Status report of the Charged Kaon Group

Erika De Lucia

On behalf of the Charged Kaon Group

Physics issues

- Absolute BR of $K \to \mu\nu(\gamma)$
- Absolute BR of $K \to \pi\pi^0$
- Lifetime

} topics of this talk

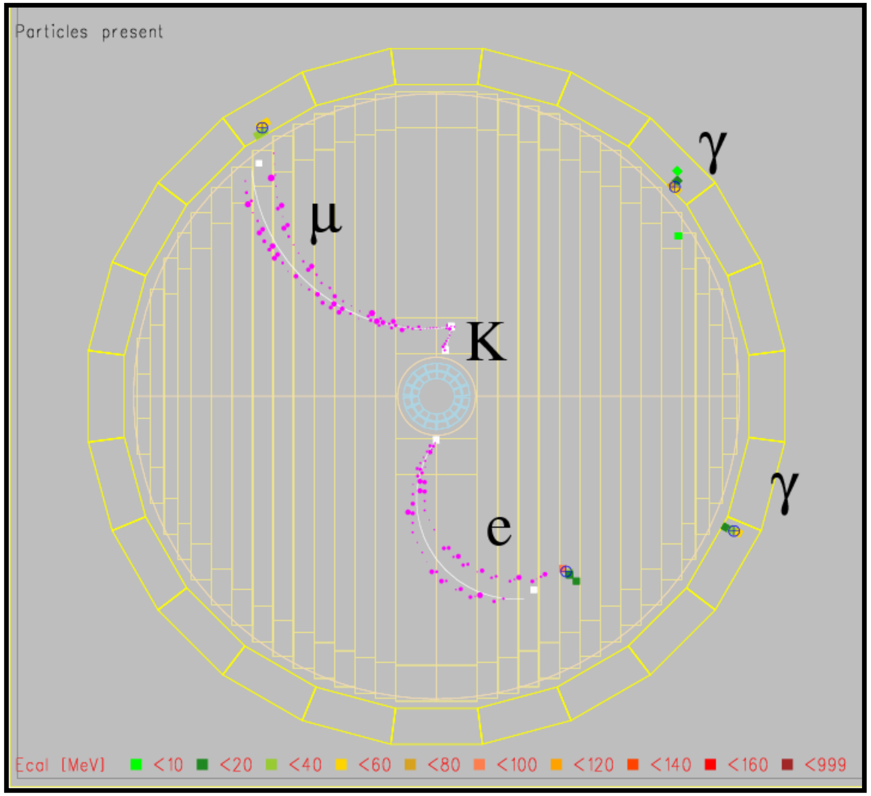
- Absolute BR of semileptonic decays

Common Strategy for signal selection

1) tag on one side with $K^- \to \mu^- \nu$ (or $K^- \to \pi^- \pi^0$)

- **preselection**
  - $|z_{PCA}| < 20$cm
  - $\rho_{PCA} < 10$cm
  - $p_K \in (70,130)$ MeV
- **selection**
  - $\rho_{VTX} \in (40,150)$ cm
  - $dp \in (-320,-120)$ MeV
  - $p^*(m_\pi) \in (180,270)$ MeV
- **self-triggering tag**

  (2 trigger sectors fired)



Pure kaon beam obtained → normalization (N_{TAG})

2) look for signal on the other side (K^+ beam)

- Kaon selection + vertex in fiducial volume $\rho_{VTX} \in (40,150)$ cm

1) $K \rightarrow \mu\nu(\gamma)$

Overview

PDG fit $BR(K^{\pm} \to \mu\nu) = (63.43 \pm 0.17)\%$ $\Delta BR/BR = 2{,}7\times10^{-3}$

CHIANG '72 $BR(K^{\pm} \to \mu\nu) = (63.24 \pm 0.44)\%$ $\Delta BR/BR = 1{,}6\times10^{-2}$

Method:

- Self-triggering $K^{-} \to \mu^{-}\nu$
- Counting the events in the distribution of the momentum of the secondary track (p*) in the kaon reference frame, after background subtraction, we can extract $BR(K^{+} \to \mu^{+}\nu(\gamma))$

The selection efficiency is only related to DC reconstruction:

$\Rightarrow$ global efficiency $\varepsilon_{TRK+VTX}$

The method

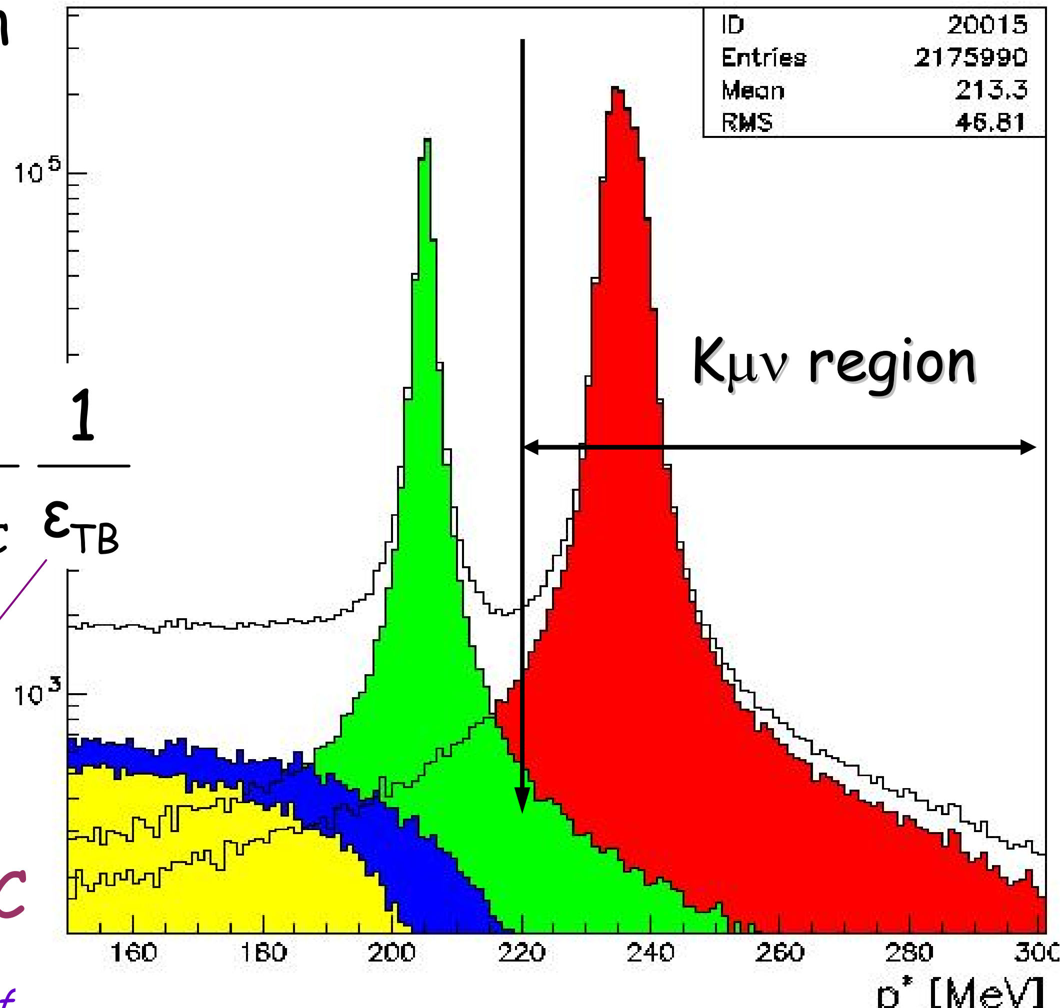
- Select the signal sample asking for a vertex in the FV
- Select and subtract the background given by events with a π^0 in the final state:

$K \to \pi\pi^0$ $K \to \pi^0 e\nu$ $K \to \pi^0 \mu\nu$

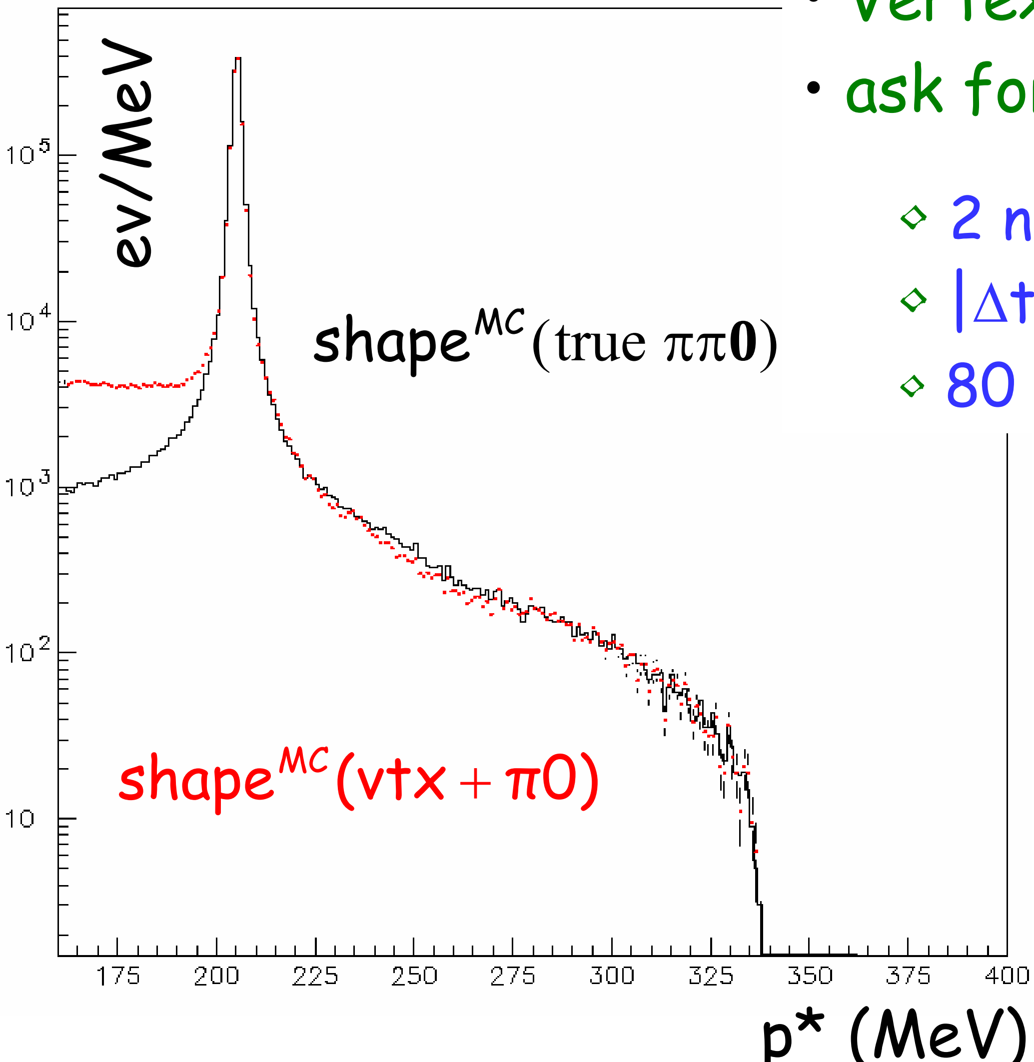
$$BR(K^+ \to \mu^+ \nu(\gamma)) = \frac{N_{K\mu\nu(\gamma)}}{N_{TAG}} \frac{1}{\varepsilon_{DC}} \frac{1}{\varepsilon_{TB}}$$

$$\varepsilon_{DC} = \varepsilon_{DATA} \times corr_{MC}$$

tagb estimated from MC



Background selection



- Vertex in the DC
- ask for a π^0 :
  - 2 neutral clusters "on-time"
  - $|\Delta t_{12}|$ (wrt vtx) within $5\sigma_t$
  - 80 < 2γ invariant mass < 200 MeV

Negligible difference between the true and selected π^0 bck in the $K\mu\nu$ region with respect to the signal peak

Signal spectrum background subtracted

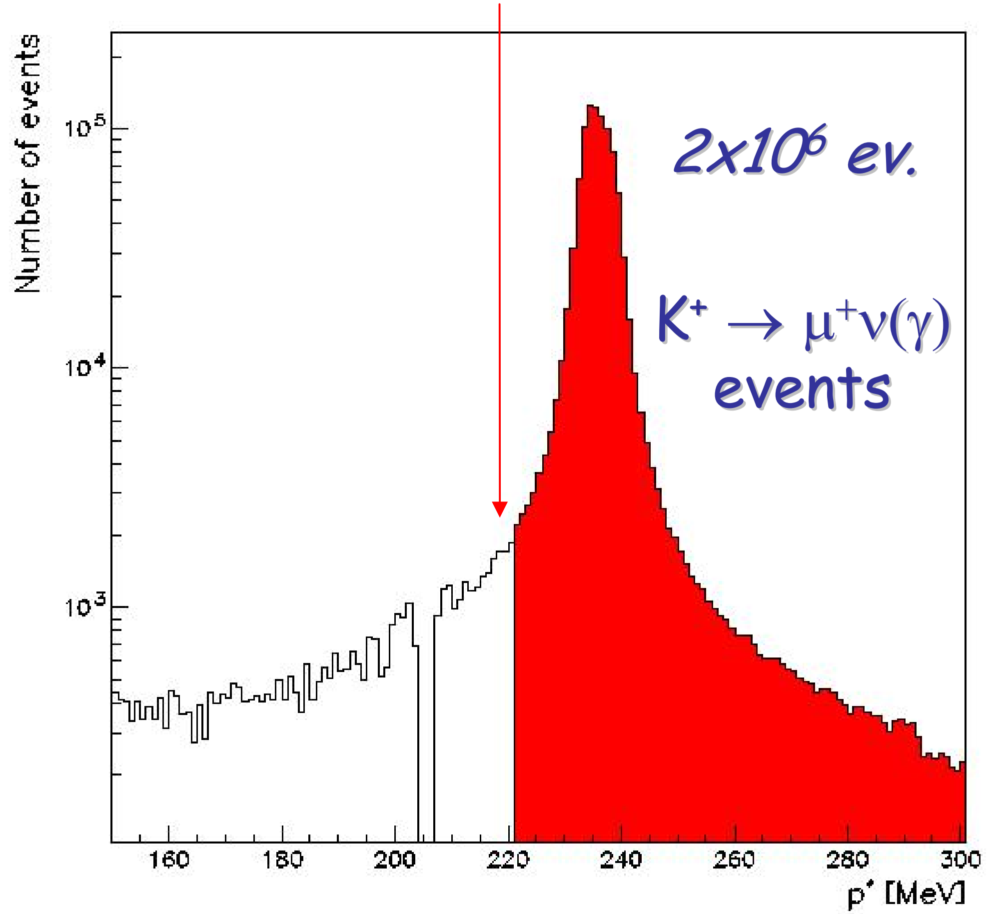
After the bck subtraction we are left with $\mu\nu$ signal

Corresponding to the $\pi^+\pi^0$ peak a hole appears

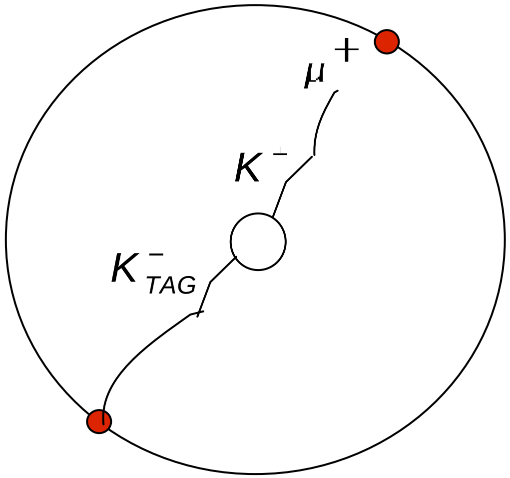
We integrated the signal from 220 to 400 MeV that is 15 MeV above the hole
$\Rightarrow$ keep as much event as possible without getting close the pion peak

$N_{K\mu\nu(\gamma)}$ measured

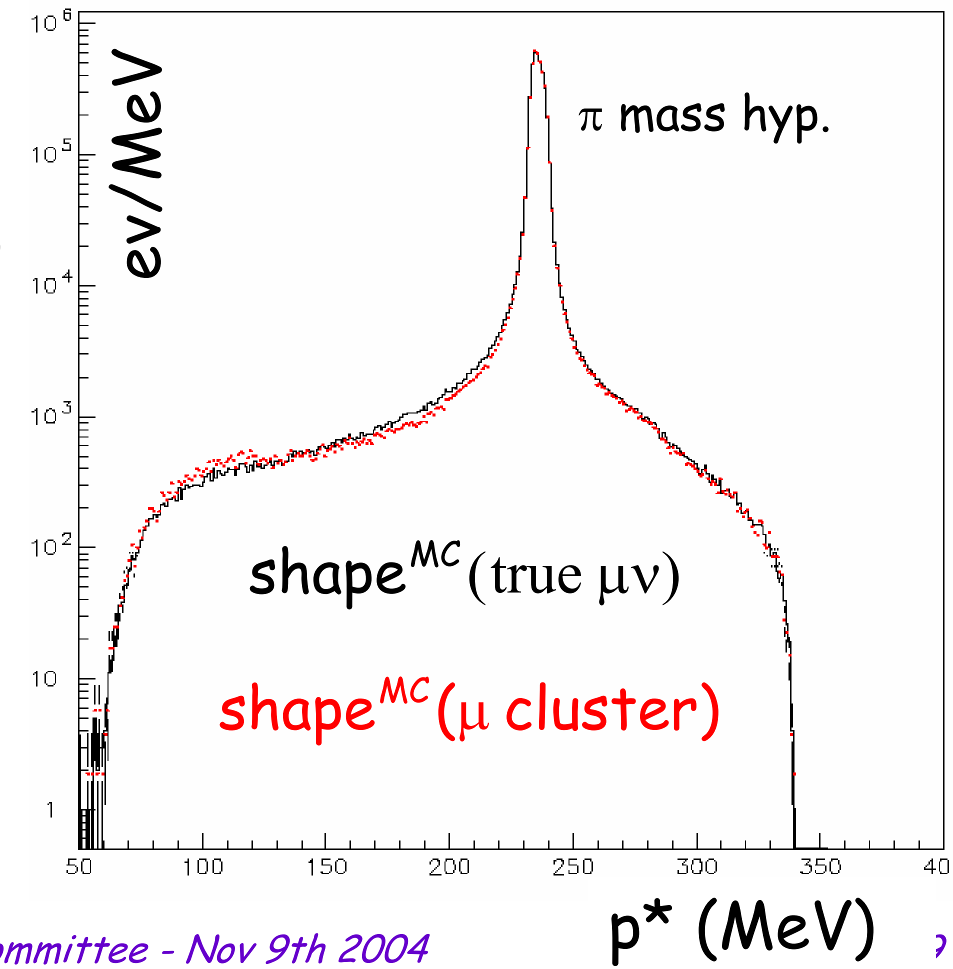
p^*_{min} lower extreme of the sum



Efficiency evaluation (I)



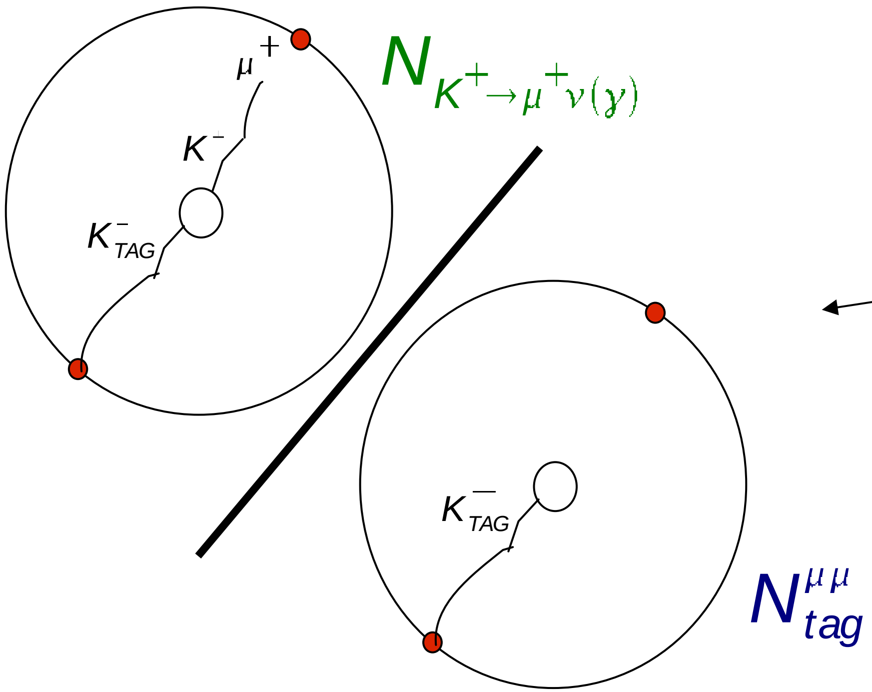
To avoid correlation with the DC driven sample selection, we select the efficiency sample using mainly EMC information



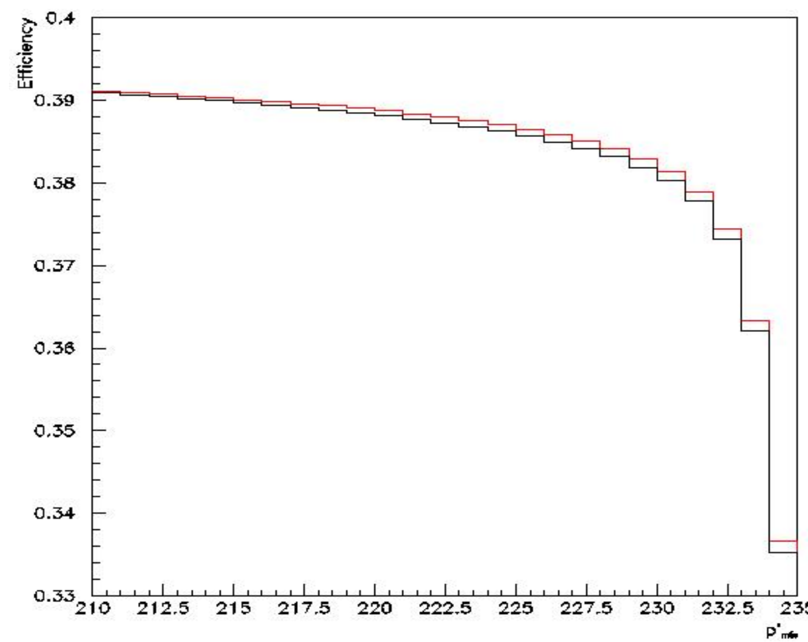
Double $K \to \mu\nu(\gamma)$ events selection

1) isolate triggering cluster of the muon tag
2) ask for :
   - 1 cluster with $90 < E_{CLU} < 320$ MeV
   - no clusters with $20 < E_{CLU} < 90$ MeV
   - anything with $E_{CLU} < 20$ MeV (*low E γ rad.*)

Efficiency evaluation (II)



$$\varepsilon_{DC} = \varepsilon_{DATA} \times corr_{MC}$$



Small discrepancy (~0.1%) between reconstructed efficiency and "true" MC efficiency

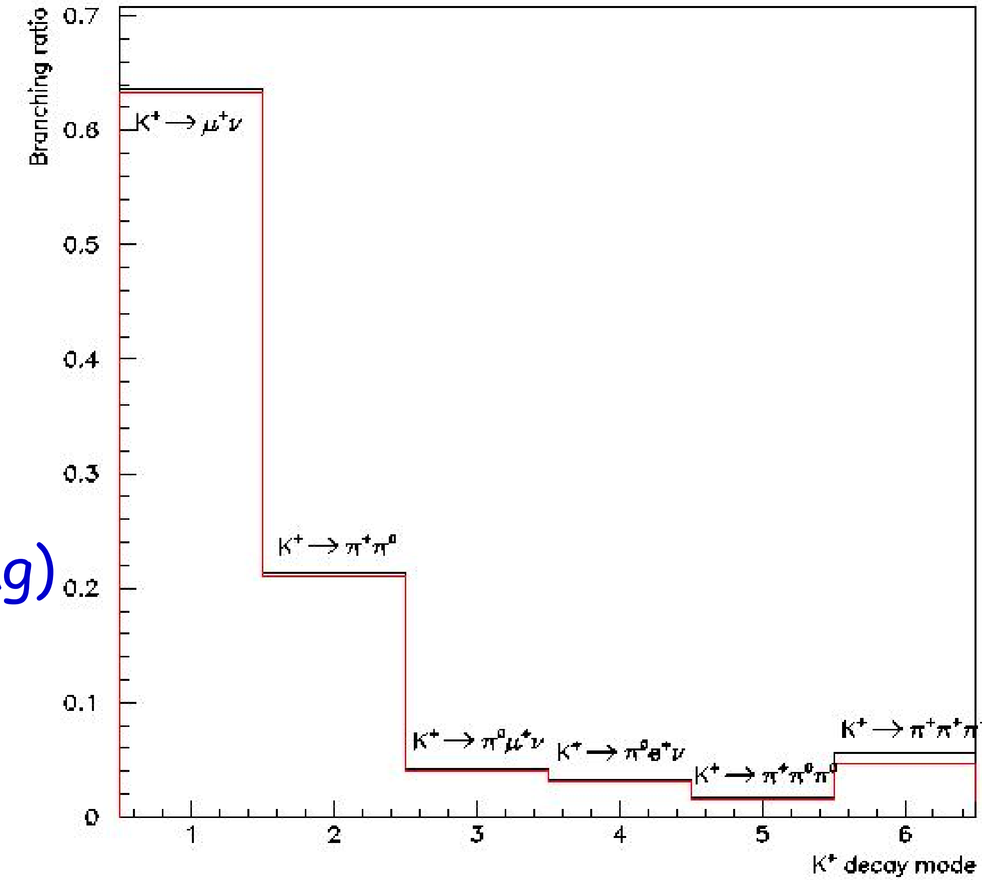
Tag Bias

The tag request on one hemisphere can modify the BR distribution on the other side.

This correction is evaluated from MC and is given by:

ε_{TB} = BR(with tag)/BR(without tag)

(35pb^{-1} MC sample was used)



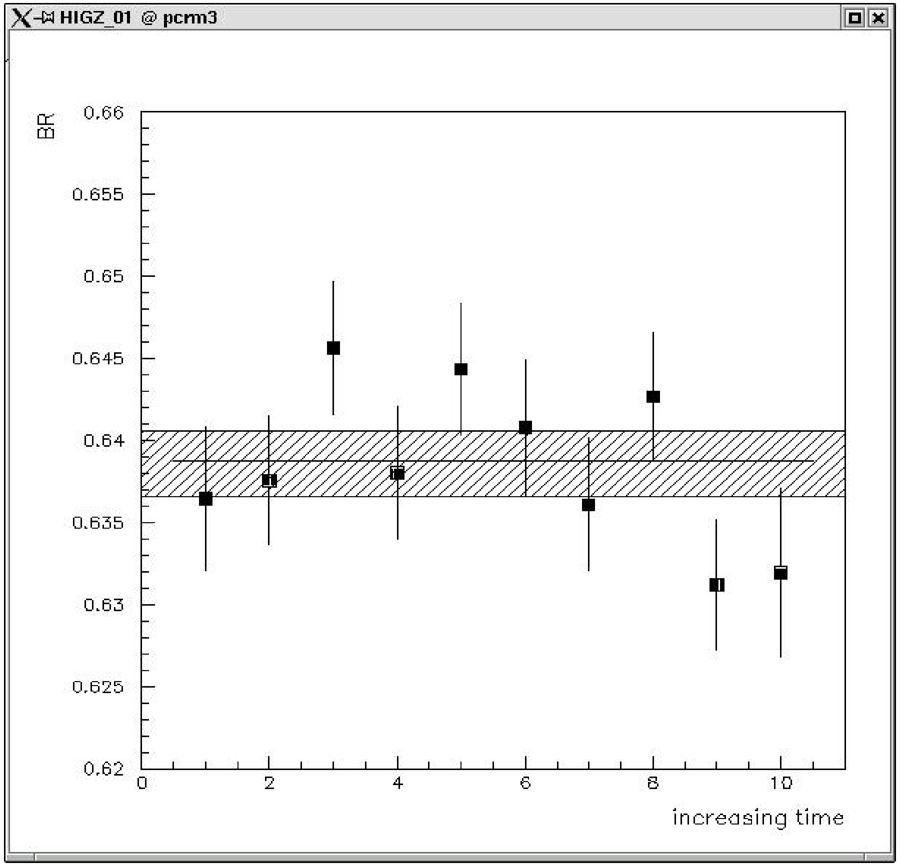
TB correction for $K^+ \to \mu^+\nu(\gamma)$: ε_{TB}= 1.0165±0.0002

$$BR(K^+ \to \mu^+\nu(\gamma)) = \frac{N_{K\mu\nu(\gamma)}}{N_{TAG}} \frac{1}{\varepsilon_{DC}} \frac{1}{\varepsilon_{TB}}$$

Consistency check & Time Stability

We compared the BR used for the MC generation with the BR we measure treating MC like data:

$$\left| BR_{MC\ reconstructed} - BR_{MC\ generated} \right| = 6 \cdot 10^{-4}$$



BR measured on 10 sub-samples

Fitting with a constant:

BR = 0.6388 ± 0.0013

χ^2 / **dof = 12.37 / 9**

Preliminary !

Summary of the systematic uncertainties

$\delta_{Eff.\ Low\ energy\ cut}$	$3 \cdot 10^{-4}$
$\delta_{Radiative\ \gamma\ tail}$	$7 \cdot 10^{-4}$
$\delta_{Eff.\ Medium\ energy\ cut}$	$12 \cdot 10^{-4}$
$\delta_{Eff.\ High\ energy\ cut}$	$11 \cdot 10^{-4}$
$\delta_{Fiducial\ volume}$	$5 \cdot 10^{-4}$
$\delta_{Backgorund\ fit}$	$6 \cdot 10^{-4}$
$\delta_{Background\ spectrum}$	$< 1 \cdot 10^{-4}$
$\delta_{\sum 's\ Lower\ extreme}$	$5 \cdot 10^{-4}$

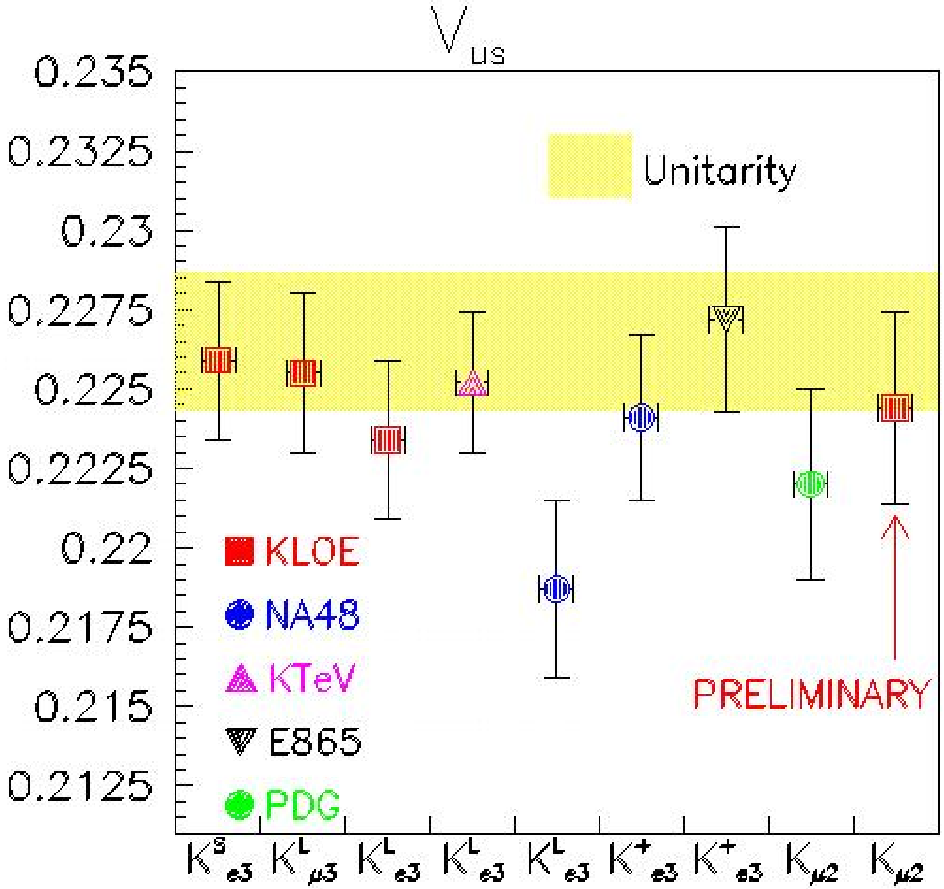
Still to be finalized

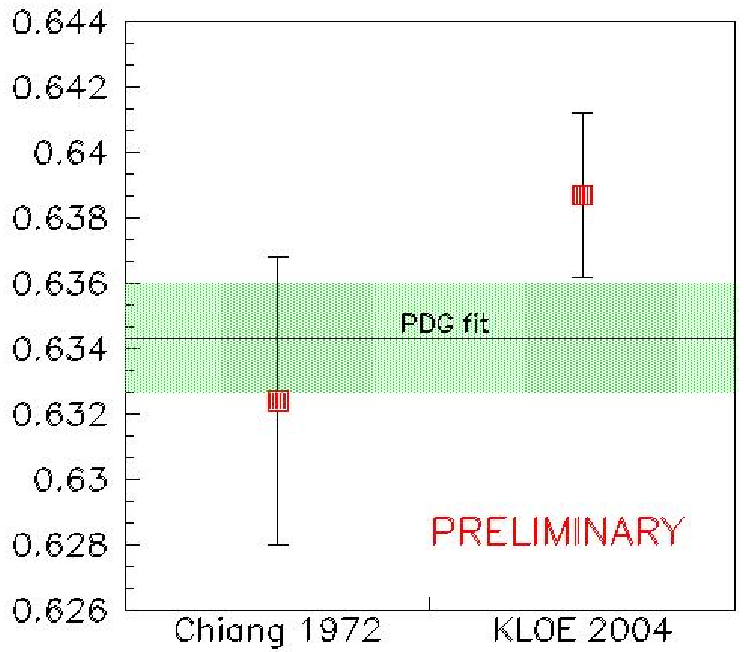
Total systematic error $22 \cdot 10^{-4}$

Preliminary results

BR ($K^+ \rightarrow \mu^+\nu(\gamma)$) = 0.6387 ±0.0013 (stat.) ± 0.0022 (syst.)

Using the Marciano method for Vus $V_{us} = 0.2244\ (30)$





PDG fit = 0.6343 ± 0.0017

Chiang = 0.6324 ± 0.0044

2) $K \to \pi\pi^0$

Overview

PDG fit BR($K^{\pm} \rightarrow \pi^{\pm}\pi^{0}$) = (21,13 ± 0.14)% $\Delta BR/BR = 6{,}6 \times 10^{-3}$

CHIANG '72 BR($K^{\pm} \rightarrow \pi^{\pm}\pi^{0}$) = (21,18 ± 0.28)% $\Delta BR/BR = 1{,}3 \times 10^{-2}$

Method:

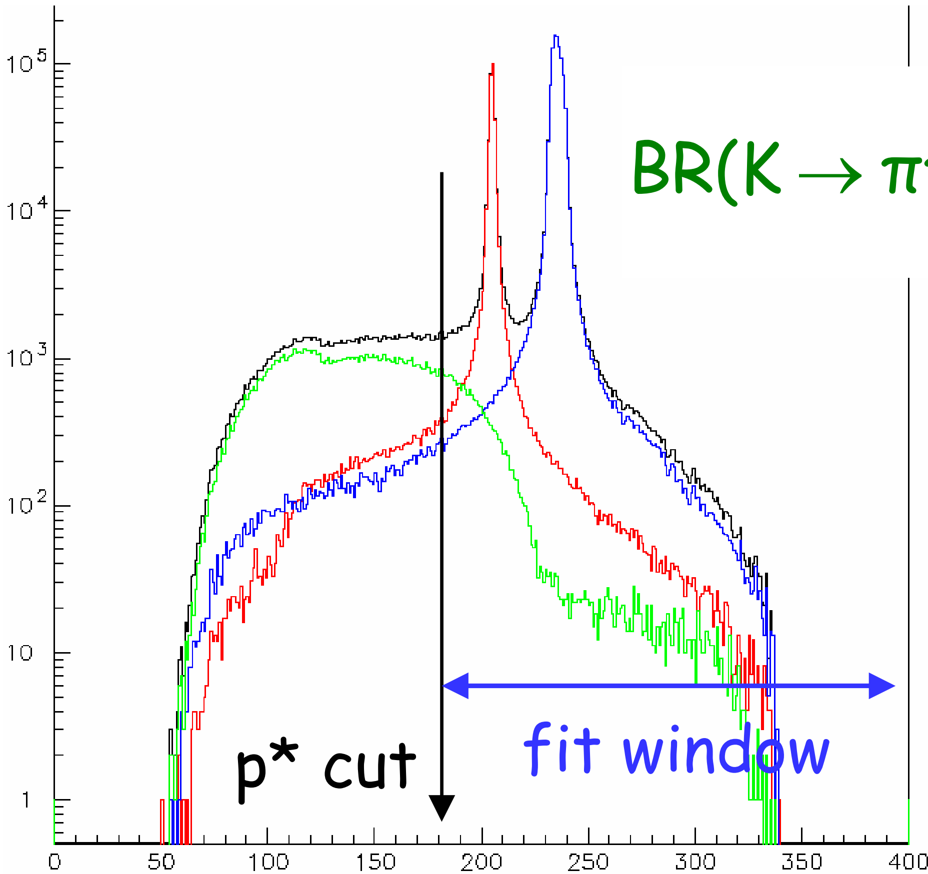
- Self-triggering $K^{-} \rightarrow \mu^{-}\nu$
- Fitting the distribution of the momentum of the secondary track (p*) in the kaon reference frame we can extract BR($K^{+} \rightarrow \pi^{+}\pi^{0}$)

The selection efficiency is only related to DC reconstruction:

$\Rightarrow$ global efficiency $\varepsilon_{TRK+VTX}$

The method

1) $\mu\nu$ peak: p^*(π mass) distribution from "μ-cluster" sample
2) $\pi\pi^0$ peak: p^*(π mass) distribution requiring the π^0
3) 3-body decays: p^*(π mass) distribution from MC



$$BR(K \to \pi\pi^0) = \frac{N_{\pi\pi}\big|_{FIT}}{N_{TAG}} \frac{1}{\varepsilon_{DC}(p^*cut)} \times tagb$$

$$\varepsilon_{DC}(p^*cut) = \varepsilon_{DATA} \times corr_{MC}$$

tagb estimated from MC kpm04

$\mu\nu$ shape

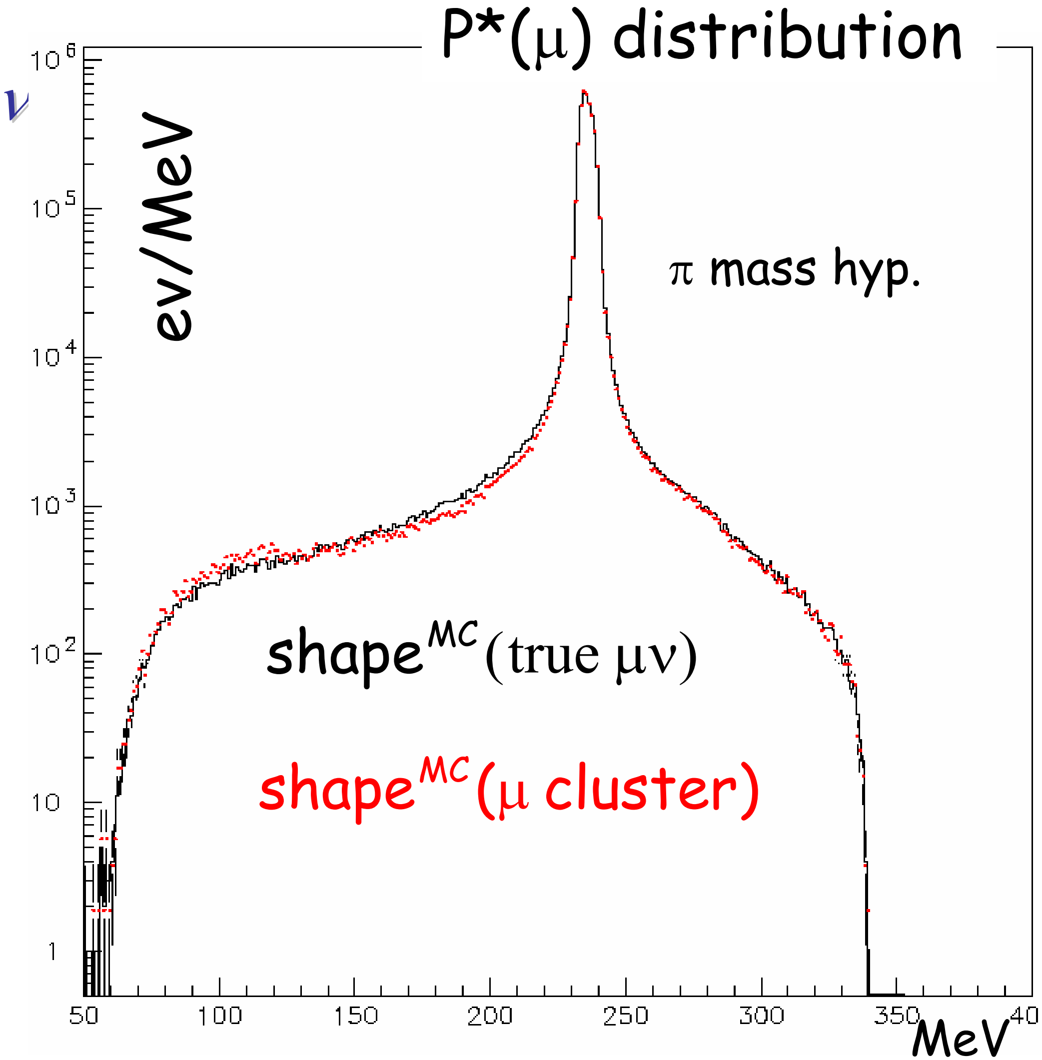
1) tag on one side with $K \to \mu\nu$

2) isolate muon cluster of the tag

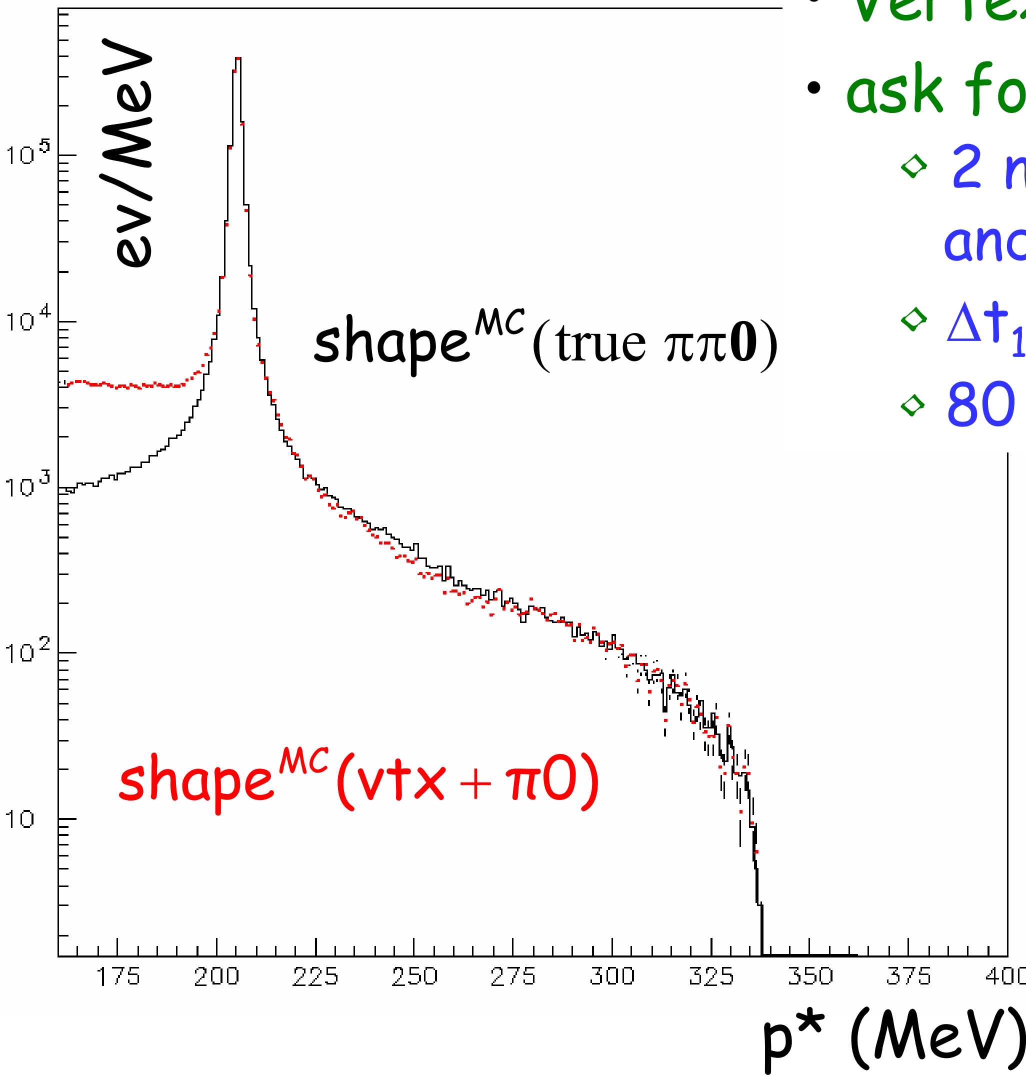
3) ask for :

- 1 cluster with $90 < E_{CLU} < 320$ MeV
- no clusters with $20 < E_{CLU} < 90$ MeV
- everything with $E_{CLU} < 20$ MeV

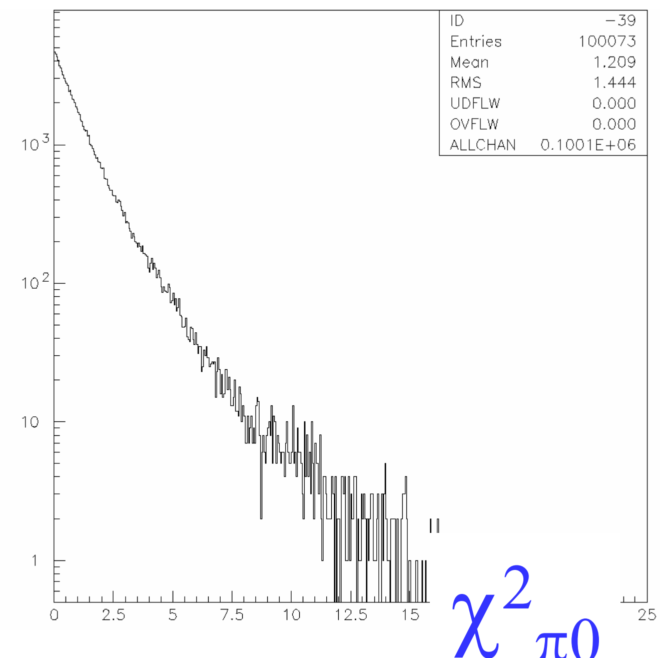
4) vertex in fiducial volume



$\pi\pi^0$ shape (1)

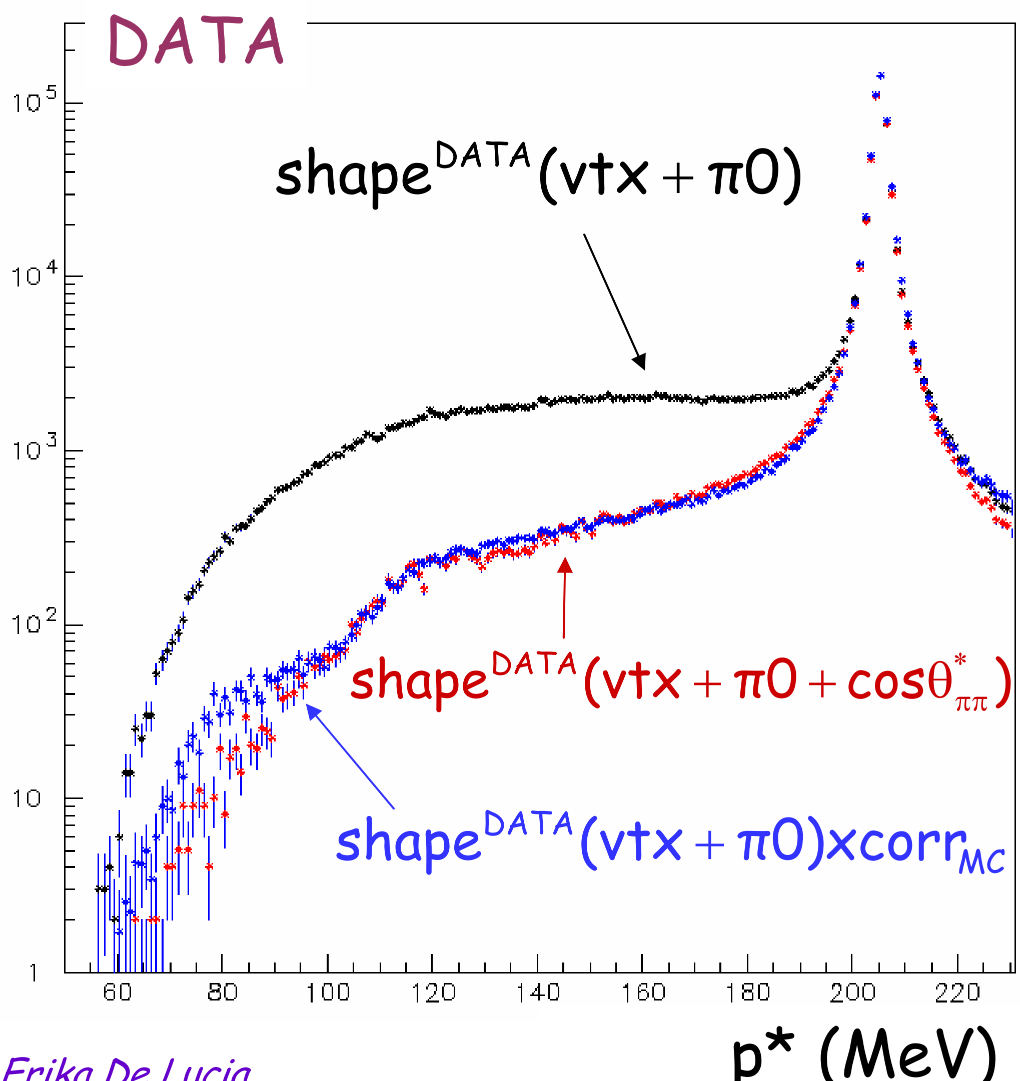


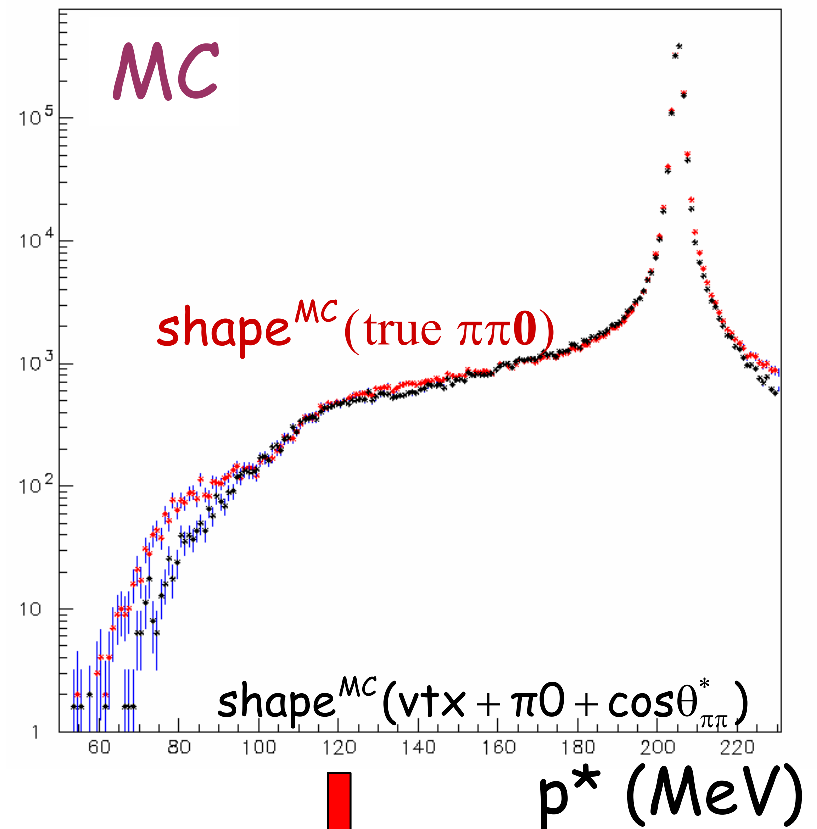
- Vertex in the DC
- ask for a π^0 :
  - 2 neutral clusters "on-time" and $24^o < \theta_{CLU} < 156^o$
  - Δt_{12} (wrt vtx) within $5\sigma_t$
  - $80 < 2\gamma$ invariant mass < 200 MeV



$\pi\pi^0$ shape (2)

- The final shape is obtained from a bin by bin MC correction
- Comparison with the DATA shape with $\cos\theta^*_{\pi\pi}$ selection





$$corr_{MC} = \frac{shape^{MC}(\pi\pi 0)}{shape^{MC}(vtx + \pi 0)}$$

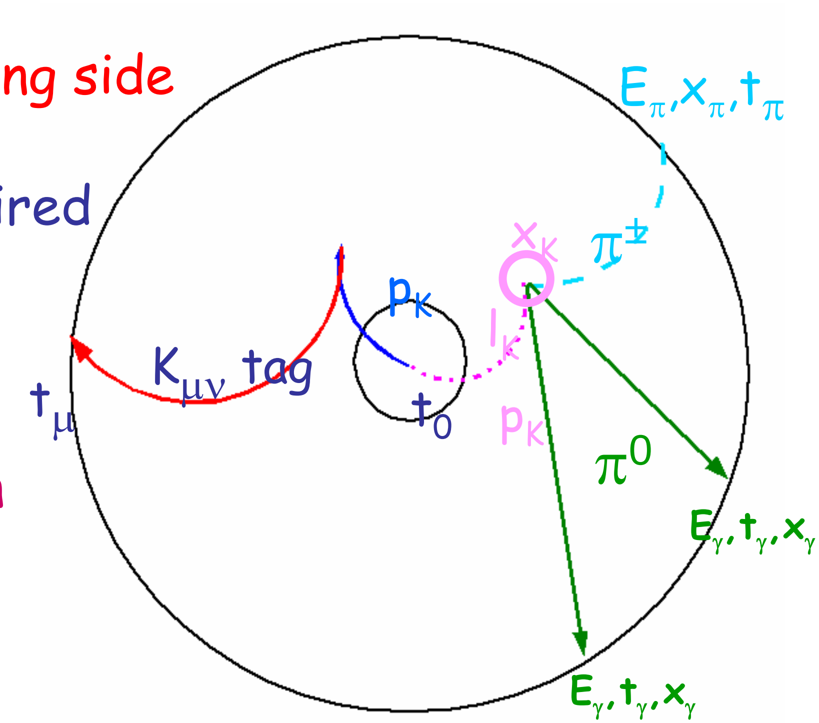
Global efficiency evaluation

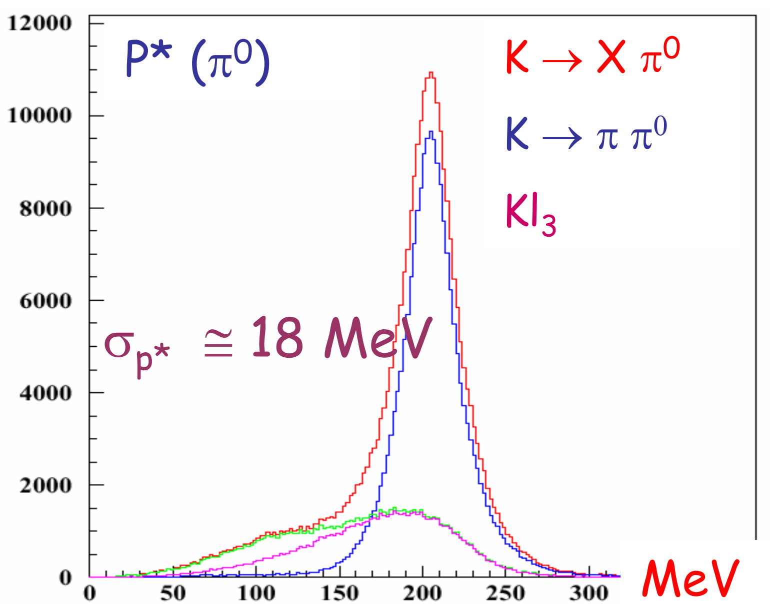
1) Extrapolate the K^- track from the tagging side to the signal hemisphere

2) use the timing of the neutral clusters fired by the photons of the π^0 decay

3) step along the path given by the extrapolated kaon

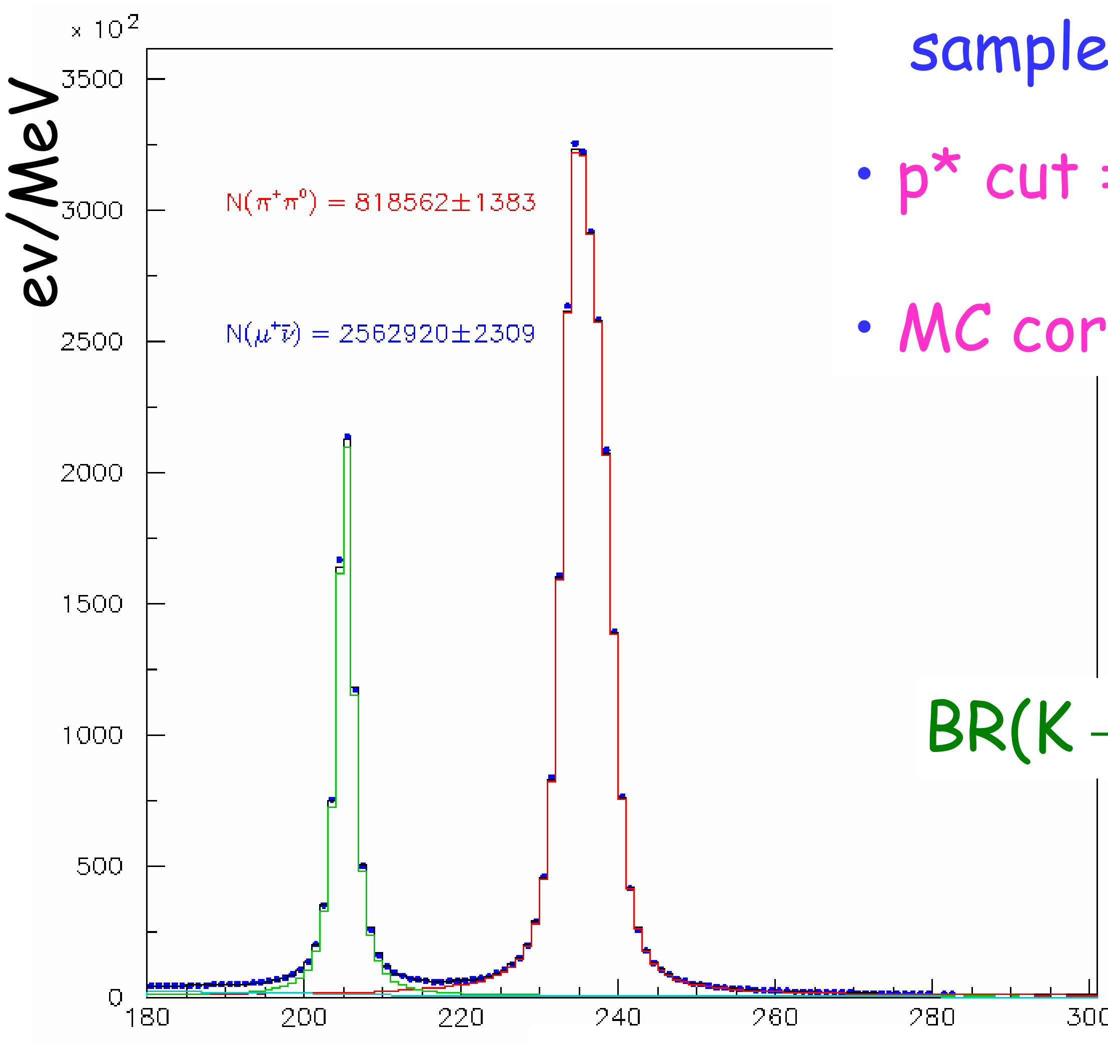
4) find the point giving the best evaluation of the position of the neutral vtx





$\pi\pi^0$ events selected cutting on the distribution of $p^*(\pi^0)$ to minimize 3-body contamination of the sample

First glance at 175 pb^{-1} (2002)



- Efficiency from neutral vertex sample with $p^*_{\pi 0}$(peak) $\pm\sigma$
- p^* cut = 180 MeV/c
- MC correction from kpm04 prod.

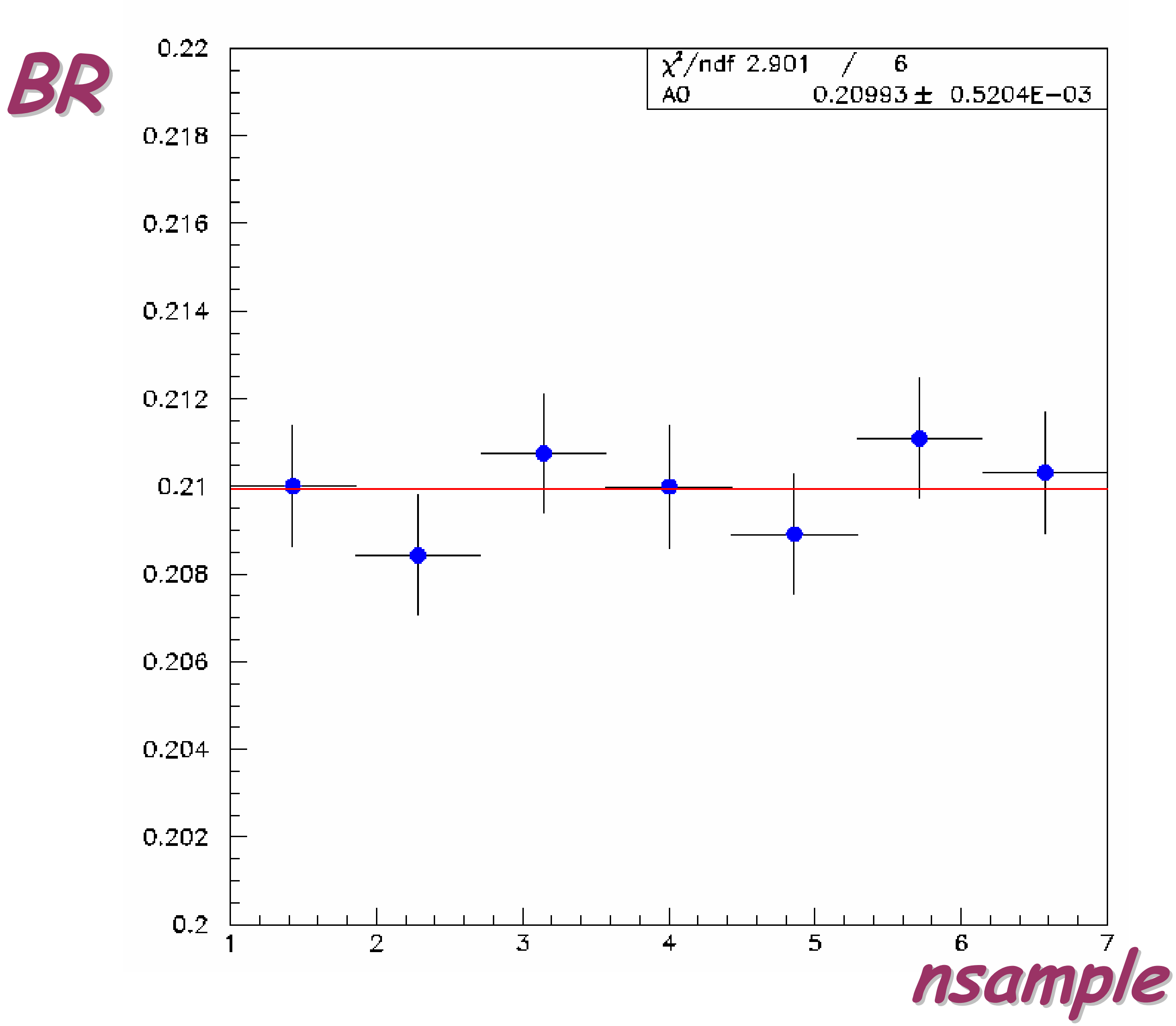
$$BR(K \to \pi\pi^0) = 21.05 \pm 0.05\%$$

(only statistics)

p*(MeV)

First look at BR vs time

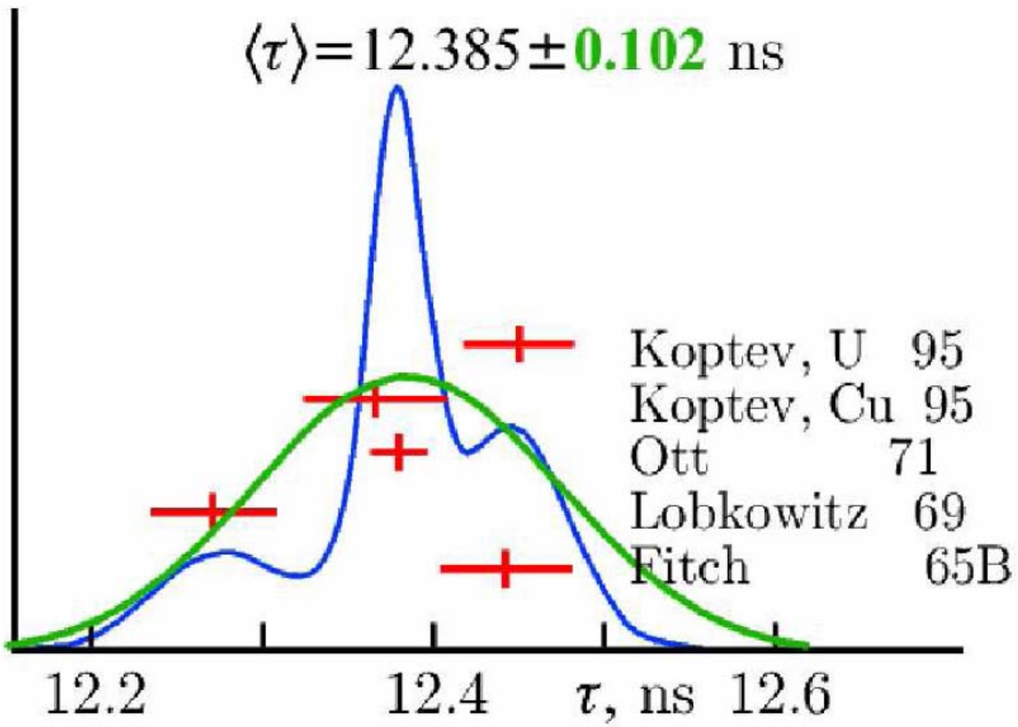
The 2002 data sample has been divided into 7 sub-samples



3) Charged Kaon Lifetime

Present experimental picture

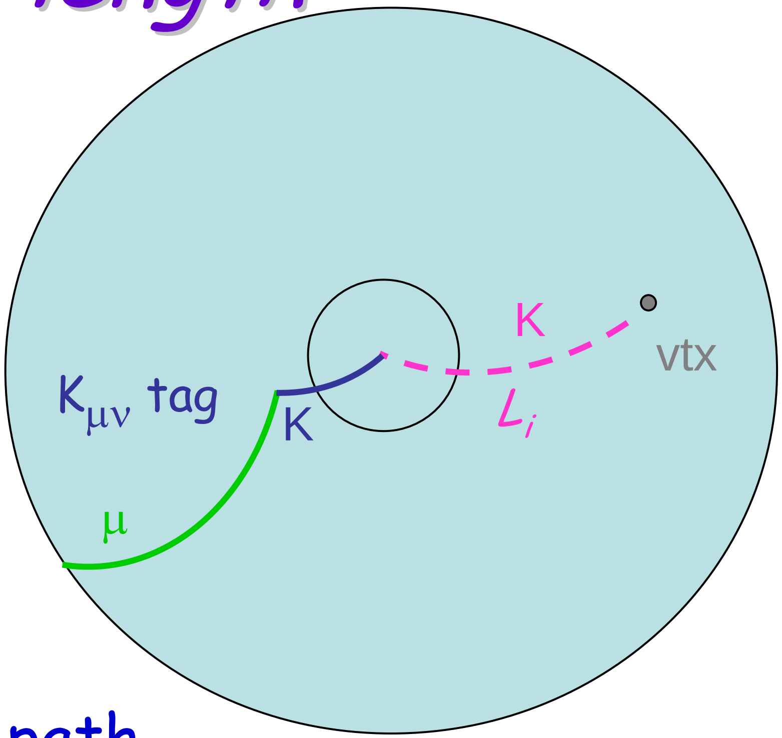
The Particle Data Group values are questionable.
We have two different methods to measure the charged kaon lifetime : (1) by kaon decay length and (2) by kaon t.o.f.



~~$= (12.385 \pm 0.024)$ ns~~

$\tau = (12.385 \pm 0.102)\,\text{ns}$

Method 1: τ from decay length



Signal selection

- Self triggering muon tag
- K track on the signal side
- Decay vertex

Signal K extrapolated to the IP.

dE/dx correction applied along the path.

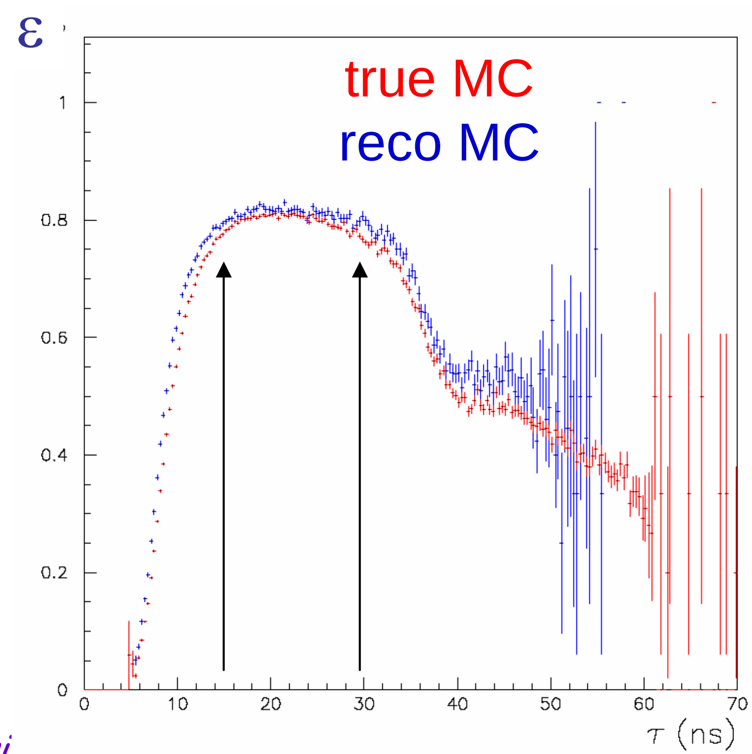
$$\tau = \sum \frac{L_i}{\beta_i}\sqrt{1-\beta_i^2}$$

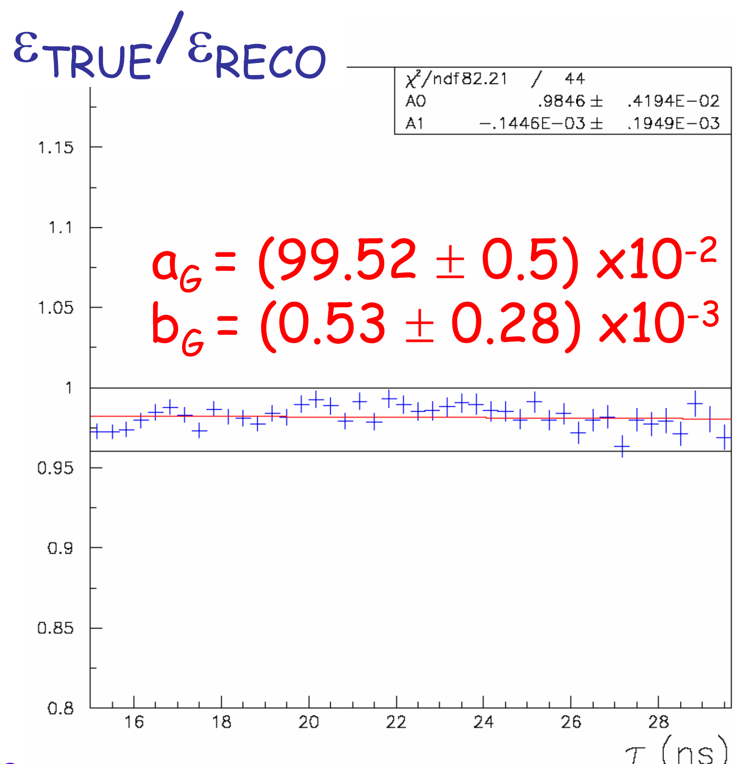
L_i = step length

Vertex efficiency needed wrt the decay length of the Kaon

Reconstruction efficiency

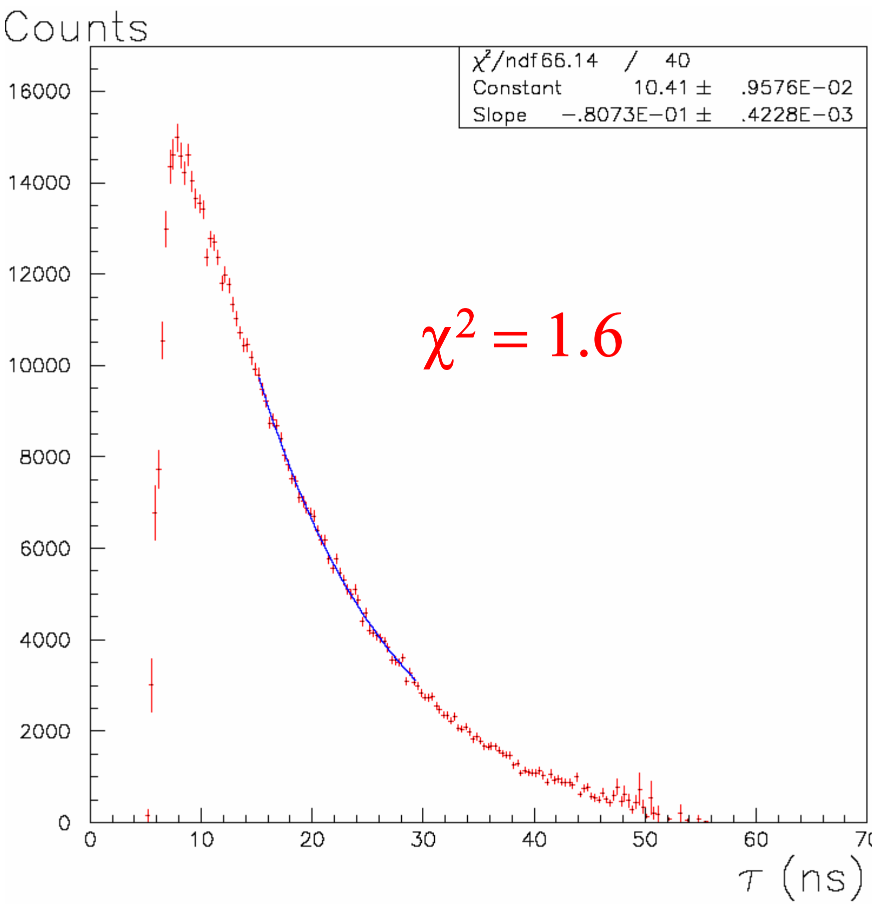
- Same technique used for the efficiency of the $\pi\pi^0$ analysis.
- This technique provides efficiencies as function of Kaon decay length/position/proper time.
- Measurement performed in a proper time interval (15-30 ns) where the ratio $\varepsilon_{TRUE}/\varepsilon_{RECO}$ is constant (within few 10^{-3})

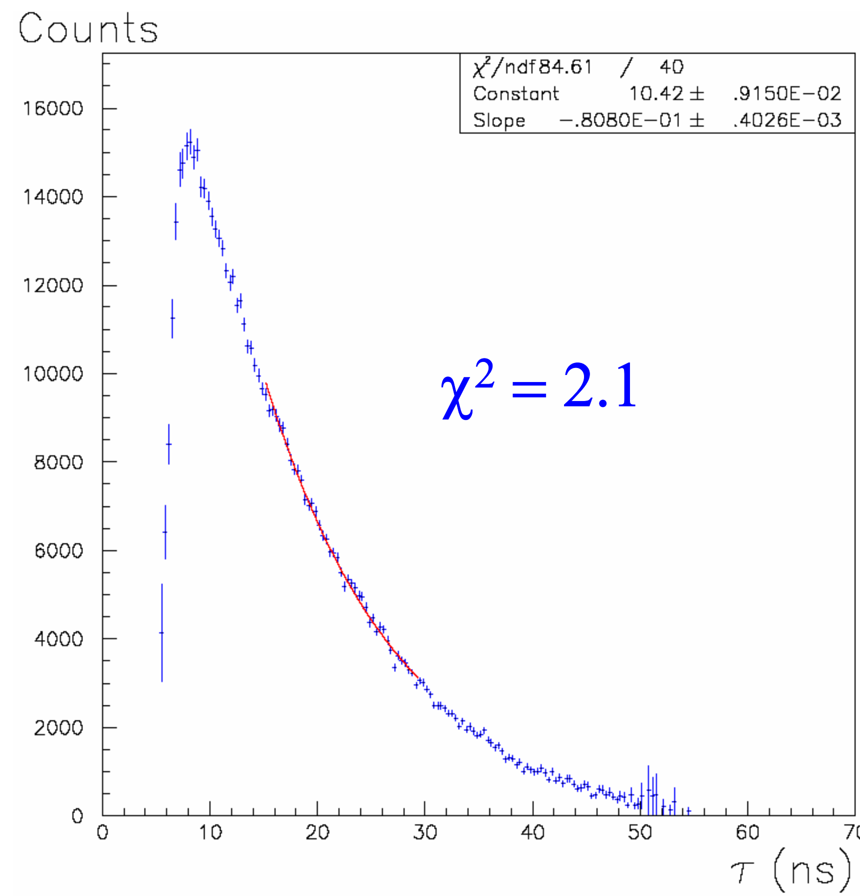




MC results for method n.1

τ^{+}_{true} = 12.37 ns

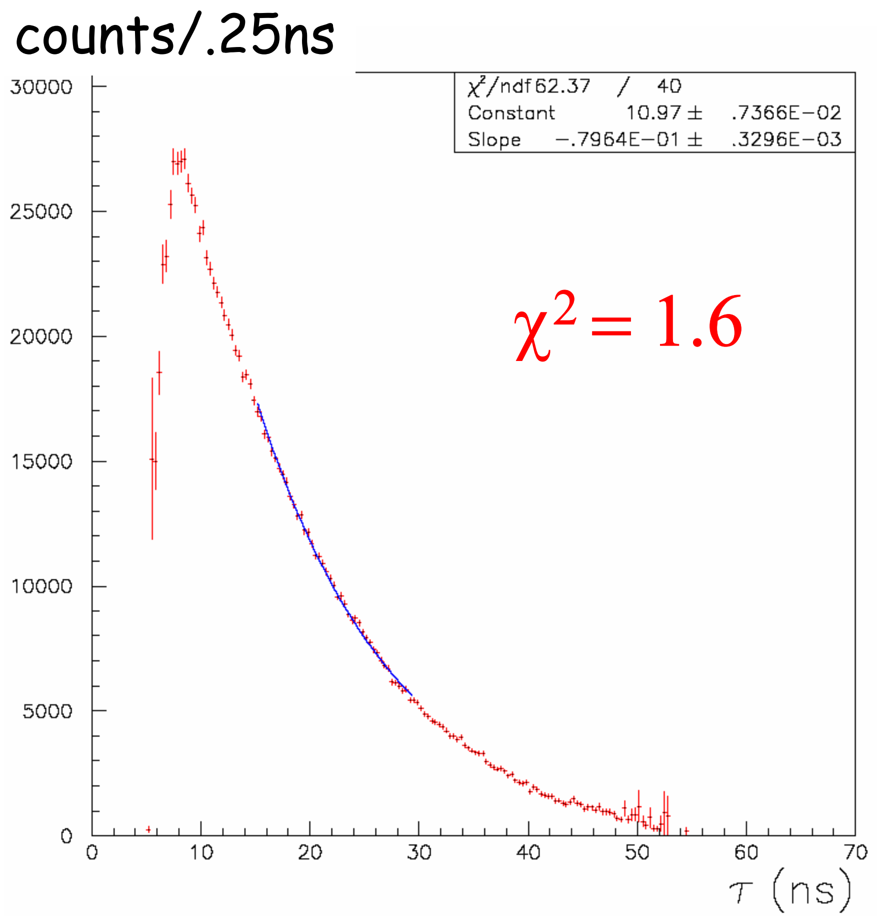


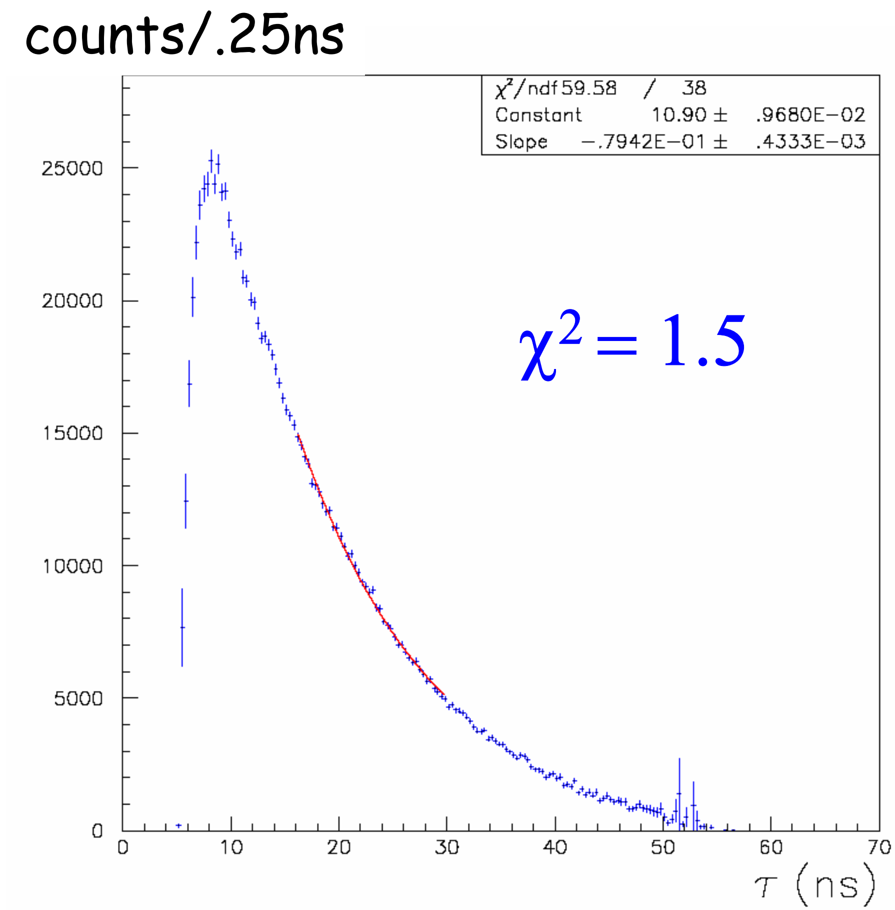


τ^{+}_{MC} = (12.38±0.06) ns

τ^{-}_{MC} = (12.38±0.06) ns

Preliminary results on data



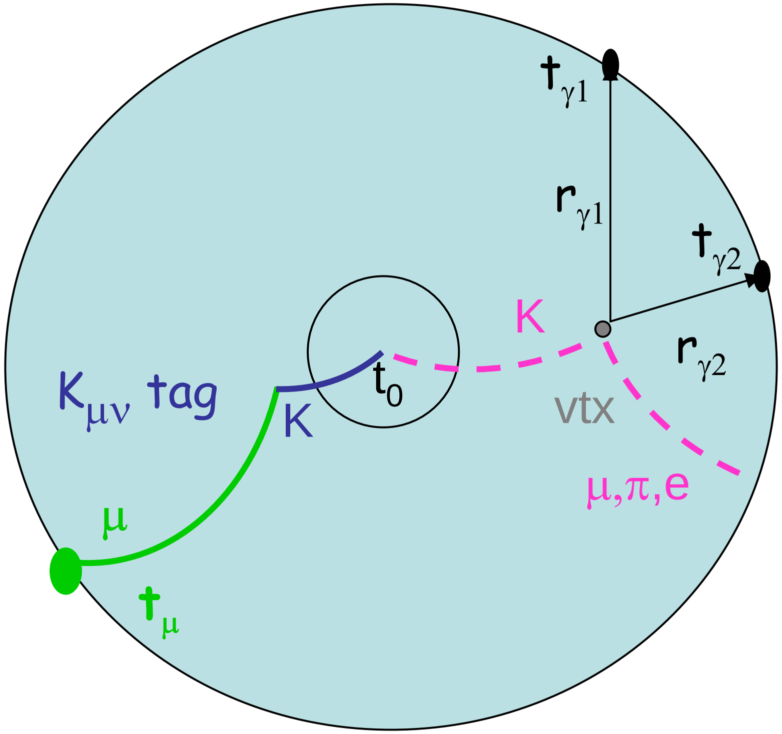


τ^{+}_{data} = (12.557±0.061) ns τ^{-}_{data} = (12.601±0.069) ns

Method 2: τ from time of flight

Signal selection

- Self triggering muon tag
- K track on the signal side
- Decay vertex
- π^0 coming from the vertex



For each γ from π^0:

$$\tau_{K^\pm} = \left(t_\gamma - \frac{r_\gamma}{c} - t_0 \right) \sqrt{1 - \beta_K^2}$$

Charged vertex efficiency *and π^0 efficiency* needed wrt the decay path of the Kaon

Neutral vertex efficiency (I)

1) The true neutral vtx efficiency is:

$$\varepsilon_{nvtx \quad true} = \frac{N_{nvtx}}{N_{\pi^0}}$$

(MC true)

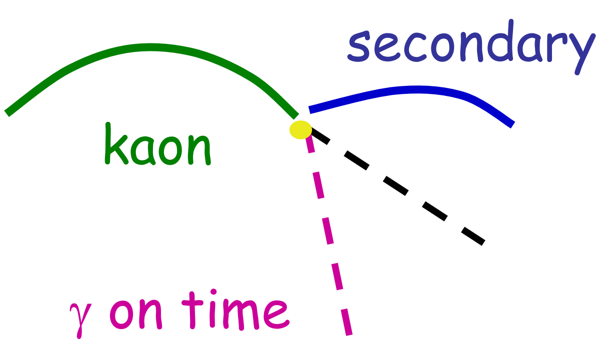
2) the reconstructed efficiency is :

$$\varepsilon_{nvtx \quad reco} = \frac{N_{nvtx \ \& \ cha\_vtx}}{N_{cha\_vtx \ \& \ \gamma \ on \ time \ \& \ P^* \ cut}}$$

(MC/DATA reco)

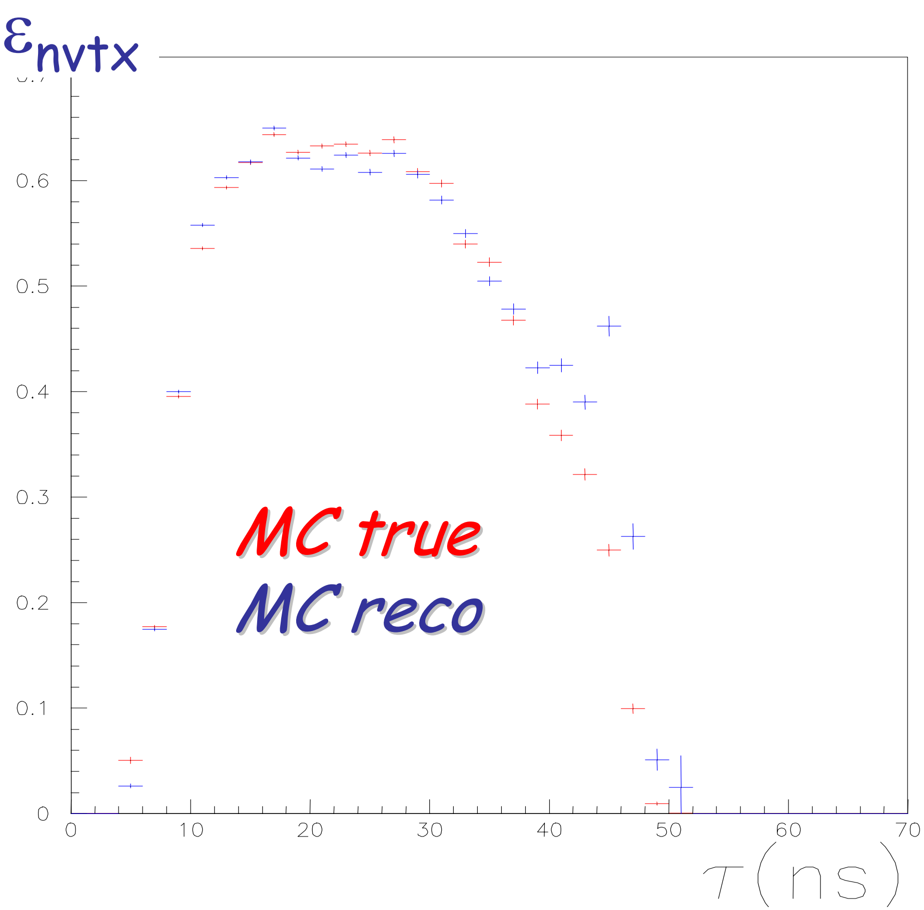
the normalization sample requires:

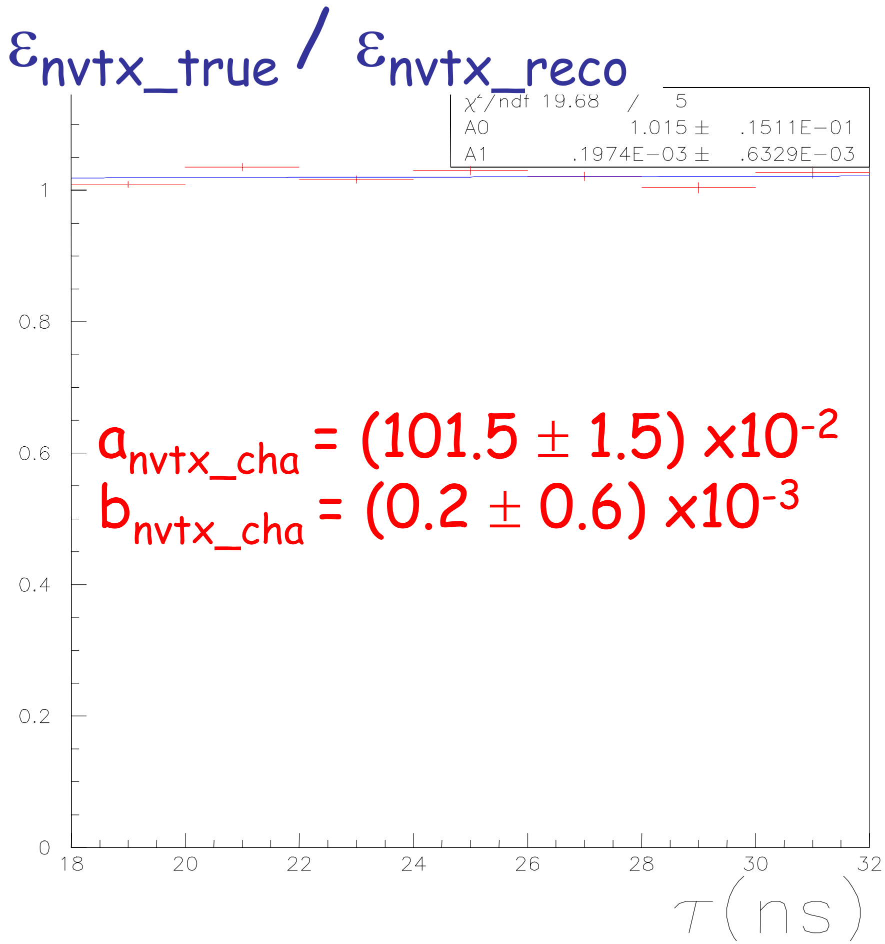
- charged vertex
- 1 γ on time
- p* < 220 MeV



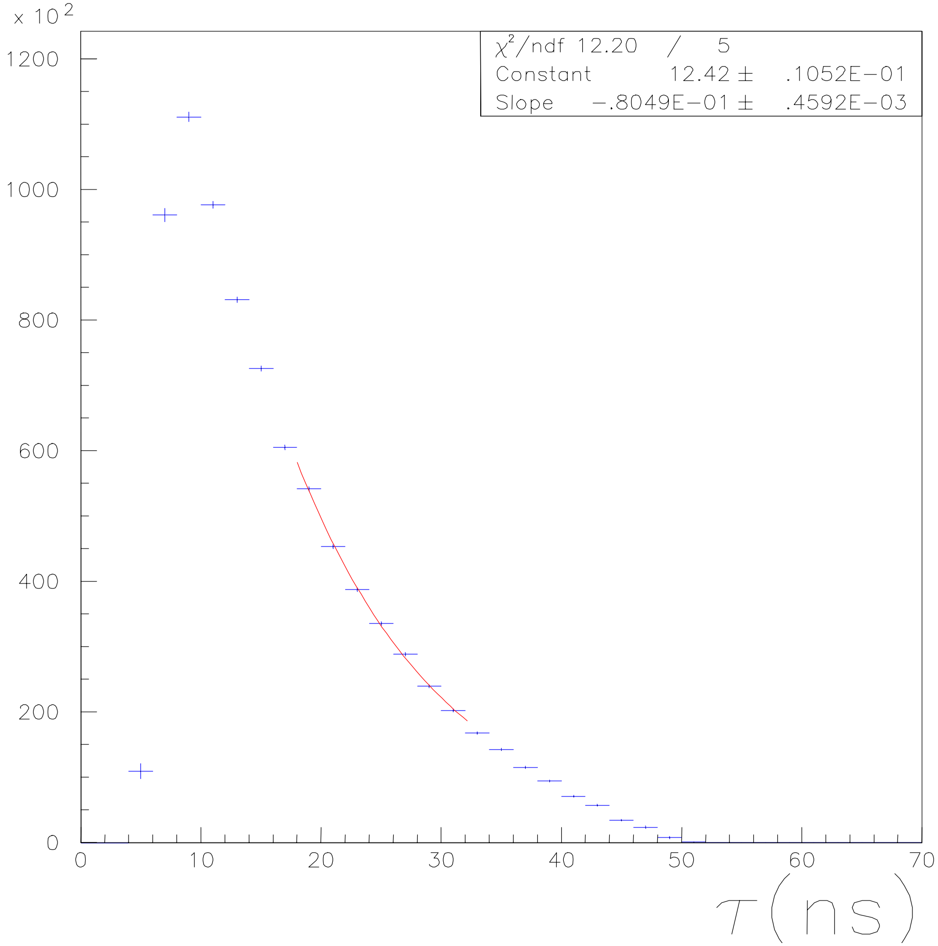
Neutral vertex efficiency (II)

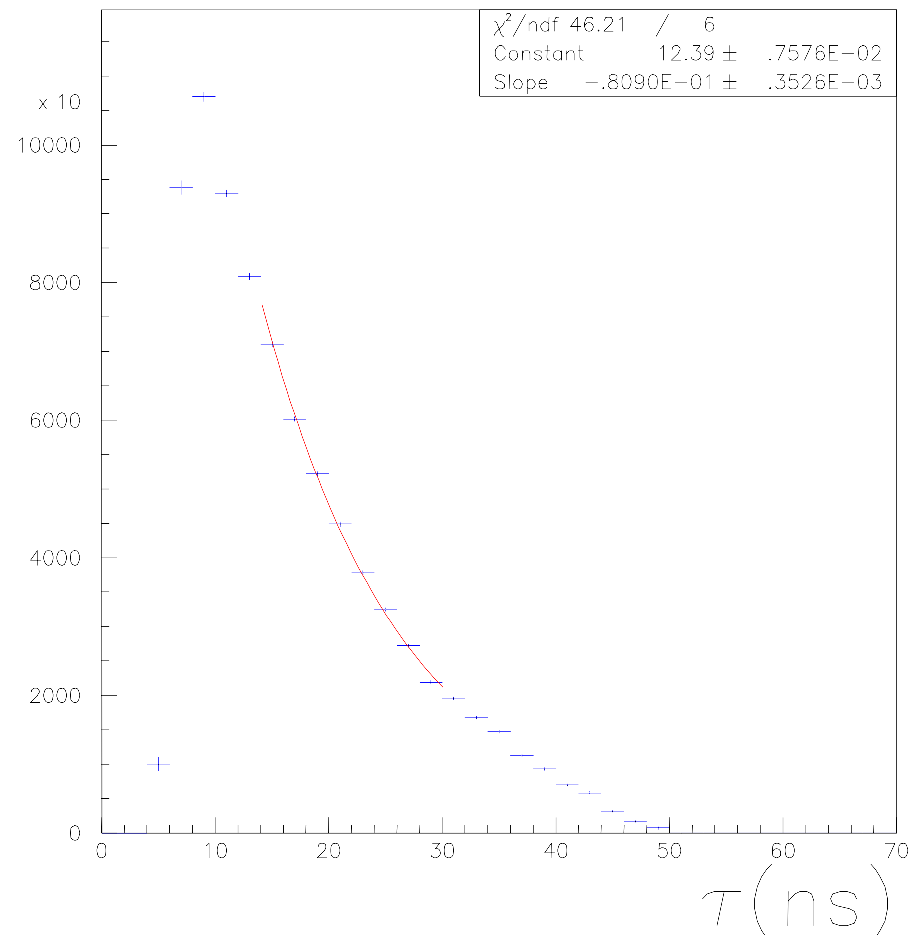
- Measurement performed in a proper time interval (18-32 ns) where the ratio $\varepsilon_{TRUE}/\varepsilon_{RECO}$ is constant (within few 10^{-3})





MC results for method n.2





τ^{-}_{MC} = (12.42 ± 0.07) ns τ^{+}_{MC} = (12.36 ± 0.07) ns

Physics issues – Time schedule

- Absolute BR of $K \rightarrow \mu\nu(\gamma)$

  Winter Conferences

- Absolute BR of $K \rightarrow \pi\pi^0$

  Preliminary for Winter Conferences

- Lifetime

  Winter Conferences