Update on the Analysis of $K_L \rightarrow \gamma\gamma$

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Introduction

- selected $K_L \rightarrow \gamma\gamma$ as thesis topic (May/June 2005)

- this analysis is an overhaul of an unfinished study on $K_L \rightarrow \gamma\gamma$ by X. R. Qi of Fermilab.

- nearly finished analyzing the signal mode.

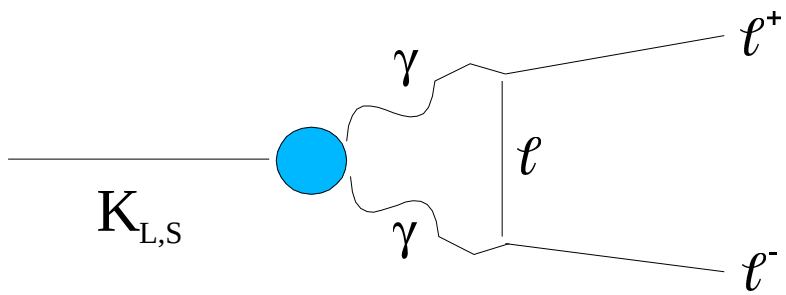
- gearing up to begin analysis on the normalization mode.

- however, we are still deciding on which decay to use for the normalization mode: possibilities are $K_L \rightarrow \pi^0\pi^0$ or $K_L \rightarrow \pi^0\pi^0\pi^0$.

Motivation for Studying $K_L \rightarrow \gamma\gamma$

- the decay of $K_L \rightarrow \gamma\gamma$ and $K_S \rightarrow \gamma\gamma$ provide fascinating inquiries into Chiral Perturbation Theory.

- a good measurement of the $K_L \rightarrow \gamma\gamma$ decay rate is a necessary component of several analyses, such as the $K_L \rightarrow \mu^+\mu^-$ decay.



- $K_L \rightarrow \gamma\gamma$ is also instrumental in extracting the V_{td} component of the CKM Matrix

Previous Measurements

- The most recent measurements of $K_L \to \gamma\gamma$ using $K_L \to \pi^0\pi^0$ and $K_L \to \pi^0\pi^0\pi^0$ as normalization modes were given by CERN NA31, CERN NA48 and KLOE respectively:

$$\left.\begin{aligned} \frac{\Gamma(K_L \to \gamma\gamma)}{\Gamma(K_L \to \pi^0\pi^0)} &= 0.632 \pm 0.004(stat) \pm 0.008(syst) \\ N_{\gamma\gamma} &= 109{,}058 \text{ events} \end{aligned}\right\} (NA31,\ 1987)$$

$$\frac{\Gamma(K_L \to \gamma\gamma)}{\Gamma(K_L \to \pi^0\pi^0\pi^0)} = (2.81 \pm 0.01(stat) \pm 0.02(syst))\, x10^{-3} \quad (NA48,\ 2003)$$

$$\left.\begin{aligned} \frac{\Gamma(K_L \to \gamma\gamma)}{\Gamma(K_L \to \pi^0\pi^0\pi^0)} &= (2.793 \pm 0.022(stat) \pm 0.024(syst))\, x10^{-3} \\ N_{\gamma\gamma} &= 27,\ 375 \text{ events} \end{aligned}\right\} (KLOE,\ 2003)$$

- also noteworthy is the preliminary result of the following ratio given by KTeV:

$$\frac{\Gamma(K_L \to \pi^0\pi^0)}{\Gamma(K_L \to \pi^0\pi^0\pi^0)} = (4.465 \pm 0.016(stat) \pm 0.019(syst))\, x10^{-3} \quad (KTeV, 2003)$$

- PDG 2004 gives the branching ratio of $K_L \to \gamma\gamma$ as:

$$B(K_L \to \gamma\gamma) = (5.90 \pm 0.07)\, x10^{-4} \quad (PDG, 2004)$$

Our result : $N_{\gamma\gamma}$ = 142, 240 events

Preliminary Result from data!!!

$K_L \rightarrow \gamma\gamma$ Analysis

-Data Selection-

- the data used in this study was from trigger 13 of the 1997 KTeV E832 run and is encompassed within 32 tapes.
(tapes KZGG11 – 42)

- the normalization modes ($K_L \rightarrow \pi^0\pi^0$ and $K_L \rightarrow \pi^0\pi^0\pi^0$) are also available from trigger 13.

- KTeVMC v6_04 was used to generate MC.

TRIG13[$K_L \rightarrow \gamma\gamma$] =
SPILL*ET_NEUT*VETO_CHRG*!HA_PION*!CA*!BAGAM*HCC_GE2

(note: TRIG13 has a prescale of 1/20)

- what do the symbols in the trigger definition mean???

ET_NEUT = ET_THR3 + ET_THR4 (used for neutral modes)

→ $E_{tot,\ neut} \geq 26$ GeV

VETO_CHRG = !SA2 * !SA3 * !SA4 * !CIA * !REG * !MU2

HA_PION → 3 MIP Pion veto (rare decay veto)

CA = CA_LEFT | CA_RIGHT (used for neutral mode triggers)

BAGAM = BA_LEFT | BA_RIGHT

(!BAGAM rejects > 10 GeV photon energy and < 350 mV)

HCC_GE2 $\geq$2 hardware clusters

(logic symbols: & or * = AND, | or + = OR, ! = NOT)

- $K_L \rightarrow \gamma\gamma / \pi^0\pi^0$ Crunch Cuts -

- note that the crunch was performed with KTeVANA v6_02!!!

- used the crunch output data files generated by X. R. Qi.

Variable	$K_L \rightarrow \gamma\gamma$ / $\pi^0\pi^0$ Cuts
# hardware clusters	2 / 4
# CsI slices	6
Cluster Timing	< 1000
Cluster Shape	< 1000
Cluster Separation	> 0.05 m
Cluster Energy	> 2 GeV
Kaon Energy	> 30 GeV
Z Vertex	100 m – 160 m
Ring Number	< 1000 cm^2

- $K_L \rightarrow \gamma\gamma / \pi^0\pi^0$ Analysis Cuts -

Variable	$K_L \rightarrow \gamma\gamma$ Cuts
# hardware clusters	2
extra clusters	0
# tracks	0
VV' Hits	≤ 2
Intprs DC 4	≤ 2
Intprs DC 234	< 6
Intprs DC TOT	--
Pos. Clus.	iseedring ≤ 18
Cluster Timing	< 1000
Cluster Shape	< 10
Cluster Pairing	--
Evto RC	< 0.2 GeV
Evto CA	< 1.0 GeV
Evto SA, MA, CIA	< 0.3 GeV
Evto BA1	< 5.0 GeV
Evto HA	--
Evto Regpb	< 0.7 Mips
Reg ADC	< 2.0 Mips
Cluster Separation	> 0.20 m
Beamhole	mnpipefrac > 0.04
Cluster Energy	> 3 GeV
Kaon Energy	40 - 160 GeV
Z Vertex	125 m – 155 m
Ring Number	< 110 cm^2

- the analysis was performed with KTeVANA v6_04!!!

- we required no software clusters of more than 0.6 GeV, which reduces accidentals and backgrounds due to misidentified decays.

- currently, we're studying how well timing chi sq. is modeled by the MC.

- we're also looking at how loosening fusion chi sq. affects the background.

- in addition, we're studying how increasing the cut on the separation between clusters affects this analysis.

- note that the z range used in the MC Job was (100.0 – 165.0) m.

- the momentum range for the MC was (20 – 250) GeV.

Data/MC Overlays for $K_L \rightarrow \gamma\gamma$

- in the following overlays, dots are data and histograms are monte carlo.

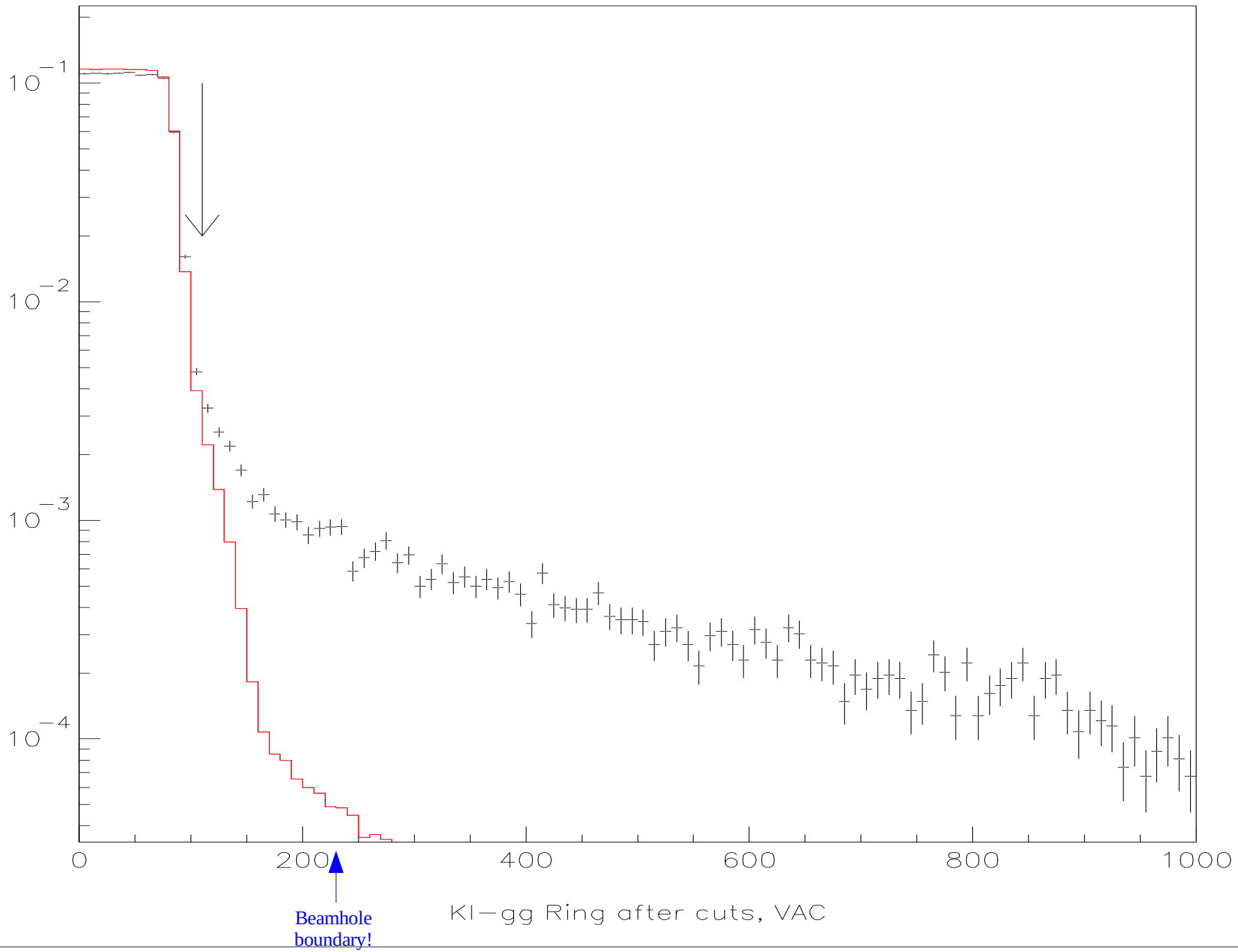
- black arrows signify current cuts and red arrows indicate cuts that are being studied.

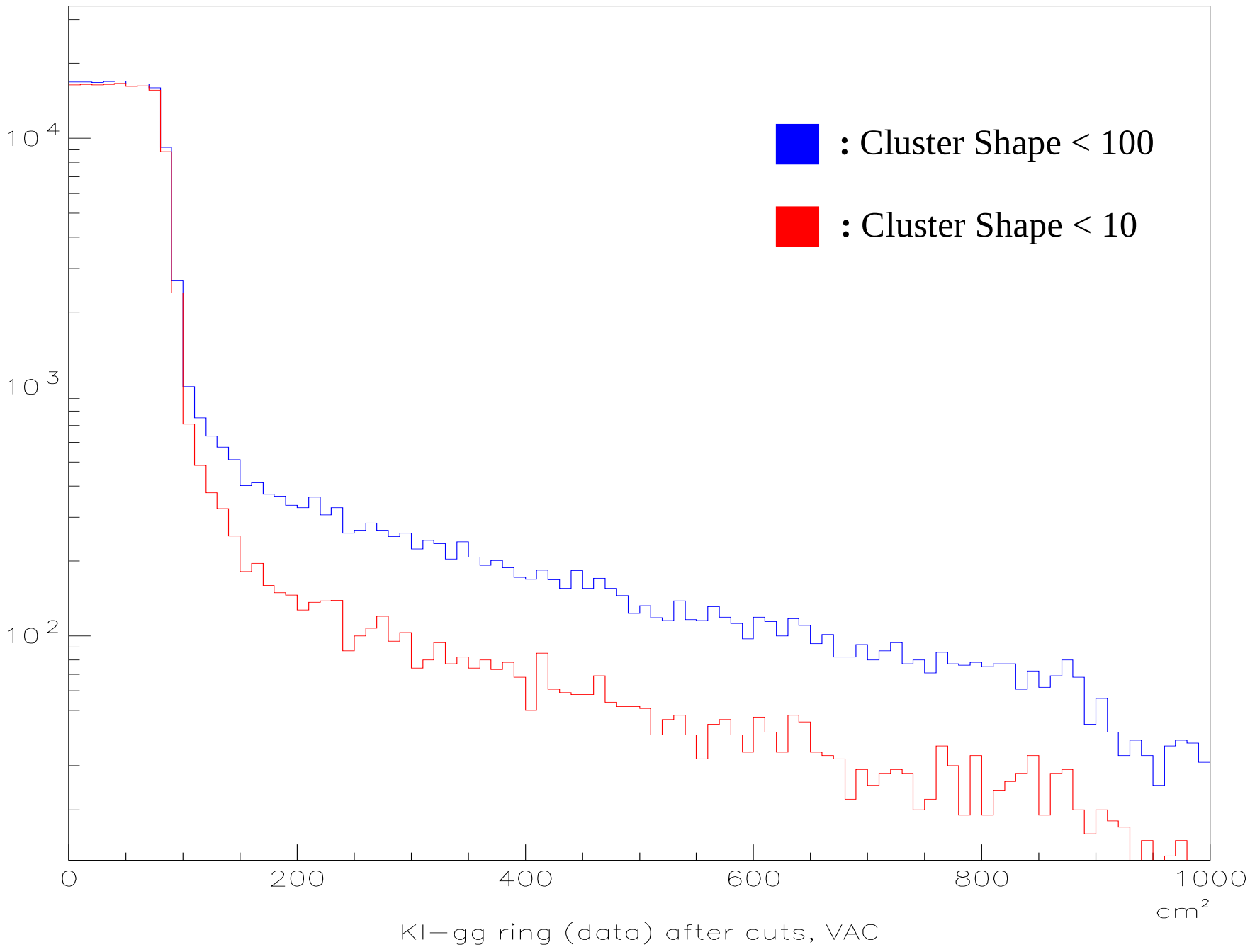
- all of the following plots are for the Vacuum Beam only!

- once again, these overlays are for the 1997 data set only!

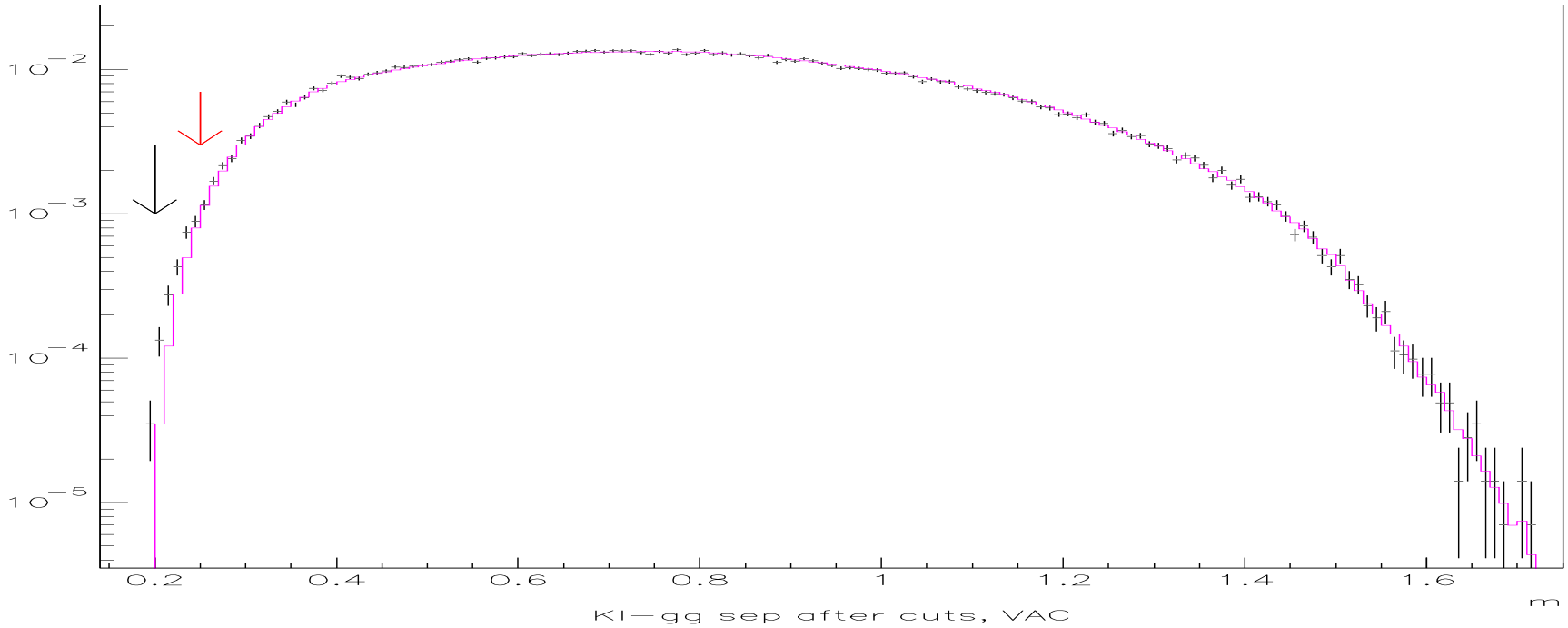
- all Data/MC overlays and ratios for a given variable are made after all cuts, save the cut on the variable being observed.

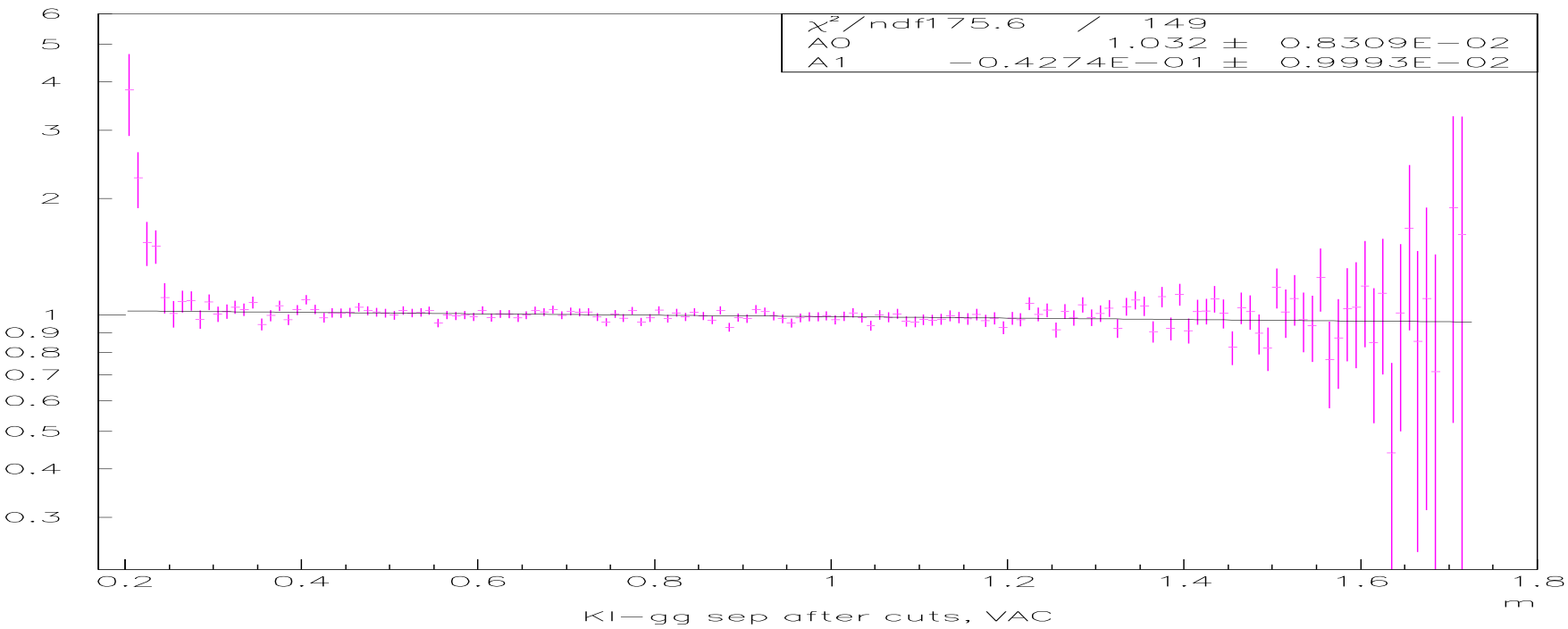
$$Ring = 4 \cdot (Max(x_{COE}[cm], y_{COE}[cm]))^2$$



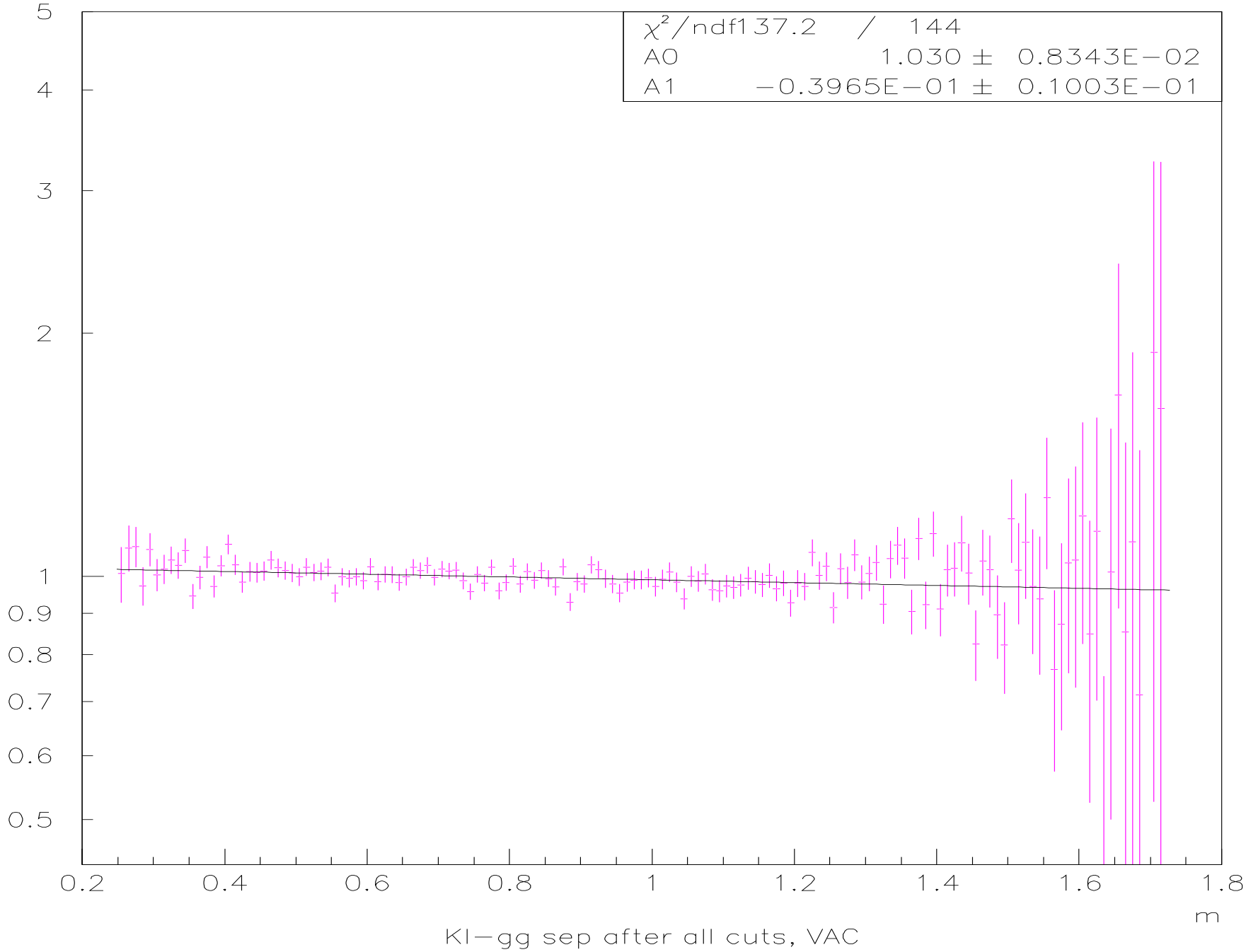

: Cluster Shape < 100
: Cluster Shape < 10
10 4
10 3
10 2
0
200
400
600
800
1000
cm²
KI—gg ring (data) after cuts, VAC

$$Cluster\ Separation = \sqrt{(x_{\gamma_1} - x_{\gamma_2})^2 + (y_{\gamma_1} - y_{\gamma_2})^2}$$





- Data/MC ratio for sep > 0.25 m



- the next variable mnpipefrac was required to be less than 0.04

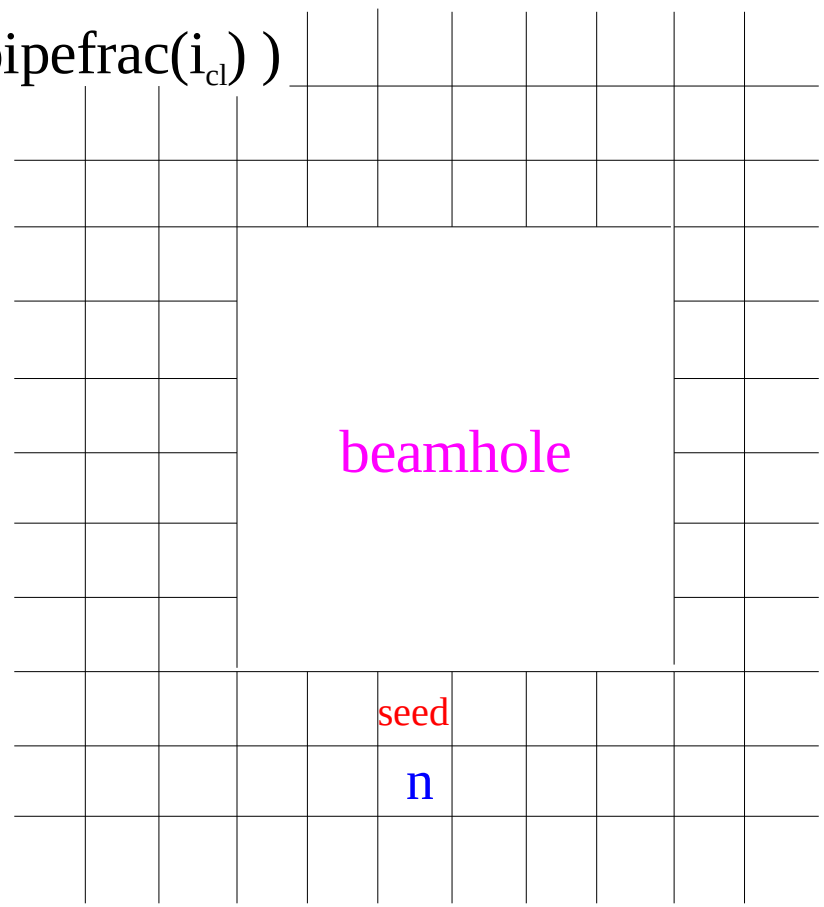
$$\text{pipefrac}(i_{cl}) = \begin{cases} 2.0, \text{ if cluster seed is not adjacent to the beamhole} \\ \dfrac{E_{neighborblk}}{E_{seedblk}}, \text{ otherwise} \end{cases}$$

$= 2.0$

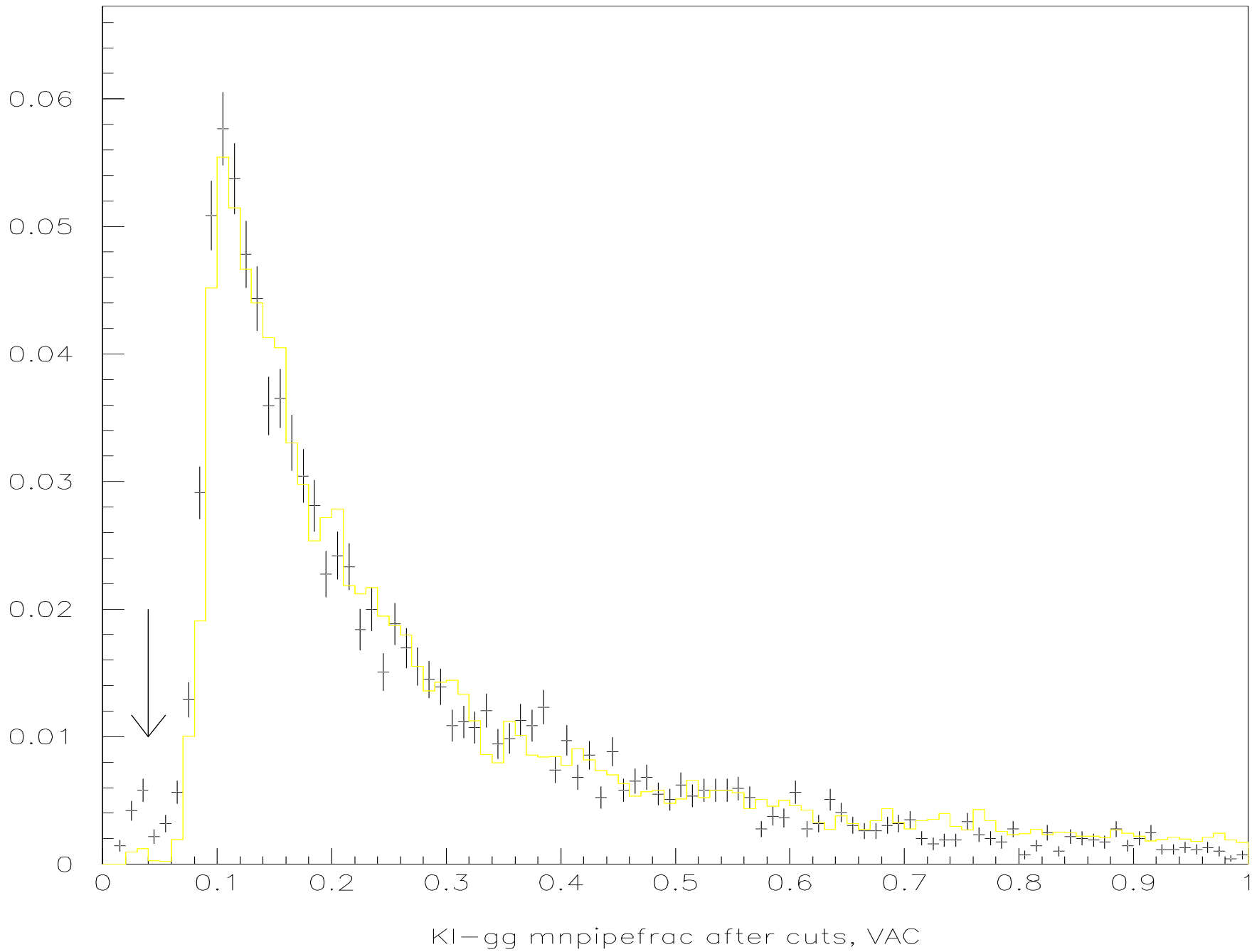
mnpipefrac = MIN (MNPIPEFRAC, pipefrac(i_{cl}))

$E_{neighborblk}$ = energy of block nearest to seed, but not a pipeblock

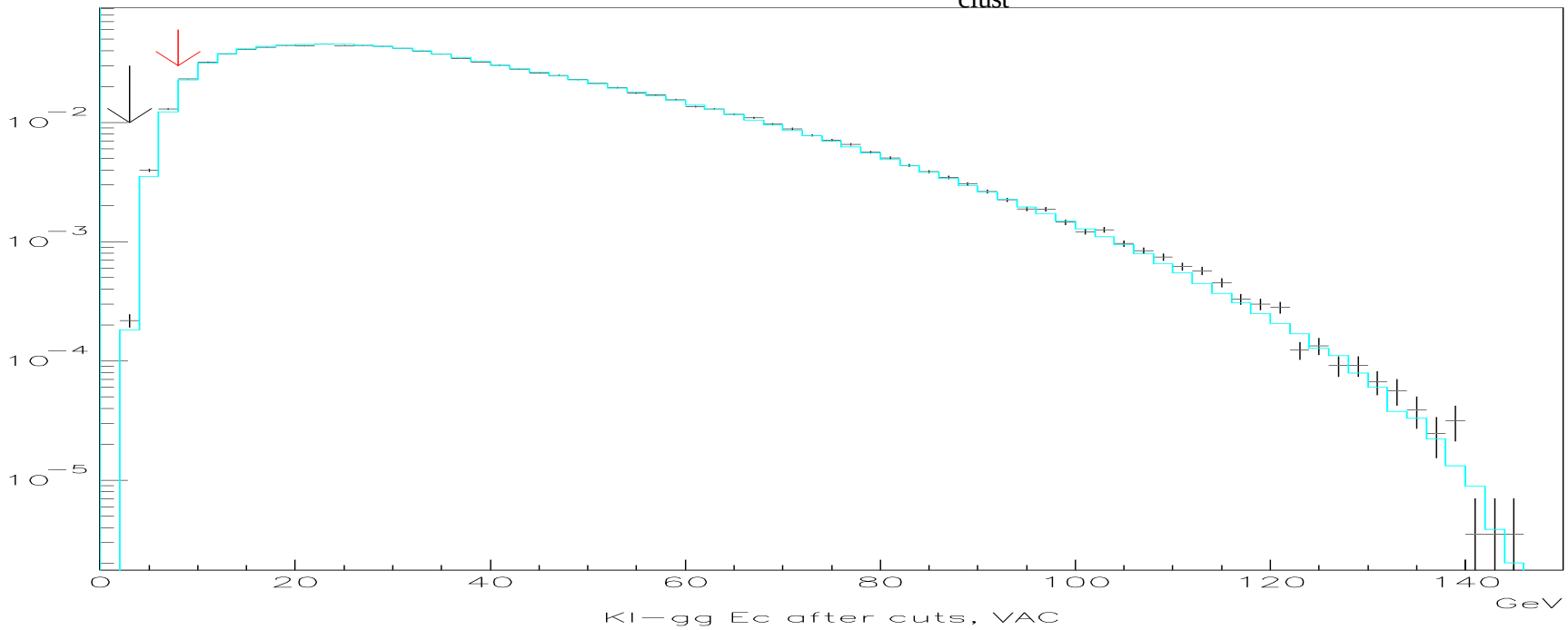
- the cut on mnpipefrac is made to weed out beamhole photon events

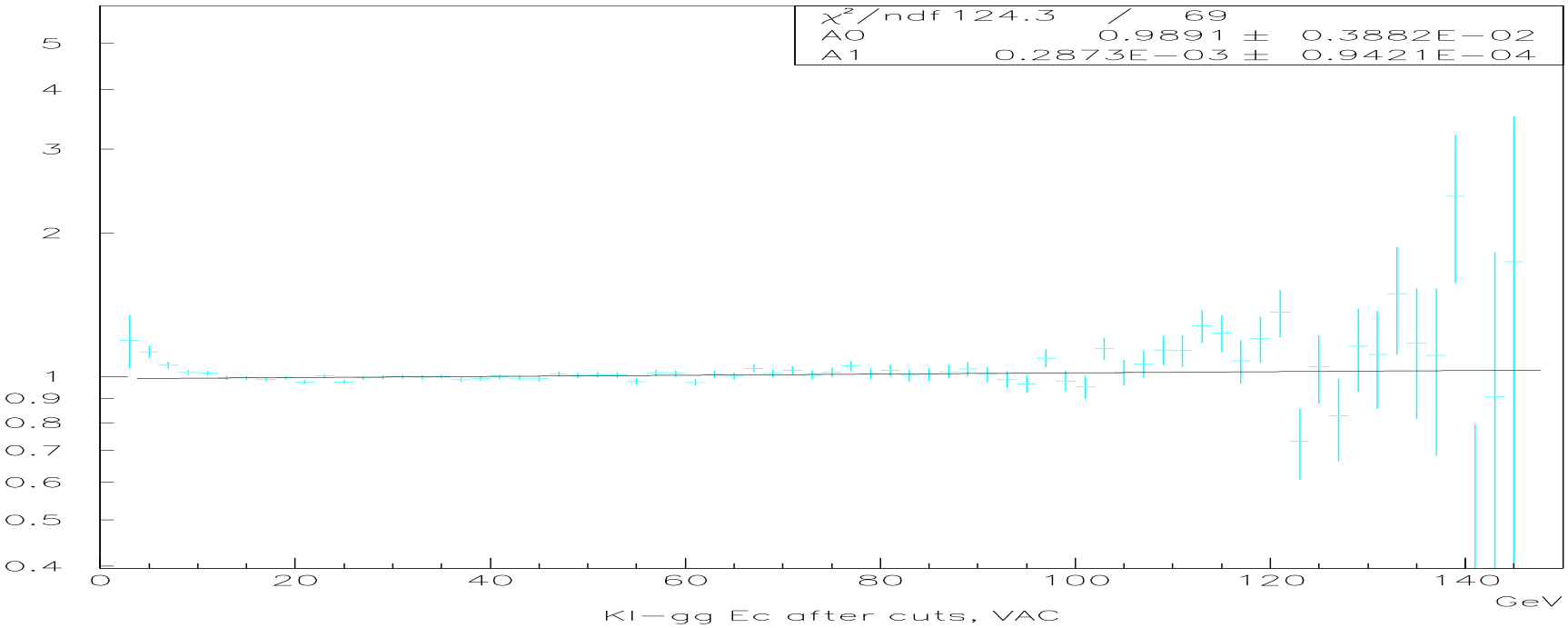


- roughly 5% of the mnpipefrac spectrum is contained within {0,1}

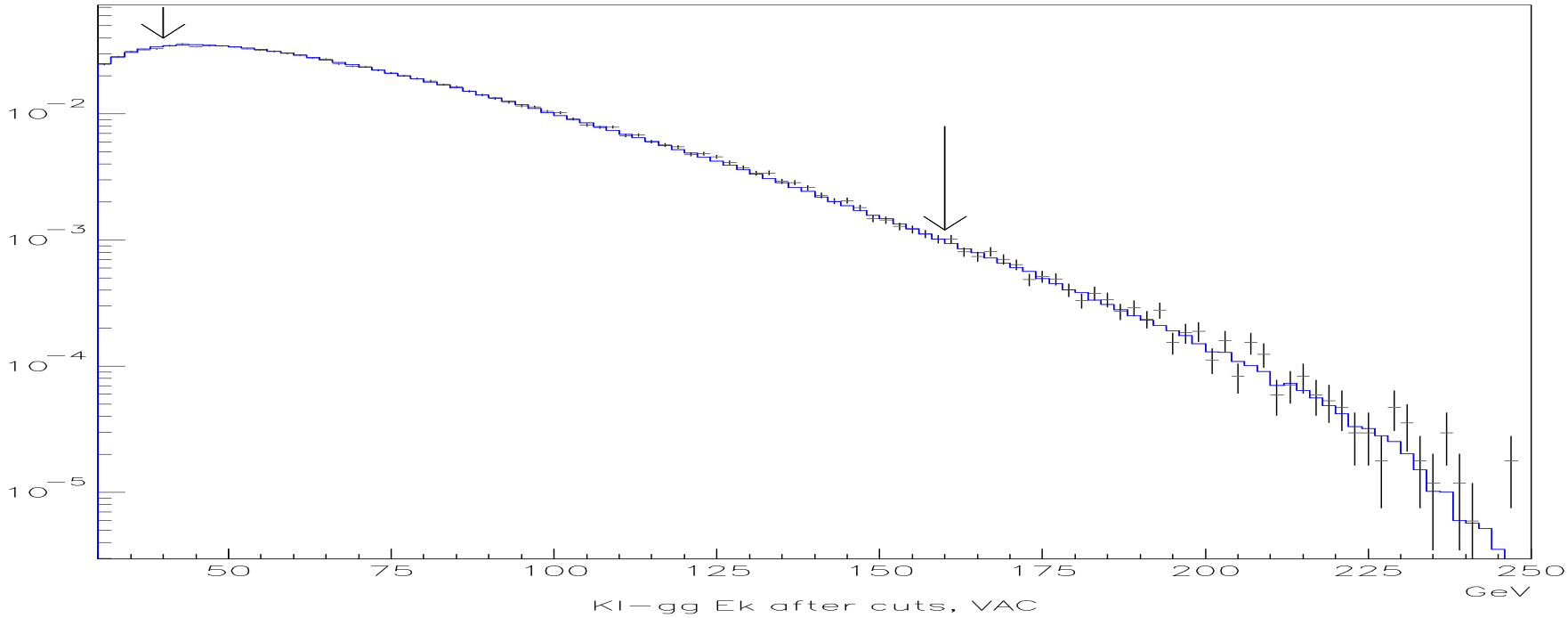


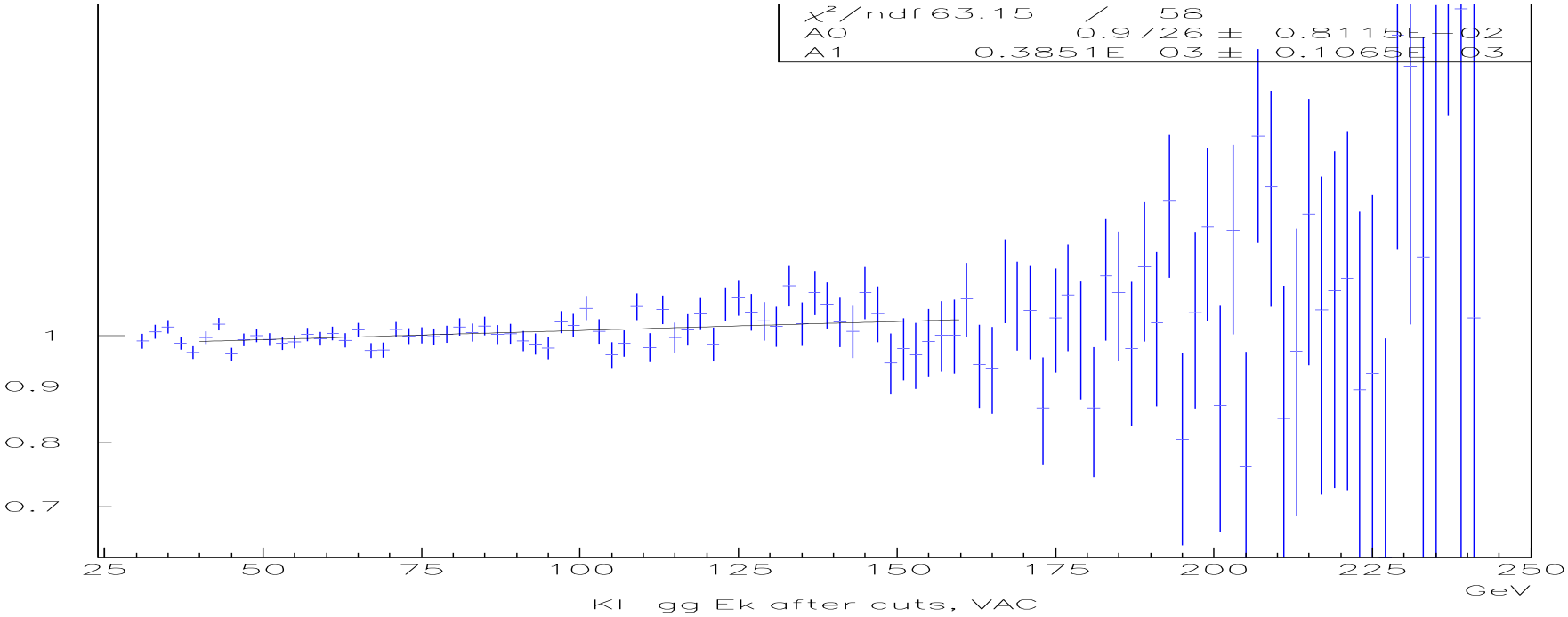
- the Data/MC ratio for E_{clust} > 3 GeV

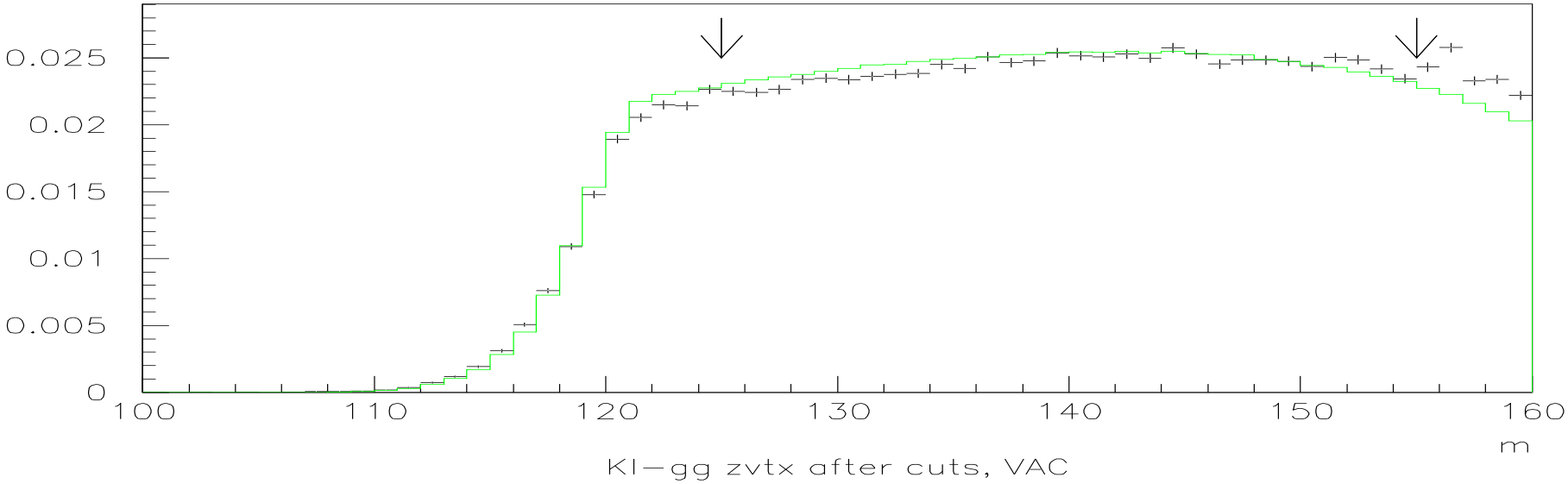


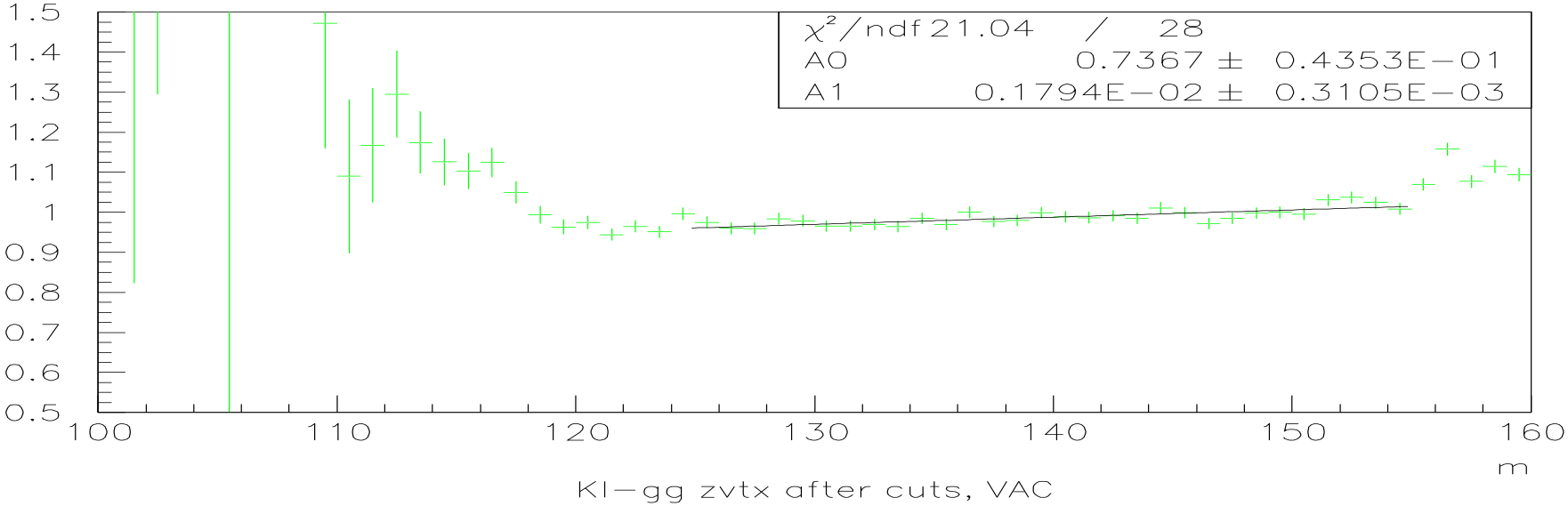


The Kaon Energy Spectrum









$$K_L \text{ vertex} = \frac{\sqrt{E_{\gamma_1} \cdot E_{\gamma_2}} \cdot \sqrt{(x_{\gamma_1} - x_{\gamma_2})^2 + (y_{\gamma_1} - y_{\gamma_2})^2}}{m_{K_L}}$$

Future Background Studies

The background possibilities for $K_L \rightarrow \gamma\gamma$ include:

- $K_L \rightarrow \pi^0\pi^0$ and $K_L \rightarrow \pi^0\pi^0\pi^0$ with 2 + photons missing

- $K_L \rightarrow \gamma\gamma$ scattering (collimator and regenerator)

- $K_L \rightarrow \pi^0\gamma\gamma$; $B(K_L \rightarrow \pi^0\gamma\gamma) = (1.41 \pm 0.12)\, x10^{-6}$ (*PDG*, 2004)

Preliminary Results

	$K_L \to \gamma\gamma$ (D. Phillips)	$K_L \to \gamma\gamma$ (X. R. Qi)
# of data	142,240	124,240
# of MC	6,188,740	4,576,270
# of MC Gen'd	70,214,465	54,637,016
Fluxes gen'd	43.51	36.83
MC acceptance	0.08814	0.0838
# of background	~3500 (~2.5%)	2633 (2.1%)

Conclusions

- still need to analyze either $K_L \rightarrow \pi^0\pi^0$ or $K_L \rightarrow \pi^0\pi^0\pi^0$ to obtain a preliminary estimate on the branching ratio.

- need to have a better understanding of the slopes between data and MC in the zvtx and Ekaon distributions.

- afterwards, systematics will be studied.

- in short, lots of work still needs to be accomplished!!!