Central Exclusive Higgs production at the LHC

Andrew Pilkington
The University of Manchester

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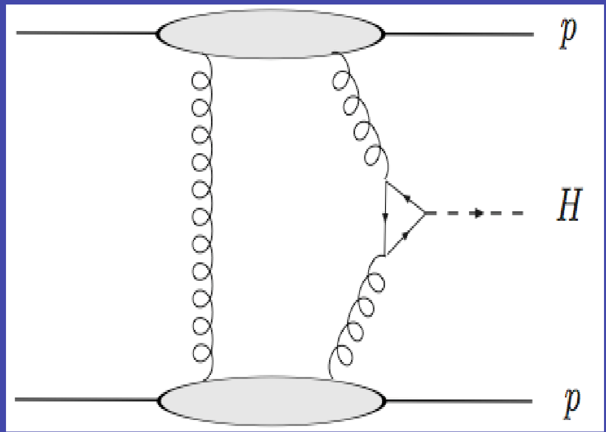
Overview

- Introduction -Motivation for b-decay channel in MSSM
- Luminosity dependent backgrounds
- Impact on Higgs boson observations in the MSSM

Central Exclusive Production - Motivation



- Protons remain intact and all energy lost during interaction goes into production of a central system.
  - Central mass measurement from 4-momentum conservation if protons are detected.
- Central system produced (mainly) in J_z=0 state. Thus observation implies measurement of quantum numbers of any produced resonance.

- However, need new forward proton detectors at 220m and 420m either side of IP. This analysis assumes these detectors are installed.

MSSM Higgs in b-quark decay channel

- Based on work with B.E. Cox and F.K. Loebinger.
- Motivation:
  - Cross section increased (w.r.t SM) at high $\tan\beta$.
  - CEP filters out psuedo-scalar Higgs boson.
  - Can search in b-quark decay channel as CEP QCD background is suppressed by spin selection rules.

- Parameter choice:
  - M_h^{max} scenario
  - $\tan\beta = 40$
  - $m_A = 120$ GeV.

- Results in a light Higgs of 119.5 GeV, with a width of 3.2 GeV.
- Cross section for $H \rightarrow b\bar{b}$ is 17.8 fb (approx 10x SM cross section).
- CEP generated using ExHuME version 1.3.3.

Diffractive Backgrounds

- CEP:
  - $b\bar{b}$ acts as irreducible background
  - gg acts as a background when each gluon is mis-tagged as a b-jet
  - $c\bar{c}$ is negligible w.r.t $b\bar{b}$.

- Double pomeron exchange:
  - Shown in hep-ph/0702213 to be small
  - Same result in this work for both of the latest H1 diffractive PDF's (generated using the POMWIG MC).

Luminosity dependent (Overlap) backgrounds

- There exists a class of backgrounds that mimic the signal by obtaining particles from different interactions in the same bunch crossing.
- It is built up by 'sowing' pieces of each interaction together to create a background event of 2 protons and a di-jet system.
- [p][X][p] background. This is built up from a three-fold coincidence between an inclusive event and two soft single diffractive events (each of which produces a forward proton).
- [pp][X] and [p][pX] are two-fold coincidences. [pp][X] implies a soft-DPE event in conjunction with an inclusive di-jet event and [p][pX] is a soft-SD event in conjunction with a hard single diffractive event.

Overlap calculation : Principle

- The calculation of these backgrounds is simple combinatorics - i.e [p][X][p]: for a given number of interactions in a bunch crossing, what is the probability that a hard scatter event is accompanied by two single diffractive events…

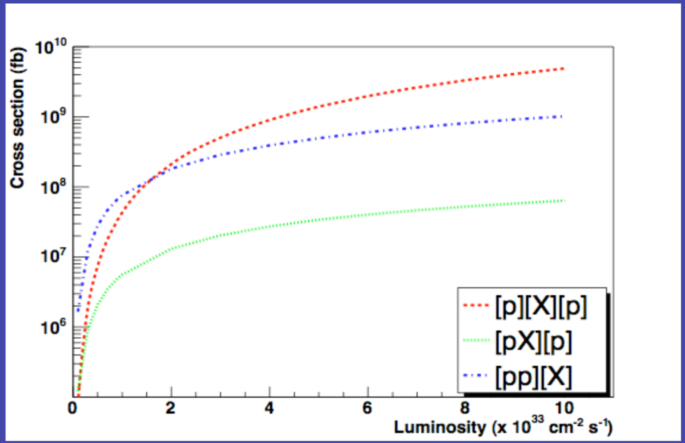
$$\sigma_{olap} \quad = \quad \sigma_{[X]} \sum_{N=3}^{\infty} \frac{\lambda^N e^{-\lambda}}{N!} P_{2[p]}\,(N-1)$$

- $\sigma_{[X]}$ is the cross section for the hard-scatter
- λ is the average number of interactions at a particular luminosity
- Sum over all possible number of interactions at each luminosity (given by poisson distribution). But require at least 3 because it is a three-fold coincidence.
- Multiply by the probability of having 2 soft single diffractive events (given by a trinomial distribution and using the fraction of events at LHC that have a forward proton that gives a hit in a forward detector).

Overlap backgrounds: Luminosity dependence.

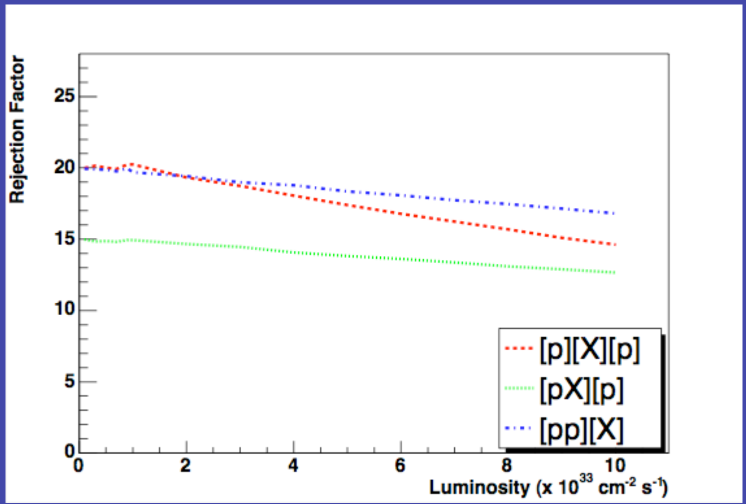
- [p][X][p] background increases (roughly) as $(L/L_0)^2$.
  - Probability of a particular event occurring is increases linearly with the number of interactions in the bunch crossing.
  - For [p][X][p] want the probability of two interactions occuring - quadratic dependence.

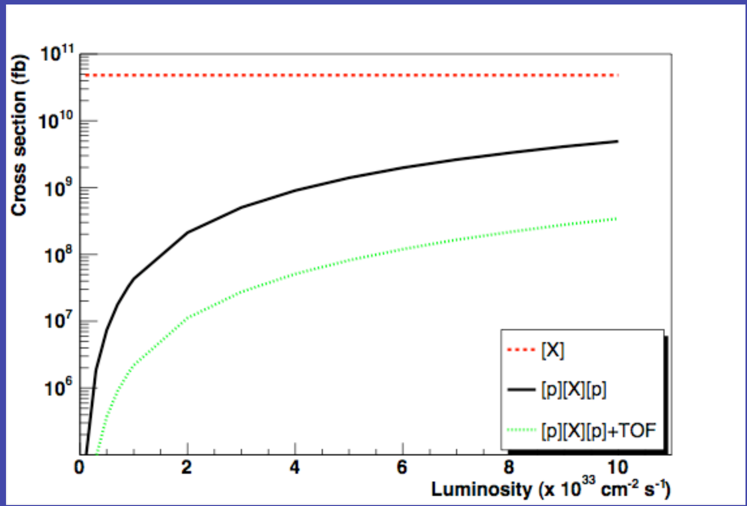
- [p][pX] and [pp][X] increase as L/L_0.



Overlap rejection (I): Time-of-flight

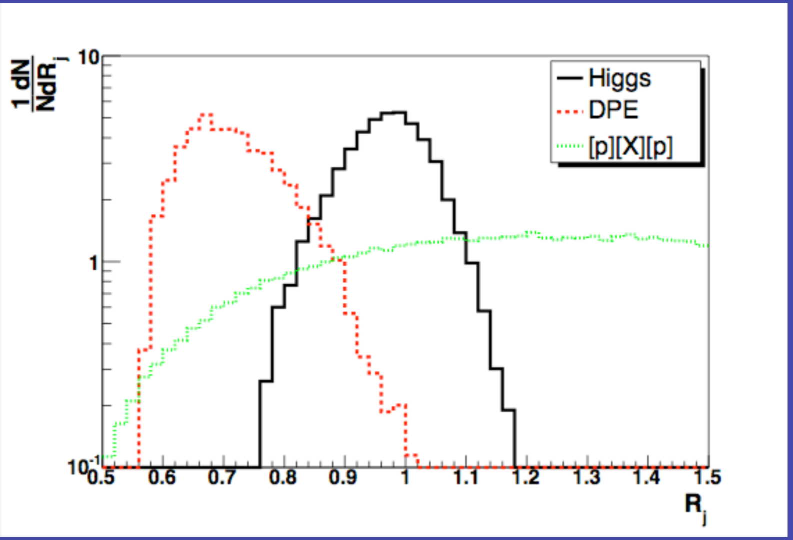
- Forward proton detectors capable of measuring time-of-flight of each proton from the IP to an accuracy of 10ps.
- If the time taken through for the protons to travel through the LHC lattice is well known, then the difference in TOF gives a vertex measurement accurate to 2.1mm under the assumption that the two protons originated from the same vertex.
- Require that the di-jet vertex is within 4.2mm of the TOF vertex.

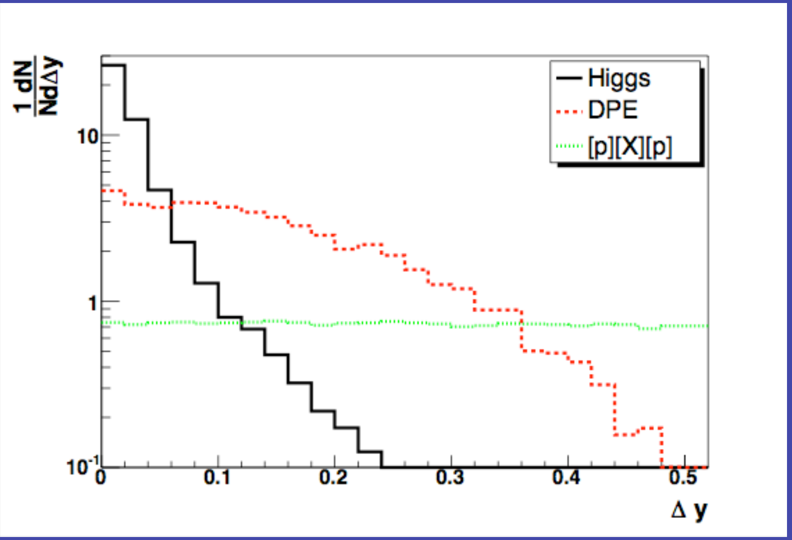




Overlap rejection (II): Kinematic Matching

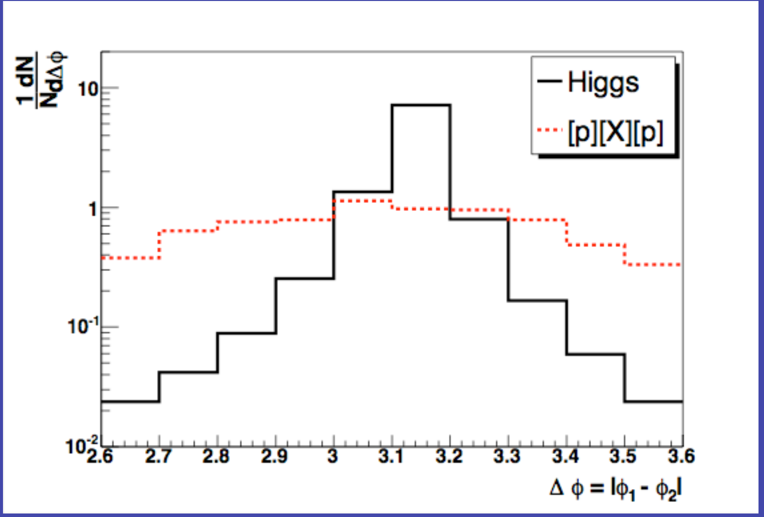
- Require that mass and rapidity of di-jets matches the mass and rapidity measured by the forward detectors.
  - Use the di-jet mass fraction, R_j, which compares the mass of the di-jets to the mass measured by the forward detectors (hep-ph/0605113).
  - and the rapidity difference, Δy, between the central system rapidity (measured by the forward detectors) and the average rapidity of the di-jets.

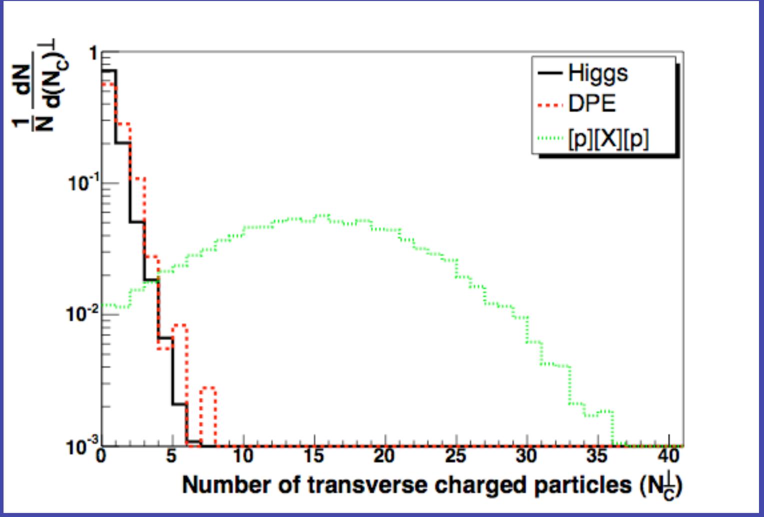




Overlap rejection (III): Underlying event

- ISR forbidden in CEP due to Sudakov suppression factor. The central system has net transverse momentum < 1 and so the di-jets should be back-to-back in azimuth.
- Protons remain intact and so there are no additional scatters between spectator partons in the proton. There should be little charged track activity perpendicular in azimuth to the leading jet (Also have looser cut on total charged track activity outside of di-jet system).





Experimental Cuts

- Jet Algorithm:
  - Jets found with cone algorithm with $R = 0.7$.
  - Leading jet has $E_T > 40$ GeV and second jet has $E_T > 30$ GeV.
- Forward detector acceptance:
  - ξ_1 and ξ_2 lie in the acceptance defined by the FPTrack program, with 420m detectors 5mm from beam and 220m detectors 2mm from beam. (28% acceptance for 420-420, 10% for 220-420).
  - $80 < M < 160$ GeV.
- Kinematic:
  - $0.75 < R_j < 1.1$ and $\Delta y < 0.06$.
- Underlying event:
  - $N_c^{\perp} \leq 1$ and $N_c \leq 3$
  - $|\Delta\phi - \pi| \leq 0.15$

Trigger strategies

- 420m detectors too far away to be included in level 1, but information can be used at level 2 to substantially reduce the non-diffractive background by requiring two proton hits plus vertex matching from time-of-flight.

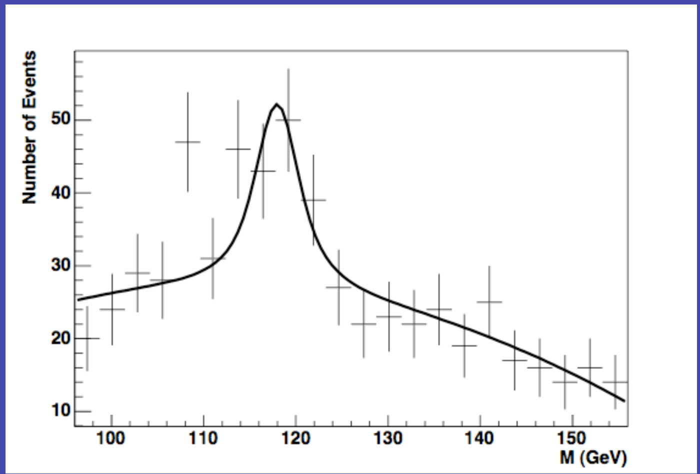
- Two triggers:
  - Low transverse momentum muon in conjunction with a 40 GeV jet (jet requirement to reduce rate at high luminosity). Notation MU6 = muon with $p_T > 6$ GeV.

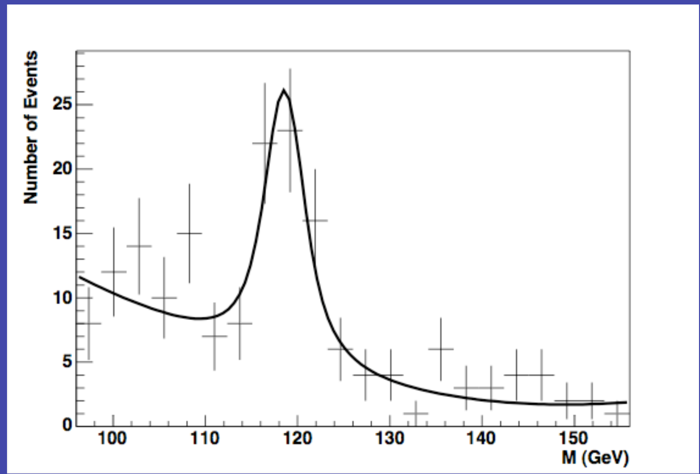
  - Fixed L1 jet rate (pre-scaled if necessary) for jets that satisfy $E_T > 40$ GeV. Notation J10 = 10kHz rate at level 1.

- Efficiencies:
  - MU6 approximately 11%. MU10 approximately 6%.
  - J10 is 40% efficient at $L=10^{33} cm^{-2}s^{-1}$ and 4% efficient at $L=10^{34} cm^{-2}s^{-1}$.
  - J25 is 100% efficient at $L=10^{33} cm^{-2}s^{-1}$ and 10% efficient at $L=10^{34} cm^{-2}s^{-1}$.

Example data sets

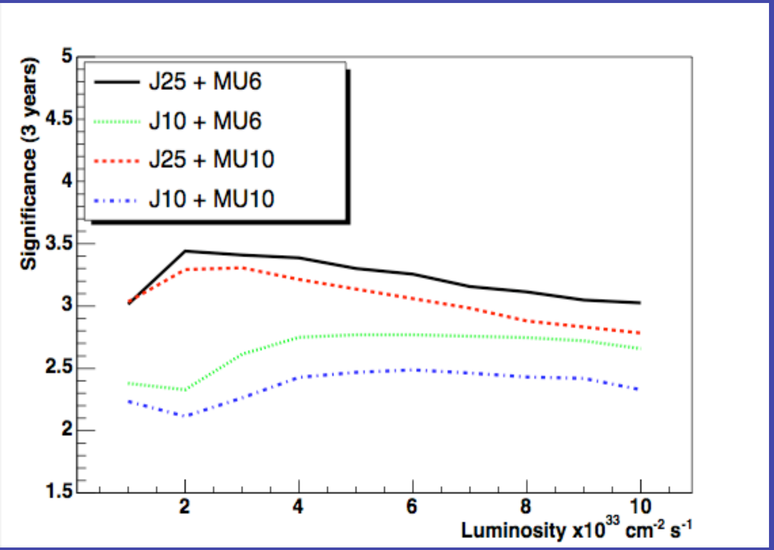
- Idea: Select at random the predicted number of events (after selection cuts) for each process for three years of data acquisition at each luminosity.
  - $30\ fb^{-1}$ at $L=10^{33}\ cm^{-2}\ s^{-1}$ and $300\ fb^{-1}$ at $L=10^{34}\ cm^{-2}\ s^{-1}$
- Fit the distributions with a null (background only) hypothesis and a signal + background hypothesis.
- The significance is then given by $(\Delta\chi^2)^{1/2}$.
- Example plots below for J25 + MU6 trigger at $L=10^{34}\ cm^{-2}\ s^{-1}$.
  - Same data set with (left) and without (right) overlap events.

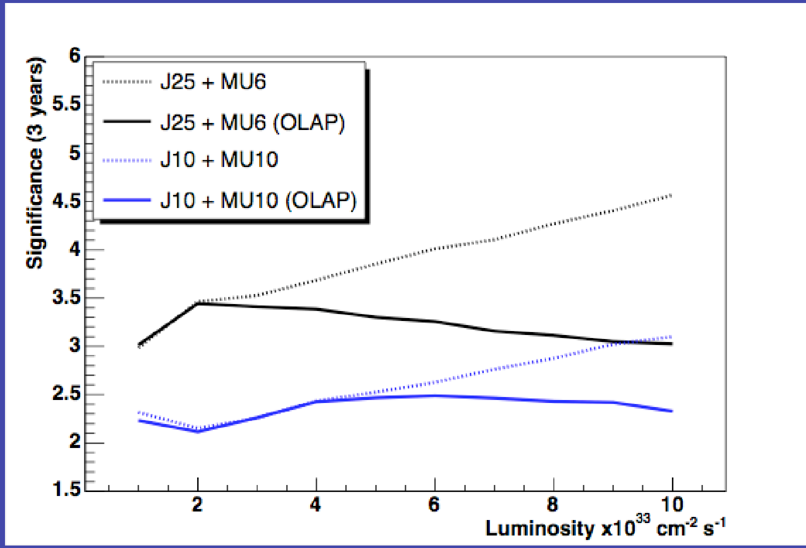




Significance (420 only)

- Repeat analysis 500 times at each luminosity for each trigger, to estimate the expected averaged significance.
- Results below for analysis with protons tagged only at 420m.

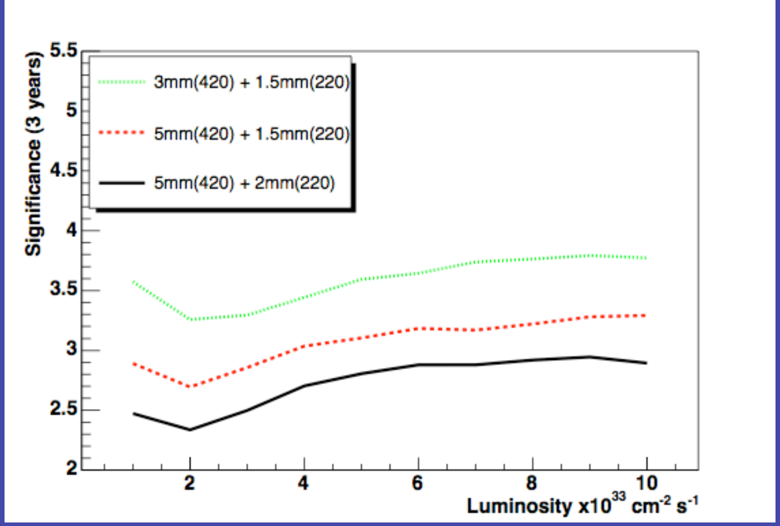


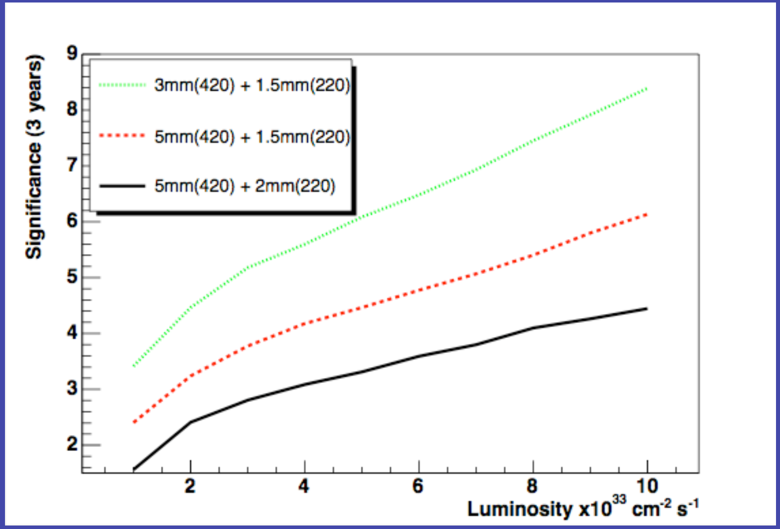


Significance (420 + 220)

- Not yet included the asymmetric analysis for one proton tagged at 220m and one at 420m. Use previous 'worse trigger' of J10 + MU10 (left). Significance can be much larger if detectors can get very close to the beam.

- Possibility for using 220m detectors in L1 trigger. Evaluate the potential for a 100% effective trigger (right). Significance or 220m-420m analysis only.





Summary

- Luminosity dependent backgrounds are important. Here we have shown that the backgrounds arising from inclusive QCD events can be kept under control up to the highest luminosities.

- MSSM Higgs boson potential affected at high luminosity. However, still have significances larger than 3σ for just 420 m analysis. Increases with the inclusion of 220m detectors. Can be very large if 220m detectors are able to effectively trigger at L1 at high luminosity.

- Conclude that a resonance that decays to $b\bar{b}$ is observable if the cross section is > 10fb.

- If TOF vertexing improved, can have very large significances in the central exclusive channel.