Angular distributions of Drell-Yan events at CMS

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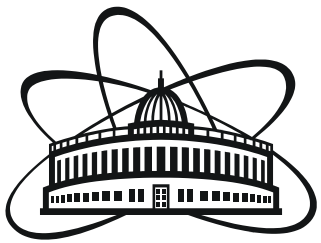
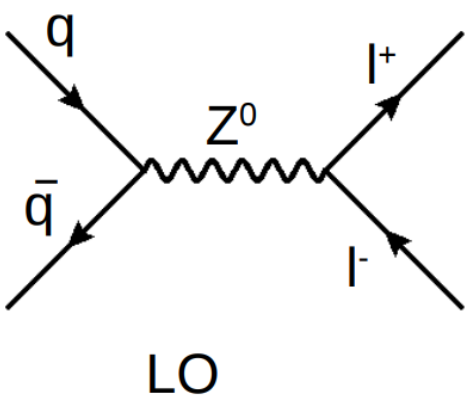
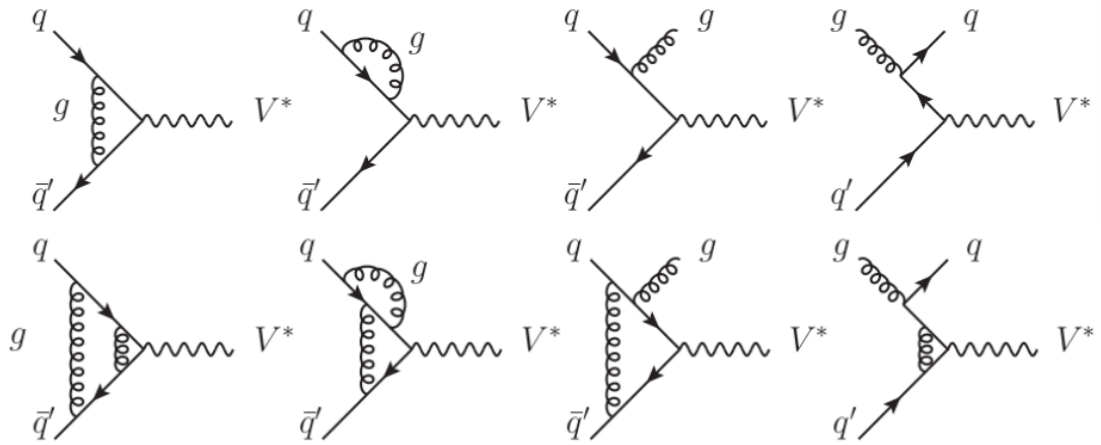


Motivation



LO



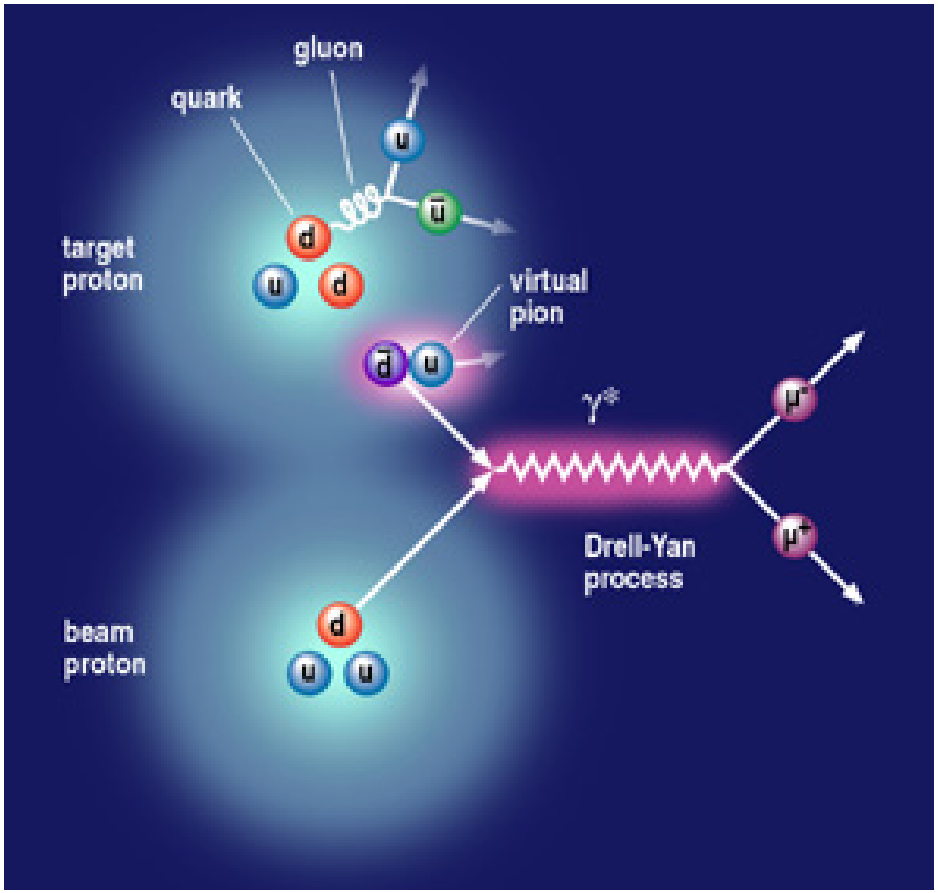
$p_T(\ell\ell) \sim 0$

$p_T(\ell\ell) \gg 0$

- Testing Standard model (SM)
- Constraining parton distribution functions (PDFs)
- Extracting parameters
- Background evaluation
- Testing different Monte Carlo models
- Testing production mechanism dynamics
- Precise measurements with a hadron collider!

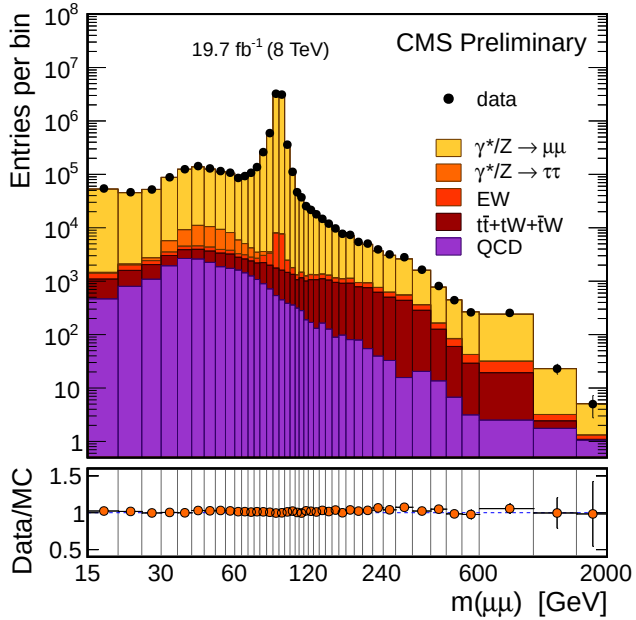
The Drell-Yan process

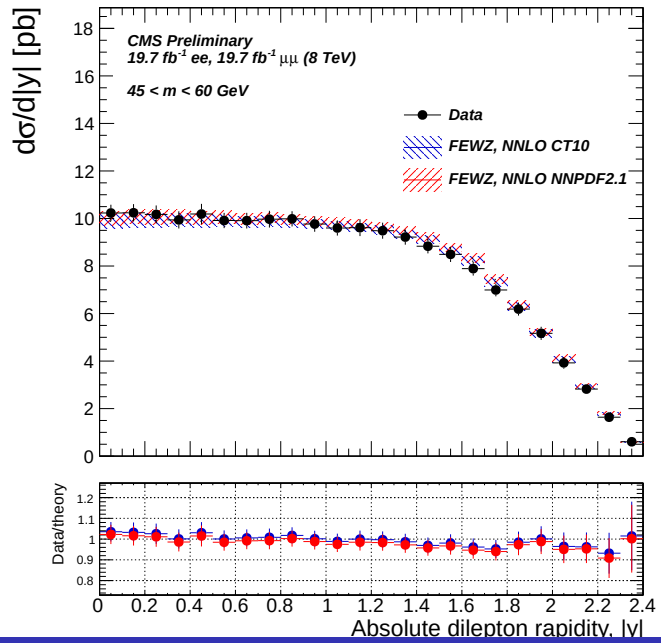
- The production of lepton pairs in pp-collisions is described by the s-channel exchange of $\gamma^* Z$
- Theoretical calculations are well established up to NNLO order
- Comparison of Data and MC provide stringent tests of QCD and significant constraints on the evaluated PDFs
  - DY is a major background for $t\bar{t}$ and diboson measurements as well as for searches for new physics (high mass dilepton resonances)



Double Differential Drell-Yan x-section at 8 TeV

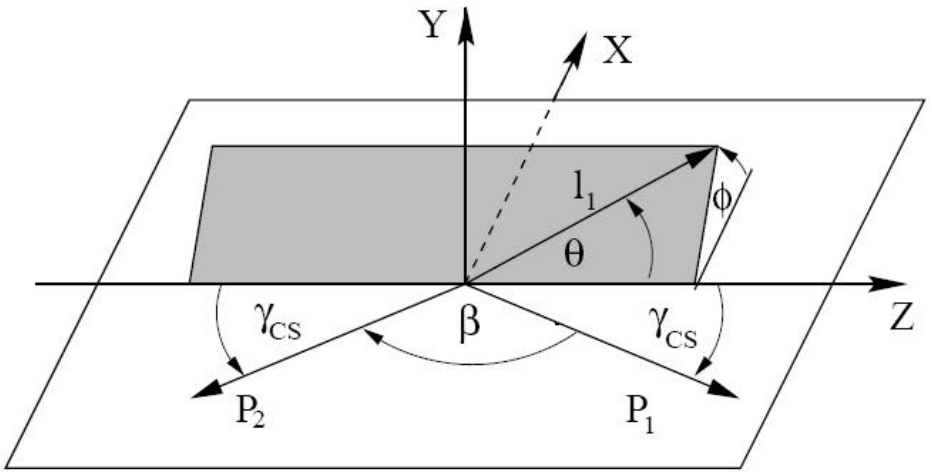
- Double differential invariant mass and rapidity cross section measured at 8 TeV using $19.7 fb^{-1}$ CMS-PAS-SMP-14-003, EPJC 75 (2015) 147
- Measured in 15 2000 GeV mass range and 0 to 2.4 absolute dilepton rapidity
- inclusive x-section in the Z-peak (60–120 GeV) – $\sigma(ll) = 1139.0 \pm 0.2(stat.) \pm 7.9(exp.syst.) \pm 25.2(th.syst.) \pm 29.6(lumi.)$
- $\tau^+\tau^-$ and QCD dijets are the dominant sources of background below the Z peak and $t\bar{t}$ is dominant at high mass
- Measurements are compared to NNLO and NLO predictions
- Results are in good agreement with SM predictions (see A. Lanev talk)





Angular Coefficients

The lepton angular distribution of the Drell-Yan process in the γ/Z rest frame (Collins-Soper frame) can be expressed as follows:



$$\frac{d^2\sigma}{dcos\theta^\star d\phi^\star} \propto (1+cos^2\theta^\star) + A_0\frac{1}{2}(1-3cos^2\theta^\star) + A_1 sin(2\theta^\star)cos\phi^\star + A_2\frac{1}{2}sin^2\theta^\star cos(2\phi^\star) + A_3 sin\theta^\star cos\phi^\star + A_4 cos\theta^\star + A_5 sin^2\theta^\star sin(2\phi^\star) + A_6 sin(2\theta^\star)sin\phi^\star + A_7 sin\theta^\star sin\phi^\star$$

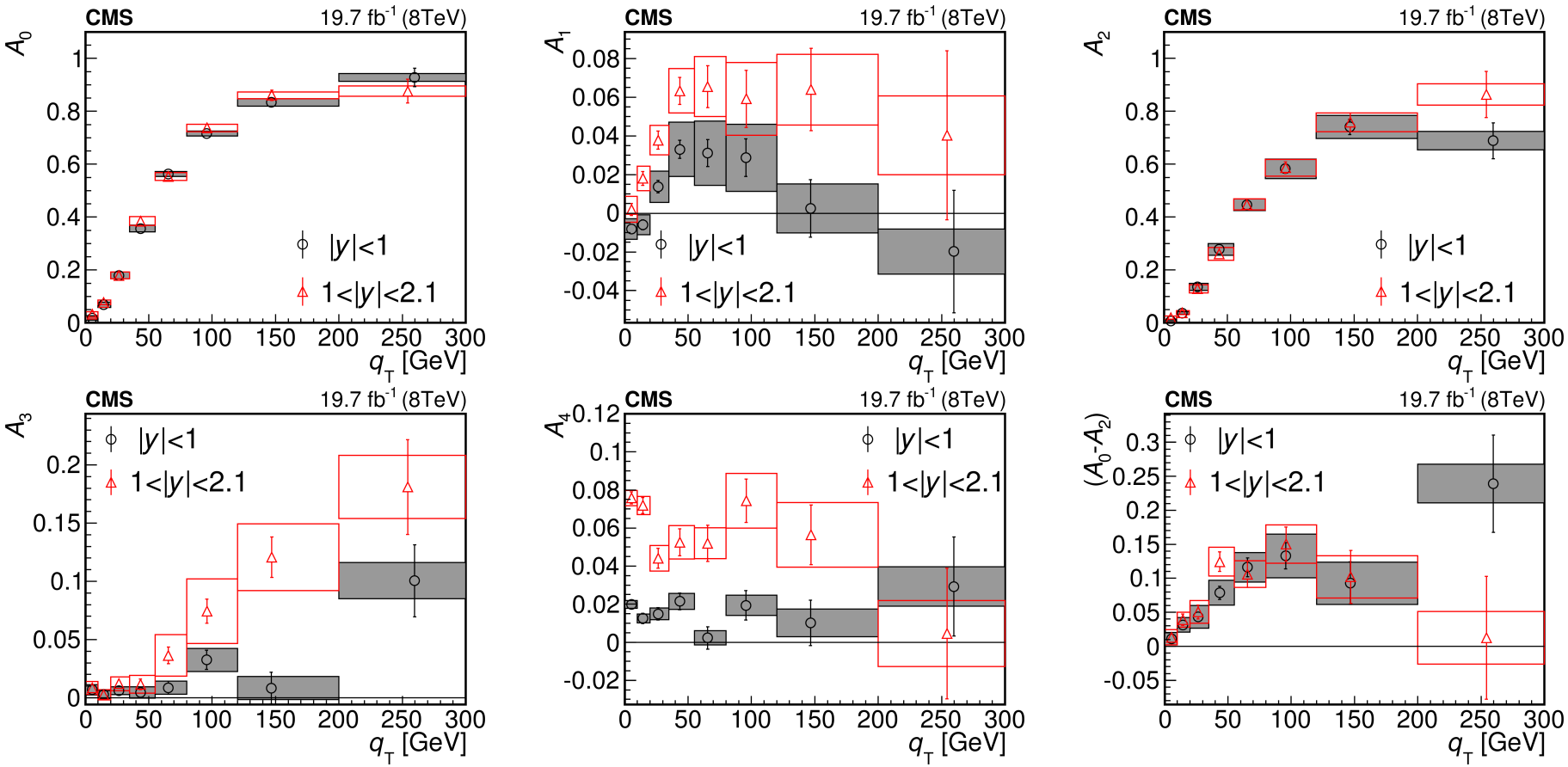
, where $\theta^\star$ and $\phi^\star$ are the polar and azimuthal angles of μ^- in the Collins-Soper frame.

If integrate over $\phi^\star$:

$$\frac{d\sigma}{dcos\theta^\star} \propto \frac{3}{8}(1+cos^2\theta^\star) + A_{FB}cos\theta^\star$$

, where A_{FB} is the Forward-Backward Asymmetry.

Angular Coefficients at 8 TeV



Measured at 8 TeV for the invariant mass range from 60 to 120 GeV using 19.7 fb^{-1} of data as a function of p_T and rapidity.

Phys. Lett. B Vol. 750, 2015, pp. 154-175

Angular Coefficients

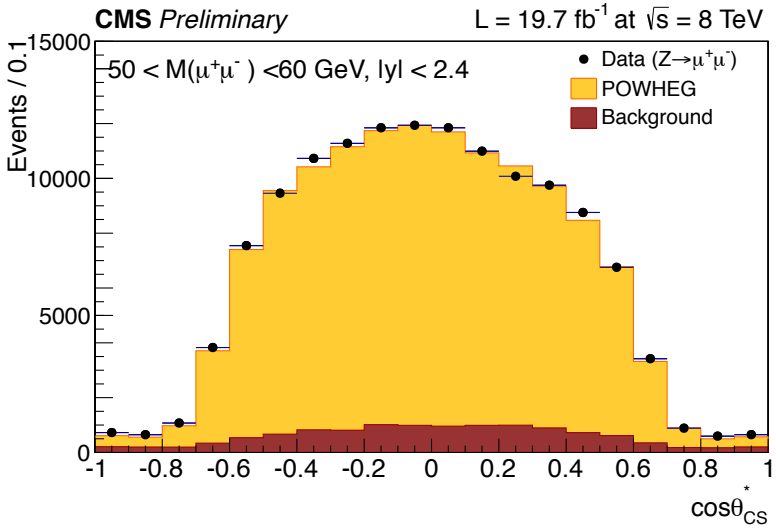
- At LO only A_4 is non-zero (proportional to the A_{FB})
- $A_0 \sim A_2$ – Lum-Tung relation violated at high p_T
- $A_0 - A_2$ related to the Z-boson polarisation
- $A_3 - A_6$ sensetive to V-A contributions
- A strong rapidity dependence observed

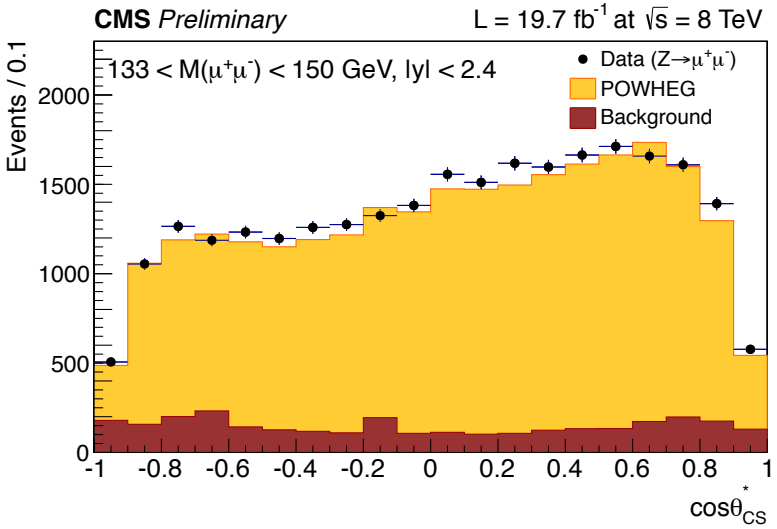
Can extend the measurement by:

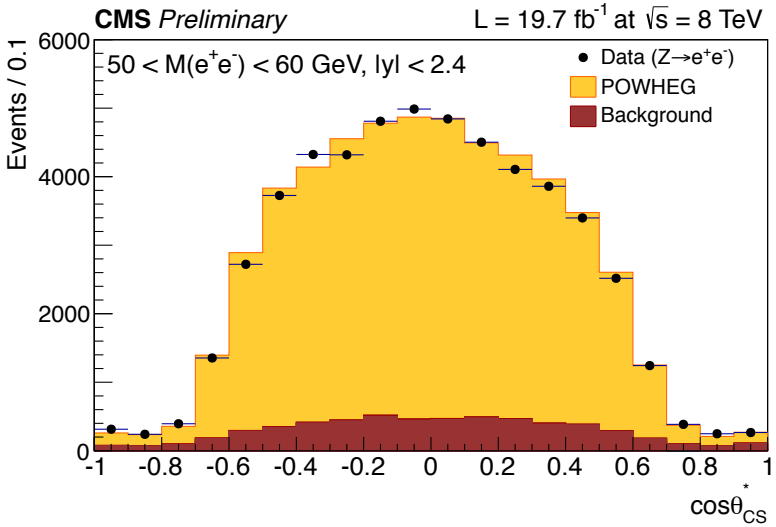
- Measure coefficients outside of the Z peak
- Introduce additional coefficients ($A_i cos^4\theta^s tar$ and $A_i cos^3\theta^s tar$ will be sensetive to graviton contributions)
- Measure coefficients for qg and $q\bar{q}$ production mechanisms separetely

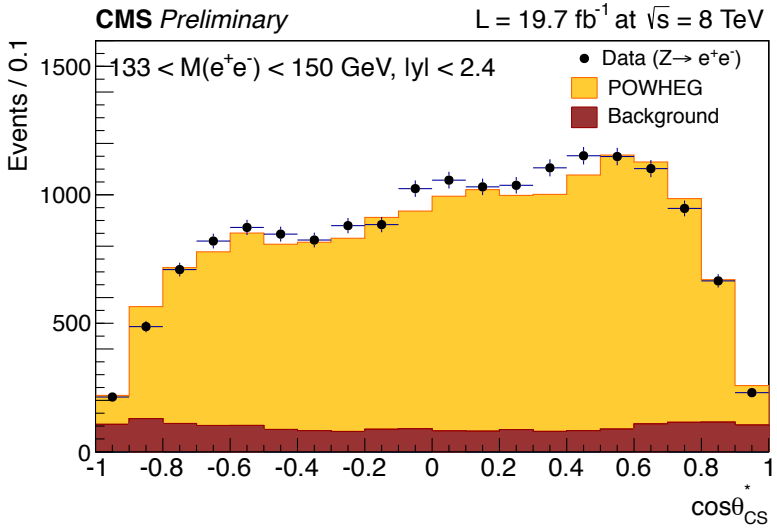
13 TeV analysis is ongoing (with V. Shalaev, JINR)

The $cos\Theta^{\star}_{CS}$ distribution



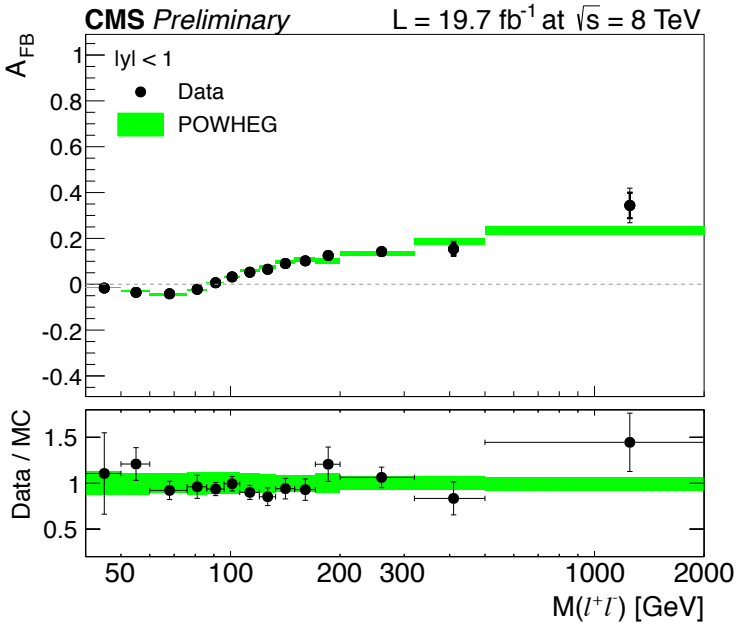


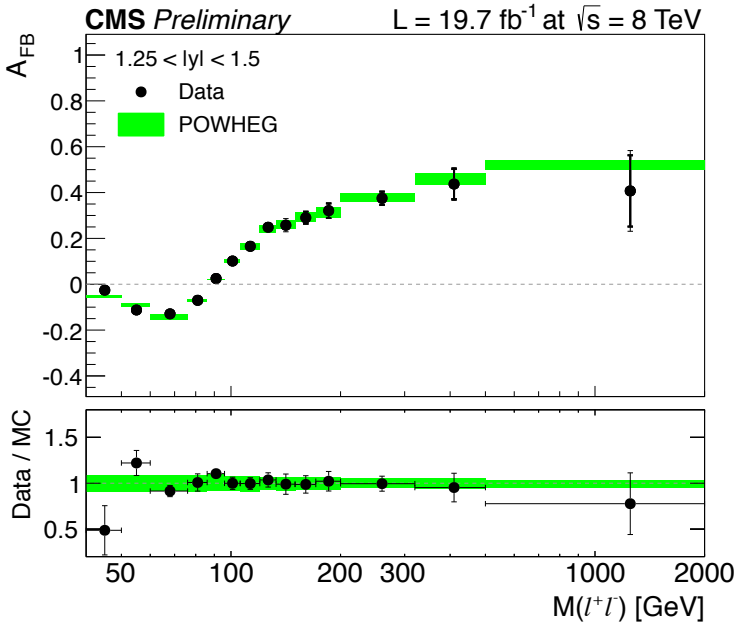


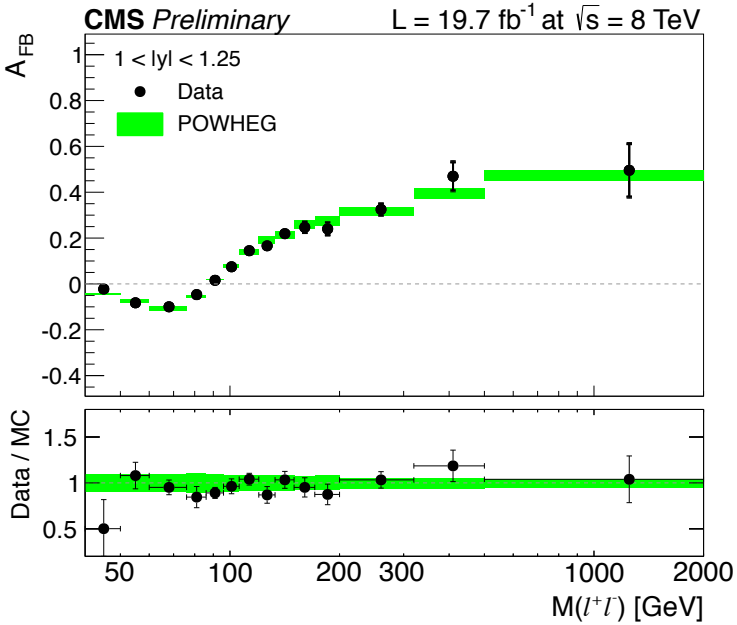


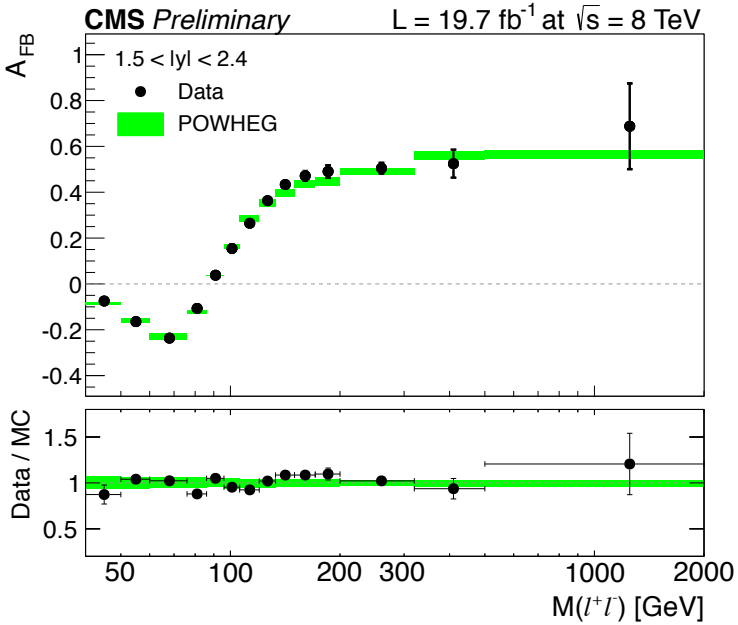
The $cos\Theta^{\star}_{CS}$ distribution for $\mu^+\mu^-$ (top) and e^+e^- (bottom) events. The left (right) plots correspond to the events in $50 < M < 60\ GeV$ ($133 < M < 150\ GeV$)

The combined A_{FB} distribution at 8 TeV

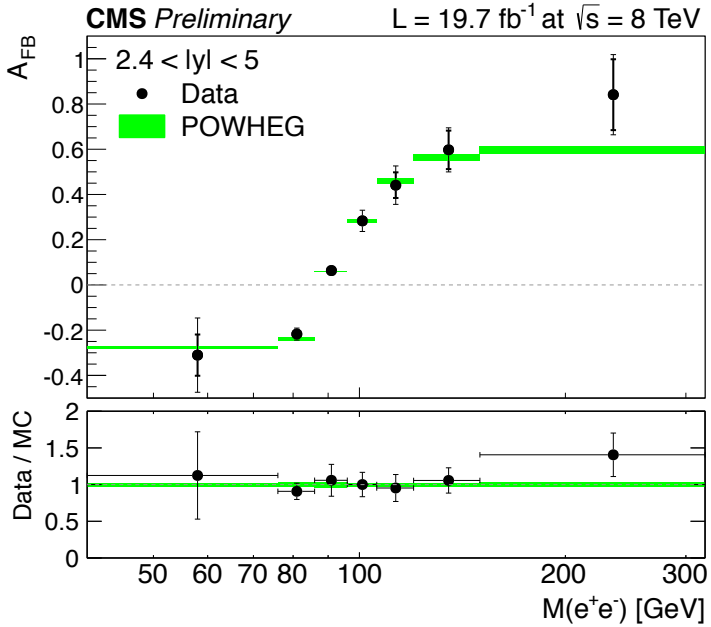


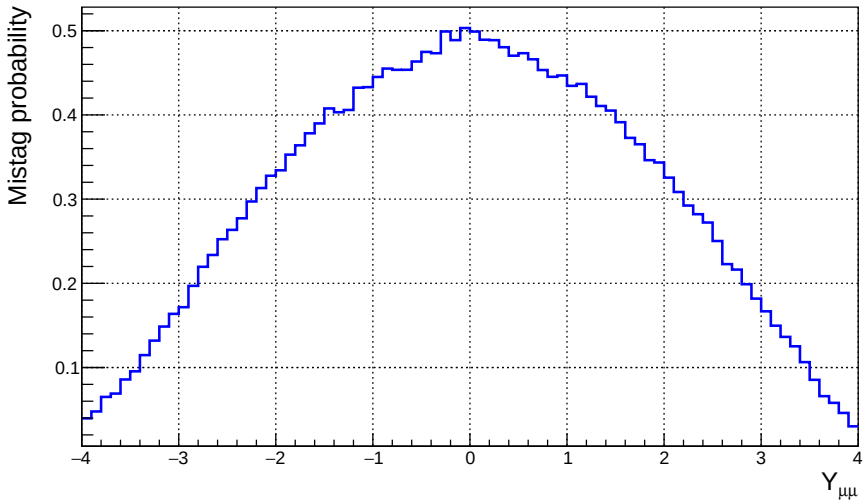






The unfolded A_{FB} distribution for $2.4 < |Y| < 5$ at 8 TeV

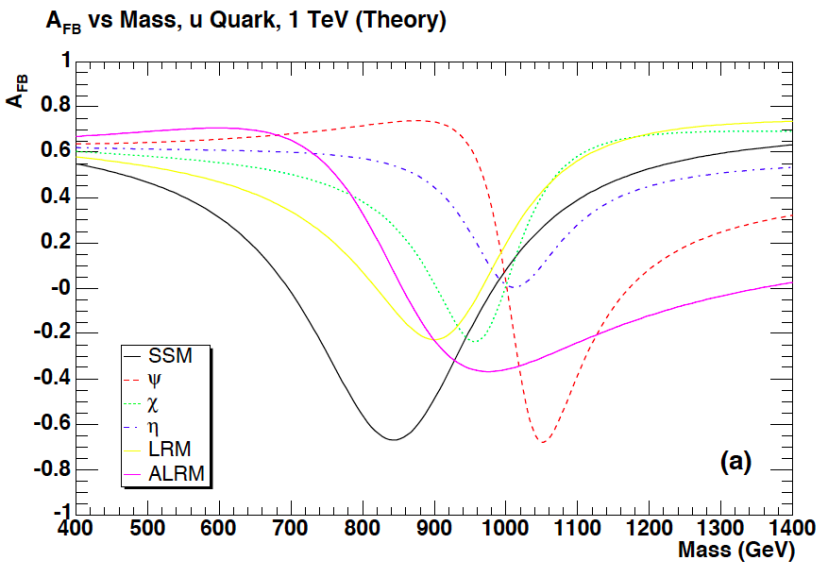


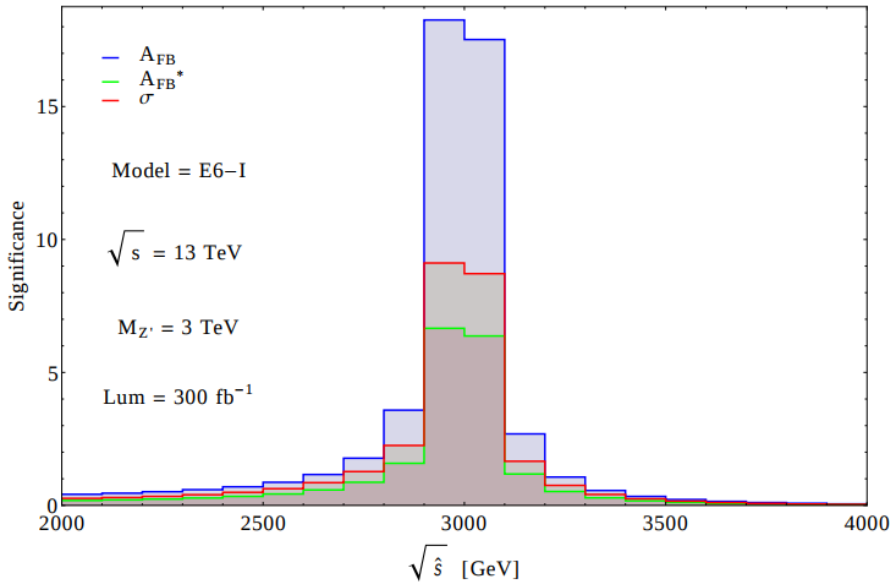


- Measured at 7 and 8 TeV and the 13 TeV (with U. Yevarouskaya, BSU) measurement is ongoing
- Mass range from 40 to 2000 GeV
- Rapidity range of up to 5
- Increased accepatance will improve measurement
- Measuremetns are in agreament with SM predictions

SMP-14-004, EPJC 76 (2016) 325

A_{FB} Measurements



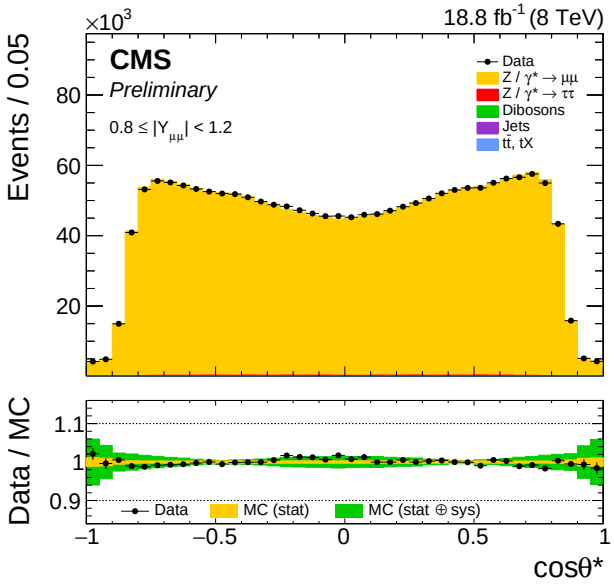


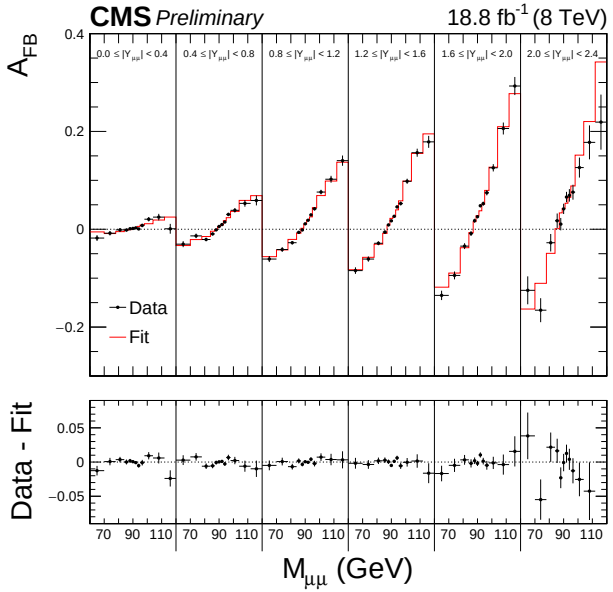
Usualy considered as a way to discriminate between different Z' models

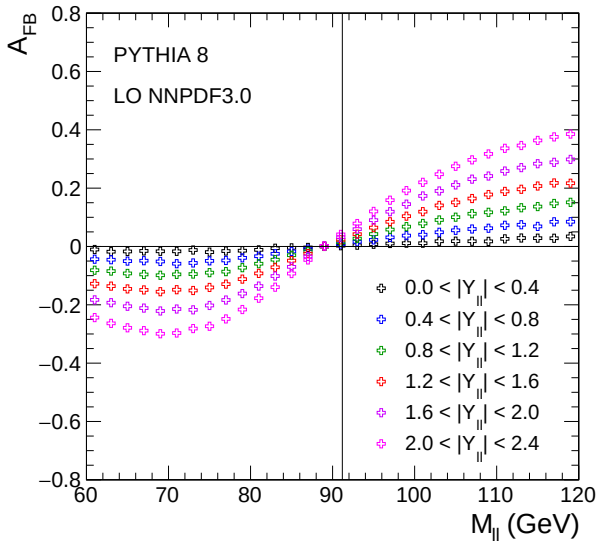
For some of the Z' models A_{FB} sensetivity is larger then the one of the invariant mass spectra studies.

Can also provide additional information for non-resonant signals. JHEP01(2016)127

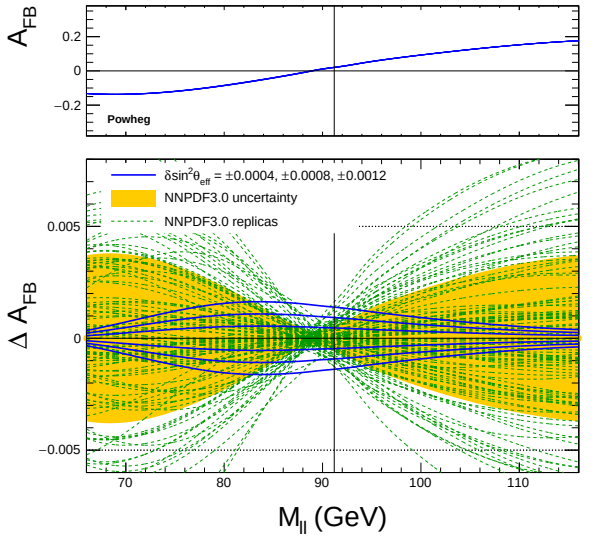
Weak mixing angle using A_{FB} at 8 TeV





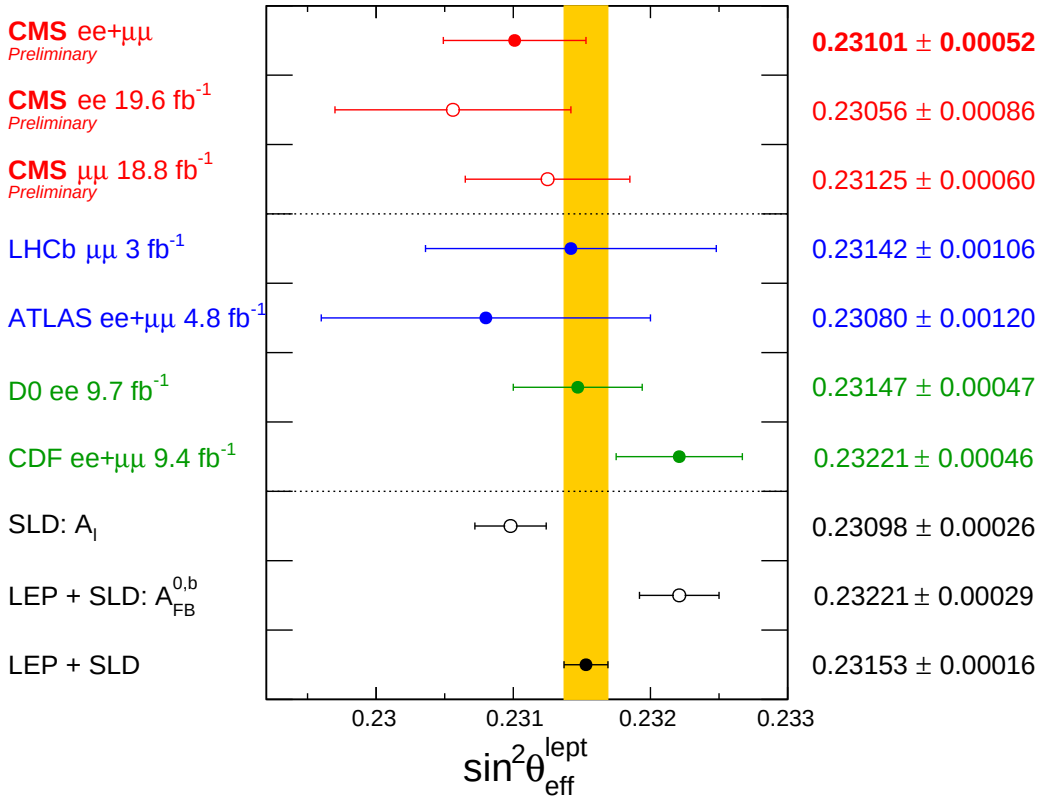


- $\sim 19\ fb^{-1}$ of 8 TeV data used
- The statistical and systematic uncertainties are significantly reduced
- Fit of experimental A_{FB} with theory
- CMS-PAS-SMP-16-007



Weak mixing angle using A_{FB} at 8 TeV (II)

- One of the most precise measurements
- PDF are constrained in-situ
- $sin^2\theta^{lept}_{eff} = 0.23101 \pm 0.00036(stat) \pm 0.00018(syst) \pm 0.00016(theory) \pm 0.00030(pdf)$
- CMS-PAS-SMP-16-007
- Can reach better precision then LEP+SPD after LHC and CMS upgrade CMS-PAS-FTR-17-001



L_{int}	$\delta_{stat}[10^{-5}]$		$\delta^{nominal}_{nnpdf3.0}[10^{-5}]$		$\delta^{constrained}_{nnpdf3.0}[10^{-5}]$	
(fb^{-1})	$\|\eta\| < 2.4$	$\|\eta\| < 2.8$	$\|\eta\| < 2.4$	$\|\eta\| < 2.8$	$\|\eta\| < 2.4$	$\|\eta\| < 2.8$
10	76	51	75	57	39	29
100	24	16	75	57	27	20
500	11	7	75	57	20	16
1000	8	5	75	57	18	14
3000	4	3	75	57	15	12
19	43		49		27	
19 (from [1])	44		54		32	

Conclusion

- Differential and double differential DY cross sections measured 13 and 8 TeV using 2.8 and 19.7 fb^{-1} of data
- $\sin^2\theta_W$ measured at 8 TeV
- A_{FB} measured at 7 and 8 TeV using 5 and 19.7 fb^{-1} of data respectivly 13 TeV measurements are ongoing
- Angular Coefficients are mesured at 8 TeV the 13 TeV analysis is ongoing
- Measurements are consistent with the Standard Model predictions within uncertainties
- Drell-Yan angular distribution measurements are a powerfull tool both for precision SM studies and BSM Physics searches
- Angular distribution studies will benefit from the CMS muon system upgrade

Backup Slides