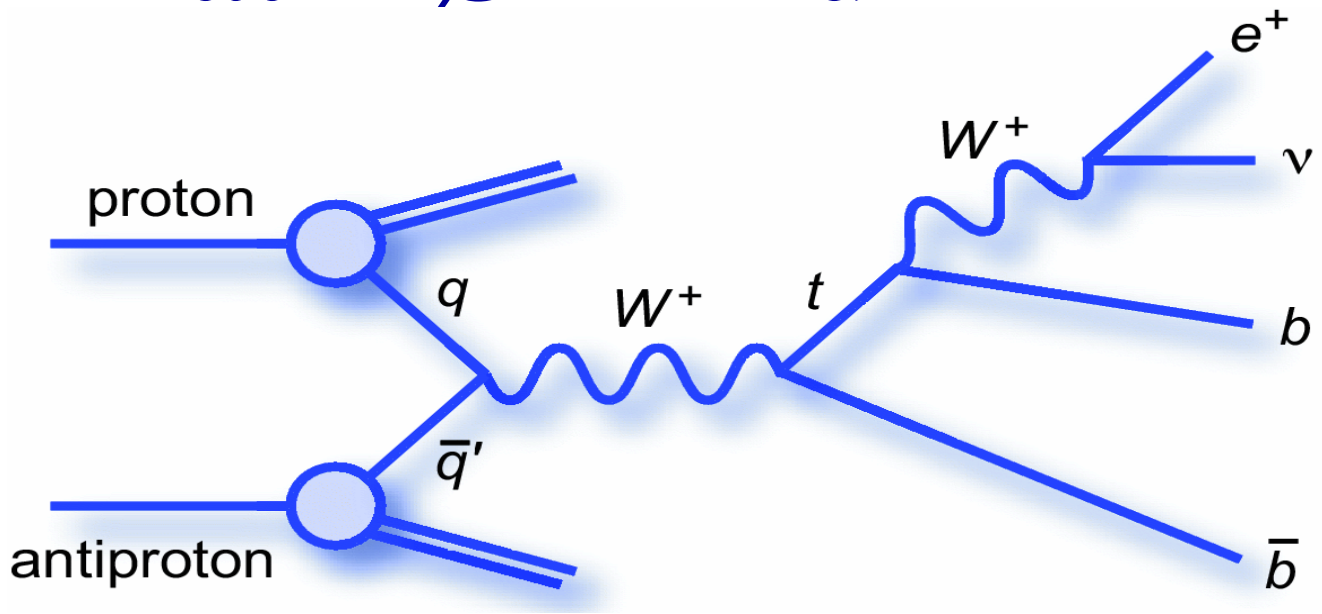
Search for Single Top Quark Production in the Electron Channel at DØ in Run II



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on behalf of the DØ collaboration

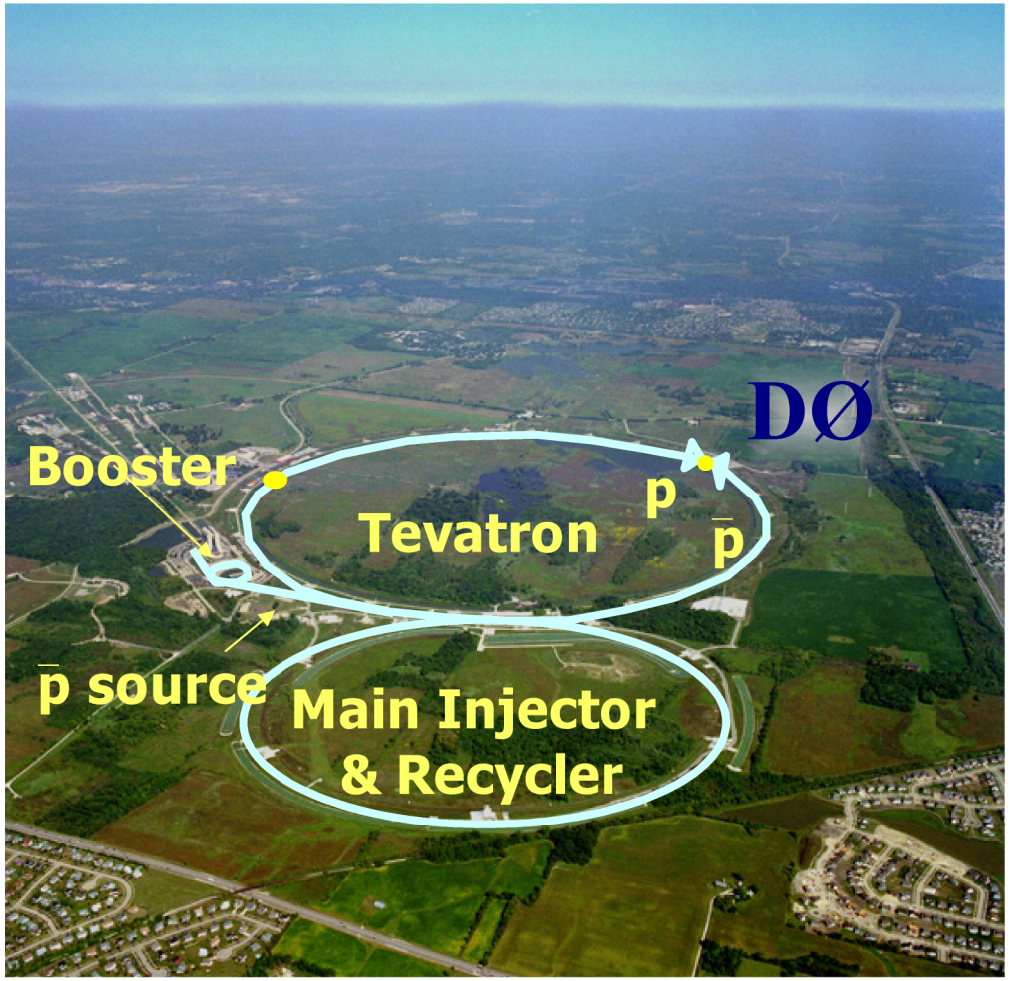
Pheno 2004, April 26-28 2004

Outline

- Introduction
  - Tevatron $p\bar{p}$ Collider
  - Single Top Quark Production
- Experimental Setup
  - DØ Detector
  - Final State Reconstruction
- Single Top Analysis
  - Preselection
    - Event Yield Estimates
  - Final Selection Cuts
- Result
- Outlook

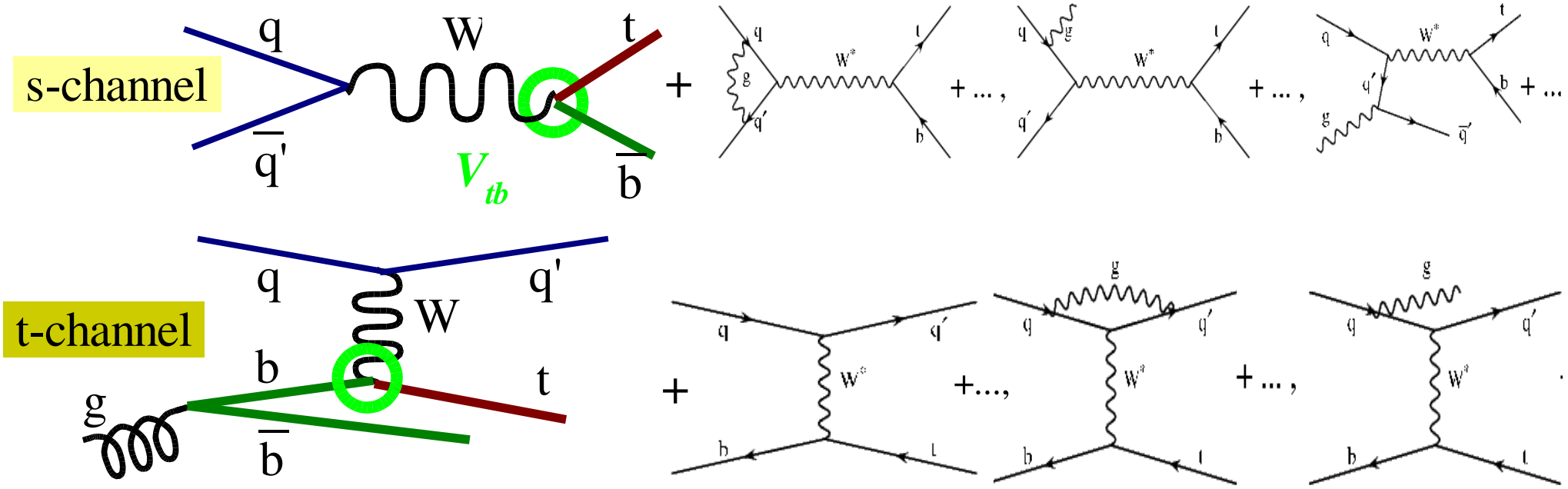
Introduction

- Tevatron is the highest-energy accelerator in the world
  - Test predictions of the Standard Model in detail
  - Search for new interactions not predicted by the Standard Model
  - Only place in the world to observe top quarks
    - Observation of top quark through pair production
    - Measurement of top quark mass



- Search for interactions predicted by the Standard Model but not yet observed → Single Top Production

Single Top Quark Production

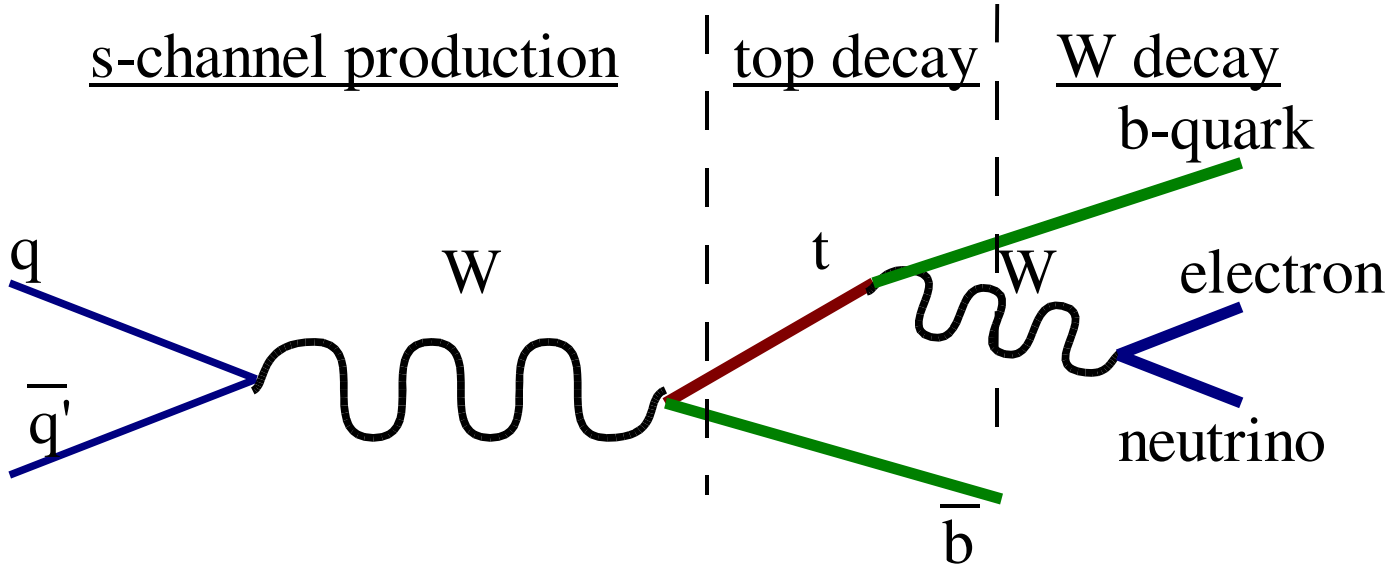


- Electroweak production of top

	s-channel	*t-channel*
– NLO cross-sections:	0.88pb ± 8%	1.98pb ± 11%
– Run I: DØ: 95% CL:	<17pb	<22pb
CDF: 95% CL:	<18pb	<13pb

- Test predictions of the Standard Model
  - Measure CKM matrix element V_{tb} (test CKM unitarity)
  - Observe top polarization

Single Top Event Signature



Final State

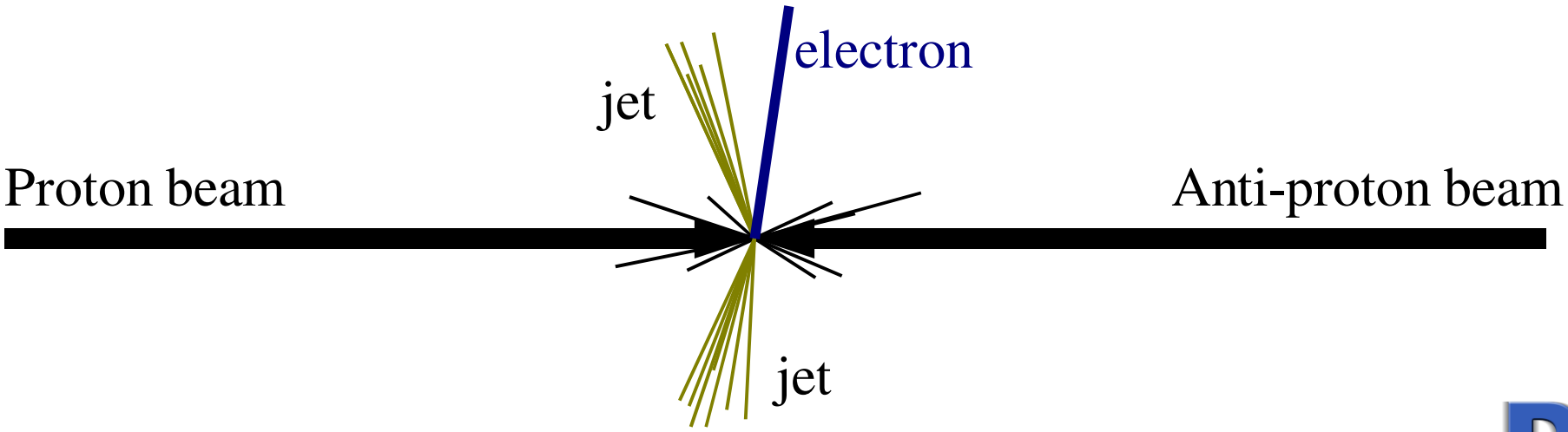
b-quark jet

electron

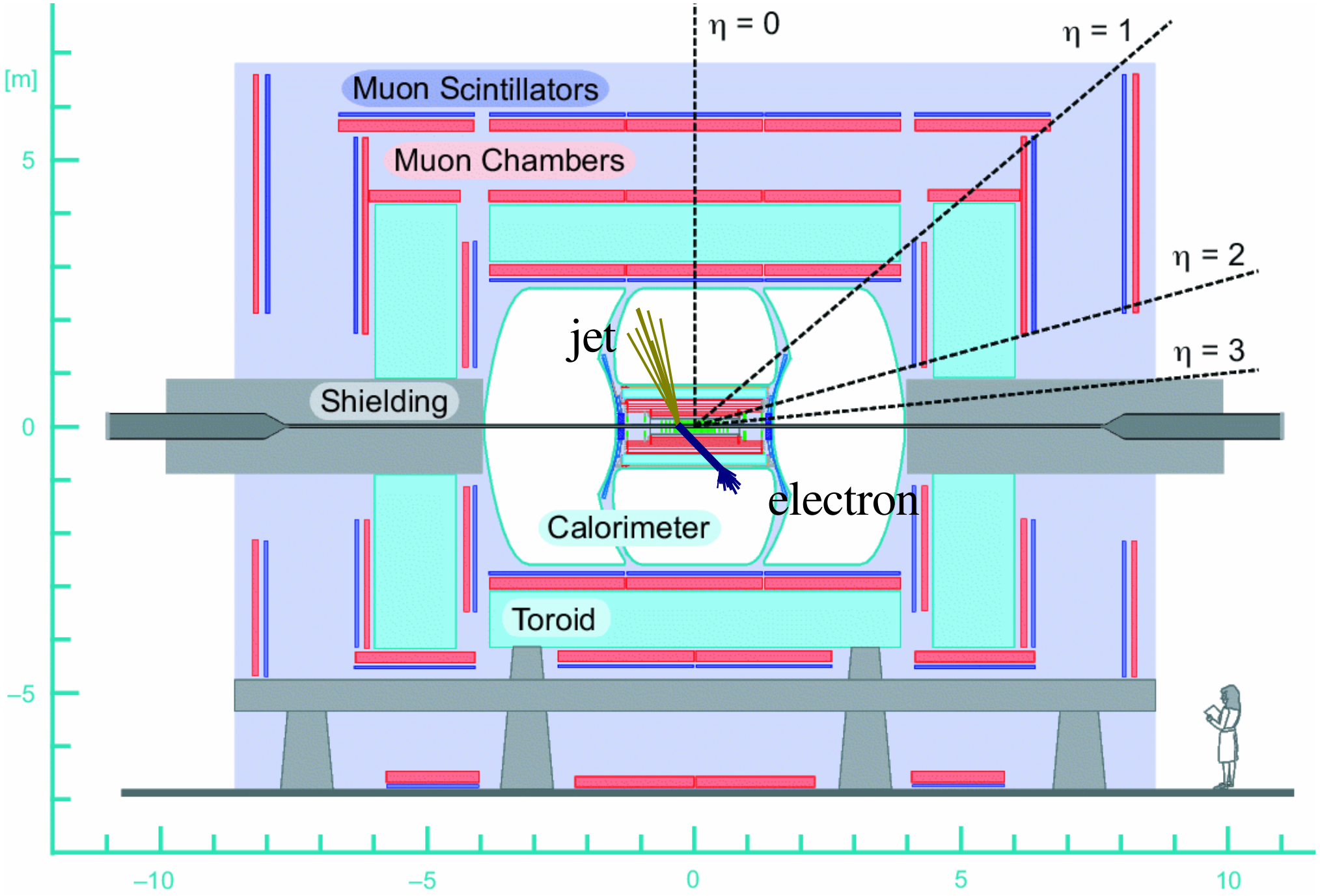
missing E_T

b-quark jet

Final State Objects

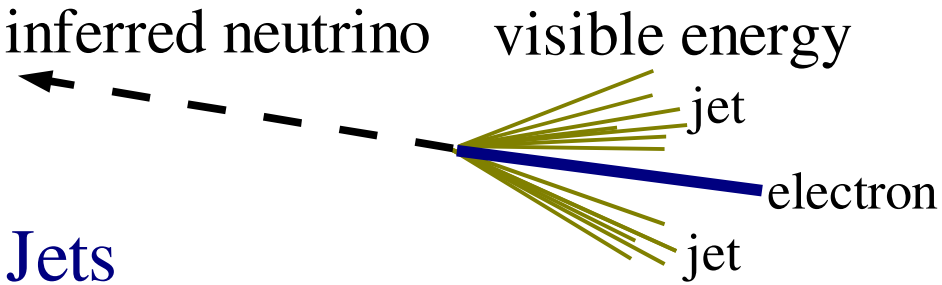


Experimental Setup: DØ Run II Detector



Final State Reconstruction

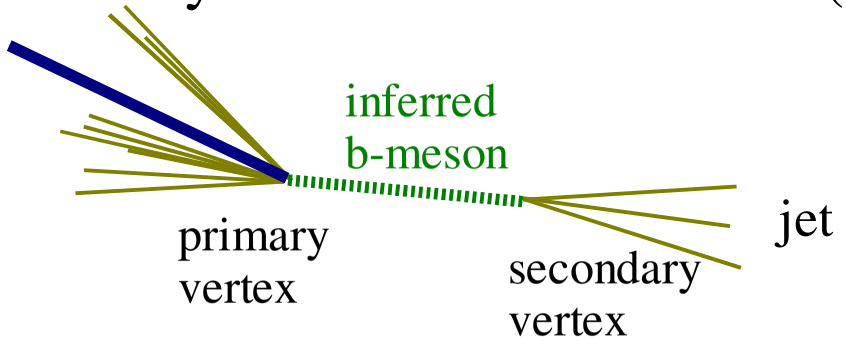
- Electron
  - Clustering in the calorimeter
  - Matched to central track
  - Likelihood estimator to distinguish from jets
- Neutrino (MET)
  - Indirectly through energy imbalance in transverse plane



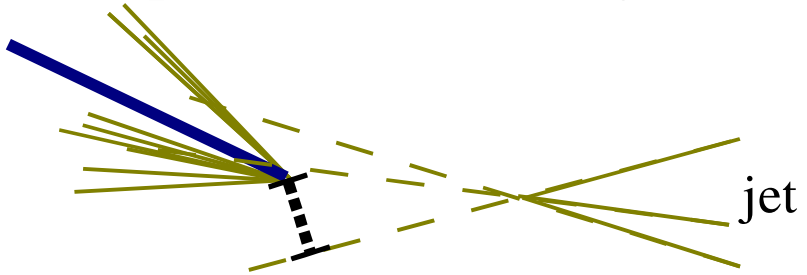
- Jets
  - Clustering calorimeter energy
  - Corrected to get particle p_T (Jet Energy Scale)

- b-quark identification
  - Muon-in-jet from b-meson decay
    - Soft-muon tag
  - Tracking-based lifetime tagging

Secondary Vertex Reconstruction (SVT)



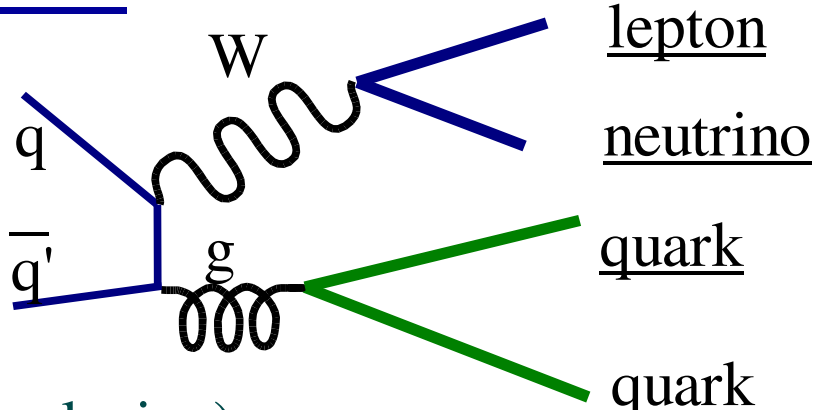
Impact Parameter Tag (JLIP)



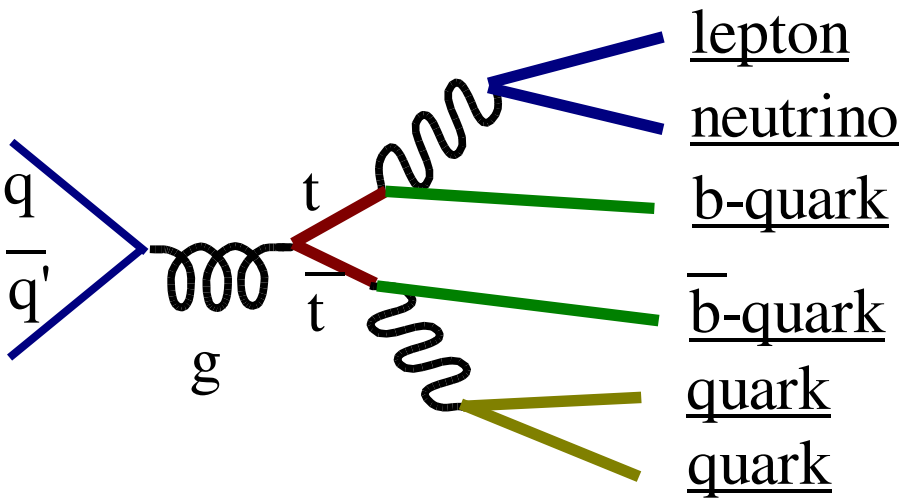
Probability for each track in the jet to originate from the primary vertex

Backgrounds

- W+jet production
  - Wjj, Wcc, Wbb, ...
  - Estimated from data
    - Normalized untagged W+jets sample by probability to tag a jet in the data (inclusive)
      - Probability is derived from a multi-jet sample
      - Same jet flavor composition as W+jets (within 20% uncertainty)



- Mis-reconstructed multi-jet events
  - Jet mis-identified as electron
  - Estimated from data
- Top-pair production
  - Lepton+jets and di-lepton
  - Estimated from MC
- Other (WZ, WW, cosmic rays)
  - Negligible, not yet included



Analysis Outline

1)Split Analysis into orthogonal channels

2)Preselection based on Single Top Event Signature

- Select events containing W and jets with at least one b-tag
  - Loose requirements to retain high signal acceptance
- Study background estimation in detail
  - Prove that background model reproduces data
  - Reject regions of phase space that are not well modeled

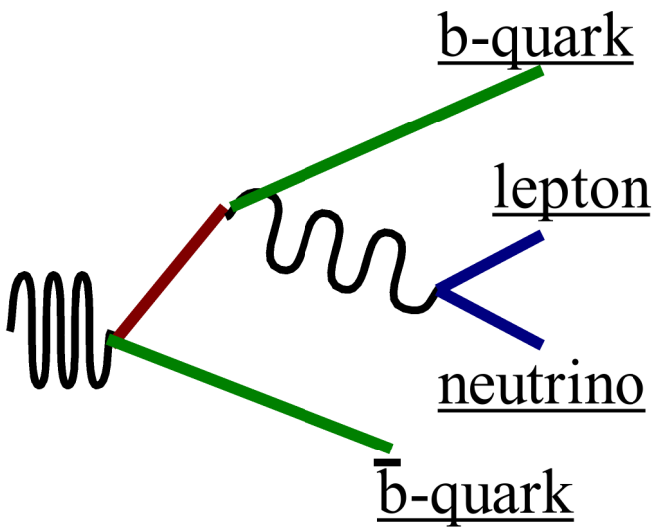
3)Final Event Selection

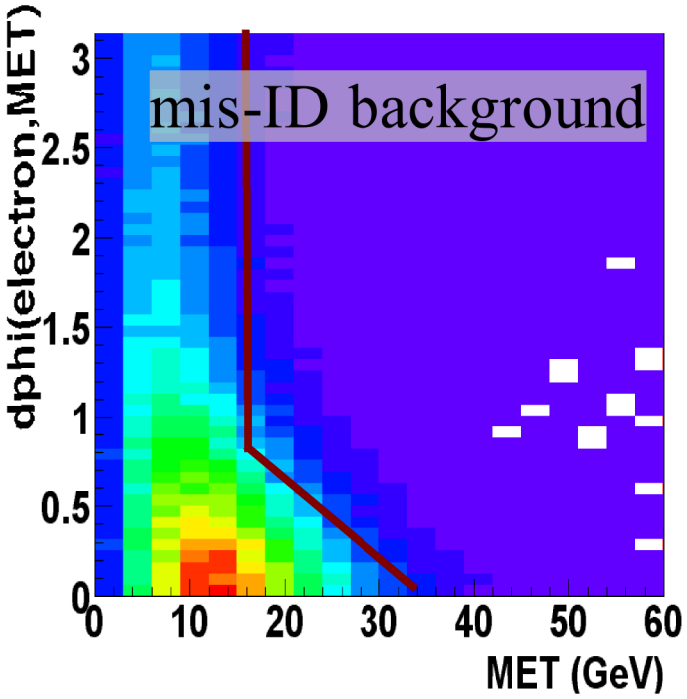
- Separate single top from backgrounds

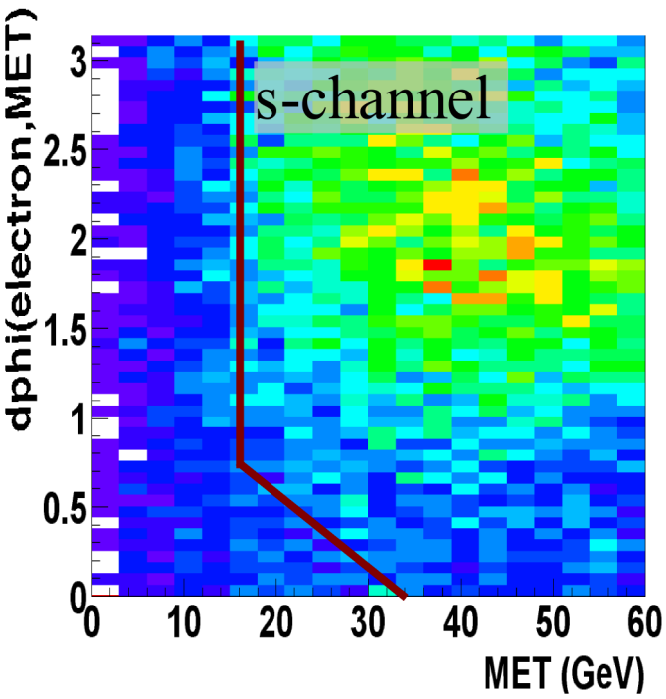
4)Combine orthogonal channels for highest sensitivity

Preselection Cuts

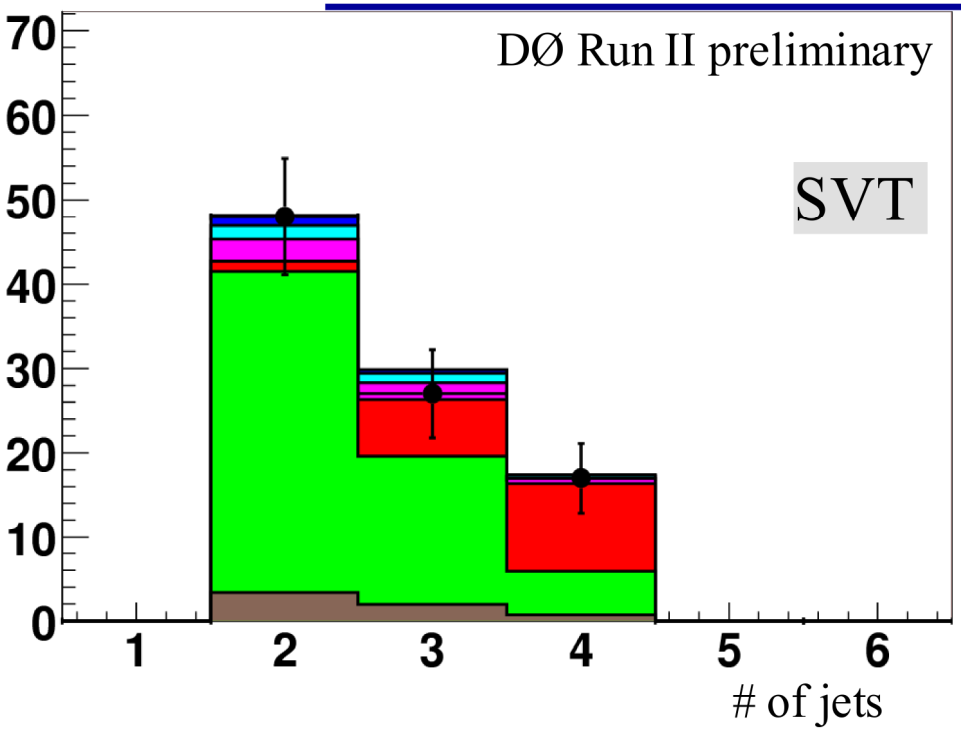
- Lepton: 1 electron, $p_T > 15$GeV
- Neutrino: missing $E_T > 15$GeV
- Jets: $2 \leq n \leq 4$
  - $p_T > 15$GeV, leading jet $p_T > 25$GeV
  - ≥1 b-tag
- Trigger Requirement: ≥1 EM object, ≥1 jet
- Reject mis-reconstructed events
  - Cosmic ray muons
  - Mis-identified jets
  - → Triangle cuts

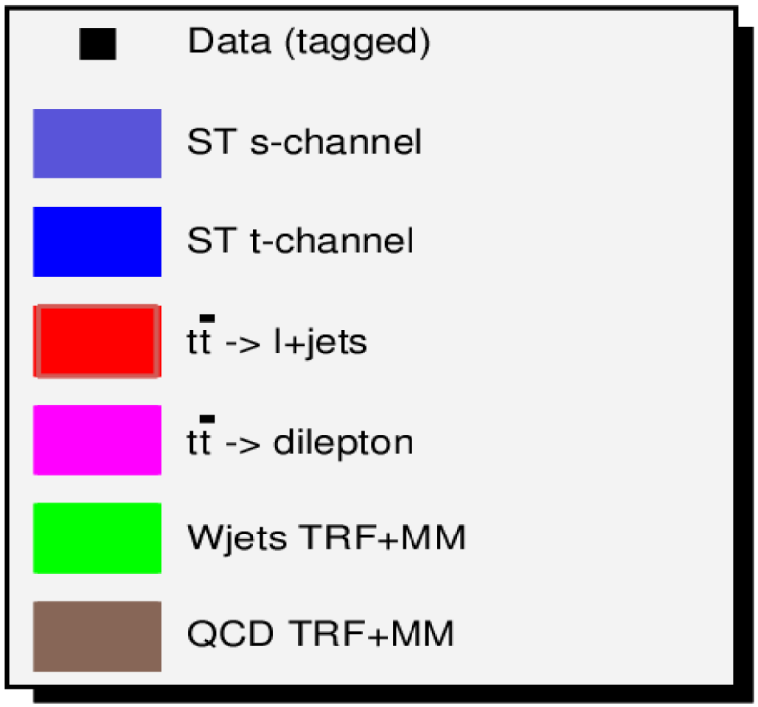


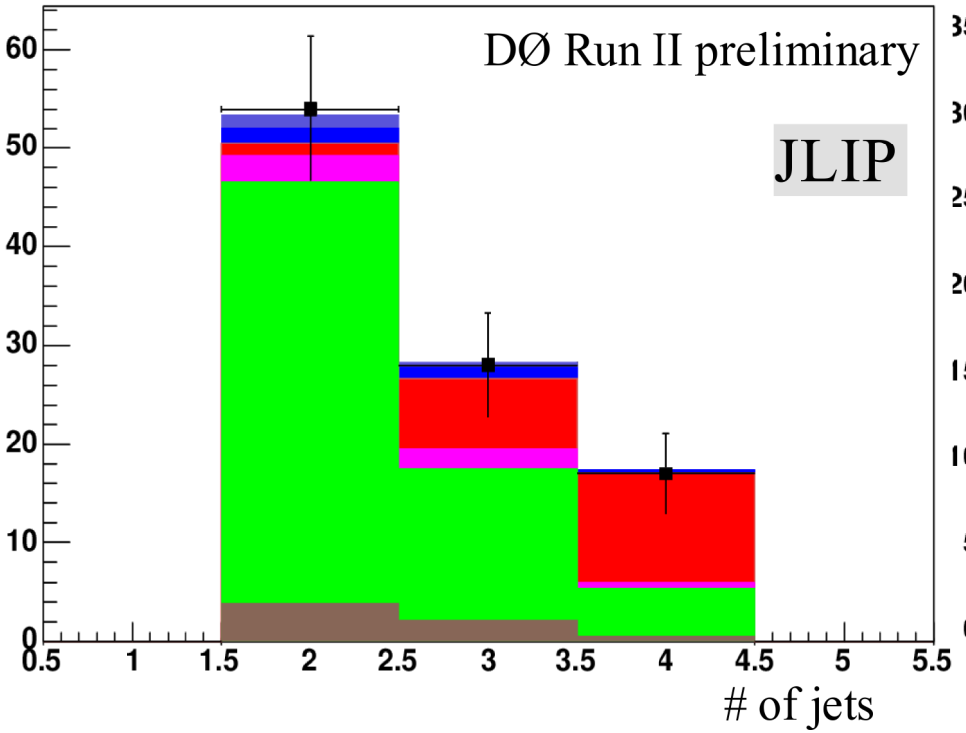


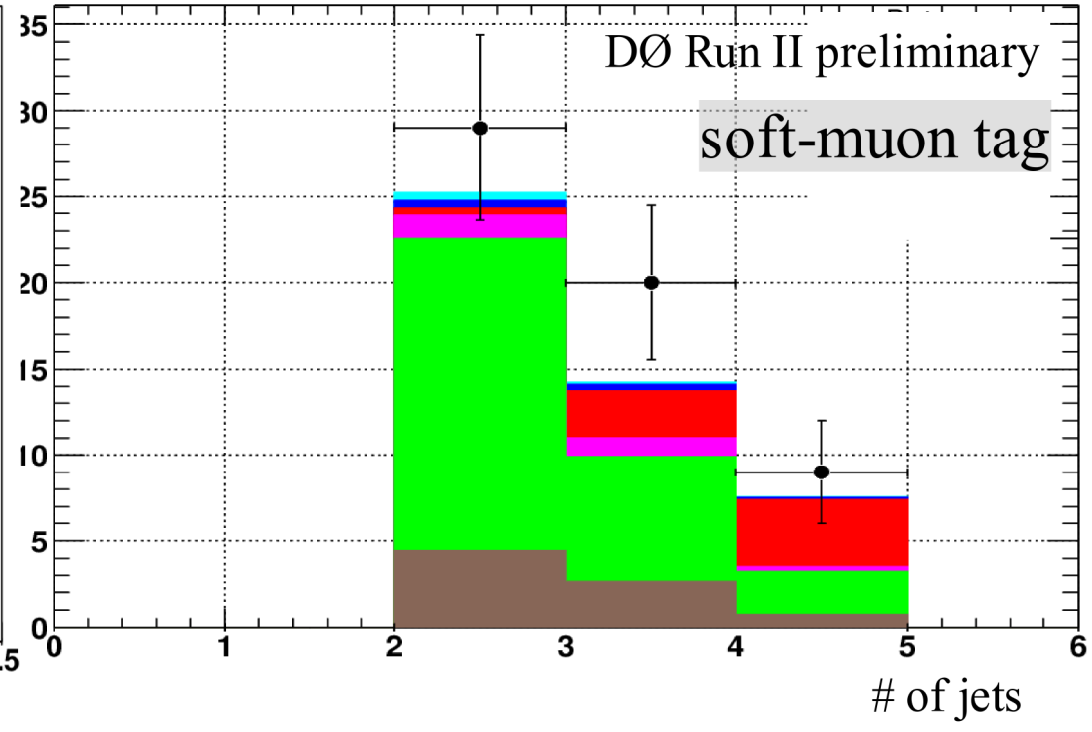


Event Yields: Number of Jets

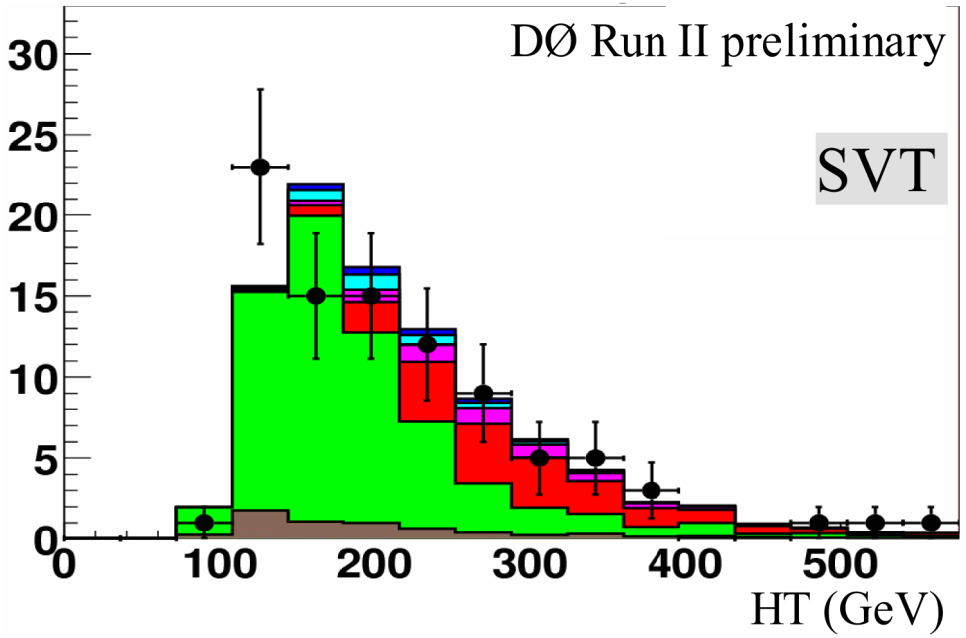




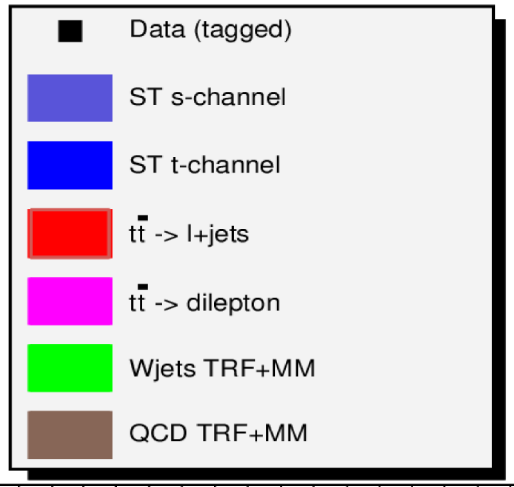


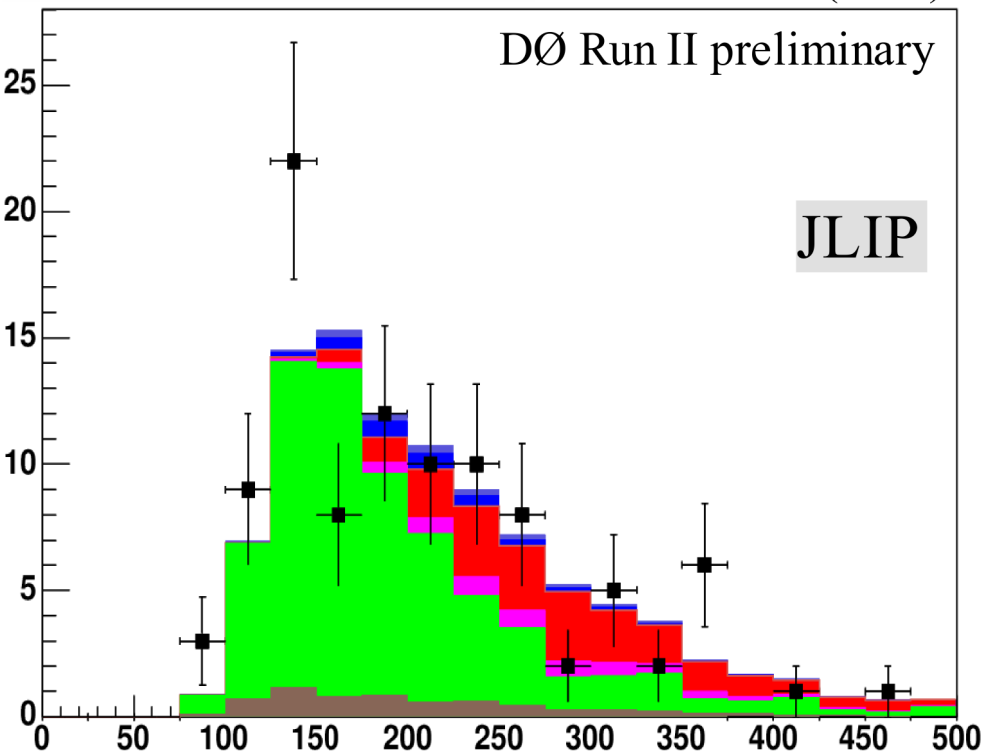


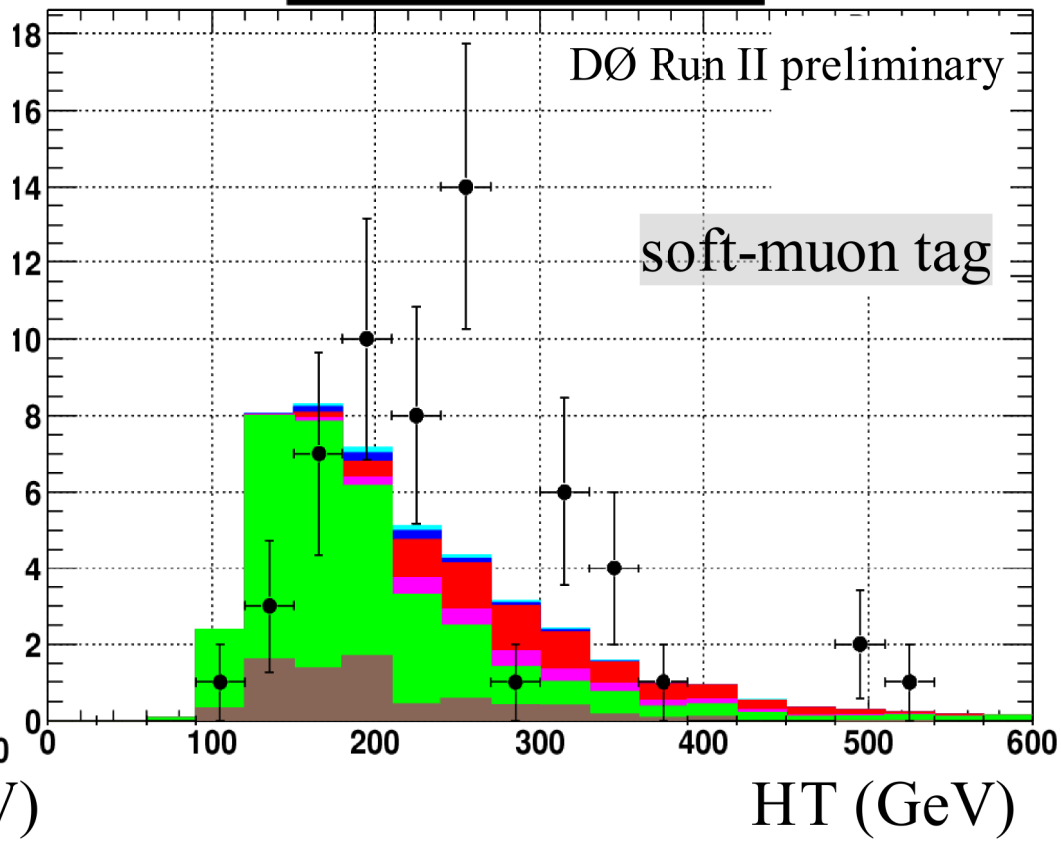
Event Yields: Event Energy HT



$$HT = E_T^{lepton} + MET + E_T^{jet1} + E_T^{jet2}$$



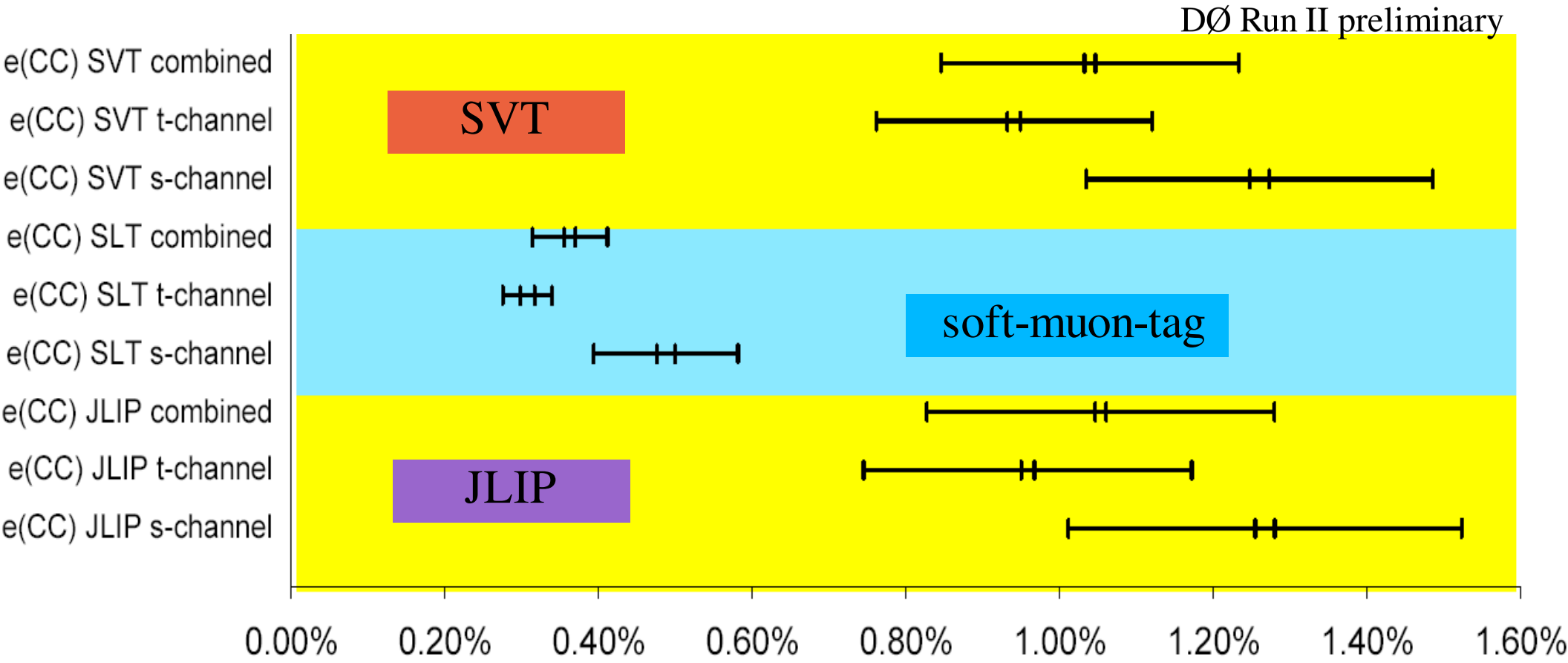




Final Event Selection

- Dominant background is from W+jets
- → Cut on HT>150GeV
  - $HT = E_T^{lepton} + MET + E_T^{jet1} + E_T^{jet2}$
  - Reduces W+jets background by about 50%
  - Reduces Single Top signal by about 5%
- Systematic Uncertainties
  - Data: largest contribution from determination of tagging probability: ~20%
  - MC: large contributions from
    - Jet-Energy-Scale,
    - Trigger modeling
    - MC flavor-dependent b-tag modeling
    - Combined: ~20%

Signal Acceptance



Result

- Final Event Yield
  - based on ~160pb of DØ Run II data
  - Soft-muon and secondary vertex tagger combined:

    Sum of backgrounds: 103 ± 15 events

    Observed: 117 events

    Expected from Single Top: 6.2 ± 1.8 events
- Observation consistent with Background expectation
- Estimate sensitivity: expected cross section limits
  - Modified frequentist approach (CLs method)
  - Include all systematic uncertainties and correlations
  - Set limit separately for s-channel, t-channel, s+t combined
  - Combine tagging methods and electron and muon channels

Conclusion/Outlook

DØ Run II preliminary

Expected 95% Cross-Section Limit

s-channel: <14pb

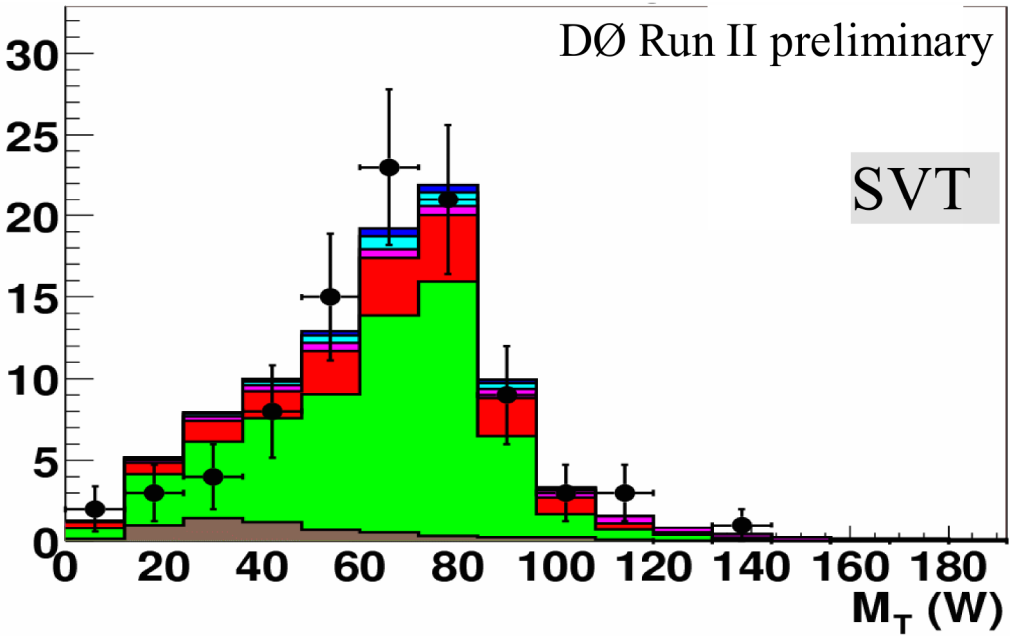
s+t-channel: <16pb

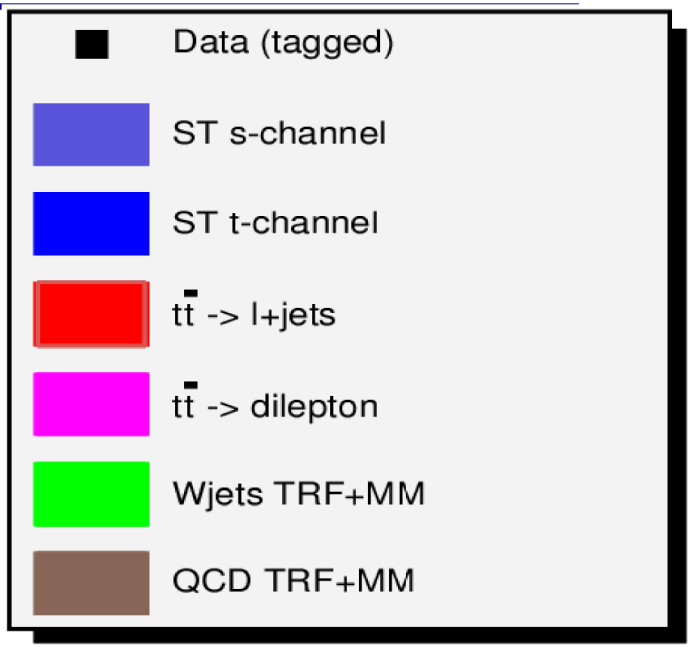
t-channel: <18pb

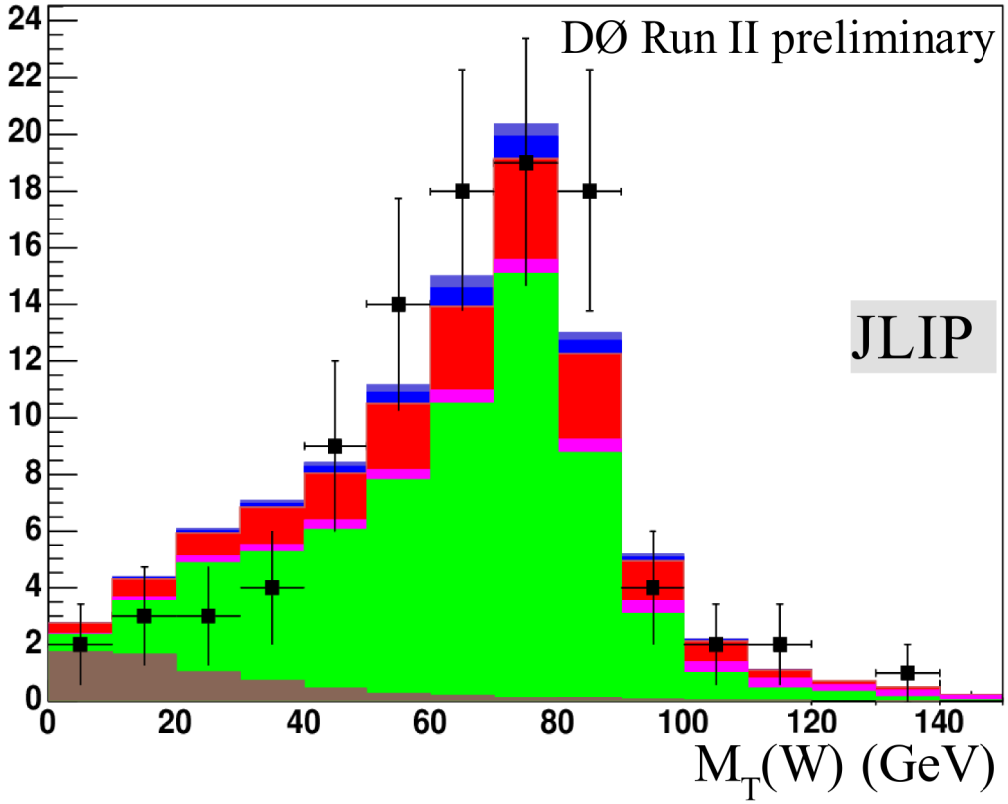
- DØ Run II Single Top Search Program is on its way
- Sensitivity from Run I already exceeded
  - Increased Data Sample
  - DØ detector is performing and understood well
- DØ is working towards observation of single top production
  - Collecting more data
  - Improve detector understanding
  - Improve analysis

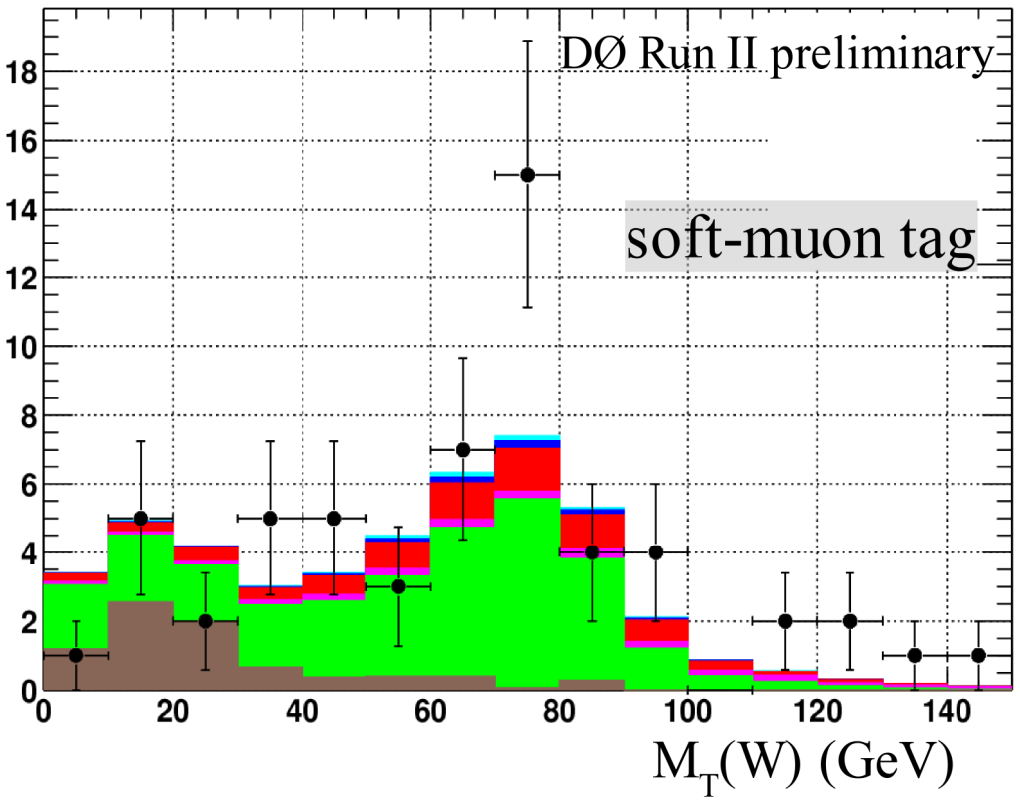
Supporting Slides

Event Yields: W Transverse Mass



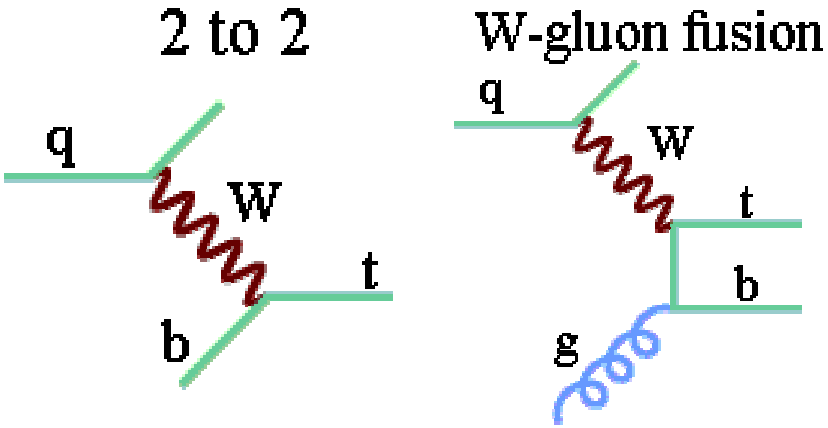




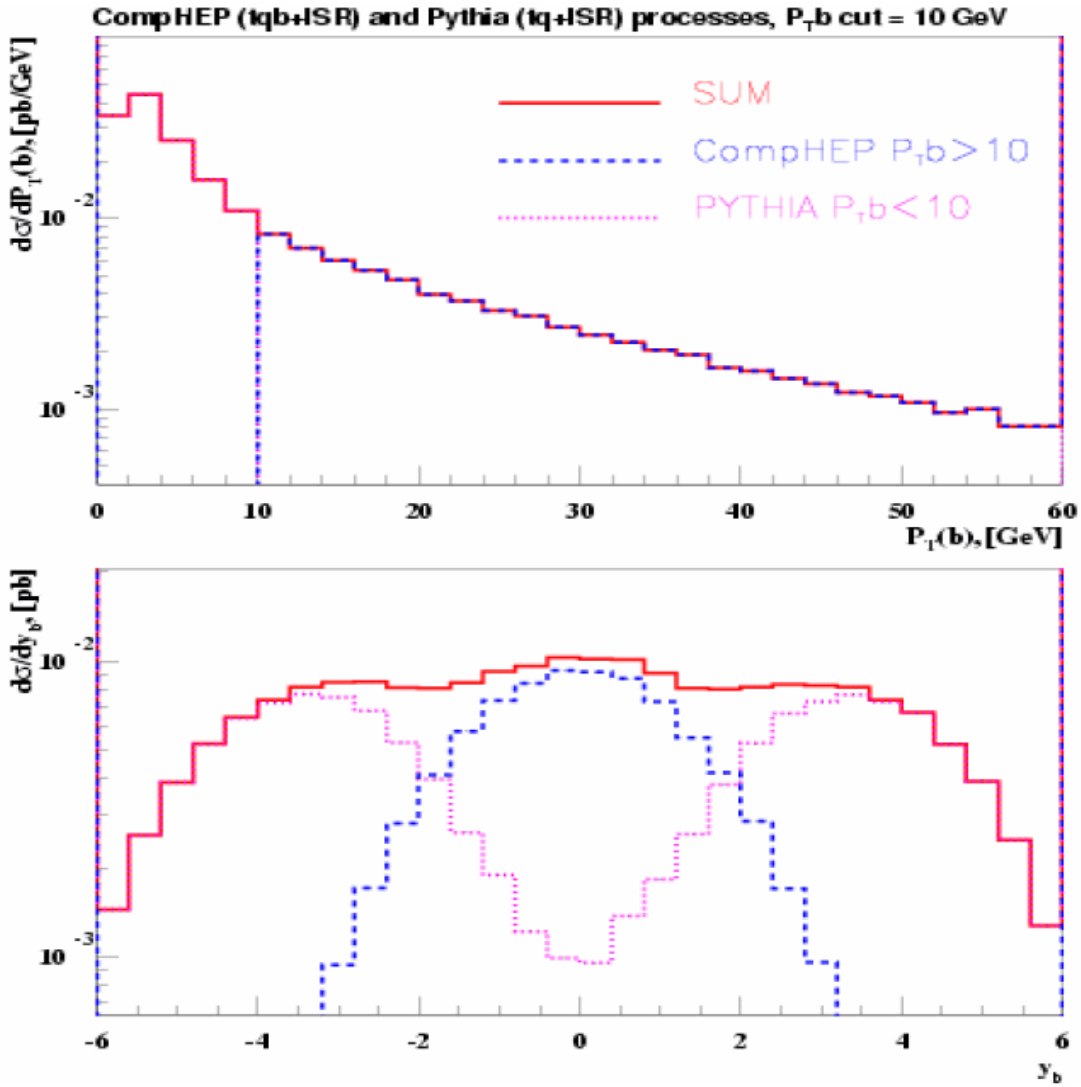


MC Modeling

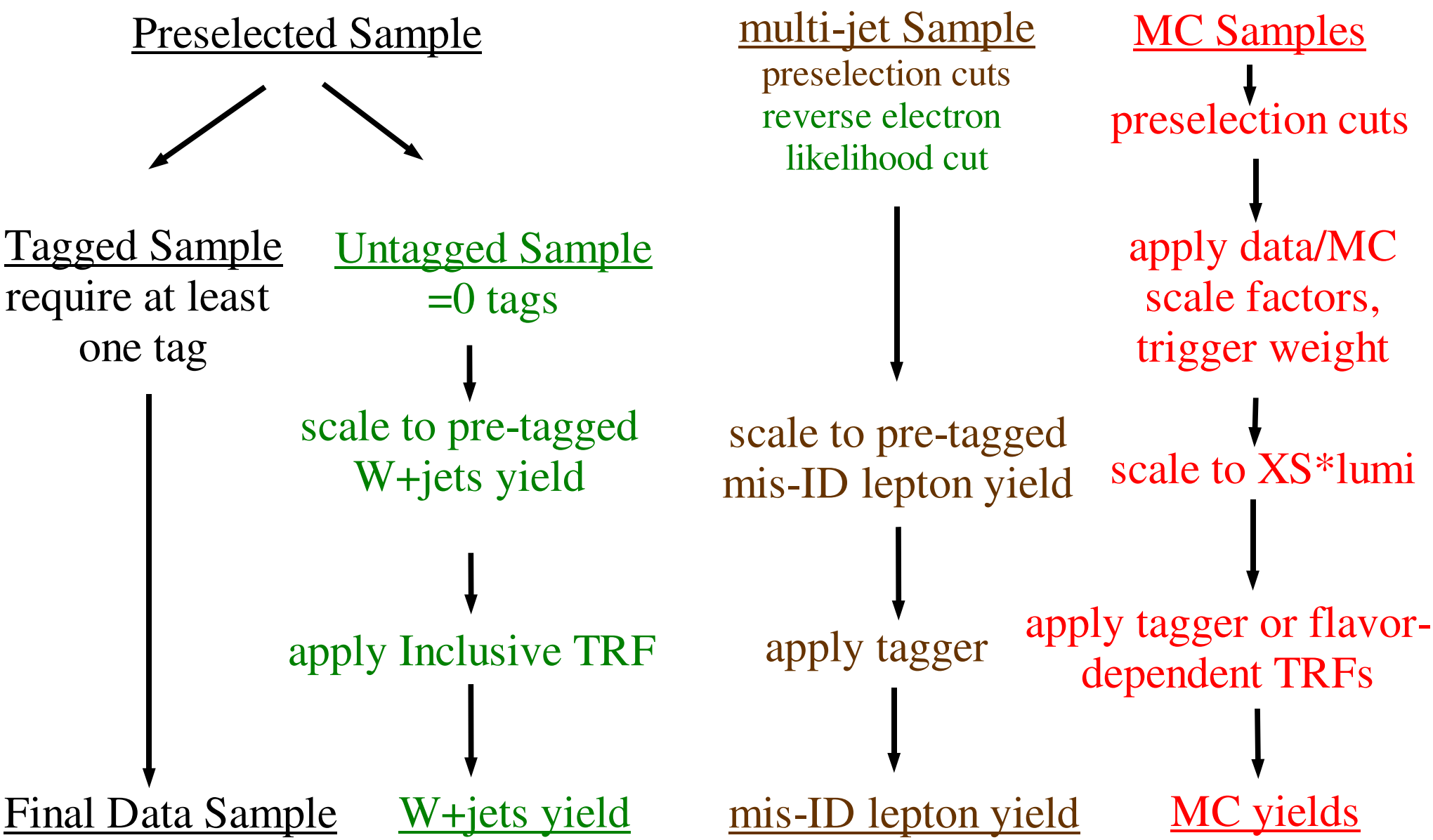
- Single Top modeling: CompHep
  - gives NLO-corrected distributions, not just LO diagrams
  - including full spin correlations
- t-channel problem:
  - how to match 2 to 2 with W-gluon fusion



solution:
phase-space matching
  - b from Pythia for soft region
  - ME generator for hard region



Background Estimation



Background Estimate: pre-tagging

- Preselected, Pretagged sample contains two components:
  - Events with *real* isolated lepton
  - Events with *fake* isolated lepton
    - Jet faking an electron
    - Muon in jet faking isolated muon
- Matrix Method to estimate relative contribution
  - Count events before/after a cut that separates the two (loose/tight)
    - Electron channel: electron likelihood cut (combination of cal/tracking)
      - Background efficiency ϵ_{QCD} determined in multi-jet QCD sample (low MET)
      - Signal efficiency ϵ_{sig} determined in Zee sample
    - Muon channel: muon isolation from jet
      - Background efficiency ϵ_{QCD} determined in QCD sample (low MET)
      - Signal efficiency ϵ_{sig} determined in Z$\mu\mu$ sample

Pre-tagged Background Yield: W+jets and QCD

$$N_L = \tilde{N}_{sig} + \tilde{N}_{QCD}$$

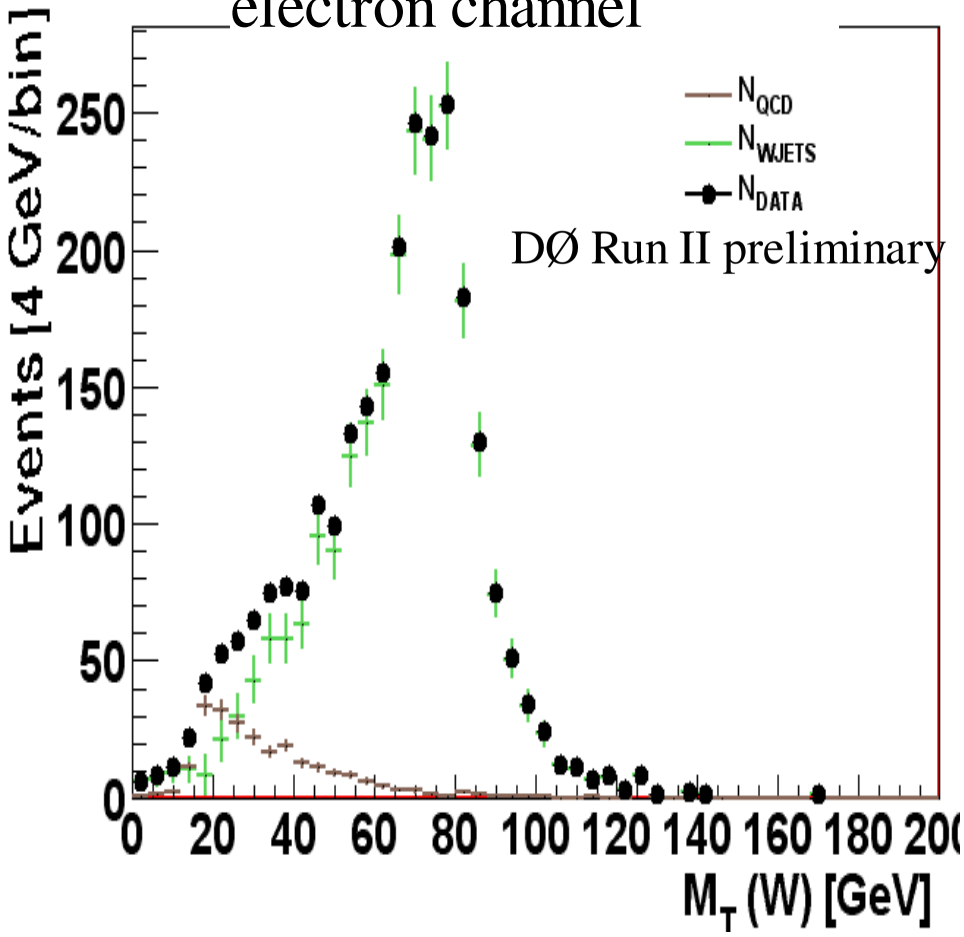
$$N_T = \varepsilon_{sig}\tilde{N}_{sig} + \varepsilon_{QCD}\tilde{N}_{QCD}$$

$$\Rightarrow$$

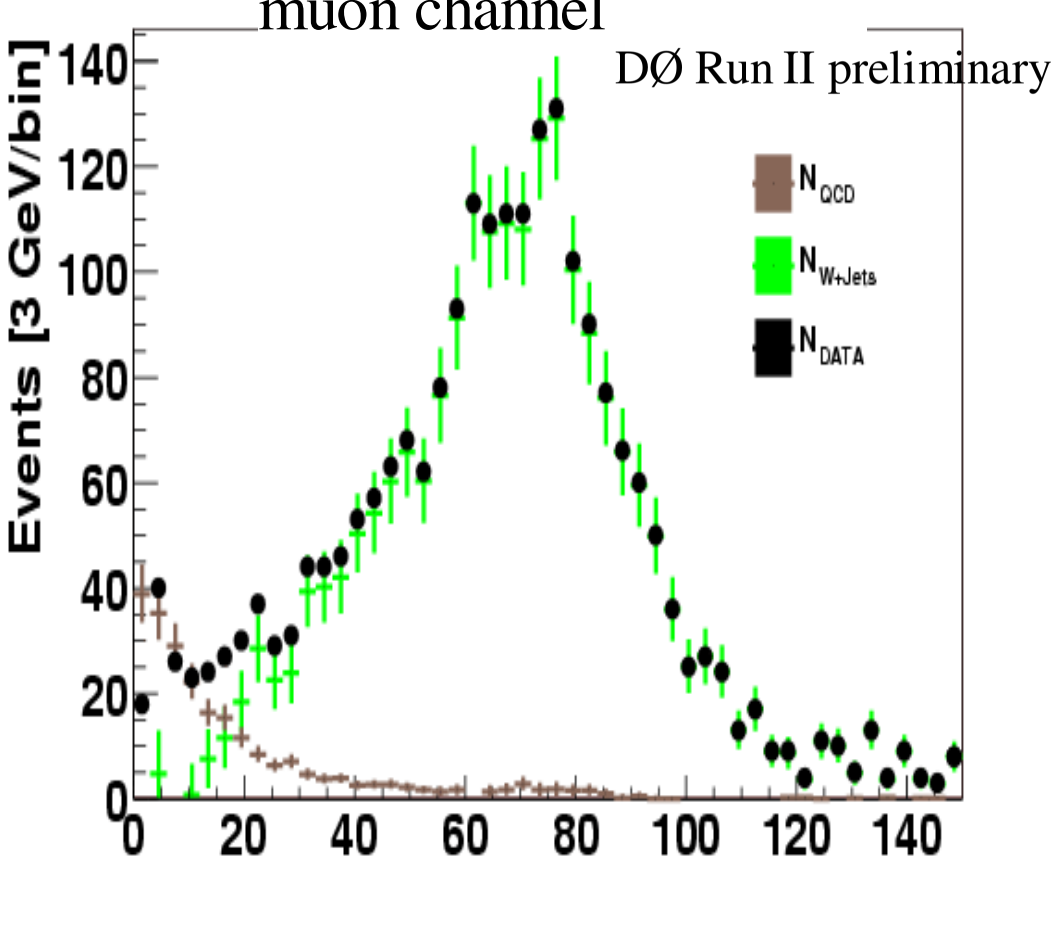
$$\tilde{N}_{sig} = \frac{N_T - \varepsilon_{QCD} N_L}{\varepsilon_{sig} - \varepsilon_{QCD}}$$

$$\tilde{N}_{QCD} = \frac{\varepsilon_{sig} N_L - N_T}{\varepsilon_{sig} - \varepsilon_{QCD}}$$

electron channel



muon channel



Background Estimate: tagged

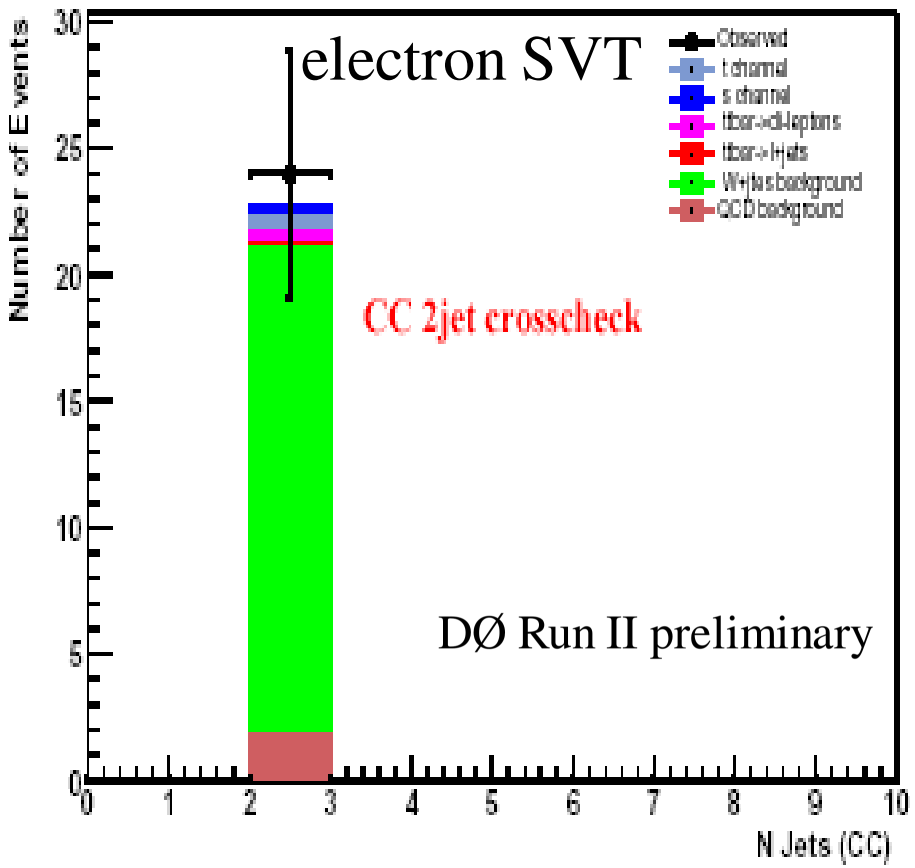
- Data backgrounds: divide preselected sample into orthogonal sets
  - Tagged signal data
    - Require at least one jet to be tagged
  - Un-tagged sample for W+jets background
    - Require that none of the jets be tagged
  - Multi-jet sample with fake isolated leptons for QCD
    - Lepton fails tight cut
- MC for signal and top pair production background
- Check prediction in W, QCD-dominated sample
  - Suppress ttbar, single top:
    - $n_{jets}=2$
    - total energy in the event HT<200GeV

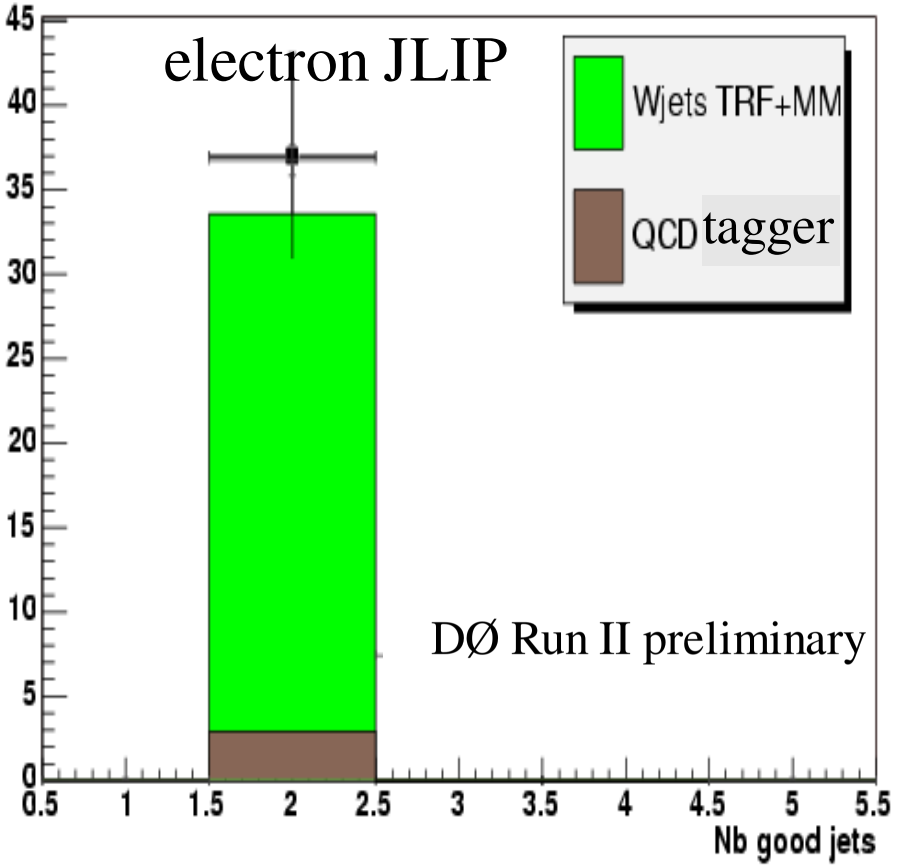
Tag-Rate-Functions

- Flavor-dependent TRF (for b-jets, c-jets, other jets)
  - determined from data with scale factors from MC
  - used to determine tagging-probability in MC events
- Inclusive TRF
  - Used to estimate tagged W+jets background from data
  - Average probability to tag a jet in an inclusive W+jets sample
  - → Approximately same as in multi-jet sample
    - Within uncertainty
  - Determine per-jet probability in multi-jet sample (=1-3%)
    - Then apply as weight to each jet in untagged W+jets sample
  - Flavor composition assumption tested in cross-check samples
    - Z+≥2 jets sample
    - In W+jets cross-check sample (n_{jets}=2, HT<200GeV)
    - Find good agreement in all samples (uncertainty ~20%)

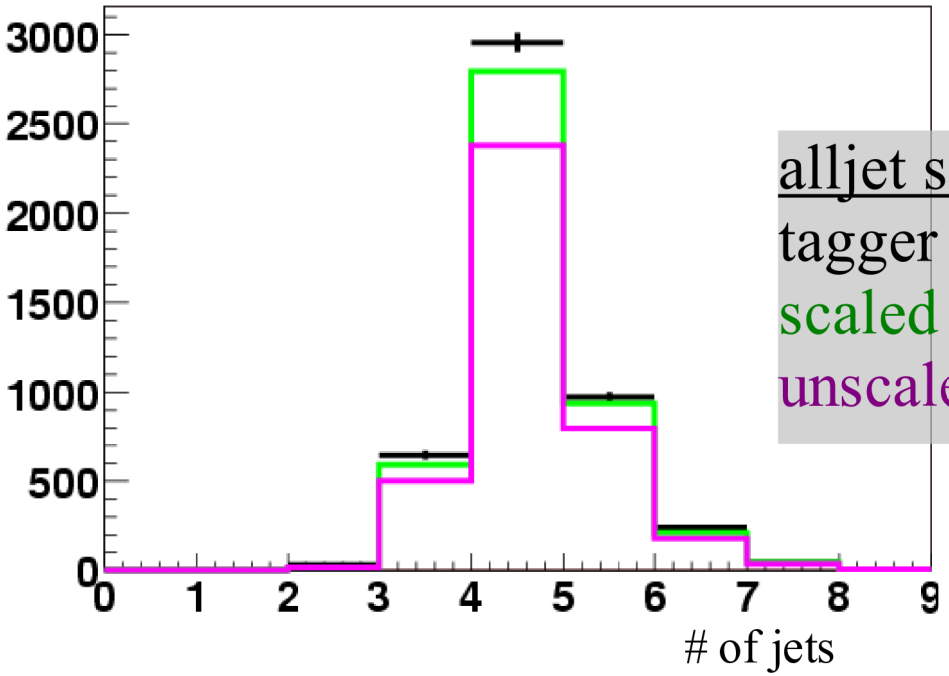
Inclusive TRF cross-checks

- Z+≥2jet sample:
  - SVT: TRF prediction: 15.7 events, tags found: 17
  - JLIP: TRF prediction: 14.9 events, tags found: 20
- W cross-check sample
  - muon channel SVT: prediction: 31.6, tags found: 27

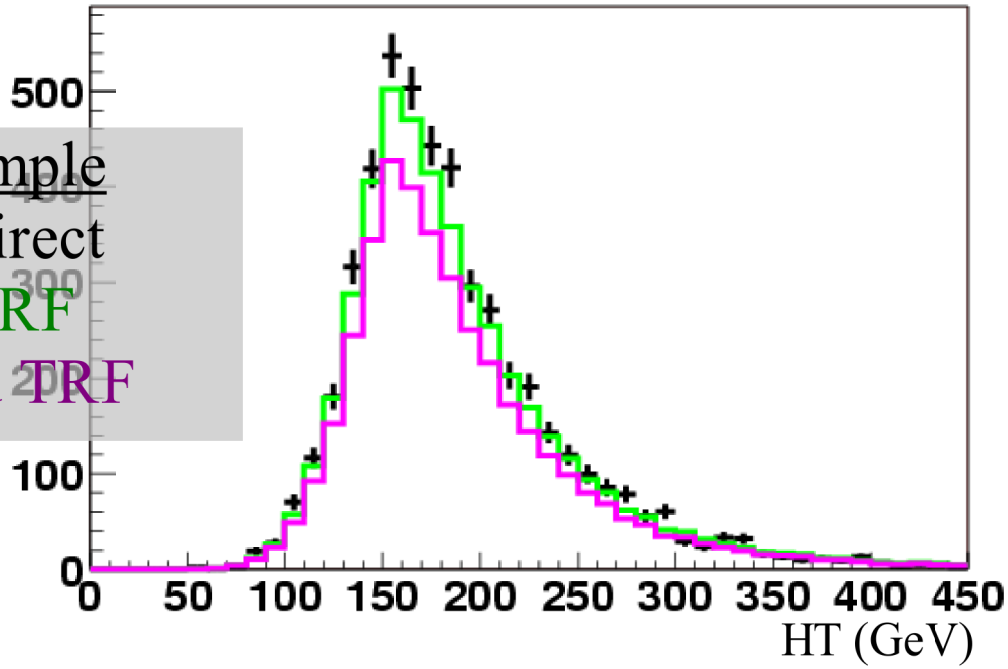


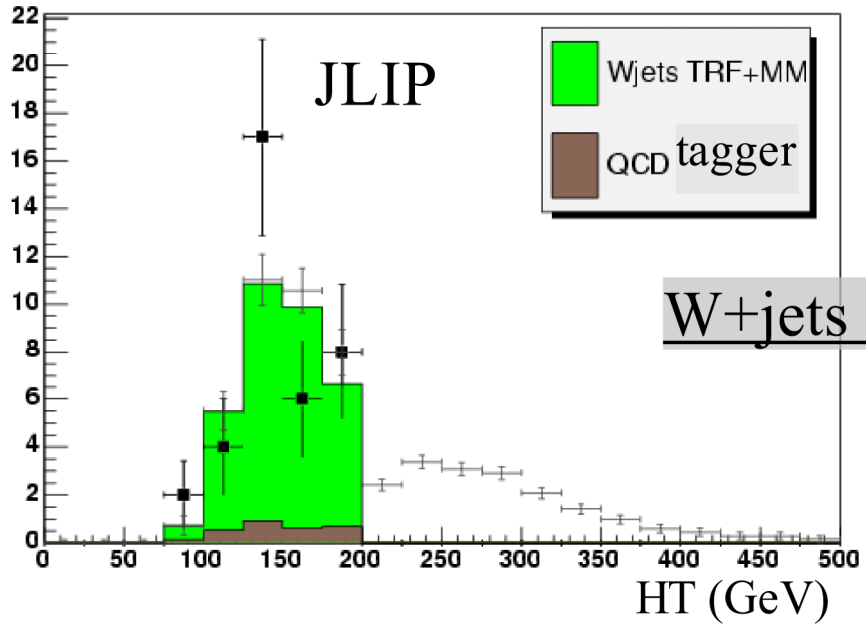


inclusive TRF cross-checks

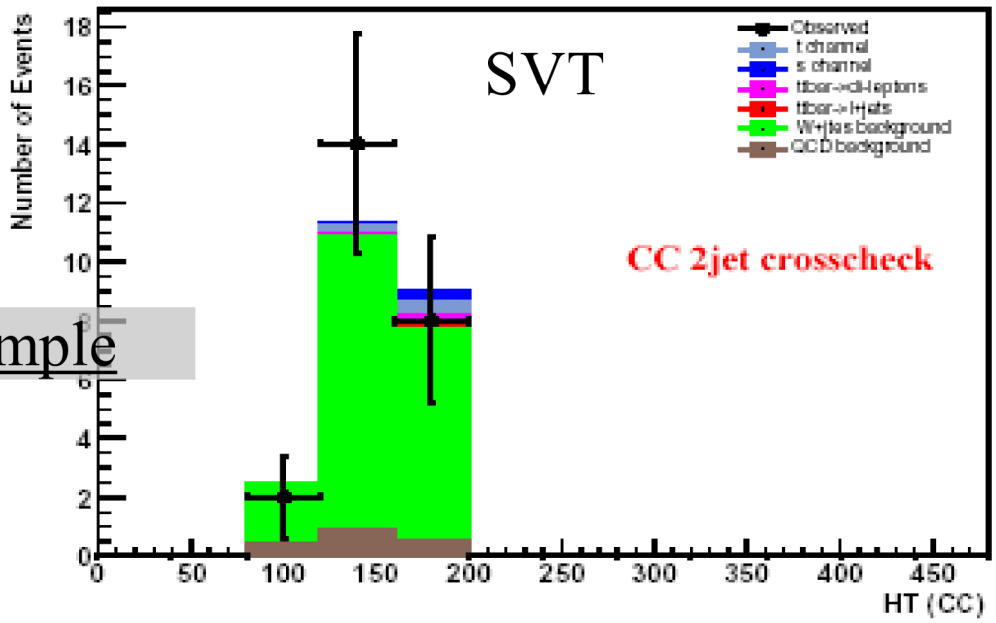


alljet sample
tagger direct
scaled TRF
unscaled TRF





W+jets sample



Event Yields

	SLT	SVT	JLIP
Signals			
MC s-channel	0.6 ± 0.2	1.8 ± 0.4	1.8 ± 0.5
MC t-channel	0.9 ± 0.3	2.9 ± 1.0	3.0 ± 1.1
MC s+t combined	1.6 ± 0.4	4.7 ± 1.4	4.7 ± 1.5
Backgrounds			
MC $t\bar{t} \to \ell$+jets	7.0 ± 1.6	18.3 ± 4.4	19.2 ± 5.2
MC $t\bar{t} \to \ell\ell$	2.7 ± 0.3	5.0 ± 0.8	5.2 ± 1.0
W+jets + fake-ℓ data	24.7 ± 4.1	45.8 ± 8.9	49.7 ± 9.9
Sum of backgrounds	34 ± 5	69 ± 10	74 ± 12
Observed data	54 ± 7	63 ± 8	65 ± 8
Acceptance	0.35%	0.97%	0.98%