Measurement of angular distributions for

$$\gamma\gamma \to h \to ZZ \to ll\ jj$$
$$\to WW \to 4j$$

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NŻK

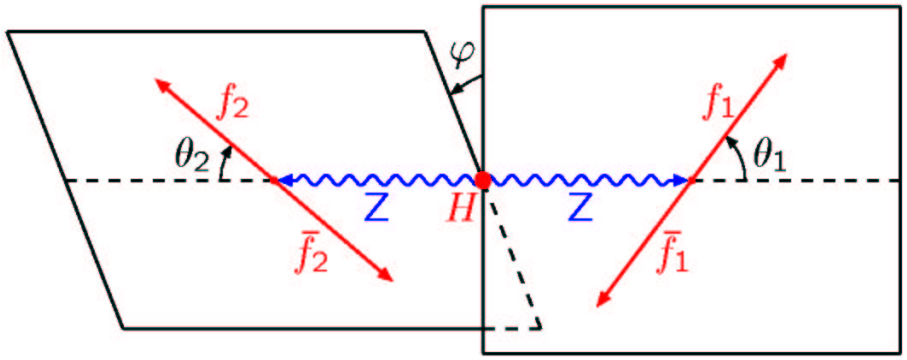
Workshop of the Extended ECFA/DESY Study
Amsterdam, April 2003

Outline

- Introduction
- Resolution and acceptance
- $h \to ZZ$ results
  (new: background contribution)
- $h \to WW$ results (new)
- Summary

Introduction

Angular distributions



5 angles:

- polar angle θ_Z for $h \to ZZ$ decay
- polar angle θ_l for $Z \to l^- l^+$ decay
- polar angle θ_j for $Z \to q\bar{q}$ decay
- azimuthal angles between higgs and Z decay planes: ϕ_l and ϕ_j

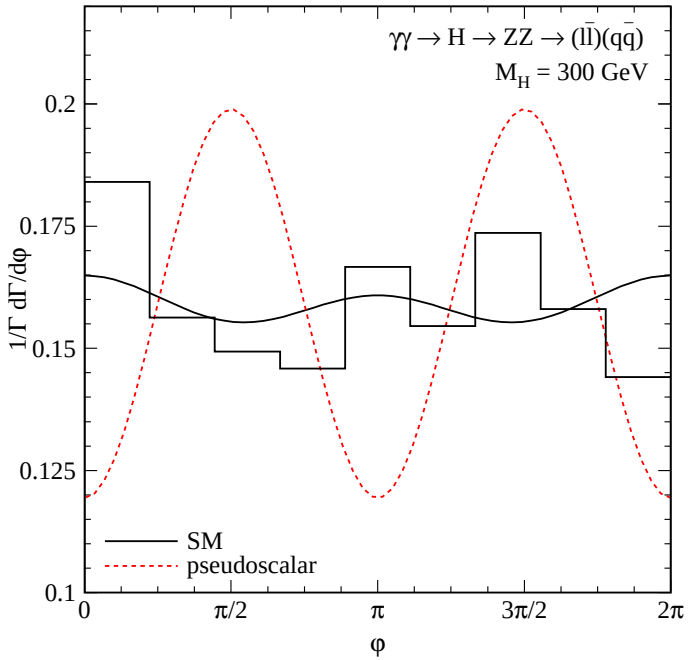
angle between two planes: $\Delta\phi = \phi_j - \phi_l$

S.Y.Choi, D.J.Miller, M.M.Muhlleitner, P.M. Zerwas, Phys.Lett.B553(2003)61, hep-ph/0210077

D.J.Miller, Prague, November 2002:

Measurement of angular distributions

$\Rightarrow$ higgs spin and parity



$\Rightarrow$ **Can PC measure this ?!**

Introduction

Simulation

$\gamma\gamma$ spectra from **CompAZ**,

$\sqrt{s_{ee}}$ = 270 – 500 GeV

higgs events generated with PYTHIA 6.214

$\gamma\gamma \to h \to ZZ \to e^+e^-q\bar{q}$ / $\mu^+\mu^-q\bar{q}$

$\gamma\gamma \to h \to WW \to q\bar{q}\,q\bar{q}$

m_h = 170 – 350 GeV

PYTHIA properly simulates all angular distributions for SM higgs

"pseudoscalar" higgs

$\Rightarrow$ reweighting of angular distributions

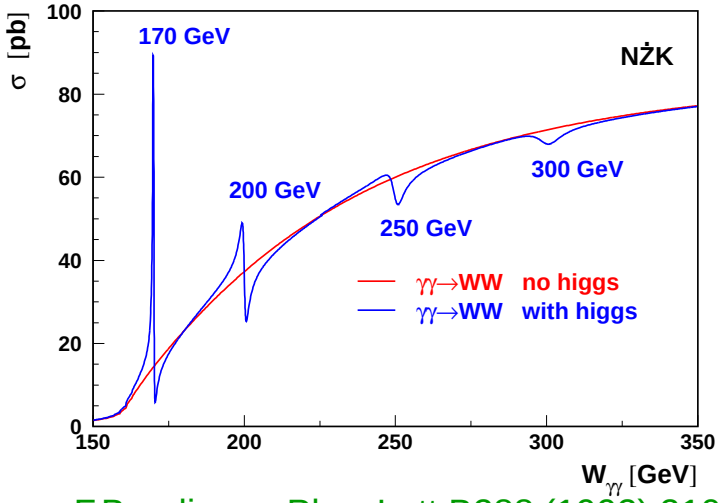
(σ and BR assumed same as for h)

angular distributions for background

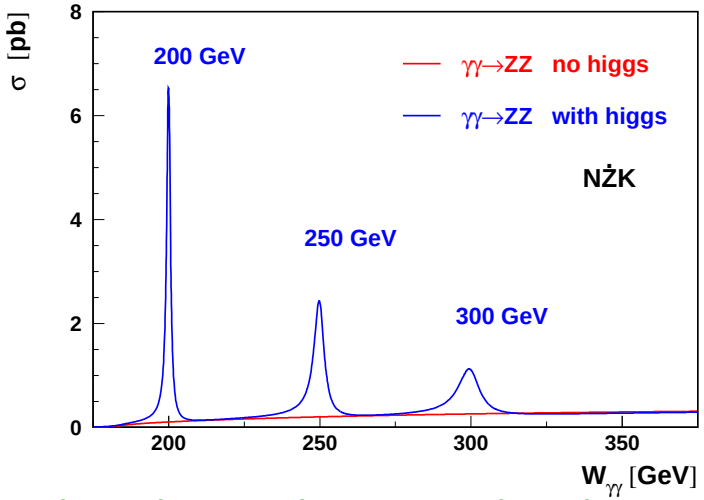
$\Rightarrow$ PYTHIA + reweighting

detector simulation with SIMDET v. 3.01

Cross sections for $J_Z = 0$:



G.Belanger, F.Boudjema, Phys.Lett.B288 (1992) 210;
D.A.Morris, et al., Phys. Lett. B323 (1994) 421;
I.F.Ginzburg, I.P.Ivanov, Phys. Lett. B408 (1997) 325.



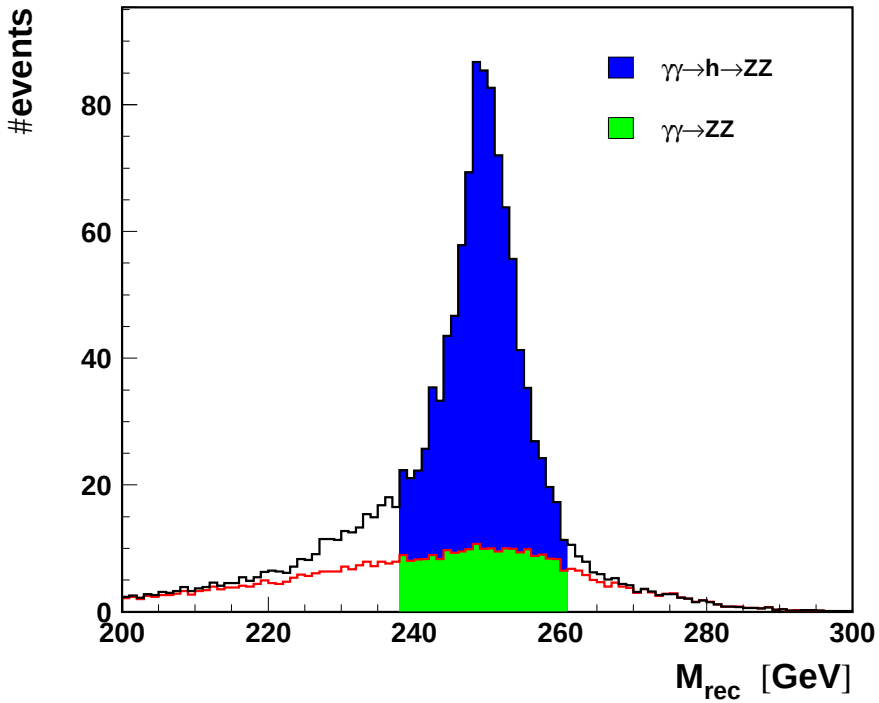
G.J.Gounaris et al., Eur. Phys. J. C13 (2000) 79.

Selection

$h \to ZZ \to llqq$ event selection

- balanced transverse momentum:
  $$P_T/E_T < 0.1$$
- 2 leptons ($e^{\pm}$ or $\mu^{\pm}$) + 2 hadronic jets
- cut on lepton and jet angle
  $$\cos\theta_l < 0.98, \quad \cos\theta_{jet} < 0.95$$
- leptons and jets reconstruct into two Z° with probability $P_Z > 0.001$
  based on reconstructed invariant mass
- invariant mass cut
  optimized for background rejection

Invariant mass cut for m_h=250 GeV:



SM higgs selection efficiency ∼40%
(for $ZZ \to q\bar{q}\,l^+l^-$ events, $l = \mu, e$)
$\times BR(ZZ \to q\bar{q}\,l^+l^-) \approx 9.4\%$

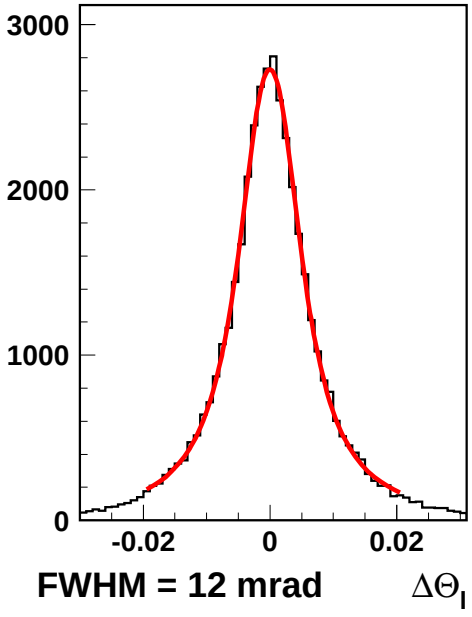
P. Nieżurawski, A.F. Żarnecki, M. Krawczyk,
Study of the Higgs-boson decays into W^+W^- and ZZ at the Photon Collider
JHEP 0211 (2002) 034 [hep-ph/0207294]

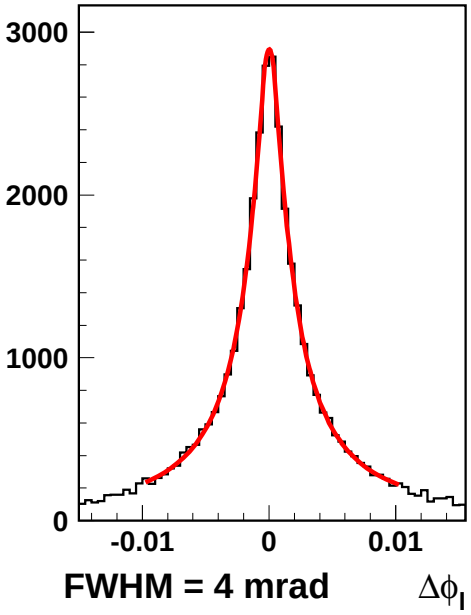
Resolution

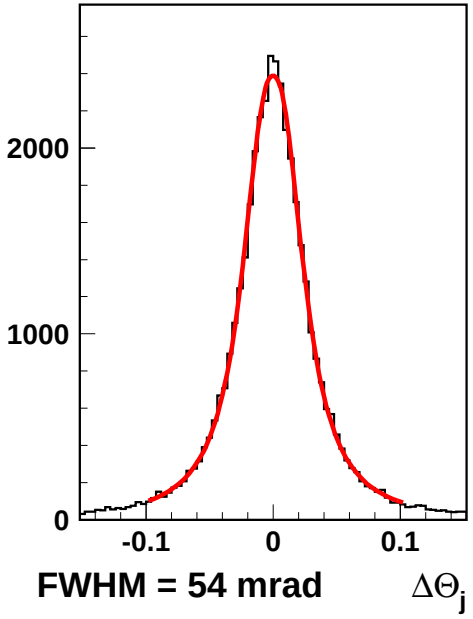
Expected accuracy of decay angles measurement:

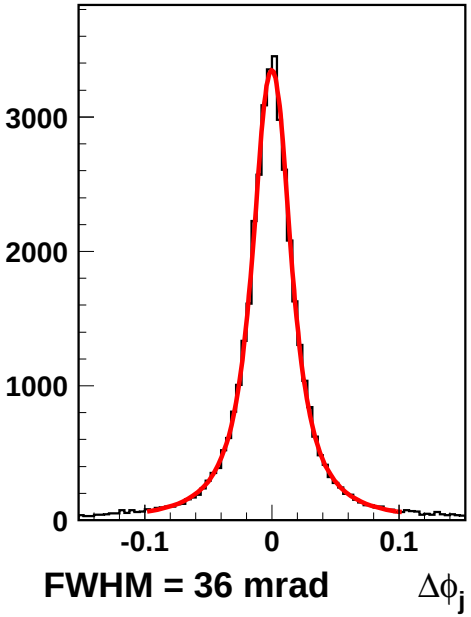
$Z \to l^+ l^-$ $\qquad$ $Z \to q\bar{q}$

polar angle θ_l $\qquad$ azimuthal angle ϕ_l $\qquad$ polar angle θ_q $\qquad$ azimuthal angle ϕ_q









$\sim$ same for $\Delta\phi$

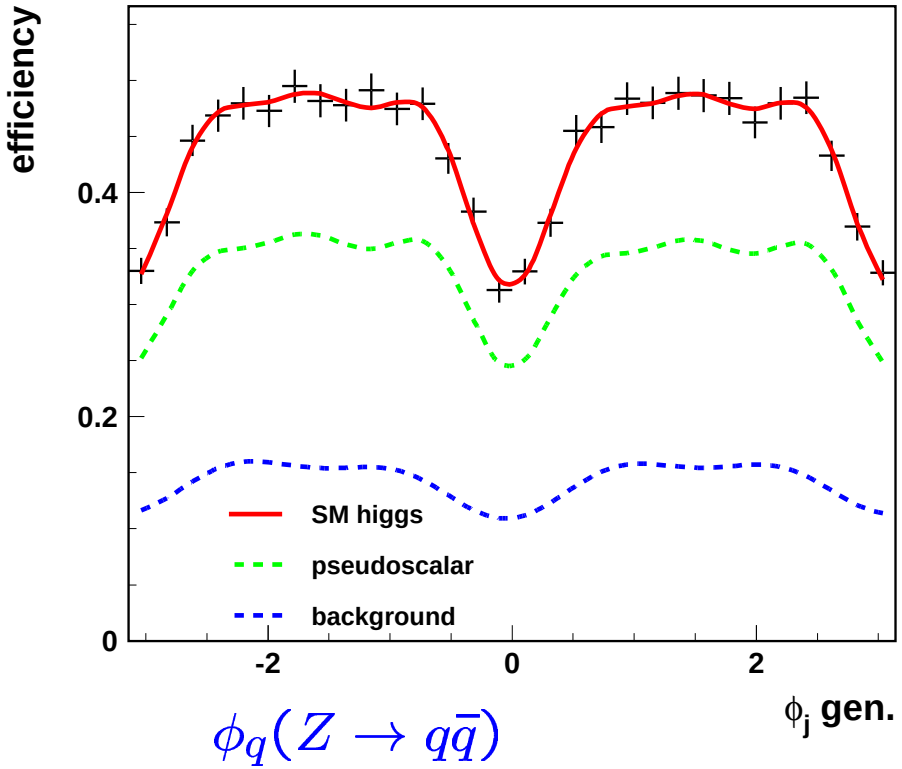
All angles can be measured with high accuracy

Shape described by Breit-Wigner distribution

Acceptance

Selection efficiency as a function of the azimuthal angle ϕ_q

m_h = 300 GeV, $\sqrt{s_{ee}}$=418 GeV

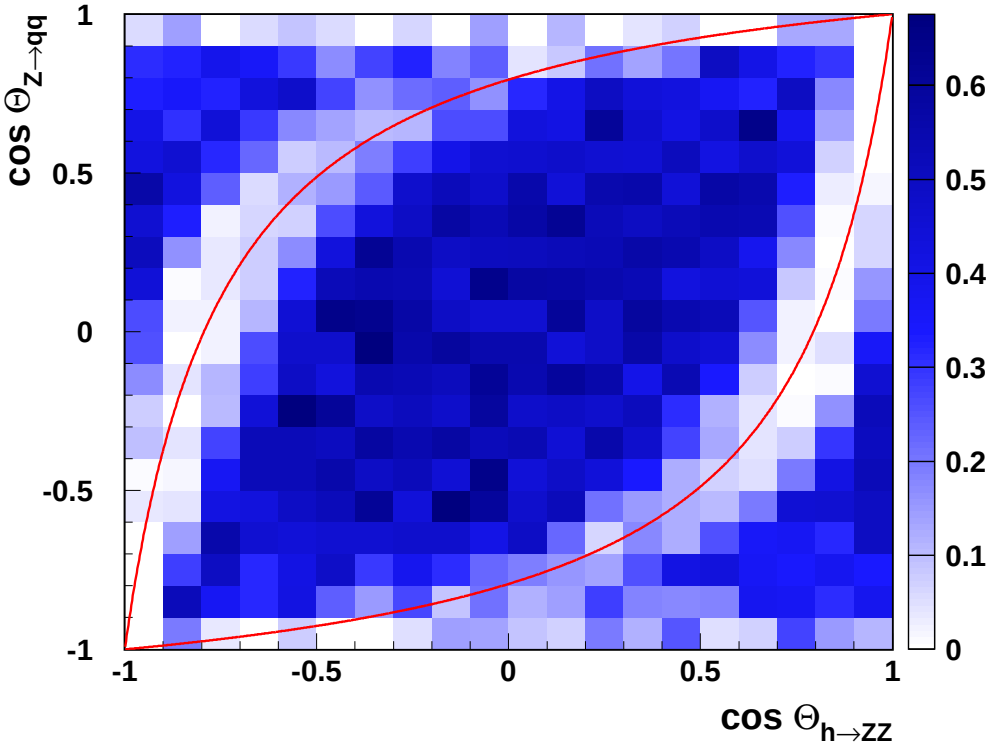


$\phi_q(Z \to q\bar{q})$

similar pattern observed for $Z \to l^- l^+$

Acceptance losses for $\phi = 0, \pi, \ldots$ are due to the jet/lepton going in the beam direction

Selection efficiency for $\phi_j \approx 0$:

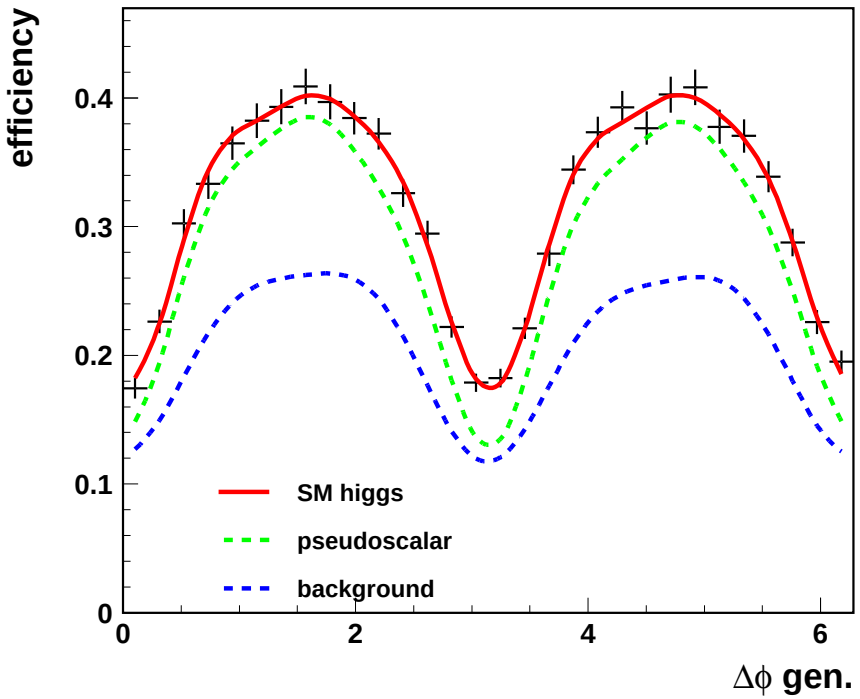


red lines: $\cos\theta_j^{LAB} = \pm\cos\theta_Z^{LAB}$

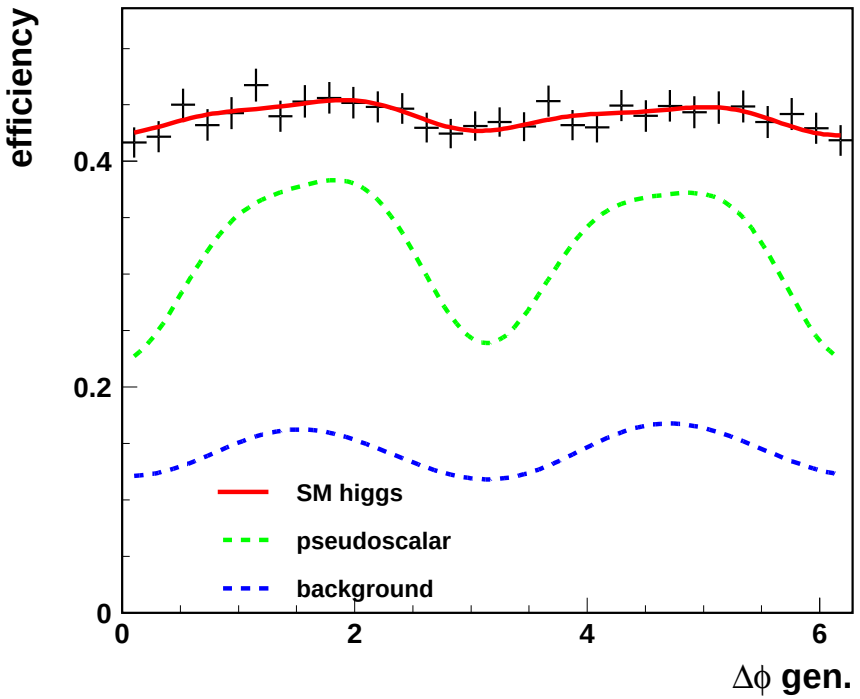
Acceptance

Nonuniformity of selection efficiency in $\Delta\phi$ largest for small m_h

m_h = 200 GeV, $\sqrt{s_{ee}}$=305 GeV



m_h = 300 GeV, $\sqrt{s_{ee}}$=418 GeV



Effect much stronger for background events and pseudoscalar higgs due to different $\cos\theta_{j,l}$ distribution

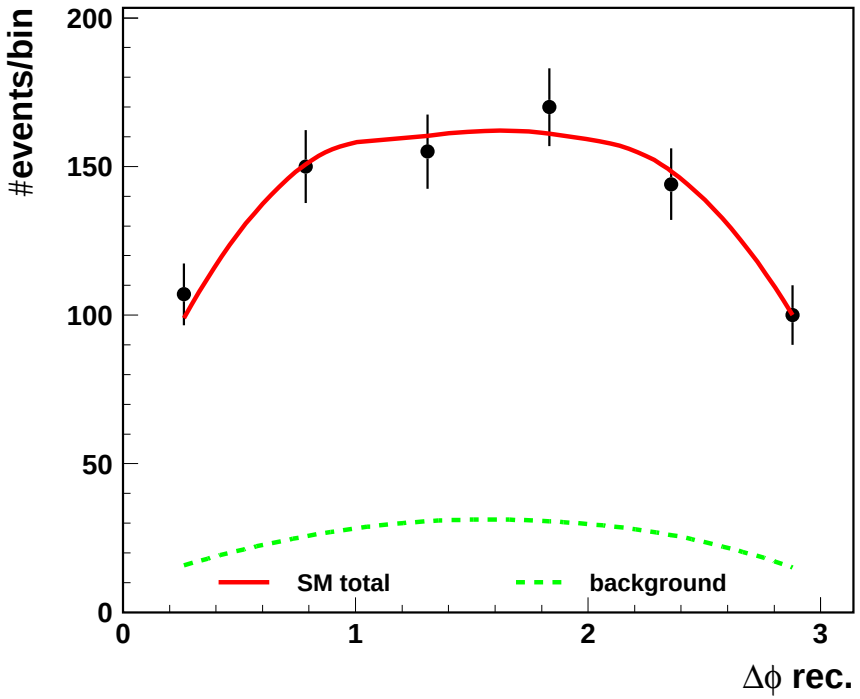
Results

Measured $\Delta\phi$ distribution for m_h = 200 GeV

after 1 year of PC running at $\sqrt{s_{ee}}$=305 GeV, $\mathcal{L} = 610\ fb^{-1}$

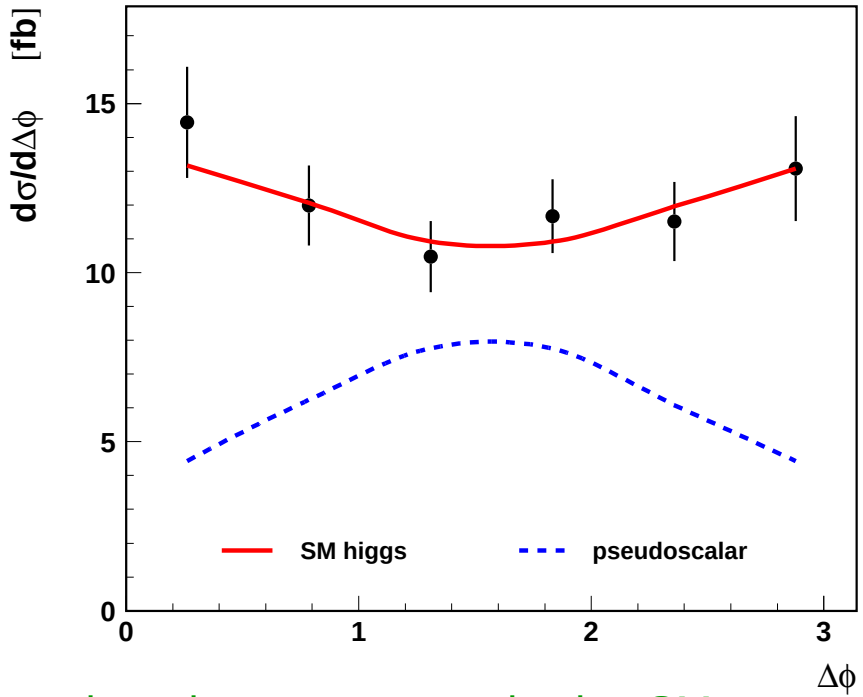
$\Rightarrow$ ~675 reconstructed SM higgs events expected + 145 ZZ background events

Measured distribution:



$q \leftrightarrow \bar{q}$ ambiguity $\Rightarrow 0 \leq \Delta\phi \leq \pi$

Extracted $\frac{d\sigma}{d\Delta\phi} \times BR(h \to ZZ)$



pseudoscalar reconstructed using SM acceptance

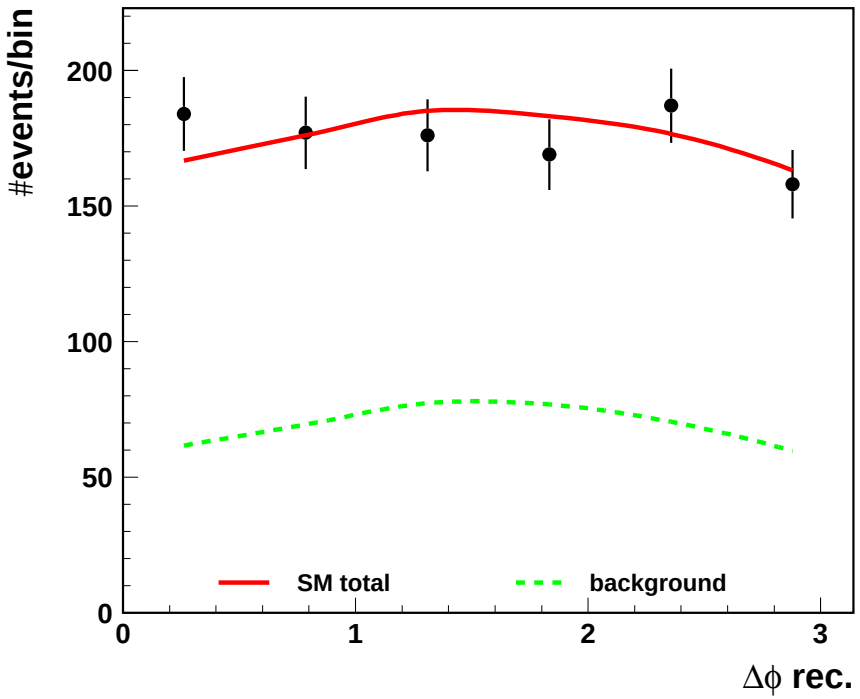
Results

Measured $\Delta\phi$ distribution for m_h = 300 GeV

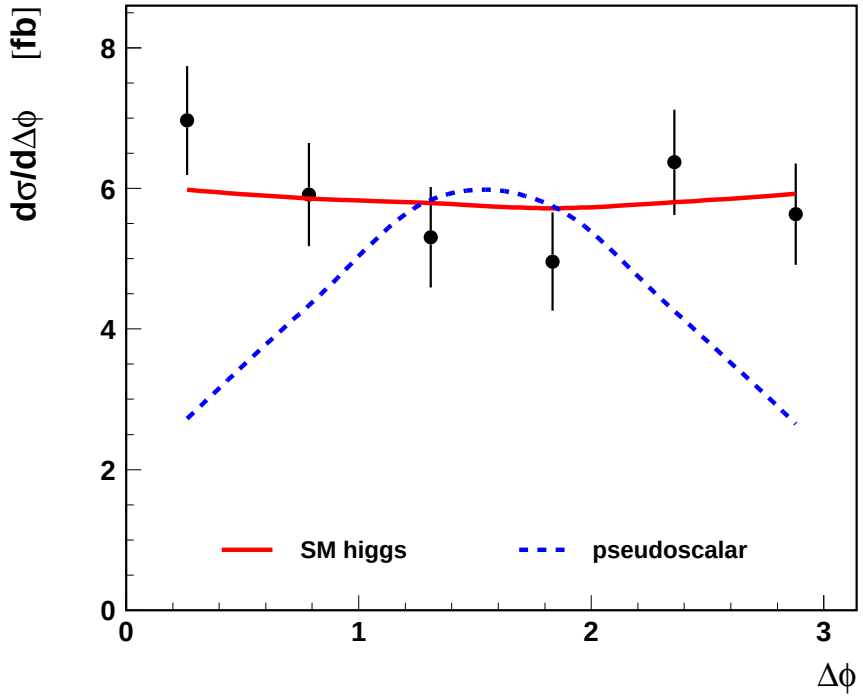
after 1 year of PC running at $\sqrt{s_{ee}}$=418 GeV, $\mathcal{L} = 830\ fb^{-1}$

$\Rightarrow$ $\sim$635 reconstructed SM higgs events expected + 415 ZZ background events

Measured distribution:



Extracted $\frac{d\sigma}{d\Delta\phi} \times BR(h \to ZZ)$



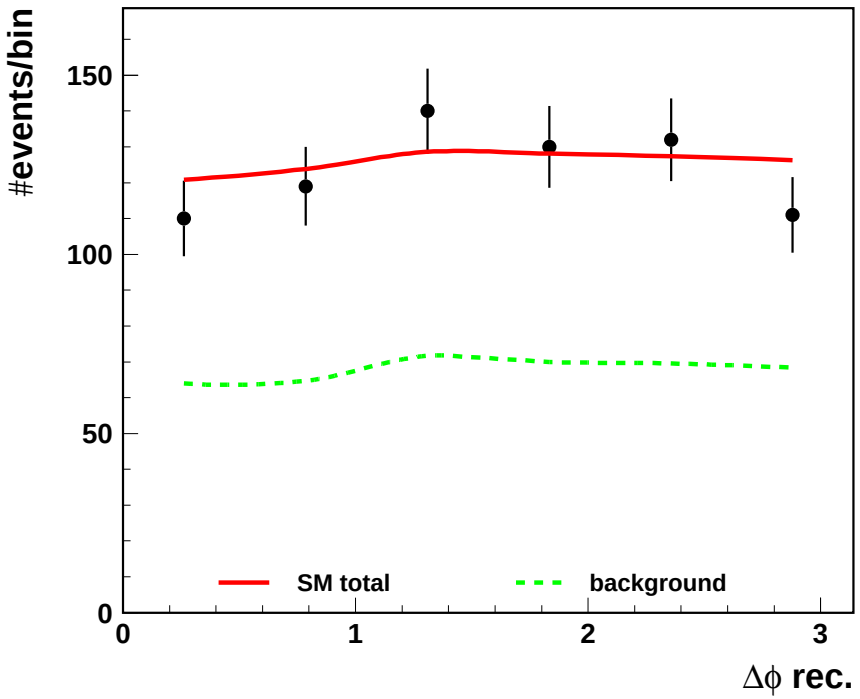
Results

Measured $\Delta\phi$ distribution for m_h = 350 GeV

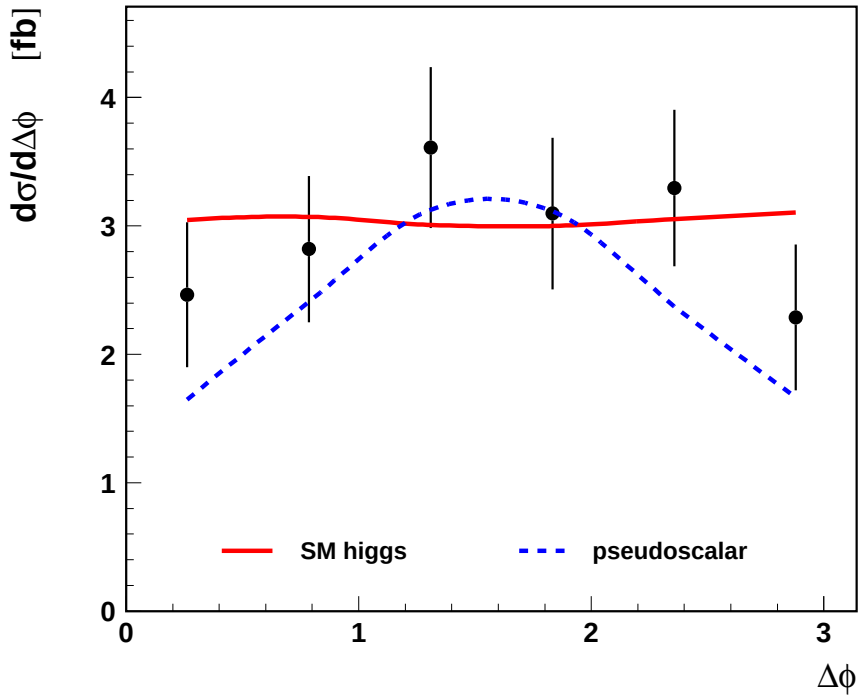
after 1 year of PC running at $\sqrt{s_{ee}}$=500 GeV, $\mathcal{L} = 1000\ fb^{-1}$

$\Rightarrow$ $\sim$345 reconstructed SM higgs events expected + 410 ZZ background events

Measured distribution:



Extracted $\frac{d\sigma}{d\Delta\phi} \times BR(h \to ZZ)$

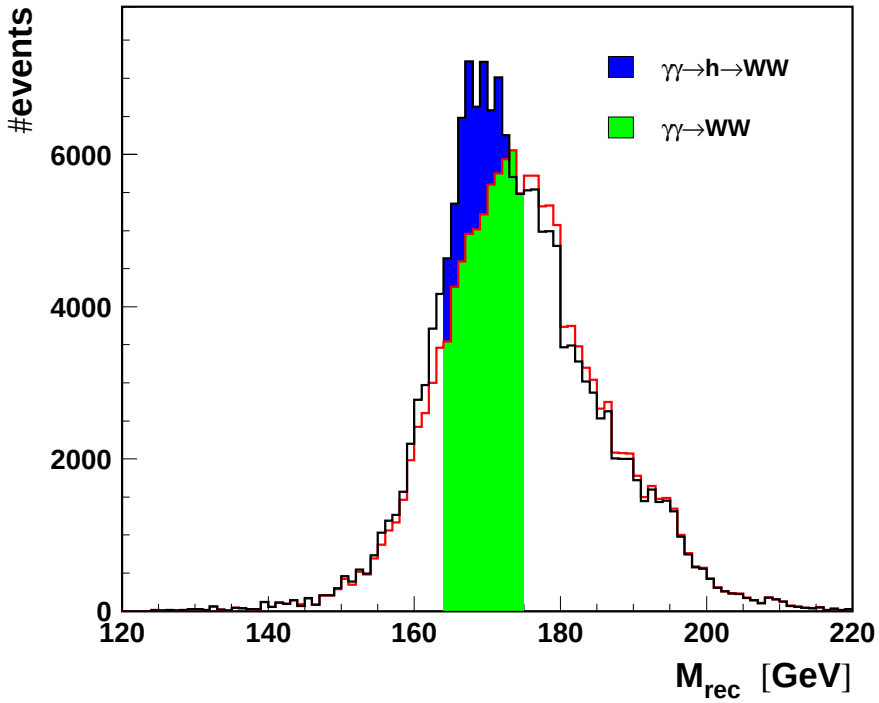


Selection

$h \to WW \to 4j$ event selection

- balanced transverse momentum:
  $$P_T/E_T < 0.1$$
- 4 hadronic jets
- cut jet angle
  $$\cos\theta_{jet} < 0.95$$
- jets reconstruct into two $W^{\pm}$
  with probability $P_W > 0.001$
  based on reconstructed invariant mass
- invariant mass and
  higgs decay angle cuts
  optimized for background rejection

Invariant mass cut for m_h=170 GeV:



SM higgs selection efficiency ∼30%
(for $WW \to q\bar{q}q\bar{q}$ events)
$\times BR(WW \to q\bar{q}q\bar{q}) \approx 46.9\%$

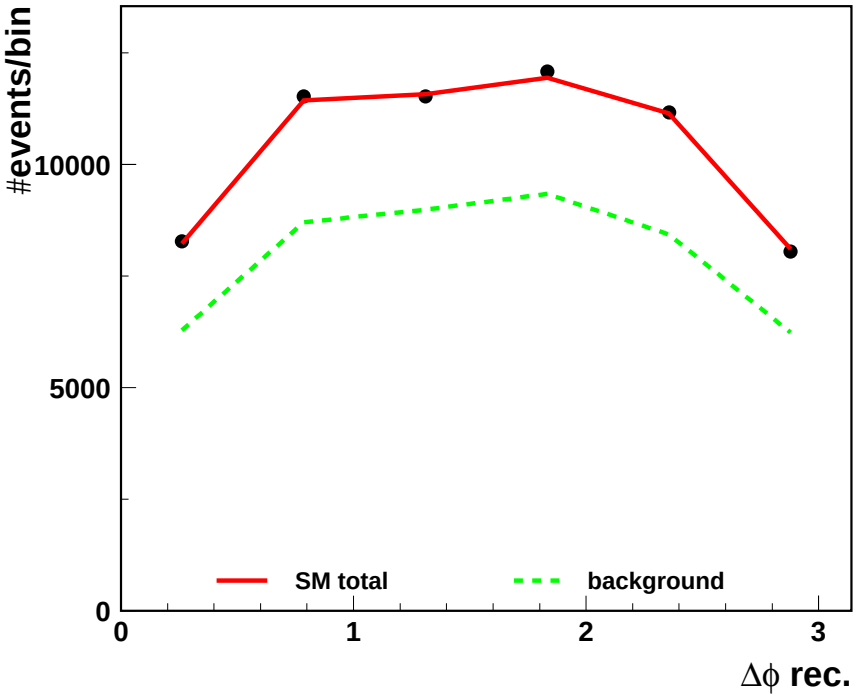
Results

Measured $\Delta\phi$ distribution for m_h = 170 GeV

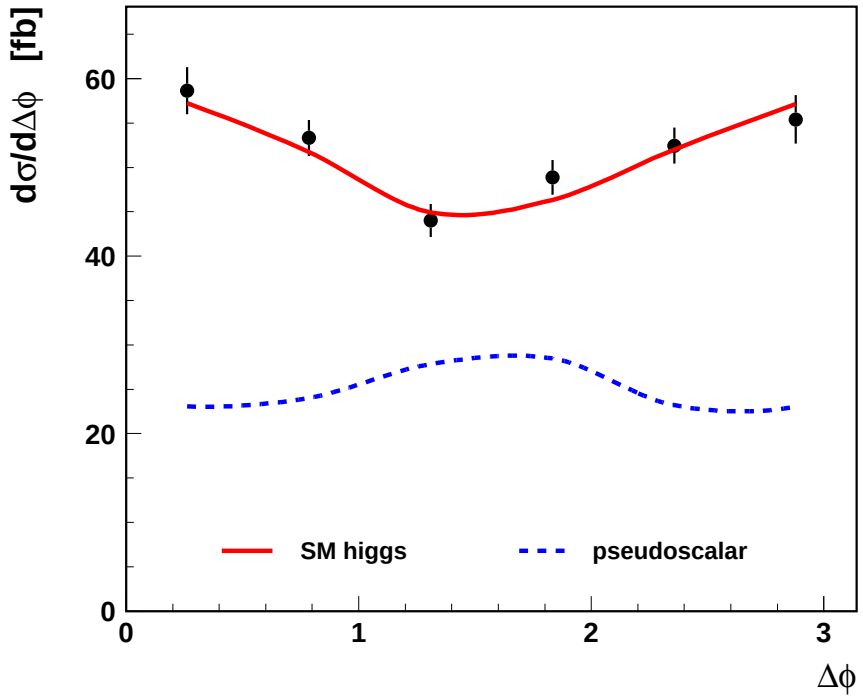
after 1 year of PC running at $\sqrt{s_{ee}}$=270 GeV, $\mathcal{L} = 540\ fb^{-1}$

$\Rightarrow$ $\sim$14 400 reconstructed SM higgs events expected + 48 000 WW background events

Measured distribution:



Extracted $\frac{d\sigma}{d\Delta\phi} \times BR(h \to WW)$

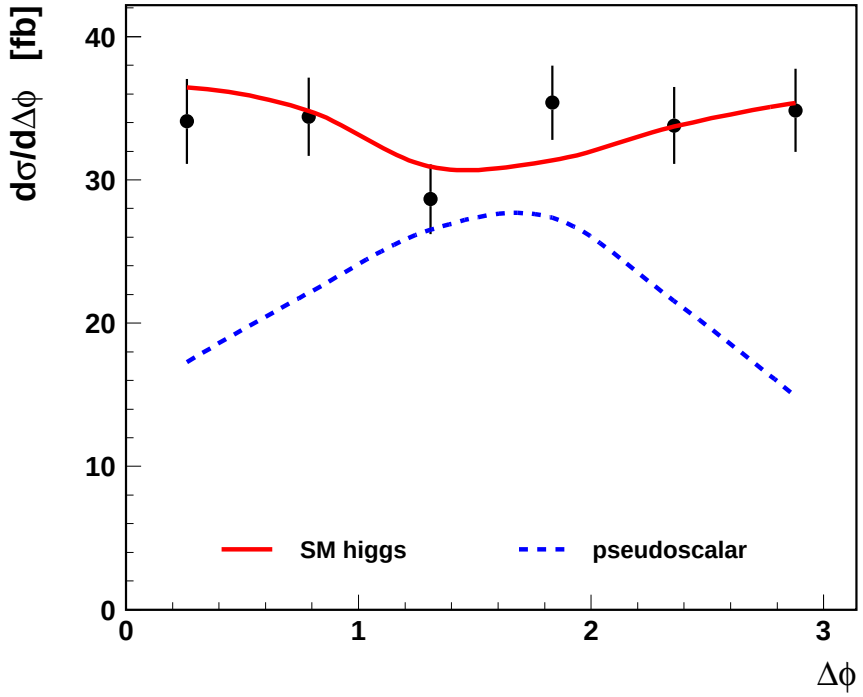


Results

m_h = 200 GeV

$\sqrt{s_{ee}}$=305 GeV, $\mathcal{L} = 610\ fb^{-1}$

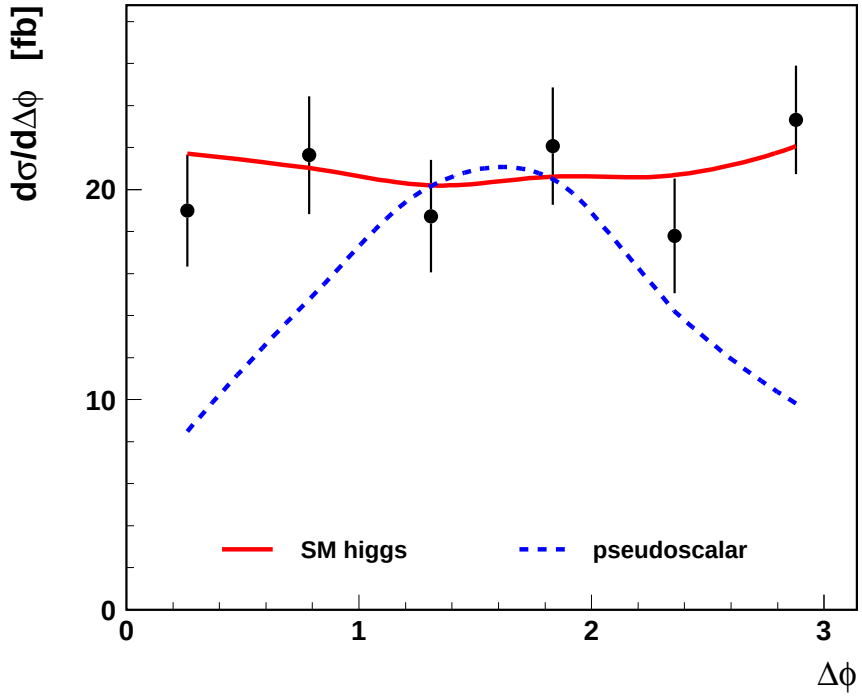
$\sim$8 000 SM higgs + 173 000 WW events



m_h = 250 GeV

$\sqrt{s_{ee}}$=362 GeV, $\mathcal{L} = 720\ fb^{-1}$

$\sim$5 500 SM higgs + 189 000 WW events



Large background contribution subtracted $\Rightarrow$ systematic effects can be very important !

Conclusions

Detector effects are important

$\Rightarrow$ significantly modify angular distributions...

Measurement of higgs parity possible:

- with $h \to ZZ \to ll\ jj$, for $m_h < 300$ GeV
- with $h \to WW \to 4j$, for $m_h < 250$ GeV

Analysis in progress. Still to be studied:

- other angular distributions (θ_j, θ_l)
- other background contributions (e.g. full $\gamma\gamma \to 4f$)
- systematic uncertainties (crucial for $h \to WW$)

Summary

$\gamma\gamma \to h \to ZZ/WW$

(hep-ph/0207294)

Angular distributions

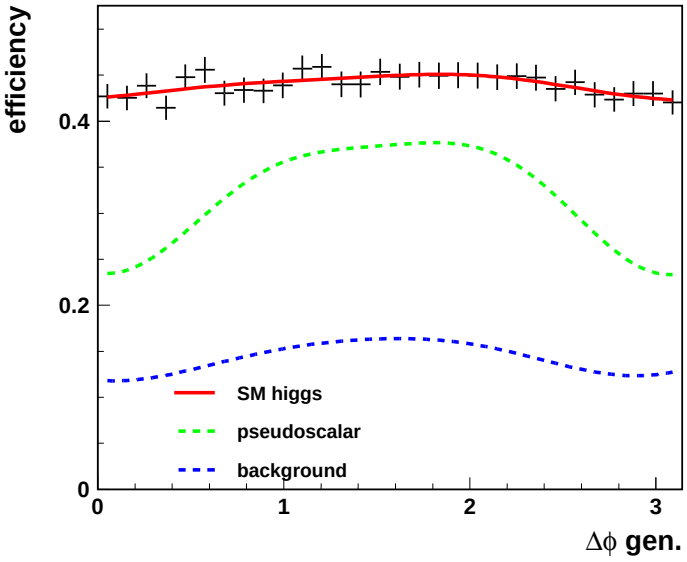
$\Rightarrow$ higgs spin and parity

(see e.g. hep-ph/0210077)

Detector effects important

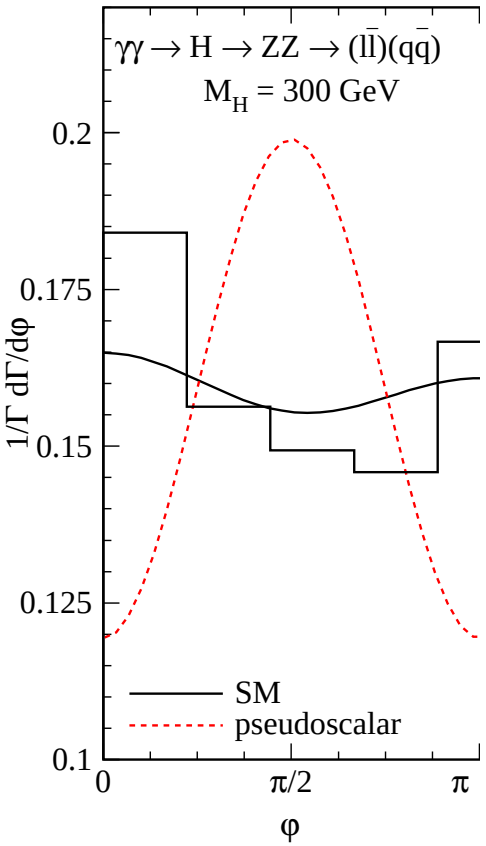
selection efficiency in $\Delta\phi$

m_h = 300 GeV, $\sqrt{s_{ee}}$=418 GeV



D.J.Miller,

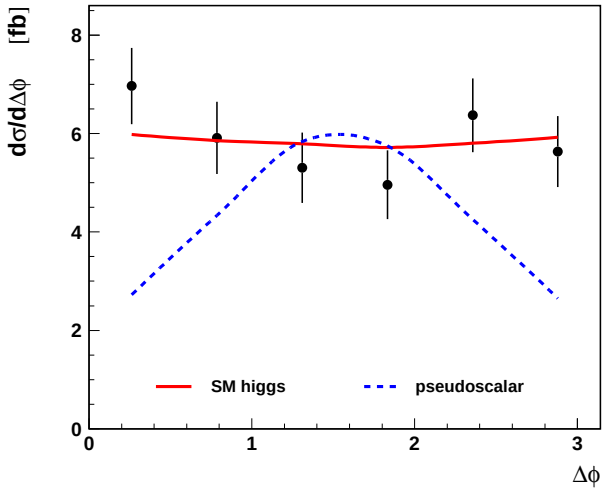
Prague, Nov. 2002:



Realistic simulation

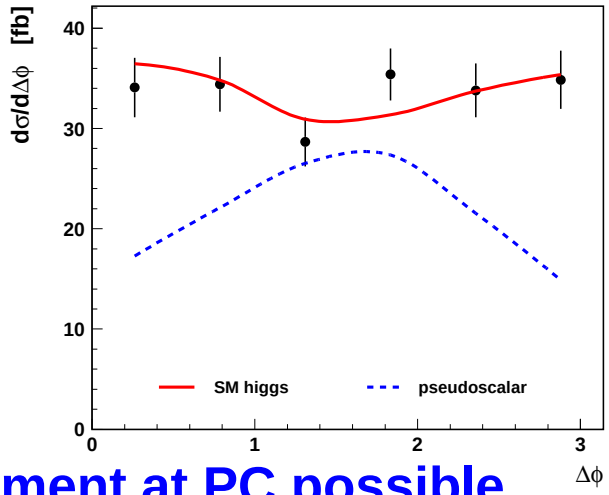
Extracted $\frac{d\sigma}{d\Delta\phi} \times BR(h \to ZZ)$

m_h = 300 GeV, $\sqrt{s_{ee}}$=418 GeV



Extracted $\frac{d\sigma}{d\Delta\phi} \times BR(h \to WW)$

m_h = 200 GeV, $\sqrt{s_{ee}}$=305 GeV



$\Rightarrow$ **Measurement at PC possible**