# Status report

Matrix Element application for A-ZZH coupling study

$$e^+e^- \to ZH \to \mu^+\mu^- H \text{ at } 250 \text{ GeV}$$

Fitting function

$$\chi^2 = -2\log\Delta\mathcal{L} = -2(\ln\mathcal{L}(\vec{a}_V) - \log\mathcal{L}_{SM})$$

Likelihood function

$$\begin{aligned}\mathcal{L}(\vec{a}_V) &= \mathcal{L}_{\text{shape}}(\vec{a}_V)\cdot\mathcal{L}_{\text{norm}}(\vec{a}_V) \\ &= \prod_{i=1}^{\text{events}} P_{\text{shape}}(\vec{p}_i^{\,\mu};\vec{a}_V)\cdot P_{\text{norm}}(\vec{a}_V)\end{aligned}$$

anomalous parameters

momenta: μ, μ, and it's recoil info.

Event probability
based on diff. cross-section

Integration over phase-space
for four momenta

Acceptance function

$$P_{\text{shape}}(\vec{p}^{\,\mu};\vec{a}_V) = \frac{1}{A_{cc}\,\sigma(\vec{a}_V)}\int d\bar{\Phi}\,|\mathcal{M}(\vec{\bar{p}}^{\,\mu};\vec{a}_V)|^2\,T(\vec{p}^{\,\mu}\to\vec{\bar{p}}^{\,\mu})A_{cc}(\vec{p}^{\,\mu})$$

Normalization

Matrix Element

Transfer function
(detector resolution)

Matrix Element using $e^+e^- \to ZH \to \mu^+\mu^- H$ at 250 GeV

$T(\vec{p}^{\,\mu};\vec{\bar{p}}^{\,\mu}) = \delta(\vec{p}^{\,\mu} - \vec{\bar{p}}^{\,\mu})$ The transfer is perfectly delta
: ATLAS, CMS also are assuming this

Acceptance (function)
*f* ( cosZ, cosFh, dPhi )
5x5x5

**Signal part** **Bkgs. part**

Event probability

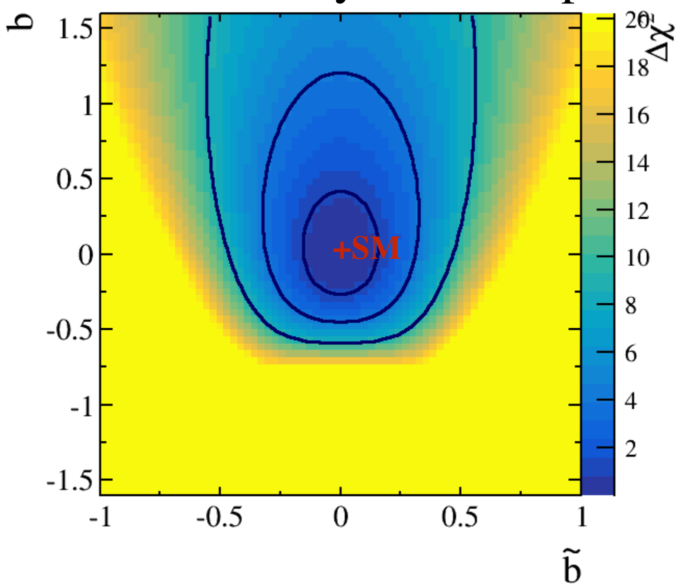
$$P_{\text{shape}}(\vec{p}^{\,\mu};\vec{a}_V) = \frac{A^{\mu\mu H}_{cc}(\vec{\mathcal{O}})|\mathcal{M}_{\mu\mu H}(\vec{p}^{\,\mu};\vec{a}_V)|^2 + A^{\mu\mu Z}_{cc}|\mathcal{M}_{\mu\mu Z}(\vec{p}^{\,\mu})|^2}{A^{\mu\mu H}_{cc}(\vec{a}_V)\sigma_{ZH\to\mu\mu H}(\vec{a}_V) + A^{\mu\mu Z}_{cc}\sigma_{ZZ\to\mu\mu Z}}$$

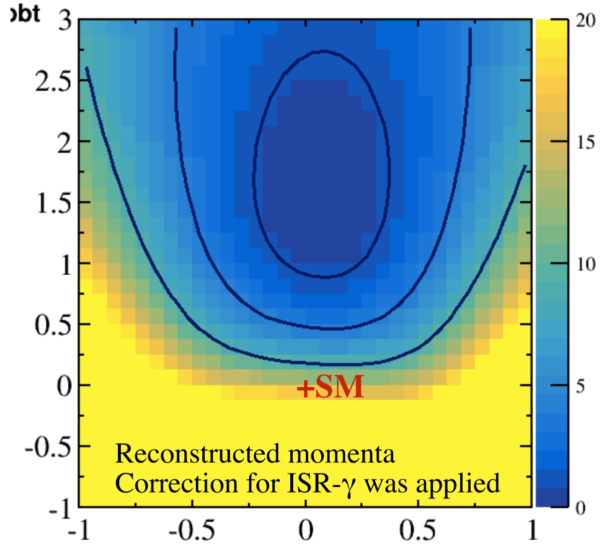
if the ave.(fixed) of
the acceptance is used,

Acceptance (fix)
~ 0.6

Analytic calculation
$= |A_0 + aA_a + bA_b + btA_{bt}|^2$

Binned analysis w/ shape



# Matrix Element using $e^+e^- \to ZH \to \mu^+\mu^- H$ at 250 GeV

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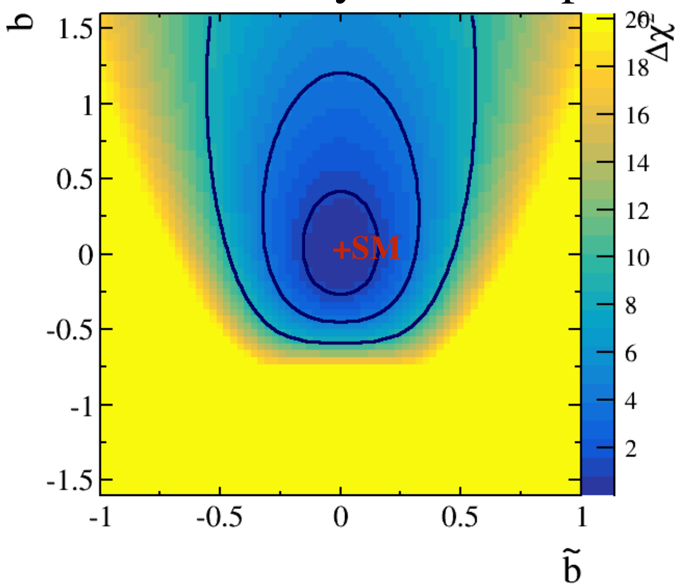
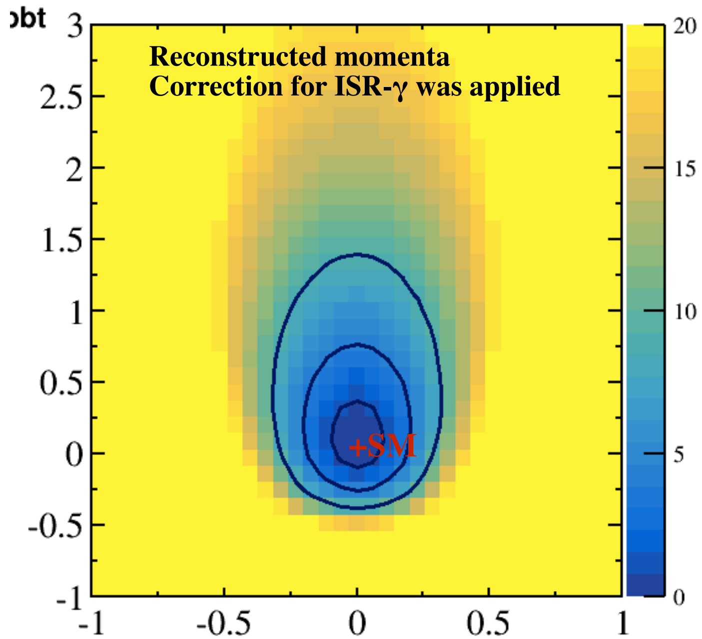
is given by integrating
remaining

, where Acc is
automatically included

Binned analysis w/ shape



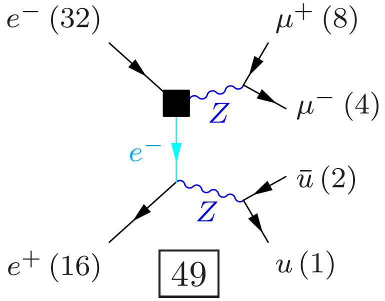

If MC-Truth is used, the Minimum is almost SM

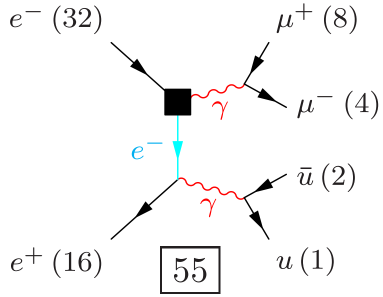
# Matrix Element using $e^+e^- \to ZH \to \mu^+\mu^- H$ at 250 GeV

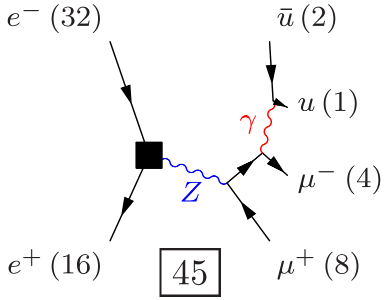
| Cut variables | $\mu\mu H$ | $\epsilon$ | $2f$ | $4f$ | $S_{sig}$ |
|---|---|---|---|---|---|
| No cut | 2603 | 100 | $2.9 \cdot 10^7$ | $1.0 \cdot 10^7$ | - |
| $\mu^+\mu^-$ ID | 2433 | 93.5 | $4.3 \cdot 10^5$ | $8.3 \cdot 10^4$ | 3.4 |
| $N_{tracks}\in[6,60]$ | 2246 | 86.3 | 6771 | $2.4 \cdot 10^4$ | 12.3 |
| $E_Z\in[14.6,111.7]$ GeV | 1740 | 66.8 | 156 | 1470 | 30.0 |
| $M_Z\in[83.0,96.4]$ GeV | 1673 | 64.3 | 104 | 995 | 31.6 |
| $E_{sub}\in[60.0,168.5]$ GeV | 1628 | 62.5 | 34 | 954 | 31.7 |
| $M_{rec}\in[120,137]$ GeV | 1624 | 62.4 | 34 | 923 | 31.8 |

**The Background** :

dominant ZZ_sl (DBD name) → μμ + qq

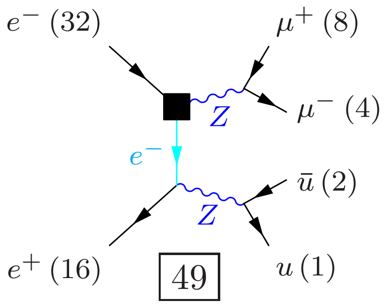



**MarlinPhysisim - LCMEZZ :**

can handle ZZ process



Check Response of **MarlinPhysisim - LCMEZZ** :

Events are weighted with 1 / |ME|2 (weighted with diff. cross-section => flat)

**MarlinPhysisim - LCMEZZ :**

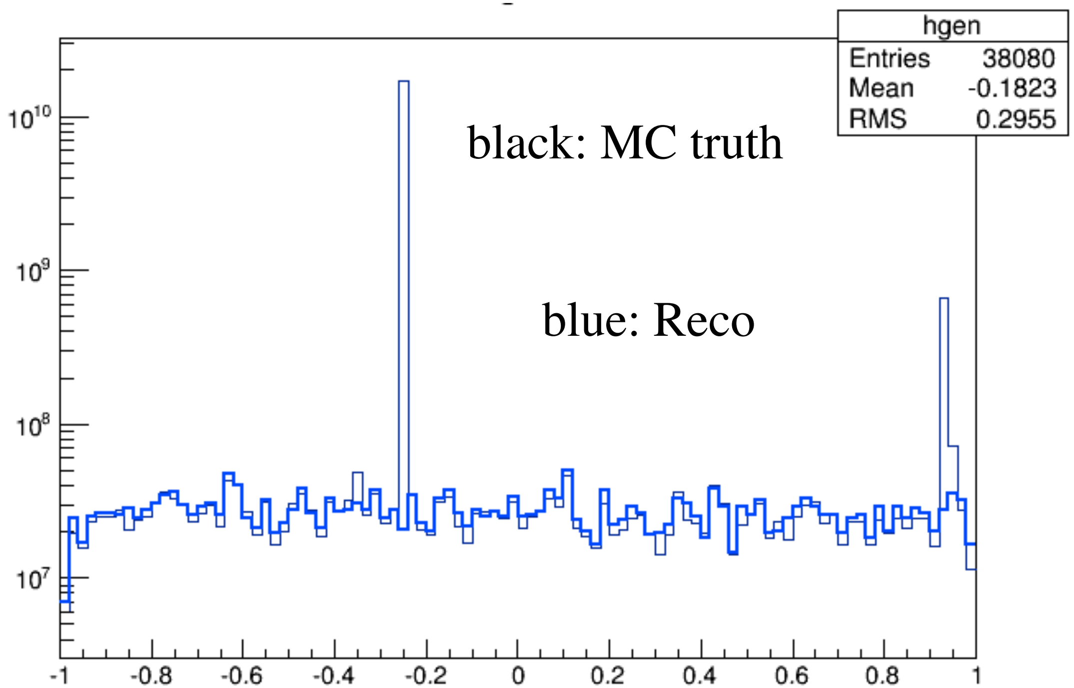
the settings is ZZ→ μμ + Z decay

a histogram is weighted with 1 / |ME|2

**— selection terms of Events**
**( just test with loose cuts )**

μ-pair ID
recoil > 10

input μ, μ, and its recoil




Production angle of μ-

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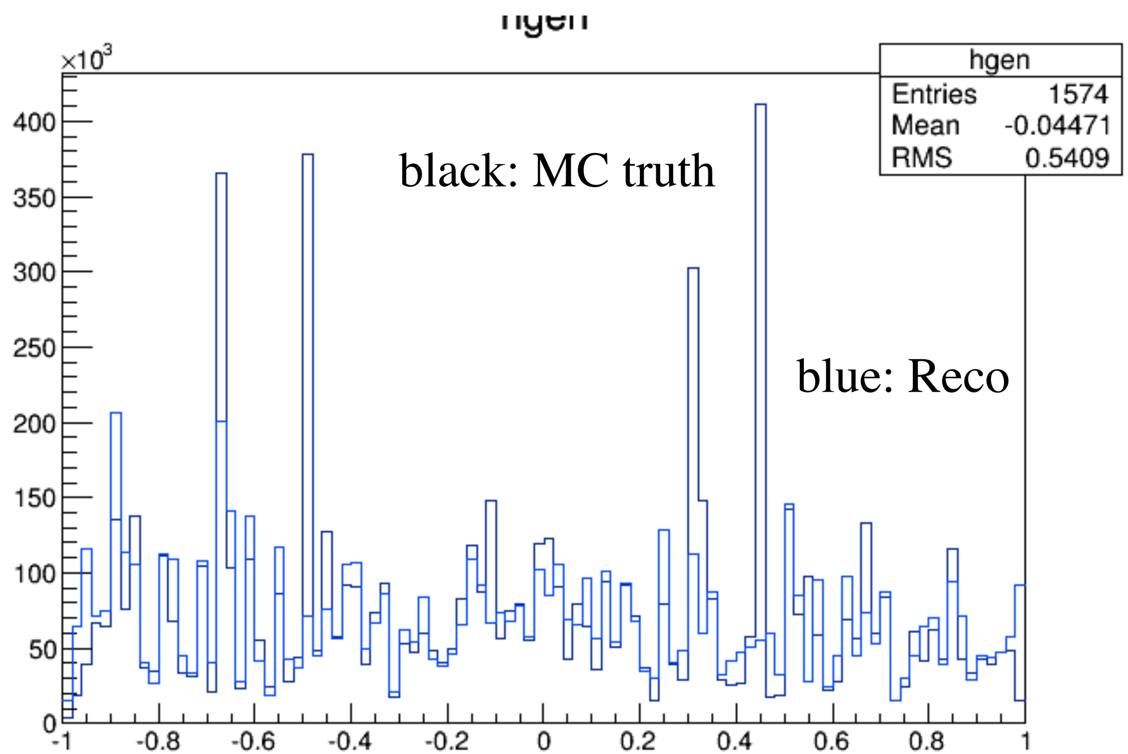
— selection terms of Events

( **full cuts :**

**same with the shape study**)

MC truth dist. have spikes?




Production angle of μ-

# Matrix Element using $e^+e^- \to ZH \to \mu^+\mu^- H$ at 250 GeV

## Come back to P

Consistency b/w
Physsim and Whizard

Acceptance (function)
$f$( cosZ, cosFh, dPhi )

(Physsim)

Event probability

$$P_{\rm shape}(\vec{p}^{\,\mu};\vec{a}_V) = \frac{A^{\mu\mu H}_{cc}(\vec{\mathcal{O}})|\mathcal{M}_{\mu\mu H}(\vec{p}^{\,\mu};\vec{a}_V)|^2 + A^{\mu\mu Z}_{cc}|\mathcal{M}_{\mu\mu Z}(\vec{p}^{\,\mu})|^2}{A^{\mu\mu H}_{cc}(\vec{a}_V)\sigma_{ZH\to\mu\mu H}(\vec{a}_V) + A^{\mu\mu Z}_{cc}\sigma_{ZZ\to\mu\mu Z}}$$

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$$A^{\mu\mu Z}_{cc} = \frac{ZZ \to \mu\mu Z^{\,accpt}}{ZZ \to \mu\mu Z^{\,gene}}$$ = 7.744e-03

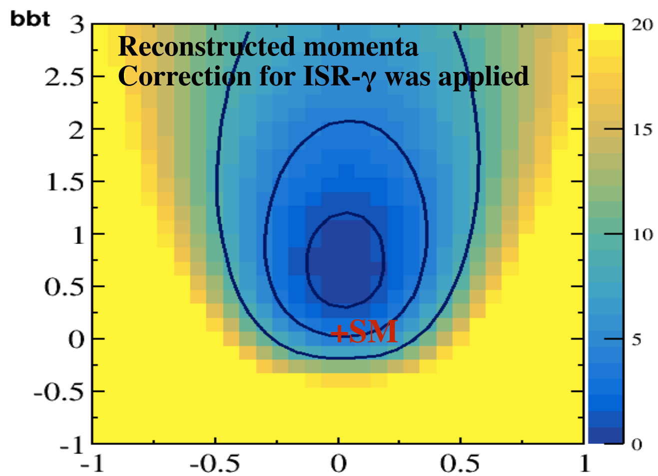
X_ZZ_LR * BR_Zmu (Whizard)

I counted #of generated samples

DBD: ZZ_sl
- **μ + q,**
- νμ + q,
- τ + q,
- ντ + q,

DBD: ZZ_l
- **μ + μ,**
- **μ + τ,**
- **μ + ντ**
- τ + τ,
- τ + νμ

**μ + e / νe / νμ**



Event probability

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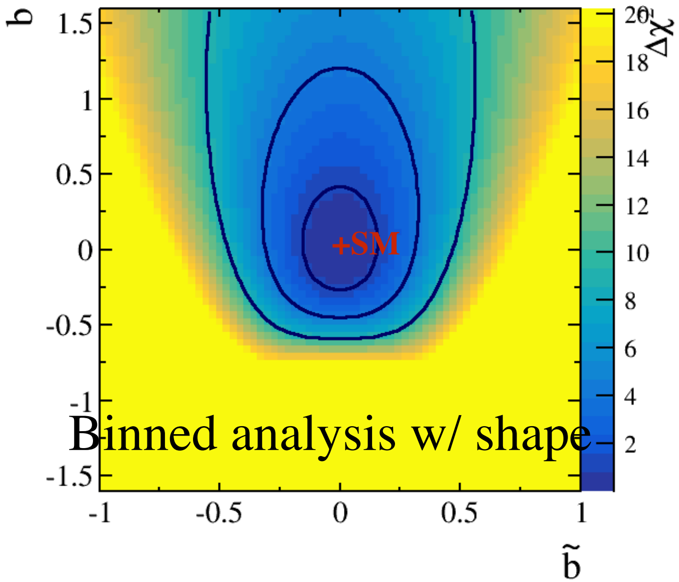
I'm thinking should be a function which gives the acceptance depending on P

should be given by integrating

how to handle 2f backgrounds




Binned analysis w/ shape