

ATLAS

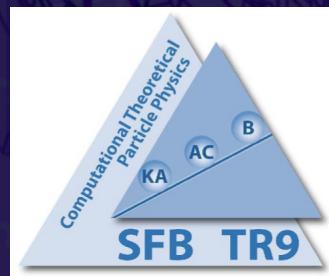
Forward
Calorimeters

S.C. Solenoid

S.C. Air Core
Toroids

tT cross section: theory and experimental results

Latest developments in generators and NNLO computations



EM Calorimeters

Muon Shieldings

M. Czakon

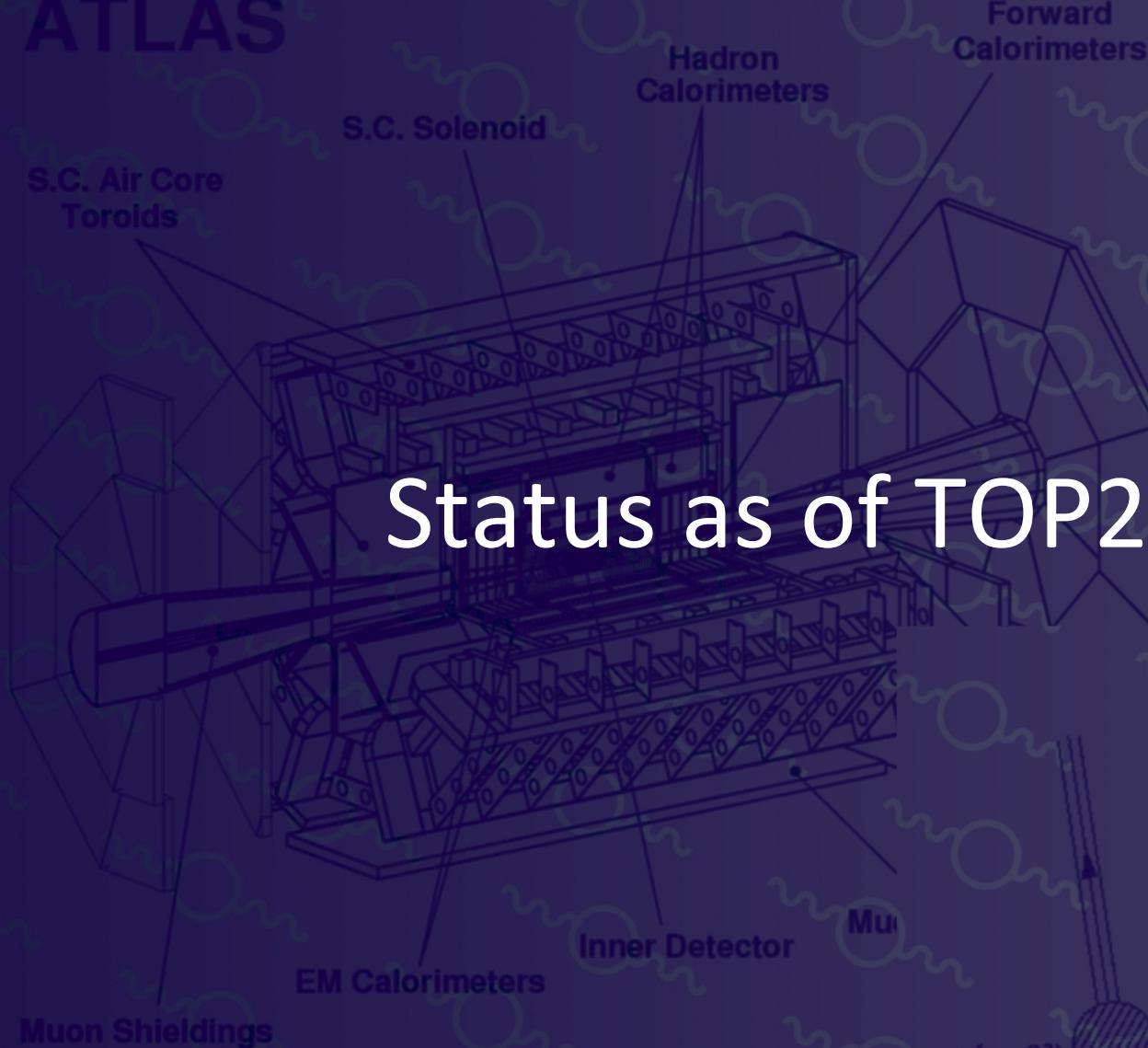
RWTH Aachen

In collaboration with: P. Fiedler, A. Mitov

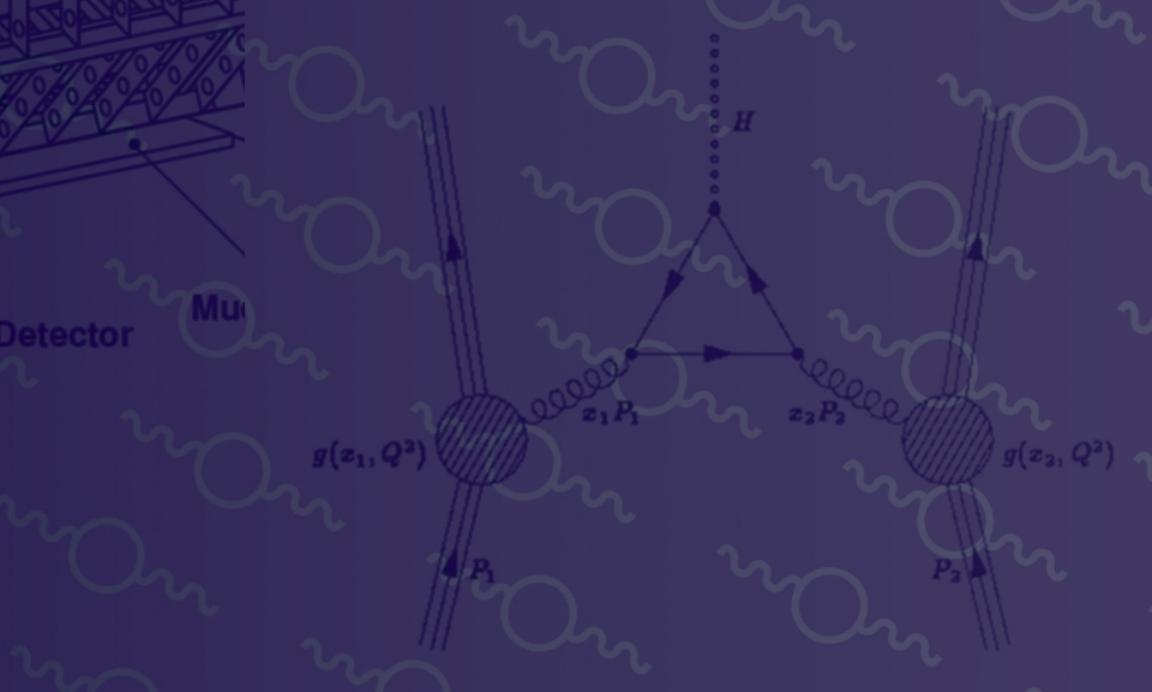


1. Status as of TOP2013
2. What we can do now
3. Differential description at the TeVatron and the asymmetry
4. Differential distributions for the LHC

ATLAS



Status as of TOP2013



ATLAS Predictions for hadron colliders

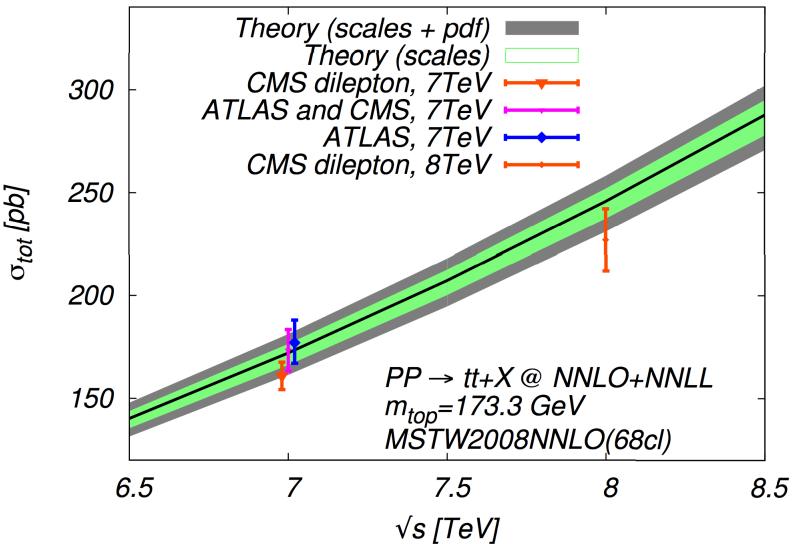
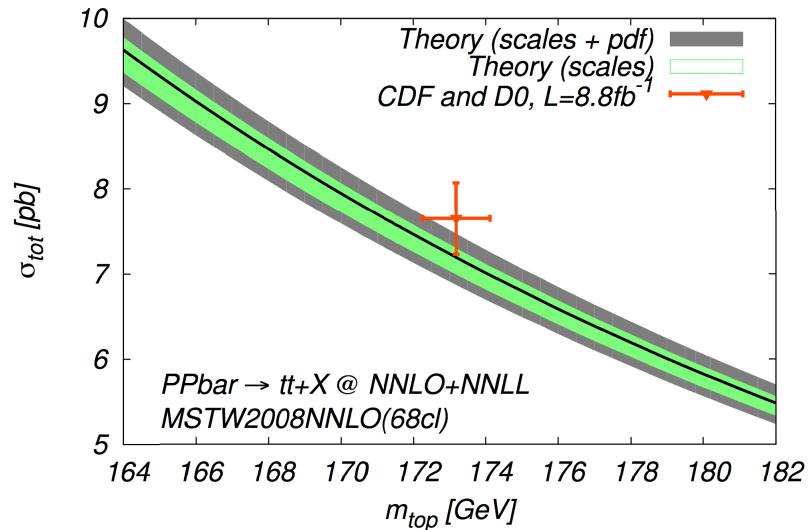
MC, Fiedler, Mitov '13

NNLO + NNLL

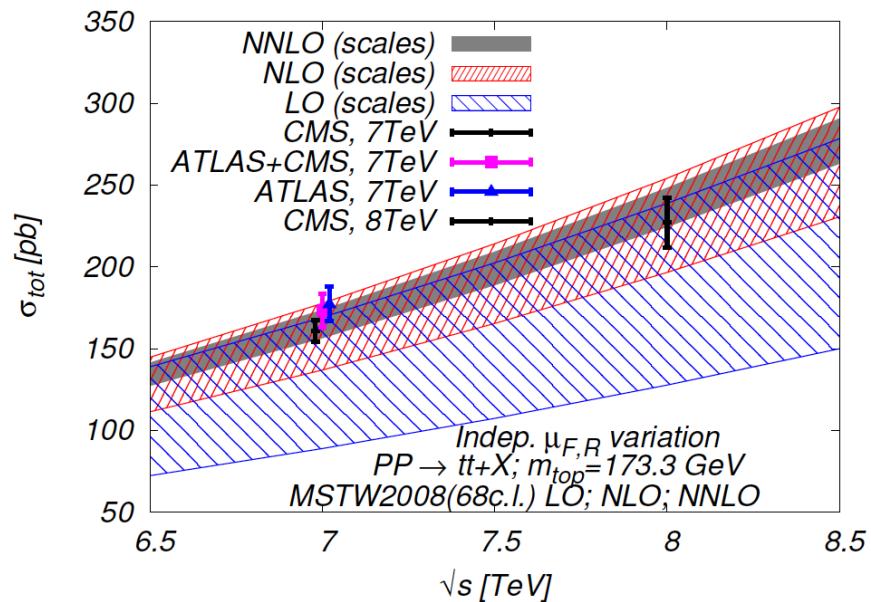
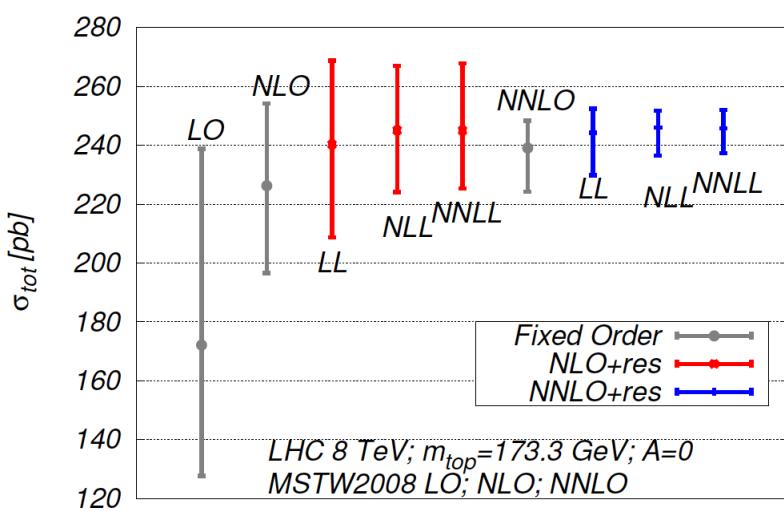
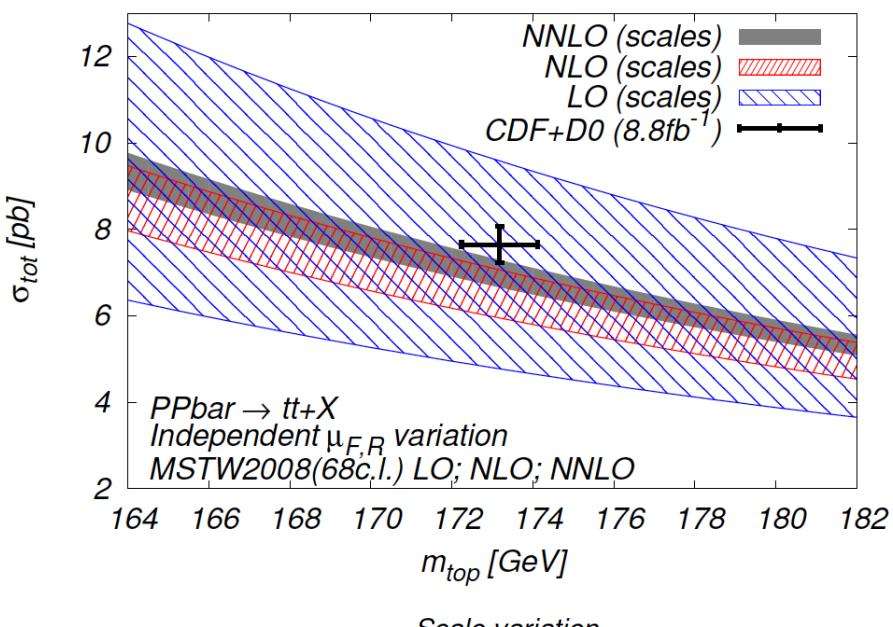
Collider	σ_{tot} [pb]	scales [pb]	pdf [pb]
Tevatron	7.164	+0.110(1.5%) -0.200(2.8%)	+0.169(2.4%) -0.122(1.7%)
LHC 7 TeV	172.0	+4.4(2.6%) -5.8(3.4%)	+4.7(2.7%) -4.8(2.8%)
LHC 8 TeV	245.8	+6.2(2.5%) -8.4(3.4%)	+6.2(2.5%) -6.4(2.6%)
LHC 14 TeV	953.6	+22.7(2.4%) -33.9(3.6%)	+16.2(1.7%) -17.8(1.9%)

NNLO

Collider	σ_{tot} [pb]	scales [pb]	pdf [pb]
Tevatron	7.009	+0.259(3.7%) -0.374(5.3%)	+0.169(2.4%) -0.121(1.7%)
LHC 7 TeV	167.0	+6.7(4.0%) -10.7(6.4%)	+4.6(2.8%) -4.7(2.8%)
LHC 8 TeV	239.1	+9.2(3.9%) -14.8(6.2%)	+6.1(2.5%) -6.2(2.6%)
LHC 14 TeV	933.0	+31.8(3.4%) -51.0(5.5%)	+16.1(1.7%) -17.6(1.9%)



Perturbative convergence



Concurrent uncertainties:

Scales	$\sim 3\%$
pdf (at 68%cl)	$\sim 2-3\%$
α_s (parametric)	$\sim 1.5\%$
m_{top} (parametric)	$\sim 3\%$

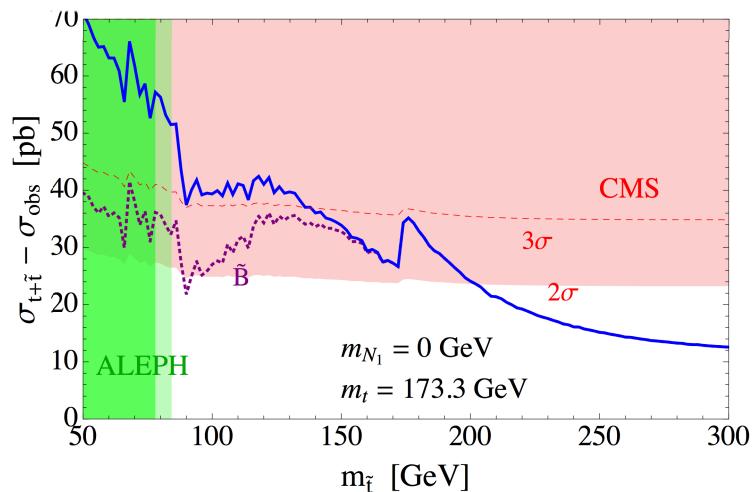
Soft gluon resummation makes a difference:

5%

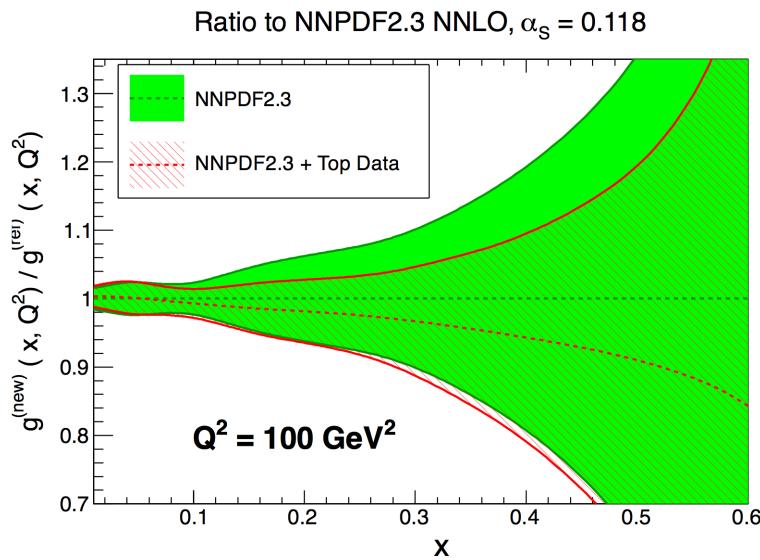
->

3%

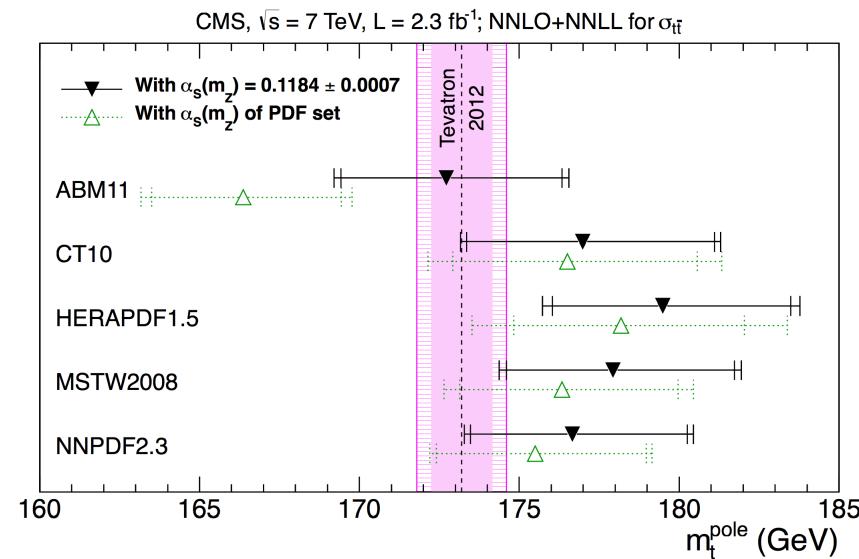
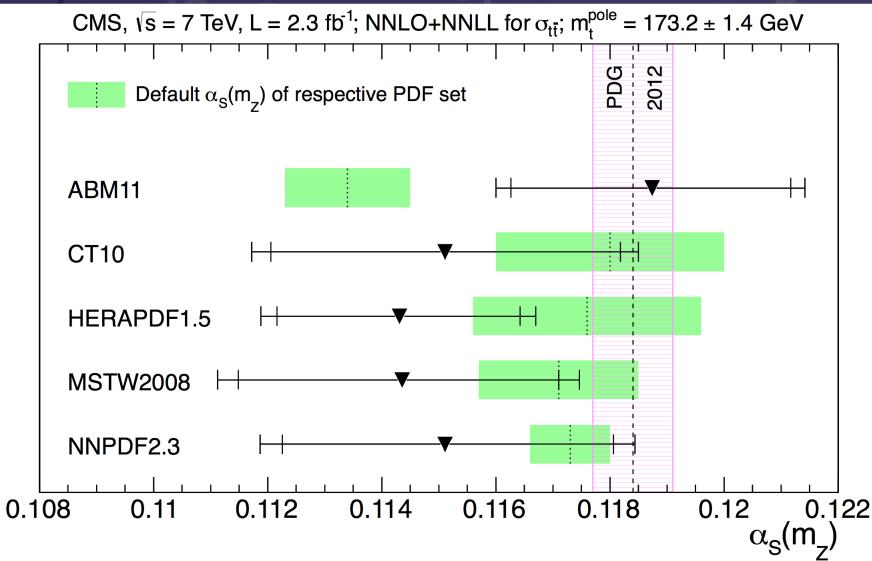
Applications



MC, Mitov, Papucci, Ruderman, Weiler, '14



MC, Mangano, Mitov, Rojo '13



arXiv:1307.1907 (CMS-TOP-12-022)

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What we can do now



What we can do now

- Fully differential top pair production at NNLO
- Everything is included – no approximations!
- Stable top quarks only. Down the road include decay but not a priority now.
- For the moment we compute only pre-decided binned distributions.
- For the moment we compute simultaneously with several fixed scales $\mu_R, \mu_F = (1/2, 1, 2) * M_{top}$. Dynamical scales in the future.
- Use mostly MSTW2008, but we also have almost everything computed also with NNPDF, CT10 and HERA. Different PDF sets evaluated simultaneously.
- Calculations for now only for LHC7 and LHC8
Tevatron computed, too.
- $M_{top} = 173.3$ GeV only

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S.C. Air Core
Toroids

S.C. Solenoid

Hadron
Calorimeters

Forward
Calorimeters

Differential description at the TeVatron (the asymmetry puzzle)

Muon Shieldings

EM Calorimeters

Inner Detector

Mu

$g(z_1, Q^2)$

P_1

$z_1 P_1$

H

$z_2 P_2$

P_2

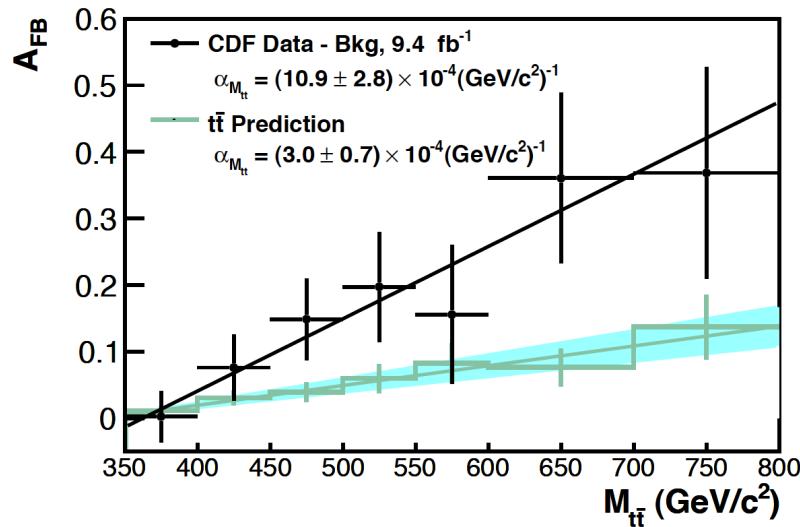
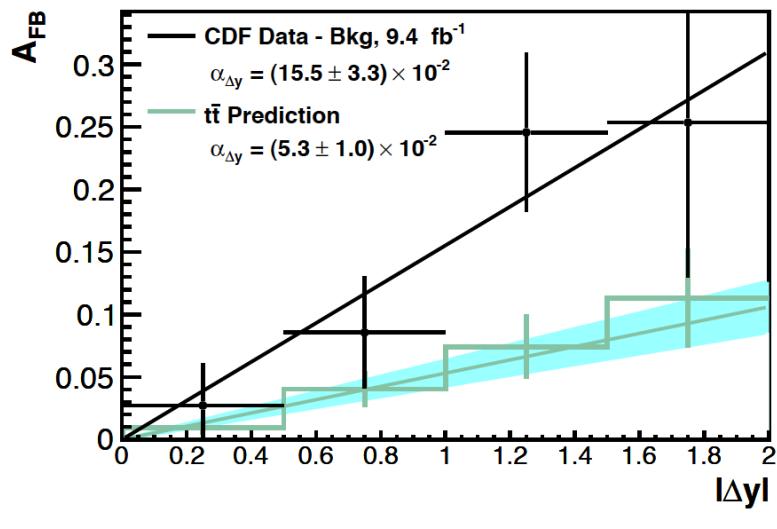
$g(z_2, Q^2)$

Definition of the asymmetry

Definition of the asymmetry:

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

... and the CDF measurement versus (known) SM:



Discrepancy $\leq 3\sigma$

New D0 measurement (2014): it is much lower than CDF and in good agreement with SM

- ✓ The largest known contribution to A_{FB} is due to NLO QCD, i.e. $\sim(\alpha_s)^3$.

Kuhn, Rodrigo '98

- ✓ Higher order soft effects probed. No new effects appear (beyond Kuhn & Rodrigo).

Almeida, Sterman, Wogelsang '08

Ahrens, Ferroglio, Neubert, Pecjak, Yang '11

Manohar, Trott '12

Skands, Webber, Winter '12

- ✓ F.O. EW effects checked. ~25% effect: not as small as one might naively expect!

Hollik, Pagani '11

Bernreuther, Si '12

- ✓ BLM/PMC scales setting does the job? Claimed near agreement with the measurements.

Brodsky, Wu '12

- ✓ Higher order hard QCD corrections? Next slide.

- ✓ Final state non-factorizable interactions? Unlikely.

Mitov, Sterman '12

Rosner '12

Our contribution at NNLO

Czakon, Fiedler, Mitov, to appear

- ✓ Computed AFB following the definition and binning of CDF '12

- Inclusive
- $|\Delta y|$
- M_{tt}
- $P_{T,tt}$

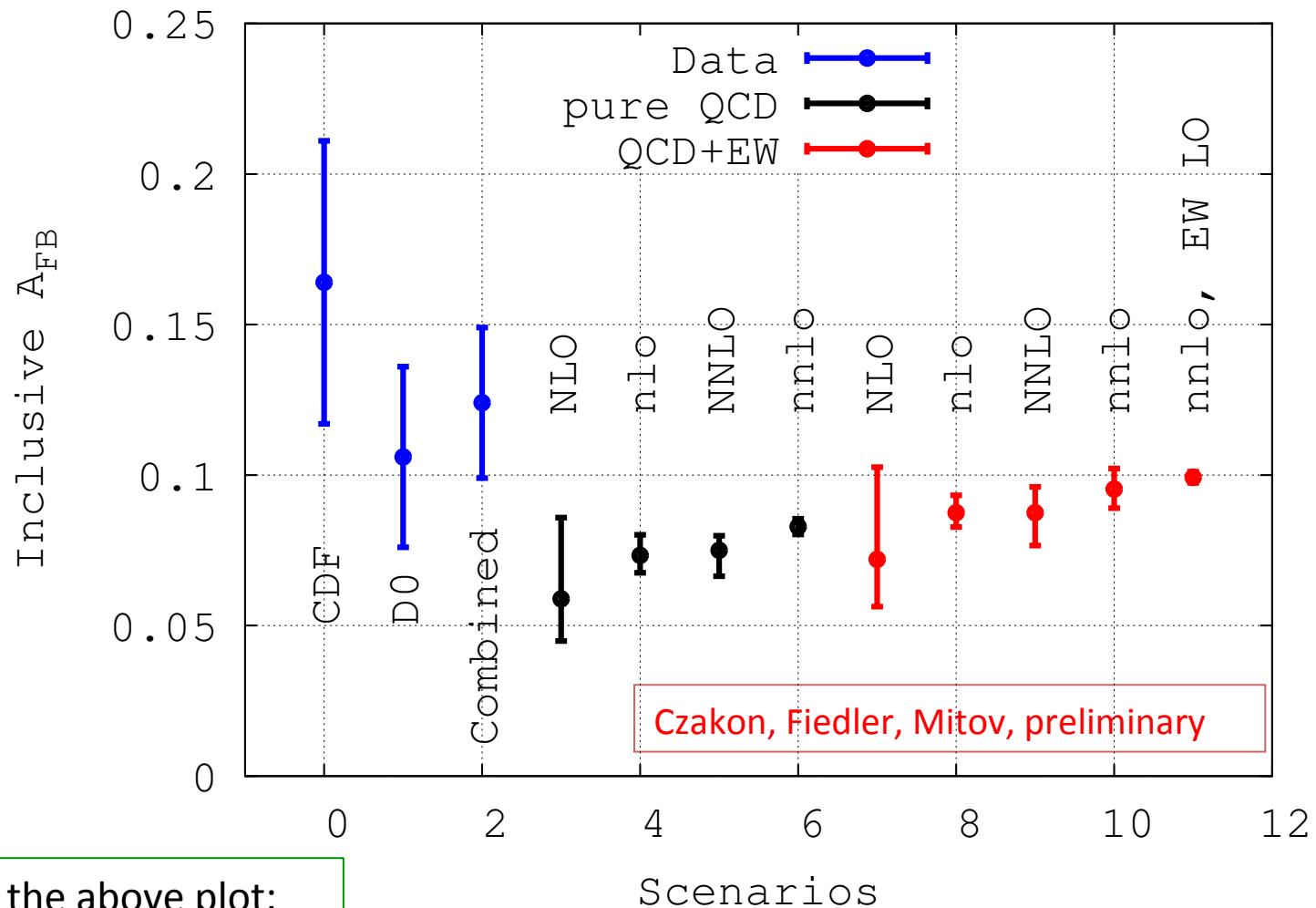
$$A_{FB} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}, \quad \text{where } \sigma^\pm \equiv \int \theta(\pm \Delta y) d\sigma$$

- ✓ The EW corrections to inclusive A_{FB} included (from Bernreuther, Si '12)

$$\begin{aligned} A_{FB} &\equiv \frac{N_{ew} + \alpha_S^3 N_3 + \kappa \alpha_S^4 N_4}{\alpha_S^2 D_2 + \alpha_S^3 D_3 + \kappa \alpha_S^4 D_4} \\ &= \alpha_S \frac{N_3}{D_2} + \kappa \alpha_S^2 \left(\frac{N_4}{D_2} - \frac{N_3}{D_2} \frac{D_3}{D_2} \right) + \mathcal{O}(\alpha_S^3) \\ &\quad + \frac{N_{ew}}{\alpha_S^2 D_2} \left(1 - \kappa \frac{\alpha_S D_3}{D_2} \right). \end{aligned}$$

Two alternative expansions

Our contribution at NNLO



How to read the above plot:

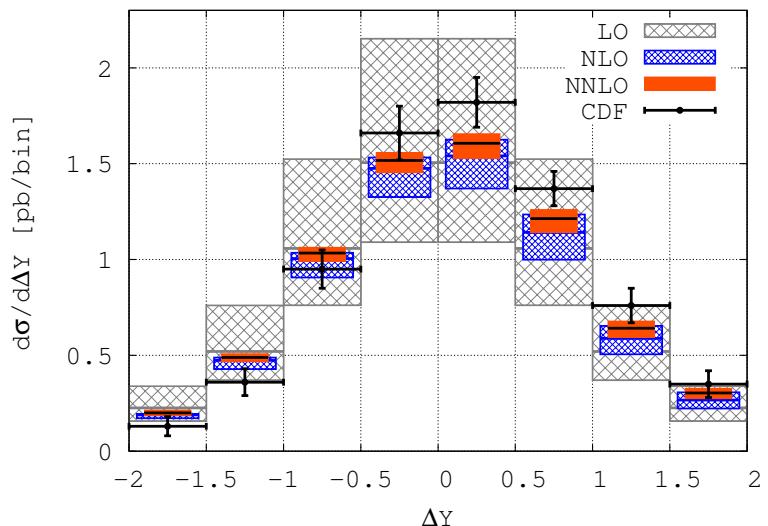
- ◆ $NLO, NNLO$: exact numerator and denominator (see previous slide)
- ◆ $nlo, nnlo$: expanded in powers of a_s

Our contribution at NNLO

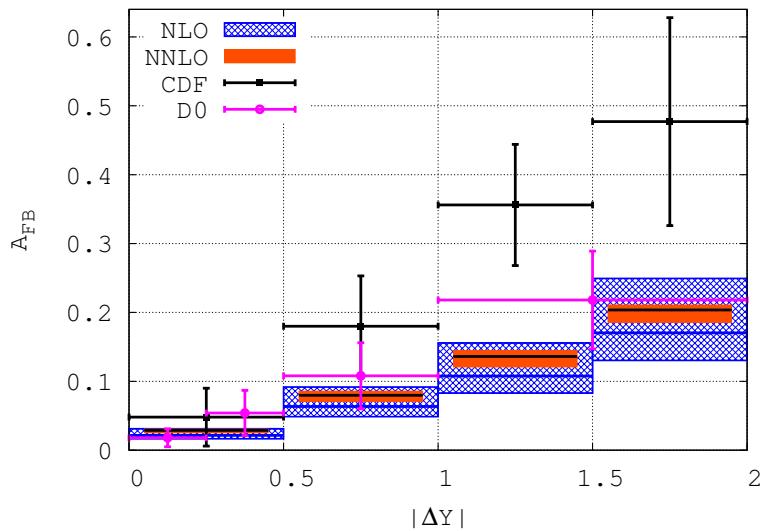
- ✓ We find large QCD corrections: NLO $\sim 30\%$ of LO (recall EW is 25% of LO).
 - This was not expected, given soft-gluon resummation suggests negligible correction.
- ✓ Adding all corrections $A_{FB} \sim 10\%$.
 - ✓ Agrees with D0 and CDF/D0 naive combination
 - ✓ Less than 1.5σ below CDF
- ✓ We consider this as *agreement* between SM and experiment.
- ✓ We observe good perturbative convergence (based on errors from scale variation)
- ✓ Expanded results (both *nlo* and *nnlo*) seem to have accidentally small scale variation

Our contribution at NNLO

Czakon, Fiedler, Mitov, preliminary

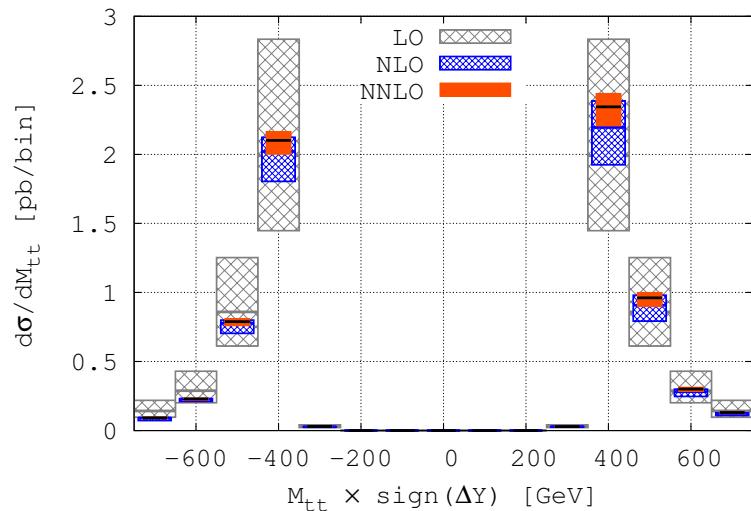


Errors due to scale variation only

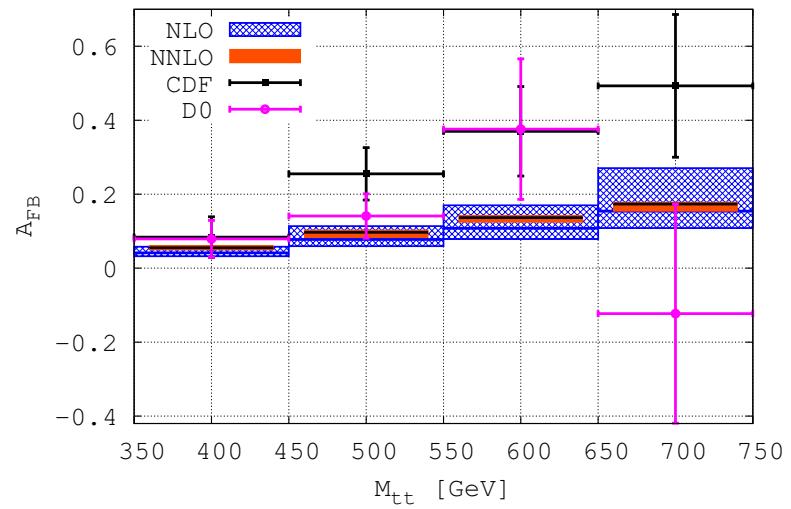


Our contribution at NNLO

Czakon, Fiedler, Mitov, preliminary

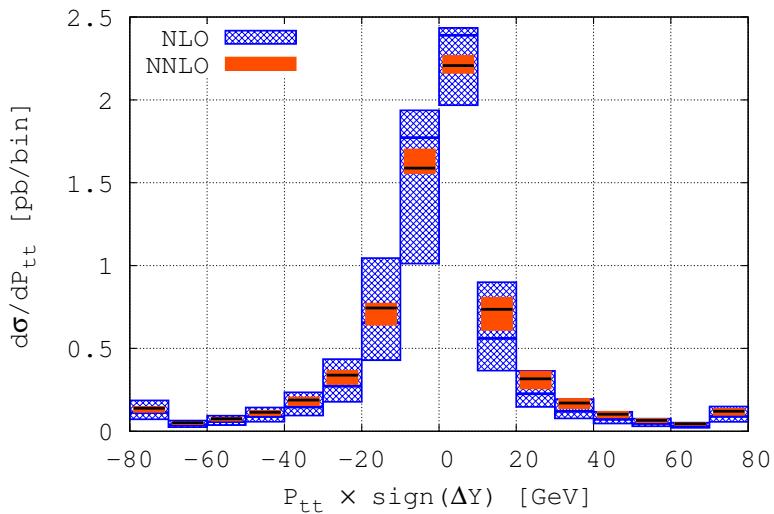


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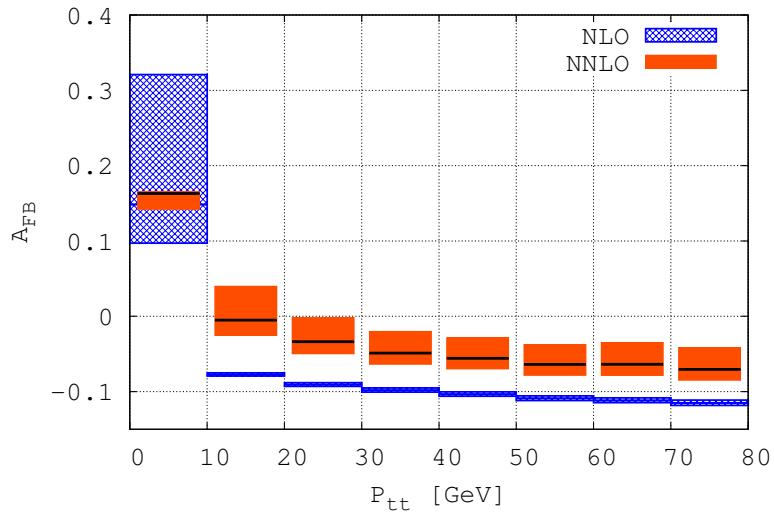


Our contribution at NNLO

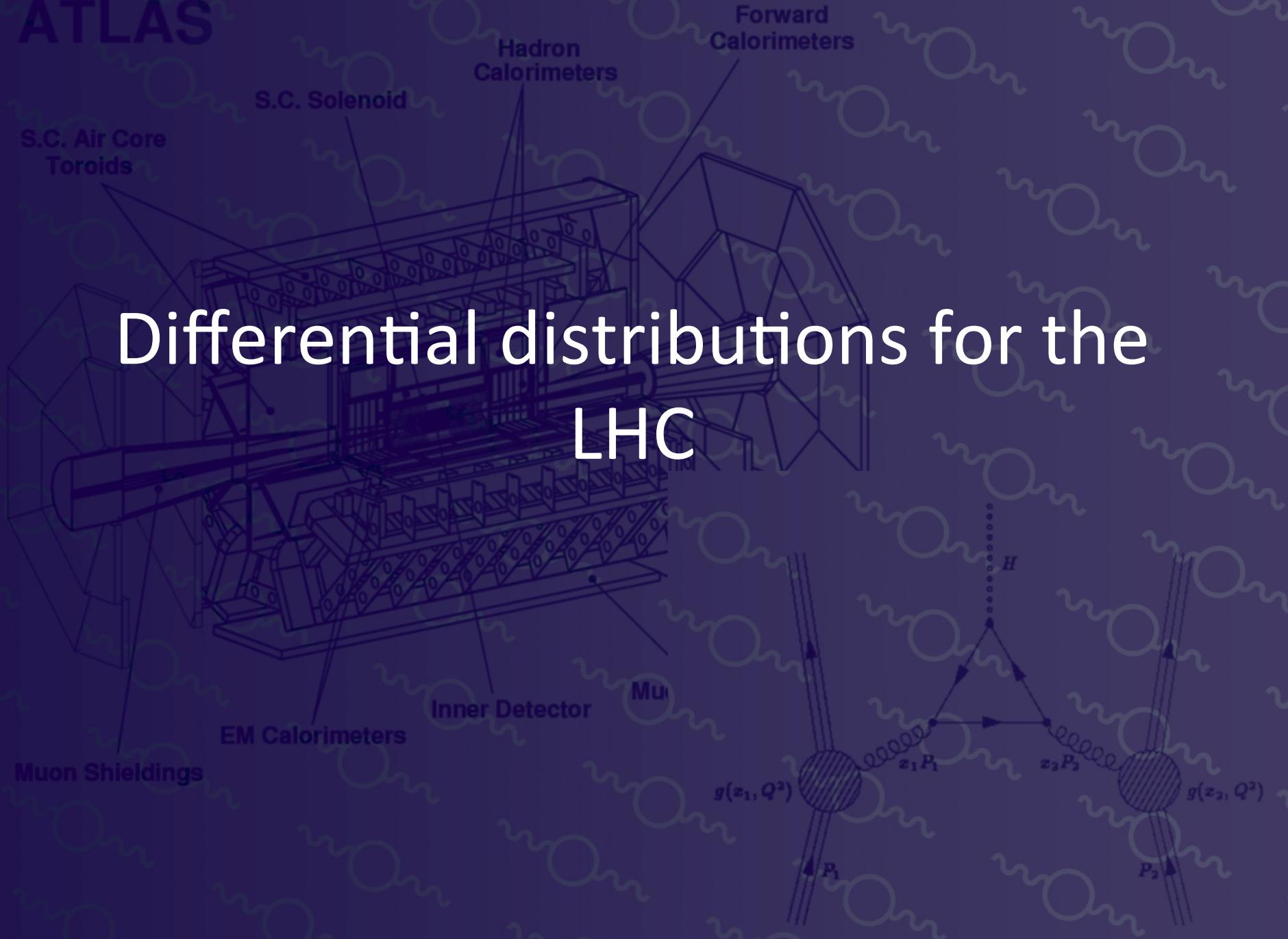
Czakon, Fiedler, Mitov, preliminary



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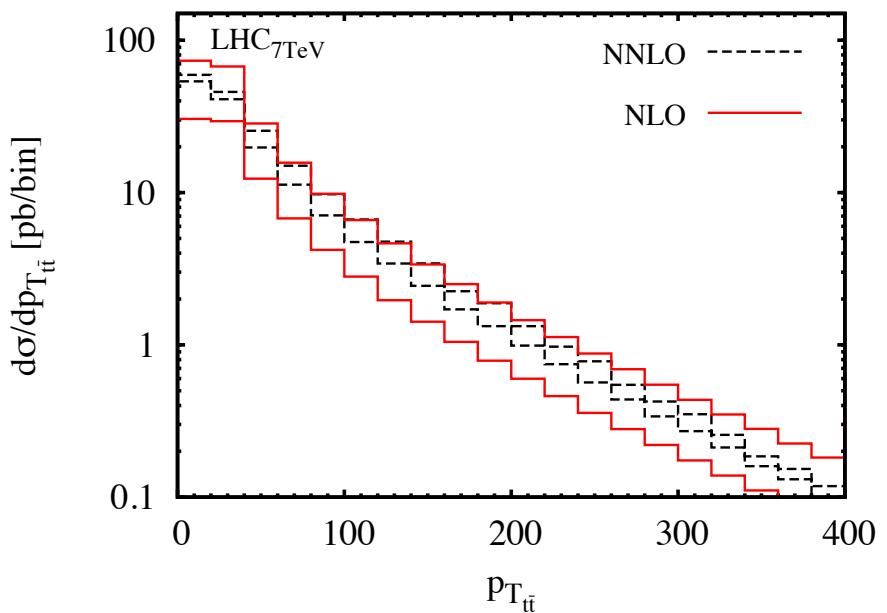
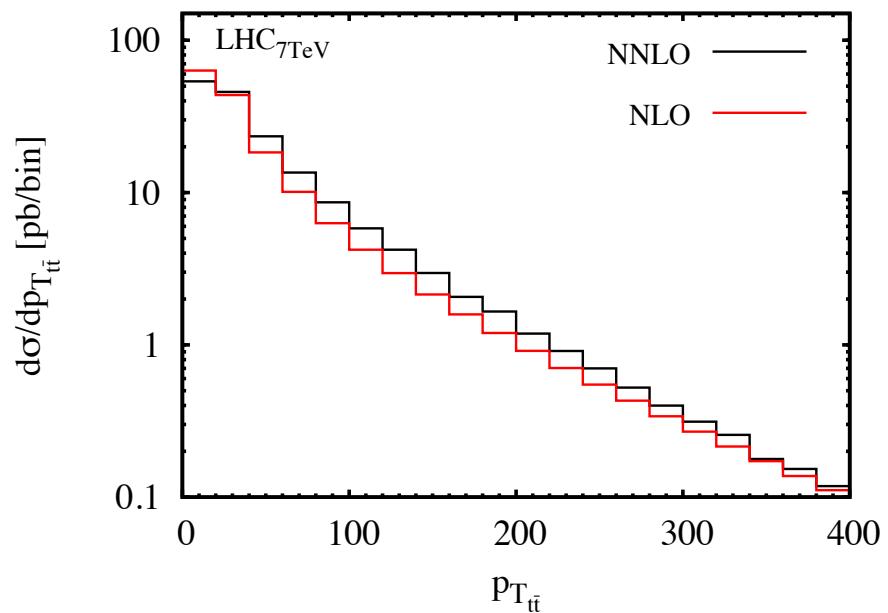


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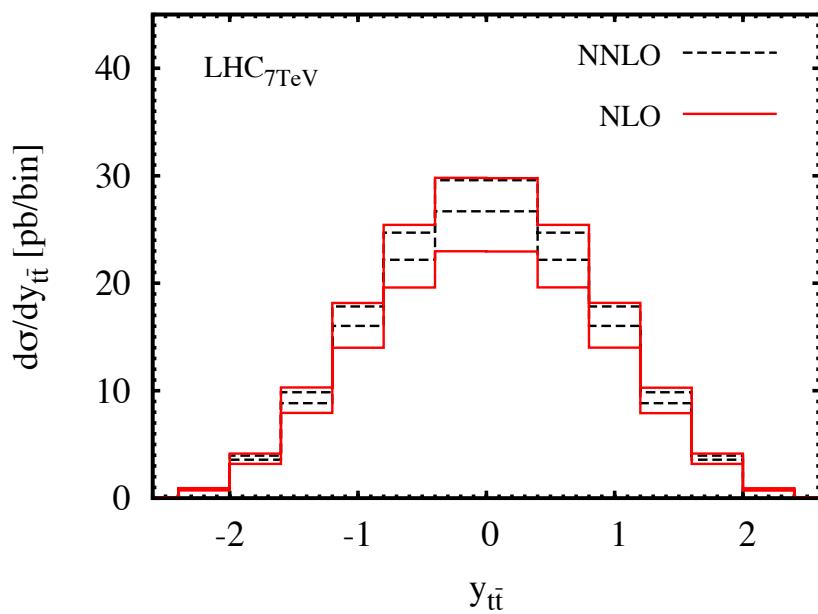
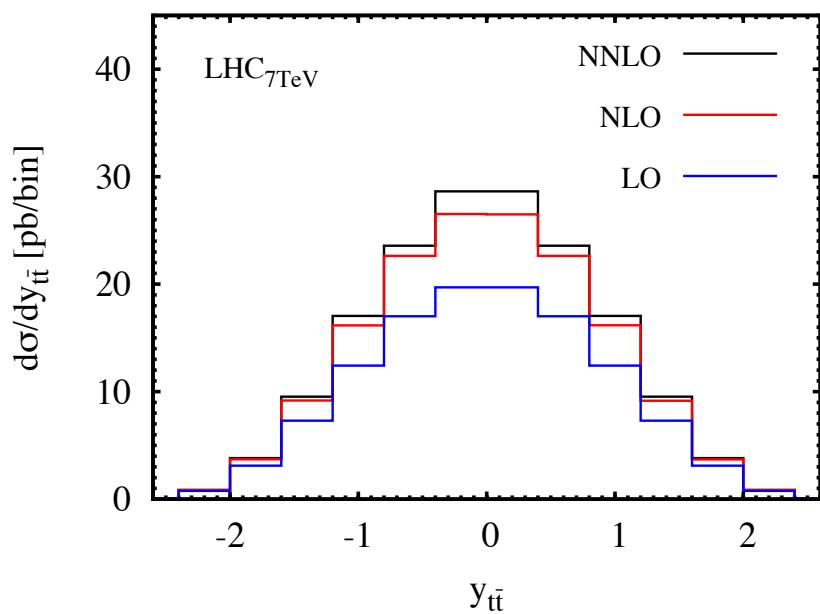


Differential distributions for the LHC

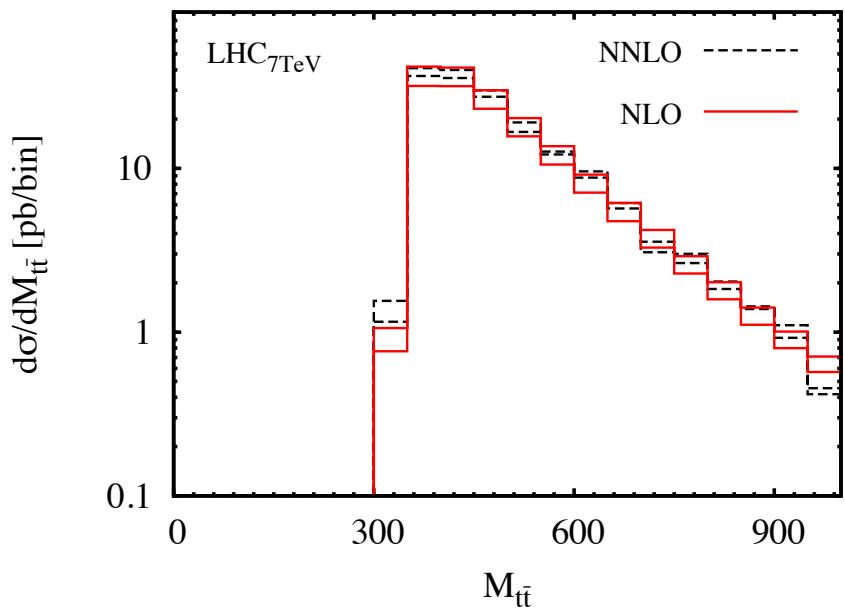
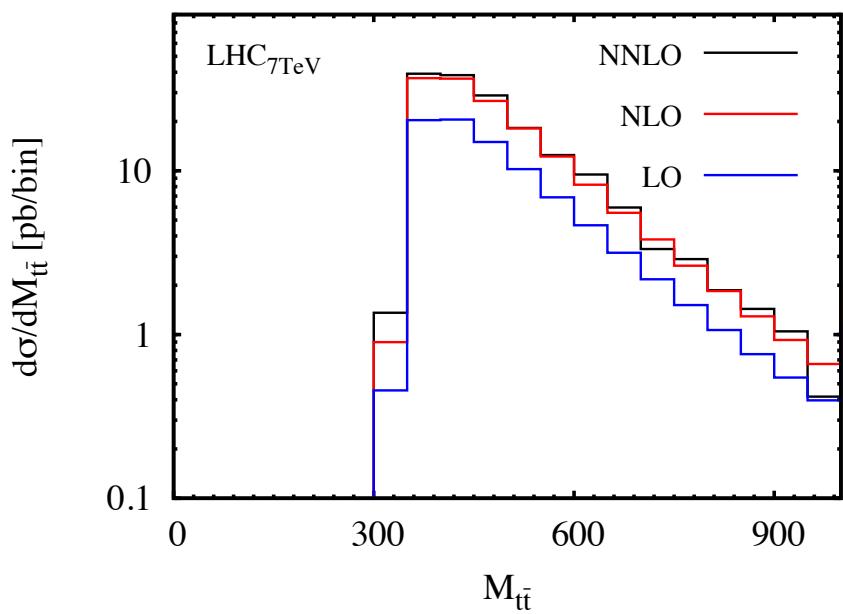
Czakon, Fiedler, Mitov, very preliminary



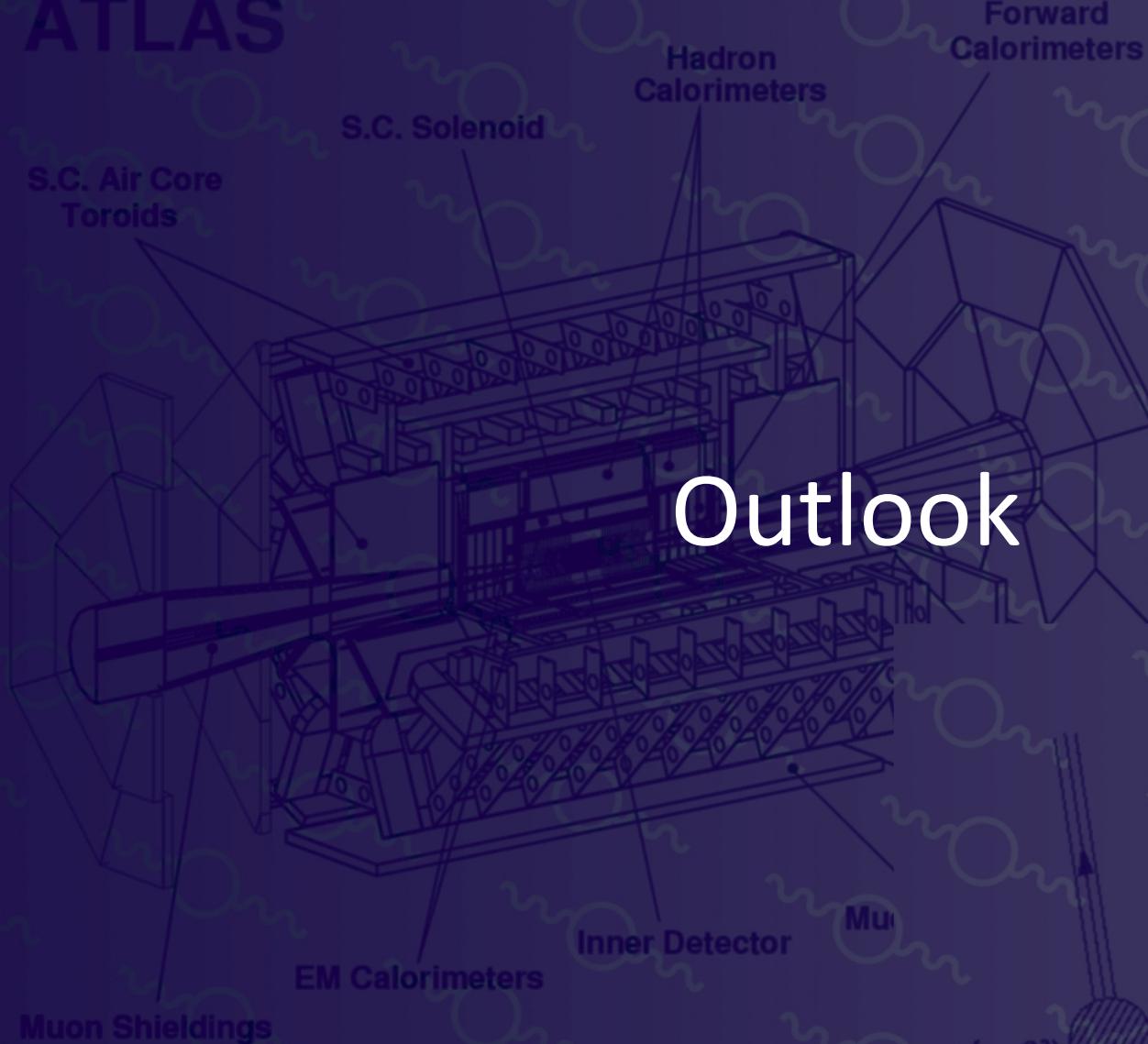
Czakon, Fiedler, Mitov, very preliminary



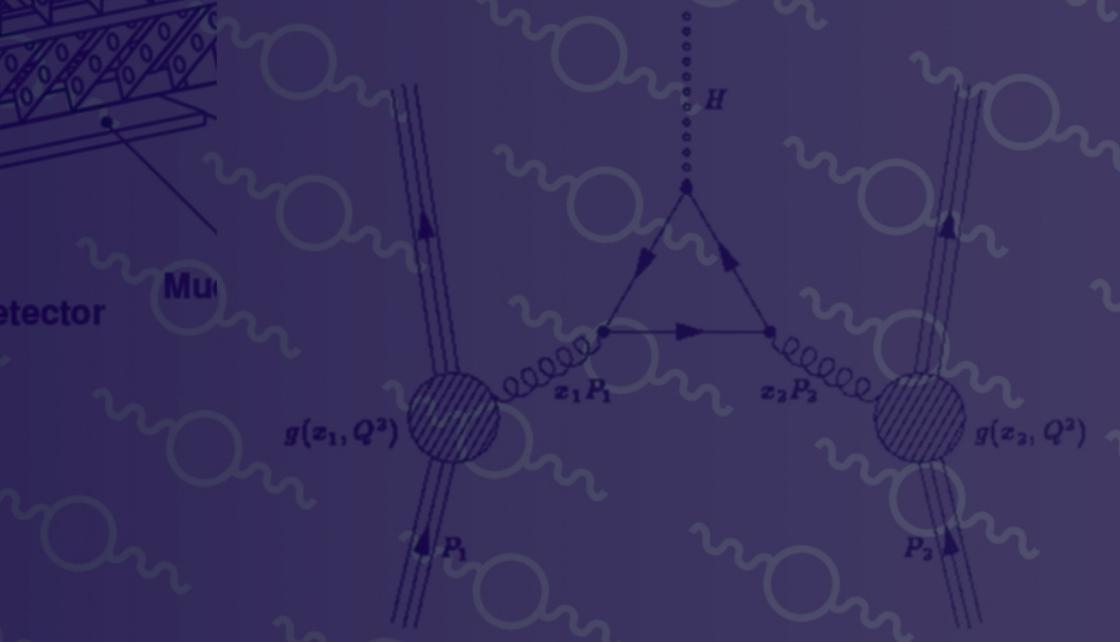
Czakon, Fiedler, Mitov, very preliminary



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Outlook



Outlook

Current work on: improvement of the quality of all the distributions
in particular top/anti-top distributions