CP VIOLATION IN B MESON DECAYS USING l+JETS $t\bar{t}$ IN 8 TEV ATLAS DATA

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Motivation

CPV expected in b-quark decays in $t\bar{t}$ final states:

Mixing :: $P(b \to \bar{b} \to l^+X)$ vs $P(\bar{b} \to b \to l^-X)$

Direct :: $P(b \to l^+X)$ vs $P(\bar{b} \to l^-X)$

LHC provides $B^0_{d,s}$ decays from $t\bar{t}$: Alternative source, kinematics and energy regime to b-factories

Very clean technique for measuring CPV in $B^0_{d,s}$ decays

Top provides b-charge at production
Sensitivity to A^{bl}_{dir}, A^{cl}_{dir}, A^{bc}_{dir}

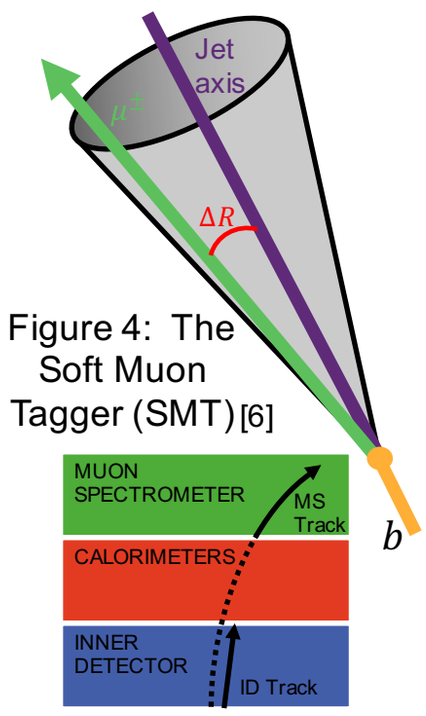


Figure 4: The Soft Muon Tagger (SMT) [6]

W-lepton provides b-quark charge at production, but must know which top decay leads to the SMT jet

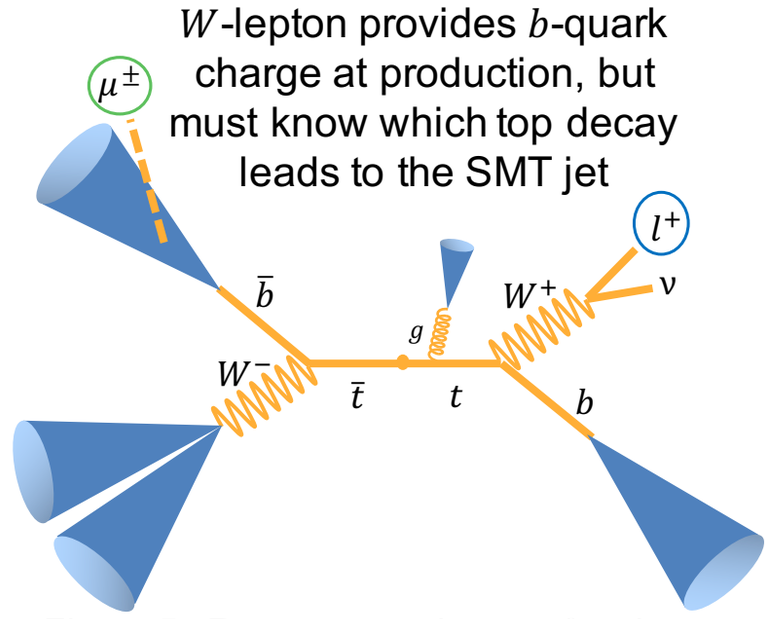


Figure 5: Reconstructed event, four jets, a lepton and missing energy (ν)

DØ Interperetation as Mixing CPV

$A^b_{\rm sl} > 3\sigma$ with SM

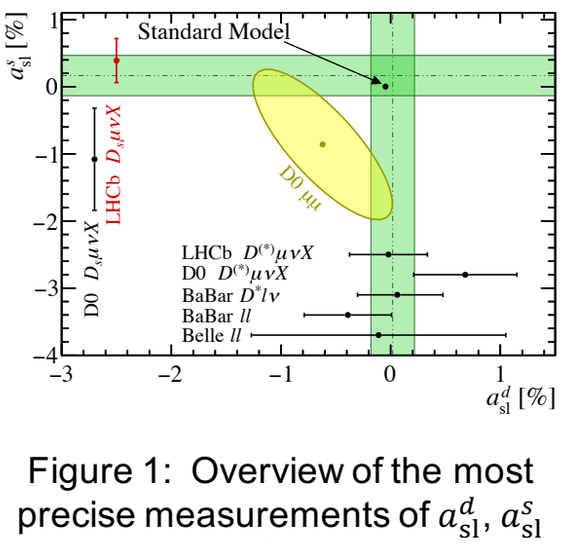


Figure 1: Overview of the most precise measurements of $a^d_{\rm sl}$, $a^s_{\rm sl}$ (related to $A^b_{\rm sl}$), with DØ for comparison [1]

DØ Interperetation as Direct CPV

$A^{bl}_{\rm dir} \sim 0.3\%$, $A^{cl}_{\rm dir} \sim 1.0\%$

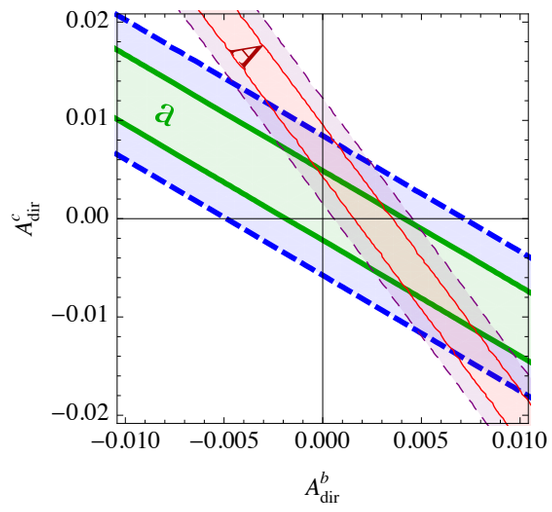


Figure 2: Required values of $A^{bl}_{\rm dir}$, $A^{cl}_{\rm dir}$ to satisfy the DØ measurement assuming SM $A^b_{\rm sl}$ [2]

Kinematic Fitting using a likelihood approach [7]

SameTop (ST) or DifferentTop (DT)? Purity ~80% [7]

- KLFitter permutes reconstructed jets between four possible positions in l+jets decay
  - W-boson light jets and b-jets
- Transfer functions account for measurement resolutions
- Breit-Wigner functions provide constraints
  - $BW(m_{l\nu}|M_W)$, $BW(m_{l\nu j}|M_t)$
- Uses B-Tagging information in jet assignment
- 16 fitted object kinematics used to minimise likelihood for each jet permutation
  - Energy of four quarks and lepton
  - Missing energy assigned to a neutrino
  - Angular properties of four quarks

Same Sign (SS)

$t \to l^+\nu\,(b \to \bar{b}) \to l^+l^+X$

$t \to l^+\nu\,(b \to c) \to l^+l^+X$

$t \to l^+\nu\,(b \to \bar{b} \to c\bar{c}) \to l^+l^+X$

Opposite Sign (OS)

$t \to l^+\nu\, b \to l^+l^-X$

$t \to l^+\nu\,(b \to \bar{b} \to \bar{c}) \to l^+l^-X$

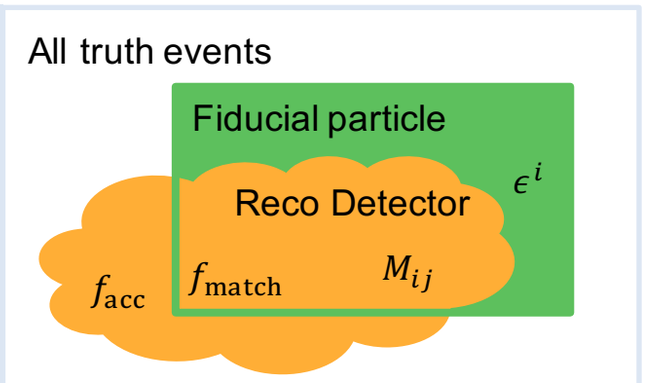
$t \to l^+\nu\,(b \to c\bar{c}) \to l^+l^-X$

$$A^{ss(os)}(A_{\rm mix}, A_{\rm dir}) = \frac{P(b \to l^{+(-)}) - P(\bar{b} \to l^{-(+)})}{P(b \to l^{+(-)}) + P(\bar{b} \to l^{-(+)})}$$

$$A^{ss(os)} = \frac{\frac{N^{++(-)}}{N^+} - \frac{N^{--(+)}}{N^-}}{\frac{N^{++(-)}}{N^+} + \frac{N^{--(+)}}{N^-}}$$

Unfolding

1. Count events (N^{++}, N^{--}, N^{-+}, N^{+-})
2. Remove backgrounds, mistags
3. Correct for ST/DT mis-ID
4. Unfold to particle-level fiducial volume



$$N^i_{\rm fid} = \frac{1}{\epsilon^i} \cdot \sum_j M^{-1}_{ij} \cdot f^j_{\rm match} \cdot f^j_{\rm acc}\left(N^j_{\rm reco} - N^j_{\rm bkg}\right)$$

i=Truth-bins
j=Reco-bins

$$A^{ss(os)} = \sum_i r_i A^q_{\rm mix,dir}$$

$A^{ss(os)}$ are simple functions of the direct and mixing CPV parameters

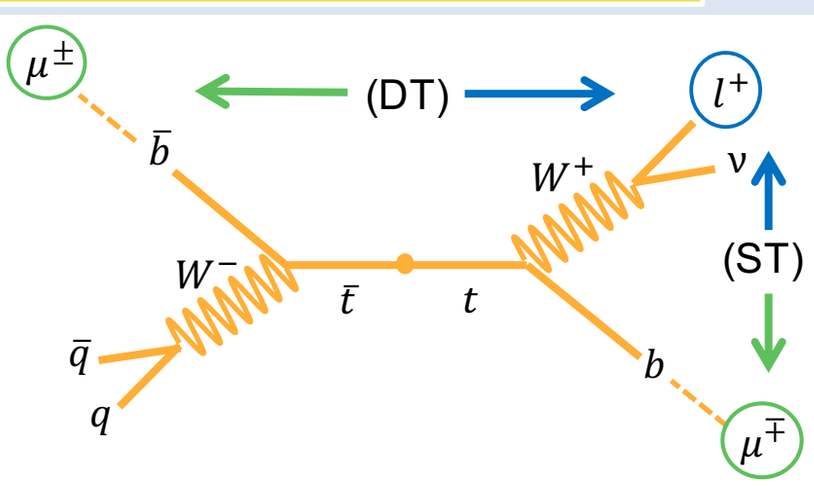


Figure 3: Decay topology with SMT muons, showing 'SameTop' (ST) and 'DifferentTop' (DT) event types

Predicted Sensitivity at 8 TeV (Statistical) [3]

$A^q_{\rm mix} < 10^{-2}$ [3]

$A^{cl}_{\rm dir} < 1.0\times10^{-2}$ [3]

$A^{bl}_{\rm dir} < 1.0\times10^{-2}$ [3]

$A^{bc}_{\rm dir} \to 1.0\times10^{-2}$ [3]

Existing limits	$A^q_{\rm mix}$	$A^q_{\rm dir}$
Standard model predicts: $A^{ss}, A^{os} < 10^{-4}$ [3]	$< 10^{-4}$ [4]	$< 10^{-7}$ [3]
Current limits (indirect): $A^{ss}, A^{os} < 10^{-3}$ [3]	$< 10^{-3}$ [5]	$A^{bl}_{\rm dir} < 1.2\times10^{-2}$ [2] $A^{cl}_{\rm dir} < 6.0\times10^{-2}$ [2] $A^{bc}_{\rm dir} \to$ None [3]

LHC $t\bar{t}$ data provides a clean source of b-quarks with unambiguous production charge for CP violation studies.
Possible to measure CP violation asymmetries
Sensitivity to direct CP violation parameters

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[1] LHCb-PAPER-2016-013 [2] PRD 87, 074036 (2015) [3] PRL 110, 232002 (2013) [4] arXiv:1511.09466v1 [5] arXiv:1412.7515v1 (HFAG) [6] JINST 11 P04008 (2016) [7] NIMA 748 (2014)

ATLAS EXPERIMENT