# Electroweak corrections to single-top production processes

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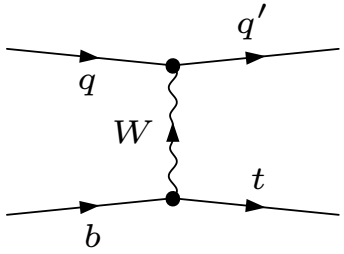
# Outline

- Motivation
- Experimental status
- LO & NLO QCD corrections
- EW corrections
  - $t$-channel
  - $tW$ production
  - $s$-channel
- Conclusions

# Motivations

- Single top production in the SM . . .

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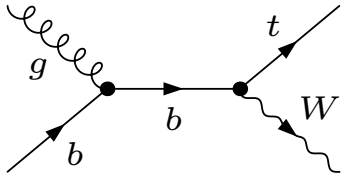


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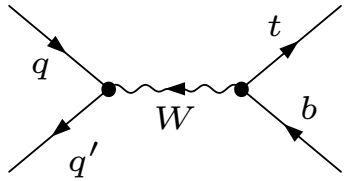


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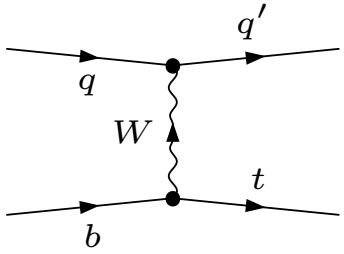


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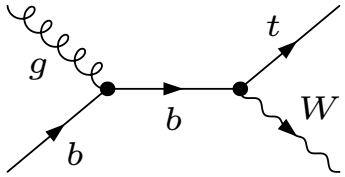


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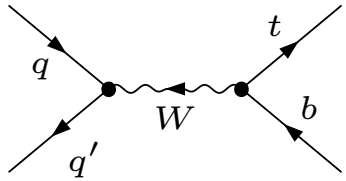
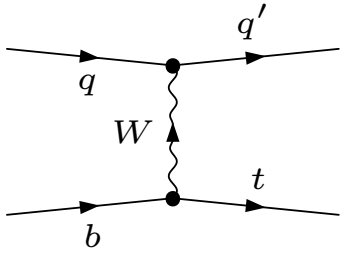



$s$-channel

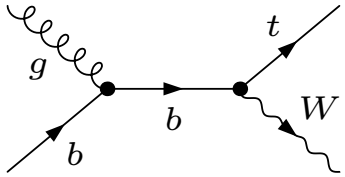
- . . . is important:
  - direct way to measure $V_{tb}$.
    - ↪ no assumptions on the # of quarks
  - benchmark for the $Wtb$ coupling.
    - ↪ $V - A$ structure . . .
    - ↪ . . . via the $t$ polarization
  - background of other processes.
    - ↪ Higgs searches, SUSY-like signals . . .
  - sensitive to new physics
    - ↪ new couplings & production modes
    - ↪ loop effects.

# Experimental status

- Single top production @ the Tevatron . . .




$t$-channel $62\%$

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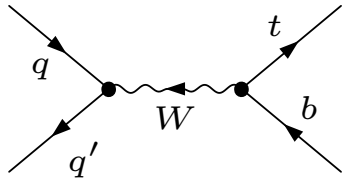


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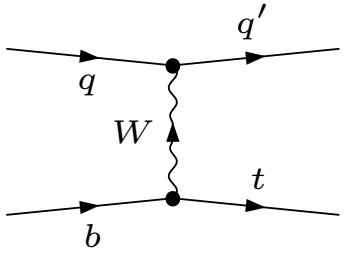


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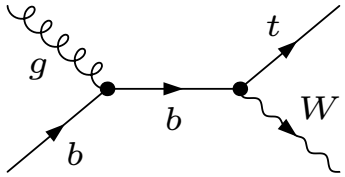


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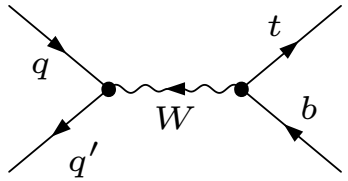


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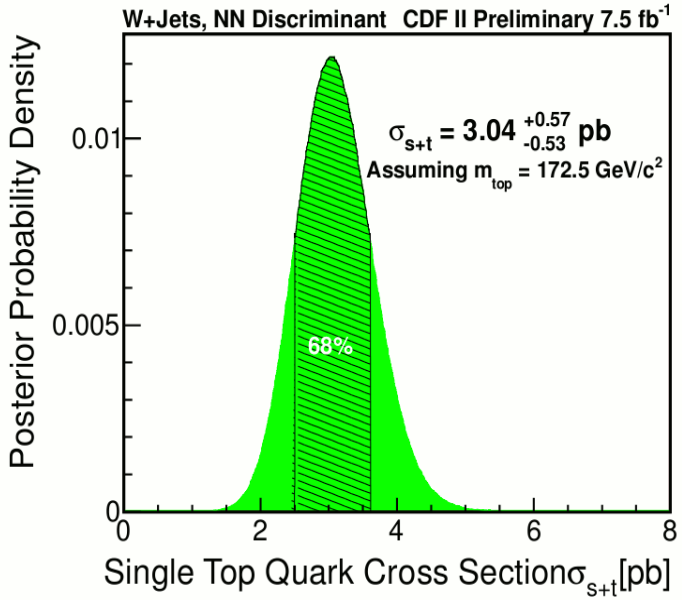
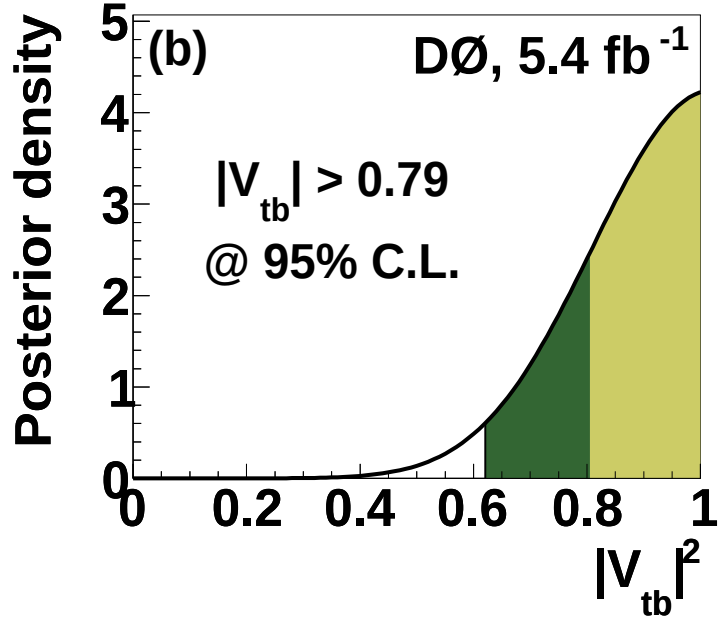
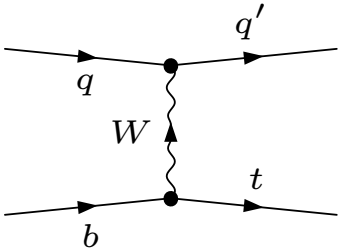



- signal: $\ell + \not{E}_T + 2, 3\, j$ (at least 1 $j_b$ )
- $\delta\sigma$: $\sim 20\%$ (D0)  $\sim 30\%$ (CDF)

# Experimental status

- Single top production @ the LHC . . .

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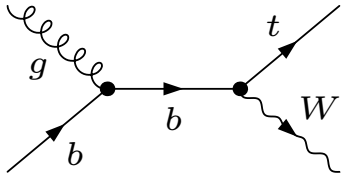


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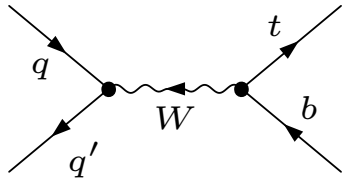


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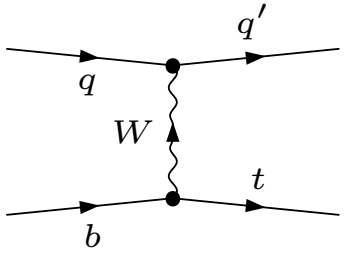


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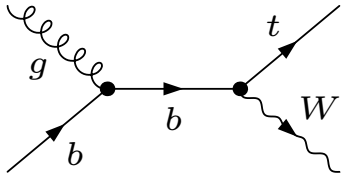


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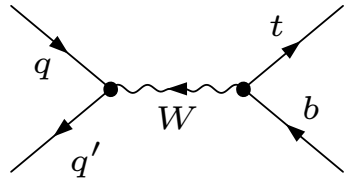


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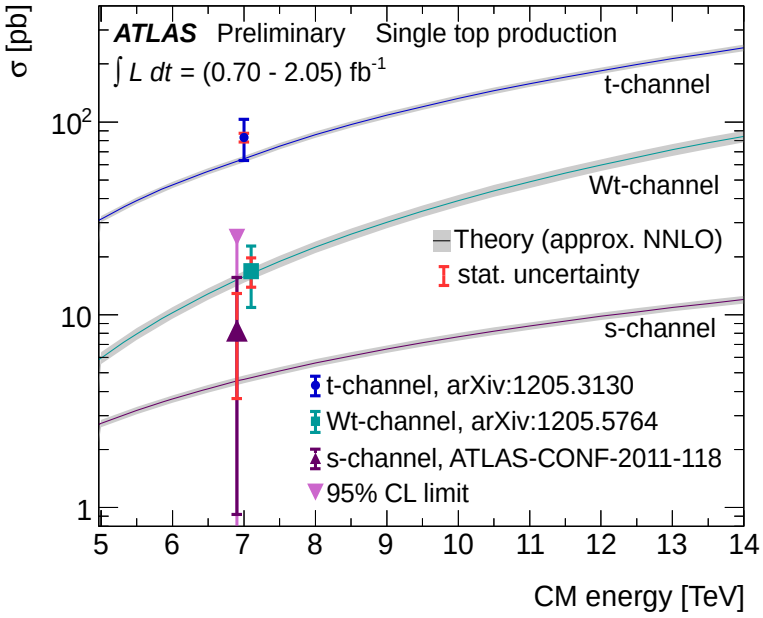
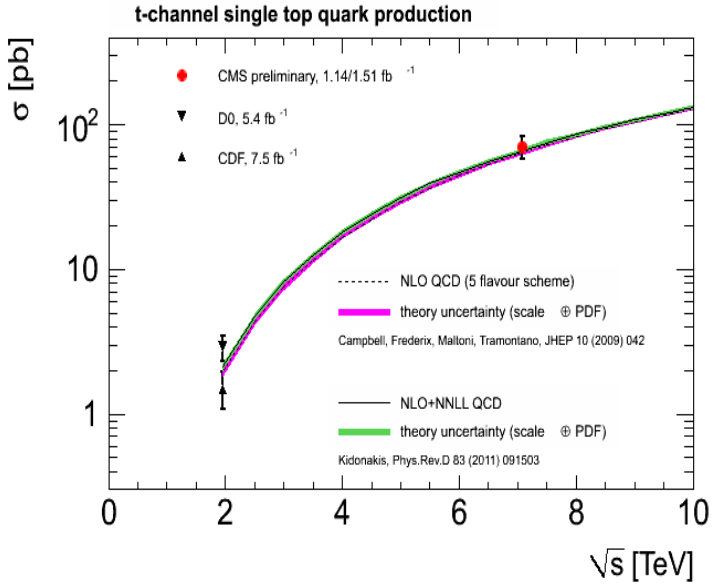
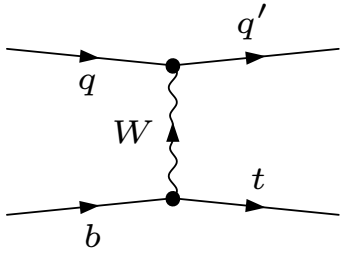



- signal: $\ell + \not{E}_T + 2,3\, j$ (at least $1\ j_b$ )
- $\delta\sigma$: $\sim 20\%$ (ATLAS) $\sim 9\%$ (CMS)

# QCD Corrections

- Single top production in the SM: . . .

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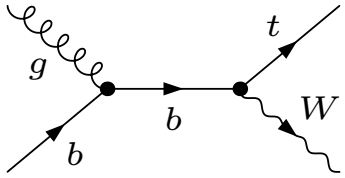


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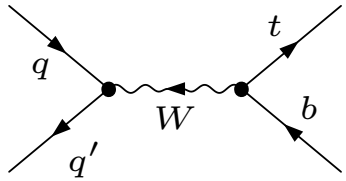


$s$-channel

- Next-to-leading order (NLO)
  - ↪ $5$-flavor schemes [Bordes, van Eijk '95; Giele, Keller, Laenen '96; Smith, Willenbrock '96; Stelzer, Sullivan Willenbrock '97 '98; Zhu '02; Harris, *et al.* '02; ; Sullivan '04 '05 ]
  - ↪ $t$-channel in $4$-flavor schemes [Campbell *et al.* '06 '09 ]

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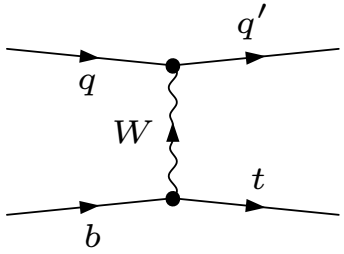


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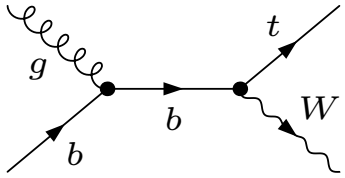


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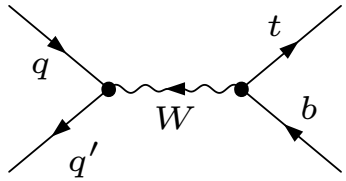


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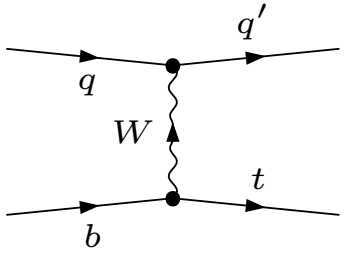


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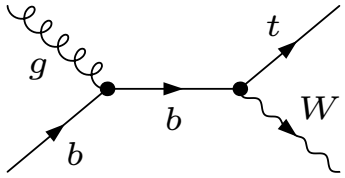


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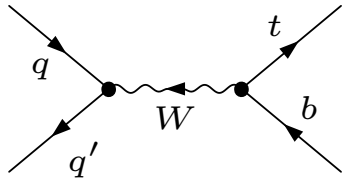


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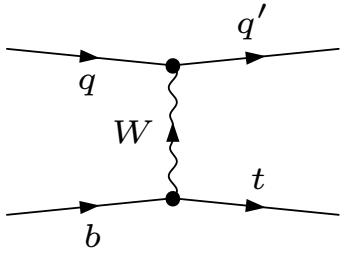


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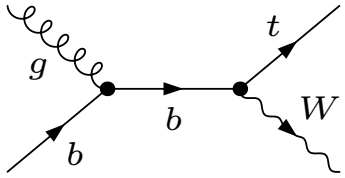


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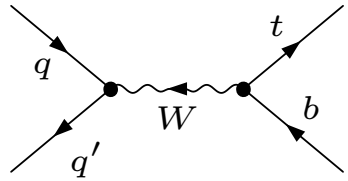


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- NLO + PS
  - MC@NLO [Frixione *et al.* '06 '08; Frederix, Re, Torrielli '12 ]
  - MCFM [Campbell, Ellis '12; ]
  - POWHEG [S. Alioli *et al.* '09; E. Re '11; Frederix, Re, Torrielli '12 ]

# QCD Corrections

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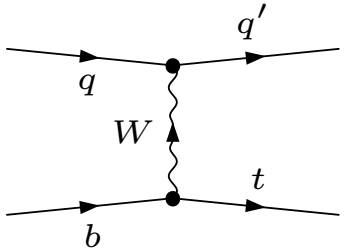


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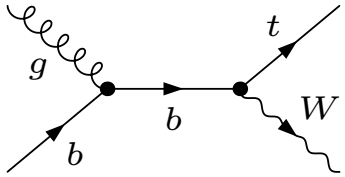


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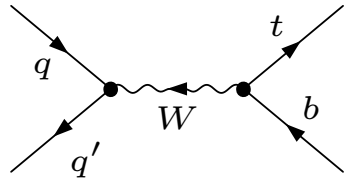
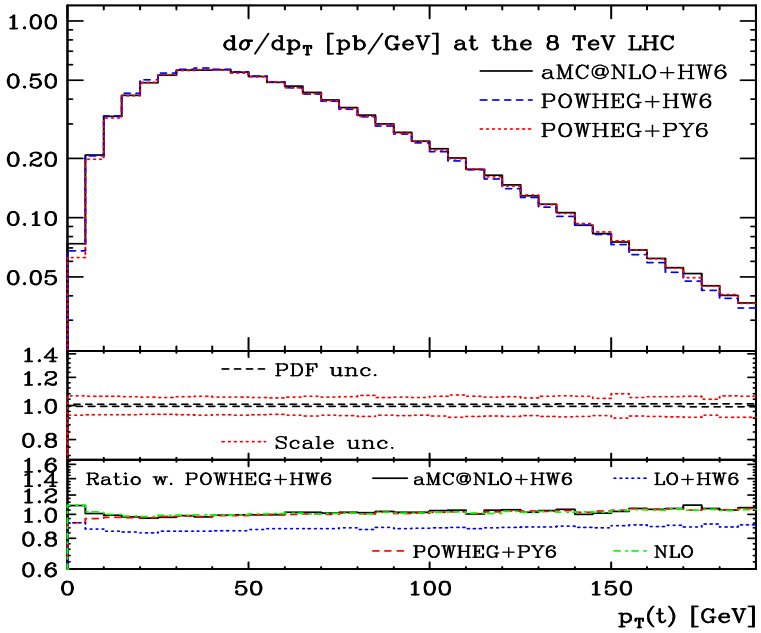
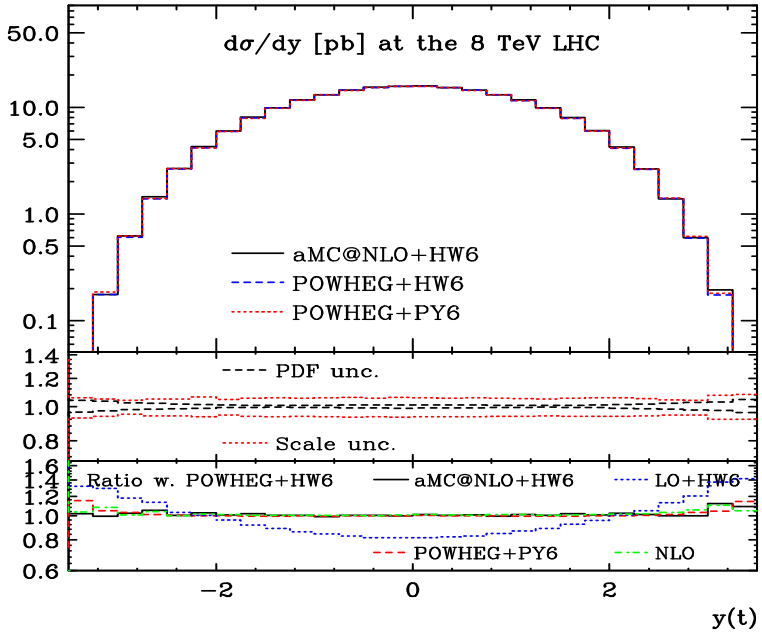



$s$-channel

- Impact of the corrections @ LHC

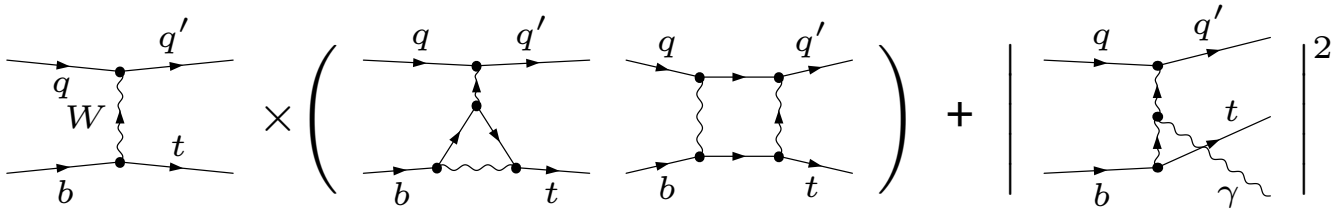



[Frederix, Re, Torrielli '12 ]

# $t$-channel – EW Corrections

- $\mathcal{O}(\alpha^3)$ :



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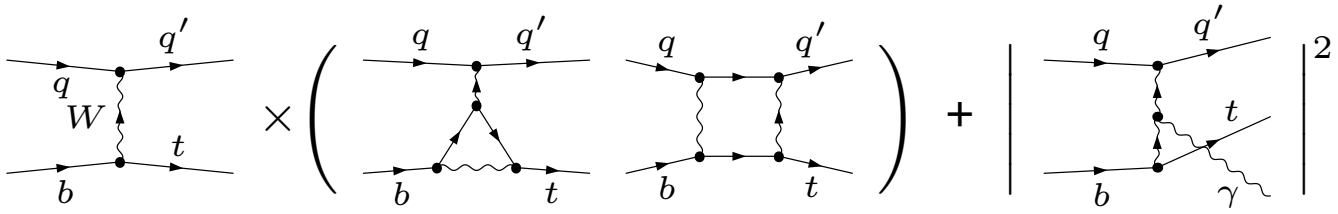


STATUS

- Computed in the Sudakov limit [Beccaria, Renard, Verzegnassi '05 ]
  ↪ kinematc invariants $\gg M_W^2$
- full NLO within the SM and MSSM [Beccaria, Macorini, Renard, Verzegnassi '07;
  Beccaria, Carloni Calame, Macorini, EM, Piccinini, Renard, Verzegnassi '08 ]
- parton-level computation within SM [Bardin, Bondarenko, Kalinovskaya, Kolesnikov, von Schlippe '10 ]
  ↪ within the SANC framework
- photon induced production missing
  ↪ may be important ( e.g. $PP \to t\bar{t}$)

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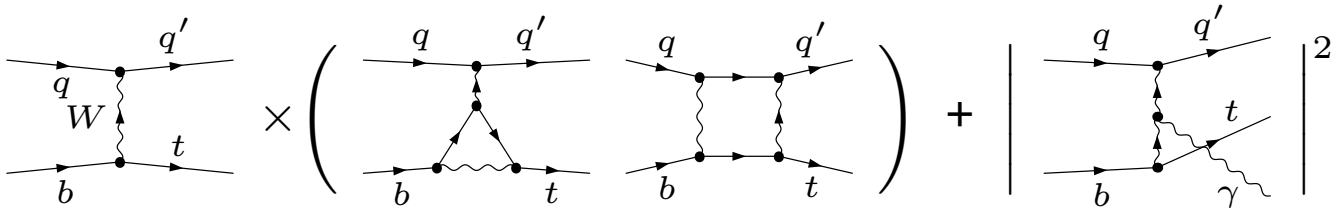


## Technical Details

- UV Renormalization
  - OS scheme
  - $\alpha$ in $G_\mu$ scheme
    - ↪ large logs absorbed in the $\alpha$-definition
    - ↪ inclusion of $\mathcal{O}(\alpha m_t^2/M_W^2)$ two-loop terms. [Consoli *et al.* '89; Diener *et al.* '07]
- IR divergences
  - regularized using mass regularization
  - cancelled using phase space slicing & dipole subtraction
- Five-flavor scheme used
    - ↪ **but** phenomenology in the four-flavor scheme

# $t$-channel – EW Corrections

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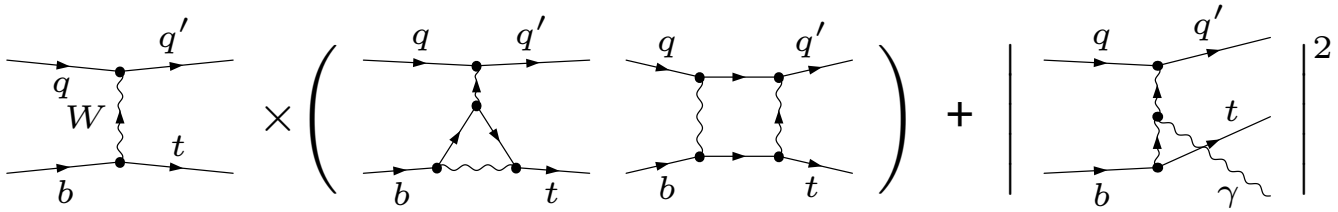
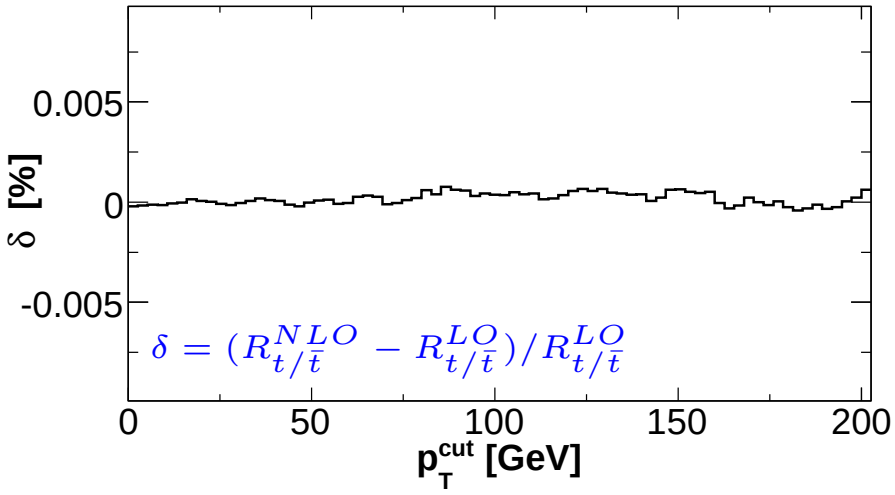
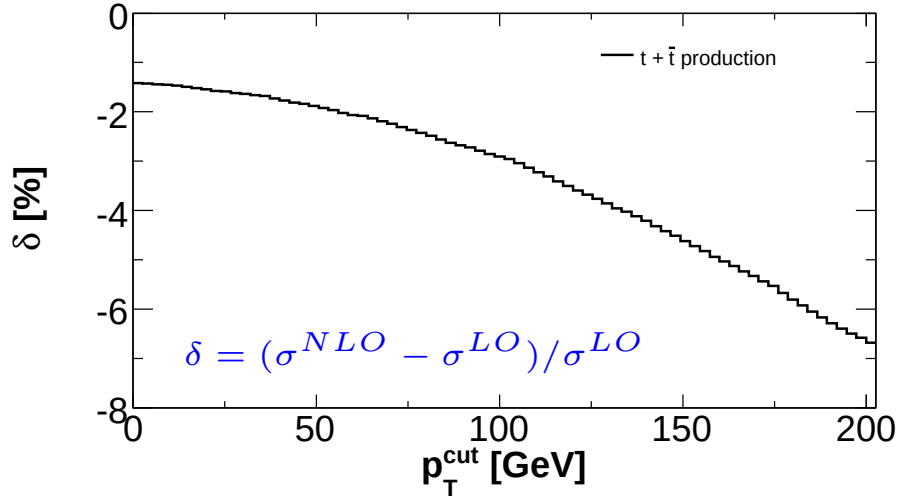



RESULTS $(\sqrt{S} = 14$ TeV $)$

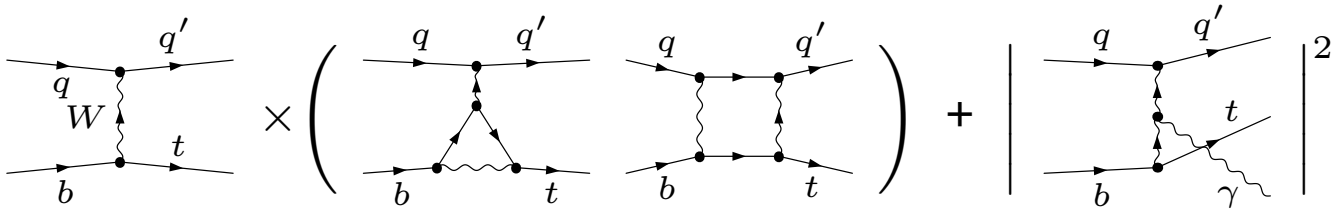


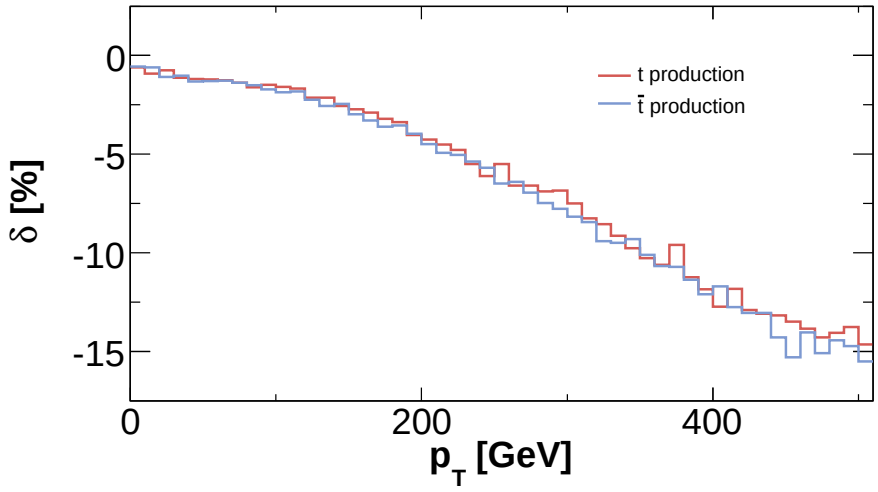

- Relative EW corrections in $t$ & $\bar{t}$ prod.
  - ↪ the ratio $R_{t/\bar{t}} = (t \text{ prod.})/(\bar{t} \text{ prod.})$ unaffected
- EW corrections on $t + \bar{t}$ production:
  - ↪ more important as the value of the cut increases

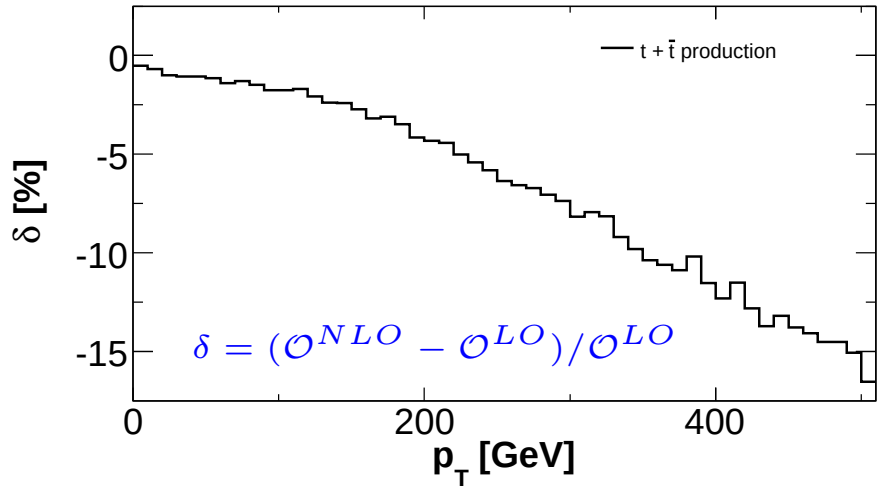
# $t$-channel – EW Corrections

- $\mathcal{O}(\alpha^3)$ :




RESULTS ($\sqrt{S} = 14$ TeV )

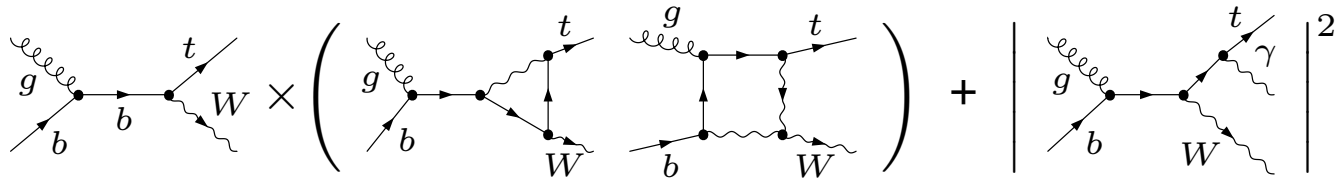



- $p_T$ distribution for single $t$ & $\bar{t}$ prod.
  - ↪ $t$ production dominates
  - ↪ EW corrections similar in the two cases
- EW corrections on $t + \bar{t}$ production:
  - ↪ some percent in the low $p_T$ region
  - ↪ more than $10\ \%$ in the $p_T > 300$ GeV region

# $Wt$-production – EW Corrections

- $\mathcal{O}(\alpha_s\alpha^2)$ :



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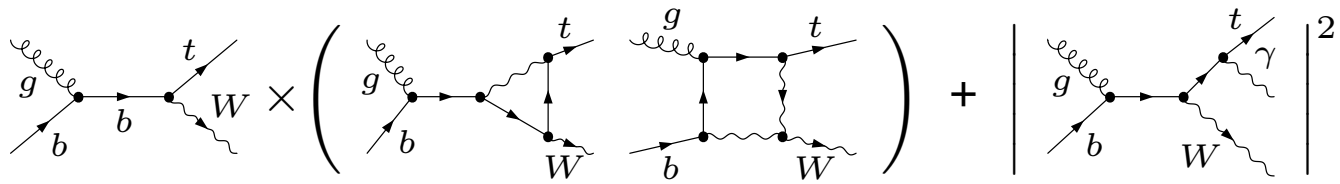
- $\mathcal{O}(\alpha_s\alpha^2)$ : 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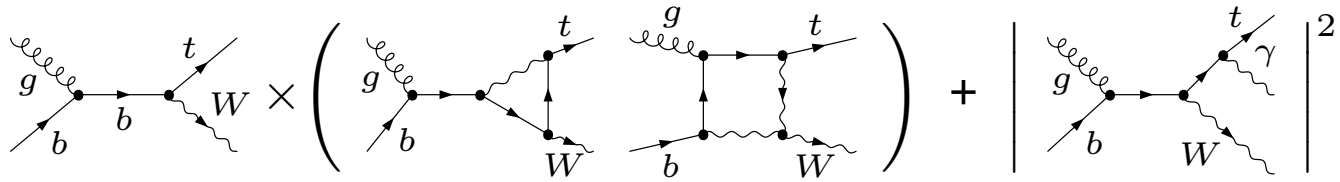
- $\mathcal{O}(\alpha_s\alpha^2)$ : 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## Technical Details

- UV Renormalization in OS scheme
- IR divergences
  - mass regularization + phase space slicing
- Five-flavor scheme used . . .
  ↪ . . . as implemented in PS MC event generators

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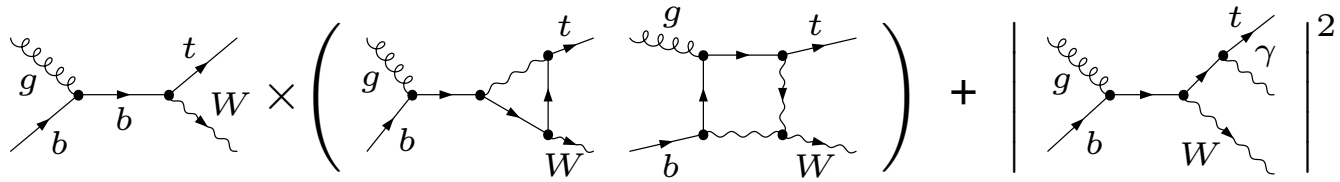
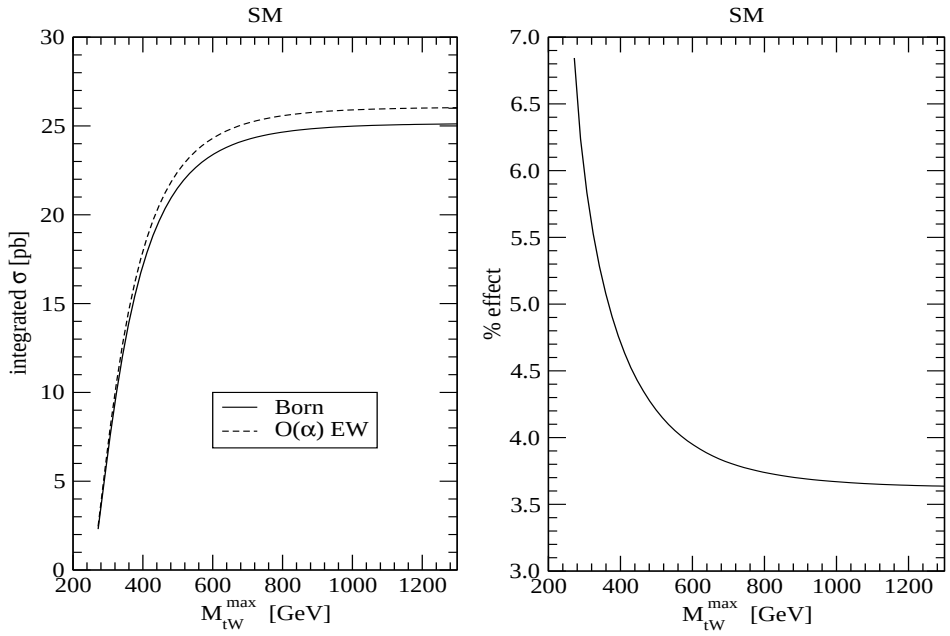



RESULTS $(\sqrt{S} = 14$ TeV )

- Cumulative Invariant Mass
  - ↪ $\sigma(M_{\text{tW}}) = \int_{\text{th.}}^{M_{\text{tW}}} dM' \frac{d\sigma}{dM'}$
  - ↪ EW corrections positive
  - ↪ $\sim 6\%$ near threshold
  - ↪ $\sim 3.5\%$ in the total cross section



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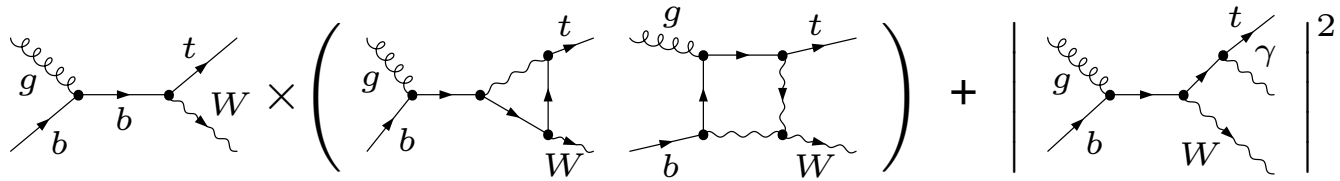


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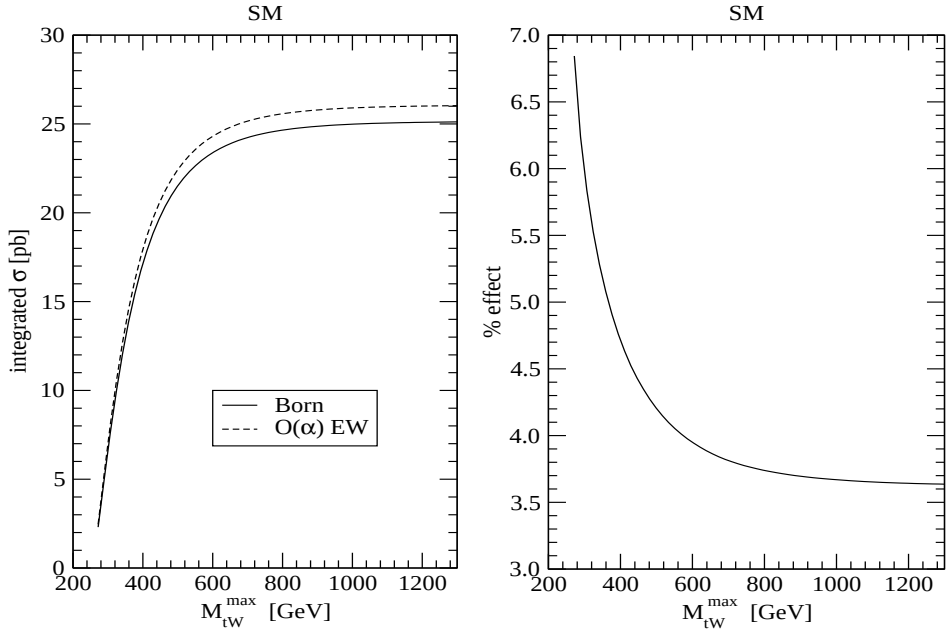


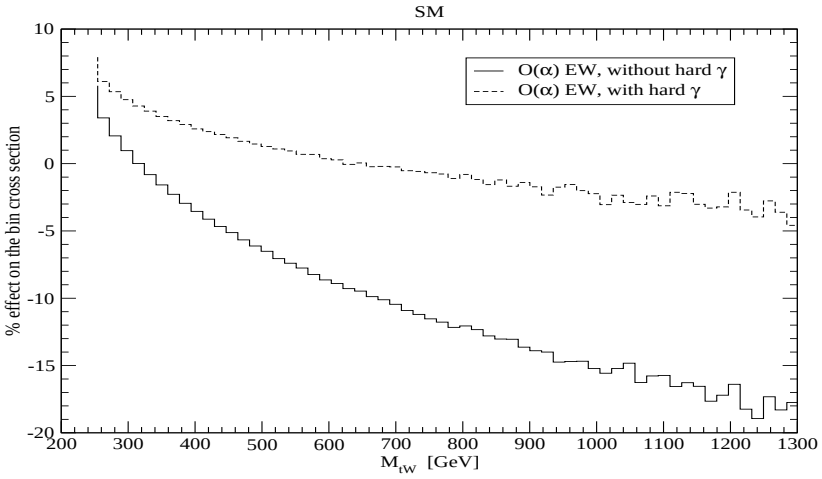


- Invariant Mass distribution
  - ↪ positive (negative) for high (low) $M_{\text{tW}}$
  - ↪ $\delta$ below $5\%$ in the all range

# $s$-channel – EW Corrections

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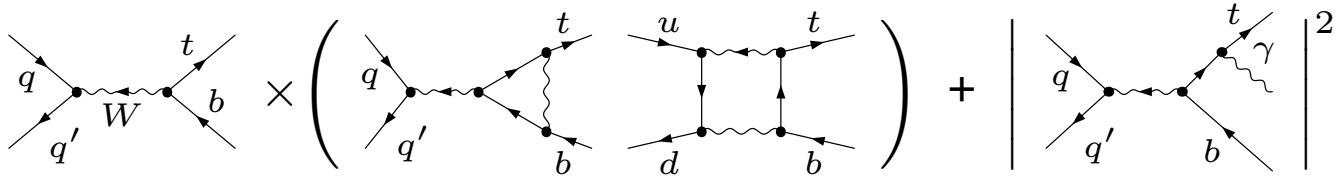

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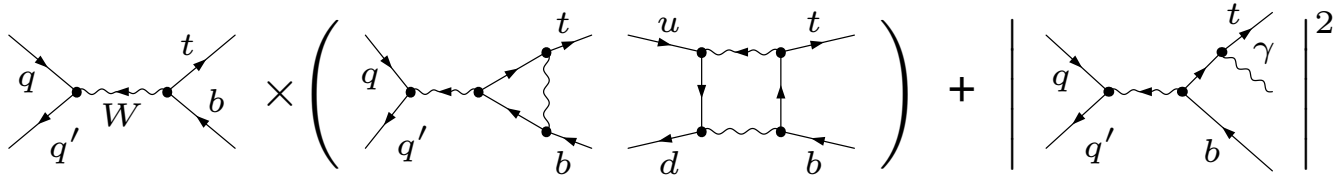
- $\mathcal{O}(\alpha^3)$ : 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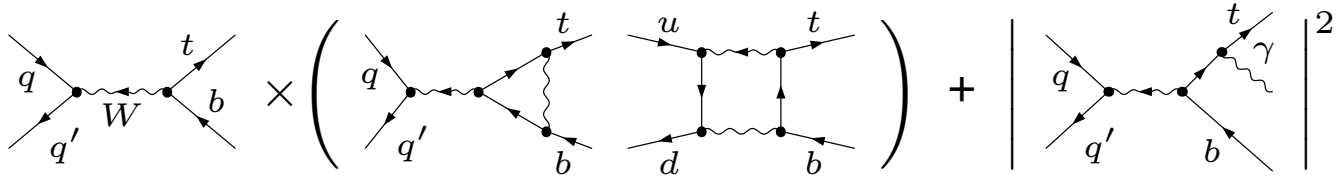


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## Technical Details (parton level)

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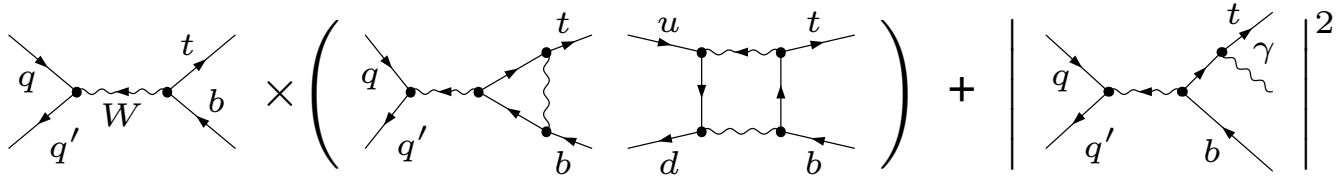


RESULTS (parton level + PDF factorization )

| $\sqrt{s}$ (TeV) | $\sigma^{\text{NLO}}$ (pb) | $\delta_{\text{EW}}$ (%) |
|---|---|---|
| 0.2 | 0.328 | 6.5% |
| 1.0 | 0.100 | −5.6% |
| 7.0 | $1.46 \cdot 10^{-3}$ | −35% |

[Bardin *et al.* '10 ]

- above $5\%$ close to threshold
- negative for high enough $\sqrt{s}$
- big in the high energy region
  - ↪ suppressed by the PDF
  - ↪ compatible with Sudakov logs

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Single top production

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Outlook

- $t$-channel in the $4$-flavor scheme @ NLO EW
- merge the channels in a single code . . .
  - ($s$-channel as well)
- . . . interfaced with PS (BLHA? )