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Improved description of charged Higgs production at hadron colliders

Johan Alwall

Uppsala, Sweden

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hep-ph/0409094, 0410151

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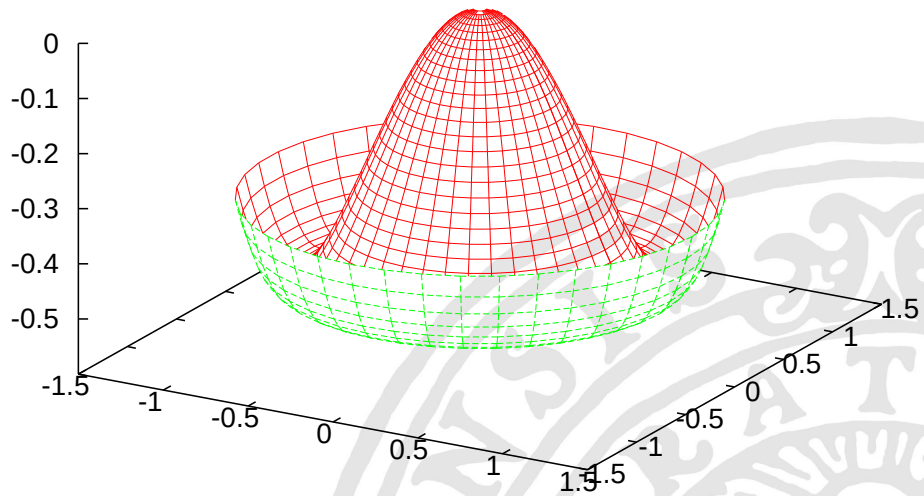
The Higgs mechanism in the Standard Model

- One of the Higgs doublet components gets a vacuum expectation value (vev) v

- Three of the four Higgs degrees of freedom are absorbed by the three massive vector fields

- Fermions get mass from Yukawa couplings



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Supersymmetric extensions

- One Higgs doublet can't give mass to both up and down type fermions
- Anomalies don't cancel because of extra fermions (Higgsinos)

$$\Downarrow$$

Must have (at least) two Higgs doublets with opposite hypercharge

This is an example of a (type II) Two Higgs Doublet Model (2HDM)

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Two Higgs Doublet Models

- 8 scalar degrees of freedom $\Longrightarrow$ 5 Higgs particles:

$$h,\ H^0,\ H^+,\ H^-,\ A \text{ (pseudoscalar)}$$

- Two parameters in MSSM (7 or more in general 2HDM):

$\tan(\beta) = \frac{v_1}{v_2}$	Ratio of vev's for the doublets
M_A	One of the masses, usually the pseudoscalar

- Finding a charged Higgs would be a clear signal of physics beyond the Standard Model!

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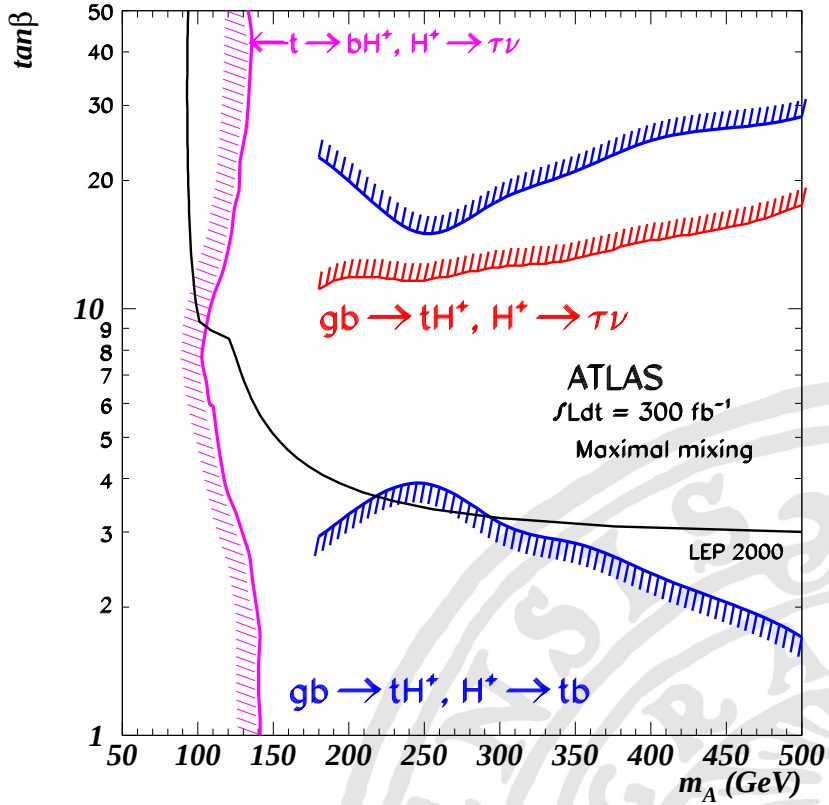
Our goal

Need accurate description of Higgs production in event generators to devise search strategies/ suppress SM background.



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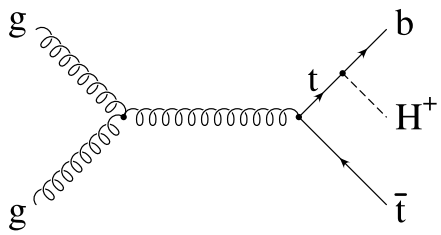
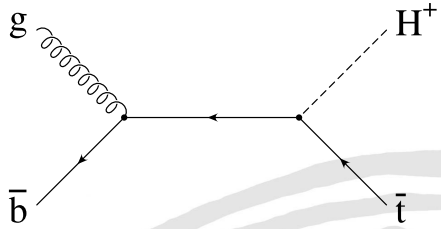
Production channels for charged Higgs in MC generators

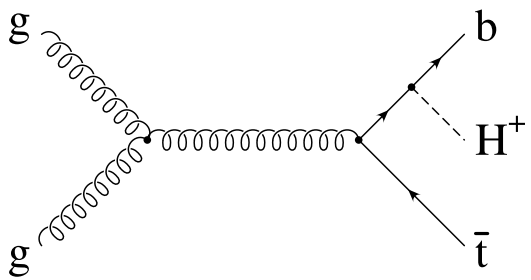
- $gg(q\bar{q}) \to t\bar{t} \to bH^+\bar{t}$ $(m_{H^+} \leq m_t - m_b)$:

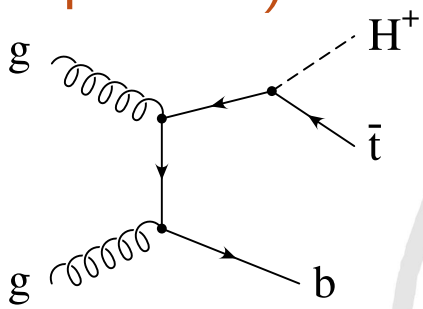


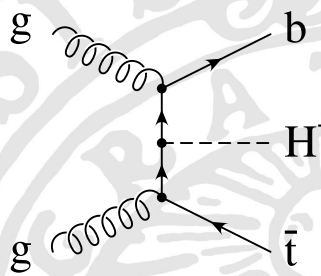
- $g\bar{b} \to \bar{t}H^+$ ($2 \to 2$ process):



- $gg(q\bar{q}) \to \bar{t}bH^+$ ($2 \to 3$ process):







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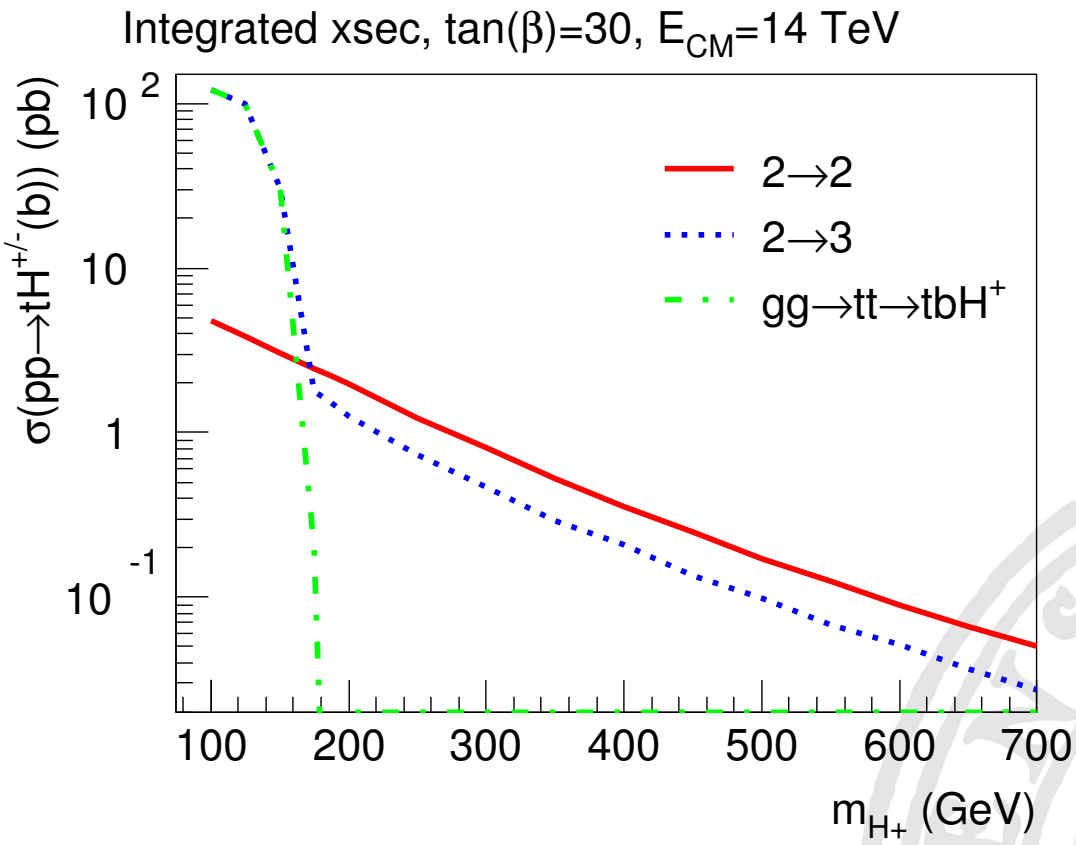
Importance of the H^+ production processes



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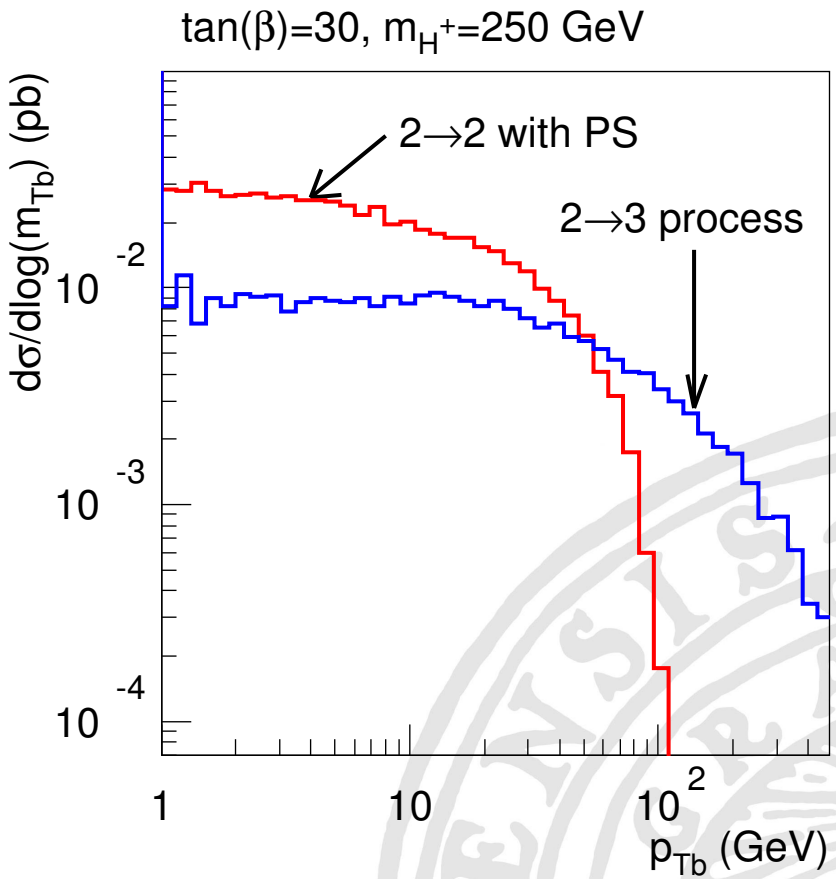
Importance of the H^+ production processes (cont.)

$\mathbf{2 \to 2}$:

The b-density resums collinear logs $\left(\alpha_s \ln \frac{\mu_F^2}{m_b^2}\right)^n$

$\mathbf{2 \to 3}$:

Gives a better discription of large $p_\perp$ cross-section



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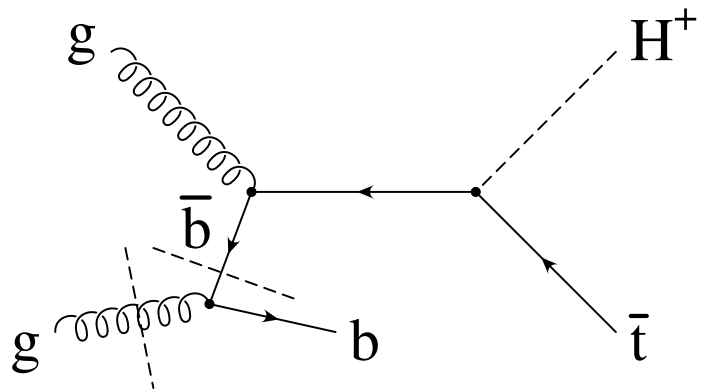
Matching the $2 \to 2$ and $2 \to 3$ processes

Overlap when the b of the $2 \to 3$ process is collinear with the beam



$\Longrightarrow$ Must subtract collinear double counting term

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Matching the $2 \to 2$ and $2 \to 3$ processes (cont)

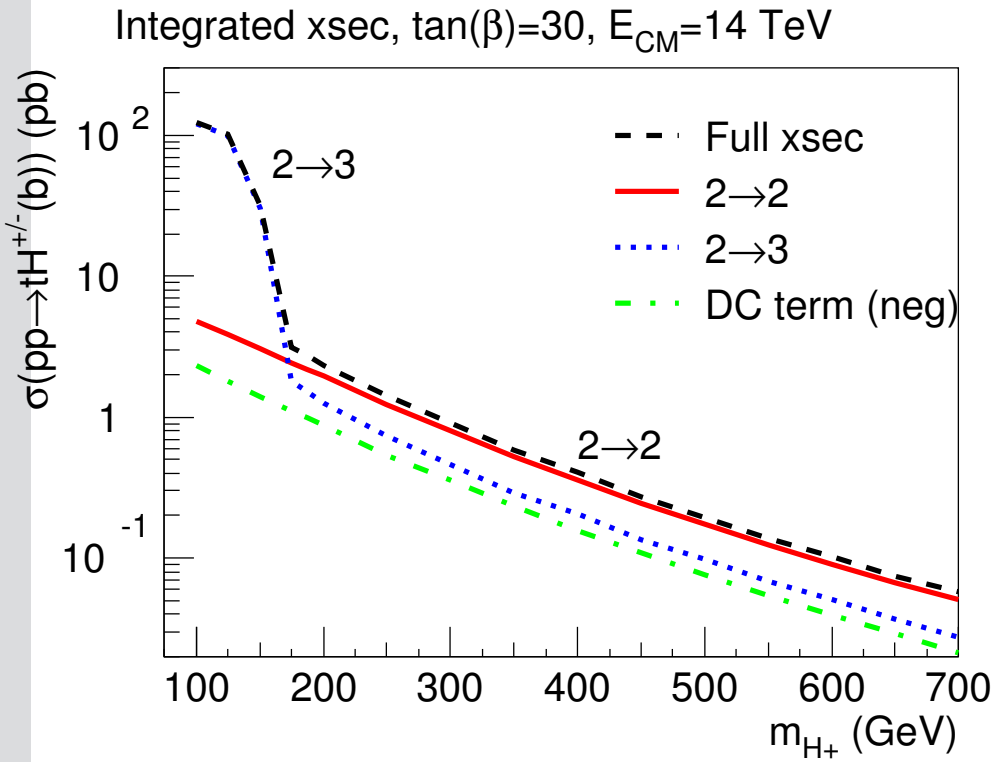
Using Monte Carlo (PYTHIA with external process):
Choose events from DC distribution and add with negative weight

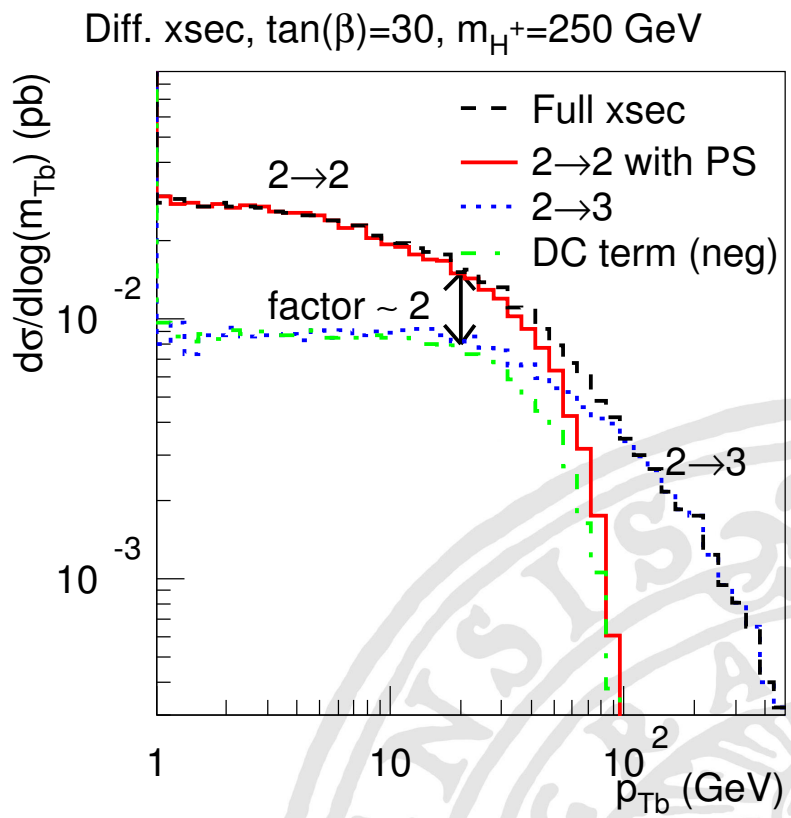
$$\sigma = \sigma_{2\to 2} + \sigma_{2\to 3} - \sigma_{\mathrm{DC}}$$

$$\sigma_{\mathrm{DC}} = \int dx_1 dx_2 \left[g(x_1) b'(x_2) \frac{d\sigma_{2\to 2}}{dx_1 dx_2}(x_1, x_2) + x_1 \leftrightarrow x_2 \right]$$

$$b'(x, \mu^2) = \frac{\alpha_s(\mu^2)}{\pi} \int \frac{dQ^2}{Q^2 + m_b^2} \int P_{gb}(z)\, g(x/z, \mu^2)\, dz$$

Results from matching of processes





Smooth interpolation between $2 \to 2$ and $2 \to 3$ processes

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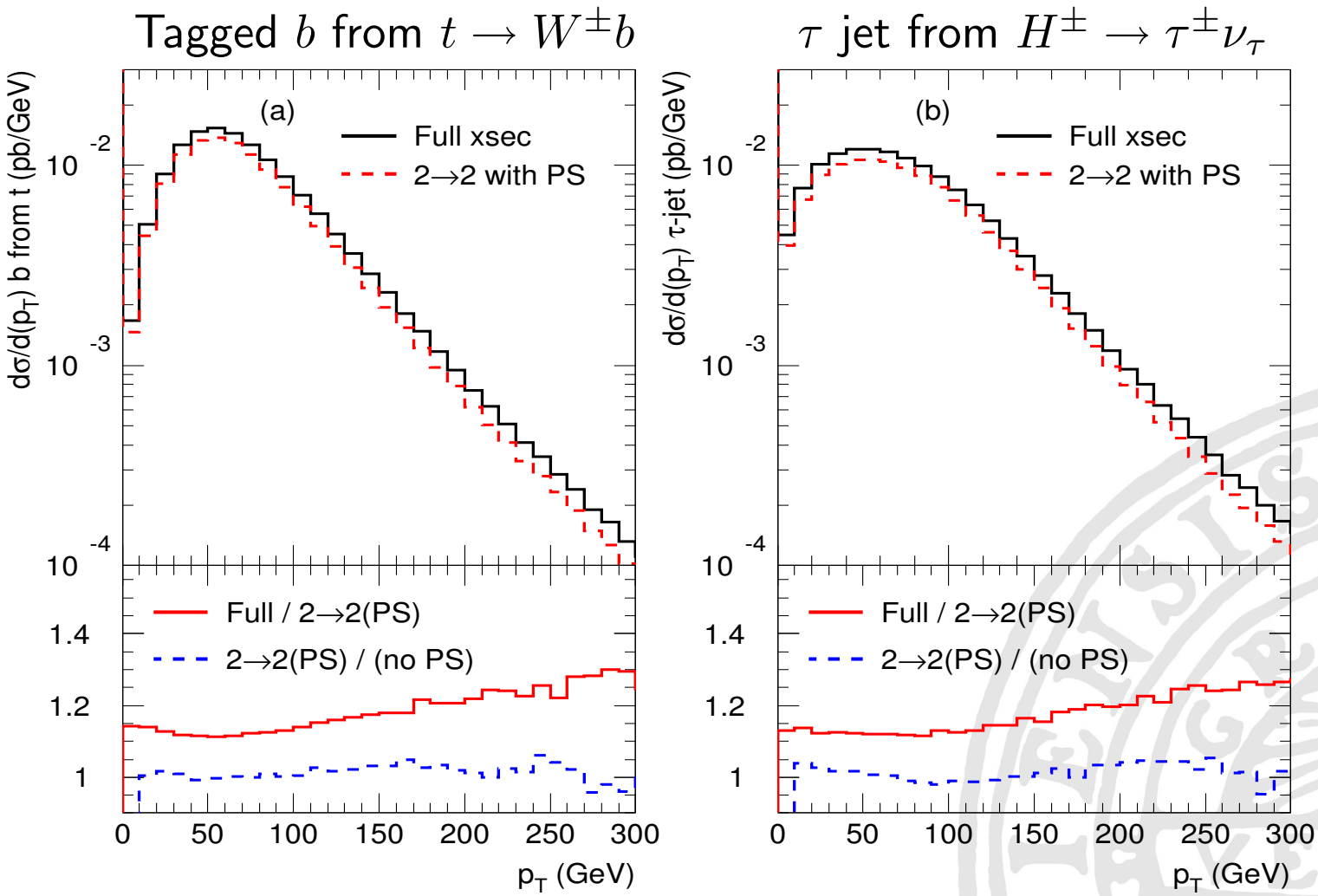
More results from matching of processes



$\sim 10 - 20\%$ Effect even if b-quark not tagged!

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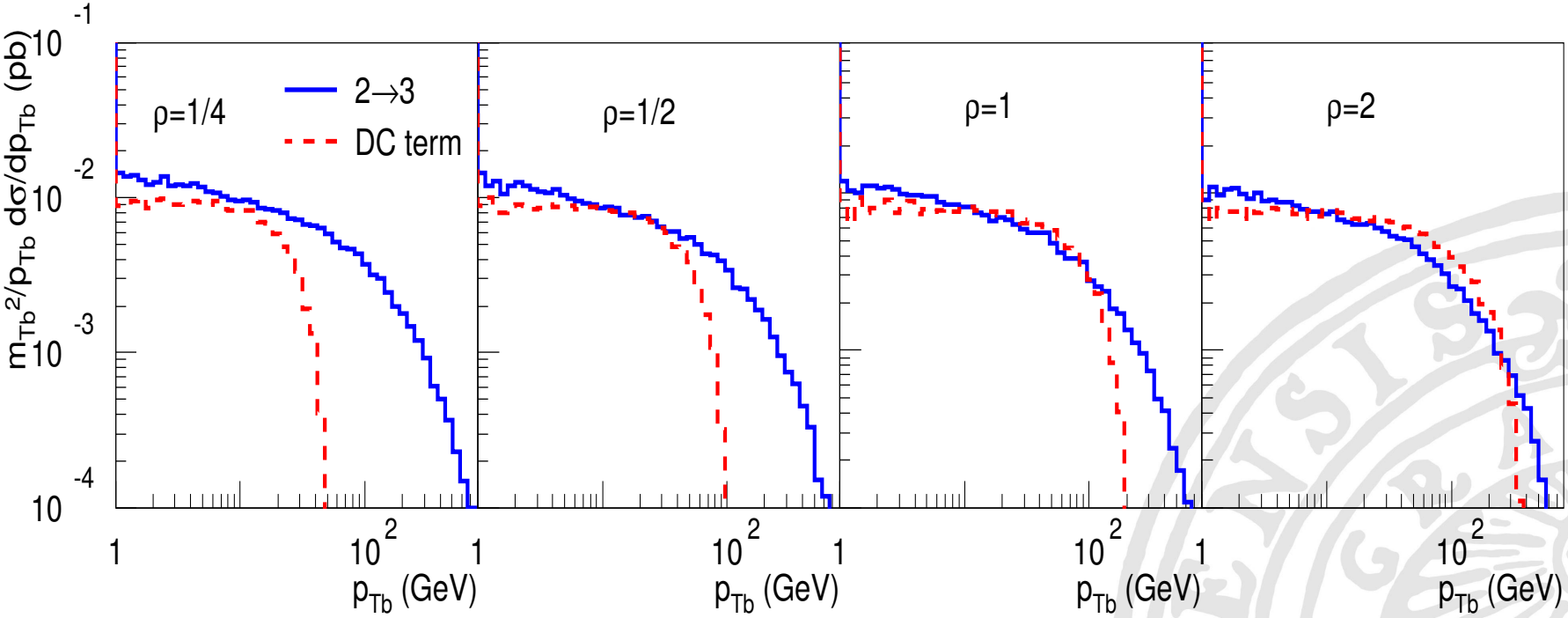
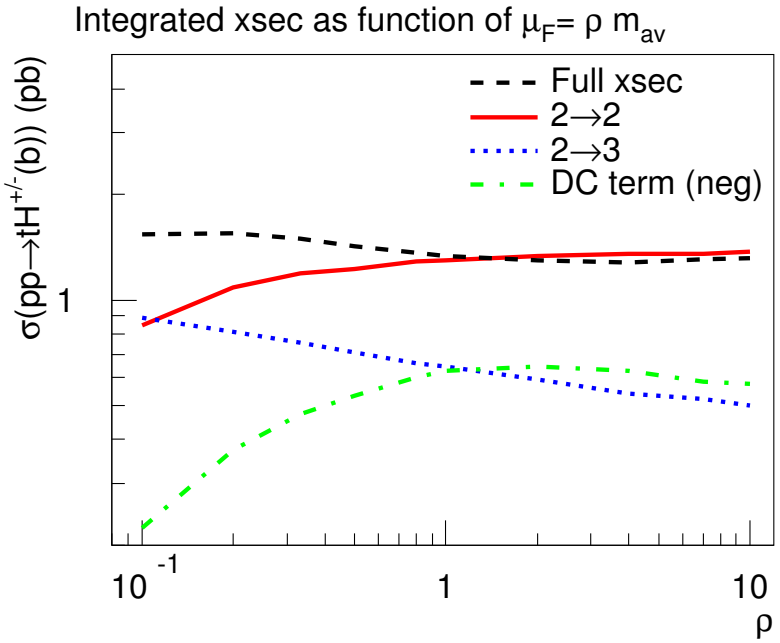
Choice of factorization scale

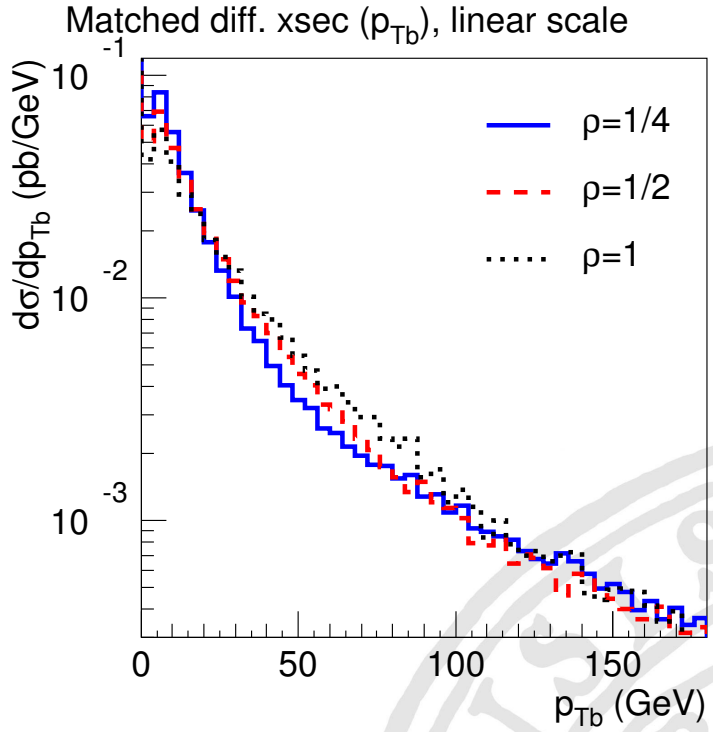
$\mu_F = \rho \frac{m_{H^+} + m_t}{2}$ - scale where the parton densities are evaluated



For $\rho \gtrsim 1$ double counting term overshoots $2 \to 3$ term!

More factorization scale effects





Matched cross-section much less factorization scale dependent!

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Conclusions

- Discovery of a charged scalar particle would be a clear signal of new physics
- Need Monte Carlos to device search strategies and reduce background
- Event generation need both $gb \to tH^+$ and $gg \to tbH^+$
- These two processes must be properly matched, which we do by Monte Carlo-simulation
- Matching can help determine correct factorization scale
- Look at `hep-ph/0409094` or `0410151` for details