Determination of α_s at LEP (L3 experiment)

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Outline

- Hadronic samples at $\sqrt{s}$ up to 208 GeV

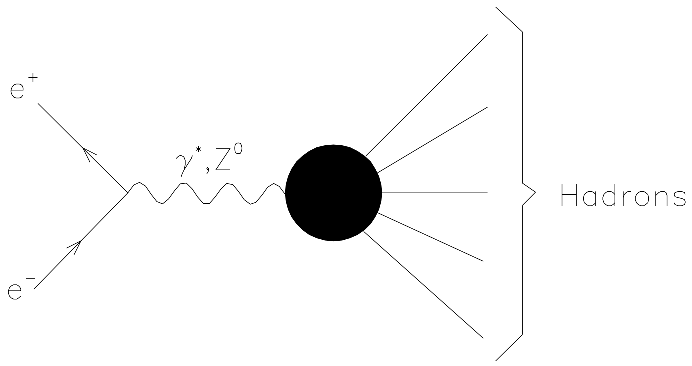
- ....:
  - ......
  - Event shape variables
  - .....

- Test of QCD and α_s at LEP
- Conclusions

Over a decade of Lep running:

- $2.5 \cdot 10^6$ Z hadronic decays recorded at LEP 1 (1989-1995)
- Target luminosity at LEP 2 ($\sqrt{s} > m_Z$) 500 pb^{-1} /expt

Delivered luminosity (1995-2000) $\approx$ 700 pb^{-1} /expt



Precise measurements of QCD at LEP:

- Clean initial state (e^+e^-)
- Small hadronization corrections ($\propto 1/E$)

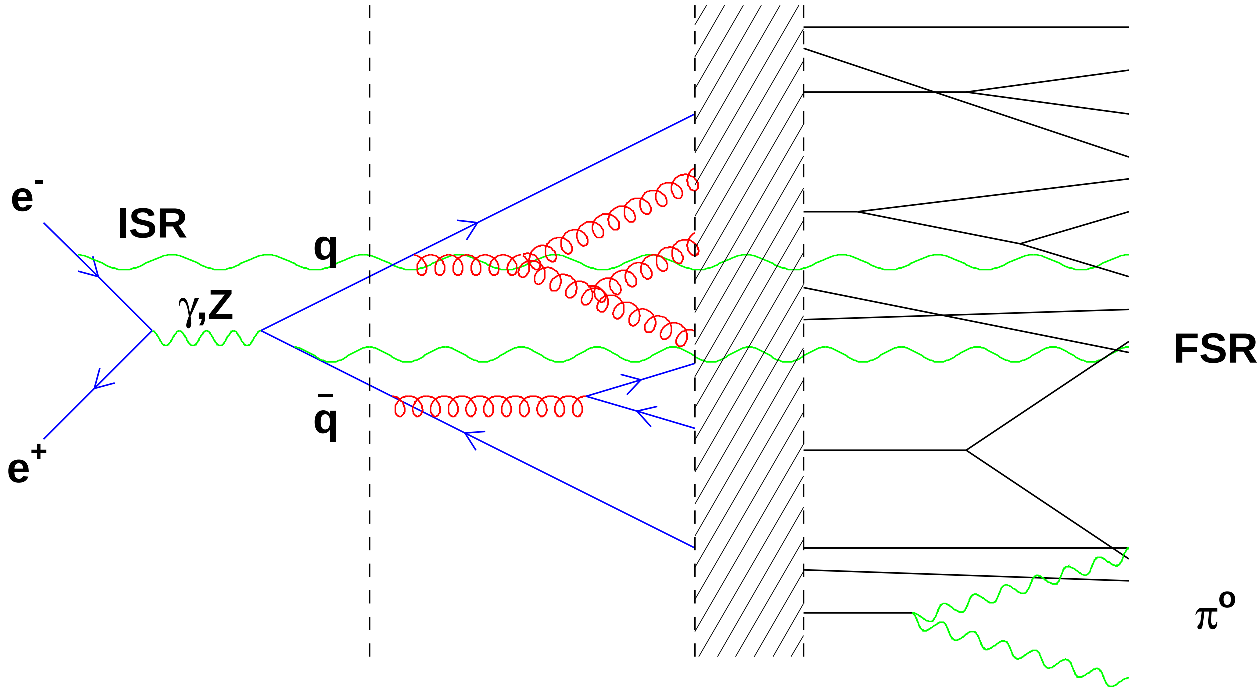
Study Hadronic events $30 \leq \sqrt{s} \leq 208$ GeV

- Hard Gluon Radiation:

Multi-jet topology, Event Shape Variables

Measurement of Strong coupling constant α_s

Measurement of Active # of quark flavours n_f



- $\sqrt{s'} < m_Z$. Reduced $\sqrt{s'}$ from Z decay with isolated γ (FSR).

$$\sqrt{s'} = \sqrt{\sqrt{s}\left(1 - \frac{2E}{\sqrt{s}}\right)}$$

$$\sqrt{s'}(\text{GeV}) = \underbrace{40, 55, 65, 75, 82, 84}_{\text{L3}}$$

$\mathcal{O}(1000)$ events with purity $70 - 90$ %

- $\sqrt{s} \sim m_Z$. Hadronic Z decays. Purity $\approx 90\%$

- $\sqrt{s} > m_Z$. Rejecticting initial state radiation. Four fermion final state (WW,ZZ). Purity $\sim 78 - 90\%$

- High energy sample. $192 \leq \sqrt{s} \leq 208$ GeV

Comparison with QCD Event Generators

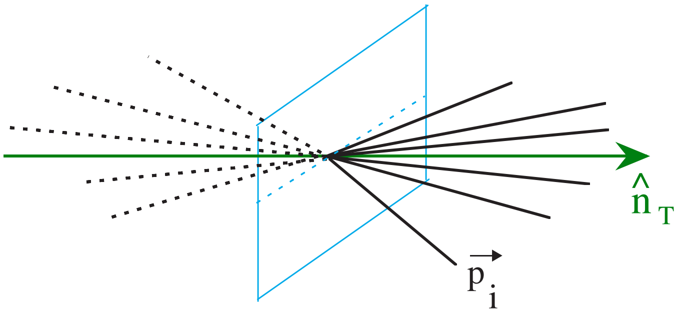
QCD Model	Shower Development	Fragmentation
JETSET/PYTHIA	Parton Shower	String
HERWIG	Parton Shower	Cluster
ARIADNE	Color Dipole	String
COJETS	Incoherent	Independent

All models tuned at $\sqrt{s} = m_Z$ using LEP I data

Jet Durham algorithm

$$y_{ab}^{\mathrm{Durham}} = 2\,\frac{(E_a^2, E_b^2)_{\min}}{E_{\mathrm{vis}}^2}(1 - \cos\theta_{ab})$$

- Collinear and infrared safe variables nalytically calculable.
- Perturbative calculations more complete than in jet rate.



Thrust

$$\mathbf{T} = \left(\frac{\Sigma_i |\vec{p}_i \cdot \hat{n}_T|}{\Sigma_i |\vec{p}_i|}\right)_{max}$$

Heavy jet mass

$$\rho_H = (\Sigma_i p_i)^2_{max} / s$$

$$(i \text{ in } S_\pm)$$

Jet broadenings

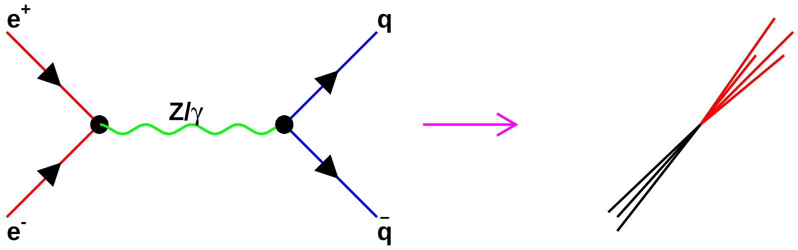
$$B_\pm = \left(\frac{\Sigma_i |\vec{p}_i \times \hat{n}_T|}{2\Sigma_i |\vec{p}_i|}\right)$$

$$B_T = B_+ + B_-, \quad B_W = \max(B_+, B_-)$$

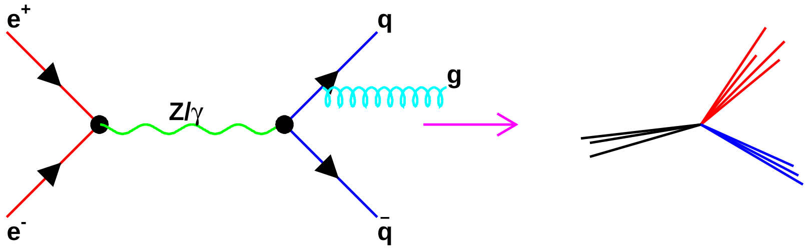
C-parameter

$$C = \left(\frac{3}{s}\right) \Sigma_{i<j} |\vec{p}_i| * |\vec{p}_j| * \sin^2(\theta_{ij})$$

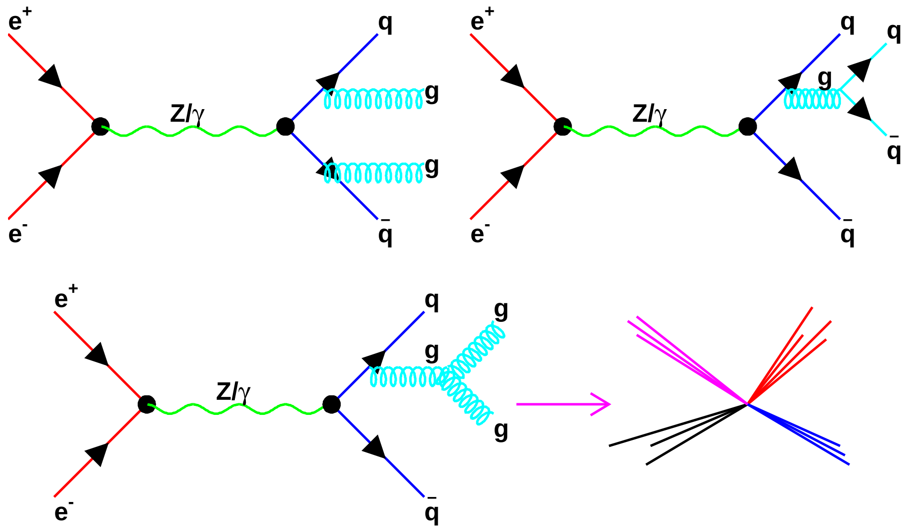
Event Shapes: relative contributions from n-jet configuration



2 jets: $1 - \mathrm{T} \simeq 0$ ρ_H, B_T, B_W, $\mathrm{C} \simeq 0$



3 jets: $\mathrm{T}\ [\frac{2}{3}, 1]$, $\rho_H \approx 1 - \mathrm{T}$, $B_T\ [0, \frac{1}{2\sqrt{3}}]$, $\mathrm{C}\ [0, \frac{3}{4}]$



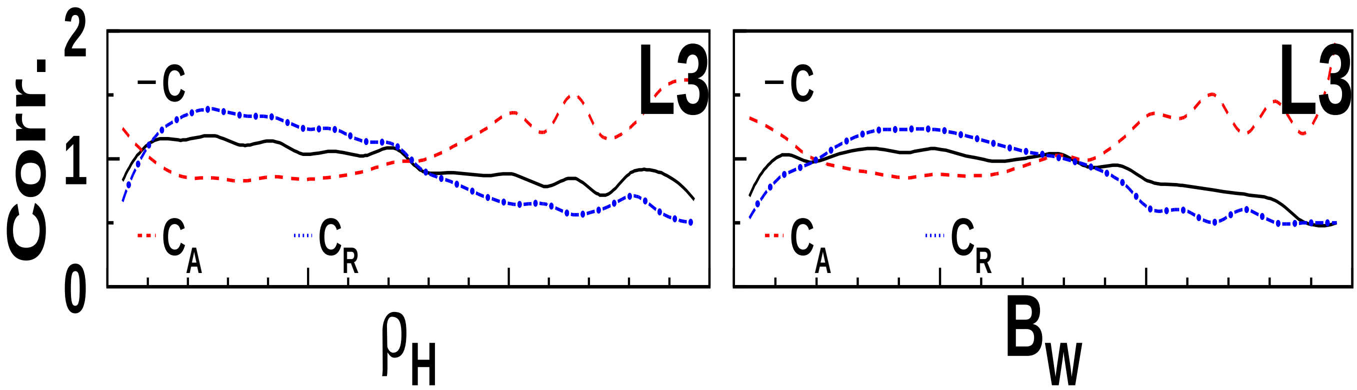
4 jets: $\mathrm{T}\ [\frac{1}{\sqrt{3}}, 1]$, <u>Planar Topology</u> $(\mathrm{C})_{max} = 1.$
<u>Spherical Topology</u>, $(B_T)_{max} = \frac{\pi}{8}$, $(B_W)_{max} = \frac{\pi}{16}$

From Distribution of event shapes from total hadronic event sample → precise determinatio of α_s

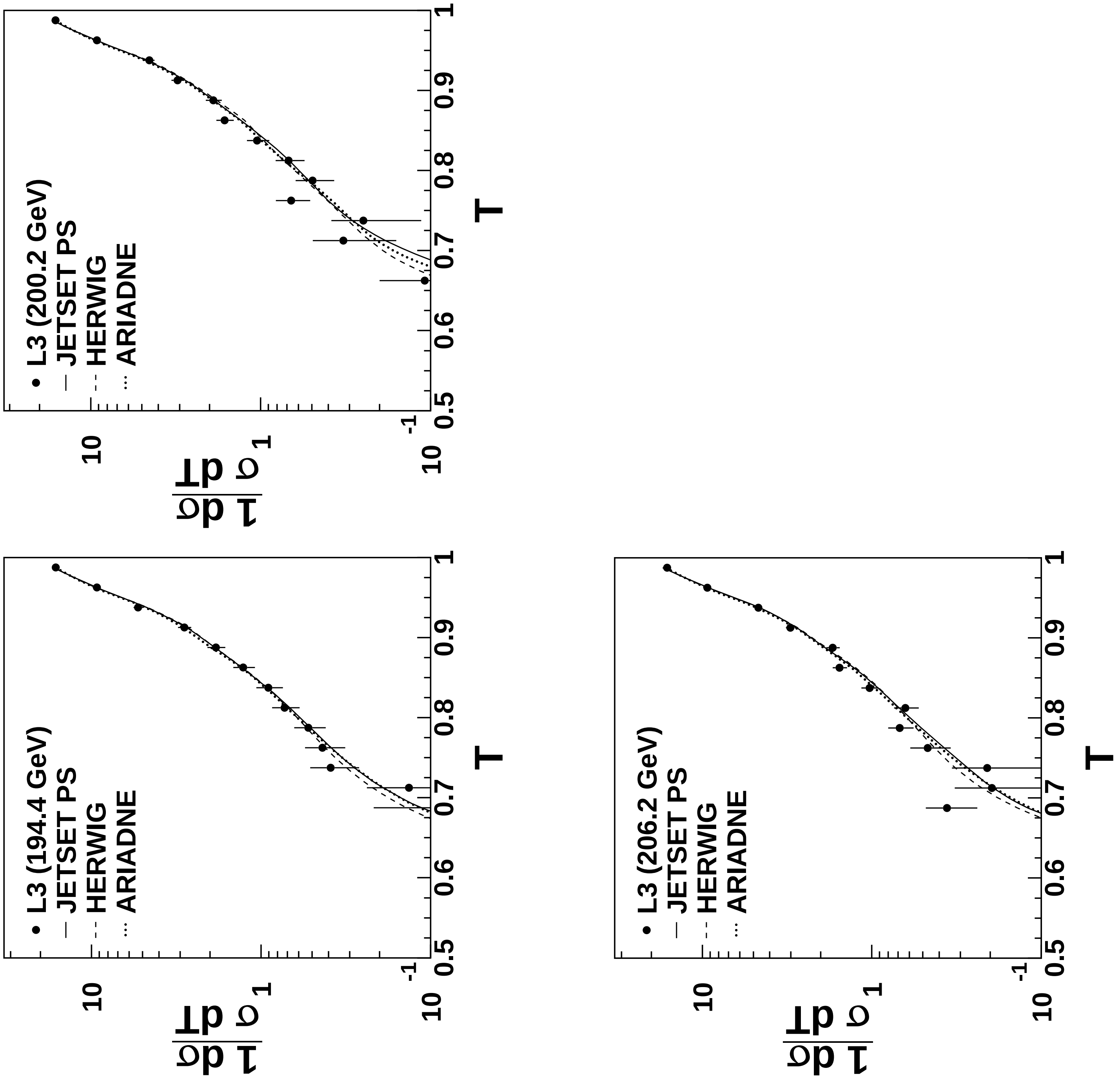
..... distribuzioni del trust con WW sottratti

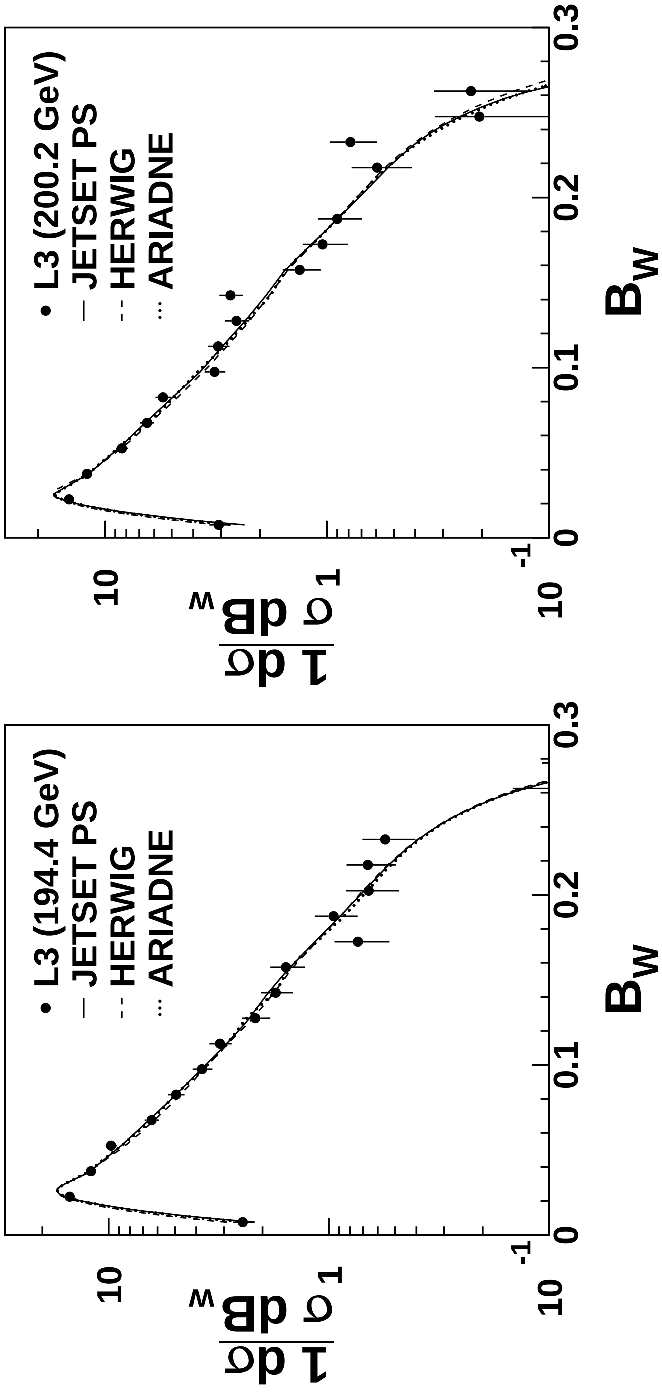
Detector level distributions corrected *bin-by-bin* for:

- Remaining Background
- Detector Resolution
- Acceptance
- Initial/Final State Radiation

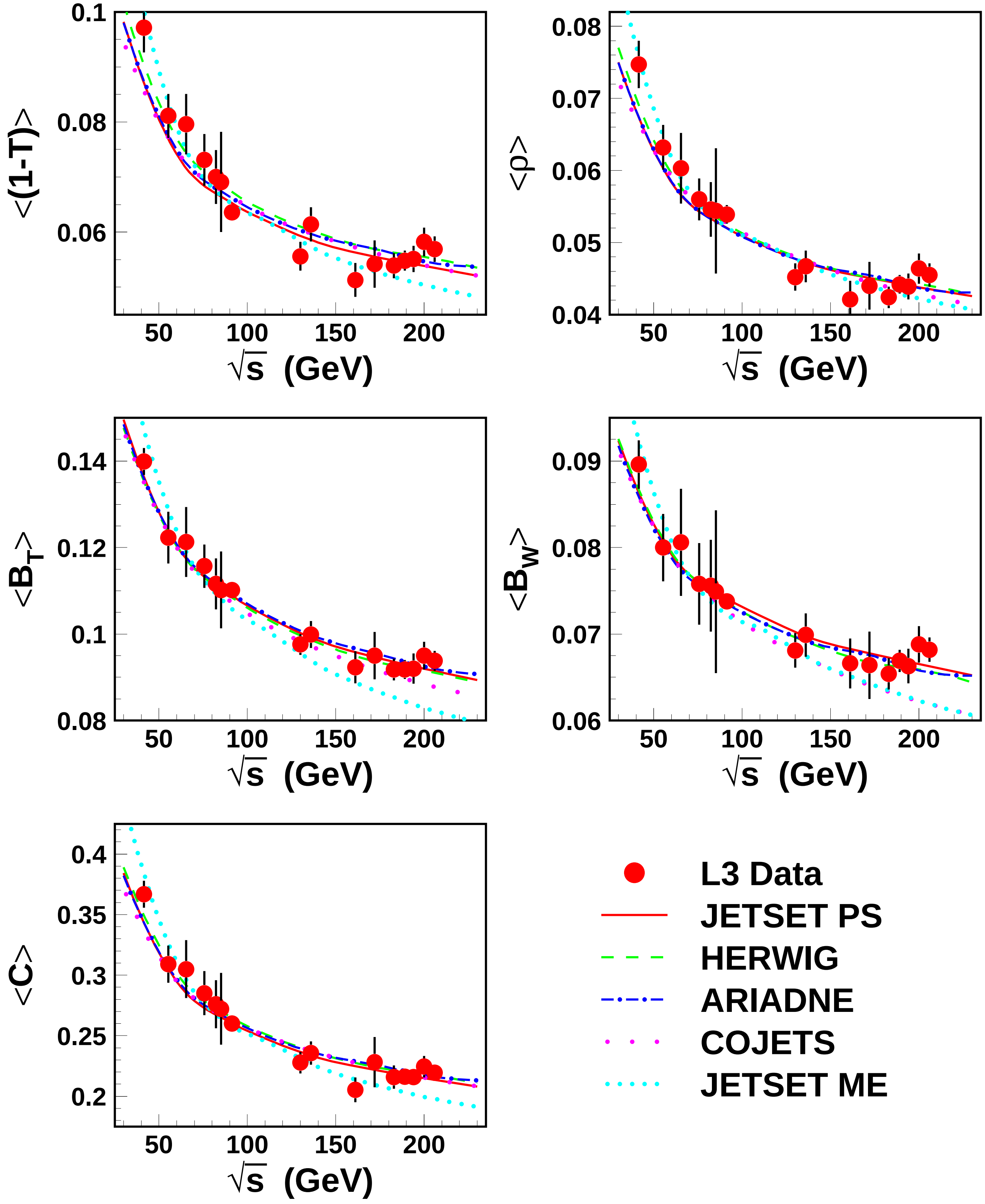


distributions:Trust

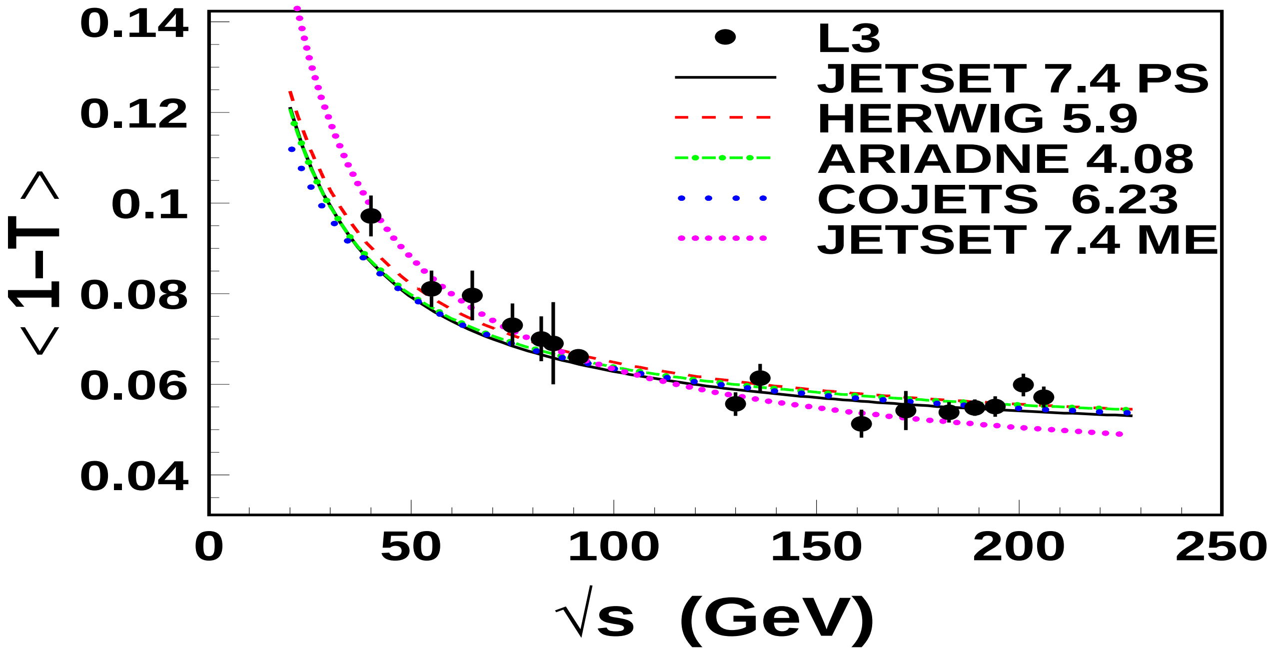


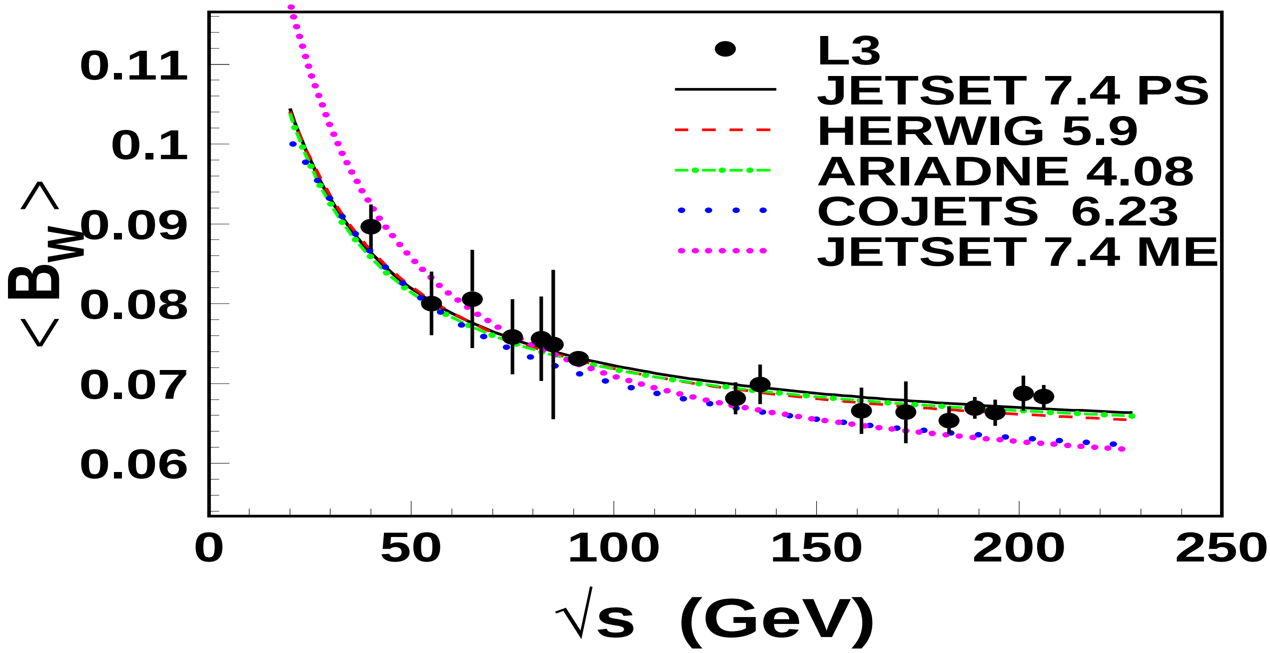

L3 (200.2 GeV)
JETSET PS
HERWIG
ARIADNE
L3 (194.4 GeV)
JETSET PS
HERWIG
ARIADNE
L3 (206.2 GeV)
JETSET PS
HERWIG
ARIADNE
B_W
$\frac{1}{\sigma}\frac{d\sigma}{dB_W}$

Energy Evolutions



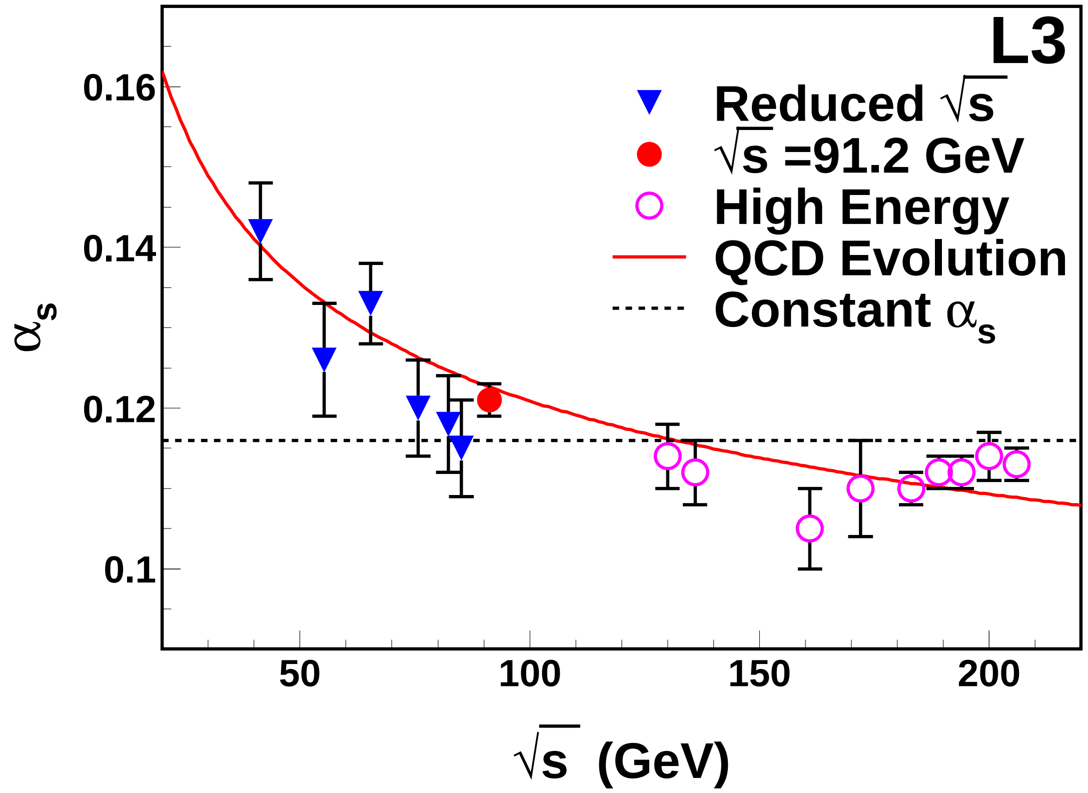
⇒ QCD Models with parton shower describe data well

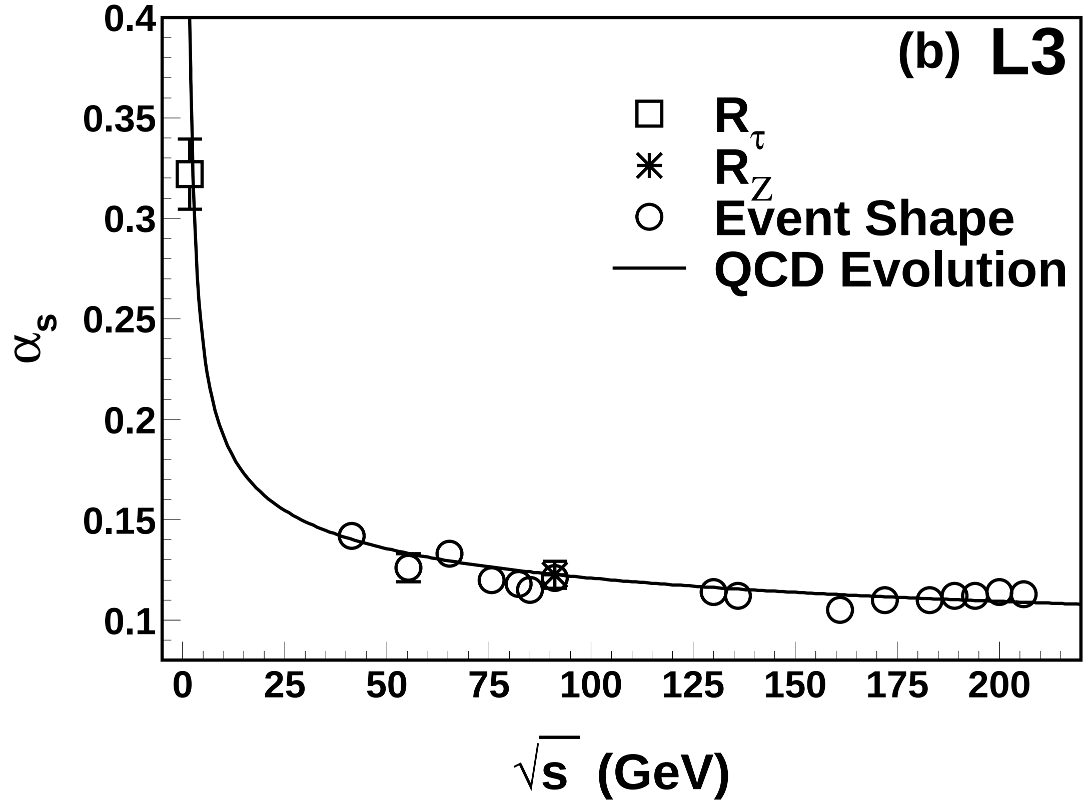




Error bars include experimental systematic uncertanties

Running α_s from 39 to 208 GeV





Combined α_s values from the five event shape variables.

$<\sqrt{s}>$ (GeV)	α_s measurement from T, ρ, B_T, B_w, C				
	α_s	stat	syst	hadr.	hi. order
41.4	0.1418	±0.0053	±0.0030	±0.0055	±0.0085
55.3	0.1260	±0.0047	±0.0056	±0.0066	±0.0062
65.4	0.1331	±0.0032	±0.0042	±0.0059	±0.0064
75.7	0.1204	±0.0024	±0.0059	±0.0060	±0.0053
82.3	0.1184	±0.0028	±0.0053	±0.0060	±0.0051
85.1	0.1152	±0.0037	±0.0051	±0.0060	±0.0055
91.2	0.1210	±0.0008	±0.0017	±0.0040	±0.0052
130.1	0.1138	±0.0033	±0.0021	±0.0031	±0.0046
136.1	0.1121	±0.0039	±0.0019	±0.0038	±0.0045
161.3	0.1051	±0.0048	±0.0026	±0.0026	±0.0044
172.3	0.1099	±0.0052	±0.0026	±0.0024	±0.0048
182.8	0.1096	±0.0022	±0.0010	±0.0023	±0.0044
188.6	0.1122	±0.0014	±0.0012	±0.0022	±0.0045
194.4	0.1123	±0.0018	±0.0016	±0.0020	±0.0047
200.2	0.1138	±0.0018	±0.0021	±0.0020	±0.0046
206.2	0.1132	±0.0014	±0.0016	±0.0019	±0.0047

α_s at m_Z

$$\alpha_s(m_Z) = 0.1227 \pm 0.0012\ (\text{exp}) \pm 0.0058\ (\text{theo})$$

$$N_f = 6.8 \pm 1.3\ (\text{exp}) \pm\ 1.8\ (\text{theo})$$