Practical use of pdf uncertainties and trying to understand any Sudakov errors that may result

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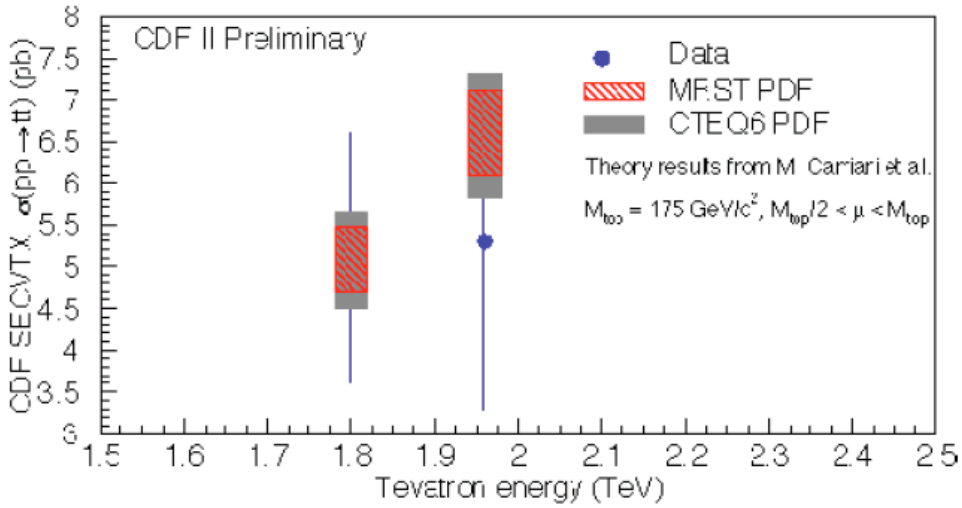
Using pdf uncertainties

- CTEQ or MRST pdf's are meant to be used with NLO programs
  - but are also often used in parton shower Monte Carlos as well
- It's relatively straightforward, for example, to calculate the central cross section and the pdf uncertainty for something like t-tbar production at the Tevatron

$$\sigma(t\bar{t}) = f_1(x_1,M) \otimes f_2(x_2,M) \otimes \sigma(\alpha_s(\mu))$$

- $\Delta\sigma \rightarrow \Delta f_1, \Delta f_2, \Delta\alpha_s, (\Delta(\mu,M))$



Using pdf uncertainties: LHAPDF

- PDF uncertainties are important both for precision measurements (W/Z cross sections) as well as for studies of potential new physics (a la jet cross sections at high E_T)
- Most Monte Carlo/matrix element programs have "central" pdf's built in, or can easily interface to PDFLIB
- Determining the pdf uncertainty for a particular cross section/distribution might require the use of many pdf's
- **->LHAPDF**
  - a replacement for PDFLIB as the source for up-to-date pdf's
  - originated by Walter Giele; now maintained by Mike Whalley of Durham

- Using the interface is as easy as using PDFLIB (and much easier to update)
- call InitiPDFset(*name*)
  - called once at the beginning of the code; *name* is the file name of external PDF file that defines PDF set
- call InitPDF(*mem*)
  - *mem* specifies individual member of pdf set
- call evolvePDF(*x*,*Q*,*f*)
  - returns pdf momentum densities for flavor *f* at momentum fraction *x* and scale *Q*

Version 3 of LHAPDF

LHAPDF Version 3

released Sept 2004

http://durpdg.dur.ac.uk/lhapdf/ -> http://durpdg.dur.ac.uk/lhapdf3/
http://durpdg.dur.ac.uk/lhapdf2/
http://durpdg.dur.ac.uk/lhapdf1/

older versions are "frozen" and kept available

(1) More PDFs available:

New : ZEUS – LHpdf file using QCDNUM (thanks to Mandy Cooper-Sarkar)
H1 – LHgrid file (thanks to Christian Pascaud)
MRST2003c (nlo and nnlo) – LHpdf and LHgrid files

Legacy: CTEQ4, CTEQ5, GRV98 – all using the original interpolation codes – ie LHgrid files

From talk of Mike Whalley at HERALHC meeting at CERN in October

Version 3 of LHAPDF

LHAPDF Version 3

released Sept 2004

http://durpdg.dur.ac.uk/lhapdf/

(2) New Feature:

LHAGLUE – a PDFLIB like interface to LHAPDF

→ developed by/with Dimitri Bourilkov and Craig Group of U. of Florida

→ available in addition to the standard LHAPDF calling routines

→ initial development has been with PYTHIA and HERWIG

Version 3 of LHAPDF

LHAGLUE

"The LHAGLUE package, plus a unique PDF numbering scheme, enables LHAPDF to be used in the same way as PDFLIB, without requiring *any* changes in the PYTHIA or HERWIG codes"

"LHAGLUE fortran calls:-

```
      CHARACTER*20 parm(20)
      DOUBLE PRECISION value(20)
      …
→     Call PDFSET(parm,value)
      …
      …
→     Call STRUCTM(X,Q,UPV,DNV,USEA,DSEA,STR,CHM,BOT,TOP,GLU)
      …
```

Control of which PDFs sets to use and other settings is through the paired parm() and value() arrays – similar to PDFLIB.

Using pdf uncertainties, continued…

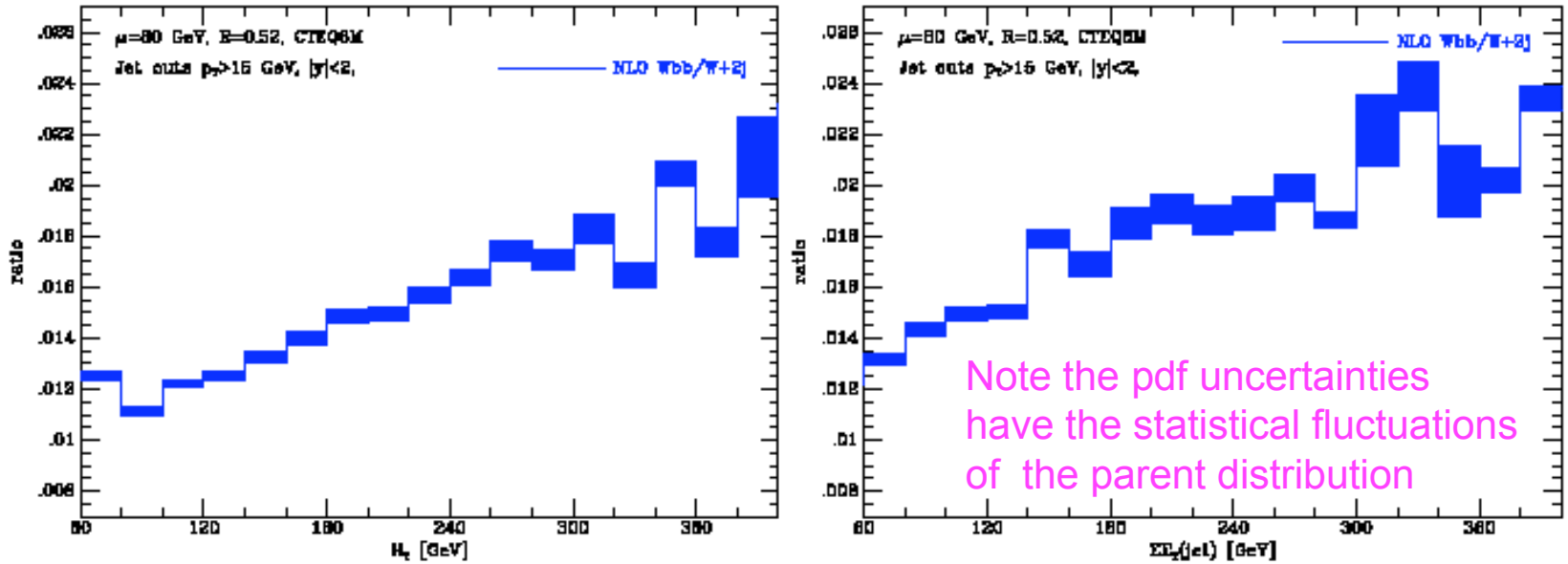
NLO programs can be slow, especially if you have to run 41 pdf's
But if new version of LHAPDF is used, can run full cross section with central pdf and store pdf*pdf luminosity for each event and then re-weight

- Total cross-section uncertainty: Using MCFM, ~~see CDF6849~~

J. Campbell and J. Huston:hep-ph/0405276->PRD

$$Wb\bar{b} \rightarrow 2.5\% \,, \qquad W + 2j \rightarrow 1.5\%.$$

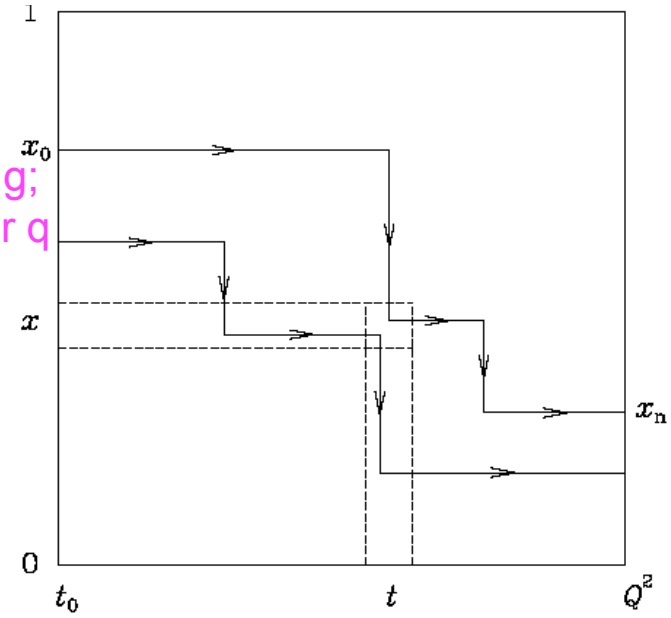
- Uncertainty in the $(Wb\bar{b}/W + 2$ jet) ratio:



In Version 3 of LHAPDF, all pdf's can be stored in memory at the same time

Using pdf weight techinique in Monte Carlos

- An error may be introduced when using this technique with parton shower Monte Carlos
- The backward evolution in the initial state depends not only on the value of the pdf at a specific x and Q^2 value but also the slope of the pdf in going to higher x and lower Q^2
- In ISR, parton evolves backwards towards higher x and lower Q^2
- Backwards evolution Sudakov factors are weighted by the ratio of pdf's
- So the larger a pdf is at higher x and lower Q^2, the larger is the probability of a gluon emission having occurred



0.4 for g;
0.34 for q

0.25 on average

At the Tevatron, for top production, quarks start at about x=0.34 at Q_o and end at x=0.25 at $Q^2=10^4$ GeV^2;
gluons start higher at x=0.4

Using pdf weight technique in Monte Carlos

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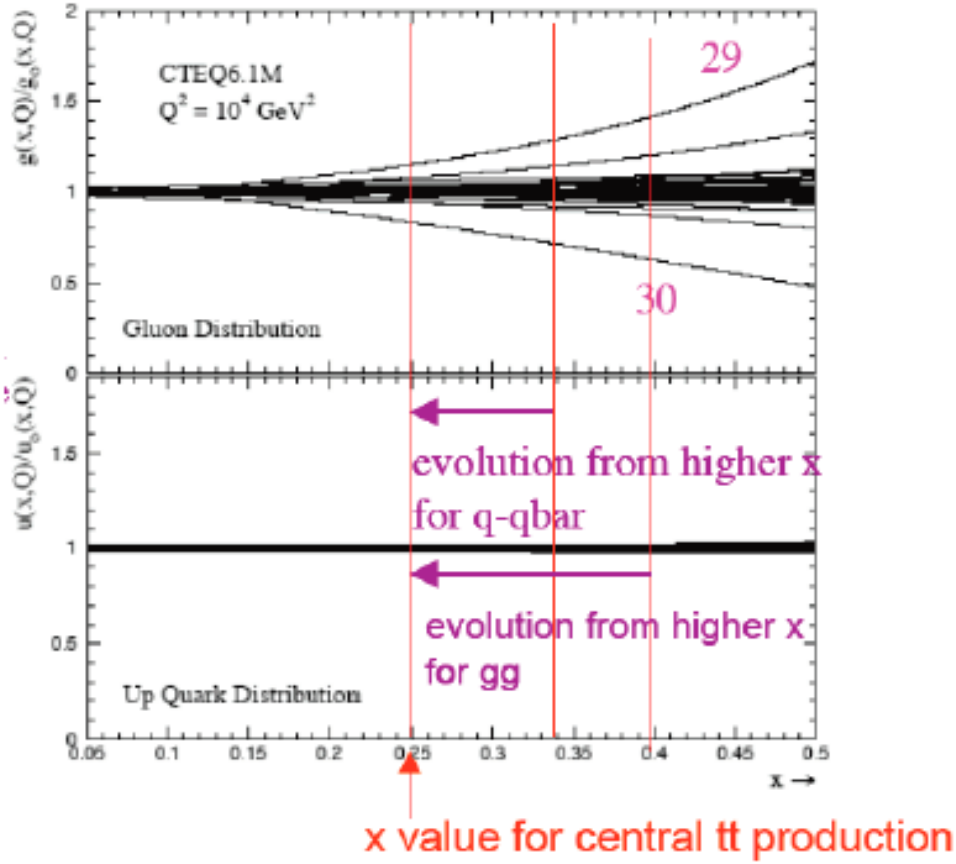
- The backward evolution in the initial state depends not only on the value of the pdf at a specific x and Q^2 value but also the slope of the pdf in going to higher x and lower Q^2
- The backward evolution uses only the slope of the central pdf
  - for qqbar->ttbar, there is no difference in slope
  - but for gg->ttbar, pdf's 29 and 30 have different slope than cteq6m
- So expect pdf 29 to give more gluon radiation than CTEQ6M; pdf 30 to give less
  - other error pdf's should be no different than cteq6
- Compare large statistics fully generated samples of cteq6, pdf29 and pdf30 to error pdf-weighted samples based on cteq6
- If little difference observed, then "average" Sudakov factor is sufficient



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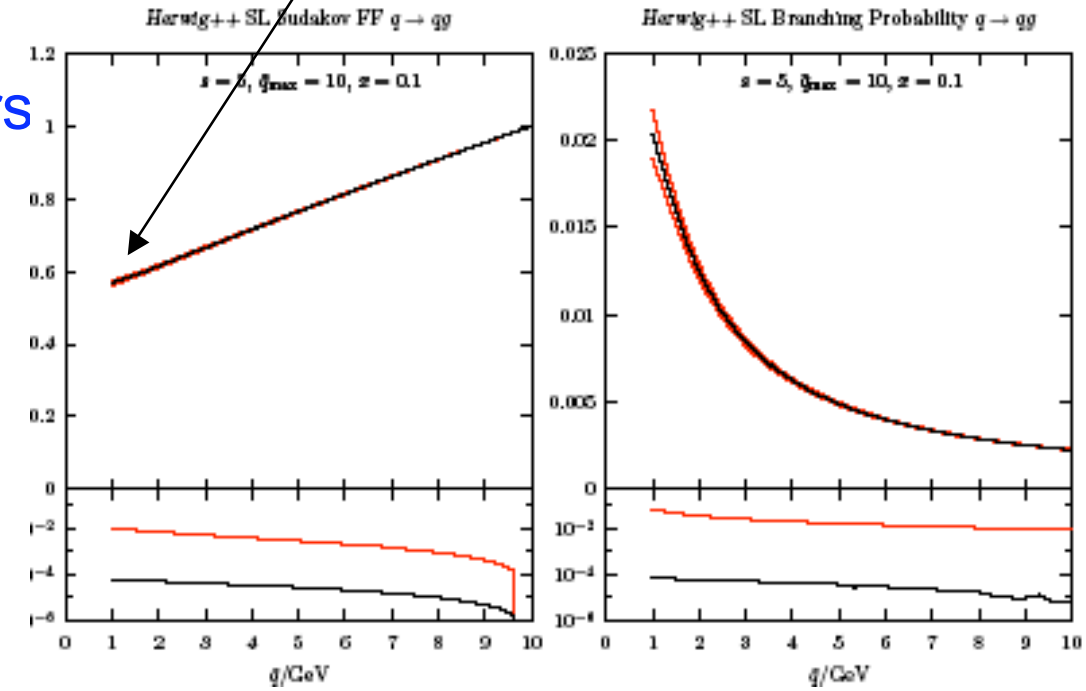
Helpful magazine

- At first I thought a magazine devoted to ISR might prove helpful
- But then I took a closer look at the title and realized that this is a magazine that Steve Mrenna would never subscribe to

Study in progress by Stefan Gieseke

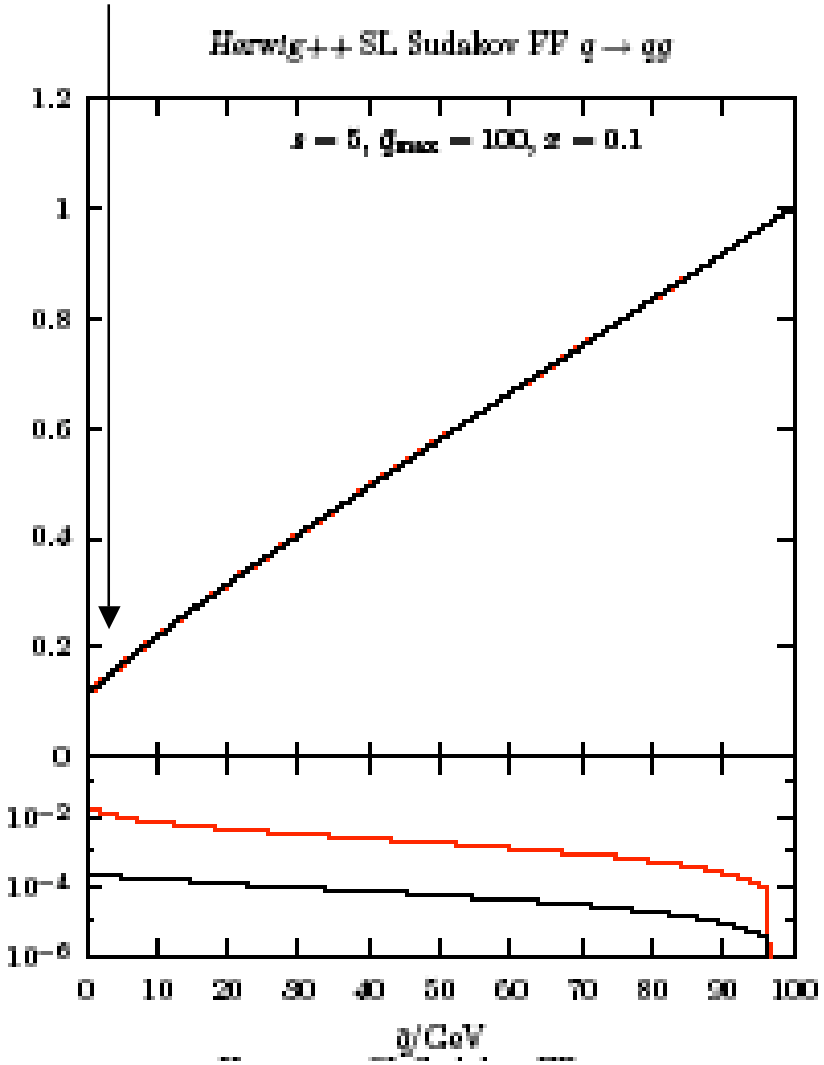
- Look at pdf uncertainties for Sudakov form factors
- For example, on the right is shown the Sudakov FF for q->qg
- Width of the band gives the pdf error using MRST2001 pdf errors

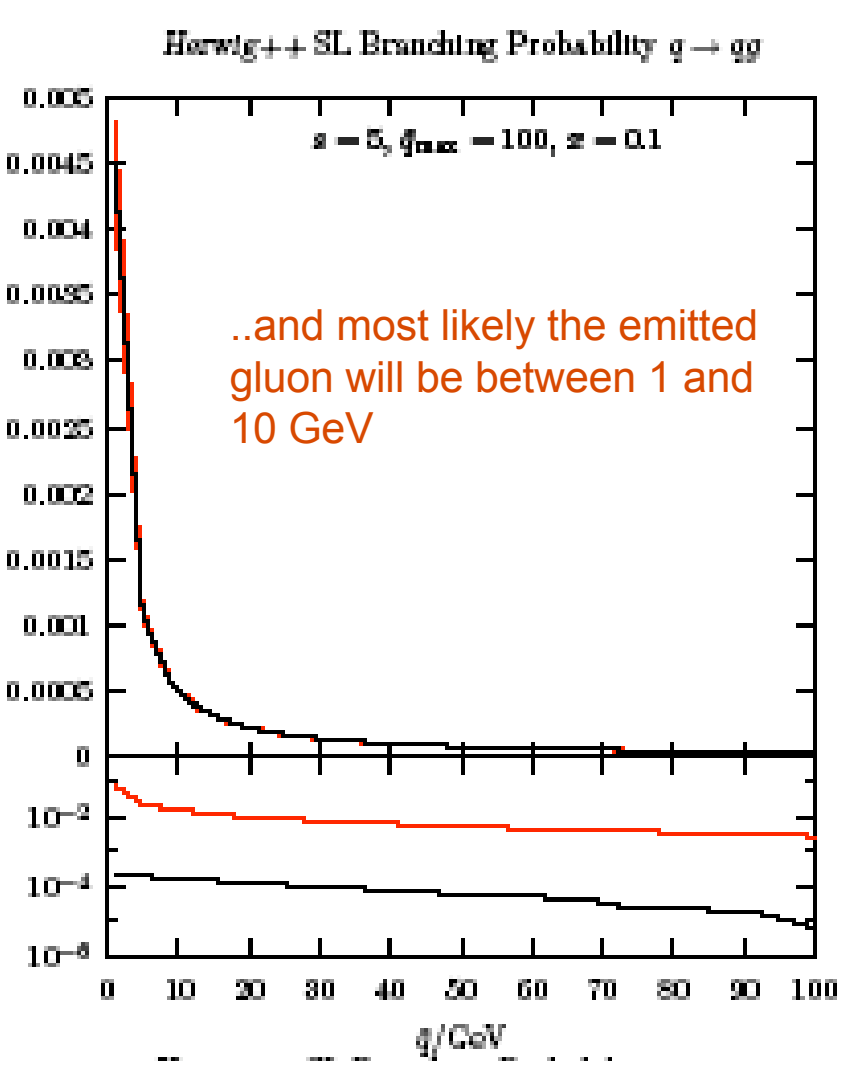
There's a 60% chance for the quark to evolve from 1 GeV to 10 GeV without emitting any gluons more than 1 GeV



Gieseke study

Here for example, there's less than a 20% probability for a quark at an x of 0.1 to evolve from 1 GeV to 100 GeV without emitting a resolvable gluon of energy greater than 1 GeV

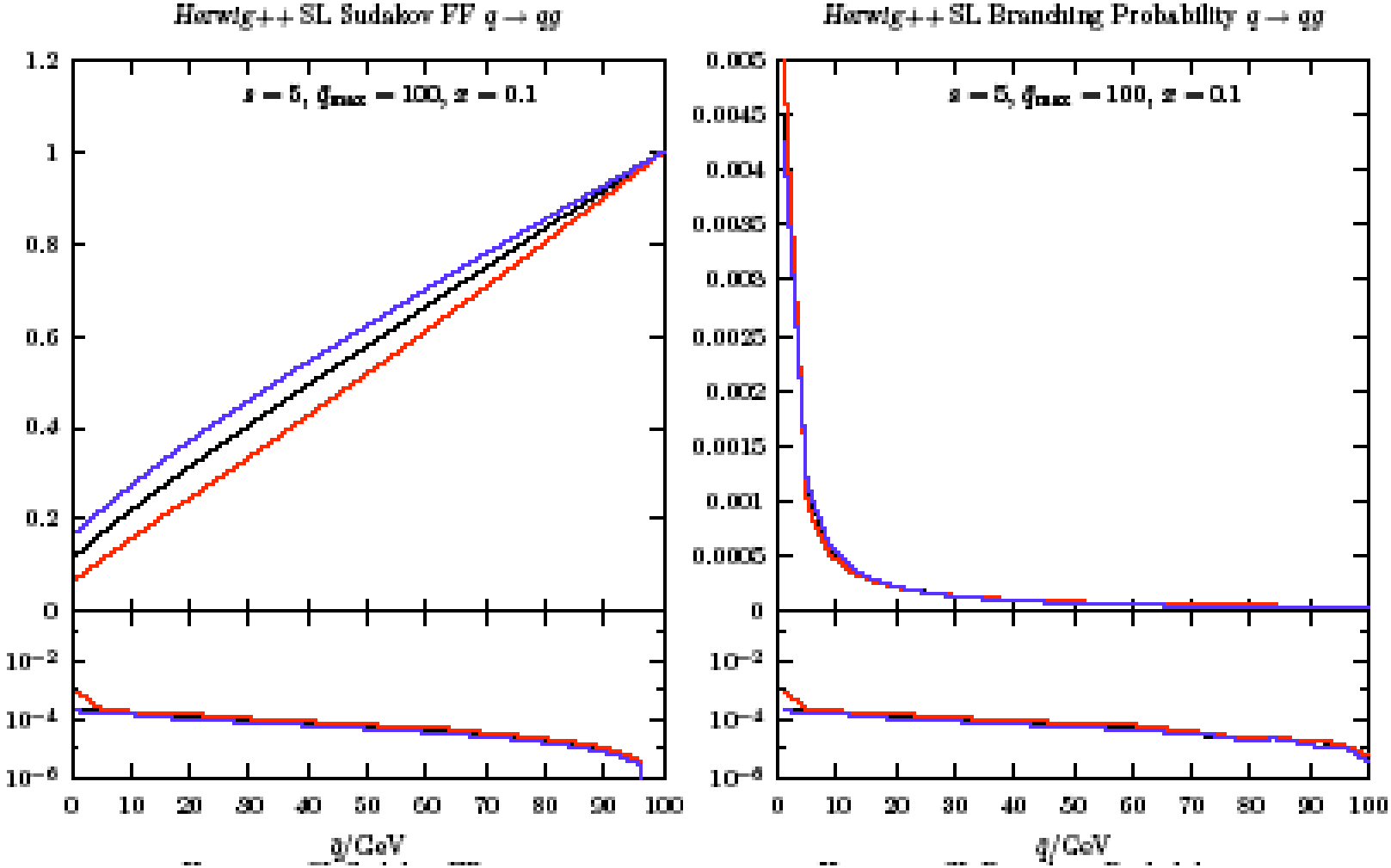




..and most likely the emitted gluon will be between 1 and 10 GeV

Gieseke study

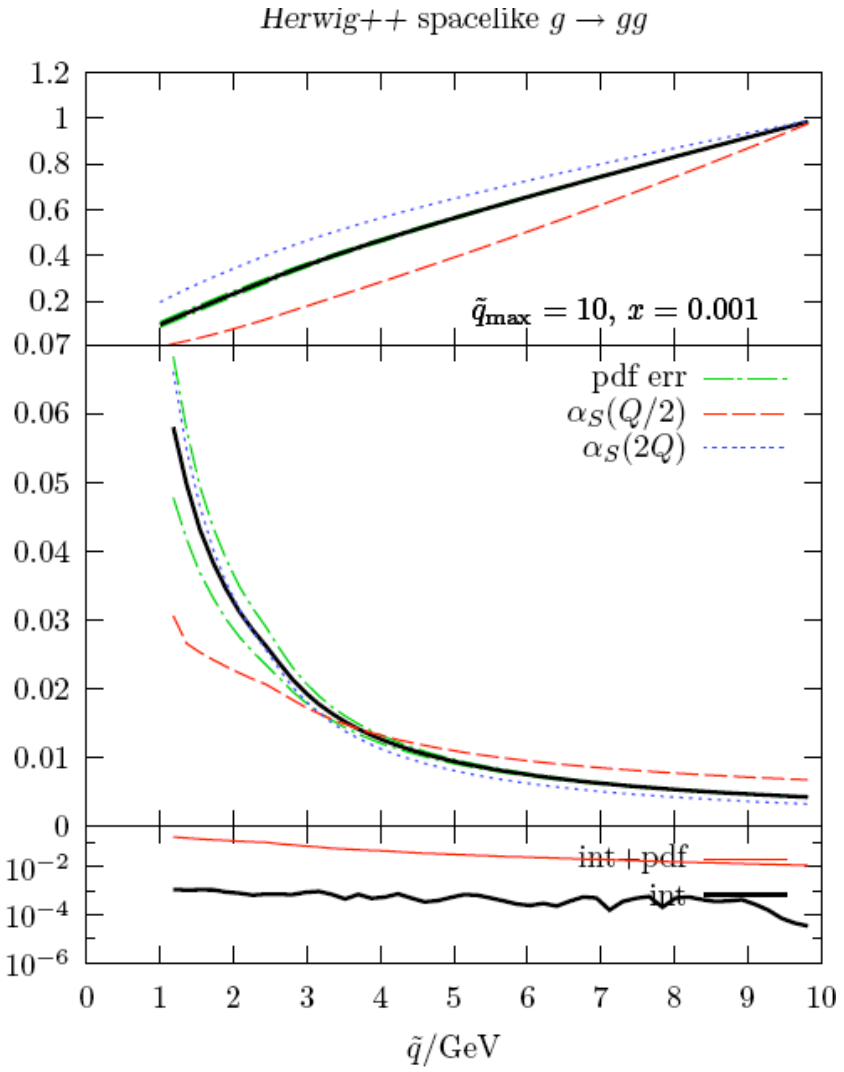
Compare to uncertainties in Sudakov form factor arising by changing α_s scale by a factor of 2



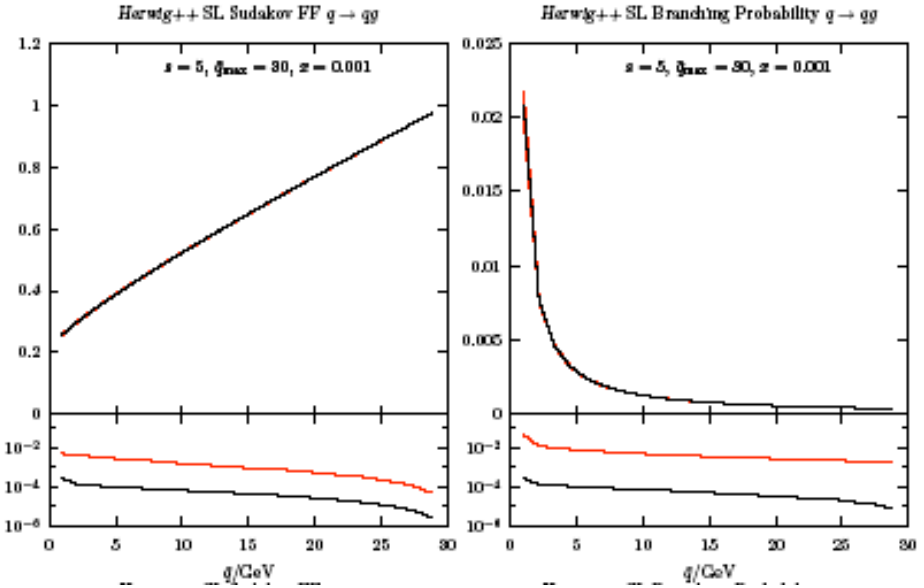
Next

- Calculate Sudakov FF for g->gg
- Use CTEQ6.1 pdf errors
- Make quantitative estimates for pdf differences relating to top production
- On-going study by Un-Ki Yang and Eun-ju Jeon of pdf uncertainty on top mass using HEPG level reconstruction of 40 CTEQ6 error pdf's

Late-breaking news



Compare to q->qg (but at q_{max}=30 GeV rather than 10 GeV)



Last word: PDF's in Monte Carlos

- Often, we need to calculate the pdf uncertainty on something like an acceptance
- And we often use a Monte Carlo so that we can work at the detector level
- Technically, should use LO pdf's with MC's
  - no LO error pdf's
  - but resulting error of using NLO pdf's is NLO, beyond scope of MC
- But, LO central fit can differ from NLO central fit by more than NLO pdf uncertainty
  - should check in any study