Measurement of $BR(H \to \gamma\gamma)$ via $Z \to q\bar{q}$ channel in e^+e^- colliders at 250 GeV

Yitian Sun

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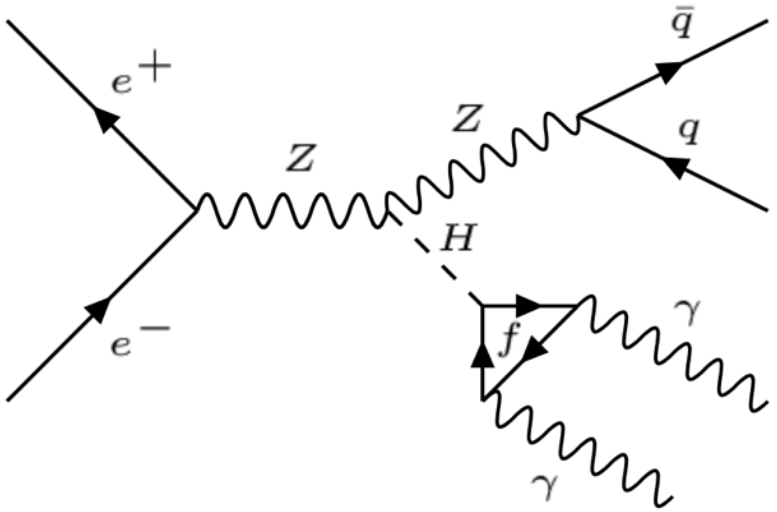
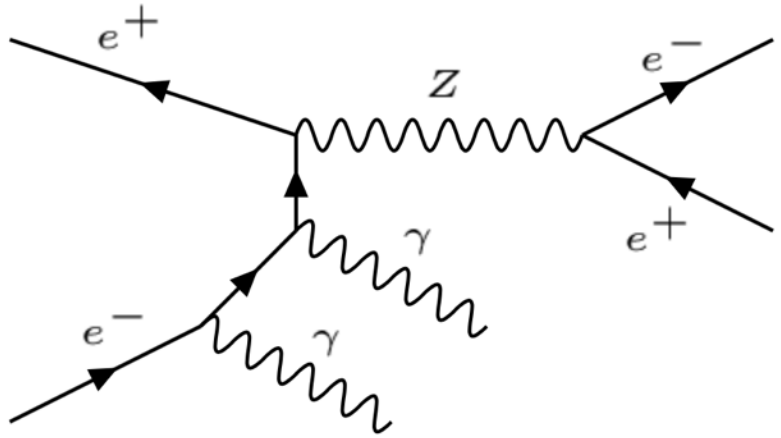
I. Introduction.

- $e^+e^- \rightarrow ZH \rightarrow q\bar{q}\gamma\gamma$ as part of the measurement of $\mathrm{BR}(H \rightarrow \gamma\gamma)$.
- II. Signal and background.
- III. Photon recovery in the di-jet environment.
- IV. Event selection (motivation and optimization).
- V. Uncertainty of the BR measurement (Monte Carlo).
- VI. Dependence on Ecal performance and photon reconstruction.

II. Signal & Background.





event #	signal	irreducible background
$5ab^{-1}$ expect:	1633	11011914
full simulation:	40000	11300000

SM expect: BR(H-->γγ) = 0.23% at M_{Higgs} = 125 GeV.

III. Photon recovery.

General reconstruction:

single γ: ~ 90%

pair γ: ~ 81%

recon γ1 matches… ($E_{\gamma1} > E_{\gamma2}$).

recon γ2 matches…	10000 signal	γ1Truth	γ2Truth	non
	γ2Truth	80.22%	<0.01%	0.30%
	γ1Truth	<0.01%	2.30%	<0.01%
	non	8.29%	7.84%	1.05%

Good.

Good but reversed.

May caused by conversion; to save.

III. Photon recovery.

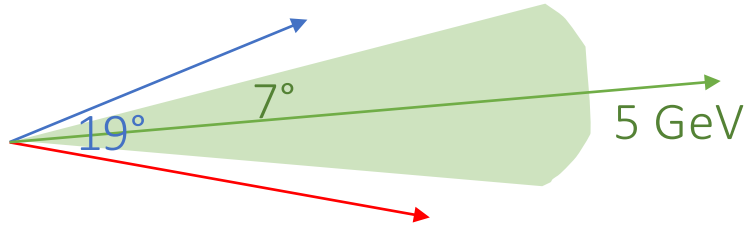
Additional reconstruction:*

for all pairs of e^+e^-:

momentum angle < 19 deg,

invariant mass < 5 GeV,

clean cone of 7 deg radius.



Efficiency boost:

γ1:	90.8%		97.1%
γ2:	90.7%	⟶	95.3%
pair:	82.5%		92.5%

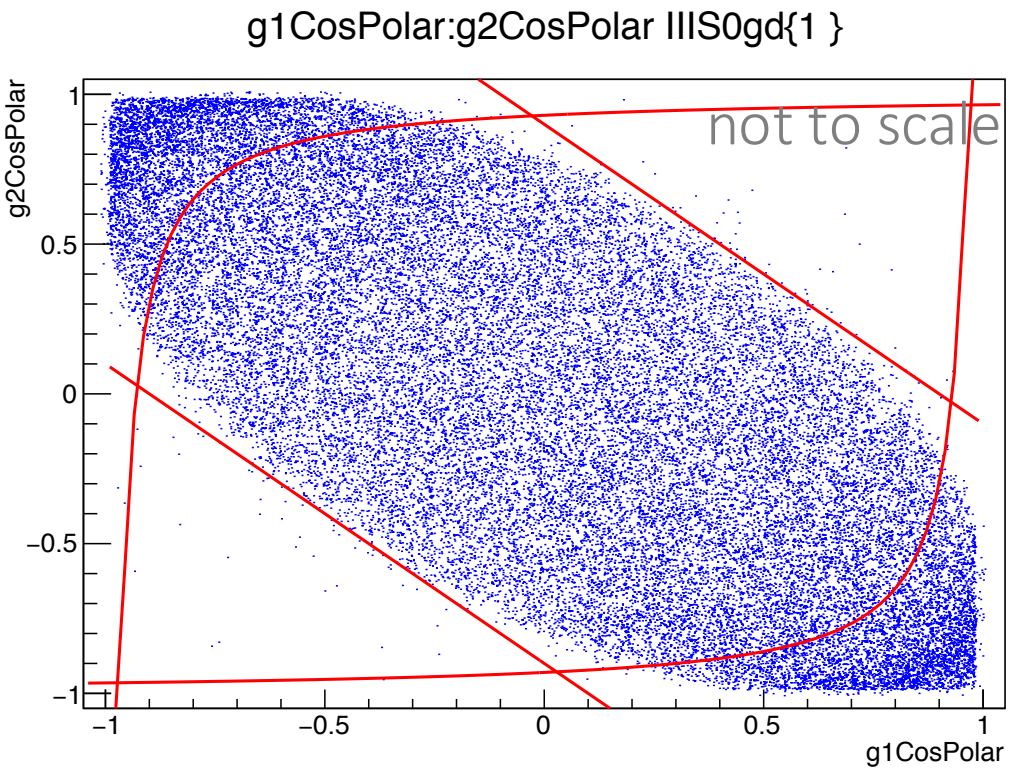
	γ1		γ2	
	recon	!recon	recon	!recon
!conv	83.58%	1.43%	83.07%	2.55%
conv	13.50%	1.50%	12.26%	2.12%
total	97.08%	2.92%	95.33%	4.67%

*Motivated by Boos, 2000.

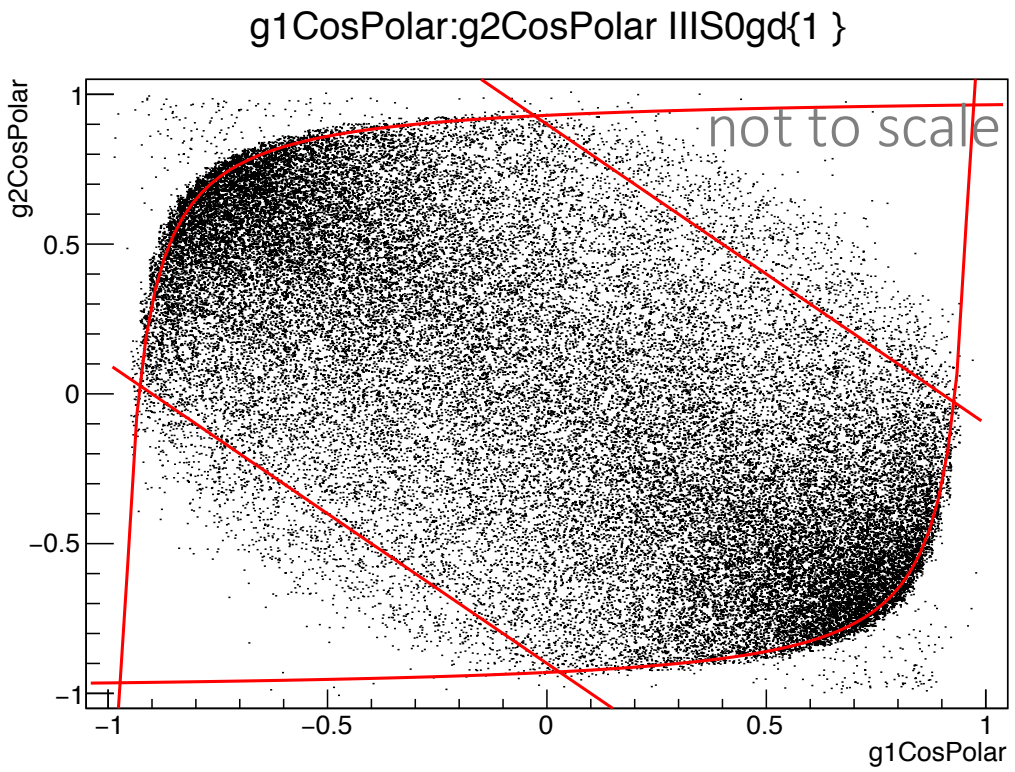
IV. Event selection.

- How to separate signal from background?
- Guideline:
  - Signal has 1 degree of freedom less than irreducible background. However, should not exploit this until fitting.
  - Differences in distribution are always related to external geometry (like z-axis).
    - Cut1 – Paraxial ISR. Direction consideration require a 2D cut.

IV. Event selection.



signal



background

Optimized w.r.t. G=S/√S+B, where S and B signal and background event counting with diphoton invariant mass in the range 125+/-3 GeV (~ signal width).

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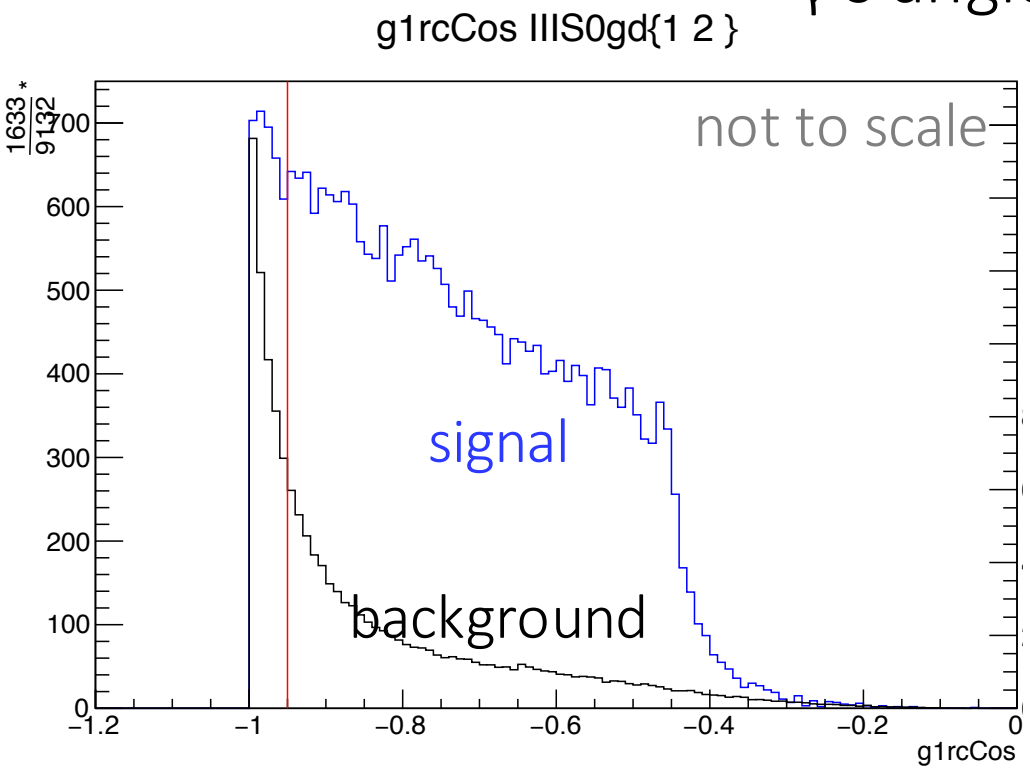
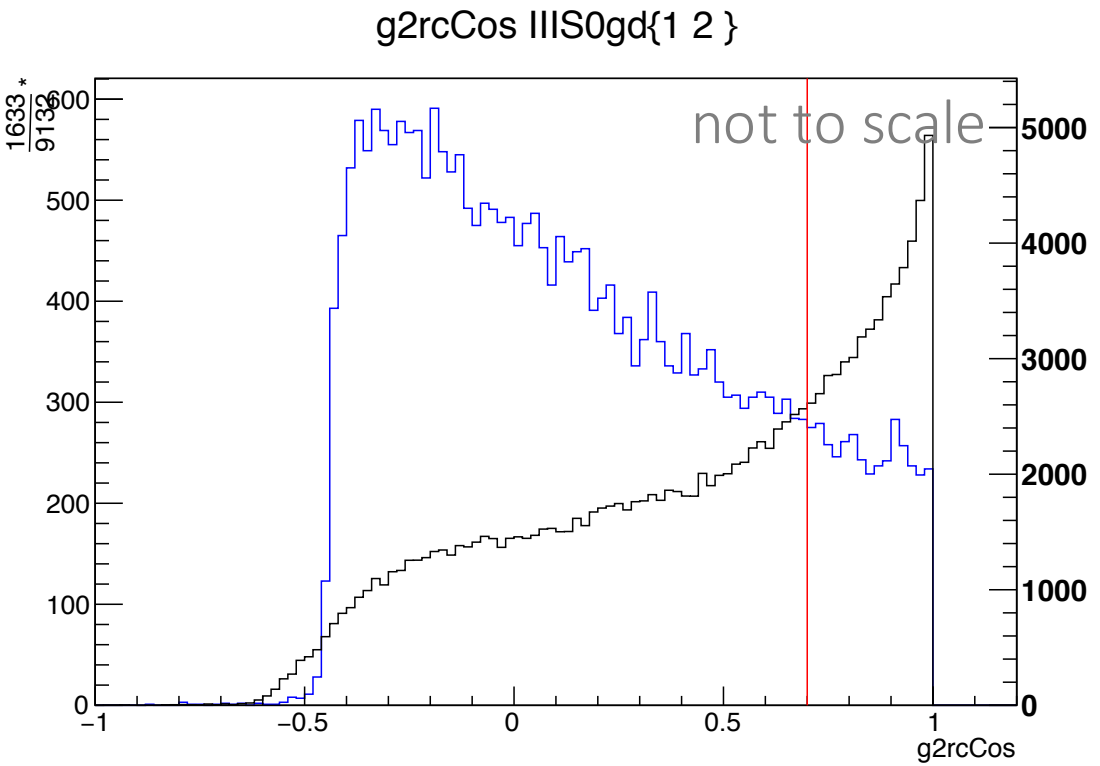
    - Cut2 - Angle with recoil momentum: further exploit the paraxial feature.

IV. Event selection.

γ's angle with recoil





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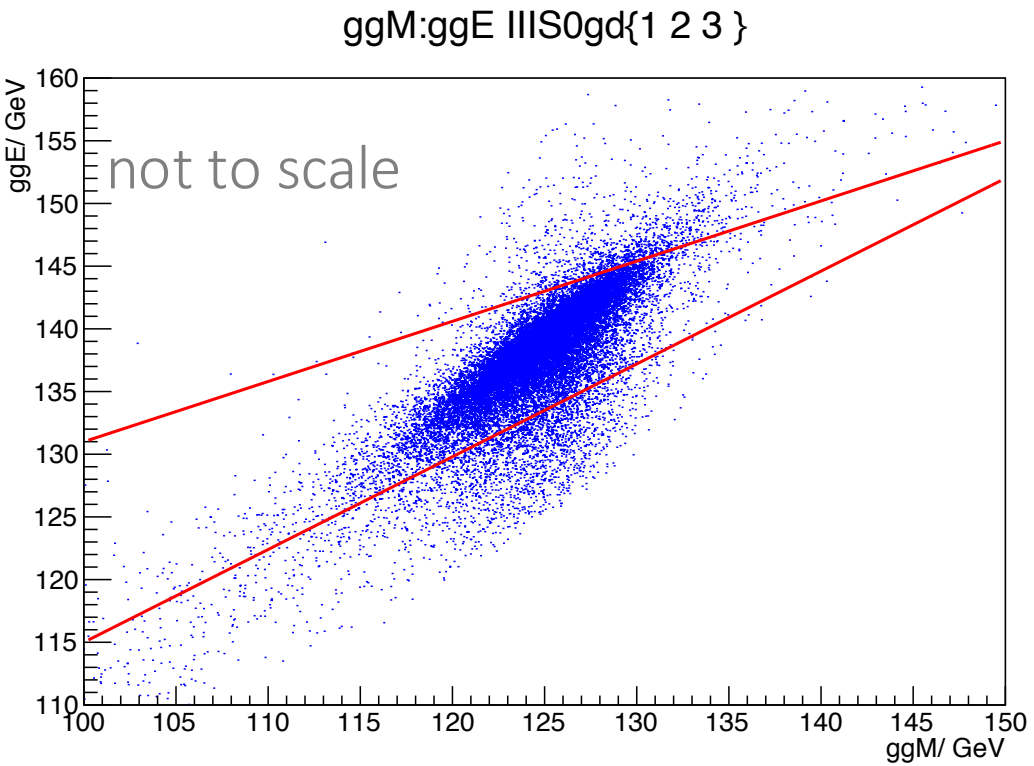

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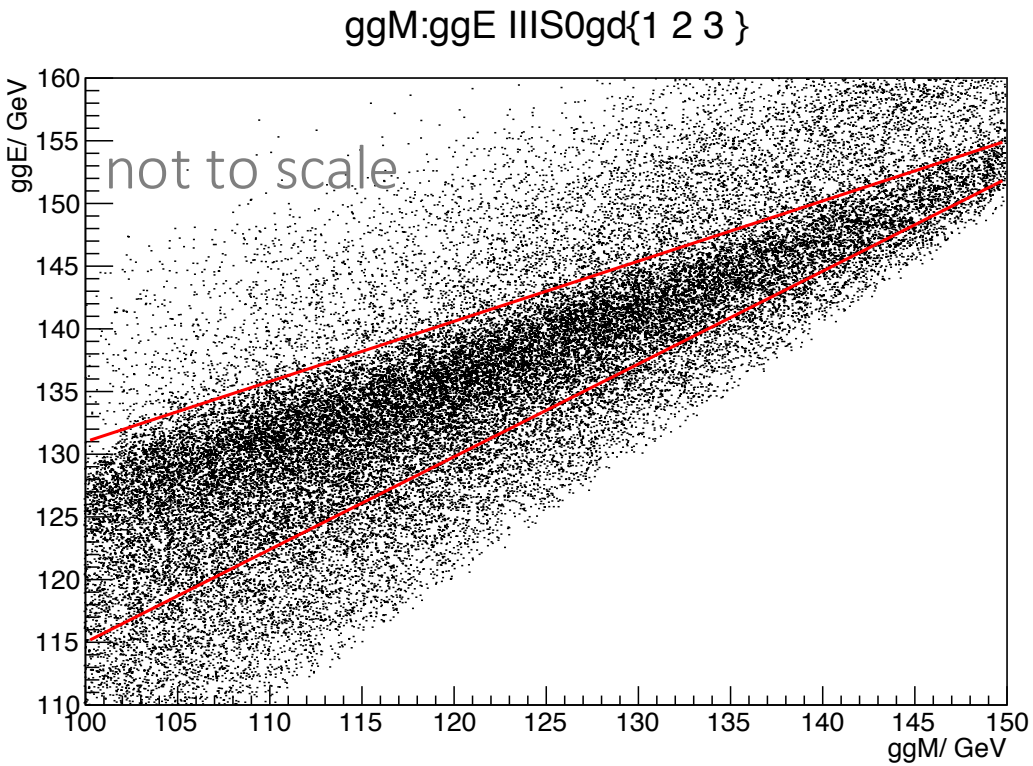

background

(1 d.o.f. less)

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- Guideline:
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  - Differences in distribution are always related to external geometry (like z-axis).
    - Cut1 – Paraxial ISR. Direction consideration require a 2D cut.
    - Cut2 - Angle with recoil momentum: further exploit the paraxial feature.
    - Cut3 - Trimming in E-M plane of di-photon system for better projection.
  - Precut simply loosen up the event selection criterion.

IV. Event selection: Cuts

- Polar angle $\cos\theta_{\gamma} < 0.99$; energy $E > 25$ GeV.
- Polar angles satisfy $(\cos\theta_{\gamma1}+1)(\cos\theta_{\gamma2}-1) < -0.07$ and $(\cos\theta_{\gamma1}-1)(\cos\theta_{\gamma2}+1) < -0.07$.
- Angle with recoil momentum

$$\cos\theta_{\gamma1,recoil} > -0.95 \text{ and } \cos\theta_{\gamma2,recoil} < 0.70.$$

- Invariant mass- Energy plane of di-photons system

$$E_{\gamma\gamma} < 0.48*M_{\gamma\gamma}+83 \text{ and } E\gamma\gamma > 0.74*M_{\gamma\gamma}+41.$$

Unit: GeV

Precut.

- Polar angle $\cos\theta_\gamma < 0.99$; energy $E > 25$ GeV.
- Polar angles satisfy $(\cos\theta_{\gamma 1}+1)(\cos\theta_{\gamma 2}-1) < -0.05$ and

$$(\cos\theta_{\gamma 1}-1)(\cos\theta_{\gamma 2}+1) < -0.05.$$

- Invariant mass of di-photons system

$$100\ \text{GeV} < M_{\gamma\gamma} < 160\ \text{GeV}.$$

Background reduced to 326503 expected (from 11011914).
Signal not significantly affected.

IV. Event selection: Efficiency.

122 GeV < $M_{\gamma\gamma}$ < 128 GeV		UnCut	Cut0	Cut1	Cut2	Cut3
SIGNAL	Event:	24078	23909	18489	16027	14238
	Expect:	982	976	754	654	581
	AccumuEff:	100%	99.30%	76.79%	66.56%	59.13%
	StageEff:	100%	99.30%	77.33%	86.68%	88.84%
BACK-GROUND*	Event:	335045	17724	16402	9897	6339
	Expect:	326503	17272	15983	9644	6177
	AccumuEff:	100%	5.29%	4.90%	2.95%	1.89%
	StageEff:	100%	5.29%	92.54%	60.34%	64.05%
113 GeV < $M_{\gamma\gamma}$ < 150 GeV						
SIGNAL	Event:	37154	36540	27597	23821	20296
	Expect:	1516	1491	1126	972	828
	AccumuEff:	100%	98.35%	74.28%	64.11%	54.63%
	StageEff:	100%	98.35%	75.53%	86.32%	85.20%
BACK-GROUND*	Event:	335045	92362	85041	51049	29900
	Expect:	326503	90007	82872	49747	29137
	AccumuEff:	100%	27.57%	25.38%	15.24%	8.92%
	StageEff:	100%	27.57%	92.07%	60.03%	58.57%

Near signal.

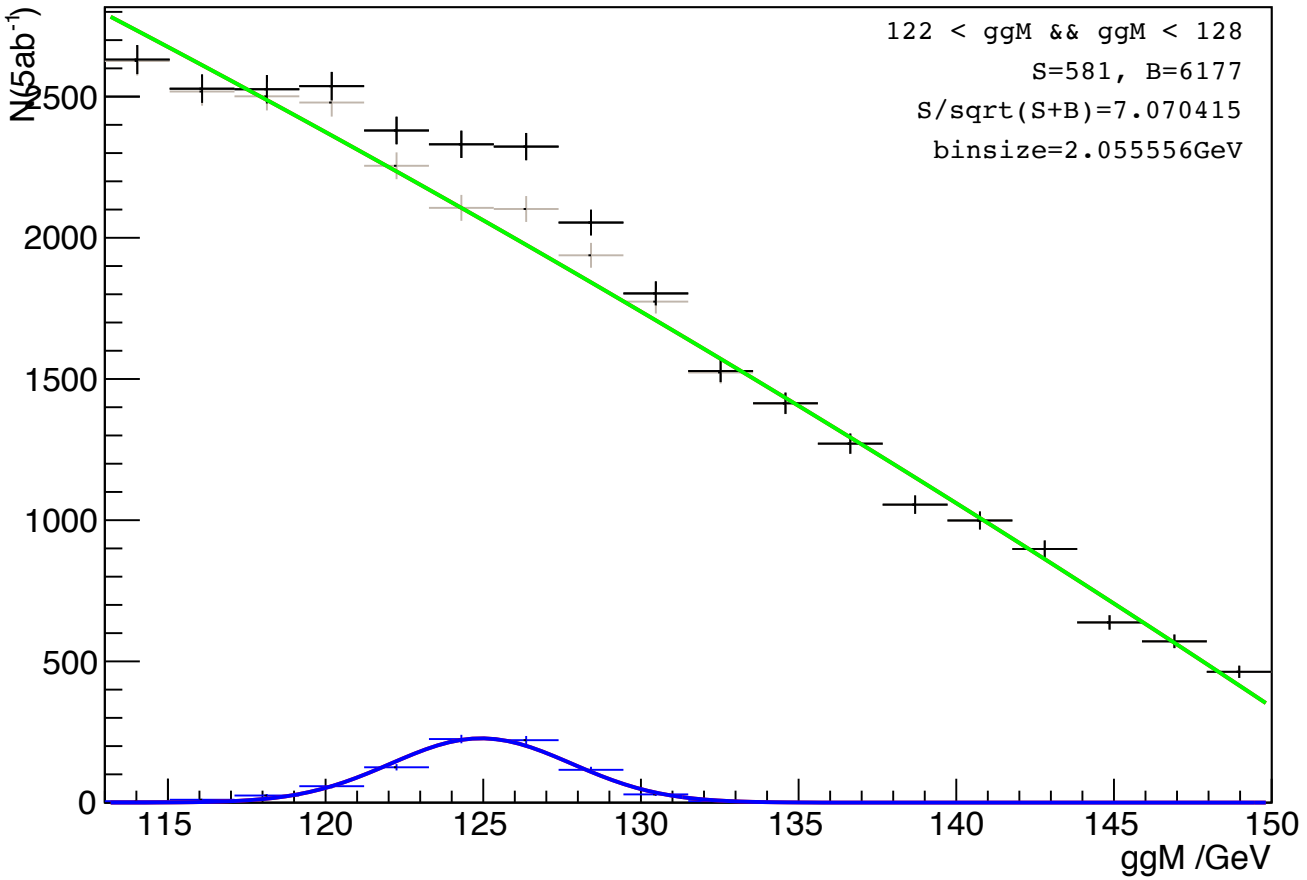
$G = S/\sqrt{S+B} = 7.07$

Fit region.

* background # is after precut

V. Uncertainty of BR measurement

Di-photon invariant mass (after selection).



Signal and background: fitted independently to perform Monte Carlo to evaluate uncertainty.

Fit region:
113 GeV - 150 GeV, 18 bins.

Signal: gaussian (signal width >> Higgs width).

Background: quadratic.

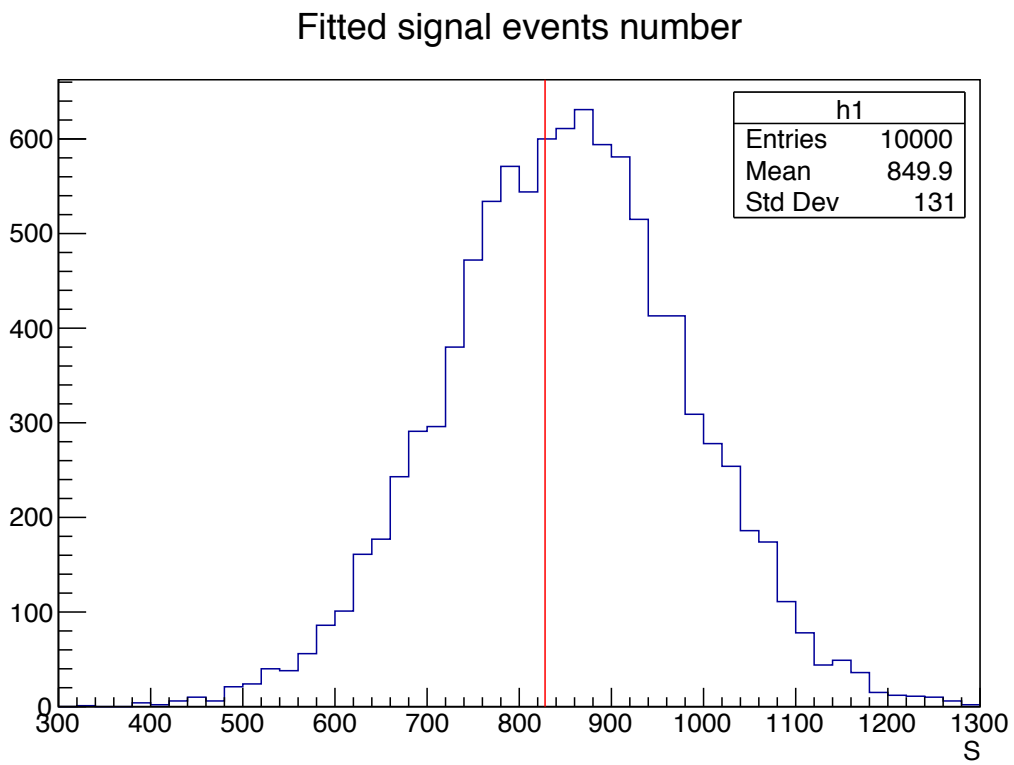
V. Uncertainty: MC results

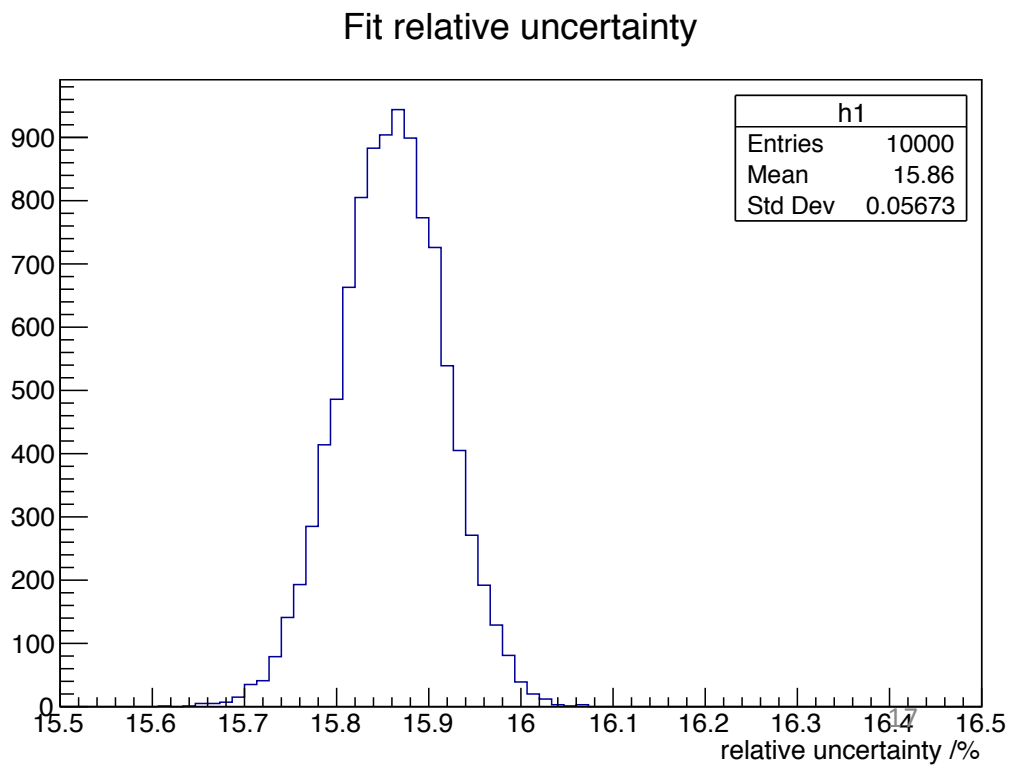
for current photon recovery efficiency of 92.5% and signal width of 2.9 GeV:

Signal count S Truth = 828. Fitted S = 850 +/- 131 (15.4%).

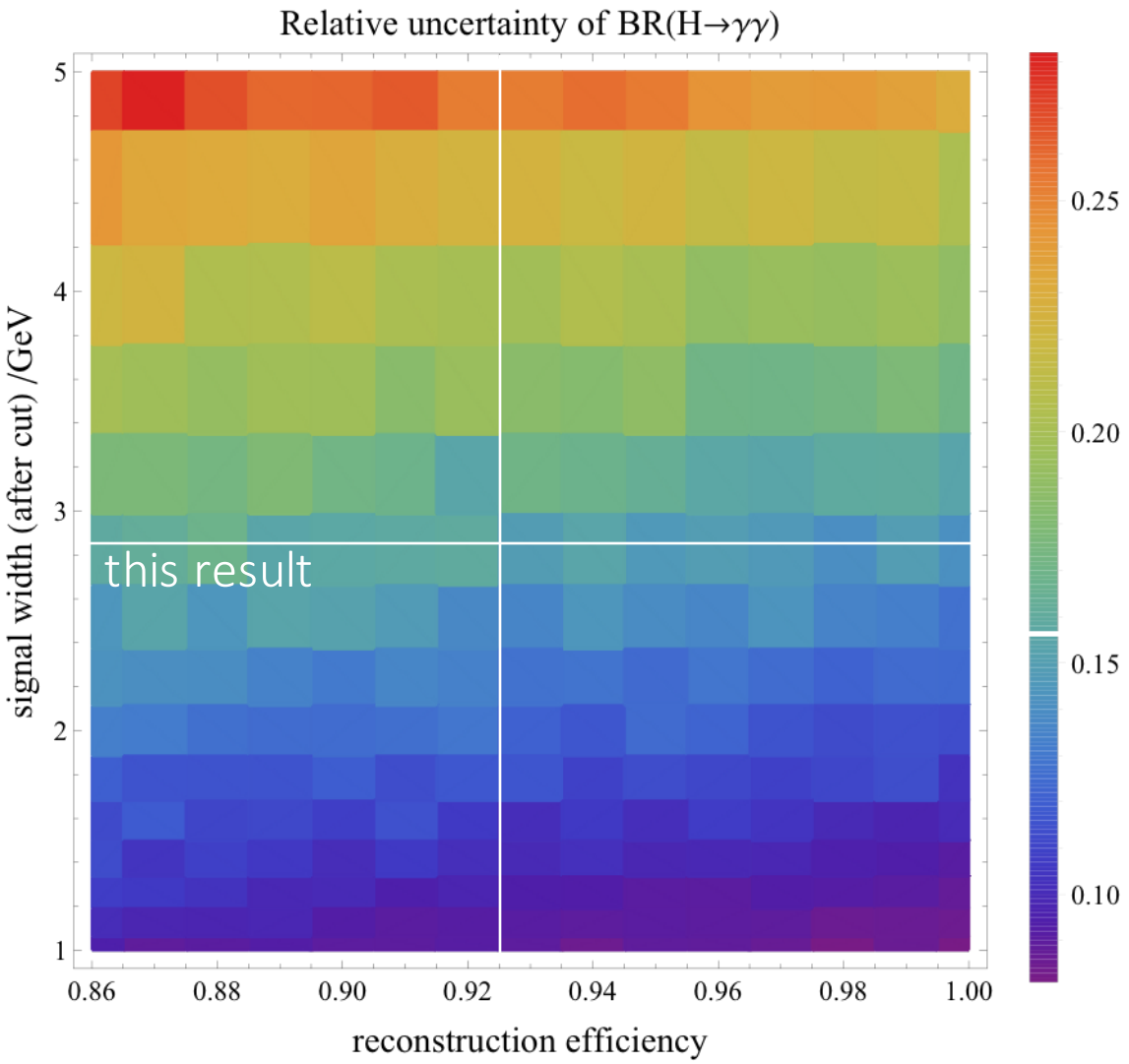
Fit program reported uncertainty mean: 15.86% +/- 0.06% (0.4%).

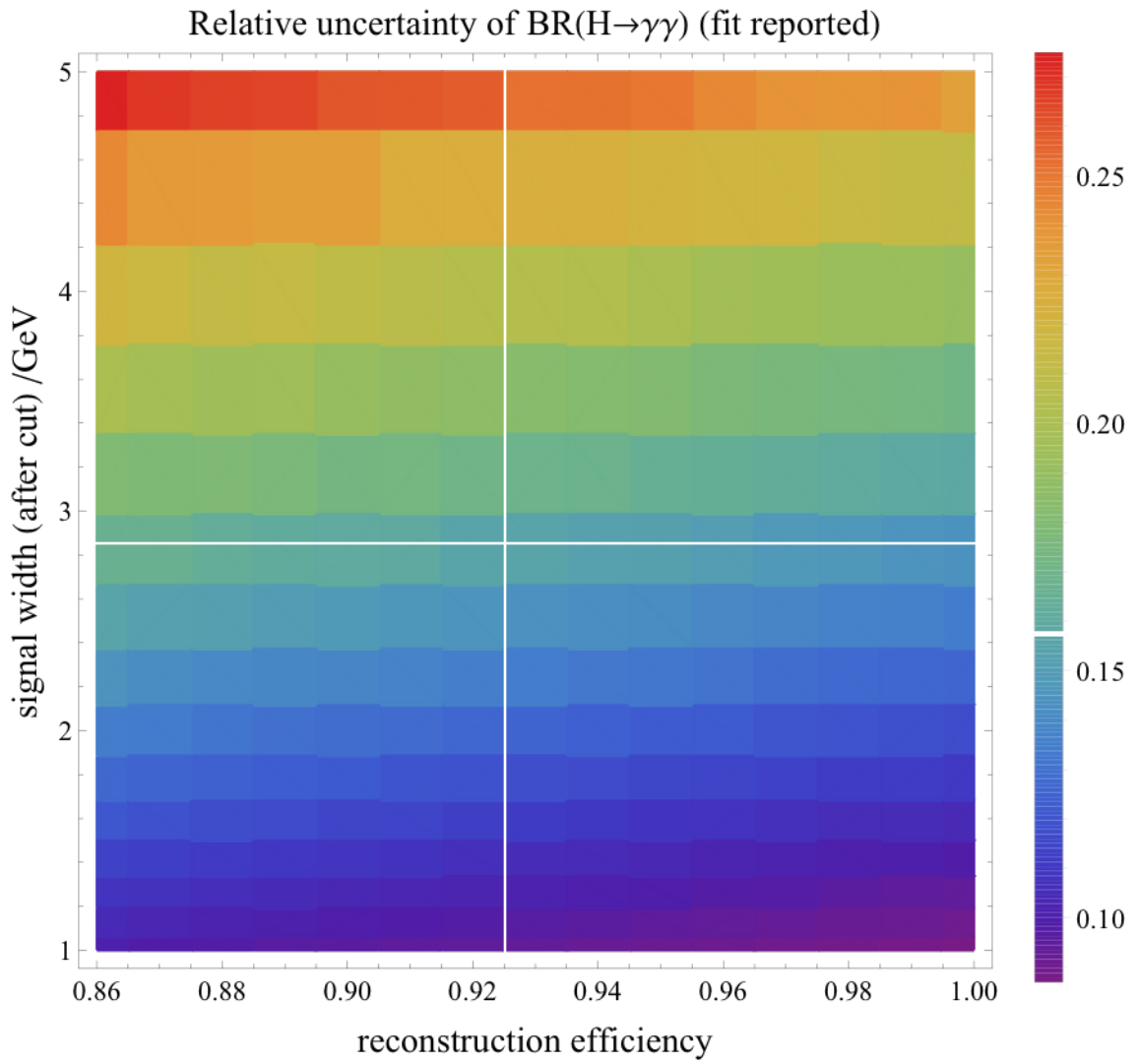
systematic shift (2.7%) ⊕ statistical uncertainty (15.4%) ≈ 15.6%





VI. Dependence on Ecal and photon recovery





Agrees well apart from small uniform shift (shown before)

Conclusion.

- Motivated and optimized photon recovery algorithm and event selection for this specific channel.
- Uncertainty of BR(H-->γγ) = 15.6%.
- Dependence on Ecal performace and photon recovery as expected.