Track Jets in VBF $H \to WW$

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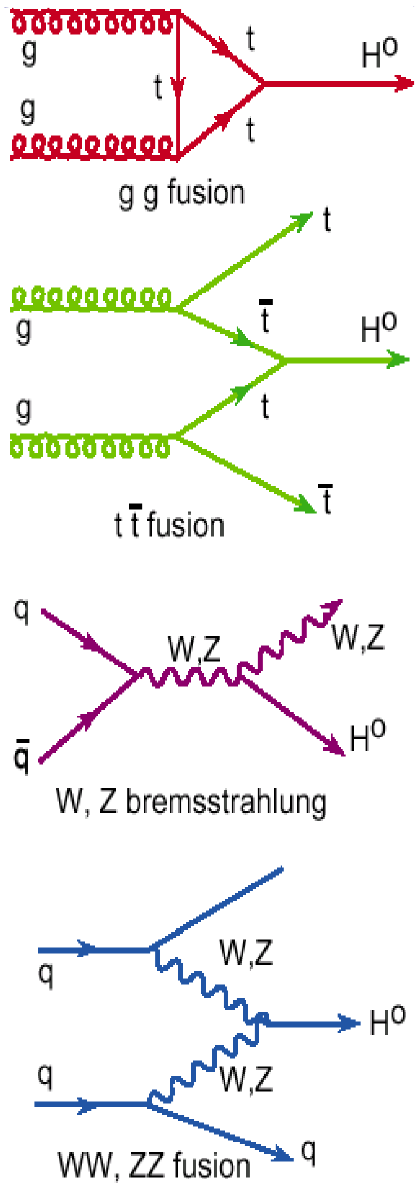
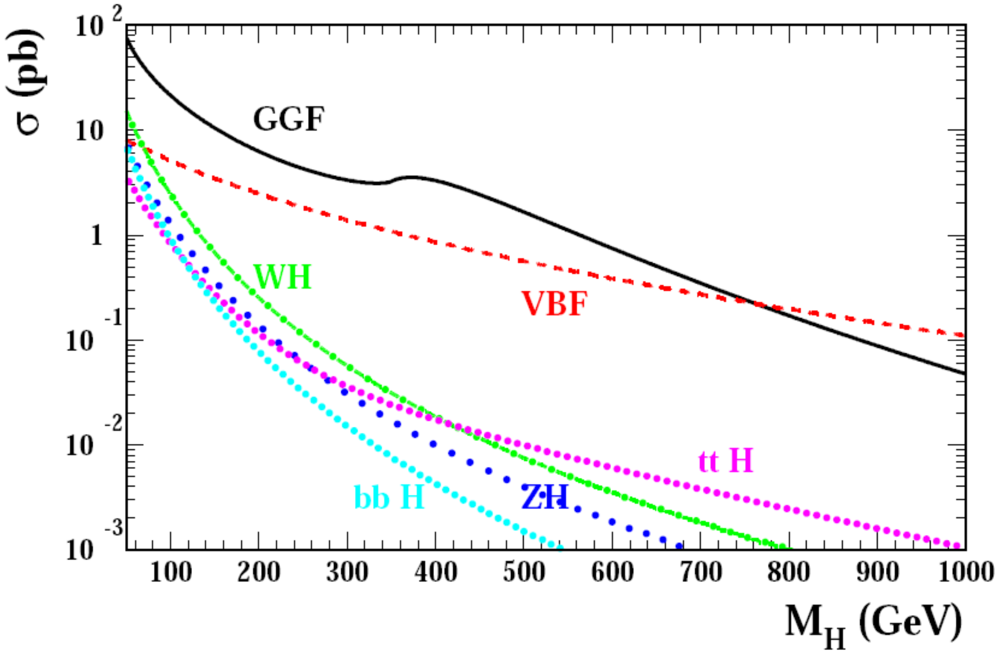
SM Higgs Production

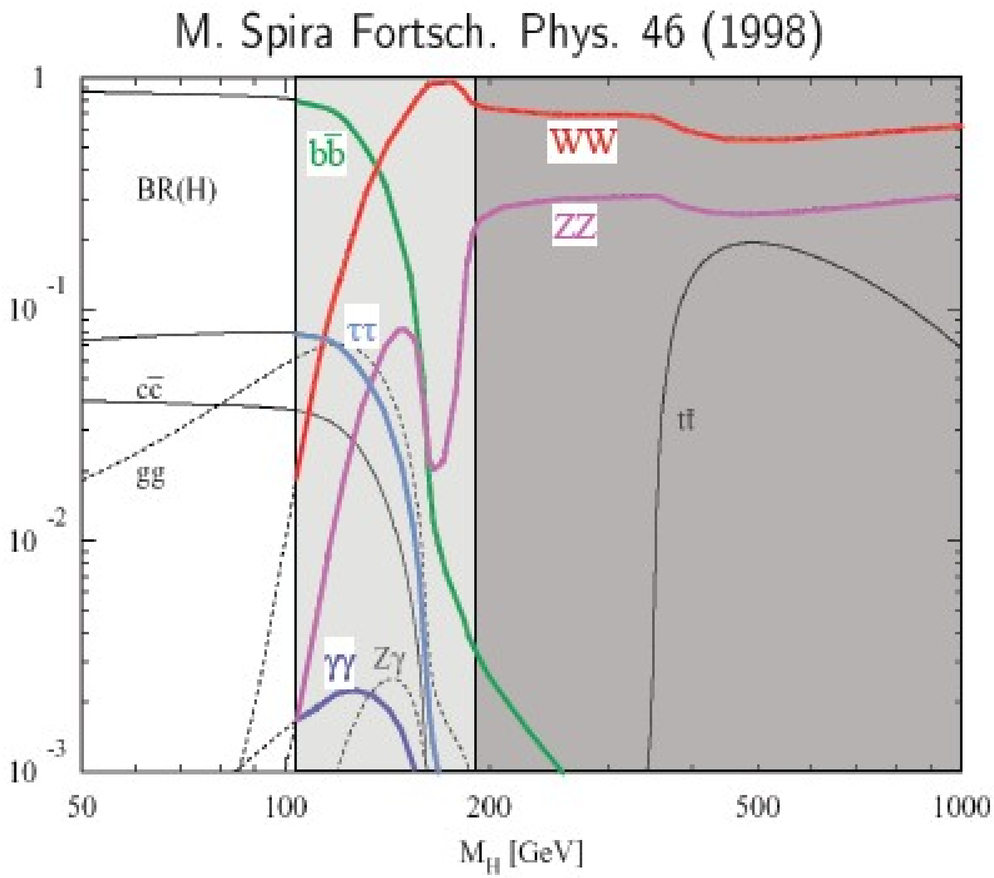




- Gluon fusion dominant up to 800 GeV
- σ(VBF) ~ 0.2 σ(gluon fusion) at low masses
  ~ σ(gluon fusion) for large M_H
- HW, HZ, Htt only relevant for small M_H

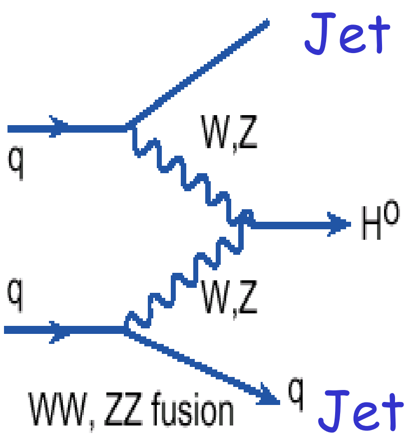
VBF ... Vector Boson Fusion

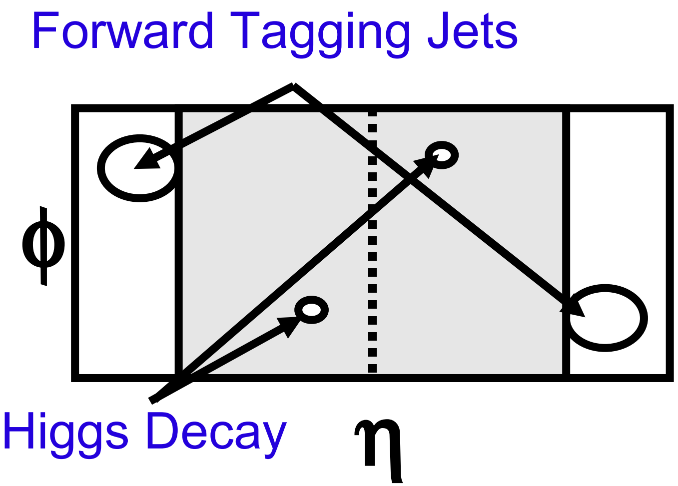
SM Higgs Decays



- M_H < 114.4 GeV (at 95% CL) excluded by LEP
- For $M_H < 2M_W$:
  - $H \to bb$, $\to \tau\tau$ dominant
  - $H \to \gamma\gamma$ small but also relevant (high precission γ reconstruction)
- For $M_H > 2M_W$:
  - $H \to WW$, $\to ZZ$ dominant

Higgs Production via VBF: qq $\rightarrow$ qqH





<u>Signature</u>:

• 2 forward jets with large rapidity gap

• Suppressed central-jet activity

$\rightarrow$ Only Higgs-decay products in central part of the detector

Motivation

<u>Motivation</u>:

• Central-jet veto (cjv) crucial in VBF channels

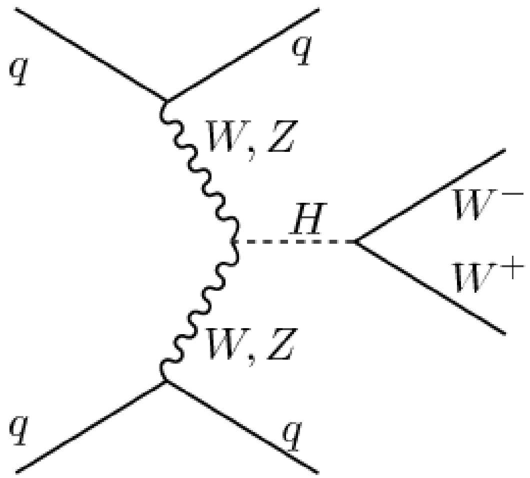
• Additional jets from pile-up events can spoil the cjv efficiency

$\rightarrow$ Vertex information from tracks allows to separate particles from different inelastic pp collisions

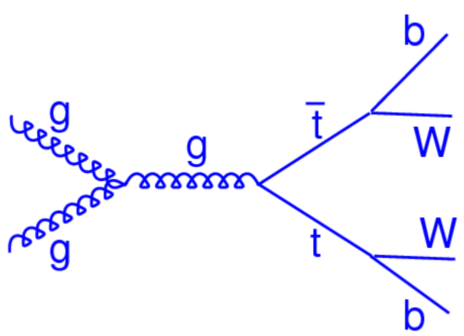
<u>Strategy</u>: (to avoid central jets created by pile-up)

1. Select vertex with highest E_T sum of tracks emerging from it
2. Reconstruct jets based on tracks emerging from this vertex

Data Samples



- 5322: VBF H $\rightarrow$ WW $\rightarrow$ ll, m_H=170 GeV (Pythia)
  - w/o pile-up: 15k
  - w/ pile-up: 12k



- 5200: $t\bar{t}$ (MC@NLO)
  - w/o pile-up: 596k
  - w/ pile-up: 509k

Only release 12.0.6 samples used for these studies

Track-Jet Reconstruction

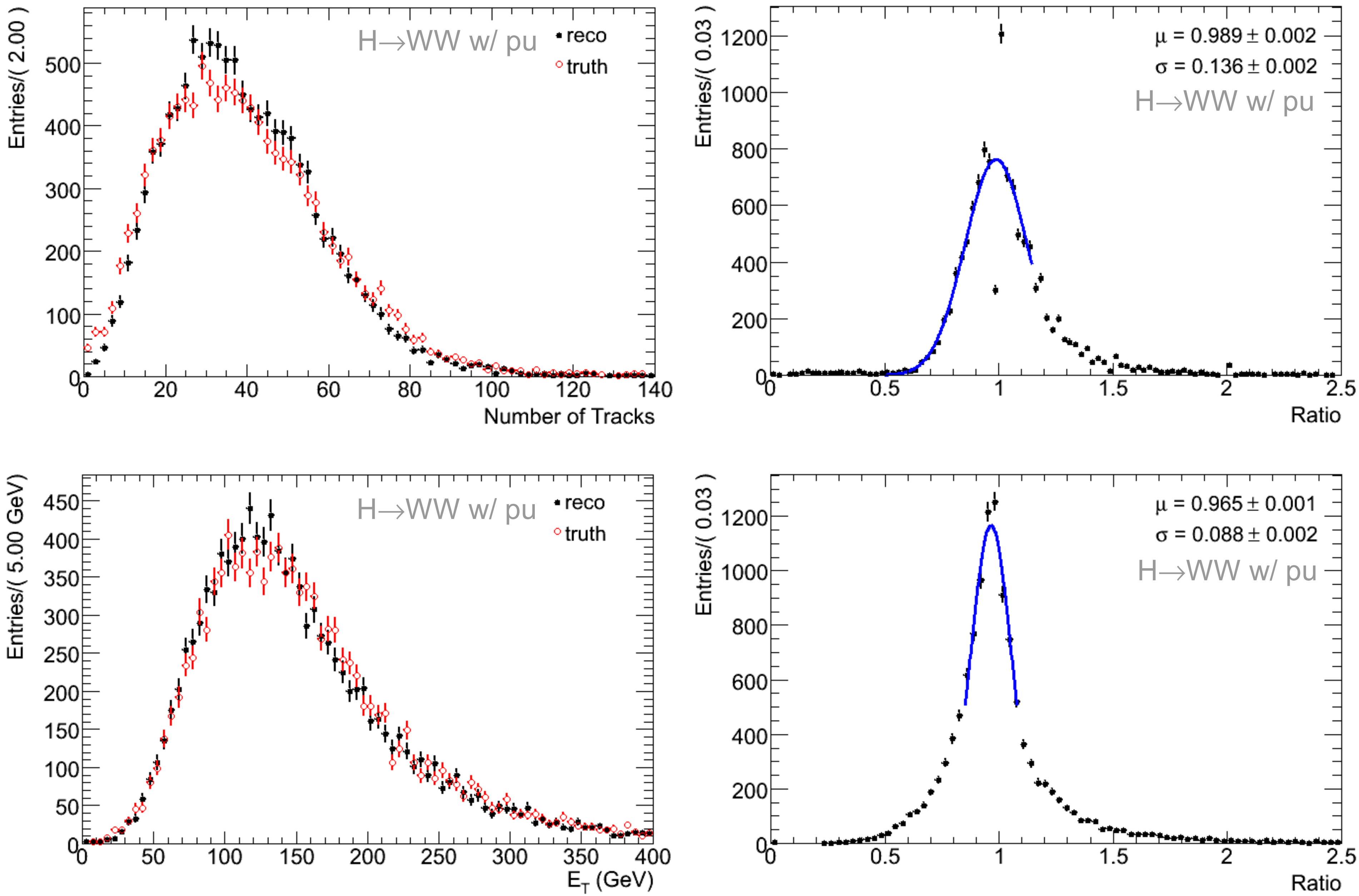
Track Jets:

- Cone-4 algorithm performed on TrackParticleCandidate's emerging from highest E_T vertex
- Skip tracks which can be matched to isolated leptons coming from the same vertex (loose electrons and staco muons with track match)
- Isolation: ΣE_T(tracks from same vertex) in cone($0.01 < \Delta R < 0.2$) < 5 GeV

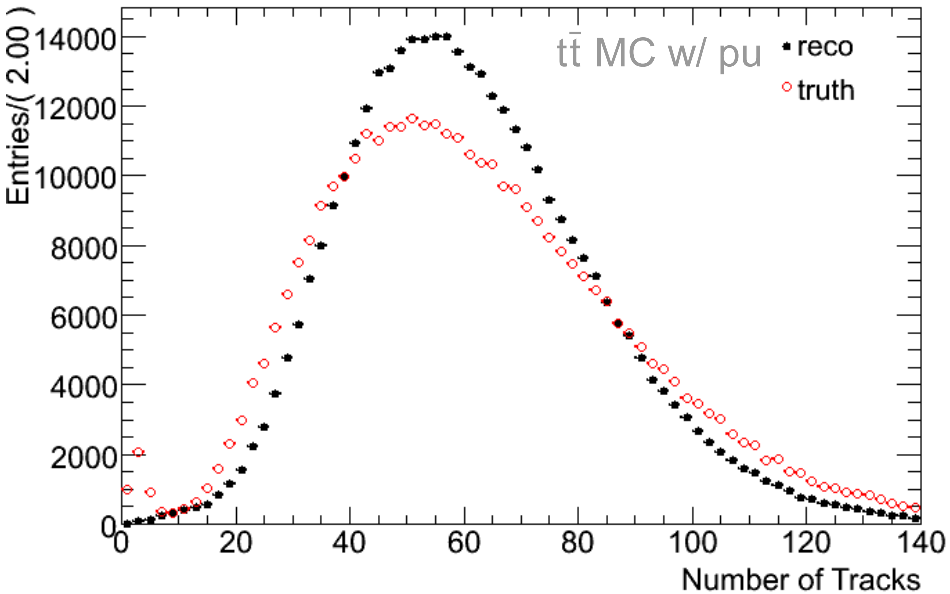
Truth Track Jets:

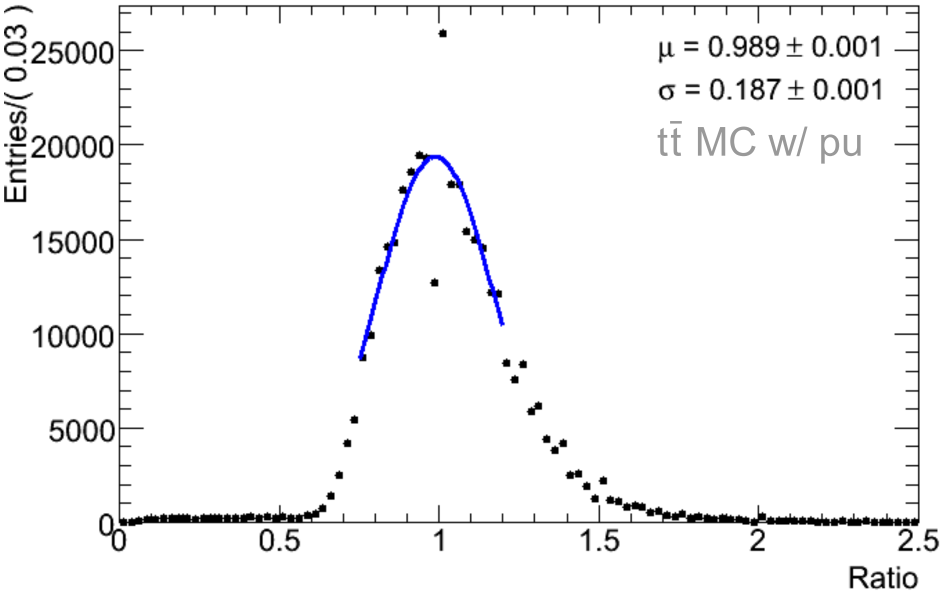
- Truth vertices with a distance of < 165 μm confined to one vertex (impact parameter resolution of single track is 55 μm)
- No vertex finding algorithm
- Isolation: E_T cut is chosen such to obtain same cut efficiencies as for reconstructed leptons

Vertex-Selection Performance



Vertex-Selection Performance





- Truth vertex selection works fine on H$\rightarrow$WW
- Does not work well on more complicated topologies such as $t\bar{t}$

$\rightarrow$ Current approach too simple

$\rightarrow$ Vertex reconstruction algorithm should be run on truth particles

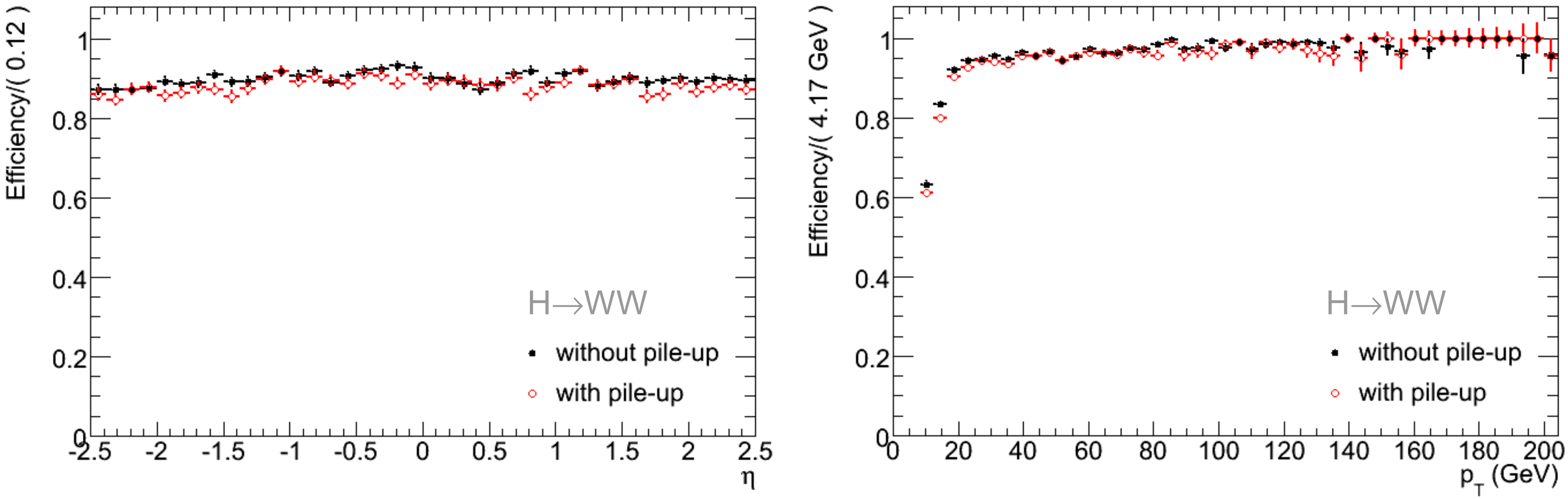
Track-Jet Performance

$$\text{Efficiency} = \frac{\text{nb of truth jets with matched reco jet in } \Delta R = 0.4}{\text{total nb of truth jets}}$$

$$\text{Fakerate} = \frac{\text{nb of reco jets w/o matched truth jet in } \Delta R = 0.4}{\text{total nb of reco jets}}$$

Due to a bug in the 12.0.x pile-up samples concerning the truth information no values are given for standard jets.

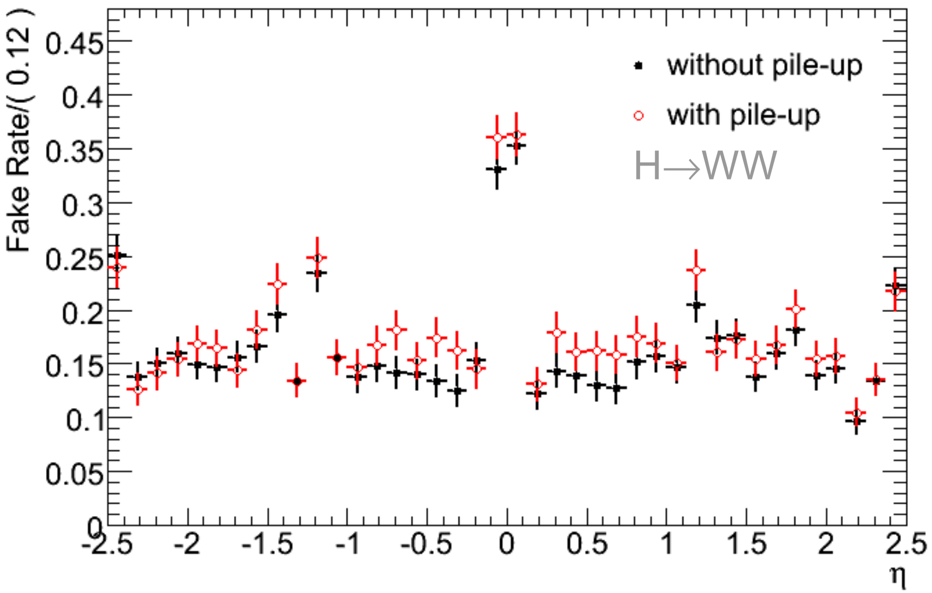
Track-Jet Efficiency



	w/o pile-up		w/ pile-up
H→WW	89.8	90.8	88.3
$t\bar{t}$	88.6	91.7	87.8

— Track Jets
— Std Jets (|η|<2.5)

Track-Jet Fake-Rate



	w/o pile-up		w/ pile-up
H→WW	17.5	14.4	18.7
$t\bar{t}$	31.1	8.0	31.5

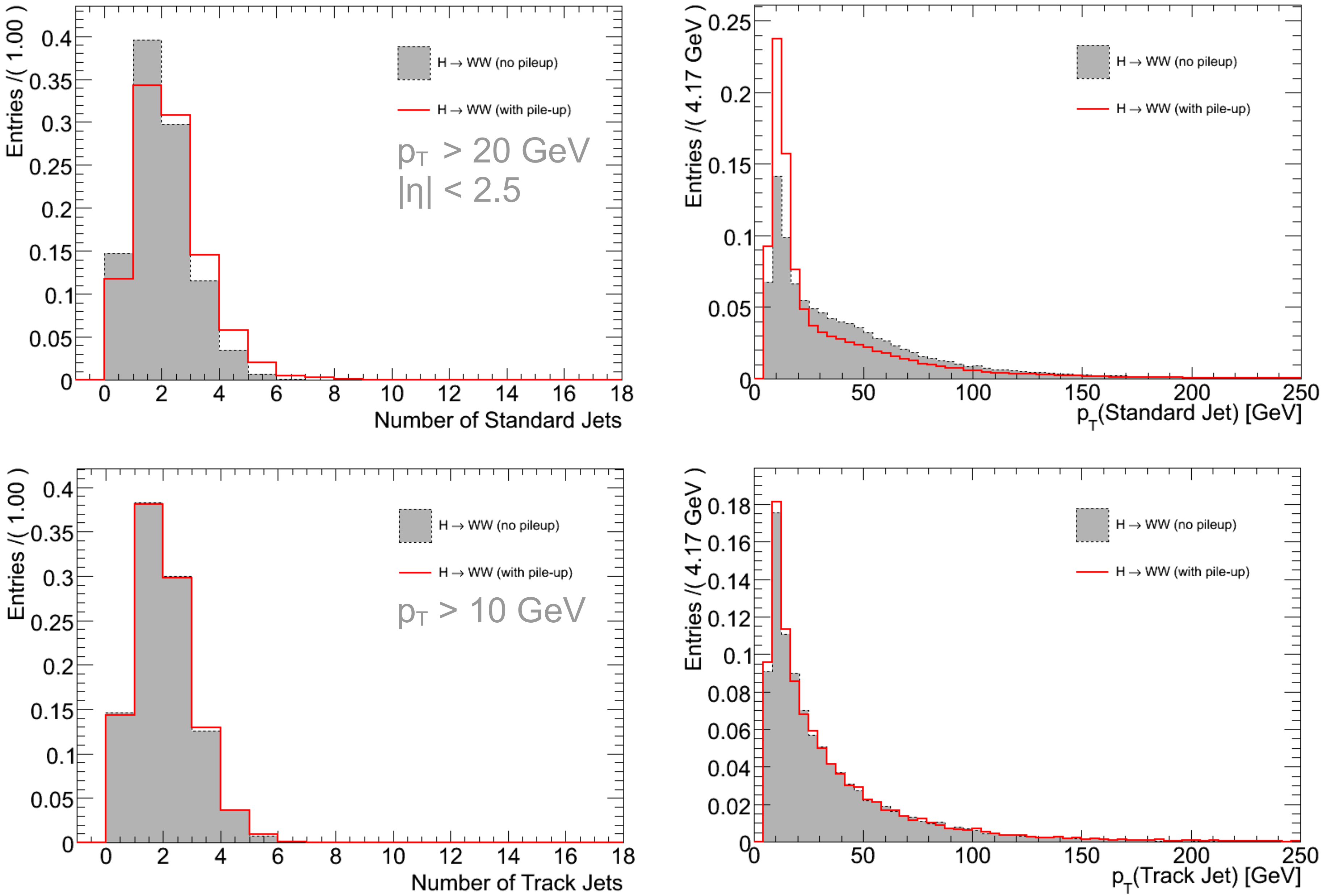
—— Track Jets
—— Std Jets (|η|<2.5)

- Track-jet efficiency and fake rate independent of pile-up
- Track-jet fake-rate rather high on $t\bar{t}$

→ Imperfect truth vertex selection

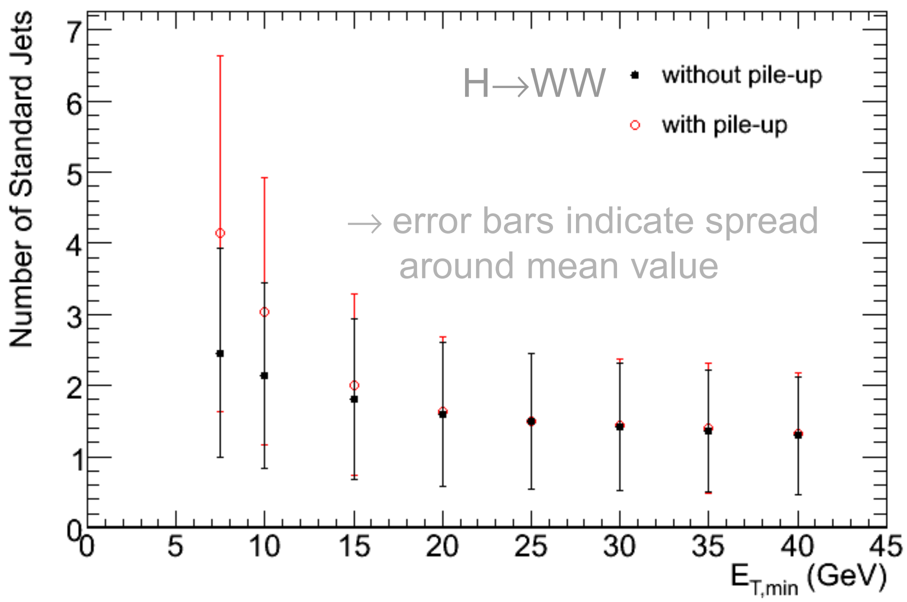
→ Isolation cuts of leptons for thruth track jets determined on H→WW

Jet Multiplicity and p_T Distribution

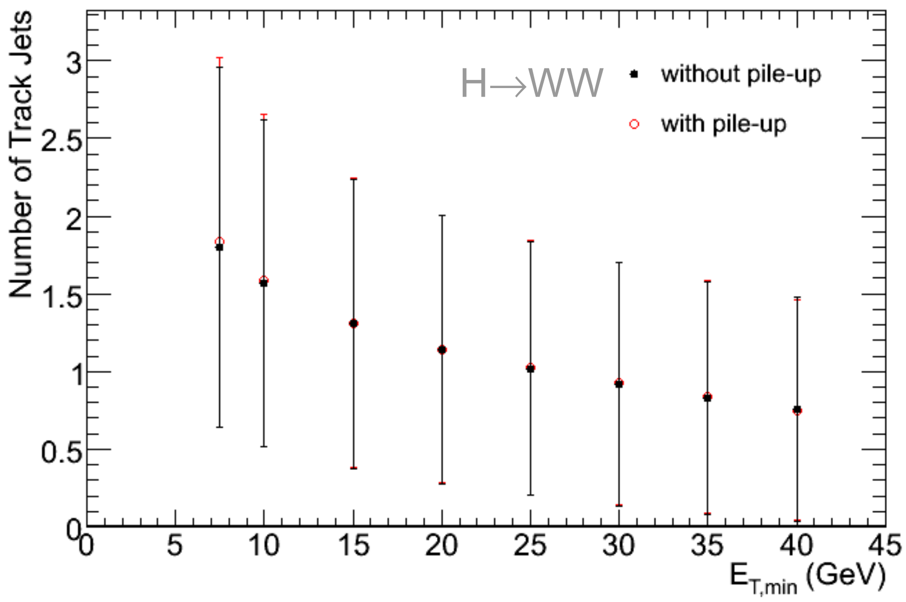


Jet Multiplicities

Standard Jets (|η|<2.5)



Track Jets



- Pile-up leads to additional standard jets at low E_T (as expected)
- Number of standard jets with $E_{T,min}$ > 20 GeV rather independent of pile-up
- Very good agreement of the number of track jets w/ and w/o pile-up

Event Selection

Preselection:

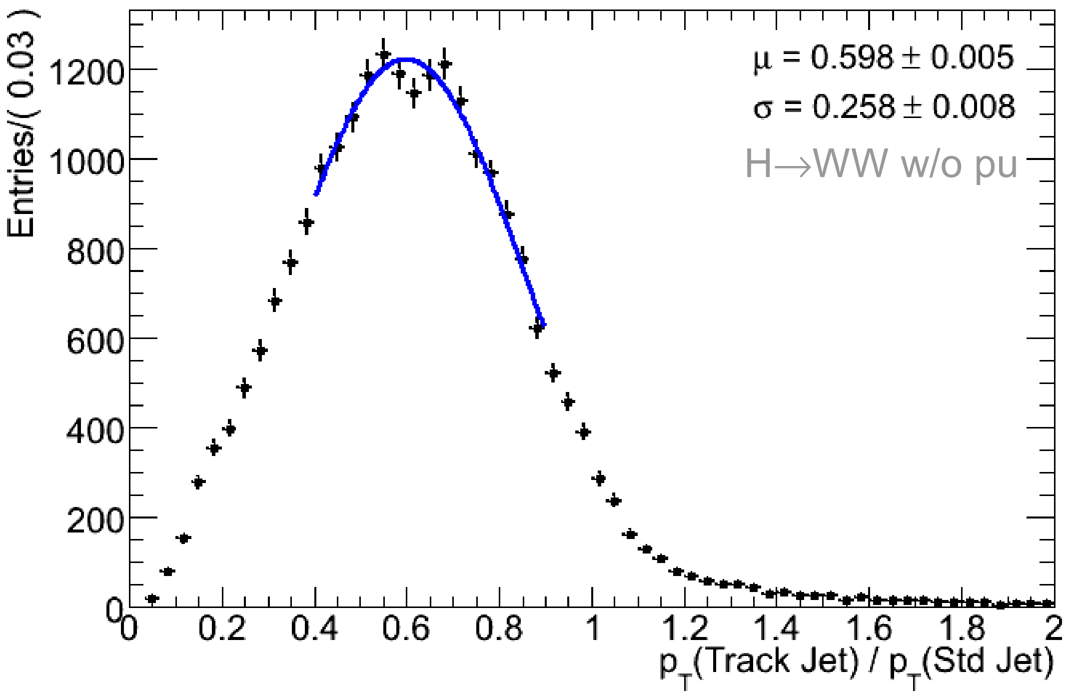
- Leptons e,μ: ◦ p_T > 15 GeV, $|\eta| < 2.5$
  ◦ track E_T in cone($0.01 < \Delta R < 0.2$) < 5.0 GeV
- Electrons: ◦ track match, isEM = 0x3FF (medium)
- Jets: ◦ p_T > 20 GeV, $|\eta| < 5.0$,
  ◦ overlap removal w/ 'loose' electrons (0x7) in $\Delta R = 0.4$

Event Selection:

- Trigger: ◦ 1e (p_T > 25 GeV), 1m (p_T > 20 GeV), 2l (p_T > 15 GeV)
- b-jet veto: ◦ no jets with b-weight > 4 in the event (IP3D+SV1)
- Fwd Jets: ◦ 2 leading jets, p_{T1} > 40 GeV, p_{T2} > 20 GeV
  ◦ $\eta_1 \cdot \eta_2 < 0$, $|\Delta\eta_{jj}| > 3.8$, M_{jj} > 550 GeV
- Missing E_T > 30 GeV
- Central-jet veto

Due to low statistics: only cuts on jet variables are applied

p_T Cut



- Track jets have about 2/3 of the p_T of standard jets
- p_T cut on track jets has to be modified
- Choose p_T cut such that cjv efficiency for $H \rightarrow WW$ w/o pile-up is the same for standard and track jets in $|\eta| < 2.5$

$\rightarrow$ p_T(std jet) > 20.0 GeV, p_T(track jet) > 12.3 GeV

Central-Jet Veto

CJV - Combination

- Track jets (|η|<2.5)
- Std jets (2.5<|η|<3.2)

Fraction of events passing the cjv:

	$H \to WW$		$t\bar{t}$	
	no pile-up	with pile-up	no pile-up	with pile-up
std jets ($\lvert\eta\rvert < 2.5$)	72.0 ± 1.0	63.0 ± 1.2	28.6 ± 3.4	19.7 ± 3.3
track jets	72.0 ± 1.0	73.5 ± 1.1	28.6 ± 3.4	25.9 ± 3.6
std jets ($\lvert\eta\rvert < 3.2$)	65.4 ± 1.0	57.0 ± 1.2	24.0 ± 3.2	16.3 ± 3.0
combination	65.8 ± 1.0	65.9 ± 1.1	24.0 ± 3.2	23.1 ± 3.5
all jets	58.4 ± 1.1	51.8 ± 1.2	13.7 ± 2.6	10.9 ± 2.6

- Standard jet cjv sensitive to pile-up
- Track jet cjv shows only small sensitivity to pile-up

Summary and Outlook

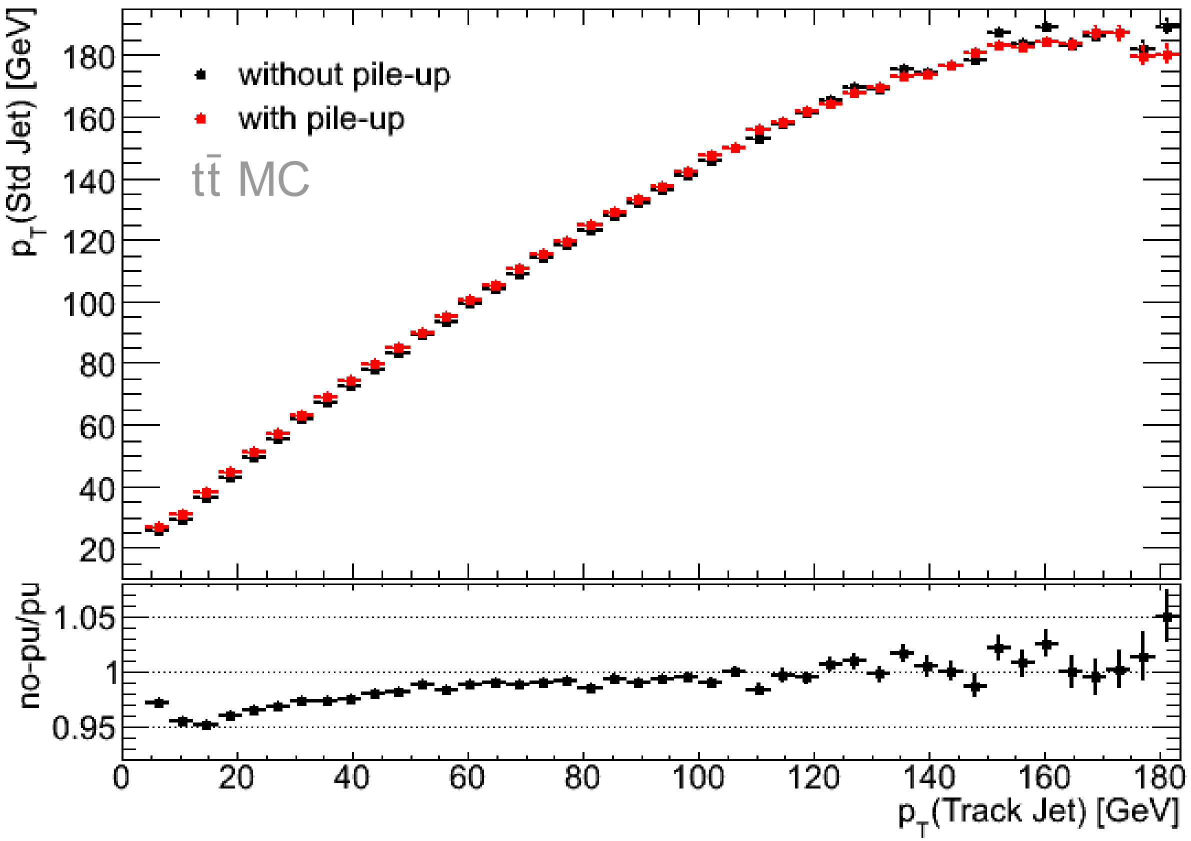
- Central-jet veto with standard jets is sensitive to pile-up
- Vertex reconstruction allows for the separation of different inelastic pp interactions in an event
- Track jets look promising since they show small sensitivity to pile-up
- Tools have been ported to release 13 and will be included in JetRecTools (after being rewritten as SelectorTool)

ToDo-List

- Comparison of reco efficiency and fake rate with std jets in release 13
- Vertex reconstruction on truth particles
- Optimization of track-jet reconstruction (overlap removal with isolated leptons, cone size, ...)
- SelectorTool

Backup Slides

p_T Ratio



• Difference of p_T(std jet)/p_T(trk jet) of matched jets (ΔR=0.4) less than 5%

$\rightarrow$ Pile-up has rather small influence on p_T of std jets (Cone4Topo) wrt the p_T of track jets

Reco Efficiency

	Standard Jets		Track Jets	
ΔR	Efficiency	Fake Rate	Efficiency	Fake Rate
0.05	77.19 ± 0.22	24.68 ± 0.23	78.73 ± 0.28	27.66 ± 0.30
0.10	89.14 ± 0.17	13.03 ± 0.18	86.03 ± 0.24	20.96 ± 0.27
0.15	90.93 ± 0.15	11.29 ± 0.17	87.80 ± 0.23	19.32 ± 0.26
0.20	91.66 ± 0.15	10.57 ± 0.16	88.74 ± 0.22	18.47 ± 0.26
0.25	92.08 ± 0.14	10.16 ± 0.16	89.30 ± 0.21	17.95 ± 0.26
0.30	92.26 ± 0.14	9.99 ± 0.16	89.61 ± 0.21	17.66 ± 0.25
0.35	92.31 ± 0.14	9.94 ± 0.16	89.73 ± 0.21	17.56 ± 0.25
0.40	92.33 ± 0.14	9.92 ± 0.16	89.77 ± 0.21	17.52 ± 0.25
0.45	92.34 ± 0.14	9.91 ± 0.16	89.82 ± 0.21	17.47 ± 0.25
0.50	92.35 ± 0.14	9.90 ± 0.16	89.85 ± 0.21	17.44 ± 0.25

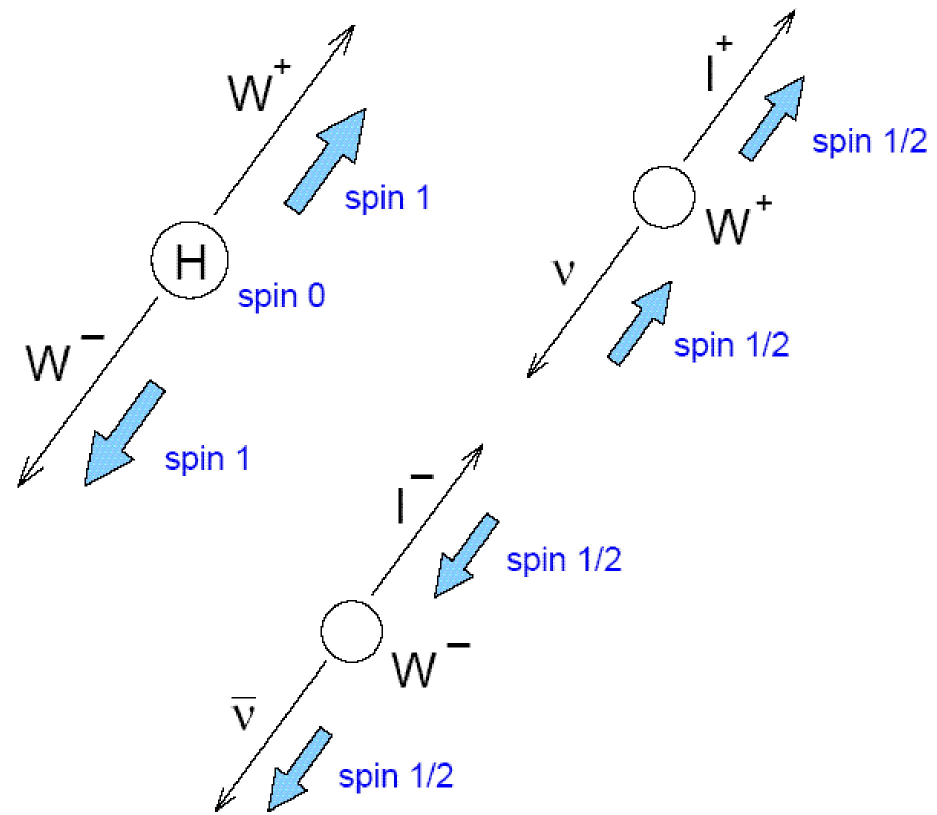
Higgs Decay: H $\rightarrow$ WW $\rightarrow$ lνlν

Signature:

- 2 high p_T leptons + large missing E_T
- lepton spin correlation (spin 0↔1)

$\rightarrow$ W^+ and W^- have opposite spins

$\rightarrow$ leptons $l^\pm$ tend to be emitted in the same direction



- no mass peak $\rightarrow$ transverse mass

$$M_T = \sqrt{(E_T^{\ell\ell} + E_T^{\nu\nu})^2 - (\vec{p}_T^{\,\ell\ell} + \vec{\not{p}}_T)^2}$$

Event Selection

- Leptons:
  - ◦ electrons/muons, $p_T > 15$ GeV
  - ◦ opening angle between the leptons
- Fwd Jets:
  - ◦ 2 jets, $p_{T1} > 40$ GeV, $p_{T2} > 20$ GeV
  - ◦ $\Delta\eta$ between the jets
  - ◦ leptons between the jets in η
- $Z \rightarrow \tau\tau$ veto:
  - ◦ apply collinear approximation

  $\rightarrow$ reject event if $x_1 > 0$, $x_2 > 0$

  and $|M_Z - M_{\tau\tau}| < 25$ GeV
- missing transverse energy
- central jet veto: no other jets in central region ($|\eta| < 3.2$)