High p_T Cross Section for Muon-Tagged Jets in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV

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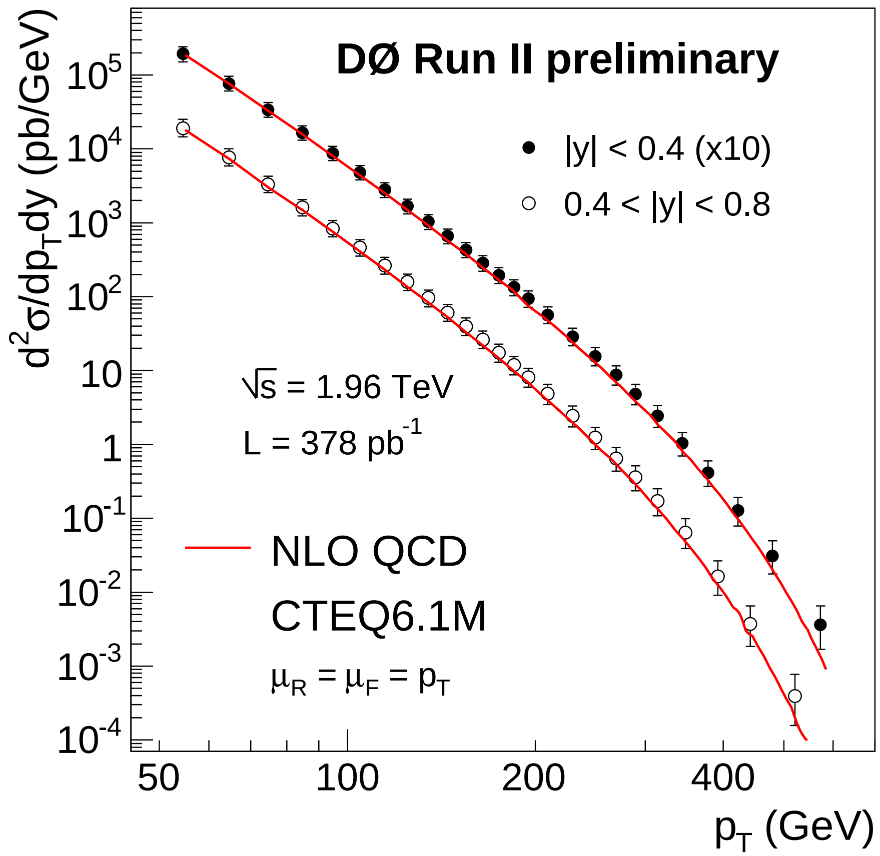
- Motivation
- Measurement
- Results

So Far ...

- ... we have measured the inclusive jet cross section in $p\bar{p}$ collisions (see talks by Z. Hubacek, J. Dittman) ⟶
- one of the most important measurements at a hadron collider
- test SM predictions at largest energies (sensitive to quark compositeness)
- inclusive jet sample is dominated by gluon- and light quark-jets



This talk:

Look into a very small subset ⟹ Study jets with high energetic collinear muons

Motivation

Standard Model:

- quarks and leptons - why three families?
- one family: everything we see
  plus two families (carbon copies)
- hypothesis:
  quarks and leptons might be composed of smaller particles
- second and third generations might be excited states
  of the ground state ($\leftarrow$ first generation)
- if true:
  third generation would show largest deviation
  from point-like Standard Model behavior

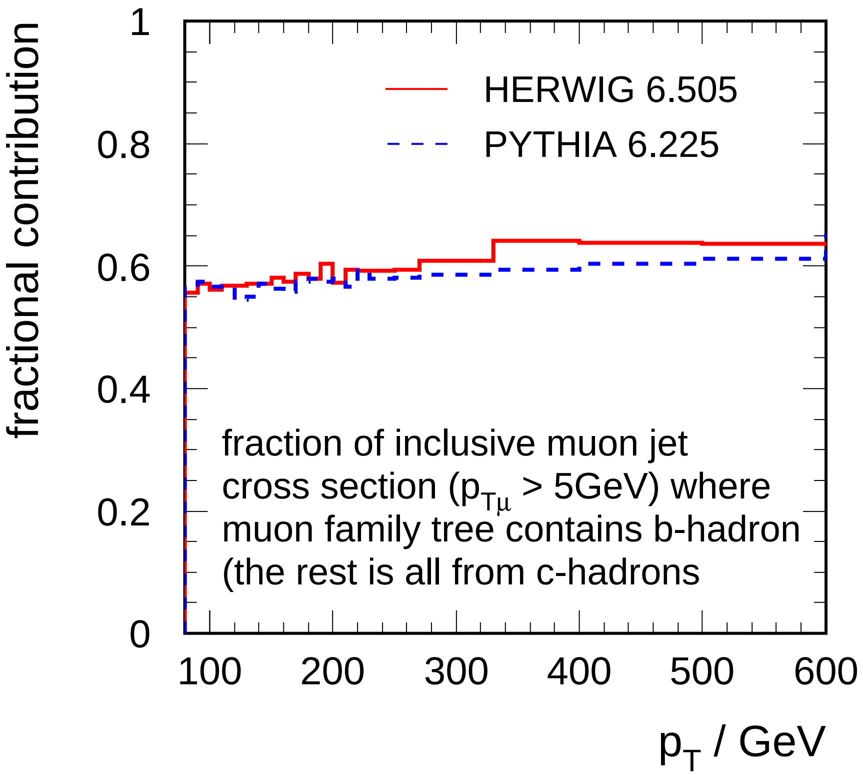
$\Longrightarrow$ **Study Heavy Flavor Production at highest p_T**

Why Muon-Tagged Jets?

Decay of b-Hadrons → in 20% → collinear muons (same as in c-Decays)
⟹ requires separation of b- and c-jets (model dependent!)

our approach: choose observable

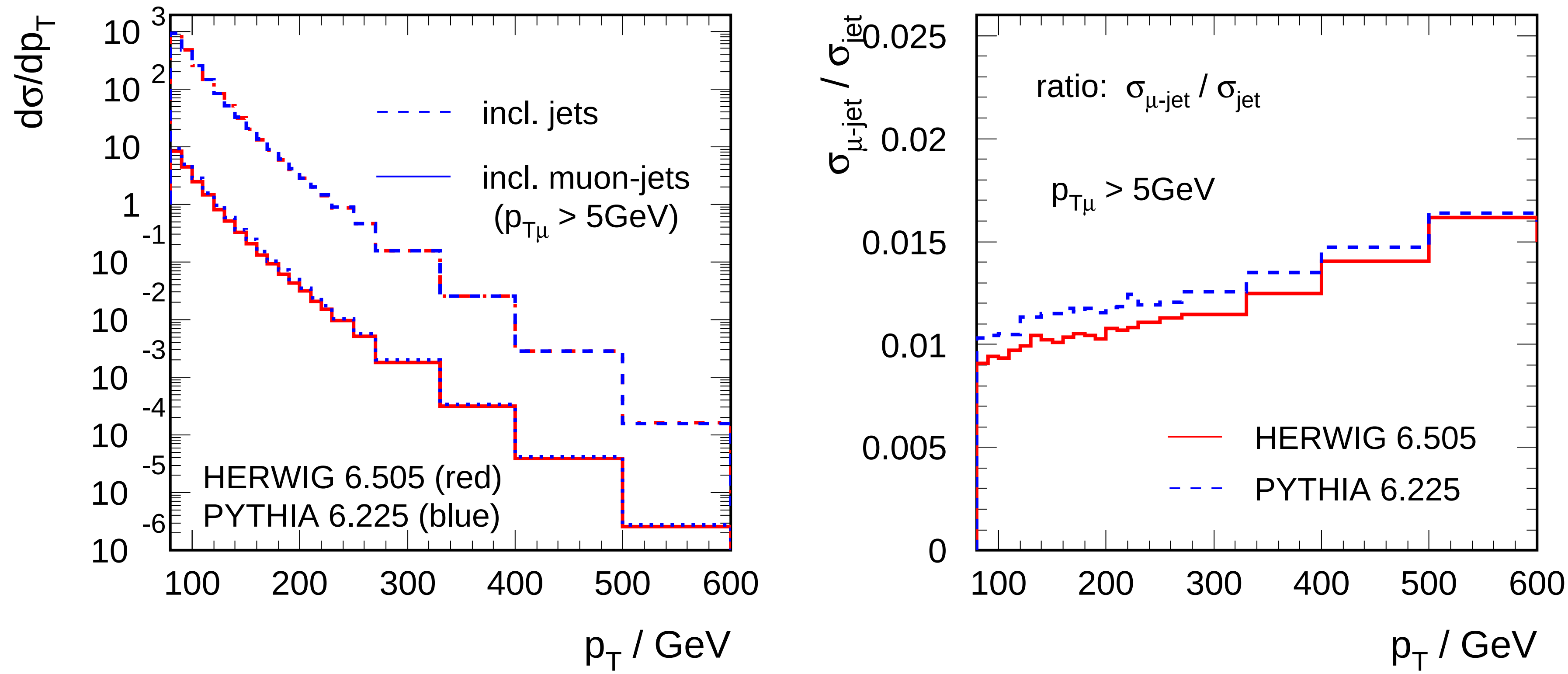
- with no model dependence
- with a high sensitivity to heavy flavor production
- simple: require a tagged muon within a jet
- model predictions suggest:
  60% from b-Hadrons
  40% from c-Hadrons



⟹ **Simple Observable**
with high sensitivity to Heavy Flavor Production up to highest p_T

Model Predictions (1)

How many inclusive jets ($|y| < 0.5$) have a collinear muon ($p_T > 5$ GeV)?



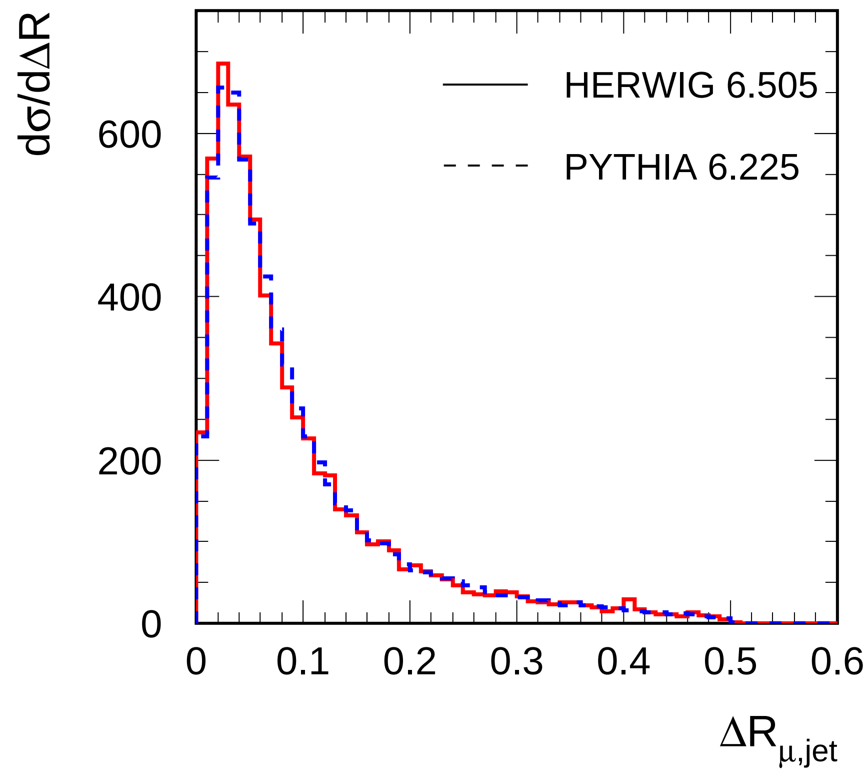
$\Longrightarrow$ Model Predictions: Muon-Tagged Jets 1-2% from all Jets

Model Predictions (2)

How good is the Angular Correlation between the Muons and the Jet Axis?

- Study separation in distance ΔR:

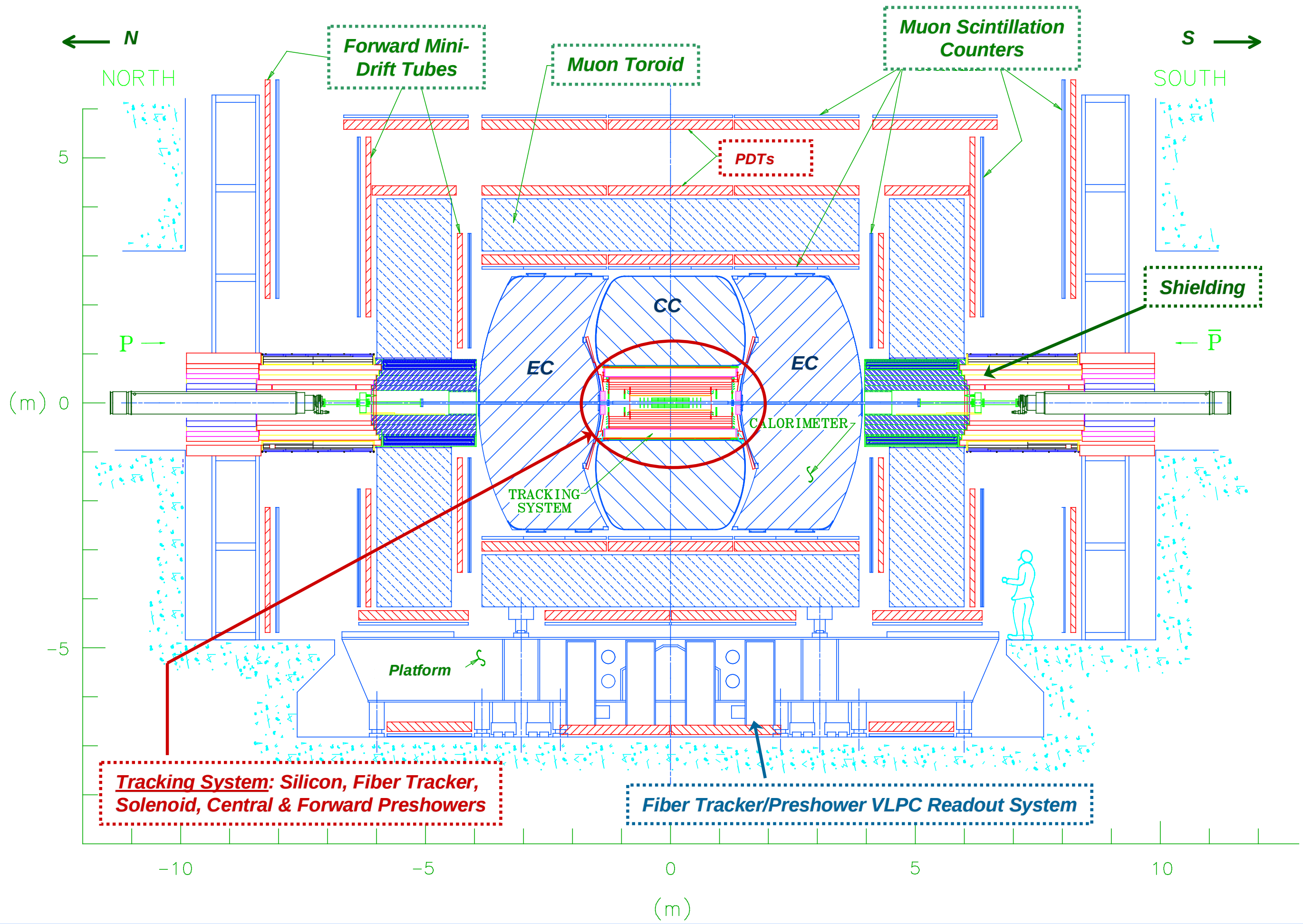
$$\Delta R = \sqrt{\Delta^2 y + \Delta^2 \phi}$$



$\Longrightarrow$ Model Predictions: Muons are really Collinear with Jets

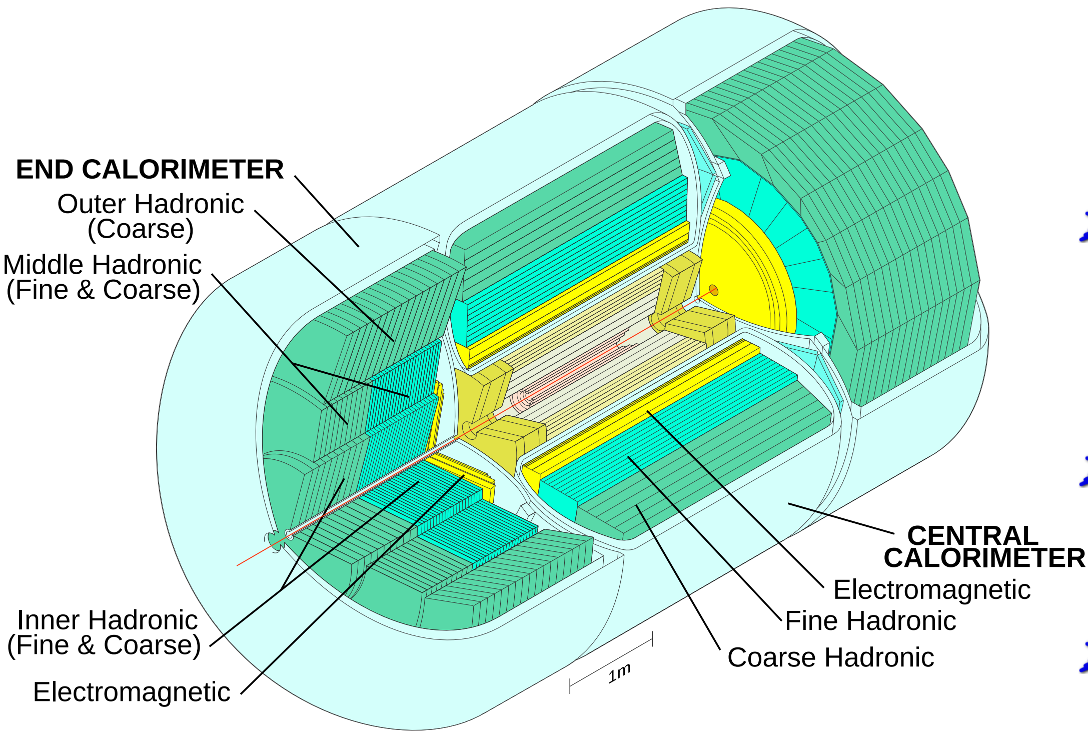
The Run II DØ Detector

Tevatron Run II: $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV / average rate: 1.7 MHz



Central Muon System:
3 Layers of Scintillators plus Proportional Drift Tubes

The DØ Calorimeter



- uniform and hermetic
  active material: liquid Argon
  absorber: Uranium
- segmentation: $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
  for EM showers max.: 0.05×0.05
- coverage up to $|\eta| \lesssim 5$

Run II upgrades:

shorter times between bunch crossing $\Rightarrow$ 396 ns $\Rightarrow$ faster trigger and readout electronics

more material in front of calorimeter $\Rightarrow$ magnet, tracker, new pre-shower detector

Event Selection

- Good Run Selection based on:
  - Silicon Vertex Detector, Central Fiber Tracker, Calorimeter, Muon System
  - (offline: missing ET, jet quality)

- primary vertex reconstructed in Central Tracker

- Calorimeter Jet:
  - triggered by four Calorimeter Jet Triggers (highest p_T unprescaled)
  - Iterative Midpoint Cone Algorithm: $R_{\text{cone}} = 0.5$, $|y_{\text{jet}}| < 0.5$ (central region)
  - matching at trigger thresholds of 100% efficiency

- matched with a muon:
  - reconstructed in outer muon detector and central tracker
  - (only azimuthal regions with full coverage of all three layers $\rightarrow$ top half of detector)

- in total: 4,460 jets with a muon (integrated luminosity: 294 pb^{-1})

Efficiencies: (total: $31 \pm 4\%$)
trigger (=100%), primary vertex $(= 84 \pm 1\%)$, jet quality $(= 99 \pm 1\%)$,
muon acceptance (50%), muon-finding $(74 \pm 7.4\%)$

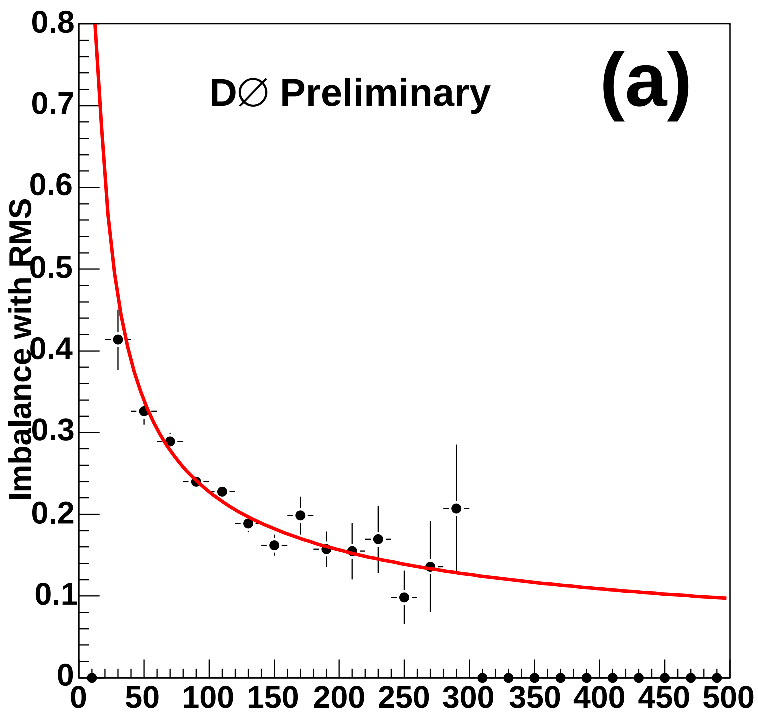
Muon-Jet p_T Calibration

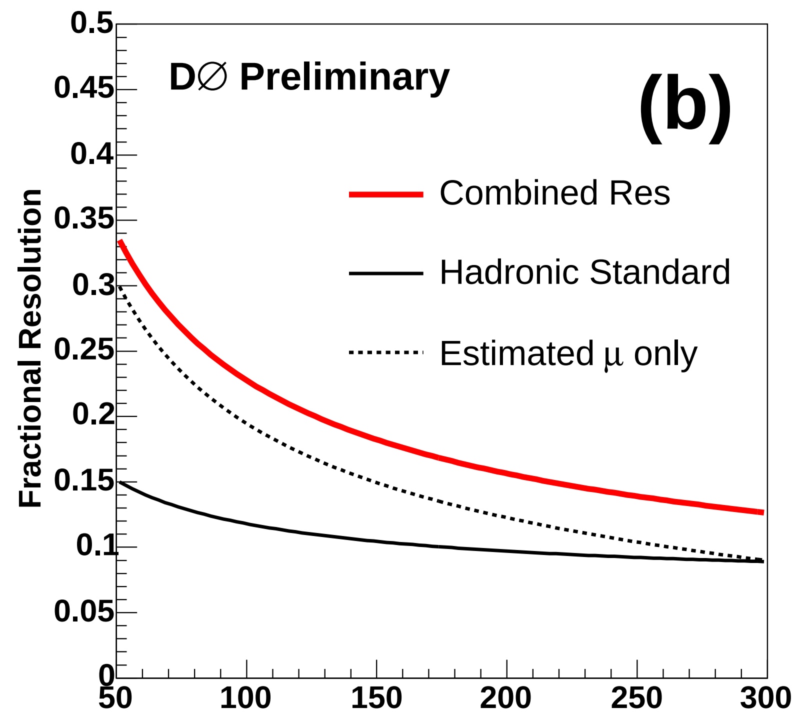
- need to determine true jet energies (= "particle level")
- standard DØ jet energy calibration is not made for muon-jets
- study p_T balance of dijets (with and w/o a muon) with $\Delta\phi > 2.84$:

$$A = 2\,\frac{p_T(\mu) - p_T(\text{no}\,\mu)}{p_T(\mu) + p_T(\text{no}\,\mu)}$$

- plot A as function of $p_T = 1/2\ (p_T(\mu) + p_T(\text{no}\,\mu))$
- find: additional energy correction of 3.8% for muon-tagged jets (independent of p_T)

Muon-Jet p_T Resolution





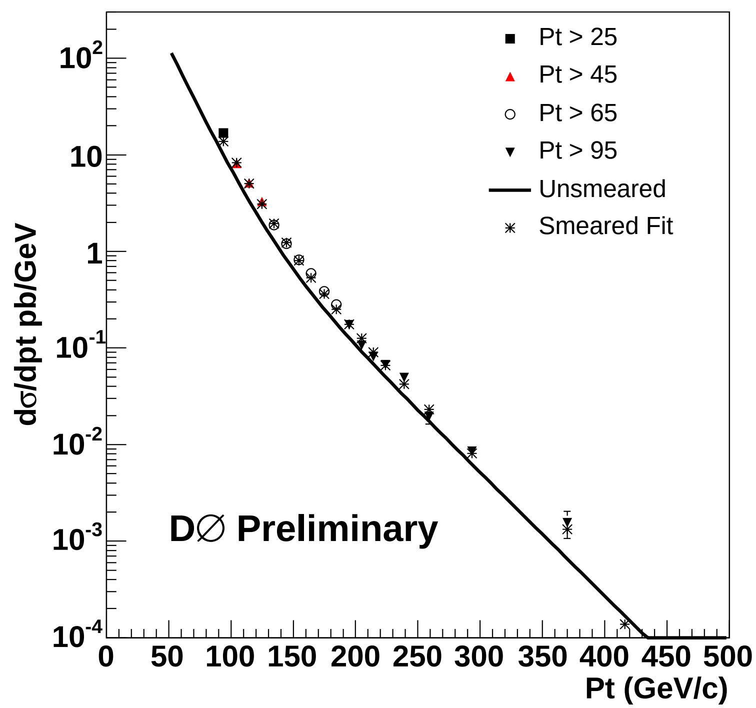
- study RMS of asymmetry variable $A(p_T)$ (left):

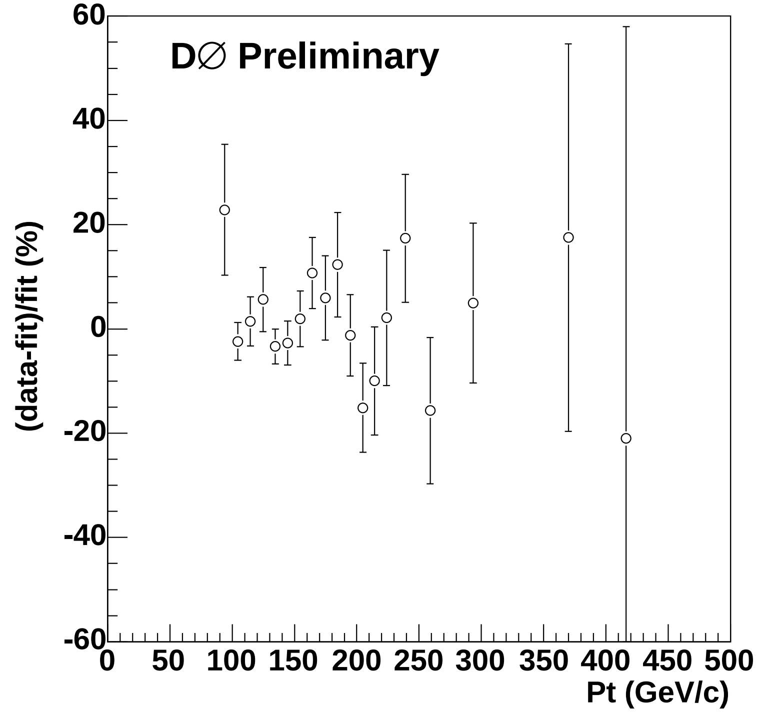
$$\left(\frac{\sigma_{\text{meas.}}}{p_{T,\text{meas.}}}\right)^2 = \frac{N^2}{p_T^2} + fracS^2 p_T + C^2 \quad \Longrightarrow \quad \left(\frac{\sigma_\mu}{p_{T,\mu}}\right)^2 = \left(\frac{\sigma_{\text{meas.}}}{p_{T,\text{meas.}}}\right)^2 - \left(\frac{\sigma_{\text{no muon}}}{p_{T,\text{nomuon}}}\right)$$

$\Longrightarrow$ Extract muon-jet resolution from total and hadron-only resolutions (right)

Unsmearing of Detector Effects

$\Longrightarrow$ still need to correct the p_T distribution for smearing due to resolution





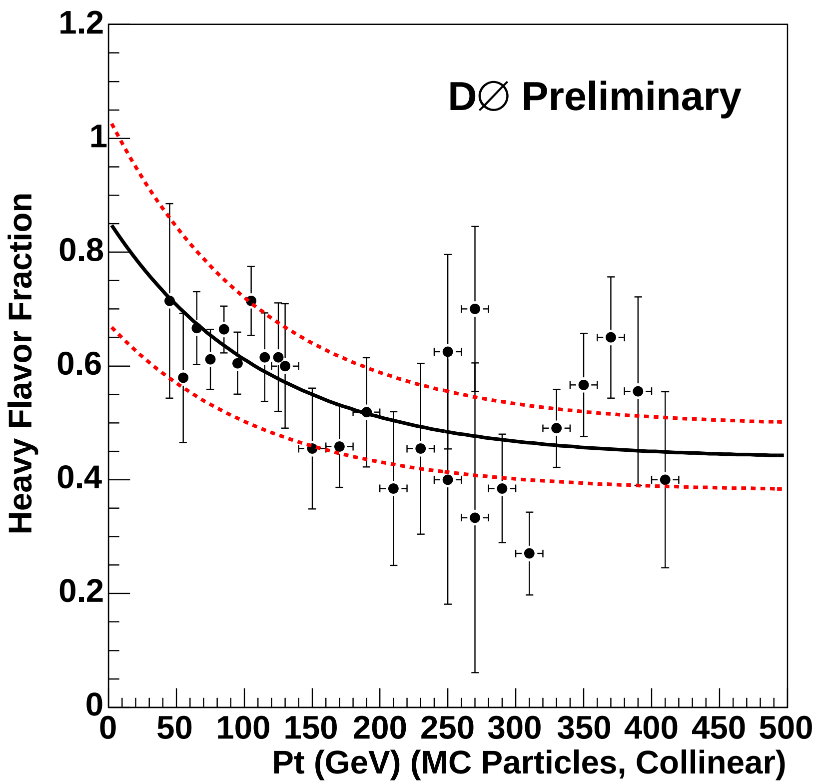
- show: Cross Section for each trigger — corrected for efficiencies only
- use smooth Ansatz function as representation of true underlying distribution (left: line)
- smear Ansatz function, according to the p_T resolution (left: stars)
- fit smeared Ansatz to data $\Longrightarrow$ use ratio Ansatz/(smeared Ansatz) to correct the data
- Fit Residuals are shown on the right: (data – smeared Ansatz)/(smeared Ansatz)

Heavy Flavor Correction

So far Model independent cross section:
- includes muons from heavy flavor decays
- muons from pion/kaon decays in detector volume
  (at distances $\gtrsim$ 10cm)

$\Rightarrow$ goal:
correct back to the particle-level at $\approx$ 10cm
where $\approx$ all muons are from heavy flavor decays

$\Rightarrow$ determine correction using PYTHIA and
full simulation of DØ detector (GEANT)



$\Longrightarrow$ Fraction of Muon-Tagged Jets which contain a least one b- or c-Hadron

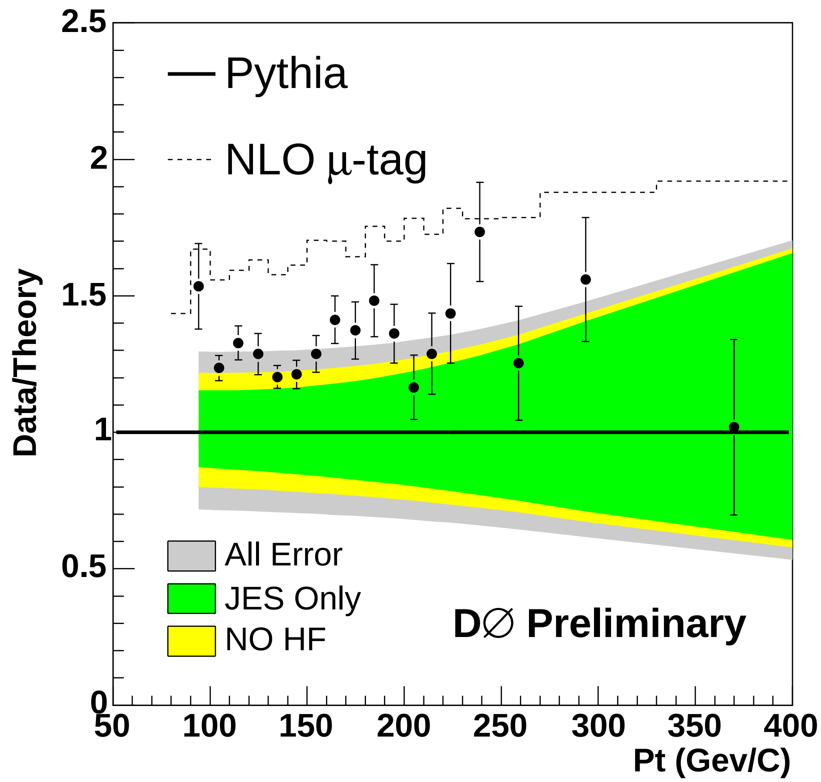
(here: still low statistics!! – improvements are in progress)

Result – Comparison with Theory

fully corrected data are compared with:

- PYTHIA
  prediction for muon-jets from heavy flavor jets
  $\longrightarrow$ slightly too low (20% - 30%)

- "NLO"
  - compute NLO prediction for inclusive jets
  - multiply with muon-jet fraction
    (from PYTHIA/HERWIG)
  $\longrightarrow$ slightly too high (20% - 30%)



$\Longrightarrow$ reasonable agreement with PYTHIA (can't expect much more from LO matrixelents...)
waiting for true NLO calculation (inclusive jet production may soon be in MC@NLO)

$\longrightarrow$ yellow band shows potential when error from heavy flavor correction is reduced

Summary / Outlook

- New measurement: inclusive Muon-Tagged Jet Cross Section
- sensitive to b- and c-Production
- Data are slightly higher than the predictions from PYTHIA (20% - 30%)
  (... not unreasonable for a LO Monte-Carlo ...)
- work in progress:
  - remove explicit correction for heavy flavor contribution
  - replace by an experimentally well-defined criterion:
    count only muons which were produced within 10cm from the beam-axis
- hope for NLO calculation (MC@NLO has promised to include inclusive jet production)
- Need to work on jet energy calibration
  before we can exclude quark-compositeness models