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b Fragmentation and Energy Correlation in $Z \longrightarrow bb$ Decays (LEP-1 and SLD results)

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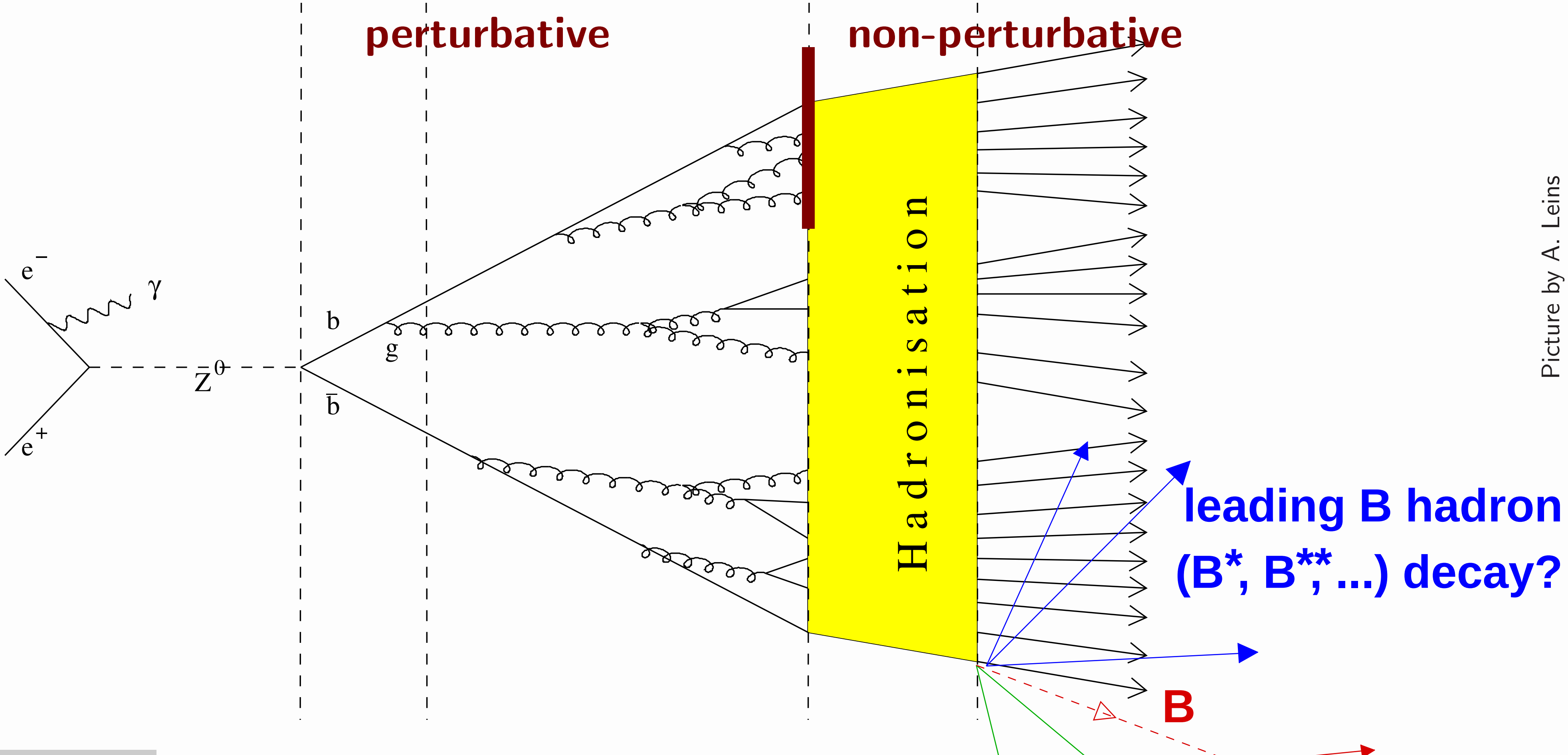


variables

distrib. of z defines hadronisation model

z

$$x_L = E_{lead.B} / E_{beam}$$

$$x_{wd} = E_{wd.B} / E_{beam}$$

Recent analyses: b fragmentation in $\mathrm{e^+e^-}$ reactions at 90 GeV

B hadron energy distribution at 90 GeV, test of hadronisation models

ALEPH	abstract 204
DELPHI	583 (prelim.)
OPAL	526
SLD	968

(presentation: first B hadron selection in all analyses, then results)

angle-dependent $\mathrm{B\bar{B}}$ energy correlation at 90 GeV

SLD	abstract 967 (prelim.)

ALEPH: B meson reconstruction

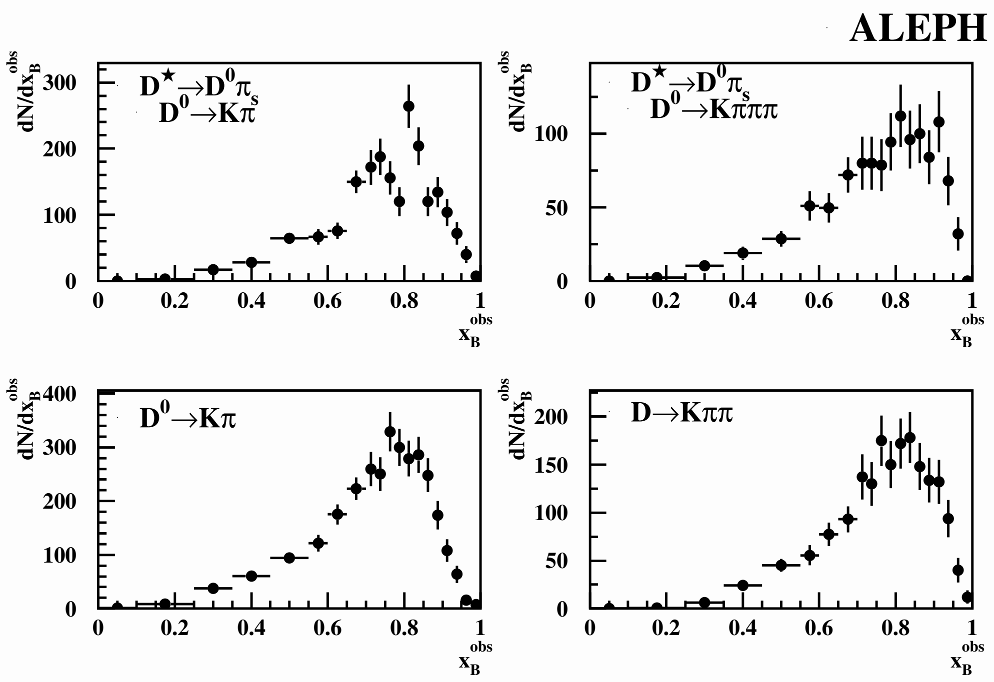
exclusive B meson decays:
$B \longrightarrow D^{(*)}\ell\nu$

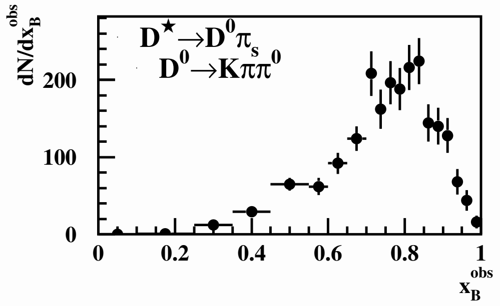
- ℓ: either e or μ
- five $D^{(*)}$ channels:

$$
\begin{aligned}
&D^{*+} \longrightarrow D^0 \pi^+, \\
&\qquad\qquad \hookrightarrow K^- \pi^+ \\
&\qquad\qquad \hookrightarrow K^- \pi^+ \pi^+ \pi^- \\
&\qquad\qquad \hookrightarrow K^- \pi^+ \pi^0 \\
&D^+ \longrightarrow K^- \pi^+ \pi^+ \\
&D^0 \longrightarrow K^- \pi^+
\end{aligned}
$$

- ν energy := missing energy

B energy resolution: 3–5%
≈3400 candidates

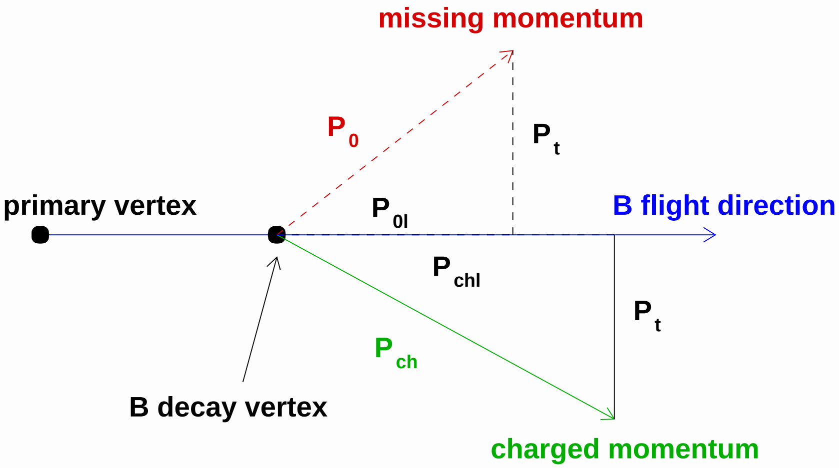




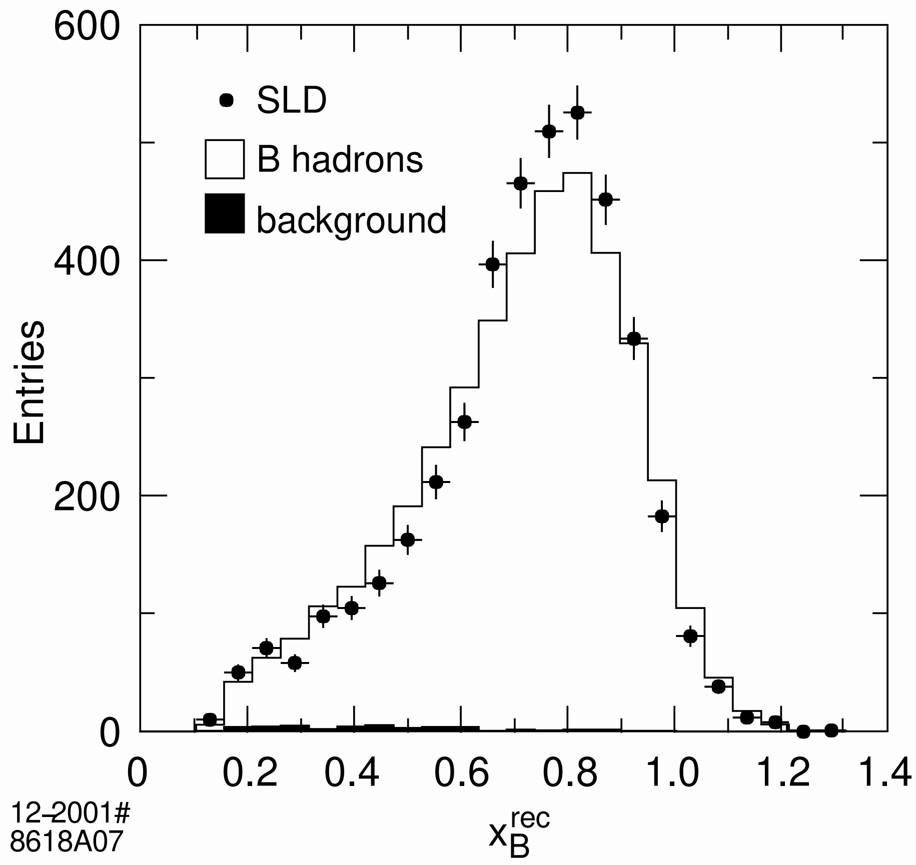
distribution of uncorrected scaled energy x^{rec}_{wd}

SLD: inclusive B hadron reconstruction

inclusive B energy reconstruction
from vertex flight direction
and charged B decay products



B energy resolution: 10%
≈4200 candidates



uncorrected scaled energy x_{wd}^{rec}

DELPHI, OPAL: inclusive B hadron reconstruction

inclusively identify and reconstruct

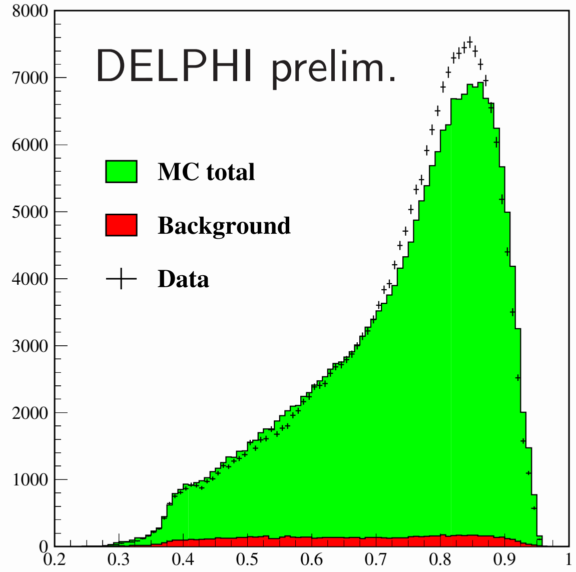
B hadrons from

- weak B hadron decay vertices
- leptons from weak B hadron decay
- charged and neutral decay products

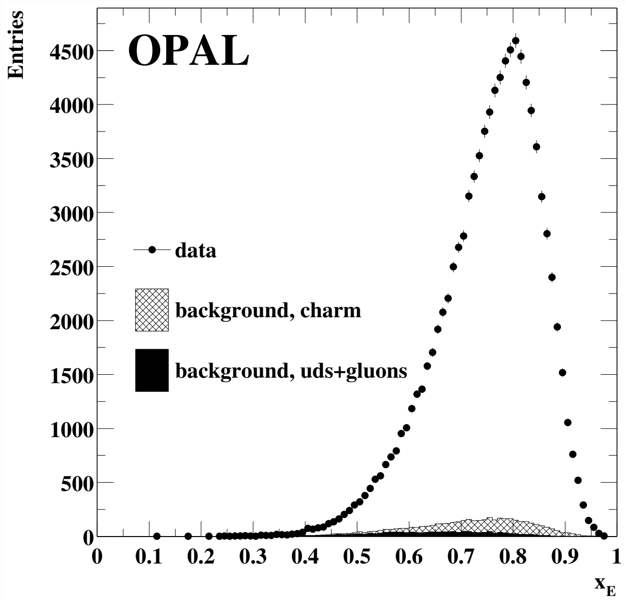
using Artifical Neural Nets, Likelihoods

(OPAL: x_{wd}^{rec}; DELPHI: x_{wd}^{rec}, x_{L}^{rec}, z^{rec})

DELPHI: B energy resolution: $\mathcal{O}(10\%)$
≈230,000 candidates
OPAL: B energy resolution: $\mathcal{O}(10\%)$
≈270,000 candidates



x_{wd}^{rec}



x_{wd}^{rec}

Comparison of hadronisation models with data

ALEPH, OPAL, SLD:

Monte Carlo simulation with

- fragmentation parameters tuned to other measurements
- different hadronisation models
- full detector simulation

compare x_{wd}^{rec} distribution, fit fragmentation function parameters

DELPHI:

unfold detector effects, fit at generator level (x_{wd}, x_L, z)

under investigation:

Jetset 7.3/7.4	(parton shower + Lund string model)	$\longrightarrow$ next page
Jetset 7.4	(parton shower + UCLA string model)	(SLD)
Herwig 5/6	(parton shower + cluster hadronisation)	(OPAL, SLD)

Fragmentation functions for string hadronisation

Peterson et al. $f(z) \propto \frac{1}{z(1-\frac{1}{z}-\frac{\varepsilon}{1-z})^2}$

$\longrightarrow$ Estimate of transition matrix elements by energy difference

Collins/Spiller $f(z) \propto (\frac{1-z}{z} + \frac{(2-z)\varepsilon}{1-z})(1+z^2)(1-\frac{1}{z}-\frac{\varepsilon}{1-z})^{-2}$

$\longrightarrow$ from correspondence to heavy meson structure functions

Kartvelishvili et al. $f(z) \propto z^{\alpha}(1-z)$

$\longrightarrow$ from correspondence to different model of heavy meson structure functions

Lund symmetric $f(z) \propto \frac{1}{z}(1-z)^a \exp(-\frac{bm_t^2}{z})$

$\longrightarrow$ symmetry wrt. start of string hadronisation at either end of the string

Bowler $f(z) \propto \frac{1}{z^{1+r_b m_t^2}}(1-z)^a \exp(-\frac{bm_t^2}{z})$

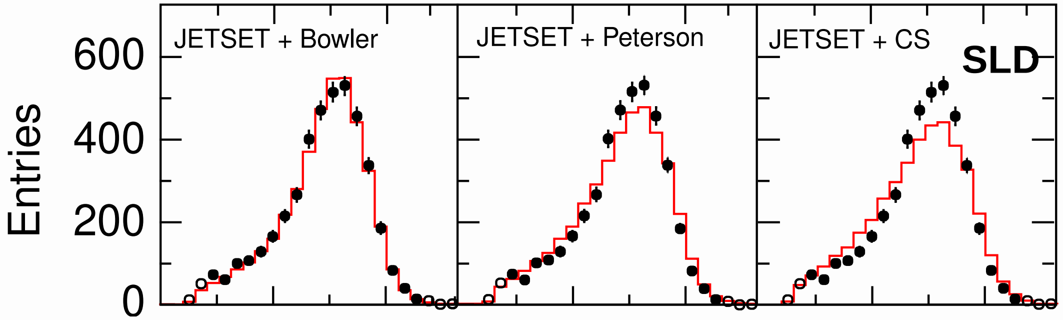
$\longrightarrow$ constant probability per length and time for $q\bar{q}$ creation on the string

BCFY $f(z) \propto \frac{z(1-z)^2}{(1-(1-r)z)^6}\left(3+\sum_{i=1}^{4}(-z)^i f_i(r)\right)$

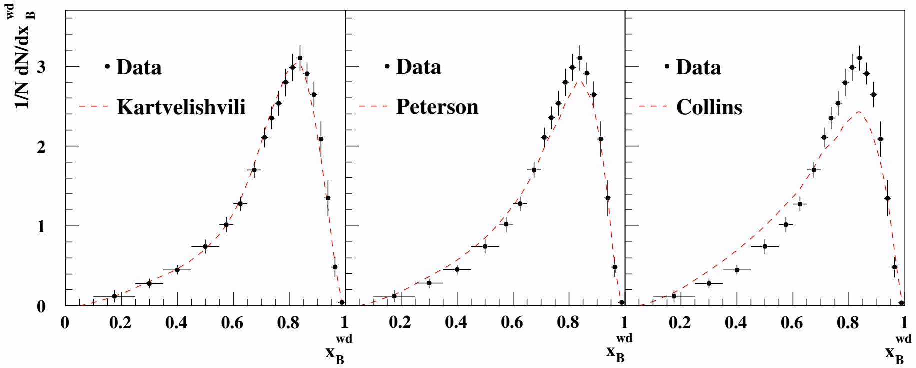
$\longrightarrow$ perturbative ansatz

Results of model tests

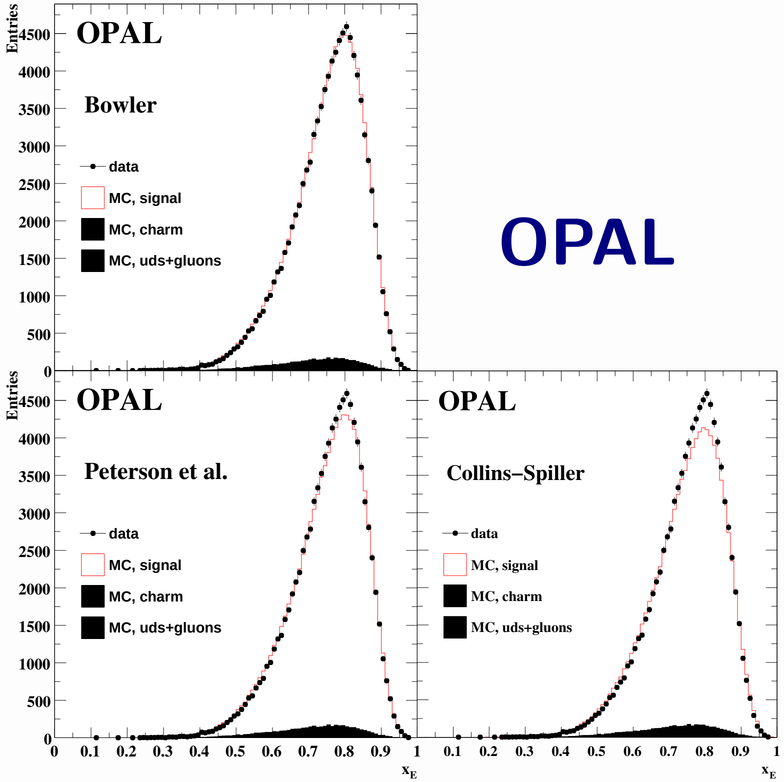
SLD



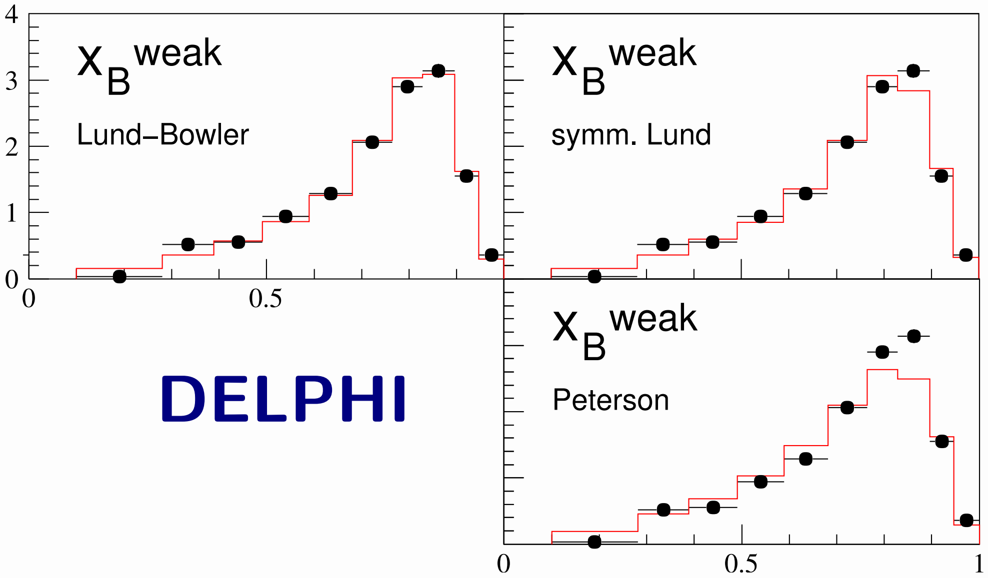
ALEPH



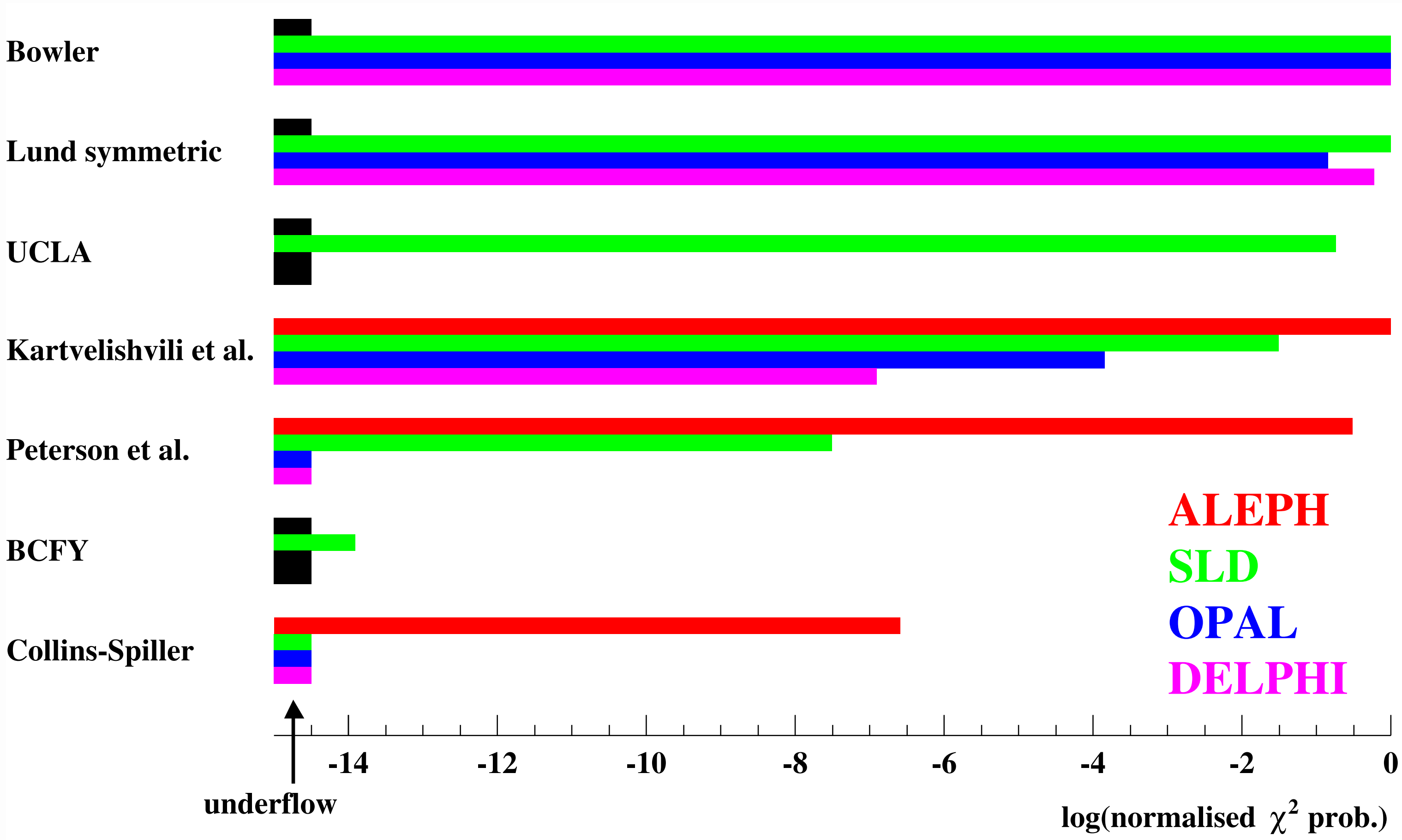
OPAL



DELPHI



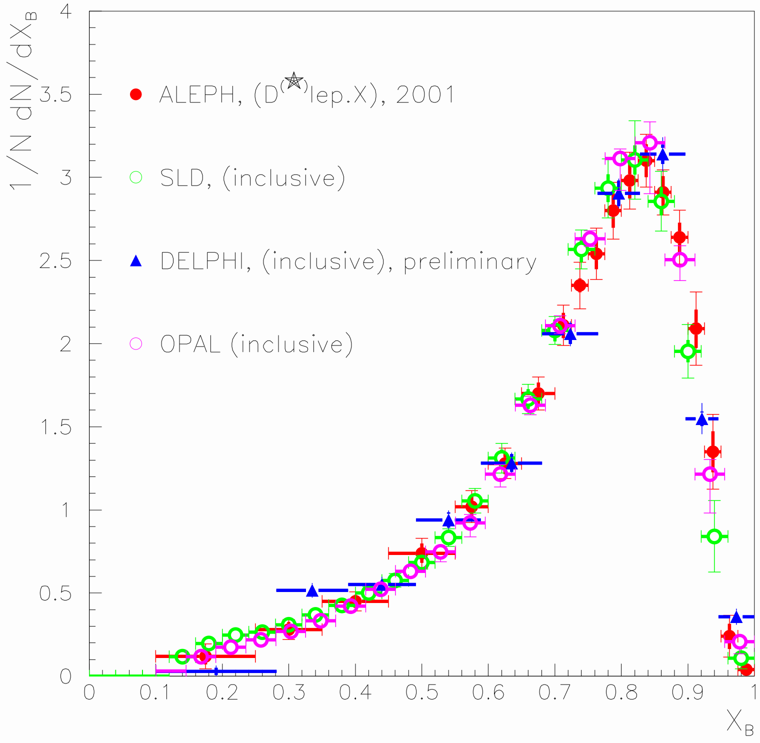
Model tests: normalised χ^2/d.o.f. probabilities



same ranking seen by all experiments! Herwig 5/6: tested by OPAL+SLD, but disfavoured

Model-independent description of B hadron energy spectrum

unfolded x_{wd}



description of the shape in terms of x_{wd} moments:

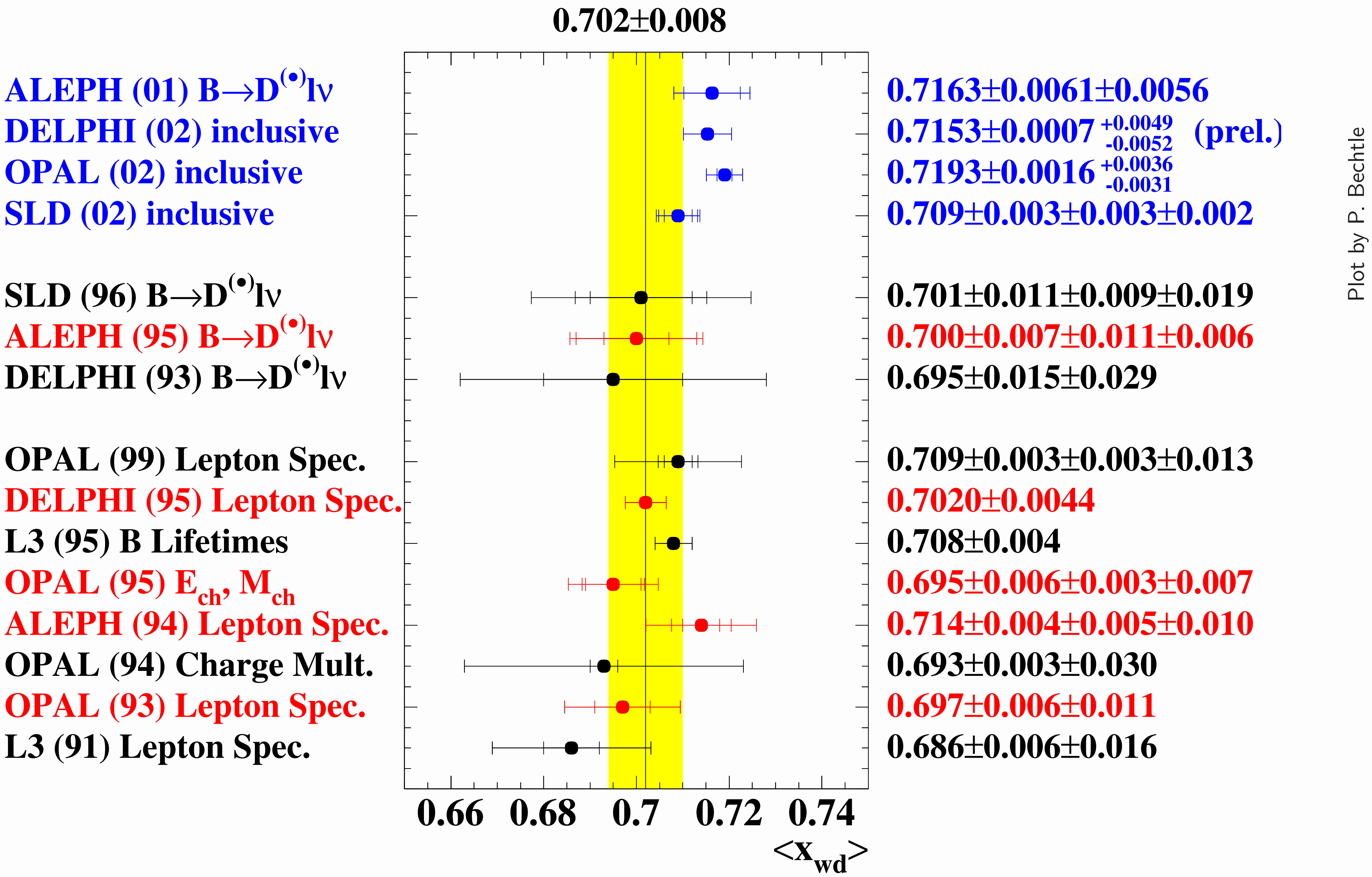
$$D_i = \int_0^1 dx\; x^{i-1} D(x)$$

values from *very* preliminary LEP/SLD combination (P. Roudeau, E. Ben Haim):

$$\begin{aligned} D_1 &= 1 \text{ (definition)} \\ \langle x_{wd} \rangle = D_2 &= 0.7151 \pm 0.0025 \\ D_3 &= 0.5426 \pm 0.0012 \\ D_4 &= 0.4268 \pm 0.0010 \\ D_5 &= 0.3440 \pm 0.0017 \end{aligned}$$

motivation: for future tests of hadronisation models without redoing analysis
higher moments needed for application in hadron collider physics

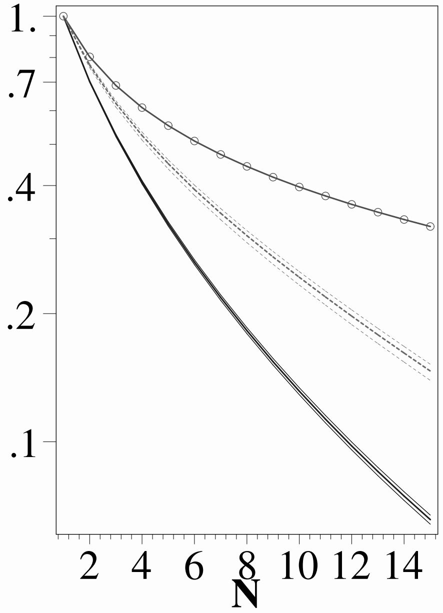
Overview of $\langle x_{wd} \rangle$ measurements



Hadronisation model test in moments space

factorisation theorem $\longrightarrow$ moments expressed as $D_i = M_i \times P_i$
P_i: from perturbative calculations
M_i: non-perturbative

$\longrightarrow$ can isolate non-perturbative contribution M_i as D_i/P_i



P_i: Jetset perturbative

P_i: NLL calculation Cacciari/Catani

D_i: DELPHI (prelim.)

M_i: same information on hadronisation model as x_{wd} distribution

Fit hadronisation models to M_i:

Kartvelishvili et al.	115/4
Peterson et al.	189/4
Collins/Spiller	845/4

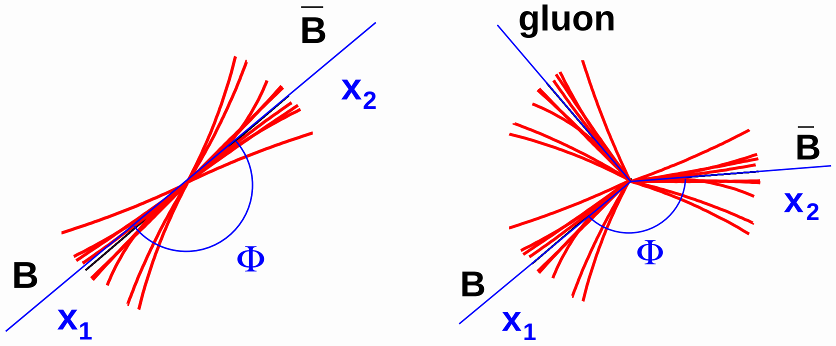
!!!nothing new, just different method!!!

different topic: look at *perturbative* part of fragmentation

Angle-dependent $B\bar{B}$ energy correlations

two B hadrons in event:

pQCD predicts correlation between B hadron energies and angle



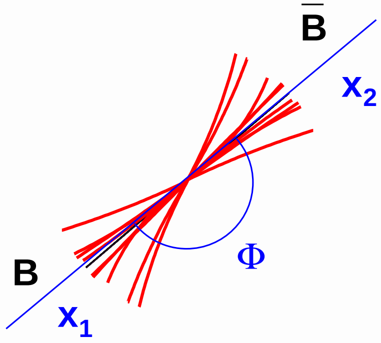
very simple example:
presence of hard gluon radiation affects angle and energies!

but: correlation smeared out due to non-perturbative (hadronisation) energy loss

Can one somehow extract the perturbative effects only?

first measurement of angle-dependent $\mathrm{B\bar{B}}$ energy correlations

- find two B hadrons in event
- measure 2d fragmentation function $D(x_1, x_2, \Phi)$
  x_1, x_2: scaled B hadron energies
  Φ: angle between B hadron momenta



- extract perturbative contribution from moments

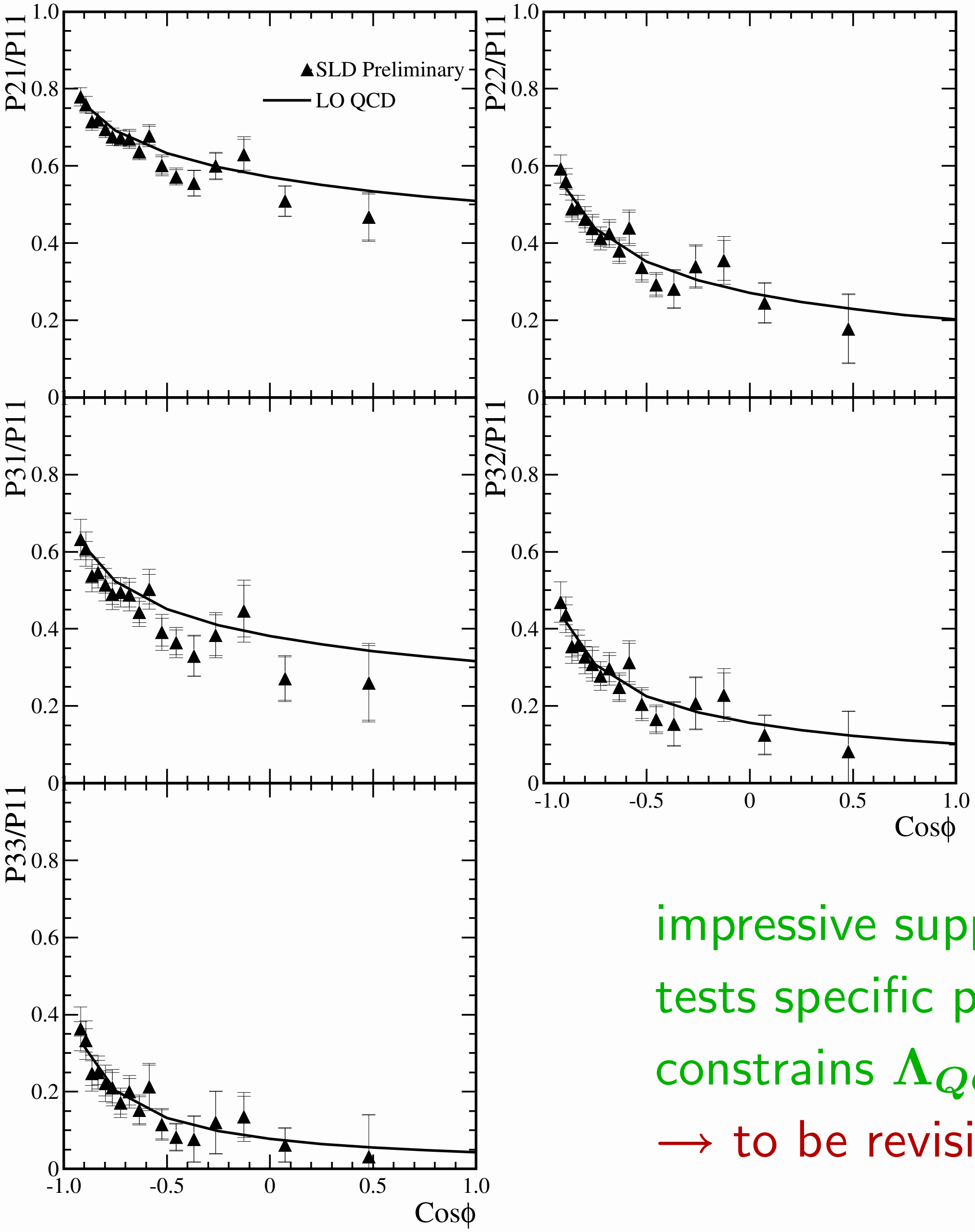
moments of 'usual' (1d) fragmentation function:

$$D_i \;= \int_0^1 dx\; x^{i-1} D(x) = M_i \times P_i$$

moments of 2d fragmentation function:

$$D_{ij} = \int_0^1 dx_1 \int_0^1 dx_2\; x_1^{i-1} x_2^{j-1} D(x_1, x_2, \Phi) = M_i \times M_j \times P_{ij}(\Phi)$$

$\longrightarrow$ can extract $P_{ij}(\Phi)$



normalised double moments P_{ij}/P_{11}:

LO pQCD prediction

(Burrows, Del Duca, Hoyer)

and preliminary SLD measurement

impressive support for factorisation approach!

tests specific perturbative calculations

constrains Λ_{QCD} (separately for different flavours)

$\longrightarrow$ to be revisited at a future Linear Collider!

Summary

- new round of b fragmentation measurements, mostly inclusive
- test of hadronisation models:
  — Jetset/Bowler, Jetset/Lund favoured by data
  — Peterson function too broad
- model-independent description of B hadron energy spectrum:
  — $\langle x_{wd} \rangle = 0.7151 \pm 0.0025$ (*very* preliminary LEP/SLD combination)
  — higher x_{wd} moments available
- SLD $\mathrm{B\bar{B}}$ energy correlation measurement:
  — verification of factorisation and pQCD calculations
  — road towards investigation of more aspects of fragmentation!

Acknowledgements:
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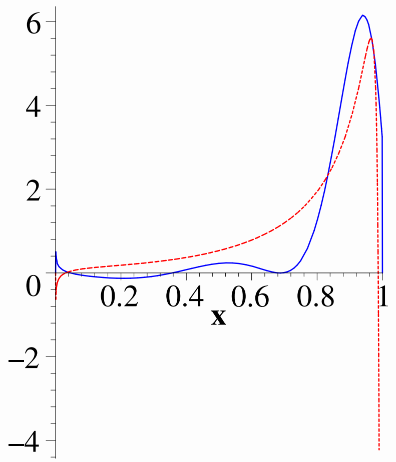
Not mentioned, but not to be forgotten



DELPHI: x-dependence of non-perturbative component
SLD: fit of functional forms to x_{wd} distribution
ALEPH: $\langle x_L \rangle = 0.7361 \pm 0.0063(stat) \pm 0.0063(syst)$
DELPHI: $\langle x_L \rangle = 0.7346 \pm 0.0008(stat) \pm 0.0055(syst)$
DELPHI: $\langle z \rangle = 0.8872 \pm 0.0012(stat) \pm 0.0054(syst)$

Overview: model test χ^2/d.o.f.

	ALEPH	DELPHI (prelim.)			OPAL	SLD
		x_{wd}	x_L	z		
Bowler	—	35/8	43/8	1/2	67/44	17/15
Lund	—	42/8	53/8	2/2	75/44	17/15
UCLA	—	—	—	—	—	27/17
Kartvelishvili et al.	107/94	—	—	36/3	99/45	32/16
Peterson et al.	117/94	287/9	245/9	187/3	159/45	70/16
BCFY	—	—	—	—	—	105/16
Collins/Spiller	181/94	—	—	536/3	407/45	142/16
Herwig 6 cldir=1	—	—	—	—	540/46	—
Herwig 5 cldir=1	—	—	—	—	4279/46	149/17
Herwig 5 cldir=0	—	—	—	—	—	1015/17

same ranking observed by all experiments!
(fragm. function parameters: rough agreement)