$K_L \rightarrow e^+e^-\gamma$ Branching Ratio and Form Factor Results

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KTeV Collaboration Meeting

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Outline

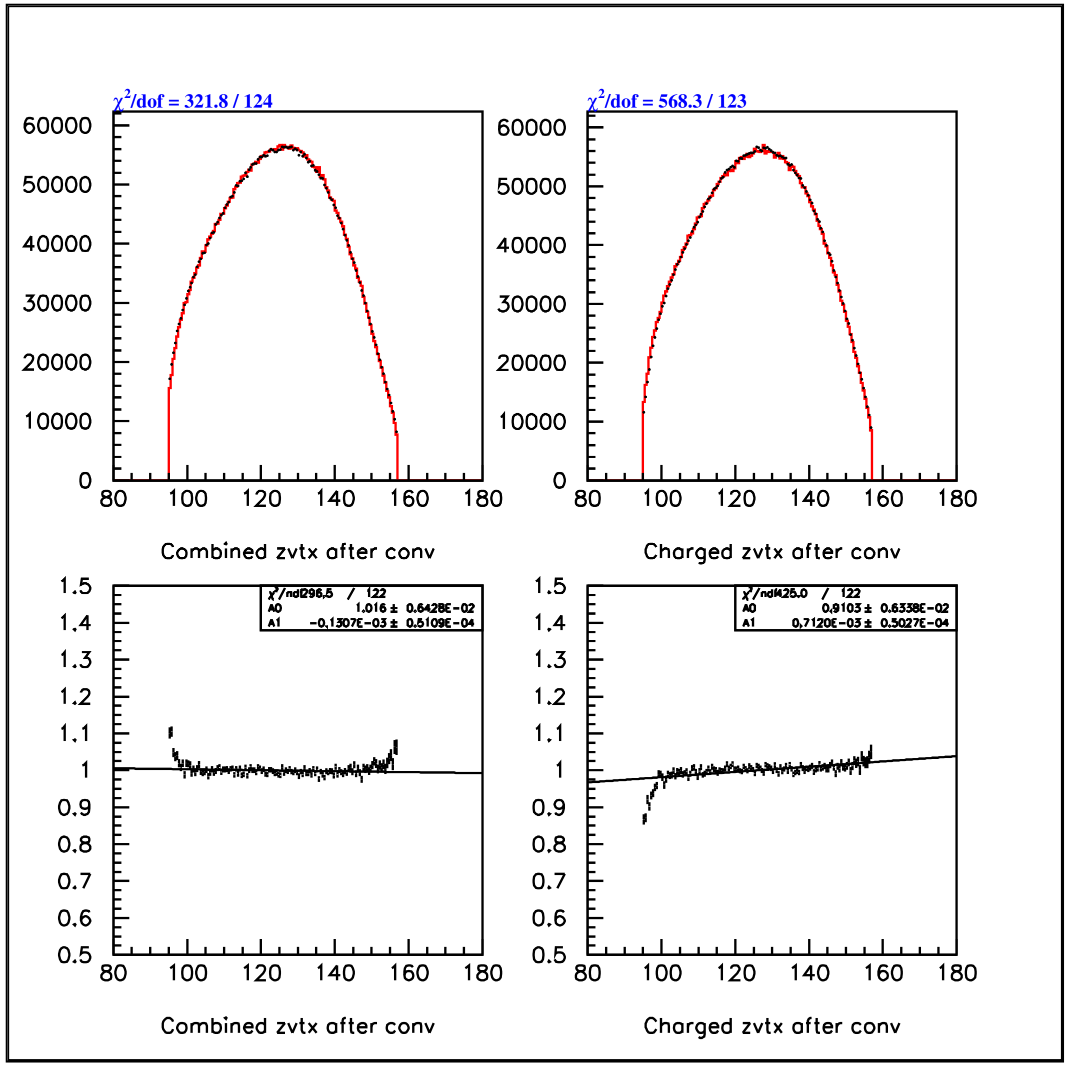
- Branching ratio update
- More than you ever wanted to know about the BMS form factor model
- Jason's form factor measurement
- My form factor measurement

Branching Ratio Update: z-vertex cut

- In the signal mode ($K_L \rightarrow e^+e^-\gamma$) only a charged vertex can be calculated
- In the normalization mode ($K_L \rightarrow \pi^0\pi^0\pi^0_D$) both a charged vertex and a neutral vertex can be calculated
- Any neutral vertex cut should be much looser than the charged vertex cut so that any systematic bias in the tracking system will cancel
- Jason’s thesis stated that his neutral vertex cut was [90m,160m] but in the code it was set to [95m,157m], which is the value of his charged vertex cut

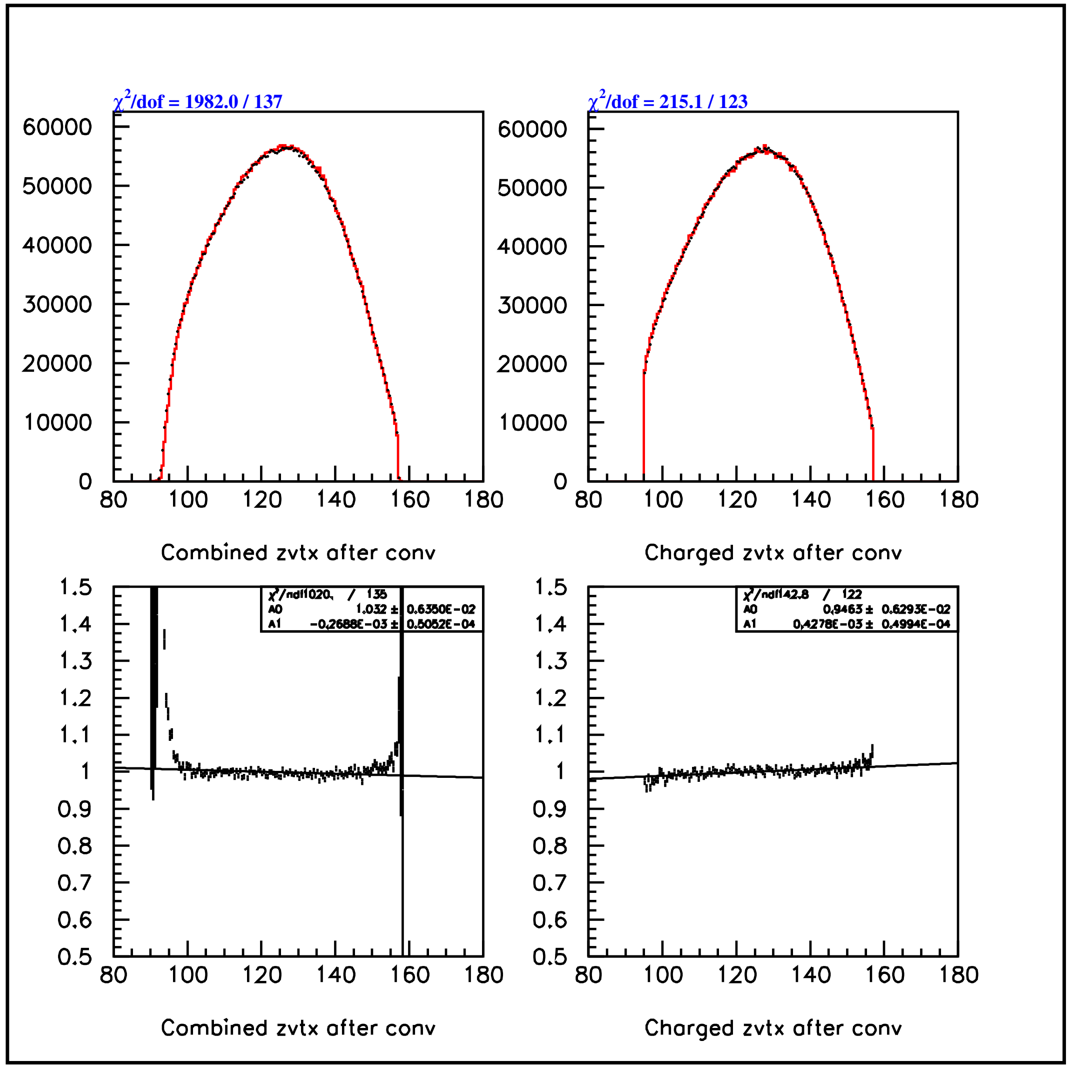
Thesis $K_L \rightarrow \pi^0 \pi^0 \pi^0_D$ z-vertex

- charged cut = [95m,157m]
- neutral cut = [95m,157m]
- Data / MC ratios:
  - left: neutral z-vertex
  - right: charged z-vertex



New $K_L \rightarrow \pi^0\pi^0\pi^0_D$ z-vertex

- charged cut
  = [95m,157m]
- neutral cut
  = [90m,160m]
- Data / MC ratios:
  - left: neutral z-vertex
  - right: charged z-vertex



Error in Branching Ratio Calculation

- At the last meeting I reported a measurement of:
  - $BR(K_L \rightarrow e^+e^-\gamma)/BR(K_L \rightarrow \pi^0\pi^0\pi^0_D)$
    $= 1.3478 \pm 0.0045_{stat} \pm 0.0104_{syst}$
    which is 2.3% lower than Jason's thesis measurement
- The number of reconstructed Monte Carlo events used in this calculation were accidentally set to the values in Jason's thesis (all other input numbers were correct)
- When I perform the calculation correctly, I get a result that is 3.1% lower than Jason's thesis
- I now calculate the branching ratio in PAW using the numbers read directly from the histogram files

$BR(K_L \to e^+e^-\gamma)/BR(K_L \to \pi^0\pi^0\pi^0_D)$ Changes

- thesis:
  - $(1.38197 \pm 0.00459 \pm 0.01064) \times 10^{-3}$
- after replacing run 8578 & using the correct summer data number:
  - $(1.36671 \pm 0.00455 \pm 0.01052) \times 10^{-3}$ $\Delta_{thesis} = -1.1\%$
- after energy smearing / reweighting and moving the pairing χ^2 cut to 100:
  - $(1.33860 \pm 0.00445 \pm 0.01031) \times 10^{-3}$ $\Delta_{thesis} = -2.0\%$
- after moving neutral z-vertex cut to [90m,160m]:
  - $(1.33315 \pm 0.00443 \pm 0.01027) \times 10^{-3}$ $\Delta_{thesis} = -0.4\%$

BMS Form Factor Model

$$f_{BMS}(x) = \frac{1}{1 - x \cdot \frac{M_K^2}{M_\rho^2}} + \frac{C\alpha_{K^*}}{1 - x \cdot \frac{M_K^2}{M_{K^*}^2}} \left(\frac{4}{3} - \frac{1}{1 - x \cdot \frac{M_K^2}{M_\rho^2}} - \frac{1}{9}\frac{1}{1 - x \cdot \frac{M_K^2}{M_\omega^2}} - \frac{2}{9}\frac{1}{1 - x \cdot \frac{M_K^2}{M_\phi^2}} \right)$$

- $x = m^2_{e+e-} / m^2_K$
- $C = (8\pi\alpha_{EM})^{1/2} G_{NL} f_{K^*K\gamma} m^2_\rho A_{\gamma\gamma} / (f_{K^*} f^2_\rho)$
- In Breese Quinn's thesis it states that all previous measurements used C=2.5, but he used C=2.3 due to a 1988 change in $\Gamma(K_L \rightarrow \gamma\gamma)$
- Jason's thesis states C=2.3, but C is set to 2.5 in the code
- To calculate C, Breese (and presumably everyone else) used $G_{NL} = 1.1 \times 10^{-5} / m^2_p$
- In the BMS paper it mentions that $G_{NL} = G_{Fermi}$ if Cabibbo angle is ignored
- Using the formulae from both Jason's and Breese's thesis, I get $C = 2.62 \pm 0.048$
- I now fit for $C\alpha_{K^*}$. The C will be explicitly divided out in the paper

More BMS stuff

$$f_{BMS}(x) = \frac{1}{1 - x \cdot \frac{M_K^2}{M_\rho^2}} + \frac{C \cdot \alpha_{K^*}}{1 - x \cdot \frac{M_K^2}{M_{K^*}^2}} \left(\frac{4}{3} - \frac{1}{1 - x \cdot \frac{M_K^2}{M_\rho^2}} - \frac{1}{9} \frac{1}{1 - x \cdot \frac{M_K^2}{M_\omega^2}} - \frac{2}{9} \frac{1}{1 - x \cdot \frac{M_K^2}{M_\phi^2}} \right)$$

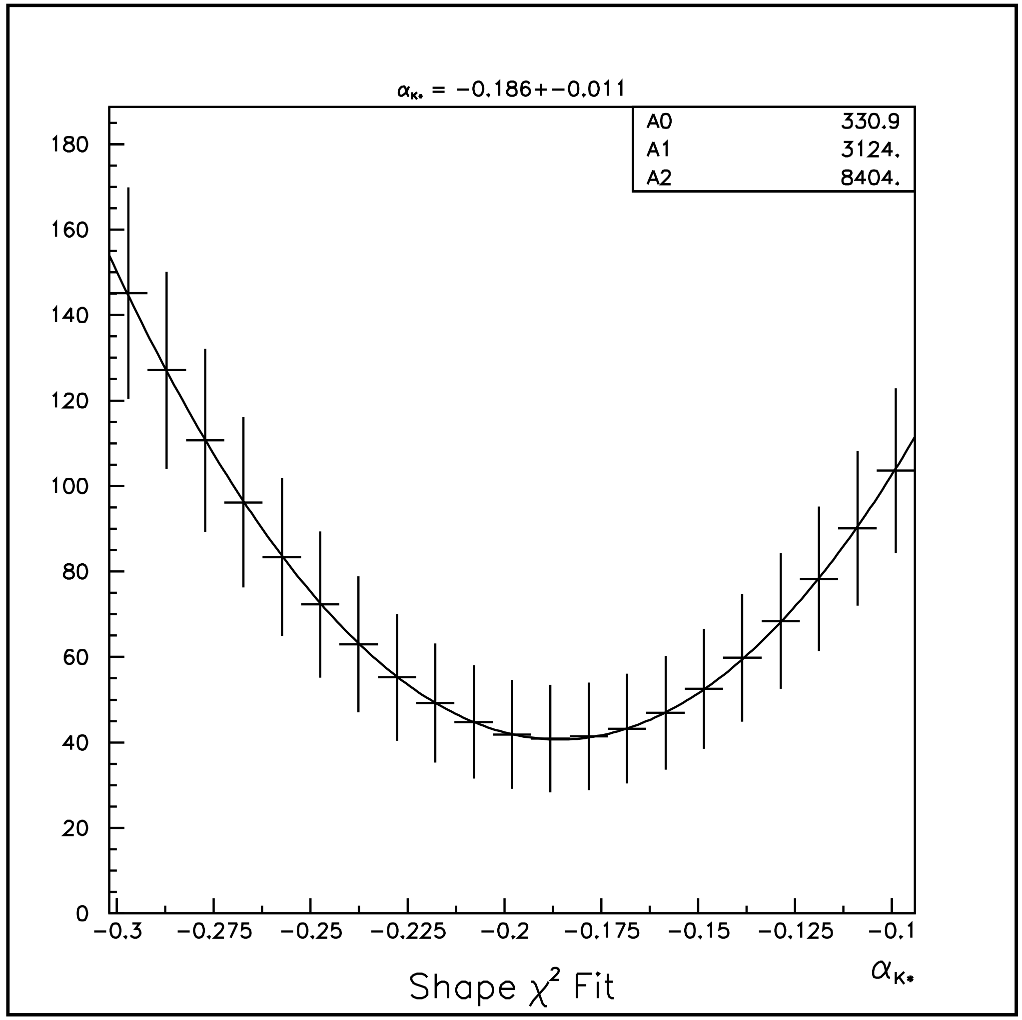
- In the Particle Data Book there are 3 different ρ masses:
  - from e^+e^- = 775.8 ± 0.5 MeV
  - photoproduced = 768.5 ± 1.1 MeV
  - other reactions = 769.0 ± 0.9 MeV
- There are 3 masses because the r has a large width, even though the above formula assumes that it is very narrow
- Since f_ρ depends on $\Gamma(\rho \rightarrow e^+e^-)$, and this decay has only been measured from e^+e^-, I have chosen to use the "from e^+e^-" mass
- Jason used m_ρ = 770 MeV

Jason's Form Factor Measurement

- The Monte Carlo was generated at $\alpha_{K^*} = -0.16$
- In the analysis, the e^+e^- mass distribution was reweighted according to $(f(x,\alpha_{K^*,gen})/f(x,\alpha_{K^*,new}))^2$
- A bin-by-bin χ^2 calculated: $\chi^2 = (n_{data} - r^*n_{MC})^2 / (n_{data} + r^{2*}n_{MC})^2$
- Jason neglected the r^*n_{MC} term in the denominator despite the fact that it is ~20% of the unsquared denominator and it varies as the form factor changes

Jason's Form Factor Measurement

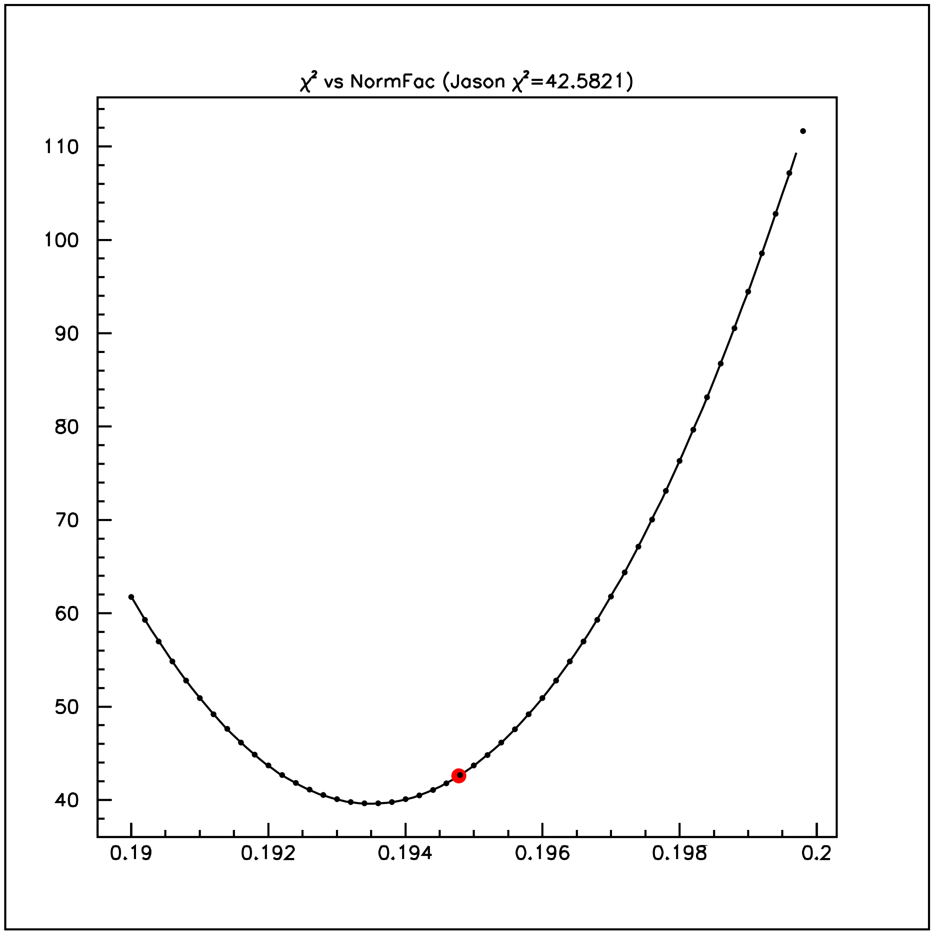
- The χ^2 vs α_{K^*} plot from Jason's thesis (right)
- The fit range in χ^2 is from 40 to 145
- The spacing in α_{K^*} is roughly equal to the fit error

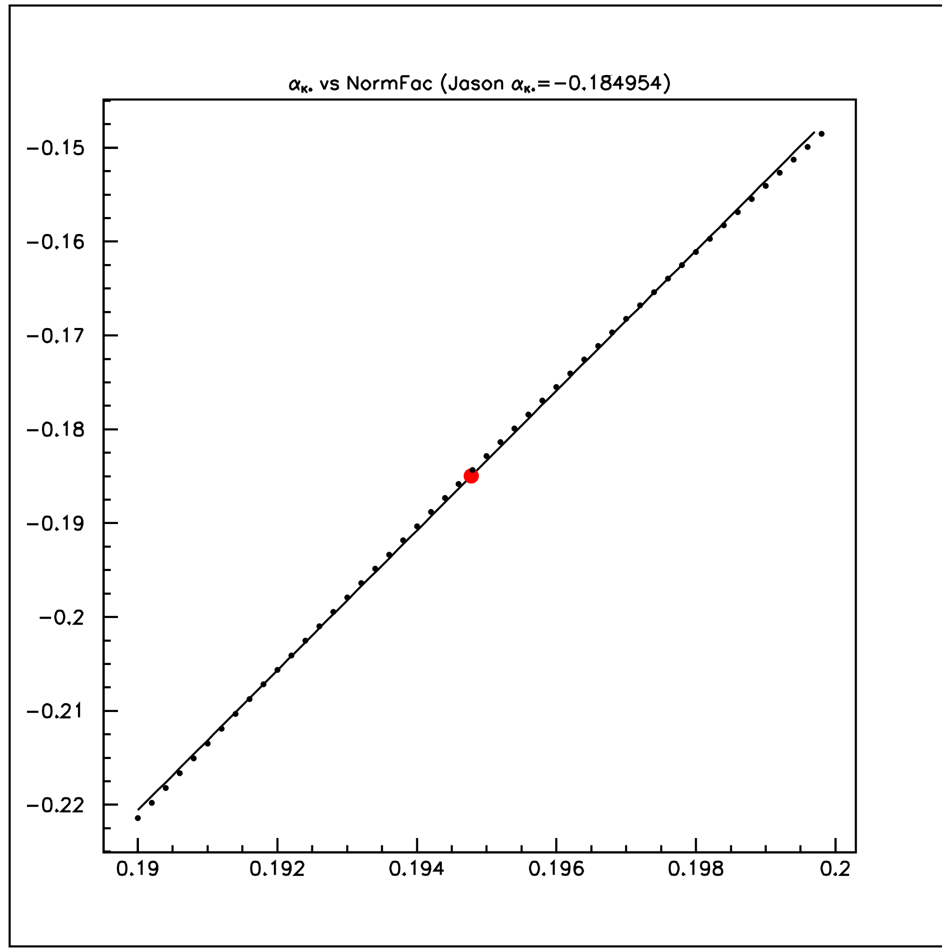


Other Issues With the Thesis Measurement

- The reconstructed x was used to reweight each e^+e^- mass distribution instead of the generated x
- Any previous weight for the event was ignored (energy reweighting was not used)
- In the thesis the Monte Carlo normalization factor was calculated for the generated α_{K^*} and kept the same for every new value of α_{K^*} despite the fact that the normalization is not constant

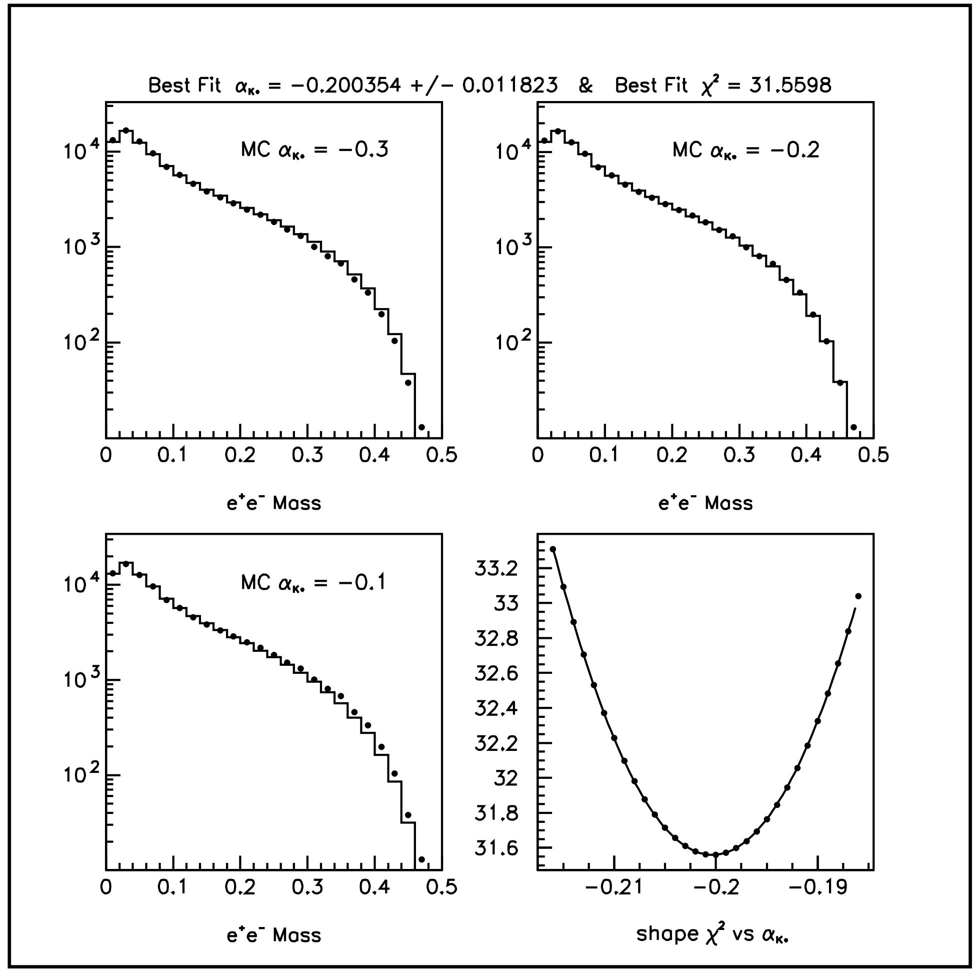
α_{K^*} and shape-χ^2 vs MC normalization





My Form Factor Fit

- First, using Jason's form factor routine (i.e. C=2.5, Jason's masses), but varying the normalization for each comparison, I get the fit on the right



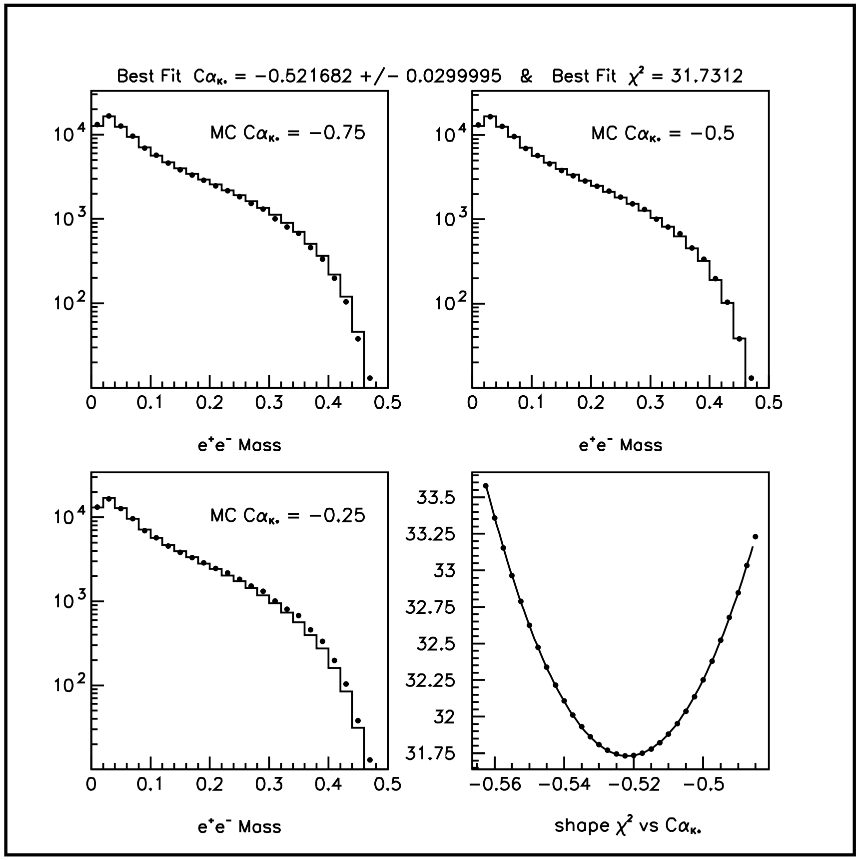
Shape-χ^2 formula

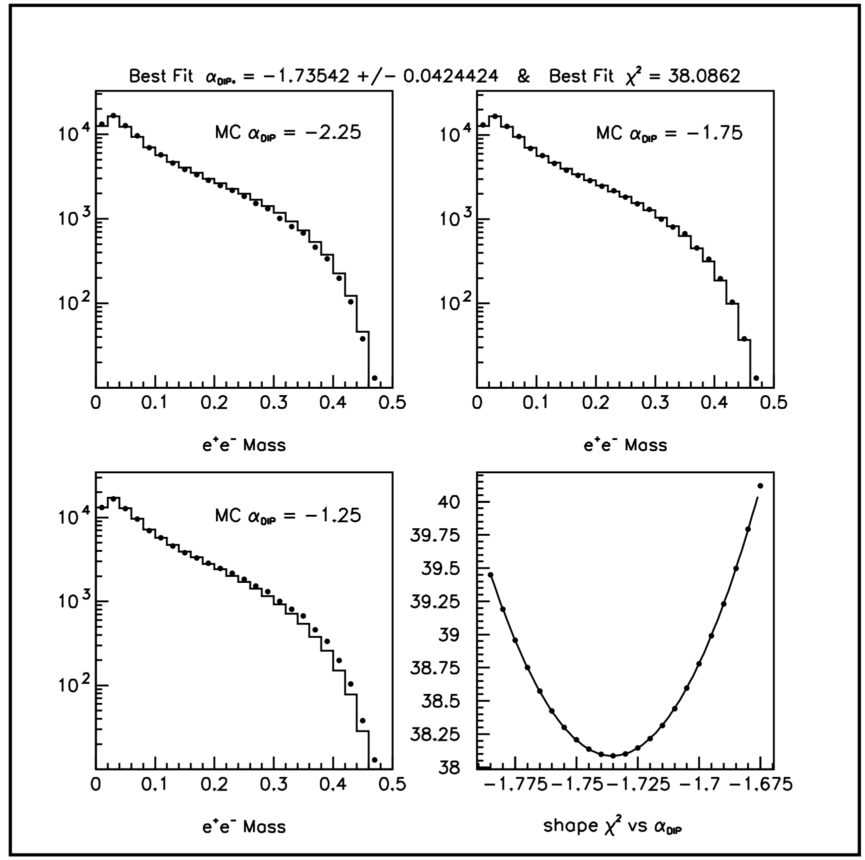
- Thesis:
  - $\chi^2 = (n_{data} - n_{MC})^2 / n^2_{data}$
- After reinstating the MC statistics in the denominator
  - $\chi^2 = (n_{data} - n_{MC})^2 / (n_{data} + r^2 * n_{MC})^2$
- However, since the Monte Carlo e+e- mass distribution is better known than the data, we treat the Monte Carlo as the "true" distribution and the data points as fluctuations away from the true distribution.
  - $\chi^2 = (n_{data} - n_{MC})^2 / (r * n_{MC} + r^2 * n_{MC})^2$
  - This changes the result by ~2/3 σ_{fit}

My Fit Results

$C\alpha_{K^*}$ = -0.522 ± 0.030

α_{DIP} = -1.735 ± 0.042





The systematic errors due to varying meson masses are very small
(< 10% of the fit uncertainty)