ETH Institute for
Particle Physics

gg→H for different MCs:

uncertainties due to jet veto

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Motivation

$gg \to H \to WW \to l\nu l\nu$:

- **Higgs discovery channel between $2M_W$ and $2M_Z$**
- **Dominant background: nonresonant WW, ttbar and Wtb**

jet veto crucial to reduce top-background

→ get uncertainty of jet veto for different Monte Carlos

MCs compared :
PYTHIA 6.319, HERWIG 6.505 + ME correction*, MCatNLO 2.31 and CASCADE 2.009

- **NO underlying events**
- **M(Higgs) = 165 GeV, M(top) =175 GeV**
- **CASCADE 2.009 (CCFM hadron level MC) with PYTHIA final state parton shower**
- **HERWIG:** **gg→ H : no hard ME Corrections,**
  here:preliminary version with ME corrections used (exact)

PYTHIA, MCatNLO : **with ME Corrections (PYTHIA: m(top)→∞, MCatNLO exact)**

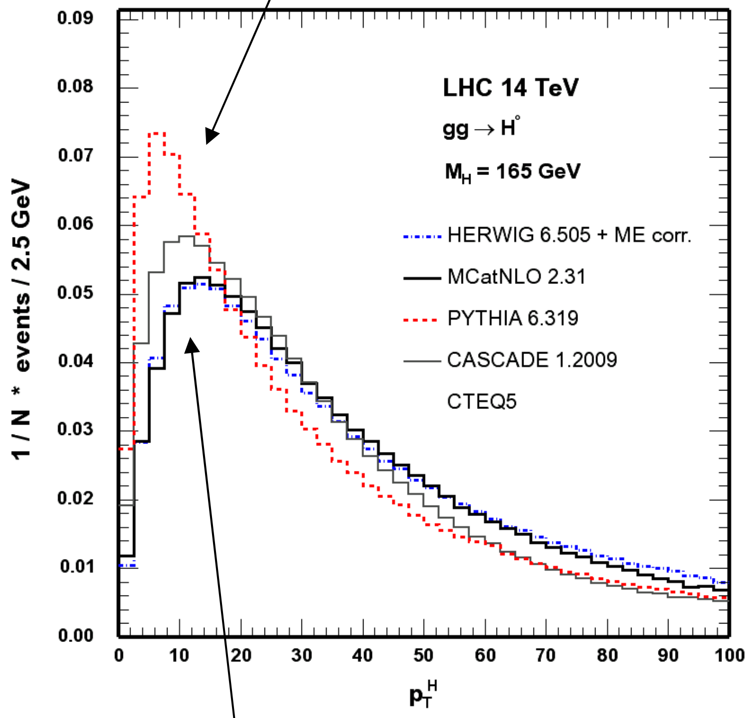
pdf	**MCatNLO:** **PYTHIA, HERWIG :**		**CTEQ 5M1** **CTEQ 5L**
CTEQ5M1 (NLO) **CTEQ5L (LO)**	**α_s(Mz)=0.118** **α_s(Mz)=0.127**	**Λ_{QCD}^4 = 0.326** **Λ_{QCD}^4 = 0.192**	**Λ_{QCD}^5 = 0.226** **Λ_{QCD}^5 = 0.146**
Λ_{QCD}	**PYTHIA:** **HERWIG:** **MCatNLO:** **CASCADE**		MSTP(3)=**2 (Λ_{QCD} = Λ_{QCD} of pdf)** QCDLAM=**0.18** LAMDAFIVE=**0.226** MSTP(3)=2

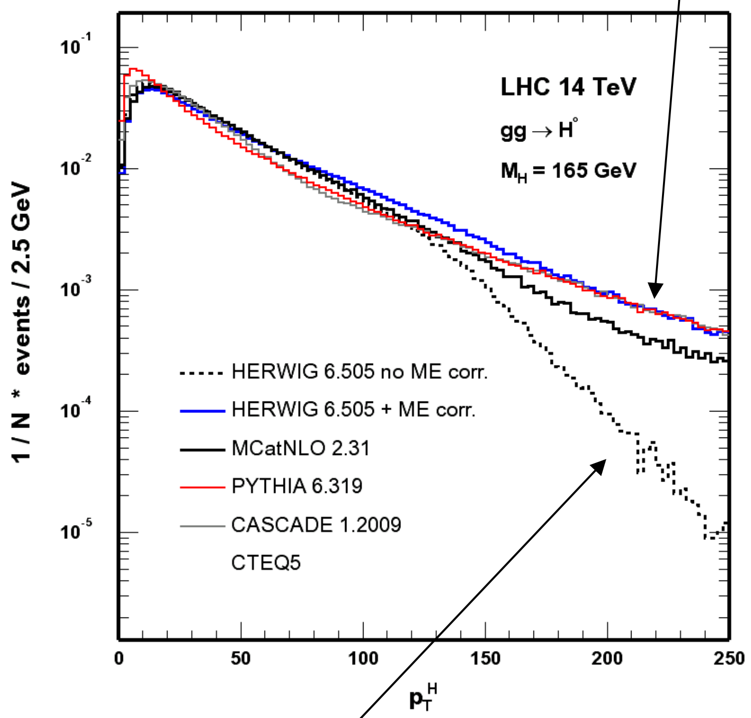
* provided by G. Corcella (see Phys.Lett.B 590 (2004)249-257)

p_T Higgs varies for different MCs old Pythia showering

Low pt: different shape for Pythia

High pt: Pythia + Herwig+ME ≈ same



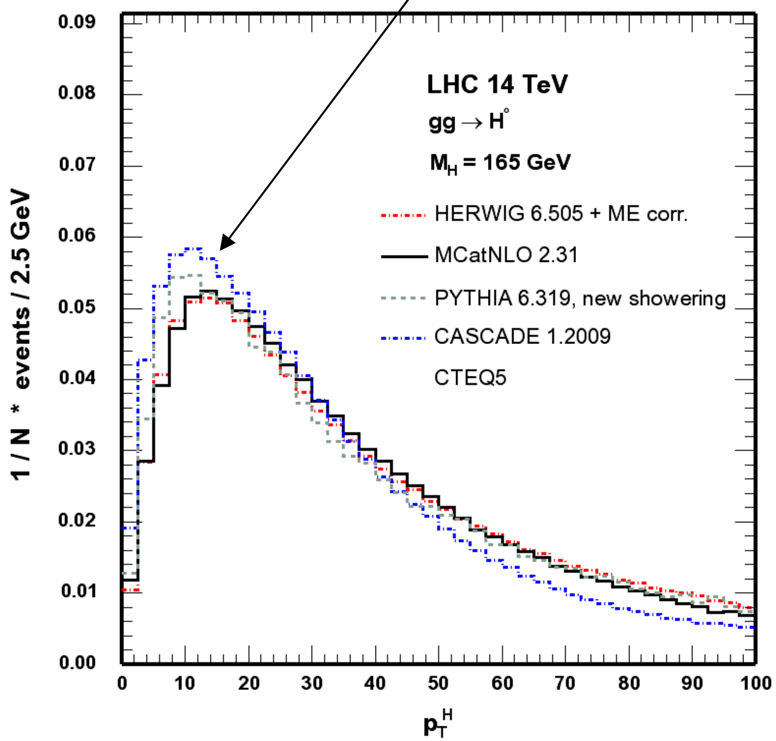


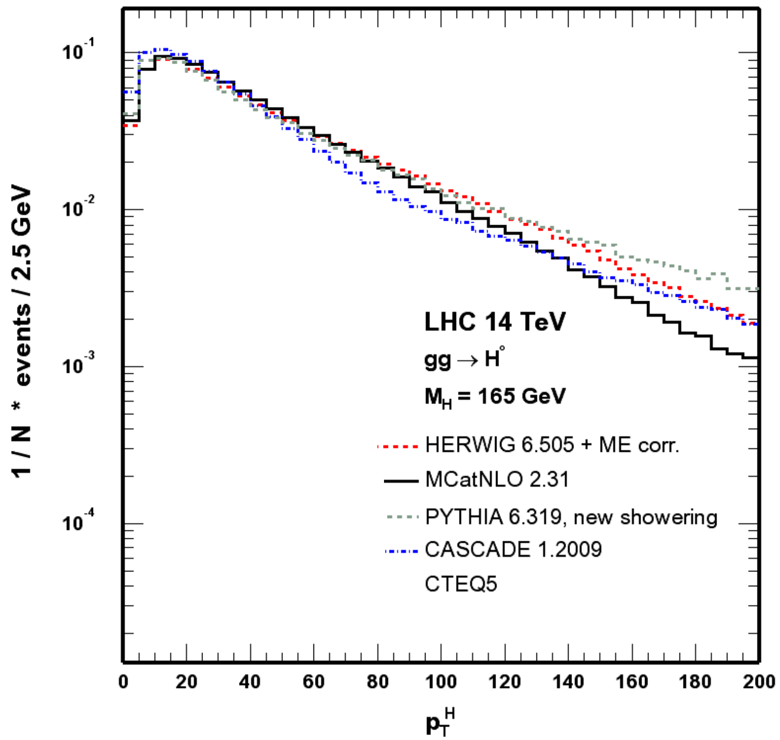
Low pt: Herwig+ME and MCatNLO ≈ same

Herwig without ME correction

p_T Higgs varies for different MCs new (from now on new showering for Pythia used)

Pythia now much more like Herwig and MCatNLO in low pt





p_T Higgs versus jet p_T

for this study:

Cone algorithm

p_T jet>20 GeV, |η| jet<4,5, R=0.5,

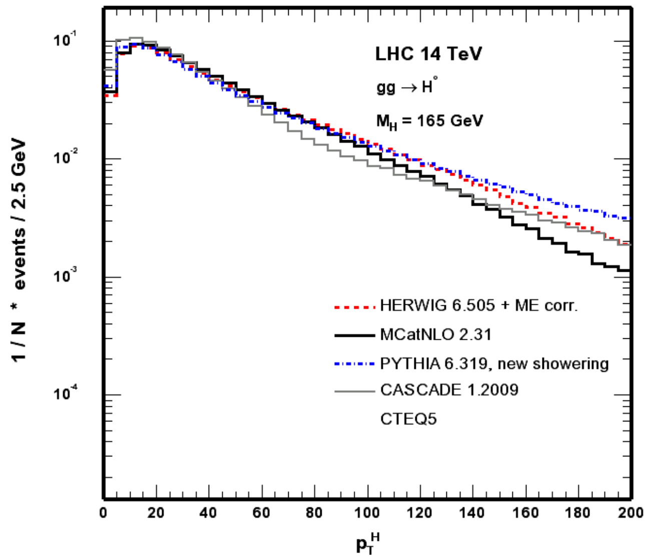
p_T seed>1 GeV

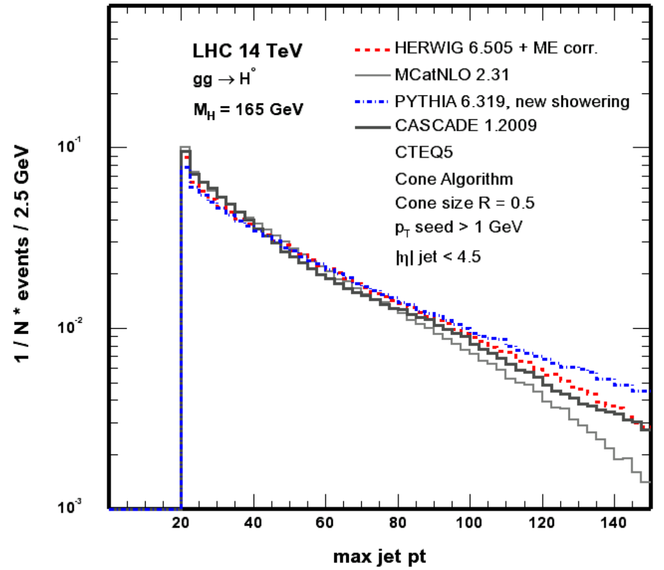
p_T Higgs balanced by one or more jets

→ similar but not identical pt spectrum

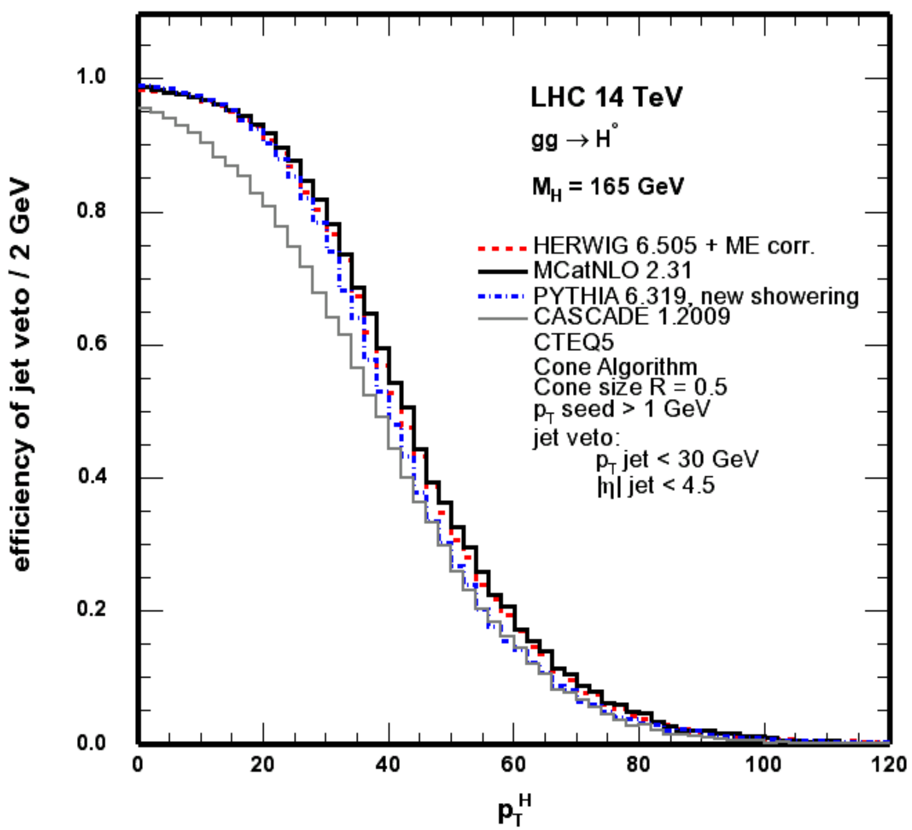
Apply jet veto of 30 GeV

→ get the efficiency





Efficiency numbers of the jet veto



Differences vary over the p_T spectrum:

Integrated efficiency over whole p_T spectrum and up to a p_T Higgs of 80 GeV:

	ε total	ε up to 80 GeV
PYTHIA	0.53	0.68
HERWIG	0.54	0.68
MCatNLO	0.58	0.69
CASCADE	0.55	0.65

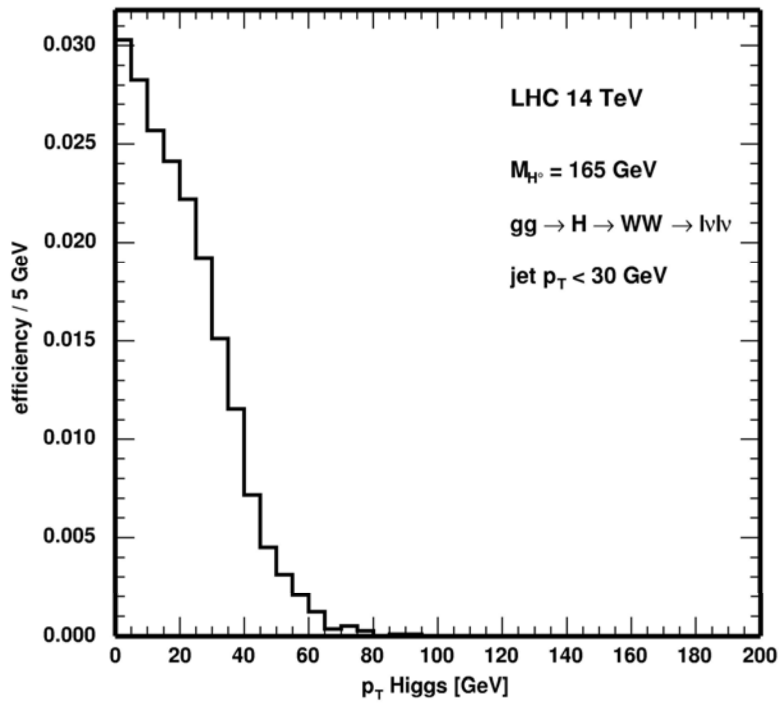
→ efficiency spread ≈ 10%

(without CASCADE up to 80 GeV 1%)

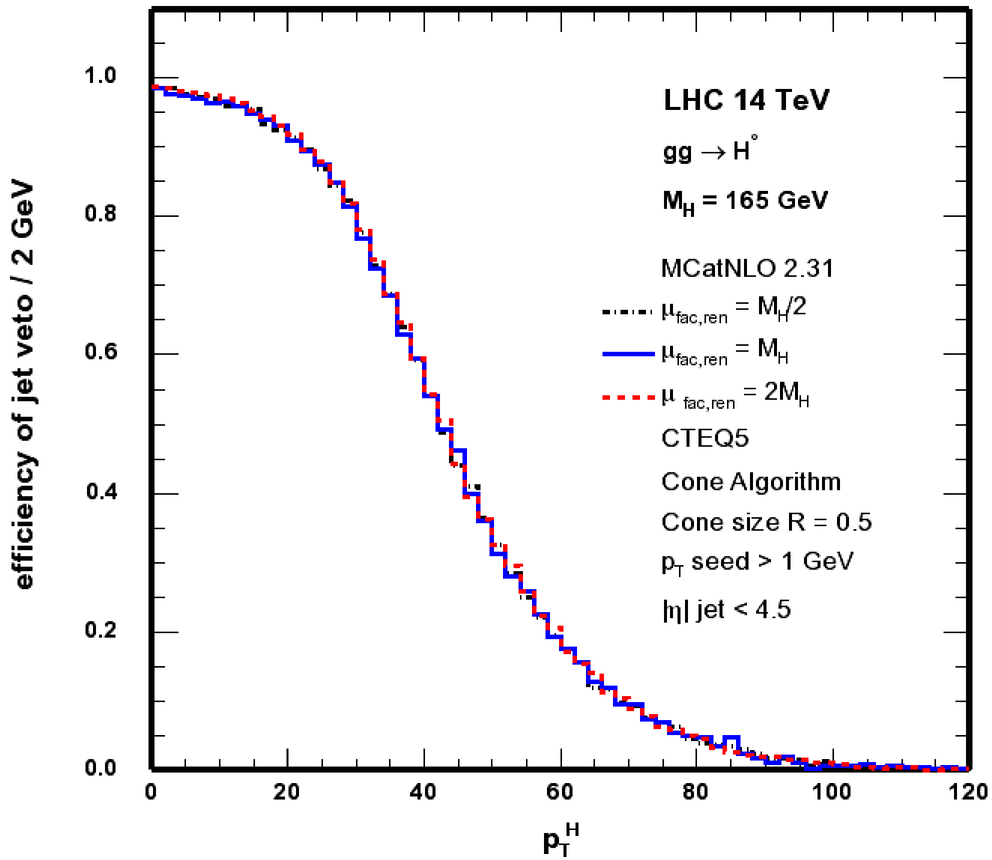
$gg \rightarrow H \rightarrow WW \rightarrow l\nu l\nu$ selection with all cuts

$gg \rightarrow H \rightarrow WW \rightarrow l\nu l\nu$ selection
(GD et al jhep05(2004)009)
shows:

small p_T Higgs region most important



Efficiency numbers of the jet veto for MCatNLO, different scales

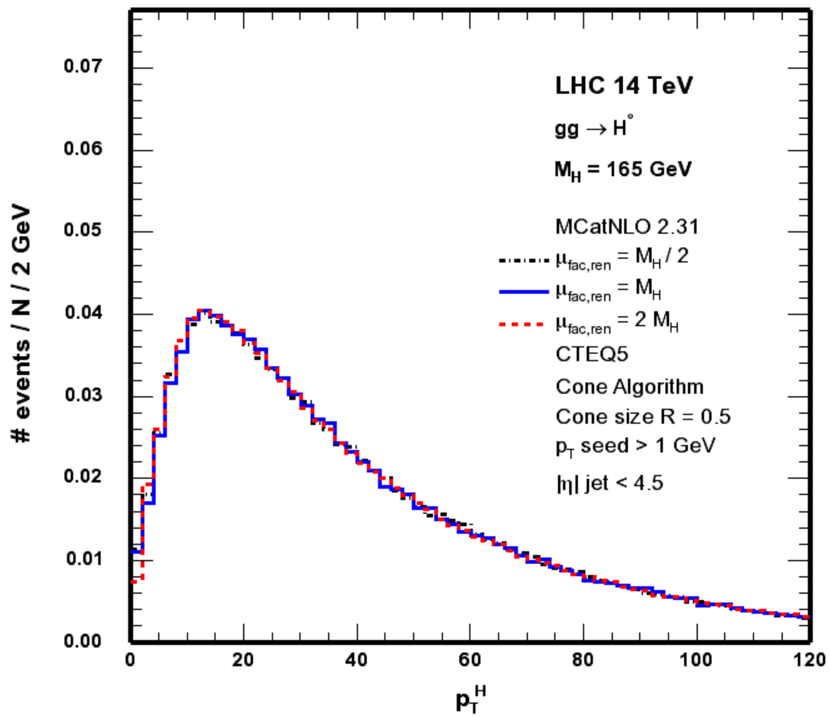


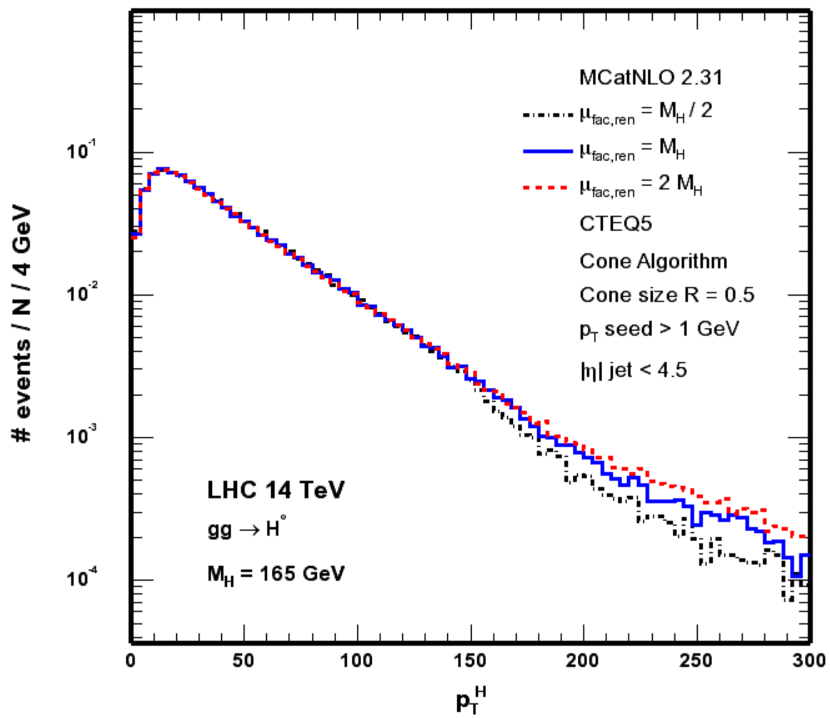
Integrated efficiency over whole p_T spectrum and up to a p_T Higgs of 80 GeV:

	ε total	ε up to 80 GeV
$\mu_{fac,ren} = M_H/2$	0.585	0.685
$\mu_{fac,ren} = M_H$	0.583	0.692
$\mu_{fac,ren} = 2\,M_H$	0.582	0.687

→ efficiency spread < 1%

p_T Higgs spectrum MCatNLO for different scales





Results

- **In low p_T region, HERWIG, MCatNLO and PYTHIA are now very similar**

- **The total efficiencies for HERWIG, MCatNLO, PYTHIA and CASCADE vary around 10%**

- **In the region of interest for the $gg \rightarrow H \rightarrow WW \rightarrow l\nu l\nu$ signal selection (up to p_T^H 80 GeV), the difference for HERWIG, MCatNLO and PYTHIA are smaller than 2% !**

- **If we smear the E_T of the jet to get realistic CMS efficiency for jet veto with jet resolution: $\Delta E_T / E_T = 118\% / sqrt(E_T) + 7\%$, the difference in the efficiencies between smeared and not smeared case is smaller than 1%**

Results

- **Including higher order corrections (by reweighting) leads to about same efficiency uncertainty as without reweighting**
- **Including UE, the difference in the efficiency between PYTHIA with and without UE is smaller than 1% (tested CDF tune A and ATLAS tune)**
- **The uncertainty of the efficiency for different scales in MCatNLO is lower than 1%**
- **Results with CASCADE have to be treated carefully**

Ongoing work

Staying with ATLAS tune, change p_T cut for UE within 3σ of fit error as proposed by Paolo Bartalini

…

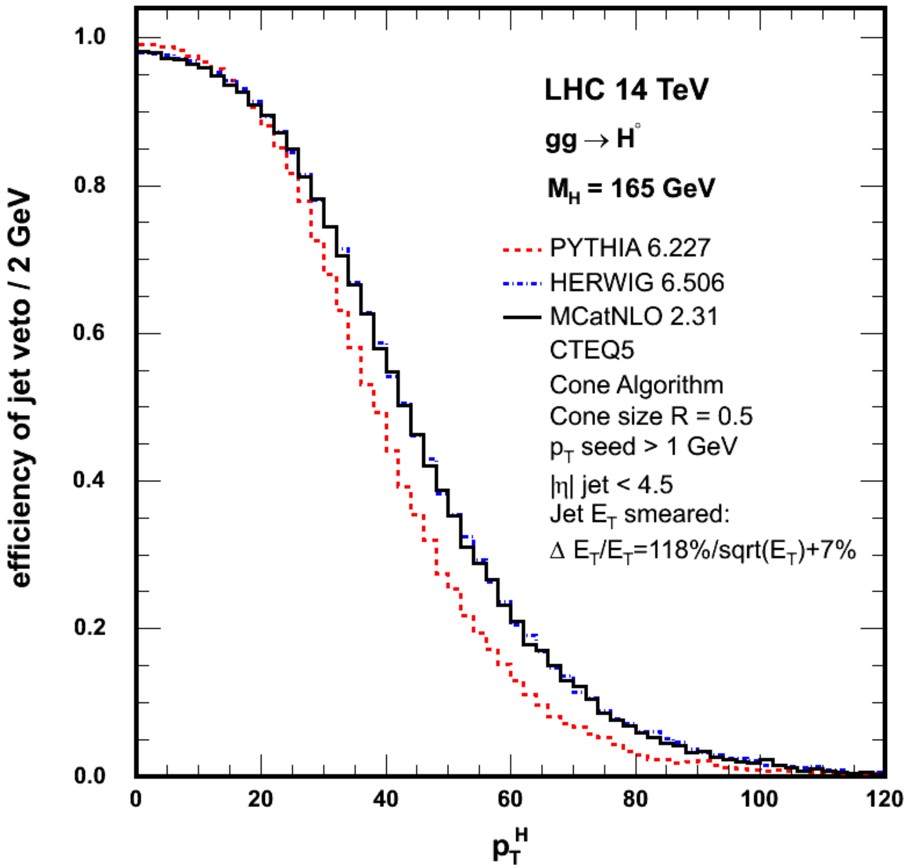
backup

Efficiency after smearing
(pythia, mcatnlo, herwig without ME correction)

Efficiency after smearing

Get realistic CMS efficiency for jet veto with smeared Jet Et:

jet resolution: $\Delta E_T / E_T = 118\% / \mathrm{sqrt}(E_T) + 7\%$



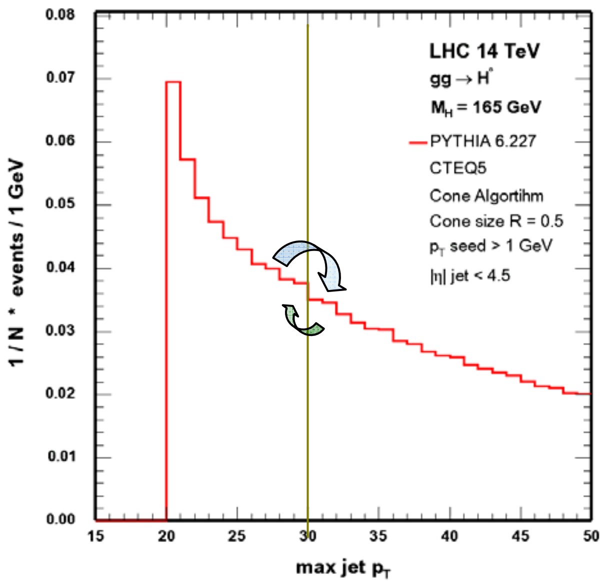
	ε	ε smeared
PYTHIA	0.61	0.61
HERWIG	0.62	0.61
MCatNLO	0.59	0.58

$p_T^H < 80$ GeV	ε	ε smeared
PYTHIA	0.72	0.72
HERWIG	0.70	0.70
MCatNLO	0.69	0.69

Efficiency after smearing

Smearing: tendency to lower efficiency,
as can be expected:

there are more jets at low pt than high pt
→smearing: more jets which had pt below 30 GeV now have pt above 30 GeV than vice versa



→ jet veto should affect more events after smearing

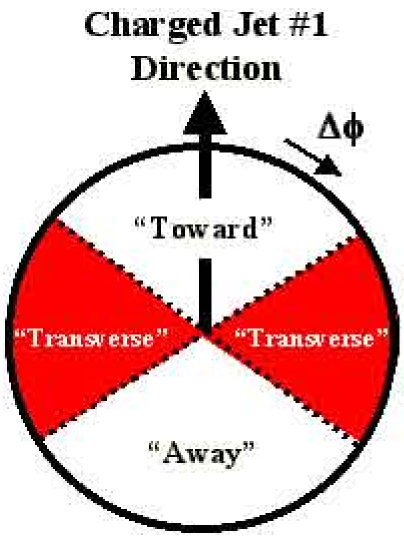
but: effect very small

Including Underlying events in Pythia

→ Estimate uncertainty for UE according to the CDF and ATLAS tunings for PYTHIA

Current PYTHIA tunings (used in CMS production)

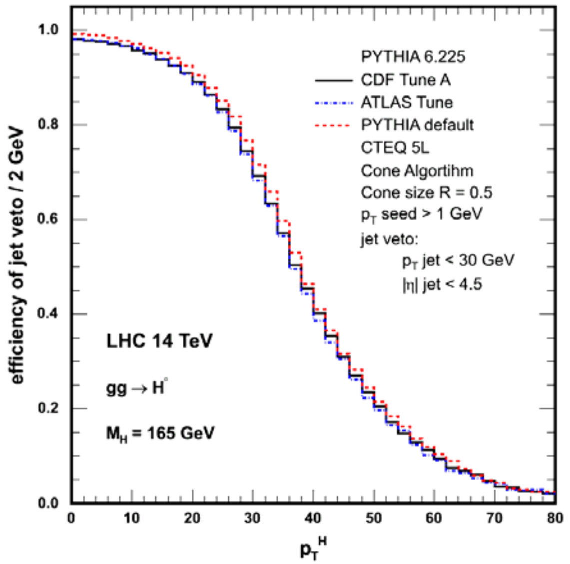
R. Field; CDF UE tuning method



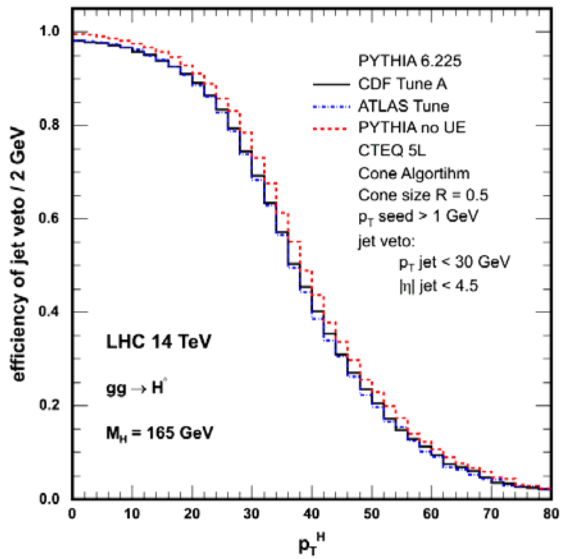
Comments	CDF – Tune A (PYTHIA6.206)	PYTHIA6.214 – Tuned (ATLAS)
Generated processes (QCD + low-pT)	Non-diffractive inelastic + double diffraction (MSEL=0, ISUB 94 and 95)	**Non-diffractive + double diffraction (MSEL=0, ISUB 94 and 95)**
p.d.f.	CTEQ 5L (MSTP(51)=7)	**CTEQ 5L (MSTP(51)=7)**
Multiple interactions models	MSTP(81) = 1 MSTP(82) = 4	**MSTP(81) = 1 MSTP(82) = 4**
pT min	PARP(82) = 2.0 PARP(89) = 1.8 TeV PARP(90) = 0.25	**PARP(82) = 1.8 PARP(89) = 1 TeV PARP(90) = 0.16**
Core radius	40% of the hadron radius (PARP(84) = 0.4)	**50% of the hadron radius (PARP(84) = 0.5)**
Gluon production mechanism	PARP(85) = 0.9 PARP(86) = 0.95	**PARP(85) = 0.33 PARP(86) = 0.66**
α_s and K-factors	MSTP(2) = 1 MSTP(33) = 0	**MSTP(2) = 1 MSTP(33) = 0**
Regulating initial state radiation	PARP(67) = 4	**PARP(67) = 1**

Jet veto efficiency with underlying events (PYTHIA)

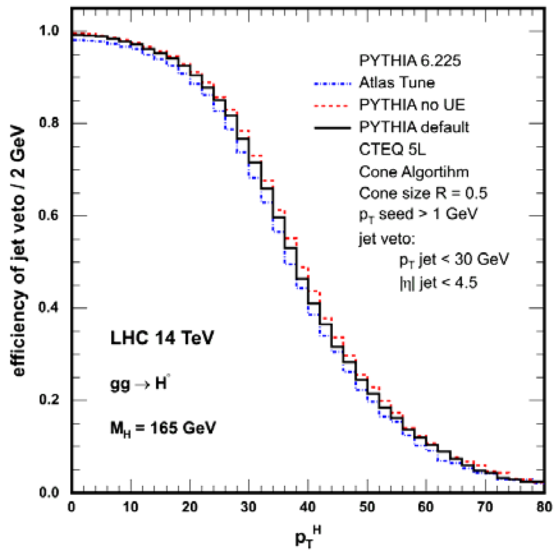
ATLAS Tune, CDF Tune A, PYTHIA default



ATLAS Tune, CDF Tune A, PYTHIA no UE



CDF Tune A, PYTHIA default, PYTHIA no UE



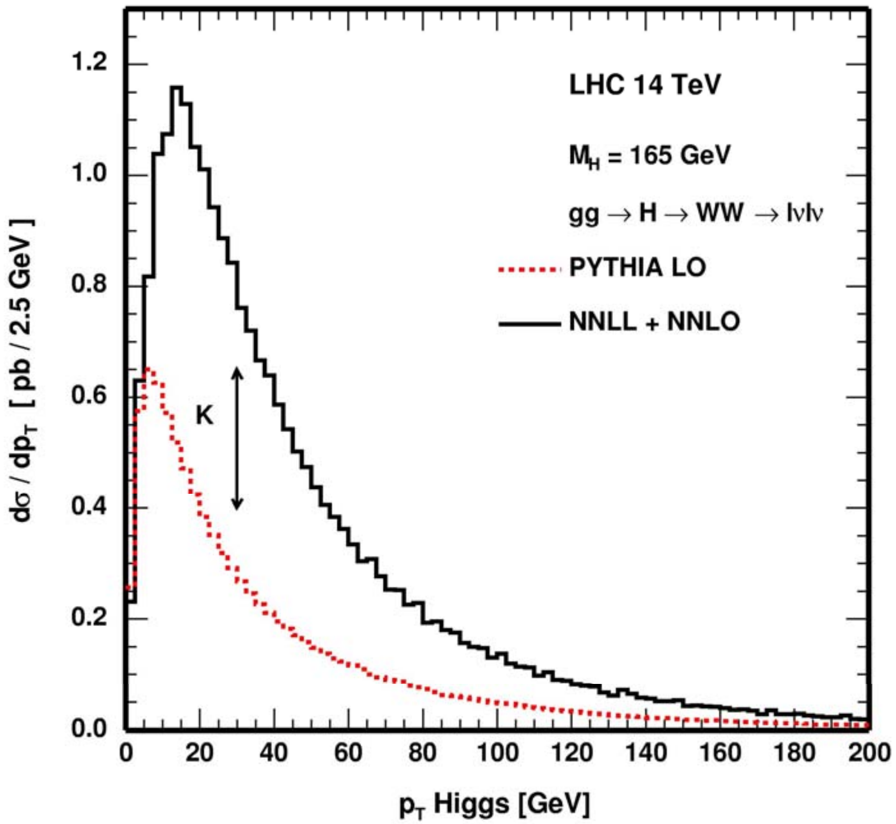
	Total ε	ε for pt^H < 80 GeV
CDF tune A	0.596	0.709
ATLAS tune	0.600	0.706
PYTHIA default	0.613	0.723
PYTHIA no UE	0.620	0.730

- **CDF and ATLAS tuning ≈ same ε**
- **PYTHIA default and tuned PYTHIA: difference < 1 %**
- **PYTHIA with and without UE: difference < 1%**

Including HO corrections

Reweighting procedure *(GD et al. jhep05(2004)009)*

Simple method to include HO QCD corrections



gg→H→WW→lνlν :

pt Higgs balanced by pt jets

cannot use const. K-factor
(because of jet veto)

Reweight Pythia with effective
pt-dependent K-factors

Very promising results!

(for M_H=165 GeV, 5σ with already 0.4 fb^{-1})

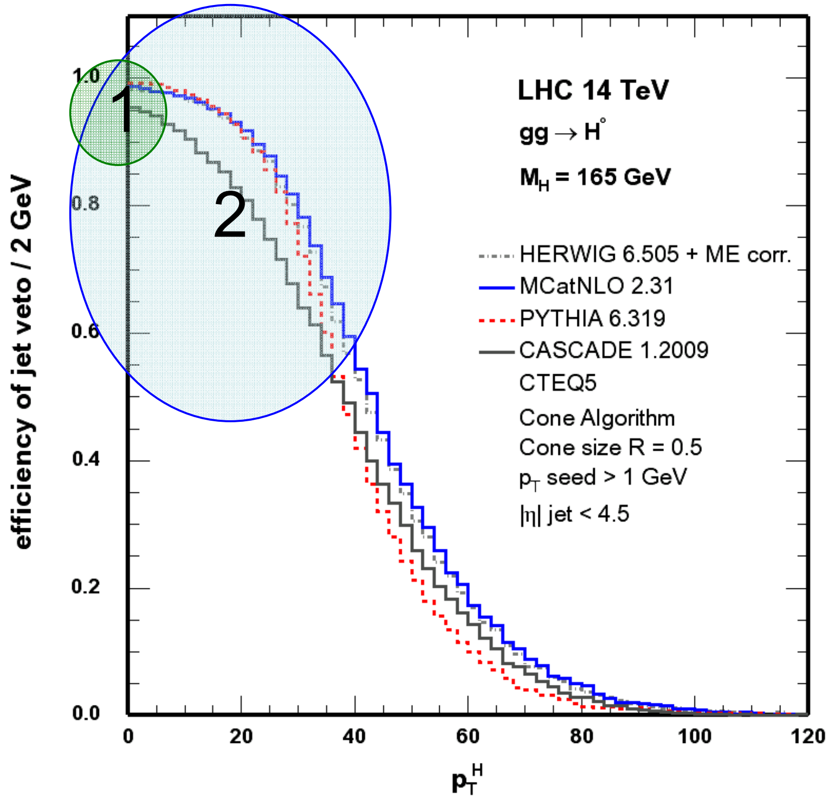
Results:

Integrated efficiency for PYTHIA, HERWIG and MCatNLO and after reweighting

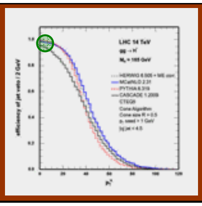
	ε	ε reweighted
Pythia 6.225	**0.62**	**0.56**
Herwig 6.505	**0.63**	**0.60**
MCatNLO 2.31	**0.59**	**0.57**

Analyse of Cascade efficiency shape

Efficiency of jet veto with CASCADE



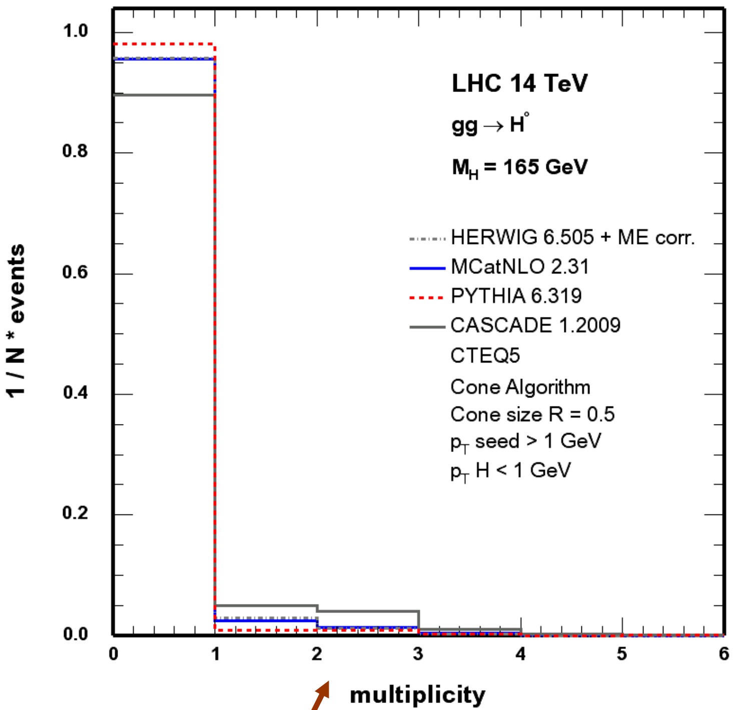
Jet veto at 30 GeV

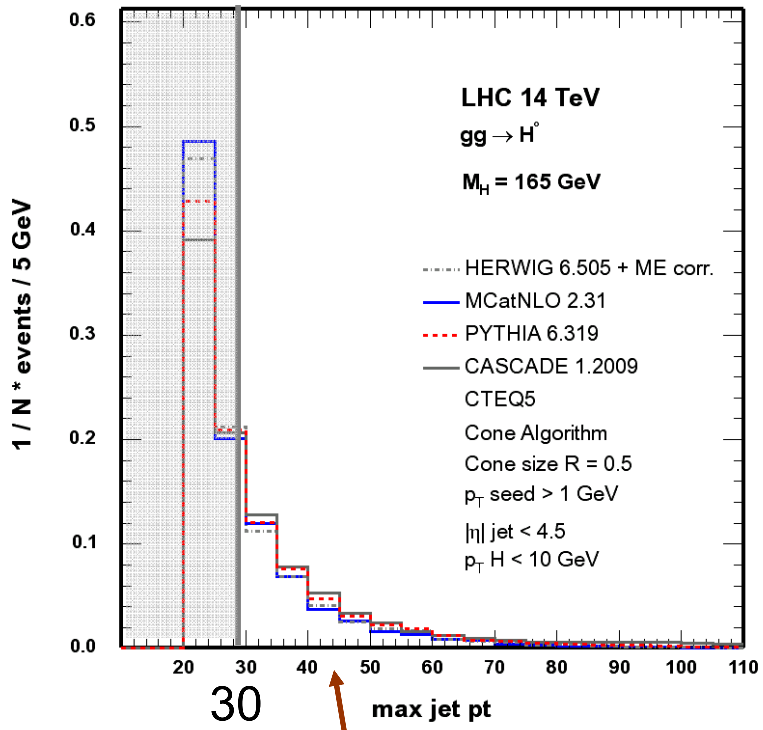


1. Efficiency at p_T Higgs = 0 GeV

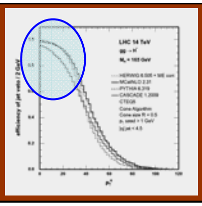
Why is the efficiency not 1 at p_T Higgs = 0 GeV ?

Possible answer: p_T Higgs balanced by more than 1 jet. Σ p_T jets = 0 ($\approx$ p_T Higgs), but at least one jet has a p_T higher than 30 GeV → jet veto removes event





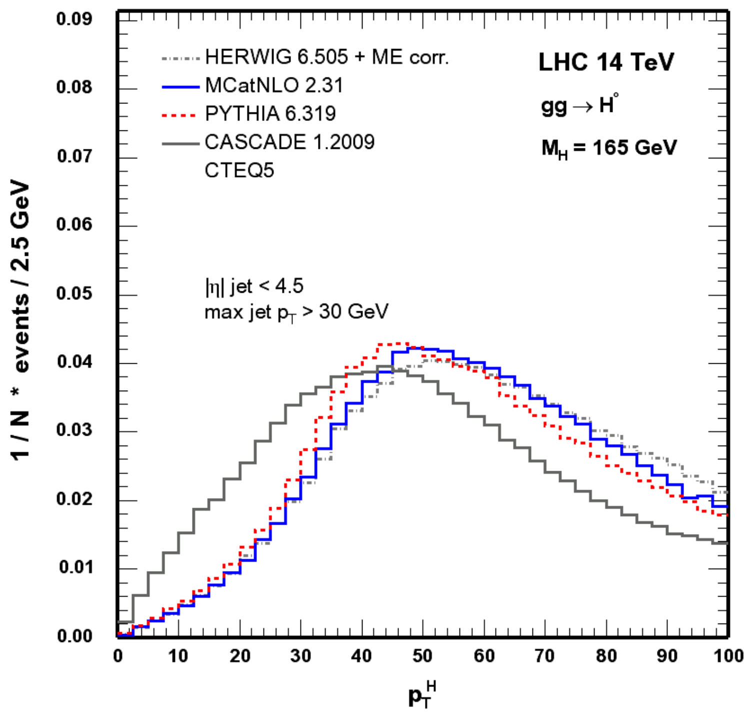
Indeed! At very low p_T Higgs:
CASCADE has more events with jets and the jets are harder than in other MCs



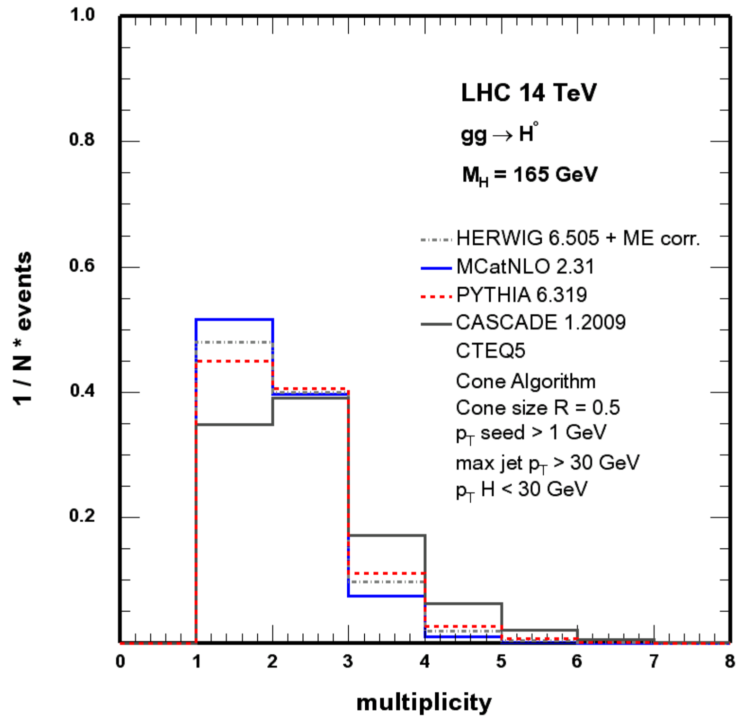
2. Efficiency for CASCADE between p_T Higgs 0 and 30 GeV

p_T Higgs spectrum for max jet pt > 30 GeV:

more events at low p_T Higgs with a max jet pt > 30 GeV in CASCADE than in the other MCs
those events will be removed → jet veto for CASCADE more efficient



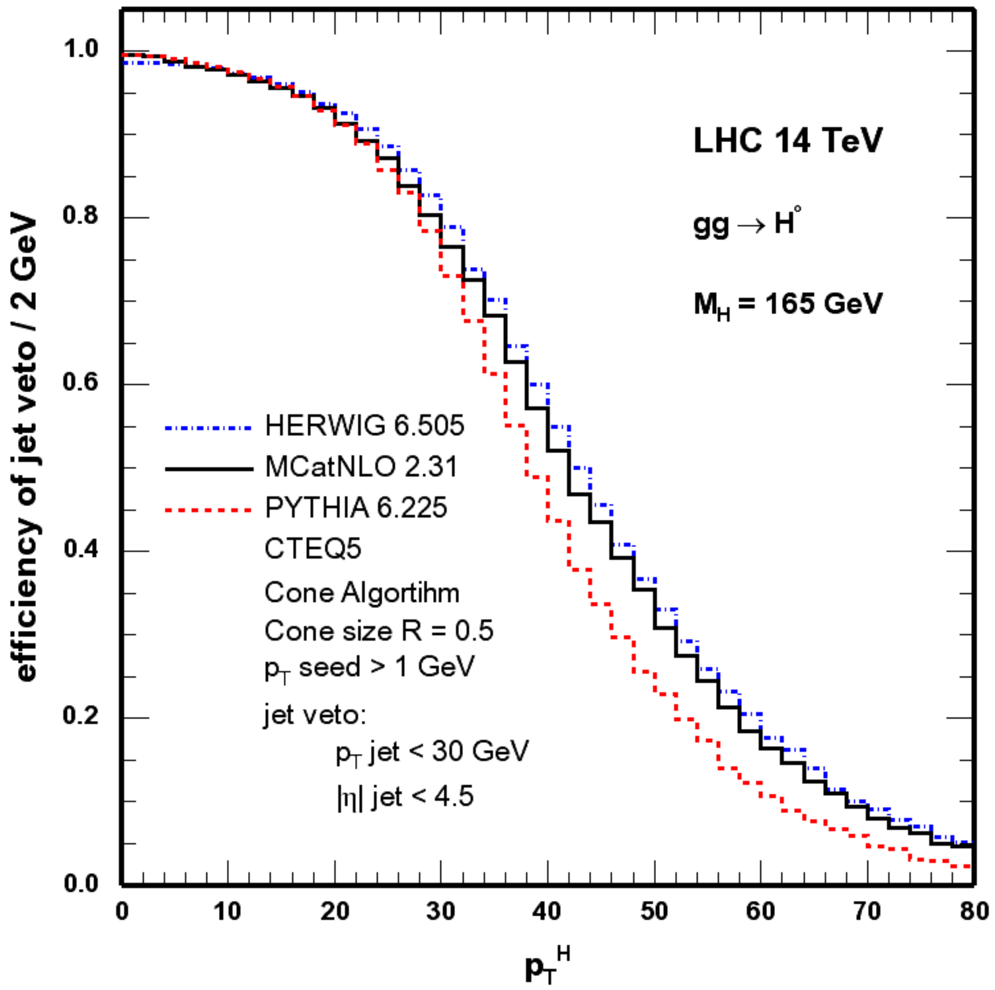
max jet pt > 30 GeV



max jet pt > 30 GeV, p_T Higgs <30 GeV

Efficiency for the jet veto with Herwig without ME correction

Efficiency for the jet veto



Differences vary over the pt spectrum:

eg :

- **pt H < 20 GeV: differences very small**
- **pt H ≈ 50 GeV : difference around 30%**

Integrated efficiency over whole pt spectrum:

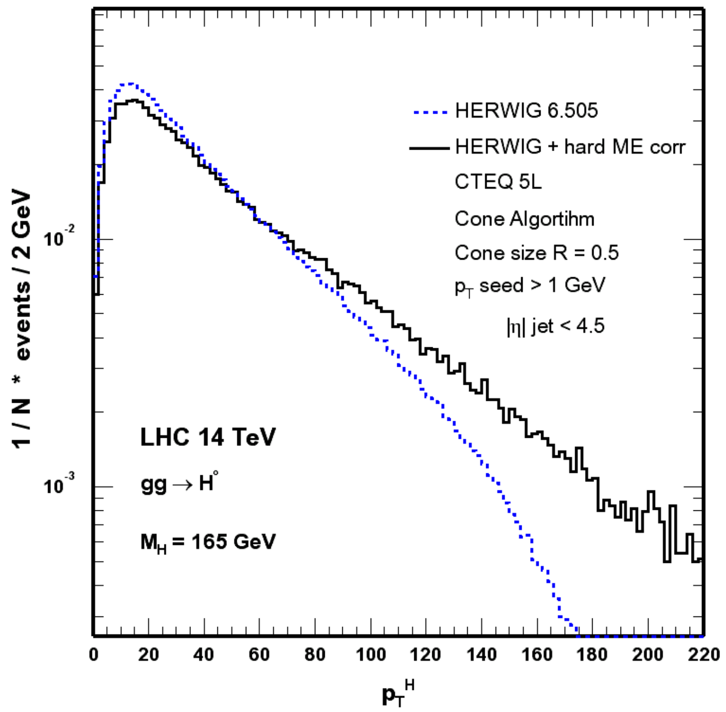
	ε
PYTHIA	0.62
HERWIG	0.63
MCatNLO	0.59

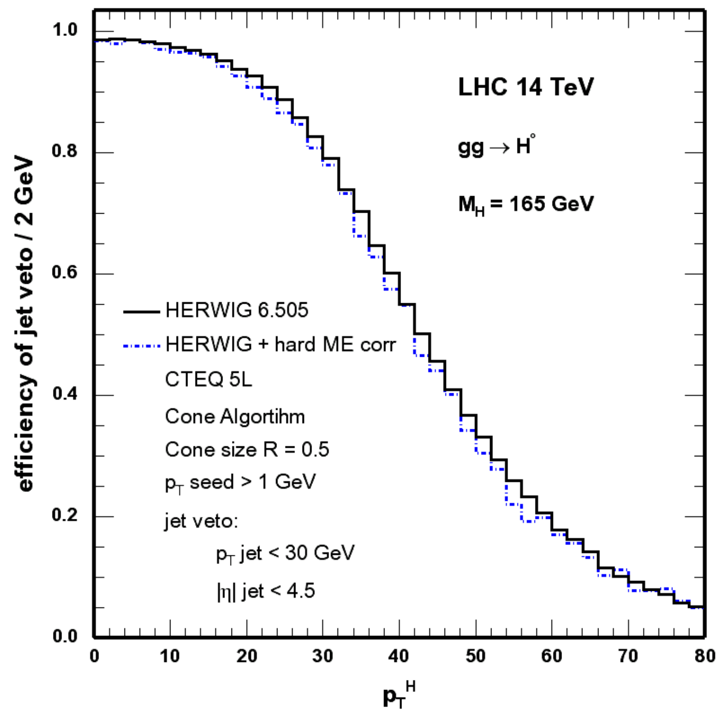
→ efficiency spread < 5%

Herwig with ME correction

HERWIG + ME Corrections

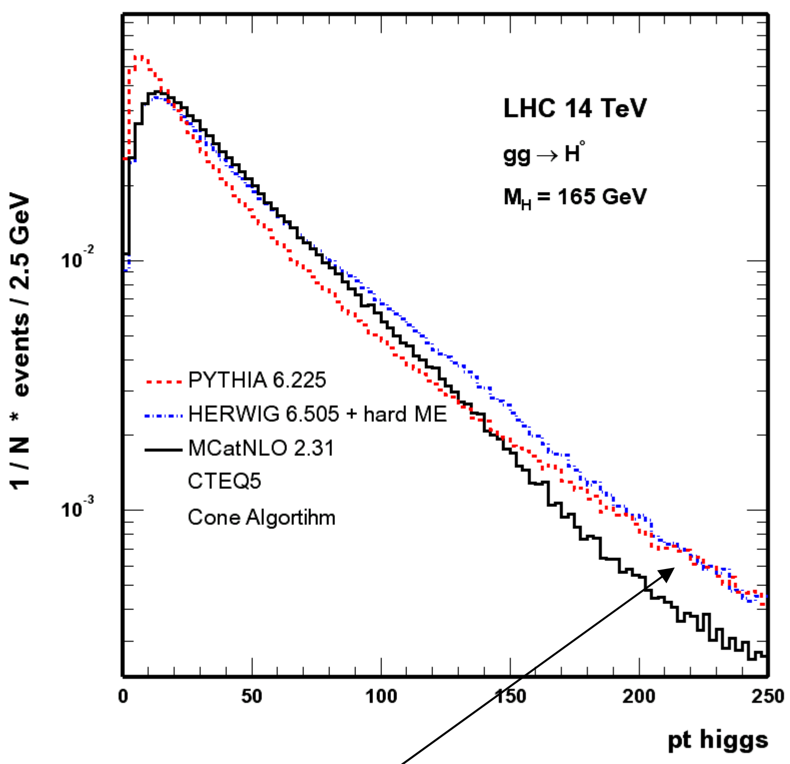
if hard ME corrections included *→ more jets with high pt
→total σ the same → less jets with low pt
→ overall efficiency ≈ 0.55 (10% smaller than for HERWIG 6.505)

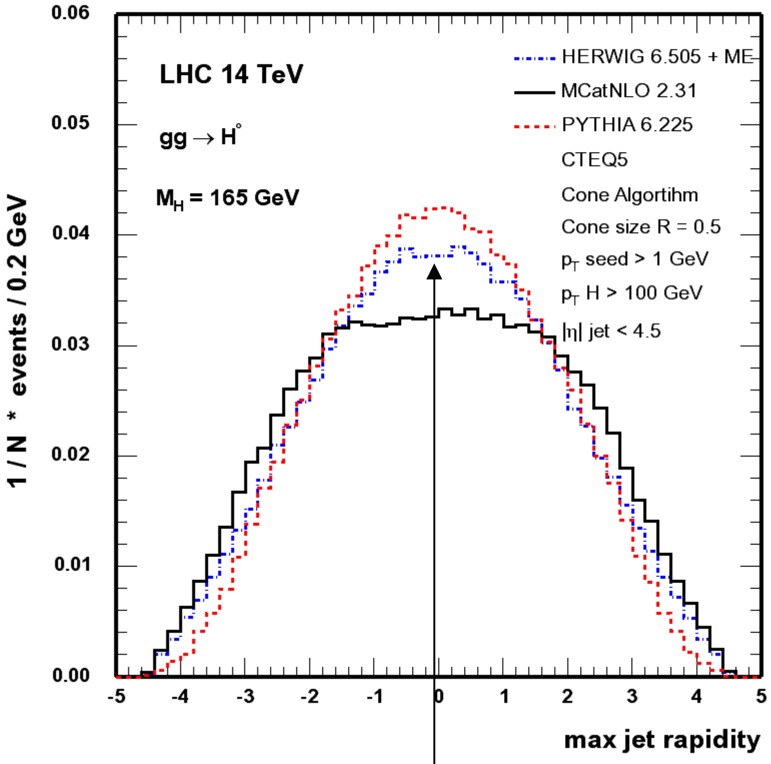




* This preliminary HERWIG + hard ME version was provided by G. Corcella (see Phys.Lett.B 590 (2004)249-257)

HERWIG + ME Corrections



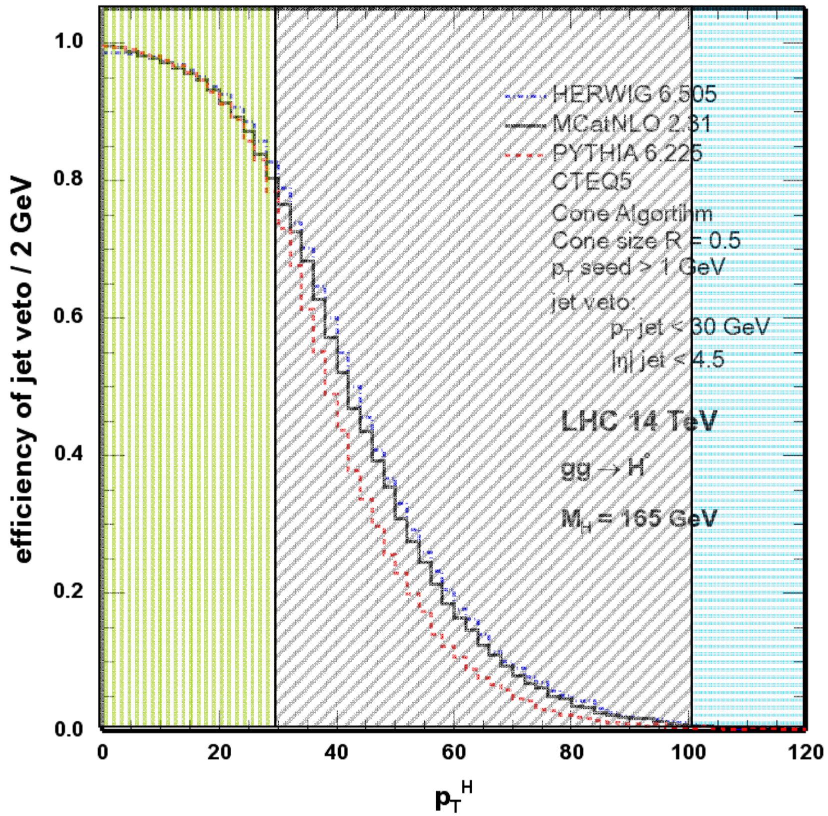


High pt: Pythia + Herwig ≈ same

Pythia + Herwig: Similar rapidity shape also for pt Higgs>100 GeV

Different pt Higgs regions with Herwig without ME correction

To understand differences between the MC's: look at particular pt Higgs regions



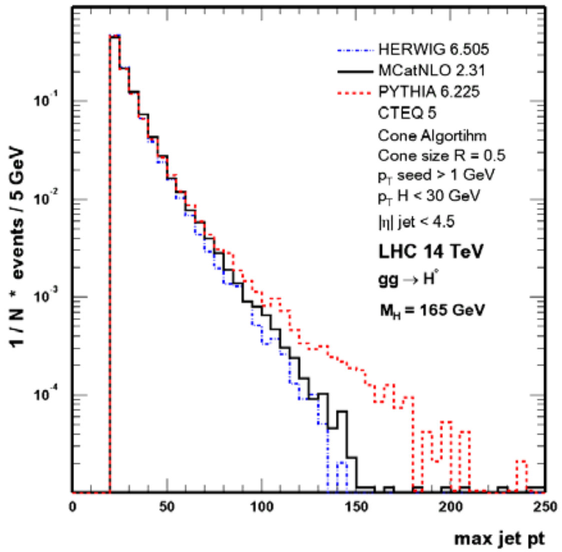
A) pt Higgs < 30 GeV

B) 30 GeV ≤ pt Higgs <100 GeV

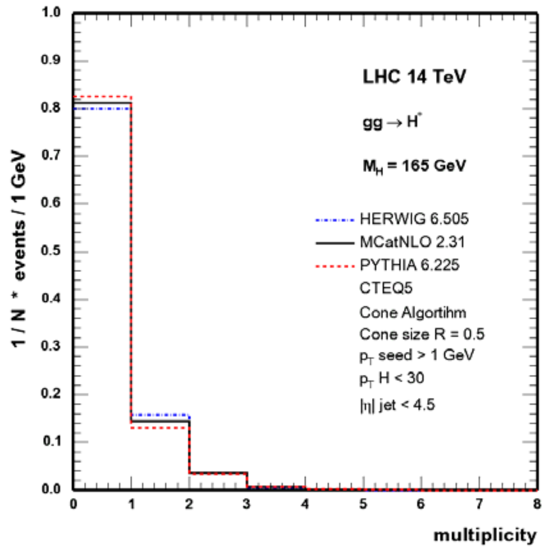
C) pt Higgs ≥100 GeV

A) pt Higgs < 30 GeV

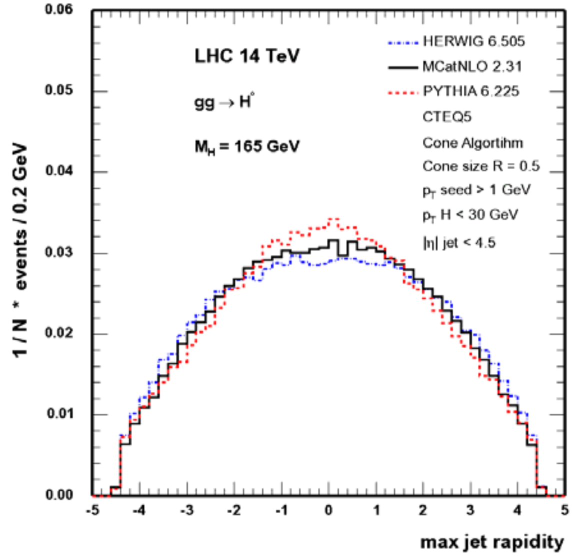
max jet pt



multiplicity



max jet rapidity

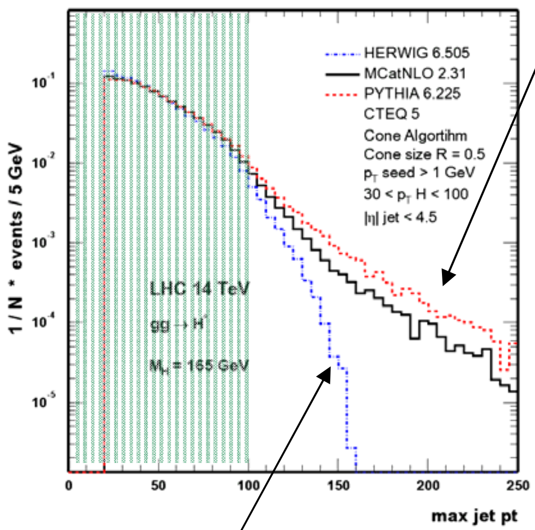


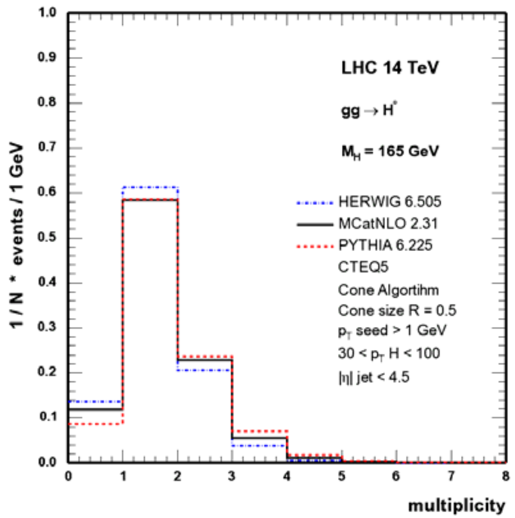
essentially identical distributions,
minor effects for very high pt

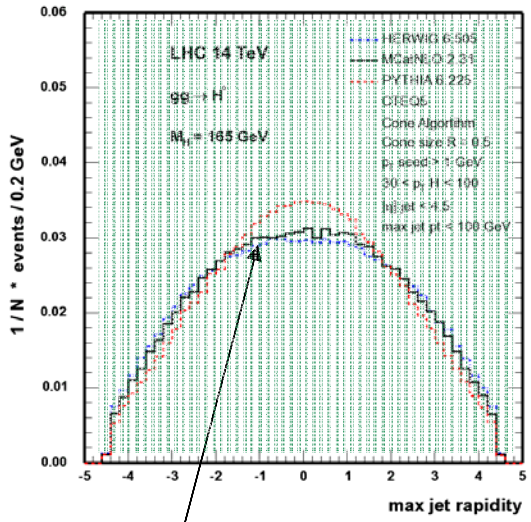
B) 30 GeV ≤ pt Higgs < 100 GeV

max jet pt | **multiplicity** | **max jet rapidity**

Pythia/MCatNLO: m(top)→ ∞ / m(top) exact , Λ_{QCD} , pdf





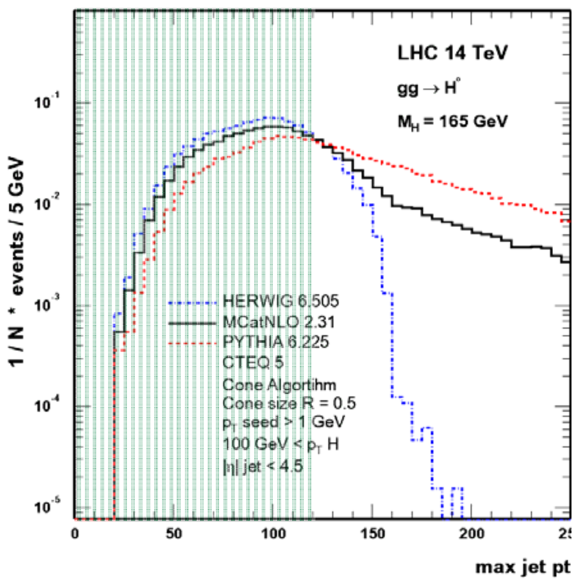


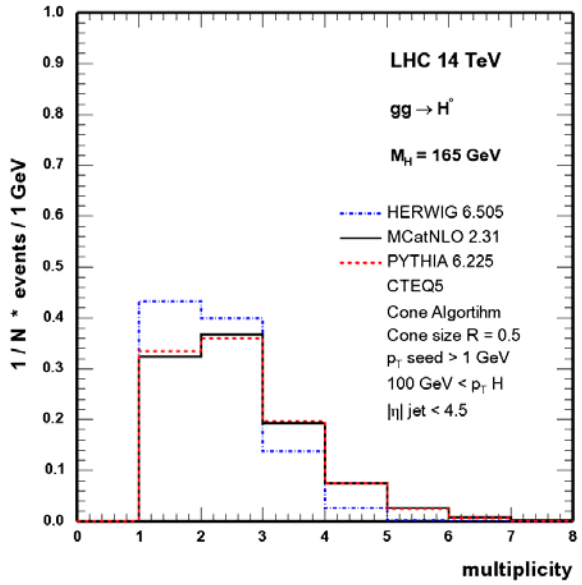
Herwig has no hard ME corrections

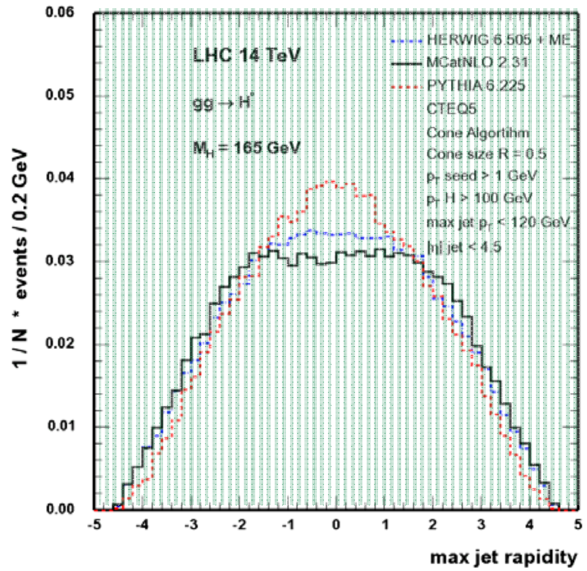
Pythia has more central jets

C) 100 GeV ≤ pt Higgs

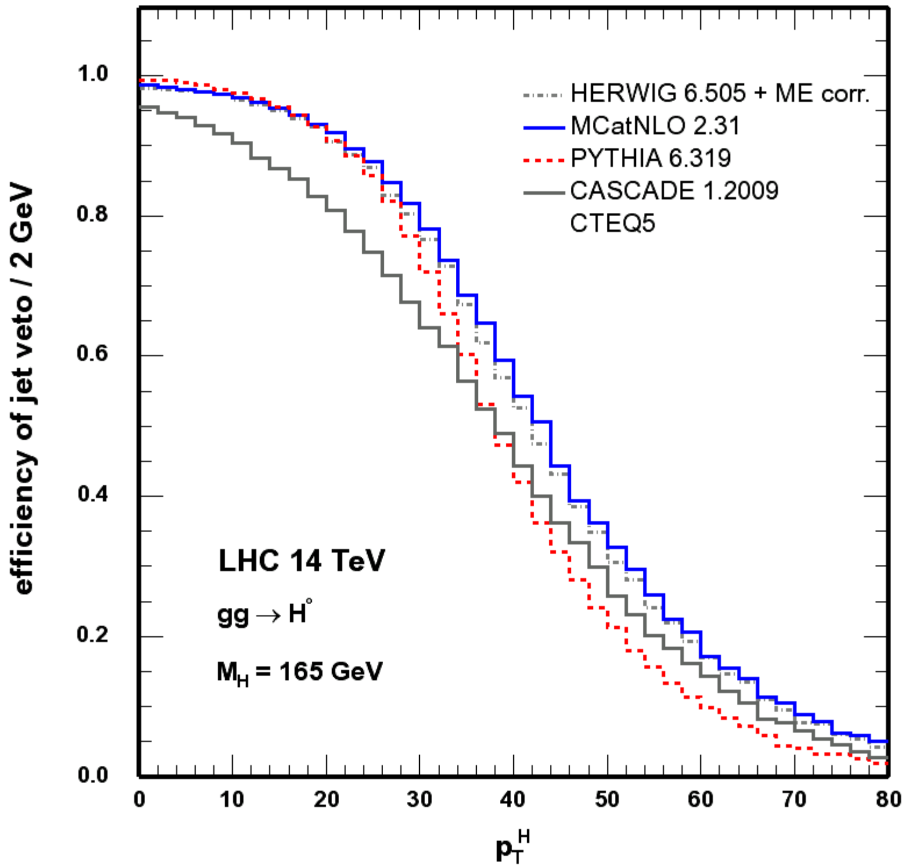
max jet pt **multiplicity** **max jet rapidity**







Efficiency numbers of the jet veto old



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