Recent forward physics predictions at the LHC

Andrew Pilkington The University of Manchester

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- Central exclusive production introduction
- Luminosity dependent backgrounds
- MSSM Higgs boson measurement at high tan β

Central Exclusive Production

Main details of Central Exclusive Production: 1) Protons remain intact, lose approximately 1% of their momentum, scattered through very small angles.

2) All momentum lost by the protons goes into the production of the central system.
3) Central resonance is produced in a 0⁺⁺ state.



Use proposed forward proton detectors at 220m and/or 420m to measure the momentum loss, x, of each outgoing proton. The mass of the central system is given by

$$M \simeq \sqrt{x_1 \, x_2 s}$$

and the rapidity by

$$y = \frac{1}{2} \ln \left(\frac{x_1}{x_2} \right).$$

A 120 GeV 'object' would have a mass resolution of approximately 2 GeV if measured with 420m detectors

The overlap background

- Defined as a three-fold coincidence between two single diffractive events and an event which looks like the central system of interest.
- The protons from the single diffractive events give the hits in the forward detectors.
- The background cross section is calculated by

$$\sigma_{olap} = \sum_{N=3}^{\infty} \frac{\lambda^N e^{-\lambda}}{N!} P_1(N-1) P_2(N-2) \sigma$$

- The cross section depends roughly on λ^2 , where λ is the average number of interactions in each bunch crossing.
- This background is therefore luminosity dependent.
- The $P_i(N)$ are the probabilities that, given N interactions, there is at least one single diffractive interaction that produces a hit in a forward detector. For 420m detectors, $P_i(1) = 0.8\%$, $P_i(35) = 25\%$.

Rejection of overlap background (I)

- Each forward detector can make a time-of-flight measurements of the protons from the interaction point.
- \odot Vertex measurement possible from ΔTOF with knowledge of beam optics.
- If time-of-flight is measured to 10ps, then the vertex will be known to 2.1mm.
- Matching primary vertex (of e.g jets) to reconstructed vertex reduces overlap background by a factor of 40.

Further rejection by standard kinematic matching – see later slides.

Rejection of overlap background (II)

Can also reject overlap by measuring the underlying event.

Look for charged particles that are transverse to the leading jet in the event, i.e particles that satisfy

$$\frac{\pi}{3} < |\phi_k - \phi_j| < \frac{2\pi}{3}$$
 and $\frac{4\pi}{3} < |\phi_k - \phi_j| < \frac{5\pi}{3}$

Result?

For the HERWIG+JIMMY sample shown here, get a factor of 100 rejection.

A warning: Some level of uncertainty from different event generator tunings.

We will not know how effective the cut really is until we see early LHC data.



Which charged particles?

 Nominal ATLAS acceptance for charged particles is

> $p_T > 0.5 \text{GeV}$ $|\eta| \le 2.5$

- Need to measure low transverse momentum particles.
- Not much need for high pseudorapidity.
- Can we go to even lower transverse momentum?
- In this talk use: $p_T > 0.5 {
 m GeV}$

 $|\eta| \le 1.75$





MSSM $H \rightarrow bb$ using 420m detectors

- MSSM a good place for Higgs boson measurement using CEP because
 - Spin-selection rules filter out the pseudo-scalar higgs contributions. Have a pure scalar sample.
 - Cross section increases at high tan β .
 - The MSSM point studied here has $m_A = 120 \text{ GeV}$ and $\tan\beta = 40$. This gives a scalar Higgs boson with a mass of 119.5 GeV and a width of 3.2 GeV.

bb decay channel interesting because

- \odot CEP of bb is suppressed due to spin selection rules.
- Other sources of background are CEP gg (misidentified as b-jets), double pomeron exchange and the overlap background from di-jets at LHC.
- © CEP events generated by ExHuME 1.3.2, DPE by POMWIG 1.4 and overlap by HERWIG+JIMMY (with SD protons added in using MC methods and formula in hep-ph/0609312).

Double Pomeron Exchange

Protons remain intact.

- Central system produced by pomeron-pomeron fusion.
- Hard scatter accompanied by pomeron 'remnants'.



OMWIG updated (beta version) with latest H1 2006 PDFs.

• Use Fit B as it gives a better fit to H1 diffractive jet data.

Kinematic matching

 $oldsymbol{arsigma}$ Use the R_j and Δy variables, defined as

 $R_j = \frac{2E_T}{M} \cosh\left(\eta_j - y\right) \qquad \Delta y = y - \frac{(\eta_1 + \eta_2)}{2}$

These compare mass and rapidity of hard scatter to mass and rapidity of central system measured by FP420.

• Central exclusive events have $R_j \sim 1$ and $\Delta y \sim 0$.

• DPE events have $R_j < 1$.





Exclusivity requirements

- The transverse momentum of the leading jet must satisfy $E_T \ge 40 \, {
 m GeV}$.
- Protons restricted to FP420 acceptance range as defined by the FPTrack program.
- Kinematic matching: $0.82 \le R_j \le 1.1$ and $|\Delta y| \le 0.06$.
- Underlying event: $N_C^{\perp} \leq 1$. Additional cut on all charged particles outside of the di-jet system, $N_C \leq 5$.
- Mass measured by FP420 must satisfy $114.5 \le M \le 124.5 \, \text{GeV}$.
- ø ISR cut: The jets must be back to back in azimuth, i.e $|\Delta \Phi \pi| \le 0.2$.

Cross sections

- MSSM signal has a cross section of 0.5fb after cuts but before trigger.
- © CEP di-jets have a cross section of 0.47fb.
- DPE background is negligible 0.02fb (even H1 2006 Fit A is 10 times smaller than signal).
- Overlap background depends upon luminosity 0.025fb at
 2.10³³cm⁻²s⁻¹. However, larger than the signal at high luminosity!

Results



- Cannot trigger on forward protons at 420m.
- Use central detector quantities of muons and jets.
- Trigger on muon plus jet or (prescaled) 40GeV di-jets.

- With very large jet rate trigger, FP420 can make the measurement.
- If 220m detectors are used as well, the muon plus jet significance (red curve) increases to approximately 4.0 at high luminosity.

Summary

- Central exclusive production allows an excellent mass measurement of any produced resonance.
- Luminosity dependent backgrounds due to high rate processes can in principle be controlled by hardware and analysis cuts.
- It is possible to measure MSSM Higgs boson production for high tan β scenarios in the $b\overline{b}$ decay channel.