First Measurement of $\Xi^0 \to \Sigma^+ e^- \overline{\nu}$ Form Factors

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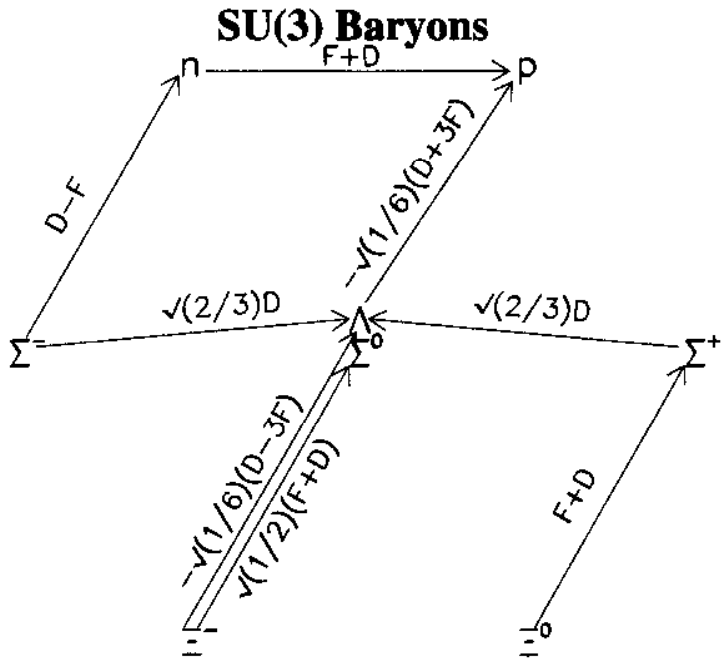
Hyperon 99
27 Sept 1999

For the decay $\Xi^0 \to \Sigma^+ e^- \bar{\nu}$ we have

$$\begin{aligned} \mathcal{M} &= G_F V_{us} \frac{\sqrt{2}}{2} \bar{u}(\Sigma^+)(O_\alpha^V + O_\alpha^A) u(\Xi^0) \\ &\times \overline{u_e} \gamma^\alpha (1+\gamma_5) v_\nu \end{aligned}$$

where

$$\begin{aligned} O_\alpha^V &= f_1 \gamma_\alpha + \frac{f_2}{M_{\Xi^0}} \sigma_{\alpha\beta} q^\beta + \frac{f_3}{M_{\Xi^0}} q_\alpha, \\ O_\alpha^A &= (g_1 \gamma_\alpha + \frac{g_2}{M_{\Xi^0}} \sigma_{\alpha\beta} q^\beta + \frac{g_3}{M_{\Xi^0}} q_\alpha)\gamma_5, \\ q^\alpha &= (p_e + p_\nu)^\alpha = (p_{\Xi^0} - p_{\sum^+})^\alpha, \end{aligned}$$



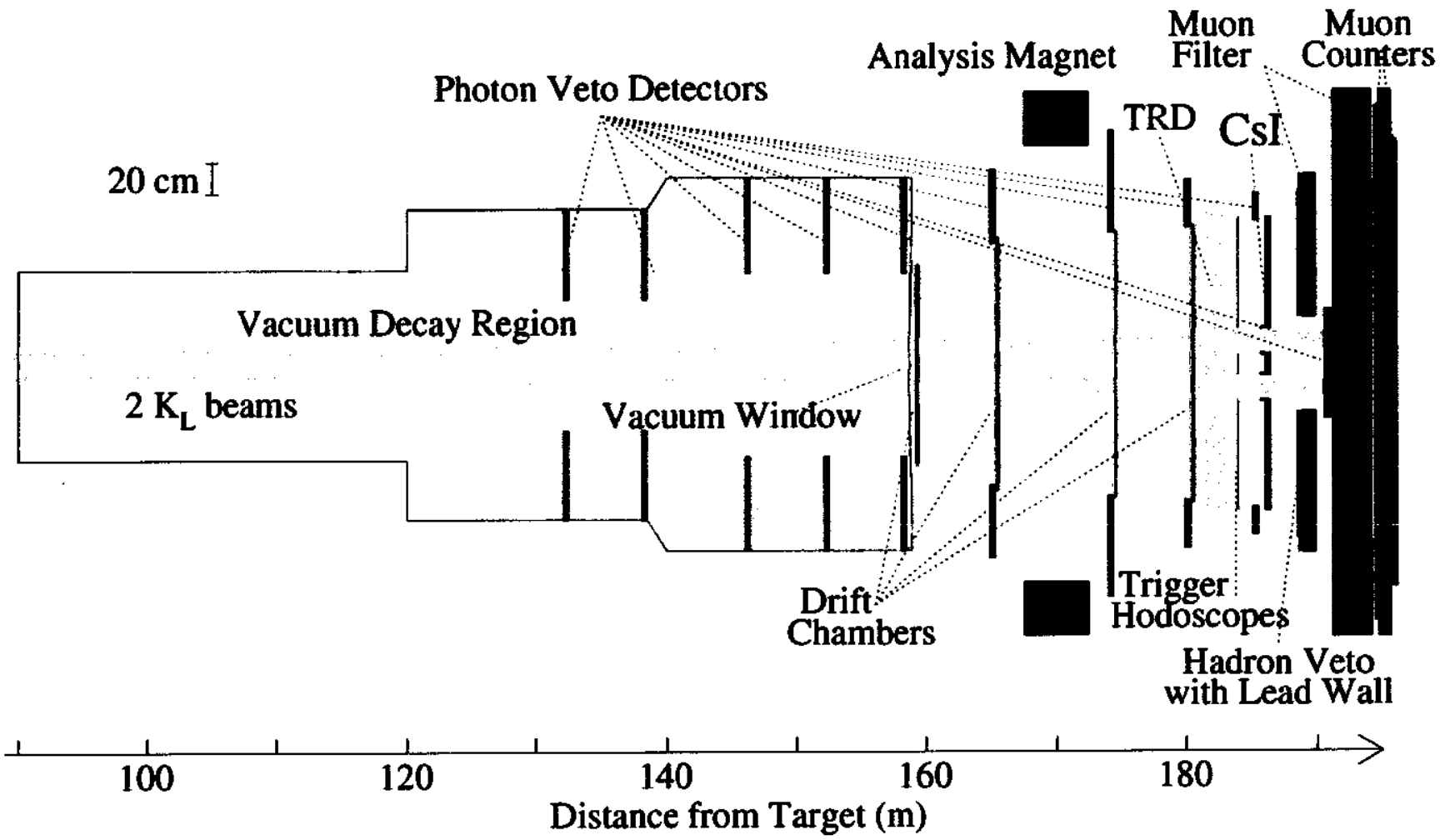
Coefficients for Hyperon Octet Beta Decays

$$f_i = C(B,b)_F * F_{f_i} + C(B,b)_D * D_{f_i}$$
$$g_i = C(B,b)_F * F_{g_i} + C(B,b)_D * D_{g_i}$$

- $\Xi^0 \rightarrow \Sigma^+ e^- \overline{\nu}$ is the same as $n \rightarrow p\, e^- \overline{\nu}$

$$
\begin{aligned}
f_1(q^2=0) &= 1.0\,(CVC) \\
g_1(q^2=0) &= 1.26\,(n \to p\,e^-\,\overline{\nu}) \qquad g_1/f_1 > 0 \text{ FOR } n \to p e \nu \\
f_2 &= 2.597\,(CVC : \frac{\mu_p - \mu_n}{2}\frac{M_\Xi}{M_p}) \\
g_2 &= 0.0\,(2nd\,class) \\
f_3 &= 0.0\,(2nd\,class - CVC) \\
g_3 &= Non - zero
\end{aligned}
$$

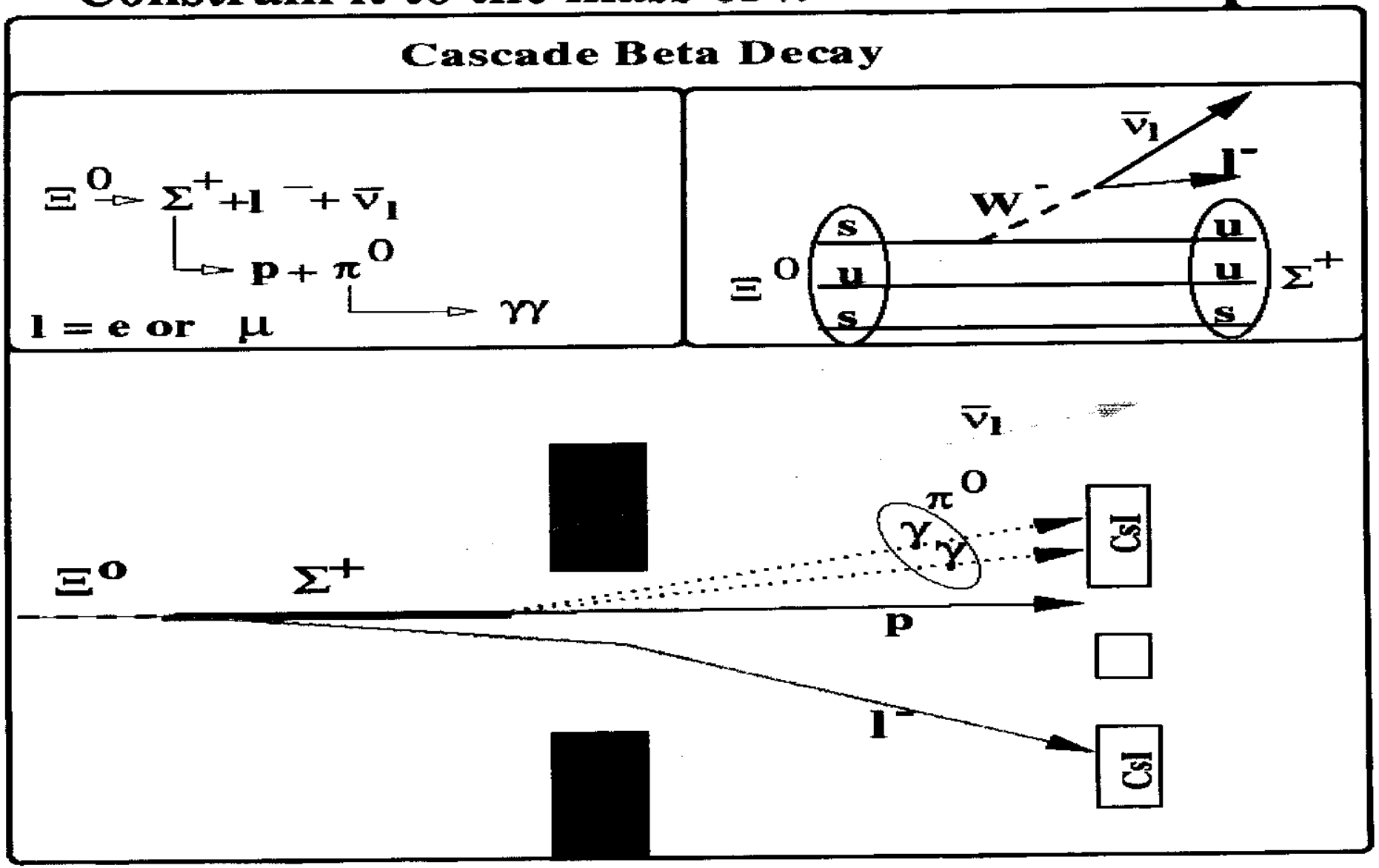
- Form factors determined experimentally from rate, Dalitz plot, and polarization of Σ^+(via $\Sigma^+ \to p\,\pi^0$)
- α_{Σ^+}= -.98 (98 % Polarization)


Muon
Filter
Muon
Counters
Analysis Magnet
Photon Veto Detectors
TRD
CsI
20 cm
Vacuum Decay Region
2 K_L beams
Vacuum Window
Drift
Chambers
Trigger
Hodoscopes
Hadron Veto
with Lead Wall
100
120
140
160
180
Distance from Target (m)

Reconstruction of $\Xi^0 \longrightarrow \Sigma^+ e^- \bar{\nu}_e$

$\rightarrow p\pi^0$

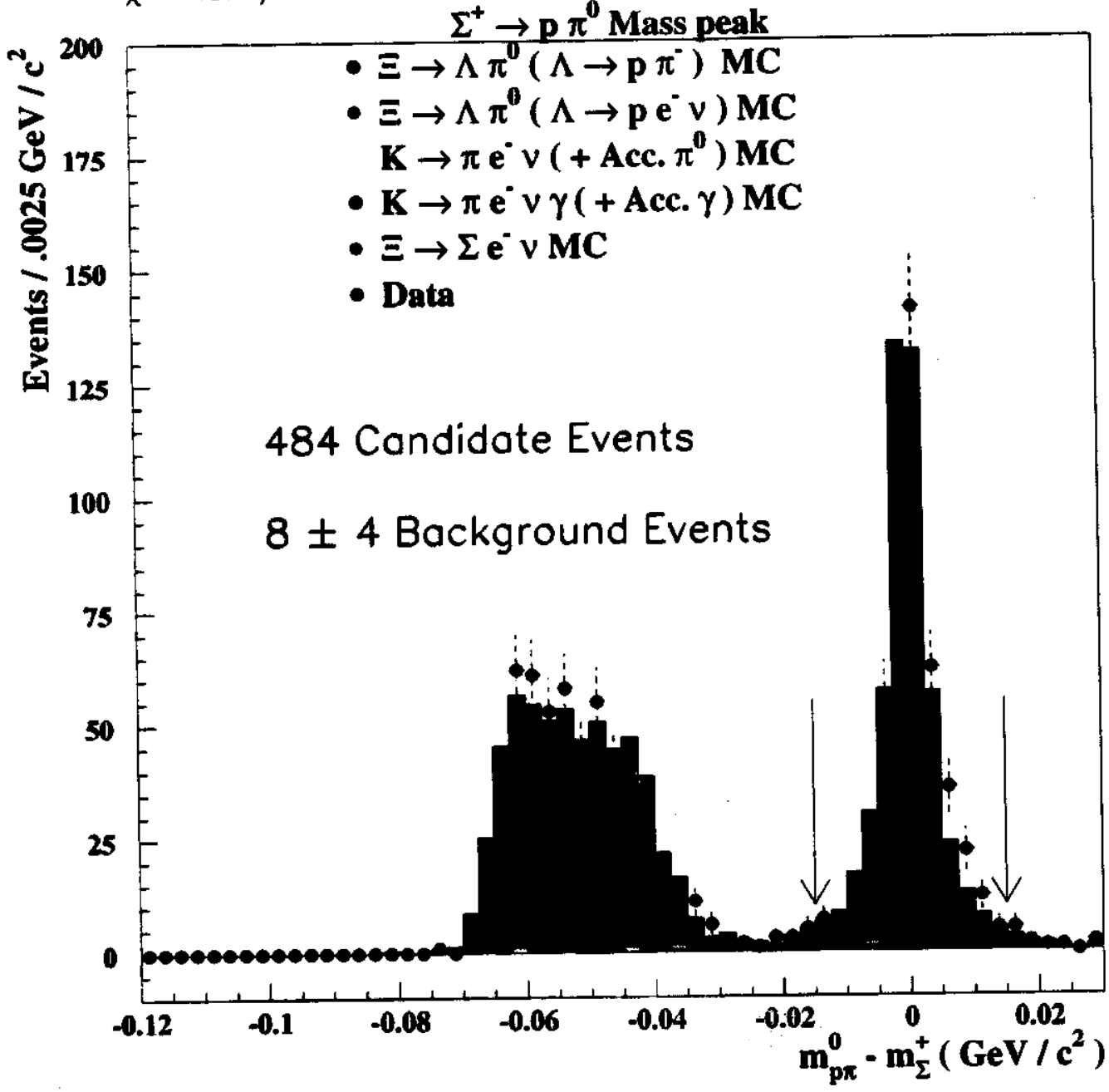
- Constrain it to the mass of π^0



$\Xi^0 \to \Sigma^+ e^- \overline{\nu}$ Event Selection (Kinematics and particle ID)

- $40.0m > z_\Sigma - z_\Xi > -6.0m$
- $1.1 > E/p_{e^-} > 0.9$
- $m_{K_L \to \pi^+\pi^-\pi^0} > 0.57GeV$ (reject $K_L \to \pi^+\pi^-\pi^0$)
- $m_{K_L \to \pi^0\pi^+e^-\overline{\nu}} > 0.50GeV\, OR\, z_\Sigma - z_\Xi > 3.0m$ (reject $K_L \to \pi^0\pi^+e^-\overline{\nu}$)
- Distance between either photon and upstream segment of electron at calorimeter $> 0.02m$ (reject $K_L \to \pi^+e^-\overline{\nu}\gamma$)
- $.010 > p^2_{\nu\|} > .0(GeV^2)$ (Longitudinal momentum of neutrino in Ξ^0 frame)
- total $p^2_T < .02GeV^2$
- Number of proper Ξ lifetimes < 10.0
- No extra hits in X views in upstream chambers (reject γ conversions in vacuum window)
- TRD cut (gives about 9:1 π/e rejection)

NO $\Xi^0 \to \Sigma^+ \pi^-$



$\Xi \to \Sigma^+ e^- \bar{\nu}$ ONLY SOURCE OF Σ^+

Determination of g_1/f_1

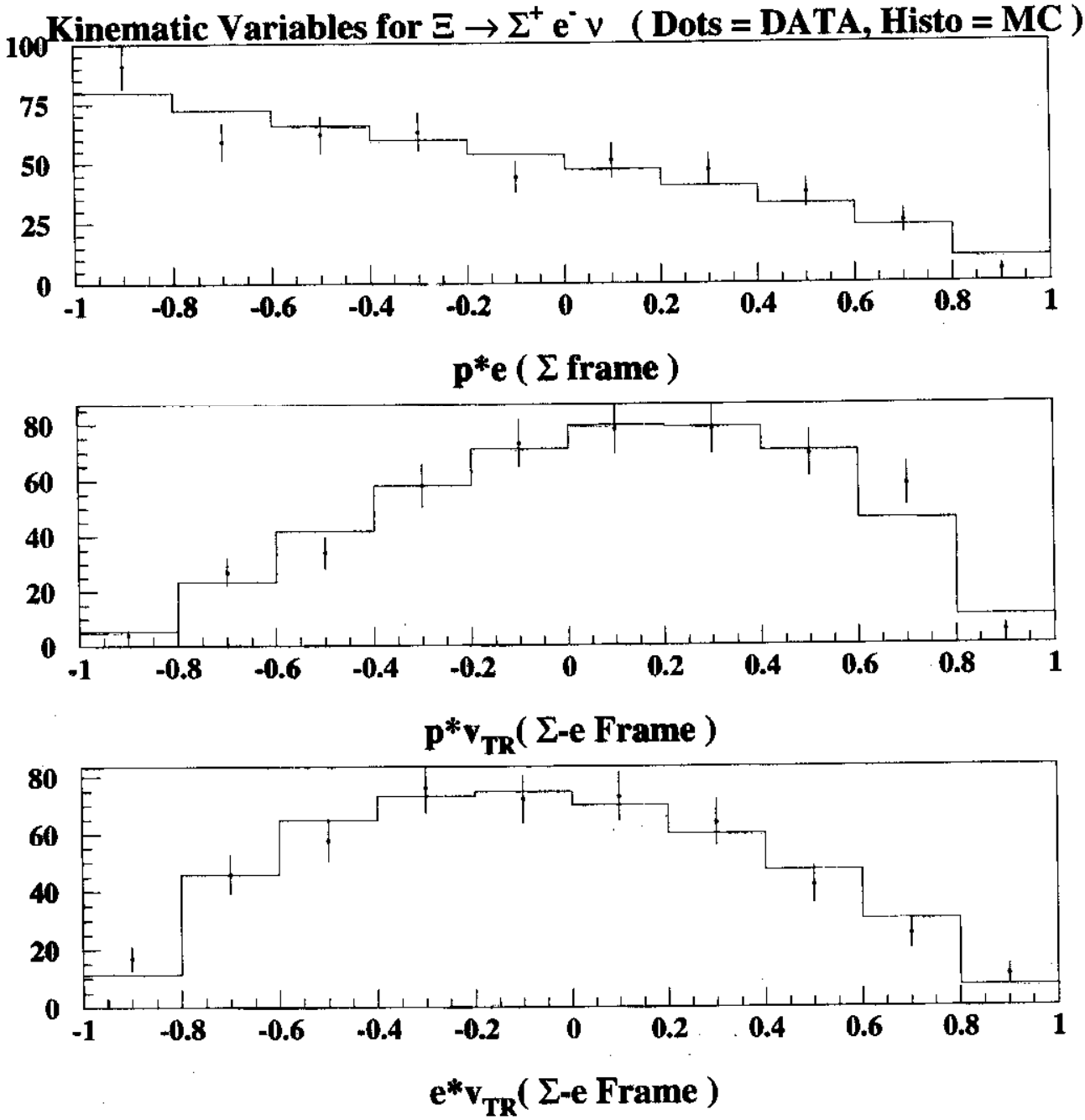
- Calculate proton-electron direction cosine (Σ^+frame)

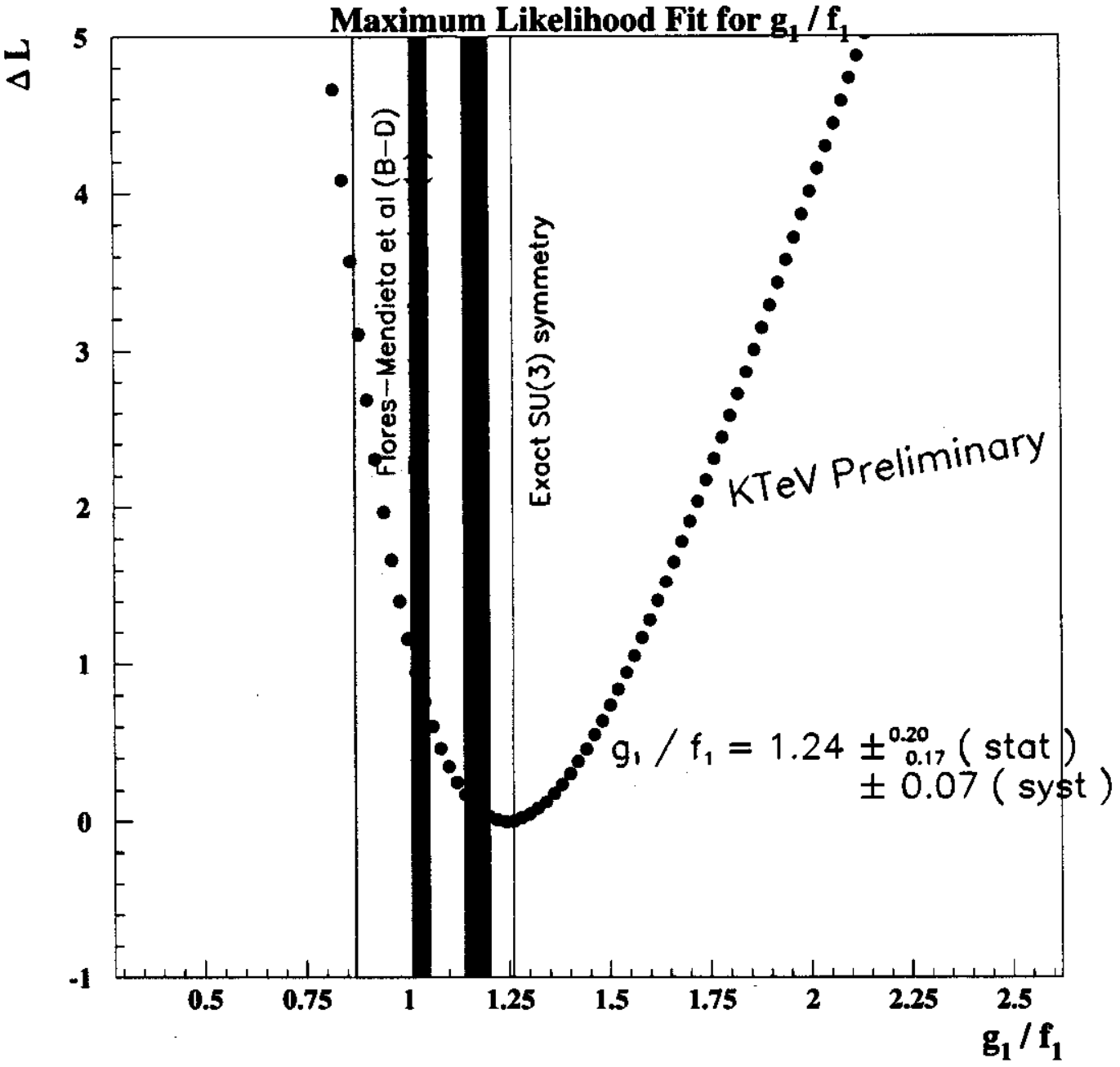
- Determine proton-neutrino, and electron-neutrino direction cosines TRANSVERSE TO PARENT PARTICLE DIRECTION ($\Sigma^+ e^-$ frame)

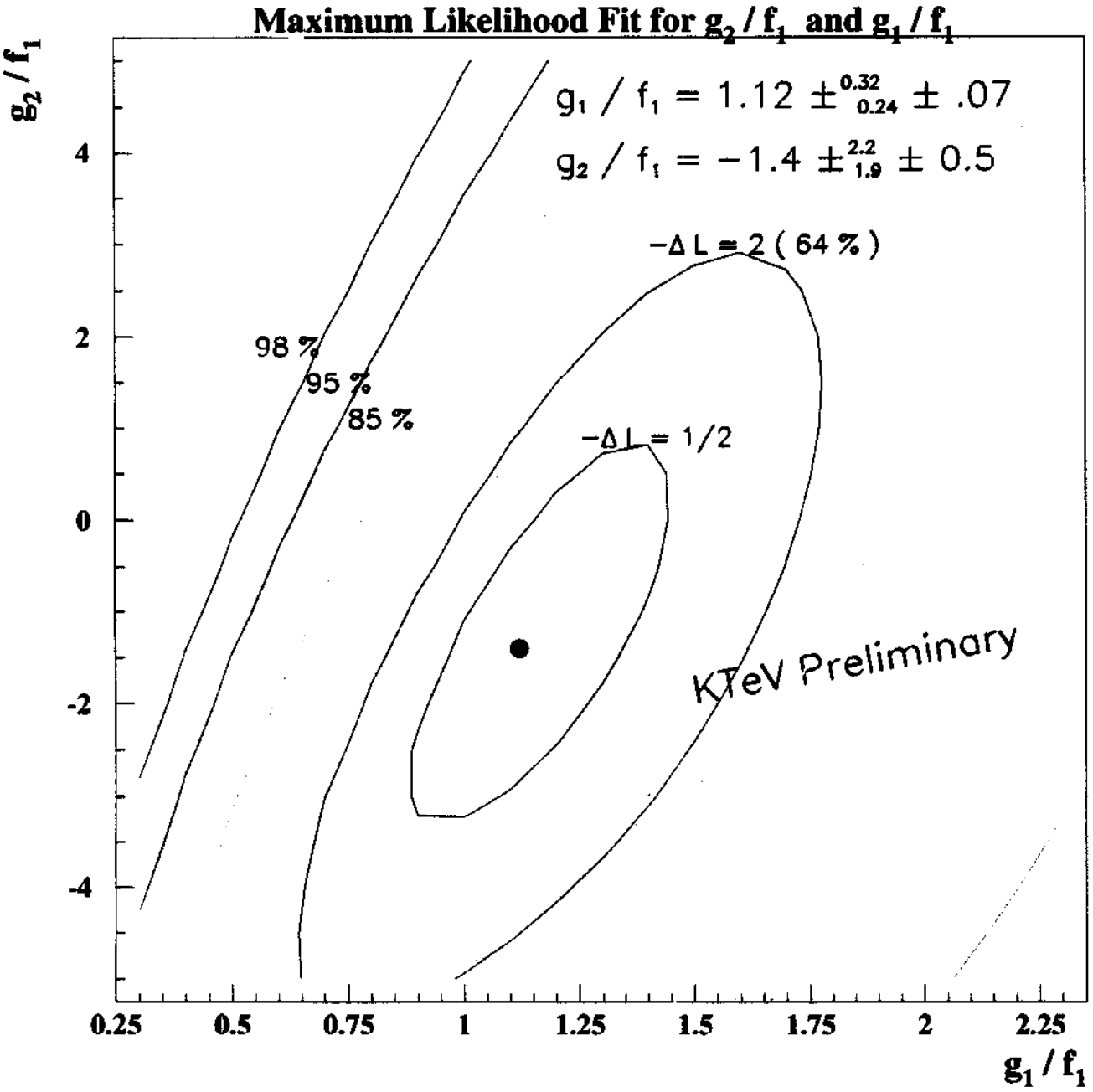
$$x_{e\nu\perp} = \frac{\vec{p}_e \cdot \vec{p}_{\nu\perp}}{E_e E_\nu}$$

$$x_{p\nu\perp} = \frac{\vec{p}_p \cdot \vec{p}_{\nu\perp}}{|\vec{p}_p| E_\nu}$$

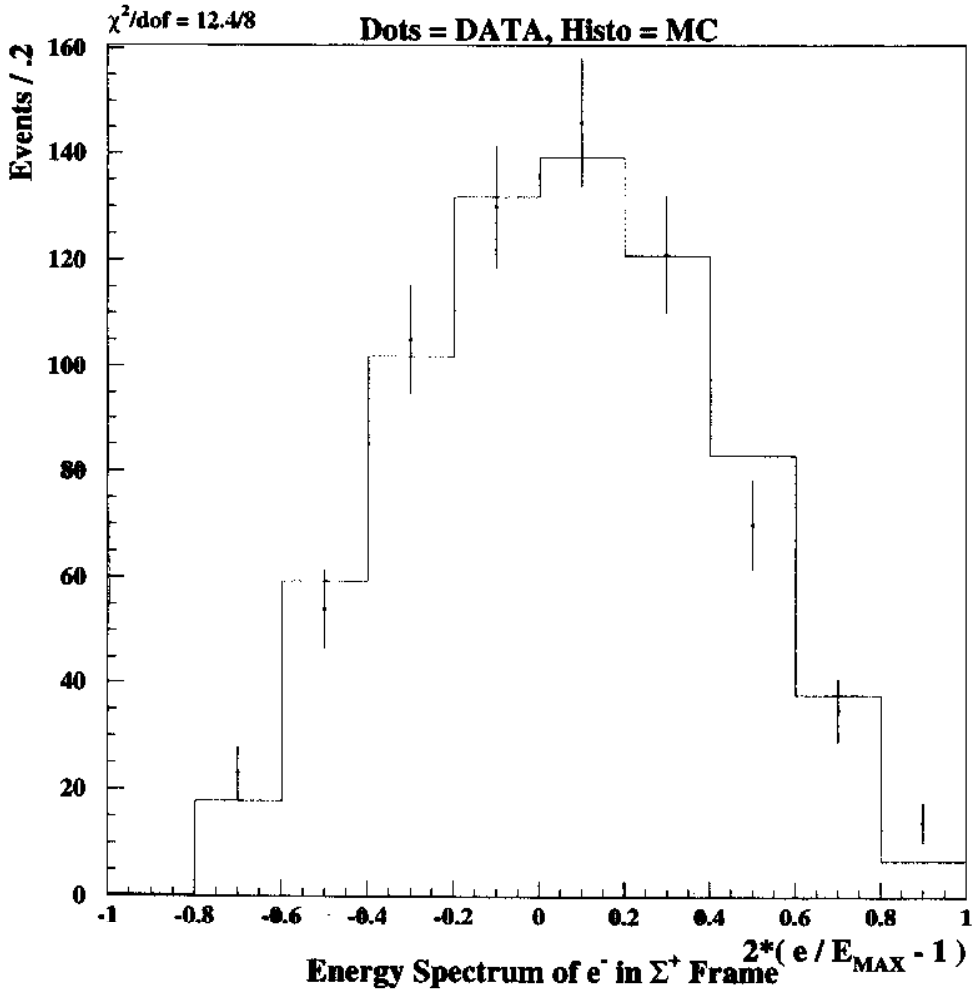
- Maximum Likelihood fit to 3 kinematic variables


Kinematic Variables for Ξ → Σ+ e- ν (Dots = DATA, Histo = MC)
p*e (Σ frame)
p*vTR(Σ-e Frame)
e*vTR(Σ-e Frame)


Maximum Likelihood Fit for g_1 / f_1
ΔL
5
4
3
2
1
0
-1
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
g_1 / f_1
Flores–Mendieta et al (B–D)
Exact SU(3) symmetry
KTeV Preliminary
$g_1 / f_1 = 1.24 \pm^{0.20}_{0.17}$ (stat)
$\pm$ 0.07 (syst)

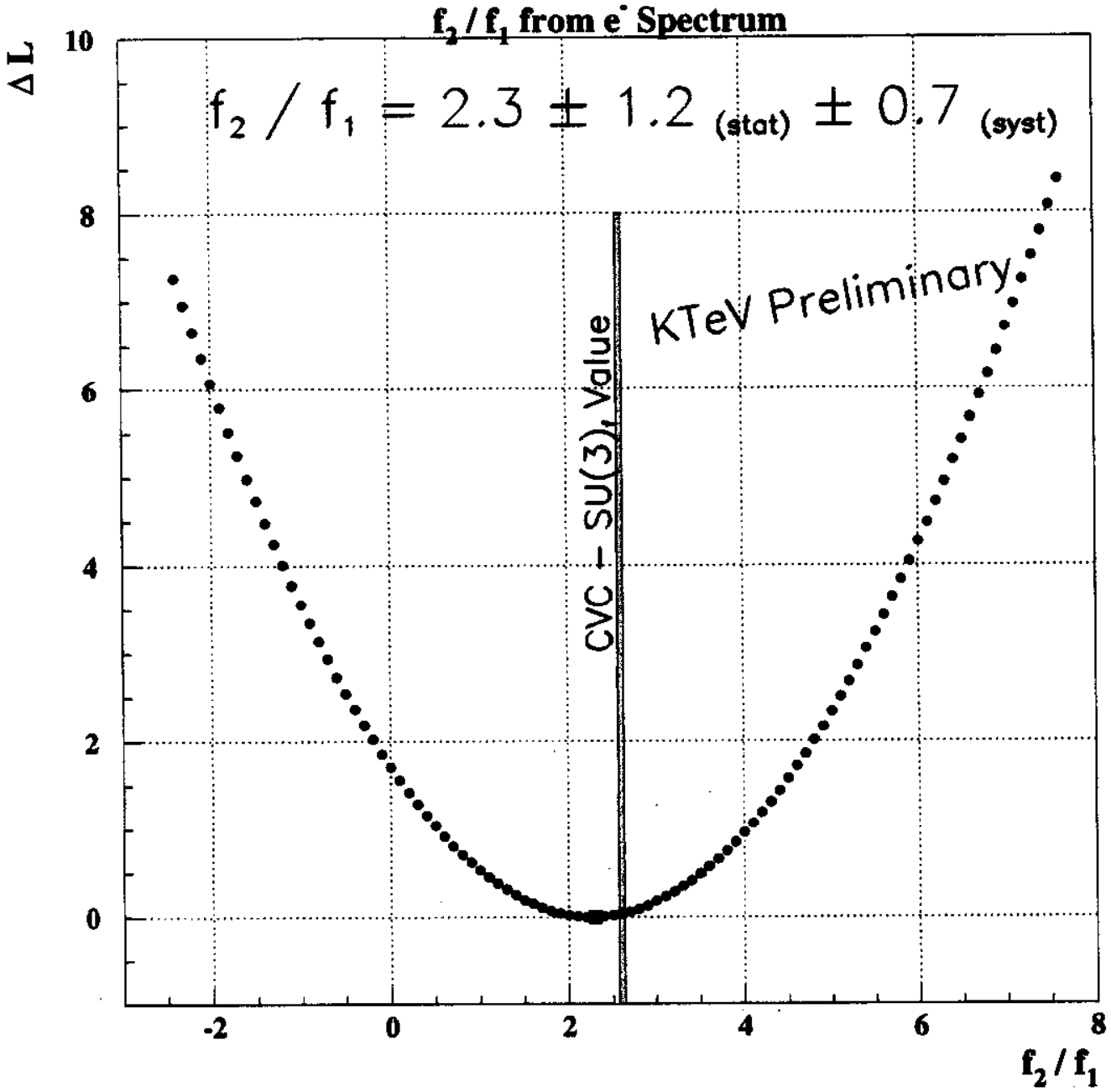

Maximum Likelihood Fit for g_2 / f_1 and g_1 / f_1
$g_1 / f_1 = 1.12 \pm^{0.32}_{0.24} \pm .07$
$g_2 / f_1 = -1.4 \pm^{2.2}_{1.9} \pm 0.5$
$-\Delta L = 2$ (64 %)
$-\Delta L = 1/2$
98 %
95 %
85 %
KTeV Preliminary
g_2 / f_1
g_1 / f_1
4
2
0
-2
-4
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25

Determination of f_2/f_1



$$\frac{dN}{de} \approx e^2(e^{MAX}-e)^2[1+\frac{e}{M_\Sigma}a]R_{em}(e)$$

$$a = \frac{(-2f_1^2-10g_1^2+4f_1g_1+8f_2g_1)}{f_1^2+3g_1^2}$$


f_2 / f_1 from e^- Spectrum
$f_2 / f_1 = 2.3 \pm 1.2_{(stat)} \pm 0.7_{(syst)}$
KTeV Preliminary
CVC + SU(3)$_f$ Value
ΔL
10
8
6
4
2
0
-2
0
2
4
6
8
f_2 / f_1

Conclusions

- Value for g_1/f_1 using Σ^+ polarization and $e-\nu$ correlation gives $1.24 \pm ^{.20}_{.17}\,(stat) \pm .07(syst)$. Consistent with exact $SU(3)_f$ symmetry (1.26)

- No evidence for non-zero g_2 ($g_2/f_1 = -1.4 \pm ^{2.2}_{1.9}\,(stat) \pm .5(syst)$).

- Weak magnetism term $f_2/f_1 = 2.3 \pm 1.2(stat) \pm 0.7(syst)$ consistent with $CVC/SU(3)_f$ value.

- Combining with rate gives $f_1 = 1.01 \pm .14$, $g_1 = 1.24 \pm .07$. The exact $CVC/SU(3)_f$ values for f_1 and g_1 are favored over those incorporating fits to $SU(3)_f$ breaking parameters.

- Expect $\approx 4\times$ dataset with ongoing run