DPE $H \longrightarrow b\bar{b}$ feasibility studies at Atlas

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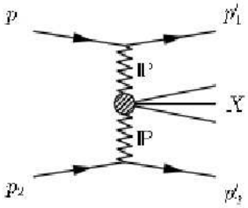
Outline

1. Exclusive DPE Higgs boson production
2. Simulation of $H \longrightarrow b\bar{b}$ at Atlas
3. Used cuts and generator comparison
4. Results and conclusions

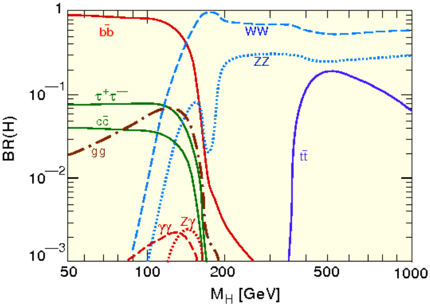
Double pomeron exchange

- pp→p+gap+X+gap+p (at higher luminosities there will be no rapidity gaps because of pile-up)
- Both protons remain intact
- If both protons are detected in RP, proton energy lost can be measured: $\xi = 1 - \frac{p_z'}{p_z}$
- Constraint on central object mass and rapidity
- $M_X \simeq \sqrt{\xi_1 \xi_2 s}$
- $y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$



$H \to b\bar{b}$

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



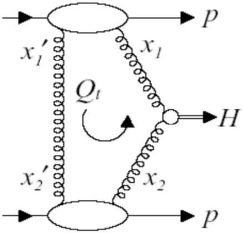
Exclusive DPE Higgs boson production

Advantages:

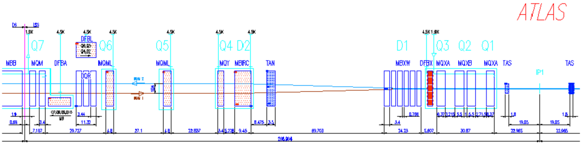
- Precise measurement of Higgs mass
- Good signal background ratio ($\frac{H \rightarrow b\bar{b}}{gg \rightarrow b\bar{b}}$ better in diffractive processes than in non-diffractive)

Disadvantages:

- Small cross section (2fb)
- Sensitive on pile-up (more hits in RP) from other soft diffractive events



Roman pots at 220 and 420



- Roman pots detect intact protons scattered at small angles
- There are two project RP220 and FP420
- RP220 and FP420 are complementary
- Acceptance of RP220 is 0.01-0.15 in ξ ($\xi = 1 - \frac{p_z'}{p_z}$)
- Acceptance of FP420 is 0.002-0.02 in ξ

Goals and assumptions of the simulation

- Exclusive diffractive Higgs production at Atlas, $H \to b\bar{b}$ channel
- Feasibility study of measurements in this channel
- Fast detector simulation (Atlfast)
- Higgs mass = 120GeV
- In first approximation RP220 and FP420 considered as one system
- Considered acceptance in ξ: $\xi \in < 0.002, 0.1 >$ (RP220 + FP420)
- Mass resolution of this system 1.5% (the best case)
- Suppressing factor from timing detector of 40 considered for pile-up background
- After all cuts mass window 120$\pm$1.8GeV (1σ mass window) was applied

Cross sections

- Two MC generators were used: Dpemc and Exhume
- In Dpemc Bialas-Landshoff model was used
- In Exhume is implemented KMR model

$$H \rightarrow b\bar{b}$$

- There are uncertainties in this cross section 1-10fb
- Bialas-Landshoff σ = 2.0 *fb*
- KMR σ = 1.9 *fb*

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

- Bialas-Landshoff σ = 520 *fb*
- KMR σ = 269 *fb*

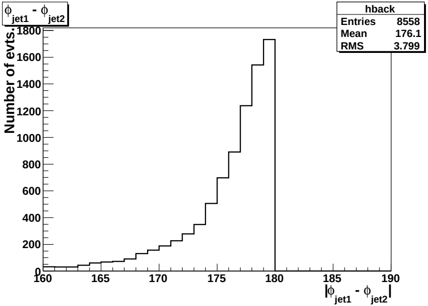
- Inclusive DPE $q\bar{q}$, Dpemc $\sigma = 5.5\text{E}+04$pb (almost completely suppressed by cuts on exclusivity, but insufficient statistics and old PDF)

Pile-up

- More interaction in bunch crossing
- The most dangerous is the overlap of three events: hard scale $b\bar{b}$ production and two single diffraction event detected by RP $=>$ same signal as $H \to b\bar{b}$
- For pile-up considered σ as cross section of hard event ($b\bar{b}$ production), in Pythia $\sigma =$ 7.2E+05pb
- Number of pile-up events per bunch crossing generated using Poisson distribution (accordin to the luminosity)

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 (effectively of b-tagging is $\sim 60\% => $ two b-jets $\sim 36\%$)
- Jets are back-to-back ($170 < \phi_{bjet1,bjet2} < 180$)

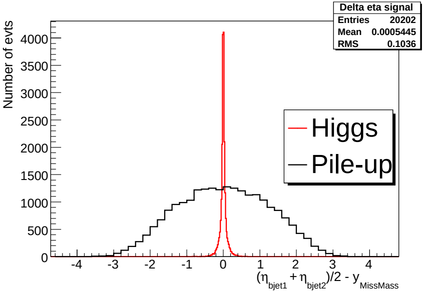


Exclusivity cuts: cut on R_{jj} or R_j

- $M_X \simeq \sqrt{\xi_1 \xi_2 s}$ mass of central object
- $R_{jj} = \frac{M_{dijet}}{M_X}$
- $R_j = \frac{2E_T^{jet1}}{M_X} cosh(\eta^{jet1} - y_X)$, $y_X \simeq \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$
- $0.8 < R_{jj} < 1.2$
- $0.8 < R_j < 1.1$
- For cuts I'm using R_j has almost the same rejection factor as R_{jj}

Exclusivity cuts: $\Delta\eta$ 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 $|\Delta\eta| < 0.1$



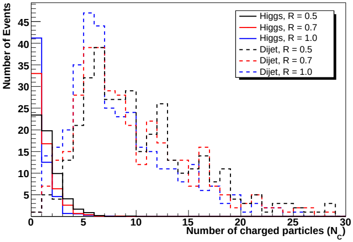
- Other 2 exclusivity cuts (on p_x and p_y) weren't used because of background has very similar distributions of this quantities

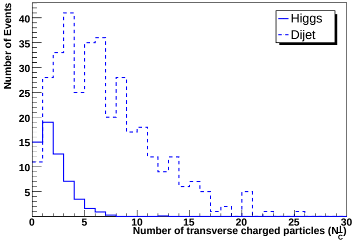
N_C and $N_C^{\perp}$ cuts

- 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 $\frac{4\pi}{3} < |\phi_{track} - \phi_{jet1}| < \frac{5\pi}{3}$
- Full simulation is needed

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

Number of events outside dijet for various R (dijet generated by Herwig)





I've chosen following cuts:

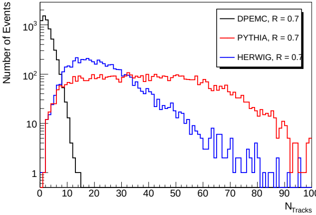
- Cone radius R = 0.7
- $N_C < 4 \wedge N_{C\perp} < 3$

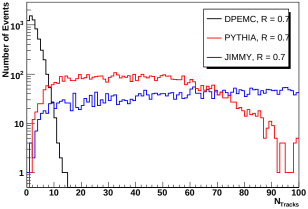
As cut on p_T taken Atlfast default:

- $p_T^{Track} > 0.5$GeV

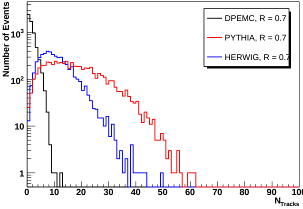
Generator comparison

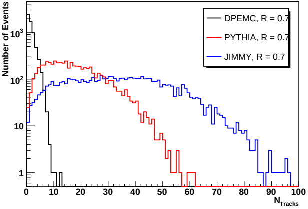
Multiplicity of tracks ($p_T^{track} > 0.2\text{GeV}$)



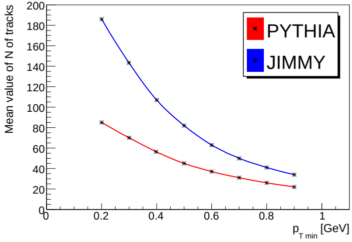


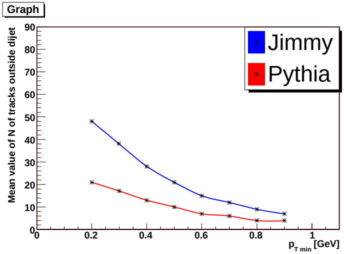
Multiplicity of tracks ($p_T^{track} > 0.5\text{GeV}$)

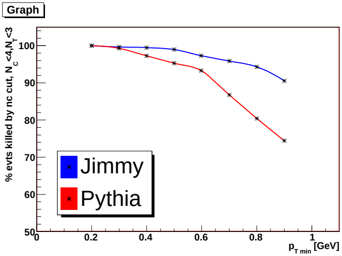




Generator comparison







- Mean value of tracks multiplicity as function of track p_T (only cut on jet p_T was applied)
- Big differences between generators - tuning according to the first data is needed

Luminosities

- Integrated luminosity $30fb^{-1} \sim 1.5$ year of running at $2 * 10^{33} cm^{-2} s^{-1}$
- $1 * 10^{33} cm^{-2} s^{-1} \sim 3.5$ interactions in bunch crossing
- $2 * 10^{33} cm^{-2} s^{-1} \sim 7$ interactions in bunch crossing
- $5 * 10^{33} cm^{-2} s^{-1} \sim 17.5$ interactions in bunch crossing

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

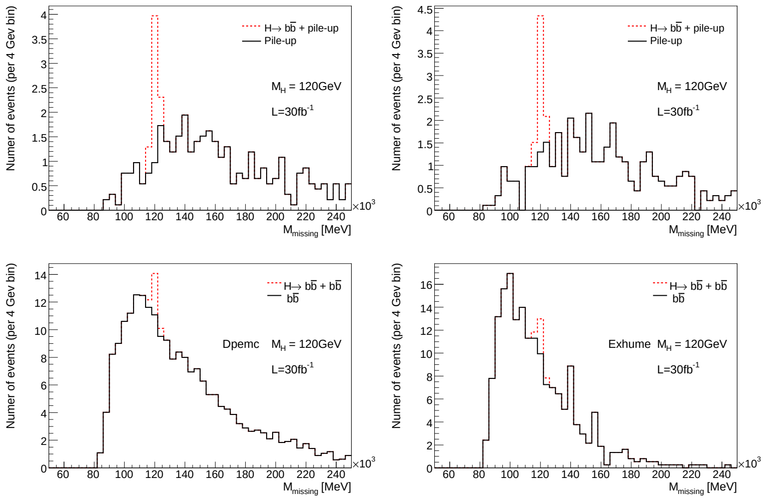
Acceptance factors for cut flow

DPE $H \longrightarrow b\bar{b}$	Kin.	B-jets	RP accept	back to back	R_j	η	$N_C \wedge N_C^{\perp}$	mass window
Dpemc	0.42	0.35	0.68	0.88	0.87	0.94	0.97	0.68
Exhume	0.38	0.36	0.76	0.87	0.88	0.94	0.97	0.68

DPE $b\bar{b}$	Kin.	B-jets	RP accept	back to back	R_j	η	$N_C \wedge N_C^{\perp}$	mass window
Dpemc	0.09	0.36	0.76	0.86	0.79	0.92	0.95	0.05
Exhume	0.04	0.4	0.71	0.9	0.67	0.95	0.96	0.04

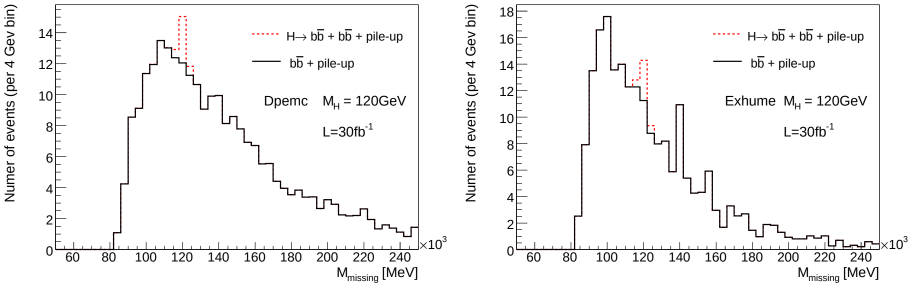
Pile-up	Kin.	B-jets	RP accept	back to back	R_j	η	$N_C \wedge N_C^{\perp}$	mass window
Herwig	0.17	0.075	0.005	0.37	0.114	0.054	0.117	0
Pythia	0.21	0.32	0.005	0.53	0.11	0.054	0.07	0.021
Jimmy	0.21	0.074	0.005	0.37	0.12	0.056	0.026	0

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



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)



S/B ratios

Number of events for signal and $b\bar{b}$ after all cuts above for $30fb^{-1}$

Dpemc

#int bunch cross	#evts S (Dpemc)	#evts B	S/B	$\frac{S}{\sqrt{B}}$
3.5	2.8	11.2	0.25	0.8
7	2.8	10.5	0.27	0.9
17.5	2.8	9.5	0.29	0.9

Exhume

#int bunch cross	#evts S (Exhume)	#evts B	S/B	$\frac{S}{\sqrt{B}}$
3.5	2.8	7.8	0.35	1.0
7	2.8	9.7	0.29	0.9
17.5	2.8	11.3	0.25	0.8

Number of events for signal and $b\bar{b}$ + pile-up after all cuts above for $30fb^{-1}$

Dpemc

#int bunch cross	#evts S (Dpemc)	#evts B	S/B	$\frac{S}{\sqrt{B}}$
3.5	2.8	12.1	0.23	0.8
7	2.8	16.5	0.17	0.7
17.5	2.8	50	0.06	0.4

Exhume

#int bunch cross	#evts S (Exhume)	#evts B	S/B	$\frac{S}{\sqrt{B}}$
3.5	2.8	9.0	0.31	0.9
7	2.8	15.5	0.18	0.7
17.5	2.8	53.0	0.05	0.38

Conclusions

- Physical cuts (exclusivity, N_C) kill only small amount of signal
- Signal is mostly killed due to detector acceptance and b-tagging
- All cuts have similar rejection factor in all generators except $N_C \wedge N_C^{\perp}$ cut
- The range of rejection factor for $N_C \wedge N_C^{\perp}$ cut is from 8.5 for Herwig, 14.7 for Pythia to 38.5 Jimmy (resp. 46 at higher luminosities where was bigger statistics)
- The generators must be tuned - first data from LHC are needed
- To improve cuts full simulation is needed - in progress
- MSSM Higgs much more promissing (10 times bigger cross section), see talks by Valery and Marek