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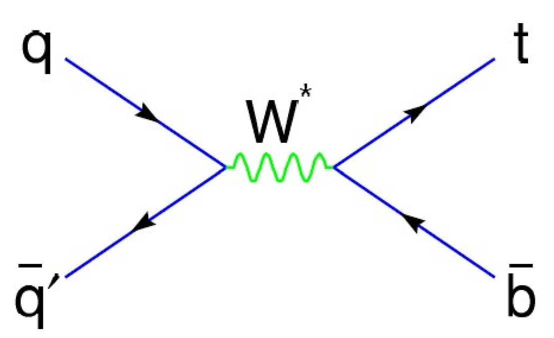
The Lonesome Top Quark

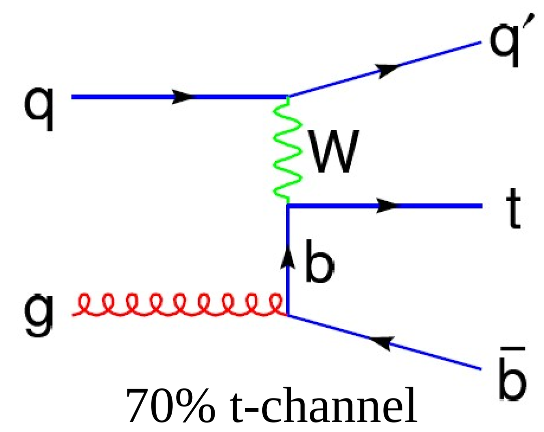
The top quark has only been observed when produced in pairs of top and antitop by means of the strong interaction. But top quarks may also be produced through the electroweak interaction, and produced alone, along with a bottom quark. The production rate of this "single top quark" process is smaller than that of pairs of top quarks and it poses an experimental problem to disentangle from the large backgrounds, one of which is pair production itself!
We expect to observe this new mode of production at the Tevatron and look for deviations from the Standard Model.

Single Top Quark Production

According to the Standard Model, at the Tevatron top quarks can be produced via the exchange of a W-boson in two dominant modes: **s-channel** and **t-channel**.



30% s-channel



70% t-channel

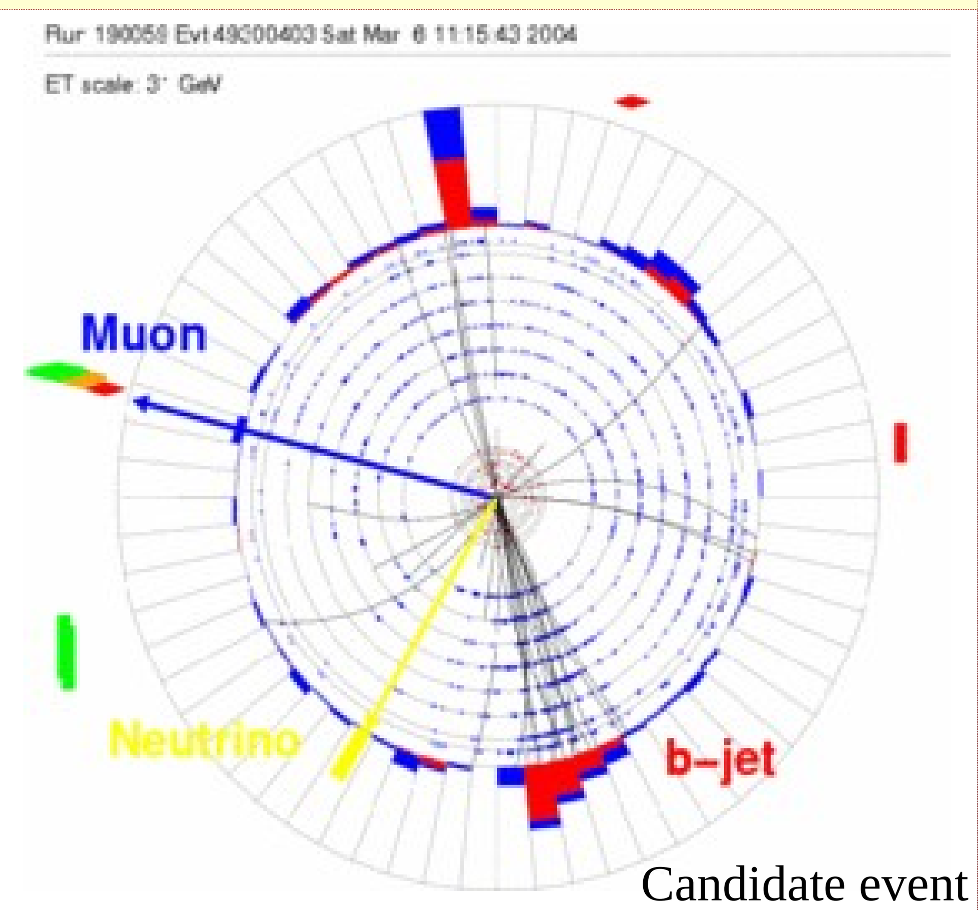
The theoretically expected **production rate** (cross-section) at the Tevatron's center of mass energy of 1.96 TeV is **2.9 picobarns** (1 pb = 10^{-12} barn = 10^{-36} cm^2), 0.88 pb for the s-channel and 1.98 pb for the t-channel. The final state, concentrating only on semileptonic top decays ($t \to bW \to bl\nu$), consists of: **one isolated lepton, missing transverse energy (neutrino), and two b-jets or one b-jet and a light (non-b) jet**.

By observing the interaction vertex between a W-boson, a top quark and a bottom quark at production, we can measure directly -and for the first time- the strength of the coupling between these particles: the so-called **V_{tb} element** of the Cabibbo-Kowayashi-Maskawa (CKM) mixing matrix. So far only indirect constraints exist on this parameter.

But the interest of this process goes beyond the Standard Model:

- **New heavy particles** could enhance the production cross section in the s-channel,
- **Anomalous couplings** (like those predicted from a 4th family of quarks or other exotic theories) would enhance the t-channel production.

Thus, top quarks offer a vantage point to study new phenomena beyond the Standard Model given their high mass and their preferred coupling to the Higgs boson that is thought to give mass to all particles.



Candidate event

Search for Single Top Quarks

Selection cuts & b-tagging

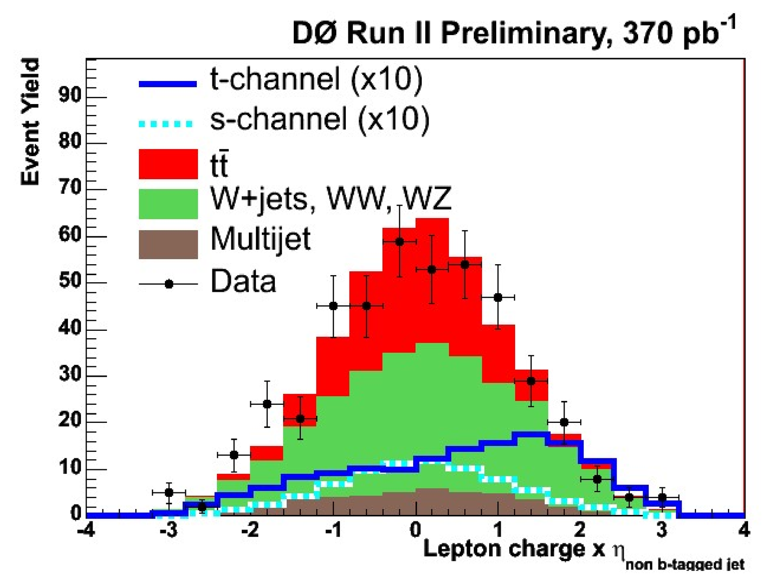
Selection

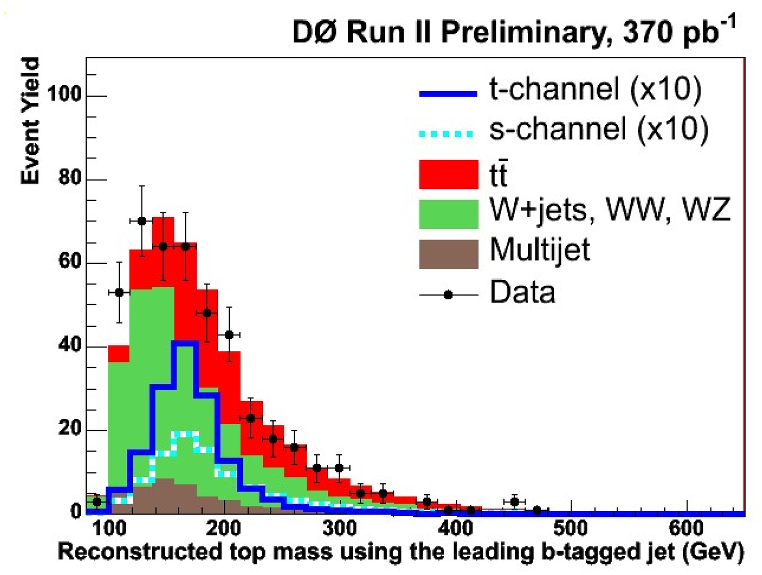
Events are selected loosely, trying to keep a high acceptance since this is a search, with a basic set of cuts: One electron or muon with p_T>15 GeV, Missing Energy >15 GeV, and 2, 3 or 4 jets each with energy >15 GeV, the leading jet with energy >25 GeV.

We apply the **Jet Lifetime Probability** (JLIP) algorithm to identify a b-jet with **~50% efficiency** and **~99.6% purity**, greatly reducing the W+jets and multijet backgrounds. The algorithm relies on the fact that tracks from B-hadrons have a **large impact parameter** with respect to the primary vertex.

At this point we expect around **25 single top events** in our data sample of **443** events, where we expect some **451 background** events.

Discriminant variables

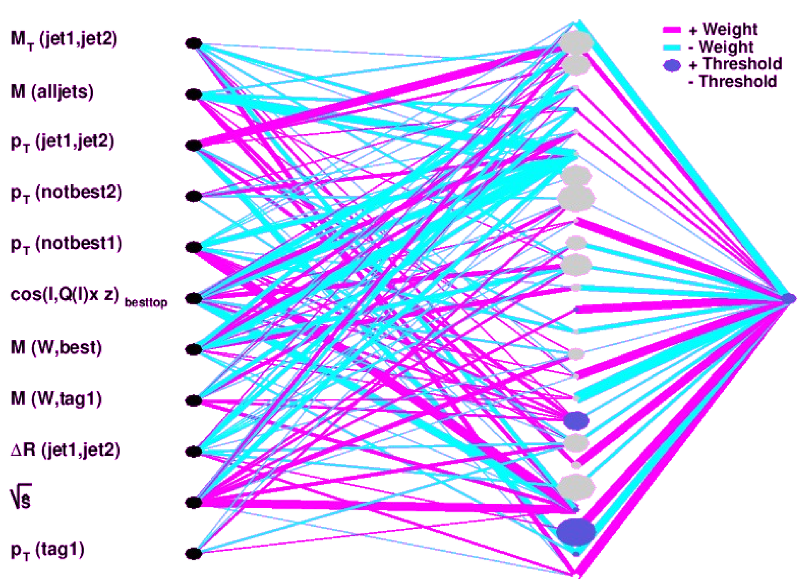




Multivariate analyses to separate signal from background

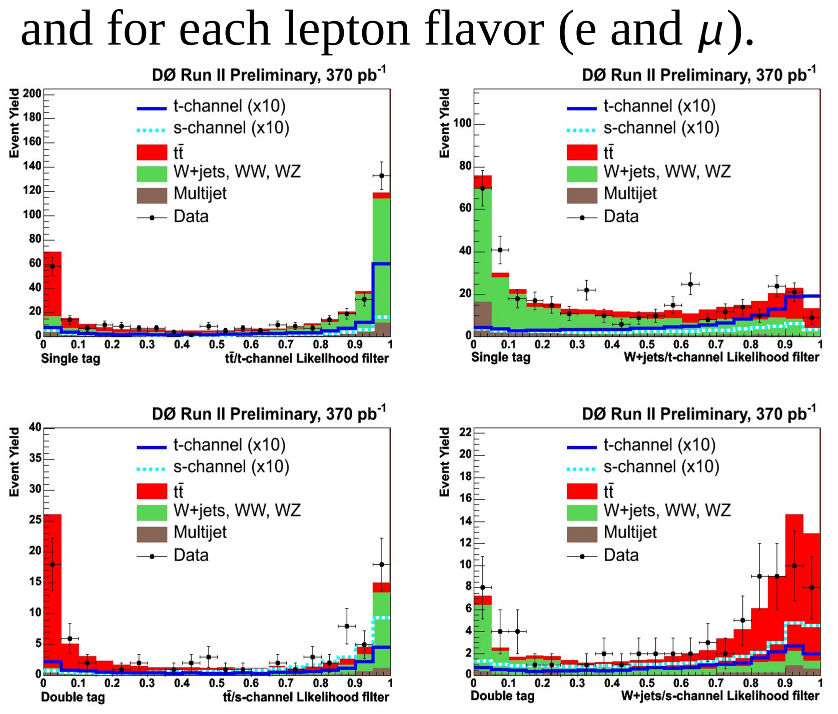
The selection is loose intentionally so that advanced multivariate techniques can exploit the kinematic differences between the single top signal and backgrounds.

One example is **Neural Networks**, which define curved surfaces in the phase space of the input variables to optimally separate between signal and backgrounds.



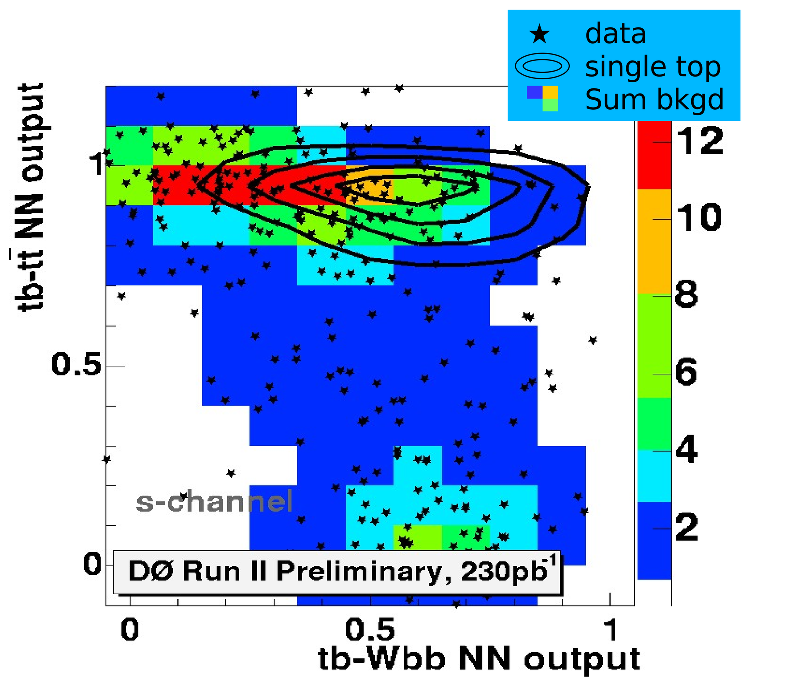
PLB 622, 265 (2005)

A **likelihood discriminant** is another multivariate technique which incorporates the shapes of mostly uncorrelated input variables to distinguish between signal and backgrounds. We form a discriminant for each s- and t-channel signal, for the two major backgrounds (W+jets and $t\bar{t}$), for one and more than one b-tags and for each lepton flavor (e and μ).

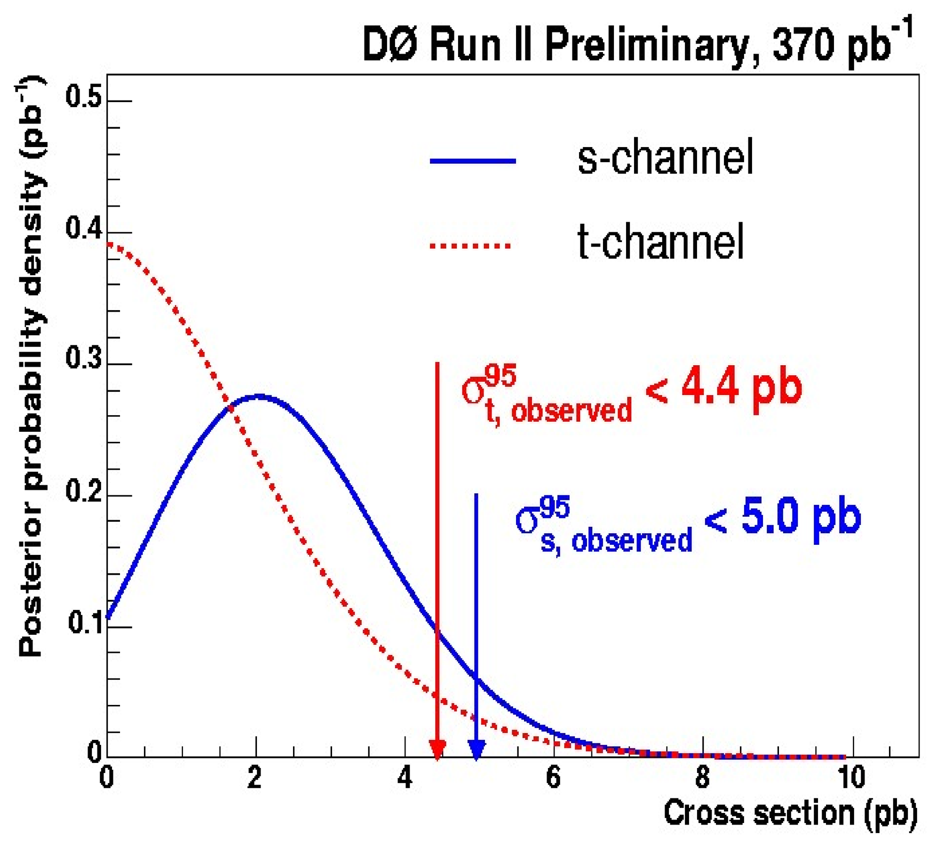


Limit setting procedure

Instead of cutting on the output of the discriminant to count the expected number of single top events versus the backgrounds, we build a binned likelihood function based on the Poisson probability to observe the number of events in each bin of each distribution. A Bayesian analysis returns a posterior probability density function which can be used to calculate the limit.



Summary of Results and Projected Sensitivity



Likelihood discriminant results with 370pb^{-1} of data, 95% CL upper limits:

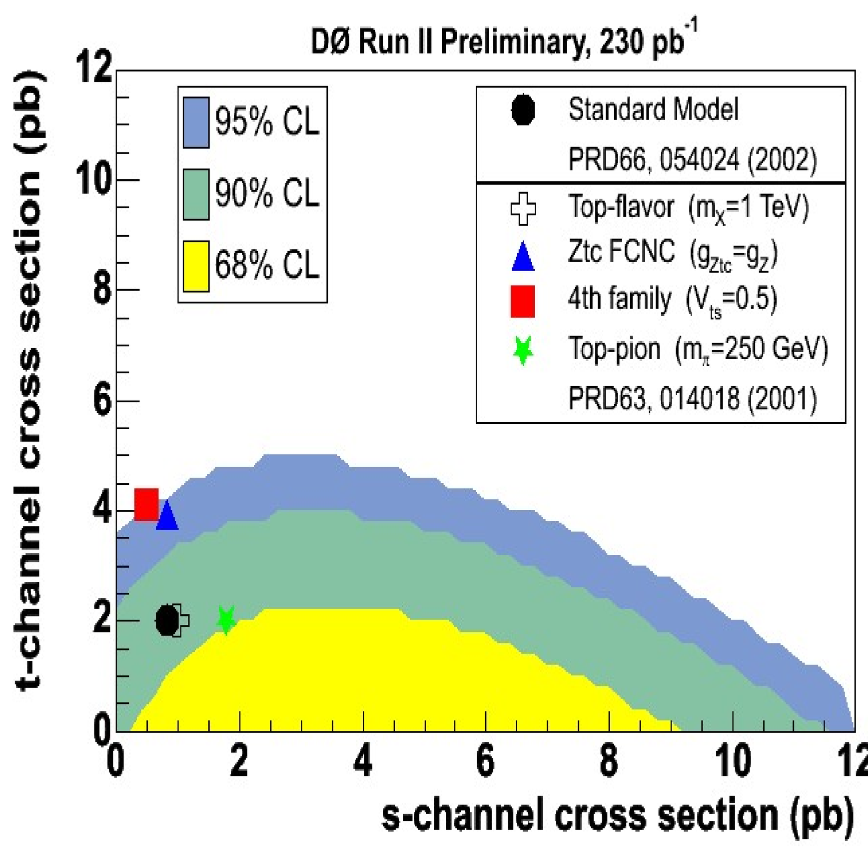
s-channel cross section < 5.0 pb

t-channel cross section < 4.4 pb

Neural networks and likelihoods have similar sensitivity.

Most stringent limits obtained thanks to:

- **Multivariate analysis** (NN and Lhood)
- Use the **shape information** from the multivariate output to set the limits



←Exclusion on the plane of s- and t-channel cross sections. The colored points represent models of physics beyond the Standard Model

→Given the current DØ analysis, we would need a few fb^{-1} for an observation. But of course we are going to improve the analysis, so expect an observation sooner!