Top charge @ATLAS

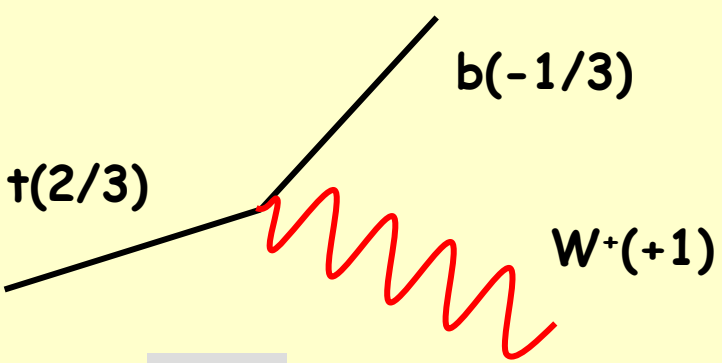
Preliminary study

B. Zilka, S.Tokar and J.Coss
Comenius University, Bratislava

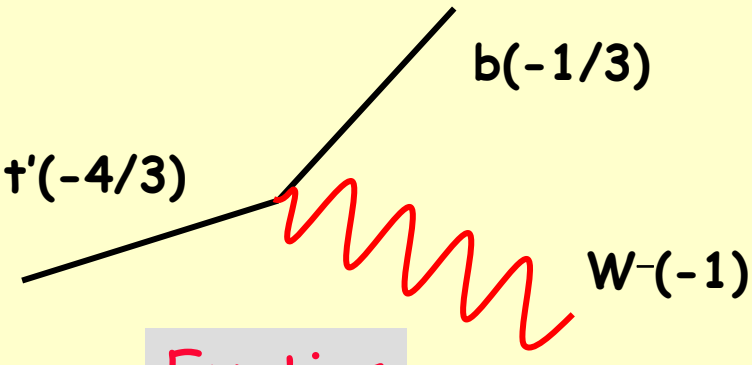
Top Quark Charge Determination

Motivation:

CDF and D0 analyses + precision EW data do not exclude:
quark seen in Fermilab is an exotic quark with Qtop= - 4/3.
(D. Chang et al., Phys. Rev. D59, 091503)



SM



Exotics

D0: top charge is compatible with SM prediction (19 dilepton events)

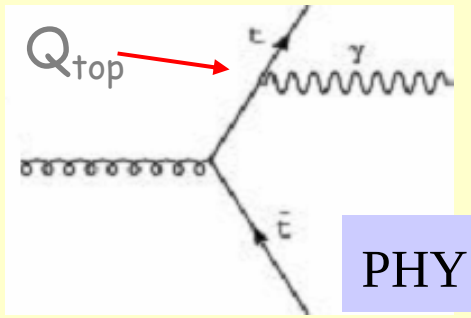
ATLAS wants more: the value of top charge

How to determine the top charge?

- **via radiative tt_bar events (sensitive to Qtop)**

→ to measure X-section of $pp(\bar{p}) \rightarrow t\bar{t}\gamma + X$

Direct measurement of top-to-photon coupling →



PHYS-2003-35

- **by measuring the charges of top decay products**

main drawback: b-jet charge

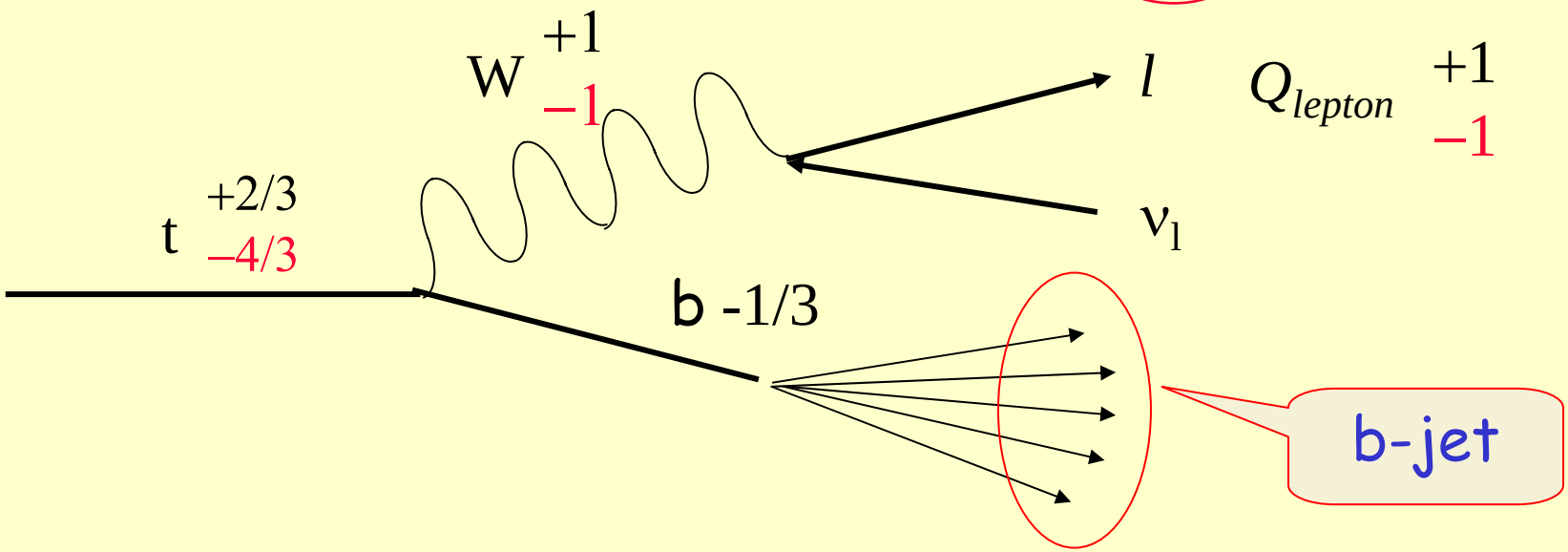
⇒ weighting b-jet tracks charges -> AtlFast

⇒ semileptonic b-decay (done at partonic level)

⇒ reconstructed B-hadrons (not treated yet)

Charge analysis of top quark decay

- SM (Qtop=2/3): $t^{2/3} \rightarrow b^{-1/3} + W^{+1} \rightarrow l^{+1} + \upsilon_e$
- exotics (Q = -4/3): $\hat{t}^{-4/3} \rightarrow b^{-1/3} + W^{-1} \rightarrow l^{-1} + \upsilon_e$



- for top quark determination
  - -determination of b-jet charge
  - -lepton – b-jet association

} Critical moment

b-jet charge determination

- weighting method

$$Q_{b-jet} = \frac{\sum_i^N q_i w_i}{\sum_i^N w_i}$$

$q_i \equiv i^{th}$ part. Charge
$w_i \equiv i^{th}$ part. weight

- Semileptonic B-meson decay

Not treated yet

$$b^{-1/3} \rightarrow c, u^{2/3} + W^{-1} \qquad W^{-1} \rightarrow l^{-1} + \overline{\upsilon_e}$$

- single lepton in bjet cone (soft lepton trigger)
- need to take into account B_0 oscillations ~ 1/10 bkgr.

Weighting methods

Charging algorithms differ in way we assign weight to bjet tracks...

** Absolute pt:*

$$Q_{b-jet} = \frac{\sum_i^N q_i p_T^{\kappa}}{\sum_i^N p_T^{\kappa}}$$

** Delta R relative to bjet axis:*

$$Q_{b-jet} = \frac{\sum_i^N q_i |\Delta R|^{\kappa}}{\sum_i^N |\Delta R|^{\kappa}}$$

Longitudinal momentum relative to bjet axis:

$$Q_{b-jet} = \frac{\sum_i^N q_i \left|\vec{j} \cdot \vec{p}_i\right|^{\kappa}}{\sum_i^N \left|\vec{j} \cdot \vec{p}_i\right|^{\kappa}}$$

$q_i \equiv$ ith particle charge
$\vec{p}_i \equiv$ ith particle momentum
$\vec{j} \equiv$ b-jet direction
$\kappa \equiv$ an exponent

Optimization for CDF: $\kappa \approx 0.5$

Analysis first done for ATLAS (Atlfast, PHYS-2003-35)

Event samples and Selection criteria

❖ **Samples for analysis:** ~310,000 ev., Rome 4100 data in AOD`s
dilepton & lep.+jets ttbar events w/o fully hadronic

✓ dilepton events: $t\bar{t} \to (l\nu)(l\nu)b\bar{b}$

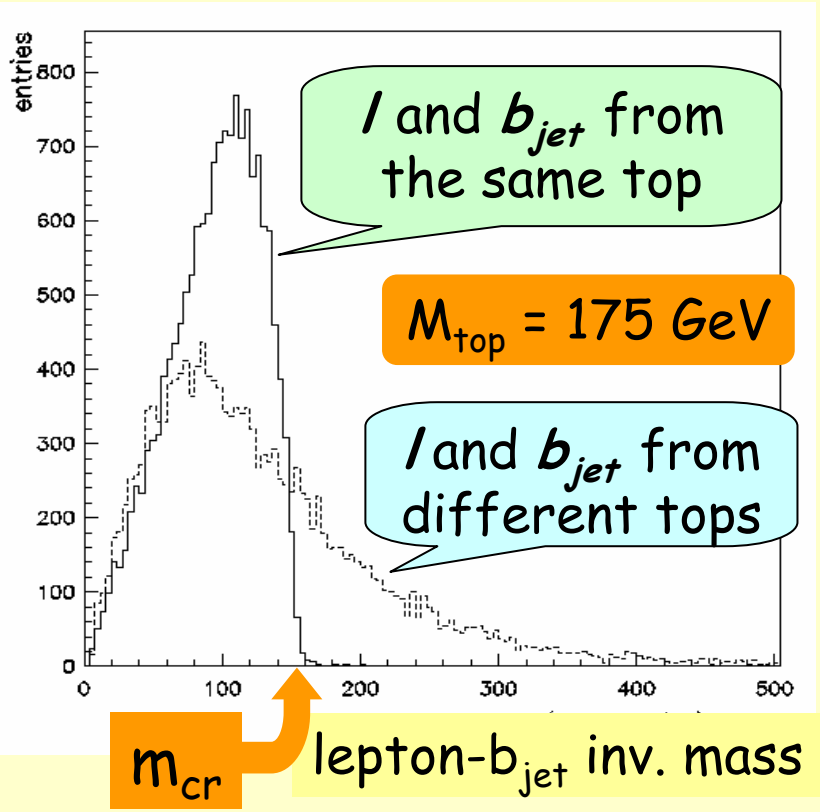
✓ lepton+jets events: $t\bar{t} \to (l\nu)(jj)b\bar{b}$

ATLAS s/w 10.0.1

All jet modes not suitable due to huge QCD bkgd !

Dilepton	Lepton+jets
2 isolated leptons (e, μ) p_T > 25 GeV, $\|\eta\|$<2.5	1 isolated leptons (e, μ) p_T > 20 GeV, $\|\eta\|$<2.5
Missing E_T > 40 GeV	Missing E_T > 20 GeV
≥ 2 jets , p_T > 25 GeV, $\|\eta\|$<2.5 1 or 2 b-tagged	≥ 2 b-jets, p_T > 25 GeV
	Tot. 4 jets, p_T >25 GeV, $\|\eta\|$<2.5

lepton b-jet association



❑ **Invariant mass criterion**

lepton+jets case (1 hi-pt lep.)

$$m(l,b_{jet}^{(1,2)}) < m_{cr} \;\&\; m(l,b_{jet}^{(2,1)}) > m_{cr}$$

dilepton case (2 hi-pt leps.)

$$m(l^{(1,2)},b_{jet}) < m_{cr} \;\&\; m(l^{(2,1)},b_{jet}) > m_{cr}$$

Our cut: M_{cr}=160 GeV

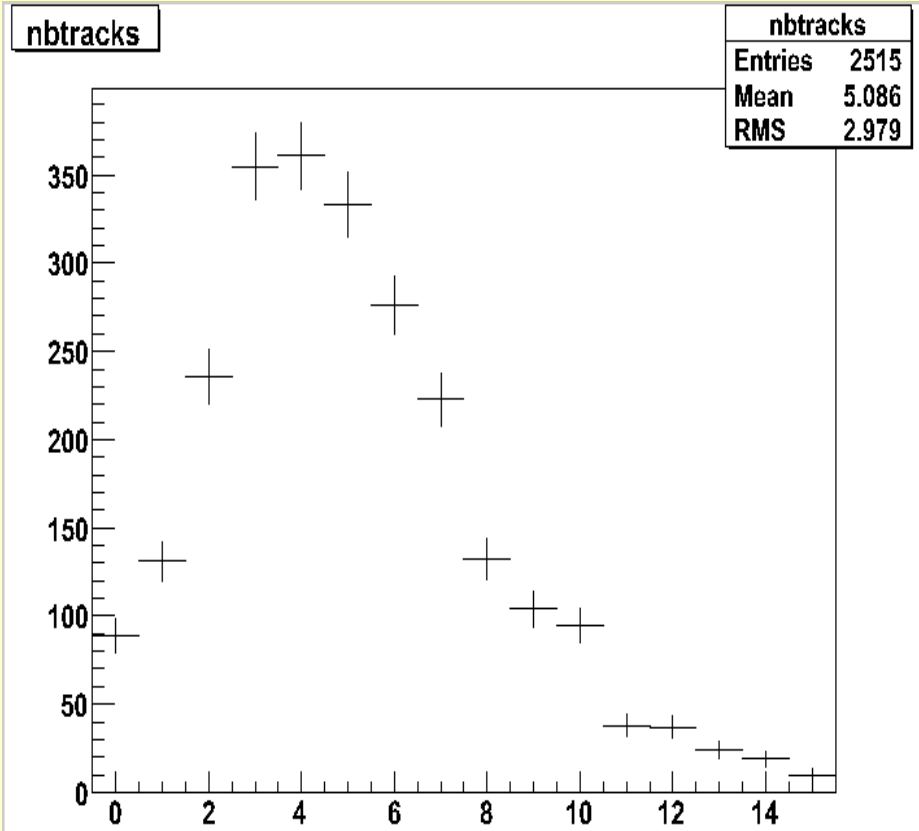
❑ **Alternative:** Event kinematic fit (event-by-event)→ full reconstruction of event – a lepton +jets combination with minimal χ^2 defines correct l-b_{jet} association.

Charge weighting criteria

B-jets reconstructed by Athena were taken:

- Tracks pointing to bjet in $\Delta R < 0.4$ cone are treated
- Tracks with PileUp flag were rejected
- Only tracks with pt higher than 0.5 GeV were taken
- When more than 10 bjet tracks, only first 10 with highest pt were taken

✓ tracks with d0 > d0-threshold taken (sample does not contain tracks matching b-jet)



Multiplicity of tracks inside bjet cone, taken from inv.mass b-matching sample

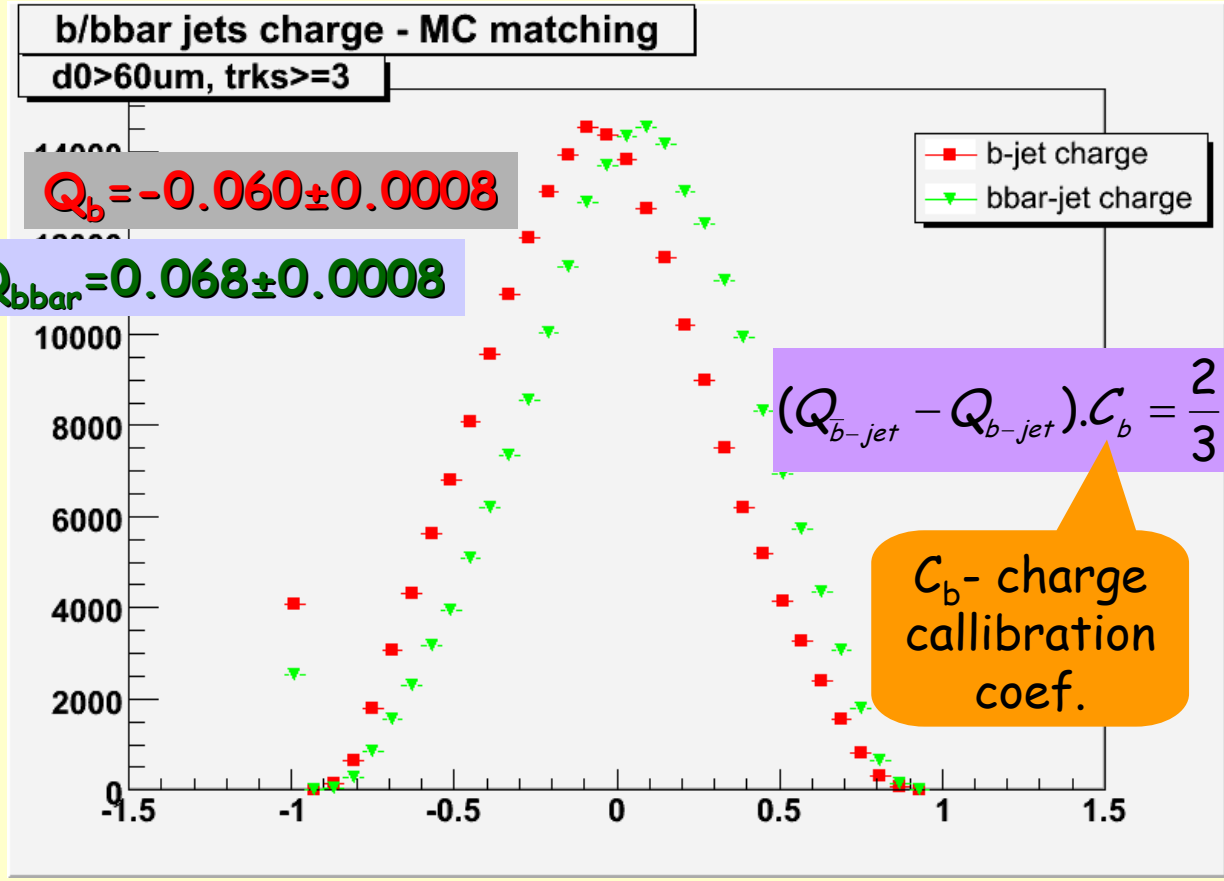
MC truth *b*-tagging

- MC truth used for b-tagging: jet reconstructed by Athena found in cone $\Delta R=0.4$ around b-quark direction

charge of b-jet initiated by b-quark and by bbar-quark

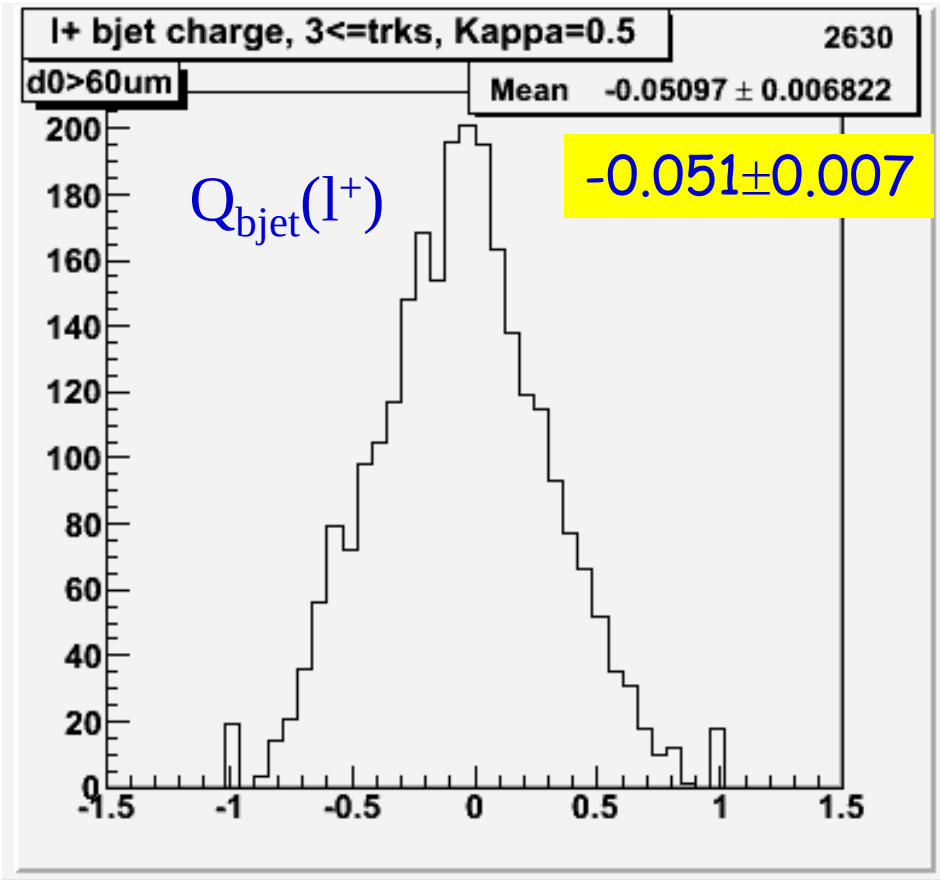
track charge weighting technique used to find b-jet charge

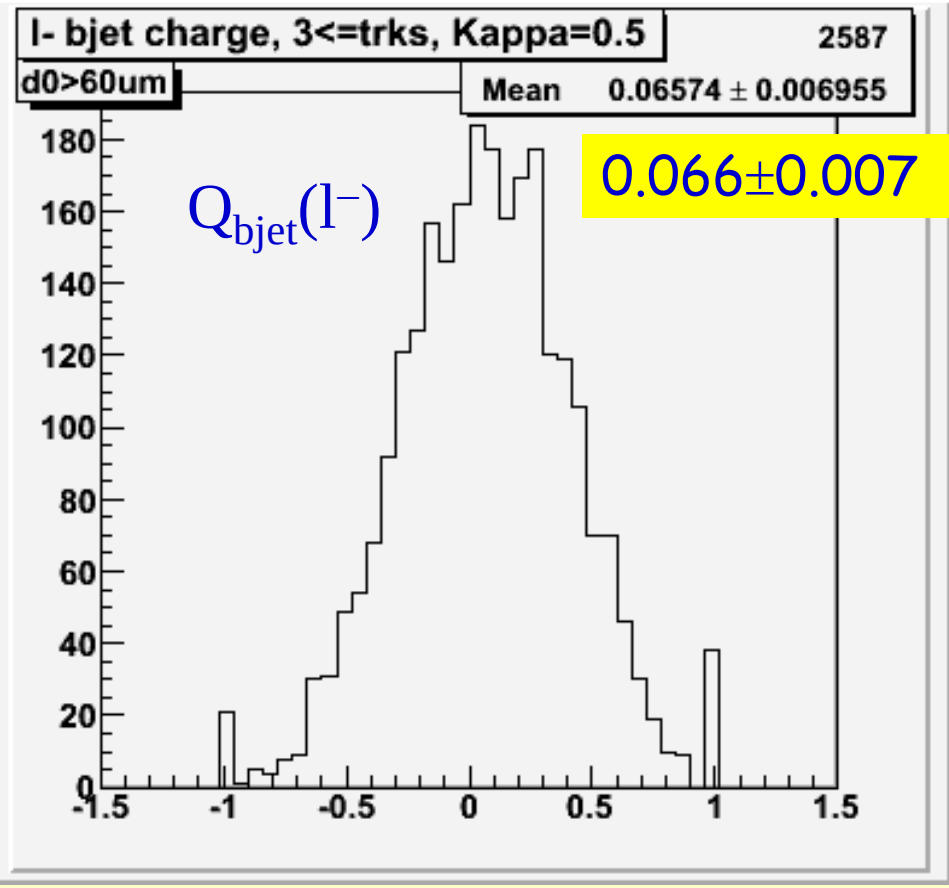
$d_0 > 60\mu m$,
$3 \leq$ tracks to b-jet



b-jet charge associated with l^+ and l^-

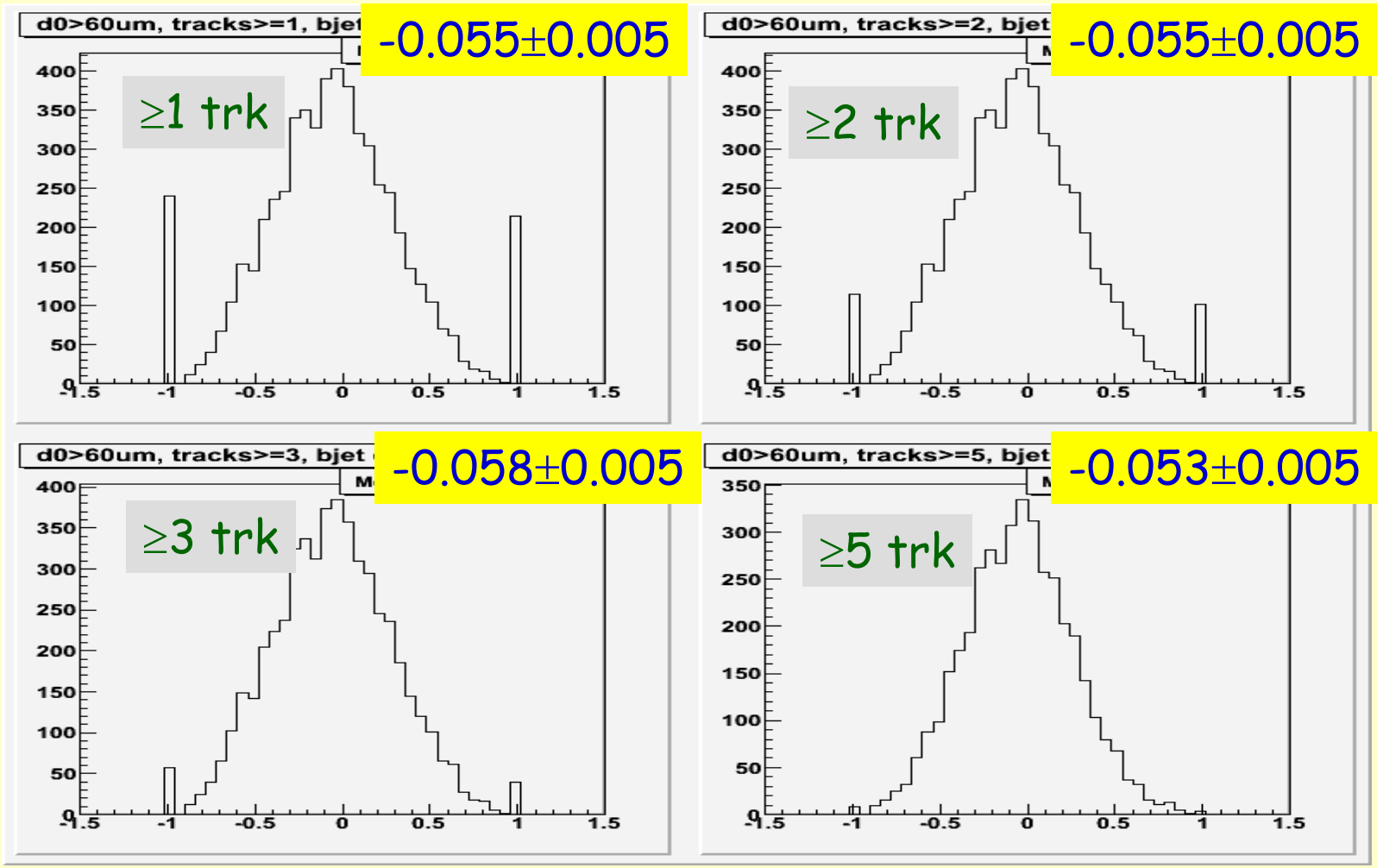
- Invariant mass criterion used for l-b association (Athena reconstruction, sample ≈310000 tt-bar events)





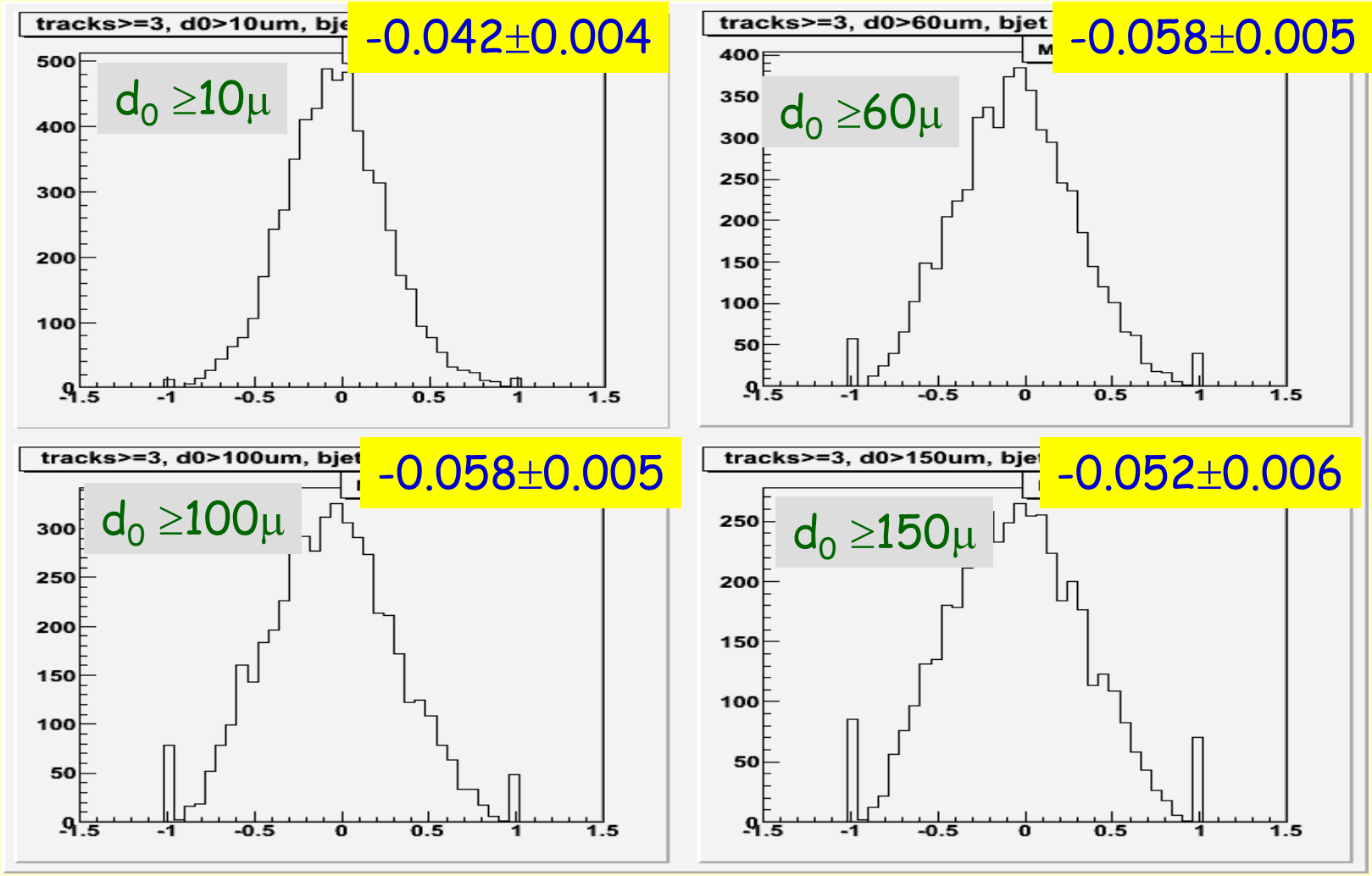
b-jet charge vs minimal # tracks

- Common distribution of $Q_{bjet}(l+)$ and $-Q_{bjet}(l-)$
- Only bjet with # tracks >= threshold (all with d0 ≥ 100 um)

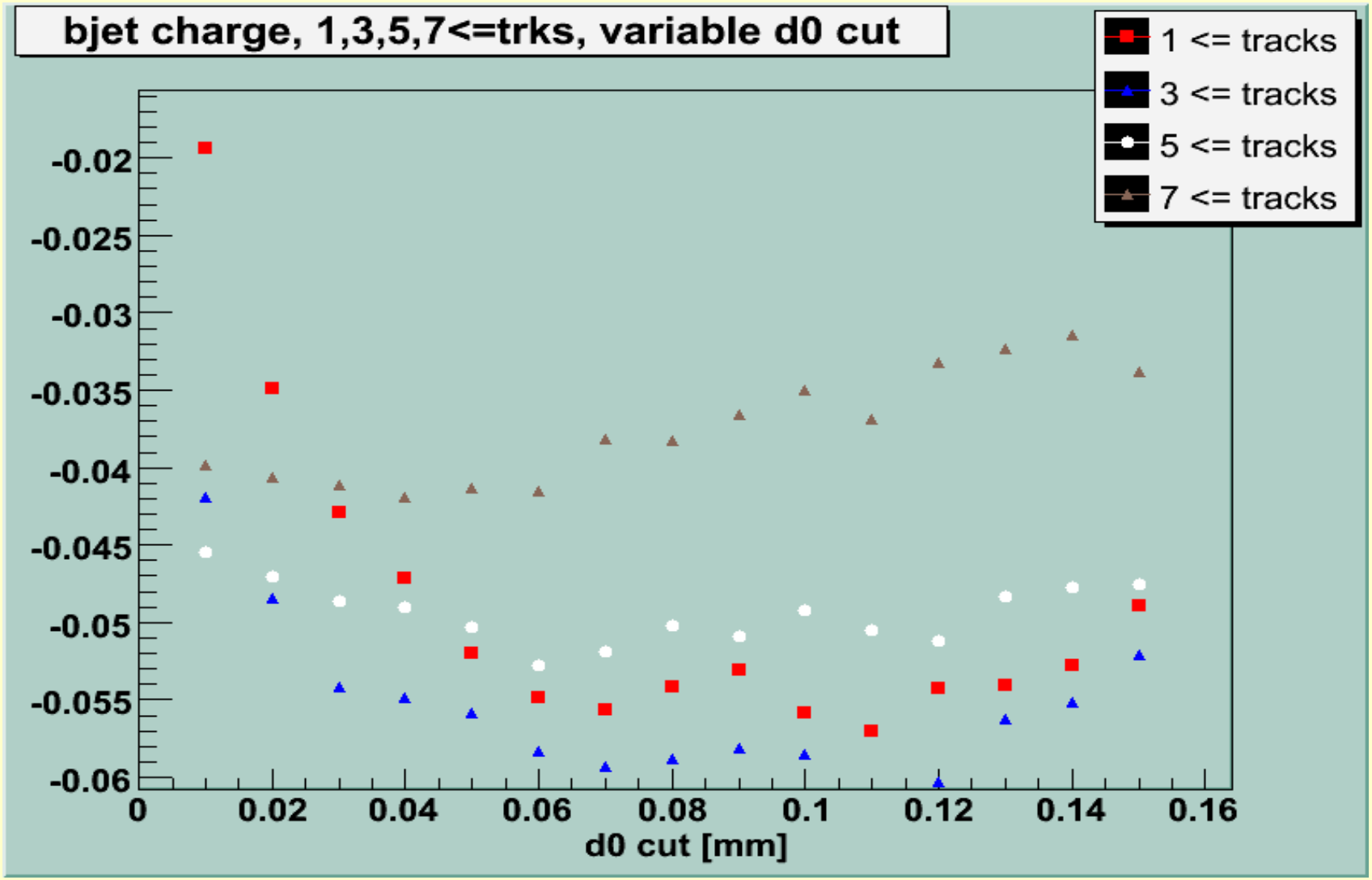


b-jet charge vs track d_0

- Common distribution of $Q_{bjet}(l+)$ and - $Q_{bjet}(l-)$
- Only tracks with d_0> threshold taken (≥ 3 trk needed)



b-jet vs d0, # of tracks

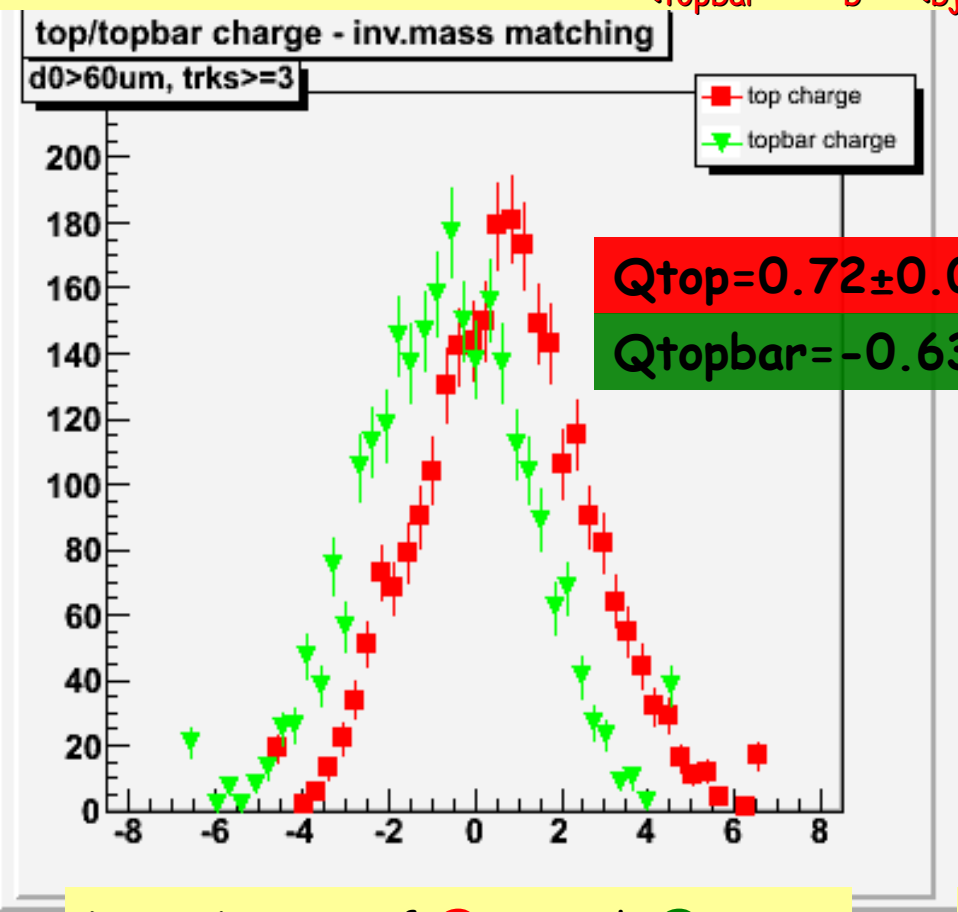


top & topbar charge from lepton and b-jet charge

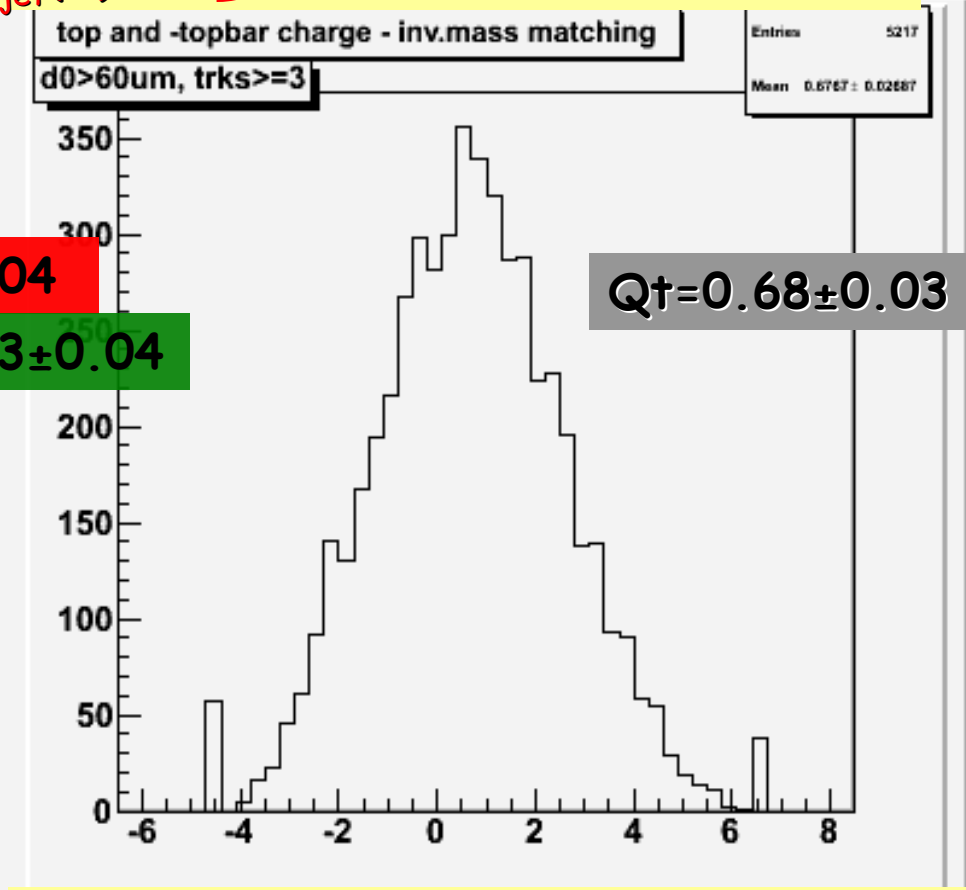
- Invariant mass criterion used for l-bjet association
- top charge reco:

$$Q_{top} = C_b \cdot Q_{bjet}(l+) + 1$$
$$Q_{topbar} = C_b \cdot Q_{bjet}(l-) - 1$$

C_b (≈5.5) – from MC match



Distribution of Q_{top} and Q_{topbar}



Common distribution of Q_{top} and - Q_{topbar}

Background study

	charge asymmetry
❖ **Di-lepton mode:**	
- Drell-Yan	(no)
- fakes from W+jets	(Wc: yes, Wcc,Wbb ?)
- di-boson production	(no)
❖ **Lepton +jets mode:**	
- mistags (W+uds-jets)	(no)
- W + heavy flavor	(Wc :yes, Wcc,Wbb ?)
- QCD fakes	(no)
- di-bosons	(no)
- Single top	(yes)

ATLAS: proper sel. criteria can provide S/B > 10

Summary

- Very preliminary analysis of ~310kEvents sample (Rome 4100 data, ttbar lepton+jets and dilepton samples) has been carried out
- bjet charge determined by charge weighting of bjet tracks
- l-bjet invariant mass criterion enables to distinguish between bjet charges associated with l^+ and l^-
- (No doubt) experiment ATLAS has a big potential for finding top quark charge

Our Plans

- Continue top charge via weighting (upgrade reco: "b-tracks" by b-matching algorithm)
- In final procedure independent b-jet charge calibration needed
- Study of background processes
- Other b-charge approaches
- Determination of photo-top quark coupling (radiative tt production, renew the results in PHYS-2003-35)

Thank You!