BESIII

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1 The BESIII experiment

BESIII is a multi-purpose detector operating at the e^+e^- storage ring BEPCII at the Institute of High Energy Physics, IHEP, in Beijing. The machine is the only one currently running in the center-of-mass energy range $\sqrt{s} \approx 2 \div 4.6\,\mathrm{GeV}$. It has recently achieved the design luminosity of $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and up to now it has collected the world largest samples of J/ψ, $\psi(3686)$, $\psi(3770)$, $\psi(4040)$, $Y(4260)$ and $Y(4360)$.

The LNF group is working since 2013 in the upgrade of the BESIII Inner tracker (IT) with a new Cylindrical GEM (CGEM) detector. The project, that since 2014 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 and it is being funded by the European Commission within the call H2020-MSCA-RISE-2014 which will last until 2018.
The group is also involved, together with the Perugia group, in the analysis of several physics processes involving nucleons and light hadrons.

2 Physics analysis

2.1 G-parity violation in some J/ψ decays

The J/ψ meson has negative G-parity hence, in the limit of isospin conservation, the decay into $\pi^+\pi^-$ should be purely electromagnetic. However, the measured branching fraction $BR(J/\psi \to \pi^+\pi^-)$ exceeds by about 5 standard deviations the expectation computed according to BABAR data on the $e^+e^- \to \pi^+\pi^-$ cross section [1]. The possibility that the two-gluon plus one-photon mechanism, usually neglected, could be responsible for such a high branching fraction has been discussed [2], and a phenomenological model to quantify its contribution has be proposed [3].
A new measurement of the $e^+e^- \to \pi^+\pi^-$ cross section in the J/ψ mass energy region is under way in BESIII. Preliminary results seem to corroborate such a "strong" (because due to a gluonic intermediate mechanism) G-parity violation, by confirming BABAR data.
The same phenomenological model [3] has been used to compute the strong G-parity-violating contribution in the decay $J/\psi \to K^+K^-$. The obtained value, compatible with zero, is in agreement with the expectations, that are inferred by comparing the rates of $J/\psi \to K^+K^-$ and $J/\psi \to K_S K_L$ decays.

2.2 Relative phase of electric and magnetic Λ form factors

The self-analysing weak decays of Λ hyperons into protons and pions, namely, $\Lambda \to p\pi^-$ and $\overline{\Lambda} \to \overline{p}\pi^+$, allow to measure hyperons polarization in the annihilation process $e^+e^- \to \Lambda\overline{\Lambda}$. The amplitude of this process, at

Born level, depends on two form factors, G_E^Λ and G_M^Λ, that are complex scalar functions of q^2, the squared-four-momentum transferred of the virtual photon. It is just the complex nature, namely the imaginary part, of the form factors that determines a polarization of final hyperons along the direction orthogonal to the scattering plane. On the other hand, by measuring such a polarization, is it possible to access the relative between $G_E^Ł$ and $G_M^Ł$, i.e., $\Delta\phi = \arg\left(G_E^\Lambda/G_M^\Lambda\right)$ [4]. The usual expectation is $\Delta\phi \simeq 0^o$, being the relative phase zero at the threshold, where $G_E^\Lambda = G_M^\Lambda$, and expecting the form factors being asymptotically real.

The still preliminary BESIII measurement gives, instead, $\Delta\phi \simeq 45^o$ at $\sqrt{q^2} = 2.396$ GeV, about 165 MeV away from the λ production threshold.

Inspired by a similar behavior that proton form factors seems to follow [4], we are studying the possibility that such a value of $\Delta\phi$ could be due to presence of a zero for the Ł electric form factor in the space-like region, i.e., for negative q^2's.

2.3 Dynamics of the $J/\psi \to \gamma p\overline{p}$ decay

The $p\overline{p}$ invariant mass distribution of the $J/\psi \to \gamma p\overline{p}$ decay shows a pronounced enhancement towards the threshold [5], that is interpreted either as the tail of a below threshold resonance or as a final state interaction. Recently BESIII presented the measurement, still preliminary, of the differential decay rate of $J/\psi \to \pi^+\pi^-e^+e^-$ [6]. By following the same procedure developed for the similar process $\phi \to e^+e^-\pi^0$ [7], where the initial vector meson is a strageonium $s\overline{s}$ instead of charmonium $c\overline{c}$, and the π^0 plays the role of the would-be resonance decaying into $p\overline{p}$, we plan to study the dynamics of the decay by connecting all available data on the crossed processes, to shed light on the nature of the enhancement.

2.4 Angular distributions of $J/\psi \to \Lambda\overline{\Lambda}$ and $J/\psi \to \Sigma^0\overline{\Sigma}^0$

The measured baryon-antibaryon angular distributions in the decays $J/\psi \to \Lambda\overline{\Lambda}L$ and $J/\psi \to \Sigma^0\overline{\Sigma}^0$ have different behaviors, being $\propto \cos^2(\theta)$ and $\propto \sin^2(\theta)$, respectively. This particular feature is not seen in the $\psi(3686)$ decay, where for both channels the angular distribution in $\propto \cos^2(\theta)$.

We are investigating this phenomenon by considering, for the two J/ψ decay channels, different D-wave contributions. In particular, these contributions are given by different flavor-SU(3) breaking effects.

Different Λ and Σ^0 angular distributions can be explained using an effective model with the SU(3)-driven Lagrangian $\mathcal{L}_{\Sigma\Lambda} = (G_0 + G_1)\Sigma^0\overline{\Sigma}^0 + (G_0 - G_1)\Lambda\overline{\Lambda}$. The interplay between leading G_0 and sub-leading G_1 contributions to the decay amplitudes determines signs and values of polarization parameters for the two mesons J/ψ and $\psi(3686)$. Furthermore this structure is related the G_E^Λ and G_M^Λ contribution to the total BR.

2.5 Measurement of $\psi(3686) \to N\overline{N}$

As a byproduct of this measurement, it has been found that $\psi(3686) \to p\overline{p}$ and $\psi(3686) \to n\overline{n}$ angular distributions are not compatible within the experimental errors, pointing again to a G-parity violating amplitude in $\psi(3686) \to p\overline{p}$. This amplitude would interfere negatively with the G-parity conserving amplitude, and have the same order of magnitude as the one found in the $J/\psi \to \pi^+\pi^-$ decay mode. Since the sign of the G-parity violating amplitudes in decays of ψ's into baryon-antibaryon pairs depends on the baryon charge, estimates of the strength of such amplitudes can be done by measuring the difference between the angular distributions of $\psi(3686) \to \Sigma^-\overline{\Sigma^-}$ and $\psi(3686) \to \Sigma^+\overline{\Sigma^+}$.

3 The BESIII CGEM Inner Tracker

3.1 Construction in LNF Clean Room

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. In 2017 the first layer L1 has been constructed in all five cylinders and assembled with the Vertical insertion Machine (VIM), moreover the five cylinders of the new L2 have been constructed.

- The first months of 2017 have been employed in assembling the 5 separate cylinders forming Detector Layer 1 (L1), the smaller of the 3 layers. During this construction the new procedures devised during construction of L2 prototype in 2016 were actually employed and found very satisfactory. They were of 2 kinds: one stage of additional sealings around critical inside boundaries of L1 components was proven to be very effective in ensuring the gas tightness of L1; and a special supporting structure in the Vertical Insertion Machine, used during detector assembly, was also extremely helpful to hold L1 elements in precise positions during assembly and glueing.
- L1 was then equipped with HV connections and electronics, finished in June 2017, and underwent a beam test at CERN in July. It is now taking data since many months in a cosmic-ray setup in Ferrara, waiting for final shipment at IHEP in Beijing.
- As for layer L2, all the 5 cylinders have been constructed in the second half of 2017, but an accident occurred in December while getting ready for final assembly with the Vertical Insertion Machine: one anode strip was broken in an un-repareable way, so that it was decided not to use it and to do a new anode that was immediately procured at CERN.

3.2 High and Low voltage systems

The CGEM IT High Voltage distribution system has been developed by the LNF SEA group. The system allows to supply independently all the macro/micro sectors of the three CGEM layers, with the possibility to disconnect a single micro-sector in case of local discharges. The system is made of an active section to generate the single layer seven main voltages, and a passive section to distribute each voltage to the required lines.

In 2017 we have designed and started the production of the BES IT LV distribution chain. The system, designed to supply 80 TIGER boards requiring 1.08A@1.4V and 0.32A@2.5V each, is made of two sections: the main power supplies for both on-detector and off-detector electronics. The section is located in the experiment area (5 m far from GEMROC modules). They are made of two SY5527 BASIC (600W) mainframe. Each mainframe is instrumented with two LV A2519 (GEMROC PS) and two A2517 boards each (TIGER boards PS). The on-detector (TIGER boards) power supply chain foresees three interconnections:

1. Main power supply GEMROC modules (5 m four cores 12 AWG shielded cables)
2. GEMROC - LV-PATCH boards (10 m four cores 17 AWG shielded cables)
3. LV-PATCH TIGER boards (1 m seven cores 24 AWG unshielded)

Single channel on/off and voltage/current monitor are managed by the Experiment Slow Control system.

Besides the HV system, LNF is in charge of the readout anode design: on each circuit, a "foil" made of flexible PCB, we implemented a pattern of X and V strips of 650 um pitch, routed to the readout connectors. The final version of the L3 anode to be cosntructed in 2018 has been designed.

References

1. J. P. Lees *et al.* (BABAR Collaboration), Phys. Rev. D **86**, 032013 (2012).

2. R. B. Ferroli *et al.*, arXiv:1608.07191 [hep-ph], Phys. Rev. D **95**, 034038 (2017).

3. R. B. Ferroli, A. Mangoni and S. Pacetti, arXiv:1611.04437 [hep-ph].

4. S. Pacetti, R. Baldini Ferroli and E. Tomasi-Gustafsson, Phys. Rept. **550-551**, 1 (2015).

5. M. Ablikim *et al.* [BESIII Collaboration], Phys. Rev. Lett. **108**, 112003 (2012) [arXiv:1112.0942 [hep-ex]].

6. Shihai Zhu and Tao Luo (BESIII Collaboration), "Study of $J/\psi \to e^+e^- p\overline{p}$", presented at the "Light hadron" Group Meeting, Decembertg, 2017.

7. S. Pacetti, Nucl. Phys. A **919**, 15 (2013) [arXiv:0904.3684 [hep-ph]].

8. The BESIII Collaboration, "Conceptual Design Report: BESIII Cylindrical GEM Inner Tracker" (2014).

9. A.Amoroso et al (BESIII CGEM group), "A Cylindrical GEM Inner Tracker for the BESIII experiment" , Il Nuovo Cimento **39** C (2016) 261.