Systematics Studies for the $K_L \rightarrow \pi^+\pi^-\gamma$ Analysis

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KTeV Collaboration
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Overview

- Reminder of fit results with STAT error
- Results of Systematic Error due to Kaon Momentum slope
- Results of Systematic Error due to Background
- Partial Results of Systematic Error due to Cut Variation
- Future Plans

$K_L \rightarrow \pi^+ \pi^- \gamma$ Fit Results

- 3-parameter fit (ge1 assumed non-zero) (**STAT ONLY!**)
  - $g_{m1} = 1.19 +/- 0.03$
  - $a1/a2 = -0.740 +/- 0.007$
  - $ge1 < 0.12$ (90% confidence) **

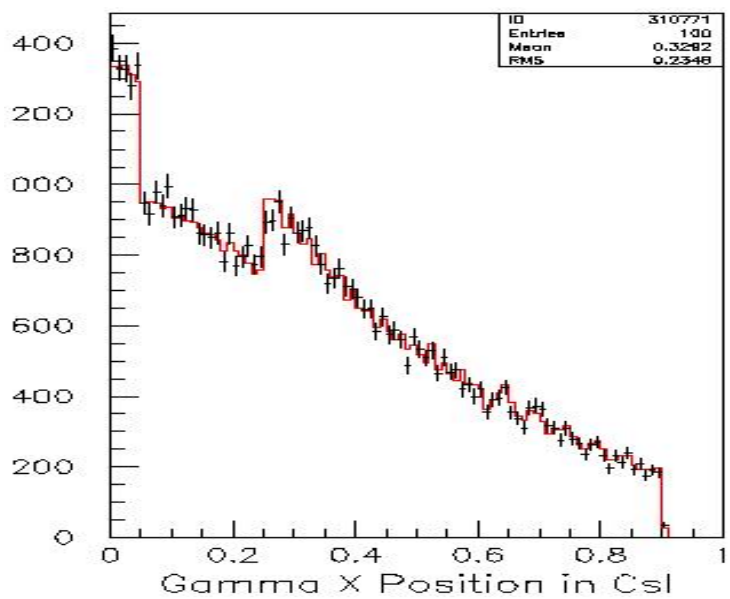
** $ge1 = 0.037 +/- 0.060$

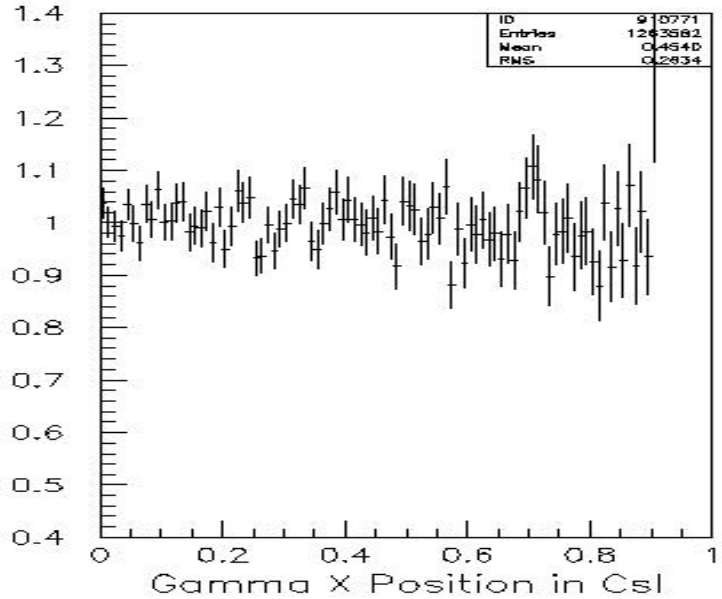
- For comparison:
  - J. Belz, 1997 ($K_L \rightarrow \pi^+ \pi^- \gamma$) : DE/(DE+IB) = 0.68 +/- 0.01
    a1a2 = -0.737 +/- 0.034
  - UVa, 1997 ($K_L \rightarrow \pi^+ \pi^- e^+e^-$) : gm1 = 1.35 +/- 0.17
    a1/a2 = -0.720 +/- 0.028

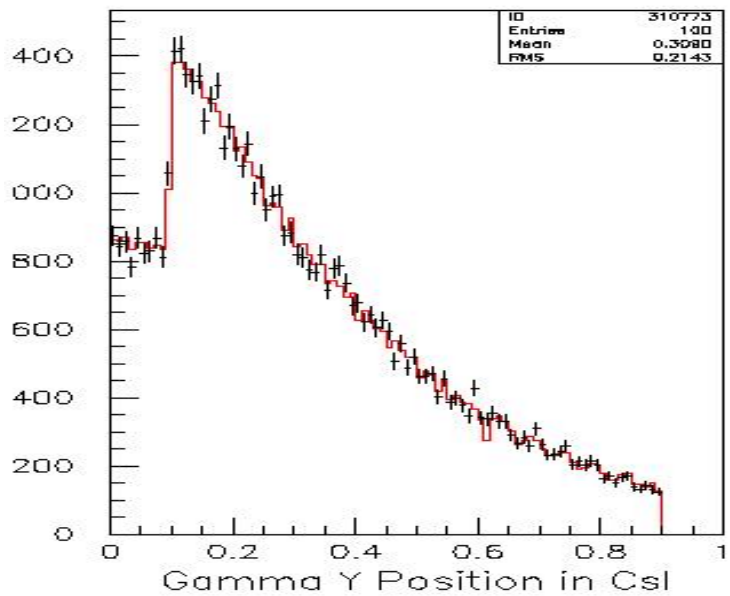
Analysis cuts: $K_L \rightarrow \pi^+\pi^-\gamma$

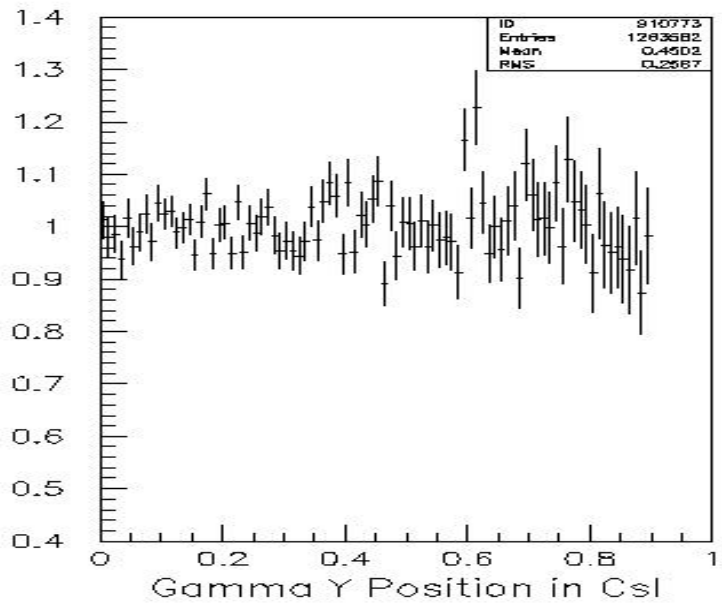
Criterion:	Event in sample if…
Recon832	Recon832 ok
L1VER832	istat ≠ 0
NTRKS	NTRKS = 2
Clusters	1 or more non-track clusters
Magnet offset χ^2	< 50
Vertex χ^2	< 50
Vertex Z	120.0 < VTXZ < 158.0
Track X-separation in CsI	> 3 cm
Track momentum	> 8 GeV
π^{+-} E/p	< 0.85 GeV
Pp0kine	< -0.0055 GeV^2
γ energy (Lab)	> 1.5 GeV
γ energy (Center of Mass)	> 20 MeV
γ-track separation in CsI	> 30 cm
Fusion χ^2	< 48
γ CsI pipe block exclusion	smallring > 4.5 cm
γ CsI outer fiducial cut	seedring < 18.1 cm
$\pi^+\pi^-$ invariant mass	< 0.492 GeV
$\pi^+\pi^-\gamma$ momentum	$25.0 < P_{\pi+\pi-\gamma} < 160.0$
$\pi^+\pi^-\gamma$ P_T^2	$< 2.5 \times 10^{-4}$ GeV^2
$\pi^+\pi^-\gamma$ invariant mass	$0.48967 < M_{\pi+\pi-\gamma} < 0.50567$

Photon x,y position in CsI: Data/MC (N_{MC} = 10x data)

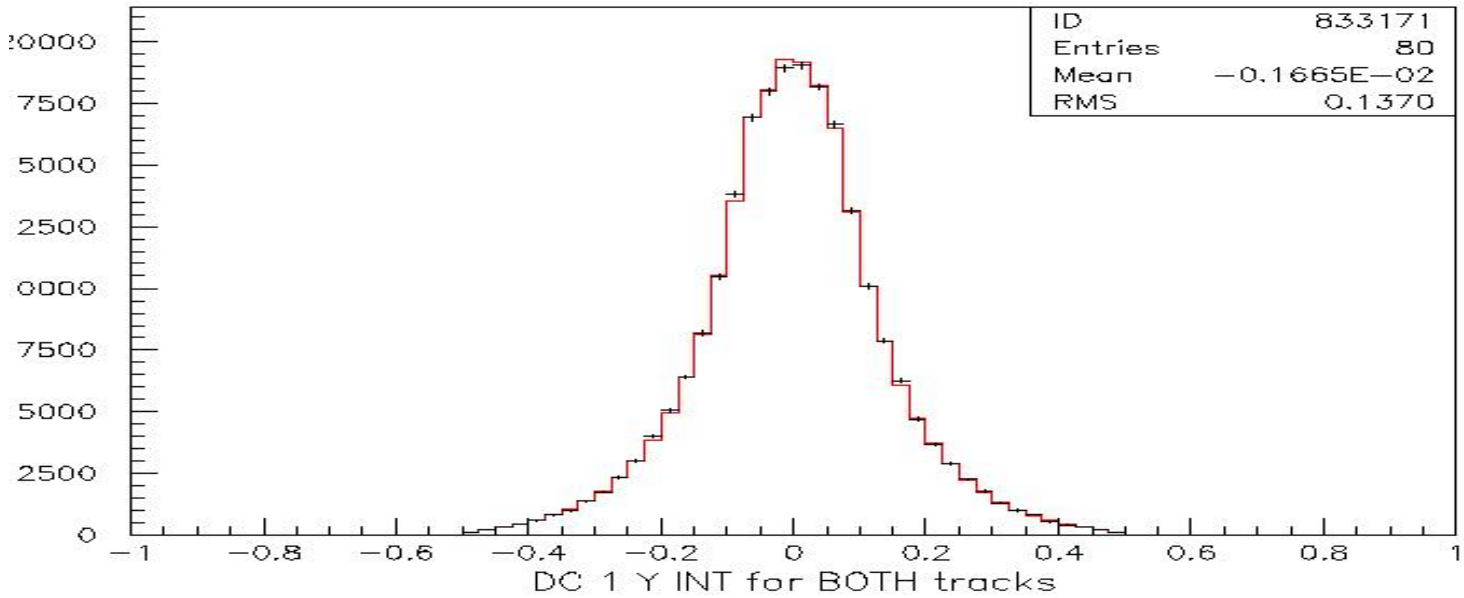


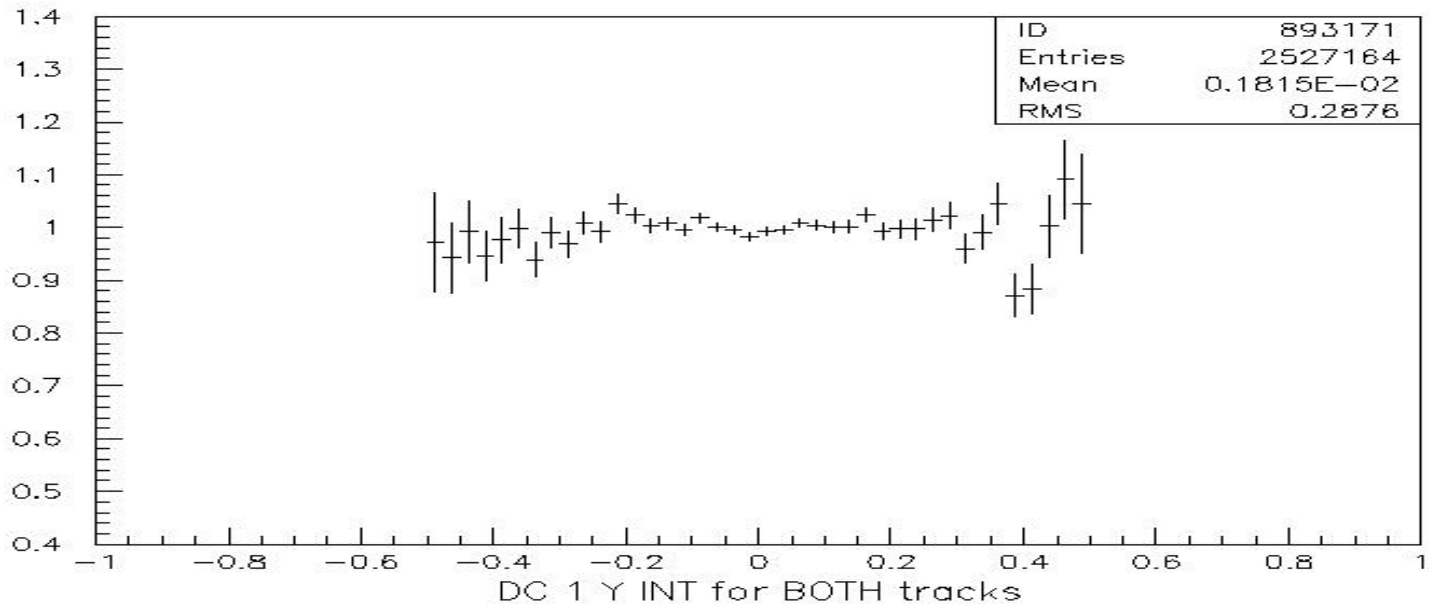




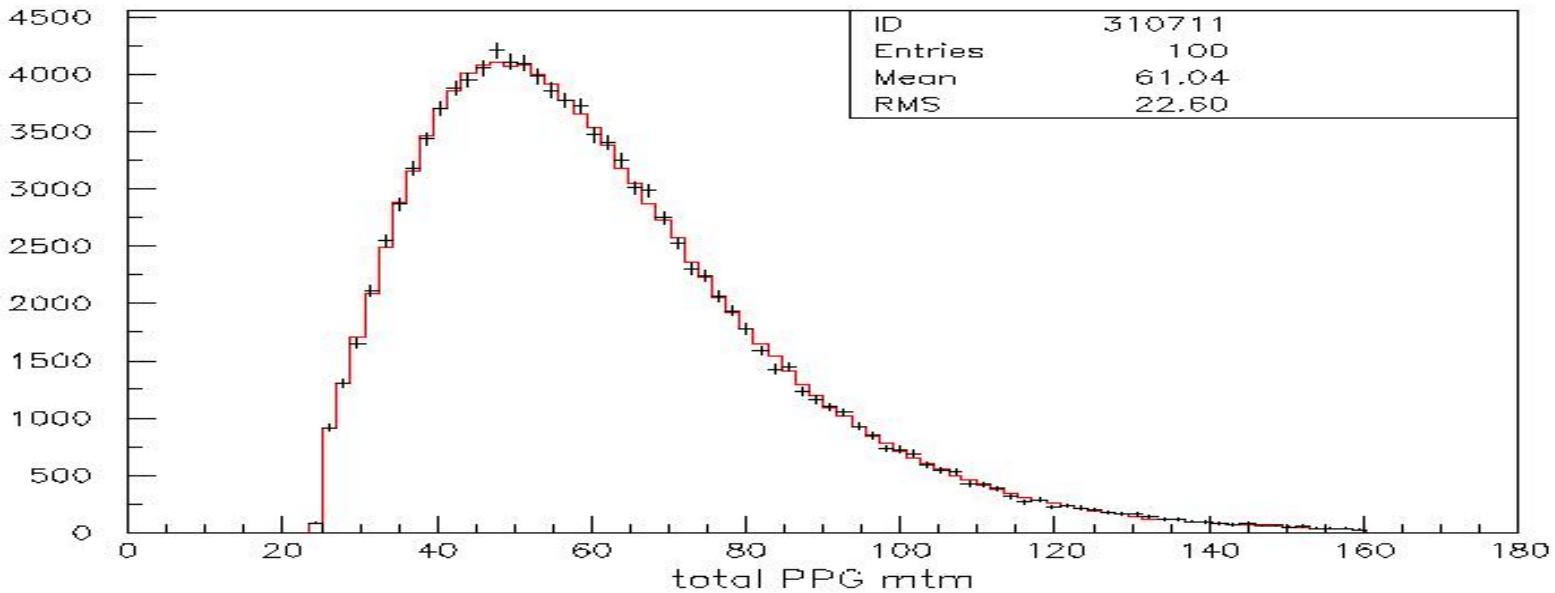


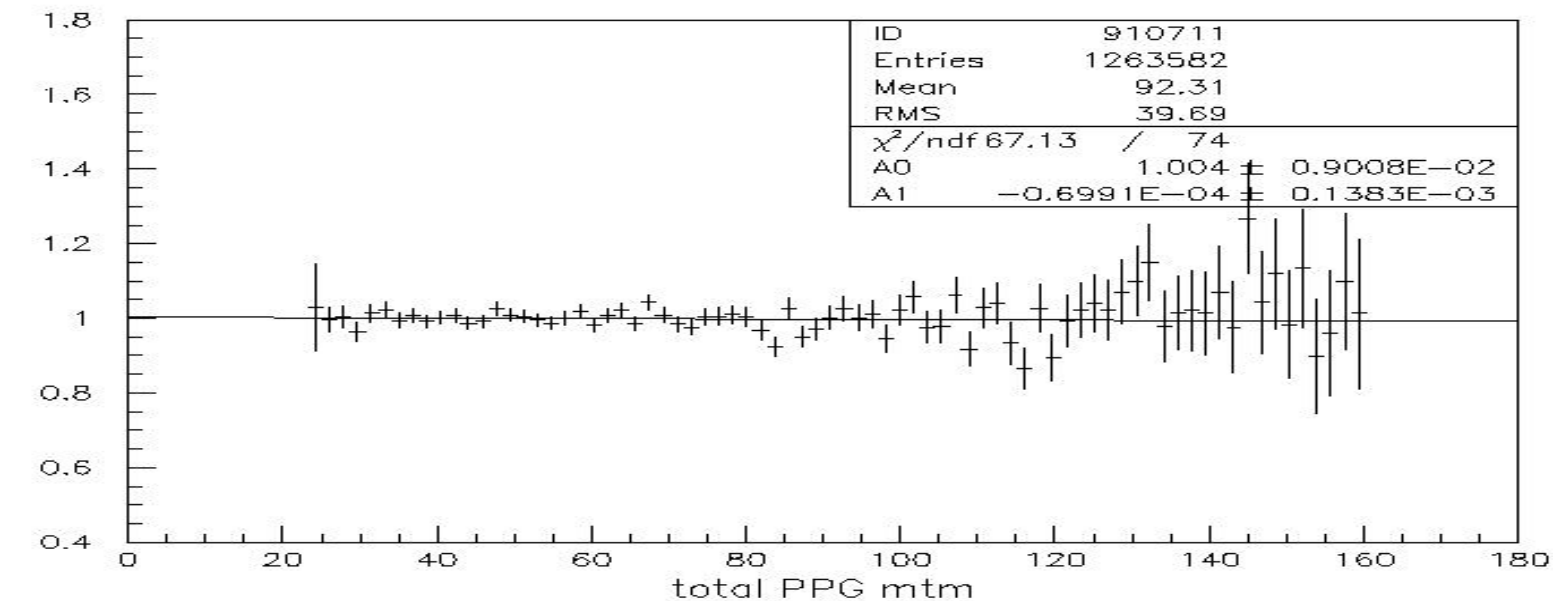
Track position in DC 1





Kaon momentum



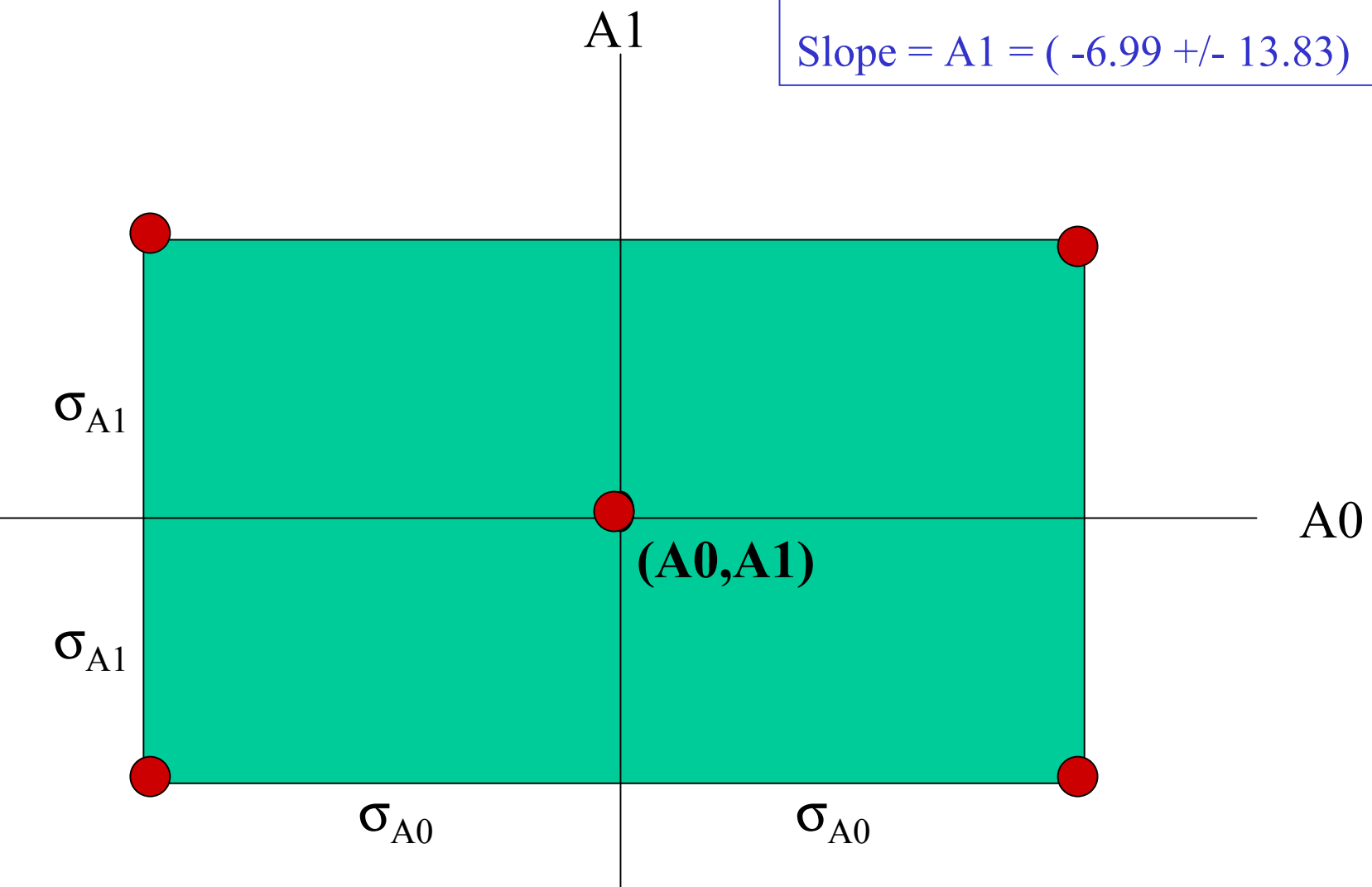


Systematic Error due to the Kaon Momentum Slope

Reweighted Monte Carlo at 5 values & refit max loglikelihood

Y-int = A0 = 1.004 +/- 0.009

Slope = A1 = (-6.99 +/- 13.83) x 10^{-5}



Systematic Error on kaon momentum slope

Reweighting	Δg_{m1} (from nominal)	$\Delta a1/a2$ (from nominal)	ΔG_{e1} (from nominal)
A0 , A1	+0.0010	-0.00012	-0.002
$A0 + \sigma_{A0}$, $A1 + \sigma_{A1}$	-0.0009	+0.00011	+0.002
$A0 + \sigma_{A0}$, $A1 - \sigma_{A1}$	+0.0031	-0.00039	-0.005
$A0 - \sigma_{A0}$, $A1 + \sigma_{A1}$	-0.0009	+0.00011	+0.002
$A0 - \sigma_{A0}$, $A1 - \sigma_{A1}$	+0.0031	-0.00040	-0.005
Net Result	0.003	0.0004	0.005
Stat Error size (for comparison)	0.03	0.007	0.06

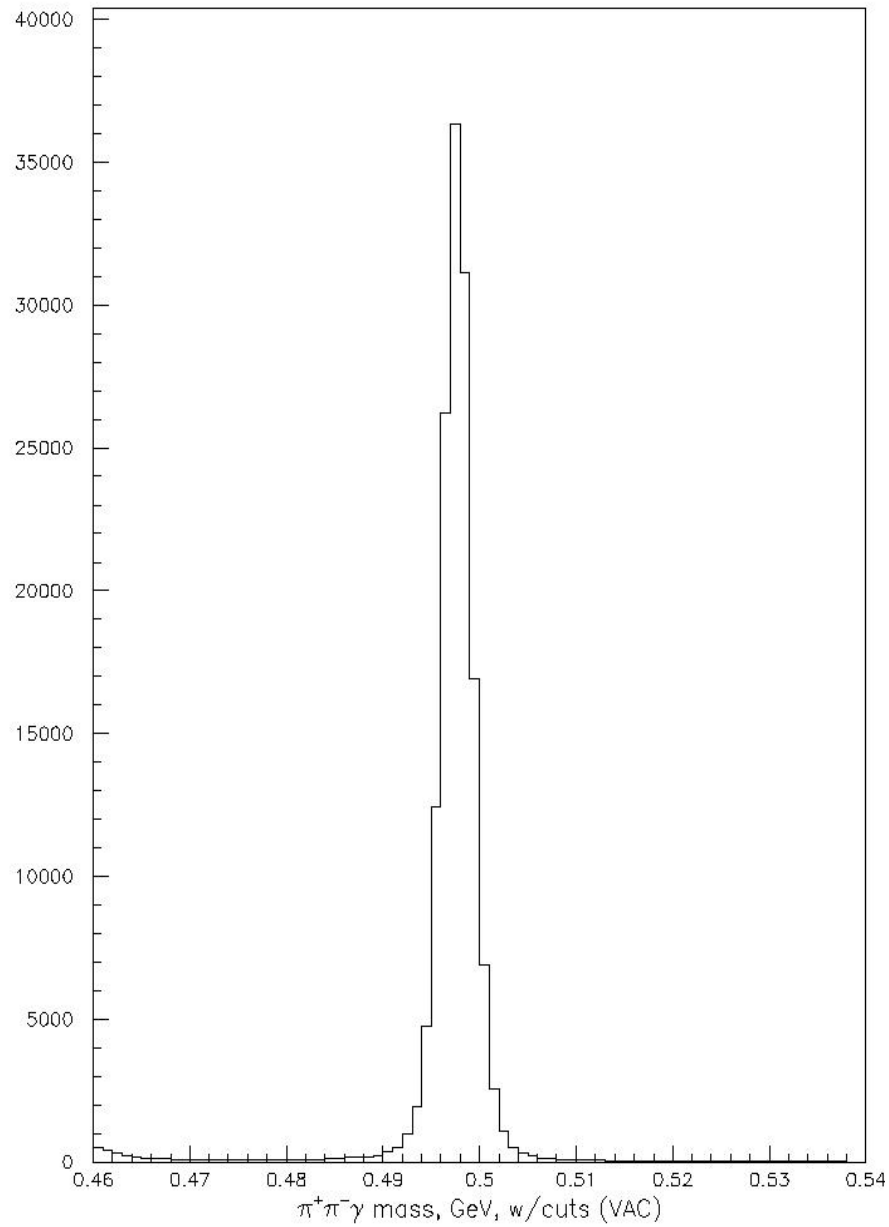
*error is < 10% of stat error!

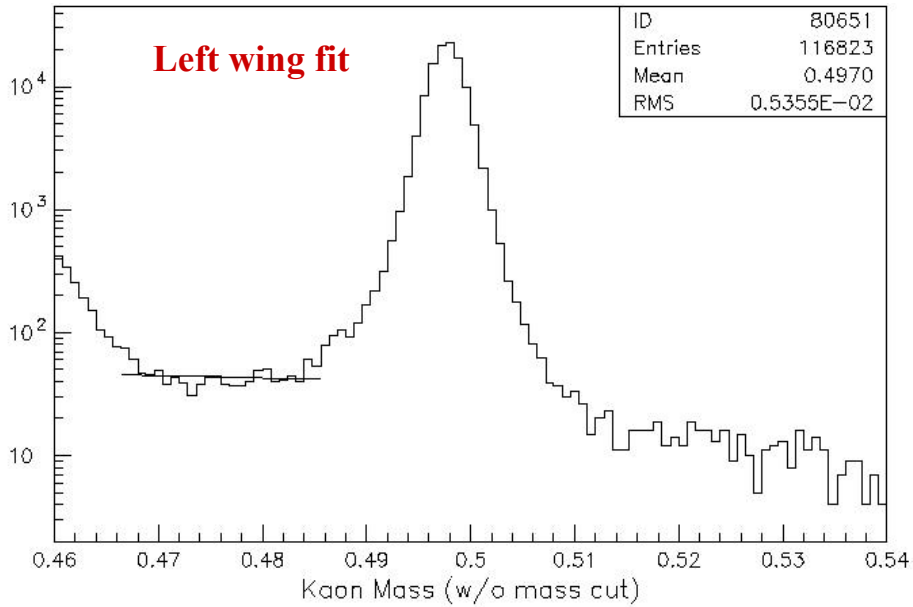
Systematic error due to Background effects

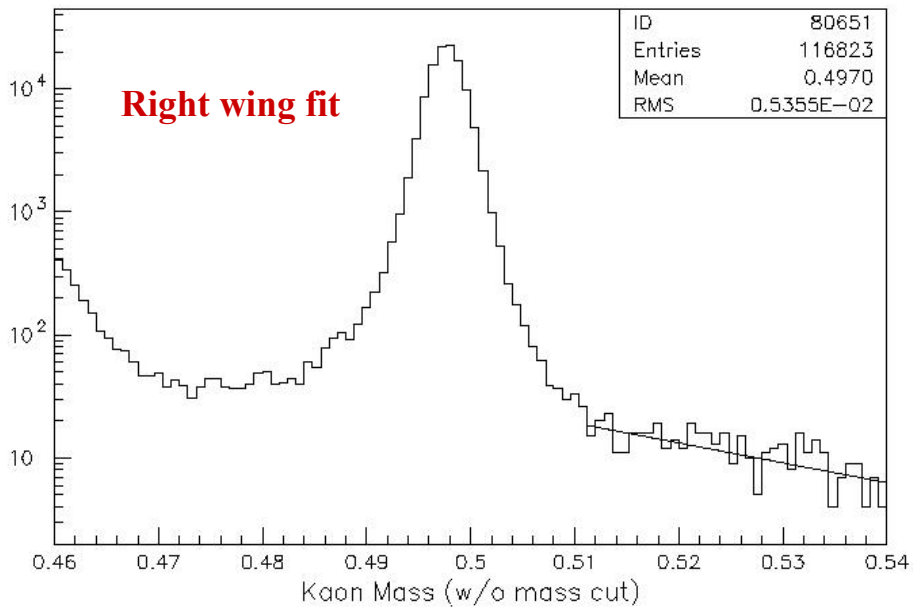
- Made separate best-fit exponentials from left & right sides of kaon mass peak
- Left wing est ~ 789 events, Right wing est. ~618 events
- Made 6 indep, randomly distributed 400-event wing-region samples
  - Each sample added separately to data and the maximum likelihood computed for each of the 6 "data-wing-400" samples
- Combined the 6 400-event wing samples into 3 800-event wing samples
  - Computed Max likelihood for each of the 3 resulting "data-wing-800" samples

Fit parameter	400 event variation (from nominal)	800 event variation (from nominal)	STAT ERROR (for comparison)
gm1	+/- 0.02	+/-0.03	**+/- 0.03**
a1/a2	+/- 0.003	+/- 0.004	**+/- 0.007**
Ge1	+/- 0.05	+/-0.09	**+/- 0.06**

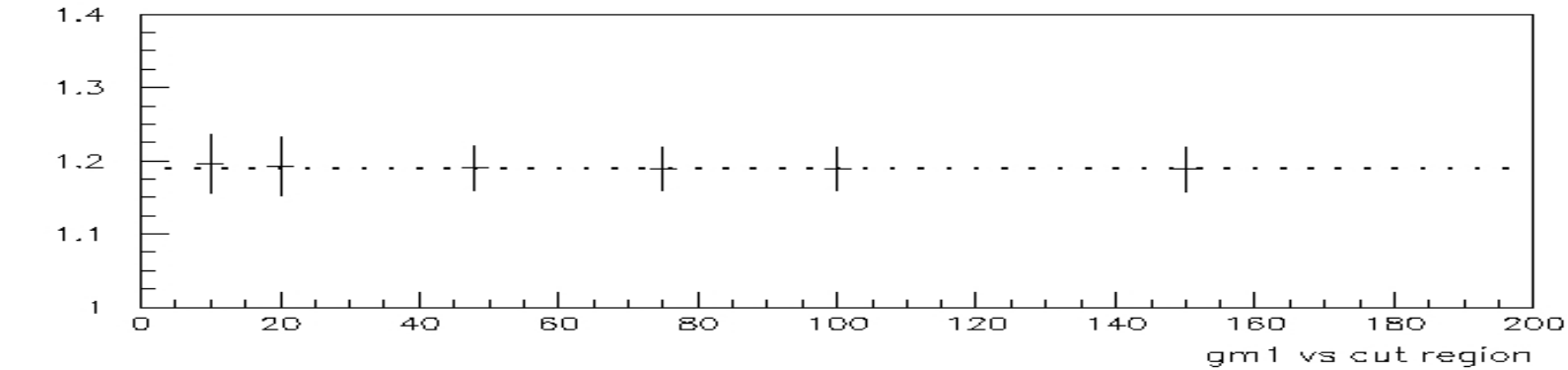
Kaon Mass Peak: Standard and Log Plots

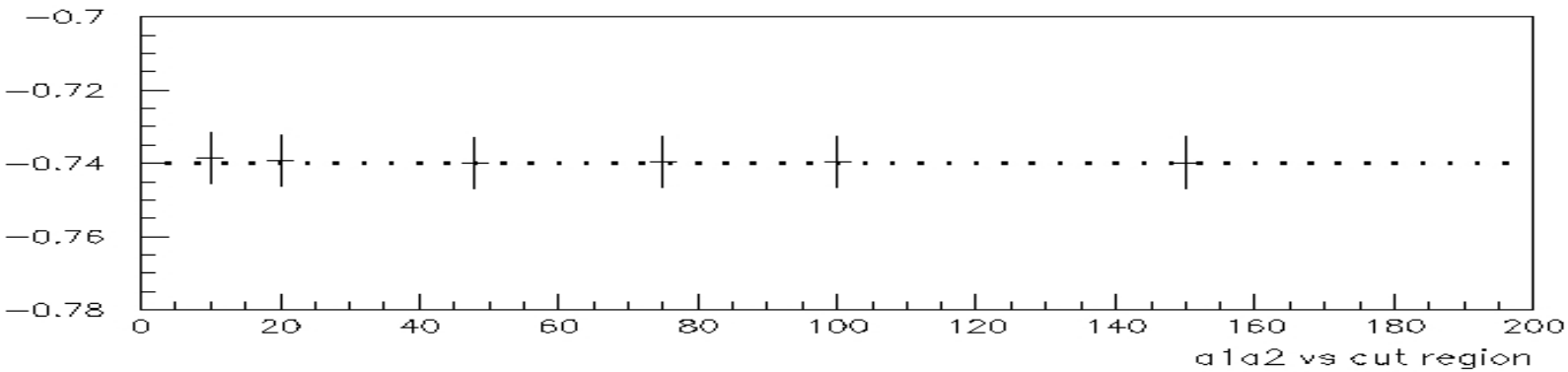


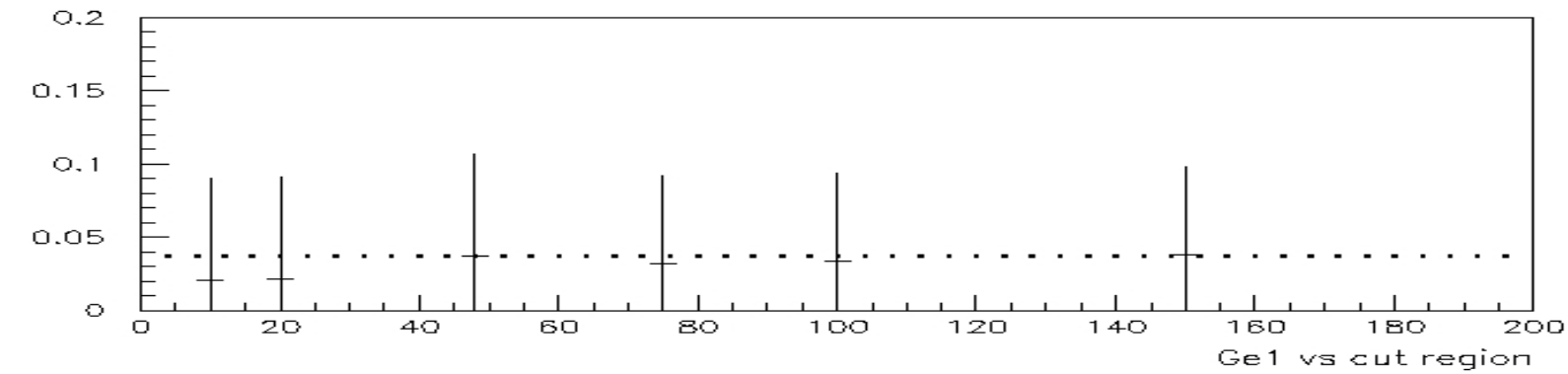




Fusion Chi2 Cut Variation







Cut Variation Systematics Study

✓Analysis job was rerun for each cut choice

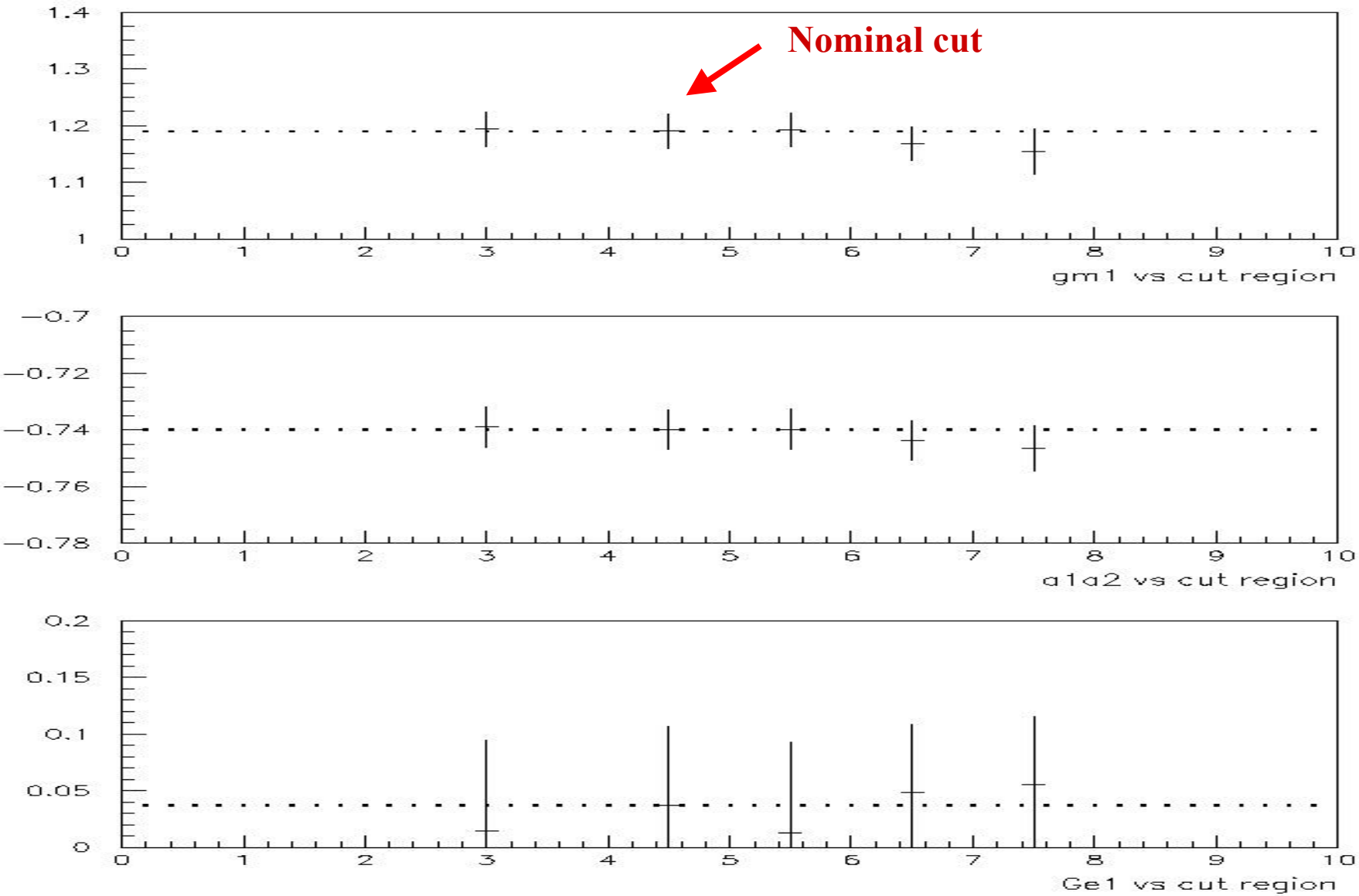
✓ Maximum loglikelihood was recomputed

✓Cuts were varied one at a time

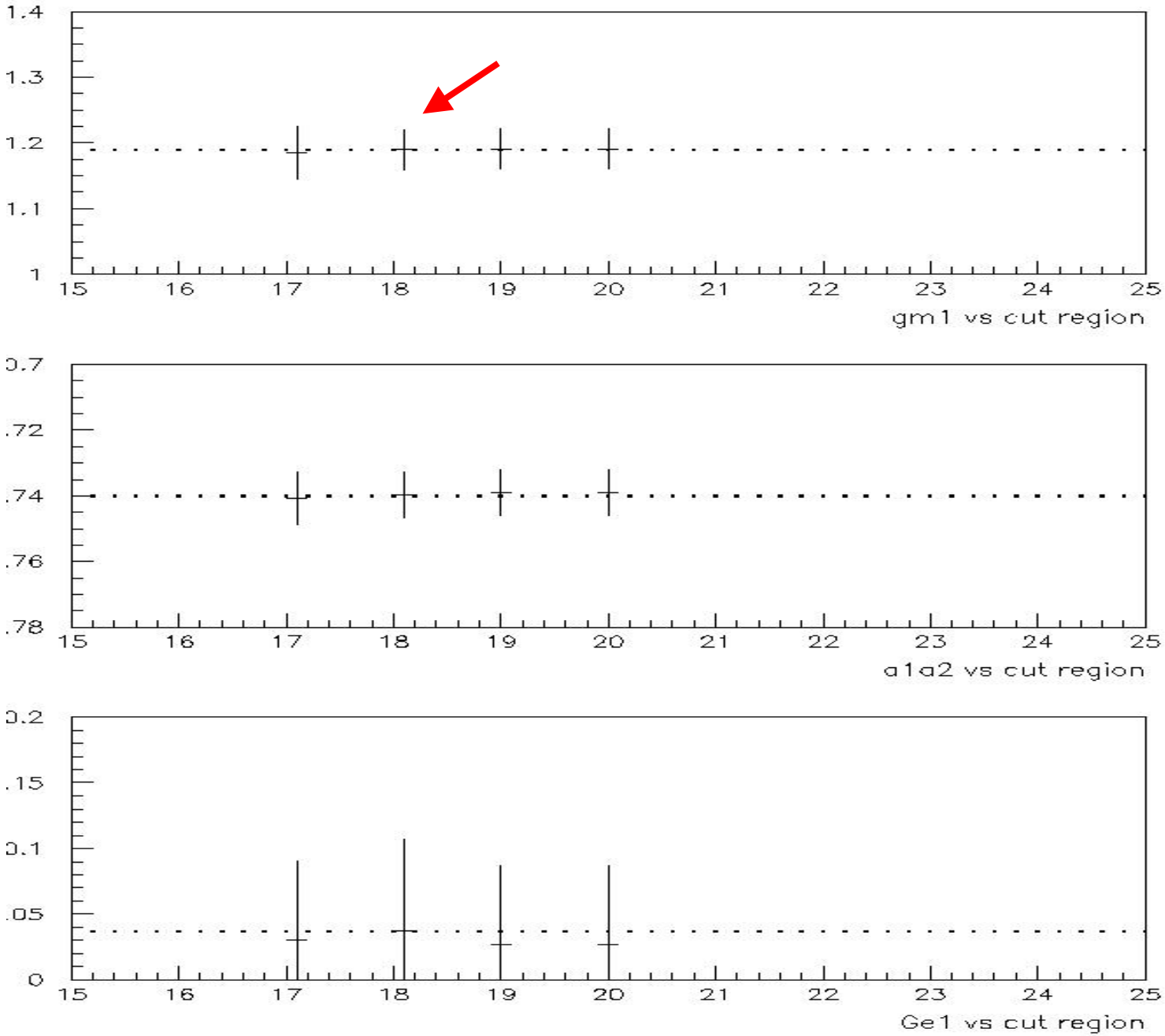
✓Error on the new fit parameter values was determined using a grid of parameter values, centered on the best-fit values from the loglikelihood. 1 sigma fluctuations were determined as values < 0.5 away from max loglikelihood

- Note that the finite width of the grid bins introduces additional error
- Cut choices that seem to be outside, or nearly outside, statistical fluctuations are rerun with finer binning
- (as a result, some of the errors quoted here are upper limits and may shrink with further study)

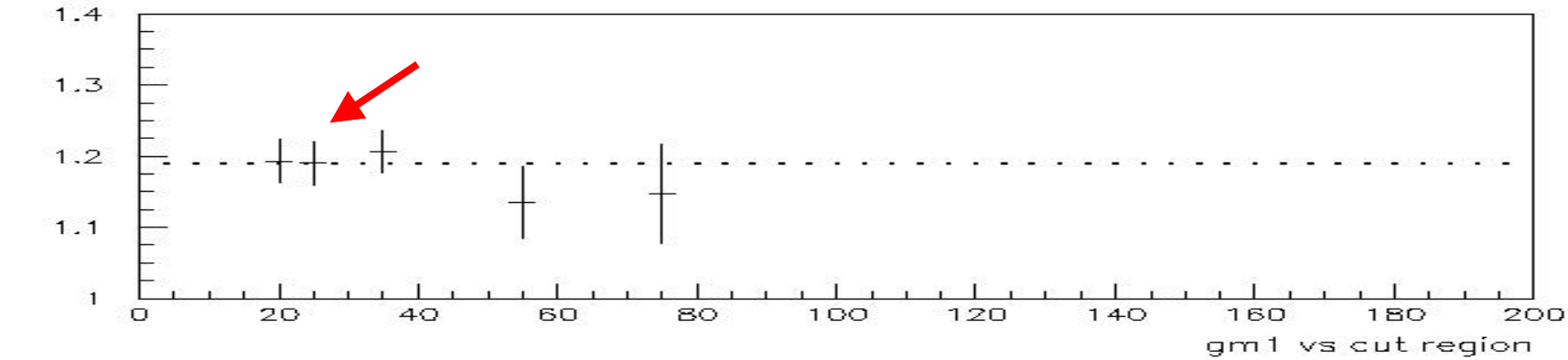
Inner CsI Ring Cut Variation

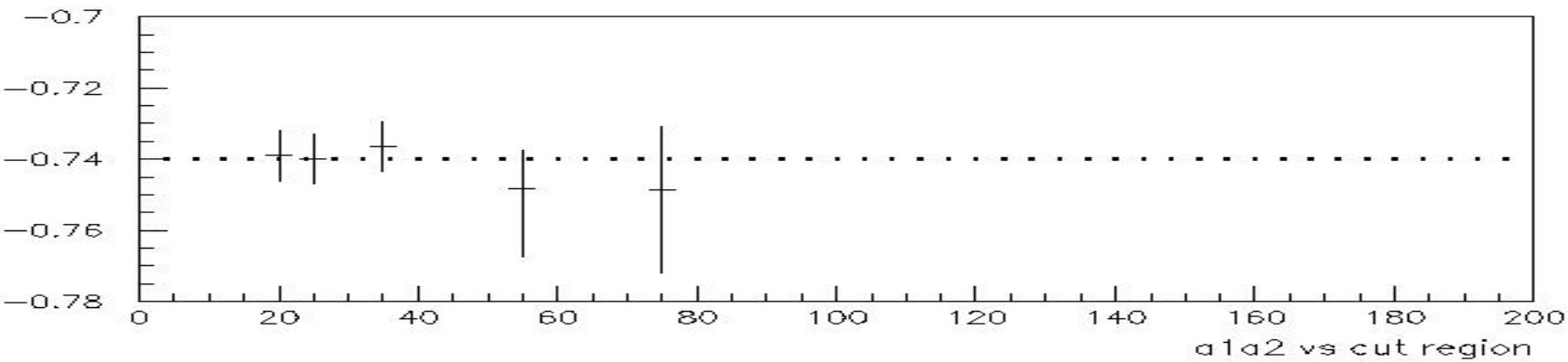


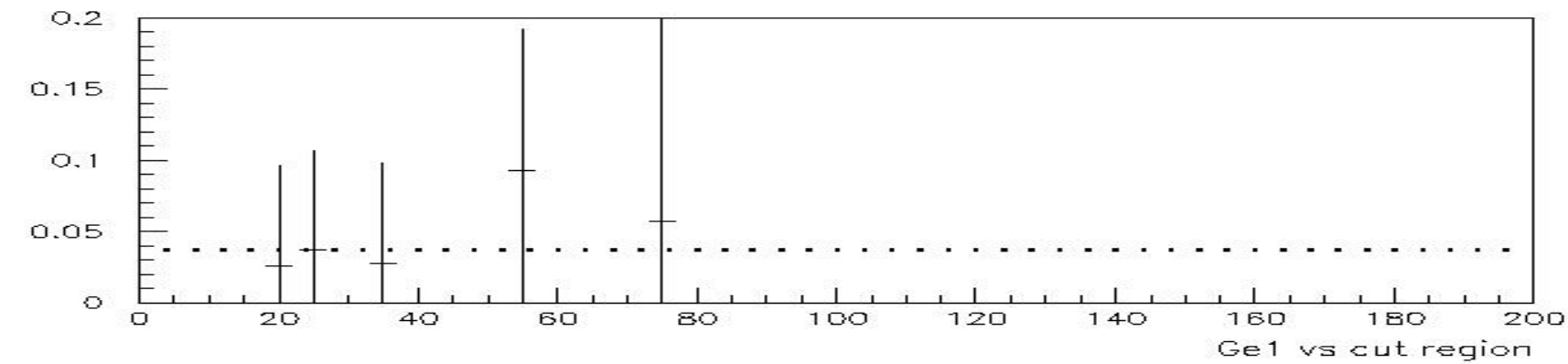
Outer CsI Ring Cut Variation



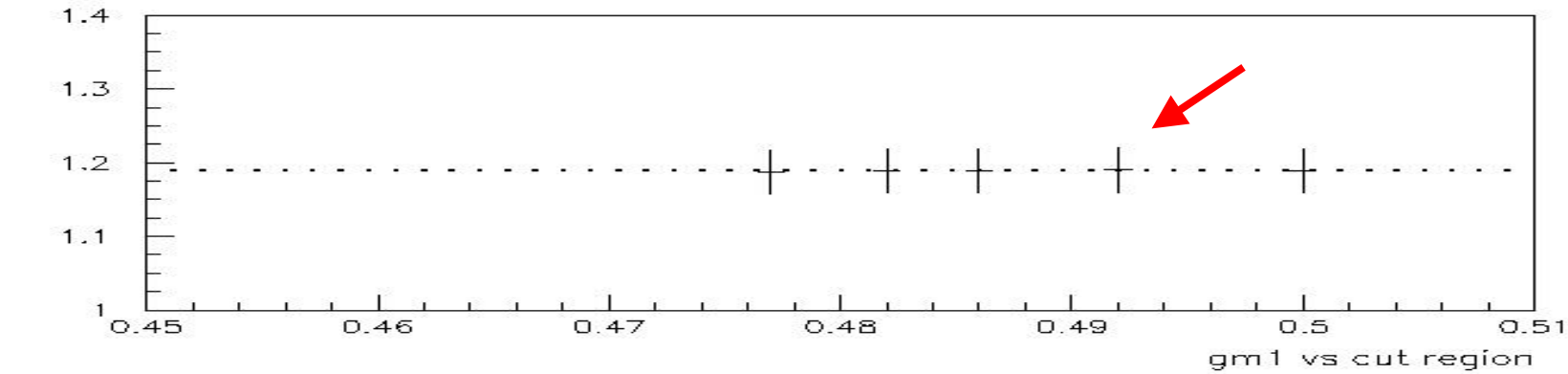
$\pi^+\pi^-\gamma$ Combined Momentum Cut Variation

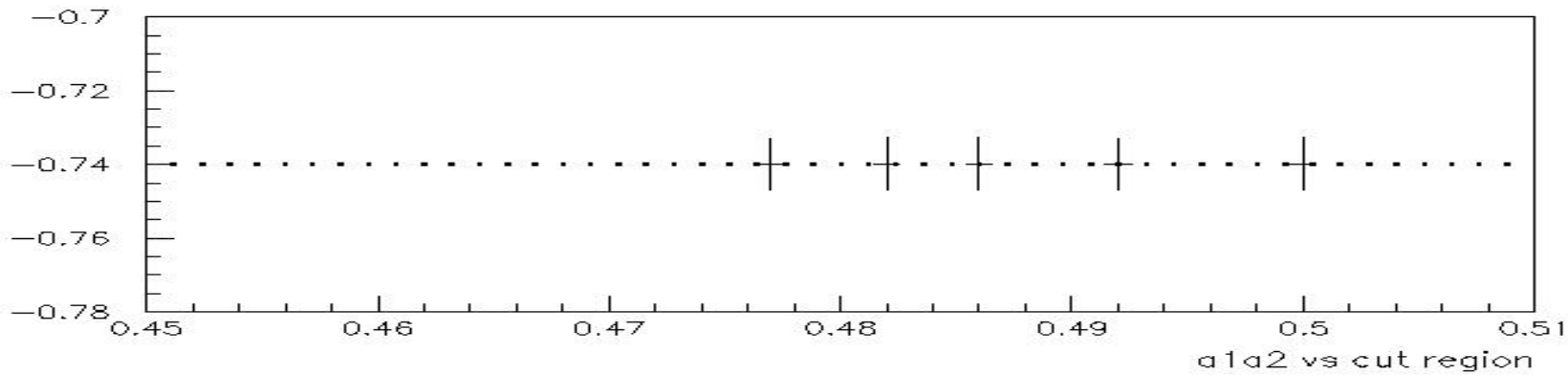


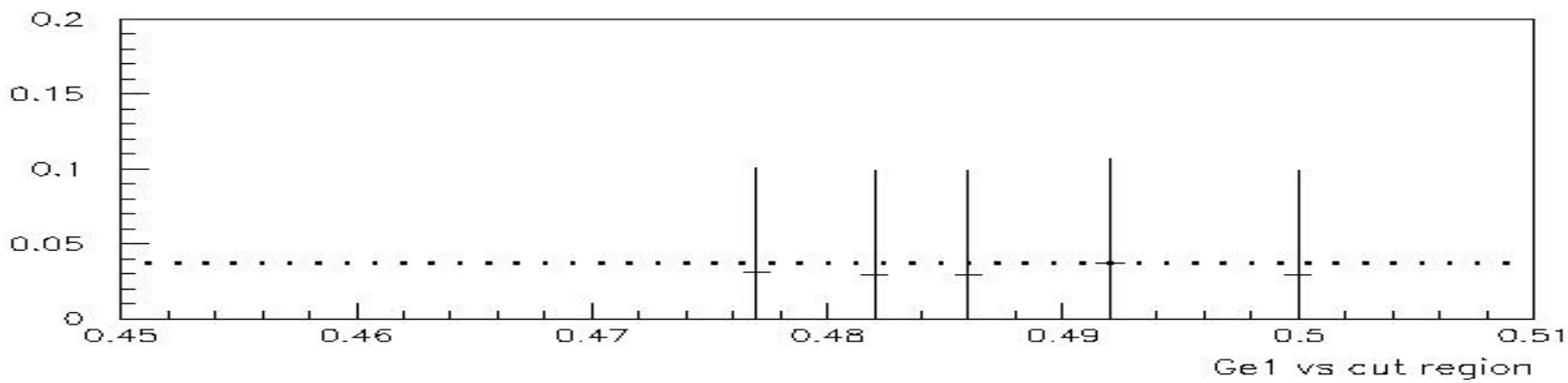




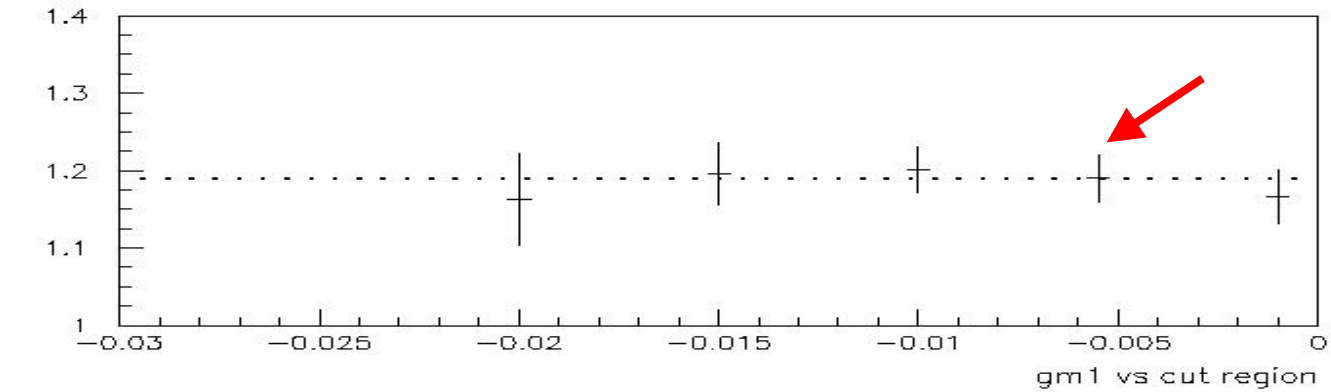
ππ Invariant Mass Cut Variation

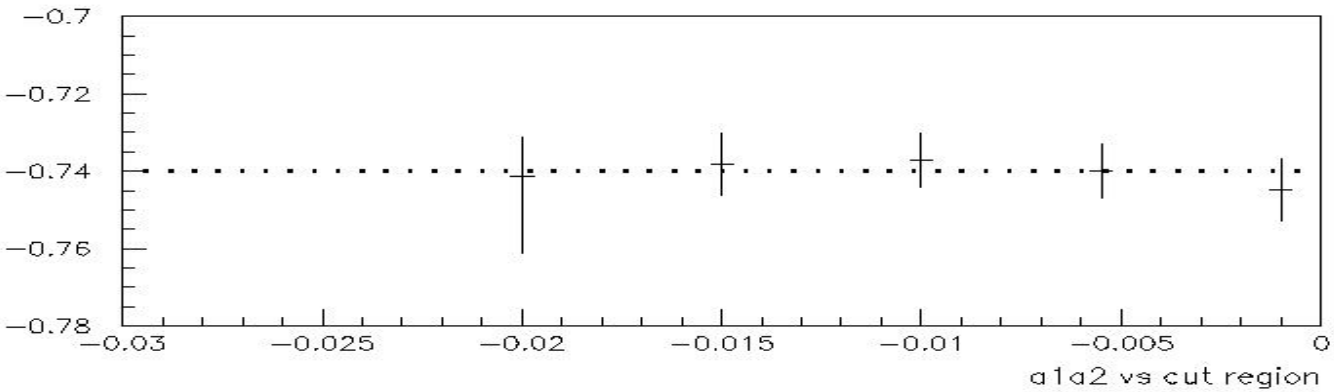


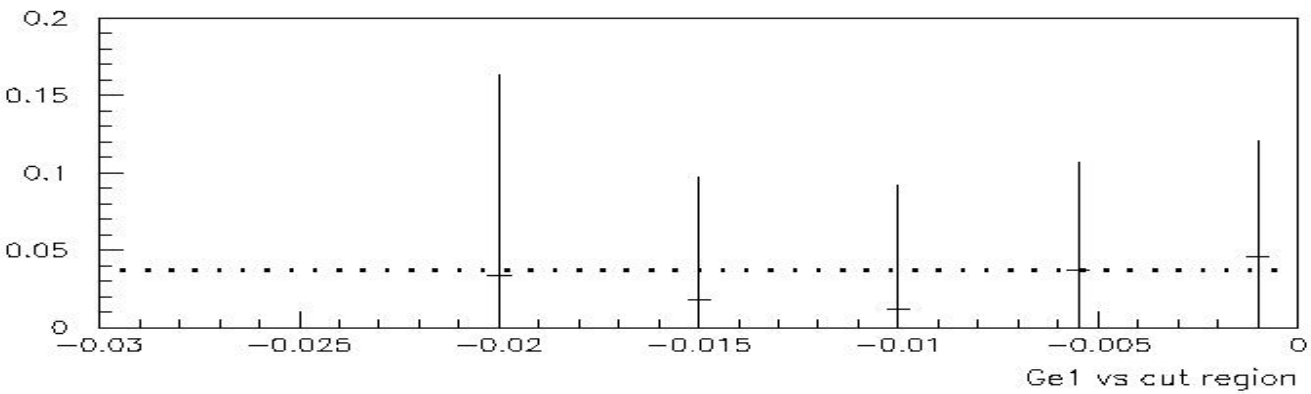




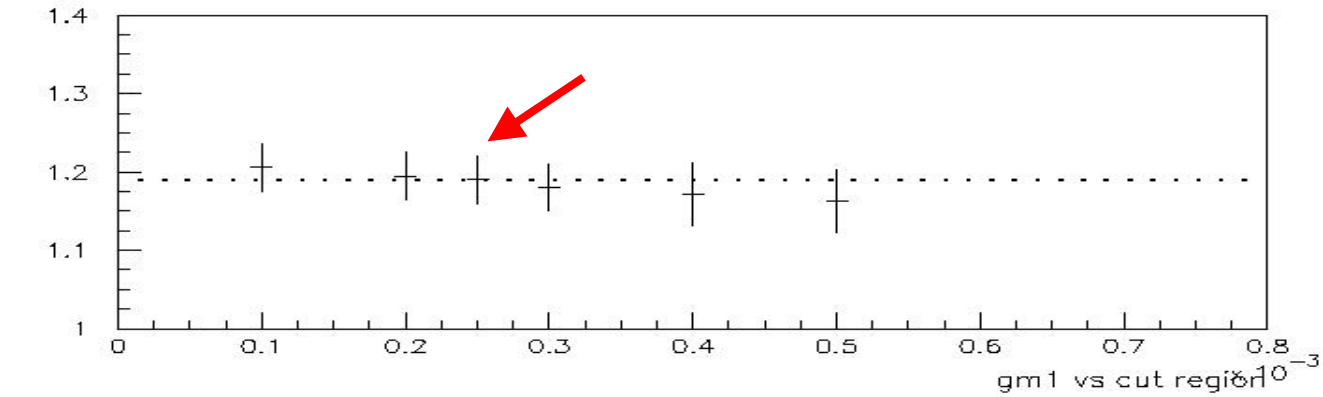
pp0kine Cut Variation

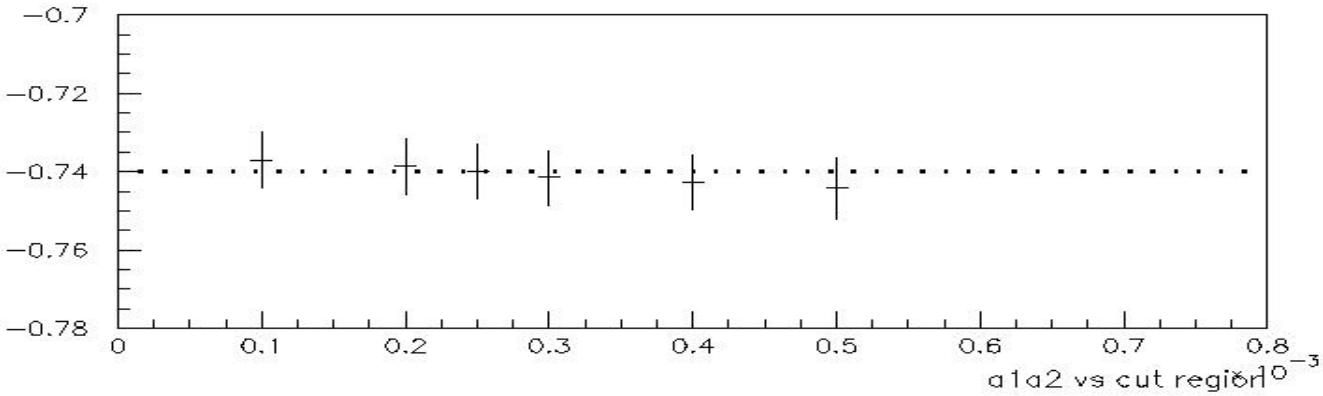


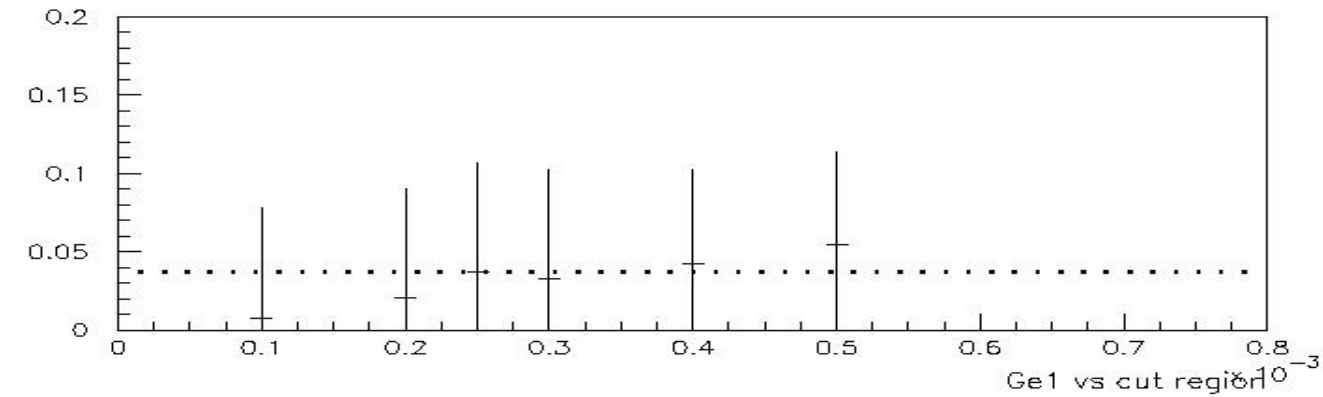




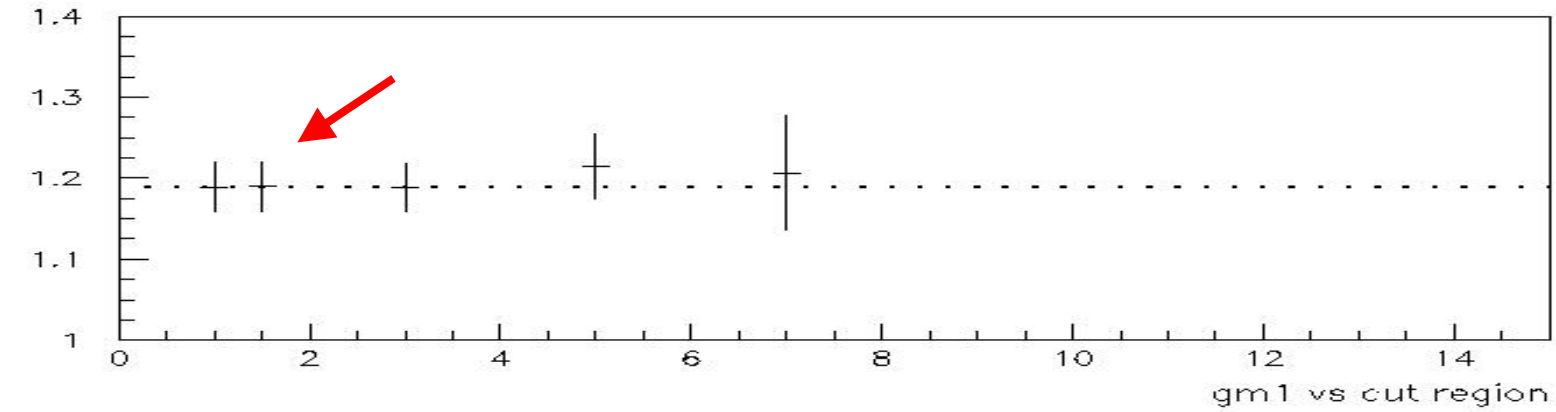
π+π-γ pt2 Cut Variation

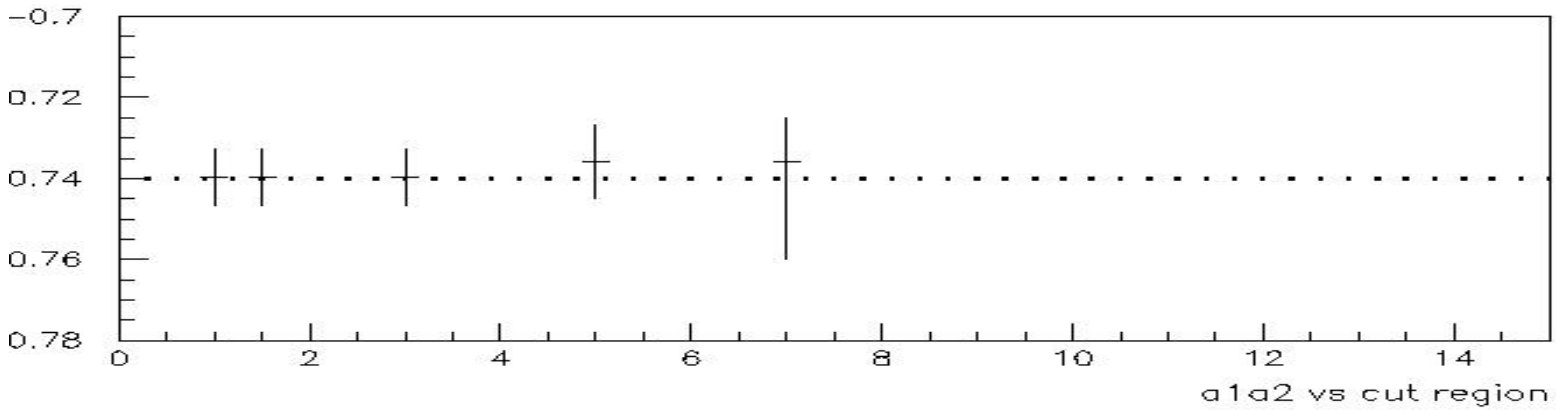


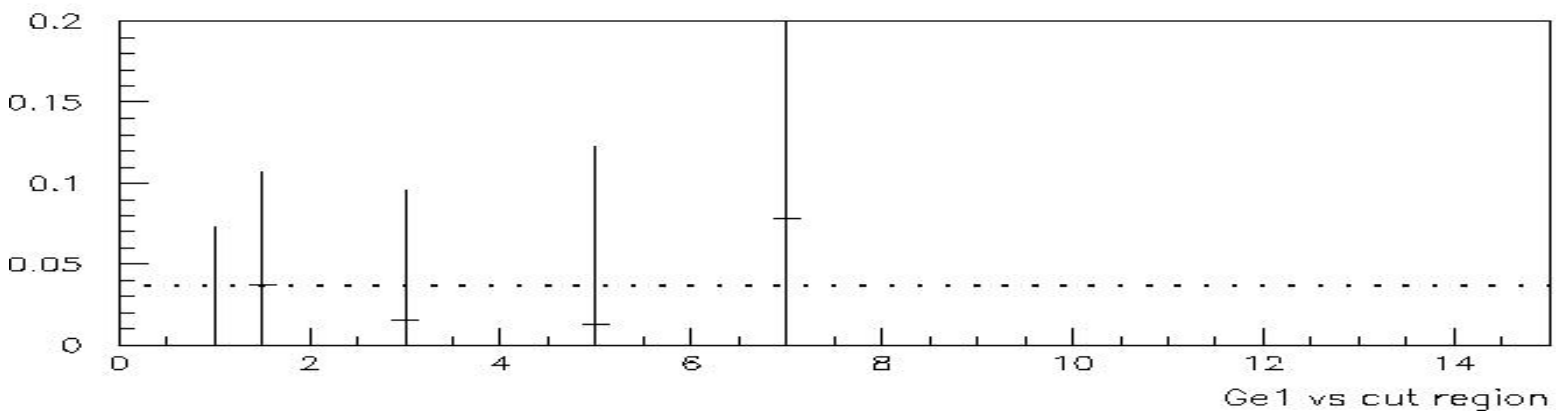




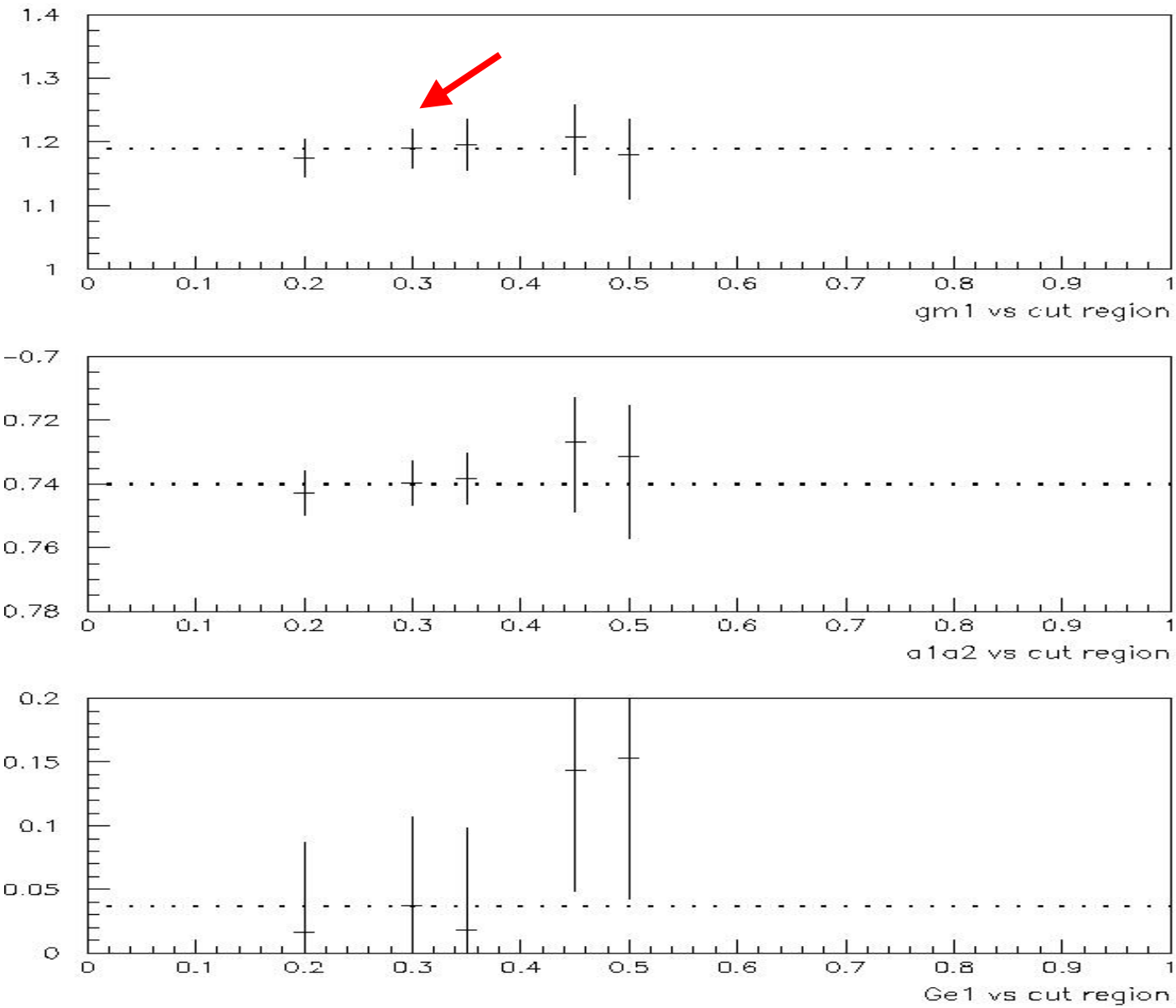
Egamma Lab Cut Variation



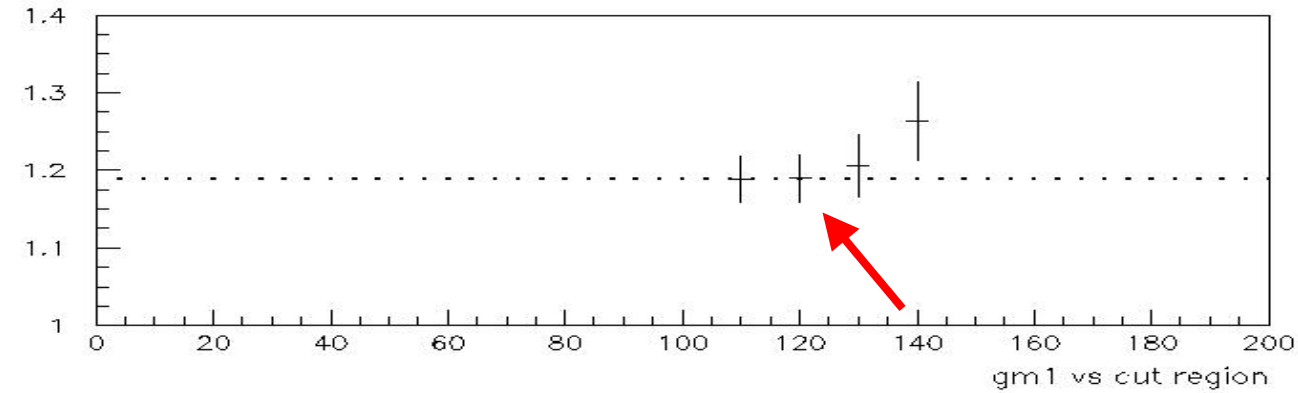


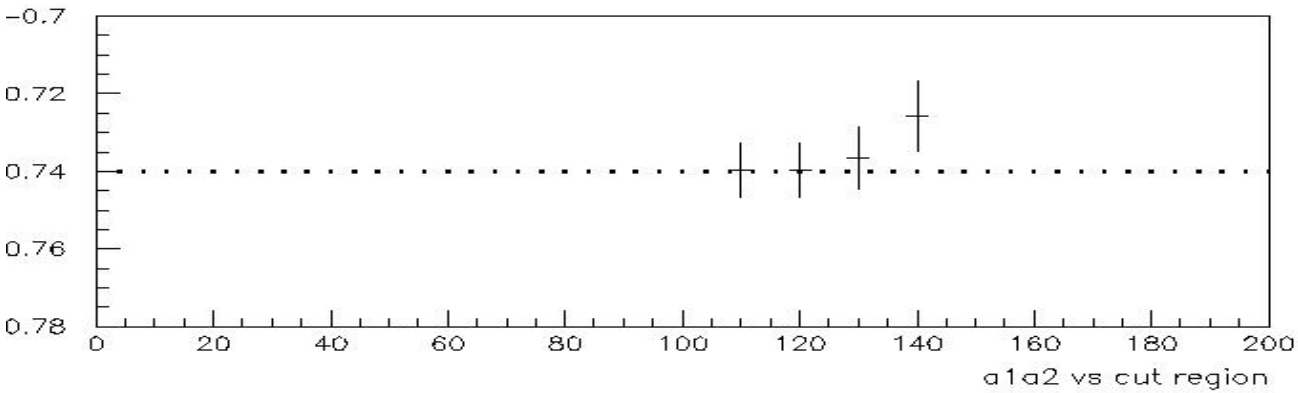


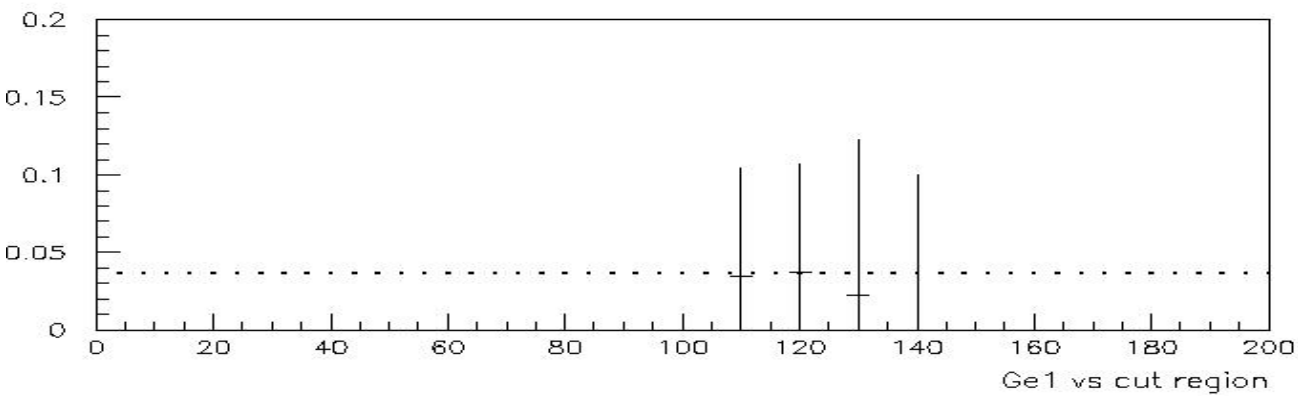
Cut Variation: Track-Photon Separation in Csi



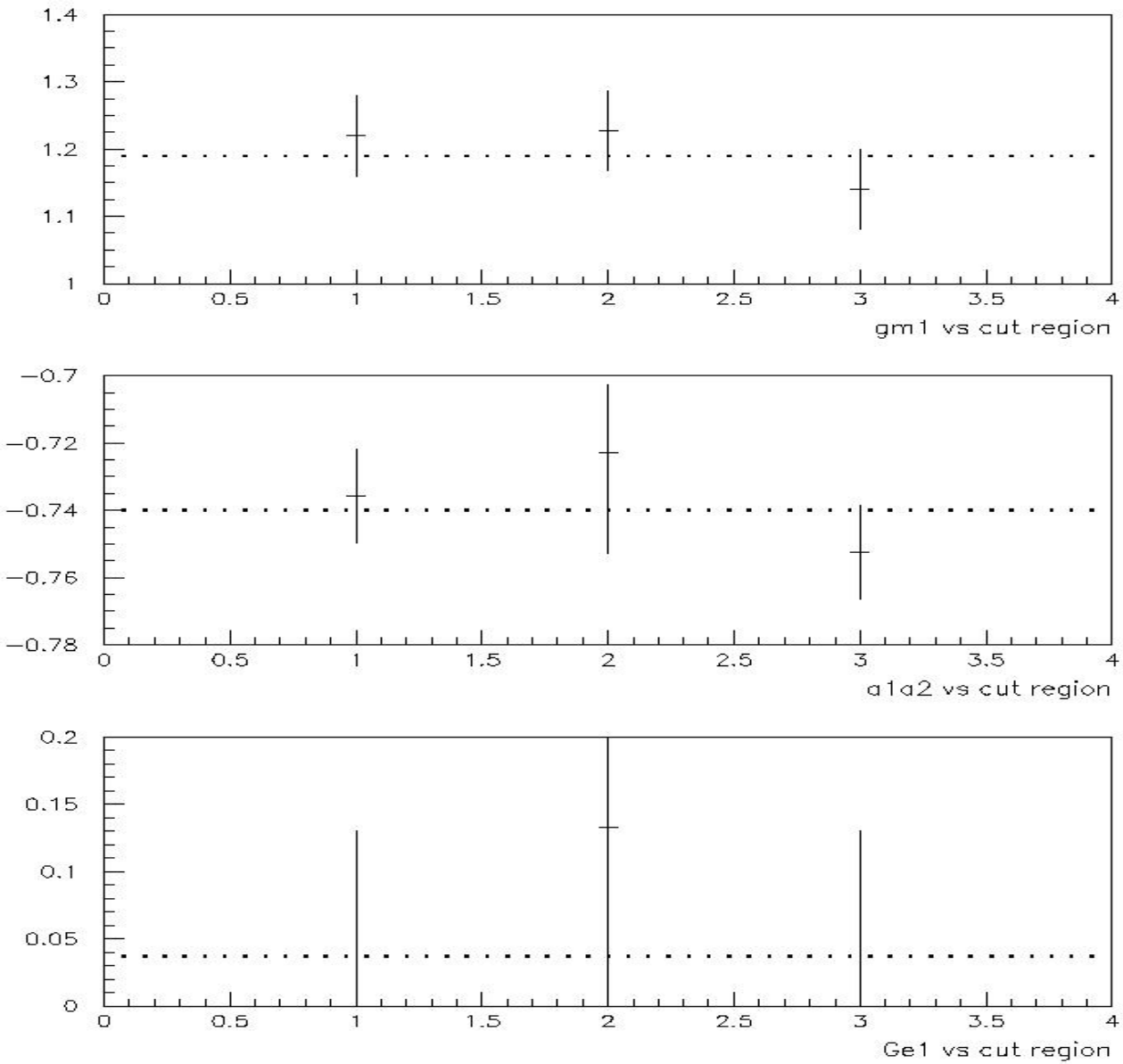
Vertex Z Cut Variation







“Time” Cut Variation (Run separated into 3 Consecutive Regions)



Summary of Systematic Errors

systematic	σ_{gm1}	σ_{a1a2}	σ_{Ge1}
background	0.03	0.004	0.09
Kaon slope	0.003	0.0004	0.005
Fusion chi2	0.0	0.0	0.0
Inner ring	< 0.005	0.0	0.0
Outer ring	0.0	0.0	0.0
Mpipi	0.0	0.0	0.0
pt2	0.0	0.0	0.0
pp0kine	0.0	0.0	0.0
P kaon	< 0.009	0.0	0.0
Track-γ sep	0.0	< 0.0005	< 0.025
Time (run no.)	0.0	< 0.0017	0.0
Vertex Z	< 0.026	< 0.0045	0.0
Egamma lab	0.0	0.0	0.0
Kaon mass	(in progress)	(in progress)	(in progress)
E/p	(in progress)	(in progress)	(in progress)
OTHER??	??????	??????	?????

variable	Stat error
gm1	0.03
a1/a2	0.007
Ge1	0.06

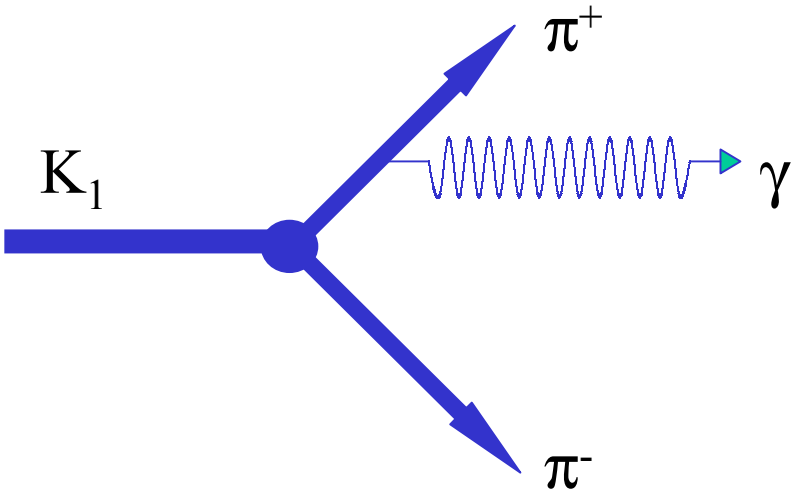
variable	σ_{quad}
Gm1	0.041
a1/a2	0.0063
Ge1	0.094

Summary and Future Plans

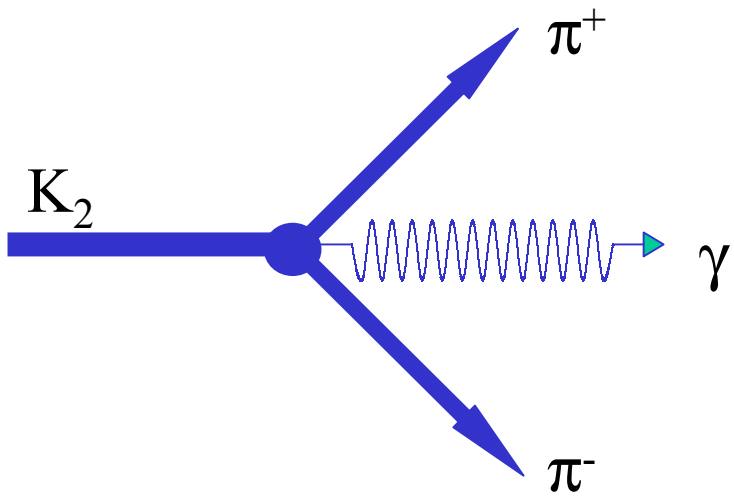
- Kaon momentum slope & bkgrd studies complete
- Cut Variation Studies should be completed within the next couple of weeks
- Remaining systematics studies to begin shortly:
  - $K_S \rightarrow \pi^+\pi^-\gamma$ contamination
  - CsI photon resolution effects
  - Uncertainty in input parameters to the Monte Carlo ($\pi\pi$ phase shifts, etc)
  - **OTHER??????????**
    - if anyone has systematics to add to my list, **please** let me know!!
- **Long Writeup Draft will be available this spring**
- **GRADUATE: SUMMER, 2004**

(end of presentation)

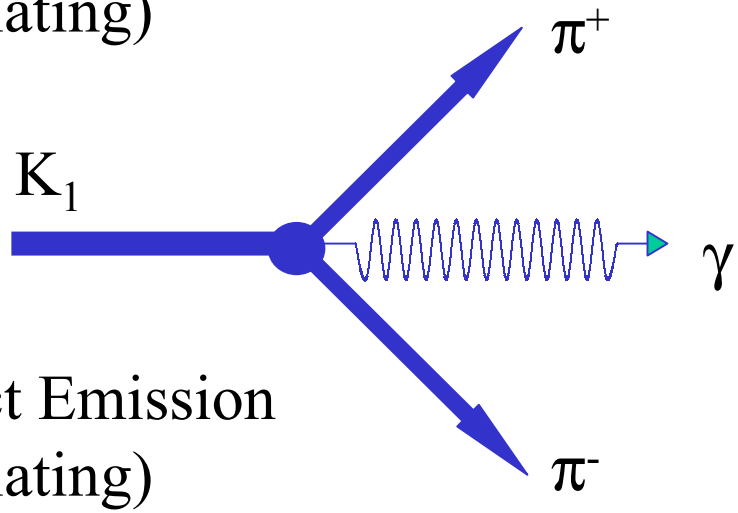
$K_L \rightarrow \pi^+\pi^-\gamma$ Decay



Inner Bremsstrahlung
(CP Violating)



M1 Direct Emission
(CP conserving)



E1 Direct Emission
(CP Violating)

$K_L \rightarrow \pi^+\pi^-\gamma$ Differential Decay Rate, Sehgal Model

$$\frac{d\Gamma}{d\omega d\cos\theta} = (const)\left[\left|\xi_E\right|^2 + \left|\xi_M\right|^2\right]\omega^3\beta^3\left(1-\frac{2\omega}{M_K}\right)\sin^2\theta$$

where:

$$\left|\xi_E\right| = C_2\left|\frac{\eta_{+-}}{\omega^2\left(1-\beta^2\cos^2\theta\right)}\right| + g_{e1}$$

$$\left|\xi_M\right| = \tilde{g}_{m1}\left[1 + \frac{a_1/a_2}{\left(M^2\rho - M^2 K\right) + 2M_K E^*\gamma}\right]$$