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Status of the BESIII experiment

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Summary. — The BESIII spectrometer is hosted at the e^+e^- collider BEPCII, at the IHEP of Beijing. Since 2009, the BESIII experiment collected the world's largest data sample of J/ψ, $\psi(2\mathrm{S})$, and $\psi(3770)$, and can address a wide physics program. The possibility to access directly 1^{--} states offers a unique window to study the Standard Model and to investigate the presence of new physics. An overview of the BESIII latest results as well as the main experimental innovations will be here discussed.

1. – The BESIII experiment

BESIII [1] is an internal experiment of the e^+e^- collider BEPCII. The Beijing Electron-Positron Collider II (BEPCII) can provide instant luminosities up to $1\cdot 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, and the beam energy can be tuned according to the required center-of-mass energy, ranging from 1.0 up to 2.3 GeV. The excellent performances of the BESIII spectrometer offer the appropriate scenario to provide a high-precision measurement as well as search for new resonances. The shell-like structure of the spectrometer provides a geometrical acceptance of about 93%. From the interaction point, it is composed of a 43 small-cell, helium-based, main drift chamber (MDC), a time-of-flight (TOF) detector, and an electromagnetic calorimeter (EMC), all enclosed in a 1 T solenoidal magnetic field; the magnet iron yoke is segmented in order to host a muon chamber (MUO) system.

2. – Detector upgrade

Due to aging problems, the inner layers of the MDC are suffering from loss of efficiency. For this reason, a new inner tracker, based on three layers of cylindrical GEM (CGEM) [2,3] and shown in fig. 1(a), is going to be built and installed in the spectrometer; each CGEM layer is composed of 3 GEM foils (see fig. 1(b)). The low material budget, its high-rate capability, and its momentum resolution will allow the GEM detector to grant excellent performances. Strips are placed on the anode in order to provide x-y coordinates of the hits. The spatial resolution along the z-coordinate is expected to be sensibly increased. Charge centroid as well as μTPC techniques will be employed in order to reconstruct the hits' position. The analog readout, exploited to collect both

(a) (b)

Fig. 1. – Scheme of the three CGEM layers positions (a), and construction detail of each CGEM layer (b).

charge and time signals, implies the design and the construction of a new ASIC chip [4]. Such choice allows to reduce the strip pitch, and to handle about 10000 channels.

3. – Physics

The excellent spectrometer performances allowed to collect a huge amount of data in the charmonium region, including the world's largest data sample at the J/ψ, $\psi(2S)$, $\psi(3770)$, and $\psi(4040)$ resonance energies. Fine and coarse scans were also performed in order to access hadron, meson, and XYZ physics as well in the whole accessible region. Among all the published results some of the most significant ones were chosen, in order to characterize the spectrometer performances.

3˙1. *Dark-photon searches.* – The search for an explanation to several astrophysical anomalies, so far not completely understood in the Standard Model, is pointing towards the dark sector. One of the simplest models implies the presence of an extra $U(1)$ force carrier (the γ' dark photon) which couples to the Standard Model by means of kinetic mixing. Exploiting the data collected by the BESIII experiment at the $\psi(3770)$ and the ISR technique, reactions of the kind $e^+e^- \to \gamma'\gamma_{ISR} \to l^+l^-\gamma_{ISR}$, where $l = e, \mu$, were investigated in the energy region between 1.5 and $3.4\,\mathrm{GeV}/c^2$ [5]. An enhancement in the invariant mass distribution of the leptonic pairs would have lead to the presence of the dark photon. The main irreducible backgrounds are coming from the ISR QED processes $e^+e^- \to e^+e^-\gamma_{ISR}$ and $e^+e^- \to \mu^+\mu^-\gamma_{ISR}$. For this reason, the background distributions were deeply investigated by means of MC simulations, while the J/ψ region was escluded from this study. No peaking structure was observed, and it was possible to set an upper limit on the mixing parameter ε, which appears in the cross-section definition, between 10^{-3} and 10^{-4} as a function of the dark-photon mass with a confidence level of 90%. As shown in fig. 2(a), it was possible to exclude a certain kinematic region compatible with the one excluded by the BABAR experiment [6].

3˙2. *Muon magnetic moment.* – Standard Model predictions are extremely accurate, but in certain cases they differ from the experimental data. The high-quality of the data collected by the various experiments allows an increasing precision of the measurements. This is the case of the muon anomalous part of the magnetic moment. Quantum fluctuation as well as weak and hadronic contributions have to be taken into account in order to provide a precision measurement of the muon anomaly. The precision of the hadronic contributions limits the theoretical predictions. In this scenario, the hadronic vacuum polarization (HVP) and the hadronic light-by-light (HLBL) processes are the main hadronic effects. A discrepancy of $\alpha_\mu^{theo} - \alpha_\mu^{exp} = 27.6 \cdot 10^{-10}$ arises when comparing the prediction with the experimental data. It is worth noticing that this difference

(a) (b)

Fig. 2. – Exclusion region for the dark-photon searches (a), and comparison with the literature of the $\pi^+\pi^-$ form factor (b).

is even higher than the weak contribution. The main contribution to the HVP comes from the low-mass region, in particular it depends on pionic events. Our knowledge is limited by a 3–5% discrepancy between the KLOE [7] and BABAR [8] measurements, although they both managed to reach the sub-percent precision. By means of the data collected at $\psi(3770)$, the BESIII Collaboration implied the ISR technique in order to address the proper energy range suitable for the measurement. The cross-sections for the $e^+e^- \to \pi^+\pi^-$ [9], $e^+e^- \to \pi^+\pi^-\pi^0$, $e^+e^- \to \pi^+\pi^-2\pi^0$, and $e^+e^- \to \pi^+\pi^-3\pi^0$ final states, where the last three are preliminary results, were measured. The obtained results are compatible with the ones in the literature, as shown in the comparison of the $\pi^+\pi^-$ form factor of fig. 2(b). The discrepancy between predictions and data is not yet explained and two new experimental measurements are planned at J-PARC, in Japan, and at Fermilab, in USA.

4. – Conclusions

The charmonium energy region which can be addressed by BESIII has been proved to be very fruitful for both Standard Model tests and searches for new physics. The discoveries performed by BESIII confirm the ones in the literature and improve our knowledge on the different topics. The maximum center-of-mass energy will be increased up to 4.9 GeV in order to address the $Y(4660)$ resonance. New, larger and more precise data samples are expected for the future data taking periods, especially taking advance of the inner detector upgrade, which could provide a significant contribution to our studies.

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