Vector Boson Fusion Higgs in Pythia and Herwig++

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Christoph Hackstein[1),2)], Peter Krauss[1)],
Günter Quast[1)], Manuel Zeise[1)], Dieter Zeppenfeld[2)]

1) Institut für Experimentelle Kernphysik – Universität Karlsruhe
2) Institut für Theoretische Physik – Universität Karlsruhe

Higgs activities in Karlsuhe

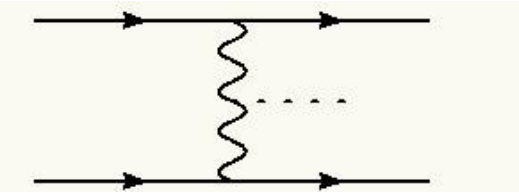
- Comparisons of different generators for vector boson fusion signal and backgrounds, $H \rightarrow WW$, $H \rightarrow \tau\ \tau$
- $Z \rightarrow \tau\ \tau$ Background modelling with hybrid events
- Full production of boson pair + jet samples for the VBF Higgs group

Vector Boson Fusion

Vector Boson Fusion is a promising Higgs production process

The kinematic signature is given by two hard jets, one forward and one backward in rapidity, with a big gap between them

This gap should be visible at hadron level, since the process is a color singlet exchange



So for the study of this channel it is important to investigate this gap after parton shower, hadronization and underlying event

Since this is strongly model dependent (only models available for parton shower, hadronization and underlying event), different generators should be compared, for signal and backgrounds

Analysis

Compare the effect of different models for the various steps in event generation like parton shower (virtuality ordered, angular ordered), hadronisation (string, cluster hadro.) underlying event (MPI) and decays on signal and backgrounds for VBF Higgs production by using Pythia 6 and Herwig++ for the same processes

Processes studied: Signal — VBF Higgs, m_H = 120 GeV

VBF Higgs, m_H = 160 GeV

Background — W^+W^- + 2j (QCD)

W^+W^- + 2j (EWK)

tt + j

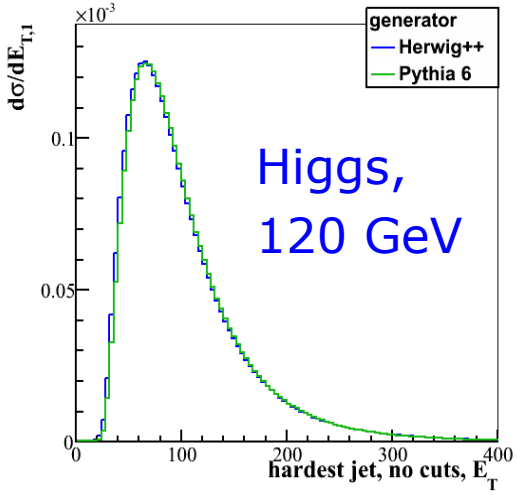
The same input used for Pythia and Herwig++

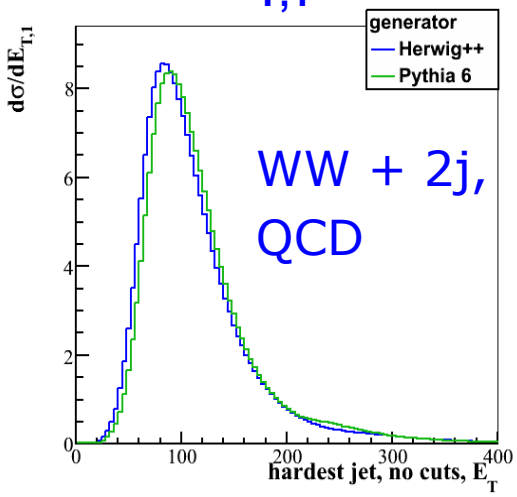
Cteq 6ll PDF set, Kt 0.6 jets used for Analysis.

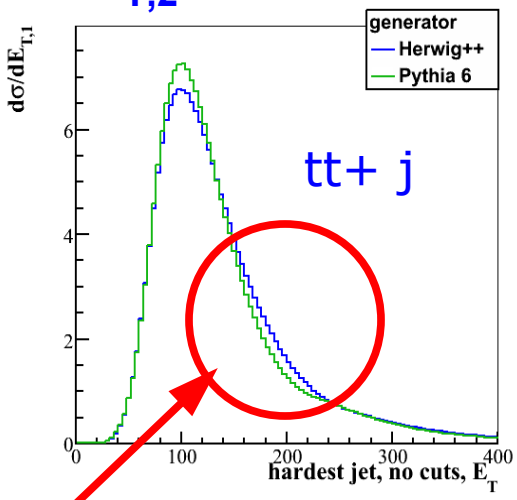
Analysis according CMS NOTE 2007/11 and arXiv:hep-ph/0012351

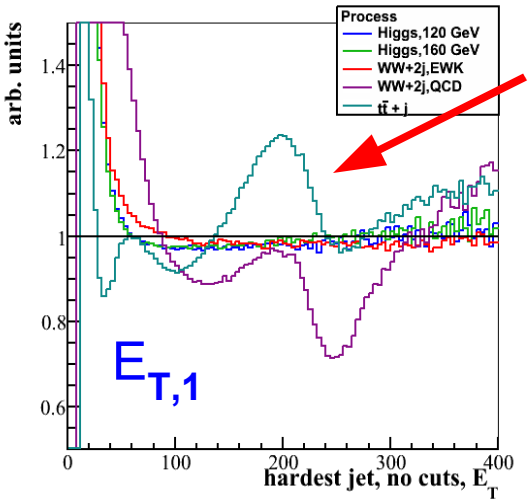
Event selection: Jet E_T

Require two hard tagging jets: $E_{T,1} > 50$ GeV $E_{T,2} > 30$ GeV









Different treatment of massive particles in showering algorithm leads to different kinematics

Ratio Herwig++/Pythia for the tagging jet E_T distributions

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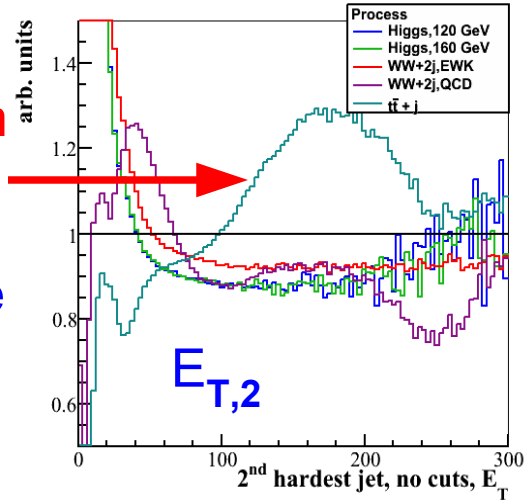
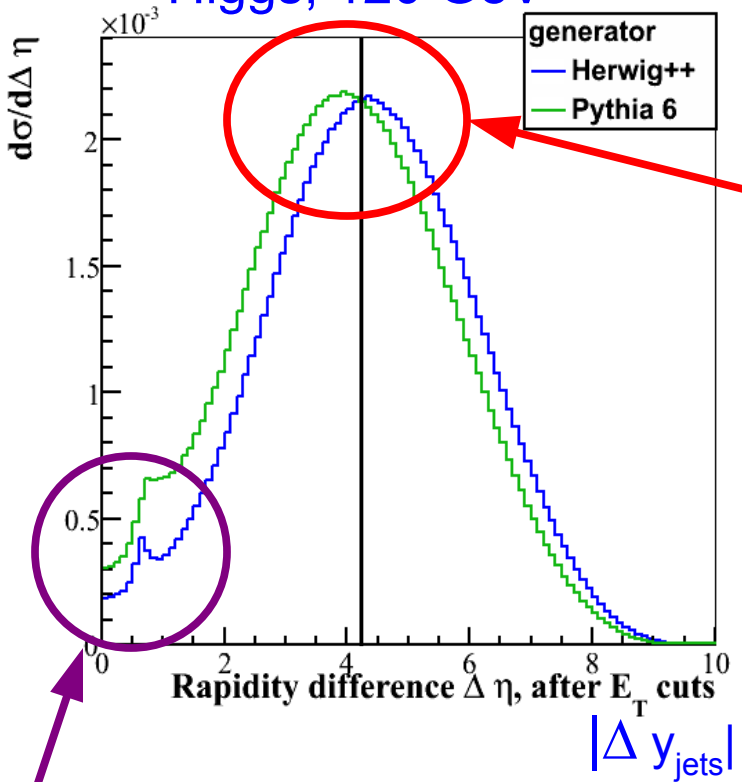


Event selection: forward jet tagging

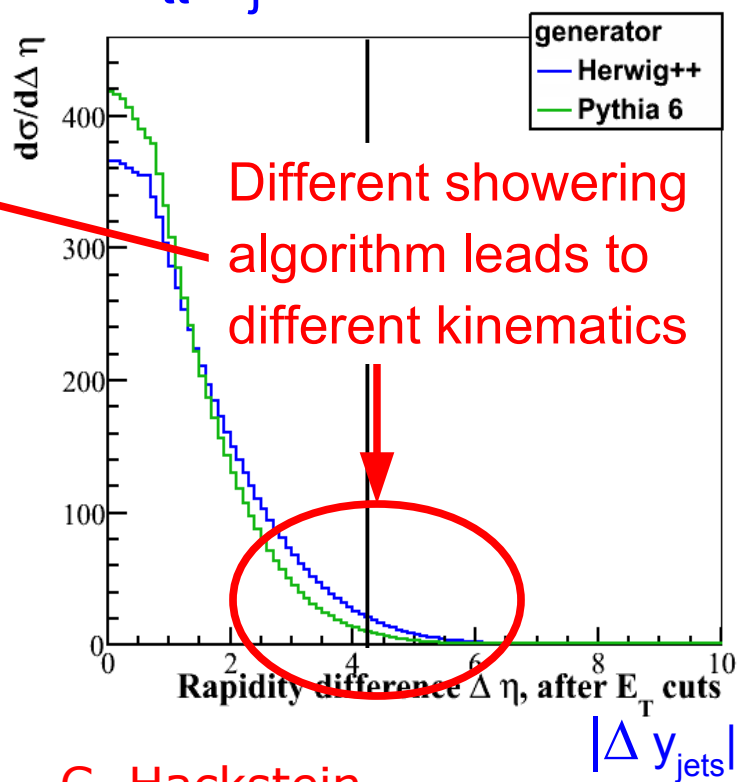
Require rapidity gap and jets in opp. hemispheres

$|\Delta y_{jets}| > 4.2$ $y_1 * y_2 < 0$

Higgs, 120 GeV



tt + j



Different showering algorithm leads to different kinematics

Artefact of parton-parton separation (technical cut) at ME level

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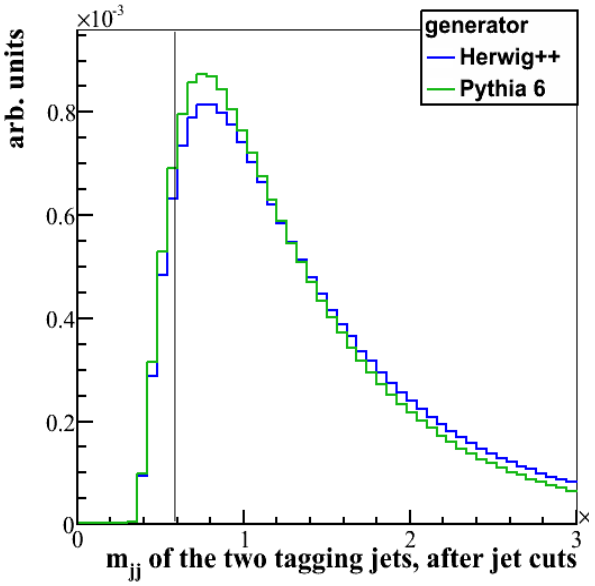
Event selection: m_{jj}

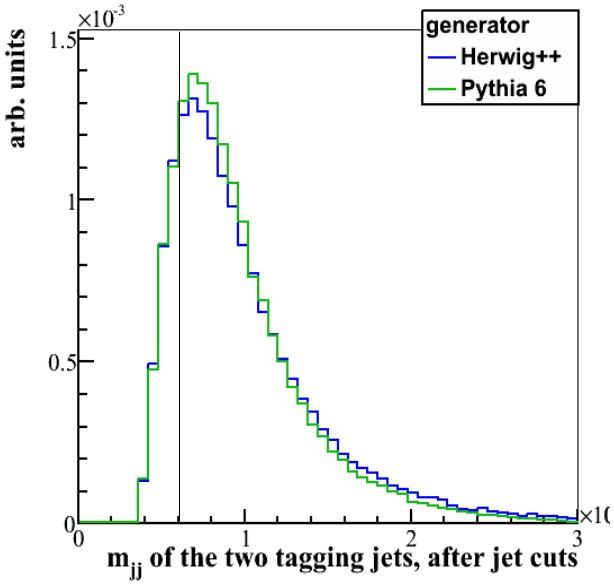
Require large invariant dijet mass for tagging jets:

$m_{jj} > 600$ GeV

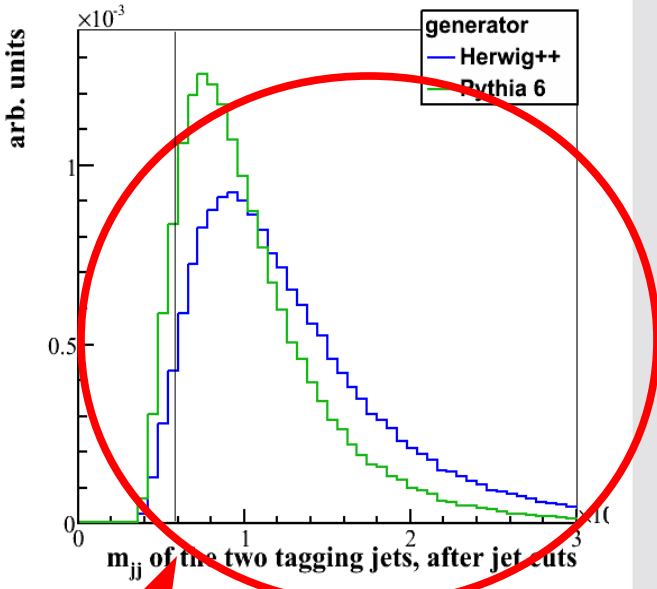
Higgs, 120 GeV



WW + 2j, QCD



tt+1j



Jet pair invariant mass m_{jj}

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Different treatment of massive particles in showering algorithm leads to different kinematics

Event selection: Central Jet Veto

Veto Events with hard central jets, signal is color singlett exchange

For each additional jet with $E_T > 20$ GeV, calculate $y^* = y_i - \frac{1}{2}(y_1+y_2)$,

Veto event if $|y^*| < 2.0$ for any additional jet

Additional hadronic activity in EW processes differs extremely in Pythia and Herwig++

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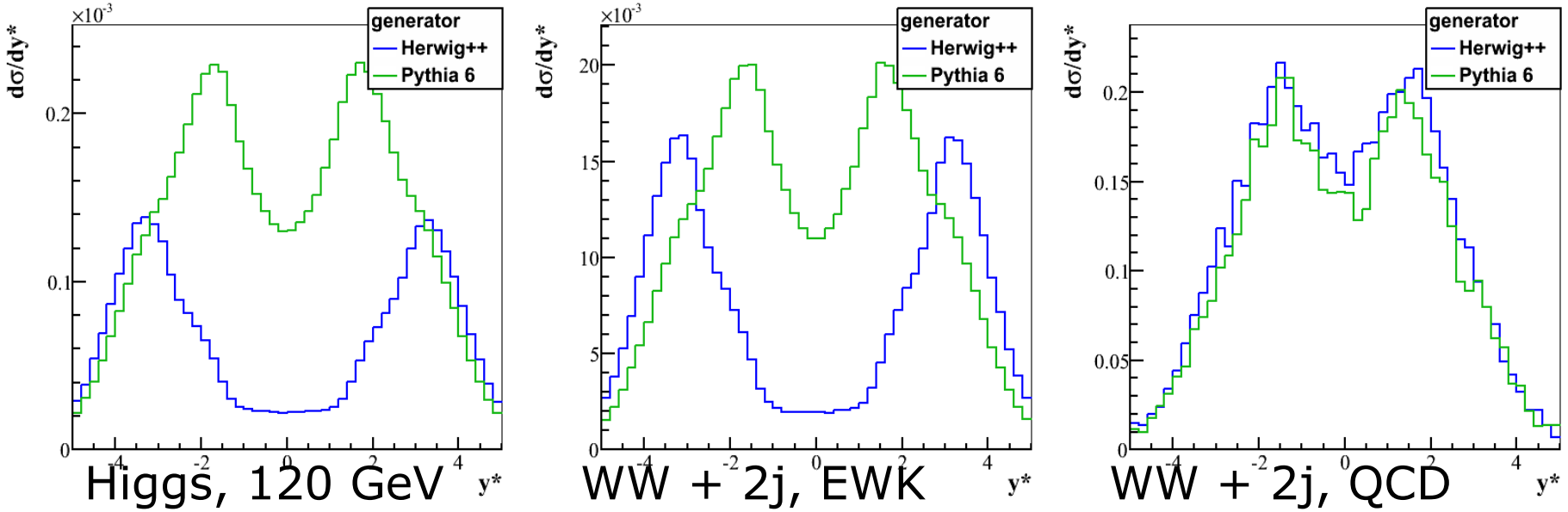
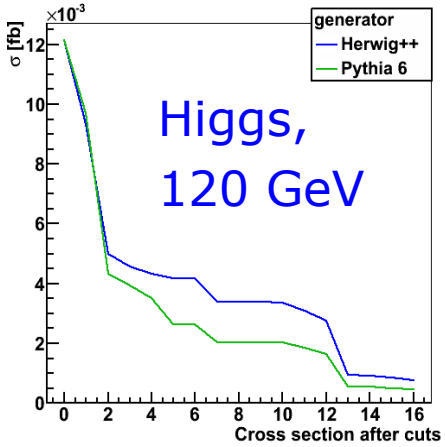
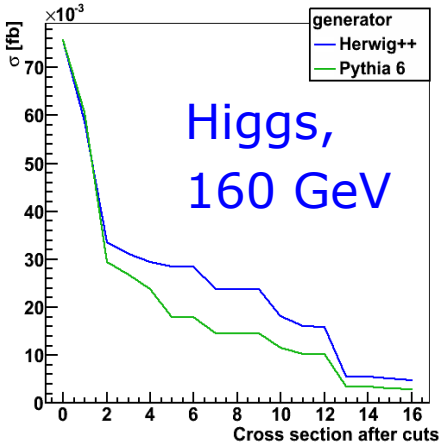
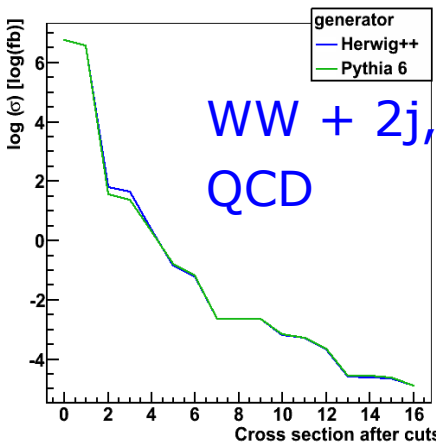


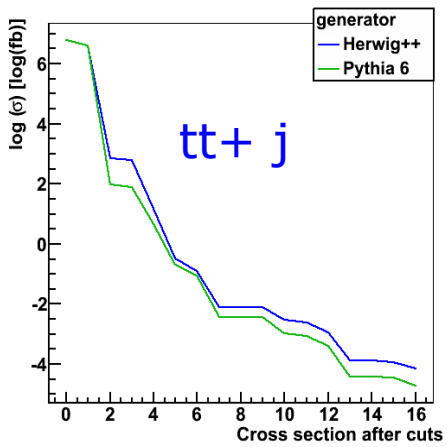
$y_0 = y_3 - \frac{1}{2}(y_1+y_2)$ for third jet in event

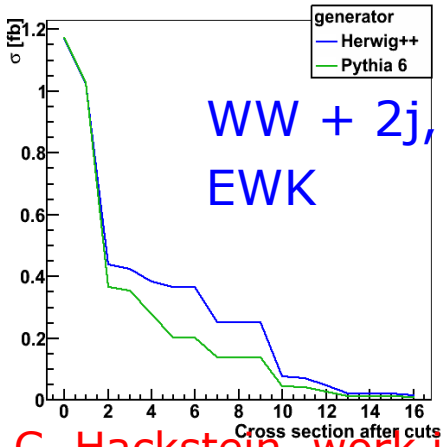
Cut efficiency











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Cuts:
0: all events
1: Jet E_T cuts
2: Jet rap. Cuts
3: m_{jj} cut
4: P_T - balance
5: Central Jet veto
6: 2 leptons
7: lepton p_T cuts
8: ΔR(l,j) cut
9: leptons between jets
10: m_{ll} cut
11: lepton Δφ cut
12: m_T^{WW} cut
13: $p_{T,H}+\Delta\varphi(ll,E_{T,miss})$ cut
14: $E_{T,miss} + p_{T,H}$ cut
15: $E_{T,miss} + m_{ll}$ cut
16: $\Delta\varphi(ll,E_{T,miss}) + \Delta\varphi(ll)$

Significant differences between the generators for signal and background processes observable

Studies with H→ τ τ

The same difference has been observed in the H → τ τ case

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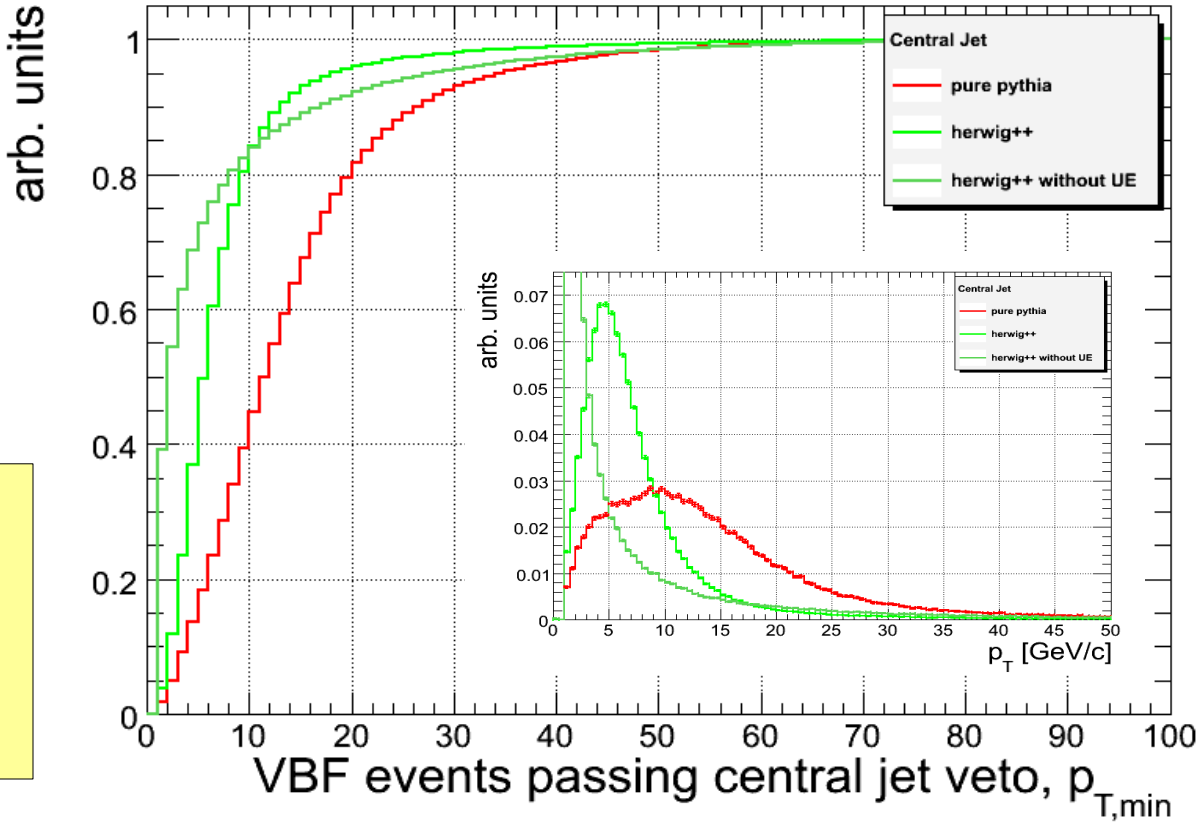
The p_T spectrum of the hardest central jet can be used to obtain a Central Jet Veto Efficiency – Herwig++ and Pythia differ

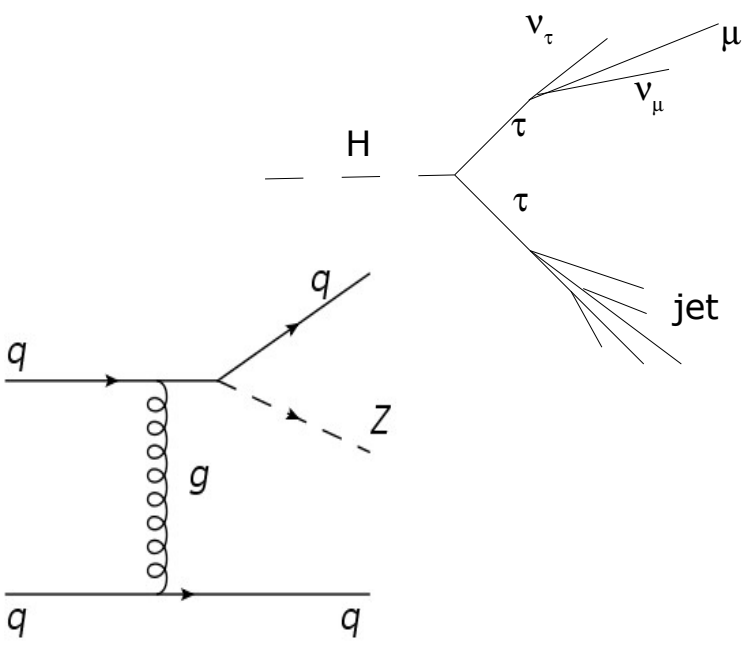
Veto Efficiency: fraction of VBF events passing a central jet veto with given p_T

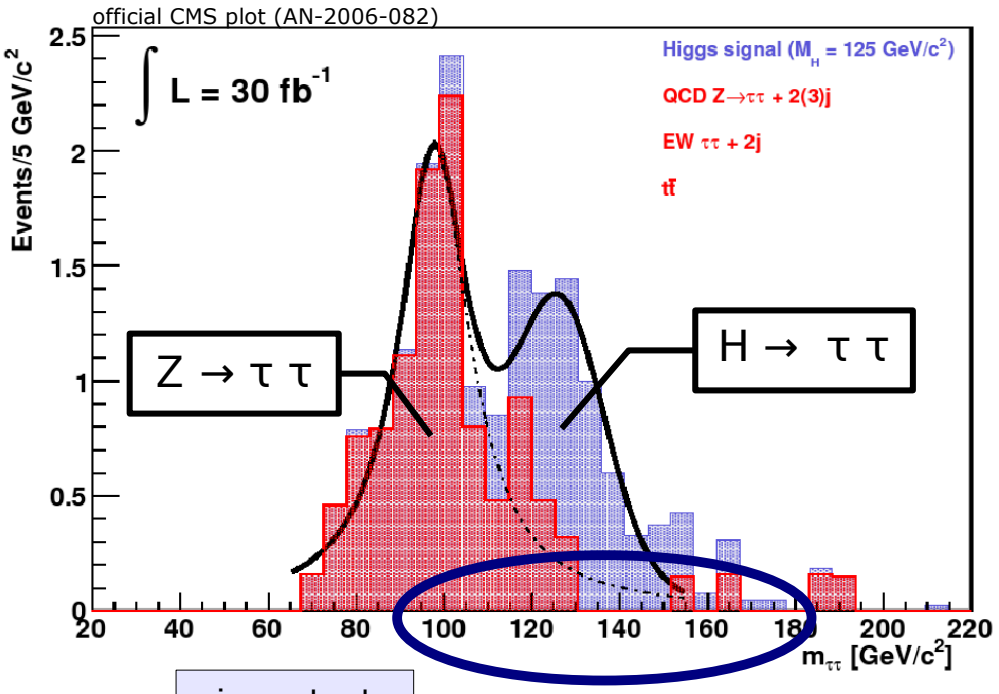


Background studies with Z → τ τ

Introduction

- Z → τ τ is an irreducible background for H → τ τ
- use a data-driven method for the qualitative and quantitative estimation of this background
- similar for other analyses ($H^+ \rightarrow \tau \nu$ or $W \rightarrow \mu \nu$)

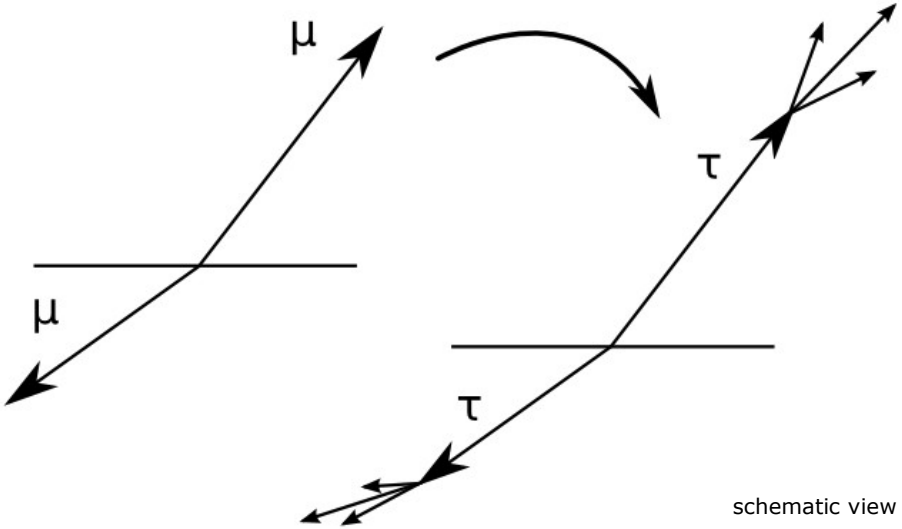




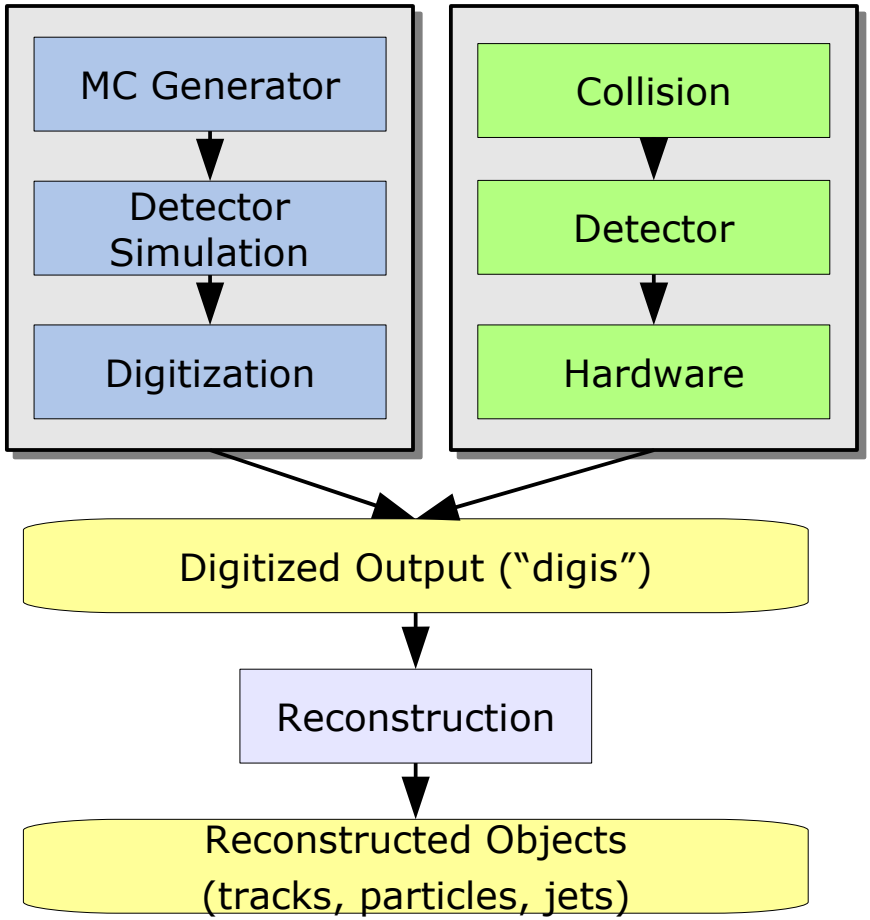
important mass range

Idea of the method

- remove the muon pair from a measured Z → μ μ event
- replace it by two simulated taus
- get a hybrid Z → τ_μ τ_μ event
- take pile-up and underlying event from measured event



schematic view



Application

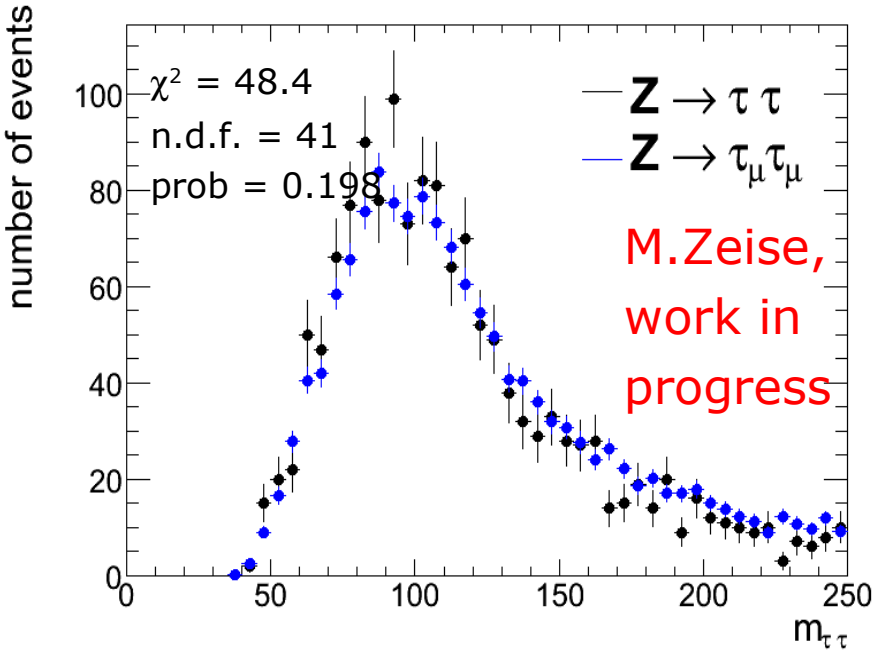
Current status

- contribution as background template to Higgs boson search in the channels $H \rightarrow \tau\,\tau$ and $H^+ \rightarrow \tau\,\nu$
- as signal template in $Z \rightarrow \tau\,\tau$
- participation in CMS Oct09X
- code publicly available

Future plans

- quantitative estimation of $Z \rightarrow \tau\,\tau$ events
- study the tau reconstruction efficiencies with hybrid events
- Testing of the method with first data

•both distributions are normalised to the number of available MC $Z \rightarrow \tau\tau$ events
•error bars show uncertainties of the monte carlo sample



$Z \rightarrow \tau_\nu\,\tau_\nu$ can reproduce $Z \rightarrow \tau\,\tau$ precisely

Conclusion

Pythia and Herwig++ differ strongly in the description of jet activity

Especially different treatment of VBF like events

Massive partons (top-quark) handled differently by the different shower models

$Z \rightarrow \tau\,\tau$ can be modeled using $Z \rightarrow \mu\,\mu$ events.

Method very independent from theoretical models (underlying event, pile up)

Used for $H \rightarrow \tau\,\tau$ now, also useful for $H^{+} \rightarrow \tau\,\nu$