Extraction of $\eta_{+-\gamma}$

using 97 + 99 data

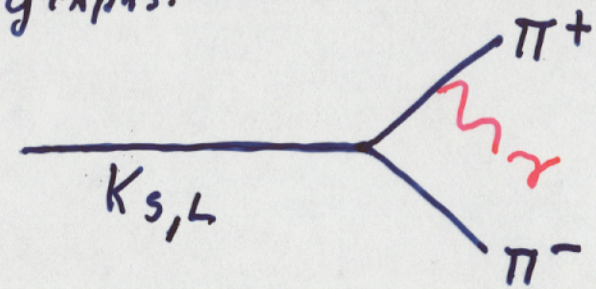
First Steps
and
Sneak Peeks
of 99 data

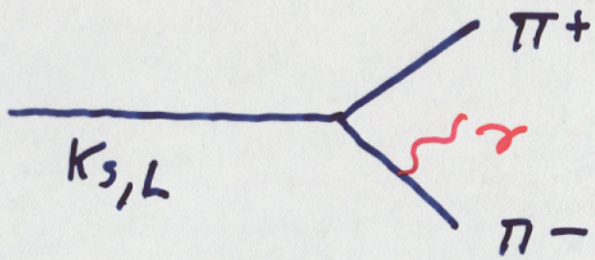
Michael Ronquest
University of Virginia

$\eta_{+-\gamma}$ describes the amount of CP violation present in the decay $K \to \pi^+\pi^-\gamma$

These decays occur through the following graphs:

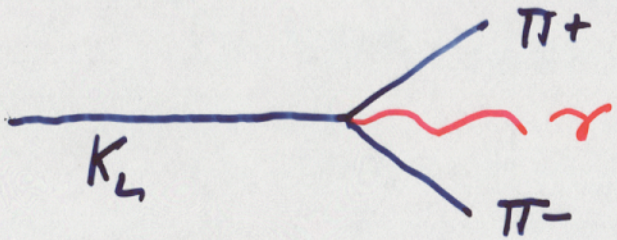
Inner Brem





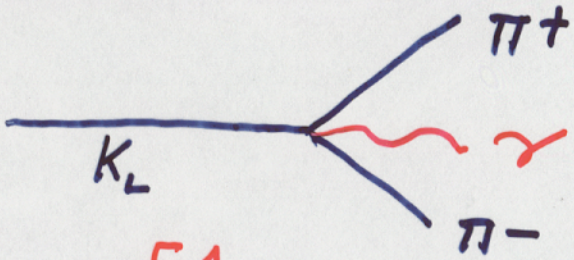
IB is CP conserving for K_S (dominant term)
CP violating for K_L (due to $K_L \to \pi^+\pi^-$)

Direct Emission



M1

CP conserving
Dominant term



E1

CP violating
(not yet observed)

The CP-violation parameter, $\eta_{+-\gamma}$ is defined as

$$\eta_{+-\gamma} = \frac{A(K_L \to \pi^+\pi^-\gamma, \text{ CP violating})}{A(K_S \to \pi^+\pi^-\gamma)}$$

$$\simeq \frac{A(K_L \to \pi^+\pi^-\gamma, \text{ IB; DE } E1)}{A(K_S \to \pi^+\pi^-\gamma, \text{ IB})}$$

A Direct Emission E1 transition of the K_L would cause the value of $\eta_{+-\gamma}$ to deviate from that of η_{+-}. John Shields and Sasha Golossanov are looking for this E1 transition, in $K_L \to \pi^+\pi^-\gamma$ and $K_L \to \pi^+\pi^-e^+e^-$, respectively.

The magnitude and phase of $\eta_{+-\gamma}$ can be extracted from decays in the regenerator beam by fitting the decay distribution

$$\frac{\partial N}{\partial \tau} \propto \mathcal{F}(p)\, T_{reg}(p) \Big[|\rho(p)|^2 e^{-\tau/\tau_S} + (1+r)|\eta_{+-\gamma}|^2 e^{-\tau/\tau_L} + 2|\rho||\eta_{+-\gamma}| \cos(\Delta m \tau + \Phi_\rho - \Phi_\eta)\, e^{-\tau\left(\frac{1}{\tau_S}+\frac{1}{\tau_L}\right)} \Big]$$

to the data.

Here

T_{reg} = regenerator transmission coefficient

$|\rho|, \Phi_\rho$ = magnitude and phase of regenerator amplitude.

$\mathcal{F}(p)$ = Kaon flux on regenerator.

r = ratio of DE to IB K^0_L decay rates.

T_{reg}, $\mathcal{F}(p)$, $|\rho|$ and Φ_ρ have been determined for the 97 data. Will they have the same values in 99 ??

So, in order to do the fit, we must measure:

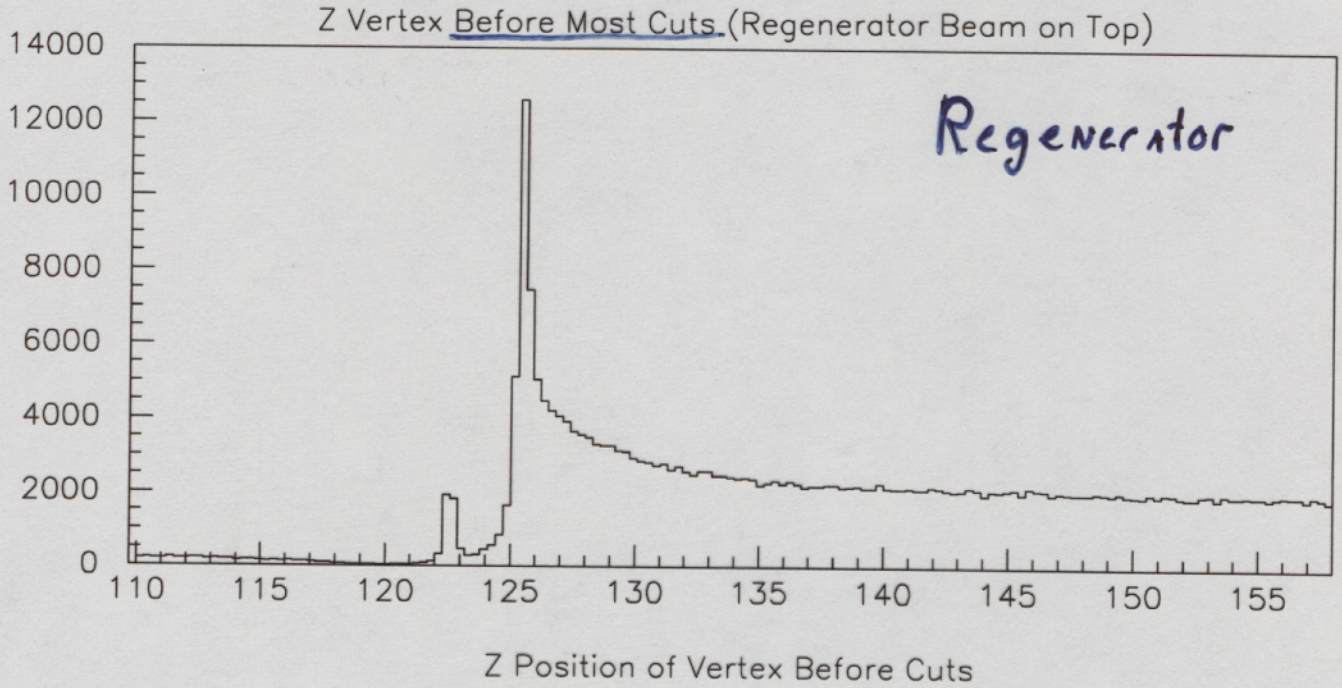
- Kaon Momentum
- Z position of vertex with respect to the regenerator.

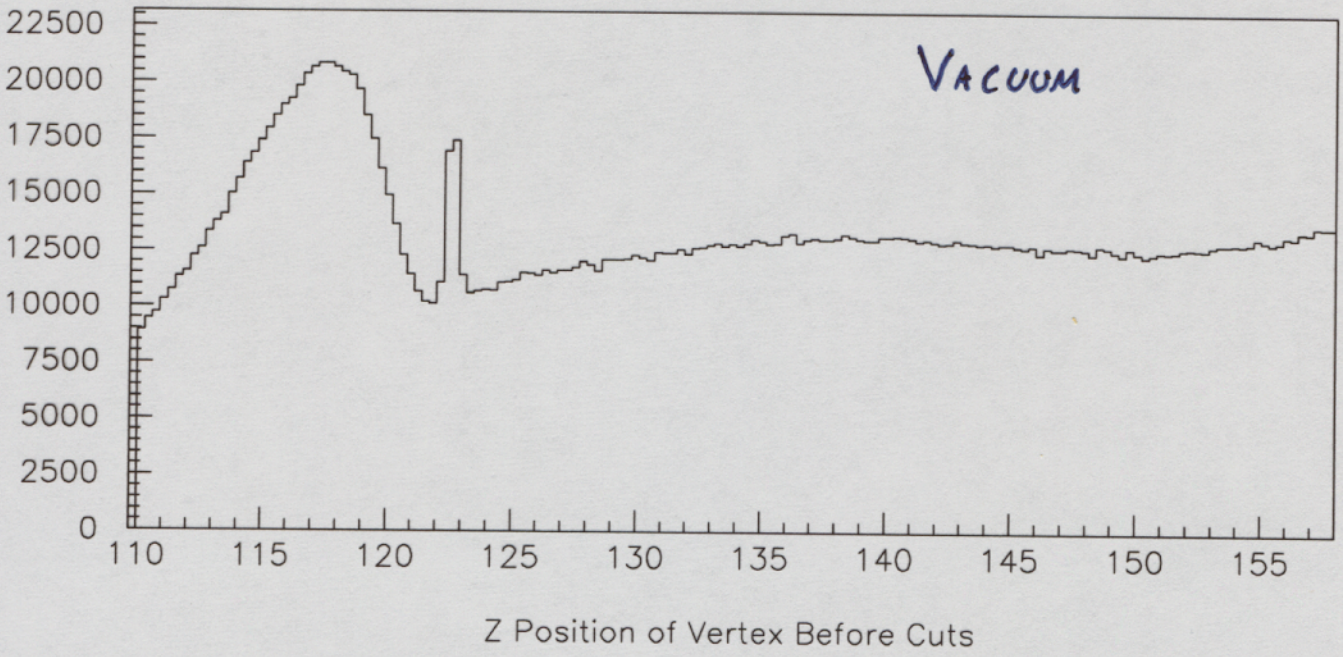
What I've been doing:

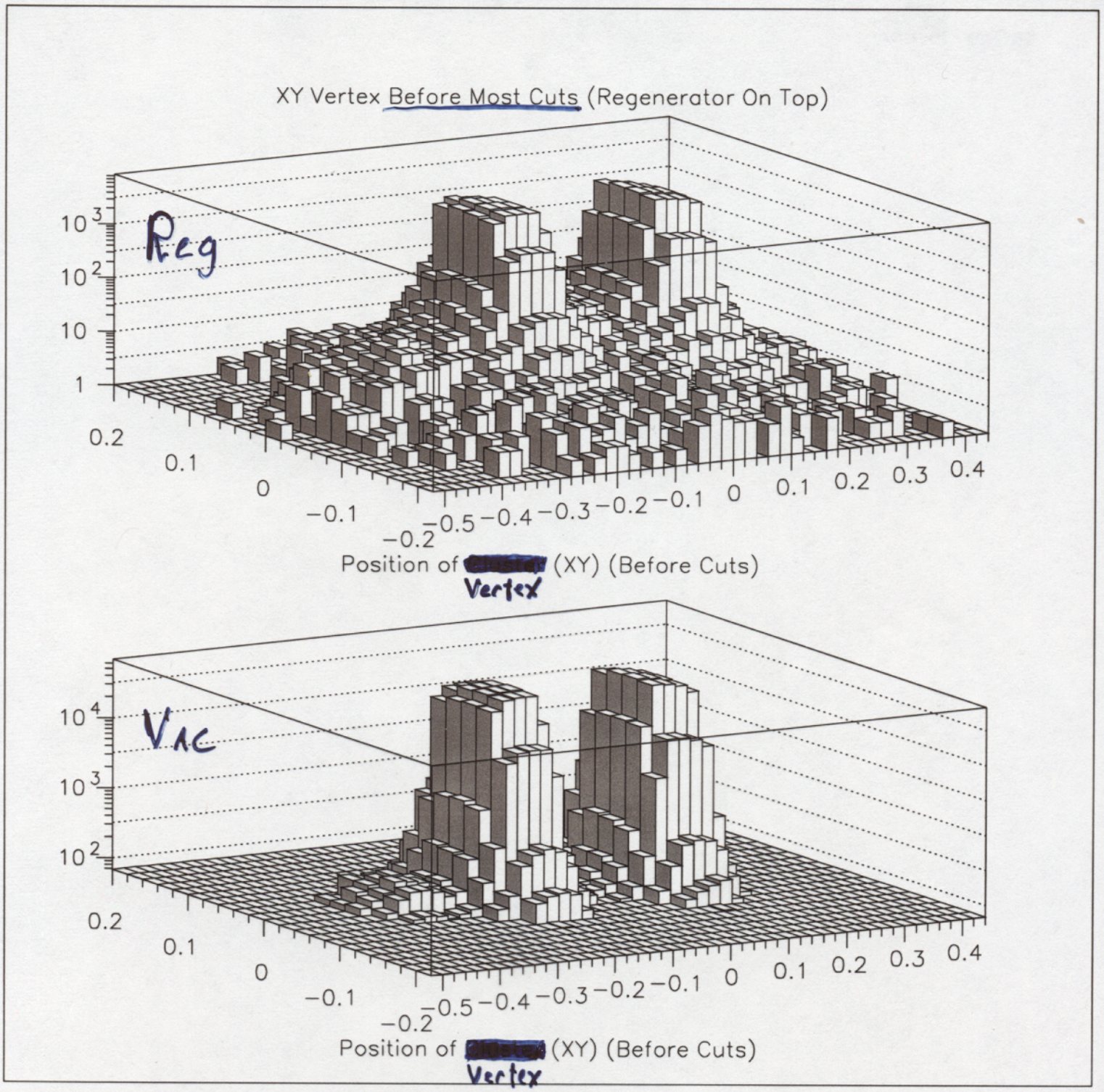
- Acquainting myself with KtevAna and KtevMC.

- Pulling data from tape. We have ~ 2 tapes of 99 data on disk. This accounts for ~ 7% of the 99 data. We have the tapes for both 97 and 99 data.

- Using a modified version of John Shield's code to apply some preliminary cuts to these data. This produced the plots I'll show today. The sample will allow a rough estimate for the amount of $K \to \pi^+\pi^-\gamma$ events in the full (97+99) dataset.


Z Vertex Before Most Cuts (Regenerator Beam on Top)
Regenerator
14000
12000
10000
8000
6000
4000
2000
0
110
115
120
125
130
135
140
145
150
155
Z Position of Vertex Before Cuts


VACUUM
22500
20000
17500
15000
12500
10000
7500
5000
2500
0
110
115
120
125
130
135
140
145
150
155
Z Position of Vertex Before Cuts


XY Vertex Before Most Cuts (Regenerator On Top)
Reg
10^3
10^2
10
1
0.2
0.1
0
−0.1
−0.2
−0.5 −0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4
Position of [redacted] (XY) (Before Cuts)
Vertex
Vac
10^4
10^3
10^2
0.2
0.1
0
−0.1
−0.2
−0.5 −0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4
Position of [redacted] (XY) (Before Cuts)
Vertex

Cuts applied to sample

- At least 2 X tracks in DC
- At least 2 Y tracks in DC
- only 2 reconstructed tracks
- track momentum > 8.0 GeV/c
- track $E/p < .85$
- $P^2_{\pi^0} < -.025\ (GeV/c)^2$
- Reconstructed $\pi^+\pi^-$ mass < .495 GeV/c^2
- Reconstructed $p\pi$ (Λ) mass > 1.12 GeV/c^2 or mass < 1.11 GeV/c^2
- # Clusters in CSI between 2 and 19.
- VTXZ between 126m and 158m.
- Reconstructed $\pi^+\pi^-$ mass not between .490 GeV/c^2 and .504 GeV/c^2 when p_T^2 2body < .004 $(GeV/c)^2$
- no two clusters reconstruct a π^0.
- Fusion $\chi^2 < 100$
- Reconstructed Kaon: momentum between 40 GeV/c and 160.0 GeV/c
  : $p_t^2 < .0005$ GeV/c^2
  : has momentum that points to either beam hole.
- Vertex $\chi^2 < 100$
- π seperation at CSI > .03m in X and Y
- $\pi - \gamma$ seperation at CSI > .2m
- E_γ in lab > 1.5 GeV
- Final Kaon Mass Cut: between .492 GeV/c^2 and .502 GeV/c^2

The subroutine RECON-832 was used for vertex reconstruction.

After all cuts with ~7% of the 99 data,

~15000 vacuum events

~11000 regenerator events

remain.

With the full (97+99) data set, we should see

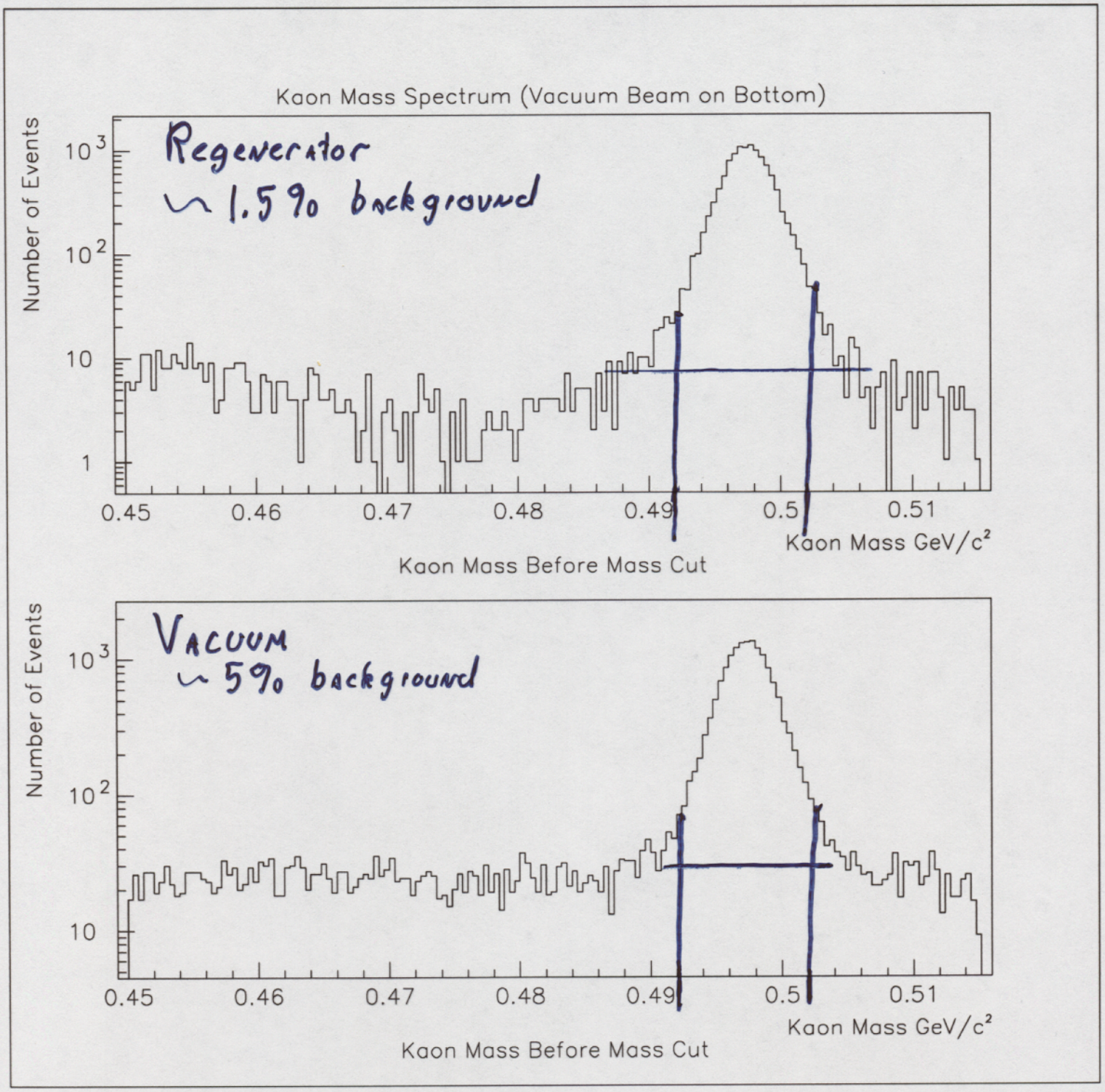
~440,000 vacuum events

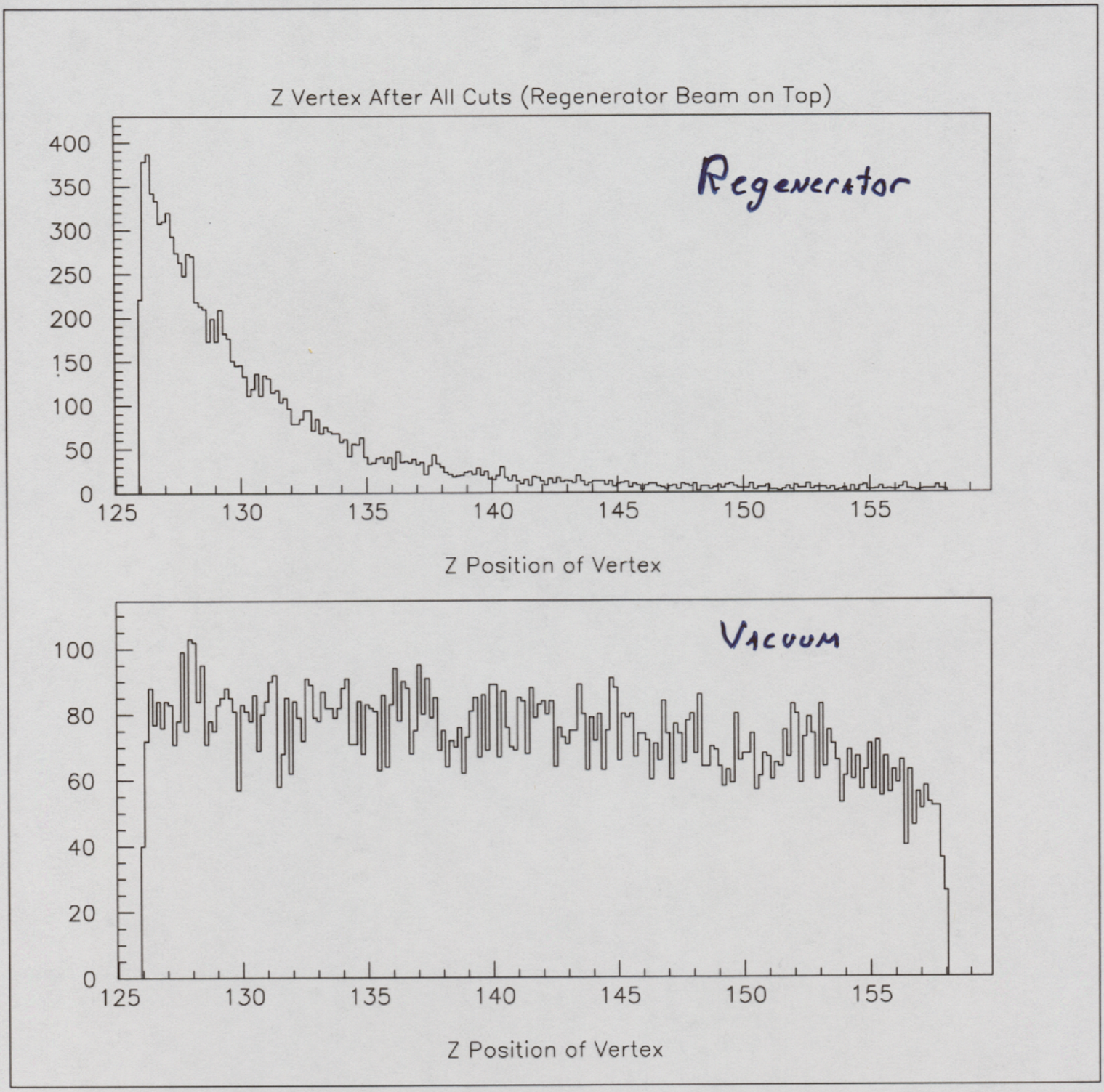
~329,000 regenerator events.

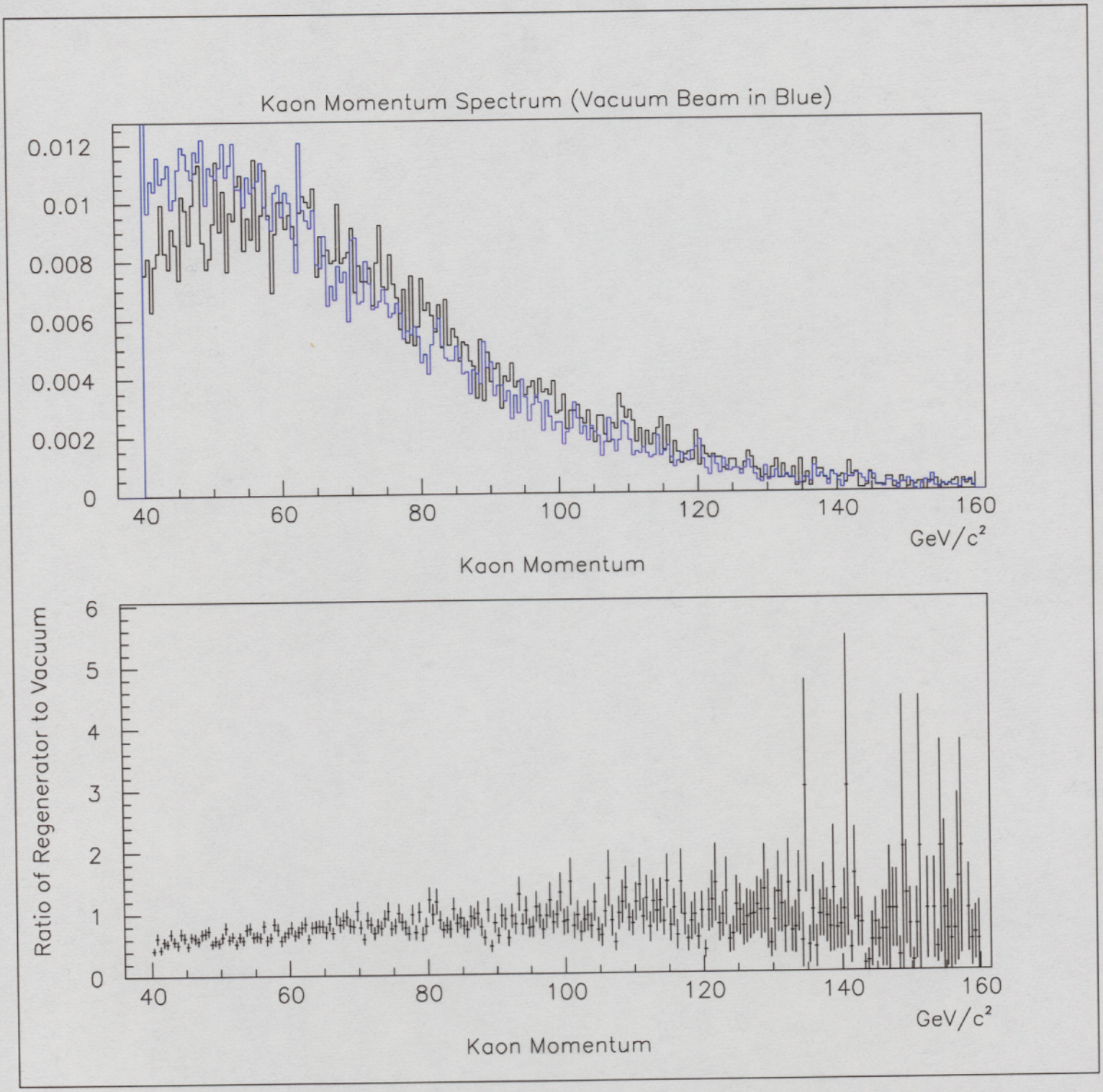
In comparison,

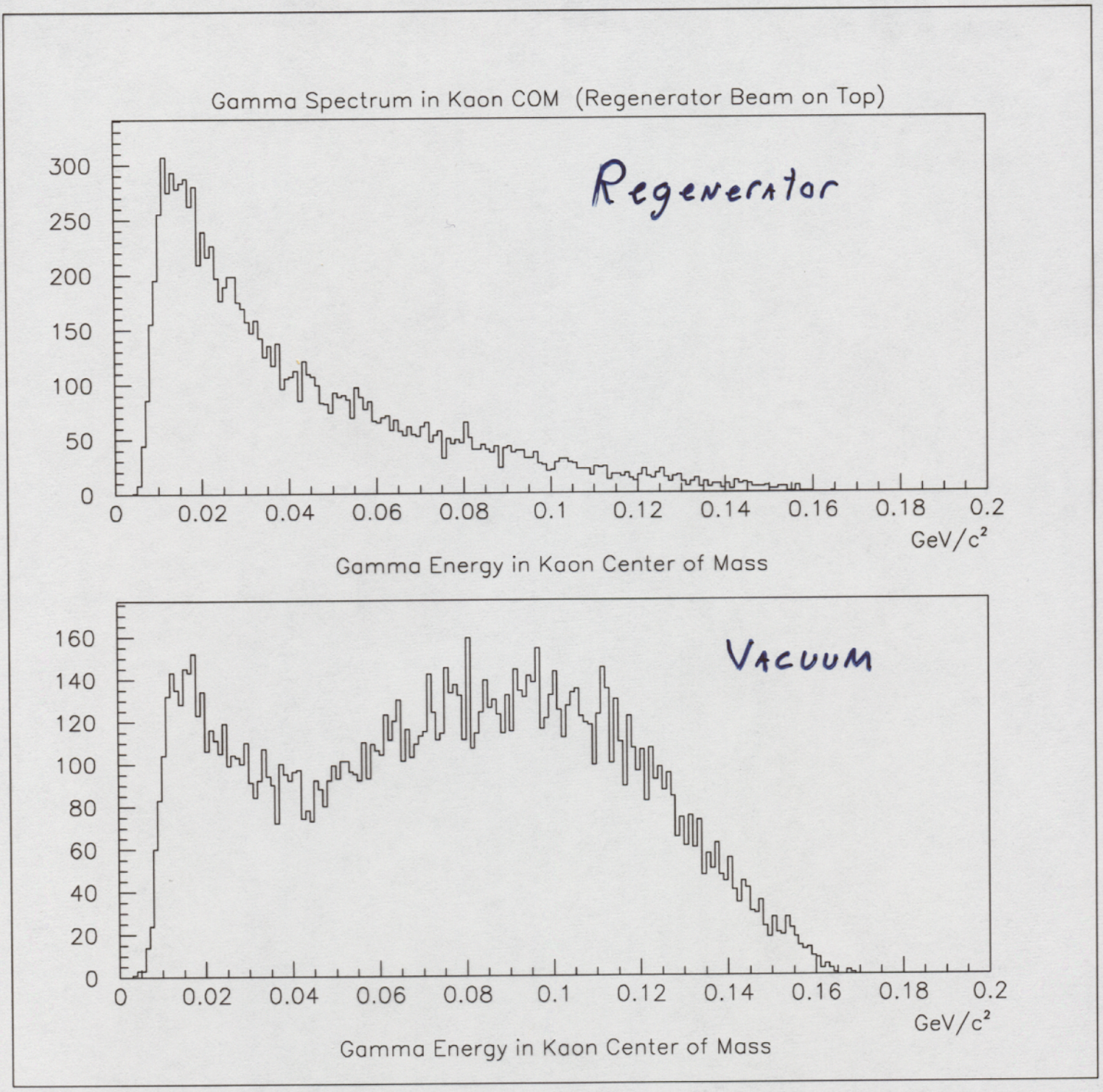
E731 yielded 3841 $K \to \pi^+\pi^-\gamma$ events for $\eta_{+-\gamma}$

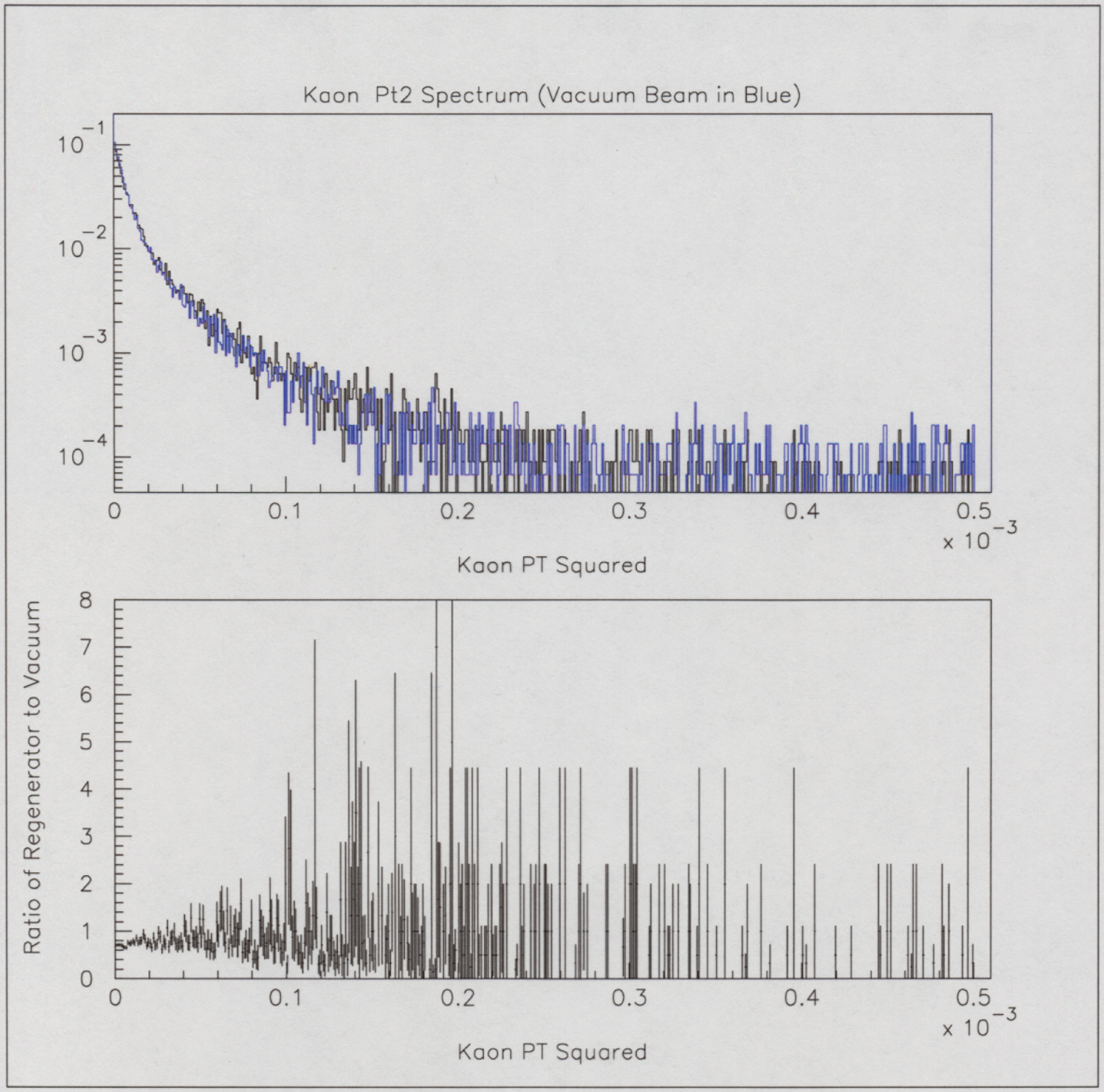
E773 yielded 8836 $K \to \pi^+\pi^-\gamma$ events for $\eta_{+-\gamma}$


Kaon Mass Spectrum (Vacuum Beam on Bottom)
Regenerator
~ 1.5% background
Number of Events
10^3
10^2
10
1
0.45
0.46
0.47
0.48
0.49
0.5
0.51
Kaon Mass GeV/c²
Kaon Mass Before Mass Cut
VACUUM
~ 5% background
Number of Events
10^3
10^2
10
0.45
0.46
0.47
0.48
0.49
0.5
0.51
Kaon Mass GeV/c²
Kaon Mass Before Mass Cut


Z Vertex After All Cuts (Regenerator Beam on Top)
Regenerator
400
350
300
250
200
150
100
50
0
125
130
135
140
145
150
155
Z Position of Vertex
Vacuum
100
80
60
40
20
0
125
130
135
140
145
150
155
Z Position of Vertex


Kaon Momentum Spectrum (Vacuum Beam in Blue)
0.012
0.01
0.008
0.006
0.004
0.002
0
40
60
80
100
120
140
160
GeV/c²
Kaon Momentum
Ratio of Regenerator to Vacuum
6
5
4
3
2
1
0
40
60
80
100
120
140
160
GeV/c²
Kaon Momentum


Gamma Spectrum in Kaon COM (Regenerator Beam on Top)
Regenerator
300
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
GeV/c²
Gamma Energy in Kaon Center of Mass
VACUUM
160
140
120
100
80
60
40
20
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
GeV/c²
Gamma Energy in Kaon Center of Mass


Kaon Pt2 Spectrum (Vacuum Beam in Blue)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
0.1
0.2
0.3
0.4
0.5
x 10^{-3}
Kaon PT Squared
Ratio of Regenerator to Vacuum
8
7
6
5
4
3
2
1
0
0
0.1
0.2
0.3
0.4
0.5
x 10^{-3}
Kaon PT Squared

Things To Do

(not at all comprehensive)

- Pull some 97 data to disk
- Compare 97 and 99 data sets
- work on Monte Carlo
- Background Studies
- Data/MC studies
- write least liklihood fitter
- extract n_{t-g} !

Conclusion

- The extraction of $\eta_{+-\gamma}$ using 97+99 data has begun.
- I have plenty of: data (but might be limited by systematics)
  work to do
  things to learn!