

# Likelihood-based analysis of SM-Higgs Coupling Structure at the LHC

*in collaboration with  
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# Outline

- Introduction
- Model
- Angular correlations
- Results of the analysis
- Conclusion

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- Consider higgs decay  $H \rightarrow ZZ^{(*)} \rightarrow l^+l^- l^+l^-$
- Consider all possible couplings of a scalar to two spin 1 particles

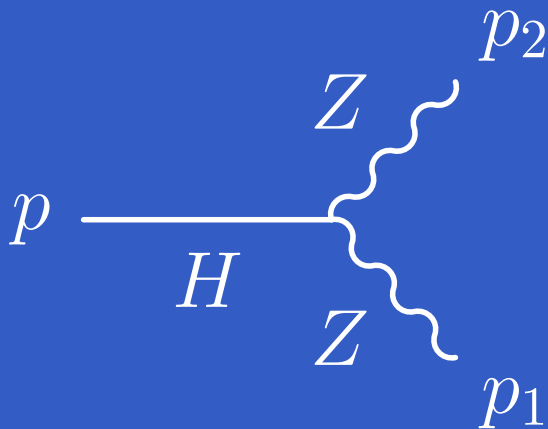
# Model

$$\mathcal{L} \approx X g^{\mu\nu} + Y \frac{p^\mu p^\nu}{M_H^2} + P \epsilon^{\mu\nu\rho\sigma} \frac{p_1^\rho p_2^\sigma}{M_H^2}$$

Standard model

CP-even

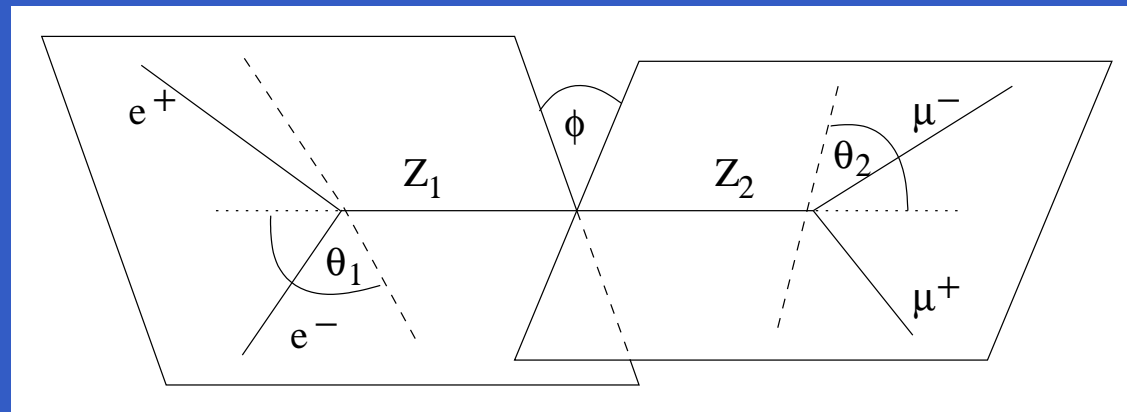
CP-odd



# Cross section: Definition of angles

Consider the triple differential cross section for the process  $H \rightarrow ZZ \rightarrow l^+l^- l^+l^-$ :

$$\frac{d\sigma}{d \cos \theta_1 d \cos \theta_2 d \phi}$$





# Decay plane distributions

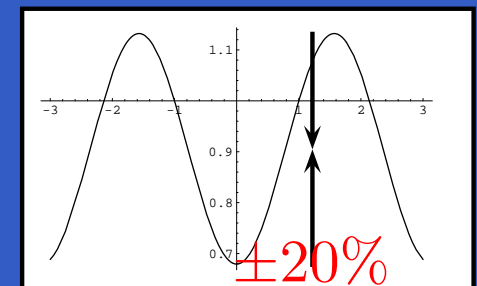
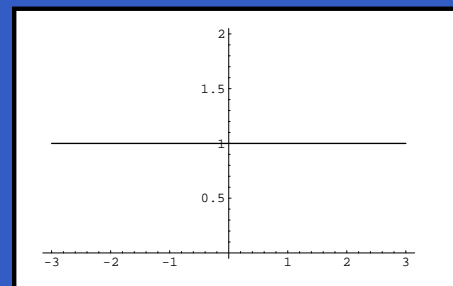
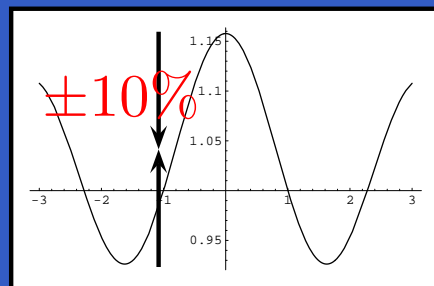
$M_H$

$X = 1$

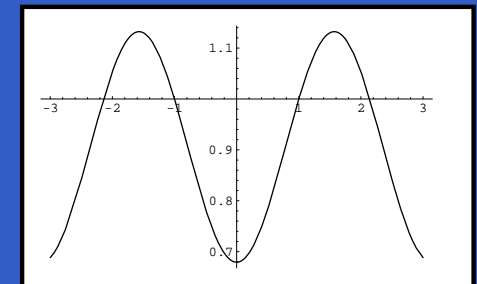
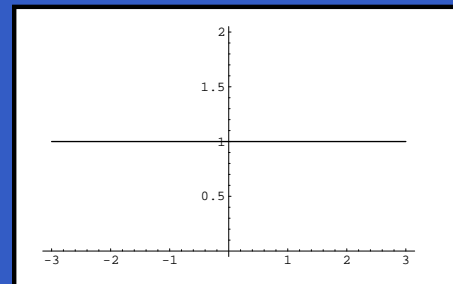
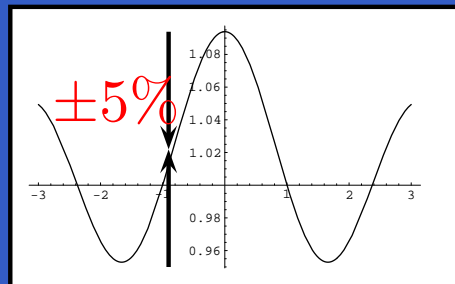
$Y = 1$

$P = 1$

130

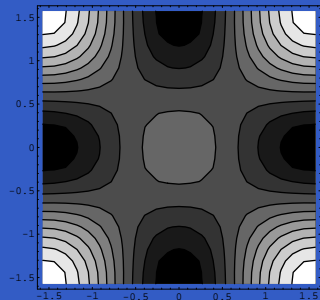
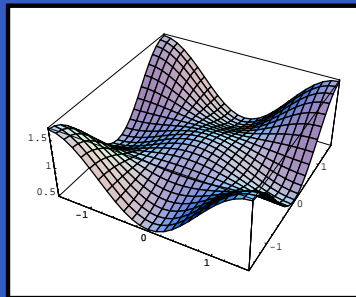


200

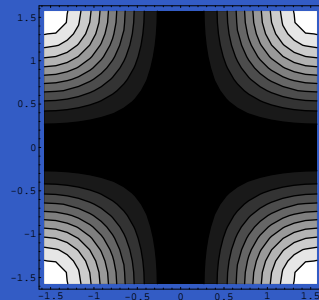
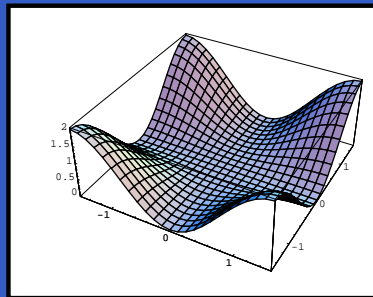


# Polar angle distributions $M_h = 130 \text{ GeV}$

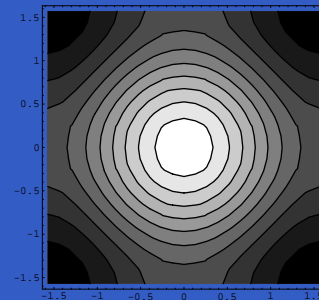
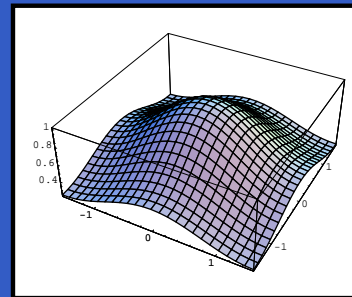
$X = 1$



$Y = 1$

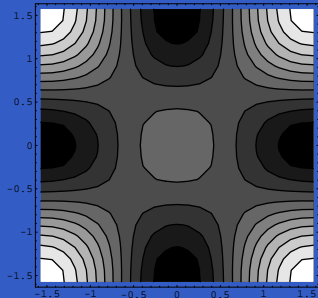
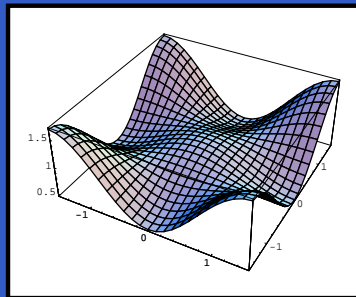


$P = 1$

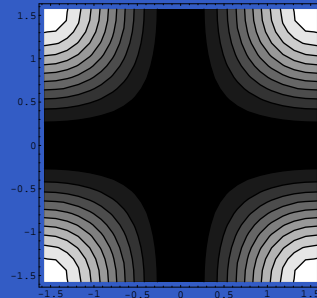
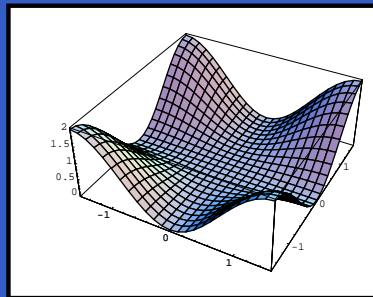


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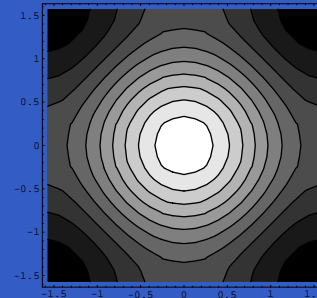
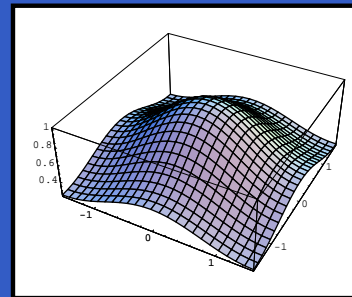
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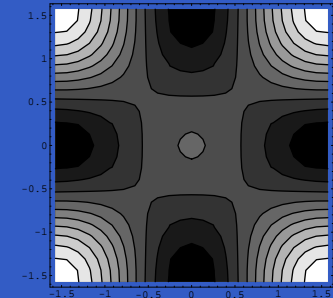
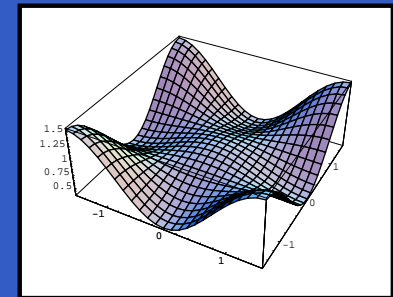
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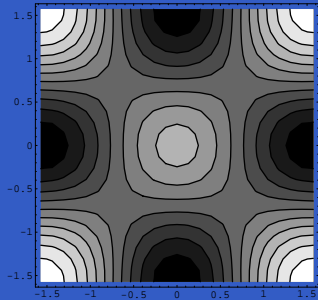
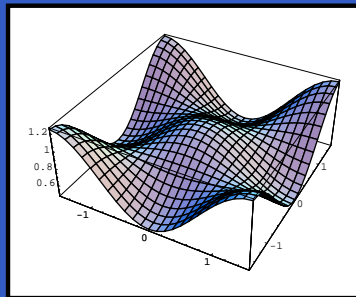


$Y = P = 1$

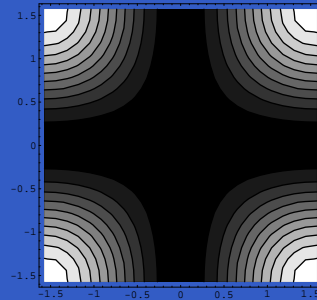
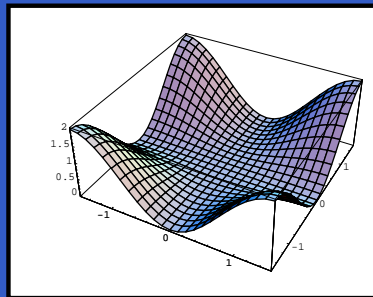


# Polar angle distributions $M_h = 200 \text{ GeV}$

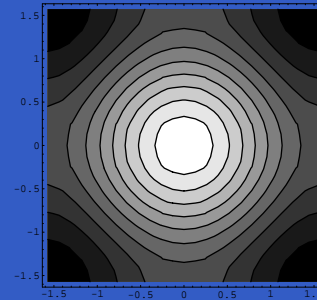
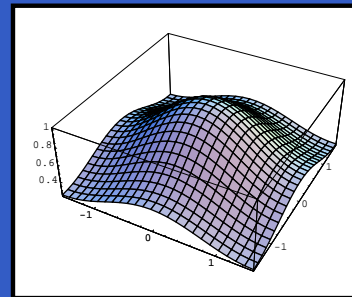
$X = 1$



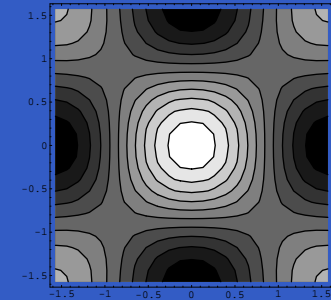
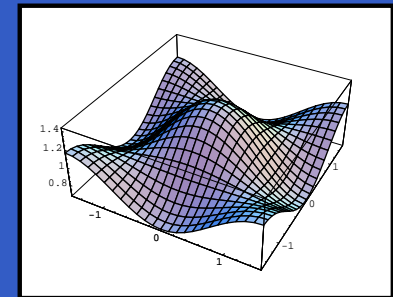
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$Y = P = 1$



# Interpretation of the couplings

- No fundamental theory → How do we interpret the strength of the couplings ?

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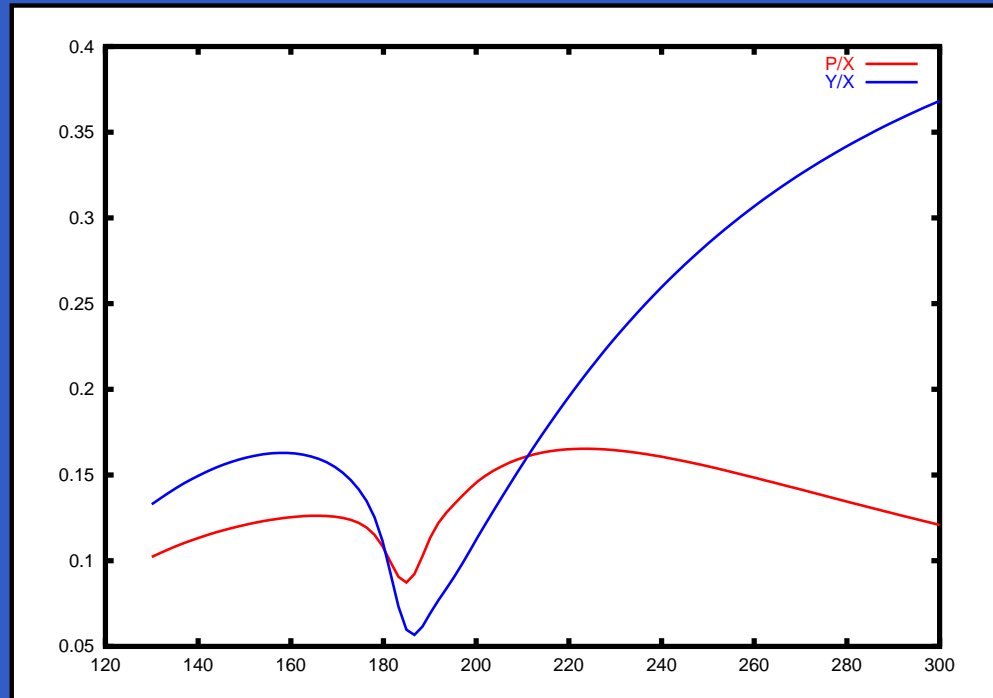
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- Possible solution: Compare the decay width  $\Gamma_X, \Gamma_Y, \Gamma_P$  of the pure Higgs states

# Interpretation of the couplings

- No fundamental theory → How do we interpret the strength of the couplings ?
- Possible solution: Compare the decay width  $\Gamma_X, \Gamma_Y, \Gamma_P$  of the pure Higgs states
- Rescale the coupling constants to get  $\Gamma_{X'} = \Gamma_{Y'} = \Gamma_{P'}$

# Comparison of decay width

Ratio of the decay width of the pure  $X, Y, P$  states.





# Likelihood analysis

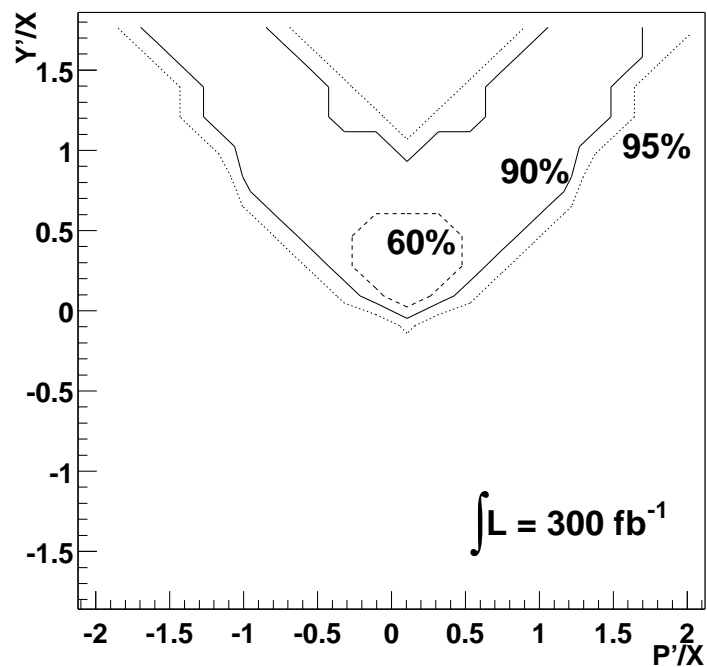
Evaluate the log-likelihood function

$$L(P, Y) = \sum \log \frac{\mathcal{M}^2(\phi, \theta_1, \theta_2, P, Y, X = 1)}{\int \mathcal{M}^2(\phi, \theta_1, \theta_2, P, Y, X = 1) d\phi d\theta_1 d\theta_2}$$

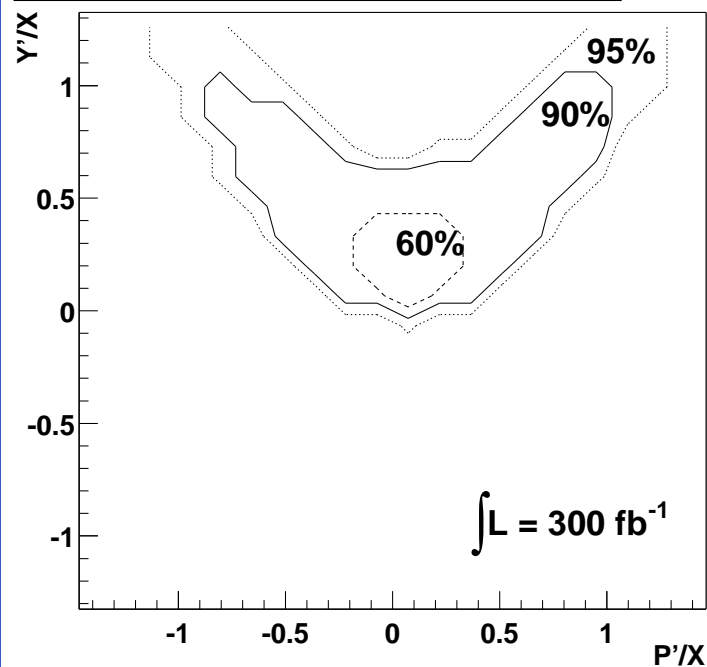
for a sample of standard model higgs events for different values of  $Y$  and  $P$ . The most likely scenario corresponds to the maximum of  $L$  in the  $Y - P$  plane.

# Results/below threshold

Measurement of  $P'/X$  and  $Y'/X$  -  $m_H = 130$  GeV

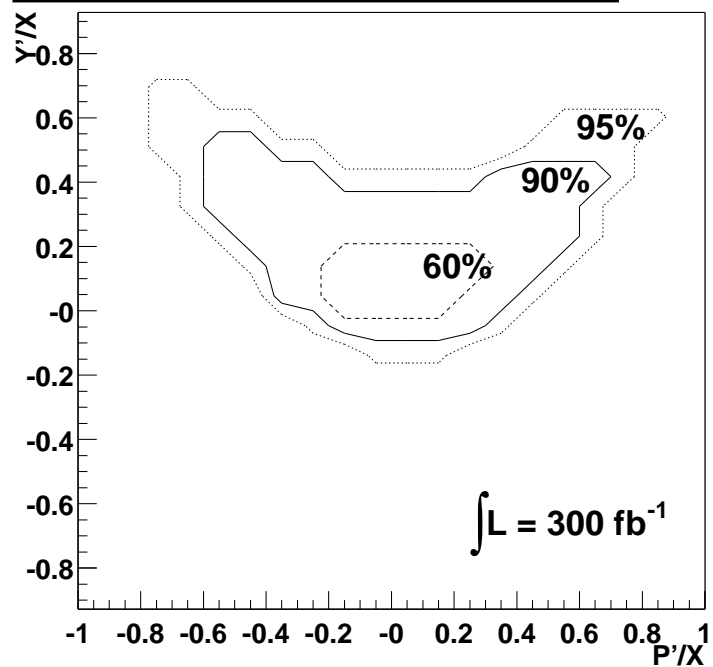


Measurement of  $P'/X$  and  $Y'/X$  -  $m_H = 140$  GeV

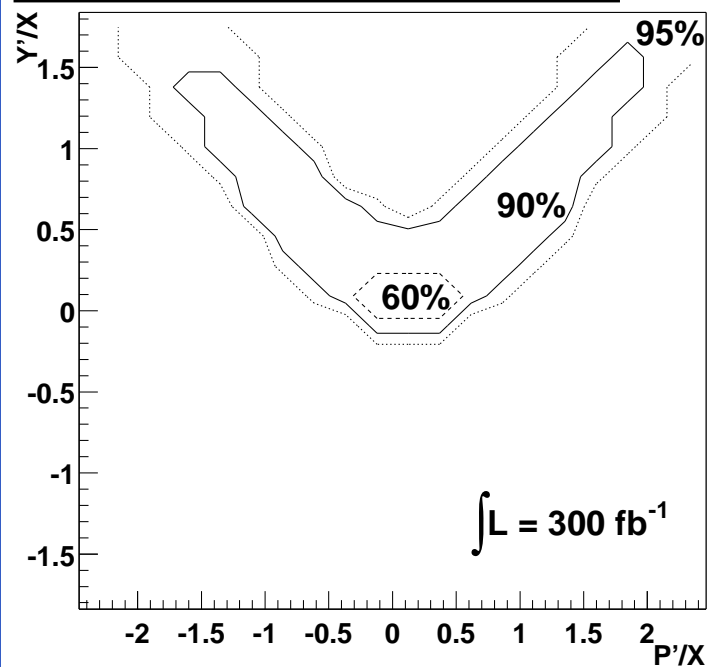


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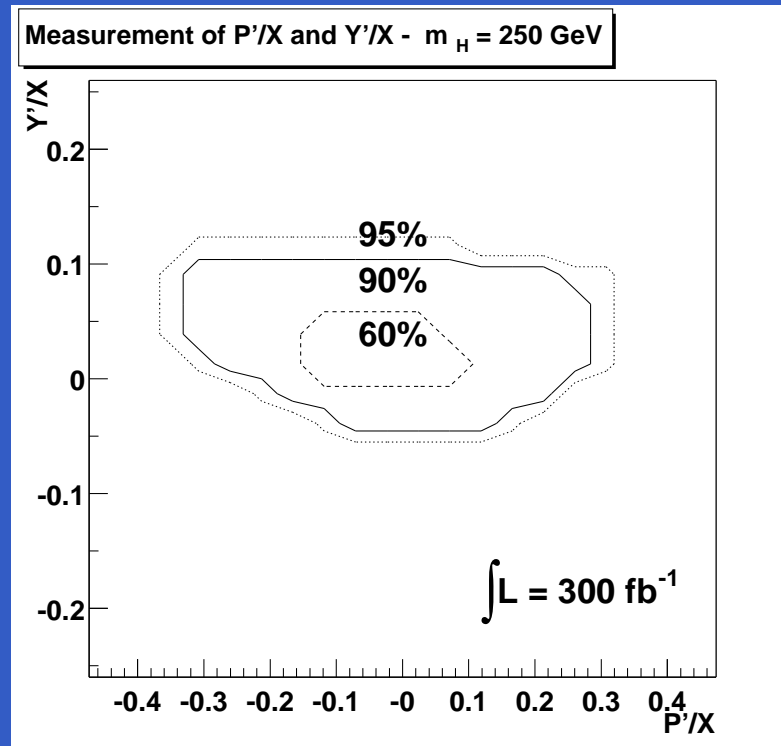
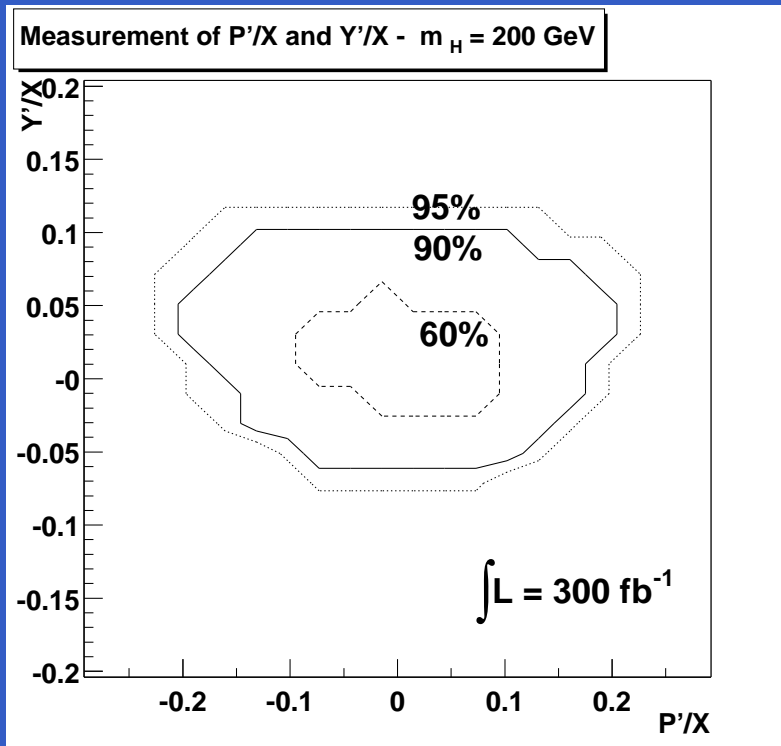
Measurement of  $P'/X$  and  $Y'/X$  -  $m_H = 150$  GeV



Measurement of  $P'/X$  and  $Y'/X$  -  $m_H = 160$  GeV



# Results/above threshold



# Conclusions

- It is possible to determine the Spin and CP of the standard model Higgs at the LHC using the full information of the angular correlations.
- Above the ZZ threshold strong bounds on the couplings can be achieved.
- The analysis below the threshold is limited by statistics.