Jet-gap-jet events at CMS

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QFTHEP '15
Jun 27, 2015

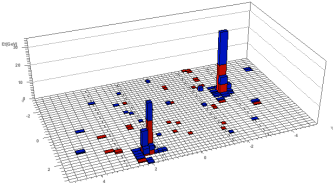
Overview

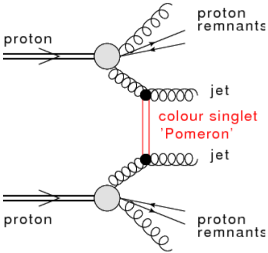
Jet-gap-jet event:

Parton scattering (2->2) through hard **color singlet exchange** [1]

Event signature:

- Two high p_T jets, separated by a large **rapidity gap**

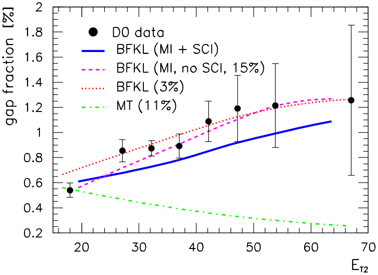




[1] A. Mueller, W. Tang, Phys. Lett. B284 (1992)

Motivation

- The absence of particles between the jets – signature of a diffractive process
- Four-momentum transfer squared is larger than in standard diffractive events
- Can be understood in BFKL-inspired pQCD approach to parton-parton scattering



D0 Collaboration, Phys. Lett. B440 (1998) 189;
R. Enberg, G. Ingelman, L. Motyka, Phys.Lett.B524:273-282,2002

The study of CSE events may allow:

→ to disentangle the BFKL dynamics from the DGLAP evolution;

→ to estimate the value of S^2 (gap survival probability): sensitive to the contribution from rescattering processes

Samples

Data:

- Run 2010 A,B
- $\sqrt{s} = 7$ TeV
- $L = 8\ pb^{-1}$
- low pile-up ($2 - 3$ interactions per bunch crossing)

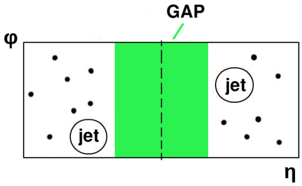
Monte Carlo (MC):

- Background: PYTHIA6 Tune Z2*
- Signal: HERWIG color singlet exchange
  (Mueller and Tang model, reweighted to reproduce rising of CSE contribution with jet p_T scale, observed in the data)

Measurement in three exclusive bins of p_T^{jet2} : $40 - 60, 60 - 100, 100 - 200\ GeV$

Selection cuts

Aim: study gap fraction, defined as $N_{events\_with\_gap}/N_{all\_dijet\_events}$, as function of p_T^{jet2} and $\Delta\eta$ between two leading jets.



Event selection:

- $N^{vtx} = 0$ *or* 1, $|z^{vtx}| < 24$ *cm*
- *at least 2 jets (R=0.5) in event*
- *two leading jets*

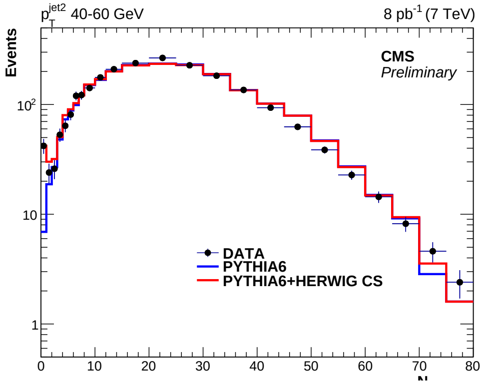
in different hemispheres
and $|\eta^{jet1,jet2}| > 1.5$

Gap definition:
fixed η window between two leading jets, devoid of charged particles.

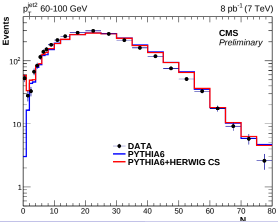
⇒ Looking for tracks in $|\eta| < 1$ window:

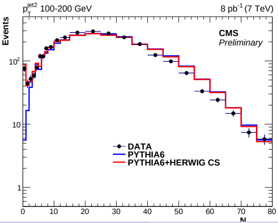
- $p_t > 0.2$ GeV
- standard CMS track quality requirements

Charged multiplicity in $|\eta| < 1$ window

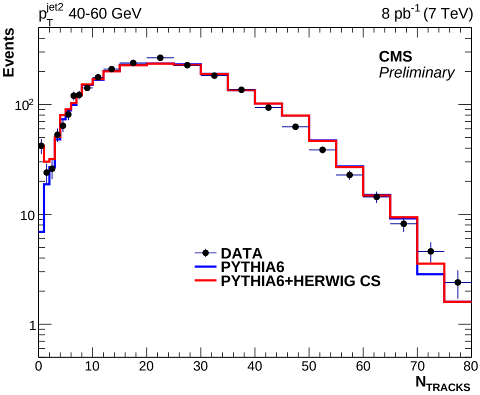


- excess of events in the lowest track multiplicity bins
- not described by PYTHIA6 (QCD background)
- addition of HERWIG color singlet MC (LL BFKL) $\rightarrow$ reasonable agreement





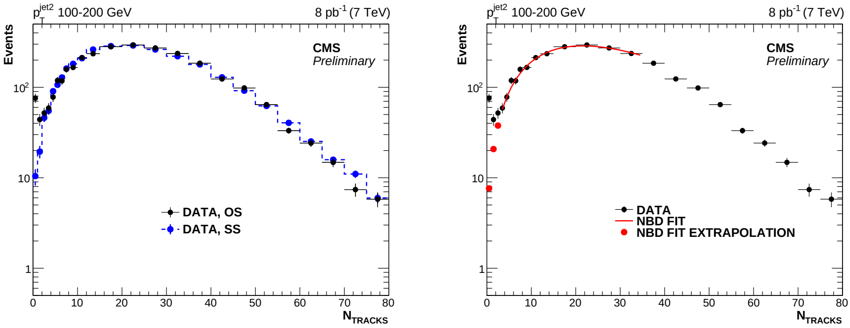
f_{CSE} definition



f_{CSE}:

ratio of event yields in first bins after background subtraction to total yield.

Background: QCD dijet events



- Several approaches to background estimation were tested:

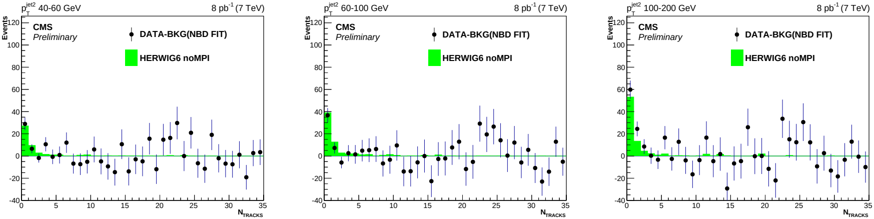
1) Data-driven: using orthogonal sample of dijet events – i.e. with 2 leading jets in the same hemisphere ('SS sample')

2) Negative Binomial Distribution fit (NBD) to the multiplicity tail extrapolated into the signal region

→ use NBD fit as the main approach; SS sample – for systematic check

Use HERWIG CS MC for guidance

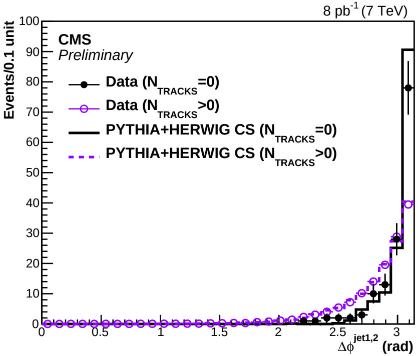
→ The signal MC includes simulation of MPI interactions (via JIMMY package)
⇒ Divide MC signal events into MPI/noMPI interactions subsamples.
Compare to the data after background subtraction (MPI subtracted).

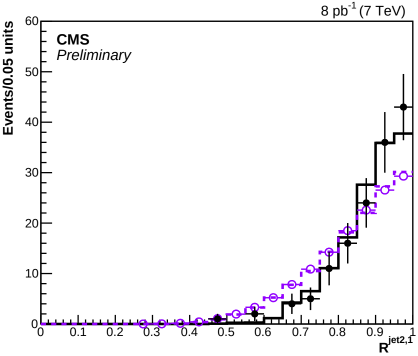


• Excess of signal over background prediction also in the 2nd multiplicity bin and also the 3rd bin for the highest p_T^{jet2} selection. The excess is described by HERWIG noMPI.

•**Signal is defined in 0-1 bins for** $p_T^{\mathrm{jet2}} = 40 - 60$ **and** $60 - 100$ **GeV and 0-2 bins for the** $p_T^{\mathrm{jet2}} = 100 - 200$ **GeV bin.**

0-multiplicity events: $\Delta\phi$ and $R = \frac{p_T^{jet2}}{p_T^{jet1}}$





- Data from 0-multiplicity bin for three p_T^{jet2} samples
- The peaks in the distributions at $\Delta\phi^{\mathrm{jet1,2}} = \pi$ and $\mathrm{R}^{\mathrm{jet2,1}} = 1$ are more pronounced for events with no tracks
- The CSE dijets are more balanced in azimuthal angle and momentum than the non-CSE ones.

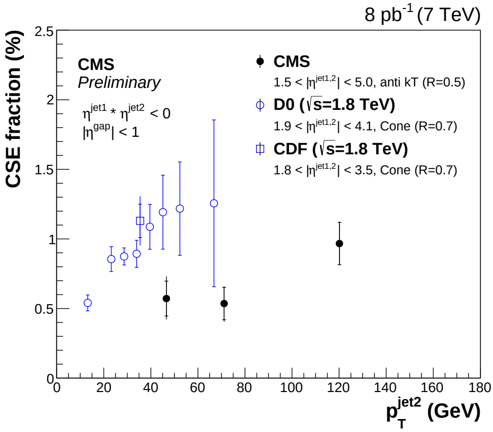
Systematic errors

Sources:

- **Background subtraction uncertainty**
- **Jet-energy scale (JES) uncertainty**
- Track p_T threshold
- Track quality

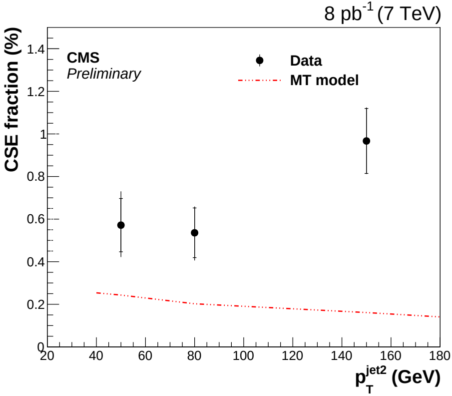
• Results are presented as fractions: many systematic uncertainties cancel in the ratio — hence systematic uncertainties smaller than statistical ones
• The average systematic uncertainty in the f_{CSE} vs p_T^{jet2} measurement is **10-15**%.

f_{CSE} vs p_T at CMS compared to the earlier data



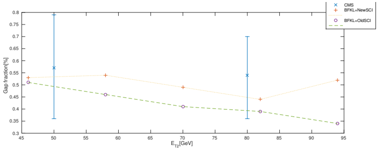
- A suppression of the CSE fraction measured at $\sqrt{s} = 7$ is observed with respect to those at lower energies
- behavior is in agreement with observations reported by D0 and CDF: the gap fraction decreases by a factor of 2.5 ± 0.9 and 3.4 ± 1.2, respectively, when $\sqrt{s}$ increases from 0.63 TeV to 1.8 TeV.

f_{CSE} vs p_T

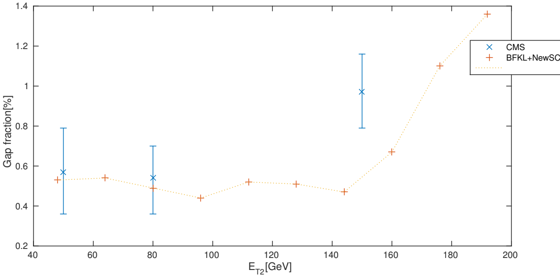


- Modest increase with p_T
- Comparison with the theoretical prediction of the Mueller and Tang model (no simulation of MPI).
- The gap fractions are plotted relative to the standard LO QCD dijet production, calculated with PYTHIA6-Z2*.
- The MT prediction does not reproduce the rising behavior of f_{CSE} with p_T^{jet2}, as already observed for the 1.8 TeV data. It also underestimates the fractions.

f_{CSE} vs p_T: BFKL+updated SCI model



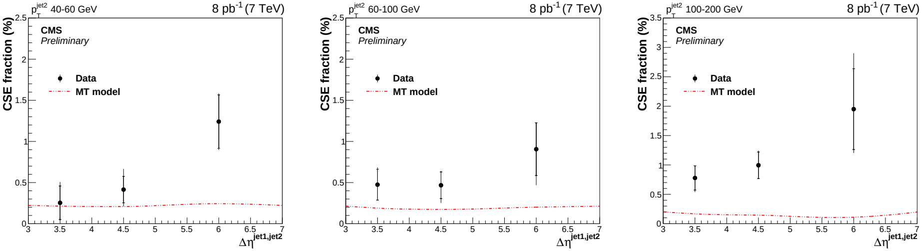
(a) $100 > E_{T2} > 40\text{GeV}$



- Preliminary results by A. Ekstedt, R. Enberg, G. Ingelman and L. Motyka – *private communication*
- **BFKL equation solved numerically at NLL**[2]
- **Soft color interaction model (SCI)**: color transfer via very soft gluon exchanges between partons (old SCI) or strings (new SCI; more color screening, smaller suppression)
- For large p_T scales the old SCI model destroys too many gaps
- $\Rightarrow$ modified SCI model — relatively good description of the gap fraction distribution as a function of p_T

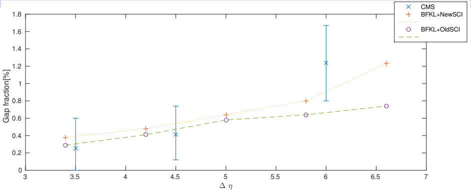
[2] R. Enberg, G. Ingelman and L. Motyka, Phys. Lett. B 524, 273 (2002) [hep-ph/0111090]

f_{CSE} vs $\Delta\eta^{jet1,jet2}$

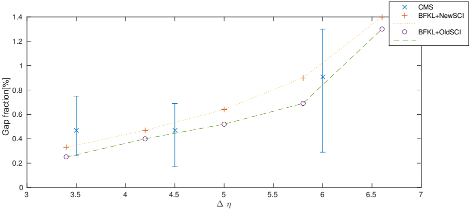


- The gap fraction increases with $\Delta\eta_{\mathrm{jj}}$, although uncertainties are large at high $\Delta\eta$.
- The data are compared with the prediction of the MT model
- The MT model does not reproduce the growth of f_{CSE} with $\Delta\eta_{\mathrm{jj}}$, and underestimates the measured gap fractions.

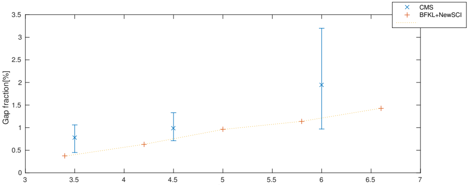
f_{CSE} vs $\Delta\eta^{jet1,jet2}$: BFKL+updated SCI model



(a) $60 > E_{T2} > 40$GeV



(b) $100 > E_{T2} > 60$GeV



- Both of the SCI implementations provide a good description of f_{CSE} vs $\Delta\eta$

Summary:

• The fraction of dijet events with a rapidity gap to all dijet events has been measured as a function of the second leading jet p_T^{jet2} and as a function of the size of the pseudorapidity interval between the jets $\Delta\eta_{\mathrm{jj}}$.

The measured CSE fractions are compared

• to the results of the D0 and CDF collaborations, obtained at center-of-mass energies of 0.63 and 1.8 TeV.

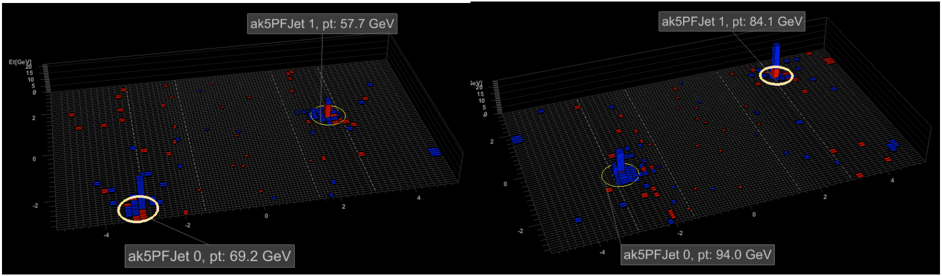
$\rightarrow$ A suppression of the CSE fraction measured at $\sqrt{s} = 7\ TeV$ is observed with respect to those at lower energies — a behavior consistent with the suppression seen in the Tevatron data when the center-of-mass energy rises from 0.63 TeV to 1.8 TeV.

• to the Mueller and Tang (LL BFKL) model predictions

• to the 'numerical NLL BFKL+updated SCI' model predictions

• More models coming (including NLL BFKL calculations by Kepka, Marquet, Royon (Phys. Rev. D83 (2011) 034036))

BACKUP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ak5PFJet 0, pt: 69.2 GeV
ak5PFJet 1, pt: 84.1 GeV
ak5PFJet 0, pt: 94.0 GeV