A ME-Generator for Non-SM Higgs-Couplings and Analysis of Spin/CP-dependent Variables.

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CP Violation and Nonstandard Higgs Physics
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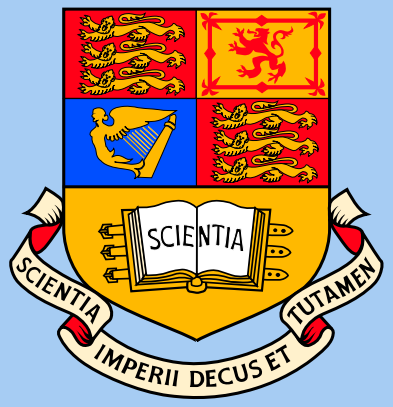
- ME-Generator
- Angular distributions H $\rightarrow$ZZ $\rightarrow$4l
- Angular distributions H $\rightarrow$ZZ* $\rightarrow$4l
- Vector boson fusion - jet angle correlations
- VBF: H$\rightarrow$WW $\rightarrow$ll$\nu\nu$ lepton correlations



General lagrangian and basic idea

$$\mathcal{L}_{scalar} = \mathbf{X} g^{\mu\nu} + \mathbf{Y} p^{\mu} p^{\nu} / M_h^2 + \mathbf{P} \epsilon_{\mu\nu\rho\sigma} p_1^{\rho} p_2^{\sigma} / M_h^2$$

$$\mathcal{L}_{vector} = \mathbf{X_V} (g^{\rho\mu} p_1^{\nu} + g^{\rho\nu} p_2^{\mu}) + \mathbf{P_V} (\epsilon_{\mu\nu\rho\sigma} p_1^{\sigma} - \epsilon_{\mu\nu\rho\sigma} p_2^{\sigma})$$

- Require signal compatible with SM-like Higgs
- i.e. measured mass and width, CS and BR ...
- Use above lagrangian to predict angular distributions.
- i.e. generate events for expected mass, width, CS ...
- This has to include detector effects.
- Use sidebands to check background prediction and subtract BG statistically

$\Rightarrow$ **Need ME-Generator for SM and hypothetical cases!**

$\Rightarrow$ + Background and SHG (Pythia) needed

Higgs production and decay

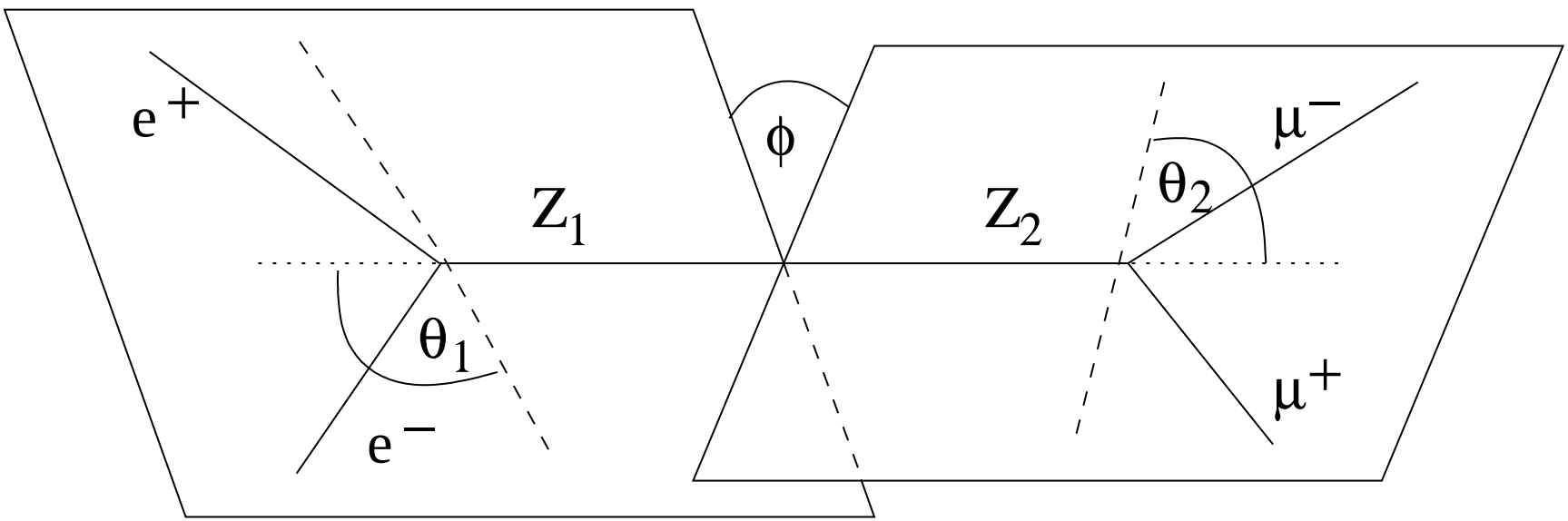
Process	**gg $\rightarrow$H**	**VBF**	W/Z$^*\rightarrow$W/Z H
Spin/CP information	-	+	+
Z/W-width	-	+	+

Decay	**H $\rightarrow$ZZ**	**H $\rightarrow$WW**	H $\rightarrow\tau\tau/b\bar{b}$
Spin/CP information	+	+	-
Z/W-width	+	+	-

- Decays to **leptonic**, semileptonic or 4 jets
- Full ME with all **pure** and mixed states for every HVV Vertex
- Processes implemented as C++ Objects within own Framework
- Interfacing to Athena via Acermc module (Les Houches)

Angular correlations in H→ZZ →4l

Signal definition:
4 leptons, $P_T^{1,2} > 20\text{GeV}, P_T^{3,4} > 7\text{GeV}$ within $|\eta| < 2.5$



Decay plane angle

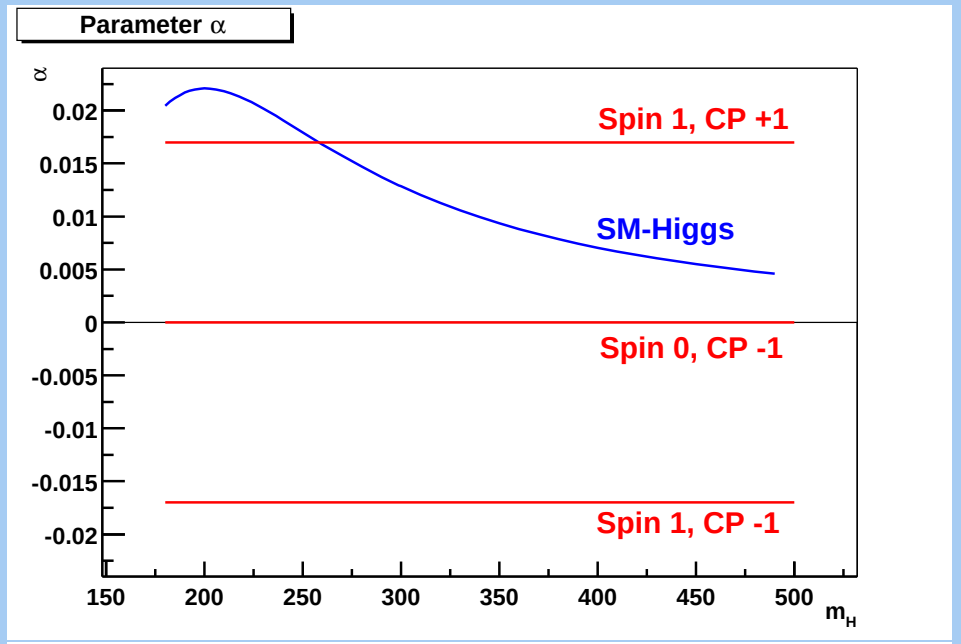
$$F(\phi) = 1 + \alpha \cdot \cos(\phi) + \beta \cdot \cos(2\phi)$$

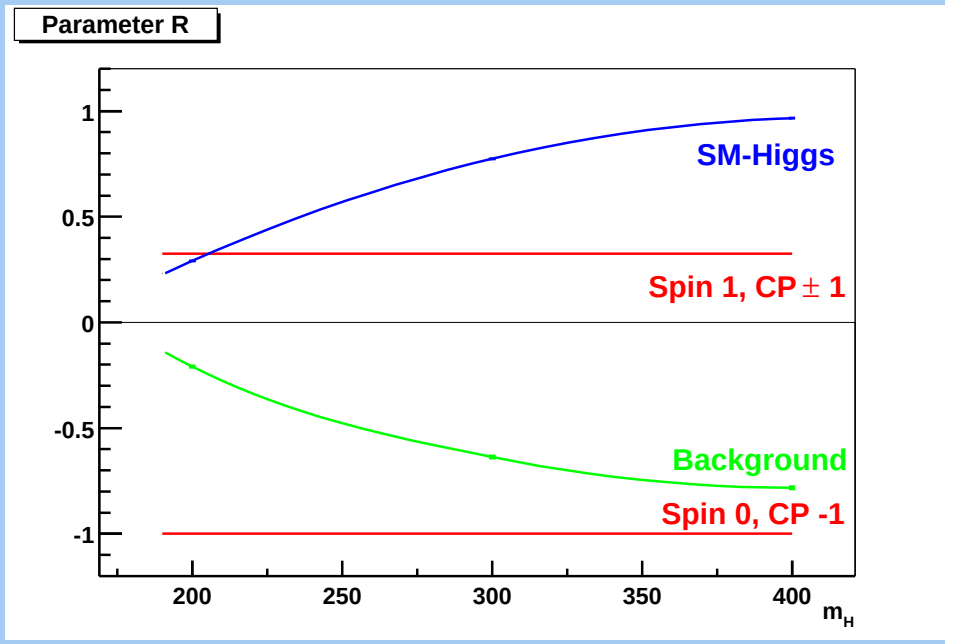
Polar angle

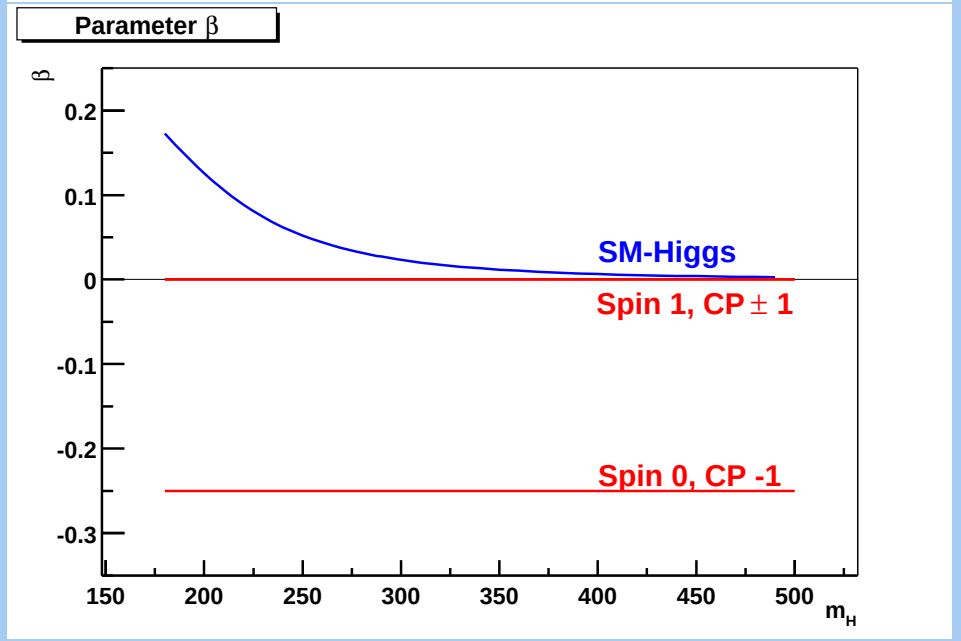
$$G(\theta) = T \cdot (1 + \cos^2(\theta)) + L \cdot \sin^2(\theta)$$

$$R := \frac{L - T}{L + T}$$

The Parameters α, β, R

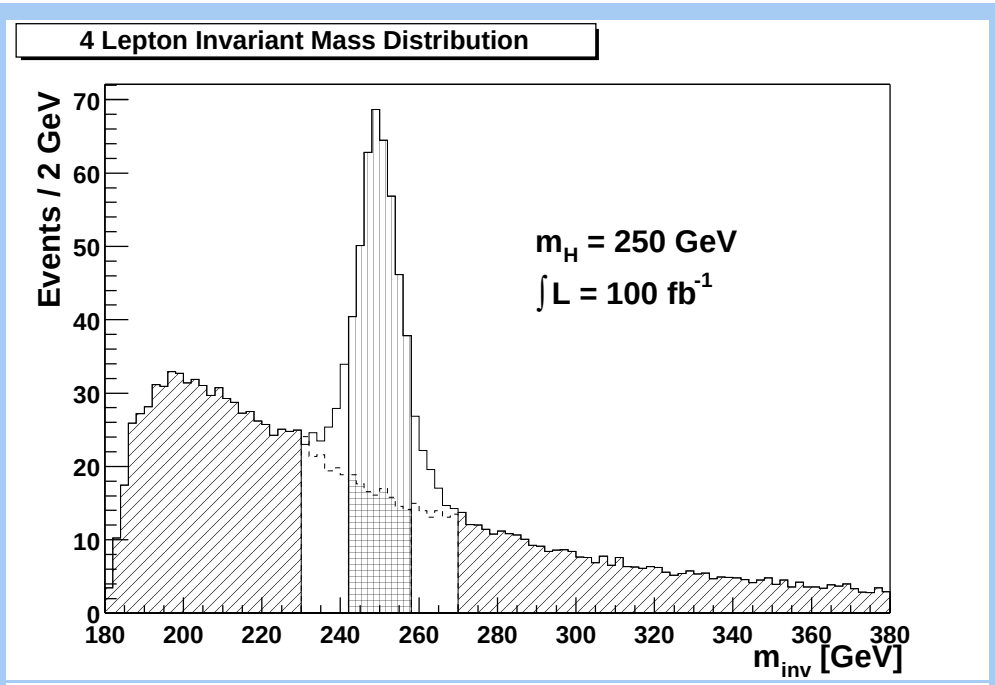


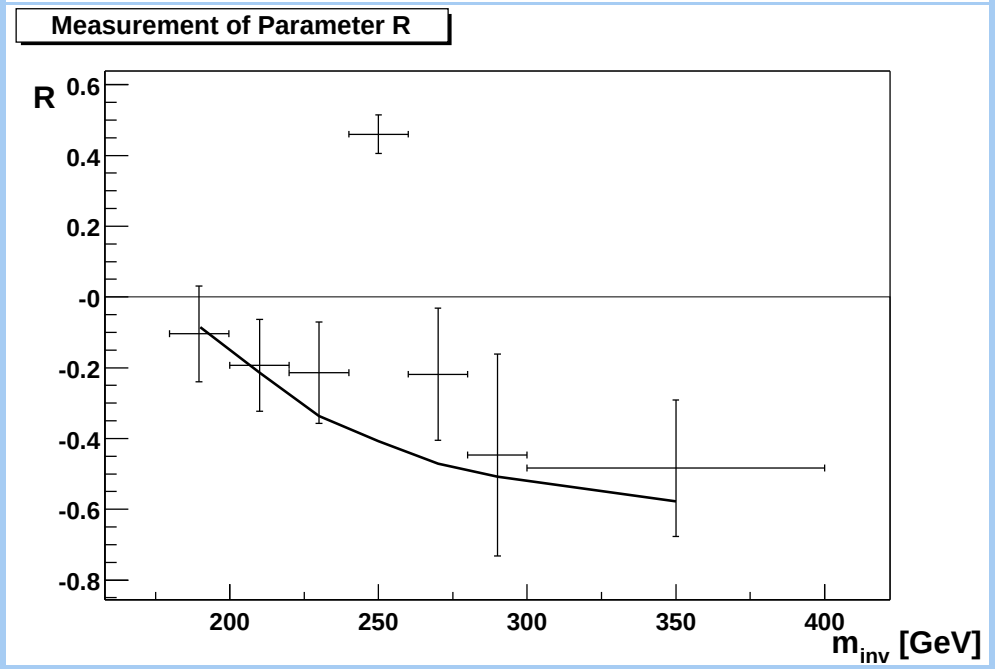




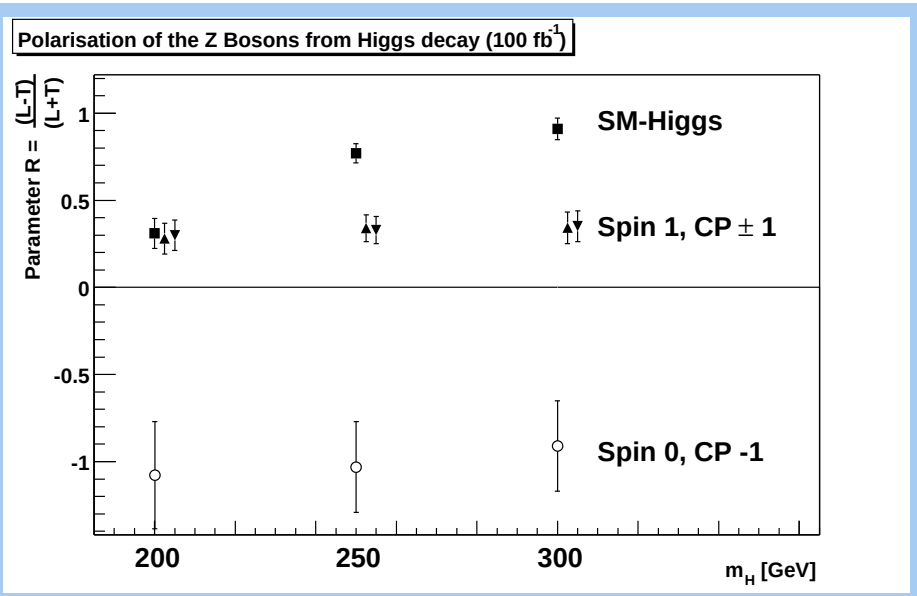
- SM Higgs parameters vary with mass
- Non-SM parameters constant
- R and β "complementary"
- α suppressed due to c_a, c_v
- Mind the background!

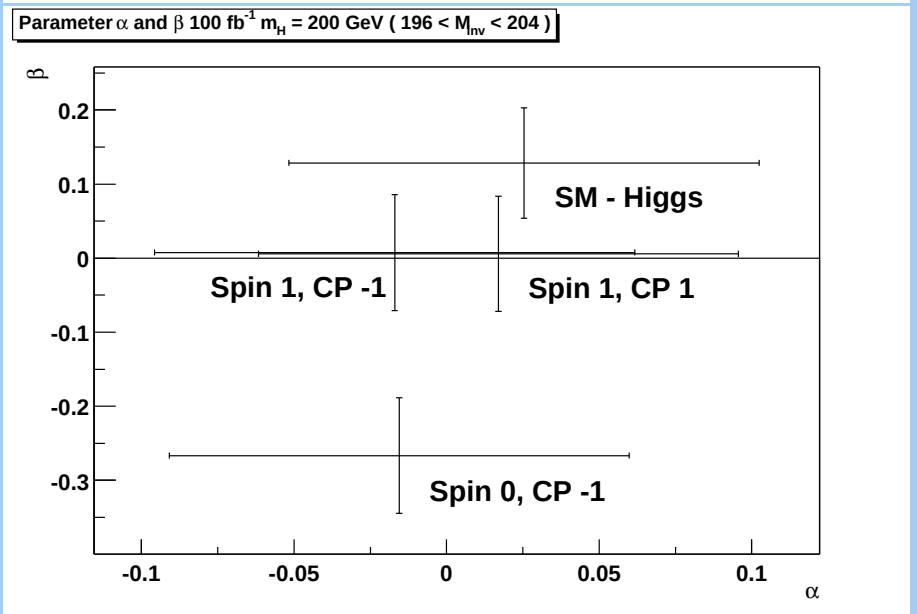
Background normalisation

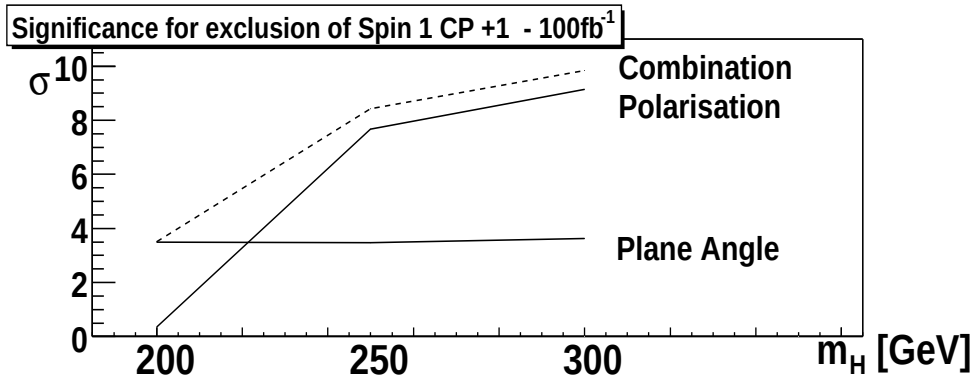


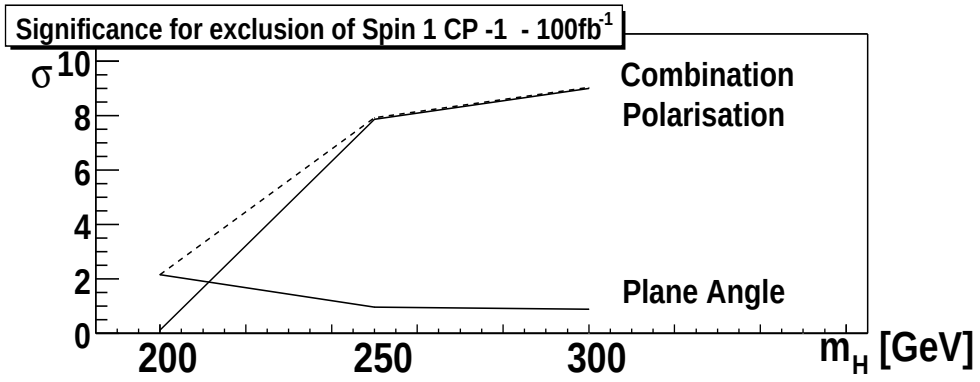


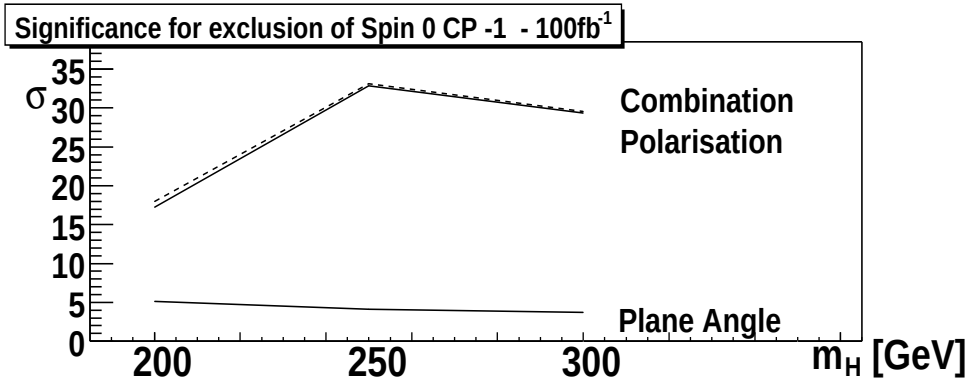
Results











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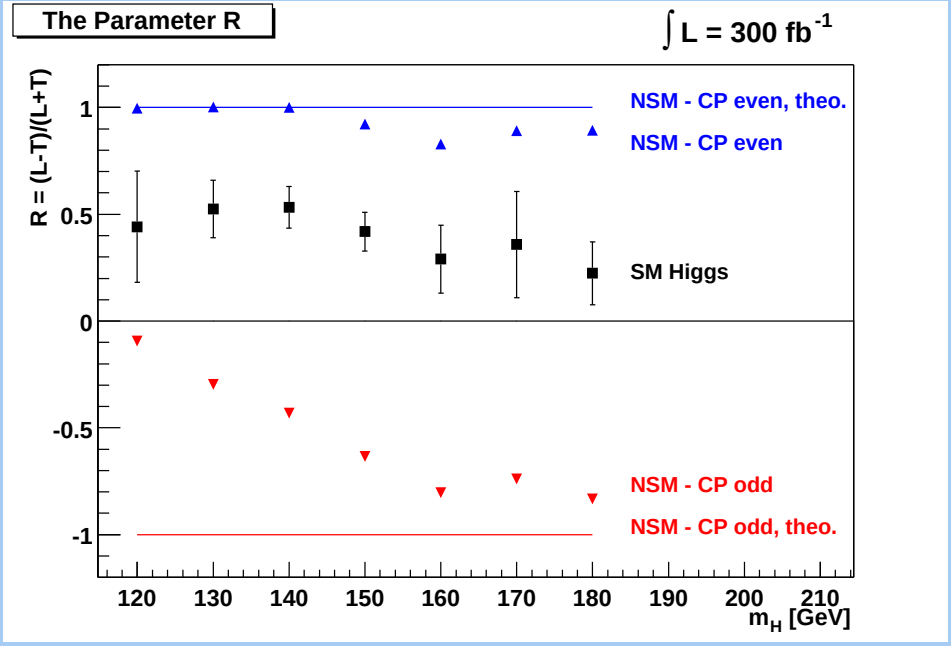
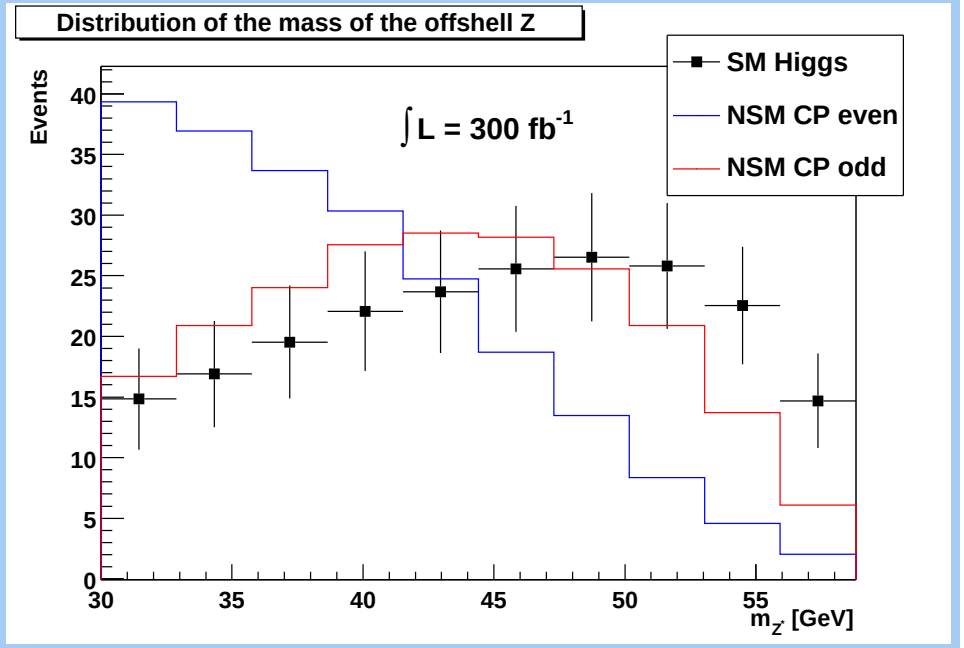
$H \rightarrow ZZ^*$

- Analysis basically the same.
- Additionally:
  Mass-window for "on-shell" Z and threshold for "off-shell" Z.
- $t\bar{t}$ and $Zb\bar{b}$ reduction using IP.
- Lower statistics $\Rightarrow$forget about α and β.
- **New variable:** "Off-shell" Z Mass.





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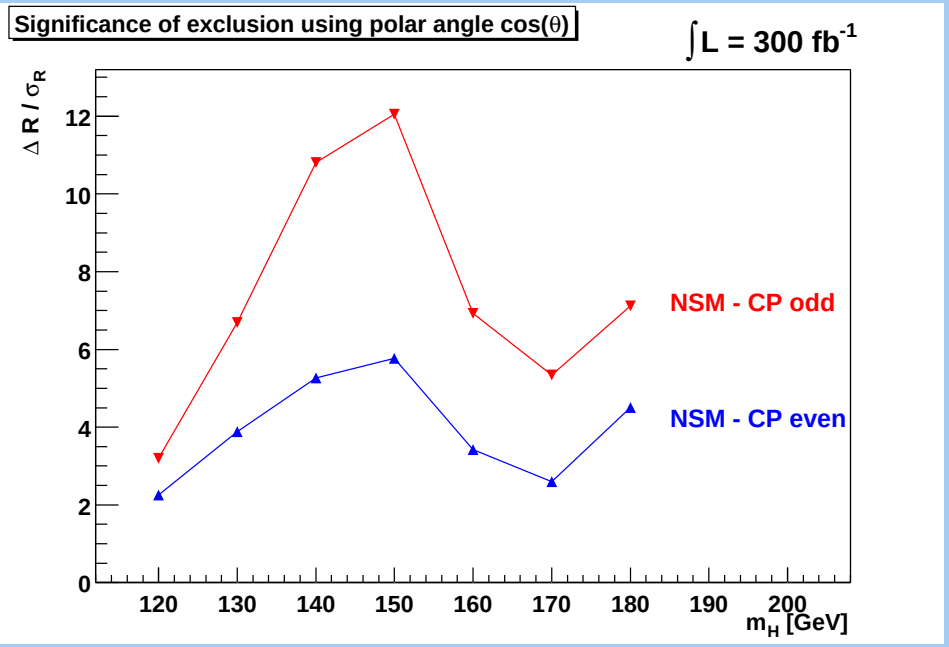
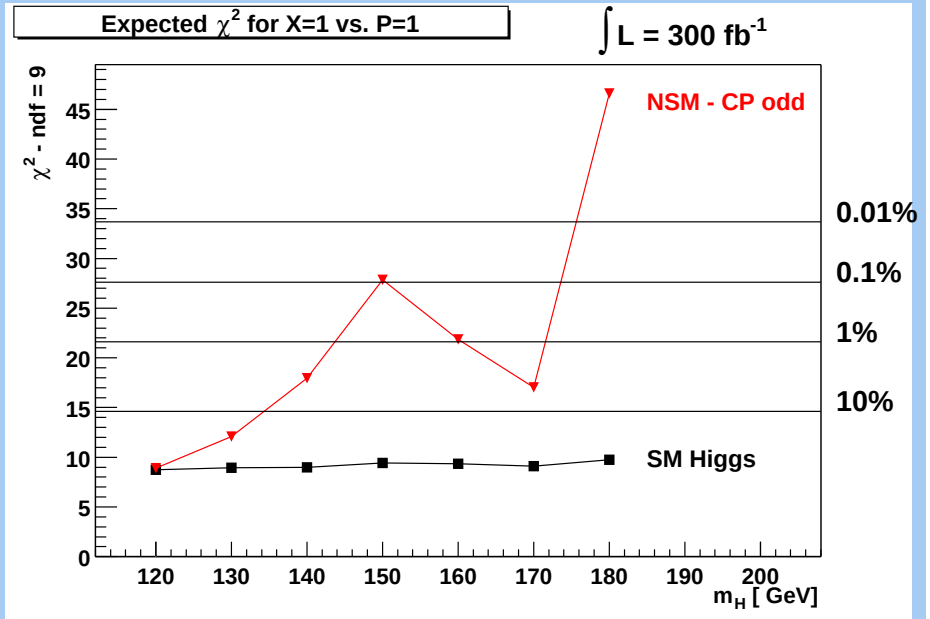
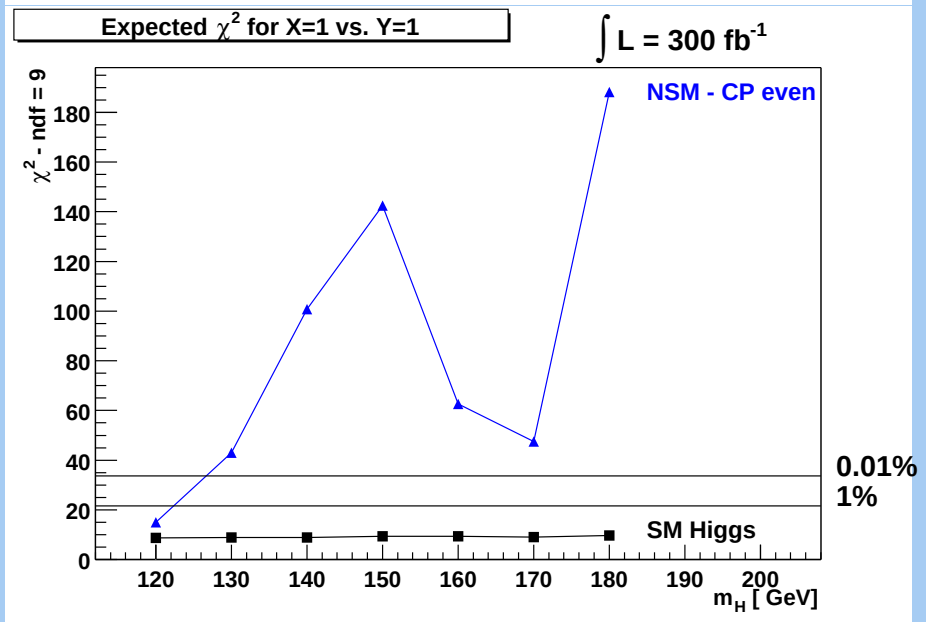






→Close to threshold OK

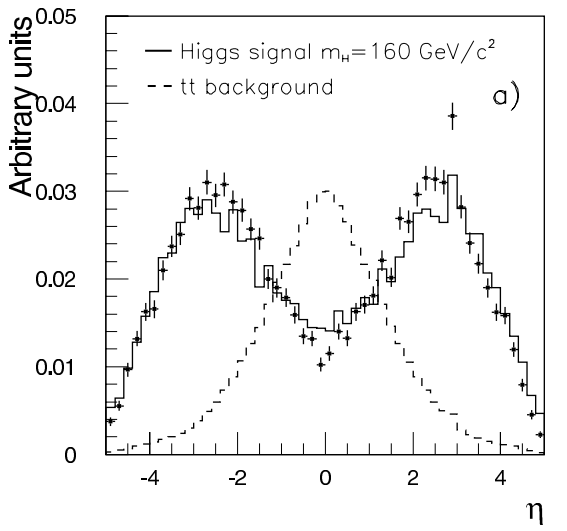
→Around 150 GeV OK

→Masses < 130 GeV difficult

→WW threshold as well

→need **300 fb^{-1}**

VBF at Atlas

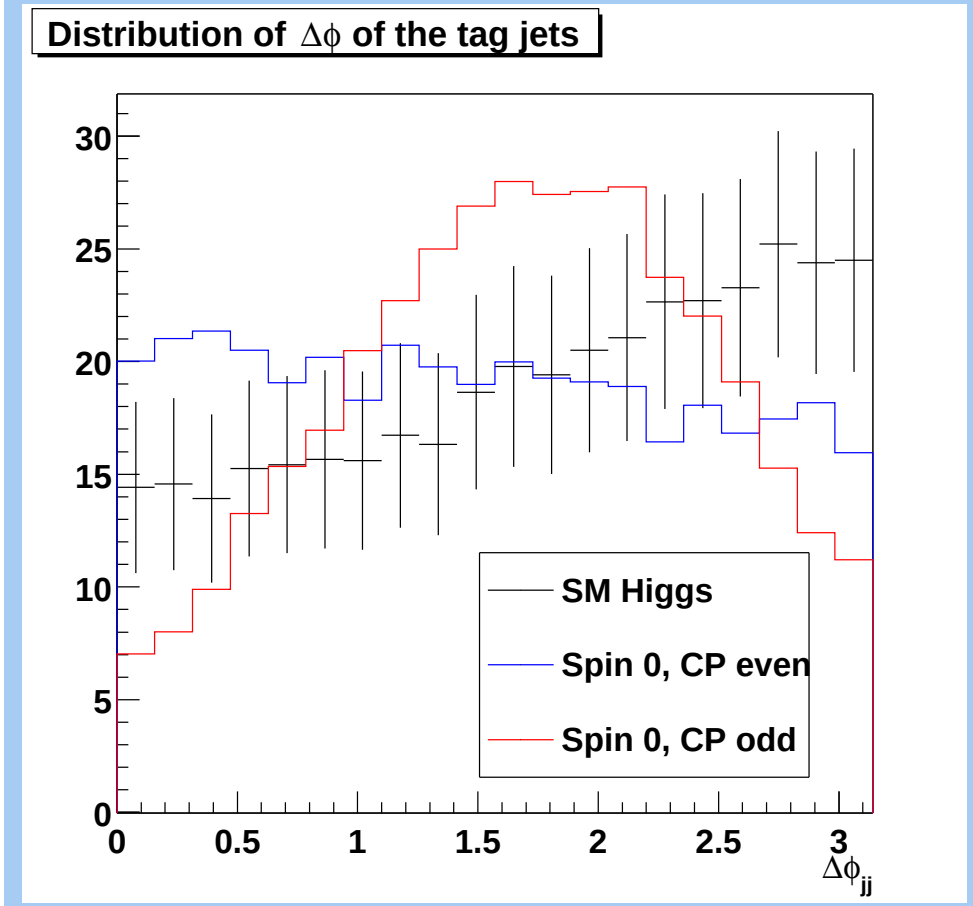


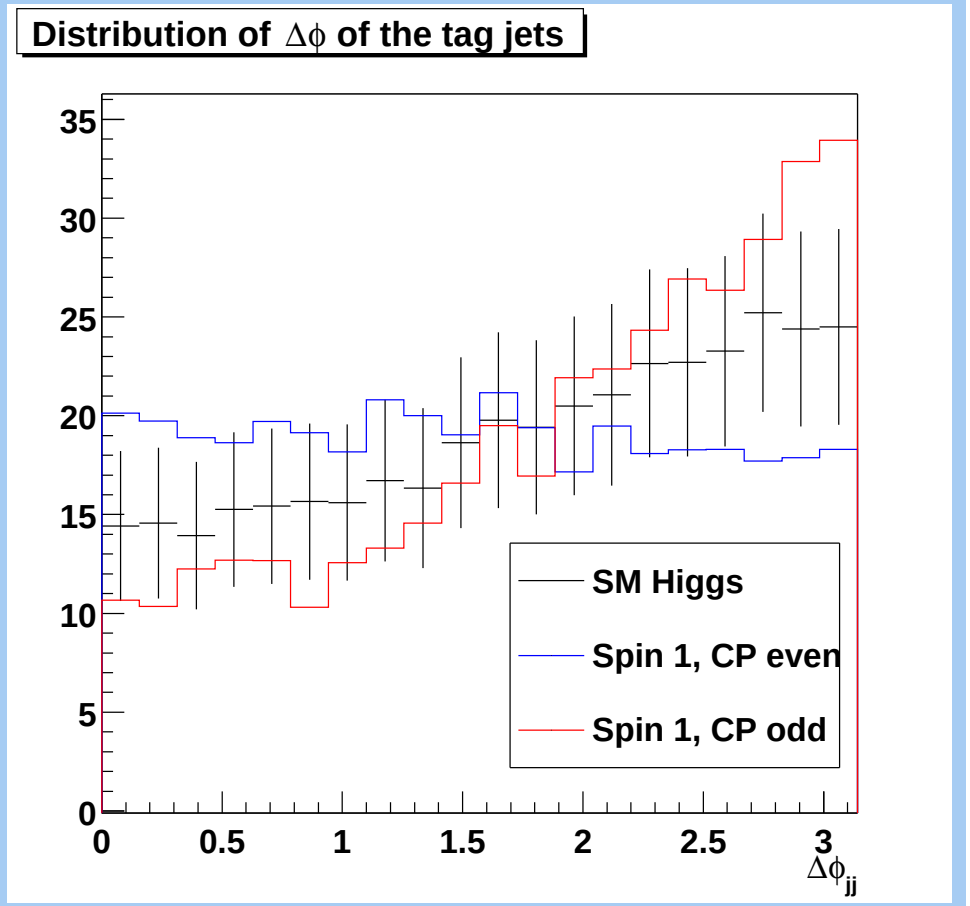
Basic idea:

- Leptons from H $\rightarrow$WW $\rightarrow$ll$\nu\nu$ trigger the experiment
- Use separated jets in forward region as tags (reduces tt)
- Leptons within rapidity gap.
- Central jet veto.
- Cut on dijet mass
- Angular correlations between leptons
- Jets balance transversal momentum of leptons+missing
- Upper bound on transversal mass of leptons+missing defines signal and non-signal region.

S. Asai et al., SN-ATLAS-2003-024

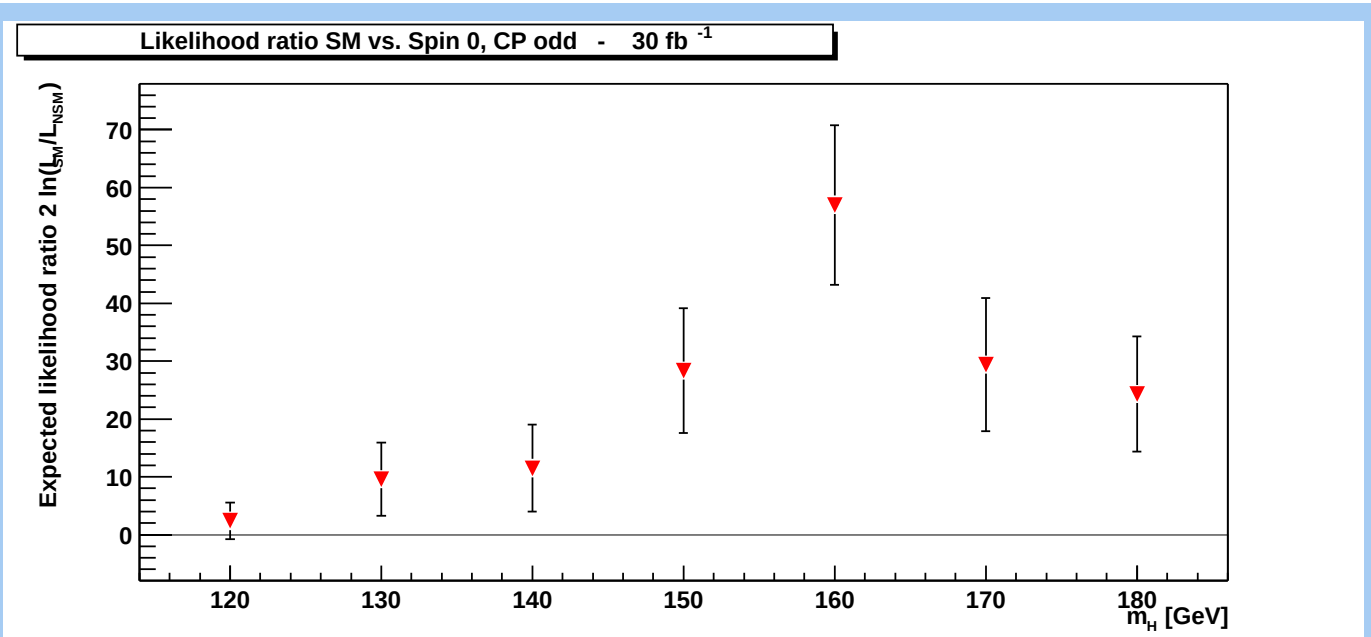
Jet angle distributions

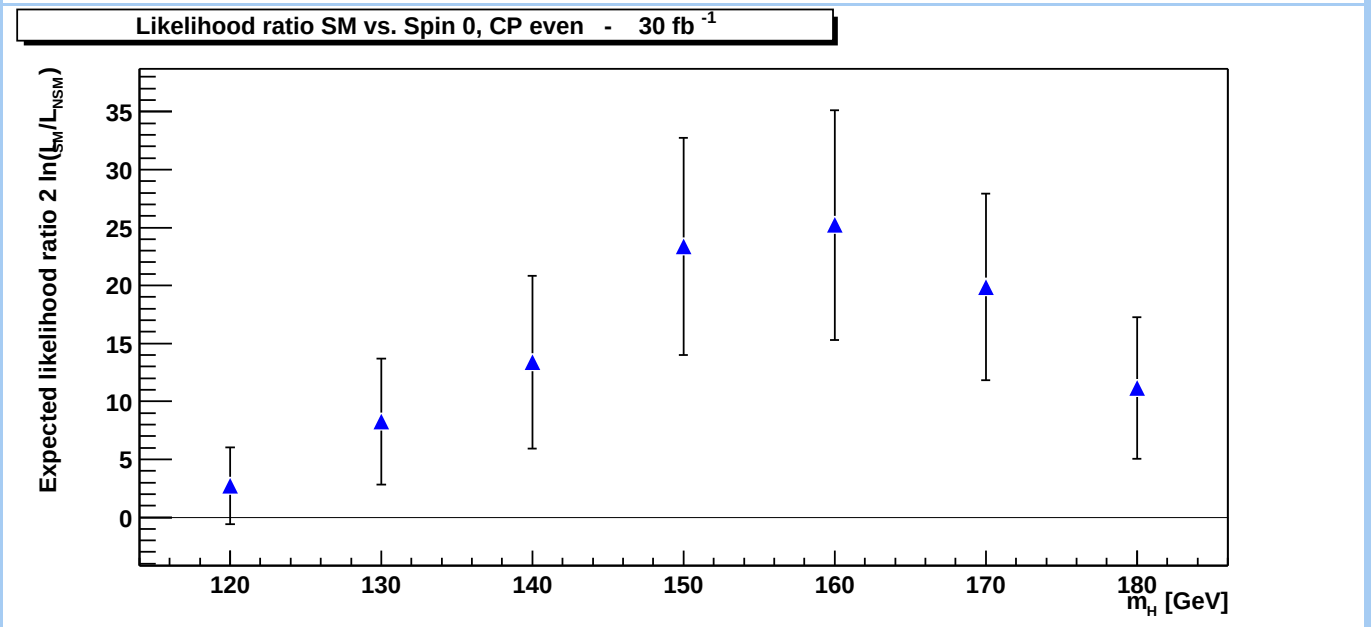




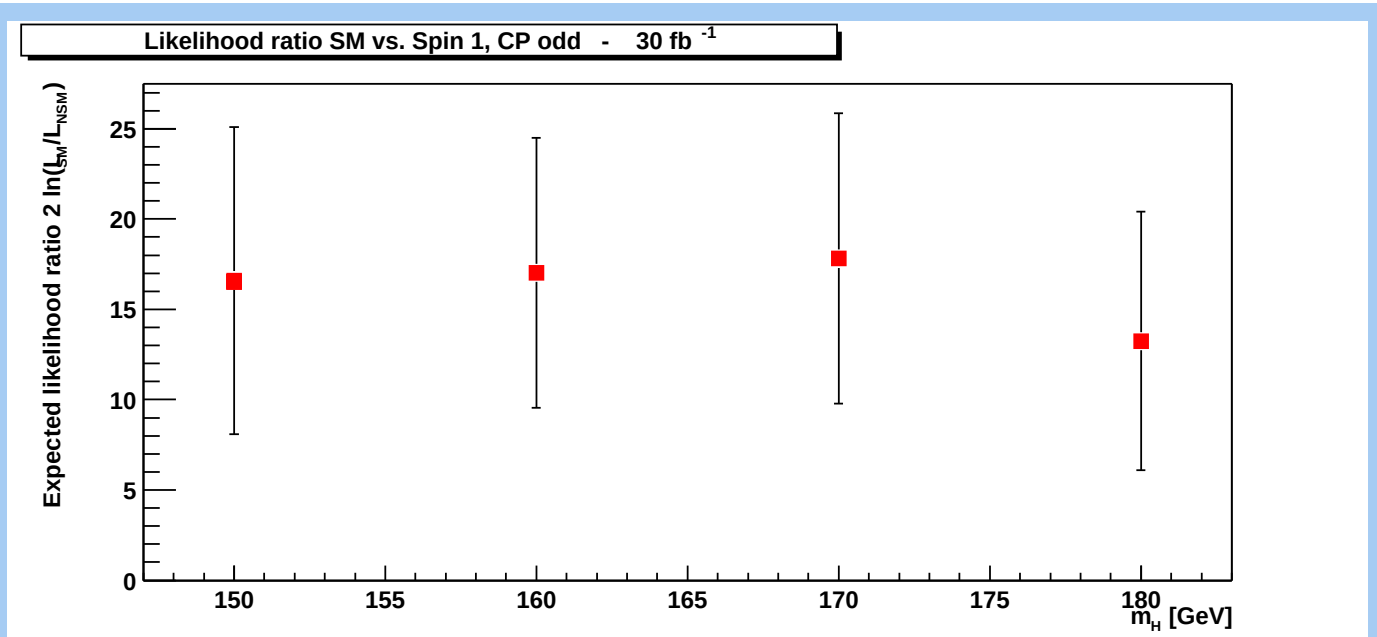
- Errorbars reflect statistical error assuming 30 fb^{-1}
- Spin 1 distributions distorted differently than SM Distributions
  $\Rightarrow$Need for good detector simulation.
- Use likelihoodratio of many MC experiments to determine
  $\chi^2 \approx -2ln(L_{SM}/L_{NSM})$

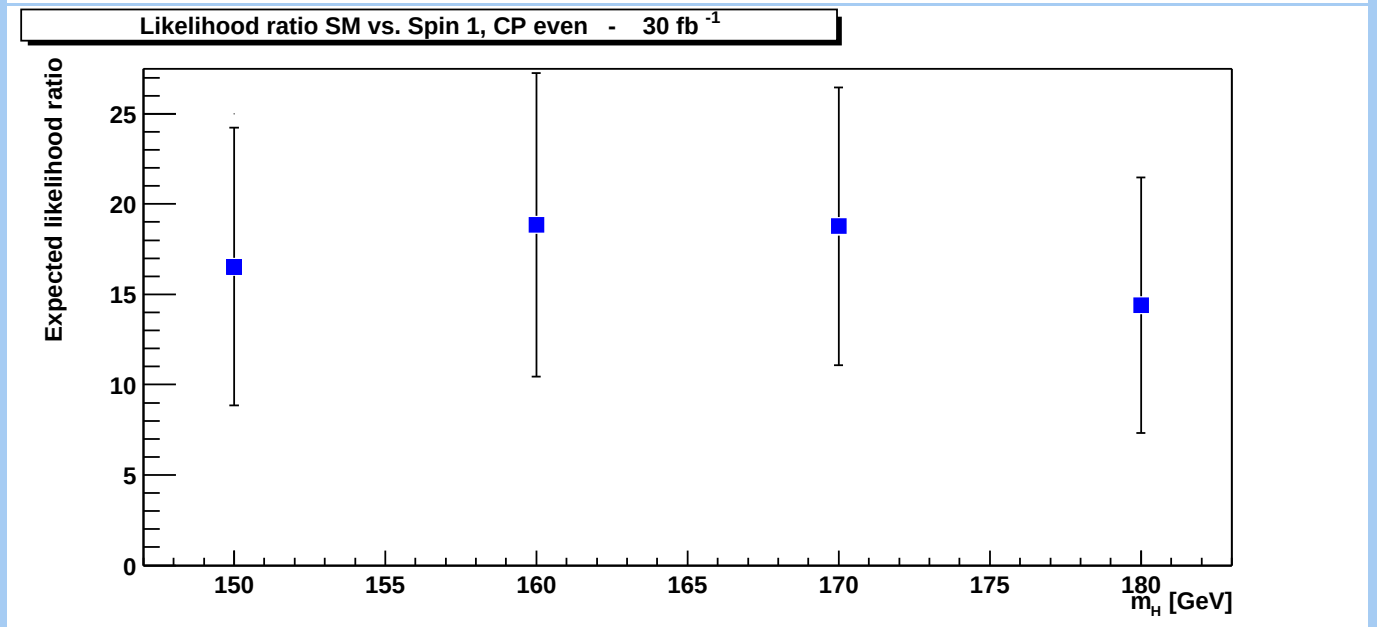
Exclusion significance - Spin 0



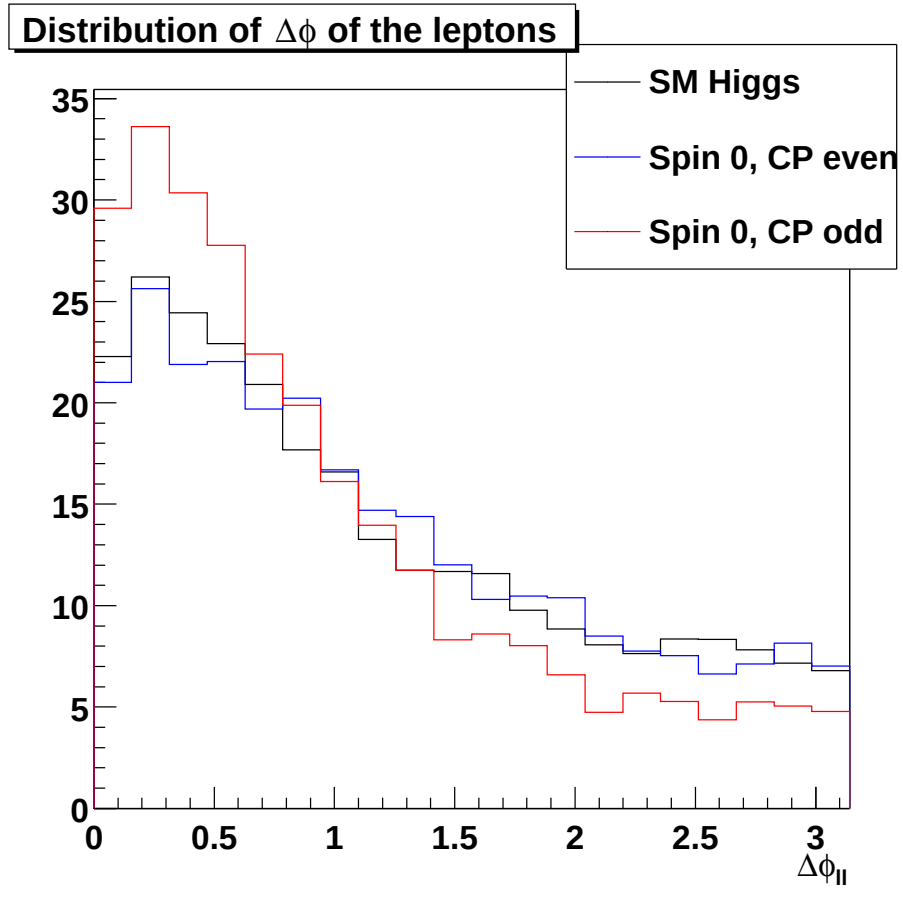


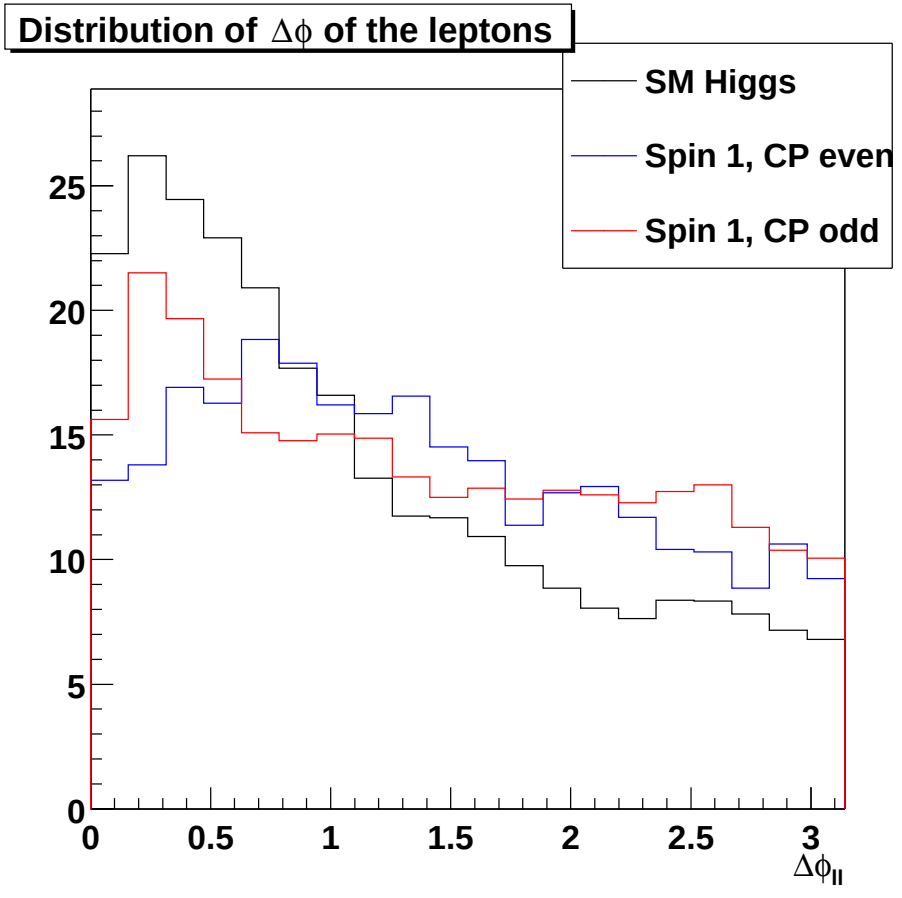
Exclusion Significance - Spin 1





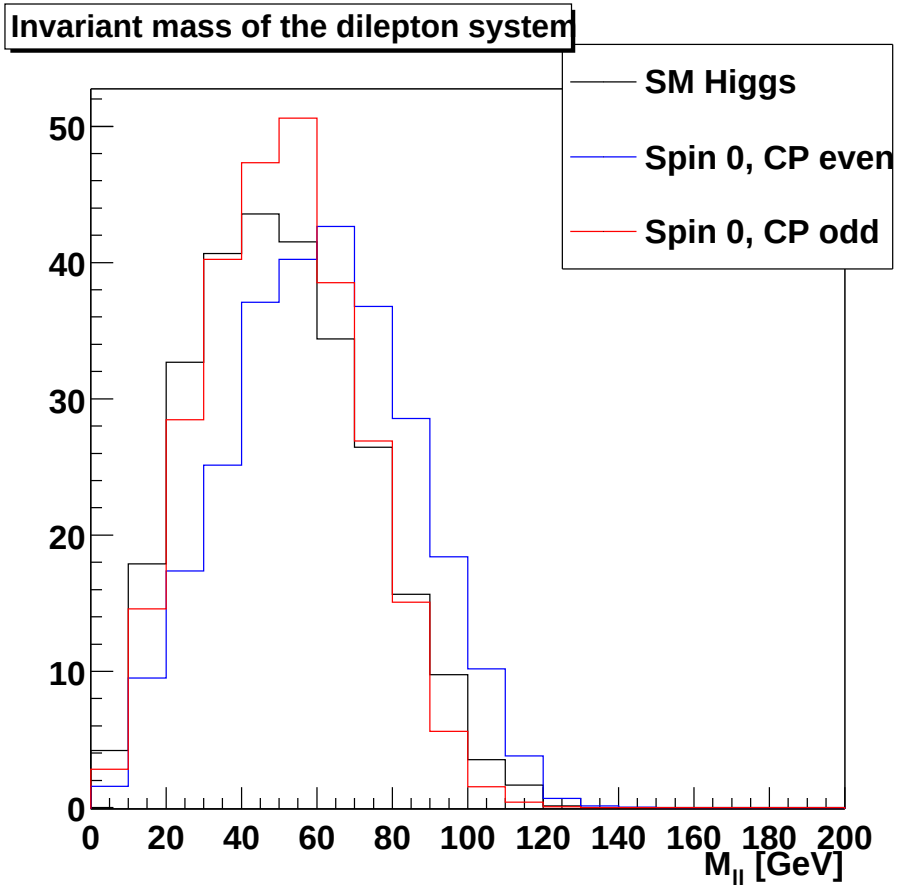
Lepton angle distributions

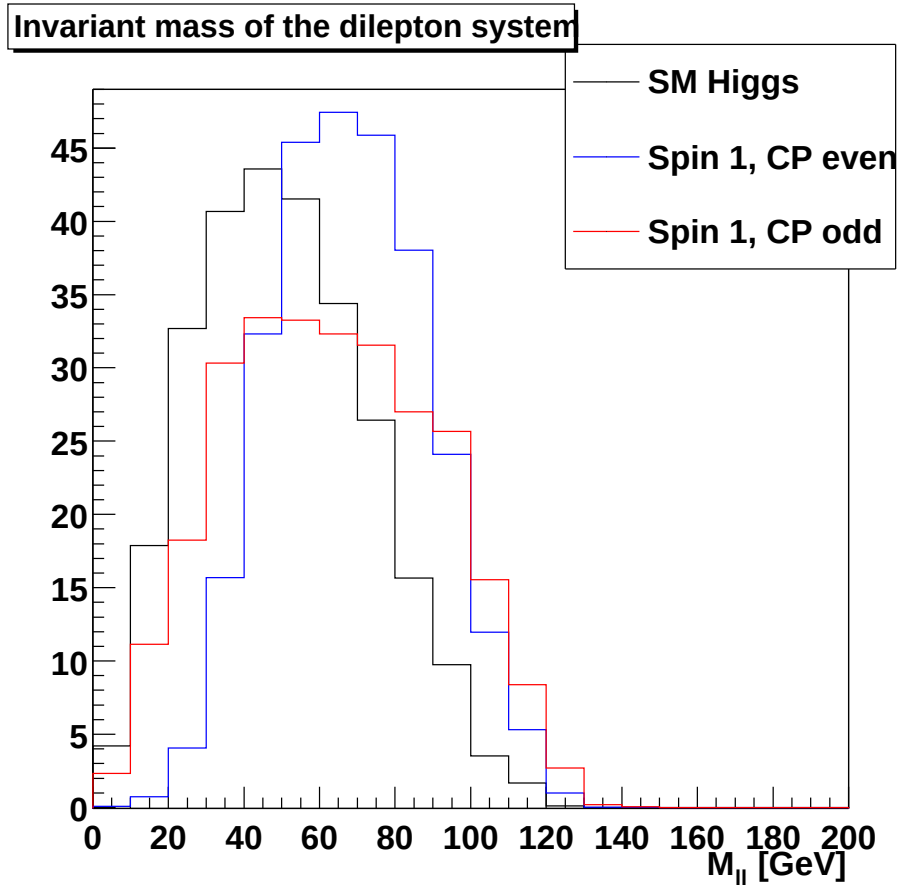




Azimuthal angle mainly effected by boost of Higgs and W-pair. Thus less powerful.

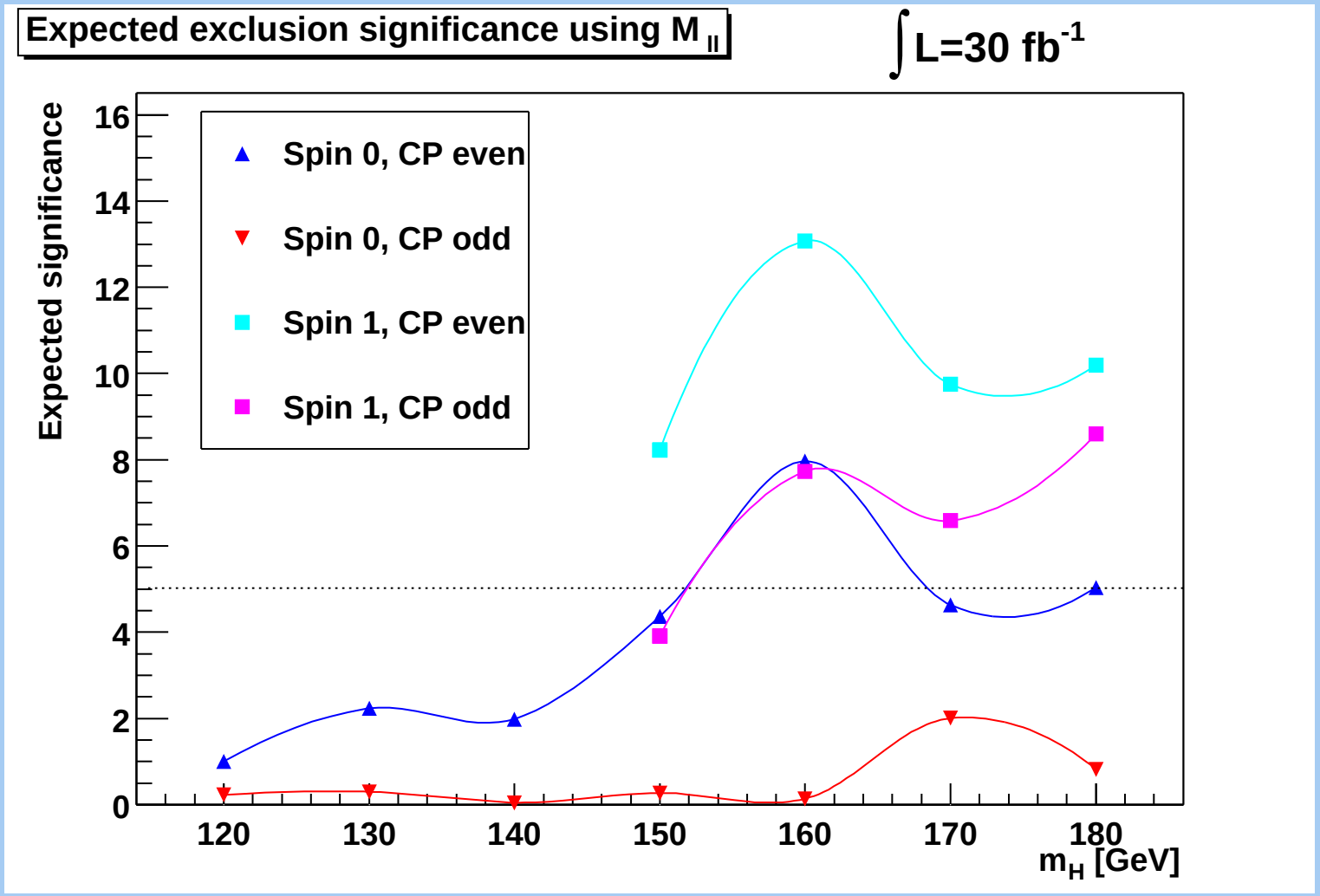
Dilepton Mass





- Simply use mean of dilepton masses as CP dependent variable.
- Effectively combines some angular correlations.
- Compute expected values and errors from many MC experiments.

Significance



Summary

A ME generator for general spin 0 and 1 "Higgs" to Vectorbosons exists.

Atlas will be able to demonstrate the compatibility of a SM-like Higgs with a spin/CP Hypothesis of 0^+

- Clean **4l** signal provides nice variables for CP measurement. Polarisation of Z Bosons provides the best results
- Below ZZ threshold "off-shell"-Z mass provides additional information.
- Jet angles in **VBF** allow determination with only 30 fb^{-1}
- Dilepton mass in **H** $\rightarrow$**WW** combined wih VBF provide spin/CP determination for wide massrange below ZZ

Even more: The ME (and thus the generator) includes **mixed states** not mentioned so far $\Rightarrow$Peter's talk!