Rare Decays of Kaons: the Fermilab Program

BNL Seminar

Past:

- $K_L \to \pi^0 e^+ e^-$, $\pi^0 \mu^+ \mu^-$
- $K_L \to \mu^+ \mu^-$

Present:

- $K_L \to \pi^0 \mu^\pm e^\mp$
- δ_L
- K_L charge radius

Future:

- More Data!
- CKM & KaMI

Leo Bellantoni

10 May 2001

$K_L \to \pi^0 e^+ e^-$ (I)

$|K_L> \cong |K_{ODD}> + \varepsilon |K_{EVEN}>$

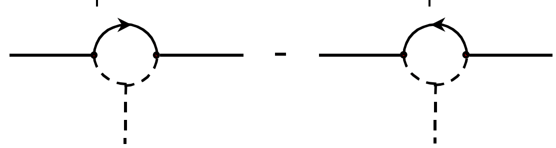
$\pi^0\gamma^* \longrightarrow \pi^0 e^+ e^-$ **Indirect CP Violation**

$$Br(K_L \to \pi^0 e^+ e^-) = |\varepsilon|^2 \frac{\tau(K_L)}{\tau(K_S)} Br(K_S \to \pi^0 e^+ e^-)$$

NA48: $Br(K_s \to \pi^0 e^+ e^-) < 1.6 \times 10^{-7}$

$\pi^0\gamma^*$, $\pi^0 Z^*$, $\pi^0 W^{+*} W^{-*}$ $\longrightarrow \pi^0 e^+ e^-$ **Direct CP Violation**

$$|K_{ODD}> \propto |K^0> - |\overline{K}^0>$$



$$V_{td}V_{ts}^* - V_{td}^*V_{ts}$$

$$\propto \Im(V_{td}V_{ts}^*) \quad \propto A^2\lambda^5\eta$$

$\pi^0\gamma^* \longrightarrow \pi^0 e^+ e^-$ **CP conserving**
Helicity suppressed

From $K_L \to \pi^0\gamma\gamma$

Background from radiative Dalitz decay of the kaon,
$K_L \to e^+ e^- \gamma\gamma$

(Greenlee 1990)

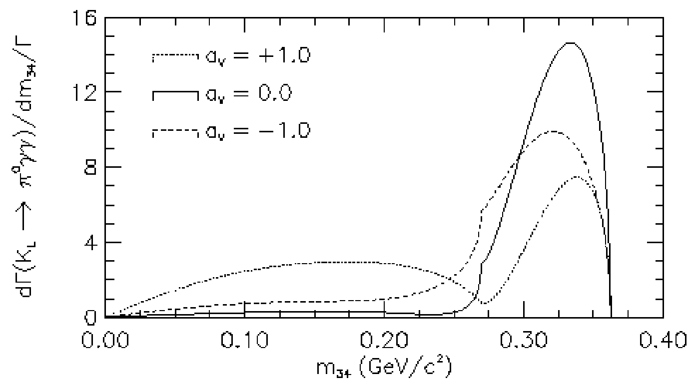
$K_L \to \pi^0 \gamma \gamma$

Calculated to $\mathcal{O}[p^6]$ cPT + a_V(VMD)

Gives CPC amplitude of $K_L \to \pi^0 e^+ e^-$

Donoghue & Gabbiani
PRD 51 (1995) 2187

D'Ambrosio & Portolés
Nucl Phys B497 (1997) 417



KTeV result:

Br = (1.68 ±0.07 ±0.08) x10^{-6} — PRL 83 (1999) 917

a_V = -0.72 ±0.08 from fit — 1997 data only

{884 events w/ 111 ±12 bkg}

NA48 preliminary result:

Br = (1.51 ±0.05$_{STAT}$ ±0.20$_{SYS}$) x10^{-6}

M. Contalbrigo, Moriond EW 2000 — {1397 events w/ ~30 bkg}

MC assumes a_V = -0.45

Late-breaking news

ISU-HET-01-8
hep-ph/0105006
April, 2001

$K_L \to \pi^0\gamma\gamma$ and the bound on the CP-conserving $K_L \to \pi^0 e^+e^-$

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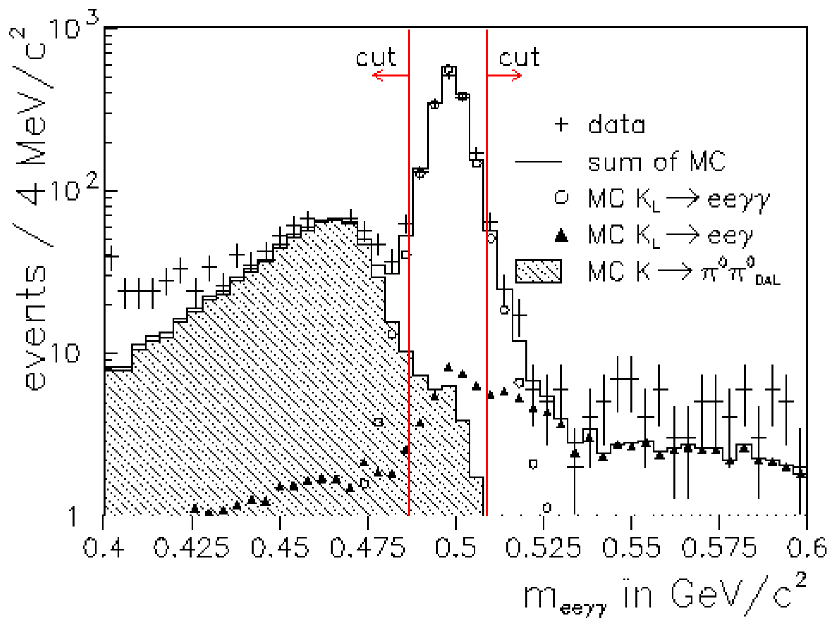
Abstract

It has been known for many years that there is a CP-conserving component for the decay mode $K_L \to \pi^0 e^+e^-$ and that its magnitude can be obtained from a measurement of the amplitudes in the $K_L \to \pi^0\gamma\gamma$ decay mode. We point out that the usual description of the latter in terms of a single parameter, a_V, is not sufficient to extract the former in a model independent manner. We further show that there exist known physics contributions to $K_L \to \pi^0\gamma\gamma$ that cannot be described in terms of the single parameter a_V. We conclude that a model independent analysis requires the experimental extraction of three parameters.

$K_L \rightarrow e^+e^- \gamma\gamma$



From 1543 events:

32.2 ±1.2 $K_L \rightarrow e^+e^-\gamma$
26.6 ±1.2 $K_L \rightarrow \pi_D^0\ \pi^0$
1484.2 ±1.7 signal

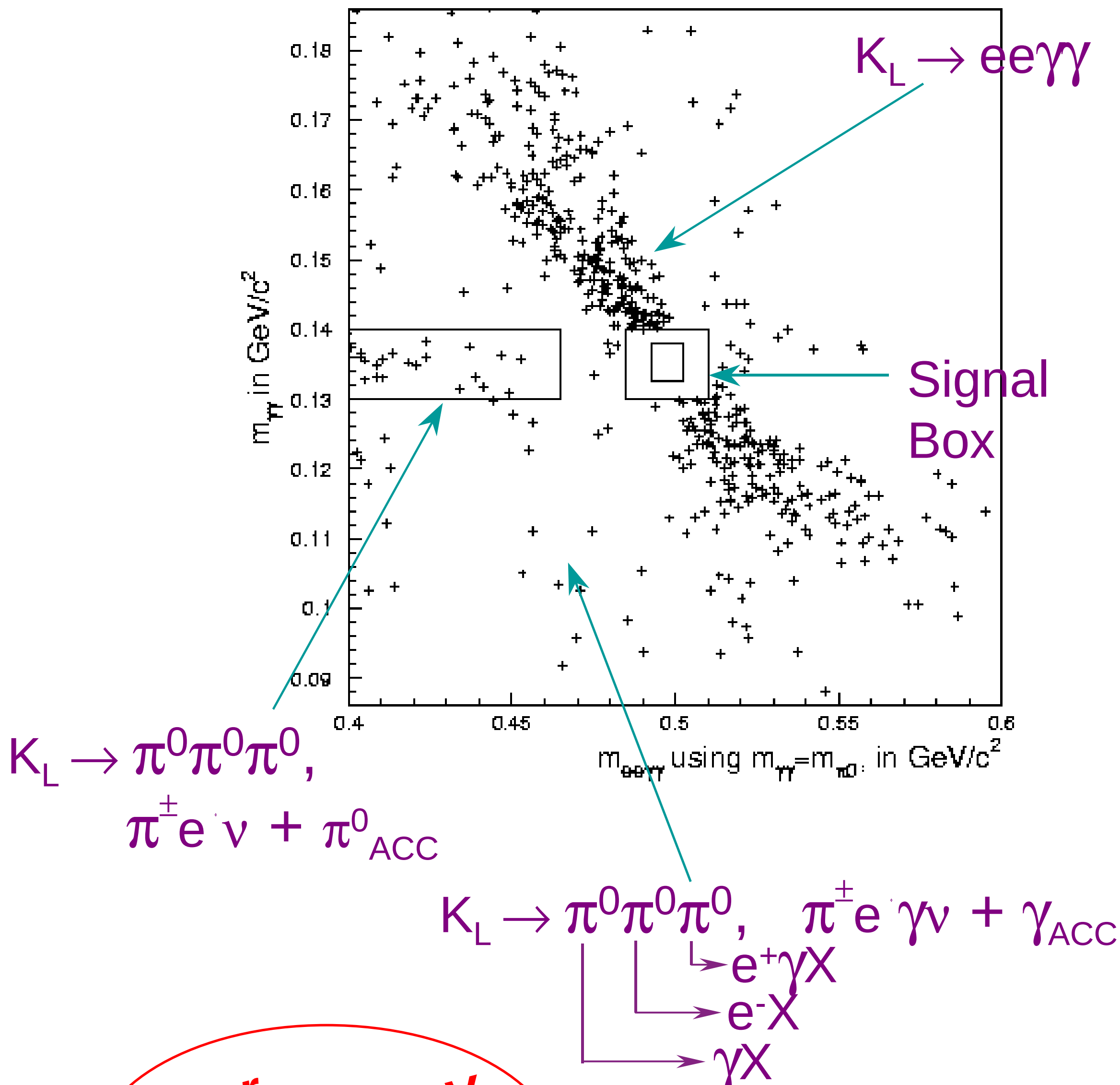
KTeV result, 1997 data:

$$Br(K_L \rightarrow e^+e^- \gamma\gamma,\ E_{\gamma*} > 5MeV) = (5.84 \pm 0.15_{STAT} \pm 0.32_{SYS}) \times 10^{-7}$$

Theory: $(5.8) \times 10^{-7}$
E799-I: $(6.5 \pm 1.3) \times 10^{-7}$
NA48: $(6.32 \pm 0.46) \times 10^{-7}$
(492 events, 25±3 bkg)

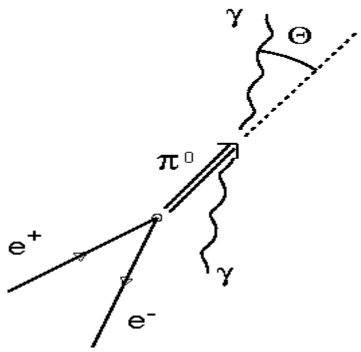
hep-ex/0010059

$K_L \to \pi^0 e^+ e^-$ (II)

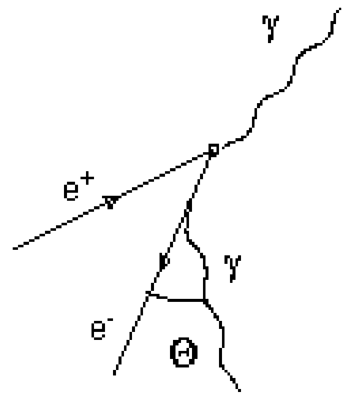


After
m_{ee} > 140MeV requirement

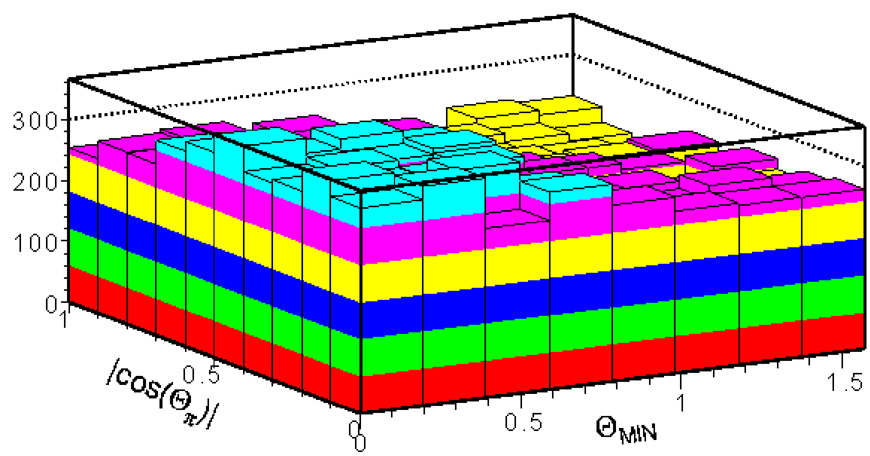
$K_L \to \pi^0 e^+ e^-$ *vs.* $K_L \to e^+ e^- \gamma\gamma$



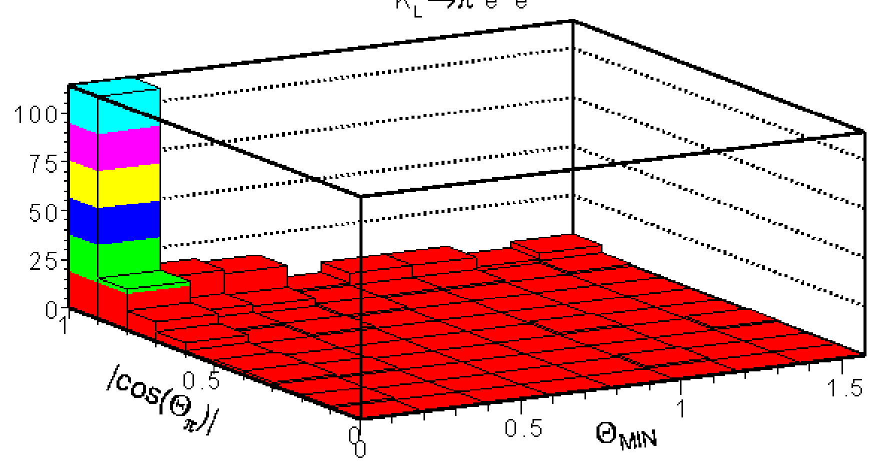
$\cos(\Theta_\pi)$



Θ_{min}



$K_L \to \pi^0 e^+ e^-$

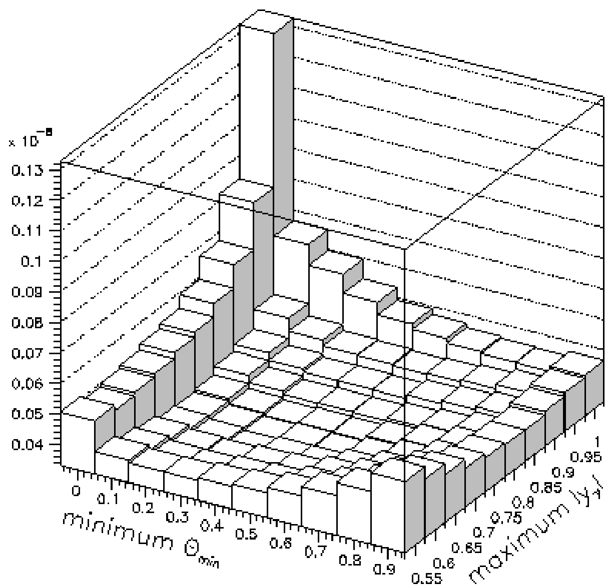


$K_L \to e^+ e^- \gamma\gamma$

$K_L \to \pi^0 e^+ e^-$ (III)

For any particular kinematic cuts,

- Estimate background from fit
- Estimate acceptance from signal MC
- Compute $\langle N_{90} \rangle$=90% C.L. on possible signal for N_{BKG}, weighted by Poisson(N_{BKG})



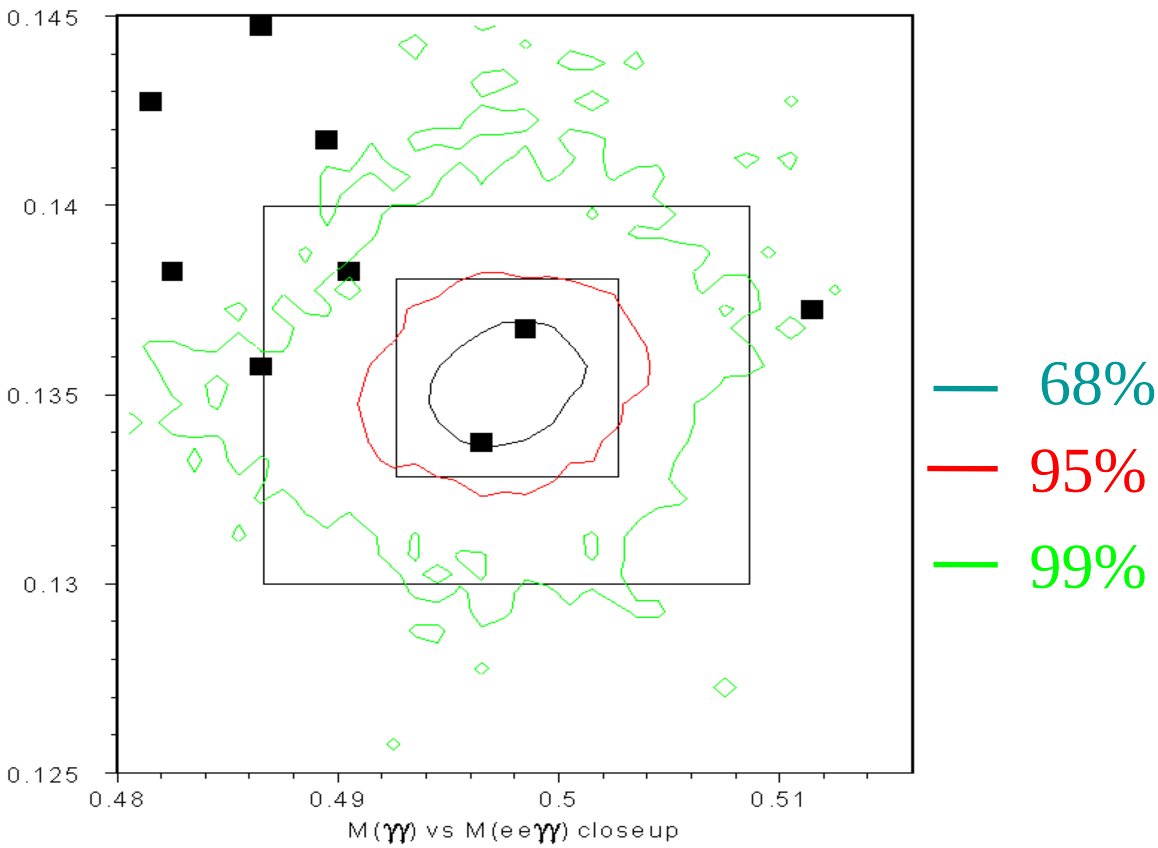
Best cut: $|\cos(\theta)|<0.788$ $\theta_{MIN}>0.349$ rad

N_{BKG} = 1.06$\pm$0.41 events 0.91$\pm$0.41 $ee\gamma\gamma$

Acceptance = 3.609$\pm$0.086%

$\langle$Br limit$\rangle$ = 3.3×10^{-10}

$K_L \to \pi^0 e^+ e^-$ (IV)



2 events in data *vs* 1.06 ±0.41 background

$Br(K_L \to \pi^0 e^+ e^-) < 5.1 \times 10^{-10}$ (90% C.L.)
KTeV 1997 data

~10x improvement over previous limit

*PRL **86**, 397 (2000)*

$K_L \rightarrow \pi^0 e^+ e^-$ (V)

Compare: $Br(K_L \rightarrow \pi^0 e^+ e^-) < 5.1 \times 10^{-10}$

From NA48's $K_S \rightarrow \pi^0 e^+ e^-$ *limit,*

$Br(K_L \rightarrow \pi^0 e^+ e^-)_{INDIRECT} < 4.8 \times 10^{-10}$

From KTeV's $K_L \rightarrow \pi^0 \gamma\gamma$,

$Br(K_L \rightarrow \pi^0 e^+ e^-)_{CPC} = (1.8 \pm 0.6_{av} \pm 0.4_{Model}) \times 10^{-12}$

Standard Model expectation:

$Br(K_L \rightarrow \pi^0 e^+ e^-)_{DIRECT} = (3.2 \pm 1.0) \times 10^{-12}$

[using hep-ph/0012308]

Conclusions:

- $\eta_{CKM} < 4.4$
- **Background limited, and** $Br \propto \eta^2$
- **Further progress will require VERY large event samples & fit of proper time, Dalitz-type variables; see D.Harris (1994), Donoghue & Gabbiani**

$K_L \to \pi^0\mu^+\mu^-$ (I)

Pros:

- No $\pi^0 \to \mu^+\mu^-\gamma$ background
  - $\Rightarrow$ ~20% more acceptance

  Less $K_L \to \mu^+\mu^-\gamma\gamma$ background
  - $\Rightarrow$ ~1/3 more acceptance
- Backgrounds ($K_L \to \pi^+\pi^-\pi^0$, $\mu^+\mu^-\gamma$) experimentally amenable
- Heavier μ mass *might* couple to new physics

Cons:

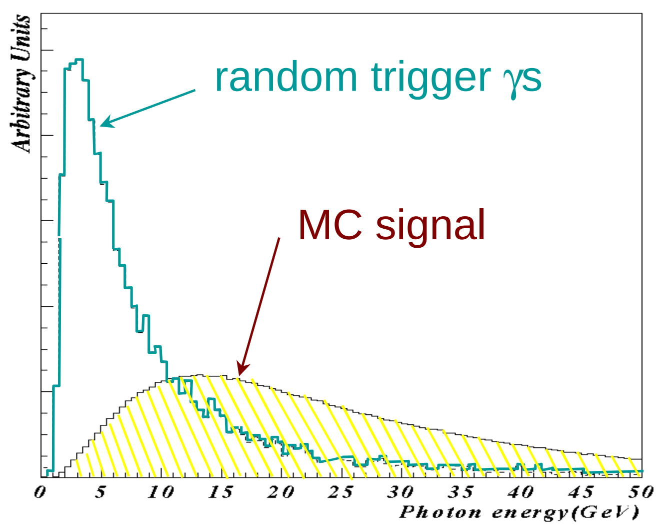
- $K_L \to \mu^+\mu^-\gamma\gamma$ background harder to suppress
- Less phase space for any short-range physics - 0.305 times e^+e^- case
- CP conserving contribution not helicity suppressed

$K_L \rightarrow \mu^+\mu^- \gamma\gamma$ (I)

Backgrounds are:

•K_L! $\mu^+\mu^-\gamma$ + coincident γ

$\Rightarrow$ Require E_γ > 10 GeV



•K_L! $\pi^+\pi^-\pi^0$ with $\pi^\pm$ MisId as $\mu^\pm$

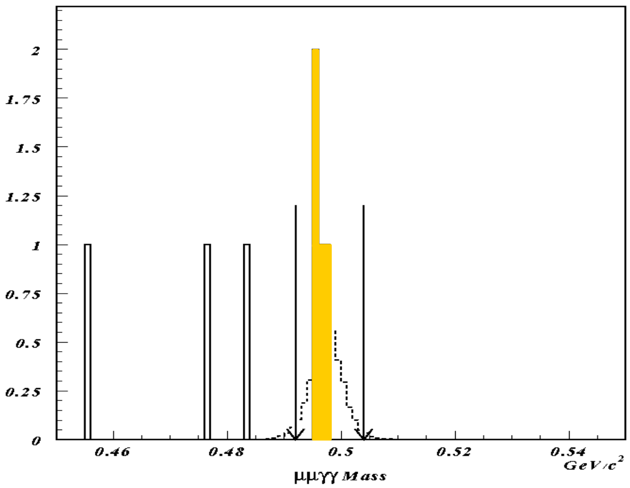
$\Rightarrow$ Kinematic requirements

•K_L! $\pi\mu\nu$ with $\pi^\pm$ MisId + coincident

$\Rightarrow$ Require E-M shape for neutrals

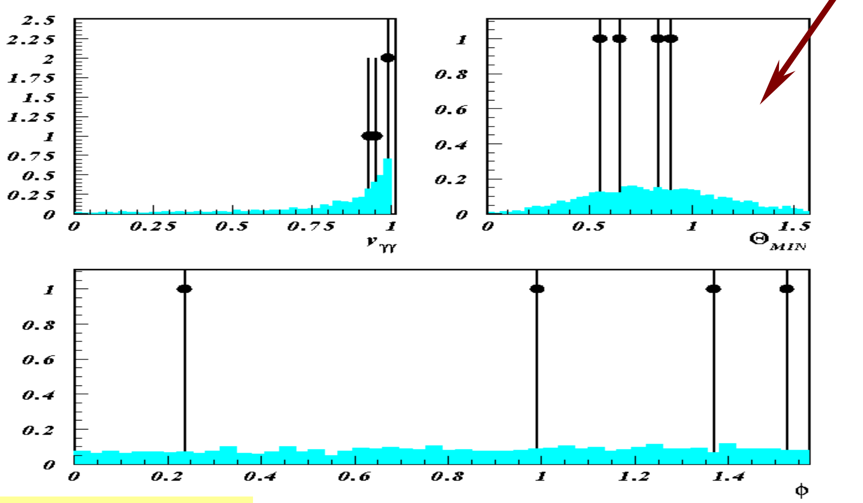
$\Rightarrow$ Require $M_{\mu\mu}$ < 340 MeV

$K_L \rightarrow \mu^+\mu^-\gamma\gamma$ (II)



4 events in data vs 0.16 $\pm$0.08 background

Kinematic distributions consistent with signal



KTeV 1997 data:

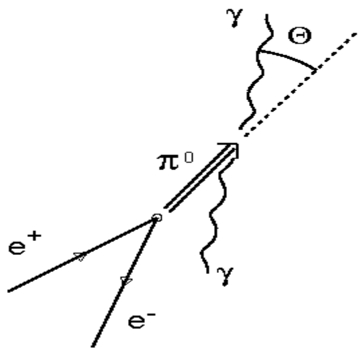
$Br(K_L! \mu^+\mu^-\gamma\gamma,\ m_{\gamma\gamma} > 1\ \text{MeV}) =$

$$(10.4^{+7.5}_{-5.9}\ _{STAT} \pm 0.7_{SYS}) \times 10^{-9}$$

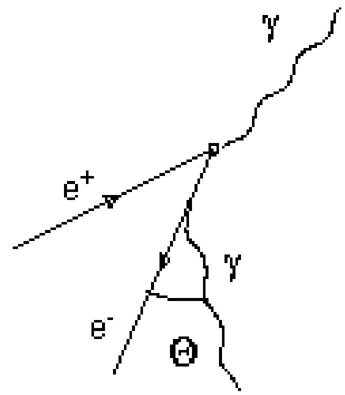
QED predicts (9.1 ±0.8) x 10^{-9}

*PRD **62**, 112001 (2000)*

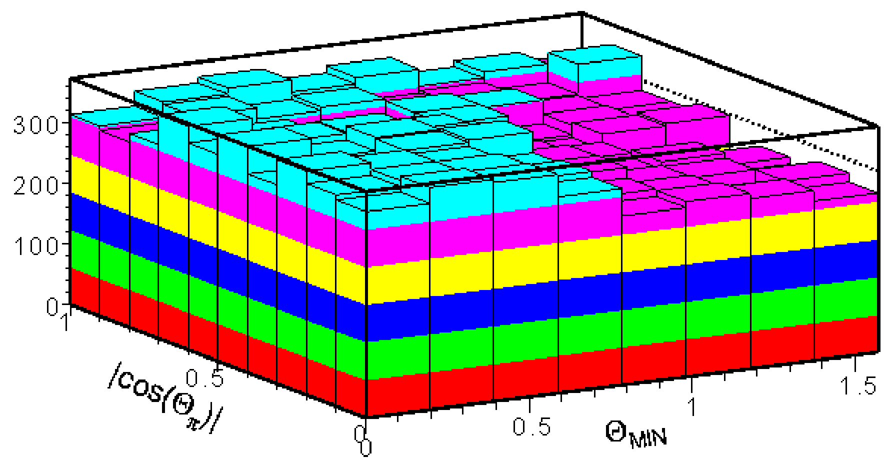
$K_L \rightarrow \pi^0 \mu^+ \mu^-$ *vs.* $K_L \rightarrow \mu^+ \mu^- \gamma\gamma$



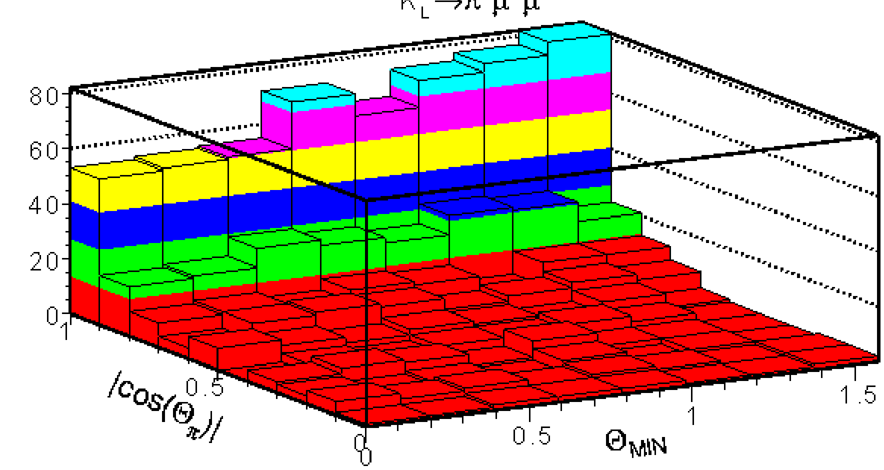
$\mathrm{Cos}(\Theta_\pi)$



Θ_{min}

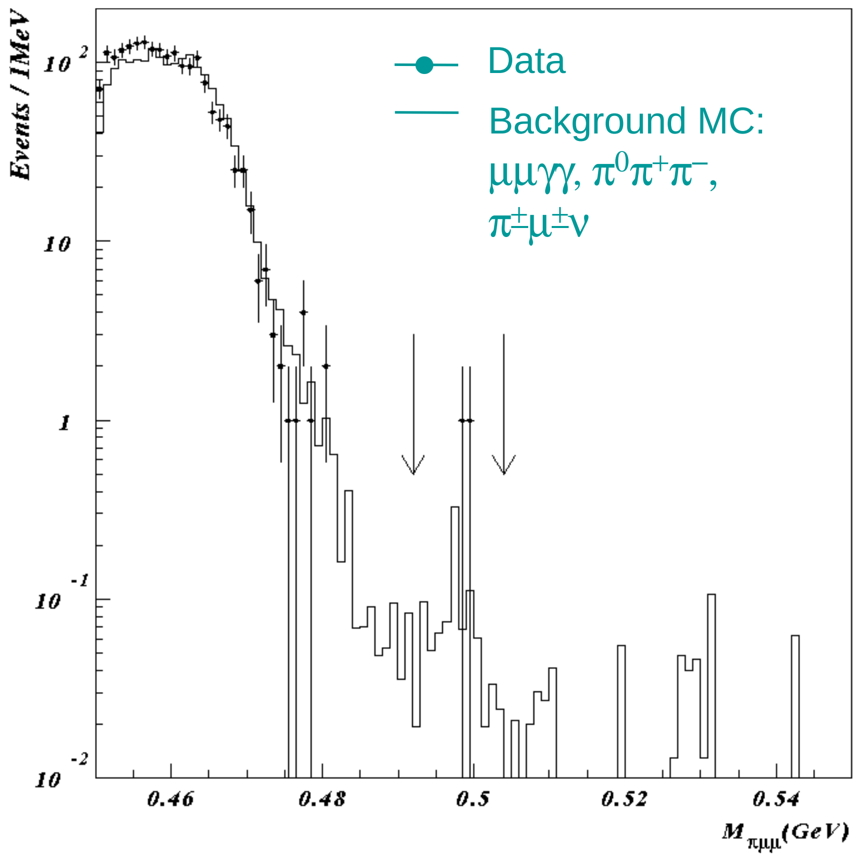


$K_L \rightarrow \pi^0 \mu^+ \mu^-$



$K_L \rightarrow \mu^+ \mu^- \gamma\gamma$

$K_L \to \pi^0\mu^+\mu^-$ (II)



2 events in data *vs* 0.87 ± 0.15 background
(0.37 ± 0.03 $\mu^+\mu^-\gamma\gamma\gamma$)

Br($K_L \to \pi^0\mu^+\mu^-$) < 3.8×10^{-10} (90% C.L.)
KTeV 1997 data

η_{CKM} < 6.9

*PRL **84**, 5279 (2000)*

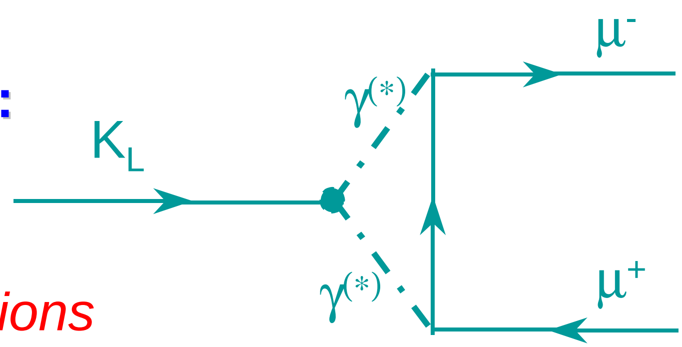
$K_L \to \mu^+\mu^-$ (I)

$$Br(K_L^0 \to m^+ m^-) = \frac{a^2 Br(K^+ \to m^+ n)}{p^2 \sin^4 \Theta_W} \left[\frac{t\left(K_L^0\right)}{t\left(K^+\right)} \right] \times \left\{ \left(1 - l^2/2\right) Y_{NL} + A^2 l^4 (1 - r) Y_t \right\}^2$$

Buchalla & Buras, Nucl. Phys. B412 (1994)106; Eq.111

Unfortunately:

Vile and heinous long range contributions



Amplitude for two real γs from $Br(K_L \to \gamma\gamma)$:

$Br(K_L ® gg ® m^+m^-) = (7.07 \pm 0.18) \times 10^{-9}$

$Br(K_L ® m^+m^-)_{BNL\ E871} = (7.18 \pm 0.17) \times 10^{-9}$

⇒ < 3.7 x 10^{-10} left at 90%C.L. for $K_L \to \gamma^*\gamma^* \to \mu^+\mu^-$ *and* $K_L \to W^+W^- \to \mu^+\mu^-$

⇒ Need $K_L\gamma^{(*)}\gamma^{(*)}$ form factor

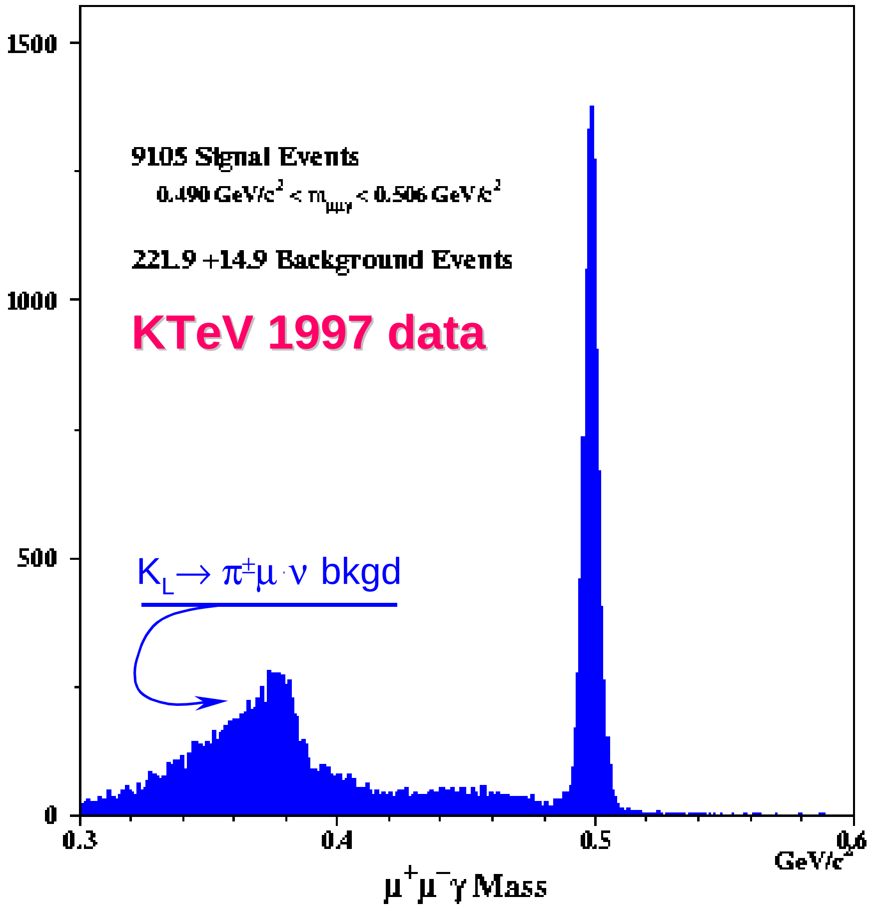
$K_L \to \mu^+\mu^-$ (II)

Q: What tools do we have to quantify the $K_L\gamma^{(*)}\gamma^{(*)}$ vertex?

- $K_L \to \mu^+\mu^- e^+ e^-$ - low stats (38 events from KTeV, 21 from NA48)
- $K_L \to e^+e^-e^+e^-$ - better stats (441 events at KTeV, 132 at NA48) – but radiative corrections ~ 4x(stat uncertainty in α_{K^*})
- $K_L \to \mu^+\mu^-\gamma$ - 9105 events, but 1 γ on-shell
- $K_L \to e^+e^-\gamma$ - NA48 (1999) has 6864 events KTeV $\mathcal{O}[10^5]$ unpublished events - both radiative corr's and 1 γ on-shell

At this time, strongest constraints on ρ are from $\mu^+\mu^-\gamma$

$K_L \to \mu^+\mu^- \gamma$



$$BR(K_L \to \mu^+\mu^-\gamma) = (3.66 \pm 0.04_{stat} \pm 0.07_{sys}) \times 10^{-7}$$

Form Factors from Br and $m_{\gamma\gamma}$ fit obtained for 2 models:

Bergström, Massó and Singer [PL B131(1983)229; B249(1990)141]

D'Ambrosio, Isidori, and Portolés [PL B423(1998) 385]

$K_L \to \mu^+\mu^-$ (III)

BMS model: $a_{K^*} = -0.157^{+0.025}_{-0.027}$

DIP model: $a = -1.53 \pm 0.09$

Using these form factors to compute the $\gamma^{(*)}\gamma^{(*)}$ contributions to $K_L \to \mu^+\mu^-$, we find that the short distance contribution corresponds to (at the 90% C.L.):

BMS model:	$\rho_{CKM} > -1.0$
DIP model:	$\rho_{CKM} > -0.2$

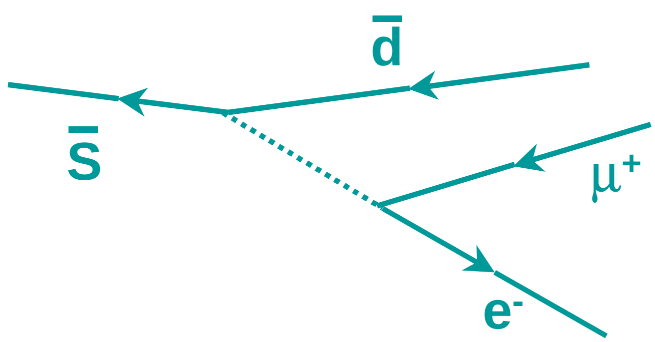
But a warning is called for ~ one can not find the form factor for $q^2(\gamma^{(*)}) > m_K$ from kaon decays.

Perhaps this region can be probed with $e^+e^- \to \gamma^{(*)}\gamma^{(*)}$ measurements at colliders?

$K_L \to \pi^0 \mu^\pm e$ (I)

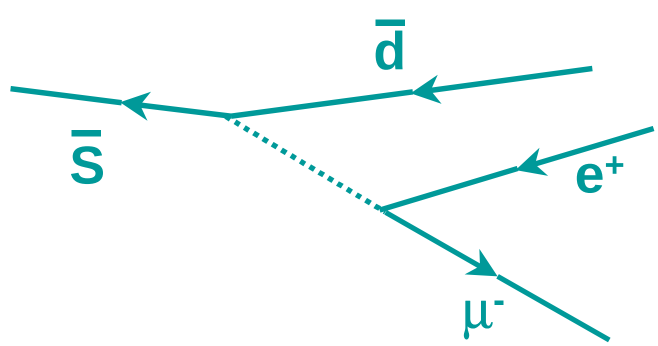
"The concept of a generation is… not well defined mathematically. The known Cabibbo mixing of quarks tells us that, even if we develop an exact meaning to the generation concept, we must encounter generation mixing"

Cahn & Harari, Nucl Phys B176(1980) 135



$-2 \to -1\ -2\ +1$

$\Delta G = 0$



$-2 \to -1\ -1\ +2$

$\Delta G = 2$

$K_L \rightarrow \pi^0 \mu^\pm e^\mp$ (II)

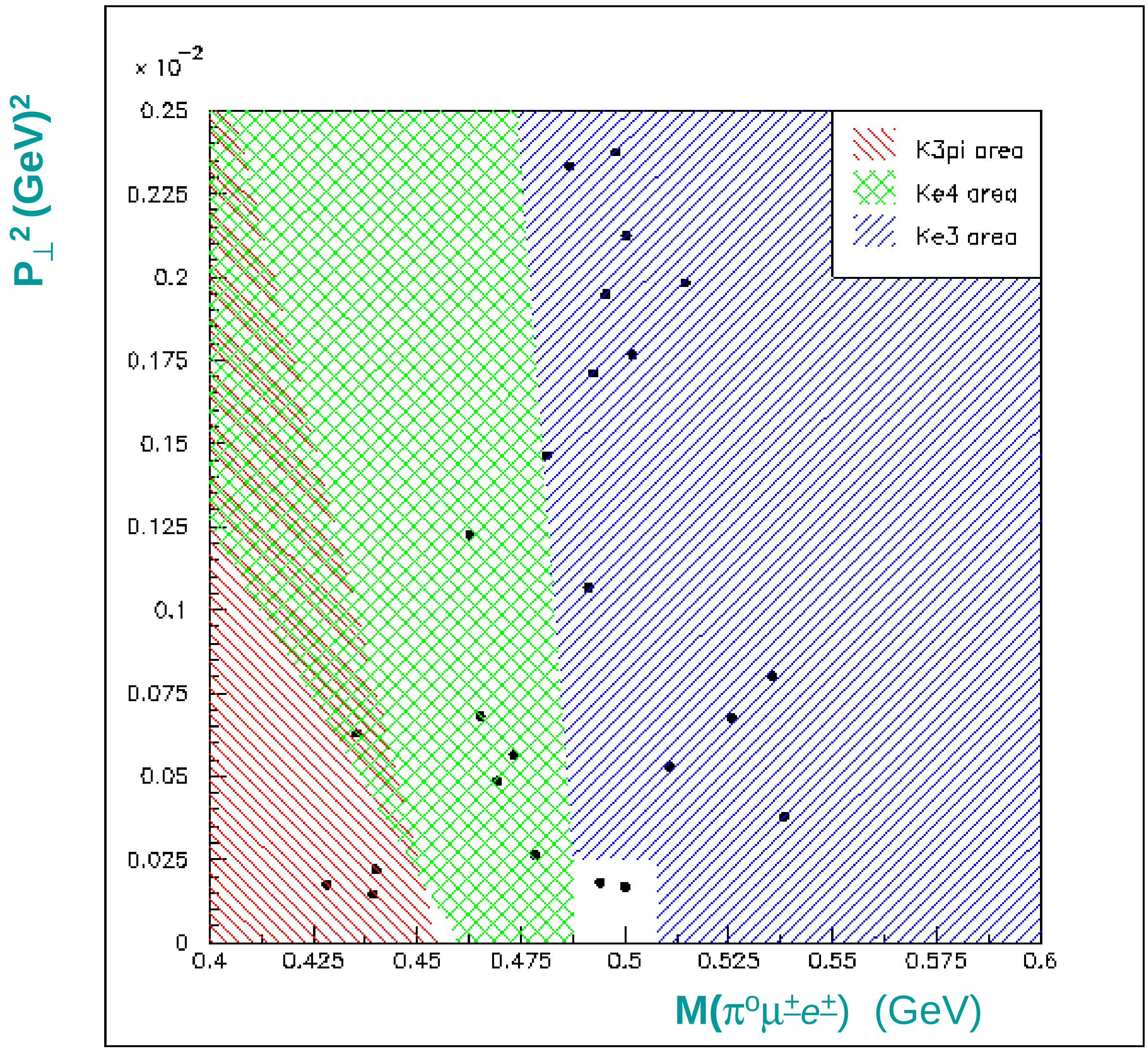
- $|K_L> \cong |K_{ODD}> + \varepsilon |K_{EVEN}>$
- Charge symmetric detector

$\Rightarrow$ Equal reach for $\Delta G = 0, 2$ transitions (which are indistinguishable)

Backgrounds:

- $K_L \rightarrow \pi^\pm e^\pm \nu$, $\pi^\pm$ fakes $\mu^\pm$, 2 accidental "γ"s
  - Br = (0.2717 ± 0.0028) x (a few x 10^{-3})
  - Suppress with $P_\perp$, $M_{\gamma\gamma}$, "γ" cluster quality cuts
  - Dominant background, $e^\pm \rightarrow e^\pm \gamma$ small
- $K_L \rightarrow \pi^\pm \pi^\pm \pi^0$ One $\pi^\pm$ fakes $\mu^\pm$, other fakes $e^\pm$
  - Br = (0.1255 ± 0.0020) x (a few x 10^{-3}) x ($\pi^\pm$ rejection rate)
  - Suppress with TRDs, CsI
- $K_L \rightarrow \pi^\pm \pi^0 e^\pm \nu$, $\pi^\pm$ fakes $\mu^\pm$
  - Br = (5.18 ± 0.29) x 10^{-5} x (a few x 10^{-3})
  - Suppress with cuts on P^2(ν in K_L frame)

K_L! $\pi^0\mu^\pm e^\pm$ (III)

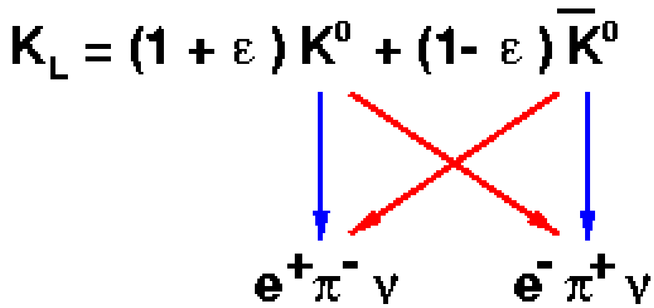


2 events in data *vs* 0.61 ±0.56 background
(We have set background to zero so far)

$Br(K_L \rightarrow \pi^0\mu^\pm e^\pm) < 4.4 \times 10^{-10}$ (90% C.L.)
Preliminary 1997 data

~10x improvement over previous limit

Charge Asymmetry



$$d_L = \frac{N(e^+) - N(e^-)}{N(e^+) + N(e^-)} = 2\Re(e - Y - X)$$

Where Y is CPT violation in $\Delta S = \Delta Q$ amplitude
X " $\Delta S = -\Delta Q$ "

PDG 2000 average, ($e^{\pm}$ and $\mu^{\pm}$)

$\delta_L = (3.27 \pm 0.12) \times 10^{-3}$

Best $e^{\pm}$ result **CERN-Heidelberg 1974**

$\delta_L = (3.41 \pm 0.18) \times 10^{-3}$

using 34×10^6 events

This analysis based on 300×10^6 events

Charge Asymmetry

Very **hard to build a detector with same detection efficiency for both charges at the required level.**

Instead, define subsamples with cancelling geometric acceptance

e$^+$ **with spectrometer magnet positive** ***vs.***
e$^-$ **from east beam, negative polarity:**

$$R = \frac{N(e^+;+mag)}{N(e^-;-mag)} = \frac{Br(\to e^+)\,Flux(K_L;+mag)\,Accept(e^+;+mag)}{Br(\to e^-)\,Flux(K_L;-mag)\,Accept(e^-;-mag)}$$

…similarly for N(*e*$^+$;-mag) / N(*e*$^-$;+mag) and 2 beams

Find 4 values of R, multiply them, take 4th root

δ_L = (R-1) / (R+1)

… but you better be sure those ratios really cancel!

Charge Asymmetry

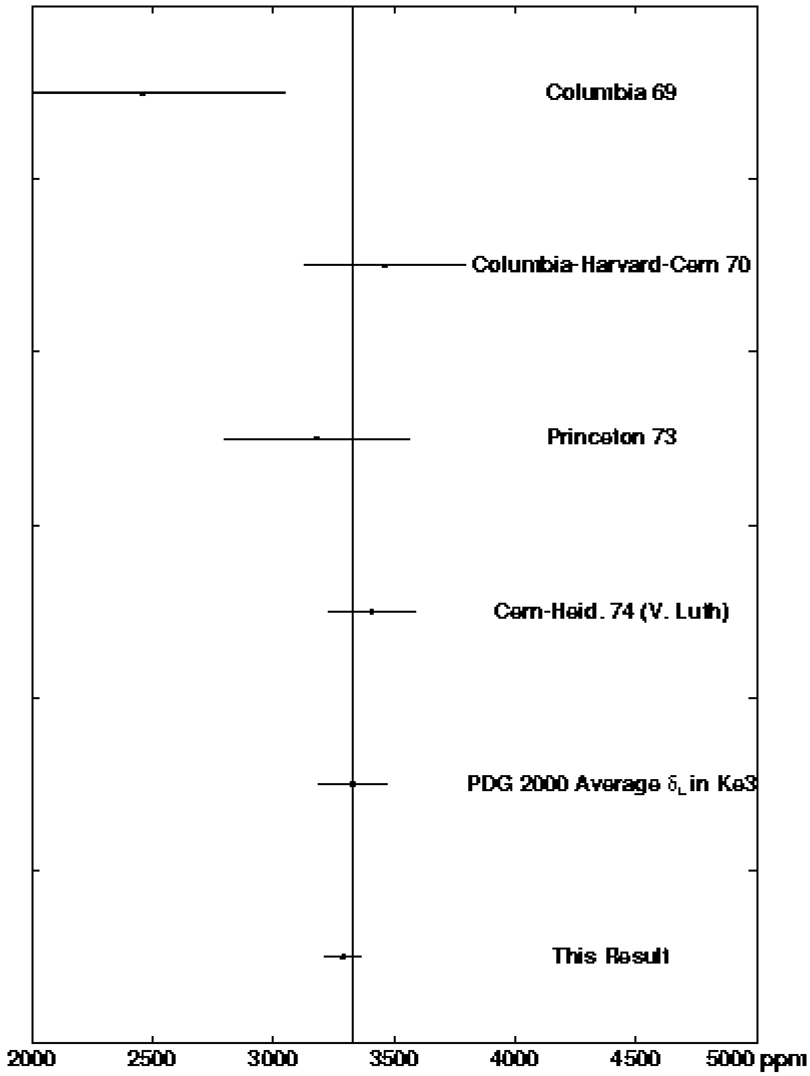
Summary of corrections for systematic effects

$\pi^+ \pi^-$ different in CsI	-156±10	x10^{-6}
$\pi^+ \pi^-$ loss in trigger scintillator	54±10	"
$\pi^+ \pi^-$ loss in spectrometer	3± 3	"
$\pi^+ \pi^-$ punchthrough	34±40	"
$e^+ e^-$ different in CsI	-19±18	"
δ-ray production difference	-8± 4	"
e^+ annihilation in spectrometer	11± 1	"
Backgrounds ($K_{\pi 3}$, $K_{\mu 3}$, Λ)	1± 1	"
Target/absorber interference	-2± 1	"
Collimator, regenerator scatter K_L	-1± 1	"
Spectrometer reversal mismatch	-3± 2	"
Total	-97±46	x10^{-6}

Preliminary result on 1997 data

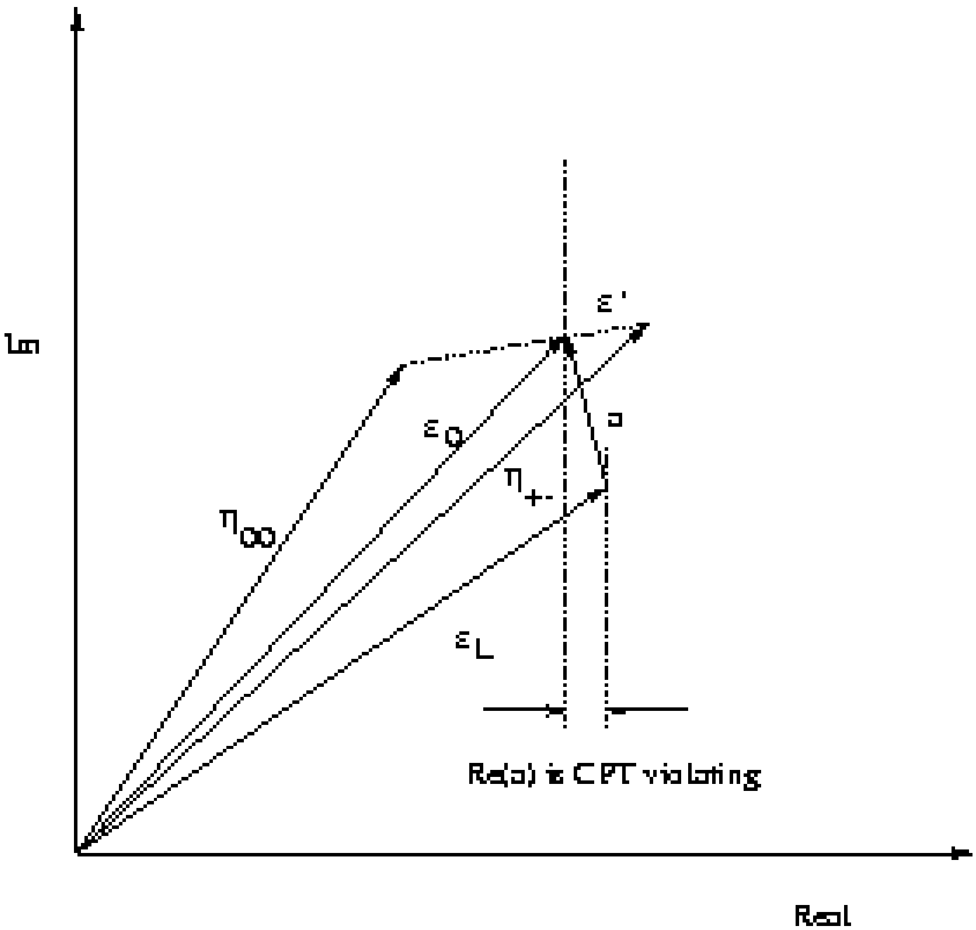
$$\delta_L = (3.320 \pm 0.058_{STAT} \pm 0.046_{SYS}) \times 10^{-3}$$

Charge Asymmetry



New World Average (3.305 ±0.063) x10^{-3}

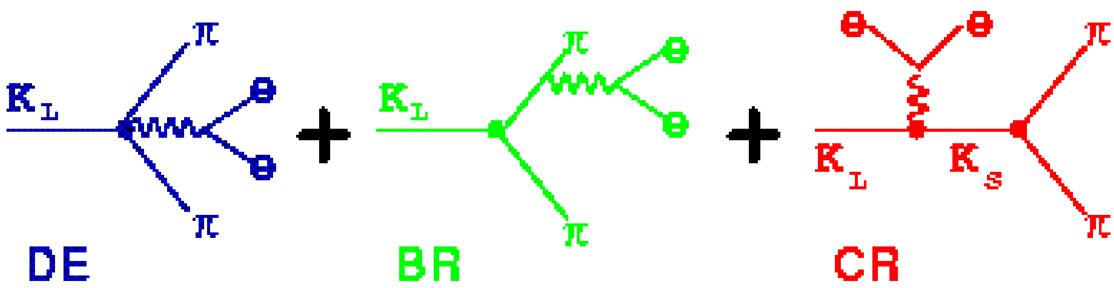
Charge Asymmetry



$$\Re(a) = \tfrac{2}{3}\Re(h_{+-}) + \tfrac{1}{3}\Re(h_{00}) - \Re(e_L)$$

$= -2 \pm 35$ ppm   (assuming $\Delta S = -\Delta Q$)

K^0 Charge Radius



Each amplitude is multiplied by a coupling constant, and then summed to get total *A*

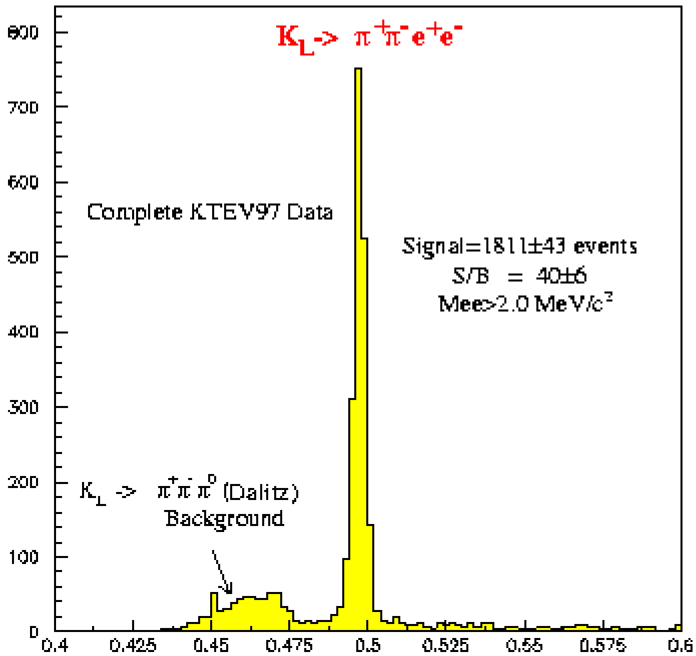
Different contributions populate phase space differently

The coupling constant for the CR term is

$$g_{CR} = -\frac{1}{3}\left\langle R^2 \right\rangle m_K^2 e^{id_o} = -\frac{1}{3}\left\langle \sum q_i \left(\vec{r}_i - \vec{R}\right)^2 \right\rangle m_K^2 e^{id_o}$$

Charge Radius

K^0 Charge Radius



The 1997 KTeV data contains 1811 ±43 events over a 45 ±11 event background

⇒ ***A very clean sample***

We fit the data's phase space distribution as embodied in dΓ • (acceptance) with g_{CR} as the free parameter…

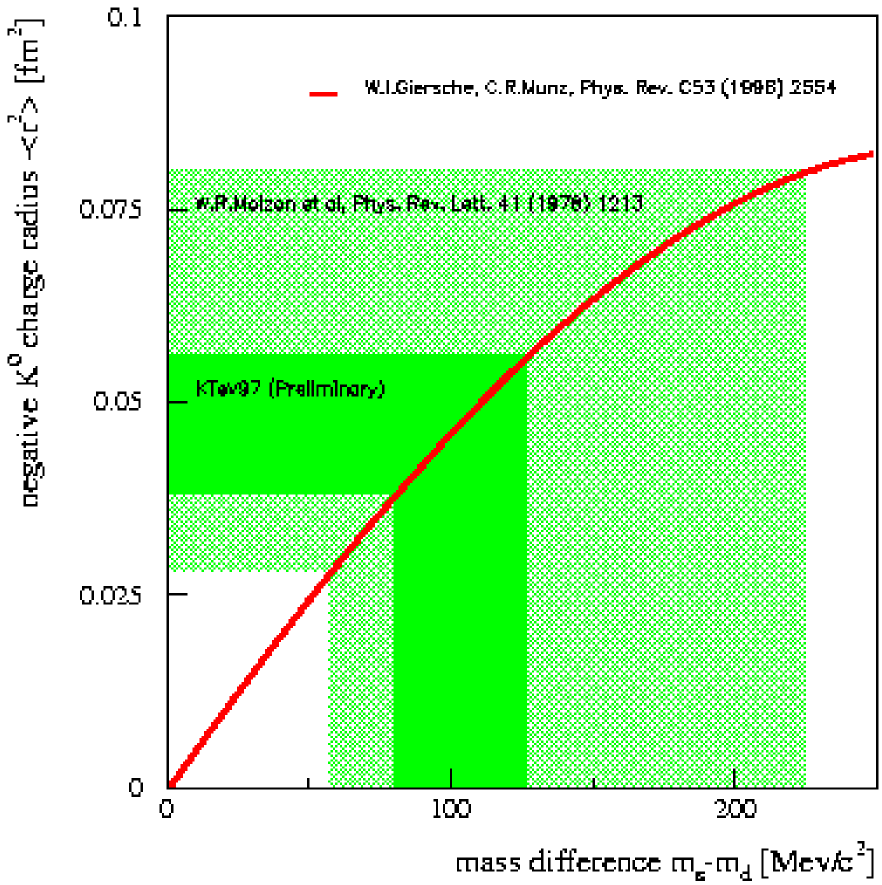
KTeV preliminary 1997 data:

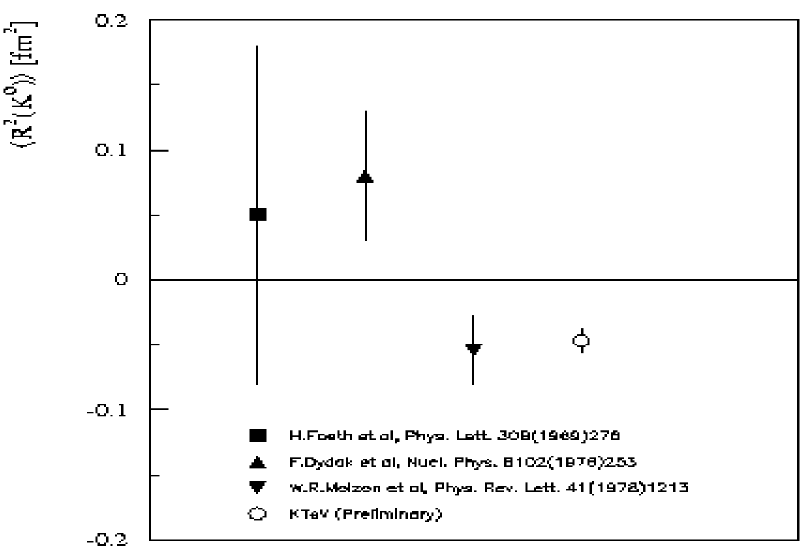
$$|g_{CR}| = 0.100 \pm 0.018_{STAT} \pm 0.013_{SYS}$$

$$\langle R^2 \rangle = -0.047 \pm 0.008_{STAT} \pm 0.006_{SYS}\ fm^2$$

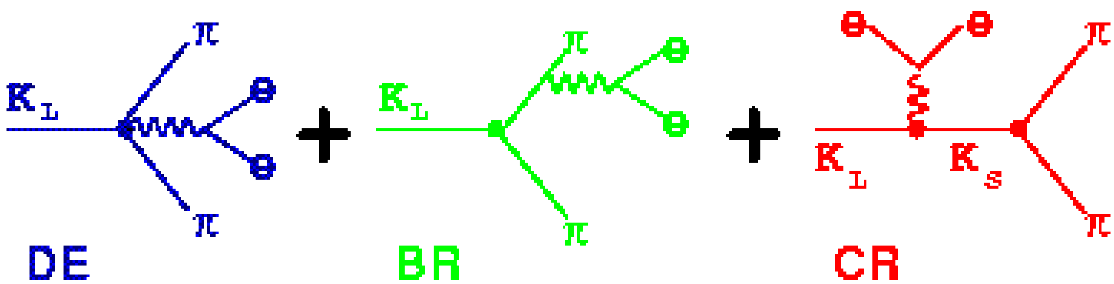
K^0 Charge Radius

Using Bethe-Salpeter equation to infer $m_s - m_d$





$K_L \to \pi^0\pi^0 e^+e^-$



For neutral pions, there is no bremsstrahlung and Bose statistics & gauge invariance suppresses direct emission – charge radius effects dominate

Existing *Br* predictions in χPT:

0.8×10^{-10}	[R.Funck & J.Kambor, Nucl. Phys. B396, (1993) 53]
2.0×10^{-10}	[P.Hellinger & L.M.Sehgal, Phys. Lett. B307, (1993) 182]

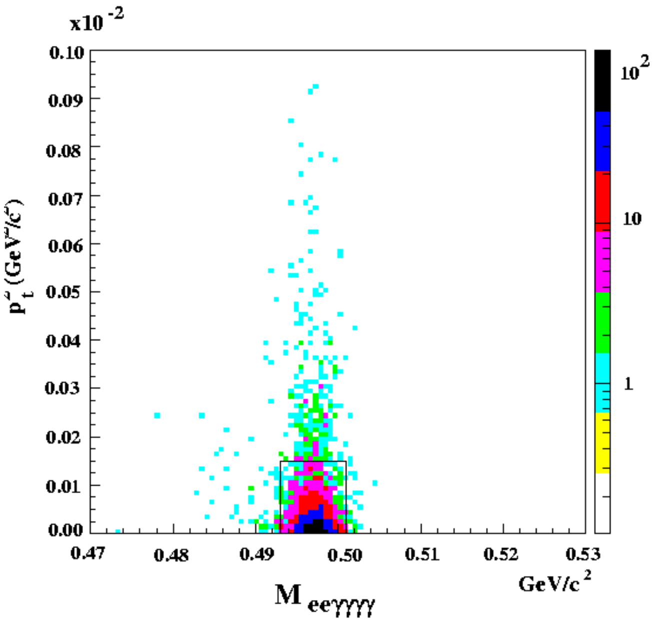
Experimental background is

$K_L \to \pi^0\pi^0\pi^0$

$\hookrightarrow \gamma\gamma$

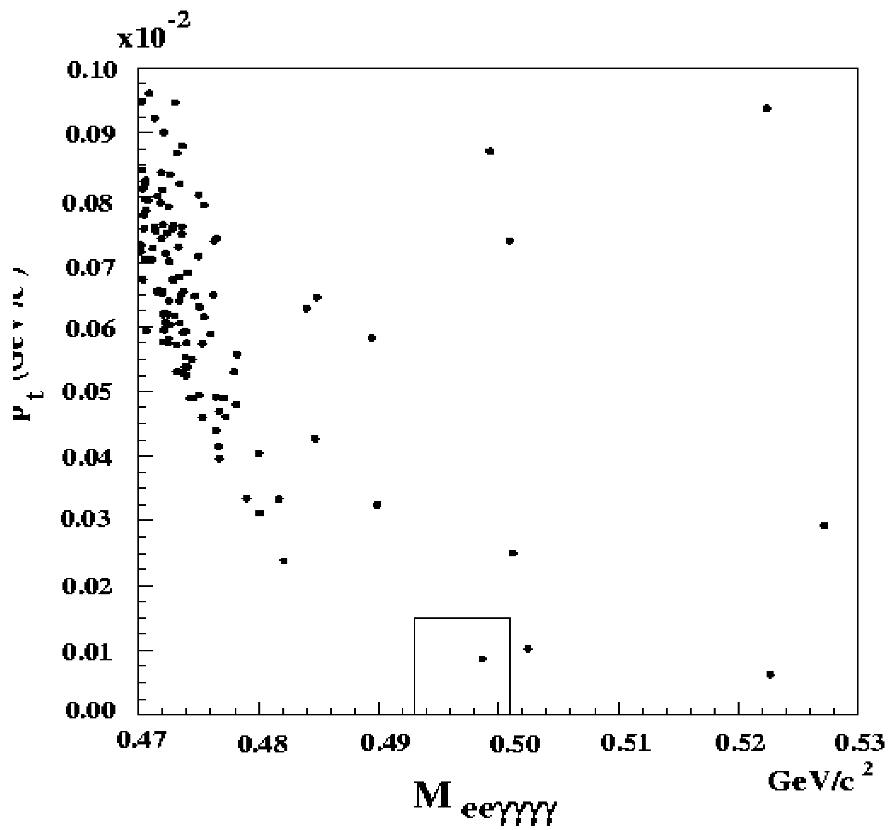
$\hookrightarrow e^+e^-$**, either internally or externally**

$K_L \to \pi^0\pi^0 e^+e^-$



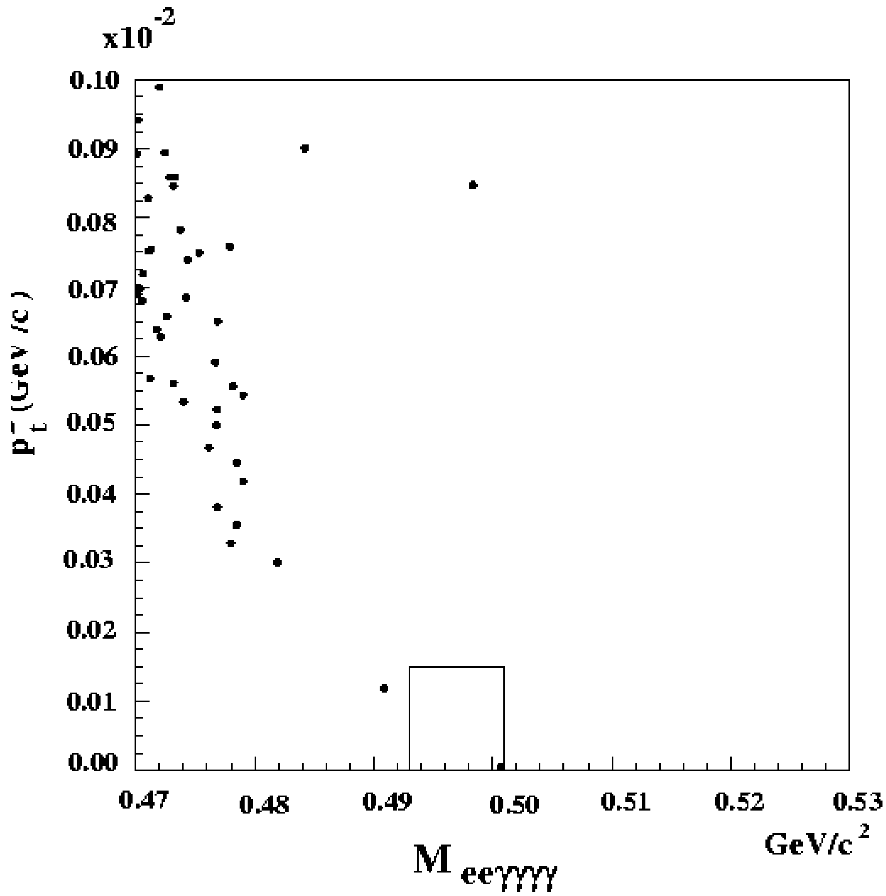
MC signal

MC background 3x equivalent data sample



$0.4^{+0.4}_{-0.3}$ *events*

$K_L \to \pi^0\pi^0 e^+e^-$



One event in the data…

$Br(K_L \to \pi^0\pi^0 e^+e^-) < 5.4 \times 10^{-9}$

KTeV preliminary result, 1997 data

First experimental result

The 1999 Run

Rare Decay running Sept 1999 to Jan 2000:

- *$\pi^0 e^+ e^-$, $\pi^0 \mu^+ \mu^-$, $\pi^0 \mu^\pm e^\mp$ datasets » 2.5x larger*
- *$\pi^+ \pi^- e^+ e^-$, $\mu^+ \mu^- e^+ e^-$, $e^+ e^- e^+ e^-$ datasets » 3.2x larger*

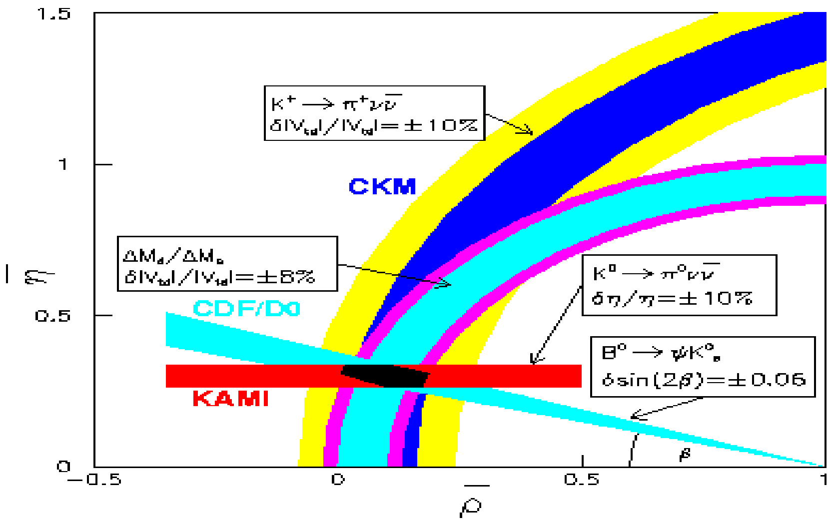
$K_L \to \mu^+ \mu^- e^+ e^-$, $e^+ e^- e^+ e^-$, $\pi^0 \mu^\pm e^\mp$, $\pi^0 \pi^0 e^+ e^-$ analyses profit directly from more data

$K_L \to \mu^+ \mu^- \gamma$, $e^+ e^- \gamma$, $\pi^+ \pi^- e^+ e^-$ become high-statistics analyses

$K_L \to \pi^0 e^+ e^-$, $\pi^0 \mu^+ \mu^-$ are reaching background limits already

$K^+ \to \pi^+ \nu\bar{\nu}$ (I)

A well understood mode



With recent V_{CKM} values

$Br(K^+ \to \pi^+\nu\bar{\nu}) = (0.82 \pm 0.32) \times 10^{-10}$

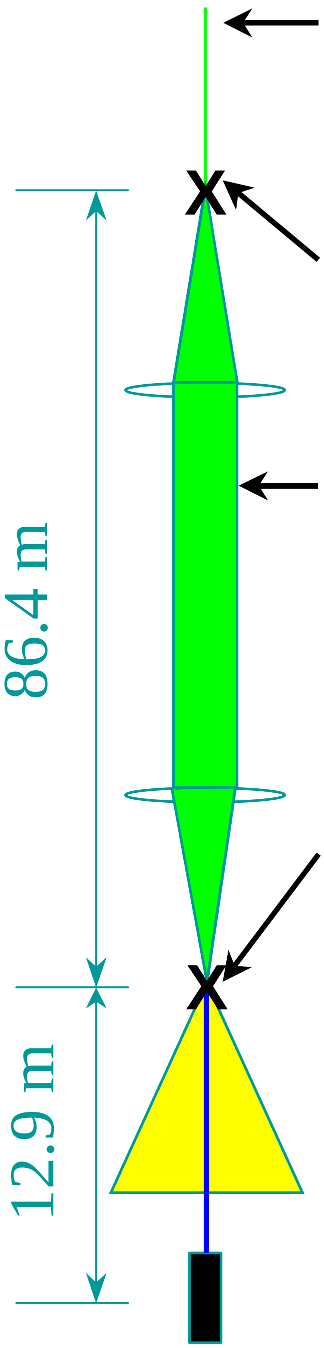
BNL E787 has 1 clean event with 0.08±0.02 background in 1995-7 data:

$$Br(K^+ \to p^+ n\overline{n}) = 1.5^{+3.4}_{-1.2} \times 10^{-10}$$

1998 data should double sensitivity

…plus also, E949!

RF separated K^+ beam



Initial momentum-selected beam *DP/P ~ 2%*

RF deflection: *Asin(wt)*

A = 15 MeV/c

Transport *Dt* = L / $b_\pi c$

= (1124.00 / f) for π^+

= (1124.26 / f) for K^+

= (1125 .00/ f) for p

2nd RF deflection: *-Asin(wt+wDt)*

Net deflection:

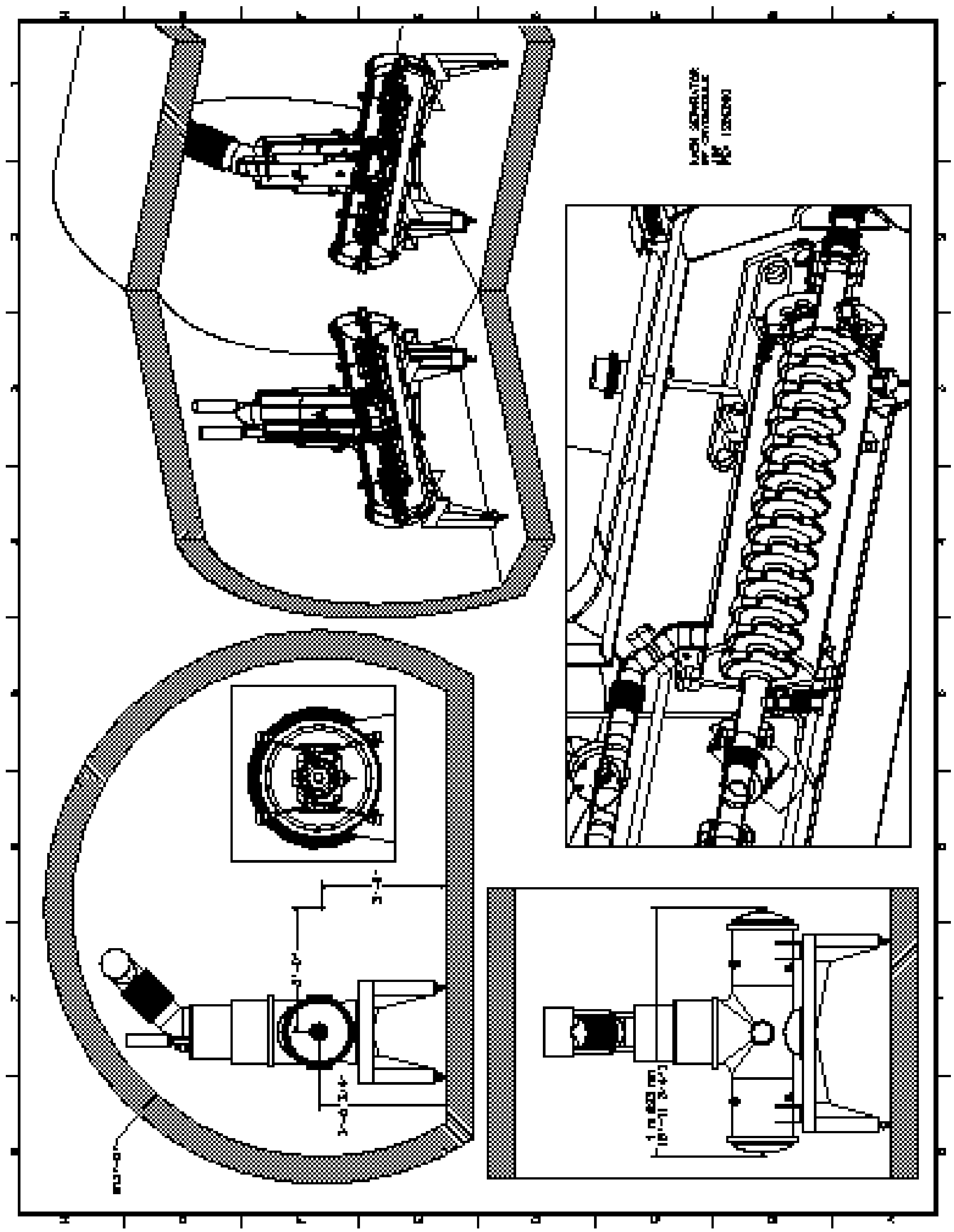
-2A sin(*wDt* /2) • cos(*wt* + *wDt* /2)

= 0 for π^+, p

= -1.458 cos(ωt + 43.1°) for K^+

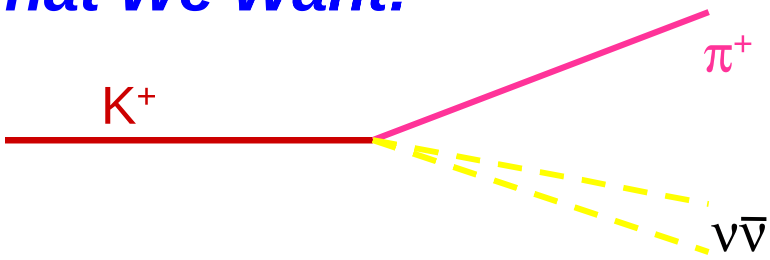
Stop π^+ with beam plug, collect K^+

RF separated K⁺ beam



$K^+ \to \pi^+ \nu\bar{\nu}$ (II)

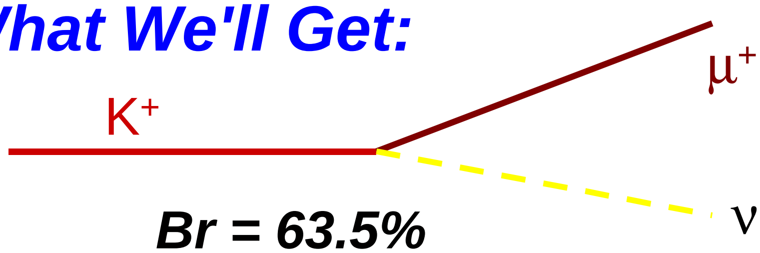
What We Want:



Kinematics

Momentum, direction & position of K^+ and π^+

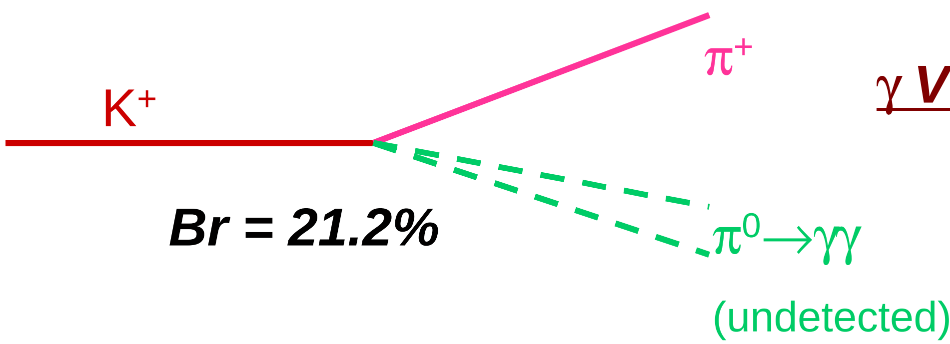
What We'll Get:



μ^+ Veto

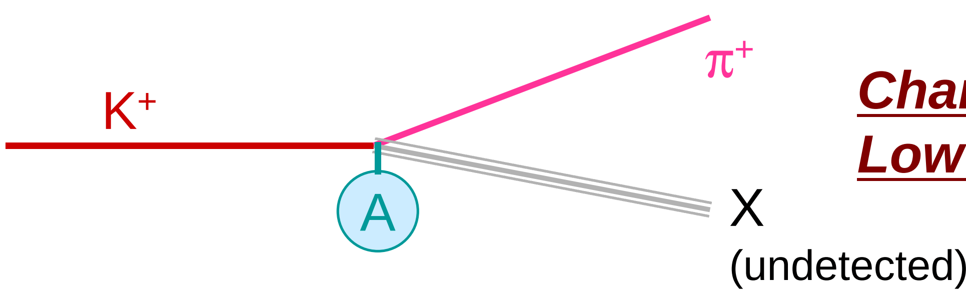
Br = 63.5%

Also K+®m+ng



γ Veto

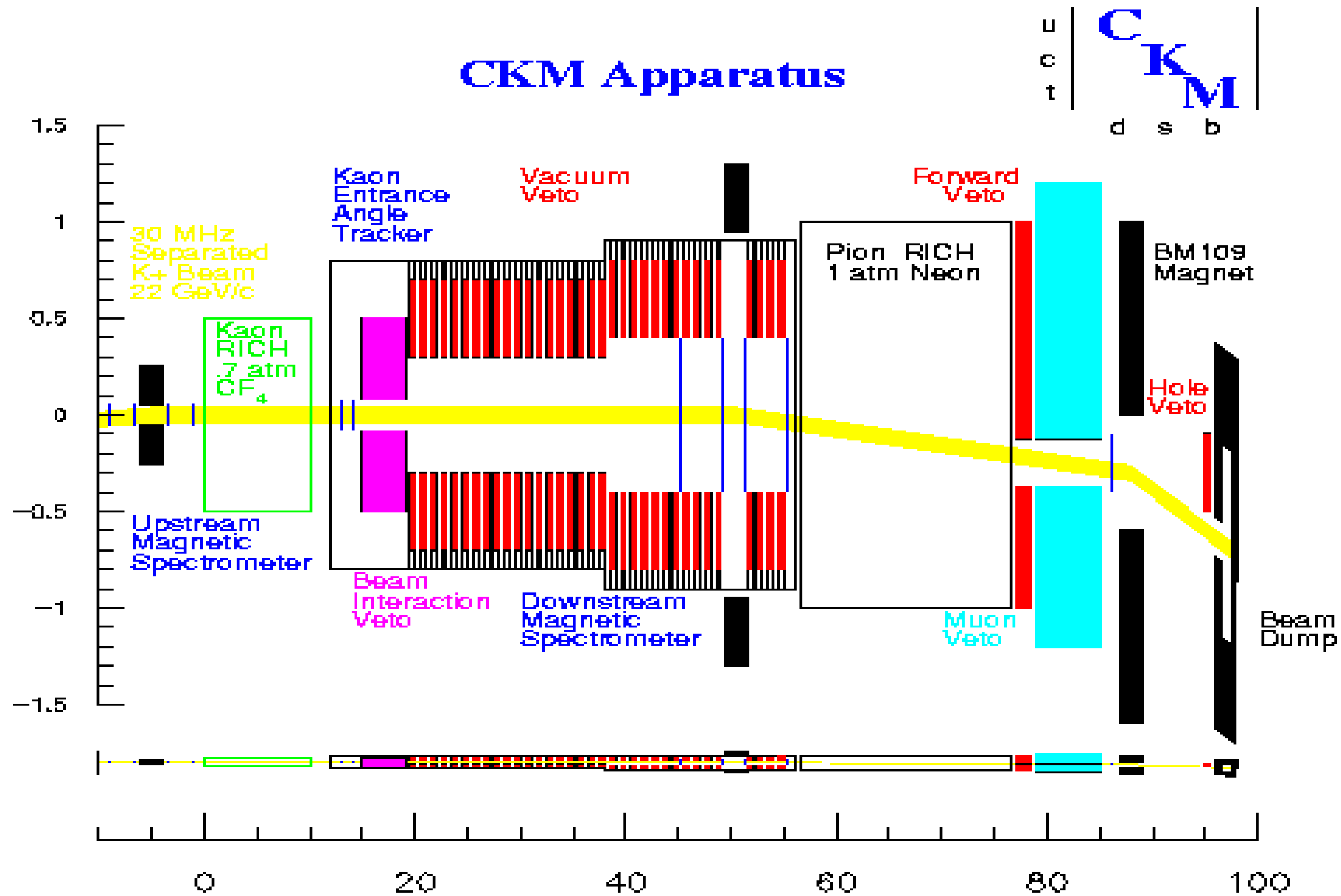
Br = 21.2%



Charged Veto

Low Material

CKM



- Redundant measurements
- K^+ in flight

- Aiming for 90 signal, 10 bkgd events
- R & D underway

$K_L \to \pi^0 \nu\bar{\nu}$

Experimental signature is a single π^0

Branching ratio ~ 3 x *10*$^{-11}$ **P_{COM} < 231 MeV**

But 34% of all K_L *decays produce a* π^0 ...

worst: $K_L \to \pi^0\pi^0$ **P_{COM} = 209 MeV**

also there are hyperons…

e.g.: $\Xi^0 \to \Lambda\pi^0$

$n\pi^0$ **P_{COM} < 230 MeV**

KTeV result with $\pi^0 \to e^+e^-\gamma$ **PRD 61 (2000)** 072006

$$Br(K_L \to \pi^0\nu\bar{\nu}) < 5.9 \times 10^{-7}$$

O[10^2*] improvement over previous limit, but…*

$Br(K_L \to \pi^0\nu\nu) = (0.31 \pm 0.13) \times 10^{-10}$ in S.M.

Model independent result of Grossman & Nir :

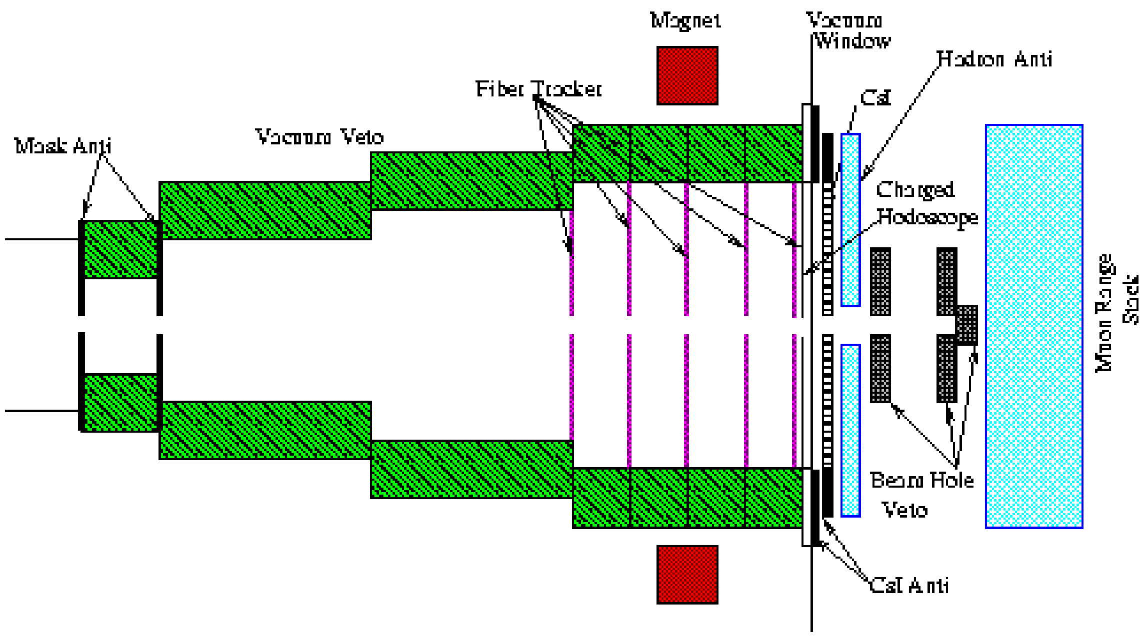
PLB 398 (1997) 163-8

$Br(K_L \to \pi^0\nu\bar{\nu}) < 4.4 \times Br(K^+ \to \pi^+\nu\bar{\nu})$

$< 2.7 \times 10^{-9}$ **(my number)**

KaMI (I)

KAMI DETECTOR LAYOUT



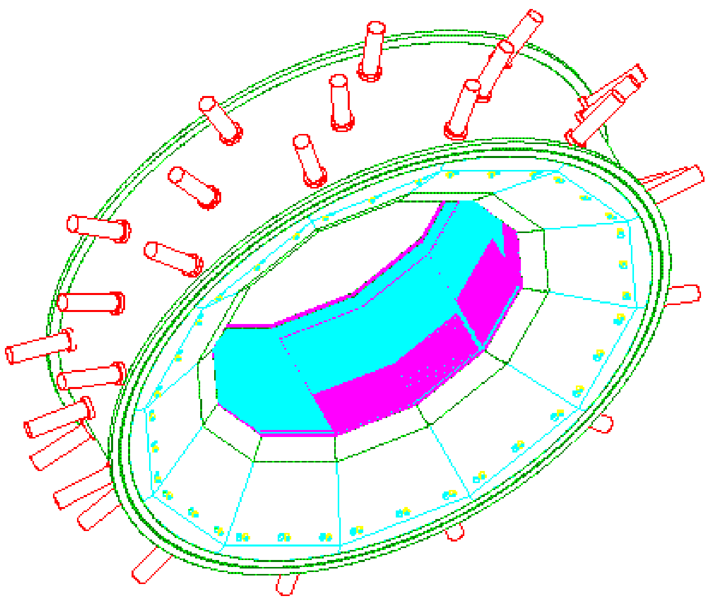
- *Very* hermetic γ veto system
- Minimal material seen by neutrons
- High rate fiber tracking inside vacuum
- Aiming for ~100 events, ~20 bkgd
- Recycle KTeV detector components
- R & D underway

Broad Range of Physics Topics

KaMI (II)

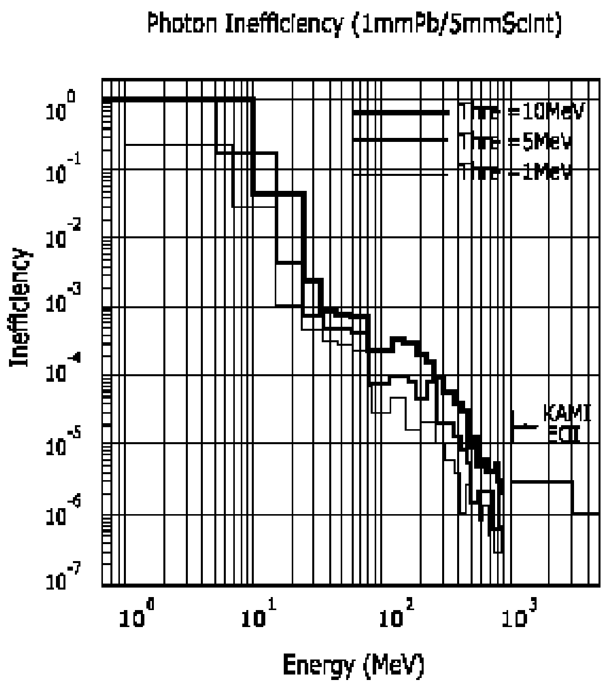
Background is ~85% $K_L \rightarrow \pi^0\pi^0$

Suppressed with $P_\perp$, vertex and γ veto cuts



Sketch of γ veto module

10MeV E_γ threshold
$\Rightarrow$ 19 background events / year



Beam tests for E_γ > 1.5GeV at Spring 8 (Japan)

Potentially Accurate Statements

- Modes with K_L or K^+ decaying into $\pi\nu\bar{\nu}$ are the best chance to discover non-CKM CP violation with kaons
- Modes with final state charged leptons are harder. One must disentangle several contributions, each of which can be hard to measure
- Still no lepton flavor violation
- Still no CPT violation
- Rare kaon decays continue to provide a window into New Physics possibilities and a host of opportunities to sharpen the Standard Model image