Measurement of BR(K → eν)/BR(K → μν)

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for the NA62 (CERN) Collaboration

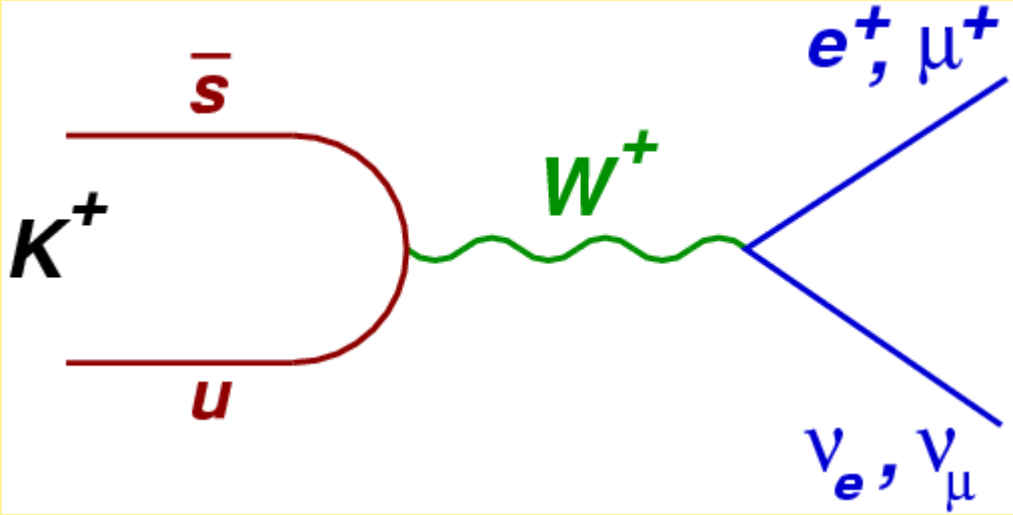
Ultra-rare Kaon Decays

$$\mathbf{K} \to \pi\nu\bar{\nu}$$

Leptonic Decays

$$\Gamma(P^+ \to \ell^+ \nu) = \frac{G_F^2 \left|V_{qq'}\right|^2 f_{P+}^2}{8\pi} m_{P+} m_\ell^2 \left(1 - \frac{m_\ell^2}{m_{P+}^2}\right)^2$$

- Test theoretical tools
- Search for new physics
  - Rates
  - Lepton Universality



Lepton Universality

$$\mathbf{K^+ \to \ell^+ \nu}$$

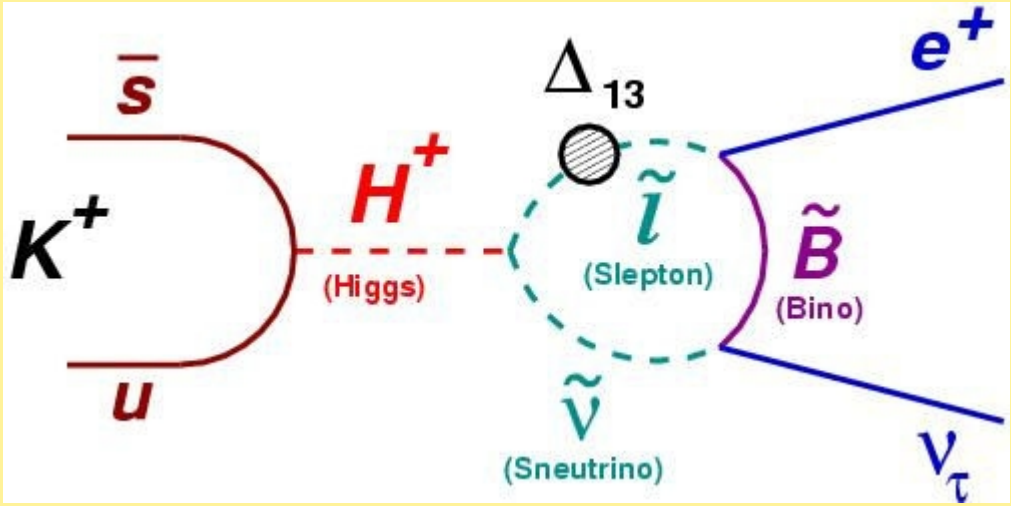
$$\mathbf{R_K \equiv \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)}}$$

$$\mathbf{= \frac{m_e^2}{m_\mu^2} \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2} \right)^2 (1 + \delta R_K^{\mathrm{rad\ cor}})}$$

[a few %]

$$\mathbf{R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}}$$

New Physics
eg., MSSM

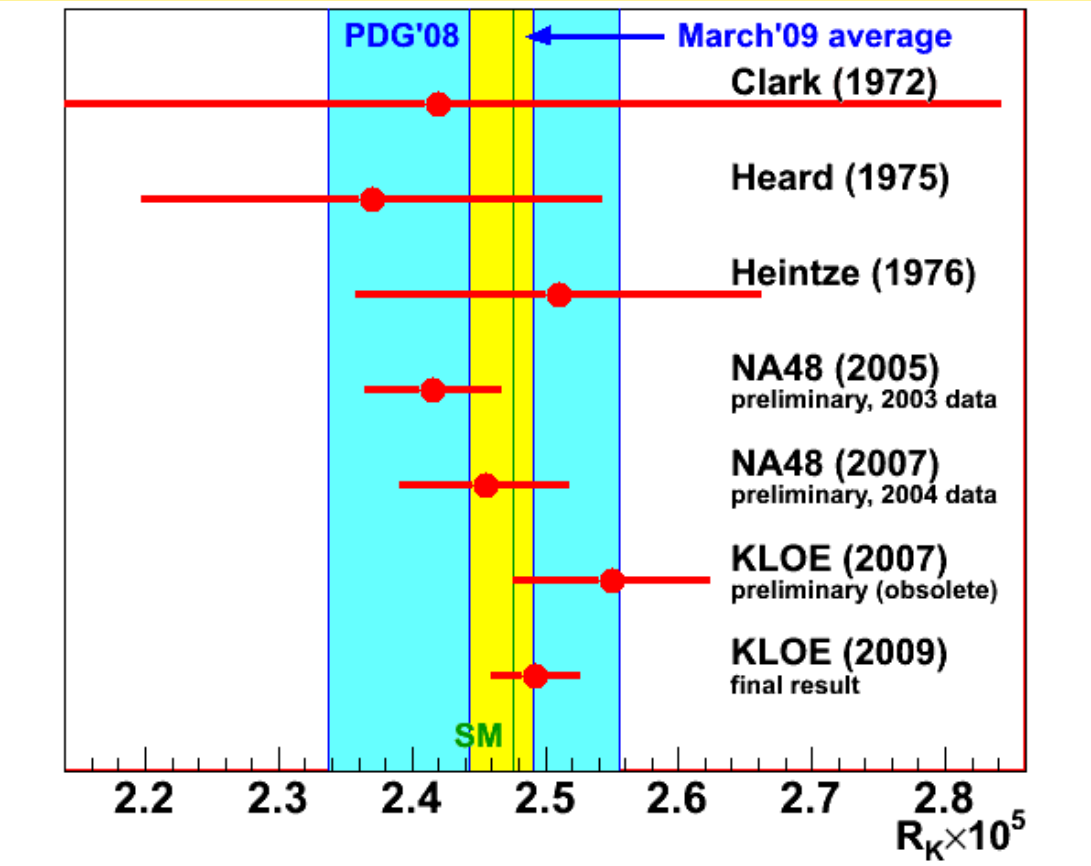


$$\mathbf{R_K^{MSSM} = R_K^{SM} \cdot \left[1 + \left(\frac{m_K}{m_{H^\pm}} \right)^4 \left(\frac{m_\tau}{m_e} \right)^2 |\Delta_{13}|^2 \tan^6 \beta \right]}$$

Experimental Status

$$\mathbf{R_K^{PDG} = (2.45 \pm 0.11) \times 10^{-5}}$$

PDG '08 (based on '70s measurements)

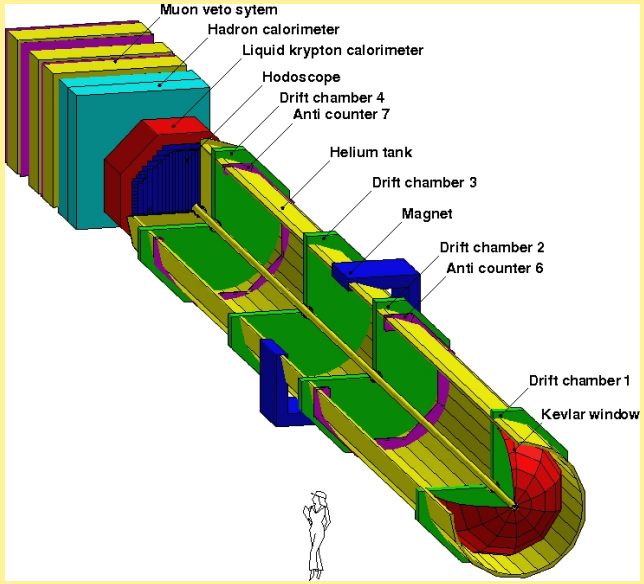


KLOE '09
~14K K_{e2} events

$$\mathbf{R_K^{KLOE} = (2.493 \pm 0.031) \times 10^{-5}}$$

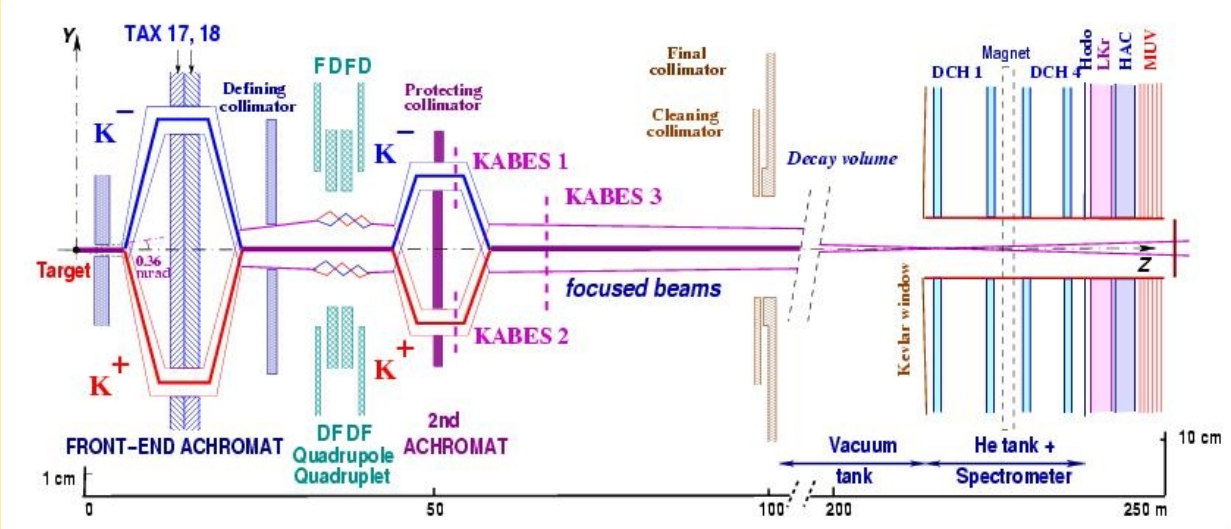
$$\mathbf{R_K^{AVE} = (2.467 \pm 0.024) \times 10^{-5}}$$

NA62
(Phase I: Using the NA48 Detector)



Goal:

- ~150 K K_{e2} events
- < 10% background
- $\delta R_K/R_K < 0.5\%$

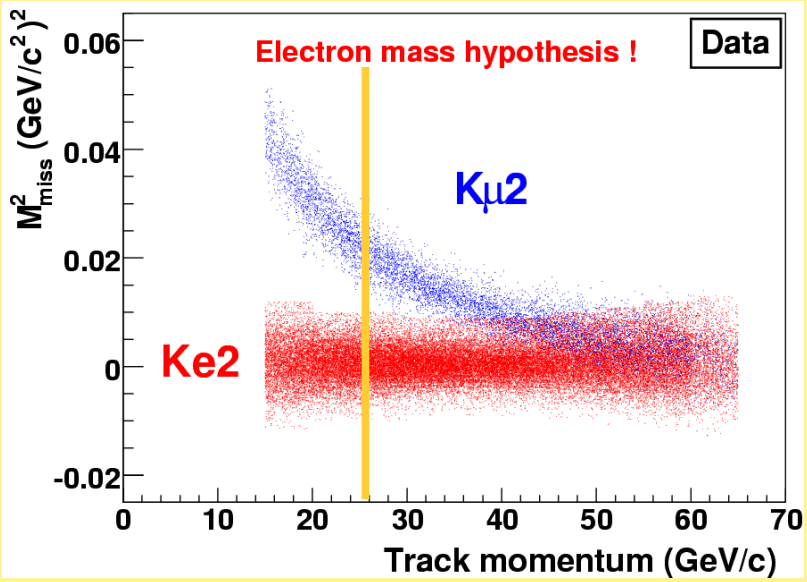


Data Taking and Analysis

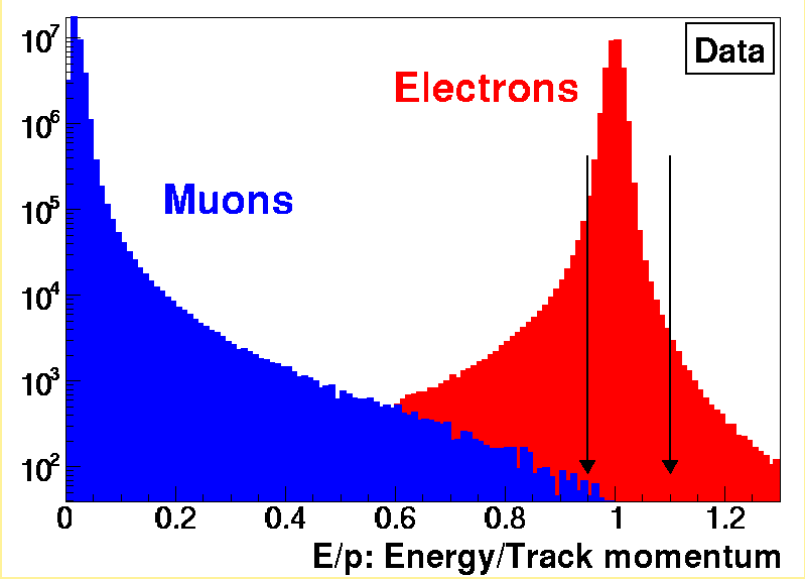
- 4-month run in 2007; 2-week (systematics) run in 2008
- Simultaneous K_{e2} – $K_{\mu 2}$ collection
- $$\mathbf{R_K = \frac{N(K_{e2}) - N_B(K_{e2})}{N(K_{\mu 2}) - N_B(K_{\mu 2})} \frac{A(K_{\mu 2})\epsilon_\mu \epsilon_{K_{\mu 2}}}{A(K_{e2})\epsilon_e \epsilon_{K_{e2}}} \frac{1}{\epsilon_{LKr}}}$$
- R_K calculated in 10 momentum bins (account for background-momentum dependencies)
- Primary systematic: $N_B(K_{e2})$

Event Selection

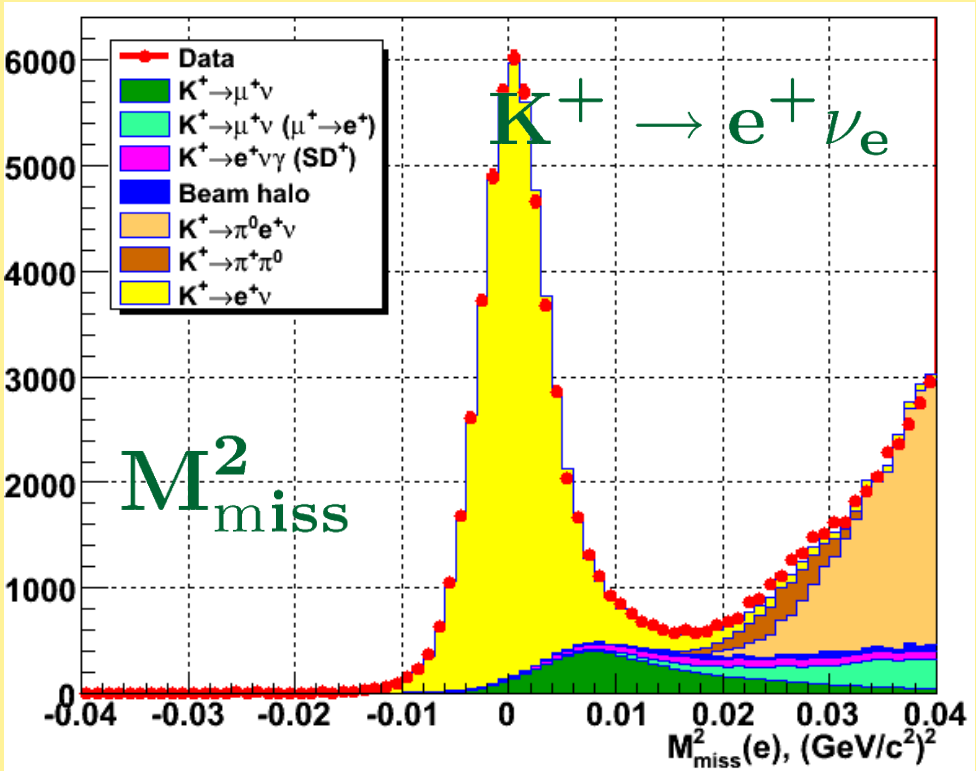
- Kinematics
  - Good for $p_\ell < 25$ GeV/c

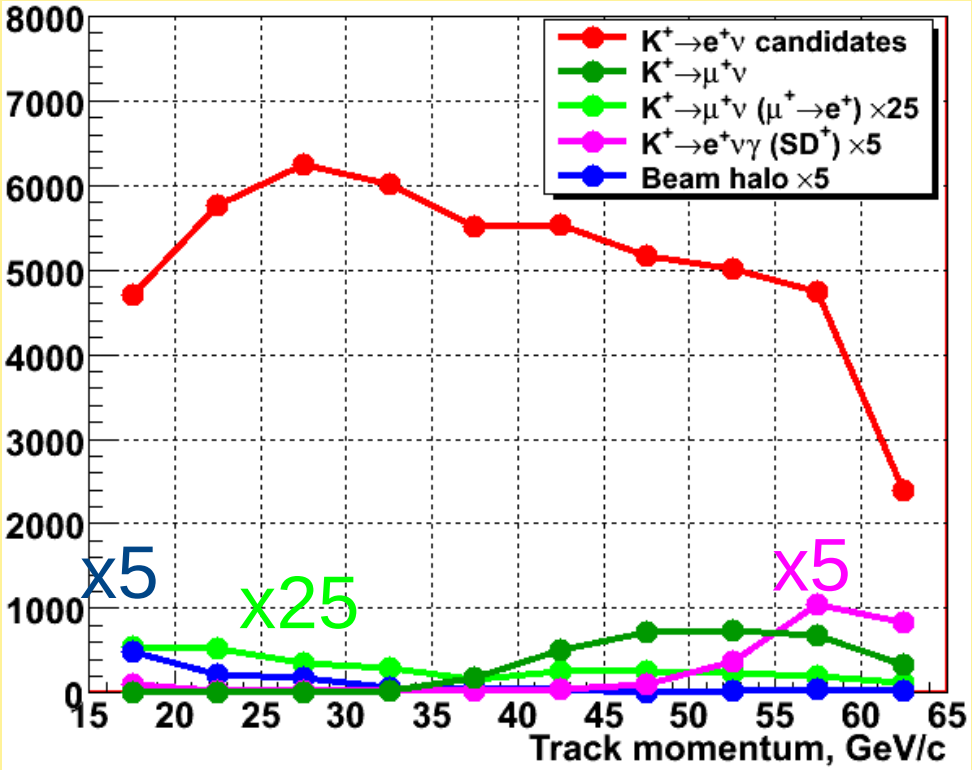


- E/p
  - e: $0.9 < E/p < 1.1$
  - μ: $E/p < 0.85$



40% of the Data, Preliminary

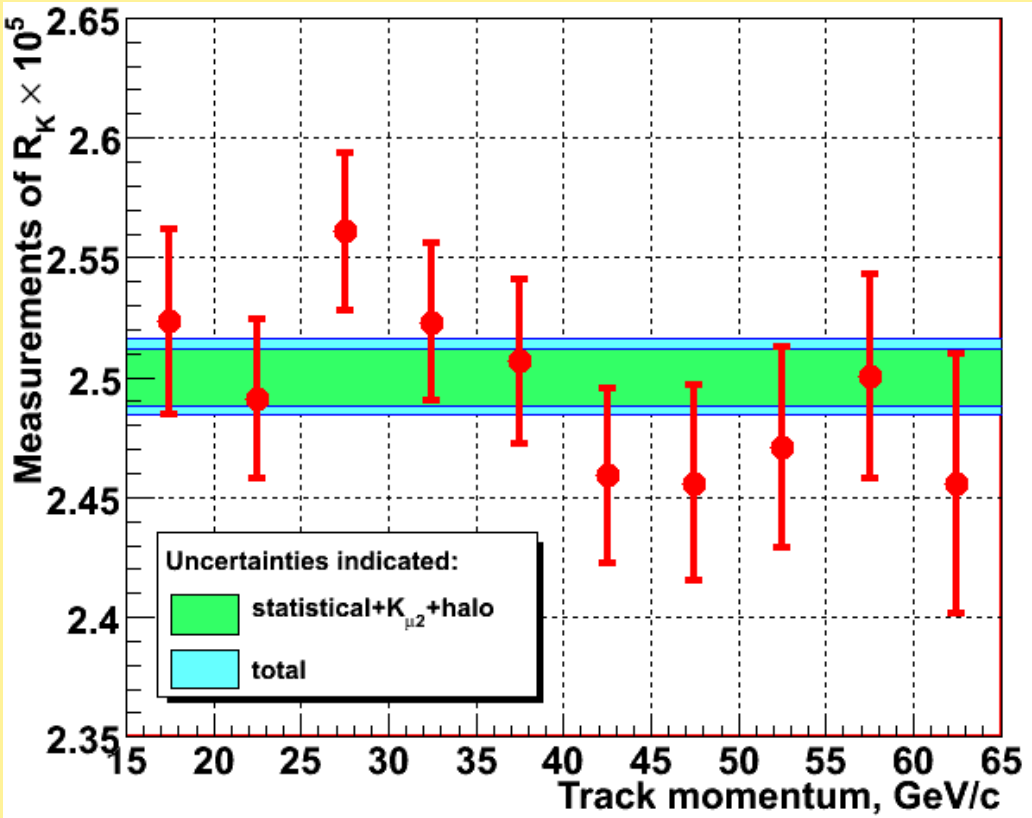


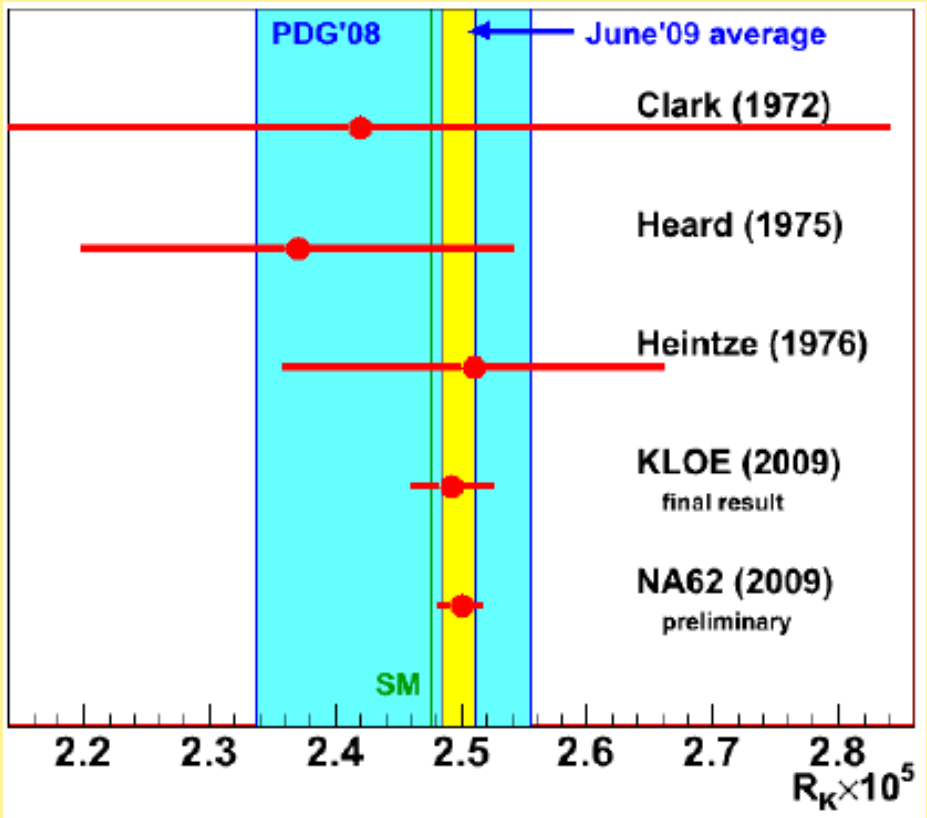


~51 K K_{e2} events, ~8% background

Preliminary Result

$$\mathbf{R_K = (2.500 \pm 0.012_{stat} \pm 0.011_{sys}) \times 10^{-5}}$$



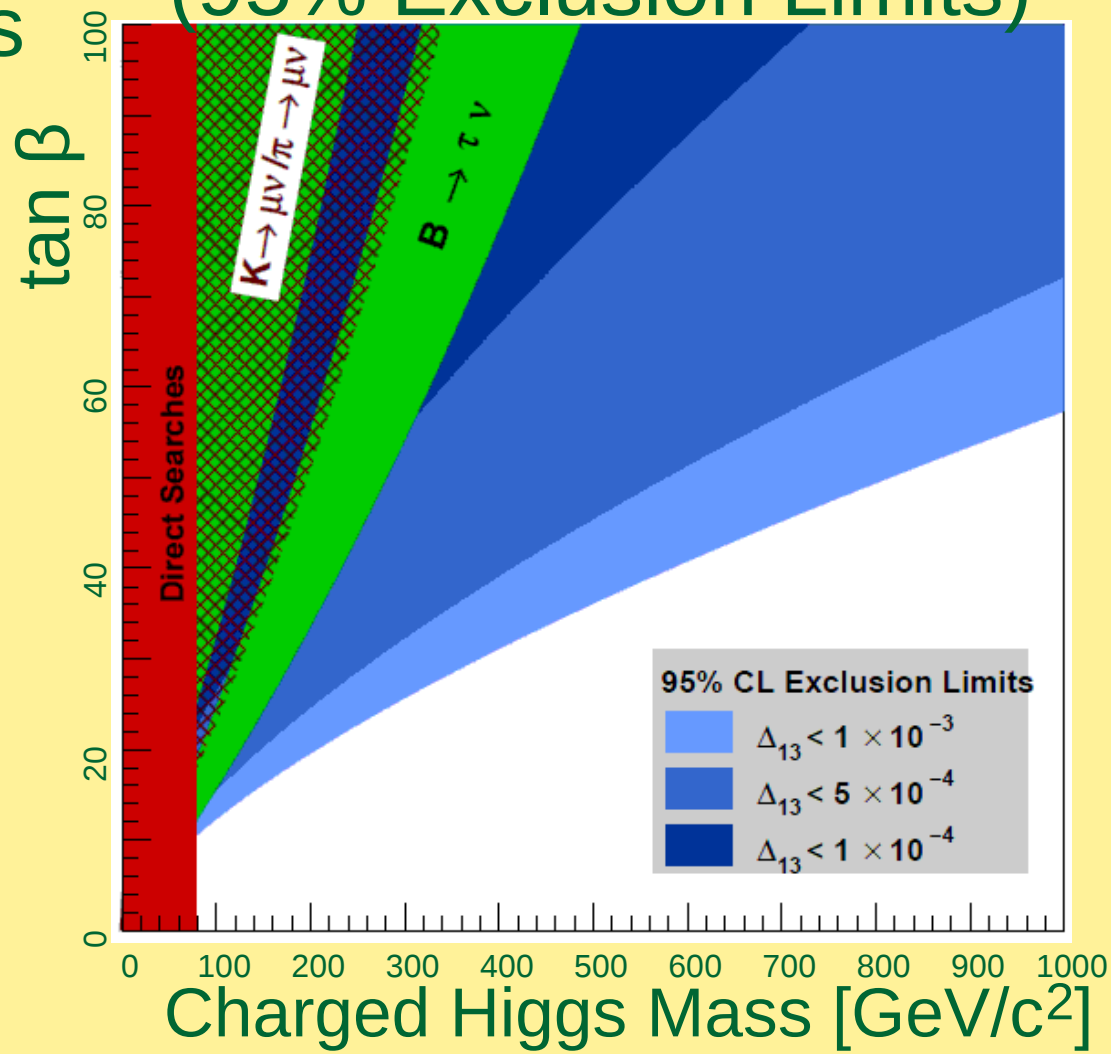


$$\mathbf{R_K^{Ave.} = (2.498 \pm 0.014) \times 10^{-5}}$$

R_K Conclusion

- Measurement agrees with Standard Model prediction to 1.5σ
- Total NA62 data set will yield 0.4%-0.5% measurement.

tan β vs m_H
(95% Exclusion Limits)

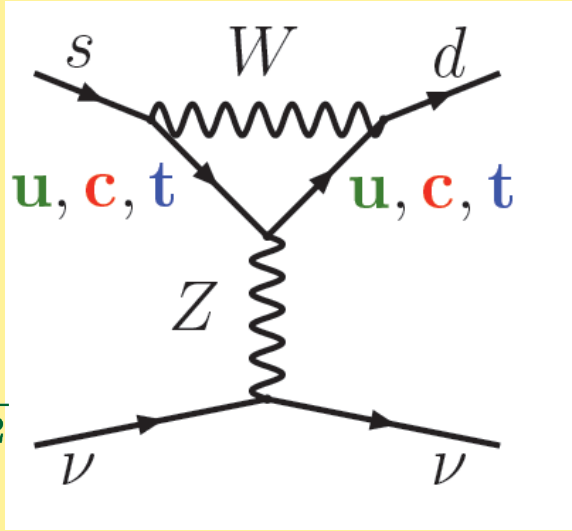


$\mathbf{K} \to \pi\nu\bar{\nu}$

- Strongly suppressed $(< \mathbf{10^{-10}})$
- Calculable with uncertainty $O(10\%)$

$$\mathcal{B}(\mathbf{K}^+ \to \pi^+\nu\bar{\nu}) = \mathbf{6r_{K^+}}\mathcal{B}(\mathbf{K}^+ \to \pi^0\mathbf{e}^+\nu)\frac{|\mathbf{G}_\ell|^2}{\mathbf{G_F^2}|\mathbf{V_{us}}|^2}$$

$$\mathcal{B}(\mathbf{K_L^0} \to \pi^0\nu\bar{\nu}) = \mathbf{6r_{K_L}}\frac{\tau_{\mathbf{K_L}}}{\tau_{\mathbf{K}^+}}\mathcal{B}(\mathbf{K}^+ \to \pi^0\mathbf{e}^+\nu)\frac{(\Im\mathbf{G}_\ell)^2}{\mathbf{G_F^2}|\mathbf{V_{us}}|^2}$$

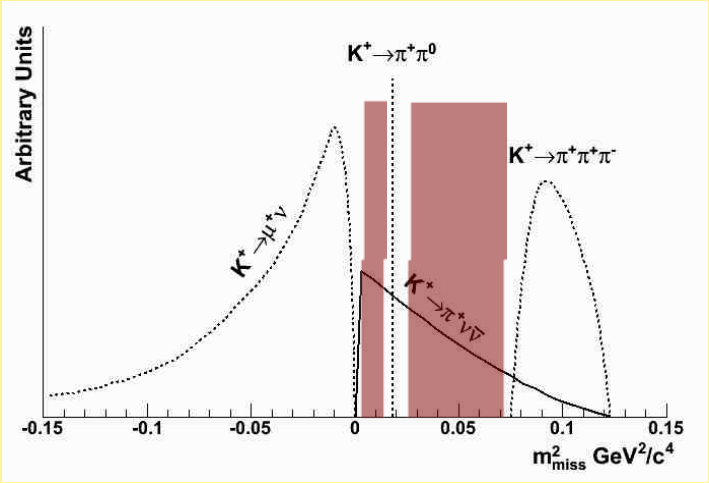


- Very sensitive to new physics

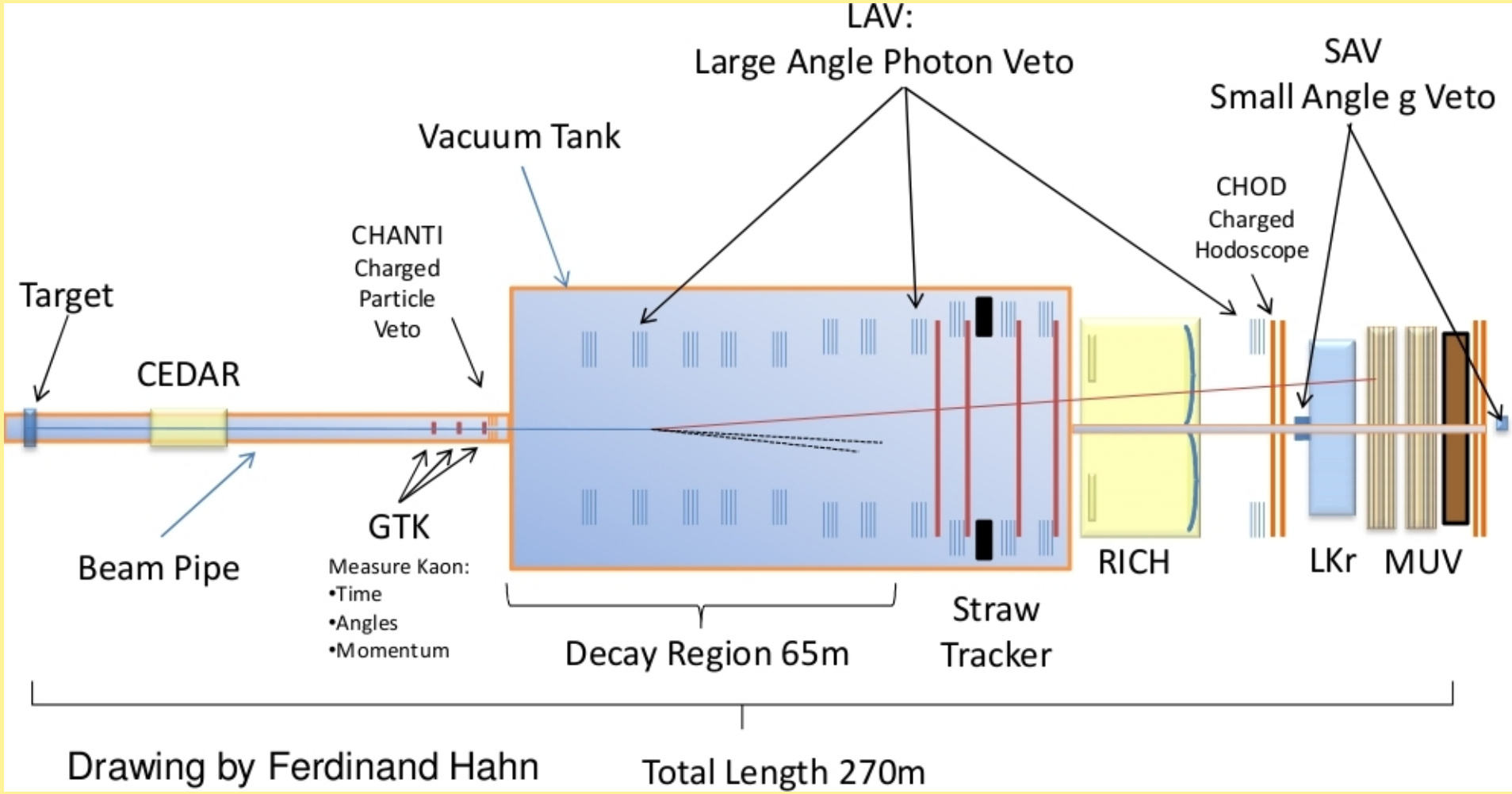
Decay	Branching Fraction $(\times 10^{10})$	
	Theory (SM)	Experiment
$K^+ \to \pi^+\nu\bar{\nu}(\gamma)$	0.85 ± 0.07	$1.73^{+1.15}_{-1.05}$ $\binom{\text{BNL}}{\text{E949}}$
$K_L^0 \to \pi^0\nu\bar{\nu}$	0.26 ± 0.04	< 670 [90% CL] $\binom{\text{KEK}}{\text{E391a}}$

NA62

- 10% measurement of $\mathbf{K}^+ \to \pi^+ \nu \bar{\nu}$
  - 10^{13} kaon decays (2 yrs); 10% bkgd uncertainty
- Decay-in-flight from high momentum beam
- High resolution and hermiticity
  - 92% of Γ constrained kinematically
  - $\sigma(m^2_{\mathrm{miss}}) \sim 10^{-3}\ \mathrm{GeV}^2/c^4$
  - Timing to match Kπ
  - Veto photons and muons
- Particle identification



NA62 Detector Layout



Schedule and Sensitivity

- First $\mathbf{K}^+ \to \pi^+ \nu \bar{\nu}$ data in second half of 2012

Source		Events/yr
Signal		55
Background		7.5-9.4
Channel	Fraction (%)	
$\mathbf{K}^+ \to \pi^+ \pi^{\mathbf{0}}$	4.3-7.5	
$\mathbf{K}^+ \to \mu^+ \nu$	2.2	
$\mathbf{K}^+ \to \mathbf{e}^+ \pi^+ \pi^- \nu$	≤3	
$\mathrm{Other\ 3-track\ modes}$	≤1.5	
$\mathbf{K}^+ \to \pi^+ \pi^{\mathbf{0}} \gamma$	~2	
$\mathbf{K}^+ \to \mu^+ \nu \gamma$	~0.7	