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 has been selected as one of the projects funded by the European Commission within the call H2020-MSCA-RISE-2014.

The group is also involved in the analysis of several physics processes involving nucleons and light hadrons.

2 Measurement of the vector quarkonium relative phase φ, between strong and electromagnetic decay amplitudes

Using scan data collected by BESIII, all the J/ψ decay modes phases φ measured up to now are consistent with 90^o, so that strong and electromagnetic decay amplitudes do not interfere. There is still some tension in the measurement of the $J/\psi \to K^+K^-$ branching ratio, likely due to uncertainties on the ISR corrections, and to uncertainties on the continuum interference, related to the unknown sign of φ. To avoid these uncertainties we intend to make another independent measurement using the large $\psi(3686)$ sample collected by BESIII, analyzing the decay chain $\psi(3686) \to \pi^+\pi^- J/\psi$ with $J/\psi \to K^+K^-$ decay, that does not depend on ISR and continuum interference.

Present data on $\psi(3686)$ hadronic decays are not consistent with a common 90^o phase, some are better described by a 180^o phase. Moreover, an estimation of the phase in the bottomonium decay $\Upsilon(1S) \to K^*K$ (charged and neutral)similar G-parity violating amplitude is observed in J/psi-¿ KK. has been done by us, resulting in $\varphi = (143 \pm 20)^o$. To investigate further, a $\psi(3686)$ scan has been proposed and it will be performed in the Spring of 2017.

3 G-parity violation in some J/ψ decays

The J/ψ meson has negative G-parity and, in the limit of isospin conservation, its decay into $\pi^+\pi^-$ should be purely electromagnetic. However, the measured branching fraction $BR(J/\psi \to \pi^+\pi^-)$ exceeds by more than 4.5 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 decay mechanism is not suppressed by $G-$parity conservation has been discussed, considering also other multi-pion decay channels. In the context of phenomenological computation, such a decay mechanism could be responsible for the observed discrepancy. Finally, we notice that the BESIII experiment, having the potential to perform an accurate measurement of the $e^+e^- \to \pi^+\pi^-$ cross section in the J/ψ mass energy region, can definitely prove or disprove this strong G-parity-violating mechanism by confirming or confuting the BABAR data. Moreover, present data on $J/\psi \to K^+K^-$ and K_SK_L described above could be interpreted in terms of G-parity violating amplitude. The future BESIII $\psi(3686)$ scan should clarify this subject.

This study, with substantial contribution by Frascati-Perugia collaborators, has been submitted to Physical Review Letters in 2016 and published [2] at the beginning of 2017 by a subset of the BESIII collaboration.

4 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 $\psi(3686) \to \Sigma^+\overline{\Sigma^+}$.

5 The BESIII CGEM Inner Tracker

Based on the experience of the KLOE2-CGEM Inner Tracker, we started developing a three-layer triple-GEM detector [3] 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 2015 the first BESIII CGEM layer, L2, has been build at LNF, while 2016 has been devoted to its instrumentation and tests:

- it has been thoroughly checked for gas leaks, worrysome for a construction essentially composed of various plastics: many small leaks were found, by closing the L2 gas circuit on a pressure sensor, and blowing N2 gas at small pressure over the surface. Small leaks were evidentiated by a sudden increment of the pressure sensor reading, and fixed by the application of small quantities of glue. At the end of March, L2 was essentially leakless, but the number of points that had to be fixed led us to study changes in the gluing procedure, improvements to be implemented for the next layer.

- Instrumentation of the leakproof L2: all HV connections were made, using small printed circuit boards. These HV boards, very similar to those made for KLOE, unexpectedly showed of difficult attachment. The problem was due to different geometries: BESIII cylinders have a greater curvature with respect to KLOE, and the HV boards, being plane and of the same size as KLOE ones, are a worse match to the curvature. Solving this problem required design and construction of plastic brackets with a 3D printer, to be fixed on top of the HV boards with small plastic screws.

- The signal connections were made. In this case, since the final BESIII electronics is in the design stage, we had to recourse to a temporary one, designed and made at CERN. This temporary electronics does not match the signal connectors on L2, and an intermediate "transition" board, designed and produced in 2015, had to be connected to L2, in spite of some interference with the above mentioned HV additional holding brackets.

- From May to September, L2 was run in cosmic rays (fig. 1), and in October a beam test at CERN was performed. An analysis of the data taken at CERN is currently in progress, and will show the performance of L2 in terms of resolution and efficiency. Preliminarly it can be said that the cylinder performances are compatible with the results of the planar prototypes previosly tested [4].

- 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.

  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. We designed in 2016 a first version of the L2 anode (to be redone in 2017 because of changes in the kapton support foil) and the final version of the L1 anode.

Construction of L1 and L3 has been during 2016 seriously hampered by unavailability of GEM foils from CERN. GEM foils having been a great success in the field of High Energy detectors, the CERN atelier has had to front a very exceptional and completely unexpected flow of orders. This has induced the CERN management to a change of policy: the CERN atelier will be reserved only for CERN-based experiments; all others, including BESIII, will be produced at a factory set up in Poland. This factory has unfortunately shown in the first months to be unable to produce GEM of the needed quality with the expected yield, and only at the end of 2016, after many improvements, is getting nearer to the goal.

Given the very tight time schedule for BESIII installation in Summer 2018, and the failing of the first attempts in Poland, we have been able to convince the CERN atelier to waive CERN policy for this time, and dedicate the month of February 2017 to production of our GEM foils.

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. The BESIII Collaboration, ”Conceptual Design Report: BESIII Cylindrical GEM Inner Tracker” (2014).
4. A.Amoroso et al (BESIII CGEM group), ”A Cylindrical GEM Inner Tracker for the BESIII experiment” , Il Nuovo Cimento **39** C (2016) 261.

Talks given by LNF members:

1. M.Bertani, Seminario al Dipartimento di Fisica dellUniversit di Perugia, La fisica di BSIII, risultati inattesi?.
2. G.Morello, XYZ studies at BESIII, 54th International Winter meeting on Nuclear Physics a Bormio.
3. P.Patteri, Fattori di forma di barioni e padroni leggeri IFAE2016, Nuovo Cimento C Colloquia on Physics.
4. P.Patteri, SIF 2016, Form factor of baryons and light hadrons at BESIII: recent results and next program.
5. G.Morello, P.Patteri SIF 2016, The CGEM detector for BESIII.

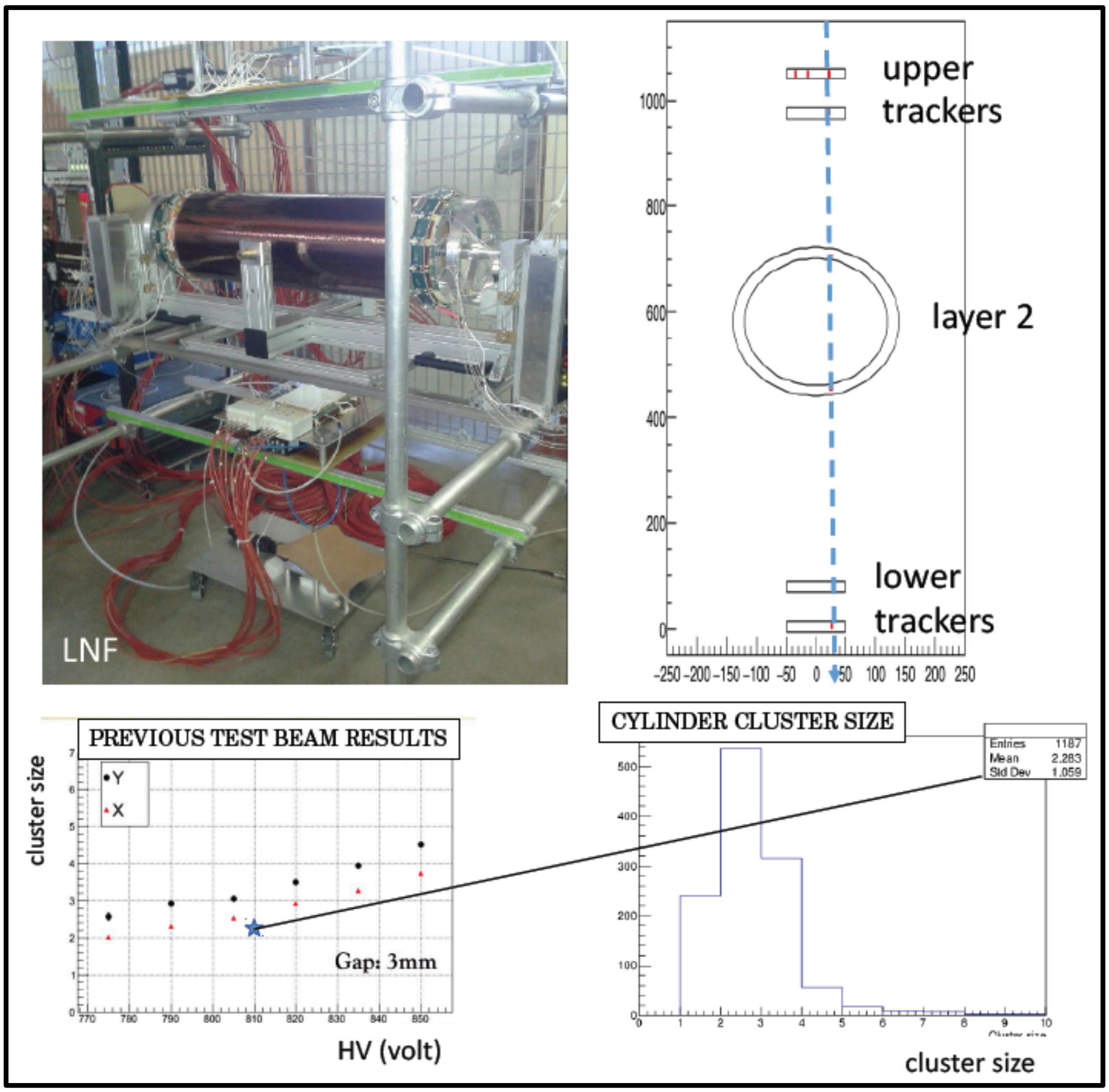

Figure 1: Cosmic ray test setup in Frascati with L2(top-left), track reconstruction through L2 (to-right), and cluster size comparison between plane chambers (bottom left) and cylinder (bottom right).