Top-Higgs Production in MC@NLO

Tilman Plehn

Universität Heidelberg

Charged Higgs Workshop, 9/2010

Top-Higgs associated production

why charged Higgs?

- extension of minimal Higgs sector
- MSSM only one example
- additional neutral scalar not conclusive

why top-Higgs associated production?

- no tree level $WZH^\pm$ coupling due to $\Delta\rho \ll 1$ [electroweak precision data]
- large Yukawa coupling $btH^\pm$
- processes in a type-II THDM
  tree level $2 \to 3$ process $gg \to b\bar{t}H^-$ largest
  tree level $q\bar{q} \to H^+H^-$ small [Alves, TP]
  loop-induced $gg \to H^+H^-, H^+W^-$ small [Krause, TP, Spira, Zerwas]
  tree level $b\bar{b} \to H^+H^-$ tiny [Kniehl,...; Alves, TP]

why bottom-initiated?

- $\sigma(gg \to \bar{b}tH^-)$ divergent for $m_b \to 0$
  collinear divergence $d\sigma/dp_{T,b} \propto 1/p_{T,b}$

  1– regularize with separation cuts [part of analysis?]
  2– regularize with $m_b \neq 0$ [large logarithm?]
  3– resum in analogy to usual DGLAP [bottom partons]

Top-Higgs associated production

consistency check for 5 flavors: $m_b \to 0$

- check distributions [Berger, Han, Jiang, TP]
- check perturbative behavior [Harlander, Kilgore: $b\bar{b} \to h^0$]
- uncertainties on bottom parton densities?
- understand differences to 4 flavor scheme [we know which log it is; Michael's talk]

gluon-induced vs bottom-induced at NLO

- LO diagram $gg \to b\bar{t}H^-$ included in 5FS
  perturbative log m_H/m_b included in 4FS
- difference only higher order
  improved agreement at NLO on both sides expected [Michael's talk]

	4 flavors	5 flavors
$\sigma^{\text{LO}}_{\text{tot}}$	α_s^2	α_s log
$\sigma^{\text{NLO}}_{\text{tot}}$	α_s^3	α_s^2 log
t distrib	NLO	NLO $\otimes$ LL
H distrib	NLO	NLO $\otimes$ LL
b distrib	NLO	LO

- leading SUSY-QCD corrections identical [Berger, Han, Jiang, TP; many talks]
- 5FL-NLO code private add-on to Prospino2.1 [tested with Zhu and MC@NLO]

Top-Higgs in MC@NLO

why combining NLO/hard radiation/parton shower?

- promised at end of CHARGED06
- parton shower for jet and recoil simulations [Alwall & Rathsmann: MATCHING]
  NLO normalization to reduce scale issues [Boos & TP: scales of bottom pdf]
  complete bottom jet kinematics for analysis design
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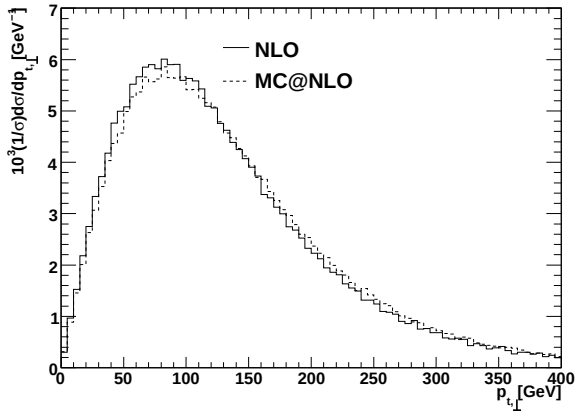

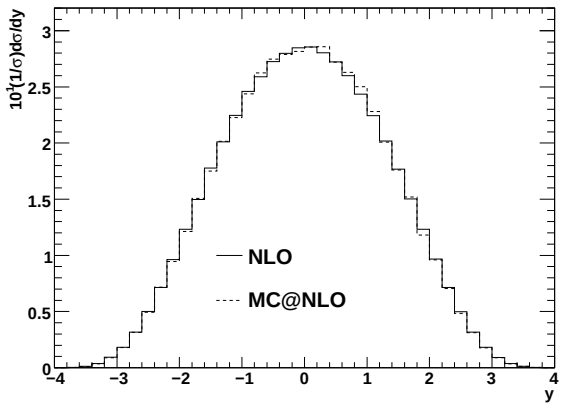

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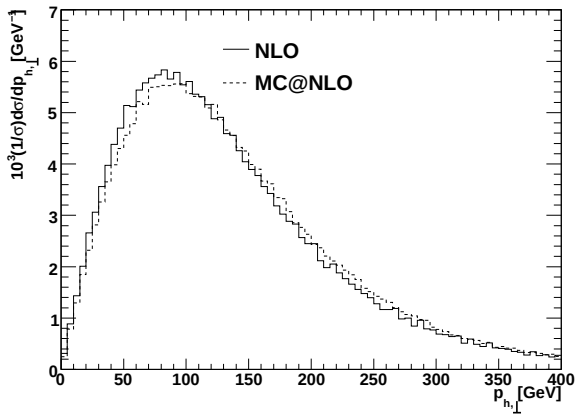

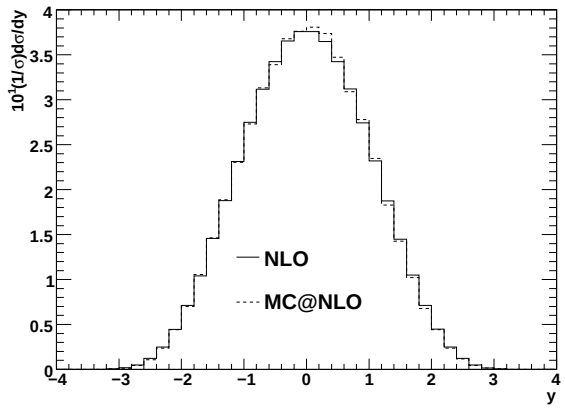

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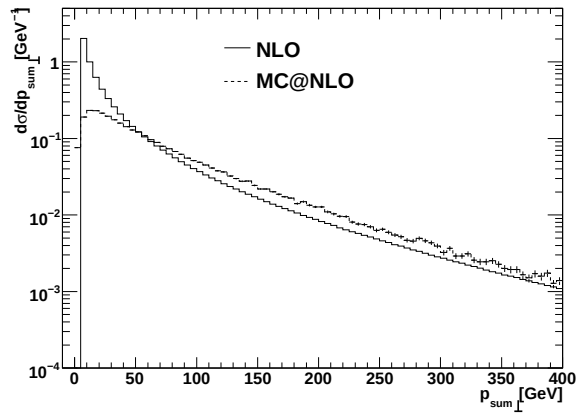

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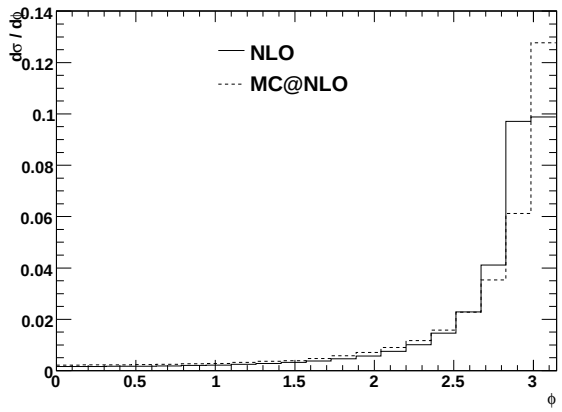

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$\Rightarrow$ matching ready to be used

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decay jets vs jet radiation [TP, Rauch, Spannowsky]

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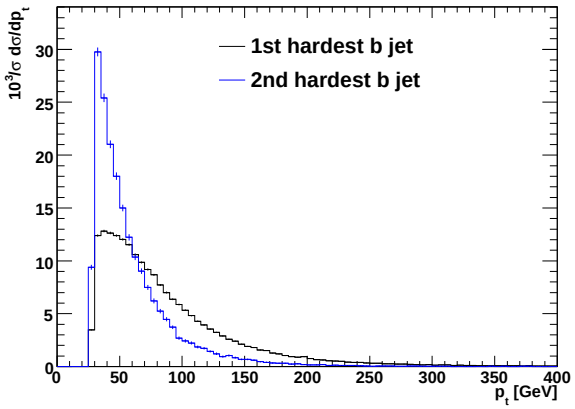

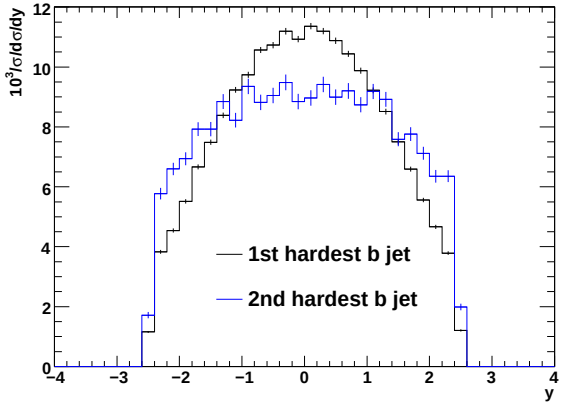

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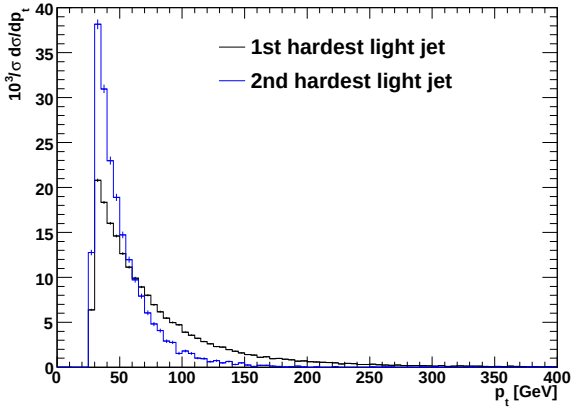

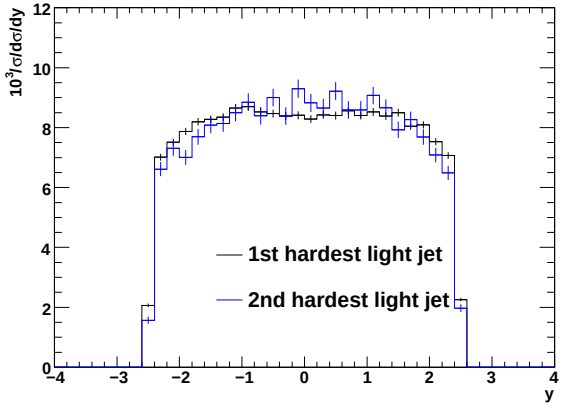

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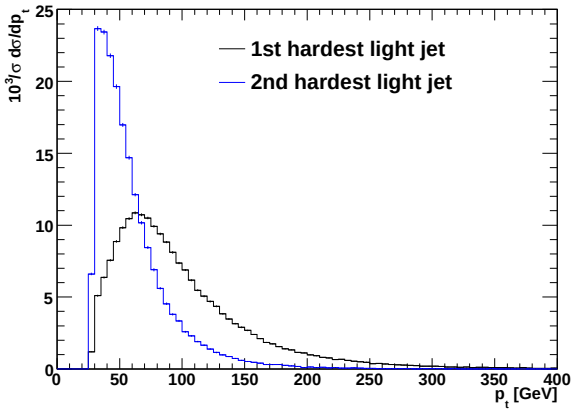

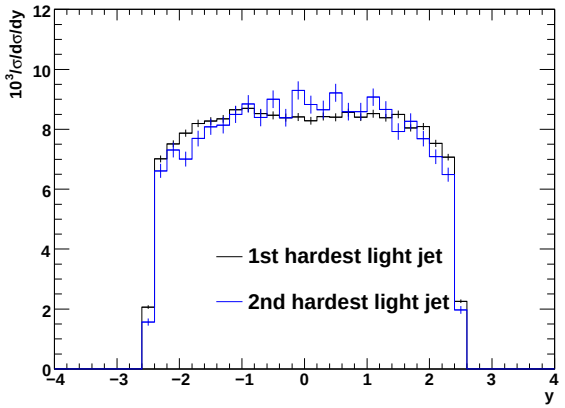

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more QCD questions we can answer now

- probability to in addition to a b jet observe $[|\eta| < 2.5; p_T > 25\,\text{GeV}]$
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  (b) a light jet from t_h
  (c) a second b jet

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	$p_{T,\text{cut}}$	η_{cut} 2.5	2.0	1.5	1.0	0.5
(a)	25 GeV	45.9	40.0	32.7	23.9	13.0
	45 GeV	32.4	27.8	22.3	16.1	9.0
	65 GeV	22.3	18.8	14.7	10.4	5.8
	85 GeV	16.2	13.4	10.3	7.3	4.2
(b)	25 GeV	94.9	91.0	84.3	72.2	48.4
	45 GeV	83.2	79.2	72.3	61.0	39.9
	65 GeV	60.9	57.3	51.7	43.2	28.8
	85 GeV	44.4	41.5	37.1	31.1	21.3
(c)	25 GeV	17.8	14.3	10.0	5.7	2.3
	45 GeV	12.9	10.6	7.6	4.5	1.8
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  (a) a light jet from t_ℓ
  (b) a light jet from t_h
  (c) a second b jet
- light jets everywhere
  not only soft and now only forward
- second bottom rare [gluon splitting vs decay?]
- jet radiation correct for all p_T and η

$\Rightarrow$ whatever...data makes you smart...

Low-ish Higgs masses

combination of $t\bar{t}$ with $t \to bH^+$ at NLO

- in principle: $gg \to t\bar{t} \to t(\bar{b}H^-)$ counted as $t\bar{t}$
- experiment: start from understood $t\bar{t}$ sample [including normalization]
  add tH^- sample for signal hypothesis [compute tH^- without on-shell $t\bar{t}$]

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- MC@NLO: removing $t\bar{t}$ diagrams on amplitude level [crap solution]
- MC@NLO: diagam subtraction [re-inventing Prospino scheme]

$$d\sigma^{\text{sub}}_{H^- t} = \left|\mathcal{M}^{(t\bar{t})}\right|^2 \frac{f_{\text{BW}}(m_{H-\bar{b}})}{f_{\text{BW}}(m_t)} = \left|\mathcal{M}^{(t\bar{t})}\right|^2 \left(1 + \mathcal{O}\left(\frac{\Gamma_t}{m_t}\right)\right)$$

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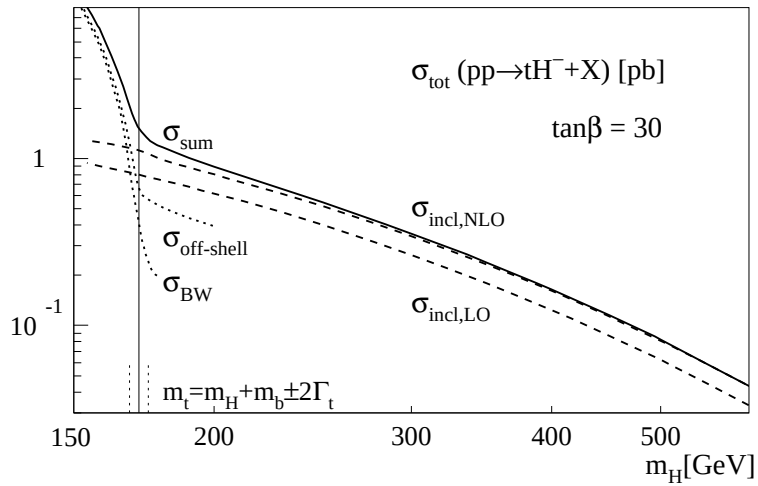
scheme dependence

- Γ_t issue well known
- sample combination a la Prospino



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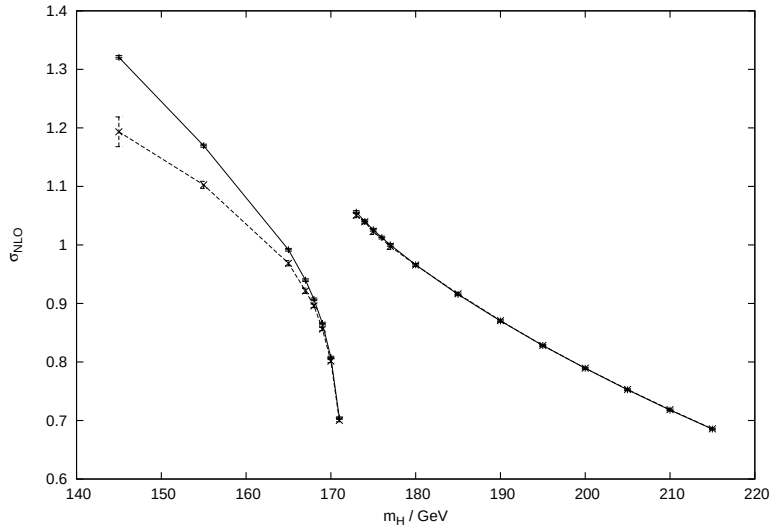
- gauge invariance not a big issue
- interference terms big difference

$\Rightarrow$ sample combination available for tH^-



Tagging tops from charged Higgses

Anyone interested?

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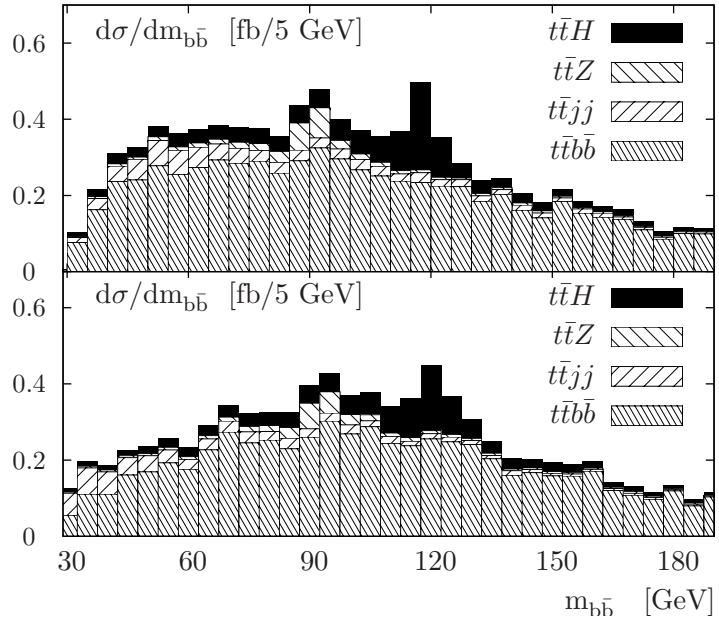
  killed by continuum $t\bar{t}b\bar{b}$
- look for boosted tops
  reconstruct with jet algorithm [TP, Salam, Spannowsky: HEPTopTagger]
  reduce QCD and combinatorics
  reconstruct 4-momentum
  promising for $t\bar{t}h^0$, $h^0 \to b\bar{b}$



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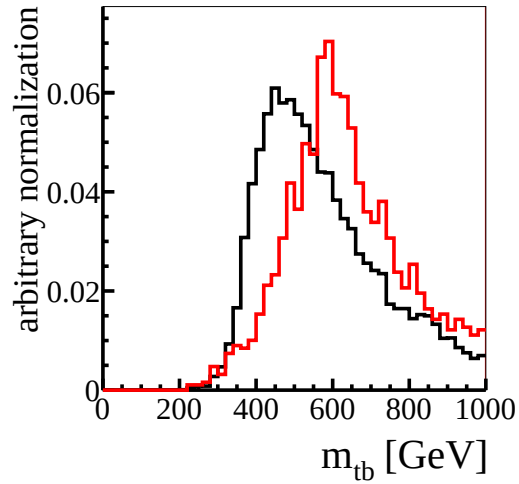
- signature $t_h H^- \to t_h(\bar{t}_h b)$

  1– hardest b from H^- tagged
  2– tag two tops
  3– reconstruct m_H [$S/B \gtrsim 1/8$]
  ...
- only fun with experimental help



Outlook

tH^- production included in MC@NLO

- difference between 4FS and 5FS of higher order
- numerics confirming small differences
- combination with $t\bar{t}$ sample sorted
- remaining difference: jet radiation from LO/NLO/shower
- try MC@NLO and tell us what else is needed [ask us for a test code]

MC@NLO

Tilman Plehn

MC@NLO

fat jets