$\mathbf{p(e,e'p)\omega^0}$ Analysis Update
July 19, 2005 Tele-Conference

Garth Huber

University of Regina, Regina, SK, S4S 0A2, Canada

Many of the following plots are somewhat tedious, so I draw your attention in particular to pages 1–7, 22–23, and 36.

1 Changes from last report:

- The cause of the "spiky" ρ^0 distributions has been identified and corrected.
- The Soding (skewness) factor to the ρ^0 lineshape has been modified.
- The three MC's have been refit to the data. The contribution of the phase-space MC is much larger than before. Generally, the fits to the data are quite good, but the $-t$-dependence needs some modification.
- The fits to the data are finally good enough that one can begin to make some conclusions on what changes need to be made to the models in preparation for the final analysis.

2 Modification of the ρ^0 MC

In the May 26 report, I reported that the ρ^0 event distributions always looked like they suffered large statistical variation, even when very large event samples were run. This appeared to be due to a small proportion of the events with weighting factors several orders of magnitude larger than the typical event. There was some indication that the Soding skewness factor was partly to blame, because the "spikiness" was reduced when the Soding correction was removed, but no correlation of the large weight events with any kinematic variable could be found.

With further investigation, it was discovered that these large weight events corresponded to events with very large radiated photon energy. This is shown clearly in the lower left panel of Fig. 1, which shows the normally expected peak at small radphot made up of the overwhelming majority of events (with small weights) and a long tail. But above 250 MeV, the radphot distribution becomes anomalous, made up of a few events with large radphot and very large weights. These are events which have very low ρ^0 mass and because of their large radiated energy manage to make it into the acceptance. For these events, the Soding skewness correction $(M_\rho/M_x)^{5.2}$ diverges. Because of the large radiated energy, the missing mass and other variables do not correspond to the kinematics at the reaction vertex and so any kinematic correlation is lost. The upper right plot in Fig. 1 is a close approximation to the ρ^0 mass at the reaction vertex, the disproportionate contribution from low mass ρ^0 events is clearly seen.

This problem was fixed by 1) reducing the range of masses chosen within the ρ^0 distribution, and 2) turning off the Soding factor 3 σ below the ρ^0 mass centroid. The lowest ρ^0 mass which is now sampled is about 375 MeV, which should still be more than adequate. The Soding factor is turned off below 575 MeV. The resulting distributions are smooth, but different in shape than before. Apparently, contribution of the large weight large radiated energy events was enough to distort the shape of all of the resulting kinematic distributions.

Because the shapes of the ρ^0 distributions are now changed, its good description of the broad distribution underneath the ω^0 peak that was observed in the May 26 report is now gone. Because the Soding correction skews the ρ^0 distribution towards lower masses, the resulting distribution is more biased to low masses than the data require. Removal of the Soding correction improves the description of the description of the data, but it is still not acceptable.

According to the well-known review article of T.H. Bauer et al. [Rev.Mod.Phys. **50**(1978)261, Fig. 71], the value of the exponent in the skewness correction factor is t-dependent, falling rapidly from 5.2 at $t = 0$ to < 1 at $-t = 0.5$ GeV^2. In the recent analysis of CLAS data

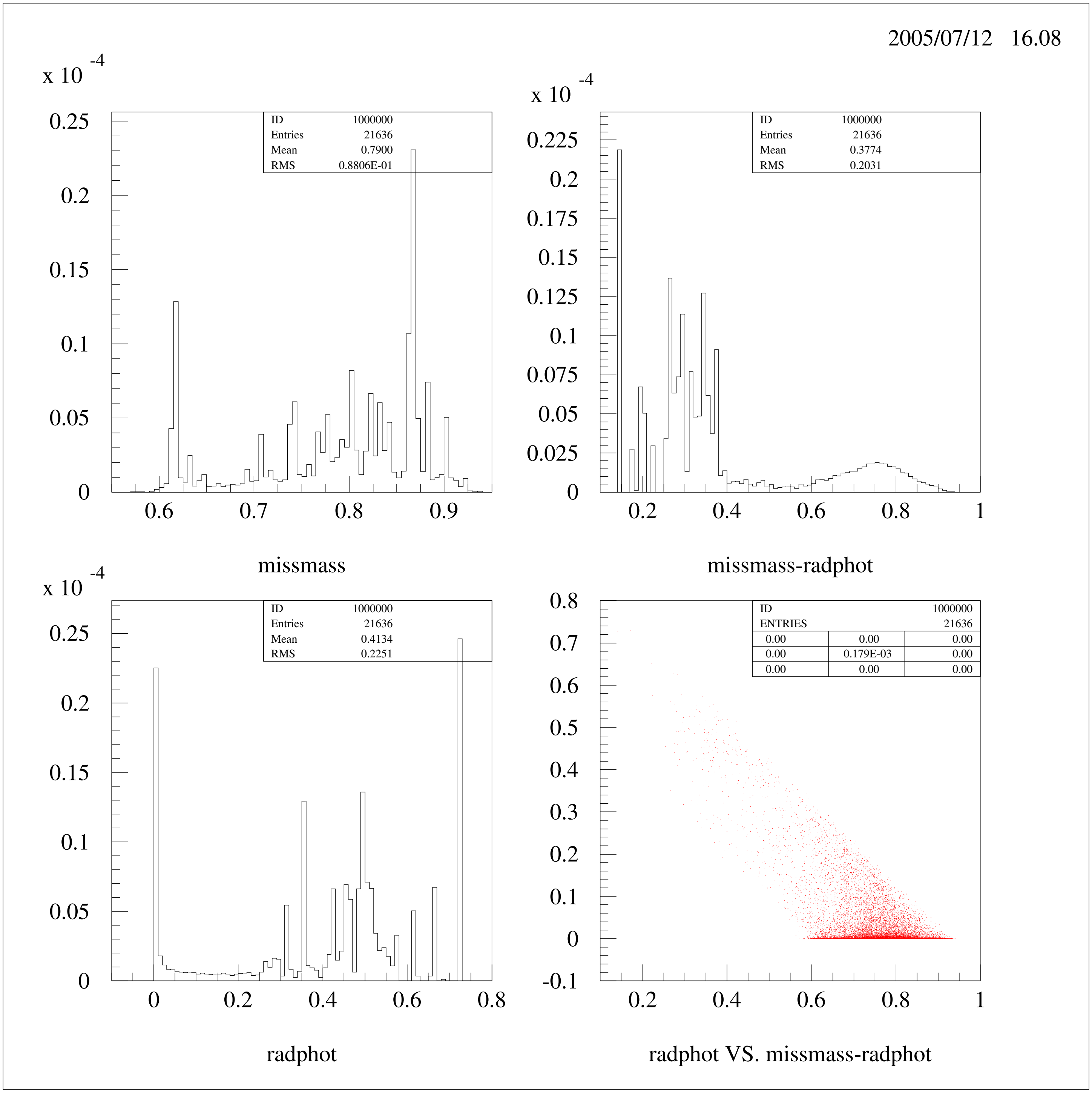

Figure 1: Weighted event distributions for the ρ^0 MC using the modified Hermes cross-section model and the $(M_\rho/M_x)^{5.2}$ skewness correction. The MC was run for 500k events, and acceptance cuts are applied.

by C. Hajidakis, the skewness factor was determined to be 0 ± 0.09 [thesis, p. 113]. The exponent value used in the MC to date has been 5.2, because this was the value appropriate for the near-threshold data of P. Ambrosewicz et al.

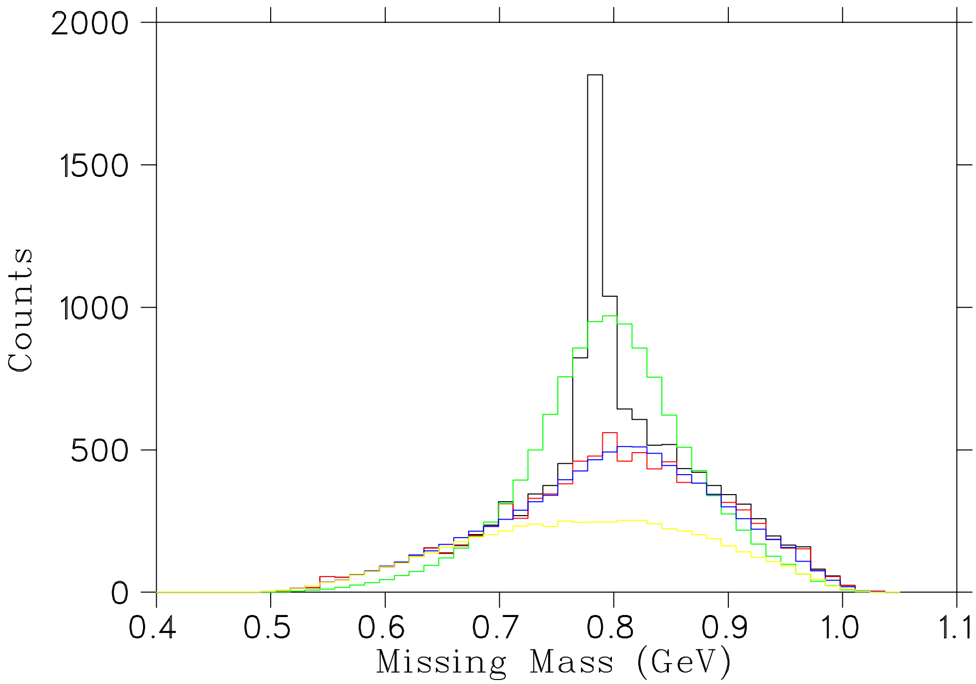

Figure 2: The black curve is $Q^2 = 2.45$ GeV^2, $\epsilon = 0.27$ $\theta_{pq} = +1^o$ data. After subtracting the suitably normalized ω^0 MC (normalized by eye), I obtain the red curve. The green curve is the ρ^0 MC with skewness correction turned off. The blue curve is the fit $a * (\rho^0 MC) * (M_\rho/M_x)^b + c * (PS\ MC)$, with an exponent fit value of $b = -5.49 \pm 0.02$, and the yellow curve is the fit phase-space distribution $c * (PS\ MC)$.

The ρ^0 MC was re-run with the skewness correction turned off and fits were made to data from four kinematic settings to determine the optimum value of the skewness correction exponent. An example is shown in Fig. 2. The best-fit value of the exponent is -5.5 ± 0.5. This value is sensitive to the amount of ω^0 MC subtracted, and the uncertainty reflects the sensitivity obtained for a reasonable variation of the subtracted ω^0 MC, as well as the variation with kinematic setting. Given that the exponent value drops steeply with increasing $-t$, this value of -5.5 is likely reasonable for our high $-t$ data. All following distributions have a skewness correction of $(M_\rho/M_x)^{-5.5}$ applied.

3 $\mathbf{Q^2}$ =2.45 GeV^2 $\epsilon = 0.54$

Fit parameters after the diamond cut is applied are given in the table below for all three HMS settings. Unlike the May 26 report, the background is now best described by a sum of phase-space and ρ^0 MCs, with the greatest contribution being from the phase-space MC. The data is described quite well by the sum of the three MCs, with the $-t$ distribution being in greatest need of modification.

	Counts	Fit Fraction	MC multiplier
Central HMS $\theta_{pq} = 00$			
Data	10501		
Omega	2618	0.249	23.0
Rho	556	0.053	25.1
Phase-space	7324	0.698	1452.6
Right HMS $\theta_{pq} = +3$			
Data	12178		
Omega	3005	0.247	16.6
Rho	769	0.063	27.5
Phase-space	8400	0.690	1286.8
Left HMS $\theta_{pq} = -3$			
Data	10452		
Omega	2472	0.259	23.6
Rho	569	0.055	25.2
Phase-space	7408	0.709	1276.6

The fit is only to the missing mass histogram. A variation in the MC multiplier with HMS angle indicates a deficiency in the θ^*-dependence in the cross section model.

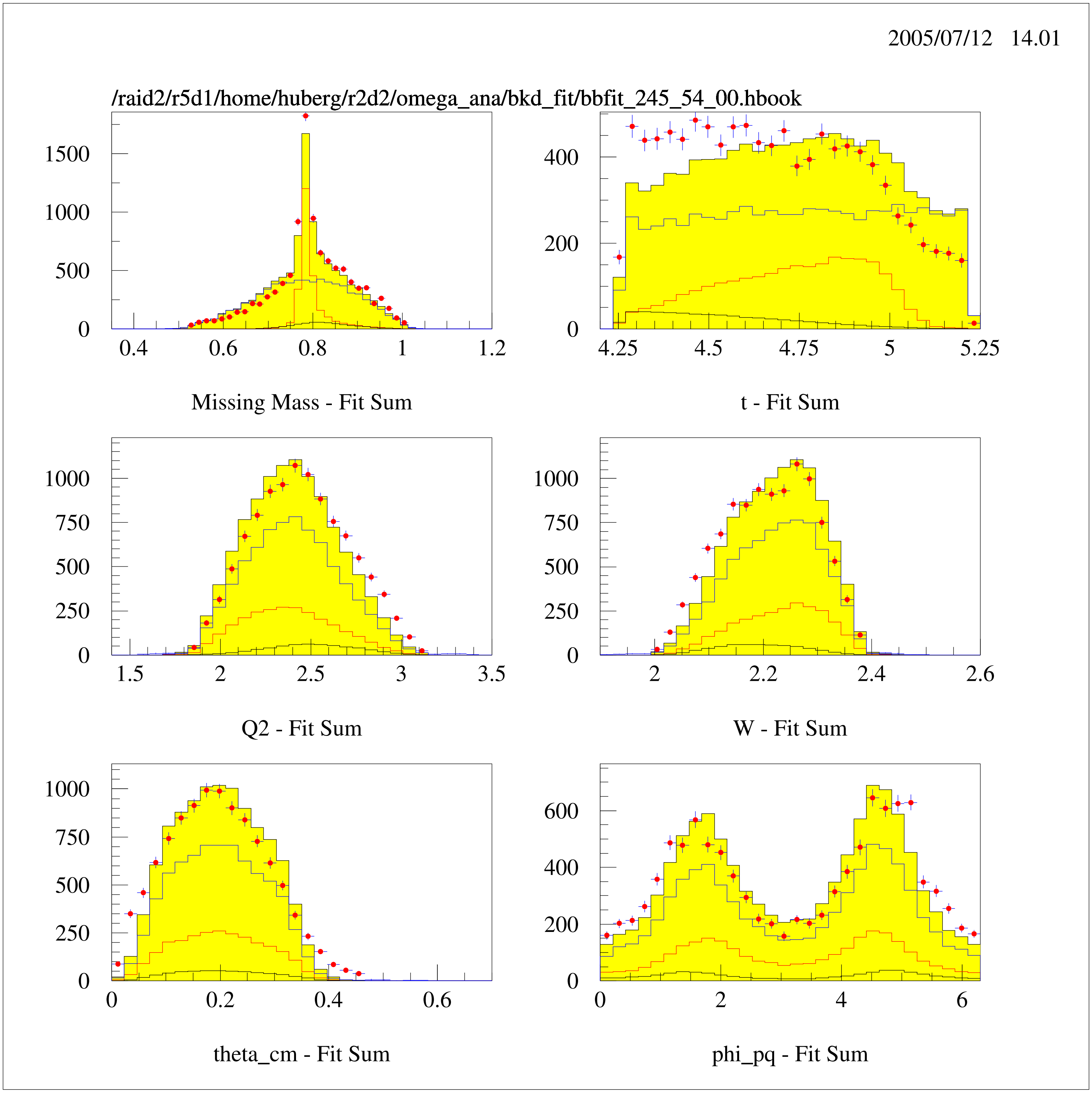

Figure 3: Fit to central HMS setting data at Q^2=2.45, ϵ=0.54. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

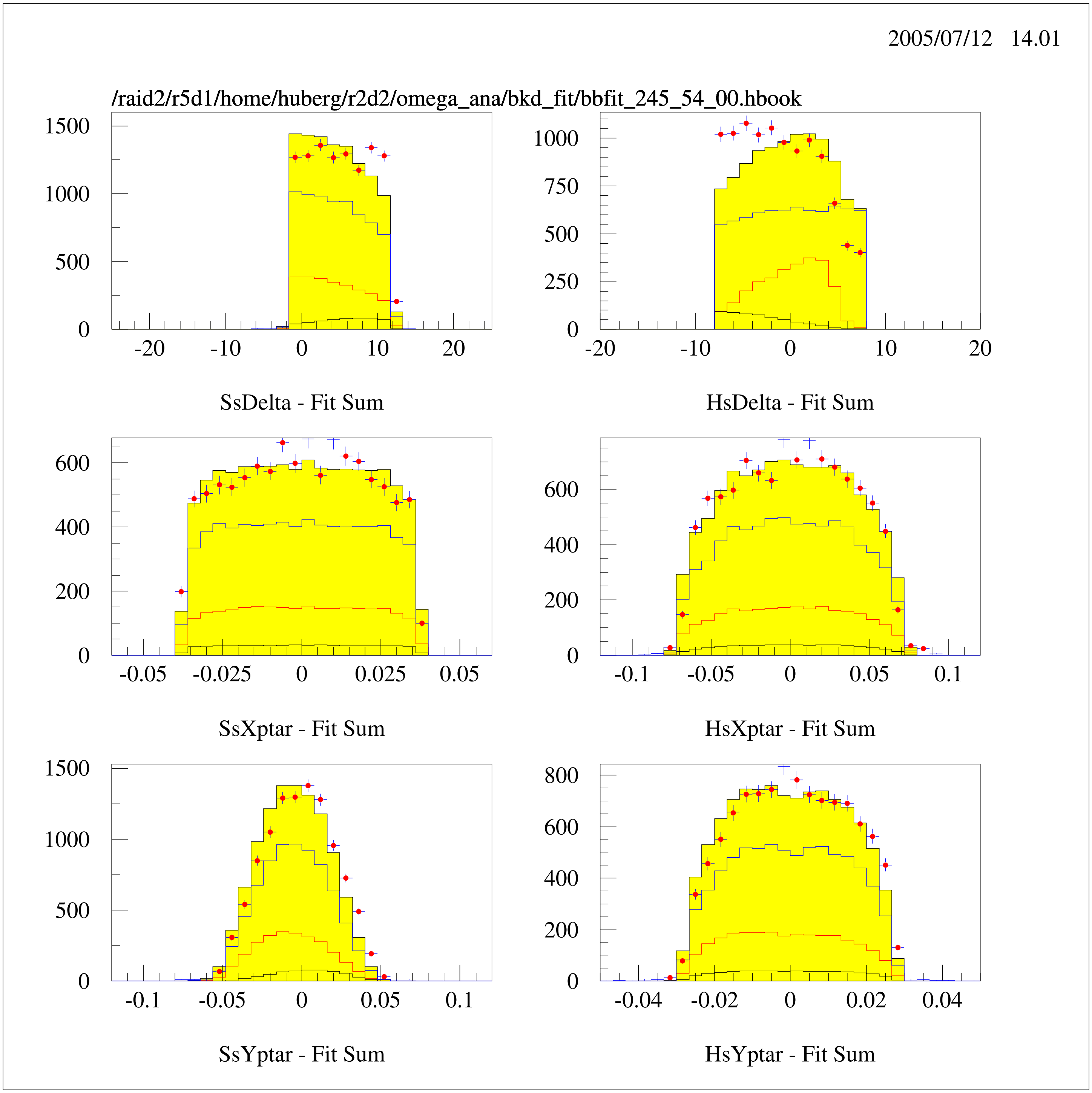

Figure 4: Spectrometer variable distributions for the same fit to missing mass shown on the previous page.

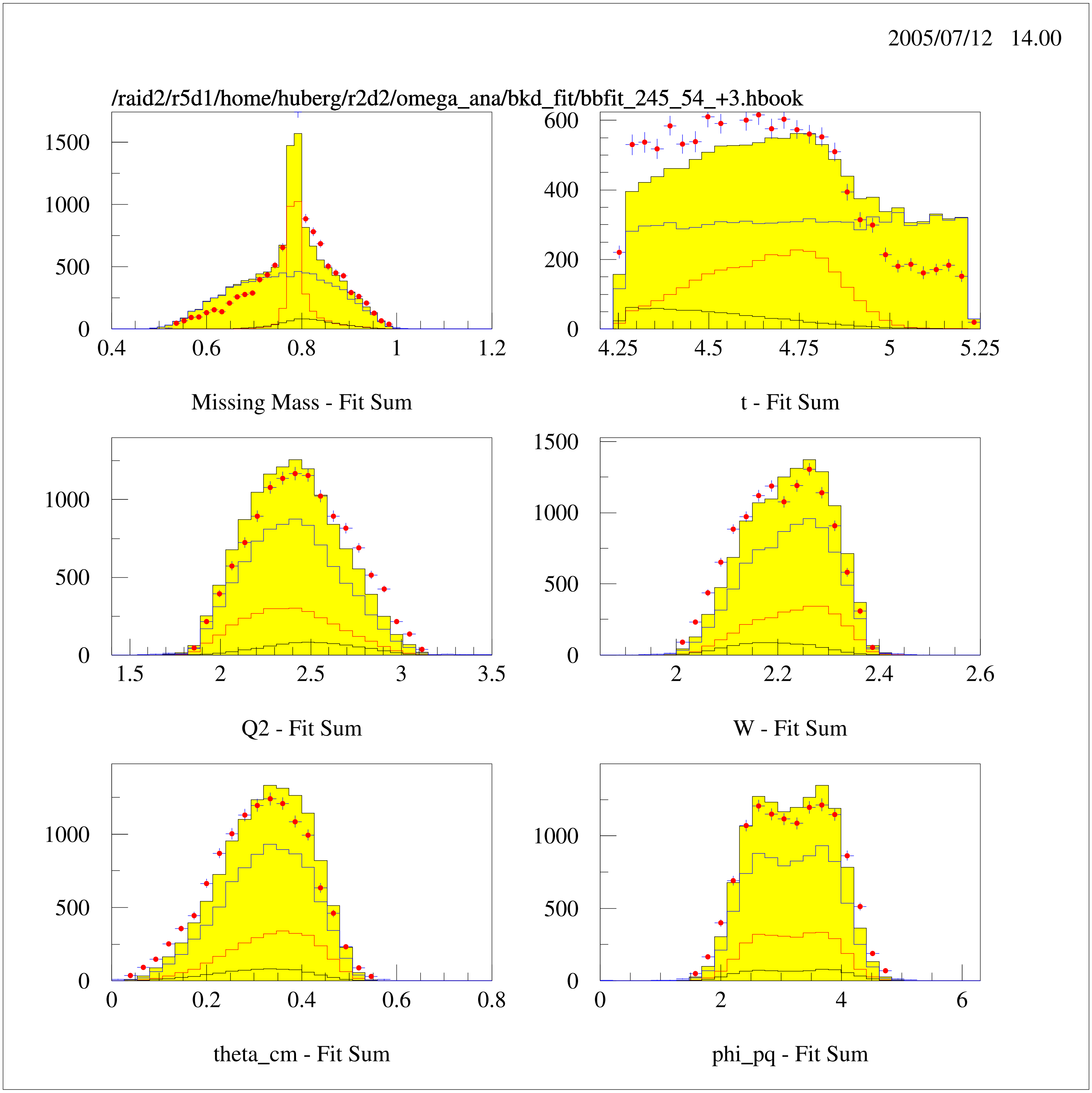

Figure 5: Fit to right HMS setting data at Q^2=2.45, ϵ=0.54. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

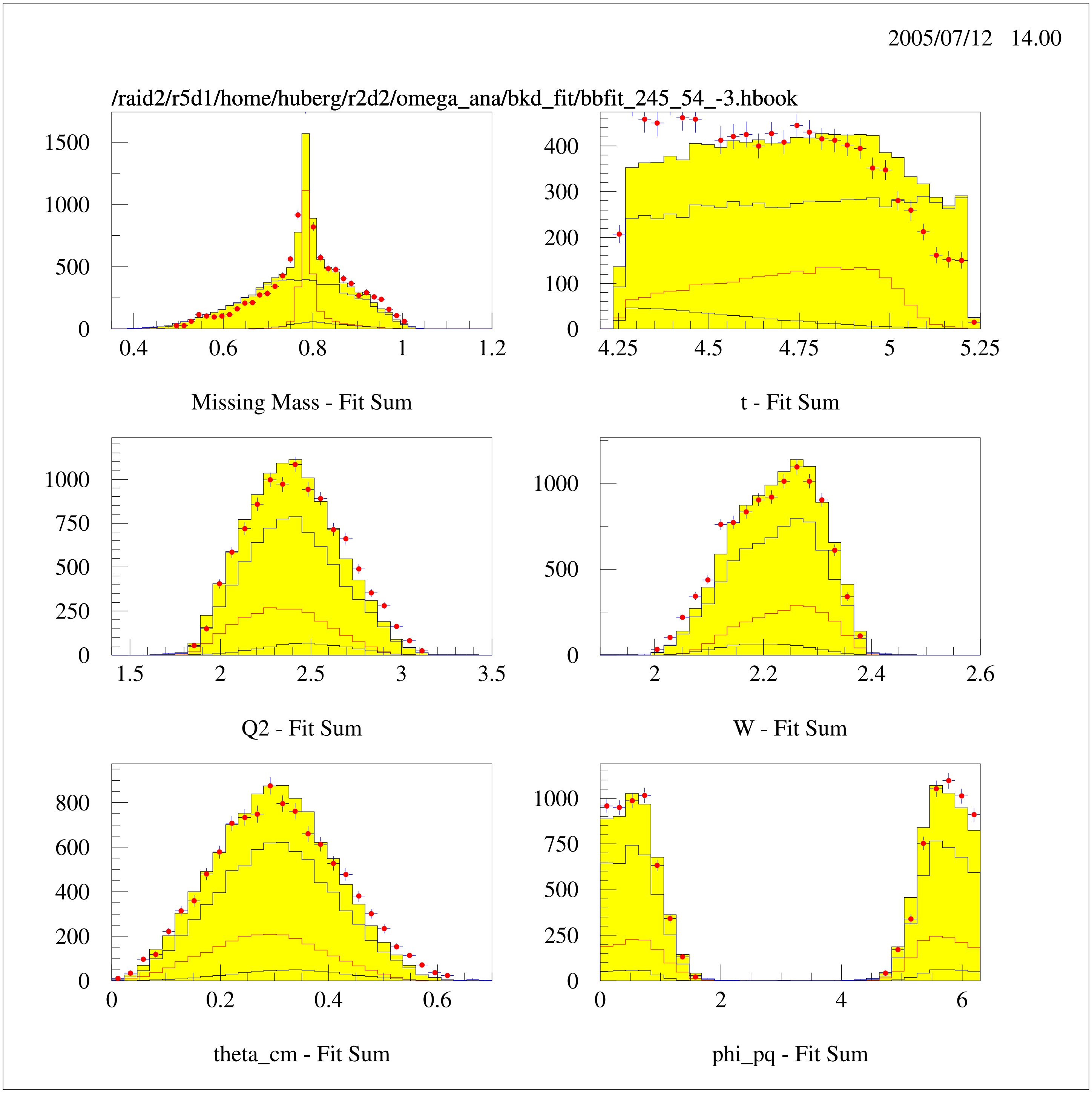

Figure 6: Fit to left HMS setting data at Q^2=2.45, ϵ=0.54. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

Binning in M_x, $-t$, θ^*_{pq} and ϕ_{mq} is done as follows:

- Missing mass is divided into three unequal width bins, 660-770 MeV, 770-800 MeV, and 800-1000 MeV. The central bin encloses nearly all of the ω events, as the peak is $\sim$25 MeV wide at its base. The other two bins are to indicate the θ^* and ϕ distribution of the ρ background underneath.

- $-t$ is divided into four equal bins, spanning 4.15-5.30 GeV^2 at $Q^2 = 2.45$ and 3.45-4.55 GeV^2 at $Q^2 = 1.60$.

- The center of mass pq scattering angle θ^*_{pq} from 0 to 22^o is divided into four equal bins.

- The azimuthal angle between the missing mass and the q-vector, ϕ_{mq} is divided into eight equal bins spanning 0 to 2π.

- The data coincidences (after random and dummy target subtraction) are individually binned and divided by the experimental efficiency (but not charge) for the three different HMS settings. The bins for the three HMS settings are then combined to yield the complete ϕ distributions.

- For each MC, the simulated distributions for each HMS setting are individually binned, and normalized to the effective beam charge used in each HMS setting. No further correction should then be necessary for the different luminosities of the three HMS settings.

- For each MC, the bin values for all three HMS settings are further multiplied by the fit factor obtained from the fit to the central HMS setting data. A common fit factor is used for all three HMS settings, so as not to obsure the flaws in the θ^* description of the data.

- The Data/MC ratio is then computed separately for each bin, with full error propagation.

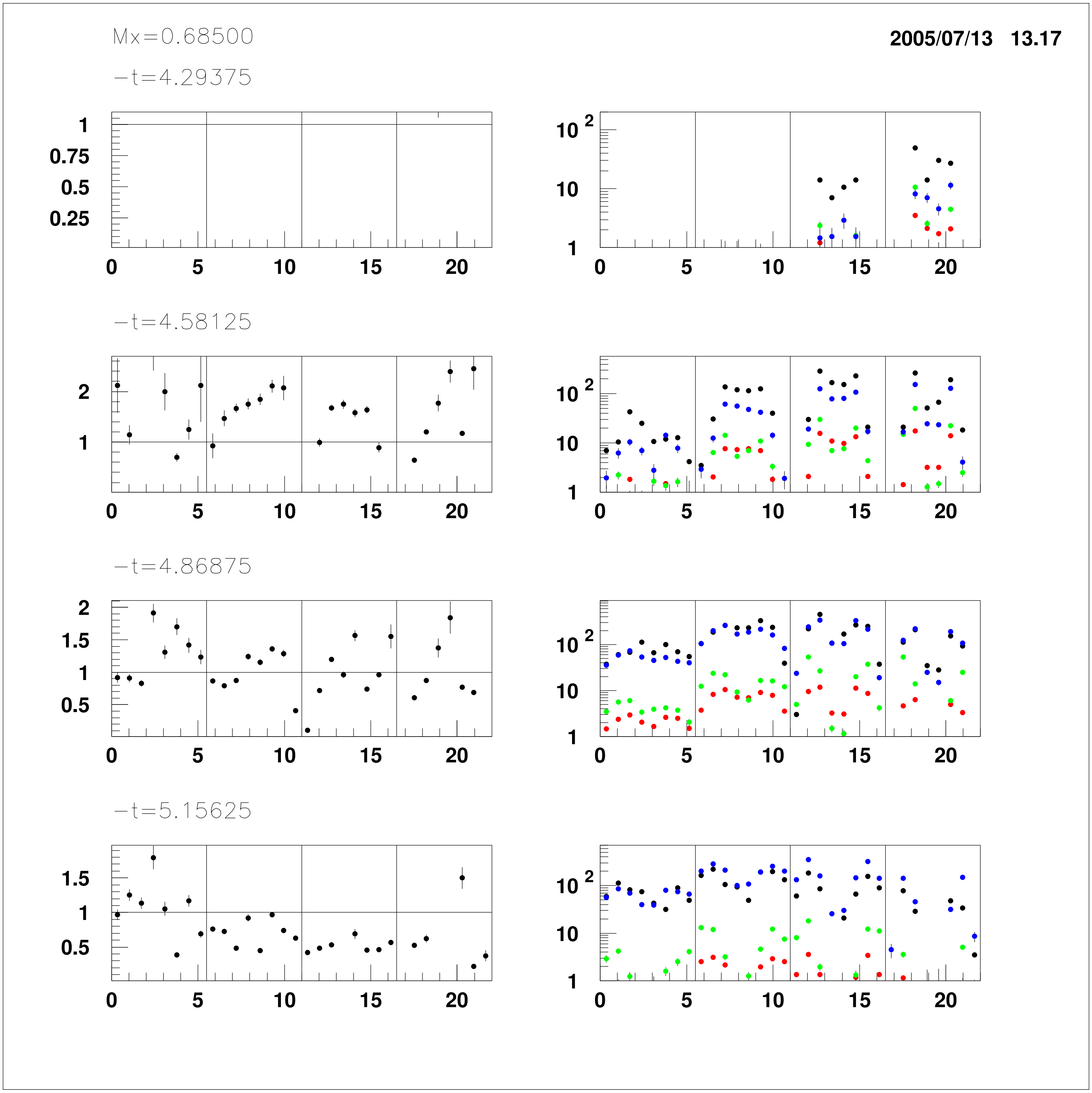

Figure 7: Low M_x bin data at $Q^2 = 2.45$, $\epsilon = 0.54$. For each $-t$ bin, ϕ distributions are shown for each of the four θ^* bins, in order of increasing θ^*_{pq}. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

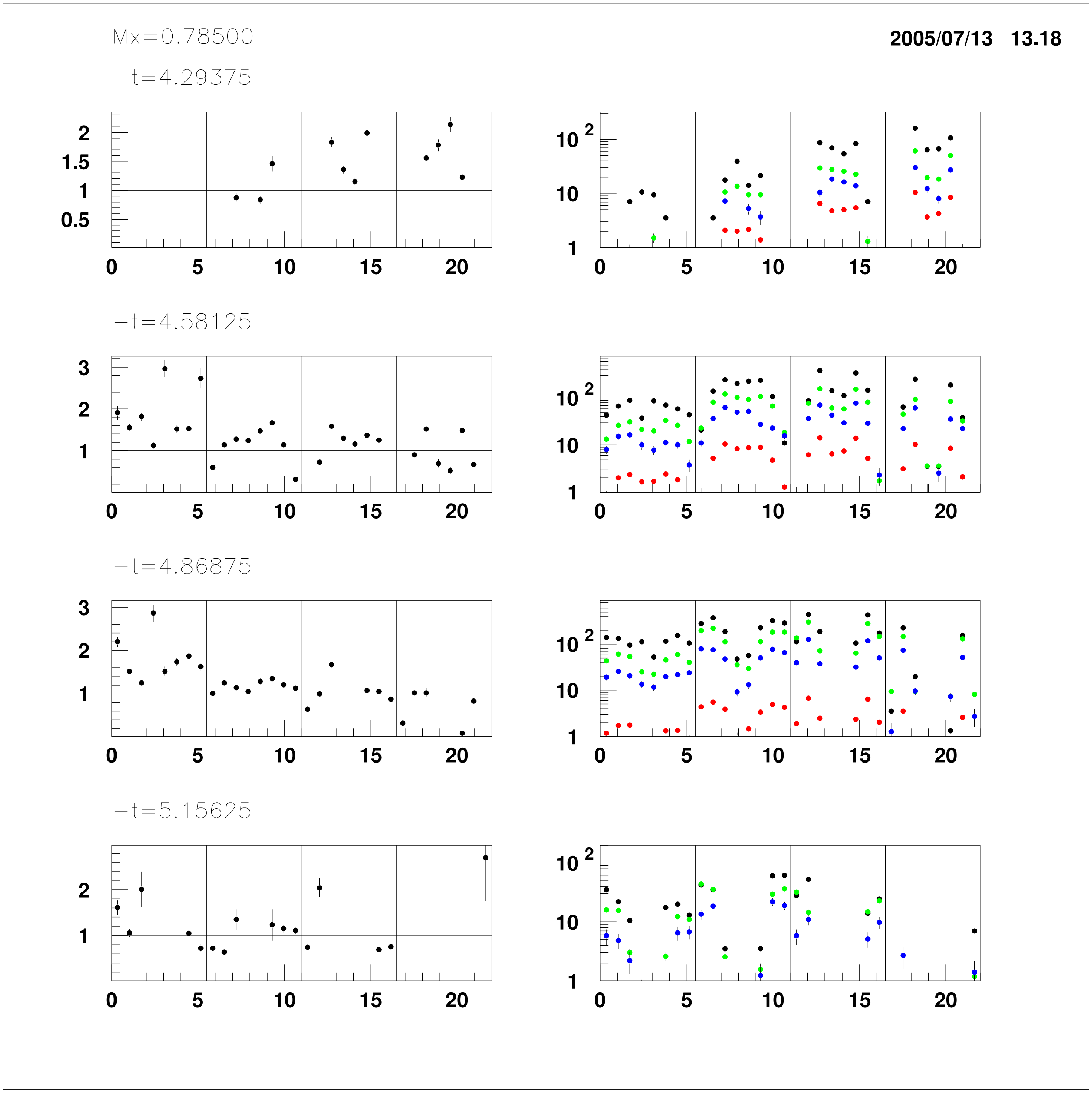

Figure 8: M_x centered on ω peak, for $Q^2 = 2.45$, $\epsilon = 0.54$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

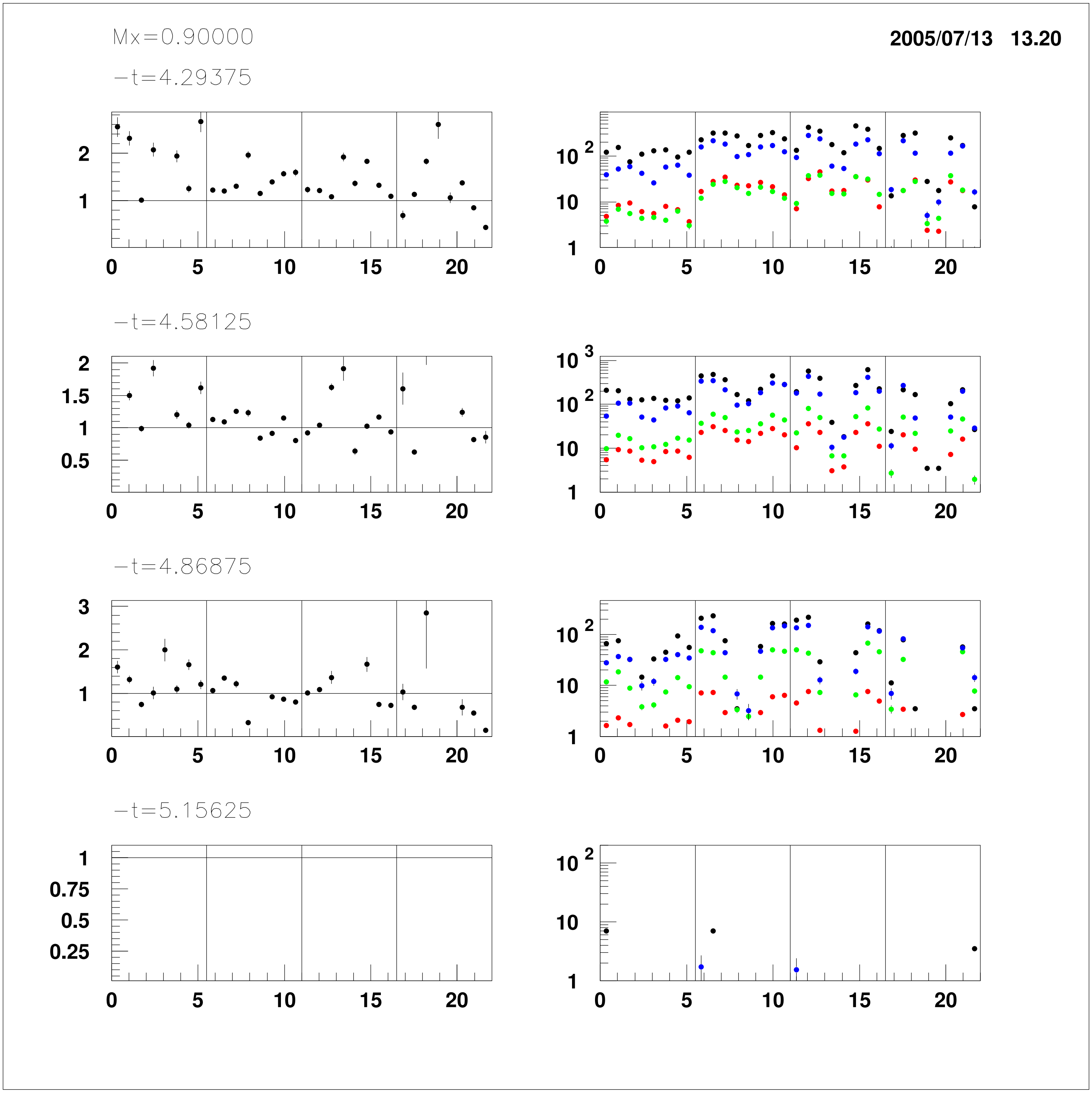

Figure 9: High M_x bin data at $Q^2 = 2.45$, $\epsilon = 0.54$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

4 $\mathbf{Q^2}$ =2.45 $\mathbf{GeV^2}$ $\epsilon = \mathbf{0.27}$

	Counts	Fit Fraction	MC multiplier
Central HMS $\theta_{pq} = +1$			
Data	12049		
Omega	3273	0.272	22.8
Rho	477	0.040	19.0
Phase-space	8295	0.688	1299.4
Right HMS $\theta_{pq} = +3$			
Data	12359		
Omega	3570	0.289	21.4
Rho	553	0.045	20.9
Phase-space	8233	0.666	1196.5

The fit is only to the missing mass histogram. A variation in the MC multiplier with HMS angle indicates a deficiency in the θ^*-dependence in the cross section model.

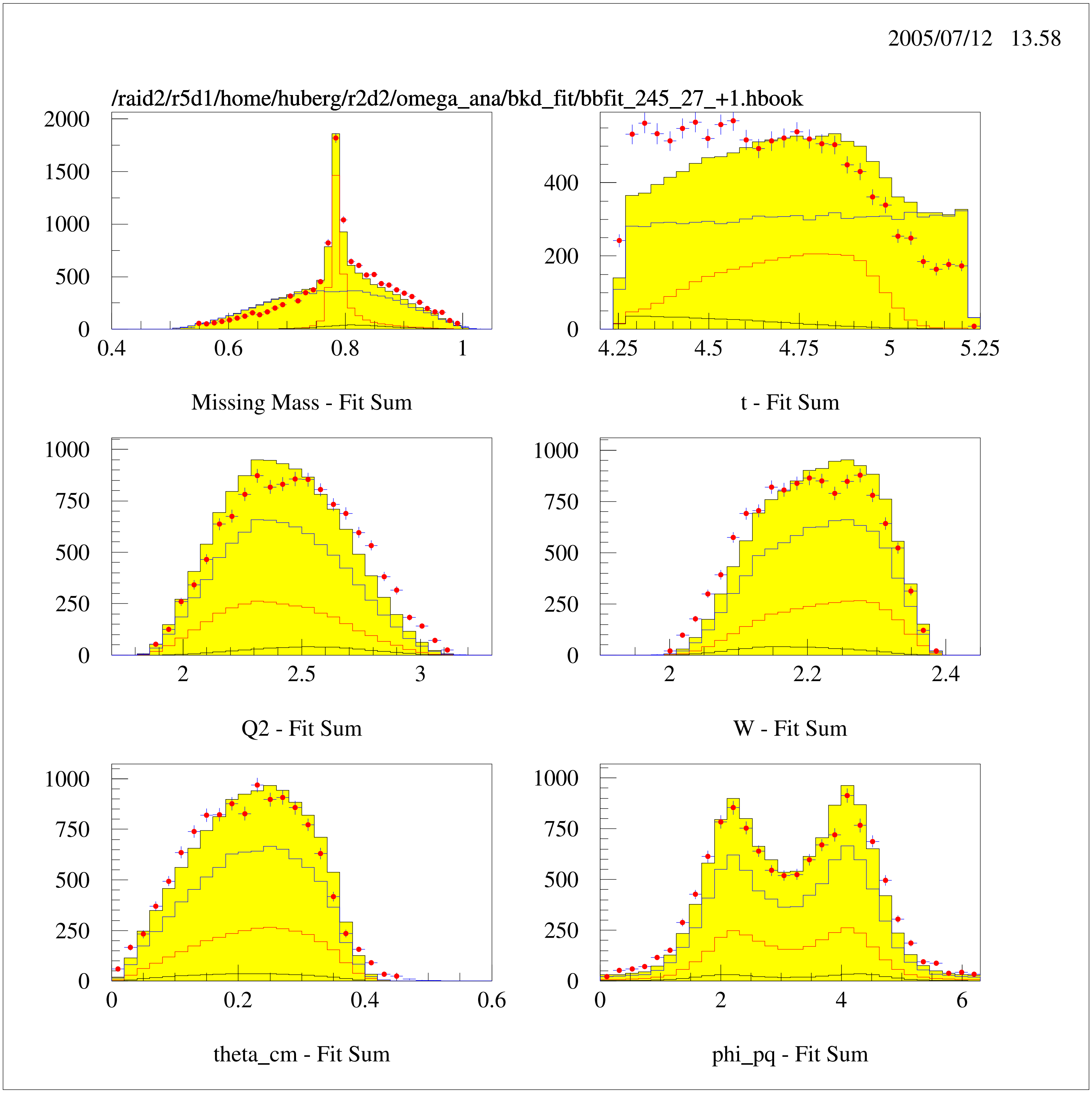

Figure 10: Fit to central HMS setting data at Q^2=2.45, ϵ=0.27. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

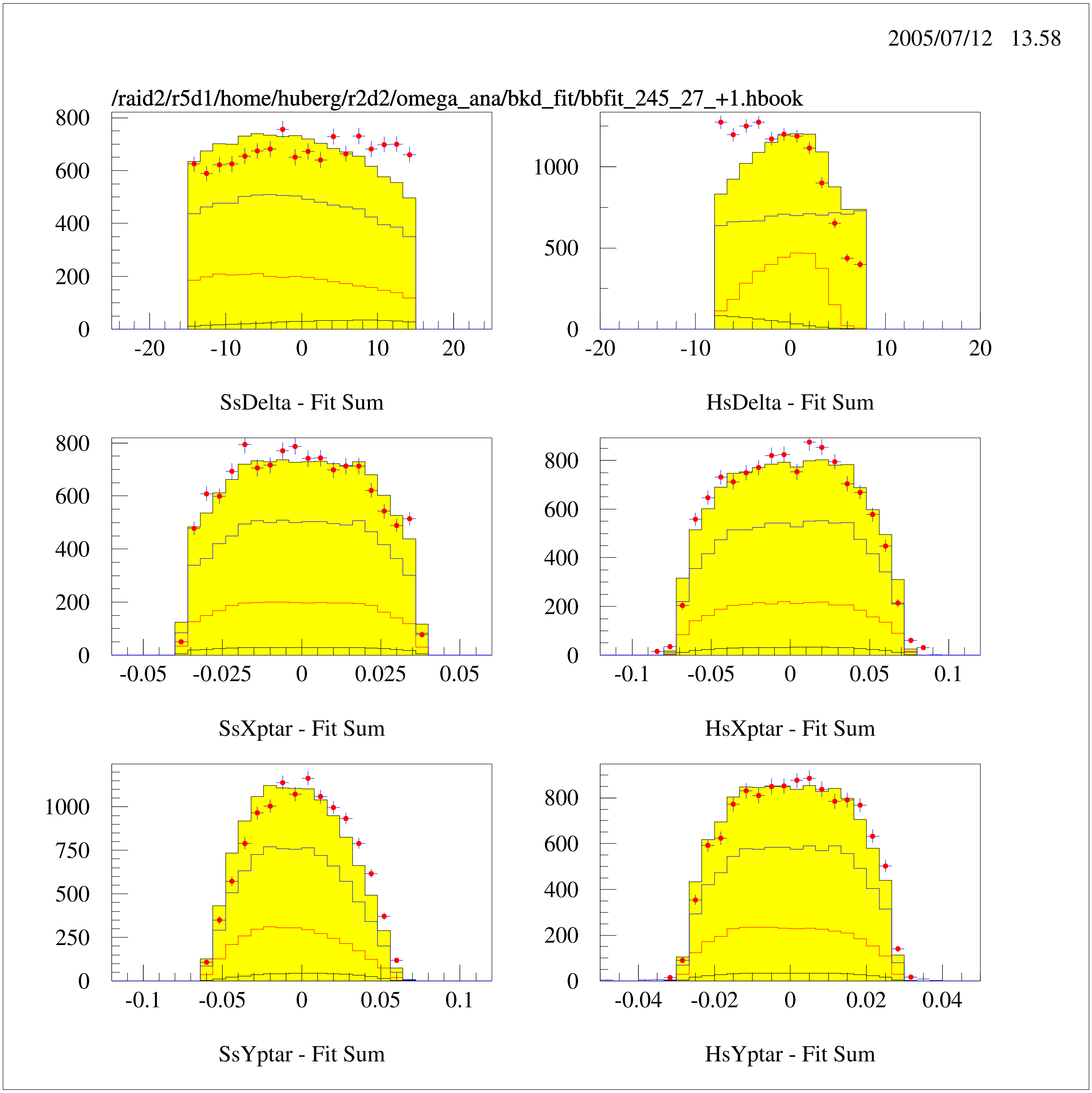

Figure 11: Spectrometer variable distributions for the same fit to missing mass shown on the previous page.

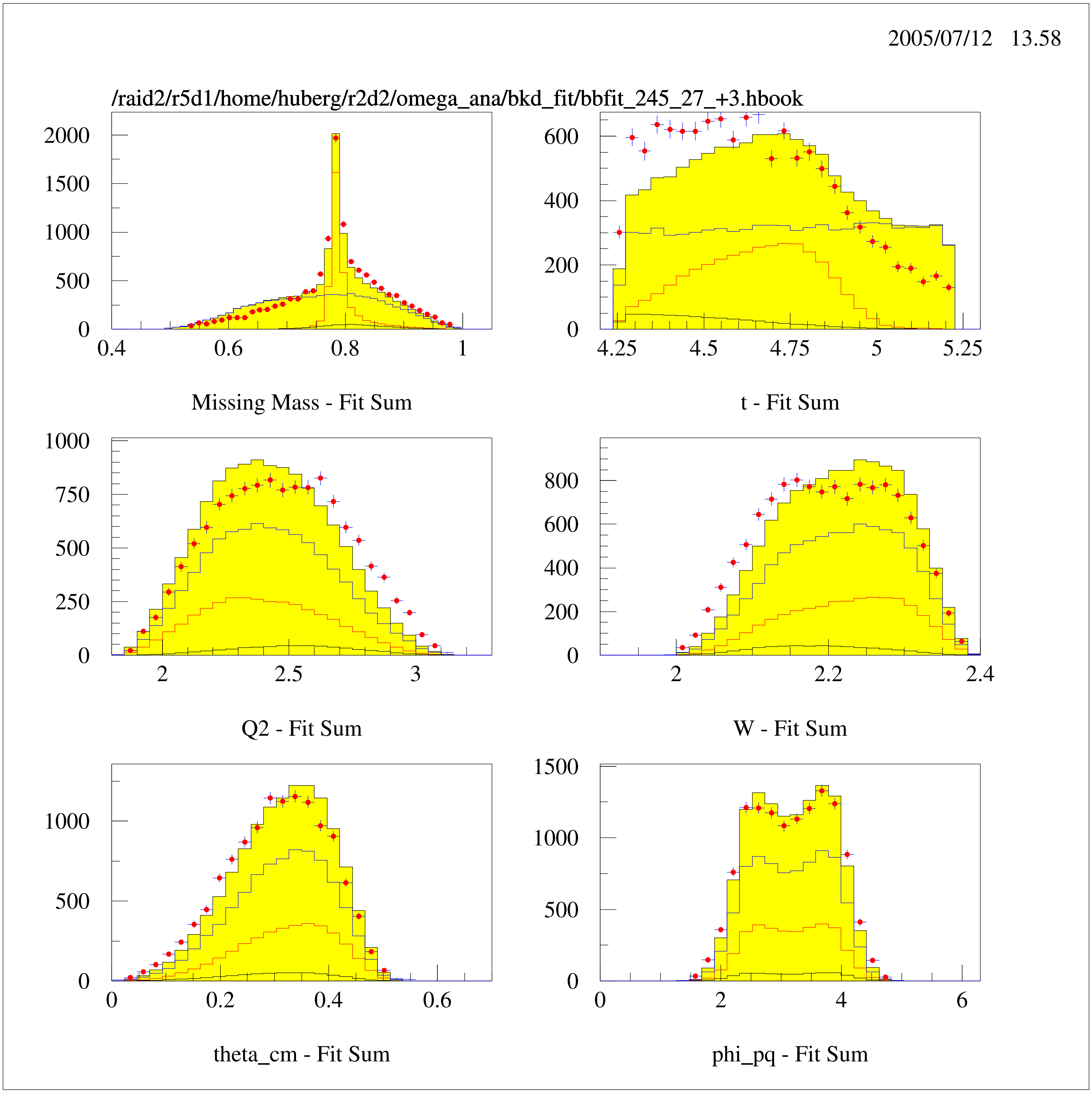

Figure 12: Fit to right HMS setting data at Q^2=2.45, ϵ=0.27. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

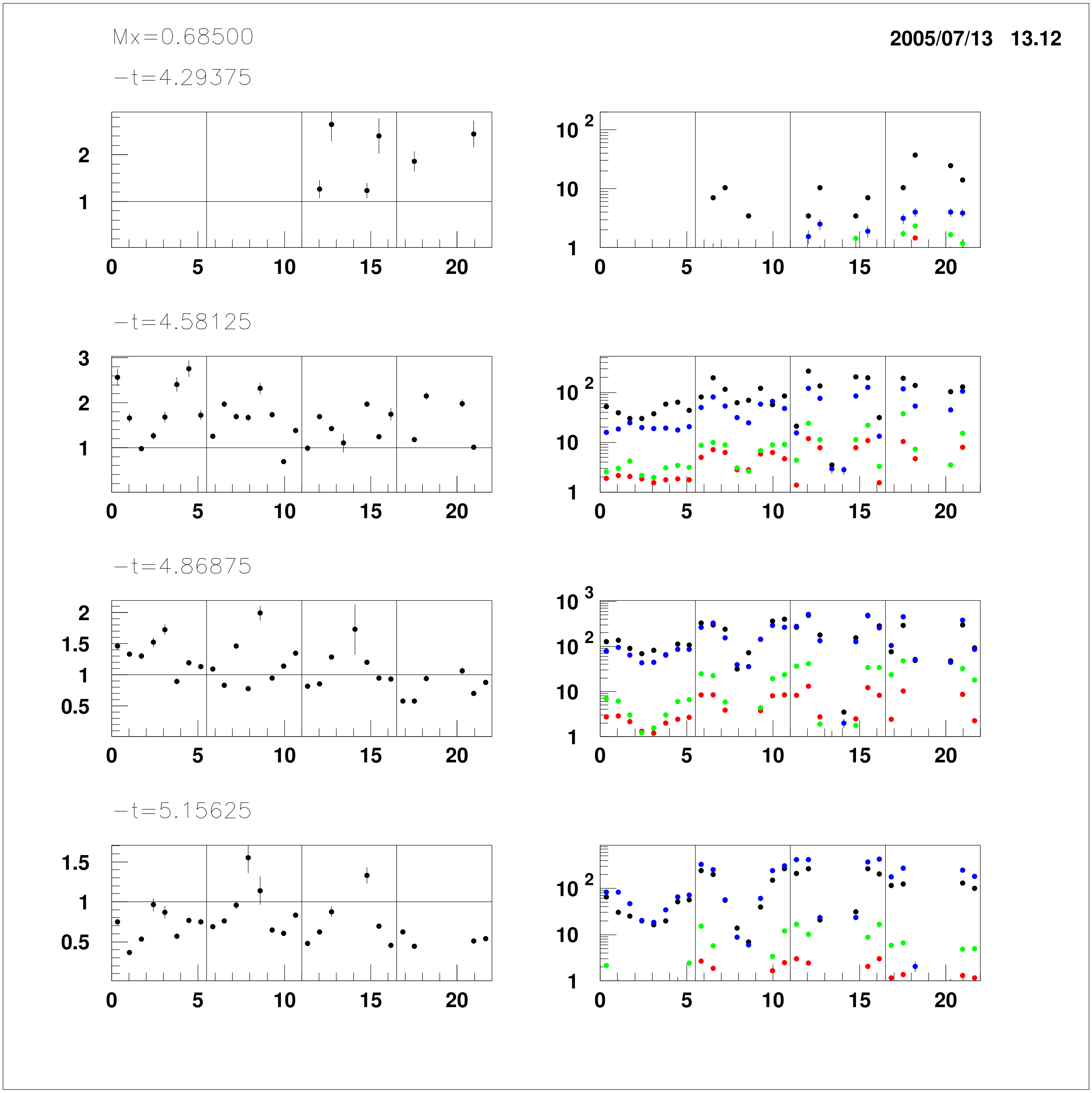

Figure 13: Low M_x bin data at $Q^2 = 2.45$, $\epsilon = 0.27$. For each $-t$ bin, ϕ distributions are shown for each of the four θ^* bins, in order of increasing θ^*_{pq}. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

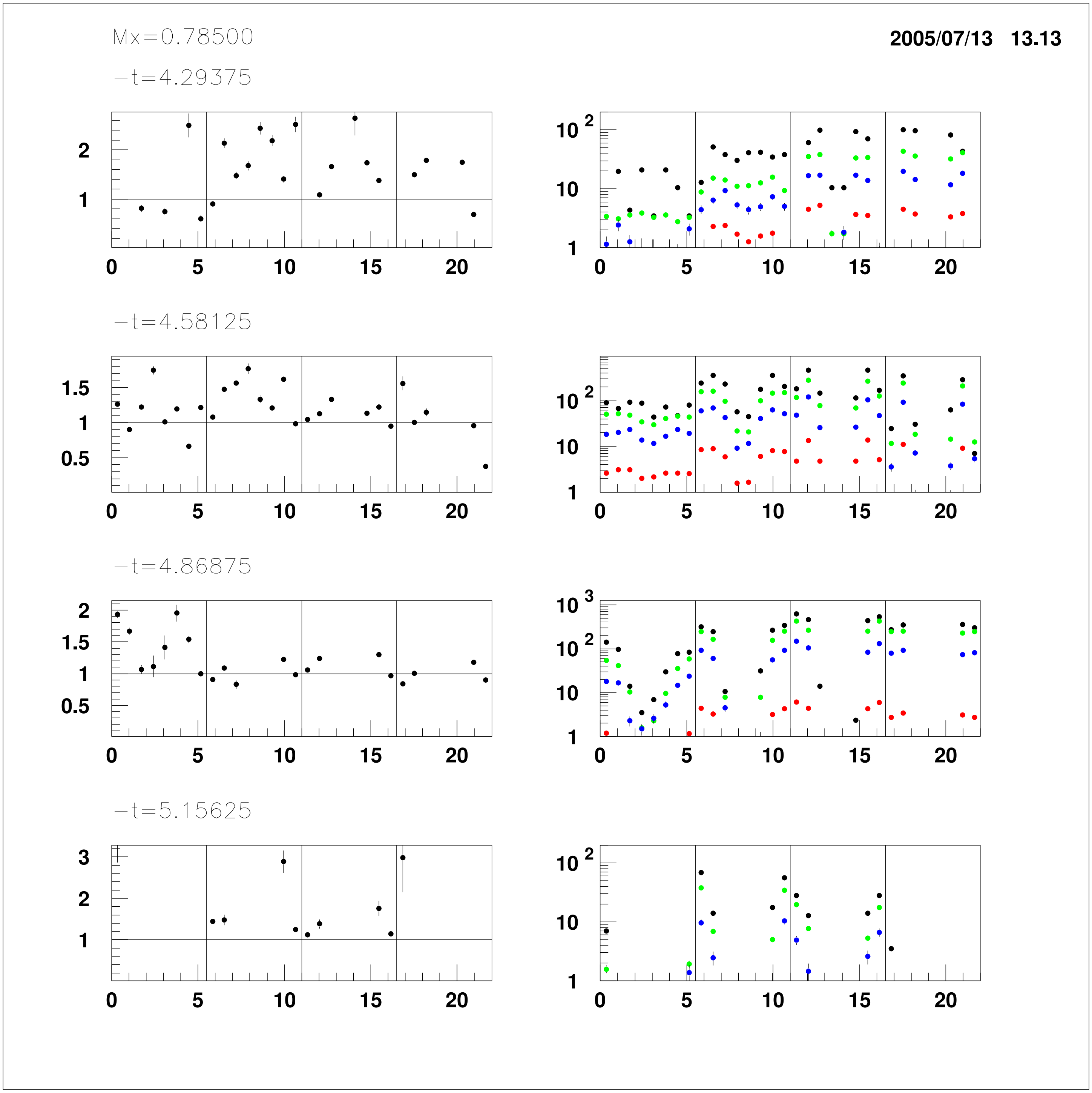

Figure 14: M_x centered on ω peak, for $Q^2 = 2.45$, $\epsilon = 0.27$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

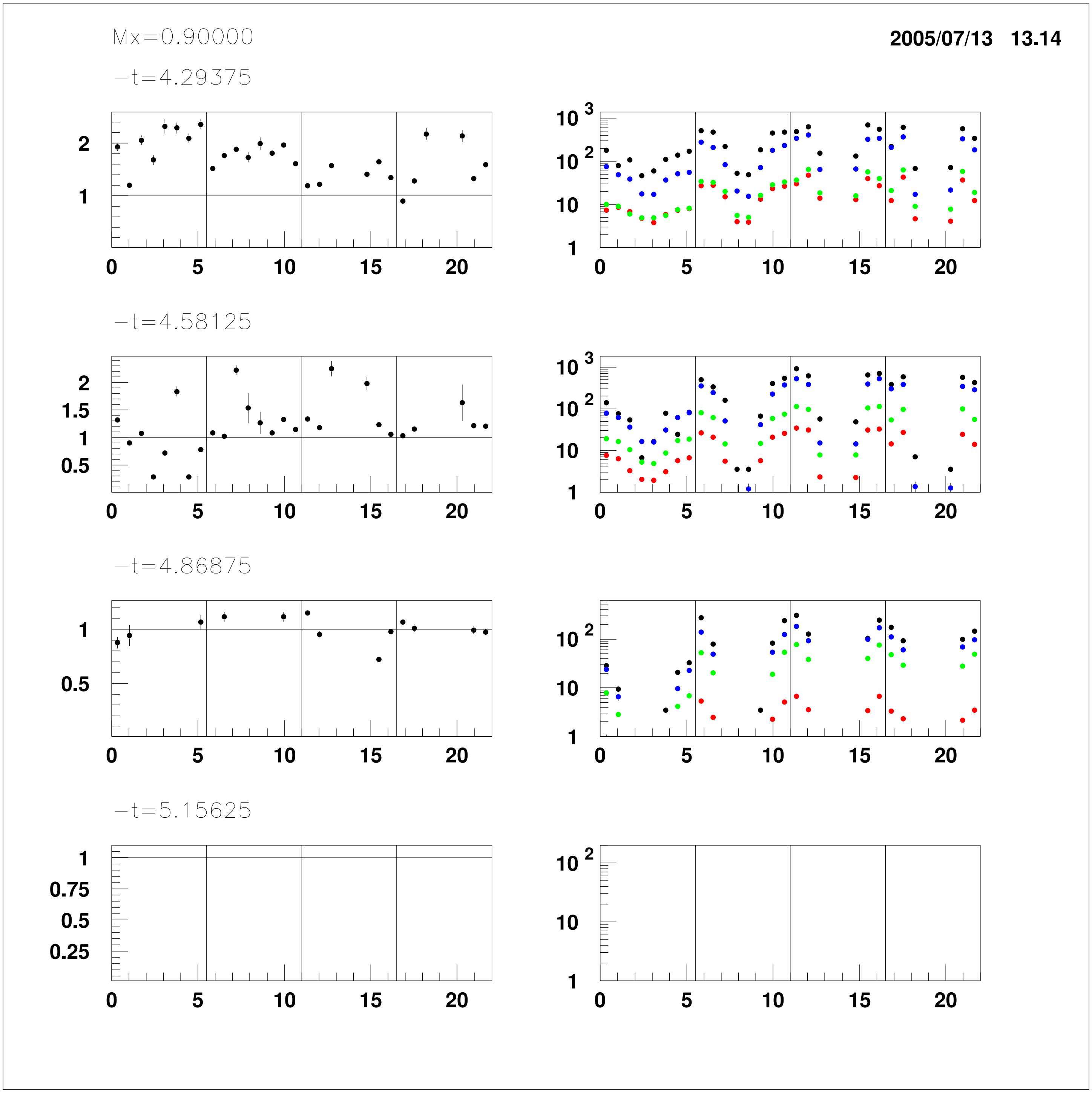

Figure 15: High M_x bin data at $Q^2 = 2.45$, $\epsilon = 0.27$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

5 Q^2 =1.60 GeV^2 $\epsilon = 0.58$

	Counts	Fit Fraction	MC multiplier
Central HMS $\theta_{pq} = 00$			
Data	8592		
Omega	2882	0.335	15.9
Rho	986	0.115	46.5
Phase-space	4723	0.550	1547.4
Right HMS $\theta_{pq} = +3$			
Data	10145		
Omega	2920	0.288	10.8
Rho	689	0.068	26.6
Phase-space	6534	0.644	1752.9
Left HMS $\theta_{pq} = -3$			
Data	9440		
Omega	2392	0.254	13.0
Rho	853	0.091	35.4
Phase-space	6191	0.656	1632.6

The fit is only to the missing mass histogram. A variation in the MC multiplier with HMS angle indicates a deficiency in the θ^*-dependence in the cross section model.

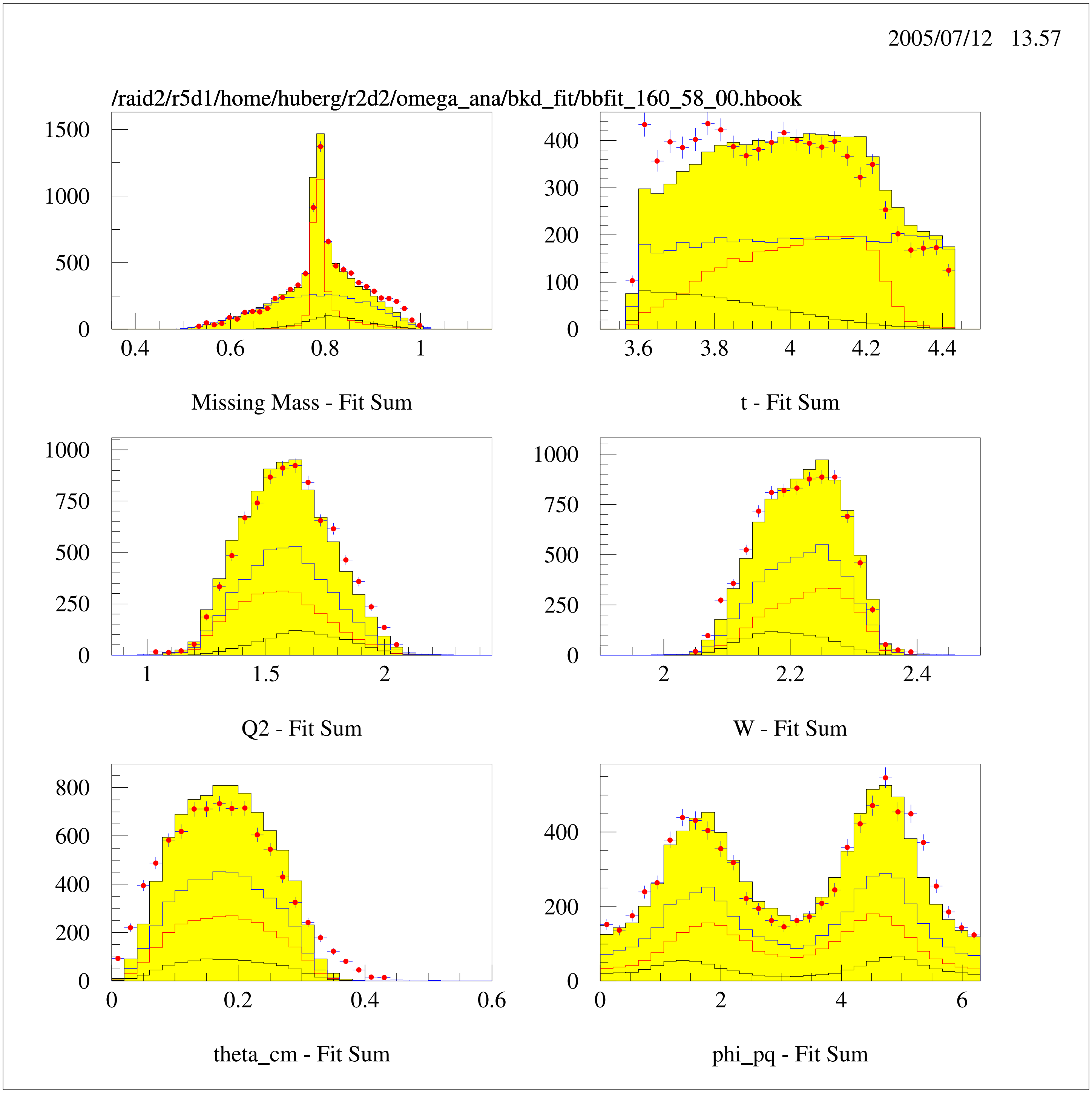

Figure 16: Fit to central HMS setting data at Q^2=1.60, ϵ=0.58. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

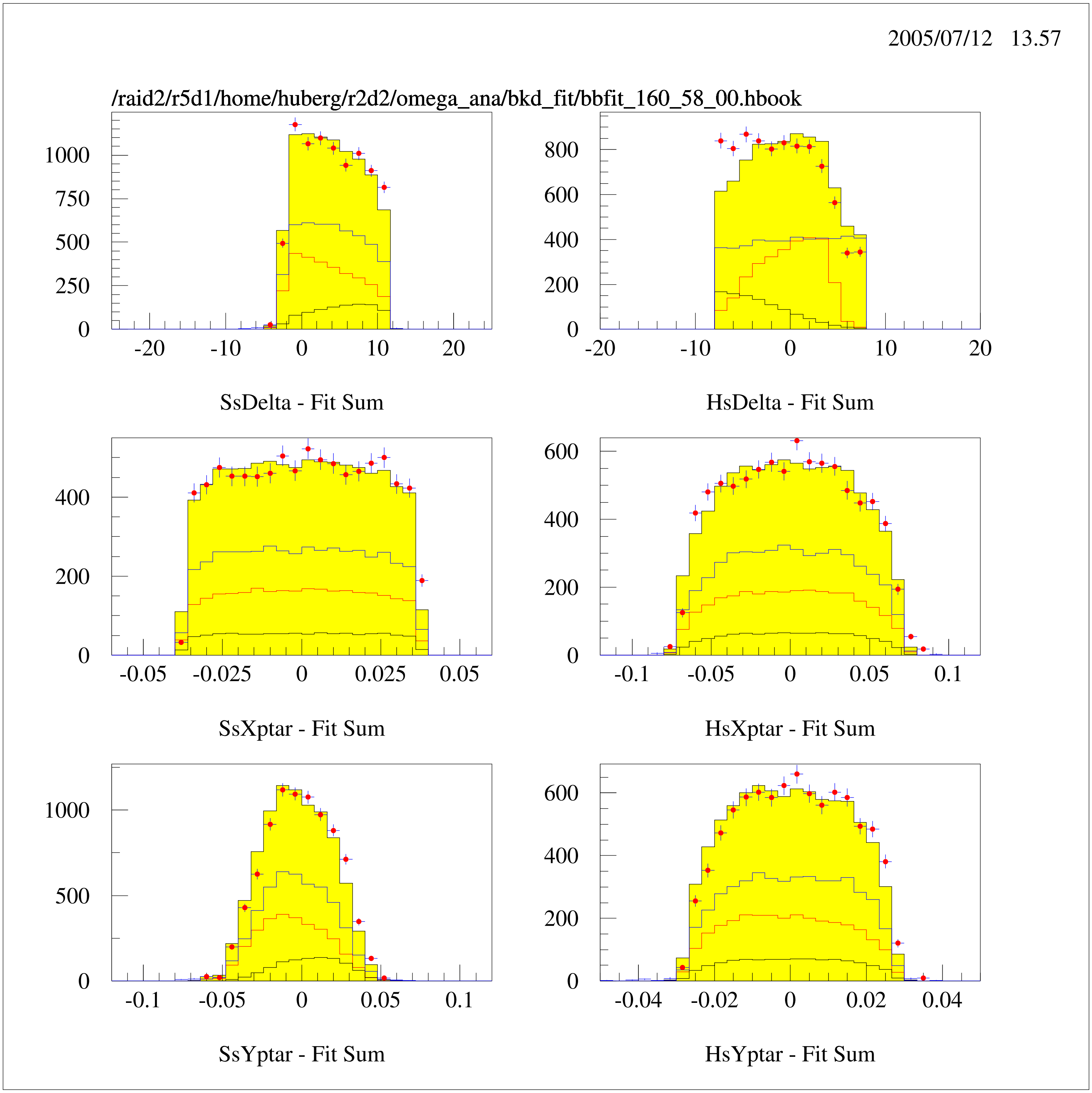

Figure 17: Spectrometer variable distributions for the same fit to missing mass shown on the previous page.

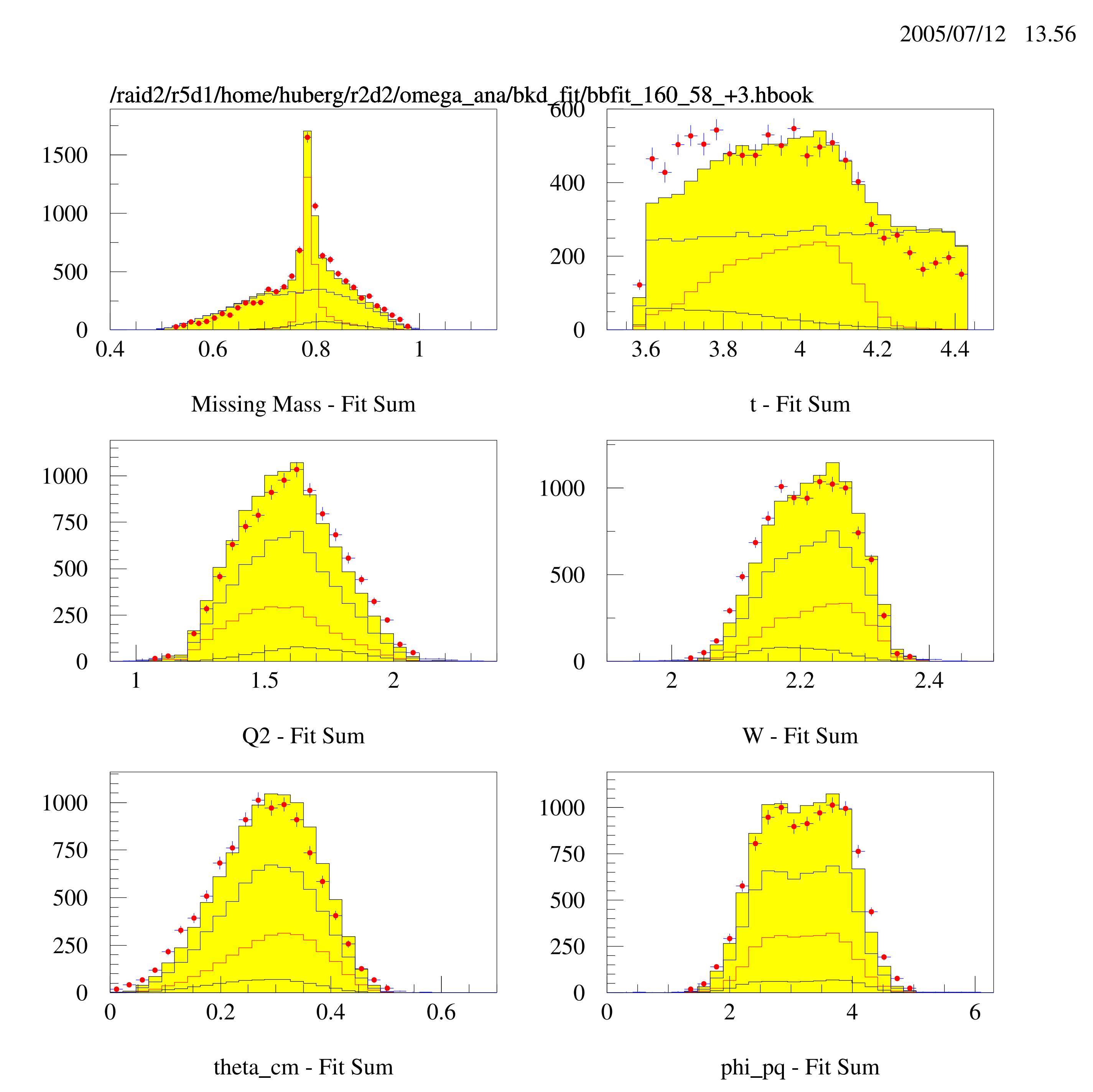

Figure 18: Fit to right HMS setting data at Q^2=1.60, ϵ=0.58. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

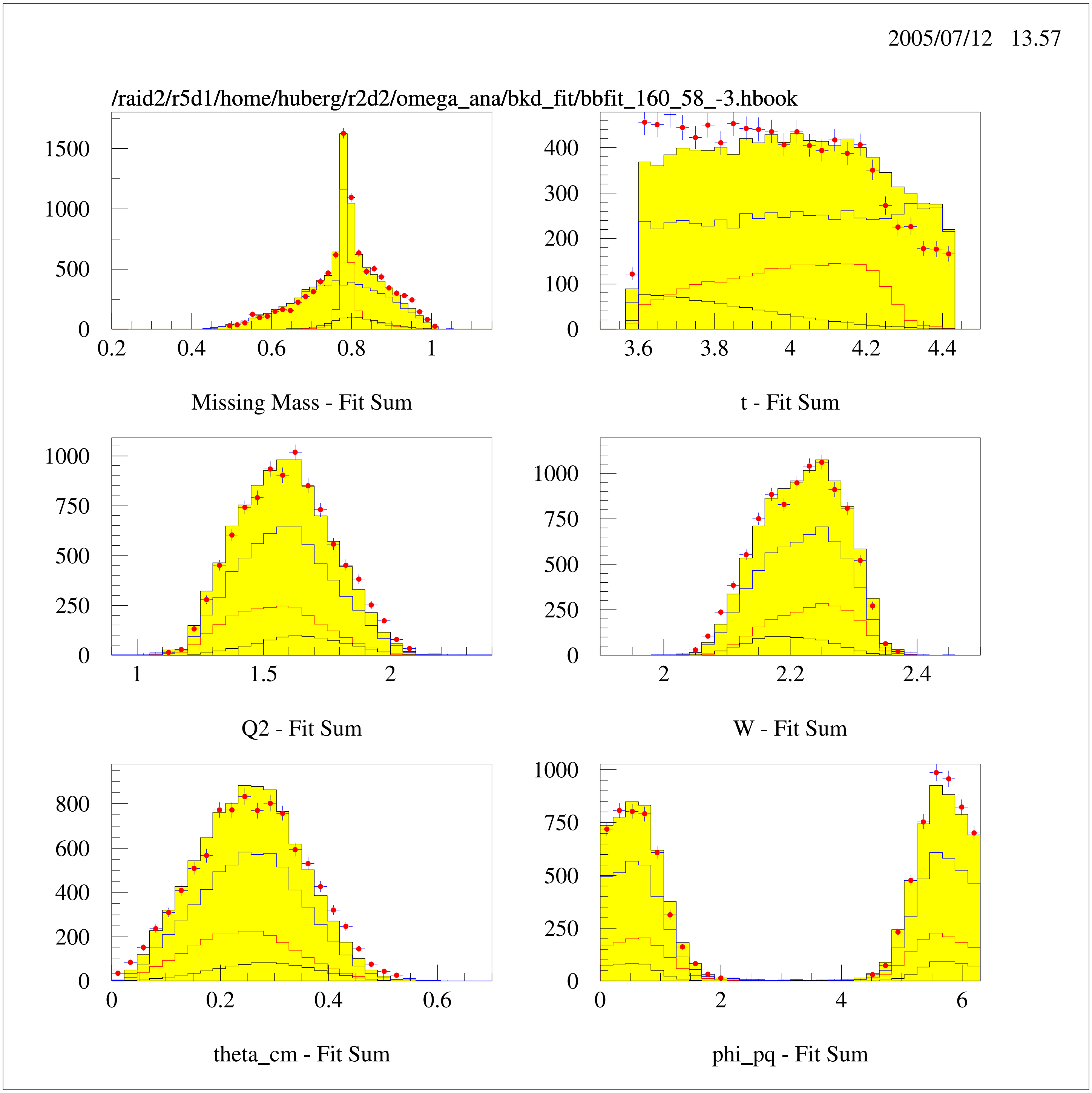

Figure 19: Fit to left HMS setting data at Q^2=1.60, ϵ=0.58. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

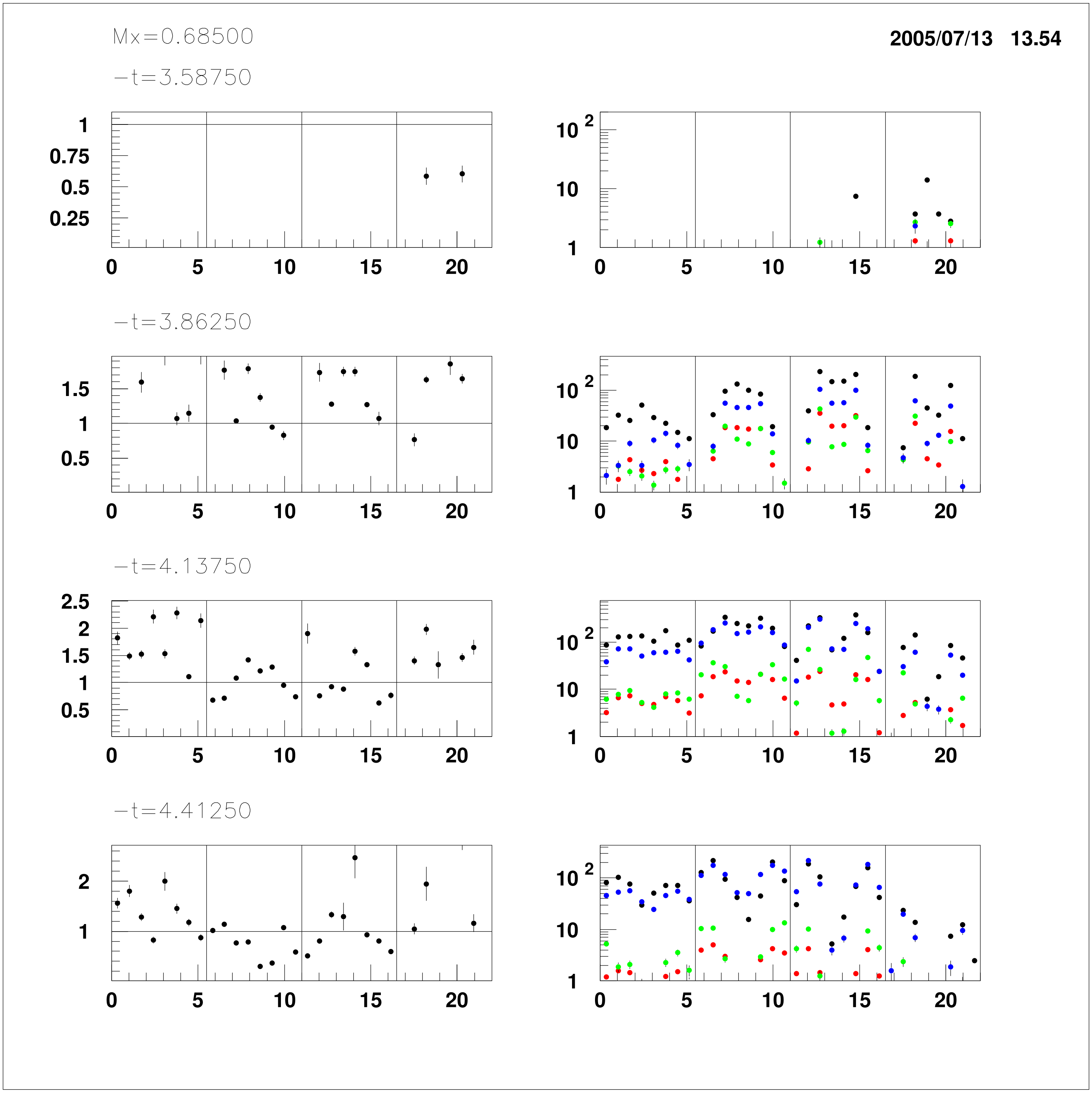

Figure 20: Low M_x bin data at $Q^2 = 1.60$, $\epsilon = 0.58$. For each $-t$ bin, ϕ distributions are shown for each of the four θ^* bins, in order of increasing θ^*_{pq}. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

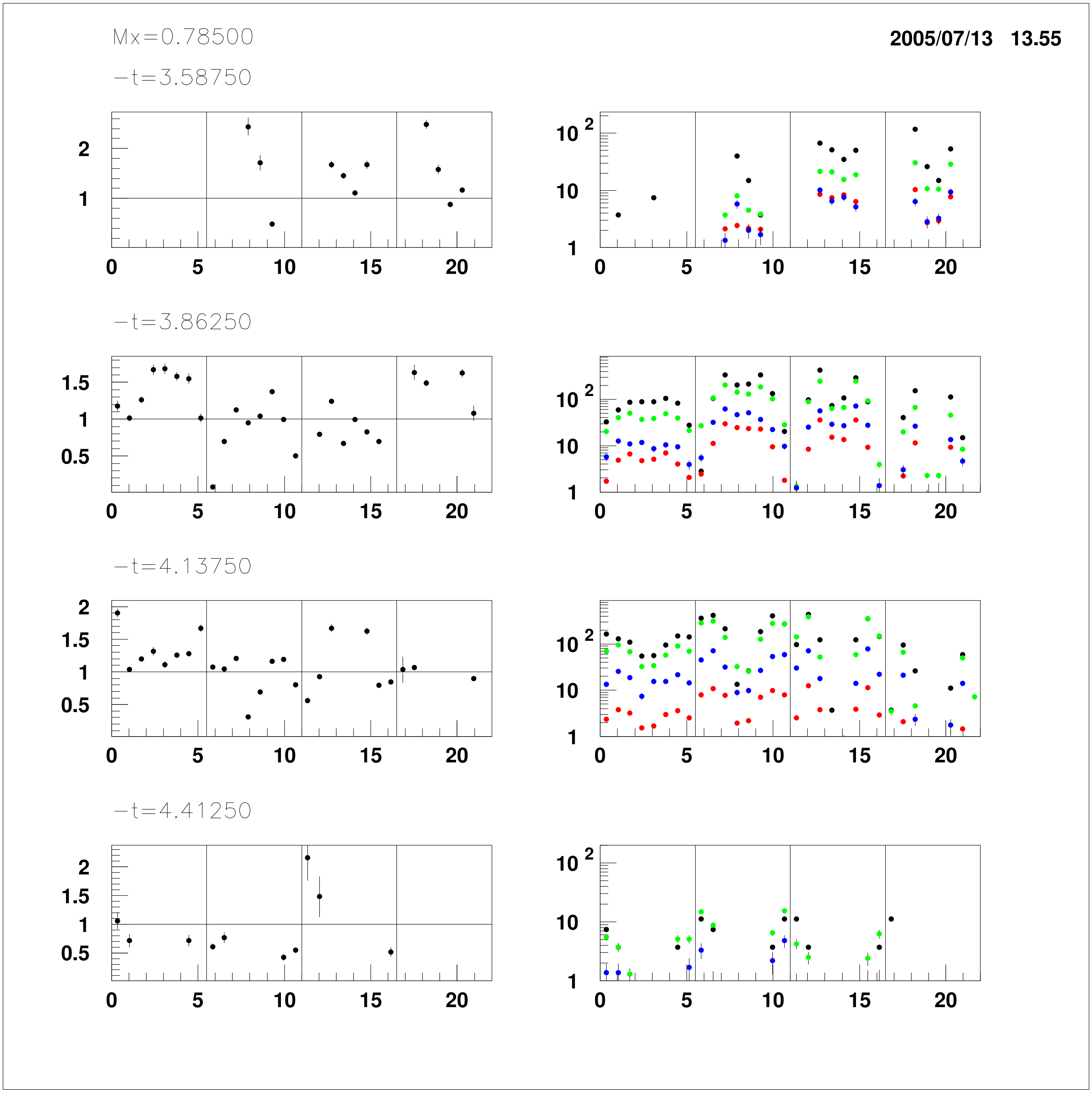

Figure 21: M_x centered on ω peak, for $Q^2 = 1.60$, $\epsilon = 0.58$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

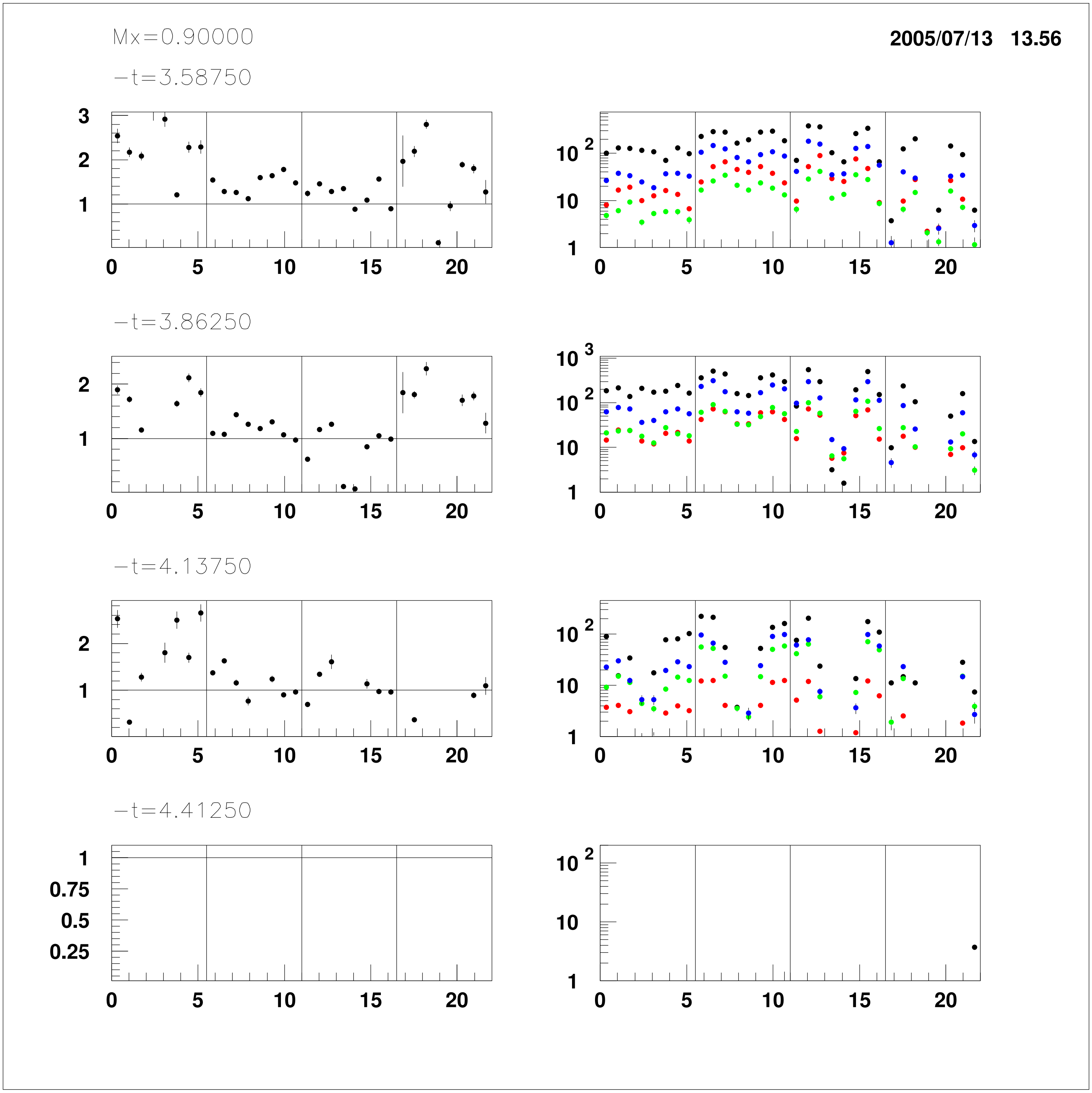

Figure 22: High M_x bin data at $Q^2 = 1.60$, $\epsilon = 0.58$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

6 $\mathbf{Q^2}$ =1.60 GeV^2 $\epsilon = 0.33$

The resulting fit parameters for the two remaining HMS settings are given in the table below.

	Counts	Fit Fraction	MC multiplier
Central HMS $\theta_{pq} = +1$			
Data	9770		
Omega	3241	0.331	15.0
Rho	866	0.782	35.2
Phase-space	5660	0.698	1451.9
Right HMS $\theta_{pq} = +3$			
Data	10959		
Omega	3888	0.355	14.2
Rho	1036	0.095	37.7
Phase-space	6031	0.551	1369.9

The fit is only to the missing mass histogram. A variation in the MC multiplier with HMS angle indicates a deficiency in the θ^*-dependence in the cross section model.

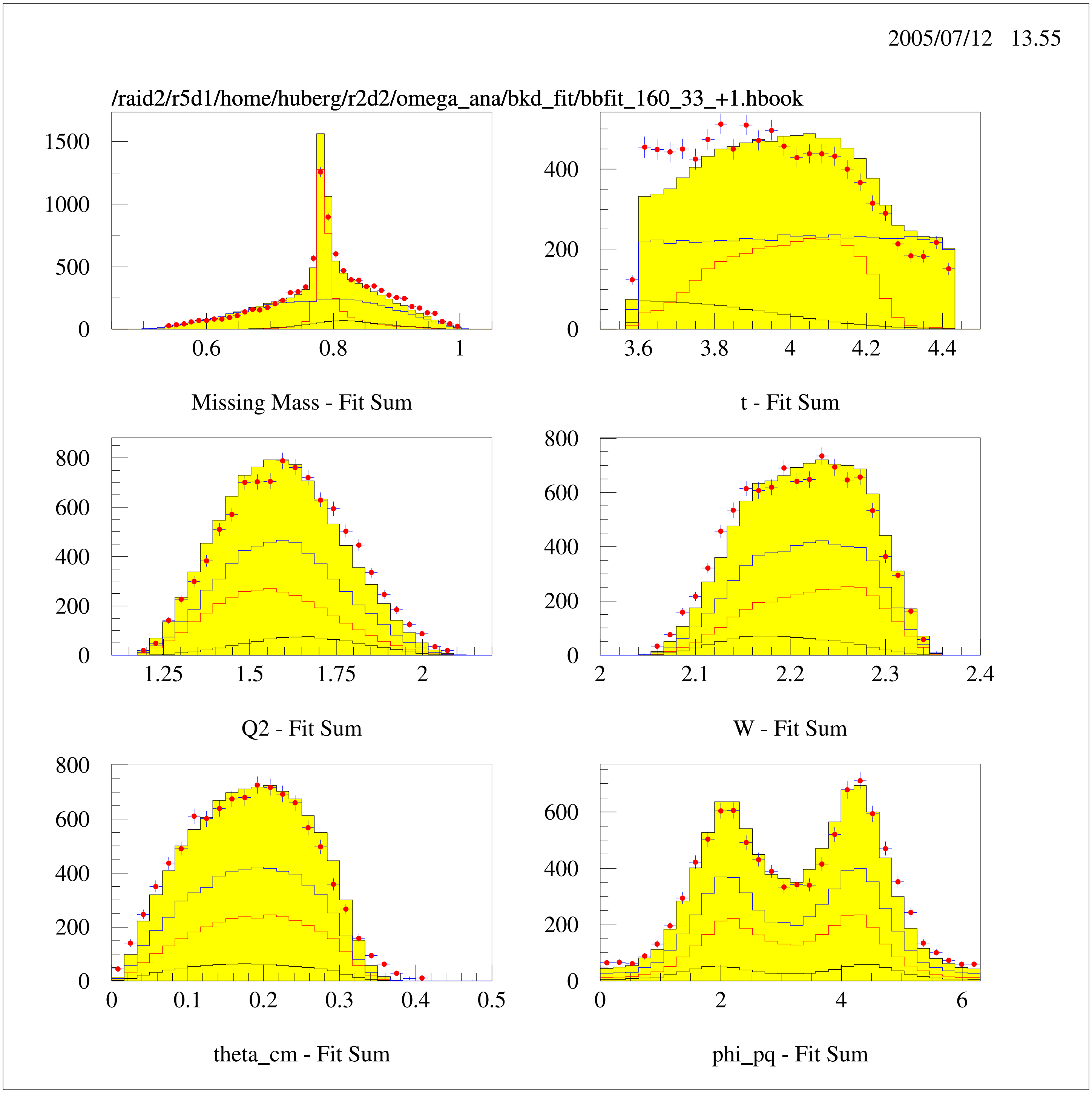

Figure 23: Fit to central HMS setting data at Q^2=1.60, ϵ=0.33. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

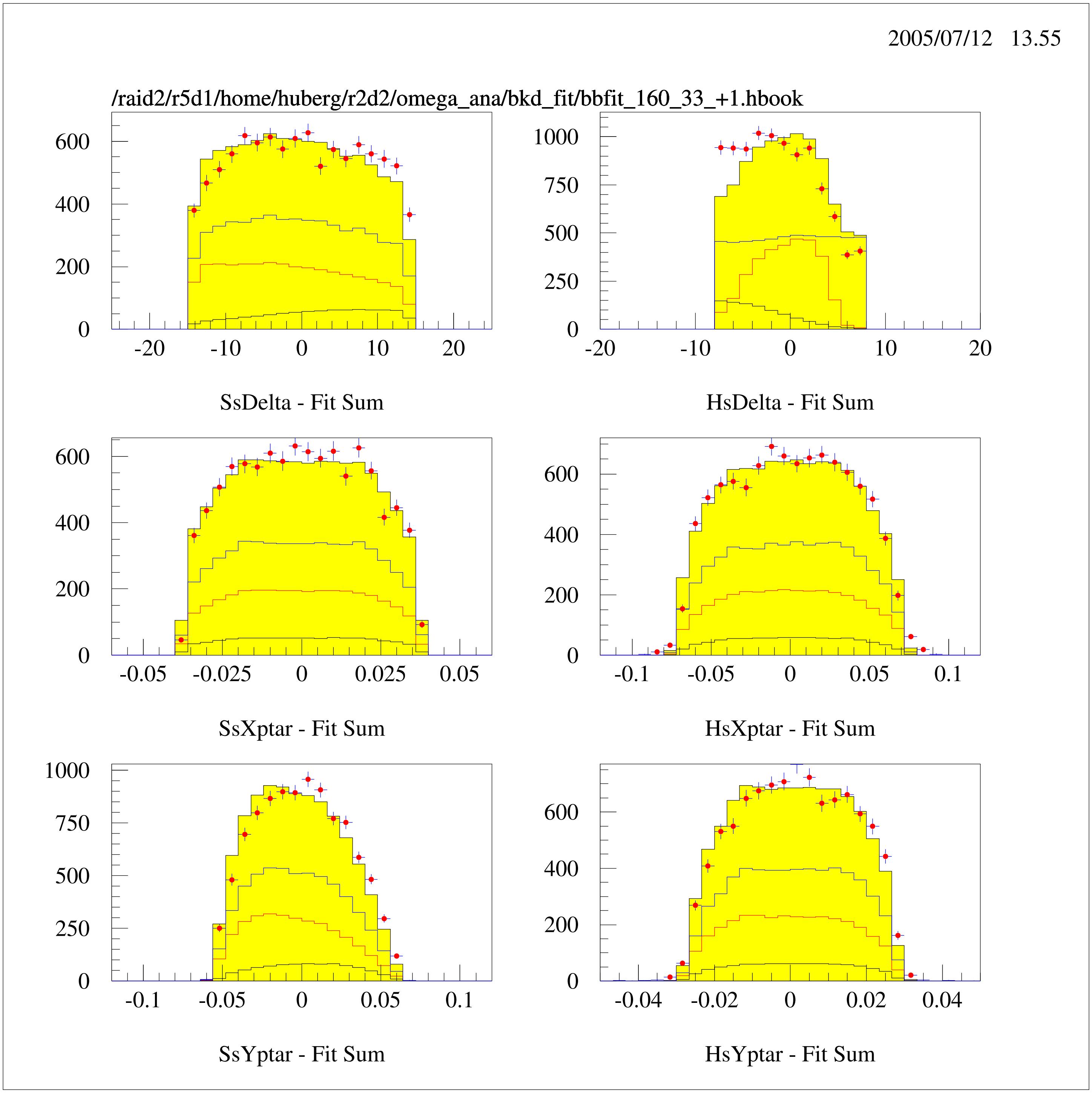

Figure 24: Spectrometer variable distributions for the same fit to missing mass shown on the previous page.

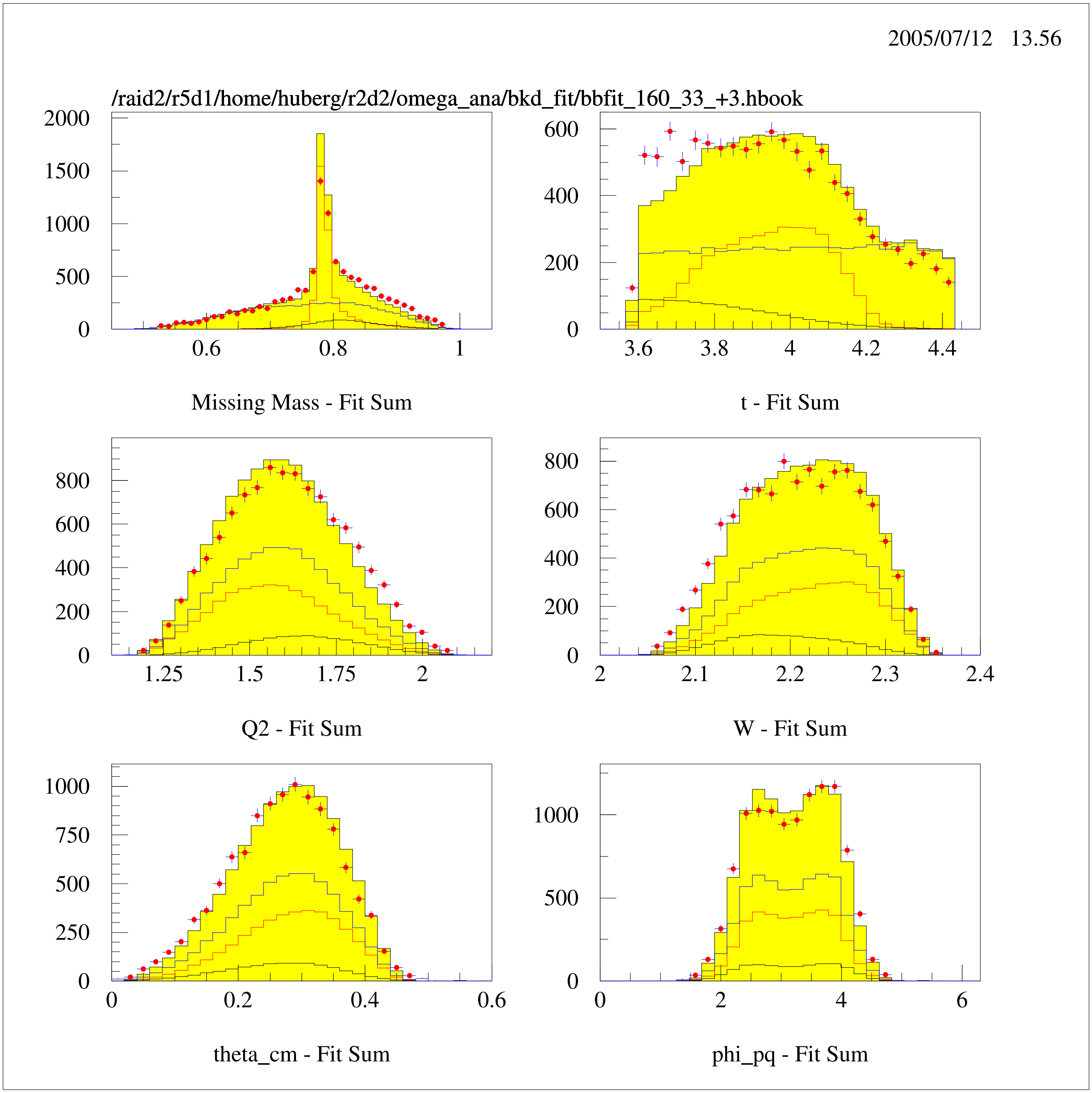

Figure 25: Fit to right HMS setting data at Q^2=1.60, ϵ=0.33. The red points are the experimental data. The red curve is the fit ω MC, the blue curve is the PS MC, and the black curve the ρ MC. The yellow region the sum of the three MC's.

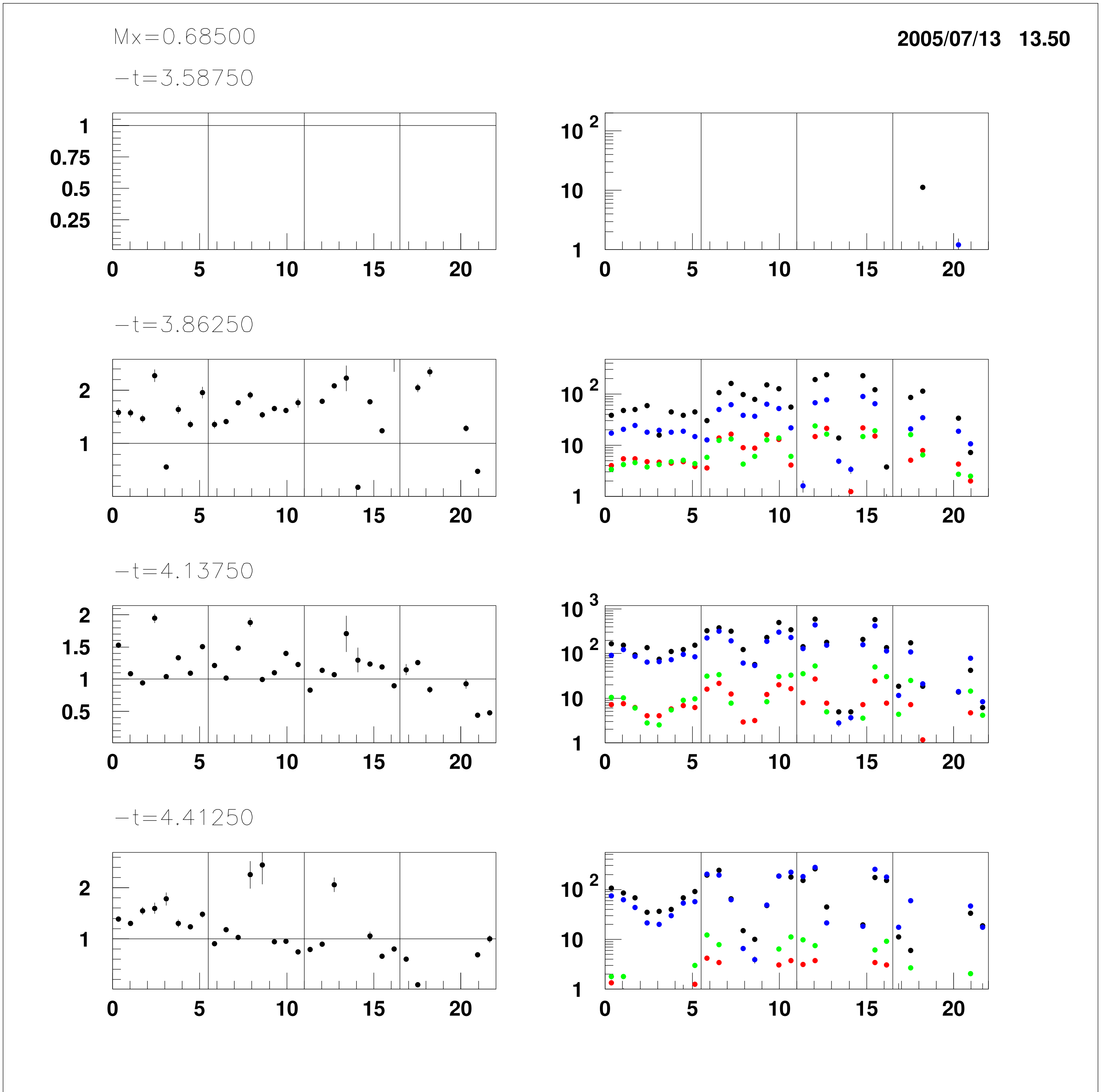

Figure 26: Low M_x bin data at $Q^2 = 1.60$, $\epsilon = 0.33$. For each $-t$ bin, ϕ distributions are shown for each of the four θ^* bins, in order of increasing θ^*_{pq}. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

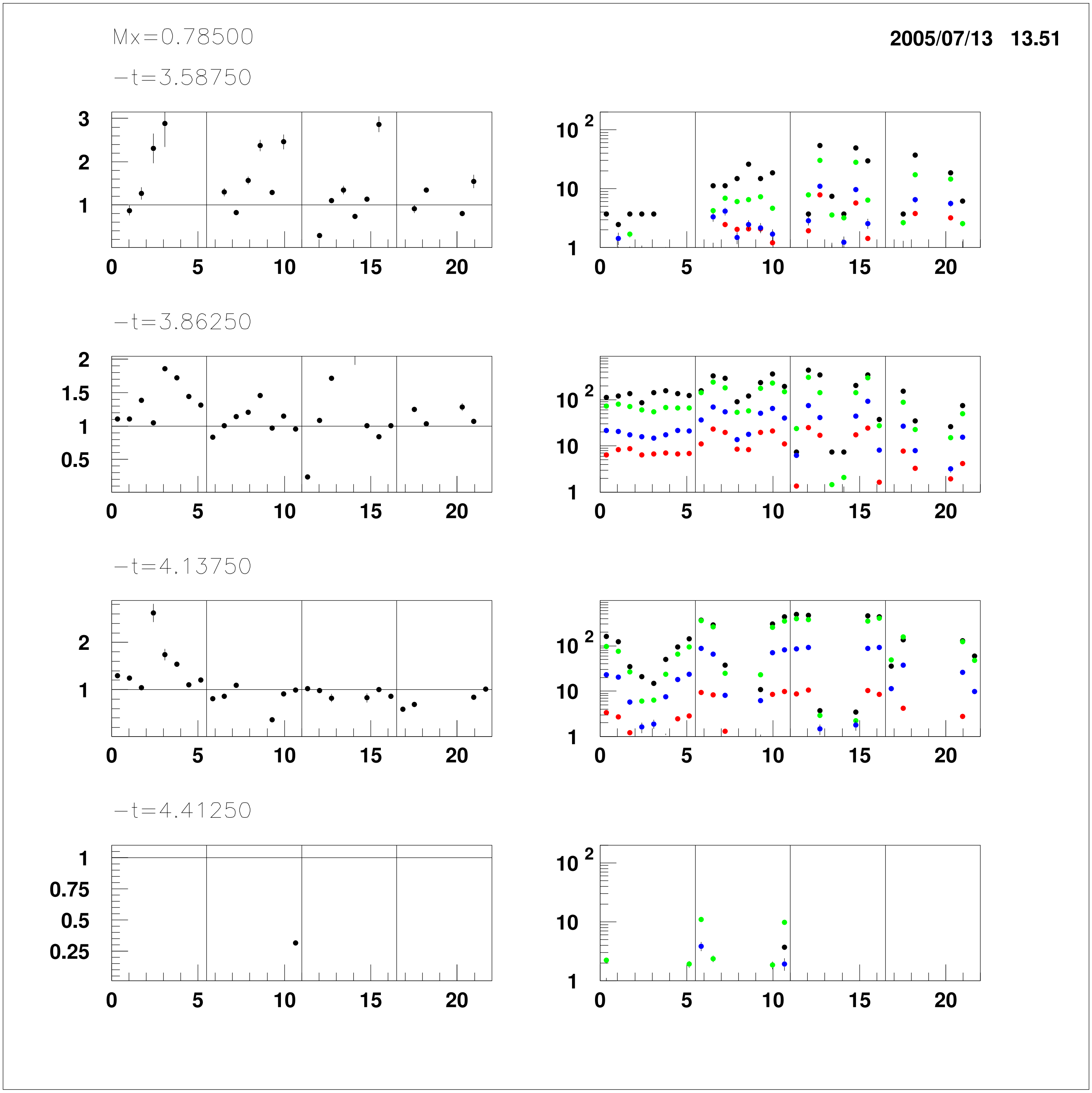

Figure 27: M_x centered on ω peak, for $Q^2 = 1.60$, $\epsilon = 0.33$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

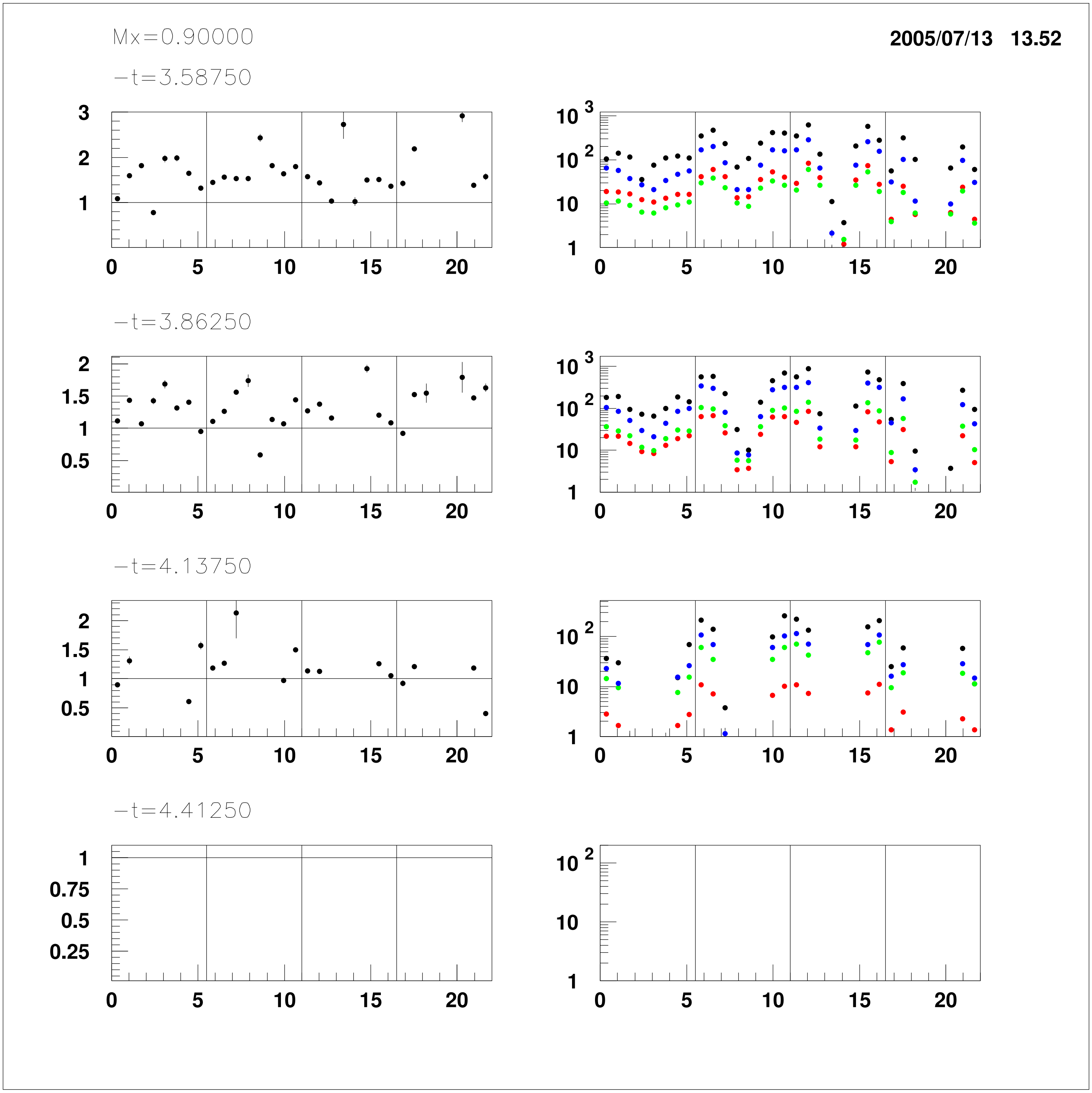

Figure 28: High M_x bin data at $Q^2 = 1.60$, $\epsilon = 0.33$. On the left are the Data/(Σ MC) ratios. On the right are the counts per bin, black=experiment, red=rho MC, green=omega MC, blue=phsp MC.

7 Tentative Conclusions and Open Questions

1. At $Q^2 = 2.45$, the top of the ω peak is generally under-fit by the fitting algorithm, to compensate for a slight over-fit of the missing mass region to the left of the peak. Should I compensate by making the ρ^0 skewing exponent even more negative?

2. The fit to the $Q^2 = 1.60$ missing mass histogram is generally better, except that here the tendency is to over-fit the ω peak, and under-fit the region to the right of the peak. So, perhaps the ρ^0 skewing exponent for this Q^2 should be less negative?

3. The Data/MC ratio per M_x, $-t$, θ^*, bin is generally between 0.5 and 2. Typically, the ratios are either low or high because of the problems with the missing mass described in 1,2. The ϕ-dependence of the ratio seems to be mostly governed by statistics. I assume this means that the LT and TT terms in the ω model in particular are not so bad(?)

4. Of the non-fit kinematic observables, $-t$ is described the least well by the sum of the MCs. The discrepancy in $-t$ appears to be worse for the M_x bins left and right of the ω peak than for the central bin. It is not clear to me what is the best strategy for fixing this. For example, should I change the phase space distribution by a t-dependent function?

5. Should I concern myself with the SOS-delta discrepancy, by modifying the Q^2-dependence of the model(s)? If so, what level of agreement should I aim for?