# $K_S \rightarrow \pi^+ \pi^-$ / $K_S \rightarrow \pi^0 \pi^0$ status

*S. Miscetti, M. Palutan, T. Spadaro and P. Valente*

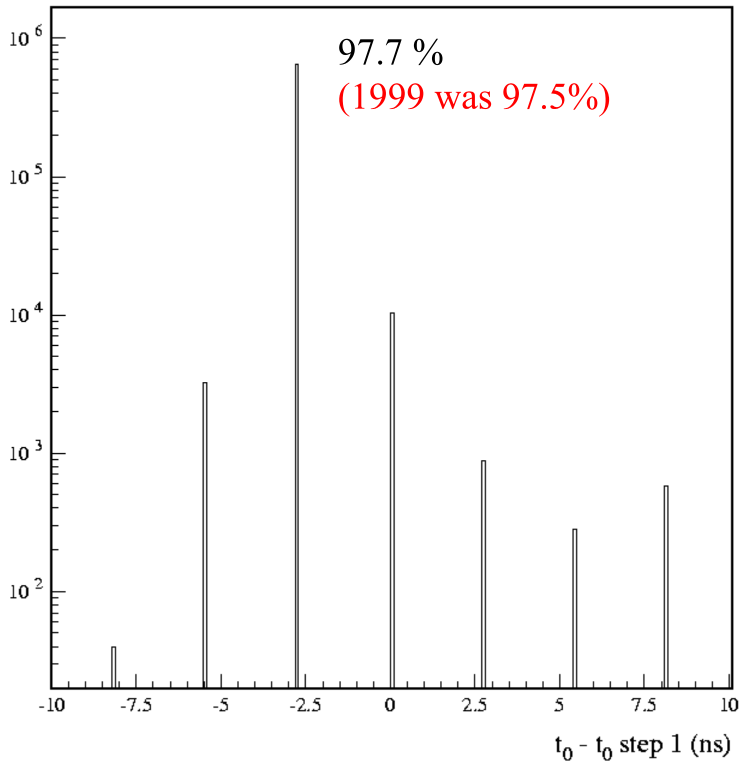
# Summary

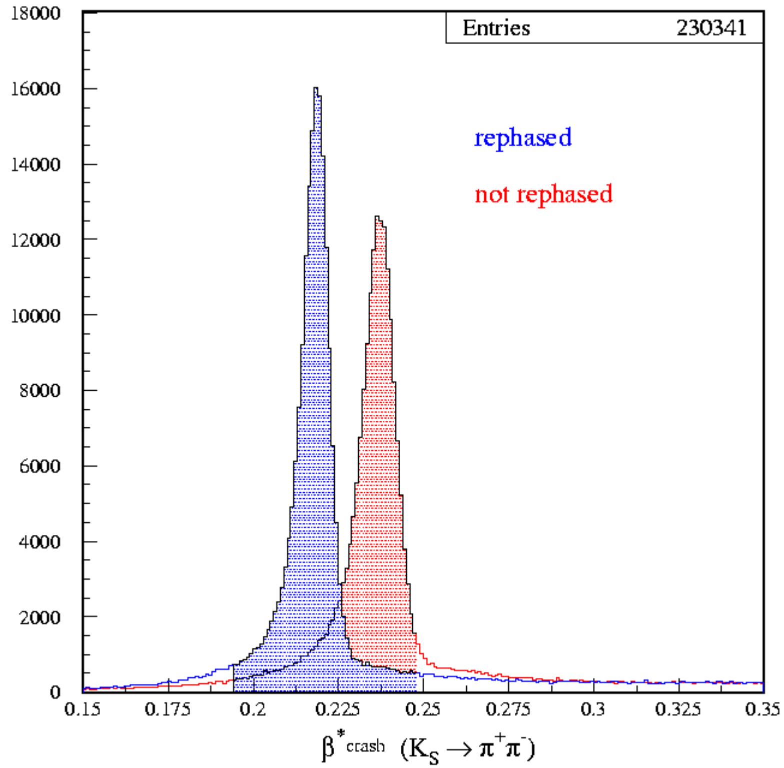
1. $K_L$ crash tag efficiency ratio
2. $K_S \rightarrow \pi^0 \pi^0$ selection ➡ *Prompt cluster counting*
3. $K_S \rightarrow \pi^+ \pi^-$ selection ➡ *Track selection and counting methods*

# Tag efficiency ratio (1)

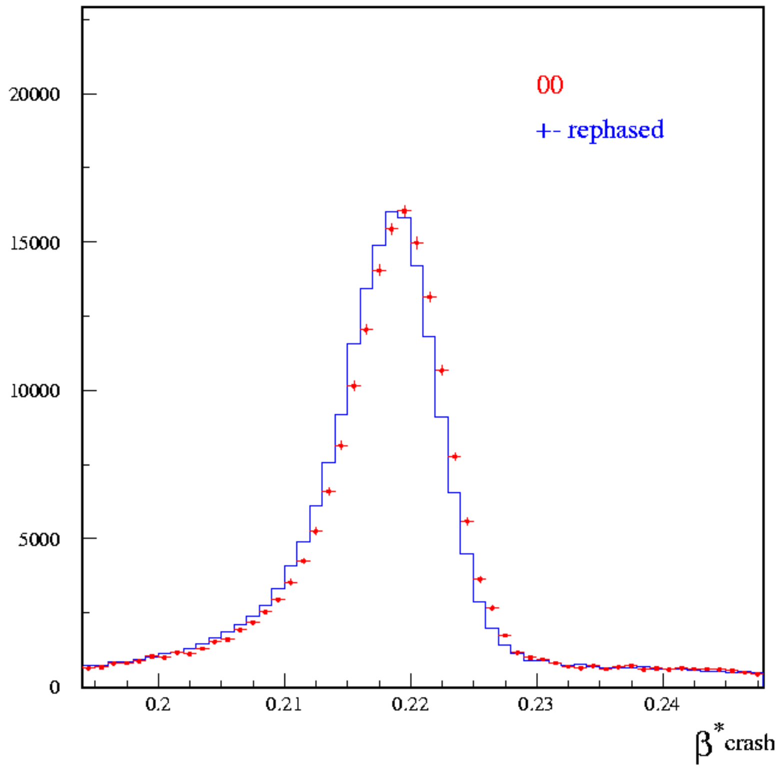
$K_S \to \pi^+ \pi^-$ sample (2 track + inv. mass cut): comparison between $\beta^*$ spectra before and after T0STEP1 correction

$\varepsilon$ (events in window) = $(95.03 \pm 0.005)$ %



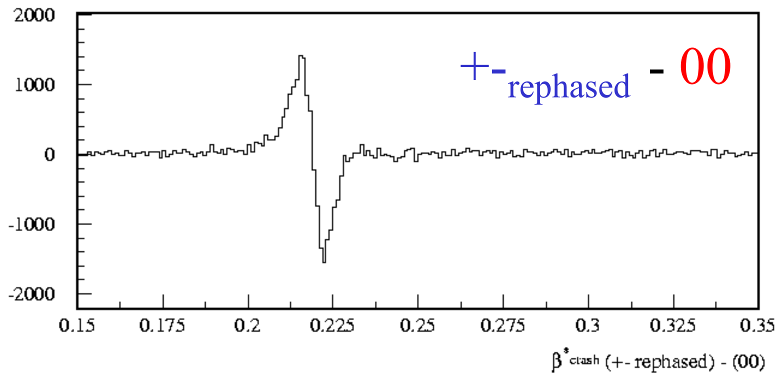



# Tag efficiency ratio (2)



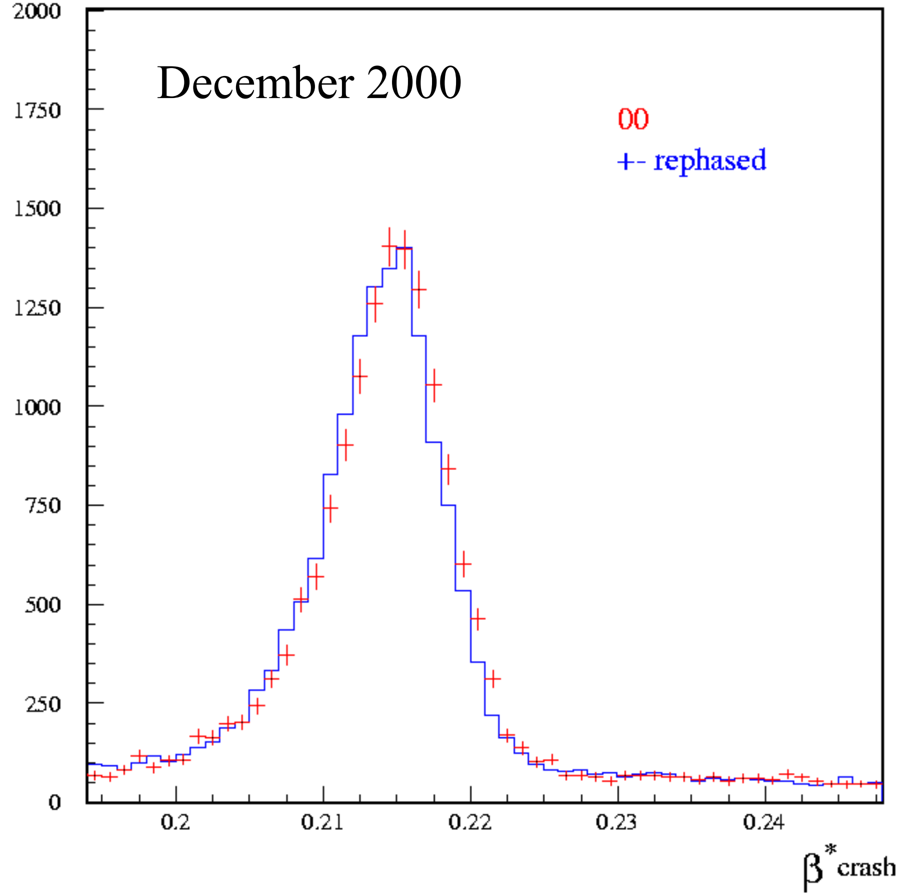

Systematics from comparison
Between $\beta^*$ spectra of:

$(K_S \rightarrow \pi^+ \pi^-)_{rephased}$ and $(K_S \rightarrow \pi^0 \pi^0)$




$$\frac{+-_{rephased} - 00}{00} = 1.33\ \%$$

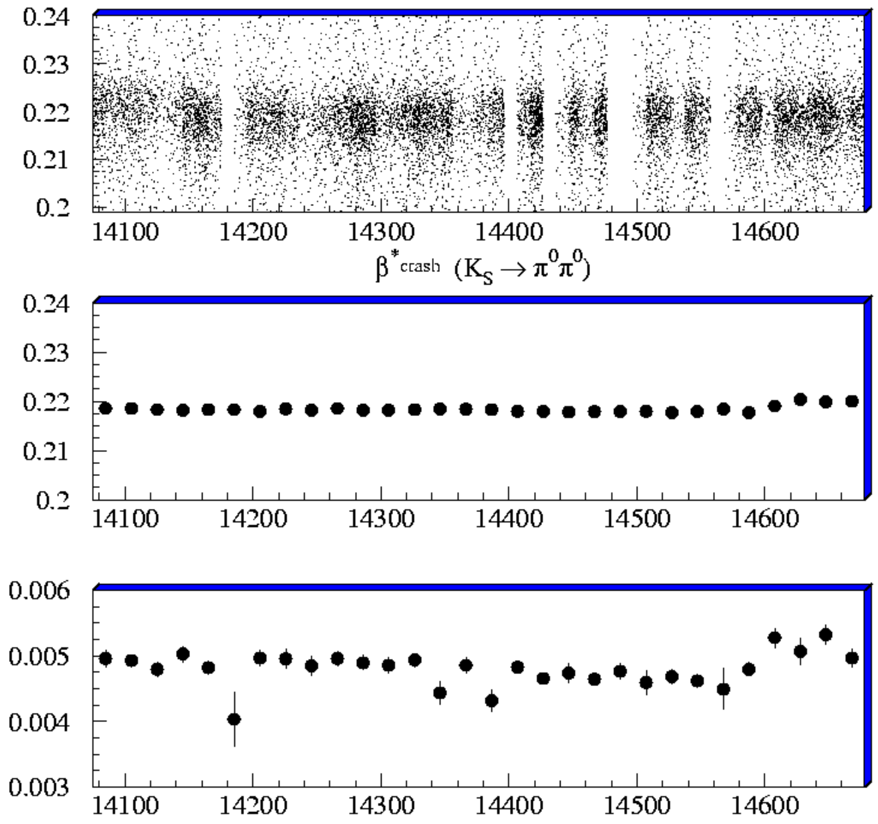
# Tag efficiency ratio (3)



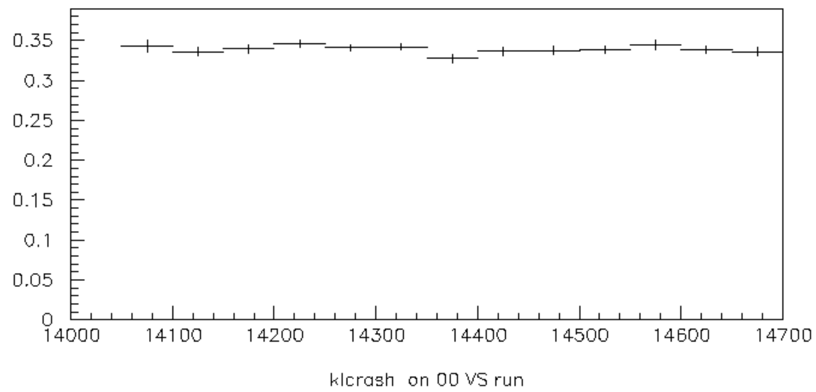

ε (events in window) = 95.8 ± 0.02(stat) ± 1.1(syst) %

# Tag stability (Summer 2000, ≈ 3.5 pb-1)

$K_S \to \pi^0 \pi^0$ : $\beta^*$ distribution vs. run




$K_L$ crash / $K_S \to \pi^0 \pi^0$ tagged:
efficiency vs. run



# $K_S \to \pi^0 \pi^0$: prompt cluster counting (1)

## Selection:

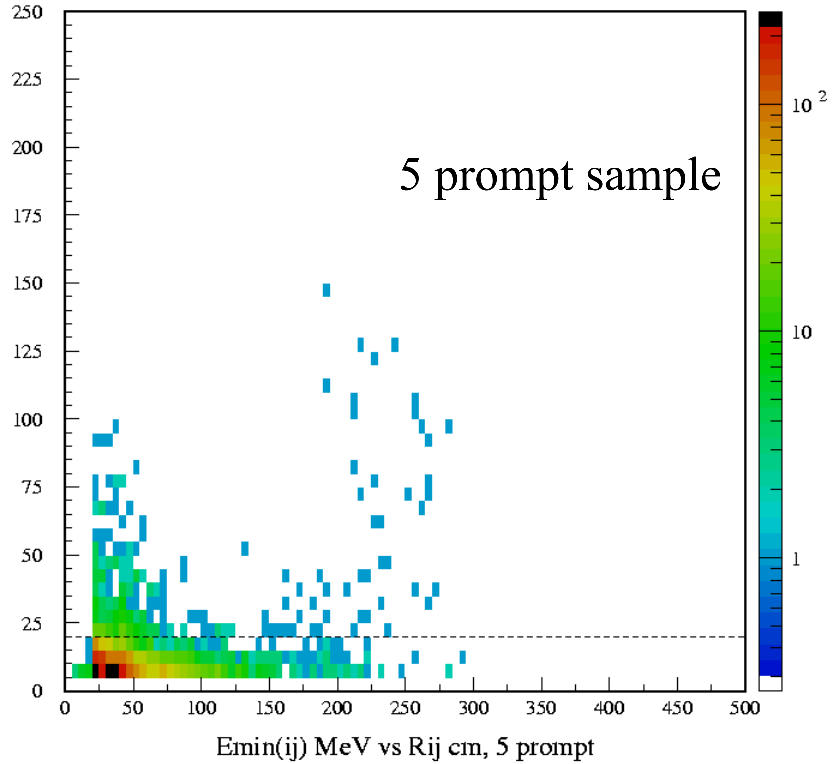
- K crash
- $|t - R/c| \leq \min(5\,\sigma_t\,;\,3\text{ ns})$
- $\cos\theta < 0.9$
- $E > E_{cutoff}$

$E_{cutoff} = 7$ MeV

| # prompt | 3 | 4 | ≥ 5 |
|---|---|---|---|
| DATA | 33.8 % | 62.7 % | 3.5 % |
| MC no thr | 30.8 % | 66.0 % | 3.2 % |
| MC thr* | 32.0 % | 66.0 % | 2.0 % |

*All numbers normalized to ≥3 cluster*

- prompt clusters with smallest distance: $E^{ij}_{min}$ vs $d^{ij}$




* Cells with E<3 MeV are excluded from cluster reconstruction

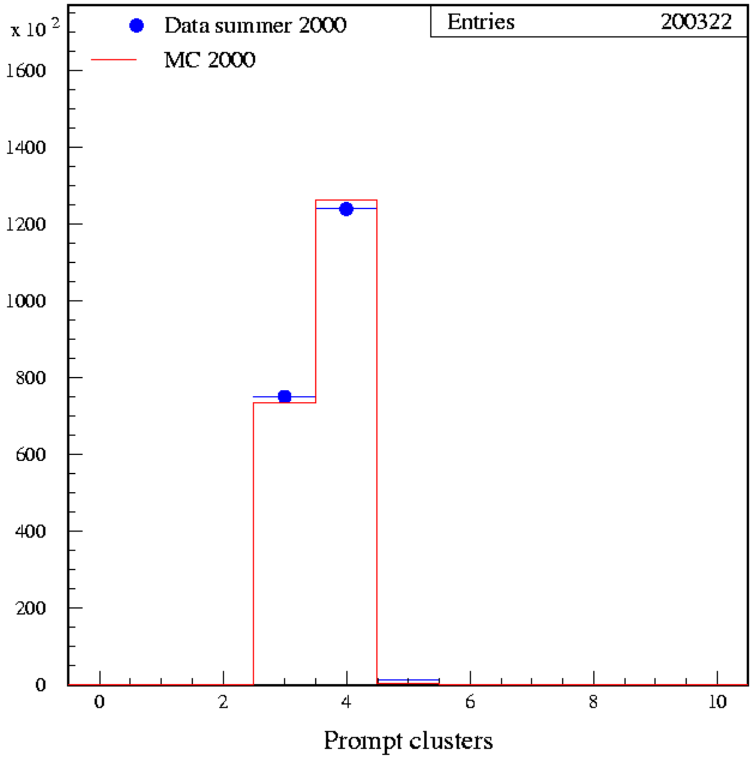
# $K_S \to \pi^0 \pi^0$: prompt cluster counting (2)

$E_{cutoff} = 20$ MeV

| # prompt | 3 | 4 | ≥ 5 |
|---|---|---|---|
| DATA | 37.5 % | 61.8 % | 0.7 % |
| MC thr | 36.7 % | 63.0 % | 0.3 % |

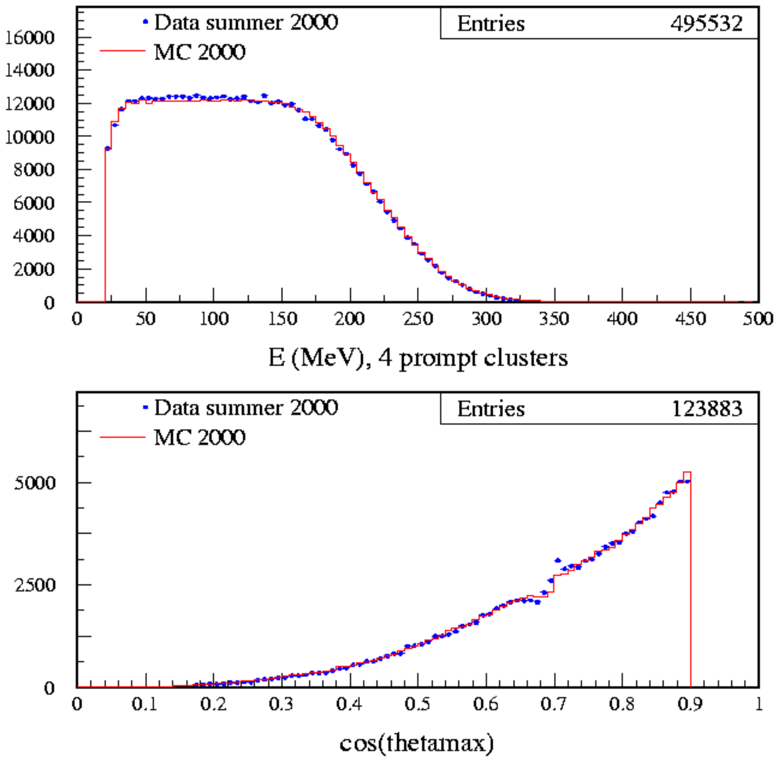
*All numbers normalized to ≥3 cluster*

• prompt clusters distribution:
DATA vs. Monte Carlo, E > 20 MeV

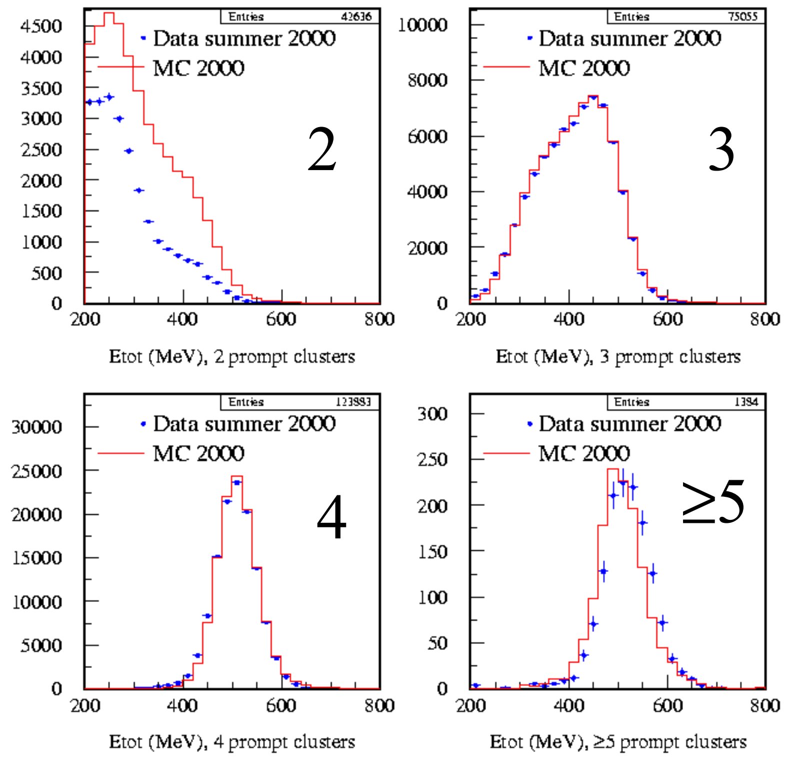


# Prompt clusters: DATA vs MC

- 4 prompt clusters:
Energy spectrum and angular distribution



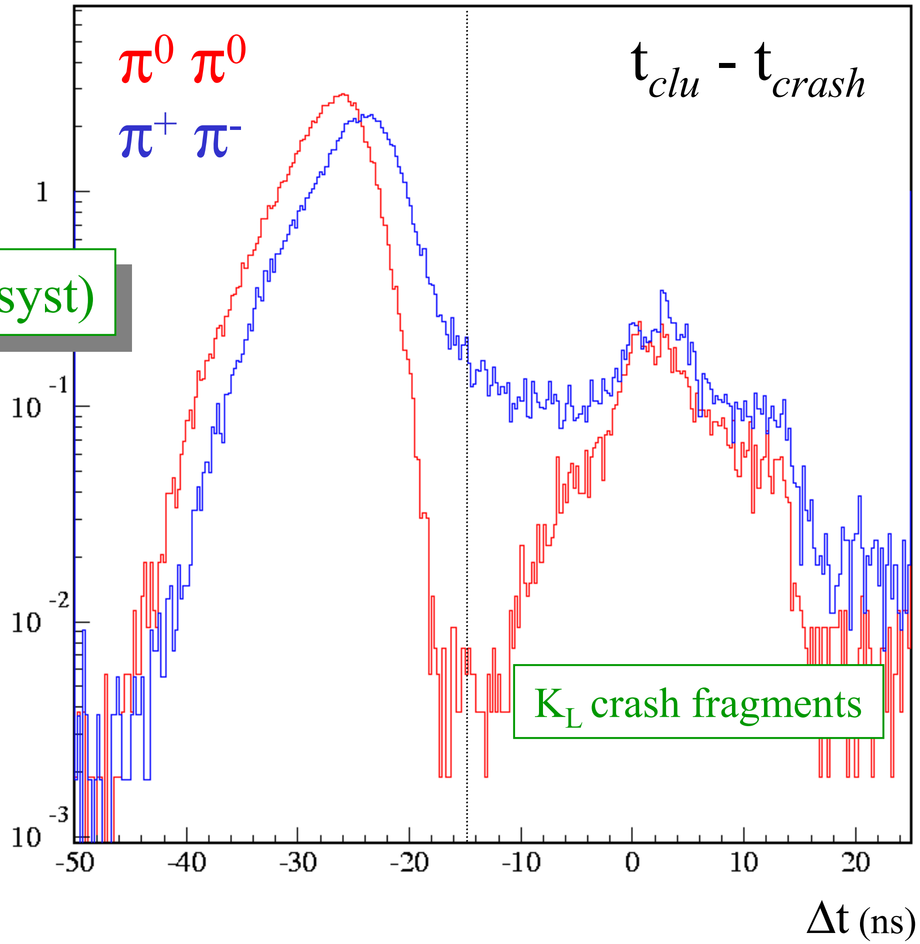

- Total energy distribution



# $K_S \to \pi^0 \pi^0$ trigger efficiency

1. Assignment of the clusters to the $K_S$ and $K_L$ hemievent cutting at **–15 ns**
2. Cluster → trigger sector → unbiased multiplicities
3. $1-\varepsilon_{trig} = S(0)\bullet L(0) + S(1)\bullet L(0) + S(0)\bullet L(1)$

$\varepsilon_{trig} = 99.69 \pm 0.03\ (stat) \pm 0.02\ (syst)$



# $K_S \to \pi^0 \pi^0$ signal

- $\geq 4$ prompt clusters

$$S^{00}_4 = \frac{125267}{0.567} = 220951 \qquad \left.\frac{\delta S^{00}_4}{S^{00}_4}\right|_{stat} = 2.8 \times 10^{-3}$$

$$\frac{S^{00}_3 - S^{00}_4}{S^{00}_{ave}} = 1.2 \times 10^{-2}$$

- $\geq 3$ prompt clusters*

$$S^{00}_3 = \frac{200322}{0.896} = 223561 \qquad \left.\frac{\delta S^{00}_3}{S^{00}_3}\right|_{stat} = 2.2 \times 10^{-3}$$

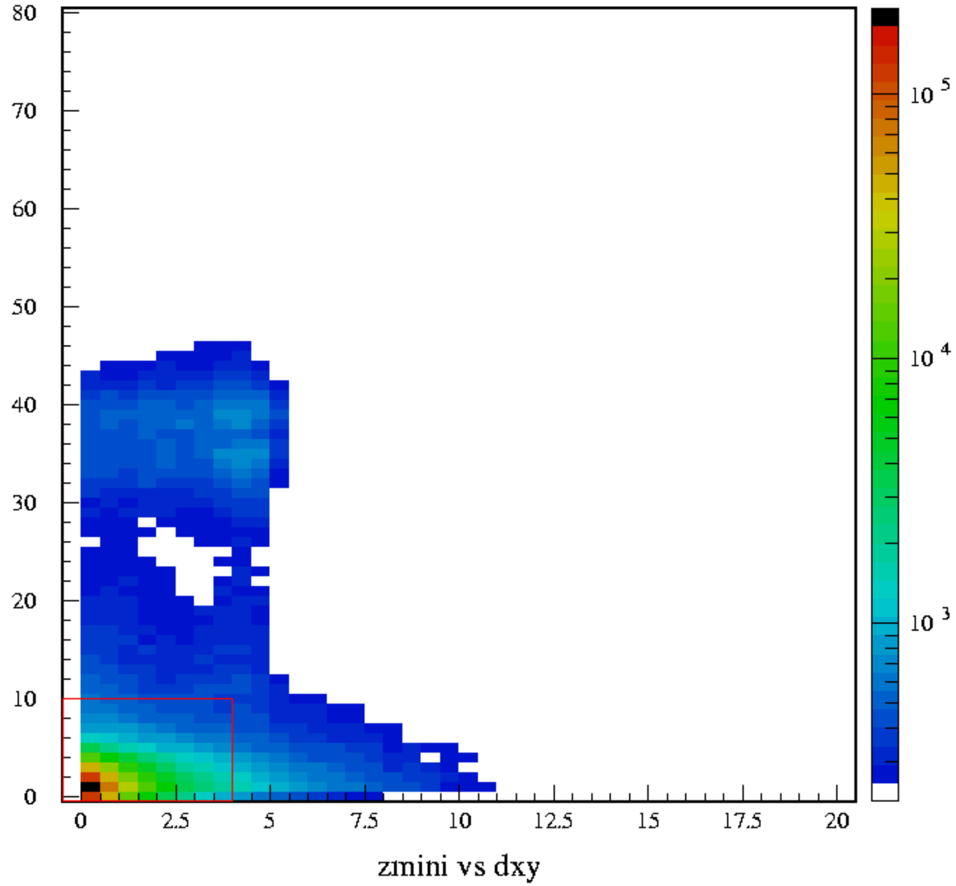
* $K_S \to \pi^+ \pi^-$ background estimated from:

DATA: $5 \times 10^{-5}$

Monte Carlo: $2.5 \times 10^{-4}$

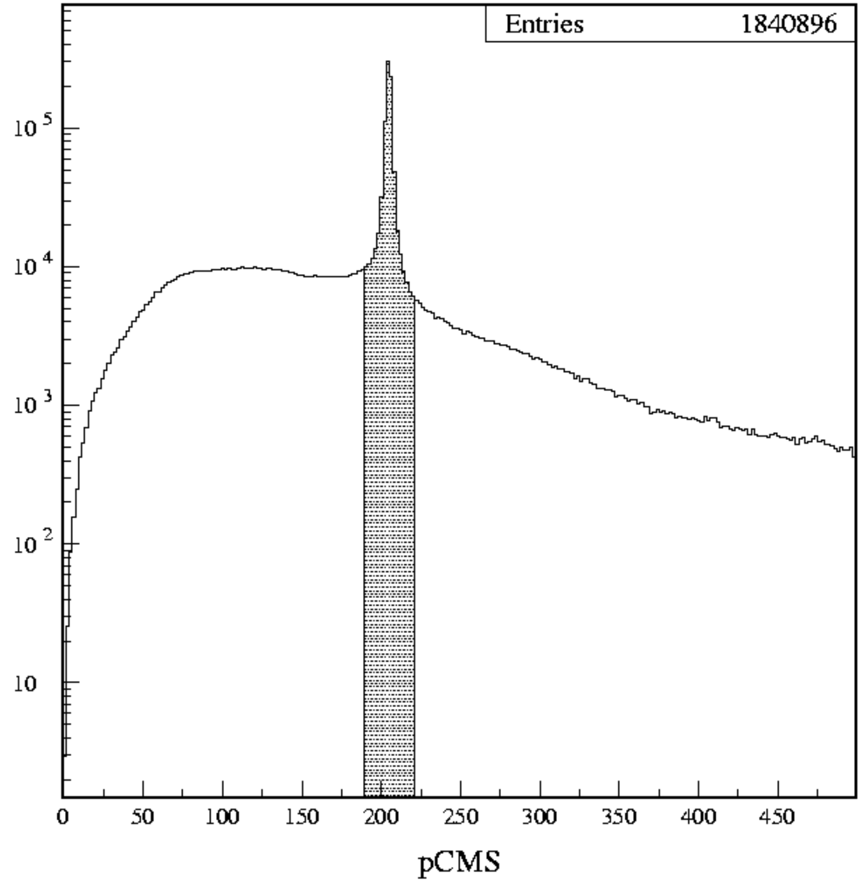
# $K_S \to \pi^+ \pi^-$: track selection (1)

- K crash
- tracks from IP:
  - closest approach: $|z| \leq 10$ cm; $d_{xy} \leq 4$ cm
  - first hit: $|z| \leq 40$ cm; $d_{xy} \leq 35$ cm



# $K_S \to \pi^+ \pi^-$: track selection

- acceptance and momentum cuts:
  - $\cos\theta < 0.9$
  - $190 \leq p^* \leq 220$ MeV/$c$

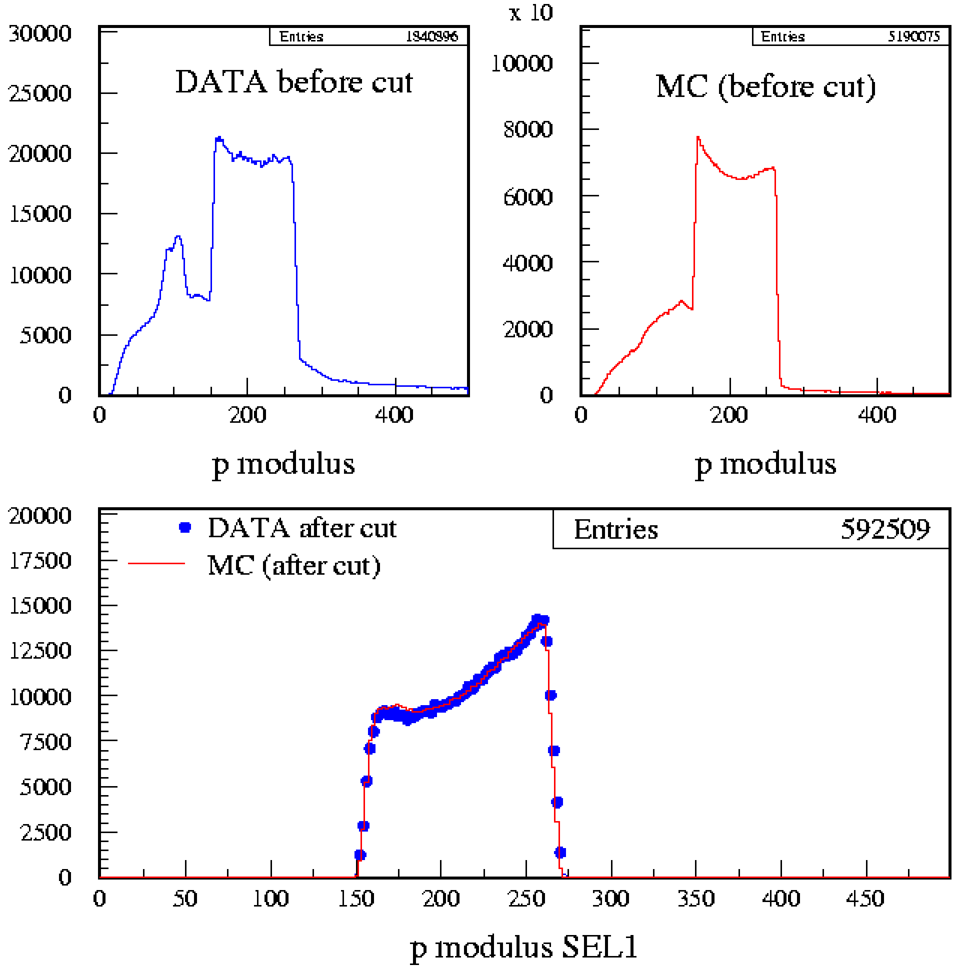



$p^*$ = track momentum in the center of mass system of $K_S$

$(p_S = p_\phi - p_L)$

# $K_S \to \pi^+ \pi^-$: DATA vs. MC

## LAB momentum




Background after cut (estimated from Monte Carlo):

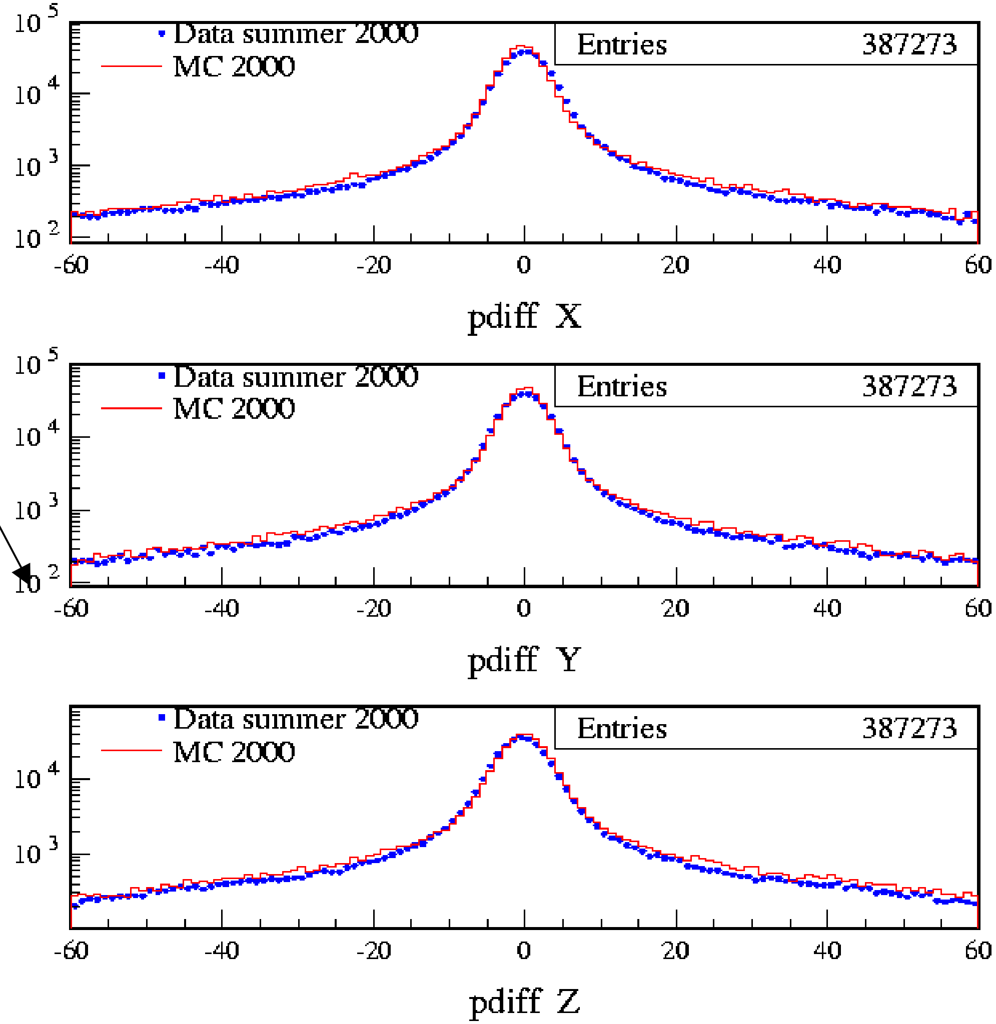
1 track events: $2.8 \times 10^{-3}$

2 track events: $\approx 10^{-5}$

# Track efficiency: DATA vs. MC (1)

- 1 track selected according to previous cuts and looking for the second one with $p_{2,\,estimated} = p_{\phi} - p_{L} - p_{1}$

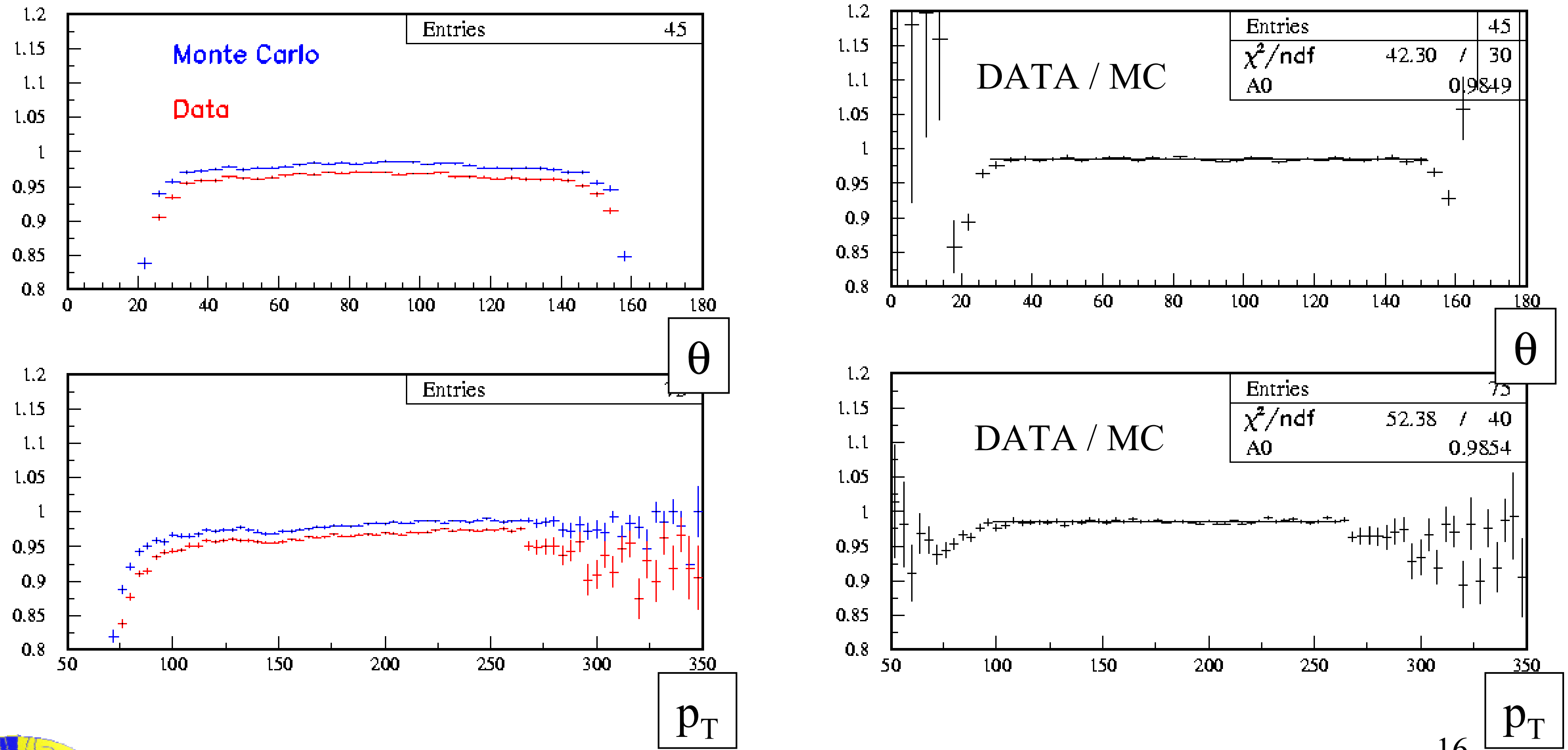
$p_{2,\,estimated} - p_{2,\,found}$



# Track efficiency: DATA vs. MC (2)

- track efficiency vs. θ and $p_T$

DATA/MC = 98.5 %



# $K_S \to \pi^+ \pi^-$ signal (1)

**Method 1**: Use 2 track sample and MC efficiency

$$S^{+-} = N_{2TRK} / \varepsilon_{t0\cdot trig} / \varepsilon^{MC}_{2TRK}$$

($\varepsilon^{MC}_{2TRK}$ corrected for DATA/MC)

**Method 2**: Double tag

$N_1 = 2\cdot\varepsilon_{single}\cdot S^{+-}$

$N_2 = (1-\rho)\cdot(\varepsilon_{single})^2\cdot S^{+-} = \varepsilon_{double}\cdot S^{+-}$

$N_1 = N_{1TRK}/\varepsilon_{t0\cdot trig} + 2\cdot N_{2TRK}/\varepsilon'_{t0\cdot trig}$

$N_2 = N_{2TRK}/\varepsilon'_{t0\cdot trig}$

$1-\rho = (N_2/S) / (N_1/2S)^2$ from MC

$N_1$ and $N_2$ from DATA

$$S^{+-} = (1-\rho) \cdot (N_1)^2/4N_2$$

# $t_0$ and trigger efficiency corrections

1. Efficiencies estimation

$t_0$

trigger

} pion efficiencies from data (in bins of $p_T$ and $\theta$)

2. Convolution with Monte Carlo spectrum, separately for events with 1 and 2 track

$$\varepsilon^{1,2} = \varepsilon_L \times \varepsilon^{1,2}{}_{t0} + (1 - \varepsilon_L)\, \varepsilon^{1,2}{}_{t0 \cdot trig}$$

$\varepsilon_L =$ $K_L$ crash trigger efficiency = $(40.5 \pm 2.5)\%$

# $K_S \to \pi^+ \pi^-$ signal (2)

| | DATA | Monte Carlo |
|---|---|---|
| $K_L$ crash | 1 055 596 | 461 397 |
| 2 tracks | 239 726 | 260 187 |

Method 1

$$\varepsilon_2 = 96.49\%$$

S+- = 454 106

$$\left.\frac{\delta S^{+-}}{S^{+-}}\right|_{stat} = 2.0 \times 10^{-3}$$

$$R = 2.16\ (1 \pm 3.6 \times 10^{-3}\ (stat))$$

# $K_S \to \pi^+ \pi^-$ signal (3)

| | DATA | Monte Carlo |
|---|---|---|
| $K_L$ crash | 1 055 596 | 1 839 914 |
| 1 track | 162 634 | 618 962 |
| 2 tracks | 214 831 | 962 650 |

Method 2

$1-\rho = 1.095$ ( 1.024 in acceptance)

$$\varepsilon_1 = 84.9\ \%$$
$$\varepsilon_2 = 97.8\ \%$$

S+- = 493 500

$$\left.\frac{\delta S^{+-}}{S^{+-}}\right|_{stat} = 1.7 \times 10^{-3}$$

$R = 2.35\ (1 \pm 3.4 \times 10^{-3}\ (stat))$

# Conclusions

Systematics

| | | |
|---|---|---|
| ❑ Tag efficiency | 1.3% | $\beta^*$ spectra deviation |
| ✓ Cluster counting | ≈1% | |
| ❑ Track efficiency | 1.5% | |
| ❑ $t_0$ and trigger | | convolution to be checked |

Method 1

- ✓ Reasonable results, with respect to 1999 and PDG
- ❑ Stability to be checked on whole statistics

Method 2

- ❑ Larger impact of MC efficiency convolution problems/errors on final result mainly arising from the single tagged events

Improvements

- ❑ Use $K_L \to \pi^+\pi^-\pi^0$ events for rephasing and $t_0$