Di-jet production in $\gamma\gamma$ collisions in OPAL

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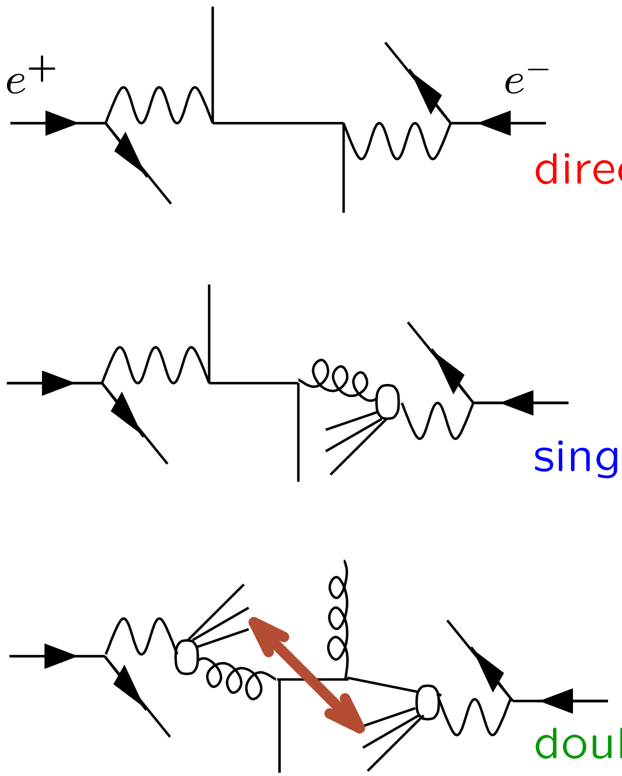
Di-jet production mechanisms in $\gamma\gamma$ collisions

Estimate of fraction of photon momentum entering hard collision

$$x_\gamma^\pm = \frac{\sum_{\text{jet1,2}} E \pm p_z}{\sum_{\text{hadrons}} E \pm p_z}$$

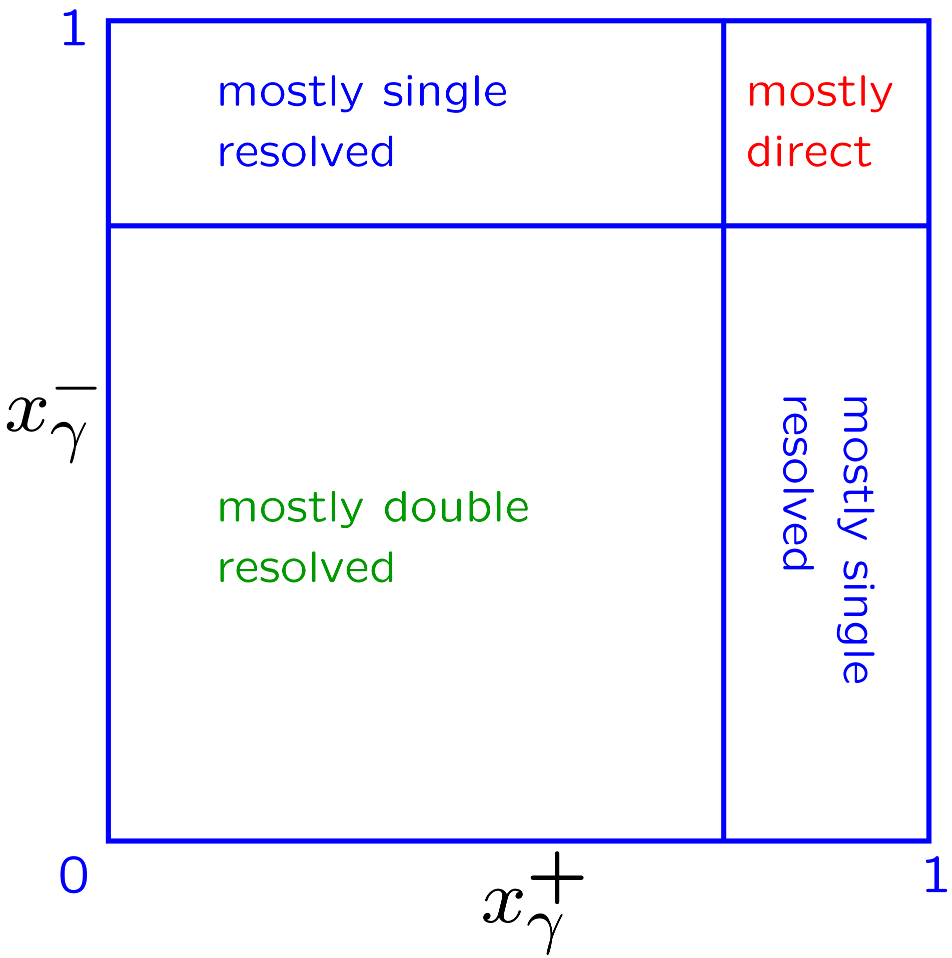


direct

single resolved

double resolved

multiple parton interactions (MIA)?



Data selection and background

Data sample:

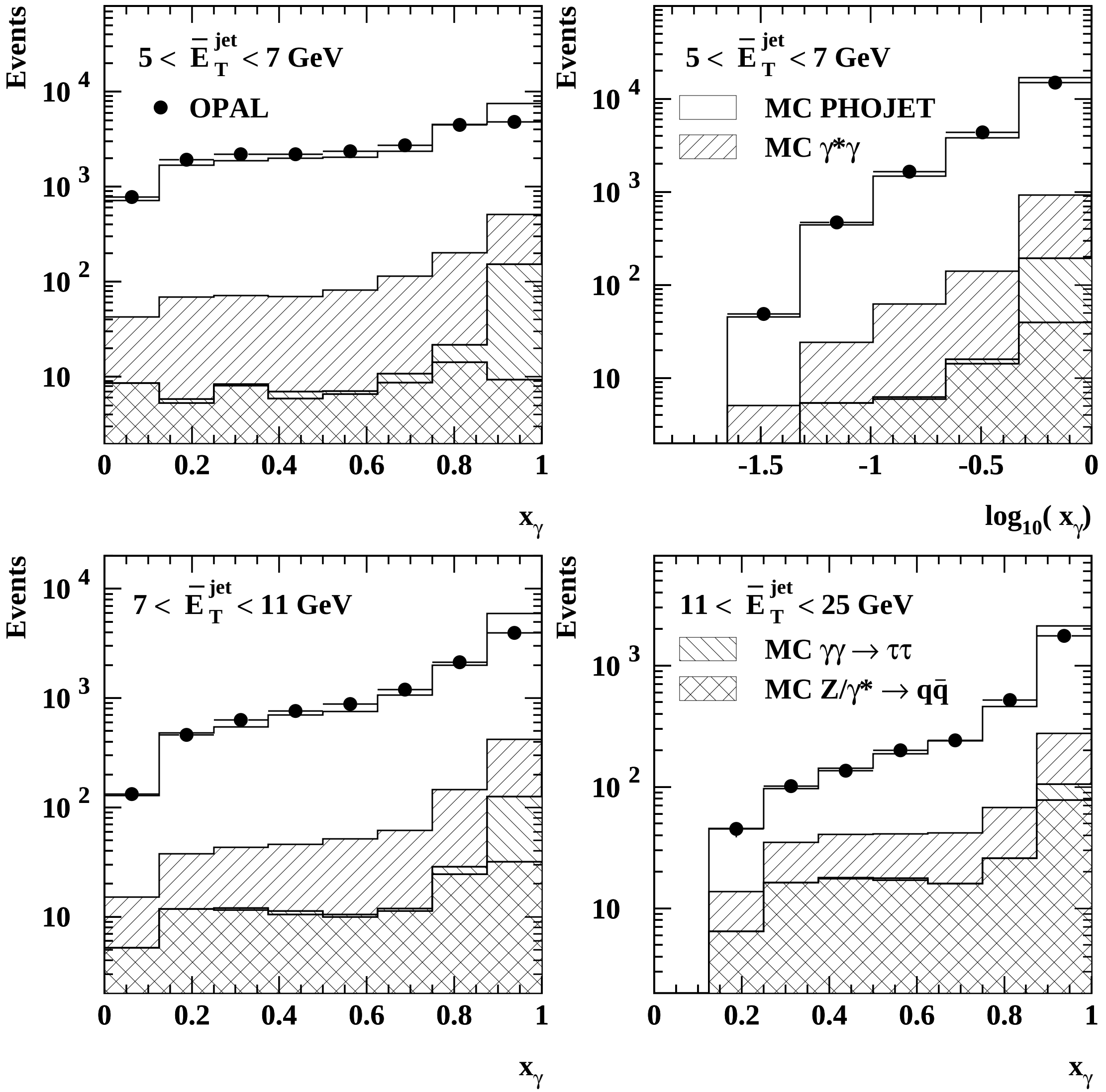
- $\sqrt{s} = 189 - 209\,\text{GeV}$, $\mathcal{L} = 593\,\text{pb}^{-1}$

Standard $\gamma\gamma$ event selection:

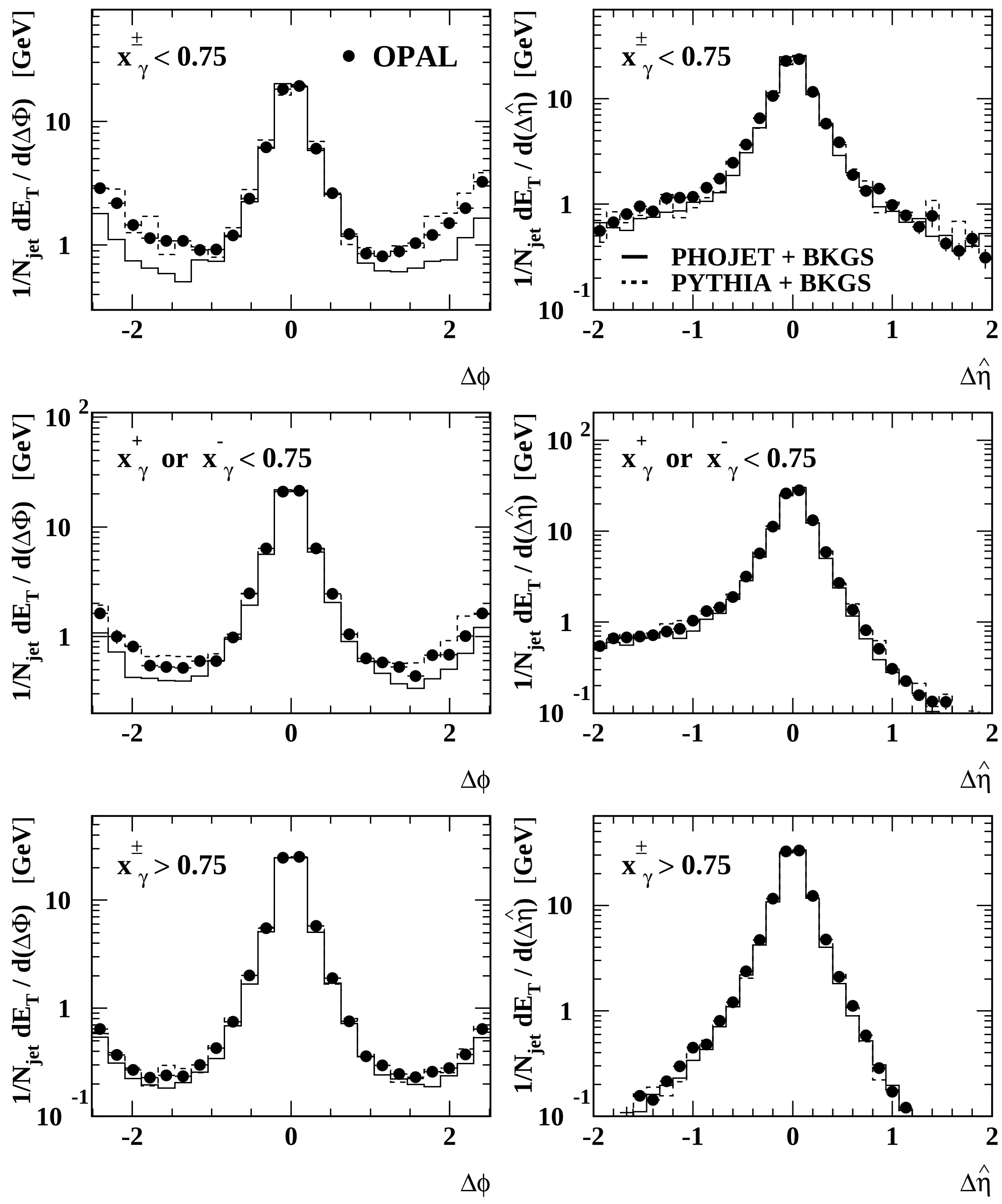
- $\sum E_{\text{calo}}$ & (Leading jet, opposite hemisphere)$_{\text{inv.mass}} < 55\,\text{GeV}$
- Number of tracks > 6
- Antitag in forward detectors
- Quality cuts on missing momentum, vertex position
- Total remaining background is about 5%

Jet selection:

- Inclusive $k_\perp$ with $R_0 = 1.0$
- Cone with $\eta\phi$–radius $= 1.0$ for jet structure comparisons



Energy flow around jets (jet profiles)

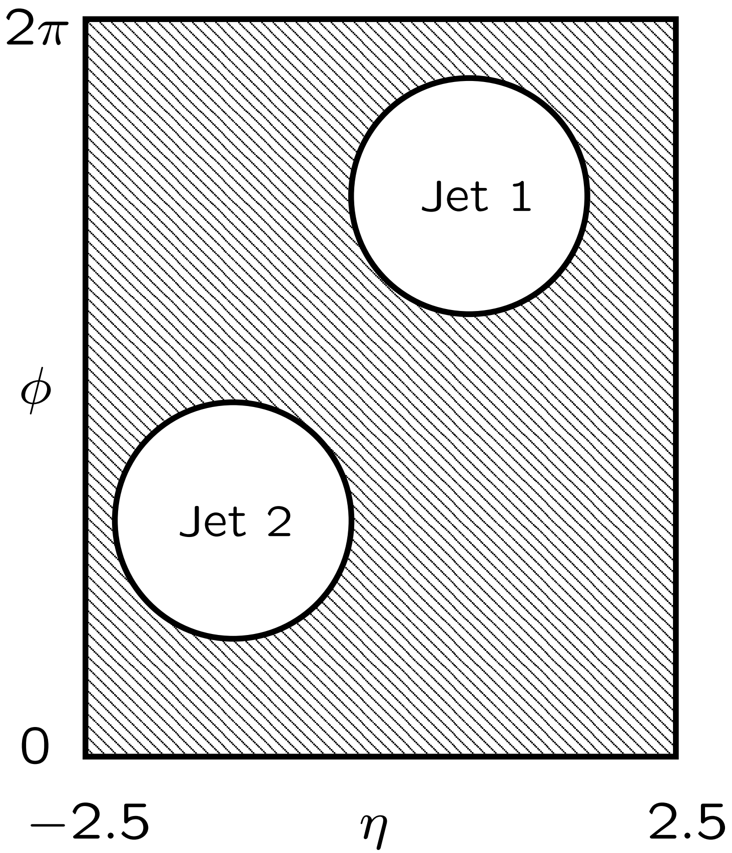


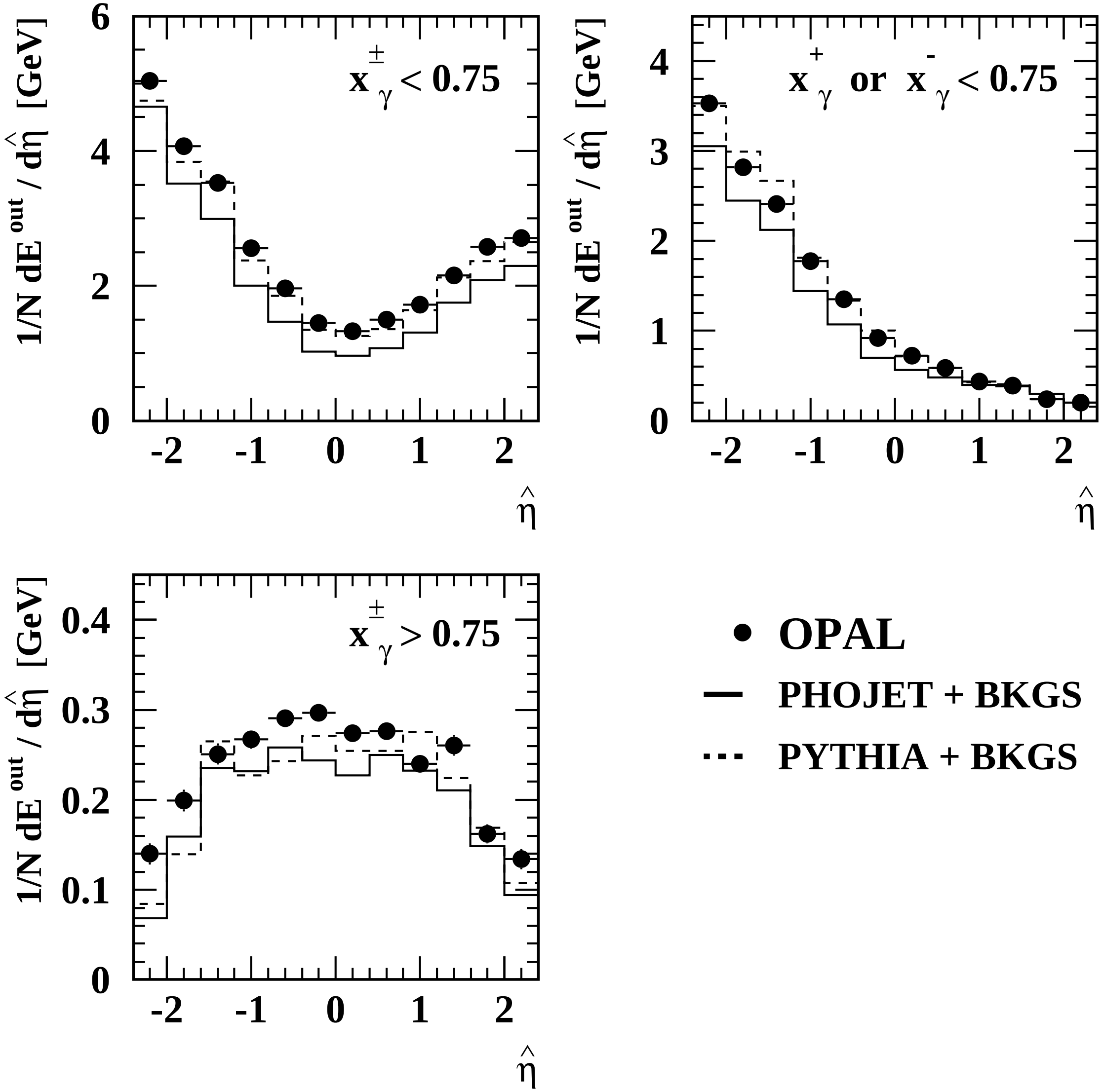
$10 < E_{\mathrm{T}}^{\mathrm{jet}} < 25\,\mathrm{GeV}$

$\hat{\eta}$: η ordered by x_γ
(more resolved γ is left)

Some discrepancy for PHOJET in region between jets, but well described by Monte Carlo in general

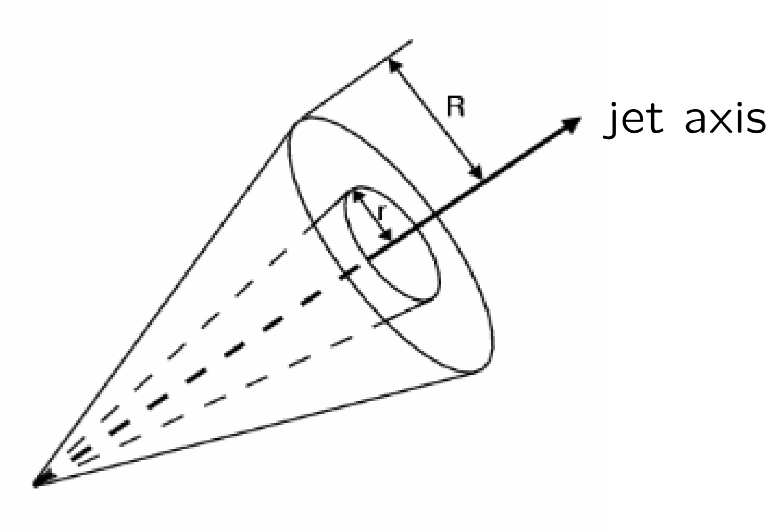
Energy flow outside the two leading jets





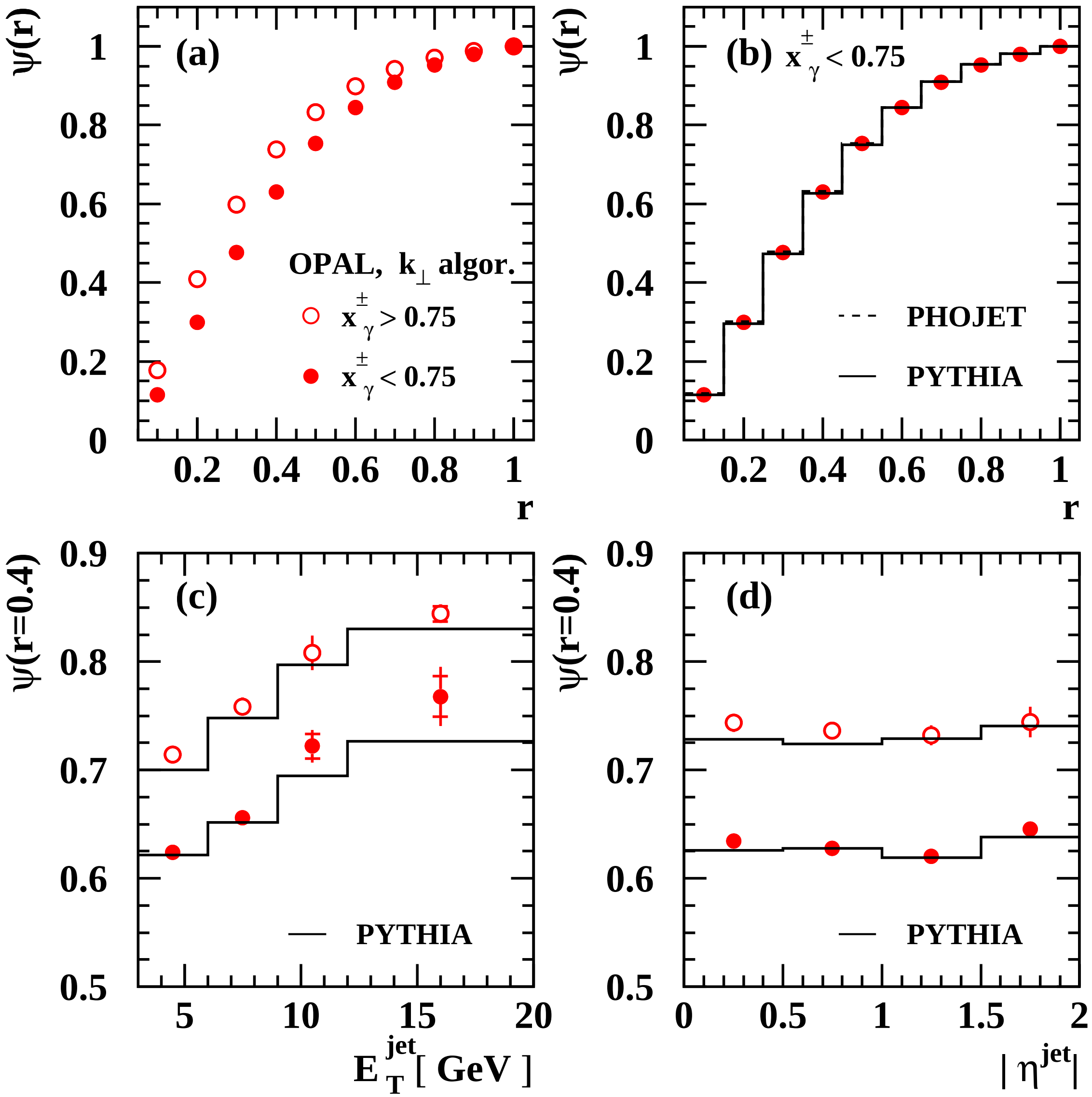
Energy flow in shaded region vs. η ordered by x_γ (more resolved γ is left)

The internal structure of jets: quarks vs. gluons

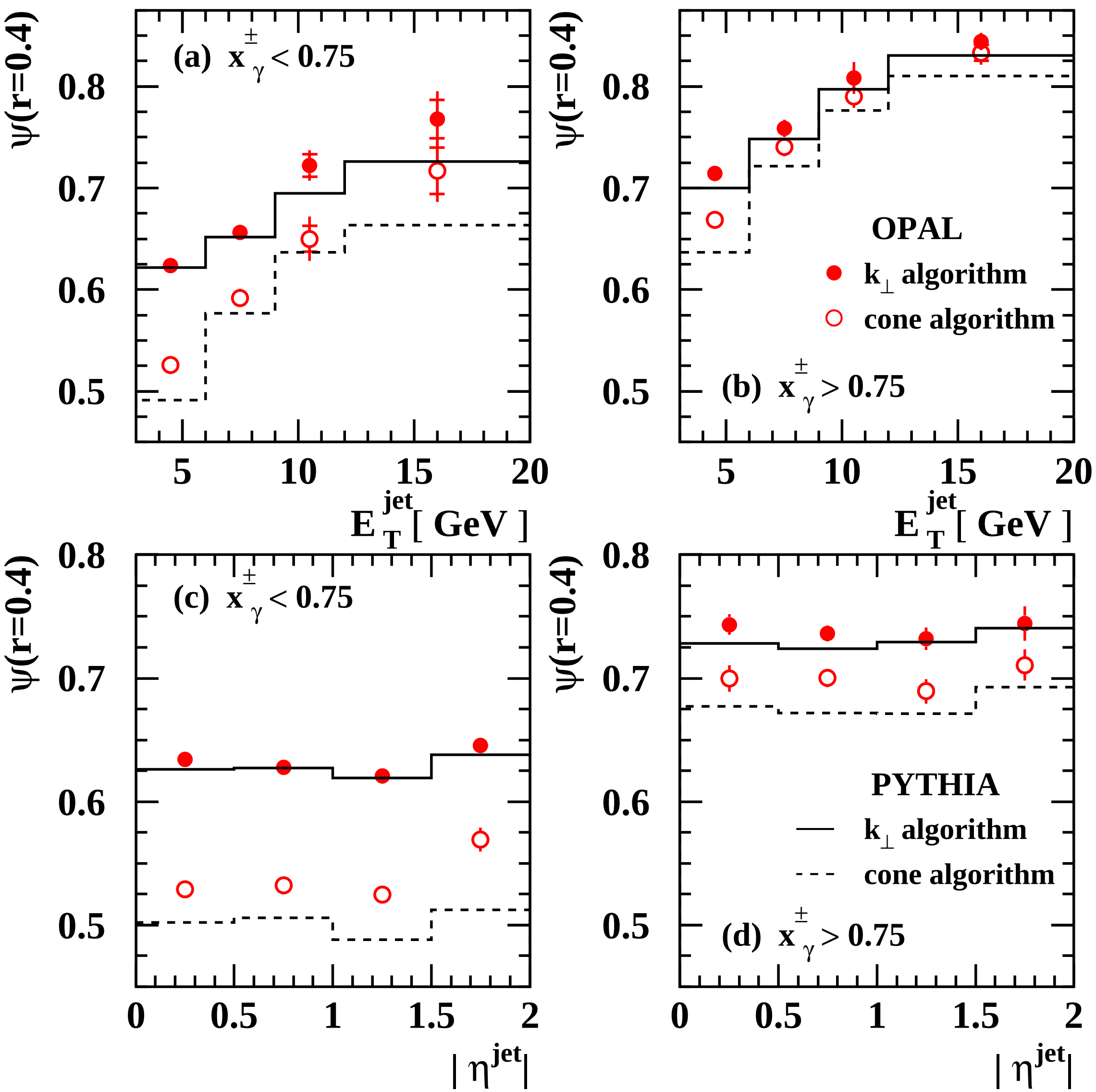


$$\psi(r) = \frac{1}{N_{\text{jets}}} \sum_{\text{jets}} \frac{E_T^{\text{jet}}(r)}{E_T^{\text{jet}}(R{=}r|_{1.0})}$$

$$r = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$



The internal structure of jets cont.

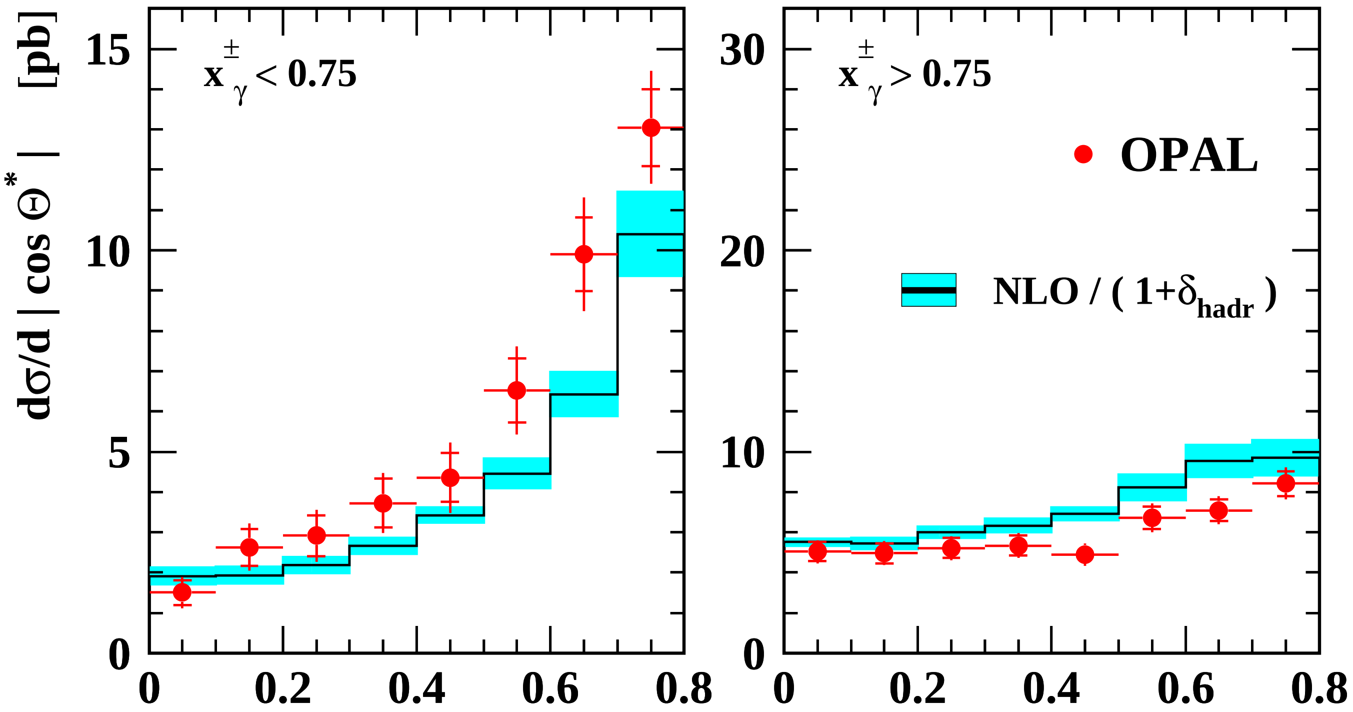


Quark jets are more collimated than gluon jets, but both show the same dependence on E_T and η

$k_\perp$ jets are more collimated than cone jets and are better described by the Monte Carlo

Di-jet angular distributions: quarks vs. gluons

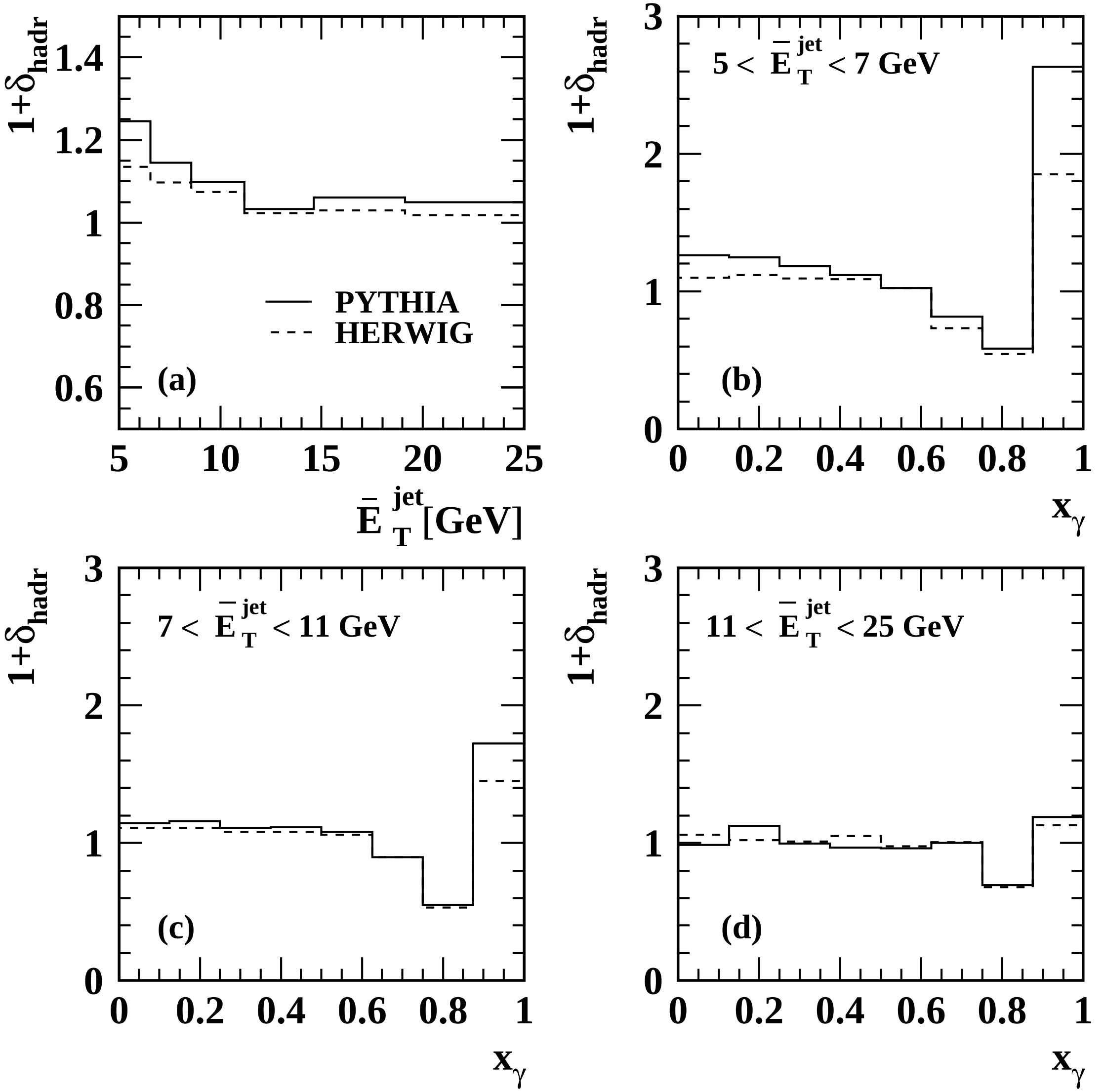
NLO: Klasen et al.



$|\cos\Theta^*| = |\tanh\left(\frac{\eta_1^{jet}-\eta_2^{jet}}{2}\right)|$

Different shape for gluon and quark dominated sample

Example of hadronisation corrections

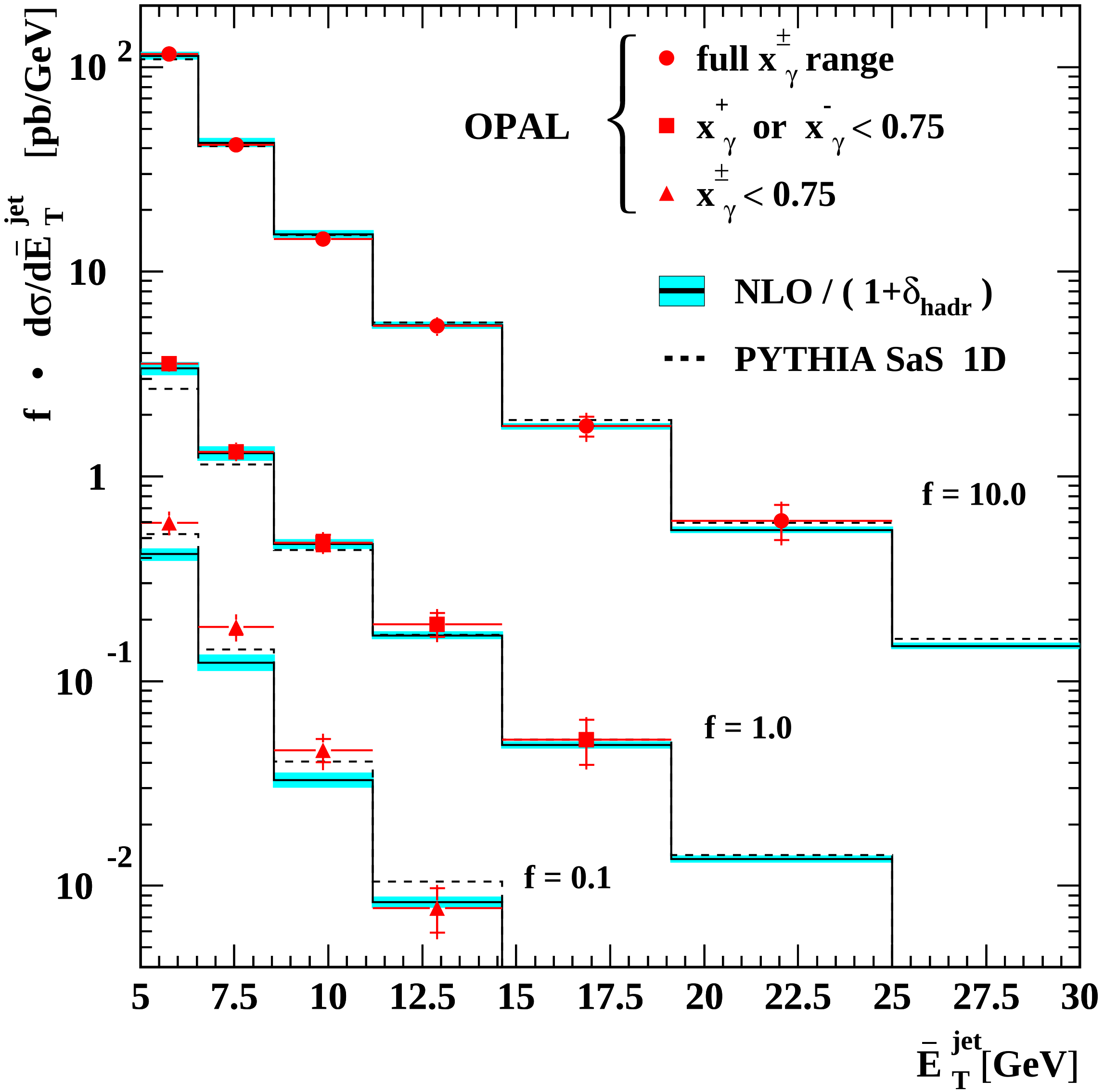


Large corrections at $x_\gamma \approx 1$

(better look at sum of the highest two bins in x_γ)

At high E_T hadronisation corrections are small $\sim 5\%$

The di-jet cross-section vs. mean $E_{\mathrm{T}}^{\mathrm{jet}}$



Well described by NLO for total sample and

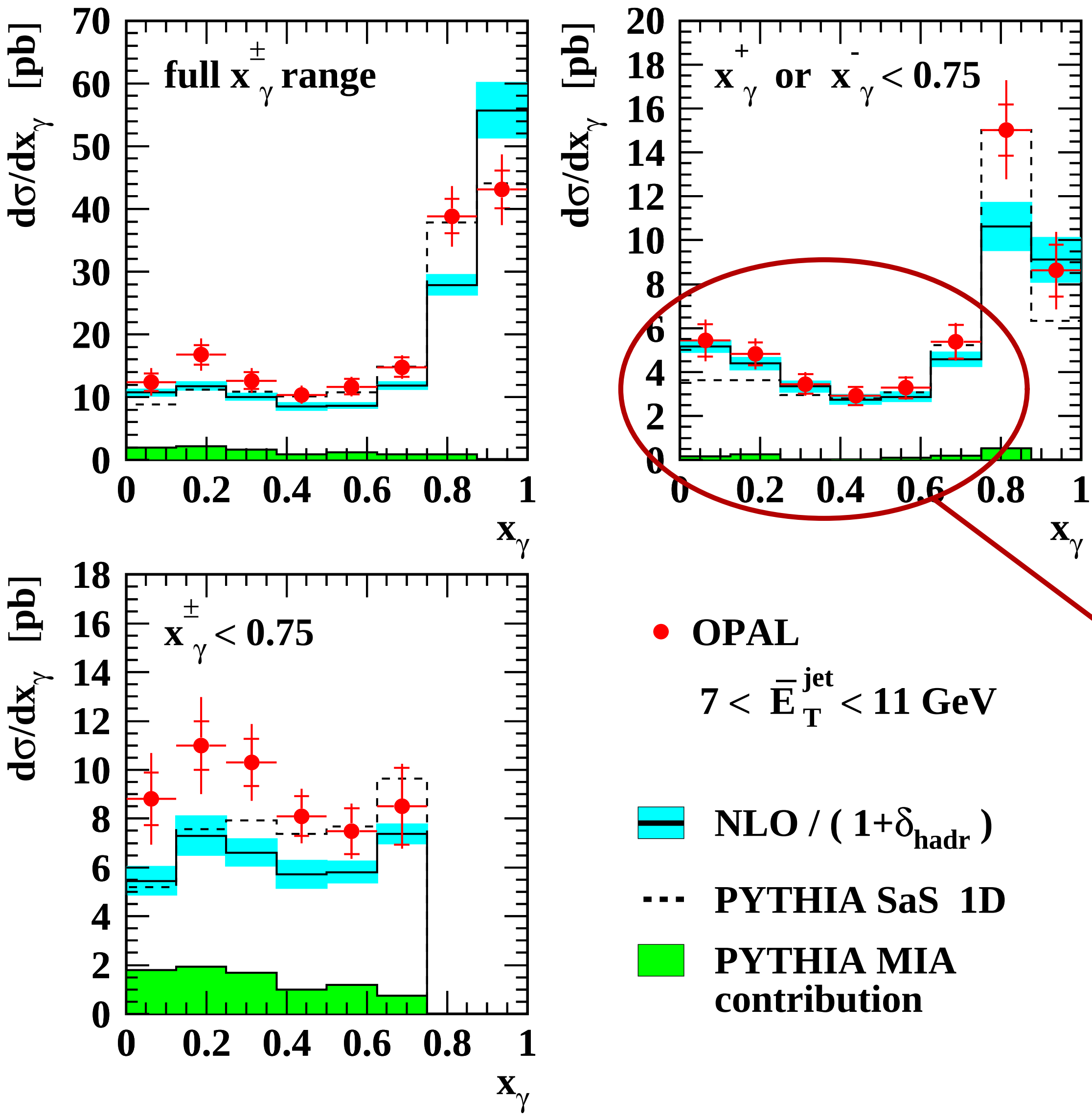
"single resolved enhanced"

But too low for

"double resolved enhanced"

Which might be due to . . .

The di-jet cross-section vs. x_γ

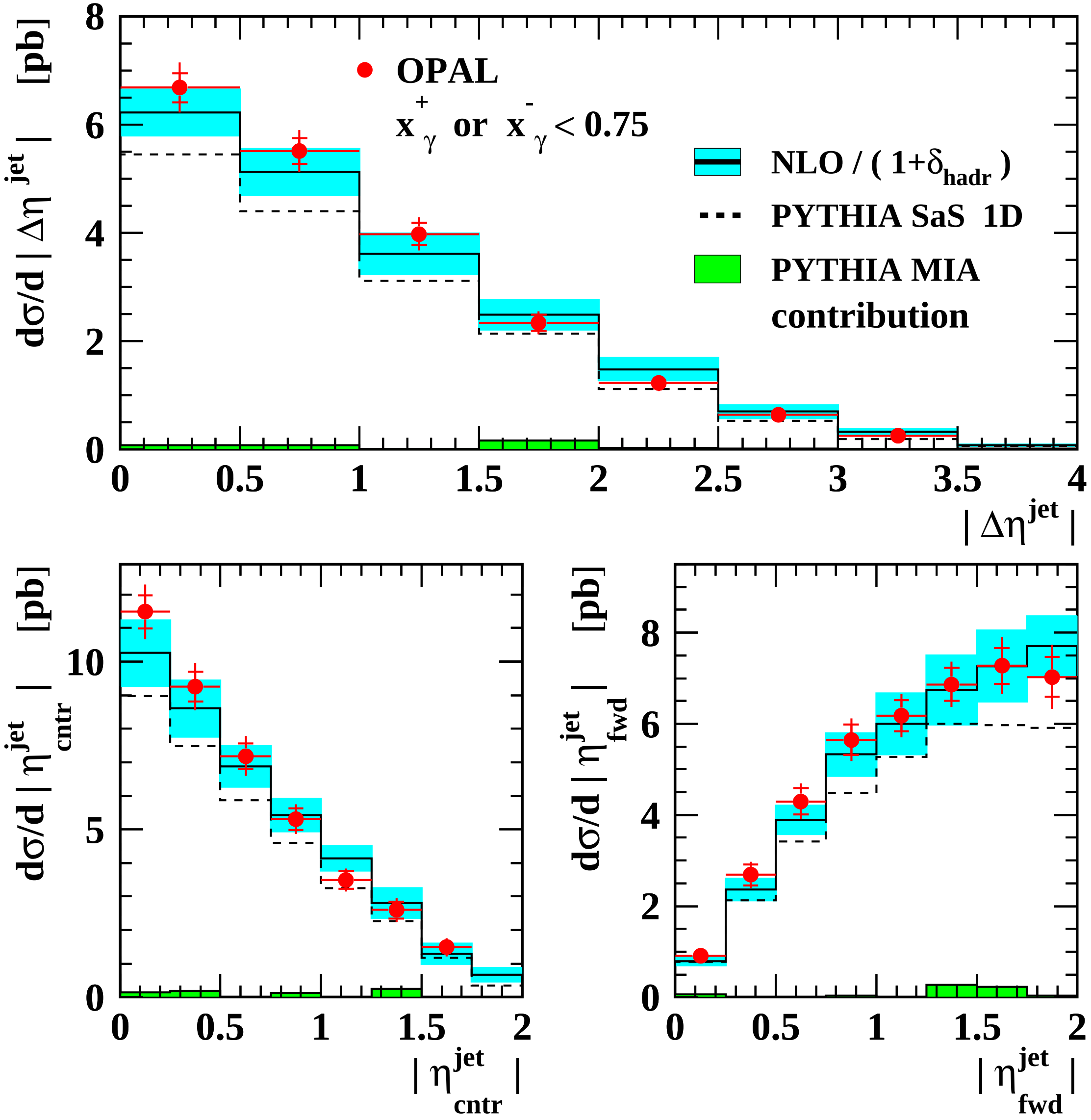


. . . MIA, which (PYTHIA says) are very small for single res. enhanced sample, as expected

Small hadronisation corrections and no disturbance from MIA

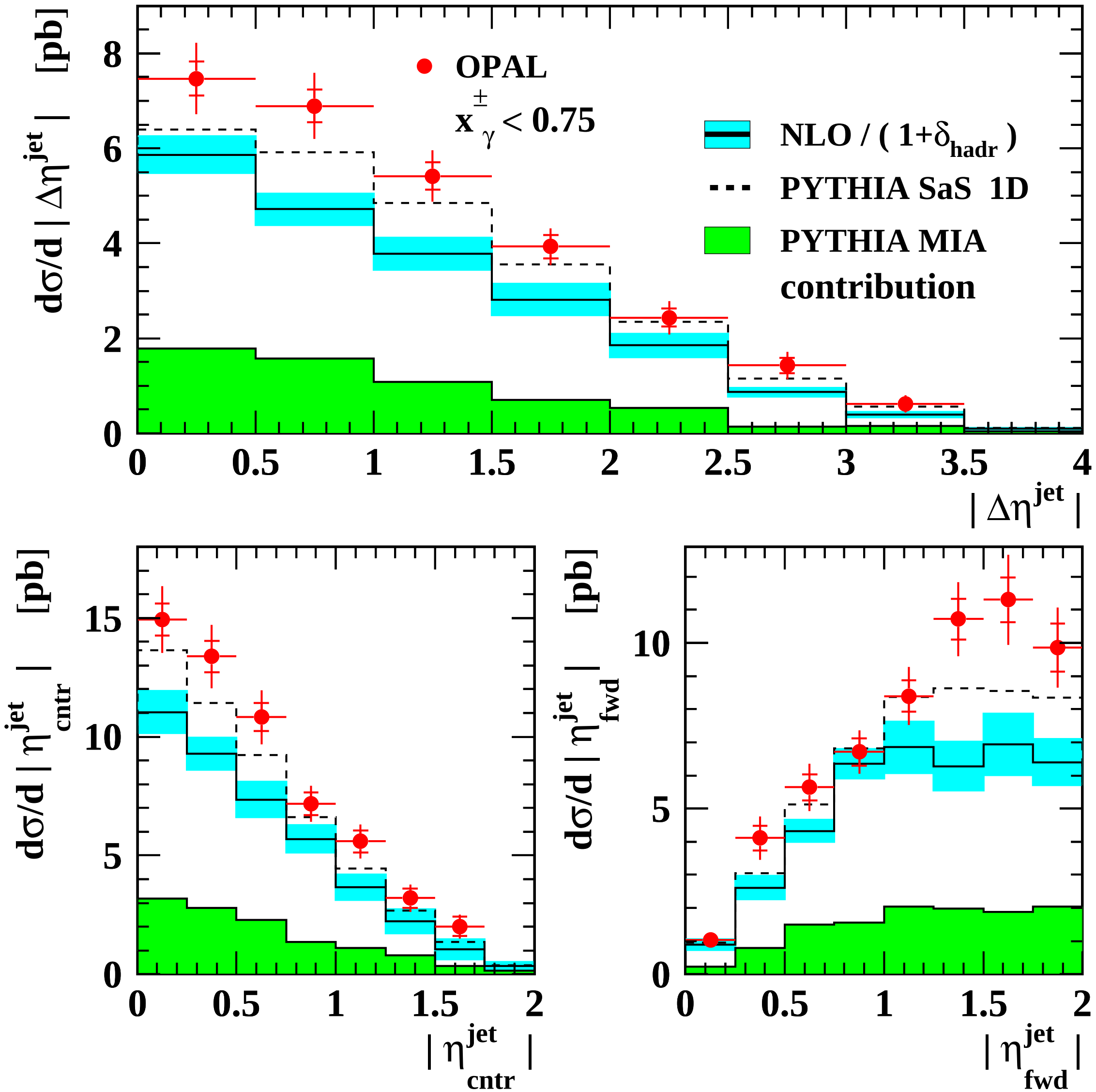
NLO should work here – and it does!

The di-jet cross-section vs. η for "single resolved enhanced" sample



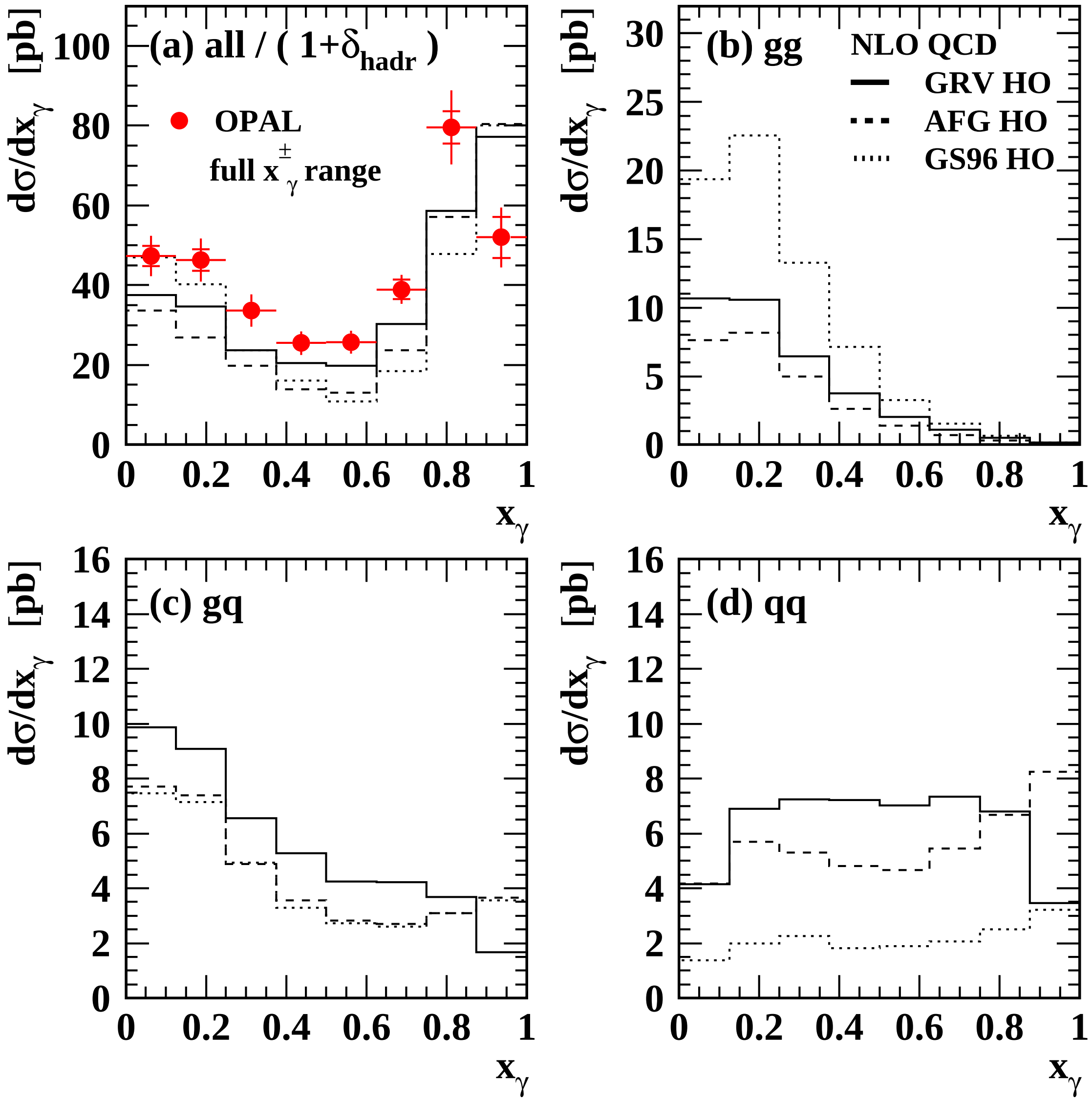
NLO describes "single resolved enhanced" sample well

The di-jet cross-section vs. η for "double resolved enhanced" sample



NLO everywhere too low for "double resolved enhanced" sample

The influence of the choice of PDF on NLO



Gluonic processes are very sensitive to the amount of glue at low x_g

But for the cross-section this is compensated by inverse behaviour of quark densities

Need global fit to fix both at the same time . . .

Conclusions

We have studied di-jet production in $593\,\mathrm{pb}^{-1}$ of data taken at $\sqrt{s}$ from 189 to 209 GeV

Quark and gluon dominated sub-samples are studied and show the behaviour expected from QCD for jet structure and angular distributions

Di-jet cross-sections are measured in regions with small and regions with large expected contributions from MIA

NLO QCD agrees well with the data in regions where it is expected to be reliable

Definition of di-jet cross-section observables

$$\frac{d\sigma_{\text{dijet}}}{d\bar{E}_T^{\text{jet}}} \quad \text{with } \bar{E}_T^{\text{jet}} \equiv \frac{E_{T,1}^{\text{jet}} + E_{T,2}^{\text{jet}}}{2} \text{ and } \bar{E}_T^{\text{jet}} > 5 \text{ GeV}$$

$$\frac{d\sigma_{\text{dijet}}}{dx_\gamma} \quad \text{in 3 bins of } \bar{E}_T^{\text{jet}}\, [5 - 7 - 11 - 25] \text{ GeV}$$

$$\frac{d\sigma_{\text{dijet}}}{d\log 10\,(x_\gamma)} \quad \text{for } 5 \text{ GeV} < \bar{E}_T^{\text{jet}} < 7 \text{ GeV}$$

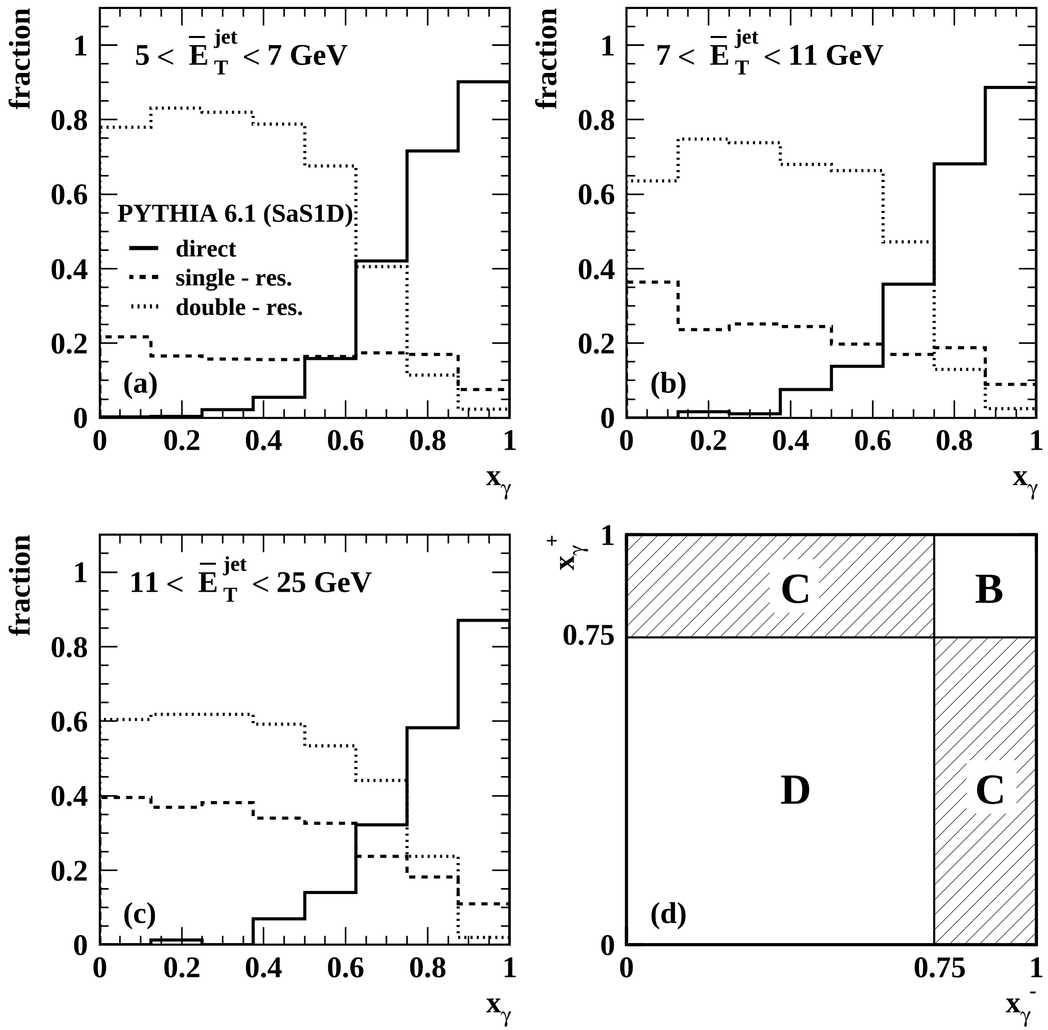
$$\frac{d\sigma_{\text{dijet}}}{d|\eta_{\text{cntr}}^{\text{jet}}|}, \frac{d\sigma_{\text{dijet}}}{d|\eta_{\text{fwd}}^{\text{jet}}|}, \frac{d\sigma_{\text{dijet}}}{d|\Delta\eta^{\text{jet}}|} \quad \text{for } \bar{E}_T^{\text{jet}} > 5 \text{ GeV}$$

$$\frac{d\sigma_{\text{dijet}}}{d|\cos\Theta^\star|} \quad \text{for } \bar{E}_T^{\text{jet}} > 5 \text{ GeV}, \ |\bar{\eta}^{\text{jet}}| < 1, \ M_{\text{jj}} > 15 \text{ GeV}$$

with in all cases

$$|\eta_{1,2}^{\text{jet}}| < 2 \quad \text{and} \quad \frac{|E_{T,1}^{\text{jet}} - E_{T,2}^{\text{jet}}|}{E_{T,1}^{\text{jet}} + E_{T,2}^{\text{jet}}} < \frac{1}{4}$$

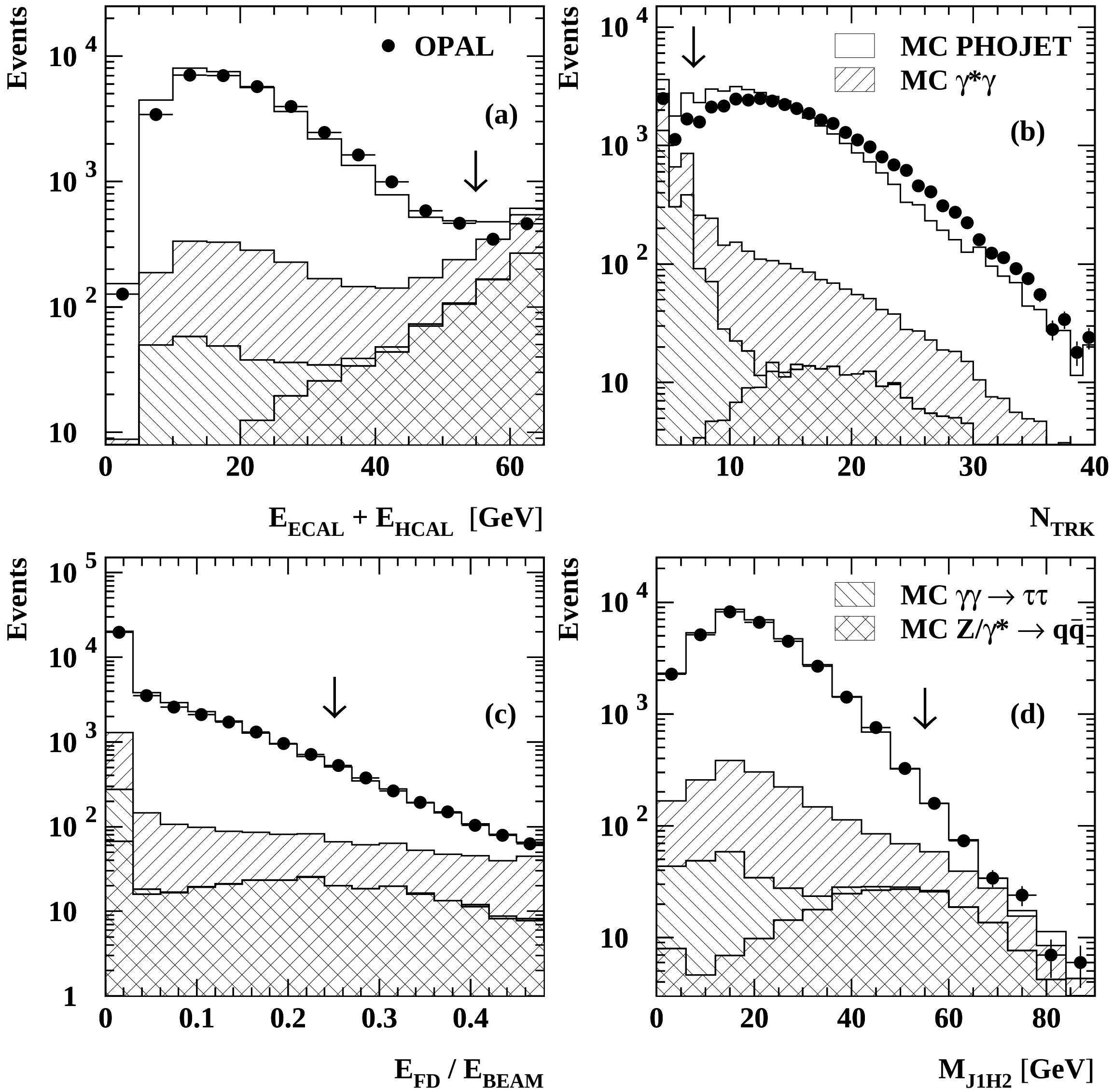
Resolved vs. direct event fractions



For higher jet energies the fraction of resolved events at low x_γ is still high

(but the cross section decreases)

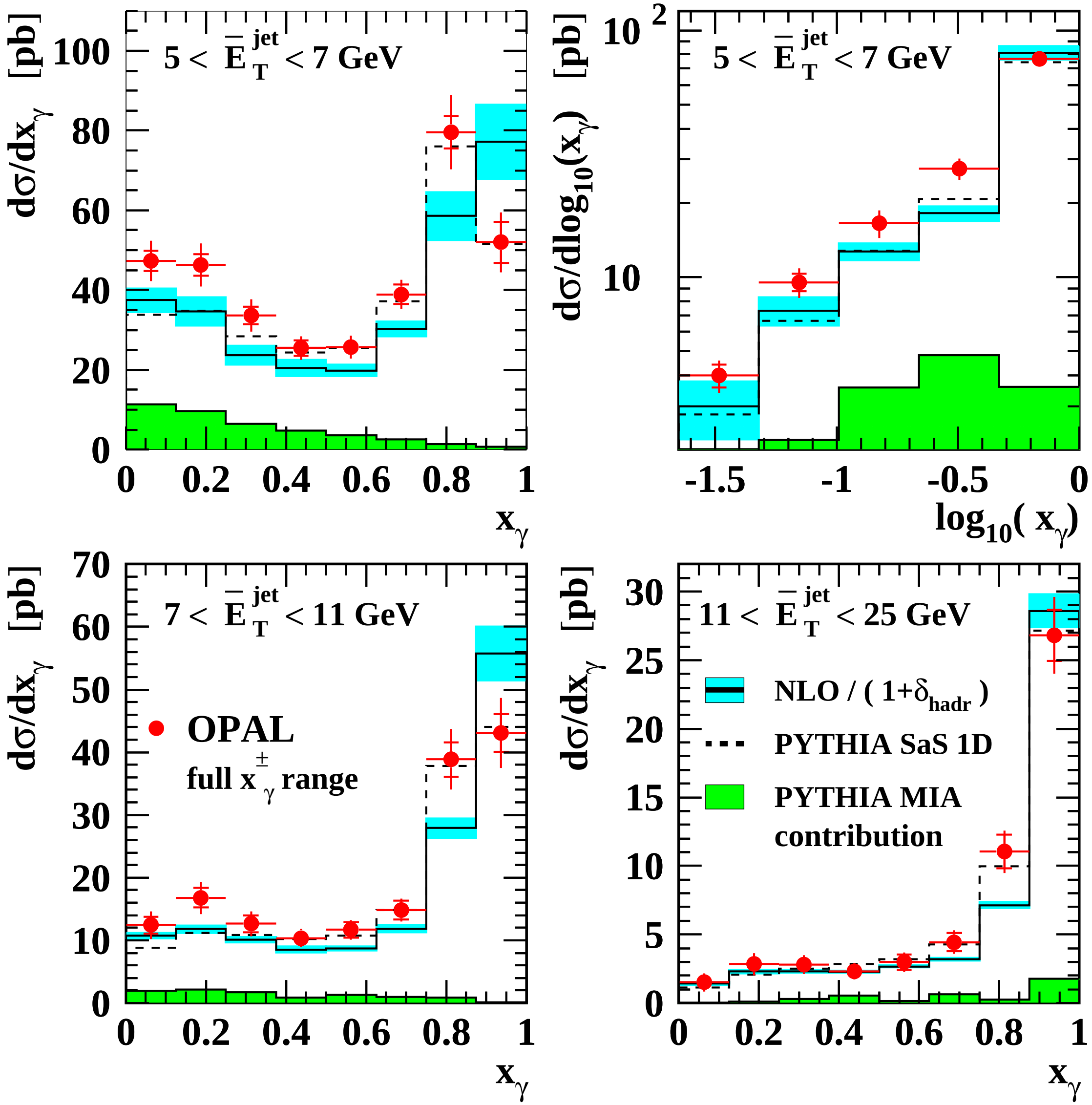
Selection of the $\gamma\gamma$ sample



The arrows indicate the cut value

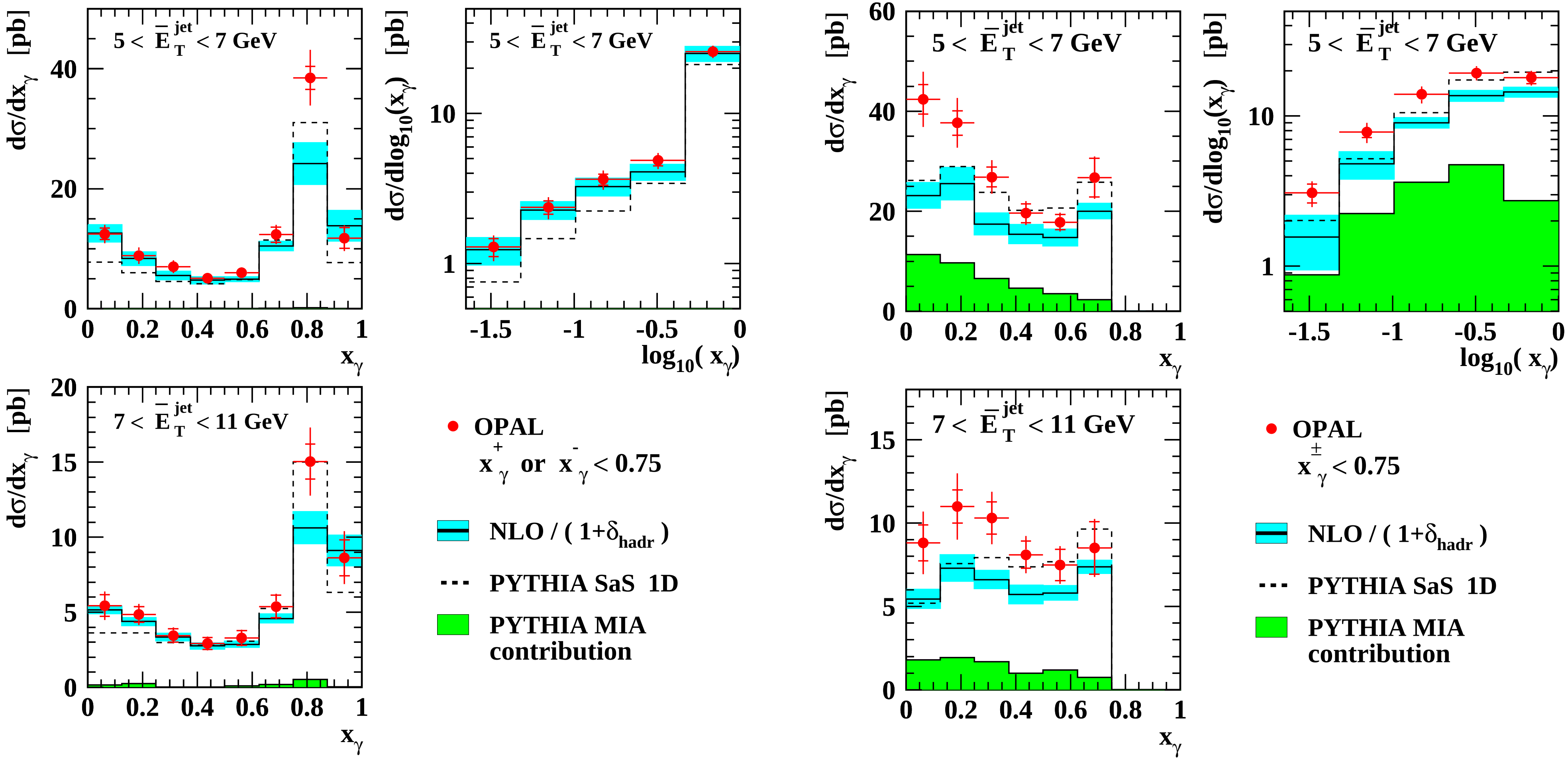
In each case all cuts are applied except on the quantity shown

The di-jet cross-section vs. x_γ



Measurement for the full x_γ^- - x_γ^+ - space

The di-jet cross-section vs. x_γ



"Single resolved enhanced"

"Double resolved enhanced"