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

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Outline

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

- Studies about $H \rightarrow b\bar{b}$ so far:
  - A. Pilkington (Manchester): estimates based on counting probabilities + MC simulations at generator level + smearing (JHEP0710:090,2007),
  - M. Taševský (Prague): MC simulations at detector level - fast CMS simulation (CERN-LHC 2006-039/G-124),
  - V. Juránek (Prague): MC simulations at detector level - fast Atlas simulation, acceptance RP220 + FP420,

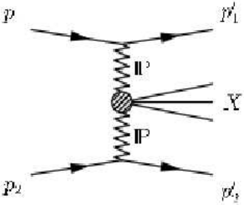
Double pomeron exchange

- 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:

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

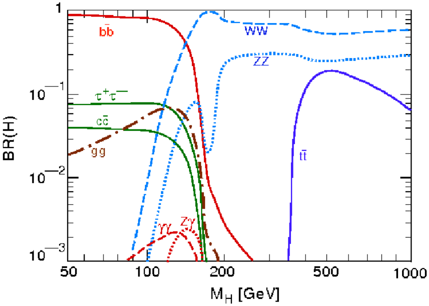
- If both protons are detected in forward proton detectors (FPDs), we have a constraint on central object mass and rapidity:

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



$H \longrightarrow b\bar{b}$

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



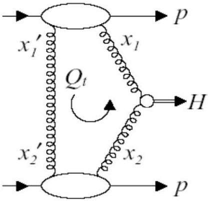
Exclusive DPE Higgs boson production

Advantages:

- Precise measurement of Higgs mass ($M_H \simeq \sqrt{\xi_1 \xi_2 s}$).
- 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 to pile-up (more hits in FPDs) from other soft diffractive events.



Exclusive and Inclusive DPE Background

Exclusive:

- $gg \rightarrow b\bar{b}$
  - The same behavior as signal.
  - $J_Z = 0$ selection rule (suppressed by factor $\frac{m_b^2}{M_{jj}^2}$).
- $gg \rightarrow gg$
  - 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:

- $pp \rightarrow p + A + X + p$
  - X is $b\bar{b}$ dijet, A pomeron remnants.
  - Strongly suppressed by new PDF from Hera.
  - Could be suppressed by exclusivity cuts.

Cross sections

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

$H \to b\bar{b}$

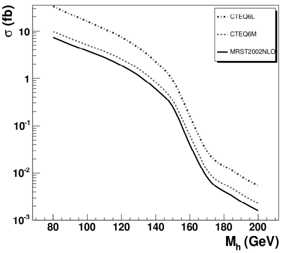
- There are uncertainties in this cross section 1-10fb.
- Exhume $\sigma^{(NLO)}_{H \to b\bar{b}} = 1.9\ fb$ (Dpemc $\sigma = 2.0\ fb$).

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

- Exhume $\sigma^{(LO)}_{b\bar{b}} = 269\ fb$ (Dpemc $\sigma = 520\ fb$).

CEP $gg, p_T^{min} = 30GeV$

- Exhume $\sigma^{(LO)}_{gg} = 714 \cdot 10^3 fb$ (probability to identify gluon jet as b-jet in Atlas is $\simeq 0.013$ $\Rightarrow \sigma_{gg}(misstag) \simeq 120fb$).



A.Pilkington [1]

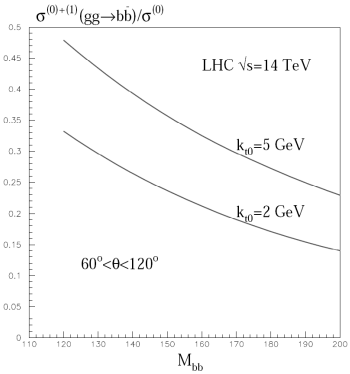
Inclusive DPE $q\bar{q}$.

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

$b\bar{b}$ background cross section

- Recent study by A. Shuvaev and KMR group about one loop $gg \to b\bar{b}$ effects, arXiv:0806.1447 [hep-ph]

- Recommend choice of IR cutoff $k_{t0} = 5\text{GeV}$ (for smaller value of cutoff the suppression is stronger, but signal is also suppressed in the same way).



- For this choice of the cutoff, cross section for $b\bar{b}$ around $M_{bb} = 120\text{GeV}$ is two times smaller (with comparison to Born level approximation).

Pile-up

- Overlap of three events: non-diffractive QCD di-jet production and two single diffraction events (which cause hit on both sides of FPDs).
- 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 $[p][X][p]$).

Timing Detector

- Number of fake proton pairs seen on opposite FPDs per bunch crossing can be expressed as:

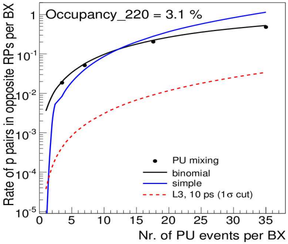
$$N^{RP}(simple) = N^{PU} \cdot (N^{PU} - 1) \cdot Acc^2 \qquad (1)$$

or more precisely (A. Kupčo):

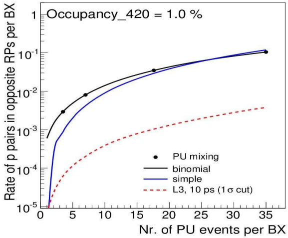
$$N^{RP}(binomial) = 2e^{-\mu}(\cosh\mu - 1) + 1 - e^{-\mu_{LR}}, \qquad (2)$$

where

- $\mu = Acc \cdot N^{PU}$, $Acc(220) \approx 3.1\%$, $Acc(420) \approx 1.0\%$,
- $\mu_{LR} = Acc_{LR} \cdot N^{PU}$, $Acc_{LR}(220) \approx 0.3\%$, $Acc_{LR}(420) \approx 0.05\%$



A. Kupco and
M. Tasevsky [4]



Timing Detector

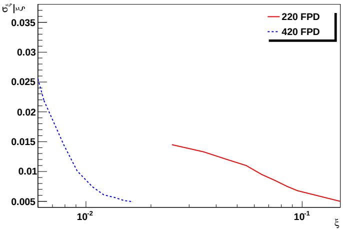
- Hits in both sides of FPDs.
- Z coordinate of vertex position can be computed as

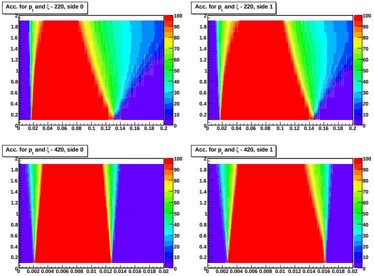
$$z_{pp} = c\frac{t_L - t_R}{2}, \tag{3}$$

  where t_L resp. t_R is time of flight to left resp. right FPD.
- By matching of this z_{pp} position with z_{hard} position of hard vertex the 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.
- Considered pile-up suppression factor for this study was 40, which corresponds to $\simeq$ 5ps resolution.
- Suppression factor depends on time resolution of the detector but not so much on luminosity.

Simulation of diffractive protons

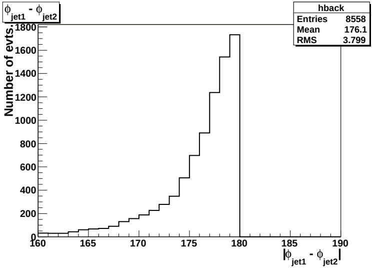
- Based on simulation done by Peter Bussey using FPTrack.
- Considered configuration for forward proton detectors (FPD): 220 FPD 20σ (2mm) far from beam, 420 FPD 16σ (4mm) far from beam.
- The resolution of the fractional momentum loss ξ, of protons tagged in the FPDs on Fig. on the left.
- Acceptances for FPDs at 220m and 420m from IP in ξ, t plane on Fig. on the right.





Acceptances and jet cuts

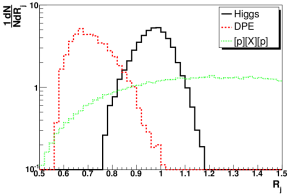
- RP acceptances for protons: previous slide.
- Detector acceptance cuts for jets:
  - Two jets, $p_T^{bjet1} > 45GeV$, $p_T^{bjet2} > 30GeV$.
  - Jets must be central ($|\eta| < 2.5$).
- Both jets are b-jets (b-tagging efficiency is $\sim 60\% => $ two b-jets $\sim 36\%$).
- Jets are back-to-back ($170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



Exclusivity Cuts

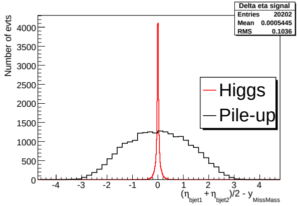
R_j and R_{jj} cuts:

- $M_X \simeq \sqrt{\xi_1 \xi_2 s}$ mass of central object.
- $R_{jj} = \frac{M_{dijet}}{M_X}$
- $R_j = \frac{2E_T^{jet1}}{M_X} cosh(\eta^{jet1} - y_X),\ y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$
- R_j has very similar rejection factor as R_{jj}
  - $0.75 < R_j < 1.2$
  - $0.8 < R_{jj} < 1.2$
- R_j is not so sensitive on QCD bremsstrahlung, hadronization effect etc.



A.

Pilkington [5]



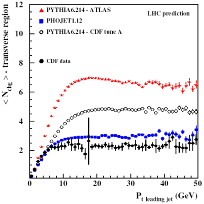
$\Delta\eta$ cut:

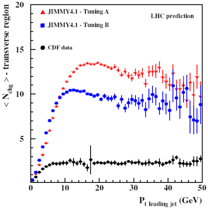
- y_X is rapidity of central object, $y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$
- Cut on $\Delta\eta = (\eta_{bjet1} + \eta_{bjet2})/2 - y_X \approx 0$
  - Cut $|\Delta\eta| < 0.06$ (1σ cut for Exhume, for Dpemc 1σ cut is 0.1).

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

N_C and $N_C^{\perp}$ Cuts

- Cut on number of charged particles (tracks) coming from primary vertex (requirement of rapidity gap).
- N_C is number of 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.
- Transverse mean $\frac{\pi}{3} < |\phi_{track} - \phi_{jet1}| < \frac{2\pi}{3}$ or $\frac{4\pi}{3} < |\phi_{track} - \phi_{jet1}| < \frac{5\pi}{3}$.
- Only tracks from primary vertex considered.
- Then 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.





Hera-LHC

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

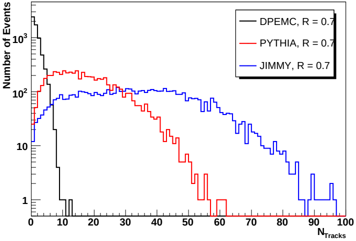
Cuts:

- $N_C \leq 3 \wedge N_C^\perp \leq 1$.
- $N_C < 4 \wedge N_C^\perp < 3$.
- $p_T^{Track} > 0.5$GeV (for Atlas).

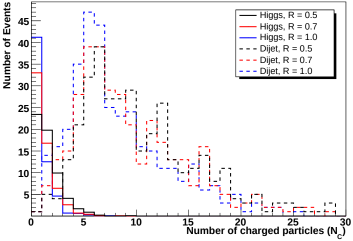
Choice of R:

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

Number of events outside dijet:



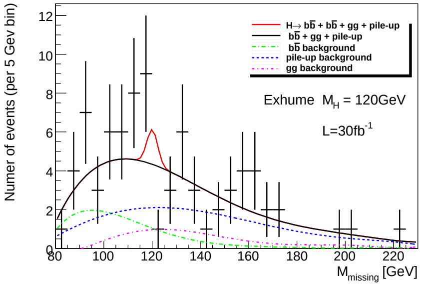
Number of events outside dijet for various R:

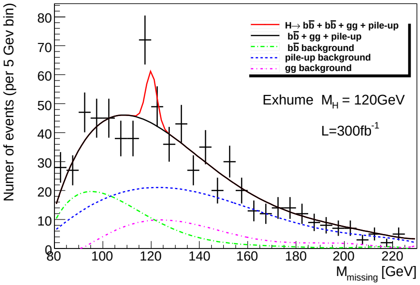


$b\bar{b}$, gg and pile-up background (Pythia DWT)

- Number of events for signal and $b\bar{b}$ + gg + overlap background after all cuts above for $30fb^{-1}$ in 2σ mass window.
- Mass window for 220-420 is $M_H \pm 2.6$ GeV.
- Mass window for 420-420 is $M_H \pm 1.1$ Gev.

$\mathcal{L}[\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	$\#b\bar{b}$	$\#gg$	#pile-up ([p][X][p])	#All bkg.	$\#H \rightarrow b\bar{b}$.
$1 \cdot 10^{33}$	1.2	1.6	3.3 (?)	6.1	2.0





Conclusions

- Results are in agreement with studies by A. Pilkington and M. Tasevsky.
- It is expected about 2 events of signal and 6 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 (and gap survival prob. = 0.03, ...).
- Physical cuts (exclusivity, N_C) kill only small amount of signal.
- Signal is mostly killed due to detector acceptance and b-tagging efficiency.
- Huge differences between generators in case of pile-up simulation (Pythia, Jimmy).
- The generators must be tuned - first data from LHC are needed.

References

- B. Cox, K. Loebinger, A. Piklington; JHEP0710:090,2007
- A. G. Shuvaev, V. A. Khoze, A. D. Martin, M. G. Riskin; arXiv:0806.1447 [hep-ph]
- CMS/Totem Note; CERN-LHC 2006-039/G-124
- M. Taševský; presentation at Hera-LHC workshop 2007 (http://indico.cern.ch/conferenceDisplay.py?confId=11784)
- A. Pilkington; presentation at Hera-LHC workshop 2007 (http://indico.cern.ch/conferenceDisplay.py?confId=11784)
- V. Juránek; presentation at Diffraction at LHC, Krakow (http://indico.cern.ch/conferenceTimeTable.py?confId=22401)