The potential of the ttbar charge asymmetry measurement at an FLC with $\sqrt{s}$ = 500 GeV – 3 TeV

or

Challenges and opportunities of boosted top quarks at lepton colliders

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Charge asymmetry in the LEP era...

Precision measurements of electroweak observables: a sensitive probe for BSM physics

Forward-backward asymmetry of leptons/quarks at LEP/SLD

Polarized asymmetries (extraction of A-parameters)

Z-pole summary table from PDG 2011

(for a complete table follow this link, see also A. Schael et al., hep-ex/0509008)

Quantity	Value	SM	Pull Dev.
A LOT of measurements with rather too good agreement with the SM prediction			
$A_{FB}^{(0,e)}$	0.0145 ± 0.0025	0.01633 ± 0.00021	-0.7, -0.7
$A_{FB}^{(0,\mu)}$	0.0169 ± 0.0013		0.4, 0.6
$A_{FB}^{(0,\tau)}$	0.0188 ± 0.0017		1.5, 1.6
$A_{FB}^{(0,s)}$	0.0976 ± 0.0114	0.1035 ± 0.0007	-0.6, -0.4
$A_{FB}^{(0,c)}$	0.0707 ± 0.0035	0.0739 ± 0.0005	-0.9, 0.8
$A_{FB}^{(0,b)}$	0.0992 ± 0.0016	0.1034 ± 0.0007	**-2.7, -2.3**

Shown to be sensitive to certain warped ED setups

Example: Djouadi, Moreau, Richard, Nucl.Phys.B773:43-64,2007, hep-ph/0610173

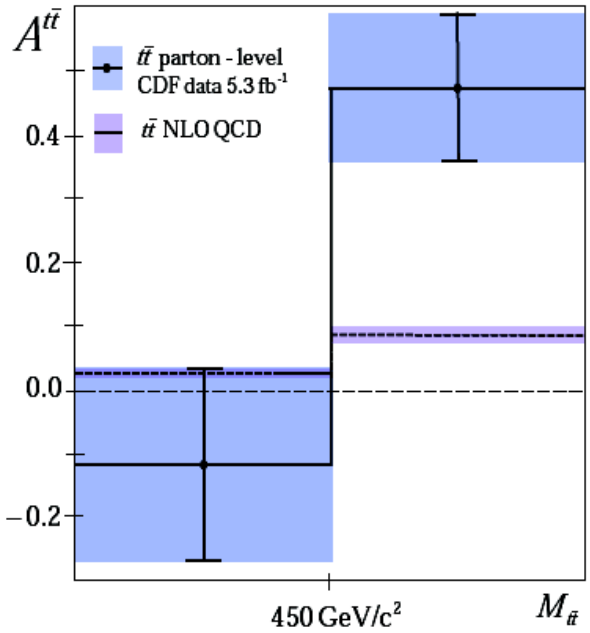
AC at hadron colliders

FB asymmetry @ Tevatron

Kuhn & Rodrigo, Phys.Rev.,vol. D59, p. 054017, 1999.

CDF, “Evidence for a Mass Dependent Forward-Backward Asymmetry in Top Quark Pair Production,” Phys.Rev., vol. D83 p. 112003, 2011.

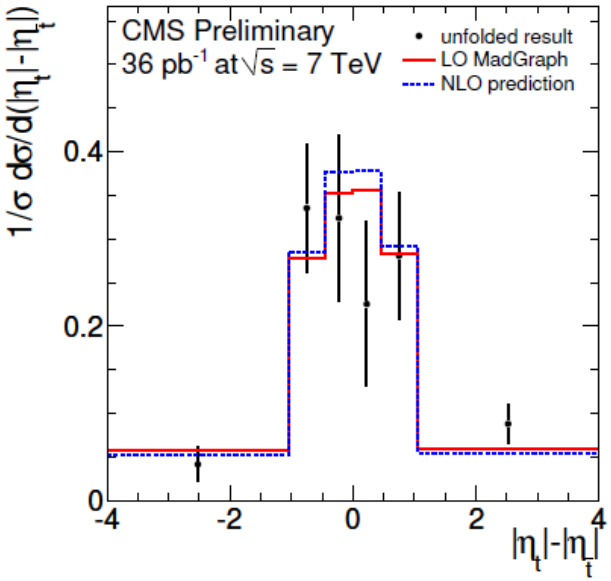
D0, “Forward-backward asymmetry in top quark-antiquark production,” Phys.Rev.,vol. D84, p. 112005, 2011



Charge asymmetry @ LHC

Aguilar-Saavedra, Perez-Victoria, JHEP,vol. 1105, p. 034, 2011.

Bai, Hewett, Kaplan, Rizzo, JHEP, vol. 1103, p. 003, 2011.



First CMS measurement (2010 data):

$A_C = 0.06 \pm 0.134\ (stat) \pm 0.026\ (syst)$

ATLAS (0.7/fb of 2011 data):

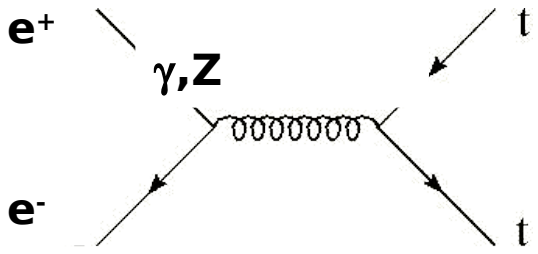
$A_C = -0.024 \pm 0.016\ (stat) \pm 0.023\ (syst)$

The whole family of models is constrained by a combinatio of ttbar resonance, same-sign top search, ttbar cross-secti... measurement and asymmetry measurements

FLC

We'll investigate the potential of an $A^{(0,t)}_{FB}$ measurement at an FLC

- Considering FLC options √s = 500 GeV, 1 TeV, 3 TeV
  complementary to LAL study presented by M. Poeschl and CLIC study by M. Battaglia et al.
- Focusing on experimental issues that affect precision measurements on ttbar final state
- Using a mixture of analytical theory prediction, MadGraph and Pythia, *later on attempt to include corrections... see Fleischer et al. hep/ph0302259, Glover et al. hep/ph04010110*
- For a start, using a simple fast simulation for the detector response
  benchmarked against ATLAS simulation, using DBD samples for ILC detectors as soon as samples are available



tt production at ILC:
s~0.6 pb
at √s = 500 GeV
~0.2 pb
at √s = 1000 GeV

120k tt events/year
Assuming L =10^{34} $cm^{-2}s$

Sensitivity to BSM physics

FLC has a sensitivity to Z' resonances with masses that are well beyond it's direct reach due to interference of γ/Z/Z'.

First attempt to quantify sensitivity: evaluate up to which mass the deviation from the Standard Model is larger than 1.5 %:

ILC500 GeV: sensitive for Z'_{SSM} mass up to ~3 TeV

Z' mass	SM	1 TeV	2 TeV	3 TeV	4 TeV	5 TeV
A_{FB}^{tt}	0.41 ± 0.01	0.289	0.382	0.397	0.401	0.407

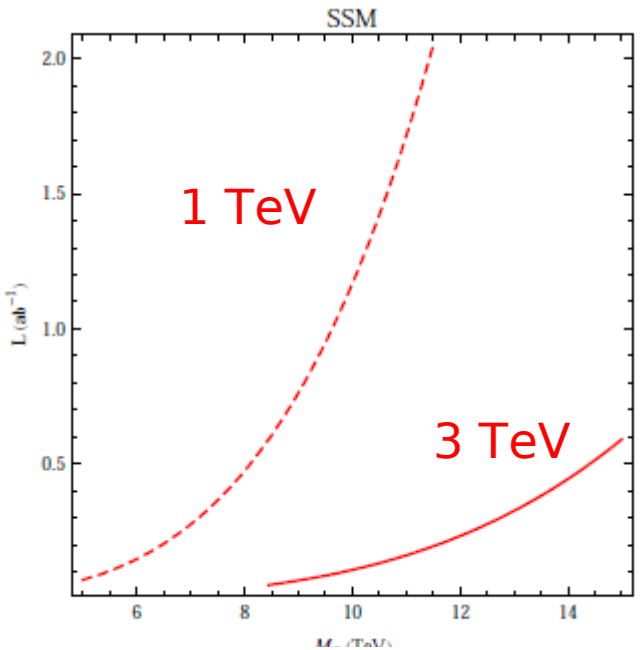
ILC1 TeV : mass reach for Z'_{SSM} O(3 TeV)

Z' mass	SM	1 TeV	2 TeV	3 TeV	4 TeV	5 TeV
A_{FB}^{tt}	0.554	0.289	0.434	0.513	0.532	0.537

Sensitivity

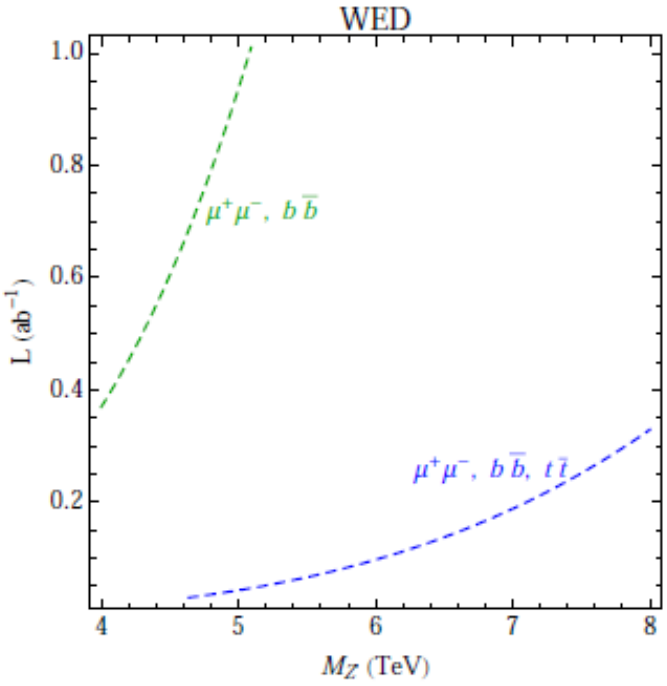
See for example:
F. Corradeschi, LCWS10
(and also arXiv:1202.0660
and M. Battaglia, LCWS11)

Same message as the previous slide:



Warped Extra Dimension (WED)
Model based on SU(2) x SU(2) x U(1) symmetry on a slice of AdS5, features a composite top quark with preferential coupling to the extra gauge bosons!

Mass reach strongly enhanced by ttbar measurement



The FB asymmetry - experimental

Simple study of sensitivity typically assumes a fixed experimental sensitivity:

- theory error assumed constant (or irrelevant)
- experimental error → constant with √s?
- statistical error → x-sec drops strongly

We'll explore whether these assumptions hold for a complex measurement like the ttbar asymmetry → provide a better-founded set of errors to evaluate the BSM potential of this measurement

Statistical error after 1 ab^{-1} (acceptance = 12 %)

@ 500 GeV ->>> $\Delta A_{FB} = 0.4$ % ($\sigma = 0.6$ pb)

@ 1 TeV ->>> $\Delta A_{FB} = 0.7$ % ($\sigma = 0.2$ pb)

@ 3 TeV ->>> $\Delta A_{FB} = 1.0$ % ($\sigma = 0.1$ pb)

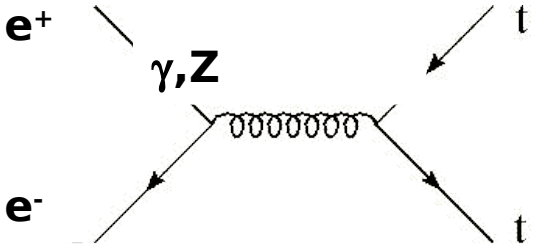
Error on A_{FB} due to a top mass error of 1.6 GeV

@ 500 GeV ->>> $\Delta A_{FB} = 0.4$ %

@ 1 TeV ->>> $\Delta A_{FB} = 0.1$ %

LHC vs ILC

ILC



tt production cross section at ILC:

~0.6 pb

At √s = 500 GeV

~0.2 pb

At √s = 1000 GeV

120k tt events/year

Assuming L =10^{34} $cm^{-2}s$

Top quark reconstruction

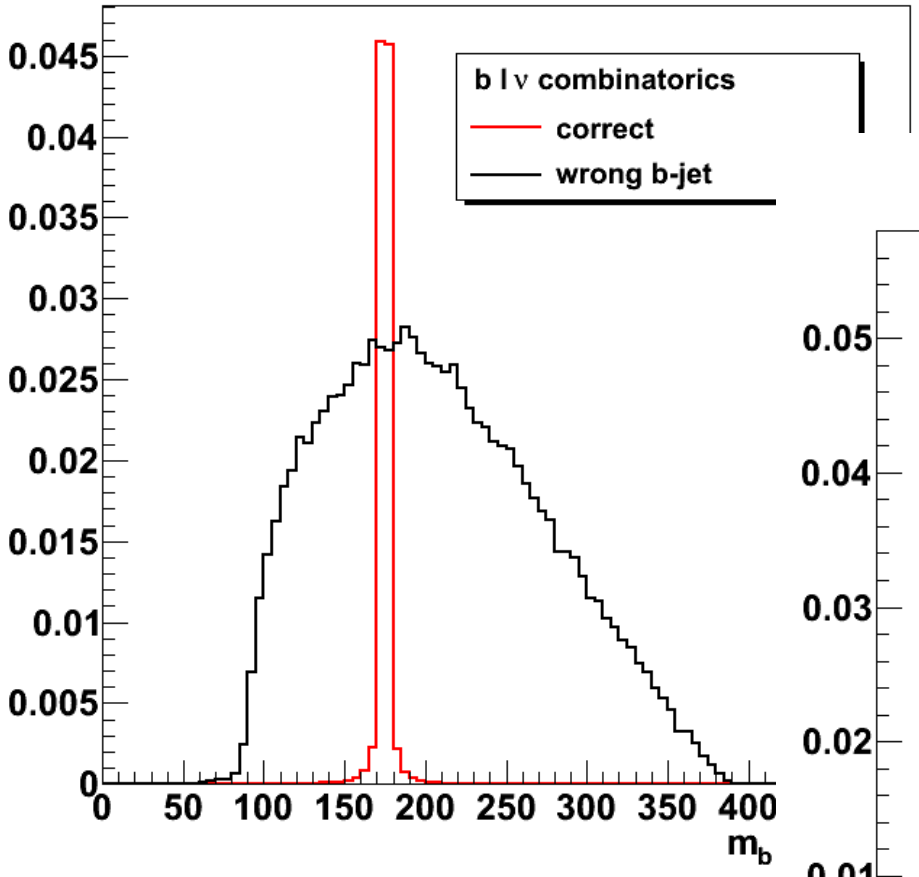
Pythia for ttbar production (ISR and $\gamma\gamma$->ttbar production discarded)

Detector response modeled using fast simulation
(to be replaced with full ILD simulation)

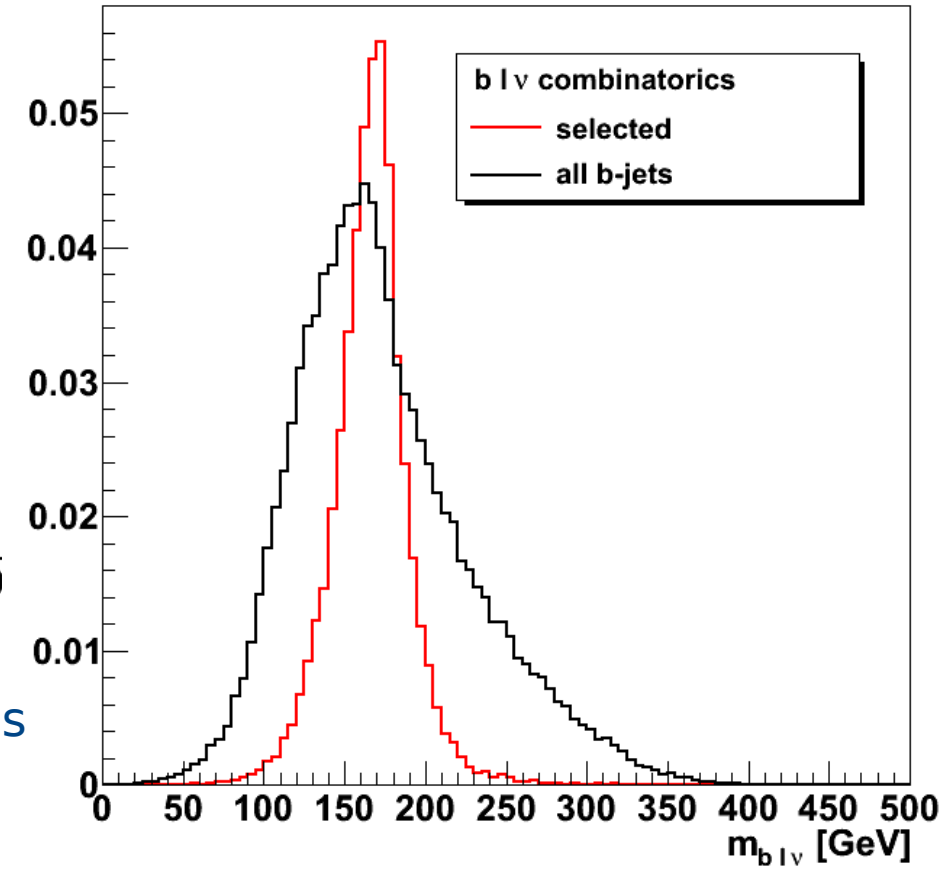
Combine lepton + neutrino + b-jet
Combine two light and one b-jet

Choose combination that gives best overall match (W-mass, leptonic top mass, hadronic top mass, b-tagging)

Reconstruct top quarks

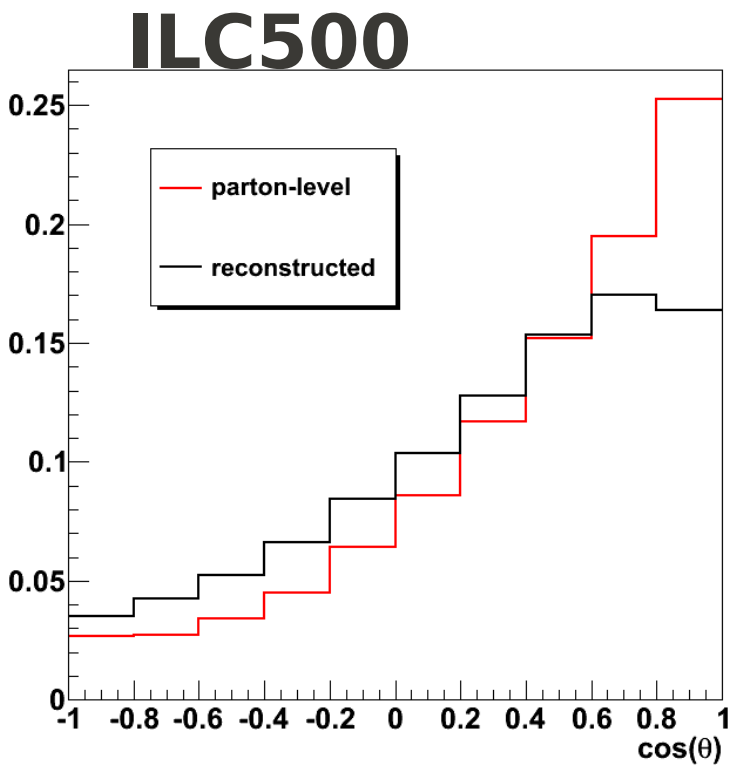


Observation: wrong combinations peak at ~ top mass



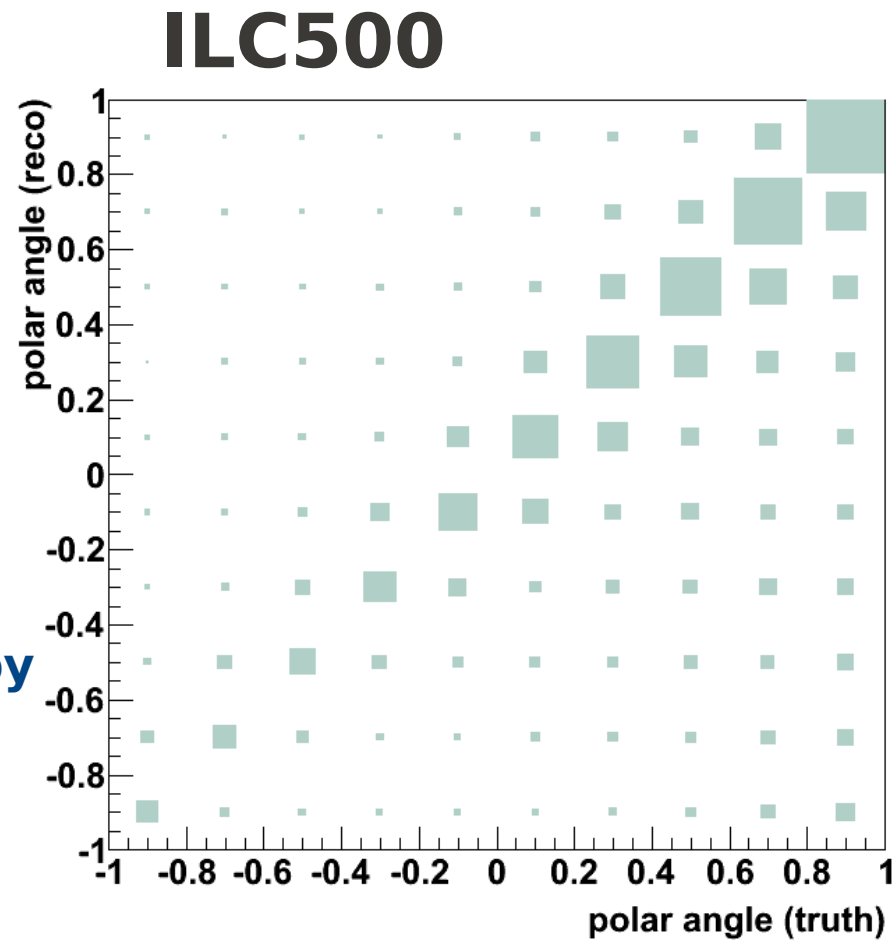
Observation: confusion depends on jet energy resolution

The FB asymmetry @ 500 GeV



reconstructed direction maps very poorly on parton level: ΔA_{FB} = 17 %

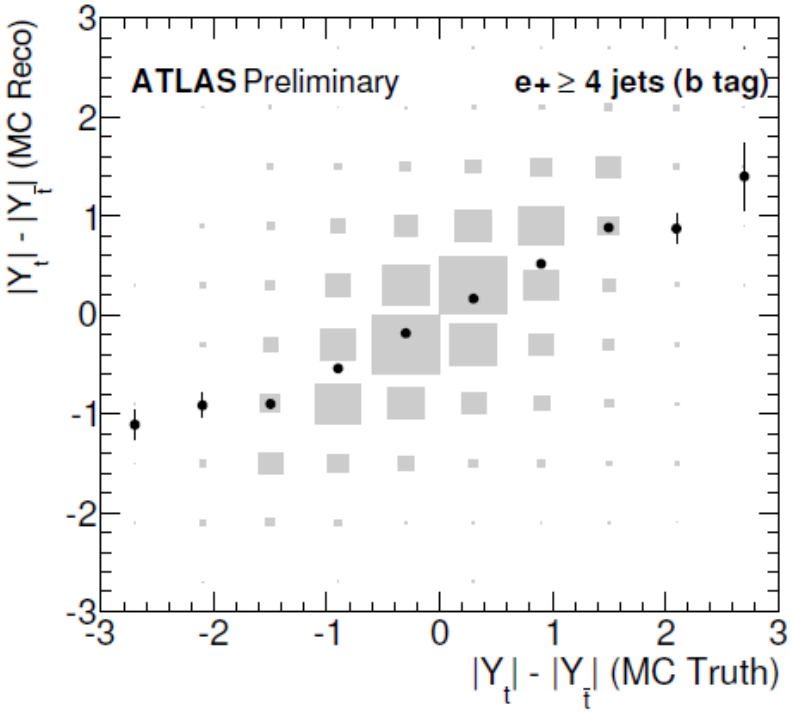
(see talk by R. Poeschl in this workshop)



Off-diagonal elements caused by wrong association b-jets

(mass constraint is rather weak)

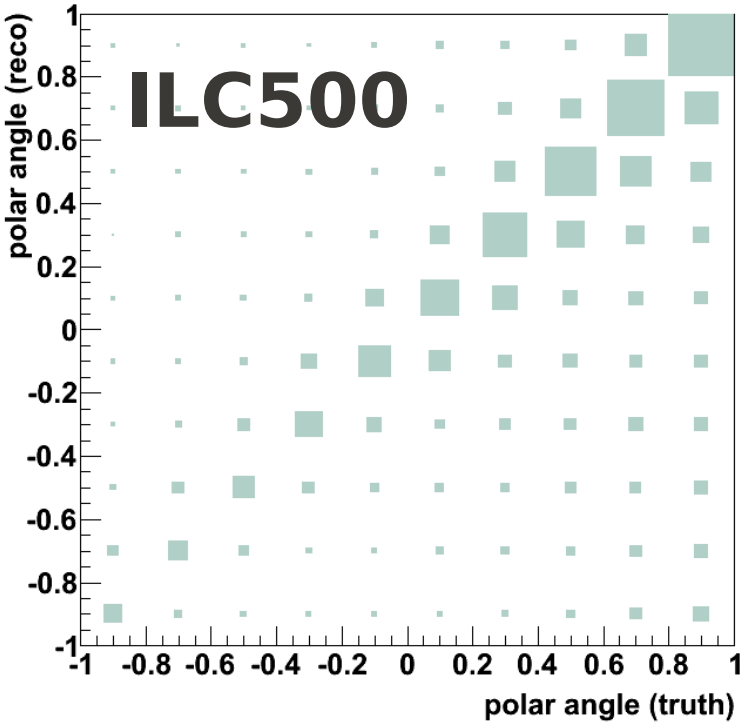
The FB asymmetry at 500 GeV



ATL-CONF-2011-106: sophisticated reconstruction cannot resolve all ambiguities

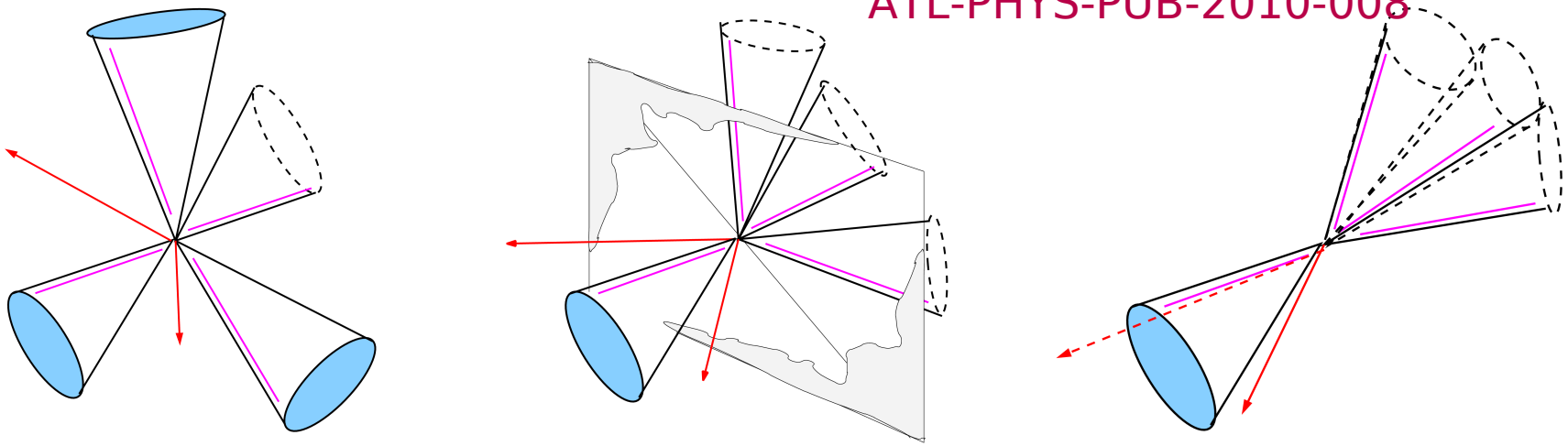
74% of events is correctly reconstructed
ttbar modeling is dominant systematic

One handle remains to be explored at the ILC: b-jet charge determination



ttbar event topologies – boosted top quarks

ATL-PHYS-PUB-2010-008



tt event “at rest”

“Transition region”

“Mono-jet”

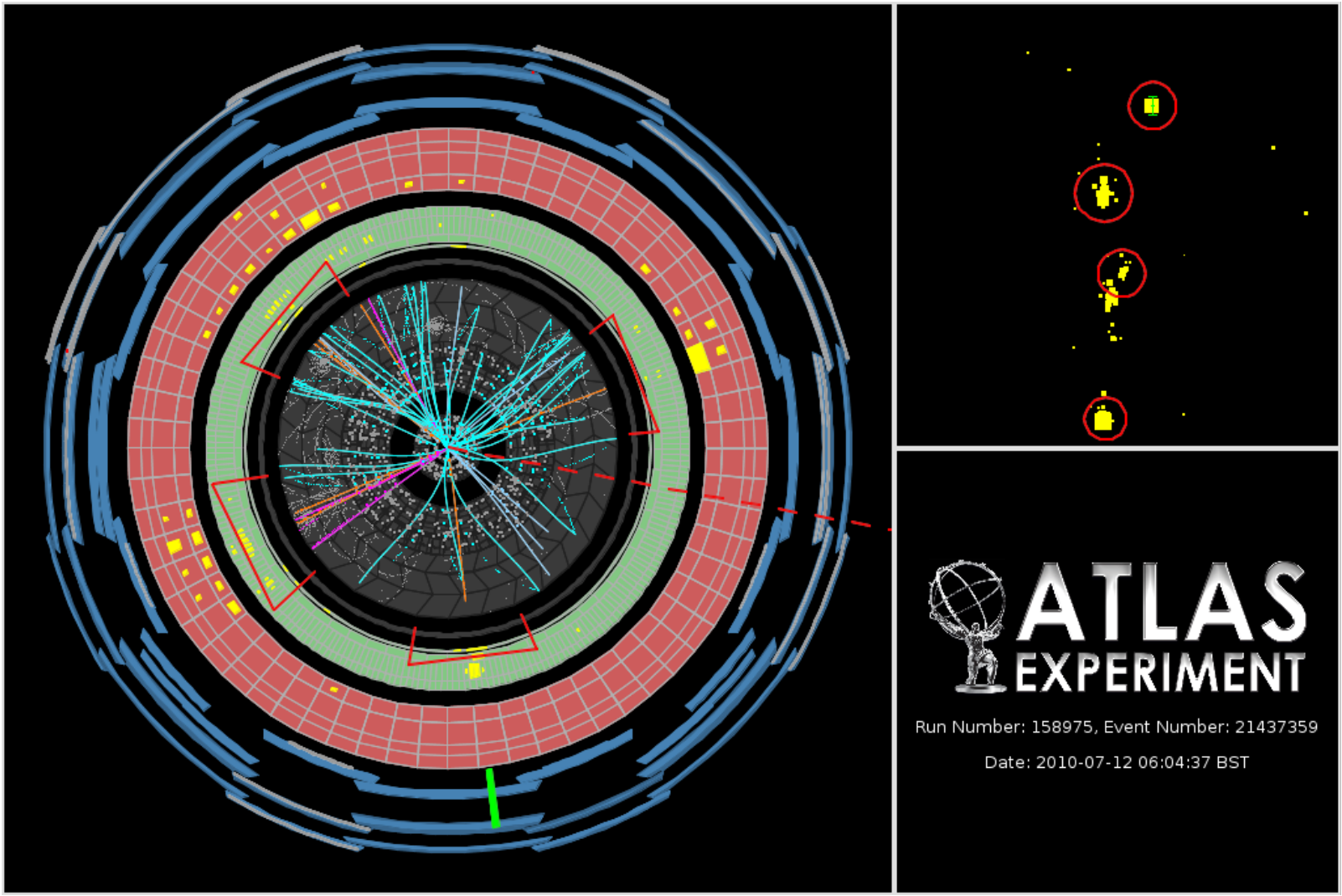
Increasing invariant mass of the tt system

The topology varies with m_{tt} (~ $\sqrt{s}$ for e^+e^-)

The reconstruction algorithm must follow:

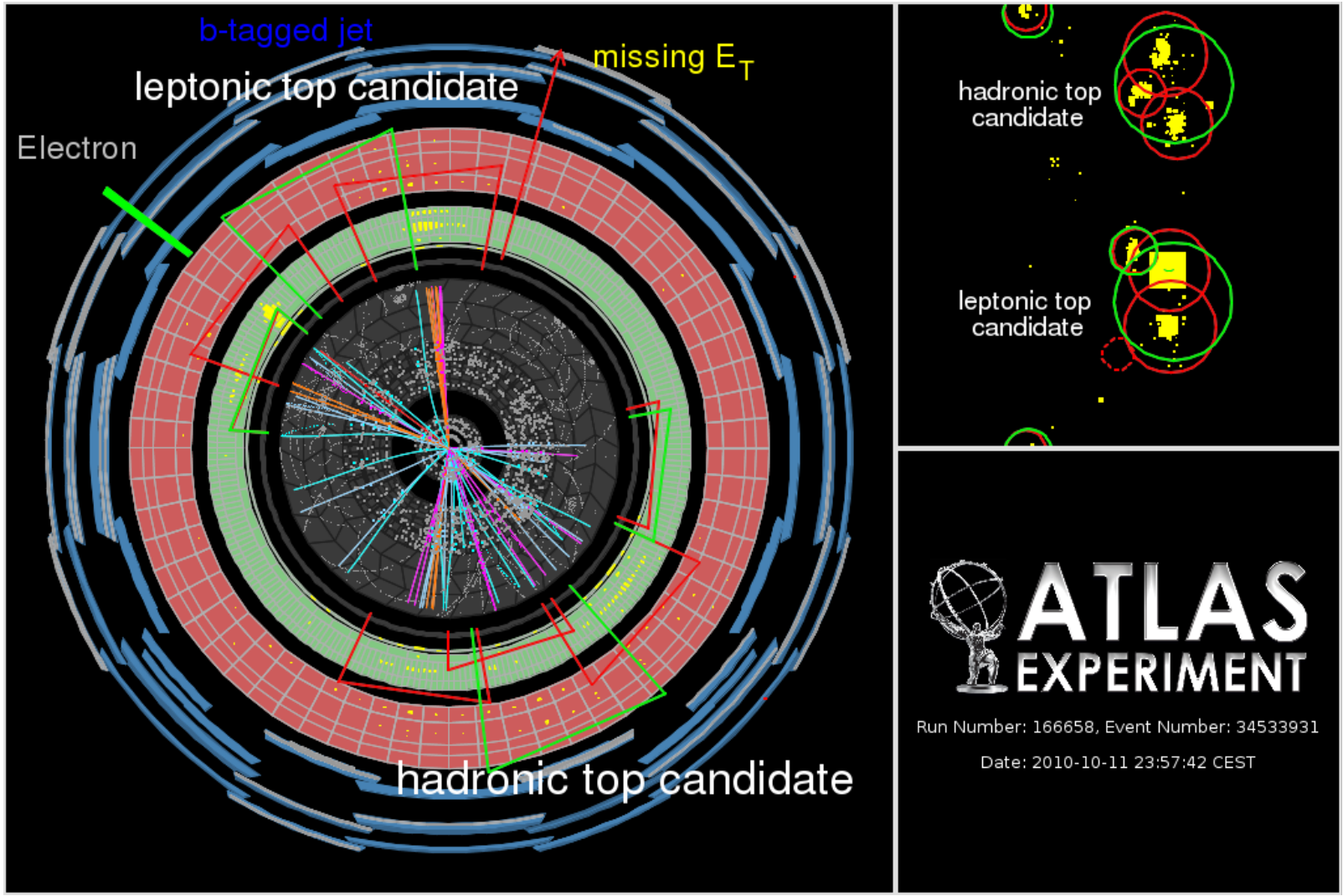
- For events at rest (500 GeV): resolve all partons
- Transition region (1 TeV): top and anti-top decay products remain back-to-back, but objects can still be resolved
- For highly boosted top quarks (3 TeV): reconstruct top decay as a single jet

Production “at rest”



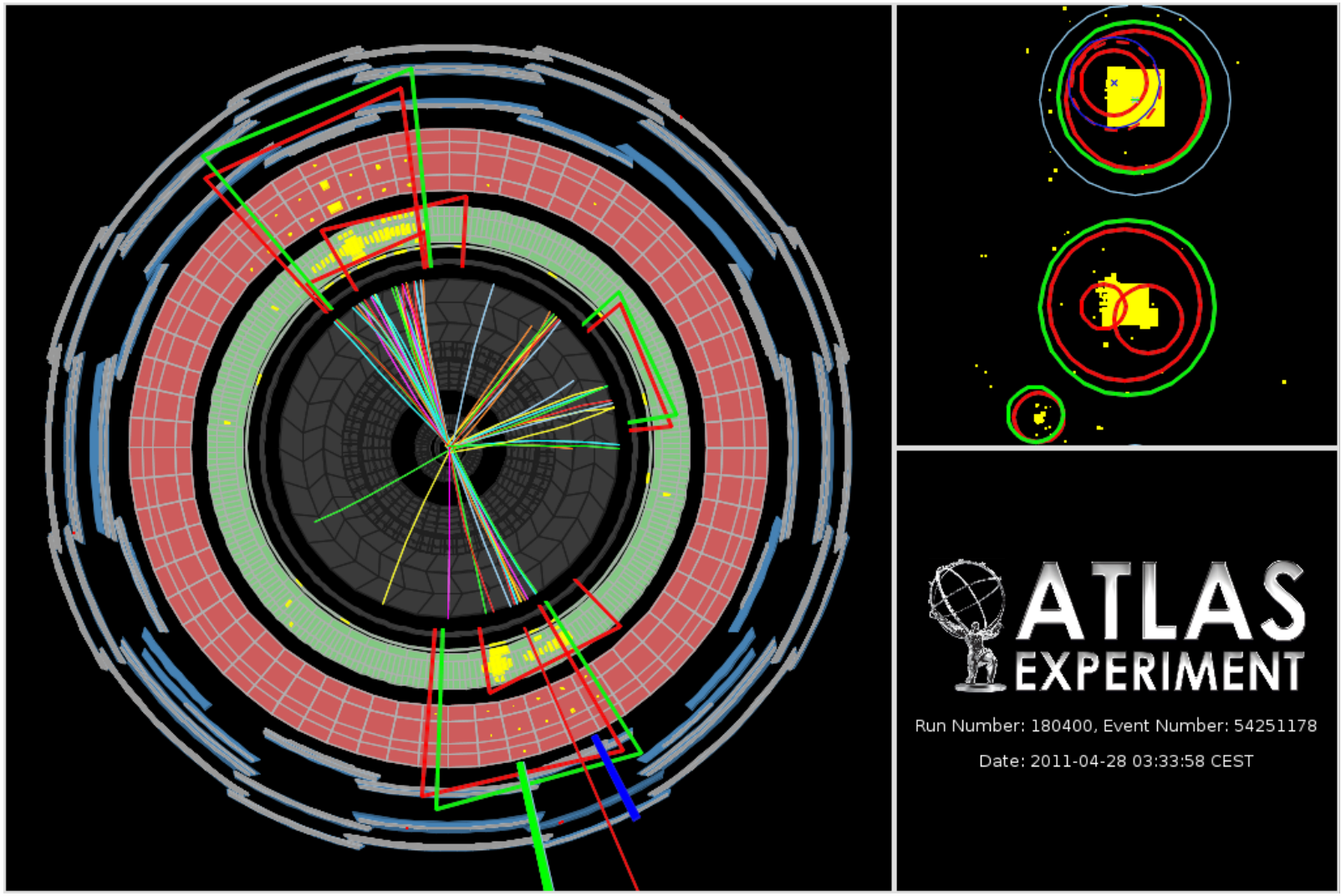
Early “l+jets” candidate
ATLAS-CONF-2010-063

Moderate boost



First boosted top quark
ATLAS-CONF-2011-073

Highly boosted top quarks

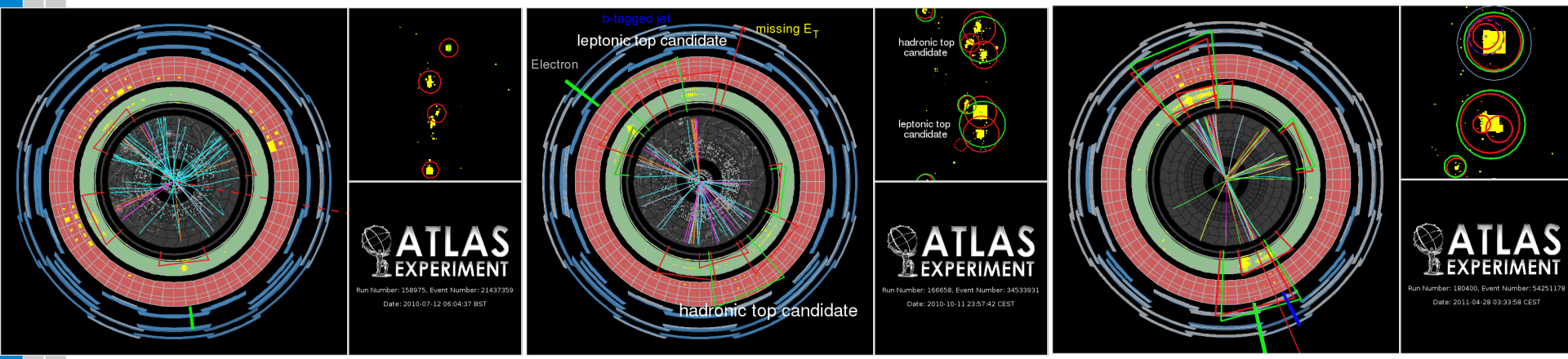


$m_{tt} > 1$ TeV

ATLAS-CONF-2011-083

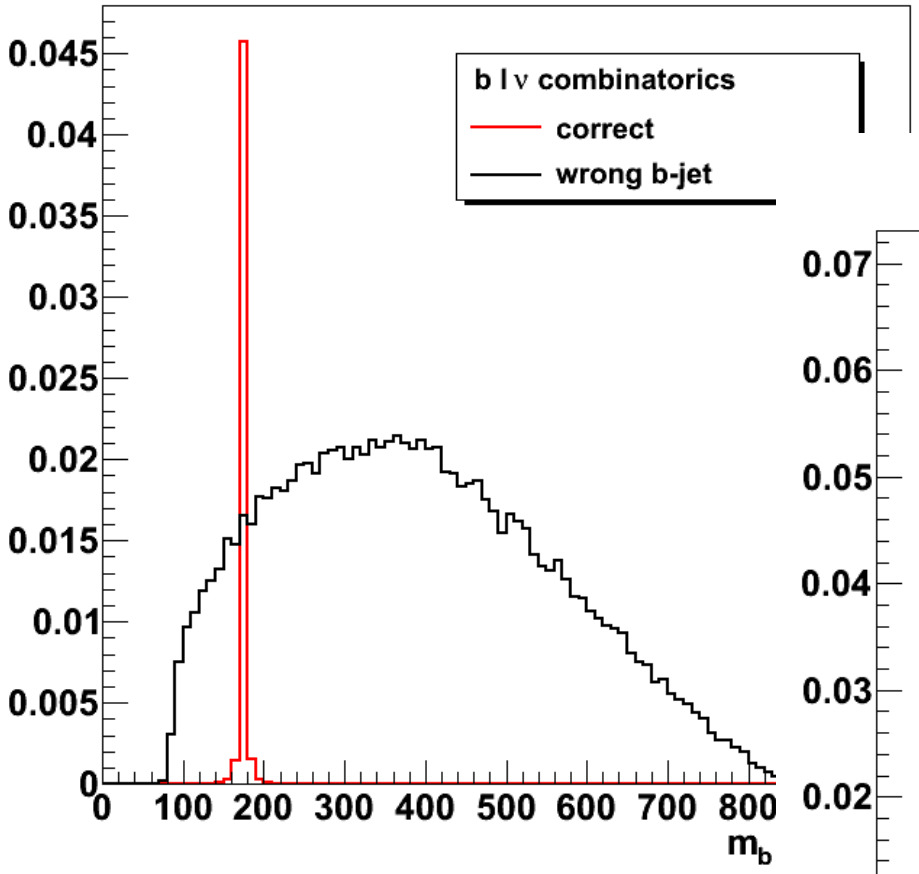
The FB asymmetry - experimental

Now that the LHC experiments have gained first “hands-on” experience with boosted top quarks, we can assess their challenges & opportunities, comparing the acceptance and systematics for low and high mass selection → input to this study

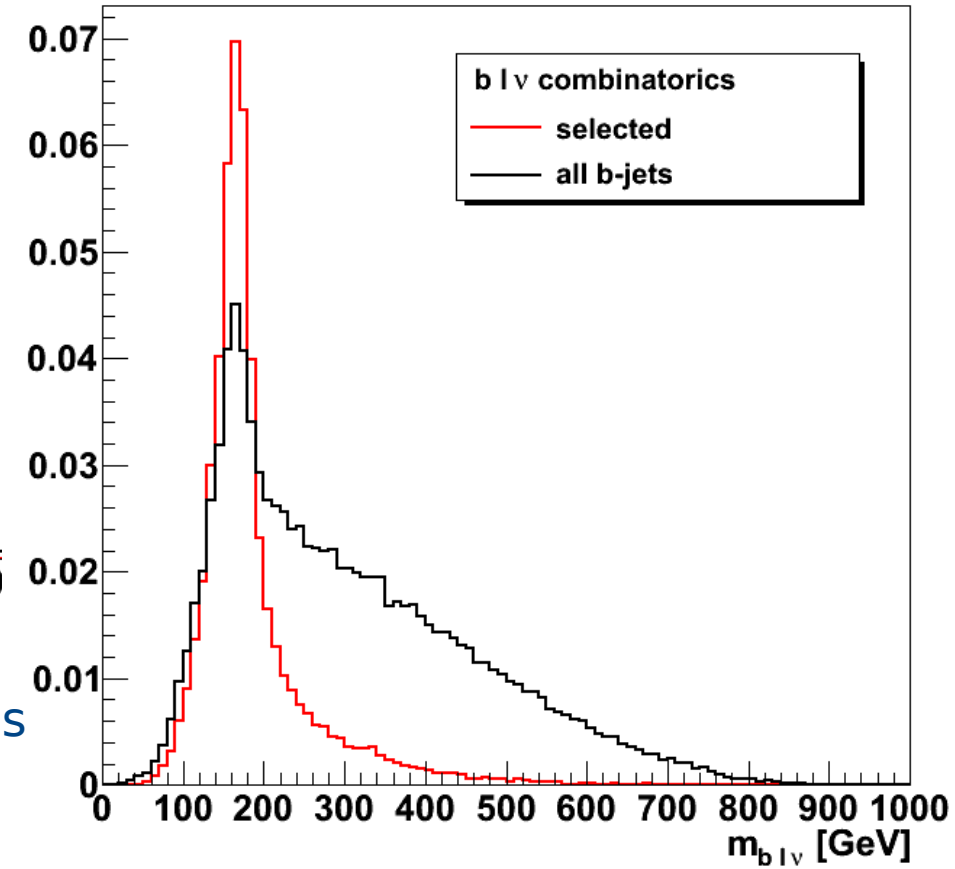


See also: Plehn & Spannowsky on top-tagging
Reports from BOOST2010 & BOOST2011
BSM at LHC Forum, Heidelberg, Dec 2011
CMS & ATLAS ttbar resonance searches

Top quark reconstruction @ 1 TeV

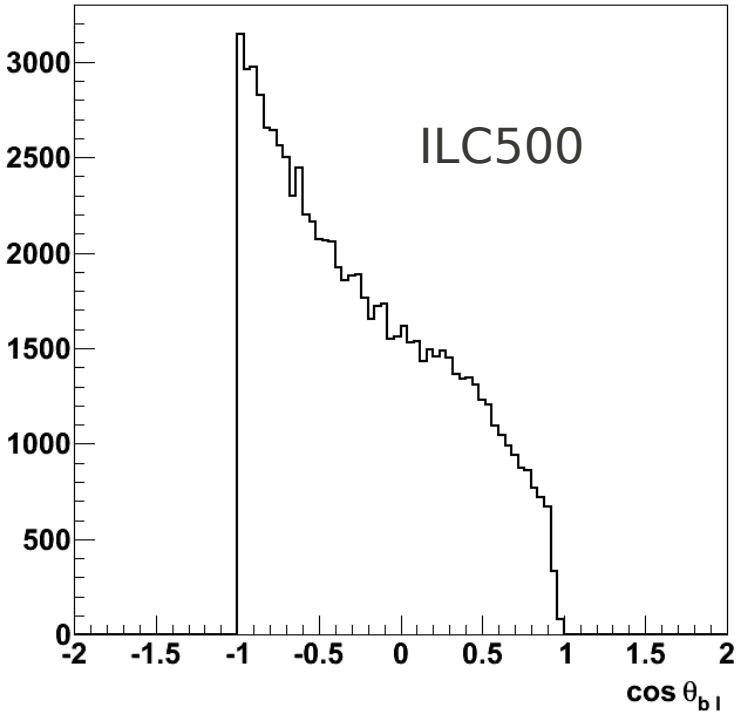


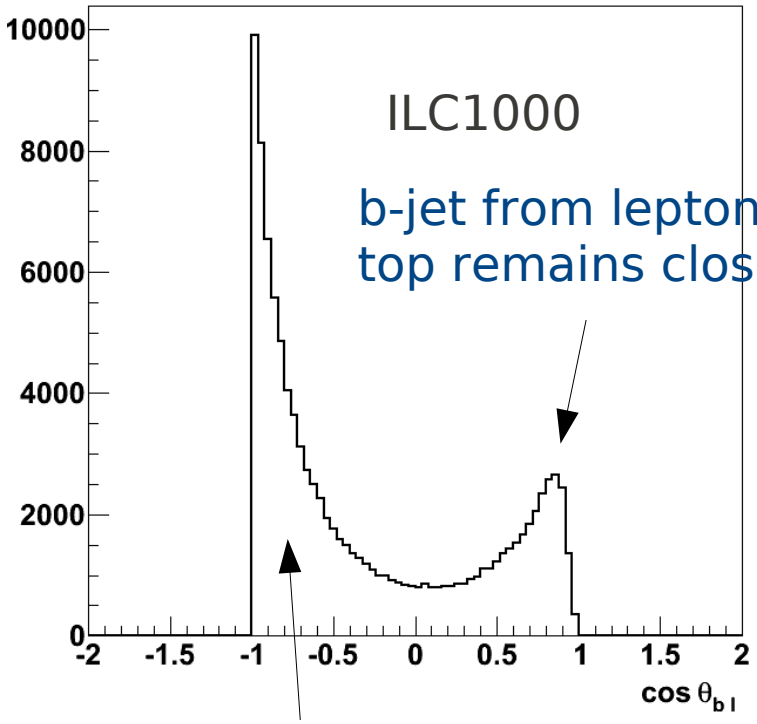
Observation: wrong combinations peak at ~ 400 GeV



Observation: confusion depends on jet energy resolution

One more handle





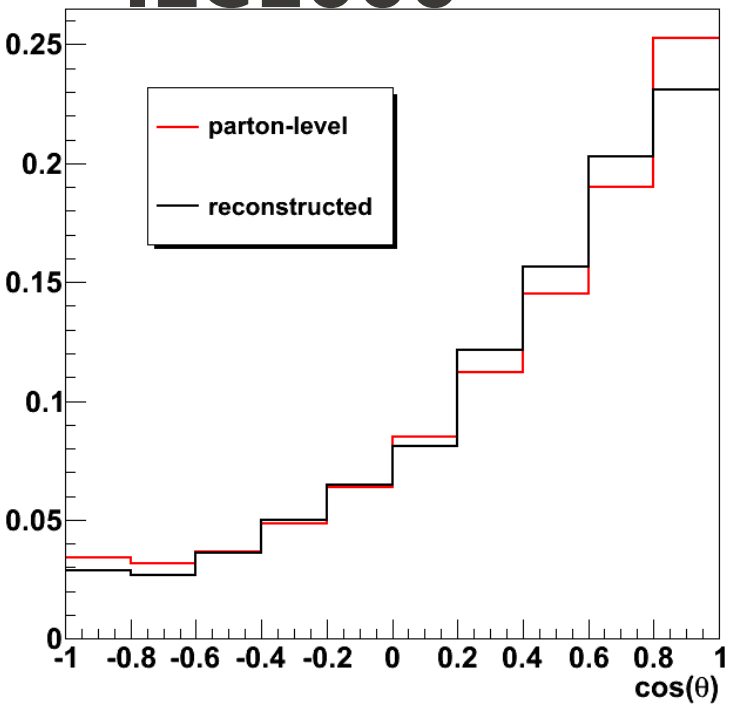
b-jet from leptonic top remains close

other jets remain "back-to-back"

Angle between b-jet and lepton is a powerful handle at 1 TeV

The FB asymmetry @ 500 GeV

ILC1000



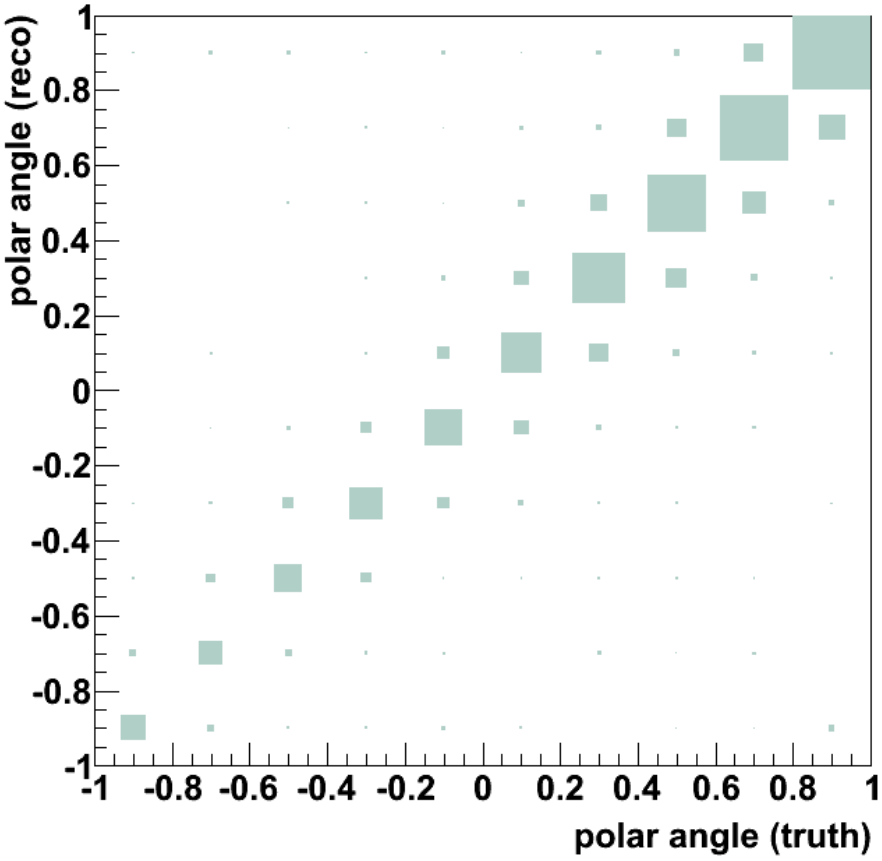
> 90 % of events is correctly reconstructed

Off-diagonal elements disappear

mapping OK

reco = truth within 2 %

ILC1000



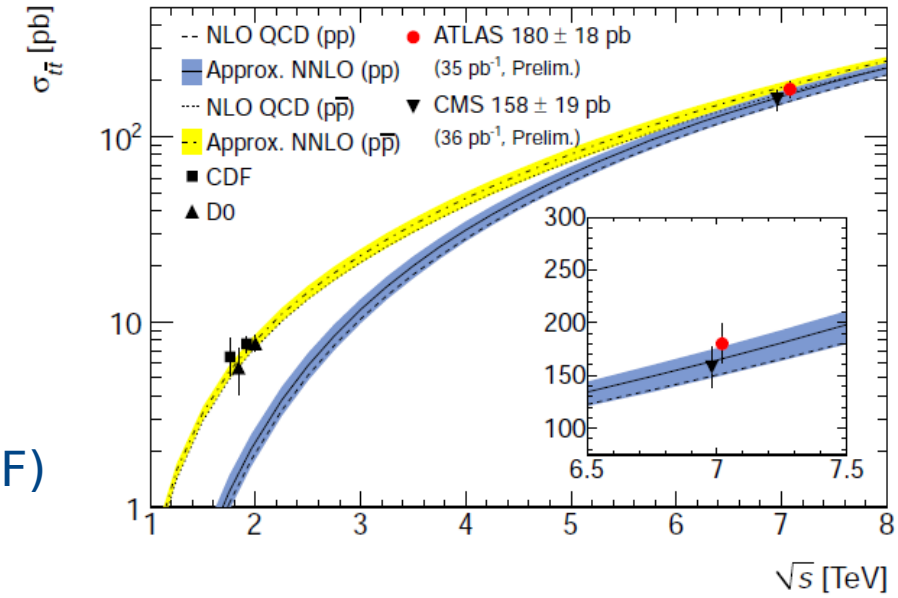
Conclusions

A measurement of the forward-backward asymmetry ILC1000 (or CLIC @ 3 TeV) is complementary in several ways to a measurement in ILC500 (theory and experimental errors, sensitivity to new physics)

The relatively modest boost at ILC@1TeV is sufficient to circumvent the potentially large systematic due to ambiguities in assignment of jets to top and anti-top quark candidate

Repeat in full simulation, extend to more extensive set of observables (left-right asymmetry, ...)

Top production I



Theory x-sec @ 7 TeV

σ_{tt} (MCFM) = 158^{+23}_{-24} pb

$\sigma_{tt}^{\text{approx NNLO}} = 163^{+7}_{-5}$ (scale) $^{+9}_{-9}$ (PDF)

N. Kidonakis, Phys.Rev. D82 (2010) 114030, arXiv:1009.4935. doi:10.1103/PhysRevD.82.114030.

Measurement	**Cross section [pb]**
*CMS l+jets+tag**	*150 ±9 (stat) ± 17 (syst) ±6(lumi)*
*CMS dilepton**	*168 ±18 (stat) ± 14 (syst) ±7(lumi)*
*CMS Combined**	*158 ±10(unc.) ± 15(cor.) ± 6(lumi)*
*ATLAS Combined***	*180 ± 9 (stat.) ± 15 (syst.) ± 6 (lumi.)*

Full 2010 data set, 36 pb^{-1}, CMS PAS TOP-11-001
***Full 2010 data set, 5 channels, 35 pb^{-1},ATLAS-CONF-2011-040*

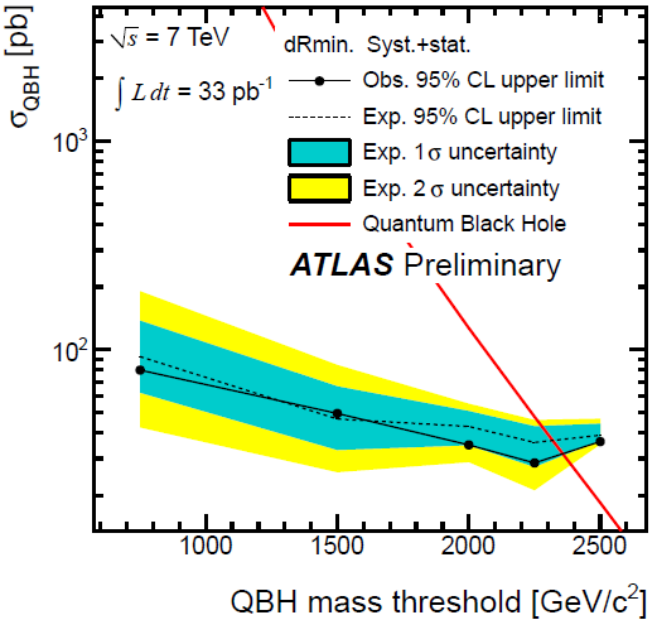
There is no super abundant exotic source of ttbar events

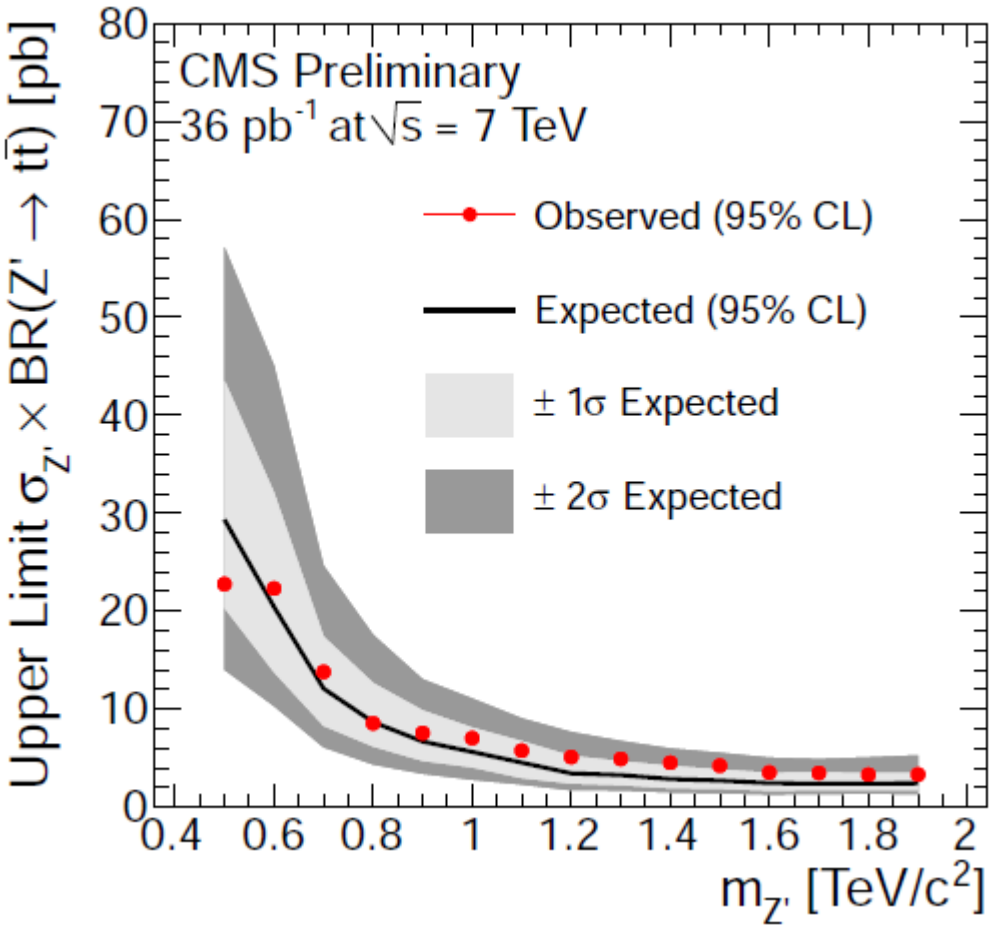
Top production II

Direct search for resonances

CMS 36 pb-1, combined e+jets and m+jets channels (TOP-10-007-PAS)
ATLAS result approved

Extend in several directions:
- more reconstruction algorithms
- more channels
- more models
- effective operators
(Zhang & Willenbrock '10, Aguilar-Saavedra '10, Degrande et al. '10)



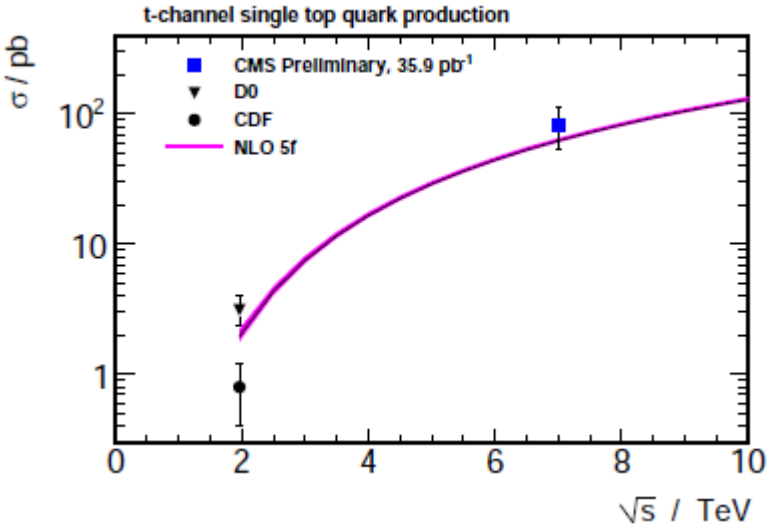


ATLAS-CONF-2011-070

Single top

- ✔ The single top production mechanisms might display different/increased sensitivity to new physics. They moreover offer an interesting field for studies of polarization.

- ✔ CMS: Selection optimized for the t-channel mode on 35.9 pb^{-1} (TOP-10-008-PAS)
  Measured cross-section: **83.6 ± 29.8(stat. + syst.) ± 3.3(lumi.) pb**
- ✔ ATLAS (ATLAS-CONF-2011-027):
  - ➔ T-channel 53 +46-36 pb (theory 66 pb)
  - ➔ Wt channel < 158 pb (theory 15 pb)

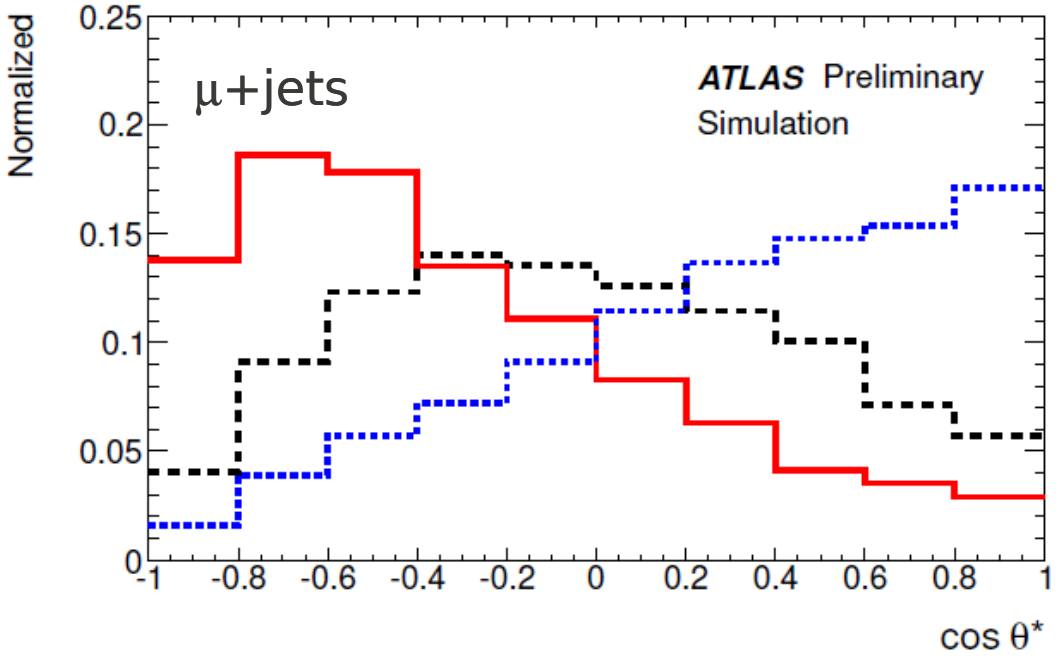


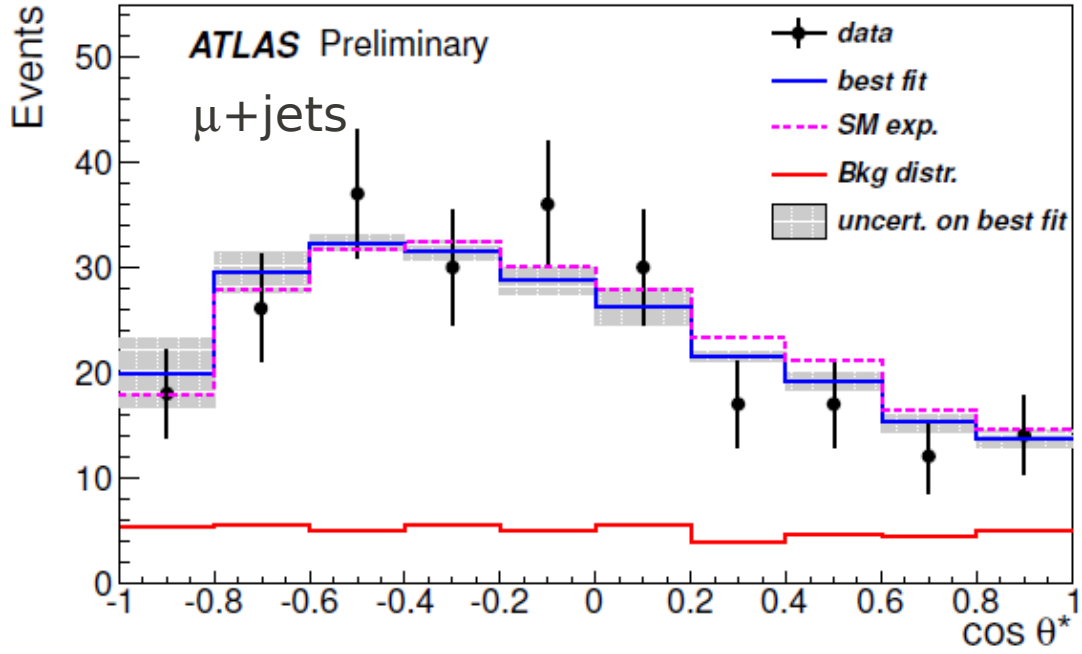
Top decay

W-boson polarization in top decays

ATLAS-CONF-2011-037

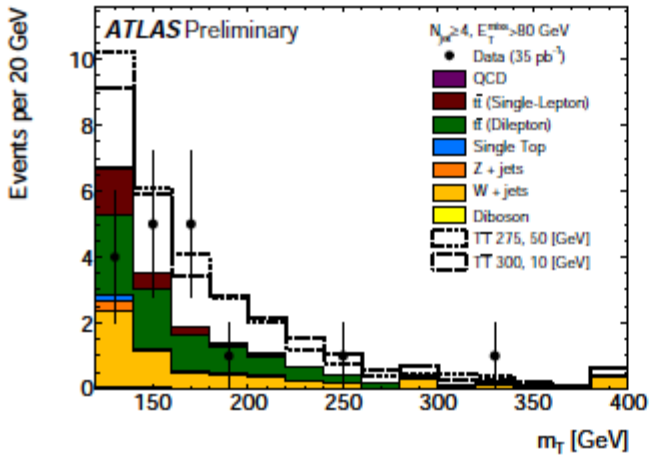
- ✔ Extract helicitiy fractions (combining lepton and muon channels):
  - ➔ $F_0 = 0.59 \pm 0.12$
  - ➔ $F_L = 0.42 \pm 0.12$
- ✔ Constrain anomalous Wtb couplings

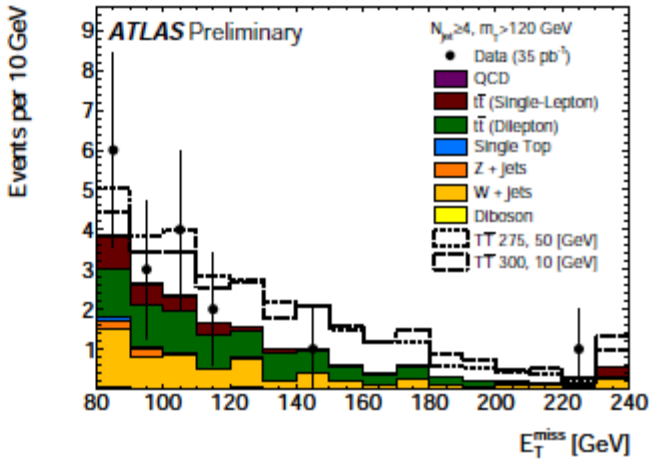




ttbar+X

- ✔ Associated production ttbar+X, where X can be anything, from gluons to bbar to ttbar to Higgs to SUSY sparticles.
- ✔ Example: ATLAS ttbar + E_t^{miss} study (ATLAS-PHYS-CONF-2011-036)





No excess found: limits on top partners T->tX, where X is a neutral particle