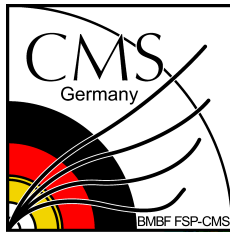
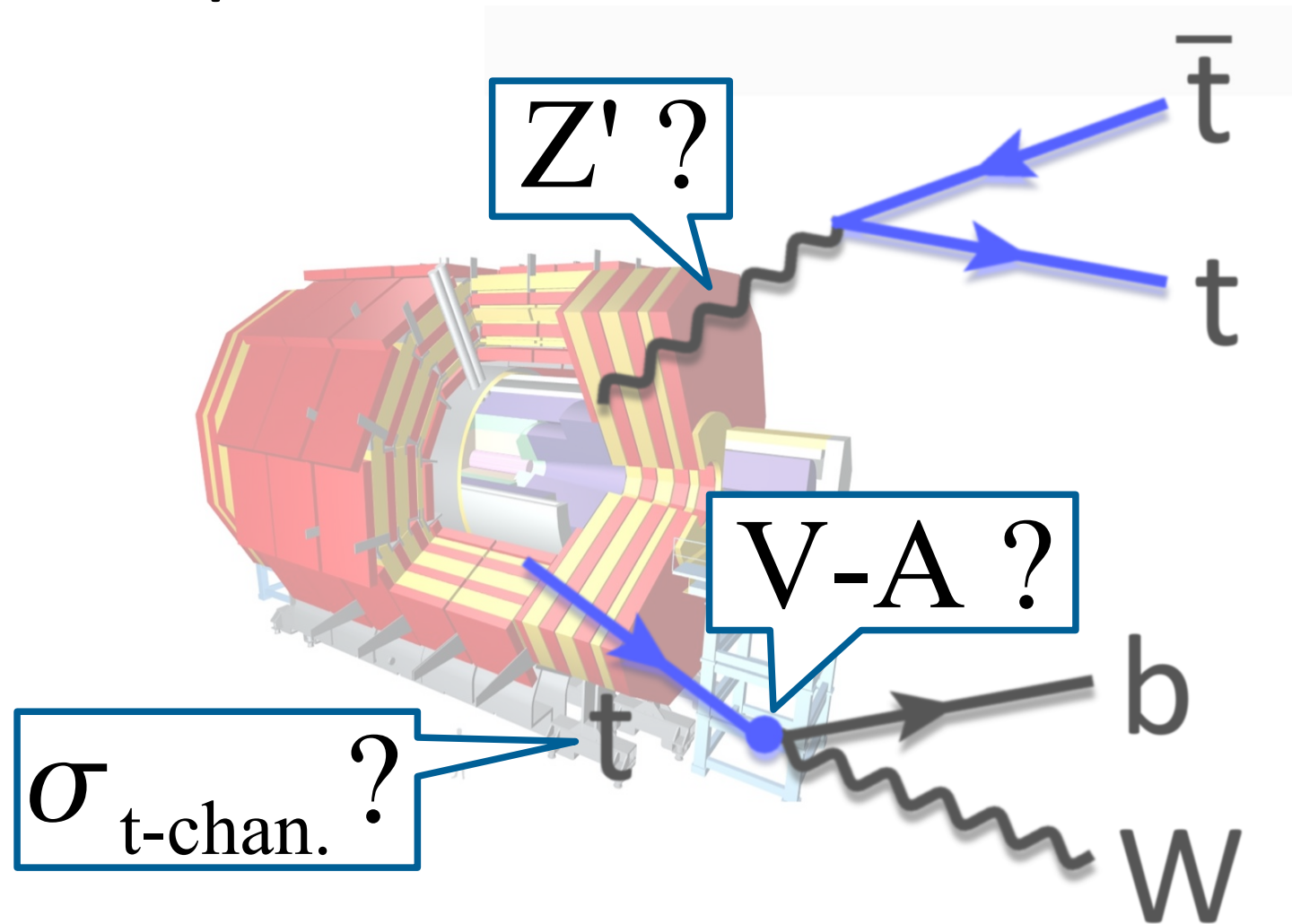
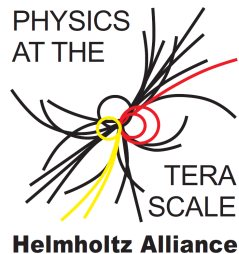


# top quark...

...pair spectrum, cross section & coupling



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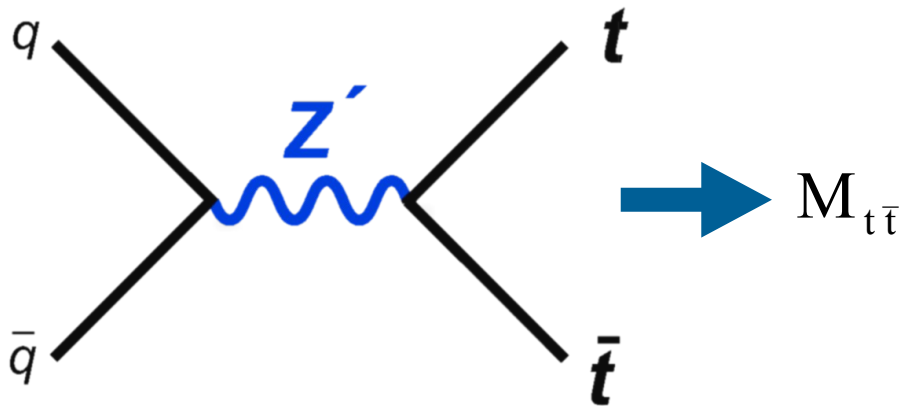
**RWTH**AACHEN  
UNIVERSITY

**Matthias Komm**, Martin Erdmann, Robert Fischer,  
Dennis Klingebiel, Marcel Rieger, Jan Steggemann

# search for s-channel resonances

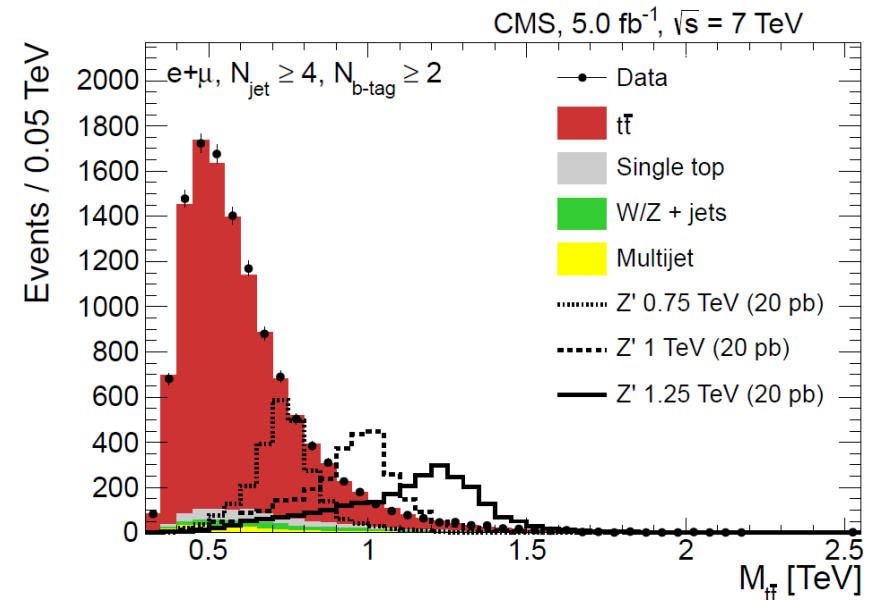
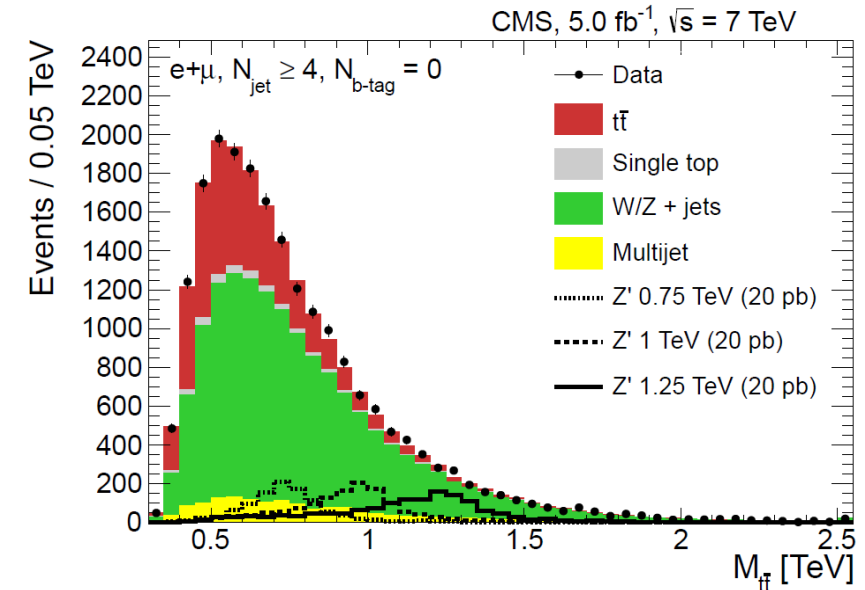
## ➤ motivation:

- benchmark models:  
topcolor Z', Kaluza Klein gluon



## ➤ strategy

- select isolated muon/electron + at least 3 jets
- reconstruction using  $\chi^2$ - method
- 8 regions from different jet & b-tag multiplicity
  - ▶ profit from different signal/background ratios



# results

## ➤ combination

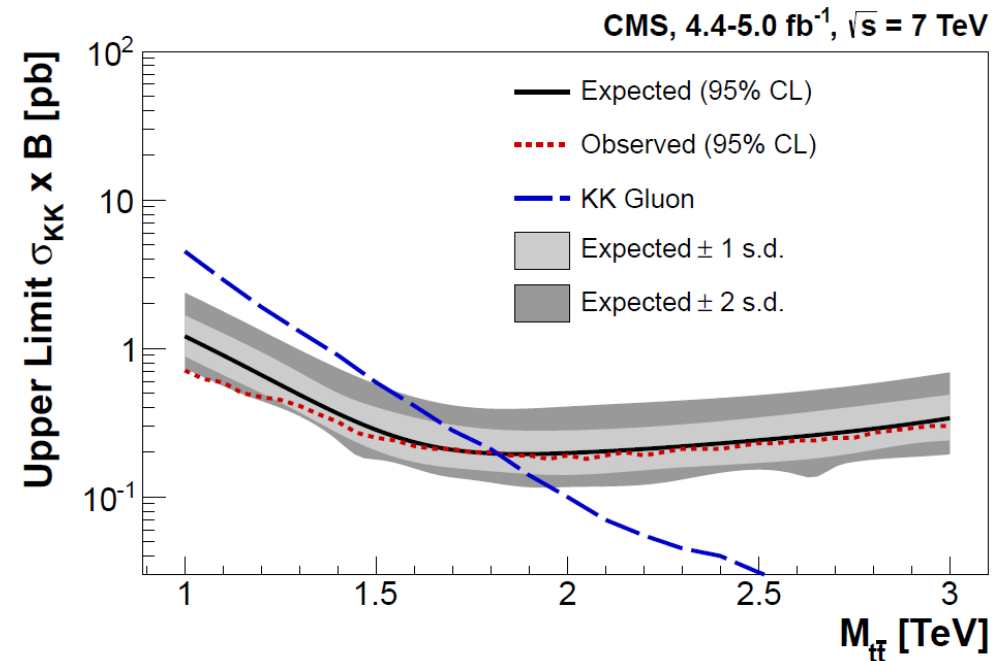
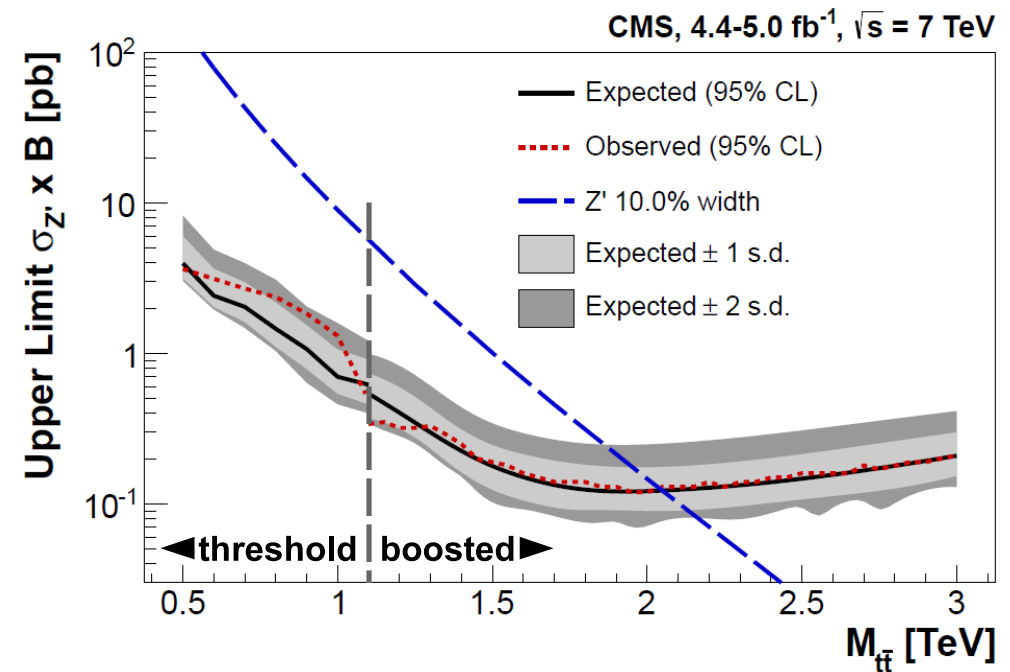
- threshold + boosted analysis  
(optimized for different  $M_{t\bar{t}}$  range)

## ➤ limits @ 95% CL

- topcolor Z' (width 1.2%): 1.49 TeV
- topcolor Z' (width 10%): 2.04 TeV
- KK gluon: 1.82 TeV

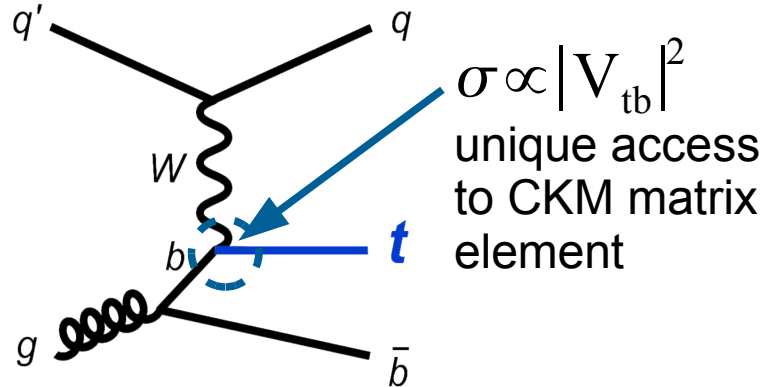
## ➤ publication

CMS-TOP-12-017  
accepted by JHEP  
arXiv: 1209.4397



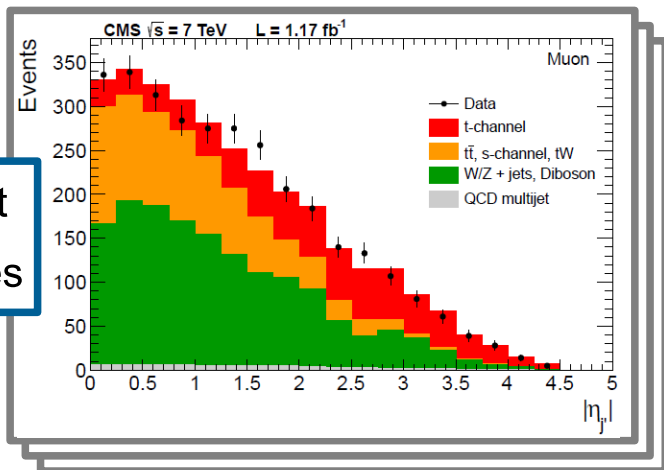
# single top t-channel: $\sigma$

## ➤ motivation



## ➤ strategy

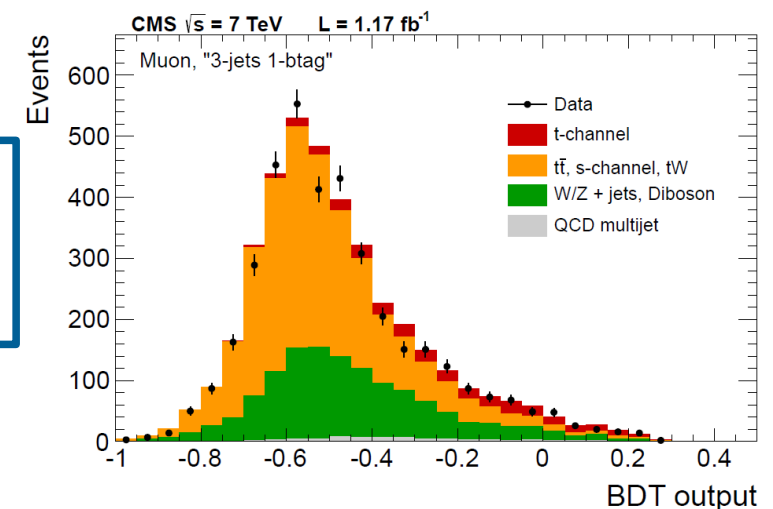
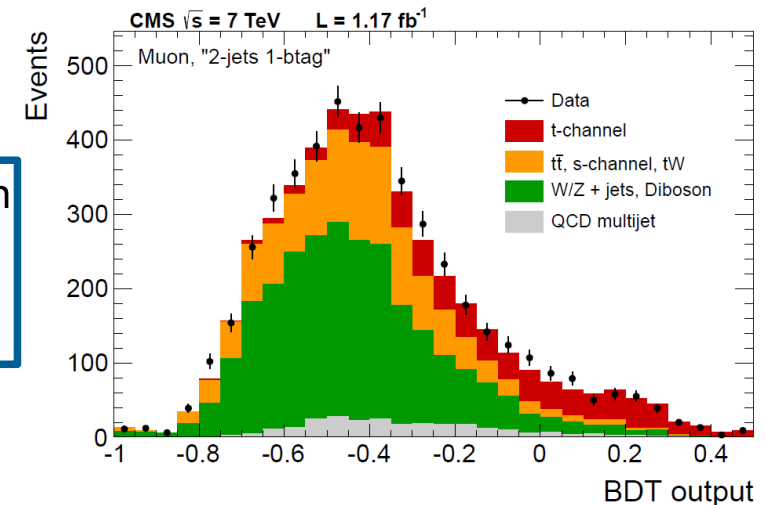
11 input  
variables



- train Boosted Decision Tree for signal and background separation
- use 2 signal and 4 control regions (electron/muon)
- blinded signal regions, understand background first

BDT in  
2 jet  
1 tag

BDT in  
3 jet  
1 tag



# results

## ➤ BDT

$$\sigma_{t\text{-ch.}} = 66.6 \pm 4.0 \text{ (stat.)} \pm 3.3 \text{ (syst.)}_{-3.3}^{+3.9} \text{ (theor.)} \pm 1.5 \text{ (lum.) pb}$$

## ➤ combination

$$\sigma_{t\text{-ch.}} = 67.2 \pm 6.1 \text{ pb} \quad (\text{BDT analysis} + \text{neutral network analysis} + \text{cut-based analysis})$$

- less than 10% uncertainty
- well compatible with SM

## ➤ constraint on $V_{tb}$

$$|V_{tb}| = 1.020 \pm 0.046 \text{ (exp.)} \pm 0.017 \text{ (theor.)}$$

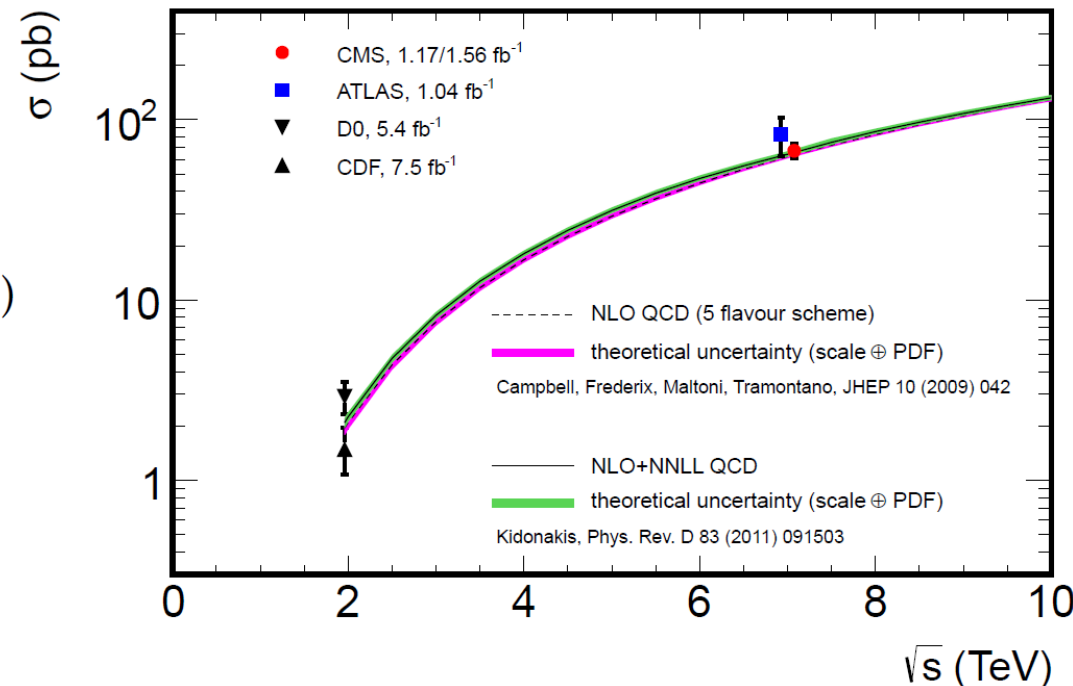
$$\blacktriangleright 0.92 < |V_{tb}| \leq 1 \quad \textbf{@ 95\% CL}$$

## ➤ publication

CMS-TOP-11-021

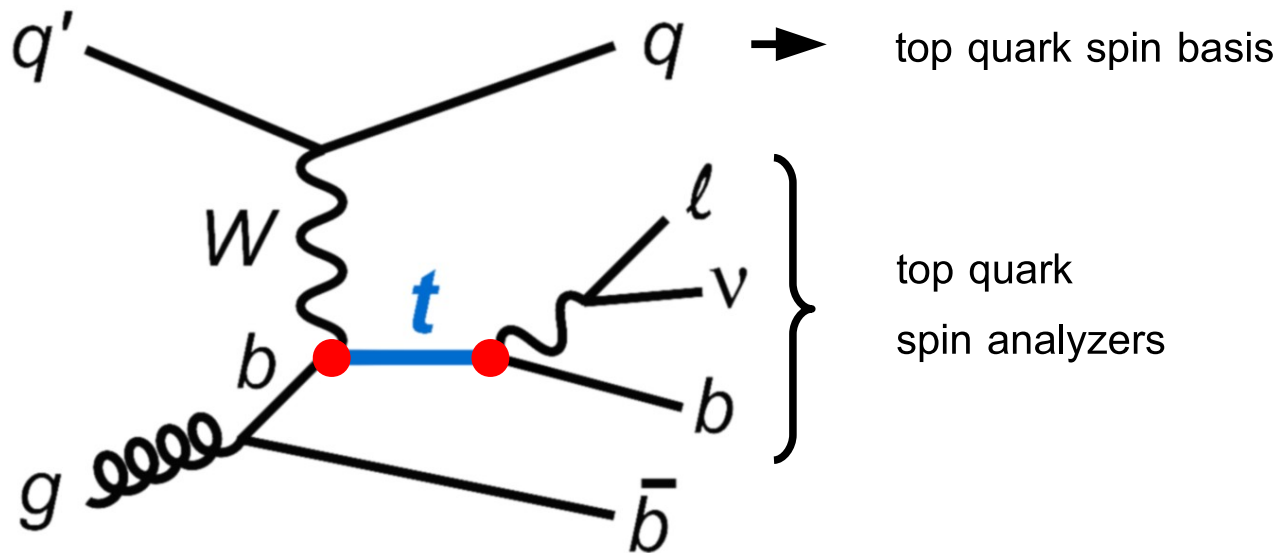
accepted by JHEP

arXiv: 1209.4533



# top quark coupling structure

## ➤ polarized top quarks in single top quark t-channel production



## ➤ effective SM extension

– Lagrangian

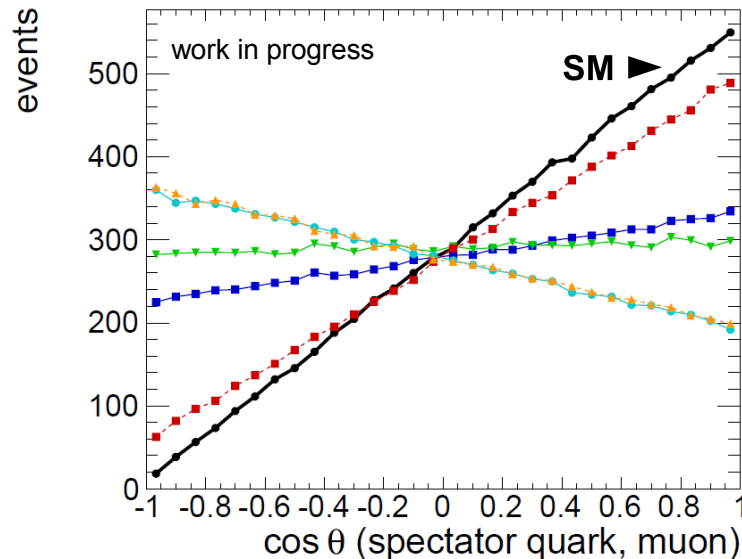
$$\mathcal{L}_{Wtb}^{\text{eff}} = -\frac{g}{\sqrt{2}} \bar{b} \gamma^\mu (\underline{V_L P_L} + \underline{V_R P_R}) t W_\mu^- - \frac{g}{\sqrt{2}} \bar{b} \frac{i\sigma^{\mu\nu} q_\nu}{m_W} (\underline{g_L P_L} + \underline{g_R P_R}) t W_\mu^- + \text{h.c.}$$

anomalous top quark couplings  
(in SM:  $V_L = V_{tb}$ ,  $V_R = g_L = g_R = 0$ )

# top quark spin asymmetries

## ➤ differential cross section

simulated coupling scenarios with WHIZARD



$$\frac{d\sigma}{\sigma_{tot} \cdot d(\cos \theta_{B,X})} = \frac{1}{2} (1 + \rho_B \cdot c_X \cdot \cos \theta_{B,X})$$

polarization:  
 $\rho_B \approx 1$

spin analyzing power:  
 $c_X = c_X(V_L, V_R, g_L, g_R)$

## ➤ observables

– asymmetry:

$$A_X^B = \frac{N(\cos \theta > 0) - N(\cos \theta < 0)}{N(\cos \theta > 0) + N(\cos \theta < 0)} = \frac{1}{2} \rho_B c_X$$

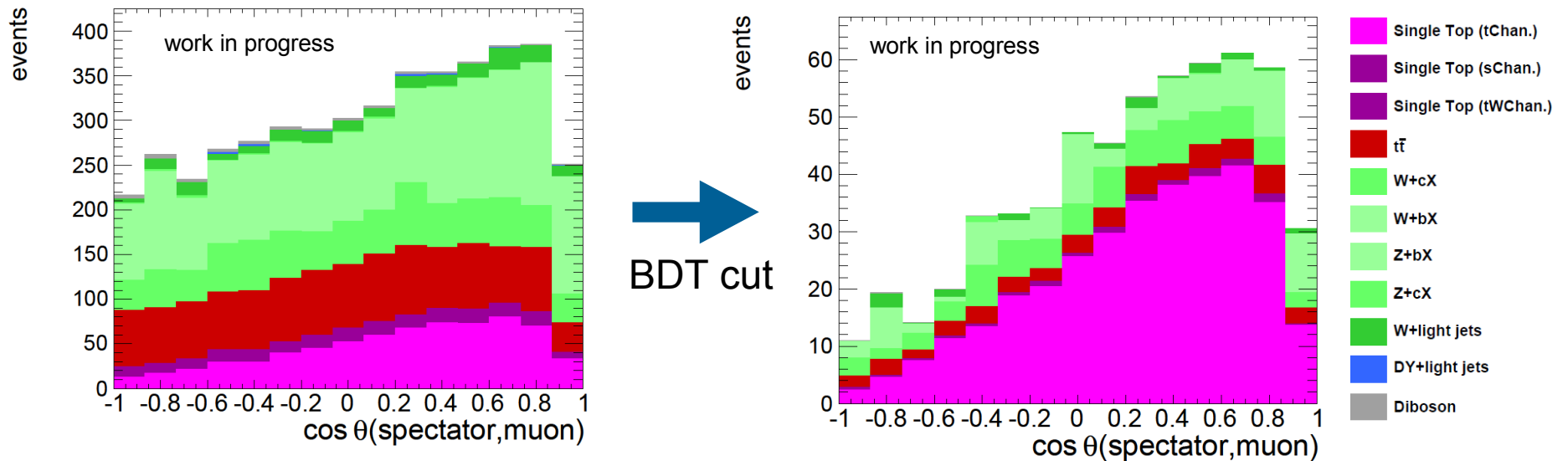
➡ sensitive to **anomalous couplings**

- spin basis **B**: spectator quark, beamline
- spin analyzer **X**: muon, bottom quark, neutrino

# analysis strategy

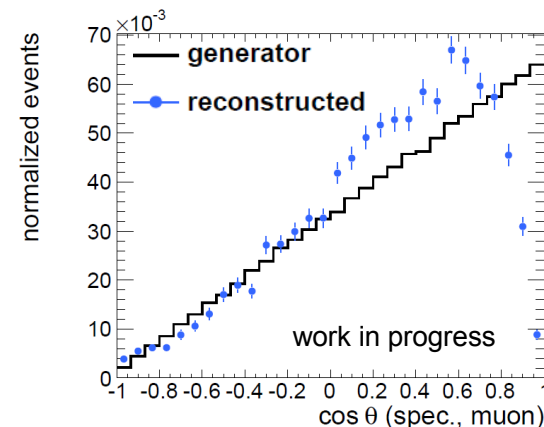
## ➤ Boosted Decision Tree

- select purest single top t-channel data
- input variables: sets of 5,10,15,...100 most uncorrelated to angular distributions

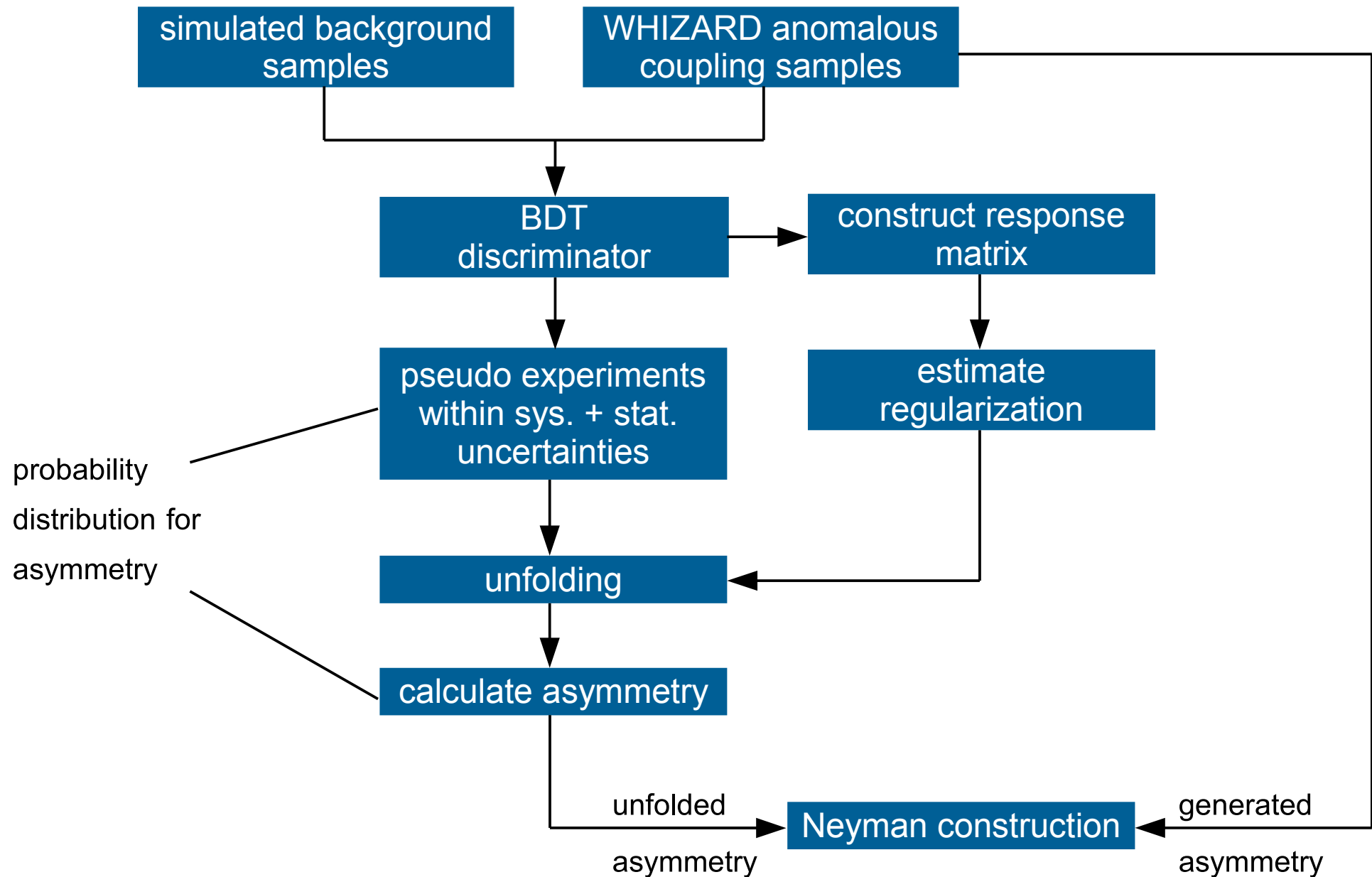


## ➤ unfolding

- correct for detector & acceptance effects
- method: TUnfold
- regularize for minimal bin-by-bin correlations

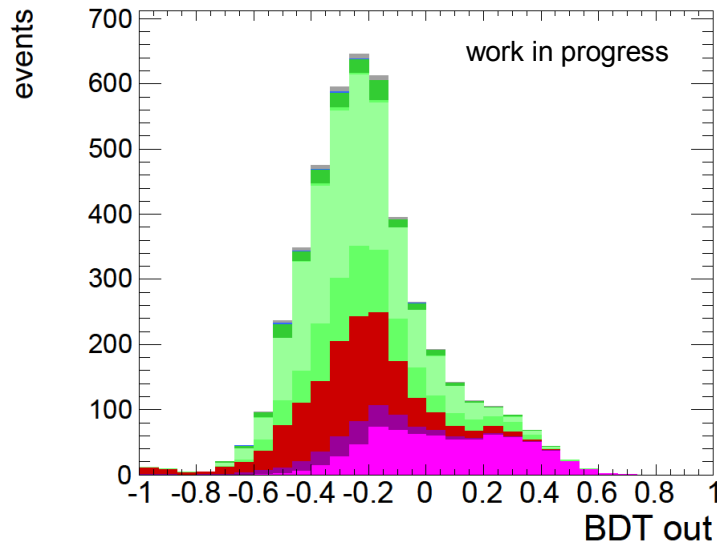


# measurement procedure



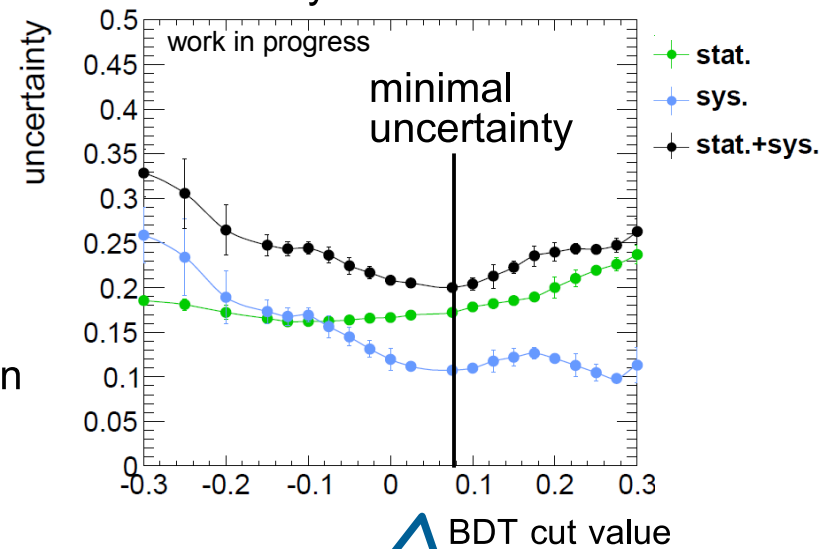
# optimization

## ➤ best BDT cut value



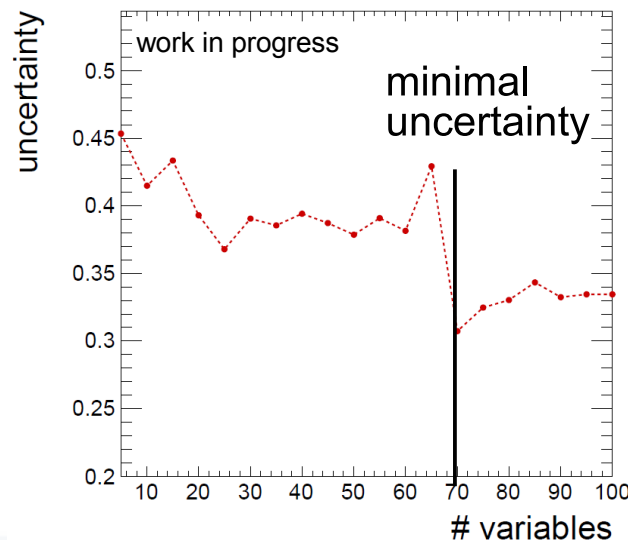
scan all BDTs for  
minimal uncertainty on  
unfolded asymmetry

tradeoff between  
stat. & sys. uncertainties



## ➤ best BDT (5,10,15,...100)

- perform measurement for all BDTs at their best cut values
- best result with BDT trained with **70 variables** and working point of 0.075



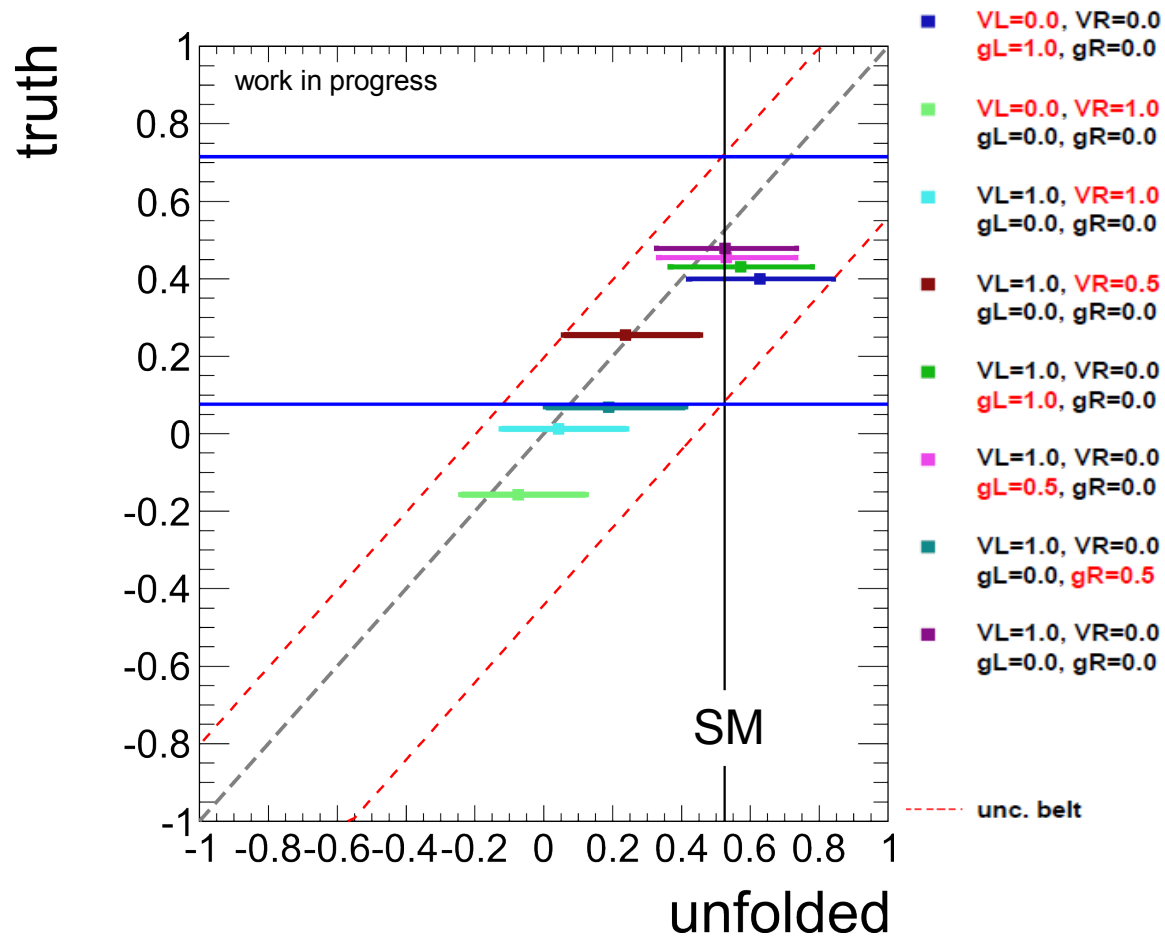
dominating sys. uncertainties:

1. W+jets (heavy flavor)
2. b-tagging efficiency

⋮

# top quark spin asymmetries

## exemplary Neyman construction:



- uncertainty belt through max 68% quantiles among all simulated coupling scenarios,
- only discrete coupling scenarios tested
- conservative estimation

## expected asymmetries in spectator basis for $1.17 \text{ fb}^{-1}$ from 2011:

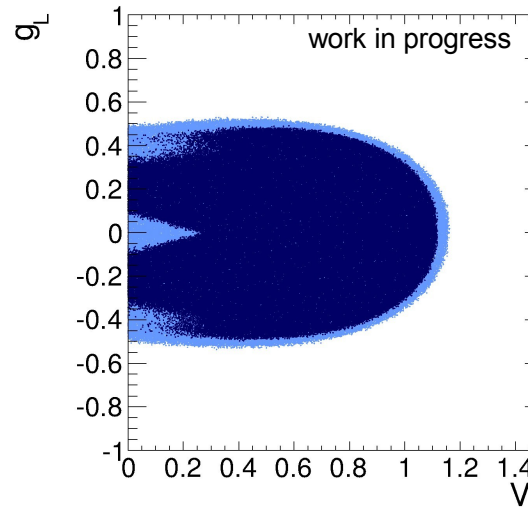
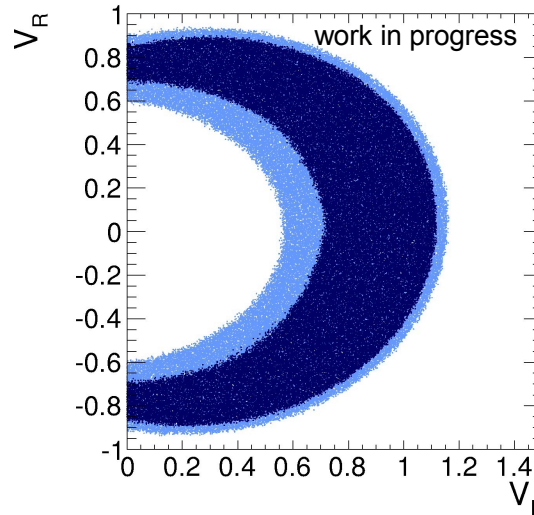
|       | spin analyzer          |                         |                        |
|-------|------------------------|-------------------------|------------------------|
|       | muon                   | bottom quark            | neutrino               |
| theo. | 0.49                   | -0.19                   | -0.17                  |
| exp.  | $0.51^{+0.20}_{-0.44}$ | $-0.13^{+0.44}_{-0.23}$ | $0.11^{+0.55}_{-0.55}$ |

# limits

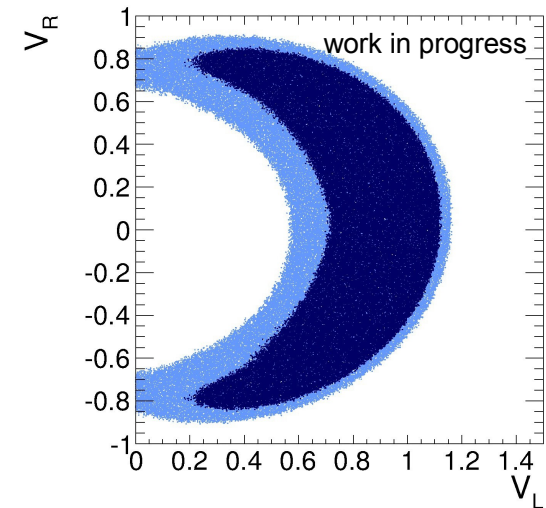
## ➤ TopFit

- simultaneous fit to anomalous couplings
- input: asymmetries, single top cross sections, W boson helicity fractions

without expected top quark spin asymmetries

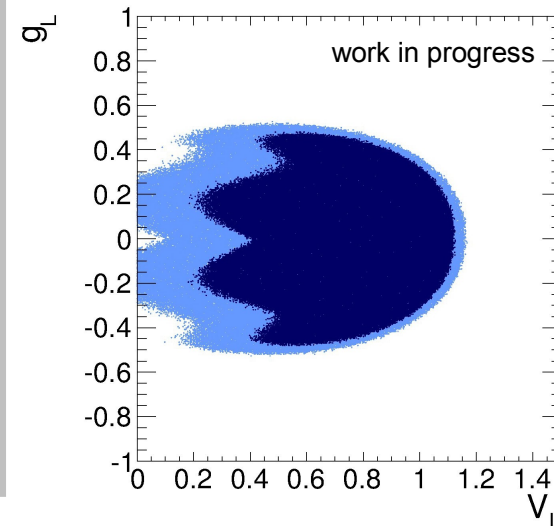


with expected top quark spin asymmetries



■ CL 68%

■ CL 95%



► already sensitive to  $V_L$ ,  $V_R$ ,  $g_L$  with  $1.17 \text{ fb}^{-1}$  from 2011

# conclusion

## ➤ resonance search

- stringent limits on benchmark models ( $Z'$ , KK gluon)
- arXiv: 1209.4397

## ➤ single top quark t-channel cross section

- uncertainty <10%
  - tight constraint:  $0.92 < |V_{tb}| \leq 1$
- arXiv: 1209.4533

## ➤ top quark spin asymmetries

- insight into  $Wtb$ -coupling structure
- new analysis strategy & optimization
- sensitive to anom. couplings

