ATLAS実験でのVector Boson Fusion $H \rightarrow \gamma\gamma$ におけるヒッグス粒子探索

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Introduction

- ヒッグスは質量が軽い（Mh<140GeV）

場合、２つのphoton に崩壊する。

- H→ γγ channelは discovery channel として有望なchannelの１つで、ヒッグス粒子がspin 0の粒子であることを示唆する。

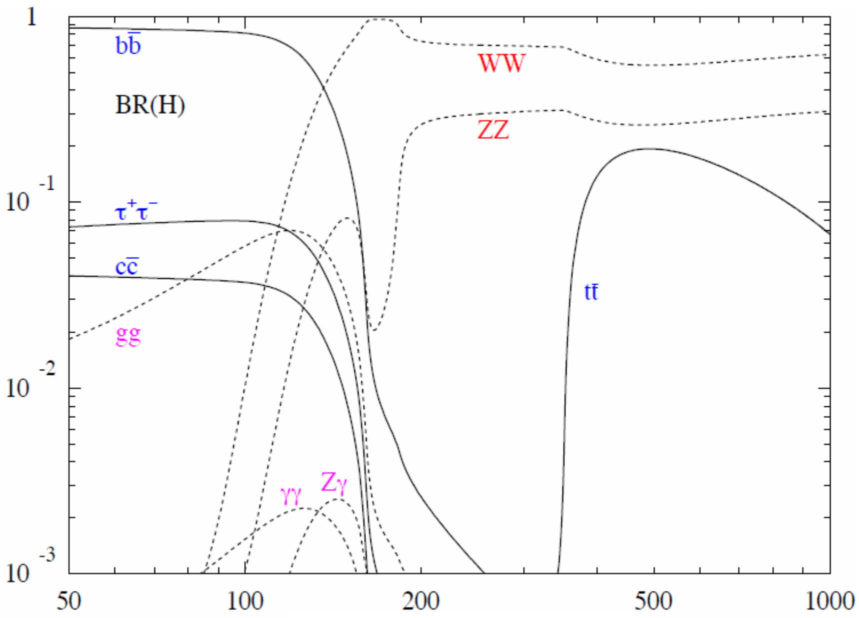
- H→ γγ channel でのヒッグスの探索は2photonのinvariant mass

$$M^2 = 2E_{T1}E_{T2} (\cosh(\delta \eta) - \cos(\delta \phi))$$

を使って行う。

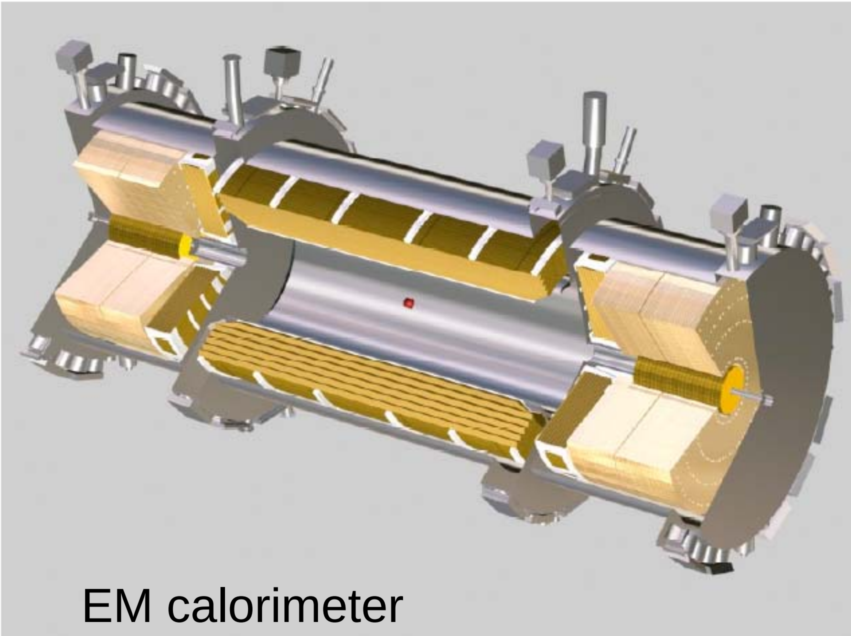
→Photonのenergy(E_{T1},E_{T2}) と位置($\delta \eta$, $\delta \phi$)はEM calorimeterで測定する。

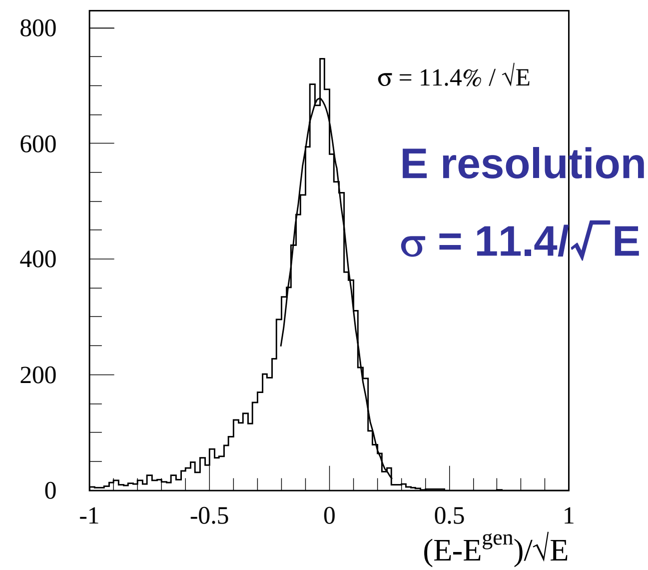
Branching ratio of Higgs

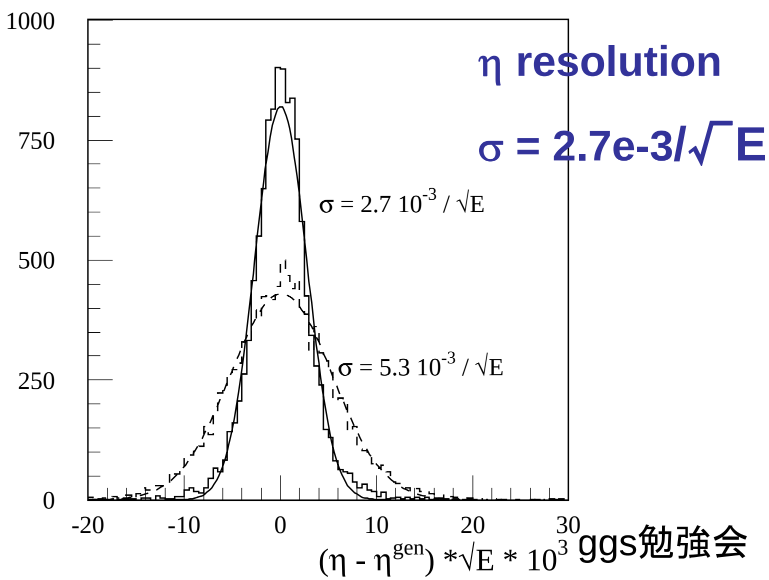


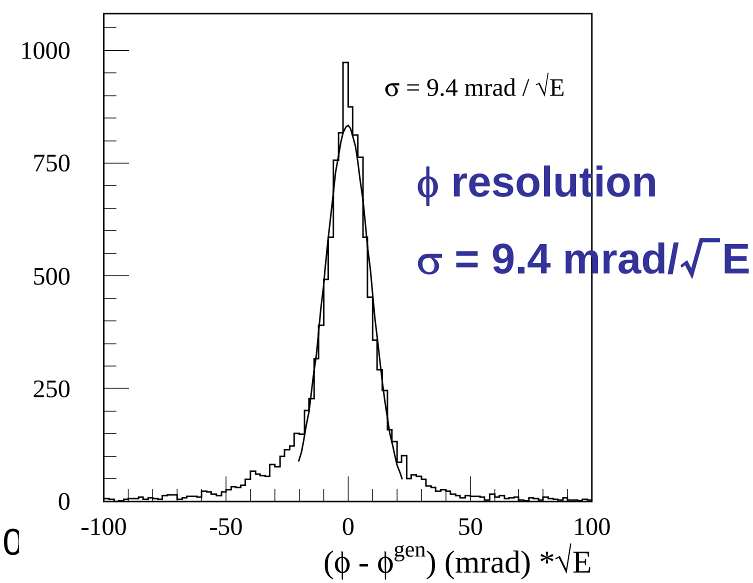
Higgs の質量

EM calorimeter



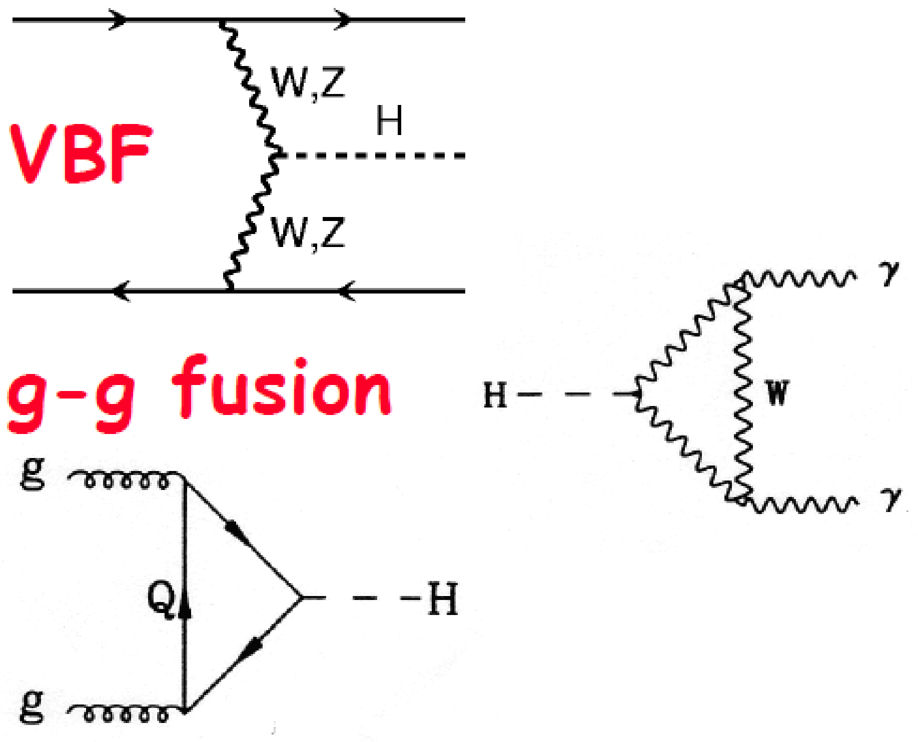






Signal sample

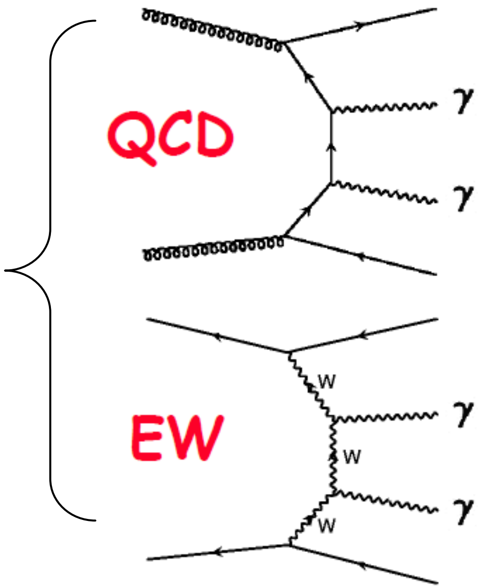
- Vector Boson Fusion : PYTHIA6.221 + PHOTOS
- g-g Fusion : PYTHIA6.221 + PHOTOS



Background sample　with real photons

終状態にreal photonを持つ

1. $\gamma\gamma$JJ(EW)　: CompHEP + PYTHIA6.221
2. $\gamma\gamma$JJ(QCD) : ALPGEN + PYTHIA6.221



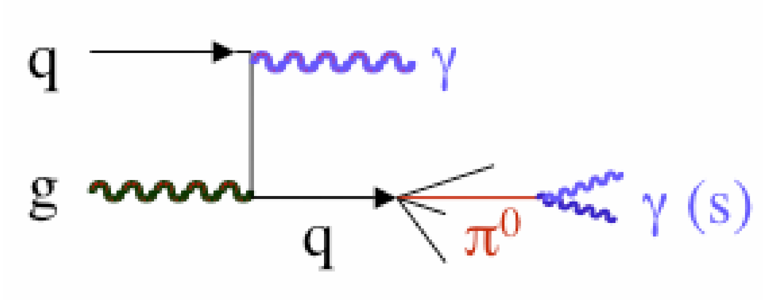
Background with fake photon(s)

“Fake photon”

Jet中のπ^0がエネルギーのほとんどを持つ場合、

→他のハドロンのactivityがsoft。 π^0 は$\gamma\gamma$に崩壊する

→Jet がγとIDされてしまう。

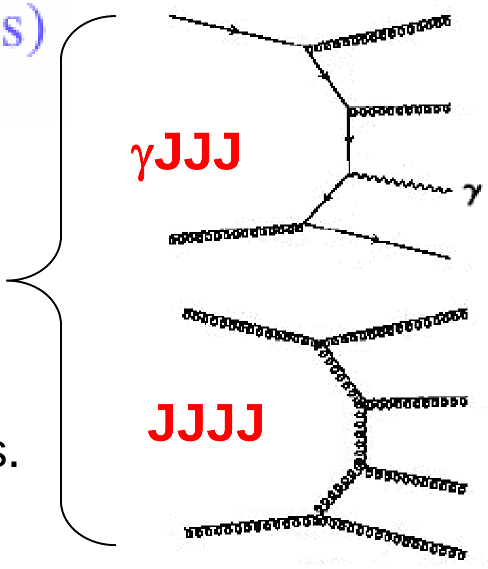


BG sample with fake photon

1. γJJJ : ALPGEN + PYTHIA6.221
2. JJJJ : ALPGEN + PYTHIA6.221

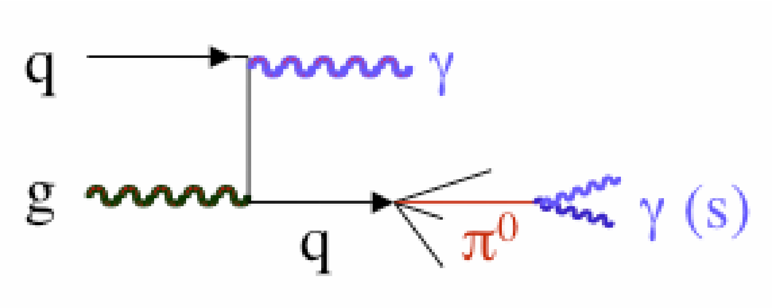
PDF : CTEQ5L

PT ordering is applied to avoid the double counts.



Fake photon rate of Jet

quark Jet (gq →γq) を使って、 full simulationでstudy



Jet rejection = 1/ fake rate

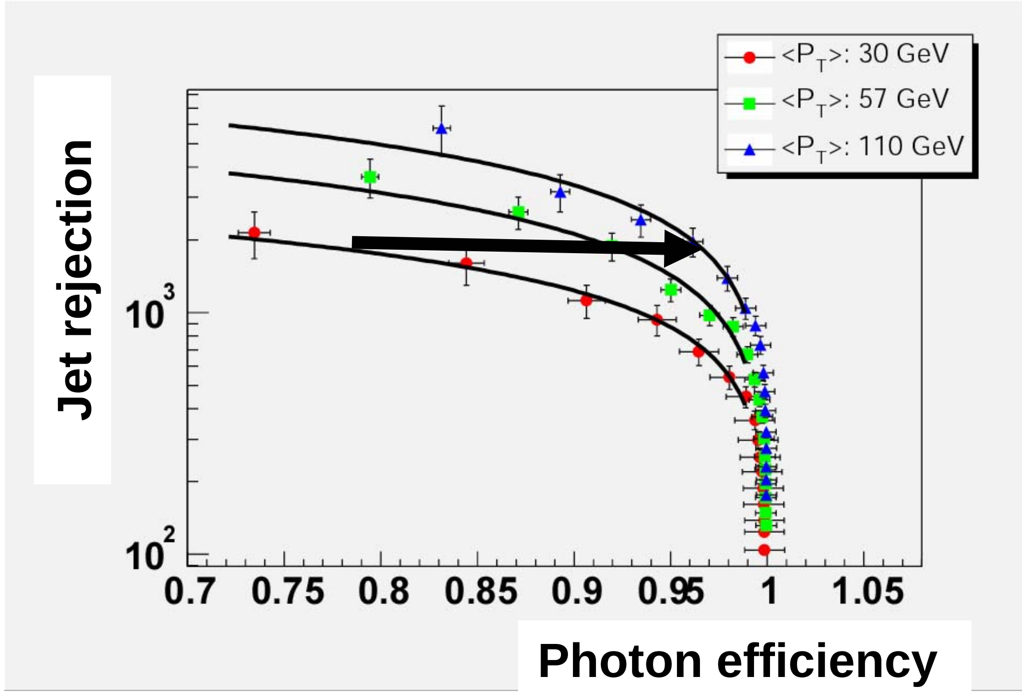
Real Photonの定義

Cone algorithm: R=0.4, Et>15GeV

→ Photon efficiencyを計算

-- Jet のP_TによらずJet rejection をfix。

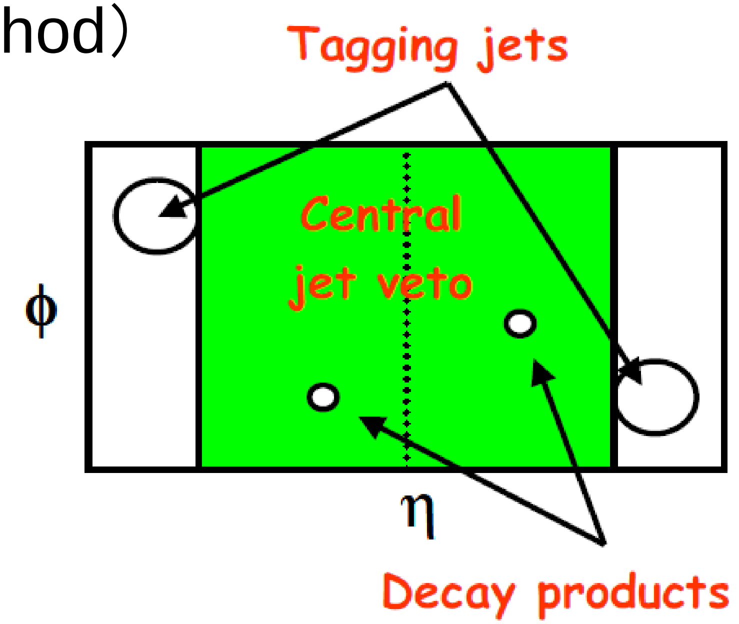
-- photon efficiency をphotonのP_Tの関数として、correction として用いる。

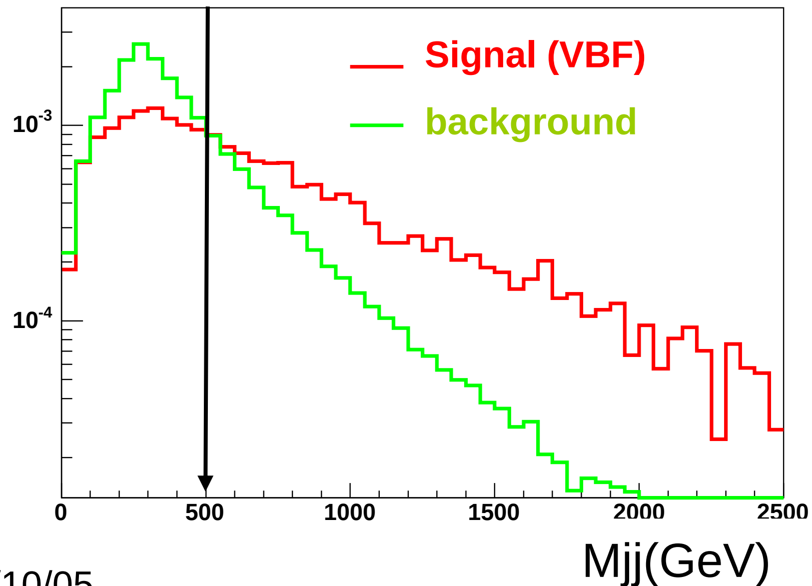


Selection Criteria（2tagging jets method）

1. Two forward tagging jets
   -- one jet in each hemisphere
   -- $P_T(jet_1) > 40GeV, P_T(jet_2) > 20GeV$
   -- $|\Delta\eta_{jj}| > 3.6$
   -- $\Delta R_{jj} > 0.7$ ($\Delta R_{jj}^2 = \Delta\phi^2 + \Delta\eta^2$)
   -- $M_{jj} > 500GeV$

2. Two Gamma selection
   -- $N\gamma = 2$, $|\eta_\gamma| < 2.5$
   -- $P_T(\gamma_1) > 50GeV$, $P_T(\gamma_2) > 25GeV$
   -- gamma should exist between two forward jets in η-ϕ plane.
   ($\Delta R(jet,\gamma) > 0.7$)



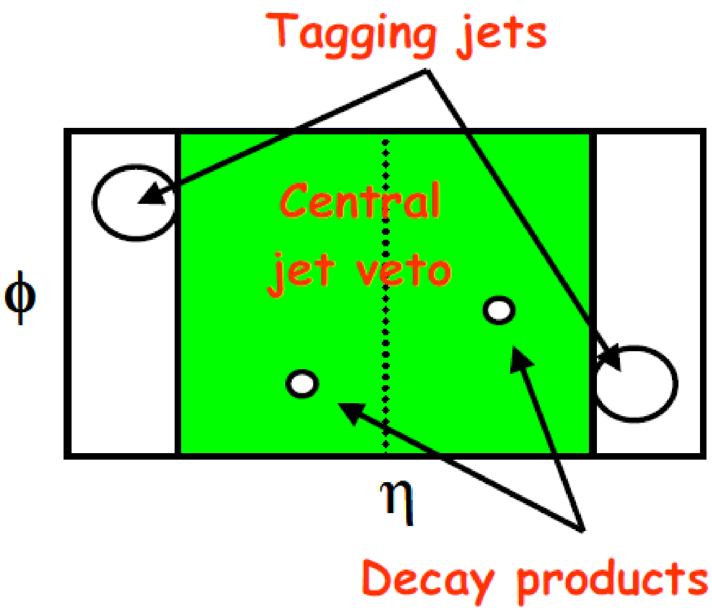


Selection criteria (2)

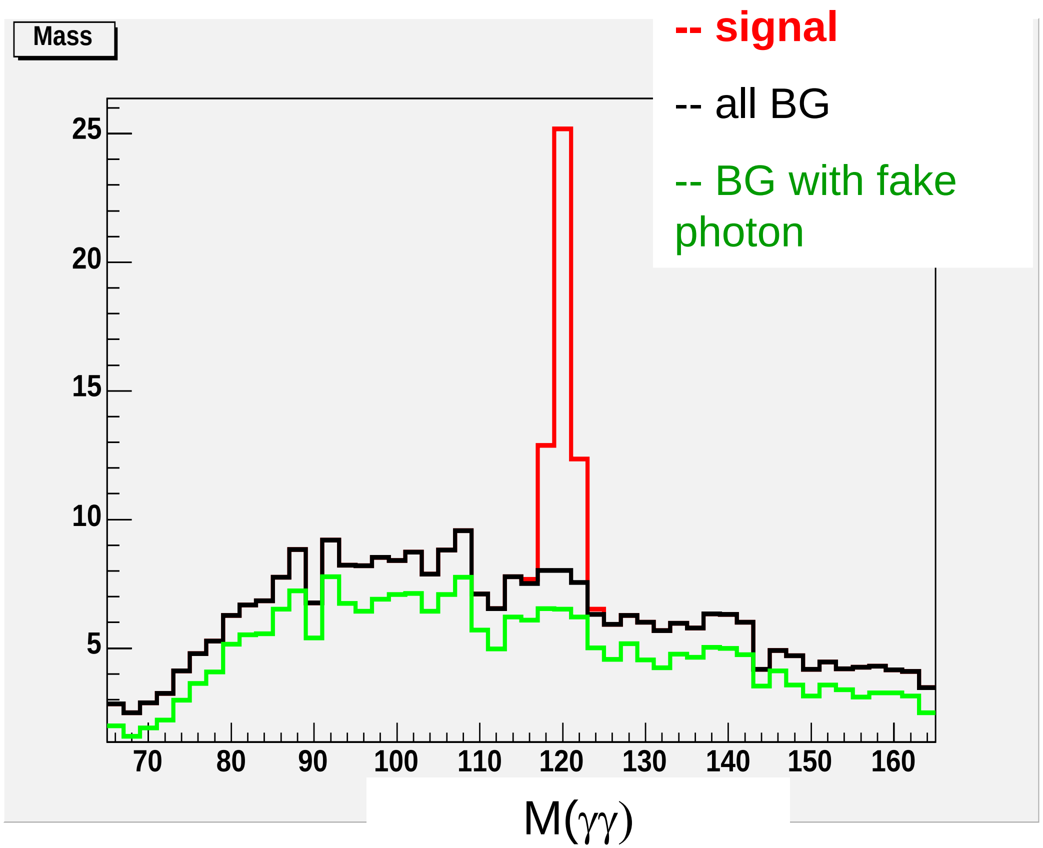
- Additional cuts for no colour exchange.
  -- Central jet veto
  (No jet with P_T (jet)>20GeV in the central region)

  -- apply inefficiency of 3.7% due to minimum bias jets

- Higgs mass window requirement
  -- 118 < Mh < 122GeV @ Mh = 120GeV



Results (Mh=120GeV,L = 30fb^{-1})



L = 30 fb^{-1}	# of events in the mass window
VBF	21.6
ggF	3.0
γγJJ (EW)	3.0
γγJJ (QCD)	3.9
γJJJ	5.4
JJJJ	7.5

Mh = 120GeV, L = 30 fb $^{-1}$

S =24.9, B = 19.9

Significance(poisson) = 4.6

"2 jets tagging analysis" is promising !!

BG with fake photonが多い

Improvement

- < gluon species >

  Full simulation でのstudyよりgluon 起源のJetのJet rejectionは、quark 起源のJetのJet rejection に比べて4倍大きい。
  (gluon jet の方が fake photon になりにくい。)

	Jet rejection
gluon 起源Jet	7800 ± 930
Quark 起源Jet	2021 ± 240

4倍

→ according to rough estimation by
Fast simulation, γ JJJ and JJJJ decreased
to 25 % and 4 %, respectively.

significance 4.6 → 6.2 @ Mh = 120GeV, L = 30 fb^{-1}

Systematic uncertainty

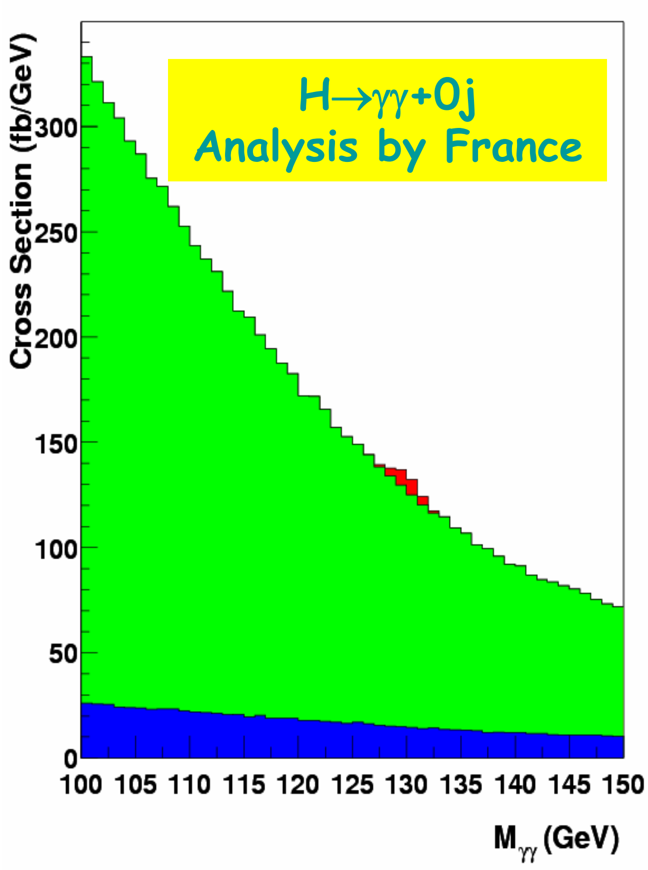
- Systematic uncertainty from renormalisation scale.

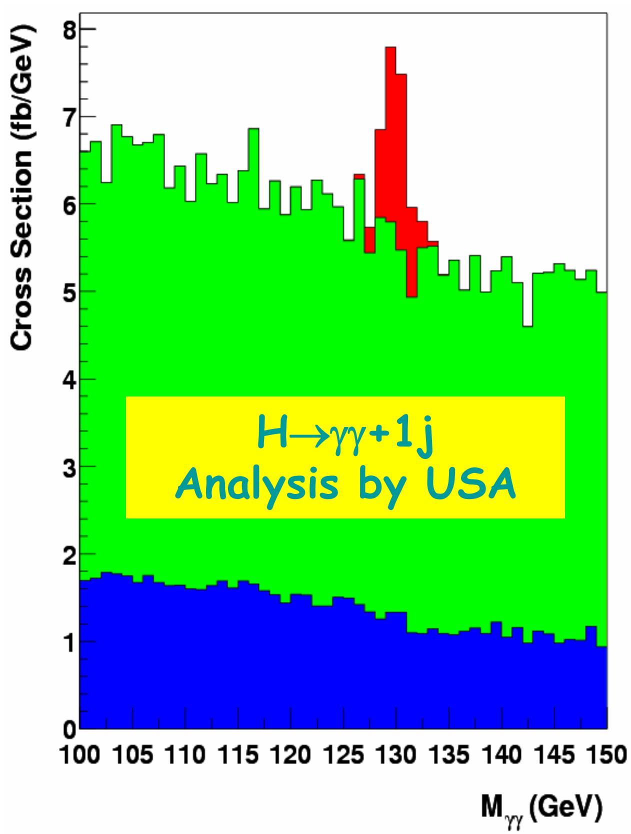
→ By changing renormalisation scale <P_T> to min. P_T cross section of γJJJ and JJJJ processes increase by factor 1.7 and 1.9, respectively.

→ Signal significance 4.6 → 4.0 @ Mh = 120GeV,L = 30fb^{-1}

→ Renormalisation uncertainty is acceptable.

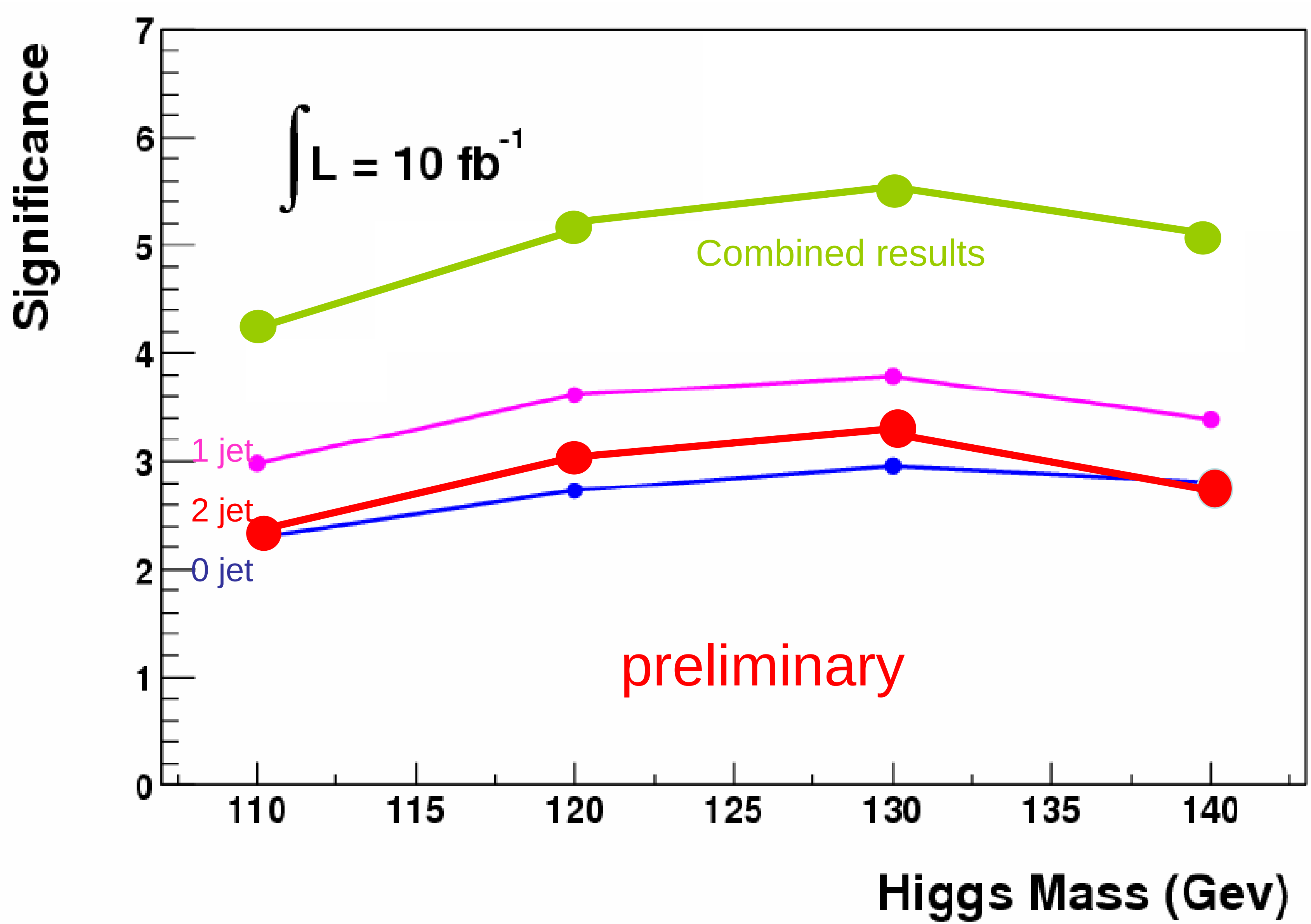
Other analyses on H→γγ @ATLAS





-- 0 jet analysis (by France)
→主にgg Fusion でsignalも多いが
バックグラウンドが非常に多い

-- 1 jet analysis (by USA)
→ gg fusion とVBFの両方
→ 統計が多い


Significance
7
6
5
4
3
2
1
0
$\int L = 10\ fb^{-1}$
Combined results
1 jet
2 jet
0 jet
preliminary
110
115
120
125
130
135
140
Higgs Mass (Gev)

summary

-- Fast simulationを用いて、VBF H→γγチャンネルにおけるヒッグス粒子探索の研究をおこなった。

-- L =10fb-1のデータ量でMh＝120GeVの場合、combined analysis で5σでヒッグス粒子を発見することができる。

To do

１. Full simulationで解析を行う

2. Full simulation でFake photonのstudyを行う。
(gluon Jet, quark Jet それぞれのrejection factor)
→具体的にはgamma identificationをしっかりstudyをして
background with fake photonを減らす。

3. Estimate systematic uncertainty from PS scale/ fragmentation on full simulation.

4. 40%のphotonがTRTでconvertしてしまう。
→ このphotonをすくうために、gammaのisolation