Coherent particle production in hadronic three jet events from Z-decays at DELPHI

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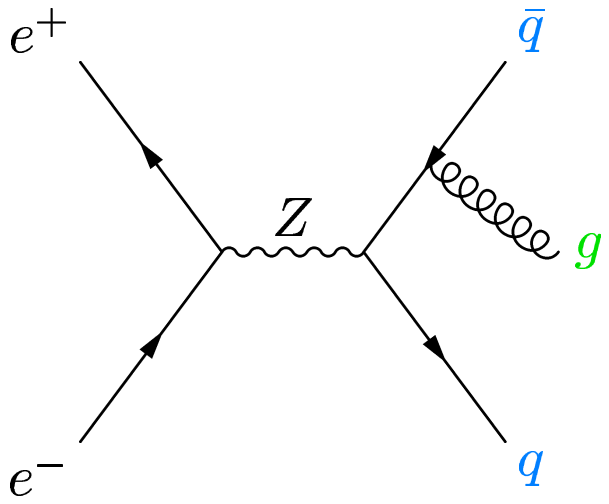
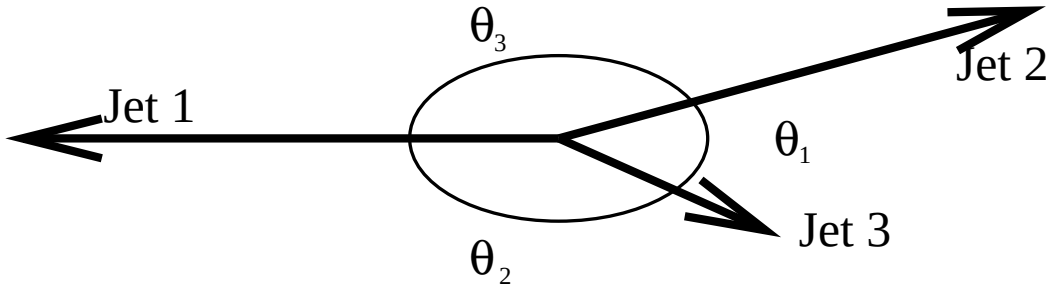
Content:

- Particle production at large angles
- Topology-dependence of event multiplicity
- Comparison of quark and gluon multiplicities

Three Jet Events





- 3^{rd} jet initiated by gluon radiated with large p_t
  $\rightarrow$ Gluon and quark jets in similar environment
- Three jet events:
  - Interjet-angles $\boxed{\vartheta_1 \leq \vartheta_2 \leq \vartheta_3}$
  - Momentum-conservation: Events planar $\rightarrow$ $\boxed{\vartheta_1 + \vartheta_2 + \vartheta_3 = 360^\circ}$
  - Jets numbered due opposing angle. $\rightarrow$ $\boxed{E_1 \geq E_2 \geq E_3}$

Particle Production at Large Angles

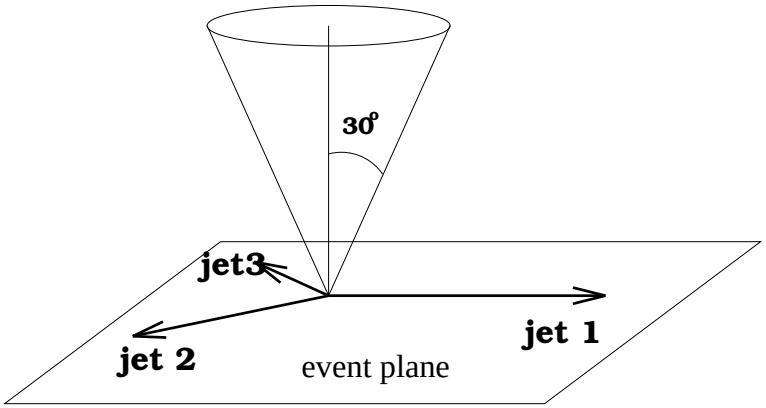
- Soft gluons emitted at large angles:
  - Large wave-length $\rightarrow$ Small resolution
  - Coherently radiated by two primary partons
  - Reduced effective colour-charge depending on the event topology

- LO-Prediction by V.Khoze, W.Ochs & S.Lupia
- Gluon radiation orthogonal to all emitters $\rightarrow$ orthogonal to event plane

$$\boxed{N_{\perp}^{q\bar{q}g} = r_t \cdot N_{\perp}^{q\bar{q}}} \qquad r_t = \frac{C_A}{4C_F}\left[(1-\cos\vartheta_{qg}) + (1-\cos\vartheta_{\bar{q}g}) - \frac{1}{N_C^2}(1-\cos\vartheta_{q\bar{q}})\right]$$

- Destructive gluon-interference term $\propto 1/N_C^2$
- Ratio directly proportional to C_A/C_F in LO without corrections

Particle Production at Large Angles



- Jet reconstruction with k_t algorithms (Durham, Cambridge, ang. ord. Durh.) with use of y_{cut}:
  - Defines separation between two and three jet events
  - Excludes four jet events
- Special event sample: symmetric topologies with $\vartheta_3 - \vartheta_2 \leq 5^\circ$
- Multiplicity in cone perpendicular to event plane
- $N_\perp^{q\bar{q}}$ from two jet events gives normalisation of prediction

Three Jet Events: Interference Term $1/N_C^2$

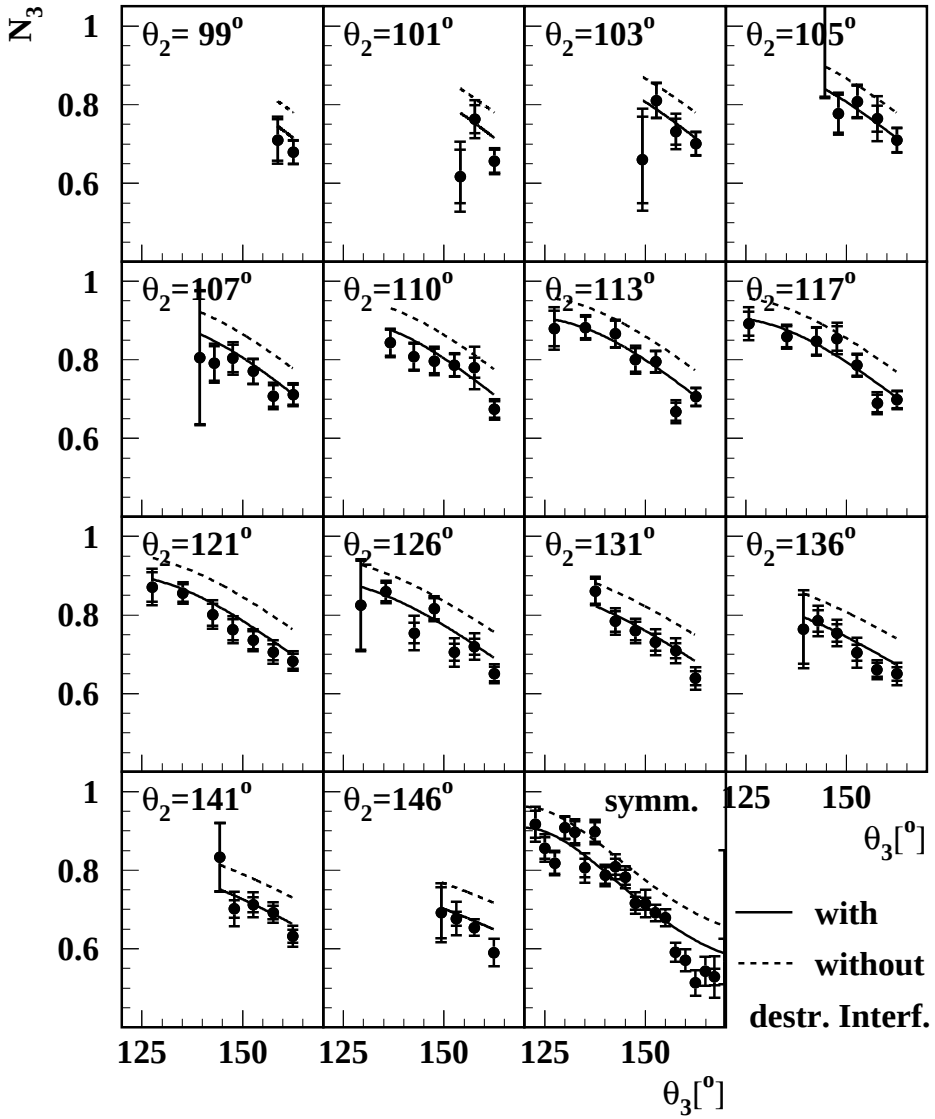
- Solid line: complete r_t,
  Dashed line: without $1/N_C^2$-term
- Measurement only described with interference
- Fit of $k \cdot 1/N_C^2$:
  general topologies:

  $$k = 1.39 \pm 0.05_{(\text{stat.})} \pm 0.28_{(\text{sys.})}$$

  symm. topologies:

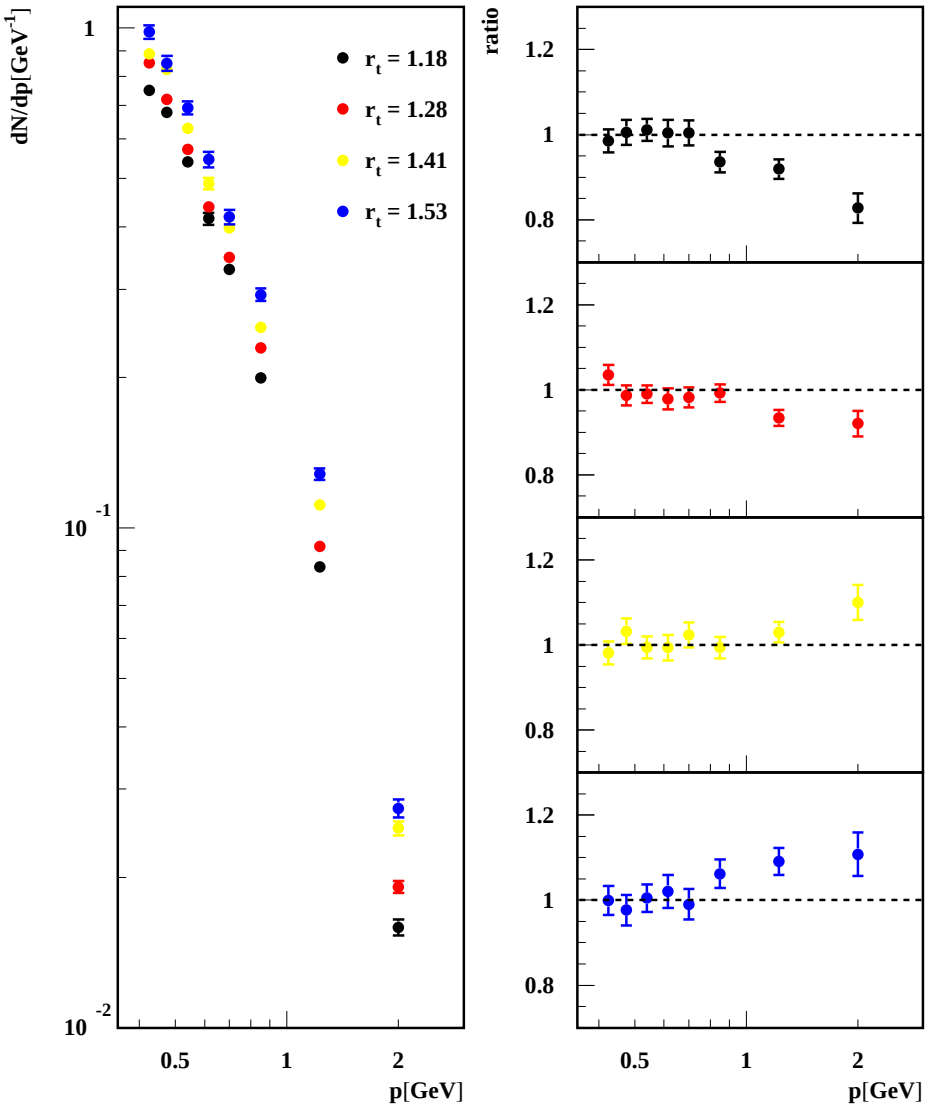
  $$k = 1.30 \pm 0.06_{(\text{stat.})} \pm 0.33_{(\text{sys.})}$$

- Sys. error from variation of y_{cut}, θ_{cone} and cluster algorithms
- Compatible with $k = 1$
- $k = 0$ excluded with $> 95\%$



Momentum-Distribution in 30°-Cone

- r_t can be used as scale to describe topologies
- p-distribution for various r_t
- Test of Local Parton Hadron Duality hypothesis for small momenta
- divided by averaged distribution
- Ratio i normalised to $\overline{r_t}/r_t(i)$
- Scaling of p-distribution up to $p \sim 1$GeV
- Scaling violated for larger p
- But: Only $\sim 10\%$ of particles with $p > 1$GeV



Event Multiplicity: Prediction by Eden et al. (1)

- Prediction by P.Eden, G.Gustafson & V.Khoze for two gluon systems: Slopes in energy are related by

$$\left.\frac{dN_{gg}(L')}{dL'}\right|_{L'=L+c_g-c_q} = \frac{C_A}{C_F}\left(1-\frac{\alpha_0 c_r}{L}\right)\frac{d}{dL}N_{q\bar{q}}(L)$$

with $L = \log\frac{s}{\Lambda^2}$, c_g, c_q, c_r, α_0 known constants

- $N_{q\bar{q}}$ measured at many E_{cm} from various e^+e^--experiments

- Integration leaves free one constant of integration
  → Constant of integration can be determined from measurement of N_{gg}
  → Here: CLEO-measurement of N_{gg} in the decay $\chi_b'(J=2) \to gg$ at $E_{\mathrm{cm}} = 9.9132\mathrm{GeV}$

Event Multiplicity: Prediction by Eden et al. (2)

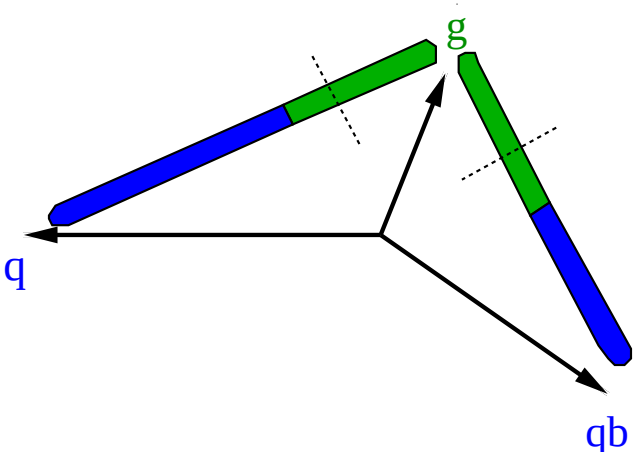
- Multiplicity of three jet events:

$$N_{q\bar{q}g}(L_{q\bar{q}}, \kappa_{Lu}, \kappa_{Le}) = N_{q\bar{q}}(L_{q\bar{q}}, \kappa_{Lu}) + \tfrac{1}{2} N_{gg}(\kappa_{Le}) \qquad (A)$$

$$N_{q\bar{q}g}(L_{q\bar{q}}, \kappa_{Lu}, \kappa_{Lu}) = N_{q\bar{q}}(L, \kappa_{Lu}) + \tfrac{1}{2} N_{gg}(\kappa_{Lu}) \qquad (B)$$

$$\text{with} \quad L = \ln\left(\frac{s}{\Lambda^2}\right), \quad L_{q\bar{q}} = \ln\left(\frac{s_{q\bar{q}}}{\Lambda^2}\right),$$

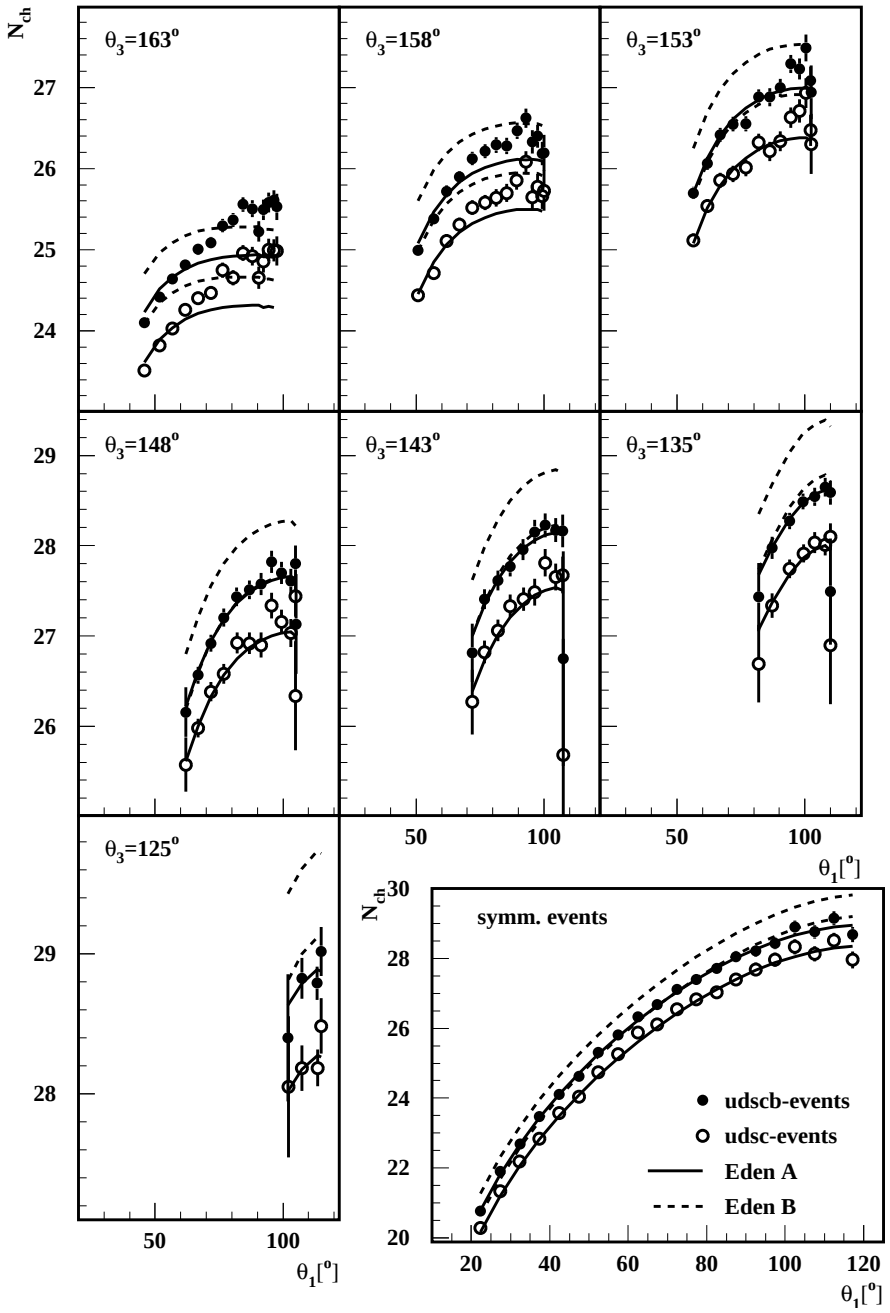
$$\kappa_{Lu} = \ln\left(\frac{s_{qg} s_{\bar{q}g}}{s\Lambda^2}\right), \quad \kappa_{Le} = \ln\left(\frac{s_{qg} s_{\bar{q}g}}{s_{q\bar{q}}\Lambda^2}\right)$$



- Coherence effects are accounted for by choice of scales
- The phase space of the $q\bar{q}$-pair is restricted by the gluon jet

$$N_{q\bar{q}}(L, \kappa_{\text{cut}}) = N_{q\bar{q}}(\kappa_{\text{cut}} + c_q) + (L - \kappa_{\text{cut}} - c_q) \left.\frac{dN_{q\bar{q}}(L')}{dL'}\right|_{L'=\kappa_{\text{cut}}+c_q}$$

- Jet reconstr.: No y_{cut} used
- Comparison of Eden A and B
- $udsc$-events:
  Rejection of $b\bar{b}$-events
- $udscb$-events:
  Constant $N_0 = 0.612$ added
- Eden A:
  - Very good agreement for symmetric and general topologies
  - Deviation, if topology is too two-jet-like
- Eden B:
  - Overall overestimation of multiplicity by ca. 0.6
  - Slope too large



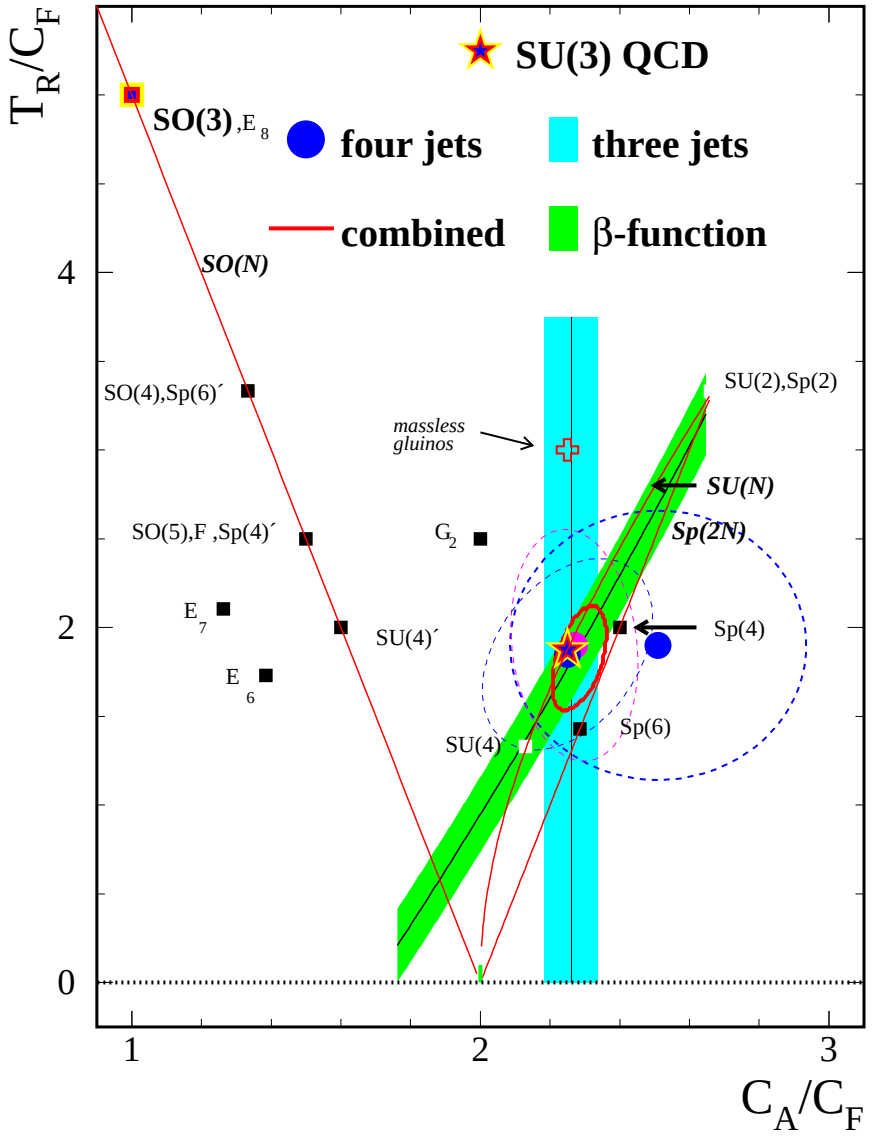
Fit of C_A/C_F

- Eden B
  - Leads to inconsistent results for symmetric and general topologies
  - N_0 comes out too low

  $\rightarrow$ rejected
- C_A/C_F from slope w.r.t. angles: Offset N_0 varied freely

$$\frac{C_A}{C_F} = 2.261 \quad \pm 0.014_{\text{stat.}} \pm 0.036_{\text{exp.}} \pm 0.052_{\text{theo.}} \pm 0.041_{\text{clus.}}$$

- Most precise measurement so far
- Fixes QCD group structure together with other measurements: SU(3)

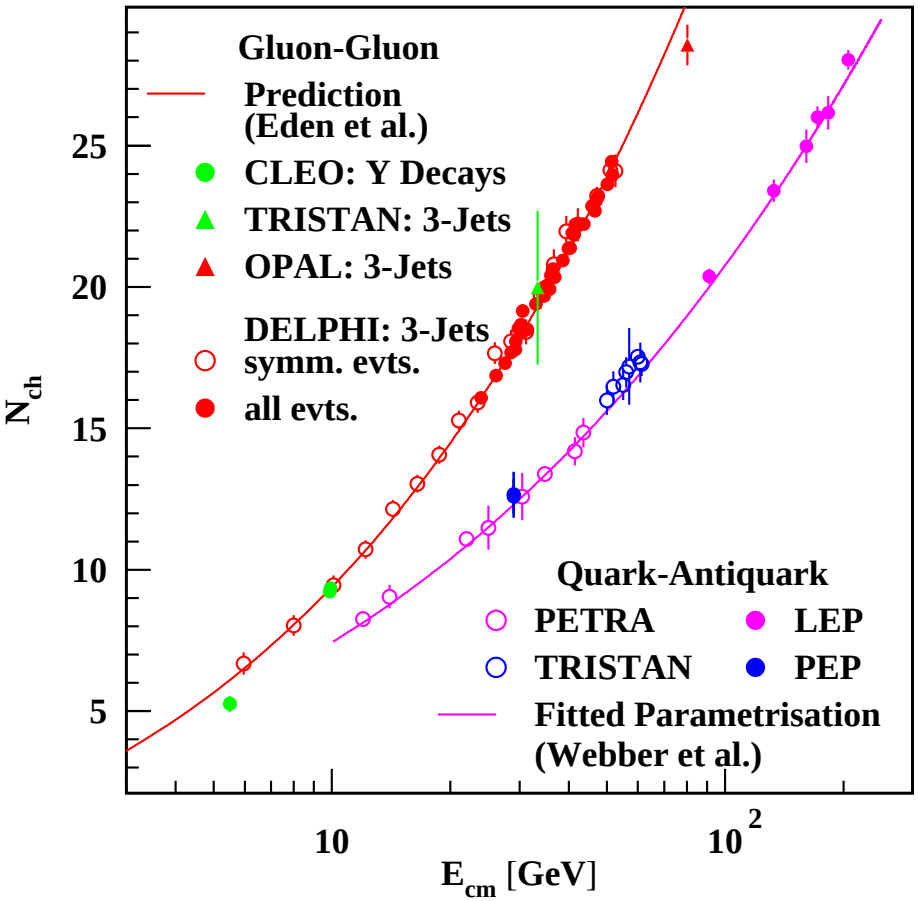


Gluon Multiplicity

- Gluon contribution can be determined:

$$N_{gg}(\kappa_{Le}) =$$
$$2 \cdot [N_{q\bar{q}g}(\theta_1) - N_{q\bar{q}}(L_{q\bar{q}}, \kappa_{Lu}) - N_0]$$

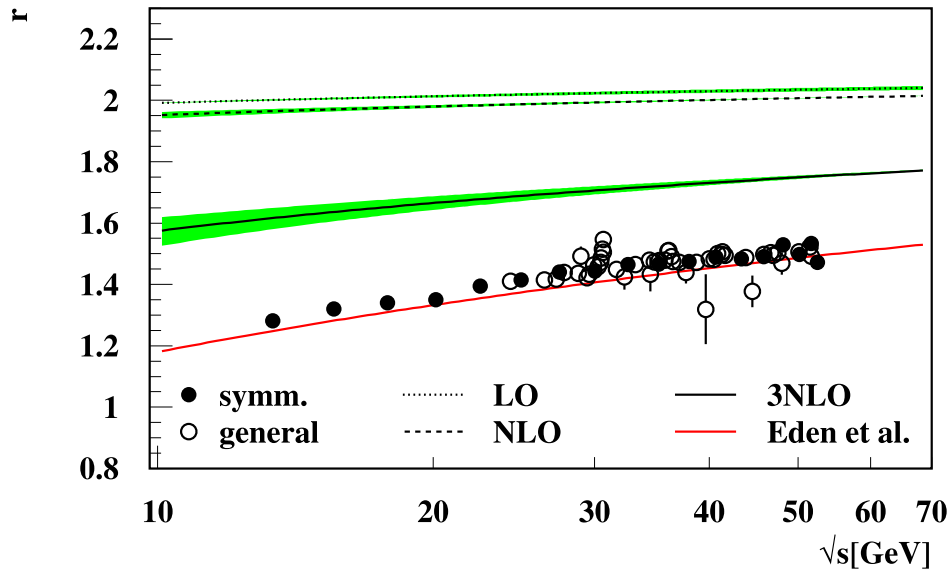
- $udscb$-events
- Good agreement between general and symmetric topologies
- Good agreement with prediction
- N_{gg}: Slope significantly larger than of $N_{q\bar{q}}$

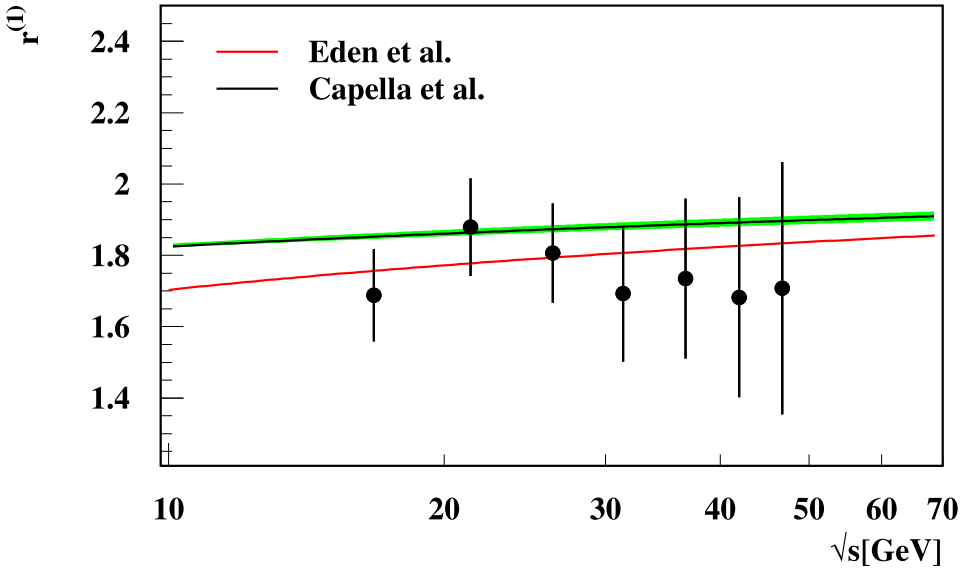


→ Ratios of N_{gg} and $N_{q\bar{q}}$ can be studied (r, $r^{(1)}$,. . .)

Multiplicity Ratios

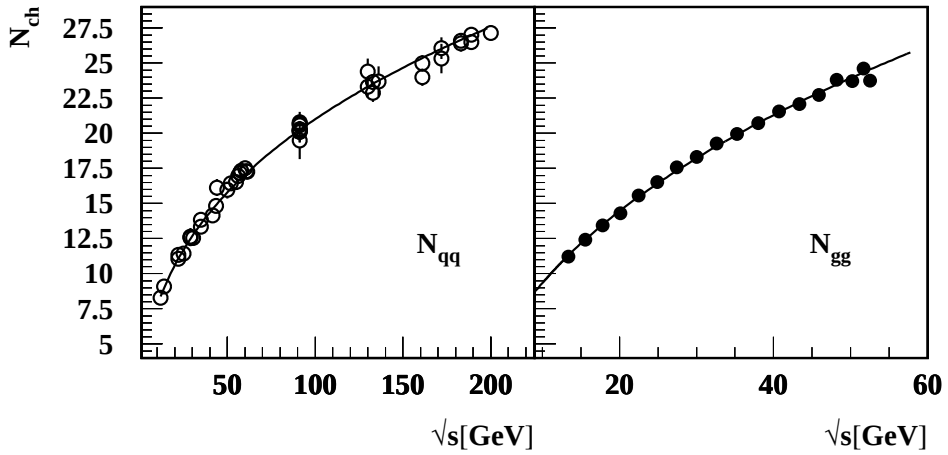
- r:
  - Large differences between LO, NLO, 3NLO
  - Data only described by Eden (which has experimental input)
  - Non-perturbative effects are important!
- $r^{(1)}$:
  - Measurement from uncorrelated linear slopes
  - Difference to C_A/C_F smaller
  - 3NLO (Capella) and MLLA (Eden) closer together
  - Good agreement with measurement
  - Non-perturbative effects less important

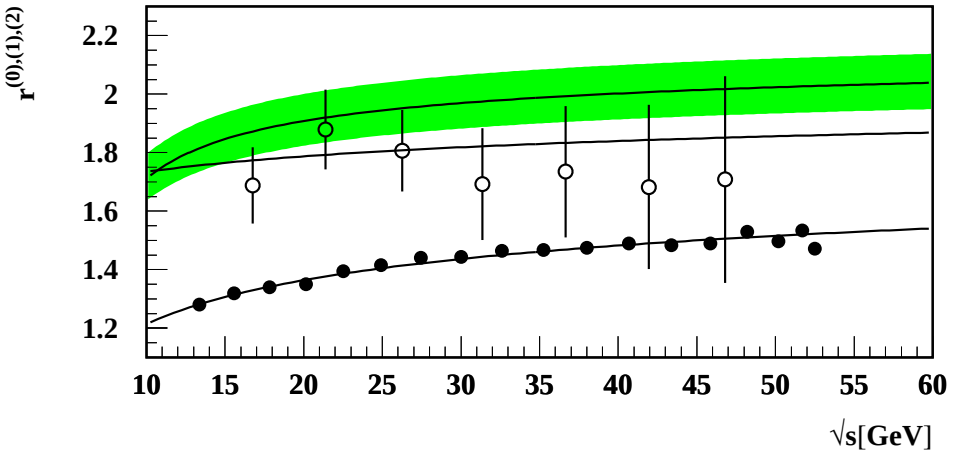




Multiplicity Ratios

- Fit of 3NLO-prediction of $N_{q\bar{q}}$ and N_{gg} to data
- Good description of data with $\Lambda_q \neq \Lambda_g$
- r, $r^{(1)}$ and $r^{(2)}$ can be calculated
- But: Determination of $r^{(2)}$ based on used parametrisation





Summary

- Particle production at large angles
  - Destructive gluon interference observed
  - Momentum distributions do scale

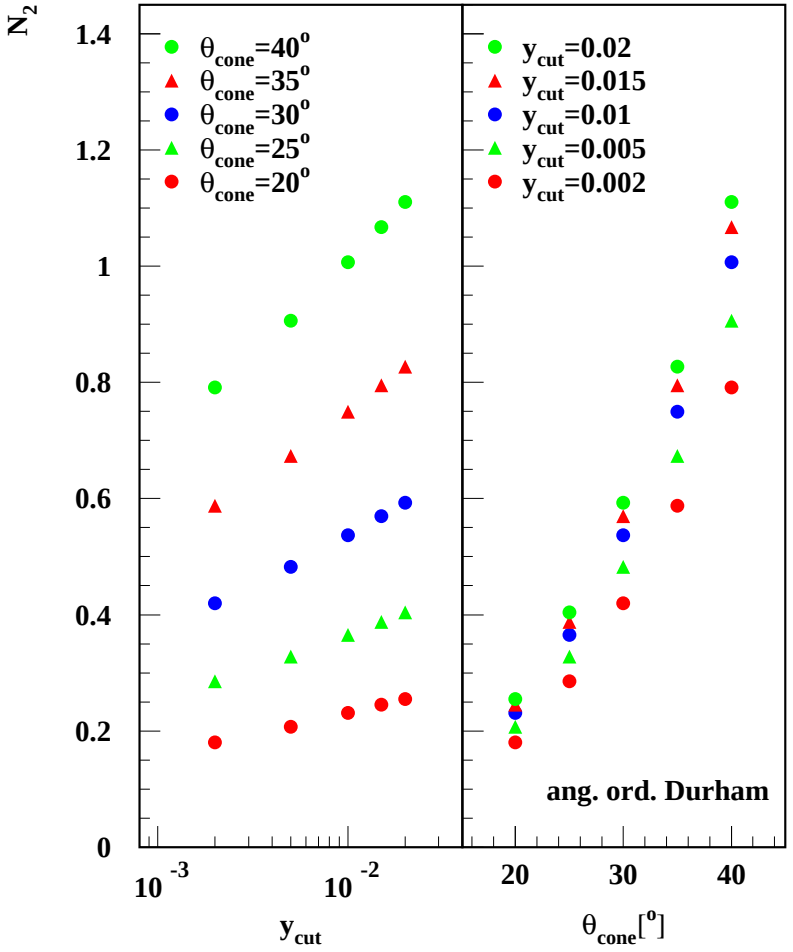
- Event multiplicities
  - MLLA-prediction Eden A describes topology dependence of multiplicity
  - Colour-factor ratio determined:

$$\frac{C_A}{C_F} = 2.261 \pm 0.014_{\text{stat.}} \pm 0.036_{\text{exp.}} \pm 0.052_{\text{theo.}} \pm 0.041_{\text{clus.}}$$

- Gluon multiplicity
  - N_{gg} measured over a wide variation of scale
  - Ratio of multiplicities r: Smaller than LO, NLO, 3NLO predictions
  - Ratio of slopes $r^{(1)}$: Good agreement with 3NLO and MLLA

Two Jet Events: N_2

- N_2 normalises prediction
- Orientation of cone:
  - $\perp$ sphericity axis
  - Random in ϕ
- N_2 in dependence of
  - $y_{\rm cut}$ $\sim$ logarithmic increase
  - $\theta_{\rm cone}$ $\sim$ increase of N_2



$$N_3 = N_2 \cdot \sum_{i=1,2,3} w_i \cdot r_t^{(i)} \quad , \quad w_i \propto \text{ME for gluon jet } i$$