Measuring the the Branching Ratios of semileptonic Kaon decays and their Form Factors

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Contents

Proposal

In addition to measure the Branching Ratios of the semileptonic Kaon decays (K_{l3}) compare also their Form Factors

Leptonic channels

Non radiative

- $K^+ \to \pi^0 e^+ \nu$ (K_{e3})
- $K^+ \to \pi^0 \mu^+ \nu$ ($K_{\mu 3}$)

Radiative

- $K^+ \to \pi^0 e^+ \nu\gamma$ ($K_{e3\gamma}$)
- $K^+ \to \pi^0 \mu^+ \nu\gamma$ ($K_{\mu 3\gamma}$)

Control sample

- $K_{\pi 2} : K^+ \to \pi^+\pi^0$

Measured Branching Ratios of non radiative modes

- $K^+ \to \pi^0 e^+ \nu$ (K_{e3}) $5.07 \pm 0.04\%$
- $K^+ \to \pi^0 \mu^+ \nu$ ($K_{\mu 3}$) $3.352 \pm 0.033\%$

Measured Branching Ratios of radiative modes

- $K^+ \to \pi^0 e^+ \nu\gamma$ ($K_{e3\gamma}$) $2.56 \pm 0.16\%$
- $K^+ \to \pi^0 \mu^+ \nu\gamma$ ($K_{\mu 3\gamma}$) $1.25 \pm 0.25\%$

Form Factors

Differential K_{l3} decay width depending on the lepton and pion energies E_l and E_π is given by the Dalitz plot density:

$$\frac{d^2\Gamma(K_{l3})}{dE_l dE_\pi} = \rho(E_l, E_\pi) = N(A_1|f_+(t)|^2 + A_2 f_+(t) f_-(t) + A_3|f_-(t)|^2)$$

$t = Q^2 = (P_K - P_\pi)$: 4-momentum transfer to the leptonic system
N: numerical factor
$f_-(t) = (f_0(t) - f_+(t))(m_K^2 - m_{\pi^0}^2)/t$
$f_+(t)$ and $f_0(t)$: **vector and scalar form factors**
m_K: kaon mass
m_{π^0}: neutral pion mass

The kinematic factors are:
$A_1 = m_K(2E_l E_\nu - m_K(E_\pi^{max} - E_\pi)) + m_l^2((E_\pi^{max} - E_\pi)/4 - E_\nu)$
$A_2 = m_l^2(E_\nu - (E_\pi^{max} - E_\pi)/2)$
$A_3 = m_l^2(E_\pi^{max} - E_\pi)/4$

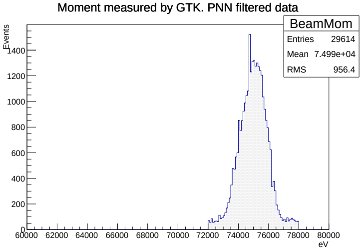
Where: $E_\pi^{max} = (m_K^2 + m_{\pi^0}^2 - m_l^2)/2m_K$
$E_\nu = m_K - E_l - E_\pi$

Event Selection Criteria

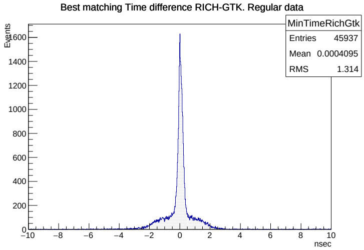
Upstream Event Selection Criteria

- Positively identified in KTAG
- Track in 3 GTK station, the closest in time with RICH
- Kaon decay vertex in the fiducial volume

  $110m < Z_{vertex} < 180m$



Momentum as measured with GTK



Minimun $Time_{rich} - Time_{GTK}$

Downstream: Charged Particle Selection Criteria

- General criteria
  - Only one charged track downstream with charge $= +1$
  - Hits in 4 STRAW chambers
  - In the geometrical acceptance of CHOD, LKr, and MUV3
  - All signals in time ($<$1.5 ns)

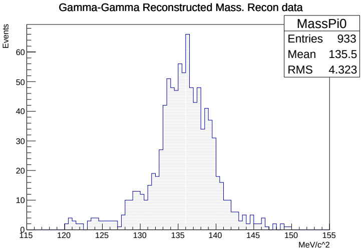
- For the e^+
  - RICH likelihood most probable for e^+
  - No MUV3 association
- For the μ^+
  - RICH likelihood most probable for μ^+
  - MUV3 positive association
- For the π^+
  - RICH likelihood most probable for π^+
  - No MUV3 association

Cut in E/P in LKr was removed due to assymetric efficiency for three cases

π^0 Selection Criteria

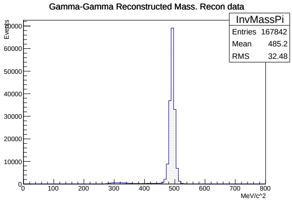
Only from LKr Clusters

- Two clusters in time in LKr
  - Far from the charged track projection
  - Far from dead cells
- $|\text{Recon mass - } m_{\pi^0}| < 15 MeV/c$

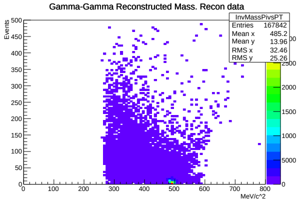


Gamma - gamma reconstructed mass

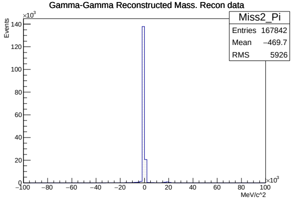
Control Sample $K^+ \to \pi^+\pi^0$



Reconstructed mass from $\pi^+\pi^0$



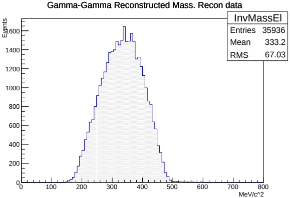
Reconstructed mass for $\pi^+\pi^0$ compared to Pt



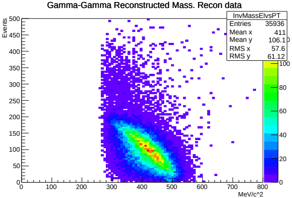
$$m^2_{miss} = (\mathbf{P_K} - \mathbf{P}_{\pi^+} + \mathbf{P}_{\pi^0})^2$$

Pt distribution is contaminated with unknown background, correlation between Pt and m^2_{miss} cuts is under study.

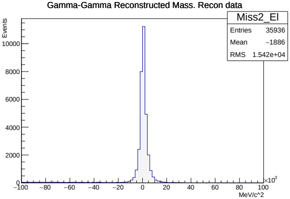
$K^+ \to e^+\pi^0\nu_e$



Reconstructed mass from $e^+\pi^0$

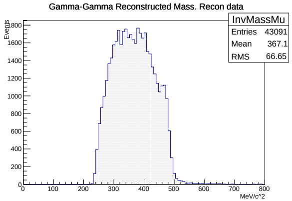


Reconstructed mass for $e^+\pi^0$ compared to Pt

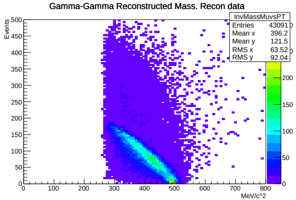


$$m^2_{miss} = (\mathbf{P_K} - \mathbf{P_{e^+}} + \mathbf{P_{\pi^0}})^2$$

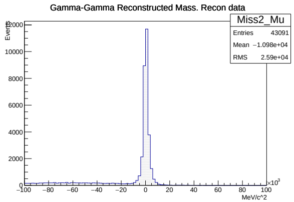
$K^+ \to \mu^+\pi^0\nu_\mu$



Reconstructed mass from $\mu^+\pi^0$



Reconstructed mass for $\mu^+\pi^0$ compared to Pt



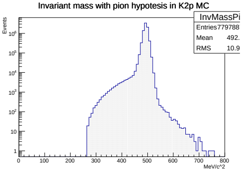
$$m^2_{miss} = (\mathbf{P_K} - \mathbf{P}_{\mu^+} + \mathbf{P}_{\pi^0})^2$$

Aproximation to Montecarlo

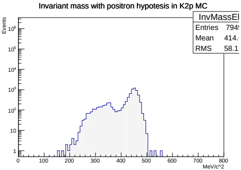
Montecarlo: K2p

$K^+ \to \pi^+\pi^0$ 40 M events simulated

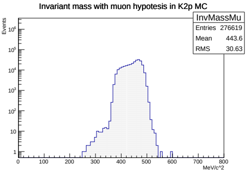
Invariant mass with different hypotesis



Recon mass for $\pi^+\pi^0$

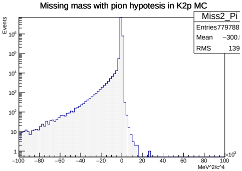


Recon mass for $e^+\pi^0$

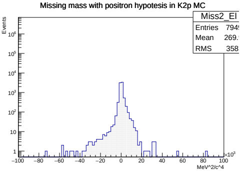


Recon mass for $\mu^+\pi^0$

Missing mass with different hypotesis



$m^2_{miss} = (\mathbf{P_K} - \mathbf{P}_{\pi^+} + \mathbf{P}_{\pi^0})^2$



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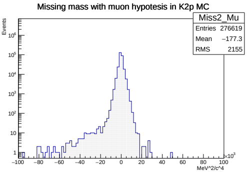
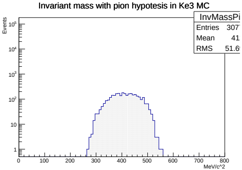


$m^2_{miss} = (\mathbf{P_K} - \mathbf{P}_{\mu^+} + \mathbf{P}_{\pi^0})^2$

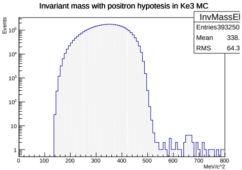
Montecarlo: Ke3

$K^+ \to e^+\pi^0\nu$ 20 M events simulated

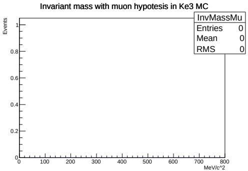
Invariant mass with different hypotesis



Recon mass for $\pi^+\pi^0$

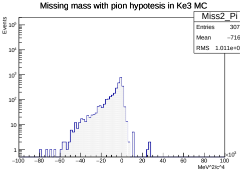


Recon mass for $e^+\pi^0$



Recon mass for $\mu^+\pi^0$

Missing mass with different hypotesis



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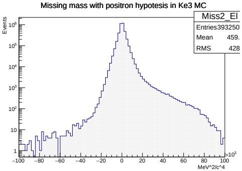

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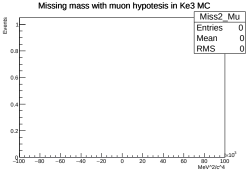
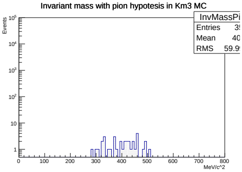


$m^2_{miss} = (\mathbf{P_K} - \mathbf{P}_{\mu^+} + \mathbf{P}_{\pi^0})^2$

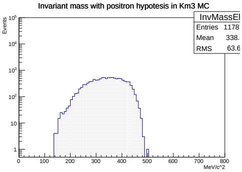
Montecarlo: Km3

$K^+ \to \mu^+\pi^0\nu$ 14 M events simulated

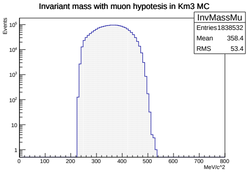
Invariant mass with different hypotesis



Reconstructed mass for $\pi^+\pi^0$

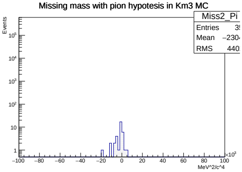


Reconstructed mass for $e^+\pi^0$



Reconstructed mass for $\mu^+\pi^0$

Missing mass with different hypotesis



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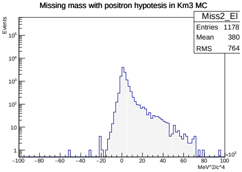

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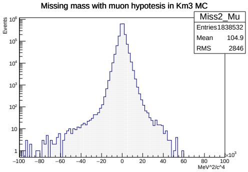
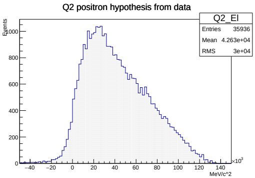


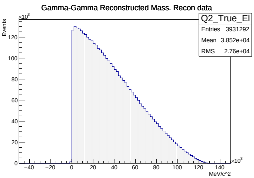
$$m^2_{miss} = (\mathbf{P_K} - \mathbf{P}_{\mu^+} + \mathbf{P}_{\pi^0})^2$$

Q^2 studies

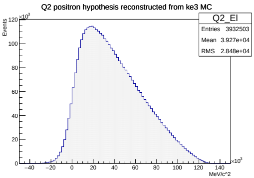
Q^2_{Ke3}



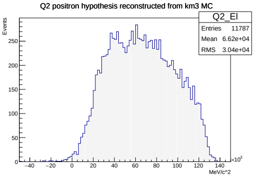
Q^2 with reconstructed data



True Q^2 extracted from MC

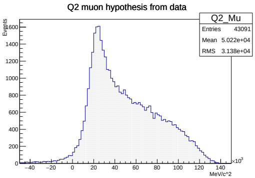


Q^2 reco from ke3 MC

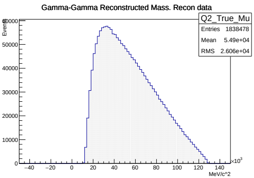


Q^2 reco from km3 MC (miss-id)

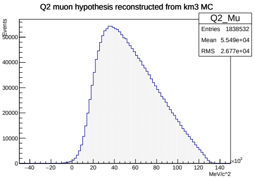
Q^2_{Km3}



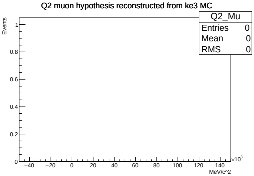
Q^2 with reconstructed data



True Q^2 extracted from MC



Q^2 reco from km3 MC



Q^2 reco from ke3 MC (miss-id)

Summary

Summary

- First perspective for studing semileptonic Form Factors.
- Selection criteria is being refined
- Background is being defined
- MC strategy is being developed for background and systematic studies
- First studies in Q2 are presented

Results shown with ∼0.2% of total data

Ongoing...

- Normalize all MC samples to fine-tune background studies
- Understand why Q^2 distributions are different (this can take a while)
  - background contamination
  - systematics
- Find sources of backgrund (this can also take a while)

Long term...

- Evaluation of trigger efficiency
- Evaluation of experimental acceptance
- Evaluation of cut efficiency

AOB

Other ongoing task

- Along the 2018 run
  - Doing shifts (a lot!!)
  - Expert of some subsystems (OM, LKr)
  - Shifts management
  - RICH efficiency checking
- Beca de Movilidad $->$ Thank you for all your help!!
- FPCP 2018 (India) $->$ HNL with NA62 2015 data.