

Les Houches 2014
CERN TH Retreat

Markus Schulze

Top quark physics

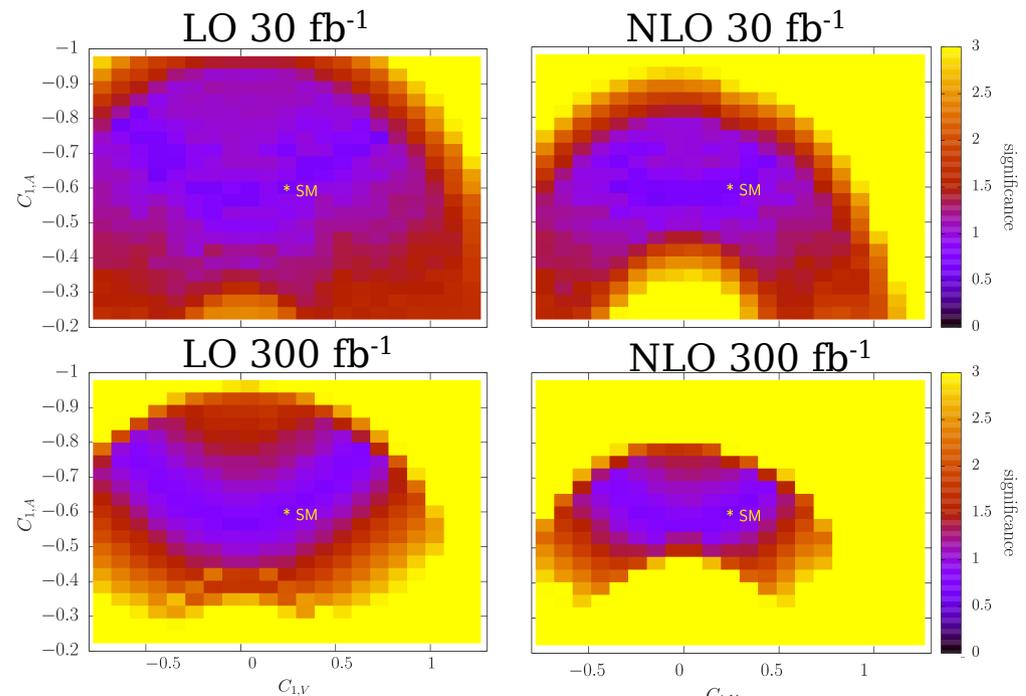
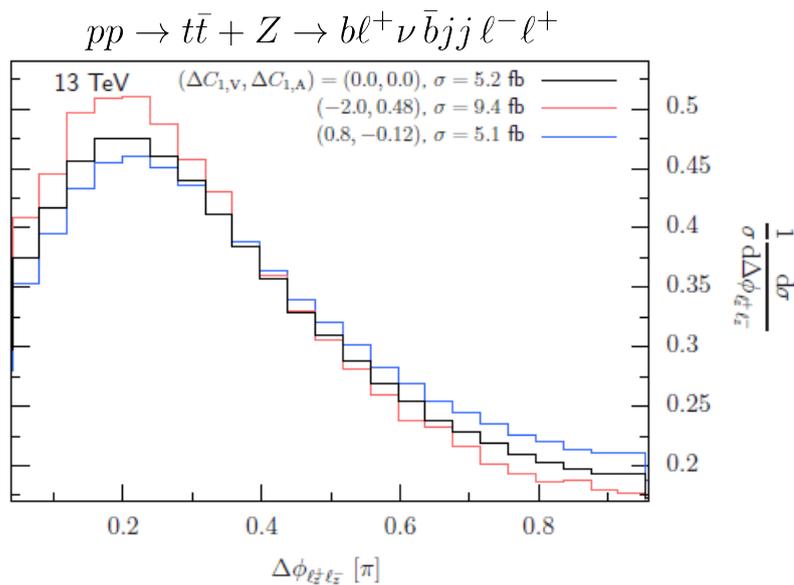
1. Probing top quark electroweak couplings at the LHC

[R.Röntsch,MS](2014)

$$\mathcal{L}_{t\bar{t}Z} = ie\bar{u}(p_t) \left[\gamma^\mu (C_{1,V} + \gamma_5 C_{1,A}) + \frac{i\sigma_{\mu\nu}q_\nu}{M_Z} (C_{2,V} + i\gamma_5 C_{2,A}) \right] v(p_{\bar{t}}) Z_\mu,$$

$$C_V^{\text{SM}} = \frac{T_t^3 - 2Q_t \sin^2 \theta_w}{2 \sin \theta_w \cos \theta_w}, \quad C_{1,V} = C_{1,V}^{\text{SM}} + \left(\frac{v^2}{\Lambda^2} \right) \text{Re} \left[C_{\phi q}^{(3,33)} - C_{\phi q}^{(1,33)} - C_{\phi u}^{33} \right],$$

$$C_A^{\text{SM}} = \frac{-T_t^3}{2 \sin \theta_w \cos \theta_w}, \quad C_{1,A} = C_{1,A}^{\text{SM}} + \left(\frac{v^2}{\Lambda^2} \right) \text{Re} \left[C_{\phi q}^{(3,33)} - C_{\phi q}^{(1,33)} + C_{\phi u}^{33} \right],$$



Top quark physics

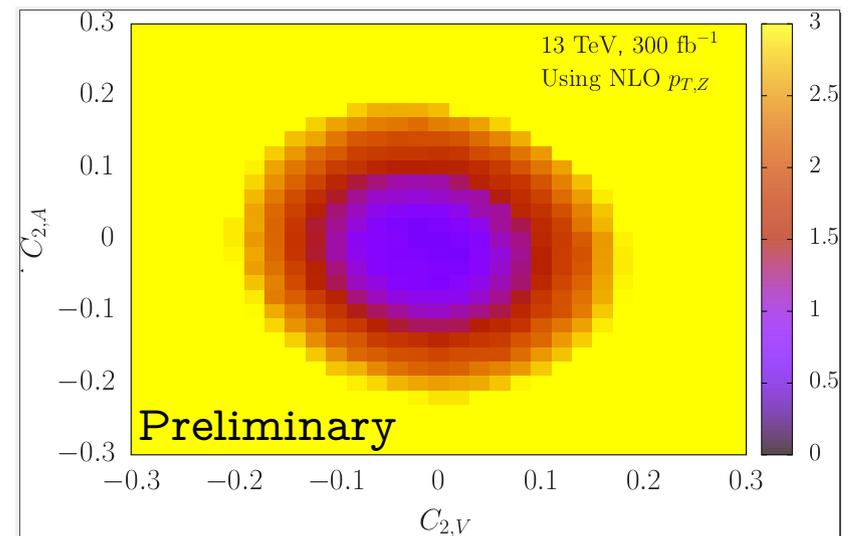
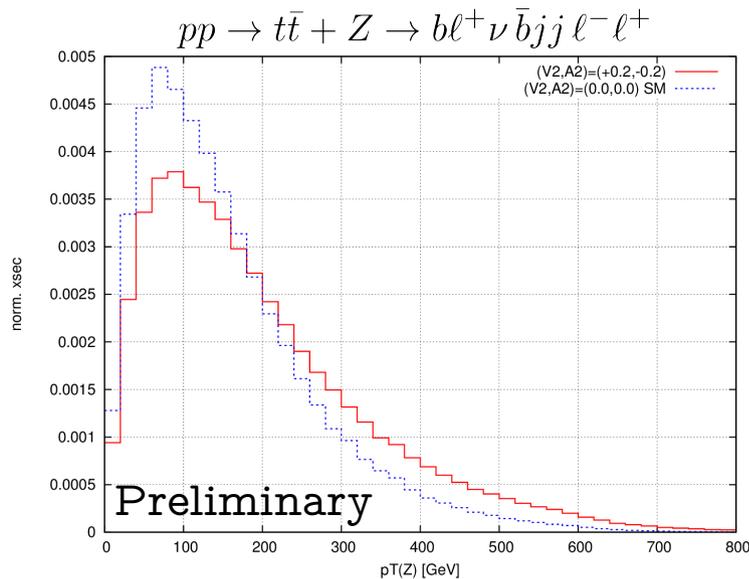
1. Probing top quark electroweak couplings at the LHC

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$$C_{2,V} \approx 0 + \left(\frac{v^2}{\Lambda^2} \right) \text{Re} [c_W C_{uW}^{33} - s_W C_{uB\phi}^{33}]$$

$$C_{2,A} \approx 0 + \left(\frac{v^2}{\Lambda^2} \right) \text{Im} [c_W C_{uW}^{33} - s_W C_{uB\phi}^{33}]$$



Top quark physics

2. Top quark mass determination from kinematic distributions

- Investigation of off-shell effects, NLO QCD top decay & Parton Shower on m_{top} extraction

[G.Heinrich,J.Schlenk,J.Winter,MS]

- Using energy peaks to determine top quark mass

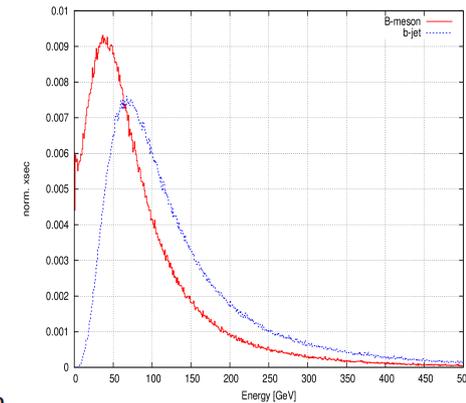
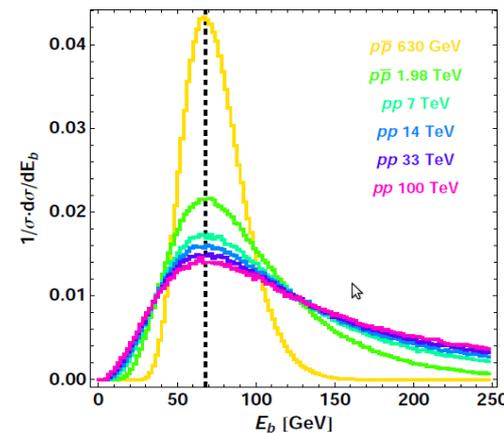
[K.Agashe,D.Kim,R.Franceschini,M.S.]

Comparison:

- WWbbar vs. ttbar (narrow-width)
- NLO decay vs. parton shower decay

Observables:

- m_{lb}
- approx. of m_{lb} without E_{b}
- m_{T2}



Also study B -meson energy distrib. via fragment. function at NLO QCD.

Higgs boson physics

3. Higgs boson characterization

[Anderson,Bolognesi,Caola,Gao,Gritsan,Martin,
Melnikov,Sarica,Tran,Whitbeck,Xiao,Zhou,MS]

- JHUGenerator + MELA: Framework for Higgs Boson characterization
- Joint experimental + theoretical collaboration
- Processes: $pp \rightarrow \text{spin-0,1,2} \rightarrow VV \rightarrow 4f$, $pp \rightarrow \text{VBF,QCD} \rightarrow H+jj$, $pp/e^+e^- \rightarrow HV$
- New features (v.4.8.1): [Anderson,Gritsan,Sarica,Xiao,Zhou,MS] (2014)
 - q^2 dependent form factors
 - $pp \rightarrow H+\text{jet}$
 - tools for matrix element analysis of VH production
 - plug-in for MCFM with anomalous H couplings in off-shell kinemat.

Higgs boson physics

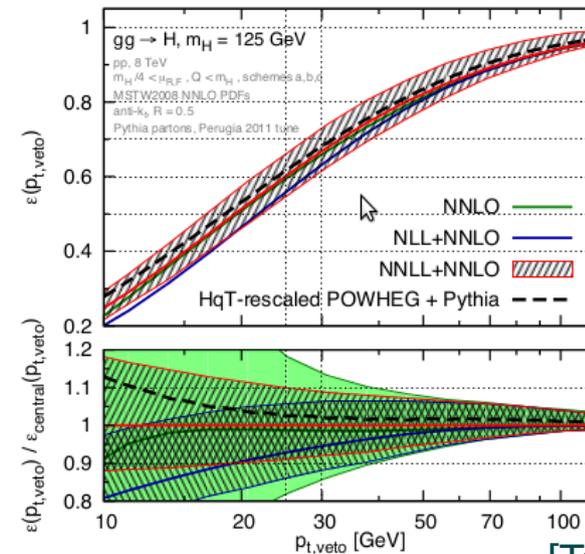
4. NNLO QCD predictions for $pp \rightarrow H + \text{jet}$

[Boughezal, Caola, Petriello, Melnikov, MS]

Source (1-jet)	Signal (%)	Bkg. (%)
1-jet incl. ggF signal ren./fact. scale	27	0
2-jet incl. ggF signal ren./fact. scale	15	0
Missing transverse momentum	8	3
W+jets fake factor	0	7
b-tagging efficiency	0	7
Parton distribution functions	7	1

ATLAS

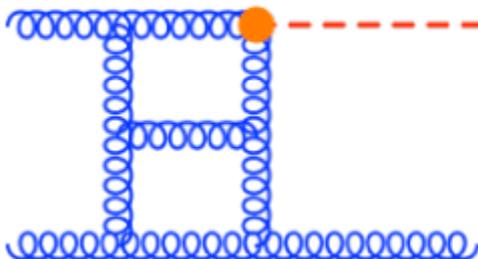
Large K-factors, error dominated by missing higher orders



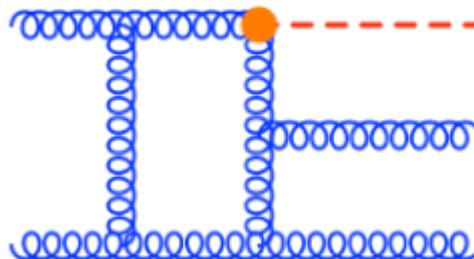
[Banfi et.al]

[Tackmann et al.]

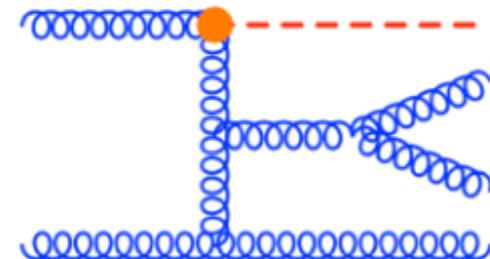
VV



RV



RR



Higgs boson physics

4. NNLO QCD predictions for $pp \rightarrow H + \text{jet}$

[Boughezal, Caola, Petriello, Melnikov, MS]

- NNLO computation is completed for all relevant channels:

$gg \rightarrow H + j$ (incl. n_f contributions)

$qg \rightarrow H + j$

(remaining channels $\sim 0.5\%$ of total cross section at NLO)

```
[maschulz@lxplus0178 Sectors]$ ls *gg*
sector_nnlo_al_41_51_1_gg.f90  sector_nnlo_al_42_52_2_gg.f90  sector_nnlo_al_43_53_3_gg.f90  sector_nnlo_rn_nlor_42_gg.f90  sector_nnlo_rr_42_51_gg.f90  sector_nnlo_rr_43_53_1_gg.f90
sector_nnlo_al_41_51_2_gg.f90  sector_nnlo_al_42_52_3_gg.f90  sector_nnlo_al_43_53_4_gg.f90  sector_nnlo_rn_nlor_43_gg.f90  sector_nnlo_rr_42_52_1_gg.f90  sector_nnlo_rr_43_53_2_gg.f90
sector_nnlo_al_41_51_3_gg.f90  sector_nnlo_al_42_52_4_gg.f90  sector_nnlo_al_43_53_5_gg.f90  sector_nnlo_rr_41_51_1_gg.f90  sector_nnlo_rr_42_52_2_gg.f90  sector_nnlo_rr_43_53_3_gg.f90
sector_nnlo_al_41_51_4_gg.f90  sector_nnlo_al_42_52_5_gg.f90  sector_nnlo_cv_gg.f90          sector_nnlo_rr_41_51_2_gg.f90  sector_nnlo_rr_42_52_3_gg.f90  sector_nnlo_rr_43_53_4_gg.f90
sector_nnlo_al_41_51_5_gg.f90  sector_nnlo_al_42_53_gg.f90    sector_nnlo_cv_nlor_41_gg.f90  sector_nnlo_rr_41_51_3_gg.f90  sector_nnlo_rr_42_52_4_gg.f90  sector_nnlo_rr_43_53_5_gg.f90
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sector_nnlo_al_41_53_gg.f90    sector_nnlo_al_43_52_gg.f90    sector_nnlo_cv_nlor_43_gg.f90  sector_nnlo_rr_41_51_5_gg.f90  sector_nnlo_rr_42_53_gg.f90    sector_nnlo_rv_42_gg.f90
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sector_nnlo_al_42_52_1_gg.f90  sector_nnlo_al_43_53_2_gg.f90  sector_nnlo_rn_nlor_41_gg.f90  sector_nnlo_rr_41_53_gg.f90    sector_nnlo_rr_43_52_gg.f90
[maschulz@lxplus0178 Sectors]$ ls *qg*
sector_nnlo_al_41_51_1_qg.f90  sector_nnlo_al_42_52_2_qg.f90  sector_nnlo_al_43_53_3_qg.f90  sector_nnlo_rn_nlor_43_qg.f90  sector_nnlo_rr_42_51_qg.f90  sector_nnlo_rr_43_53_1_qg.f90
sector_nnlo_al_41_51_2_qg.f90  sector_nnlo_al_42_52_3_qg.f90  sector_nnlo_al_43_53_4_qg.f90  sector_nnlo_rn_qg.f90         sector_nnlo_rr_42_52_1_qg.f90  sector_nnlo_rr_43_53_2_qg.f90
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[maschulz@lxplus0178 Sectors]$
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- Cancellation of IR singularities
- Differential distributions implemented
- Dynamical scales implemented
- Direct pdf integration or \sqrt{s} grid (200 pts)
- Code validation ongoing
- Higgs decay not implemented (but trivial)