BESIII

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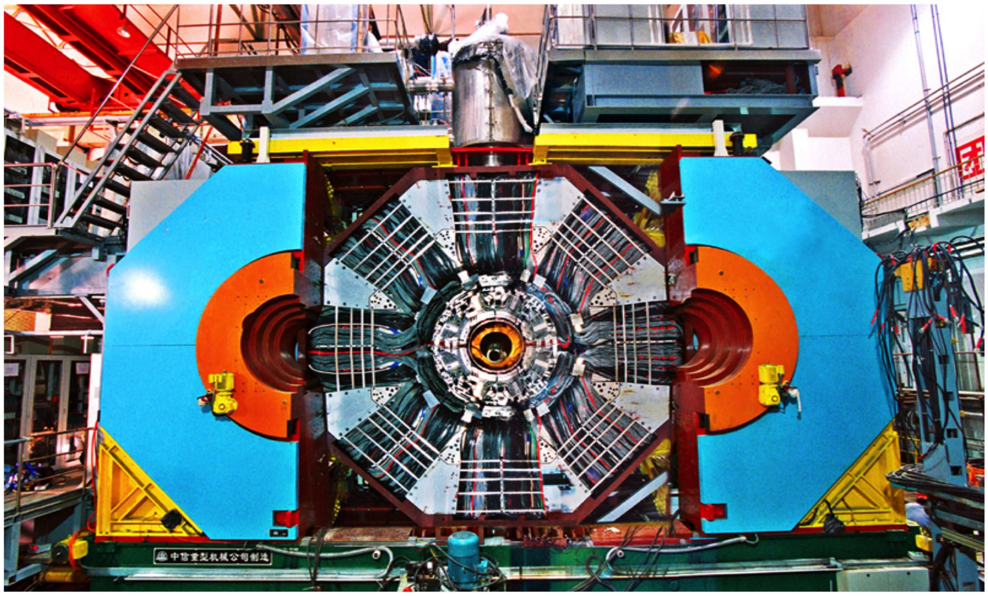


Figure 1: Overview of BESIII detector

1 The BESIII experiment

The BESIII experiment is taking data since 2009 at the Beijing Electron Positron Collider BEPC-II, at the Beijing Institute of High Energy Physics, IHEP. The BESIII detector, shown in fig. 1, is designed to study the τ-charm physics. The first physics event was observed on July 19, 2008. So far BESIII collected the world largest samples of J/ψ, $\psi(3686)$, $\psi(3770)$ and $\psi(4040)$. The actual maximum instantaneous value of the luminosity reached is 0.6×10^{33} cm^{-2} s^{-1} and the goal is to reach the goal value of 10^{33} cm^{-2} s^{-1} by 2013.
The LNF group joined the BESIII collaboration at the end of 2009 and has the full responsability of the detector for zero-degree photon tagging, ZDD, which was installed at BEPCII on 2011. In 2012 the group started to work on the proposal to upgrade the Inner BESIII tracking chamber with a Cylindrical GEM detector. They are involved in the physics analyses of processes mainly involving nucleons or light hadrons.

2 The zero degree detector

2.1 The initial state radiation technique

At τ-charm and b factories e^+e^- annihilation processes to hadrons can be investigated by means of the so-called initial state radiation technique (ISR). Such a technique consists in measuring

the reaction $e^+e^- \to H\gamma$, where H is a hadronic final state and the photon is emitted by one of the initial electrons. The differential cross section for this process is proportional to the direct $e^+e^- \to H$ cross section. The proportionality factor, the *radiator* function, gives the probability for the initial photon emission and can be computed to an accuracy better than 1%.
The angular distribution of the ISR photon in the center of mass (CoM) frame is peaked at small angles. Indeed the fraction of photons in the main detector, which has a typical geometrical acceptance $20^o \leq \theta \leq 160^o$, is lower than 20%. The possibility of measuring the small-angle photons, even in a few milliradians cone around the beam line, would increase the ISR acceptance by almost a factor of two.

2.2 The ZDD

The proposed ZDD is made of two simmetric detectors ($\mathrm{ZDD_E}$ and $\mathrm{ZDD_W}$) located in two areas close to the beam line, about 3 m away in the East and West direction from the BESIII detector. They will be used to tag the ISR photons and measure their energy, and also to replace the present BESIII luminometer. Each detector is made of two modules $4 \times 6 \times 14$ cm^3, one "upper" and one "lower". The modules are composed by the same material used for the KLOE electromagnetic calorimeter: a mixture of scintillating fibers (60% of volume) embedded in a Pb matrix (40%), with the fibers oriented vertically direction, as shown in Fig. 2.

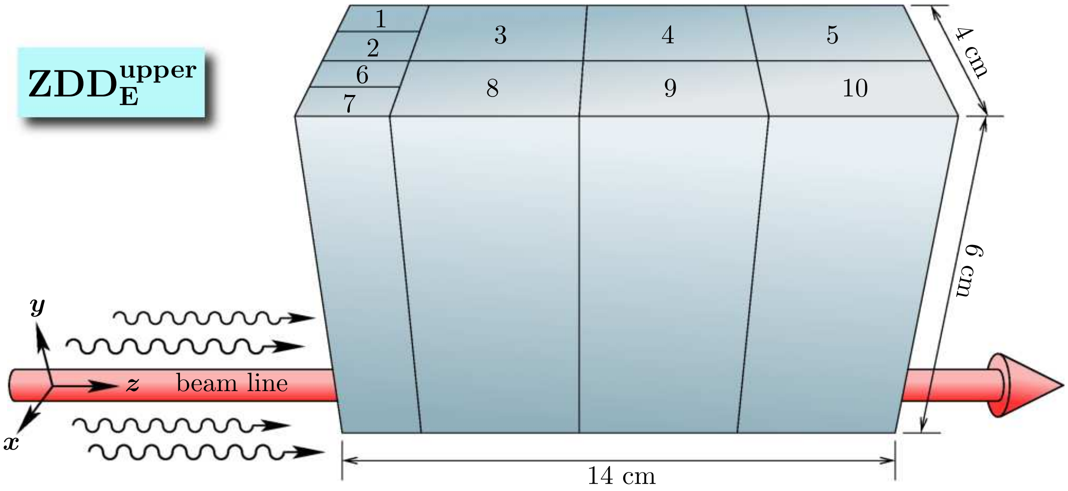


Figure 2: Upper module of the ZDD detector. The segmentation on the upper face indicates the ten reading sectors. The red arrow shows the direction of ISR (and Bremsstrahlung) photons. The lower module (not drawn) is located below the red arrow.

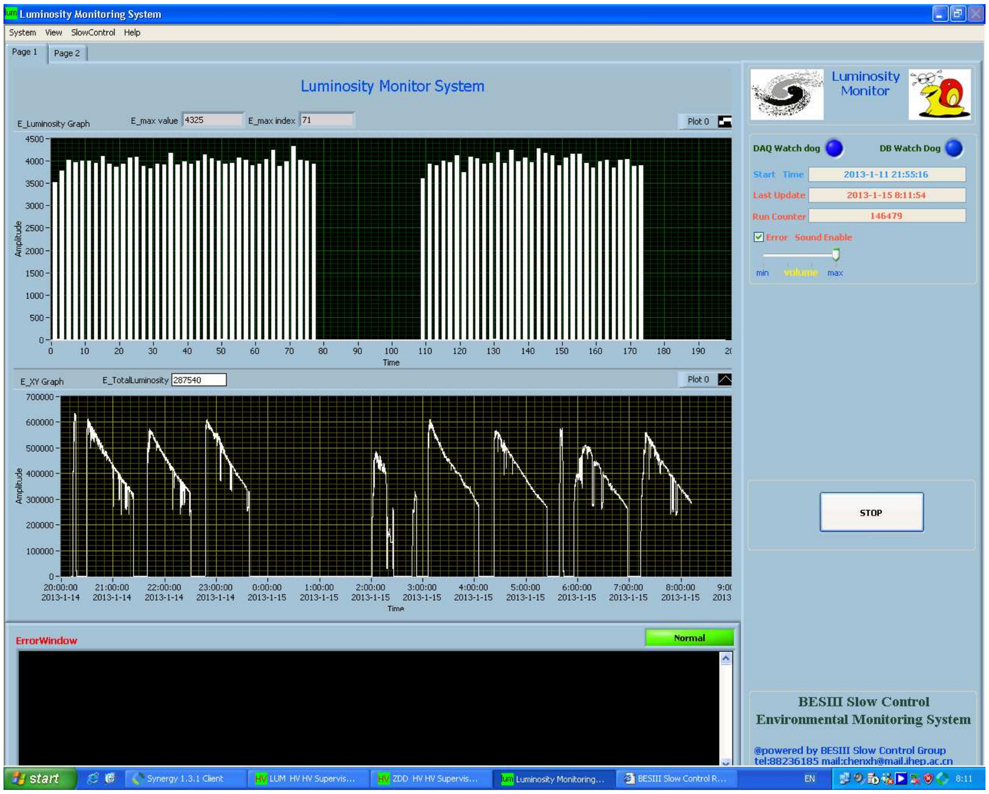
To avoid the severe background due to Bremsstrahlung photons produced in the process $e^+e^- \to e^+e^-\gamma$, which populate the very small polar angle region, the upper and lower modules of each ZDD station are separated by an empty space 10-mm wide along the vertical direction, so as to move each module approximately 5 mm away from the equatorial plane of the machine, on opposite sides. In this way, and considering that the angular distribution of Bremsstrahlungby photons is much narrower than the one for ISR photons, a big reduction of background is obtained, at the price of a small (additional) inefficiency for the ISR signal.

The scintillation light is channeled by bundles of clear optical fibers 2 m long to photomultipliers Hamamatsu H10828, that have a very fast response, and are selected to have uniform gains of $\sim 10^6$ at 1500 V. The PM signals are fed into preamplifiers ($\times 2$) located close to the experimental

area and sent, via RG58 cables 20 m long, to shaper, splitter and discriminator circuitry located in the BESIII DAQ crates.
The preamplifiers, as well as the readout electronics, are a project and realization of the "SELF" group of the LNF.

2.3 The ZDD as a luminometer

As previously said, the ZDD may be used in a parasitic way as a luminometer, giving a fast measurement of beam-to-beam relative BESIII luminosity via instantaneous rates of appropriate sums of channels. The signal used currently by BEPC-II is the analogic sum over the first 8 segments in the first layer impacted, 4 of which are shown in Fig. 2 with numbers 1–2–6–7. Fig. 3 shows a sample of ZDD data under this respect.



E_max value 4325
E_max index 71
E_TotalLuminosity 287540
Start Time 2013-1-11 21:55:16
Last Update 2013-1-15 8:11:54
Run Counter 146479
☑ Error Sound Enable

Figure 3: The ZDD as a luminometer. The top plot indicates the counting rates for the ZDD signal (see text) in 175 successive RF buckets (some buckets are empty).

2.4 ZDD upgrade

The photon impact point on the ZDD is largely unknown, and this affects adversely the energy resolution. One way to alleviate this is the 4-fold segmentation of the first layer, that could be used to obtain the impact point by some average of the energy partition between the 4 front channels.

Another method, for that fraction of photons that convert in the beam pipe, and hit the ZDD as a very close electron/positron pair, would be to use a system of very small scintillators.

Such a system, complete with its readout, has been almost completely readied in 2012, and will be installed as a ZDD upgrade in 2013.

Fig. 4 shows the finger array, currently under test at LNF. The array is read out by a Hamamatsu H7546A-200 multianode PM, and the frontend electronics is a project of INFN-SELF.

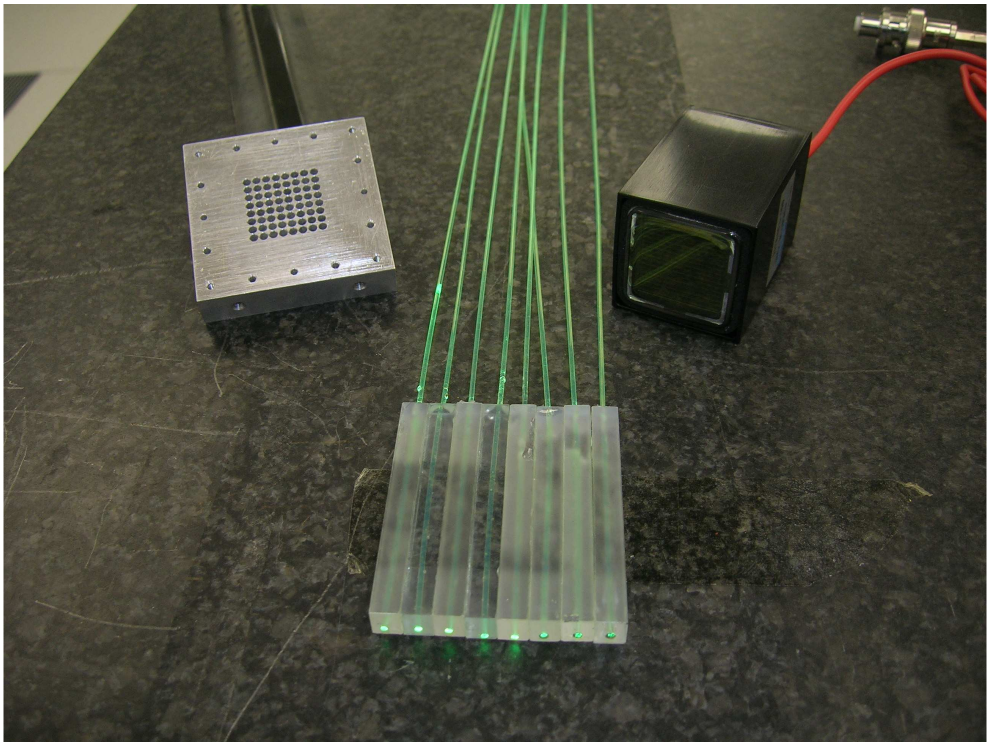


Figure 4: The finger array for measuring the impact point on the ZDD of (converted) ISR photons. Each indipendent scintillator, coupled to its own fiber, has dimensions 5x5x50 mm^3.

3 Proposal for the study of a BESIII inner tracker with Cylindrical GEMs

During the 2012 BESIII run it appeared that the increased backgrounds consequent to an increase in BEPC-II luminosity were starting to induce aging problems in the inner Drift Chamber, that is a physically separate section of the BESIII cylindrical Main Drift Chamber(MDC) carrying 8 layers of stereo wires very close to the beam, at radii from about 8 cm to about 18 cm. Since the BEPC-II is expected to further increase luminosity over the next 5 years of running, it was decided to investigate solutions alternative to the construction of a new inner Drift Chamber: the GEM (Gas Electron Multiplier) technique, already used at LNF for the KLOE2 Vertex Detector, looked very promising from the points of view of rate capability and radiation hardness.

In July 2012 INFN has encouraged and allowed the BESIII-Italy collaboration to ask the Ministry for External Affairs (MAE) cofinancing for a 3-year project destined to produce a finished layer of cylindrical detector, employing for the first time the technique of analog readout of cylindrical GEMs. This detector must have a radius and length adequate for forming in the future part of a multilayer device, should the BESIII Collaboration approve the use of GEMs in the detector.

In this connection, a workshop dedicated to cylindrical GEMs detectors was organized and held in LNF in the month of October, seeing participation by BESIII and KLOE2 physicists, and interested personnel from Russia and other countries.

In January 2013 the MAE has approved the project for participation in the Executive Programme and we have submitted an application for cofinancing the first year: an answer from MAE is expected by the end of March 2013.

4 Physics analysis

4.1 Study of $J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$

The decay of the J/ψ meson to a nucleon-antinucleon pair represents a good testbed for studying perturbative QCD. The $J/\psi \to N\overline{N}$ amplitude has a strong (QCD) and an electromagnetic (EM) contribution. The strong amplitude accounts for the lowest order QCD diagram where the decay is mediated by three gluons that produce the $N\overline{N}$ final state via single gluon-quark-antiquark vertices. The EM amplitude, instead, describes the $N\overline{N}$ production though one-photon exchange. Since the J/ψ meson has isospin zero, the strong amplitudes for decays in $p\overline{p}$ and $n\overline{n}$ should be the same. The EM amplitudes for protons and neutrons scale with the magnetic moments that are almost opposite ($\mu_p = 2.973$ and $\mu_n = -1.91$ in units of Bohr magneton). If all amplitudes are real (in phase), as it is expected at that energy, the interference terms between strong and EM part in case of $p\overline{p}$ and $n\overline{n}$ production have opposite sign so that we expect $\Gamma(J/\psi \to n\overline{n}) : \Gamma(J/\psi \to p\overline{p}) \simeq 1 : 2$. The physics analysis for the branching fractions of $J/\psi \to p\bar{p}$ and $J/\psi \to n\bar{n}$, based on a sample of 225 million J/ψ, has been performed at LNF during 2011 and 2012 and the results $^{12)}$ are:

$$\Gamma(J/\psi \to n\overline{n}) = (2.07 \pm 0.01 \pm 0.17) \times 10^{-3}$$

$$\Gamma(J/\psi \to p\overline{p}) = (2.112 \pm 0.004 \pm 0.031) \times 10^{-3}$$

These results, that represent significant improvements over previous measurements, strongly support almost orthogonal EM and strong amplitudes. This means that, contrary to the expectation, there should be a relative phase of about 90 degrees between these amplitudes: if one is real the other must be purely imaginary. The origin of this unexpected phase is still under investigation.

4.2 Measurement of the phase between J/ψ strong and electromagnetic decay amplitudes by means of a resonance scan

To clarify the experimental situation in a model independent way, in 2011 the Italian group submitted to the BESIII Collaboration a proposal $^{1)}$ which has been accepted, to measure the phase difference between EM and strong J/ψ decay amplitudes. The analysis consists in looking for an interference pattern, in all possible channels, between the resonant amplitude and the non resonant one, by means of an energy scan of the J/ψ.
More in detail, this study requires setting a continuum reference at ~100 MeV below the J/ψ and then measuring the decay rate at different energy points lying between this reference point and the J/ψ mass. The choice of these energy points with the necessary integrated luminosity has been done to maximize the capability to discriminate between the extreme cases, *i.e.* relative phase equal to zero, maximum interference, and 90 degrees, no interference.
Data taking time was dedicated to this measurement in May 2012 after the J/ψ lineshape scan and data analysis has started in LNF. The work is in progress and will go on during 2013, for the moment we can report some preliminary results. An interference pattern in the $\mu^+\mu^-$ channel was identified and measured soon after the discovery of J/ψ at SLAC, the relative phase between the resonant and non-resonant amplitudes being in good agreement with what expected. In

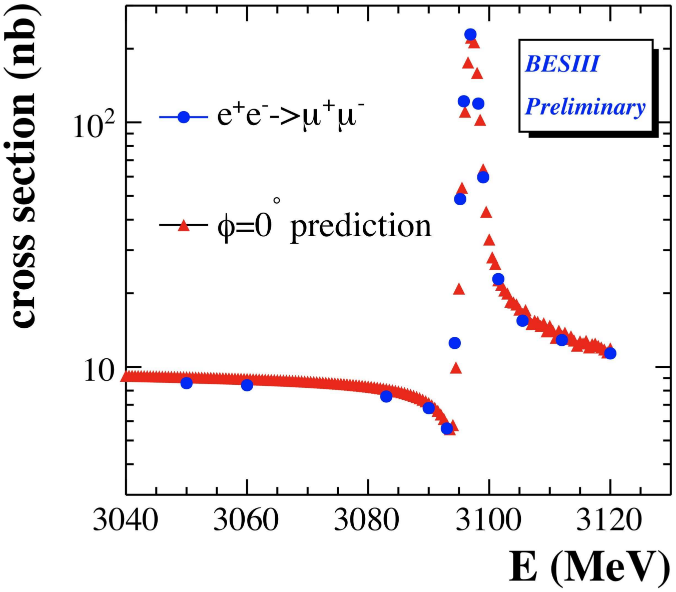


Figure 5: BESIII preliminary result on the lineshape scan of $e^+e^- \rightarrow \mu^+\mu^-$ confirming a full interference pattern between the resonant and non-resonant J/ψ amplitudes.

$e^+e^- \rightarrow 2\pi^+2\pi^-$ no strong decay is allowed because of G-parity conservation and full inteference between the e.m. decay and the continuum is expected. The sign of the interference is not established a priori and should be an interesting byproduct. In BESIII we started to analyse the $\mu^+\mu^-$ and $2\pi^+2\pi^-$ channels where interference is expected, the preliminary results are shown in figs. 5 and 6, and confirm full interference between J/ψ decay and continuum. The $\mu^+\mu^-$ result improves the significance of previous existing results, while the intereference in $2\pi^+2\pi^-$ is seen for the first time.

Work is in progress to improve to study the systematic errors and to fit the lineshapes to evaluate the phase angles. In the meantime the analysis of the $e^+e^- \rightarrow 2\pi^+2\pi^-\pi^0$ channel with strong interaction has started, results are expected for next year.

5 List of talks by LNF Authors in 2012

1. A. Zallo, "The Zero Degree Detector at BESIII", Frontier Detectors for Frontier Physics Workshop,La Biodola, Isola d'Elba, Italy, 20-25 May 2012.
2. A. Calcaterra, "A CGEM Prototype for a BESIII Inner Drift Chamber Upgrade", IHEP seminar, Beijing, 17 September 2012.

References

1. Y. Wang *et al.* "A proposal to measure the phase between J/ψ strong and electromagnetic decay amplitudes by means of an energy scan, BESIII Internal note (2011)

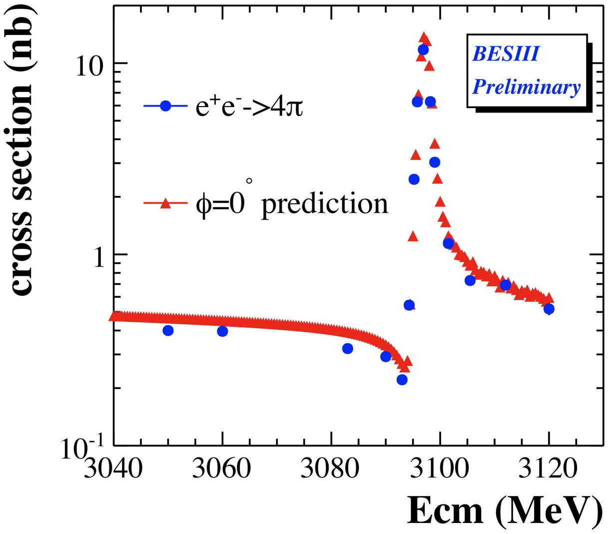


Figure 6: BESIII preliminary result on the lineshape scan of $e^+e^- \to 2\pi^+2\pi^-$ showing for the first time a full interference pattern between the resonant and non-resonant J/ψ amplitudes.

6 Publications in 2012

2. BESIII Collaboration (M. Ablikim *et al.*), Chin. Phys. C **36**, 915 (2012)
3. BESIII Collaboration (M. Ablikim *et al.*), Phys. Lett. **710**, 594 (2012)
4. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. Lett. **108**, 112003 (2012)
5. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. Lett. **108**, 182001 (2012)
6. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. Lett. **108**, 222002 (2012)
7. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **85**, 092012 (2012)
8. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **85**, 112008 (2012)
9. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. Lett. **109**, 042003 (2012)
10. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. Lett. **109**, 172002 (2012)
11. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 032008 (2012)
12. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 032014 (2012)
13. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 052004 (2012)
14. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 052011 (2012)
15. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 071101 (2012)

16. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 072011 (2012)
17. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 092008 (2012)
18. BESIII Collaboration (M. Ablikim *et al.*), Phys. Rev. D **86**, 092009 (2012)