Measurement of $\Phi^{*}$ variable in Drell-Yan $\eta$ events in p-p collisions at CMS

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Outline of Talk

➢ Compact Muon Solenoid
➢ $\phi_\eta^*$ Definition
➢ Data and MC Samples
➢ Selection Criteria
➢ Data-MC Validation
➢ Data-Driven Background Estimation
➢ Unfolding
➢ Conclusions
Compact Muon Solenoid

➢ The goal of CMS experiment is to investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, & particles that could make up darkmatter.
Motivation for $\Phi^*$ variable

- Drell-Yan process at LHC is one of most well studied, both theoretically and experimentally
- Produces non-zero transverse momentum ($p_{Z_T}$) of the dilepton system
- Direct measurements of the $Z/\gamma^*$ spectrum at low $p_{Z_T}$ is limited by experimental resolution & systematic uncertainties rather than by the statistics
- This affects the choice of bin widths and the ultimate precision of the $p_{Z_T}$ spectrum
- New variable was suggested, “$\Phi^*$” which has better experimental resolution & smaller sensitivity to experimental systematic uncertainties.
- Depends only on the angles of the muon trajectories


\[ \Phi_{\eta}^* = \tan \left( \varphi_{\text{acop}}/2 \right) \sin \left( \theta_{\eta}^* \right) \]

- \varphi_{\text{acop}} = (\pi - \Delta \Phi)
  - \Delta \Phi: azimuthal opening angle between two leptons

- \theta_{\eta}^*: scattering angle of the leptons w.r.t. proton beam direction in rest frame of dilepton system

- \cos \left( \theta_{\eta}^* \right) = \tanh \left[ \left( \eta^- - \eta^+ \right)/2 \right]
  - \eta^- and \eta^+: pseudorapidities of the -vely & +vely charged leptons

- \Phi_{\eta}^* depends exclusively on directions of two lepton tracks

† D0 Collaboration, arXiv:1410.8052

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Analysis Flow Chart

DATA -> BGND SUBTRACTION -> UNFOLDING -> SIGNAL SIMULATION

Efficiency Correction

Muon momentum Scale correction

e-µ scale factor(data Driven method)

Lead µ (trig match): \( p_T > 30 \text{ GeV} \), \( |\eta| < 2.1 \)
Sub-leading µ : \( p_T > 20 \text{ GeV} \), \( |\eta| < 2.4 \)
60 GeV < \( M(\mu\mu) < 120 \text{ GeV} \)

Data theory comparison

PU re-weighting
Work in Progress, 19.485 fb$^{-1}$, $\sqrt{s}$=8TeV

Data/MC

Number of Events

$M_{jj}$

Data/MC

$Q_T$

Work in Progress, 19.485 fb$^{-1}$, $\sqrt{s}$=8TeV

Data/MC

Number of Events

$Z_T$

DA
Work in progress, 19.485 fb^{-1}, \sqrt{s} = 8 \, TeV
Sources of Background

➢ \( q\bar{q} \rightarrow \tau^+\tau^-+X \) : Dominant in the low and intermediate invariant mass region, \( \sim 15 \text{ GeV/c}^2 < M_{\mu\mu} < 70 \text{ GeV/c}^2 \).

➢ \( t\bar{t}+\text{jets} \) : muons are mainly due to the leptonic decays of W-bosons produced in top and anti-top decays. Dominant in the high-mass region of DY mass spectrum.

➢ **Di-bosons Production (WW, WZ and ZZ)** :
  \( Z \rightarrow \mu\mu, W \rightarrow \mu\nu \) can lead to two muons in the final state.

➢ **W + jets** : \( W \rightarrow \mu\nu \) having branching ratio of about 11%, can pose as a background, when one of the associated jets, fakes as muon. Production rate of W+jets events is large at the LHC energy.
Data Driven Background Estimation

- Level of Background is quite low \((10^{-3})\)

- Estimate the background to the signal channel from e-\(\mu\) sample.

\[
\frac{\text{Data} \rightarrow e\mu}{\text{Data} \rightarrow \mu\mu} = C = \frac{\text{MC} \rightarrow e\mu}{\text{MC} \rightarrow \mu\mu} \quad \text{[Here C is a constant]}
\]

\[
\Rightarrow \text{Data} \rightarrow \mu\mu = \frac{\text{MC} \rightarrow \mu\mu}{\text{MC} \rightarrow e\mu} \times \text{Data} \rightarrow e\mu
\]

- Event Selection: “Good” electron-muon pair, close to \(Z_{\text{mass}}\) peak was selected.
  - \(60 < M_{ll} < 120\) (for “Z” candidate)

- Kinematical Cuts:
  - muon: \(P_T > 25\ \text{GeV}, \ |\eta| < 2.1\)
  - electron: \(P_T > 20\ \text{GeV}, \ |\eta| < 2.4\)
Background Estimation

Work in Progress, 19.485 fb⁻¹, √s=8TeV

![Graphs showing background estimation](image)

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Unfolding $\Phi^*$ Spectrum in data

- Effects of detector resolution on $\Phi^*$ spectrum are corrected by unfolding.

$$x = A^{-1} b$$

$X$: True unfolded $\Phi^*$ distribution

$b$: Measured $\Phi^*$ distribution in data (reco $\Phi^*$)

$A$: Response matrix, describes detector behavior determined from MC

Work in Progress....
**ATLAS Results**

ATLAS Results, 4.6 fb$^{-1}$, $\sqrt{s}=7$ TeV

- $e^+e^-$ Data 2011
- $\mu^+\mu^-$ Data 2011
- RESBOS

$\sqrt{s} = 7$ TeV
$|\eta^\ell| < 2.4$
$p_T^\ell > 20$ GeV
$66$ GeV $< m_{\ell\ell} < 116$ GeV

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**CMS Results**

Work in Progress, 19.485 fb$^{-1}$, $\sqrt{s}=8$ TeV

- Data
- RESBOS

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**Work in Progress....**
Conclusions

➢ Presented the preliminary results for the $\phi_{\eta}^*$ measurement at $\sqrt{s} = 8$ TeV for integrated luminosity of 19.5 fb$^{-1}$.

➢ Data shows overall a good agreement with the Monte-Carlo.

➢ In the process of comparing the result of the measurement with generators like MCFM and FEWZ.

➢ Currently working on calculating the systematics uncertainties.
Thanks