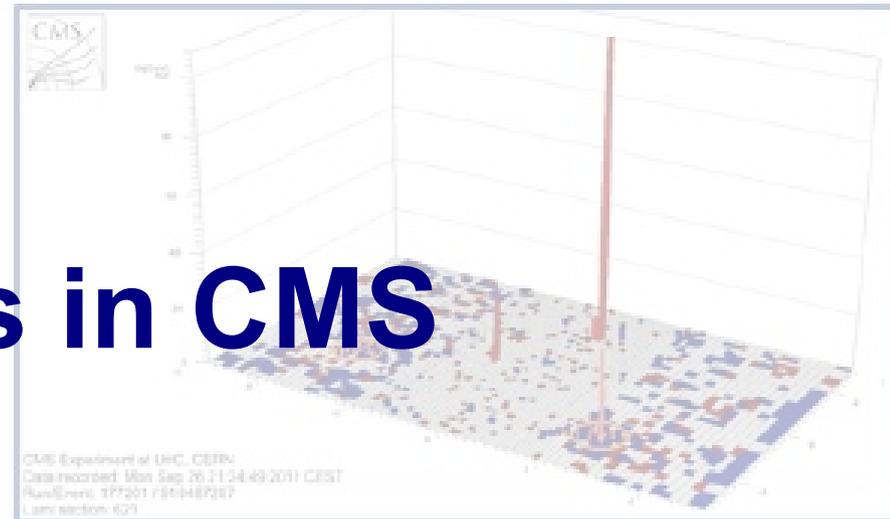# VBF analyses in CMS

γ
p_T=121.0 GeV

jet
E_T(corr)=45.7GeV
η=-3.1

Pasquale Musella,
CERN

For the CMS collaboration

jet
E_T(corr)=68.7GeV
η=2.5

m(γγ)=123.7GeV
m(jetjet)=950.7GeV

γ
p_T=29.4 GeV

Jets issues in Higgs physiscs, 12th October 2012

1

VBF signatures in CMS

- In the low mass region VBF topologies are used in 3 searches:
  - $H \to \gamma\gamma$ [CMS-PAS-HIG-12-015]
  - $H \to WW(l\nu l\nu)$ [CMS-PAS-HIG-12-017]
  - $H \to \tau\tau$ [CMS-PAS-HIG-12-018]
  - Currently working also on $H \to ZZ$ and $H \to bb$.

- Event selection varies from channel to channel.
  - Expect overall 30-70 VBF events with 30fb^{-1} at 8TeV
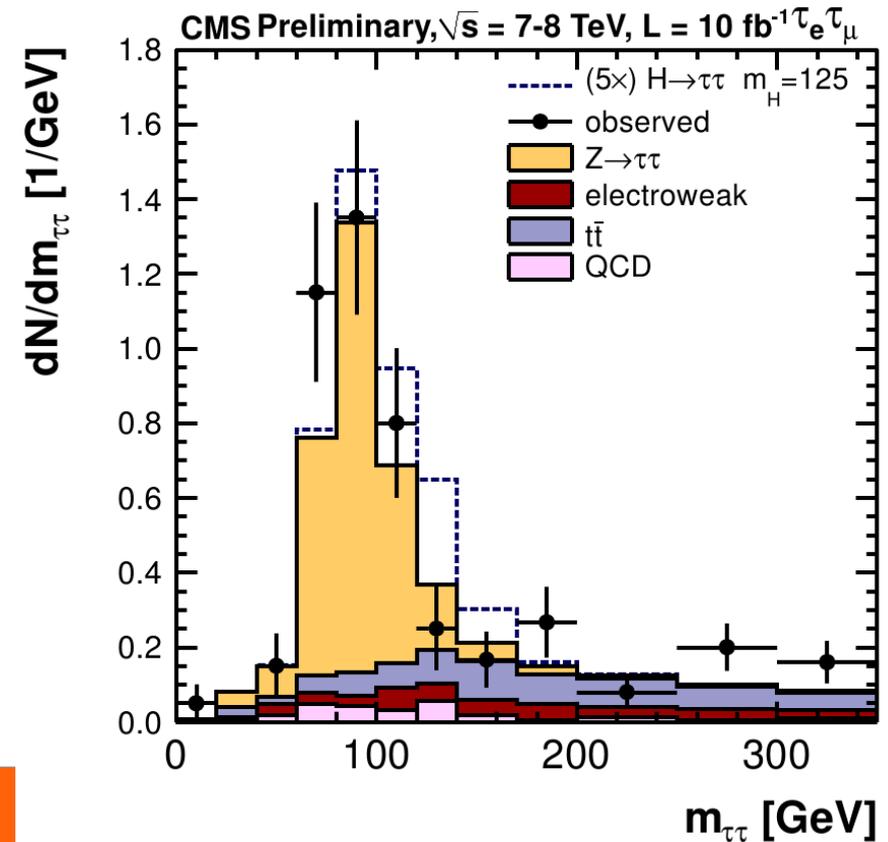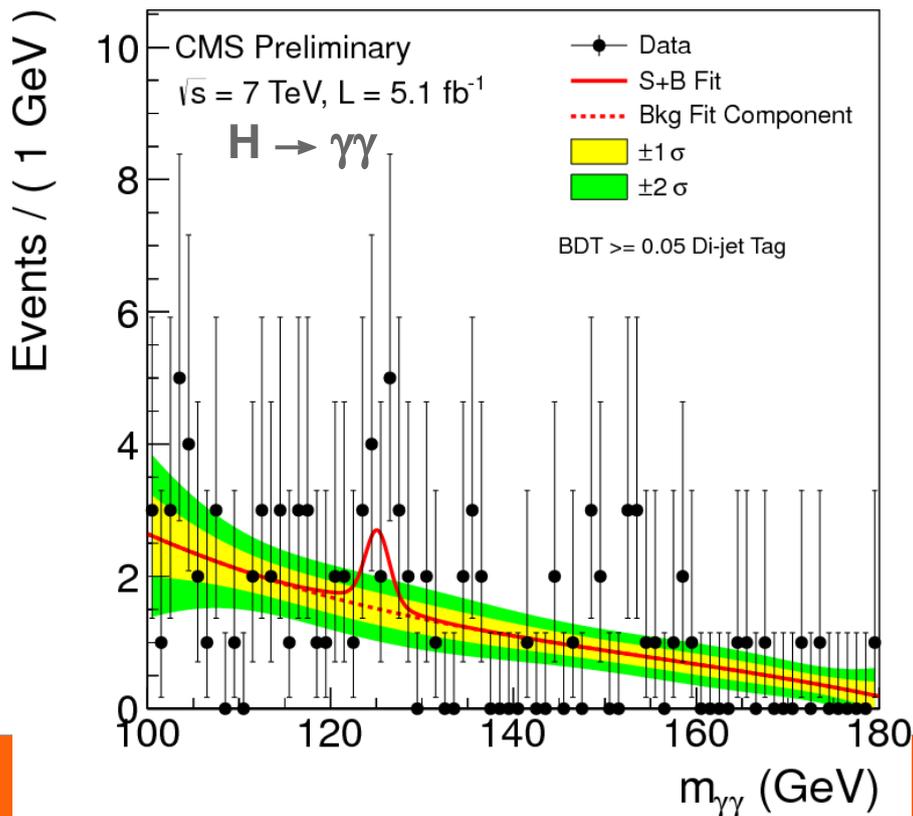
Experimental techniques

- **All channel exploit of course the specific characteristics of VBF Higgs production.**
  - Two forward jets with large rapidity separation.
  - Details vary from channel to channel.
- **With the 8TeV run all channels introduced jet identification criteria to remove pileup contribution.**

|	Jet p_T thrs. (GeV)		Central jet veto	N VBF categories	Selection
	1st	2nd			
$H \to \gamma\gamma$	30	20	no	2	cut-based
$H \to WW$	30	30	yes	1	cut-based
$H \to \tau\tau$	30	30	yes	1	multivariate

$Z \to ll+jets$
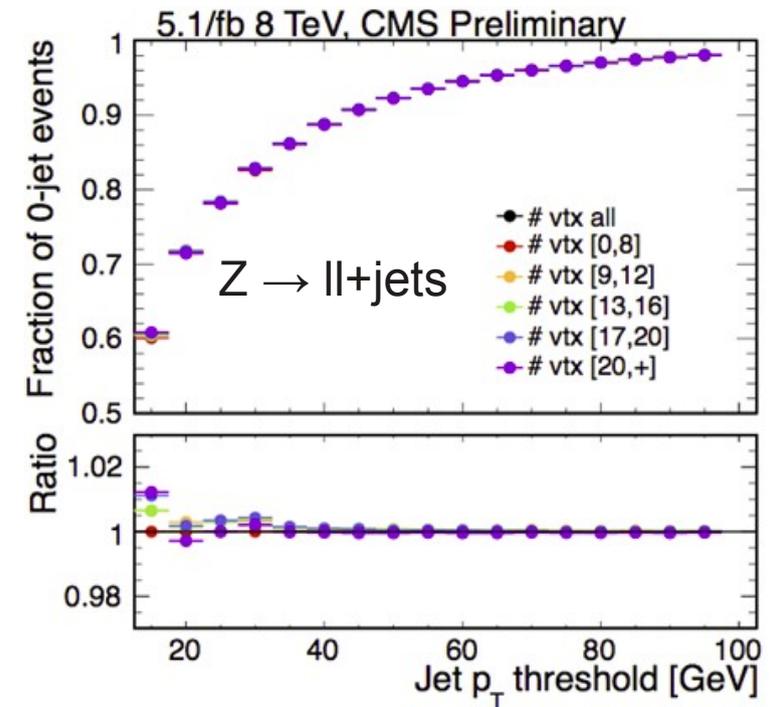
Contamination from ggH+2j

- All Higgs events used for the CMS analyses have been produced using POWHEG-BOX+PYTHIA(Tune Z2).

  - For ggH, this means than the first jet is from ME calculation at LO, while second always come from PYTHIA.

  - Some studies were carried out also with VBFNLO and Madgraph but did not enter in the analyses.

- The estimated contribution from gg → H+2j process to the VBF-tagged selection ranges from 15% to 50% of the total Higgs events.

$\sqrt{s}$=8TeV L=5fb^{-1} m$_H$=125 GeV	VBF	ggH	(VBF+ggH)/B
	(Generator: POWHEG-BOX)		
H → γγ high m$_{jj}$	2.0	0.6	0.5
H → γγ low m$_{jj}$	1.4	1.6	0.2
H → WW SF	1.1	0.2	0.3
H → WW OF	0.7	0.1	0.25
H → ττ	6.1	2	0.15

Systematic uncertainties

- Experimental uncertainties:

  - Jet identification and jet energy scale.
    Give a subleading contribution for both VBF
    and ggH processes.

- Theoretical uncertainties:

  - Scale and PDF uncertainties:
    use uncertainties from from Yellow report H+2j
    plus contribution from jet selection acceptance.

  - Showering uncertainties:
    Evaluated varying the UE event tunes in PYTHIA.

- Note: all analyses are still dominated by statistical uncertainties and will
  continue to be so for this year.
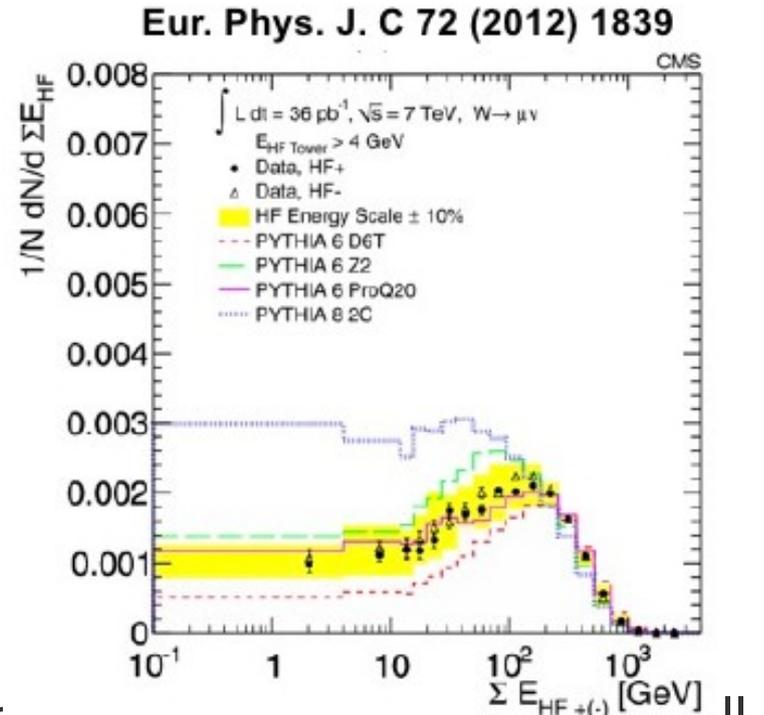
|	JES + JetID	Scale	PDF	UEPS
VBF	5%	1%	5%	10%
ggH	8%	20%	8%	30-50%

Current discussion in CMS

- We are currently reviewing all the VBF analysis in CMS in order to have common approach.

  - For ICHEP systematic uncertainties were evaluated in slightly different ways by the different analyses.

  - Oder of magnitude of the estimated uncertainties were very similar, but we are trying to come up with a common set of prescriptions.

- Currently, largest uncertainties come from parton shower. Investigating two strategies:

  - Use 'standard candles' in data (eg ttbar) to better constrain the genrators.

  - Use ME calculations for 2nd jet.
    Madgraph is available. Can vary matching-scale to estimate showering uncertanties.

  - POWHEG H+0,1,2j may be ready on the Moriond time-scale?
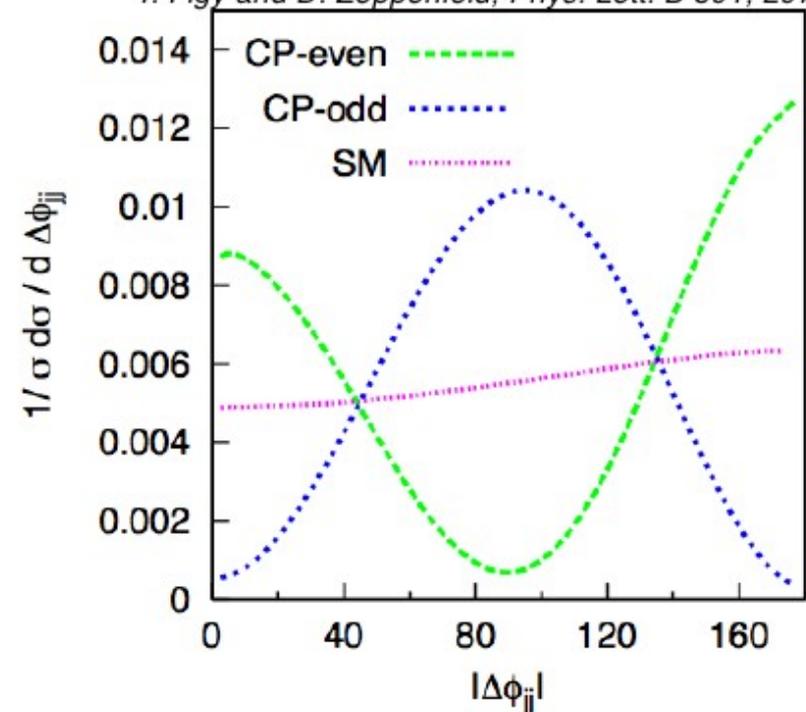
Questions for the theory community

- **Showering uncertainty:**

  - Is the current prescription sensible from the theoretical point of view?

  - How would that relate to the matching-scale variation?

- **Jet p_T thresholds:**

  - How far down in jets p_T can we go and assume that systematic uncertainties have sensible coverage?

  - How much does the answer change in the presence/absence of central jet veto?

Beyond cross-section measurement

- VBF topology is well known to provide information on the Higgs-candidate tensor structure.

- May provide contribution to spin-2 measurement this year.

- How to handle the gluon-gluon contribution in this case not clear.

  - Besides the normalization, the most pressing question is how to model angular correlations in gg->spin2 + 2j.

J. Frank diploma thesis

Higgs LO
Higgs NLO
Spin-2 LO
Spin-2 NLO
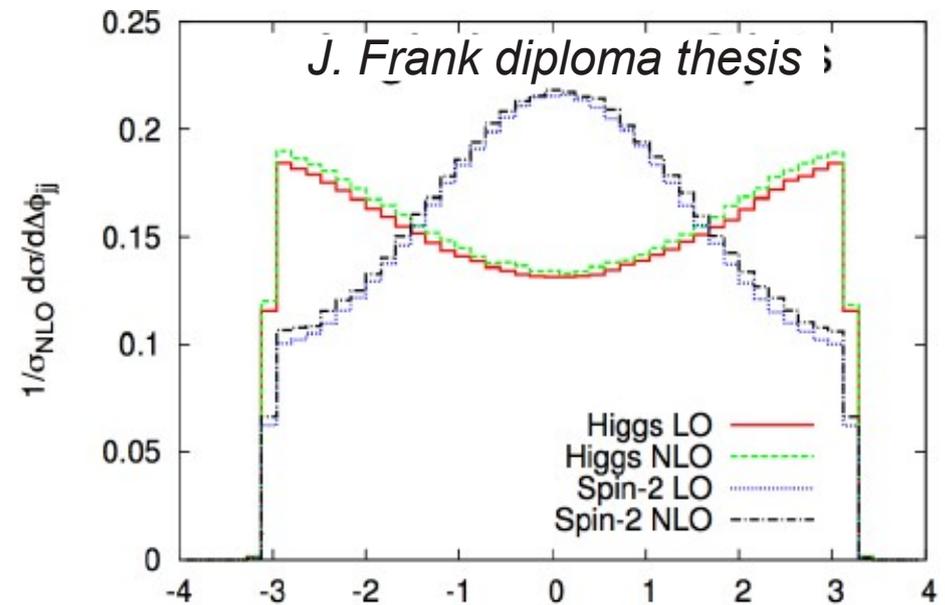
T. Figy and D. Zeppenfeld, Phys. Lett. B 591, 297 (2004)

CP-even
CP-odd
SM

Summary

- Presented a quick overview of searches with VBF topologies in CMS.

- VBF signature exploited in many Higgs search channles.

  - In all cases the signature allows to improve the S/B ratio with respect to the inclusive analyses.

- The contamination from ggH events to events with VBF topologies ranges from 15% to 50% (using POWHEG-BOX as reference).

  - The largest uncertainty on this contribution comes from uncertainties in the parton shower.

- We are currently reviewing the procedure to evaluate these uncertainties and we pretty much welcome inputs from the theory community.

- In order to exploit the VBF signature to test the tensor structure of the 125GeV Higgs-candidate we need to address the shape of jet correlations for $gg \rightarrow$ spin2 + 2jet besides its normalization.