Status of $K^{00}e4$ analysis

Outline

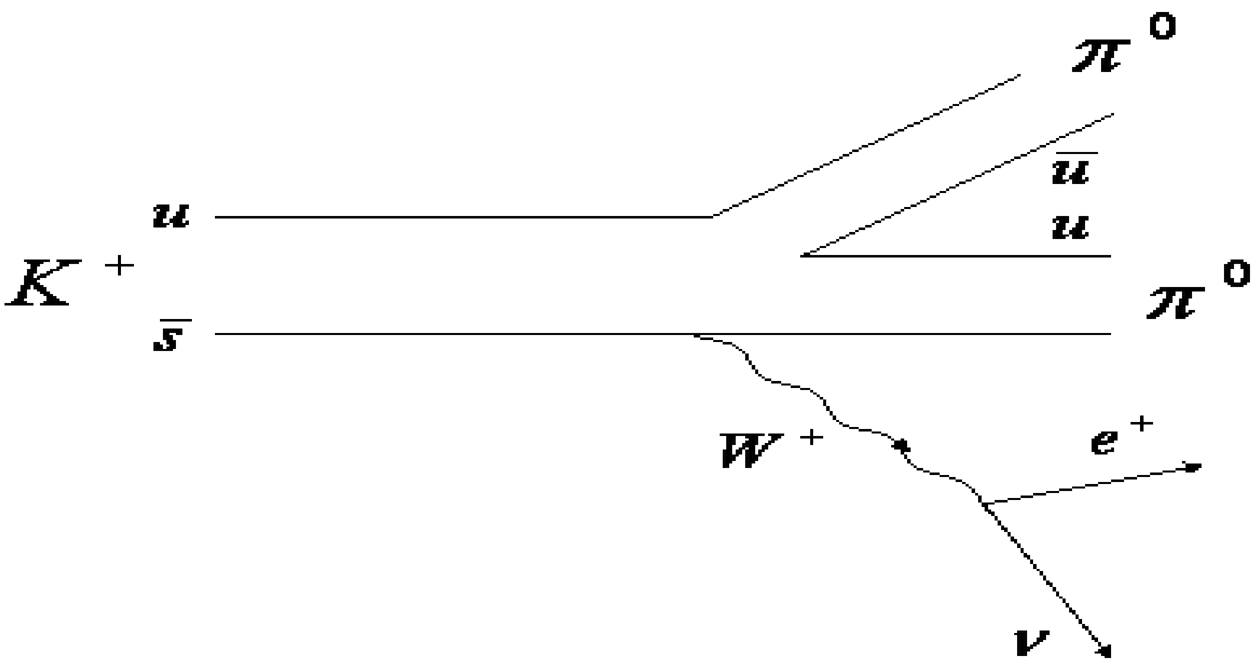
- Motivations.
- Measurement strategy.
- Background analysis and rejection.
- Conclusions.

The $K^\pm \to \pi^0\pi^0 e^\pm \nu_e$ ($K^{00}e4$) decay

Signal PDG value: $(2.2\pm0.4)\cdot10^{-5}$
$K^{00}\pi3$ PDG value: $(1.757\pm0.024)\cdot10^{-2}$
Ke3 PDG value: $(4.98\pm0.07)\cdot10^{-2}$

- Allows the study of $\pi-\pi$ scattering
- Selection rule $\Delta I=½$
- Form factor F

$$\Gamma(K^{00}e4) = 0.8\cdot|V_{us}|^2\cdot|F|^2\cdot10^3 s^{-1}$$



Aim is to measure a relative BR

Aim is to measure a relative branching ratio
normalized to $K^{00}\pi3$ events without using Tag algorithm

$$\frac{BR(K^{\pm}\rightarrow\pi^{0}\pi^{0}e^{\pm}\nu_{e})}{BR(K^{\pm}\rightarrow\pi^{0}\pi^{0}\pi^{\pm})}=\frac{N^{Obs}_{K^{00}e4}}{N^{Obs}_{K^{00}\pi3}}\cdot\frac{\varepsilon_{K^{00}\pi3}}{\varepsilon_{K^{00}e4}}$$

The normalization to $K^{00}\pi3$ events guarantees a cancellation
of the systematic effects.

Measurement Strategy

The measurement strategy is articulated in the following steps:

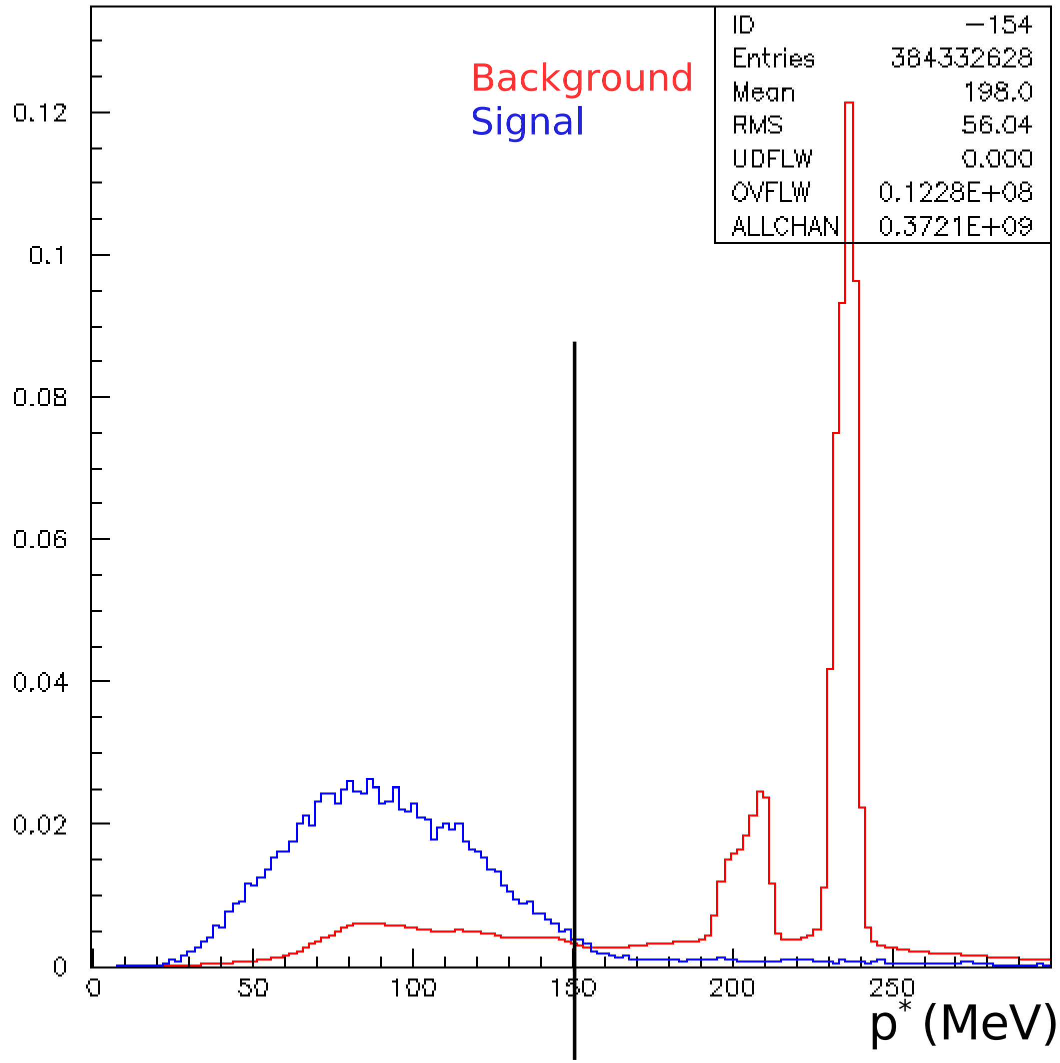
- Searching for a $K^{\pm}$ track starting from $\Phi \rightarrow K^{+}K^{-}$ stream information.
- Neutral vertex with 2 π^{0}.
- π^{0} reconstruction.
- Kinematic fits.
- π–e discrimination by t.o.f. measurement.
- Background rejection by using Likelihood ratio method.

Step 1: Looking for $K^{\pm}$

- We ask for the event to be in the $\Phi \rightarrow K^{+}K^{-}$ stream.
- We look for tracks with $80 < p < 120$ Mev.
  $|z_{pca}| < 6$ cm.
  $\rho_{pca} < 5$ cm.
- We ask for a vertex in the fiducial volume.

We have ~97.5% of true charged kaon track.

Step 1: Looking for $K^{\pm}$



p^* is the secondary charged 3-momentum in the Kaon rest frame

Step 2: Neutral vertex

Allow the selection of events with 2 π^0 in the final state

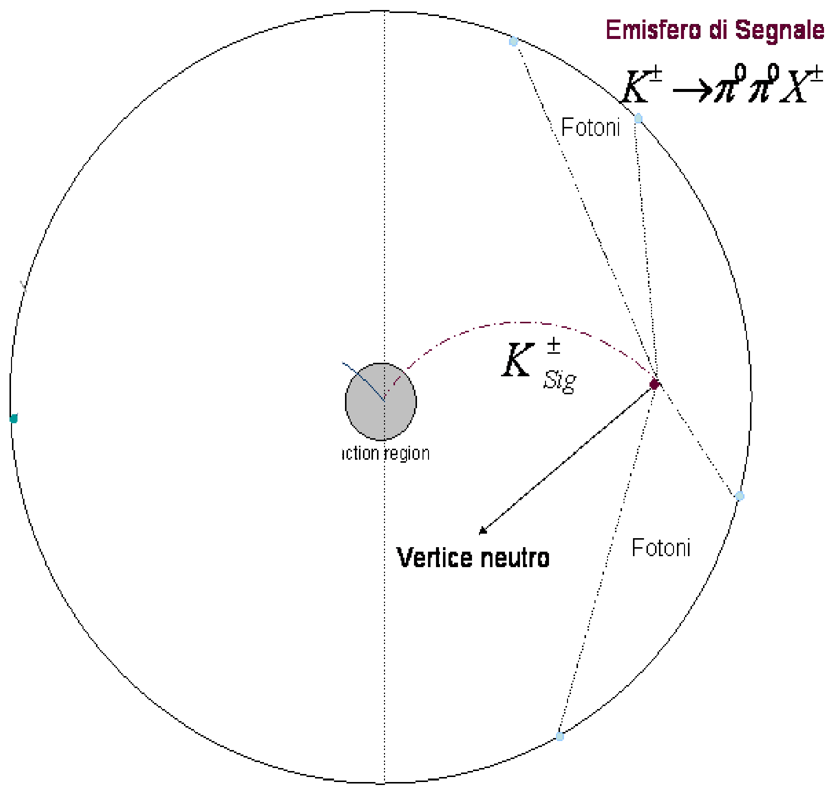
$$K^\pm \rightarrow \pi^0\pi^0X^\pm$$

The neutral vertex must satisfy the following requests:

- 4 neutral clusters on time

$(t - r/c)_{\gamma 1} = (t - r/c)_{\gamma 2} = (t - r/c)_{\gamma 3} = (t - r/c)_{\gamma 4}$

- consistecy between charged and neutral vertex



Step 3: π^0 reconstruction

- Cut on χ^2 of the association $\gamma\gamma \rightarrow \pi^0$
- Cut on $\Delta\chi^2 = |\chi^2_{best} - \chi^2_{near}|$

We have ~99.6% of true charged kaon track.

The purity (events with 2 π^0) is ~ 90%.

Signal: 2207
$K^{00}\pi3$: 1218600
Ke3: 48606
S/B ratio: 0.0017

Step 4: Kinematic fits

We run two kinematic fits:

$K^{00}\pi 3$ hypothesis

- 4-momentum conservation
- π^0 invariant mass
- clusters on time

$K^{00}e4$ hypothesis

- missing 4-momentum having zero mass
- π^0 invariant mass
- clusters on time

Step 4: Kinematic fits

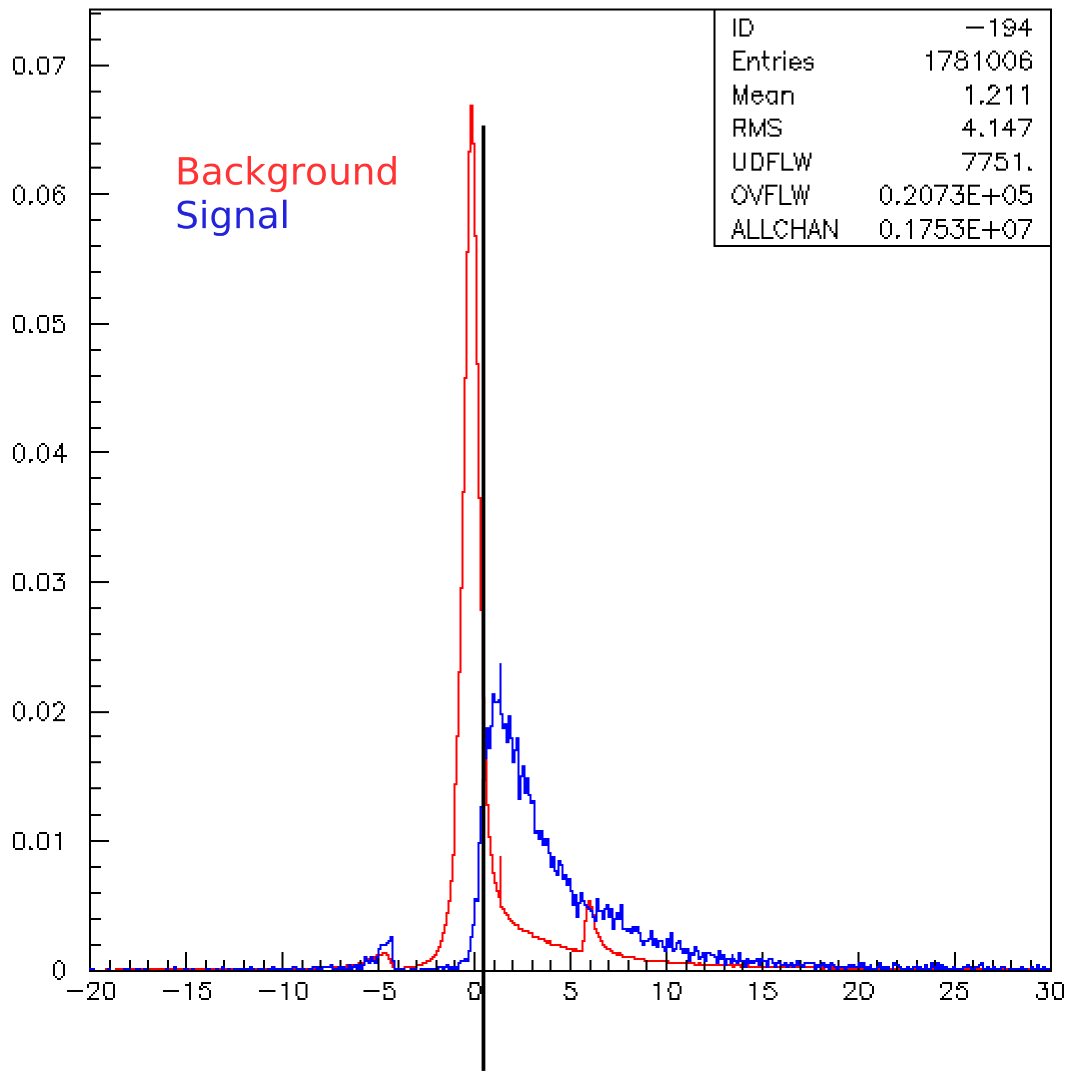
We look at the $\chi^2_B - \chi^2_S$ distribution.

χ^2_B is the χ^2 given by the kinematic fit in $K^{00}\pi3$ hypothesis

χ^2_S is the χ^2 given by the kinematic fit in $K^{00}e4$ hypothesis

We cut requiring $\chi^2_B - \chi^2_S > 0.5$

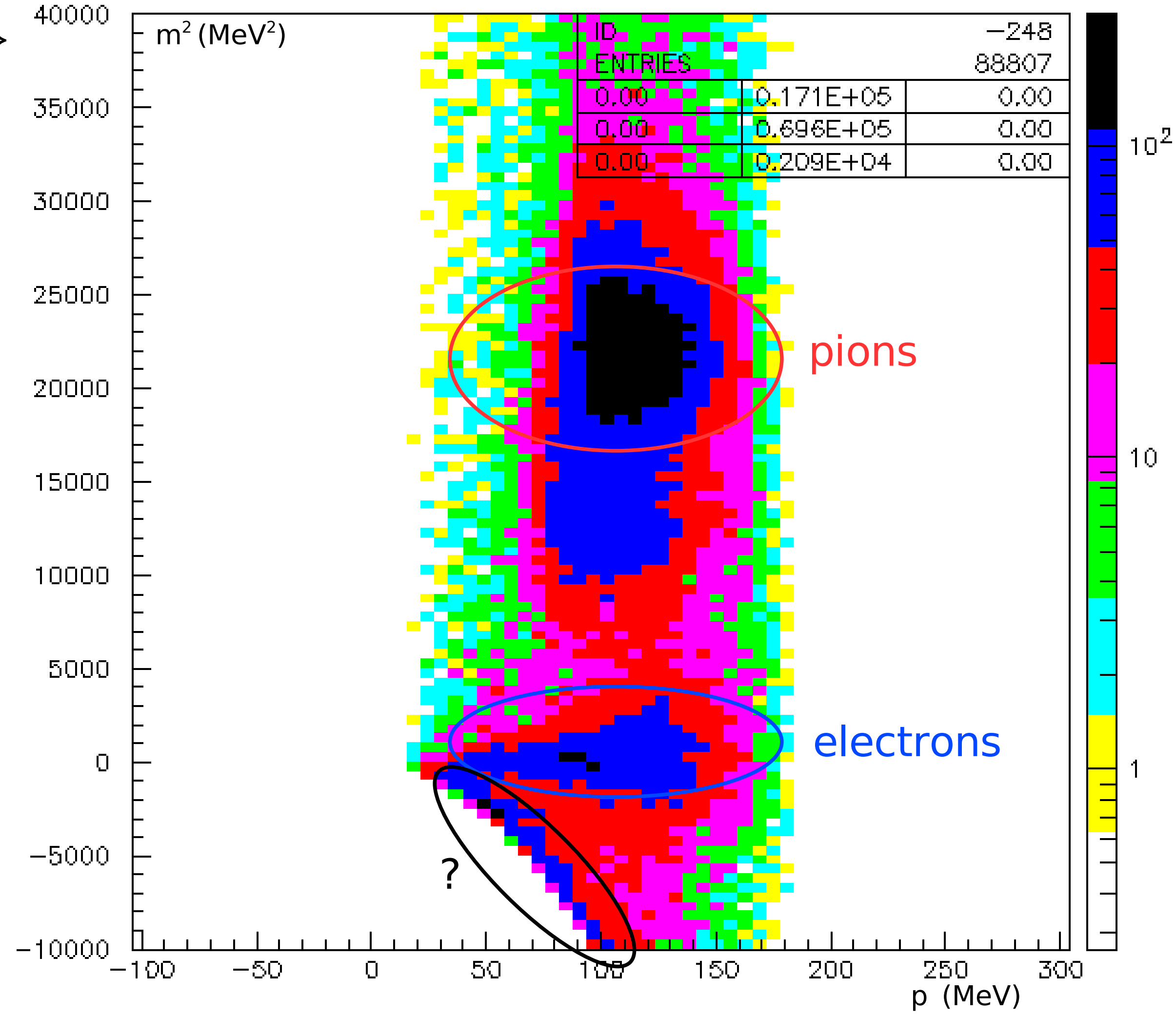
Signal: 1888
$K^{00}\pi3$: 300630
Ke3: 29163
S/B ratio: 0.0057



Step 5: TCA association

Allows to do π–e discrimination by t.o.f. measurement

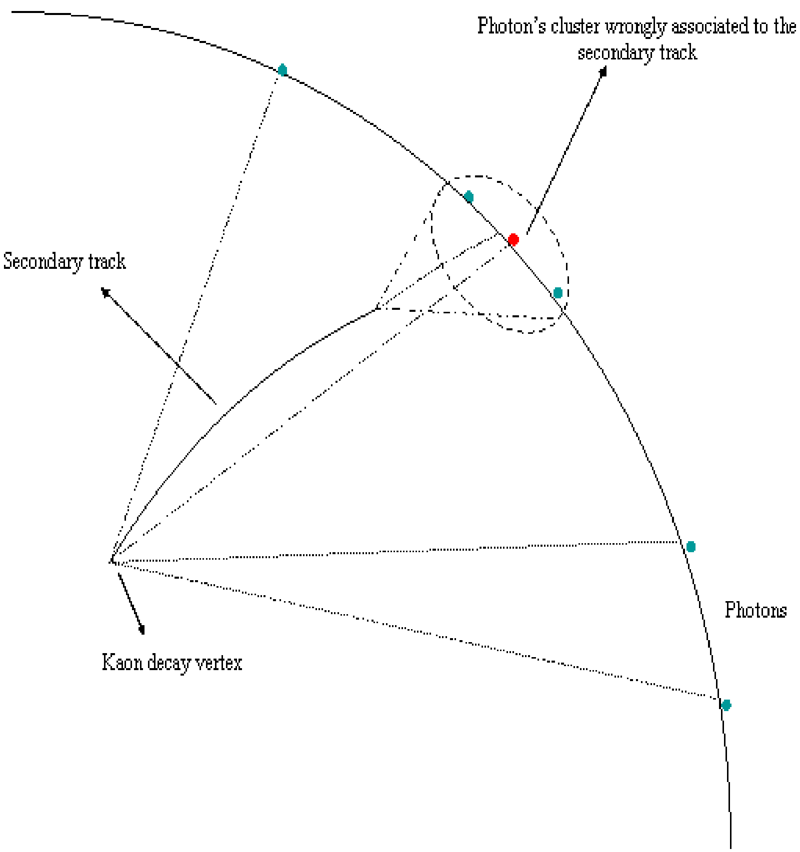
$$m^2 = p^2 \cdot \left\{ \left[\left(t_{cl}^{sec} - t_{VtxNeu} \right) \cdot \frac{c}{L_{Trk}} \right]^2 - 1 \right\}$$

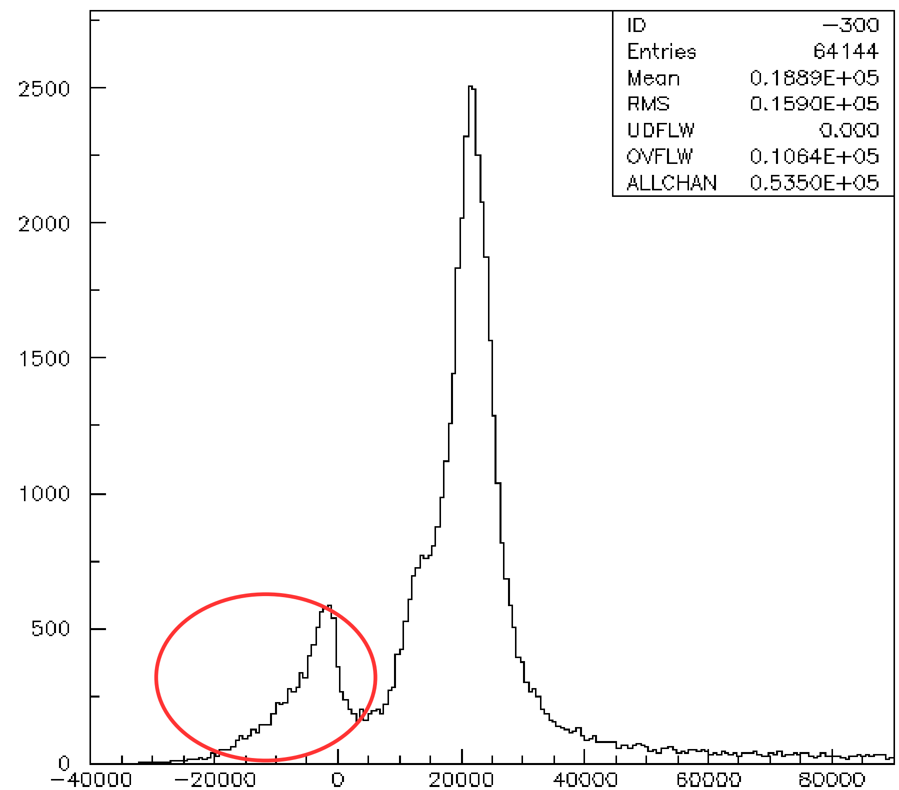


Step 5: TCA association

The unknown population is constituted by pions wrongly associated to photon's cluster.

$$\beta = \frac{L_{trk}}{\left(t_{cl}^{\sec} - t_{vtxneu}\right)\cdot c} \qquad m^2 = p^2 \cdot \left(\frac{1-\beta^2}{\beta^2}\right)$$





Contributions to background

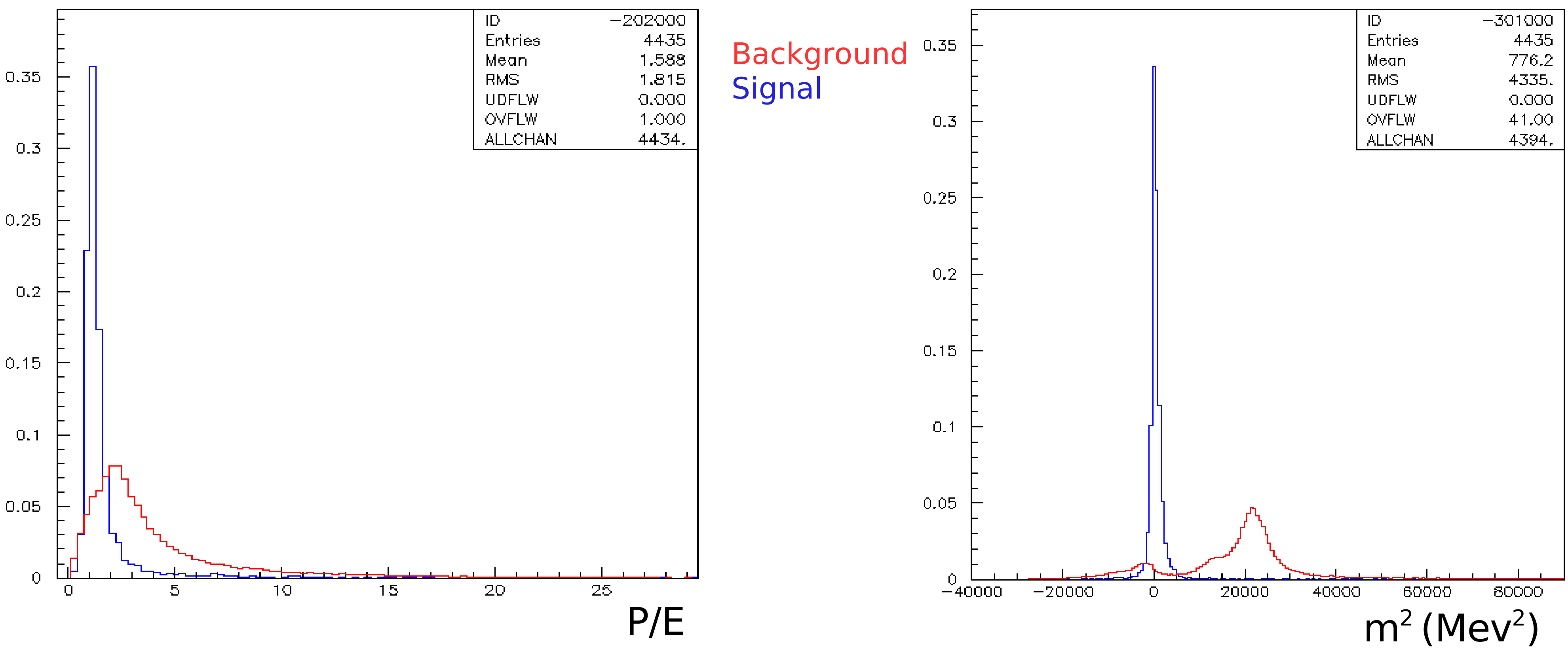
The main contribution to background is due to:

- $K^{00}\pi3$ events with a photon's clusters wrongly associated to secondary track.

- Ke3 radiative events with one split neutral cluster.

Contributions to background

Kinematic variables used to reject $K^{00}\pi 3$ events



Contributions to background

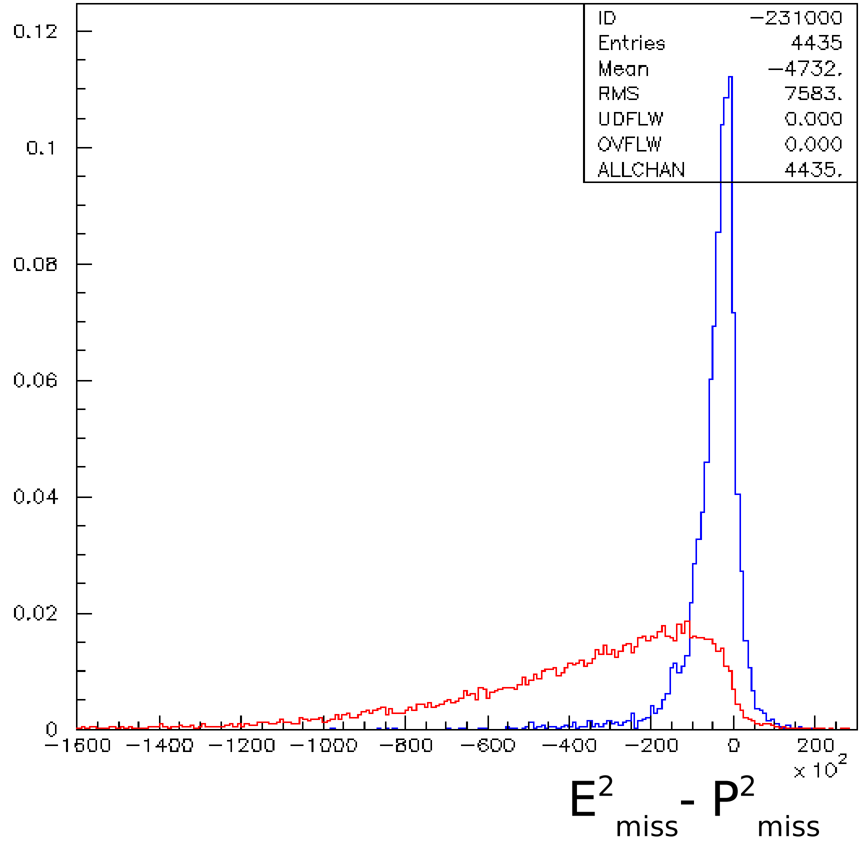
Kinematic variables used to reject **Ke3** events

$$E_{miss} = E_K - E_{\sec} - E_{\pi_1^0} - E_{\pi_2^0}$$

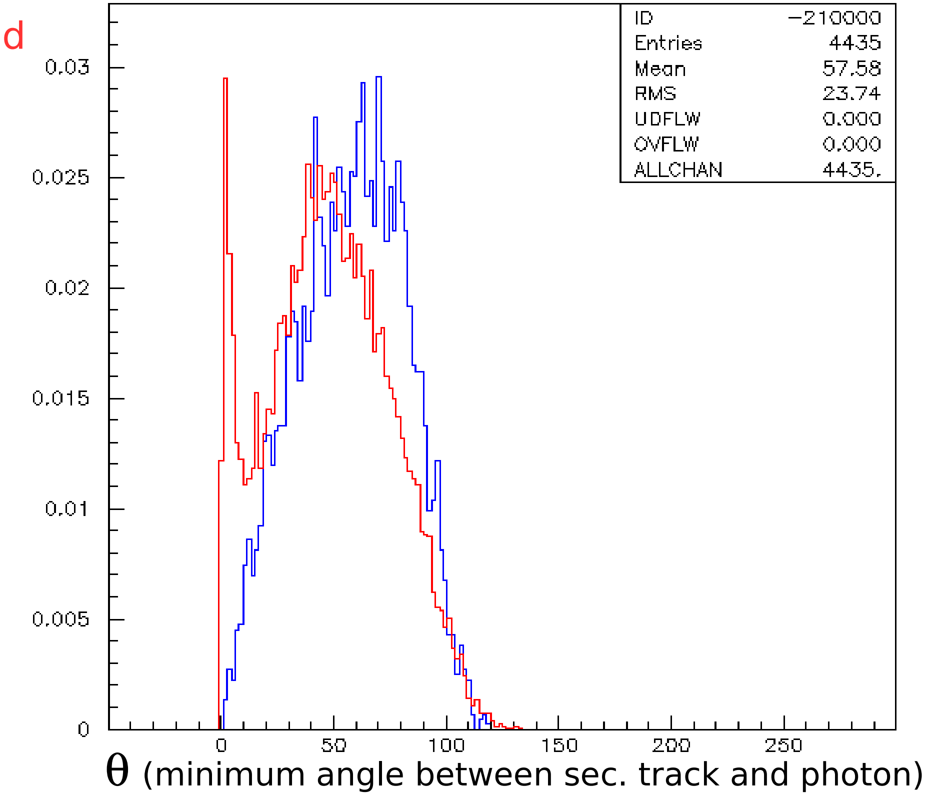
Energies constrained by a kinematic fit

$$P_{miss} = P_K - P_{\sec} - P_{\pi_1^0} - P_{\pi_2^0}$$

3-momentum constrained by a kinematic fit



Background
Signal



Background rejection

We use the Likelihood ratio method, based on the Neyman-Pearson Lemma, to reject background in order to obtain the maximum purity for a given efficiency.

To reject $\mathbf{K^{00}\pi 3}$ background we consider:

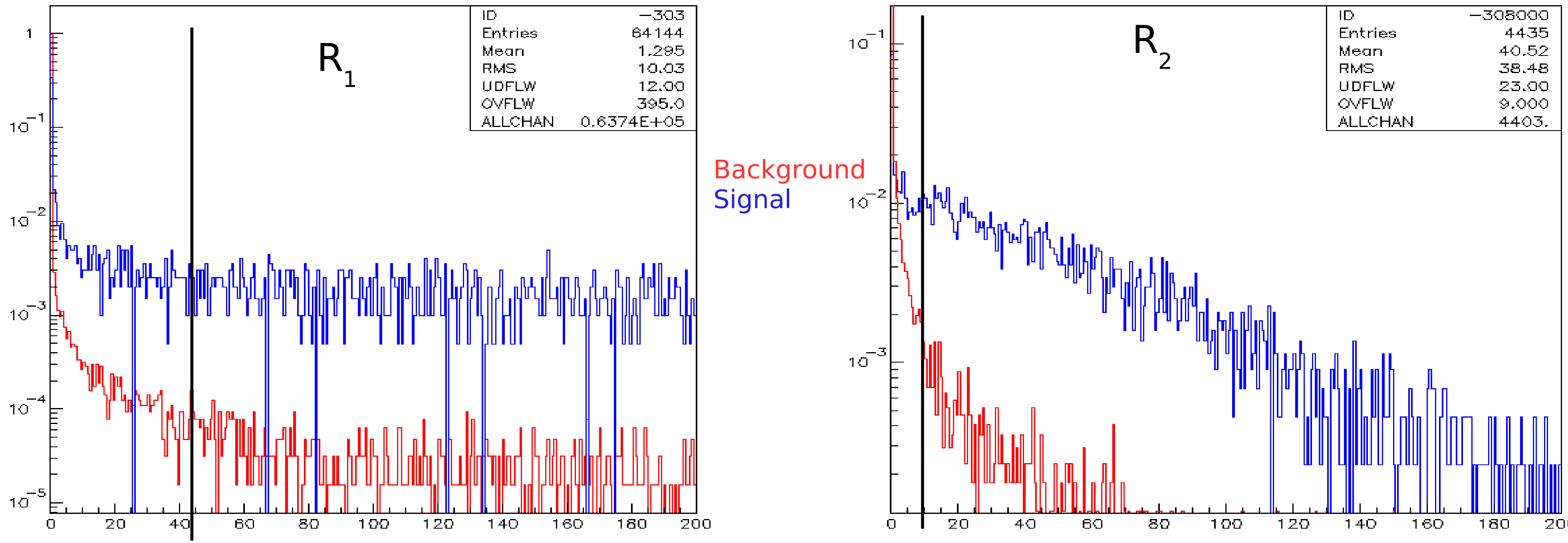
$$\mathbf{R_1} = P(S)/P(K^{00}\pi 3) = P_S(P/E)\cdot P_S(m^2) / P_{B1}(P/E)\cdot P_{B1}(m^2)$$

To reject **Ke3** background we consider:

$$\mathbf{R_2} = P(S)/P(Ke3) = P_S(E_m^2 - P_m^2)\cdot P_S(\theta) / P_{B2}(E_m^2 - P_m^2)\cdot P_{B2}(\theta)$$

Background rejection

The cut on R_1 and R_2 has been chosen by maximizing $\frac{S}{\sqrt{S+B}}$



This procedure allows to obtain the best background rejection (maximum purity) with the minimal statistic errors after background subtraction.

Signal: 390

$K^{00}\pi3$: 437

Ke3: 245

S/B ratio: 0.57

Background rejection

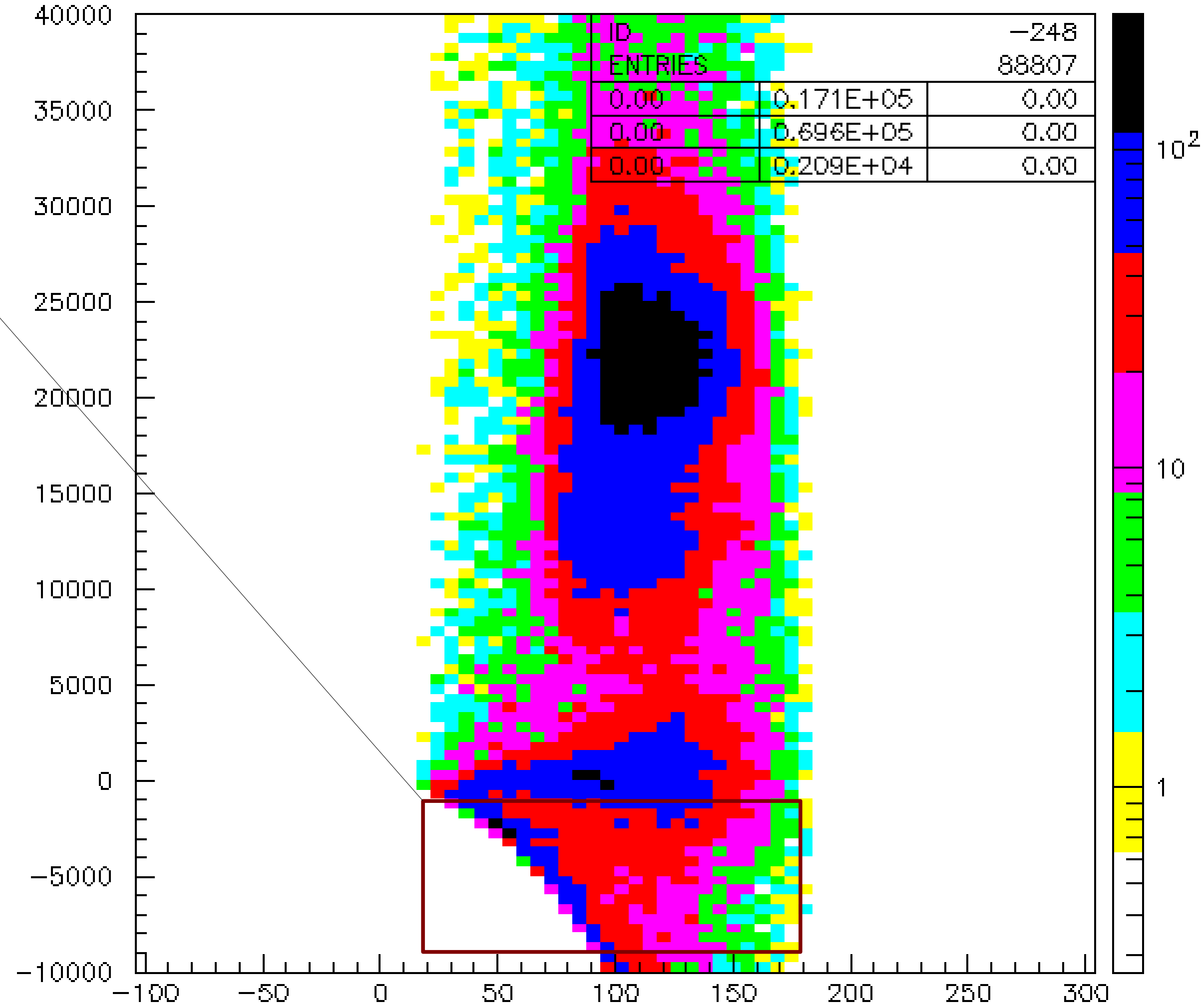
$K^{00}\pi3$ (control region):

$m^2 < -1000$ (MeV^2)
$25 < p < 180$ (MeV)

The contribution of $K^{00}\pi3$ background on data scale by:

$$N_{Data}^{K_{\pi3}^{00}} = N_{MC}^{K_{\pi3}^{00}}(1-\rho)$$

$$\rho = 0.23$$



Signal: 390
$K^{00}\pi3$: 336
Ke3: 245
S/B ratio: 0.67

Background subtraction

We keep under control the $\mathbf{K^{00}\pi 3}$ contribution to background directly on data.

We have to find a way to do the same with **Ke3** events.

We are investigating, searching for a quantity to fit the background shapes.

Background subtraction

$$\frac{BR(K^{\pm}\to\pi^0\pi^0 e^{\pm}\nu_e)}{BR(K^{\pm}\to\pi^0\pi^0\pi^{\pm})}=\frac{N^{Obs}_{K^{00}e4}}{N^{Obs}_{K^{00}_{\pi 3}}}\cdot\frac{\varepsilon_{K^{00}_{\pi 3}}}{\varepsilon_{K^{00}e4}}\cong 1.32\cdot 10^{-3}$$

$$N^{Obs}_{K^{00}e4}=N^{Obs}-N_B^{K^{00}_{\pi 3}}-N_B^{Ke3}=1067-336-245=$$

$$=486\pm 40$$

$$BR(K^{\pm}\to\pi^0\pi^0 e^{\pm}v_e)=1.32\cdot 10^{-3}\times 1.763\cdot 10^{-2}$$

$$=2.3\pm 0.2\cdot 10^{-5}$$

Relative error ~ 8%

Reconstruction Efficiency

The global reconstruction efficiency can be defined as:

$$\varepsilon_G = \frac{N_{Sel\&Vtx}}{N_{Sel}}$$

using the neutral vertex as normalization sample

Allow the selection of events with 2 π^0 in the final state

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

The neutral vertex must satisfy the following requests:

- 4 neutral clusters on time $(t - r/c)_{\gamma 1} = (t - r/c)_{\gamma 2} = (t - r/c)_{\gamma 3} = (t - r/c)_{\gamma 4}$

- consistecy with π^0 invariant mass.

Preliminary systematics

We vary the cut on R_1 and R_2 independently and in a large interval.

$$2 < R_1 < 100$$

$$5 < R_2 < 70$$

To be done

- Find a way to evaluate the Ke3 contribution to background on data.
- Complete efficiencies studies.
- Complete systematics studies.

Conclusions

- We tried successful to measure a relative BR without the Tag requirements, but we need to find a way to evaluate the Ke3 contribution on data.

- The measurement method allows to estimate the $K^{00}\pi3$ background contribution directly from data.

- Normalization to $K^{00}\pi3$ events guarantees a cancellation of the systematics effects.