Precision of $\gamma\gamma \to h \to b\bar{b}$ cross section measurement

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$M_h \approx$ 120-160 GeV

Standard Model higgs:

$\mathrm{Br}(h \to \gamma\gamma) \approx$ 0.2-0.05 %

$\mathrm{Br}(h \to b\bar{b}) \approx$ 70-5 %

$\Gamma_{\mathrm{tot}} \approx$ 5-100 MeV

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$\Gamma_{\mathrm{tot}} \approx$ 5-100 MeV

Indirect Γ_{tot} measurement available ($\sigma^{\mathrm{DET}}_{\mathrm{mass}} \approx$ 5 GeV):

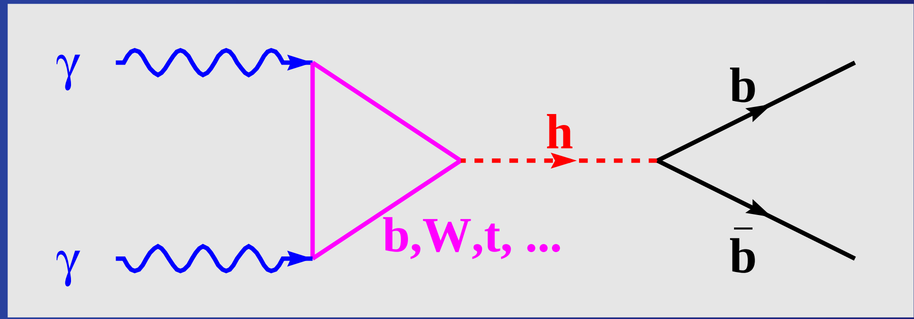
$$\sigma(\gamma\gamma \to h \to b\bar{b}) \propto \mathrm{Br}(h \to \gamma\gamma)\mathrm{Br}(h \to b\bar{b})\Gamma_{\mathrm{tot}}$$

$$\frac{\Delta\sigma(\gamma\gamma \to h \to b\bar{b})}{\sigma(\gamma\gamma \to h \to b\bar{b})} \approx \frac{\Delta\Gamma(h \to \gamma\gamma)\mathrm{Br}(h \to b\bar{b})}{\Gamma(h \to \gamma\gamma)\mathrm{Br}(h \to b\bar{b})}$$

$M_h \approx$ 120-160 GeV

Process: $\gamma + \gamma \to h \to b + \bar{b}$

$J_z = 0$



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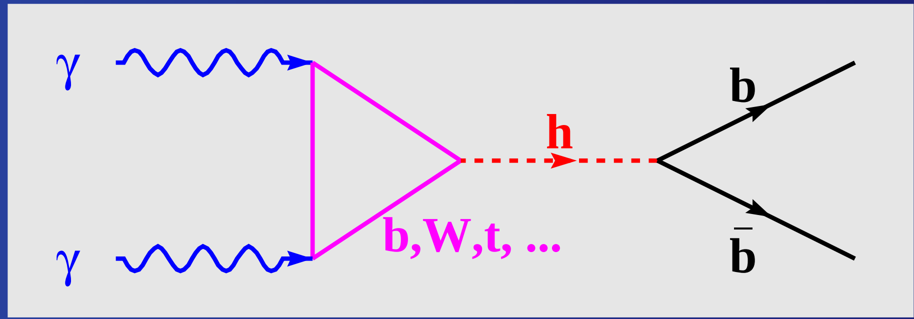
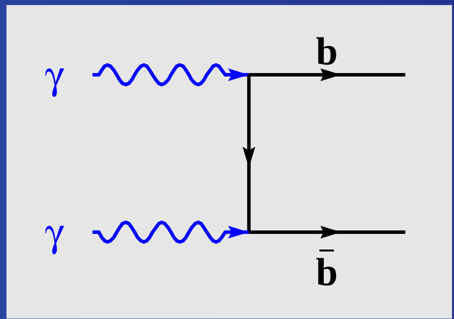


"Hard" background:

- $\gamma + \gamma \to b + \bar{b}$



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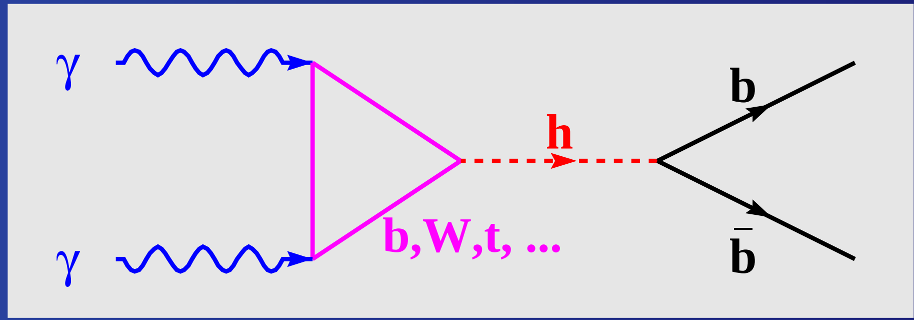
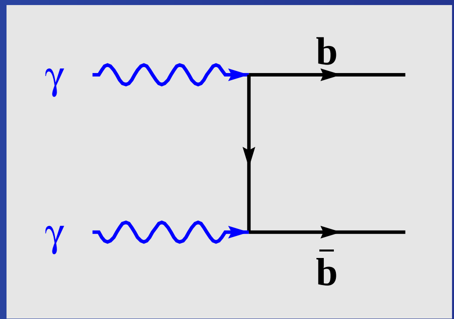
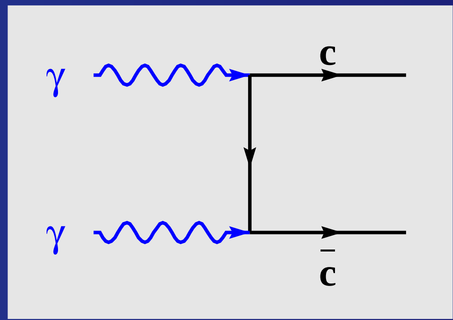


"Hard" background:

- $\gamma + \gamma \to b + \bar{b}$
- $\gamma + \gamma \to c + \bar{c}$





$$\sigma \propto Q_q^4$$

$$\sigma^{LO}(|J_z| = 2) \gg \sigma^{LO}(J_z = 0)$$

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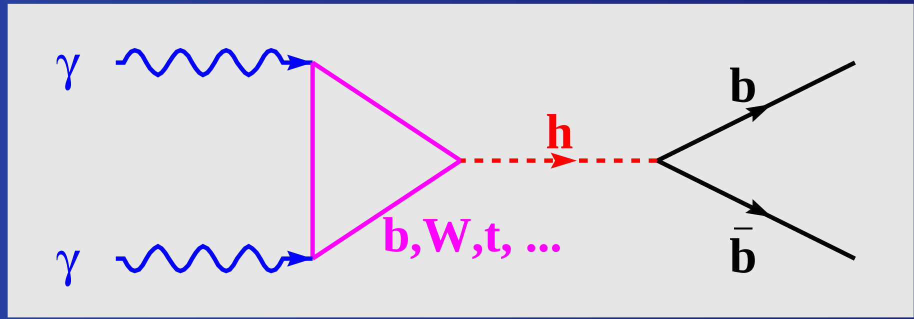

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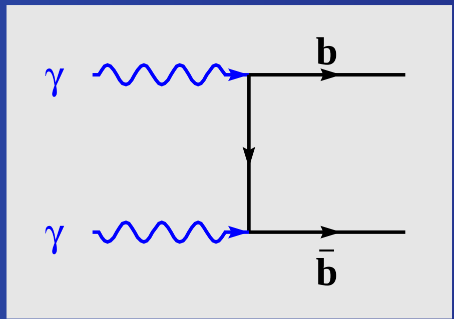

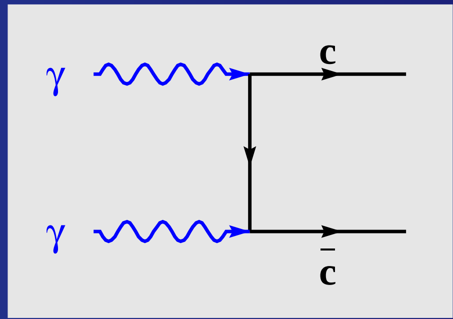

Other background:

- Overlaying events
  (high intensity of photon-beams in the low-energy part of the spectrum)

$M_h \approx$ 120-160 GeV

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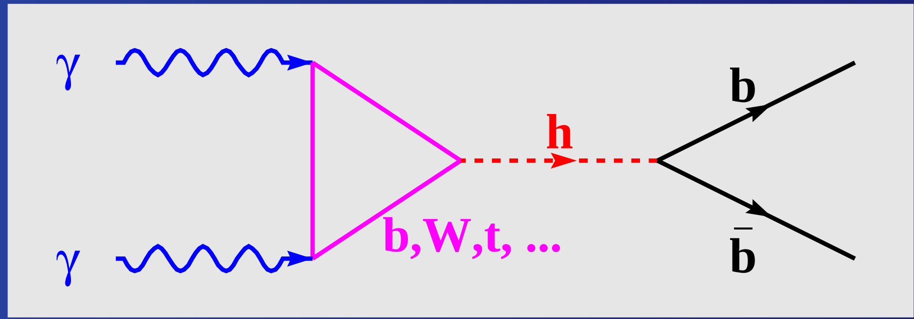

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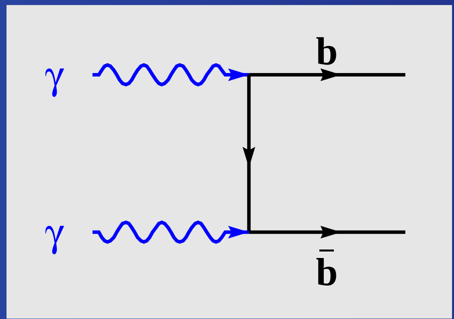

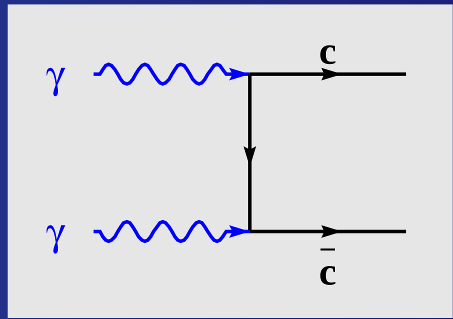

Other background:

- Overlaying events
  (high intensity of photon-beams in the low-energy part of the spectrum)
- Mistagged $\gamma\gamma \to \tau\tau$ events

$M_h \approx 120\text{-}160$ GeV

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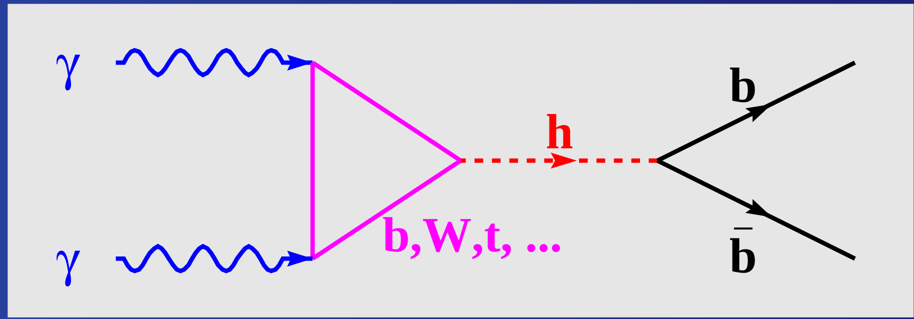

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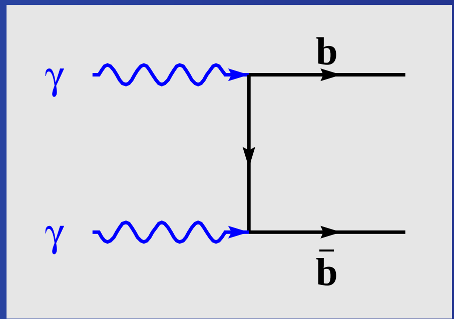

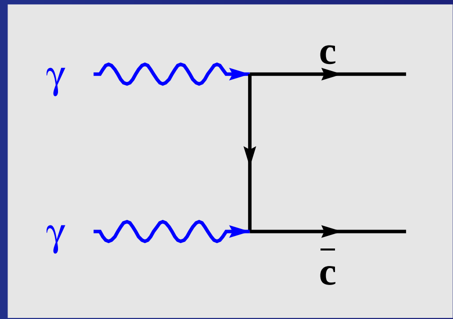

$\sigma \propto Q_q^4$

$\sigma^{LO}(|J_z| = 2) \gg \sigma^{LO}(J_z = 0)$

Other background:

- Overlaying events
  (high intensity of photon-beams in the low-energy part of the spectrum)
- Mistagged $\gamma\gamma \to \tau\tau$ events
- Resolved photon(s) interactions $\gamma + \gamma \to X + Q + \bar{Q}$

$\gamma + \gamma \longrightarrow F + \bar{F}$

- LO cross section for massless fermions

$$\sigma(J_z = 2) \propto \frac{\alpha^2}{s}$$

$$\sigma(J_z = 0) = 0$$

$\gamma + \gamma \longrightarrow F + \bar{F}$

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$$\sigma(J_z = 2) \propto \frac{\alpha^2}{s}$$

$$\sigma(J_z = 0) = 0$$

- LO cross section for massive fermions

$$S_F^\mu = P_F^\mu + \mathcal{O}(\frac{m_F}{E_F})$$

$$\Longrightarrow \sigma(J_z = 2) \propto \frac{\alpha^2}{s}$$

$$\sigma(J_z = 0) \propto \frac{m_F^2}{s} \frac{\alpha^2}{s}$$

$\gamma + \gamma \longrightarrow F + \bar{F}$

- NLO cross section for massless fermions

$$\Longrightarrow \sigma \propto \frac{\alpha^2 \alpha_s}{s}$$

$$\frac{d\sigma}{dE_g}(J_z = 2) \propto \frac{1}{E_g}$$

$$\sigma(J_z = 0) \propto E_g^3$$

$\gamma + \gamma \longrightarrow F + \bar{F}$

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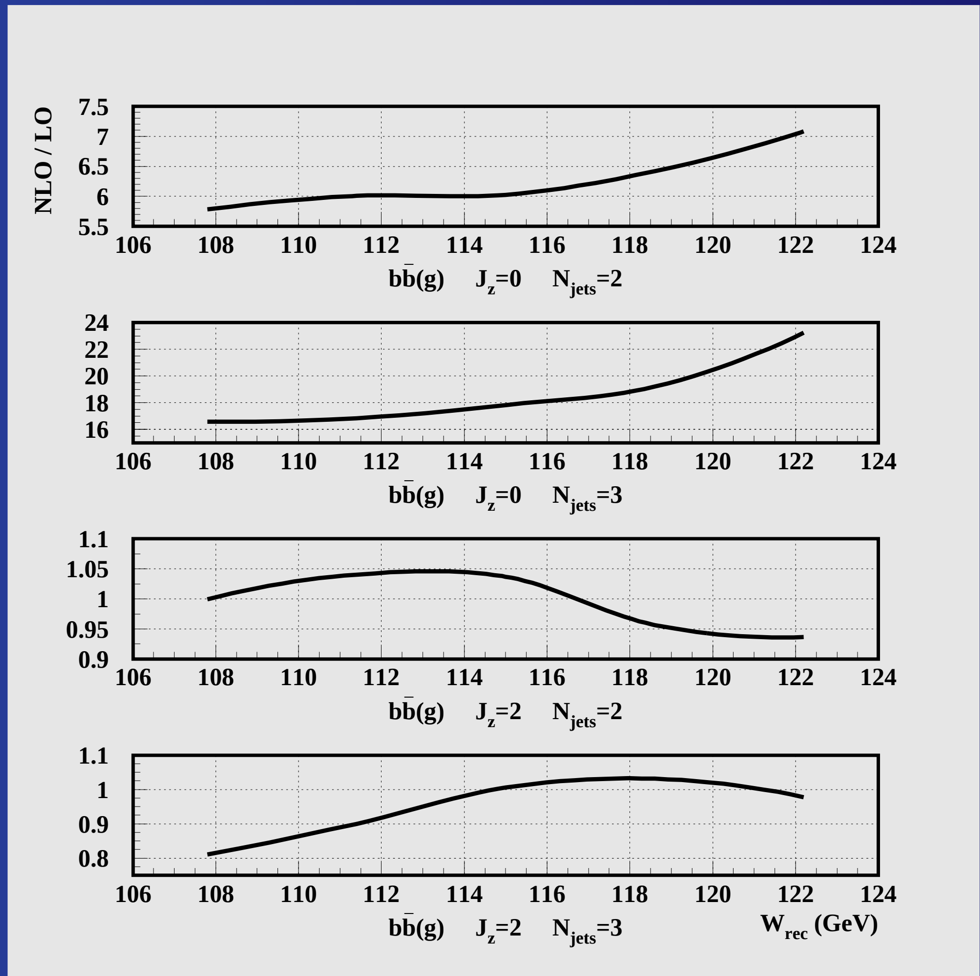
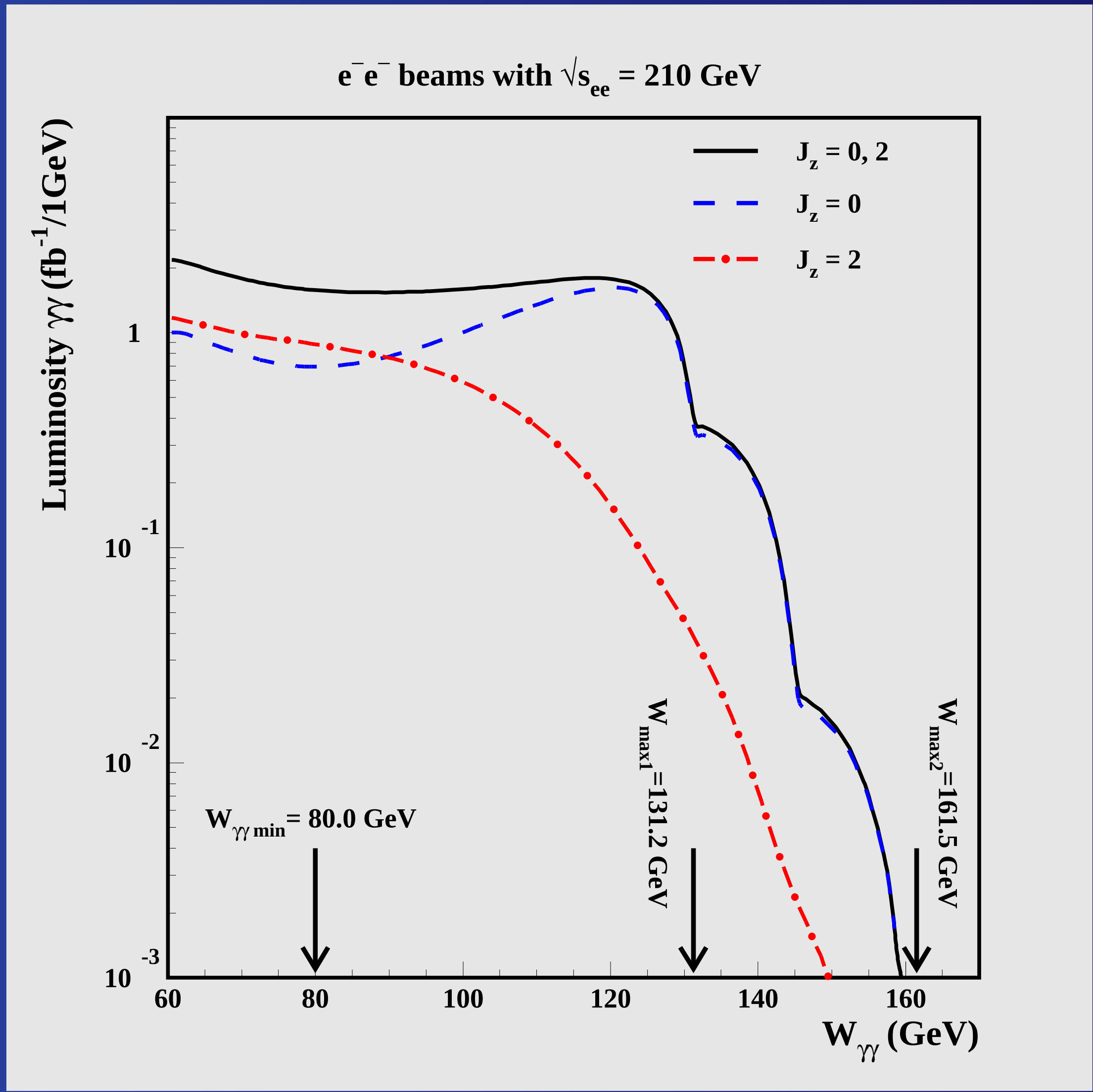


Generation & Simulation. Selection.

Photon-photon spectrum: CompAZ



Generation & Simulation. Selection.

Photon-photon spectrum: CompAZ

Signal: HDECAY, PYTHIA

Background: program by G. Jikia

Fragmentation: Lund in PYTHIA

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Detector performance: SIMDET (parametric simulation)
Jets: Durham algorithm with $y_{cut} = 0.02$

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Selection of $b\bar{b}$ events (later modified):

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  2) Using ZVTOP-B-Hadron-Tagger

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- $E_{vis} > 90$ GeV

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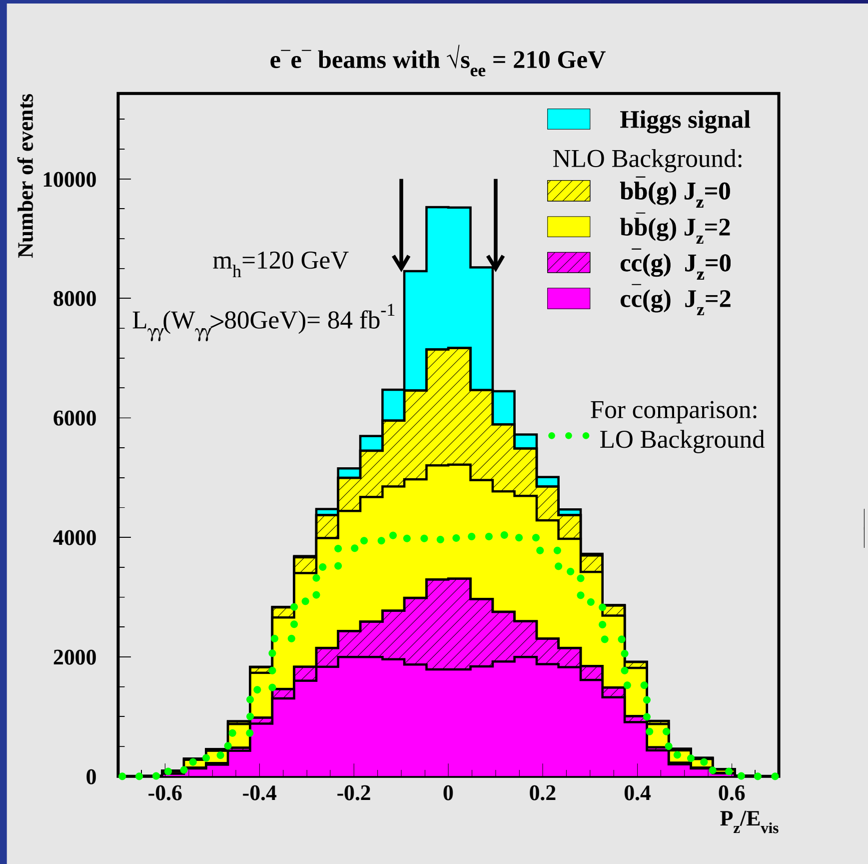
- $|P_z|/E_{vis} < 0.1$



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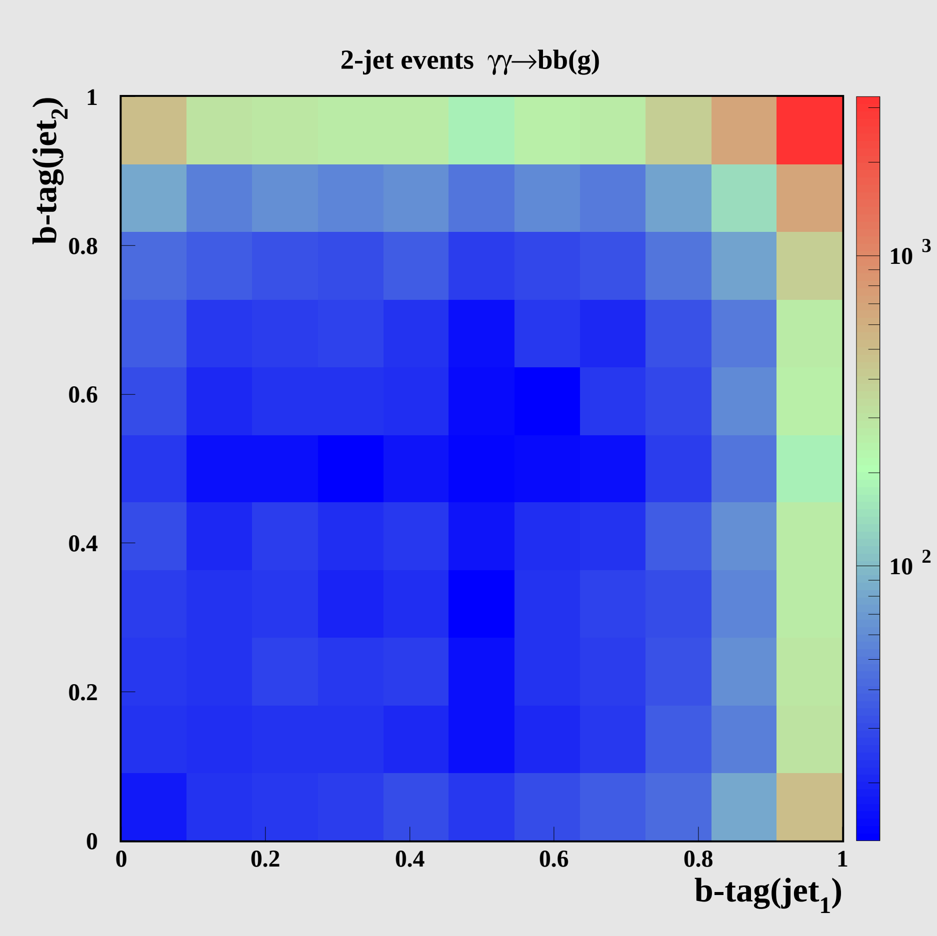
  2) Using ZVTOP-B-Hadron-Tagger
- $E_{vis} > 90$ GeV
- $N_{jets} = 2,\ 3$
- $|P_z|/E_{vis} < 0.1$
- $|\cos\theta_i| < 0.75$ for each jet

B-tagging

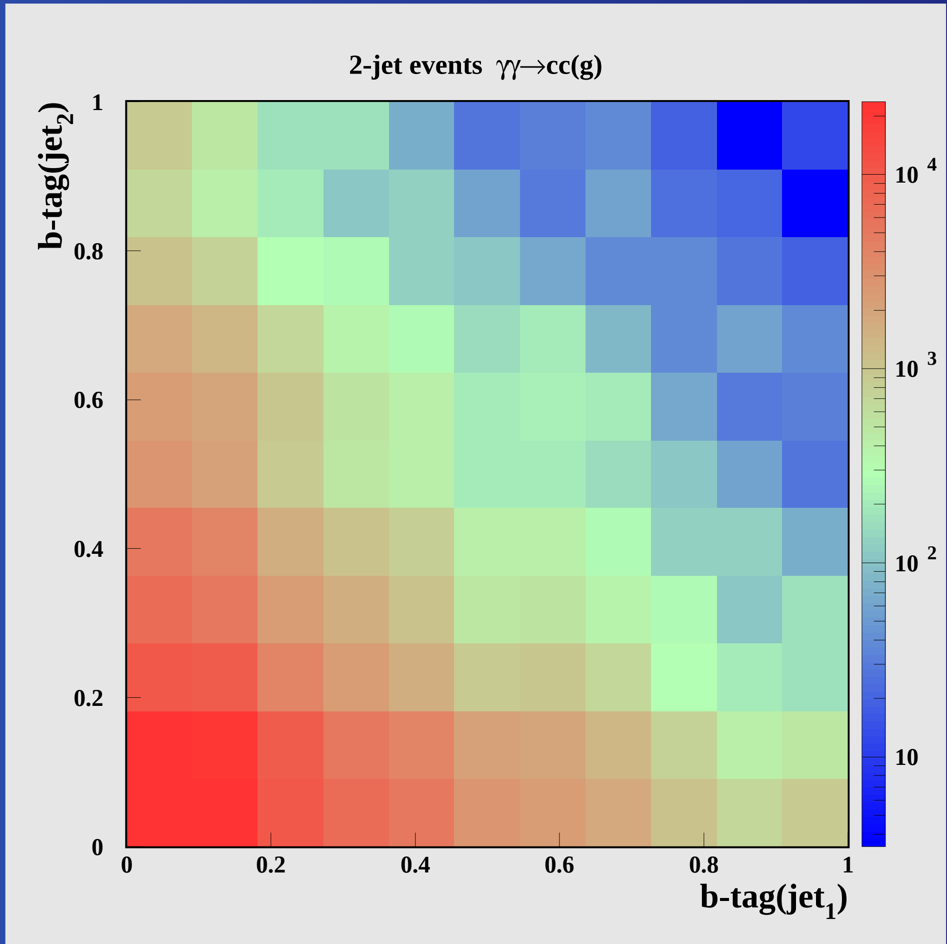
ZVTOP-B-Hadron-Tagger



Number of $\gamma + \gamma \to b + \bar{b}$ events per 1 year of collider running

B-tagging

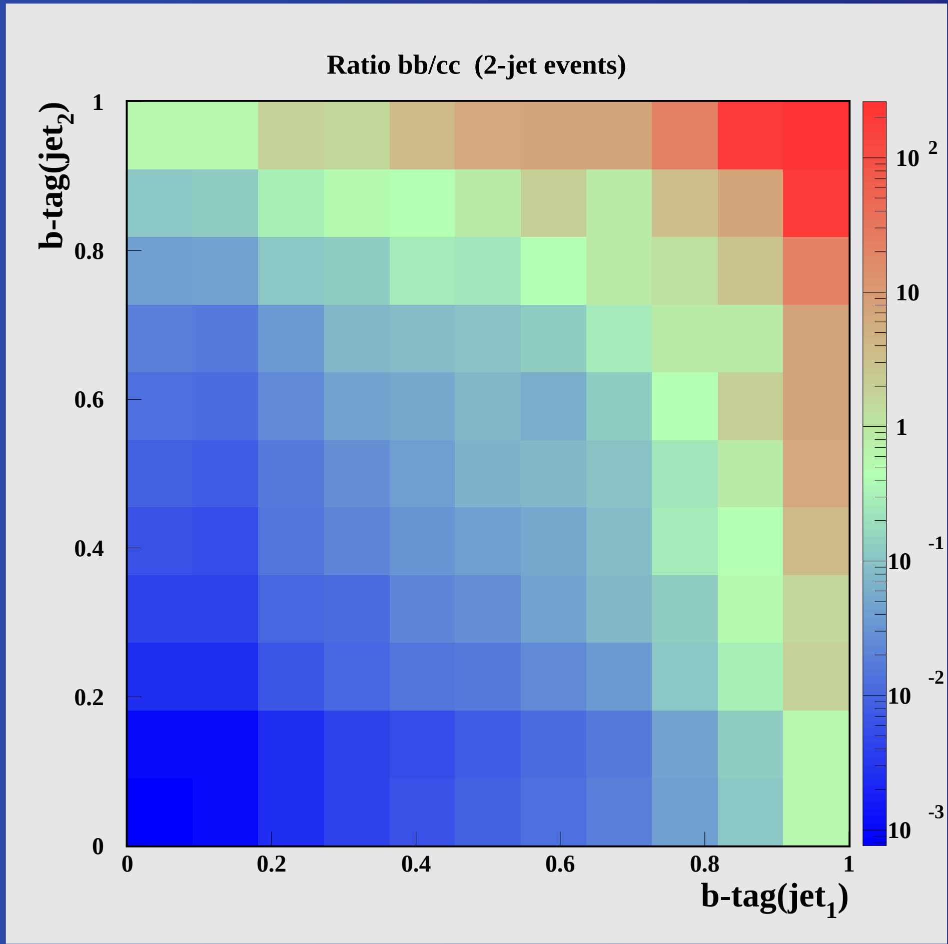
ZVTOP-B-Hadron-Tagger



Number of $\gamma + \gamma \to c + \bar{c}$ events per 1 year of collider running

B-tagging

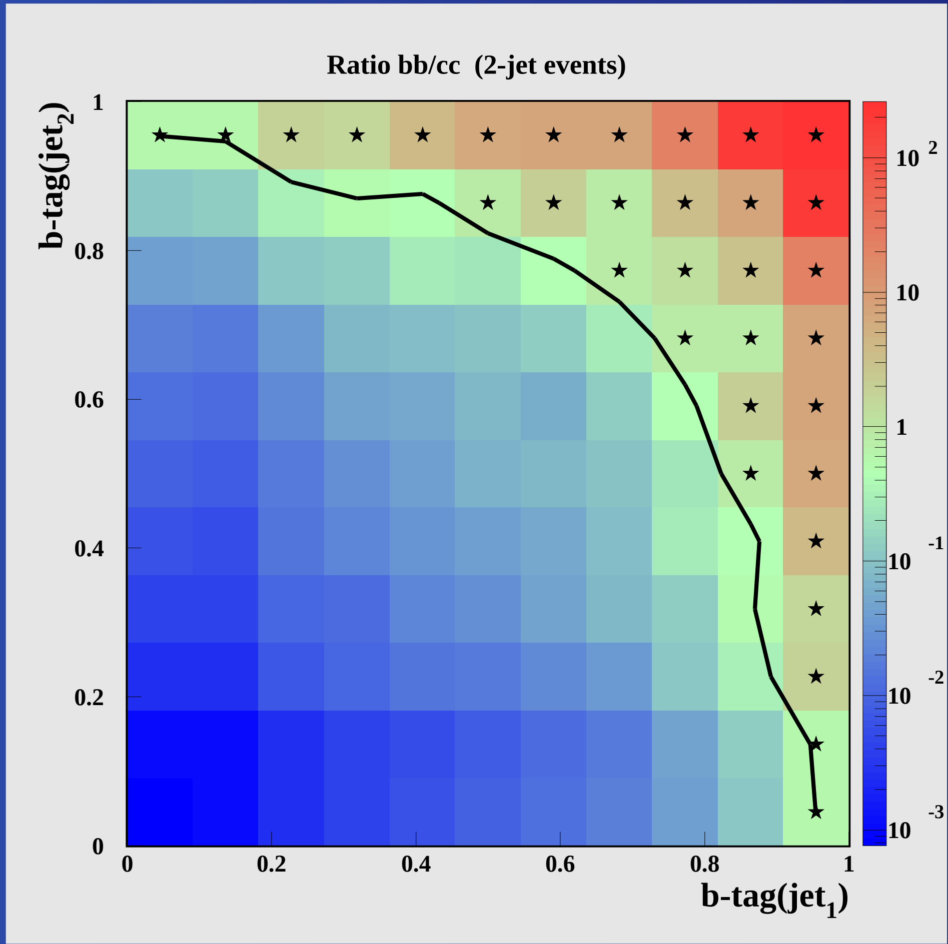
ZVTOP-B-Hadron-Tagger



$$\frac{S}{B} = \frac{\#(\gamma\gamma \to b\bar{b})}{\#(\gamma\gamma \to c\bar{c})}$$

B-tagging

ZVTOP-B-Hadron-Tagger



$\varepsilon_{bb} = 82\%$ $\varepsilon_{cc} = 2\%$

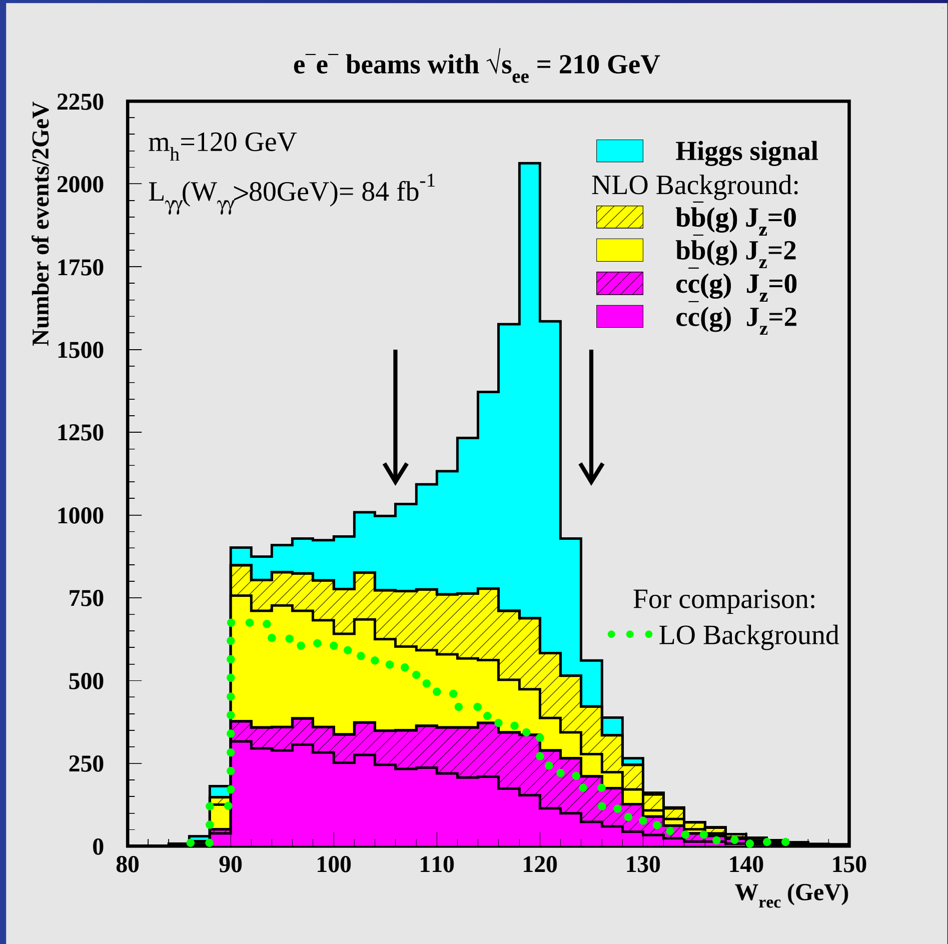
Earlier assumed: $\varepsilon_{bb} = 70\%$ $\varepsilon_{cc} = 3.5\%$

Results

$$\frac{\Delta\Gamma(h\to\gamma\gamma)Br(h\to b\bar{b})}{\Gamma(h\to\gamma\gamma)Br(h\to b\bar{b})} = \frac{\sqrt{N_{obs}}}{N_{obs}-N_{bkgd}}$$

Consecutive approaches:

- NLO cross section
  for $\gamma+\gamma\to Q\bar{Q}(g)$
  Simdet3
  Precision: 1.9%



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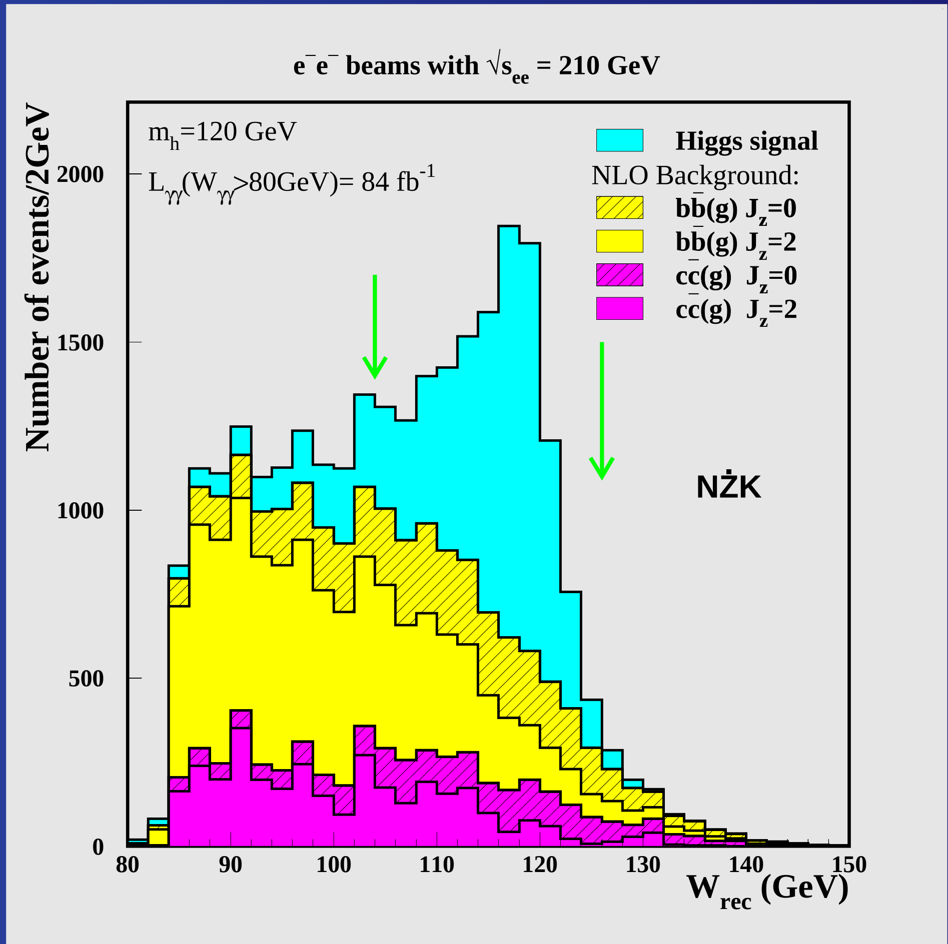
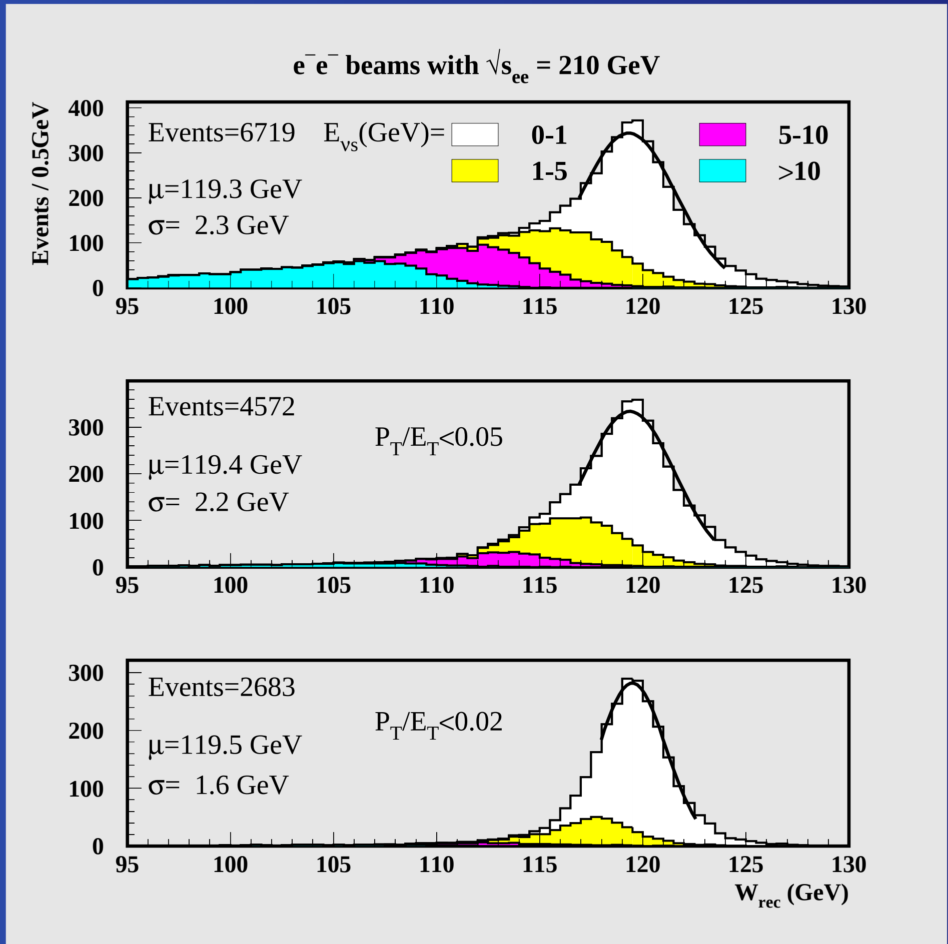
  Precision: 1.9%
- NLO cross section
  for $\gamma+\gamma\to Q\bar{Q}(g)$.
  B-tagging algorithm + Simdet4
  Precision: 1.8%



Missing P_T

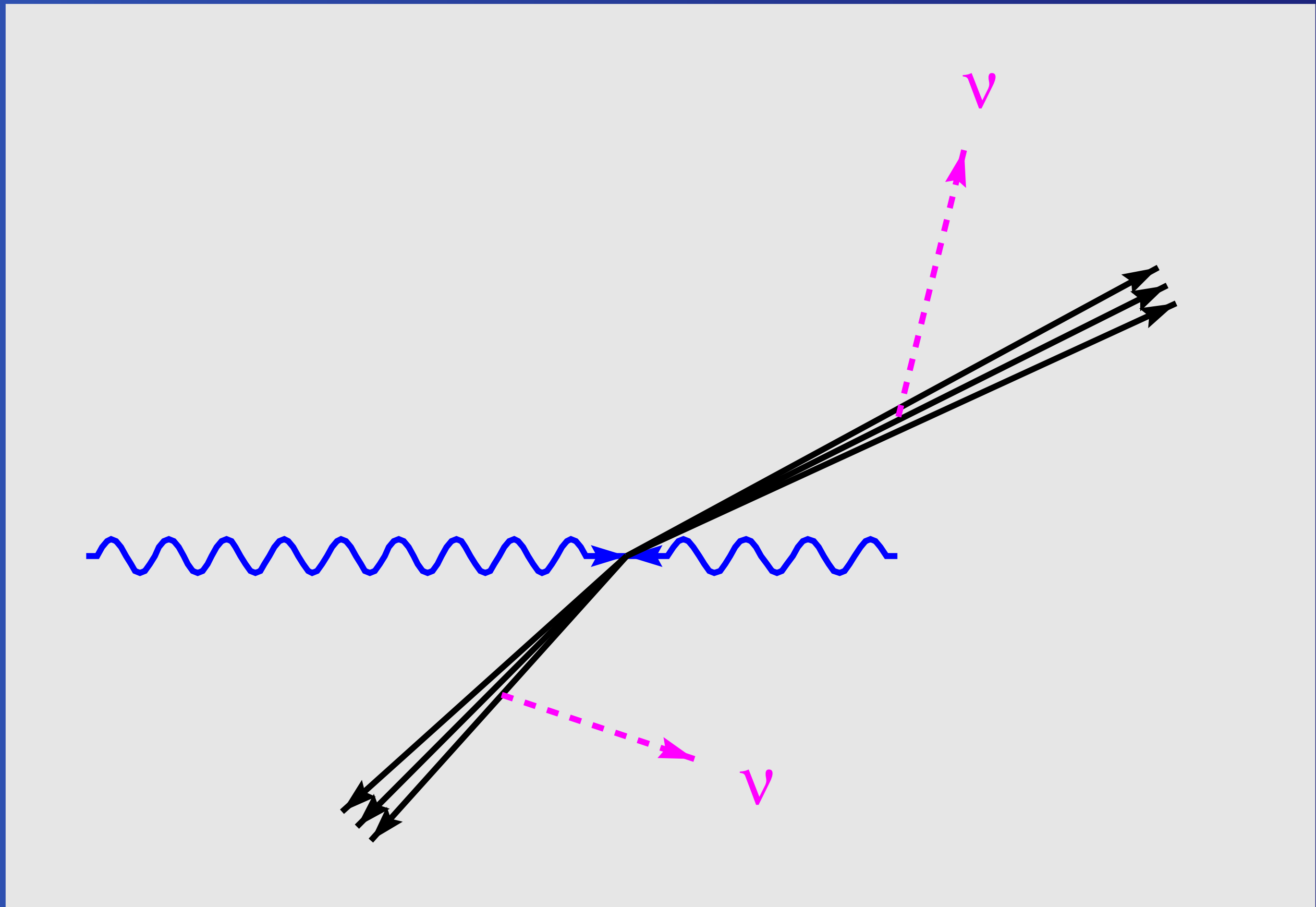
Neutrinos from semileptonic decays of D- and B-mesons (Simdet3)



Signal only

Missing P_T

Neutrinos from semileptonic decays of D- and B-mesons



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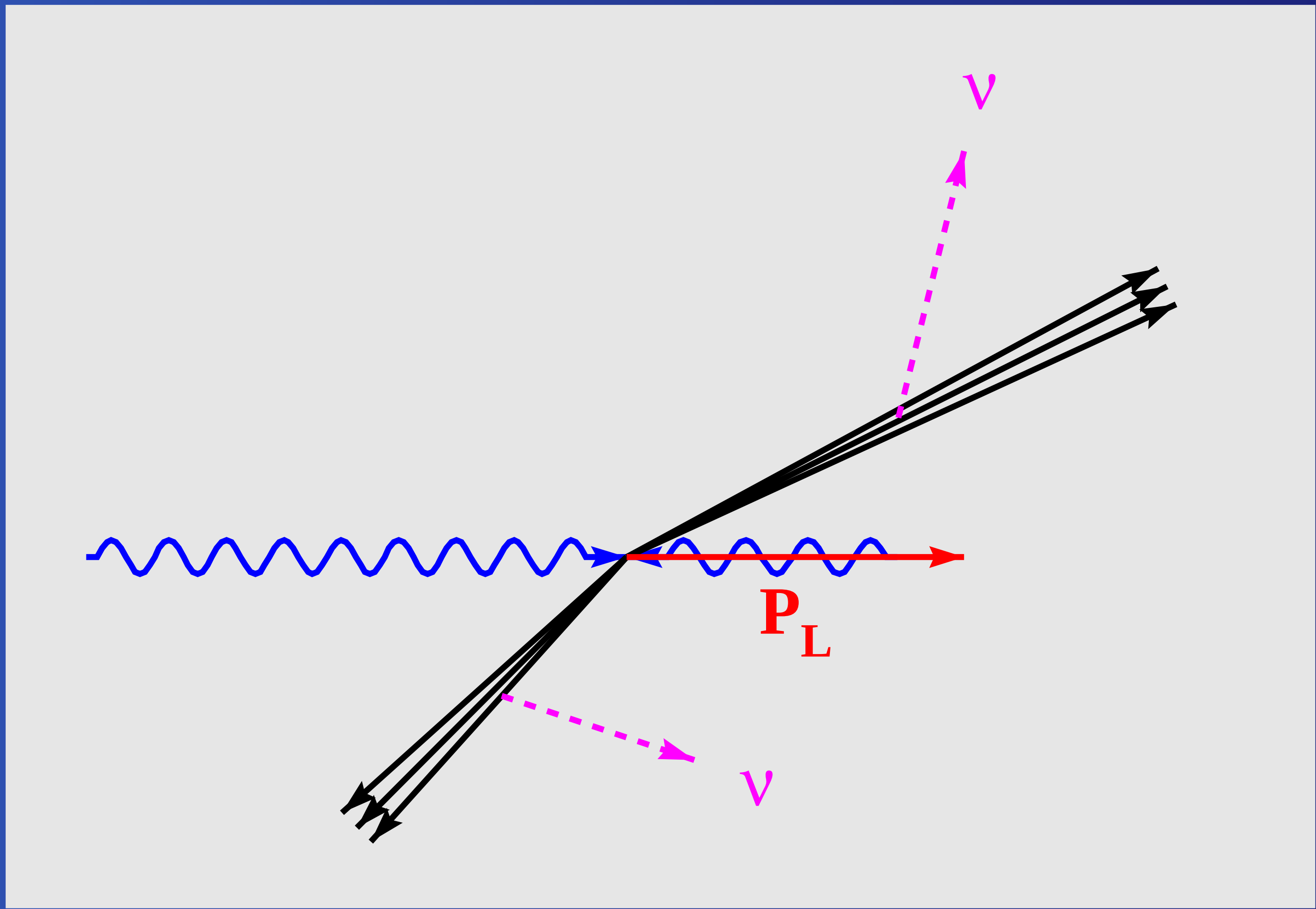

Missing P_T

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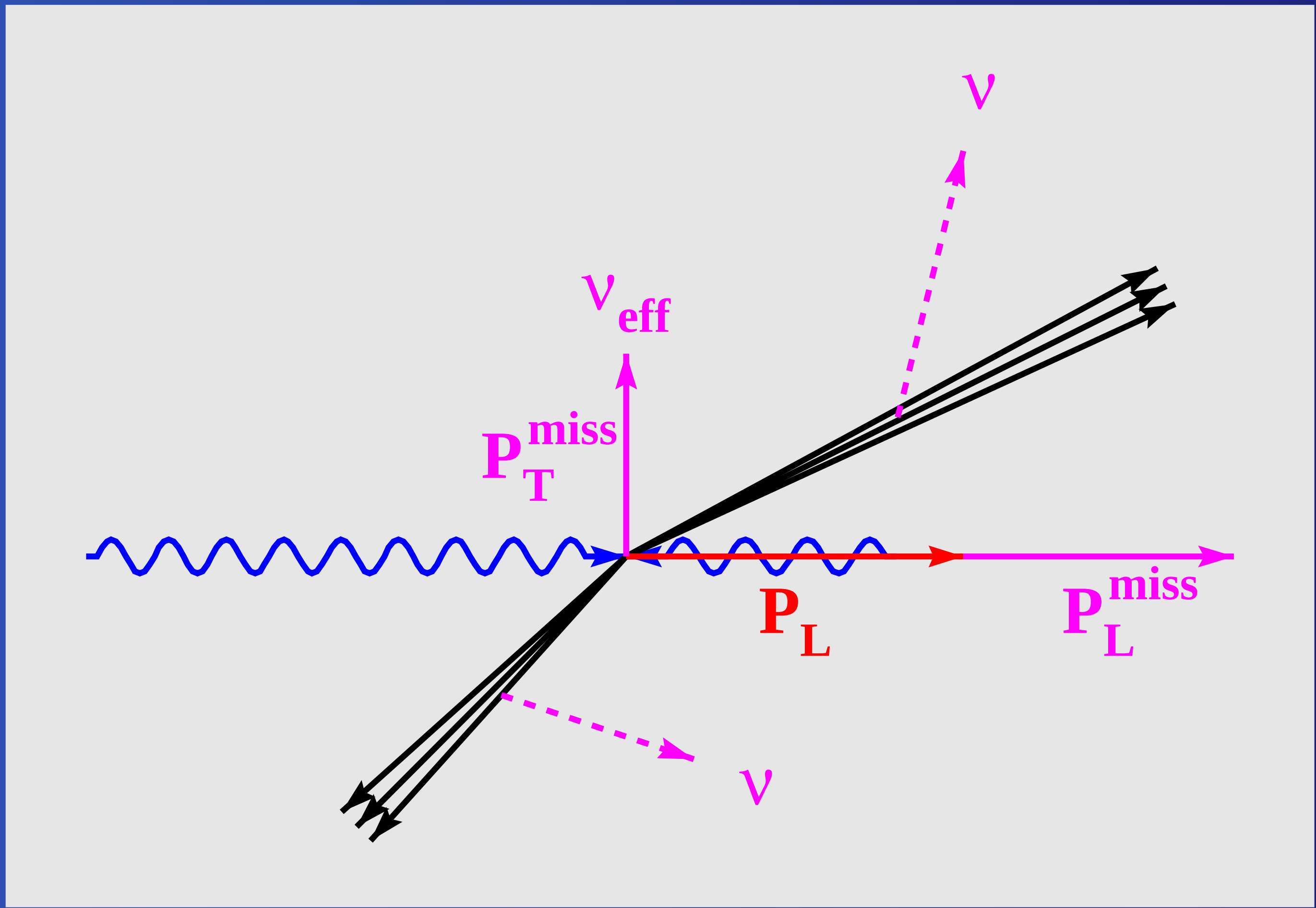
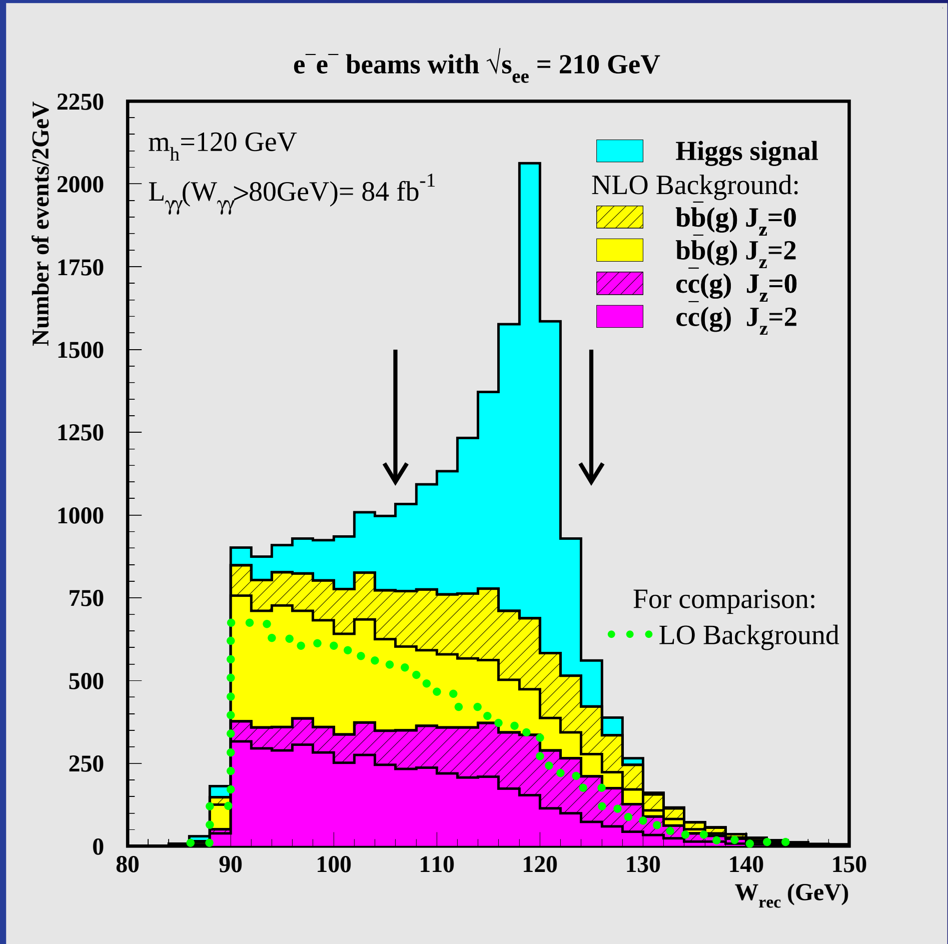


$$W_{corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E_{vis} + P_T)}$$

Final results ($W_{rec} \to W_{corr}$)

$$\frac{\Delta\Gamma(h \to \gamma\gamma)\mathrm{Br}(h \to b\bar{b})}{\Gamma(h \to \gamma\gamma)\mathrm{Br}(h \to b\bar{b})} = \frac{\sqrt{N_{obs}}}{N_{obs} - N_{bkgd}}$$

- NLO cross section for $\gamma + \gamma \to Q\bar{Q}(g)$. Simdet3 (1.9%) - with W_{rec}



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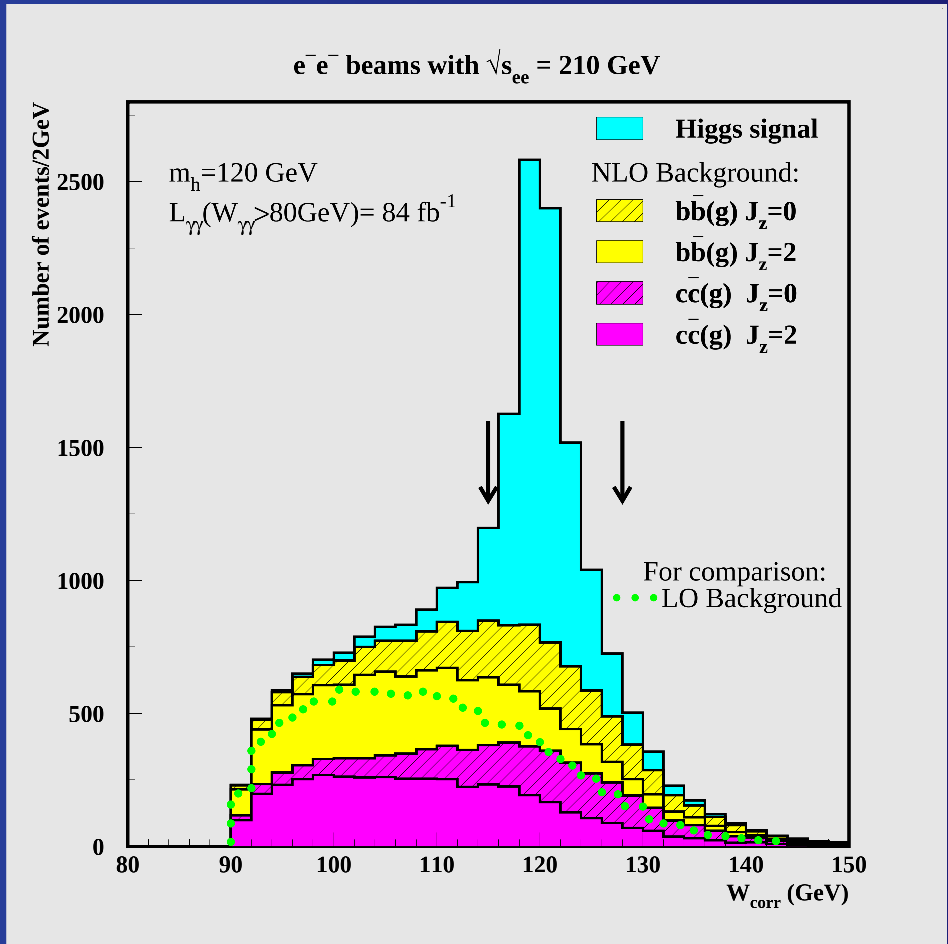
- NLO cross section for $\gamma+\gamma\to Q\bar{Q}(g)$. Simdet3
  (1.9%) - with W_{rec}
  (1.7%) - with W_{corr}



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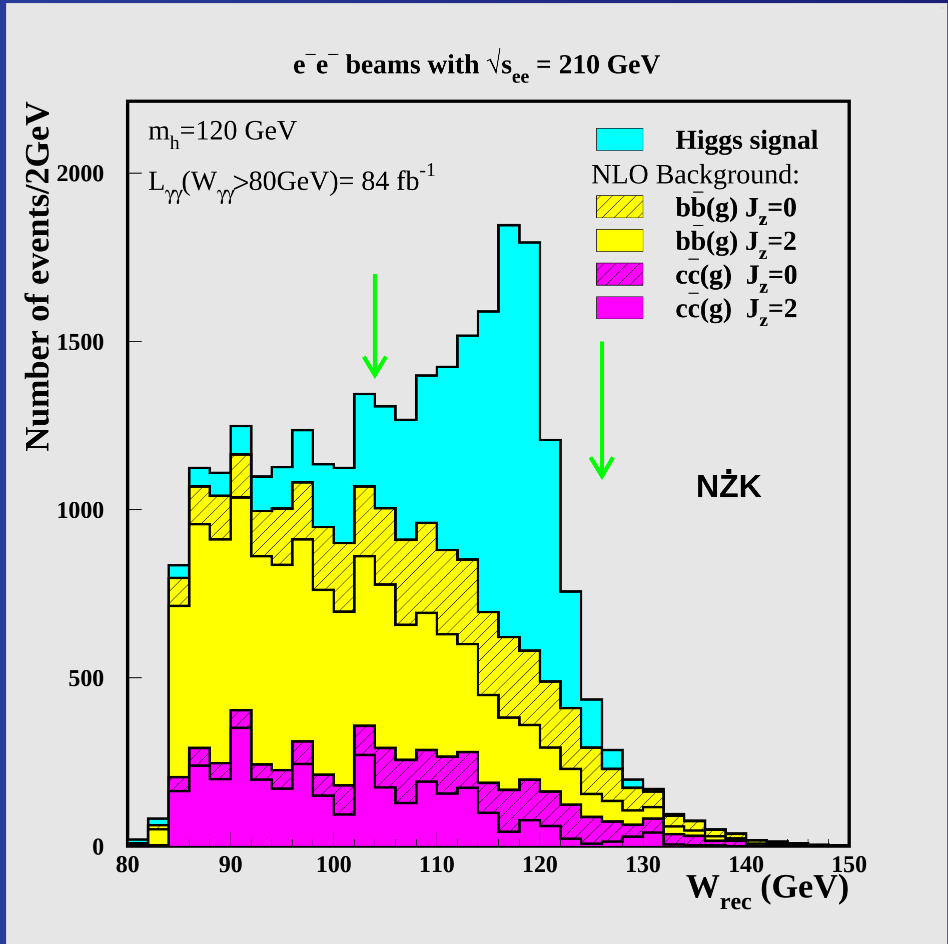
- NLO cross section for $\gamma + \gamma \to Q\bar{Q}(g)$.
  Simdet3
  (1.9%) - with W_{rec}
  (1.7%) - with W_{corr}

- NLO cross section for $\gamma + \gamma \to Q\bar{Q}(g)$.
  B-tagging algorithm + Simdet4
  (1.8%) - with W_{rec}



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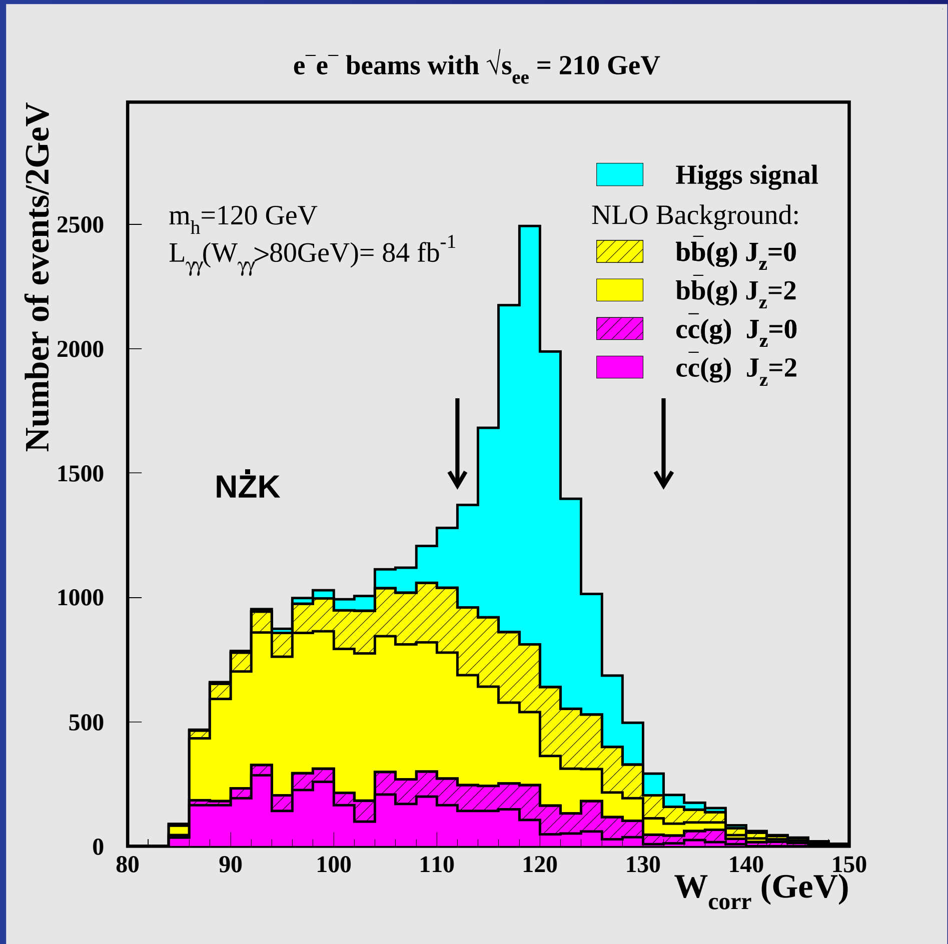
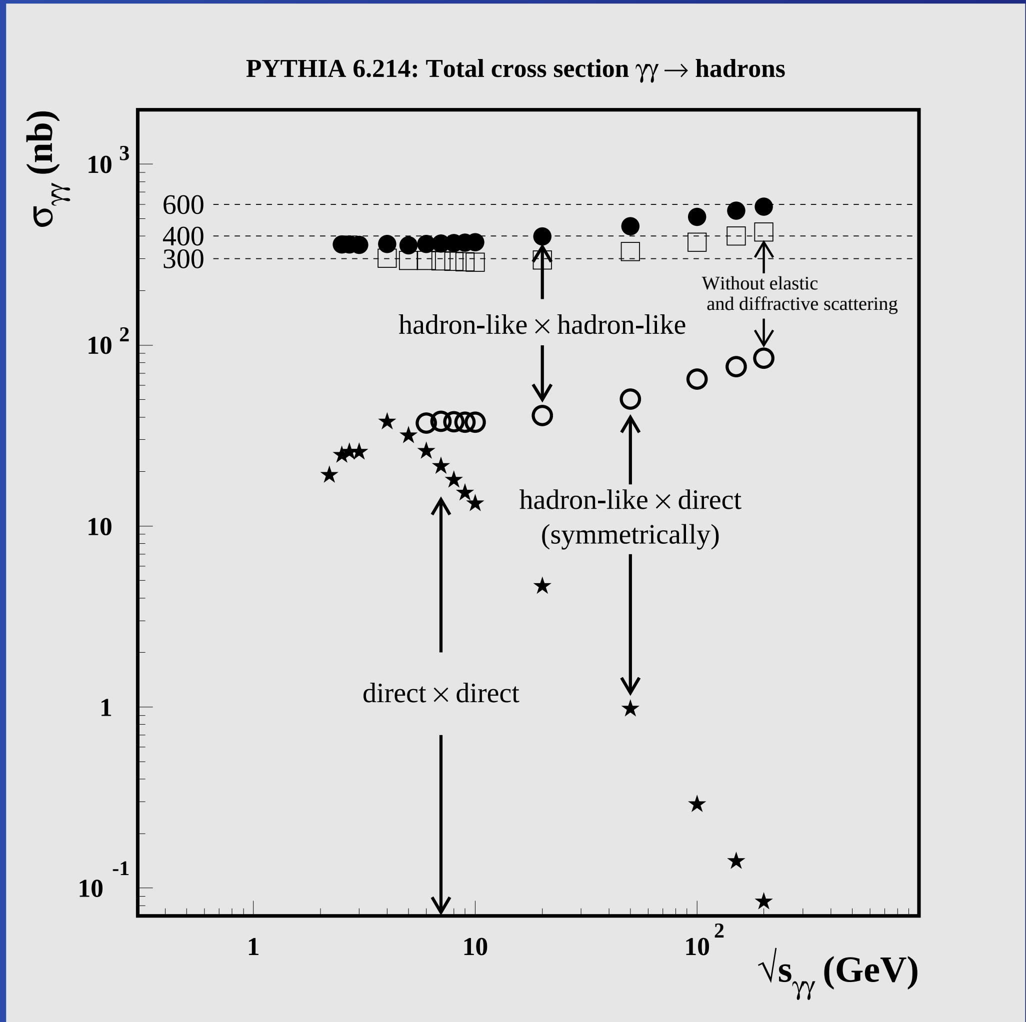
- NLO cross section for $\gamma + \gamma \to Q\bar{Q}(g)$. Simdet3
  (1.9%) - with W_{rec}
  (1.7%) - with W_{corr}

- NLO cross section for $\gamma + \gamma \to Q\bar{Q}(g)$. B-tagging algorithm + Simdet4
  (1.8%) - with W_{rec}
  (1.6%) - with W_{corr}



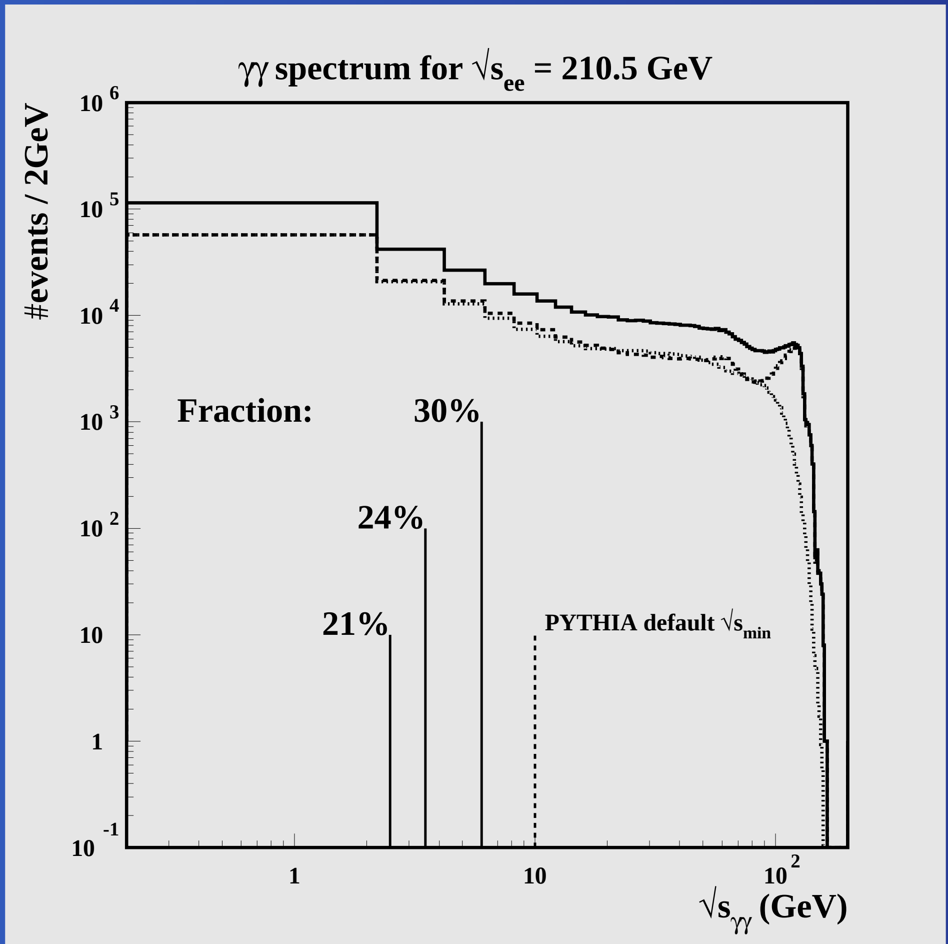
$\gamma\gamma \rightarrow$ *hadrons*: cross section



Scans with fixed energy of $\gamma\gamma$-beams.
(PYTHIA default = no elastic & diffractive interactions)

Spectrum $\gamma\gamma$

We use scaled $\gamma\gamma$ luminosity spectrum
$\sqrt{s_{ee}} = 200$ GeV $\longrightarrow 210.5$ GeV (full simulations).



$L_{tot}(\gamma\gamma) = 41 \frac{1}{\text{nb s}}$

$f_{rep} n_b = 14.1$ kHz

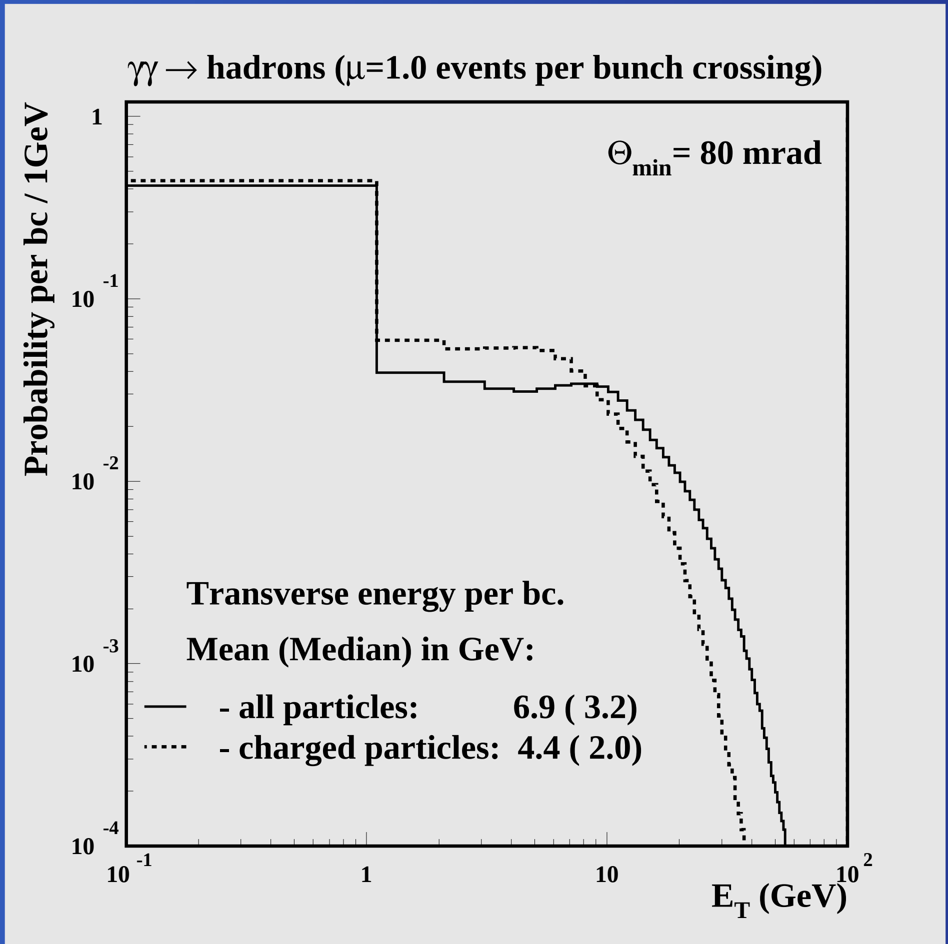
$\longrightarrow L_{tot}(\gamma\gamma) = 0.003 \frac{1}{\text{nb}}$ per bc

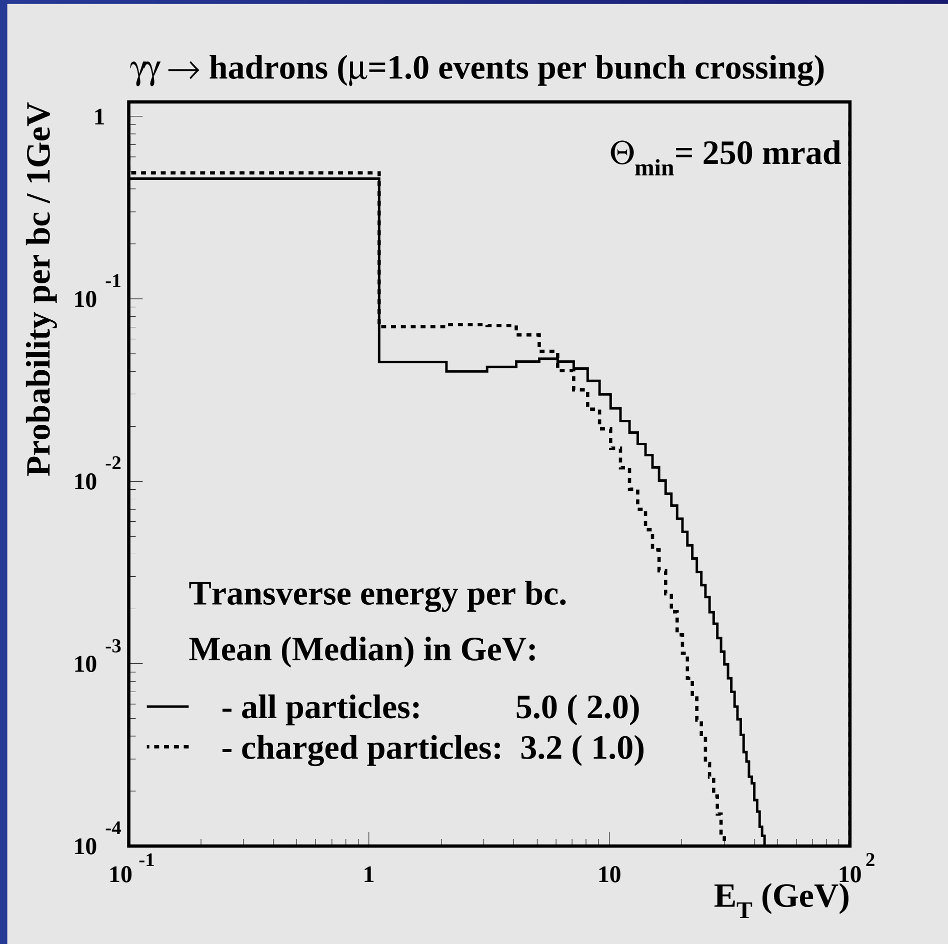
Estimation: $\sigma_{\gamma\gamma} \sim 400$ nb
$\longrightarrow 1$ event per bc

Generation:
PYTHIA 6.214 + $\gamma\gamma$-spectrum
$\longrightarrow 1$ event per bc

Our generation is with $\sqrt{s_{\gamma\gamma}}_{min} = 3.5$ GeV

$\gamma\gamma \to$ *hadrons*: E_T distributions



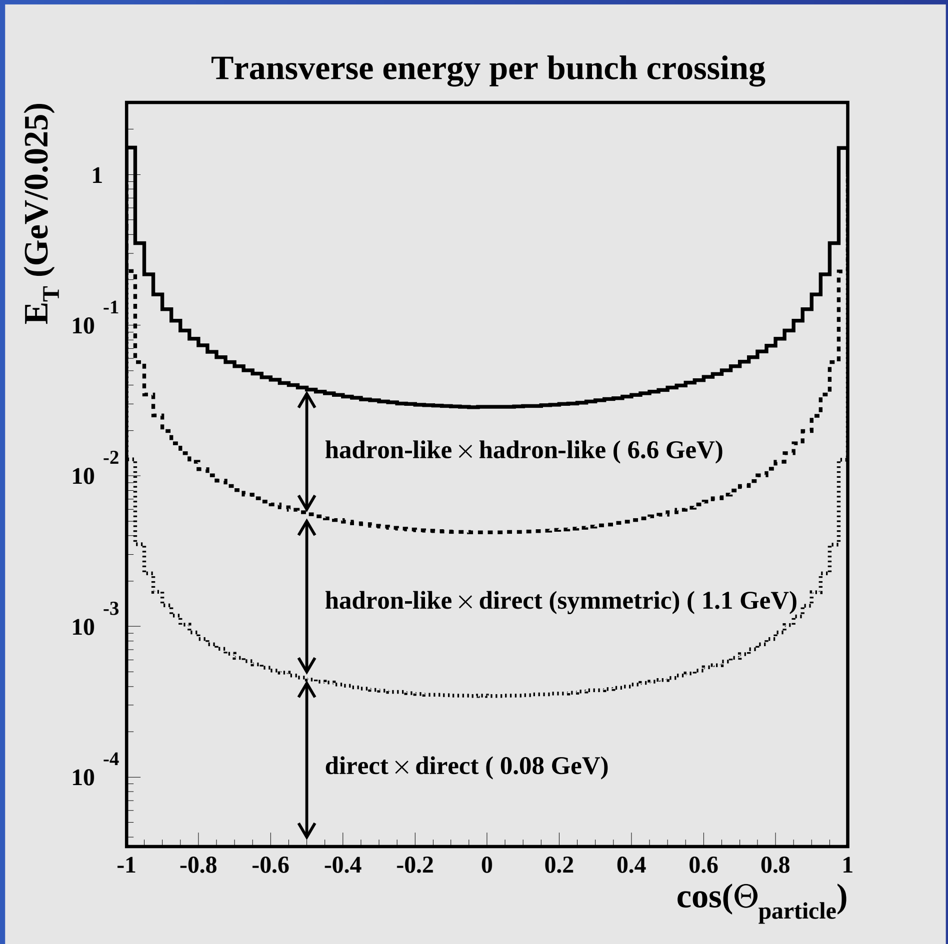


Generated according to Poisson distribution with:

$\mu =$ hh + hd + dd $= 0.89 + 0.10 + 0.01 = 1.0$ events/bc

Overlaying events $\gamma\gamma \to$ *hadrons*

Angular distributions of E_T for $\gamma\gamma \to$ *hadrons* events per bc.
Generation for $\sqrt{s_{ee}} = 210.5$ GeV.



Small-angle clusters & tracks should be ignored.

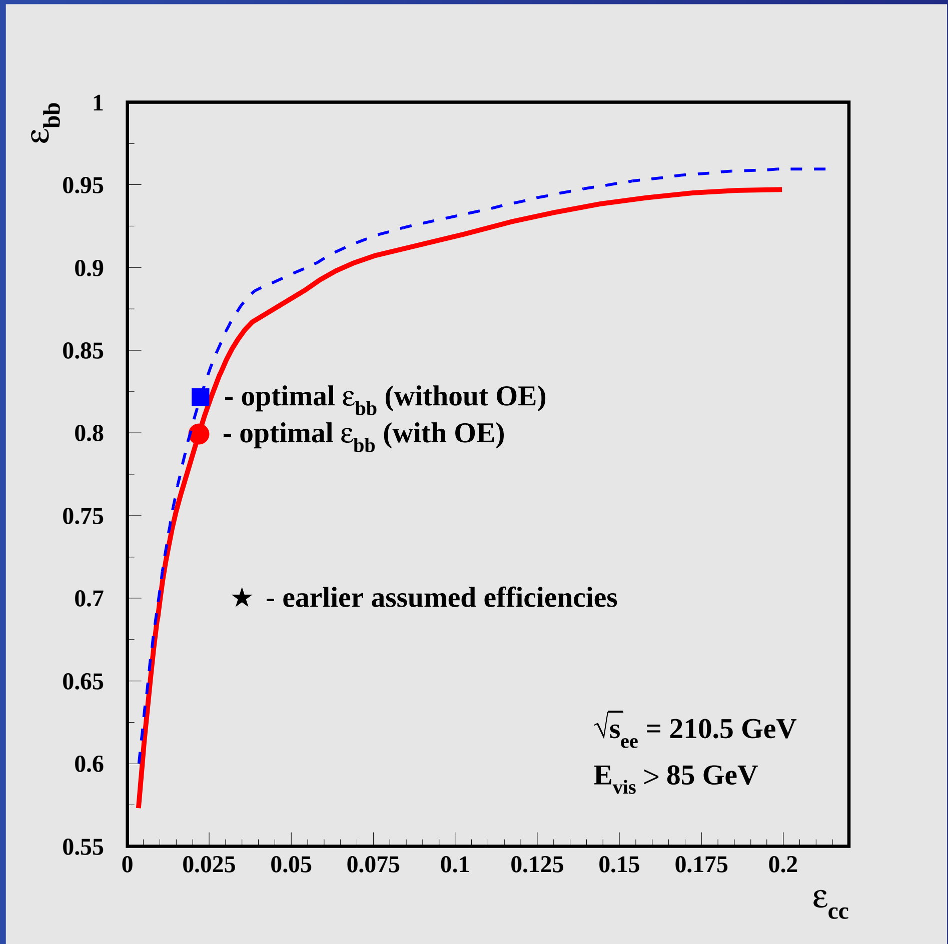
Our choice:

$\theta_{\text{min}}^{\text{DET}} = 450$ mrad

$\cos\theta_{\text{min}}^{\text{DET}} = 0.9$

$b\bar{b}$-tagging vs. $c\bar{c}$-mistagging

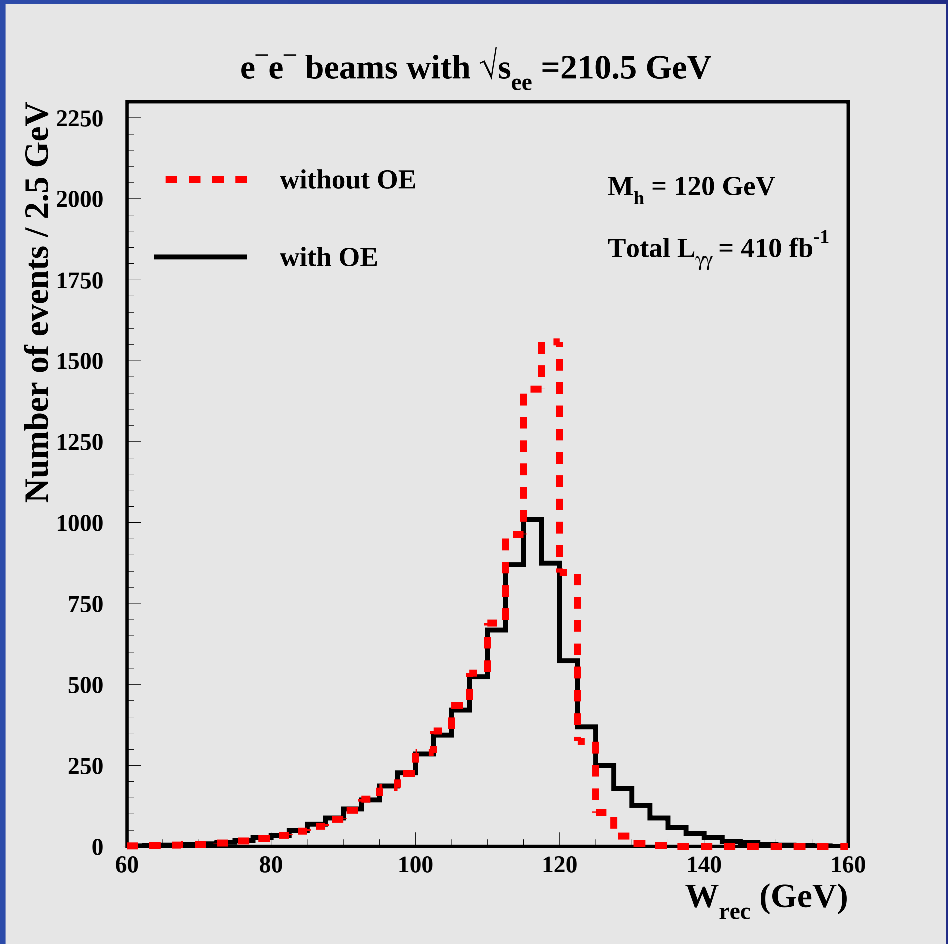
For $\sqrt{s_{ee}} = 210.5$ GeV with the additional cut $E_{vis} > 85$ GeV



$W_{\gamma\gamma}$ distributions

without/with OE

SM - signal only

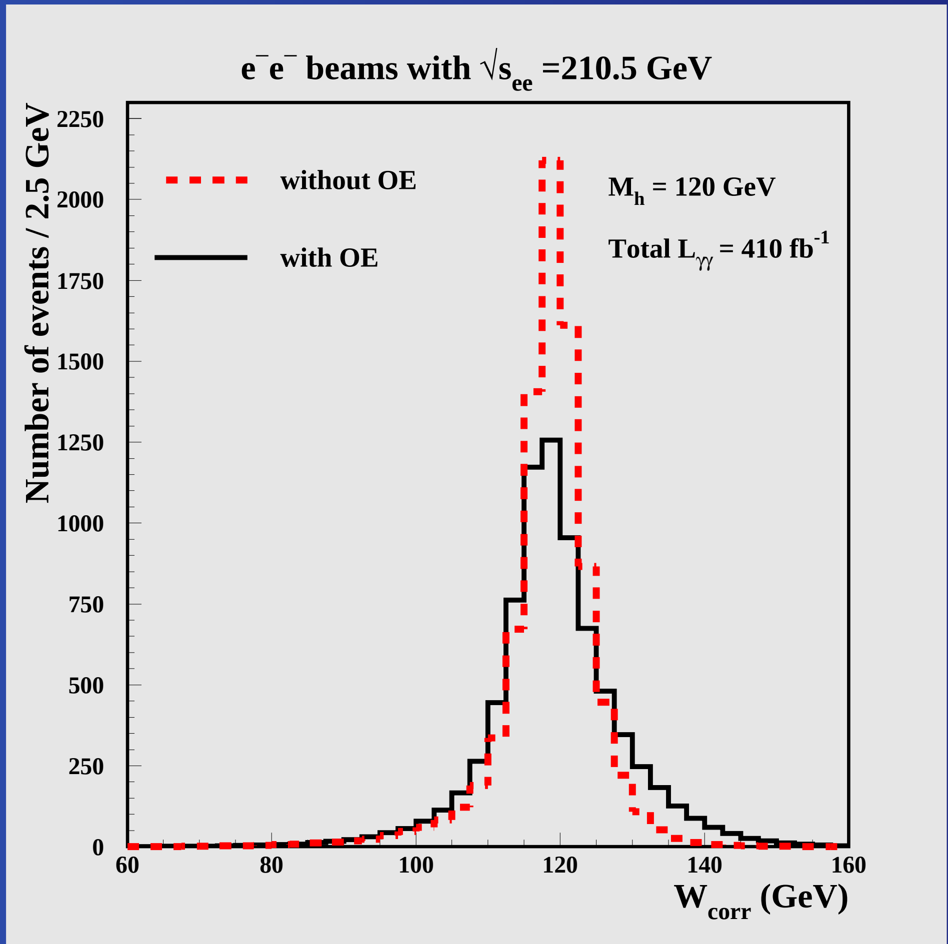


W_{rec}

$W_{\gamma\gamma}$ distributions

without/with OE

SM - signal only

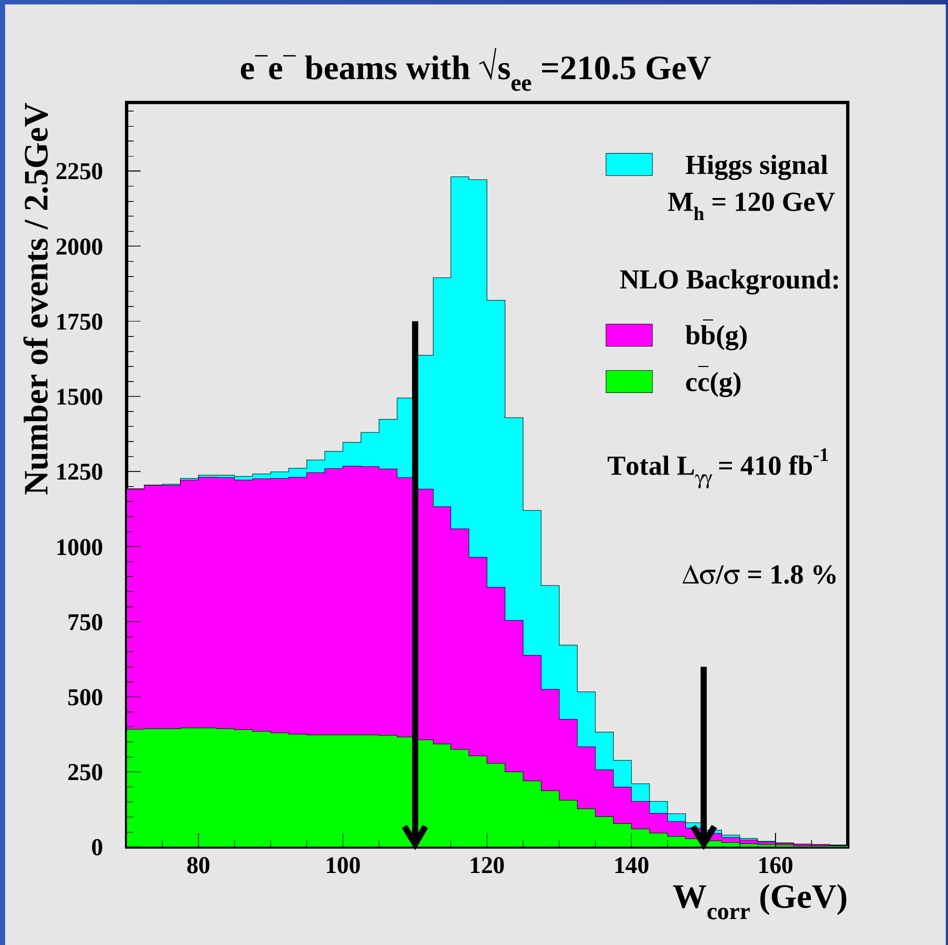


$$W_{corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E_{vis} + P_T)}$$

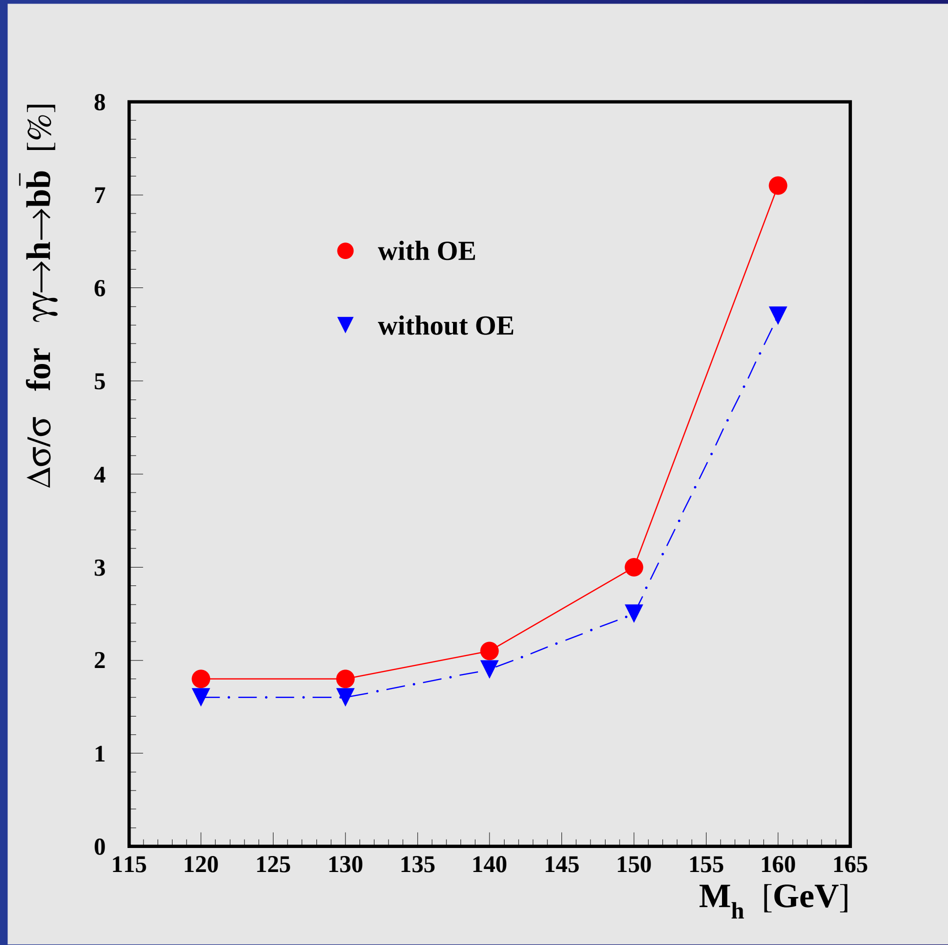
Precision for $\sigma(\gamma\gamma \to h \to b\bar{b})$

EPS'2003, hep-ph/0307183

SM - signal & background, with OE



SM - summary

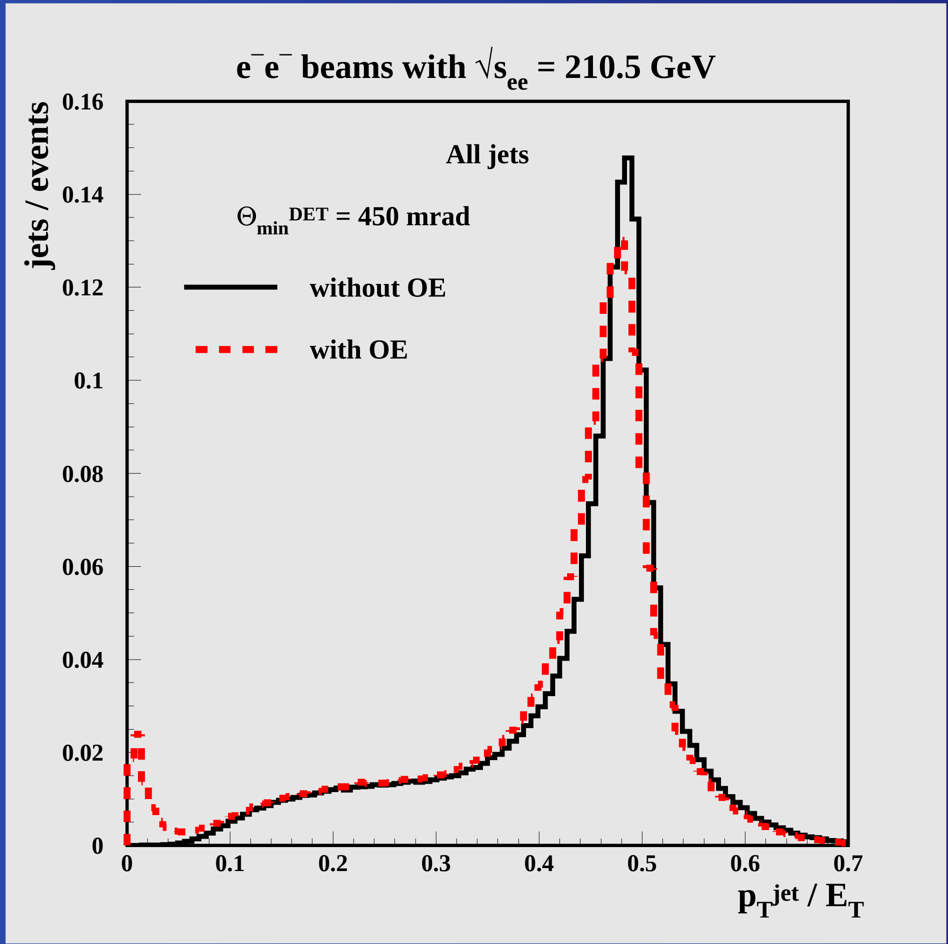


$$\frac{\Delta\sigma(\gamma\gamma \to \textit{higgs} \to b\bar{b})}{\sigma(\gamma\gamma \to \textit{higgs} \to b\bar{b})} = \frac{\sqrt{N_{\rm obs}}}{N_{\rm obs} - N_{\rm bkgd}}$$

Transverse momenta of jets

All jets

SM - signal only

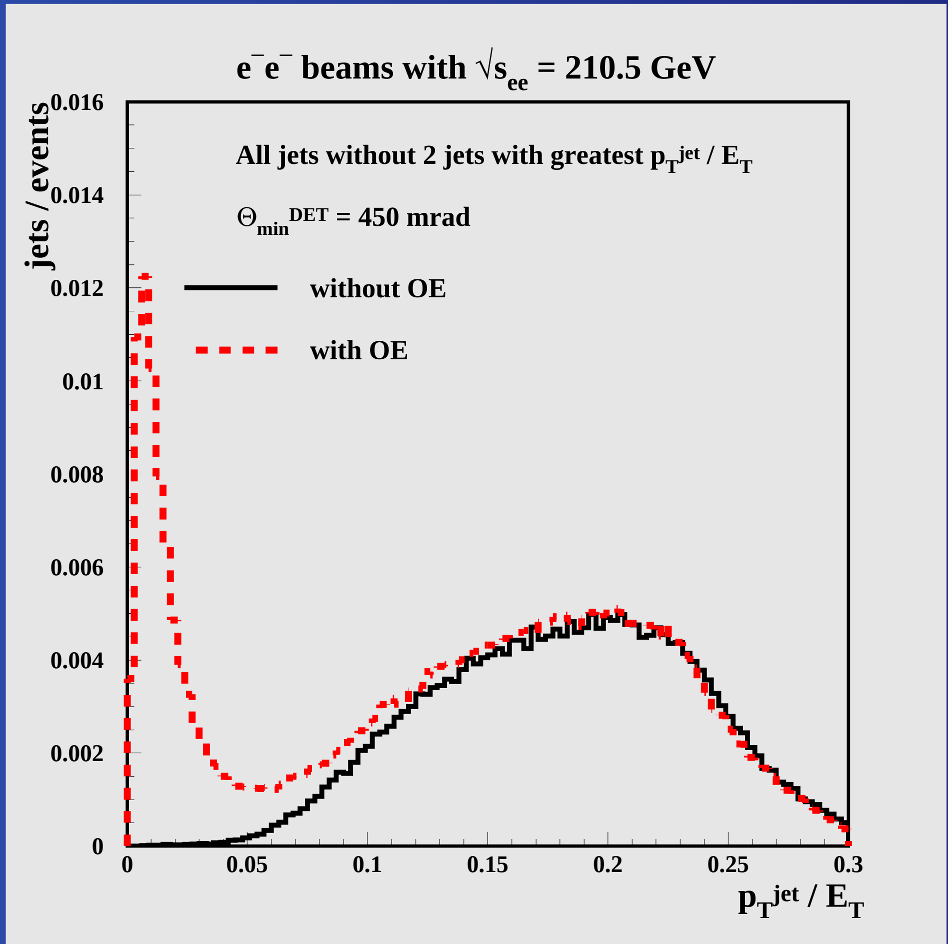


Contribution of OE. Only θ_{min}^{DET}-cut.

Transverse momenta of jets

Discriminating between gluon-jets (PS) & OE

SM - signal only

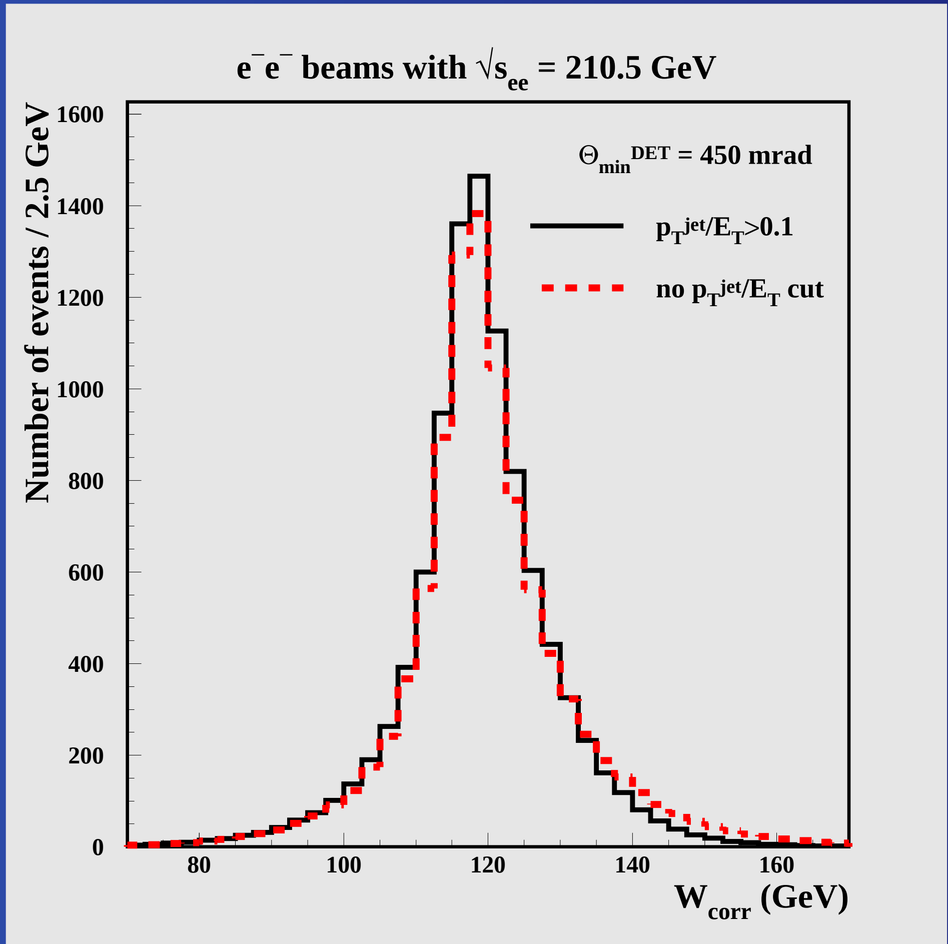


⇒ Additional cut: $p_T^{jet}/E_T > 0.1$ for each jet

W_{corr} distributions

with/without p_T^{jet}/E_T-cut

SM - signal only

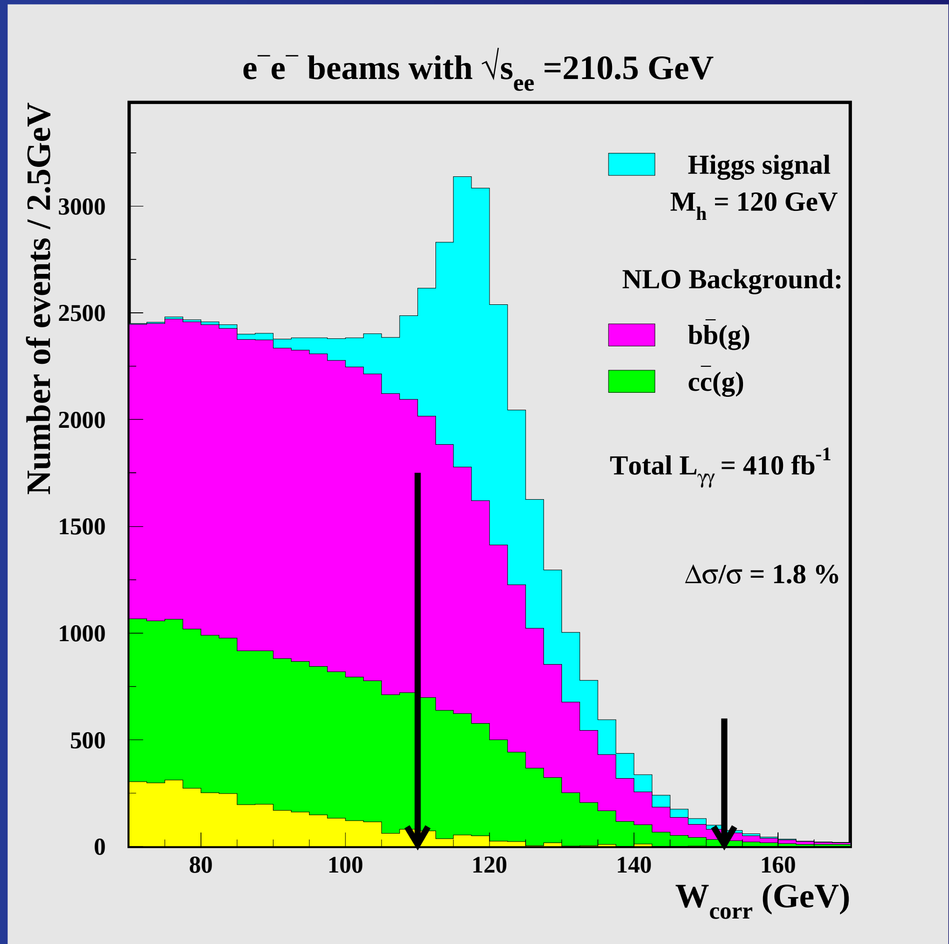


New background: $\gamma\gamma \to \tau\tau$

$$\frac{\sigma(\gamma\gamma \to \tau\tau)}{\sigma(\gamma\gamma \to c\bar{c})} \approx 5/3$$

$$\frac{\sigma(\gamma\gamma \to \tau\tau)}{\sigma(\gamma\gamma \to c\bar{c}(g))} \approx 1$$

SM - signal & background



Yellow area $= \gamma\gamma \to \tau\tau$

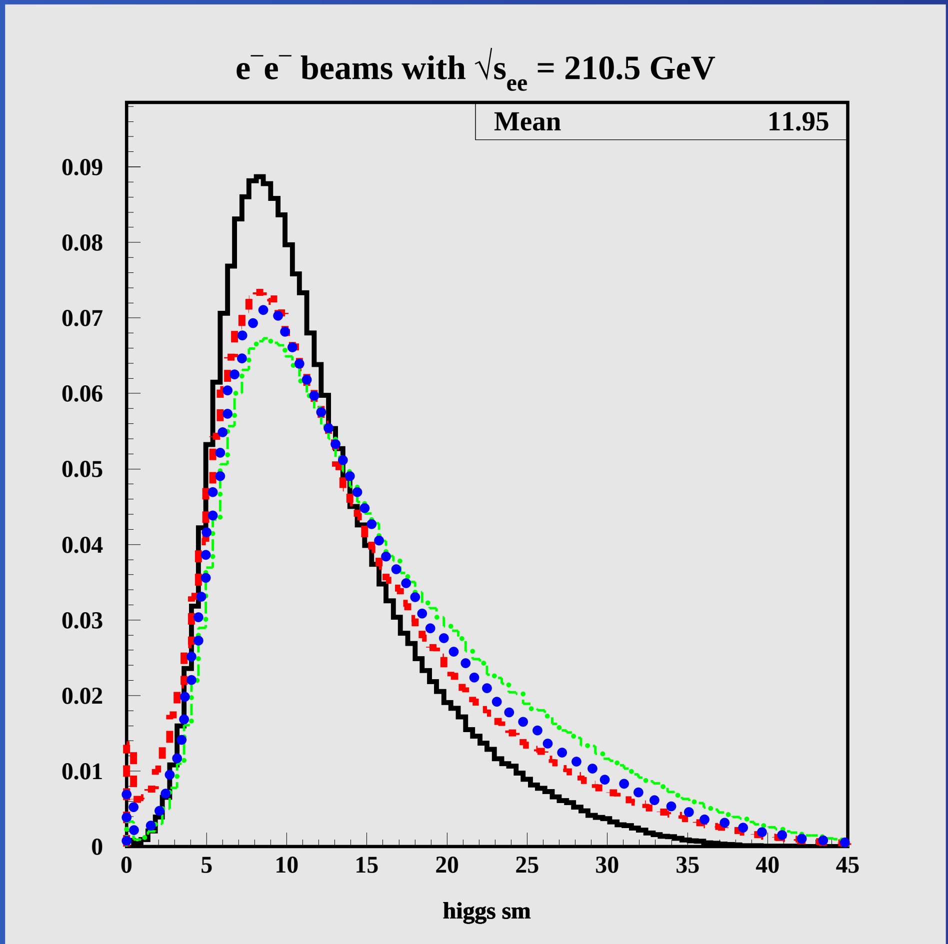
Is $\theta^{\text{DET}}_{\text{min}} = 0.450$ optimal?

$\theta^{\text{DET}}_{\text{min}}$	0.315	0.450	0.555
$\cos\theta^{\text{DET}}_{\text{min}}$	0.95	0.90	0.85

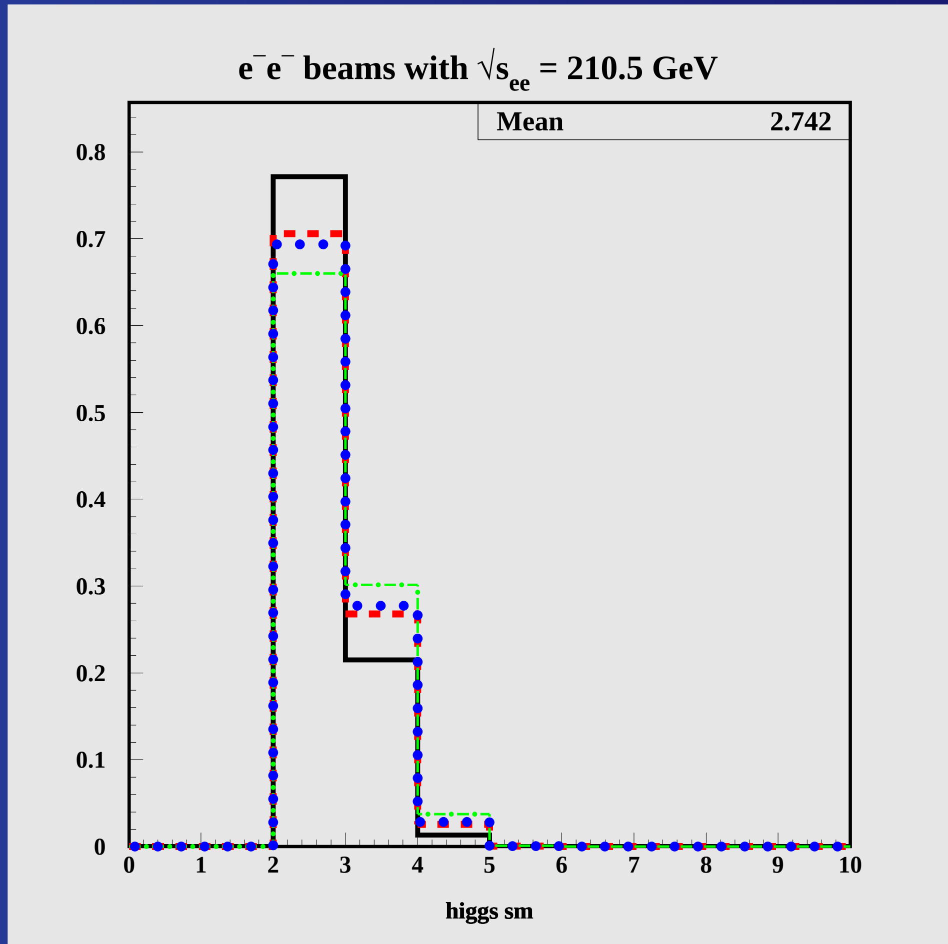
Precision($\Gamma(h \to \gamma\gamma)\text{Br}(h \to b\bar{b})$) = 1.8 % (with ↘ tendency)

Is $\theta_{\text{min}}^{\text{DET}} = 0.450$ optimal?

$\theta_{\text{min}}^{\text{DET}}$	0.315	0.450	0.555
$\cos\theta_{\text{min}}^{\text{DET}}$	0.95	0.90	0.85



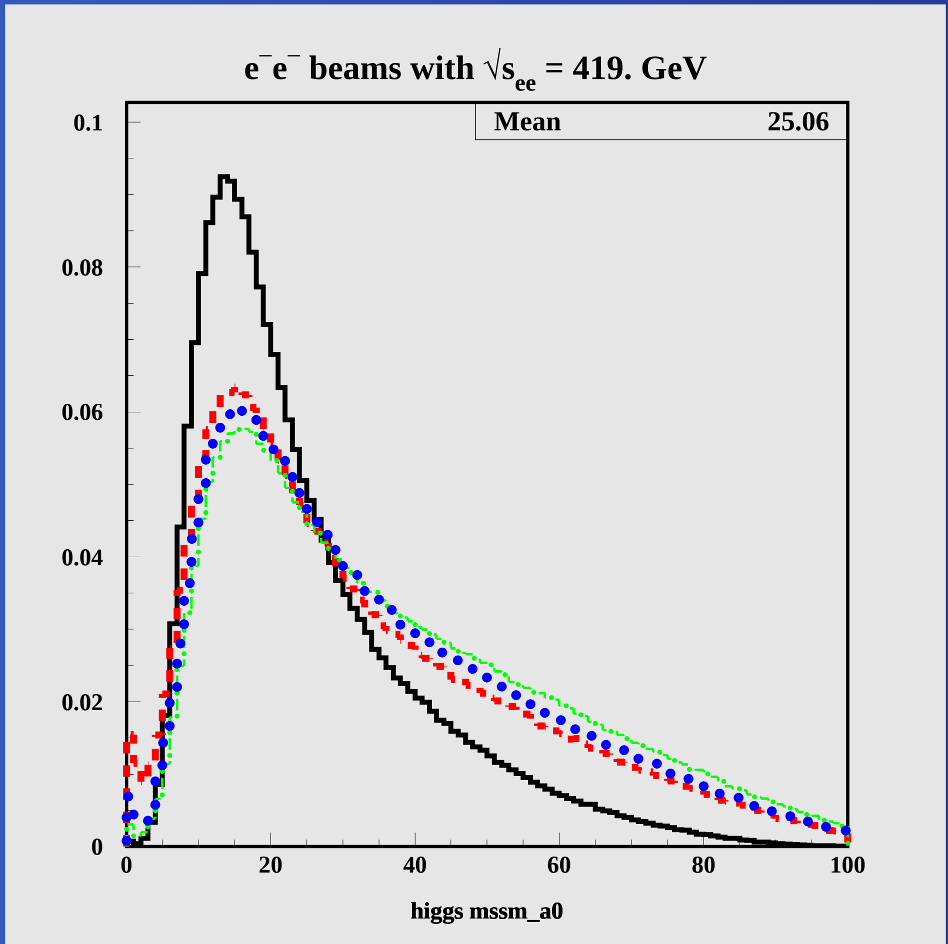
M_{jet}

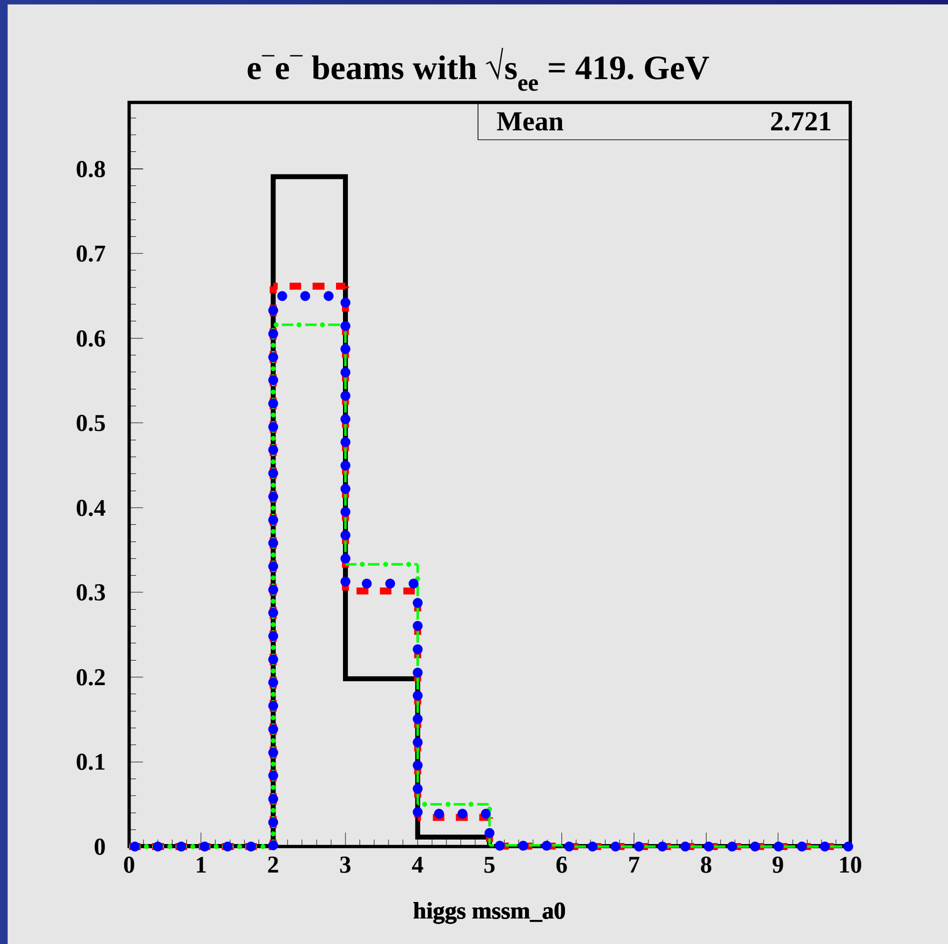


N_{jets}

Is $\theta_{\mathrm{min}}^{\mathrm{DET}} = 0.450$ optimal?

$\theta_{\mathrm{min}}^{\mathrm{DET}}$	0.315	0.450	0.555
$\cos\theta_{\mathrm{min}}^{\mathrm{DET}}$	0.95	0.90	0.85





M_{jet} N_{jets}

Conclusions

- High precision for SM higgs can be achived despite $\gamma\gamma \to$ *hadrons* pile-up events.
- Cut on p_T^{jet}/E_T discriminates OE jets.
- Background from $\gamma\gamma \to \tau\tau$ small.
  Precision of 1.8% for $\Gamma(h \to \gamma\gamma)\mathrm{Br}(h \to b\bar{b})$ at $M_h = 120$ GeV.

Plans:

- Check $\theta_{\text{min}}^{\text{DET}} > 0.555$
- Background $\gamma\gamma \to qq\ (q = u, d, s)$
- Background $\gamma\gamma \to WW$