T-TBAR CROSS SECTION CALCULATIONS

LES HOUCHES 2005

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thanks to Stefano Frixione!

Starting point

M.Beneke et al.,
"Top quarks physics at the LHC",
Proceedings 1999-2000 LHC Workshop
hep-ph/0003033

STATUS IN 2000

- Differential NLO: FMNR code

  Mangano, Nason, Ridolfi, 1992
  Frixione, Mangano, Nason, Ridolfi, 1995

- Resummed NLL results ("analytic")

  Bonciani, Catani, Mangano, Nason, 1998

- pp →t tb→(b f f′) (b f f′) : LO matrix element w/ decays (double resonant)

- EW 1-loop corrections

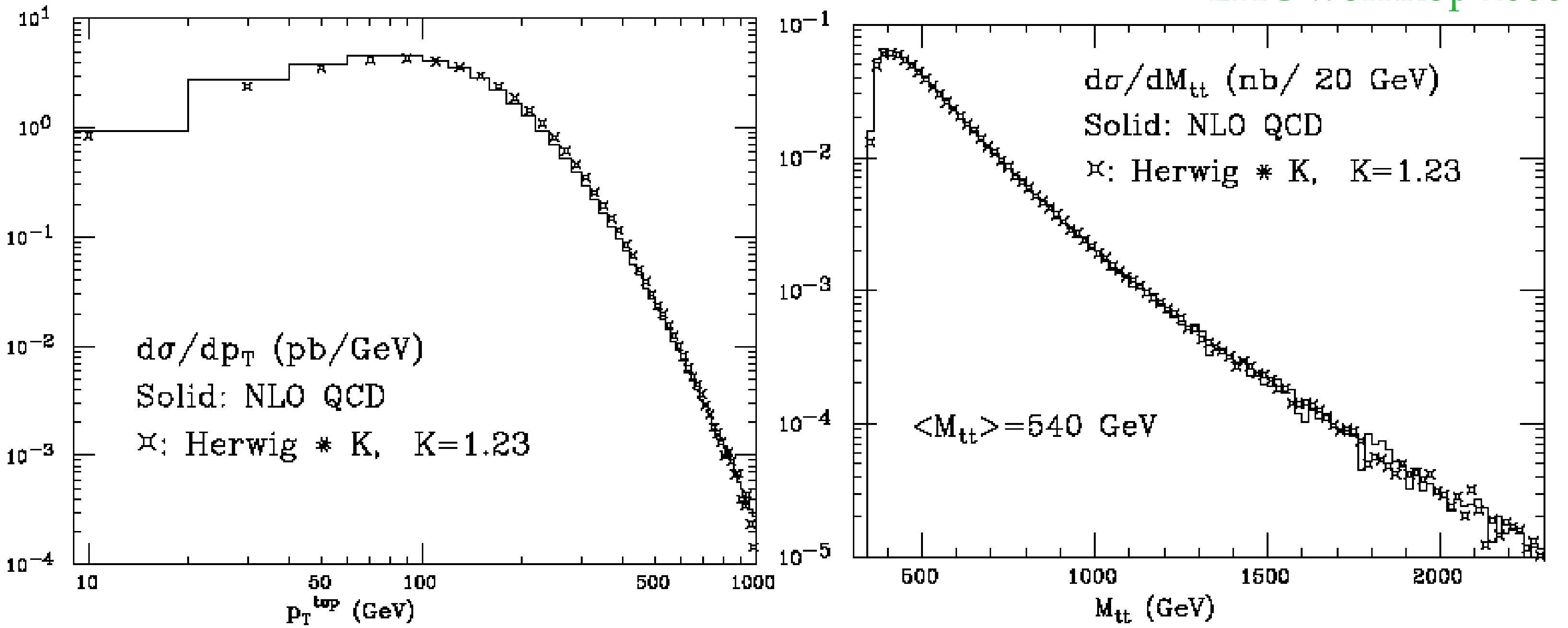
  Beenakker et al., 1994
  Kao et al., 1997
  Stange and Willenbrock, 1992

- SUSY EW and QCD 1-loop corrections

  Long list of people
  see hep-ph/003033 for refs.

STATUS IN 2000

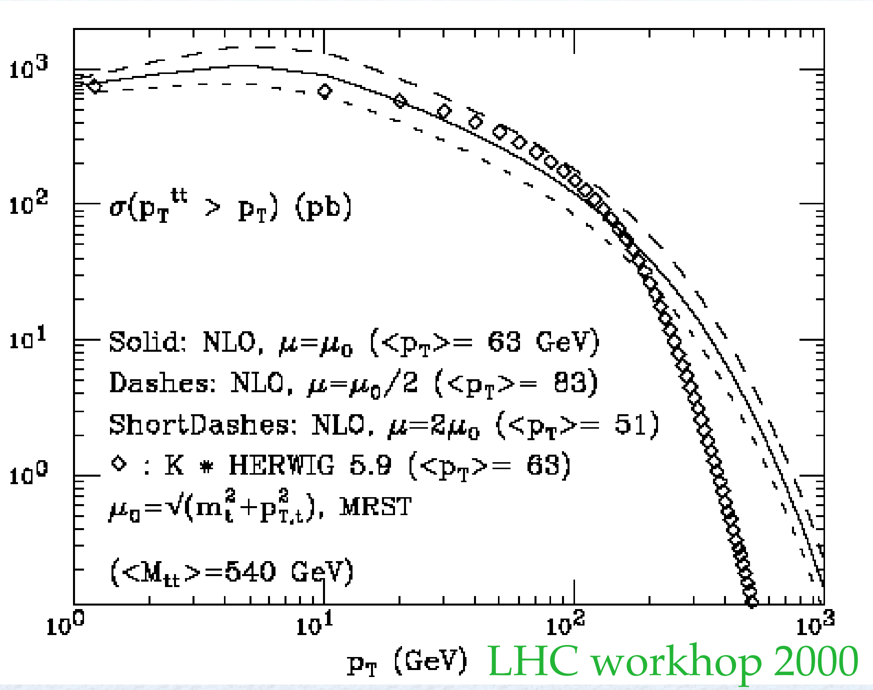
LHC workhop 2000



Pt of the tops and invariant mass distributions are very well described by Herwig ⇒

Extra radiation mostly soft compared to the mtop scale.

Status in 2000



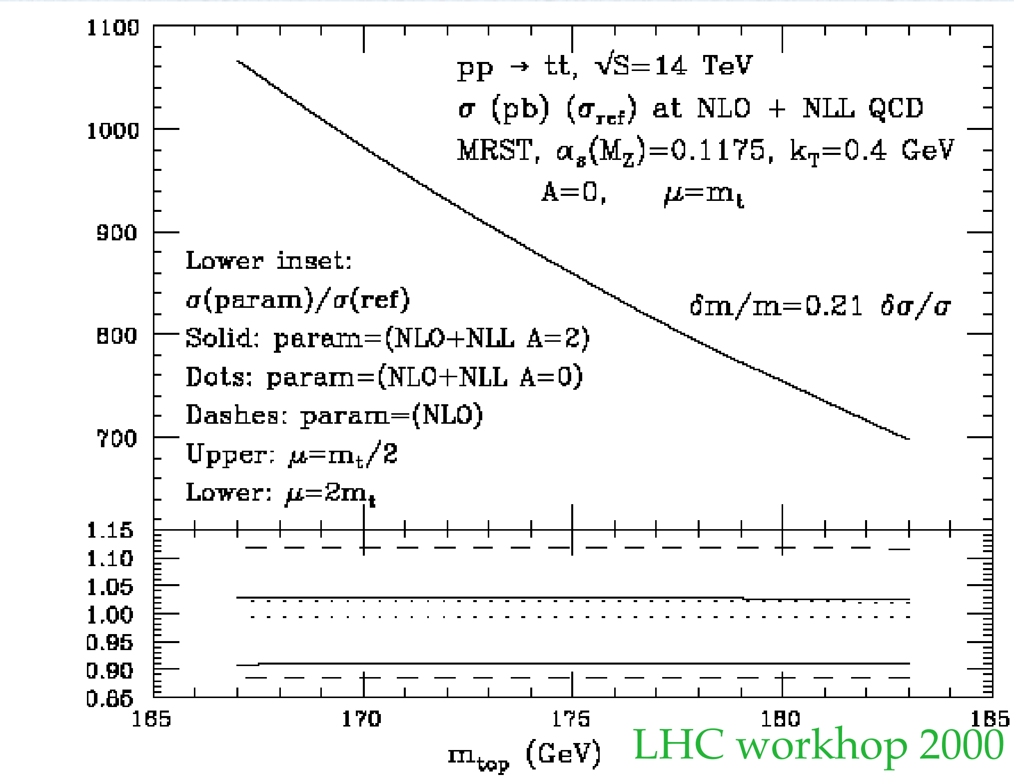
Pt of tt pair is ok at "small" pt.

At higher values of the pt, the shower is unable to reproduce the NLO result, (tt+1jet matrix element).

Process specific merging prescriptions were proposed.

STATUS IN 2000

NLO+NLL Bonciani, Catani, Mangano, Nason



LHC workhop 2000

Scale uncertainty:
from ±12% (NLO) to ±5% (NLO+NLL)

From the plot one can infer that:
Δσ= ± 6% ⇒ Δm= ± 2 GeV

which is comparable to Δm from direct measurements.

This is not the whole story though: further uncertainty comes from the PDF.... see later.

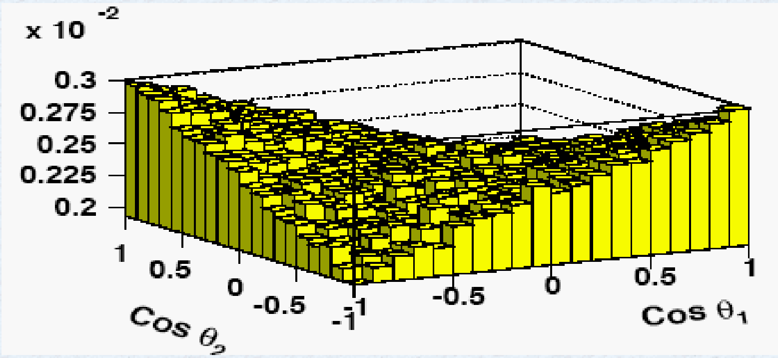
From the experimental point of view statistical errors will be quickly negligible wrt systematic ones.

Remark: this result is the best prediction for sigma(tt) available at present.

Status in 2000

Applications of the ME: pp →t t→(b f f′) (b f f′)

Spin correlations



Spin correlations in top decay t→b f f', and in production.

Top decay depend on the W polarization. Already measured at the Tevatron.

Double distribution in the angles of the leptons wrt the specific directions (which can be event-by-event dependent) show the production correlations.

More on this later....

STATUS IN 2000

Applications of the ME: pp →t t→(b f f′) (b f f′)

Matrix element based analysis

$d^n\sigma$ is the differential cross section

W(y,x) is the probability that a parton level set of variables *y* will be measured as a set of variables *x*

$$\overline{P}(x;\alpha) = \frac{1}{\sigma}\int d^n\sigma(y;\alpha)\,\underline{dq_1\,dq_2\,f(q_1)\,f(q_2)}\,W(x,y)$$

f(q) is the probability distribution than a parton will have a momentum *q*

F.Cannelli

- Only the LO matrix element is used as a weight ⇒ how the emission of an extra jet is treated?
- What about the systematics in the evaluation of W(y,x)?
- Question: with a lot more data, could this approach be validated? How?

What we know more in 2005

- PDF's with systematic uncertainties CTEQ, MRST, LHAPDF, Giele
- Differential NLO in MCFM Campbell and Ellis
- NLO+shower for tt production: MC@NLO
  Frixione, Nason, Webber, 2003
- Spin correlations at NLO Bernreuther, Brandenburg, Si, Uwer, 2004
- pp →(b f f′) (b f f′) : LO matrix element, including all (off-shell) diagrams
  Kauer and Zeppenfeld, 2002
- tt+1jet at NLO (in progress) Brandenburg, Dittmaier, Uwer, Weinzierl, 2004
- tt+jets, ME+Shower at NLL with CKKW

PDF EXERCISE

- Estimate the errors induced by the PDF's using the CTEQ and MRST set of PDF's.

MLM had some results on this already....
(obtained with the FMNR code)

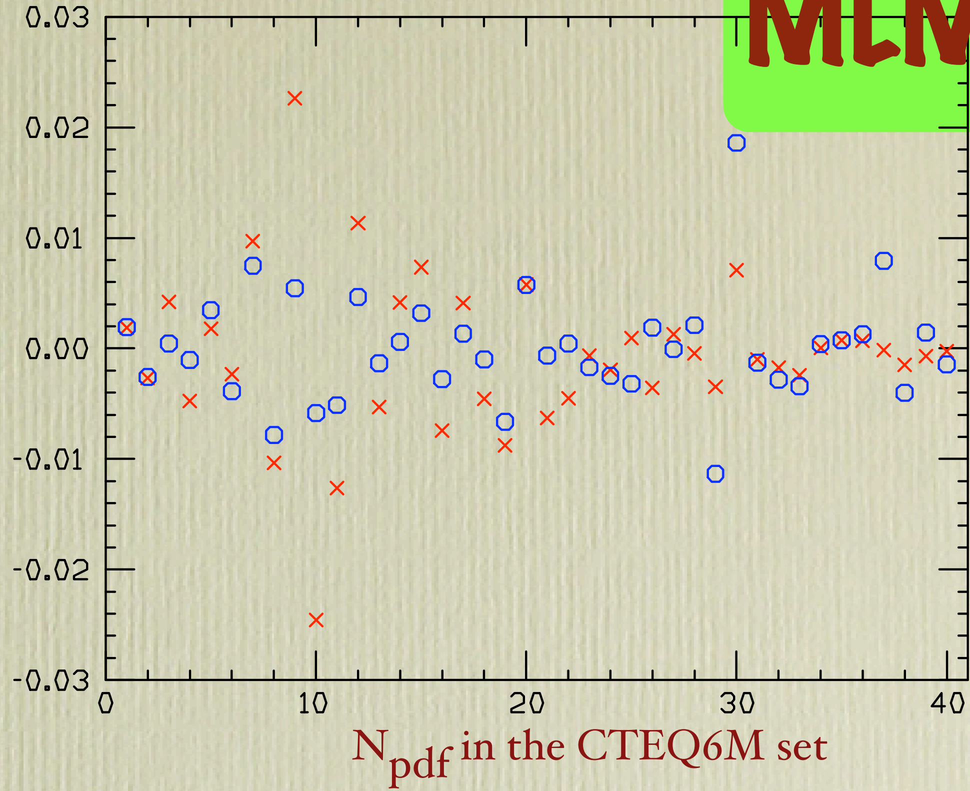
Looking for PDF correlations with the *inclusive jet sample:*

X: $\frac{\sigma_{tt}(N_{pdf})}{\sigma_{tt}(6M)} - 1$

O: $\frac{\sigma_{tt}(N_{pdf})/\sigma_{jet}(N_{pdf})}{\sigma_{tt}(6M)/\sigma_{jet}(6M)} - 1$

where:

σ_{jet}= rate of events with E_{Tjet}>175 GeV



MLM

A correlation exists, but it is not perfect. Likely due to the fact that the initial state is not precisely the same:

$\sigma_{gg}(tt) : \sigma_{qg}(tt) : \sigma_{qq}(tt) = 90\% : 1\% : 10\%$

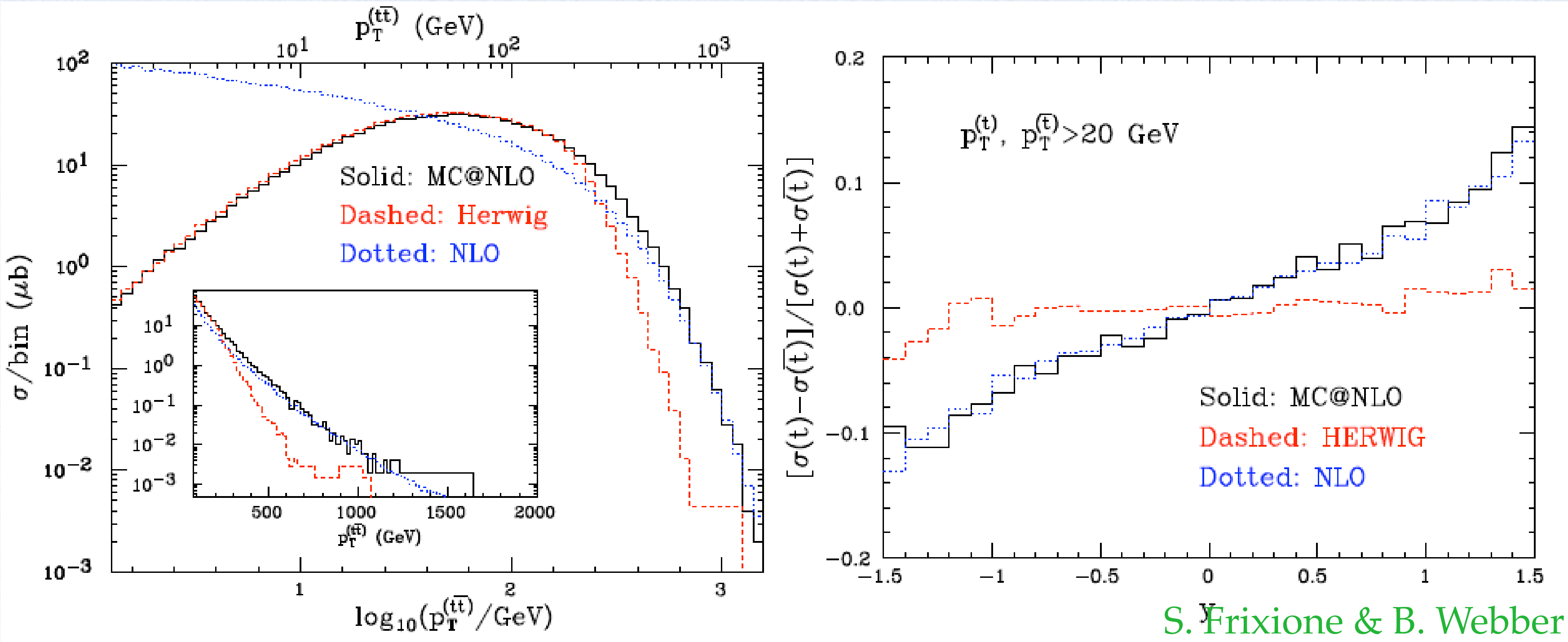
$\sigma_{gg}(jet) : \sigma_{qg}(jet) : \sigma_{qq}(jet) = 45\% : 45\% : 10\%$

What is it good for? Improve accuracy of σ_{tt}? Improve accuracy of σ_{jet} ? Help determine jet E scale?

PDF EXERCISE

- Estimate the errors induced by the PDF's using the CTEQ and MRST set of PDF's with MCFM.
- Identify other processes which may provide information on the gluon pdf in the relevant x range. Question: Maybe $gg \rightarrow bb$ or $gg \rightarrow bbZ$ with the b's at high pt could be used?

MC@NLO



S. Frixione & B. Webber

- K-factors are included consistently
- Equivalent to PS in the soft regions
- Hard radiation of one parton is correctly accounted for by the ME

Spin correlations at NLO

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_1 d\cos\theta_2} = \frac{1}{4}\left(1 - C\cos\theta_1\cos\theta_2\right)$$

		L–L	L–J	J–J
Tevatron				
C_{hel}	LO	−0.471	−0.240	−0.123
	NLO	−0.352	−0.168	−0.080
C_{beam}	LO	0.928	0.474	0.242
	NLO	0.777	0.370	0.176
C_{off}	LO	0.937	0.478	0.244
	NLO	0.782	0.372	0.177
LHC				
C_{hel}	LO	0.319	0.163	0.083
	NLO	0.326	0.158	0.076

Bernreuther, Brandenburg, Si, Uwer, 2004

Spin correlations in tt at the LHC are very much independent of NLO QCD corrections.

This is good since it suggests that the LO+PS analysis is ok.

Exercise: use the present version of MC@NLO that has the correlations in the decay but not those in the production as a test of the experimental analysis.

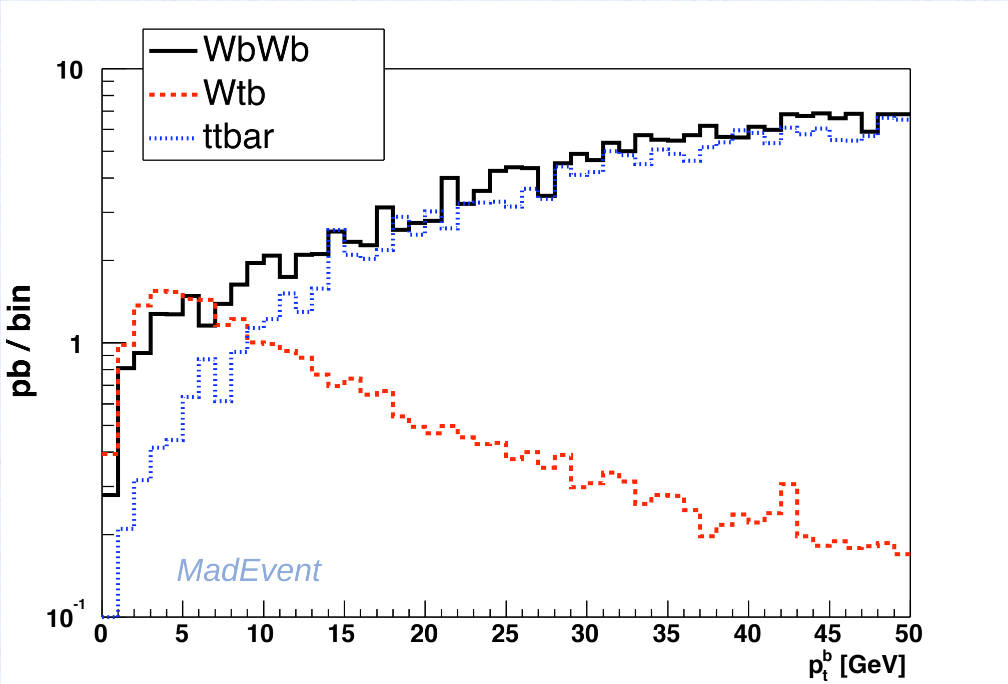
Question:
EW corrections have a small effect on total rates, but what about spin correlations?

A DIFFERENT POINT OF VIEW

tt is not only a signal but also an important background for many other SM and BSM processes

Question:
Are the available calculations accurate to describe tt as a background?

Example: tt as a background to gg→H→W+W-



In gg →H→W+W-, a jet veto is required to curb the ttbar background.

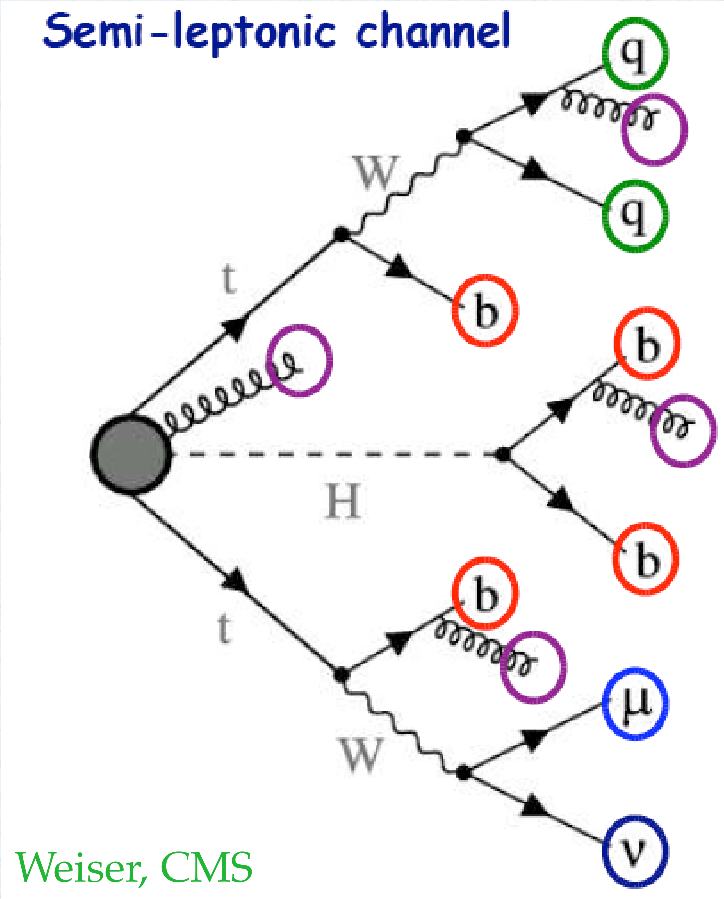
ttbar is reduced by a large factor, so that it becomes comparable to gb→tW.

Gauge invariance requires both processes to be calculated at the same time ⇒ only LO prediction is available.

Questions:

1. How does the tt cross section behave in this phase space region?
2. Are there large corrections from purely NLO processes?
3. To what extent we can use tt (NLO) and gb→tW (NLO) instead of WWbb, which we only know at LO?

Example: tt+jets as a background to ttH



Signature:
4 b-jets (all tagged)
1 isolated lepton
Missing Et
2 jets to mW

Backgrounds:

ttbb and ttcc :
probably known at NLO before the LHC start
ttj, ttb, ttc:
probably known at NLO by the end of 2005
tt + n≥2 jets:
known at LO only but inclusive sample with the right normalization can be obtained with ME+PS a la CKKW.

Question: Is there a comparison between MC@NLO and the tt+jets inclusive sample a la CKKW?

Question: What are the predictions for the flavor fractions of the jets?

New Starting Point

"Top quarks physics at TeV colliders",
Proceedings of the 2005 Les Houches Workshop
Physics at TeV colliders