Measurement of Forward-Backward Asymmetry in Drell-Yan processes of Dimuon Production in Proton-Proton collisions with the CMS experiment at the LHC

V. Shalaev, JINR
Dubna

AYSS-2018,25.04.2018

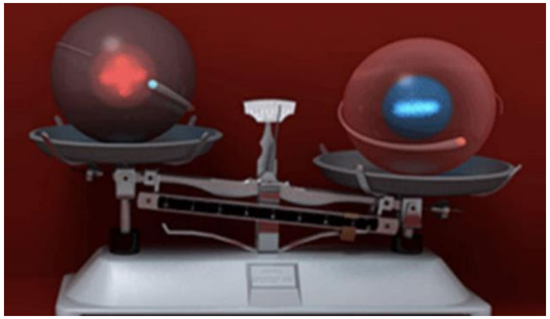
Outline

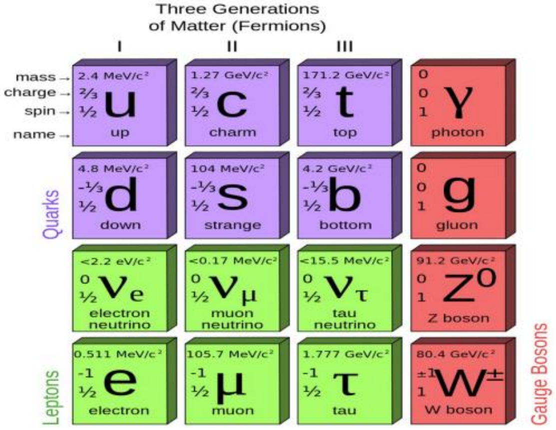
- Motivation
- Compact Muon Solenoid
- The Drell-Yan process
- The Forward-Backward asymmetry
- The asymmetry measurement at $\sqrt{s} = 8\ TeV$
- The asymmetry measurement at $\sqrt{s} = 13\ TeV$
- Conclusions

Motivation

Standard model problems:

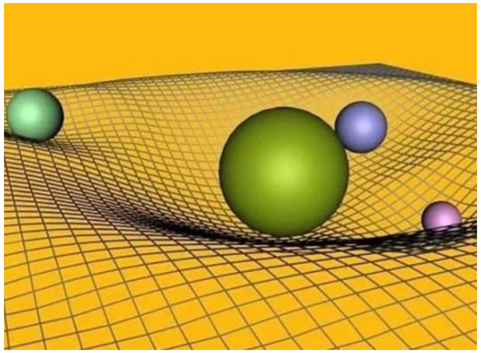
- Particles mass hierarchy

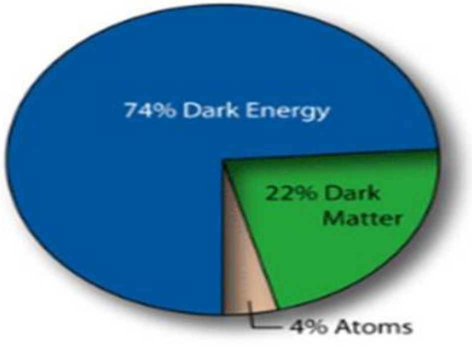




- CP Violation

- Fundamental interactions and Gravity association

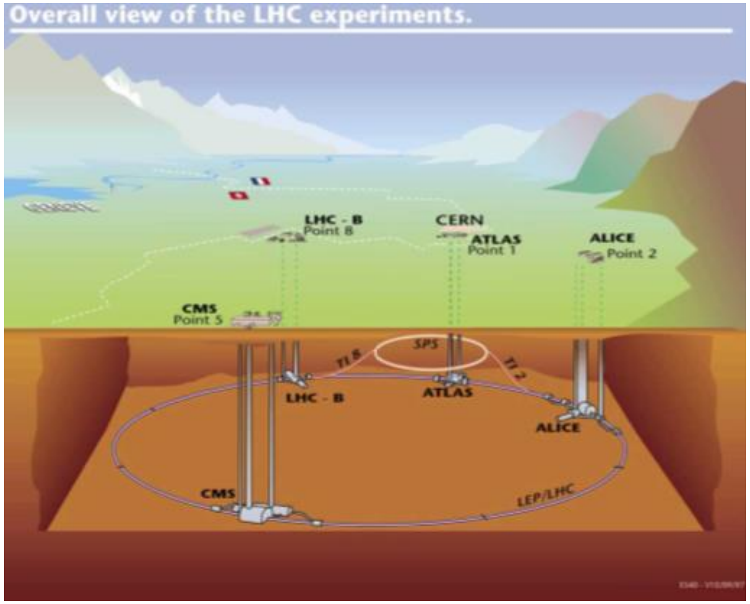


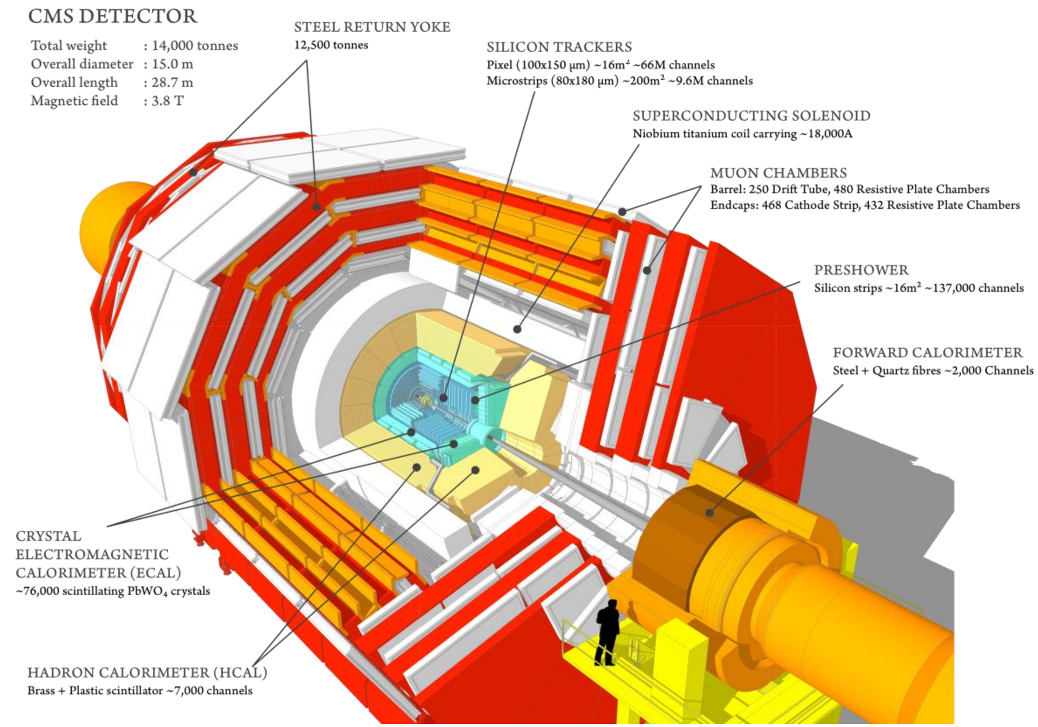


- Dark Matter and Dark Energy

Compact Muon Solenoid

- Length – 22 meters
- Diameter – 15 meters
- Weight – 14000 tons !

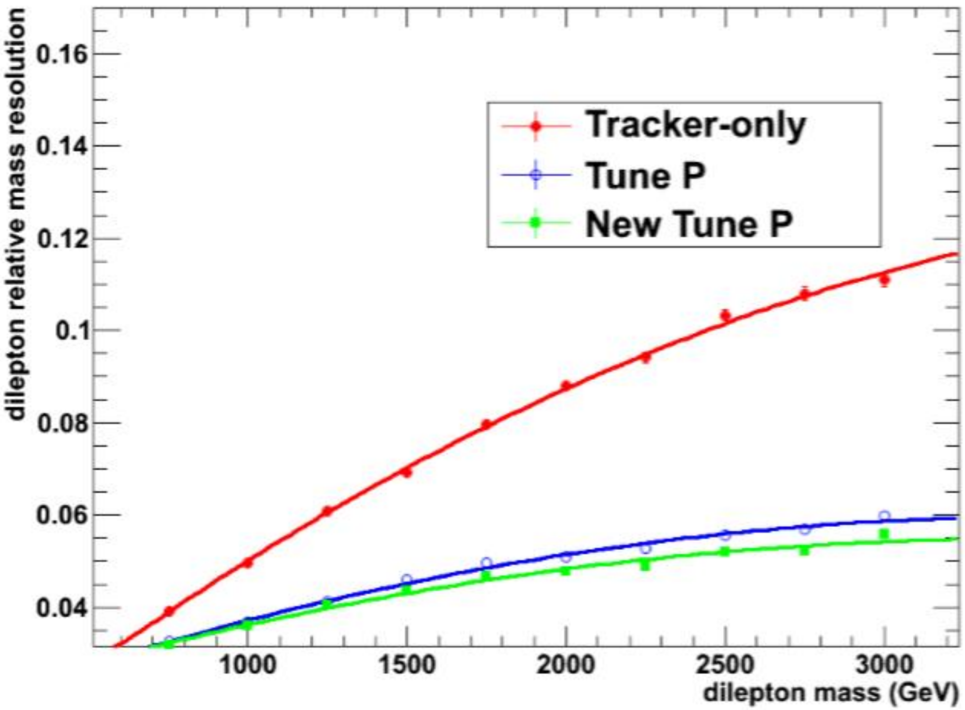




- L (pp) > $10^{34}\ cm^{-2}\ s^{-1}$
- E_{cm} (pp) = 13(14) TeV
- Number of electronic read channels ~ 10^8

CMS accomplishments

- Good momentum resolution (1.5% , $p_T < 100$ GeV) and reconstruction efficiency (< 1%)
- Mass resolution when measuring pairs of muons $\sim$ 1% (near by Z)
- High-precision measurement of muon charges
- Trigger rate of ~ 100Hz
- Wide acceptance |η| < 2.4, (−π < ϕ < π)
- Effective use of the criterion for the leptons isolation at high luminosity

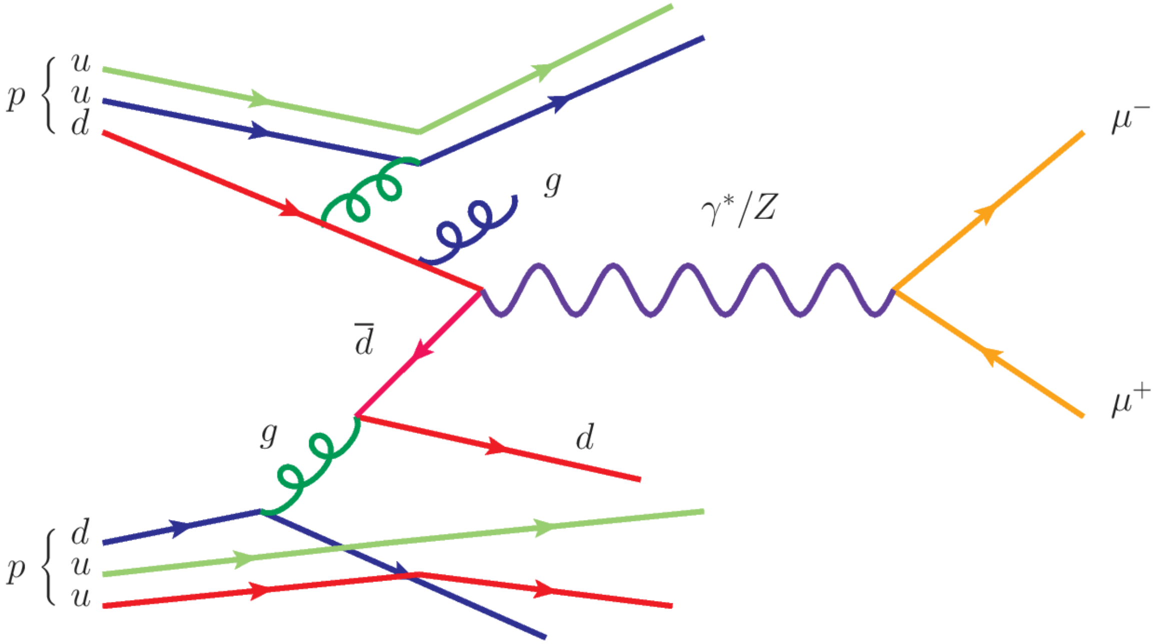


Mass resolution of lepton pairs as a function of the invariant mass for different reconstruction algorithms

The Drell-Yan process

…for checking the predictions of the Standard Model and searching for a new physics

- Differential cross section measurement
- The forward-backward asymmetry measurement
- The exploration of the spin structure of these processes



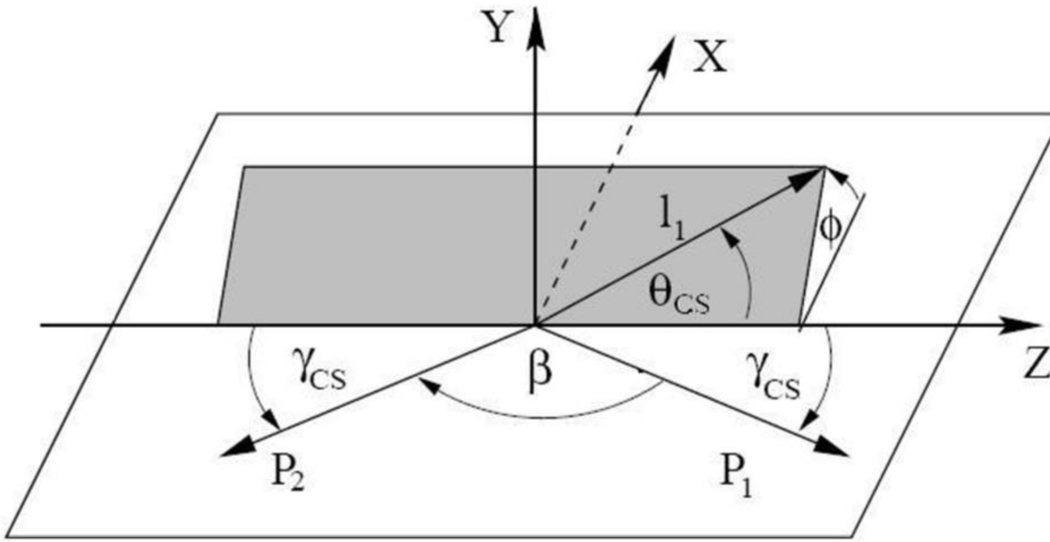
The Forward-Backward Asymmetry

The structure of weak currents in the Drell - Yan process causes the dependence of the cross section on the $cos\theta$, which leads to asymmetry in the emission angle of the lepton (antilepton) with respect to the quark (antiquark) in a leptons center of mass system.
This asymmetry can be defined as:

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

σ_F - the lepton cross section in Drell – Yan process to «Forward» direction ($cos\theta \geq 0$).
σ_B - the lepton cross section in Drell – Yan process to «Backward» direction ($cos\theta \leq 0$) .

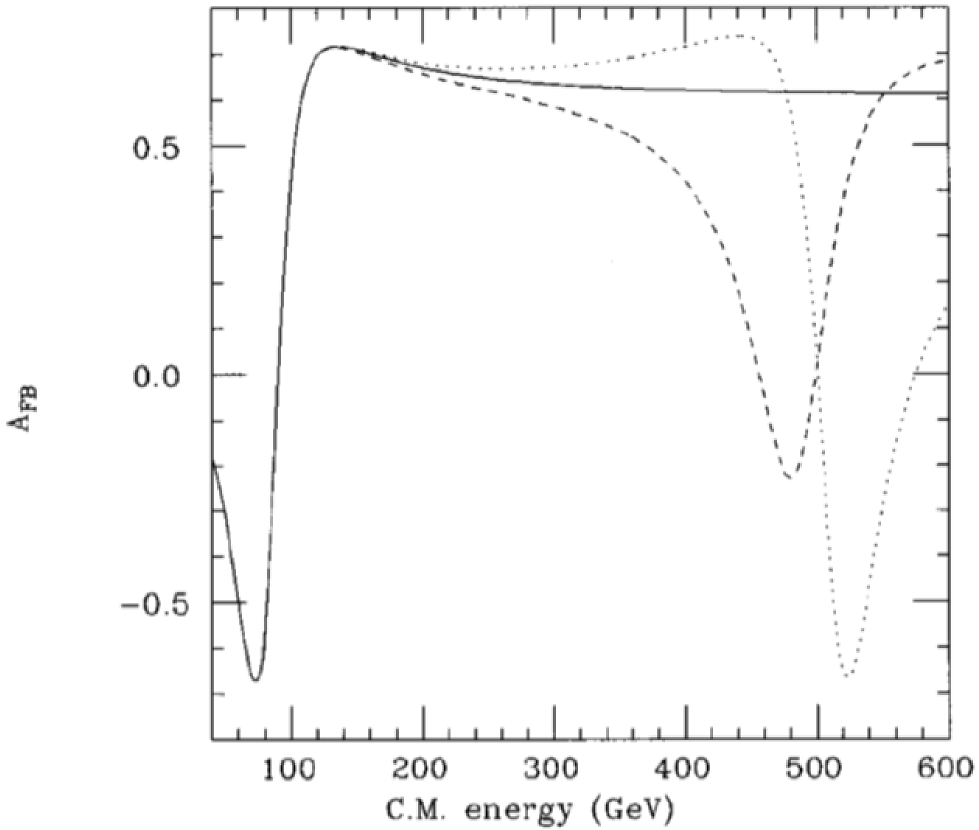
$$\sigma_F = \int_0^1 \frac{d\sigma}{d(\cos\theta)} d(\cos\theta)$$
$$\sigma_B = \int_{-1}^0 \frac{d\sigma}{d(\cos\theta)} d(\cos\theta),$$



The coordinate system of Collins-Soper is chosen in such a way that the Z axis divides the angle between the interacting quarks in half

Why should we measure A_{FB}?

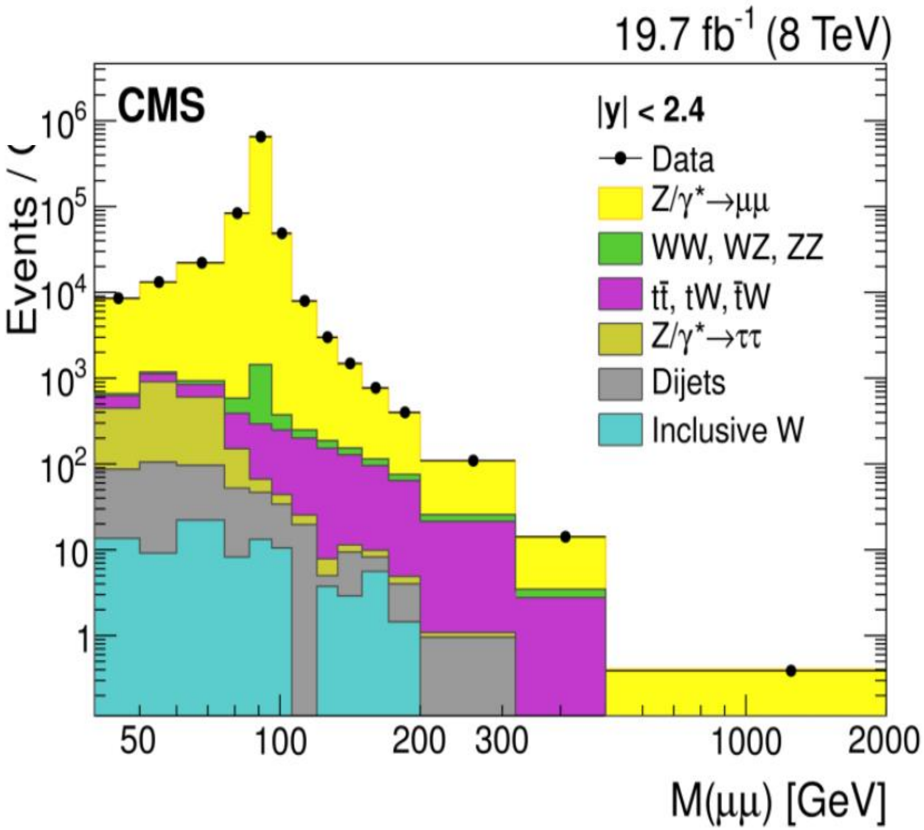
A_{FB} for DY process ($d\bar{d}$).
Solid line – Standard Model.
Dashed line – with Z_χ gauge boson.
Dotted line– with Z_ψ gauge boson.
(Phys.Rev.D. – 1987 – Vol.35, No 7. Pp. 2244-2247)



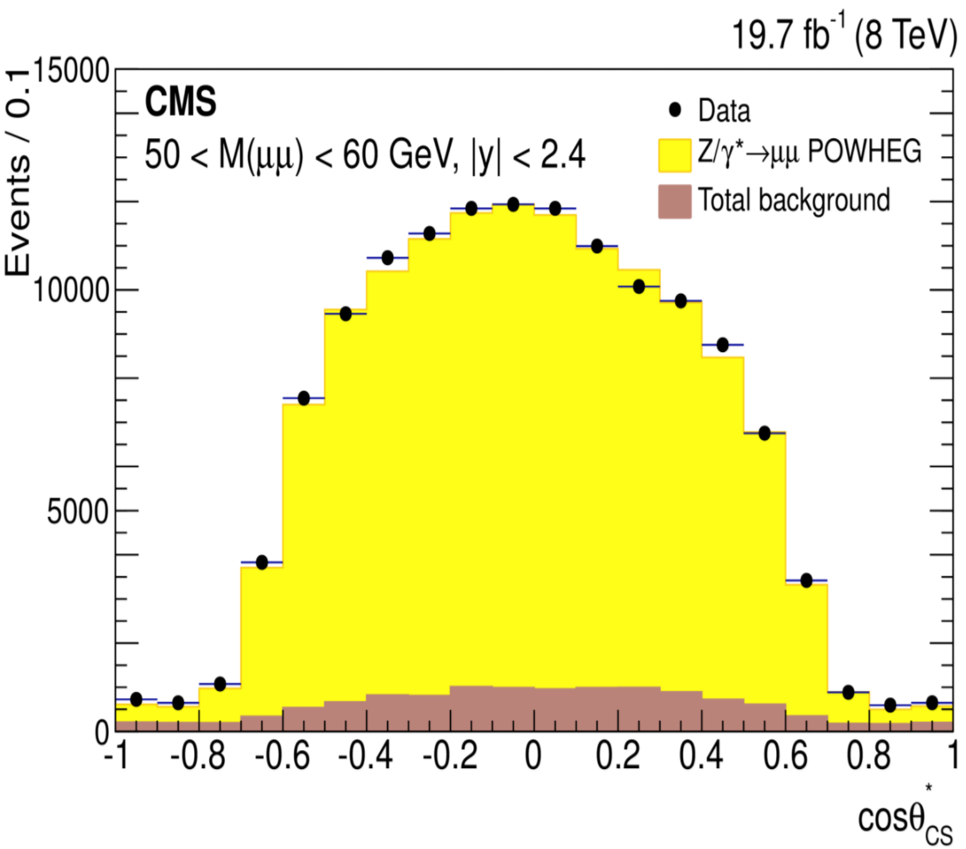
- Dependence A_{FB} on the decay width and mass of the new gauge bosons causes the sensitivity of A_{FB} to the «new» physics.
- Dependence A_{FB} on rapidity of new hypothetical gauge bosons allow us to discriminate between different theoretical assumptions.
- Measurement A_{FB} allows us to constrain parton distribution functions.

Dimuon invariant mass and $\cos\theta^*_{cs}$ at $\sqrt{s}$ = 8 TeV

Dimuon invariant mass distribution with background estimate from data at $\sqrt{s}$ = 8 TeV.
(Eur. Phys. J. C 76 (2016) 325)



Events distribution by $\cos\theta^*_{cs}$ with background estimate from data at $\sqrt{s}$ = 8 TeV.
(Eur. Phys. J. C 76 (2016) 325)

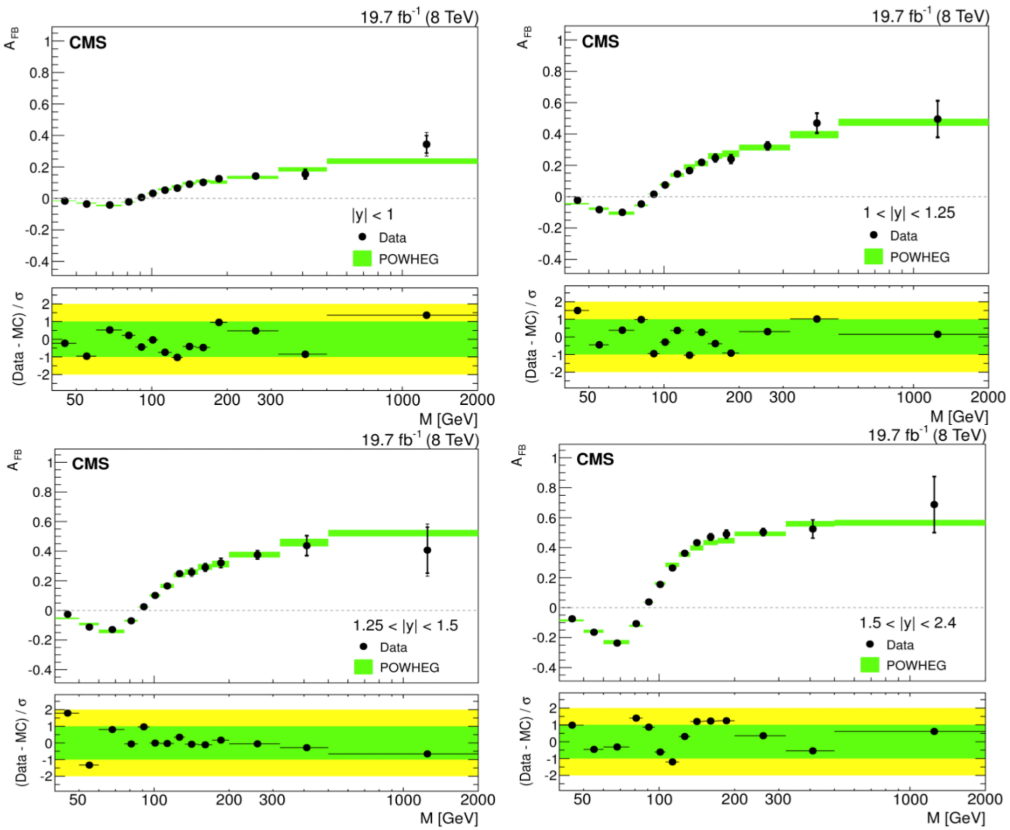


The Asymmetry measurement at $\sqrt{s}$ = 8 TeV.

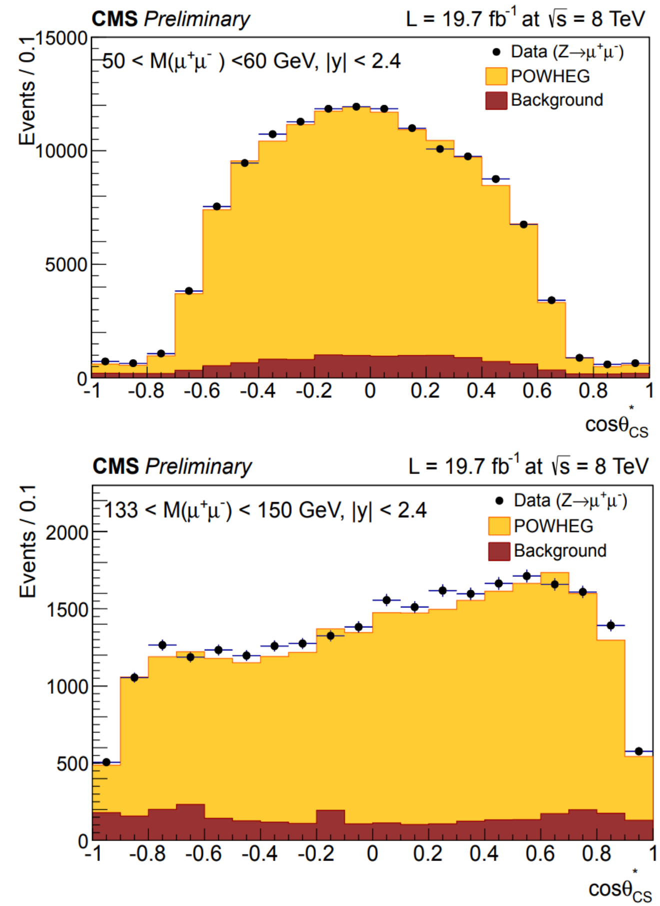
Used method of independent counting of the number of dilepton events.

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

N_F - Number of "Forward" events;
N_B - Number of "Backward" events;



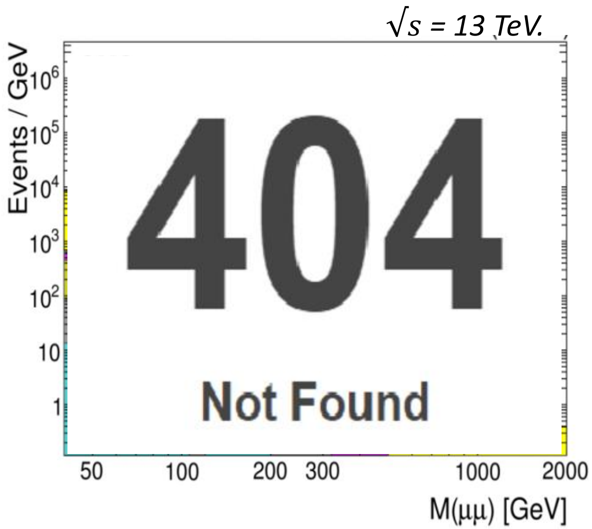
A_{FB} distribution of invariant mass and rapidity at $\sqrt{s}$ = 8 TeV. (Eur. Phys. J. C 76 (2016) 325)



Events distribution of $\cos\theta^*_{CS}$ and rapidity at $\sqrt{s}$ = 8 TeV. (Eur. Phys. J. C 76 (2016) 325)

The Asymmetry Measurement at $\sqrt{s}$ = 13 TeV

- Experimental data at $\sqrt{s}$ = *13 TeV* not published yet!



Software:

- CMSSW 8.2
- Root 5
- Grid
- CRAB 3

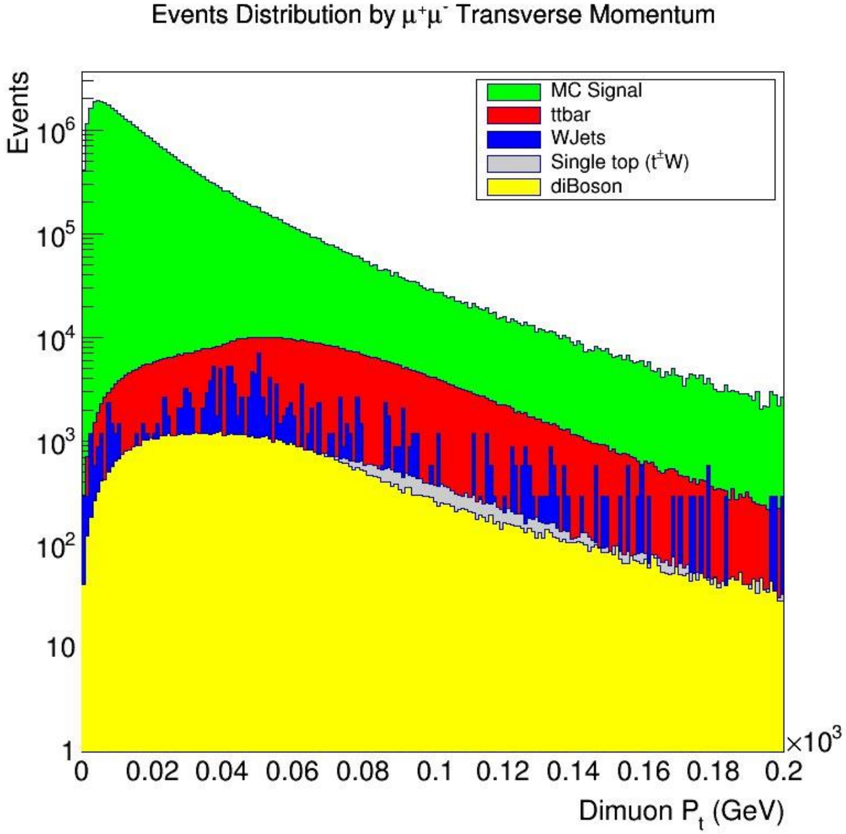
- MC-Modeling

MC Signal Samples (PYTHIYA 8): Mass binned sample 10<M<2000[GeV]

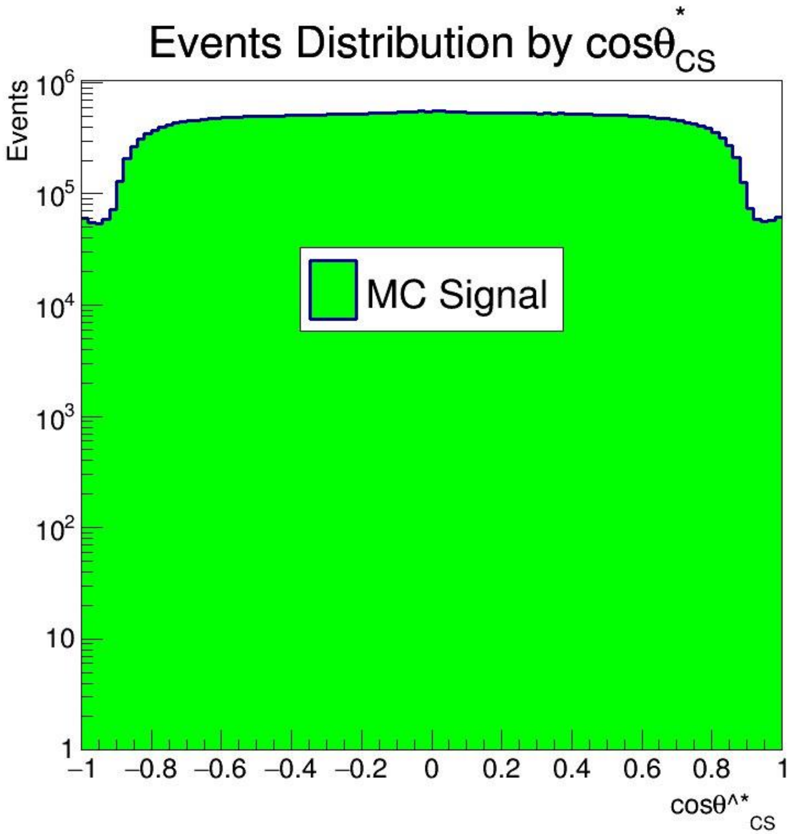
MC (aMC@NLO)	Dataset
DYMuMu (M10-50)	/DYJetsToLL_M-10to50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext1-v1/MINIAODSIM
DYMuMu (M50)	/DYJetsToLL_M-50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAOD v2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v1/MINIAODSIM
DYMuMu (M200-400)	/DYJetsToLL_M-200to400_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAOD v2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM
DYMuMu (M400-500)	/DYJetsToLL_M-400to500_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAOD v2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM
DYMuMu (M500-700)	/DYJetsToLL_M-500to700_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAOD v2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM
DYMuMu (M700-800)	/DYJetsToLL_M-700to800_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAOD v2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM
DYMuMu (M800-1000)	/DYJetsToLL_M-800to1000_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16MiniAOD v2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM
DYMuMu (M1000-1500)	/DYJetsToLL_M-1000to1500_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16Mini AODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM
DYMuMu (M1500-2000)	/DYJetsToLL_M-1500to2000_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/RunIISummer16Mini AODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TrancheIV_v6_ext2-v2/MINIAODSIM

Events Distribution By P_t and $\cos\theta^*_{cs}$, $\sqrt{s}$ = 13 TeV. (MC)

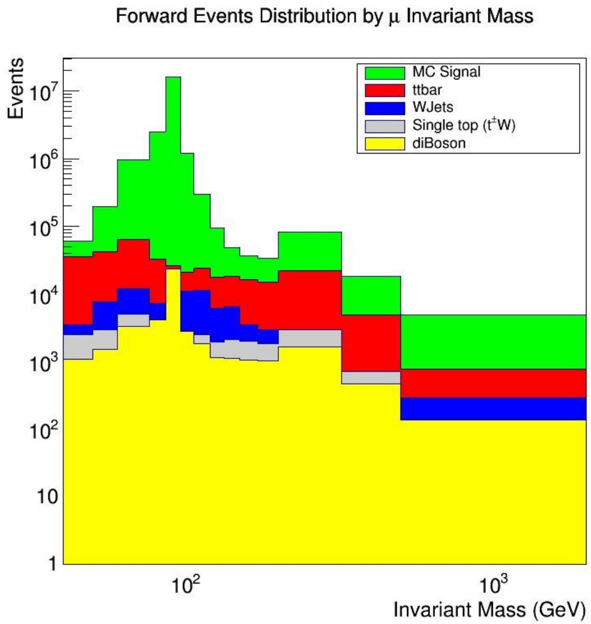
Events distribution by P_t for a dimuon (with a background)

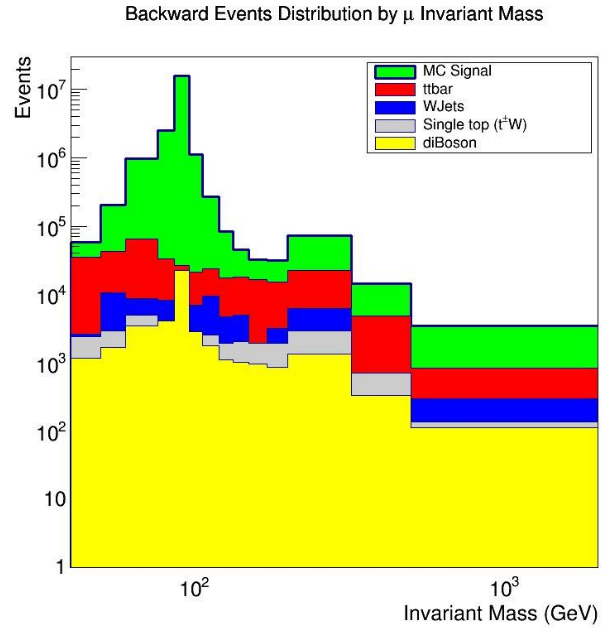


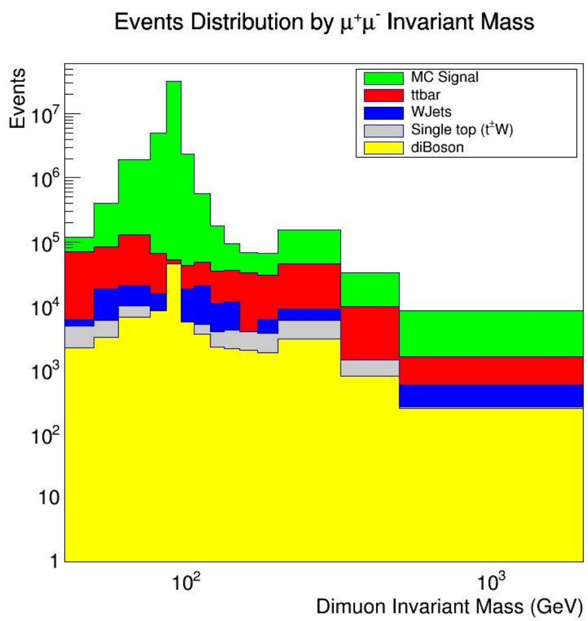
The distribution of the number of events by the $\cos\theta^*_{cs}$



Event Distribution By M_{μ} , $\sqrt{s}$ = *13 TeV.* (MC)



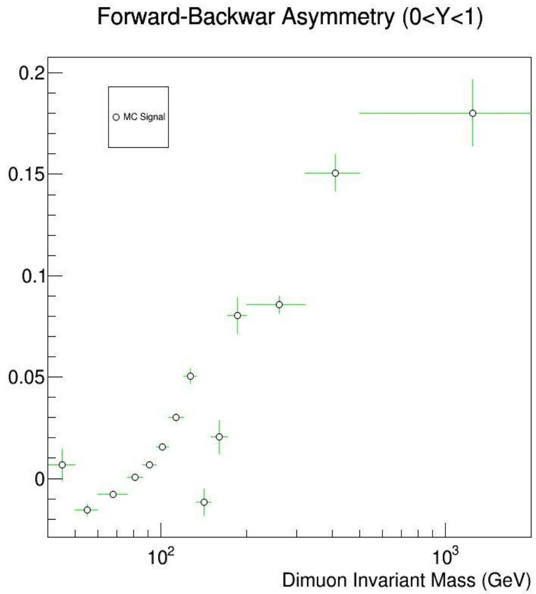


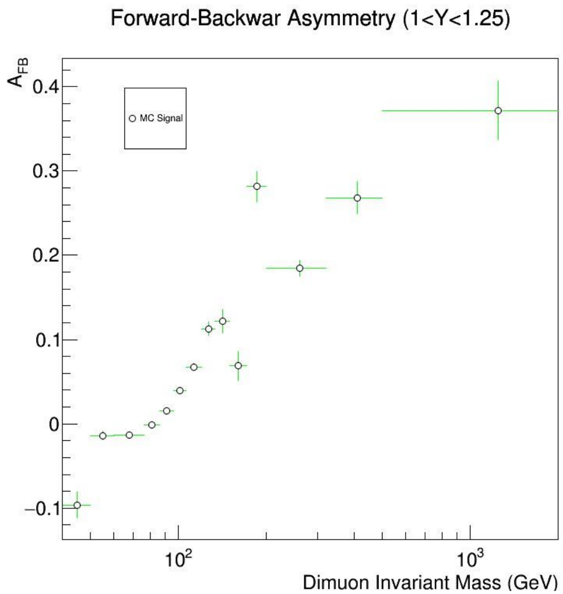


Forward (left) and Backward (right) events distribution by invariant mass with a background

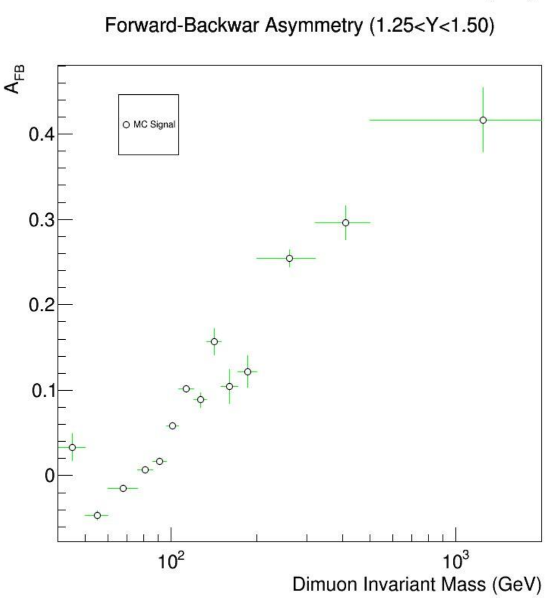
Events distribution by invariant mass (Forward + Backward) with a background

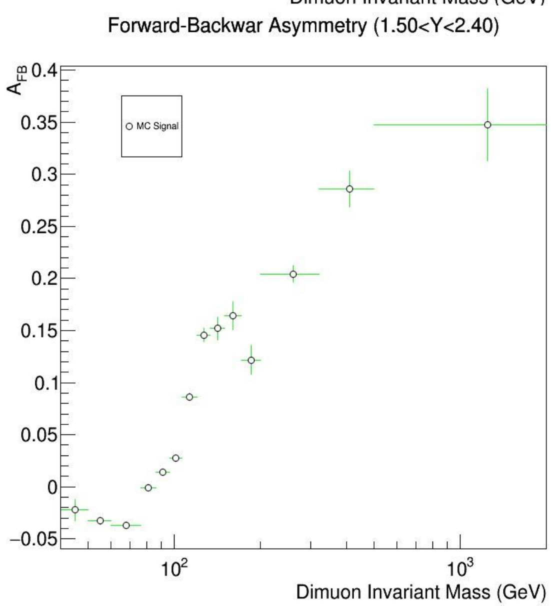
Forward-Backward Asymmetry, $\sqrt{s}$ = 13 TeV. (MC)

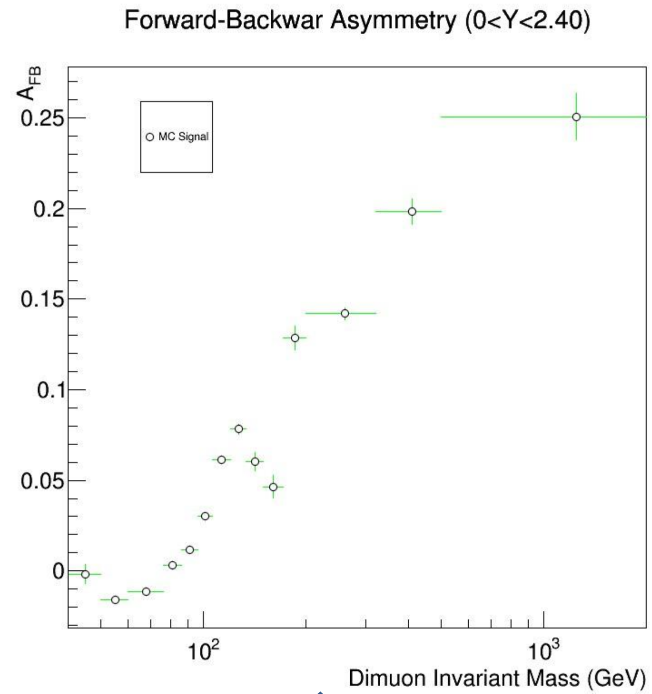




A_{FB} - depending on the invariant mass and rapidity with statistical errors







A_{FB} - depending on the invariant mass and rapidity with statistical errors (0<Y<2.4)

Conclusions and perspectives

Results

- A_{FB} was measured with CMS at $\sqrt{s}$ = *7 and 8 TeV.*
- Modeling for data at $\sqrt{s}$ = *13 TeV.* for P_t, $M_{\mu\mu}$, $cos\theta^*_{cs}$ and A_{FB} distributions were obtained
- The background was estimated
- CMSSW experimental software framework was studied.

Perspective

- Correction applying
- Obtain distributions for data at $\sqrt{s} = 13\ TeV$
- Use the distributions obtained in modeling to correct the experimental data

спасибо 谢谢

GRACIAS

THANK YOU

ありがとうございました MERCI

DANKE धन्यवाद

شُكراً OBRIGADO

Tight Muon Selection

- χ^2/ndof of the global-muon track fit < 10
- At least one muon-chamber hit included in the global-muon track fit
- Muon segments in at least two muon stations
- Its tracker track has transverse impact parameter dxy < 2 mm w.r.t. the primary vertex
- The longitudinal distance of the tracker track wrt. the primary vertex is dz < 5 mm
- Number of pixel hits > 0
- Cut on number of tracker layers with hits >5
- $P_t > 20$ GeV , $|\eta| < 2.4$

- *To suppress hadronic punch-through and muons from decays in flight*
- *To suppress hadronic punch-through and muons from decays in flight.*
- *To suppress punch-through and accidental track-to-segment matches.*
- *To suppress cosmic muons and further suppress muons from decays in flight*
- *Loose cut to further suppress cosmic muons, muons from decays in flight*
- *To further suppress muons from decays in flight.*
- *To guarantee a good pT measurement, for which some minimal number of measurement points in the tracker is needed. Also suppresses muons from decays in flight.*

Muon channel

Systematic uncertainty	$\|y\|$ bins			
	0–1	1–1.25	1.25–1.5	1.5–2.4
Background	0.062	0.080	0.209	0.051
Momentum correction	0.006	0.015	0.020	0.022
Unfolding	0.001	0.003	0.004	0.003
Pileup reweighting	0.002	0.004	0.003	0.004
Efficiency scale factors	<0.001	0.002	0.003	0.005
PDFs	0.001	0.004	0.008	0.047
FSR	<0.001	0.001	0.001	0.002

The maximum value of the systematic uncertainty in AFBAFB as a function of MM from each source for different regions of |y|.