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$K_{l3\gamma}$ decays: the experimental status

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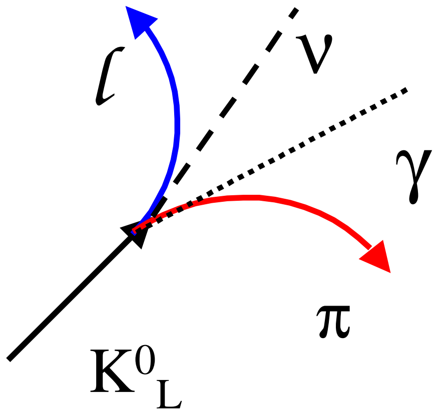


- The published experimental results versus the theoretical predictions;

- A method proposed to measure $BR(K^0_L \rightarrow \pi e \nu \gamma)$ at KLOE

Published experimental results: $BR(K_{e3\gamma})$

$$\text{KTeV}: \left(3.522 \pm 0.044(\text{stat.})^{+0.057}_{-0.053}(\text{syst.})\right) \times 10^{-3}$$

Phys. Rev. D 64 (2001) 112004

$$\text{NA31}: \left(3.61 \pm 0.14(\text{stat.})^{+0.21}_{-0.15}(\text{syst.})\right) \times 10^{-3}$$

Phys. Lett. B 369 (1996) 69-76

$$\text{PDG}: \left(3.53 \pm 0.06\right) \times 10^{-3} \quad \text{2002 w.a.}$$

Published experimental results:BR($K_{e3\gamma}$)

The KTeV analysis:

- Isolated photon counting, ~ 15,000 selected signal events, ~110 bckg
- Totally MC dependent for:
  - ➔ K^0_L lab momentum determination;
  - ➔ K_{e3} and $K_{e3\gamma}$ event acceptances;
  - ➔ photon efficiency measurement;
  - ➔ background subtraction ($K_{\pi 3}$,K_{e4})
- $K_{e3\gamma}$ event generator derived from the "Current Algebra" formalism as in H.Fearing et al., Phys. Rev. D 2 (1970) 542 and ref. therein

$M(K_{e3\gamma}) = M_{IB} + M_{DE}$; IB = Inner Bremsstrahlung, DE = Direct Em.

$$\mathrm{M}_{\mathrm{DE}} = \frac{A}{M_K^2} f_A + \frac{B}{M_K^2} f_B + \frac{C}{M_K^2} f_C + \frac{D}{M_K^2} f_D;$$

$$f_A, f_B \propto P_K \text{ => soft kaon approx.} \rightarrow A = B = 0$$

Published experimental results:BR($K_{e3\gamma}$)

The KTeV analysis:

5

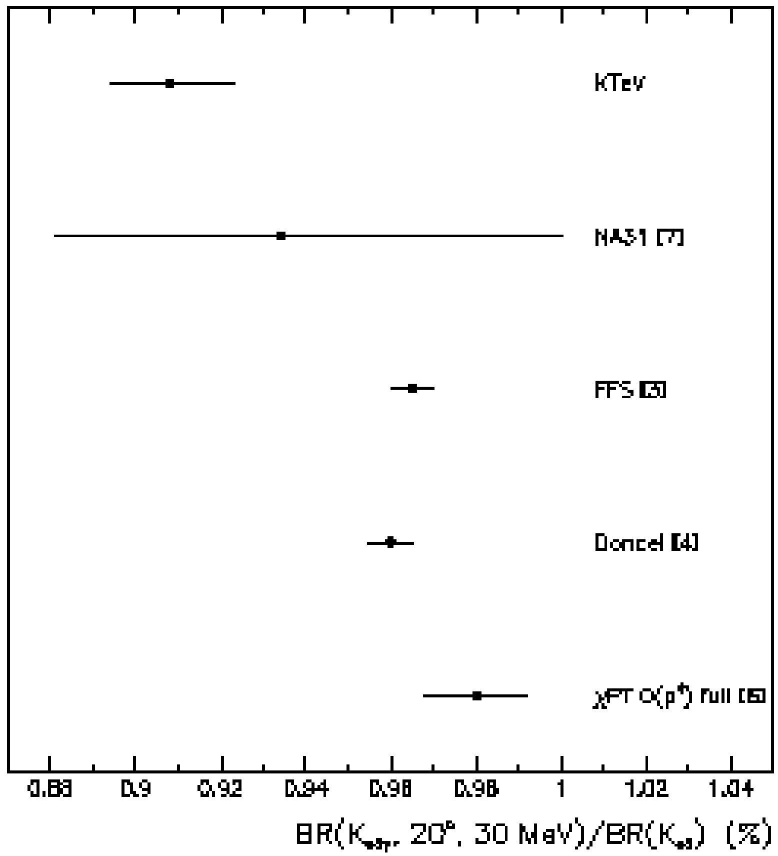


FIG. 4: A comparison of our branching ratio measurement with other recent measurements and predictions.

The conclusions:

- The measured BR($K_{e3\gamma}$)

"is significantly lower than all published theoretical predictions"

Published experimental results: BR($K_{e3\gamma}$)

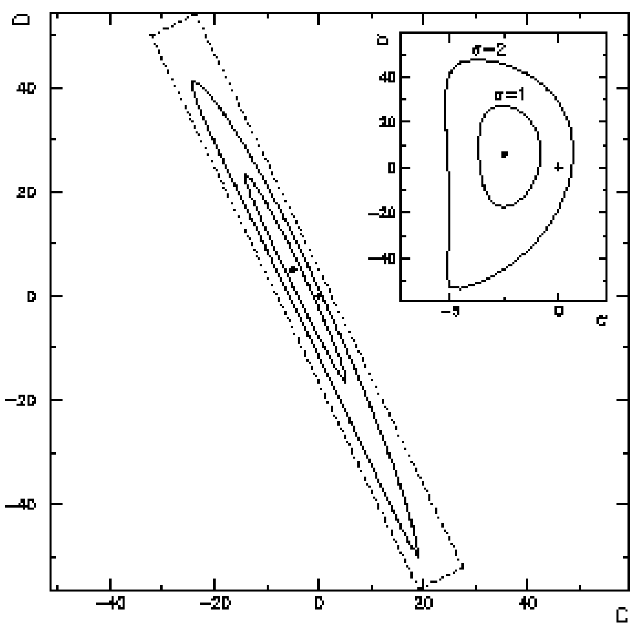
The KTeV analysis:

- In the soft kaon approx.

$C = -5 \pm 10; \quad D = 5^{+19}_{-21}$

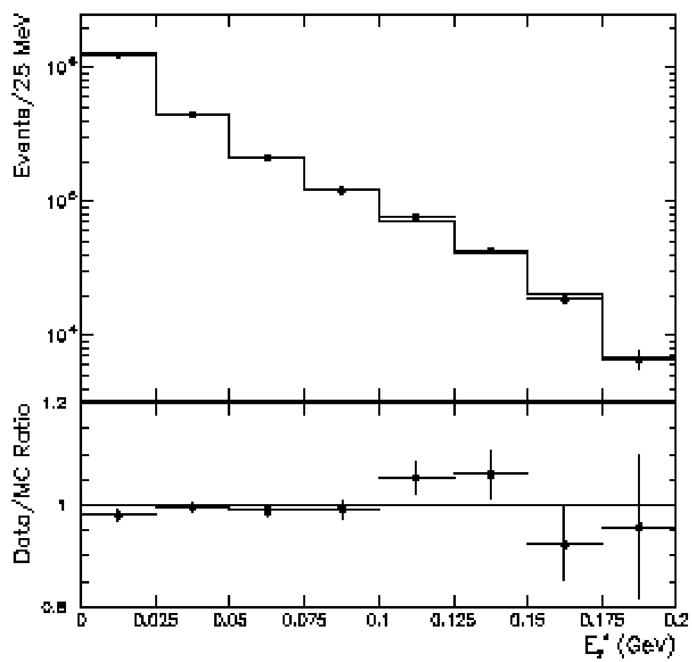
results of a 2 parameter

fit on $\dfrac{dN}{dE^{*}_{\gamma}\, d\cos\vartheta^{*}_{e\gamma}}$



The conclusions (cont'd)

- Photon spectrum consistent with IB as only source of photons



Published experimental results:BR($K_{e3\gamma}$)

The NA31 analysis: Phys. Lett. B 369 (1996) 69-76

$$N_{sign}^{ev} = 1384 \pm 53, \quad \text{S/N} > 2$$

Background sources:

- $K^0_L \rightarrow \pi^+\pi^-\pi^0$, one photon lost, one pion misidentified
- accidental photons in the K0L beam
- photons generated by the pion shower

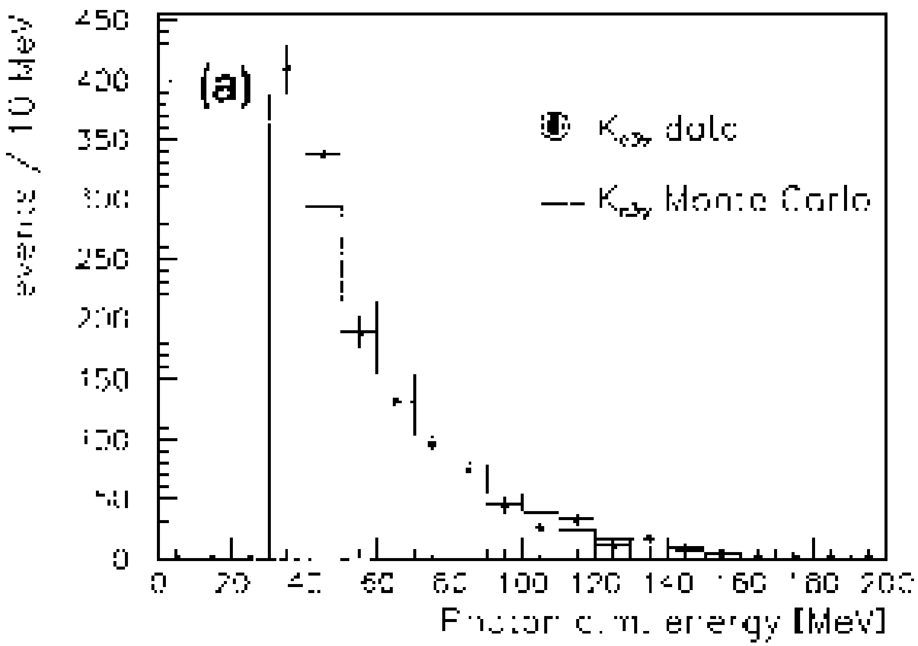
➔ All backgrounds subtracted from selected data sample

Published experimental results: BR($K_{e3\gamma}$)

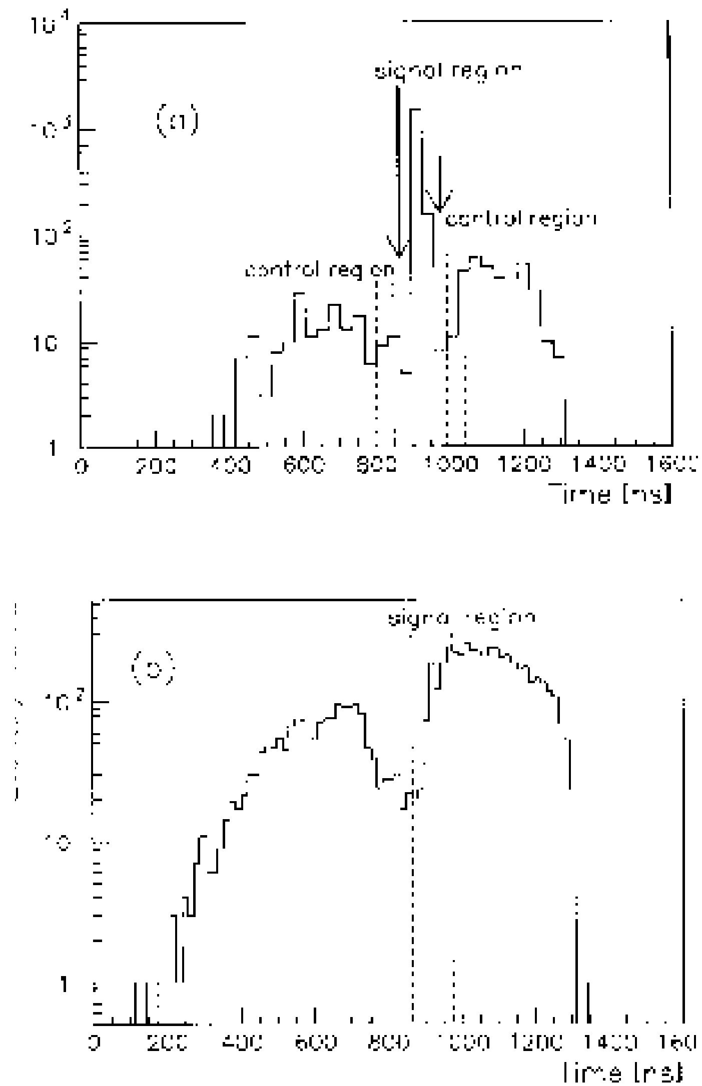
The NA31 analysis:

Discriminant observable: the cluster time

Letters B 369 (1996) 69–76 75



F. Leber et al. / Physic



Published experimental results: $BR(K_{\mu 3\gamma})$

The NA48 analysis: Phys. Lett. B 418 (1998) 411-418

$$N^{ev}_{sign} = 252 \pm 21, \qquad S/N \sim 2$$

Background sources:

- $K^0_L \to \pi^+\pi^-\pi^0$, one photon lost, one pion misidentified
- accidental photons in the K0L beam
- photons generated by the pion shower
- $K_{e3\gamma}$ events where the electron is misidentified as muon

	$BR(K^0_L \to \pi\mu\nu\gamma,\ E^*_\gamma > 30\ \mathrm{MeV},\ \theta^*_\gamma > 20^o)$
NA48	$5.65 \pm 0.46(stat.)^{+0.43}_{-0.54}(syst.) \times 10^{-4}$
Tree level	5.2×10^{-4}
Full O(p4) amplitude	5.6×10^{-4}

Published experimental results:BR($K_{\mu 3\gamma}$)

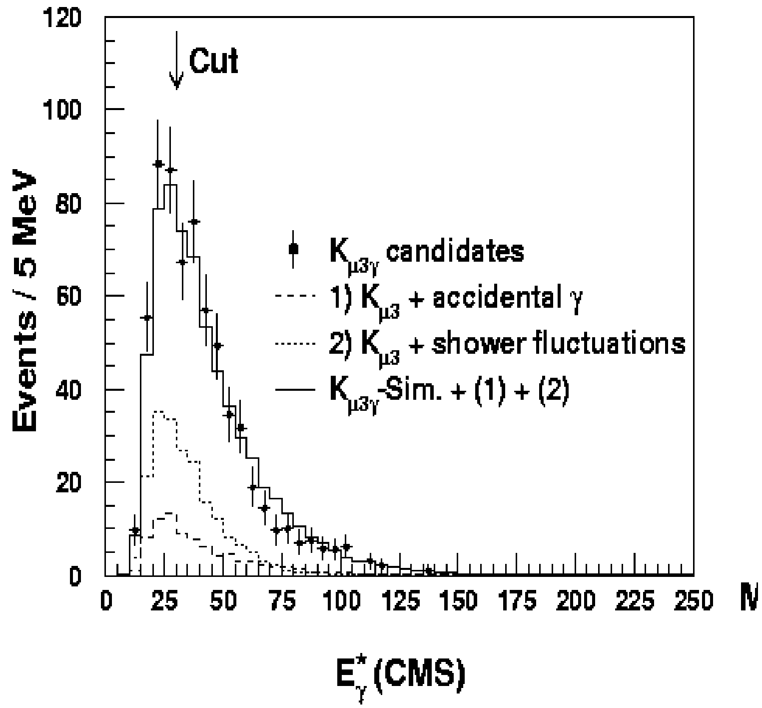
The NA48 analysis:

The discriminant observable: $p_0^{'2}(\pi\mu\gamma)$

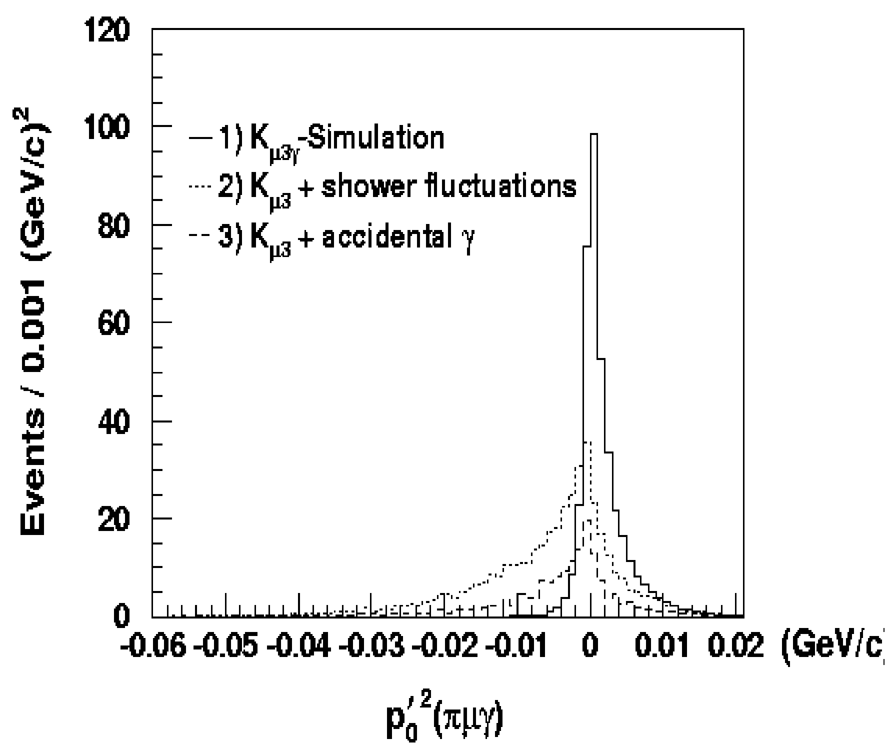
Squared $K^0{}_L$ momentum boosted in the frame where

$$p_{\parallel}^{'}(\pi)+p_{\parallel}^{'}(\mu)+p_{\parallel}^{'}(\gamma)=0$$

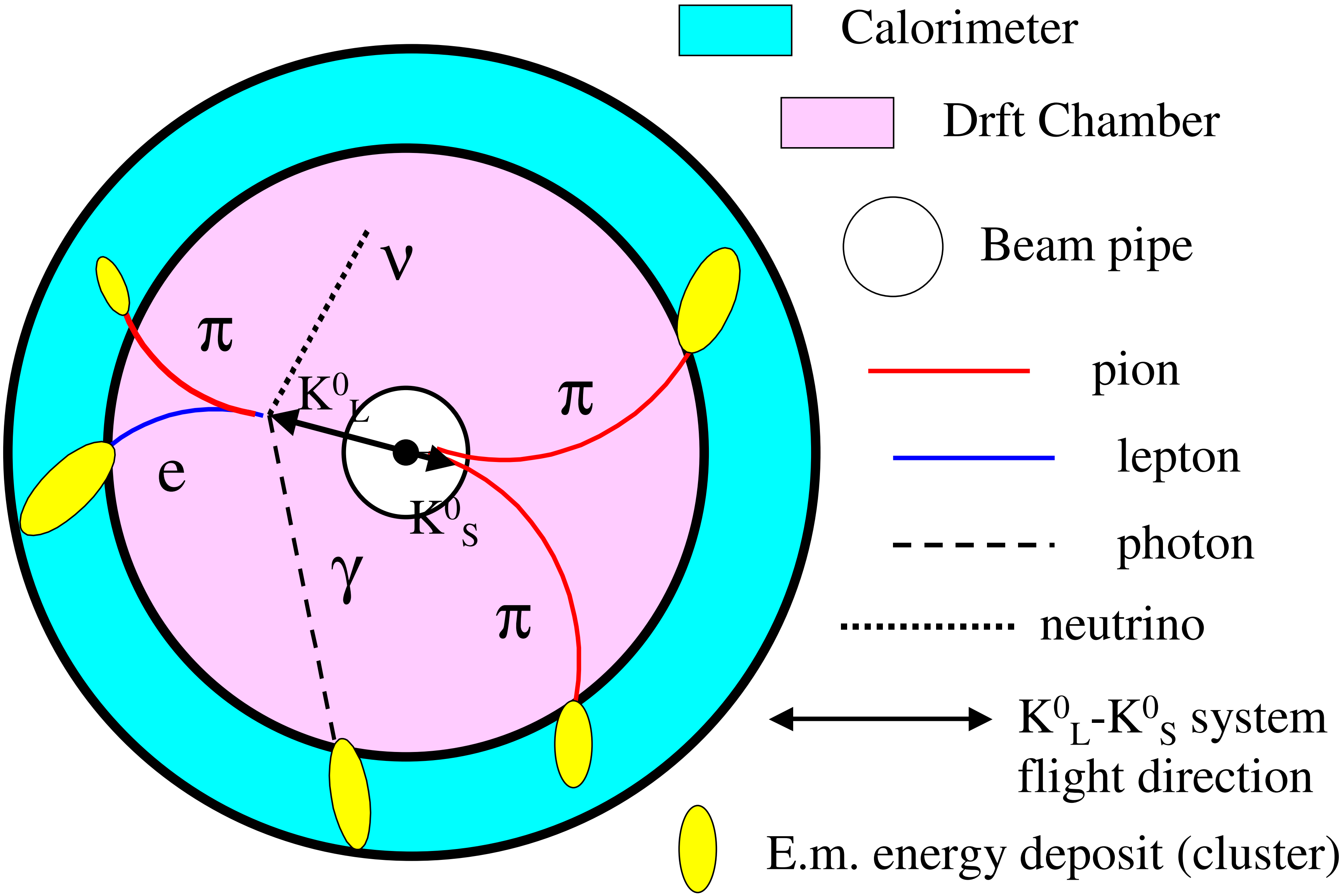
b)



a)



Topology of selected $K_{l3\gamma}$ events at KLOE



Background sources

** $K^0_L \rightarrow \pi^+\pi^-\pi^0$ events where one photon is lost and one charged pion is misidentified as a lepton (see below)

** Accidentals (clusters generated by machine background)

$\rightarrow$ $R_{clu} > 65$ cm

** Cluster fragments (splittings) not associated to any track in non radiative semileptonic decays

$\rightarrow$ $E_\gamma > 20$ MeV

and isolation cut on candidate $\gamma \rightarrow \min\{D_{clu}\} > 50$ cm

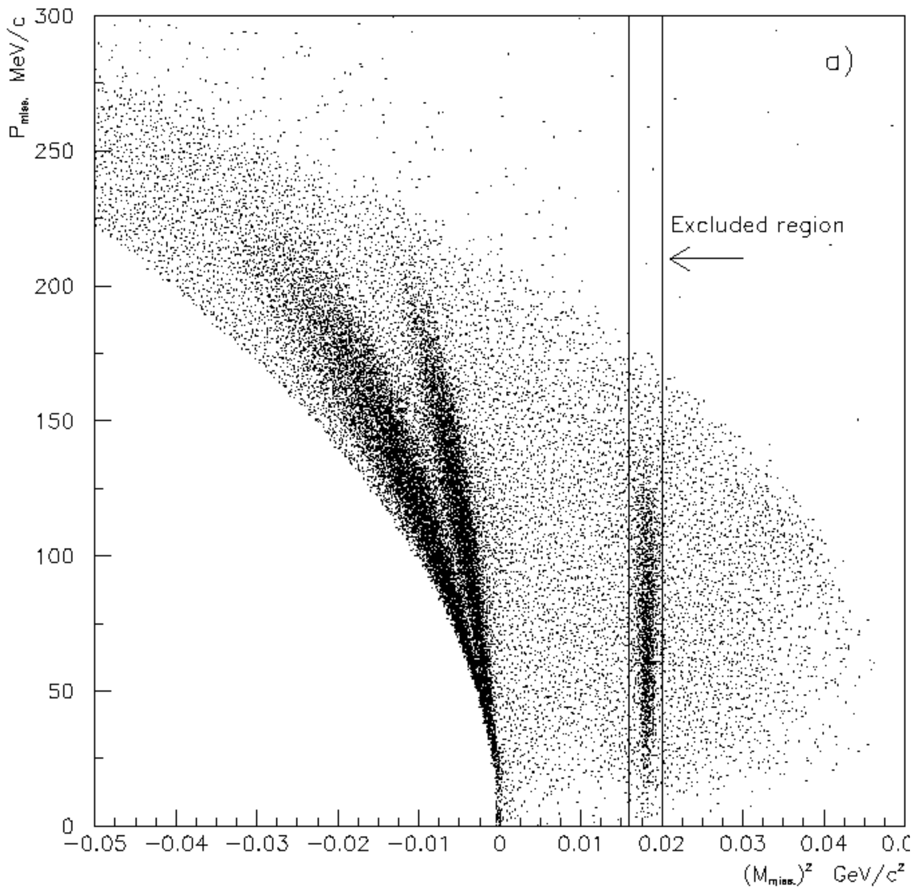
$$\left(D_{clu} = \left|\overrightarrow{X_{clu,\gamma}} - \overrightarrow{X_{clu,track}}\right|\right)$$

Dalitz plot of the K^0_L charged decay modes

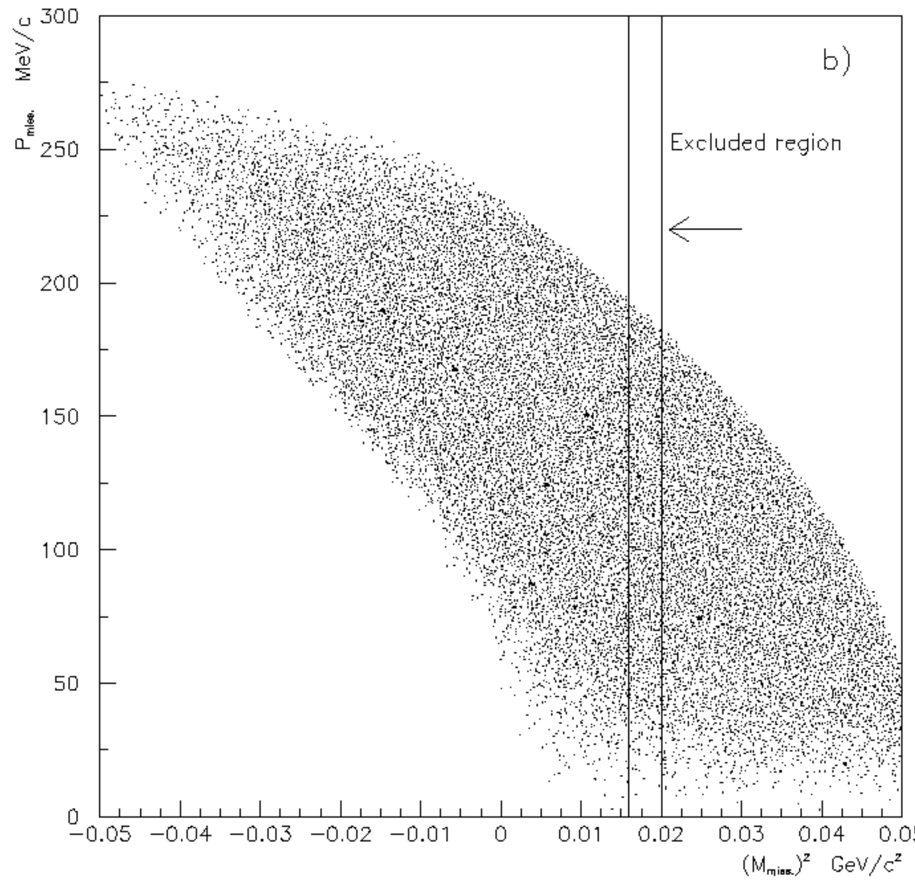
$P_{miss} = P_{K0L} - P_{tr1} - P_{t2}$ vs $M^2_{miss} = E^2_{miss} - P^2_{miss}$; $M_{tr1} = M_{tr2} = M_\pi$

Cut at $|M^2_{miss} - M^2_\pi| < 0.002\ GeV/c^2$ to deplete the $K^0_L \rightarrow \pi^+\pi^-\pi^0$ bckg.

a) Real data



b) Only $K_{l3\gamma}$ generated events (Verbeni)

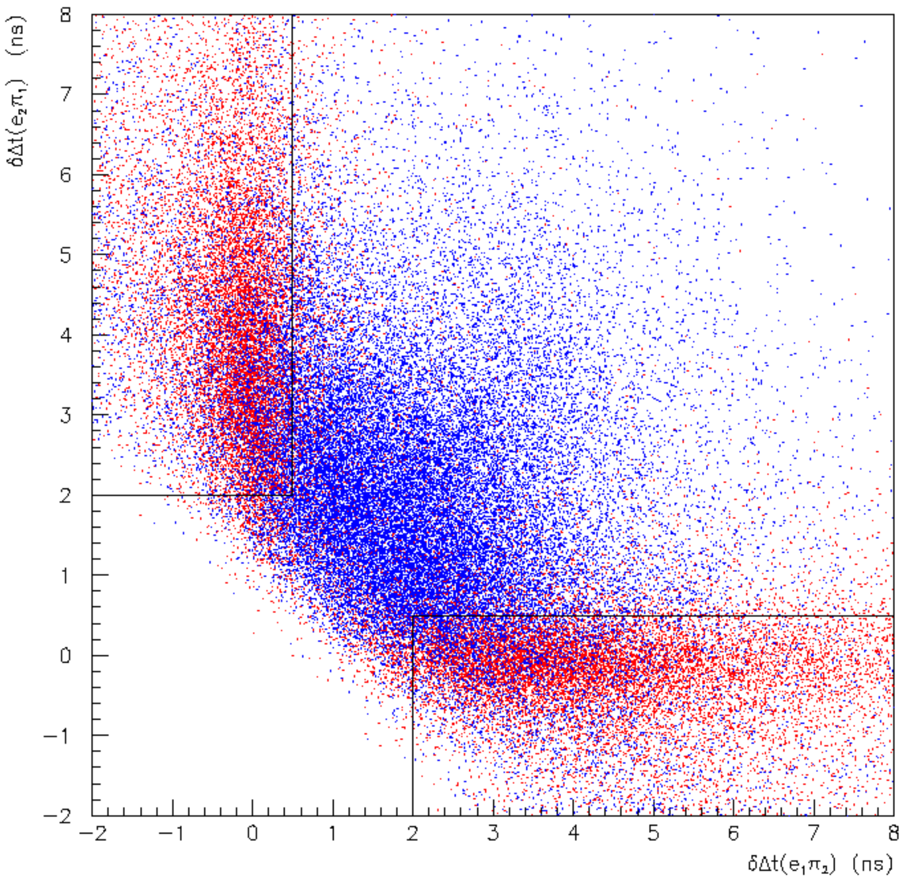


Charged pair assignment with the e.m. cluster timing

$$\delta\Delta t_{1,2} = (t_{clu1} - t^{flight}_{trk1=el.}) - (t_{clu2} - t^{flight}_{trk2=pion})$$

$$\delta\Delta t_{2,1} = (t_{clu2} - t^{flight}_{trk2=el.}) - (t_{clu1} - t^{flight}_{trk1=pion})$$

$\delta\Delta t_{1,2}$



$\delta\Delta t_{2,1}$

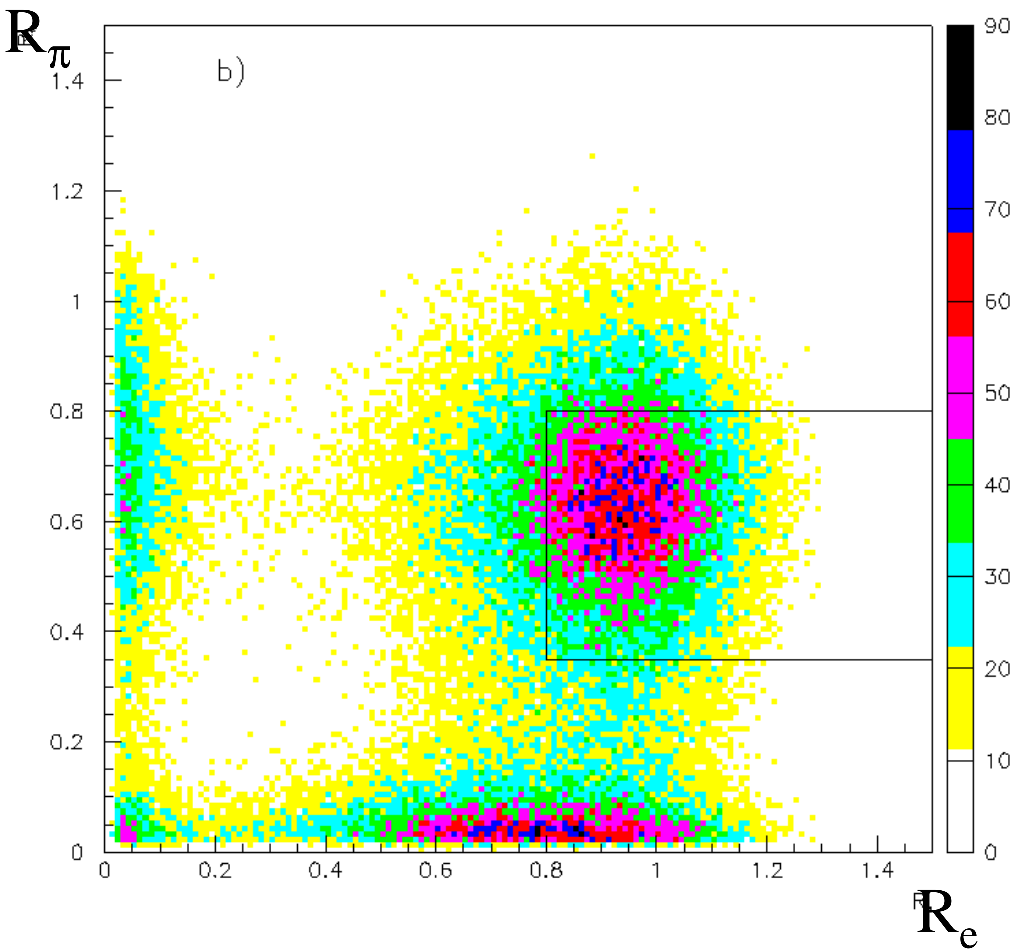
GEANFI package for full event simulation at KLOE

Red points: K_{e3} events

Blue points: $K_{\mu3}$ and $K^0_L \rightarrow \pi^+\pi^-\pi^0$

Reduction of $K_{\mu 3(\gamma)}$ contamination with cuts on the ratio between e.m. energy deposits and track momenta

$$R_{e(\pi)} = \frac{\text{Energy deposit in the calorimeter}}{\text{Momentum of the track associated to the e.m. cluster}}$$

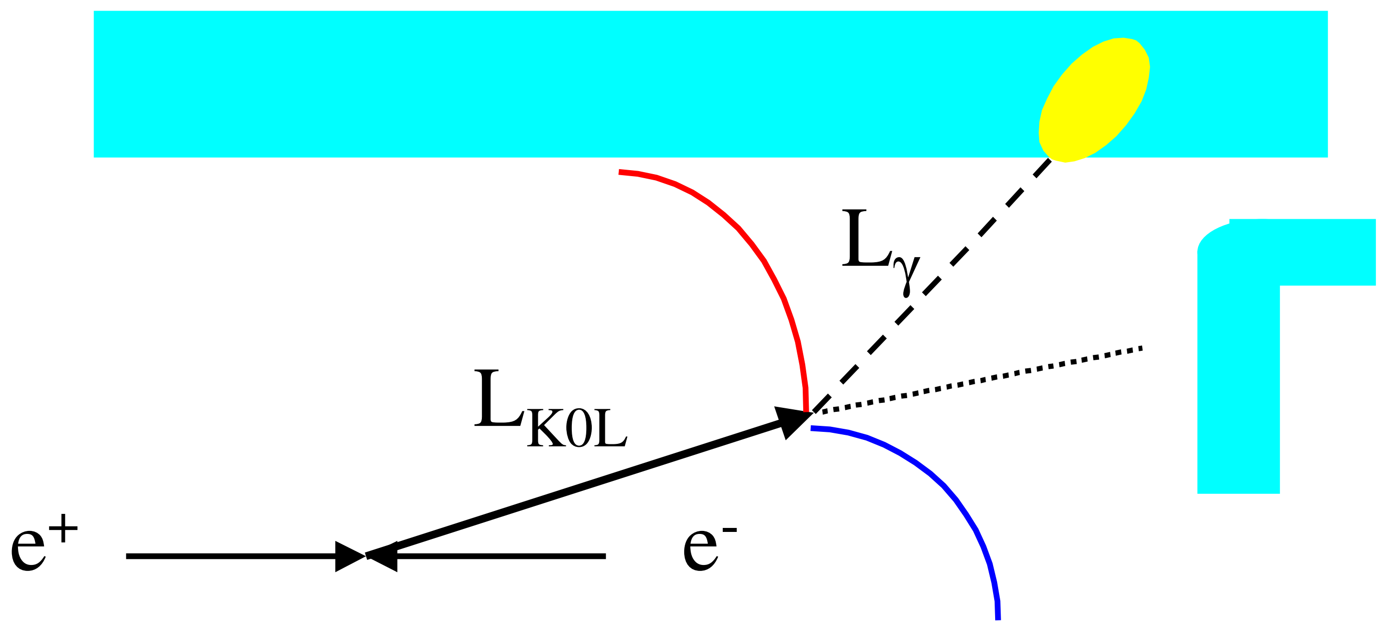


K^0_L dec. mode	Frac. of the total (%)
$\pi e \nu(\gamma)$	~87
$\pi \mu \nu(\gamma)$	~12
$\pi^+\pi^-\pi^0$	< 1
others	< 1

The studied observable for event selection

For all not associated cluster measure

$$\Delta t_{clu} = t_{clu} - \frac{L_{K0L}}{c\beta_{K0L}} - \frac{L_\gamma}{c}$$

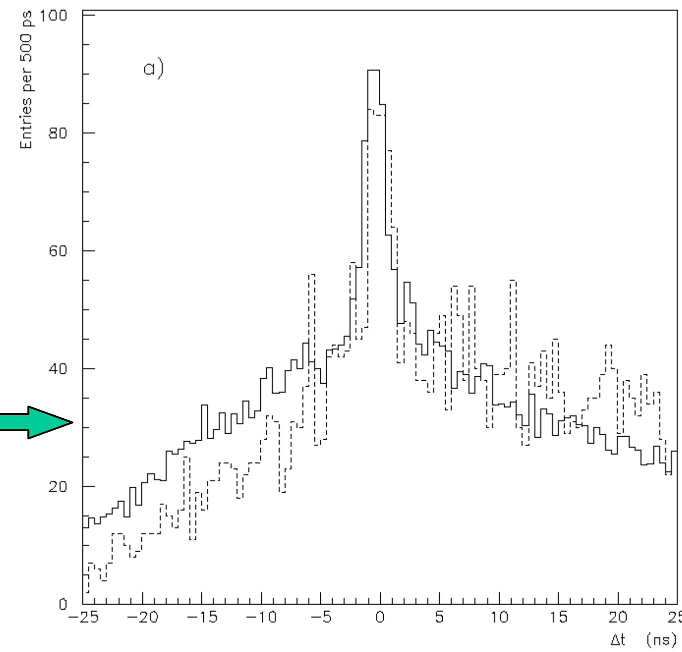


Background suppression: cluster energy and neutrino mass cuts

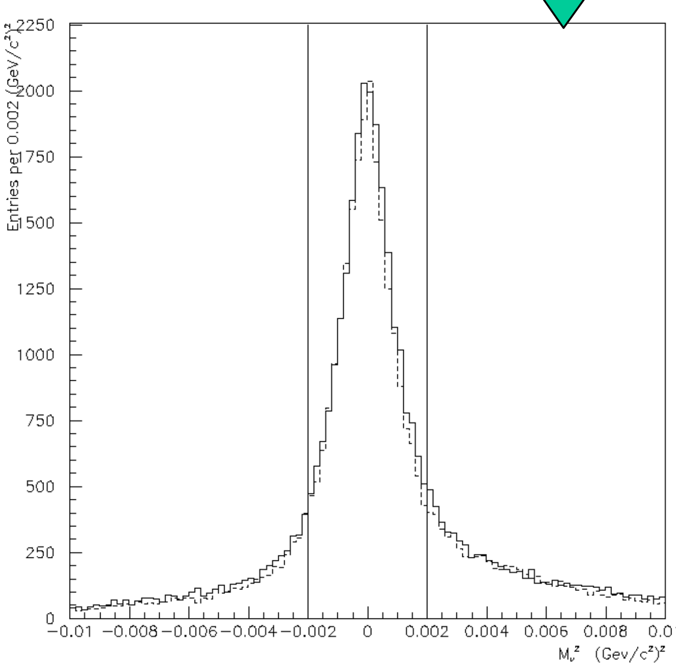
$E_\gamma > 20$ MeV; $|M^2_\nu| < 0.002$ GeV/c^2

Δt_{clu} before cuts

A.U.

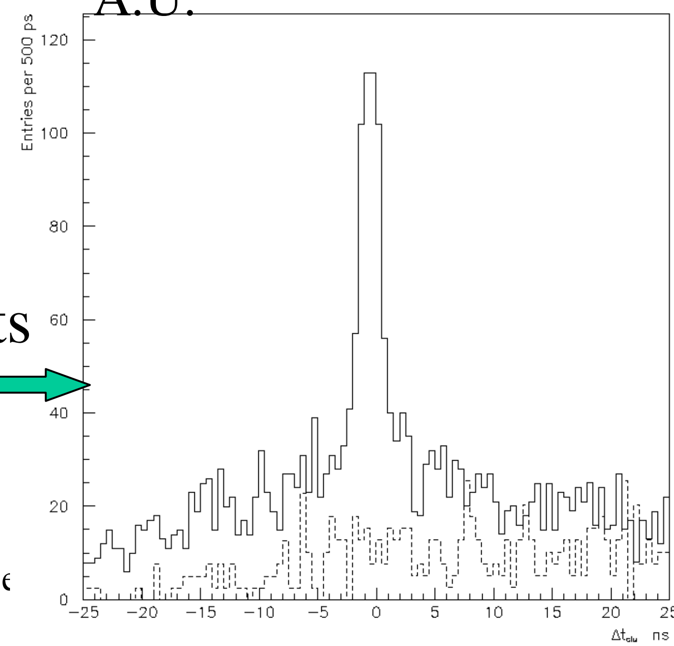


Squared neutrino mass in non raditive K_{e3} events



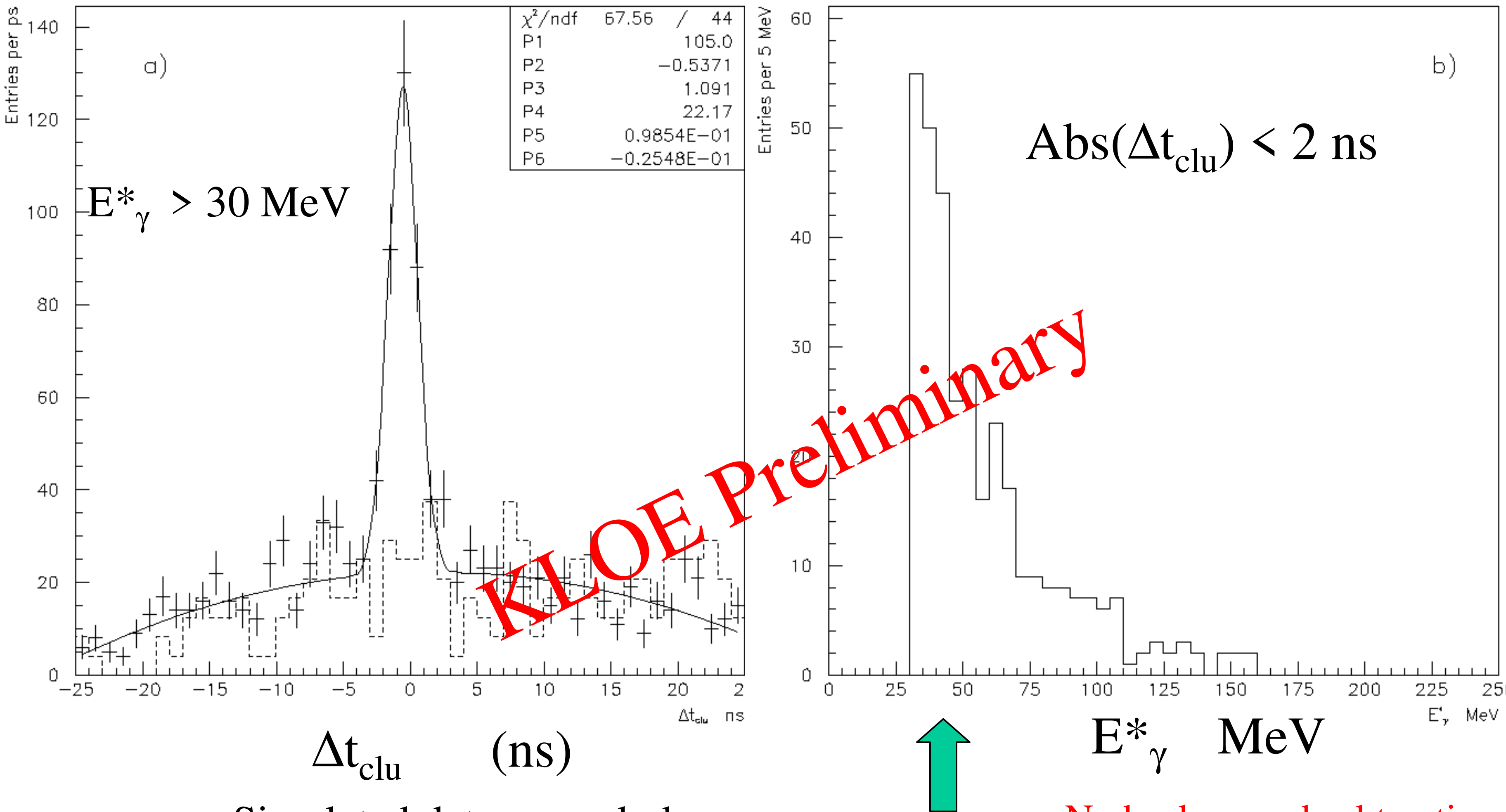
Δt_{clu} after cuts

A.U.



Kl3g decays: e

Preliminary KLOE $K_{e3\gamma}$ signal

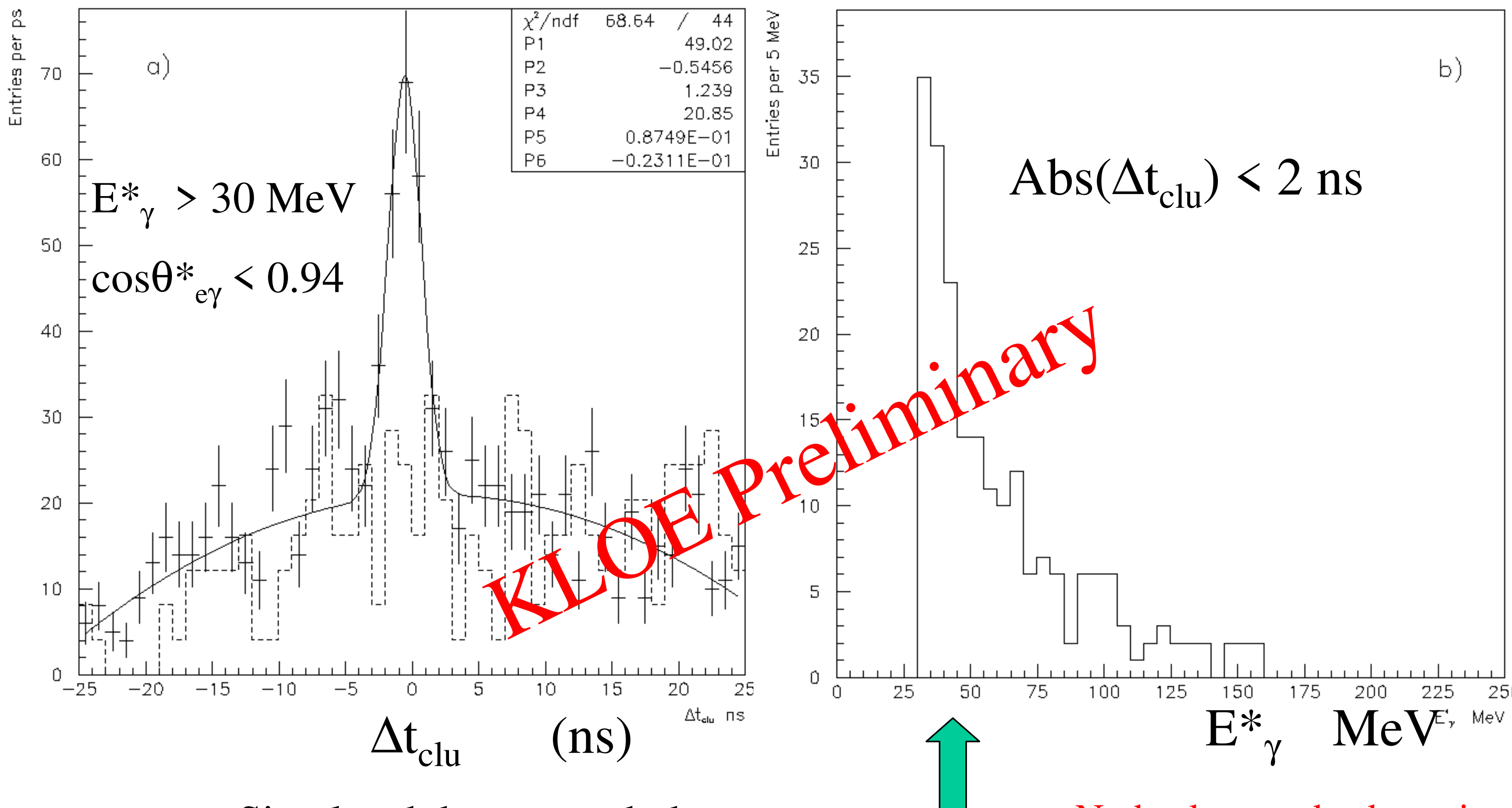


------------ Simulated data, no rad. decays

Real data { No background subtraction
no efficiency correction

+ Real data: N_{signal} = 287 +/- 27 (stat.) S/N ~ 2.2

Preliminary KLOE $K_{e3\gamma}$ signal (cont'd)

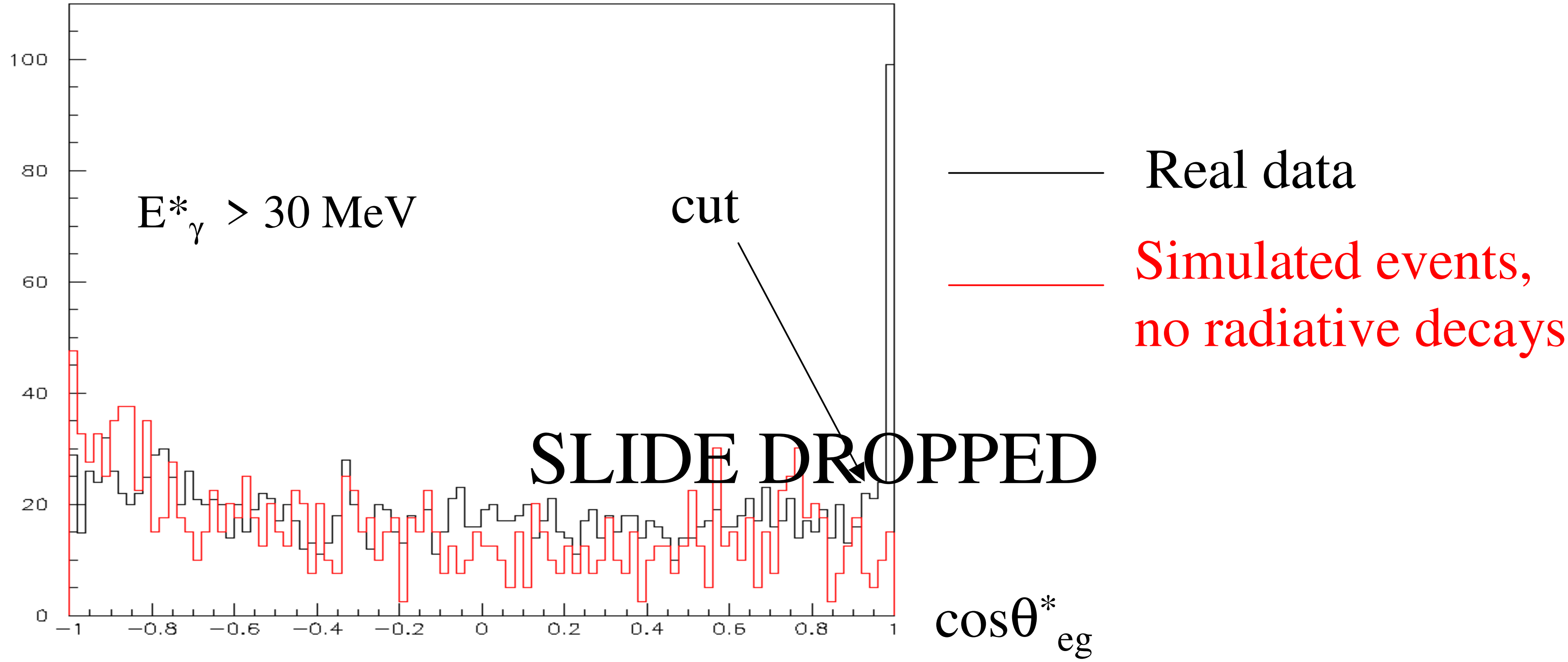


------------- Simulated data, no rad. decays

Real data { No background subtraction
no efficiency correction

+ Real data: N_{signal} = 151 +/- 21 (stat.) S/N ~ 1.2

A first check of predicted B.R.'s



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$$R_{meas} = \frac{N^{ev}_{Ke3\gamma}(E^*_\gamma \geq 30\, MeV)}{N^{ev}_{Ke3\gamma}(E^*_\gamma \geq 30\, MeV, \cos\theta^*_{e\gamma} \leq 0.94)} = 1.9 \pm 0.3(stat.)$$

No efficiency corr. for cluster recons.

$$R_{estim.} = \frac{BR(K^0_L \to \pi e \nu_e \gamma,\ E^*_\gamma \geq 30\, MeV)}{BR(K^0_L \to \pi e \nu_e \gamma\ \ E^*_\gamma \geq 30\, MeV, \cos\theta^*_{e\gamma} \leq 0.94)} = 2.4$$

(Michela Verbeni)

Conclusions and perspectives

- The only experimental measurement of BR($K_{\mu 3\gamma}$) has a total relative error (~12%) greater than the relative difference (~7%) between tree level and full O(p^4) predicted values. A more accurate result is required to confirm predicted values.

- The present experimental relative error on BR($K_{e3\gamma}$) is below 2% ; the measured central value is 2σ below any predicted value; new experimental and theoretical studies are needed to understand such a discrepancy.

- A clear $K_{e3\gamma}$ signal is seen at KLOE in a very preliminary analysis on a reduced data sample (20 over 500 pb^{-1} of int. lum. on disk) with reasonable but not yet optimized selection cuts.

- Rough extrapolation of the event yield from 20 to 500 pb^{-1} leads to a relative statistical error on the signal of about 2.5% for BR($K_{e3\gamma}$).

Conclusions and perspectives (cont'd)

Some caveats:

- The study of the systematic errors has to be still done:

  ➔ some cut efficiency ($K_{3\pi}$ background rejection, e.m. cluster reconstruction) can be estimated from selected data samples;

  ➔ other cut efficiency (cluster isolation, E^*_γ, $\cos\theta^*_{e\gamma}$) and the acceptance measurements need a full detector simulation of the radiative decays at KLOE

  ➔ integration of Bijnens et al. generator in GEANFI ?

- Machine background changed with time during data acquisition:

  ➔ some systematics a bit harder to handle

  ➔ useful statistics may be less than 500 pb^{-1}

Conclusions and perspectives (cont'd)

- The experimental KLOE analysis on $K_{l3\gamma}$ is just started based on $1/25^{th}$ data on tape.
- First feedbacks are encouraging and there is much room to improve the event selection efficiency
- If the systematics will be controlled at the level of the statistical error, a significant check of the published results will come from KLOE.