DPE $H \longrightarrow b\bar{b}$ studies

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19. 10. 2007, Diffraction at LHC, Kraków

Outline

1. Exclusive DPE Higgs boson production
2. Background
3. Used cuts and generator comparison
4. Results and conclusions

Peoples working on $H \longrightarrow b\bar{b}$

- Four studies about $H \longrightarrow b\bar{b}$ so far:
  - A. Pilkington (Manchester): estimates based on counting probabilities + MC simulations on generator level,
  - M. Taševský (Prague): MC simulations on detector level (fast CMS simulation),
  - A. Pal (UTA): MC simulations on detector level (fast Altas simulation),
  - V. Juránek (Prague): MC simulations on detector level (fast Atlas simulation).
- Review talk of this studies (except Arnab's final results, not available yet).

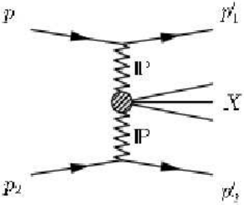
Double pomeron exchange

- pp$\rightarrow$p+gap+X+gap+p (at higher luminosities there will be no rapidity gaps because of pile-up).
- Both protons remain intact, momentum loss of protons during interaction used to create central object/system.
- Proton energy lost can be measured:

$$\xi = 1 - \frac{p'_z}{p_z}.$$

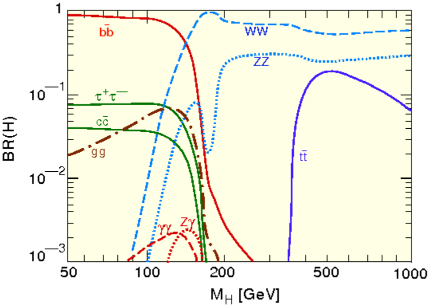
- If both protons are detected in RP, we have a constraint on central object mass and rapidity:

$$M_X \simeq \sqrt{\xi_1 \xi_2 s}$$
$$y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}.$$



$H \longrightarrow b\bar{b}$

- $H \rightarrow b\bar{b}$ channel is very interesting for Higgs mass around 120GeV.
- H decay mostly (68%) into $b\bar{b}$ for $M_H = 120GeV$.
- "Standard" $H \rightarrow b\bar{b}$ is not possible to detect due to very huge $b\bar{b}$ background.
- For $M_H = 120GeV$ the possible "standard" channels like as $\tau^+\tau^-$ or $\gamma\gamma$ are the difficult ones - others channels (like this diffractive one) are welcomed.



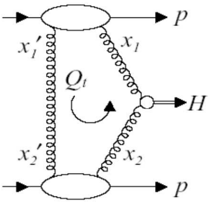
Exclusive DPE Higgs boson production

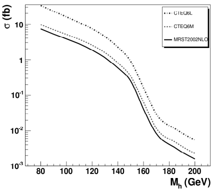
Advantages:

- Precise measurement of Higgs mass.
- Good signal background ratio ($\frac{H \to b\bar{b}}{gg \to b\bar{b}}$ better in diffractive processes than in non-diffractive).

Disadvantages:

- Small cross section (units of fb).
- Sensitive on pile-up (more hits in RP) from other soft diffractive events.





Andy [1]

Exclusive and Inclusive DPE Background

Exclusive:

- $gg \to b\bar{b}$
  - The same behavior as signal.
  - The most important background at low luminosities.
  - Suppressed by factor $\frac{m_b^2}{M_{jj}^2}$.
- $gg \to gg$
  - Due to mis-tagging gluon jets as b-jets.
  - Expected mis-tag of gluon jet as b-jet is (at Atlas) of 1.3% for a 60% b-jet efficiency.

Inclusive:

- $pp \to p + A + X + p$
  - X is $b\bar{b}$ dijet, A pomeron remnants.
  - Almost completely suppressed by cuts on exclusivity.
  - Strongly depends on PDF which is not very well known (especially for high β).

Cross sections

- Two MC generators were used: Dpemc and Exhume.
- In Dpemc, Bialas-Landshoff model was used.
- For KMR model used Exhume implementation.

$H \rightarrow b\bar{b}$

- There are uncertainties in this cross section 1-10fb.
- Dpemc σ = 2.0 *fb*.
- Exhume σ = 1.9 *fb*.

Exclusive DPE $b\bar{b}, p_T^{min} = 30GeV$

- Dpemc σ = 520 *fb*.
- Exhume σ = 269 *fb*.

Exclusive DPE $gg, p_T^{min} = 30GeV$

- Exhume $\sigma = 1.22 \cdot 10^6 fb$.

Inclusive DPE $q\bar{q}$.

- Dpemc $\sigma = 5.5 \cdot 10^4 pb$.

Pile-up

- Overlap of three events: normal QCD di-jet production and two single diffraction events (which cause hit in both sides of RP).
- In general three types:
  - $[p][X][p]$: hard event + two soft diffractions,
  - $[pX][p]$: one hard diffraction + one soft diffraction,
  - $[pp][X]$: double diffraction + hard event.
- At high luminosities the most dangerous background is $[p][X][p]$:
  - $[p][X][p]$ grows quadratically with luminosity,
  - $[pp][X]$ grows linearly with luminosity,
  - $[pX][p]$ is suppressed by gap survival probability (with comparison to $[p][X][p]$).

Pile-up

- Cross section for pile-up (used by A. Pilkington)

$$\sigma_{pile-up} = (N-1)(N-2)P_1P_2Q\sigma, \tag{1}$$

  where
  - N is average number of interactions in bunch crossing,
  - P_1 resp. P_2 probabilities of production single diffractive event which cause hit in left resp. right RP,
  - Q rejection factor from matching di-jet vertex with proton vertex,
  - σ di-jet cross section.
- P_1 and P_2 calculated from the single diffractive cross section (KMR: hep-ph/0609312) or simulated by MC.
- $P_i = 0.85\%$ for FP420 and 3% for RP220.

Timing Detector

- Number of hits of pile-up in RP in bunch crossing can be expressed as:

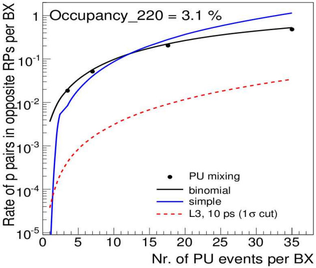
$$N^{RP}(simple) = N^{PU} \cdot (N^{PU} - 1) \cdot Acc^2 \quad (2)$$

or more precisely (A. Kupčo):

$$N^{RP}(binomial) = 2e^{-\mu}(\cosh \mu - 1) + 1 + e^{-\mu_{LR}}, \quad (3)$$

where

- $\mu = Acc \cdot N^{PU}$
- $\mu_{LR} = Acc \cdot N^{PU}$



Alexander and Marek [3]

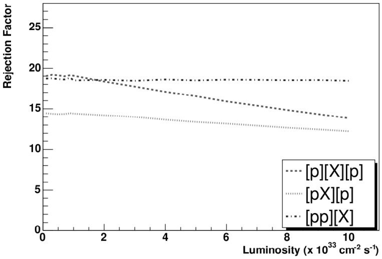
Timing Detector

- Hits in both sides of roman pots.
- Z coordinate of vertex position can be computed as

$$z_{pp} = c\frac{t_L - t_R}{2}, \tag{4}$$

where t_L resp. t_R is time of flight to left resp. right RP.

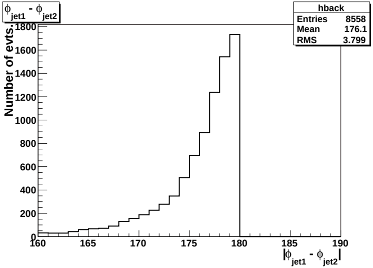
- By matching of this z_{pp} position with z_{hard} position of hard vertex pile-up background can be significantly suppressed.
- The event is rejected if z_{pp} is outside $z_{hard} \pm 2\sigma$, where σ is resolution in z direction of timing detector.
- Suppression factor depends on time resolution of the detector but not so much on luminosity:



Rejection factor for 10ps resolution and 2σ cut, Andy[1]

Jet cuts

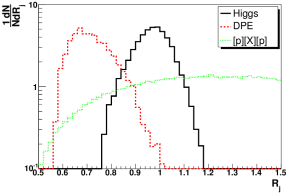
- Detector acceptance cuts:
  - Two jets, $p_T^{bjet1} > 45GeV$, $p_T^{bjet2} > 30GeV$.
  - Jets must be central ($|\eta| < 2.5$).
- Both jets are b-jets (b-tagging efficiency is $\sim$ 60% $=>$ two b-jets $\sim$ 36%).
- Jets are back-to-back ($170 < \phi_{bjet1,bjet2} < 180$).



Exclusivity Cuts

R_j and R_{jj} cuts:

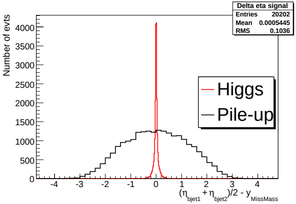
- $M_X \simeq \sqrt{\xi_1 \xi_2 s}$ mass of central object.
- $R_{jj} = \frac{M_{dijet}}{M_X}$
- $R_j = \frac{2E_T^{jet1}}{M_X} cosh(\eta^{jet1} - y_X)$, $y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$
- $0.8 < R_{jj} < 1.2$
- $0.8 < R_j < 1.1$



Andy[4]

$\Delta\eta$ cut:

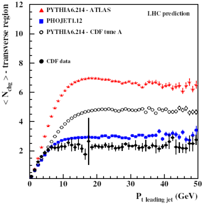
- Cut on $\Delta\eta = (\eta_{bjet1} + \eta_{bjet2})/2 - y_X \approx 0$
- y_X is rapidity of central object, $y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$
- Cut $|\Delta\eta| < 0.1$

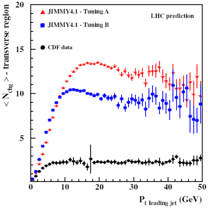


- Other 2 exclusivity cuts (on p_x and p_y) weren't used because of background has very similar distributions of this quantities.

N_C and $N_C^{\perp}$ Cuts

- Cut on number of charged particles (tracks) coming from primary vertex.
- N_C is number or charged particles outside dijet (outside cone with some radius around dijet axis).
- $N_C^{\perp}$ is number of charged particles outside of dijet but transverse to the leading jet.
- By transverse is meant that $\frac{\pi}{3} < |\phi_{track} - \phi_{jet1}| < \frac{2\pi}{3}$ or $\frac{4\pi}{3} < |\phi_{track} - \phi_{jet1}| < \frac{5\pi}{3}$.
- Considered only tracks from primary vertex.
- Rejection factor is almost independent of number of interaction in bunch crossing (M. Taševský, V.J.)
- Very important to tune MC - completely different results for various Monte Carlos.
- Full simulation is needed.





Hera-LHC

N_C and $N_C^{\perp}$, no pile-up

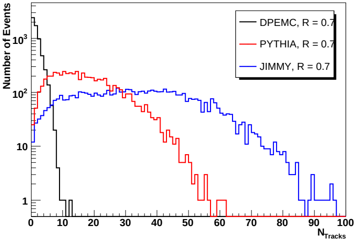
Cuts:

- $N_C < 4 \wedge N_{C\perp} < 3$
- $p_T^{Track} > 0.5$GeV (for Atlas)

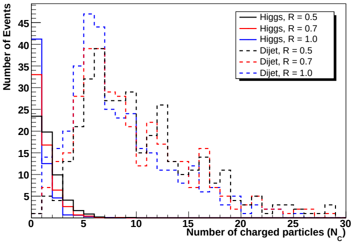
Choice of R:

- Cone radius R = 0.7.
- However cut is not very sensitive on choice of R.

Number of events outside dijet:



Number of events outside dijet for various R:



Comparison of results

- Results cut 3.5 interaction in bunch crossing and integrated luminosity $30fb^{-1}$:
- Andy: MC on generator level, Atlas accept.
- Vojtěch: Atlas accept.
- Marek: CMS accept.

Process	Andy		Vojtěch		Marek
	5mm dist. from bean	3 mm dist. from bean	Dpemc	Exhume	
$H \to b\bar{b}$	1	3.45	2.8	2.8	1.5
$gg \to b\bar{b}$	2	6	11	8	5
$gg \to gg$	3	8	-	2 (not final result)	-
$Pile - up$	0.4	1.3	1 (Pythia)	0 (Jimmy)	11
$Inclusive\ q\bar{q}$	$\simeq 0$	$\simeq 0$	$\simeq 0$	-	$\simeq 0$

- Quite good agreement.
- Differences can be explained by:
  - Different considered acceptances (main reason).
  - Different approaches.
  - Slightly different cuts setting.
  - Slightly different mass resolution of the detector.

Pile-up+$b\bar{b}$ background (3.5 int. in bunch crossing)

Acceptance factors for cut flow (by V.J.)

DPE $H \longrightarrow b\bar{b}$	**Kin.**	**B-jets**	**RP accept**	**back to back**	R_j
Dpemc	0.42	0.35	0.68	0.88	0.87
Exhume	0.38	0.36	0.76	0.87	0.88

η	$N_C \wedge N_C^{\perp}$	**mass window**
0.94	0.97	0.68
0.94	0.97	0.68

DPE $b\bar{b}$	**Kin.**	**B-jets**	**RP accept**	**back to back**	R_j
Dpemc	0.09	0.36	0.76	0.86	0.79
Exhume	0.04	0.4	0.71	0.9	0.67

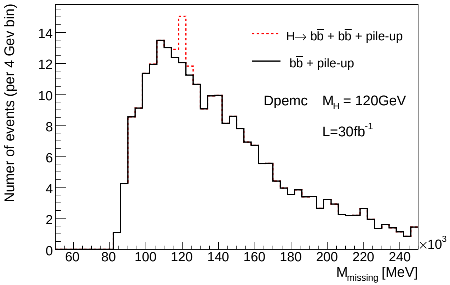
η	$N_C \wedge N_C^{\perp}$	**mass window**
0.92	0.95	0.05
0.95	0.96	0.04

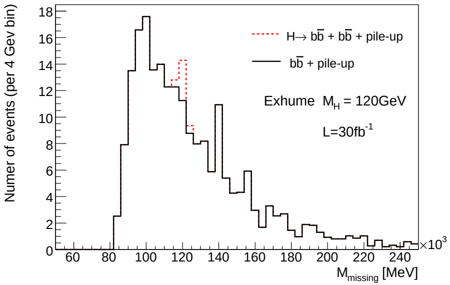
Pile-up	**Kin.**	**B-jets**	**RP accept**	**back to back**	R_j
Herwig	0.17	0.075	0.005	0.37	0.114
Pythia	0.21	0.32	0.005	0.53	0.11
Jimmy	0.21	0.074	0.005	0.37	0.12

η	$N_C \wedge N_C^{\perp}$	**mass window**
0.054	0.117	0
0.054	0.07	0.021
0.056	0.026	0

Pile-up and $b\bar{b}$ background (Pythia DWT)

- Exclusive Higgs boson production.
- Exclusive $b\bar{b}$ production.
- Pile-up+dijet (2 b-jets from non-difractive event (Pythia) + hits in RP from pile-up, 3.5 interactions in bunch crossing).





Conclusions

- Results are in quite good agreement.
- It is expected about 2-3 events of signal and 10-15 events of background for low luminosity ($1 \cdot 10^{33} cm^{-2} s^{-1}$), integrated luminosity of $30 fb^{-1}$ (3 years of data taking at low luminosity) and $1 - 2\%$ resolution of the detector in mass.
- Physical cuts (exclusivity, N_C) kill only small amount of signal.
- Signal is mostly killed due to detector acceptance and b-tagging.
- Huge differences between generators.
- The generators must be tuned - first data from LHC are needed.

References

- B. Cox, K. Loebinger, A. Piklington; arXiv:0709.3035 [hep-ph]
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- M. Taševský; presentation at Hera-LHC workshop 2007 (http://indico.cern.ch/conferenceDisplay.py?confId=11784)
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- A. Pal, V. Juránek: Atlas note - in preparation