Recent Results from the NA48 and NA48/2 Experiments

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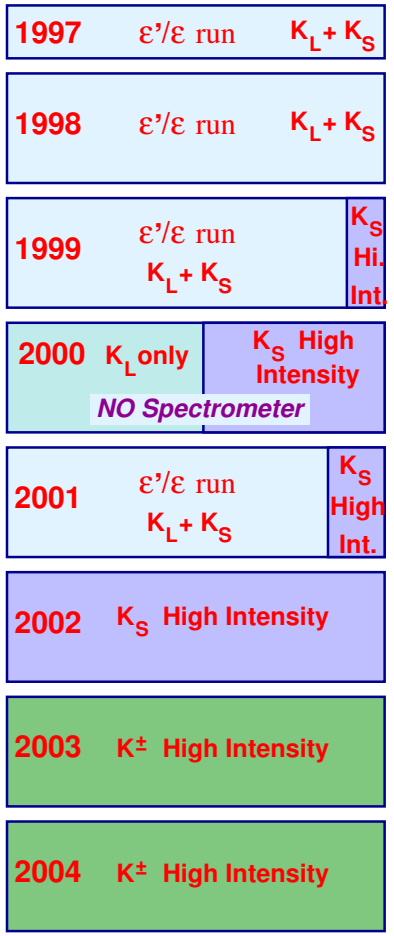
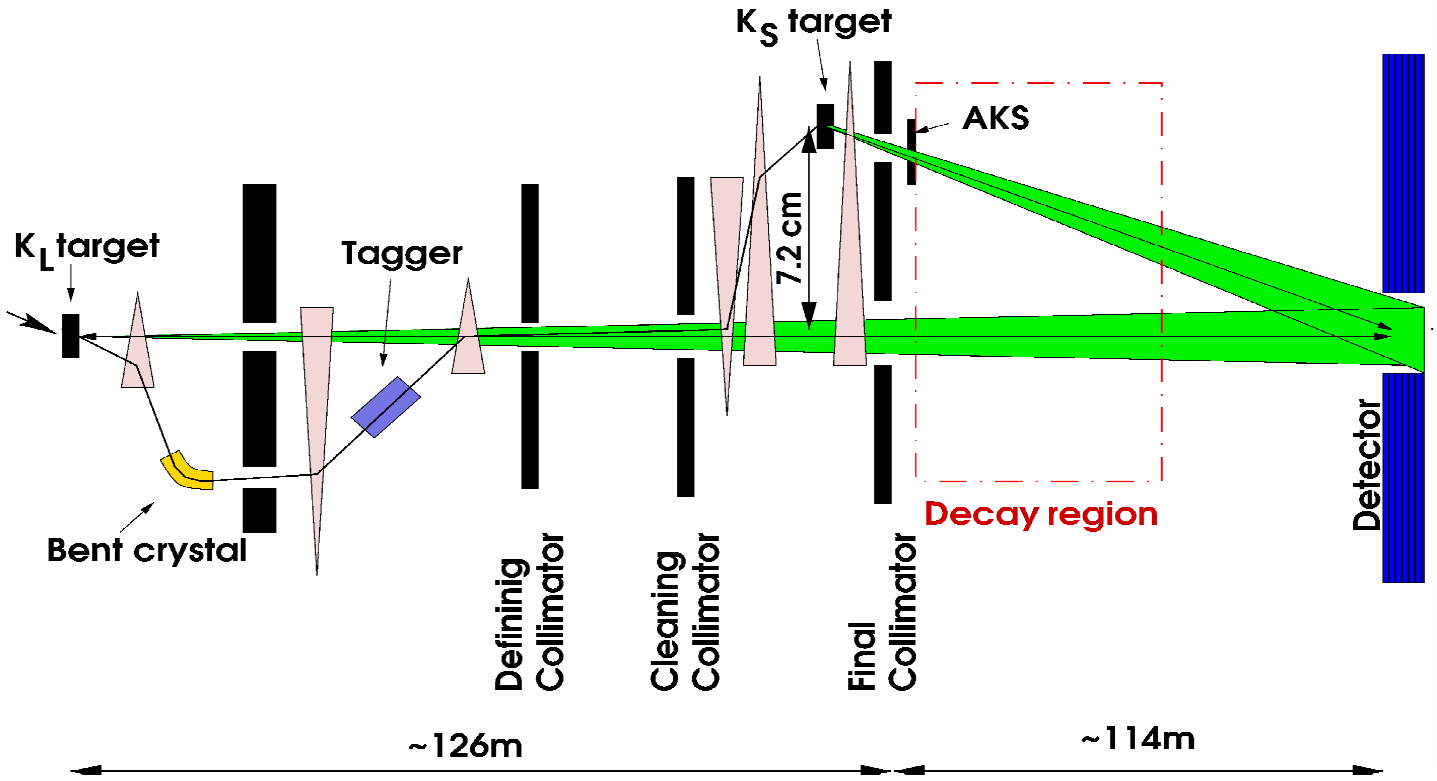
- $K^\pm$ Semileptonics: Br($K^\pm \to \pi^0 e^\pm \nu$), Br($K^\pm \to \pi^0 \mu^\pm \nu$) and Vus extraction
- $K^\pm \to \pi^\pm \pi^0 \gamma$: Direct Emission and Interference
- Summary and Outlook



The NA48 Experiment

NA48: Simultaneous K_L and K_S beams.

NA48/1 Only K_S beam used.



$\Gamma(K_L \to \pi^+\pi^-)/\ \Gamma(K_L \to \pi^{+-}e^{-+}\nu)$

Method of Measurement:
Normalize $K_L \to \pi^+\pi^-$ to K_{Le3} events

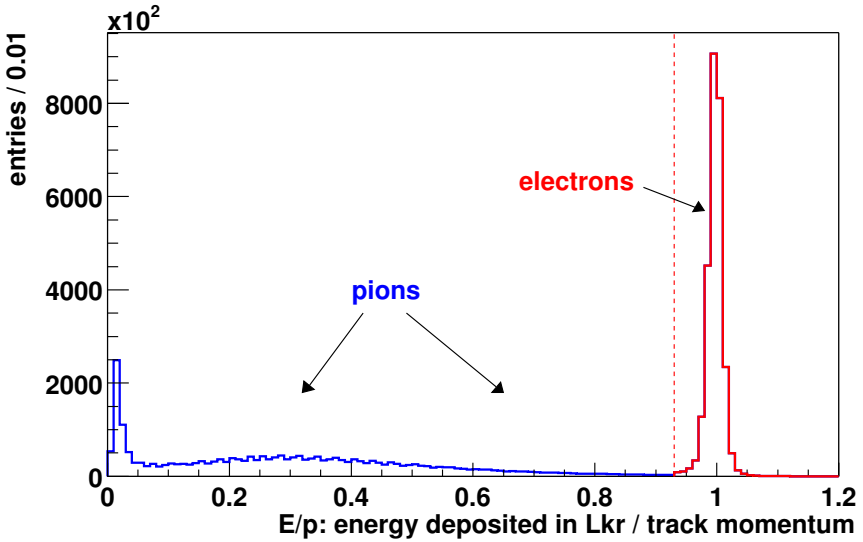
Data Sample:
Two days minimum bias run in September 1999. Events with opposite charged tracks from a common vertex triggered.

Selected Events:

$K_L \to \pi^+\pi^-$: 41473 events selected.
0.48 (GeV/c2) < $m_{\pi\pi}$ < 0.51 (GeV/c^2), small p_T, no muon, E/p < 0.93 for both tracks

K_{Le3} : 2663759 events selected.
One track with E/p > 0.93

Background < 0.5% in both channels.



Monte Carlo:
Radiative corrections applied:
KLOR used for K_{Le3}
PHOTOS (only real γ produced) used for $K_{L2\pi}$

$\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_L \to \pi^{+-}e^{-+}\nu)$

RESULTS:

(0.180 ±0.009)% $K_L \to \pi+\pi-\gamma$ (DE) subtracted

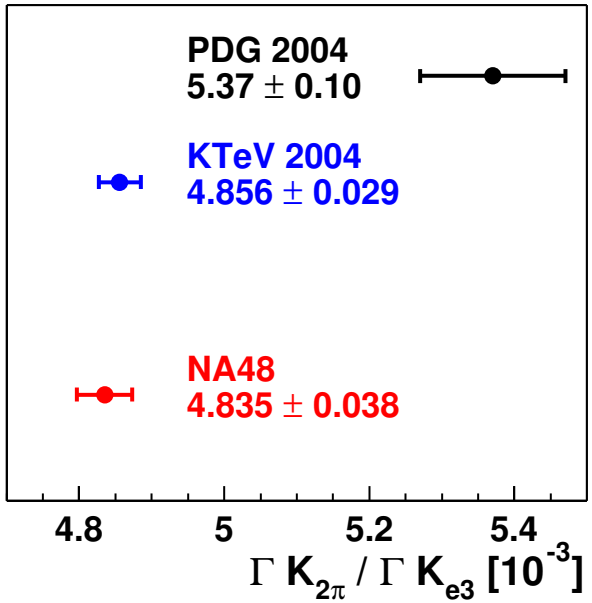
$\Gamma(K_L 2\pi)/\Gamma(K_L e3) = (4.835 \pm 0.038) \times 10^{-3}$

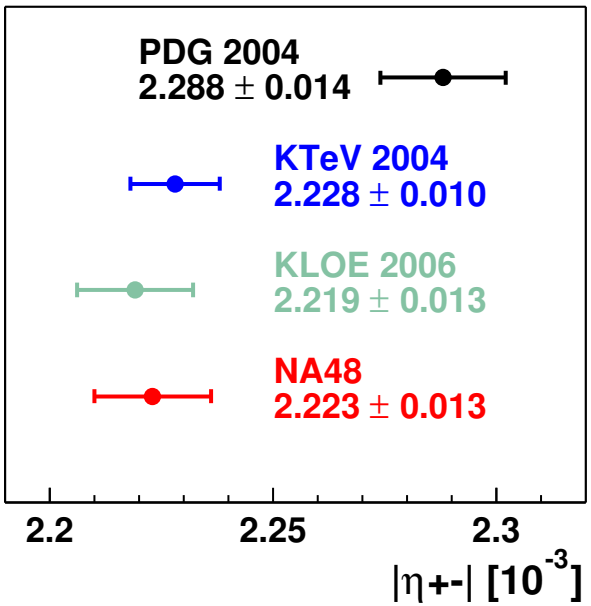
$T_{KS} = (0.89598 \pm 0.00070) \times 10^{-10}$ s (NA482002)

$T_{KL} = (5.084 \pm 0.023) \times 10^{-8}$ s (KLOE2006)

$|\eta_{+-}| = \sqrt{Br(K_L \to \pi^+\pi^-)T_{KS} / Br(K_S \to \pi^+\pi^-)T_{KL}} = (2.223 \pm 0.013) \times 10^{-3}$

$Br(K_S \to \pi^+\pi^-) = (69.169 \pm 0.051)\%$ (KLOE2006)





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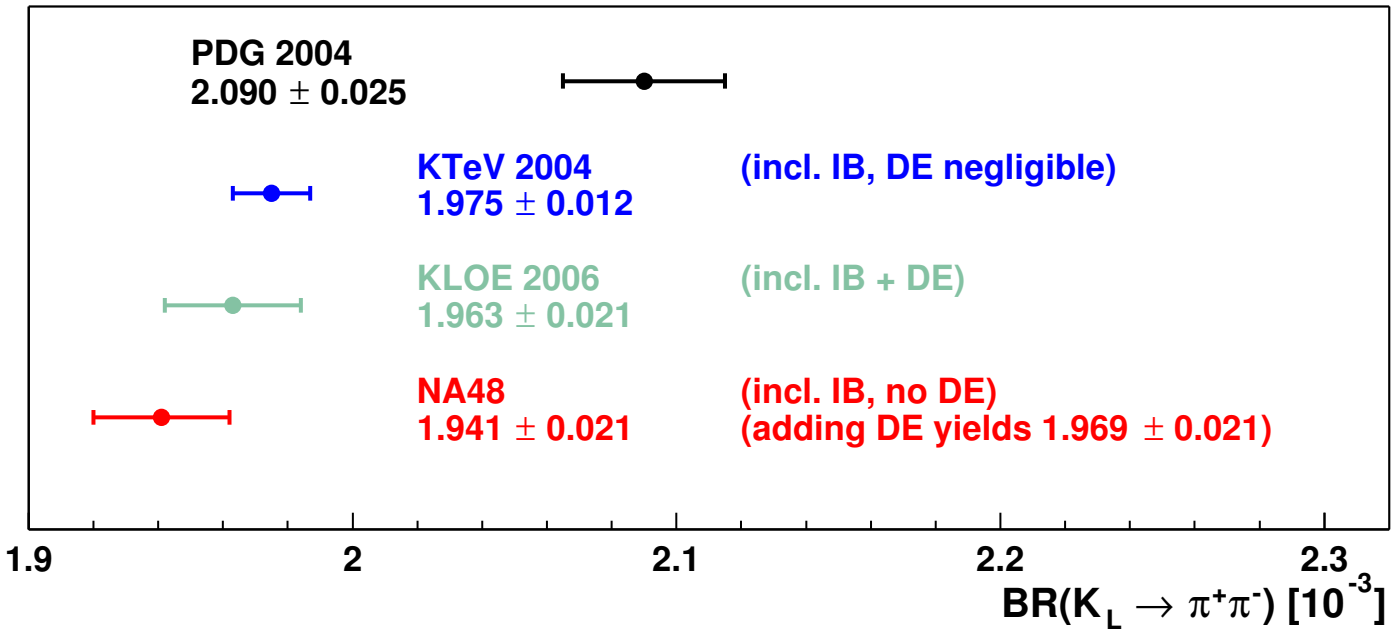
$Br(K_L \to \pi^+\pi^-)$ PRELIMINARY

RESULT:

Using NA48 updated $Br(K_{Le3})$ = (0.4022 ±0.0031)% due to change in $Br(K_L \to \pi^0\pi^0\pi^0)$

$$Br(K_L \to \pi^+\pi^- + \pi^+\pi^- \gamma\ (IB)) = (1.941 \pm 0.021) \times 10^{-3}$$



$Br(K^{\pm} \to \pi^0 l^{\pm} \nu)$

Method of Measurement:

Normalize $K^{\pm}_{e3}$ events to $K^{\pm} \to \pi^{\pm}\pi^0$

Normalize $K^{\pm}_{\mu 3}$ events to $K^{\pm} \to \pi^{\pm}\pi^0$

$BR(K^{\pm} \to \pi^{\pm}\pi^0) = (21.13 \pm 0.14)\ \%$

Data Sample:

Low intensity dedicated run (8h) with minimum bias hodoscope trigger (2003)

Selected Events:

K^+_{e3}	5.9×10^4
K^-_{e3}	3.3×10^4
$K^+_{\mu 3}$	5.0×104
$K^-_{\mu 3}$	2.7×104
$K^+ \to \pi^+\pi^0$	46.8×10^4
$K^- \to \pi^-\pi^0$	26×10^4

Background negligible.

Monte Carlo:

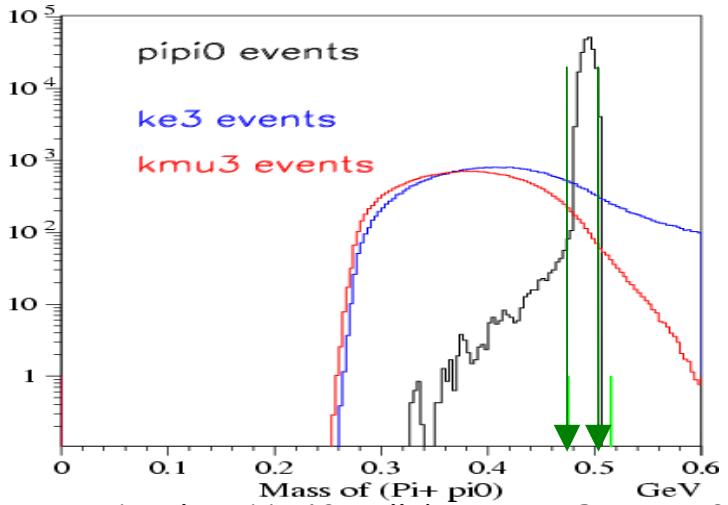
Ginsberg's radiative corrections applied to Ke3. Very good agreement with Data.

Charged Particle ID:

Ke3 electrons : E/p > 0.95

Kμ3 muons : hit associated to charged track in MUC.

$K^{\pm} \to \pi^{\pm}\pi^0$ pions: $m_{\pi^{\pm}\pi^0}$ cut.



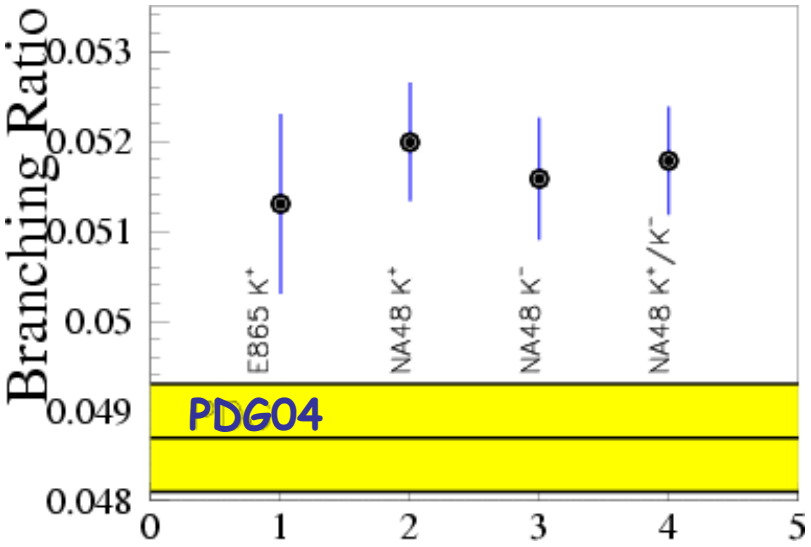
$Br(K^{\pm} \rightarrow \pi^0 e^{\pm} \nu)$ PRELIMINARY

RESULT:

$Br(K^{\pm} \rightarrow \pi^{\pm} \pi^0)$ = (21.13 ± 0.14) % (PDG04)

$$Br(K^{\pm} \rightarrow \pi^0 e^{\pm} \nu) = (5.14 \pm 0.02_{stat} \pm 0.06_{syst})\%$$

Particle Data Group 2004: BR($K^{\pm}$e3) = (4.87 ± 0.06) %



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$K^{\pm} \rightarrow \pi^0 \mu^{\pm} \nu$ PRELIMINARY

RESULTS:

(PDG04)

$\lambda_+ = (2.78 \pm 0.07) \times 10^{-2}$

$\lambda_0 = (1.77 \pm 0.16) \times 10^{-2}$

$\Gamma(K\mu 3)/\Gamma(Ke3) = (67.49 \pm 0.35_{stat} \pm 0.11_{sys} \pm 0.21_{sys\lambda+,\lambda0})\%$

PDG04: $\Gamma(K\mu 3)/\Gamma(Ke3) = (67.2 \pm 0.7)\%$

In good agreement with theory:

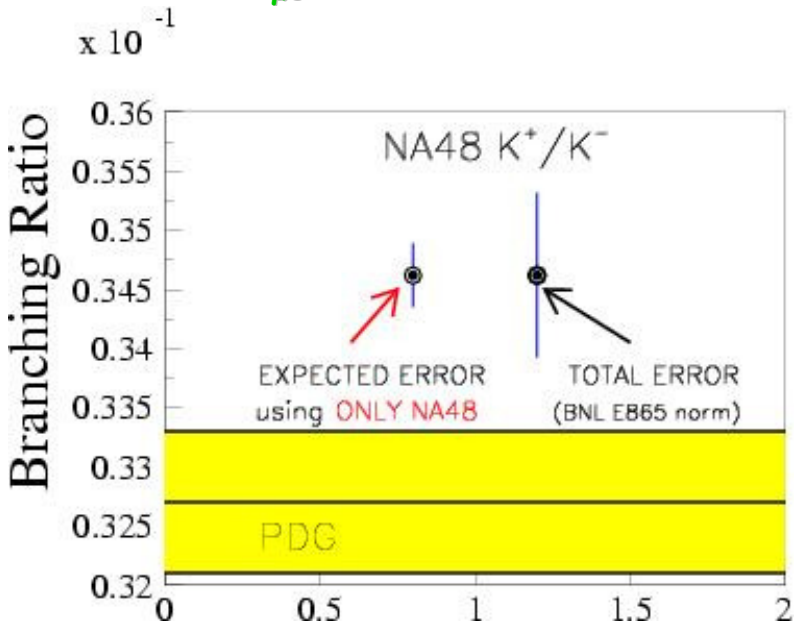
$$\frac{\Gamma(K^{\pm}_{\mu 3})}{\Gamma(K^{\pm}_{e3})} = 0.6457 - 0.1546\lambda_+ + 1.5646\lambda_0 + O(\lambda^2)$$

Fearing, Fischbach, Smith (1970)

$Br(\pi^{\pm}\pi^0) = (21.13 \pm 0.14)\%$ (PDG04)

$B(K\mu 3) = (3.462 \pm 0.018_{stat} \pm 0.006_{sys} \pm 0.011_{sys\lambda+,\lambda0} \pm 0.006_{normBNL})\%$

PDG04: $Br(K_{\mu 3}) = (3.27 \pm 0.06)\%$



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Vus NA48/2 -PRELIMINARY

- **Assuming $K_{\beta 3}$ decays: 0^- to 0^-, pure V**

$$\Gamma(K_{l3}) \propto G_F^{enh} |V_{us}|^2 |f_+(0)|^2 I_K^l(\lambda_{+,0})(1+\delta_{SU(2)}^K + \delta_{em}^{Kl})^2$$

	$\delta_{SU(2)}^K(\%)$	$\delta_{em}^{Kl}(\%)$
K_{e3}^+	**2.31(22)**	**-0.10(16)**
$K_{\mu 3}^+$	**2.31(22)**	**+0.20(20)**

hep-ph/0411097 F. Mescia

Phase space integrals from PDG04

(Pole approximation, full region)

$$I_K^e(\lambda_{+,0}, \delta) = 0.110528 \pm 0.000609$$

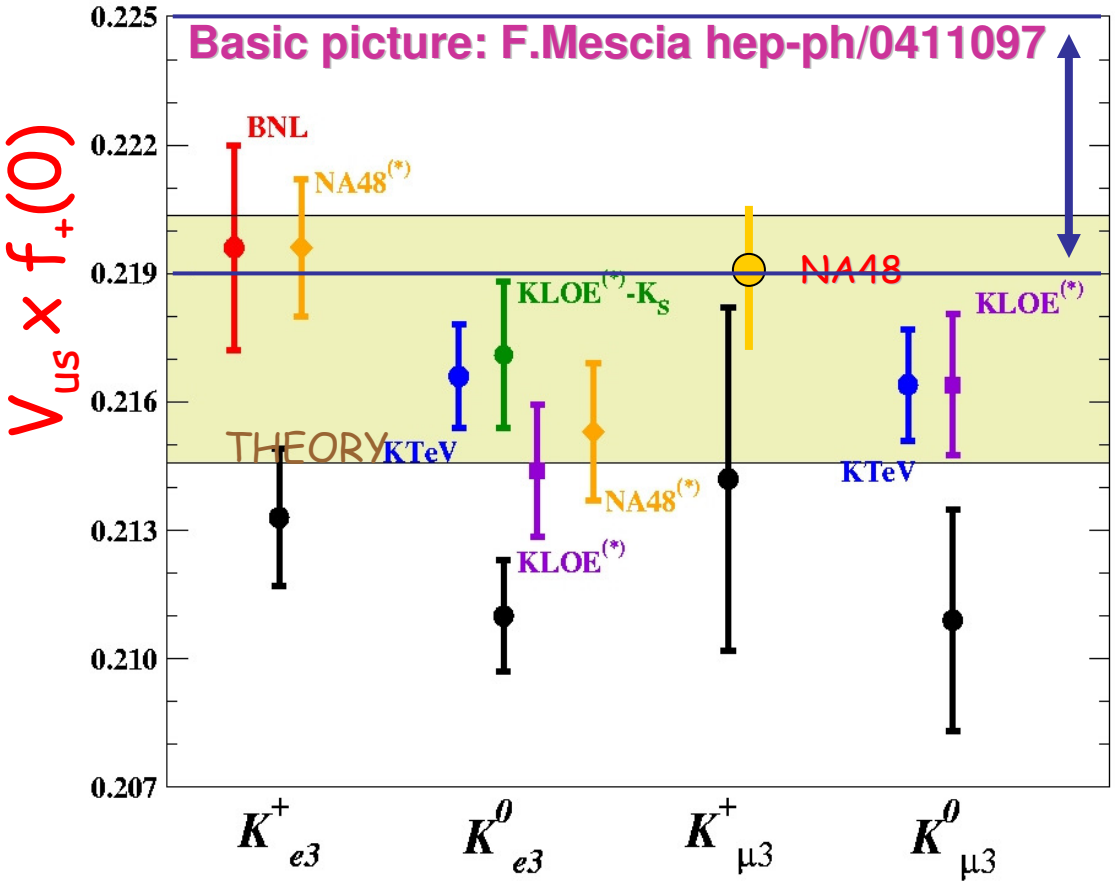
$$I_K^\mu(\lambda_{+,0}, \delta) = 0.073684 \pm 0.000459$$

→Extraction of Vus from NA48/2 results comparable !

$$K_{e3} \Rightarrow |V_{us} f_+(0)| = 0.2192 \pm 0.0015$$

$$K_{\mu 3} \Rightarrow |V_{us} f_+(0)| = 0.2204 \pm 0.0015$$

Vus from NA48/2 results



THEORY K^+
0.2224 ± 0.0028

THEORY K^0
0.2177 ± 0.0028

SM => Vus = 0.2265 ± 0.0022 – Assuming unitarity (ICHEP04)
Leutwyler-Roos $f^+(0)K_L$=0.961 ± 0.008 ➔ $f^+(0)K^+$=0.982± 0.008

$K^{\pm} \to \pi^{\pm}\pi^{0}\gamma$

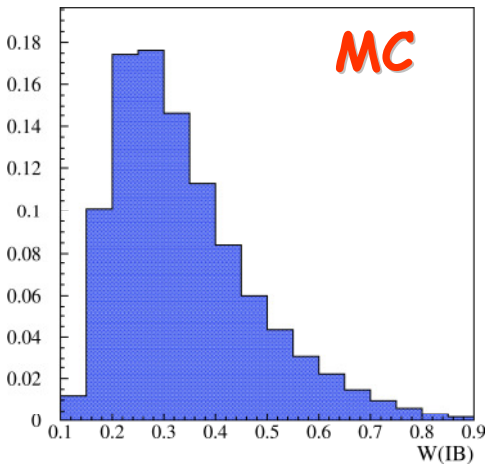
$$\frac{d\Gamma^{\pm}}{d\mathbf{W}} \simeq \underbrace{\frac{d\Gamma^{\pm}}{d\mathbf{W}}_{\mathrm{IB}}}_{\text{Inner Brems.}} \left[\underbrace{1}_{\text{Inner Brems.}} + \underbrace{2\frac{m_\pi^2}{m_K^2}\,\mathbf{W^2}\,|E|\cos(\delta_1 - \delta_0 \pm \phi)}_{\text{Interference}} + \underbrace{\frac{m_\pi^4}{m_K^4}\,\mathbf{W^4}\,(|E|^2 + |M|^2)}_{\text{Direct Emission}} \right]$$

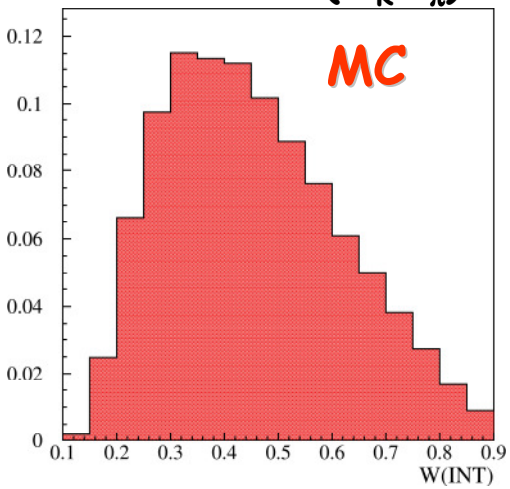
Inner Brems.
from $K^{\pm}\to\pi^{\pm}\pi^{0}$
Br = $(2.75\pm0.15)\times10^{-4}$

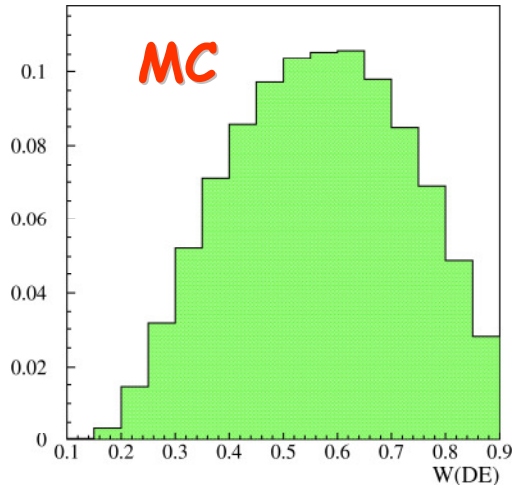
Interference
sensitive only to
electric (E) dipole
(not yet observed)

Direct Emission
emitted from the vtx
$O(p^4)$ ChPT, magnetic & electric dipole
Br = $(4.4 \pm 0.7)\times10^{-6}$ (PDG06, $55<T^*<90$MeV)

Sensitive variable: $W^2 = \dfrac{(p^*_K p^*_\gamma)\,(p^*_\pi\, p^*_\gamma)}{(m_K m_\pi)^2}$







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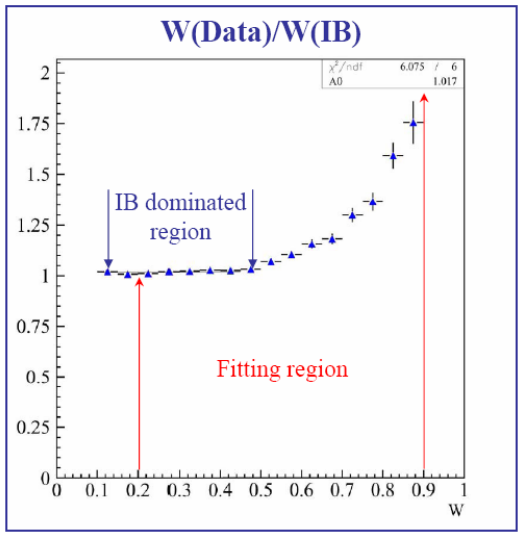
$K^{\pm} \to \pi^{\pm}\pi^{0}\gamma$ PRELIMINARY

Method: Fit W distribution to obtain relative contributions from IB, DE and INT.
RESULT :

$$\text{Frac(DE)} = (3.35 \pm 0.35 \pm 0.25)\ \%$$

$$\text{Frac(INT)} = (-2.67 \pm 0.81 \pm 0.73)\ \%$$

$0\ \text{MeV} < T^{*}_{\pi} < 80\ \text{MeV}$

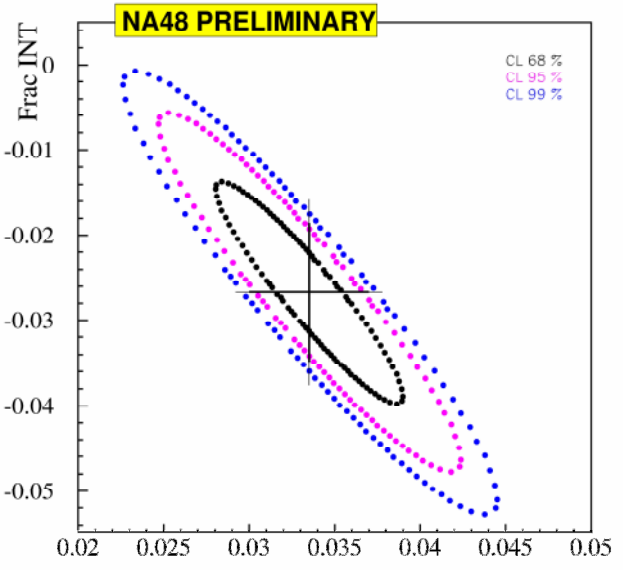


First evidence for a non-zero interference term!

- 124K events used for the fit.
- Correlation coefficient: $\rho = -0.92$
- Systematics dominated by trigger efficiency

Extrapolating to $55 < T^{*}_{\pi} < 90$ MeV :

$$\text{Frac(DE)}^{\text{INT=0}} = (0.85 \pm 0.05 \pm 0.02)\%$$

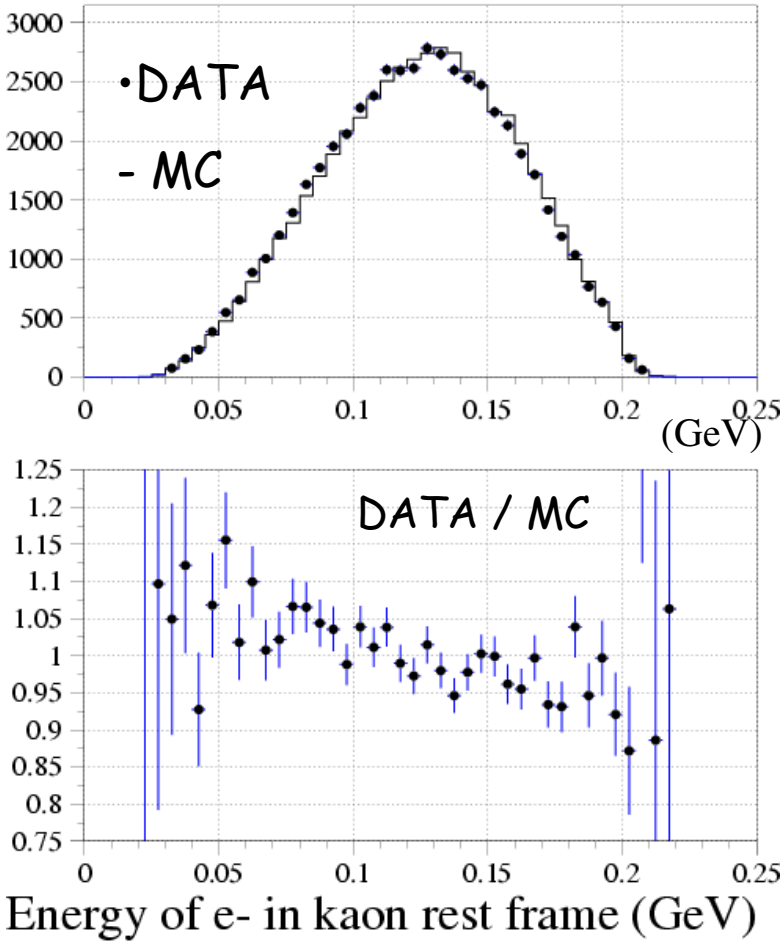


Summary and Outlook

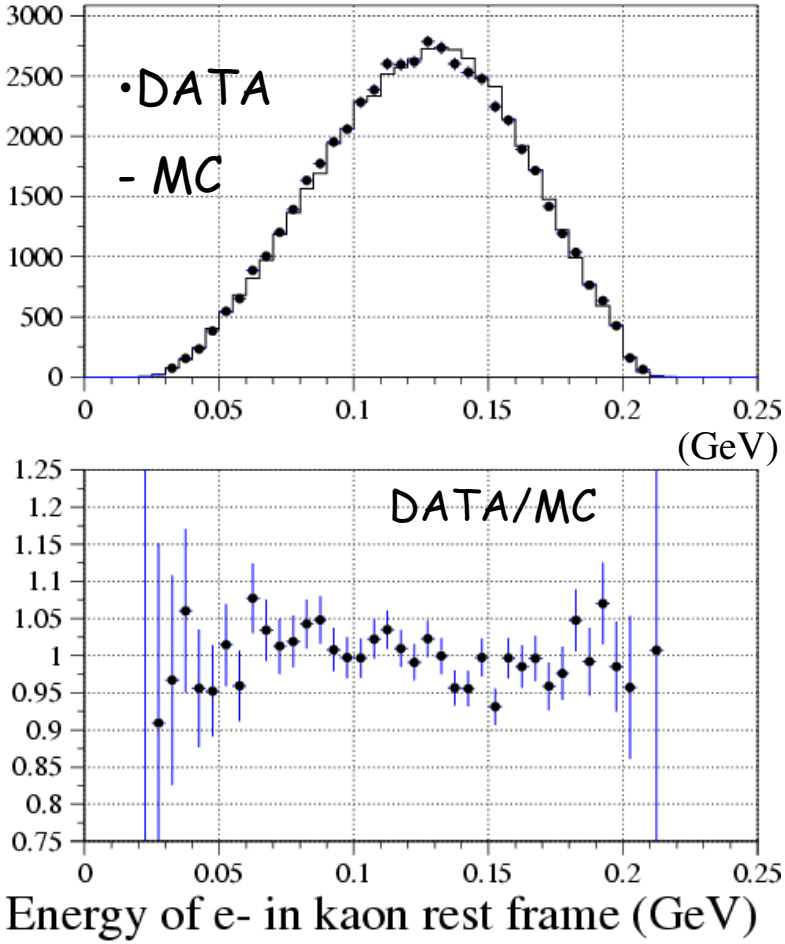
- $K_L \to \pi^+\pi^-$ results confirm disagreement with PDG04
- New Precision measurement $\Gamma(K\mu 3)/\Gamma(Ke3)$ and consistent with Standard Model
- Vus from $\Gamma(K\mu 3)$ and $\Gamma(Ke3)$ consistent
- $K^\pm \to \pi^\pm\pi^0\gamma$: 3sigma evidence for INT term
- More results from NA48/2 in neutral and semileptonic modes close to publication !

Spares

DATA/MC for $K^{\pm} \rightarrow \pi^0 e^{\pm} \nu$



Without radiative corrections



With radiative corrections

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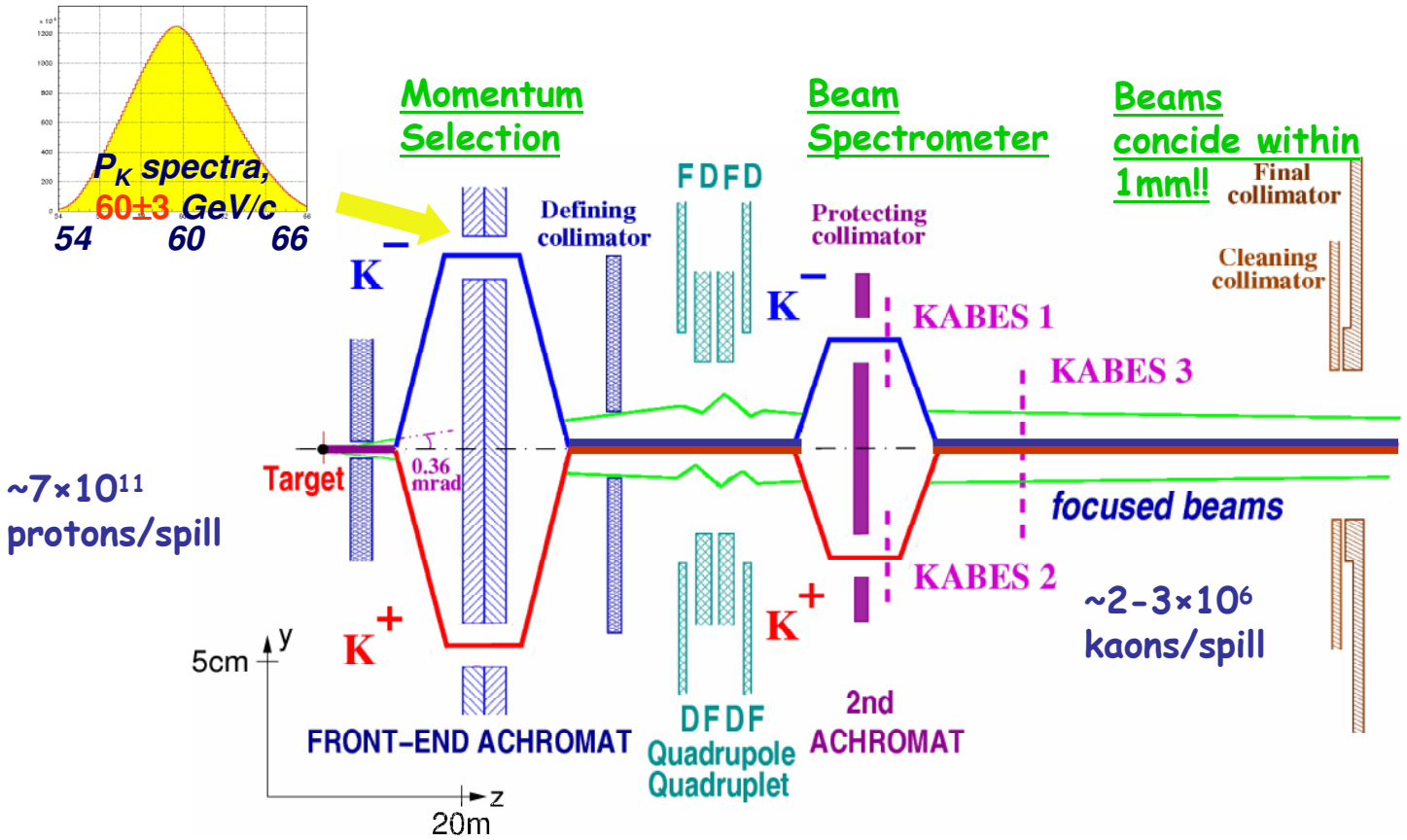
The NA48/2 Experiment

Simultaneous K^+ and K^- beams with $p_K = 60 \pm 3$ GeV/c .

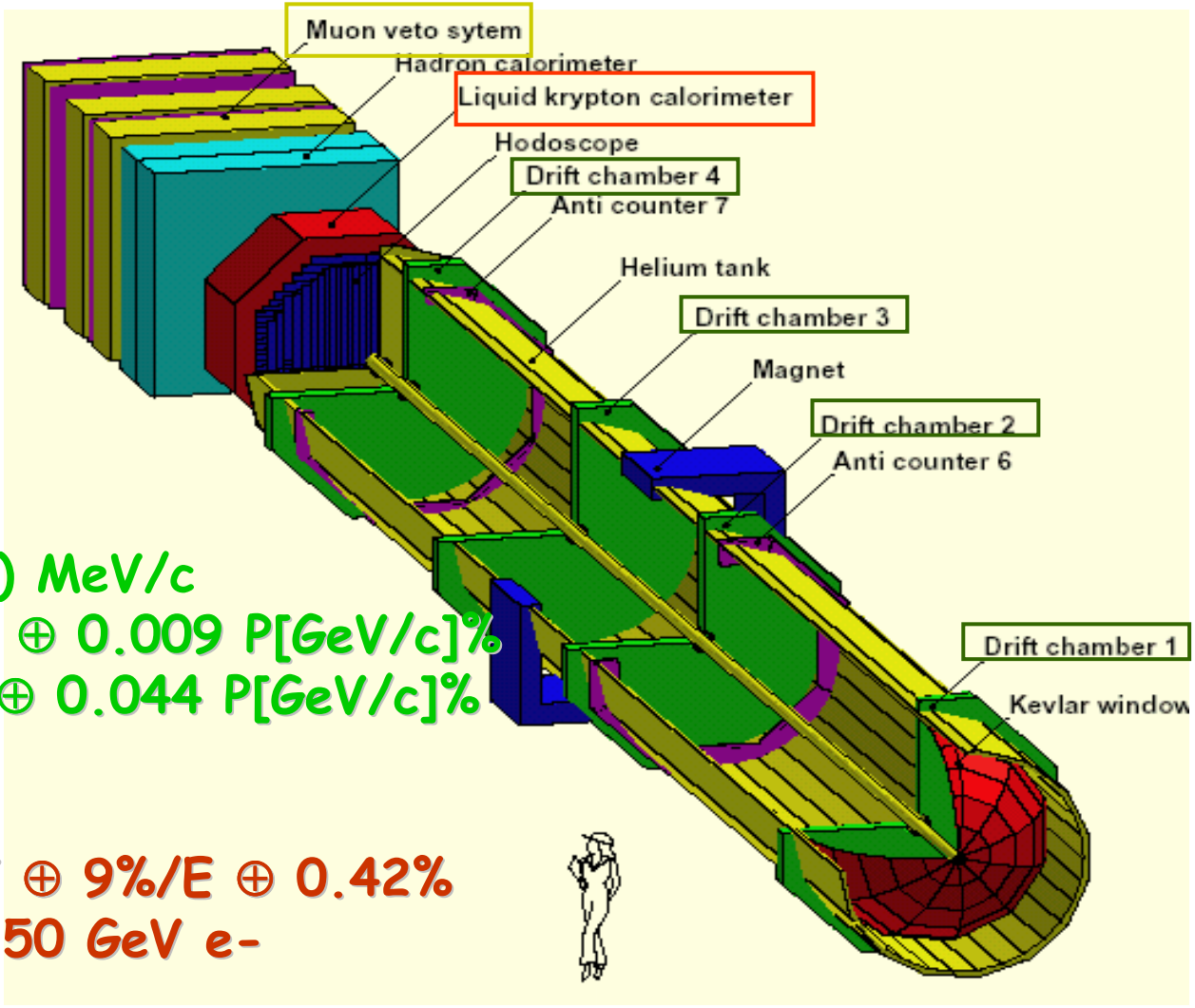


NA48 Detector

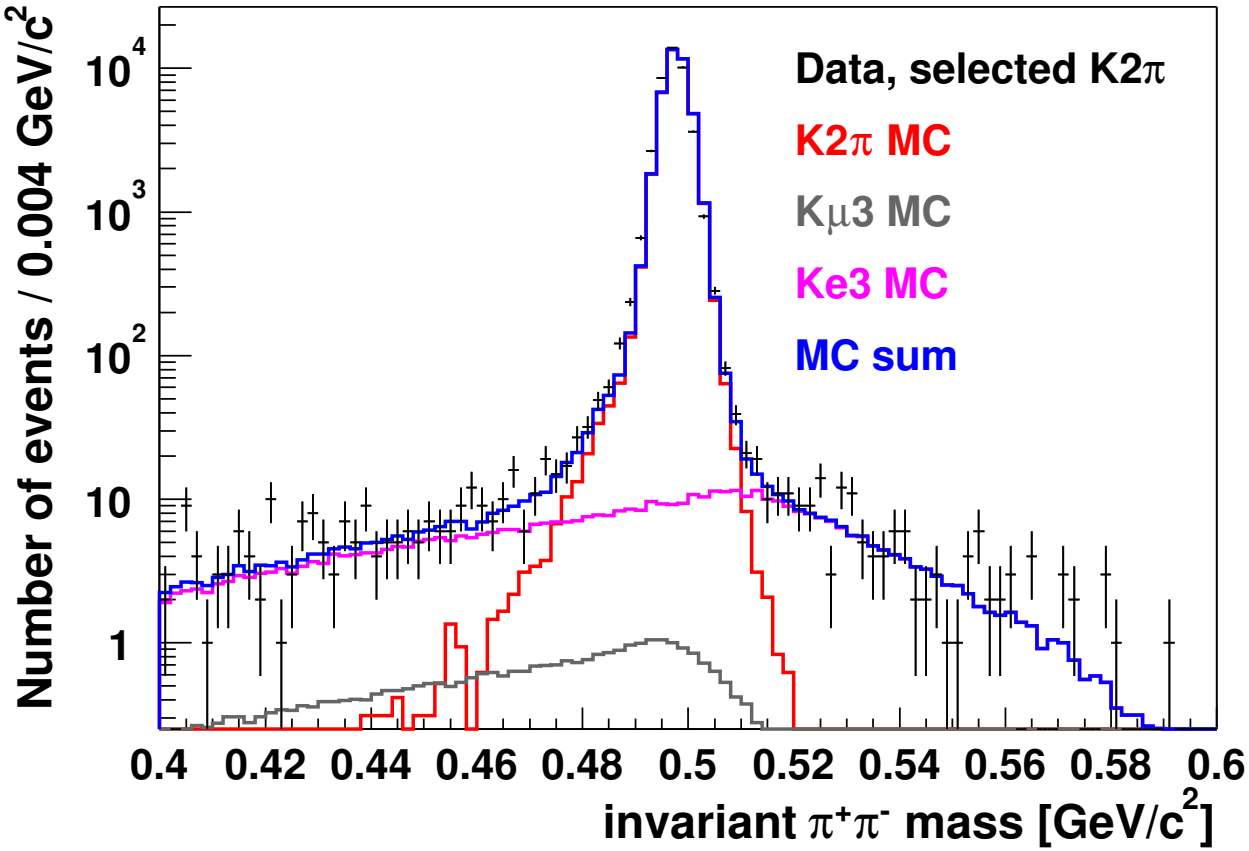
Muon system:
s(t) ~ 350 ps

Spectrometer:
p_T kick ~250 (125) MeV/c
$\sigma_{KLS}(P)/P \cong 0.48\% \oplus 0.009\ P[GeV/c]\%$
$\sigma_{K\pm}(P)/P \cong 1.02\% \oplus 0.044\ P[GeV/c]\%$

LKr Calorimeter:
$\sigma(E)/E \cong 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$
s(t) ~ 265 ps for 50 GeV e-



$\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_L \to \pi^{+-}e^{-+}\nu)$



$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$

Method of Measurement:
W distribution different for IB and DE.
Fit W distribution to obtain relative contributions from IB, DE and INT

Data Sample:
So far only used 30% of 2003-2004 data.

Region in T^*_π from $55 < T^*_\pi < 90$ MeV to:
$0 \text{ MeV} < T^*_\pi < 80 \text{ MeV}$
Selected events for fit: 124000 $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$
with $0.48 \text{ GeV/c}^2 < m_K < 0.51 \text{ GeV/c}^2$

Tiny Background (<1% of DE component).

Mistagging (wrong gamma-pairing) ~ 0.1%