D Miller
S Moretti

Measuring the Triple Higgs coupling at the NLC

Standard model Higgs Potential

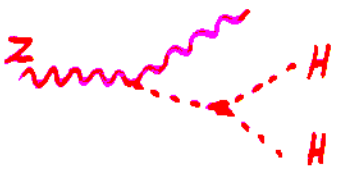
$$V = \lambda(|\phi|^2 - \tfrac{1}{2}v^2)^2$$

$$\Rightarrow \quad \lambda_{HHH} = \frac{3M_H^2}{V} \quad , \quad \lambda_{HHHH} = \frac{3M_H^2}{V^2}$$

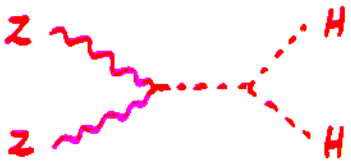
measure λ_{HHH} & λ_{HHH} $\Rightarrow$ Higgs Potential.

Triple Higgs Coupling :—

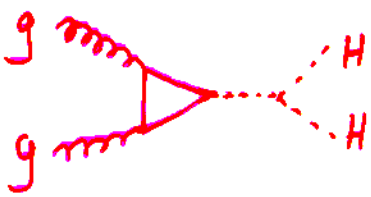
- Double Higgs-strahlung off W, Z



- WW/ZZ fusion



- gg fusion



- $\gamma\gamma$ fusion

Double Higgs-strahlung at NLC

Assume :—

- $H \to b\bar{b}$ with perfect b tagging
- Z decays leptonically

Signal Process :

$e^+e^- \to HHZ \to Zb\bar{b}\,b\bar{b}$ ↳ diagrams.

Djouadi, Kilian, Muhlleitner, Zerwas Desy 99/001, hep-ph/9903229

Can we see λ_{HHH} in signal? ↳ plot

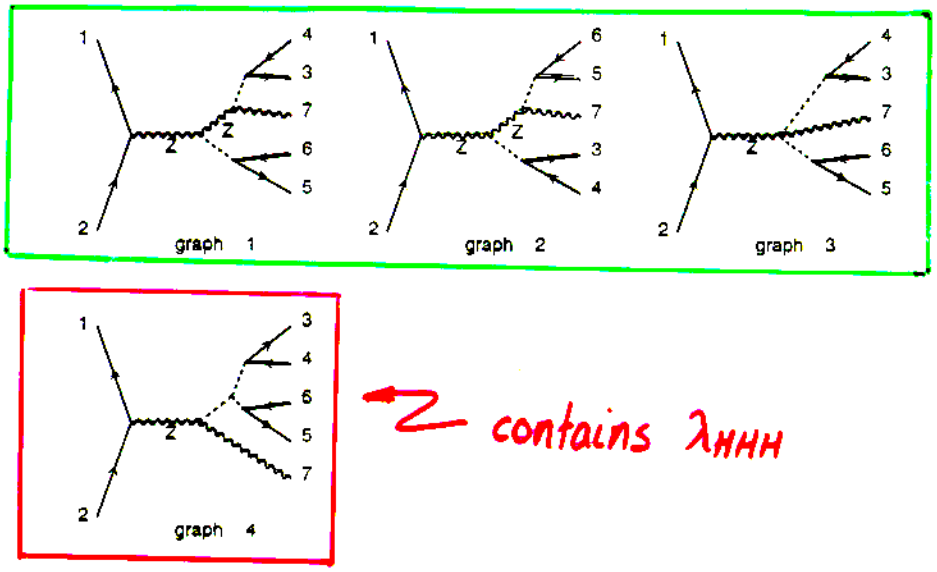
Signal small ($\sim 10^{-1}$ fb)

$\Rightarrow$ need high $\int \mathcal{L}\,dt$

This is even before cuts to remove backgrounds!
Hopefully since NLC "clean" (compared to LHC)
backgrounds managable.

3

"intrinsic" background



Z contains λ_{HHH}

Figure 1: Diagrams contributing at lowest-order to $e_1^+ e_2^- \to b_3 \bar{b}_4 b_5 \bar{b}_6 Z_7$ via purely EW interactions containing two Higgs bosons in intermediate states. An internal wavy line corresponds to a Z boson (labelled as Z). The total number of actual diagrams is 4. Finally, diagrams which differ from those above only in the exchange $3 \leftrightarrow 5$ (or. equivalently, $4 \leftrightarrow 6$) must also be considered, preceded by a minus sign.

Djouadi, Kilian, Muhlleitner, Zerwas DESY 99/001
hep-ph/9903229

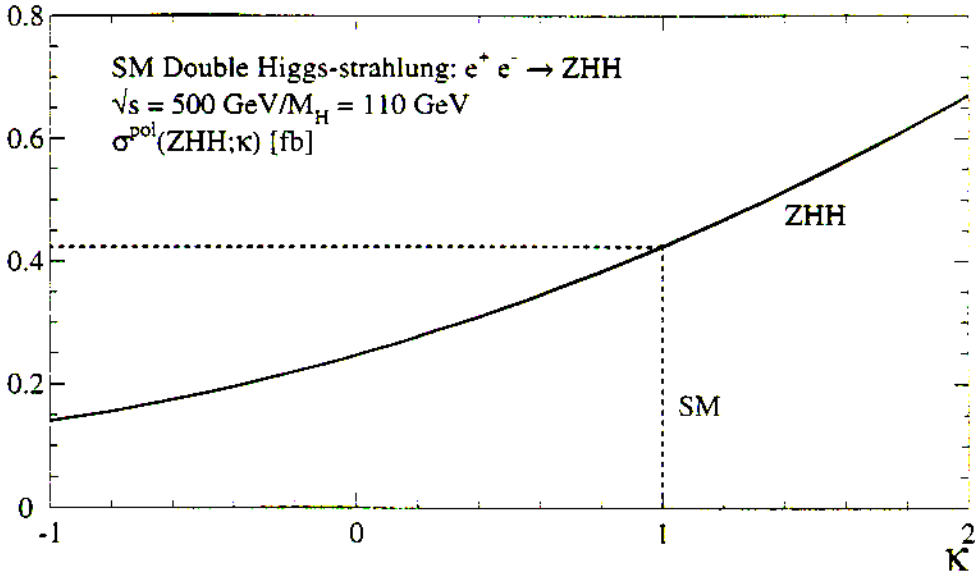


Figure 6b: *Variation of the cross section $\sigma(ZHH)$ with the modified trilinear coupling $\kappa\lambda_{HHH}$ at a collider energy of $\sqrt{s} = 500\ GeV$ and $M_H = 110\ GeV$.*

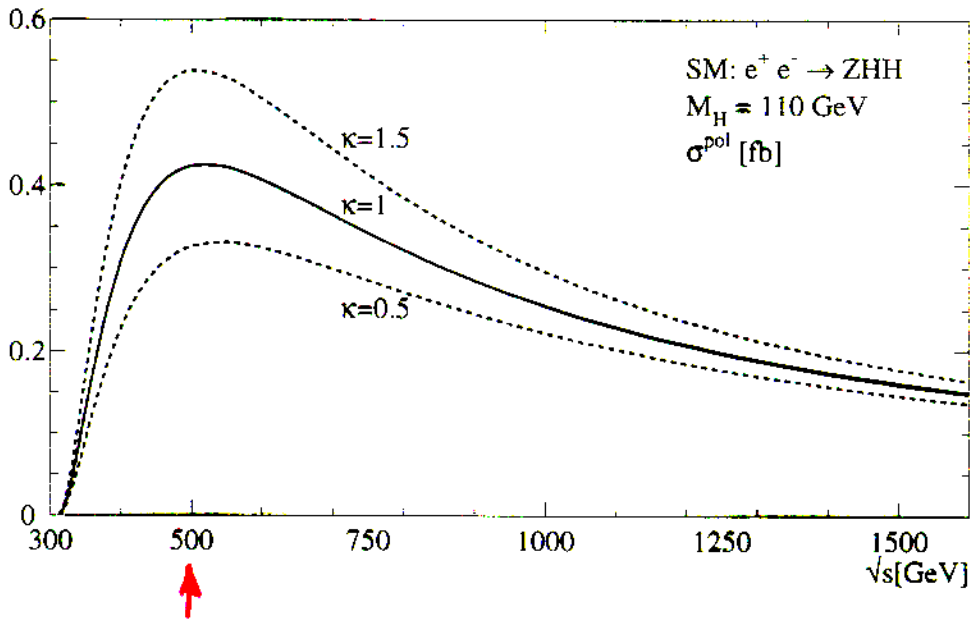


Figure 6c: *The energy dependence of the cross section for double Higgs-strahlung for a fixed Higgs mass $M_H = 110\ GeV$. The variation of the cross section for modified trilinear couplings $\kappa\lambda_{HHH}$ is indicated by the dashed lines.*

Backgrounds :— (ignore interference)

Electroweak

- Potentially biggest headache because has similar resonant structure to signal.
- 550 diagrams! ⇒ used MADGRAPH to calculate matrix elements.
- Phase space : Split diagrams into 23 different "resonant topologies"

→ 2 diagrams

QCD

- Not so problematic since resonant structure simpler

→ 2 diagrams

- M_H dependence small ~ 1%

Diagrams with Higgs

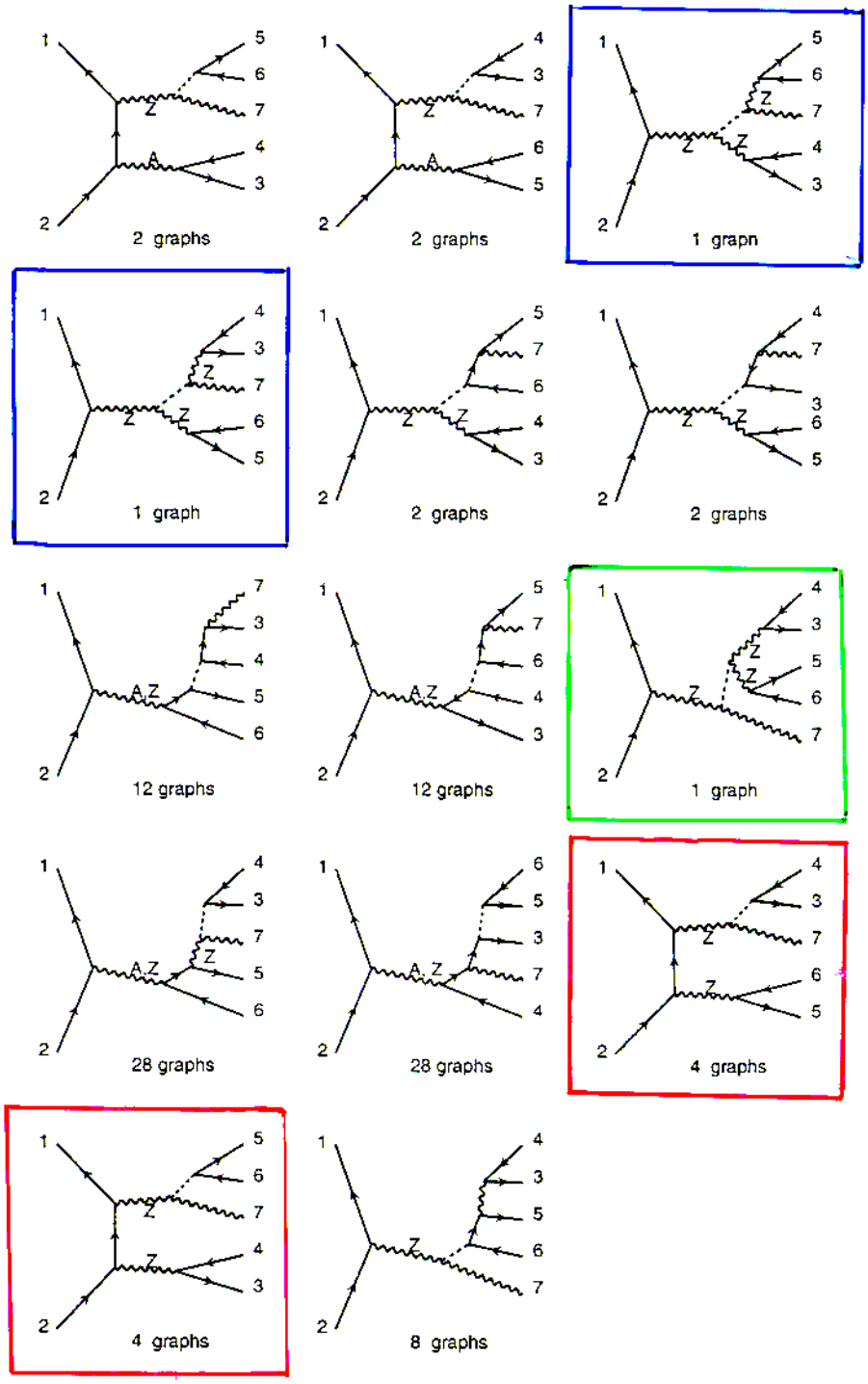


Figure 2: Topologies contributing at lowest-order to $e_1^+ e_2^- \to b_3 \bar{b}_4 b_5 \bar{b}_6 Z_7$ via purely EW interactions containing only one Higgs boson in intermediate states. An internal wavy line corresponds to a γ or a Z (labelled as A and Z, respectively), as appropriate. The total number of actual diagrams is 107. Finally, diagrams which differ from those above only in the exchange $3 \leftrightarrow 5$ (or, equivalently, $4 \underset{13}{\leftrightarrow} 6$) must also be considered, preceded by a minus sign.

7.

No Higgs

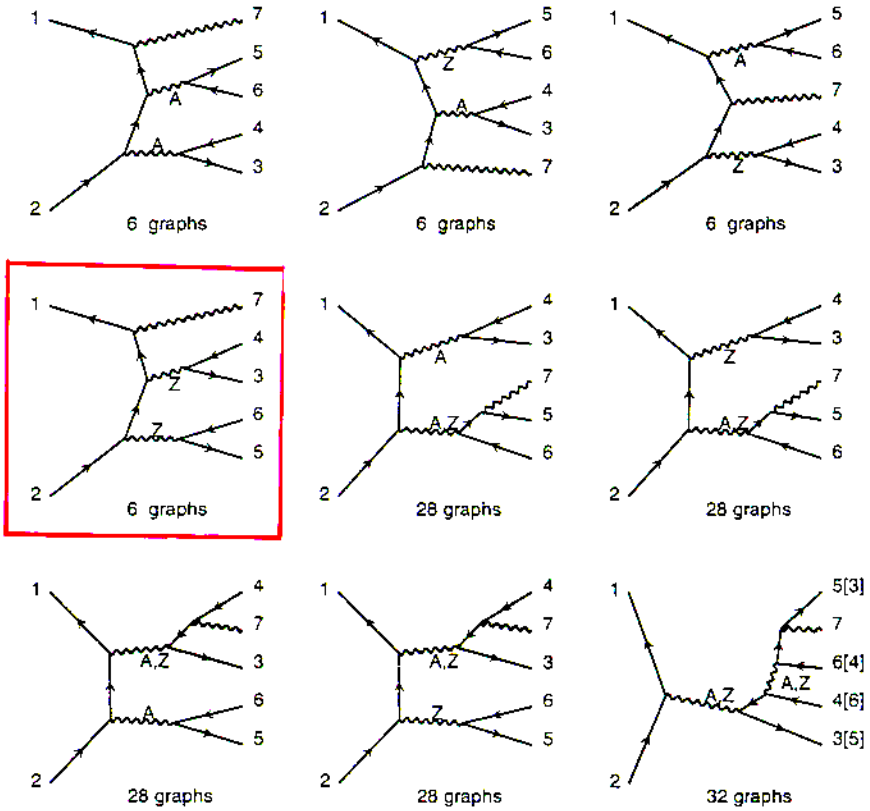


Figure 3: Topologies contributing at lowest-order to $e_1^+ e_2^- \to b_3 \bar{b}_4 b_5 \bar{b}_6 Z_7$ via purely EW interactions containing no Higgs bosons in intermediate states. An internal wavy line corresponds to a γ or a Z (labelled as A and Z, respectively), as appropriate. The total number of actual diagrams is 168. Finally, diagrams which differ from those above only in the exchange $3 \leftrightarrow 5$ (or, equivalently, $4 \leftrightarrow 6$) must also be considered, preceded by a minus sign.

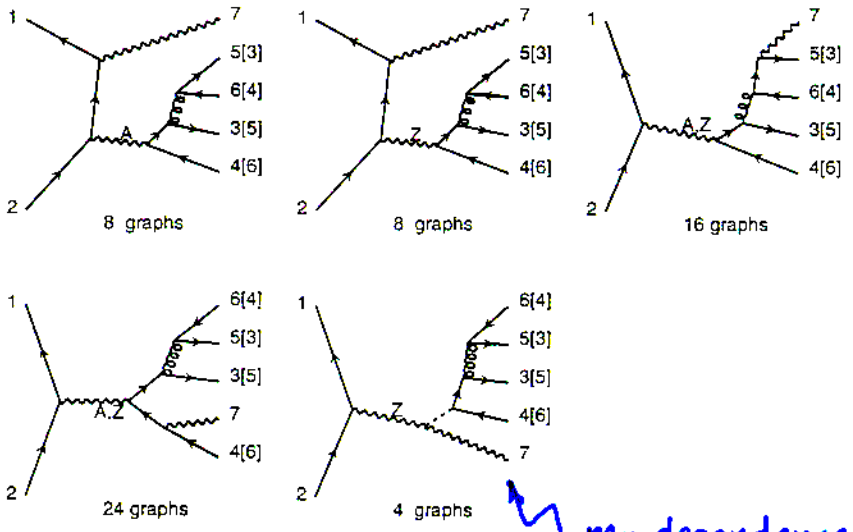


Figure 4: Topologies contributing at lowest-order to $e_1^+ e_2^- \to b_3 \bar{b}_4 b_5 \bar{b}_6 Z_7$ via QCD interactions containing one gluon in intermediate states. An internal wavy line corresponds to a γ or a Z (labelled as A and Z, respectively), as appropriate, whereas a helical one refers to a g. The total number of actual diagrams is 60. Finally, diagrams which differ from those above only in the exchange $3 \leftrightarrow 5$ (or, equivalently, $4 \leftrightarrow 6$) must also be considered, preceded by a minus sign.

Acceptance Cuts —

$E_b > 10$ GeV

$\cos(b,b) < 0.95$

In following :

$\sqrt{s} = 500$ GeV

$M_H = 110$ GeV (unless otherwise stated)

Also ignore interference between signal, EW and QCD backgrounds.

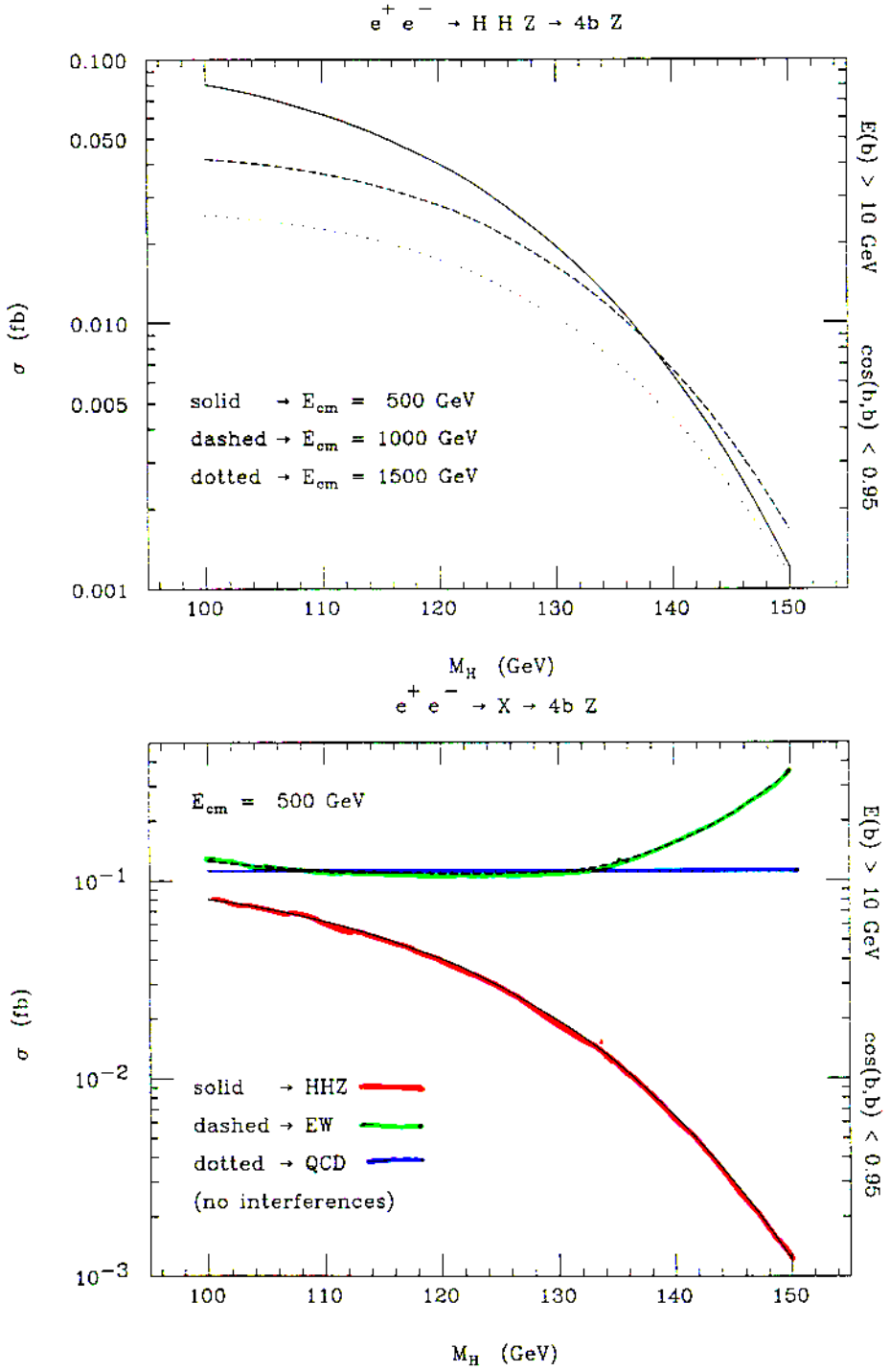


Figure 5: Top: cross sections in femtobarns for the signal at three different collider energies, 500, 1000 and 1500 GeV. Bottom: cross sections in femtobarns for the signal and the EW and QCD backgrounds at 500 GeV. Our acceptance cuts in energy and separation of the four b quarks have been implemented.

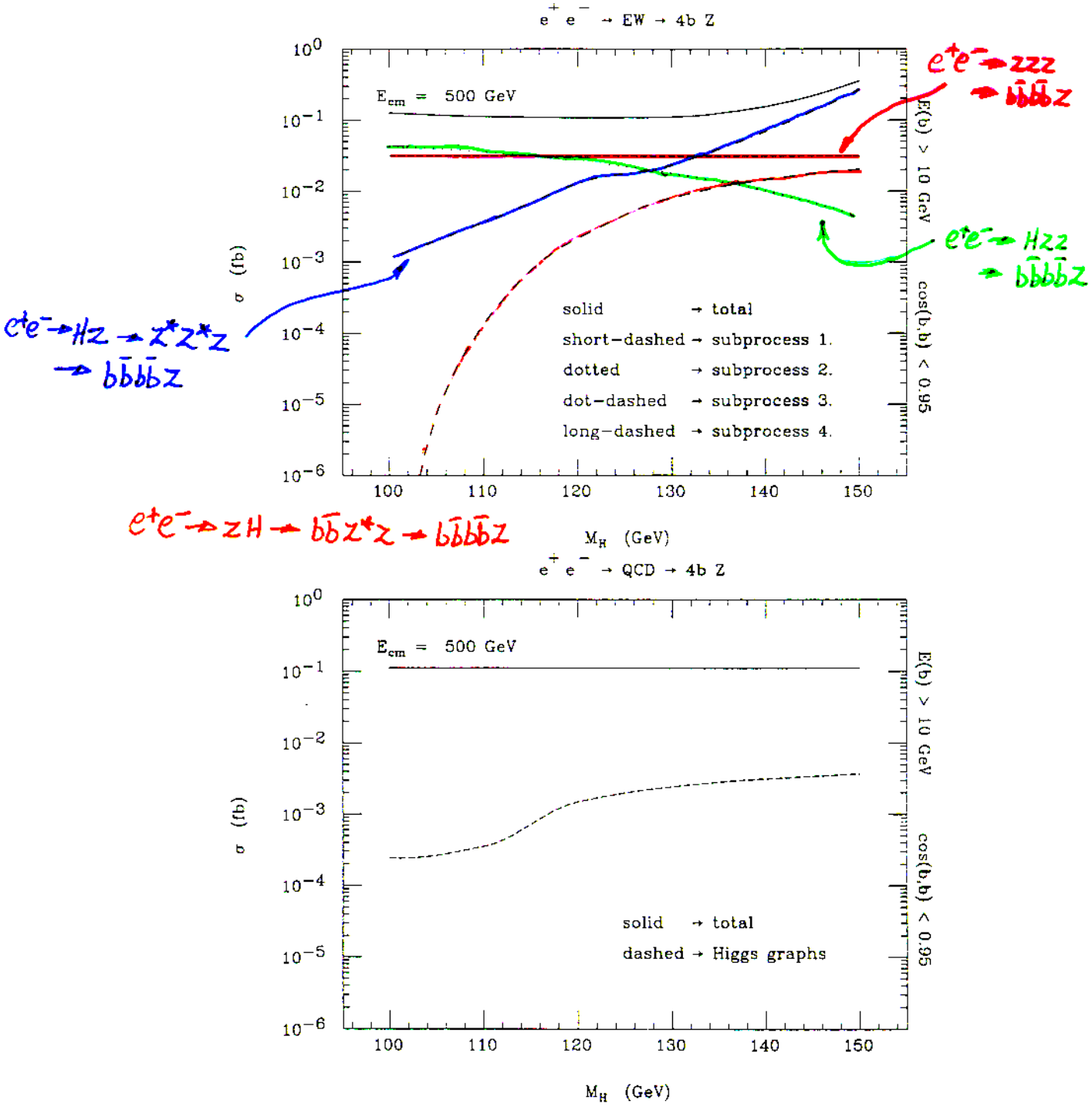


Figure 6: Top: cross sections in femtobarns for the four dominant components (see the text) of the purely EW background. Bottom: cross sections in femtobarns for the total and Higgs components (see the text) of the QCD background. The CM energy is 500 GeV. Our acceptance cuts in energy and separation of the four b quarks have been implemented.

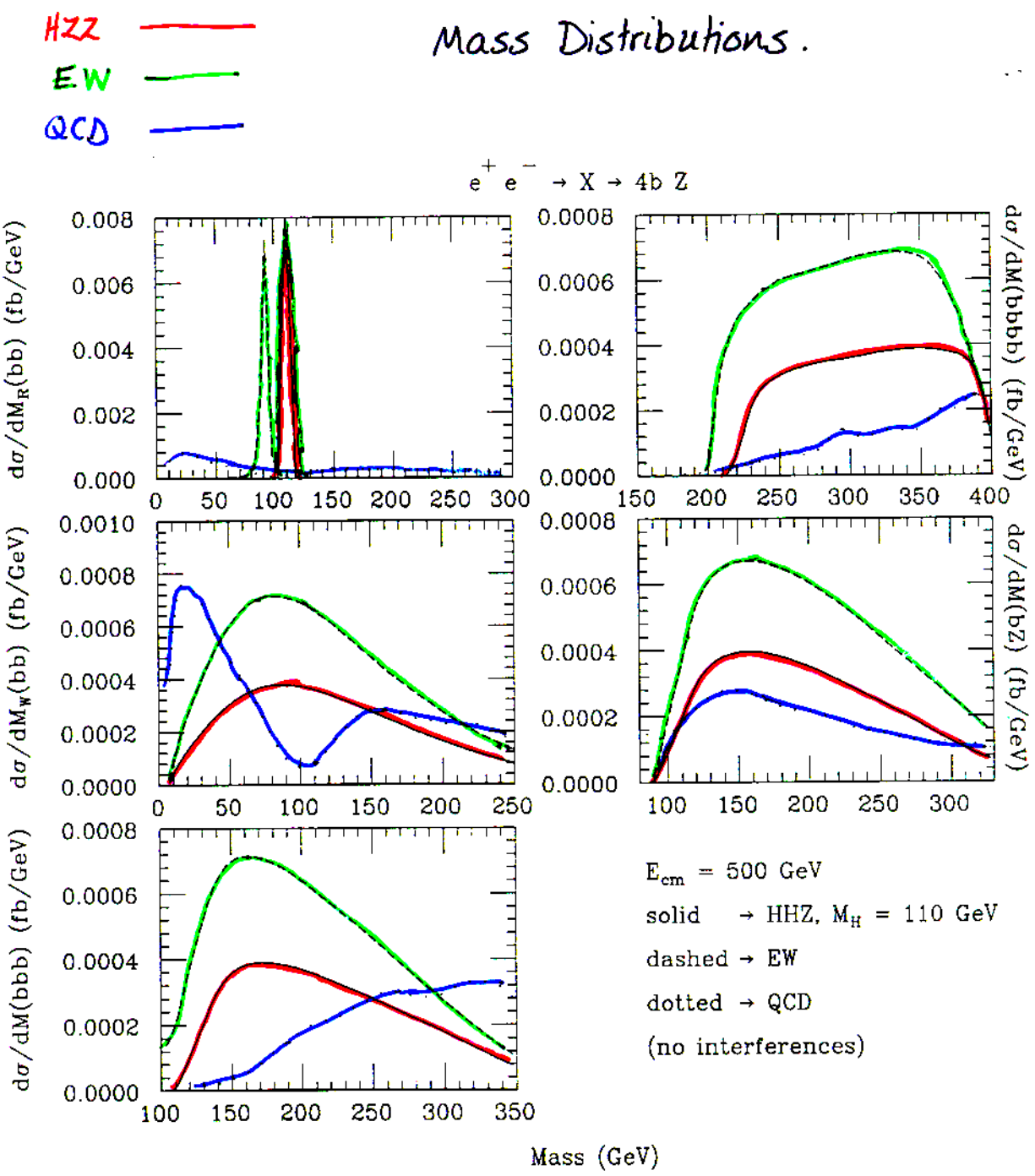


Figure 7: Differential distributions in invariant mass of multi-jet systems containing one, two, three and four b (anti)quarks. The CM energy is 500 GeV and the Higgs mass 110 GeV. Our acceptance cuts in energy and separation of the four b quarks have been implemented. Normalisation is to the total cross sections.

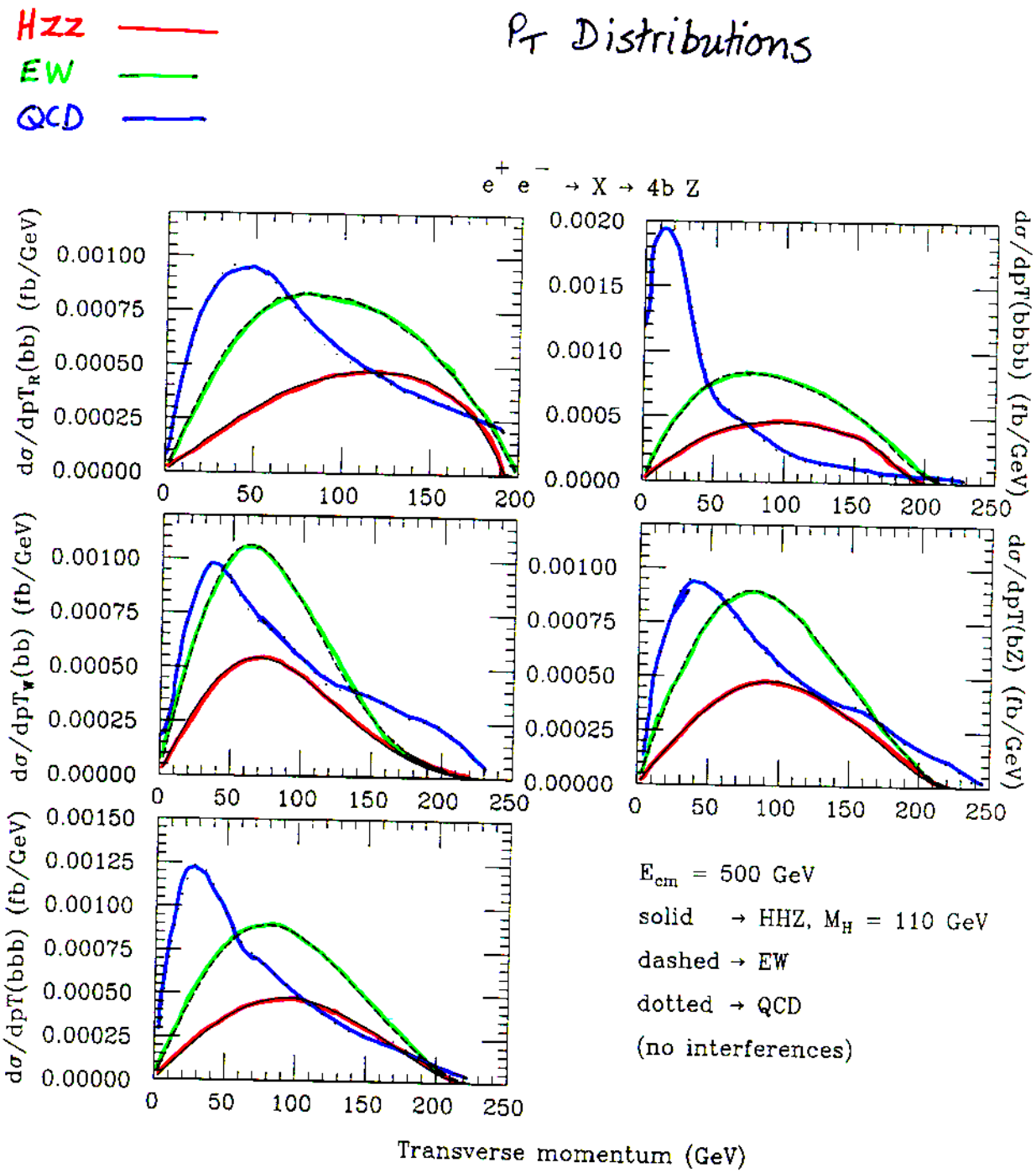


Figure 8: Differential distributions in transverse momentum of multi-jet systems containing one, two, three and four b (anti)quarks. The CM energy is 500 GeV and the Higgs mass 110 GeV. Our acceptance cuts in energy and separation of the four b quarks have been implemented. Normalisation is to the total cross sections.

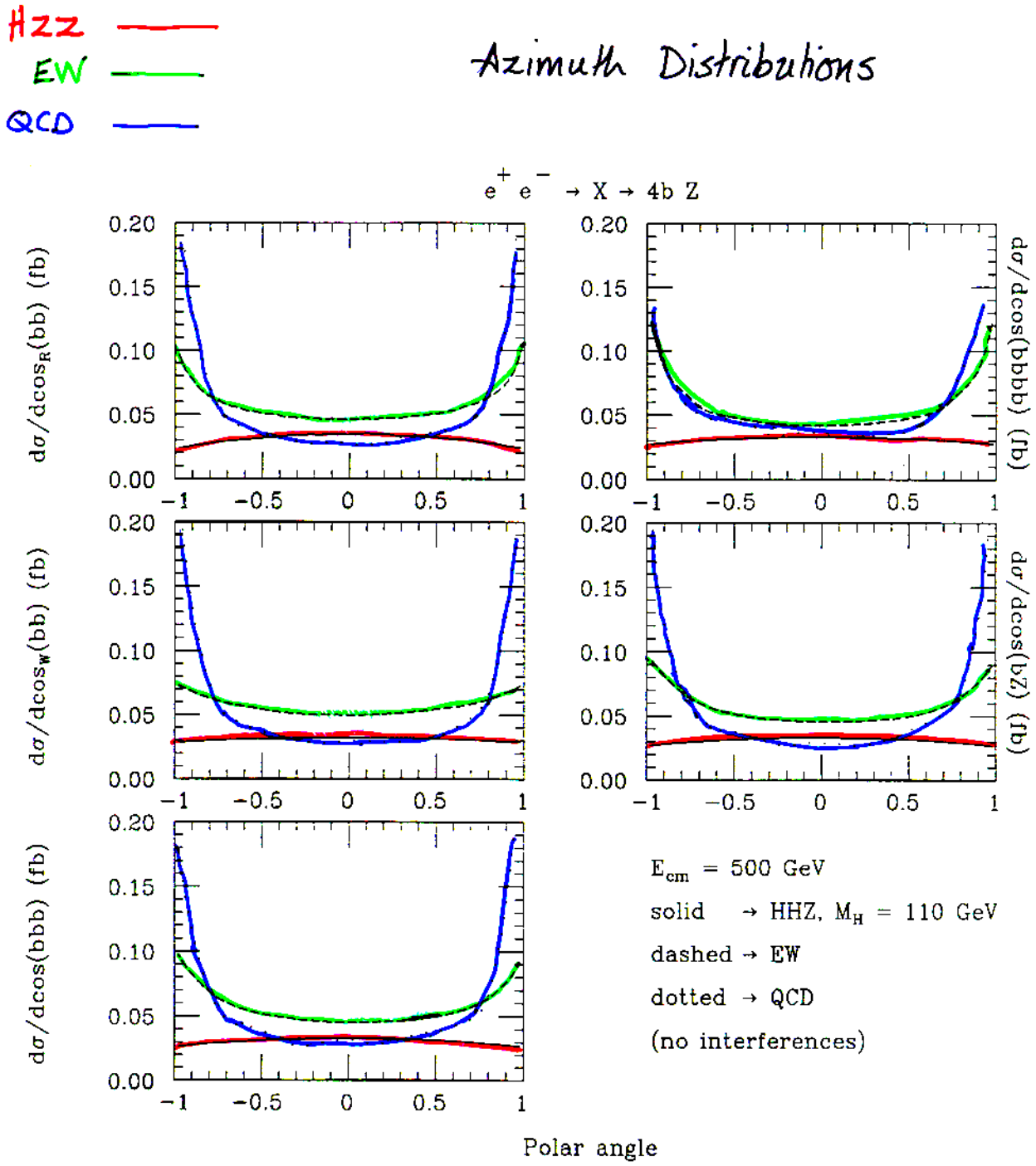


Figure 9: Differential distributions in (cosine of the) polar angle of multi-jet systems containing one, two, three and four b (anti)quarks. The CM energy is 500 GeV and the Higgs mass 110 GeV. Our acceptance cuts in energy and separation of the four b quarks have been implemented. Normalisation is to the total cross sections.