BESIII

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1 The BESIII experiment

The BESIII experiment [1] is taking data at the BEPCII electron-positron collider at IHEP, Beijing. The center-of-mass energy region from 2 to 4.6 GeV offers vast and diverse physics opportunities at the boundary between the perturbative and non-perturbative regimes of QCD. Results from BESIII are expected to play an important role in the understanding of the Standard Model and will also provide important calibrations for the Lattice Gage community. Studies of tau-charm physics could reveal or indicate the possible presence of new physics in the low energy region. The experiment started data taking in 2009 and up to 2014 has already accumulated world-record samples of J/ψ(1.3B) and $\psi'(0.6B)$. About $2.9fb^{-1}$ integrated luminosity on the $\psi(3770)$ peak (3.5 times that of CLEO-c) has been accumulated for open charm physics and $3.3fb^{-1}$ in the center of mass energy range from 3800 to 4440 MeV in order to investigate XYZ states. This latter data set has allowed for the discovery of a family of charged charmonium-like structures, that should be composed of at least four quarks; the first state that has been discovered, the $Z_c(3900)^+$, has soon been confirmed by BELLE and CLEO-c. A second excited state $Z_c(4020)^+$ has been recently announced by BESIII together with their possible neutral partners; two isospin triplets have been established. In 2016 the high luminosity data for the XYZ searches have been analyzed and it has been found an indication that the Y(4260) meson is actually the superposition of the lineshapes of two different resonances. The peak luminosity of BEPCII has reached $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (that is the design value). In Feb. 2019 the experiment collected 12 billion of J/ψmesons. An upgrade of the machine will allow to reach 4.6 GeV during the next data taking. BESIII is a multi-purpose detector designed to study physics in the tau-charm energy region of BEPCII double ring electron-positron collider. The rich physics program includes:

- tests of electroweak interactions with high precision in both the quark and lepton sectors
- high statistics study of light hadron spectroscopy and decay properties
- study of the production and decay properties of J/ψ, $\psi(3686)$, $\psi(3770)$ states with large data samples and search for glueballs, quark-hybrids, multi-quark states and other exotic states via charmonium hadronic and radiative decays
- studies of XYZ states
- studies ot tau-physics
- precision measurements of QCD parameters and CKM parameters
- barion form factors measurements via ISR process and via energy scan
- search for new physics by studying rare and forbidden decays, oscillations, and CP violations in c-hadron and tau-lepton sectors.

The LNF group joined BESIII in 2009 and since 2013 is working in the upgrade of the BESIII Inner tracker (IT) with a new Cylindrical GEM (CGEM) detector. The project, among Ferrara and Turin INFN sections, also includes groups from Mainz, Uppsala and IHEP, has been recognized as a Great Relevance Project within the Executive Program for Scientific and Technological Cooperation between Italy and P.R.C. for the years 2013-2015, it has been funded by the European Commission within the BESIIICGEM RISE-MSCA-H2020-2014 project which lasted until 2018, while in 2019 it received funding within the FEST RISE-MSCA-H2020-2020 project, starting in 2020.
The group is also involved, together with the Perugia group, in the analysis of several physics processes involving baryons and light hadrons.

2 Physics analysis

2.1 Relative phase between electric and magnetic Λ form factors

By considering the decays $\Lambda \to p\pi^-$ and $\Lambda \to p\pi^+$ it is possible to measure the $\Lambda\overline{\Lambda}$ polarization in the $e^+e^- \to \Lambda\overline{\Lambda}$ process. The imaginary part of the G_E and G_M form factors of the amplitude is related to the polarization of the hyperons along the direction orthogonal to the scattering plane. Moreover this polarization is associated to the relative phase $\Delta\phi$ between G_E and G_M [2]. The BESIII measurements [3] give a relative phase of $\Delta\phi = 37° \pm 12° \pm 6°$ to be compared with the usual expectation of $\Delta\phi \simeq 0°$. The origin of this effect is under study.

2.2 Angular distributions of J/ψ and $\psi(2S)$ decays into $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$

The angular distributions for the decay of the J/ψ and $\psi(2S)$ mesons into $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$ hyperons ave different behaviors (Fig. 1). In fact the angular distribution of the decay $\psi(2S) \to \Sigma^0\overline{\Sigma}^0$ exhibits an opposite trend with respect to that of the other three channels, having a negative polarization parameter α_B. This fact has been investigated by means of an effective strong Lagrangian [4].

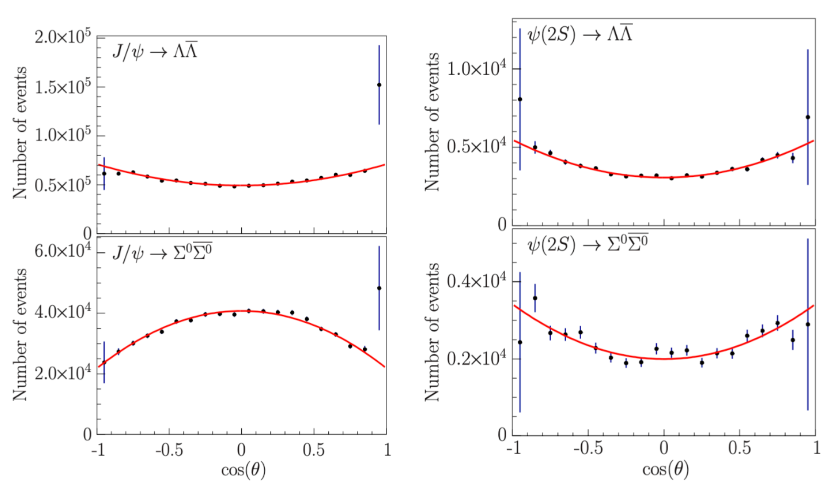

Figure 1: Angular distributions for J/ψ and $\psi(2S)$ decays into $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$.

2.3 Strong-EM relative phase in J/ψ decays into baryons

Using an effective strong Lagrangian we calculate the relative phase φ between strong and electromagnetic amplitudes for the decay of the J/ψ meson into baryon-antibaryon final states [5]. Our result is compatible with the hypothesis of orthogonality, with $\varphi = (73 \pm 8)^\circ$. This result is in agreement with other works, see Refs. [6, 7].

2.4 Strong, EM and mixed strong-EM contributions to the total BR for the J/ψ to baryon-antibaryon pairs

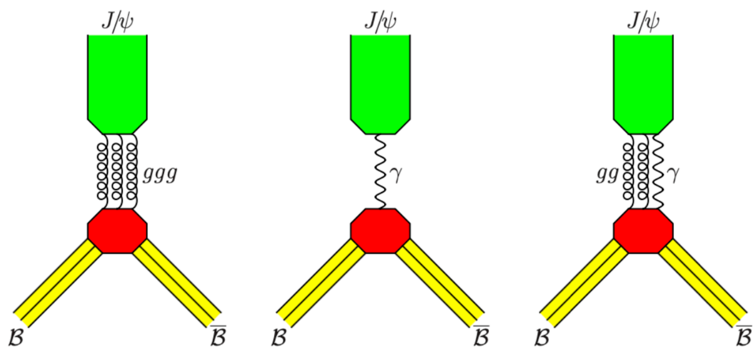

Figure 2: Feynman diagrams for the $J/\psi \to$ baryon $-$ antibaryon.

We calculate, for the first time, the strong, the EM and the mixed strong-EM contributions to the total BR of the J/ψ meson into baryon-antibaryon pairs, by using an effective strong Lagrangian [5] (Fig. 2). The ratio between the mixed strong-EM amplitude and the purely strong one has been calculated to be real and negative, as predicted by the perturbative QCD, but with a considerably different absolute value, confirming that at the mass of the J/ψ meson the regime cannot be considered completely perturbative.

3 The BESIII CGEM Inner Tracker

Based on the experience of the KLOE2-CGEM Inner Tracker, we started developing a three-layer triple-GEM detector [8] with analog readout as IT for the BESIII experiment. The analog readout is the most important improvement with respect to KLOE2, and offers the best compromise between improved spatial resolution and reasonable number of instrumented channels.

3.1 CGEM Mechanics

The beginning of the year was focused on a mechanic review of the system: the quality control and quality assurance test performed on L1 and L3 upon their arrival in Beijing last year pointed out issues on two detectors. The tests involved surface laser measurements (on L1, old L2, L3), computed tomography scan (L1, old L2, pL2, L3) and opening the detectors (old L2, L3). This review allowed us to deeply understand the criticality of the mechanical design and pointed out a problem with the vibrations during the shipment. The mechanical structure design has been upgraded by means of carbon fiber.

A new L1 was built, having anode and cathode structure built with carbon fiber and Honeycomb at LOSON company by INFN personnel, and was completed in July 2019. It was shipped to Beijing in a foam-box: upon arrival the visual inspection gave a confirmation of success, it was able to hold operational HV immediately, at present it is taking cosmic ray data together with the previously shipped L2. The new L3, almost completed in December 2019, suffered of a construction problem in the insertion phase: GEM3 and the anode were on the vertical inserting machine, glued on one side. Once the GEM3 aluminum cylinder was removed, during the inspection, the internal surface of the GEM3 showed deformations.

The permaglass ring on which GEM3 is glued has been accounted for the imperfection: the value of its diameter was on the borderline, and, also due to the tight schedule, we thought to be able to recover with a thicker layer of glue. The operation looked successful, no waves or distortions while the foil was on the aluminum cylinder. Unfortunately, the tension on the foil, caused by the squeezing of the GEM-3 by the smaller ring, came out once the cylinder was removed in the vertical insertion machine. At that point it was too late: anode and GEM-3 were already glued together, so that we had to reject both these electrodes, and decided to rebuild GEM3 and anode.

3.2 CGEM operations

The first final detector (middle layer) arrived in Beijing in February and for few months some tests on it have been performed. Starting from the quality control and quality assurance protocol to check its status after the shipment, going on with the front-end equipment and setting up a stand-alone cosmic stand. During spring the damaged inner layer has been used assembled with the new layer to go on with the commissioning of the electronics. Checks on the instrumentation and test on groundings have been done during this period to improve the performances of the final detector while waiting for the other two final layers in construction in Frascati.

Once the new layer 1 arrived, the same protocol have been followed to check its status after the shipment. After it was setup with the full readout system, it have been tested alone on a cosmic stand to improve the grounding. In December the two layer have been assembled together to go on with the integration while waiting the last, external, layer in the new year.

The old layer 1 has been installed in the BESIII experimental hall to perform electronics noise studies.

3.3 New production of HV-LV cables

In 2019 a new production of both LV and HV cables has been carried out to satisfy both the increase of Layer 3 macro-sectors (from the 8 of the previous design to 12) and the requirement of other spare cables. A total amount of 42 cables has been produced and qualified.

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