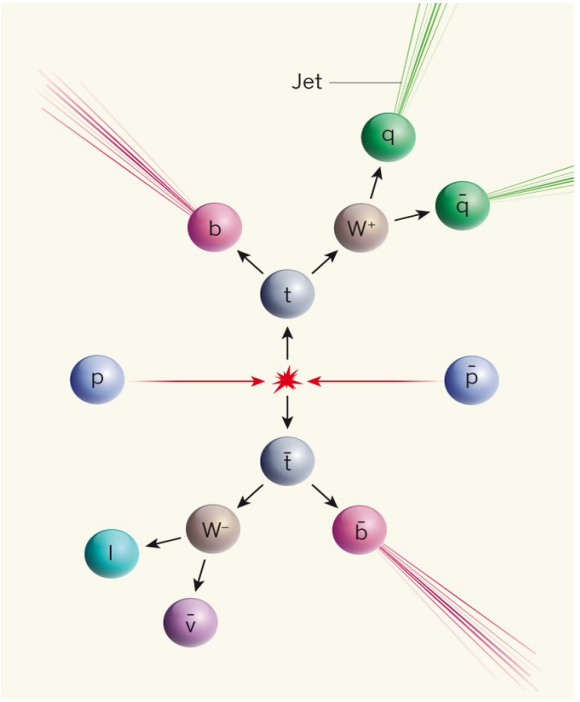

RWTH AACHEN UNIVERSITY

Computational Theoretical Particle Physics
KA AC B
SFB TR9

Recent developments and prospects in ttbar QCD calculations at NNLO

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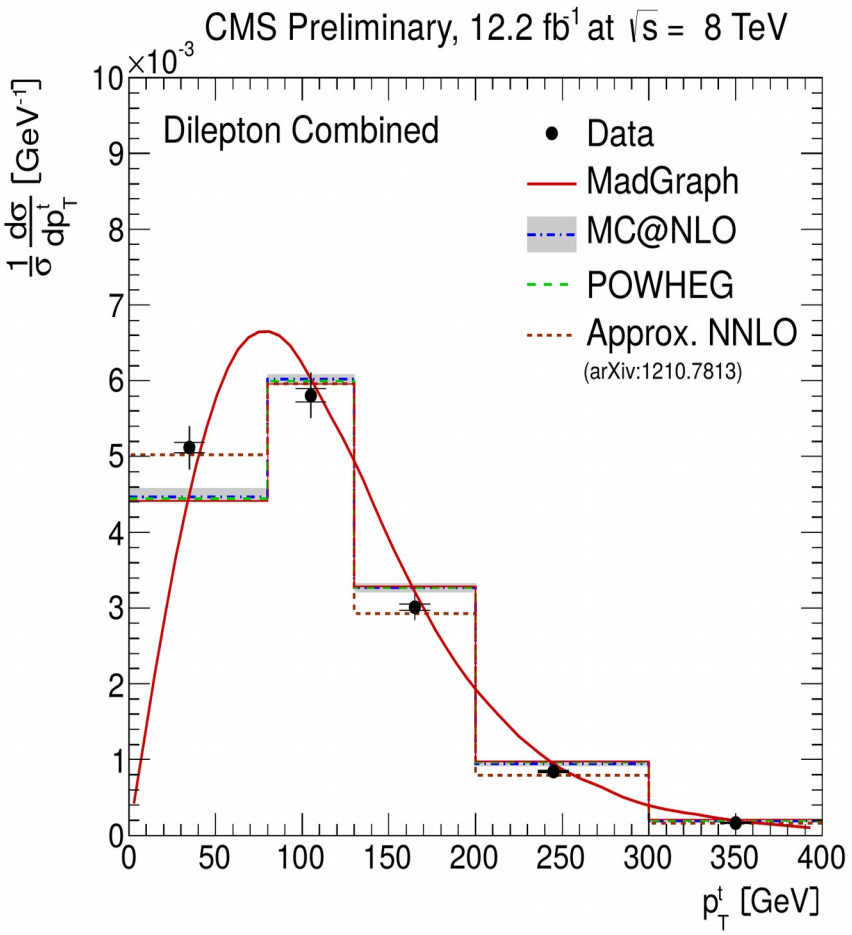
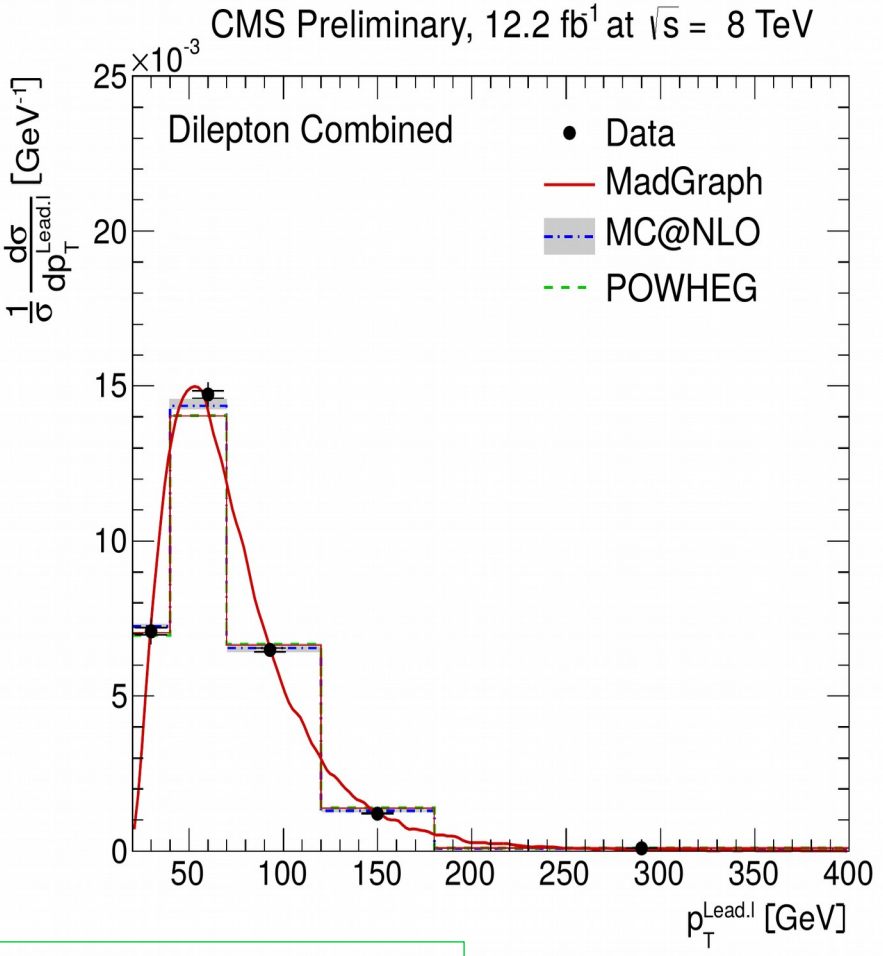
SM@LHC, April 2014

Differential ttbar cross section (NLO)

- SM@LHC 2014 (Summary)

[CMS PAS TOP-12-028]





- Differential ttbar cross section at NNLO
- Top Decays (NWA) at NNLO

Overview of ttbar at NNLO

- Total inclusive cross section is known
  [Baernreuther, Czakon, Fiedler, Mitov; 2013]
- Differential distributions for the Tevatron have been presented
  [Czakon, Fiedler, Mitov; 2014]
- Subtraction scheme STRIPPER has proven applicability
  [Czakon; '10, '11]
  - Further applications
- Independent approaches
  - Based on antennae subtraction, partial results for the quark channel are obtained
    [Abelof, Gehrmann-DeRidder, Maierhofer, Pozzorini; 2014]
  - Extending qt-subtraction to top pairs
    [Zhu, Li, Li, Shao, Yang; 2013], [Catani, Grazzini, Torre; 2014]

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This Talk

  - Further applications
- Independent approaches
  - Based on antennae subtraction, partial results for the quark channel are obtained
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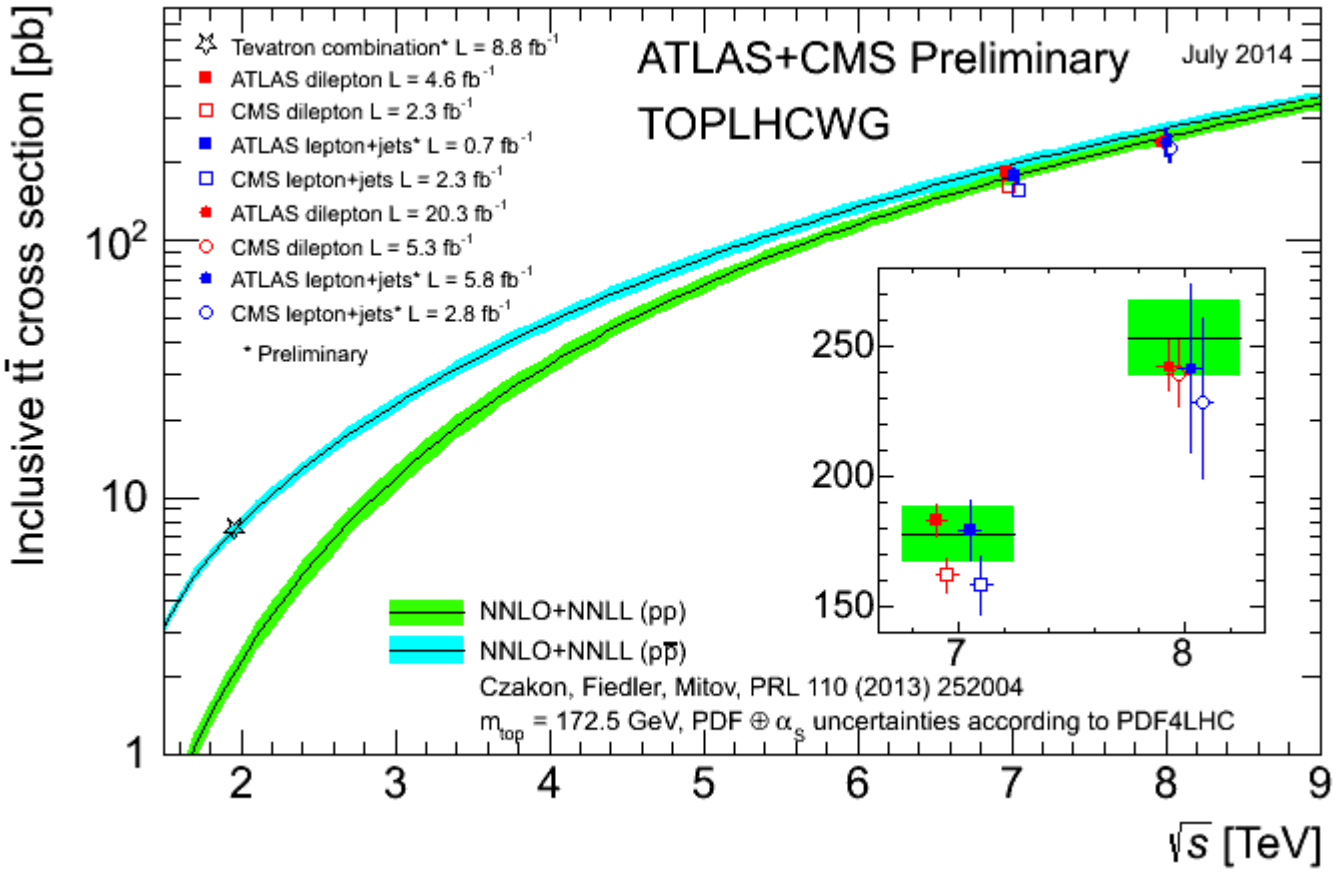
    [Zhu, Li, Li, Shao, Yang; 2013], [Catani, Grazzini, Torre; 2014]

Total inclusive cross section at NNLO (+NNLL)

[Czakon, Fiedler, Mitov; 2013]

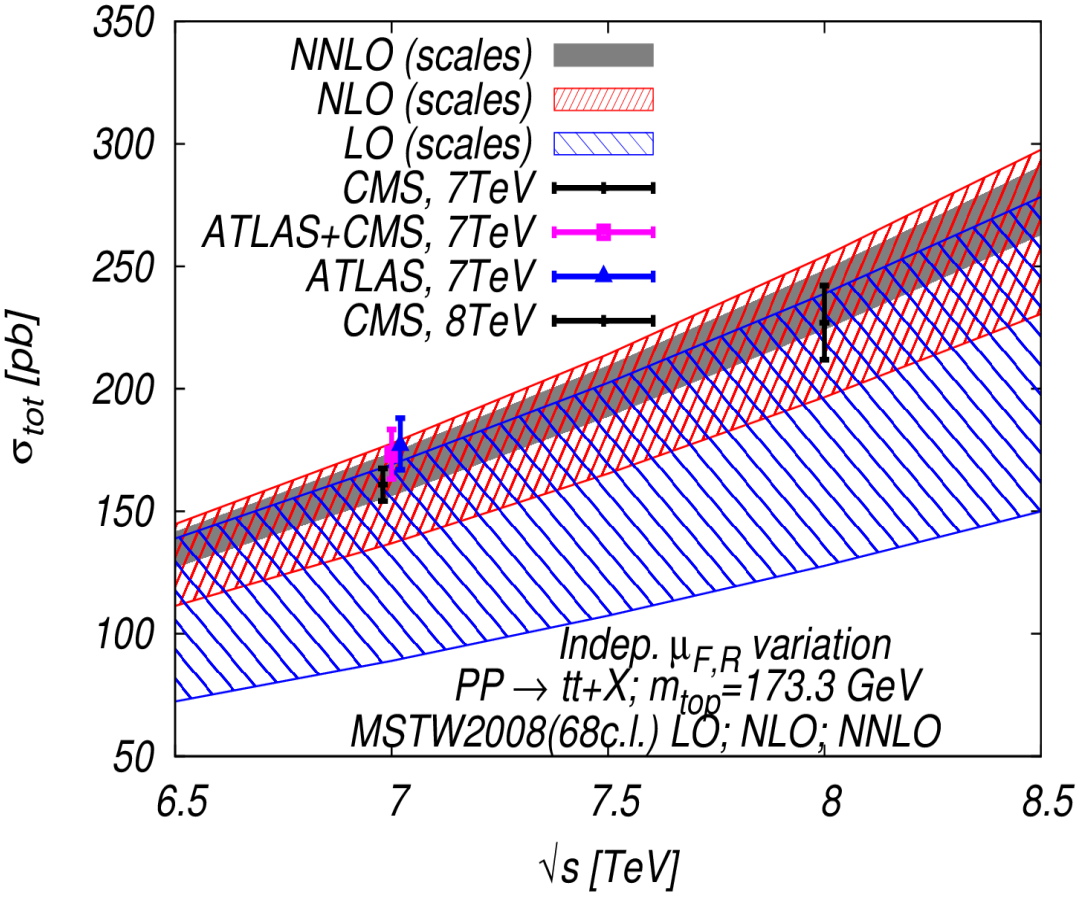
- Where we are

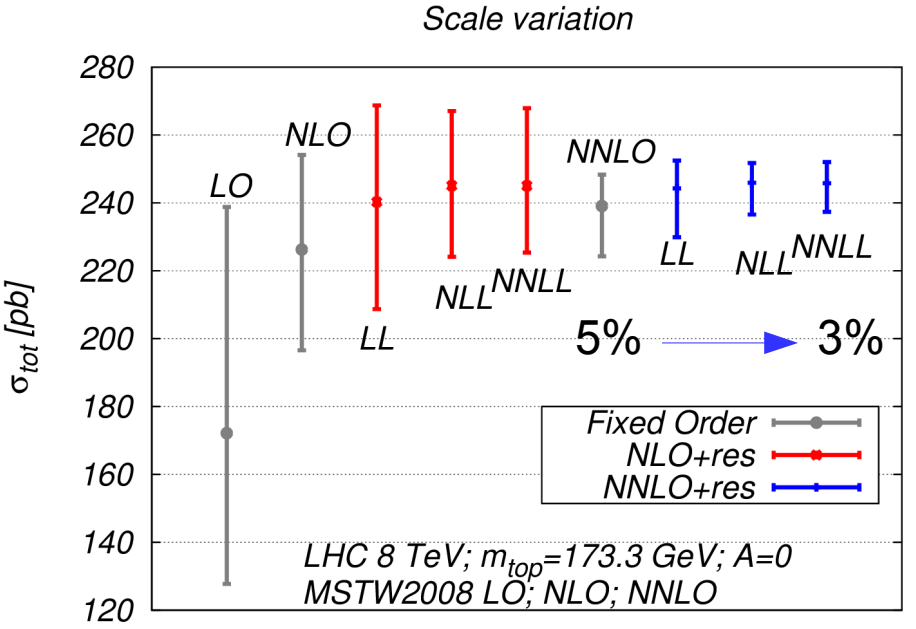


Theory convergence

[Czakon, Fiedler, Mitov, Rojo; 2013]

- Varying factorization and renormalization scale





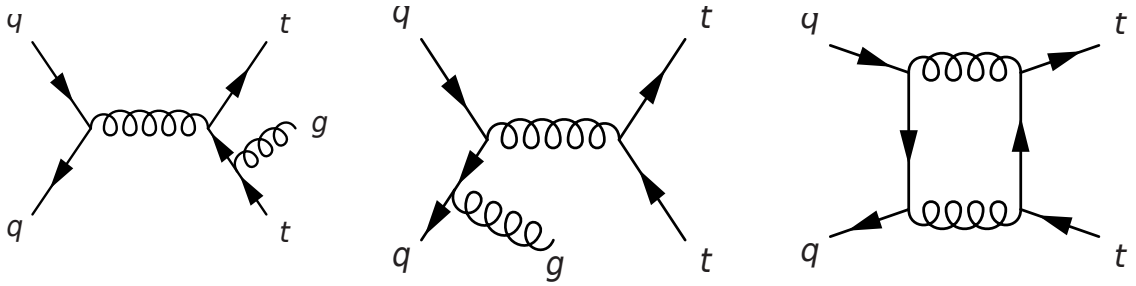
Uncertainties:

- scales ~3%
- pdf (at 68% cl) ~2-3%
- m(top) ~3%
- α_s ~1.5%

Forward- Backward Asymmetry puzzle

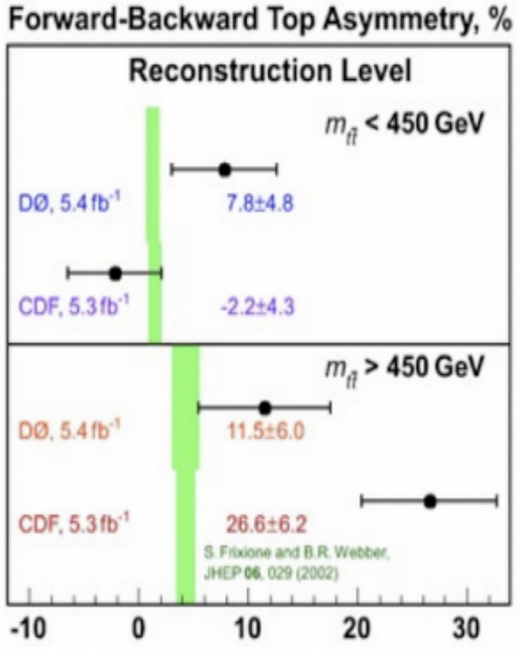
$$A_{\mathrm{FB}}^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

$$\Delta y = y_t - y_{\bar{t}}$$



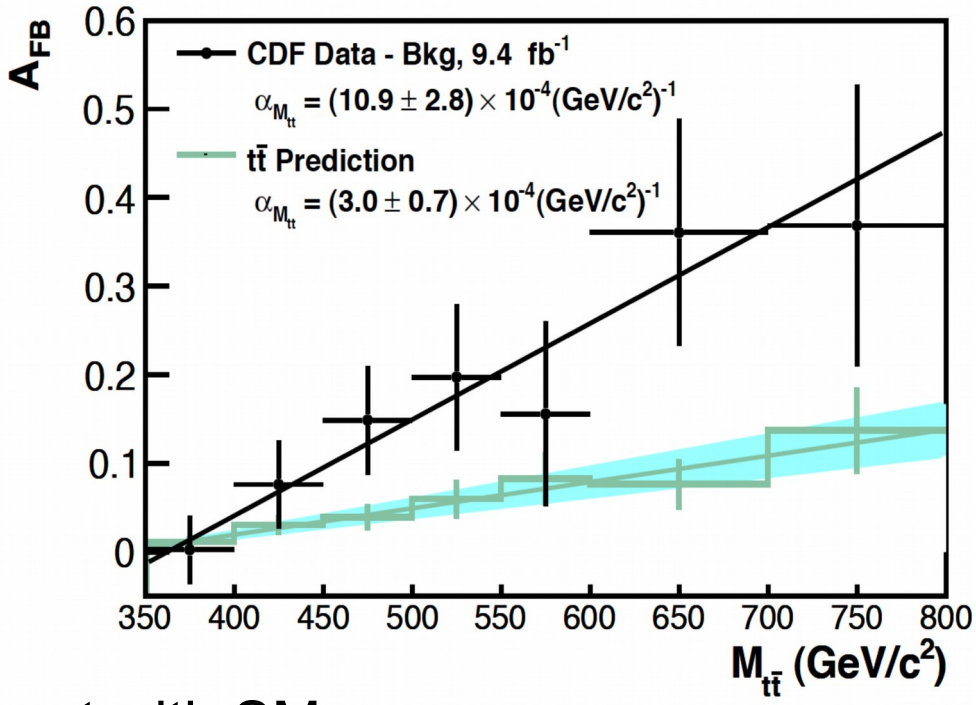
[Kühn, Rodrigo; '98, '99]

- History before NNLO



Discrepancy > 2σ

BSM ?



- D0 analysis (2014) in good agreement with SM

Forward- Backward Asymmetry (NNLO)

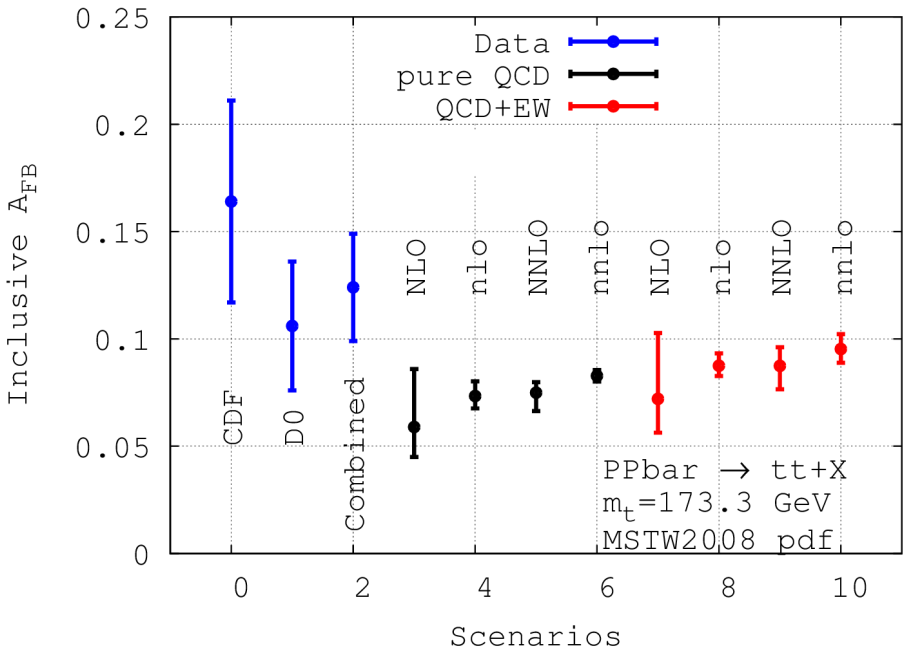
- Inclusive asymmetry
  - EW corrections included

[Bernreuther, Si; 2012]

$$A_{FB} = \frac{N_{EW} + \alpha_S^3 N_3 + \alpha_S^4 N_4 + \mathcal{O}(\alpha_S^5)}{\alpha_S^2 D_2 + \alpha_S^3 D_3 + \alpha_S^4 D_4 + \mathcal{O}(\alpha_S^5)} \quad \text{(N)NLO}$$

$$= \alpha_S \frac{N_3}{D_2} + \frac{N_{EW}}{\alpha_S^2 D_2} + \alpha_S^2 \left(\frac{N_4}{D_2} - \frac{N_3 D_3}{D_2^2} \right) - \frac{N_{EW} D_3}{\alpha_S D_2^2} + (\alpha_S^3) \quad \text{(n)nlo}$$

[Czakon, Fiedler, Mitov; 2014]



- Large QCD corrections: NNLO ~27% of NLO (EW ~25% NLO)

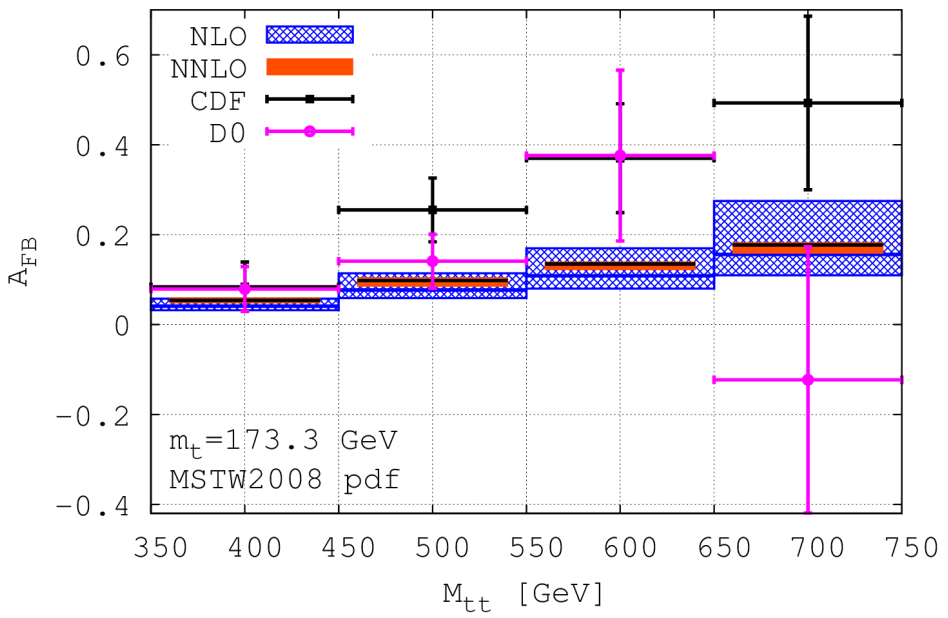
⇒ Not expected (soft gluon resummation suggests negligible correction.)

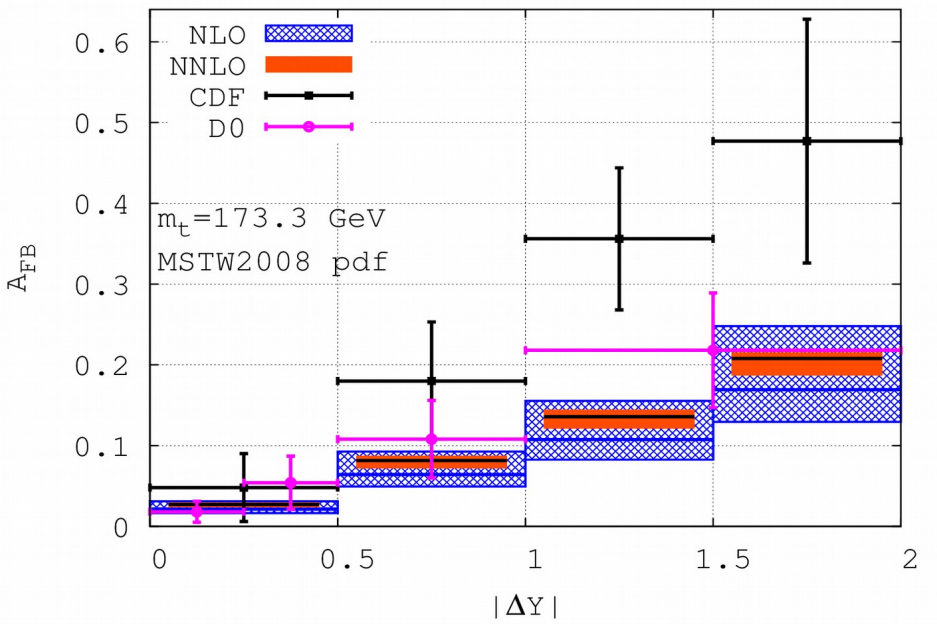
- Agreement with D0 and combination of CDF/D0
- Less than 1.5σ below CDF

Forward- Backward Asymmetry (NNLO)

- Differential asymmetry

[Czakon, Fiedler, Mitov; 2014]





$$A_{\rm FB} = \frac{\sigma^+_{\rm bin} - \sigma^-_{\rm bin}}{\sigma^+_{\rm bin} + \sigma^-_{\rm bin}}$$

$$\sigma^\pm_{\rm bin} = \int \theta(\pm\Delta y)\theta_{\rm bin}{\rm d}\sigma$$

Fully differential NNLO result for ttbar (exact, all channels included)

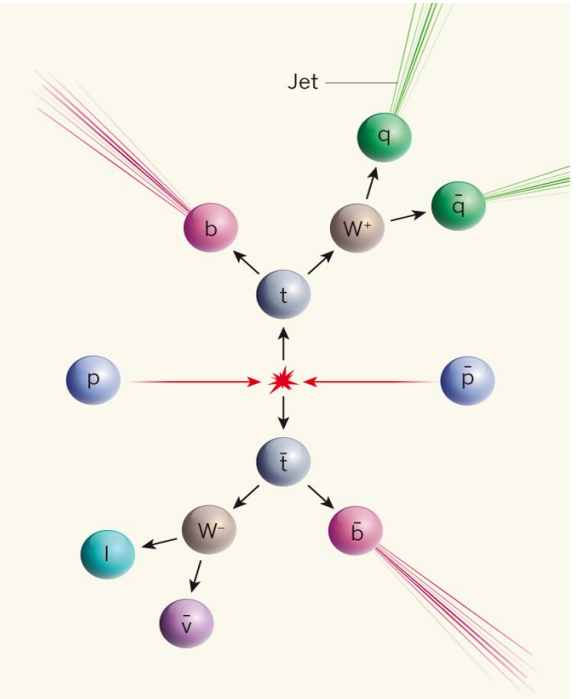
Differential distributions → LHC

- Tevatron
  - Soon to be published [Czakon, Fiedler, Mitov; '15]
- LHC
  - Possible and preliminary results were presented [TOP 2014]
  - Demands are challenging

- Ongoing and future improvements
  - Four dimensional formulation of STRIPPER [Czakon, DH; '14]
  - New implementation under development
    - General purpose, not restricted to ttbar and 2 → 2
  - Inclusion of top decays (NWA), top decay is known at NNLO
    [Gao, Li, Zhu; '12]
    [Brucherseifer, Caola, Melnikov; '13]

Summary and outlook

- Working code that calculates fully differential ttbar cross section (no approximations, all channels)
- High quality predictions for Tevatron (Asymmetry, differential distributions)
- New software under development
  - Satisfying LHC demands
  - General purpose (not restricted to ttbar)
- Soon
  - Differential distributions for LHC
  - Top Decays



Back Up

Theory ingredients

- Main parts
  - 2 – loop virtual corrections (V-V)

    High precision numerical [Czakon; '07], [Bärnreuther, Czakon, Fiedler; '13]

  - 1 – loop virtual with additional parton (R-V)

    Code by S. Dittmaier for tt + jet

    New subtraction Terms: [Bierenbaum, Czakon, Mitov; '11]

  - Tree level with two additional partons (R-R)

    Subtraction scheme STRIPPER [Czakon; '10, '11]

- Further ingredients
  - 1 – loop squared [Körner, Merebashvili, Rogal; '07]
  - ...