Measurement of R_b with the L3 detector

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- R_b measurement with impact parameter tag
- Results
- Conclusions

Motivation

$$\mathbf{R_b} = \frac{\Gamma(\mathrm{Z} \to \mathrm{b\bar{b}})}{\Gamma(\mathrm{Z} \to \mathrm{q\bar{q}})}$$

- Tests of Standard Model:

  Most of the theoretical uncertainties $(\boldsymbol{m_H}, \boldsymbol{\alpha_s})$ cancel in this ratio.

  Large dependence with $\boldsymbol{m_t}$.

- Deviations from the Standard Model:

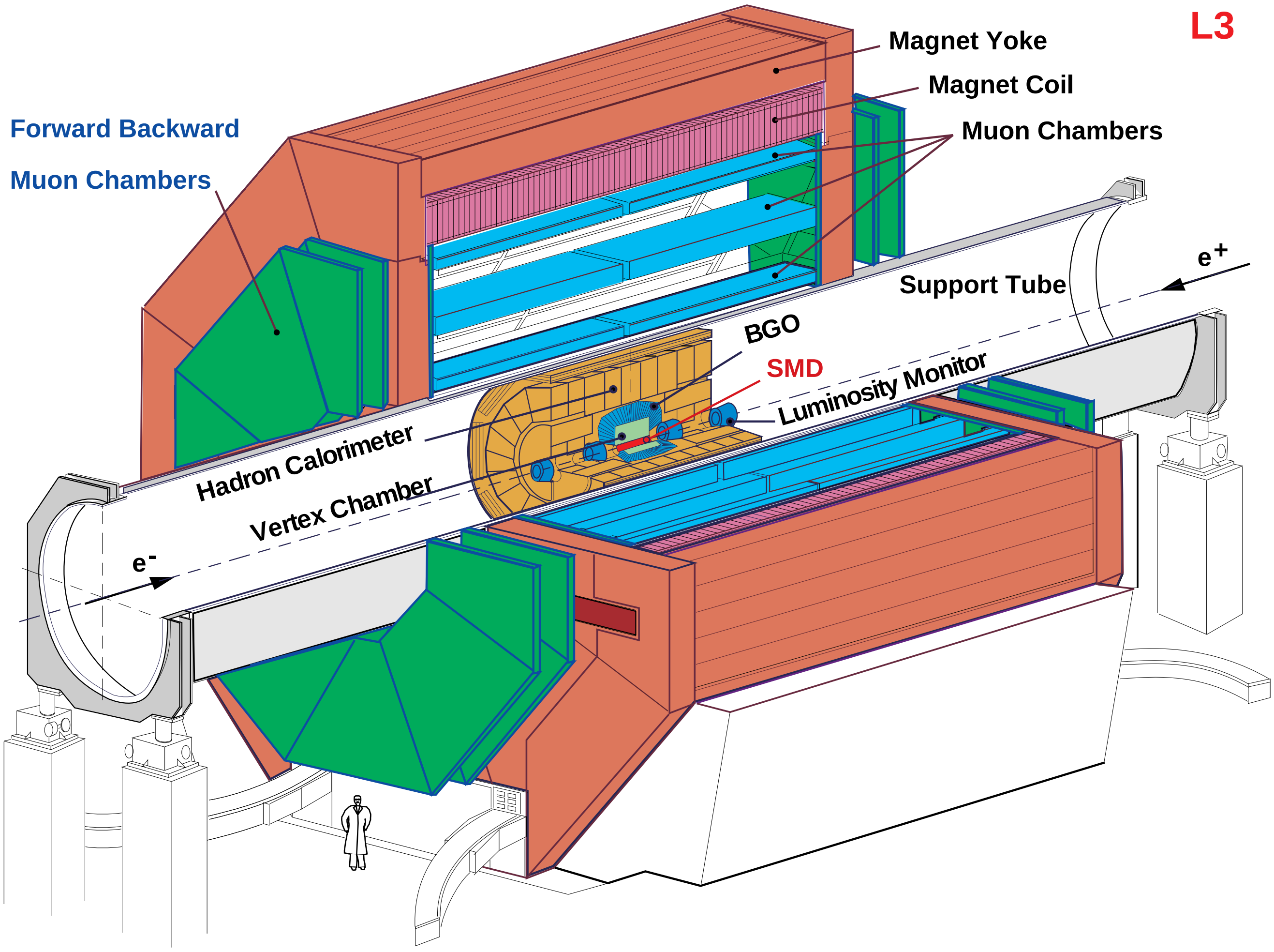
  Vertex corrections to the **Z** partial width into $\boldsymbol{b\bar{b}}$ pairs are sensitive to new physics.

To measure R_b a good identification of $b\bar{b}$ events is needed.

Some of the methods used for heavy quark tagging:

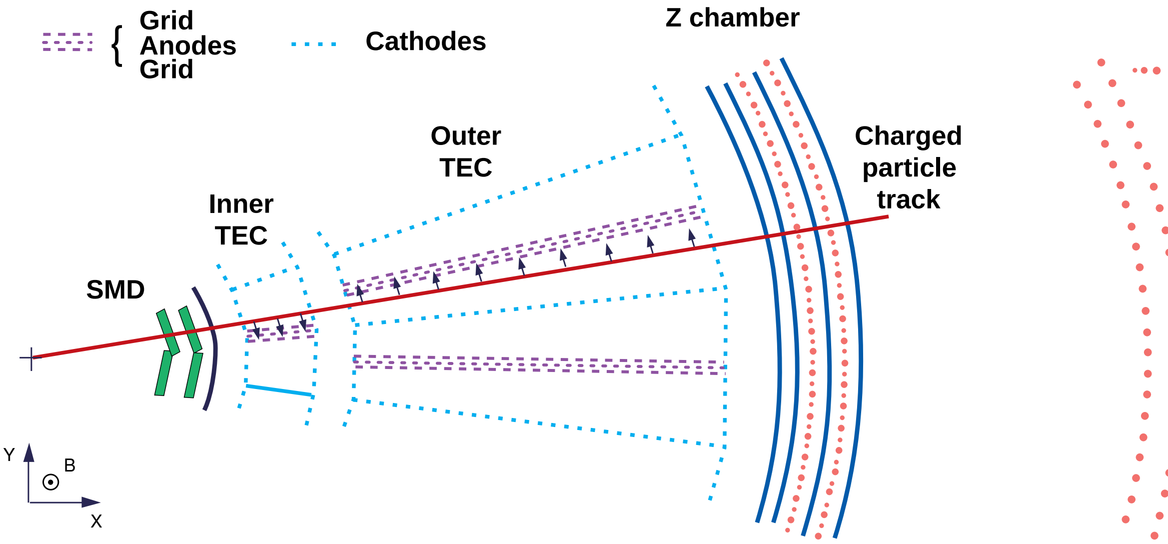
Method:	based upon:
Vertex tag	long lifetime of the b quark, (l$\approx$ 3mm) Impact Parameter Decay Length
Lepton tag	semileptonic decay of heavy b-flavoured mesons.
Topological	broad event shape caused by the large quark mass.
Mass tag	invariant mass
Multivariate analysis	different tags combination

L3 detector

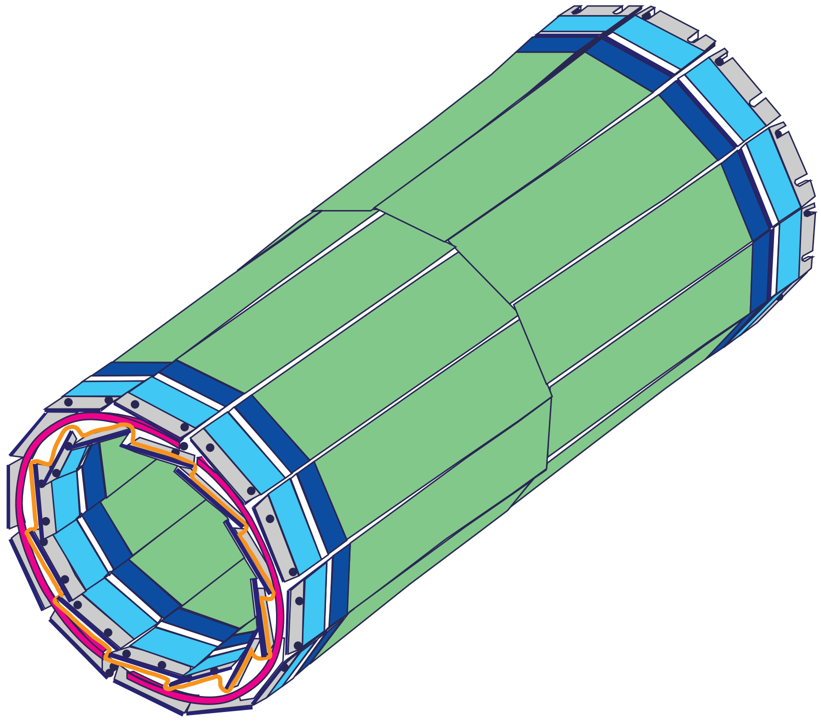

L3
Magnet Yoke
Magnet Coil
Muon Chambers
Forward Backward
Muon Chambers
e+
Support Tube
BGO
SMD
Luminosity Monitor
Hadron Calorimeter
Vertex Chamber
e-

L3 tracking

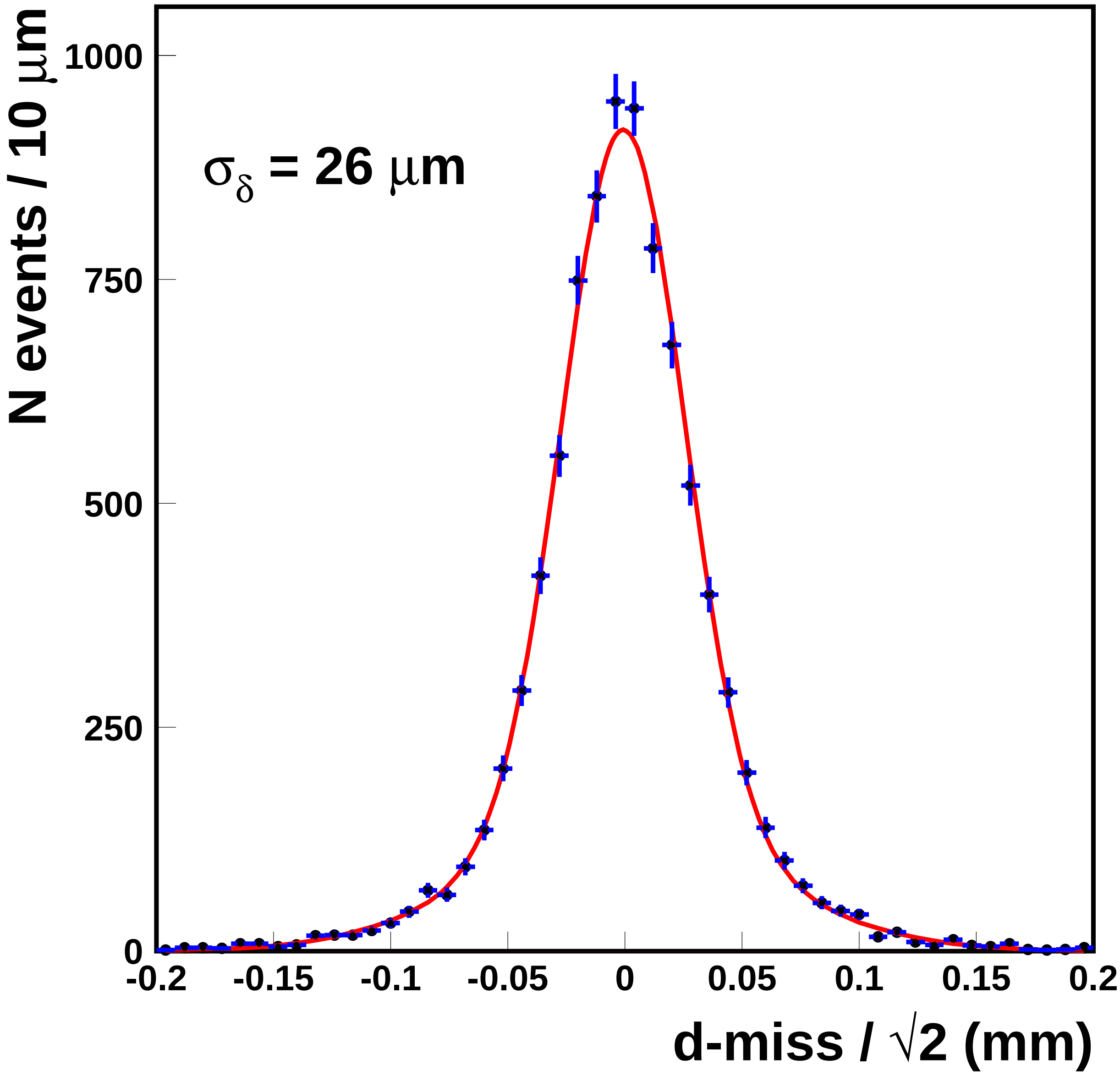
Time Expansion Chamber



Silicon microstrip detector



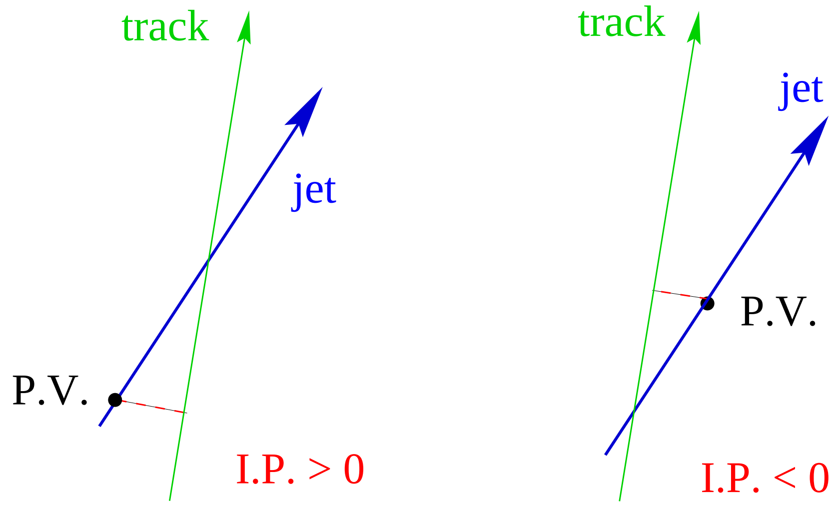
Miss distance between the two tracks in $\mu^+\mu^-$ events



Primary vertex: : determined using the beam spot constraint.

resolution $\approx 45 \times 20\ \mu m$ for uds
$\approx 77 \times 20\ \mu m$ for b

Impact Parameter: : minimum distance between the primary vertex and the track.

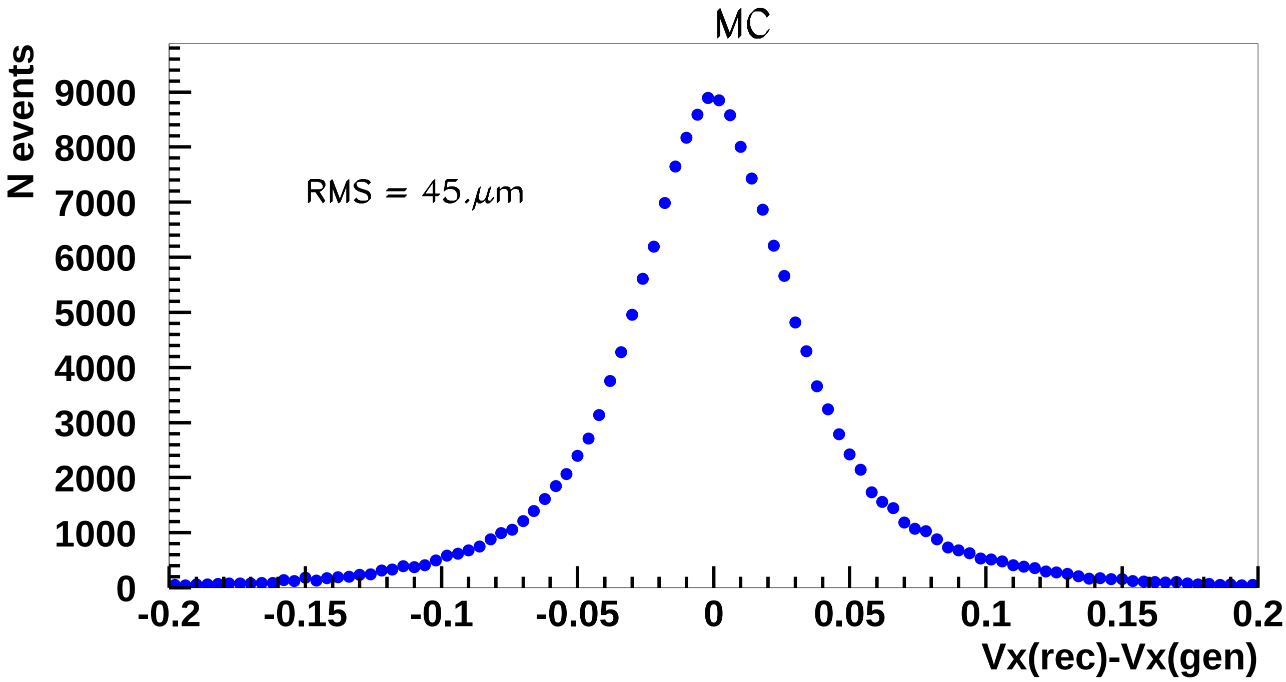


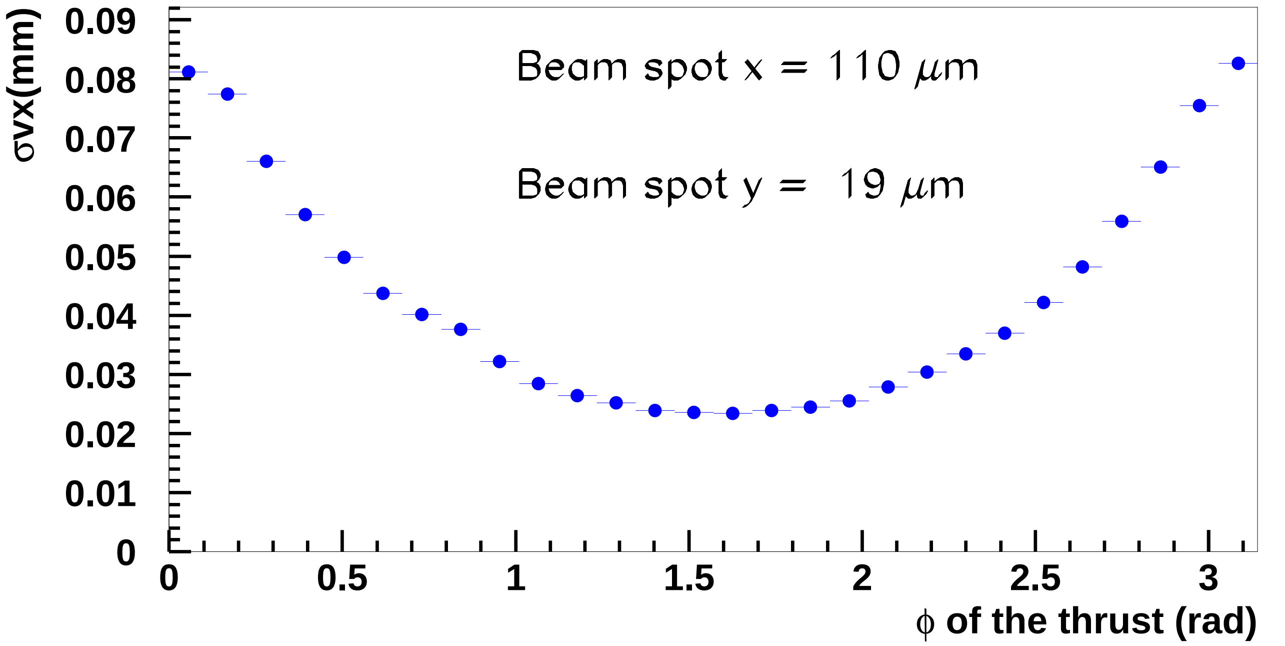
IP error: : $\sigma_{\text{IP}} = \sigma_{\text{fit}} \otimes \sigma_{\text{MS}} \otimes \sigma_{\text{vtx}}$

IP significance: : $S = \dfrac{IP}{\sigma_{IP}}$

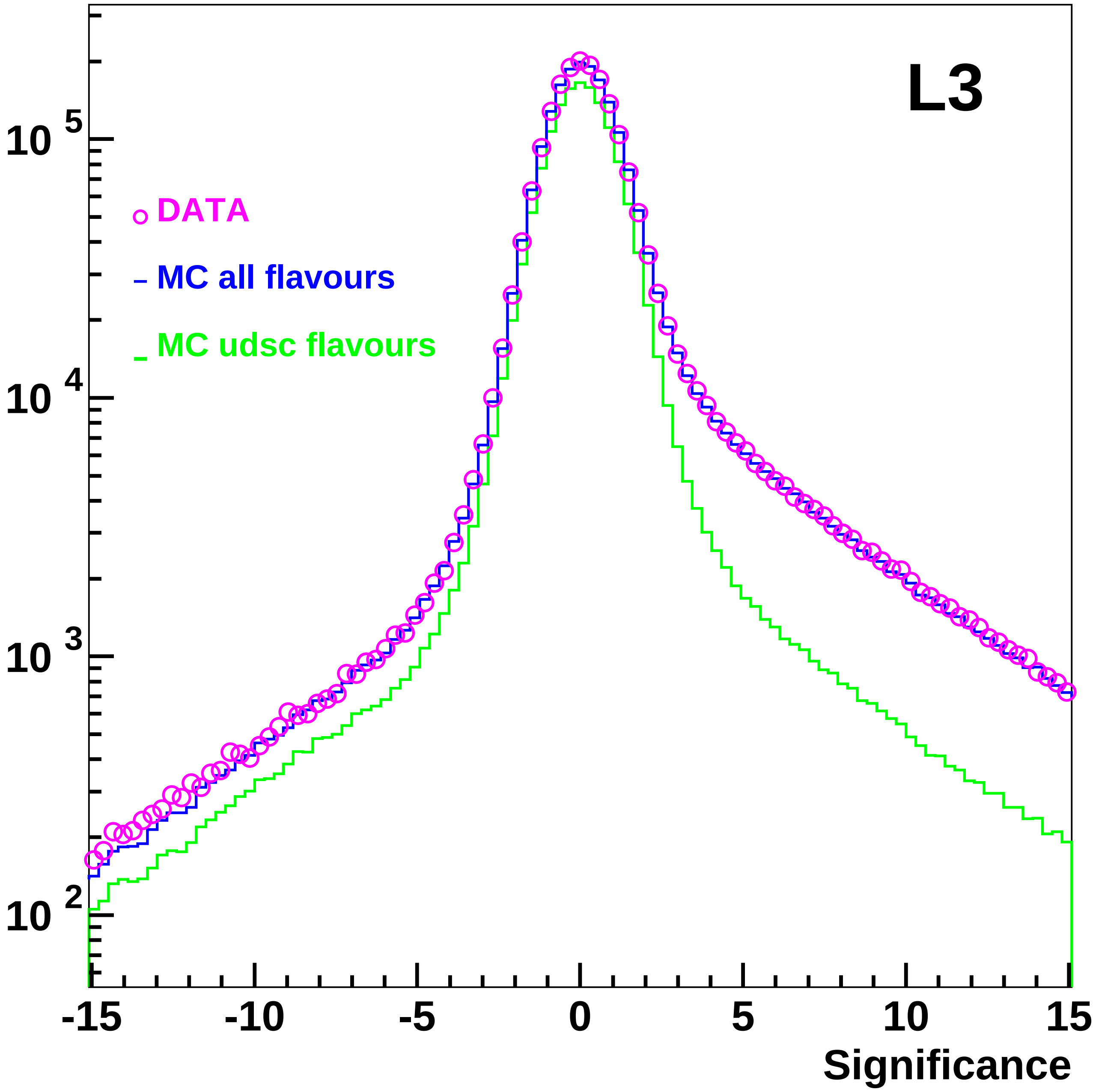
Resolution function $\mathbf{R}(\mathbf{x})$: obtained from a fit to the negative IP significance distribution.

Vertex resolution





IP significance



Tagging variable

For tracks with positive significance :

- Probability that a track coming from the primary vertex has a significance $> s$:

$$P(s) = \frac{\int_s^{\infty} R(x)dx}{\int_{-\infty}^{\infty} R(x)dx}$$

- For all the tracks in the same hemisphere calculate:

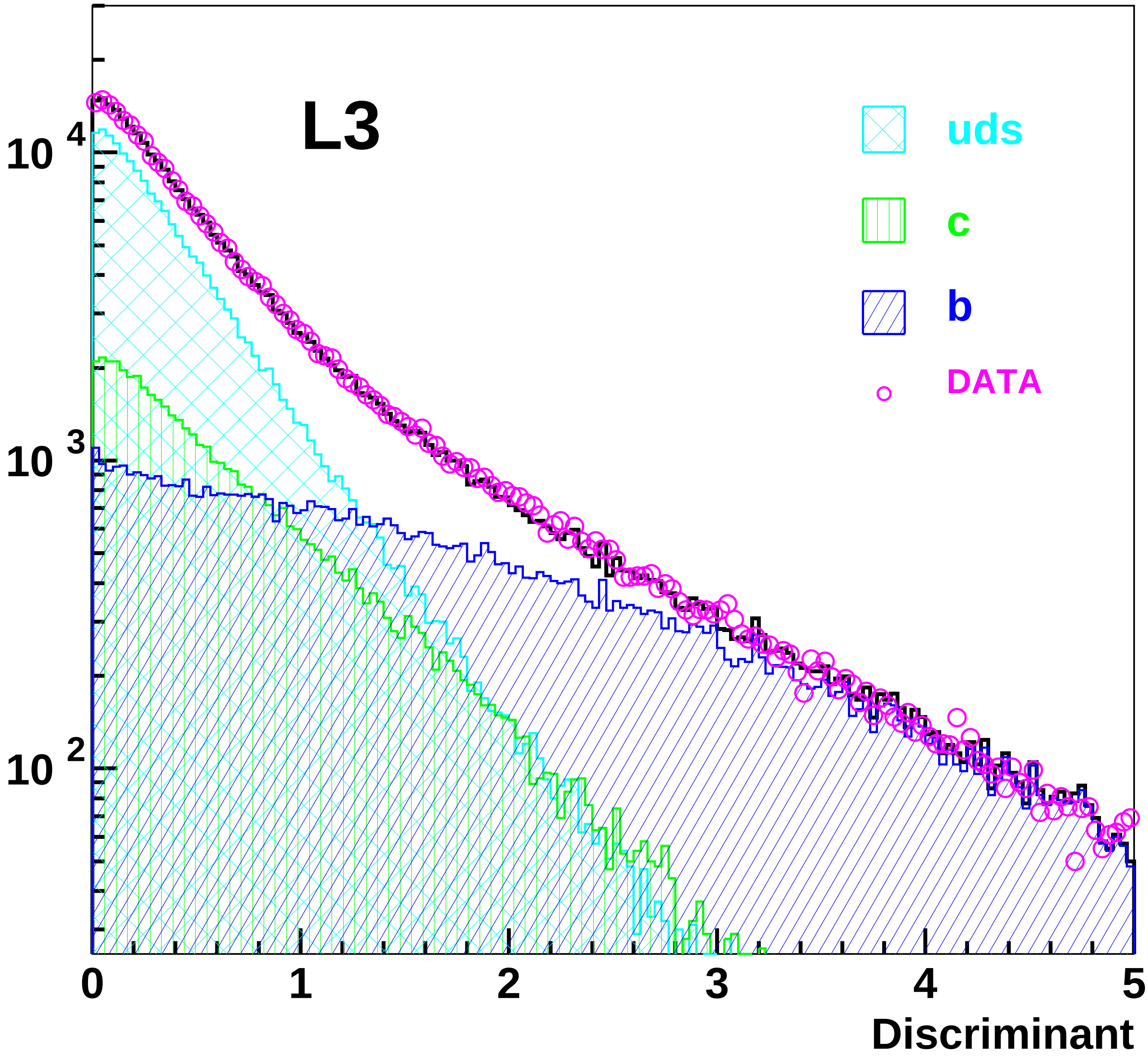
$$\Pi_n = P(s_1) \cdot \ldots \cdot P(s_n)$$

- Probability that this tracks come from the primary vertex:

$$L(n) = \Pi_n \sum_{k=0}^{n-1} \frac{(-ln\,\Pi_n)^k}{k!}$$

- Discriminant variable: $D = -log_{10} L(n)$

Tagging variable



Determination of R_b

Double tagging technique : minimizes the uncertainties from the B modeling.

$$\frac{N_t}{2\ N_{had}} = R_b\epsilon_b + R_c\epsilon_c + (1 - R_b - R_c)\epsilon_{uds}$$

$$\frac{N_{tt}}{N_{had}} = R_b c_b \epsilon_b^2 + R_c\epsilon_c^2 + (1 - R_b - R_c)\epsilon_{uds}^2$$

- **Inputs from Data :**

  N_{had} = **No. of selected hadrons**

  N_t = **No. of tagged hemispheres**

  N_{tt} = **No. of events with both hemispheres tagged**

- **Inputs from MC :**

  ϵ_{uds},ϵ_c = **efficiencies for uds,charm hemispheres**

  c_b = **hemisphere correlation for b events**

- R_c **from the Standard Model**

$\Rightarrow$ R_b **and** ϵ_b **from DATA**

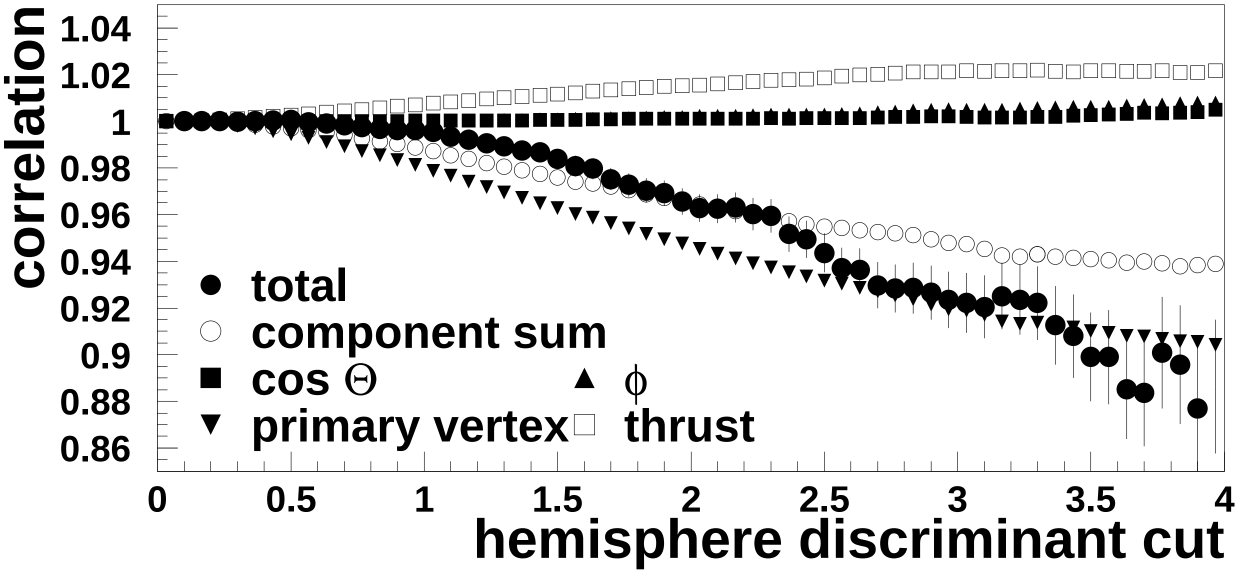
Definition:

- Probability to tag only one hemisphere: ϵ_b
- Probability to tag two hemispheres: ϵ_b^{dt}

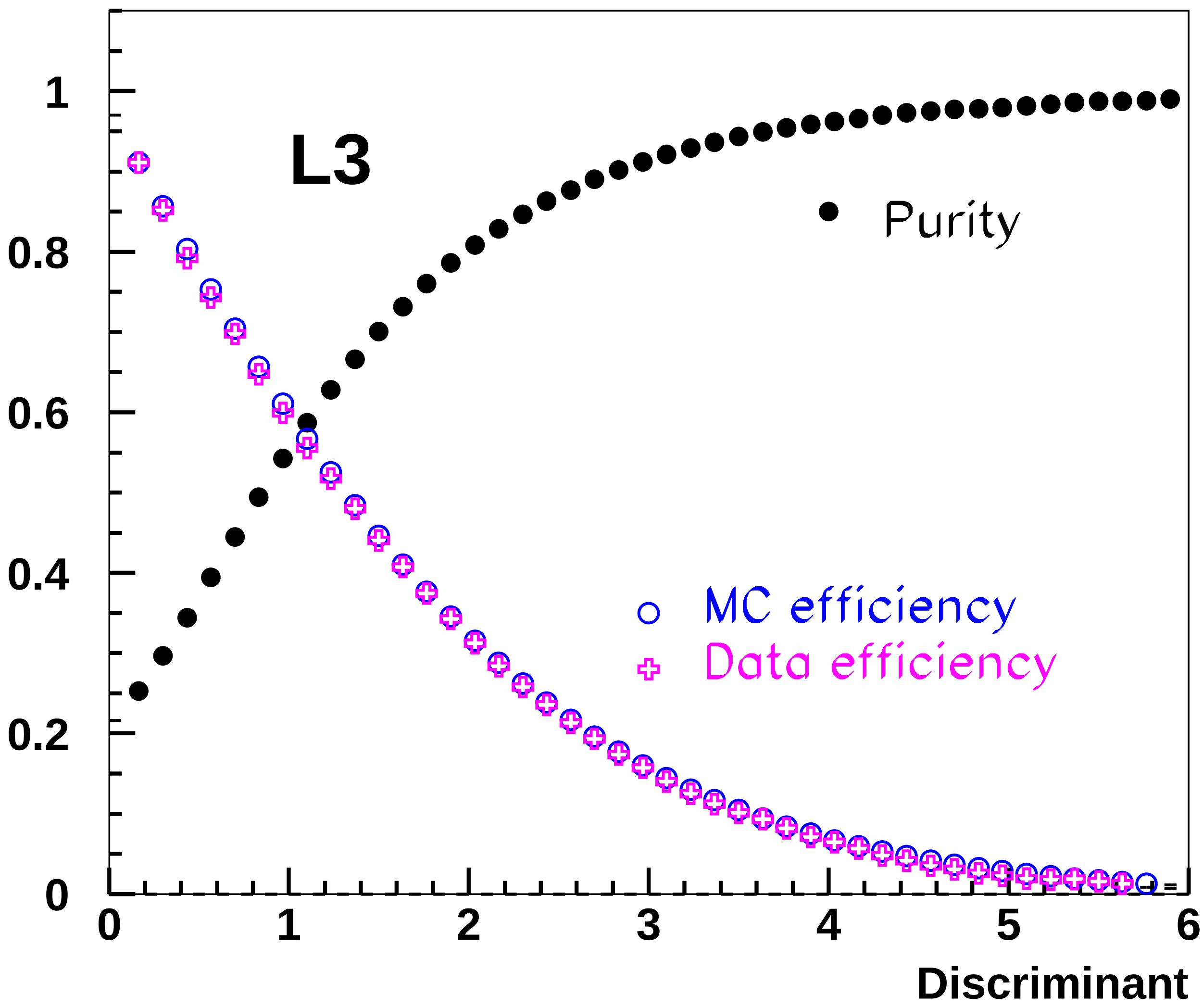
$$\epsilon_b^{dt} = (c_b \epsilon_b) \cdot \epsilon_b \implies c_b = \frac{\epsilon_b^{dt}}{\epsilon_b^2}$$

Main sources of correlation:

- **Detector :** geometrical effects
- **Vertex :** bias of the reconstructed vertex
- **Physics :** hard gluon radiation



Efficiency and purity



$$\mathbf{Pur} = \frac{\mathbf{N_t^b}}{\mathbf{N_t}}$$

Error sources in the R_b measurement :

- **Statistical error:** dominated by the number of double tagged events.

- **Systematic errors:**

  Background efficiencies (ϵ_{uds},ϵ_c)

  - Detector resolution: knowledge of the single track resolution
  - Rate of long lived hadrons in uds events
  - Rate of gluon splitting in $c\bar{c}$ and $b\bar{b}$ pairs
  - Charm parameters

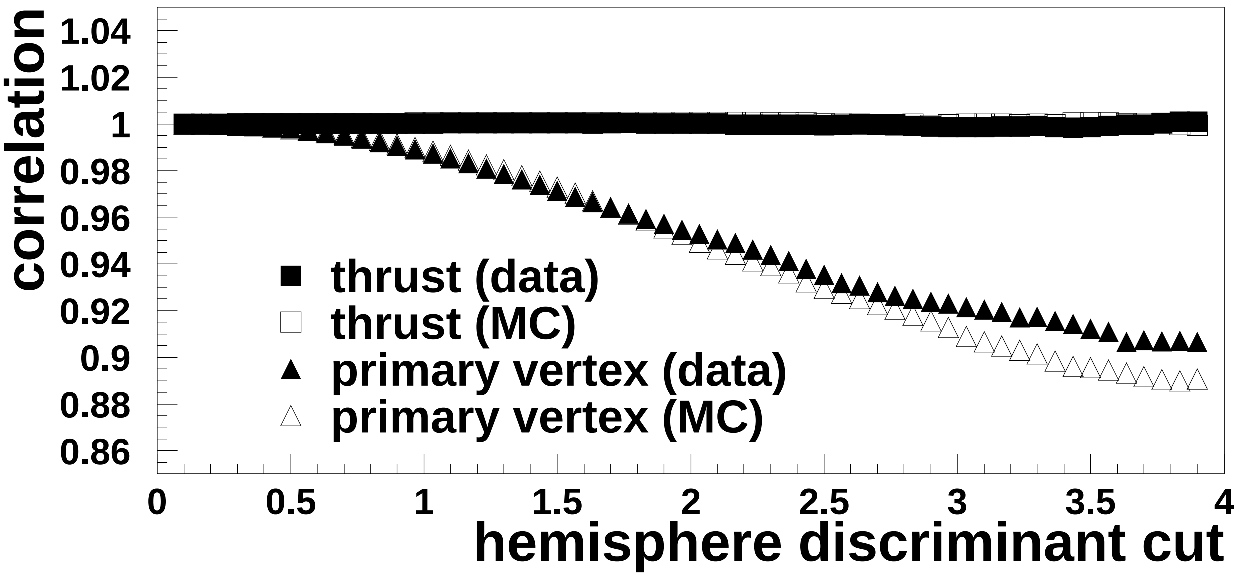
  Hemisphere correlation (c_b):

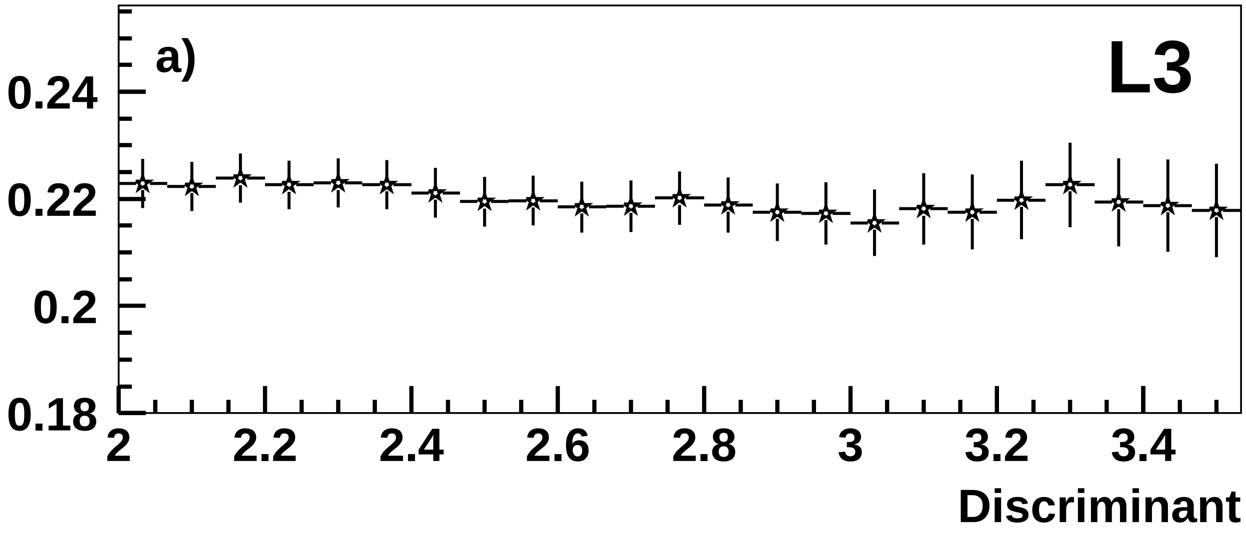
  - Detector resolution: geometrical inhomogeneities of the detector and single track resolution
  - Hard gluon production
  - Modelling of b fragmentation
  - B hadrons charged decay multiplicities
  - B hadrons lifetimes

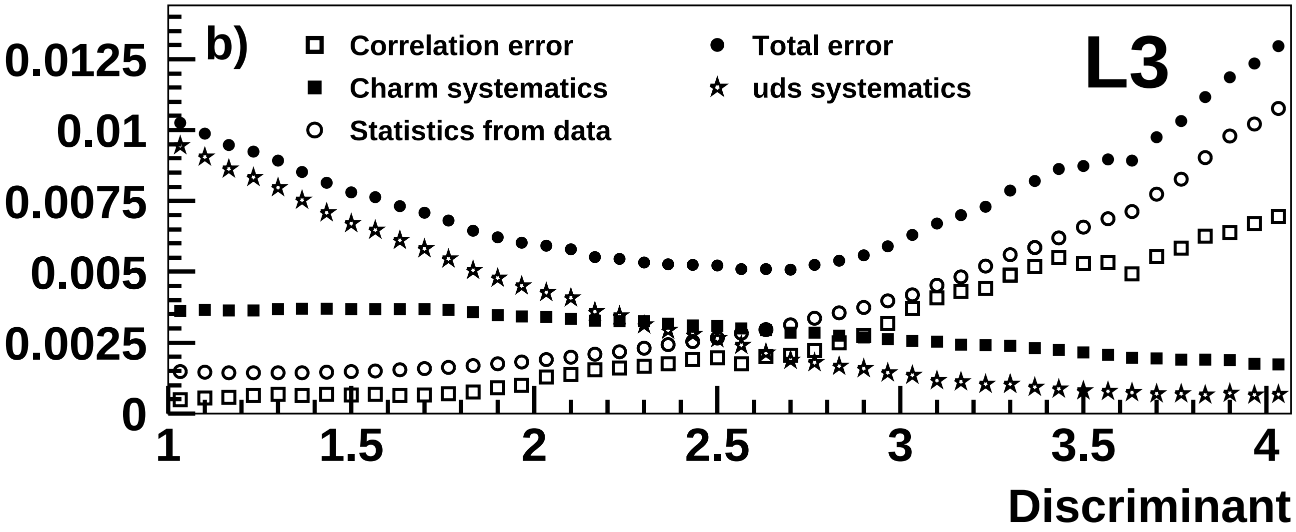
All MC parameter are adjusted according to the LEP HF '96 recomendations.

Systematic errors from hemisphere correlation:

- Find an effective variable to describe the source of correlation.
- In a 70% pure $b\bar{b}$ sample we compare the behaviour of MC and Data for each source and assign the difference as a systematic error:





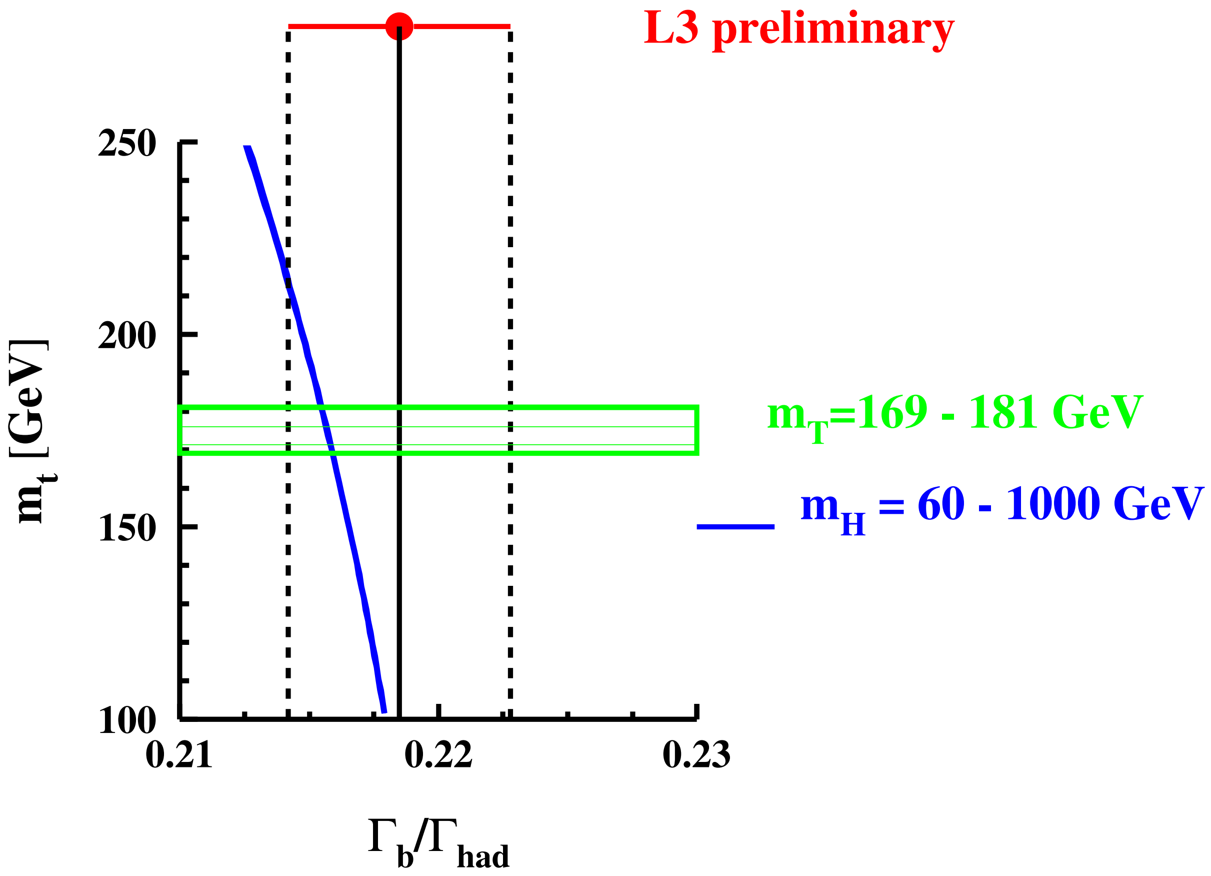


Minimum total error $\Rightarrow$ Discriminant cut $= 2.7$

ϵ_b	ϵ_c	ϵ_{uds}
19.3%	1.76%	0.36 %

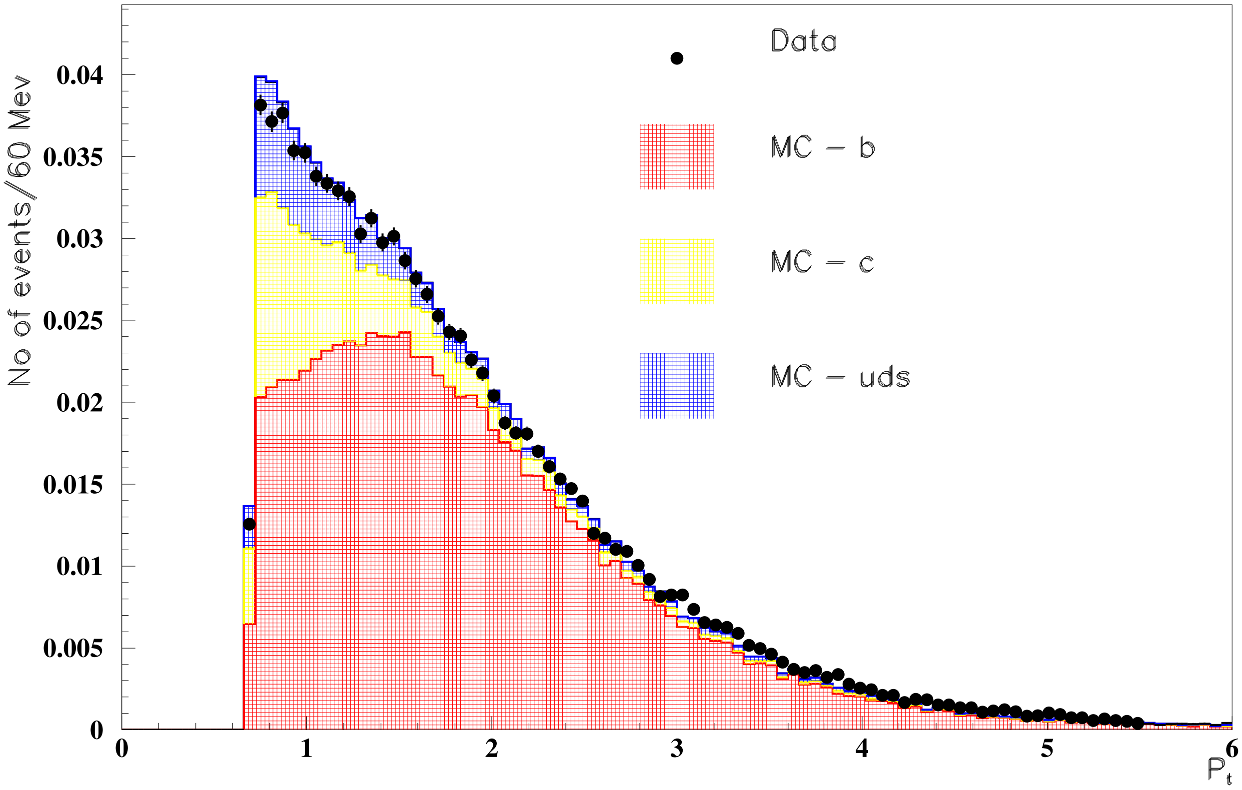
From a sample of $\approx$ 550,000 hadronic events collected in 1994 we measure:

$$\mathbf{R_b = 0.2185 \pm 0.0028(stat) \pm 0.0033(syst)}$$



Large mass and hard fragmentation of B hadrons $\Rightarrow$ high p and p_t leptons.

Discriminant $= p_t$ of electrons and muons.



For a sample of 1.7 million $q\bar{q}$ events and a p_t cut of $1.GeV$ we get:

$$\mathbf{R_b = 0.2234 \pm 0.0040(stat) \pm 0.0052(syst)}$$

Conclusions

- A measurement of R_b at L3 using a vertex tag is presented:

  $$\mathbf{R_b = 0.2185 \pm 0.0028(stat) \pm 0.0033(syst)}$$

- Consistent with the SM prediction for the measured value of m_t.

- Better understanding of the hemisphere correlation.

- Improvements in the accuracy of the measurement are foreseen using 1995 DATA and combining different tagging methods.