Single Top Turns Six

Reinhard Schwienhorst

MICHIGAN STATE UNIVERSITY

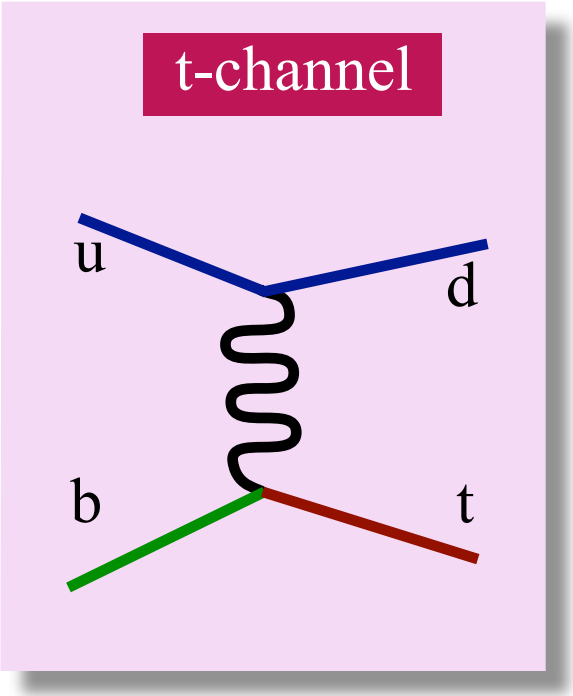
LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

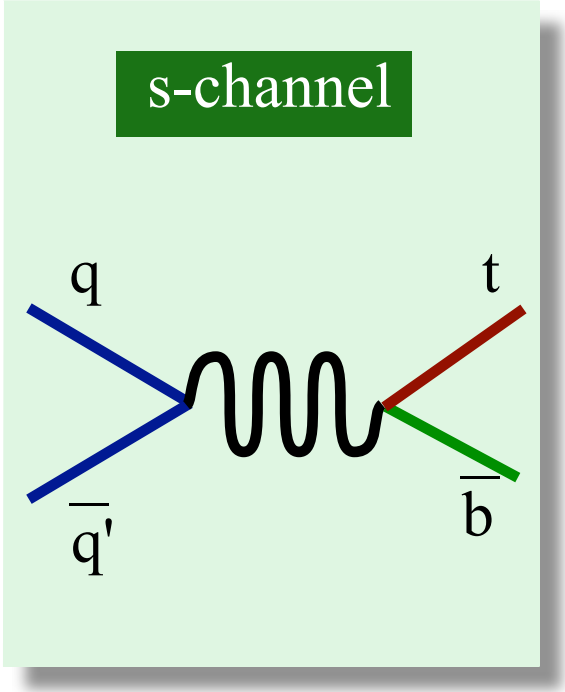
On behalf of the CDF and D0 collaborations

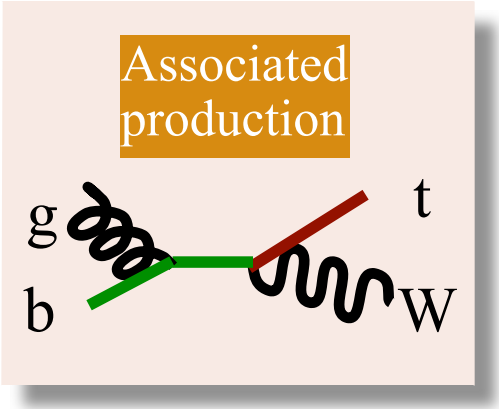
Outline

- Single top production
- MVA
- Cross section measurements in 10 fb^{-1}
- Vtb
- Conclusions

Single top production

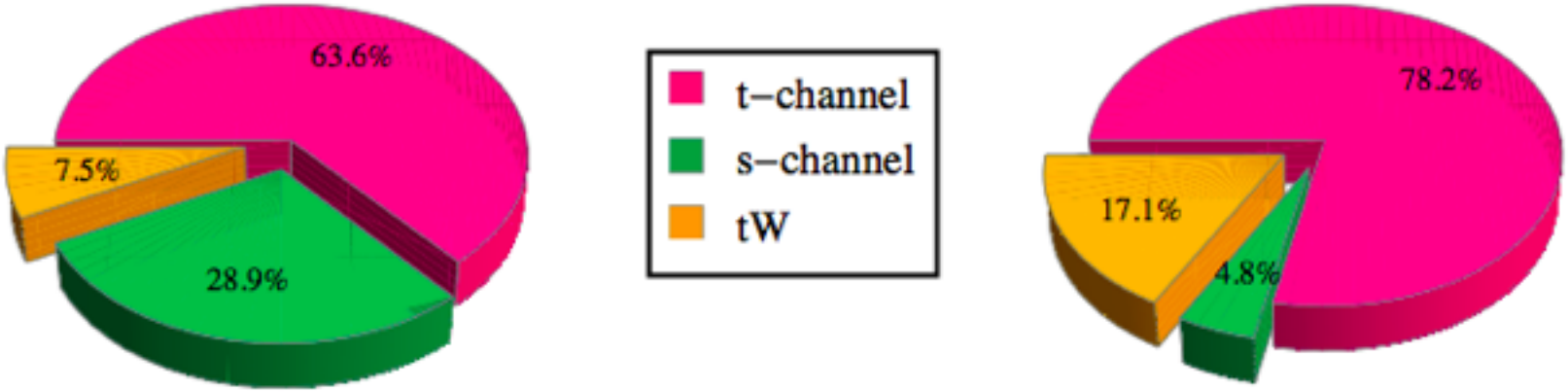






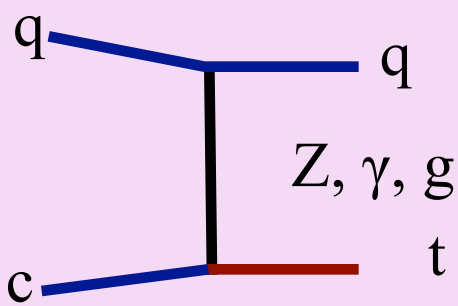
Tevatron: σ_{tot} = 3 pb

LHC: σ_{tot} = 114 pb @ 8 TeV

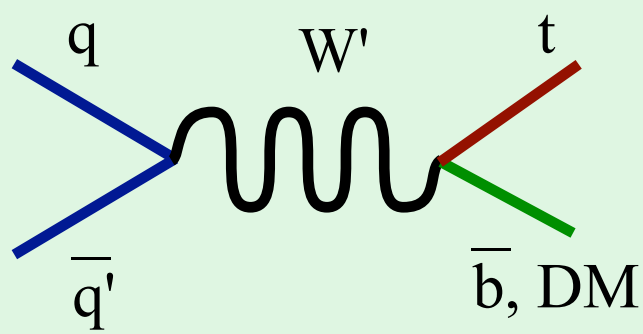


New physics in single top

New interactions or modified couplings: FCNC



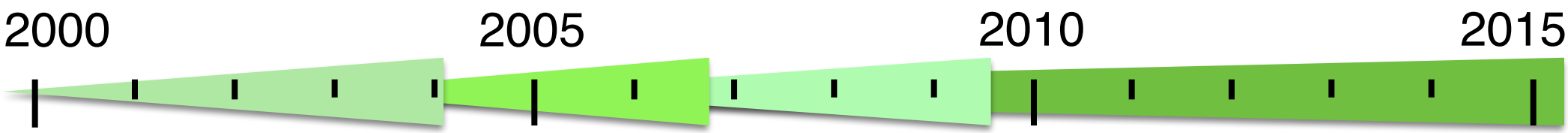
New Heavy boson, dark matter charged Higgs, top quark partners



- W’, fourth generation quarks, charged Higgs
- gluon FCNC
- anomalous Wtb couplings
- Dark matter in association with single top
- measure s-, t-channel cross sections → sensitive to different new physics

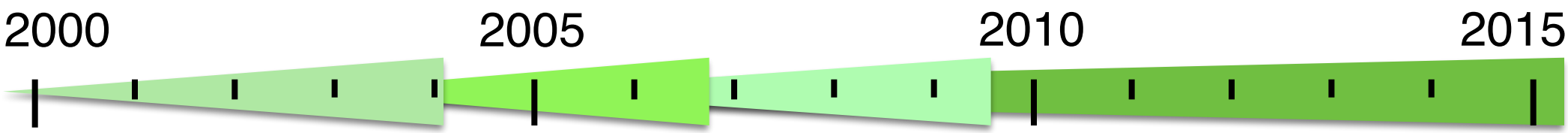
Tevatron single top history

Run I searches



Tevatron single top history

Run I searches Run II searches



Tevatron single top history

Run I searches

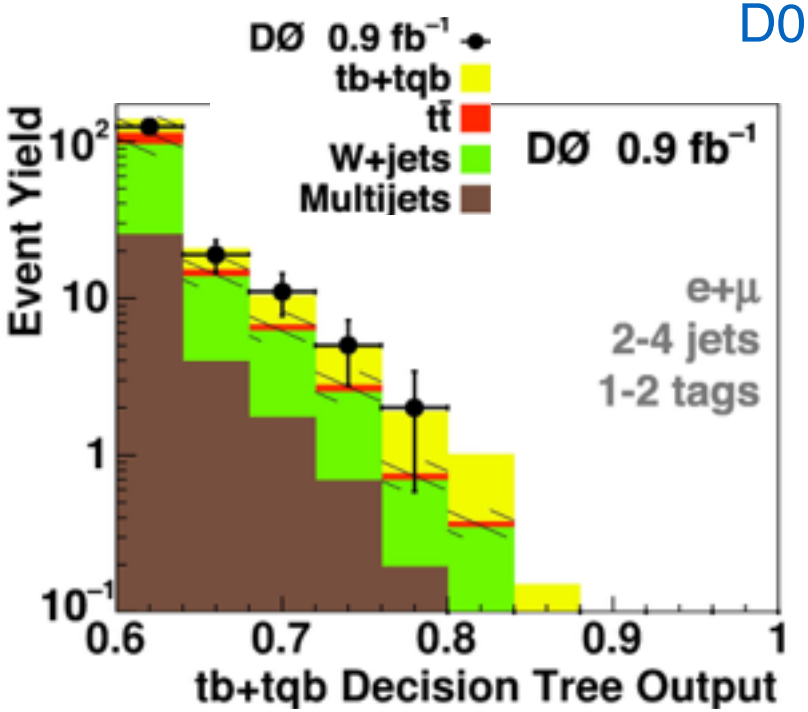
Run II searches

Run II measurements

2000 2005 2010 2015

D0 evidence

CDF evidence

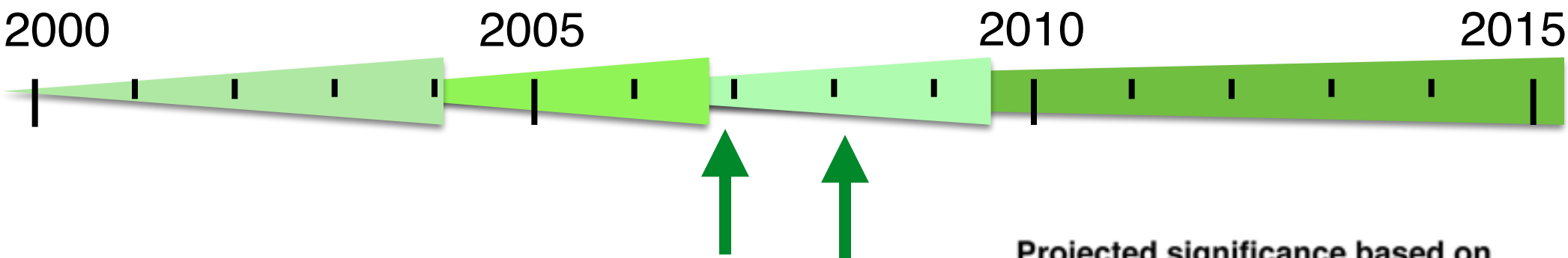


Tevatron single top history

Run I searches

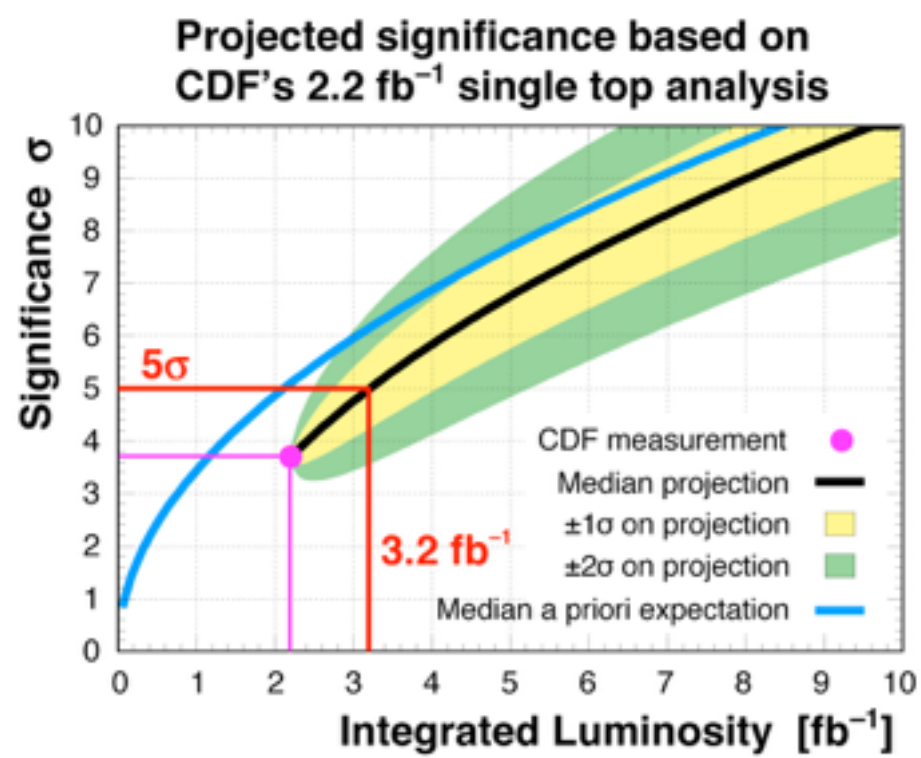
Run II searches

Run II measurements



D0 evidence

CDF evidence

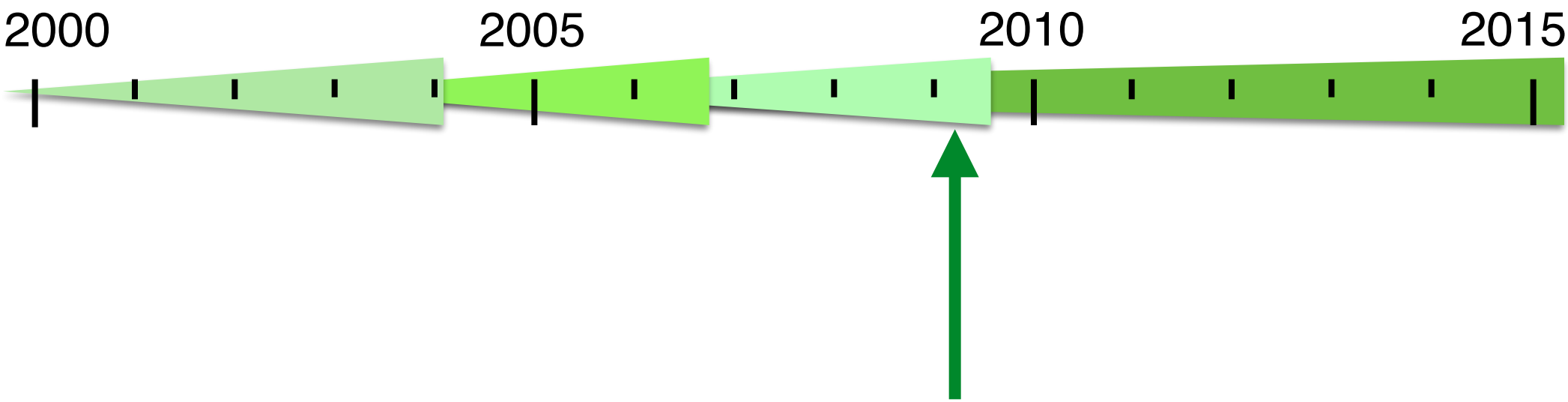


Tevatron single top history

Run I searches

Run II searches

Run II measurements



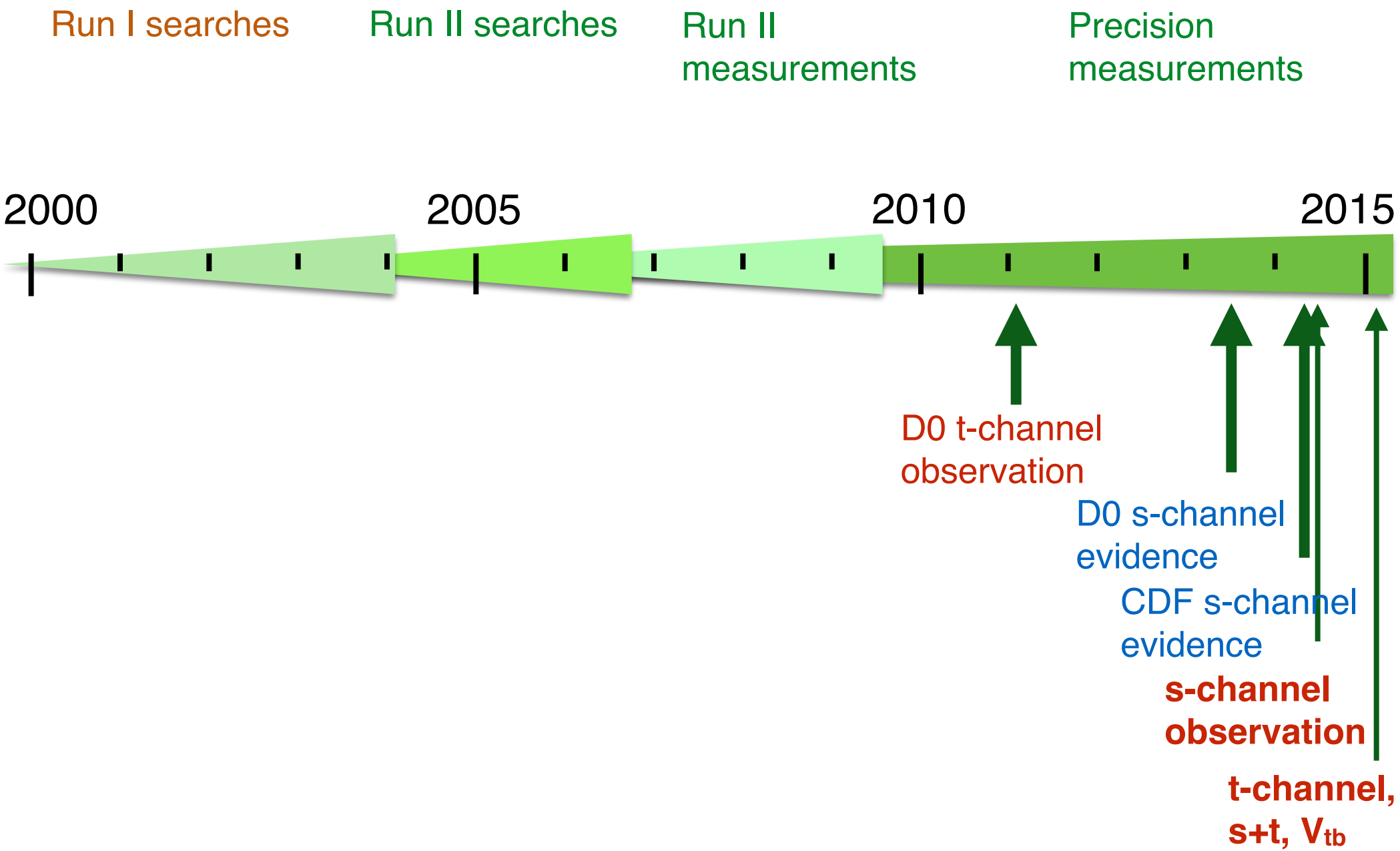
Single top observation

CDF l+jets

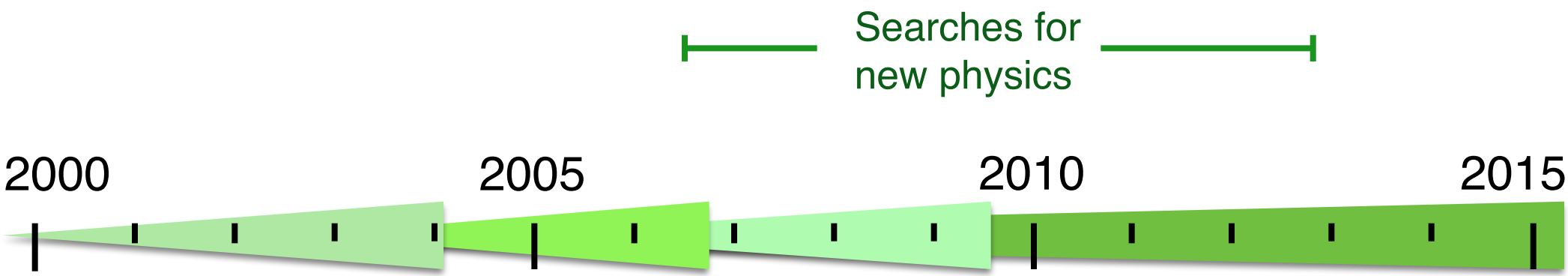
$\not{E}_T$+jets

D0 l+jets

Tevatron single top history



Tevatron single top history



See Florencia's talk on Friday

Single top history

Run I

Run II

· Search:	PRD 63, 031101 (2000)
· Search:	PLB 517, 282 (2001)
· Search:	PLB 622, 265 (2005)
· W':	PLB 641, 423 (2006)
· Search:	PRD 75, 092007 (2007)
· Evidence:	PRL 98, 181802 (2007)
· FCNC:	PRL 99, 191802 (2007)
· W':	PRL 100, 211802 (2007)
· Evidence:	PRD 78, 012005 (2008)
· Wtb:	PRL 101, 221801 (2008)
· Wtb:	PRL 102, 092002 (2009)
· H+:	(PRL) arXiv:0807.0859
· Observation:	(PRL) arXiv:0903.0850
. tau search	PLB 690, 5 (2010)
. t-chan meas.	PLB 682, 363 (2010)
. FCNC	PLB 693, 81 (2010)
. top width	PRL 106, 22001 (2011)
. W'	PLB 699, 145 (2011)
. t-chan obs.	PLB 705, 313 (2011)
. t-channel	PRD 84, 112001 (2011)
. Wtb	PLB 708, 21 (2012)
. top width	PRD 85, 091104 (2012)
. Wtb comb.	PLB 713, 165 (2012)
. s-chan evidence	PLB726, 656 (2013)

· Search:	PRD 65, 091102 (2002)
· W'	PRL 90, 081802 (2003)
· Search:	PRD 69, 052003 (2004)
· Search:	PRD 71, 012005 (2005)
· Evidence:	PRL 101, 252001 (2008)
· FCNC:	(PRL) arXiv:0812.3400
· W':	(PRL) arXiv:0902.3276
· Observation:	(PRL) arXiv:0903.0885
. MET+jets	PRD 81, 072003 (2010)
. Observation	PRD 82, 112005 (2010)
. Dark matter	PRL 108, 201802 (2012)
. s-chan	PRL 112, 231804 (2014)
. s-chan METj+lj	PRL 112, 231805 (2014)
. s+t	PRL 113, 261804 (2014)
. s+t METj+lj	(PRL) arXiv:1410.4909

Tevatron 1983-2011

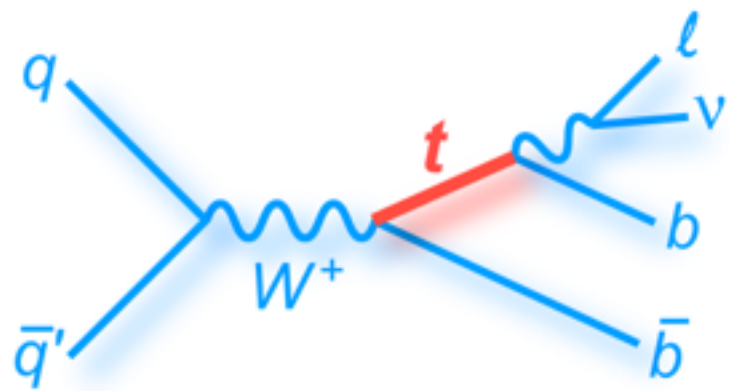
s+t	arXiv:0908.2171 (2009)
s-chan observation	PRL 112, 231803 (2014)
t, s+t	(PRL) arXiv:1503.05027

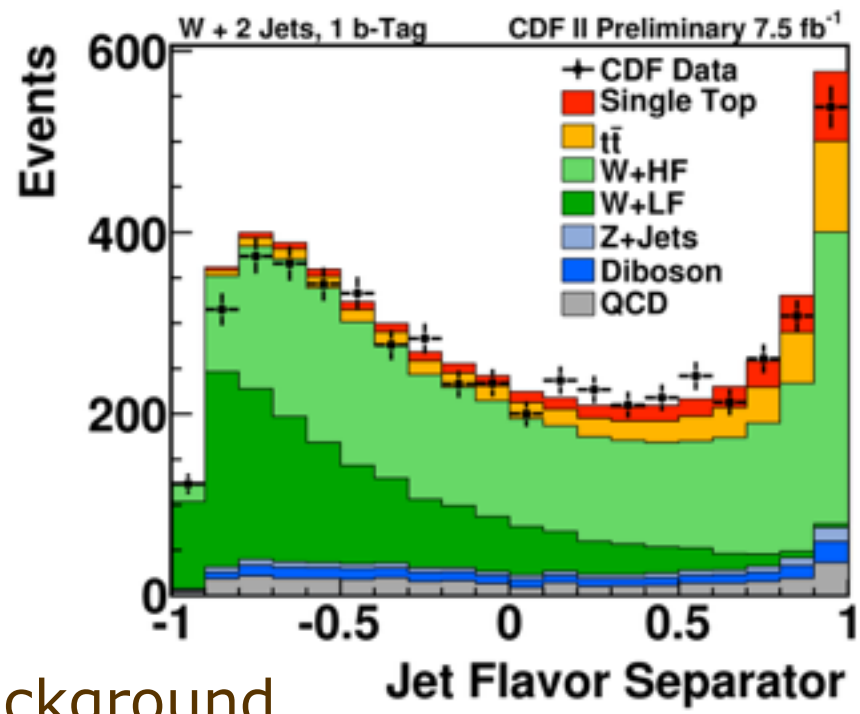
Single top with 10 fb^{-1}

Tevatron s-channel combination	PRL 112, 231803 (2014)
Tevatron s+t combination	(PRL) arXiv:1503.05027

Single top event selection

- Lepton + jets selection (CDF and D0)
  - 1 Lepton, large MET
  - 2 or 3 jets
  - ≥ 1 b-tagged jet
  - Veto "non-W", Z, dileptons, conversions, cosmics
- Expected signal events:
  ~250 s-channel
  ~400 t-channel

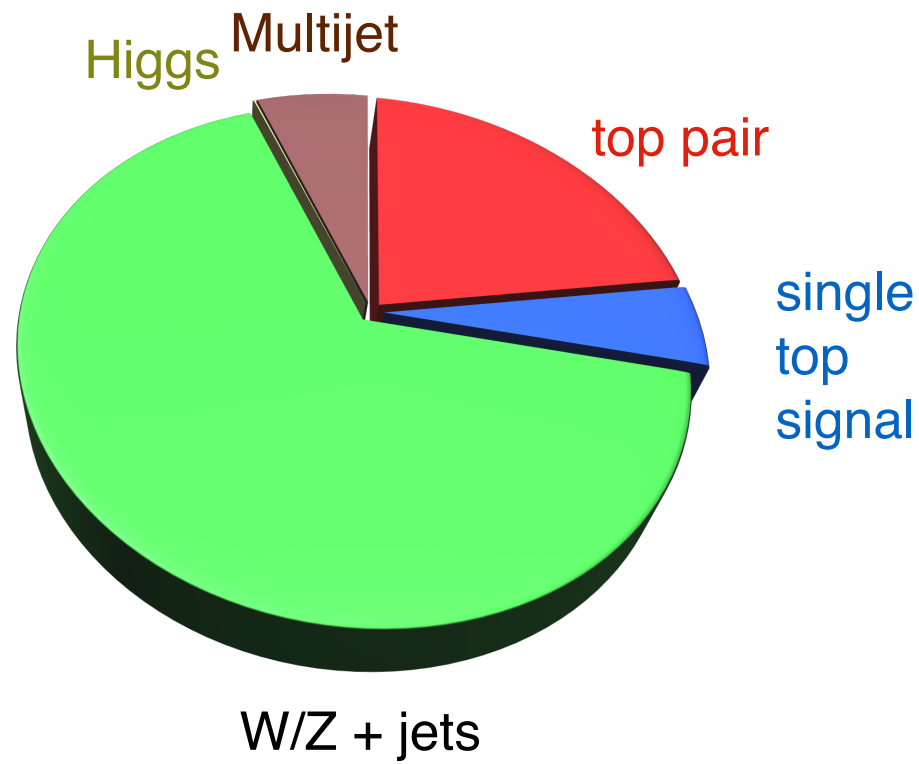




- MET + jets selection (CDF):
  - Large MET, veto leptons
  - 2 or 3 jets
  - ≥ 1 b-tagged jet
  - Neural network to suppress QCD background
  - ~250 s-channel events expected

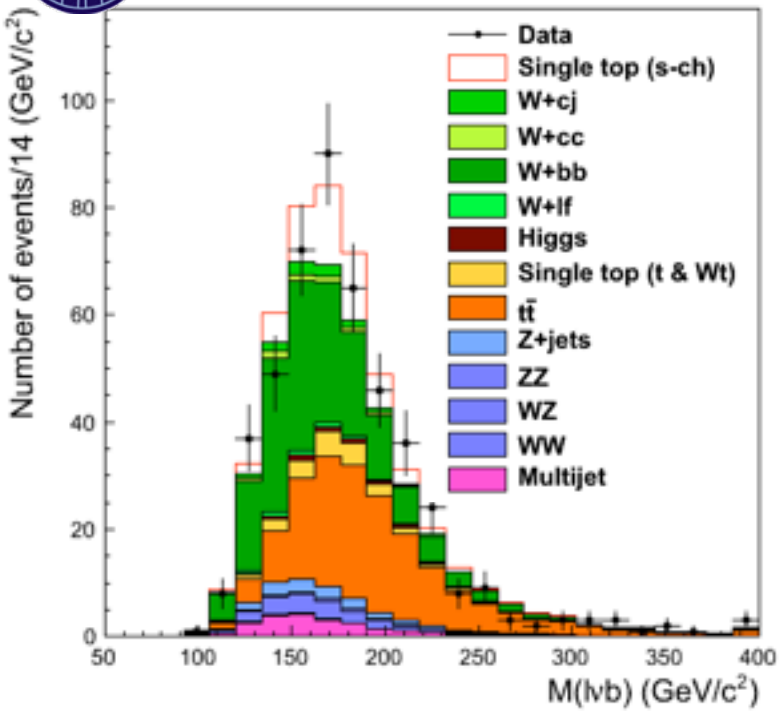
Background composition

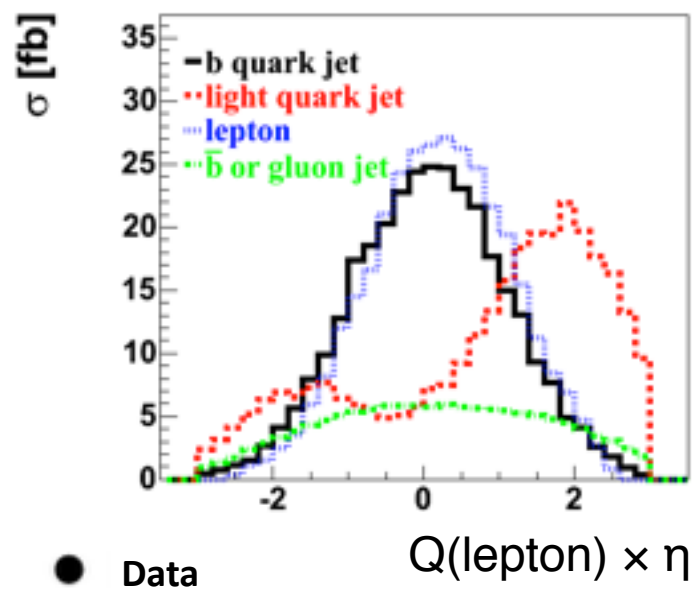
- W/Z+jets
  - W+jets Normalization and flavor composition from data
  - W+jets shape from simulation
  - Diboson from simulation
- top pair production
  - normalization to NNLO
  - Shape from Alpgen
- QCD multijet production
  - Normalization from data
  - Shape from data
- VH

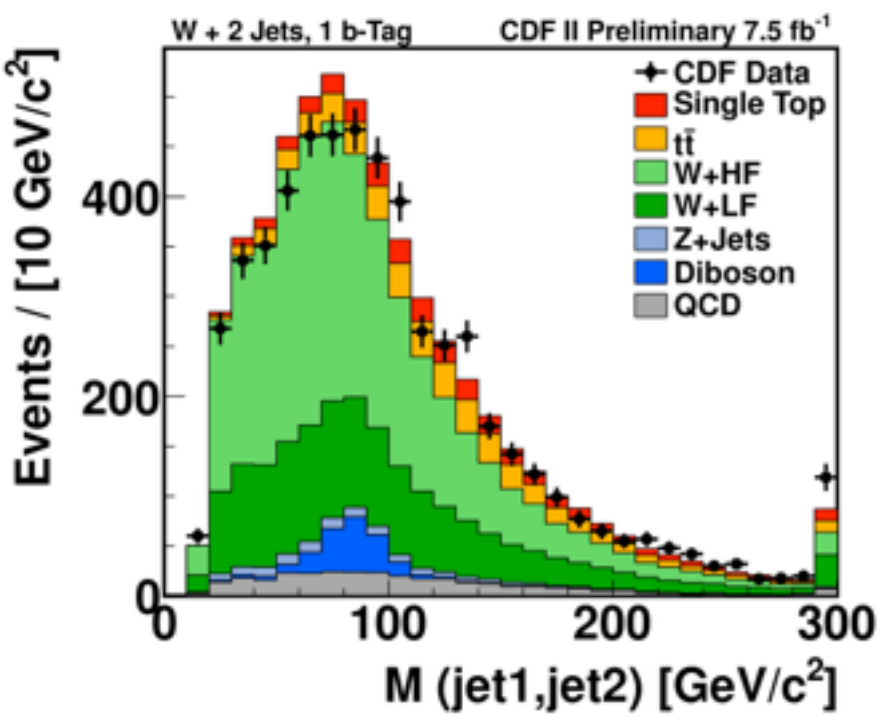


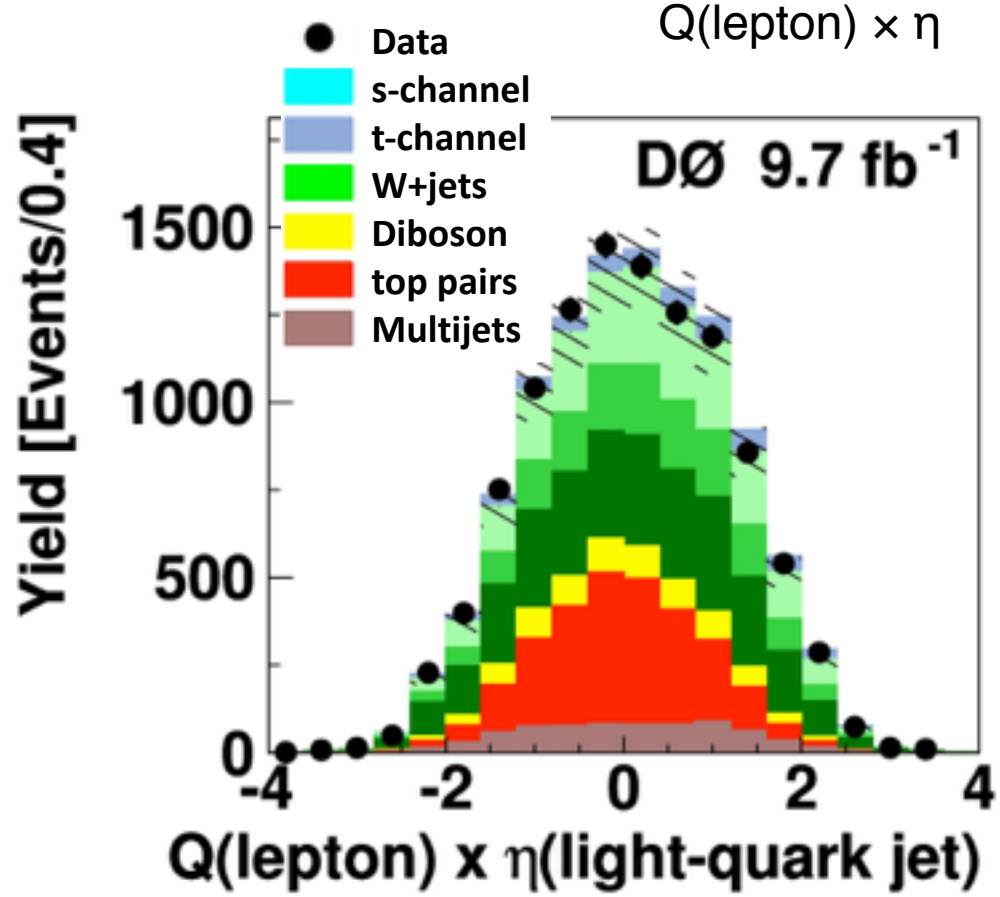
- Total:
  - 10^5 events (lepton+jets)
  - 10^6 events (MET+jets)

Discriminating variables

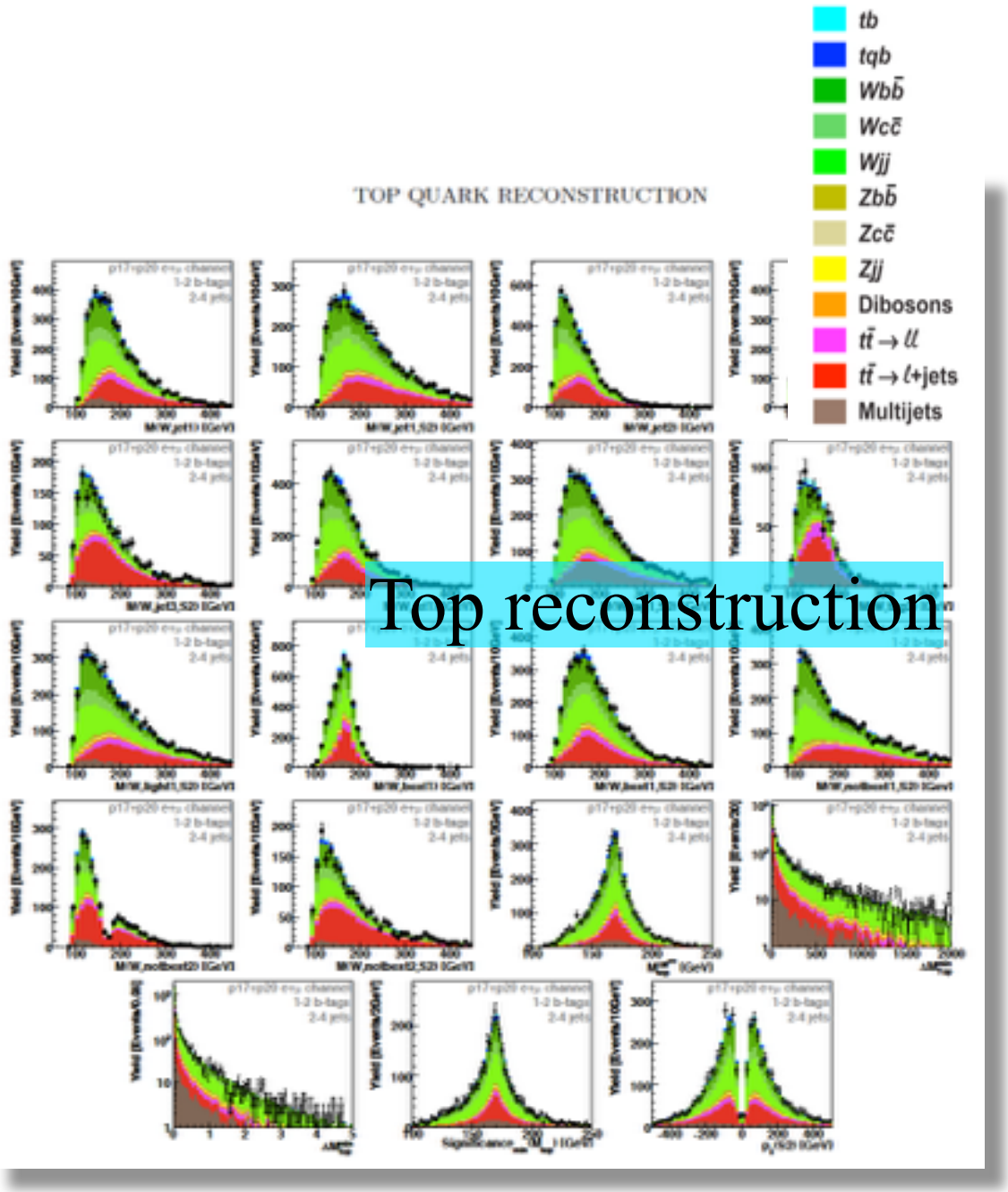




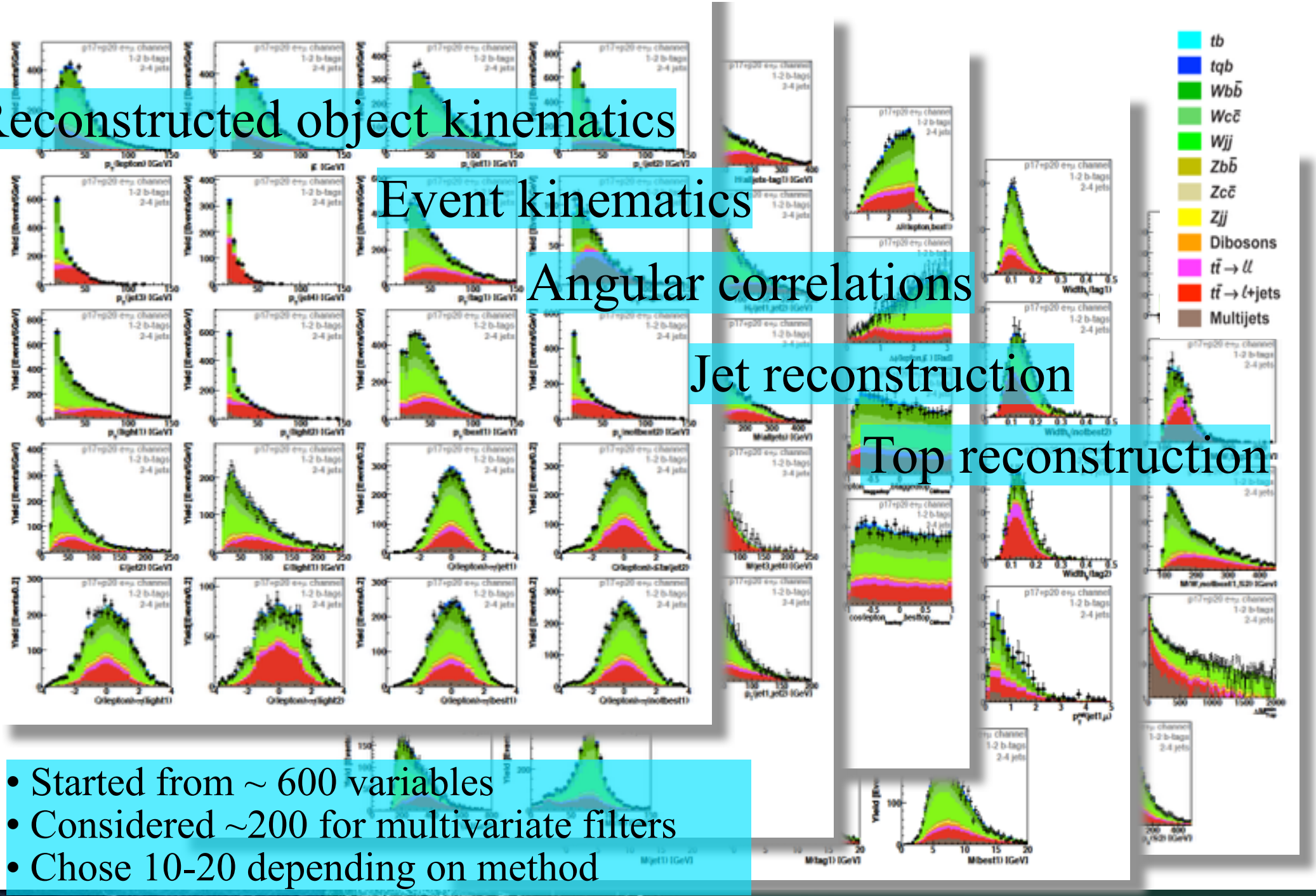




Discriminating variables



Discriminating variables



Reconstructed object kinematics

Event kinematics

Angular correlations

Jet reconstruction

Top reconstruction

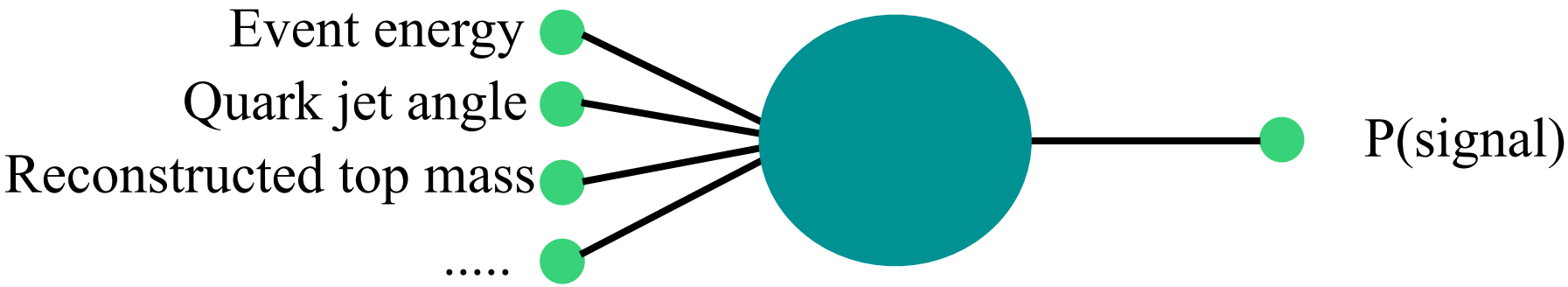
- Started from ~ 600 variables
- Considered ~200 for multivariate filters
- Chose 10-20 depending on method

Multivariate Analysis Methods

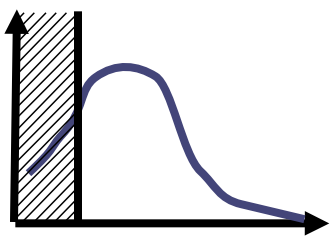
Input:
discriminating variables

Method:
multivariate analysis

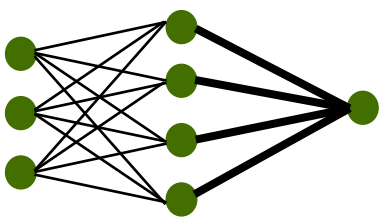
Output:
signal likelihood



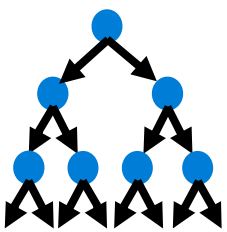
Cut-Based



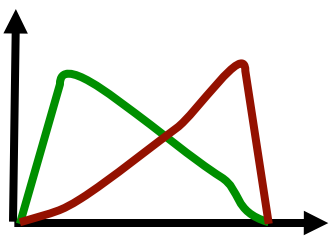
Neural networks



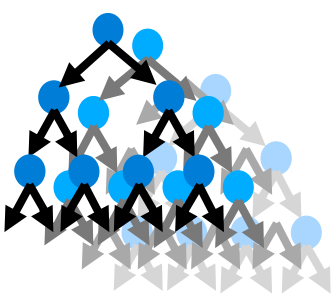
Decision trees



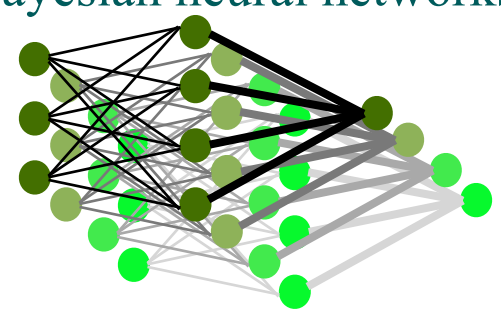
Likelihood



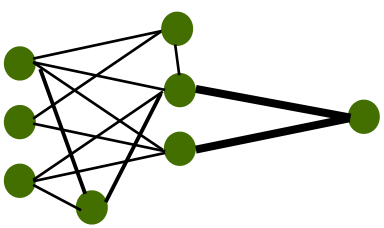
Boosted decision trees



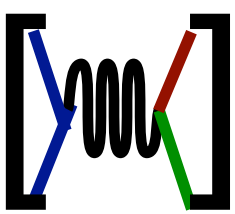
Bayesian neural networks



Neuro evolution



Matrix Elements

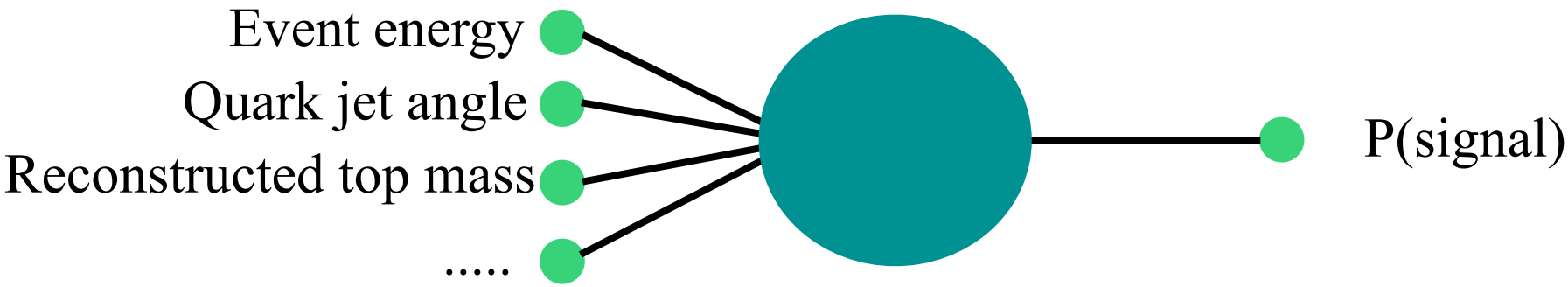


Multivariate Analysis Methods

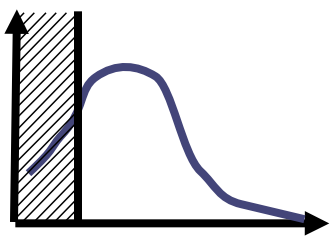
Input:
discriminating variables

Method:
multivariate analysis

Output:
signal likelihood

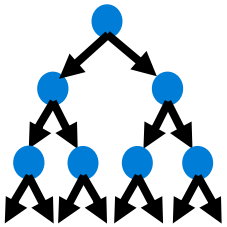


Cut-Based

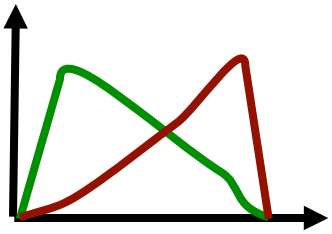


Neural networks

Decision trees

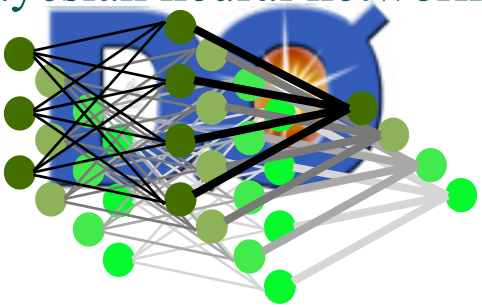


Likelihood

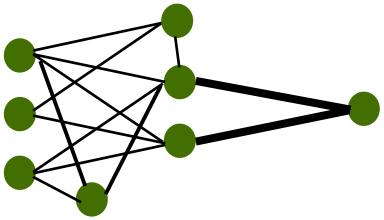


Boosted decision trees

Bayesian neural networks

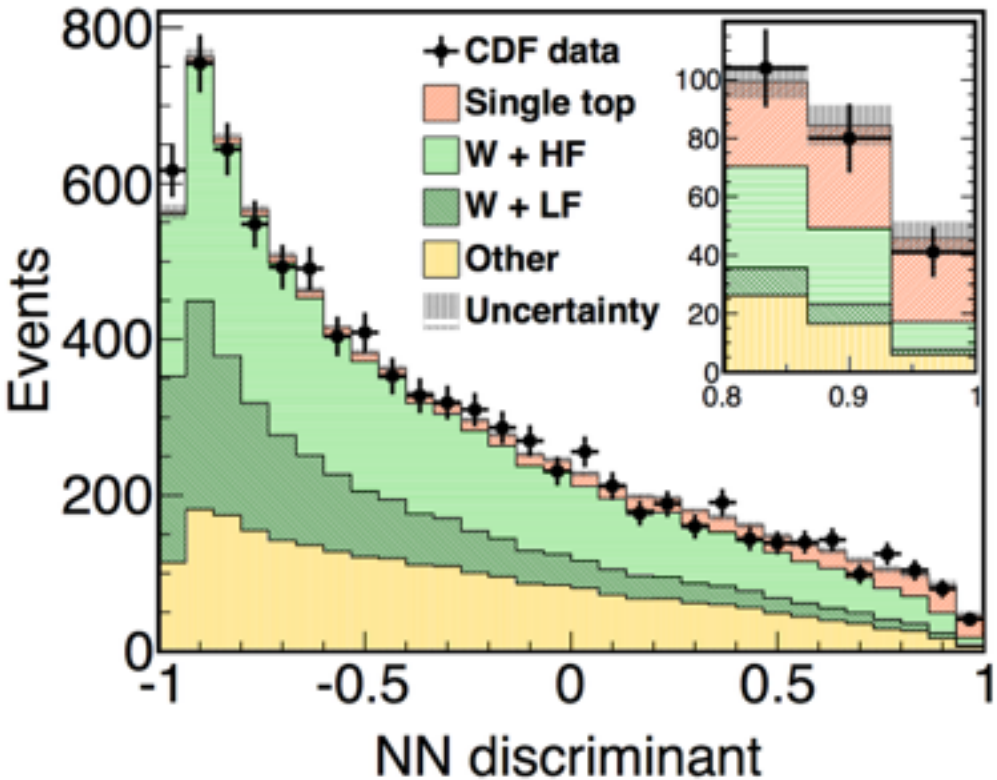


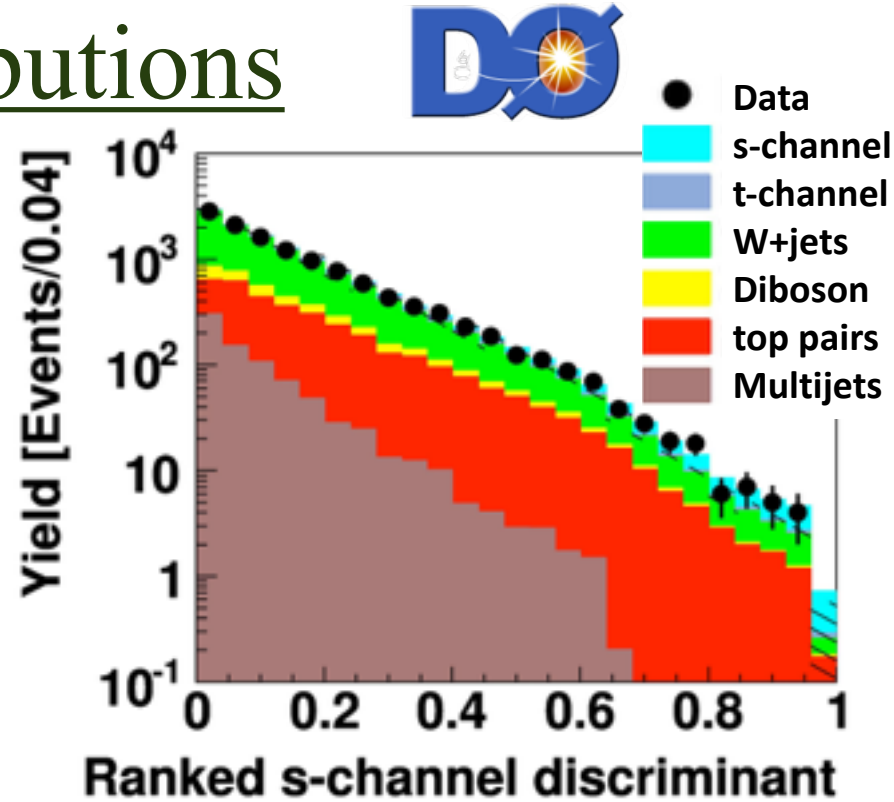
Neuro evolution

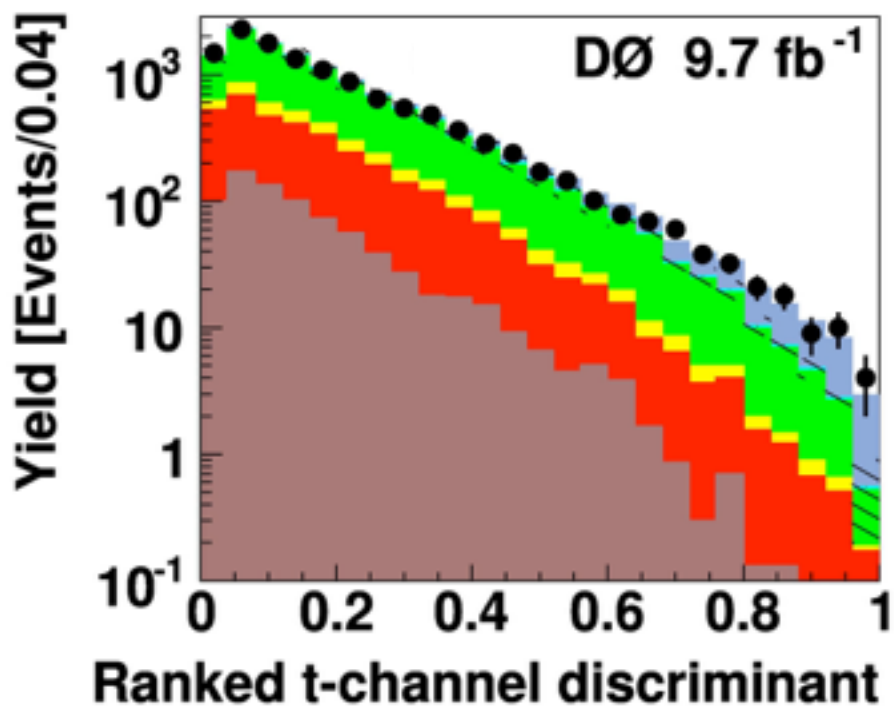


Matrix Elements

MVA distributions

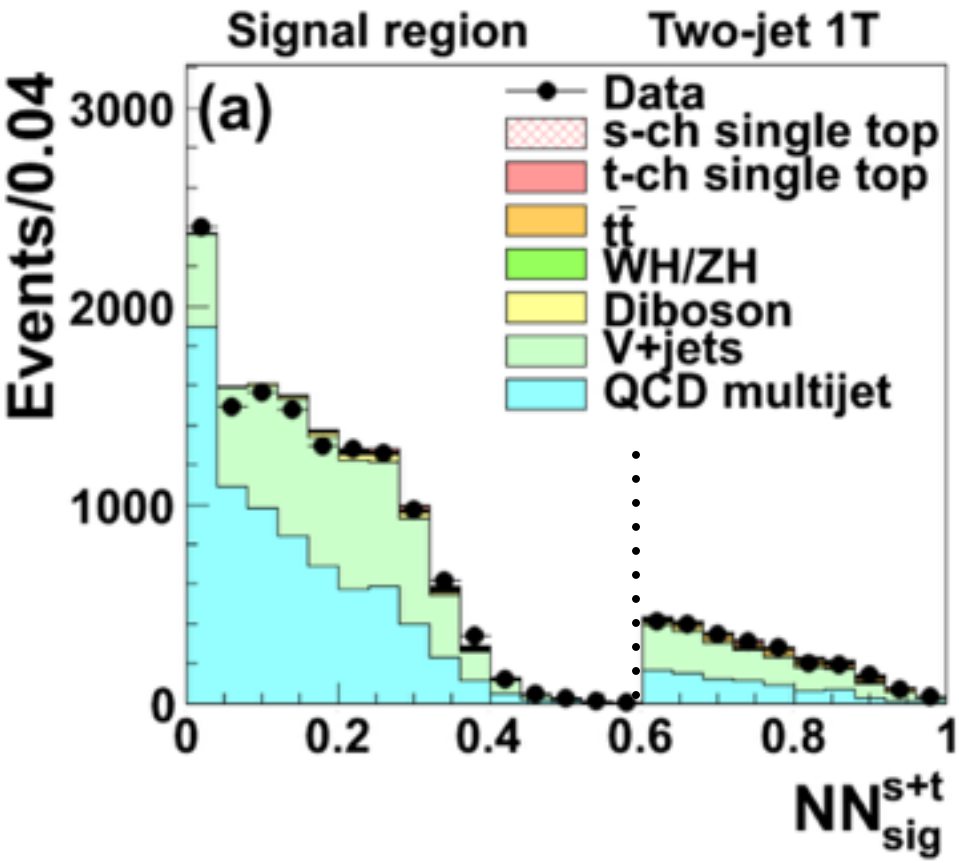


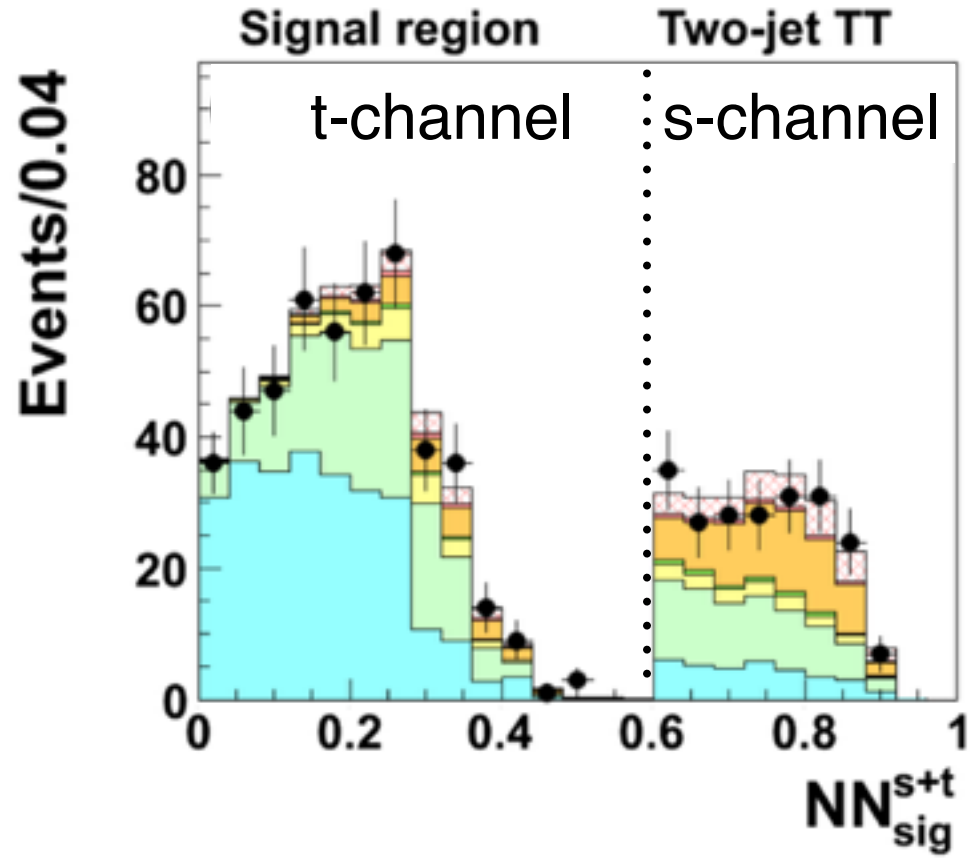




- CDF: lepton+jets
  s+t discriminant
- D0: s-channel, t-channel
  - Probability-based combined discriminant

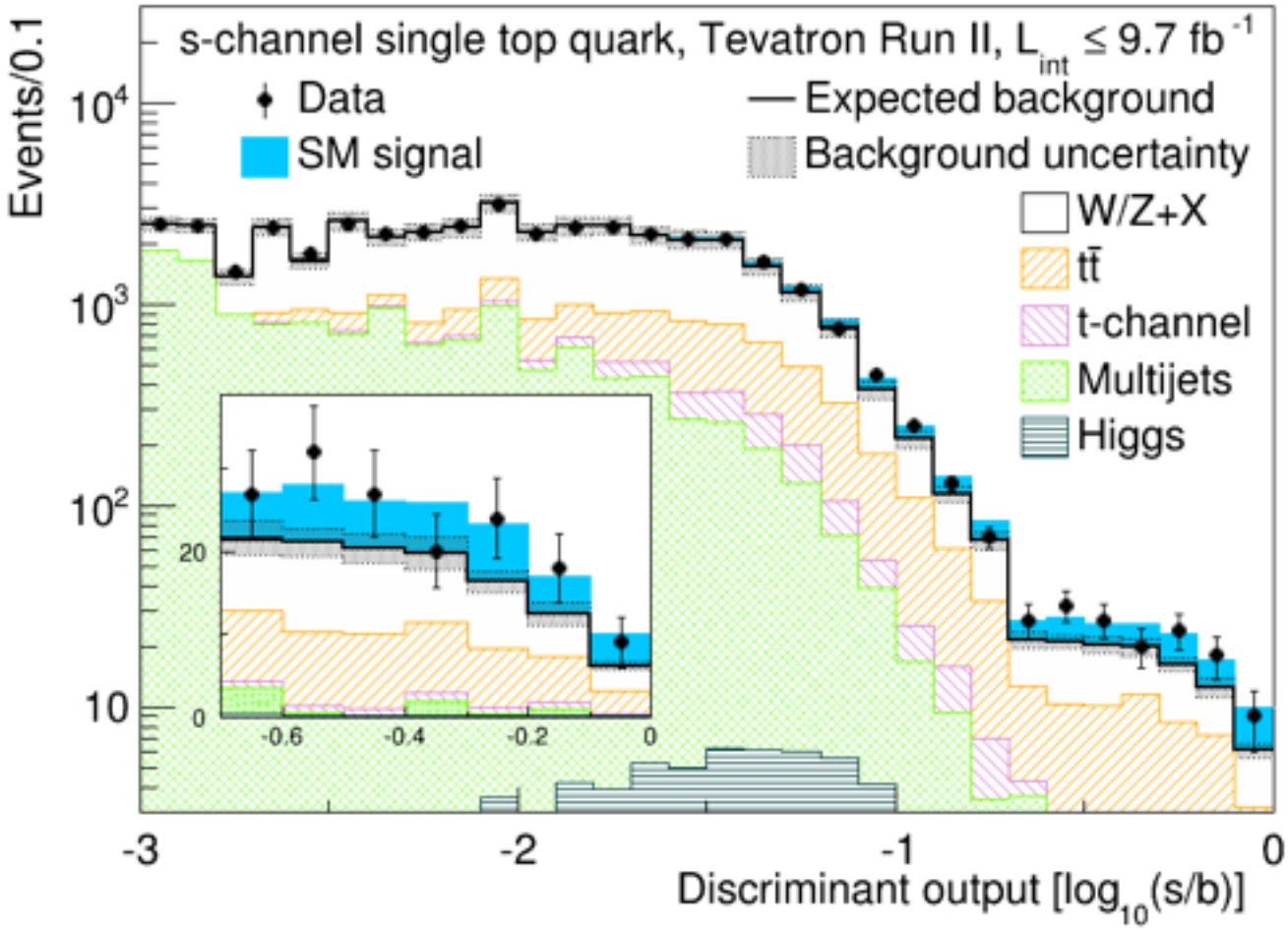
MVA discriminant in MET+jets





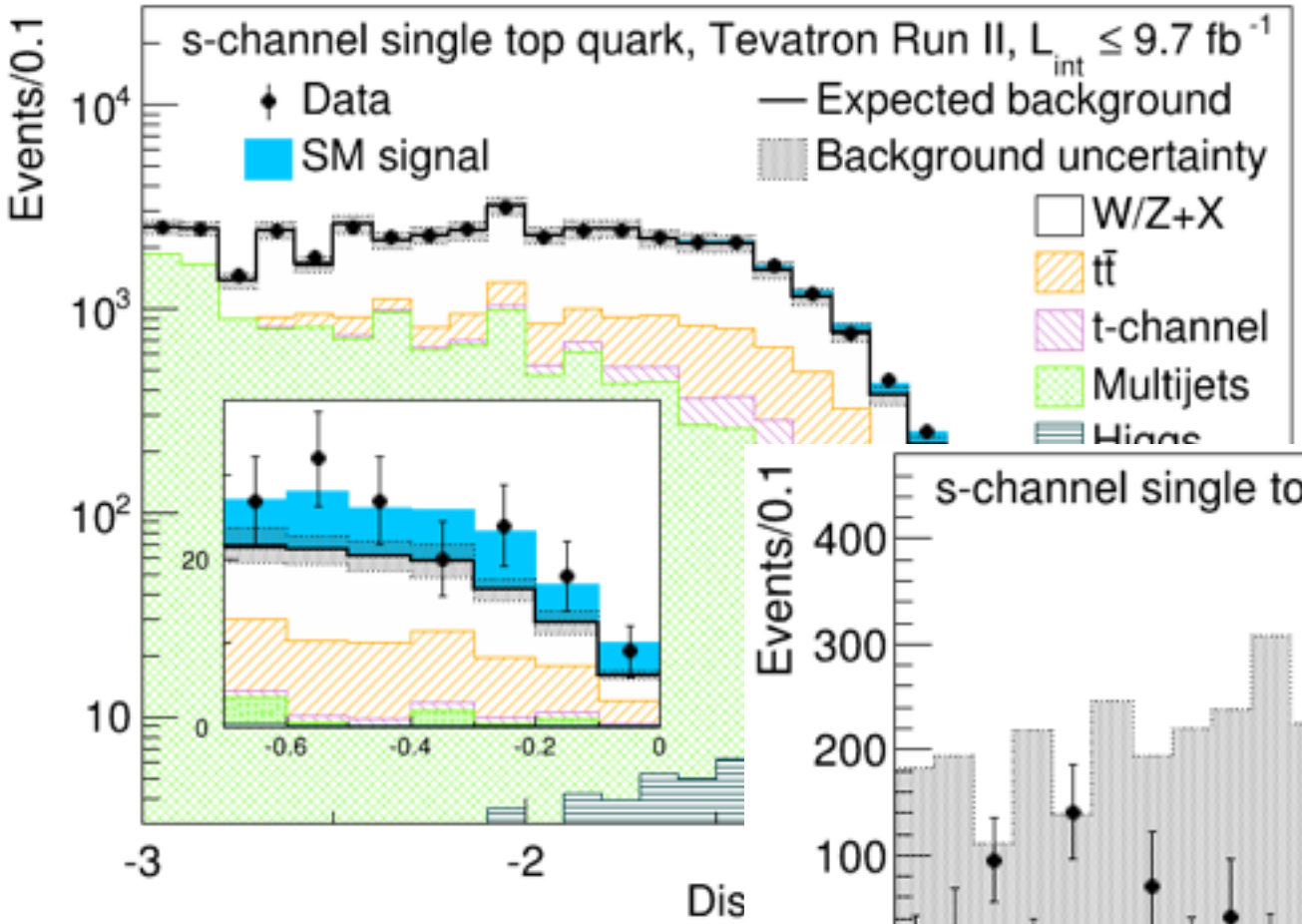
- s-channel optimized discriminant
- t-channel discriminant if NN(s-channel)<0.6

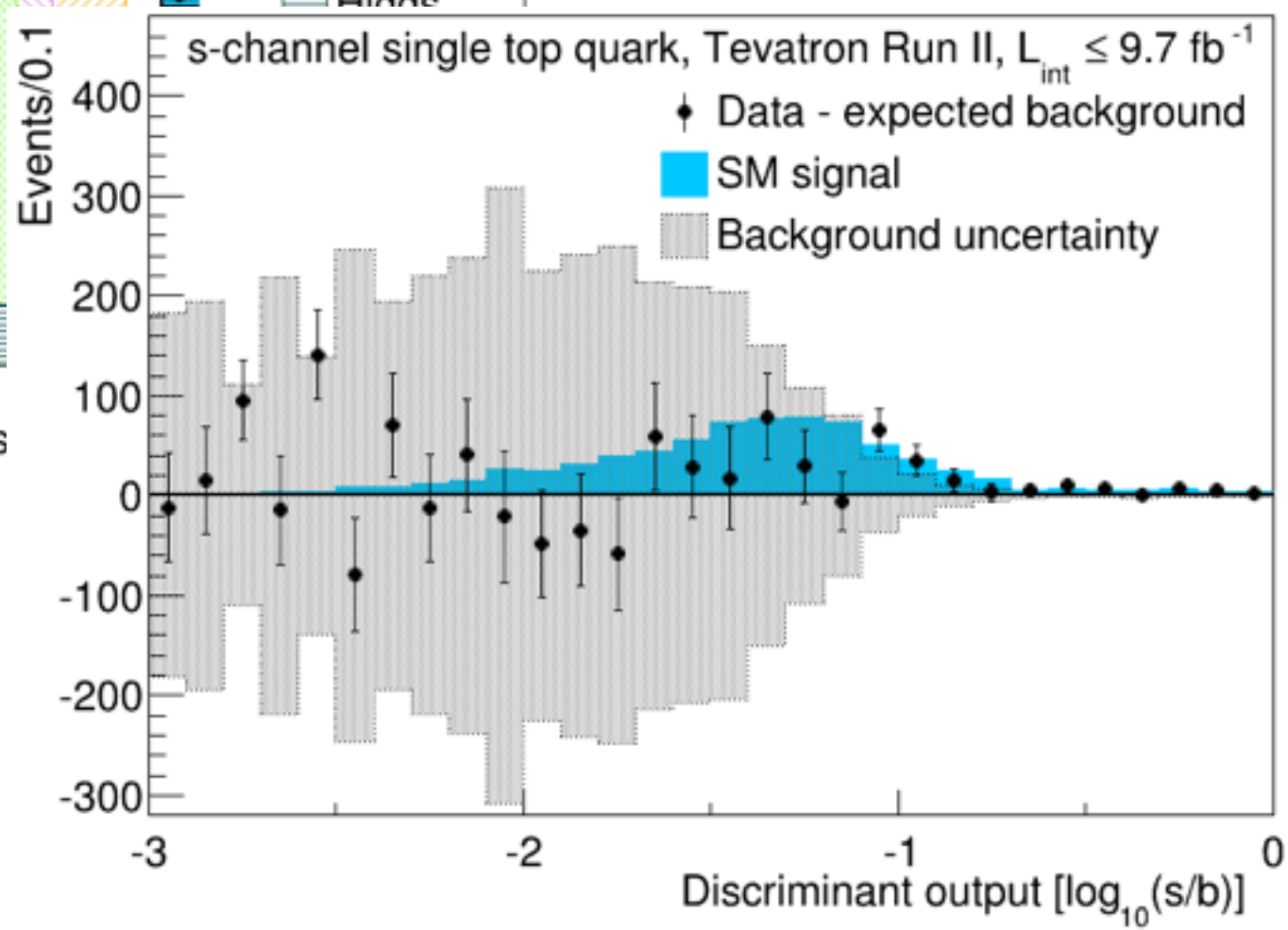
Tevatron combined s-channel discriminant



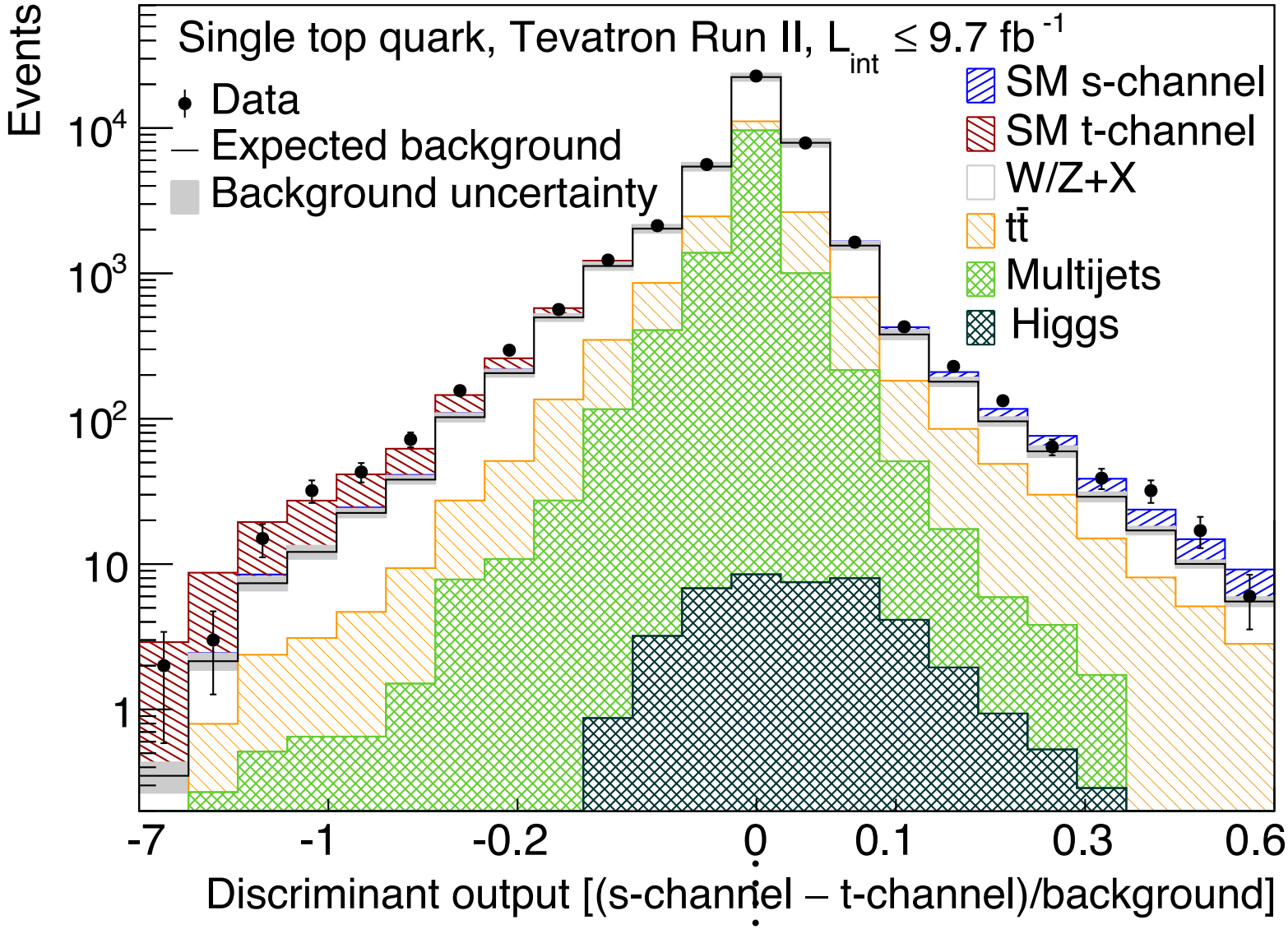
- Statistical analysis including all 600 bins of CDF and D0 discriminants
  - 600 bins total
- Include all systematic uncertainties and their correlations

Tevatron combined s-channel discriminant



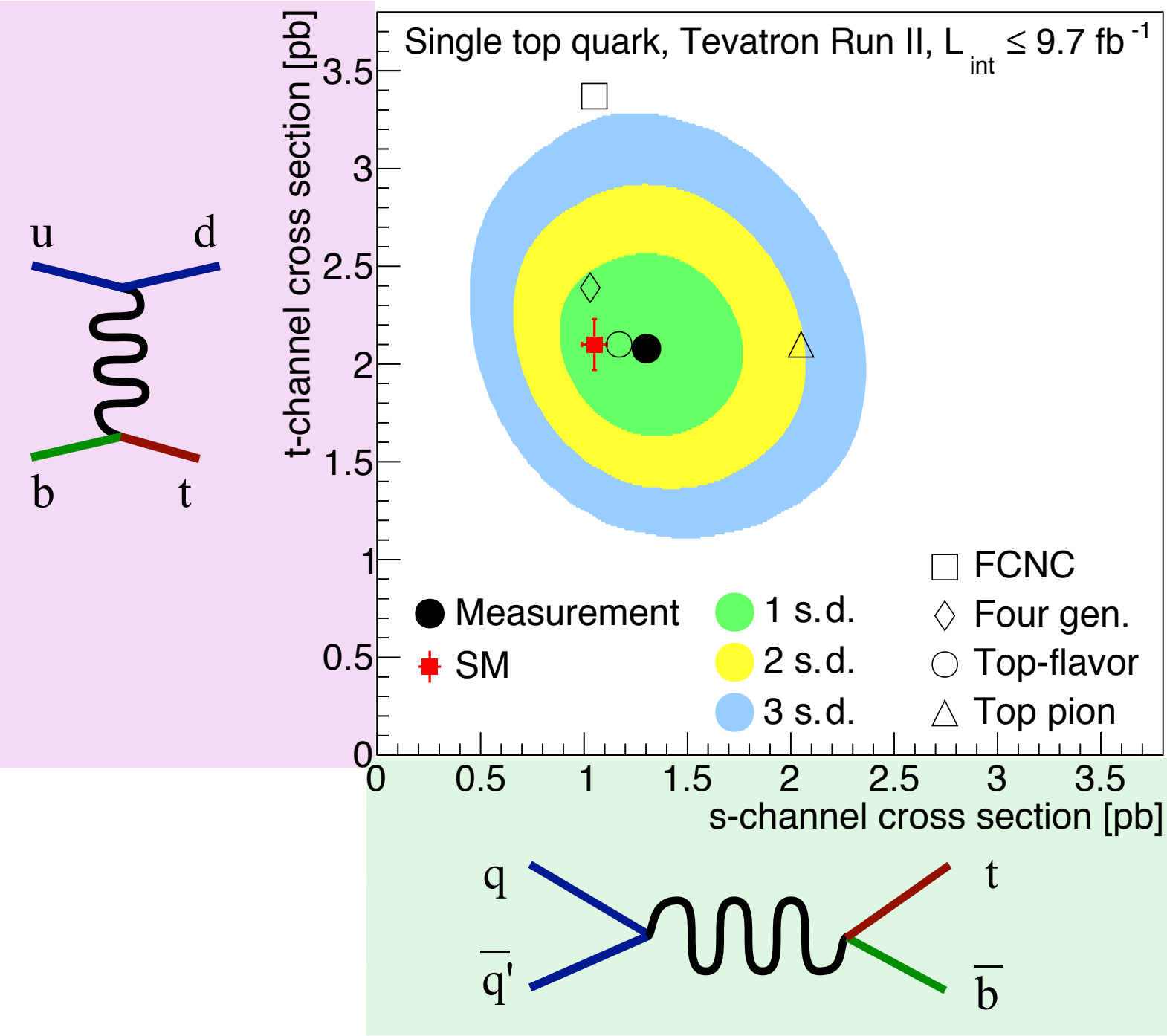


Tevatron s+t discriminant

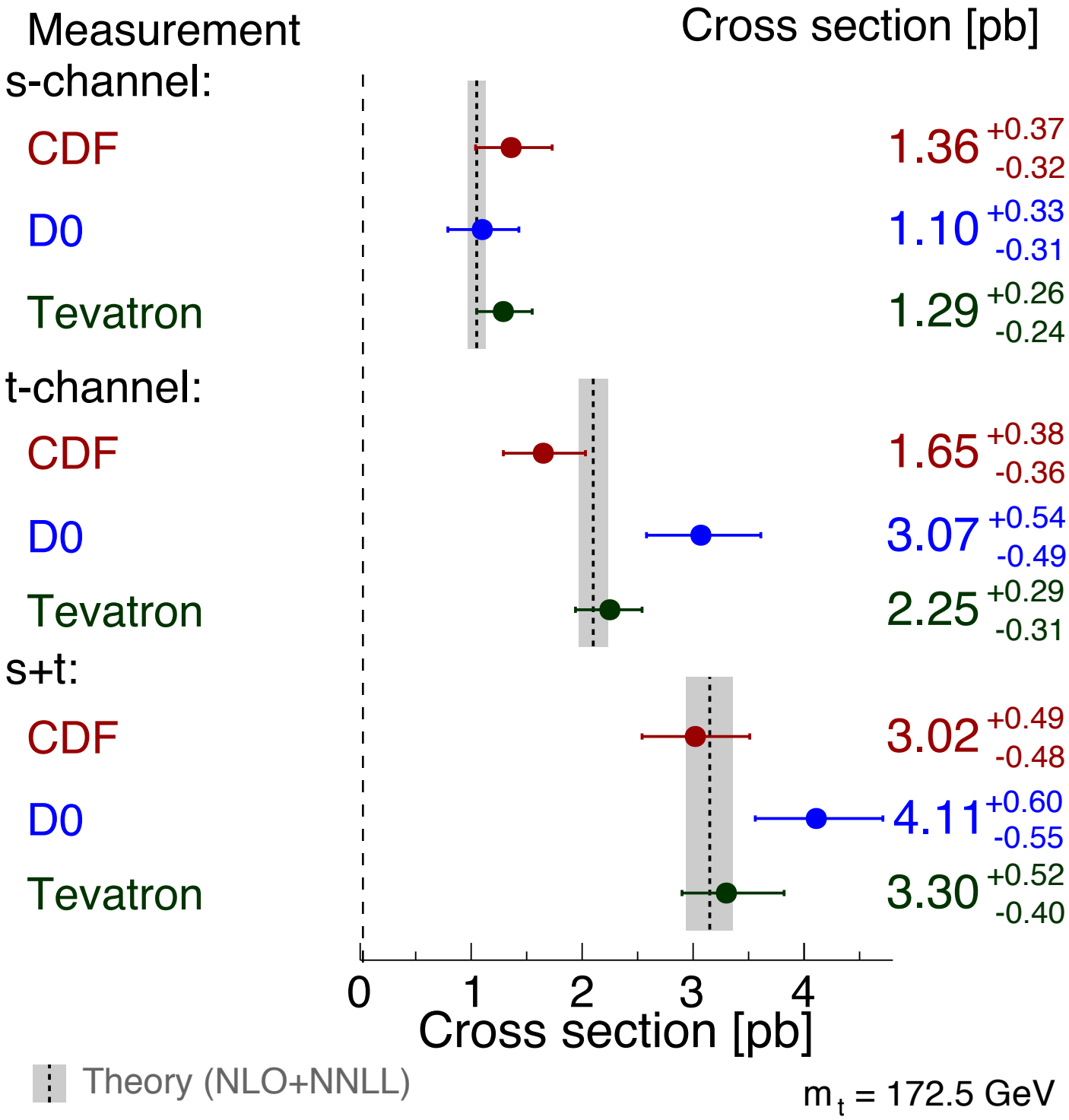


X-axis units: t-channel s/b | s-channel s/b

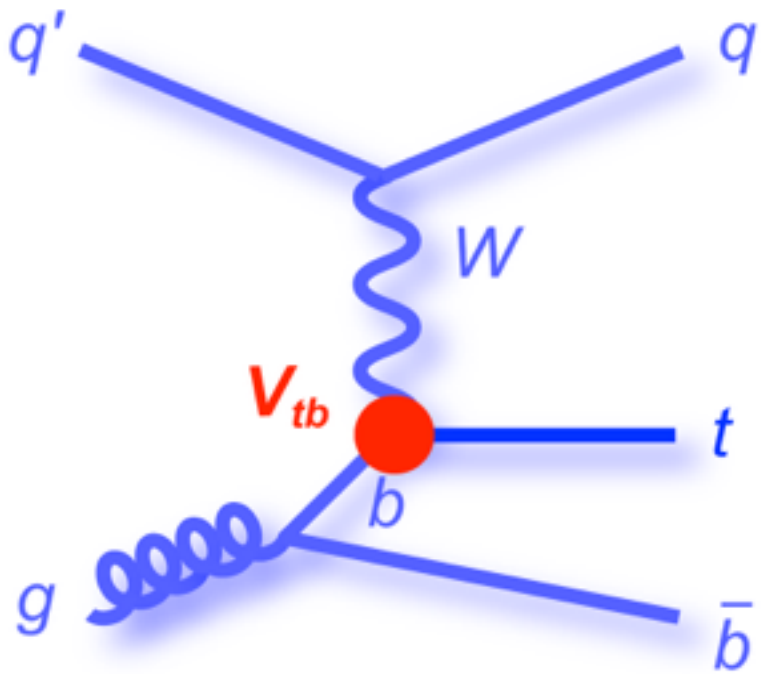
t-channel vs s-channel



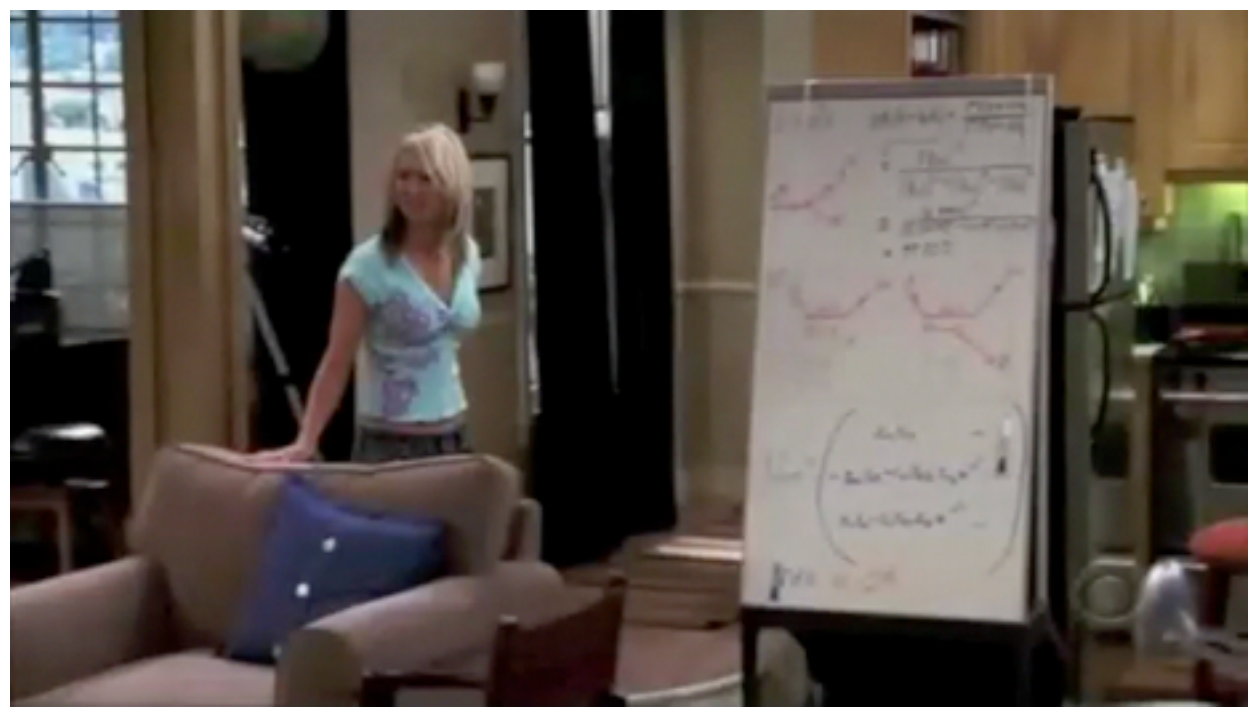
Tevatron Run II single top quark summary



Vtb

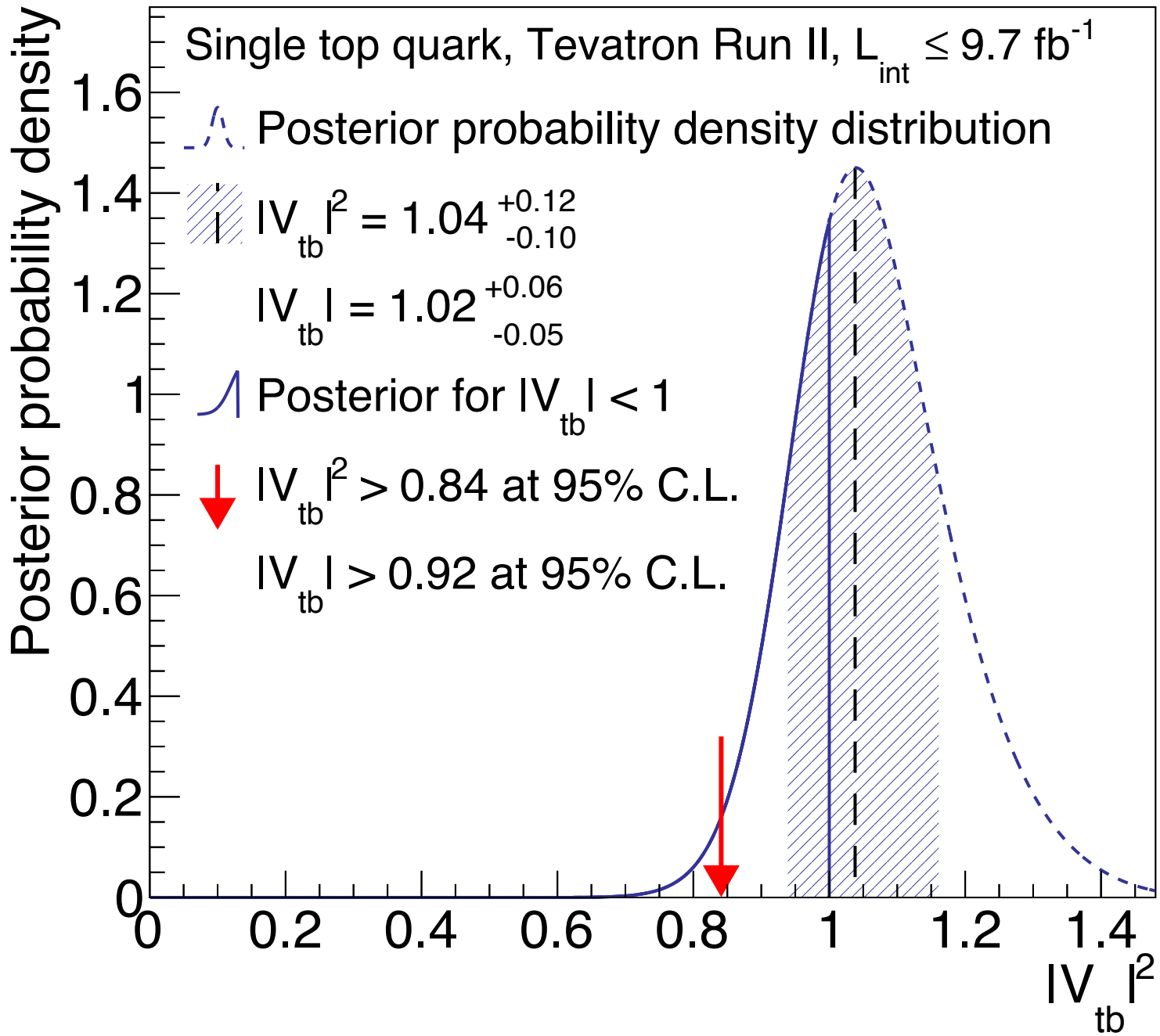


$$\mathrm{CKM4} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} & V_{ub'} \\ V_{cd} & V_{cs} & V_{cb} & V_{cb'} \\ V_{td} & V_{ts} & V_{tb} & V_{tb'} \\ V_{t'd} & V_{t's} & V_{t'b} & V_{t'b'} \end{pmatrix}$$



- $\sigma_{s+t} \propto |V_{tb}|^2$

Vtb

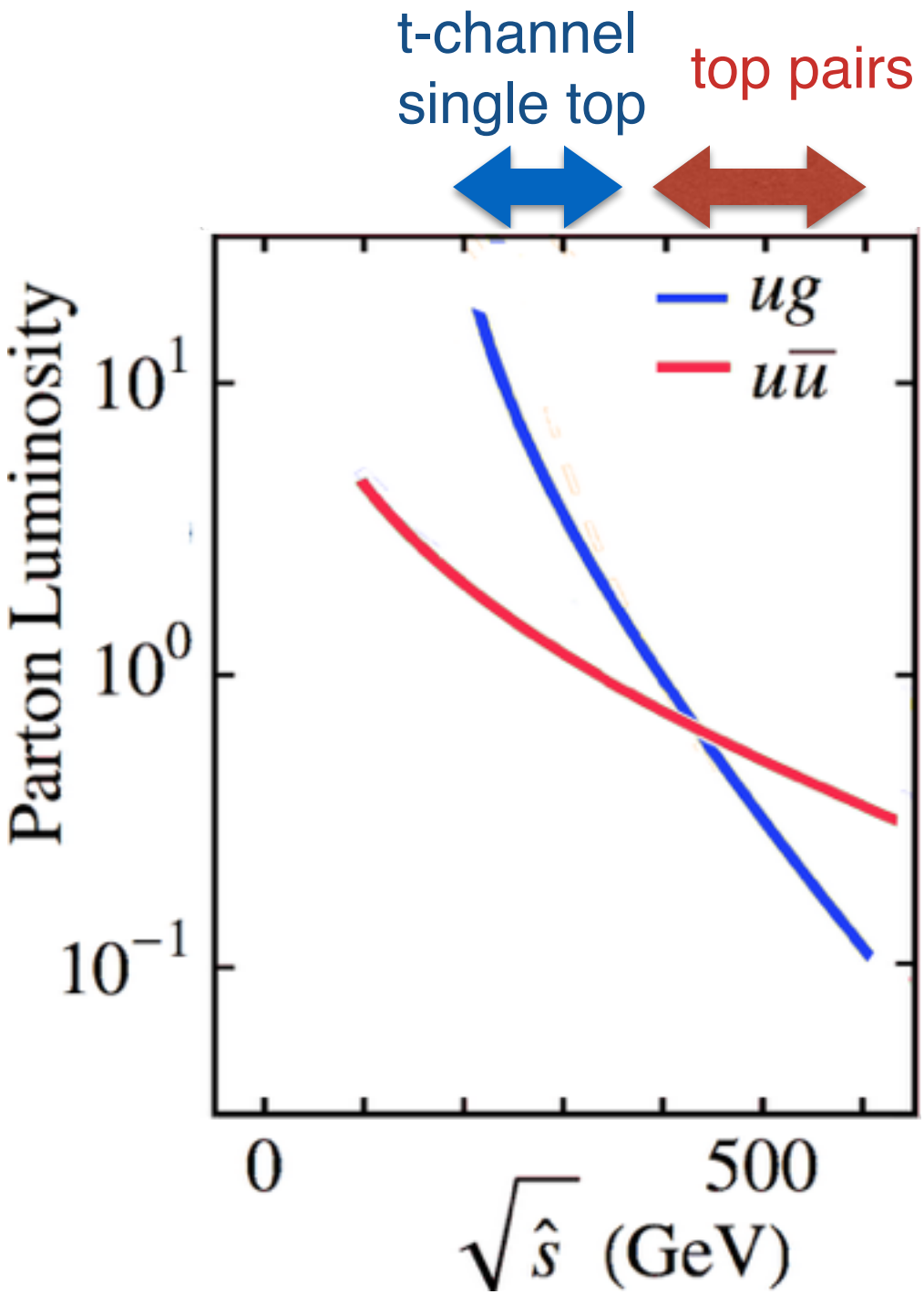

Single top quark, Tevatron Run II, $L_{int} \leq 9.7\ fb^{-1}$
Posterior probability density distribution
$|V_{tb}|^2 = 1.04^{+0.12}_{-0.10}$
$|V_{tb}| = 1.02^{+0.06}_{-0.05}$
Posterior for $|V_{tb}| < 1$
$|V_{tb}|^2 > 0.84$ at 95% C.L.
$|V_{tb}| > 0.92$ at 95% C.L.
Posterior probability density
$|V_{tb}|^2$
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

Summary

- Tevatron established single top and paved the way
  - MVA techniques at hadron colliders
  - Measurements with MET+jet
- Precision measurements of t-channel, s-channel, s+t
  - Cross sections, V_{tb}, width, couplings, new physics
- Tevatron single top program exceeded all expectations

Backup slides

Thanks!

- Tevatron physics for the informed public
  http://www.fnal.gov/pub/today/frontier_science_result
- Tevatron single top combinations
  http://tevewwg.fnal.gov/singleTop/
- CDF top physics results:
  http://www-cdf.fnal.gov/physics/new/top/top.html
- DØ top physics results:
  http://www-d0.fnal.gov/Run2Physics/top/

Parton luminosities