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# On the permanent magnet in the run 2012.

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# 1 Introduction

For DIRAC run of 2012 the additional permanent magnet([1]) was used. The field of this magnet was measured before, but it was done in the part of its volume. The field of this magnet was calculated also by OPERA program in the full volume and these results were used in the DIRAC software. The comparison of these magnetic maps shows that their difference is about 2.3%( the calculated values are higher) and their shapes are equal.

Using DIRAC experimental data with e+e- pairs( they are the Dalitz pairs and $\gamma$ conversion pairs) we can evaluate the difference between the calculated values of field and the real values of it. This can be done via the comparison of positions of peak of relative momentum e+e- pairs in $Y-Z$ projection - $Q_Y$( the axis of setup is along $Z$ and the main component of the field is along $X$ axis). We can also find out how the field of this magnet varies with time due to its radiation damage.

In about 5 cm behind the magnet(it is at the end of the field) the Pt foil is placed, it is used to breakup the metastable $\pi\pi$ atoms(created in the target) into $\pi^+\pi^-$ pairs. Therefore these pairs are bent only by this fringe field and we should know how well the calculated field describes the real field in this far region of magnet field. We can check it using $\gamma$ which convert into e+e- pairs inside this foil and then comparing the MC and real data $Q_Y$ peak positions.

In the MC calculations for generation of Dalitz pairs and $\gamma$ in the target the programs [2] and [3] were used correspondingly.

The primary analysis of $Q_Y$ peak position of for real data with e+e- pairs was done in [4].

# 2 The field variation during the run 2012

If the material of permanent magnet is subjected to radiation damage then its field decreases([5]). The permanent magnet of DIRAC setup is placed very close to the target and therefore such effect of field reduction can take place. We can investigate such reduction via the measuring of position of $Q_Y$ peak for e+e- pairs which were created in the target and then detected by the setup. The relative momentum of such pairs is proportional to the integral of $B_Y$ component of field along their trajectories.

There is the creation of e+e- pairs in the target, some of them are detected by the setup. All such data of run 2012(its duration is 6 months) were divided into eight time intervals and for each interval the corresponding $Q_Y$ distribution was fitted by Gaussian and the values of Gaussian mean parameter($Q_Y^{mean}$) are plotted on Fig.1. These values, normalized on the first interval value, are shown on Fig.2. The error for each bin is equal to RMS of all eight values of $Q_Y^{mean}$. It was done due to the fact that RMS of $Q_Y^{mean}$ is about 100 bigger than the statistical error in $Q_Y^{mean}$ for each interval and the last means that the real data calibration is pure.

The result which is present on Fig.2 shows that the relative reduction of permanent magnet field due to radiation damage during the run 2012 is very small and it is not more than a few $10^{-4}$.

# 3 The real and MC data: the positions of $Q_Y$ peak for e+e- pairs from the target

For the real data we selected the e+e- pairs which are created in the target and detected by the setup. For MC analysis we used the Dalitz pairs from the target( the probability of $\gamma$ conversion in the target is much less). Real data and MC distributions of $Q_Y$ were fitted by Gaussian and the results are shown on Fig.3: on the top and in the middle, correspondingly. For real data $Q_Y^{mean}$=12.89 MeV/c and for MC data - 13.22 MeV/c. This parameter for MC data is 2.5% higher than for the real data one. The value of 2.5% is very close to the ratio between measured values of this magnet field and calculated(OPERA) ones - 2.3%. The values of this parameter $\sigma$ for real data and MC one is very close - 1.43 and 1.47 MeV/c, correspondingly.

The obtained factor(0.975) was used then in the GEANT-DIRAC software and the simulation of Dalitz pairs was done again. The result is shown on the Fig.3(bottom); $Q_Y^{mean}$=12.90 MeV/c.

Additionally the simulation the $\gamma$ in the target was done and for these events when the conversion is in the target we obtained that $Q_Y^{mean}$=12.91 MeV/c(Fig.4). It's equal to the previous value.

# 4 The real and MC data: the positions of $Q_Y$ peak for e+e- pairs from the Pt foil

The metastable $\pi\pi$ atoms breaks into $\pi^+\pi^-$ pairs in the Pt foil which is placed behind the permanent magnet in its fringe field. Therefore we should know how well the calculated field describes the real field in this far region of magnet field. We can check it using $\gamma$s which convert into e+e- pairs inside this foil and then comparing the MC and real data $Q_Y$ peak positions.

Sure we have a few e+e- pairs from $\gamma$ conversion in this very thin foil(2 $\mu$) and also their peak position($Q_Y \simeq 2.3$ MeV/c) is very close to very big peak from e+e- pairs created after the magnet($Q_Y$=0). On Fig.5( top) where all e+e- pairs presented for real data there is no distinct peak at 2.3 MeV/c. We can try to make it more distinct if we suppose that the peak at $Q_Y$=0 is symmetrical and then we can subtract its left part from the right part of this histogram(like it was done in [4]). After this procedure the peak at 2.3 MeV/c became more clear(Fig.5( bottom)).

Nevertheless into the peak at 2.3 MeV/c the neighboring peaks, left one and right one, make significant contribution. We don't know exact shapes of these peaks and we suppose that the left peak is an exponential and the right one has Breit-Wigner shape.

Then these contribution were subtracted and we get the resulting peak for e+e- pairs created in the Pt foil - Fig.6(top). Fitting by the Gaussian gives that $Q_Y^{mean}$=2.3 MeV/c. The same value was obtained for MC data of e+e- pairs from $\gamma$ conversion in the Pt foil - Fig.6(bottom). The values of $\sigma$ for real data and MC one are very close - 0.88 and 0.90 MeV/c, correspondingly.

To get enough such events in MC simulation the cross-section of $\gamma$ conversion in the Pt foil was increased in about 1000 times by modifying GEANT software codes.

# 5 Conclusions

1. We found that the reduction of permanent magnet field during the run 2012 due to radiation damage is very small.

2. We found that the factor of 0.975 must be applied to the calculated(by OPERA) field of this magnet.

3. The part of this magnet field which is behind the Pt foil is described well by calculated field map.

# References


[1] A.Vorozhtsov [TE/MCS/MNC] , DIRAC Note 2013-4.

[2] M.Zhabitsky [JINR] , DIRAC Note 2007-11.

[3] O.Gorchakov [JINR], DIRAC Note 2012-1.

[4] D.Dumitriu [IFIN-HH, Bucharest], DIRAC Note 2014-2.

[5] P. Batyuk [JINR], O. Gortchakov [JINR], V. Yazkov [SINP, Moscow], DIRAC Note 2012-3.

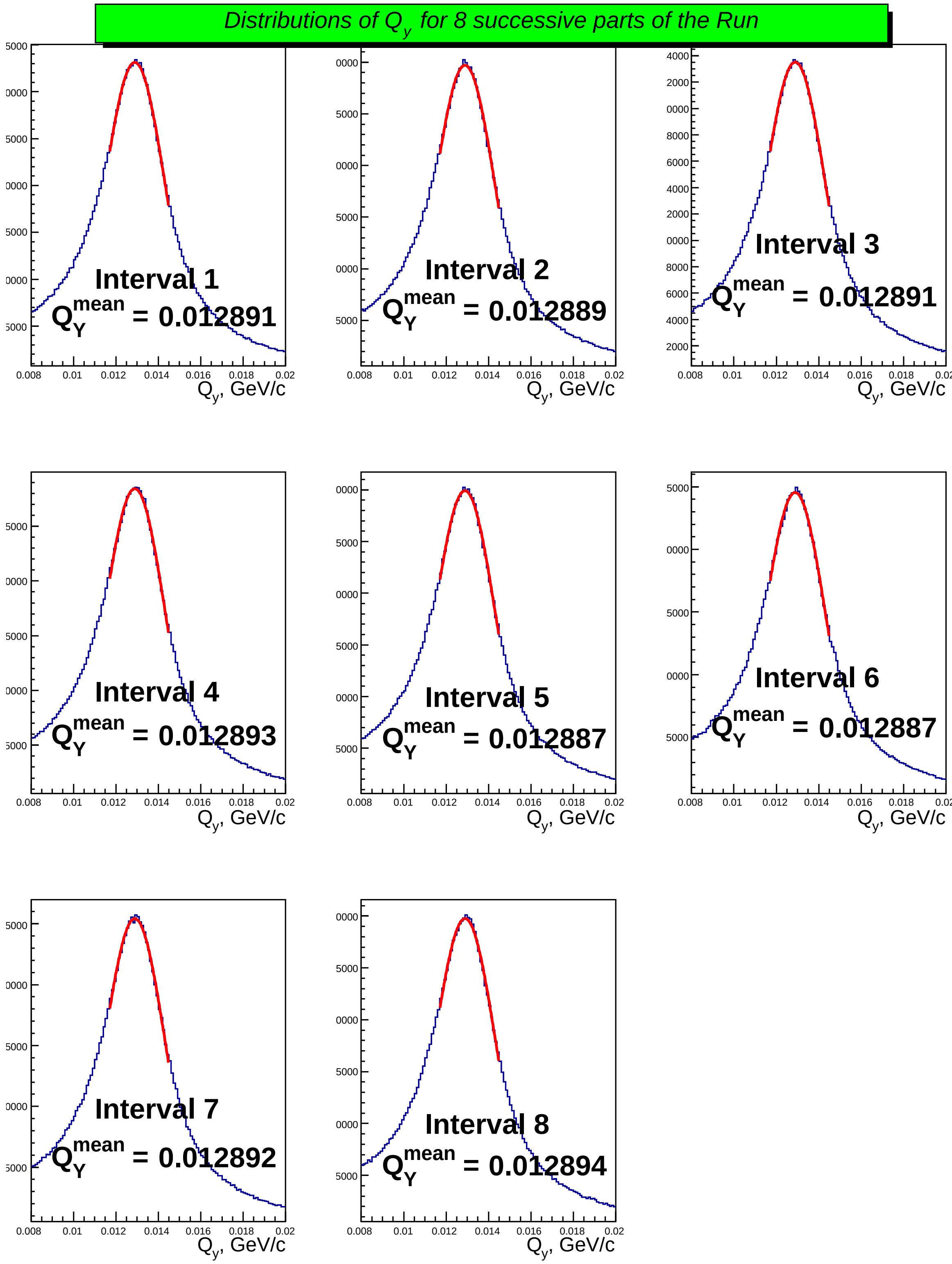


Figure 1: *Real data. The position of $Q_Y$ peak for each of eight successive time intervals of run 2012 for e+e- pairs created in the target.*

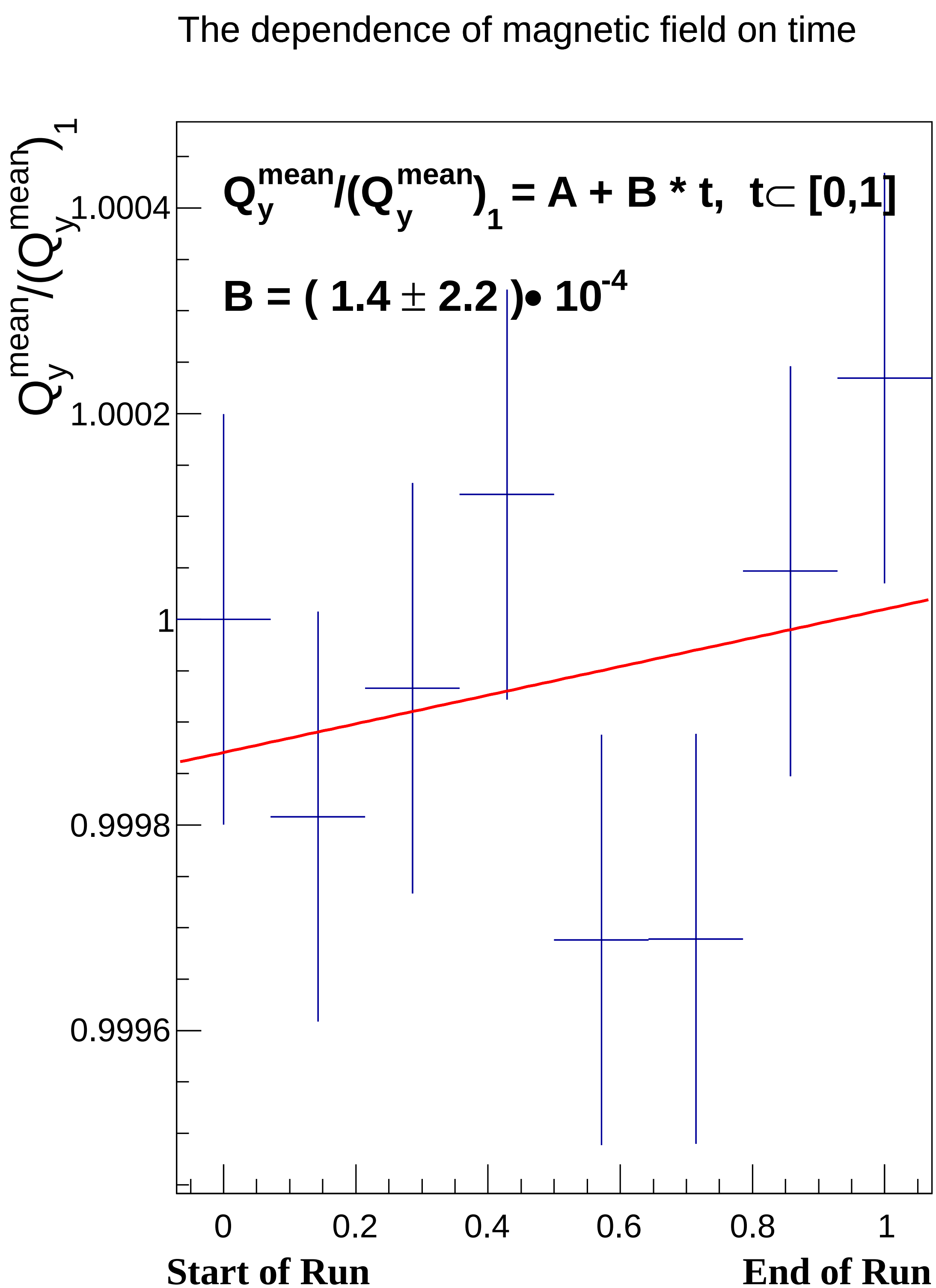


Figure 2: *The permanent magnet field variation during the run 2012.*

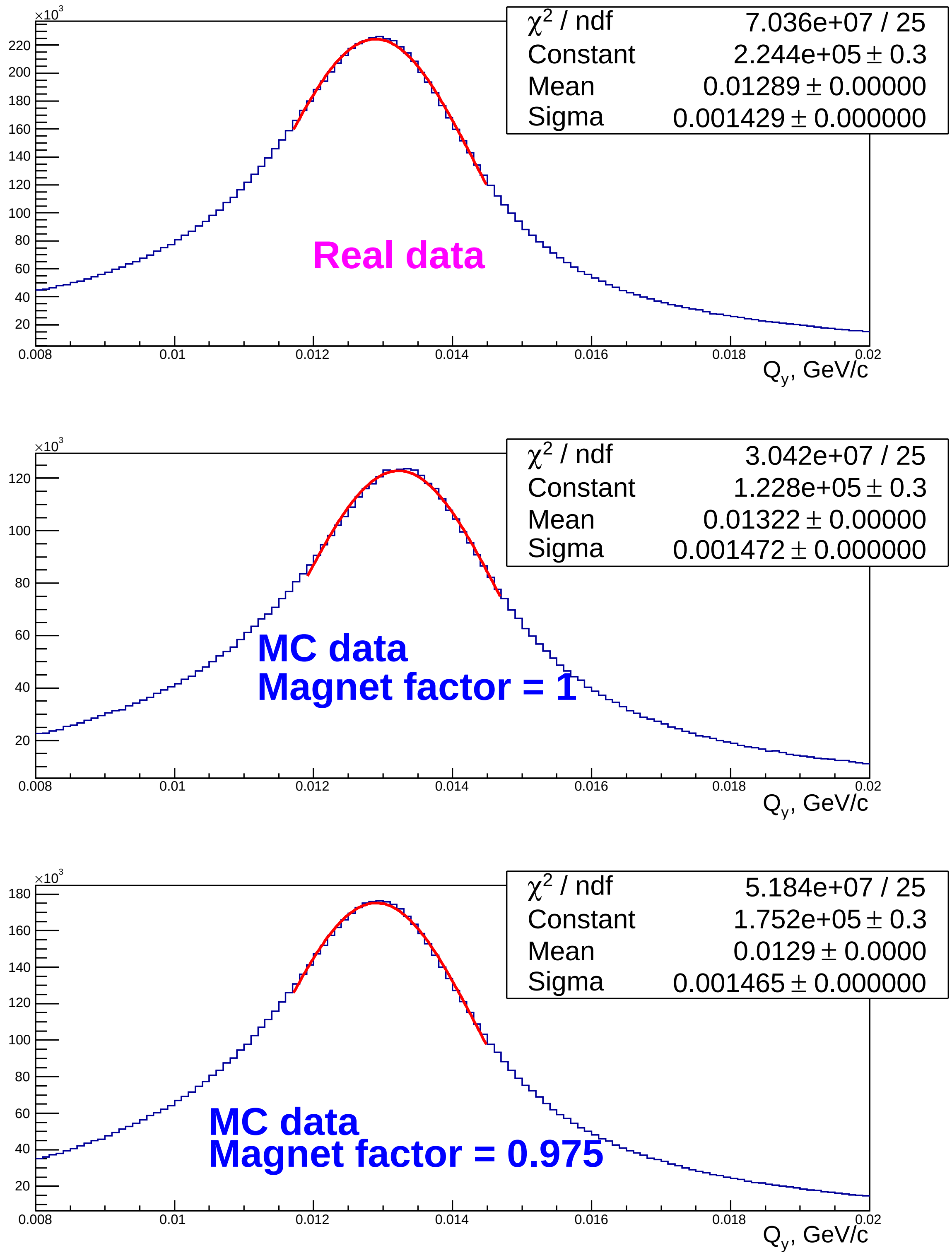


Figure 3: *The e+e- pairs from target. The distributions on $Q_Y$ for real data(top), for MC data for Dalitz pairs (in the middle - the magnetic field factor is 1, in bottom - the factor is 0.975)*

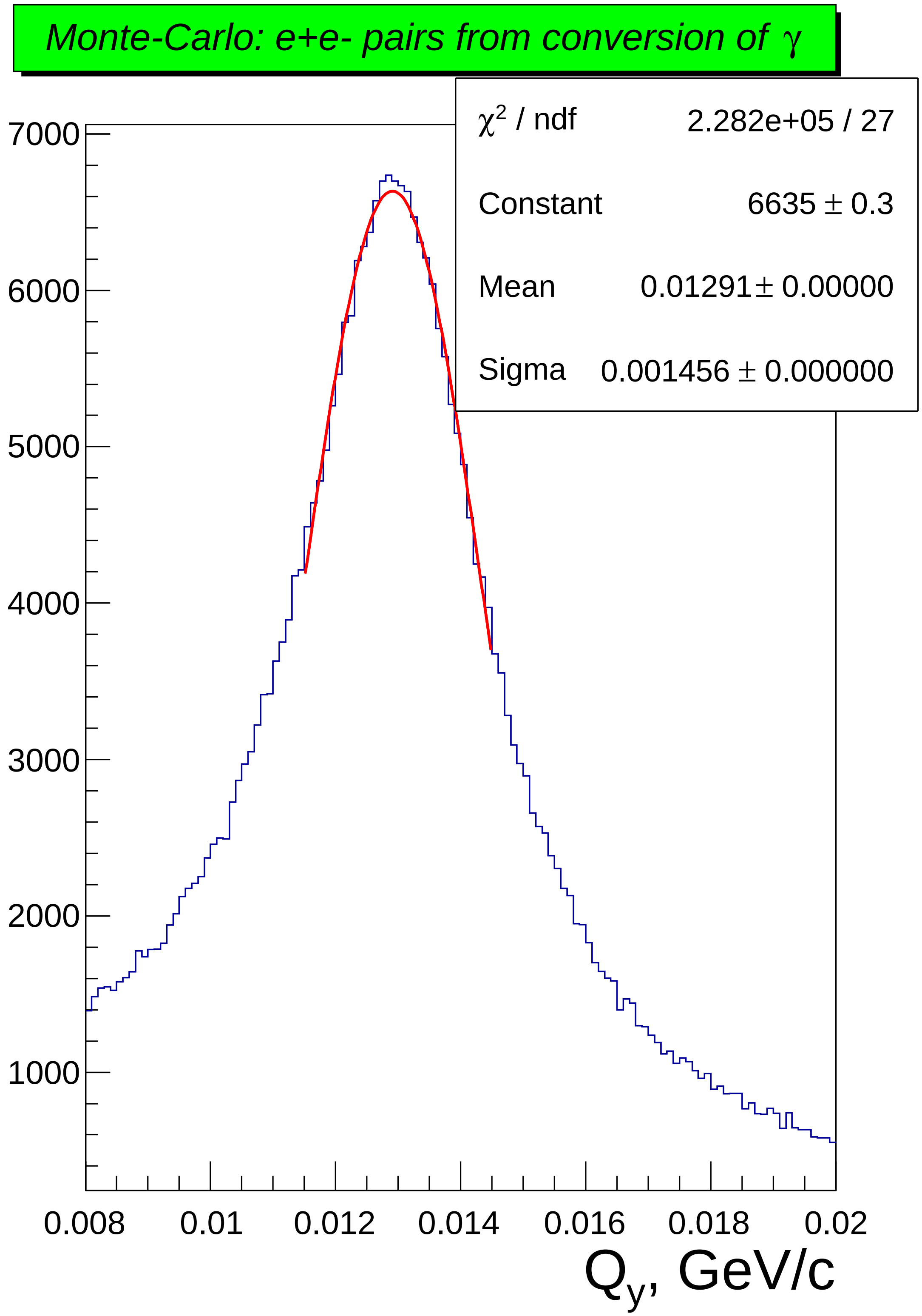


Figure 4: *The distributions on $Q_Y$ for MC of $\gamma$ conversion pairs (the magnetic field factor is 0.975)*

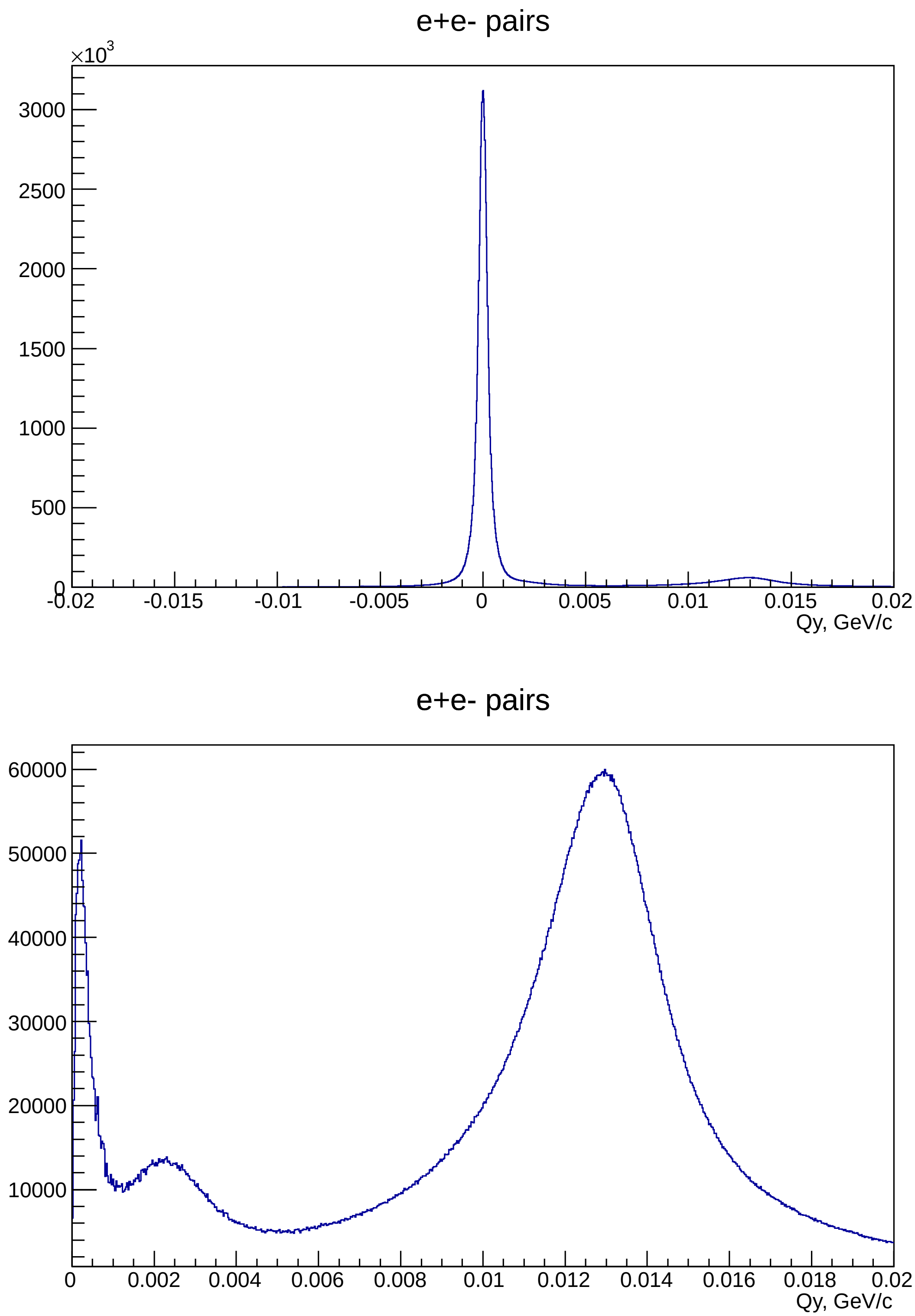


Figure 5: *The distributions on $Q_Y$ for real data. Initial distribution(top), and after subtraction(bottom)*

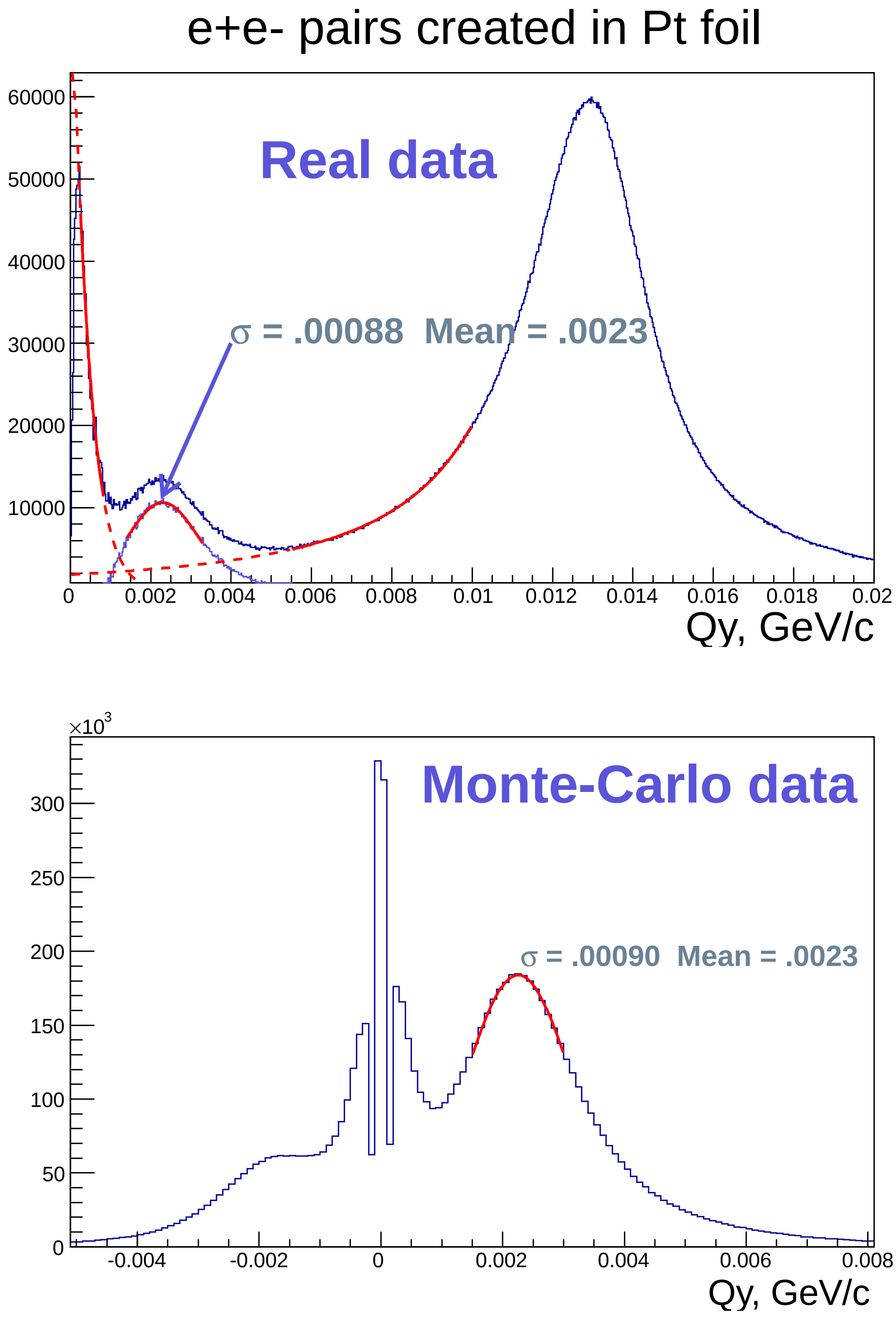


Figure 6: *The distributions on $Q_Y$ for real data(top), for MC data(bottom) for e+e- pairs created in Pt foil*