Effects of Final State Interactions, Colour Reconnection and Bose-Einstein Correlations at Small Relative Momenta of Particles and W-mass Systematics at LEP

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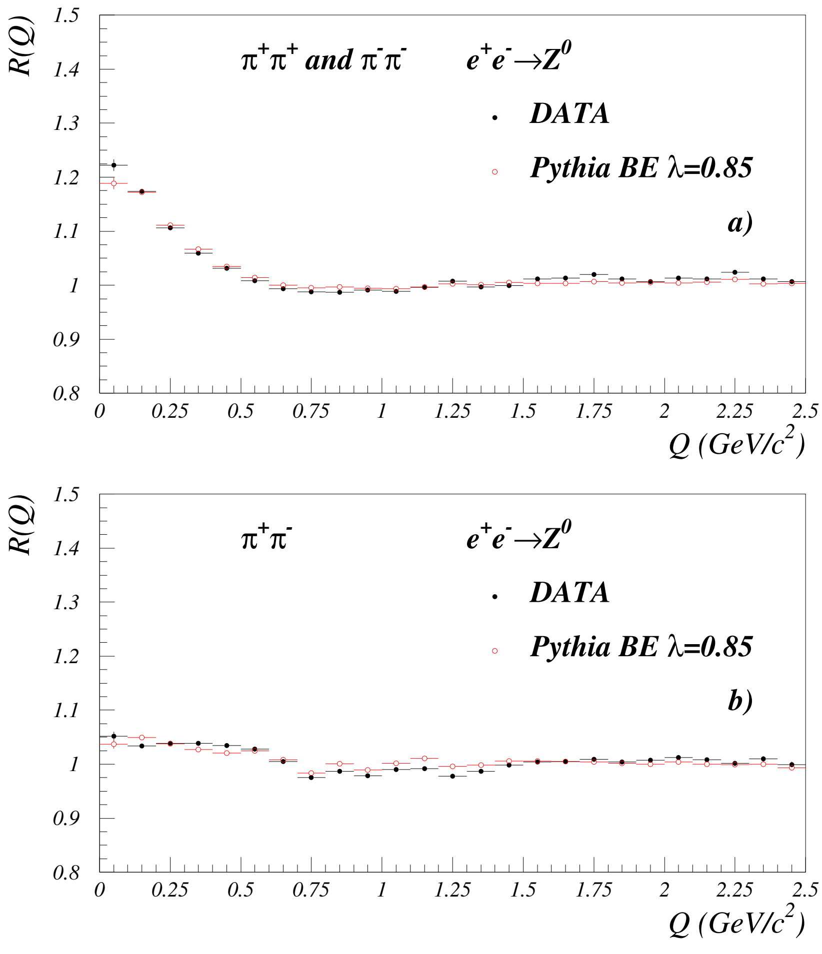
Outlook

- Two particle correlations in $e^+e^- \to Z$ events
- Genuin three particle correlations in $e^+e^- \to Z$ events
- The $\rho^0(770)$ mass shift in $\pi^+\pi^-$ decay mode in $e^+e^- \to Z$ events
- Interpretation of the LEP measurements at Z
- Correlations between pions from different Ws in $e^+e^- \to W^+W^-$ events
- W-mass systematics due to BEC
- Summary

The correlation functions $R(Q)$ which is the ratio of Q plots of data and MC (without BEC included) are shown in figure. The Q is defined by $Q^2 = -(p_1 - p_2)^2 = M_{\pi\pi}^2 - 4m_\pi^2$, where $M_{\pi\pi}$ is the invariant mass of the two pions.

DELPHI(preliminary)



The $R(Q)$ correlation functions show the enhanced production of both, like-sign and unlike-sign combinations, but the correlations for unlike-sign combinations are smaller. The LUBOEI BEC model describes the data.

The genuin three particle correlation functions $R_3(Q)$ are shown in figure.

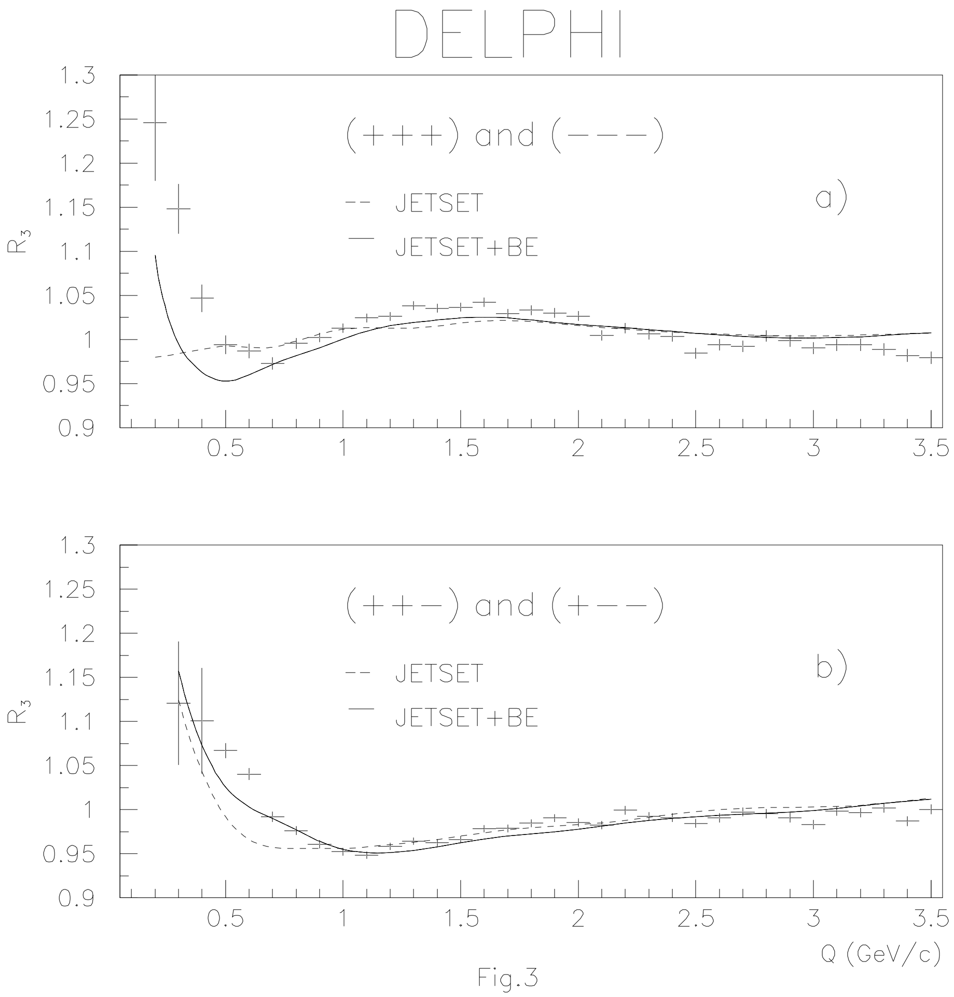


Fig.3

The $R_3(Q)$ correlation functions show the enhanced production of both, like-sign and unlike-sign configurations.

The LEP Collaborations
OPAL Coll.,Zeit. Phys. C56 (1992) 521
ALEPH Coll., Zeit. Phys. C69 (1996) 379
DELPHI Coll., Zeit. Phys. C65 (1995) 587
have found that the measured mass of the $\rho^0(770)$ into $\pi^+\pi^-$ decay mode is shifted to the lower value.

The DELPHI number of the $\rho^0(770)$ mass shift is ΔM=–20 $\pm$ 3 MeV

These LEP measurements are model independent.

Interpretation of the LEP correlation measuremets

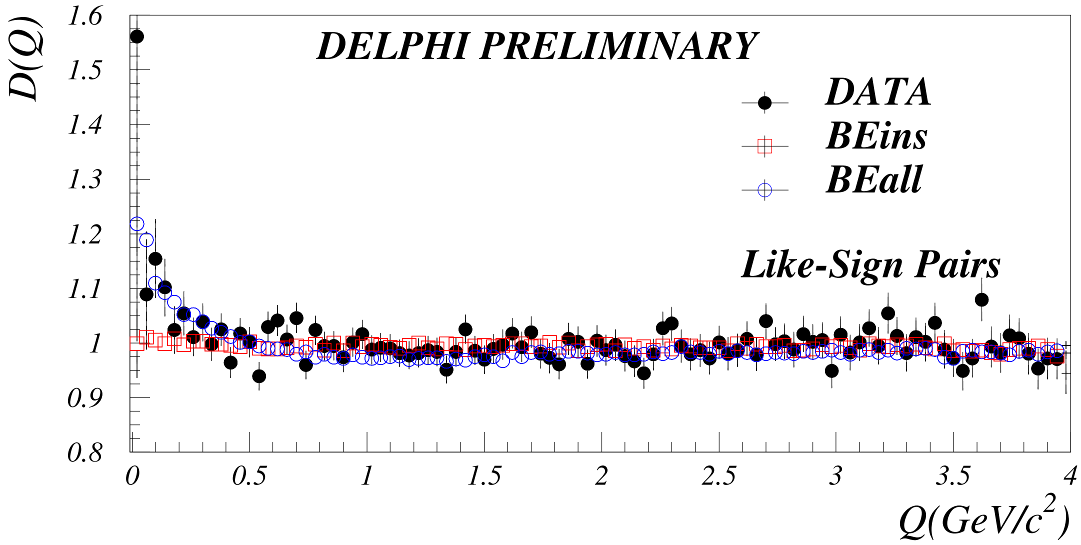
The observation of the enhanced production of like–sign particle pairs by LEP experiments at Z does not insure that the observed correlations owe their origin to Bose-Einstein correlations. They could, for example, arise from final state interactions(FSI) between pions with small relative momenta. It turns out that it is possible to discount the possibility of visible FSI effects by virtue of the smaller correlations between unlike-sign particles, which could arise from final state interaction effects too. As was shown at LEP, the unlike-sign particle configurations show also a correlations. The like-sign pions necessarily are in an isospin I=2 state and the unlike-sign pions are dominantly in the isospin I=0 state. The scattering length for I=2 is more than a factor three smaller than the one for I=0. This insures that the FSI effects for like-sign pion pairs are expected to be nearly an order of magnitude smaller than those observed in unlike-sign pions. Even if one would attribute all the correlations observed for unlike-sign pions to final state effects, then essentially none of the correlation effects observed in like-sign pairs can therefore be attributed to final state interactions. Thus, the observed at LEP particle correlations at small relative momenta are not due to FSI.
As for Colour Reconnection(CR) effects, there is a no evidence that any of CR model predicts visible correlations between pion pairs at small relative momenta.

On the other hand, from the generalised Bose statistics and isospin invariance follows also that the pairs with different charges which belong to the same isospin multiplet may show BEC enhancement. The influence of BEC to unlike–sign particles is also predicted by LUBOEI and and by a 'reweigthing' BEC model. These so-called 'residual BEC', including the $\rho^0(770) \rightarrow \pi^+\pi^-$, were observed at Z energies by LEP experiments, in agreement with the BEC model predictions.

One may conclude that the observed at LEP correlations for like-sign as well for unlike-sign particle configurations can be ascribed to Bose–Einstein Correlations.

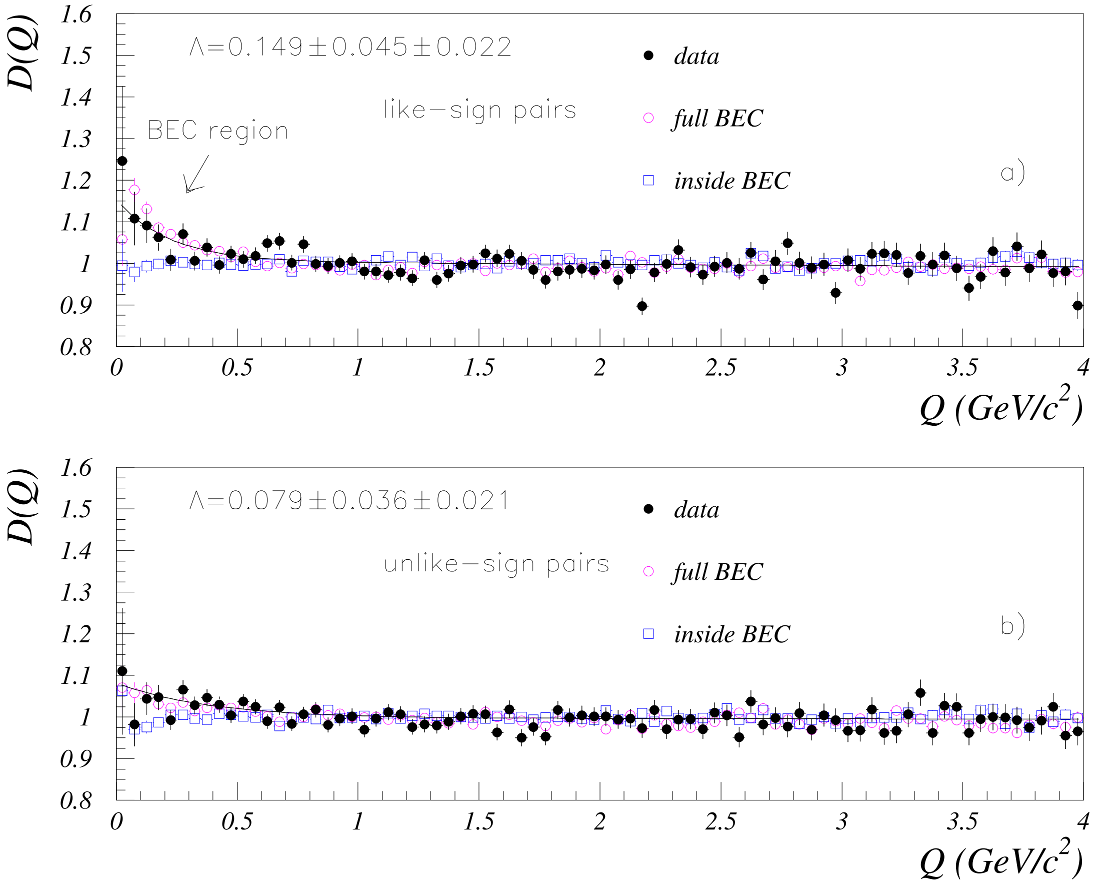
As a consequence, its not recommended to divide(or subtract) the plots of like–sign and unlike–sign particle configurations in analysis of the BEC in $e^+e^- \rightarrow Z$ and $e^+e^- \rightarrow W^+W^-$ events. Such a procedure reduces the sensitivity to these effects and may even leads to uncorrect answers. Thus, one may conclude that the like–sign and unlike–sign particle correlations should be analised separately.

The issue of Bose–Einstein correlations between particles from Different Ws in fully hadronic $e^+e^- \rightarrow W^+W^-$ events is back due to latest DELPHI results obtained using all available statistics. The ratio $D(Q)$ for data, for full (BEC inside+between Ws, 'BEall' in figure) and for inside (BEC only inside Ws, 'BEins' in figure) BEC, are shown in fugure. The $D(Q)$ is the ratio of Q–plots of WW fully hadronic to mixed semileptonic events for like–sign particle pairs. (no use of unlike-sign combinations).



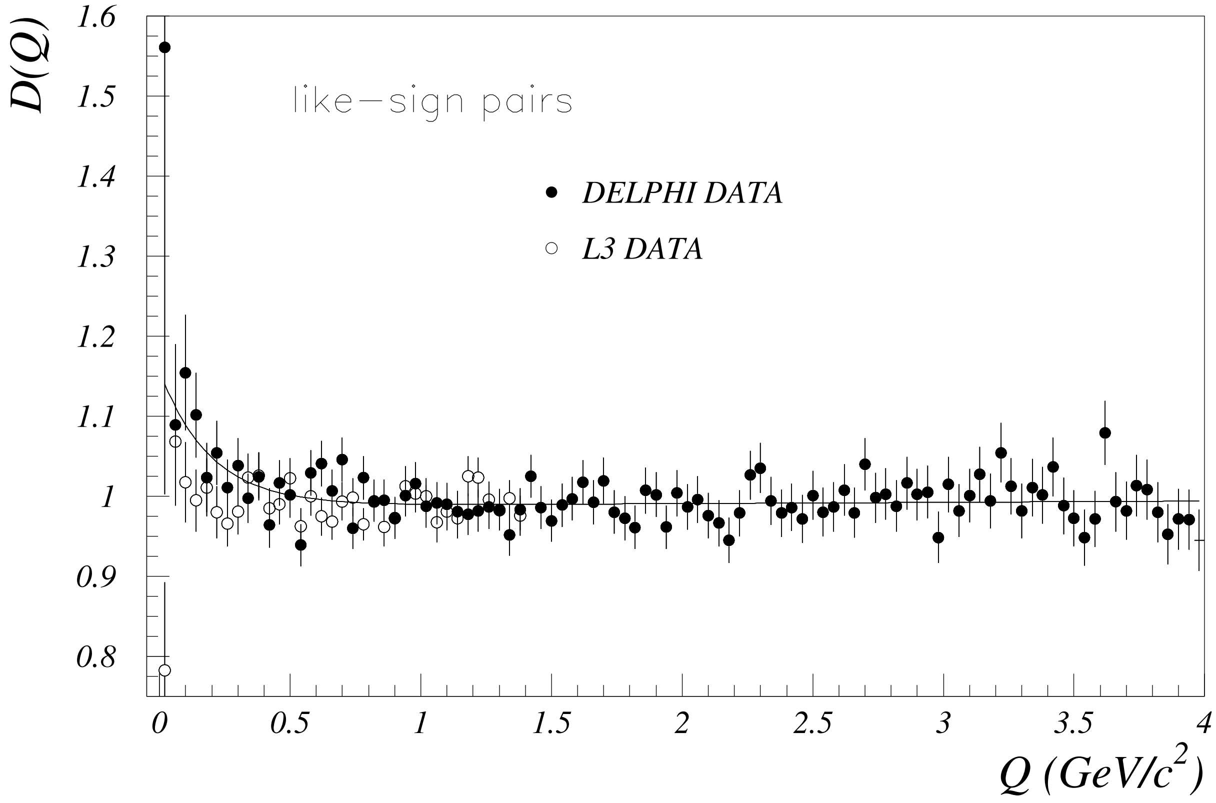
The effect of correlations between particle pairs from different Ws is clearly visible.

The analysis of the DELPHI data show the correlations between both, like-sign (fig a) and unlike-sign(fig b) particle pairs from different Ws in $e^+e^- \to W^+W^-$ events.



The correlations for unlike-sign particle pairs are smaller, as expected. The LUBOEI BE_{32} code tuned at Z-peak, leads to the reasonable description of the data.

The comparison of the DELPHI and L3 $D(Q)$ plots obtained by using all available statistics and event mixing technique is shown in figure.



The data points measured by DELPHI are systematically above of those of L3 at BEC region. The reason of the different between DELPHI and L3 data $D(Q)$ plots is not clear.

No WW BEC measurements are exist yet by ALEPH and/or OPAL using all available statistics. The ALEPH and OPAL measurements get now the increased interest.

W-mass systematics due to BEC

The LEP measurements on correlation functions and comparison with the LUBOEI BE_{32} code do not allow to reduce the W-mass systematics due to BEC for fully hadronic channel below the 35 MeV. The value of 35 MeV was obtained using the LUBOEI BE_{32} with input parameters λ=PARJ(92)=1.35 and R=PARJ(93)=0.34 GeV. The model predictions are in a reasonable agreement with the data as were shown in previous transperancies.

There was very first attempt to obtain the shift of W-mass due to BEC by 'global reweigthing' model using the simulated events, but the predictions of the model for particle correlations were not verified on data yet. Thus, presently, the predicted W-mass shift by 'global reweigthing' model should not be considered as reliable.

Summary

- The LEP data and theoretical predictions suggest that the observed at LEP correlations between like-sign and unlike-sign particles at small relative momenta are due to BEC.
- As a consequence, one should not use the unlike-sign correlations as a reference for like-sign correlations for BEC studies. Both correlations should be analised separately.
- The latest results of DELPHI indicate clearly the presence of BEC between particles from different Ws in $e^+e^- \rightarrow W^+W^-$ events. The L3 analysis show no effect. The DELPHI and L3 analysis use all available statistics.

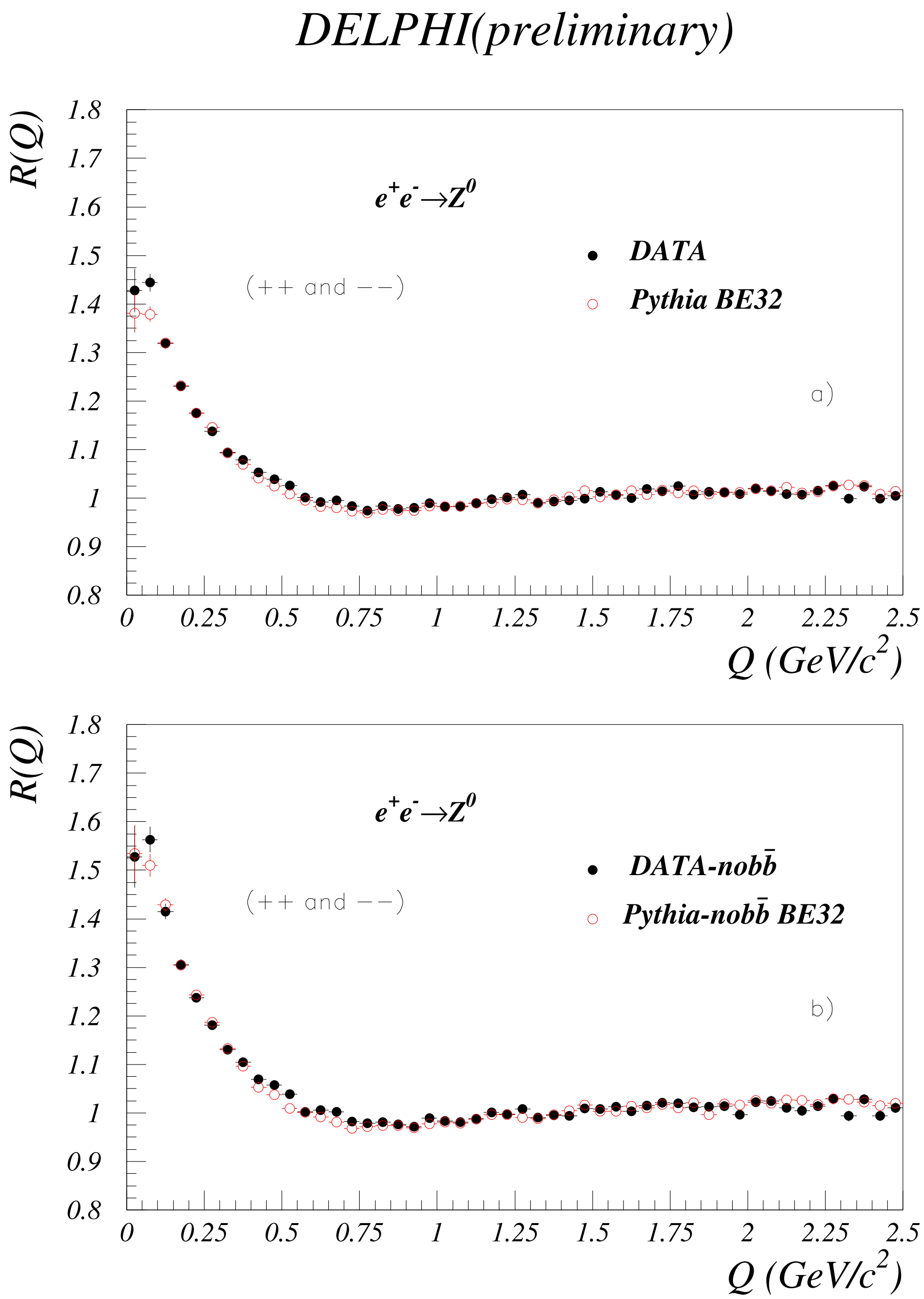
  The reason of different answers by DELPHI and L3 is not clear.

  No available results exist by ALEPH and OPAL using full statistics.

- There were many attempts to implement the various approaches of BEC effects in the models, but the LUBOEI model is still only BEC model predictions of which were compared to the LEP correlation data in details.

  The model describes the data reasonably well.

  The latest version – LUBOEI BE_{32} code with BEC included between particles from different Ws in WW fully hadronic channel yields $\sim$35 MeV shift of W-mass due to BEC.


DELPHI(preliminary)
R(Q)
$e^+e^- \rightarrow Z^0$
DATA
Pythia BE32
(++ and −−)
a)
Q (GeV/c²)
R(Q)
$e^+e^- \rightarrow Z^0$
DATA-nob$\bar{b}$
Pythia-nob$\bar{b}$ BE32
(++ and −−)
b)
Q (GeV/c²)