Measurement of the $t\bar{t}$ production cross section in the lepton+jets decay channels in $p\bar{p}$ collisions at $\sqrt{s}$=1.96 GeV

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On behalf of the DØ Collaboration

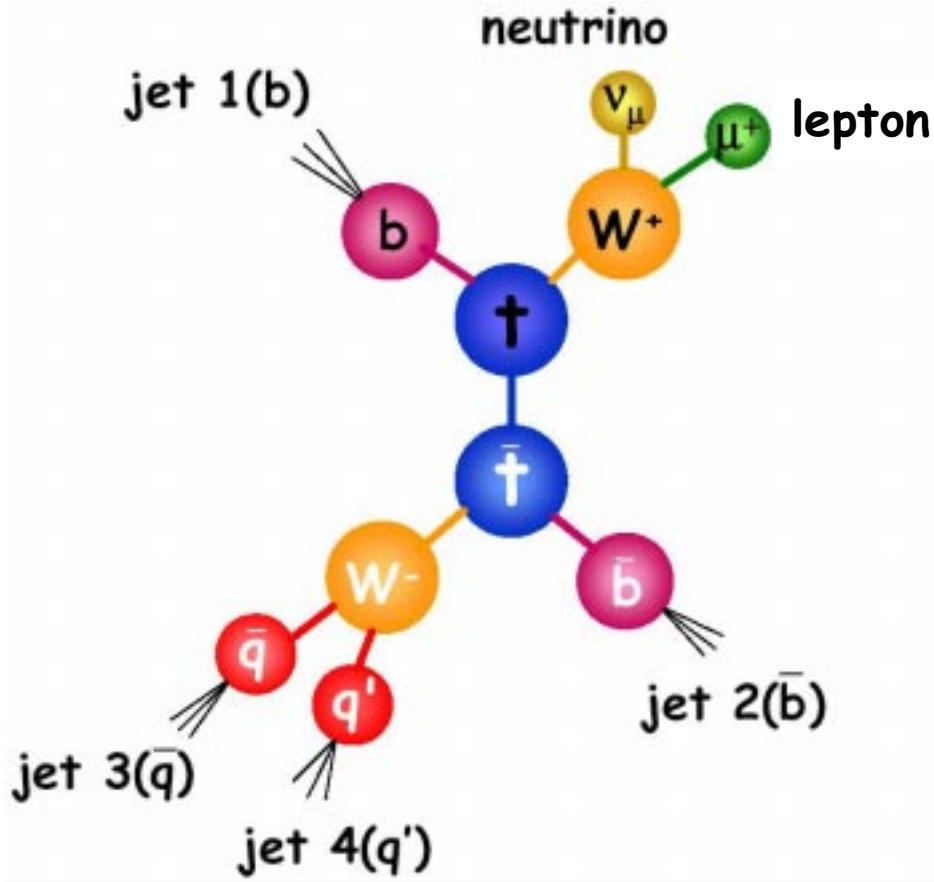
Outline

- Introduction
- Event Selection
- Object Identification
  - electrons, muons, jets, neutrinos
- Background Estimation
  - Matrix Method
  - Berends Scaling
- Topological Analysis
- Soft-Lepton-Tag Analysis
- Conclusions/Outlook

Introduction

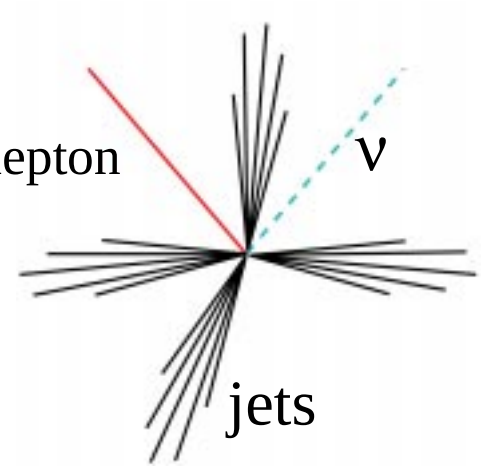
- Dataset
  - Luminosities:
    - e+jets: 49.5 pb^{-1}
    - μ+jets: 40.0 pb^{-1}
  - Backgrounds: QCD multi-jets and W+multi-jets

- Triggers
  - EM + 1 jet
  - μ + 1 jet
  - Single-lepton triggers
    - Efficiencies, background estimates



Event Selection

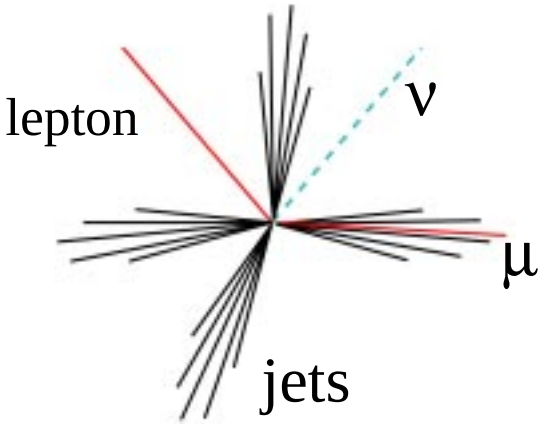
Lepton+jets
(topological)



- 1 lepton (e or μ)
- $\geq$ 4 jets
- Topological cuts to separate
  signal $\leftrightarrow$ background

$\leftrightarrow$

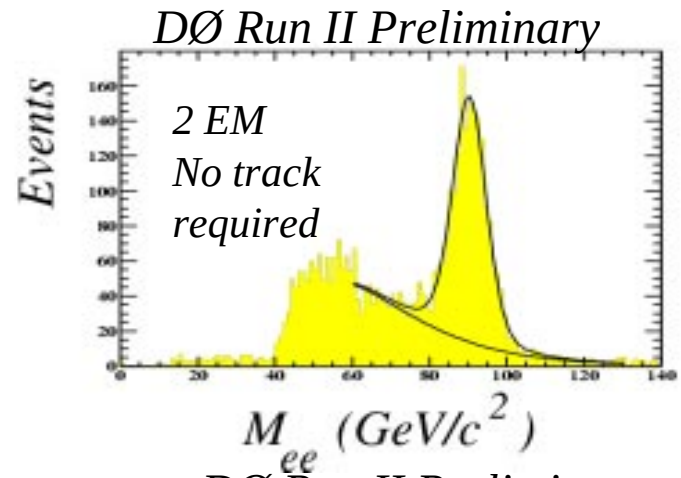
Lepton+jets
(soft lepton tag)

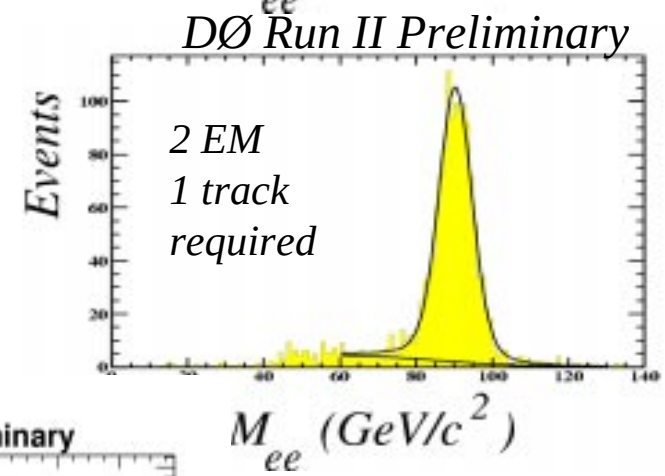


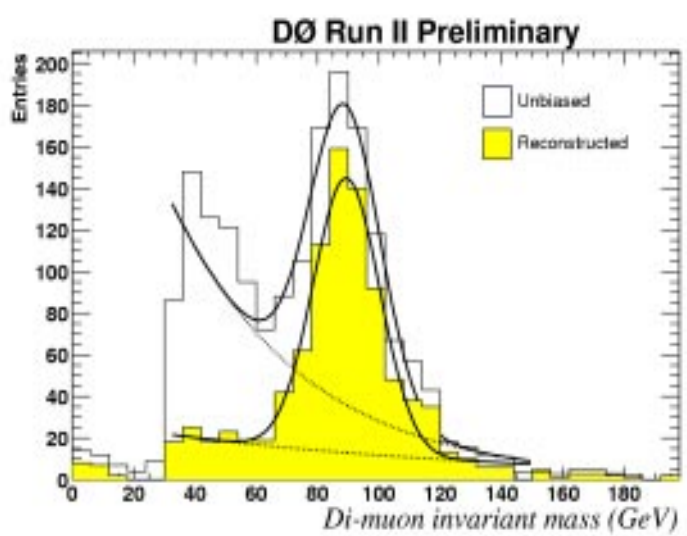
- 1 lepton (e or μ)
- $\geq$ 3 jets
- One jet tagged with μ

Object Identification

- Jets, jet energy scale:
  - Improved 0.5 cone algorithm
  - Jet Energy Scale corrections
- Electrons:
  - Simple cone
    - EM fraction, shower-shape
  - track match
- Missing E_T
  - include JES corrections
  - include muon correction
- Muons:
  - Local muon tracks
  - Central track match







Pre-Selection

- 1 EM object or 1 μ
  - $E_T > 20$ GeV
- missing E_T
  - $\not{E}_T > 20$ GeV
- Analysis-specific cuts:
  - *e+jets*: $\Delta\phi(\not{E}_T, e) > 0.5$
  - μ+*jets*: $\not{E}_{T\,CAL} > 15$ GeV; $\Delta R(\mu, jet) > 0.5$
- Separate dataset by soft μ Veto for topological/Soft-Muon-Tag analyses

QCD Background Evaluation

- "Matrix Method"
  - Samples with *L*oose and *T*ight lepton characteristics
    - *e*+jets: track match to calorimeter EM object
    - μ+jets: μ isolation
  - Determine $L \rightarrow T$ efficiency independently for signal ($\varepsilon_{W+t\bar{t}}$) and QCD background (ε_{QCD})
    - efficiencies are well separated

$$N_L = \tilde{N}_{W+t\bar{t}} + \tilde{N}_{QCD}$$

$$N_T = \varepsilon_{W+t\bar{t}} \tilde{N}_{W+t\bar{t}} + \varepsilon_{QCD} \tilde{N}_{QCD}$$

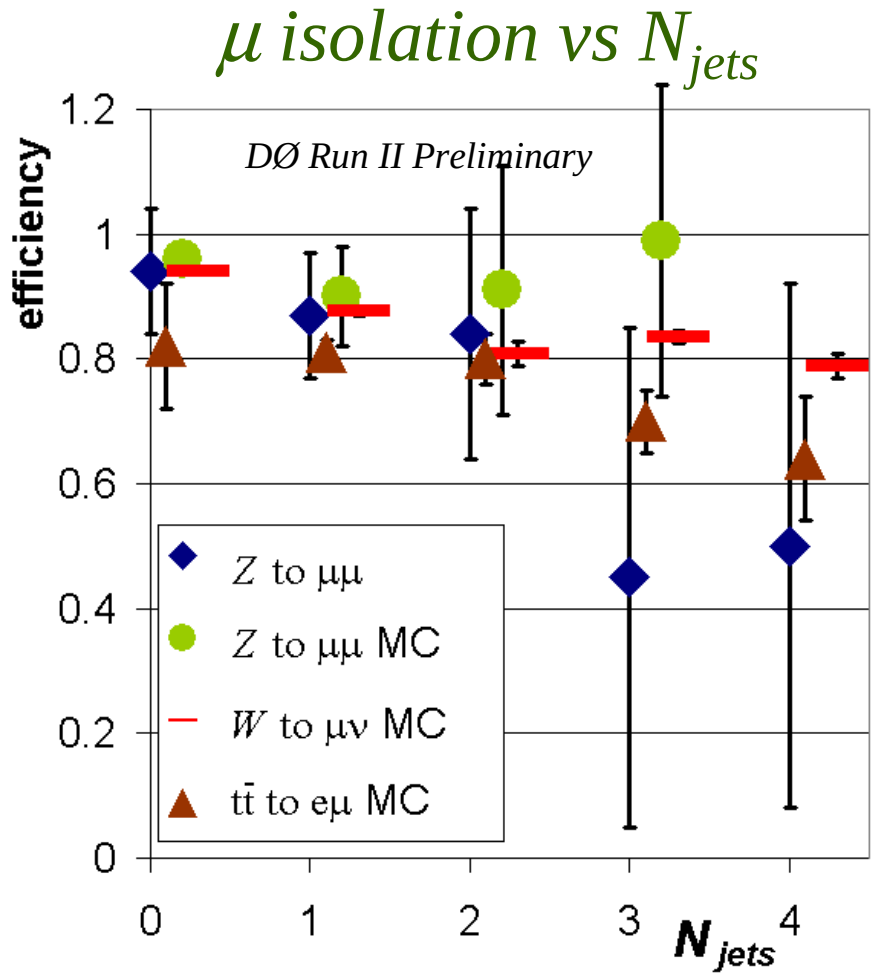
$$\Rightarrow$$

$$\tilde{N}_{W+t\bar{t}} = \frac{N_T - \varepsilon_{QCD} N_L}{\varepsilon_{W+t\bar{t}} - \varepsilon_{QCD}}$$

$$\tilde{N}_{QCD} = \frac{\varepsilon_{W+t\bar{t}} N_L - N_T}{\varepsilon_{W+t\bar{t}} - \varepsilon_{QCD}}$$

Matrix Method: $\varepsilon_{W+t\bar{t}}$

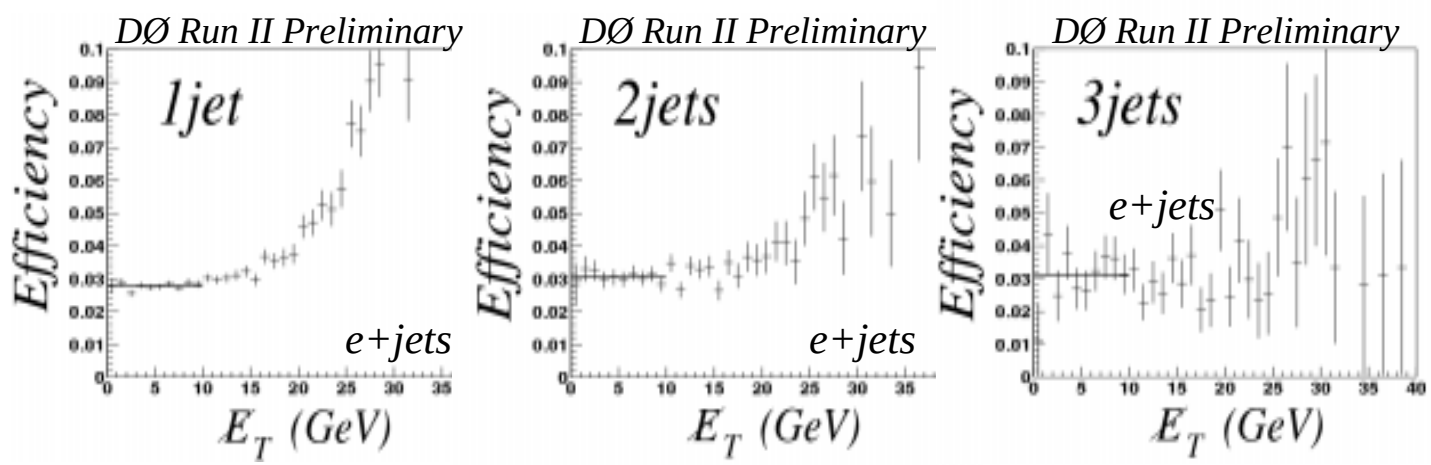
- *e+jets*:
  - tracking + track-matching
  - Independent of N_{jets}
  - $\varepsilon_{W+t\bar{t}} = (78.2 \pm 2.3 \pm 2.5)\%$
- μ+*jets*:
  - Isolation from Z→μμ data
  - Small N_{jets} dependence
    - Cross-check with MC for Z→μμ, W→μν+jets, $t\bar{t}$



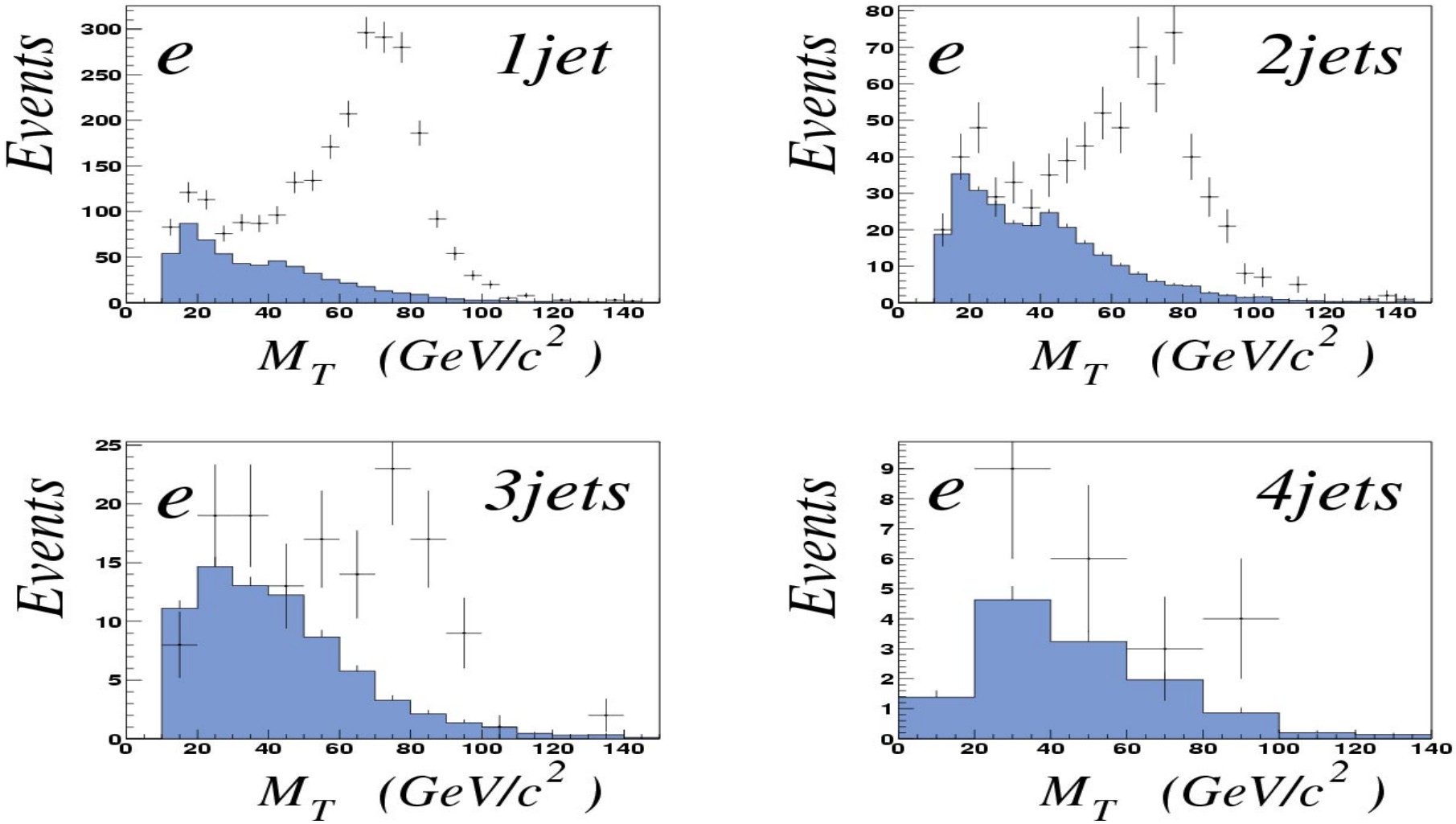
Background Evaluation: ε_{QCD}

- *e+jets*:
  - Compton QCD events
  - Misidentified jets
- μ+*jets*:
  - Heavy flavor quark decay
- Determined from background-enriched sample
  - $\not{E}_T$ <15GeV
  - Depends on N_{jets}

ε_{QCD} vs $\not{E}_T$ vs N_{jets}



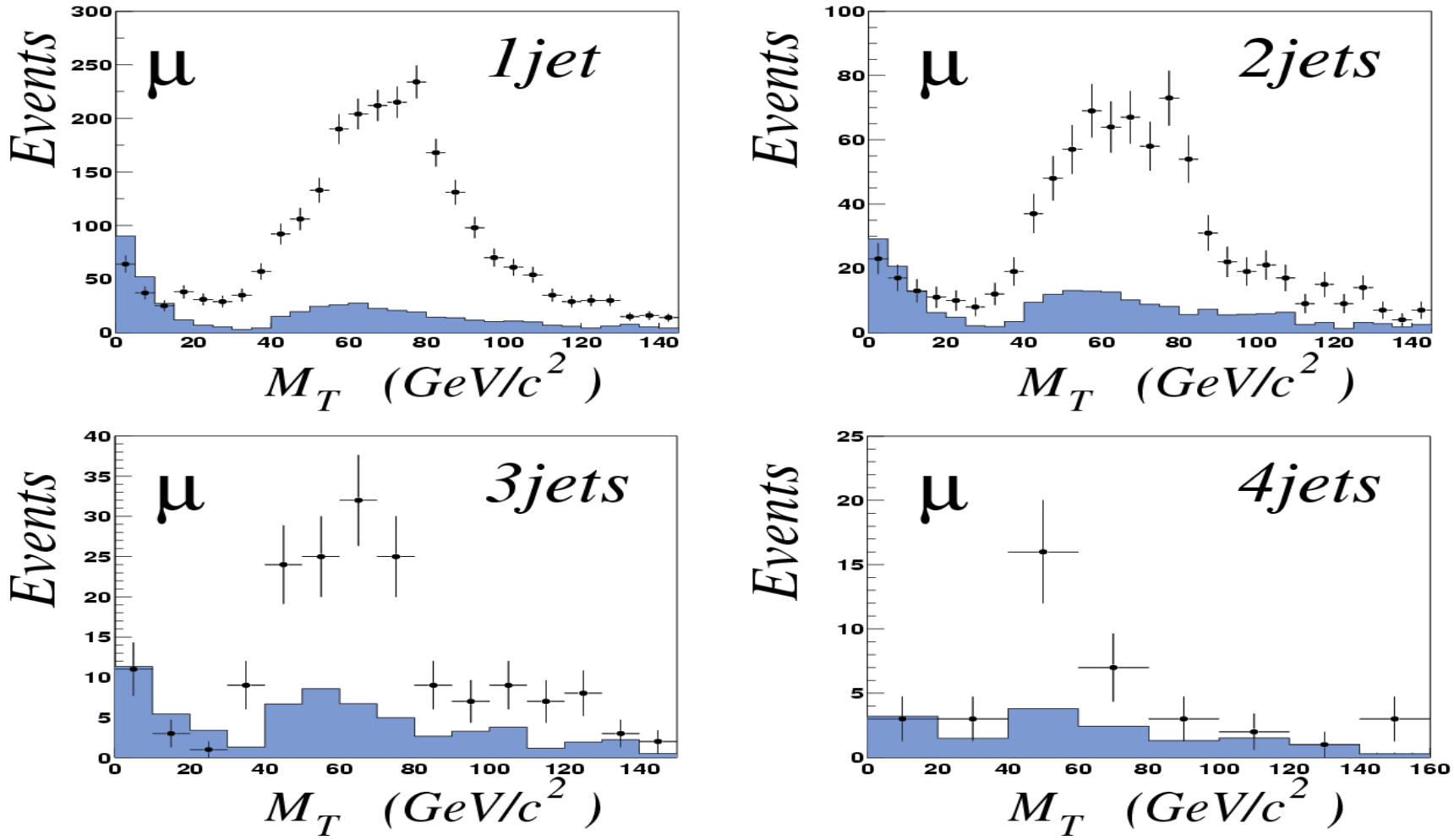
M_T, *e+jets* signal and background



- Signal sample

■ QCD background

M_T, μ+*jets* signal and background



- Signal sample ■ QCD Background

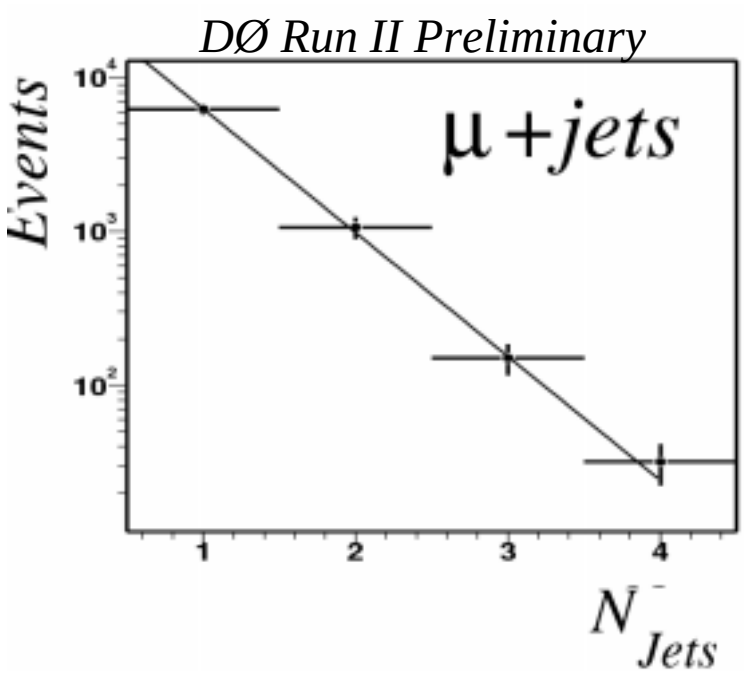
Berends Scaling Law

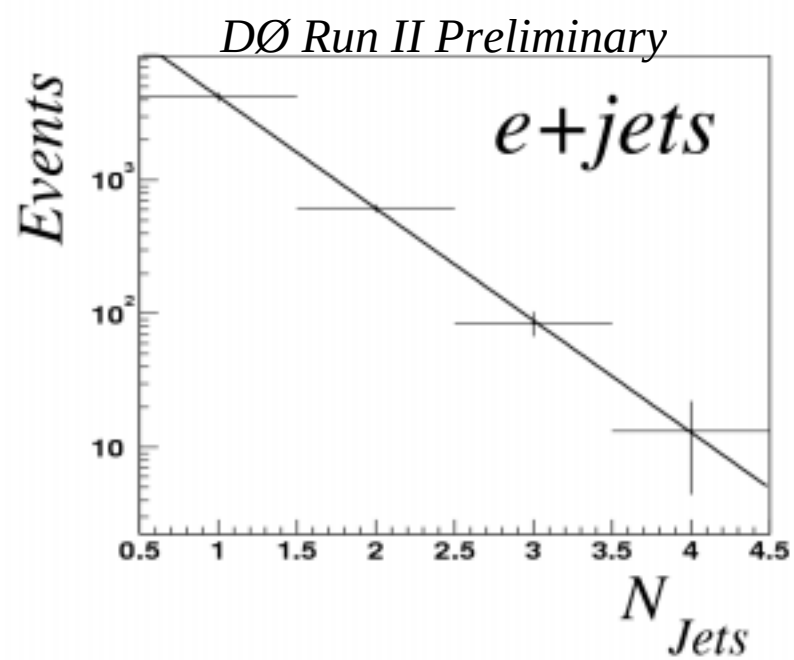
$$\alpha \equiv \frac{\sigma(W+(n+1)_{jets})}{\sigma(W+n_{jets})}$$

$$N_i^{W+t\bar{t}} = N_1^W \times \alpha^{i-1} + f_i^{t\bar{t}} N_i^{t\bar{t}}$$

- Empirical formula
- Correct $N_{W+t\bar{t}}$ for trigger bias

- Evaluate $f_i^{t\bar{t}}$ from MC
- Fit α from bins n_{jets}=1,2,3
- Extrapolate to n_{jets}=4





Topological Cuts

- Run I-based
  - excellent signal-background discrimination
- Jet transverse energy sum $H_T = \sum_{jets} E_T$
  - Also include W: $H_T(all) = H_T + P_T(W)$
- Aplanarity $\mathcal{A}$
  - Measures angular distribution of energy
    - planar (background) vs spherical ($t\bar{t}$)
  - Using jets and reconstructed W
- W momentum $P_T(W) = p^l_T + \not{E}_T$
- Veto soft muon

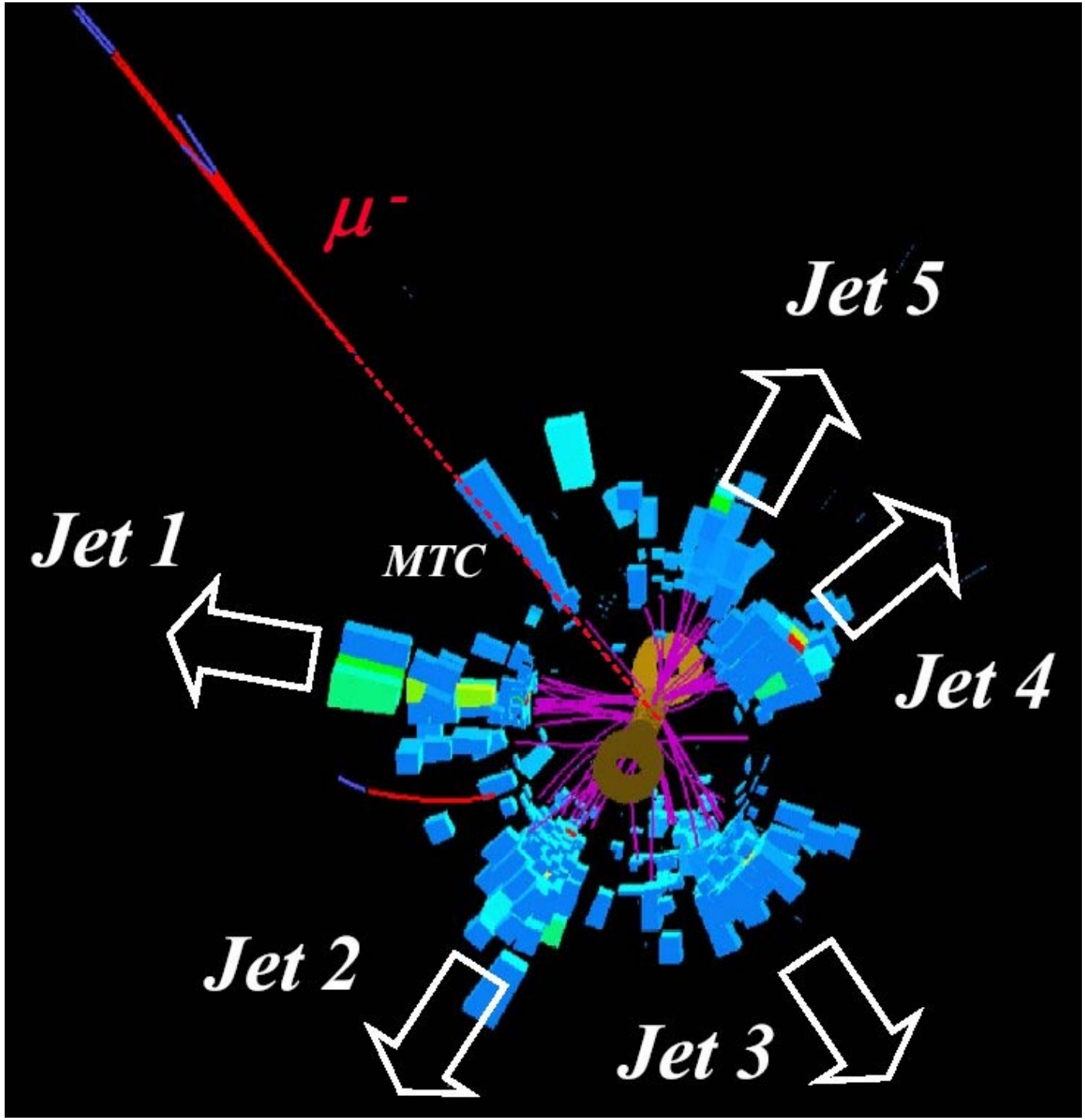
Topological Analysis Result

Analysis	N_{obs}	N_{QCD}	N_W	Bkg. Tot.	Signal*
e+jets	4	1.4±0.4	1.3±0.5	2.7±0.6	1.8
μ+*jets*	4	0.6±0.4	2.1±0.9	2.7±1.1	2.4

* *For* σ = *7pb*

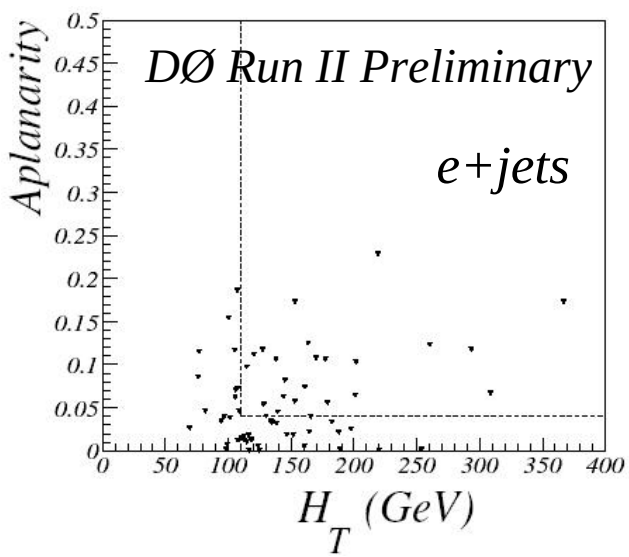
- Main Systematic uncertainties:
  - JES: ~15%
  - ID:
    - Jet ID: 8%
    - Lepton ID: 3%

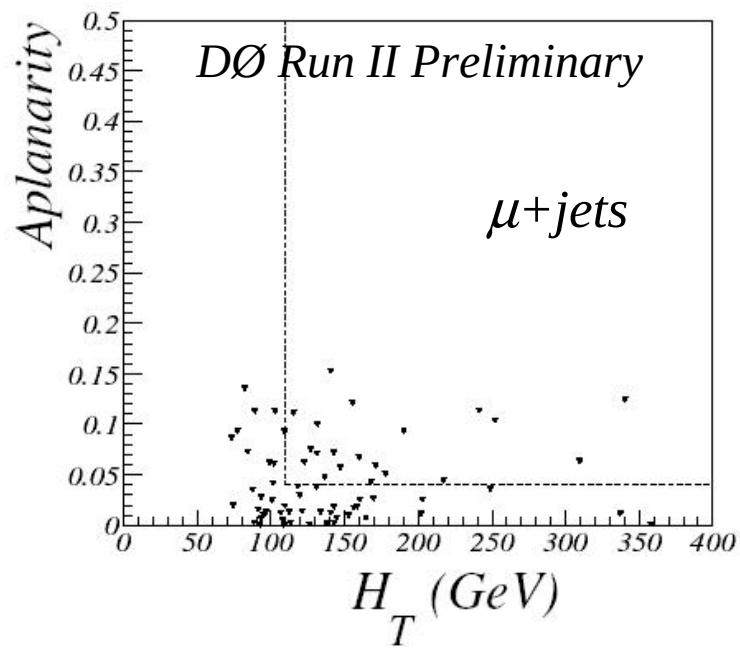
$t\bar{t} \rightarrow \mu$+jets candidate event



Soft Lepton b-jet Tagging

- Identify μ from b-decay within jets
  - p^{μ}_{T}>4GeV, $|\eta^{\mu}|$ <2, $\Delta R(\mu, jet)$<0.5
- Same preselection as for topological analysis
- Loose topological cuts
  - $H_T > 110$ GeV, $\mathcal{A} > 0.04$
- Consider only jets with $E_T^{jet} > 20$ GeV, $|\eta^{jet}| < 2$
- Consider $N_{jets} \geq 3$





Soft Lepton Tag Background Estimate

- N_{QCD} from Matrix method

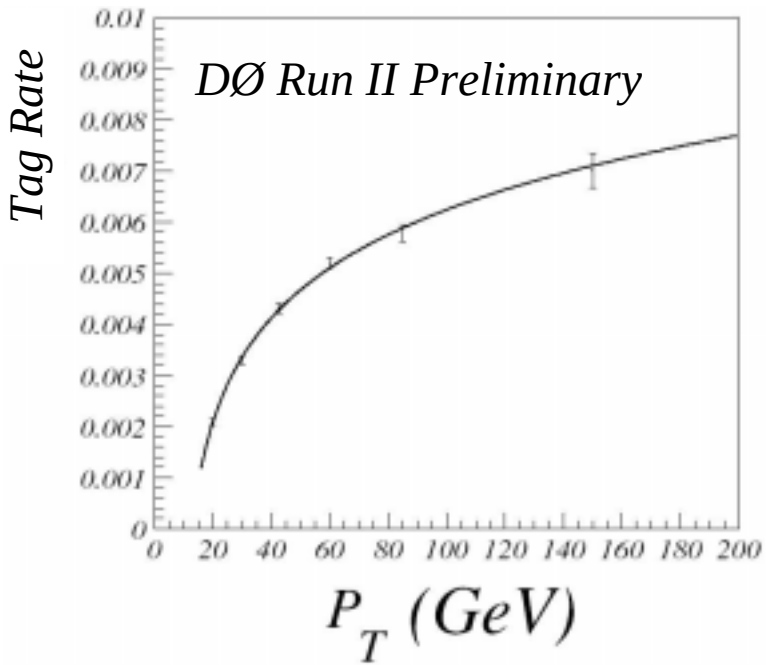
$$\text{Before tag}: N_{loose} / N_{tight} = \begin{cases} 459/27\,(e) \\ 75/23\,(\mu) \end{cases}$$

$$\text{After tag}: N_{loose} / N_{tight} = \begin{cases} 9/2\,(e) \\ 2/0\,(\mu) \end{cases}$$

$$\Rightarrow \tilde{N}^{SLT}_{QCD} = \begin{cases} 0.2 \pm 0.09\,(e) \\ 0.45 \pm 0.33\,(\mu) \end{cases}$$

- $N_{W+t\bar{t}}$ from tag-rate function

$$\Rightarrow \tilde{N}^{SLT}_{W+t\bar{t}} = \begin{cases} 0.15 \pm 0.04\,(e) \\ 0.21 \pm 0.06\,(\mu) \end{cases}$$

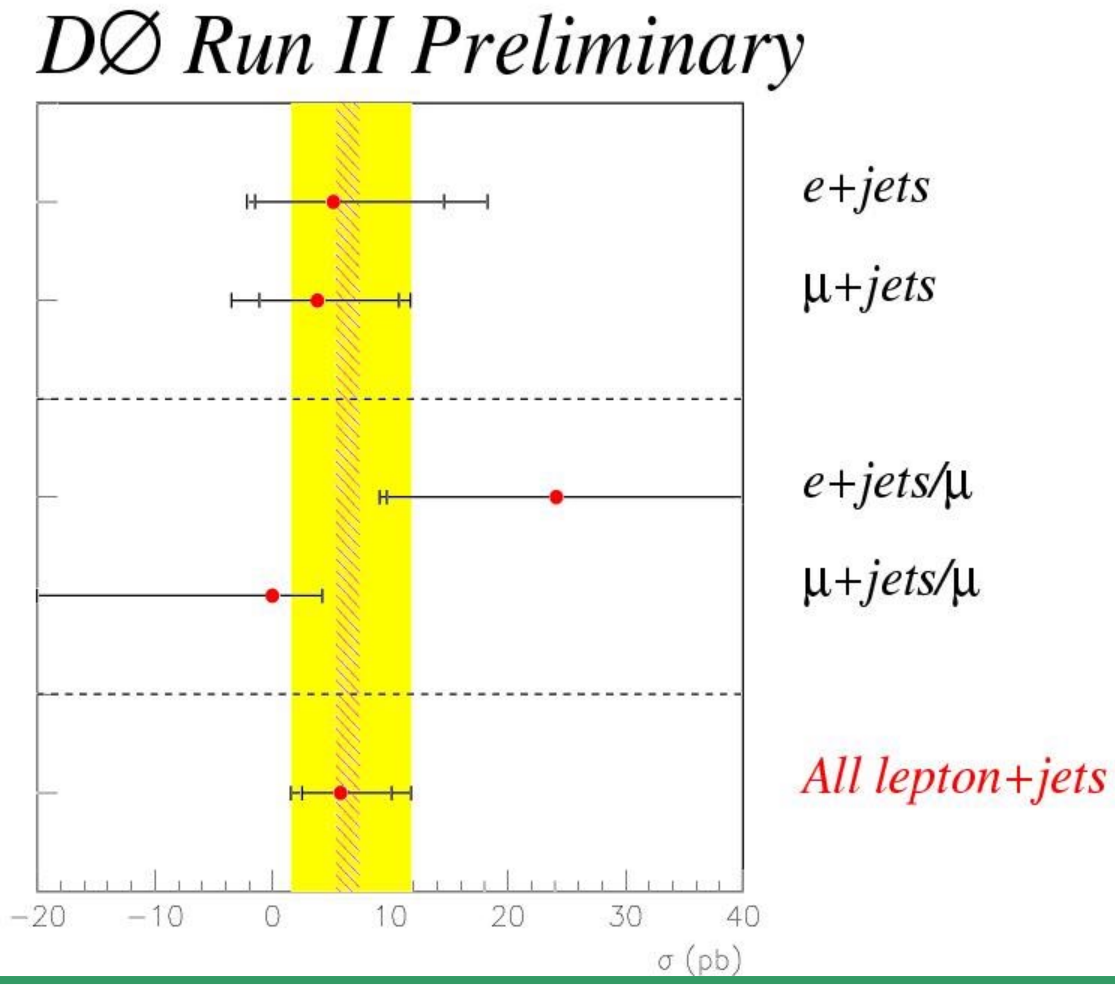


Soft Lepton Tag Result

Analysis	N_{obs}	Bkg. Tot.	Sig.*
e+jets	2	0.16±0.10	0.54
μ+*jets*	0	0.74±0.38	0.82

* For σ = 7pb

Cross-Section Results



$$\sigma_{t\bar{t}\to\ell+jets} = 5.8\ ^{+4.3}_{-3.4}\,(\text{stat})\ ^{+4.1}_{-2.6}\,(\text{sys}) \pm 0.6\,(\text{lumi})\,\text{pb}$$

Conclusions/Outlook

- First measurement of $t\bar{t} \rightarrow$lepton+jets cross section in Run II
  - Based on Run I cuts
- DØ detector commissioned
- Further analysis improvements in progress
  - Tracking
  - Particle identification
    - Jets, electrons, b-jets