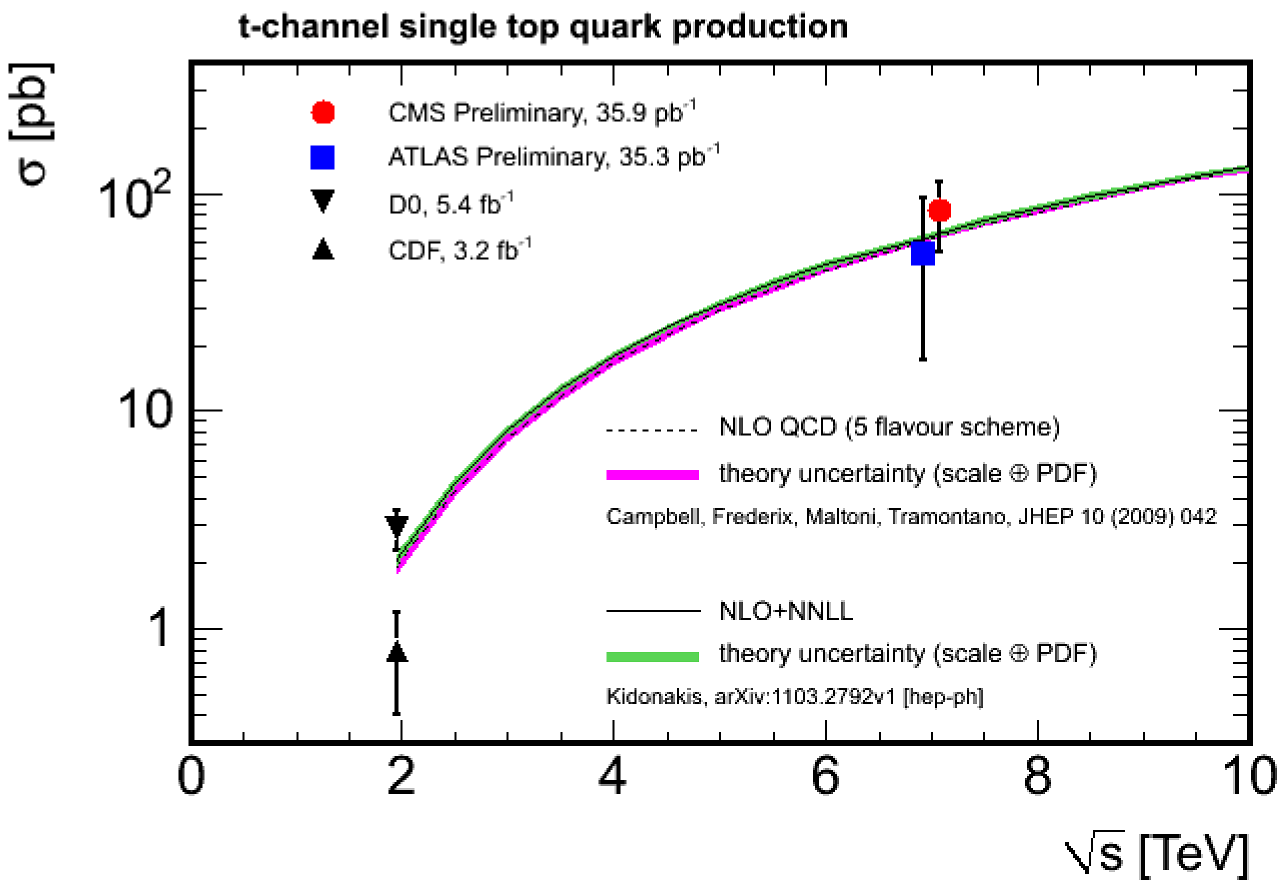
Single top at 7 TeV: the first measurement by CMS

Andrea Giammanco (FNRS & CP3-UCL)



CMS collaboration, CMS PAS **TOP-10-008**
http://cdsweb.cern.ch/record/1335719?ln=en

Acknowledgements: a team work

Cross sections
Chris Neu (Virginia)
Silvano Tosi (Lyon)

Top mass and properties
Steve Wimpenny (Riverside)
Jeremy Andrea (Strasbourg)

Single top
Andrea Giammanco (Louvain)
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The 3 subgroups of the CMS Top Physics Analysis Group

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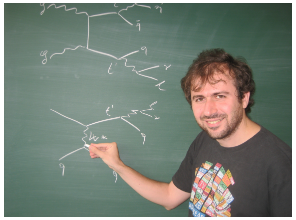
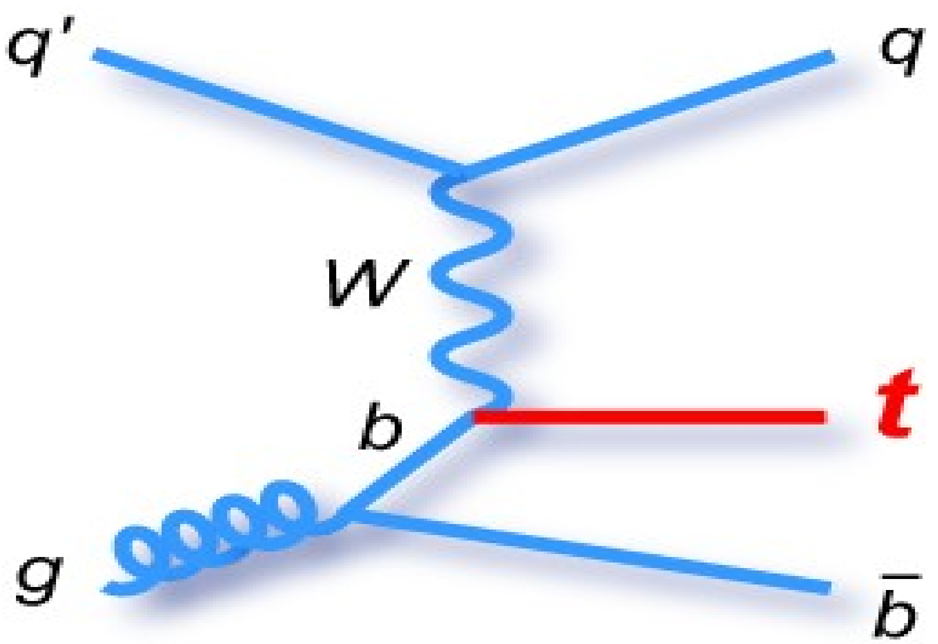


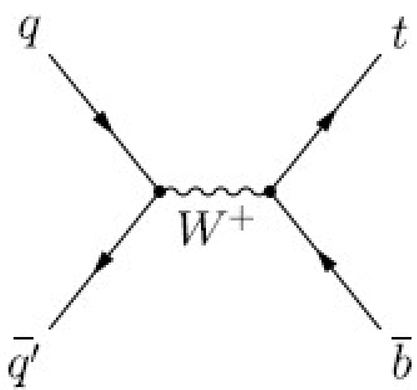
Andrea Giammanco (Louvain)

Outline

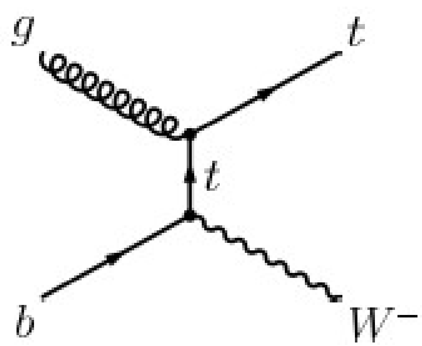
1. **Introduction**
2. **Experimental setup**
3. **Single top analysis**
   - Selection & backgrounds
   - 2D analysis
   - BDT analysis
   - $|V_{tb}|$ limits
   - Combination



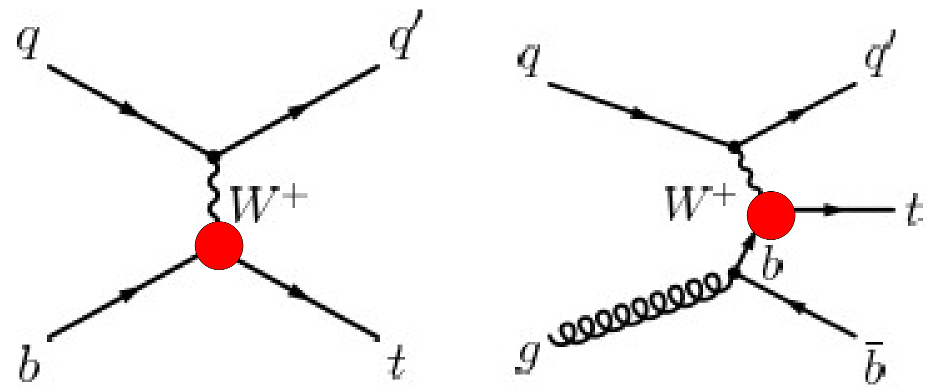
Probing EW interactions of the top quark in a new energy regime



s channel
(4 pb @ 7 TeV)



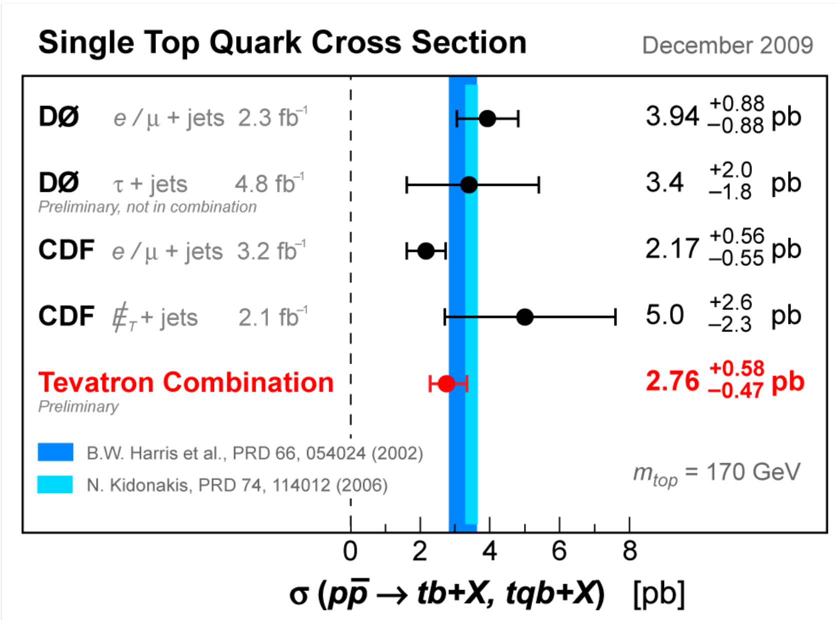
tW
(11 pb @ 7 TeV)



t channel
(62 pb @ 7 TeV)

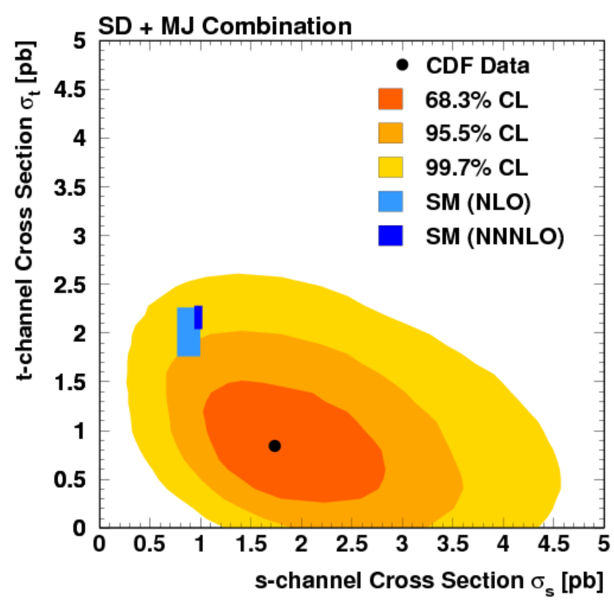
- Tevatron: >5σ in s+t (~1+2 pb)
  - Separate s/t results also appeared
  - tW negligible at 1.96 TeV
- LHC, 7 TeV: t channel dominant
  - s channel & tW are treated as backgrounds in this first study
- Goals (increasing statistics):
  - **Confirmation of Tevatron & First cross section @ 7 TeV**
  - Competitive constraint on $|V_{tb}|$ ⇒ sensitivity to 4th quark family
  - FCNC, charged resonances, etc.; the 3 channels offer complementarity

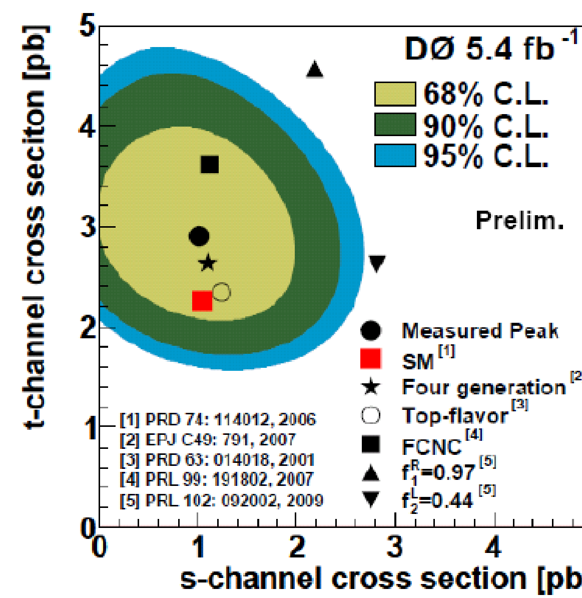
State of the art at Tevatron



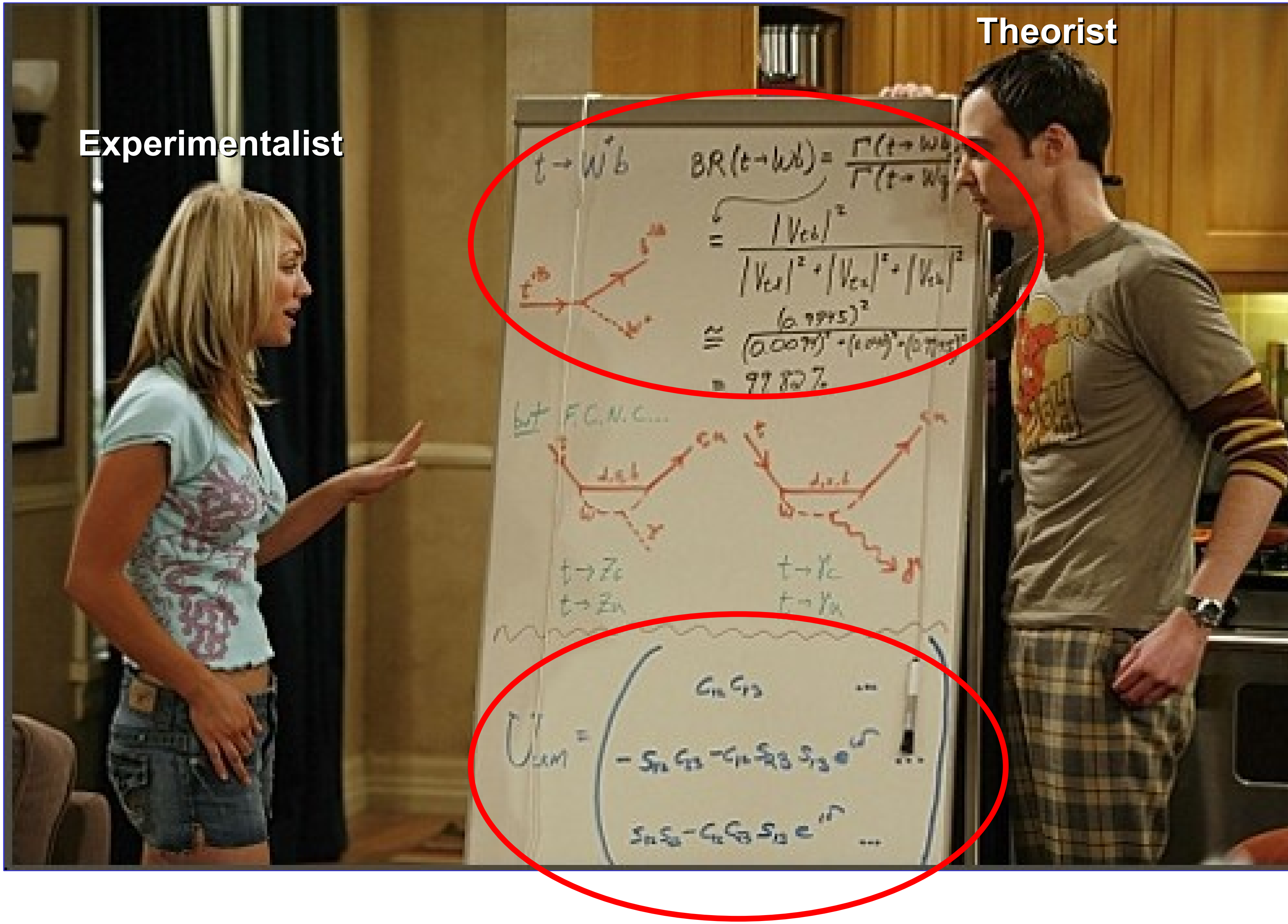
Inclusive (t+s)

t vs s:



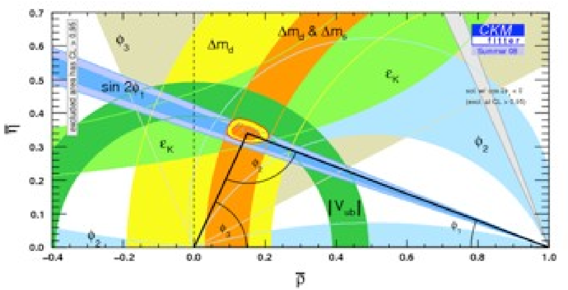


A little bit of theory



The CKM matrix

$$\begin{bmatrix} |d'\rangle \\ |s'\rangle \\ |b'\rangle \end{bmatrix} = \begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} \begin{bmatrix} |d\rangle \\ |s\rangle \\ |b\rangle \end{bmatrix} .$$



- It is **unitary**, meaning that:
  - Any two rows or columns are orthogonal; verified in K and B exps
  - The scalar product of any row and any column by its own complex conjugate is **1**; if less ⇒ evidence for new quarks
- Very precise direct measurements of the 1st and 2nd rows:
  - $|V_{ud}|$: from $0^+ \rightarrow 0^+$ β decays
  - $|V_{us}|$: mostly from semileptonic K decays
  - $|V_{ci}|$ (i=d,s): from D, D_s decays; $|V_{cd}|$ also from $\nu d \rightarrow \mu^- c$
  - $|V_{ib}|$ (i=u,c): from B decays

What about the 3rd row

- First two rows + Standard Model + 3x3 unitarity ⇒

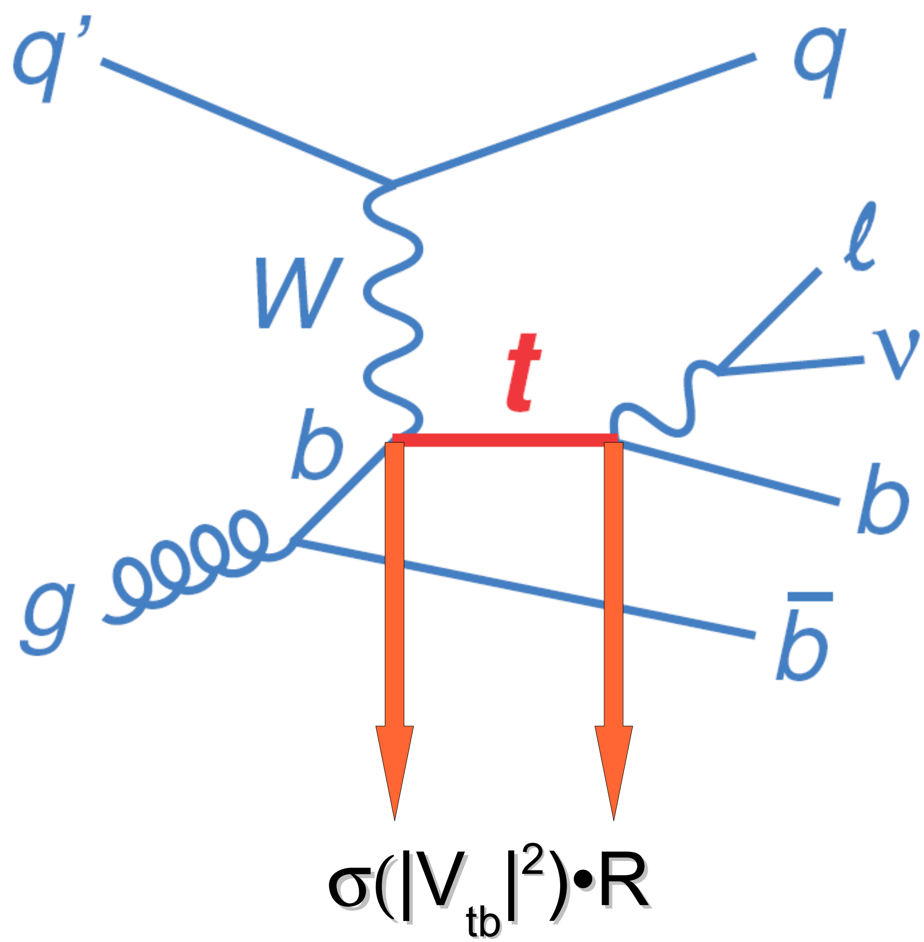
$$|V_{td}| \simeq 0.0069 - 0.0088$$
$$|V_{ts}| \simeq 0.0401 - 0.0418 \qquad \text{(at } 2\sigma \text{ level)}$$
$$|V_{tb}| \simeq 0.9990 - 0.9992$$

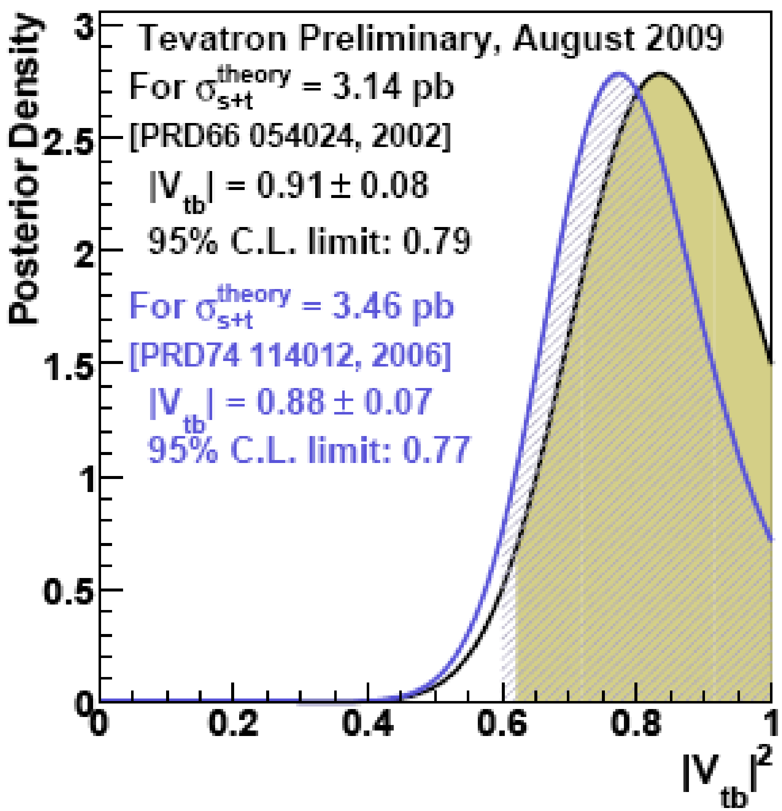
- Measuring R doesn't measure $|V_{tb}|$ directly, but a ratio:

$$R = \frac{\Gamma(t \to Wb)}{\Gamma(t \to Wq(= d, s, b))} = \frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2}$$

- Instead, single top production depends directly on $|V_{tb}|$

Single top and $|V_{tb}|$





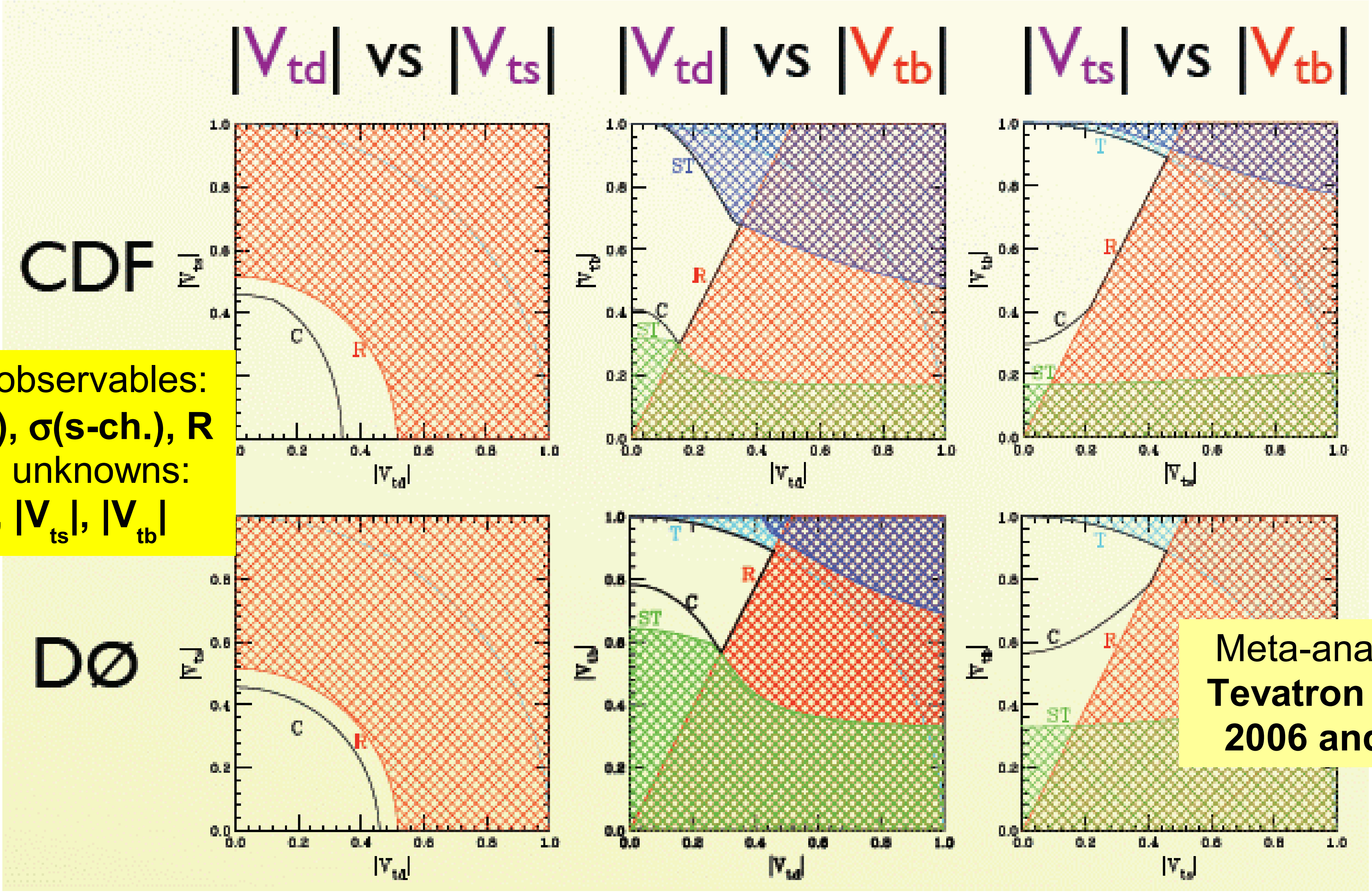
Popular simplifying assumption: $|V_{ti}| \ll |V_{tb}|$ ($i=d,s$) even if a 4th family exists,

$\Rightarrow R \sim 1 \Rightarrow |V_{tb}|^2 = \sigma^{obs}/\sigma^{SM}$; but D0 limit R>0.79 only implies $|V_{tb}| > 1.9\sqrt{|V_{td}|^2+|V_{ts}|^2}$

<u>For the moment</u> we have to live with this approximation, but ...

"Is $|V_{tb}|$~1?"

J.Alwall, A.G., E.Kou, F.Maltoni, et al., Eur.Phys.J. C49 (2007) 791



Three observables:
σ(t-ch.), σ(s-ch.), R
Three unknowns:
$|V_{td}|$, $|V_{ts}|$, $|V_{tb}|$

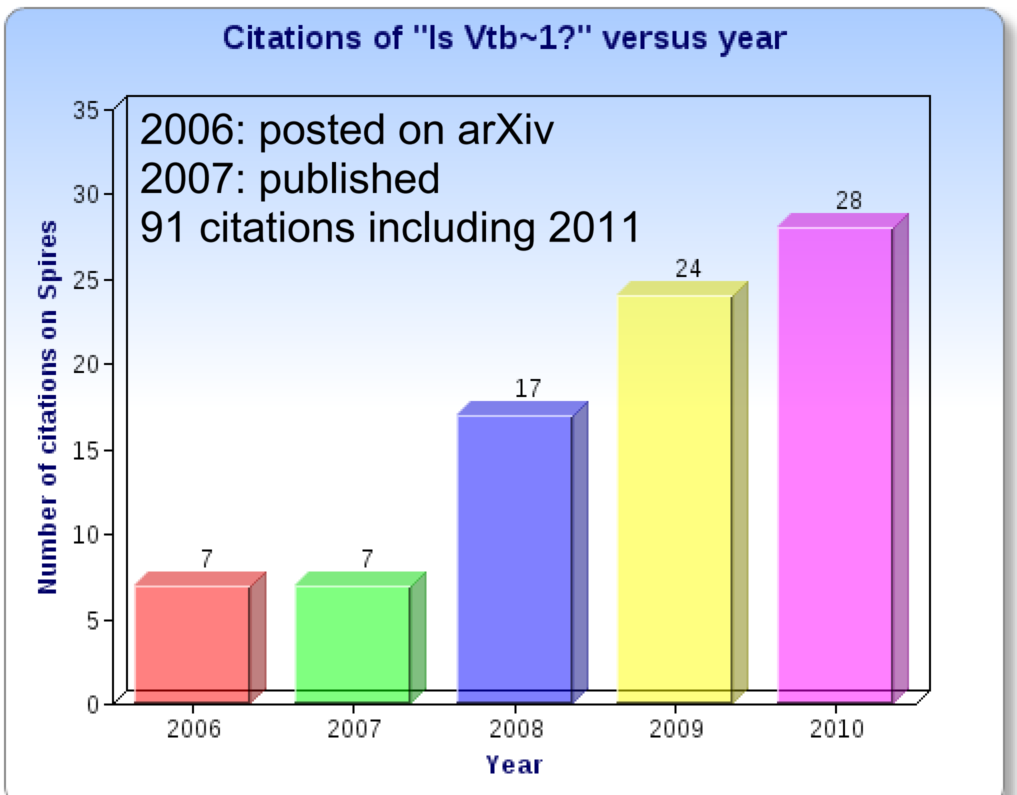
Meta-analysis of
Tevatron data in 2006 and 2008

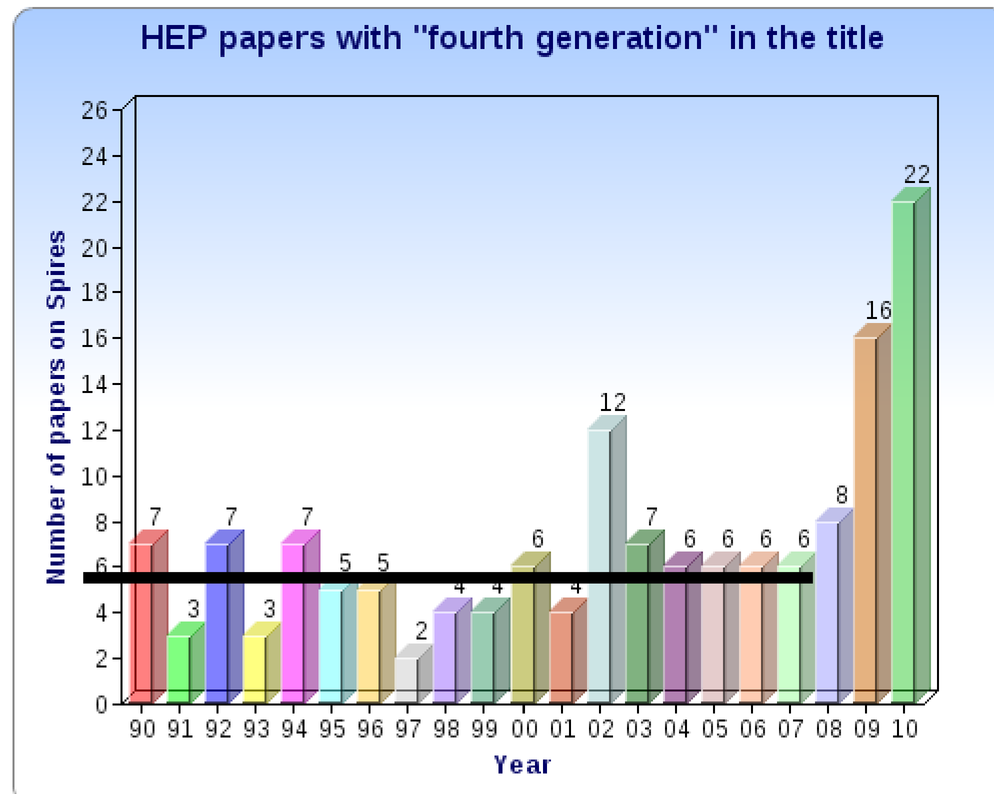
Stand-alone measurement of the 3rd row (no inputs from K, B physics);
much tighter limits in specific models, but this method gives the most "agnostic" limits

A small change in the Zeitgeist...

Particle Data Group:
An extra generation of ordinary fermions is excluded at the 6σ level on the basis of the S parameter alone... [Erler & Langacker]

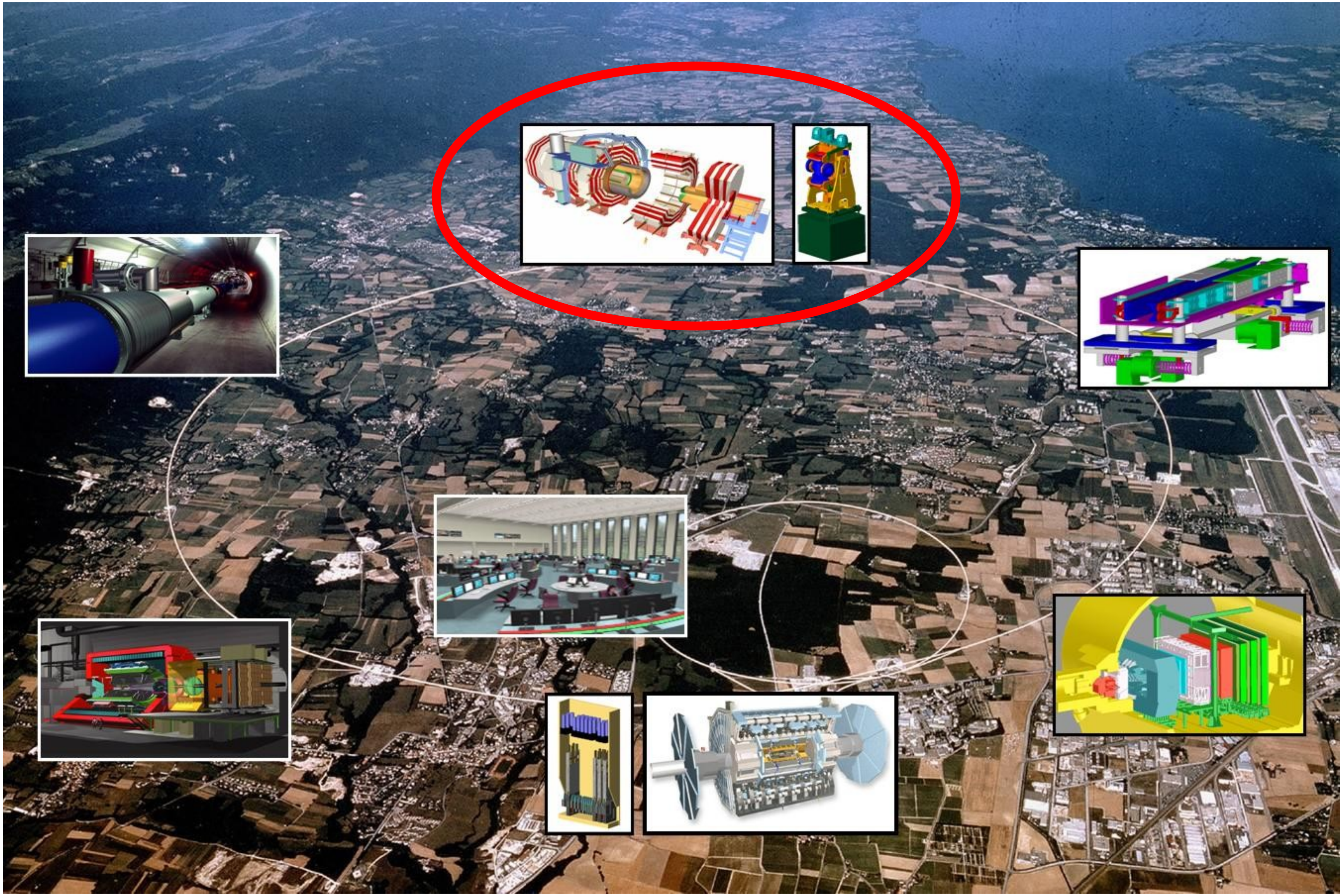
!!! *This result assumes that...any new families are degenerate* [Erler & Langacker]



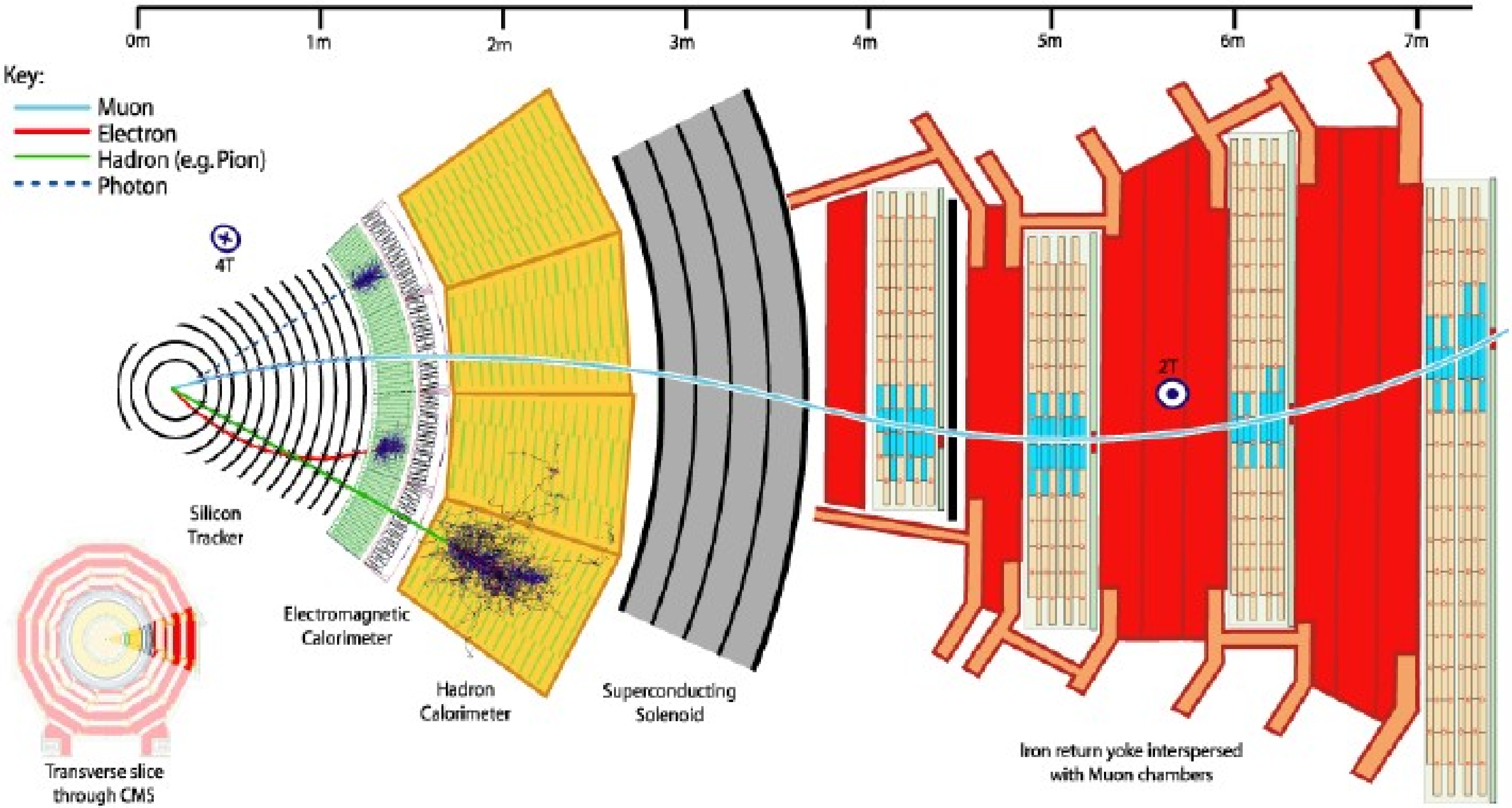


Recently revamped interest of the HEP community for new fermion generations; dedicated workshops are organized

Part II: Experimental setup



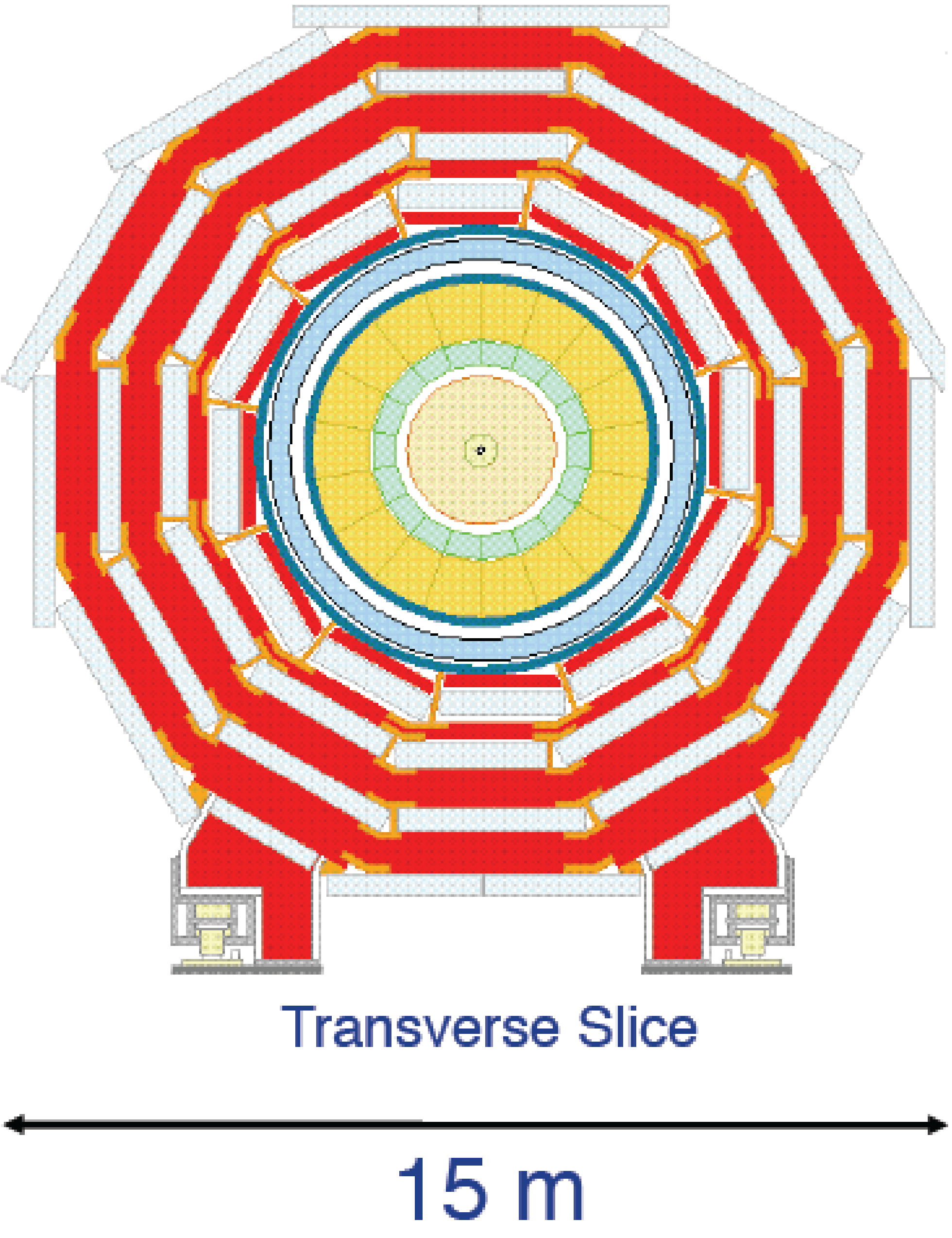
CMS detector: general concept



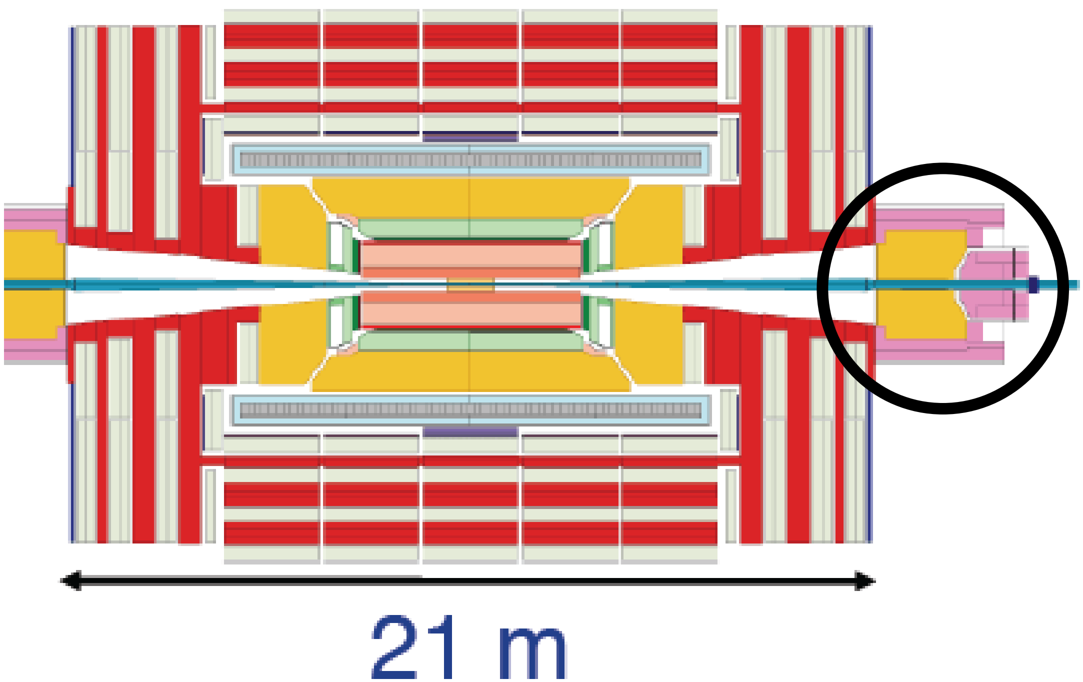
In→out: Si Pixels, Si Strips, EM calorimeter (PbWO), Hadron calorimeter (brass+scint.), Solenoid (3.8 T), Muon system (RPCs, drift tubes in barrel, CSCs in endcaps)

Neutrinos: no interaction → momentum imbalance → MET

The “Compact” Muon Solenoid

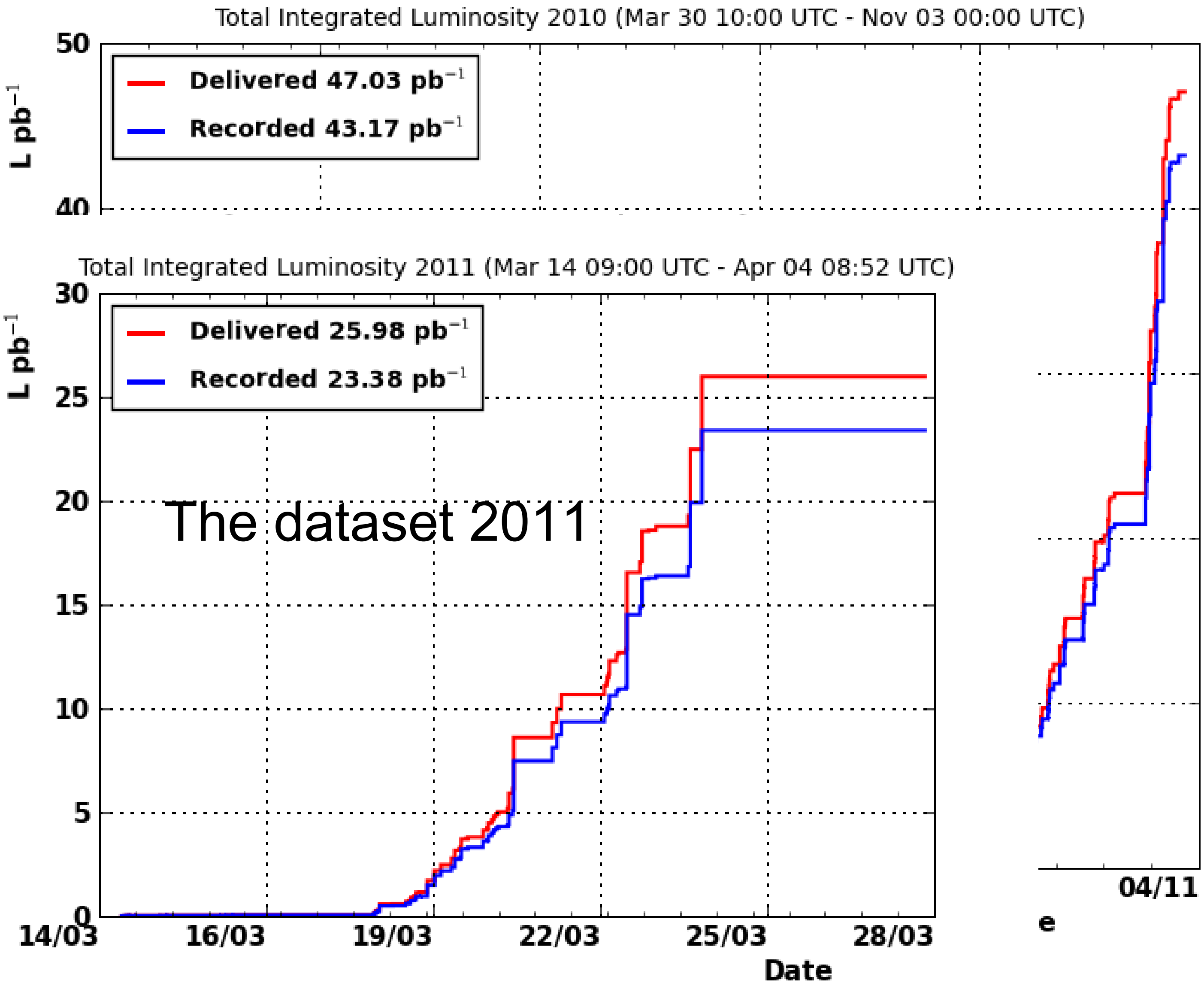


JINST 3 08004 (2008)



Hermetic calorimetry up to |η|<5
(HF: quartz fiber Cherenkov cal.)

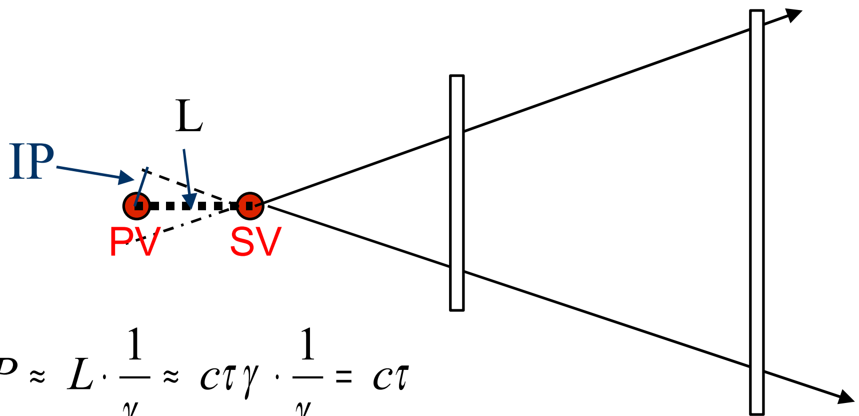
The dataset 2010



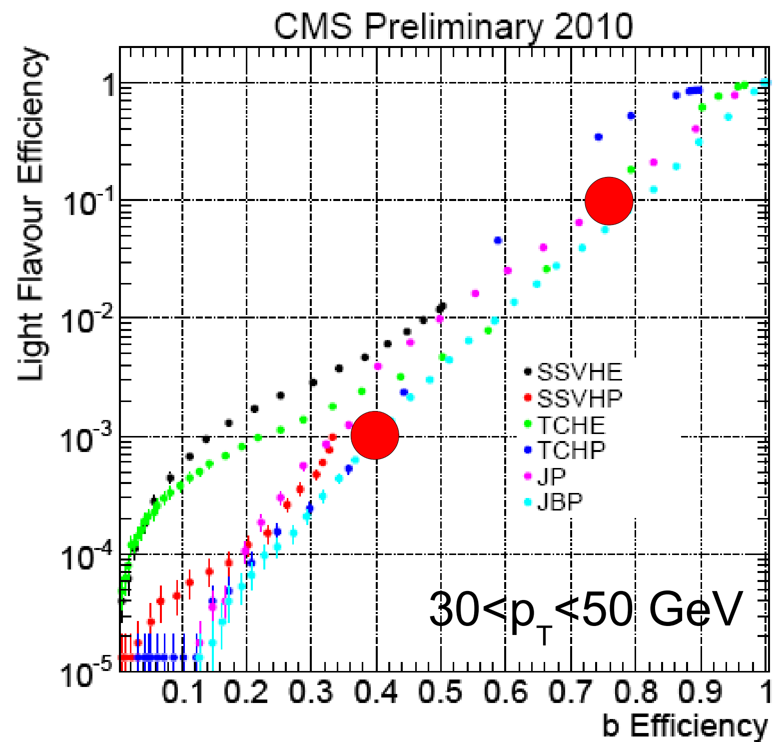
The dataset 2011

b tagging

Definition of IP:



$$IP \approx L \cdot \frac{1}{\gamma} \approx c\tau\gamma \cdot \frac{1}{\gamma} = c\tau$$



- Based on Impact Parameter (IP)
  - "Track counting" (TC): require at least N tracks with IP/σ_{IP}>cut
  - High Purity (TCHP): N=3, tight cut = 3.4 (~0.1% mistag prob.)
  - High Efficiency (TCHE): N=2, loose cut = 1.7 (~10% mistag prob.)

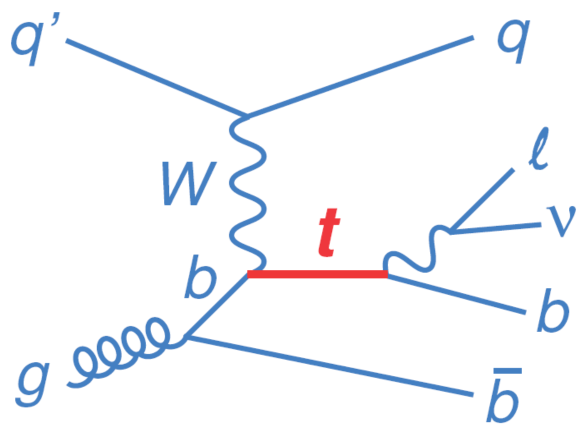
Part III: Single top search

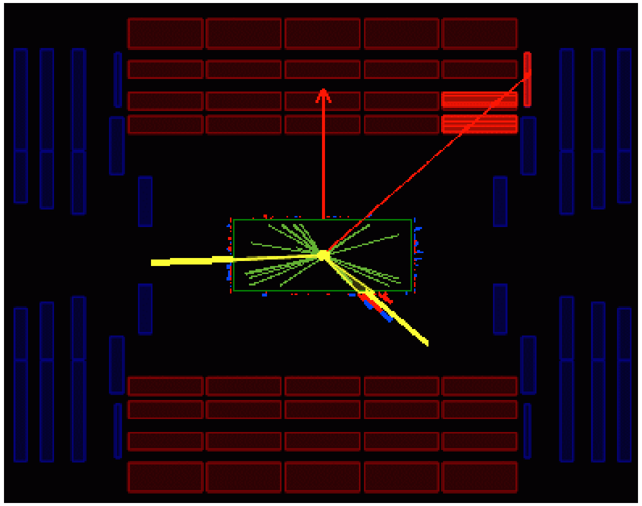
Hunts Needle in a Haystack

Two complementary methods

- Analysis #1 (2D):
  - 2D fit to angular properties of the signal
  - Main backgrounds have very similar shapes → result is robust against background composition
  - Minimum model dependence
- Analysis #2 (BDT):
  - Multivariate analysis (boosted decision tree)
  - Exploits our prior assumptions about the signal
  - Maximum sensitivity
- We combine them at the end

Main signal features

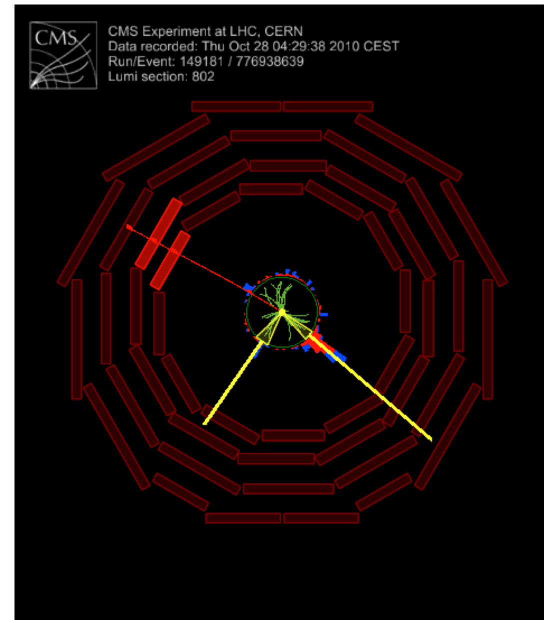




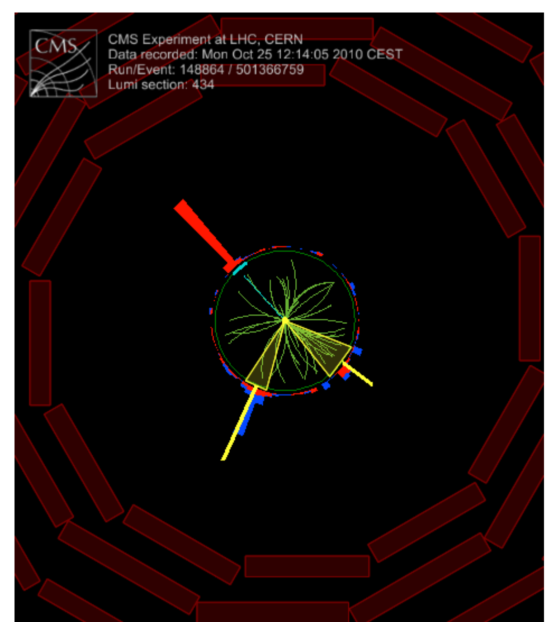
- Real W from t ($m_t > m_W$)
  - decaying 2/9 of the times into l(=e,μ)+ν
  - lν peak at the W mass (in the transverse plane: “Jacobian peak”)
- Central b jet from t
  - lνb peak at the top mass
- Light jet from recoil, rather forward
- Additional b jet has a very soft p_T spectrum

Event selection

- **Trigger: single μ/e**
- **Single lepton (pt>20(μ)/30(e) GeV)**
  - Rel. isolation (2D: < 0.05(μ)/0.1(e), BDT: <0.1)
  - Di-lepton veto
- **Exactly 2 jets (pt>30 GeV, |η|<5)**
- **1 b jet (tight tagging)**
- **Analysis-specific:**
  - 2D: veto on 2^{nd} b jet (loose tagging)
  - BDT: $\Delta\phi(j1,j2)<3$
- **Last cut: $M_T(W)$>40(μ)/50(e) GeV**



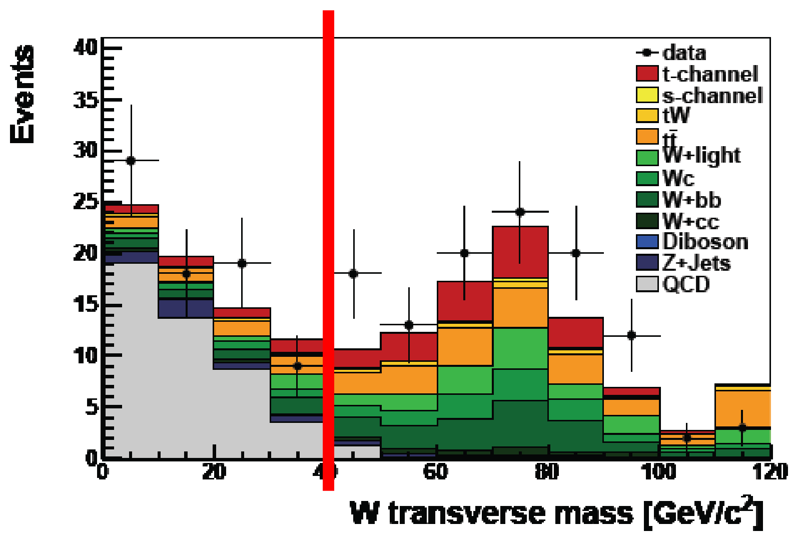
Muon channel



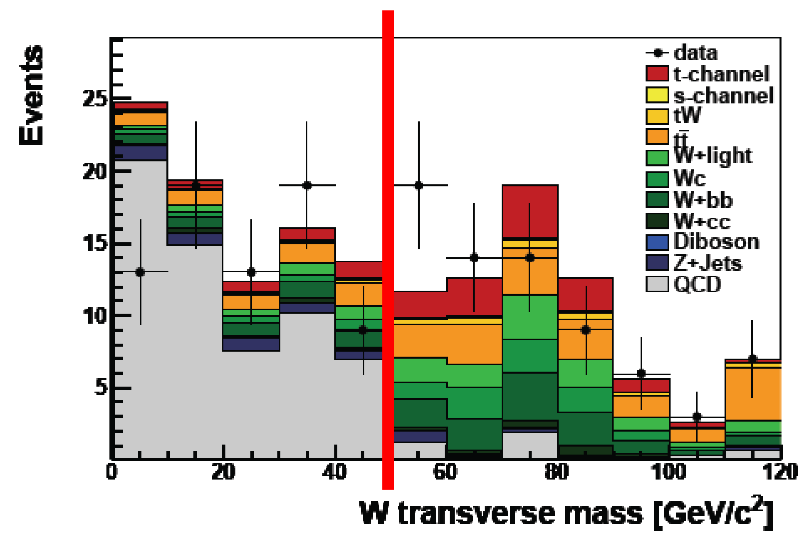
Electron channel

Invariant transverse mass (M_T):
QCD has no Jacobian peak

$$M_T = \sqrt{(p_{T,l} + p_{T,\nu})^2 - (p_{x,l} + p_{x,\nu})^2 - (p_{y,l} + p_{y,\nu})^2}$$



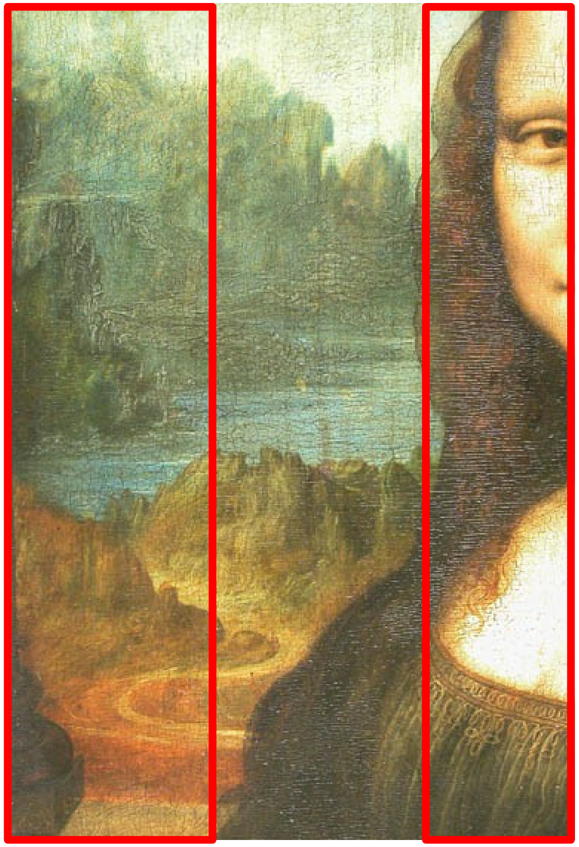
Muon channel: M_T>40 GeV



Electron channel: M_T>50 GeV

- Cut tuned on data, with blind procedure (15/pb and no b-tagging)
- This is our last cut: our bkg estimations from data are based on M_T
- Main backgrounds after this cut: ttbar, W+light partons, Wc, Wbb
- QCD above the cut is small, but has huge error from MC

Background estimations



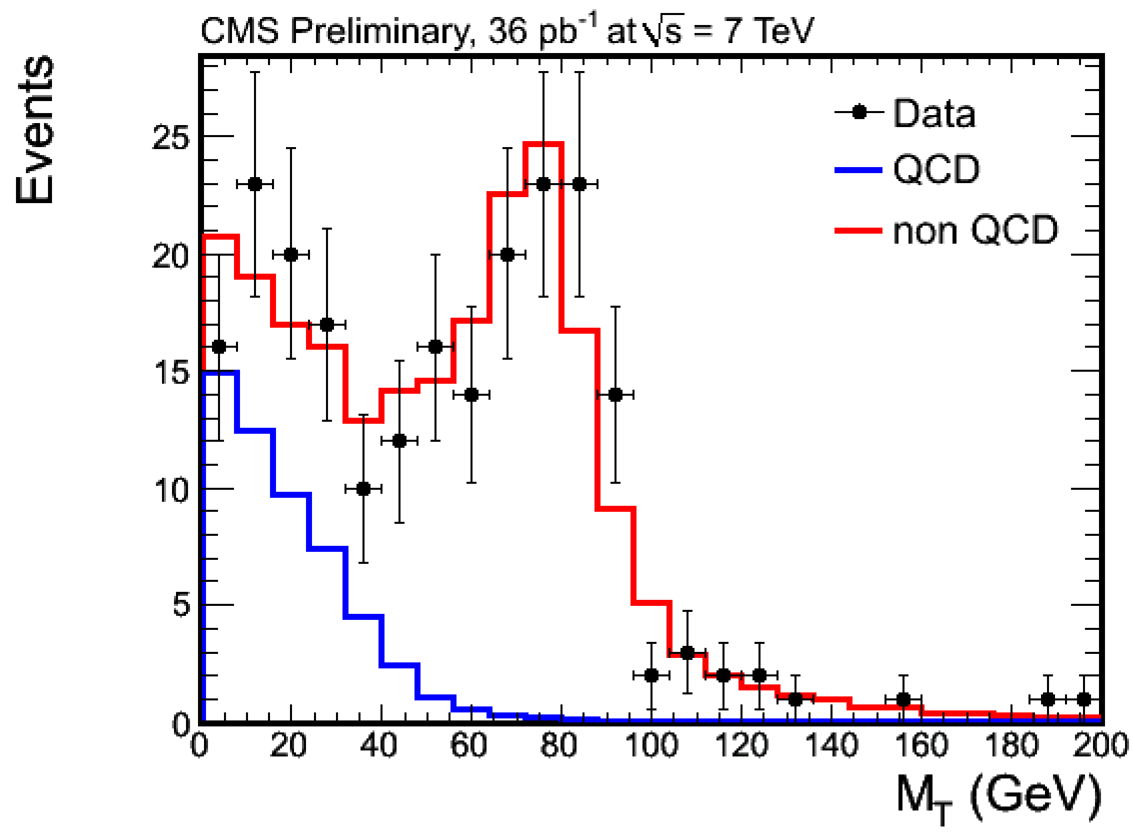
Control region

Analysis region

Q: How much water is behind Mona Lisa's head?

A: define a region with very little Mona Lisa, then extrapolate (with some reasonable assumption)

QCD estimation



Here: muon channel, BDT

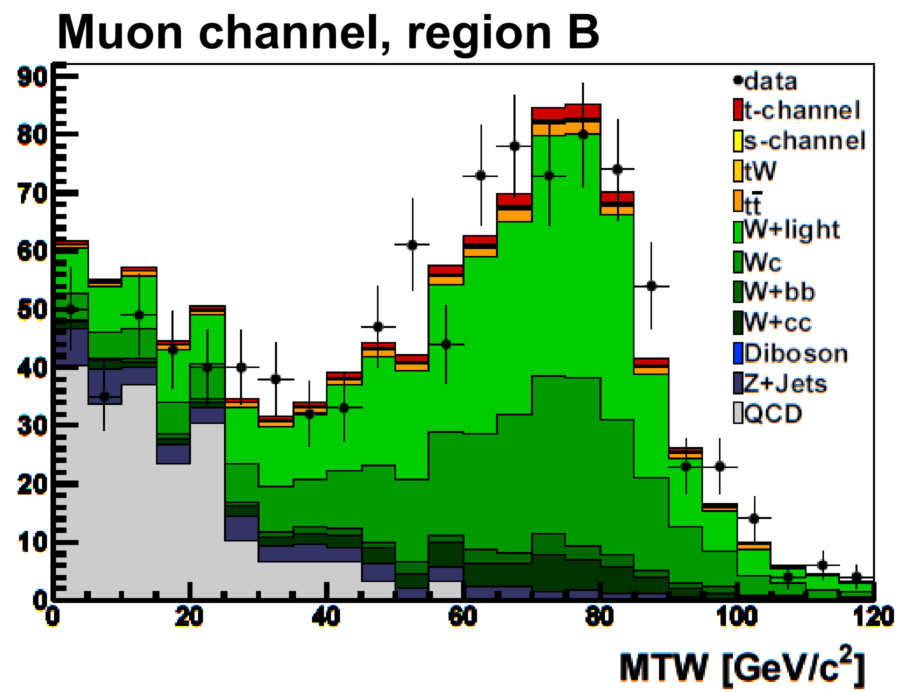
- Template fit, 2 components: QCD and non-QCD, both unconstrained
- "non-QCD" template from MC
- "QCD" template from an **orthogonal sample** with **anti-isolation**

Uncertainties on the estimation: stat ⊕ fit stability ⊕ QCD shape
~50% in the muon channel, ~100% in the electron channel

W+light partons estimation

- Two control regions, both orthogonal to signal region
  - **A:** no tight b-tag
  - **B (⊂ A):** no tight b-tag, 1 loose b-tag and 1 anti-b-tag
- Fit with 3 components:
  - W+light partons (shape from MC)
  - QCD (unconstr., shape from anti-iso)
  - Others (fixed to expectations)

This is applied only in the 2D analysis; the BDT treats this rate as a nuisance parameter in the fit and marginalises it



Process	*SF* from region *A*	*SF* from region *B*
μ channel	1.02 ± 0.03	1.27 ± 0.09
e channel	0.97 ± 0.04	1.05 ± 0.11

We take the central values from B, ±30% (μ), ±20% (e)
But the shapes of the 2D fit variables will be taken from A

Predicted event yield

Process	2D, μ channel	2D, e channel	BDT, μ channel	BDT, e channel
single top, t channel	17.6 ± 0.7 (†)	11.2 ± 0.4 (†)	17.6 ± 0.7 (†)	10.7 ± 0.5 (†)
single top, s channel	0.9 ± 0.3	0.6 ± 0.2	1.4 ± 0.5	1.0 ± 0.3
single top, tW	3.1 ± 0.9	2.4 ± 0.7	3.8 ± 1.1	< 0.1
WW	0.29 ± 0.09	0.23 ± 0.07	0.32 ± 0.10	0.23 ± 0.07
WZ	0.24 ± 0.07	0.17 ± 0.05	0.33 ± 0.10	1.5 ± 0.4
ZZ	0.018 ± 0.005	0.011 ± 0.003	0.020 ± 0.006	< 0.1
$W+$ light partons	18.2 ± 5.5	11.6 ± 2.3	8.4 ± 4.2	7.0 ± 3.5
$Z+X$	1.7 ± 0.5	1.6 ± 0.3	0.7 ± 0.2	0.05 ± 0.03
QCD	0.6 ± 0.3	$2.6^{+3.4}_{-2.6}$	4.9 ± 2.5	5.3 ± 5.3
$VQ\bar{Q}$	20.4 ± 10.2	14.1 ± 7.1	17.6 ± 8.8	11.7 ± 5.8
Wc	$12.9\ ^{+12.9}_{-6.5}$	$9.4\ ^{+9.4}_{-4.7}$	$9.2\ ^{+9.2}_{-4.6}$	$5.9\ ^{+5.9}_{-2.9}$
$t\bar{t}$	20.3 ± 3.6	15.6 ± 2.8	34.9 ± 4.9	22.9 ± 3.2
Total background	78.6 ± 15.2	58.4 ± 11.0	82.4 ± 13.1	55.9 ± 10.2
Signal + background	96.2 ± 15.3	69.6 ± 11.0	100.0 ± 13.2	66.6 ± 10.2
Data	112	72	139	82

Theory

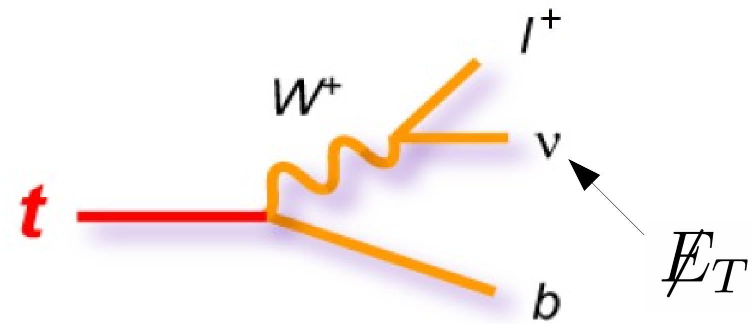
In situ

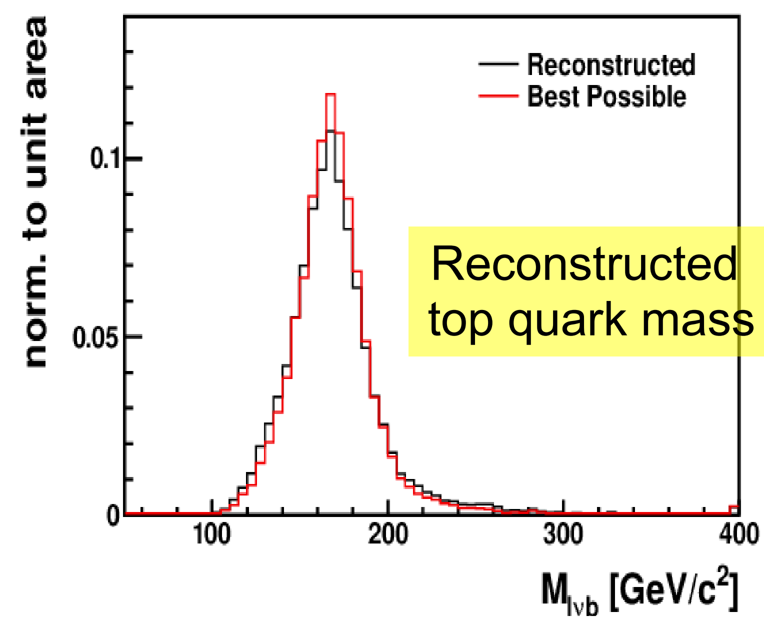
Dedicated analysis

Although at this step we have a better S/B than CDF/D0, simple cut-and-count is clearly hopeless with this level of knowledge of the main backgrounds. But we can do better.

Top quark reconstruction

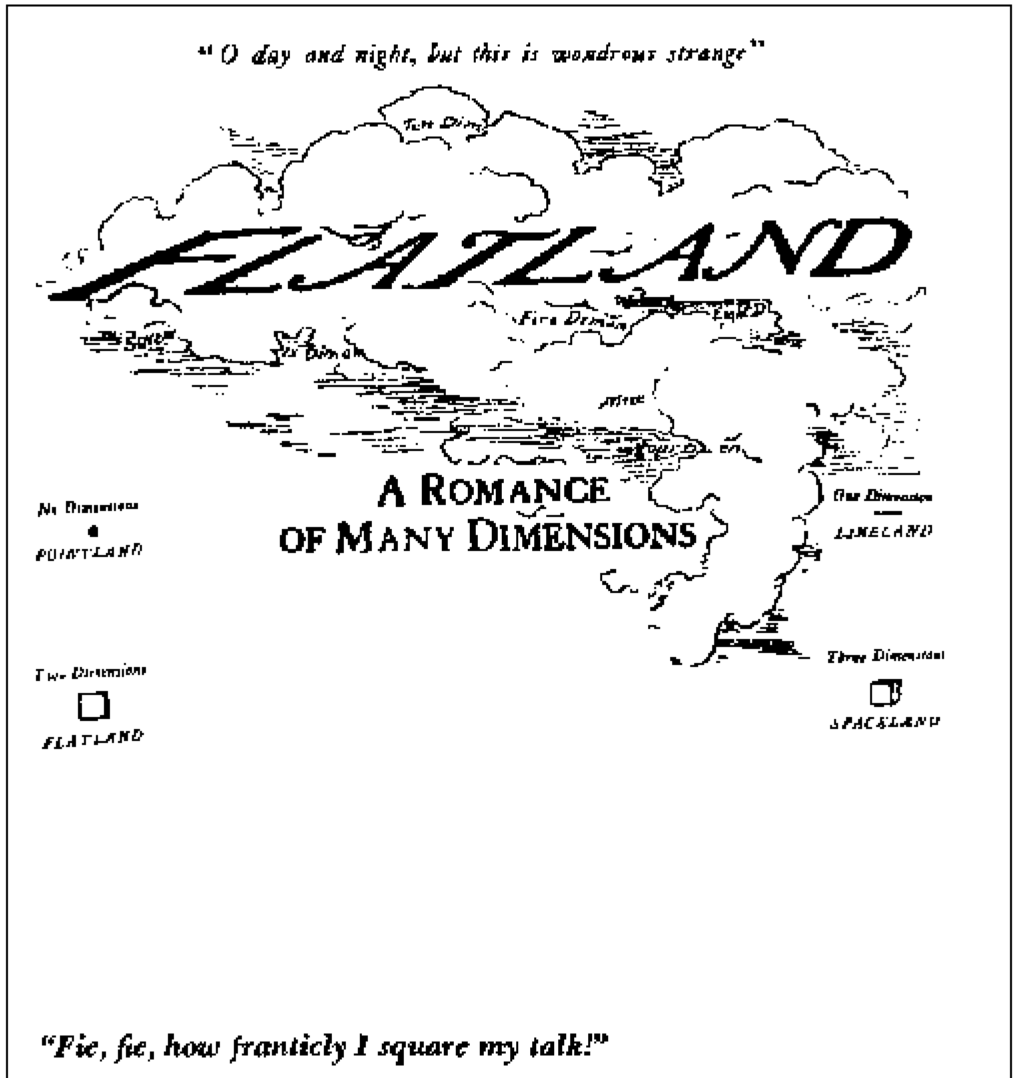
- W boson reconstruction:
  - W mass constraint
  - 2nd order equation in $P_{z,\nu}$
  - Complex solutions (22% of sel.evts.)
    - Forcing $M_T=M_W \rightarrow \mathrm{Img}(P_{z,\nu})=0$
  - Two real solutions (78% of sel.evts.)
    - Pick the one with smallest $P_{z,\nu}$
    - Correct in 60% of cases
- Pairing with a b:
  - Take the most b-tagged jet
  - Correct in 92.6% (2D) / 87.4% (BDT) of selected events



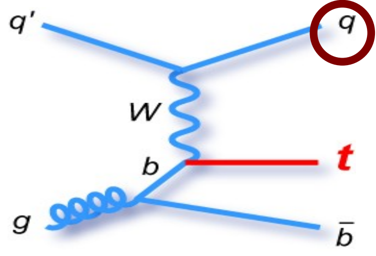


"Best possible" means minimal distance (ΔR) of ν_{reco}, b_{reco} from ν_{true}, b_{true}

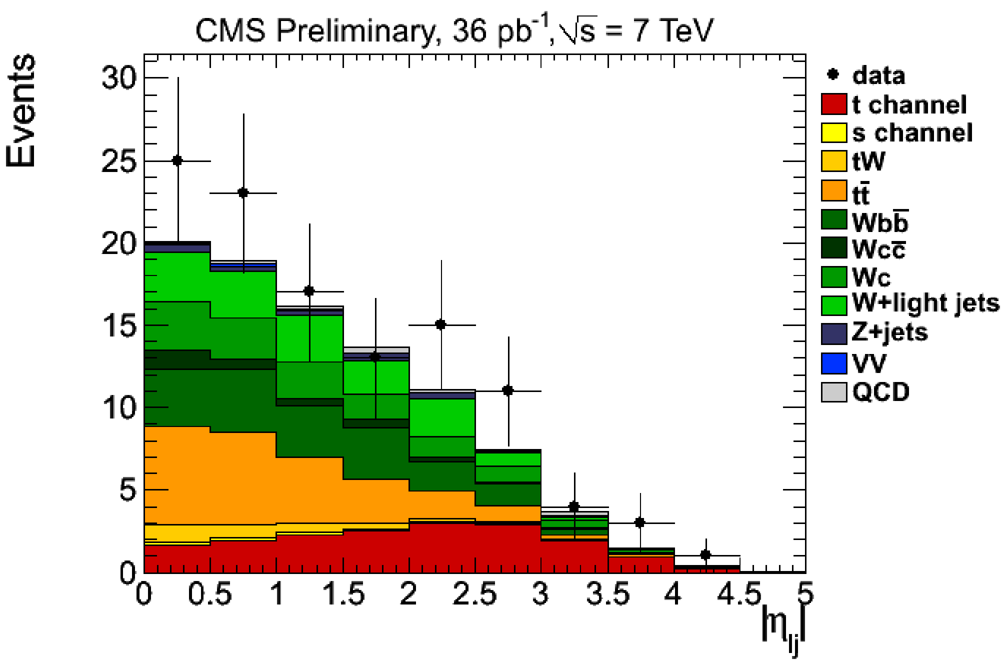
The 2D analysis



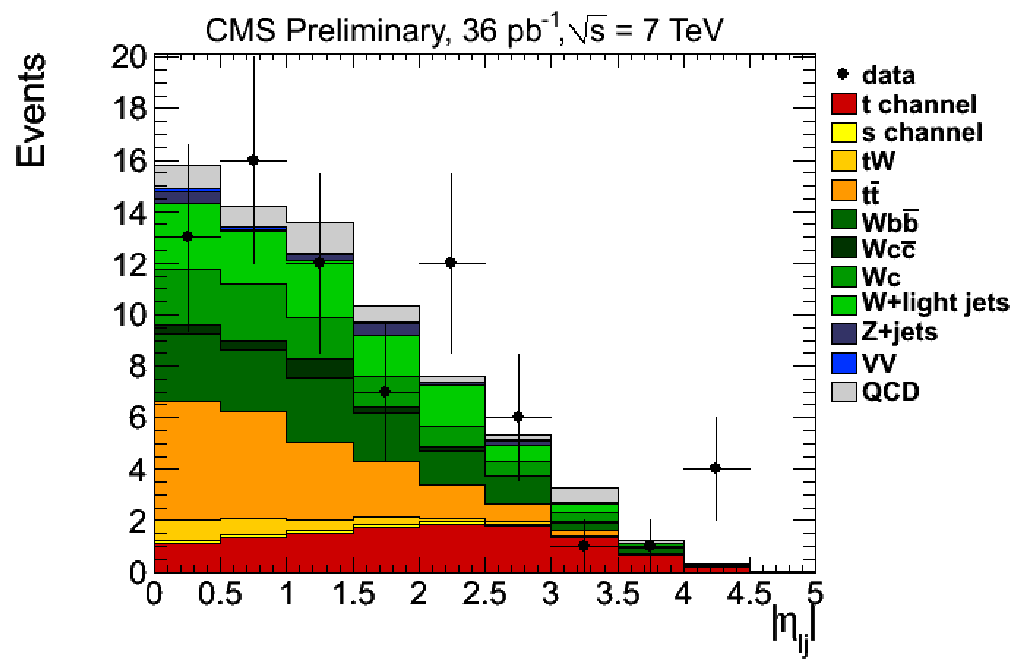
Pseudorapidity of the recoil quark



Muon channel



Electron channel



We take the jet failing the loose b tagging or outside tracker acceptance.
Small shape difference across backgrounds, all have central distributions.

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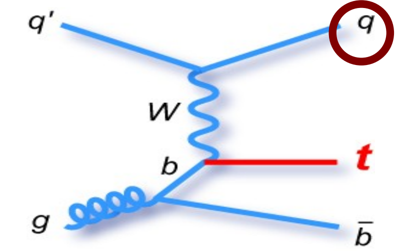
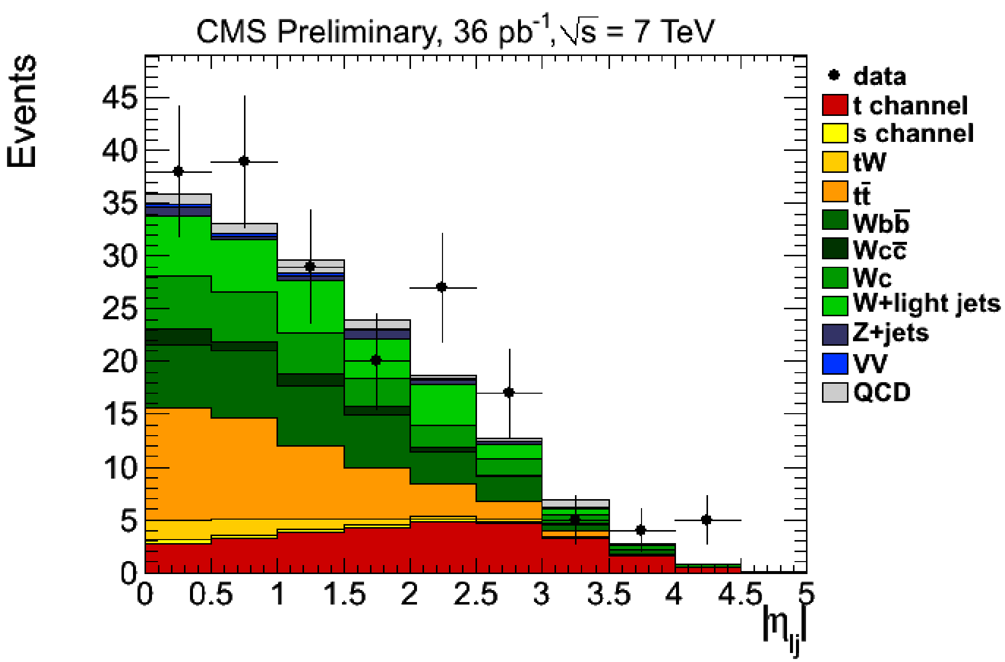
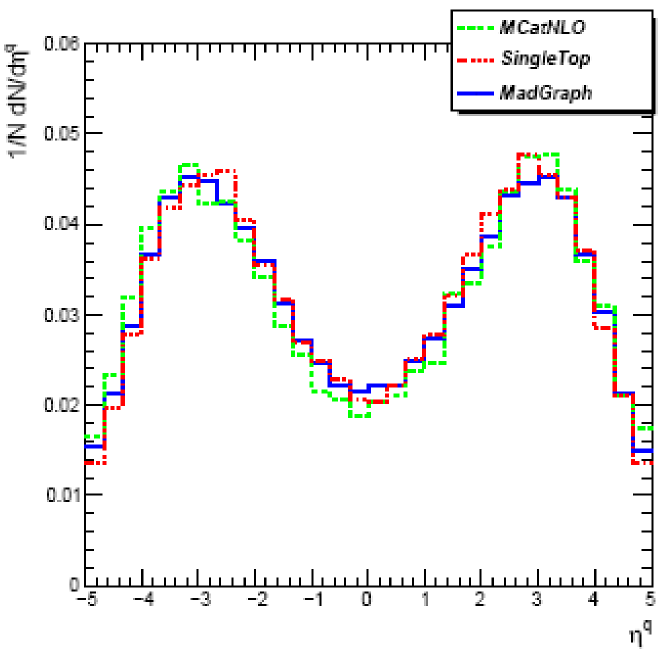
Pseudorapidity of the recoil quark



Muon+electron channels

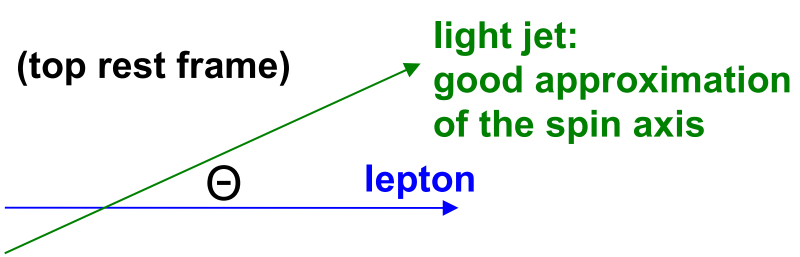


Generator level



Signal distribution is driven by pure kinematics (see VBF Higgs...)
ISR/FSR tends to be close to the recoil quark in all signal models (different from ttbar: the colourless W* cuts the diagram in two isolated colour flows.)

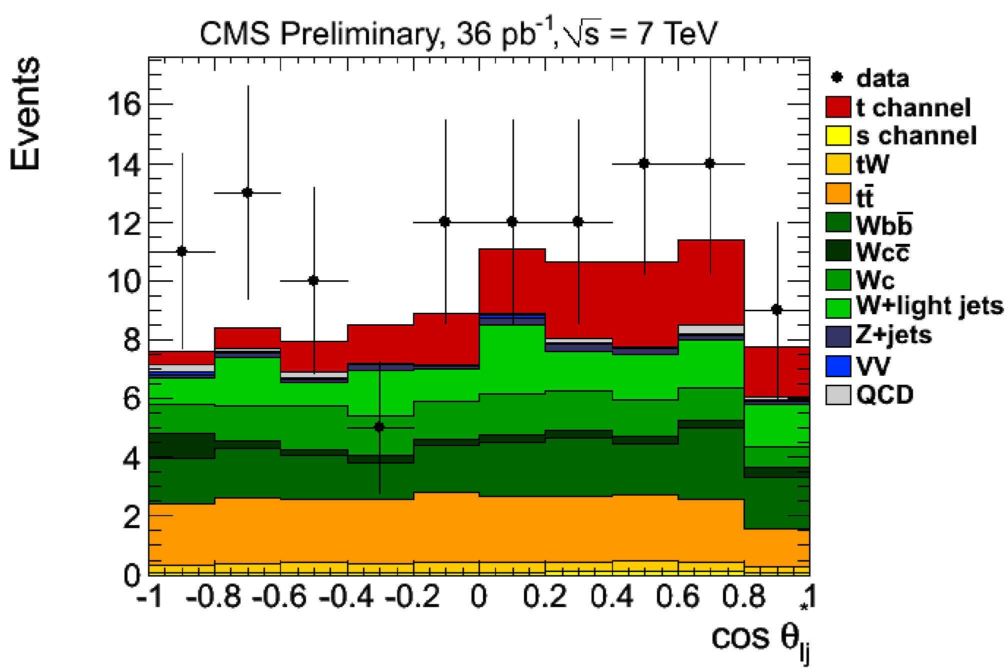
Single top is polarized



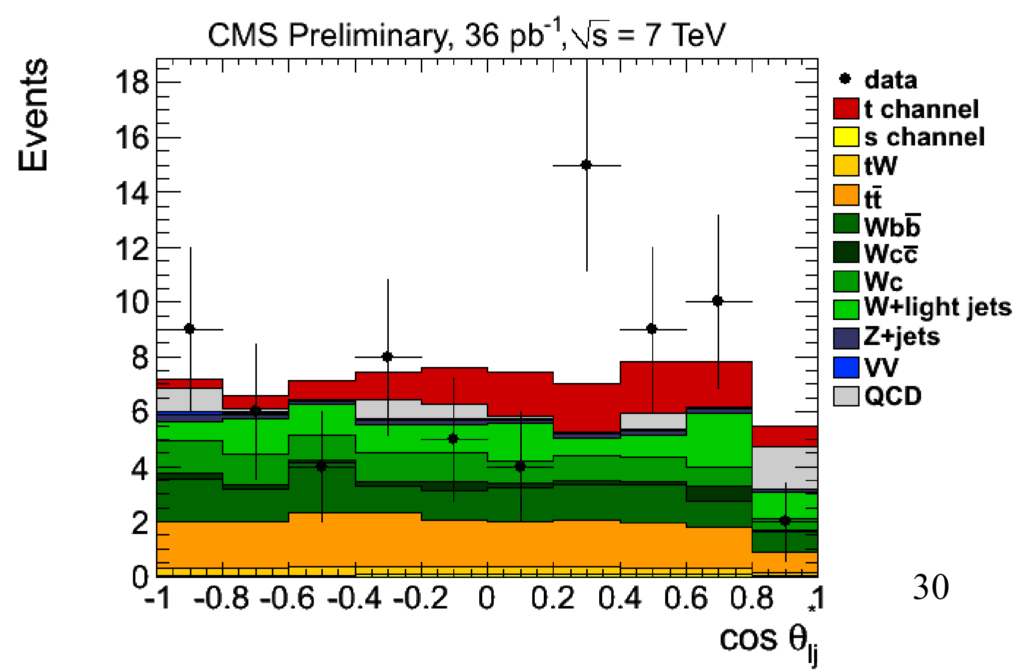
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta^*} = \frac{1}{2}(1 + A\cos\theta^*)$$

A = 1 for charged leptons

Muon channel



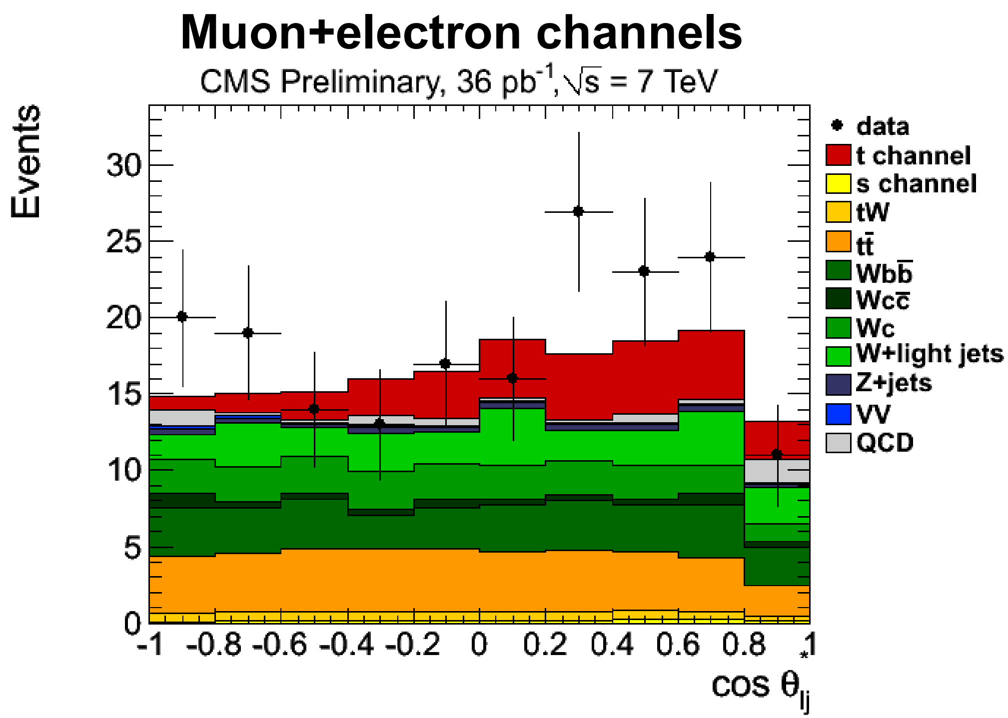
Electron channel

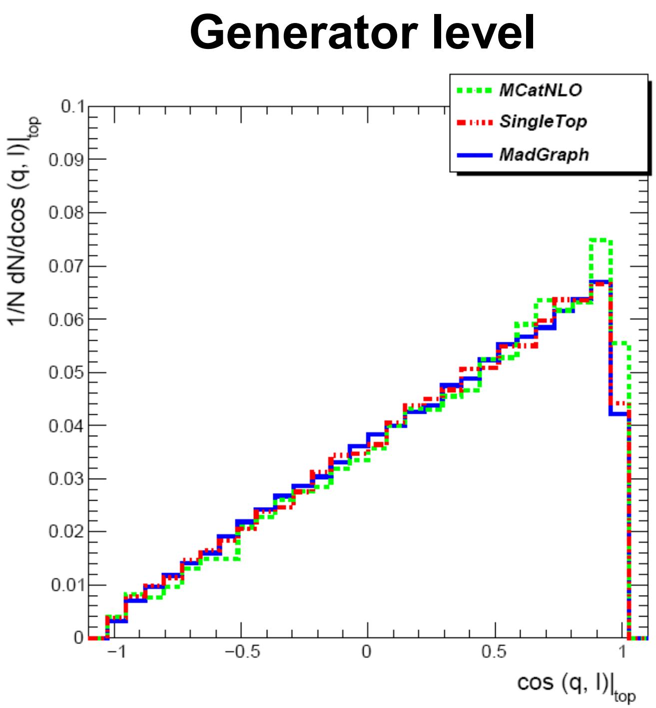


Backgrounds are all flattish (apart from the dip at ~1, due to selection)

30

Single top is polarized





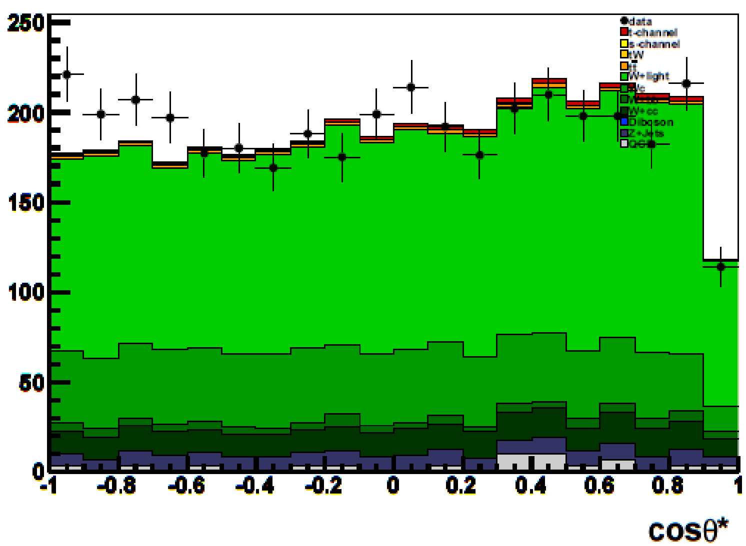
Signal distribution stems from a fundamental properties of single top (V-A); different generators give the same shapes (*), and even many non-SM scenarios behave as the SM (**)

(*) Single top group, AN2009/024: MadGraph vs SingleTop vs MC@NLO; now tested also POWHEG
Motylinski, arXiv:0905.4754 [hep-ph], Phys.Rev.D80:074015,2009: radiation, scales, PDF, etc.
(**) Batebi et al., arXiv:1102.2499 [hep-ph]: 2 Higgs doublets, top-assisted TC, non-commutative SM

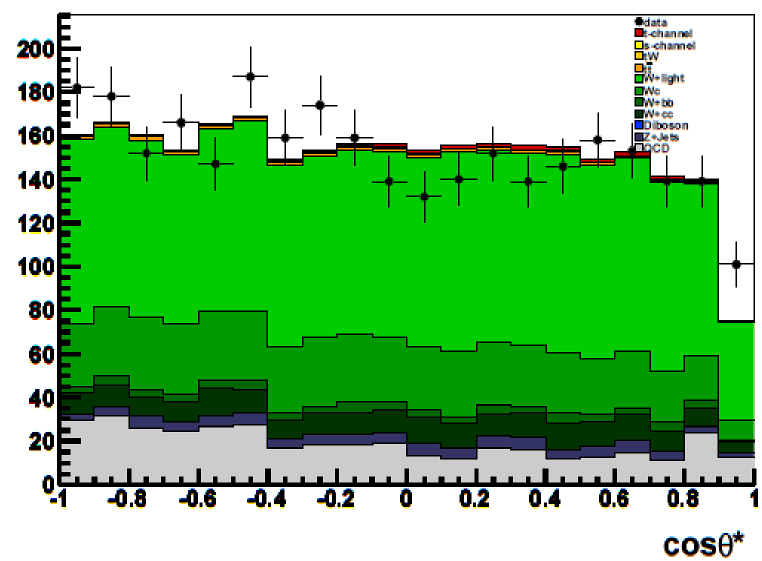
W+light jets control region

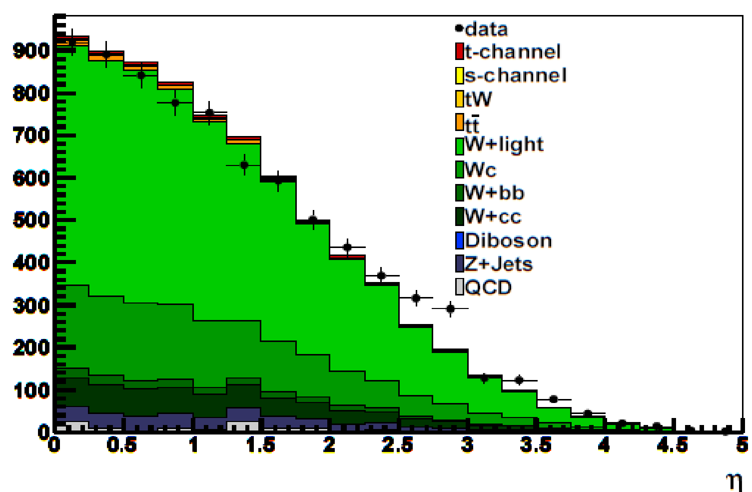
- 2-jet bin, both anti-b-tagged (“region A”); M_T > 40 (50) GeV
- top quark reconstruction: use most b-tagged jet

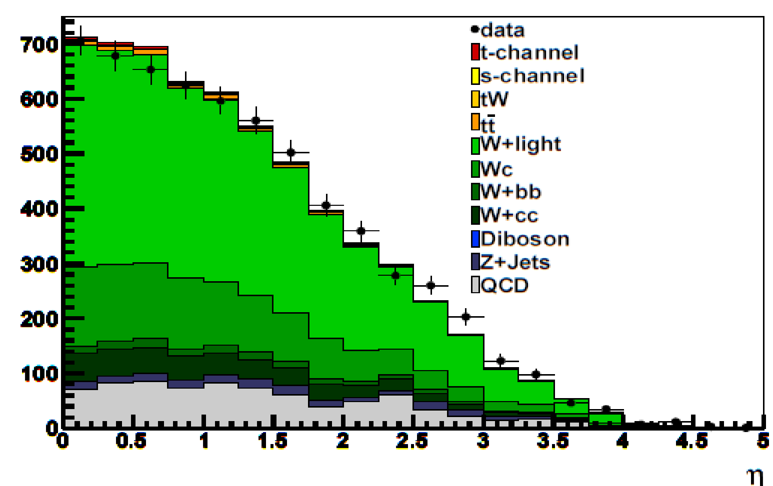
Muon channel



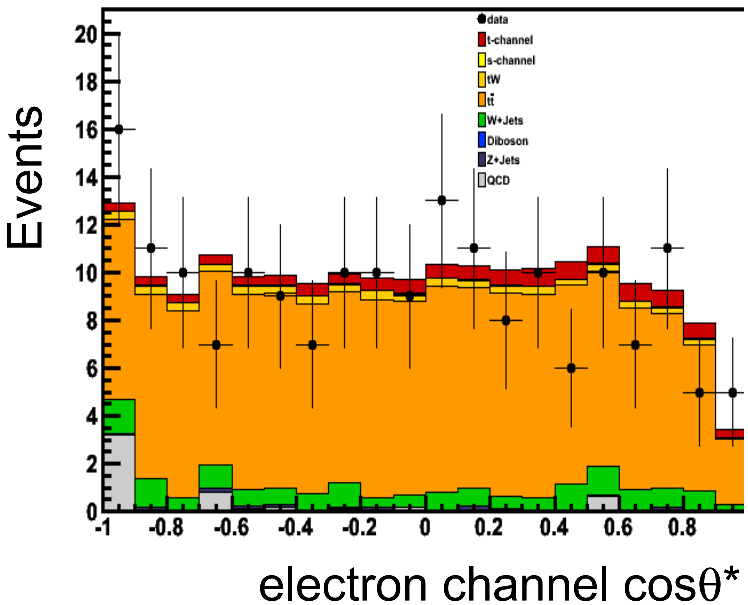
Electron channel

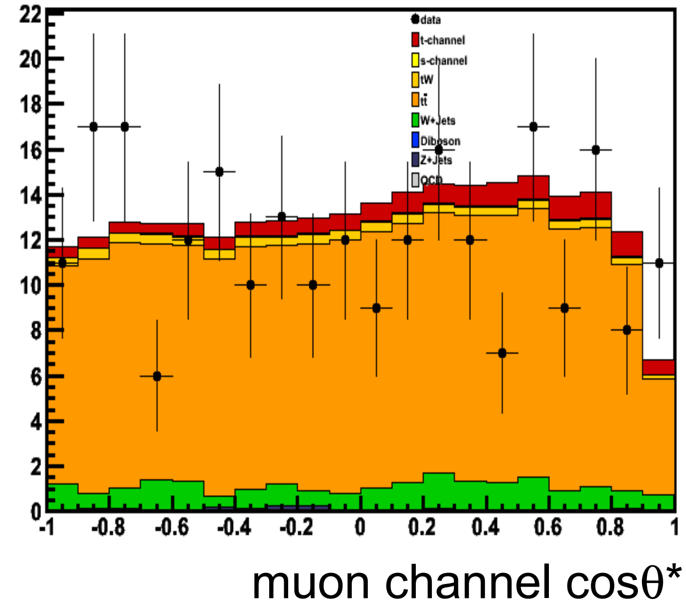


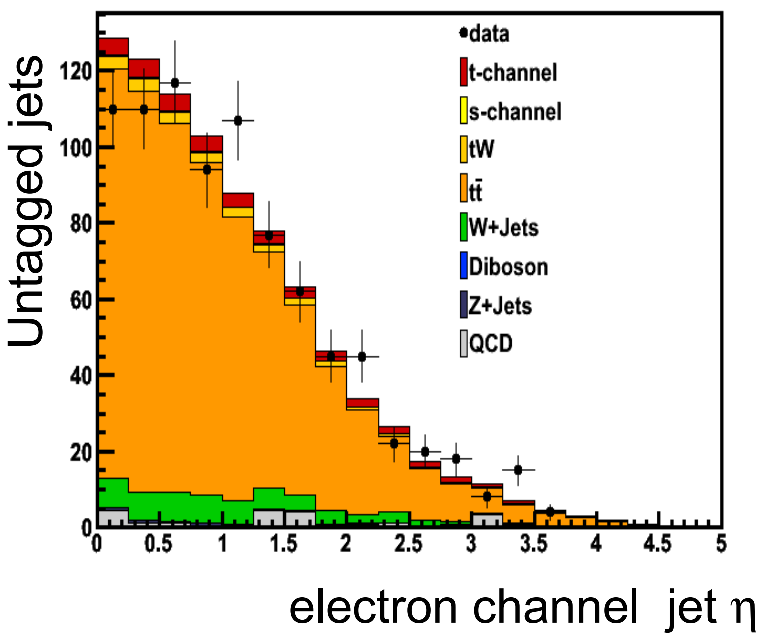


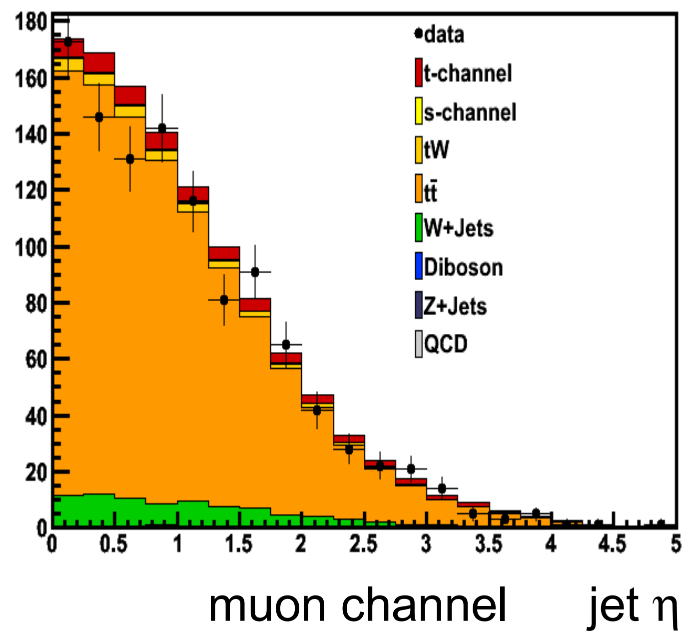


ttbar control region



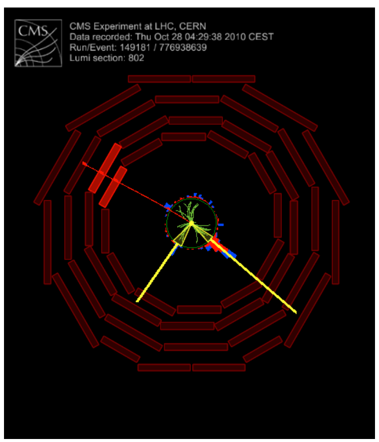


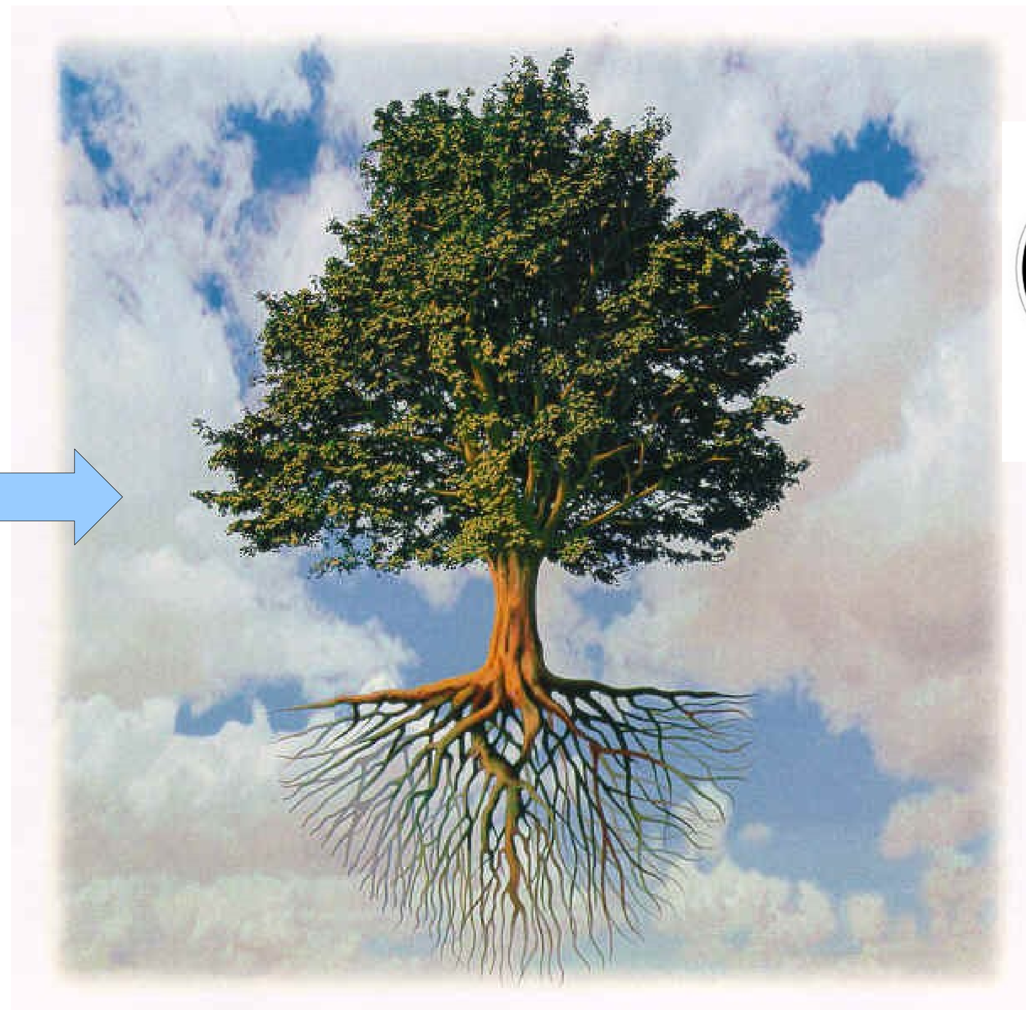




- Njets≥3, Nb≥1 (no veto)
- Highest-TCHP taken as "b", highest-|η| taken as "j"
- Muons:
  - Data 240
  - MC 259
- Electrons:
  - Data 185
  - MC 188

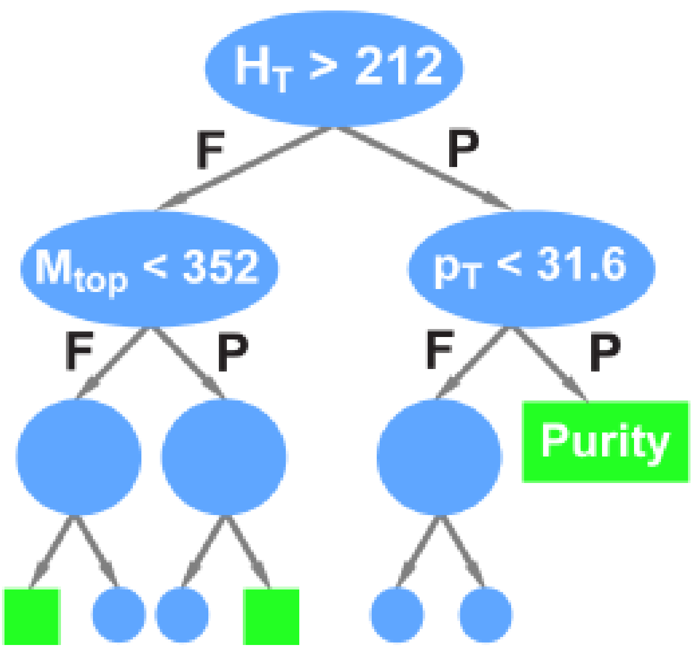
The Boosted Decision Tree analysis





Boosted Decision Tree concept

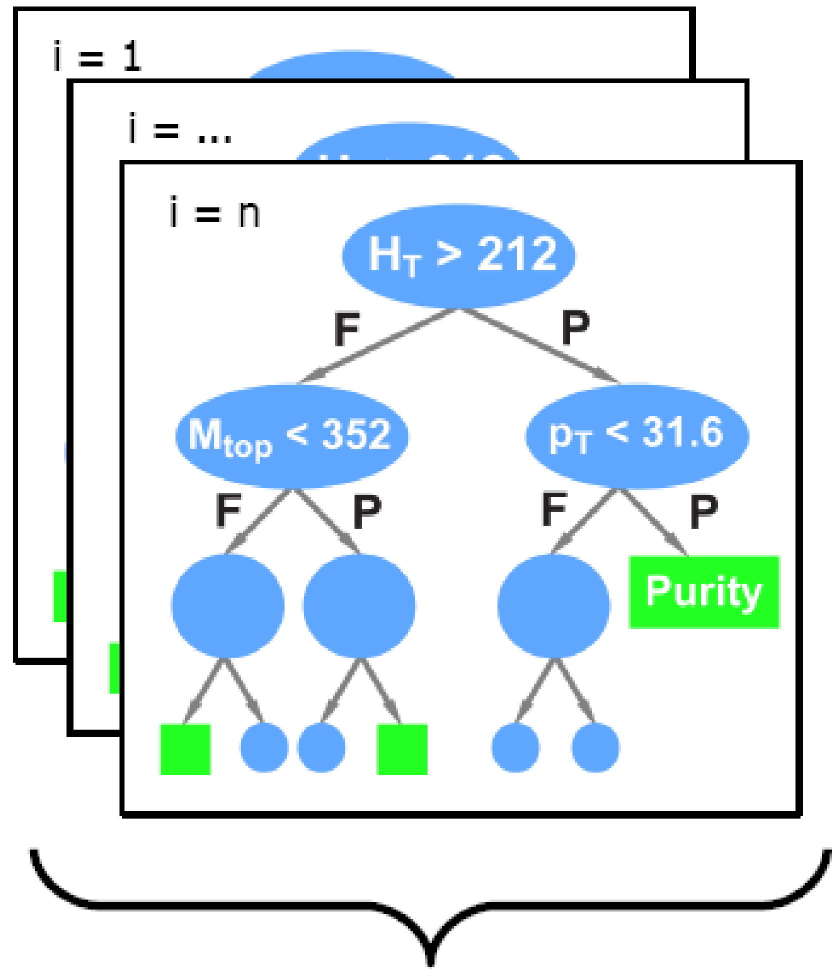
Decision Tree (example):



Reweight misclassified events

n boosting Cycles

(weight trees by their error rates)



weighted majority vote

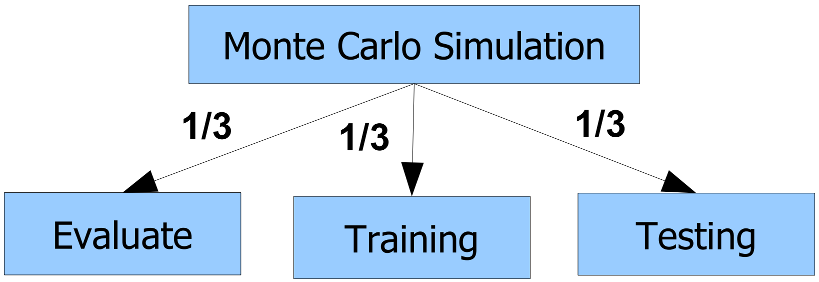
Signal-like event: weight=+1

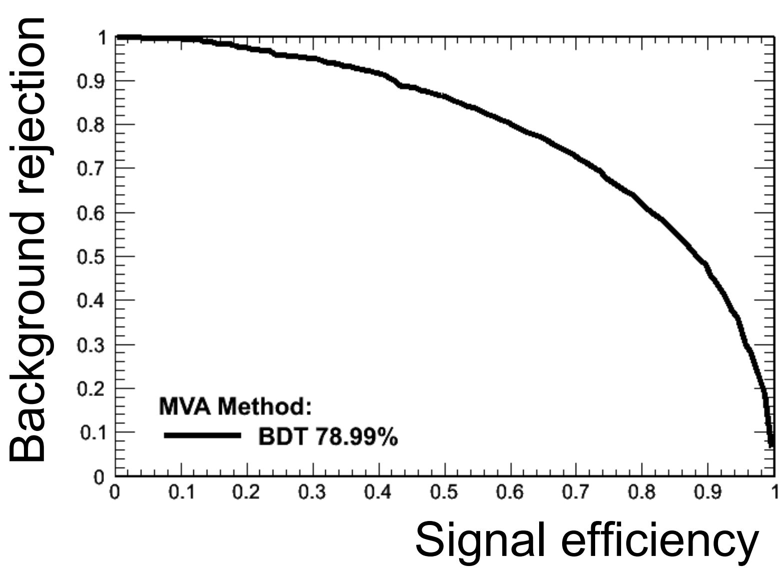
Background-like: weight=-1

(cuts are for illustration only)

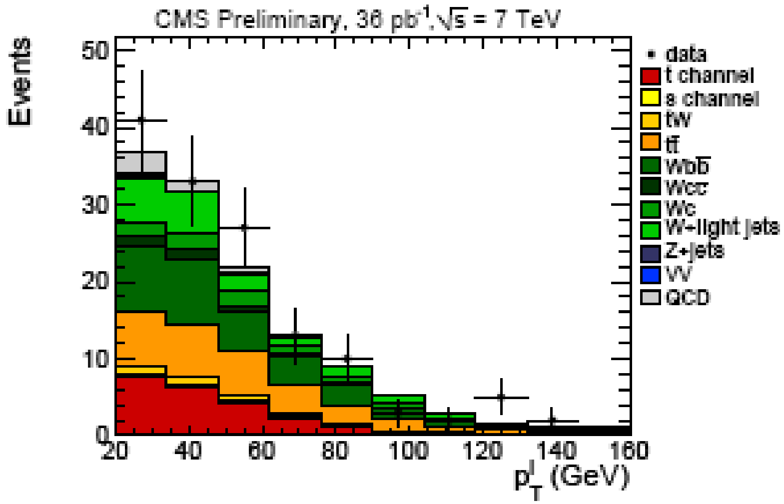
$$y_{Boost}(\vec{x}) = 1/N_{trees} \cdot \sum_{i}^{N_{trees}} ln(\alpha_i) \cdot h_i(\vec{x})$$

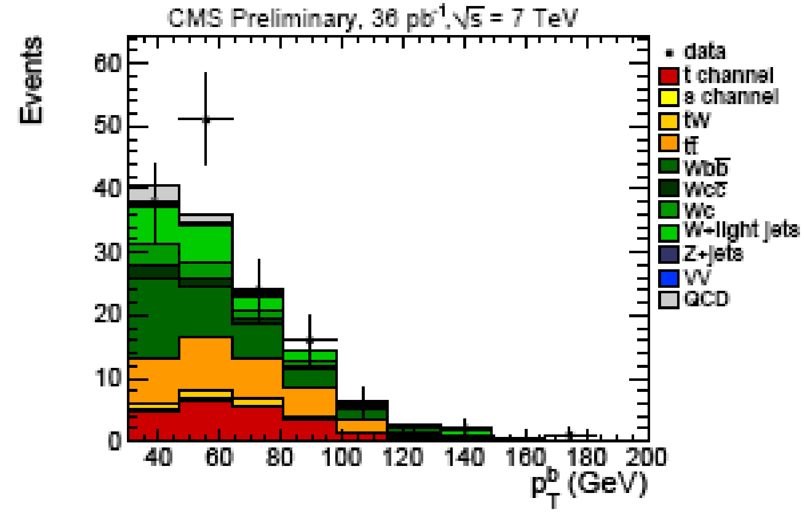
Inputs

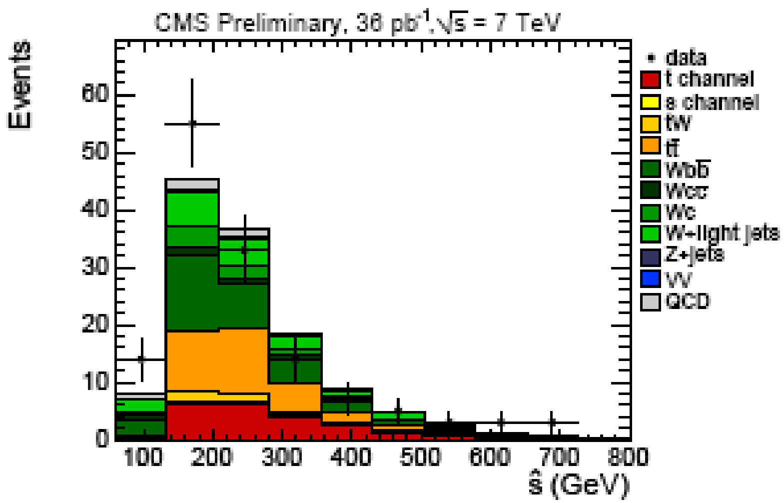


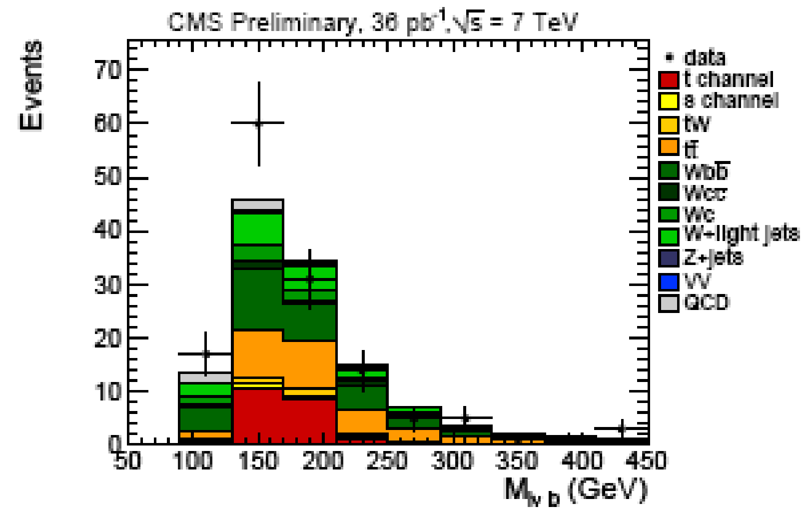


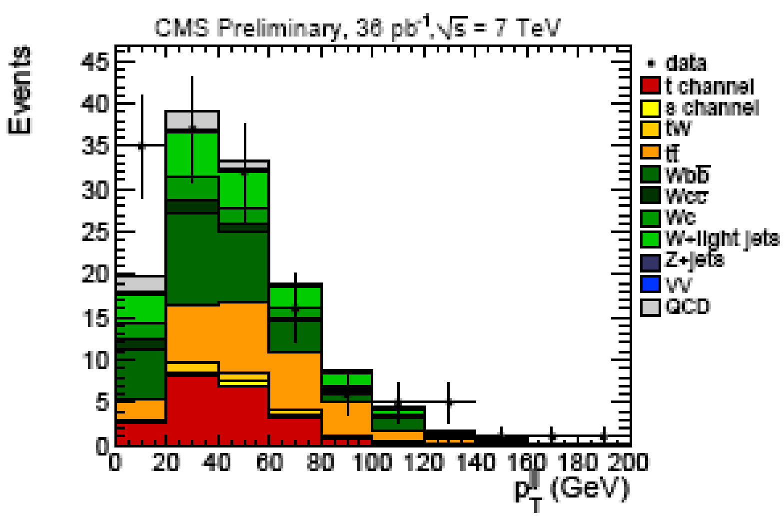
- 37 inputs in 5 categories:
  - **Kinematics** of final-state objects
  - **Correlations** of final-state objects
  - Properties of **reconstructed W, t, t+q**
  - **Angular distributions** of l,j wrt W,t,t+q
  - **Global event properties**





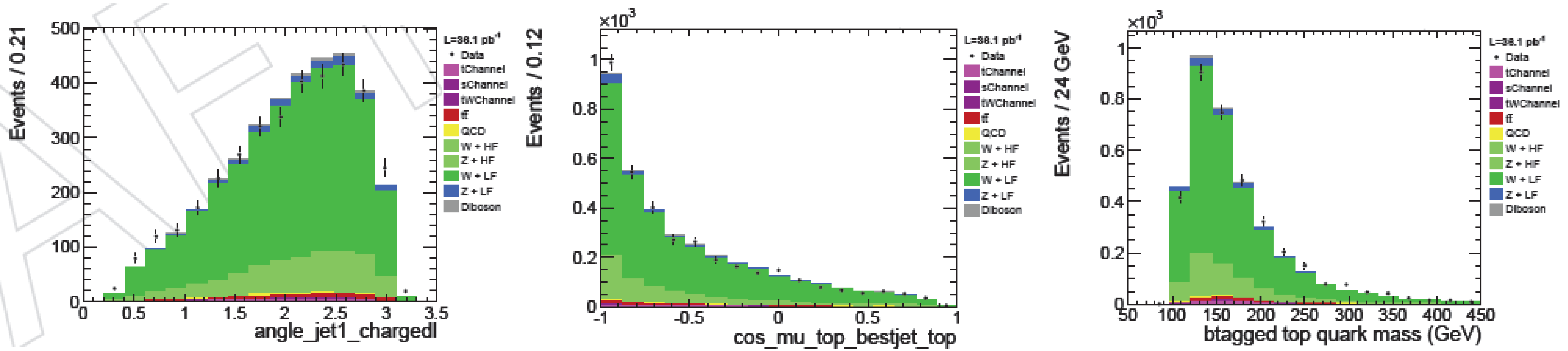






The 5 main inputs, for the muon channel.
Backgrounds normalized to the median
of the posterior from the fit (see later)

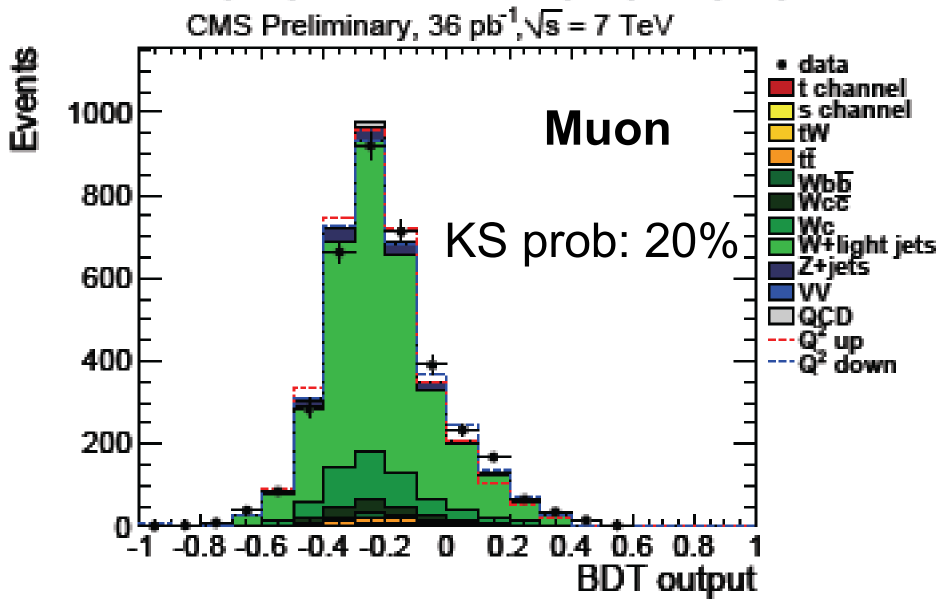
Validation of the inputs

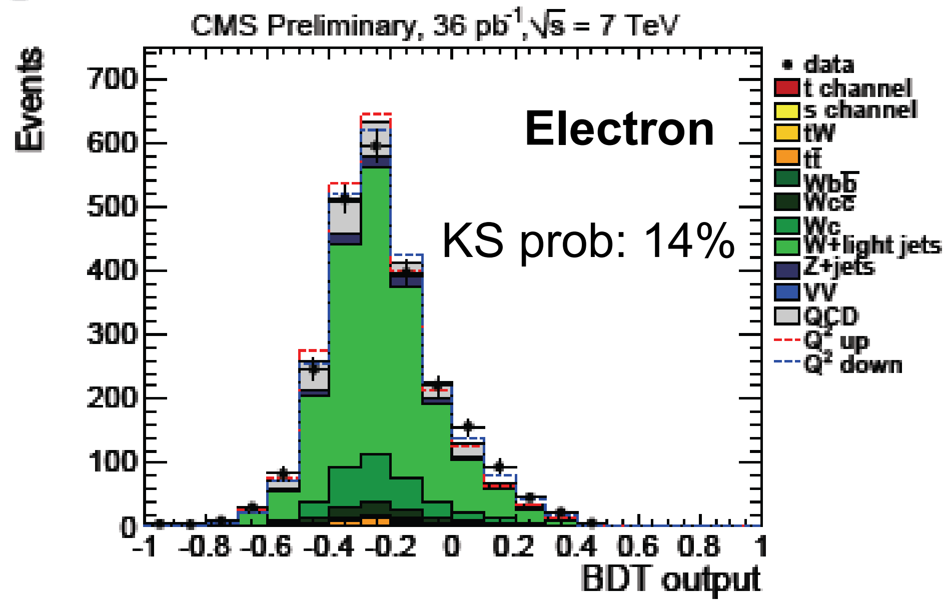


- We look at the orthogonal W-enriched control sample
  - Shape comparison (MC normalized to data)
- A Kolmogorov-Smirnov test is performed, with systematics
- Flattish distribution of probabilities across 37x2 comparisons → our W+light jets model is appropriate for describing data in this control sample at the current precision

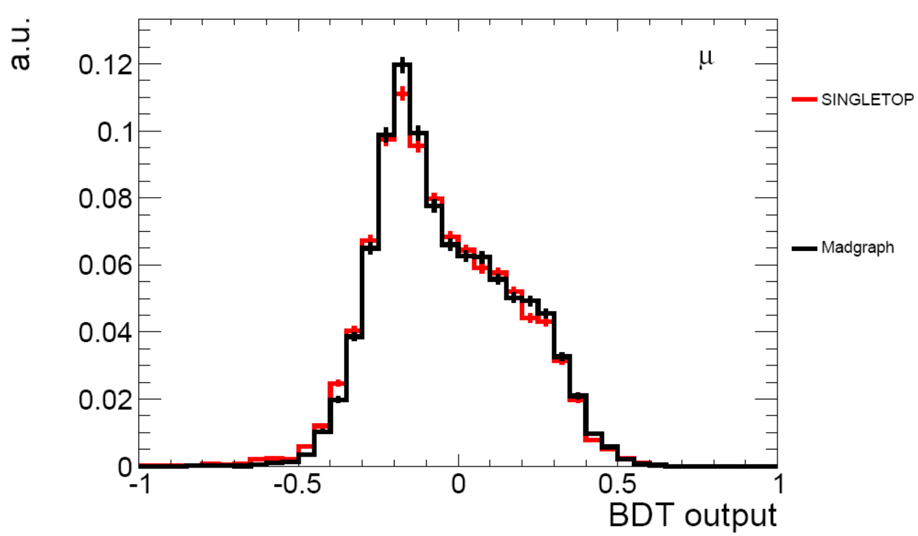
Validation of the output

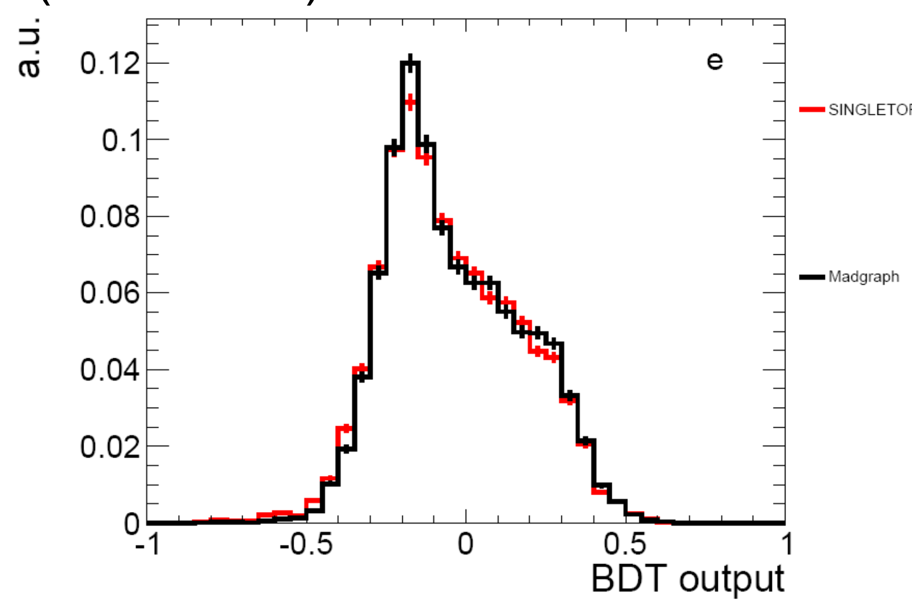
Data/MC in the W-enriched control sample (“region A”):



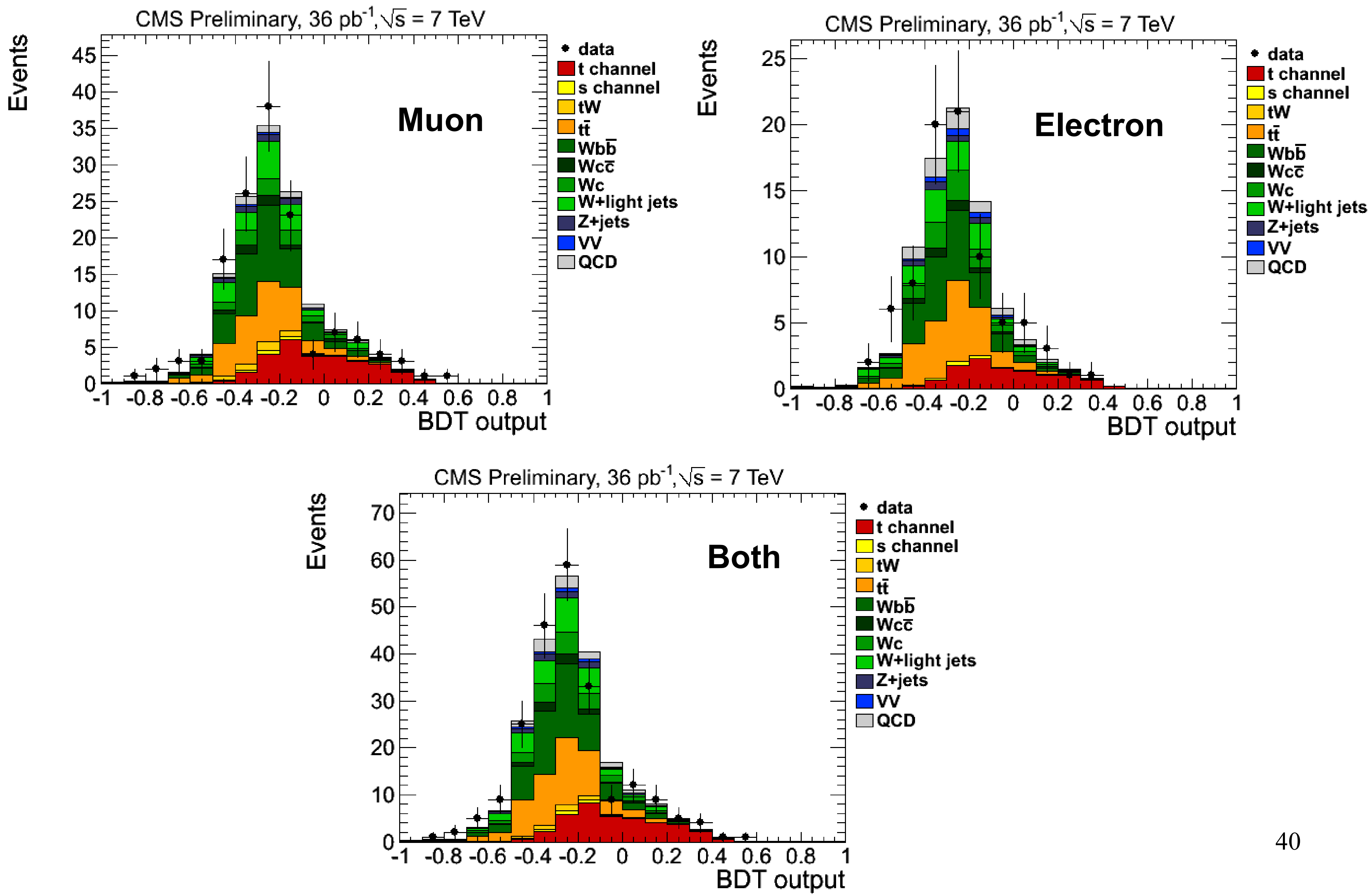


Signal: **MadGraph** (+Z2 tune) vs **SingleTop** (+D6T tune)

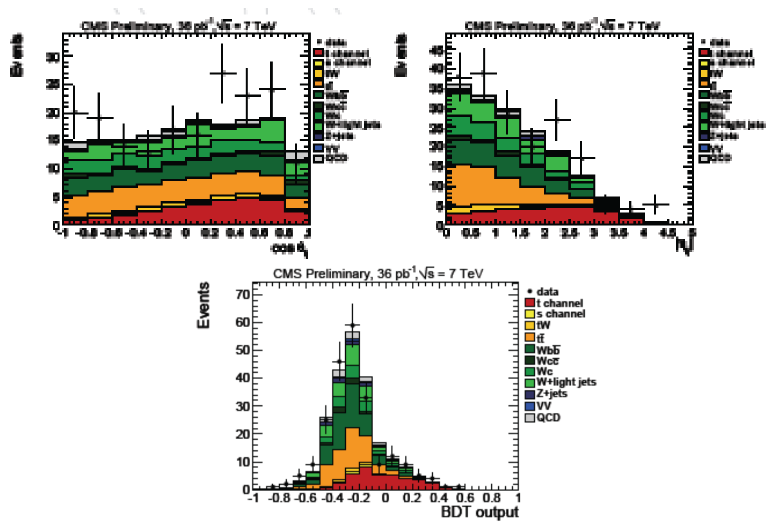




BDT output

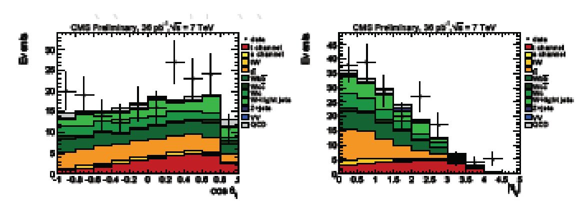

CMS Preliminary, 36 pb^{-1}, $\sqrt{s}$ = 7 TeV
Muon
Events
BDT output
data
t channel
s channel
tW
$t\bar{t}$
$Wb\bar{b}$
$Wc\bar{c}$
Wc
W+light jets
Z+jets
VV
QCD
CMS Preliminary, 36 pb^{-1}, $\sqrt{s}$ = 7 TeV
Electron
Events
BDT output
CMS Preliminary, 36 pb^{-1}, $\sqrt{s}$ = 7 TeV
Both
Events
BDT output

Statistical inference



Cross section

2D analysis



Maximum likelihood fit to the dataset using the function:

$$L(N_s, N_b | cos\theta_1^*, \ldots, cos\theta_n^*, \eta_1, \ldots, \eta_n) =$$

$$= e^{-(N_s+N_b)} \cdot (N_s + N_b)^n \prod_{k=1}^{n} \frac{1}{N_s + N_b} \left(N_s \cdot P_s(cos\theta_k^*, \eta_k) + N_b \cdot P_b(cos\theta_k^*, \eta_k) \right)$$

- Two free parameters: N_s and N_b
- N_s and N_b are the number of events for signal (S) and overall background (B)
- P_s and P_b are the signal and background distribution functions.

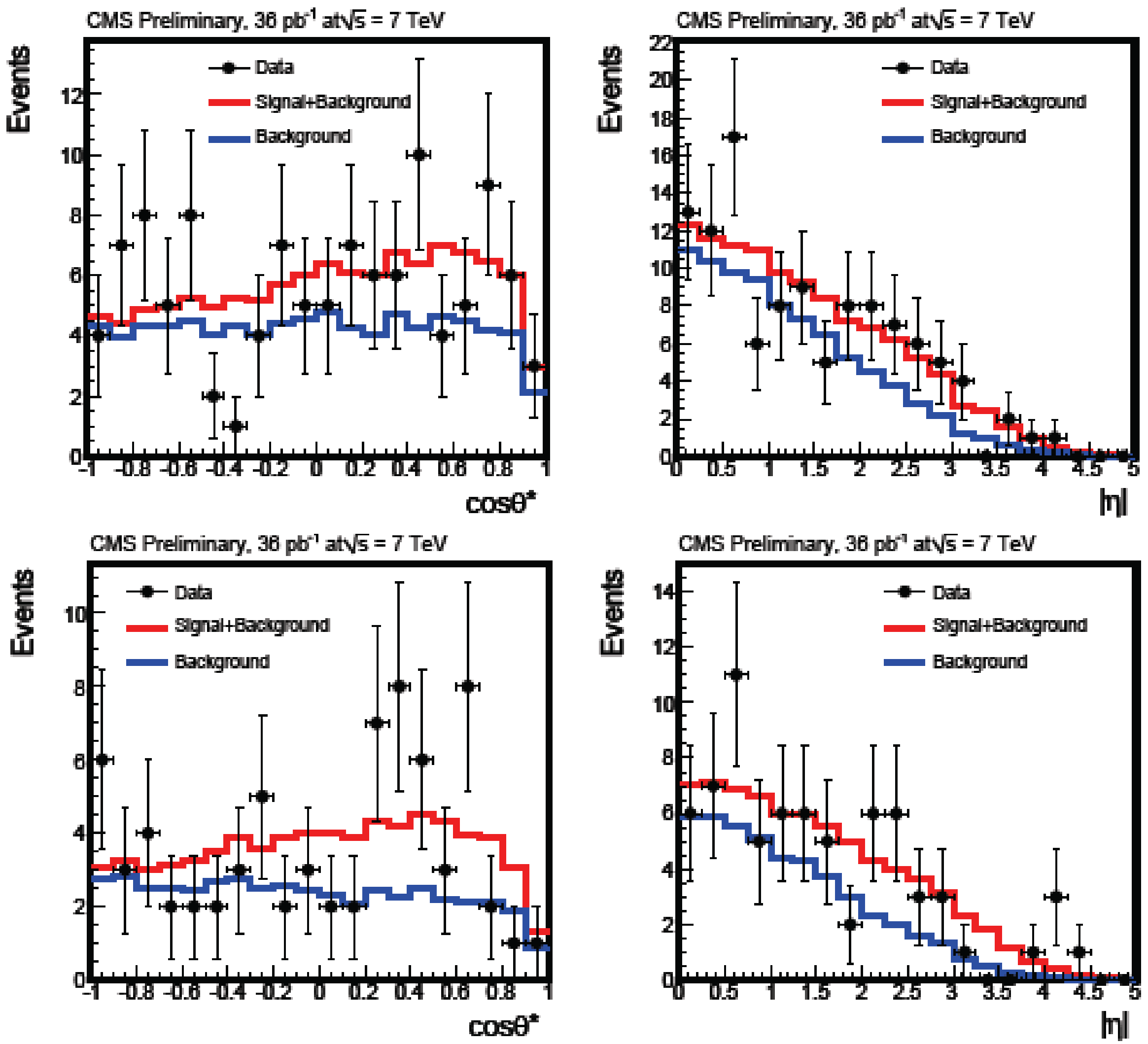
Correlation between cosθ* and η is ~6% for the signal and O(%) for all backgrounds, accounted for as systematics.
Background templates are parametrized as products of 1D templates.

W+light jets and QCD templates from orthogonal data: “region A” and anti-iso

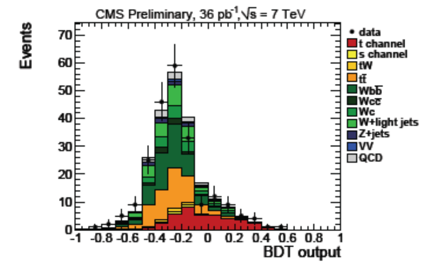
2D fit results

Muon channel

Electron channel



BDT fit



- Core method: Bayesian
  - Significance estim.: CLs, median of the signal strength posterior as test stat.
- Differences with the 2D fit:
  - Systematics as nuisance parameters with Gaussian or Lognormal prior
  - Bayesian approach to determine the posterior probabilities of signal and nuisance parameters (marginalisation w/ Markov Chain MC)

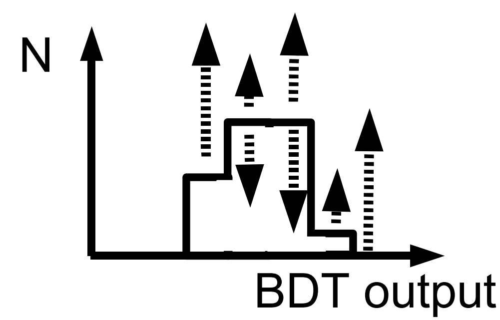
Shape-changing:

$$Pdf_i(x,\boldsymbol{\sigma}^s) = Pdf_i^{nominal}(x) + \sum_j \left(\Delta Pdf_i(x,\boldsymbol{\sigma}^{\boldsymbol{s}}_{\boldsymbol{i,j}})\right)$$

Bin x
Sample i

Vector of shape changing nuisance parameters

Difference in shape between nominal Pdf and sys. unc. for bin x



Flat or rate-changing:

$$N_i^{background} = N_{i,nominal}^{background} \cdot \prod_j s_j(\boldsymbol{\sigma}_i^r) \cdot \prod_k s_k(\boldsymbol{\sigma}_i^s)$$

Sample i

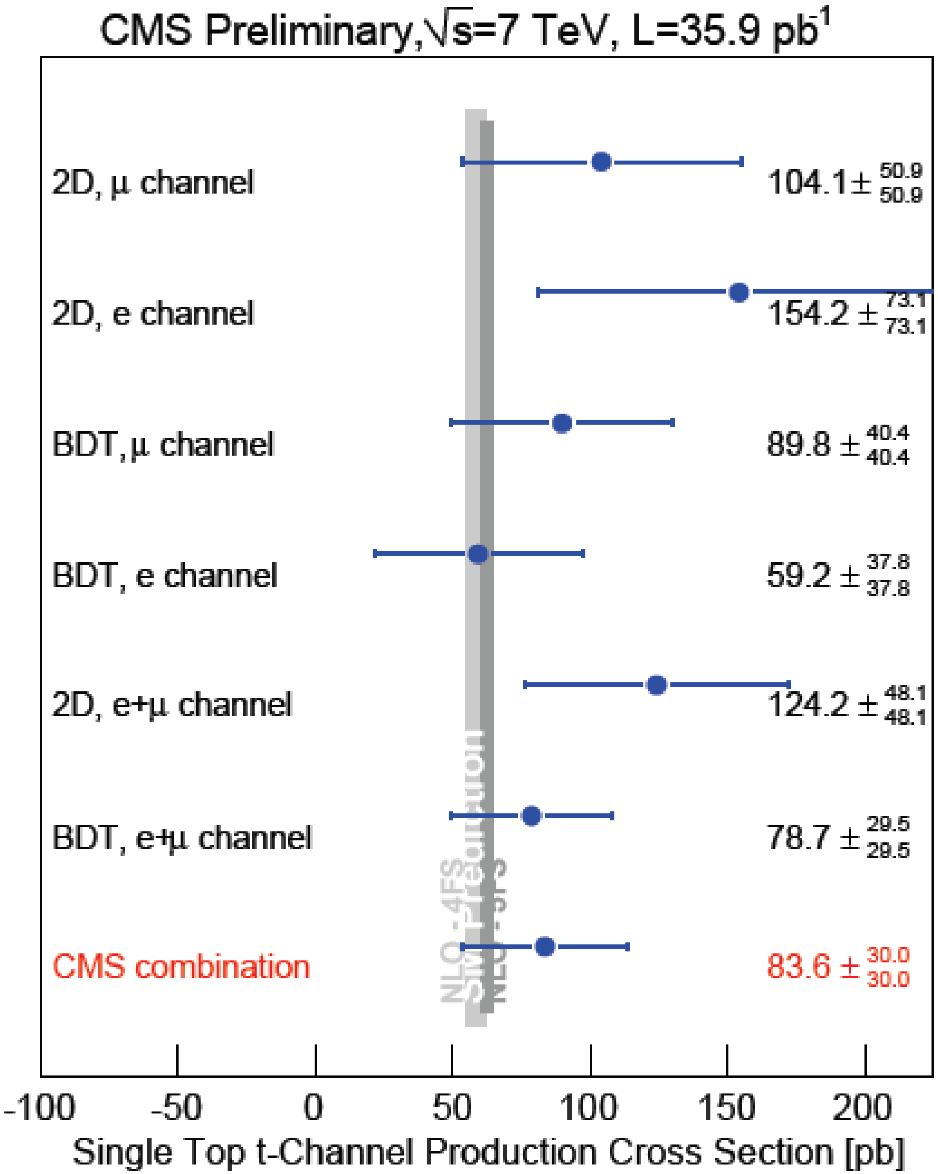
yield for sample i

scale-factor (rate-change) on sample i

(% of the SM cross section)

uncertainty	correlation	impact on 2D −	impact on 2D +	impact on BDT −	impact on BDT +
statistical only	60	52		39	
shared shape/rate uncertainties:					
ISR/FSR for $t\bar{t}$	100	−1.0	+1.5	< 0.2	< 0.2
Q^2 for $t\bar{t}$	100	+3.5	−3.5	+0.3	−0.4
Q^2 for V+jets	100	+5.7	−12.0	+2.6	−4.5
Jet energy scale	100	−8.8	+3.6	−5.1	+1.2
b tagging efficiency	100	−19.6	+19.8	−15.2	+14.6
MET (uncl. energy)	100	−5.7	+3.7	−3.9	−0.5
shared rate-only uncertainties:					
$t\bar{t}$ (±14%)	100	+2.0	−1.9	+0.5	−0.6
single top s (±30%)	100	−0.4	+0.5	−0.4	+0.4
single top tW (±30%)	100	+1.1	−1.0	< 0.2	< 0.2
$Wb\bar{b}$, $Wc\bar{c}$ (±50%)	100	−3.0	+2.9	+1.7	−1.9
Wc ($^{+100\%}_{-50\%}$)	100	−3.0	+6.1	−2.4	+4.4
Z+jets (±30%)	100	−0.6	+0.7	+0.4	−0.2
electron QCD (BDT: ±100%, 2D: $^{+130\%}_{-100\%}$)	50	+2.9	−3.7	−1.7	+1.7
muon QCD (BDT: ±50%, 2D: ±50%)	50	< 0.2	< 0.2	−2.1	+2.1
signal model	100	−5.0	+5.0	−4.0	+4.0
BDT-only uncertainties:					
electron efficiency (±5%)	0	—	—	−1.4	+1.4
muon efficiency (±5%)	0	—	—	−3.6	+3.5
V+jets (±50%)	0	—	—	−1.5	< 0.2
2D-only uncertainties:					
muon W+light (±30%)	0	−1.4	+1.4	—	—
electron W+light (±20%)	0	−0.6	+0.7	—	—
W+light model uncertainties	0	−5.4	+5.4	—	—

Results



$\sigma^{2D} = 104.1 \pm 42.3(stat.)\,^{+24.8}_{-28.0}(syst.) \pm 4.2(lumi.)$ pb — muon channel

$\sigma^{2D} = 154.2 \pm 56.0(stat.)\,^{+40.6}_{-46.6}(syst.) \pm 6.2(lumi.)$ pb — electron channel

$\sigma^{2D} = 124.2 \pm 33.8(stat.)\,^{+30.0}_{-33.9}(syst.) \pm 5.0(lumi.)$ pb — combined

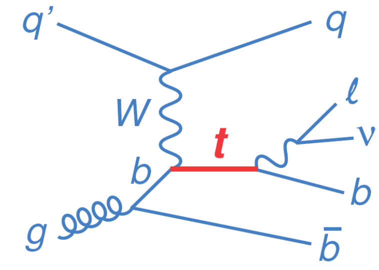
$\sigma^{BDT} = 90.4 \pm 35.1(stat.)\,^{+16.5}_{-19.7}(syst.) \pm 3.6(lumi.)$ pb — muon channel

$\sigma^{BDT} = 59.2 \pm 35.1(stat.)\,^{+13.1}_{-13.7}(syst.) \pm 2.4(lumi.)$ pb — electron channel

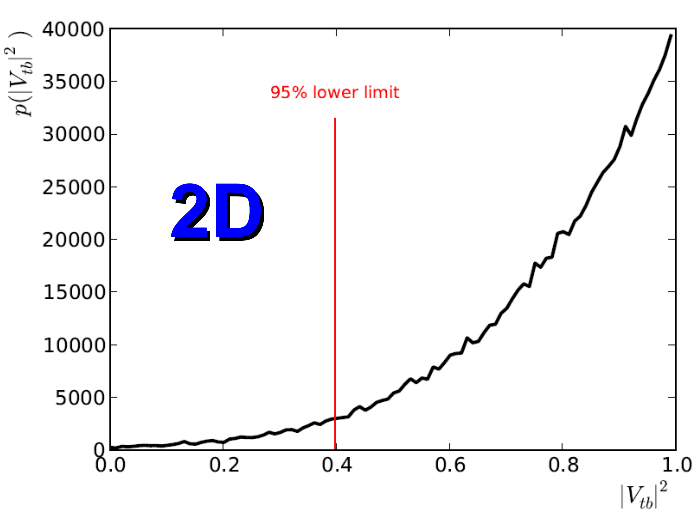
$\sigma^{BDT} = 78.7 \pm 25.4(stat.)\,^{+13.2}_{-14.6}(syst.) \pm 3.1(lumi.)$ pb — combined

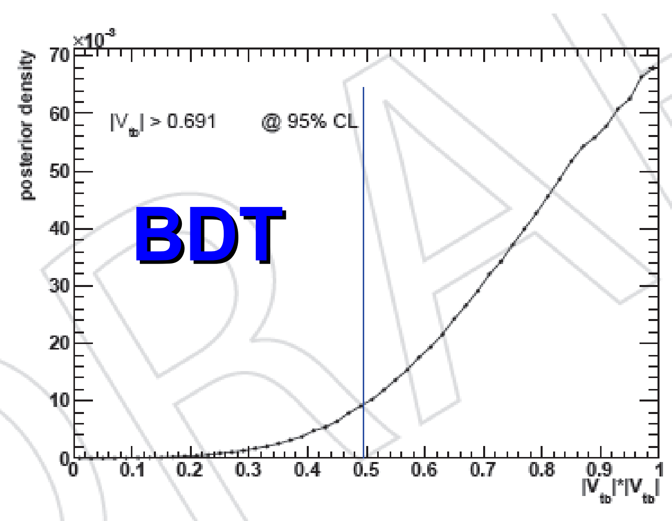
Analysis, channel	expected	observed
2D, μ-channel	$1.7^{+1.1}_{-1.0}$	2.5
2D, e-channel	$1.3^{+1.0}_{-1.1}$	3.1
2D, combined	$2.1^{+1.0}_{-1.1}$	3.7
BDT, μ-channel	$2.4^{+0.9}_{-1.0}$	3.1
BDT, e-channel	2.0 ± 1.0	1.9
BDT, combined	$2.9^{+1.0}_{-0.9}$	3.5

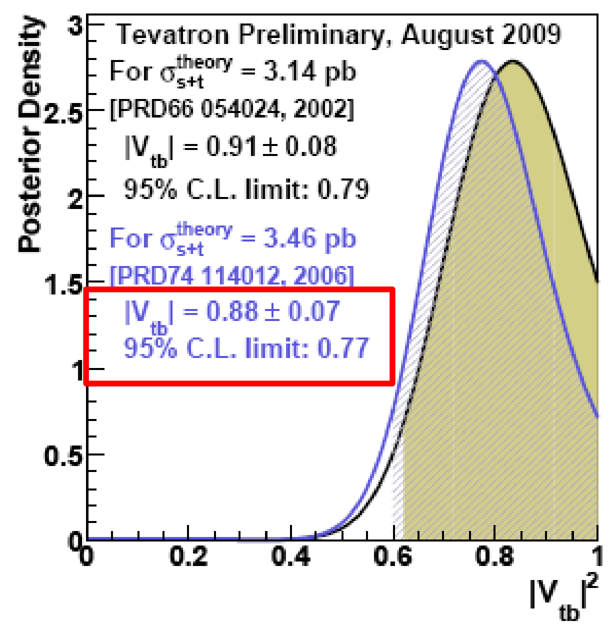
Limits on $|V_{tb}|$, with some assumptions



- Unconstrained measurement à la Tevatron:
  - Assumption: $|V_{td}|,|V_{ts}| \ll |V_{tb}| \Rightarrow BR(t\rightarrow b)\sim 1 \Rightarrow$ **$|V_{tb}|^2 = \sigma(exp)/\sigma(SM)$**
  - 2D: $|V_{tb}|=1.41\pm0.27(exp)\pm0.03(th.)$, BDT: $|V_{tb}|=1.12\pm0.21(exp)\pm0.02(th.)$
- Constrained limit à la Tevatron (i.e., flat prior $0<|V_{tb}|^2<1$)
  - 2D: $|V_{tb}| > 0.63$ @ 95%CL, BDT: $|V_{tb}| > 0.69$ @ 95%CL







Combination

- We use the Best Linear Unbiased Estimator
  - Assumptions of Gaussianity and linearity are approximately fulfilled (main uncertainties do)
  - Statistical correlation (60%) estimated with toy exps
  - 100% correlation for all common systematics, apart from QCD yield ~50%; varied within 0% and 100%, no impact
  - Weights found by minimizing the total error

$$\sigma^{2D} = 124.2 \pm 33.8(stat.)\,^{+30.0}_{-33.9}(syst.) \pm 5.0(lumi.)\ \text{pb} \qquad \sigma^{BDT} = 78.7 \pm 25.4(stat.)\,^{+13.2}_{-14.6}(syst.) \pm 3.1(lumi.)\ \text{pb}$$

$$\sigma = 83.6 \pm 29.8(stat. + syst.) \pm 3.3(lumi.)\ \text{pb} \qquad \text{combined}$$

$$|V_{tb}| = \sqrt{\frac{\sigma^{exp}}{\sigma^{th}}} = 1.16 \pm 0.22(exp) \pm 0.02(th)$$

http://www.symmetrymagazine.org/breaking/2011/03/15/speedy-single-top-sighting-at-the-lhc/

symmetrybreaking extra dimensions of particle physics
A joint Fermilab/SLAC publication

VOLUME 08 ISS
FEBRUA

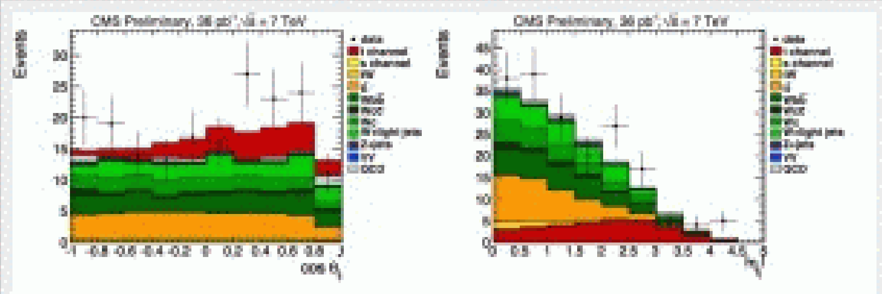
VIEW CURRENT I

Speedy single top sighting at the LHC

March 15, 2011 | 4:34 am

For the first time, scientists at the Large Hadron Collider have spotted single top quark production.

It took Fermilab scientists at the Tevatron more than 13 years to observe the particle in its solo state after they discovered it paired with its antiparticle in 1995. The CMS experiment teased signs of the single top out of 36 inverse picobarns of collision data, roughly what Tevatron experiments collect over three days.

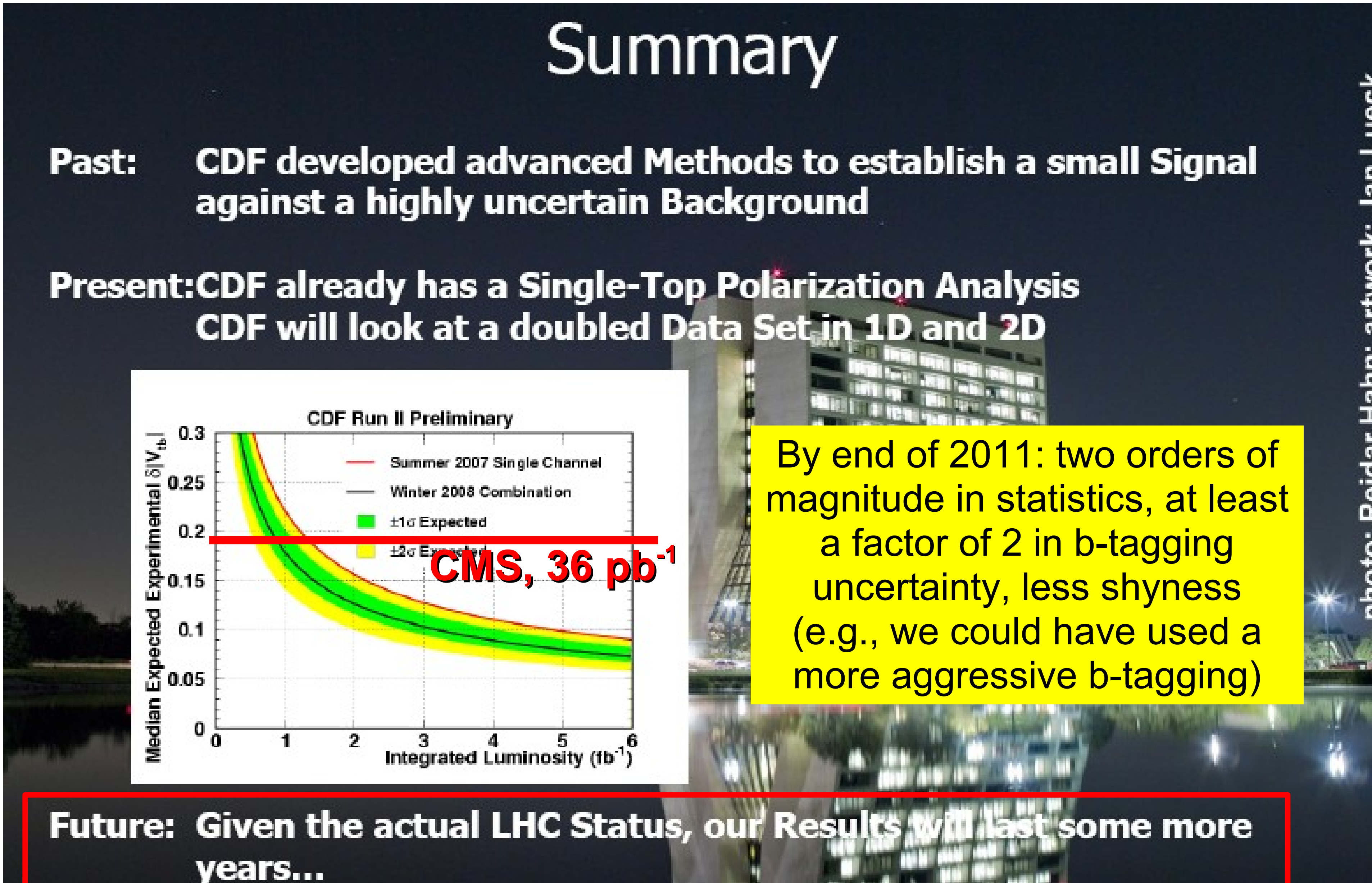


CMS scientists observed an excess in their data consistent with the production of single top quarks after combining just a couple of variables. Image courtesy of the CMS Collaboration.

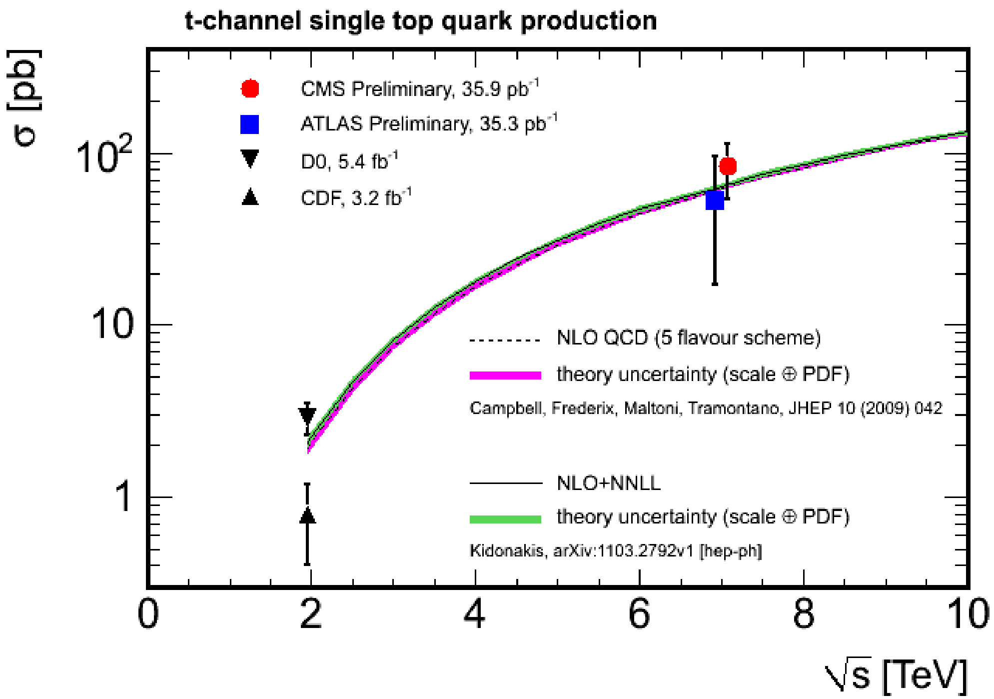
"We were surprised we saw it so soon," said CMS physicist Philip Coleman Harris, who announced the accomplishment on Monday at the Rencontres de Moriond conference. The ATLAS experiment also made public impressive limits on the single top quark.

Scientists took the news as one of many signs that experiments at the LHC are prepared to make great strides in the coming years.

Last Summer, at TOP2010...



Conclusions

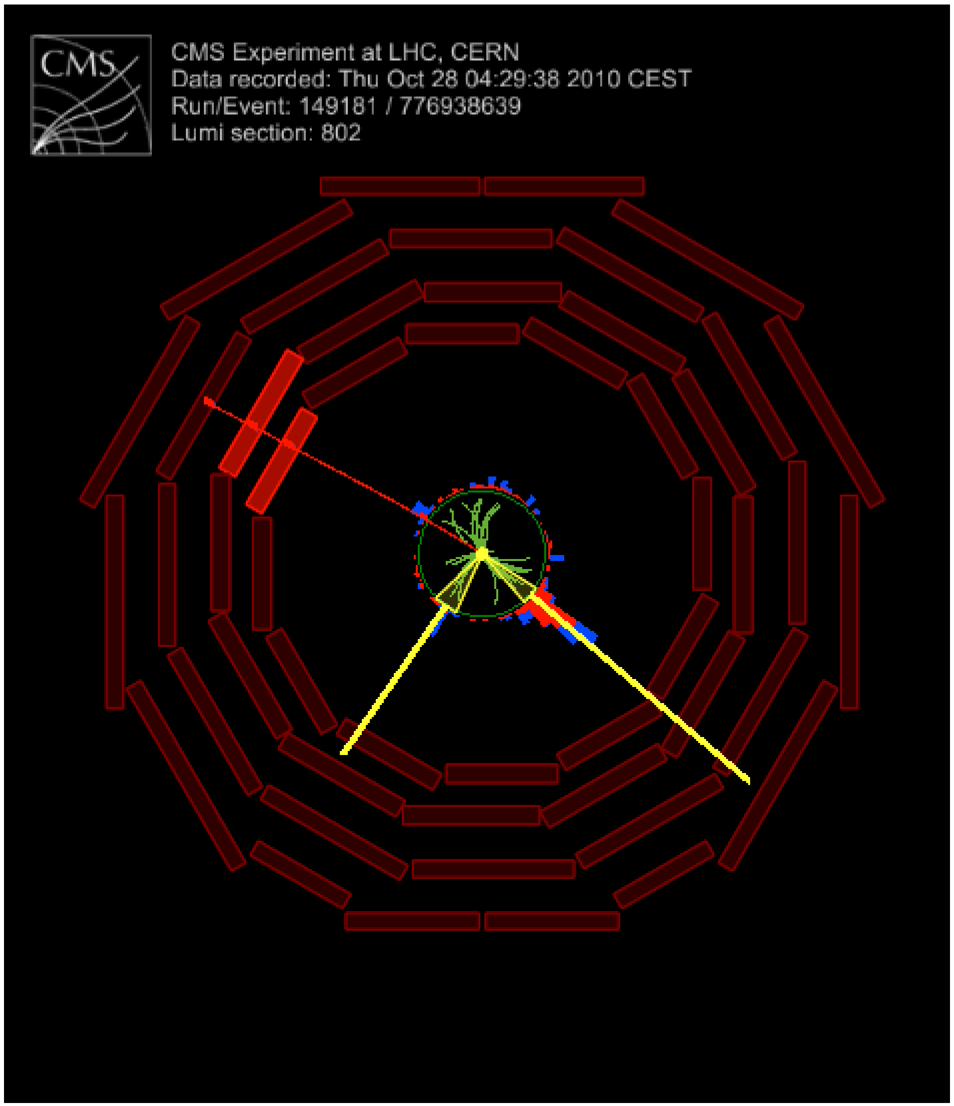


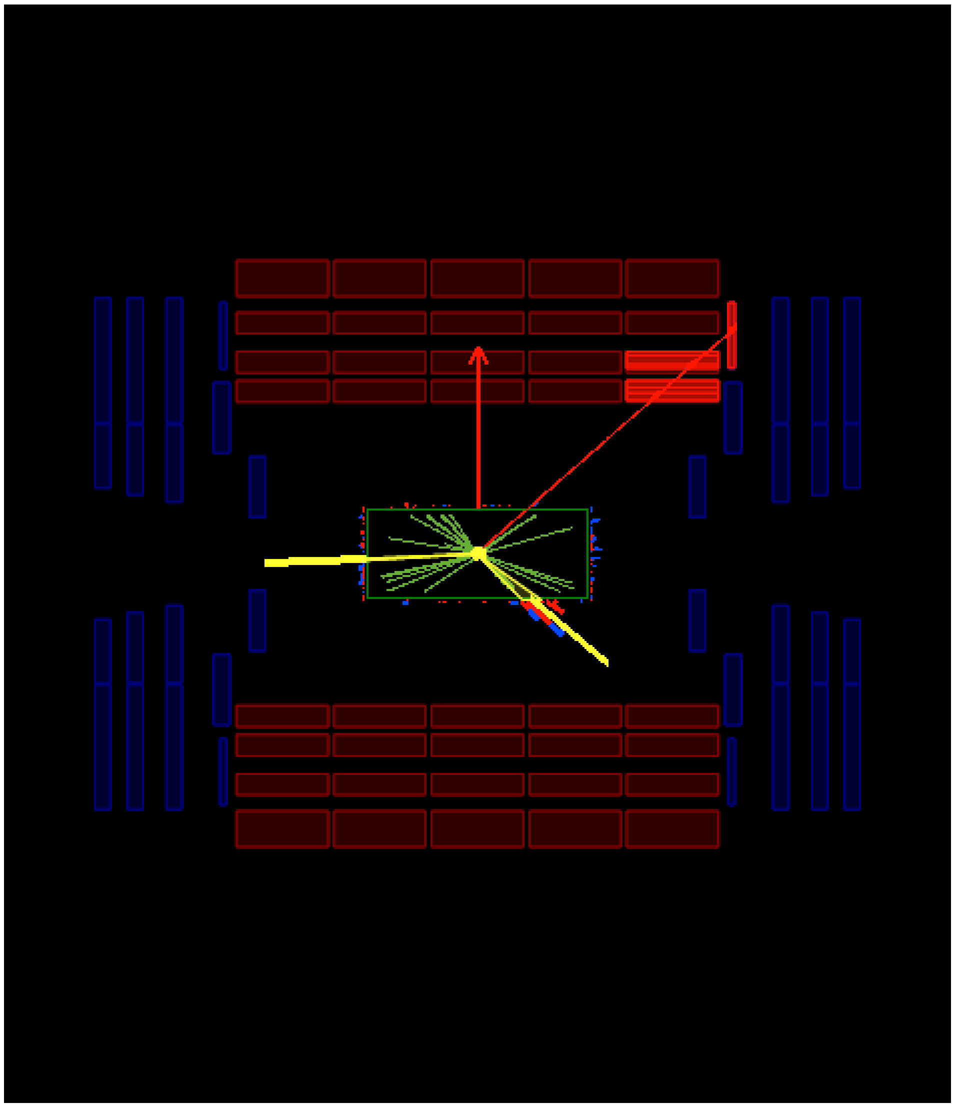
- It took 13 years to Tevatron to go from top quark observation to single top, a few months to LHC
  - But not just "brute force": making single top an analysis "for early data" required a long preparation and some original ideas
  - Historical recollection: in our kick-off meeting in Apr.2008, we set a goal of a ~30% precision with ~1000/pb @ 14 TeV!

Thanks for you attention!

Backup:
special events

Golden muon candidate

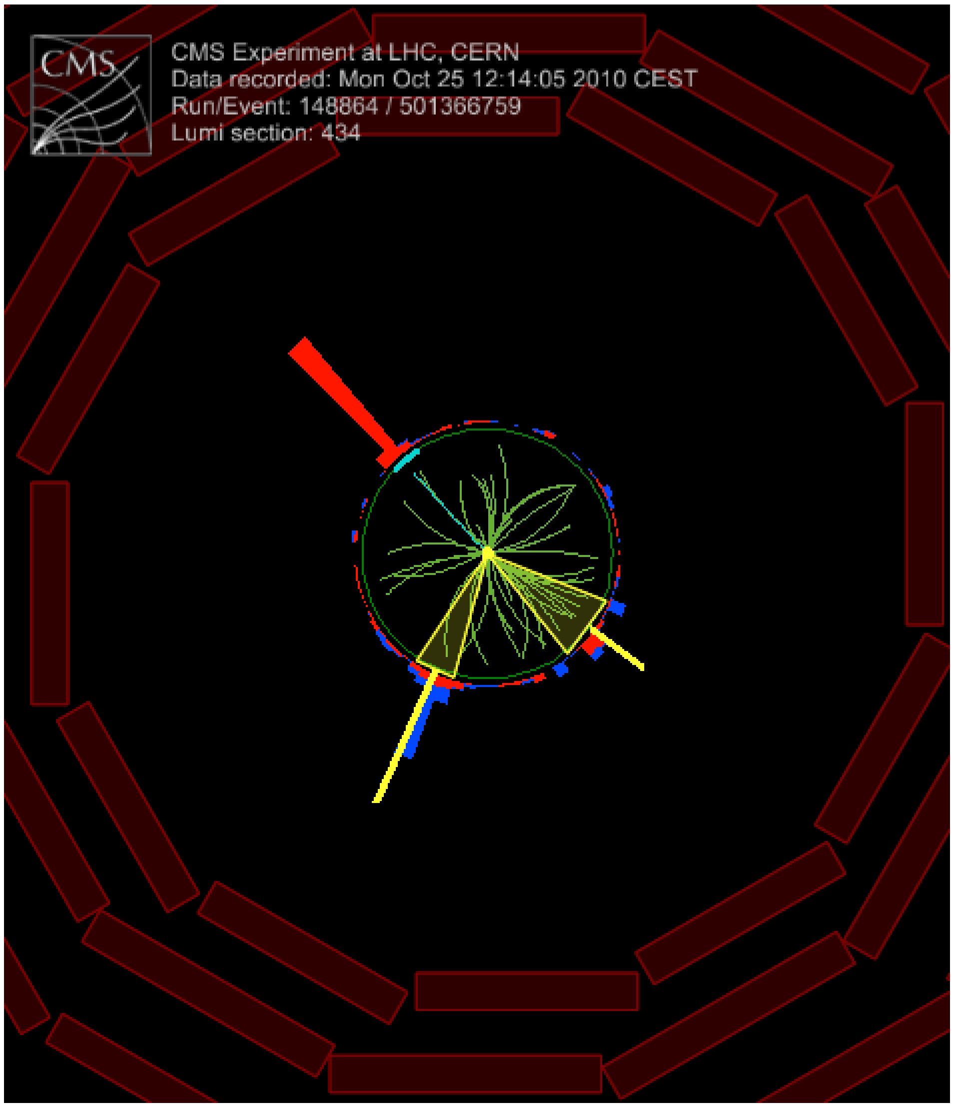


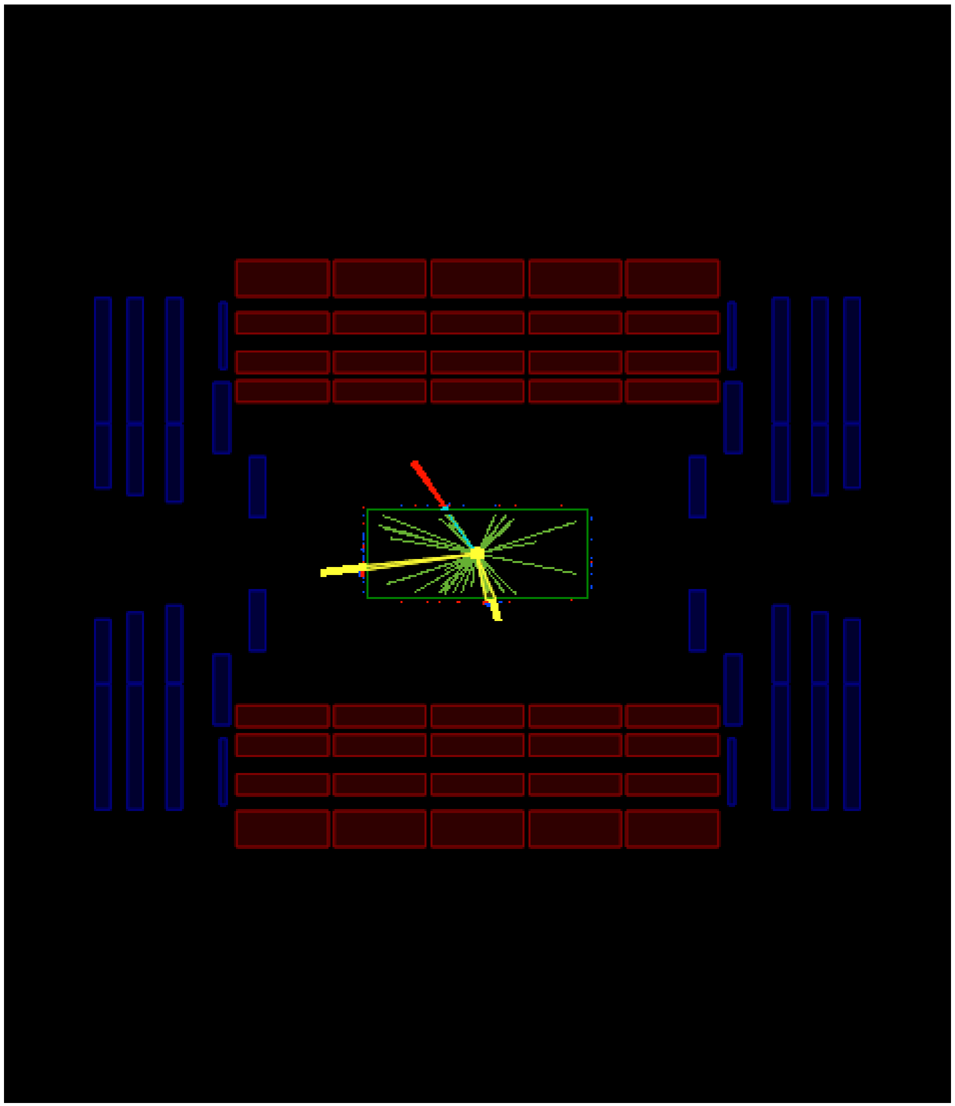


Most signal-like according to the BDT; it also passes the 2D selection

$\cos\theta_{lj}^{*}=0.24$, $\eta_{lj}=-3.76$

Golden electron candidate



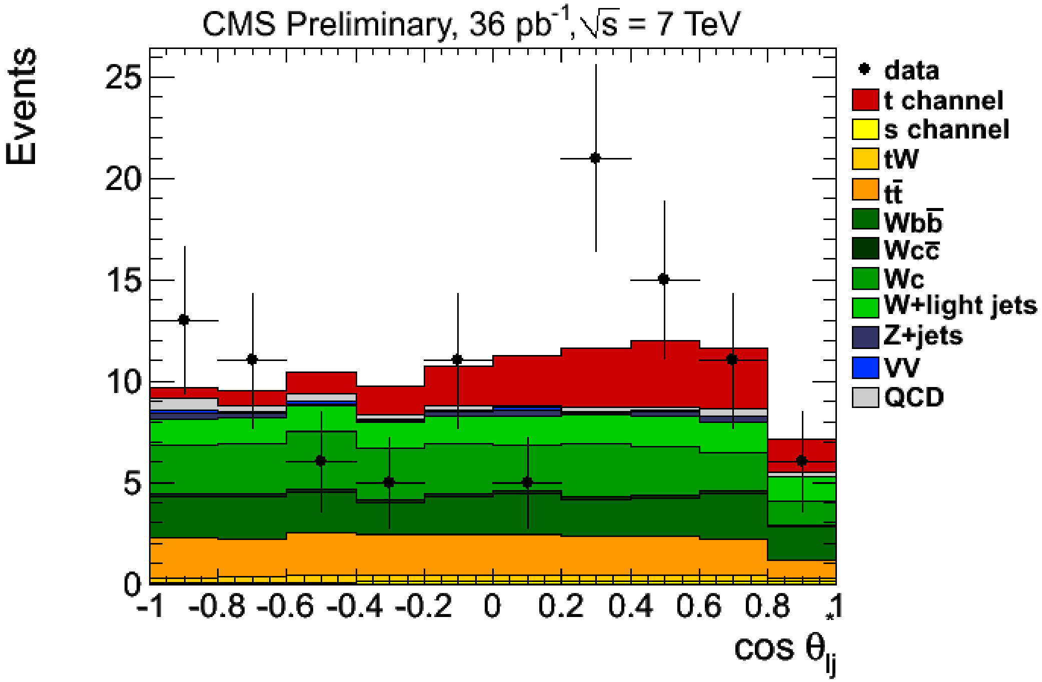


Most signal-like according to the BDT; it also passes the 2D selection

$\cos\theta_{lj}$*=0.23, η_{lj}=-2.84

Charge asymmetry

Positive lepton



Negative lepton