Observation of Three-Jet Production in Diffractive DIS

Mario Martínez
(DESY)

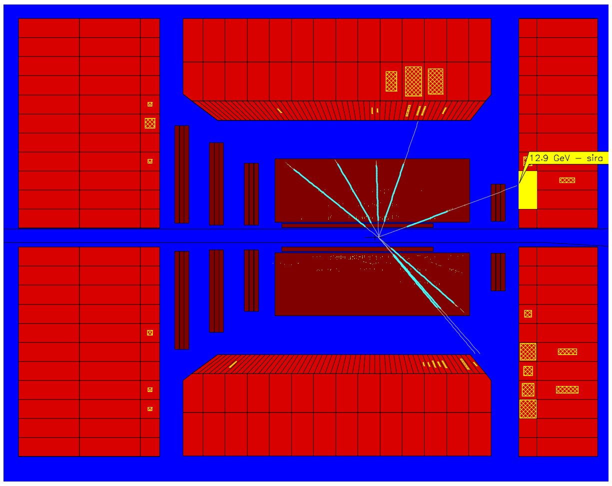
ZEUS Collaboration

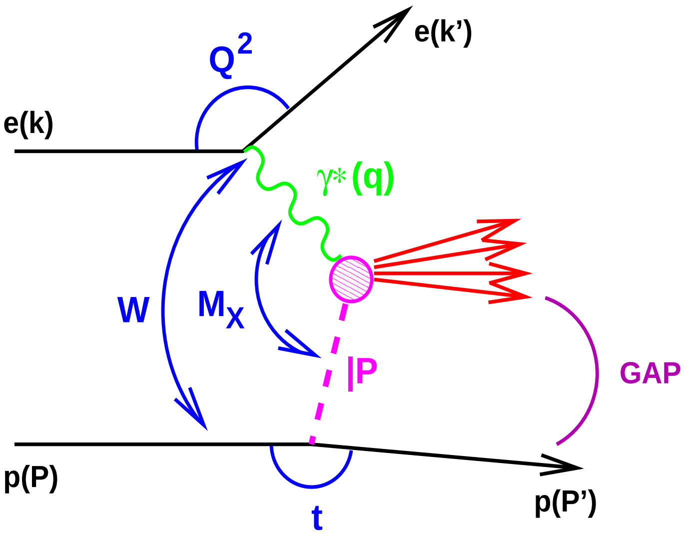
- Introduction
- Selection of Diffractive Sample
- Three-Jet Search
- Three-Jet Distributions
- Conclusions

8th International Workshop on Deep-Inelastic Scattering (DIS 2000)
Liverpool 25th-30th April 2000

Introduction (I)

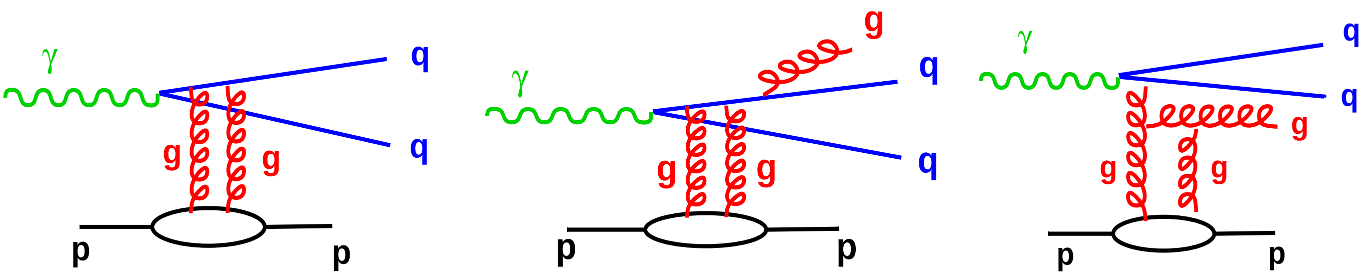
Observation of events with no activity in the outgoing proton direction $\Rightarrow$ Large Rapidity Gap events (LRG).





Exchange of colour singlet $\Rightarrow$ (Diffraction $\rightarrow$ $I\!P$-exchange)

$\Rightarrow$ pQCD inspired models (γ-dissociation picture) describe the $I\!P$omeron as two-gluons exchange.



$\Rightarrow$ The diffractive cross section can be written as a sum of different contributions ($q\bar{q}$ and $q\bar{q}g$ final states).

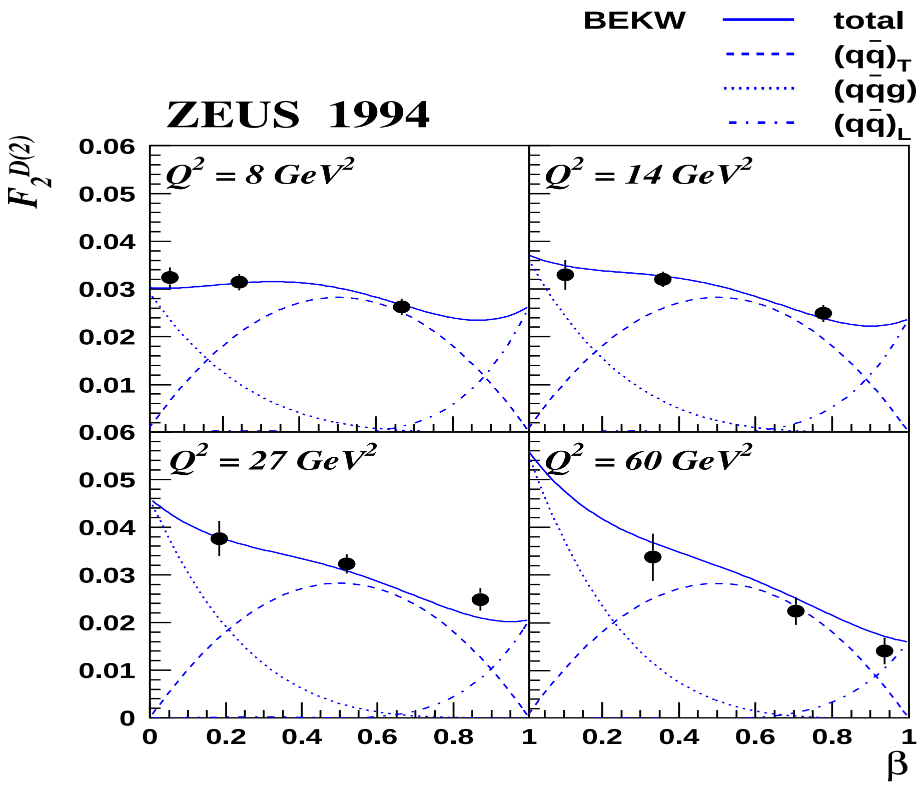
$$F_2^{D(3)}(\beta, x_{I\!P}, Q^2) = C_T\ F^T_{q\bar{q}} + C_L\ F^L_{q\bar{q}} + C_g\ F^T_{q\bar{q}g}$$

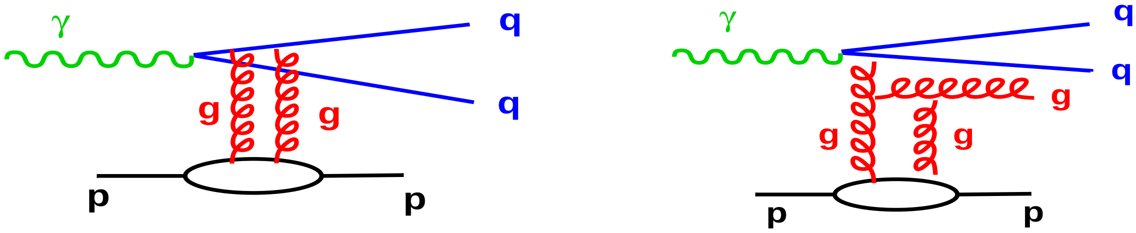
$$x_{I\!P} = \frac{M_x^2 + Q^2 - t}{W^2 + Q^2 - M_p^2}, \qquad \beta = \frac{Q^2}{M_x^2 + Q^2 - t}$$

Introduction (II)

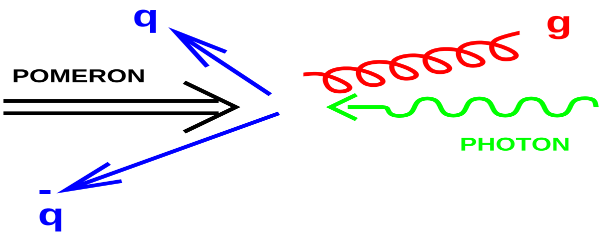
The measured diffractive cross section was found to be consistent with pQCD-inspired model predictions where the different processes dominate different β-regions.

(ZEUS Collab., Eur. Phys. J. C6 (1999) 43-66)





The diagram with three partons in the final state is expected to dominate at very low-β ($\Rightarrow$ high-M_X).

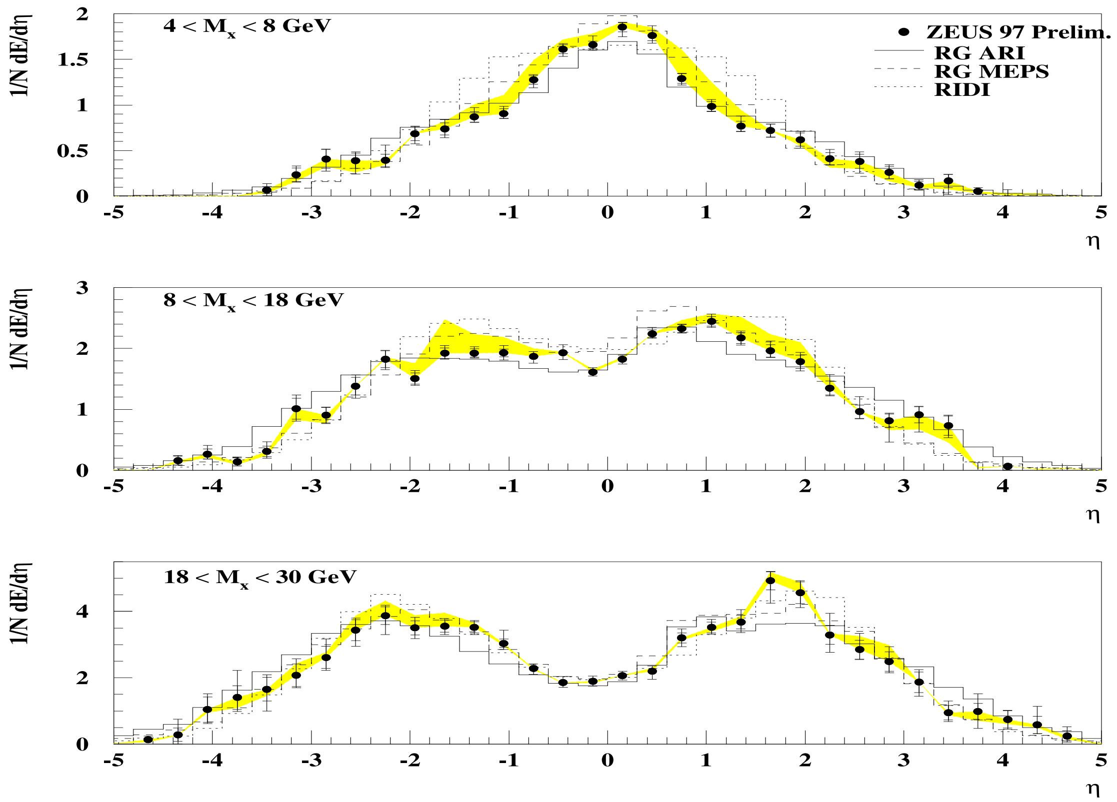


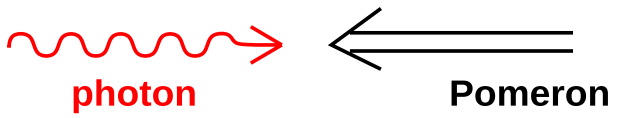
The gluon is emitted almost collinear to the $\gamma^* I\!P$-axis in the pomeron direction (with very small p_t).

Introduction (III)

The hadronic energy flow in the centre of mass system was measured for diffractive events with a tagged leading proton in the final state.

(ZEUS Collab. EPS99 Conference, Tampere)





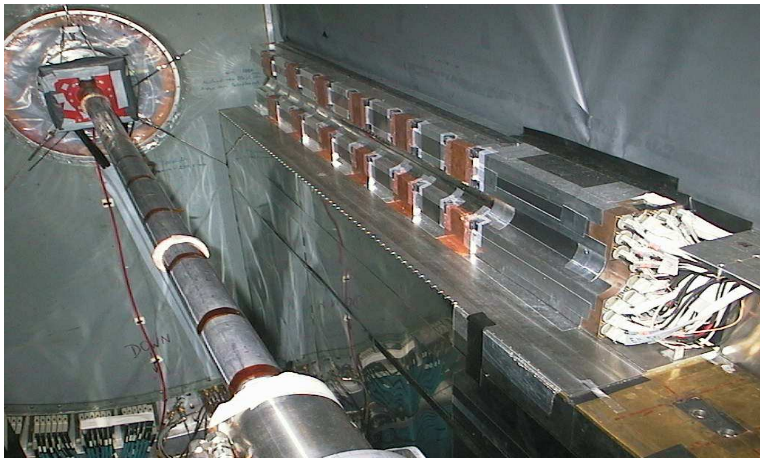
A dijet structure is observed for events with $M_X \gtrsim 8$ GeV
A small asymmetry between photon and pomeron hemispheres is also observed.

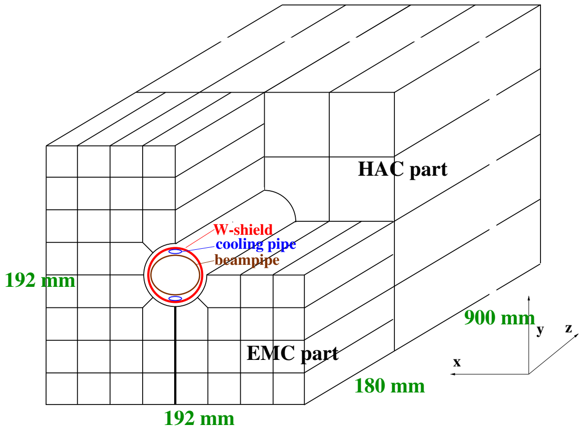
$\Rightarrow$ So far there was no evidence of the production of a third hard parton in the final state.

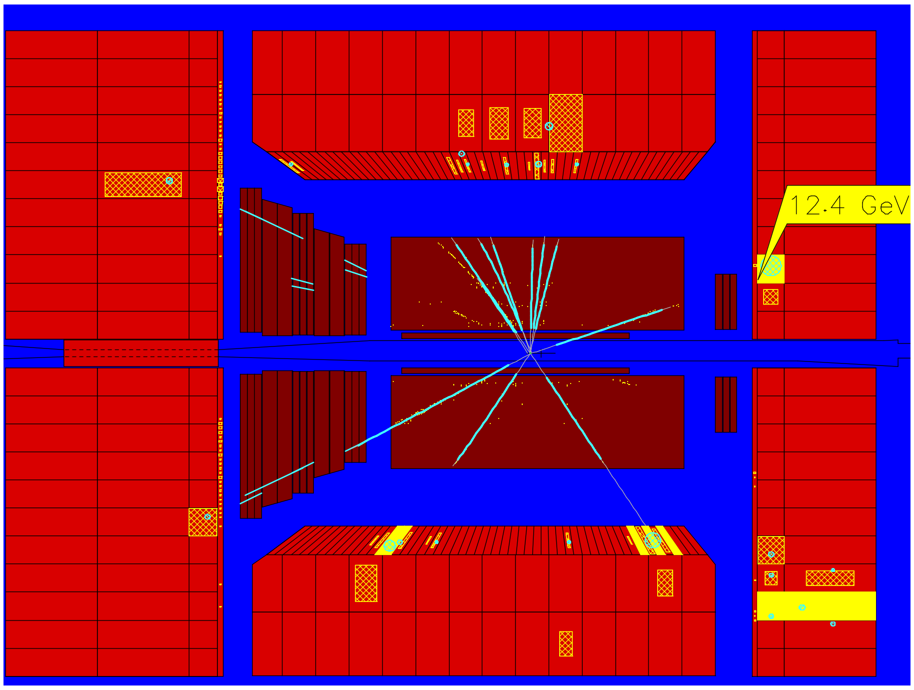
ZEUS Forward Plug Calorimeter

(DESY Report 99-194, December 1999)

In 1998 a new Forward Plug Calorimeter (FPC) was installed in ZEUS increasing the CAL pseudorapidity coverage by 1 unit (from $\eta \sim 4.0$ to $\eta \sim 5.0$ units).







For diffractive LRG events the available M_X-range was increased up to $M_X \sim 35 - 40$ GeV for $W \gtrsim 200$ GeV.

In PETRA e^+e^- experiments $\Rightarrow$ three-jet production was observed for $\sqrt{s}$ in the range $29 \lesssim \sqrt{s} \lesssim 36$ GeV.

(S.L.Wu, Phys. Rep. 107(1984) 59-324)

Selection of Diffractive DIS sample

⇒ We studied multi-jet production in diffractive DIS in the kinematic region:

$$Q^2 > 5 \text{ GeV}^2, \quad 200 < W < 250 \text{ GeV},$$

$$M_X > 23 \text{ GeV}, \quad x_{I\!P} < 0.025$$

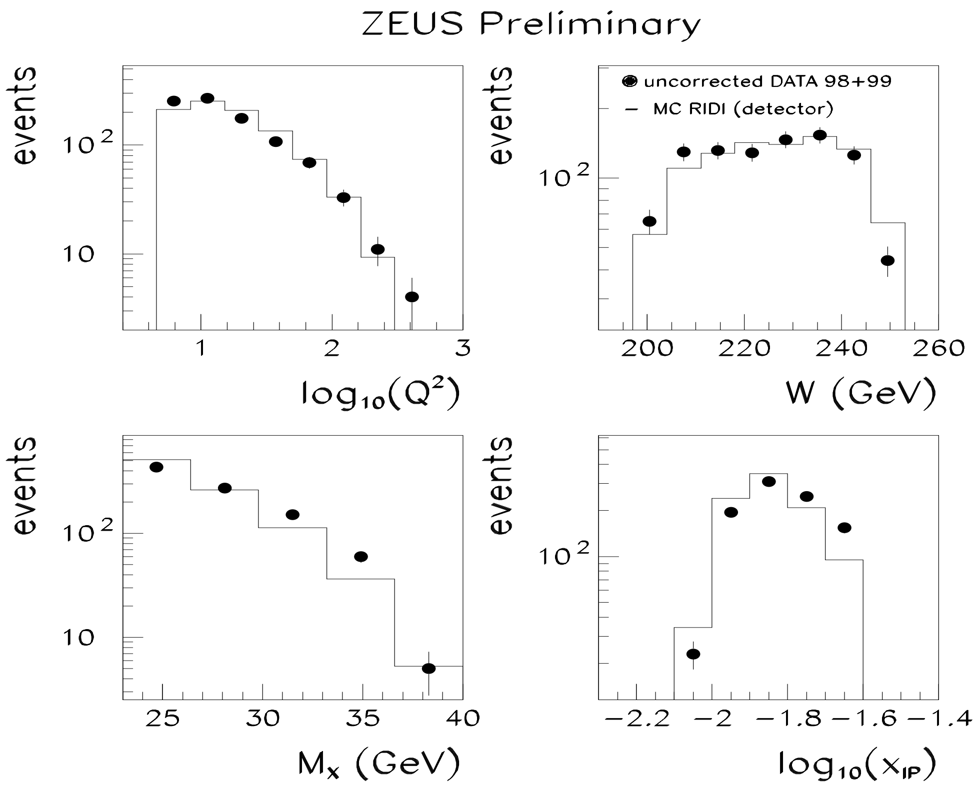
⇒ The analysis is based on 8 pb^{-1} of DIS data collected by ZEUS after the FPC installation.

⇒ Diffractive sample selected requiring $\eta^{max}_{cluster} < 2.8$

⇒ Observed LRG $\Delta\eta \gtrsim 2$ units

⇒ Backg. from non-diff. DIS estimated to be $\lesssim 5\%$

⇒ Measurements are compared with a pQCD-inspired model for diffraction as implemented in RIDI MC
(M. G. Ryskin, Sov. J. Nucl. Phys. 20 (1975) 94).

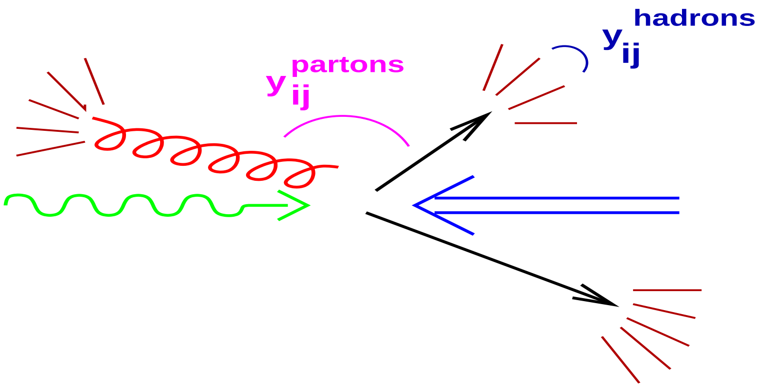


⇒ MC provides a reasonable description

Definition of the Jet-algorithm

(S. Catani et al. Phys. Lett. B269(1991)432)

The exclusive K_T-algorithm (Durham-algorithm) is used to reconstruct jets in the CMS of the observed hadronic final state:



$$y_{ij} = 2 \cdot min(E_i^2, E_j^2)(1 - cos(\theta_{ij}))/M_X^2$$

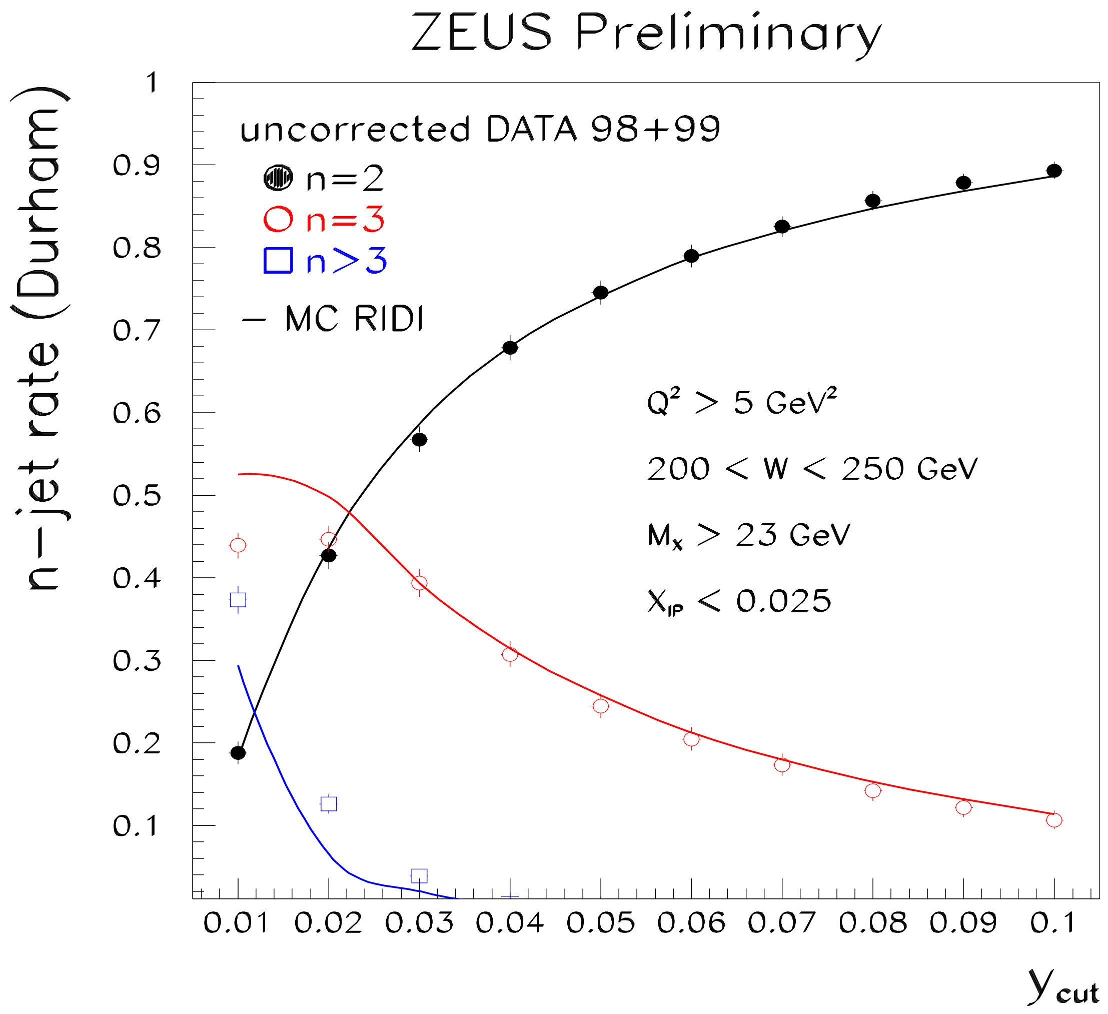
- E-recombination scheme $\Rightarrow p^{\mu}_{cluster} = p^{\mu}_i + p^{\mu}_j$
- Clustering stops when all $y_{ij} < y_{cut}$ (jet resolution scale)
- Remaining clusters $\Rightarrow$ jets

From MC studies:

- For three-jet events, good parton-hadron correlation only appears when $M_x \gtrsim$ 20 GeV.
- Jet resolution parameters $y_{cut} \sim 0.05$ were found to be the most suitable values (giving the smallest hadronization corrections).
- Jet quantities are well reconstructed in the detector.
- For $M_X > 23$ GeV jets have $\gtrsim 4$ GeV in lab. frame.

Jet Rates Measurement

The n-jet rates are measured for n=2, n=3 and $n > 3$ as a function of the jet resolution parameter y_{cut}.



For the value $y_{cut} = 0.05$ we observed in the data:

- 2-jet sample :691 events ($\sim 75\%$)
- 3-jet sample :227 events ($\sim 24\%$)

MC RIDI ($q\bar{q}g$ final state) provides a good description of the measured jet-rates for $y_{cut} \gtrsim 0.03$.

The contribution from $q\bar{q}$-processes to the three-jet signal was estimated using MC RIDI and found to be negligible (with a parton shower scale: $Q_{max} = \sqrt{m_p^2 + k_t^2}$).

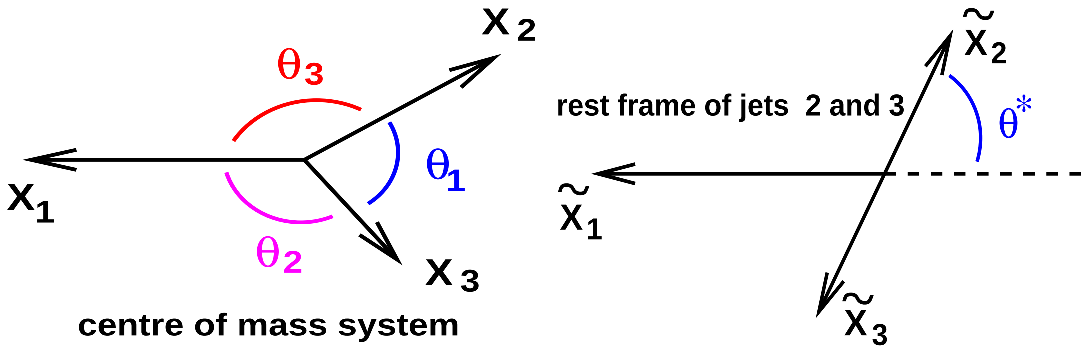
Three-Jet Final State Topologies

(J. Ellis, I. Karliner. Nucl Phys B148(1979) 141)

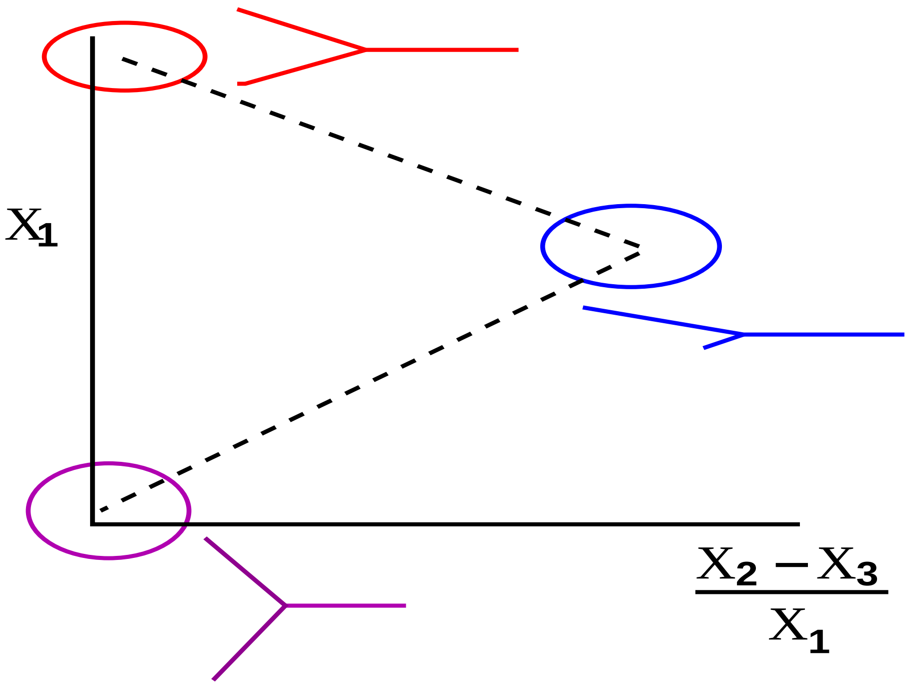
The three-jet final state topology can be described by a combination of the fractional energy variables:

$$X_i = \frac{2 \cdot E_i^{jet}}{M_X}, \qquad \frac{2}{3} \leq X_i \leq 1$$

$$X_1 \geq X_2 \geq X_3, \qquad X_1 + X_2 + X_3 = 2$$

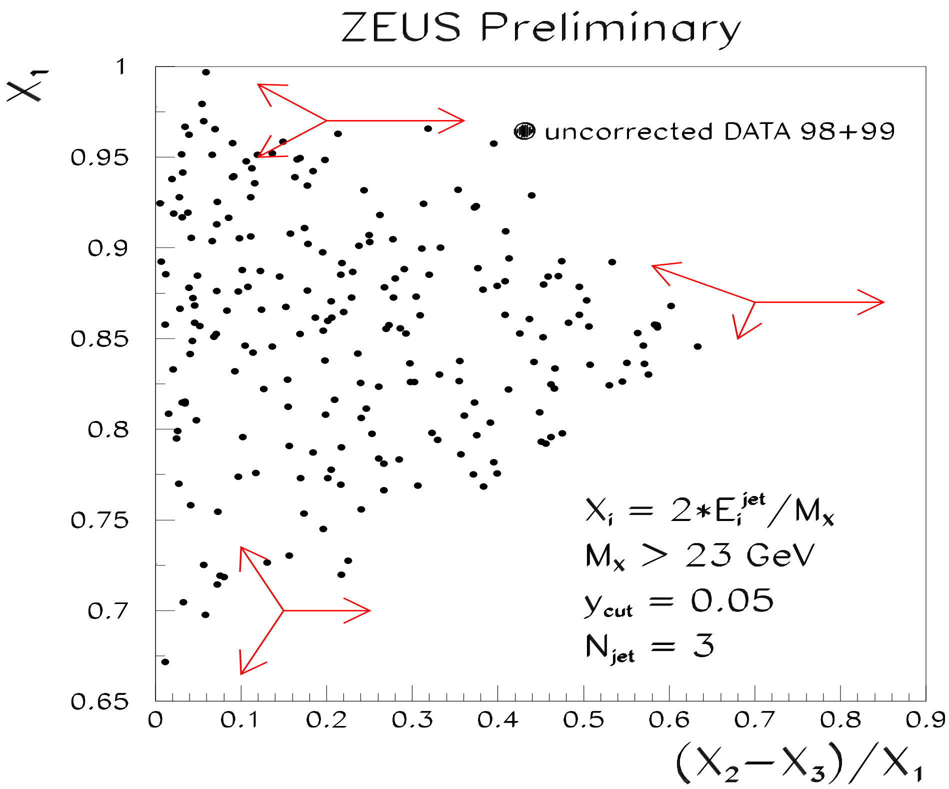


$$X_1 = \frac{2 \cdot sin\theta_1}{sin\theta_1 + sin\theta_2 + sin\theta_3}, \qquad \frac{X_2 - X_3}{X_1} = |cos\ \theta^*|$$

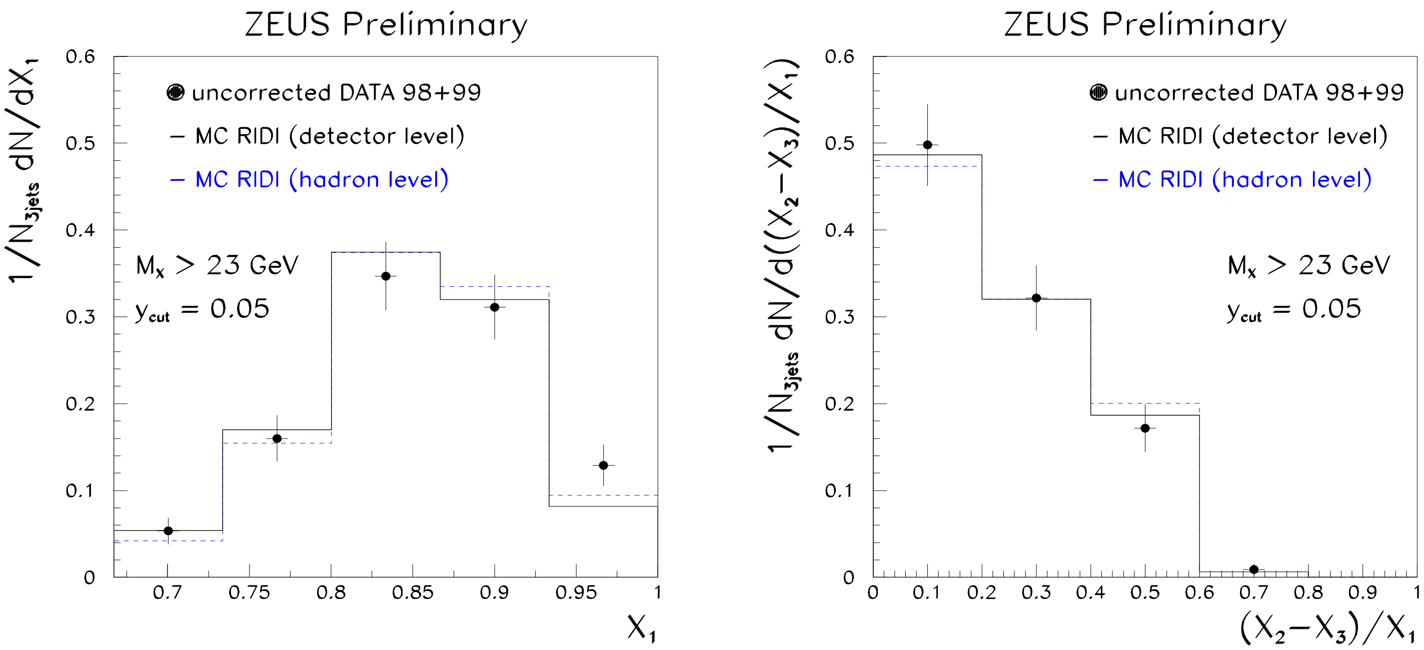


Different regions in this plane define different topologies in the three-jet final state.

Three-Jet events in $(\frac{X_2 - X_3}{X_1}, X_1)$-plane



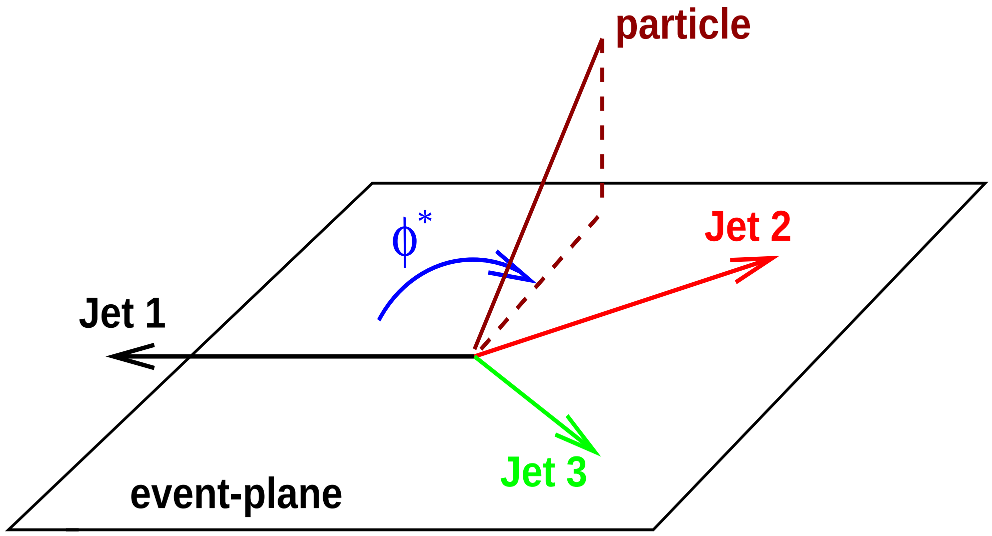
The data show that all the possible configurations for a three-body final state are present.

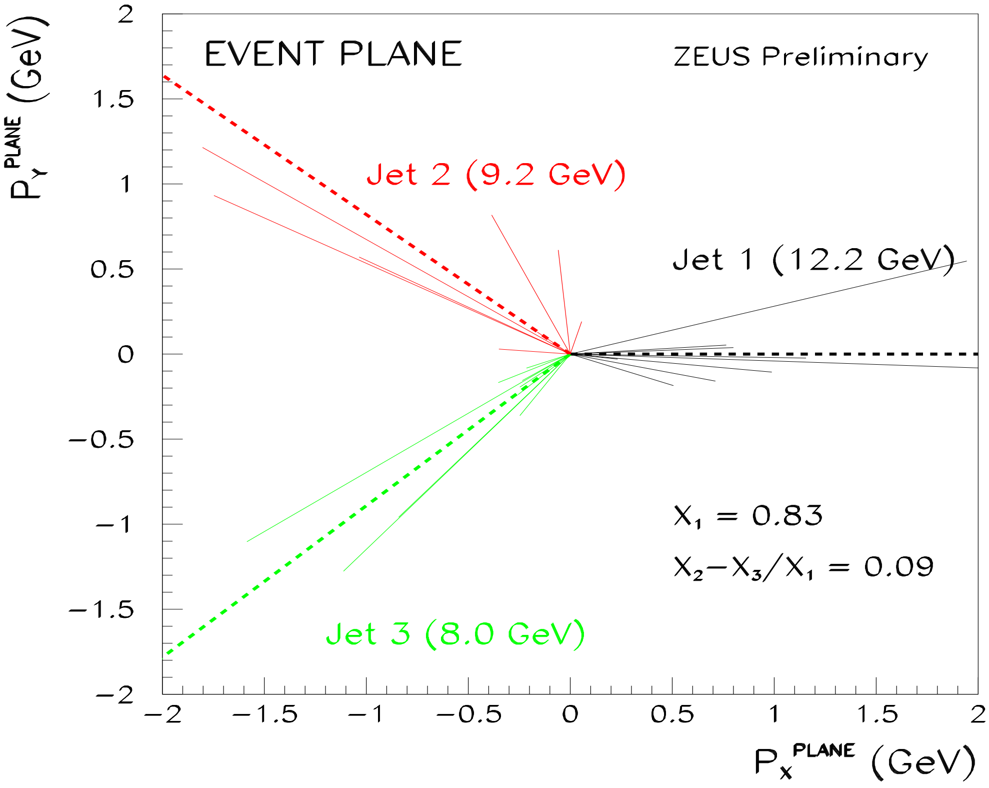


The MC RIDI($q\bar{q}g$ final state) provides a good description of how the plane is populated.

Event Display in the Three-jet plane

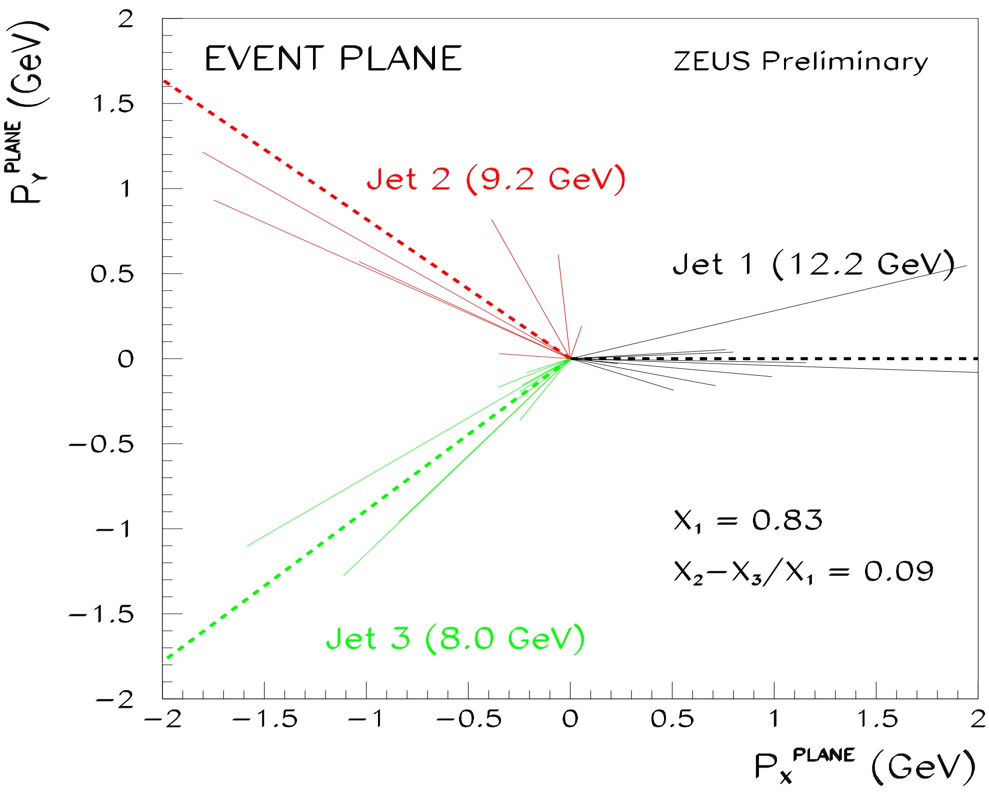
The event plane is defined using the two most energetic jets. For each particle its component into the plane is computed. The angle ϕ^* into the plane always runs from Jet-1 to Jet-2.

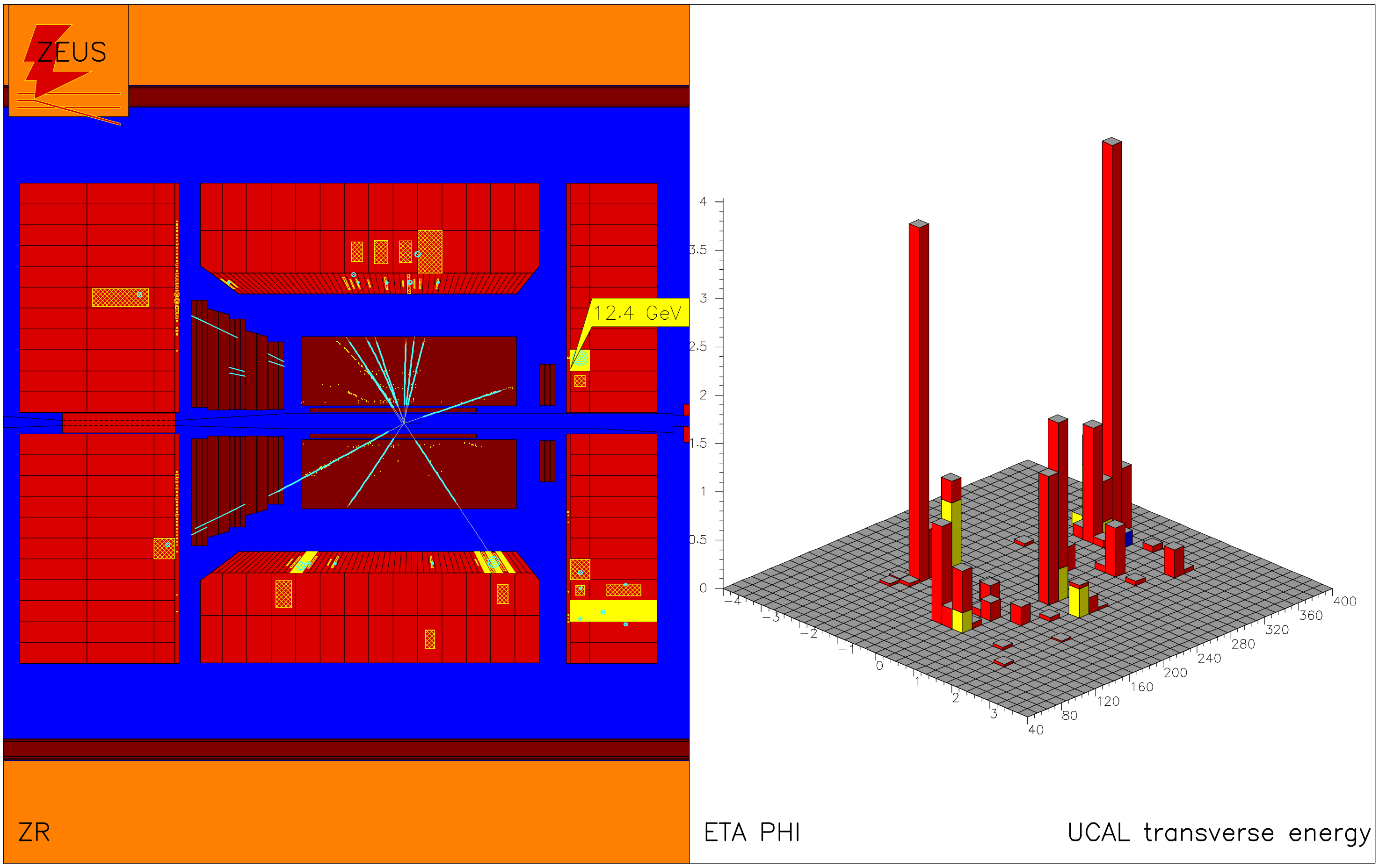




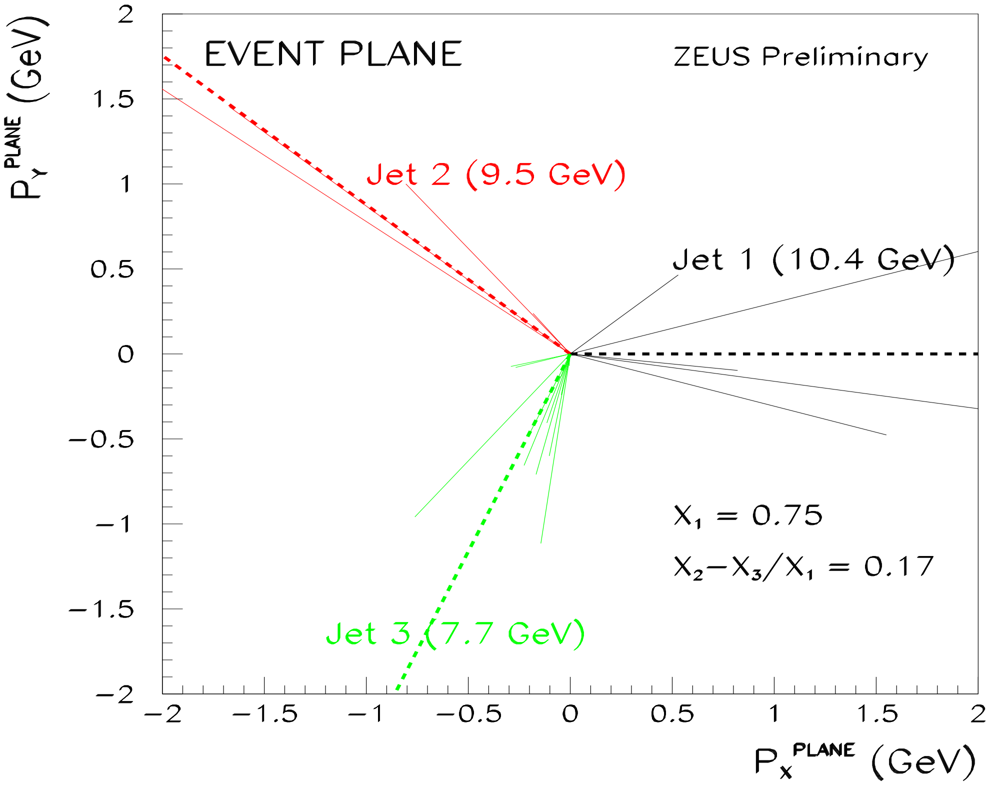
First observation of three-jets in LRG events!

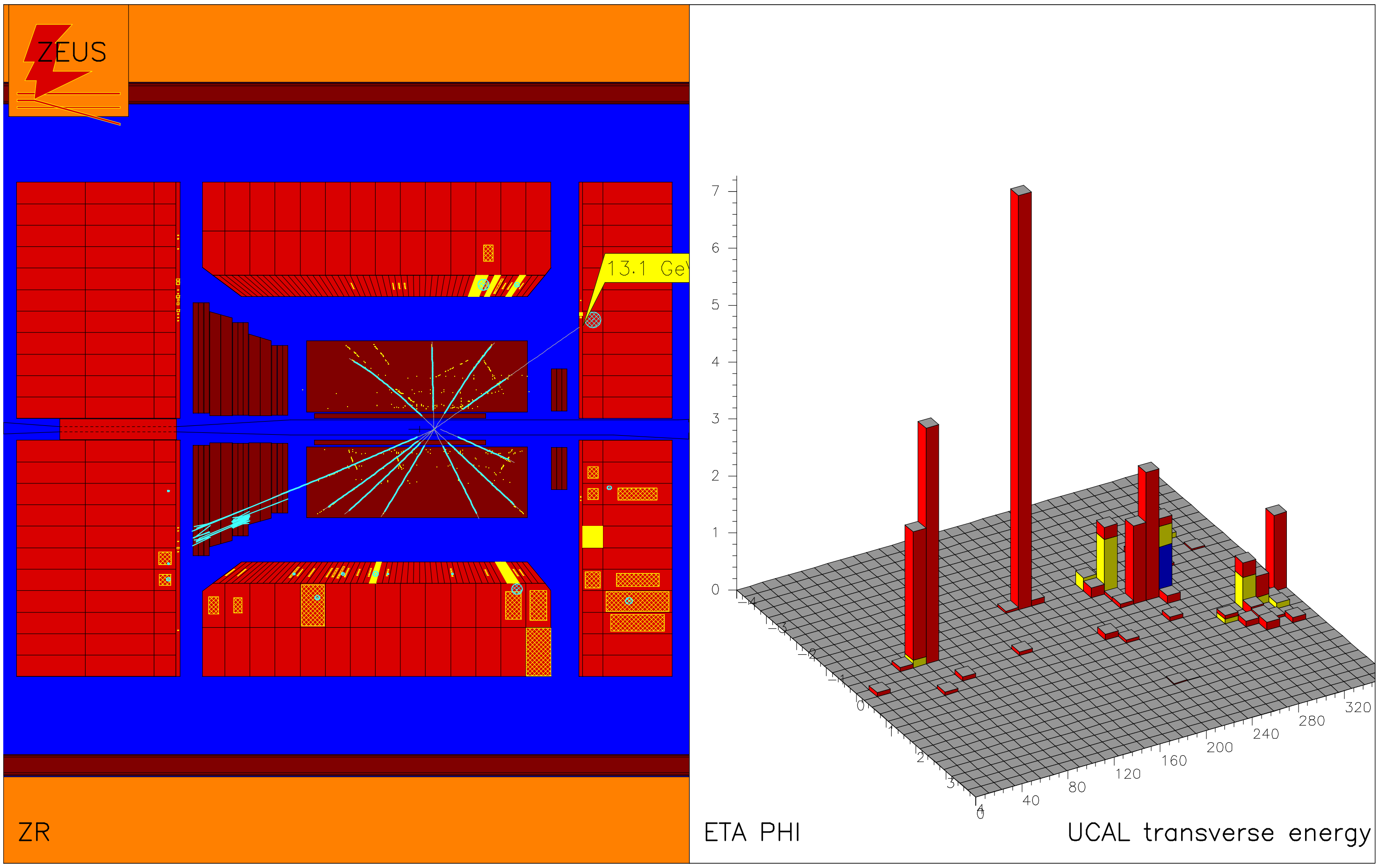
Observation of Three-Jet events



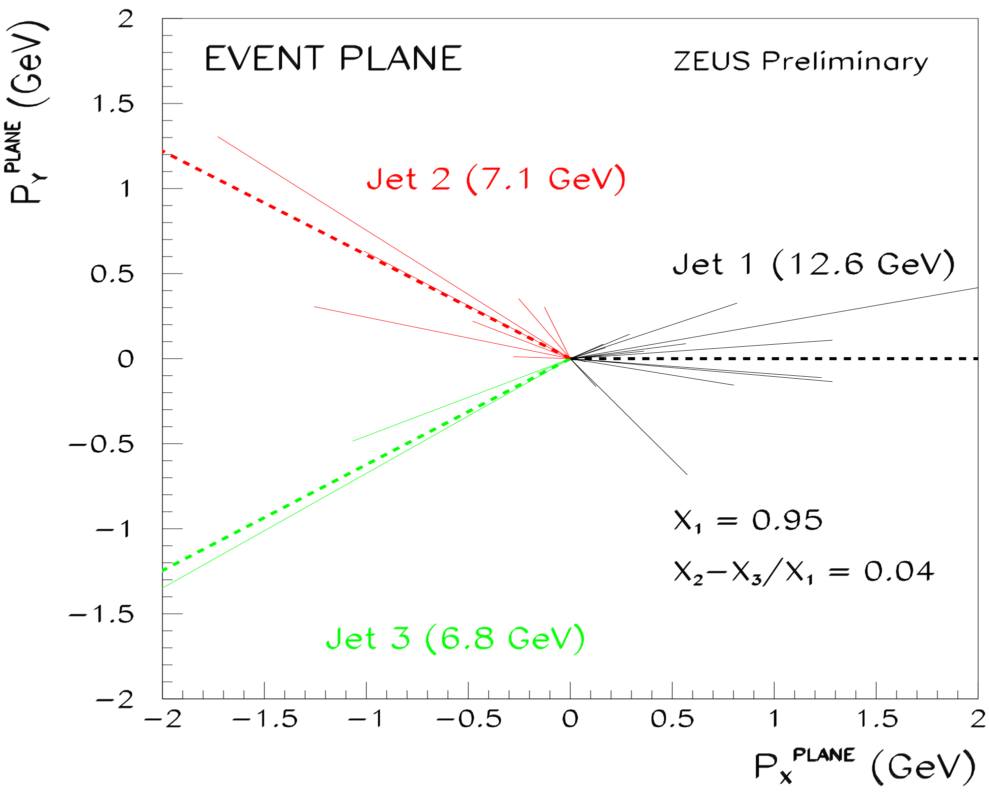


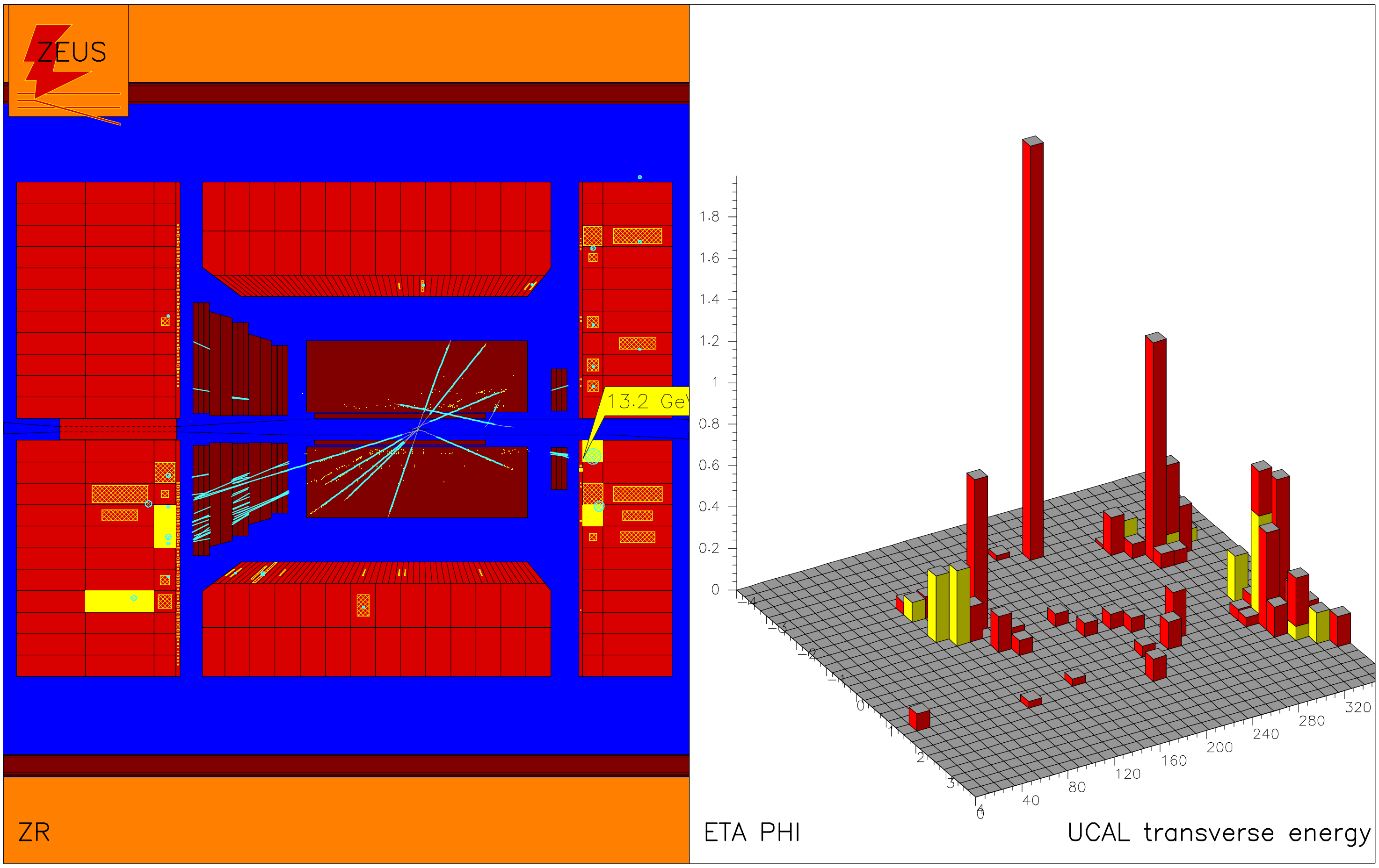
Observation of Three-Jet events





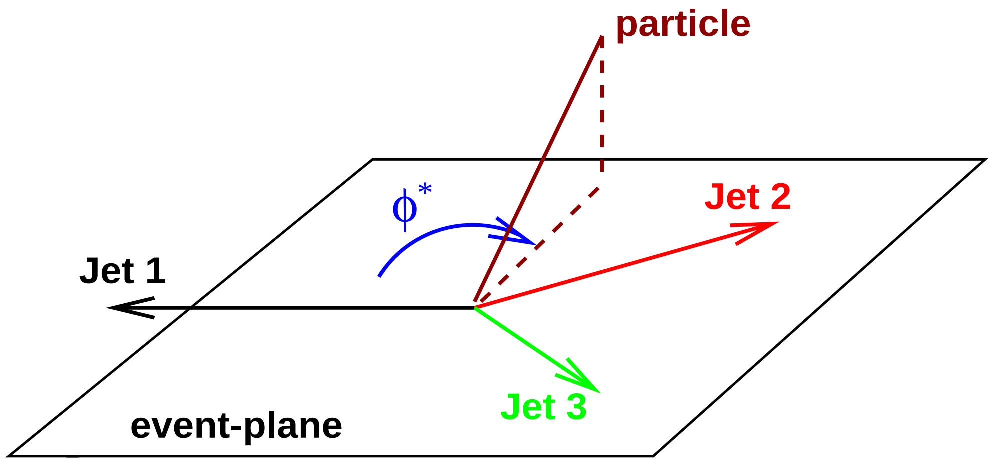
Observation of Three-Jet events



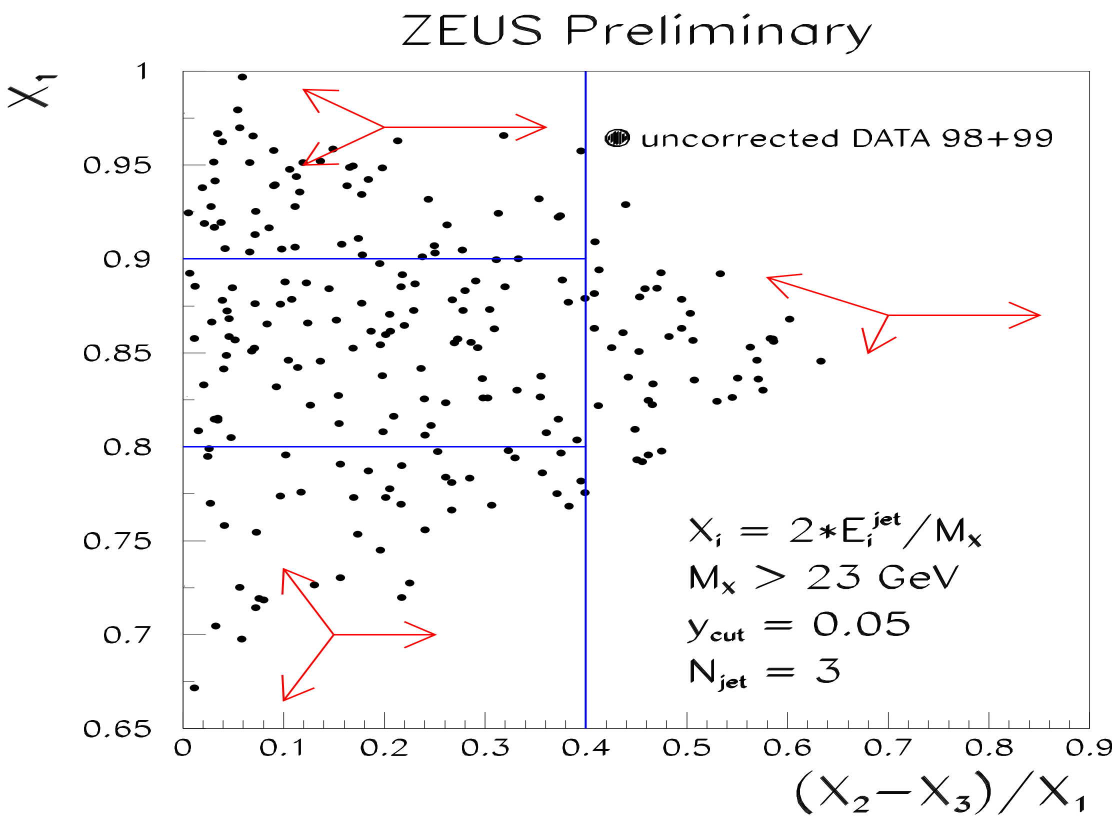


Energy and Particles Flows

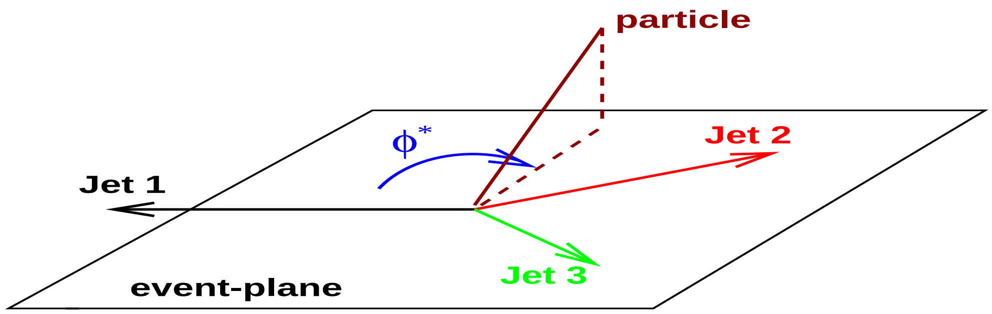
The energy (particles) flow in the three-jet plane are measured by projecting the particle momenta onto the $(\mathrm{Jet}_1, \mathrm{Jet}_2)$-plane and summing the particle energies (number of particles) in each ϕ^*-bin.



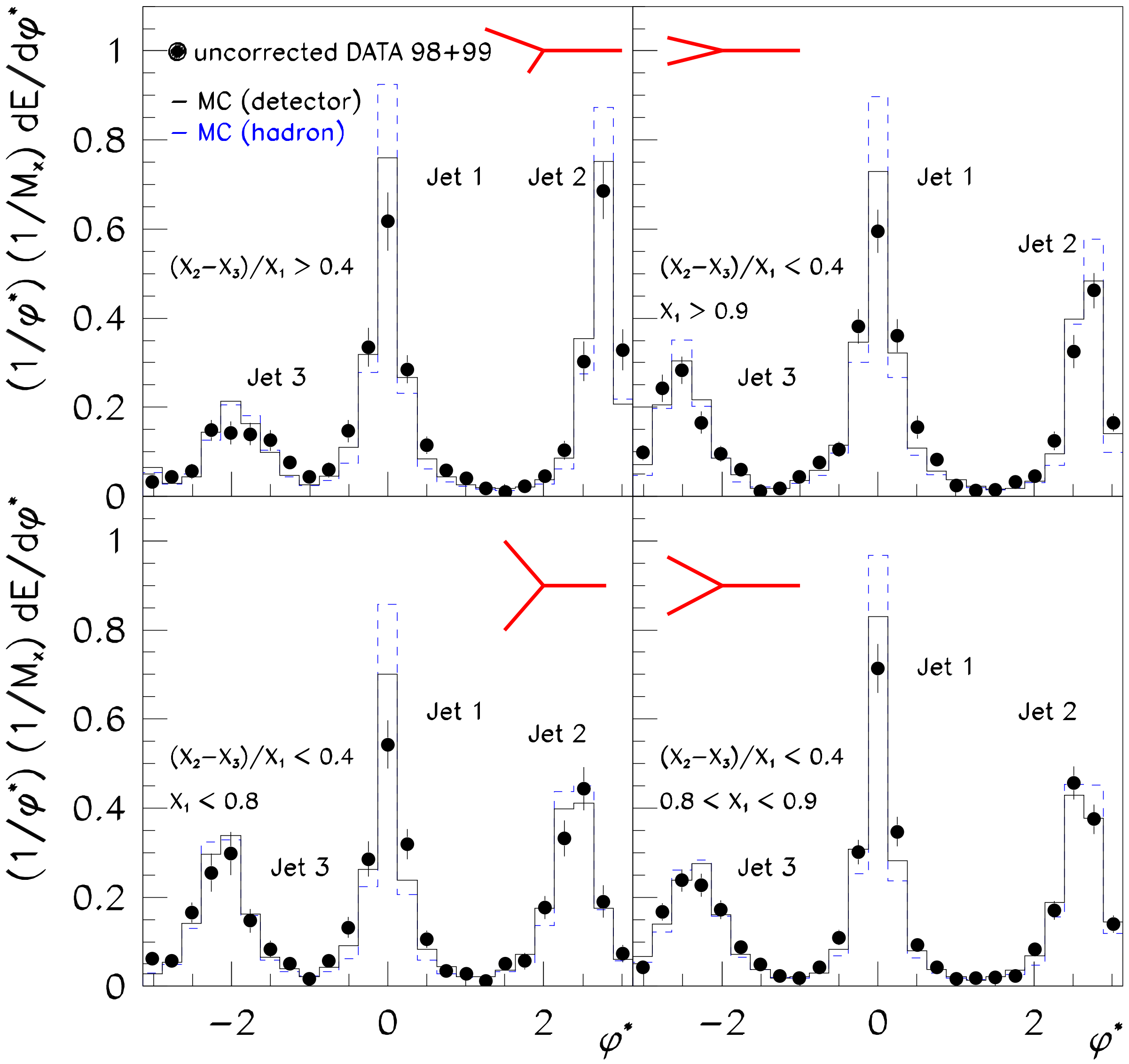
The measurements were performed in different regions of the $(\frac{X_2 - X_3}{X_1}, X_1)$-plane corresponding to different three-jet topologies:



Energy Flow in the event plane



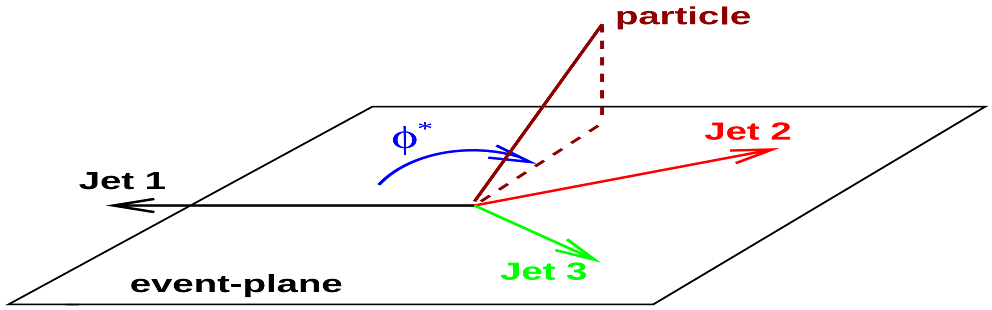
ZEUS Preliminary

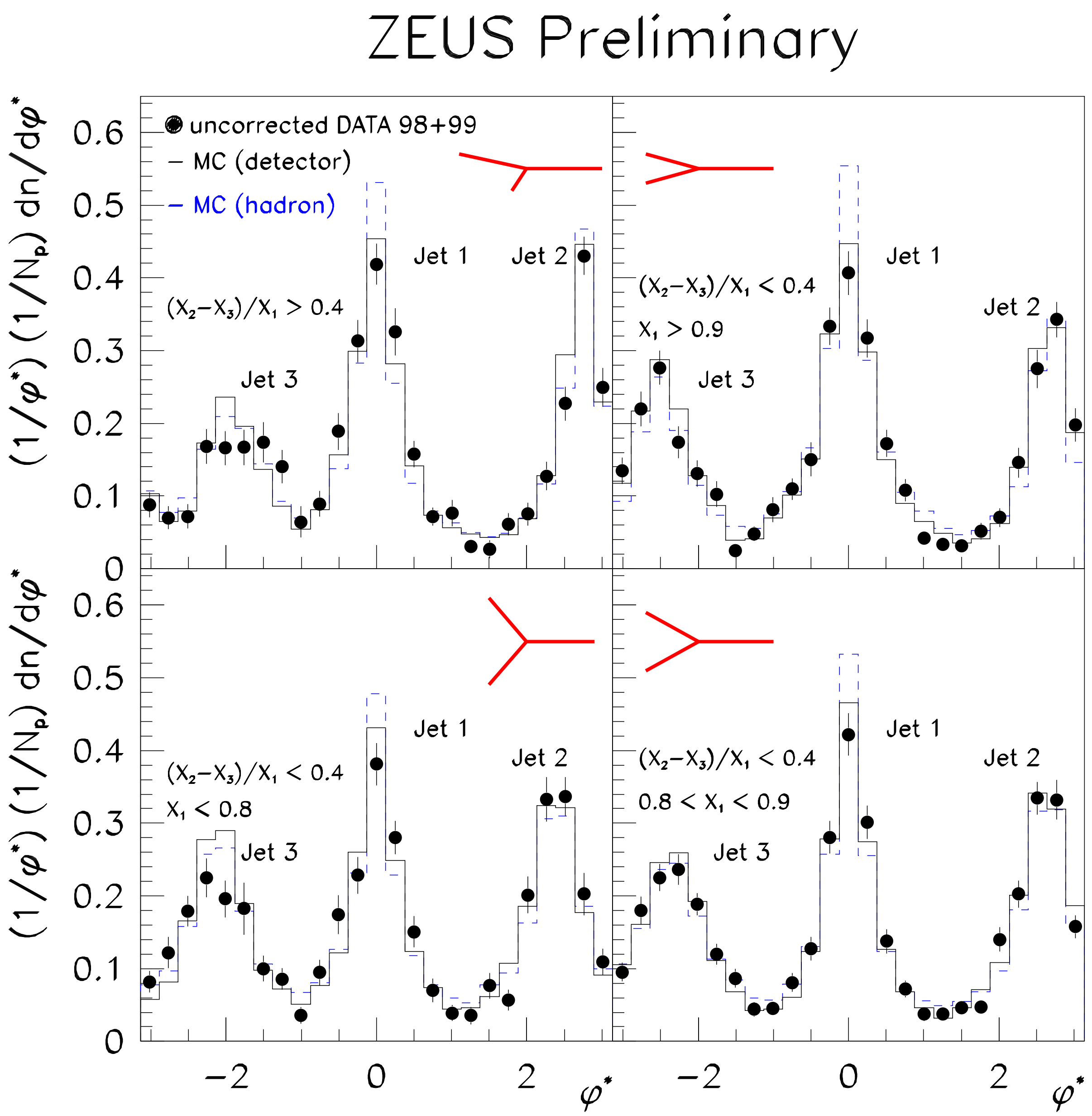


A clear three-jet structure is observed in all the regions.

MC RIDI gives a fair global description of the data.

Particles Flow in the event plane



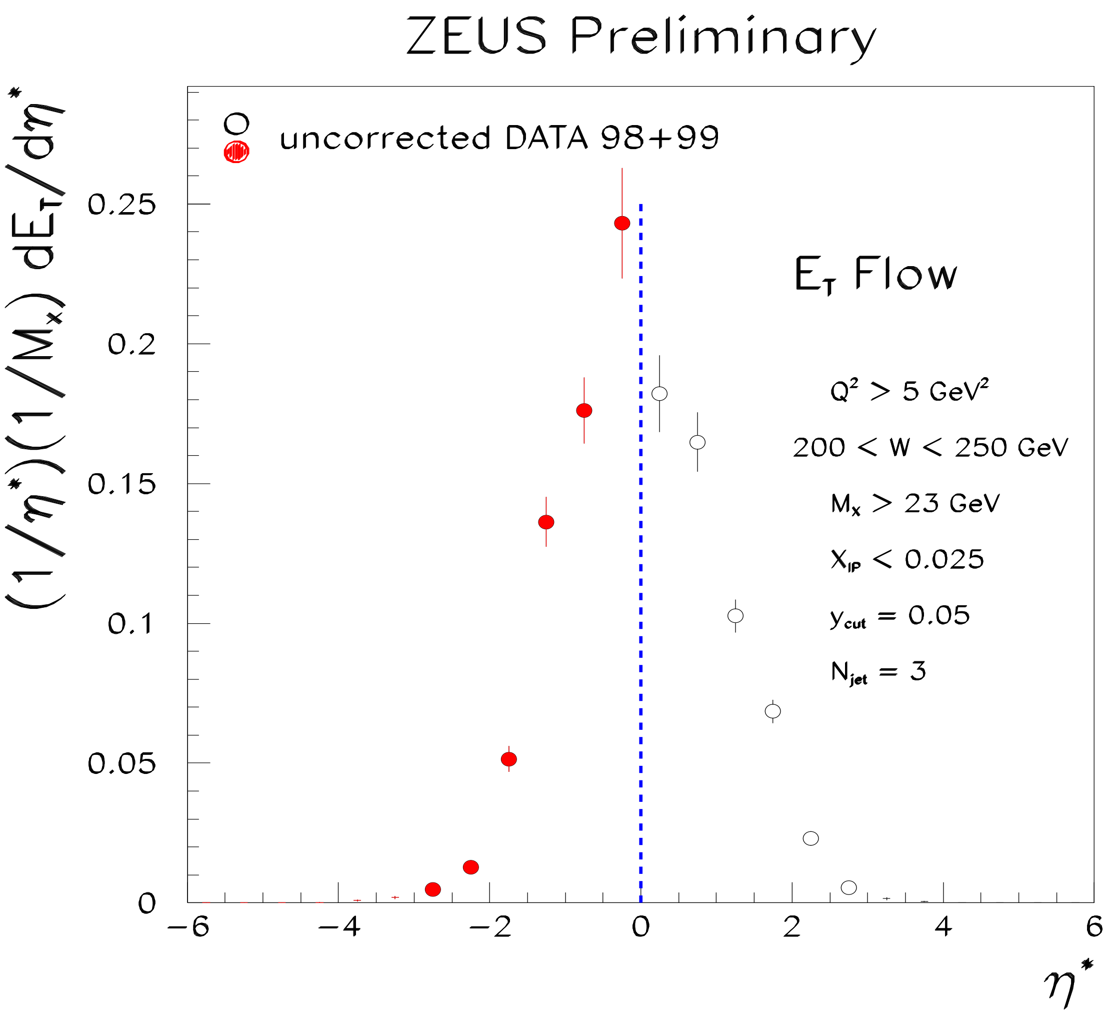


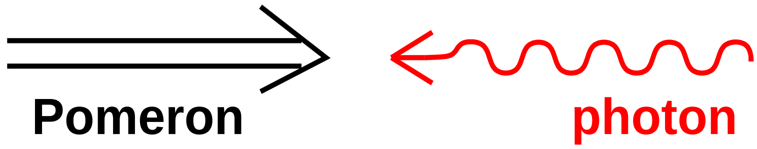
A three-jet structure also observed in the measured flows of particles.

MC RIDI also provides a reasonable description of the measured multiplicities in the event plane.

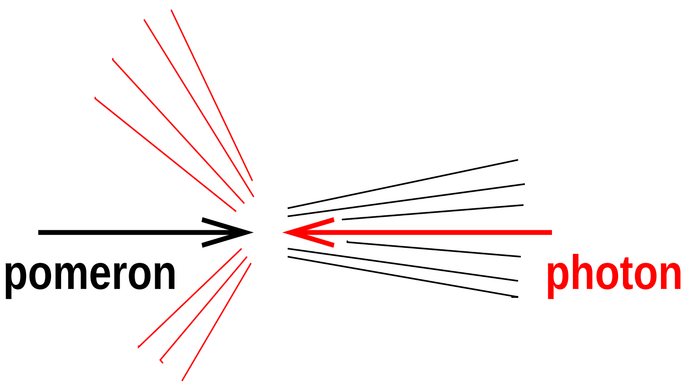
E_T Flow in the γ^*-$I\!\!P$ CMS

The transverse energy flow of the particles is measured respect to the γ^*-$I\!\!P$ direction for the three-jet sample.



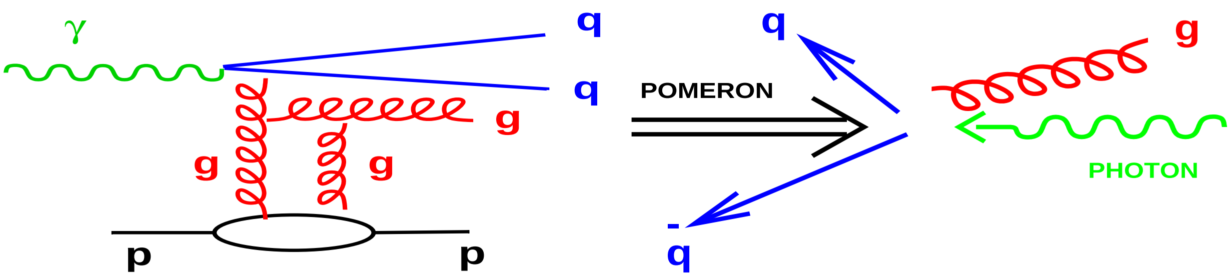


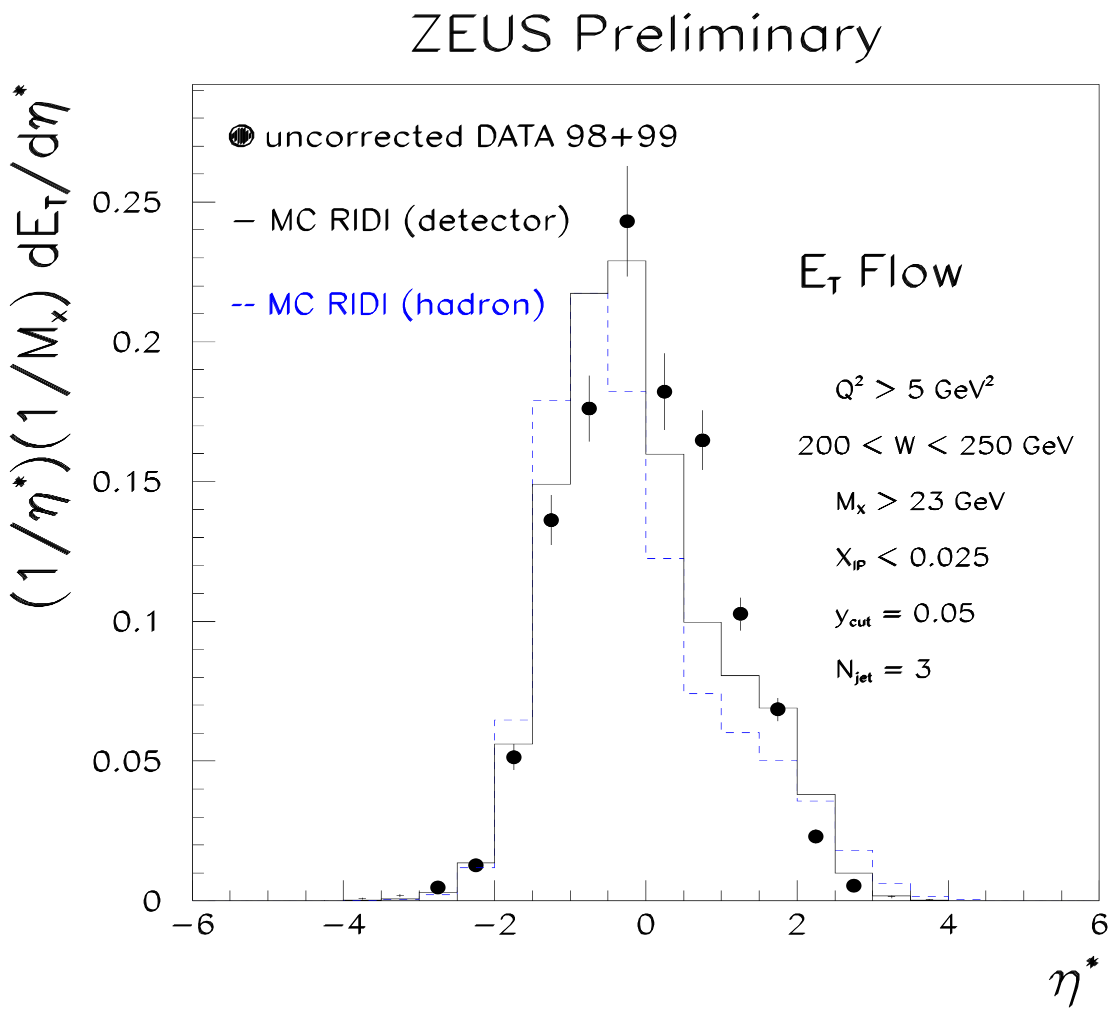
For the observed three-jet events there is an indication that the transverse energy flow is asymmetric w.r.t. the γ^*-$I\!\!P$ direction shifted towards the γ-hemisphere.

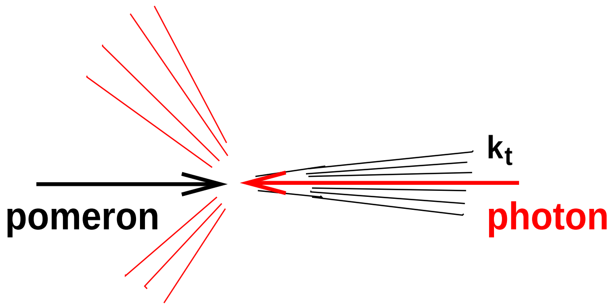


E_T Flow in the γ^*-$I\!P$ CMS

The measured transverse energy flow is compared with MC RIDI ($q\bar{q}g$ final state):







The MC follows the observed asymmetry towards the photon hemisphere and shows a lack of larger-k_T gluon radiation in the pomeron hemisphere.

Summary and Conclusions

- First observation of three-jet production for events in the kinematic region:
  - $Q^2 > 5$ GeV^2, $200 < W < 250$ GeV
  - $M_X > 23$ GeV, $x_{\mathbb{P}} < 0.025$

  with a Large Rapidity Gap in the detector.

- The measured jet-rates as a function of the y_{cut} are described by a pQCD inspired diffractive MC with three hard partons in the final state.

- For $y_{cut} = 0.05 \Rightarrow \sim 24\%$ of three-jet events.

- We studied the topologies of the observed three-jet events:
  1. All possible configurations of a three-body system are present.
  2. The diffractive MC provides a good description of the data.

- From the measured energy flows in the three-jet plane:
  1. A clear three-jet structure is observed.
  2. The diffractive MC provides a reasonable description of the data.

- For three-jet events the transverse energy flow w.r.t the $\gamma - \mathbb{P}$-axis is measured $\Rightarrow$ There is an indication that the E_T-flows is asymmetric shifted towards the photon hemisphere.