Krusche et al. Reply: The comment by Mukhopadhyay et al. does not challenge any conclusion drawn in the interpretation of our data [1] but even strengthens some of them. The comment suggests, that the effective Lagrangian analysis (ELA) [2] is better suited for a detailed interpretation of our precision data. Our analysis makes use of the fact that (1) the total cross section is strongly dominated by the excitation of the $S_{11}(1535)$ resonance and (2) that its shape can be parametrized by a Breit-Wigner type resonance curve with an energy dependent width. The ELA includes nucleon Born terms and vector meson exchange in addition to the excitation of resonances. Both analyses however, give the same results for the $S_{11}$ resonance simply because (1) and (2) are valid. This statement, which in our letter is based on the energy dependence of the total cross section and the shape of the angular distributions, is strongly supported by the results presented in the comment. In their table 1 the authors compare the helicity amplitude $A_{1/2}$ obtained from our data with their ELA (column 1) to those from Breit-Wigner fitting used by us (column 4). Both analyses give almost identical results; certainly there is no significant discrepancy within errors. The large differences between the rows of the table are due to the values used for the total width $\Gamma$ and in particular for the partial width $\Gamma_\eta$ of the $S_{11}$ resonance. As already pointed out in our letter, these hadronic widths now dominate the uncertainty of $A_{1/2}$. More explicitly, our Eq. [1] together with the resonance position $W_R = (1544 \pm 13)$ MeV and a corresponding cross section of $\sigma(W_R) = (16 \pm 0.8) \mu b$ gives the following expression for $A_{1/2}$:

$$A_{1/2}[10^{-3} GeV^{-1/2}] = (5.82 \pm 0.15) \frac{\Gamma_R [MeV]}{b_\eta}^{1/2}$$ (1)

with $b_\eta = \Gamma_\eta/\Gamma_R$. All entries in table 1 of the comment can be reproduced with this expression (the authors do not quote $\Gamma_R$ and $b_\eta$ for row (c) of their table, however a comparison of $A_{1/2}$ and $\xi$ yields $\Gamma_R/b_\eta \approx 290$ MeV). The parameter $\xi$ introduced by the authors of the comment via [2]:

$$\xi = \left(\frac{k^*}{q_0}\right)^{1/2} \left(\frac{m_p}{W_R}\right)^{1/2} \left(\frac{b_\eta}{\Gamma_R}\right)^{1/2} A_{1/2}$$ (2)

obviously avoids the uncertainty in $\Gamma_R/b_\eta$ at the expense of mixing electromagnetic and strong coupling. Assuming again the dominance of the $S_{11}$ resonance it may be calculated from our Breit-Wigner analysis via

$$\xi = \sqrt{2\pi|E_{\sigma^+}(W_R)|} = \frac{1}{\sqrt{2}} \left(\frac{k^*}{q_0}\right)^{1/2} (\sigma(W_R))^{1/2}. \quad (3)$$

Using the values for $W_R$ and $\sigma(W_R)$ given above leads to $\xi = (2.21 \pm 0.06) \times 10^{-4}$ MeV$^{-1}$ which is in excellent agreement (better than 1 %) with the most complete ELA fit (row c) of table 1. In our letter we had assumed a very conservative upper limit of 10 % for non $S_{11}$ contributions
to the total cross section giving rise to a 5% uncertainty of $|E_{cs}(W_R)|$. However, the agreement on the 1% level demonstrated here, suggests that non $S_{11}$ contributions to this number are really negligible. We thus agree that the value of the parameter $\xi$ is model independent, due to the dominance of the $S_{11}$ resonance it is entirely fixed by the measured cross section.

We thank the authors of the comment for pointing out the overall sign error of the $\cos(\Theta^*_{20})$ term in Eq.7 [1], which, however, has no consequence for any of the numbers quoted in our paper. The purpose of this equation was to indicate how different contributions influence the shape of the angular distributions. In particular, the $\cos(\Theta^*_{20})$ term involves the interference between the $S_{11}$ resonance and contributions from Born terms, vector mesons and the $P_{11}(1440)$ resonance. It has been shown [3] that this term is extremely sensitive to the background contributions and therefore its very small experimental value is one of the strongest arguments for the $S_{11}$ dominance. The $\cos^2(\Theta^*_{20})$ term is insensitive to background contributions from Born terms and dominated by an interference between the $S_{11}$ and the $D_{13}(1520)$ resonances. The fact that the experimental C-values are significantly different from zero is a clear indication for the presence of the $D_{13}$ resonance. Again this finding is supported by the ELA results. A truly quantitative analysis of the $D_{13}$ contribution was not attempted and goes beyond the scope of our approach. We are looking forward to such results derived from our data in the framework of the ELA.


$^1$II. Physikalisches Institut, Universität Gießen, D-35392 Gießen, Germany
$^2$Institut für Kernphysik, Johannes-Gutenberg Universität Mainz, D-55099 Mainz, Germany
$^3$Kelvin Laboratory, University of Glasgow, U.K.
$^4$Physikalisches Institut, Universität Bonn, D-53115 Bonn, Germany
$^5$Gesellschaft für Schwerionenforschung, D-64220 Darmstadt, Germany