# Parton kinematics

- To serve as a handy “look-up” table, it’s useful to define a parton-parton luminosity
  - this is from a ontribution to Les Houches
- Equation 3 can be used to estimate the production rate for a hard scattering at the LHC

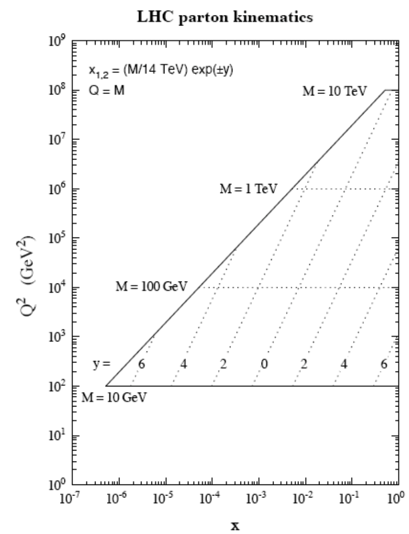



Fig. 1: Parton kinematics for the LHC.

$$\frac{dL_{ij}}{d\hat{s}\,dy} = \frac{1}{s}\,\frac{1}{1+\delta_{ij}}\,[f_i(x_1,\mu)f_j(x_2,\mu) + (1 \leftrightarrow 2)]\;. \qquad (1)$$

The prefactor with the Kronecker delta avoids double-counting in case the partons are identical. The generic parton-model formula

$$\sigma = \sum_{i,j} \int_0^1 dx_1\, dx_2\, f_i(x_1,\mu)\, f_j(x_2,\mu)\, \hat{\sigma}_{ij} \qquad (2)$$

can then be written as

$$\sigma = \sum_{i,j} \int \left(\frac{d\hat{s}}{\hat{s}}\,dy\right) \left(\frac{dL_{ij}}{d\hat{s}\,dy}\right) (\hat{s}\,\hat{\sigma}_{ij})\;. \qquad (3)$$

# Cross section estimates

$$\sigma = \frac{\Delta\hat{s}}{\hat{s}}\left(\frac{dL_{ij}}{d\hat{s}}\right)(\hat{s}\,\hat{\sigma}_{ij})$$

for the gluon pair production rate for $\hat{s}$=1 TeV and $\Delta\hat{s} = 0.01\hat{s}$, we have $\frac{dL_{gg}}{d\hat{s}} \simeq 10^3$ pb and $\hat{s}\,\hat{\sigma}_{gg} \simeq 20$ leading to $\sigma \simeq 200$ pb

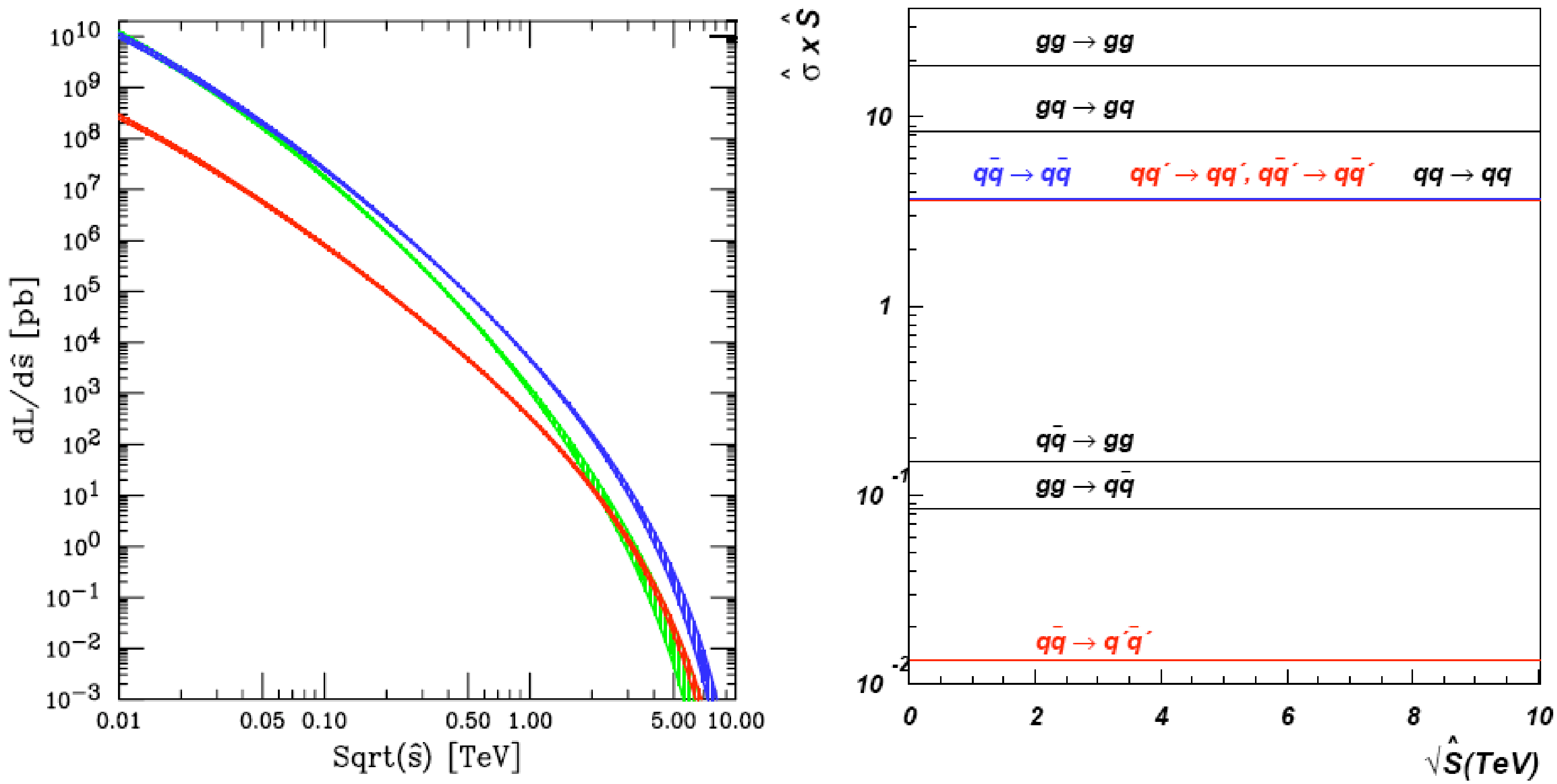



Fig. 2: Left: luminosity $\left[\frac{1}{\hat{s}}\frac{dL_{ij}}{d\tau}\right]$ in pb integrated over $y$. Green=$gg$, Blue=$g(d+u+s+c+b)+g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})+(d+u+s+c+b)g+(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$, Red=$d\bar{d}+u\bar{u}+s\bar{s}+c\bar{c}+b\bar{b}+\bar{d}d+\bar{u}u+\bar{s}s+\bar{c}c+\bar{b}b$. Right: parton level cross sections $[\hat{s}\hat{\sigma}_{ij}]$ for various processes

# Luminosities as a function of y

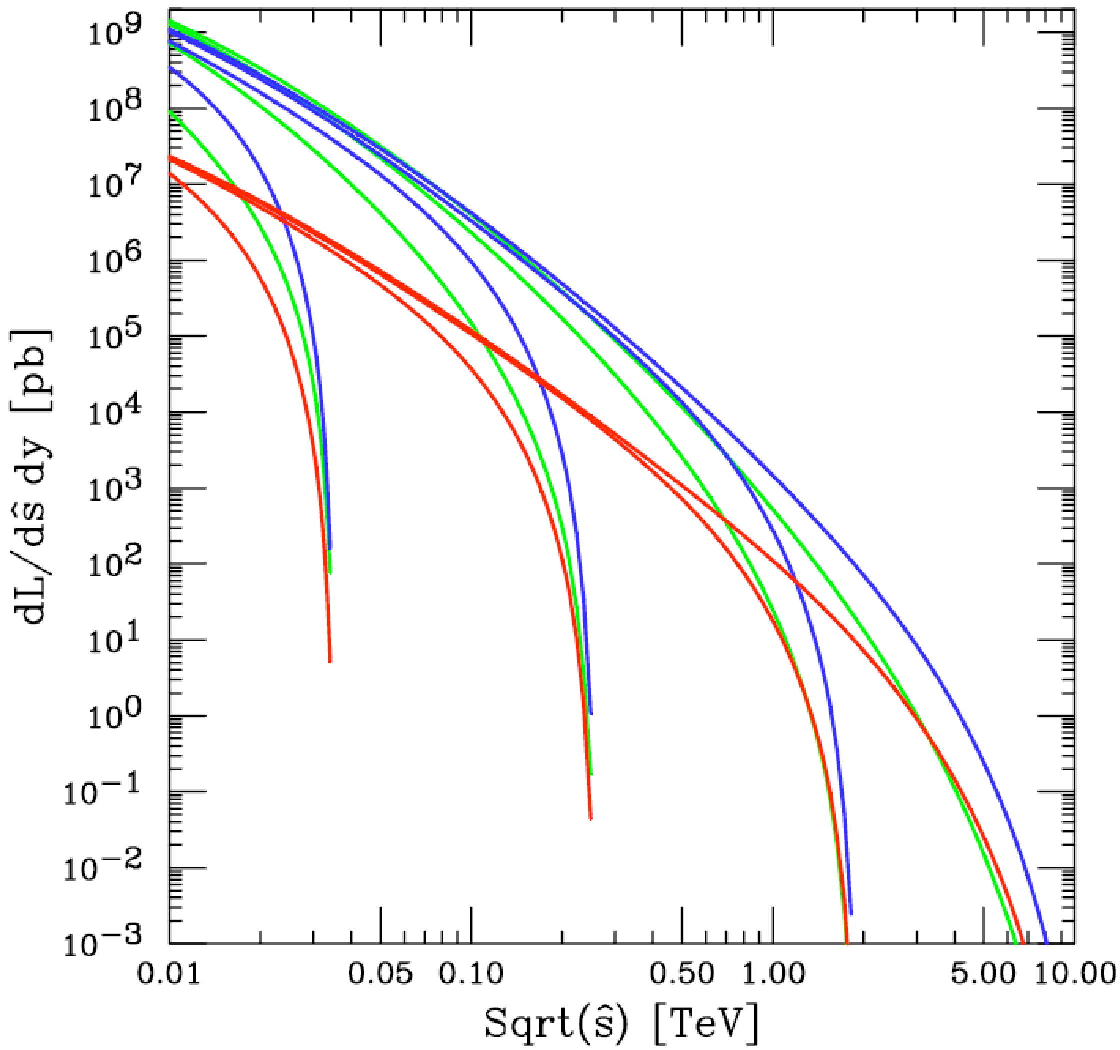



Fig. 3: dLuminosity/dy at $y = 0, 2, 4, 6$. Green=$gg$, Blue=$g(d+u+s+c+b) + g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b}) + (d+u+s+c+b)g + (\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$, Red=$d\bar{d} + u\bar{u} + s\bar{s} + c\bar{c} + b\bar{b} + \bar{d}d + \bar{u}u + \bar{s}s + \bar{c}c + \bar{b}b$.

# gg luminosity uncertainties

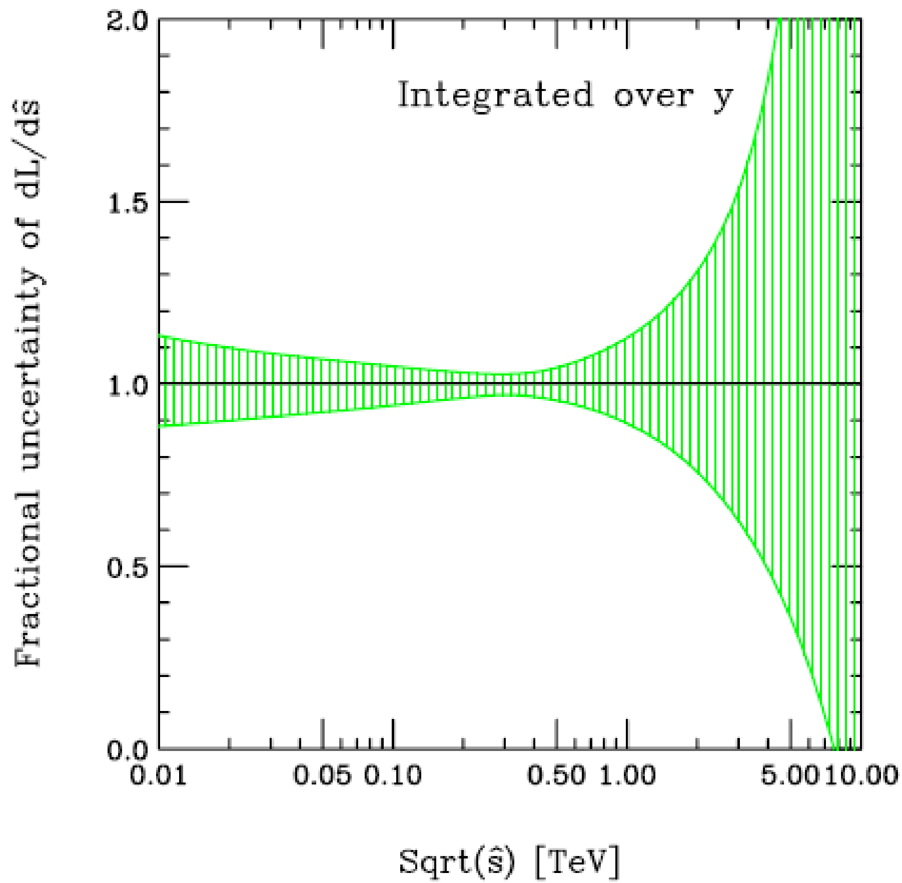



Fig. 4: Fractional uncertainty of $gg$ luminosity integrated over $y$.

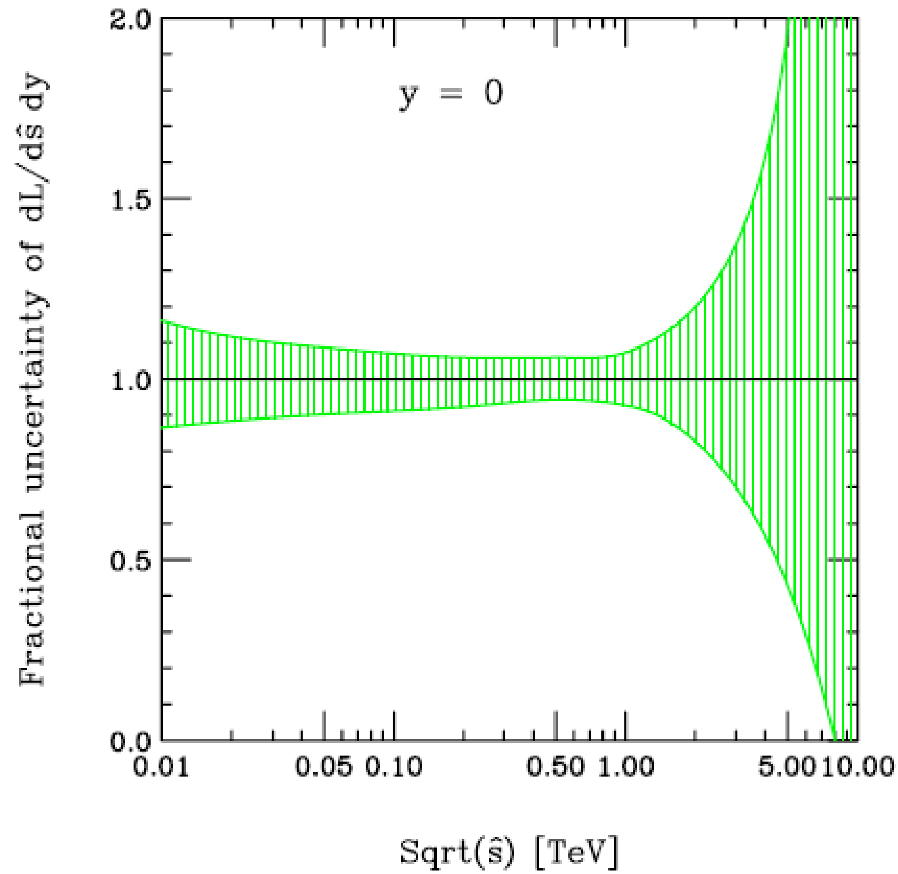
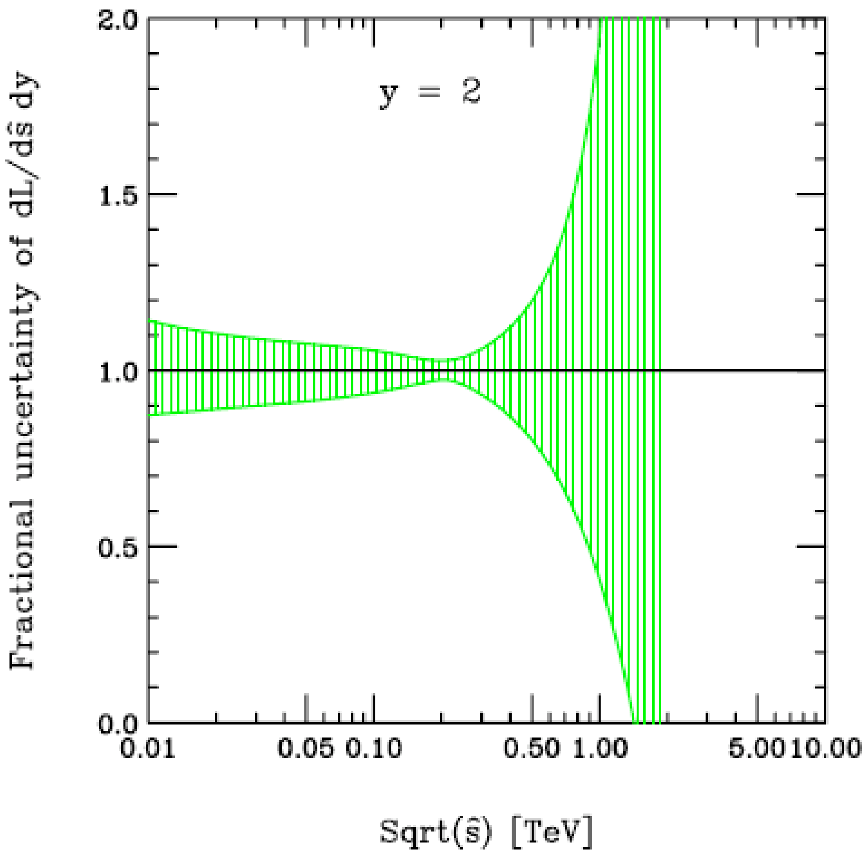
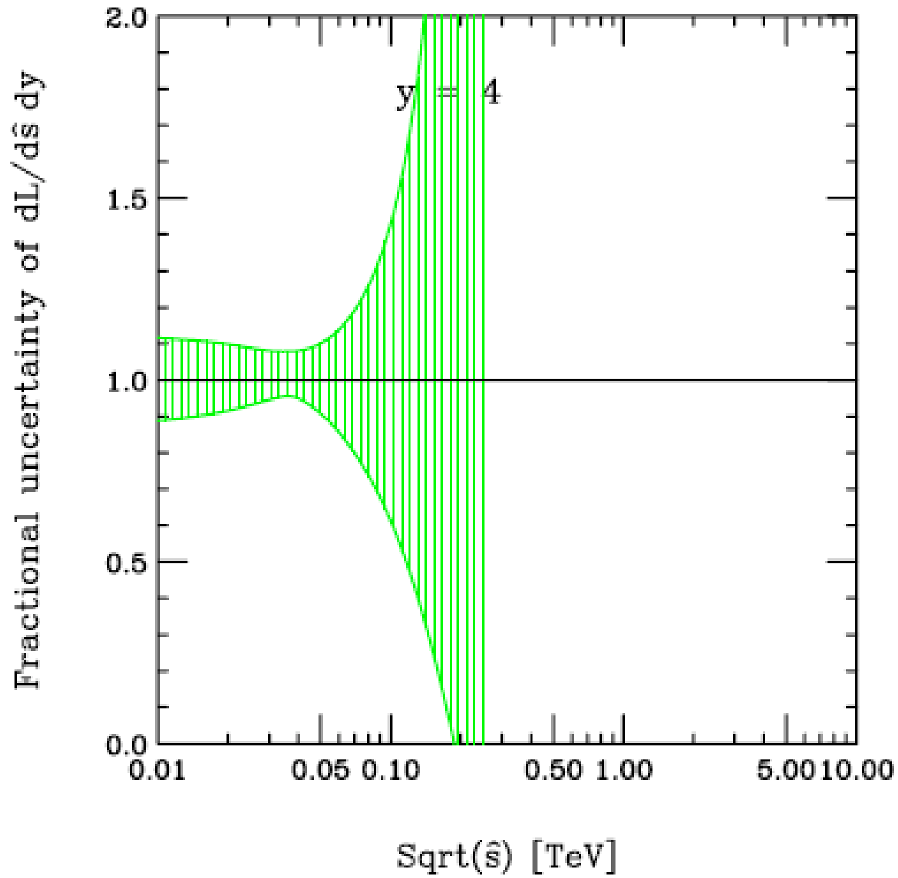


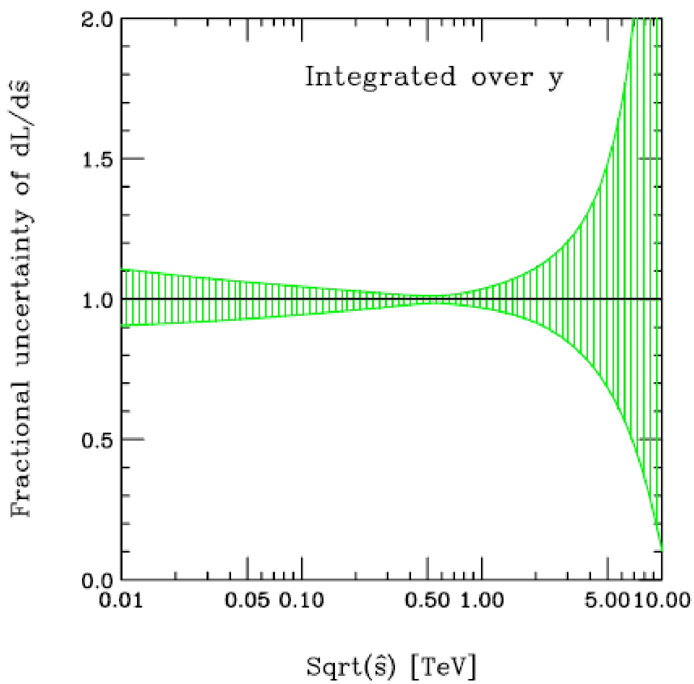

Fig. 5: Fractional uncertainty of $gg$ luminosity at $y = 0$.

# gg luminosity uncertainties



# gq luminosity uncertainties



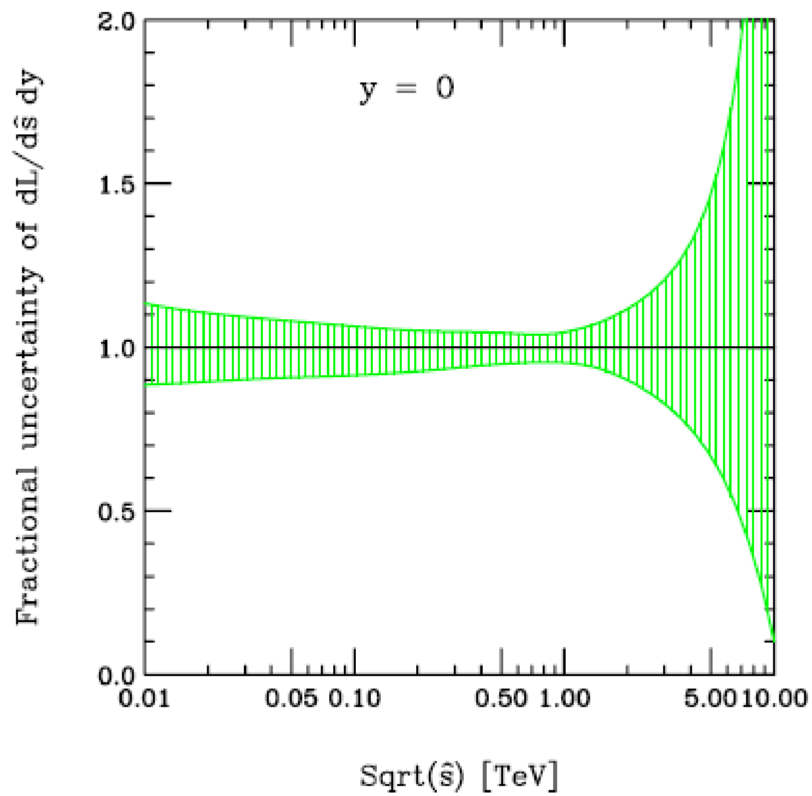
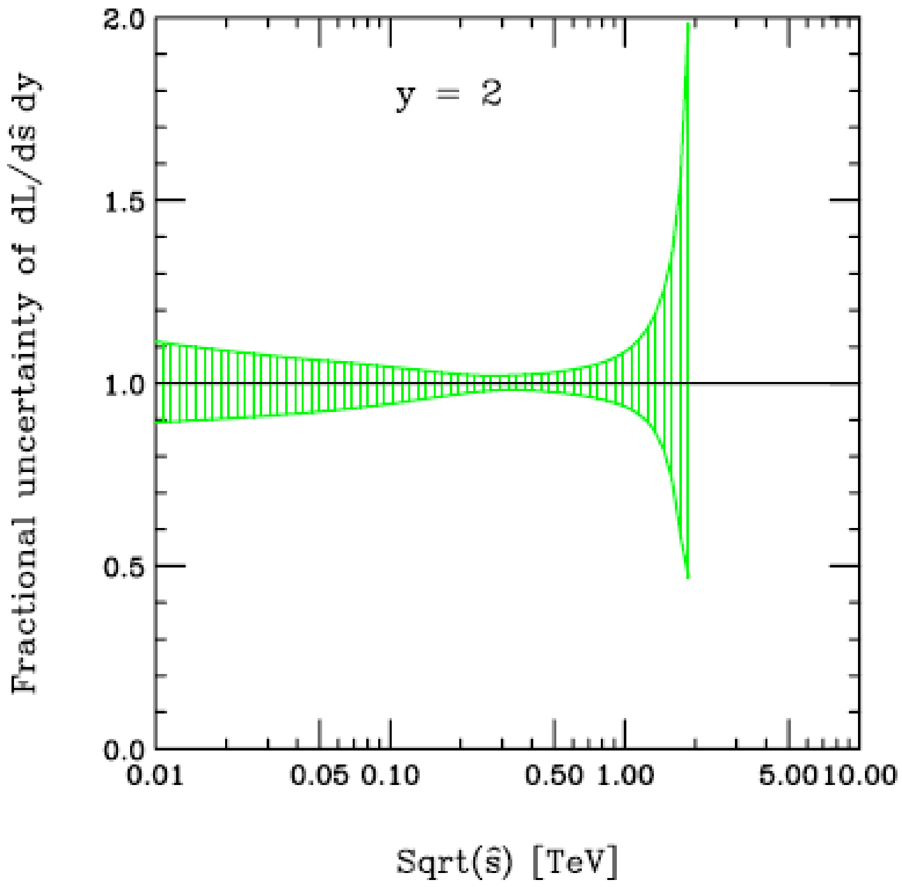
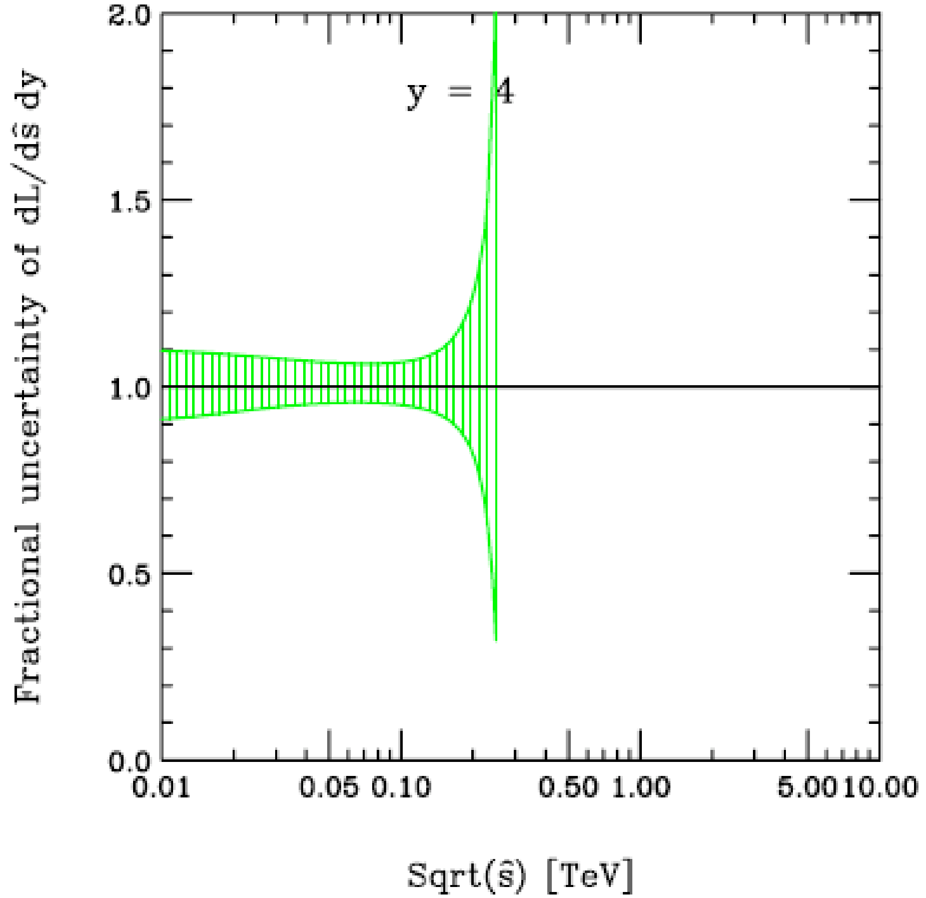




Fig. 6: Fractional uncertainty for Luminosity integrated over $y$ for $g(d+u+s+c+b)+g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})+(d+u+s+c+b)g+(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$,

# gq luminosity uncertainties



# qQ luminosity uncertainties

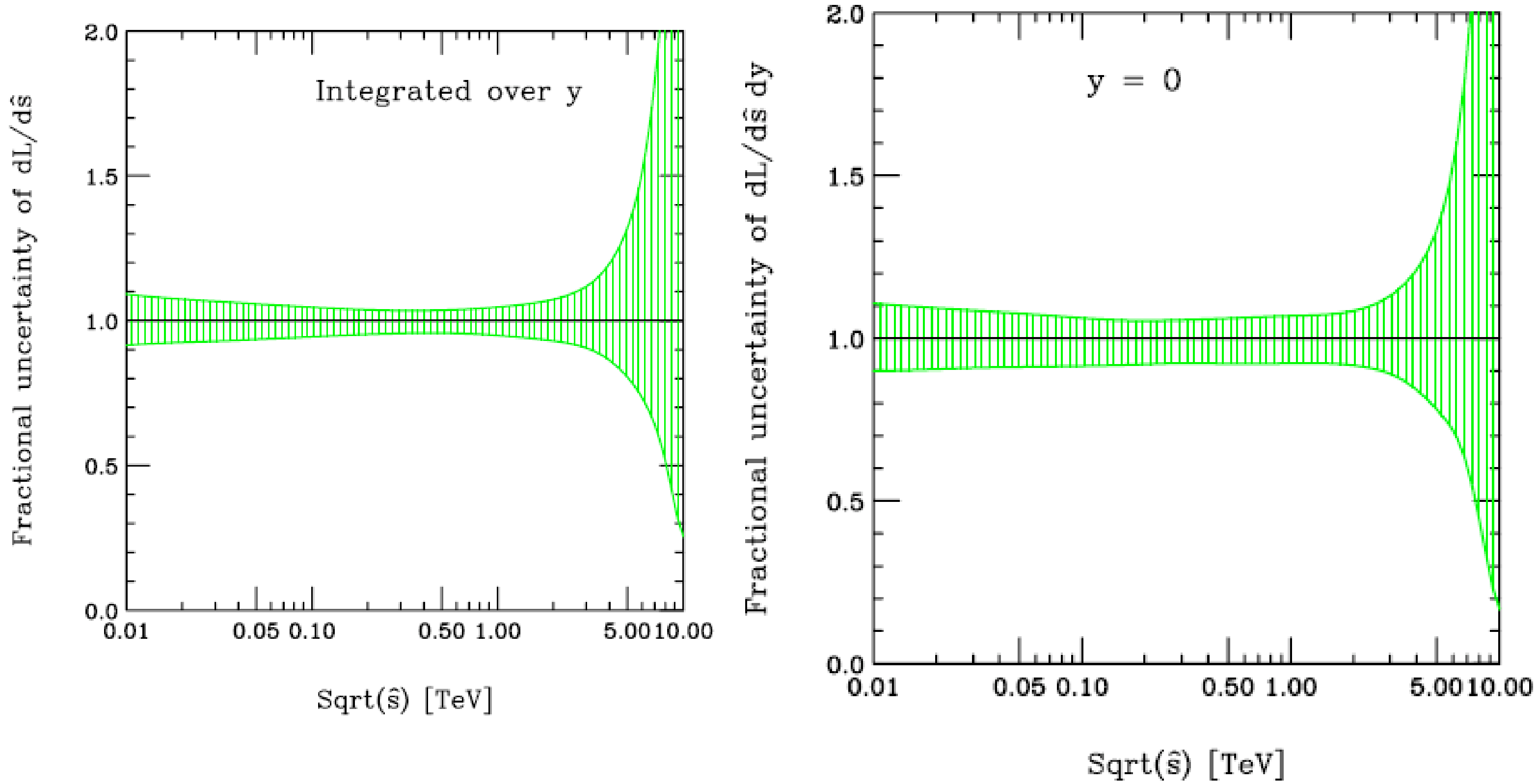
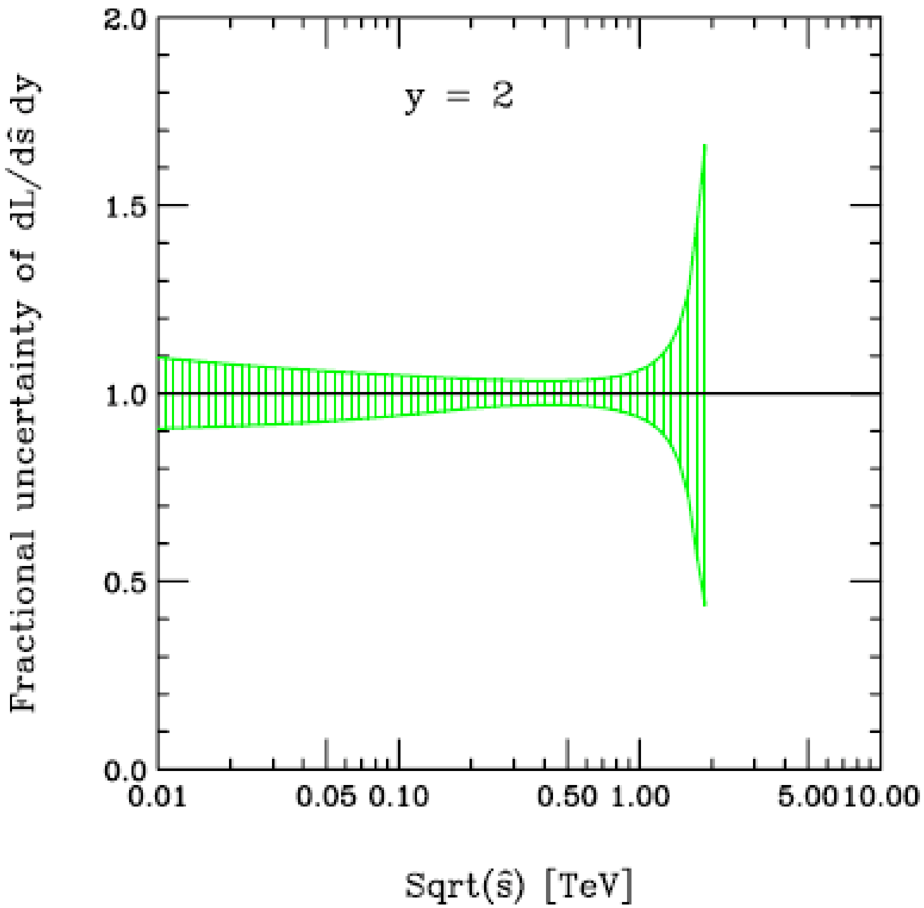
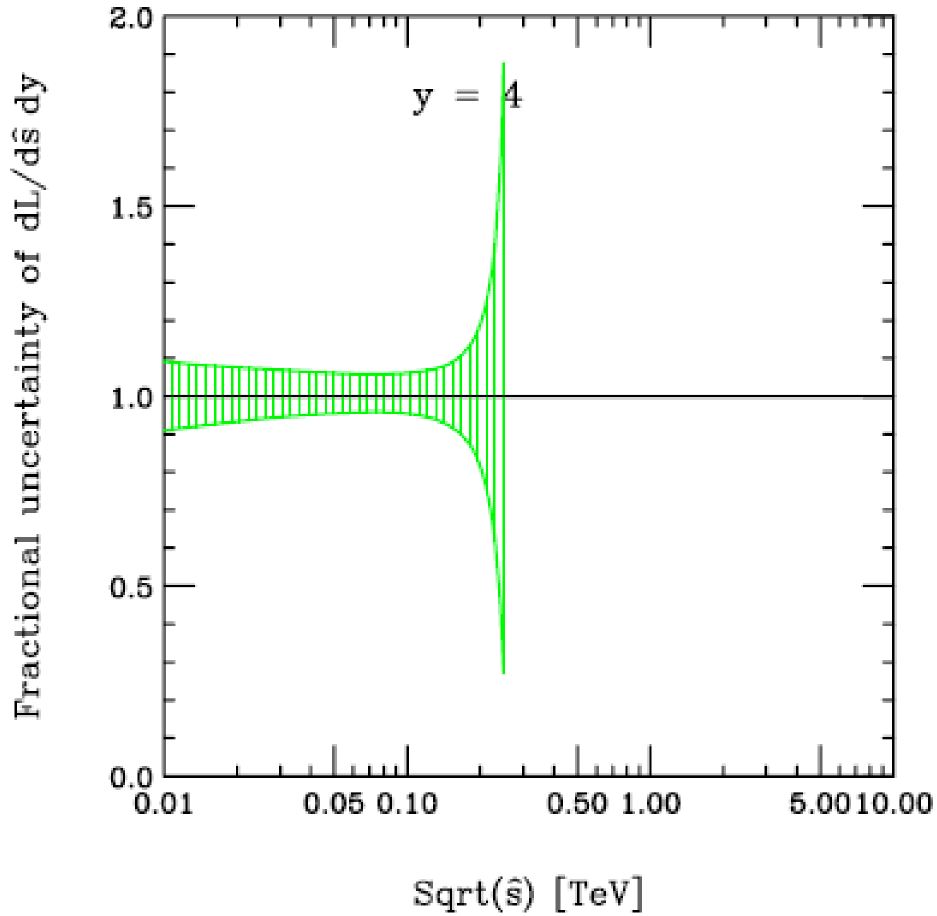



Fig. 7: Fractional uncertainty for Luminosity integrated over $y$ for $d\bar{d} + u\bar{u} + s\bar{s} + c\bar{c} + b\bar{b} + \bar{d}d + \bar{u}u + ss + cc + bb$.

# qQ luminosity uncertainties



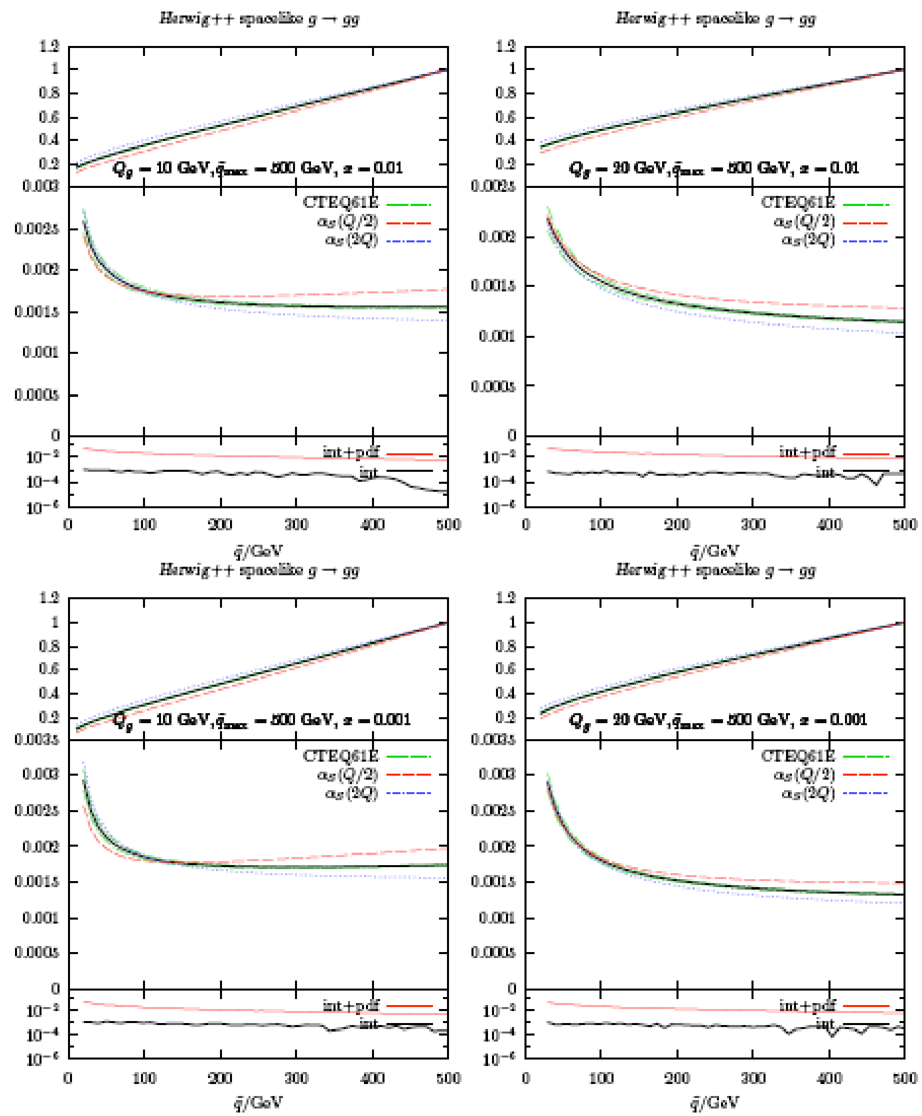



# Back to Sudakov form factors

- The Sudakov form factor gives the probability for a parton not to radiate, with a given resolution scale, when evolving from a large scale down to a small scale

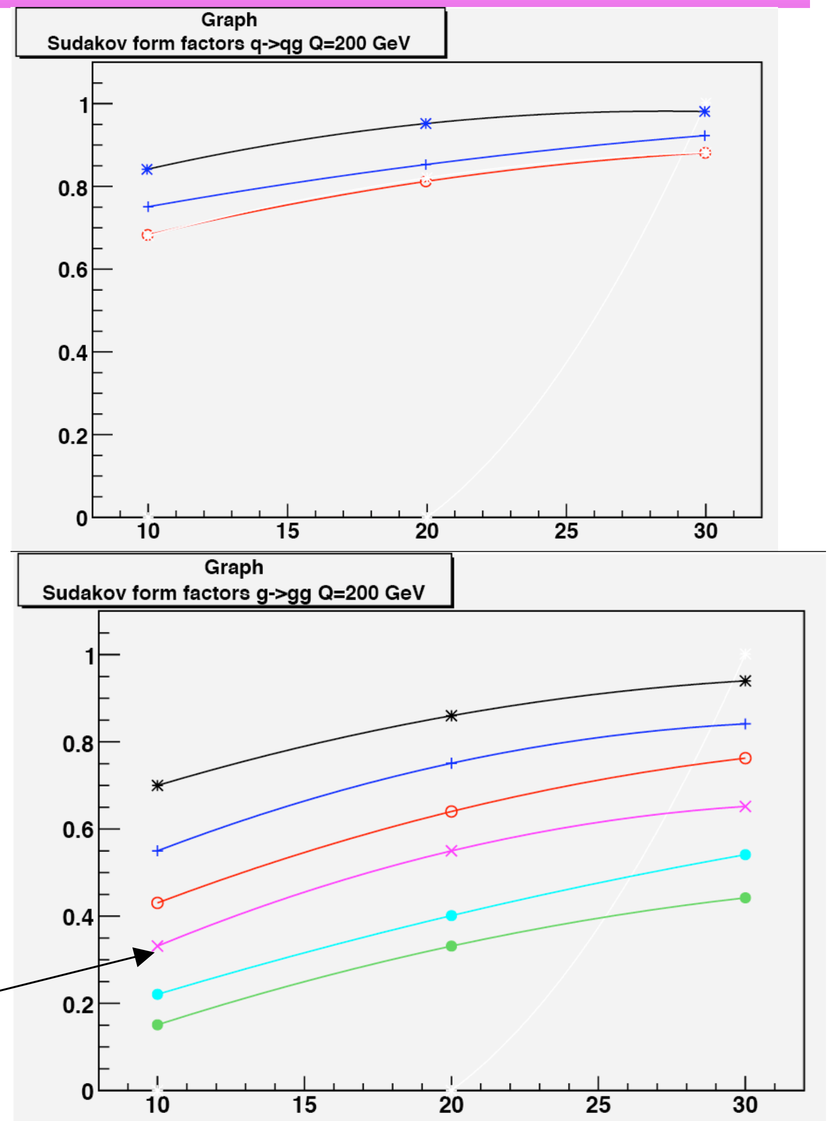
$$\Delta(t) \equiv \exp\left[-\int_{t_0}^{t} \frac{dt'}{t'} \int dz \frac{\alpha_s}{2\pi} P(z)\right]$$

- Probability of emission increases with color charge (gluon vs quark), with larger max scale, with decreasing scale for a resolvable emission and with decreasing parton x



# Sudakov form factors

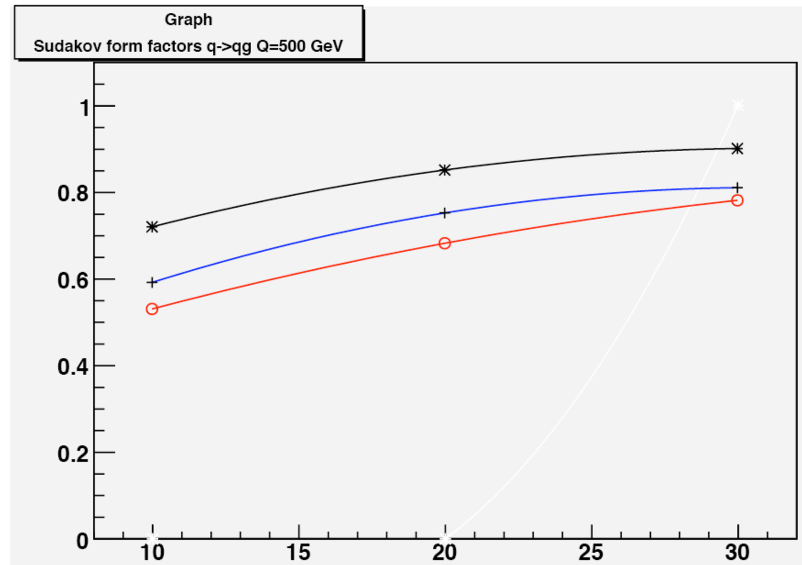
- Curves from top to bottom correspond to x values of 0.3,0.1, 0.03, 0.01, 0.001, 0.0001
- Sudakov form factors for q->qg for x<0.03 are similar to form factor for x=0.03 (and so are not shown)
- Sudakov form factors for g->gg continue to drop with decreasing x
  - g->gg splitting function P(z) has singularities both as z->0 and as z->1
  - q->qg has only z->1 singularity
- For example, probability for an initial state gluon of x=0.01 not to emit a gluon of >=10 GeV when starting from an initial scale of 200 GeV is ~35%, i.e. there is a 65% probability for such an emission

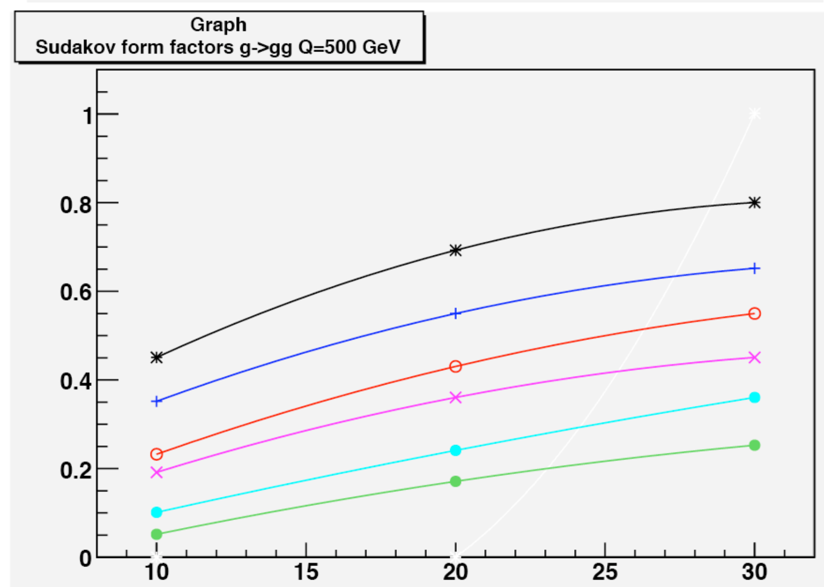



Resolution scale -> ~$p_T$ of gluon

# Sudakov form factors

- If I go to small x, or high scale or a gluon initial state, then probability of a ISR gluon emission approaches unity
- The above sentence basically describes the LHC



# Consider inclusive jet production

- 500 GeV jets at the Tevatron are produced primarily by qQ scattering (although gq still important)
- For 500 GeV jets at the LHC, scale down by a factor of 7 in x
- Most of the jet events will be produced by at least one gluon in the initial state
- High Q, smaller x, gluon initial states mean more ISR

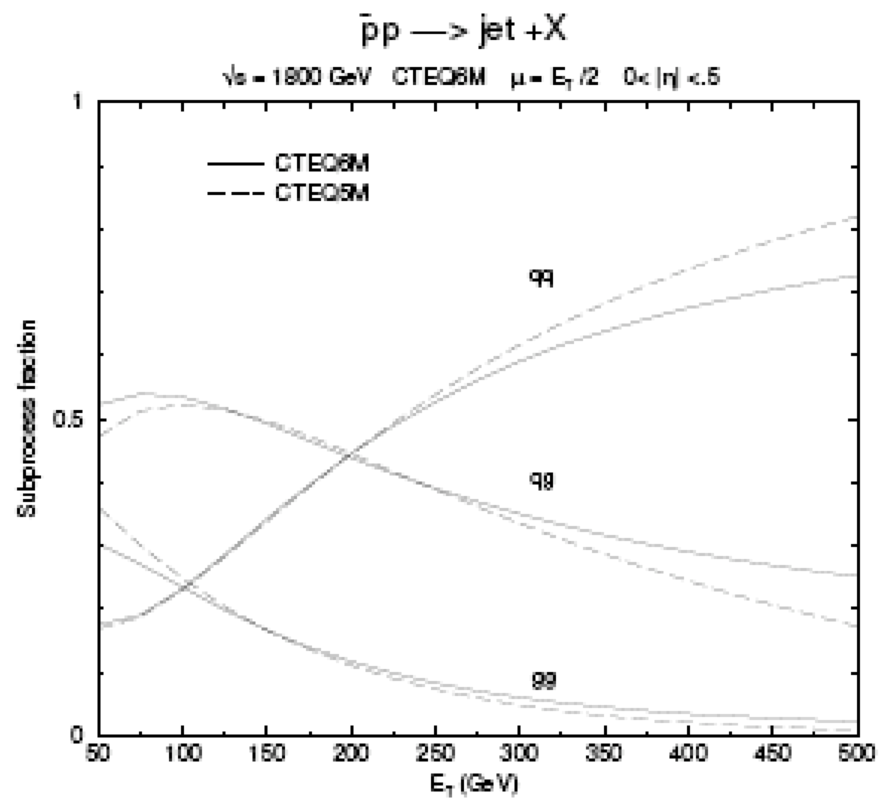



FIG. 3: The subprocess contributions to central jet production.

# Jet production

- At the Tevatron, there's a 50% chance of an additional (soft) jet in a high $p_T$ dijet event
  - there's a Sudakov suppression of events without such radiation
- First jet in an ATLAS high $p_T$ dijet MC sample that I looked at has 12 jets (but still clear dijet structure)