# Prospects for top quark phenomenology at the Large Hadron Collider

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1. **Introduction**
2. **Boosted top-quark events and searches for BSM**
3. **Charge asymmetry**
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5. **Top mass reconstruction and $b$-fragmentation**
6. **$t\bar{t}H$ production: status and perspectives**
7. **Conclusions**

Based on work by G.C., F.Mescia, V.Drollinger, M.Spannowsky, S.Schätzel, A.Mitov, M.Czakon, P.Fiedler, M.V.Garzelli, A.Kardos, C.Papadopoulos, Z. Trocsany, L.Almeida, G.Sterman, W.Vogelsang, S.Westhoff, J.Kühn, G.Rodrigo, R.Frederix, R.Pittau, V.Hirschi, P.Torrielli, S.Frixione, G.Luisoni, S.Höche, J.Huang, J. Winter, M.Schönherr,
Boost 2012 and Snowmass 2013 proceedings

Top-quark physics is one of the most interesting topics of investigation at the LHC: tests of QCD, parton model, factorization, searches for new physics scenarios

Progress in calculations and tool implementation for several top-related quantities

Cross section of $t\bar{t}$ and $t\bar{t}$+jets; forward-backward and charge asymmetries

Use of top-quark phenomenology to extract the gluon density and $\alpha_S$

Top quarks as a tool to search for physics Beyond the Standard Model, e.g. supersymmetry or charged Higgses

Single-top phenomenology opens the door to several challenging measurements and comparisons with $t\bar{t}$ events

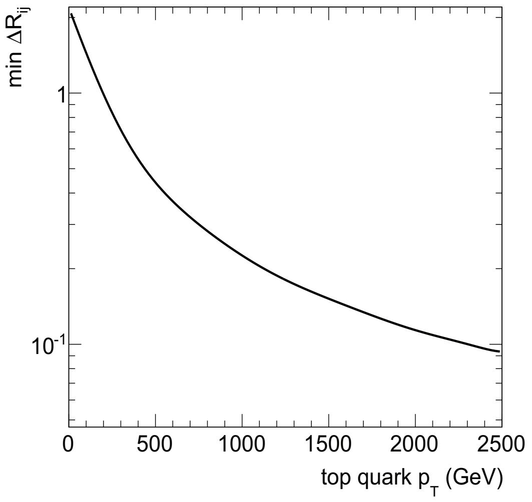
Top-pair production in association with the Standard Model Higgs boson to measure the Yukawa coupling

Strategies to measure the top mass and connect it with consistent theoretical definitions

Bottom-fragmentation in top decays to test hadronization models (my own work)

Talk concentrated on QCD/SM aspects of top phenomenology, especially on topics which have been investigated by the Italian ATLAS groups

Boosted top quarks: top decay products are clustered into a single jet
Useful to separate, e.g., $Z' \to t\bar{t}$ from QCD backgrounds
For $200\ \mathrm{GeV} < p_T < 400\ \mathrm{GeV}$ the $W$ decays yield a single jet;
for $p_T > 400$ GeV all decay products, e.g. $t \to bq\bar{q}'$, fall in a jet of $\Delta R \sim 2m_t/p_T$
Minimum $\Delta R_{ij} = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ in $t \to bq\bar{q}'$ as a function of the top $p_T$
(Spannowsky and Schätzel, '13):

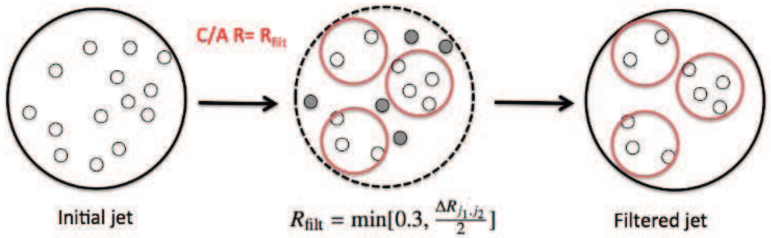



NLO rates (MCFM) of boosted ($M_{t\bar{t}} > 1$ TeV) and highly-boosted ($M_{t\bar{t}} > 2$ TeV) at past, present and future colliders (proceedings BOOST2012):

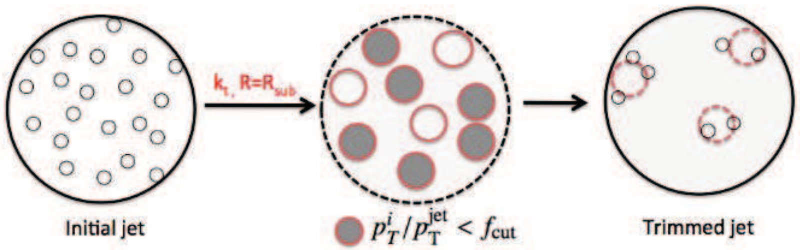
| Collider & phase process & energy, integrated luminosity | Tevatron run II $p\bar{p}$ at $\sqrt{s} = 1.96$ TeV $\mathcal{L} = 10\ \mathrm{fb}^{-1}$ | LHC 2012 $pp$ at $\sqrt{s}$ =8 TeV $\mathcal{L} = 20\ \mathrm{fb}^{-1}$ | LHC phase II $pp$ at $\sqrt{s}$ =13 TeV $\mathcal{L} = 300\ \mathrm{fb}^{-1}$ | HE-LHC $pp$ at $\sqrt{s}$ =33 TeV $\mathcal{L} = 300\ \mathrm{fb}^{-1}$ |
|---|---|---|---|---|
| Inclusive $t\bar{t}$ production | $6 \times 10^4$ | $4 \times 10^6$ | $2 \times 10^8$ | $1.4 \times 10^9$ |
| Boosted production | 23 | $6 \times 10^4$ | $5.2 \times 10^6$ | $7.1 \times 10^7$ |
| Highly boosted | 0 | 500 | $1.1 \times 10^5$ | $3.9 \times 10^6$ |

Jet grooming algorithms (pruning, trimming and filtering) weaken pile-up effects: soft/wide-angle components are removed, the jet mass is stable and S/B is enhanced

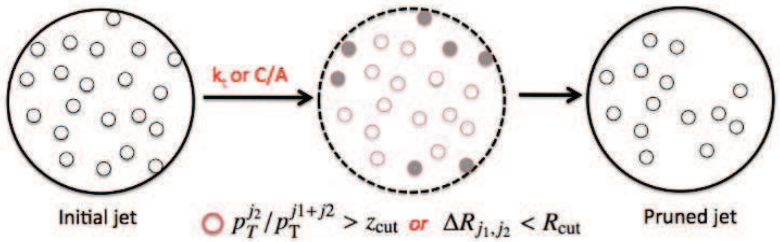
**Mass-drop filtering:** sub-jets with reduced R and significantly smaller mass are constructed. Residual energy deposits are rejected.




**Trimming:** sub-jets of smaller R are constructed. Sub-jets with $p_T$ smaller than a fixed fraction of the $p_T$ of the original jet are removed.




**Pruning:** jet reconstruction re-applied to all jet constituents. At each step of the reconstruction the constituents of small $p_T$ and spatially separated are removed.

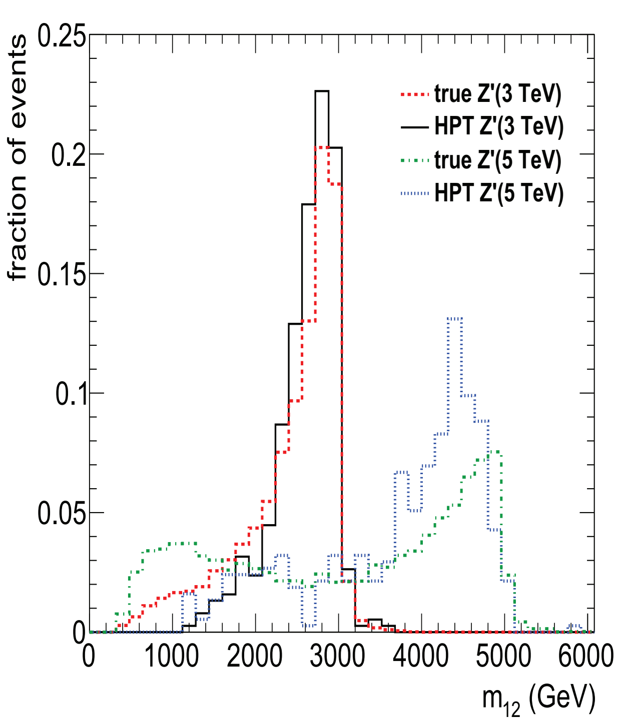


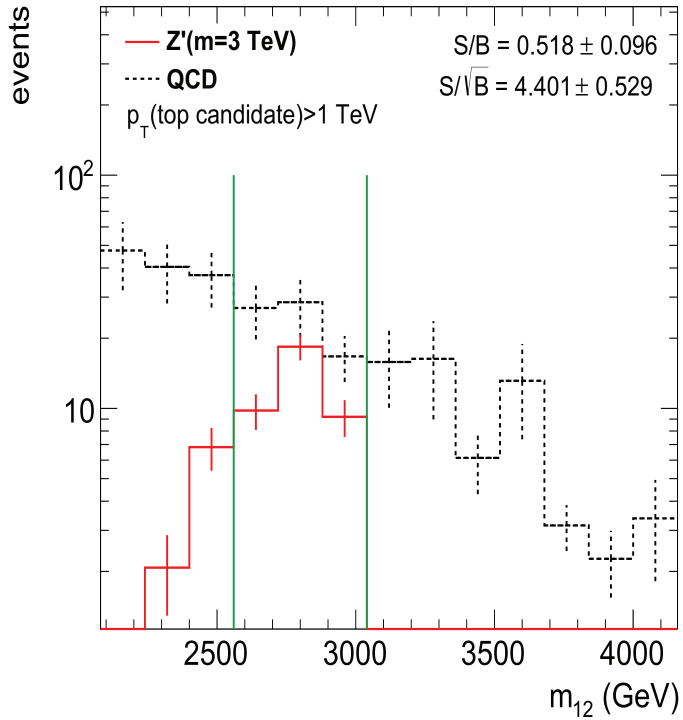

N-subjettiness: tool to identify top-like events and determine the consistency of a jet with a given number of subjets

ATLAS optimized the trimming algorithm with $p_T > 350$ GeV, $R = 1$, $R_{\rm sub} = 0.3$, $f_{\rm cut} = 0.05$

Recent proposal: a modified filtering algorithm, using track and calorimeter information for $R = 0.8$ and $p_T > 1.2$ TeV (HPTTopTagger)

Study leptophobic $Z' \to t\bar{t}$, $\mathcal{L} = 300$ fb$^{-1}$, $\sqrt{s} = 14$ TeV, $m_{Z'} = 3$ TeV

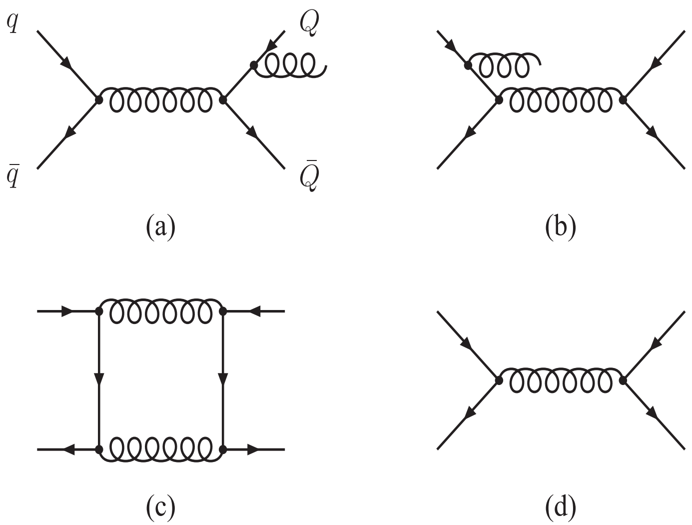


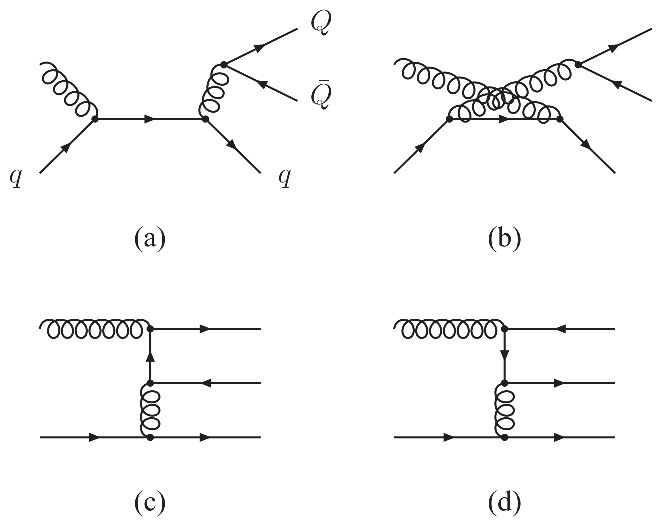




The S/B and significance values make the discovery of $Z'$ in boosted to events with HPTTopTagger within reach

Results obtained using PYTHIA8; also available NLO+NNLL resummation for a number of observables, e.g. transverse momentum and rapidity (Ferroglia, Marzani, Becjak and Yang, '13); full NNLO in progress (S.Marzani)

Charge asymmetry: in NLO QCD different $t$ and $\bar{t}$ angular distributions ($\sim d_{abc}^2$):



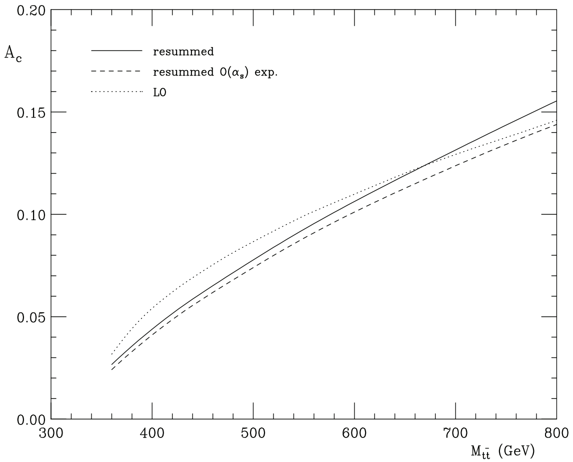

$$\sigma_{S,A} = \int d\cos\theta \left( \frac{d\sigma_{t\bar{t}}}{d\cos\theta} \pm \frac{d\sigma_{\bar{t}t}}{d\cos\theta} \right) \;, \; A_C = \frac{\sigma_A}{\sigma_S} = \frac{\alpha_S^3 \sigma_A^{(1)} + \alpha_S^4 \sigma_A^{(2)} + \ldots}{\alpha_S^2 \sigma^{(0)} + \alpha_S^3 \sigma_S^{(1)} + \alpha_S^4 \sigma_S^{(2)} + \ldots}$$

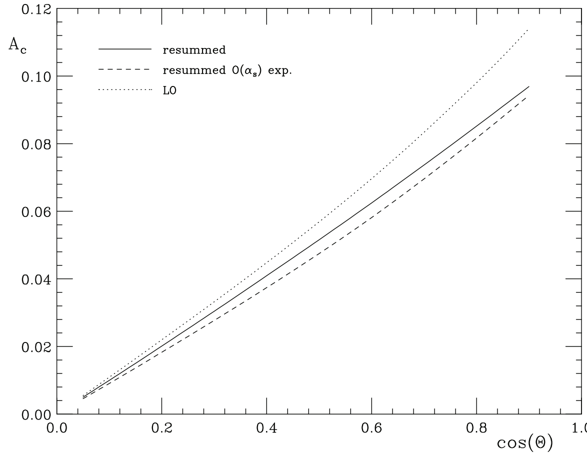
$A_C$ is measured through differences of rapidities at Tevatron ($\Delta y = y_t - y_{\bar{t}}$, i.e. forward-backward asymmetry) and of absolute rapidities at LHC ($\Delta y = |y_t| - |y_{\bar{t}}|$, forward-central asymmetry)

$$A_C^{\exp} = \frac{\sigma(\Delta y > 0) - \sigma(\Delta y < 0)}{\sigma(\Delta y > 0) + \sigma(\Delta y < 0)}$$

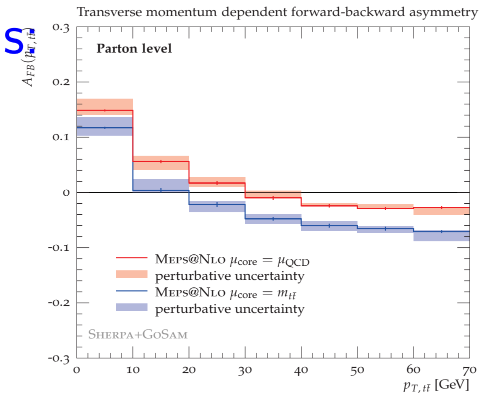
In QCD, the symmetric part is known to NNLO ($\sigma_S^{(2)}$), asymmetric to NLO ($\sigma_S^{(1)}$)
At LHC, high $gg$ contributon: milder asymmetries and higher backgrounds are expected

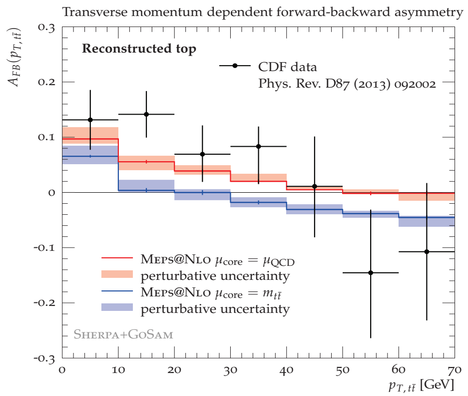
## NLL QCD threshold resummation $\tau = M^2_{t\bar{t}}/\hat{s} \to 1$ and LO+LL EW (Almeida et al., '11)

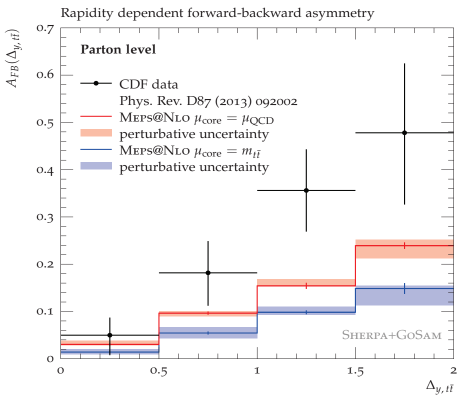


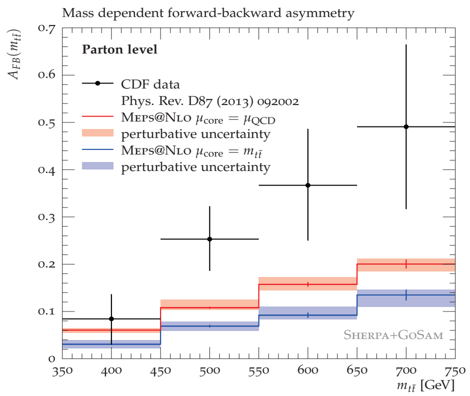




## NLO+shower predictions:

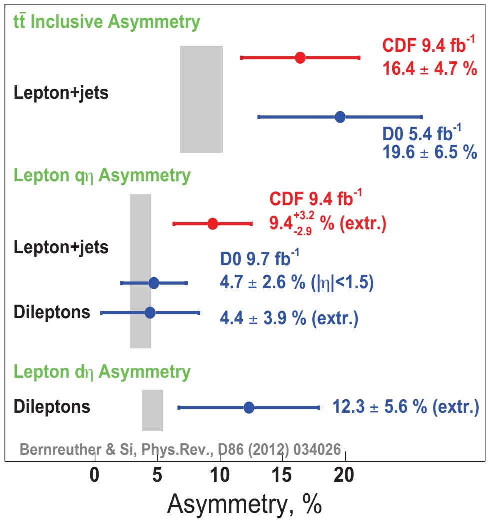


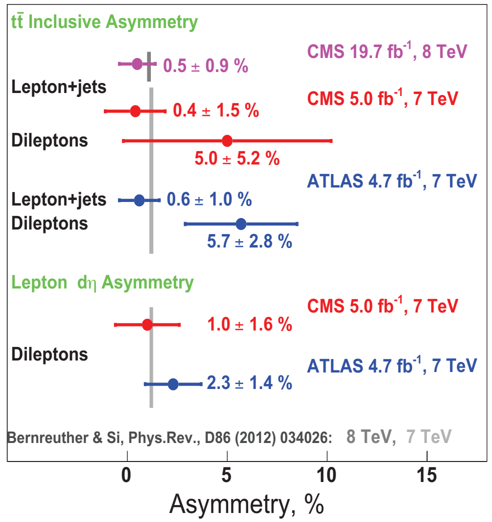



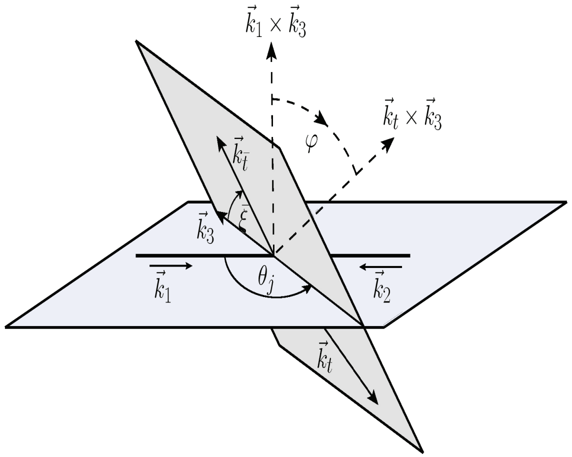



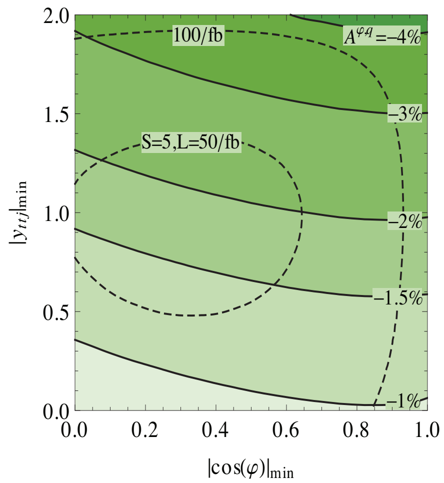
## Current limits:

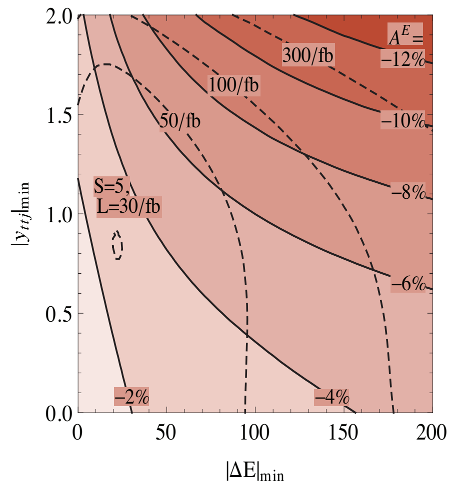



## Alternatives: incline and energy ($\Delta E = E_t - E_{\bar{t}}$ in partonic CMS) asymmetries in $t\bar{t}j$




$$A_C^{\varphi} = \frac{\sigma_A^{\varphi}(y_{t\bar{t}j} > 0) - \sigma_A^{\varphi}(y_{t\bar{t}j} < 0)}{\sigma_S} \quad ; \quad A_C^{E} = \frac{\sigma(\Delta E > 0) - \sigma(\Delta E < 0)}{\sigma(\Delta E > 0) + \sigma(\Delta E < 0)}$$

Setting appropriate cuts at 14 TeV (Berge and Westhoff): $A_C^{\varphi} \simeq -4\%$ , $A_C^{E} \simeq -12\%$

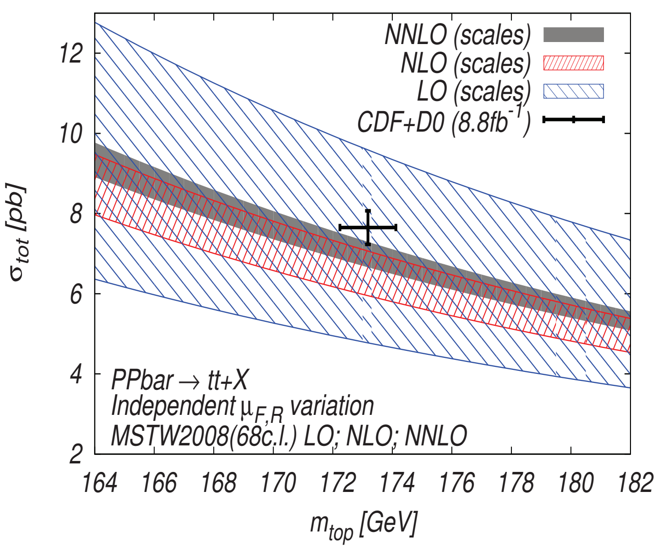
Total cross section for $t\bar{t}$ production recently computed at NNLO+NNLL:

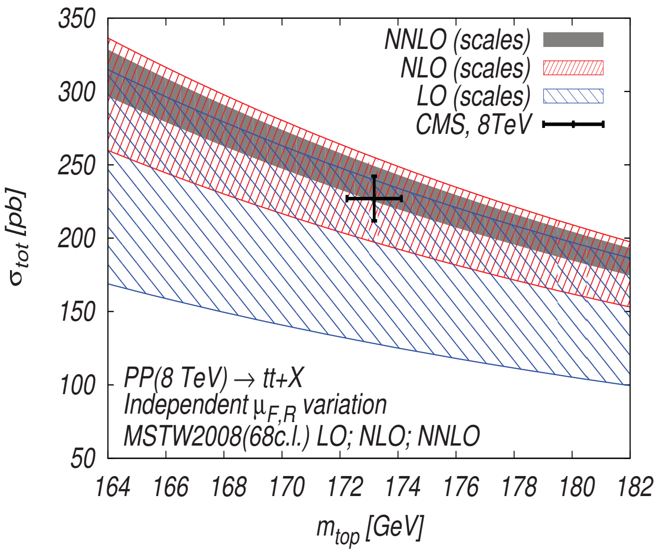
$$\sigma_{\rm tot} = \sum_{i,j} \int d\beta \; \Phi_{ij}(\beta, \mu_F^2) \; \hat{\sigma}_{ij} \quad , \quad \beta = \sqrt{1 - 4m^2/\hat{s}} \quad , \quad \Phi_{ij} = \frac{2\beta}{1-\beta^2} \, x \, (f_i \otimes f_j)$$

At NNLO, for $\mu = \mu_F = \mu_R$ and $L = \ln(m^2/\mu^2)$ (Mitov, Fielder and Czakon, '13):

$$\hat{\sigma} = \frac{\alpha_S^2}{m_t^2} \left\{ \sigma^{(0)} + \alpha_S \left[ \sigma_{ij}^{(1)} + L \sigma_{ij}^{(1,1)} \right] + \alpha_S^2 \left[ \sigma_{ij}^{(2)} + L \sigma_{ij}^{(2,1)} + L^2 \sigma^{(2,2)} \right] \right\}$$

Threshold logarithms $\alpha_S^n [\ln^m(1-z)/(1-z)]_+$, $z = m_t^2/(x_i x_j \hat{s})$ and $m \leq 2n-1$ resummed with NNLL accuracy



At NLO+NNLL all sources of uncertainties are of similar order:

Scales (missing higher orders): $\Delta\sigma \simeq 3\%$ (was 5% before NNLL resummation); pdfs: $\Delta\sigma \simeq 2-3\%$; $\alpha_S$: $\Delta\sigma \simeq 1.5\%$, top mass: $\Delta\sigma \simeq 3\%$

Results implemented in Top++, including both fixed order and resummed results

Also available as an interpolating function to fit the top mass, given $\sigma(m_{\rm ref})$:

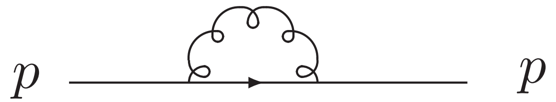
$$\sigma(m) = \sigma(m_{\rm ref}) \left(\frac{m_{\rm ref}}{m}\right)^4 \left[1 + a_1 \frac{m - m_{\rm ref}}{m_{\rm ref}} + a_2 \left(\frac{m - m_{\rm ref}}{m_{\rm ref}}\right)^2\right]$$

| $m_{ref} = 173.3$ GeV | | $\sigma(m_{ref})$ [pb] | $a_1$ | $a_2$ |
|---|---|---|---|---|
| Tevatron | Central | 7.1642 | −1.46191 | 0.945791 |
| | Scales + | 7.27388 | −1.46574 | 0.957037 |
| | Scales − | 6.96423 | −1.4528 | 0.921248 |
| | PDFs + | 7.33358 | −1.4439 | 0.930127 |
| | PDFs − | 7.04268 | −1.4702 | 0.936027 |
| LHC 7 TeV | Central | 172.025 | −1.24243 | 0.890776 |
| | Scales + | 176.474 | −1.24799 | 0.903768 |
| | Scales − | 166.193 | −1.22516 | 0.858273 |
| | PDFs + | 176.732 | −1.22501 | 0.861216 |
| | PDFs − | 167.227 | −1.2586 | 0.918304 |
| LHC 8 TeV | Central | 245.794 | −1.1125 | 0.70778 |
| | Scales + | 252.034 | −1.11826 | 0.719951 |
| | Scales − | 237.375 | −1.09562 | 0.677798 |
| | PDFs + | 251.968 | −1.09584 | 0.682769 |
| | PDFs − | 239.441 | −1.12779 | 0.731019 |

In progress: fully-differential distributions at NNLO for $t\bar{t}$ production, e.g. asymmetries, and ultimately matching with NNLO top decays in the narrow-width approximation

Top mass: LHC combination $m_t = 173.3 \pm 0.23 \pm 0.29$ GeV, but what mass?

Subtraction of the UV divergences in the self energy $\Sigma(p)$



Renormalized propagator: $S^{-1}(p) = -i[\not p - m_t^0 + \Sigma^R(p, m_t^0, \mu)]$

Mass is solution of equation $\not p - m_t + \Sigma^R(p, m_t, \mu) = 0$

Pole mass:

$$\Sigma^R(p) = 0 \ \text{ and } \ \frac{\partial \Sigma^R}{\partial \not p} = 0 \ \text{ for } \ \not p = m$$

$\overline{\mathrm{MS}}$ mass $\bar{m}_t(\mu)$– dimensional regularization $D = 4 - 2\epsilon$

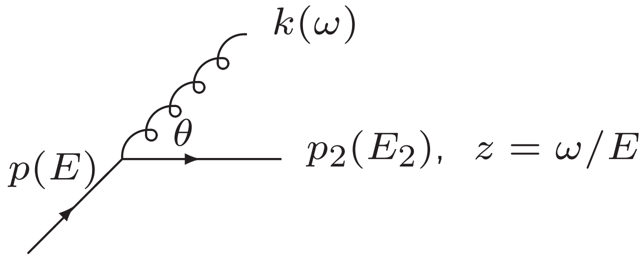
$$\Sigma(p) = \frac{i\alpha_S C_F}{4\pi}\left\{\left[\frac{1}{\epsilon} - \gamma + \ln 4\pi + A(m_t^0, p, \mu)\right] \not p - \left[4\left(\frac{1}{\epsilon} - \gamma + \ln 4\pi\right) + B(m_t^0, p, \mu)\right] m_t^0\right\}$$

Counterterm to subtract $(1/\epsilon + \gamma_E - \ln 4\pi)$

Relation with the pole mass (coefficients $c_i$ depending on $\ln[\mu^2/\bar{m}_t(\mu)^2]$)

$$m_t = \bar{m}_t(\mu)\left[1 + \alpha_S(\mu) c_1 + \alpha_S^2(\mu) c_2 + \ldots\right]$$

## Top mass measurement driven by parton shower generators




$$dP = \frac{\alpha_S}{2\pi} P(z)dz \, \frac{dQ^2}{Q^2} \, \Delta_S(Q^2_{\max}, Q^2)$$

$Q^2$: ordering variable

$\Delta_S(Q^2_{\max}, Q^2)$ : no radiation in $[Q^2, Q^2_{\max}]$ (soft/collinear virtual corrections)

$$\Delta_S(Q^2_{\max}, Q^2) = \exp\left[ -\frac{\alpha_S}{2\pi} \int_{Q^2}^{Q^2_{\max}} \frac{dQ'^2}{Q'^2} \int_{z_{\min}}^{z_{\max}} dz P(z) \right]$$

HERWIG : $Q^2 = E^2(1 - \cos\theta) \simeq E^2\theta^2/2$ (angular ordering);

PYTHIA: $Q^2 = p^2$ **or** $k_T^2$

$\alpha_S(k_T^2)$ with two-loop evolution in HERWIG and one-loop in PYTHIA

Total cross section LO thanks to unitarity $(1 = R + V)$

Distributions equivalent to threshold LL resummation, + some NLLs

$\Lambda \to \Lambda_{\rm MC} = \Lambda \exp(4K\beta_0)$: NLL Sudakov form factor at large $x$ (Catani, Marchesini and Webber)

Experimental analyses employ Monte Carlo parton showers which are not NLO QCD calculations, but LO+LL (soft/collinear), with some NLLs, neglect $\Gamma_t$ and depend on a few tunable non-perturbative parameters $(x_1, \ldots x_n)$

However, the reconstruction relies on final-state observables, then one would expect the extracted 'Monte Carlo mass' ($m_{\rm MC}$ mimicks the pole mass)

In the SCET framework (Hoang and Stewart) $m_t$ can be identified with the jet mass at the shower cutoff $Q_0 \sim \mathcal{O}(1\ \mathrm{GeV})$ and is in fact close to the pole mass:

$$m_{\rm pole} = m_J(\mu) + e^{\gamma_E}\Gamma_t \frac{\alpha_S(\mu) C_F}{\pi}\left(\ln\frac{\mu}{\Gamma_t} + \frac{1}{2}\right) + \mathcal{O}(\alpha_S^2)$$

Other strategy to address the meaning of the top mass (G.C. and M.L.Mangano):

Hadronize the top quark, i.e. meson states $T^{\pm,0} \sim t\bar{u}, t\bar{d}$ and let them decay according to the spectator model, i.e. $t \to bW$ with a spectator light quark and $W \to \ell\nu$

Showers from $b$ and spectator quarks

Invariant mass $m(Wb_{\rm jet})$ mimicks the top mass

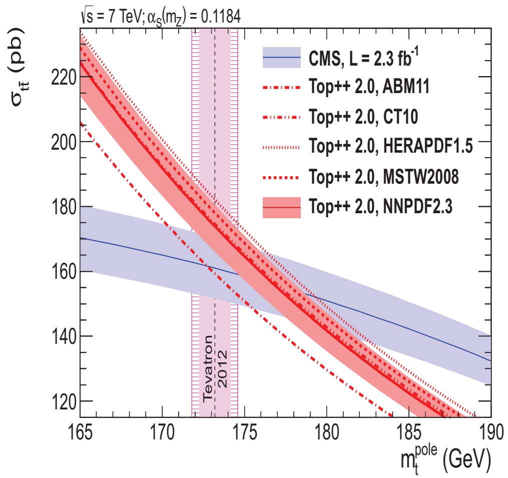
Relate meson mass to pole or $\overline{\rm MS}$ top masses via lattice, NRQCD, etc.

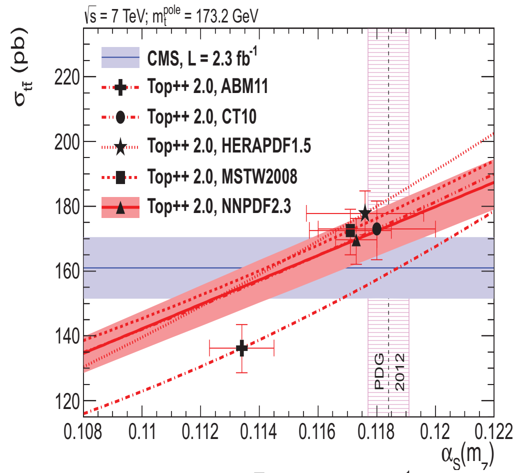
Work carried out within the LPCC and TOPLHCWG: hope of results for next meetings

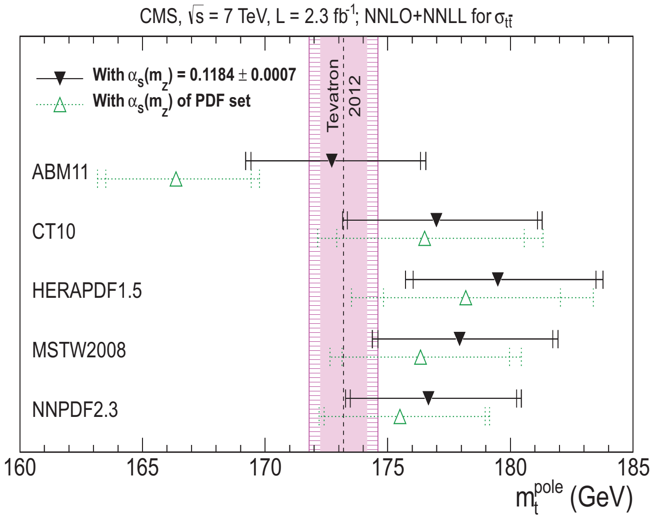
The total inclusive NNLO+NNLL $t\bar{t}$ cross section can be used to extract $m_t$ and $\alpha_S(m_Z)$: consistency with theoretical definitions, small perturbative and non-perturbative errors, very little impact of width effects

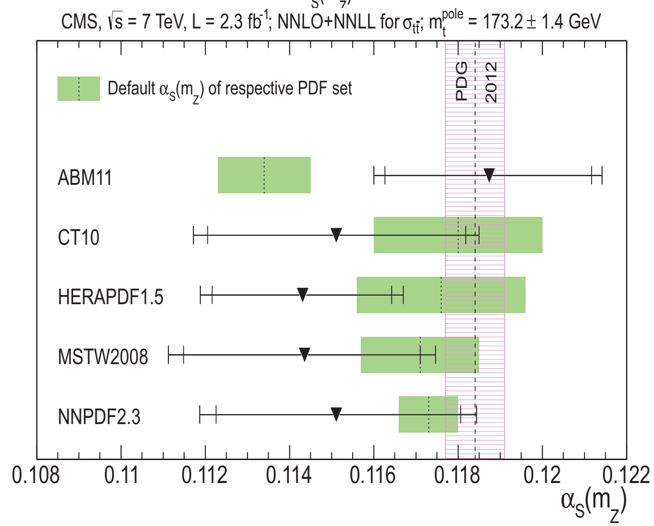
Disadvantage: mild dependence on $m_t$ implies large errors on the extracted values

Found result (CMS): $m_t^{\rm pole} = 176.7^{+3.8}_{-3.4}$ GeV agrees with the 'Monte Carlo' mass



Progress in bottom fragmentation in top decays

$b$-fragmentation contributes to the systematic error on the measurements

LHC inclusive analyses (dilepton, lepton+jets and all-hadrons) propagate the uncertainty on $b$-fragmentation to the systematic error due to $b$-jet energy scale and $b$-tagging efficiency

$J/\psi+$ lepton final states ($10^3$/year of high luminosity)

$t \to bW$ ; $b \to B \to J/\psi\ X$ ; $J/\psi \to \mu^+\mu^-$ ; $W \to \ell\nu_\ell$

A. Kharchilava, PLB 476 (2000) 73, R. Chierici and A. Dierlamm, CMS Note 2006/058

$m_{3\ell}^{\max} = 0.56\ m_t - 25.3$ GeV Systematics (theo + exp): $\Delta m_t(\mathrm{syst}) \simeq 1.47$ GeV

$b$-fragmentation (PYTHIA+Peterson model): $\Delta m_t(\mathrm{frag}) \simeq 0.51$ GeV

Several calculations and tools are available for bottom fragmentation in top decays, but not unique strategy for the systematic error

Tuning Monte Carlo models directly to LHC data, e.g. $t\bar{t}$, $b\bar{b}$ or $\gamma/Z + b$ not yet carried out, but can be useful to validate Monte Carlo programs and test hadronization models and factorization

Possibility to minimize impact of production phase and ISR by constructing clever observables, e.g. $p_T(B)/p_T(Z)$ in $Z + b$ events

G. C. and V. Drollinger, NPB (2005): weakly-decaying $B$-hadron data from OPAL (mesons and baryons), ALEPH (only mesons) and SLD (mesons and baryons)

| HERWIG | PYTHIA |
|---|---|
| CLSMR(1) $=$ 0.4 (0.0) | |
| CLSMR(2) $=$ 0.3 (0.0) | PARJ(41) $=$ 0.85 (0.30) |
| DECWT $=$ 0.7 (1.0) | PARJ(42) $=$ 1.03 (0.58) |
| CLPOW $=$ 2.1 (2.0) | PARJ(46) $=$ 0.85 (1.00) |
| PSPLT(2) $=$ 0.33 (1.00) | |
| $\chi^2/\mathrm{dof}$ $=$ 222.4/61 (739.4/61) | $\chi^2/\mathrm{dof}$ $=$ 45.7/61 (467.9/61) |

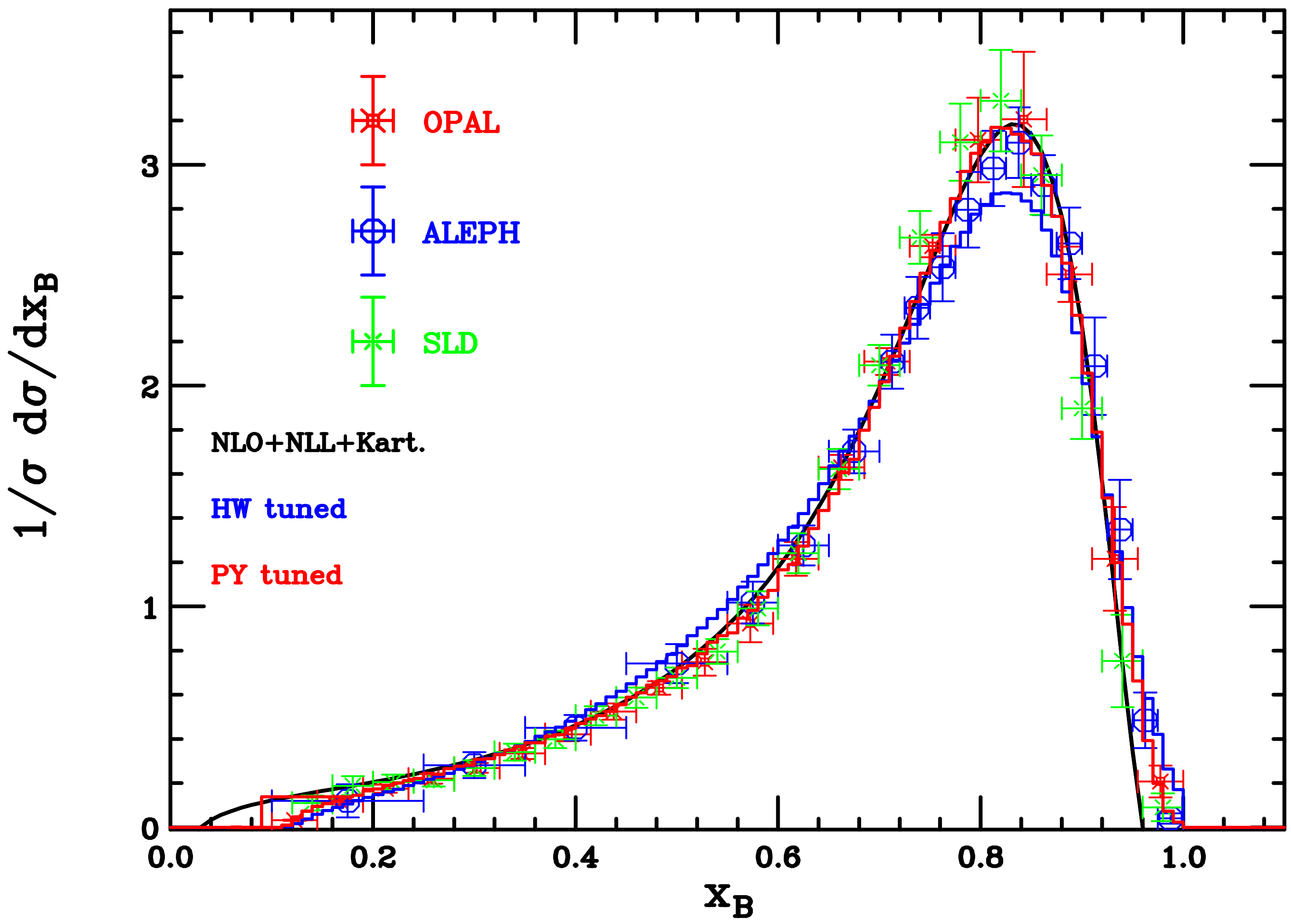
Lund/Bowler fragmentation function (PYTHIA):

$$f_B(z) \propto \frac{1}{z^{1+brm_b^2}}(1-z)^a \exp(-bm_T^2/z)$$

HERWIG tuned parameters describe hadron gaussian smearing (CLSMR), baryon/meson (CLPOW) and decuplet/octet (DECWT) ratios, mass spectrum of $b$-like clusters (PSPLT)

Our PYTHIA tuning in ATLAS jet-energy measurement (EPJ C73 (2013) 2304) and as a cross-check for top analyses

# Comparing tuned HERWIG and PYTHIA

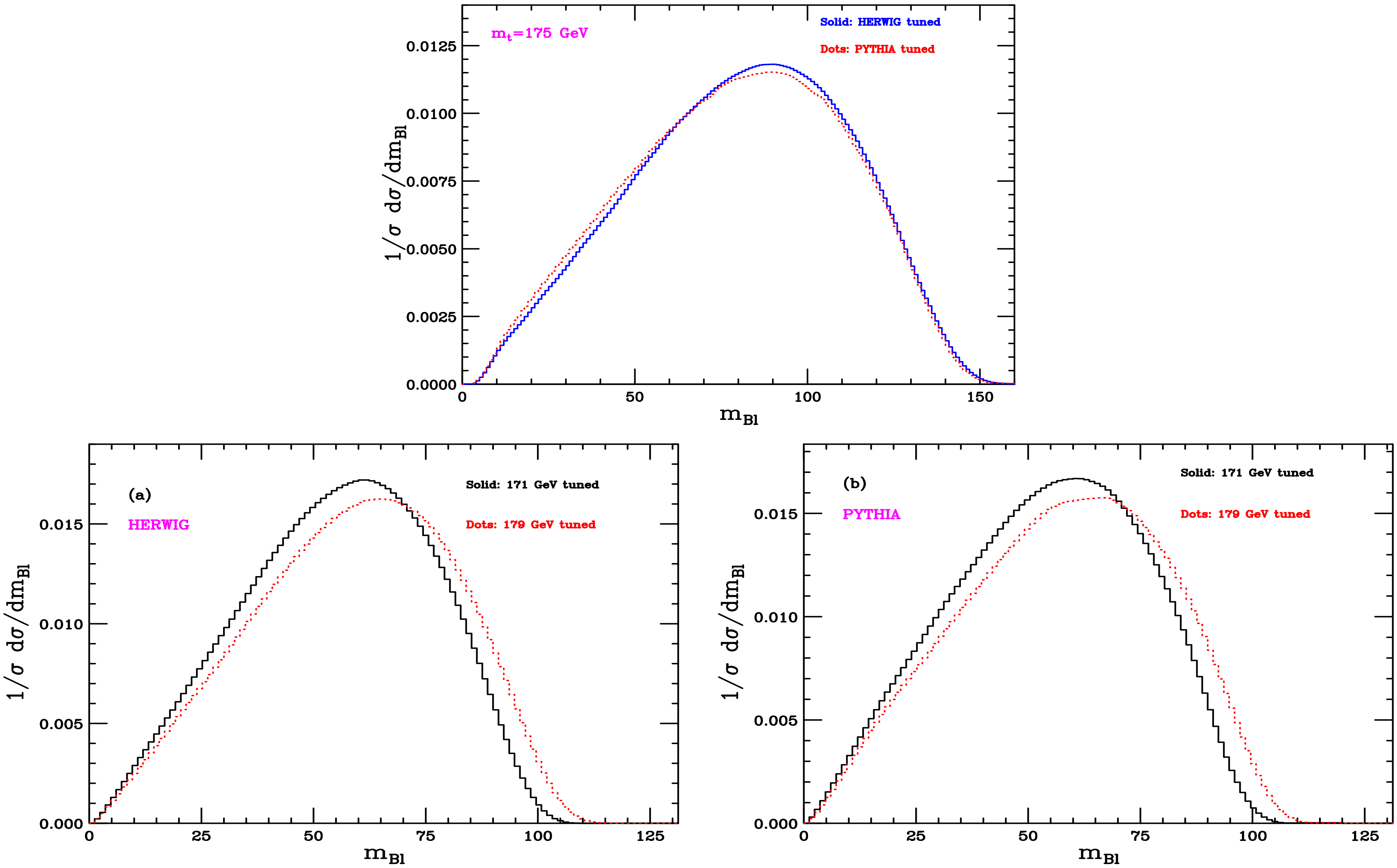



NLO+NLL calculation with Kartvelishvili model: M.Cacciari and S.Catani '01

$D_{\rm np}(x_B, \alpha) = (1+\alpha)(2+\alpha)x_B(1-x_B)^\alpha$

Best fit $(0.18 \leq x_B \leq 0.94)$: $\alpha = 17.178 \pm 0.303, \quad \chi^2/\text{dof} = 46.2/53$

# $m_{B\ell}$ according to tuned HERWIG and PYTHIA (G.C. and F.Mescia, EPJ '10)

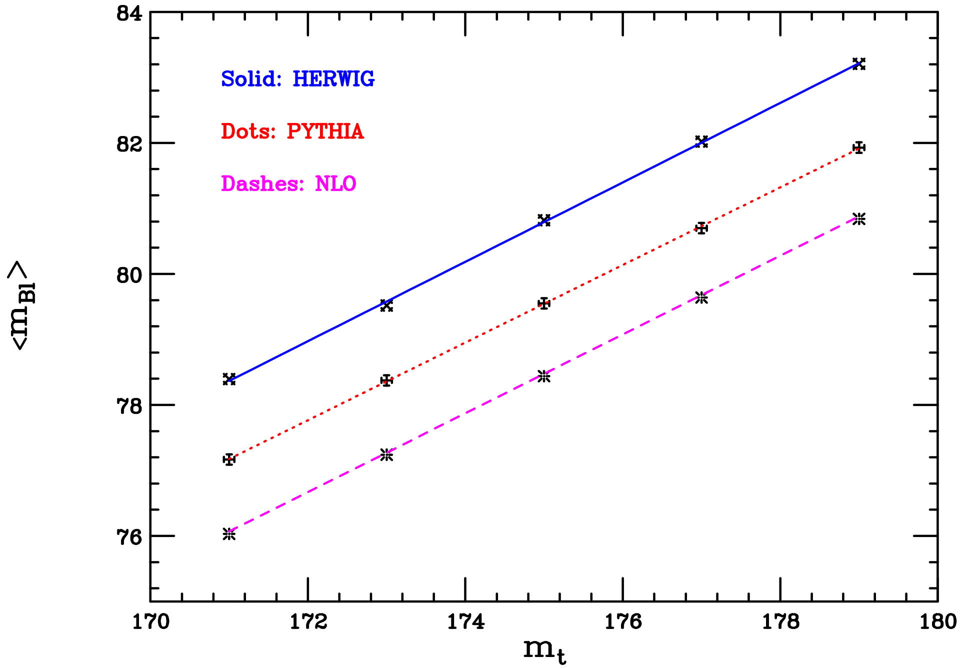


Linear fits to extract $m_t$ from $m_{B\ell}$

HERWIG: $\langle m_{B\ell}\rangle_{\rm H} \simeq -25.31 \text{ GeV} + 0.61\, m_t$ ; $\delta = 0.043$ GeV

PYTHIA: $\langle m_{B\ell}\rangle_{\rm P} \simeq -24.11 \text{ GeV} + 0.59\, m_t$ ; $\delta = 0.022$ GeV

NLO: $\langle m_{B\ell}\rangle_{\rm NLO} \simeq -26.7 \text{ GeV} + 0.60\, m_t$ ; $\delta = 0.004$ GeV




$\Delta\langle m_{B\ell}\rangle_{\rm H,P} \simeq 1.2$ GeV, $\Delta\langle m_{B\ell}\rangle_{\rm H,NLO} \simeq 2.2$ GeV, $\Delta\langle m_{B\ell}\rangle_{\rm P,NLO} \simeq 1.1$ GeV
$\Delta m_t \simeq 2$ GeV: large systematics driven by NLO vs. LO and unsatisfactory tunings

NLO+showers for top decays or C++ codes may shed light on this discrepancy

## Perspectives in (N)NLO+shower codes

POWHEG: top production at NLO, not yet $e^+e^-$ annihilation

NLO corrections to top decays in POWHEG are available, but turned off in default version: work in progress

aMC@NLO: NLO $e^+e^-$ and hadronic top production for stable top quarks

No full NLO corrections to top decays, but finite-width effects available, for single-top production including both resonant and non-resonant (non-top) diagrams

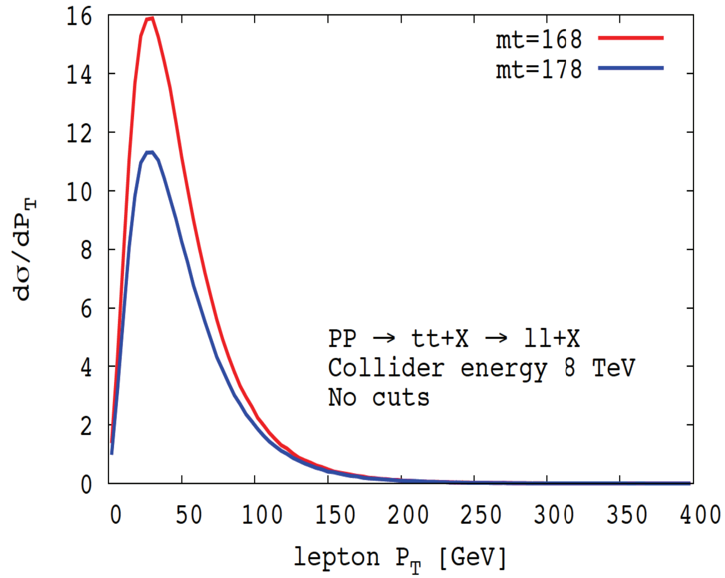
Perspectives to include shower and hadronization in the NLO calculation with off-shell tops by A.Denner et al, '12

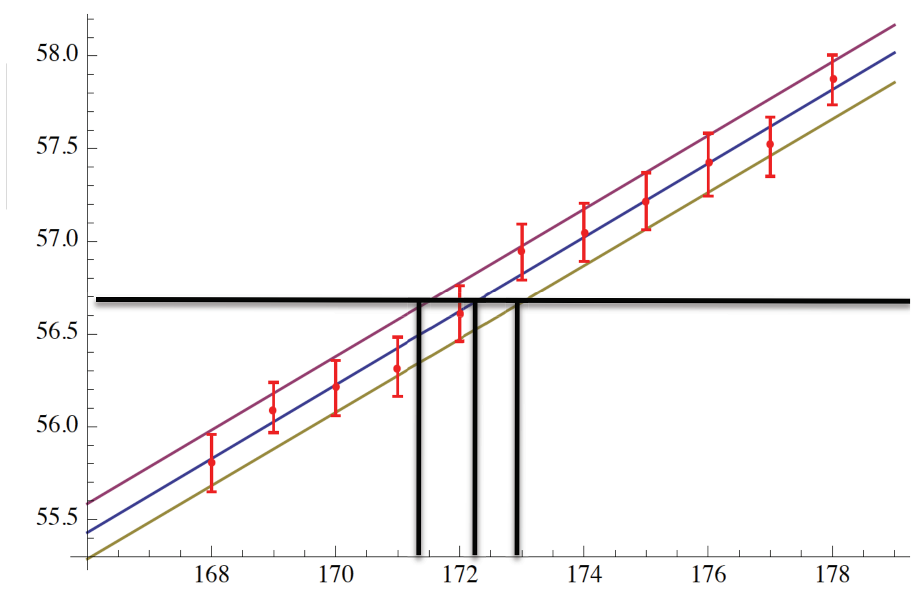
Interest by the authors of NNLO exclusive top decays (J.Gao et al. '12, F.Caola et al.'12) to include $b$-fragmentation at NNLO, but not straightforward (e.g. A.Mitov and K.Melnikov NNLO perturbative fragmentation functions in the $\overline{\mathrm{MS}}$ factorization scheme)

# Extracting $m_t$ from dilepton differential distributions

Like the $J/\psi$ method, one can measure $m_t$ from distributions on dilepton final states, such as $\ell\ell$ invariant mass, $p_T$ of single lepton or pair, (scalar) sum of lepton energies and transverse momenta

Minimizes uncertainty due to showering and hadronization corrections; available NLO calculations and Monte Carlo generators - example with $\langle p_T \rangle$ vs. $m_t$



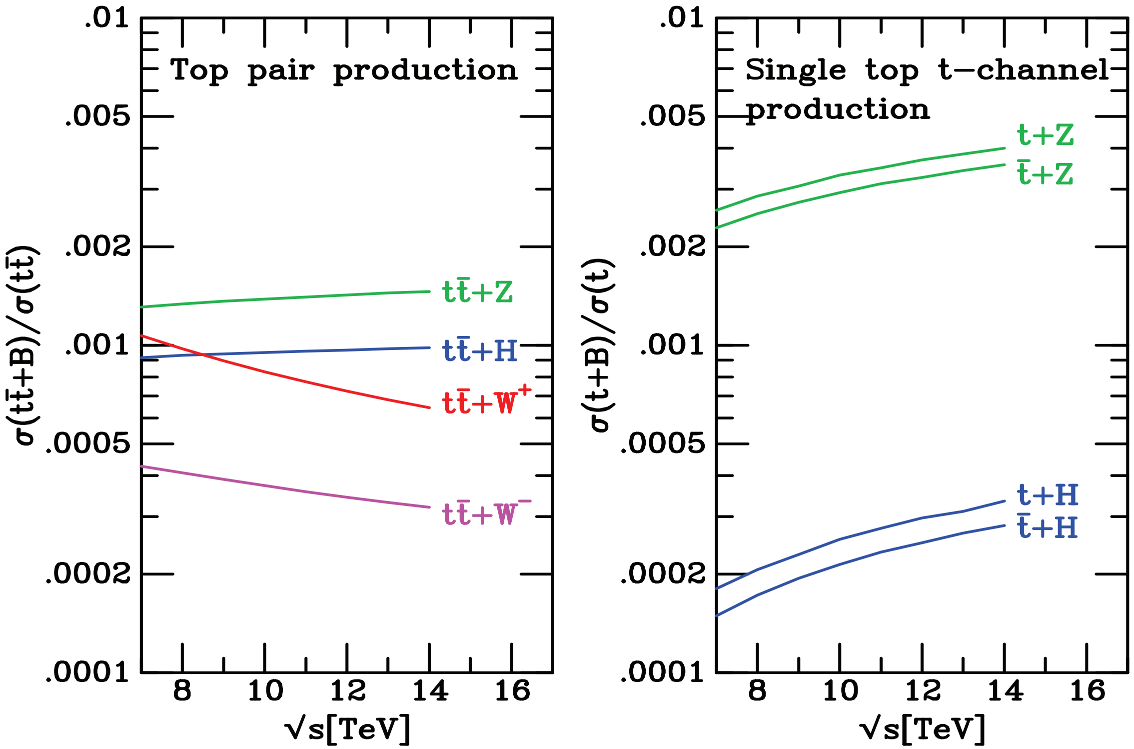

Investigation was carried out with and without spin correlatiions using aMC@NLO

Theory error on $m_t$ from dilepton distributions varies from 800 MeV (single-lepton $p_T$) to 2 GeV (sum of lepton energies)

Lepton-pair $p_T$ and invariant mass exhibit great dependence on spin correlations

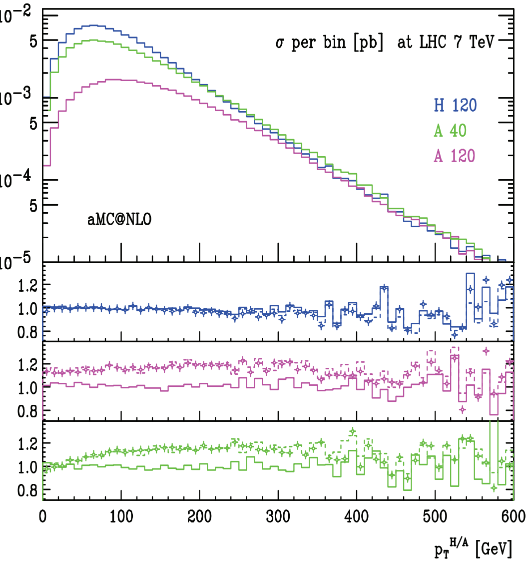
Associated $t\bar{t}+H$ production: the coupling of the top quark to the Higgs boson is of great interest, as the top yields the largest contribution to the NLO correction to the Higgs mass

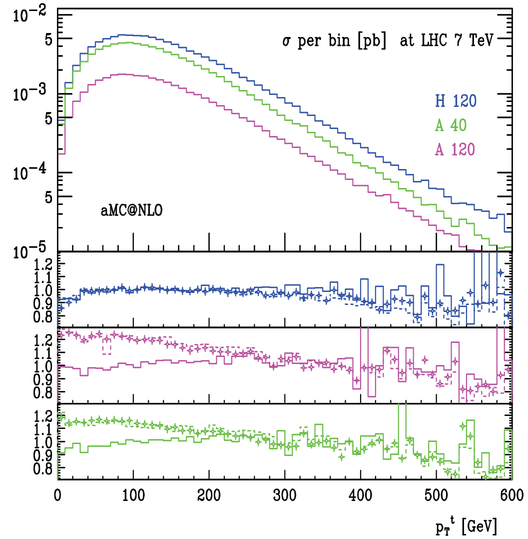
Inclusive $t\bar{t}$ and single top plus boson proton production (MCFM, NLO):

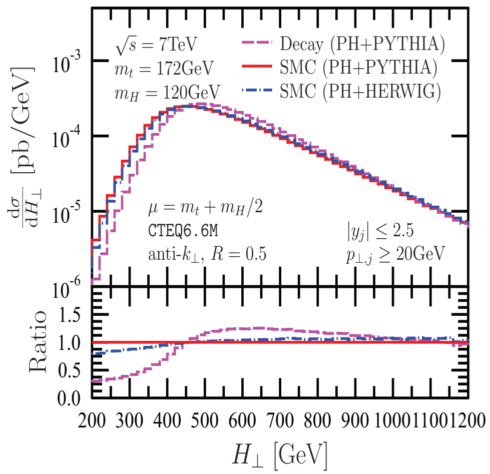


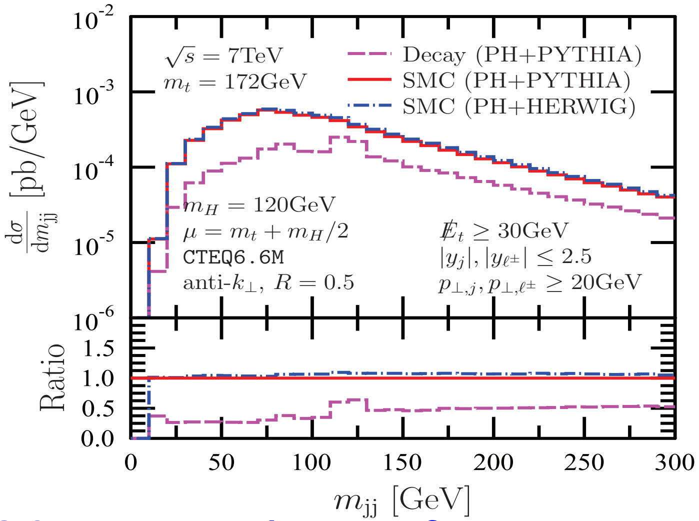

NLO corrections to $pp \to t\bar{t}H$ have been available for several years (Beenakker et al., 2001, S. Dawson et al., 2002); lately, inclusion of NLO $t\bar{t}H$ matrix elements in POWHEG box and aMC@NLO (2011)

# Impact of NLO corrections (above aMC@NLO, below POWHEG):




MC studies on the extraction of the top-Higgs Yukawa coupling $y_t$ for $H \to \tau\tau/\mu\mu/WW$, varying systematic uncertainties between 1/2 and the 2013 level at 14 TeV:

$\mathcal{L} = 300$ fb$^{-1} \Rightarrow \Delta y_t \simeq (14 - 15)\%$; $\mathcal{L} = 3000$ fb$^{-1} \Rightarrow \Delta y_t \simeq (7 - 10)\%$

## Conclusions

Top quark phenomenology at the LHC is challenging at 7, 8 and, ultimately, 14 TeV

Recent calculations on jet substructures and subjettiness are very useful to investigate boosted top events

Clever algorithms can help in New Physics searches, e.g. $Z' \to t\bar{t}$

NLO and NLO+shower tools available for associated $t\bar{t}H$ production

Novel observables suggested to investigate charge asymmetry at LHC

Late calculation on $t\bar{t}$ production cross section at NNLO+NNLL

Several strategies to reconstruct the top mass: usual matrix-element/template methods, $J/\psi$ and dilepton kinematic distributions

Investigation of bottom fragmentation in top decays and impact on the top mass: need to retune Monte Carlo codes, otherwise large uncertaintes

For most analyses at least two computations/tools for the sake of comparison

Further interactions between analysis groups and theorists (MC authors) should be encouraged