

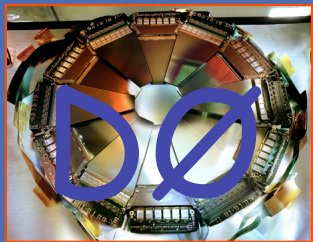
The Search for Single Top Production



G. Watts (University of Washington)

University of Oregon





10 Years Since Discovery

Mark Observation

(it feels like a long time ago and a galaxy far, far, away)

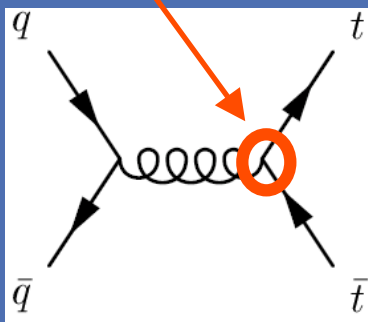
• Pair Production

Strong Force

$$\diamond = 6.8 \pm 3.6 \text{ pb}$$



$$6.4 \pm 2.2 \text{ pb}$$



• What Have We Learned?

• $W \rightarrow tb$ decay

• EWSB Connection?

• Resonance Searches

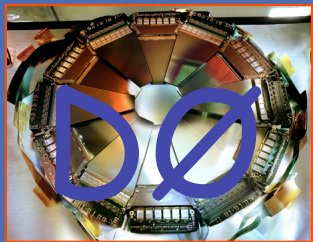
• Decay Before Hadronization

• B-Tagging

• Top Quark Mass

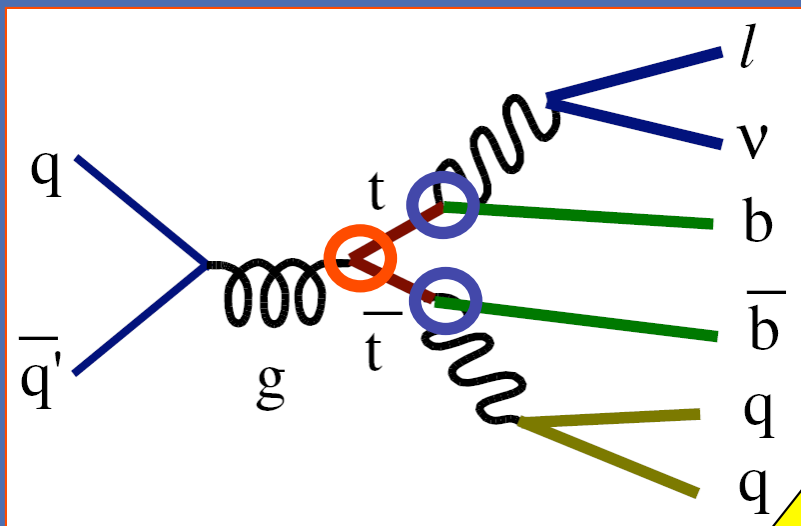
• SM Higgs Coupling





Second Way To Make Top...

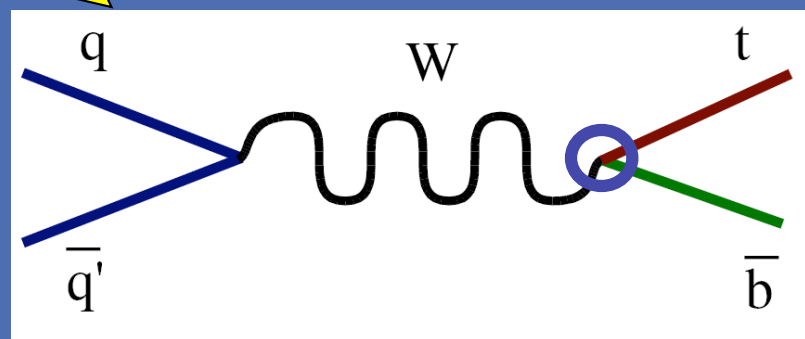
Strong Production

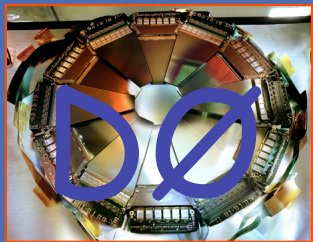


In Pair Production EW process doesn't play a major roll in the cross section

But in EW Production it plays a direct roll...

EW Production





Why Single Top?

Measure Wtb vertex

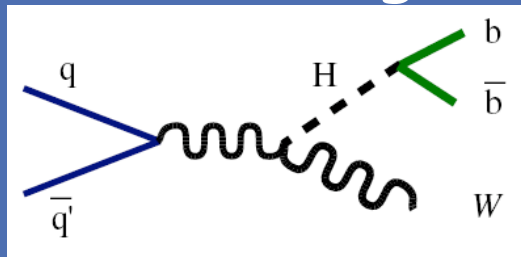
V_{tb} has not been directly measured

Is constrained by $V_{td}^2 + V_{ts}^2 + V_{tb}^2 = 1$ (implies SM test)

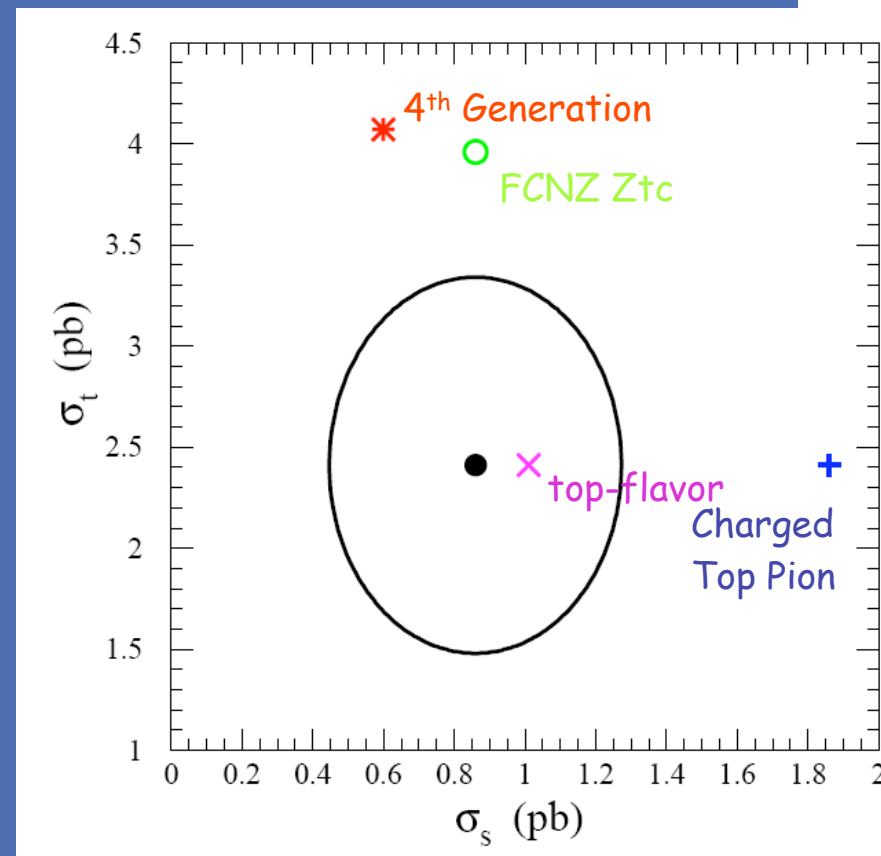
Physics Beyond The Standard Model

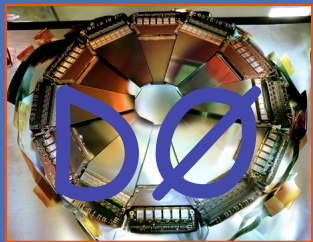


Tomorrow's Background!

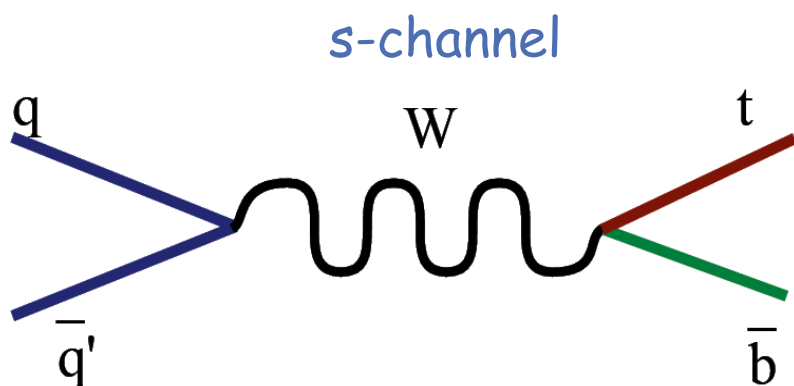


We want to see it!



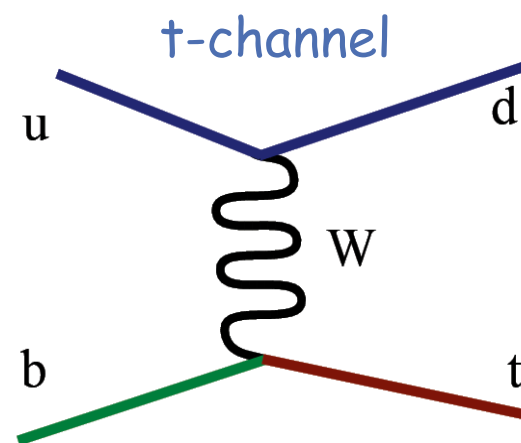


Production At The Tevatron



$$\sigma_{\text{NLO}} = 0.88\text{pb} \pm 8\%$$

hep-hp/207055 (Harris, Laenen, Phaf, Sullivan, Weinzierl)



$$\sigma_{\text{NLO}} = 1.98\text{pb} \pm 11\%$$

⇒ Top decay to Wb , W to leptons

⇒ W to jets has too high a QCD background

Too small for the
Tevatron (LHC?) Tait
- hep-ph/990352

Chicago ↑ (45 minutes)

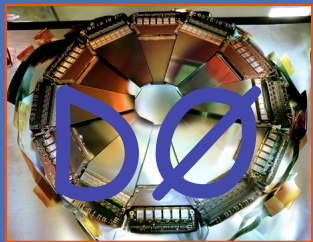


Tevatron

AP Storage

Main Injector
Recycler

Seattle ↓ (4 hours)



It's The Luminosity, Stupid!

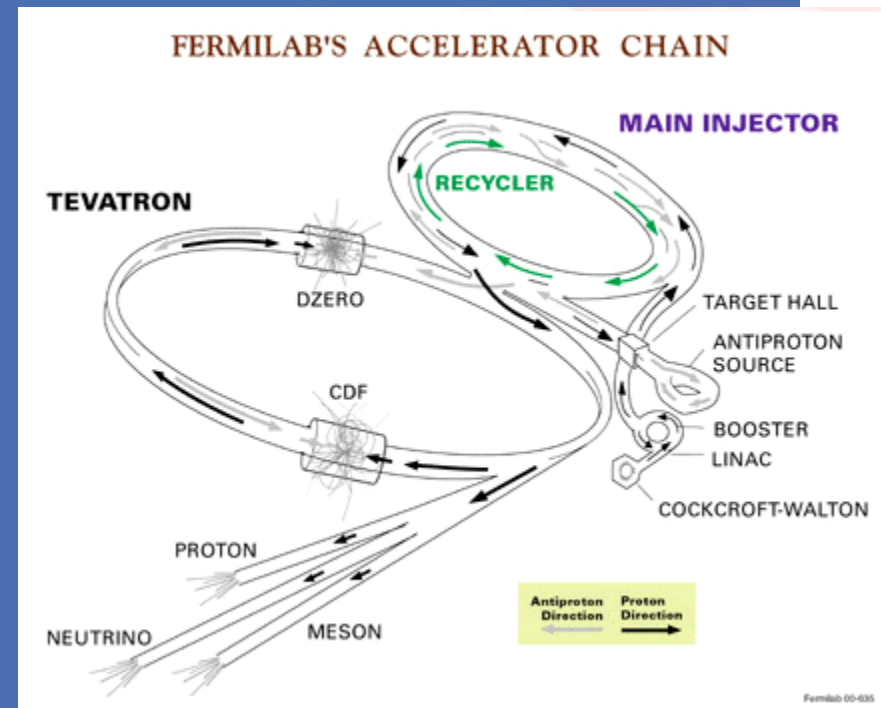
Luminosity is the Key To the Physics

Estimate need $1-2 \text{ fb}^{-1}$ to discover ST Production

CDF & DØ Discovered Top within days of each other..

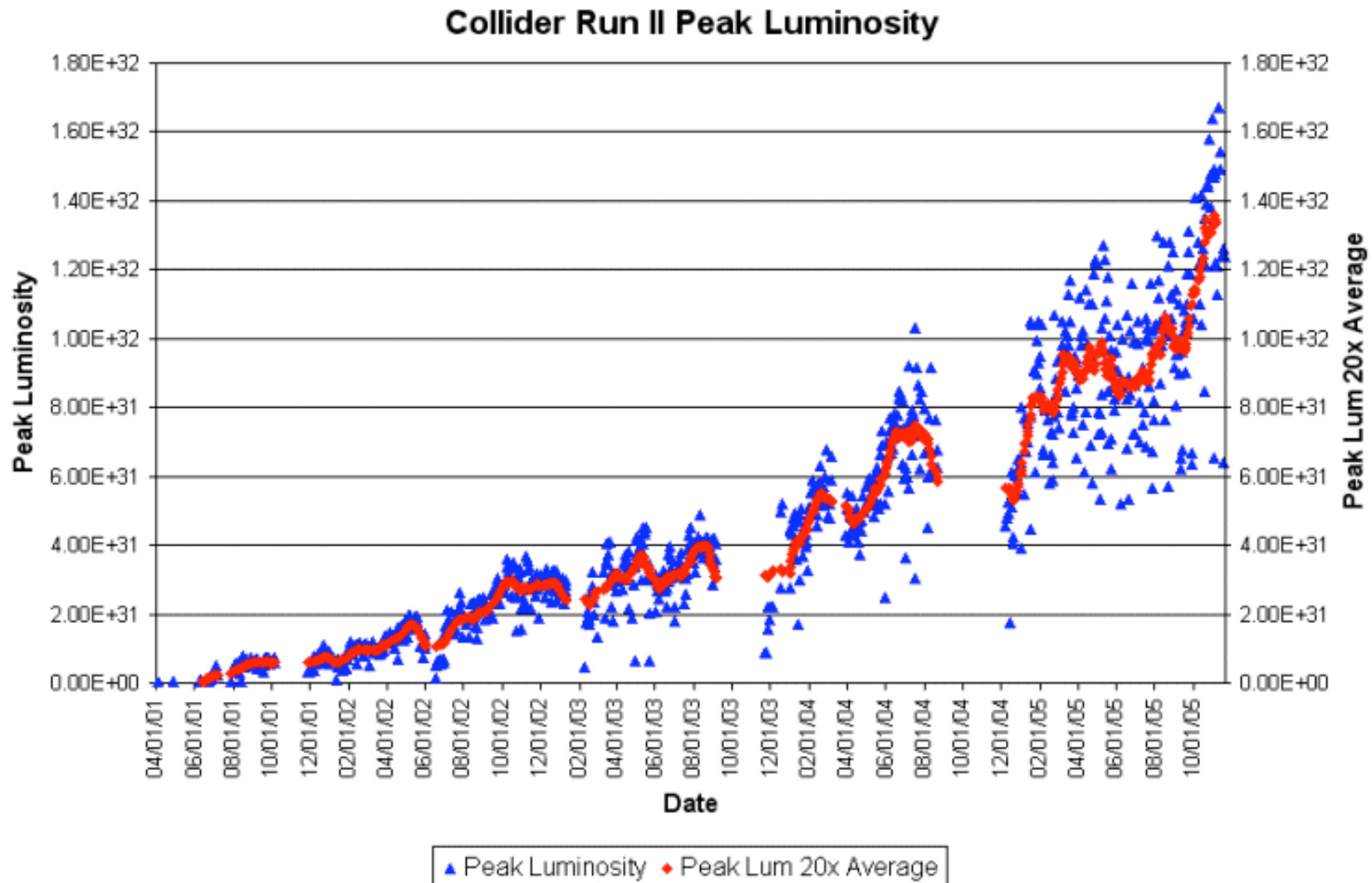
At The Tevatron The Key are the Anti-Protons

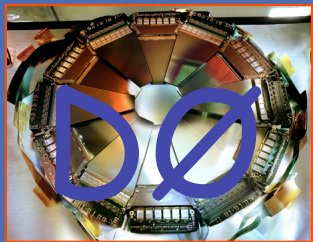
It takes >12 hours to create enough anti-protons for a store.





Setting Records...



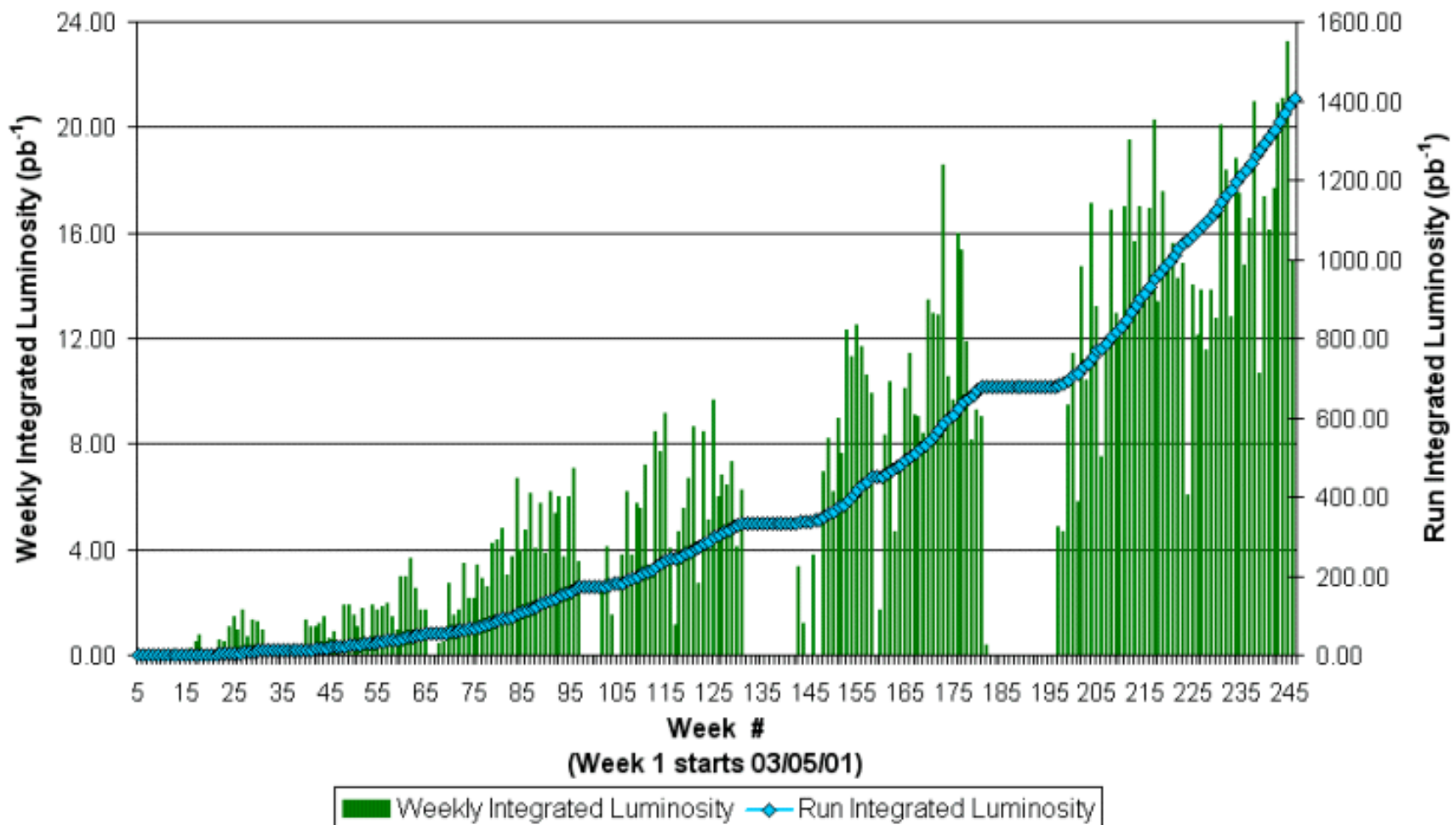


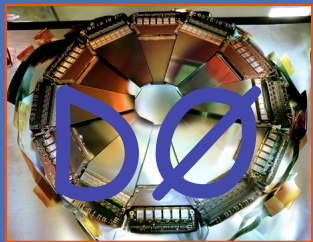
>1 fb⁻¹ Delivered...

Delivered/Experiment



Collider Run II Integrated Luminosity



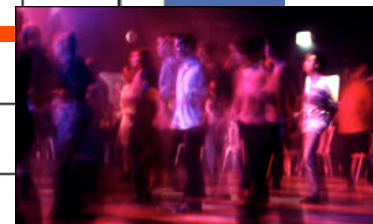
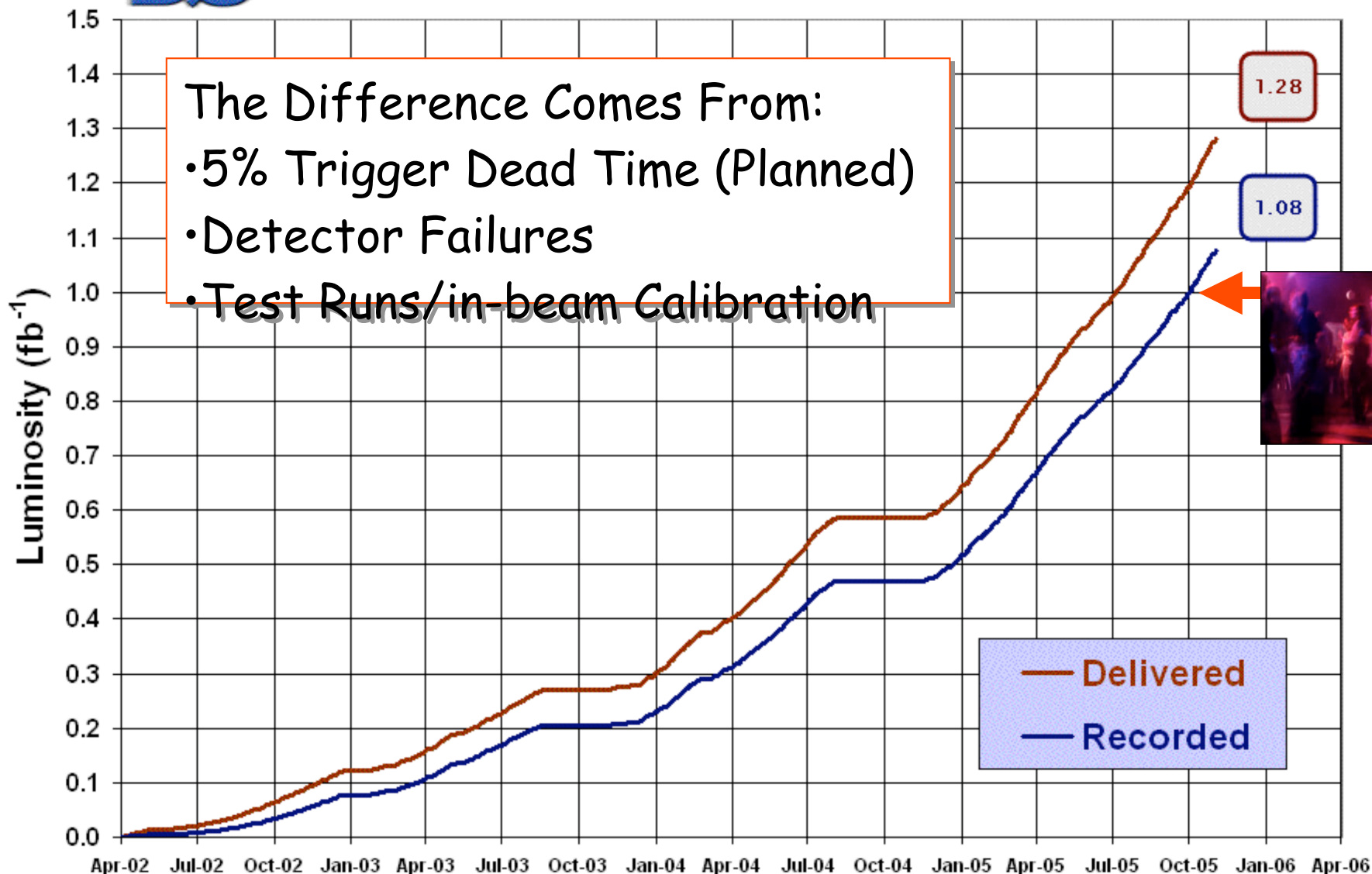


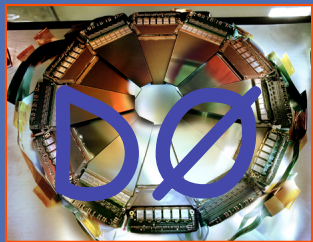
A+ DØ...



Run II Integrated Luminosity

19 April 2002 - 20 November 2005





General Comment...



Results From the Tevatron are Interesting as long
as you can keep doubling the Luminosity

Rule of Thumb for most Analysis, searches or
otherwise at the TeV...

Then there is ... P5...

see www.interactions.org

Cable Tray

Silicon Vertex
Readout Chip

Fiber Tracker
Readout Card

Fiber Tracker
Optical Cables

Inside Face of the
LaAr Calorimeter

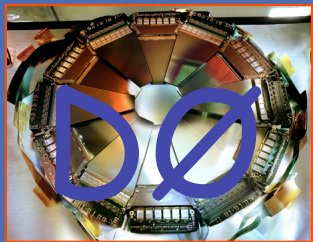
End Cap Muon
Scintillator

Fiber Tracker Cryostat

Cabling on face
of Calorimeter

4 Stories





The Detector

132ns between bunch crossing
Multiple Interactions at Every Crossing...

~ 1 million Readout Channels

~ 100 Hz to tape

PEPII: 4.2ns

ATLAS: 25ns

ATLAS: x10

Similar...

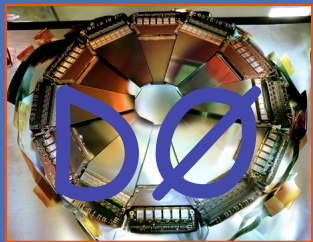


Hardware
Triggers

→ Characteristics

→ Function

Software
Triggers



The Trigger

Trigger Efficiencies At High Luminosities

Triggering at a Hadron Collider is a mess

Muon + Jets Trigger Efficiency

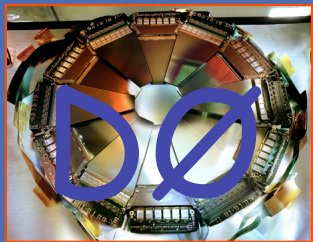
Early Run Efficiency: ~89%

Current Efficiency: ~75%

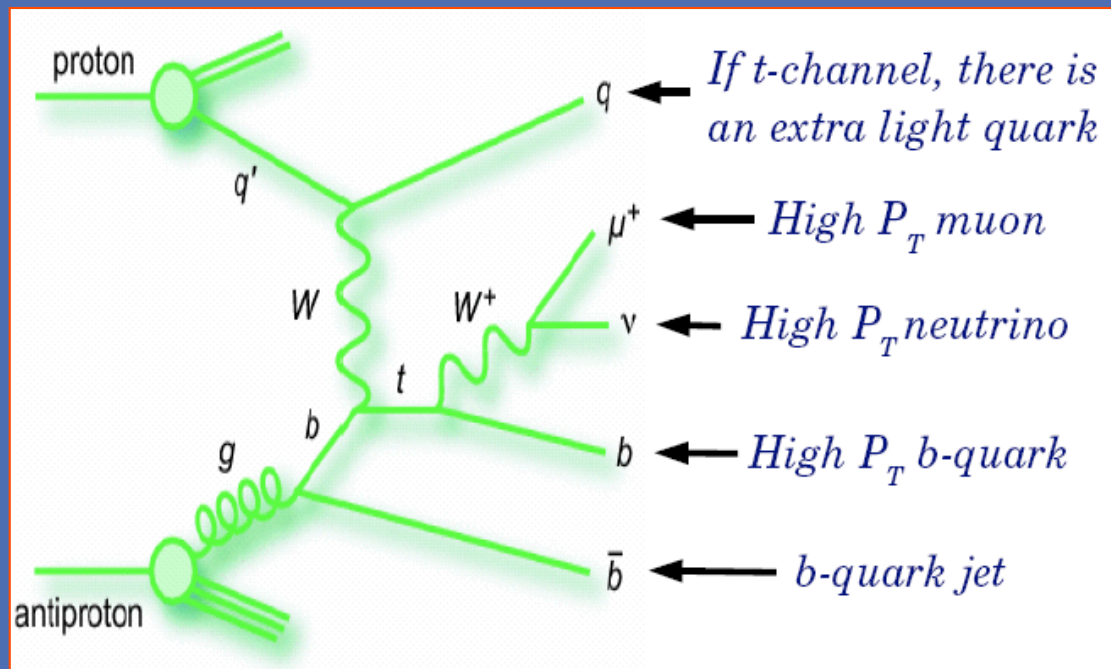
Maximize the Physics

Constrained by the Hardware

Now... Back to Singletop...



Signature & Backgrounds



Signal for s and t channel mostly similar

- Lepton + Missing E_T + Jets
- t -channel extra b tends to be forward
- Similar to top pair production, but with less jets

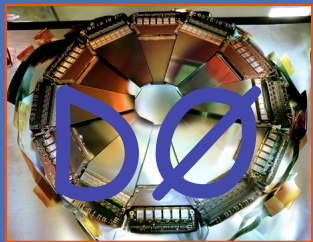
⇒ Harder To Find than $t\bar{t}$

Backgrounds

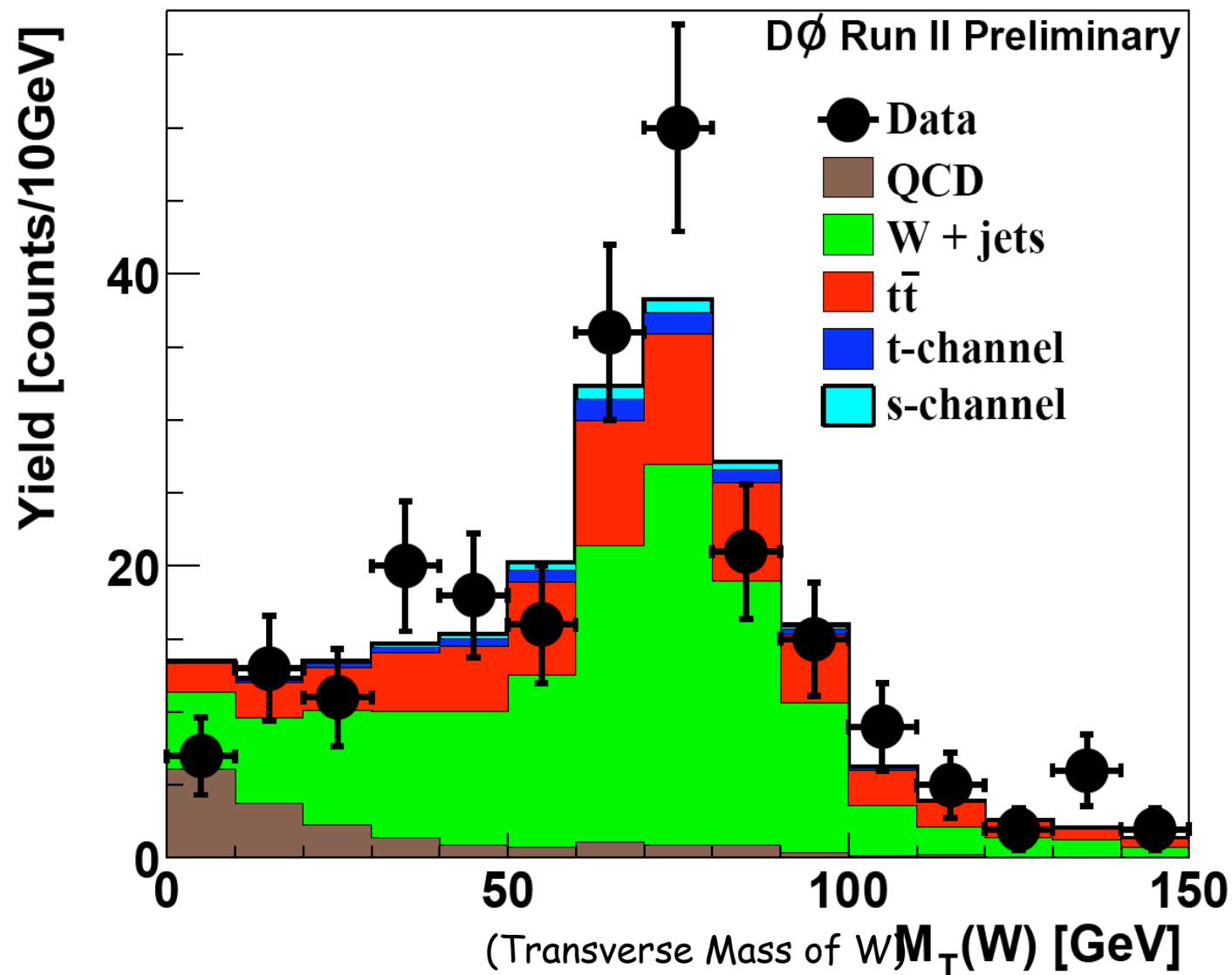
- W/Z + jets Production
- Fake Leptons
- Top Pair Production
- WW , WZ , $Z\tau\tau$, etc.

Much worse than for pair production because of lower jet multiplicity

Anything with a lepton + jets signature



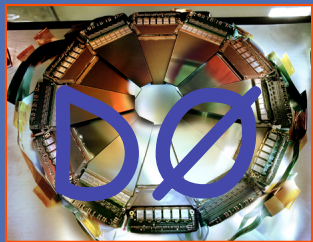
How Bad Is It?



W is Largest Background!
Also one of hardest get right!

This plot is after a single b-tag required!

From DØ Analysis, after selection cuts and requiring a b-tag.



Monte Carlo Aside...

Signal Generation

In the end, pulling signal from background is more than just counting... We will be depending on the shapes of distributions...

ZTOP (Sullivan) is gold standard

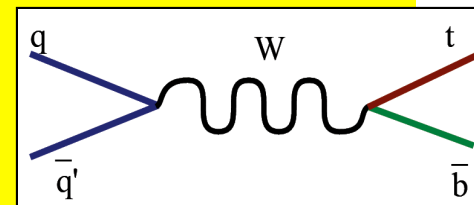
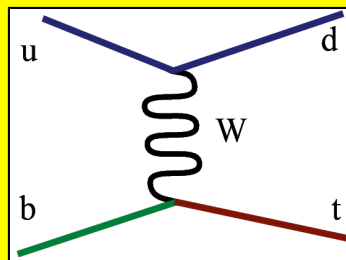
But Does Only Cross Section Calculations

DØ uses CompHEP and matches the $2 \rightarrow 2$ and $2 \rightarrow 3$ events using the extra b-quark p_T
CDF is similar (bq,gq), but uses MadEvent.

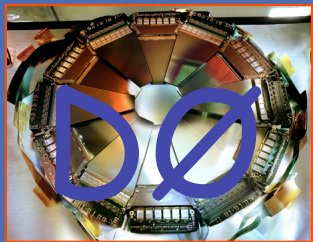
MCNLO **NLO Event Generator...**

Should make our lives simpler in the future!
(Sullivan has already cross checked it)

s-channel is easy (LO)...



t-channel has that b in the initial state...



Monte Carlo Aside...

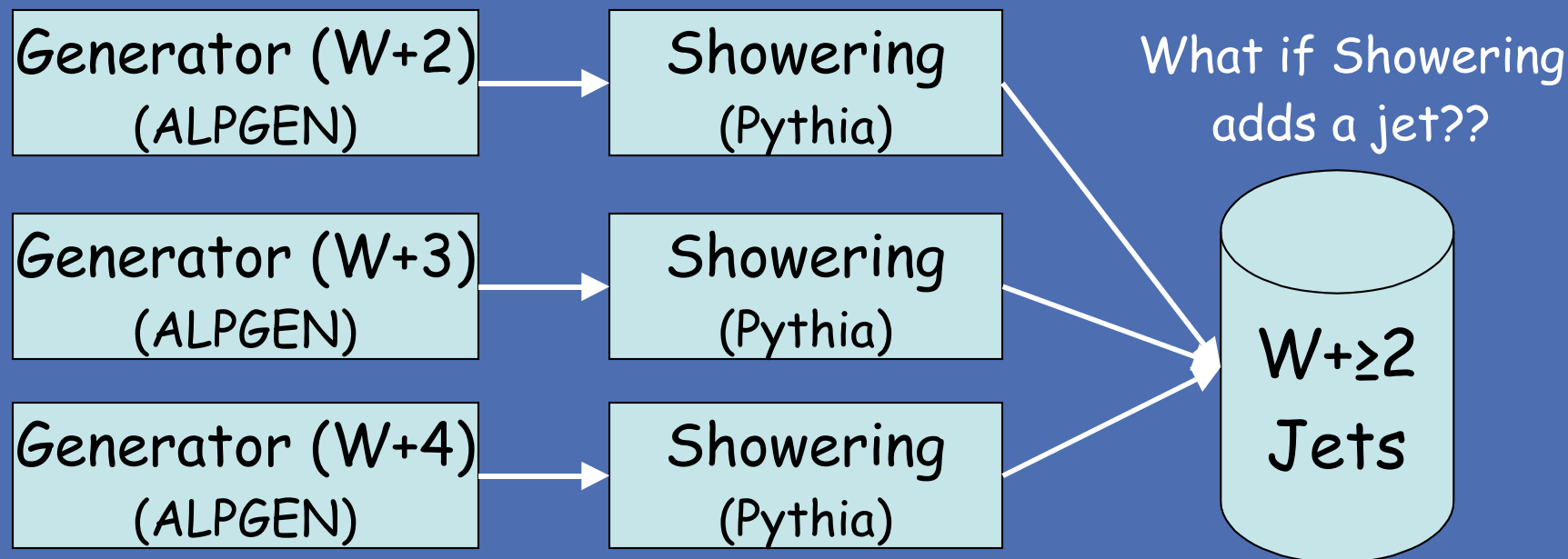
Background Generation

W+Jets and ttbar are the most important backgrounds.

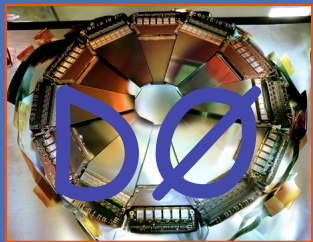
Well understood

Not Well understood

1 Jet Double Counting



We are getting our hands around this one



Monte Carlo Aside...

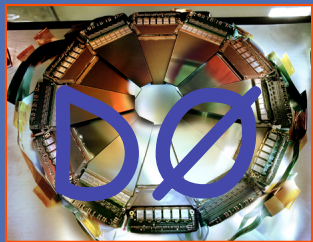
2 Sources of Heavy Flavor

This analysis makes heavy use of b-quark tagging
What we know/don't for charm, bottom production is amplified

Final States: $Wc\bar{j}$, Wcc , $Wb\bar{j}$, Wbb , etc.

Some require heavy flavor in the initial state...

Do we understand the relative proportions??
Each diagram may contribute to shape variables



Analysis Strategy

Analysis Strategy

Pre-selection
Cuts



Final Cuts

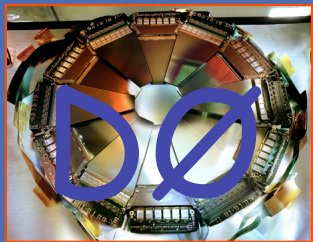


Limit Fitting

Clean up the data, remove
detector backgrounds.
Does not maximize S:B.

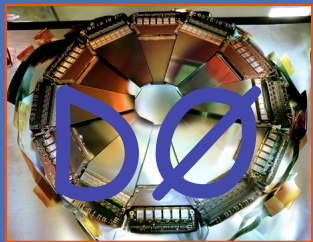
Maximize S:B

Use maximum likelihood or
shape fitting



Preselection Cuts

- One good quality isolated $e(\gamma)$, $E_T > 15 \text{ GeV}$, $|\eta| < 1.1$ (2.0)
- $\text{MET} > 15 \text{ GeV}$
- $2 \leq N_{\text{jets}} \leq 4$
 - $p_T > 15 \text{ GeV}$
 - $|\eta| < 3.4$
- $p_T(\text{jet } 1) > 25 \text{ GeV}$
- Require at least one b-tagged jet
- Reject misreconstructed events and regions not well described by backgrounds

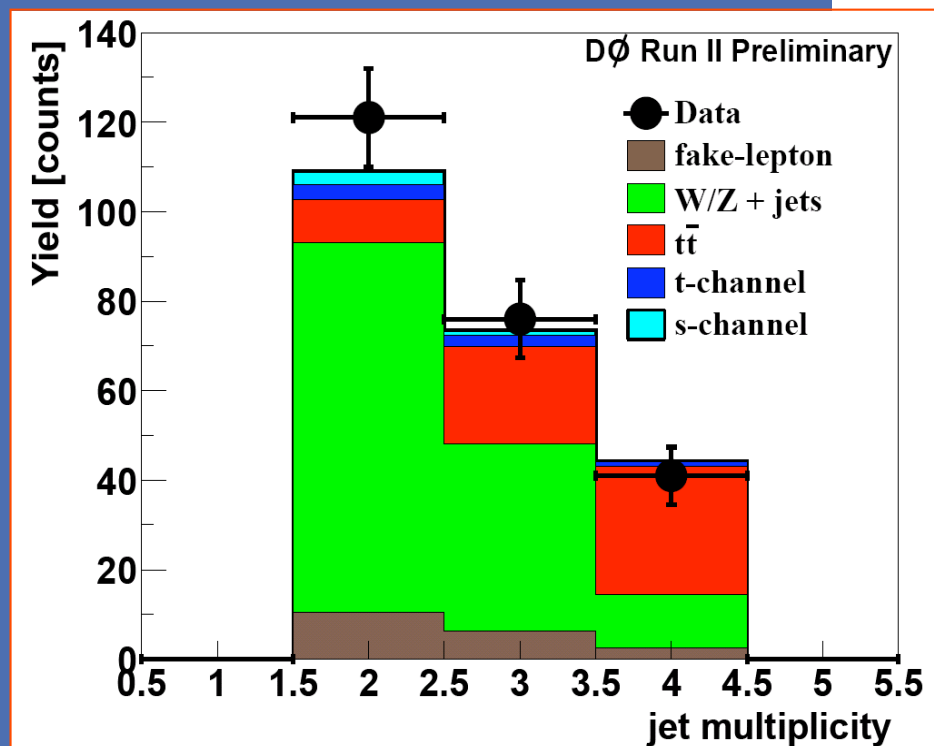


Preselection Cuts - N_J

We cut on the number of jets and use this as input into our multivariate analysis.

$$2 \leq N_J \leq 4$$

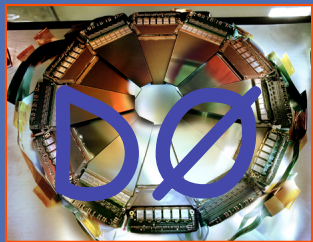
The motivation is pretty clear 



A "jet"-theorist: "Dude. What's a jet?"

Would prefer energy based variables like H_T

Even with those, however, N_J is powerful.



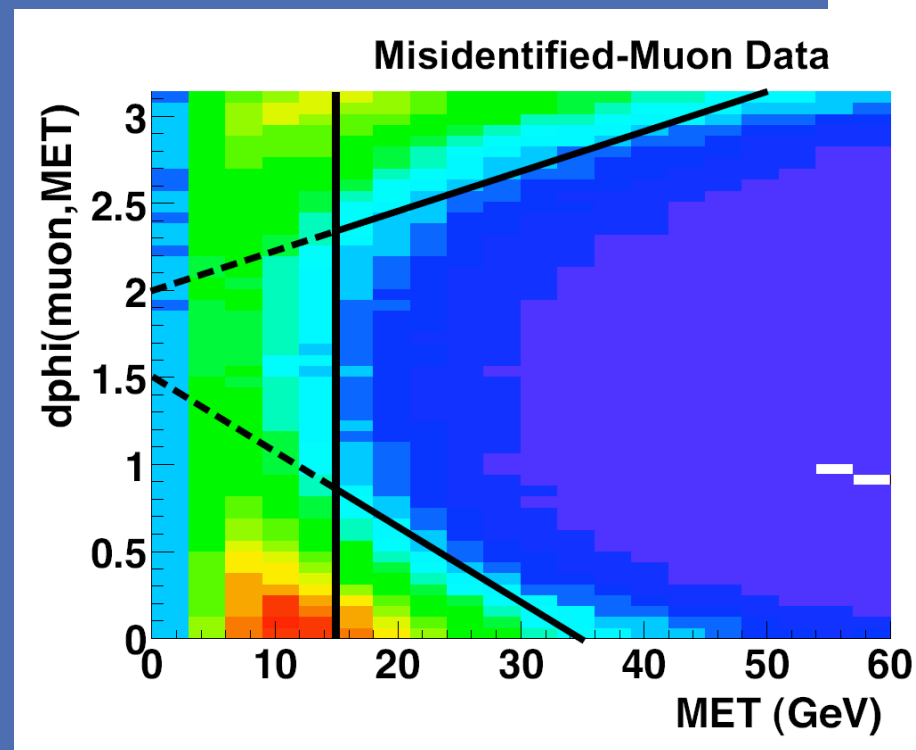
Preselection Cuts - T Cuts

Triangle Cuts

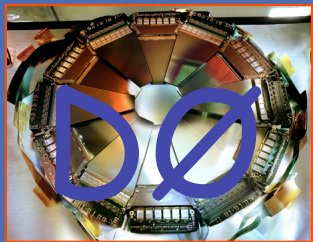
1. QCD production of $b\bar{b}$
2. b decays with a high p_T muon
3. Jet is mis-measured low



High p_T isolated muon,
aligned with missing E_T



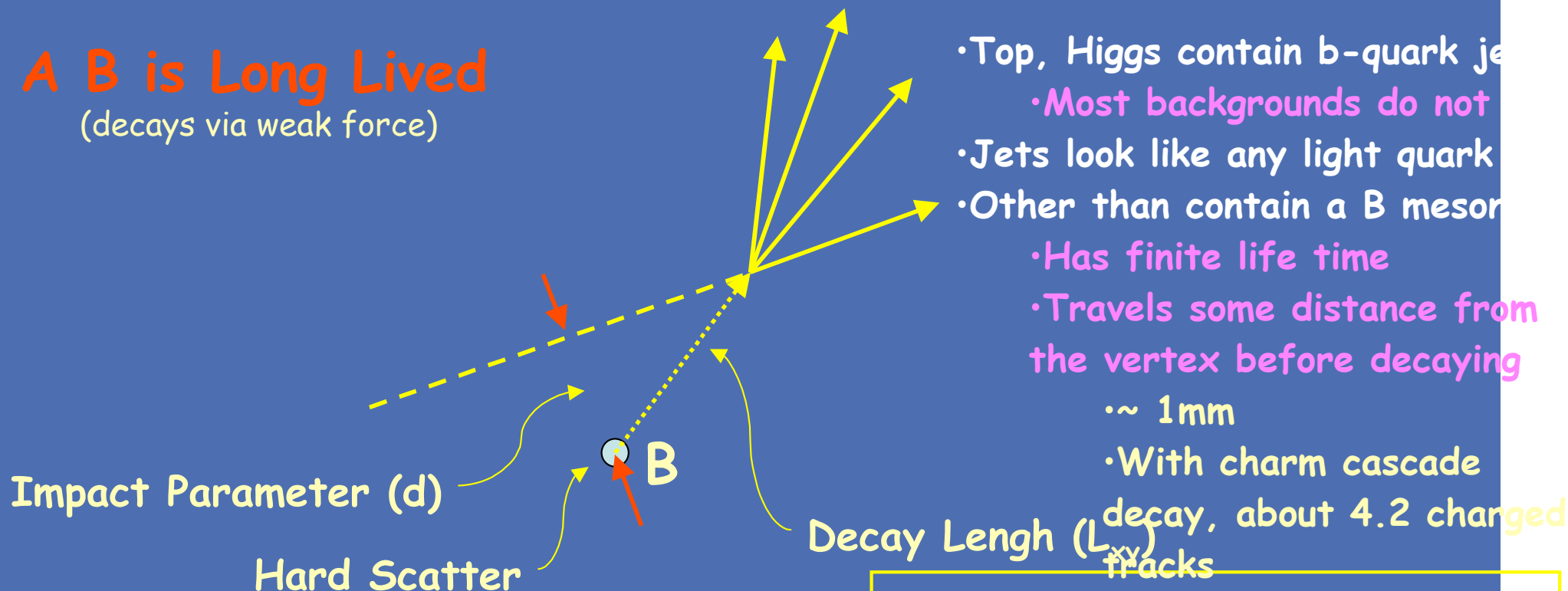
It, and other similar backgrounds are
eliminated with the triangle cuts.



Preselection - B Tagging

A B is Long Lived

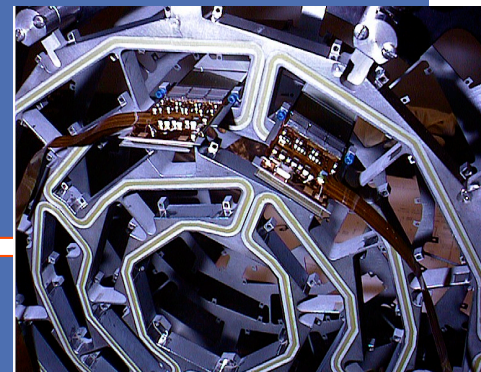
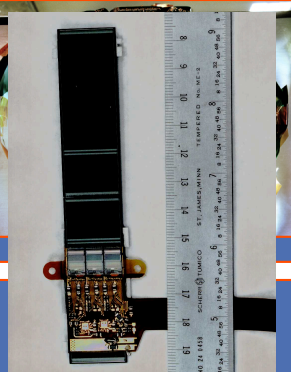
(decays via weak force)



Several algorithms under development

➔ Impact Parameter Resolution	$d/\sigma(d)$
➔ Decay Length Resolution	$L_{xy}/\sigma(L_{xy})$

An Event



"Proton View"

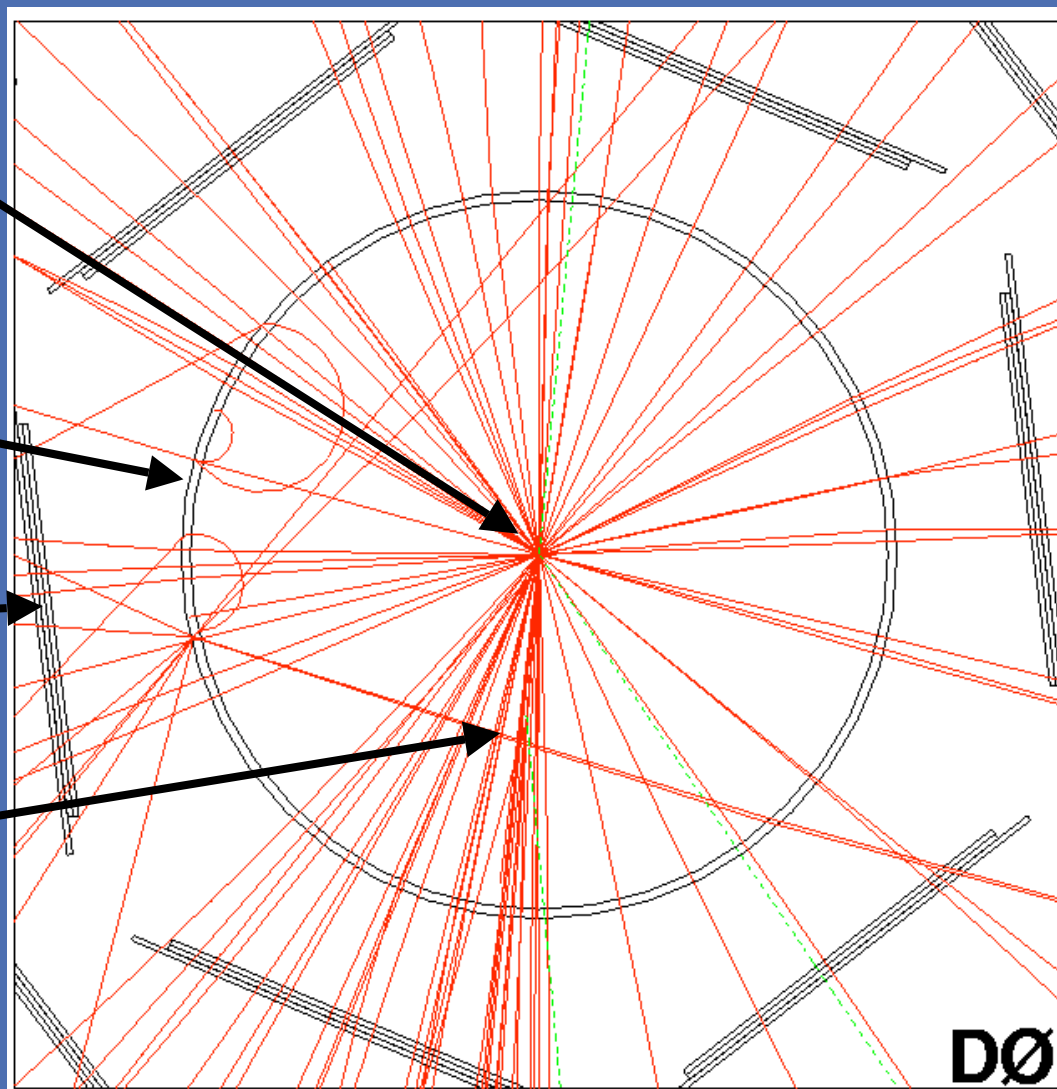
Hard Scatter
(Primary Vertex)

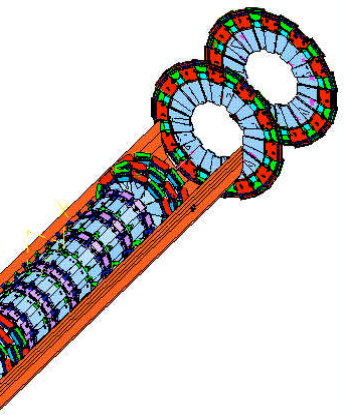
Beampipe
(2.3 in diameter)

Layer Of Silicon

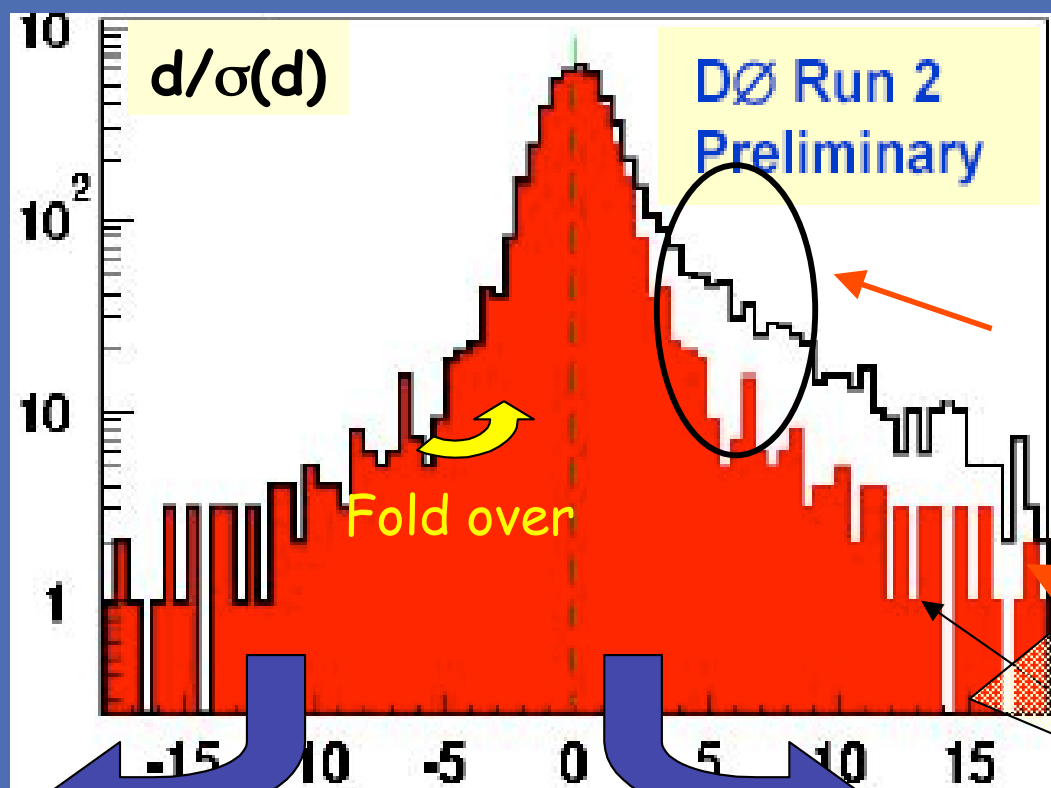
Reconstructed
Secondary
Vertex

Green Track Is Displaced





Vertex Tagging

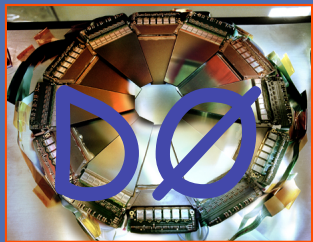


Resolution Effects,
Tracking Errors,
etc.

Evidence of
displaced vertex

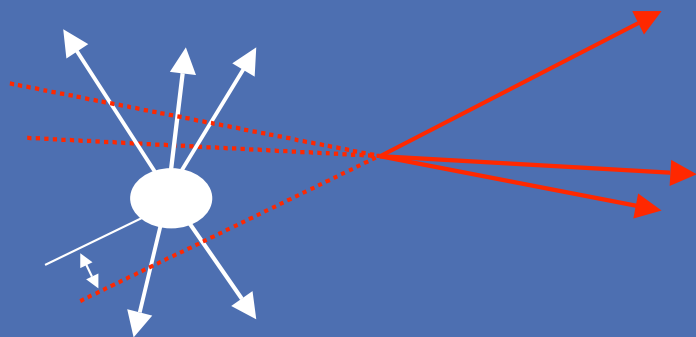
Negative Tag

Positive Tag



Algorithms

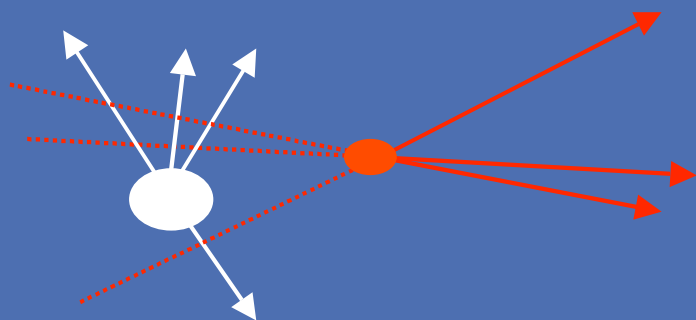
Probability Based



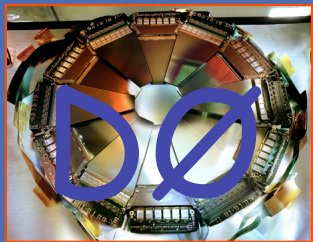
Build a probability Distribution for tracks of various types to be consistent with the hard scatter vertex

Combine for a probability for each jet

Vertex Reconstruction



Use Tracking to fit for a vertex



Performance

Fake Rate is rate you tag a light quark jet

Different physics channels require different levels of rejection

Systematics

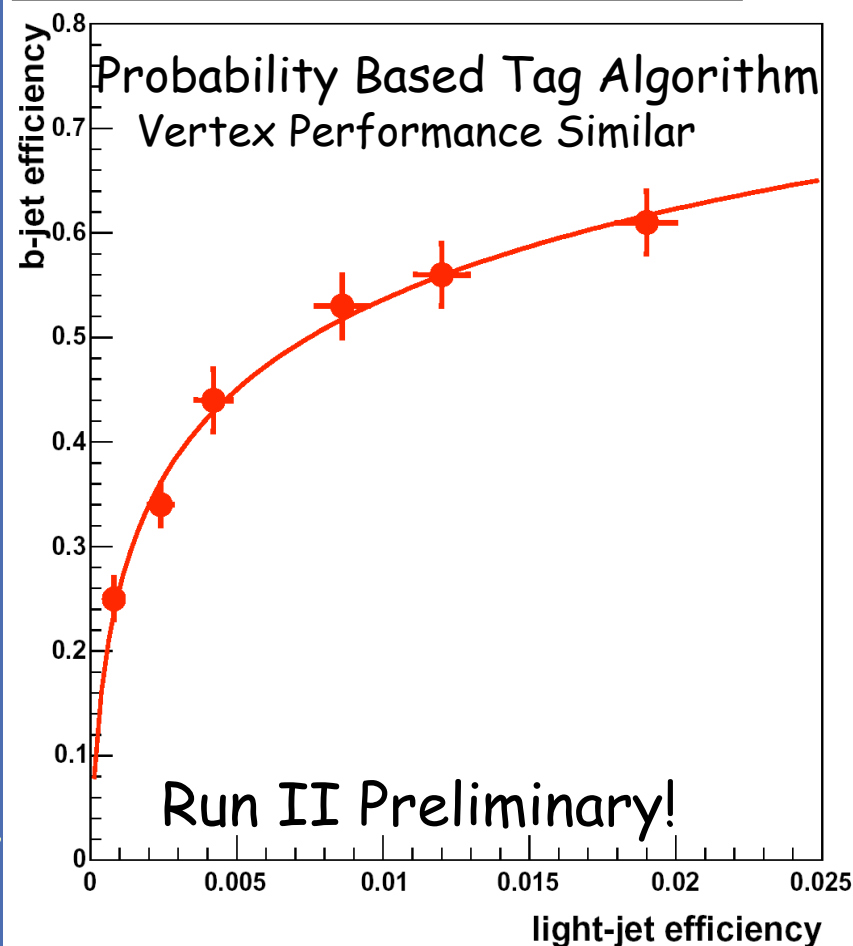
- VO's (K_s , Λ , etc.)
- Tracking Resolution/MC matching
- Charm content
- Gluon Splitting to $b\bar{b}$

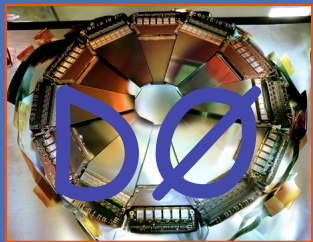
The Two Algorithms are correlated

But not totally; working on combination now...

Combination Tagger (NN) - 30% Improvement

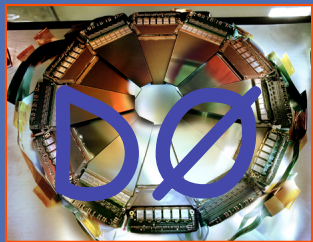
JLIP performance in p14 real Data





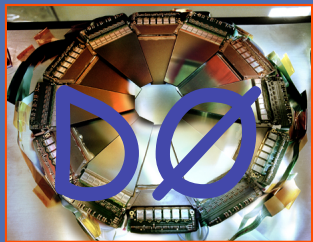
Final Sample

	<u>Event Yields after Selection</u>							
	Electron Channel				Muon Channel			
	Pretagged	=1 Tag	≥ 2 Tags	≥ 2 Tags	Pretagged	=1 Tag	≥ 2 Tags	≥ 2 Tags
			s-channel	t-channel			s-channel	t-channel
Signals								
tb	5	2.3	0.53	—	5	2.2	0.50	—
tqb	12	4.1	—	0.25	11	3.9	—	0.23
Backgrounds								
tb	—	—	—	0.14	—	—	—	0.13
tqb	—	—	0.32	—	—	—	0.29	—
$t\bar{t} \rightarrow l + \text{jets}$	59	25.0	6.12	5.74	58	24.2	5.78	5.48
$t\bar{t} \rightarrow ll$	16	6.8	1.58	0.74	17	7.2	1.62	0.75
Wbb	40	15.1	2.49	0.59	33	12.7	2.15	0.55
Wjj	3,211	68.2	1.53	0.66	2,898	62.9	1.29	0.68
WW	13	0.7	0.00	0.00	14	0.7	0.00	0.00
WZ	4	0.6	0.11	0.02	5	0.5	0.09	0.01
Mis-ID'd l	478	13.7	0.31	0.14	256	17.2	0.20	0.20
Summed signals	17	6.4	0.53	0.25	16	6.0	0.50	0.23
Summed backgrounds	3,821	130.1	—	—	3,280	125.4	—	—
Summed backgrounds+ tqb	3,833	134.2	12.47	—	3,291	129.3	11.43	—
Summed backgrounds+ tb	3,826	132.4	—	8.03	3,285	127.6	—	7.80
Data	3,821	134	15	11	3,280	118	16	8



Acceptances

Percentage Acceptances for the MC Samples								
	Pretagged	Electron Channel			Pretagged	Muon Channel		
		=1 Tag	≥ 2 Tags <i>s</i> -channel	≥ 2 Tags <i>t</i> -channel		=1 Tag	≥ 2 Tags <i>s</i> -channel	≥ 2 Tags <i>t</i> -channel
<i>tb</i>	2.6	1.1	0.27	0.07	2.5	1.1	0.25	0.06
<i>tqb</i>	2.6	0.9	0.07	0.05	2.4	0.9	0.06	0.05
$t\bar{t} \rightarrow l + \text{jets}$	3.9	1.6	0.40	0.37	3.8	1.6	0.37	0.35
$t\bar{t} \rightarrow ll$	1.0	0.4	0.10	0.05	1.1	0.5	0.10	0.05
<i>Wbb</i>	5.2	2.0	0.33	0.08	4.3	1.7	0.28	0.07
<i>Wjj</i>	4.9	0.1	0.00	0.00	4.4	0.1	0.00	0.00
<i>WW</i>	2.1	0.1	0.00	0.00	2.2	0.1	0.00	0.00
<i>WZ</i>	2.2	0.3	0.06	0.01	2.4	0.3	0.05	0.01



Final Sample Statistics

Luminosity 230 pb⁻¹

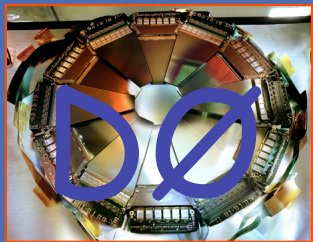
Expected Events

	DØ
s-channel	5.5 ± 0.4
t-channel	8.5 ± 0.4

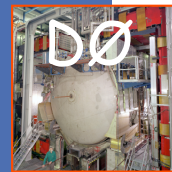
These Are Small Numbers!
DØ: Expects ~14 events on ~260

$S/\sqrt{B}$

	DØ
s-channel	0.35
t-channel	0.53



Straight Cut Analysis



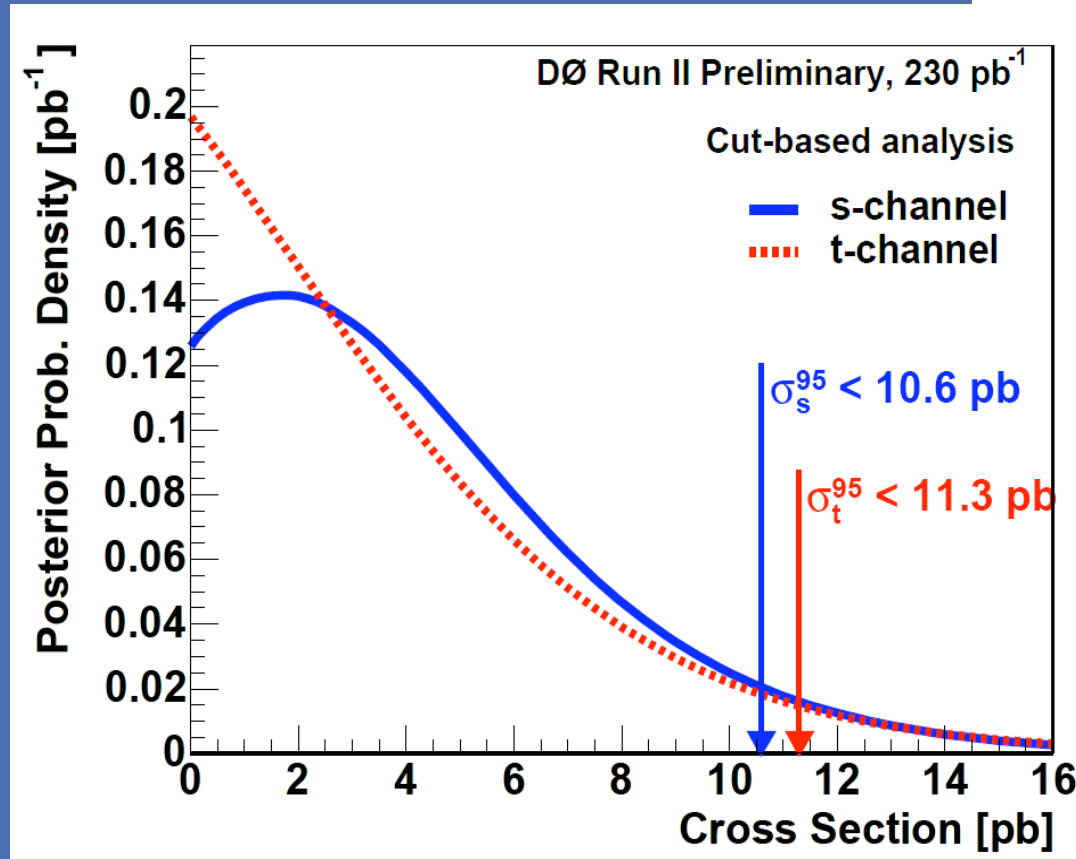
How Well Can We Do With a Straight Cut Analysis?

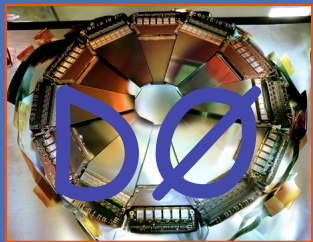
Selected Variables:

Object E_T/p_T - Jet #1

H_T - like (various sums of the object's E_T 's)

Invariant Mass of combinations of masses (like M_{lbv})

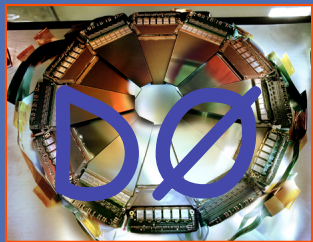




Details of Cuts Based

	<i>s</i> -channel	<i>t</i> -channel
<i>tb</i>	4.5 ± 1.0	3.2 ± 0.8
<i>tqb</i>	5.5 ± 1.2	7.0 ± 1.6
<i>t$\bar{t}$</i>	27.6 ± 7.6	55.9 ± 12.3
<i>W</i> + jets	102.9 ± 13.7	72.6 ± 9.7
Mis-ID'd lepton	17.2 ± 2.0	17.0 ± 2.0
Background sum	153.1 ± 24.5	148.7 ± 24.8
Observed events	152	148

Channel	<i>s</i> -channel Variables	Cuts	<i>t</i> -channel Variables	Cuts
Electron				
=1 Tag	$p_T(\text{jet1}_{\text{tagged}})$	$> 27 \text{ GeV}$	$H_T(\text{alljets})$	$> 71 \text{ GeV}$
	$M(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 70 \text{ GeV}$	$M(\text{alljets})$	$> 57 \text{ GeV}$
	$\sqrt{\hat{s}}$	$> 196 \text{ GeV}$	$\sqrt{\hat{s}}$	$> 203 \text{ GeV}$
			$ 175 - M(\text{top}_{\text{tagged}}) $	$< 57 \text{ GeV}$
			$p_T(\text{jet1}_{\text{tagged}})$	$> 21 \text{ GeV}$
≥ 2 Tags	$p_T(\text{jet1}_{\text{tagged}})$	$> 42 \text{ GeV}$	$p_T(\text{jet1}_{\text{tagged}})$	$> 34 \text{ GeV}$
	$M(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 98 \text{ GeV}$	$M(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 75 \text{ GeV}$
	$H(\text{alljets} - \text{jet}_{\text{best}})$	$< 304 \text{ GeV}$	$H(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 504 \text{ GeV}$
	$H(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 304 \text{ GeV}$	$H(\text{alljets} - \text{jet}_{\text{best}})$	$< 504 \text{ GeV}$
Muon				
=1 Tag	$p_T(\text{jet1}_{\text{tagged}})$	$> 33 \text{ GeV}$	$ 175 - M(\text{top}_{\text{tagged}}) $	$< 60 \text{ GeV}$
	$M(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 74 \text{ GeV}$	$\sqrt{\hat{s}}$	$> 210 \text{ GeV}$
	$H(\text{alljets} - \text{jet}_{\text{best}})$	$< 504 \text{ GeV}$	$M(\text{alljets})$	$> 70 \text{ GeV}$
	$H(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 504 \text{ GeV}$	$H_T(\text{alljets})$	$> 58 \text{ GeV}$
≥ 2 Tags	$p_T(\text{jet1}_{\text{tagged}})$	$> 33 \text{ GeV}$	$ 175 - M(\text{top}_{\text{tagged}}) $	$< 213 \text{ GeV}$
	$M(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 74 \text{ GeV}$		
	$H(\text{alljets} - \text{jet}_{\text{best}})$	$< 504 \text{ GeV}$		
	$H(\text{alljets} - \text{jet1}_{\text{tagged}})$	$< 504 \text{ GeV}$		



Simple Cuts Limit

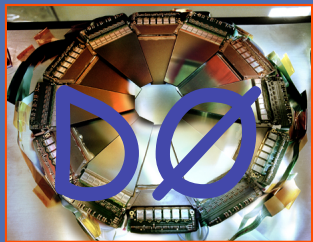
From Counting the Yields After Applying Simple Cuts:

95% CL Expected/Measured Upper Limits on the Single Top Quark Cross Sections

	<u><i>s</i>-channel, <i>tb</i></u>			<u><i>t</i>-channel, <i>tqb</i></u>		
	=1 Tag	≥2 Tags	Combined	=1 Tag	≥2 Tags	Combined
No uncertainties						
Electron channel	8.6/8.6	12.4/10.4	6.6/6.0	10.5/13.6	60.3/80.7	10.3/14.0
Muon channel	9.2/7.6	12.8/24.9	7.0/9.3	11.5/7.7	62.4/67.9	11.2/7.7
Combined	6.1/5.3	8.0/12.1	4.6/5.4	7.5/6.9	39.7/52.2	7.4/7.1
With uncertainties						
Electron channel	13.5/13.6	18.6/15.9	11.4/10.8	18.4/22.0	86.6/105.0	15.1/17.5
Muon channel	15.7/13.5	20.1/36.7	13.0/15.2	21.6/17.1	101.0/105.0	18.1/13.0
Combined	12.0/11.3	14.2/19.0	9.8/10.6	16.6/17.2	71.6/86.2	12.4/11.3

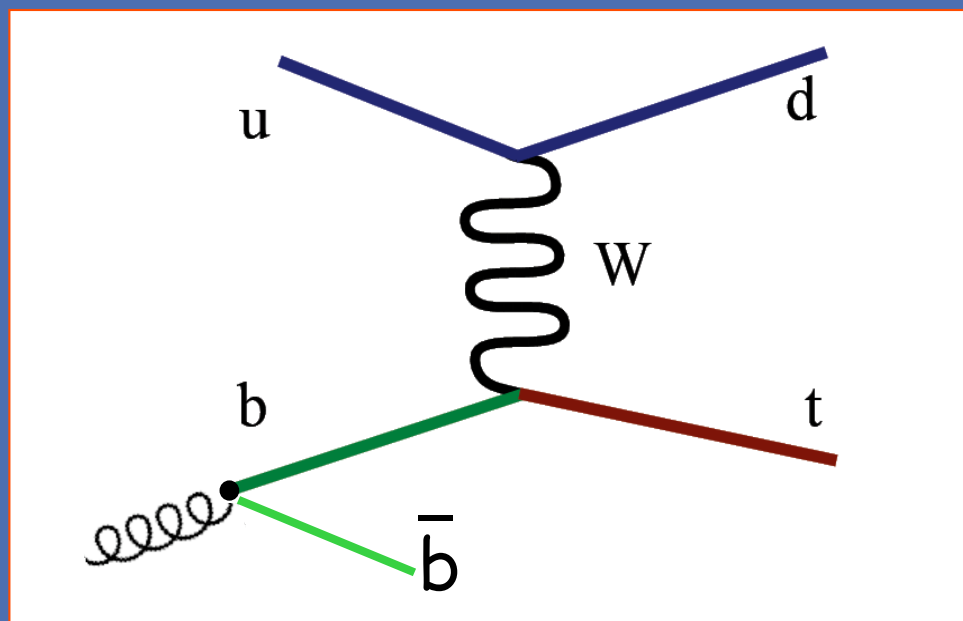
Expected

Measured



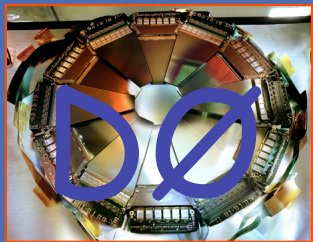
Example of... Getting Clever

t-channel

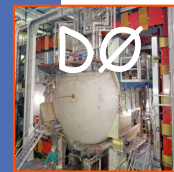


Charge of up quark determines charge of W lepton (p vs
Recoil against gluon/quark makes for asymmetry

→ Look at d-quark Jet Rapidity normalized by Charge



Other Variables



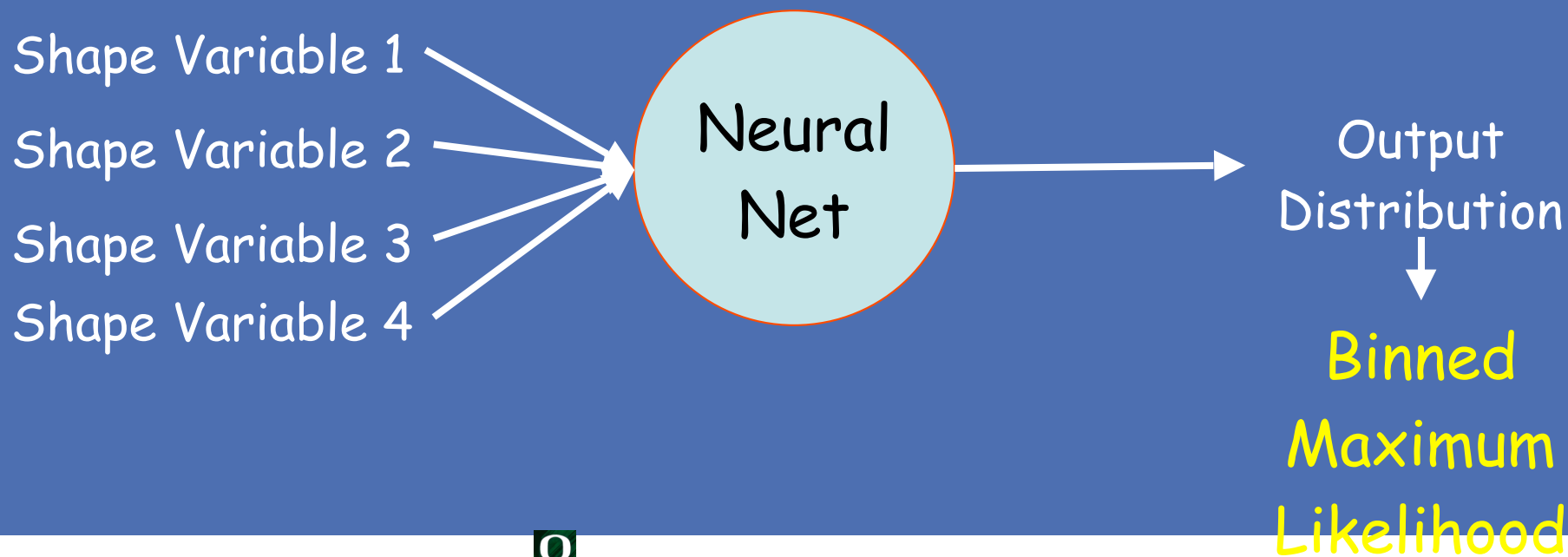
DØ S/B is worse is pretty bad... by design...

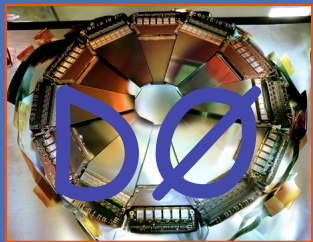
Basic Selection Cuts: Let in as much signal as possible

→ Use a Multivariate analysis to separate the signal from background

A multi-dimensional maximum likelihood possible...

Statistics are prohibitive!





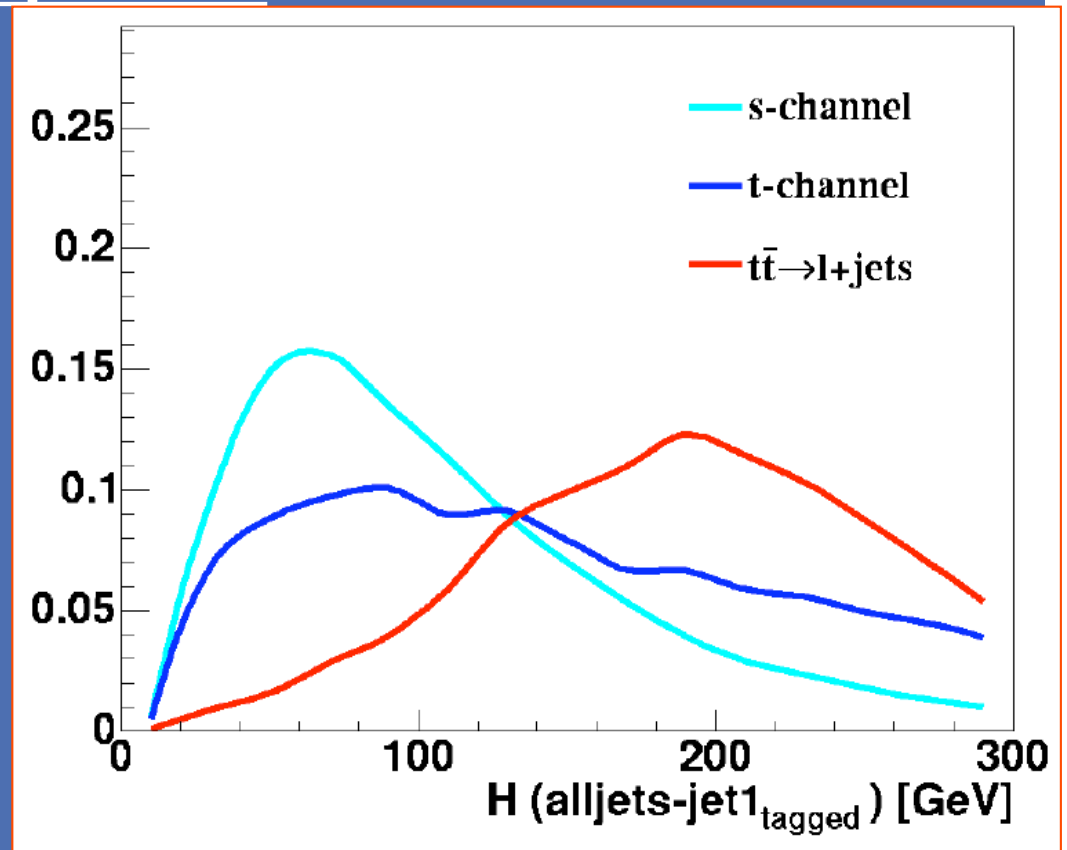
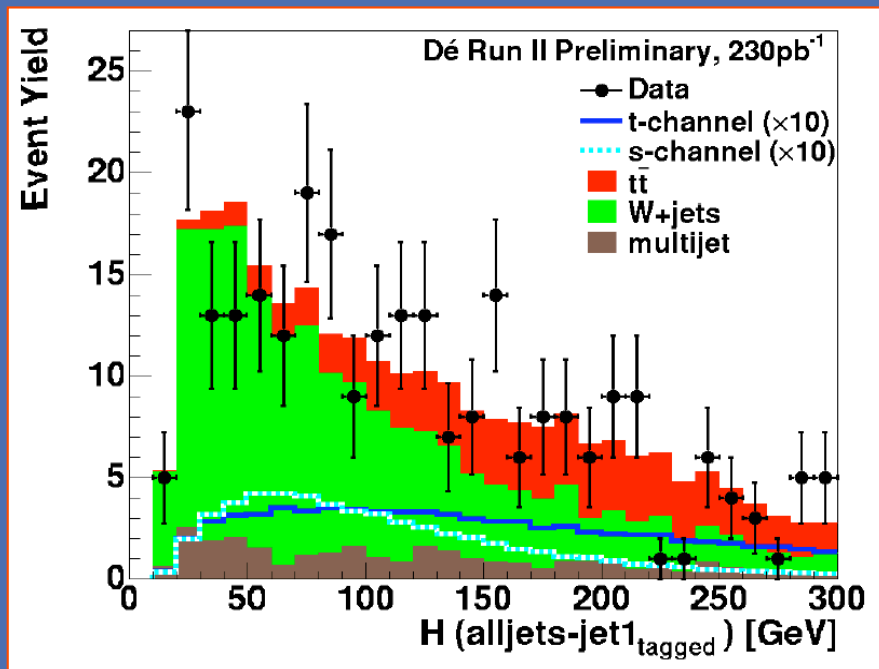
Input Variables I



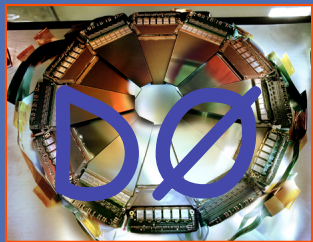
Event Energy, Object Properties

$p_{T\text{jet}1}, H, H_T \dots$

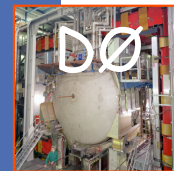
MC Shapes



Cross Check Background Mod



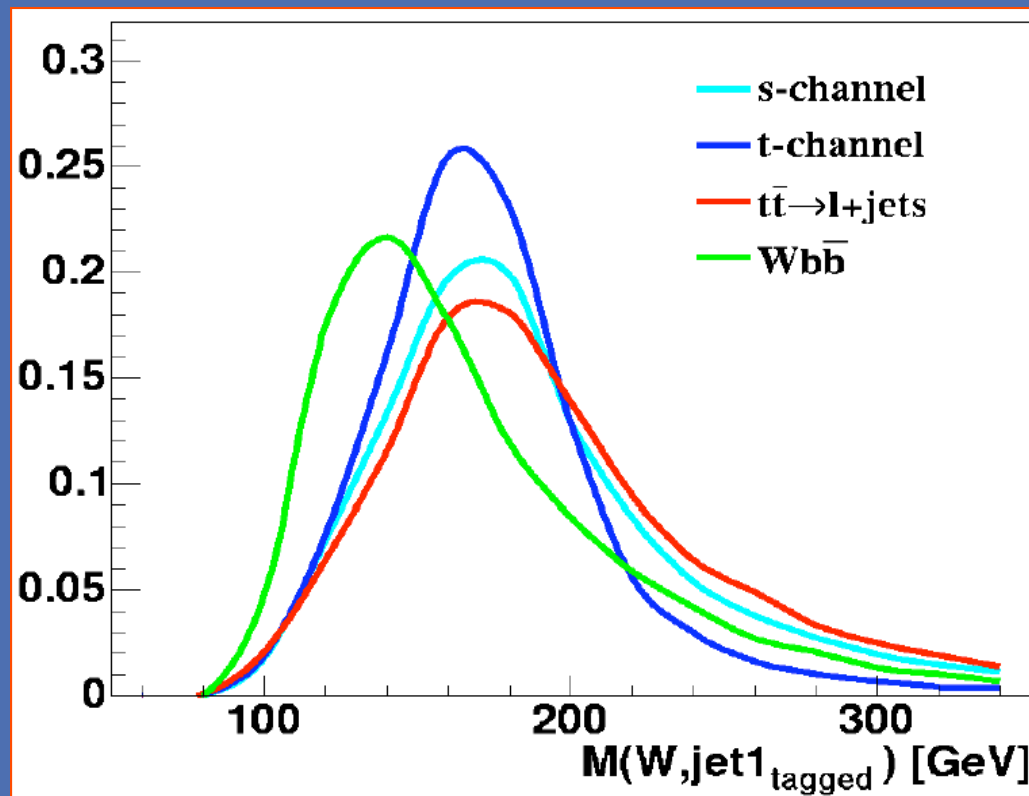
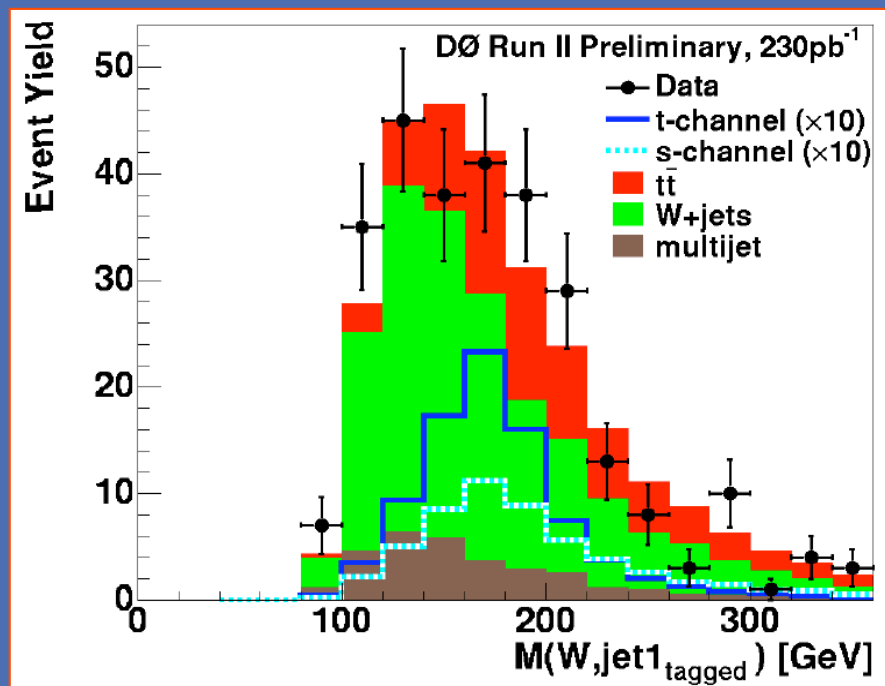
Input Variables II



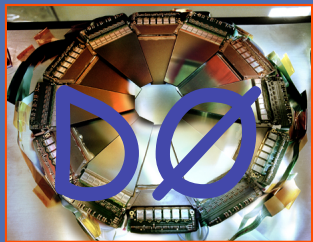
Object Combinations

$M_{\text{top}}, M_{\text{all jets}}$

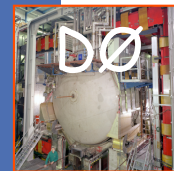
MC Shapes



Cross Check Background Mod



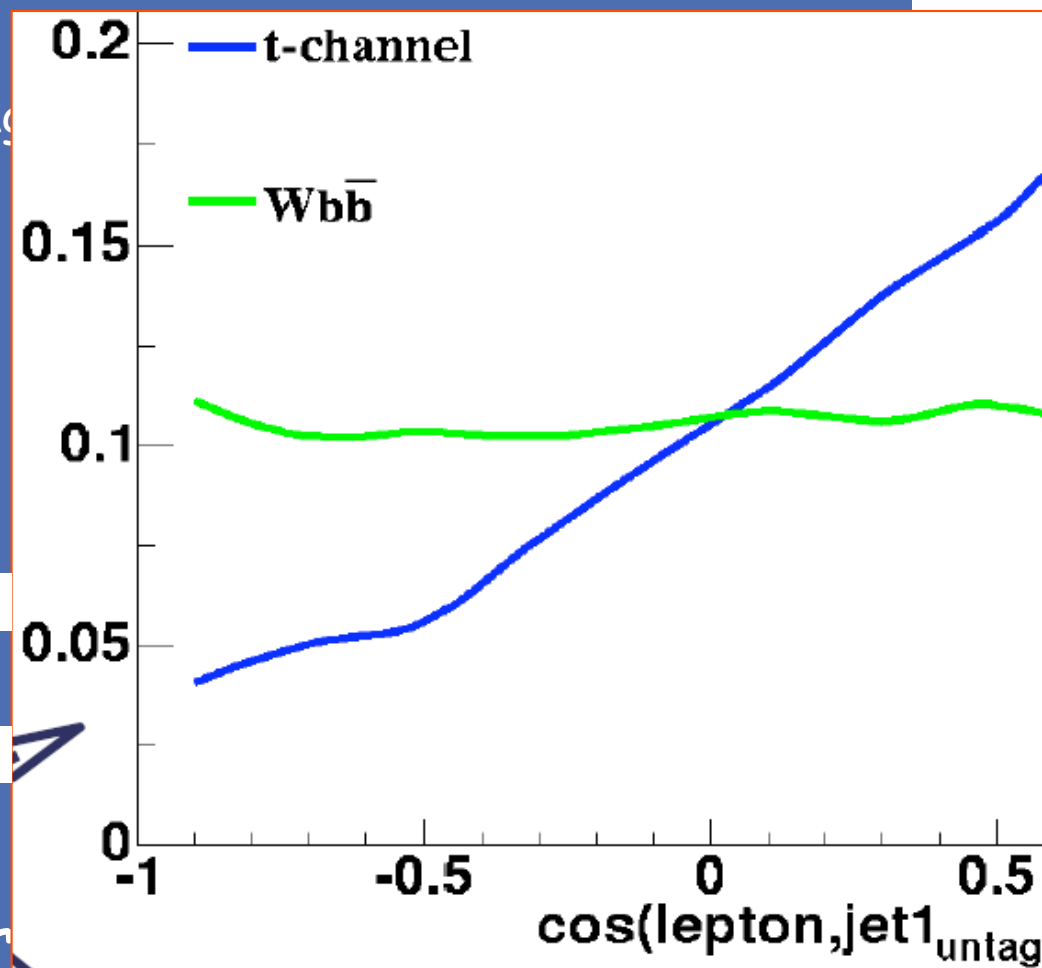
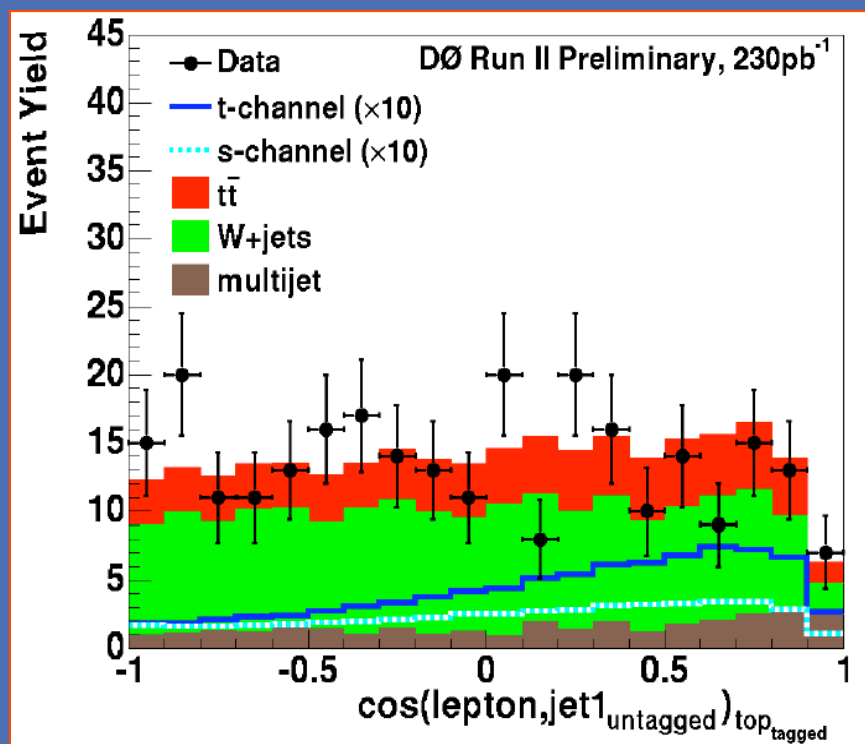
Input Variables III

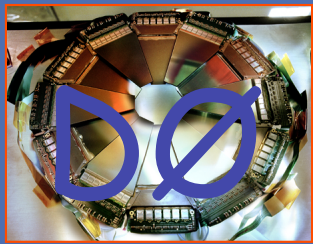


Angular Variables

$\cos(\text{lepton}, \text{jet1 untagged})_{\text{top tagged}}$

MC Shapes





Input Variables



Event Energy

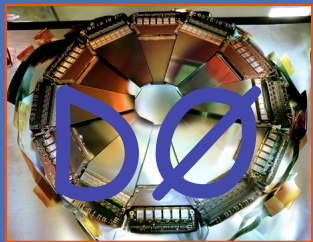
$p_{T\text{tag}}, p_{T\text{untag}}, p_{T\text{topjet}}, p_{T\text{jet1,jet2}}, H(\text{all jets but tagged}),$
 $H_T(\text{jets}), H_T(\text{jets-tagged}), H(\text{jets-top quark jet}), H_T$

Object Combinations

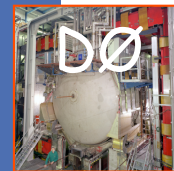
$M(\text{jets}), p_T(\text{all jets - tagged}), M_{\text{top}}(\text{tagged jet}), s,$
 $M(\text{jets-tagged}), M_T(\text{jets 1\&2}), p_T(\text{jets 1\&2}), M(\text{jets-top}$
 $\text{quark jet}), M_{\text{top}}(\text{best jet})$

Angular Variables

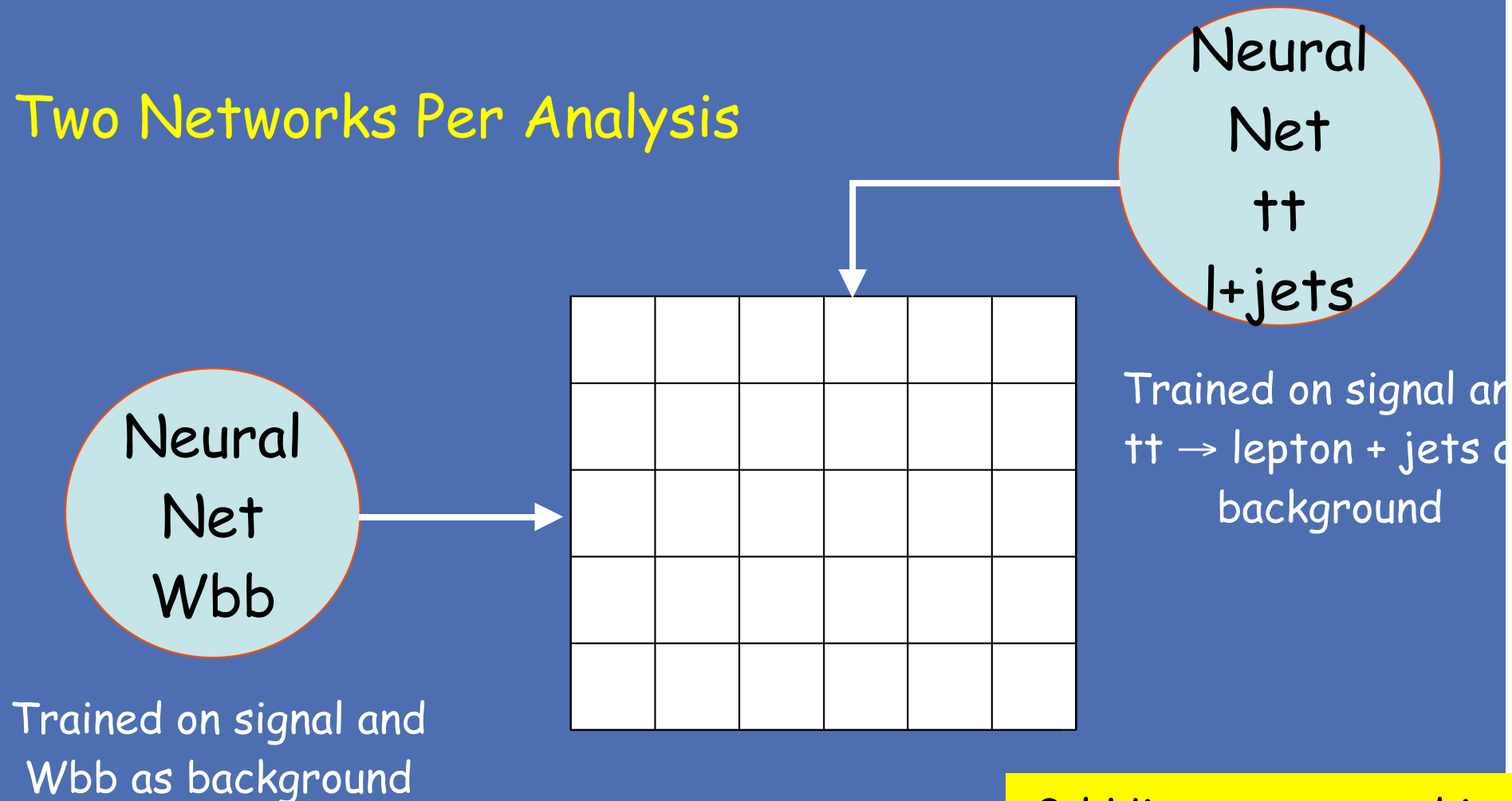
$\Delta R(\text{jets 1\&2}), \eta(\text{untagged}) \times Q(\text{lep}), \cos(\text{lepton},$
 $\text{untagged})_{\text{top rest}}, \cos(\text{jets}, \text{jet1 tagged})_{\text{all jets rest}},$
 $\cos(\text{lepton}, Q(\text{lepton}) \times z)_{\text{best top rest}}, \cos(\text{jets}, \text{jet1 not}$
 $\text{best})_{\text{all jets rest}}$
 Both s&t, t-only, s-only



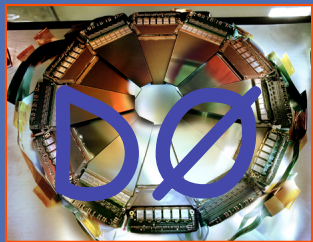
Neural Net Design



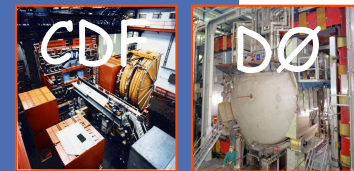
Two Networks Per Analysis



We also use Decision Trees in place of NN



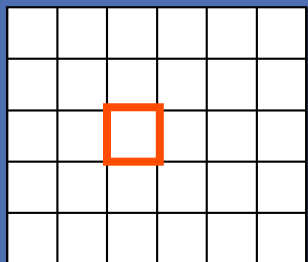
Systematic Uncertainties



Fitting Shape Variables Requires Special Handling of
Systematic Errors

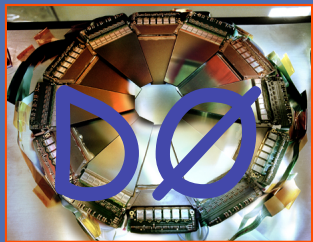
 1 bin

Calculate the Systematic Errors For That 1 Bin
Jet Energy Scale, Trigger, BTagging, etc.

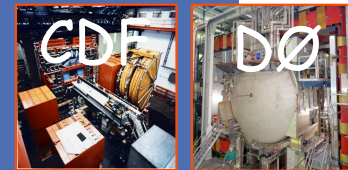


Repeat for All Bins

Shape Fluctuations Will Be Properly Accounted For



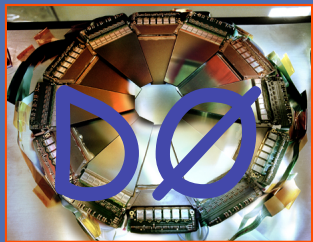
Systematics



DØ

Monte Carlo Systematic Uncertainties	
Components affecting normalization	
$\sigma_{t\bar{t}}$ theory and mass	18 %
$\sigma_{s(t)}$ theory	15 % (16 %)
Jet Fragmentation	6.0 %
ℓ ID	4.1 %
Branching Fraction	2.0 %
Components affecting shape and normalization	
SVT modeling, single (double) tag	10 % (20 %)
Jet Energy Scale	10 %
Trigger Modeling	6 %
Jet ID	5 %
Jet Energy Resolution	4 %

Some will improve with
increased Luminosity

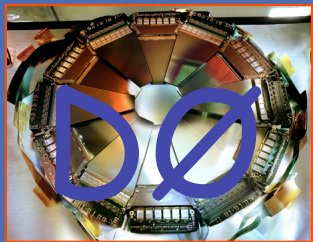


Final Results

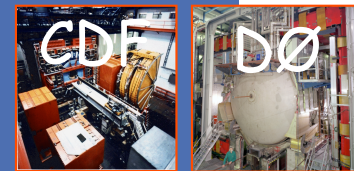
From Binned Likelihood Fits to Neural Network Outputs:

95% CL Expected/Measured Upper Limits on the Single Top Quark Cross Sections

	<i>s</i> -channel, <i>tb</i>			<i>t</i> -channel, <i>tqb</i>		
	=1 Tag	≥ 2 Tags	Combined	=1 Tag	≥ 2 Tags	Combined
No uncertainties						
Electron channel	6.8/6.4	10.5/16.2	5.3/6.6	7.2/5.6	46.7/86.8	6.9/7.2
Muon channel	7.0/6.0	11.0/22.2	5.5/7.6	7.8/5.9	46.4/63.3	7.4/7.3
Combined	4.7/4.0	6.6/14.8	3.6/5.4	4.9/3.5	27.5/55.9	4.6/5.2
With uncertainties						
Electron channel	9.0/8.0	14.2/15.7	7.0/7.3	9.3/6.5	61.2/104.4	8.8/7.5
Muon channel	8.8/7.9	13.9/26.2	7.0/8.7	10.1/7.0	60.5/78.4	9.5/7.4
Combined	6.0/5.6	8.9/14.6	4.5/6.4	6.3/4.2	36.9/69.5	5.8/5.0



Final Results



95% C.L. limits Observed (Expected)

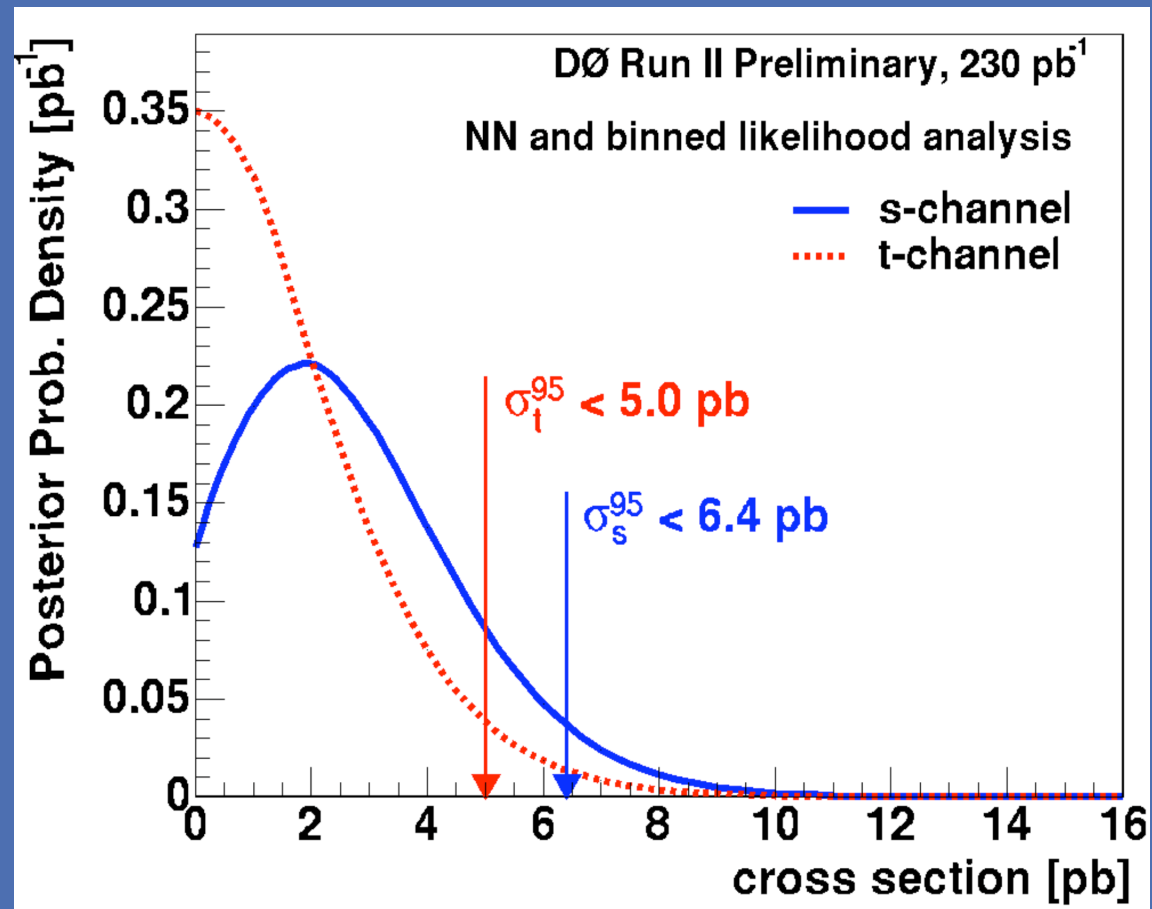
Channel	CDF (pb)	DØ (pb)	SM
s+t	<17.8 (13.6)		2.86pb
t	<10.1 (11.2)	<5.8 (5.0)	1.98pb
s	<13.6 (12.1)	<6.4 (4.5)	0.88pb

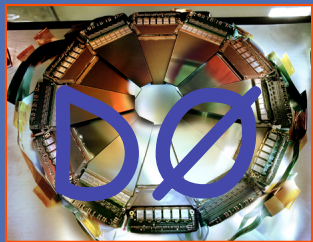
Luminosity 162 pb⁻¹ 230 pb⁻¹

(recall Straight Cut Limit was s:10.6, t: 11.3)



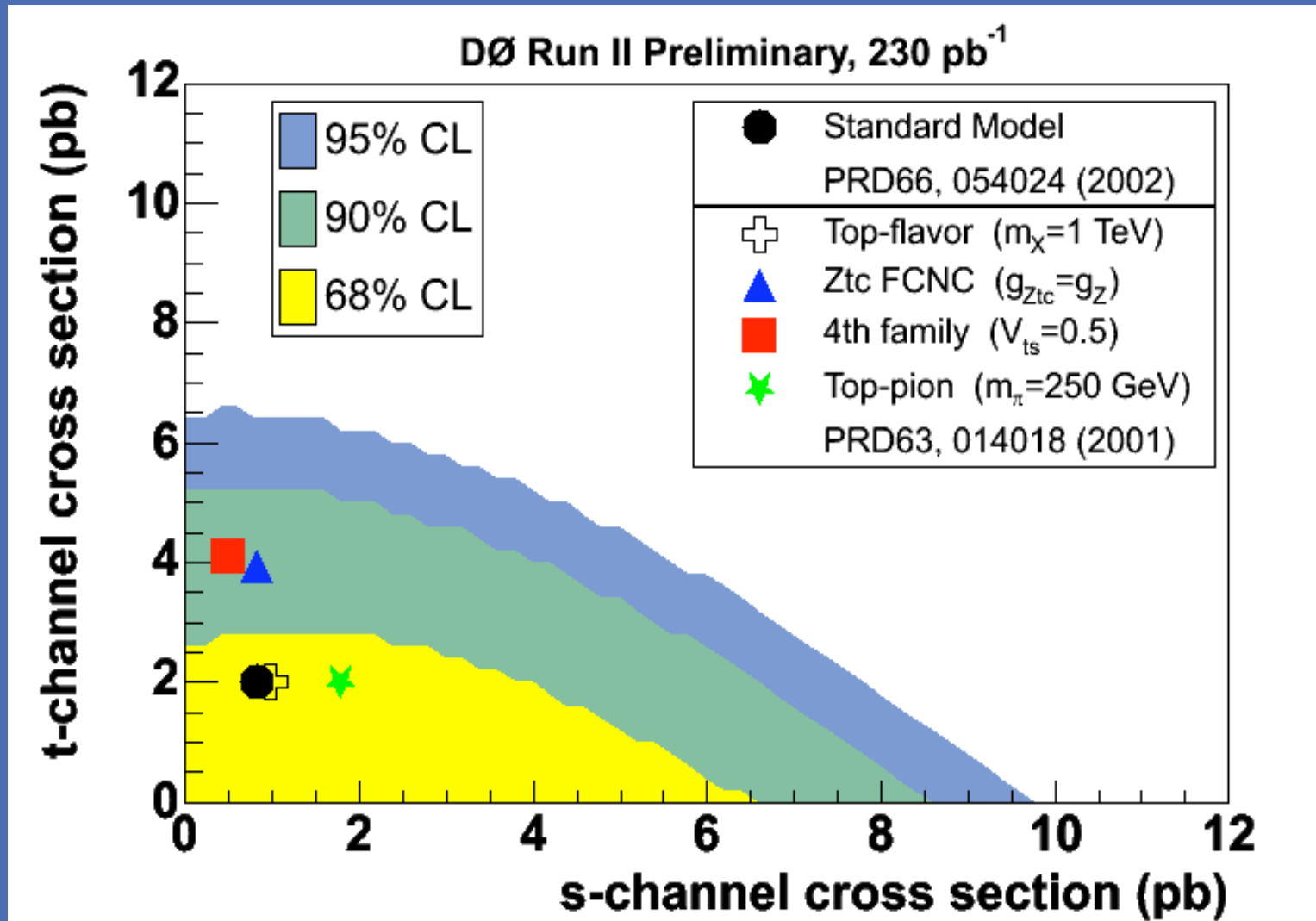
Probability Density



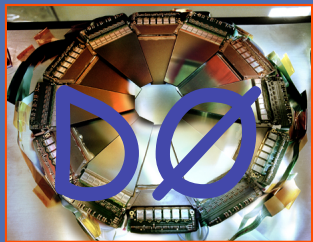


Beyond The Standard Model

μ
data
only



e data only

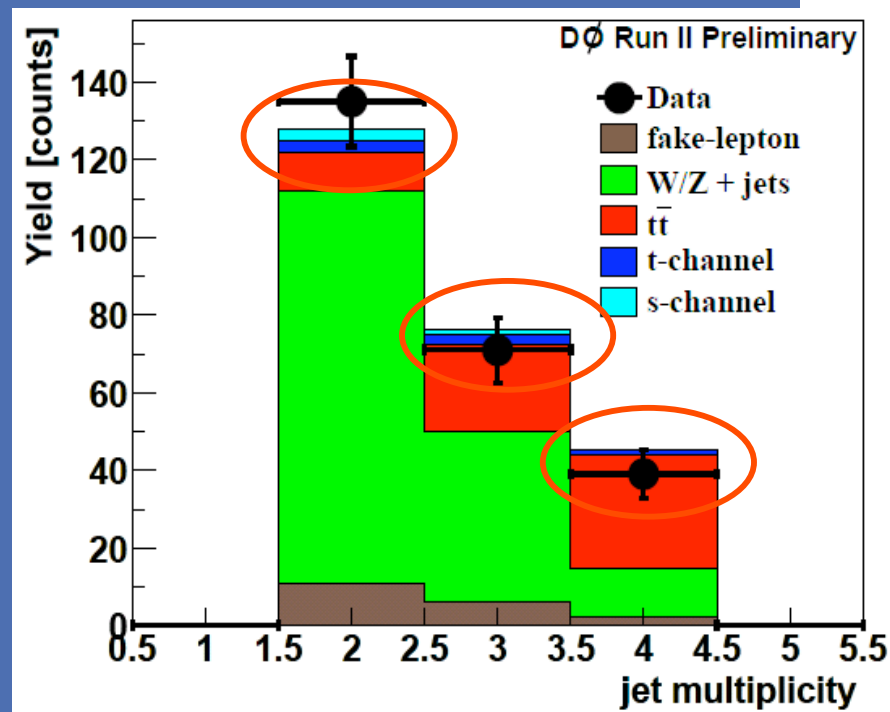


Driving Force...

Phase space of background and signal overlap

Need more than simple topological variables to extract signal from background!

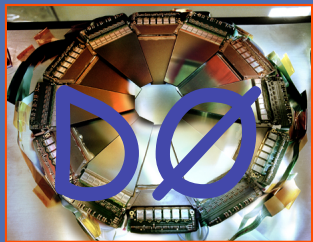
Inputs rely on a better understanding of MC than we are currently used to!



Improved models and techniques

Do we correctly account for systematic errors

Supporting effort: understanding charm tagging



Why so Little?

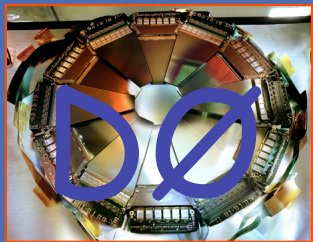
The Results I'm showing are over about 390 pb⁻¹ of data
This is about 1/3 data on tape...

1 Triggers Suck

- We tune our trigger lists to our luminosities.
- The recent increases caught us by surprise
 - Which meant a lot of new trigger lists.
- We have not completely automated the calculation of efficiencies!
- Almost a new analysis with each trigger list version!

2 Reconstruction Upgrade

- We are in the middle of a major upgrade of our reconstruction code and algorithms. Even our analysis data format has changed.
- New MC with better material modeling.
- Everything must be retuned.
- Results for Moriond will be anemic. ☹



Conclusions

- Barring a disaster the Tevatron should discover Single Top
 - But not as soon as previously predicted!
- Major effort by the theory and experiment community to understand the backgrounds
 - New modeling techniques
 - Quantify our current understanding
- Improvements on Top
 - Increased Luminosity
 - Combined b-tagging