

Underlying event in Z +jets

Alexey Miagkov, Vladimir Nikolaenko, Oleg Zenin

IHEP

January 27, 2011

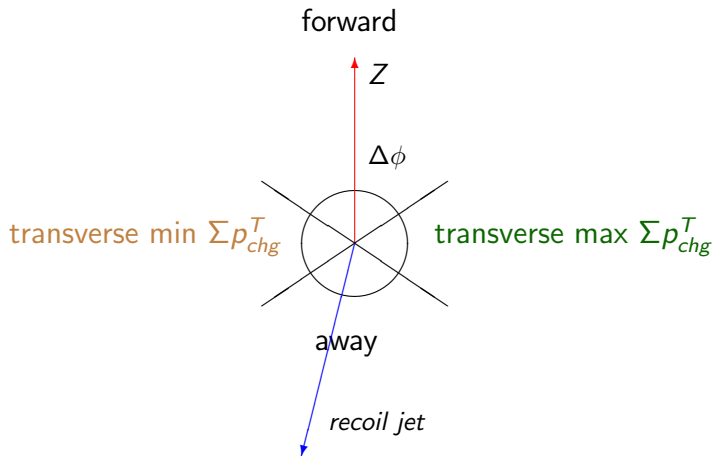
What is Underlying Event?

Everything except the hard process:

- ISR, FSR
- Multiparton scattering
- Beam remnants
- Pile up, detector noise, ... (to be subtracted)

Underlying event regions

Forward and transverse regions are sensitive to UE after removal of the leptons from Z decay



$$\Delta\phi_{forw} = \Delta\phi_{away} = 120^\circ, \Delta\phi_{trans} = 60^\circ$$

• DATA

- ▶ physics_Muons stream, periods E4–G1, runs:
160899 160953 160954 160958 160963 160975 160980 161118 161379
161407 161520 161562 161948 162347 162526 162576 162577 162620
162623 162690 162764 162843 162882 165591 165632 165703 165732
(constant trigger conditions through these periods: EF_mu10_MG
(prescale = 1) seeded by L1_MU0)
- ▶ W/Z+jets baseline 2010 GRL
- ▶ cross check: independent analyses on D3PD and ESD (**success!**, see backup slides)
- ▶ $\mathcal{L}_{int} \simeq 4.1/\text{pb}$.
- ▶ $Z/\gamma^* \rightarrow \mu^+\mu^-$, $M_{\mu\mu} > 60 \text{ GeV}$, $\sigma \cdot \text{Br} = 0.88 \text{ nb}$, 30997 events:
mc09_7TeV.106047.PythiaZmumu_no_filter.recon.ESD.e468_s765_s767_r1302....
- ▶ **QCD background**, $\sigma \cdot \text{Br} = 88 \text{ nb}$, 1970844 events:
mc09_7TeV.108488.PythiaB_bbmu4mu4X.recon.ESD.e524_s765_s767_r1302....
- ▶ **$t\bar{t}$ background**, $\sigma = 0.146 \text{ nb}$, 20981 events:
mc09_7TeV.105861.TTbar_PowHeg_Pythia.recon.ESD.e521_s765_s767_r1302....

Selections

- 2010 baseline selections:

<https://twiki.cern.ch/twiki/bin/view/AtlasProtected/...>

.../StandardModelWZjetsSubgroup#2010_Baseline_Selection

- ▶ EF_mu10_MG (prescale factor = 1 for periods E4 – G1)
- ▶ reconstructed primary vertex with ≥ 3 tracks and $|z_{\text{vtx}}| < 150$ mm
- ▶ 2 “Staco” muons:
 - ★ $p_T^{\text{comb.}} > 20$ GeV, $|p_T^{\text{MS}} - p_T^{\text{ID}}|/p_T^{\text{ID}} < 0.5$, $|\eta| < 2.4$
 - ★ μ ID track hits: $n_{\text{pixel}} > 1$, $n_{\text{SCT}} > 5$, $n_{\text{TRT}} > 0$ if $|\eta| < 2.0$
 - ★ μ combined track impact parameters w.r.t. primary vertex:
 $d_0 < 0.1$ mm, $z_0 < 10$ mm
 - ★ μ^\pm ID track isolation: $\Sigma p_T^{(\text{ID}, \Delta R=0.2)} < 1.8$ GeV

- $|M_{\mu^+\mu^-} - M_Z| < 20$ GeV

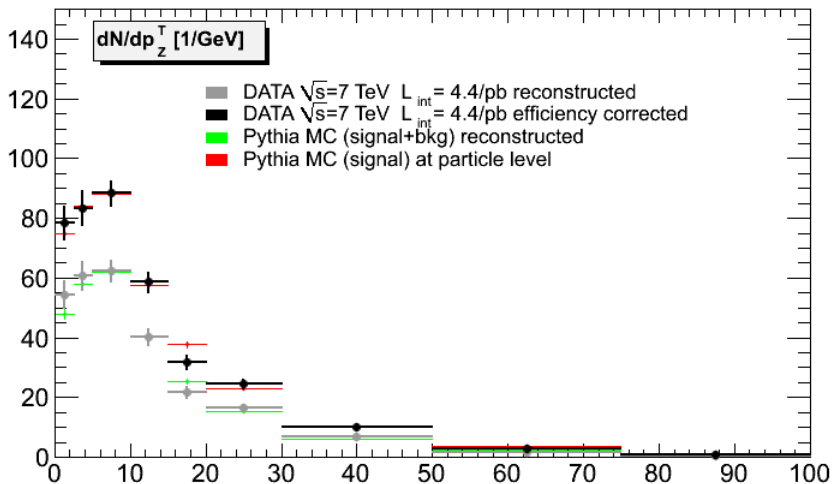
- **no E_T^{miss} cuts**, should be included to suppress $t\bar{t} \rightarrow \mu^+\mu^-X$ at large $p_T(\mu\mu)$

- ID tracks: lepton tracks from Z decay are removed, $p_T > 0.5$ GeV, $|\eta| < 2.5$, $N_{\text{pixel}} \geq 1$, $N_{\text{SCT}} \geq 6$, $|z_0 \sin \theta| < 1.5$ mm, $d_0 < 1.5$ mm w.r.t. primary vertex (χ^2 cut for high- p_T tracks to be added)

Plots

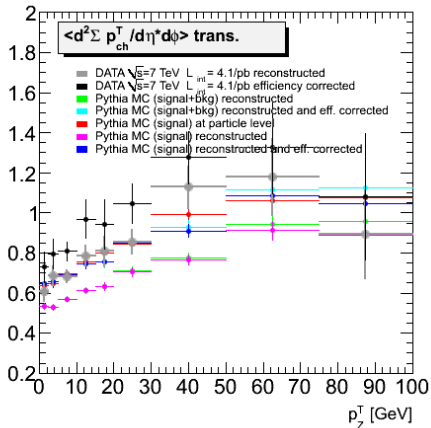
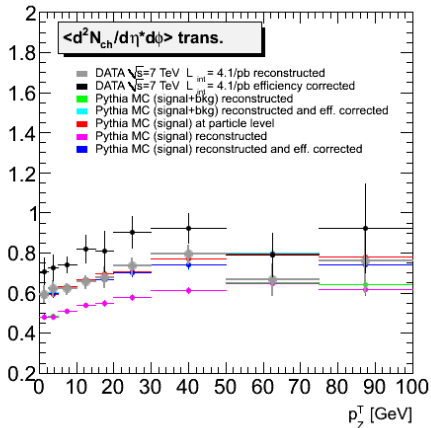
- Real data and MC09 corrected for
 - ▶ ID track reconstruction efficiencyare compared to MC09 truth from events with both muons within p_T , η acceptance.
- An exact event by event agreement between D3PD and ESD based analyses (11 out of 1289 events are missing from ESD sample due to failed grid jobs).
AOD based analysis with $Z \rightarrow ee$ is ongoing as well (D. Kar, IKTP TU Dresden).

$Z \rightarrow \mu\mu$ signal: $\mathcal{L} \times d\sigma/dp_{Tz}$



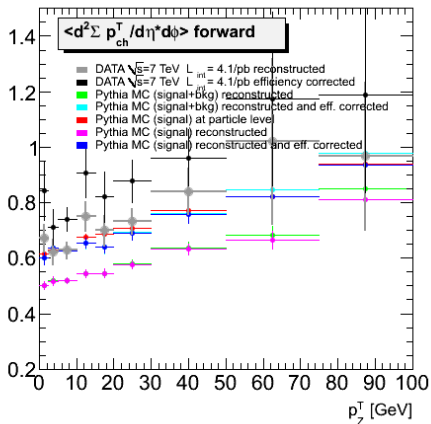
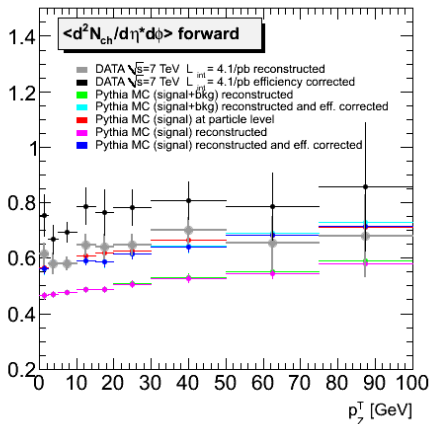
Good agreement between data corrected for muon trigger&reco eff. and Pythia MC09. Runs 160387 – 165767, L1_MU10 instead of EF_mu10_MG, muon trigger&reco eff. from tag&probe (see backup slides)

$\langle d(N_{chg}, \Sigma p_{chg}^T) / d\eta \cdot d\phi \rangle$: transverse sectors



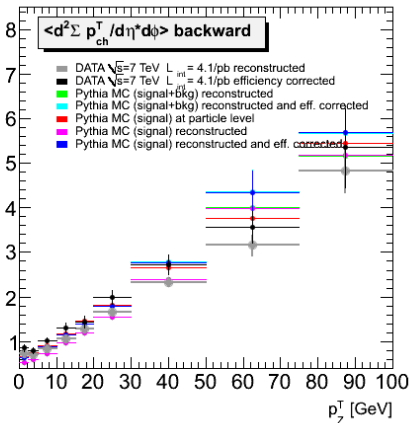
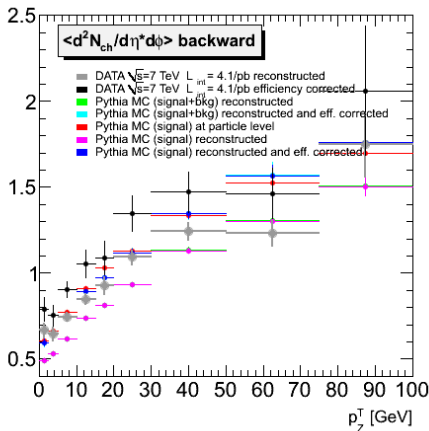
- Disagreement between data and Pythia MC at a level of $\sim 25\%$ (Alpgen+Herwig is better at $p_Z^T > 30$ GeV, not shown here).

$\langle d(N_{chg}, \Sigma p_{chg}^T) / d\eta \cdot d\phi \rangle$: towards Z



- Disagreement between data and Pythia MC at a level of $\sim 25\%$ (Alpgen+Herwig works better at $p_Z^T > 30$ GeV, not shown here).

$\langle d(N_{chg}, \Sigma p_{chg}^T) / d\eta \cdot d\phi \rangle$: away from Z



- Disagreement between data and Pythia MC at a level of $\sim 15\%$ for N_{chg} .

Summary and *to do*'s:

- $\frac{d\sigma(Z+jets)}{dp_Z^T}$ distribution corrected for muon trigger and reconstruction efficiencies is in a good agreement with Pythia MC09
- Pythia MC09 underestimates $\langle \frac{d^2 N_{chg}}{d\eta d\phi} \rangle$, $\langle \frac{d^2 \Sigma p_{chg}^T}{d\eta d\phi} \rangle$ at a level of $\sim 10 - 25\%$
- **TO DO:**
 - ▶ Utilize the full $\mathcal{L}_{tot} \sim 50 \text{ pb}^{-1}$ reprocessed sample.
 - ▶ Add muon trigger (run dependent) and reconstruction efficiency corrections.
 - ▶ Systematics!
 - ★ Estimate contribution of pile-up from data
 - ★ Estimate residual QCD background from data
 - ★ Primary vertex selection: standard 1ary vs. bare $\mu^+ \mu^-$ vertex
 - ★ *etc., etc.*
 - ▶ Compare $Z(\mu\mu)$ and $Z(ee)$ results

Backup slides

Corrections

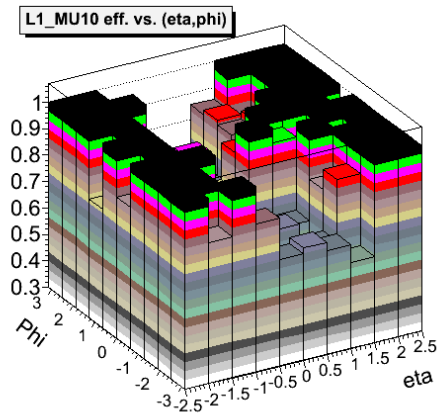
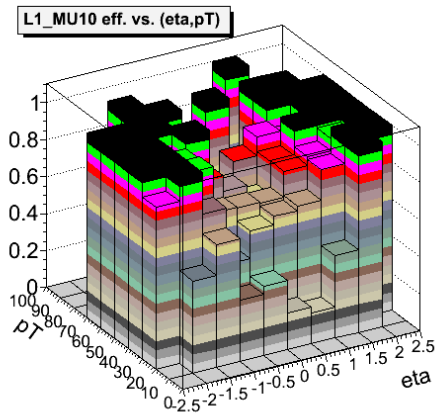
- Muons

- ▶ $\epsilon_{\text{trig, reco}} = \epsilon_{\text{trig, reco}}(p_T, \eta)$
- ▶ $\sim 2500 Z \rightarrow \mu\mu$ events in acceptance, too few for $\epsilon(p_T, \eta, \phi)$ so far

- ID tracks

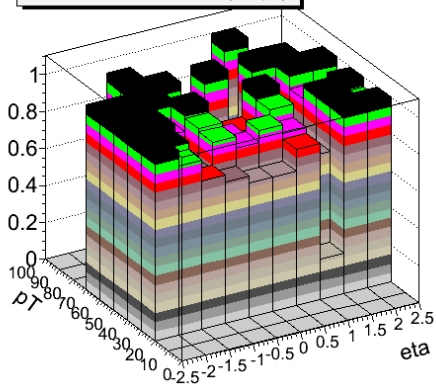
- ▶ corrections from MinBias analysis:
CorrectionPlots_7TeV_ndiff_9april.root
- ▶ used as in Minbias/src/Mb7TeV_v20.cxx

Muon trigger efficiency: tag&probe, runs 160387 – 165767

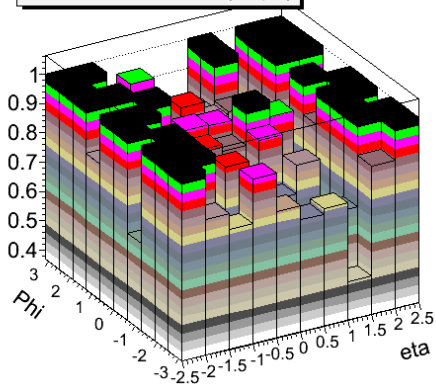


Muon reconstruction efficiency: tag&probe, runs 160387 – 165767

Staco muon reco. eff. vs. (η , p_T)



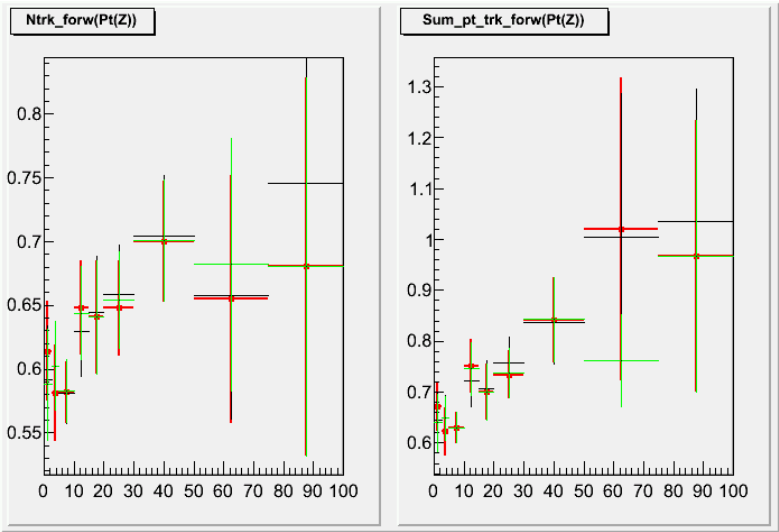
Staco muon reco. eff. vs. (η , ϕ)



Using $\mu^+\mu^-$ vertex instead of the standard primary vertex:

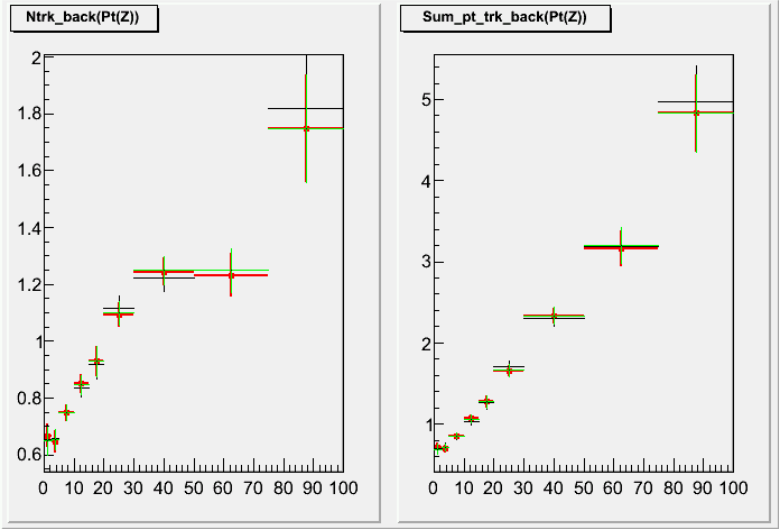
- Choose 2 good muons with $71 \text{ GeV} < M_{\mu^+\mu^-} < 111 \text{ GeV}$. No cuts on d_0 , z_0 w.r.t. the conventional primary vertex.
- Reconstruct a vertex using ID tracks of the muons.
- Select ID tracks with $d_0 < 1.5 \text{ mm}$, $z_0 \sin\theta < 1.5 \text{ mm}$ w.r.t. the $\mu^+\mu^-$ vertex.

ESD vs D3PD: forward region



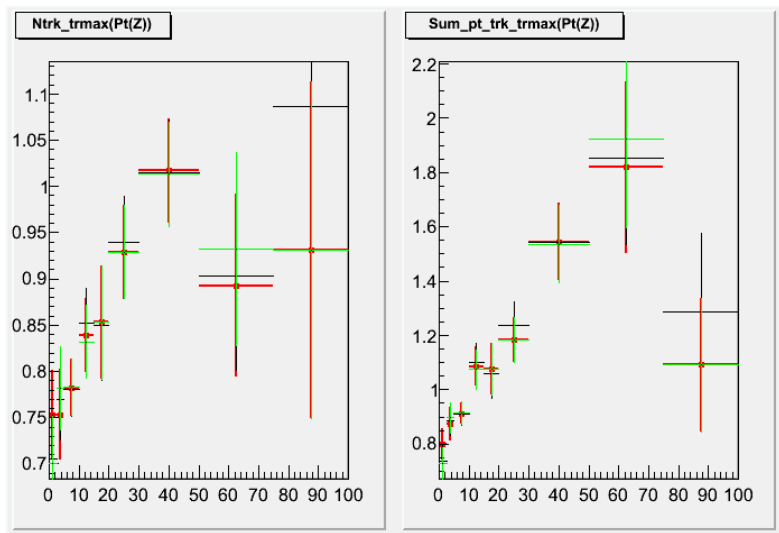
Small discrepancy due to 11 events missing from ESD sample (failed jobs).

ESD vs D3PD: backward region



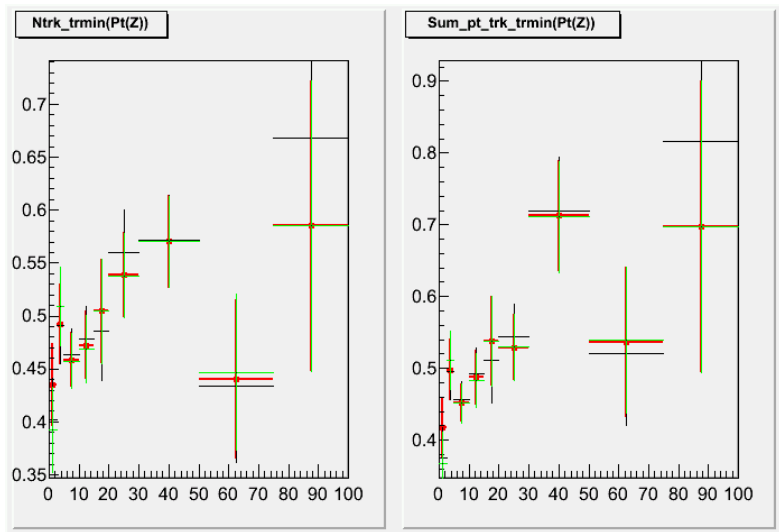
Small discrepancy due to 11 events missing from ESD sample (failed jobs).

ESD vs D3PD: transverse max. region



Small discrepancy due to 11 events missing from ESD sample (failed jobs).

ESD vs D3PD: transverse min. region



Small discrepancy due to 11 events missing from ESD sample (failed jobs).