Tau Lepton Lifetime: Classical One-Prong Impact Parameter Measurements

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- Description of the Method
- Opal and L3 measurement
- Systematic Errors
- Conclusions

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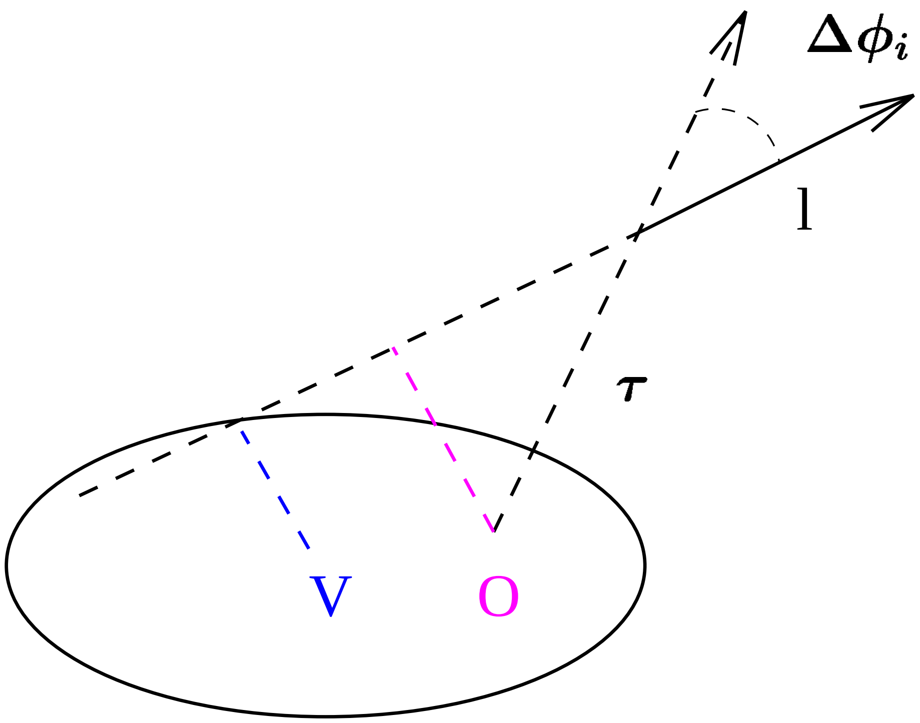
Distance of Closest Approach

$$\delta_V = \delta_O + x_\tau sin\phi - y_\tau cos\phi$$
$$\delta_O = (\beta\gamma c sin\theta)\, \underline{t}_i\ sin\Delta\phi_i$$

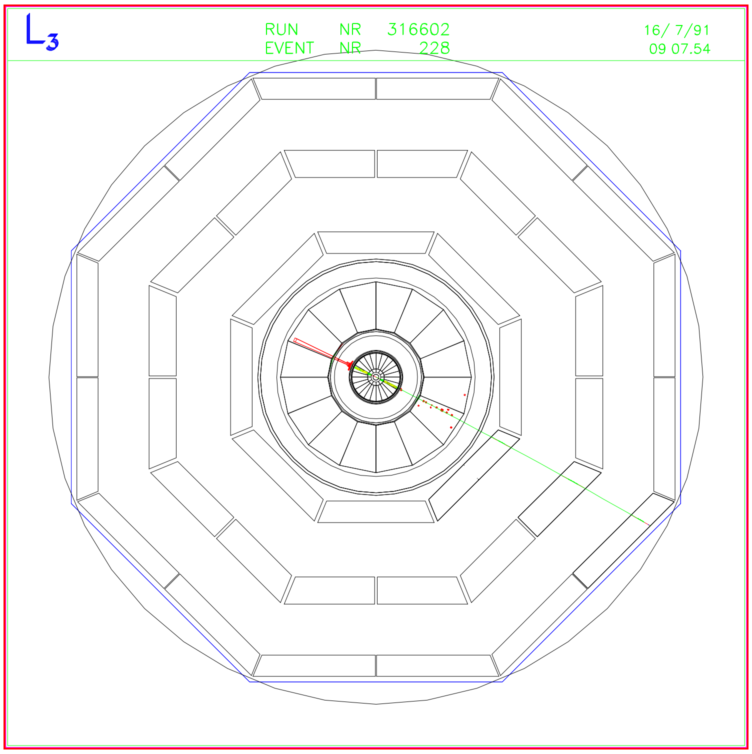


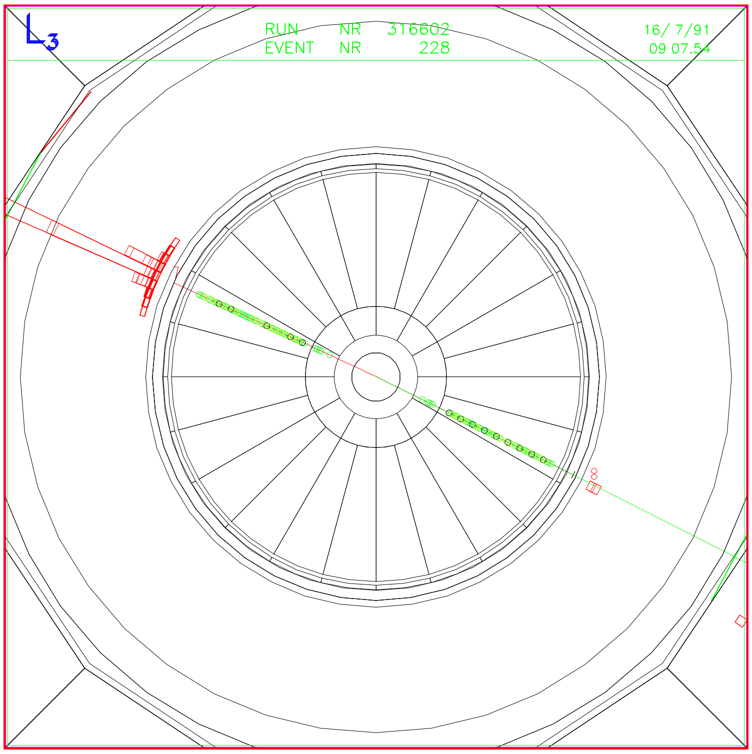
V: reference point
O: production point of the τ

To extract t_i we need both:

- Direction of the τ
- Production point of the τ

One Prong Tau Event





The Impact Parameter Method

Direction of the τ:

- Event Thrust Direction
- Signed Impact Parameter
  (intersection thrust-track)

Production point of τ:

- Average Beam Position

$$\text{Spread} \simeq \begin{array}{ll} 100\mu m \times 15\mu m & 1992 \\ 150\mu m \times 15\mu m & 1993 \end{array}$$

Uncertainties on Impact Parameter:

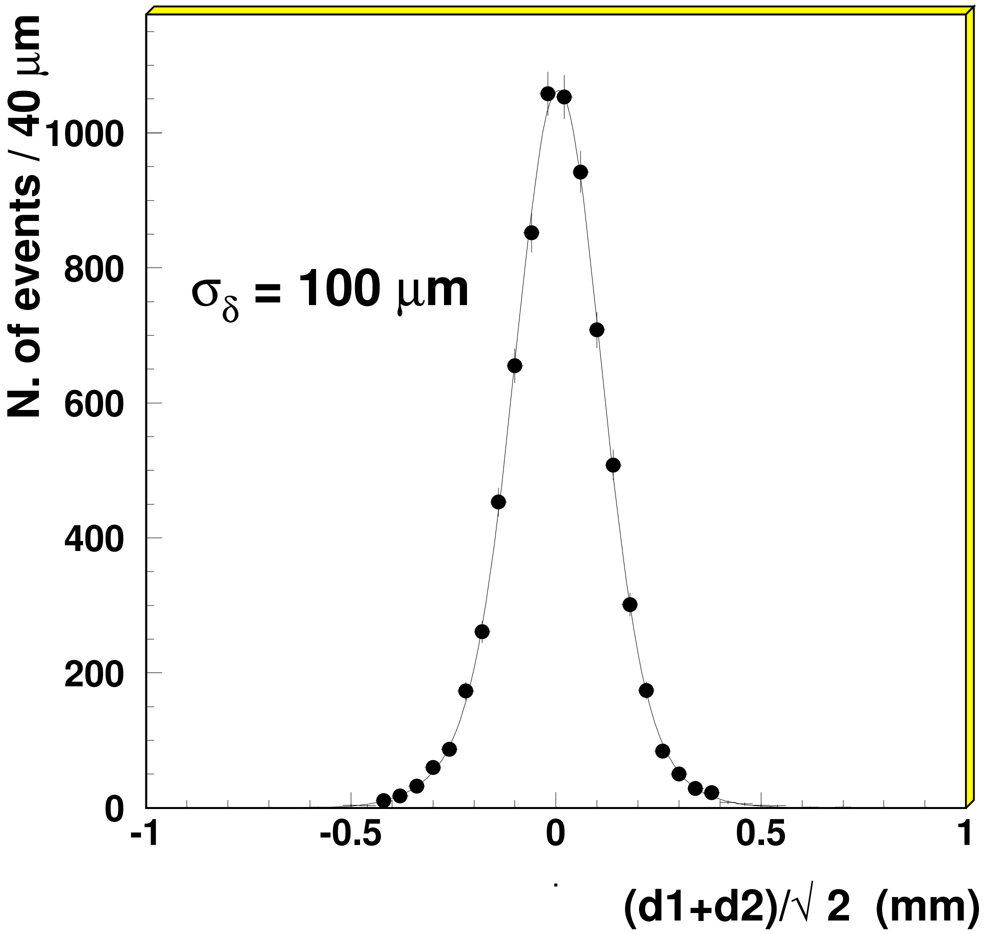
- Beam Spot Size
- Intrinsic Detector Resolution
- Multiple Scattering

L3

Detector	Intrinsic Resolution (r/ϕ)	R_{in} (cm)	R_{out} (cm)
Time Expansion Chamber	$50\mu m$	8.5	46.9

impact parameter resolution

$Z \rightarrow e^+e^-$



Detector configuration

OPAL

Detector	Intrinsic Resolution (r/ϕ)	R_{in} (cm)	R_{out} (cm)
Jet chamber	$130\mu m$	25.5	183.5
Vertex Drift Chamber	$50\mu m$	10.3	21.3
Silicon Microvertex Detector	5μ	6.1	7.5

impact parameter resolution

$Z \to e^+e^-, \mu^+\mu^-$

Maximum Likelihood (L3)

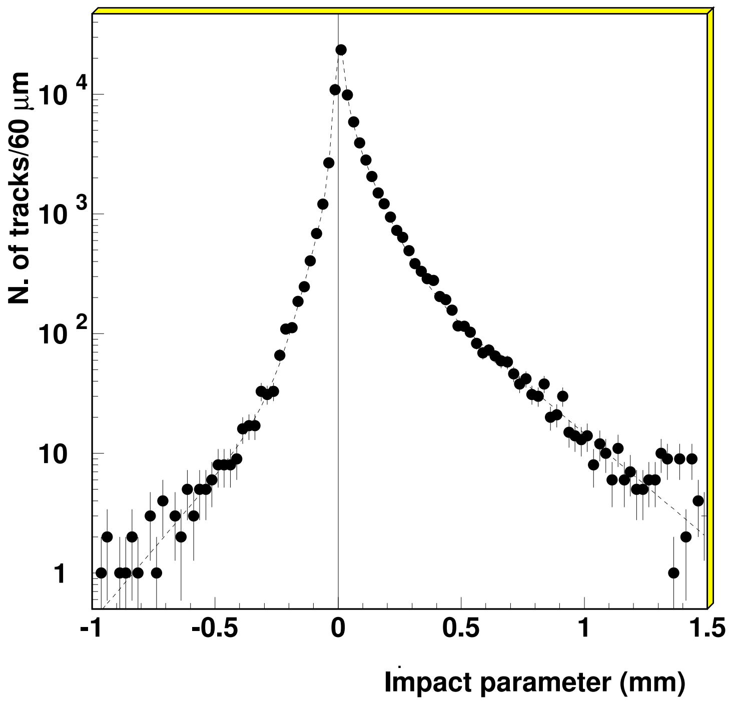
Fit function described by Convolution between

- **Underlying Physics Function**
  (Monte Carlo generator)
- **Detector Resolution Function**
  (Data $\mu^+\mu^-$ and e^+e^-)

$$P(\delta|\lambda_i;\sigma_{DCA}) = P(\delta|\delta';\sigma_{DCA}) \otimes P(\delta'|\lambda_i;F_i)$$

1) $P(\delta'|\lambda_i;F_i) = \sum_i F_i exp(-\delta'/\lambda_i)$

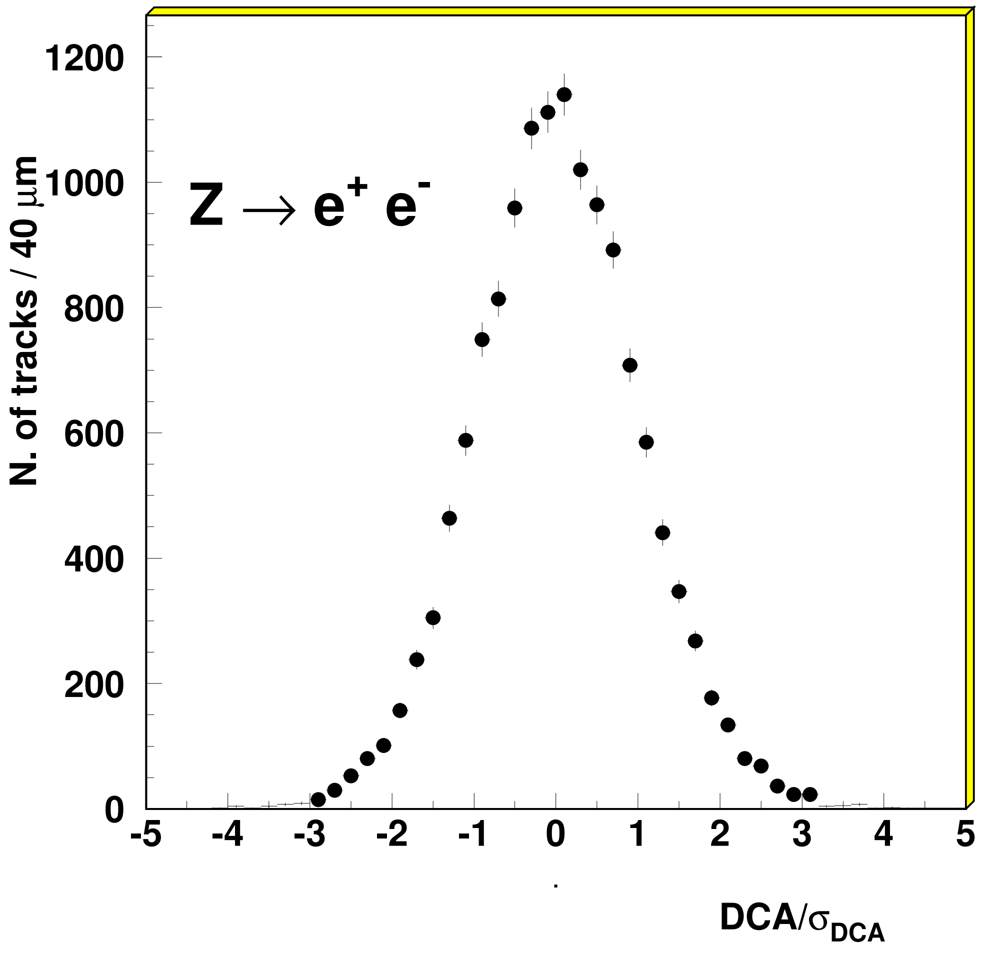
- **Slopes proportional to lifetime $\lambda_i \propto \tau$**
- **Sign of I.P. from Reconstructed Thrust**



Maximum Likelihood (L3): Resolution Function

2) $P(\delta|\delta';\sigma_{DCA})$

- Single gaussian (from Bhabha Sample) with $\sigma_{DCA} = \sqrt{K^2{\sigma_{INT}}^2 + \sigma_x^2 sin^2\phi + \sigma_y^2 cos^2\phi + \sigma_{MS}^2}$ after detector corrections ($\mu^+\mu^-$ sample)
- K from request $\sigma(DCA/\sigma_{DCA}) = 1$
- Uncertainty on K gives major source of systematics

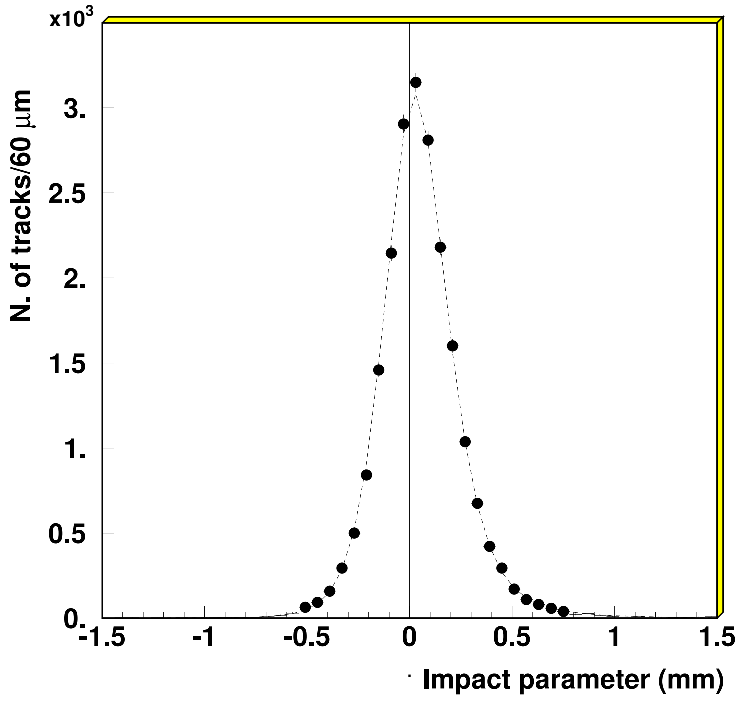


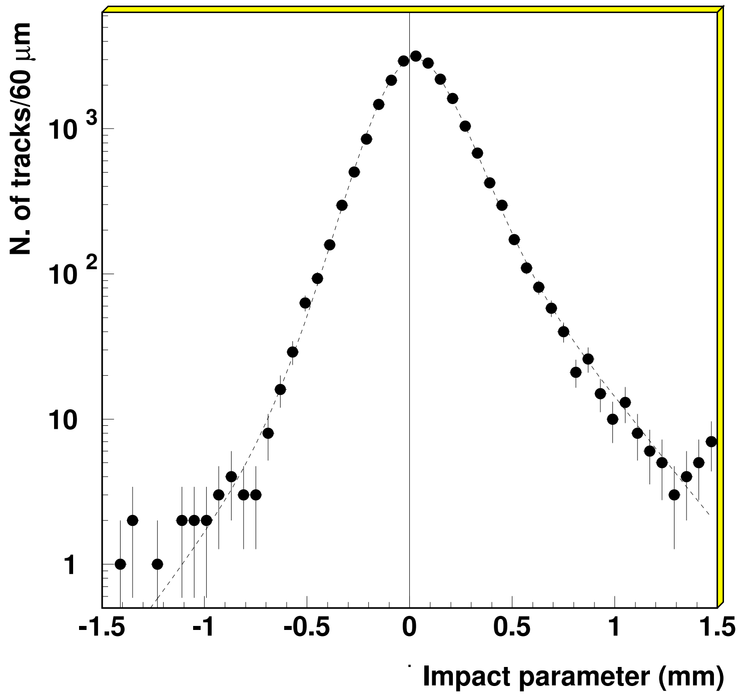
Maximum Likelihood (L3)

RESULTS (11122 + 10839 tracks)

$$\tau = (291.1 \pm 8.5)\ \mathrm{fs} \quad (1992)$$

$$\tau = (303.2 \pm 9.7)\ \mathrm{fs} \quad (1993)$$



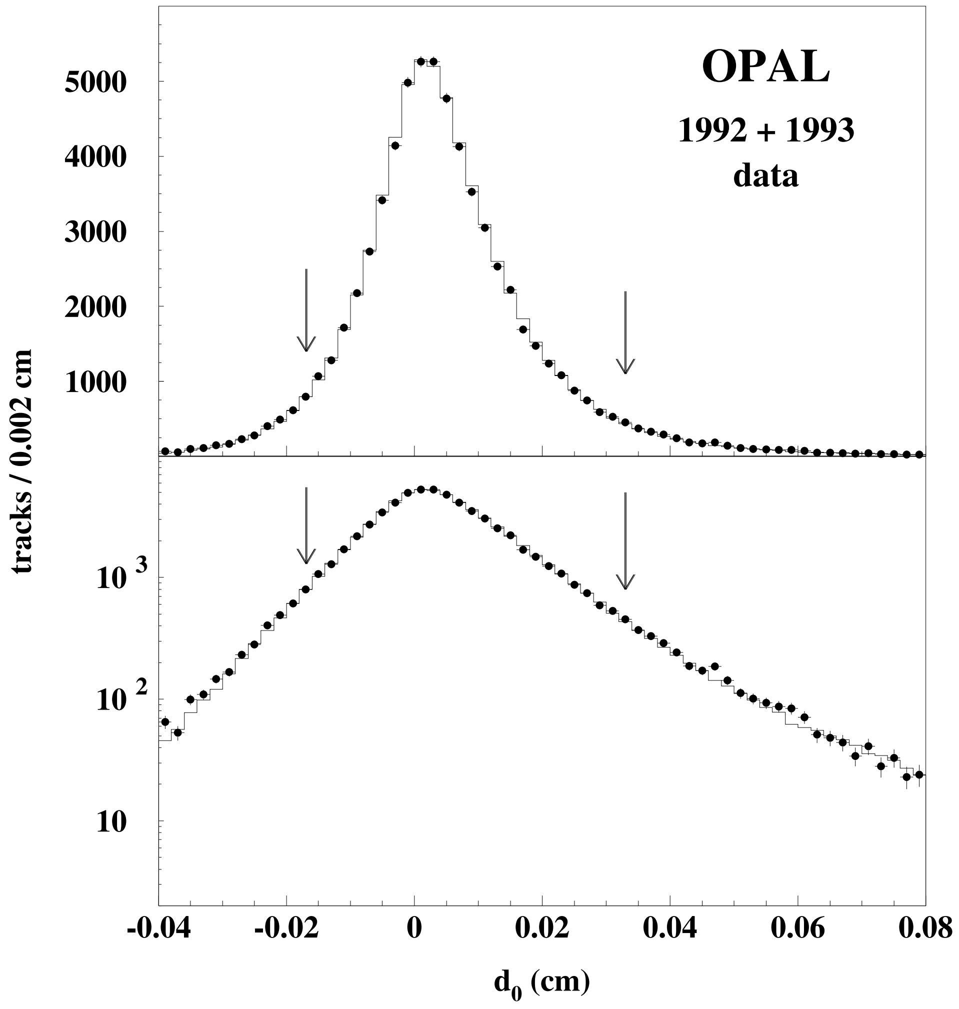


Comparison of Data and Monte Carlo
Impact Parameter Distribution on the basis of

10 % TRIMMED MEAN $\bar{x}_{meas}$
Mean after removing 5% of tracks from each tail

- **less detailed modelling**
- **insensitive to few mismeasured tracks**

Lifetime extracted from $\tau_\tau = \tau_{MC} \times \frac{\bar{x}_{meas}}{\bar{x}_{MC}}$



Trimmed Mean (OPAL)

Monte Carlo samples used with

- **Beam sizes matched to real data ones**
- **Extra Gaussian smearing in tracking resolution (determined by matching of $\mu\mu$ MC and $\mu\mu$ data)**

Because of asymmetric spot size ($\sigma_x \gg \sigma_y$)

$\sigma_{DCA} \leftrightarrow \sigma_x$ **for** $\phi = 0^o$
$\sigma_{DCA} \leftrightarrow \sigma_y$ **for** $\phi = 90^o$

I.P. distribution is strongly ϕ dependent (narrower for horizontal tracks)

6 regions in $\phi \rightarrow$ 6 different trimmed means

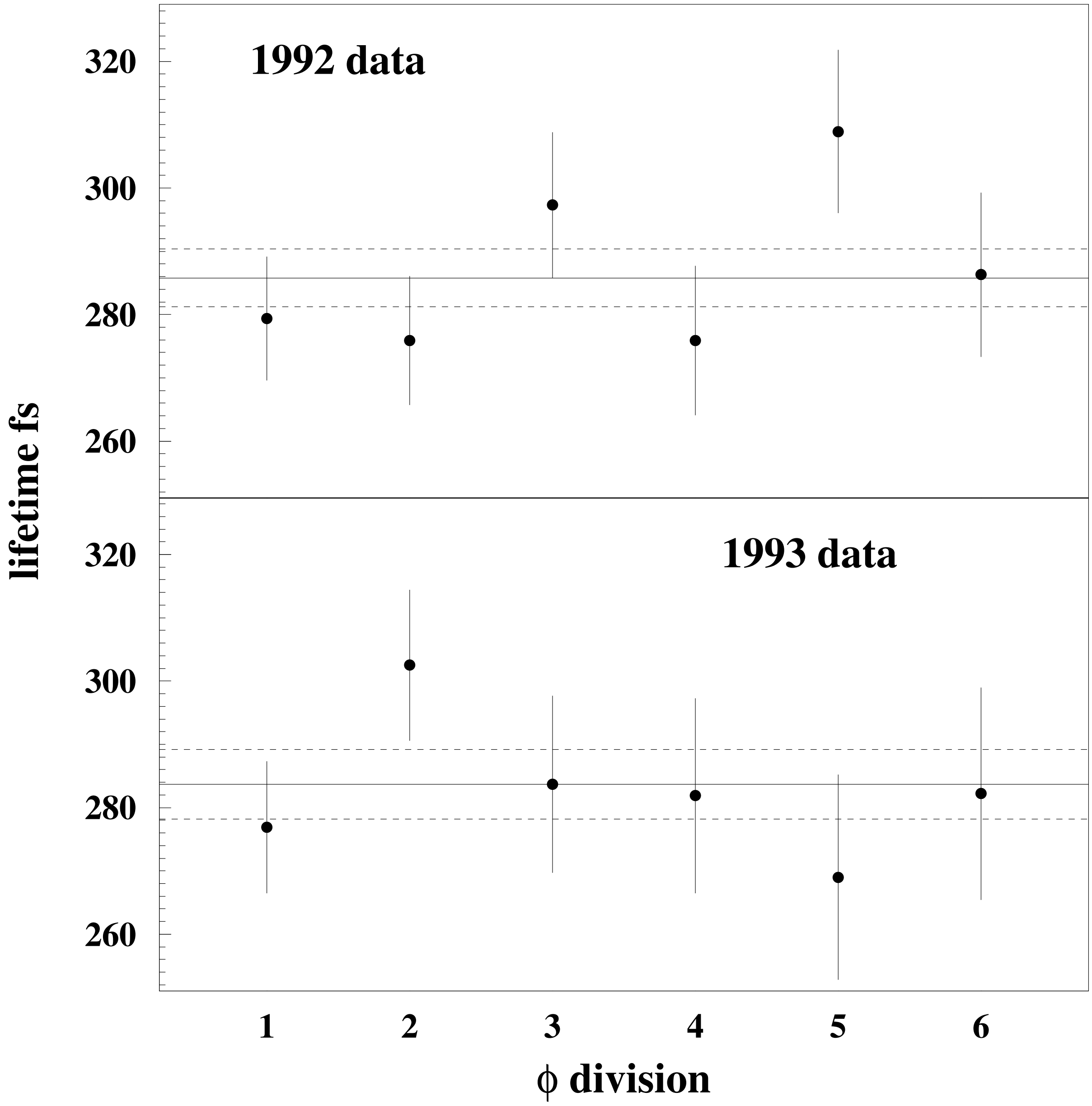
6 lifetime measurements $\rightarrow$ weighted average

Trimmed Mean in ϕ bins

RESULTS (35168 + 32703 tracks)

$$\tau = (288.1 \pm 4.4)\ \text{fs} \quad (1992)$$

$$\tau = (286.0 \pm 5.3)\ \text{fs} \quad (1993)$$



Systematic Errors (L3)

Underlying Distribution	
Linearity Slopes-Lifetime	0.3 fs
MC Thrust Reconstruction and MC Branching Fractions	1.0 fs
MC Statistics	1.8 fs
Resolution Function	
Beam Spot Size and Beam Centroid	1.3 fs
Detector Calibration	3.3 fs (92) 4.0 fs (93)

full correlation 1992 - 1993

RESULTS (1992+1993 PRELIMINARY)

$$\tau = (296.4 \pm 6.4(stat.) \pm 4.4(syst.))\ \text{fs}$$

Systematic Errors (OPAL)

source	1992	1993
resolution matching of MC	1.6 fs	1.0 fs
detector calibration and alignment$^{(*)}$	0.4 fs	0.3 fs
beam size uncertainties	1.2 fs	1.0 fs
beam position uncertainties	0.4 fs	0.3 fs
background fractions$^{(*)}$	0.8 fs	0.8 fs
MC branching ratios$^{(*)}$	0.5 fs	0.5 fs
MC statistics	1.4 fs	1.7 fs
total systematic error	2.7fs	2.5 fs

$^{(*)}$ full correlation 1992 - 1993

RESULTS (1992+1993)

$$\tau = (287.2 \pm 3.4(stat.) \pm 2.0(syst.))\ \mathrm{fs}$$

Other Results on Classical Impact Parameter

Aleph and Delphi: OLD measurements

Experiment	N. of tracks	Results (fs)
Delphi[a)]	6117	$303 \pm 10 \pm 5$
Aleph (1-1)[b)]	7726	$286 \pm 18 \pm 10$
Aleph (1-3)[b)]	1423	$329 \pm 38 \pm 18$

a) CERN-PPE/93-12
b) Phys. lett., B : 279 (1992) 411

Conclusions and Perspectives

- **Aleph and Delphi don't use the method: separation of τ production point and direction uncertainties.**

- **L3 has lowered the systematic error**
  Use of Silicon Microvertex Detector in future measurement.

- **Opal reached a very low systematic error**
  Statistical limit not yet reached.