



# Spin correlations in top pair decays

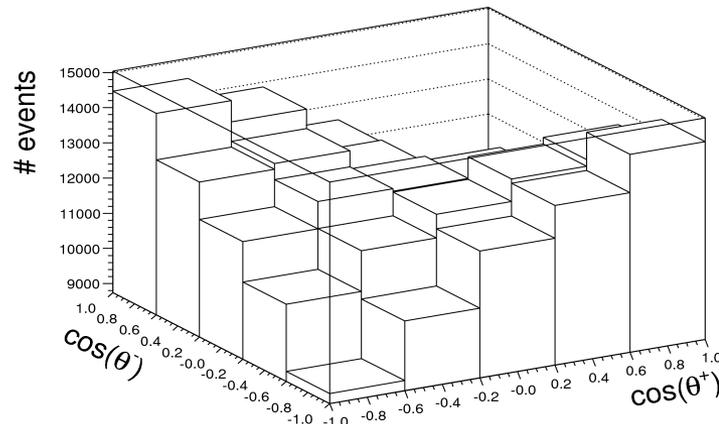
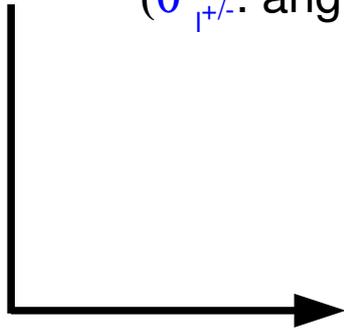
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- Spin configuration depends on production mechanism
- Top quarks decay before hadronising  $\Rightarrow$  spin information from decay products
- Best **top spin** analyser: charged lepton from W decay ( $\kappa_f = \pm 1$ )  $\Rightarrow$  dilepton channel
- Observable for **tt spin correlations**: angular distribution of charged leptons:

$$\frac{1}{N} \frac{d^2 N}{d \cos \theta_{l+}^* d \cos \theta_{l-}^*} = \frac{1}{4} (1 - \mathcal{A} \kappa_1 \kappa_2 \cos \theta_{l+}^* \cos \theta_{l-}^* + \cancel{p_+ \cos \theta_{l+}^*} + \cancel{p_- \cos \theta_{l-}^*})$$

( $\theta_{l+/-}^*$ : angle between p(l) in t rest frame and p(t) in tt pair rest frame)



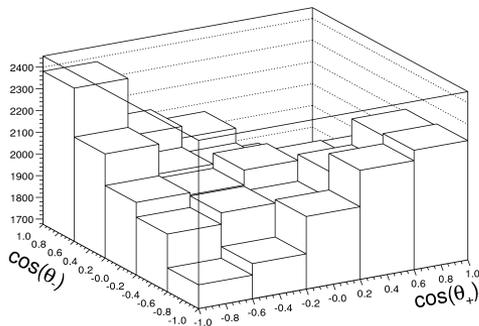
- Prediction for LHC:  $A \approx 0.326$  (14 TeV, e. g. Hep-ph/0410197, Bernreuther et al.),  
 $A \approx 0.315$  (10 TeV)

- SM can be split into basis (LL, LR, RL, RR)
- Move to physical basis ( $n$ ,  $a$ ,  $p_t$ ,  $p_{tbar}$ ) with
  - Normalization  $n$ , asymmetry  $a$ , polarizations  $p_t$ ,  $p_{tbar}$
- According to SM:  $p_t$  and  $p_{tbar}$  can be neglected  $\Rightarrow$  only 2 parameters left
- Strategy: Fit 2dim basis histograms to data  $\Rightarrow$  measure asymmetry

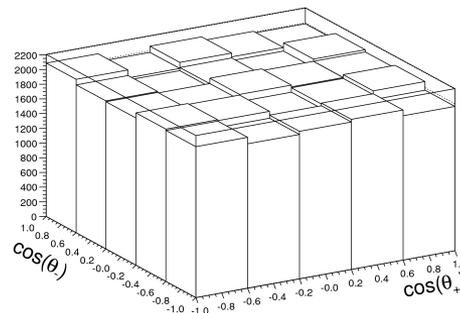
$$\text{data} = N \cdot n + A \cdot a + B \cdot b_g$$

Normalization  $n$

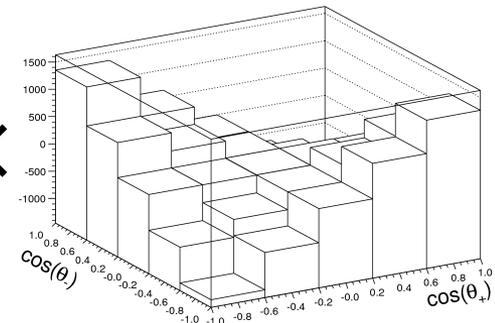
Asymmetry  $a$



**= N x**



**+ A x**





# Dilepton channel selection

## Used datasets (# events):

/TTJets-madgraph/Fall08\_IDEAL\_V9\_v2/GEN-SIM-RECO (1M)

/Wjets-madgraph/Fall08\_IDEAL\_V9\_v1/GEN-SIM-RECO (10M)

/ZJets-madgraph/Fall08\_IDEAL\_V9\_reco-v2/GEN-SIM-RECO (1M)

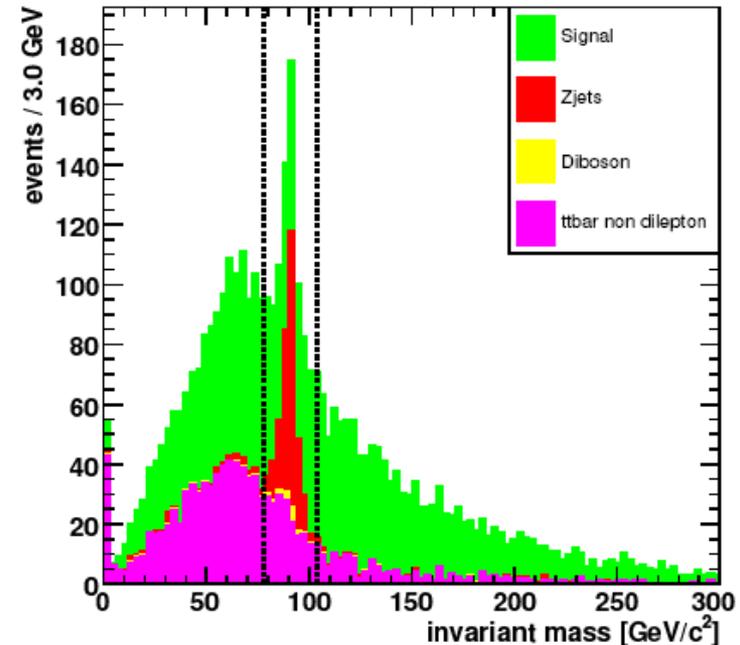
/SingleTop\_tChannel/Summer08\_IDEAL\_V9\_v1/GEN-SIM-RECO (280k)

/SingleTop\_tWChannel/Summer08\_IDEAL\_V9\_v1/GEN-SIM-RECO (170k)

/SingleTop\_sChannel/Summer08\_IDEAL\_V9\_v1/GEN-SIM-RECO (280k)

## Selection:

- 2 isolated leptons with
  - $p_T > 20$  GeV,
  - opposite charge,
  - $M_{inv}(l^+l^-) \neq 90 \pm 10$  GeV
- $\geq 2$  jets with
  - $E_T > 30$  GeV,
  - $|\eta| < 2.4$ ,
  - Btag  $> 1.0$  (TrackCountingHighEff)





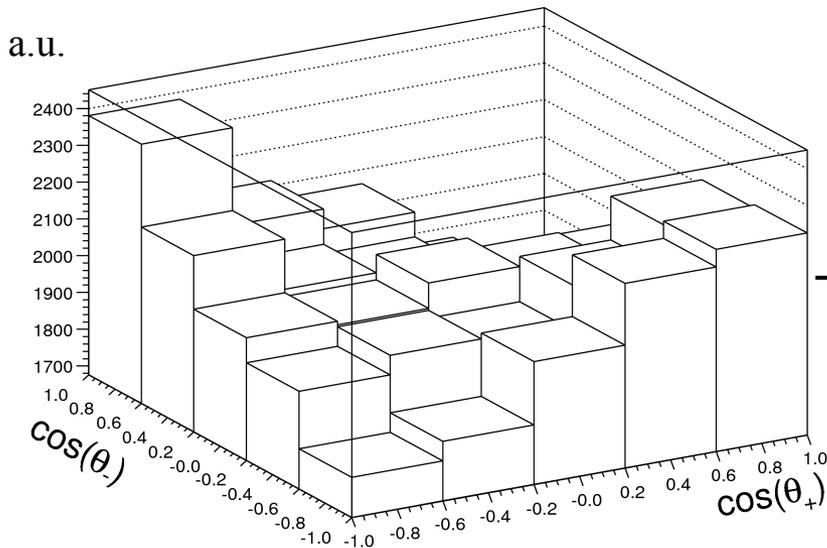
# Kinematic reconstruction

- Use **leptons** with highest  $p_T$  sum:
  - both leptons correct with  $\Delta R < 0.2$  in **95%**
- Use **jets** highest product of Btag (TrackCounting) and  $E_T$ 
  - Both jets matched within  $\Delta R < 0.5$  in **60%**
- Neutrino reconstruction from **kinematic assumptions**:
  - Massless neutrinos, top pair balanced in  $p_T$ , W mass constraint
  - Result: one **equation** in  $p_x$  of antineutrino, up to 4 solutions:

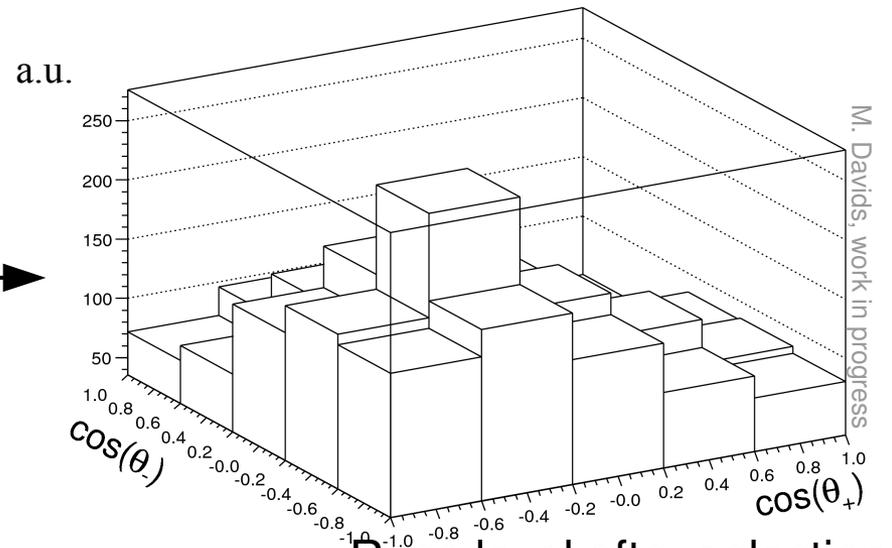
$$0 = \sum_{i=1}^4 c_i(m_t, p_{l\pm}, p_b, p_{\bar{b}}) p_x^{\bar{\nu}^i}$$

- **Weight** solutions with SM neutrino energy spectrum ( $\bar{\nu}$  and  $\nu$ )

- First estimate for signal events:
  - After selection investigate dilepton events without  $\tau$
  - $\nu$  reconstruction reduces number of events by factor of 2
  - Good reconstruction of leptons and jets in 60%
  - Shape of angular distribution changes significantly

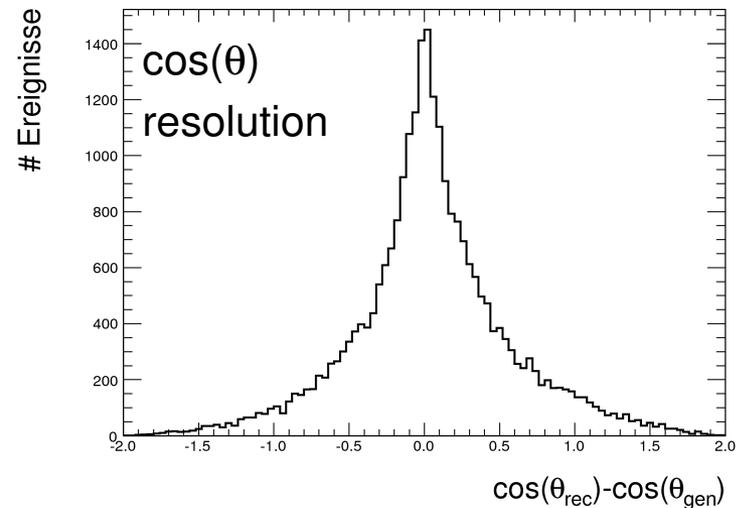


Generator level without cuts

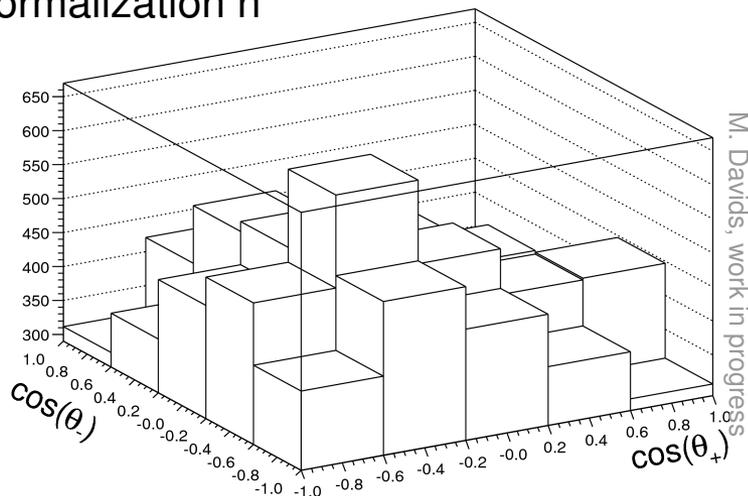


Reco level after selection and kin. reconstruction

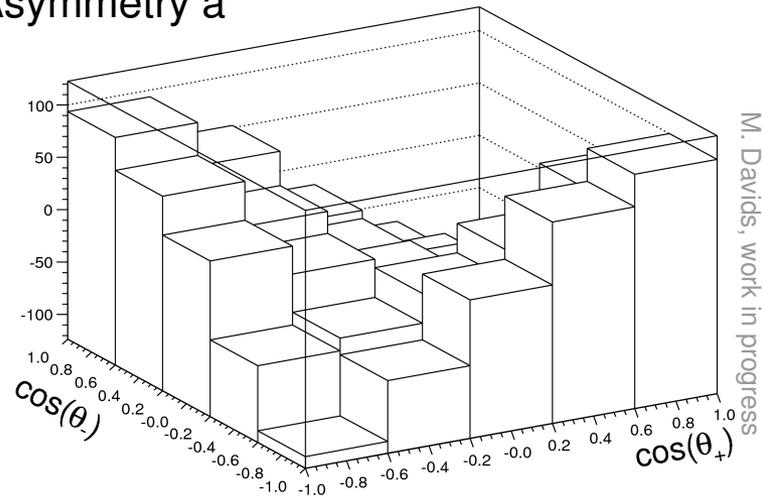
- **Resolution:**  $\text{RMS}(\Delta\cos(\theta)) \approx 0.51$   
(matched events: 0.37)
- Shape of **basis histogram** “n” changes significantly, “a” quite stable



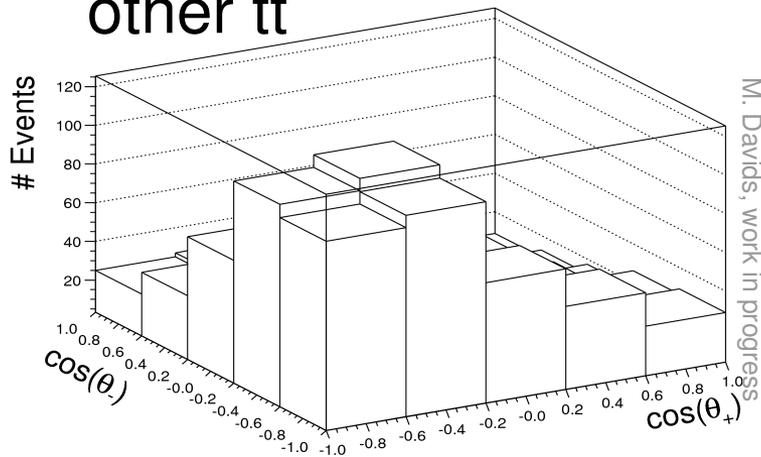
Normalization n



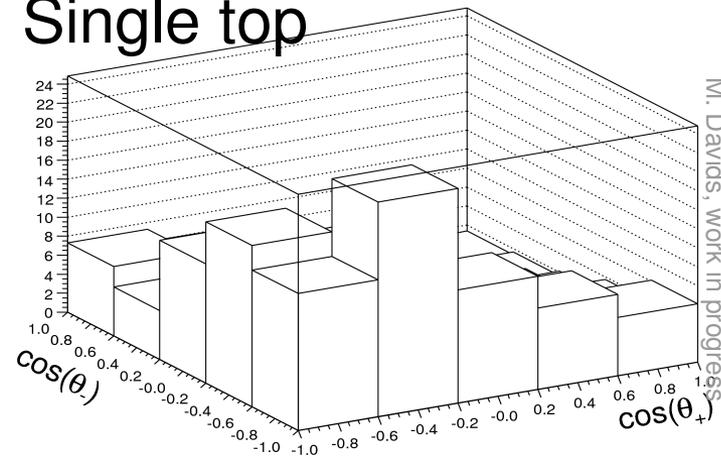
Asymmetry a



## other tt

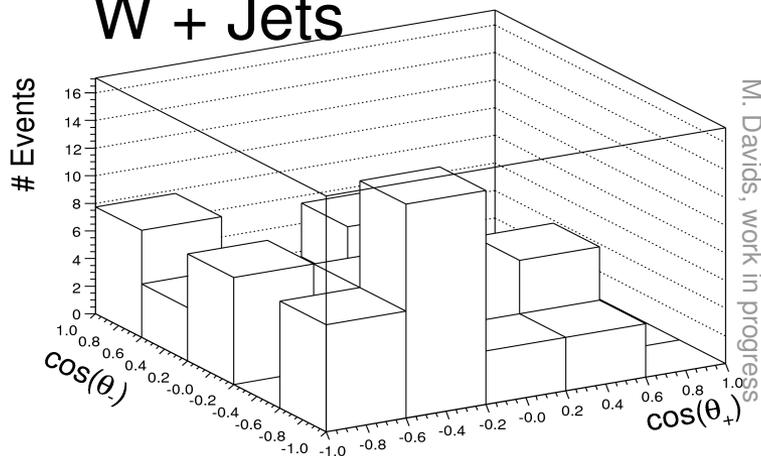


## Single top

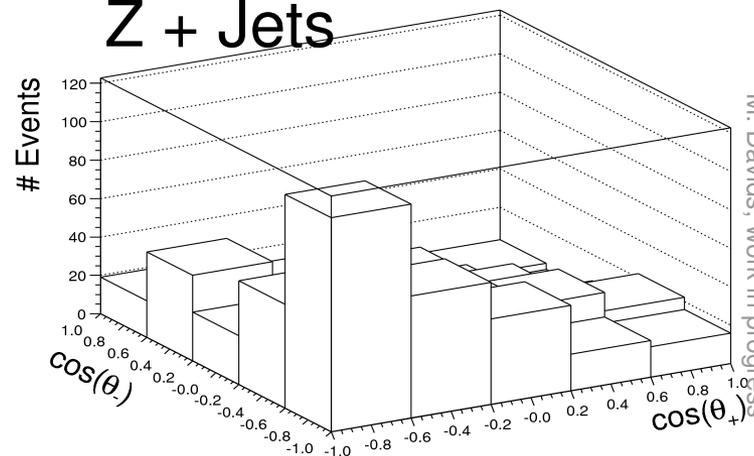


scaled to  $1\text{fb}^{-1}$

## W + Jets

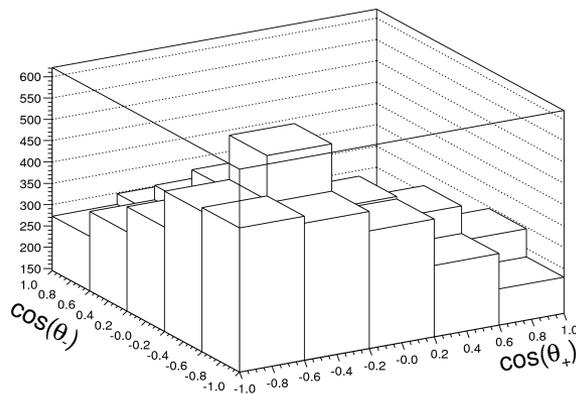


## Z + Jets

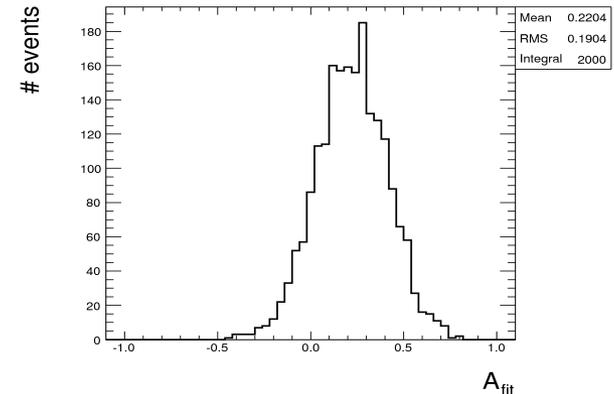


- Dice entries of each bin (poisson distributed) around bin content of reconstructed signal+background
- Perform fit:  

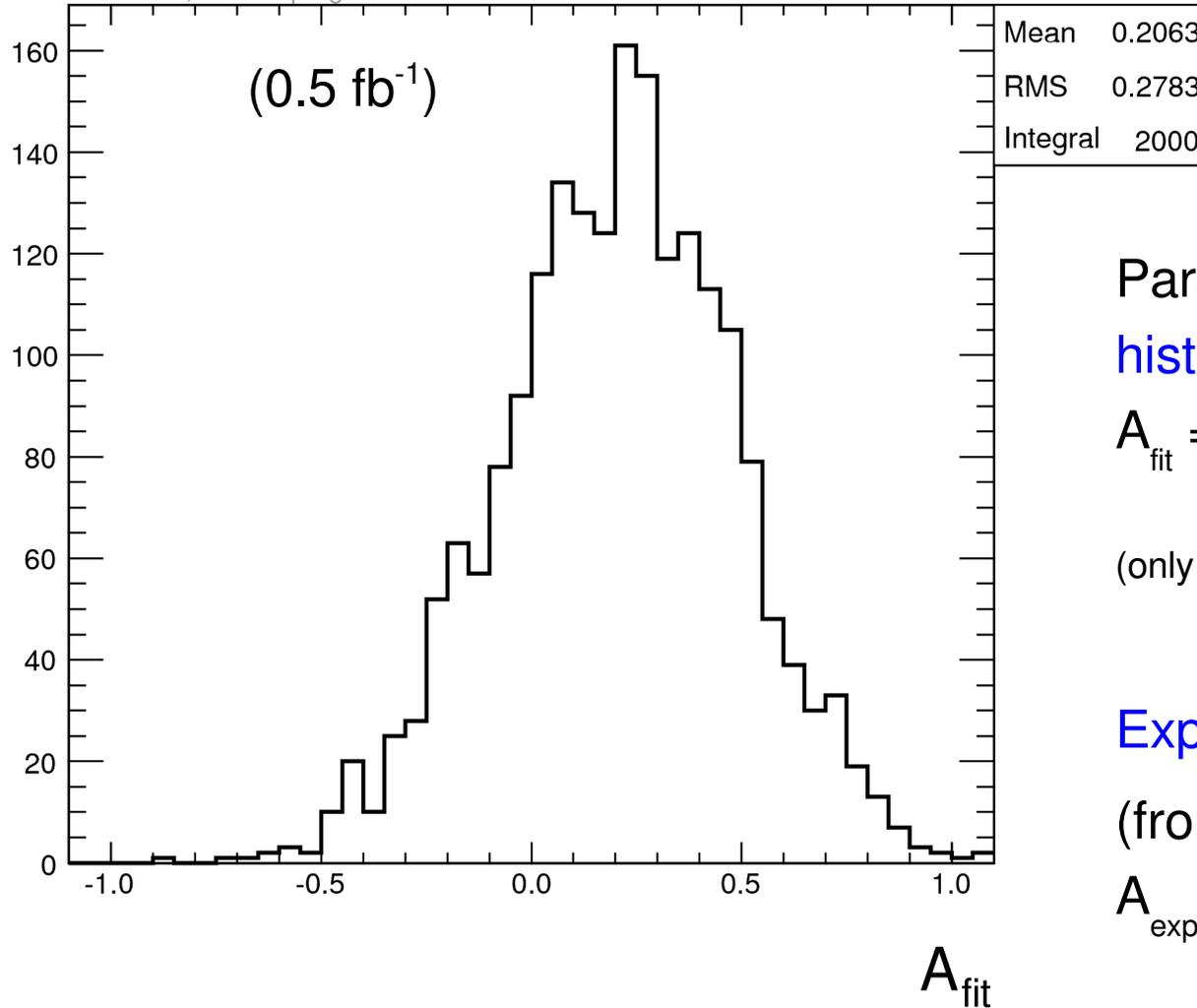
$$\text{histo}(\text{pseudodata}) = N \cdot \text{histo}(n) + A \cdot \text{histo}(a) + B \cdot \text{histo}(bg)$$
- Repeat 2000 times
- Determine distribution of fitted parameter A



2000 fits →



M. Davids, work in progress



Parameters from  
 histogram fit (1 fb<sup>-1</sup>):

$$A_{\text{fit}} = 0.21 \pm 0.28$$

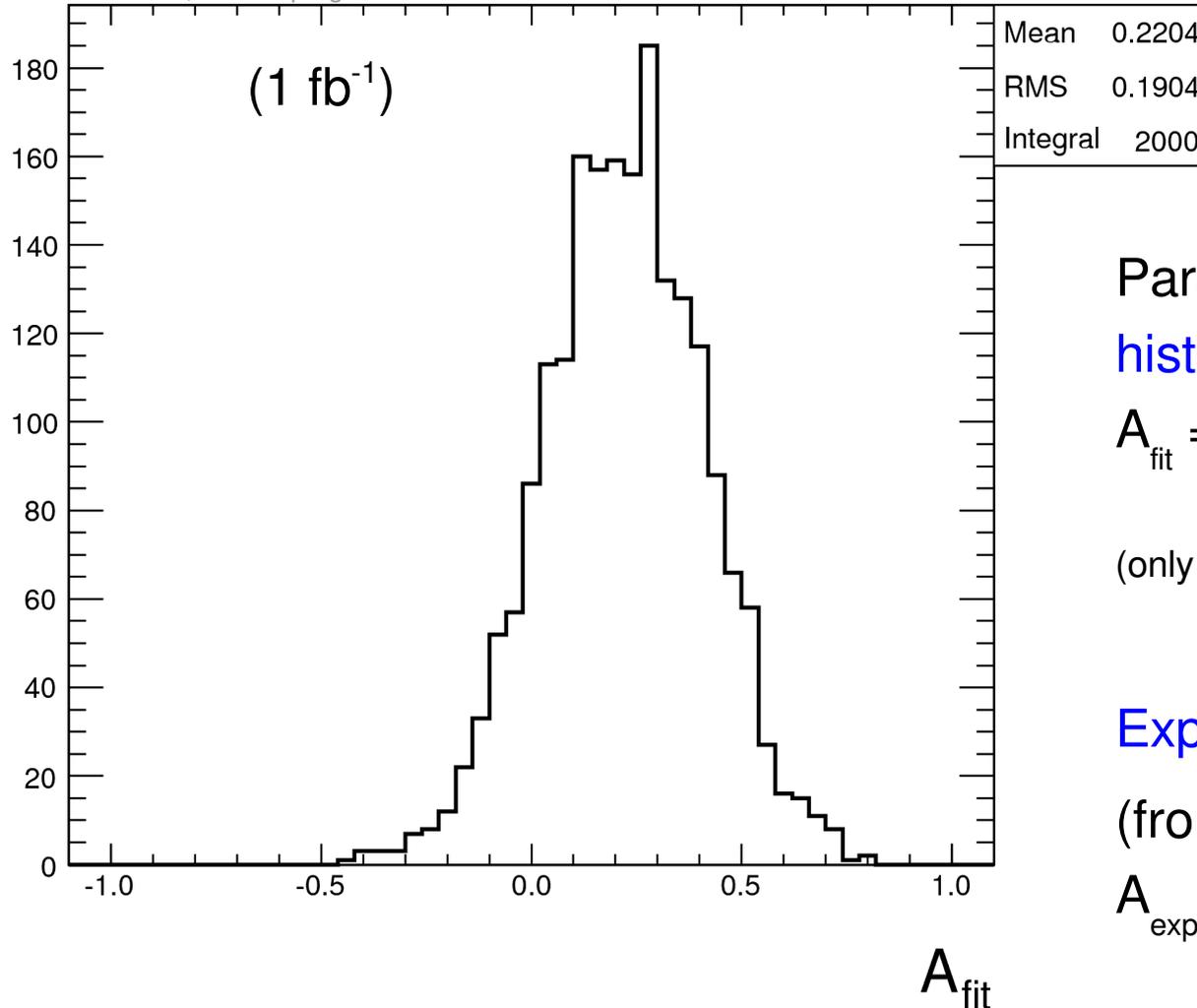
(only statistical errors)

Expectation

(from generator fit)

$$A_{\text{exp}} = 0.21$$

M. Davids, work in progress



Parameters from  
 histogram fit (1 fb<sup>-1</sup>):

$$A_{\text{fit}} = 0.22 \pm 0.19$$

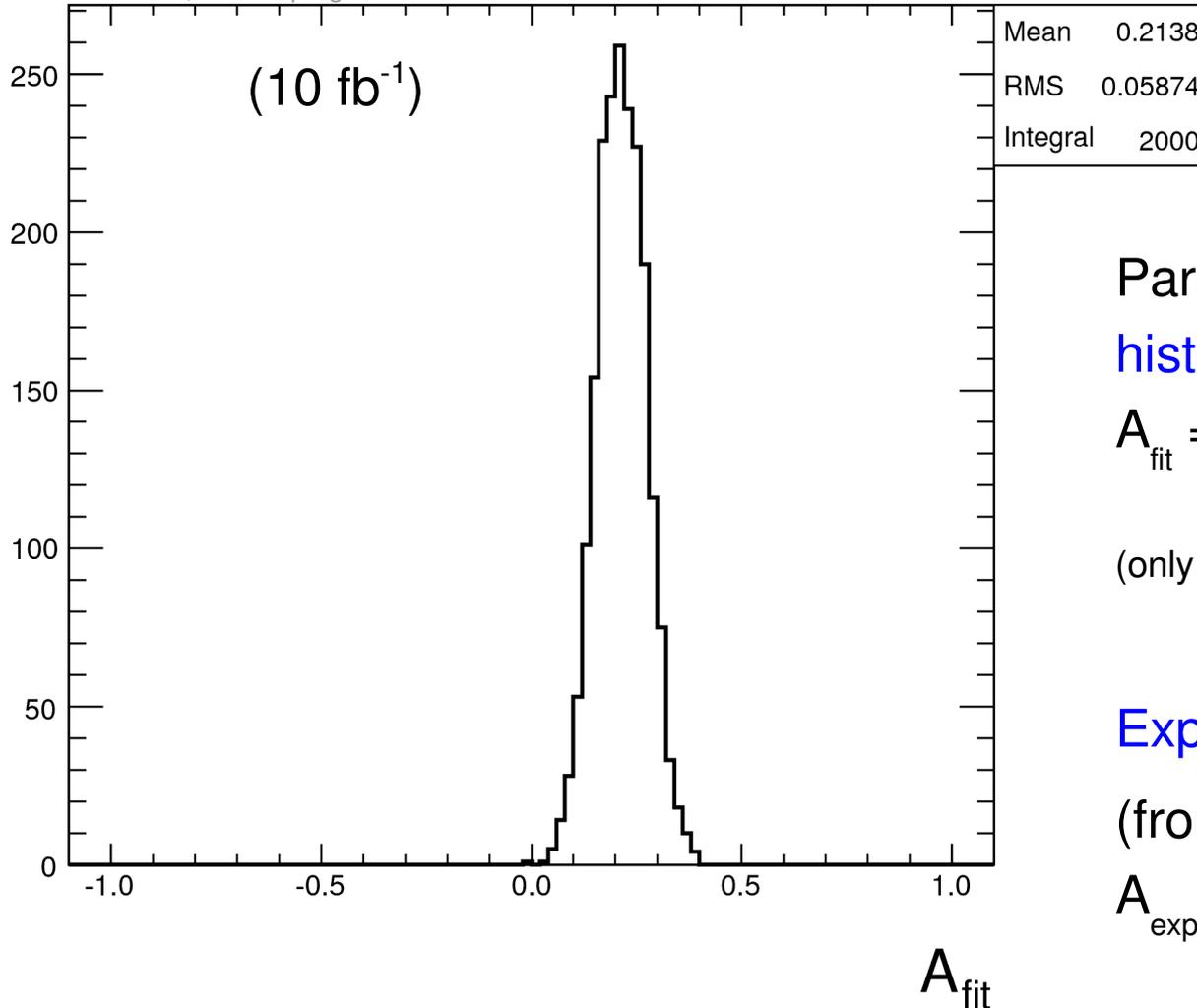
(only statistical errors)

Expectation

(from generator fit)

$$A_{\text{exp}} = 0.21$$

M. Davids, work in progress



Parameters from  
 histogram fit ( $1 \text{ fb}^{-1}$ ):

$$A_{\text{fit}} = 0.21 \pm 0.06$$

(only statistical errors)

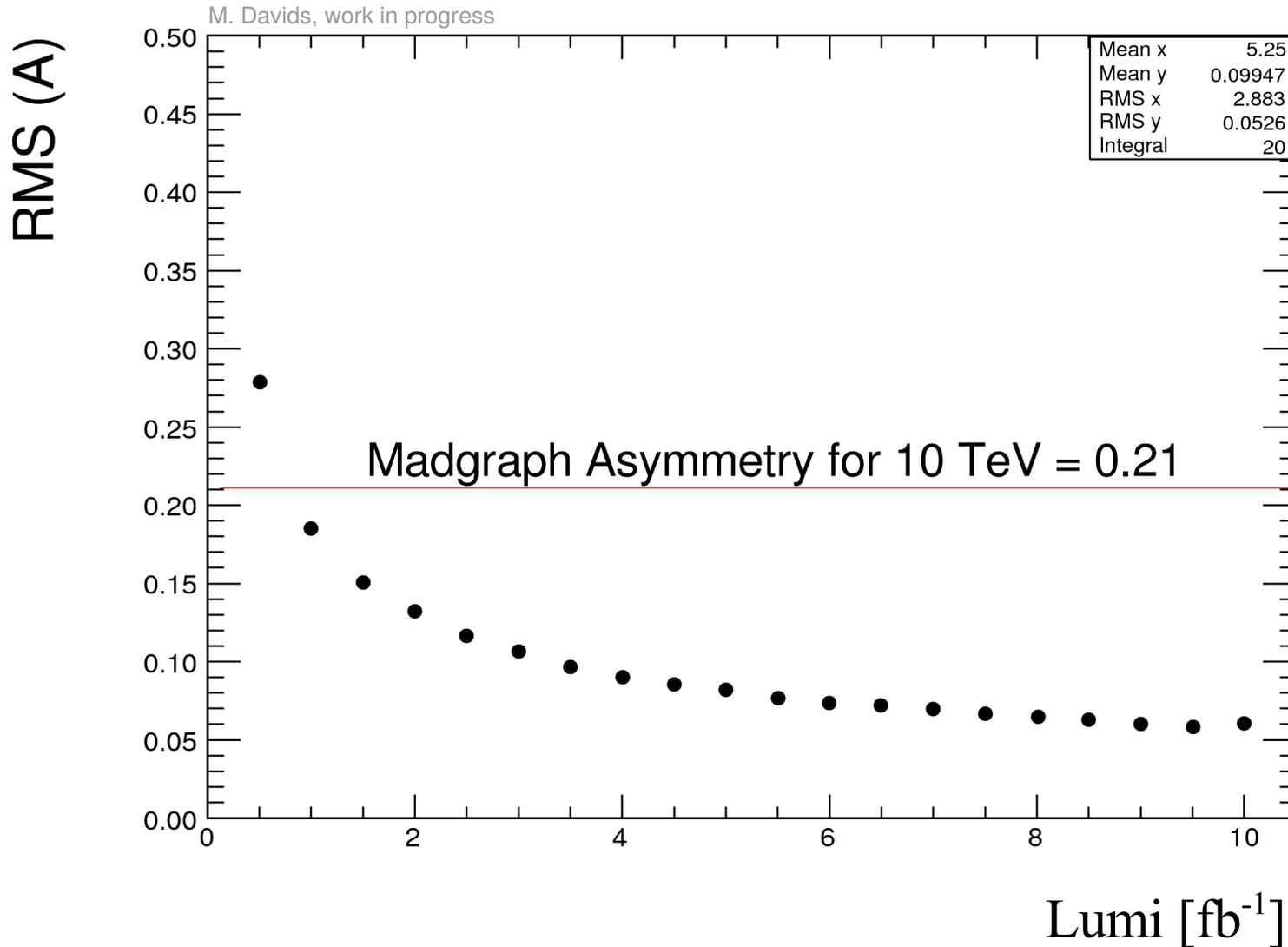
Expectation

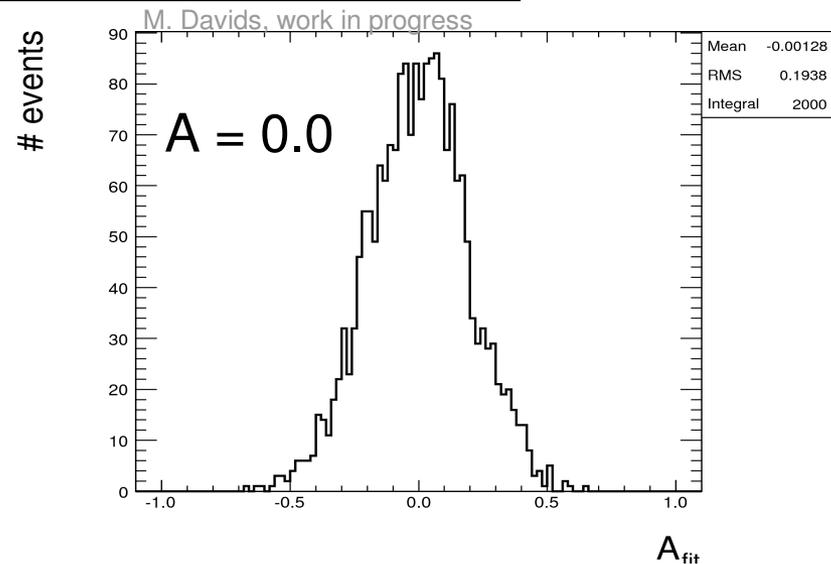
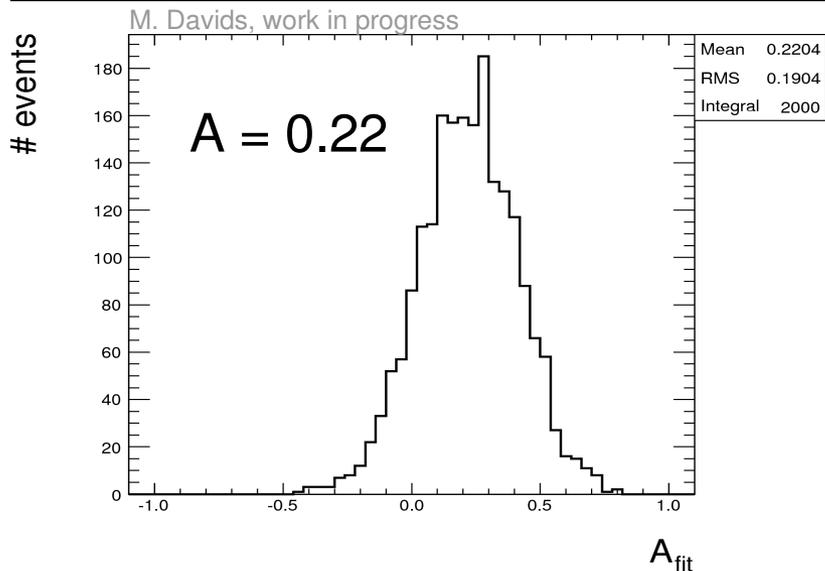
(from generator fit)

$$A_{\text{exp}} = 0.21$$



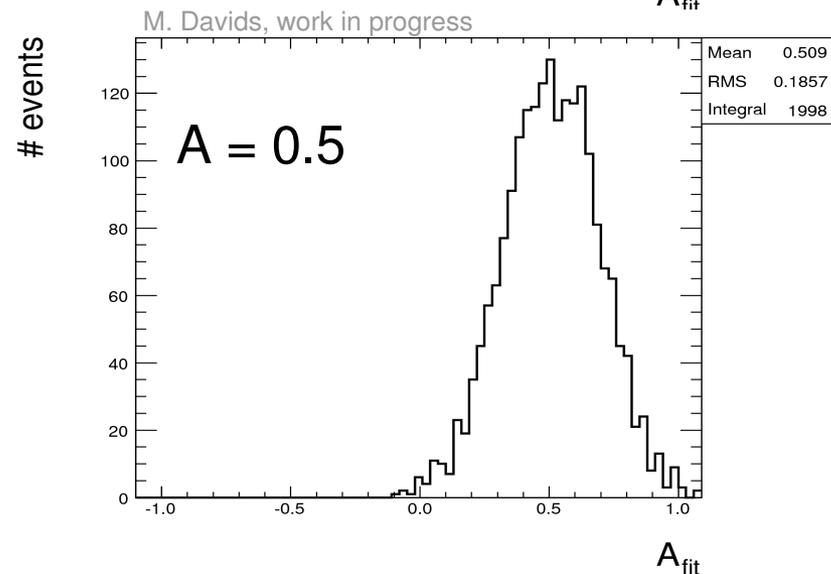
# RMS vs. Lumi





Cross check (shown for  $1 \text{ fb}^{-1}$ ):  
add and fit different values  
of asymmetry

→ results can be distinguished





# Summary

- Spin correlations in top pairs depend on **production mechanism**:
  - At the LHC:  $A \approx 0.315$  (10 TeV),  $A \approx 0.326$  (14 TeV)
- Advantage of a **histogram fit at reco level**: Effects of limited acceptance and resolution are already included
- Status:
  - Set up **selection and reconstruction** of top pairs in dilepton channel
  - **Histogram fit** implemented, **ensemble study** performed with background
  - Preliminary result:
    - **Sensitivity** of asymmetry:  $\Delta a(1\text{fb}^{-1}) = \pm 0.19$  (0.06 at  $10\text{fb}^{-1}$ )
    - **Cross check** with non-SM asymmetries allows for SM-exclusion
- Outlook:
  - Investigate missing backgrounds (QCD, diboson...)
  - Estimate most relevant systematic uncertainties
  - Migration to more recent CMSSW version
    - Use new datasets (e.g. Summer09 at 10 TeV)
    - Compare different generators (with  $\leftrightarrow$  without spin correlations)

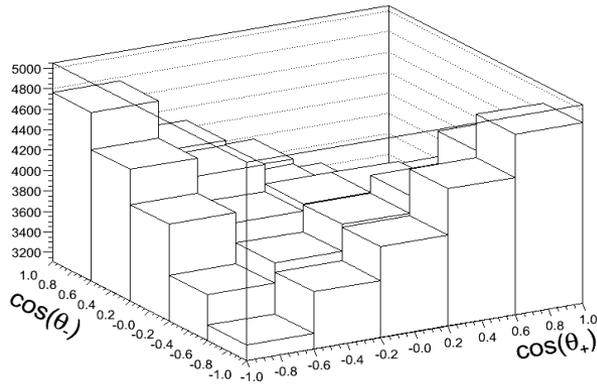


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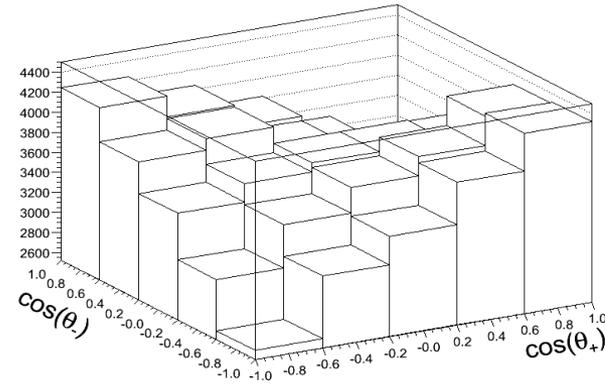
# BACKUP

Effect of a cut on  $p_T$  of the leptons for different values (on SM distribution):

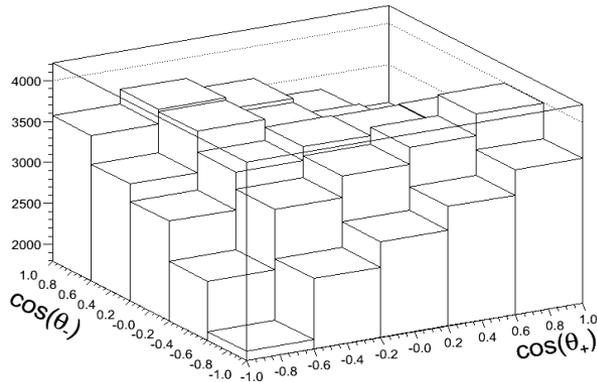
$p_T > 0$  GeV



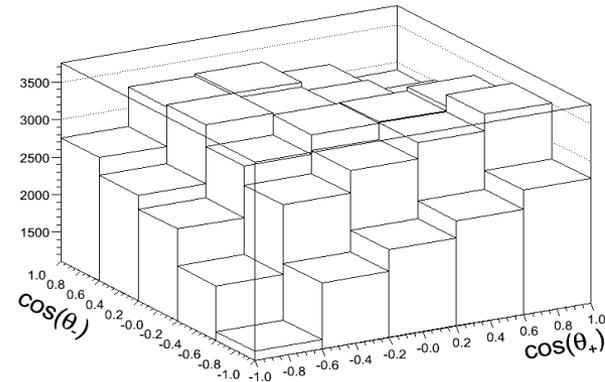
$p_T > 10$  GeV



$p_T > 15$  GeV



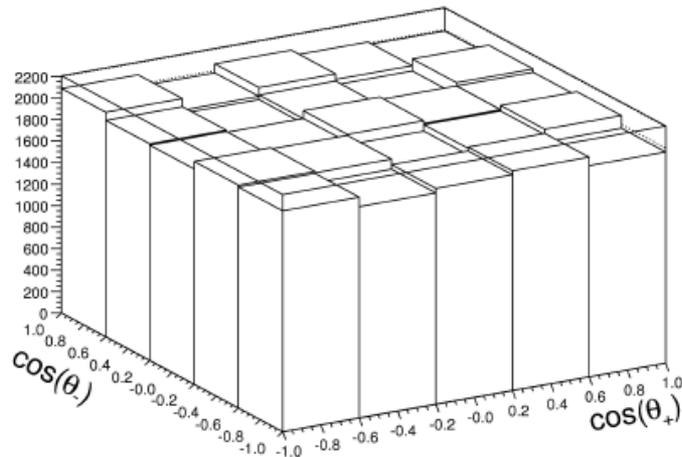
$p_T > 20$  GeV



When filling histograms multiply each event of the SM sample with the weighting factors  $w_A$  and  $w_N$  given below:

The denominator converts the SM distribution into a flat one. This is only necessary if using a generator (configuration) that takes spin correlations into account.

$$w_N = \frac{1}{1 - A_{SM} * \cos(\theta_1) * \cos(\theta_2)}$$



$$w_A = - \frac{\cos(\theta_1) * \cos(\theta_2)}{1 - A_{SM} * \cos(\theta_1) * \cos(\theta_2)}$$

