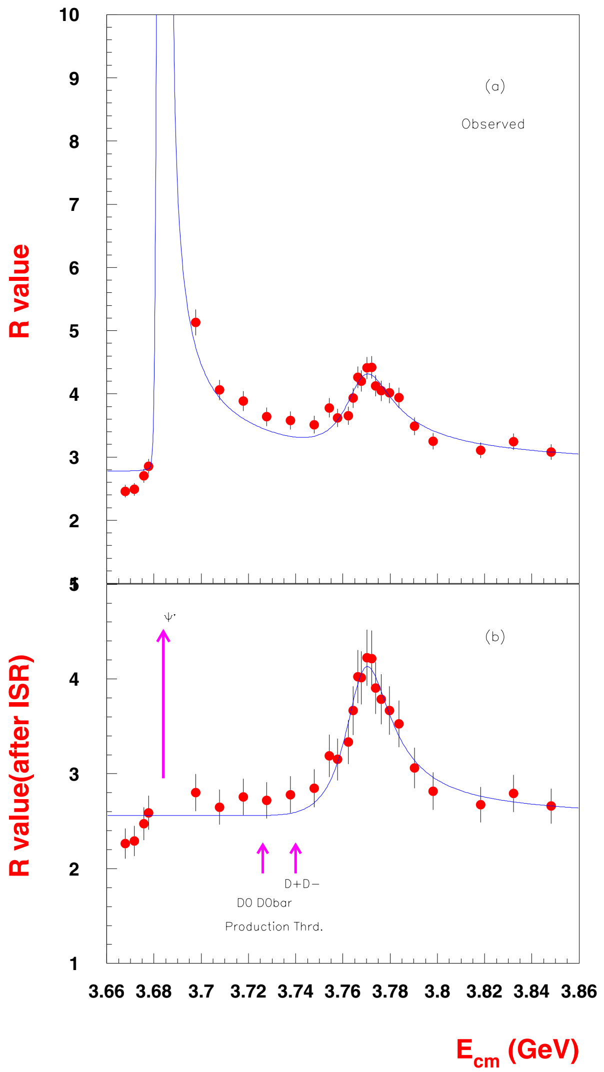

Figure 4: Preliminary R values between 3.66 and 3.83 GeV from the detailed scan done in the Spring of 2001 with BESII.

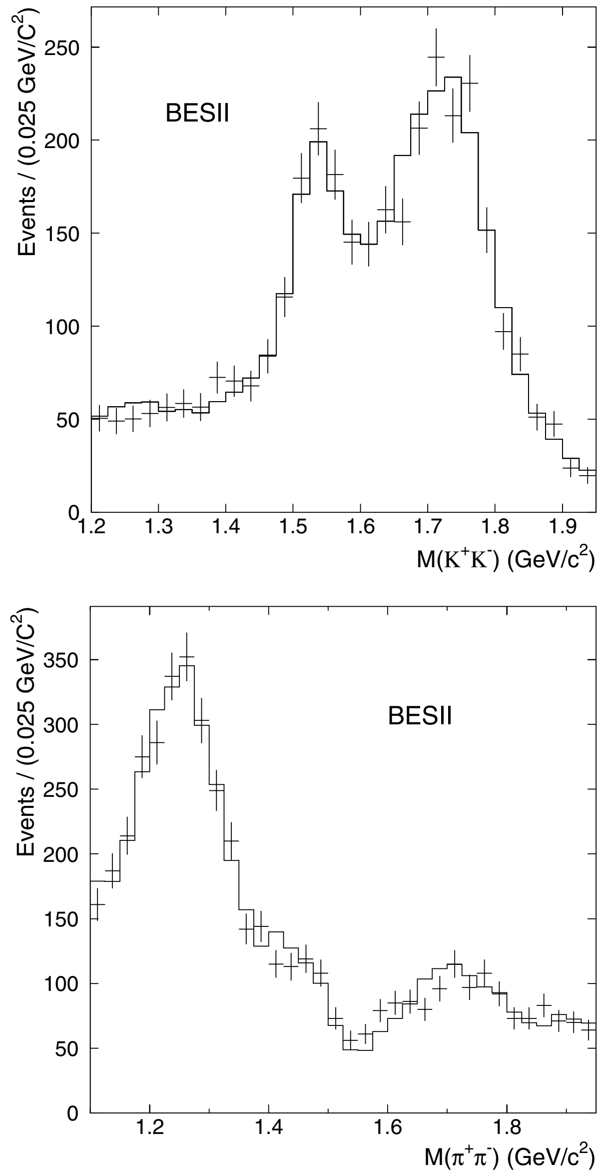

Figure 5: Invariant mass spectra of K^+K^- for $J/\psi \to \gamma K^+K^-$ (top) and $\pi^+\pi^-$ for $J/\psi \to \gamma\pi^+\pi^-$ (bottom). The crosses are data and histograms the fits.

and a dominant 0^{++} component in 1.7 GeV mass region. In the $J/\psi \to \gamma\pi^+\pi^-$ channel, there are two 0^{++} components, one located at around 1.5 GeV and another around 1.71 GeV, in addition to the $f_2(1270)$. Figure 5 shows the K^+K^- and $\pi^+\pi^-$ invariant mass spectra.

With BESII 24×10^6 J/ψ data, we performed a PWA analysis of $J/\psi \to \phi\pi^+\pi^-$ and ϕK^+K^-. Figure 6 shows the contribution of each component from the fit to $\phi\pi^+\pi^-$ and ϕK^+K^-. Three 0^{++} resonances, located at 980 MeV, 1370 MeV and 1770 MeV and one 2^{++} at 1270 MeV are observed in the $\pi^+\pi^-$ invariant mass spectrum recoiling against the ϕ. In $J/\psi \to \phi K^+K^-$, the dominant resonance is $f_2'(1525)$ in addition to the tail of $f_0(980)$. A further study on the shoulder of $f_2'(1525)$ is needed.

MarkIII, DM2, and BES all found a broad structure in the lower mass region of $\pi^+\pi^-$ in $J/\psi \to \omega\pi^+\pi^-$. Based on 7.8×10^6 BESI J/ψ data, BES analyzed this channel and found a 0^{++} wave to be required there.

5. FUTURE PLANS

The short term plan for the next 2–3 years is to continue running BESII, most likely to accumulate data at $\psi(2S)$ and $\psi(3770)$. The final decision will be made at the coming BES annual meeting. The long term plan for the future is the so called BESIII/BEPCII, a project to significantly upgrade both machine and detector. There are two options for the machine, that is, a single ring with multi-bunch trains, or a double ring machine using the same machine tunnel. A single ring option is expected to have a luminosity about $3\times10^{32} cm^{-2}\cdot s^{-1}$ at the J/ψ resonance. However, the luminosity provided by a double ring machine is expected to be at the level of $10^{33} cm^{-2}\cdot s^{-1}$. The upgraded machine is called BEPCII.

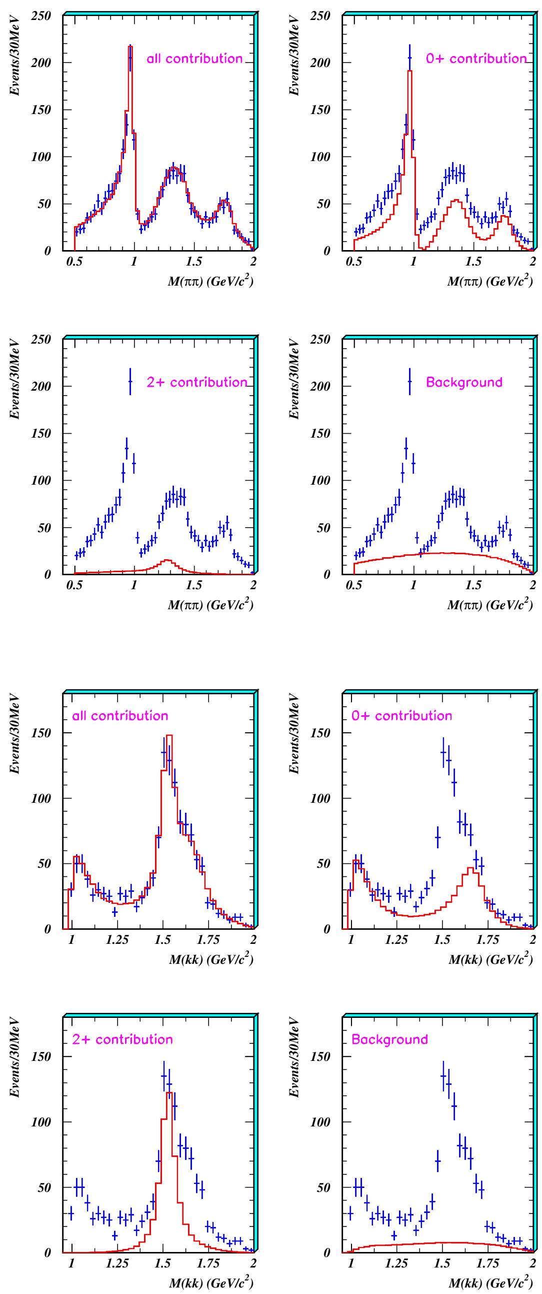

Figure 6: The mass projections of $\pi^+\pi^-$ for $J/\psi \to \phi\pi^+\pi^-$ (top 4 plots) and K^+K^- for $J/\psi \to \phi K^+K^-$ (bottom 4 plots). The crosses are data and histograms the fits.

To match the BEPCII, BESII must be significantly upgraded. Particularly the capability of particle identification and photon detection must be greatly enhanced. Currently the detector has not been well defined. One possibility is to make use of the L3 BGO crystals as an electromagnetic calorimeter (EMCAL) with a tracking chamber inside and a time-of-flight counter outside it. The muon identifier, which is outside the superconducting coil will also be rebuilt. Another possibility is to build a KLOE type EMCAL, which may provide an energy resolution of about $8\%\sqrt{E}$. In addition, new trigger, DAQ and electronics systems should be built to adapt to the new beam characteristics with high luminosity.

So far, \$40 M has been endorsed by the Chinese central government for BESIII/BEPCII, and another \$20 M is under discussion. An international review meeting was held in early April of this year for the feasibility study. The double ring machine option is strongly favored by the review committee. A proposal for the BESIII/BEPCII will be soon delivered to the Chinese funding agency. Part of the R&D work for both machine and detector has been going for half a year. The expected time for the physics run with BESIII is around the year of 2005-2006.

BEPCII, together with CESR for CLEOC [13], will be tau-charm factory machines for tau-charm physics, including the testing of QCD in the energy region between 2–5 Gev. The physics features in this energy region, as shown in Figure 7, are significant and striking, mainly: (1) many resonances and particle pairs can be directly produced at their thresholds; (2) it's a region of transition between smooth and resonance structure, between pQCD and QCD; (3) it's a region where gluonic matter, glueballs, hybrids and exotic states are considered to be located.

BESIII and CLEOC can collect data as shown in Table II.

These high statistics data samples are the best laboratory to elucidate the tricky situation in light hadron spectroscopy and offer unique opportunities for QCD studies and probing possible new physics. The major physics programs are:

1. Systematically study meson spectroscopy, $q\bar{q}$ and excited baryonic states, search for $^1P_1$, η_c', glueballs, and exotic states.

2. Study the interaction with charmed mesons and baryons, measure the absolute branching fraction of D and Ds decays, decay constant f_D, f_{D_s}, and CKM element (involving c quark).

3. Carry out a new study of the τ lepton. Such as lower the limit on m_{μ_τ}, determine m_τ to less than 1 MeV, study of τ weak current.

4. Measure the values of R to a precision of 1-3% level. Test of QCD by investigating hadronic event shape and hadron production.

5. Probe possible new physics, such as $D^0\bar{D}^0$ mixing, CP and LFV processes in τ, J/ψ, $\psi(2S)$ decays, and rare decays (like $J/\psi \to DX$, Non-SM τ decays).

6. SUMMARY

Values of R in 2–5 GeV have been improved to a precision of 6.6% by the BES collaboration. A 50 M J/ψ event sample with good quality has been accumulated with BESII. The data analysis of this data is on going. The short term future plan for BES collaboration is to run BESII for another 2–3 years. The plan for the long term

Table II Data samples collected with BESI and BESII, and maybe collected with CLEOC and BESIII.

E_{cm}(GeV)	Physics	BESI+BESII	CLEOC and BESIII
3.1	J/ψ	$7.8 \times 10^6 + 5 \times 10^7$	$10^9 - 10^{10}$
3.55	τ	$5\ pb^{-1}$	$> 10^6$
3.69	$\psi(2S)$	3.9×10^6	$10^8 - 10^9$
3.77	$\psi(3770)$		10^7
4.03, 4.14	$\tau,\ D_s^+ \bar{D}_s^-,\ D^0 \bar{D}^{*0}$	$22.3\ pb^{-1}$	10^6
4.6	$\Lambda_c \bar{\Lambda}_c$	$10^5 - 10^6$	
2-5	R scan	6+85 points (6.6%)	2-3%

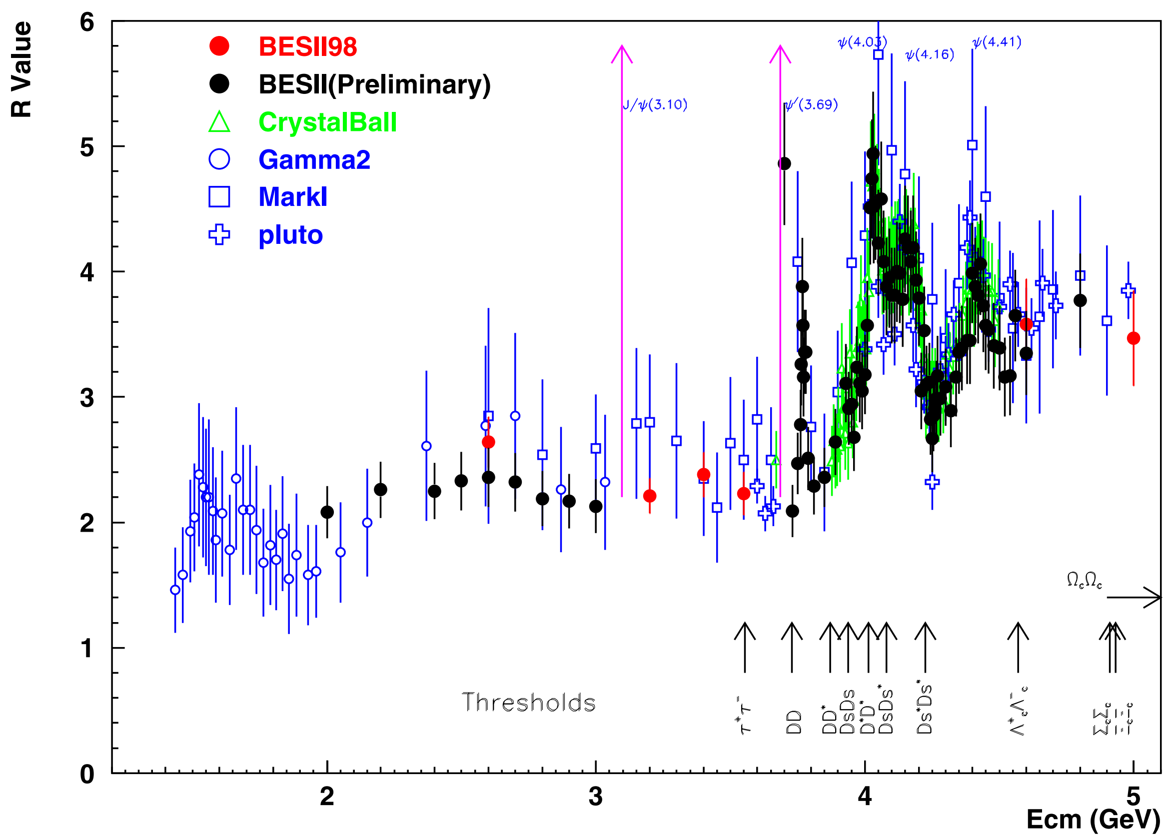

Figure 7: Physics future in 2–5 GeV.

future is to significantly upgrade both the detector (BESIII) and machine (BEPCII). Physics in the tau-charm energy region is still very rich in B-factory era. Many results need to be improved, and there are many things to be searched for. Both CLEOC and BESIII are badly needed to perform the physics in the tau-charm region. And both CLEOC and BESIII will be the eminent players and contributors to the physics in tau-charm energy region in the world in the next 5–10 years. Last but not least, it would be extremely important to have an R scan measurement from 1–3 GeV with a precision of a few percent.

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