Top to Bottom, Bottom to Top

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work in progress with Scott Thomas and Michael Graesser

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Top Physics at the LHC

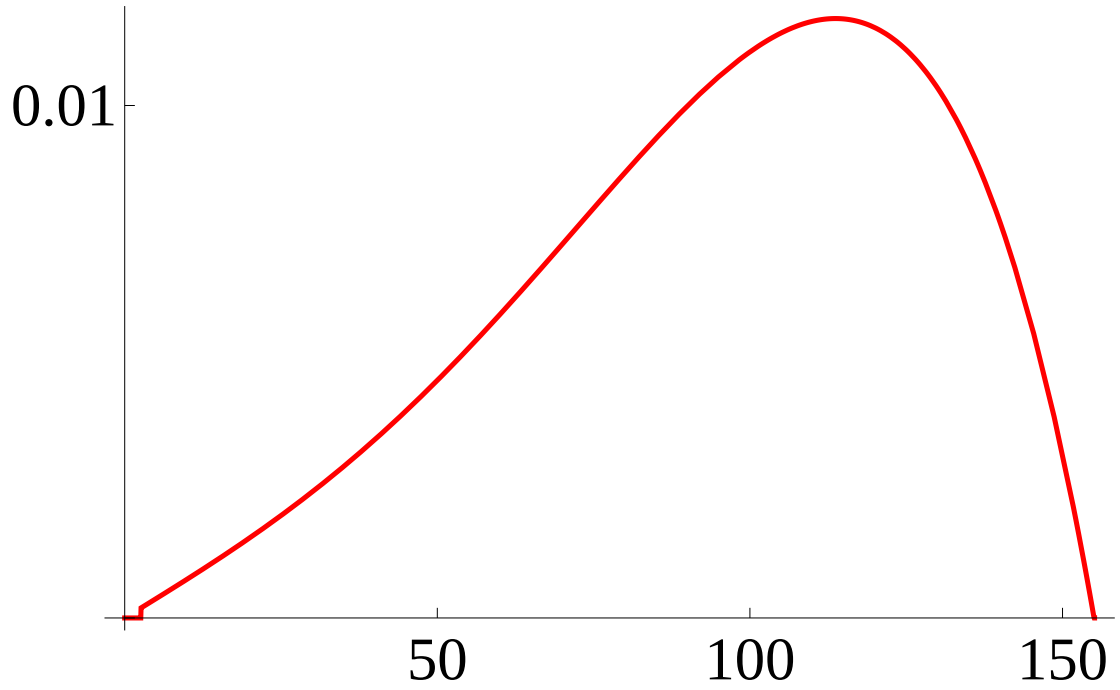
- **The LHC will be a top factory:** $\sigma(pp \to t\bar{t}) = 830$ pb
  - Nearly 1 SM top pair per second at low design luminosity

- **Precision characterization of the top system will be an important part of the physics program:**
  - large top Yukawa gives large sensitivity to EWSB physics
  - large top sample enables study of rare decays
  - SM tops are important background to new physics searches

- **Templates for precision measurements in the top system**
  - minimize theoretical and/or experimental uncertainties
  - demonstrate role of tops as useful source of bottom quarks at LHC

A template for the top mass

- **Semileptonic top decays: $m_{b\ell}$ an attractive variable for mass measurements**



Distribution of $\tilde{m}_{b\ell} = 2p_b \cdot p_\ell$ in standard model top decay

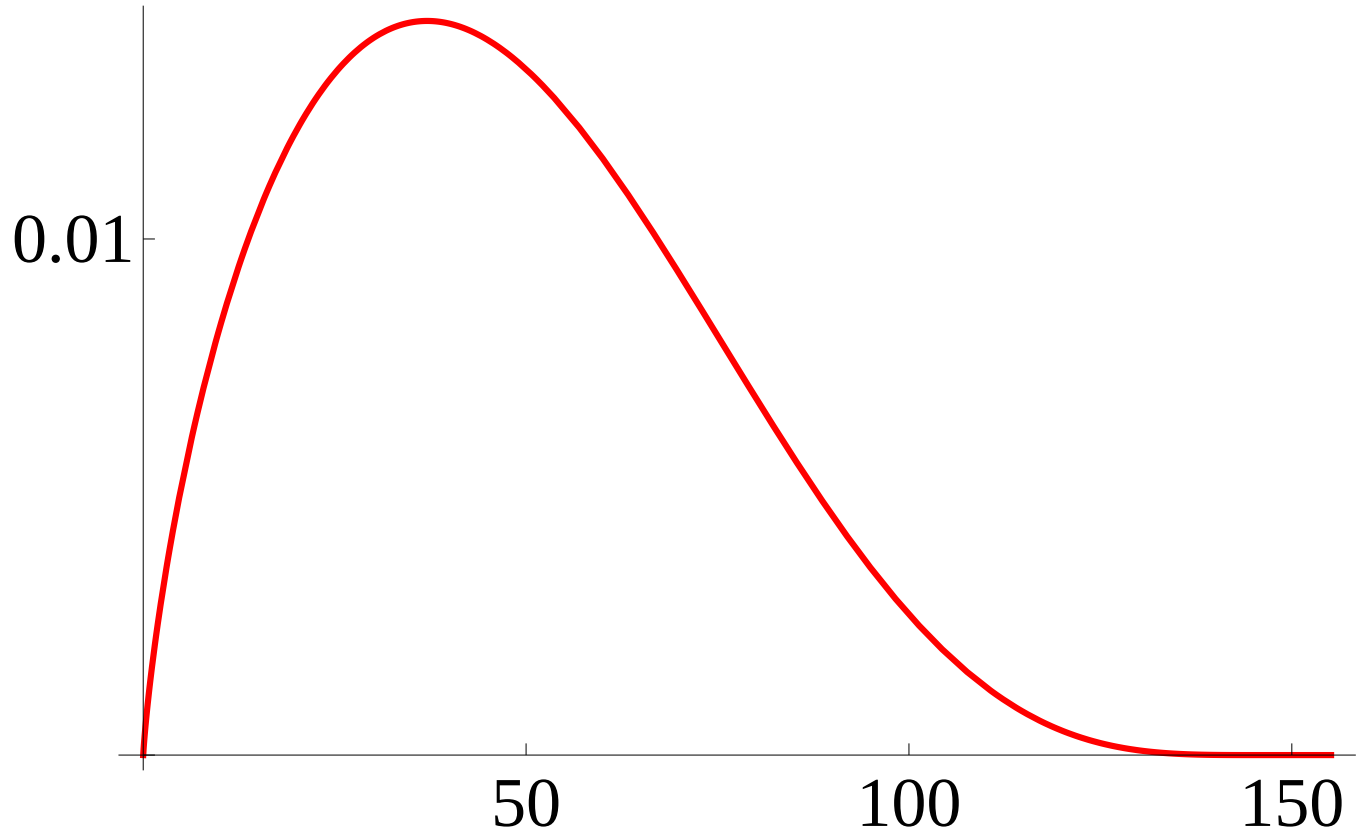
  - Lorentz invariant: insensitive to uncertainties from production mechanisms, PDFs, ISR

A template for the top mass

- **Leading source of uncertainty in top mass measurements: b-jet energy scale J_b**
  - energy rescaling relating measured energy to initial parton energy: $p_b \equiv J_b \, p_{meas}$
- **In distribution of $m_{b\ell}$, dependence on J_b factorizes:**
  - $\tilde{m}^2_{b\ell} = 2p_b \cdot p_\ell \rightarrow J_b \times 2p_b \cdot p_\ell$
- **Two independent pieces of information:**
  - scale: depends on J_b, m_t
  - shape: depends on m_t
- **Use in conjunction with other methods to measure m_t, J_b self-consistently**

Top mass from leptons

- 10% **of the time,** $b \to c\mu\nu_\mu$
- **Measure top mass in fully leptonic invariant** $m_{\mu_b \ell}$



- $(t \to b\ell\nu_\ell) \quad \otimes \quad (b \to c\mu\nu_\mu)$

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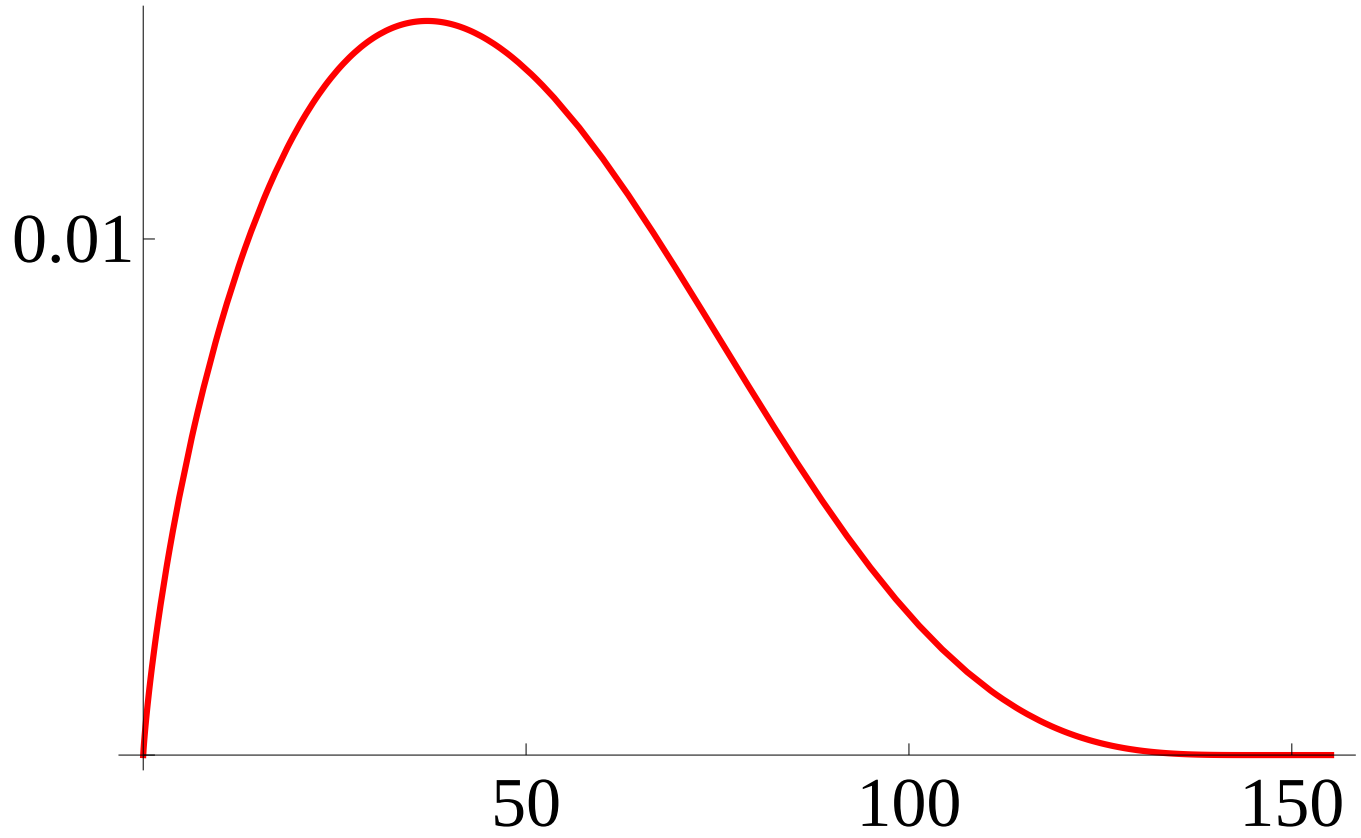

- $(t \to b\ell\nu_\ell) \quad \otimes \quad (B \to X_c\mu\nu_\mu)$

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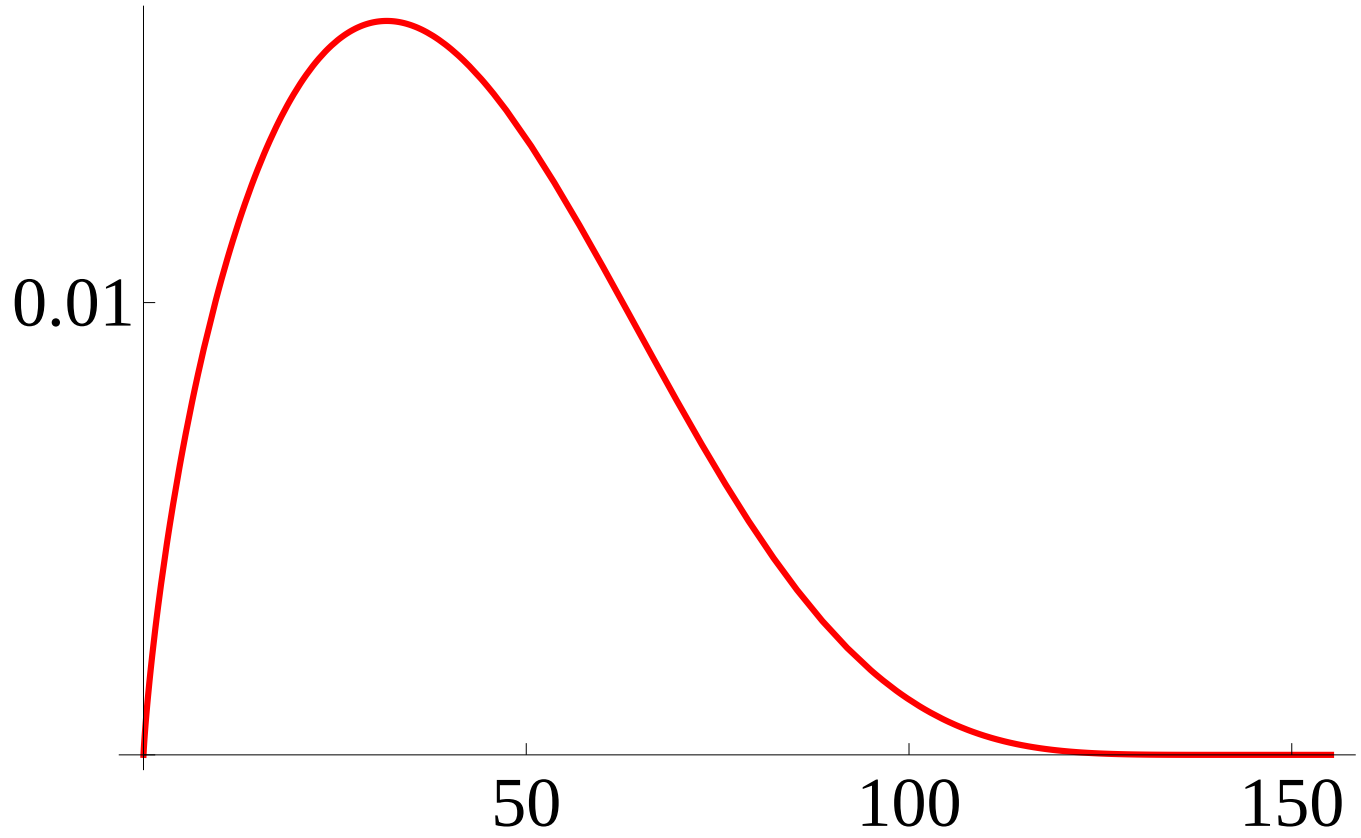

- $(t \to b\ell\nu_\ell) \quad \otimes \quad (b \to B) \quad \otimes \quad (B \to X_c\mu\nu_\mu)$

B fragmentation function

- **Fragmentation function $D_b(x_B)$: probability of finding B hadron in b-jet with momentum fraction x_B**
  - Important source of uncertainty in top mass measurements
- **Nonperturbative: must take from data**
  - Measured at Z peak at LEP, SLC
  - Evolve to $\mu \simeq m_t/2$ to describe top system
- **$m_{\mu\ell}$: a joint measurement of m_t, $D_b(x_B)$**
- **Measure $D_b(x_B)$ in top system at LHC**
  - need a source of bs with known energy
  - $Z \to b\bar{b}$ not feasible: too much background, not enough rate (di-bosons)

More Muons

- **Proposed top mass measurement in $t \to b\ell\nu$, $B \to J/\psi \to \mu\mu$ events using $m_{J/\psi\ell}$ (Karchilava)**
  - Similar idea: leptonic invariant
  - $\mathrm{BR}(B \to J/\psi \to \mu\mu) \simeq 6 \times 10^{-4}$
  - b fragmentation functions as measured in different channels are not simply related
- **Inclusive variables less sensitive to theoretical uncertainties**
- **Can be maximally inclusive: measure inclusive $D_b(x_\mu)$ in independent sample of top decays**
  - reduce modeling uncertainties at the cost of reintroducing (indirect) dependence on b-jet energy scale

Conclusions

- **Detailed characterization of top system an important part of LHC new physics program**
- **Invariant mass distributions offer clean templates for measurements in top system**
  - provide powerful cross check and help ease identification of new physics
- **Standard model tops are an important source of bottom quarks with fixed kinematics at the LHC**
  - enable measurements of b properties at new energy scales