J/Ψ and Z analysis with different datasets

ATLAS and ZEUS conversion to CMS

Achim Geiser, Leonardo Olivi, Raphael Schwenzer and Yewon Yang

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Introduction to the project

- The main goal is to analyze data for J/Ψ and Z from ZEUS, CMS and ATLAS with one code.
- Each experiment has its own convention, hence it is useful to convert them into one standard format (CMS Run 2 format).
- ZEUS conversion was done by Raphael Schwenzer
- ATLAS 2012 conversion was done by Leonardo Olivi
- A similar conversion (with some changes) was done by Aritra Bal for ATLAS 2016.

Convert data from ZEUS to CMS

- ZEUS data is already in form of *n*-tuples.
- In general many variables just have to be renamed, e.g. $\texttt{Nmu} \mapsto \texttt{nMuon}$.
- Some variables do not exist in both *n*-tuples, e.g. we map $0 \mapsto \texttt{luminosityBlock}$, since it does not exist in ZEUS data, but in CMS it does.
- Other variables need to be calculated from several variables, e.g. the error of transverse momentum we get through

$$\texttt{Muperr} \cdot \sin(\texttt{Muth}) \mapsto \texttt{Muon\_ptErr}.$$

Convert data from ZEUS to CMS

Mapping Muon-quality

$$\overbrace{\texttt{Muon\_looseId} \equiv \texttt{true}}^{\text{CMS}} \iff \overbrace{\texttt{Muqual>0}}^{\text{ZEUS}}$$

$$\texttt{Muon\_softId} \equiv \texttt{true} \iff \texttt{Muqual>3}$$

$$\texttt{Muon\_mediumId} \equiv \texttt{true} \iff \texttt{Muqual>4}$$

$$\texttt{Muon\_tightId} \equiv \texttt{true} \iff \texttt{Muqual==6}$$

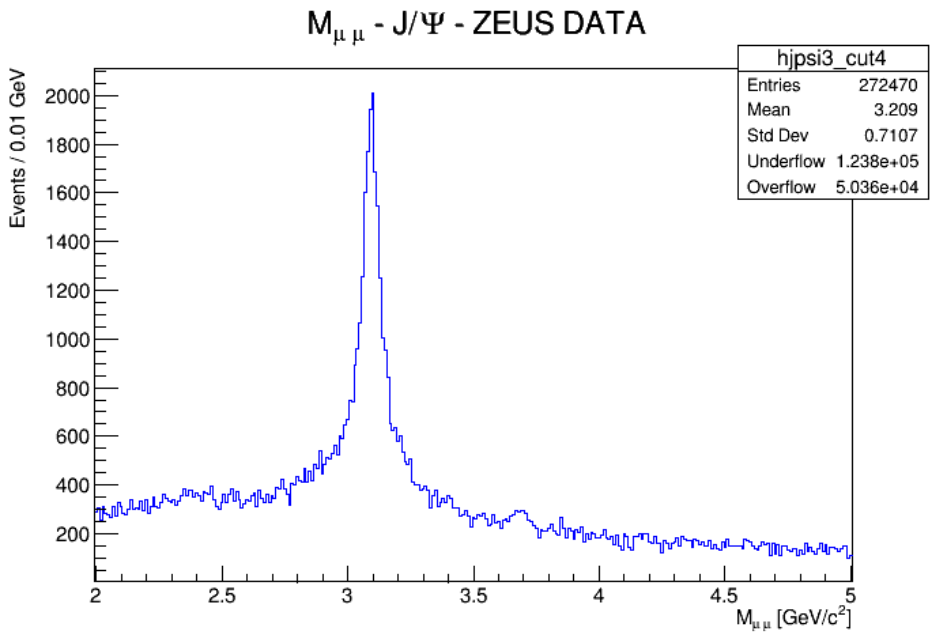
Remark: `0,3,4,6` are guesses which seem to be sensible.

ZEUS Results

- After a successful conversion from ZEUS to CMS data one can run the CMS analysis code with these files.
- The following plot shows the J/Ψ-peak from the converted ZEUS data, created with the CMS analysis code and the corresponding ZEUS cuts.
- These ZEUS cuts are mainly changes to the ATLAS $p_{\top}$ cuts and additional cosmic cuts since previous results showed that cosmic muons have not been selected out strict enough before in the ZEUS data.
- This also decreased background for the J/Ψ analysis.

ZEUS Results - J/Ψ Peak

J/Ψ
$\mathrm{pT}(\mu_1) \geq 1$ GeV $\wedge$ $\mathrm{pT}(\mu_2) \geq 1$ GeV
$Q_{\mu_1} + Q_{\mu_2} = 0$
$M_{\mu\mu} \leq 3.4$ GeV $\wedge$ $M_{\mu\mu} \geq 2.8$ GeV
`Muon_isGlobal == true`
`Muon_softId == true`
Cosmic cuts (see backup)



- Analysis of the 06p ZEUS data
- Clear J/Ψ peak shows that ZEUS conversion is working
- Some hint for the Ψ′ is recognizable

ZEUS Results - comparison of different datasamples

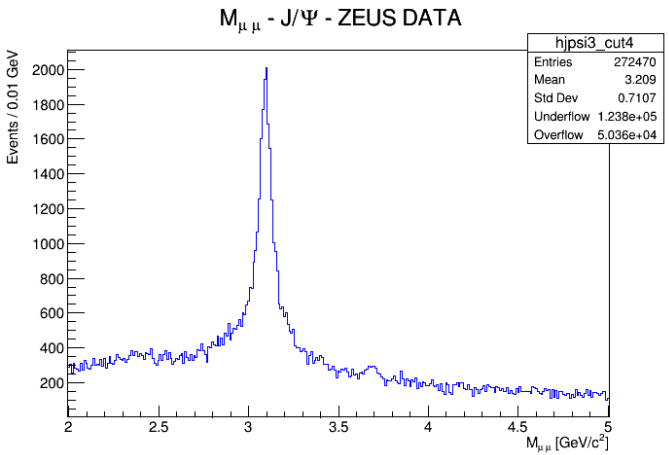


Figure: ZEUS Data 06p

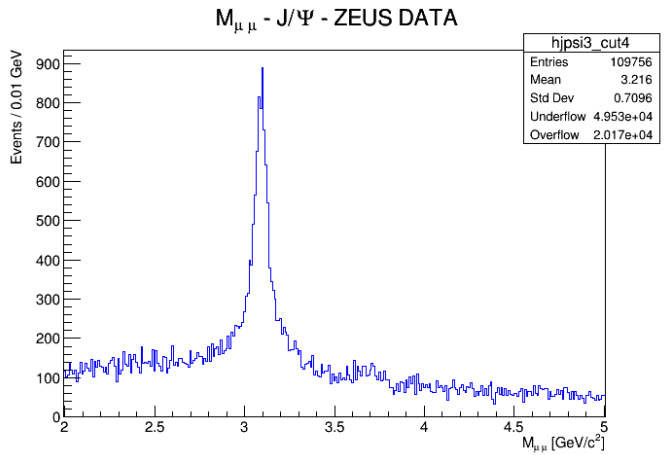


Figure: ZEUS Data 07p

ZEUS Results - comparison with ATLAS and CMS data

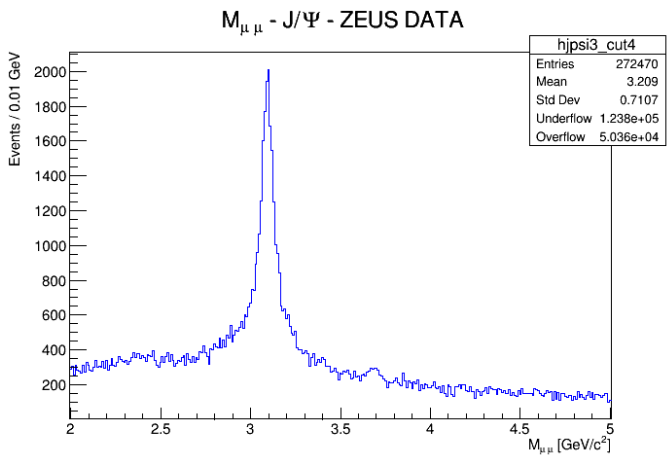


Figure: ZEUS Data 06p

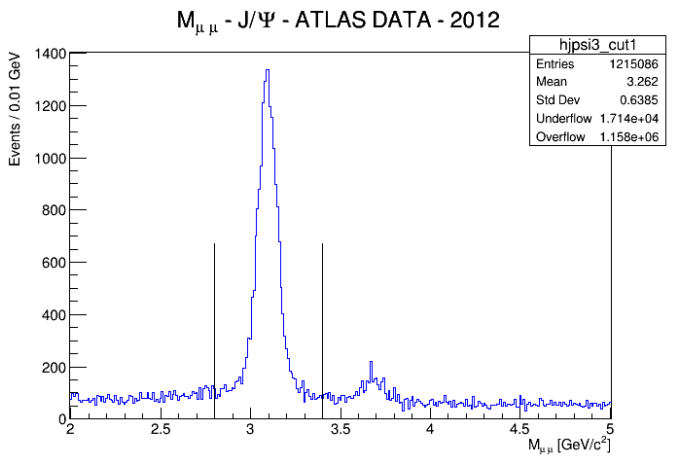


Figure: ATLAS Data 2012

Convert data from ATLAS 2012 to CMS

- ATLAS 2012 Open Data is also in form of *n*-tuples (see backup for details).
- Some variables need small adjustments, e.g. for the Muon pT

$$\frac{lep\_pT[MeV]}{1000} \mapsto Muon\_pT[GeV]$$

- Some variables need rescaling, e.g. for the relative isolation variable [1] (different ratio, rescaling with areas of the cone)

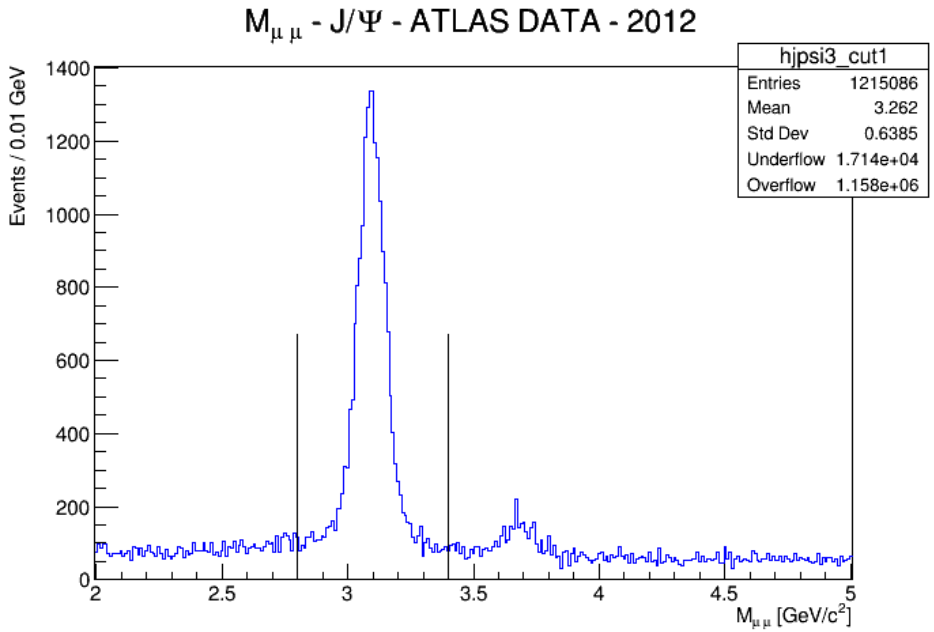
$$\frac{lep\_etcone20}{lep\_pt} \cdot \frac{9}{4} \mapsto Muon\_pfRelIso03\_all$$

- Some quality variables are set to true, e.g. *Muon_softId*, *Muon_isPFcand*, etc.

[1] *lep_etcone*20 is the scalar sum of ET's not including ET of lepton itself in a cone of radius 0.2 around the lepton

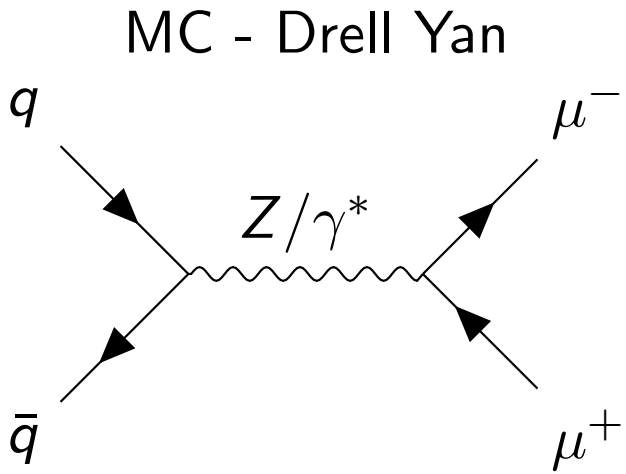
ATLAS 2012 - J/Ψ Peak

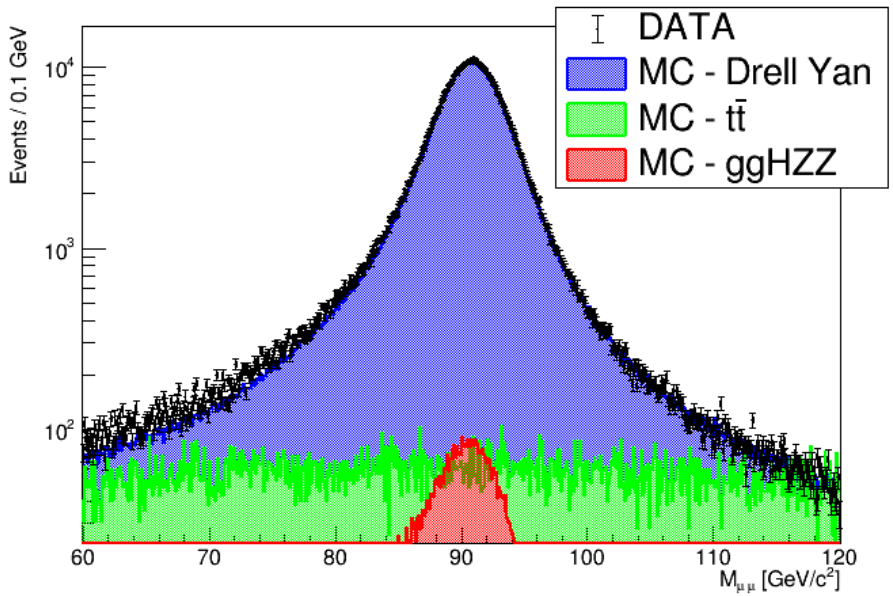
J/Ψ
$pT(\mu_1) \geq 25$ GeV $\wedge$ $pT(\mu_2) \geq 5$ GeV
$Q_{\mu_1} + Q_{\mu_2} = 0$
$M_{\mu\mu} \leq 3.4$ GeV $\wedge$ $M_{\mu\mu} \geq 2.8$ GeV
$Muon\_isGlobal = \text{true}$
$Muon\_softId = \text{true}$



- J/Ψ is reconstructed from global muons, with high pT ($\geq 25 GeV$)
- J/Ψ peak is clear, Ψ′ has also a few entries
- J/Ψ and Z peaks show that ATLAS 2012 conversion is working

ATLAS 2012 - Z Analysis with MC

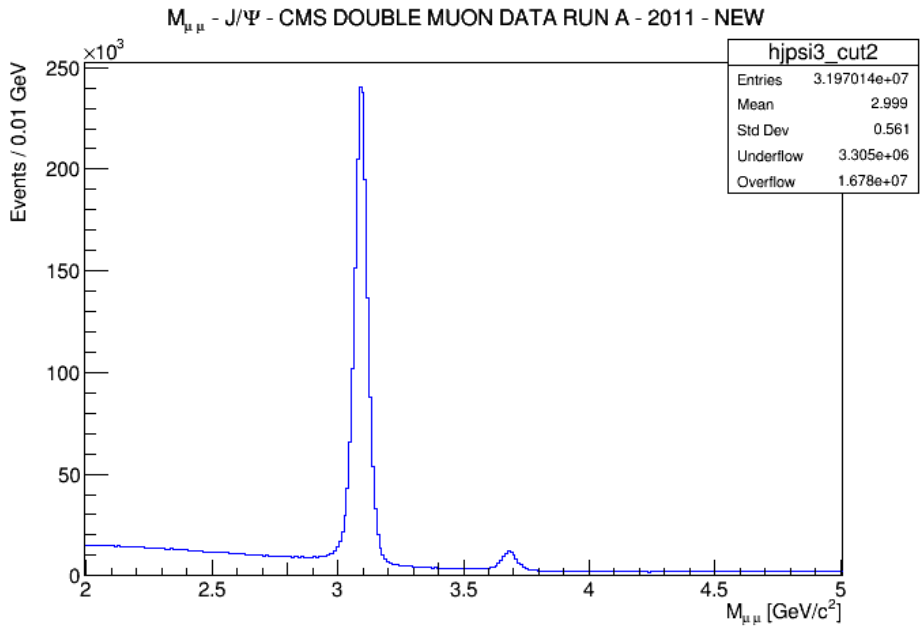




- Most significant MC contribution for the signal is Drell-Yan (see backup for the other Feynman diagrams).
- $t\bar{t}$ is the most significant MC contribution for the background.
- ATLAS 2012 conversion is also working on simulated data.

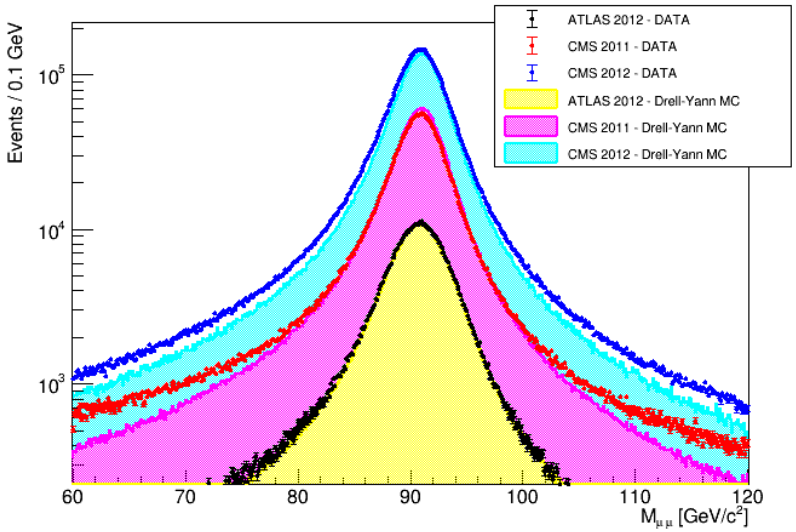
CMS 2011 - J/Ψ Peak

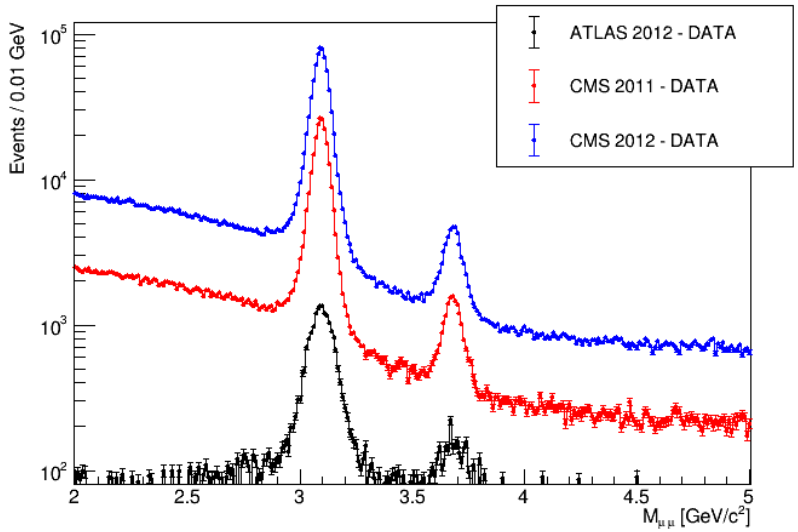
J/Ψ
$Q_{\mu_1} + Q_{\mu_2} = 0$
$M_{\mu\mu} \leq 3.4$ GeV $\wedge$ $M_{\mu\mu} \geq 2.8$ GeV
$Muon\_isGlobal[m1/m2]$
$Muon\_pfRelIso03\_all[m1/m2] \leq 0.15$
$Muon\_pt[m1/m2] \geq 20 GeV/c$
$\lvert Muon\_eta[m1/m2] \rvert \leq 2.1$
$\lvert Muon\_dxy[m1/m2] \rvert \leq 0.2$



- CMS Open Data cuts for global muons have been implemented
- J/Ψ peak is clear, Ψ' has also a few entries (CMS 2011 - Run A)
- Code is working also on other CMS Run 1 samples (see backup)

ATLAS 2012 - Comparison with CMS Run 1





	ATLAS 2012	CMS 2011	CMS 2012
$\sqrt{s}$	8 TeV	7 TeV	8 TeV
$\mathcal{L}$	1.00 fb^{-1}	5.1 fb^{-1}	11.6 fb^{-1}

- Normalizations are different $\rightarrow$ Different $\mathcal{L}$ and pre-selection.
- Distributions for both J/Ψ and Z^2 from the different datasets are similar $\rightarrow$ This will allow for direct performance comparisons (e.g. resolutions for different variables).

[2] Differences in the tails in Z plot $\rightarrow t\bar{t}$ contribution

Conclusion

- The conversion from ZEUS to CMS and ATLAS 2012 to CMS is working, and one common analysis code gives clear J/Ψ and Z peaks for all three datasets, ATLAS 2012, CMS Run 1 and ZEUS.
- The code is working also on CMS Run 1 samples (2011 and 2012)
- Z analysis shows that Drell Yan process describes well the data of both CMS Run 1 and ATLAS 2012.
- Comparisons between Run 1 datasets (CMS 2011, 2012 and ATLAS 2012) show that distributions are similar for both J/Ψ and $\mathrm{Z} \rightarrow$ This will allow for direct performance comparisons

THANK YOU

- Code to produce plots: `/afs/desy.de/user/l/lolivi/public/ATLAS_CMS_MAP/cmsanalysisv8.C`
- Code to convert ZEUS to CMS: `/afs/desy.de/user/s/schwenzr/public/zeustocms.C`
- Code to convert ATLAS 2012 to CMS: `/afs/desy.de/user/l/lolivi/public/ATLAS_CMS_MAP/atlascmsv8_2012`
- Code to produce Run 1 plots: `/afs/desy.de/user/l/lolivi/public/ATLAS_CMS_MAP/Run1.C`
- Code to compare data and MC: `/afs/desy.de/user/l/lolivi/public/ATLAS_CMS_MAP/DataMC.C`
- nanoAODplus: `https://www.desy.de/~geiser/nano/nanoAODplusv0.8.html`
- ATLAS Open Data documentation: `https://cds.cern.ch/record/2203649/files/ATL-OREACH-PUB-2016-001.pdf`

BACKUP

ZEUS - Conversion Table

ZEUS	**CMS**
Runnr	run
Eventnr	event
0	luminosityBlock
Xvtx	PV_x
Yvtx	PV_y
Zvtx	PV_z
Chivtx	PV_chi2
1	nPVtx
Xvtx	PVtx_x(1)
Yvtx	PVtx_y(1)
Zvtx	PVtx_z(1)

ZEUS - Conversion Table

ZEUS	**CMS**
Chivtx>=0	PVtx_isValid(1)
some cuts	PVTx_isGood(1)
1	PVtx_isMain(1)
Chivtx<0	PVtx_isFake(1)
Ntrkvtx	PVtx_ntrkfit(1)
Chivtx	PVtx_chi2(1)
1	PVtx_Id(1)
$\sqrt{(\text{Xvtx-Bspt\_x})^2 + (\text{Yvtx-Bspt\_y})^2}$	PVtx_Rho(1)

ZEUS - Conversion Table

ZEUS	**CMS**
Nmu	nMuon
Mucharge	Muon_charge
Mupt	Muon_pt
-log(tan(Muth/2)	Muon_eta
Muph	Muon_phi
0.105658	Muon_mass
Muqual>0	Muon_looseId
Muqual>3	Muon_softId
Muqual>4	Muon_mediumId
Muqual=6	Muon_tightId
Mutrid	Muon_trkIdx

ZEUS - Conversion Table

ZEUS	**CMS**
Muperr*sin(Muth)	Muon_ptErr
Muzufid>0	Muon_isPFcand
1	Muon_isTracker
Muqual>0	Muon_isGlobal
Muqual=6	Muon_isStandAlone
-13*Mucharge	Muon_pdgId
Muchid	Muon_chi2
Muz	Muon_z
Mudxy	Muon_dxy
Mudz	Muon_dz
Muisol/Mupt	Muon_pfreliso03_all

ZEUS - Conversion Table

ZEUS	**CMS**
Muvtxid	Muon_vtxIdx
Muvtxfl	Muon_vtxFlag
Mujetid_a	Muon_jetIdx
Bspt_x	Bsp_x
Bspt_y	Bsp_y
Bspt_z	Bsp_z
Bspt_xer	Bsp_widthx
Bspt_yer	Bsp_widthy
Bspt_zer	Bsp_sigmaz
Bspt_dxdz	Bsp_dxdz
Bspt_dydz	Bsp_dydz

ZEUS - Cosmic cuts

Define angle difference

$$\Delta\varphi := \varphi_{\mu_1} - \varphi_{\mu_2}.$$

Convert periodicity

$$\Delta\varphi \mapsto \begin{cases} \Delta\varphi, & \text{if } \Delta\varphi \in [-\pi, \pi] \\ \Delta\varphi - 2\pi, & \text{if } \Delta\varphi > \pi \\ \Delta\varphi + 2\pi, & \text{if } \Delta\varphi < -\pi \end{cases}.$$

Cut event if

$$||\Delta\varphi| - \pi| < \frac{5\pi}{100} \quad \wedge \quad |\eta_{\mu_1} + \eta_{\mu_2}| < \frac{5\pi}{100}.$$

ZEUS Results - comparison of different datasamples

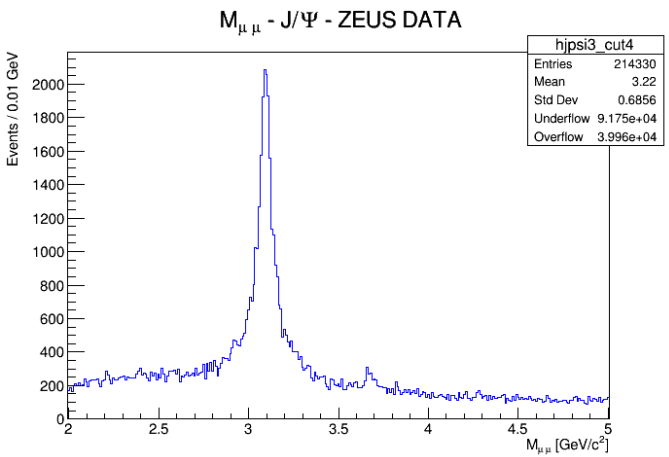


Figure: ZEUS Data 05

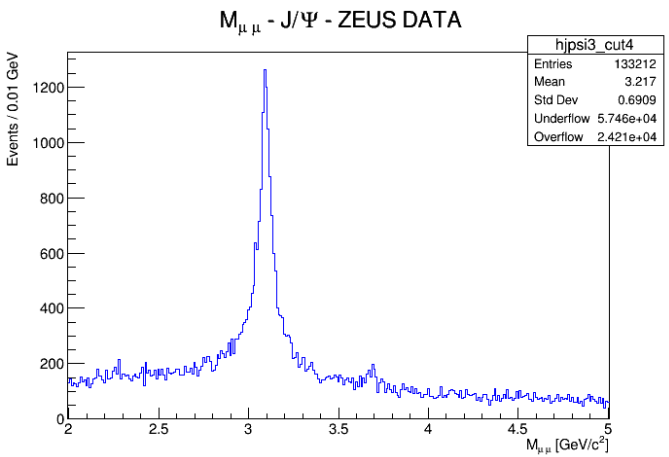


Figure: ZEUS Data 06e

ZEUS Results - Rapidity distribution

- Analysis of the 06p ZEUS data
- Rapidity distribution after cosmic cuts
- Before there was a single peak at 0 rapidity

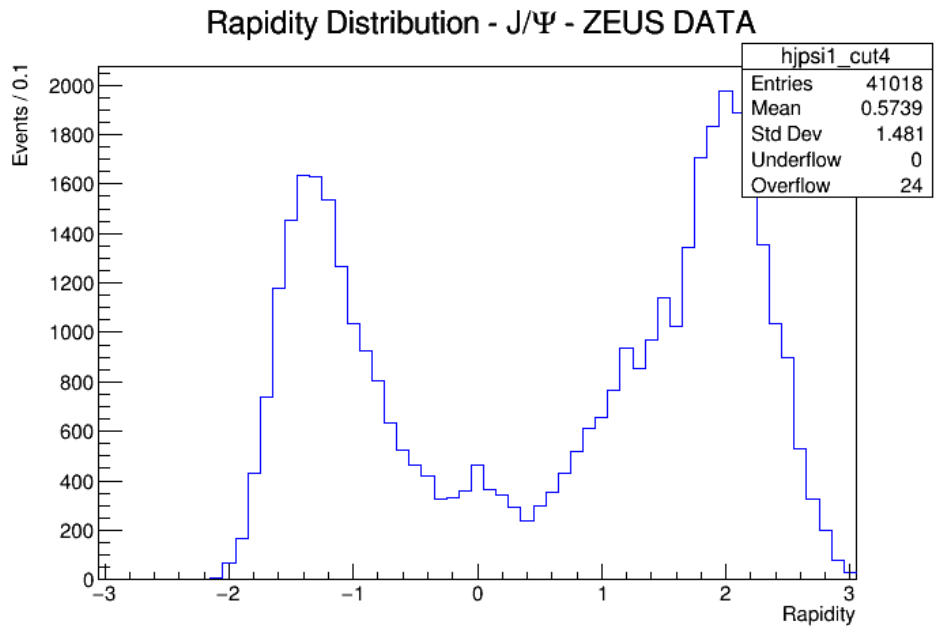


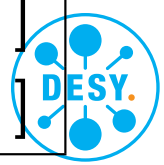
Figure: ZEUS data 06p

ATLAS 2012 - Conversion Table

ATLAS	TYPE	CMS	TYPE
runNumber	*Int_t*	*run*	*UInt_t*
eventNumber	*Int_t*	*event*	*ULong64_t*
pvxp_n	*Int_t*	*PV_npvs*	*Int_t*
lep_type	*UInt_t[ ]*	PDG code	/
lep_n	*UInt_t*	*nMuon*	*UInt_t*
lep_n	*UInt_t*	*nElectron*	*UInt_t*
lep_n	*UInt_t*	*nTau*	*UInt_t*
vxp_z	*Float_t*	*PV_z*	*Float_t*
lep_charge	*Float_t[ ]*	*Muon_charge*	*Int_t[ ]*
lep_charge	*Float_t[ ]*	*Electron_charge*	*Int_t[ ]*
lep_charge	*Float_t[ ]*	*Tau_charge*	*Int_t[ ]*
lep_eta	*Float_t[ ]*	*Muon_eta*	*Float_t[ ]*
lep_eta	*Float_t[ ]*	*Electron_eta*	*Float_t[ ]*
lep_eta	*Float_t[ ]*	*Tau_eta*	*Float_t[ ]*

ATLAS 2012 - Conversion Table

ATLAS	TYPE	CMS	TYPE
lep_phi	*Float_t*[ ]	*Muon_phi*	*Float_t*[ ]
lep_phi	*Float_t*[ ]	*Electron_phi*	*Float_t*[ ]
lep_phi	*Float_t*[ ]	*Tau_phi*	*Float_t*[ ]
$\frac{lep\_pt}{1000}$	*Float_t*[ ]	*Muon_pt*	*Float_t*[ ]
lep_pt	*Float_t*[ ]	*Electron_pt*	*Float_t*[ ]
lep_pt	*Float_t*[ ]	*Tau_pt*	*Float_t*[ ]
$\frac{lep\_ptcone30}{lep\_pt}$	*Float_t*[ ]	*Muon_pfRelIso03_chg*	*Float_t*[ ]
$\frac{lep\_ptcone30}{lep\_pt}$	*Float_t*[ ]	*Electron_pfRelIso03_chg*	*Float_t*[ ]
$\frac{lep\_etcone20}{lep\_pt} \cdot \frac{9}{4}$	*Float_t*[ ]	*Muon_pfRelIso03_all*	*Float_t*[ ]
$\frac{lep\_etcone20}{lep\_pt} \cdot \frac{9}{4}$	*Float_t*[ ]	*Electron_pfRelIso03_all*	*Float_t*[ ]
$\frac{lep\_etcone20}{lep\_pt} \cdot \frac{16}{4}$	*Float_t*[ ]	*Muon_pfRelIso04_all*	*Float_t*[ ]



ATLAS 2012 - Conversion Table

ATLAS	TYPE	CMS	TYPE
$\frac{lep\_z0}{10}$	*Float_t*[ ]	*Muon_dz*	*Float_t*[ ]
$\frac{lep\_z0}{10}$	*Float_t*[ ]	*Electron_dz*	*Float_t*[ ]
$\frac{lep\_z0}{10}$	*Float_t*[ ]	*Tau_dz*	*Float_t*[ ]
$\frac{lep\_d0}{10}$	*Float_t*[ ]	*Muon_dxy*	*Float_t*[ ]
$\frac{lep\_d0}{10}$	*Float_t*[ ]	*Electron_dxy*	*Float_t*[ ]
$\frac{lep\_d0}{10}$	*Float_t*[ ]	*Tau_dxy*	*Float_t*[ ]
$\frac{lep\_sd0}{10}$	*Float_t*[ ]	*Muon_dxyErr*	*Float_t*[ ]
$\frac{lep\_sd0}{10}$	*Float_t*[ ]	*Electron_dxyErr*	*Float_t*[ ]

- *lep_d*0 is actually *lep_trackd*0*pvunbiased*
- *lep_sd*0 is actually *lep_tracksigd*0*pvunbiased*

ATLAS 2012 - Conversion Table

ATLAS	TYPE	CMS	TYPE
$\frac{\sqrt{lep\_d0^2+lep\_z0^2}}{10}$	*Float_t*[ ]	*Muon_ip3d*	*Float_t*[ ]
$\frac{\sqrt{lep\_d0^2+lep\_z0^2}}{10}$	*Float_t*[ ]	*Electron_ip3d*	*Float_t*[ ]
0	*Float_t*[ ]	*Muon_sip3d*	*Float_t*[ ]
0	*Float_t*[ ]	*Electron_sip3d*	*Float_t*[ ]
true	/	*Muon_isGlobal*	*Bool_t*[ ]
true	/	*Muon_softId*	*Bool_t*[ ]
true	/	*Muon_isTracker*	*Bool_t*[ ]
true	/	*Muon_isPFcand*	*Bool_t*[ ]

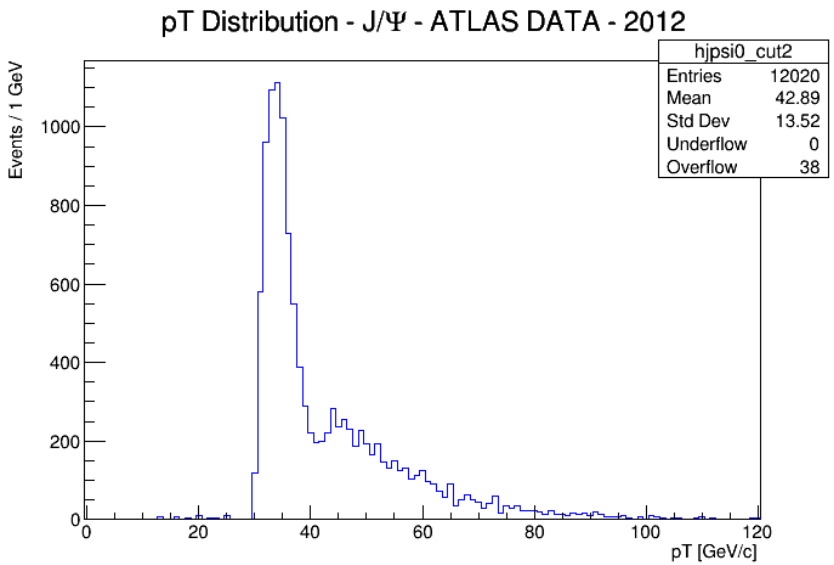
ATLAS 2012 - Conversion Table

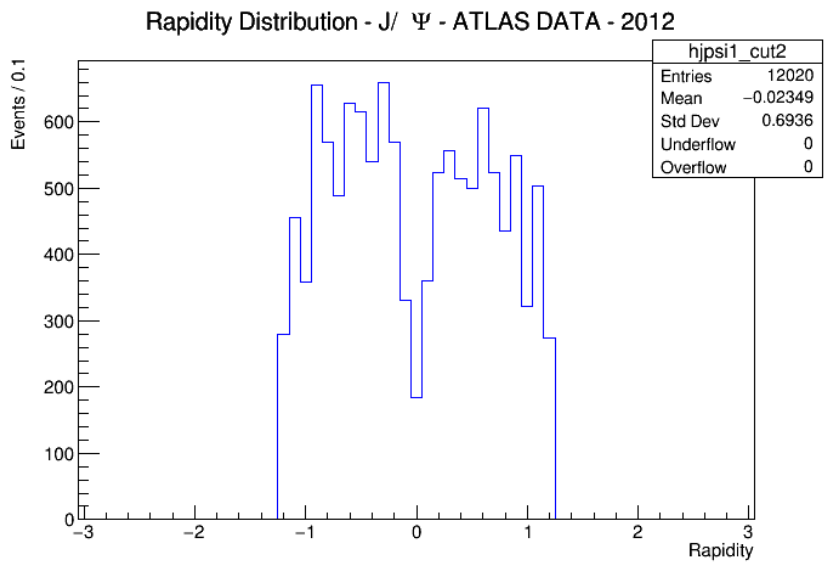
ATLAS	TYPE	CMS	TYPE
mcWeight	*Float_t*	*genWeight*	*Float_t*
scaleFactor_PILEUP	*Float_t*	*sf_pileup*	*Float_t*
scaleFactor_ELE	*Float_t*	*sf_ele*	*Float_t*
scaleFactor_MUON	*Float_t*	*sf_muon*	*Float_t*
scaleFactor_BTAG	*Float_t*	*sf_btag*	*Float_t*
scaleFactor_TRIGGER	*Float_t*	*sf_trigger*	*Float_t*
scaleFactor_JVFSF	*Float_t*	*sf_jvfsf*	*Float_t*
scaleFactor_ZVERTEX	*Float_t*	*sf_zvertex*	*Float_t*
trigE	*Bool_t*	*Trig_goodMuTrigger*	*Bool_t*
trigM	*Bool_t*	*Trig_goodETrigger*	*Bool_t*
passGRL	*Bool_t*	*GoodLumisection*	*Bool_t*
		PVtx_isGood = true	
hasGoodVertex	*Bool_t*	PVtx_isMain = true	*Bool_t*[ ]
		PVtx_isValid = true	

ATLAS 2012 - Conversion Table

ATLAS	TYPE	CMS	TYPE
lep_truthMatched	*Bool_t[ ]*	*Muon_simIdx*	*Int_t[ ]*
lep_trigMatched	*Bool_t[ ]*	*Muon_trigIdx*	*Int_t[ ]*
lep_E	*Float_t[ ]*	/	/
met_et	*Float_t*	*MET_sumEt*	*Float_t*
met_phi	*Float_t*	*MET_phi*	*Float_t*
jet_n	*Int_t*	/	/
alljet_n	*Int_t*	*nJet*	*UInt_t*
$\frac{jet\_pt}{1000}$	*Float_t[ ]*	*Jet_pt*	*Float_t[ ]*
jet_eta	*Float_t[ ]*	*Jet_eta*	*Float_t[ ]*
jet_phi	*Float_t[ ]*	*Jet_phi*	*Float_t[ ]*
jet_E	*Float_t[ ]*	/	/
jet_m	*Float_t[ ]*	*Jet_mass*	*Float_t[ ]*

ATLAS 2012 - J/Ψ pT and rapidity

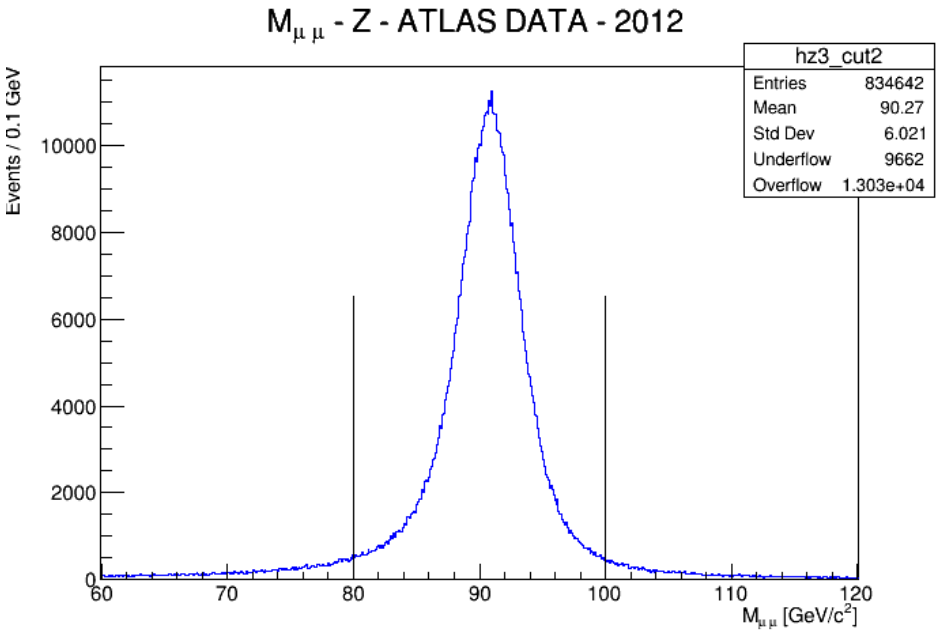




- Code also produces pT and rapidity (and ϕ) distributions
- Code also produces full double muon spectrum and single muon distributions

ATLAS 2012 - Z Peak

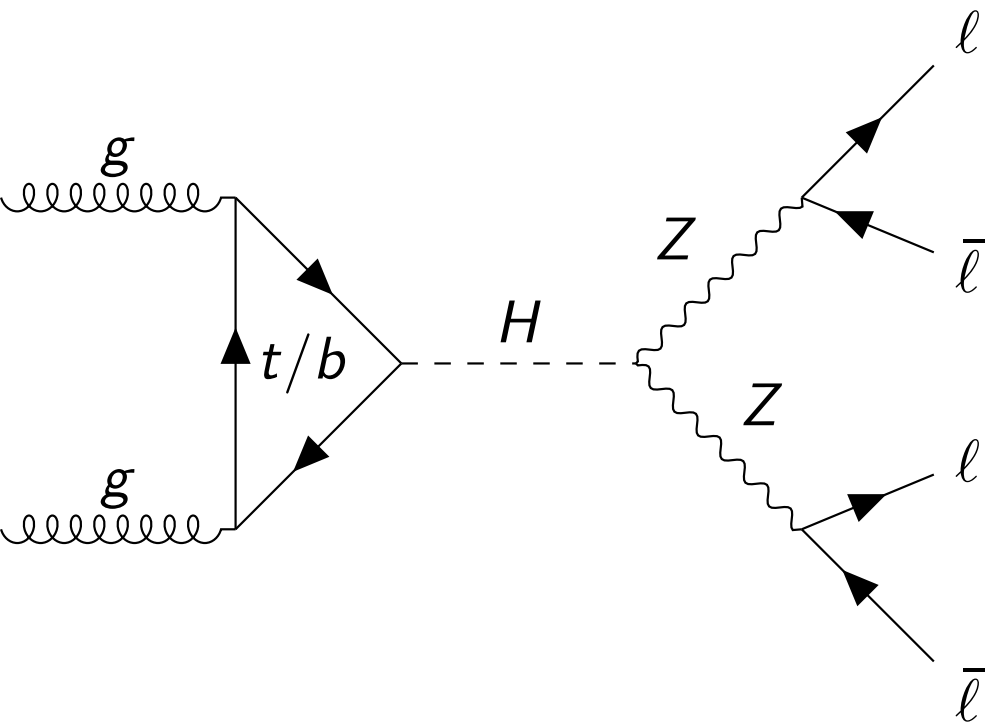
Z
$Q_{\mu_1} + Q_{\mu_2} = 0$
$Muon\_pt[m1] \geq 25 GeV$
$Muon\_pt[m2] \geq 25 GeV$
$Muon\_pfRelIso03\_all[m1] \leq 0.15$
$Muon\_pfRelIso03\_all[m2] \leq 0.15$
$Muon\_pfRelIso03\_chg[m1] \leq 0.15$
$Muon\_pfRelIso03\_chg[m2] \leq 0.15$



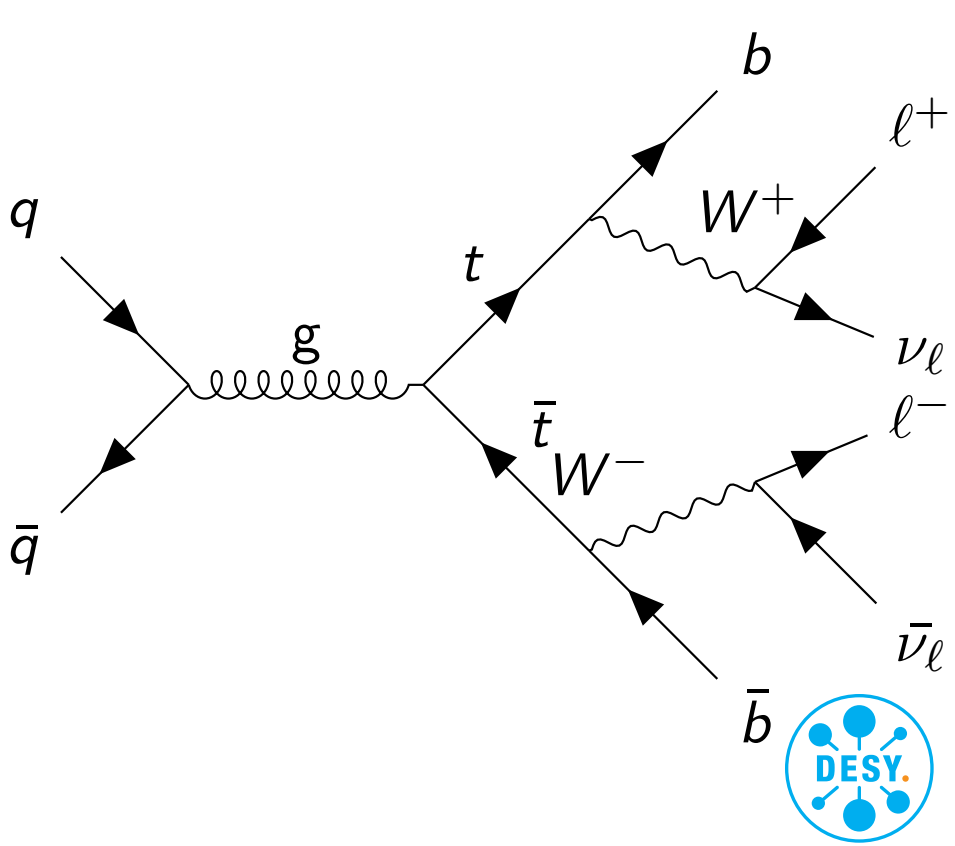
- Z is reconstructed from double muons, with high pT ($\geq 25 GeV$) and isolated.
- ATLAS Open Data cuts are implemented
- Z peak is clear, low background

Some MC Feynman Diagrams

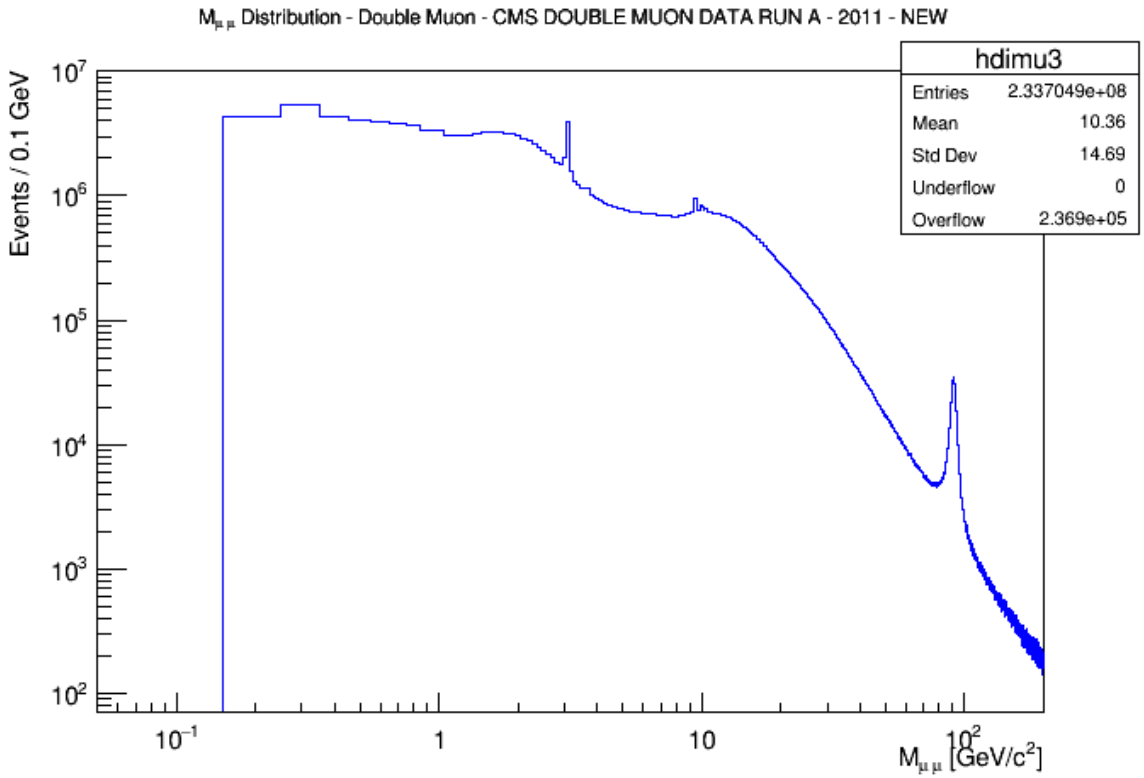
$MC - ggHZZ$



$MC - t\bar{t}$



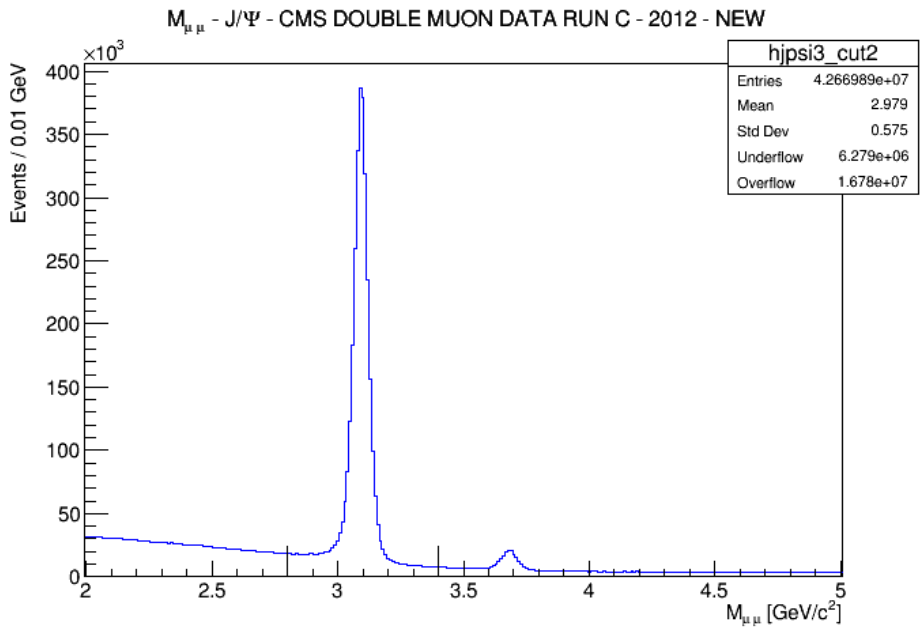
CMS RUN 1 - 2011



- CMS Run 1 samples were converted to nanoAODplus samples.
- Double Muon Full spectrum for CMS 2011 (Run A) shows Z, J/Ψ peaks along with the Υ (not part of the project)

CMS 2012 - J/Ψ Peak

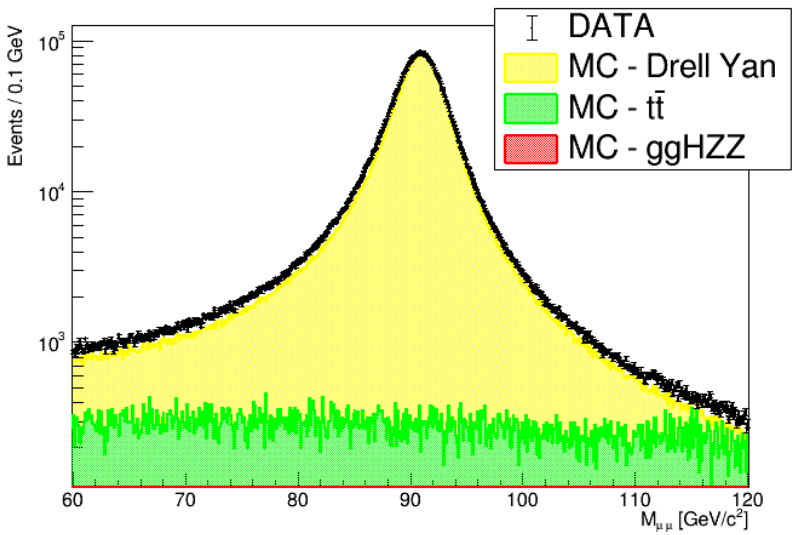
J/Ψ
$Q_{\mu_1} + Q_{\mu_2} = 0$
$M_{\mu\mu} \leq 3.4$ GeV $\wedge$ $M_{\mu\mu} \geq 2.8$ GeV
$Muon\_isGlobal[m1/m2]$
$Muon\_pfRelIso03\_all[m1/m2] \leq 0.15$
$Muon\_pt[m1/m2] \geq 20 GeV/c$
$\lvert Muon\_eta[m1/m2] \rvert \leq 2.1$
$\lvert Muon\_dxy[m1/m2] \rvert \leq 0.2$



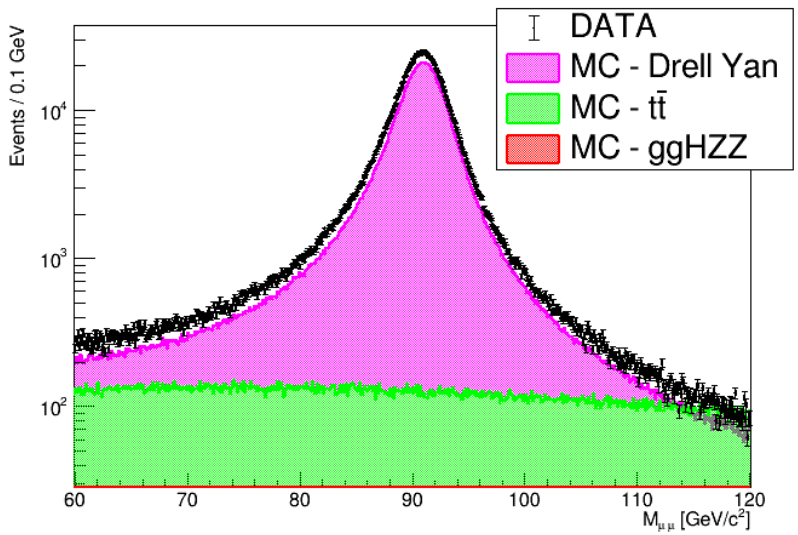
- CMS Open Data cuts for global muons have been implemented
- J/Ψ peak is clear, Ψ′ has also a few entries (CMS 2012 - Run C)

CMS Run 1 - Z analysis with MC

CMS 2012 - Run C

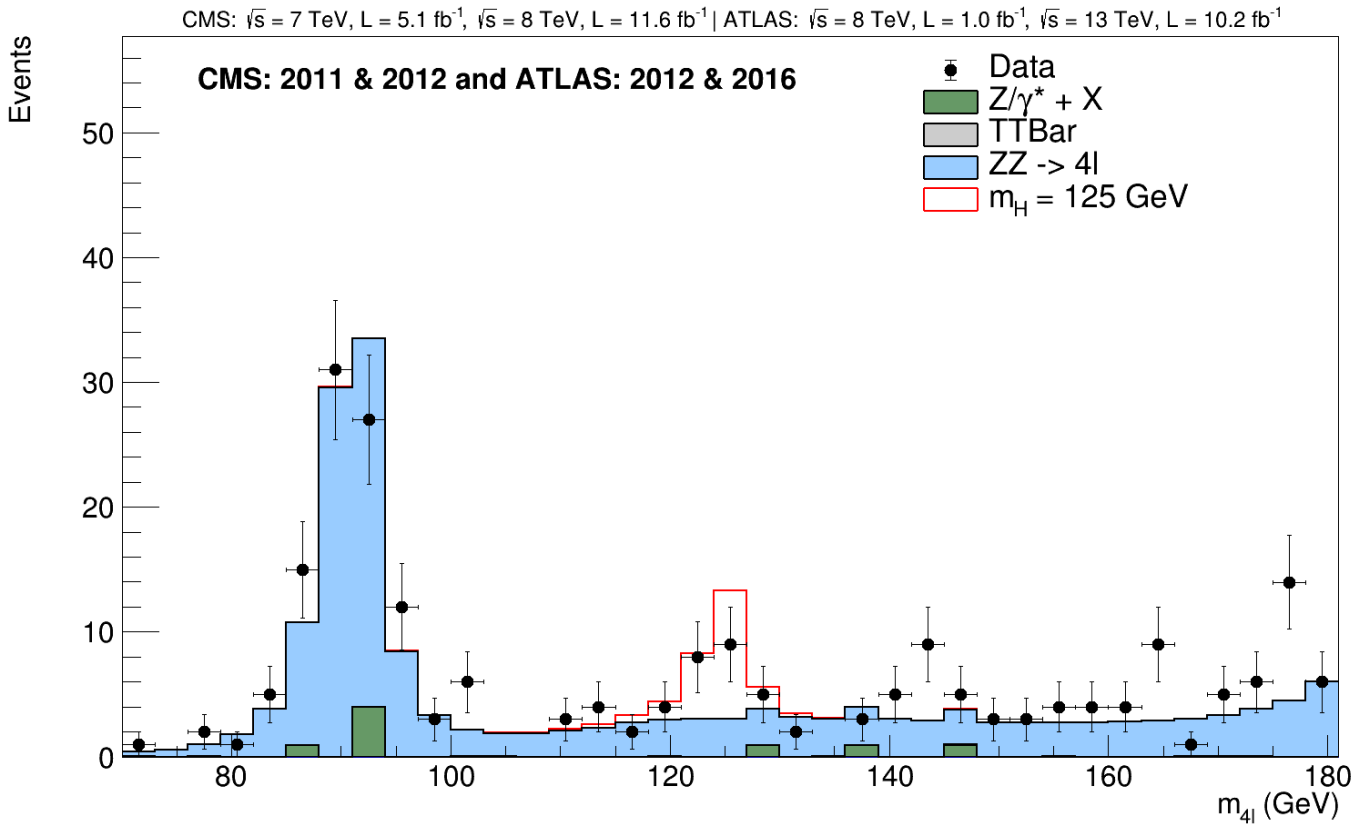


CMS 2011 - Run A



- Most significant MC contribution for the signal is Drell-Yan contribution.
- ATLAS 2012 converted samples and CMS Run 1 samples are working both with data and simulated datasets.

Project B11 - Higgs Analysis



- Project B11 → Aritra Bal, Murillo Vellasco
- ATLAS 2016 and 2012 were also used in the Higgs Analysis.