QCD Studies and Determination of α_{s} in $\mathrm{e^+e^-}$ Collisions up to $\sqrt{s} = 189$ GeV

Dr. A. Malinin (CERN&ITEP-Moscow)

L3 Collaboration

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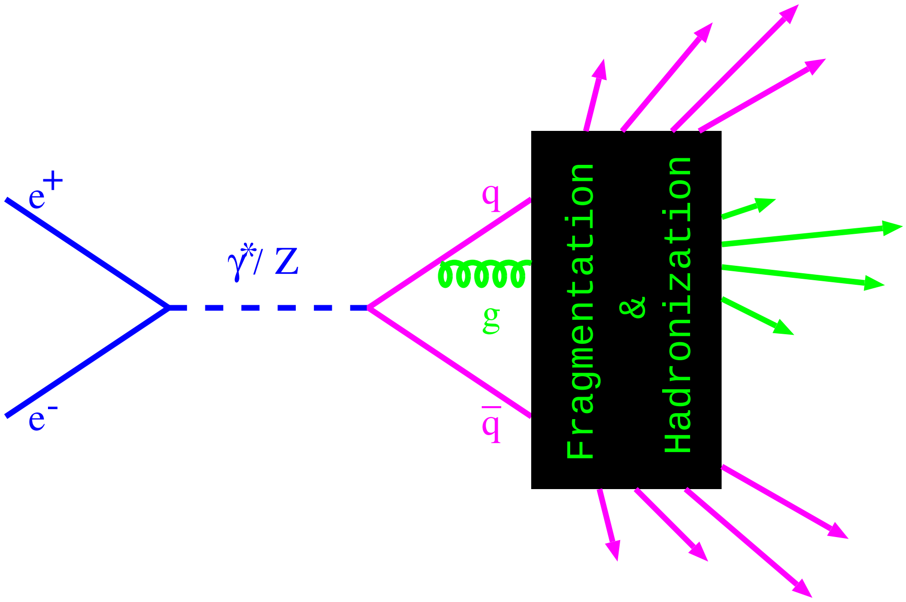
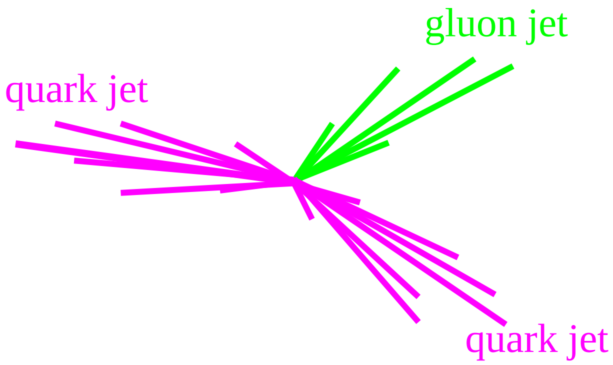
- **Introduction**
- The L3 Detector
- Selection of hadronic events
- Global Event Shape Variables
- Determination of α_s
- Charged particle multiplicity
- Inclusive particle spectrum
- **Summary**

Hadronic event $e^+e^- \rightarrow$ hadrons



Large multiplicity events
with jet-structure:



Event structure reflects 2 aspects of gluon radiation:

- **Hard radiation** $\Rightarrow$ **deviation from 2jet**

  Strong coupling α_s

- **Soft radiation** $\Rightarrow$ **particle multiplicity**

  Color coherence phenomena

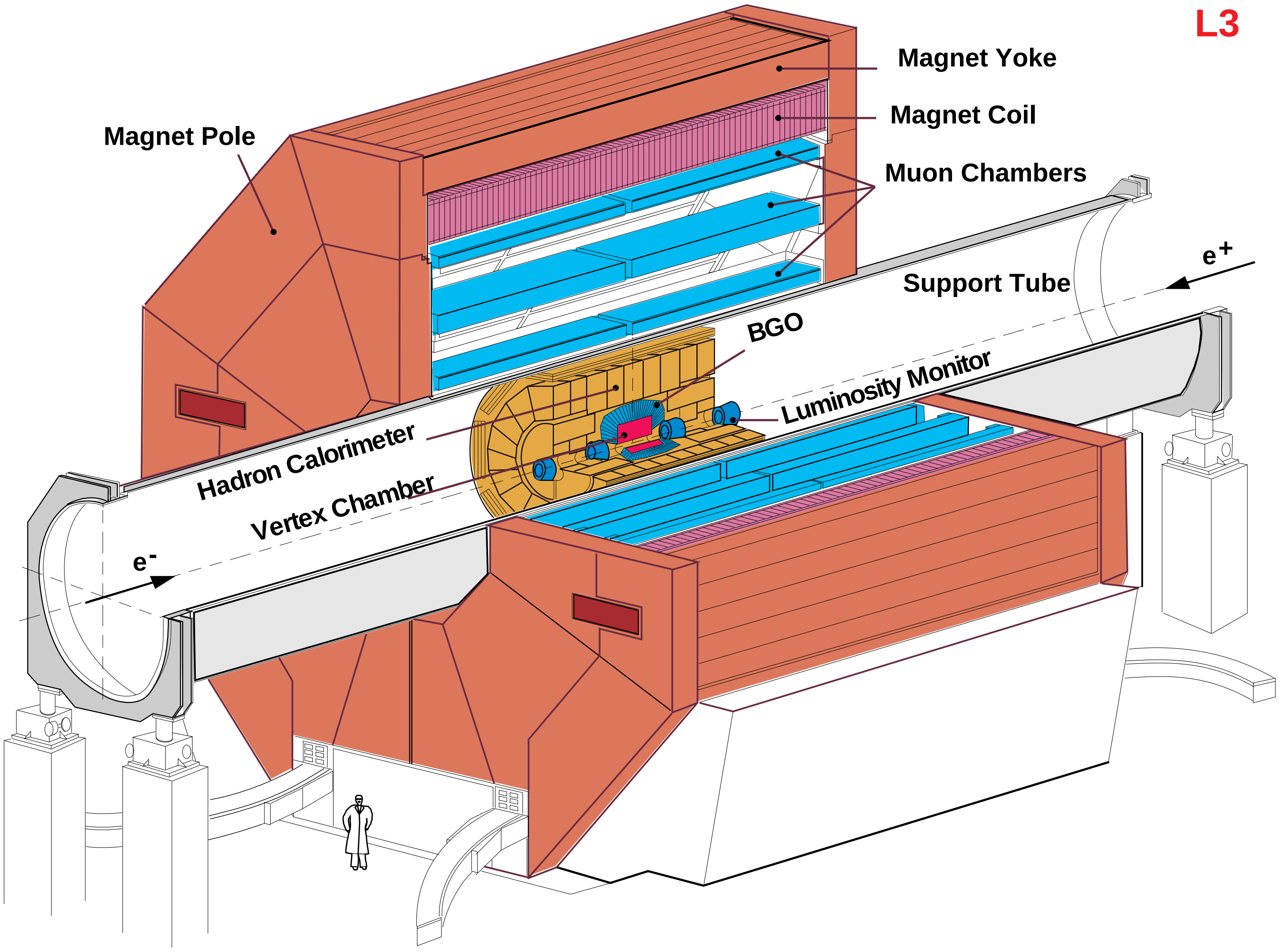
- **Primary hard-scattering QCD vertex is well-defined**
- **High** e^+e^- **CM energy is available:**
  - LEP1: During 5 years $\sqrt{s} \simeq M_Z$
    $Z \longrightarrow q q \gamma$ events: $\sqrt{s'}$ from **30** to **91** GeV
  - 1995 $\sqrt{s} =$ **130** and **136** GeV
  - 1996 $\sqrt{s} =$ **161** and **172** GeV
  - 1997 $\sqrt{s} =$ **183** GeV
  - 1998 $\sqrt{s} =$ **189** GeV

Studies of hadronic event structure at different energies allow:

$\Rightarrow$ **Test the Monte Carlo models of strong interaction and their principles**

$\Rightarrow$ **Check the energy dependence of observables with the same experiment**

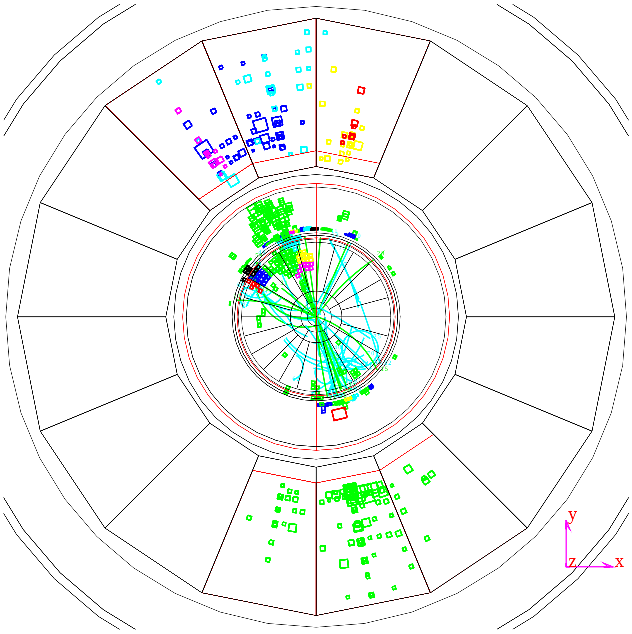
$\Rightarrow$ **Comparison with analitical perturbative QCD calculations**
which exist for several event shape variables



L3 general view

$\sqrt{s}$=189 GeV

Run # **700701** **Event #** **2359** Total Energy : 211.50 GeV



Transverse Imbalance :	.0390		**Longitudinal Imbalance :**	-.0773	
Thrust : .9121		**Major :** .2250		**Minor :** .0630	
Event DAQ Time :	*980627 204617*				

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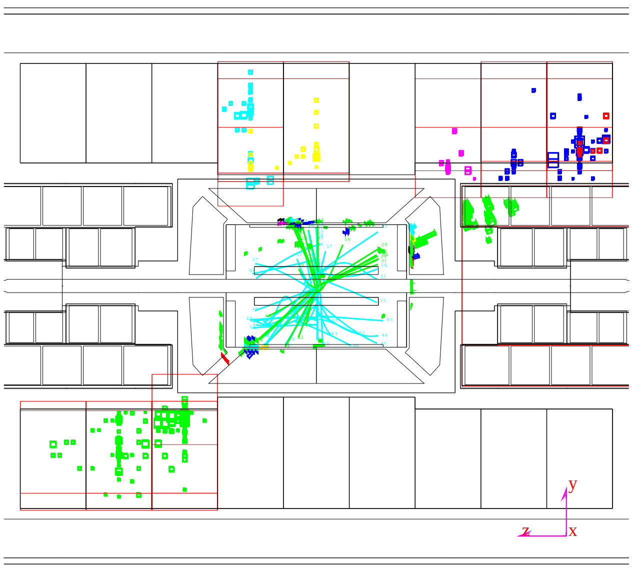
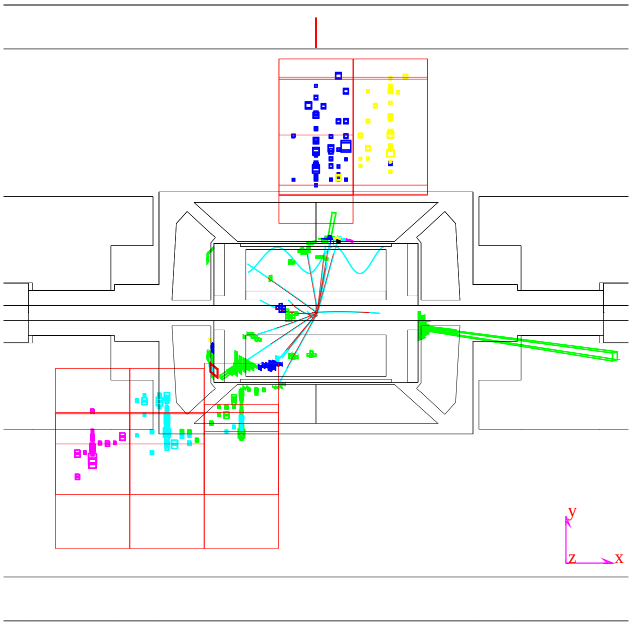


Transverse Imbalance :	.0390		**Longitudinal Imbalance :**	-.0773	
Thrust : .9121		**Major :** .2250		**Minor :** .0630	
Event DAQ Time :	*980627 204617*				

Hadronic events with ISR

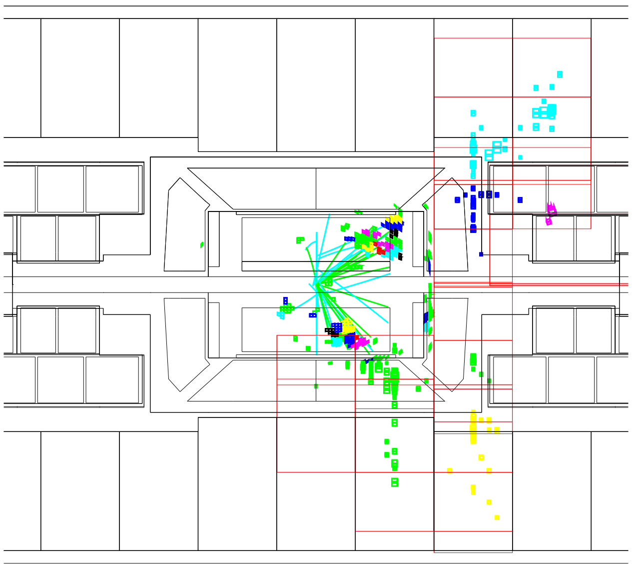
Run # 701209 Event # 4951 Total Energy : 181.00 GeV



Transverse Imbalance :	.0735	**Longitudinal Imbalance :**	-.1234
Thrust : .7964	**Major :** .4690	**Minor :** .0774	
Event DAQ Time :	*980629 90536*		

γ ISR

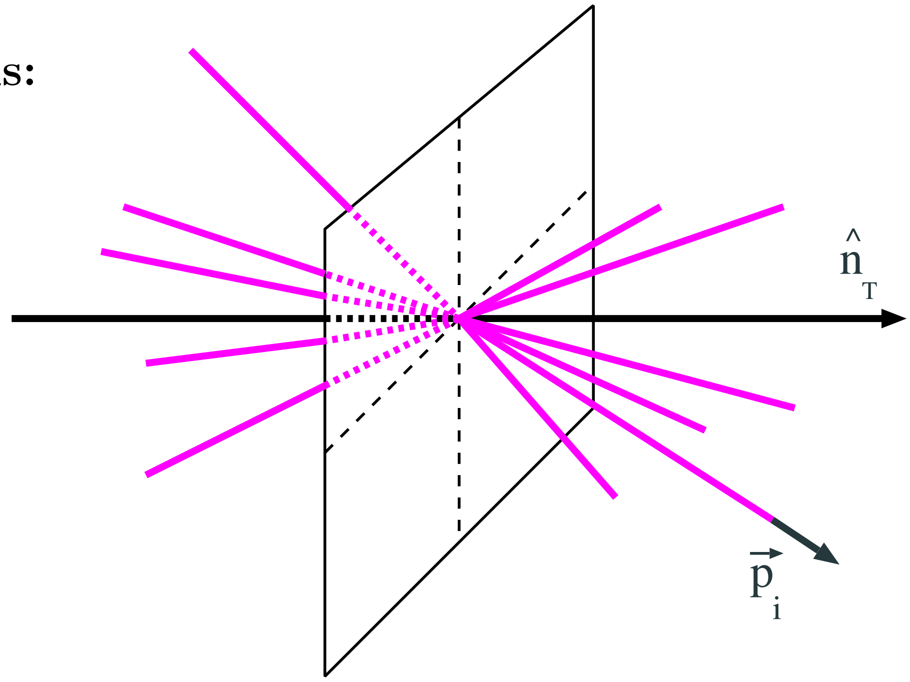
Run # 700808 Event # 286 Total Energy : 105.06 GeV



γ- not detected

Transverse Imbalance :	.0806	**Longitudinal Imbalance :**	-.5264
Thrust : .7935	**Major :** .5396	**Minor :** .1163	
Event DAQ Time :	*980628 53742*		

Definitions:



Thrust:

$$T = \max \frac{\sum |\vec{p}_i \cdot \vec{n}_T|}{\sum |\vec{p}_i|} ,$$

Scaled heavy jet mass:

$$\rho = M_H^2 / s ,$$

where:

$$M_H = \max[M_+(\vec{n}_T), M_-(\vec{n}_T)] ,$$
$$M_\pm^2 = \left(\sum_{i \in S_\pm} p_i \right)^2$$

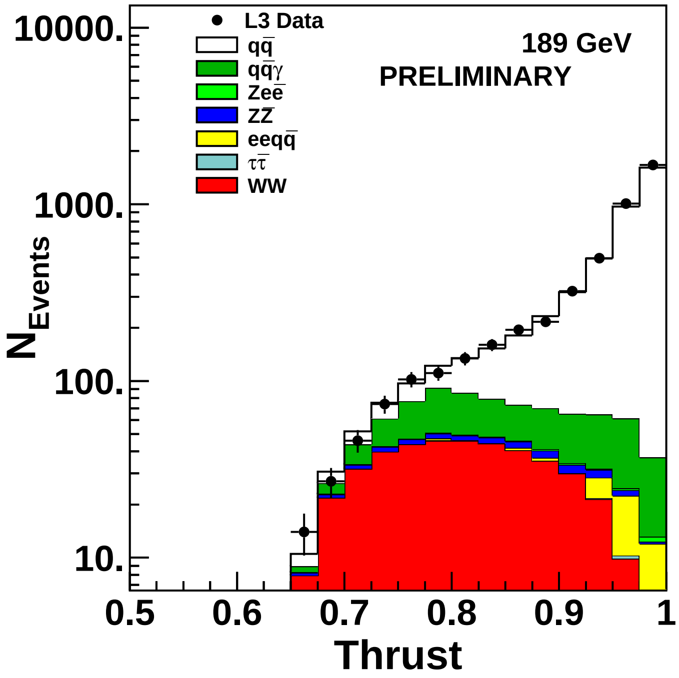
where: p_i is the four-momentum of particle i.

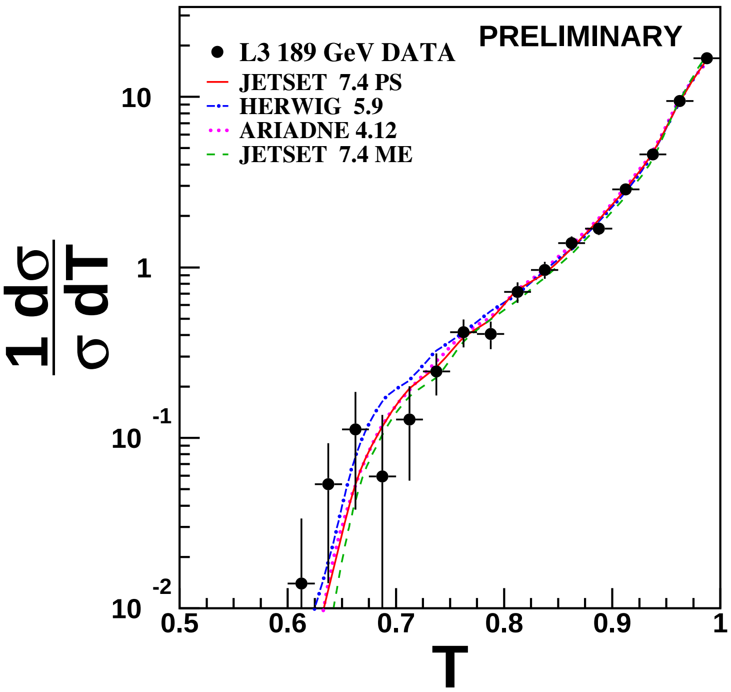
Jet broadening variables:

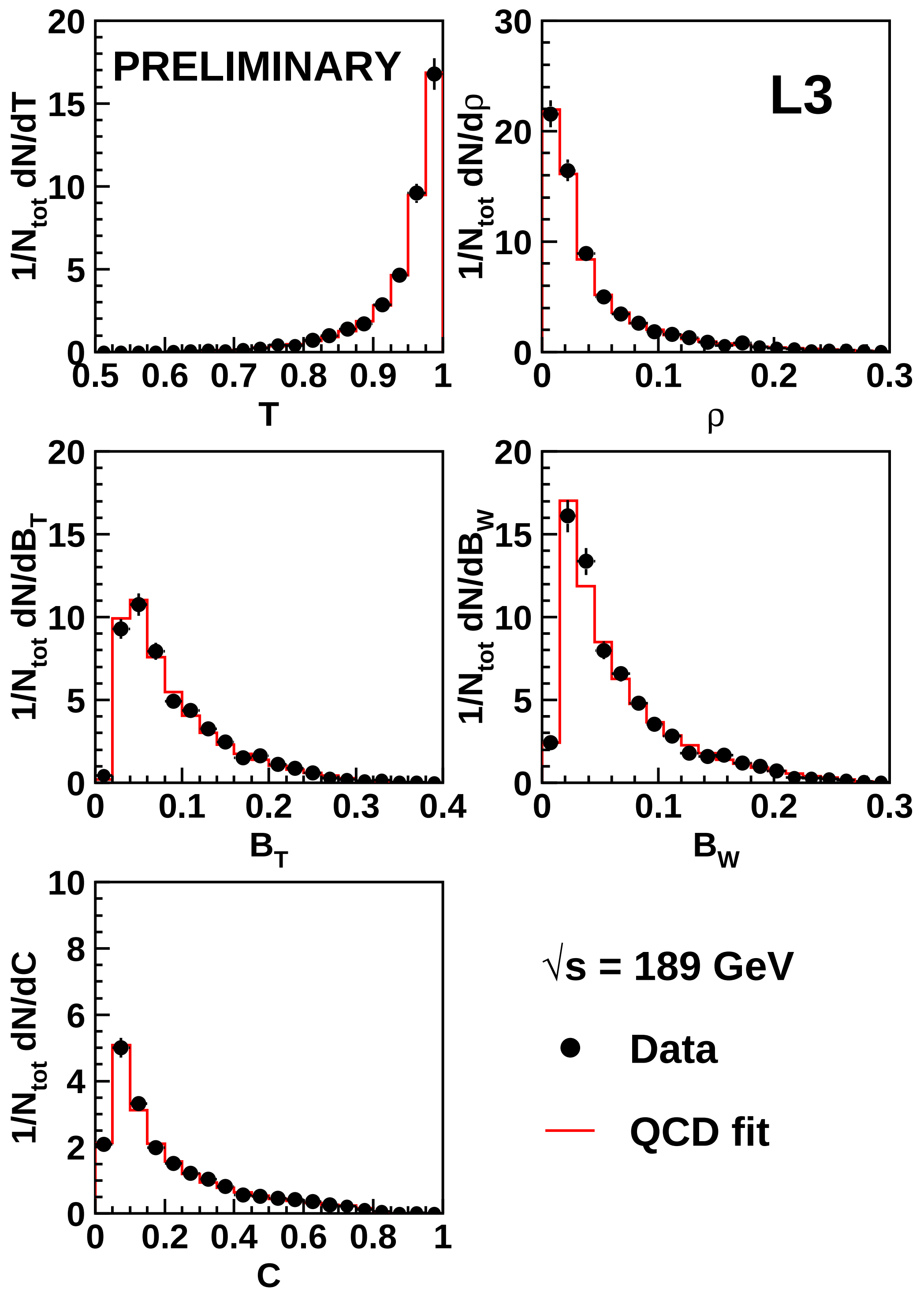
$$B_\mathrm{T} = B_+ + B_- \quad \text{and} \quad \mathrm{B_W} = \max(\mathrm{B_+}, \mathrm{B_-})$$

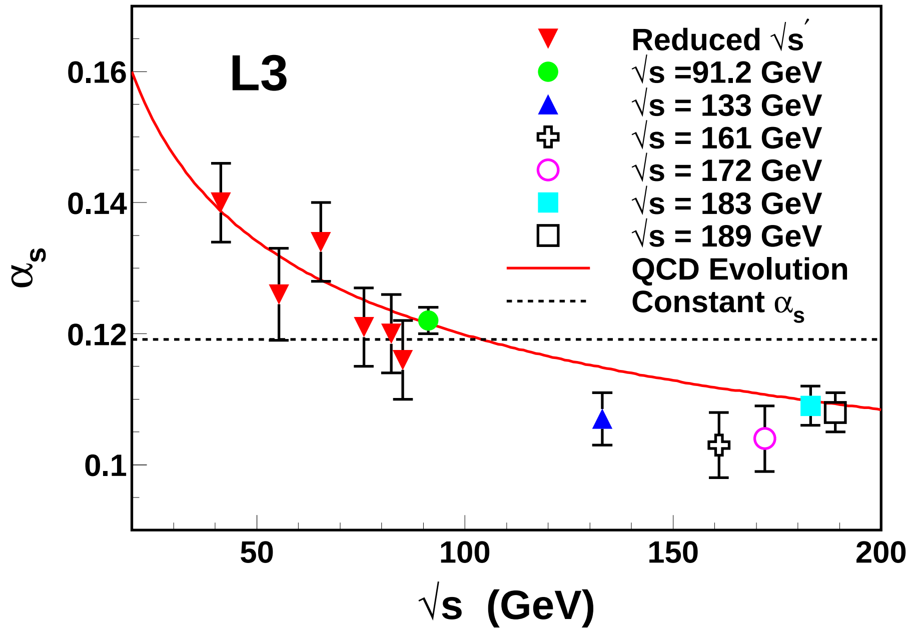
where:

$$B_\pm = \frac{\sum_{i \in S_\pm} |\vec{p}_i \times \vec{n}_T|}{2 \sum_i |\vec{p}_i|} .$$

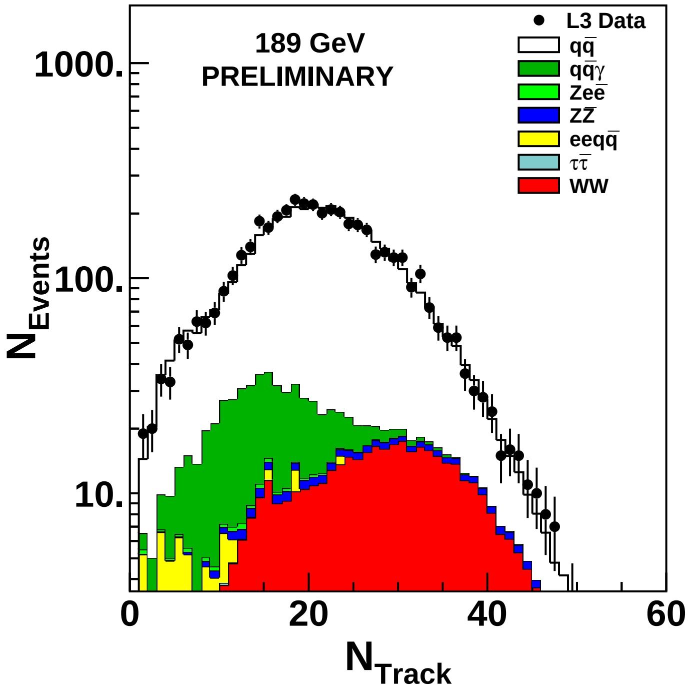

L3 Data
$q\bar{q}$
$q\bar{q}\gamma$
Zee
ZZ
$eeq\bar{q}$
$\tau\tau$
WW
189 GeV
PRELIMINARY
N_{Events}
10000.
1000.
100.
10.
0.5
0.6
0.7
0.8
0.9
1
Thrust

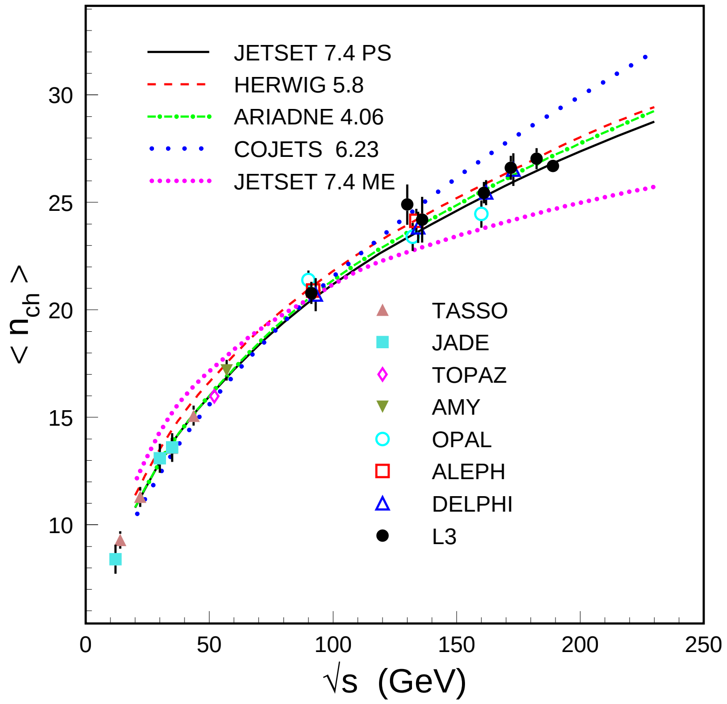

PRELIMINARY
L3 189 GeV DATA
JETSET 7.4 PS
HERWIG 5.9
ARIADNE 4.12
JETSET 7.4 ME
$\frac{1}{\sigma}\frac{d\sigma}{dT}$
10
1
10^{-1}
10^{-2}
0.5
0.6
0.7
0.8
0.9
1
T


PRELIMINARY
L3
1/N_tot dN/dT
T
1/N_tot dN/dρ
ρ
1/N_tot dN/dB_T
B_T
1/N_tot dN/dB_W
B_W
1/N_tot dN/dC
C
√s = 189 GeV
Data
QCD fit



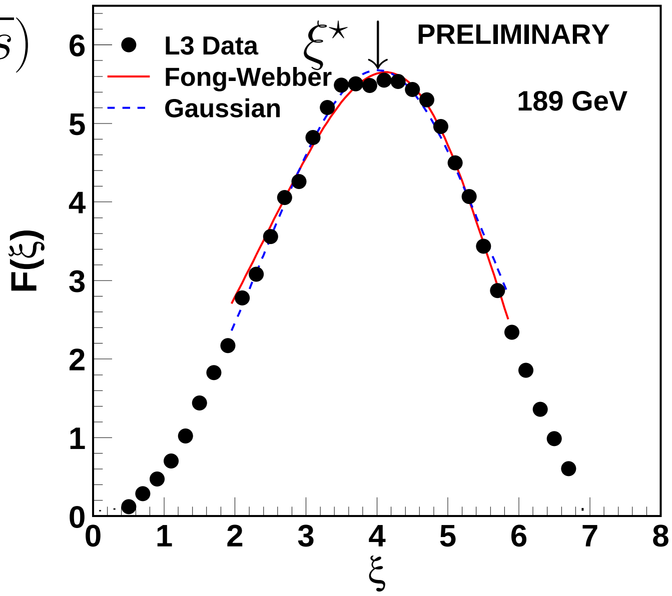
$$\alpha_s\ (189\ \mathrm{GeV})\ =\ 0.1082\ \pm\ 0.0028\ (\mathrm{exp})\ \pm\ 0.0052\ (\mathrm{th})$$

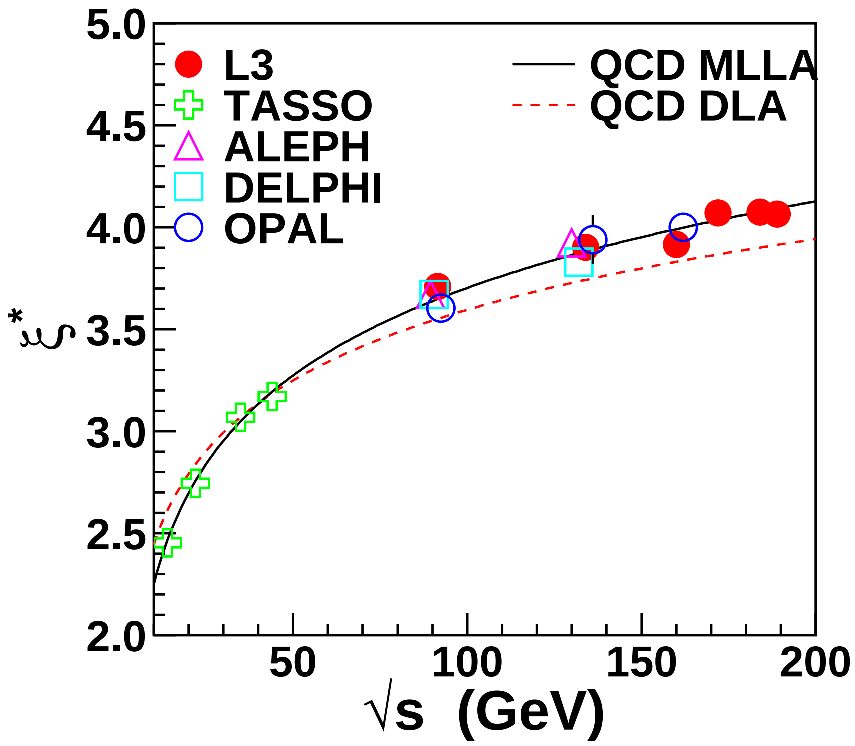




$$\langle n_{ch} \rangle \ (189 \text{ GeV}) \ = \ 26.73 \ \pm \ 0.13 \ \pm \ 0.18$$

$$\xi = -\ln(2p/\sqrt{s})$$





$$\xi^\star(s) \;=\; Y\left(\frac{1}{2} + a\sqrt{\frac{\alpha_s(Y)}{32\mathrm{N_c}\pi}} - a^2\frac{\alpha_s(Y)}{32\mathrm{N_c}\pi}\right),$$

where: $Y = \ln(\sqrt{s}/2\Lambda)$, $a = (11/3\mathrm{N_c}) + (2\mathrm{N_f}/3\mathrm{N_c}^2)$

Summary

- Structure of hadronic events from e^+e^- annihilation at $\sqrt{s} = 189$ GeV was studied.
- This measurement together with earlier measurements at lower energies demonstrates running of α_s as expected from QCD.
- QCD models implementing a coherent parton shower and cluster or string fragmentation describe well the event shape distributions (parameters tuned at 91.2 GeV).
- The energy evolution of charged particle multiplicity and inclusive momentum spectrum give evidence of the soft gluon supression.