Parton Distribution Functions and Single Top Physics

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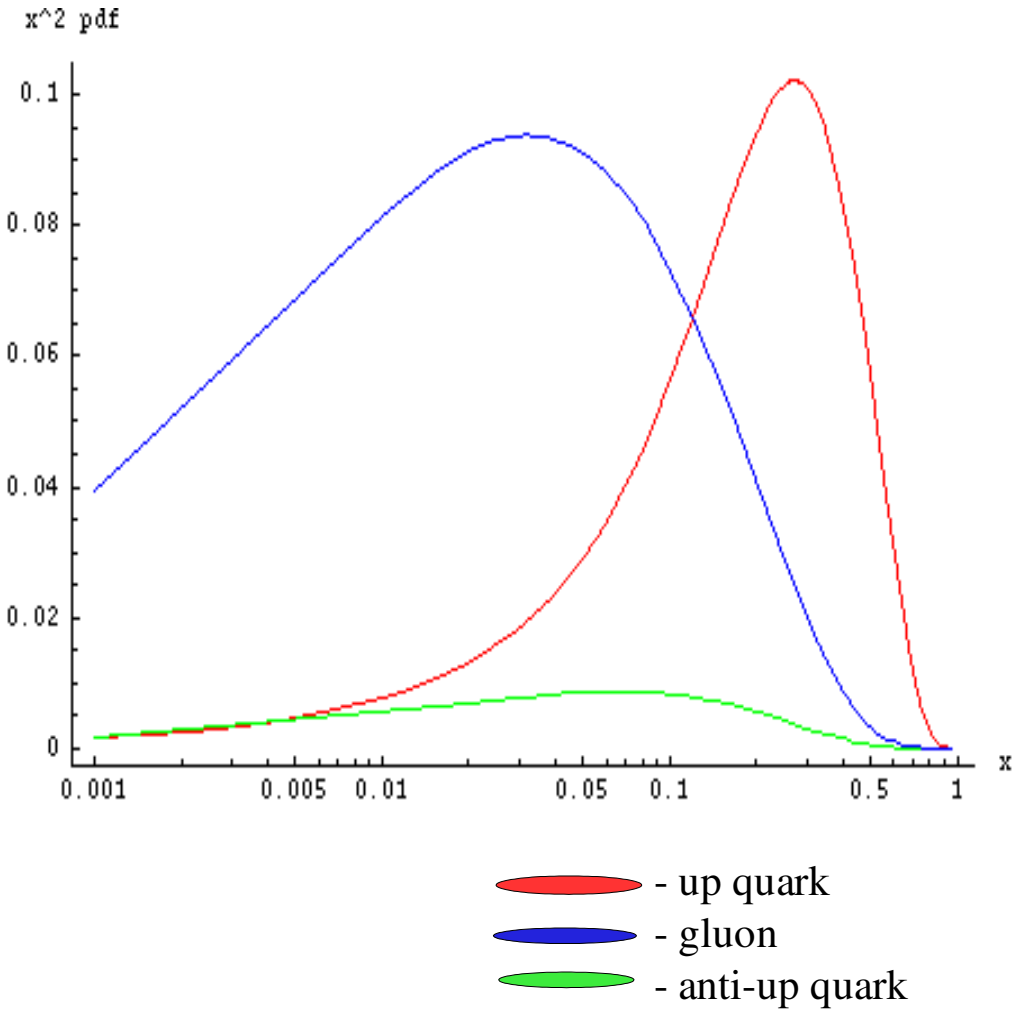
Parton Distribution Functions

- Parton distribution functions give the number of quarks and gluons in a proton.
- $pdf(i, x, \mu)$
  - i corresponds to the flavor of quark or anti-quark (up, down, strange, charm, bottom, top) or gluon.
  - x is the fraction of the proton's momentum that is carried by the parton. $f\,dx$ is the number of partons with momentum fraction between x and $x+dx$.
  - μ is the factorization scale ($\mu = 175\,GeV$).

Parton Distribution Functions

- Determined by fitting to data from particle physics experiments.
- Developed by CTEQ (Coordinated Theoretical-Experimental Project on QCD).
- CTEQ5 (LO) Mathematica version. Eur.Phys.J.C12:375-392 (2000) hep-ph/9903282.



Cross Sections and Luminosity

- The total cross section for a particular interaction is of the form

$$\underset{p\bar{p}\to X}{\sigma} = \iint_0^1 dx_1\, dx_2\, pdf(i, x_1, \mu)\, pdf(j, x_2, \mu)\ \underset{q\bar{q}\to X}{\hat{\sigma}}(x_1, x_2, \mu)$$

- make transformation $z = x_1 x_2$ (note that $\hat{s} = z s = \mu^2$)

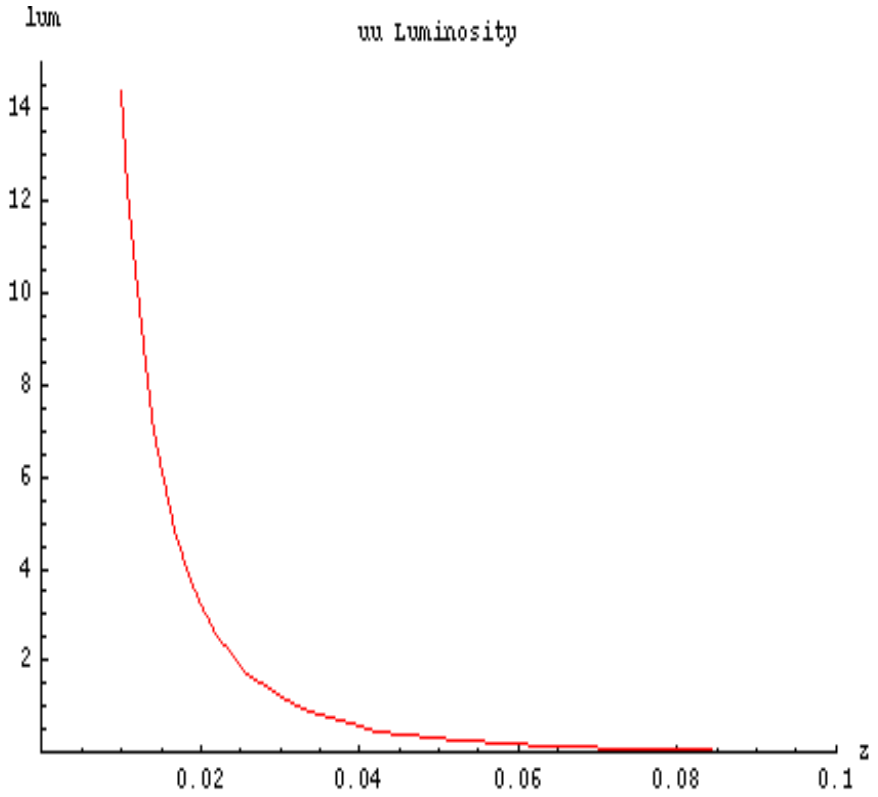
$$\underset{p\bar{p}\to X}{\sigma} = \int_0^1 dz \int_z^1 dx \frac{1}{x}\, pdf(i, x, \mu)\, pdf(j, \frac{z}{x}, \mu)\ \underset{q\bar{q}\to X}{\hat{\sigma}}(x_1, \frac{z}{x}, \mu)$$

- Luminosity

$$L = \int_z^1 dx \frac{1}{x}\, pdf(i, x, \mu)\, pdf(j, \frac{z}{x}, \mu)$$

Tevatron and LHC

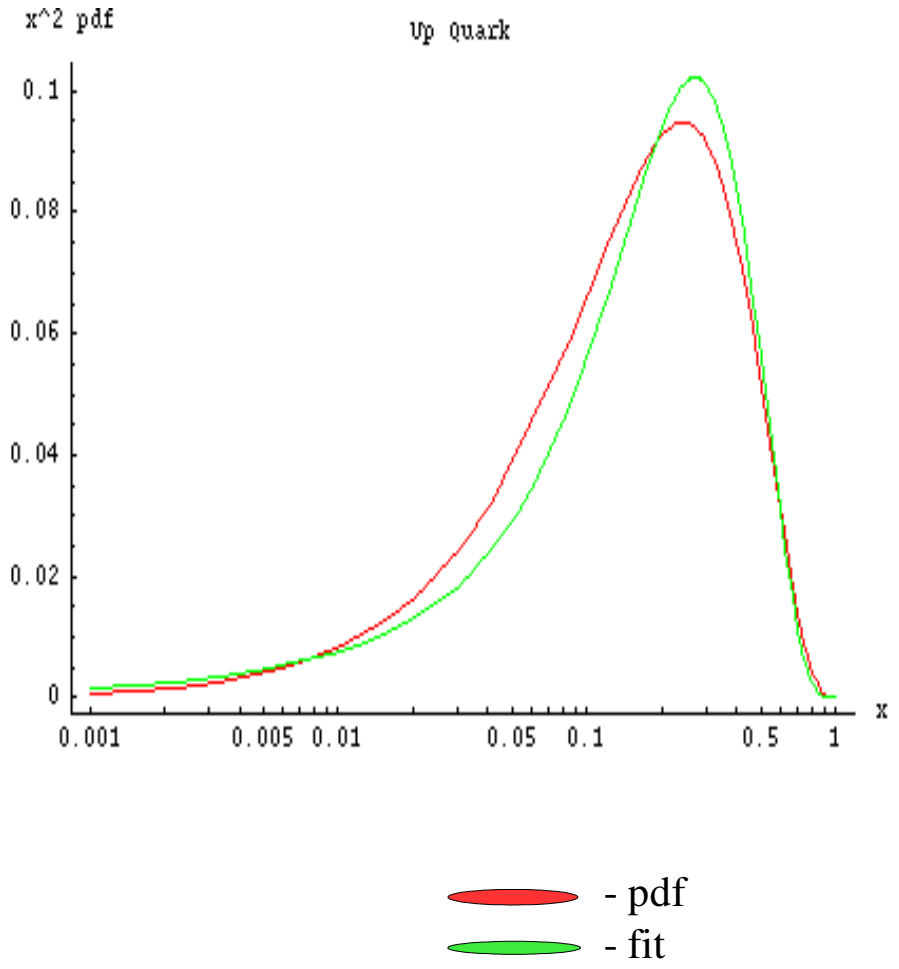
- At low $\sqrt{s}$, valence quarks carry most of momentum. Because we are often interested in electroweak physics (need $q\bar{q}$ collisions), gain a lot by $p\bar{p}$.
- At high $\sqrt{s}$, valence quarks radiate gluons, which split into $q\bar{q}$ pairs. A large fraction of the momentum is now carried by sea quarks, so gain nothing with $p\bar{p}$.
- Each particular interaction tends to be near a certain $\hat{s}$, and since $\hat{s} = z\,s$, for increased s, decreased z and higher luminosity.



Fits to Luminosities

- Developed fits to the pdf's to:
  - gain a better understanding of their behavior.
  - be able to quickly calculate cross sections without having to go to CTEQ code.
- Fit pdf's with functions of the form

$$\frac{1}{n} z^{-b} (1-z)^{a}$$



Single Top Physics

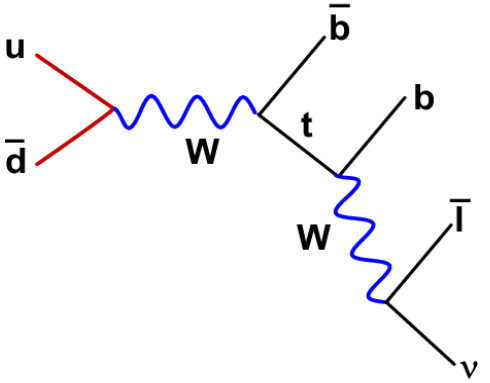
- Why is single top quark production interesting?
  - The top quark is unique because of its high mass (~175 GeV). In the SM it alone has a strong coupling to the Higgs boson (it seems to be uniquely connected to the mechanism of mass generation).
  - Can test the electroweak properties of the top quark and provides a direct measurement of the Wtb coupling and the CKM matrix element V_{tb}.
  - Single top production is predicted by the standard model, and is yet to be observed (top discovered in $t\,\bar{t}$ channel).
  - Single top channel is sensitive to physics beyond the standard model.
- Use MadGraph, a monte carlo event generator. Analysis done at Tevatron ($p\,\bar{p}$, 1.96 TeV). At MadGraph level only, no detector simulation yet.

Single Top and Backgrounds

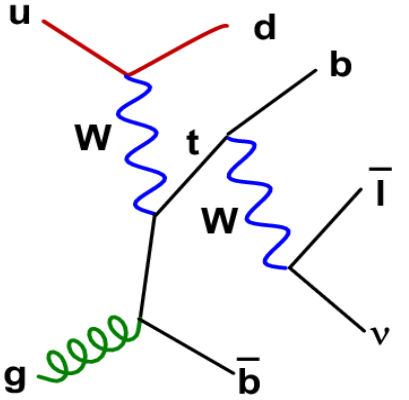
- Single top channels
  - S-channel $q\,\bar{q} \to t\,\bar{b}$
  - T-channel (gluon fusion) $g\,q \to t\,\bar{b}\,j$
  - $g\,b \to t\,W$
- Backgrounds
  - $g\,g \to t\,\bar{t}$ or $q\,\bar{q} \to t\,\bar{t}$
  - $W\,b\,\bar{b}$
- Top decays as

$$t \to W\,b \;\Big\downarrow\!\rightarrow \begin{matrix} l\,\nu \\ u\,\bar{d} \end{matrix}$$

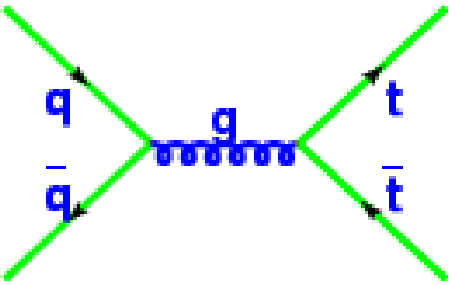
s-channel



t-channel

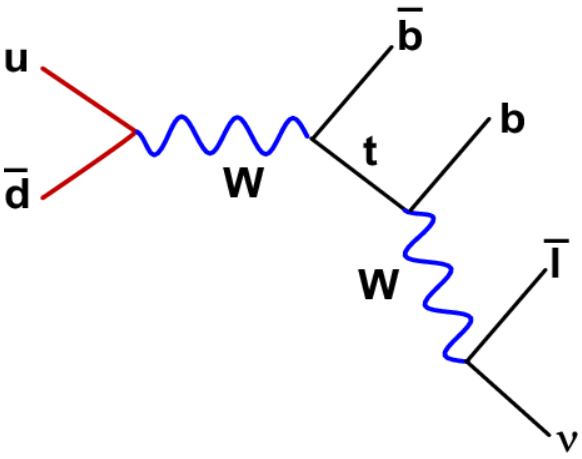


$t\,\bar{t}$



S-Channel

- Look for W (lepton plus missing E_t) together with 2 b-tagged jets, one of which comes from a top decay (reconstruct top mass with b and W).



- S-Channel both b-jets are high p_t, so require two b-tags (b quarks form B-mesons which travel ~1mm from the collision point before decaying).

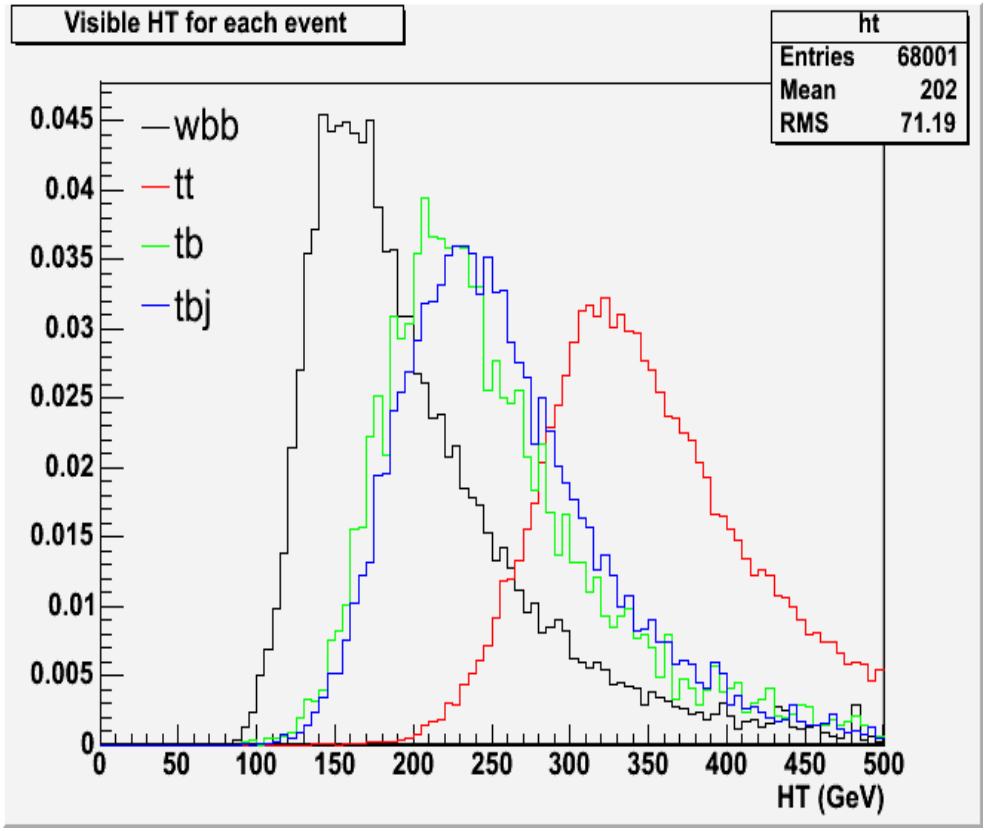
- Basic cuts:

  Isolated lepton

  2 b-tagged jets

  MET

  HT = lepton $p_t + MET + \sum_{jets} p_t$

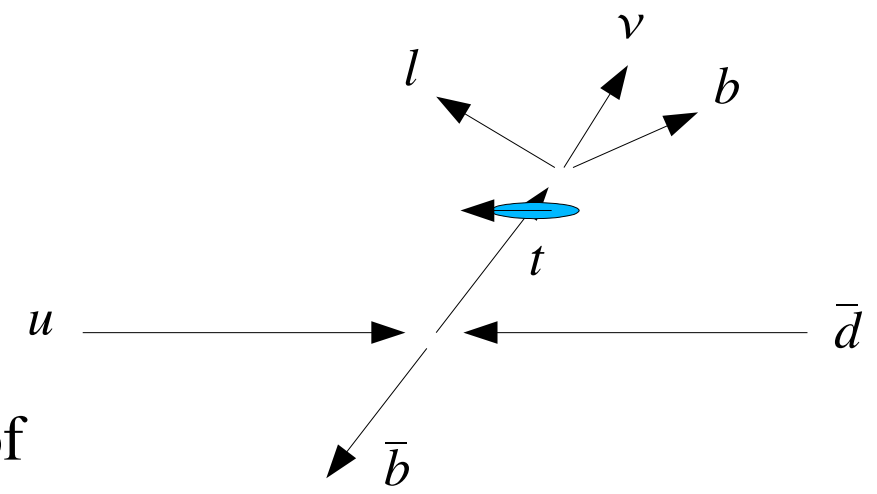


Separating $t\bar{b}$ from $t\bar{t}$

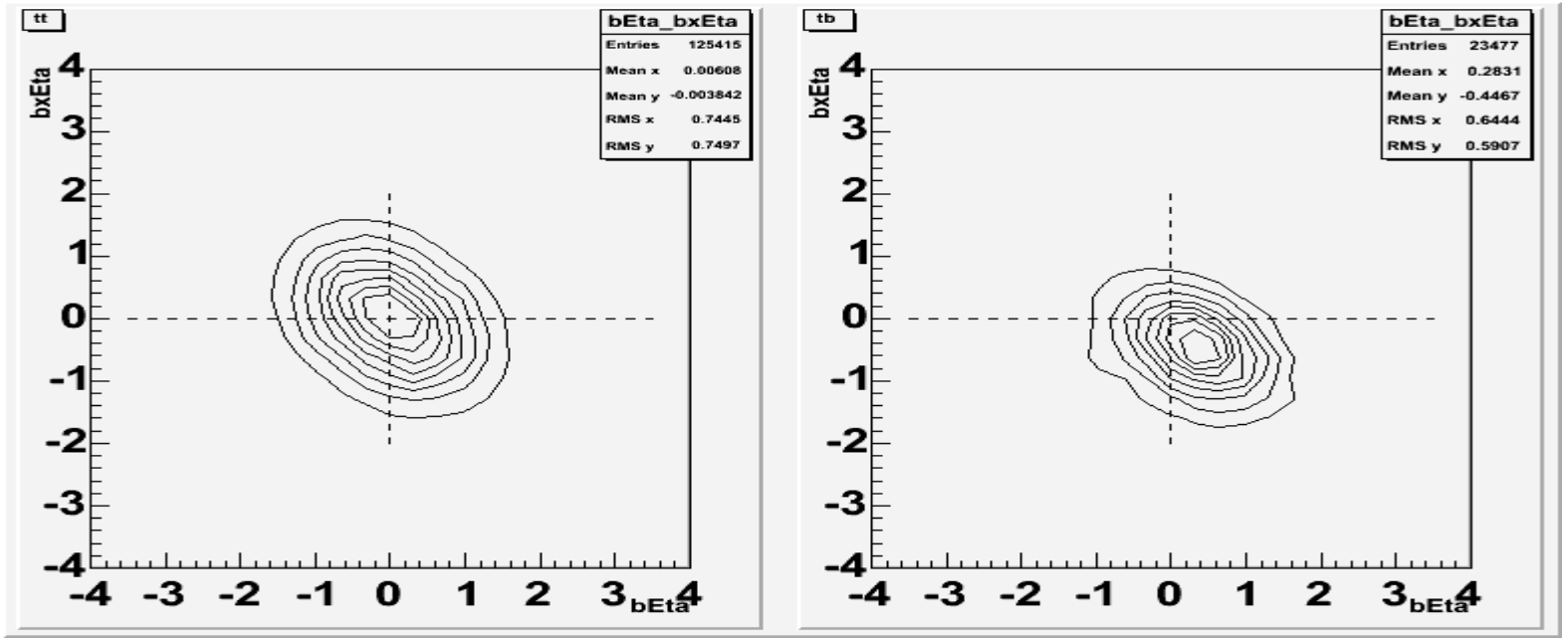
- $t\bar{t}$ is the most significant background because of its large cross section.
- Ratio of $t\bar{t}$ to S-channel is initially about 11/1.
- After basic cuts (isolated lepton, 2 b-tagged jets, MET, HT) the ratio is down to about 4/1.
- $t\bar{t}$ very problematic when jets or second lepton is missed.
- How to better separate $t\bar{b}$ from $t\bar{t}$:
  - Attempt to reconstruct top quarks, and reject the event if second is close to 175 GeV
  - Event kinematics
  - Pseudo-rapidity $\eta = -\ln(\tan(\theta/2))$

Top Quark Spin Correlations

- Up quarks tend to carry higher momentum fraction than down quarks, so top tends to be boosted in u direction.
- In s-channel, 98% of the time the top quark is polarized along the direction of the $\bar{d}$. Lepton tends to be in $\bar{d}$ direction and b tends to be in u direction.



- Symmetric initial state for $t\,\bar{t}$ so no such correlations.



Conclusions

- Found decent fits for parton distribution functions. At some point the phenomenology group will start using them to calculate cross sections.
- Discovered that s-channel single top production is difficult to isolate with such large backgrounds. In order to have any hope of seeing this channel, new handles must be found in further studies.

References

- T. Stelzer, Z. Sullivan, and S.Willenbrock, Single-top-quark production at hadron colliders, hep-ph/9807340
- G. Mahlon, Observing Spin Correlations in Single Top Production and Decay, hep-ph/0011349
- CTEQ5L Eur.Phys.J.C12:375-392 (2000) hep-ph/9903282