BESIII

R. Baldini Ferroli (ass.), M. Bertani (Resp.), A. Calcaterra, S. Cerioni (tec.), G. Felici, M. Gatta (tec.), A. Mangoni (Perugia), E. Pace, S. Pacetti (Perugia), E. Paoletti (tec.), G. Papalino (tec.), P. Patteri, A. Orlandi (tec.), A. Zallo (senior res.)

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 playing 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 has already accumulated world-record samples of J/ψ(1.3B) and $\psi'(0.6B)$. Data in the center of mass energy range from 3800 to 4440 MeV 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 Zc(3900)+, has soon been confirmed by BELLE and CLEO-c. A second excited state Zc(4020)+ has been recently announced by BESIII together with their possible neutral partners; two isospin triplets have been established.

During 2019 shutdown BEPCII has been upgraded with top-up luminosity mode (allowing 30% increase in luminosity) and the maximum beam energy has been extended from 4.6 Gev to 4.7 GeV. A peak luminosity of $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (that is the design value) has been reached. 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, started 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

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.

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 $\varphi = (73 \pm 8)°$. This result is in agreement with other works, see Refs. [6, 7].

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

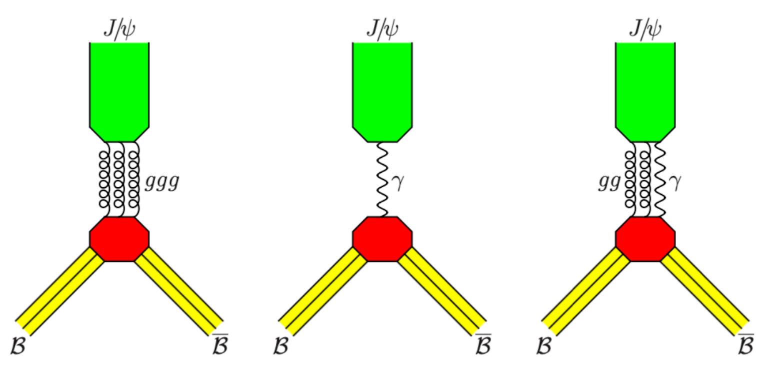

Figure 1: Feynman diagrams for the $J/\psi \to$ baryon $-$ antibaryon.

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.

Amplitudes separation and strong-EM relative phase in the $\psi(2S)$ decays into baryons

Using the available data from the BESIII collaboration and the PDG we separate, for the first time, the strong, EM and mixed strong-EM amplitudes of the $\psi(2S)$ meson decays in baryon-antibaryon pairs, using a model based on an effective Lagrangian [8]. We show that at the mass of the $\psi(2S)$ meson the QCD regime is not completely perturbative, similarly to the case of the J/ψ meson.

The cross section of $e^+e^- \to \Lambda\overline{\Sigma}^0 + \text{c.c.}$ as a litmus test of isospin violation in the decays of vector charmonia into $\Lambda\overline{\Sigma}^0 + \text{c.c.}$

Assuming the isospin conservation, the amplitudes of the decay $\psi \to \Lambda\overline{\Sigma}^0 + \text{c.c.}$ and of the reaction $e^+e^- \to \Lambda\overline{\Sigma}^0 + \text{c.c.}$ at the ψ mass, where ψ is a vector charmonium, can be parametrized using the same electromagnetic amplitude. We found that in the case of $\psi = \psi(2S)$ there is a substantial discrepancy between the two values of the modulus of such an electromagnetic amplitude extracted from the branching ratio and the cross section. Assuming the reliability of the experimental branching fraction, we propose the presence in the decay amplitude of an isospin-violating contribution as a possible explanation for this discrepancy [9].

Analysis of $e^+e^- \to J/\psi \to \omega\pi^0$

Using recent data from BESIII we analyze the cross section of $e^+e^- \to \omega\pi^0$ at $q^2 = M^2_{J/\psi}$. From a theoretical point of view, the J/ψ meson has negative G-parity hence the decay into $\omega\pi^0$ should be purely electromagnetic, in the limit of isospin conservation. We can compare the total branching ratio with the electromagnetic one to investigate for the presence of a mixed strong-electromagnetic contribution, as done in the case of $J/\psi \to \pi^+\pi^-$, see Ref. [10].

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 [11] 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 Construction of new L3 in LNF clean room

At the end of year 2019 we had to suspend the construction of the final Layer 3 (L3) because a tolerance defect in a vetronite ring had caused deformation of GEM3 after gluing it to the anode foil: after investigation, we decided to abandon both cylinders, Anode and GEM3, due to the impossibility to remove the glue.

New sets of anode foils, GEM3 ones, and gluing rings were ordered immediately but, due to the onset of COVID-19 related sanitary problems, they were received only in the late spring of 2020, just in time to run the electrical tests (successfully) on the new GEM3 foils.

After the summer, although in a situation of reduced manpower, we managed to build the new Anode and GEM3 cylinders, and completed the new L3 without apparent problems. During 2021 this L3 will undergo tests of gas tightness, and its behaviour under HV will be tested completely before shipment to Beijing.

References

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