



The Compact Muon Solenoid Experiment

Analysis Note

The content of this note is intended for CMS internal use and distribution only



Nov 20, 2008[↵]

Search for an intermediate mass SM Higgs boson
at CMS using Vector Boson Fusion

$$H \rightarrow ZZ \rightarrow 2\mu 2\nu_{\tau}$$

Data sample

Signal sample generated by Pythia

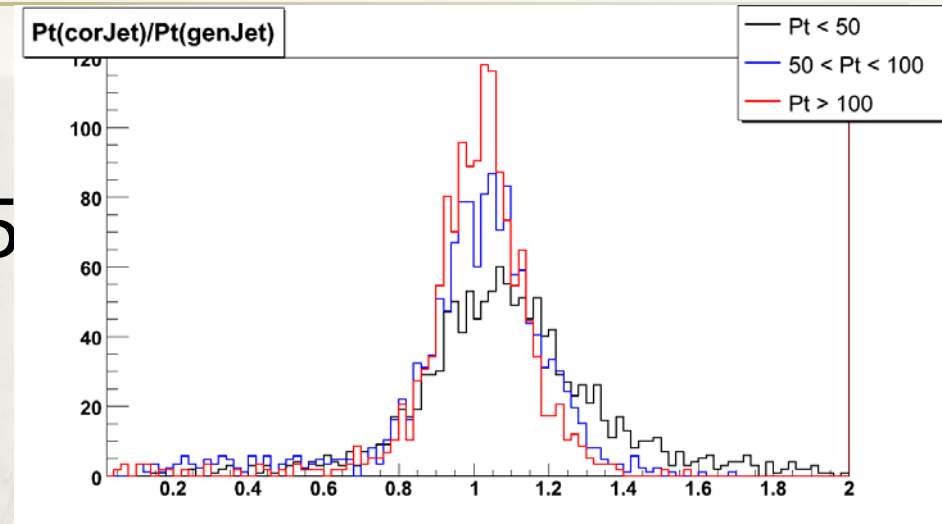
Higgs mass is set to be 200 GeV

All background samples come from official production

Sample [↕]	Total Events [↕]	Cross Section [↕]	Integrated Luminosity [↕]	Dataset Name for official sample [↕]
<i>Signal</i> [↕]	2.6k [↕]	8.90 fb [↕]	290 fb ⁻¹ [↕]	[↕]
<i>tt + jets</i> [↕]	10M [↕]	694 pb [↕]	15 fb ⁻¹ [↕]	ttnj-madgraph [↕]
<i>Z + 1j</i> [↕]	950k [↕]	940 pb [↕]	1.0 fb ⁻¹ [↕]	Z1j-0ptw100-alpgen [↕]
<i>Z + 2j</i> [↕]	320k [↕]	298 pb [↕]	1.1 fb ⁻¹ [↕]	Z2j-0ptw100-alpgen, Z2j-100ptw300alpgen [↕]
<i>Z + 3j</i> [↕]	73k [↕]	68 pb [↕]	1.1 fb ⁻¹ [↕]	Z3j-0ptw100-alpgen [↕]
<i>ZZ + 1j</i> [↕]	5.3k [↕]	637 fb [↕]	8.3 fb ⁻¹ [↕]	zz1j-alpgen [↕]
<i>ZZ + 2j</i> [↕]	7.3k [↕]	247 fb [↕]	30 fb ⁻¹ [↕]	zz2j-alpgen [↕]
<i>ZZ + 3j</i> [↕]	5.4k [↕]	239 fb [↕]	23 fb ⁻¹ [↕]	zz3j-alpgen [↕]
<i>WW + 2j</i> [↕]	5.9k [↕]	4.0 pb [↕]	1.5 fb ⁻¹ [↕]	ww2j-alpgen [↕]

Physics Objects

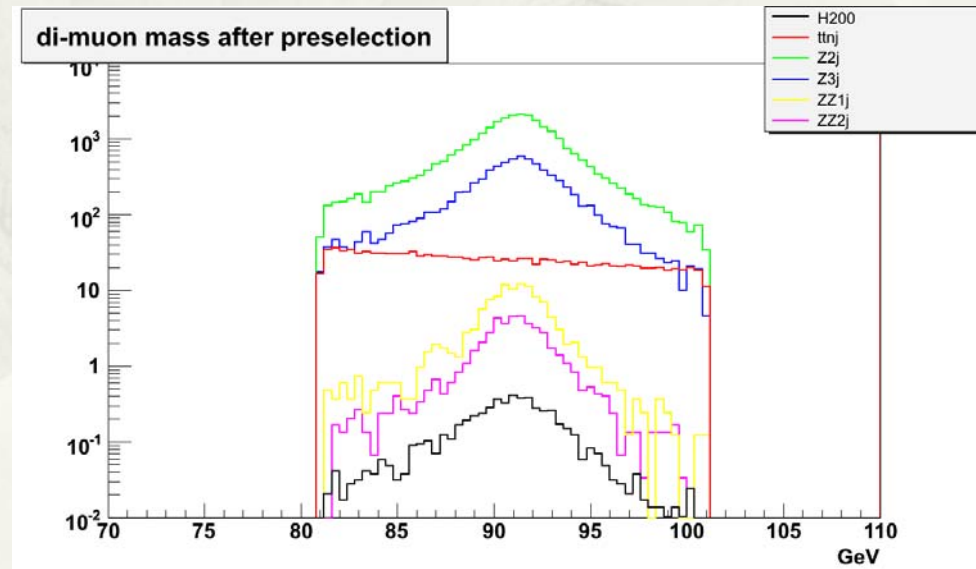
- * Global muons
- * IC Jet with cone 0.5
 - * L2+L3 corrections
- * MET
 - * JES correction + mu correction



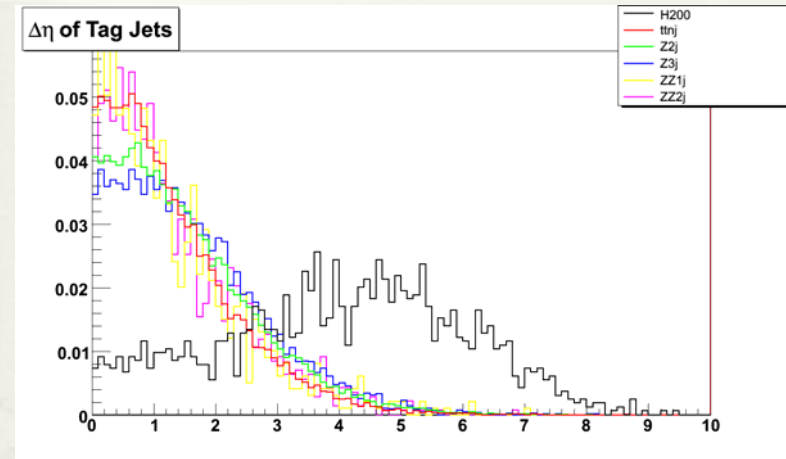
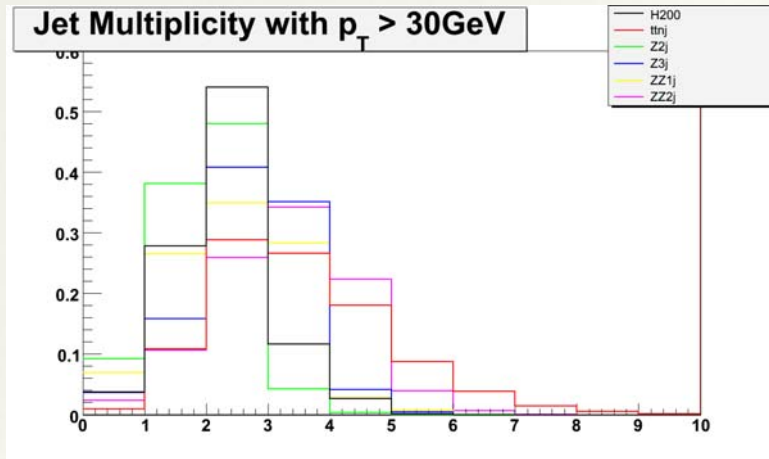
HLT, skimming & Preselection

- * **High Level Trigger:** 14TeV physics run at $10^{32}\text{cm}^{-2}\text{s}^{-1}$ luminosity
- * **Skim:** at least two muons of any sign with $p_T > 5\text{GeV}$
- * **Preselect:**
 - exactly two muons with opposite charge and $p_T > 5\text{ GeV}$.
 - $|\eta| < 2.4$.
 - $81\text{ GeV} < m_{\mu\mu} < 101\text{ GeV}$

High level trigger	Thresholds (GeV)
1MuonIso	11
1MuonNonIso	16
2MuonNonIso	(3,3)
XMuonJets	(7,40)



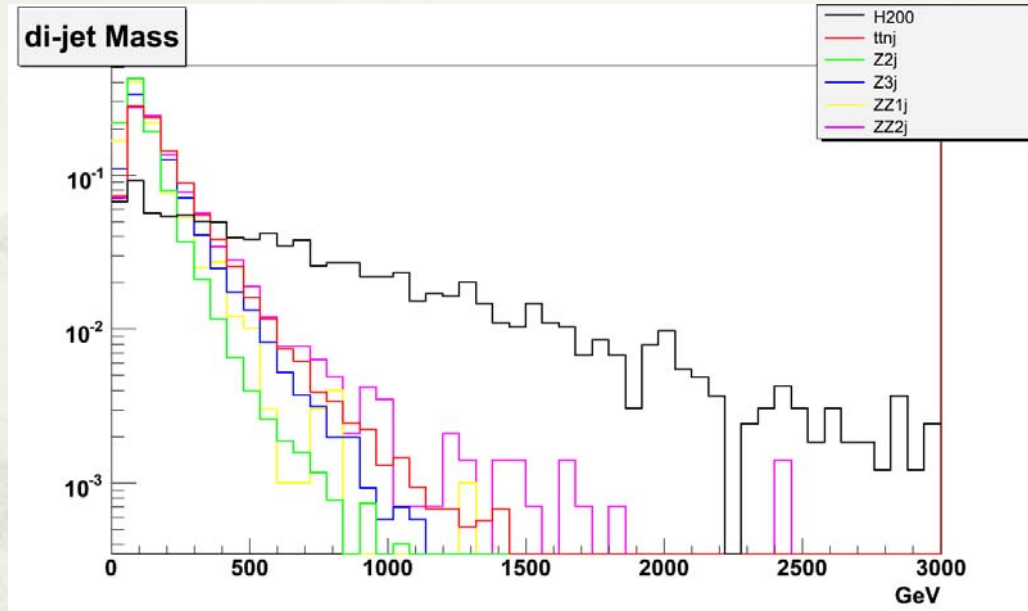
Forward jet tagging



Exactly 2 jets with $p_T > 30\text{GeV}$

$$\Delta\eta = |\eta_{j1} - \eta_{j2}| > 4.2$$

Forward jet tagging

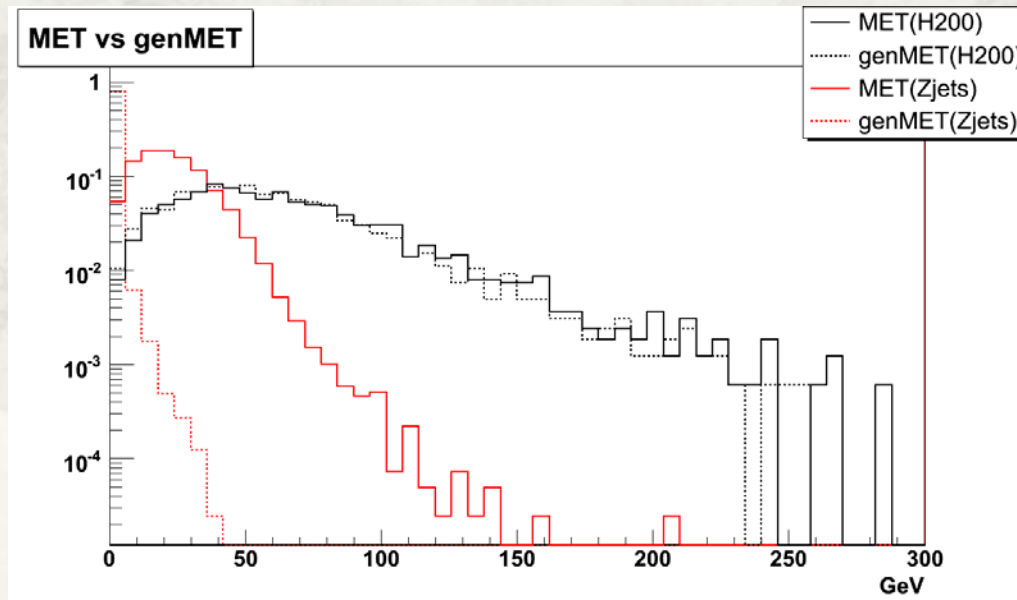


$$M_{jj} > 800 \text{ GeV}$$

$$\eta_{jet}^{low} + 0.7 < \eta_{\mu} < \eta_{jet}^{high} - 0.7$$

MET

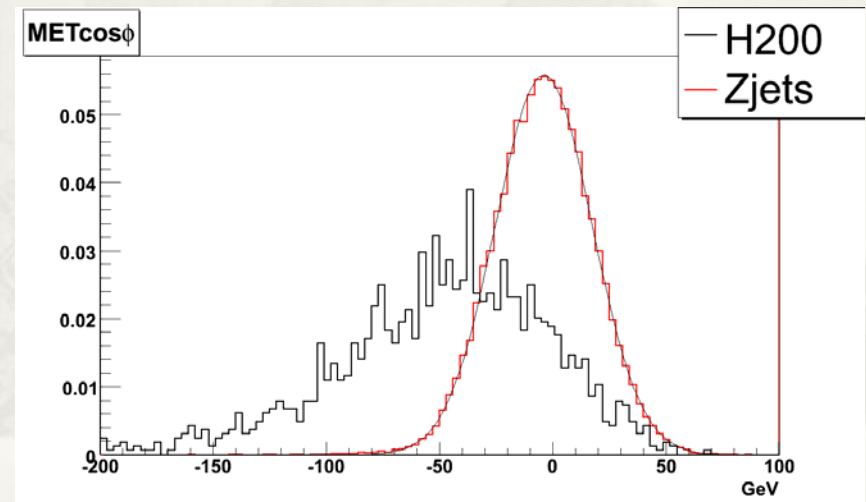
- * the signal events have large true MET in generator level due to presence of two energetic neutrinos.
- * For $Z+jets$ events, MET is primarily a detector effect



MET

- * MET component in leading jet direction
- * A better discriminating variable than MET

$$MET \cos \phi < -40 \text{ GeV}$$



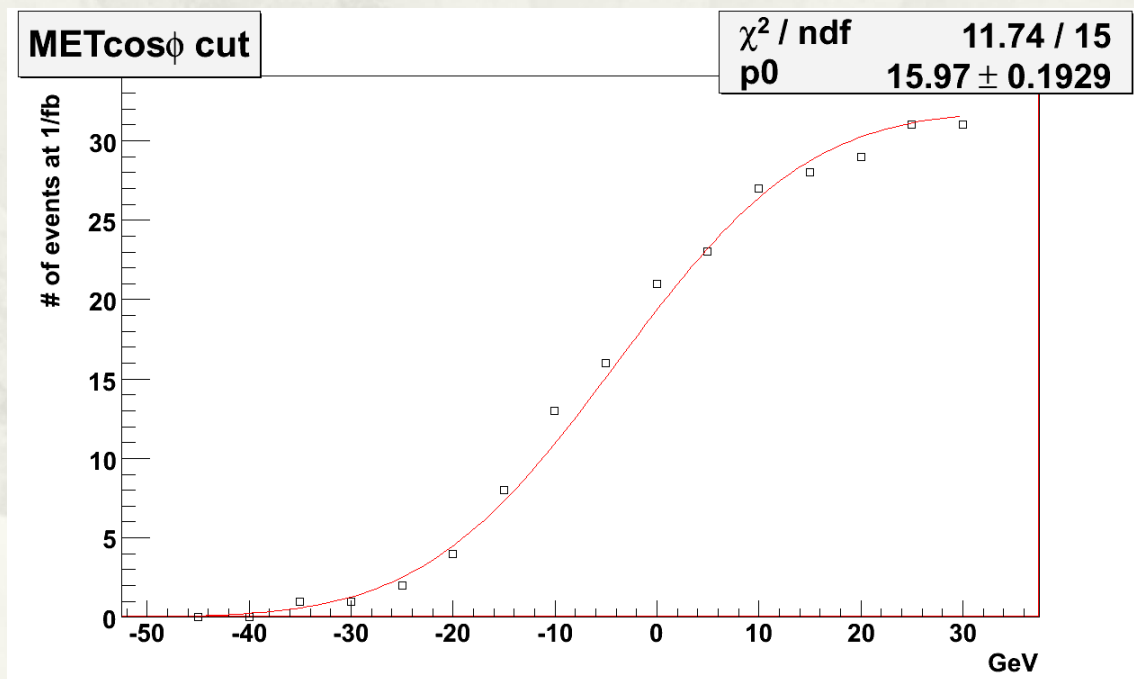
Cutflow table

Selection Cut	Signal	$tt+jets$	$Z+2j$	$Z+3j$	$ZZ+lj$	$ZZ+2j$
	8.90	694k	298k	68k	637	247
preselection	5.67	1.28k	29.4k	7.83k	120	47.7
jets multiplicity	3.06	369	14.1k	3.19k	41.9	12.3
jets $\Delta\eta$	1.74	3.66	259	93	0.24	0.36
di-jet mass	1.31	0.80	43.6	16.4	0	0.13
mu between jets	1.14	0.20	20.0	8.18	0	0.10
MET	0.72	0.13	0	0	0	0

Accepted x-section in fb

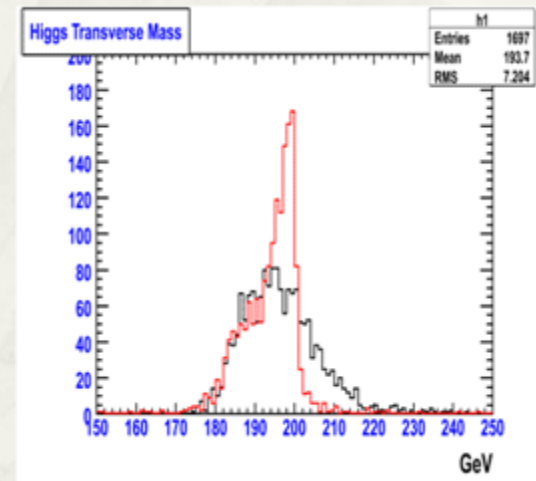
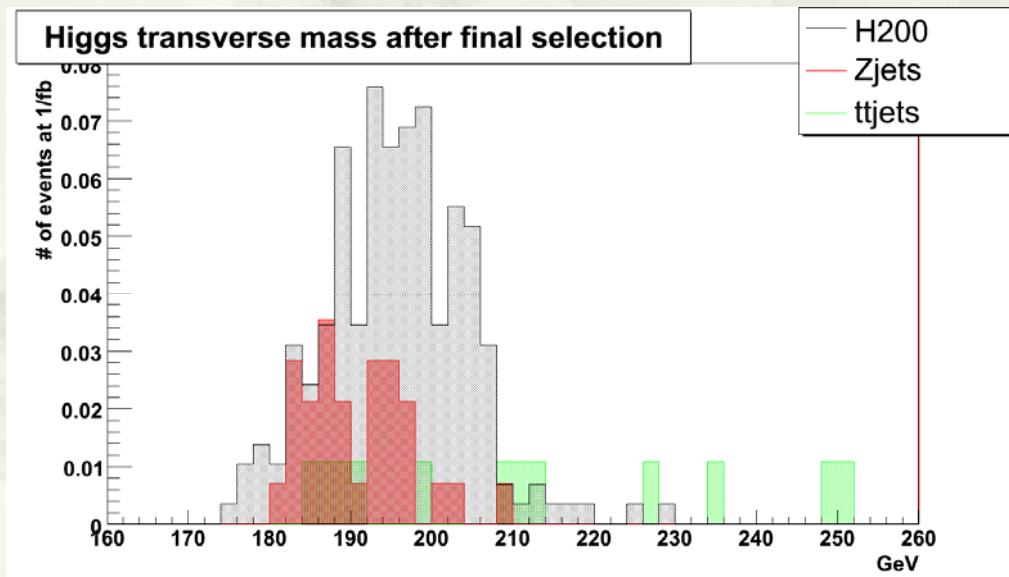
Z+jets estimation

Cumulative distribution function of Gaussian $F(x) = \frac{1}{\sqrt{2\pi}\sigma} \int_{-\infty}^x e^{-\frac{(t-\mu)^2}{2\sigma^2}} dt$



Higgs Transverse Mass

$$M_T = \sqrt{(\sqrt{P_{T,\mu\mu}^2 + M_{\mu\mu}^2} + \sqrt{P_{T,\nu\nu}^2 + M_Z^2})^2 - (\vec{P}_{T,\mu\mu} + \vec{P}_{T,\nu\nu})^2}$$



Jacobian peak

Significance

- * The significance was obtained based on the the likelihood ratio,

$$S_L = \sqrt{2 \ln Q}$$

- * Q is the likelihood ratio. As to the simple approach of the counting method,

$$S_{cL} = \sqrt{2 \left((s + b) \ln \left(1 + \frac{s}{b} \right) - s \right)}$$

- * s and b are expected number of signal and background events at a given luminosity condition. In this analysis, we got $S_{cL} = 5$ at 26fb^{-1} and $S_{cL} = 3$ at 10fb^{-1} .

Experimental systematics

- * Jet energy scale

$$\sigma_E^{jet}/E = \begin{cases} 10\% & p_T < 20 \text{ GeV/c} \\ 10\% - 7\% * (p_T - 20 \text{ GeV/c}) / (30 \text{ GeV/c}) & 20 \text{ GeV/c} < p_T < 50 \text{ GeV/c} \\ 3\% & p_T > 50 \text{ GeV/c} \end{cases}$$

3%

- * MET scale ~ 10%

10%

- * Luminosity ~ 3%

2%

Total 11%

Summary

- * A full analysis of Higgs production via Vector Boson Fusion and $H \rightarrow ZZ \rightarrow 2\mu 2\nu$ presented
- * 5σ could be achieved for Higgs mass of 200GeV at an integrated luminosity of 26/fb
- * This channel can contribute to the discovery of an intermediate mass Higgs boson