



VX+BS for Higgs boson mass measurement: follow-up

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Introduction

Within the Higgs boson mass measurement in the 4 lepton decay channel, it has been shown* that lepton pT resolution (and therefore m4l resolution) is impacted by using BS constraint information in muon reconstruction:

* Jake's slides	m(H) shift [in ggH->4μ] GeoFit AdHoc VX+BS [MeV]			σ improvement [in ggH->4μ]			
	2016	14	1	2016	(1,2±1.3)%	(3,9±1.2)%	(4,6±1,4)%
	2017	1	0	2017	(3,8±1.2)%	(4,2±1.2)%	(5,1±1,3)%
	2018	12	15	2018	(6,8±1.3)%	(6,8±1.3)%	(6,7±1,3)%

VX+BS approach has shown bigger improvement in resolution and a comparable shift in mass. For this reason **the idea will be to use this method for Full RunII results.**

In the following slides, a comprehensive studies on **VX+BS**, using both Legacy and UL samples, will be shown.

The analysis is moving to UL samples (since its target is Summer)

Muons

Muons are reconstructed following the HIG-19-001 analysis

- * **Rochester correction applied**
- * gbl or trk or PF muon [StdAlone muon only rejected]
- * muon with $pT > 5 \text{ GeV}$ and $|\eta| < 2.4$
- * $dxy < 0.5 \text{ cm}$ and $dz < 1 \text{ cm}$ [wrt PV, using “muonBestTrack”]

Muon identification:

- for $pT < 200 \text{ GeV}$, loose ID
- for $pT > 200 \text{ GeV}$, identified with High- pT ID without global track requirements

Additional requirements on the muons:

- PF relative isolation (< 0.35)
- significance of the impact parameter ($\text{SIP3D} < 4$)

muon pT scale defined as the mean of the gaussian function used to fit the distribution:

$$\frac{1/p_T^{VX+BS, SingleBS} - 1/p_T^{Roch}}{1/p_T^{Roch}}$$

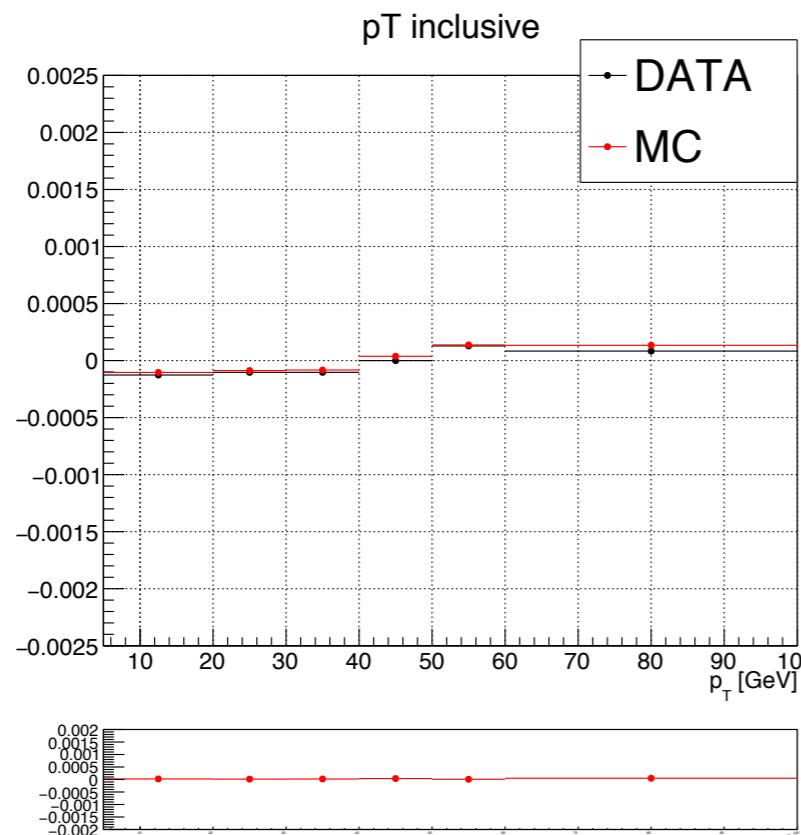
The bottom plot stands for:

$$\left(\mu \left(\frac{1/p_T^{VX+BS, SingleBS} - 1/p_T^{Roch}}{1/p_T^{Roch}} \right) \right)^{MC} - \left(\mu \left(\frac{1/p_T^{VX+BS, SingleBS} - 1/p_T^{Roch}}{1/p_T^{Roch}} \right) \right)^{DATA}$$

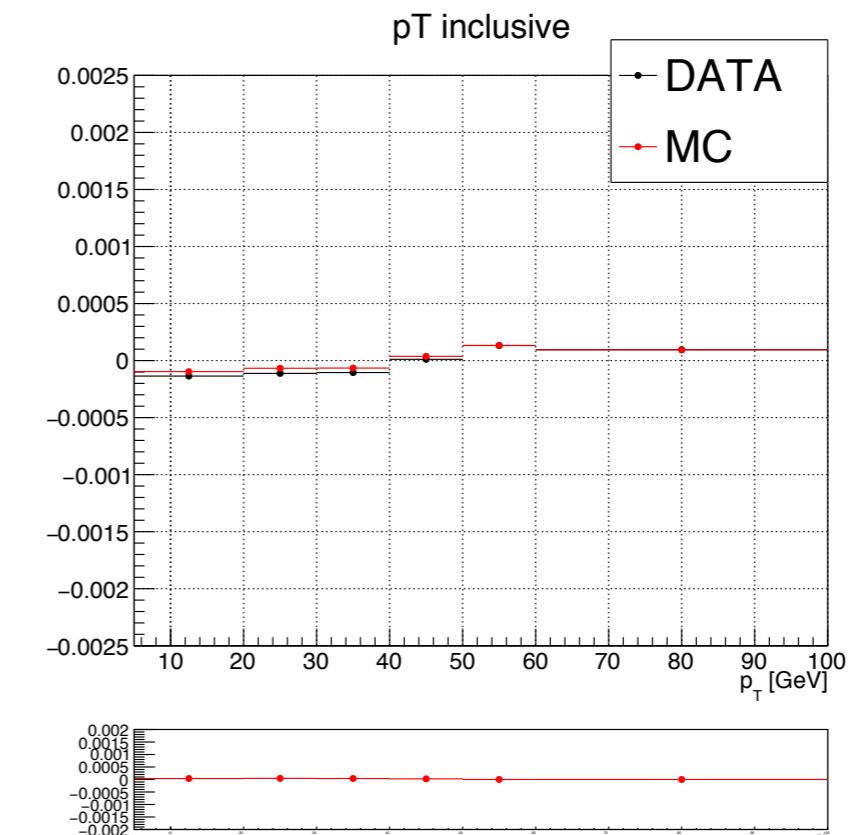
Check if VX+BS works in different way in DATA and in MC

muon pT VX+BS scale

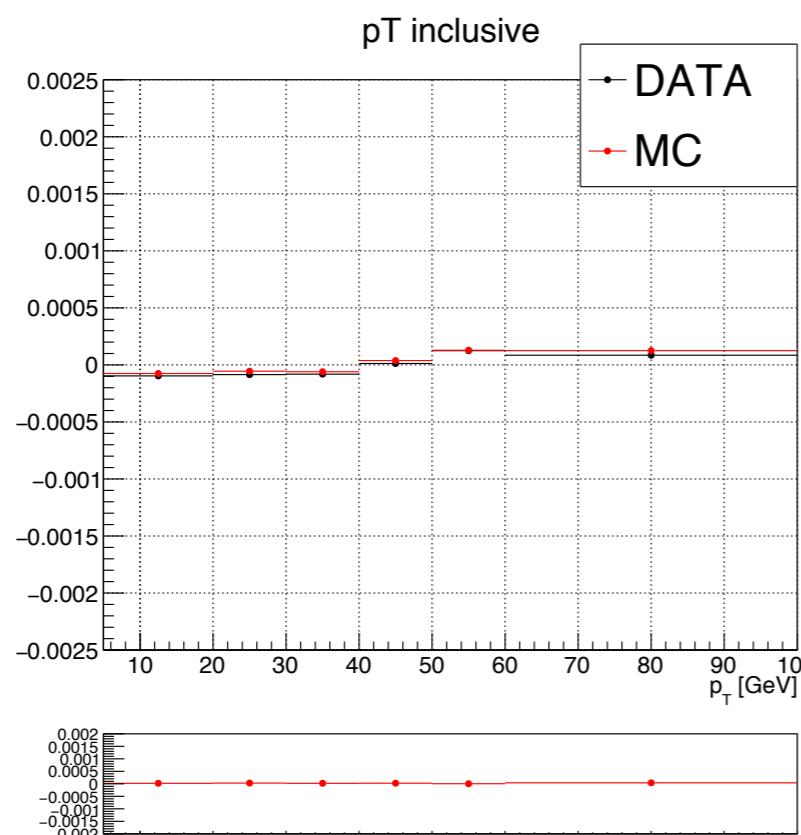
2016
pre-VPF



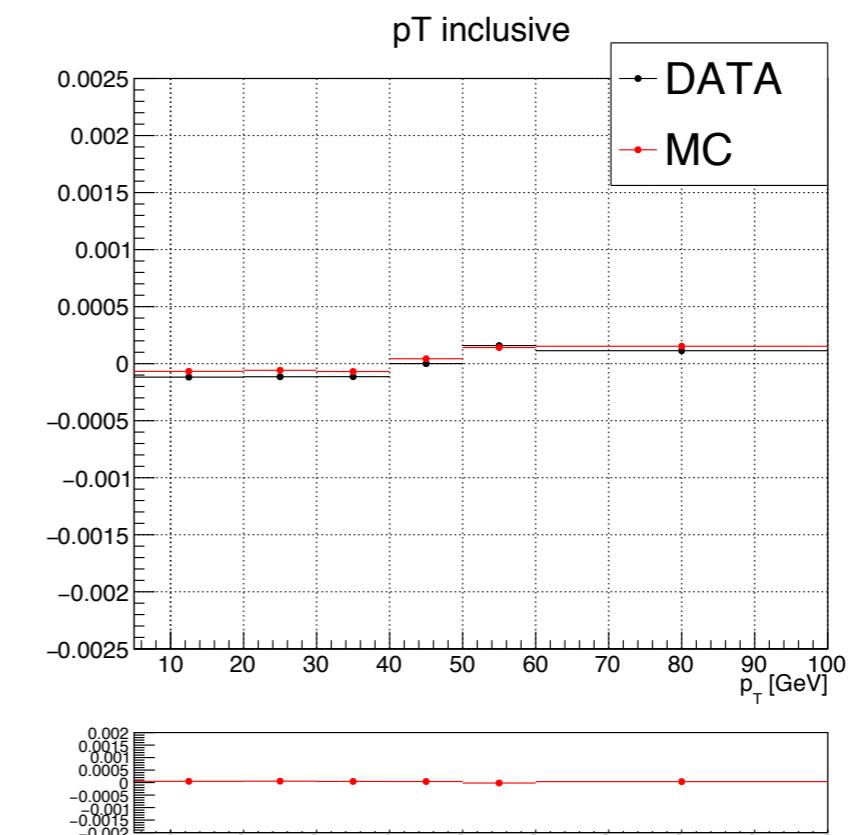
2016
post-VPF



2017



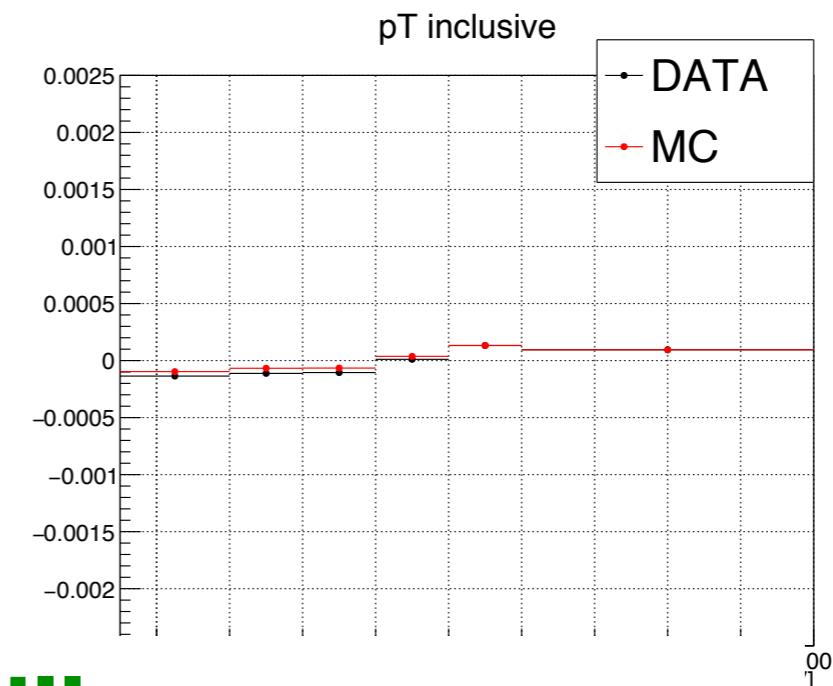
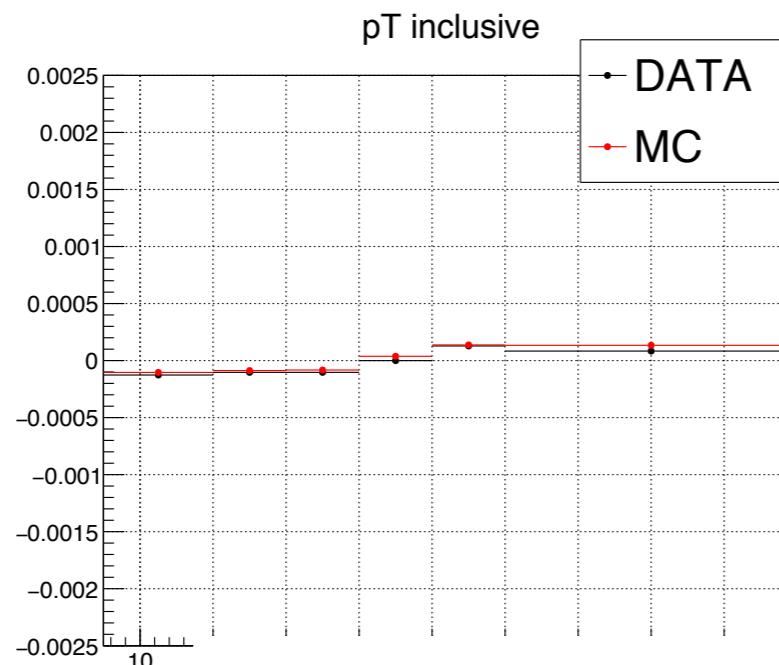
2018



muon pT VX+BS scale



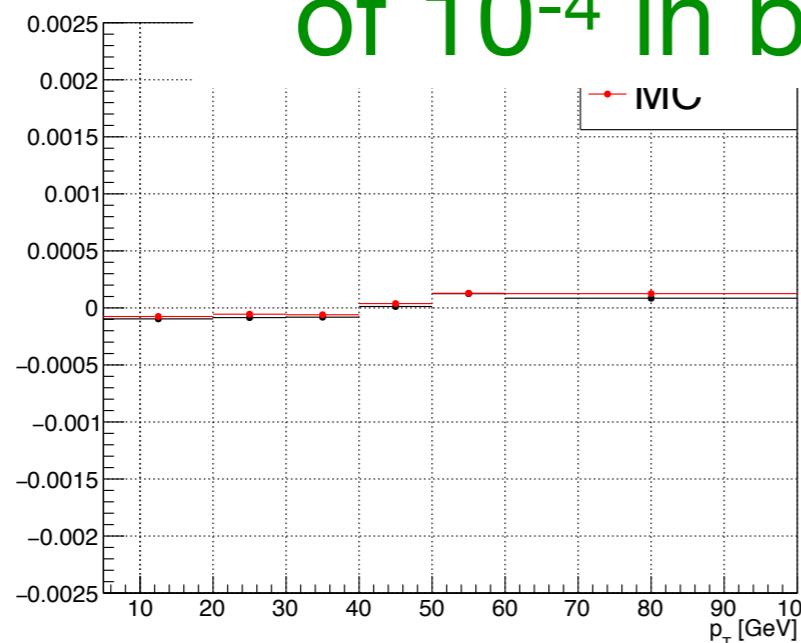
2016
pre-VPF



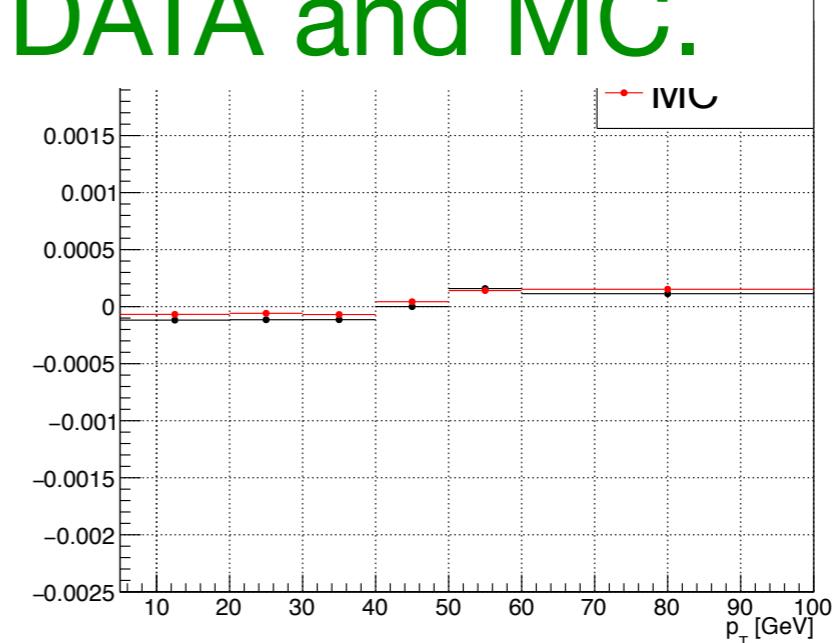
2016
post-VPF

Still:

VX+BS shifts the pT in the order of 10^{-4} in both DATA and MC.

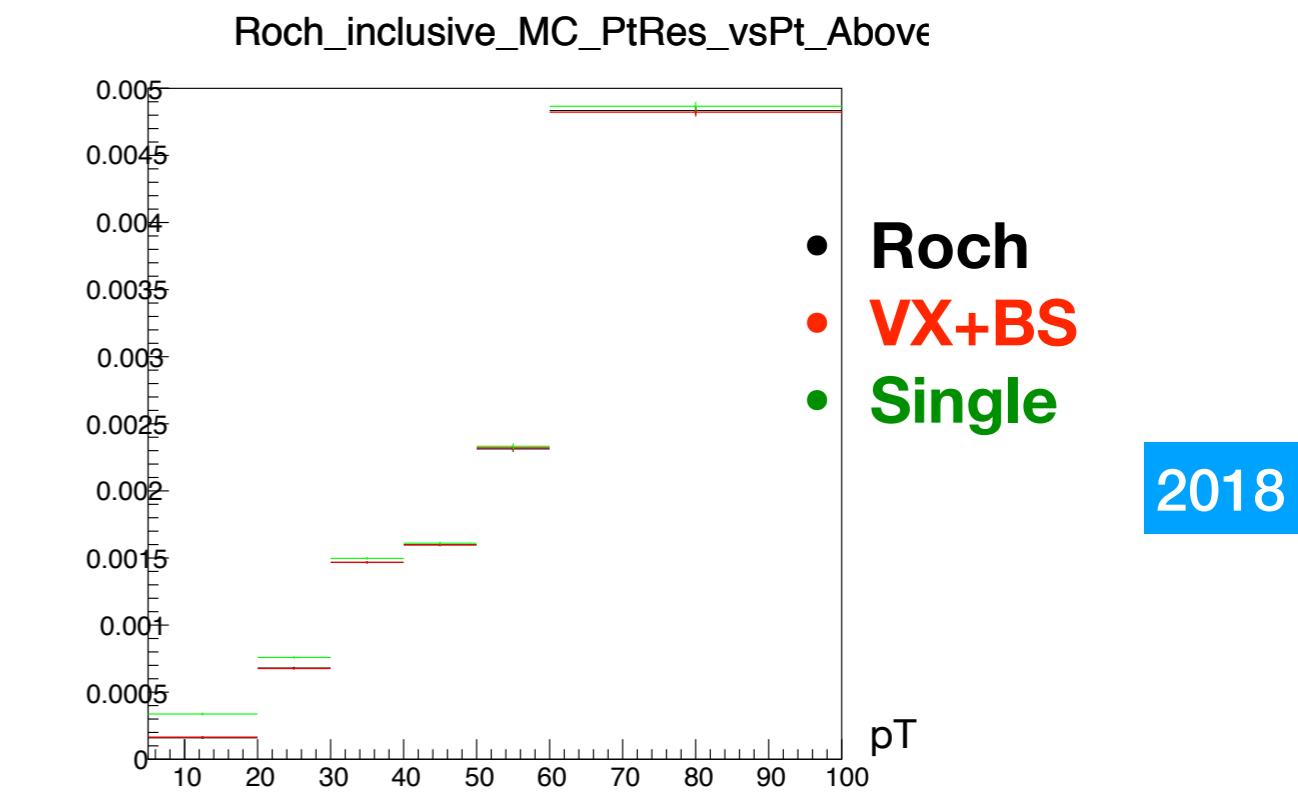
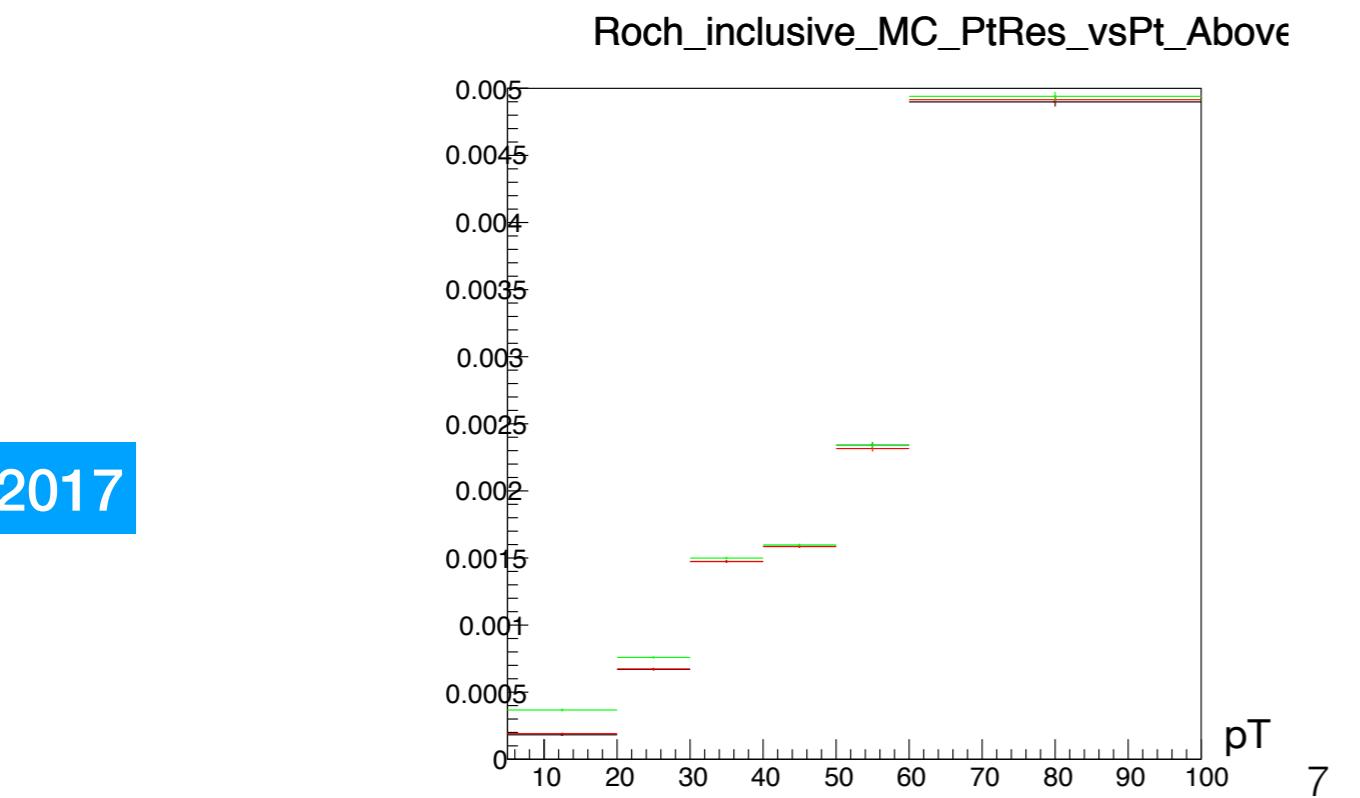
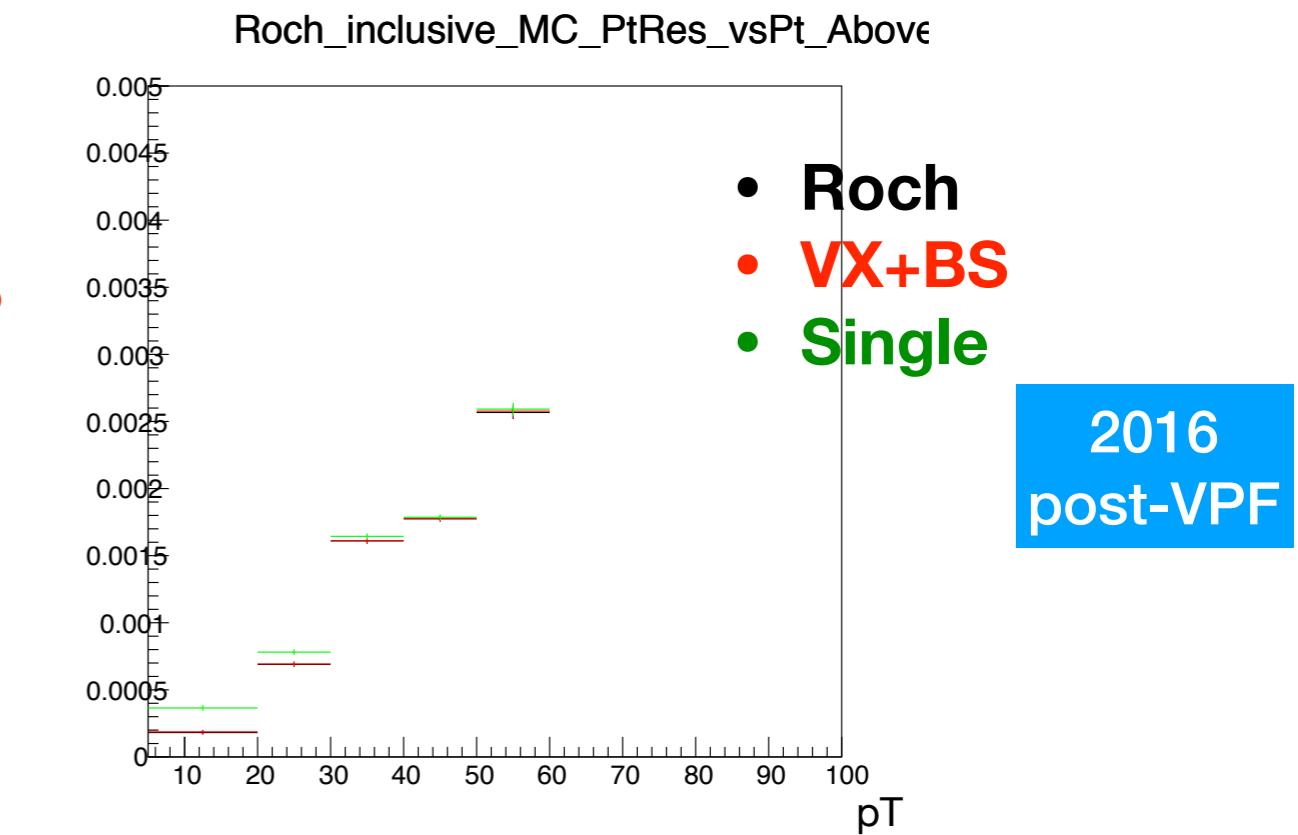
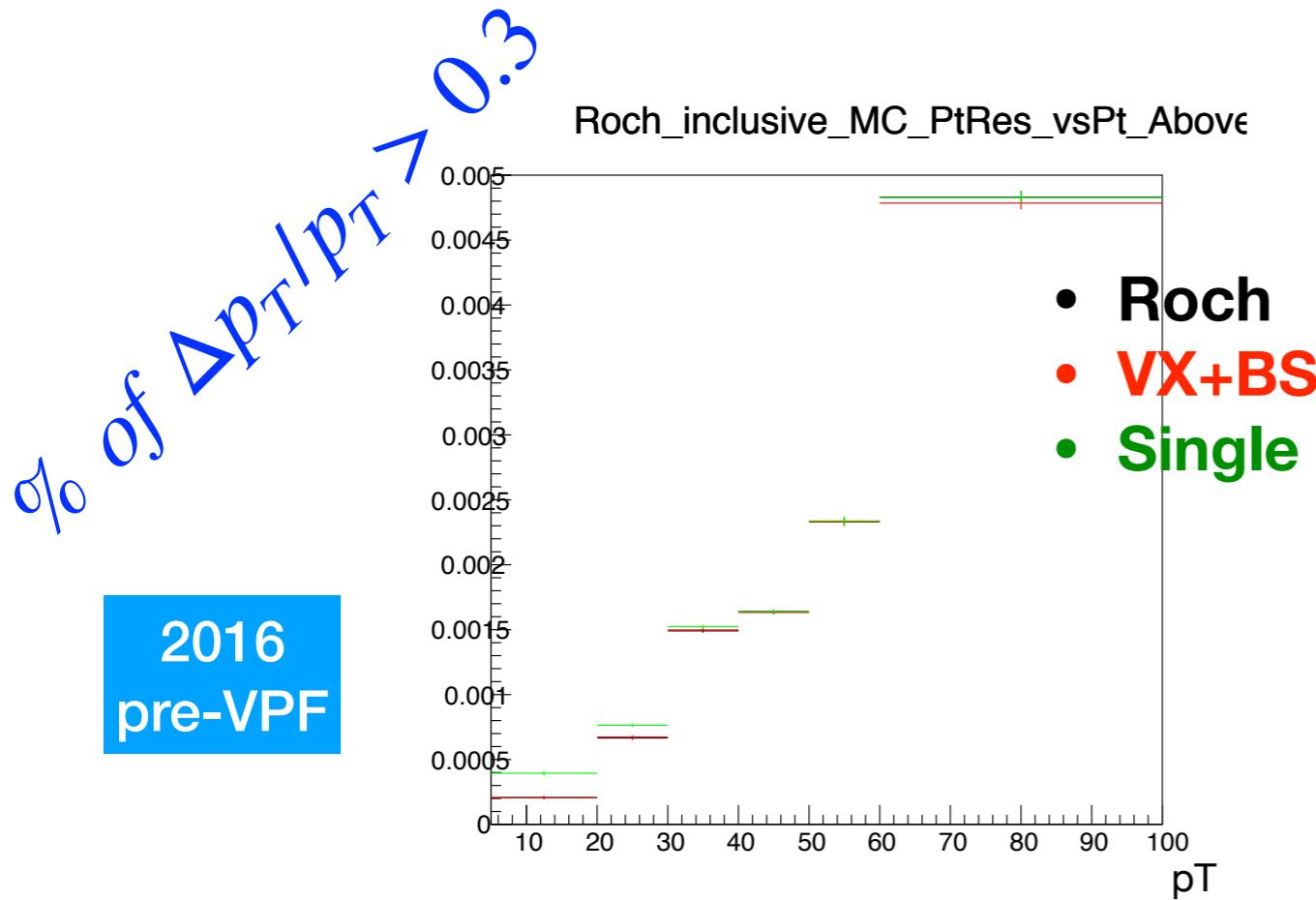


2017



2018

Check tail distribution



VX+BS muon pT resolution

muon pT resolution defined as the sigma of the gaussian function used to fit the distribution (used recursive fit):

$$\frac{p_T^X - p_T^{GEN}}{p_T^{GEN}}$$

The recursive fit consists of fitting the distribution several times, updating the fit range to $[-2\sigma, 2\sigma]$, taking the σ from the previous fit.

The bottom plot stands for:

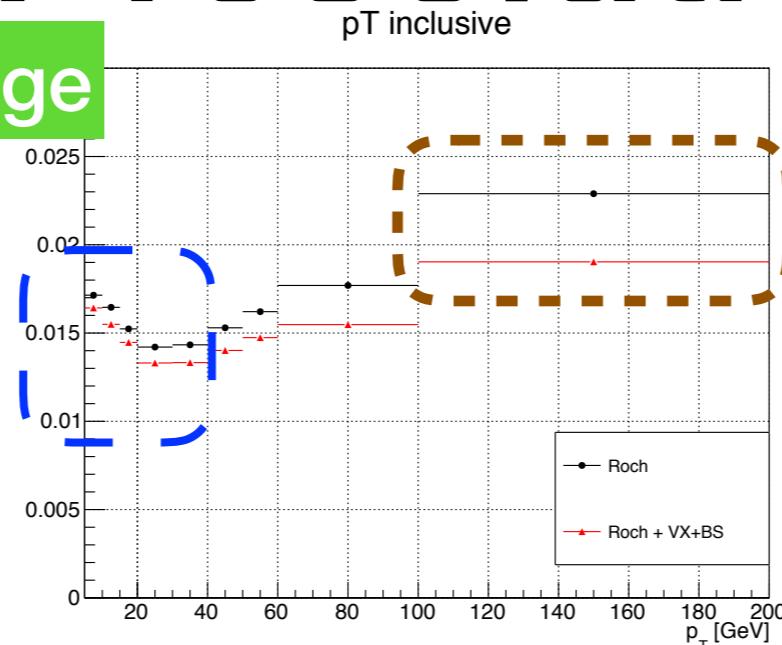
$$\mu \left(\frac{p_T^{roch} - p_T^{GEN}}{p_T^{GEN}} \right) / \mu \left(\frac{p_T^{VX+BS, SingleBS} - p_T^{GEN}}{p_T^{GEN}} \right)$$

muon pT resolution: Legacy

Inclusive η range

Now three bins:
 $[5, 10, 15, 20]$

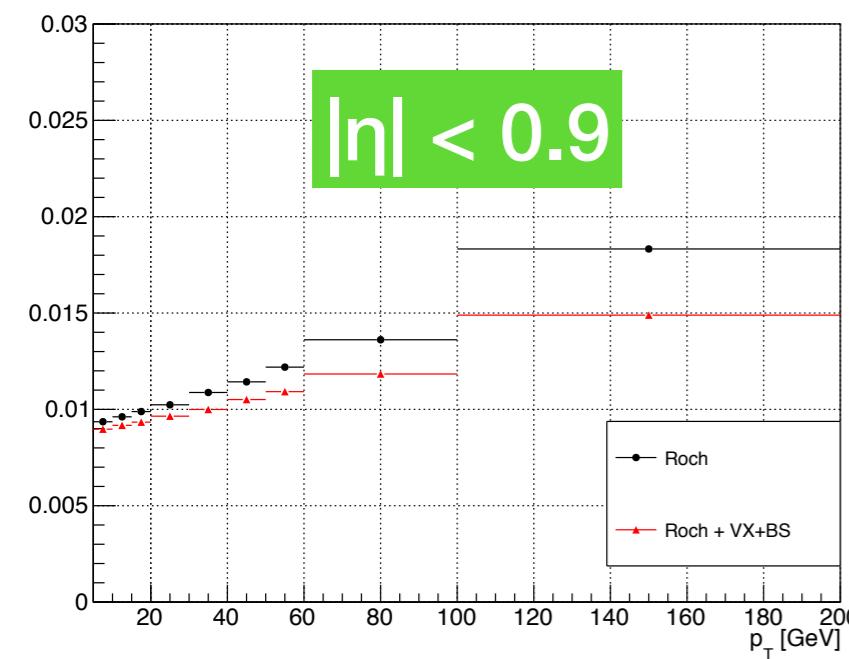
pT inclusive



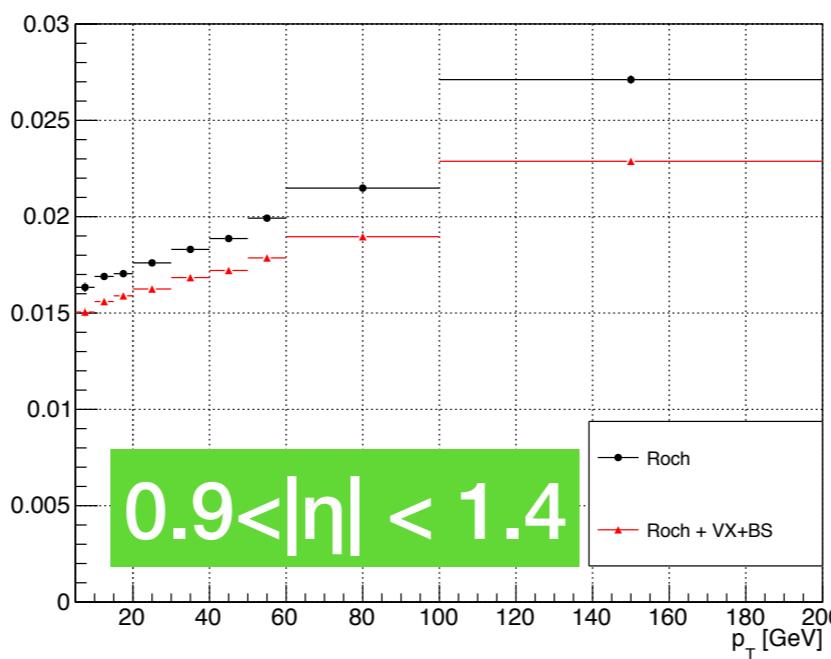
Additional bin
 $[100, 200]$ GeV

2018

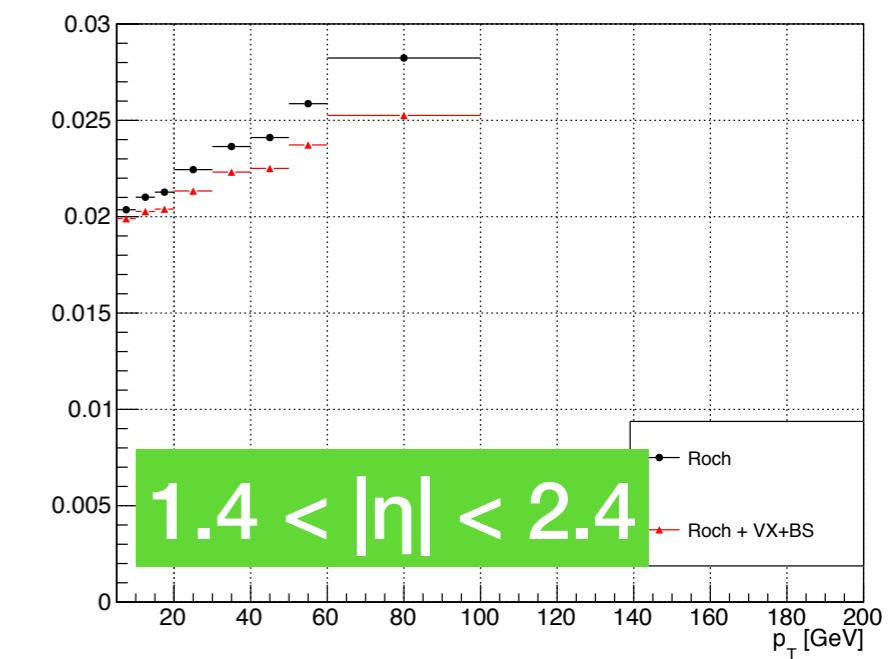
pT inclusive



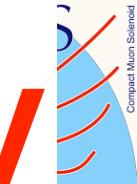
pT inclusive



pT inclusive

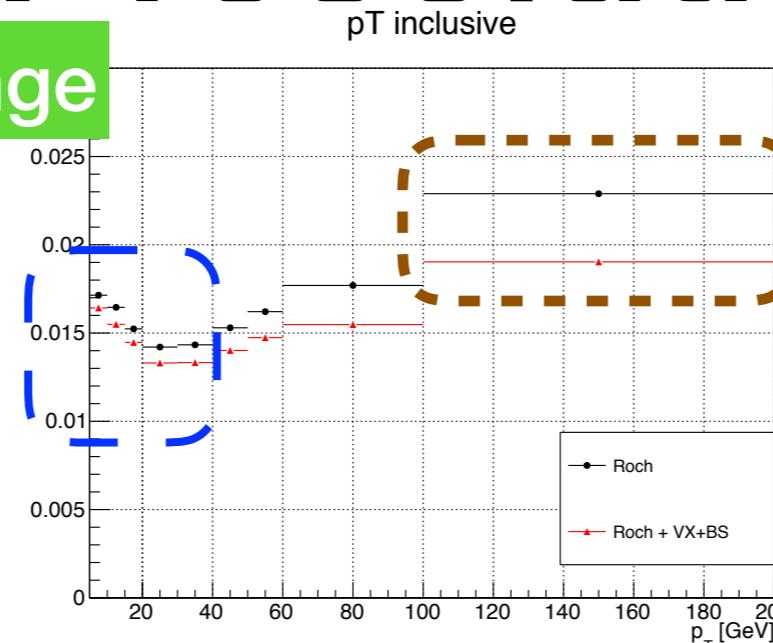


muon pT resolution: Legacy



Inclusive η range

Now three bins:
[5, 10, 15, 20]



Additional bin
[100, 200] GeV

2018

Entries	Barrel ($ \eta < 0.9$)	Overlap ($0.9 < \eta < 1.4$)	Endcap ($1.4 < \eta < 2.4$)
5-10 GeV	48k	60k	225k
10-15 GeV	227k	209k	576k
15-20 GeV	627k	463k	946k
20-30 GeV	3.524 M	1.712 M	2.959 M
30- 40 GeV	7.017 M	3.078 M	4.507 M
40 - 50 GeV	7.260 M	3.661 M	5.162 M
50 - 60 GeV	2.281 M	1.136 M	1.633 M
60 - 100 GeV	2.107 M	1.021 M	1.408
100 - 200 GeV	395 k	189k	242 k

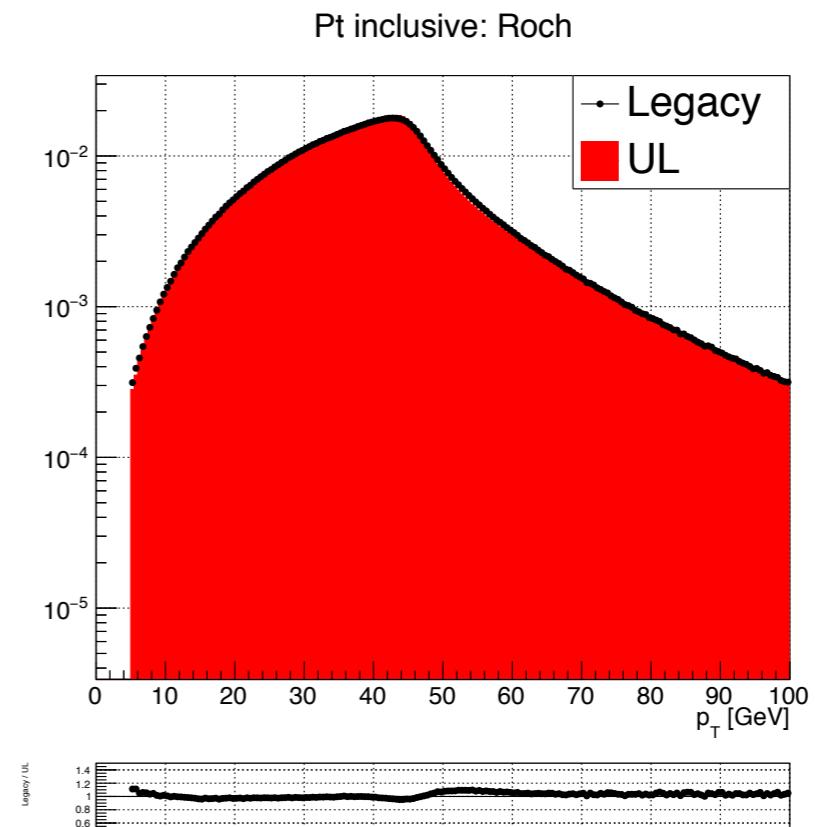
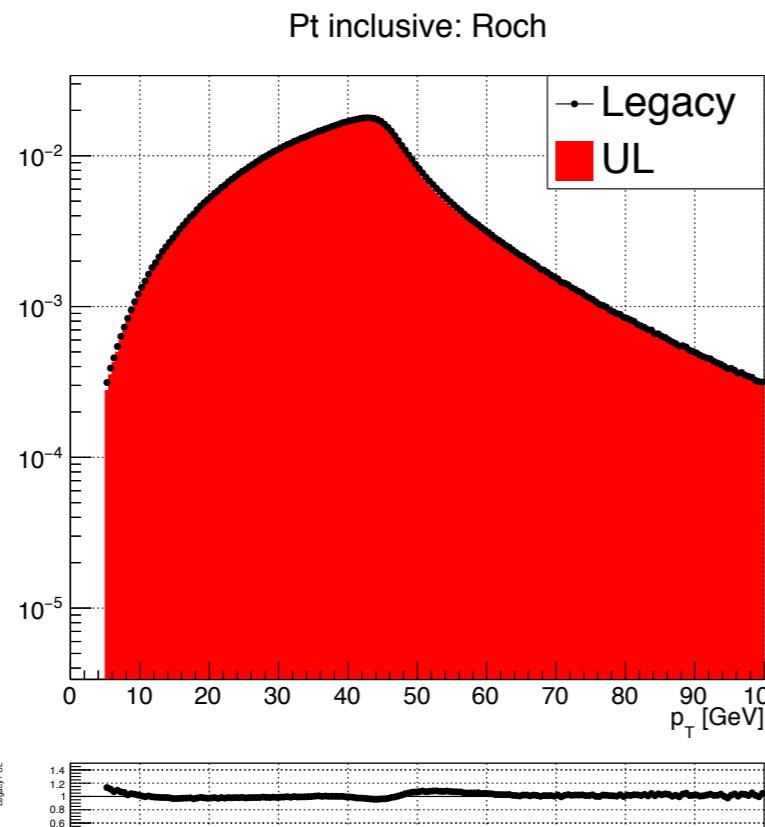
**Slides shown during
08/03 MuonPOG**

Introduction

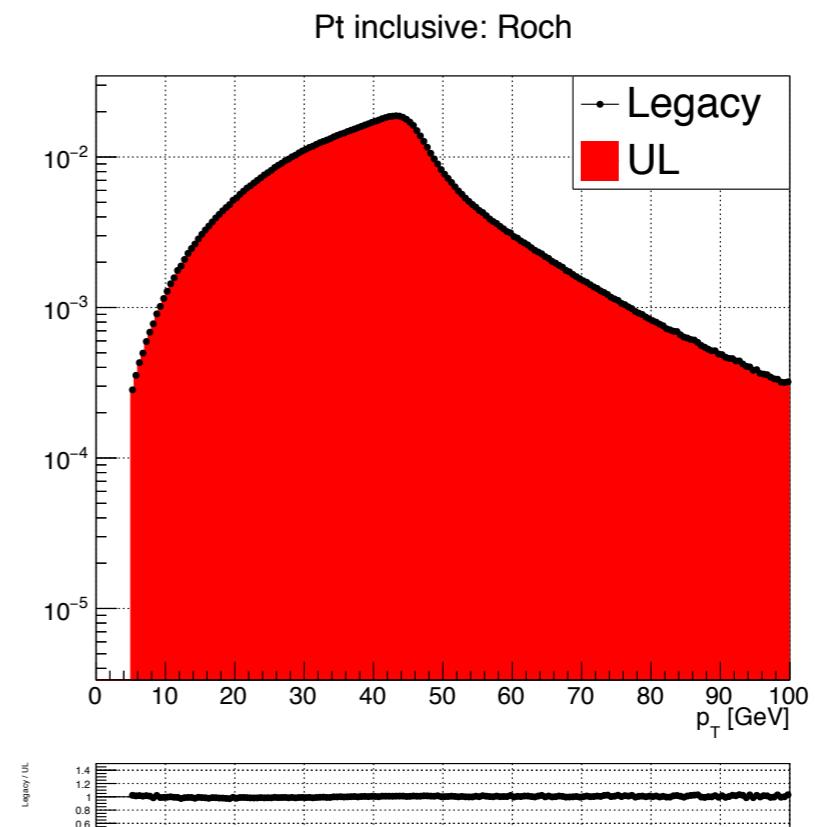
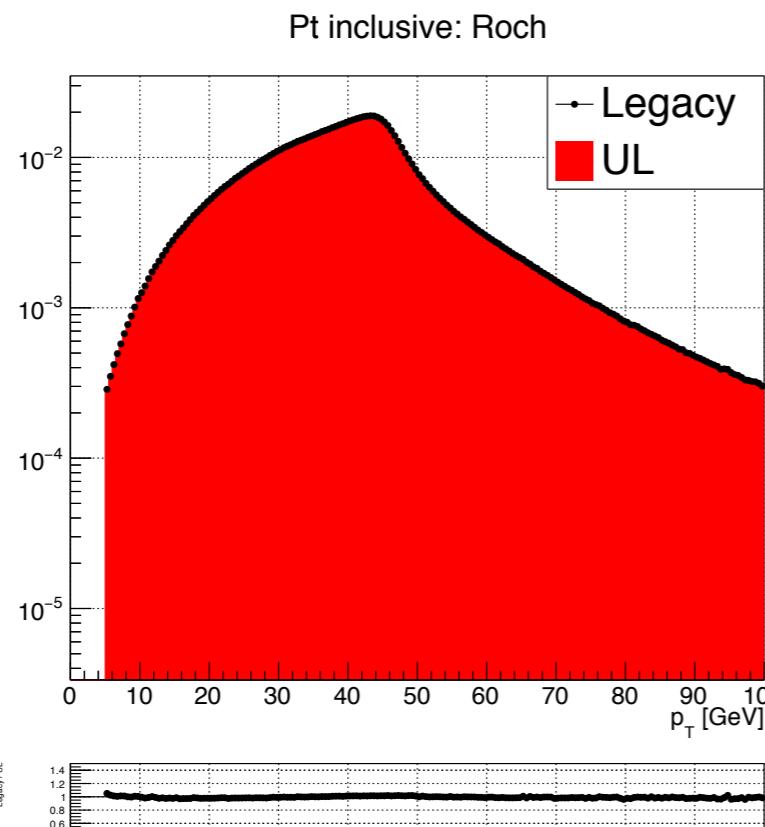
MC Samples used:

- 2016:
 - ◆ **UL** = /DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/
[RunII Summer19UL16 MiniAODAPV-106X_mcRun2_asymptotic_preVFP_v8-v1/MINIAODSIM](#) && /
DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/
[RunII Summer20UL16 MiniAOD-106X_mcRun2_asymptotic_v13-v2/MINIAODSIM](#)
 - ◆ **reReco** = /DYJetsToLL_M-50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8/
RunII Summer16 MiniAODv2-PUMoriond17_80X_mcRun2_asymptotic_2016_TranchelV_v6_ext2-v1/
MINIAODSIM
- 2017:
 - ◆ **UL** = /DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/
RunII Summer19UL17 MiniAOD-106X_mc2017_realistic_v6-v2/MINIAODSIM
 - ◆ **reReco** = /DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/
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- 2018:
 - ◆ **UL** = /DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/
RunII Summer19UL18 MiniAOD-106X_upgrade2018_realistic_v11_L1v1-v2/MINIAODSIM
 - ◆ **reReco** = /DYJetsToLL_M-50_TuneCP5_13TeV-amcatnloFXFX-pythia8/
RunII Autumn18 MiniAOD-102X_upgrade2018_realistic_v15-v1/MINIAODSIM
- Rochester correction:
 - ◆ **UL** = roccor.Run2.v5/RoccoR201*UL.txt
 - ◆ **reReco** = roccor.Run2.v3/RoccoR201*.txt

p_T distributions

Rochester

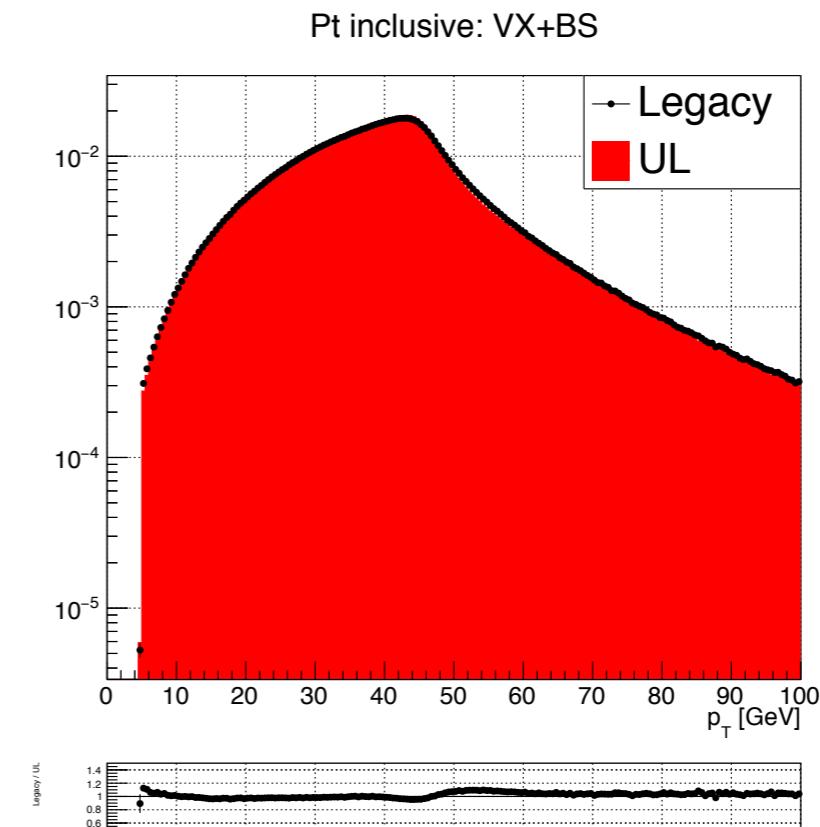
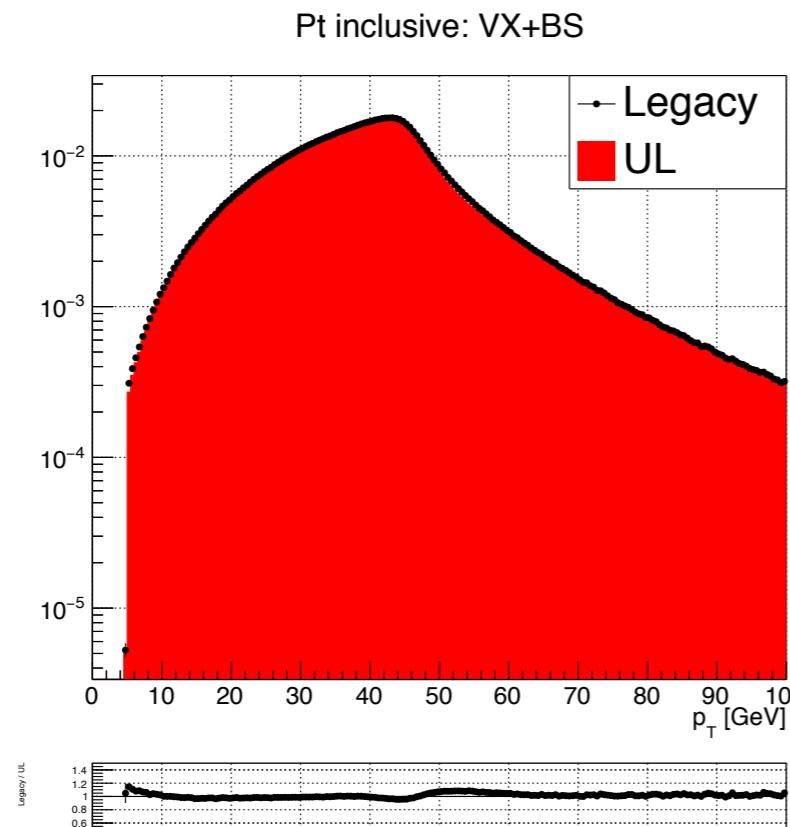
2017



p_T distributions

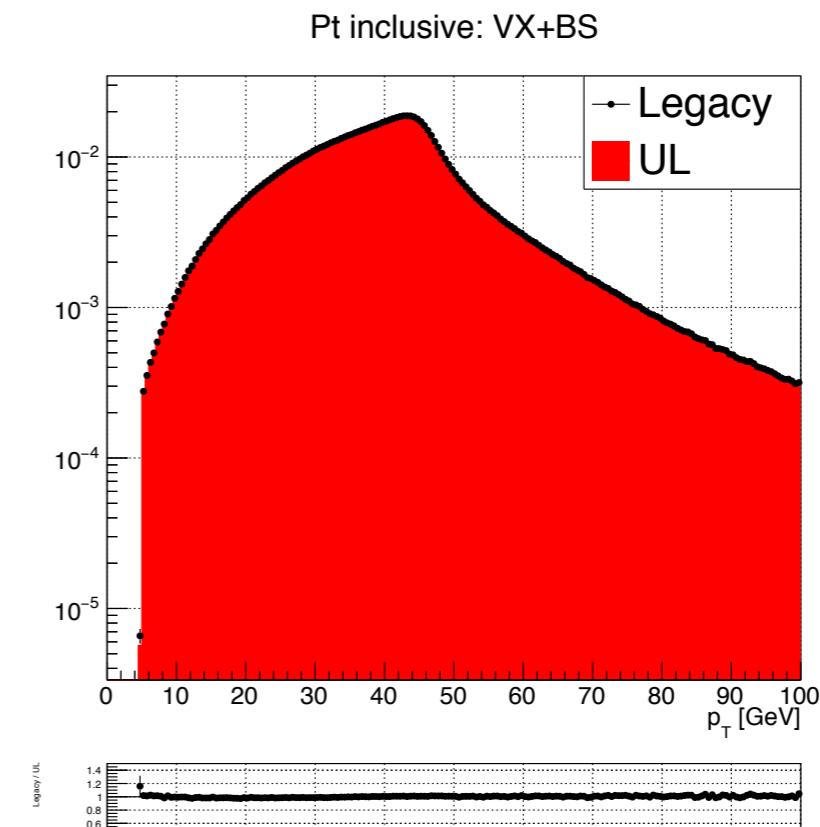
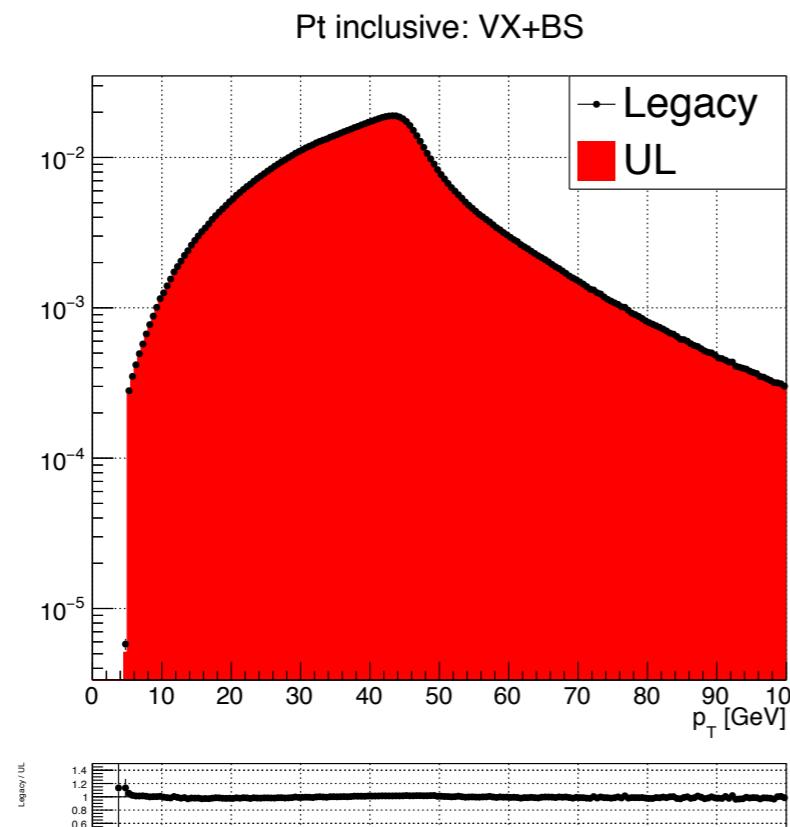
Rochester
+
VX+BS

2016
pre-VPF



2016
post-VPF

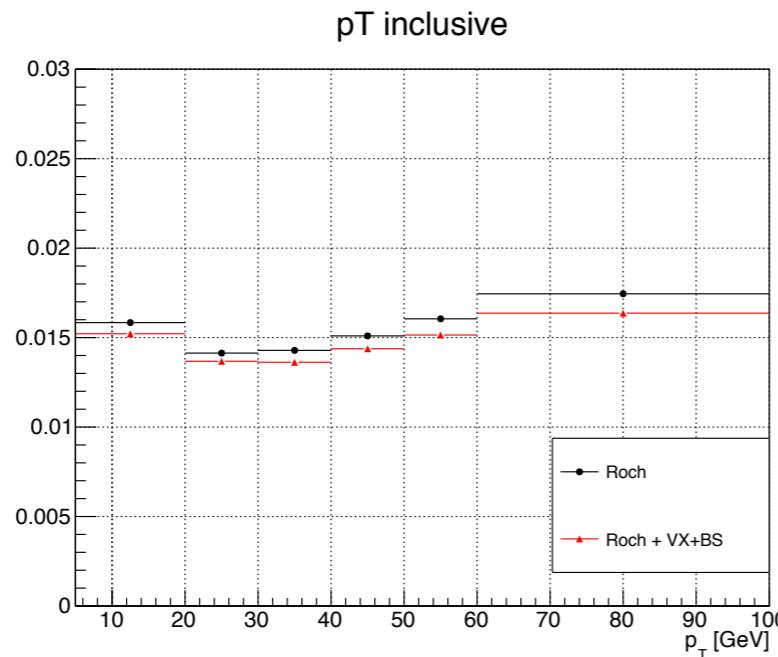
2017



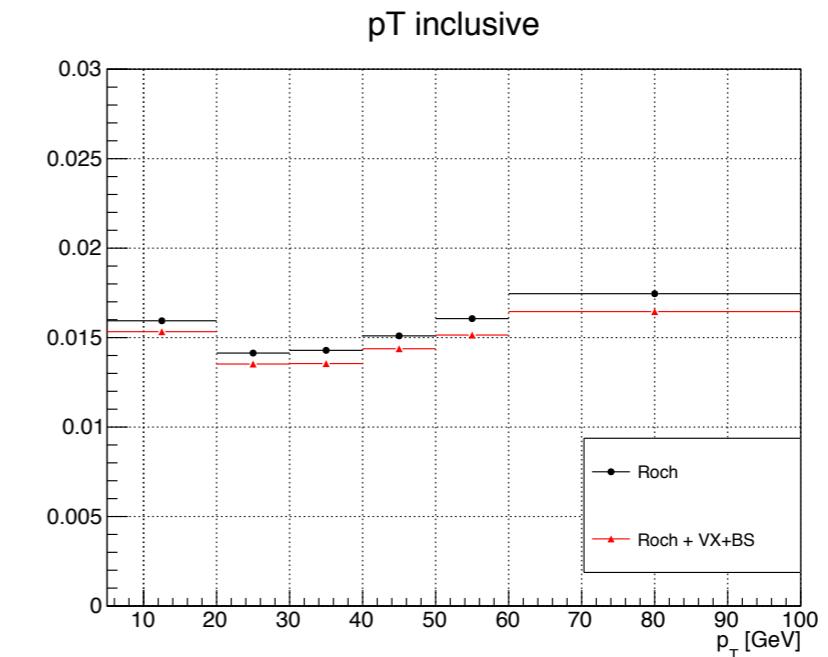
2018

muon pT resolution vs pT

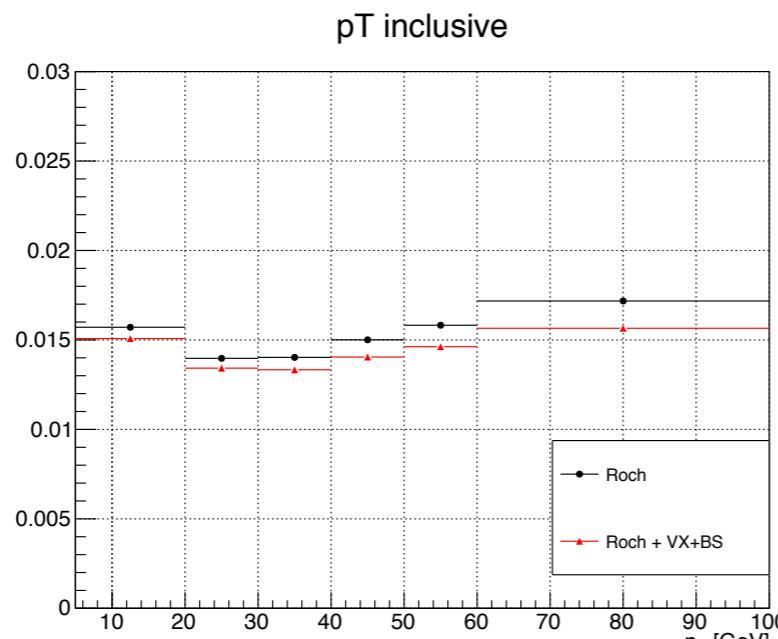
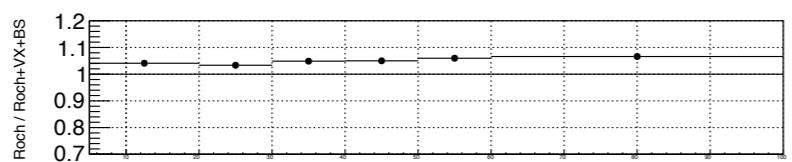
Legacy



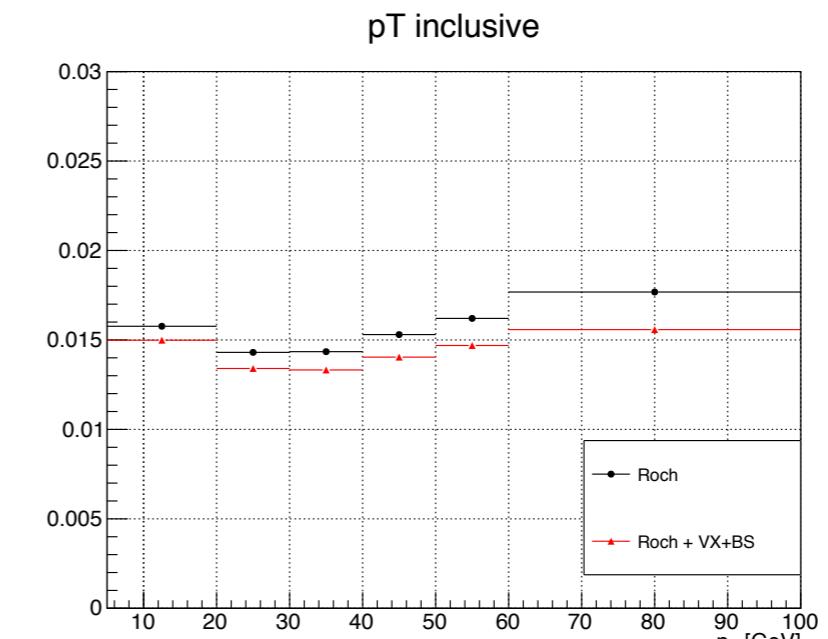
2016
pre-VPF



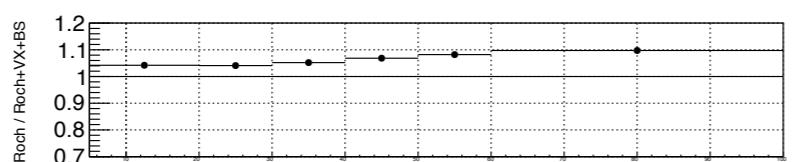
2016
post-VPF



2017

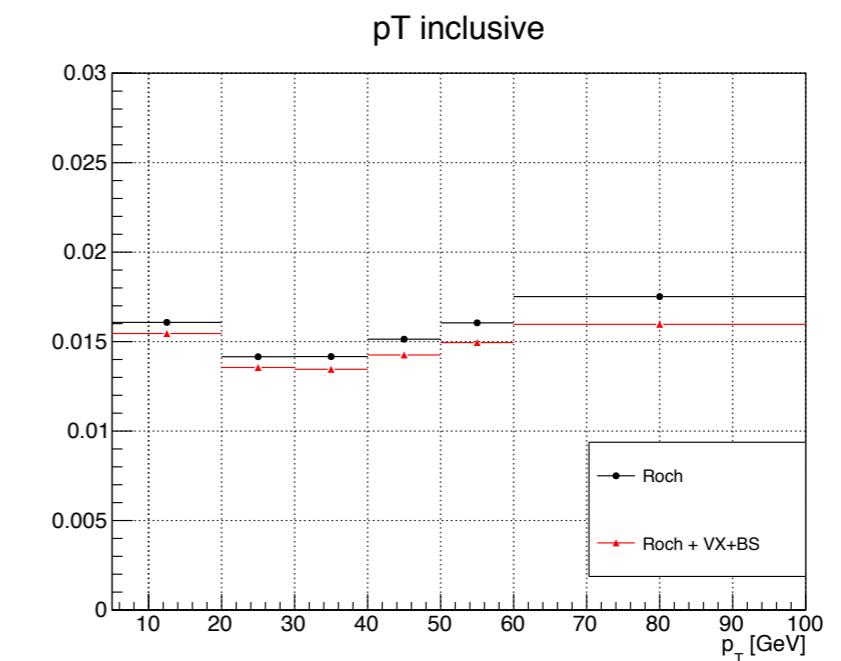
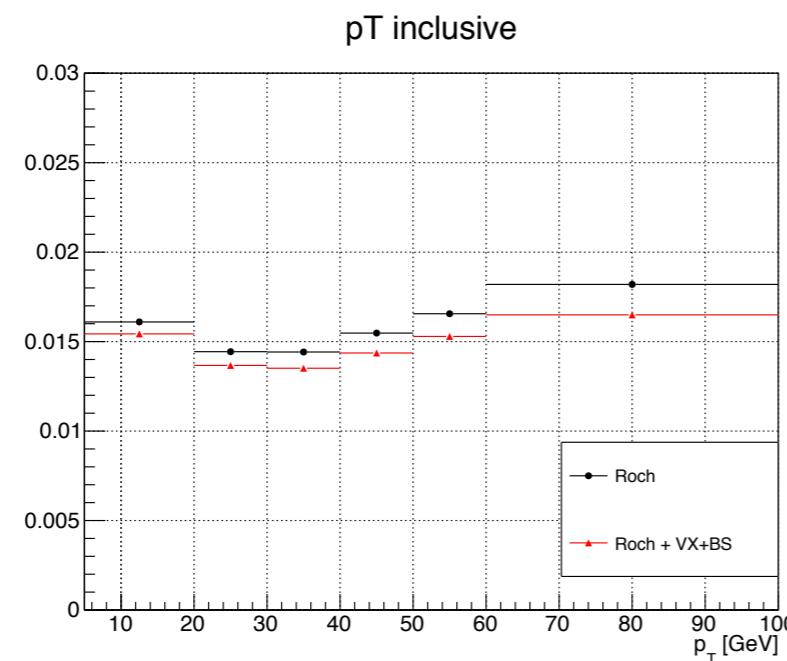


2018

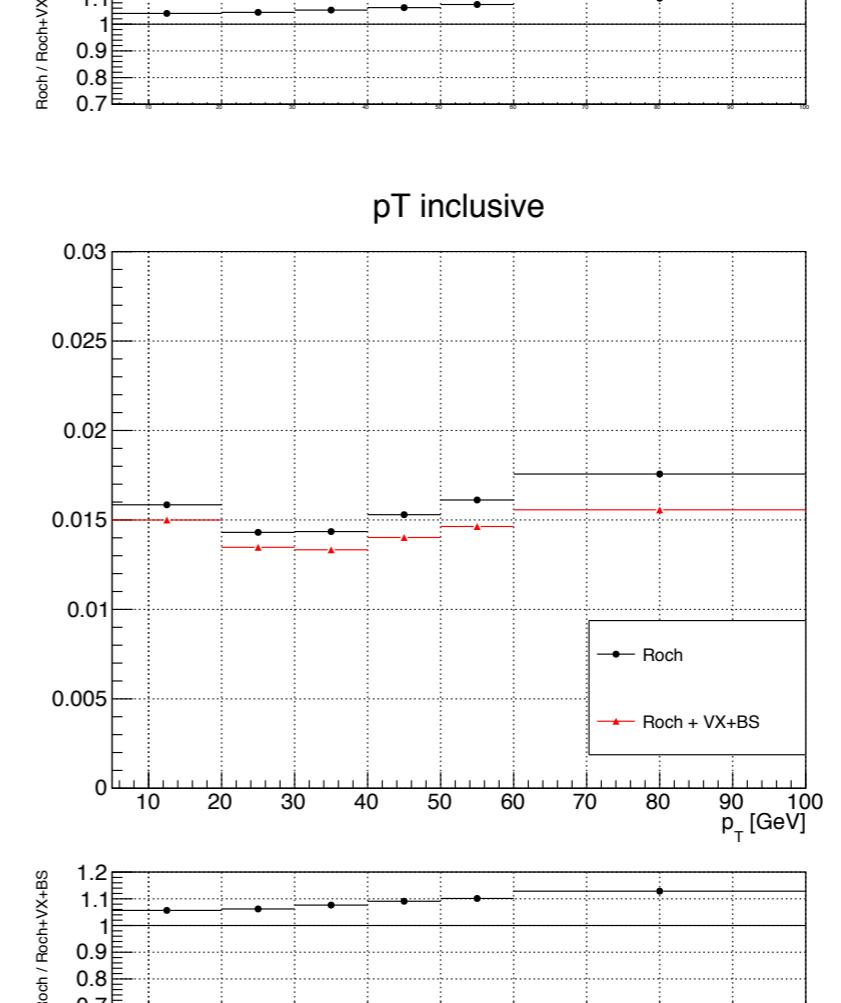
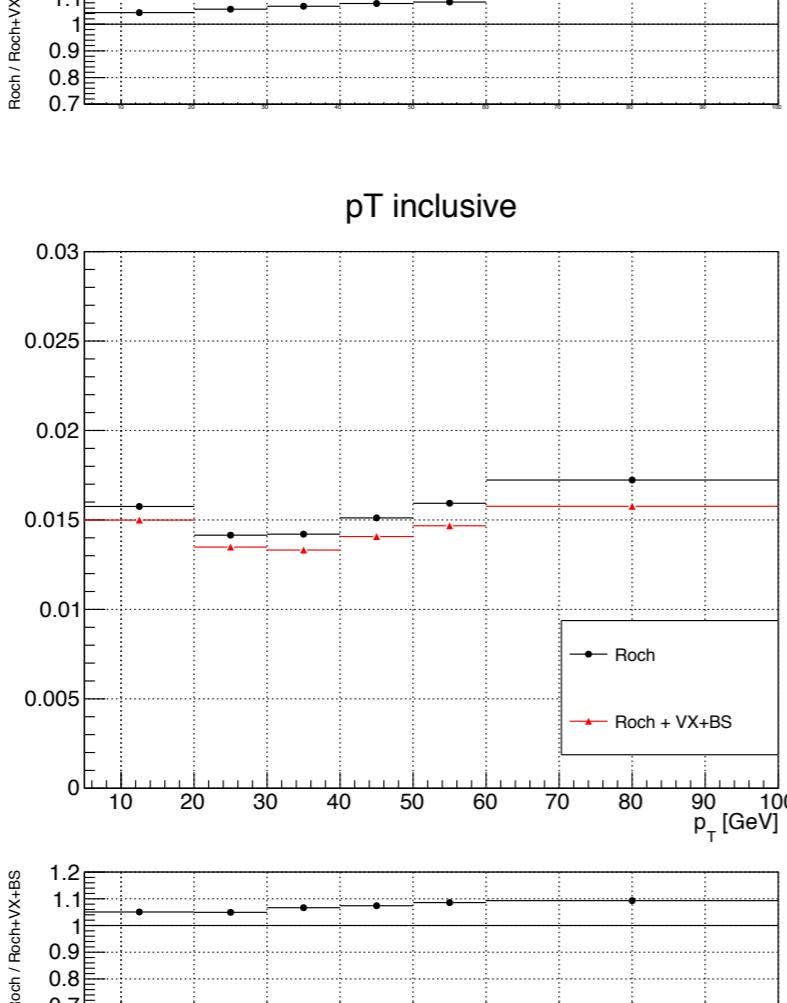


muon pT resolution vs pT

UL

2016
pre-VPF2016
post-VPF

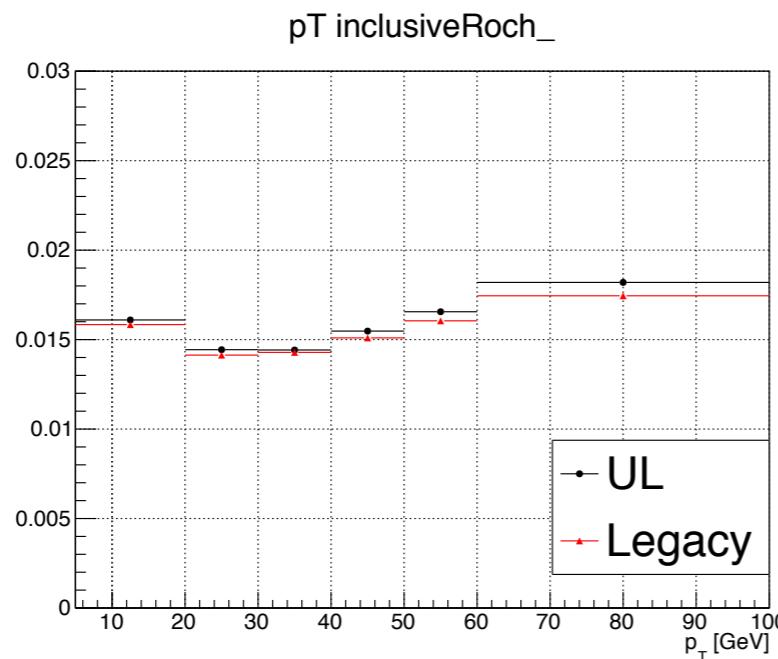
2017



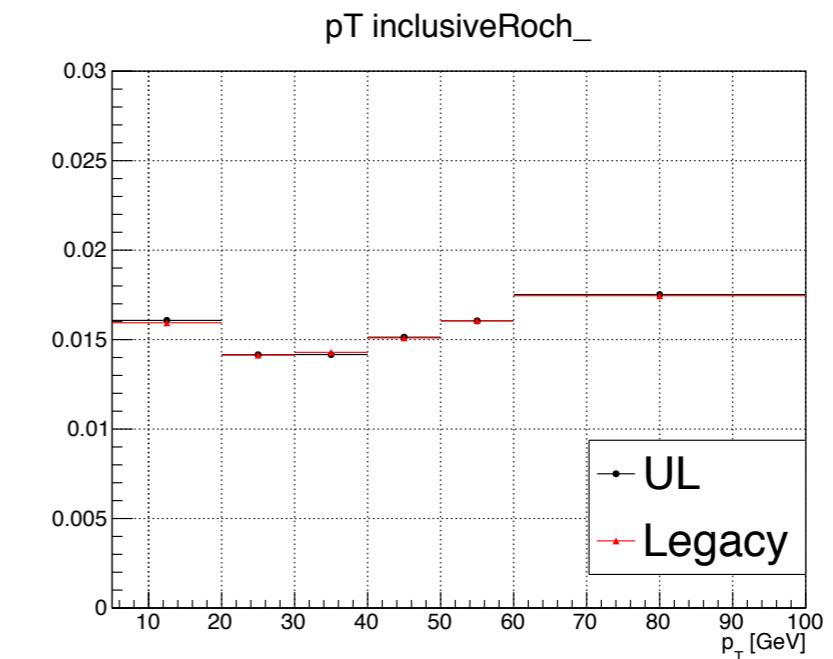
2018

muon pT resolution vs pT

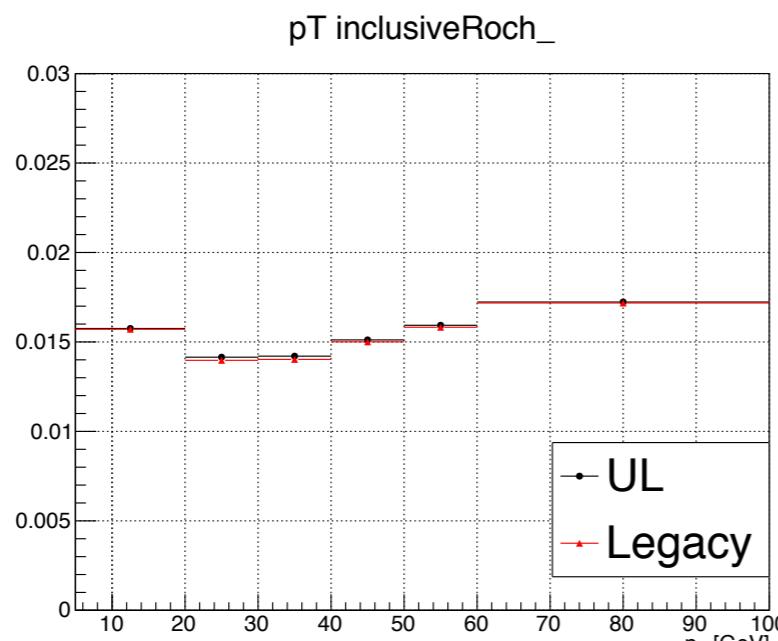
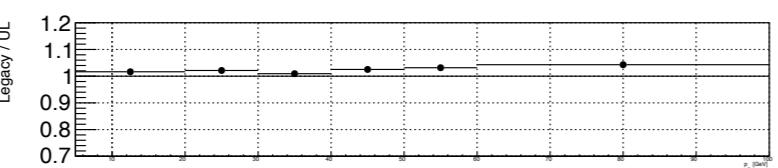
Rochester



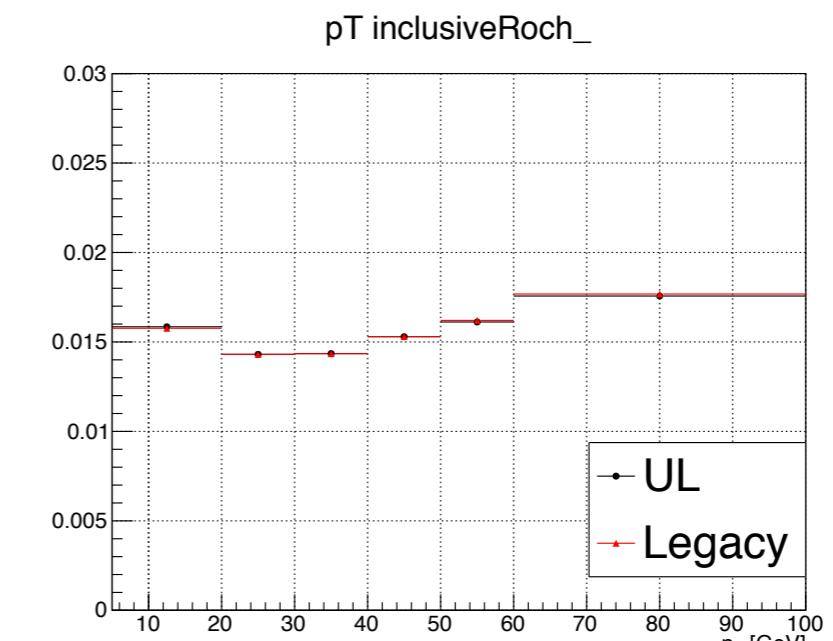
2016
pre-VPF



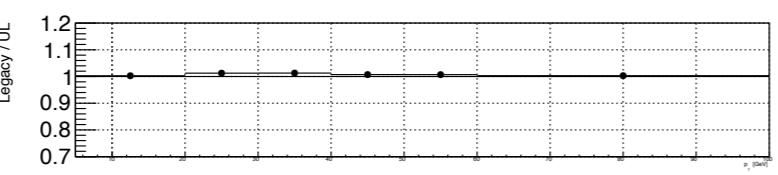
2016
post-VPF



2017



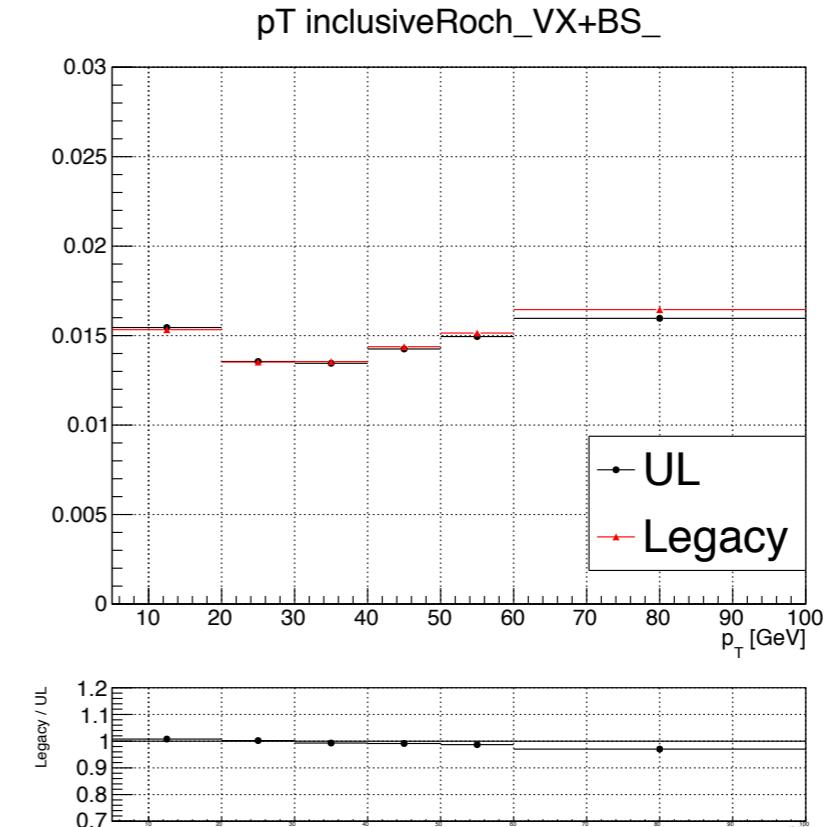
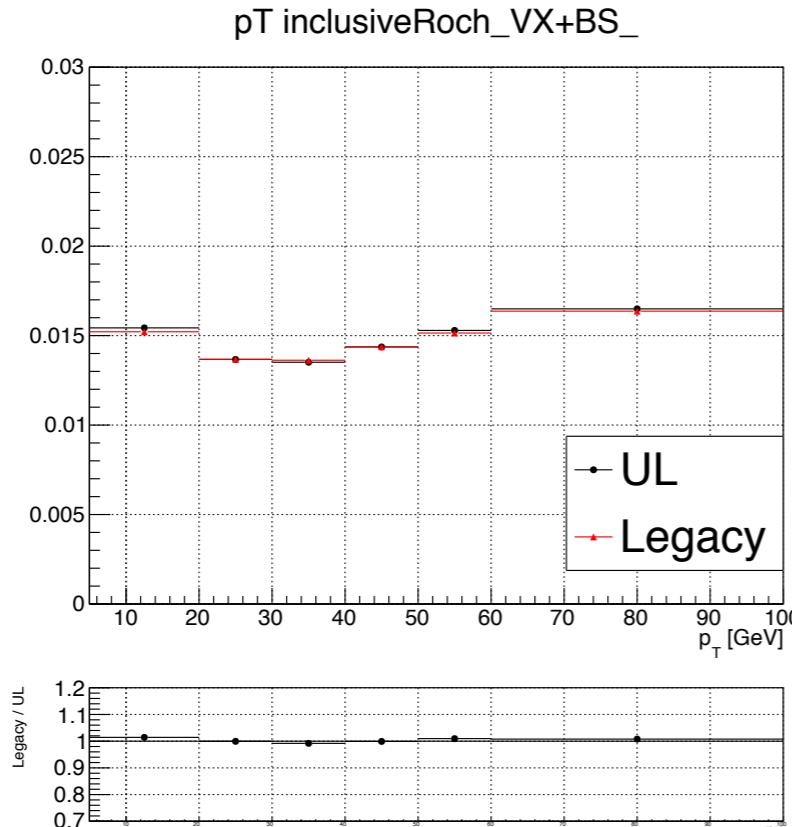
2018



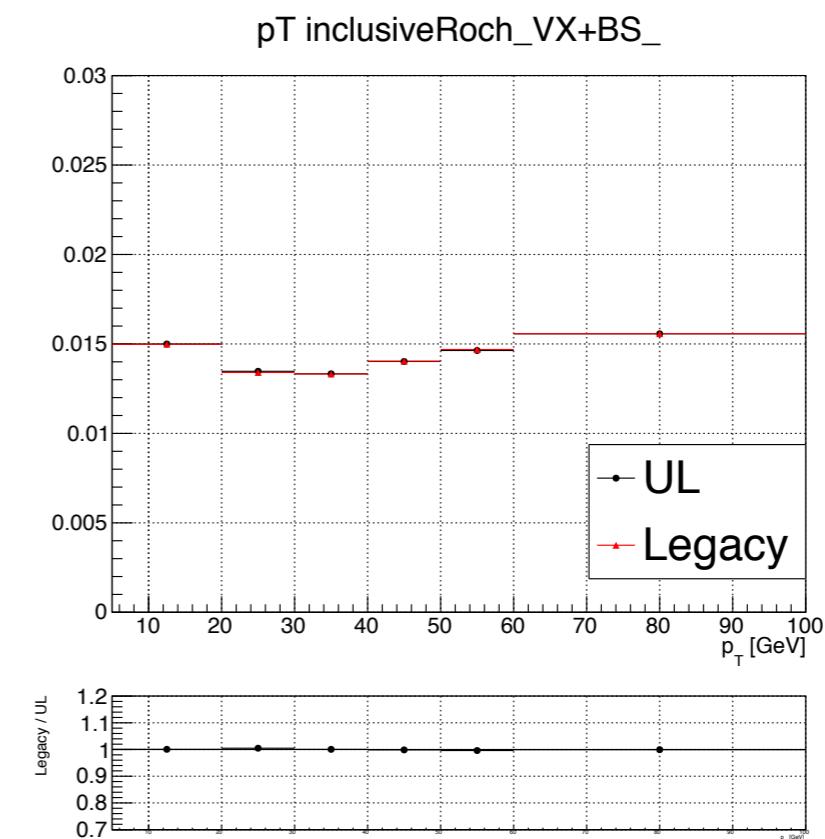
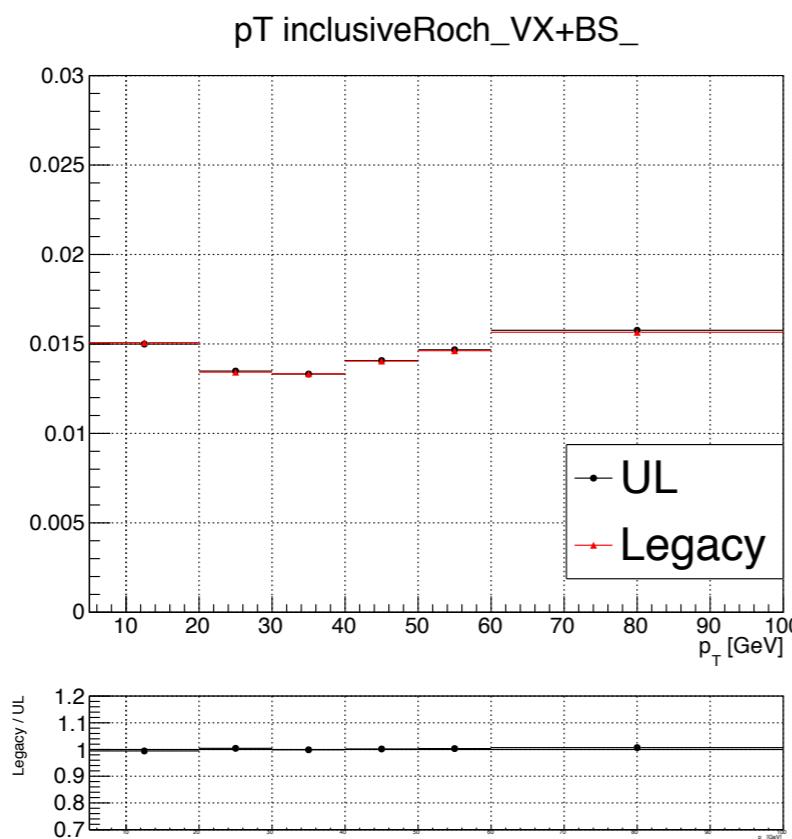
muon pT resolution vs pT

2016
pre-VPF

Rochester
+
VX+BS



2017

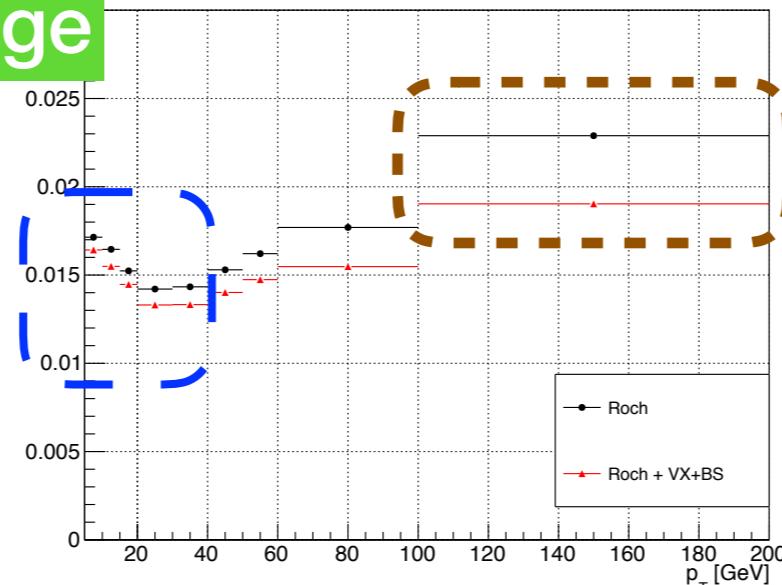


muon pT resolution: Legacy

Inclusive η range

Now three bins:
 $[5, 10, 15, 20]$

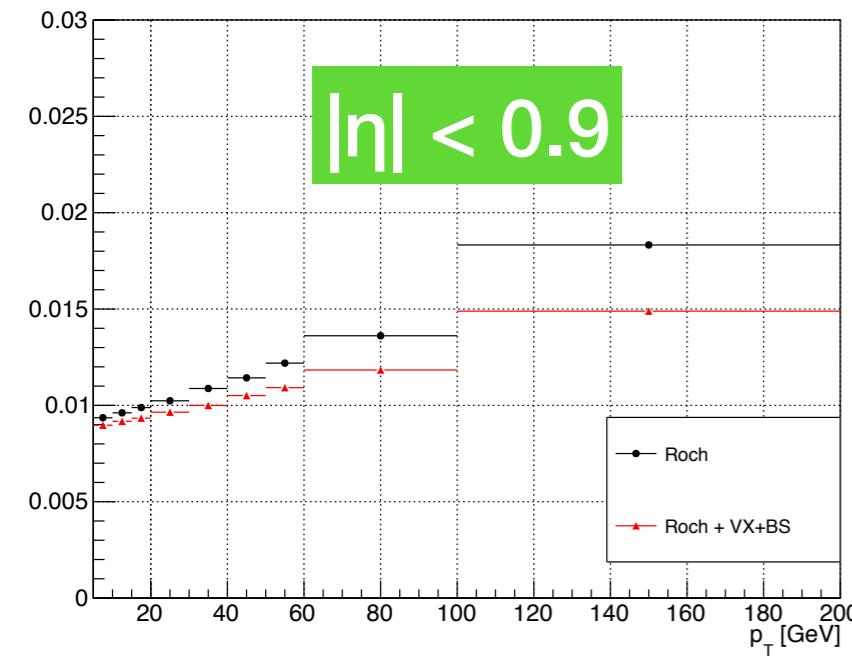
pT inclusive



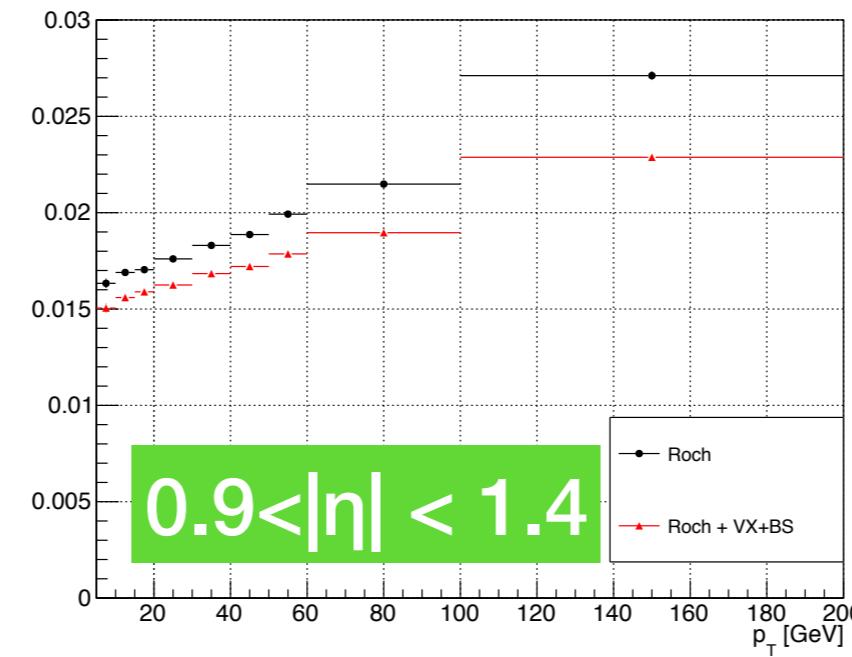
Additional bin
 $[100, 200]$ GeV

2018

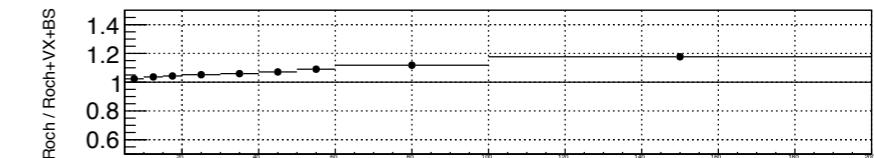
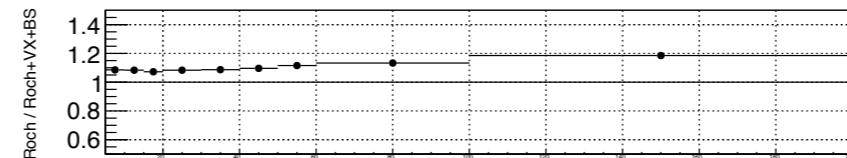
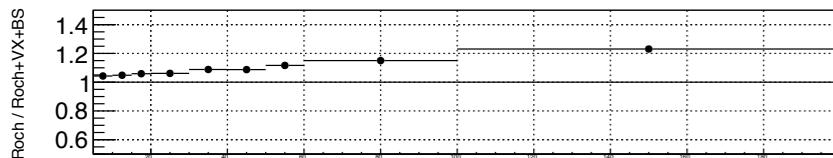
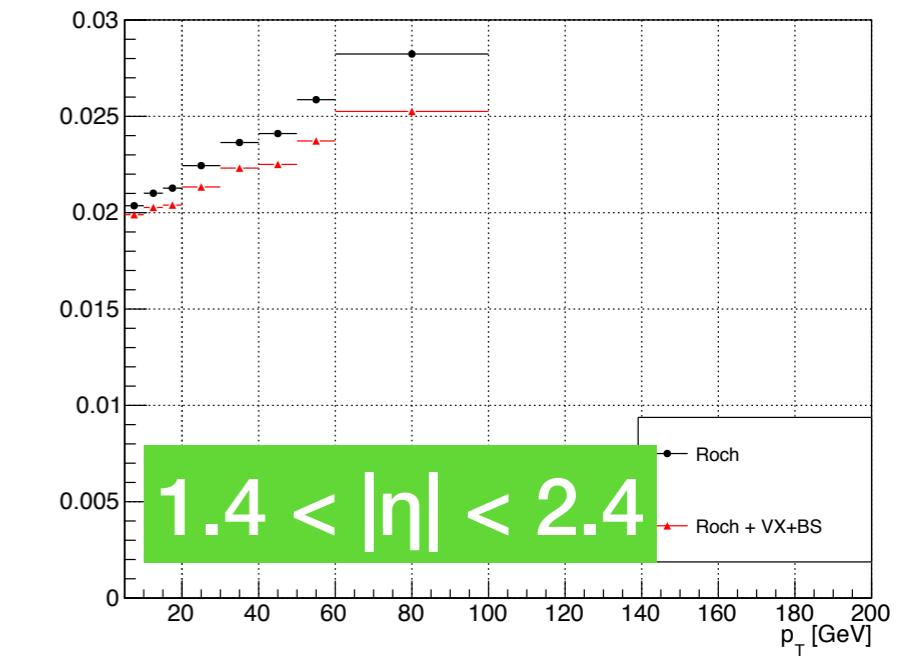
pT inclusive



pT inclusive



pT inclusive

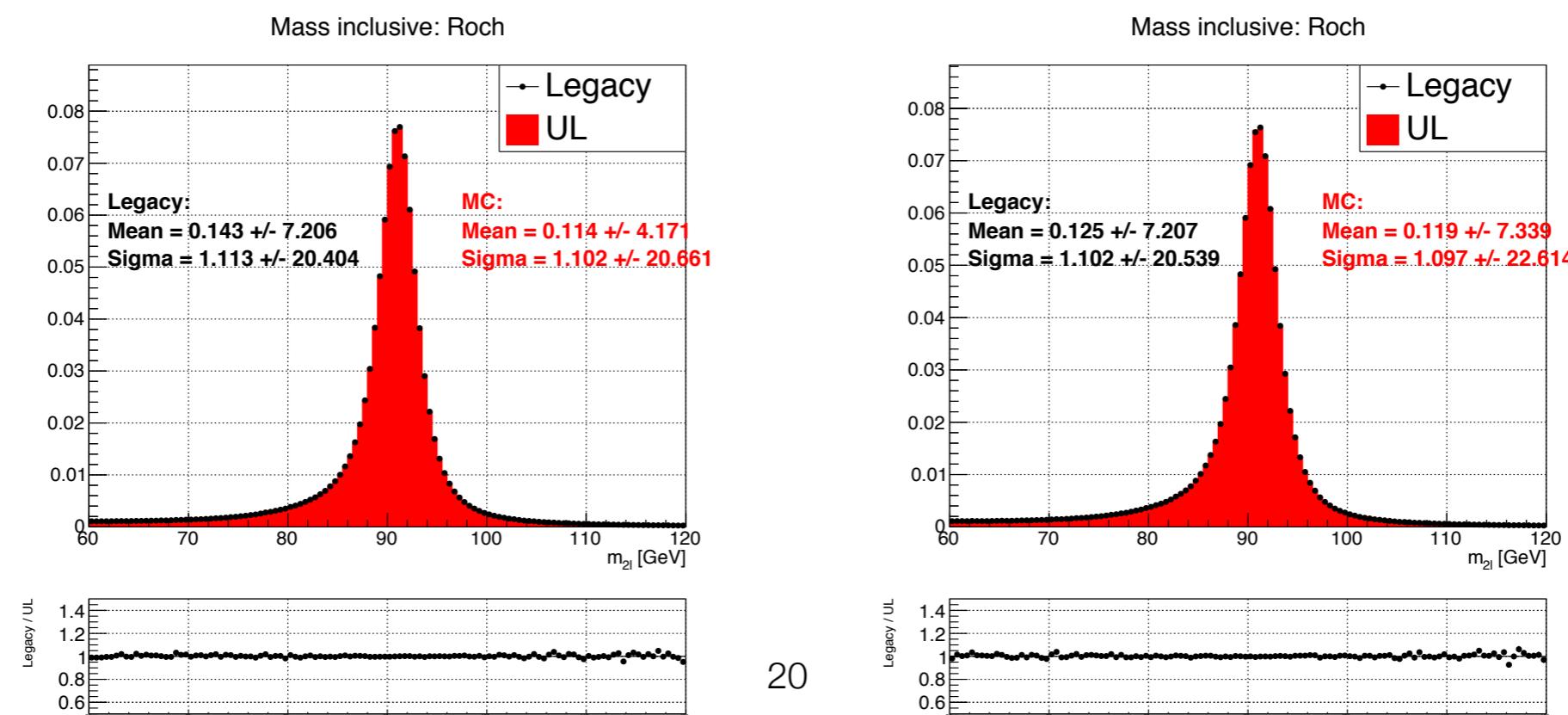
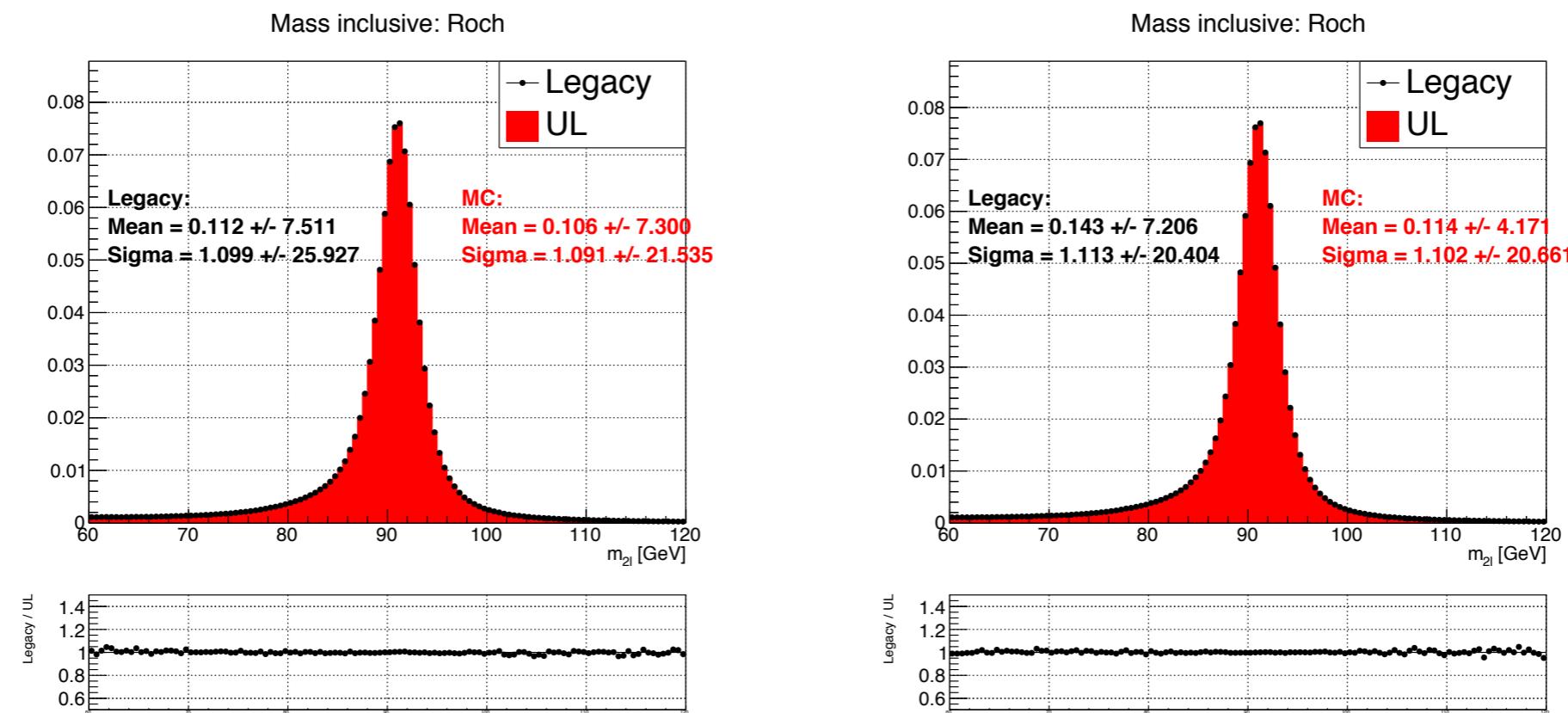


UE Dilepton mass distribution

Rochester

2016
pre-VPF

2016
post-VPF

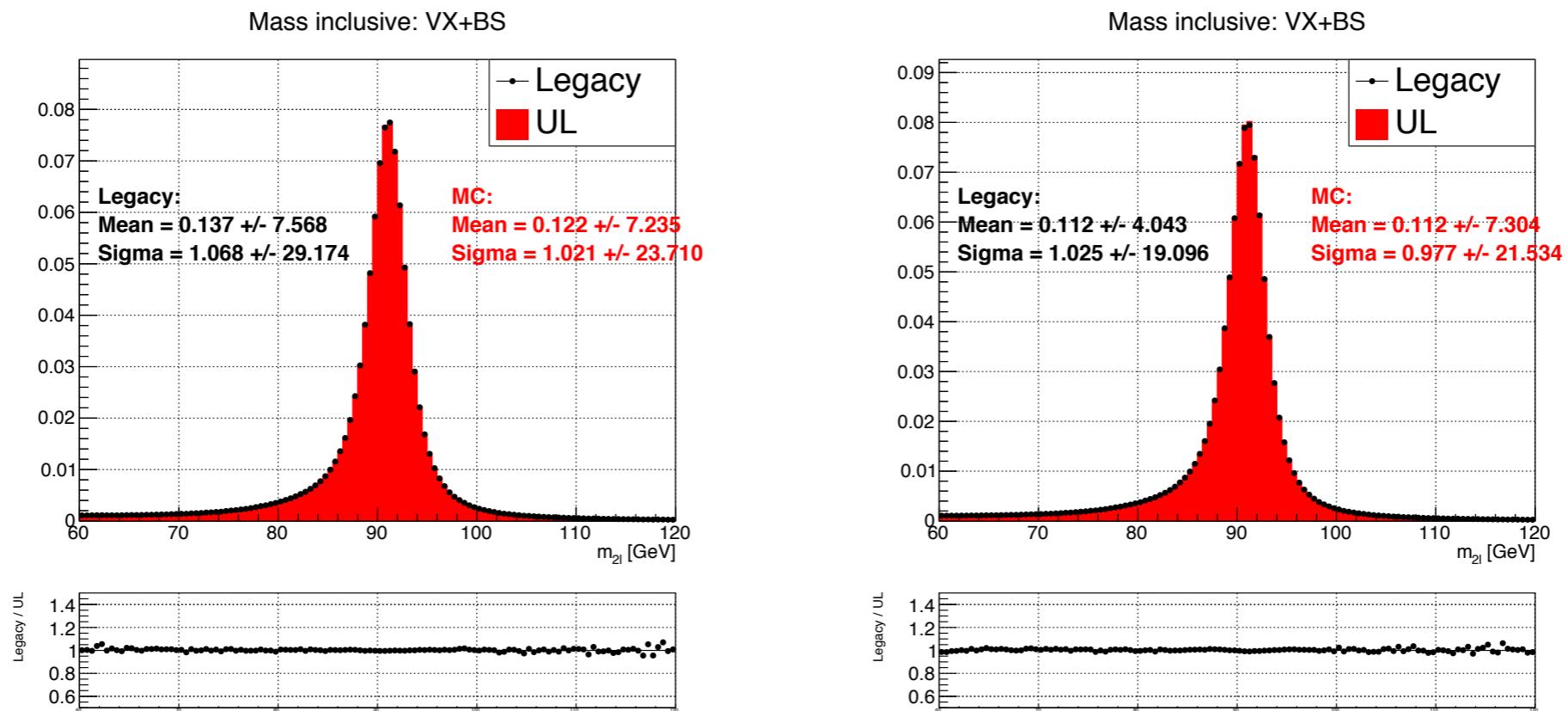


UE Dilepton mass distribution

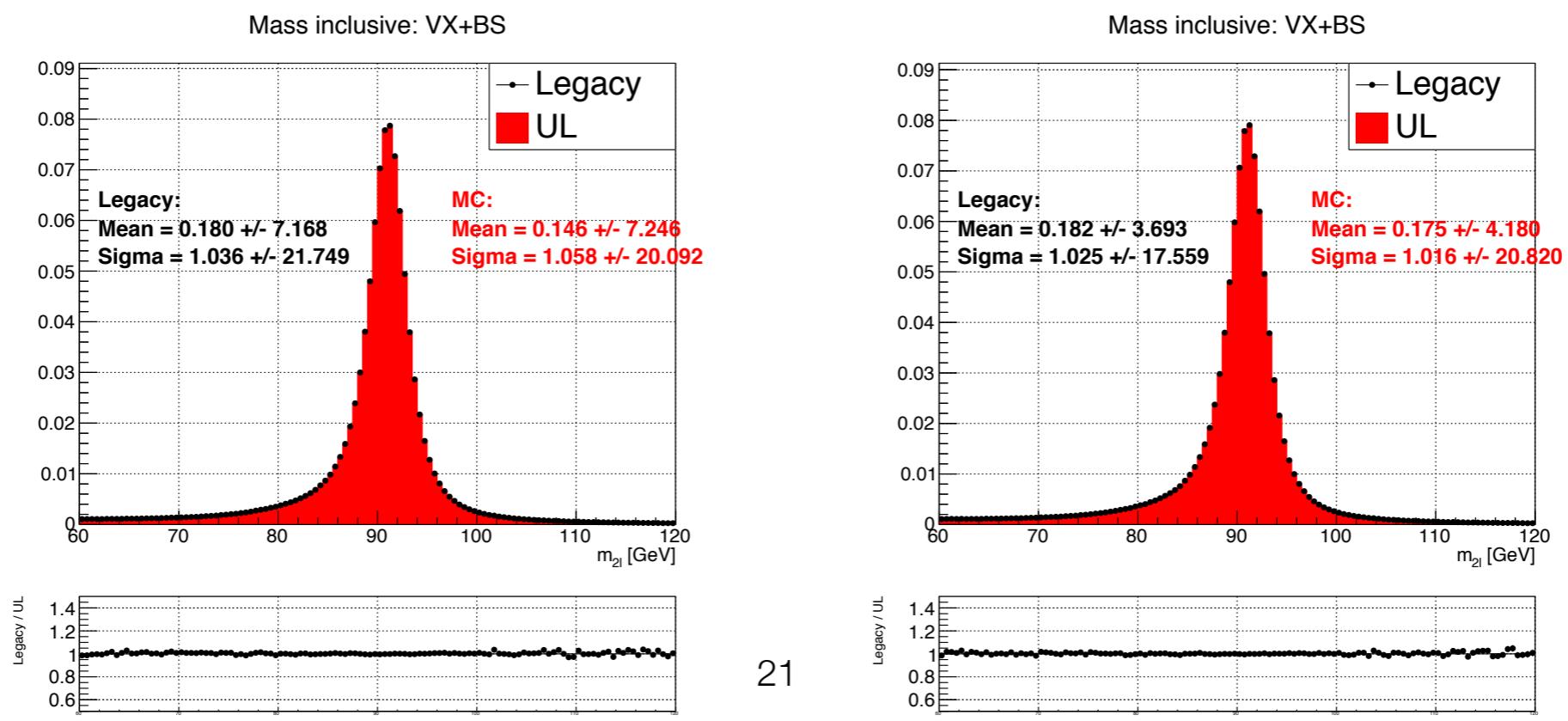
2016
pre-VPF

Rochester
+
VX+BS

2016
post-VPF



2017



2018

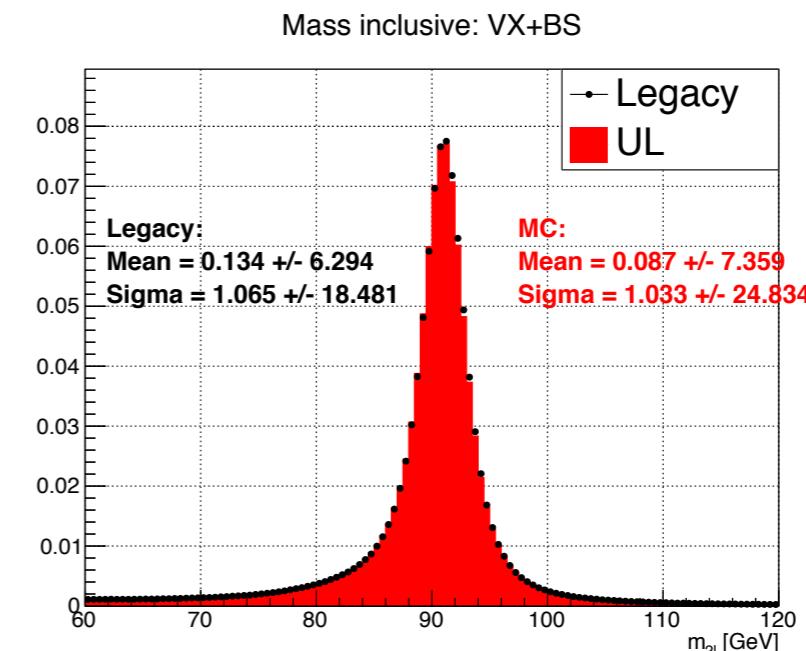
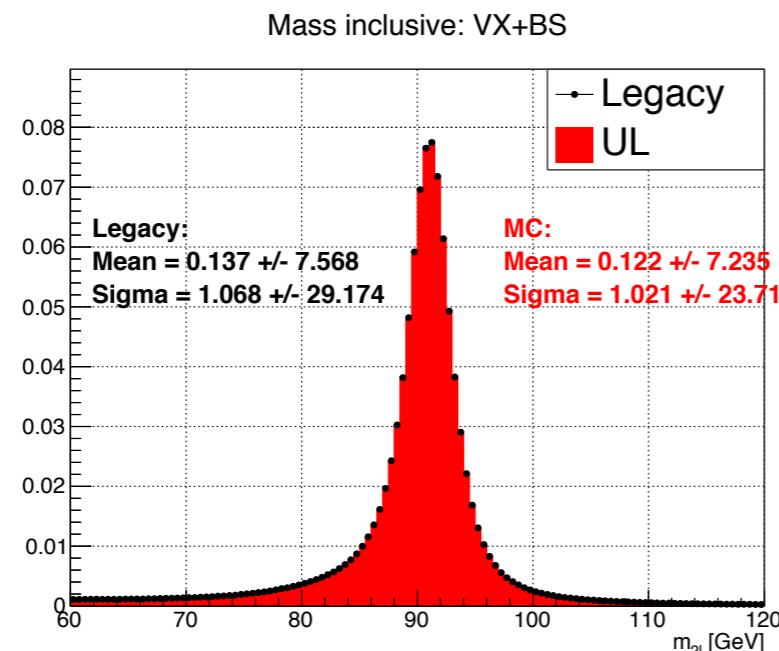
UE Dilepton mass distribution

2016
pre-VPF

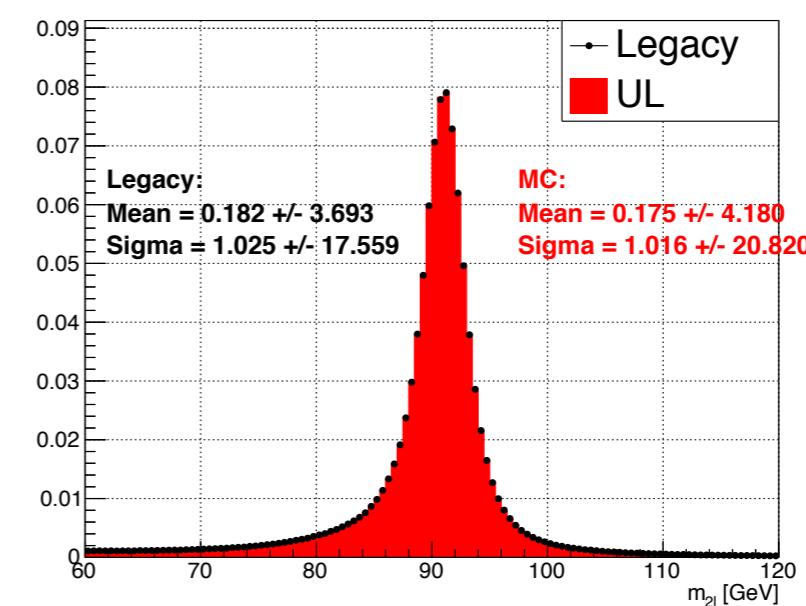
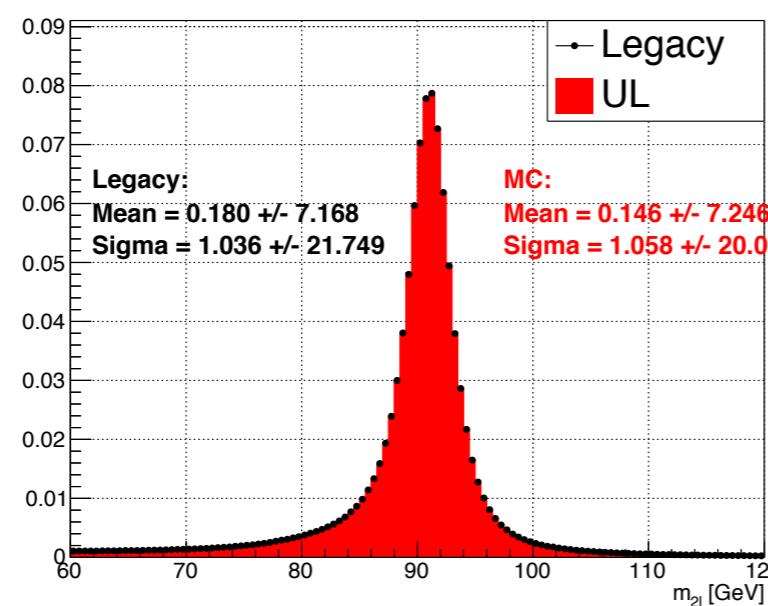
Rochester

+
VX+BS

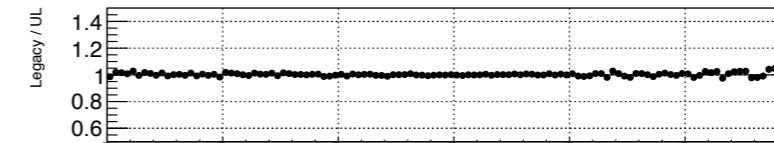
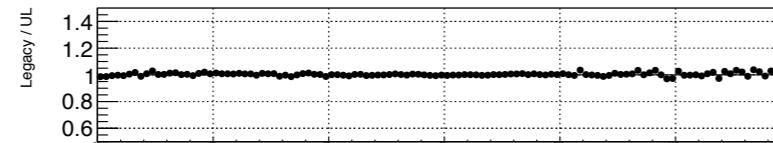
Good agreement also at dimuon mass level
after having applied VX+BS



2016
post-VPF



2018



Legacy VS UL

The previous slides have shown a good agreement in **VX+BS** approach, moving from Legacy samples to UL ones.

In the following slides, **UL only will be taken into account**, comparing also DATA and MC.

As a side-comparison, a second approach will be also shown: **SingleBS**.

In **SingleBS**, each single muon track is constrained to the beam spot. The constraint is done using track info at miniAOD level, profit of “SingleTrackVertexConstraint” function already available in CMSSW

As a remark, in the **VX+BS** approach, the system of 4 (2) tracks is constrained to the BS, profit of KalmanVertexFitter, still at miniAOD level.

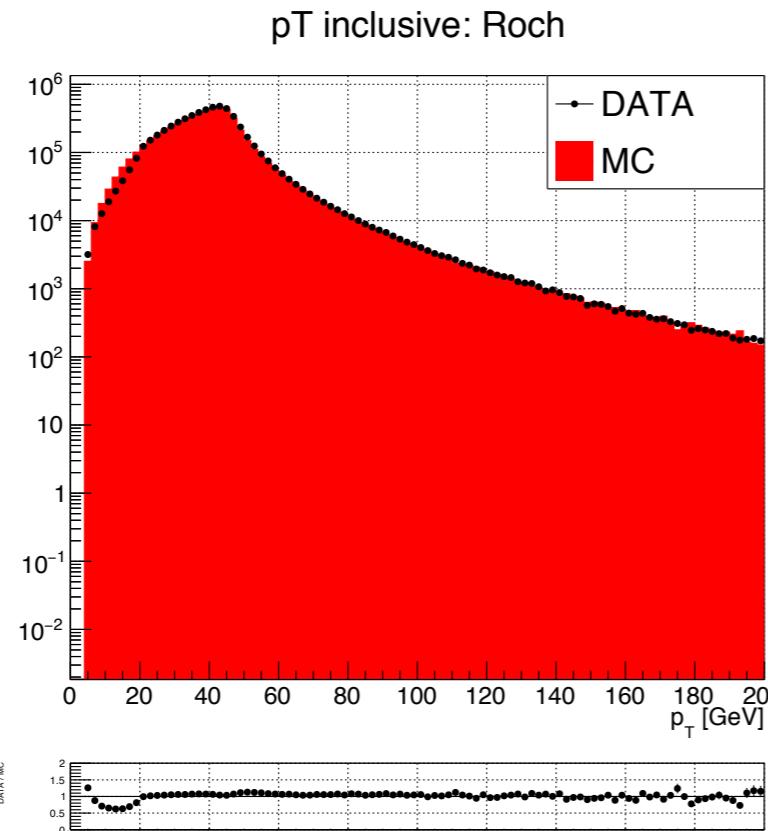
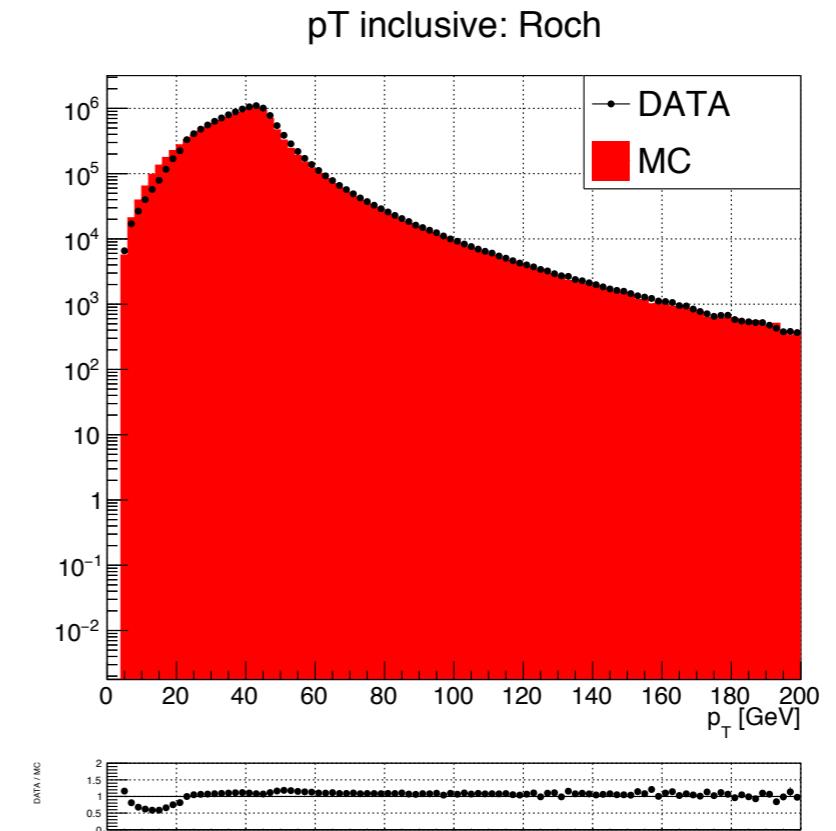
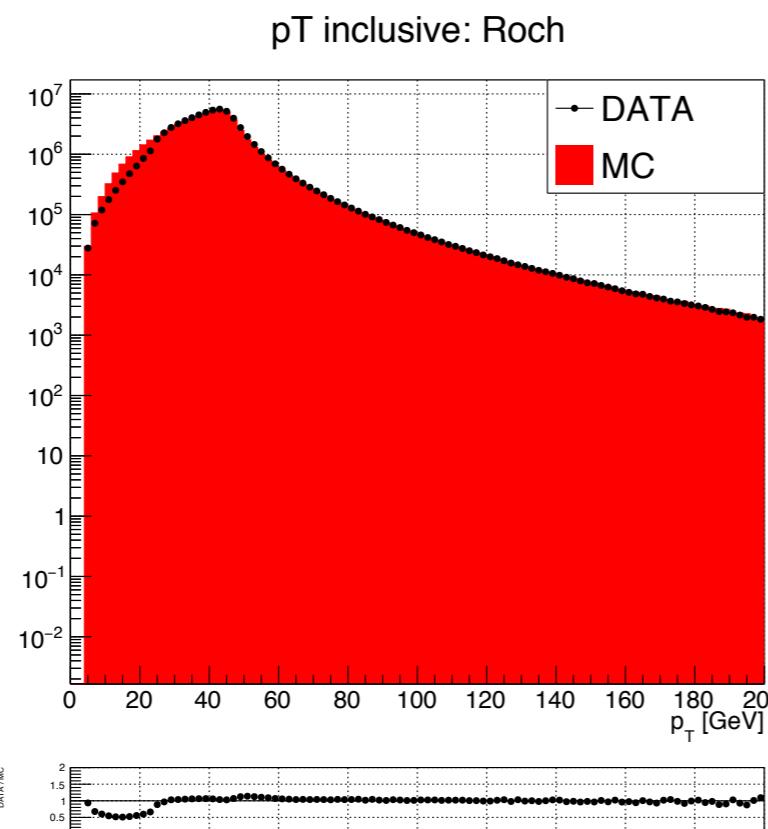
Data Samples

DATA Samples used:

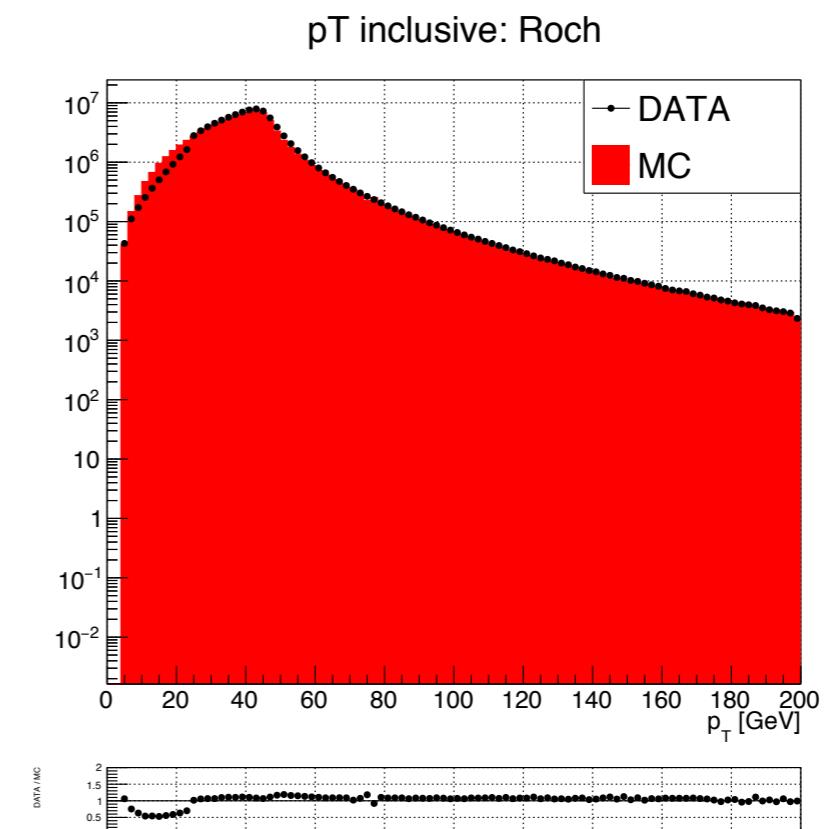
- 2016:
 - ◆ **UL** = /SingleMuon/Run2016*-21Feb2020_UL2016_HIPM-v1/MINIAOD && /SingleMuon/Run2016*-21Feb2020_UL2016-v1/
 - ◆ **reReco** = /SingleMuon/Run2016 B-17Jul2018_ver2 && /SingleMuon/Run2016 [C-H]-17Jul2018
- 2017:
 - ◆ **UL** = /SingleMuon/Run2017*-09Aug2019_UL2017
 - ◆ **reReco** = /SingleMuon/Run2017[B-F]-31Mar2018-v1
- 2018:
 - ◆ **UL** = /SingleMuon/Run2018*-12Nov2019_UL2018
 - ◆ **reReco** = /SingleMuon/Run2018 [A-C]-17Sep2018 && /SingleMuon/Run2018D-22Jan2019
- Rochester correction:
 - ◆ **UL** = roccor.Run2.v5/RoccoR201*UL.txt
 - ◆ **reReco** = roccor.Run2.v3/RoccoR201*.txt

pT distributions

Rochester

2016
pre-VPF2016
post-VPF

2017

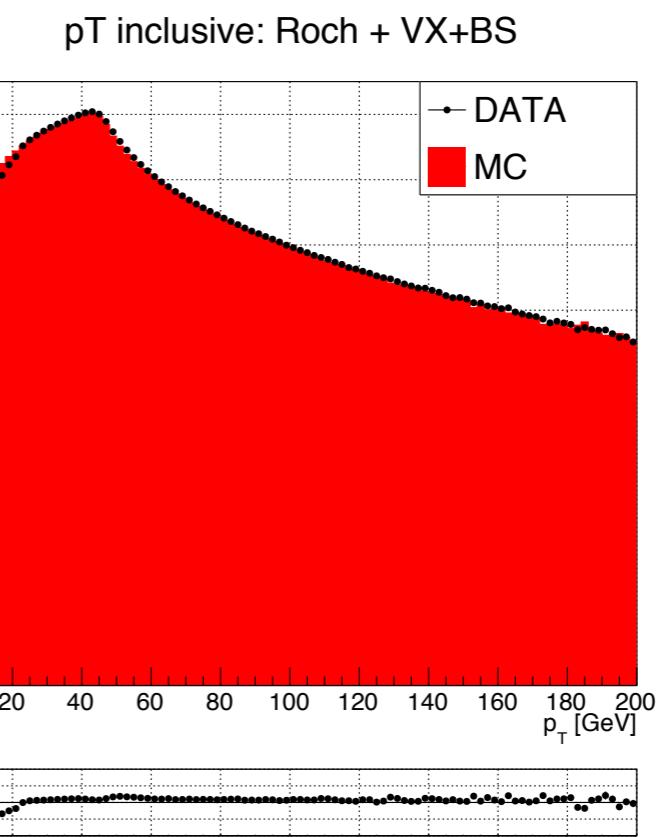
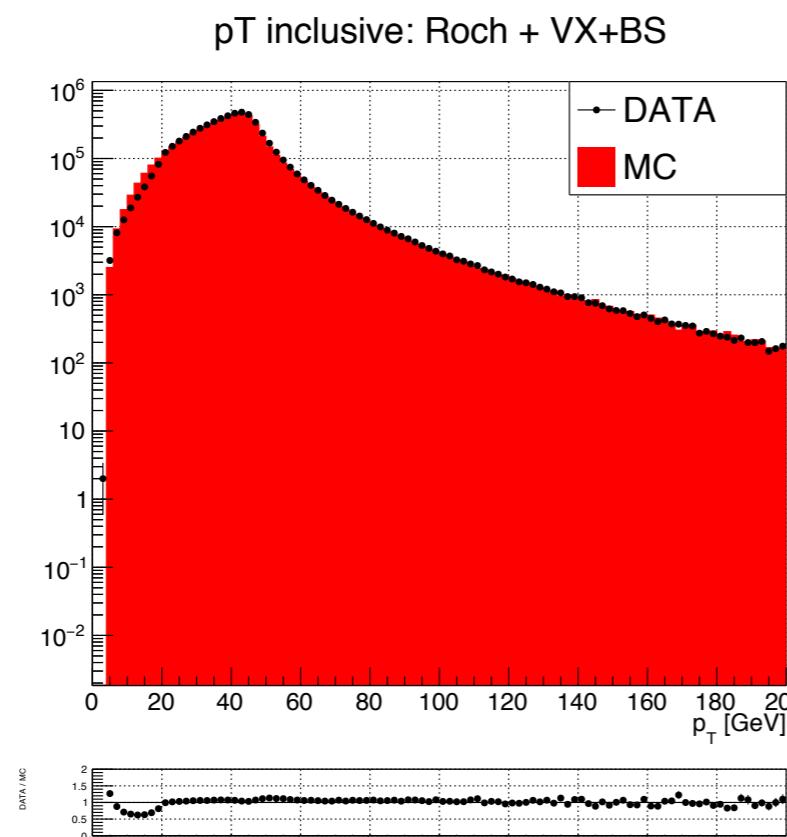


2018

pT distributions

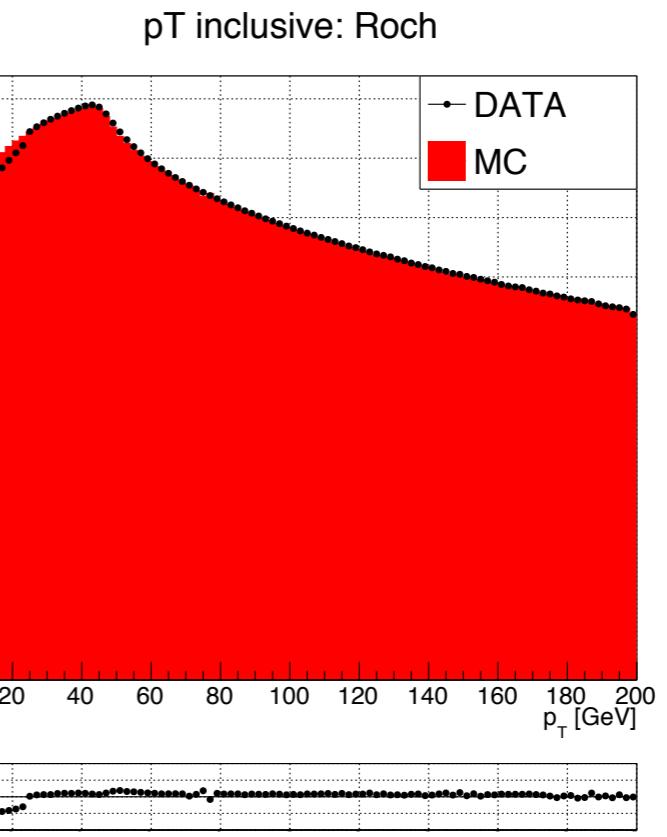
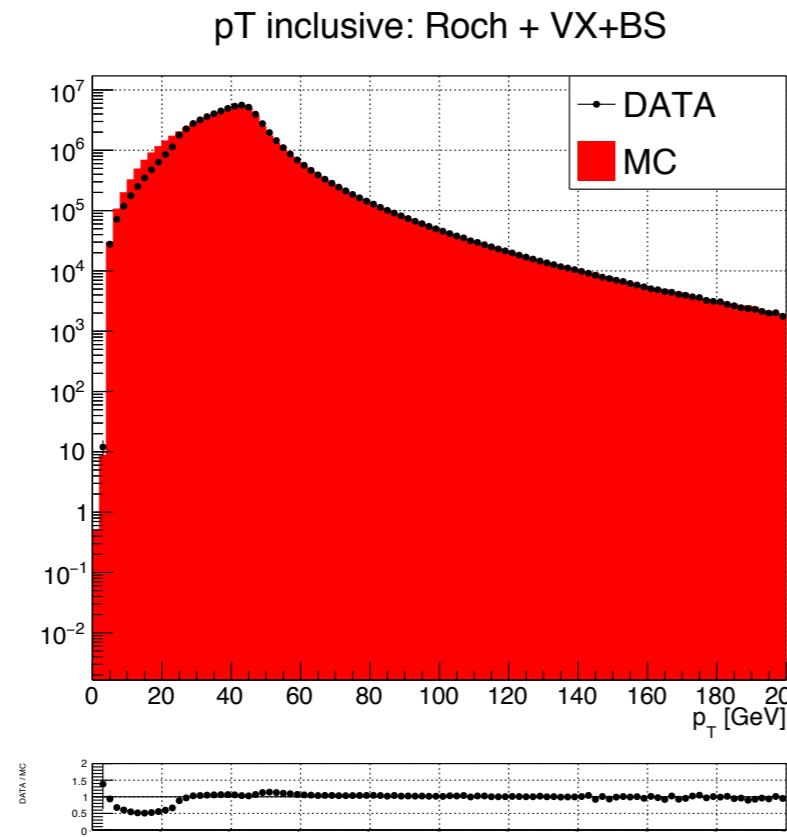
Rochester
+
VX+BS

2016
pre-VPF



2016
post-VPF

2017

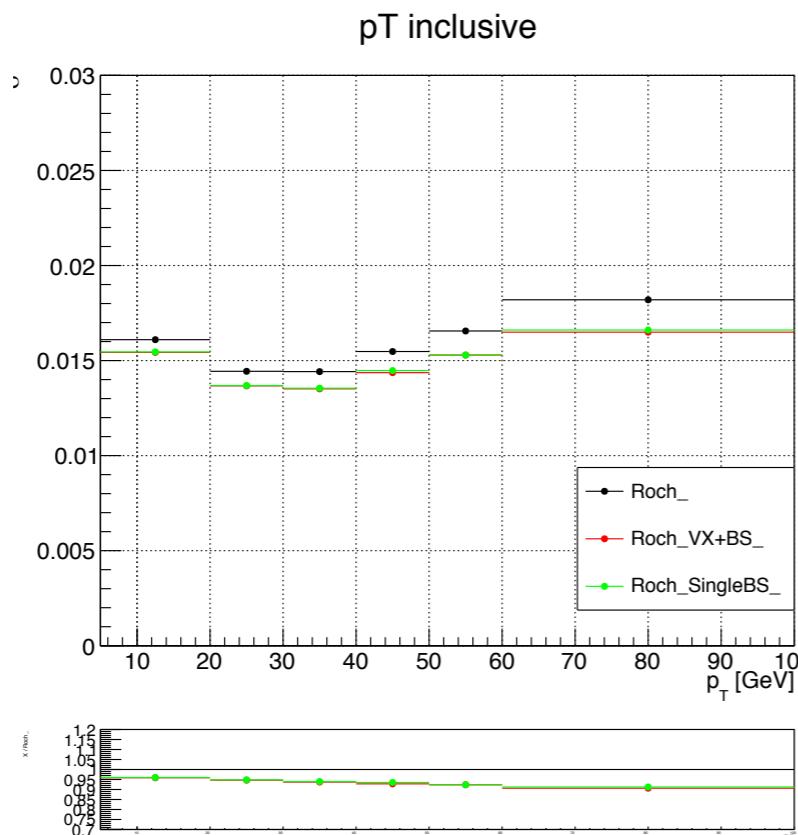


2018

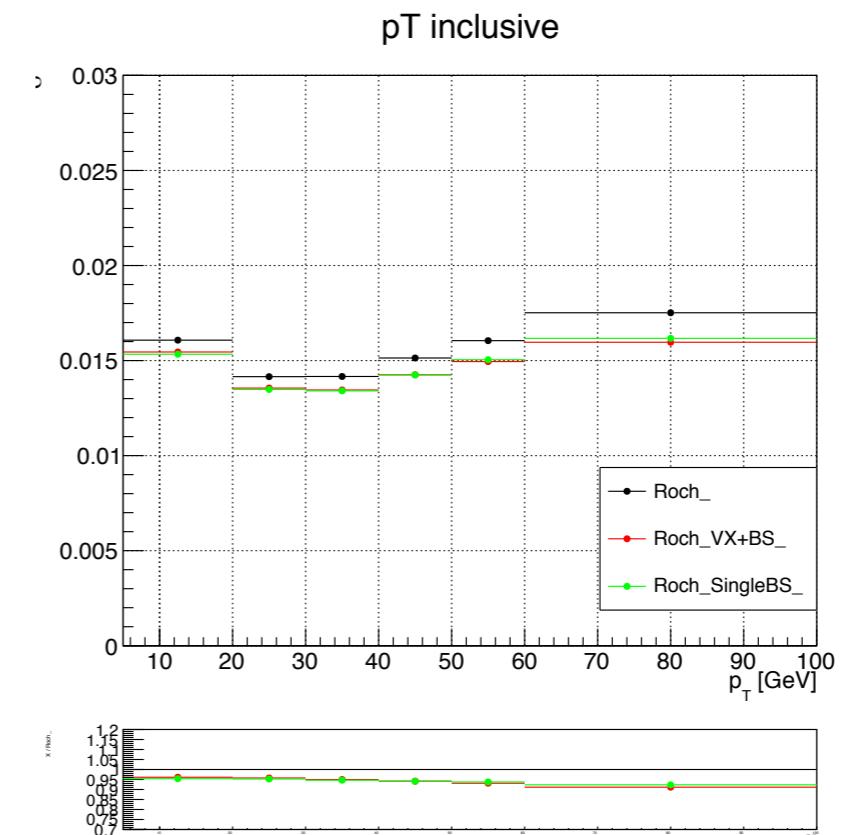
muon p_T resolution



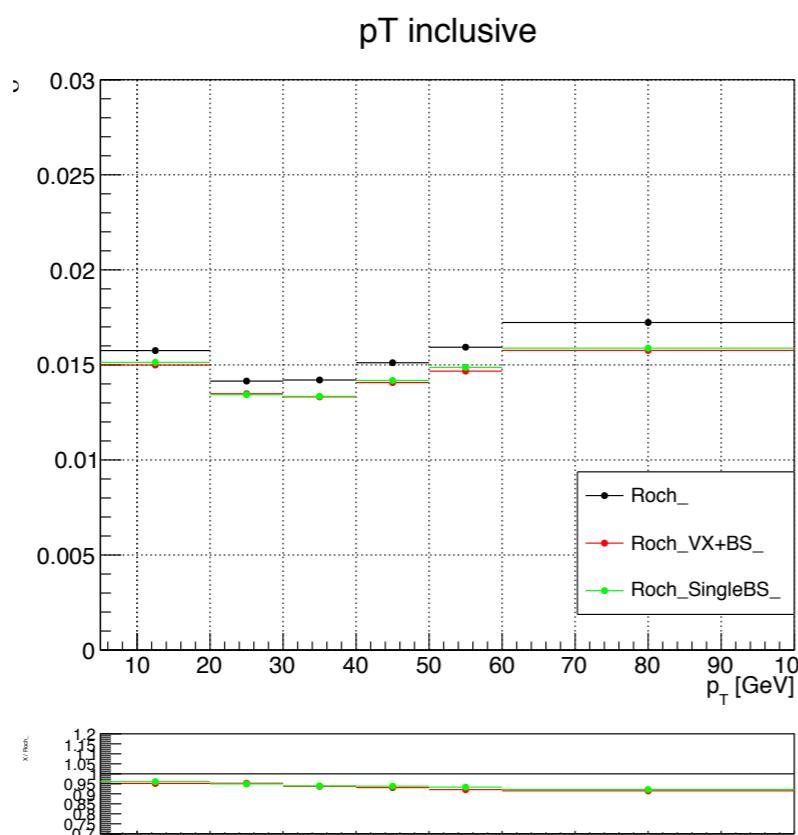
2016
pre-VPF



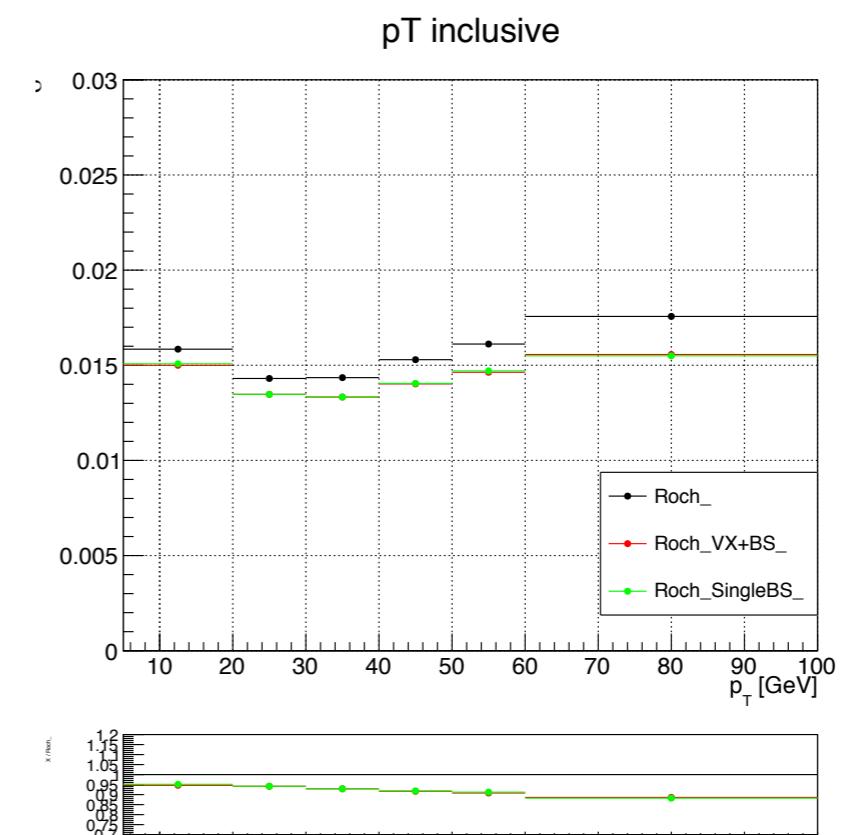
2016
post-VPF



2017



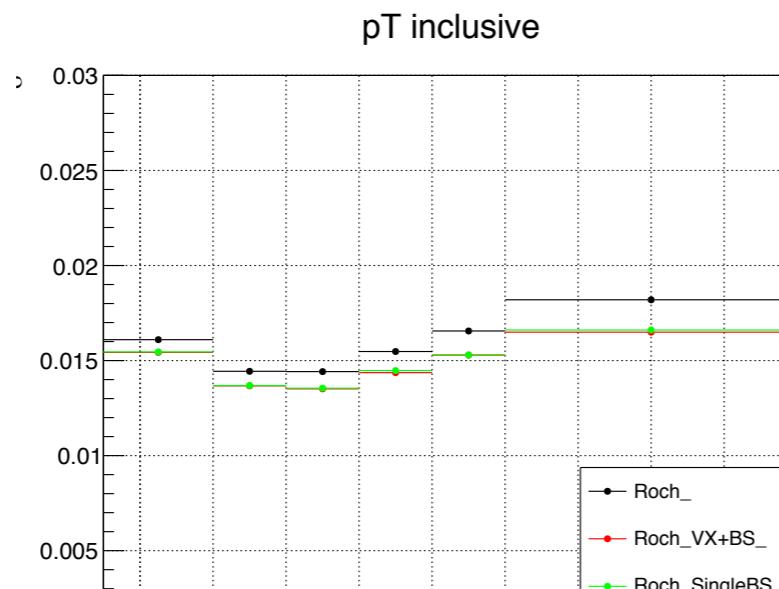
2018



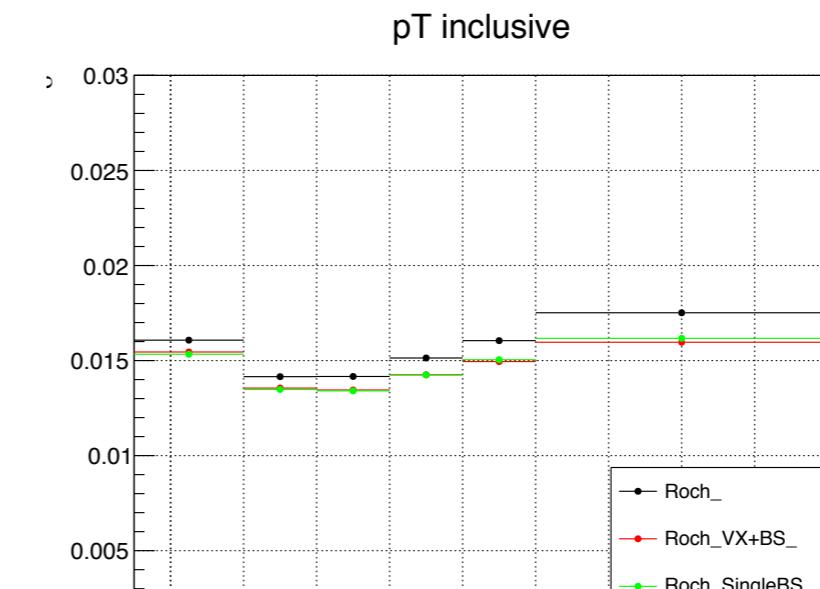
muon pT resolution



2016
pre-VPF

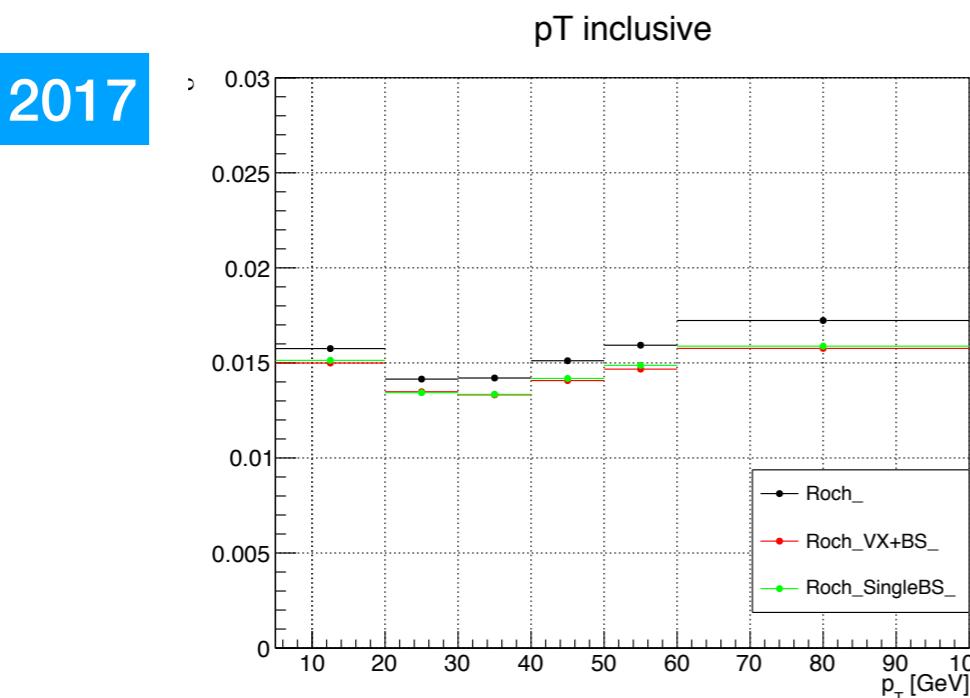


2016
post-VPF

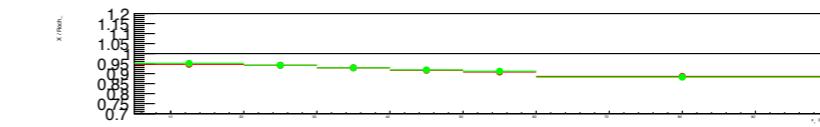
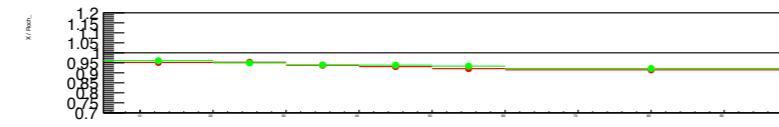
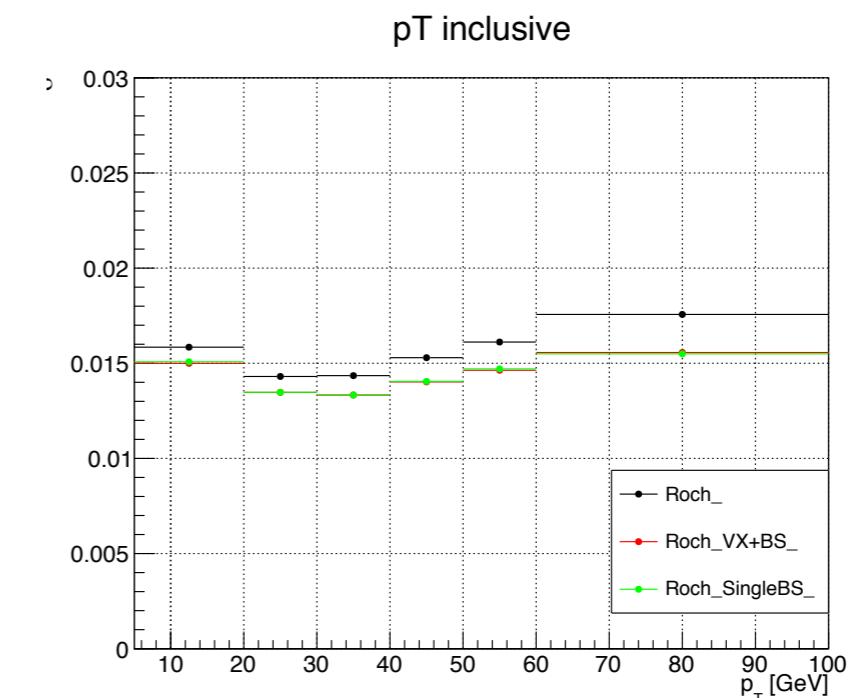


**SingleBS approach shows same improvement as
VX+BS.**

2017



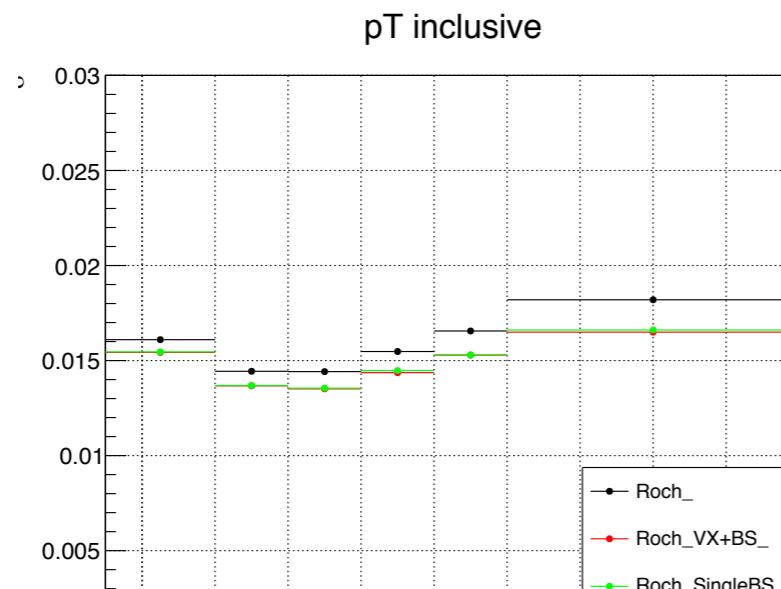
2018



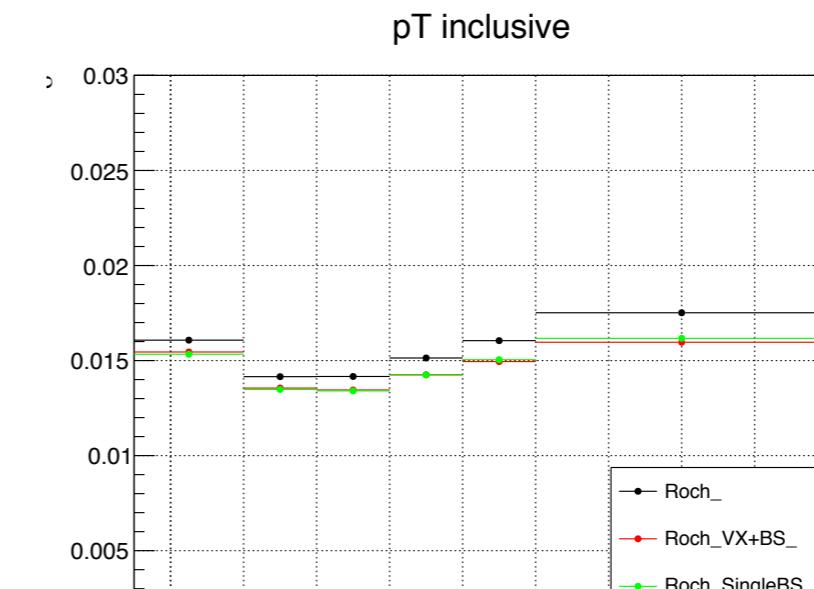
muon pT resolution



2016
pre-VPF

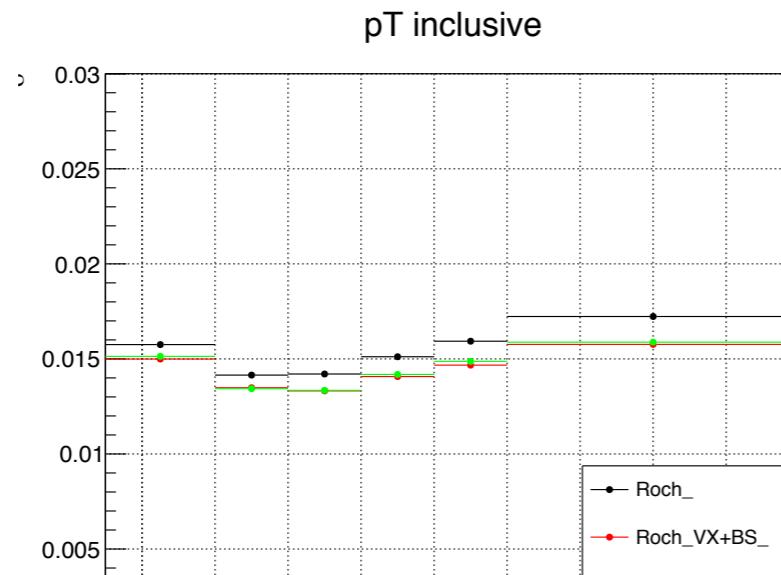


2016
post-VPF

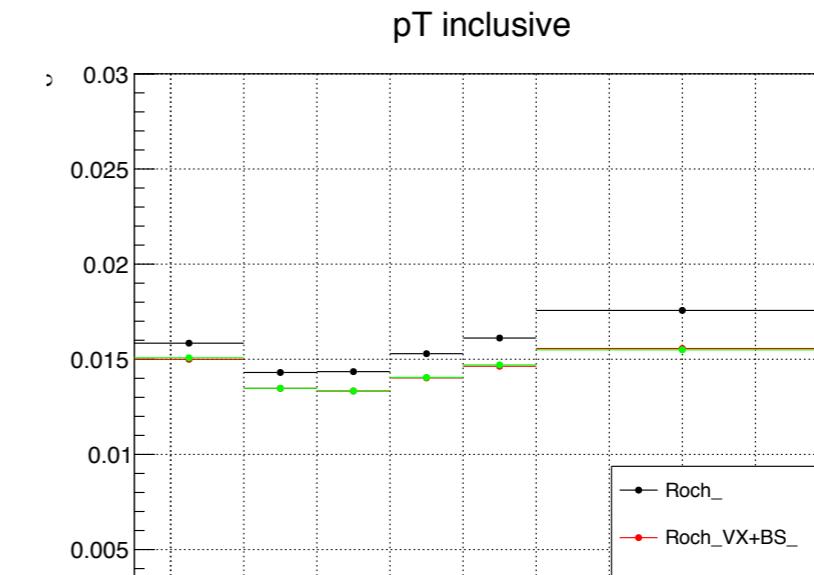


SingleBS approach shows same improvement as VX+BS.

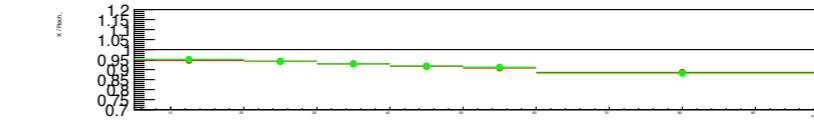
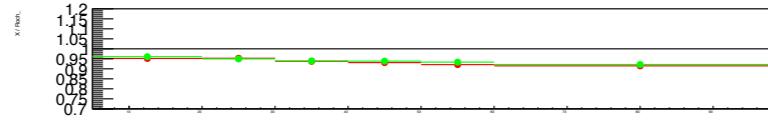
2017



2018



Resolutions vs eta and vs #vtx are in backup



muon pT scale

muon pT scale defined as the mean of the gaussian function used to fit the distribution:

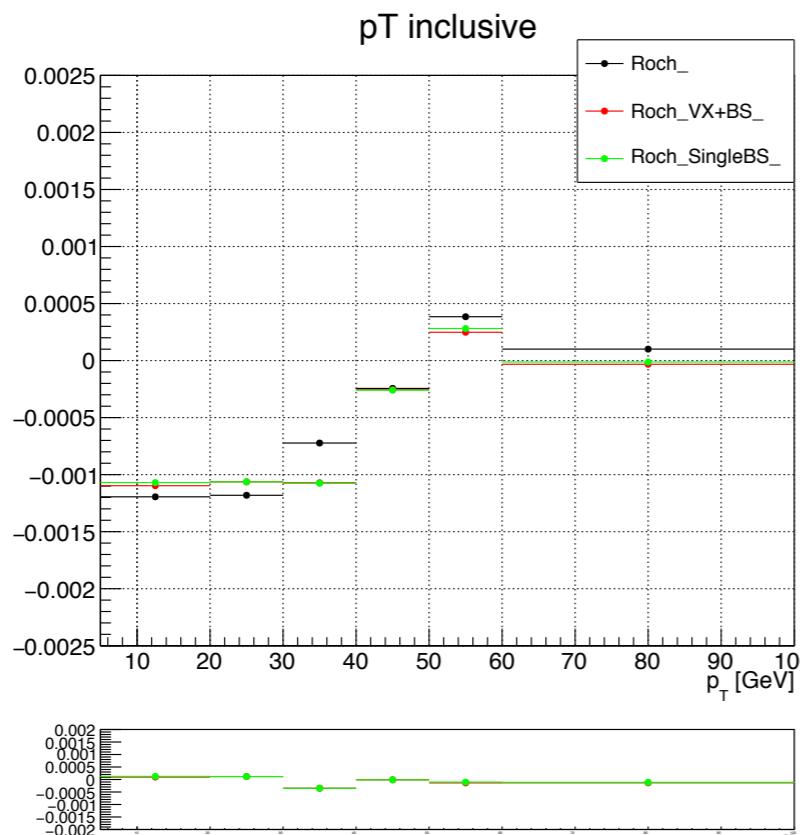
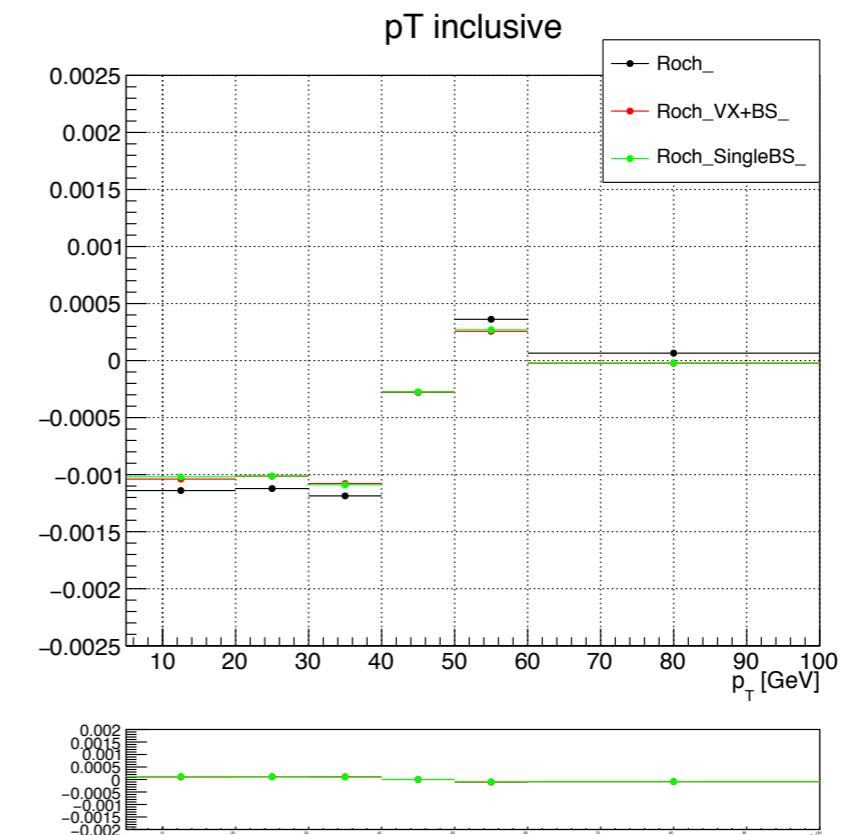
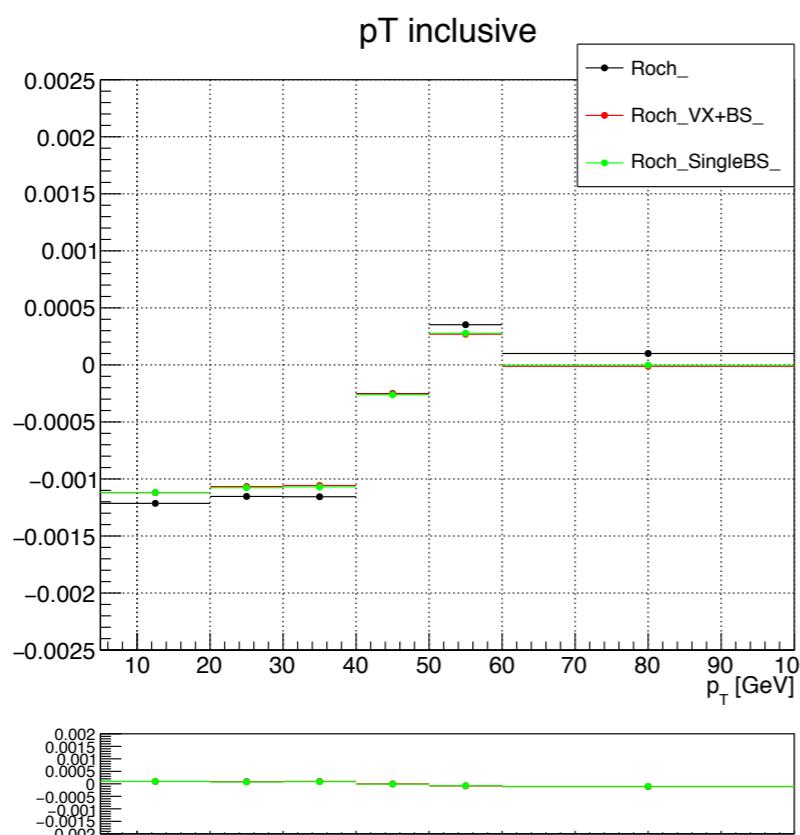
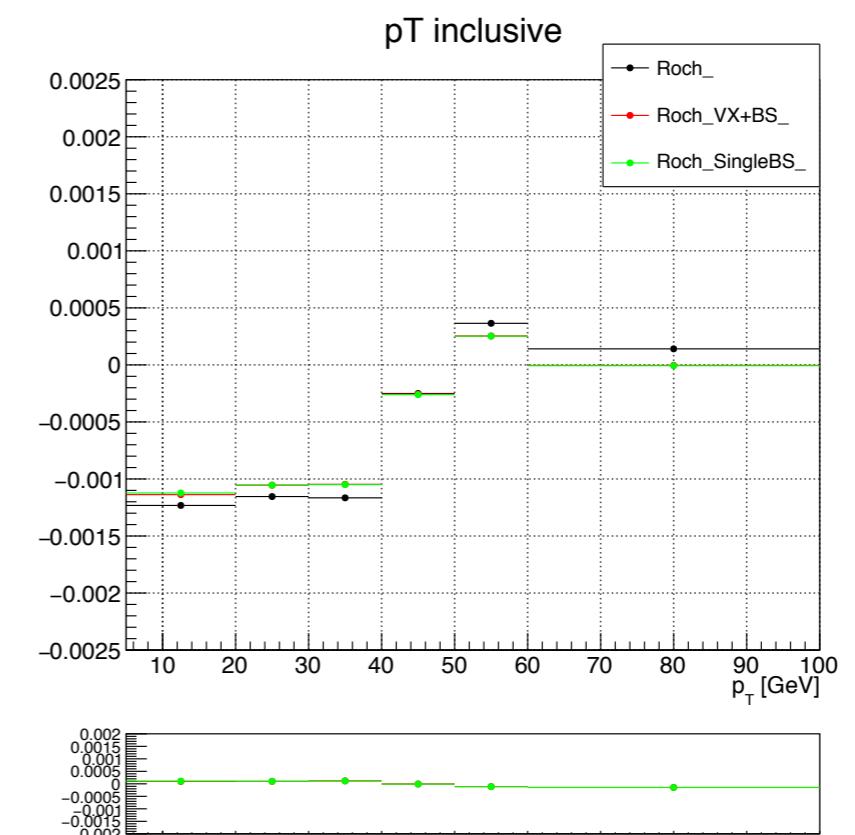
$$\frac{p_T^X - p_T^{GEN}}{p_T^{GEN}}$$

The bottom plot stands for:

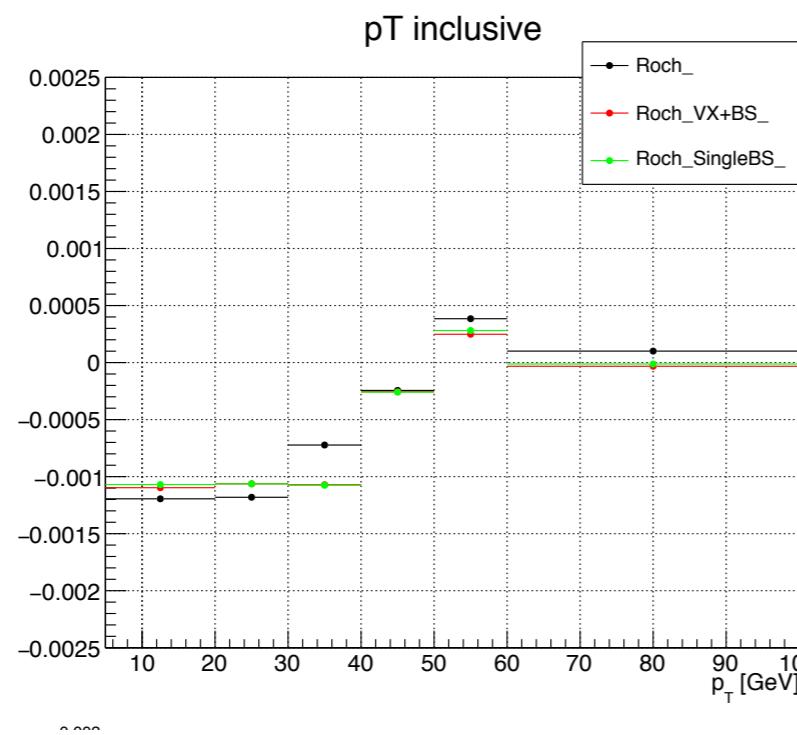
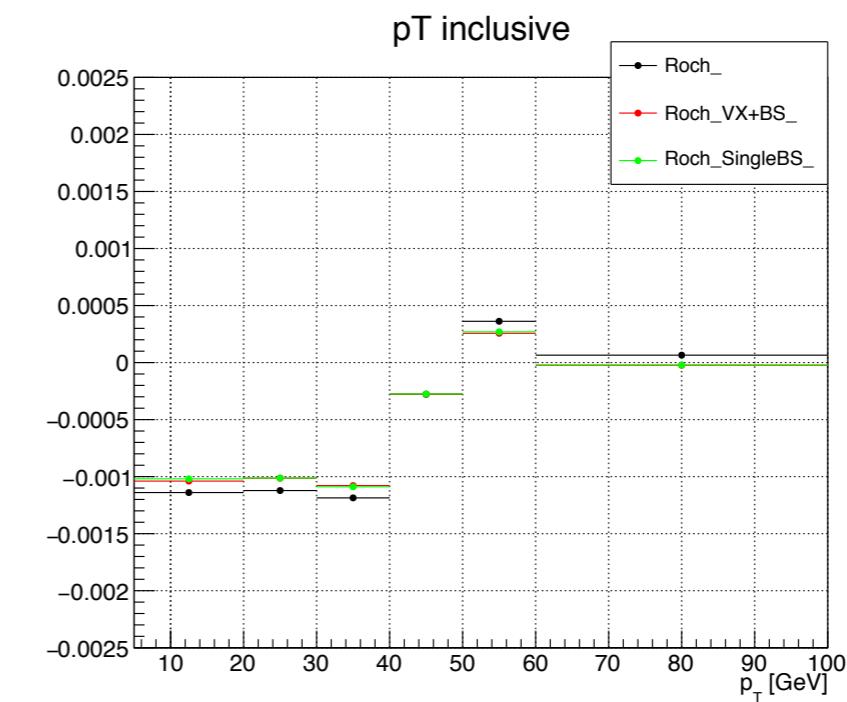
$$\mu \left(\frac{p_T^{VX+BS, SingleBS} - p_T^{GEN}}{p_T^{GEN}} \right) - \mu \left(\frac{p_T^{roch} - p_T^{GEN}}{p_T^{GEN}} \right)$$

Evaluated only for MC.

muon pT scale

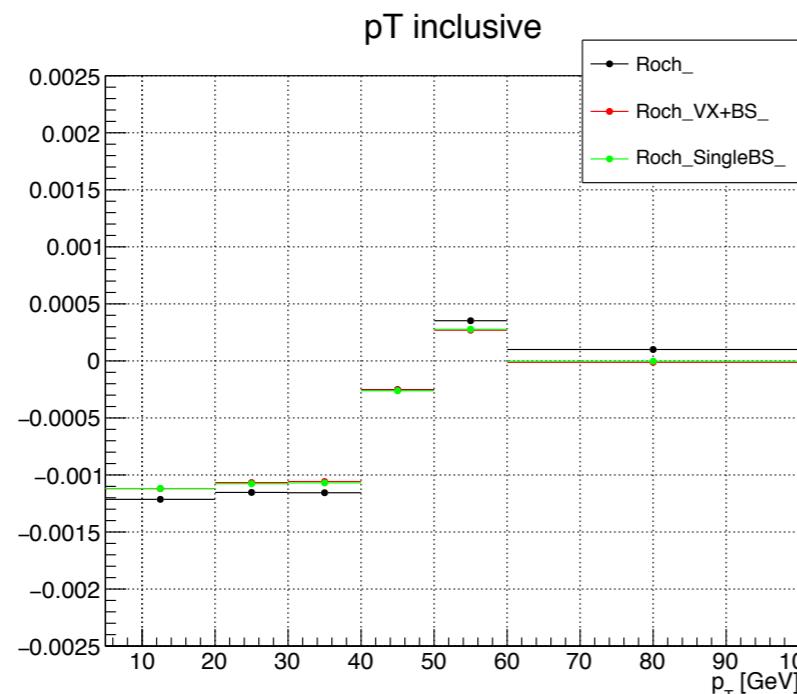
**2016
pre-VPF****2016
post-VPF****2017****2018**

muon pT scale

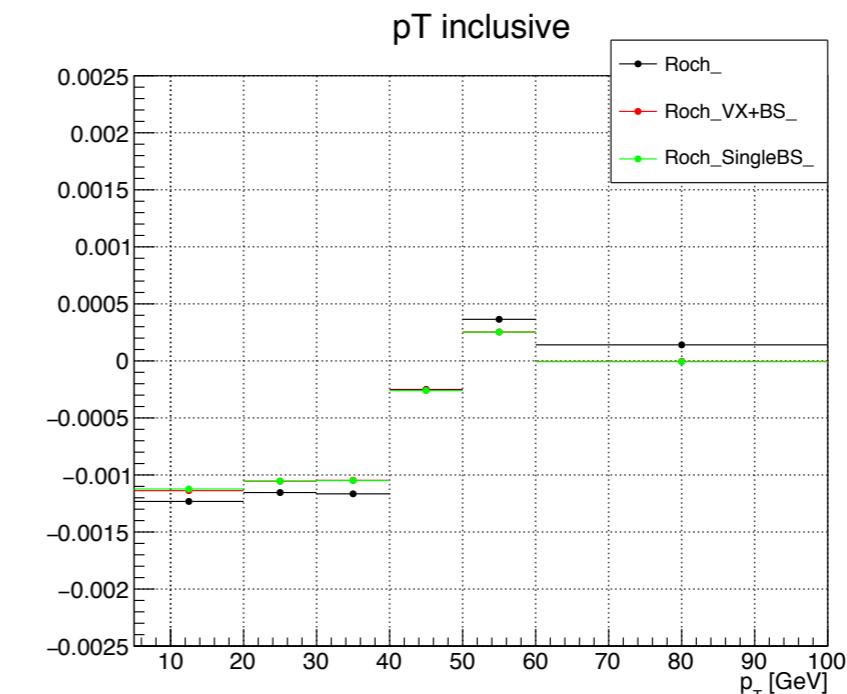
 2016
 pre-VPF

 2016
 post-VPF


VX+BS does not change the scale of muon

2017



2018



muon pT scale defined as the mean of the gaussian function used to fit the distribution:

$$\frac{p_T^{VX+BS, SingleBS} - p_T^{Roch}}{p_T^{Roch}}$$

The bottom plot stands for:

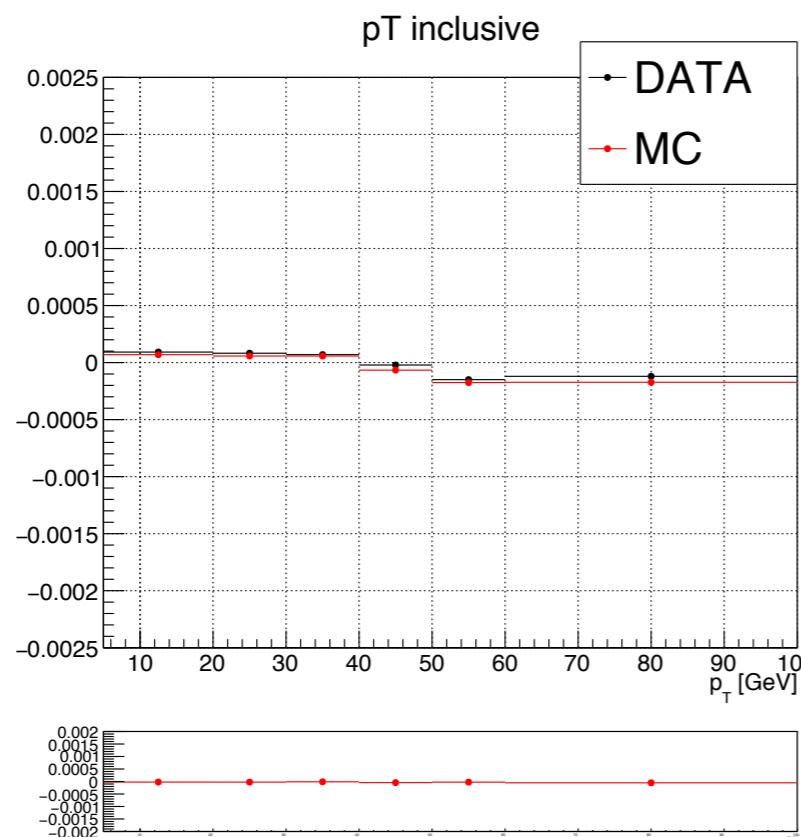
$$\left(\mu \left(\frac{p_T^{VX+BS, SingleBS} - p_T^{Roch}}{p_T^{Roch}} \right) \right)^{MC} - \left(\mu \left(\frac{p_T^{VX+BS, SingleBS} - p_T^{Roch}}{p_T^{Roch}} \right) \right)^{DATA}$$

Check if VX+BS works in different way in DATA and in MC

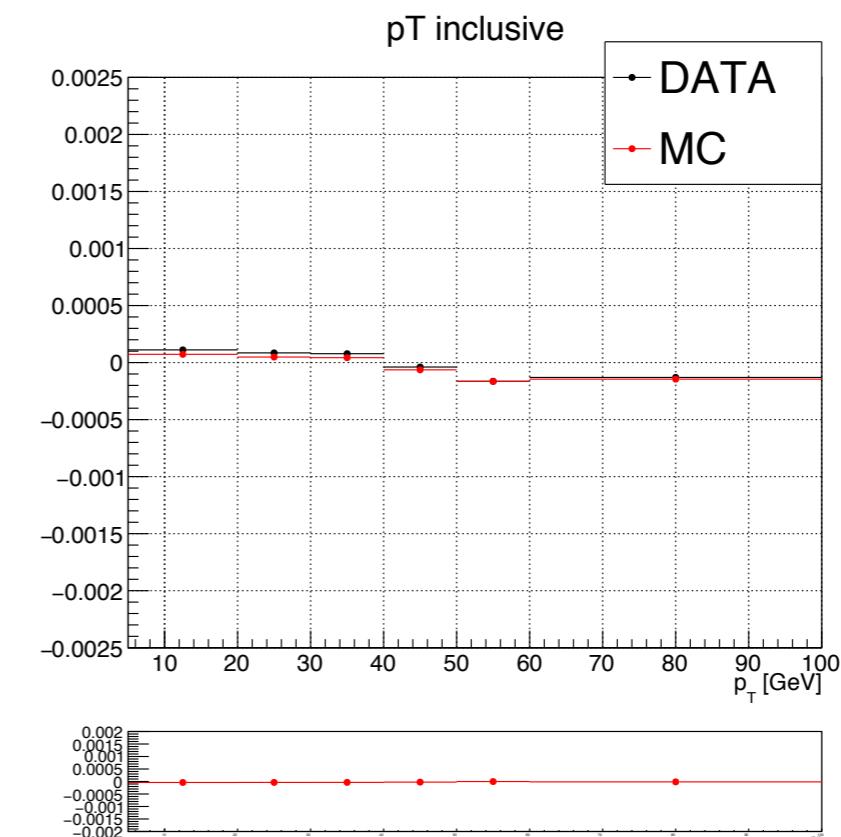
muon pT VX+BS scale



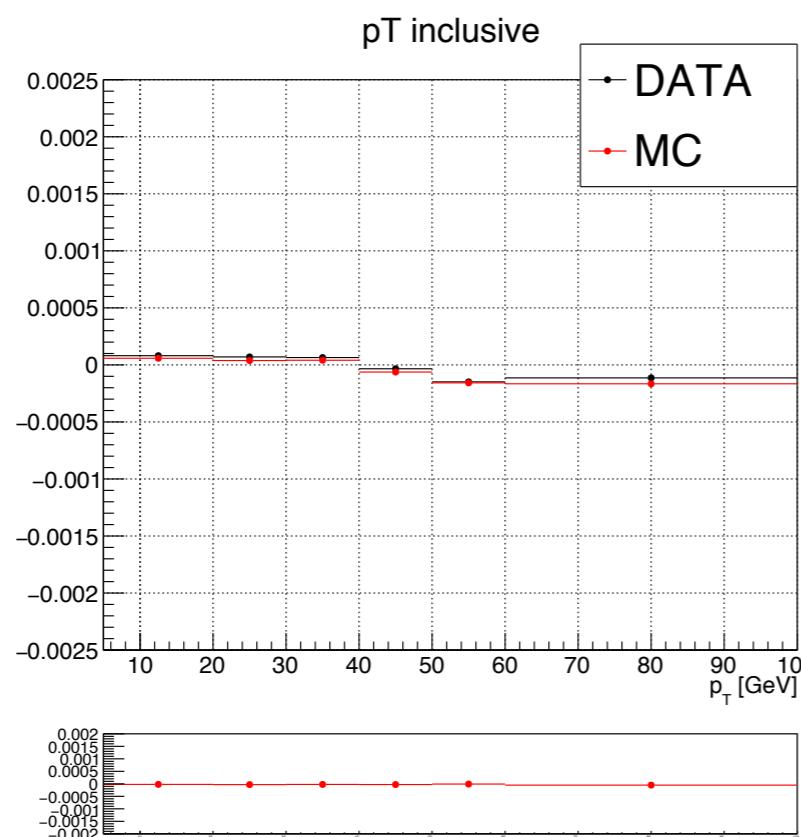
2016
pre-VPF



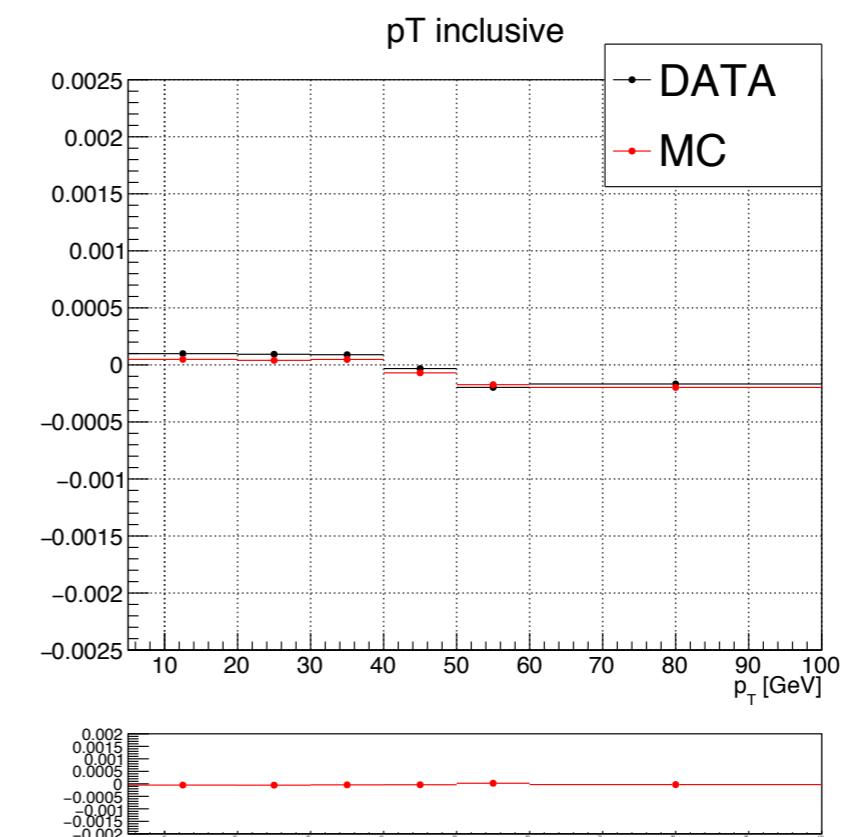
2016
post-VPF



2017

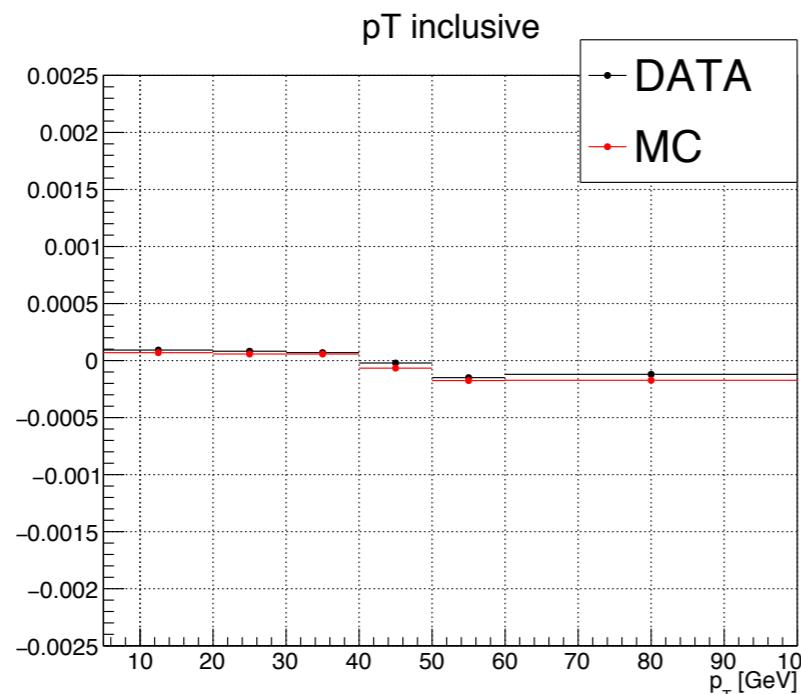


2018

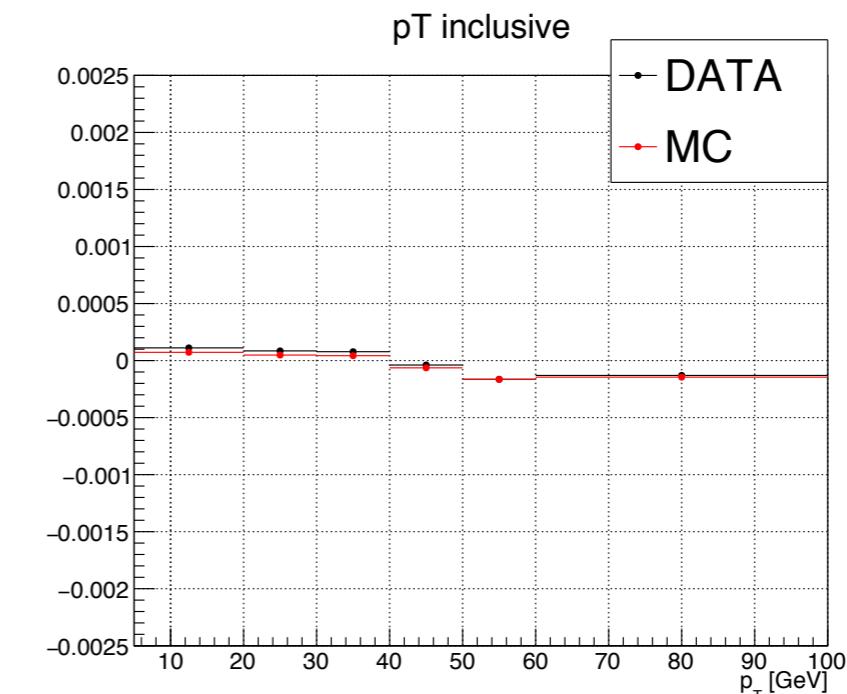


muon pT VX+BS scale

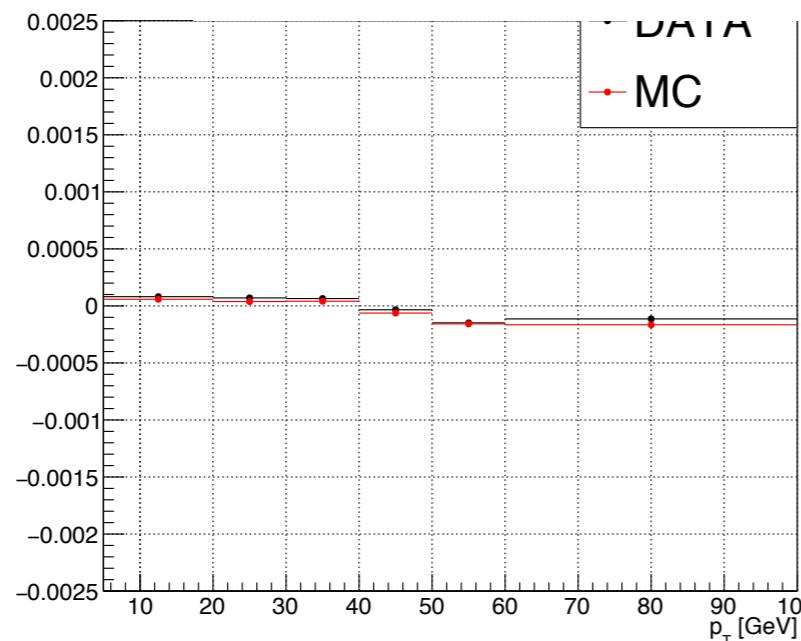
2016
pre-VPF



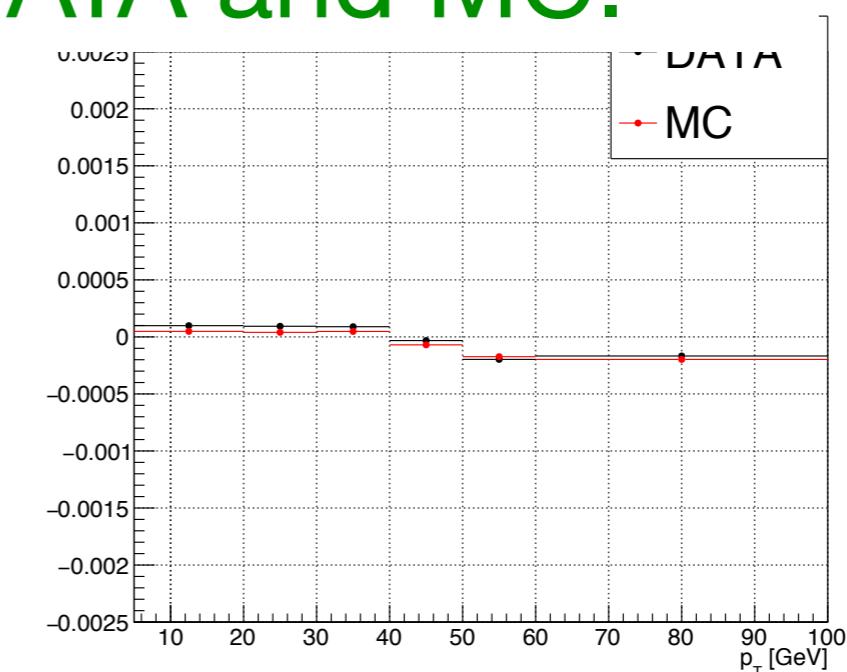
2016
post-VPF



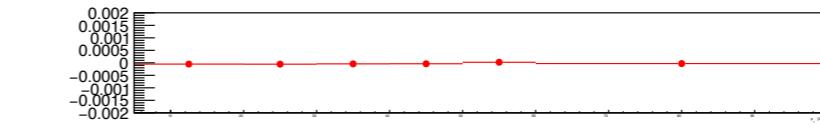
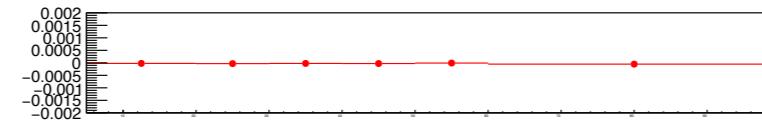
VX+BS shifts the pT in the order
of 10^{-4} in both DATA and MC.



2018



2017

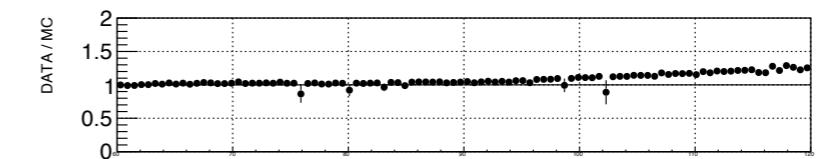
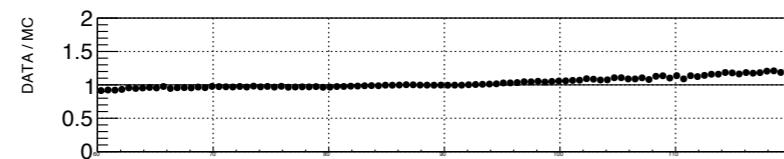
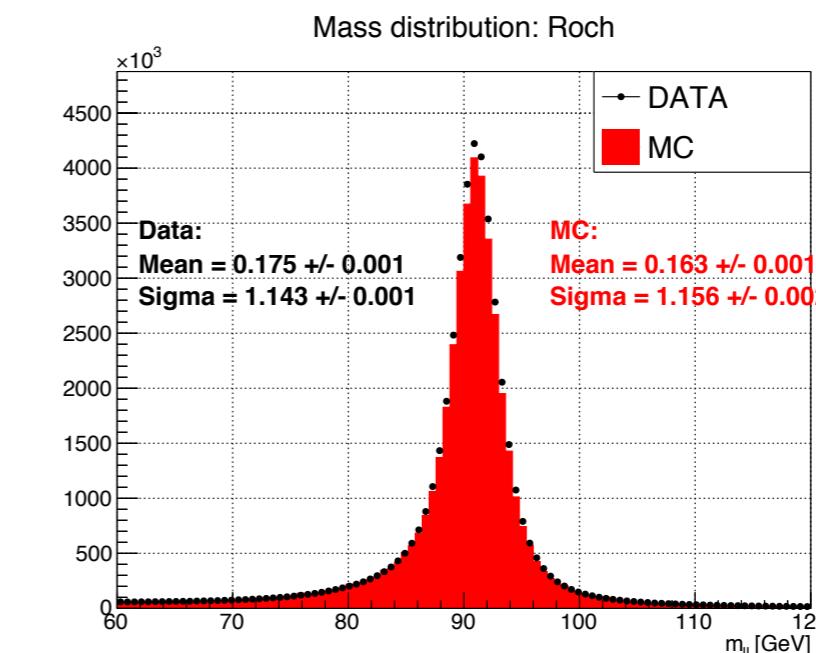
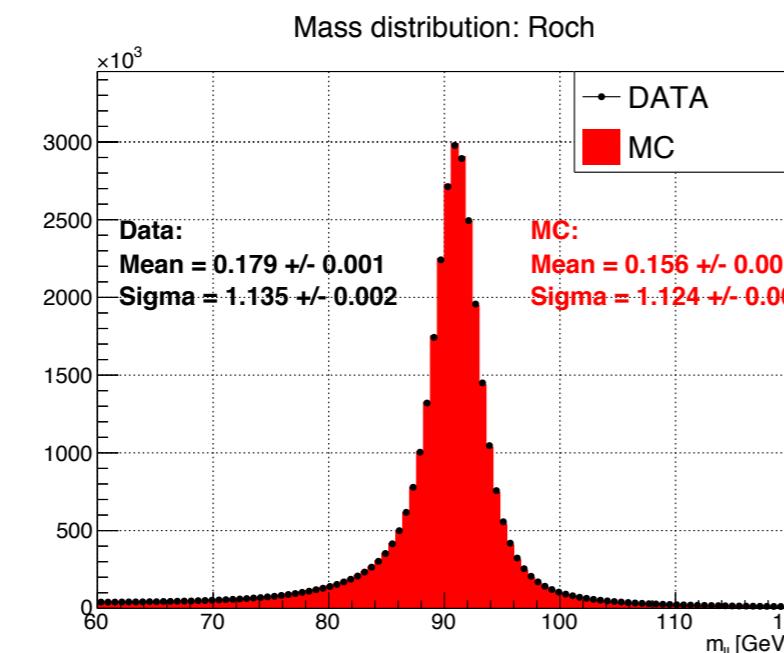
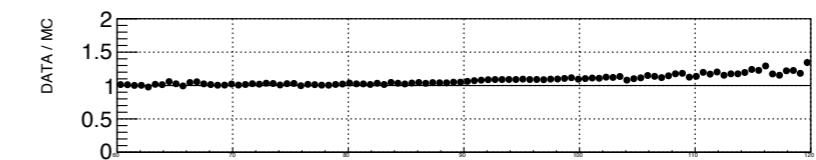
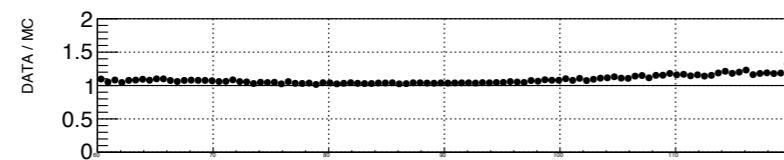
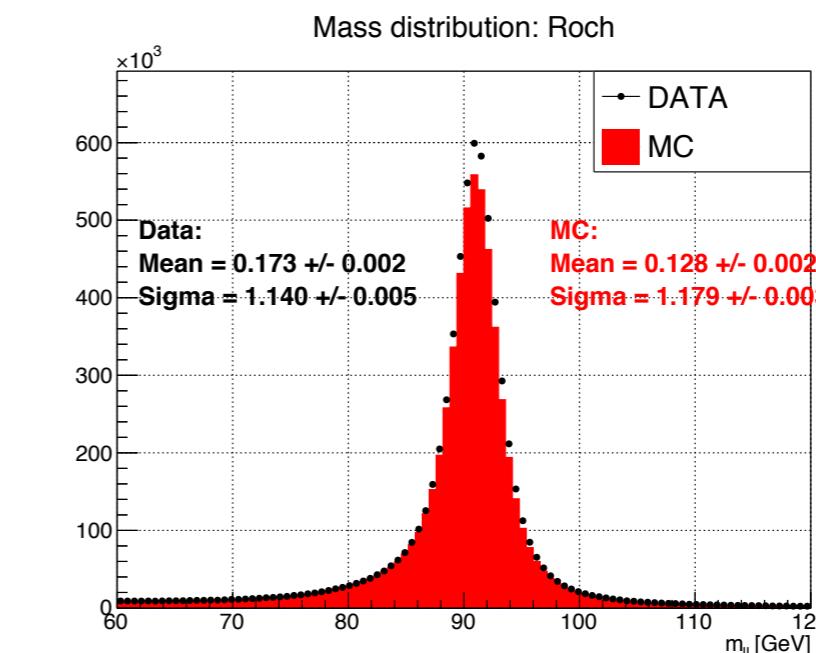
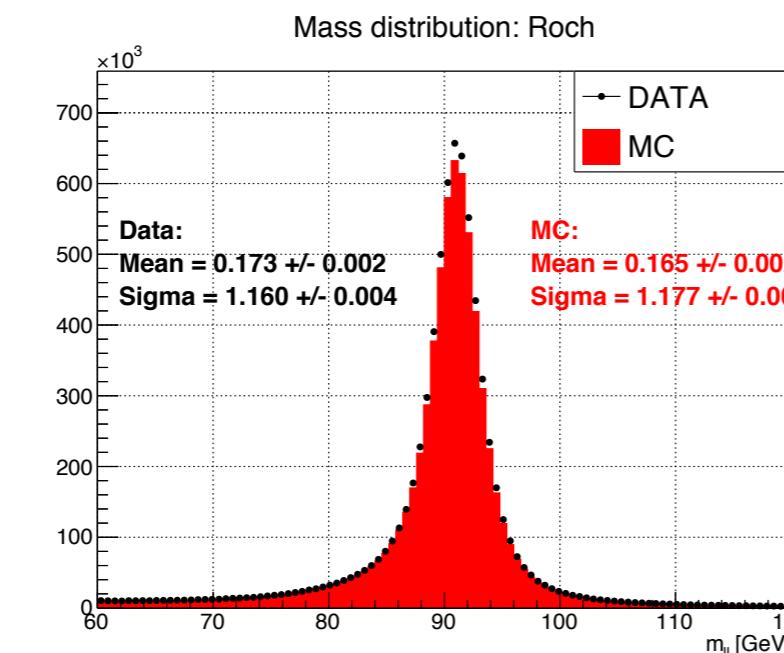


UE Dilepton mass distribution

Rochester

2016
pre-VPF

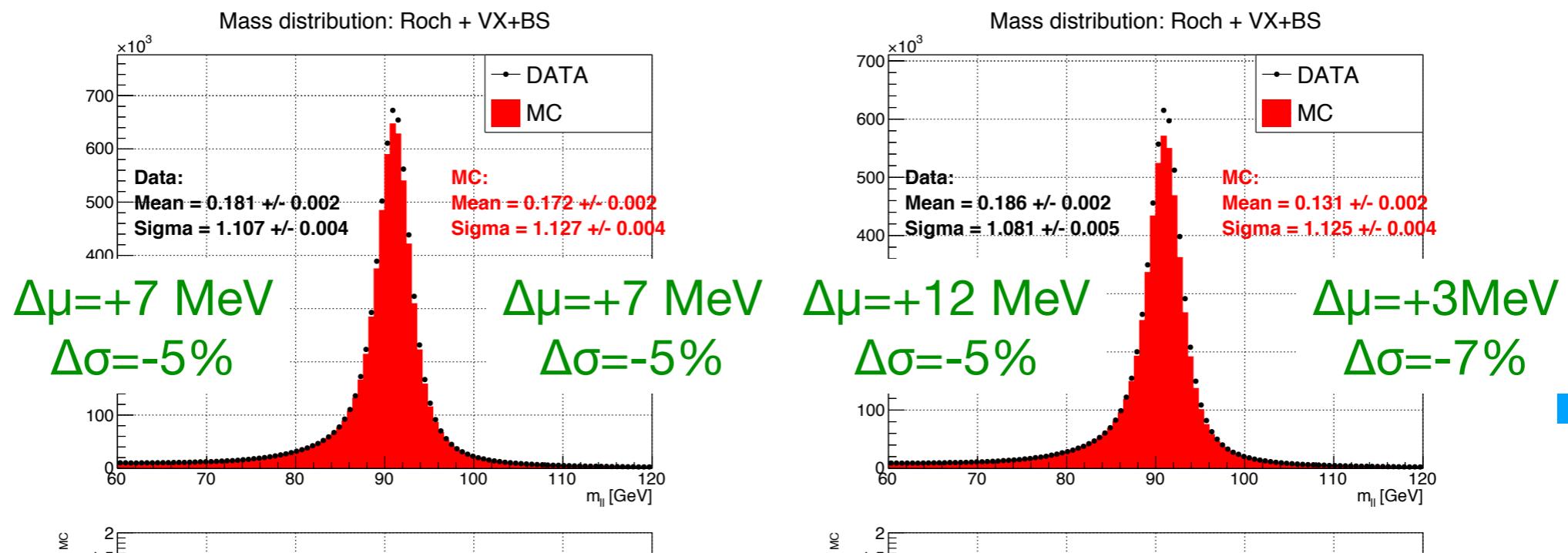
2016
post-VPF



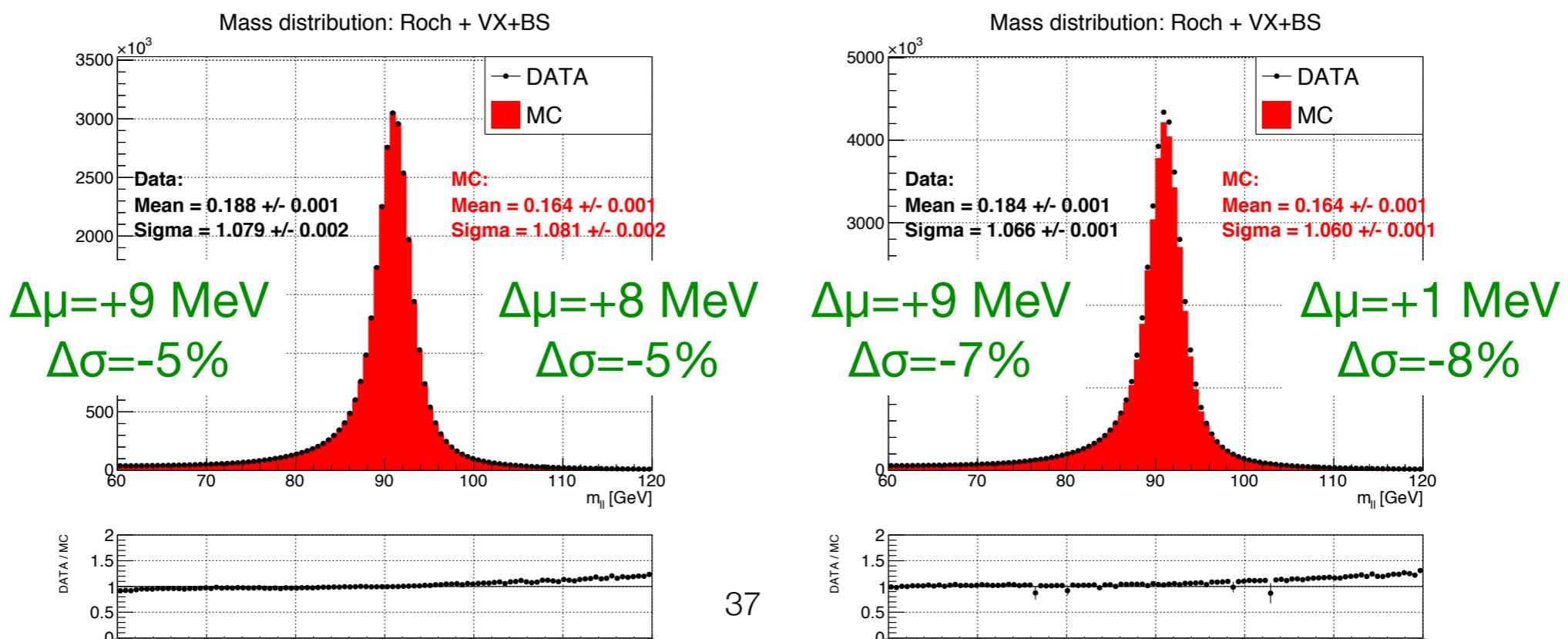
UE Dilepton mass distribution

Rochester
+
VX+BS

2016
pre-VPF



2016
post-VPF

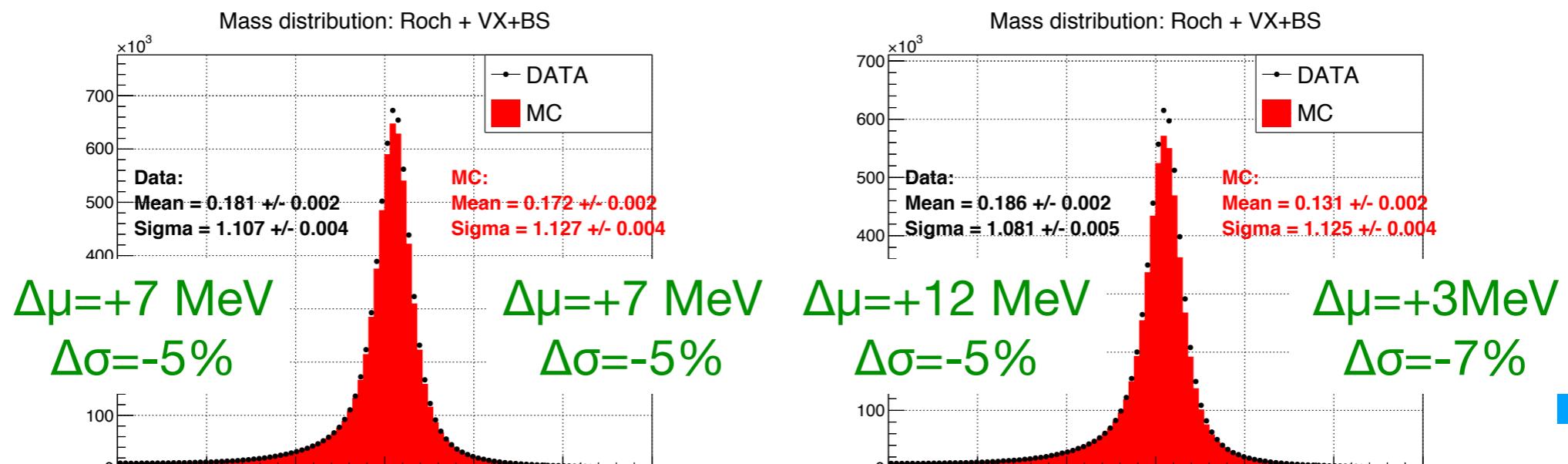


2017

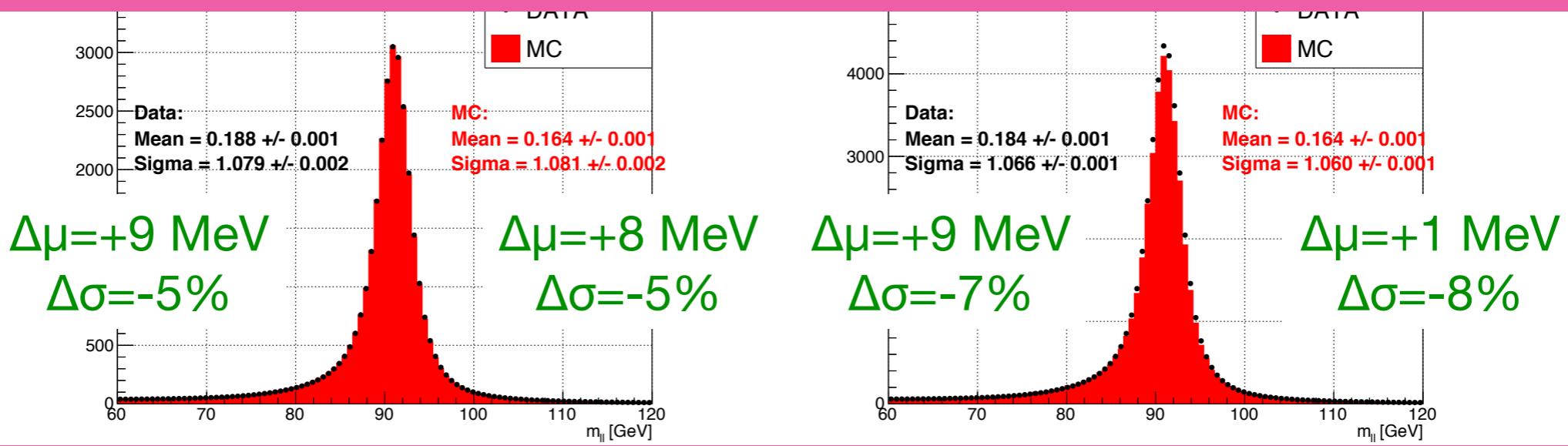
2018

UE Dilepton mass distribution

Rochester
+
VX+BS



Similar improvement in resolution and similar mean shift (in the same direction) for DATA and MC



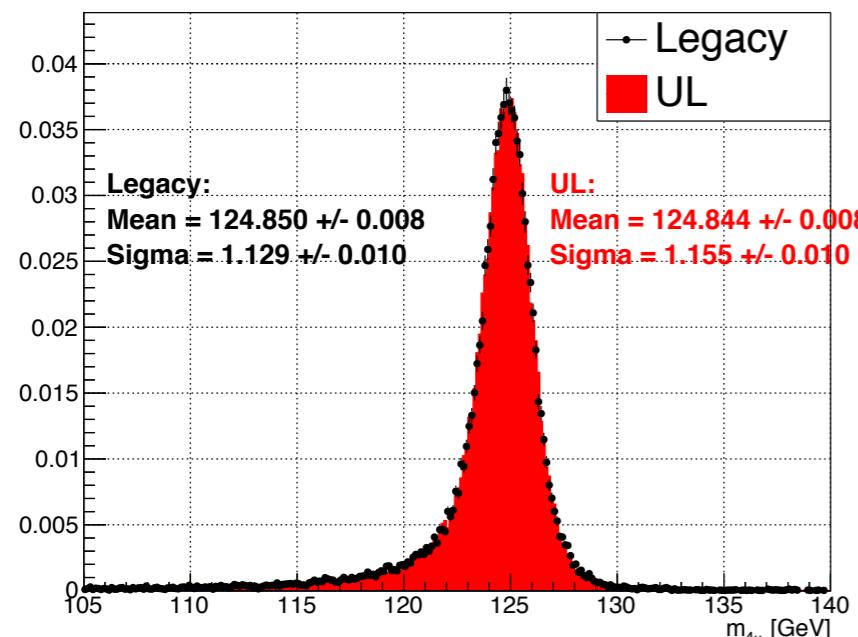
SingleBS results in backup

Moving to Higgs boson...

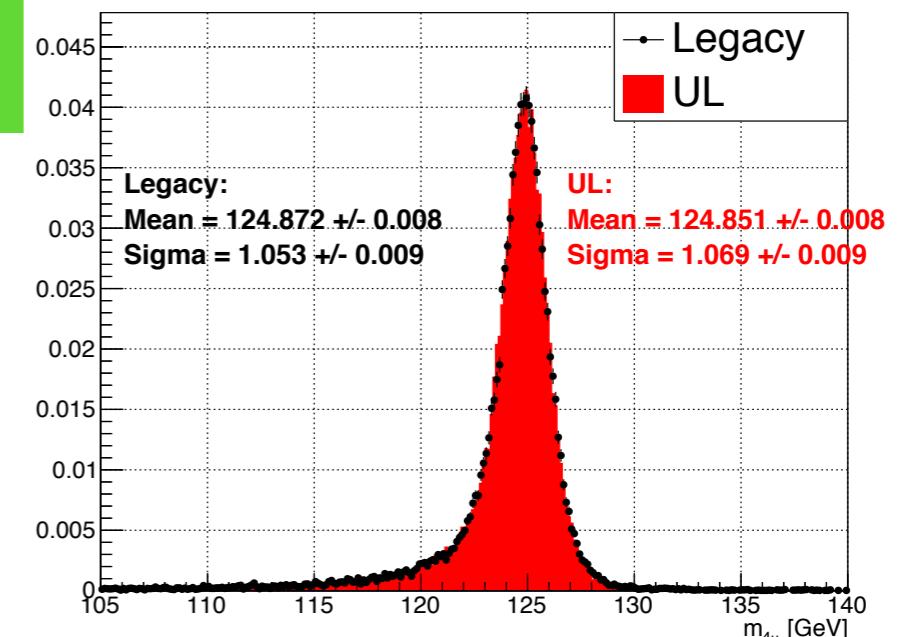


Rochester

Mass distribution: Roch

Rochester
+
VX+BS

Mass distribution: Roch + VX+BS



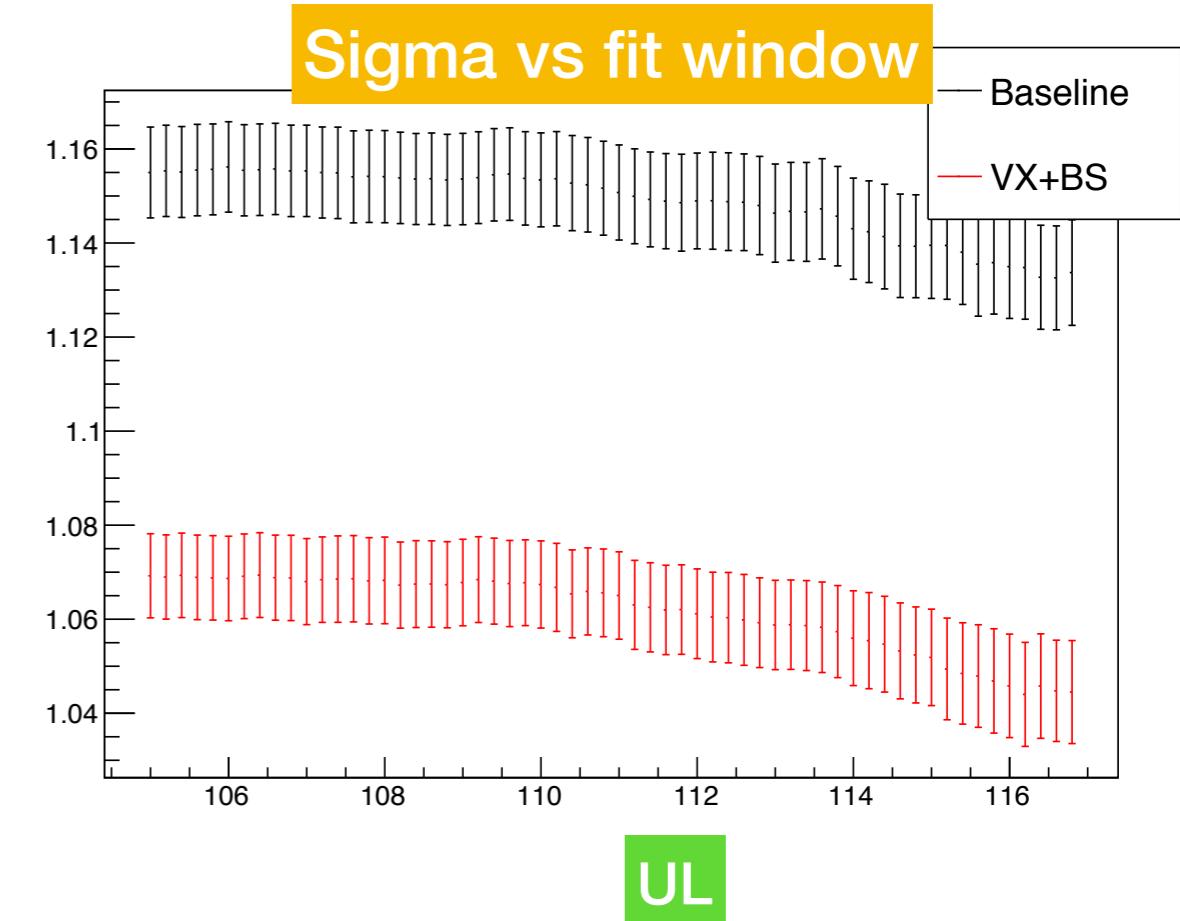
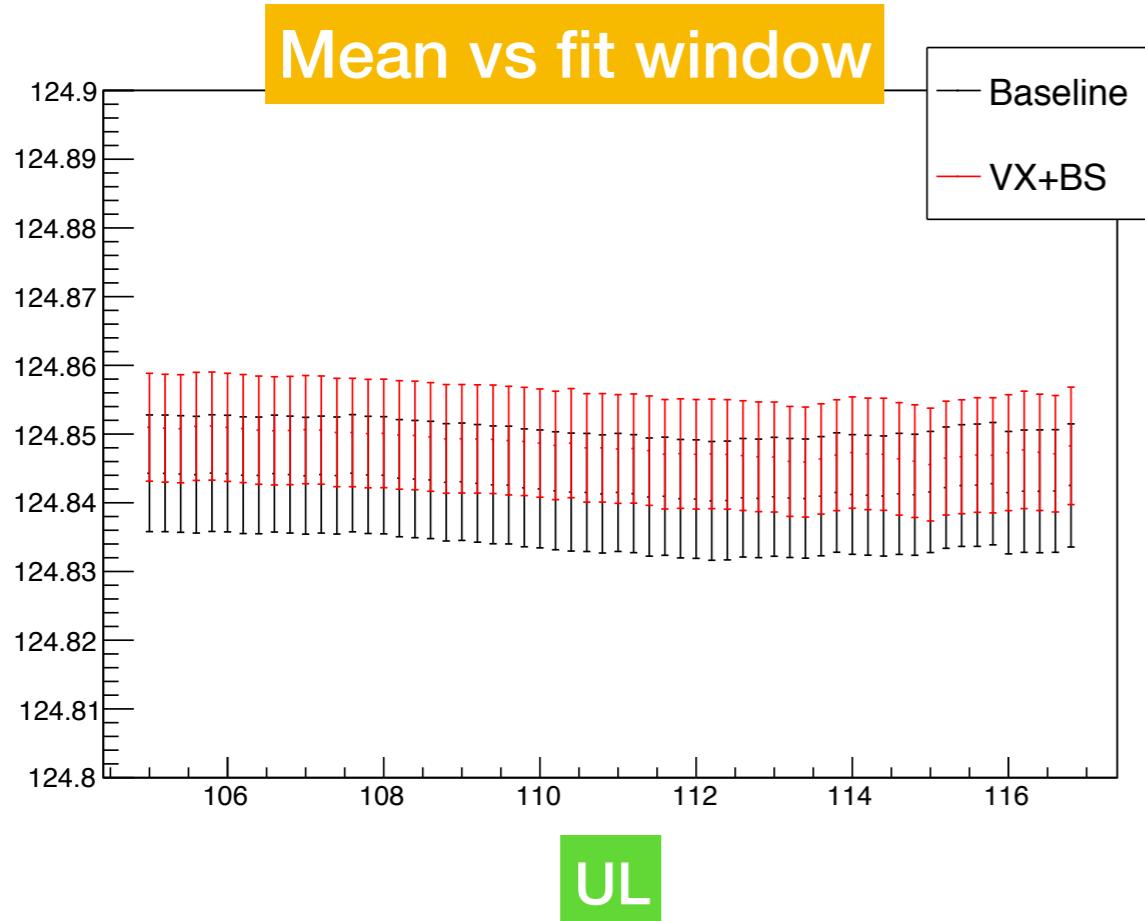
4mu

 $\Delta\mu = +22 \text{ MeV}$ $\Delta\sigma = -7\%$ $\Delta\mu = +7 \text{ MeV}$ $\Delta\sigma = -8\%$

$\sim 8\%$ improvement in sigma
 $\sim 10 \text{ MeV}$ of shift in peak position

2e2mu and 2mu2e in backup

Moving to Higgs boson: UL



Fit range: [105, 140], [105.2, 139.8], ..., [116.8, 128.2] GeV

Mean and sigma are not affected by
VX+BS, looking at different fit window.

Conclusion

Within the Higgs boson mass measurement, several approaches have been tested.

VX+BS approach has been also tested on UL samples and it shows:

- ~5-10% improvement in pT resolution
- bigger improvement in Higgs boson mass resolution (4-7%)
- compatible shift in Higgs boson peak position (order of 10 MeV)

VX+BS seems to be the best approach to be used for our analysis.

We ask for the green light.

Technical question:

UL ggH sample @125 is from ULSummer20 (as for all the other samples that are in production):

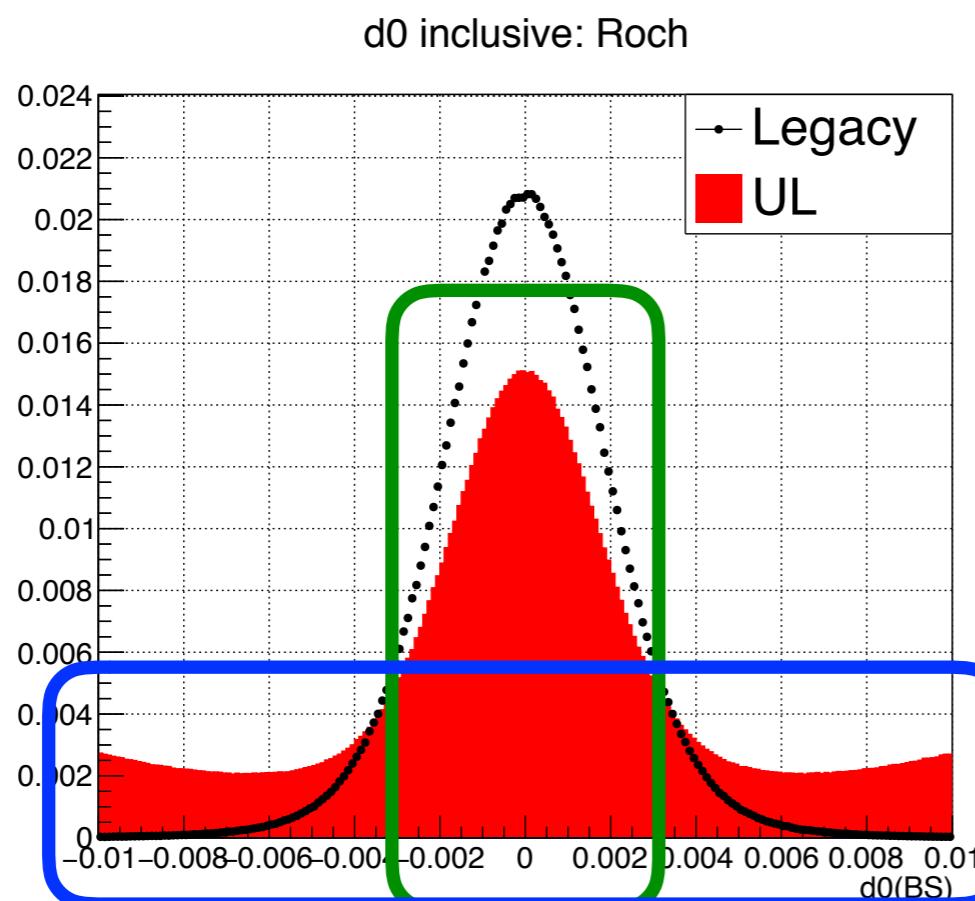
are there any plans to produce ULSummer20 Rochester correction?

Backup

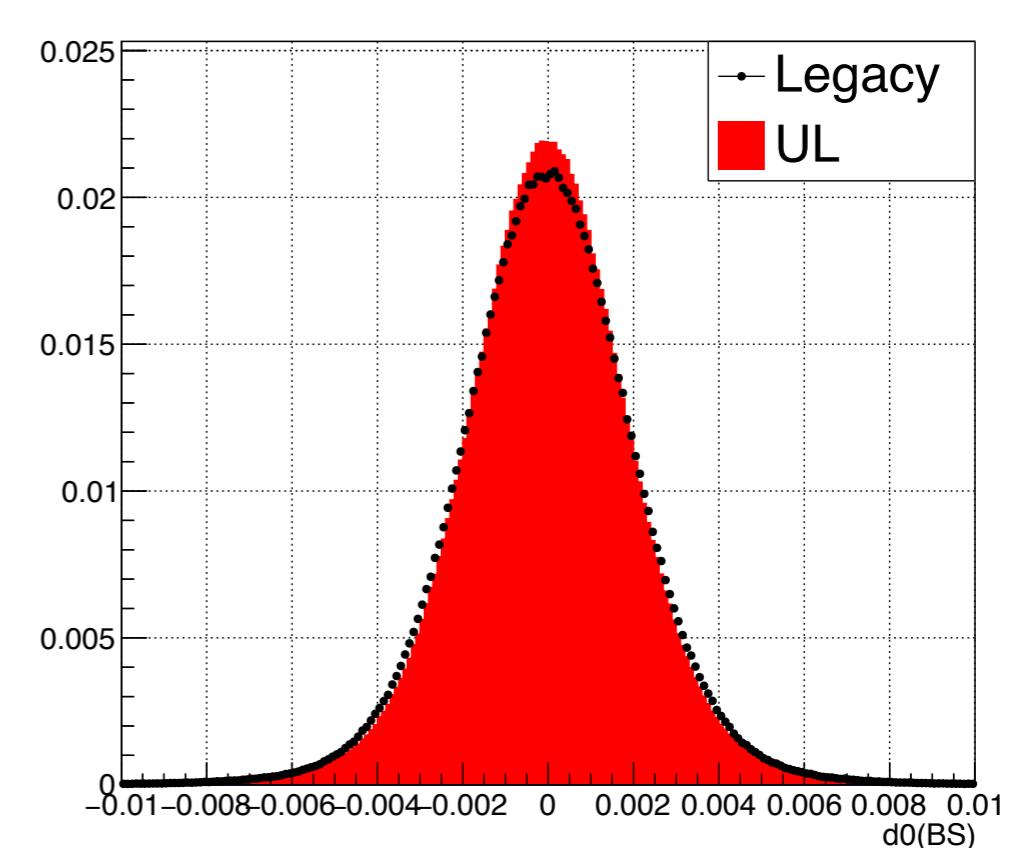
d0 distribution

muonBestTrack()->dxy(beamSpot->position())

2016_Summer19



2016_Summer20

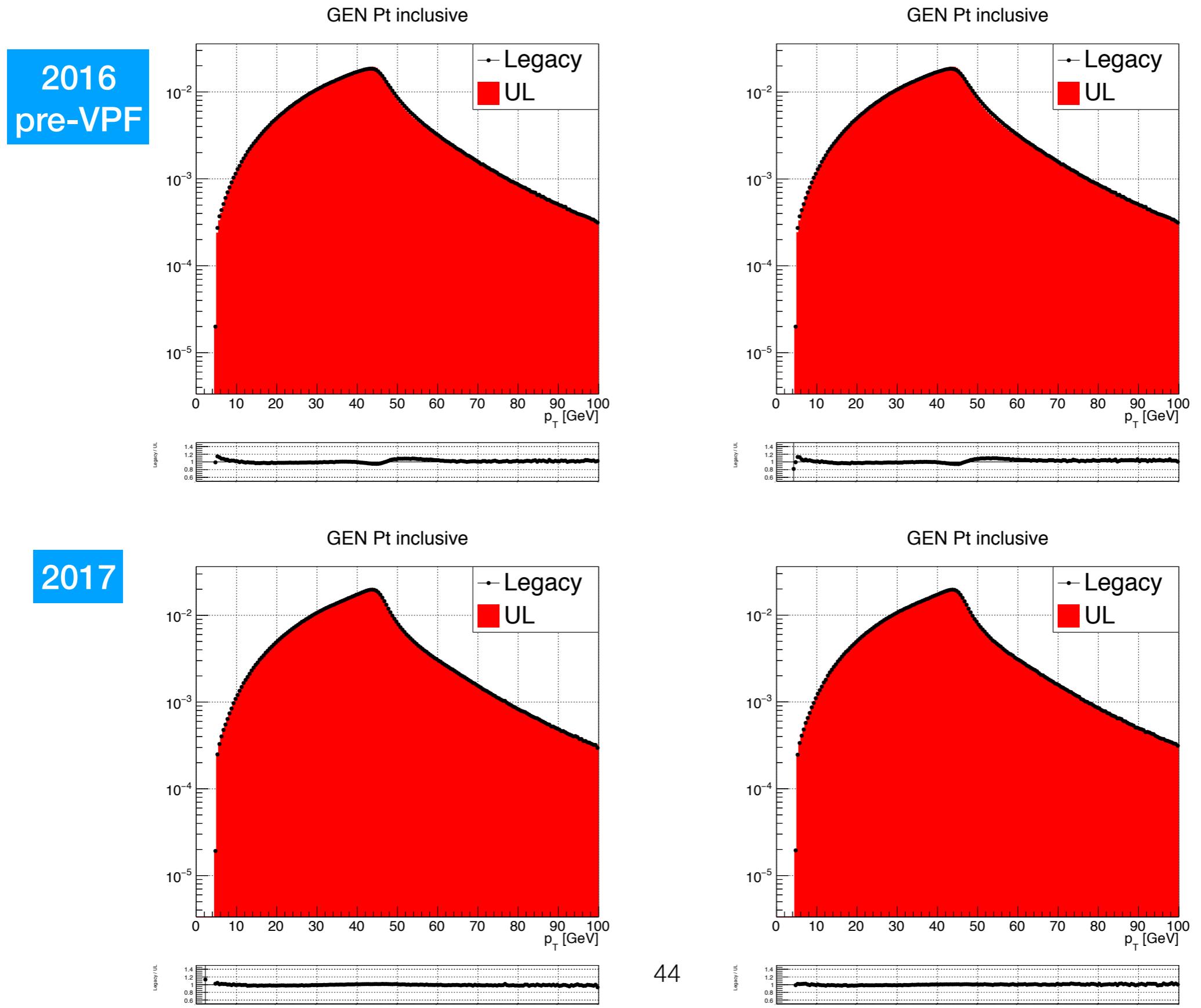


Due to post-VFP

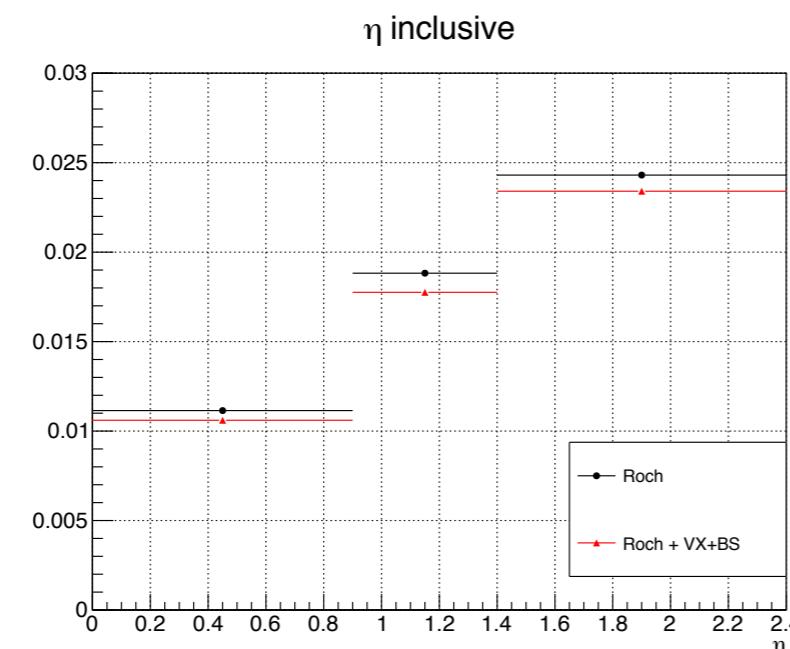
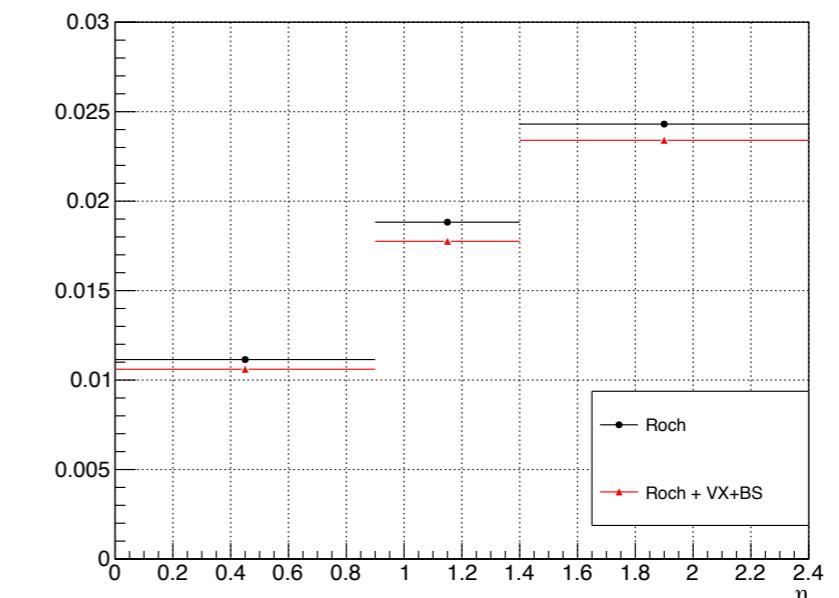
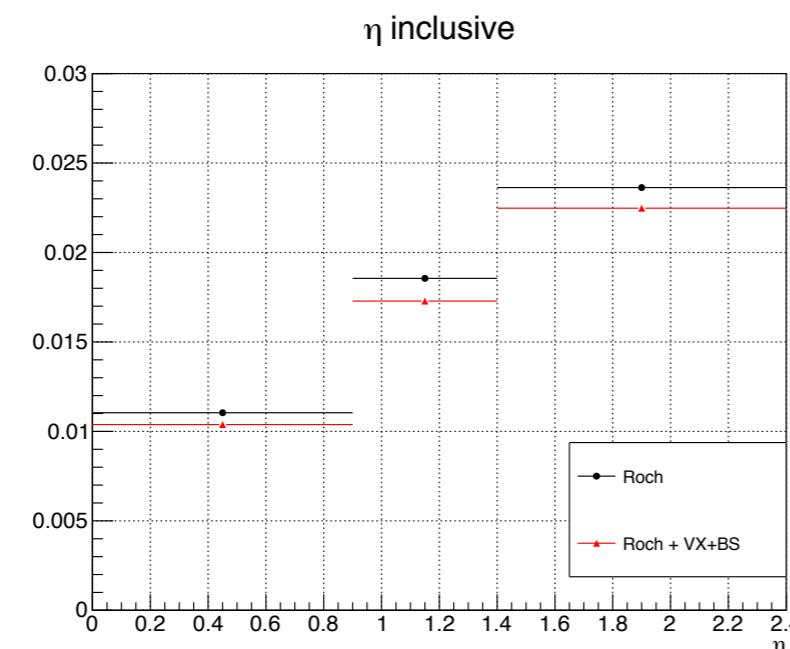
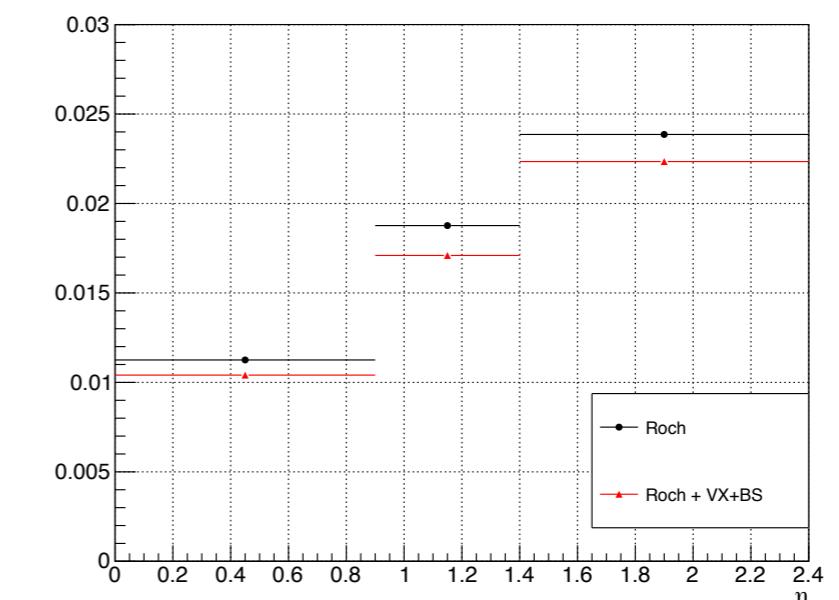
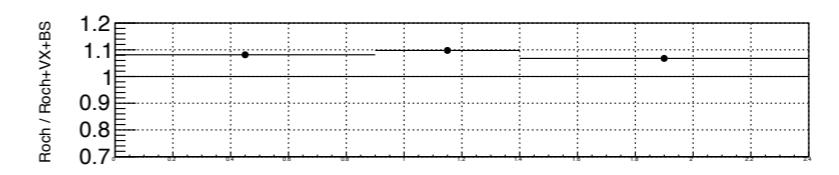
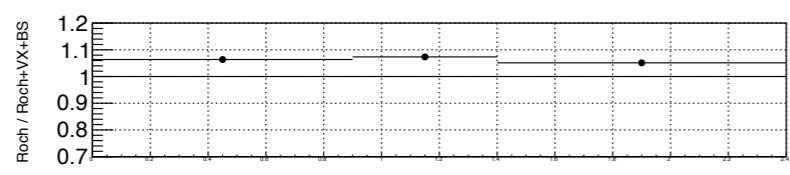
Mainly due to pre-VFP

Pre-VFP and post-VFP

gen- p_T distributions

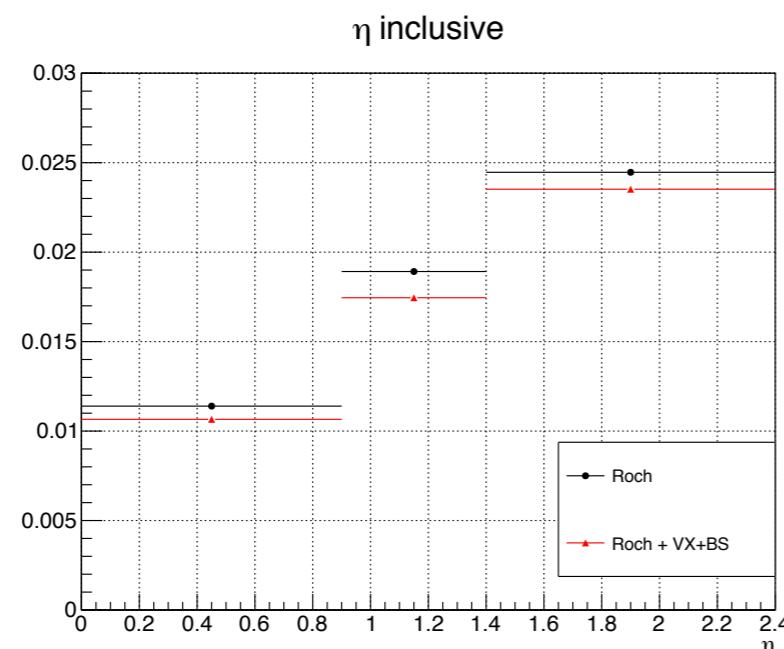
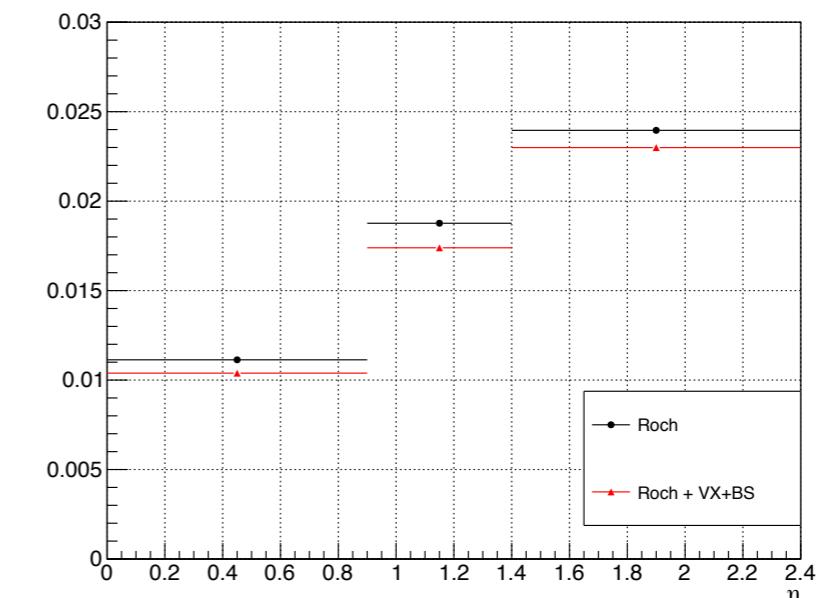


muon pT resolution vs pT

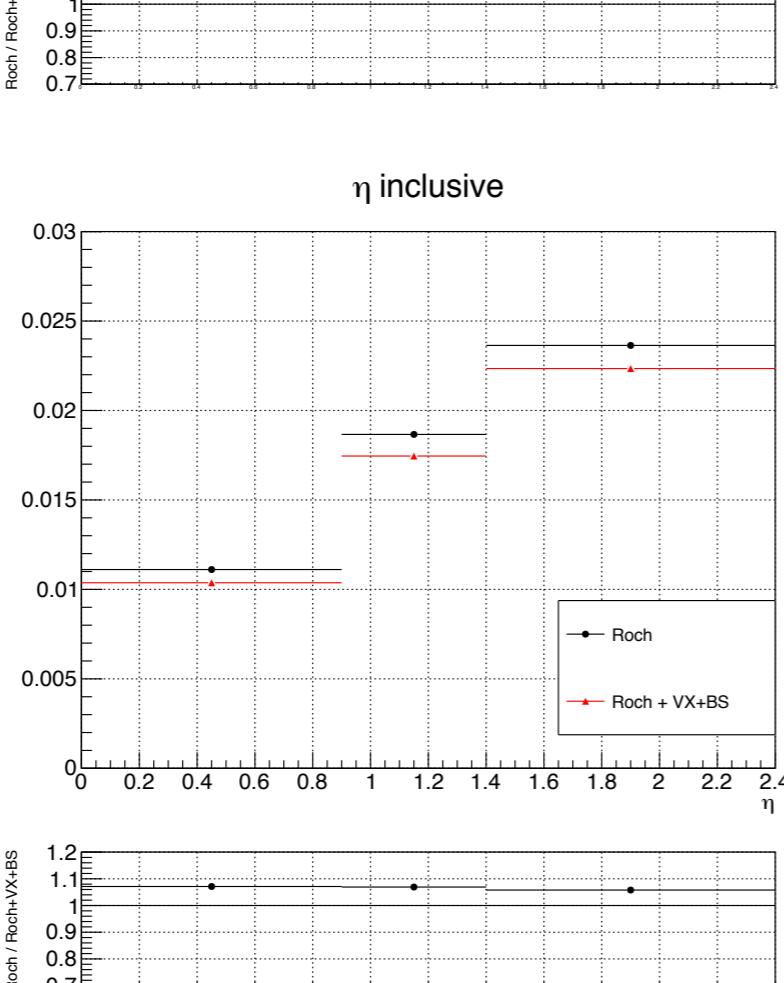
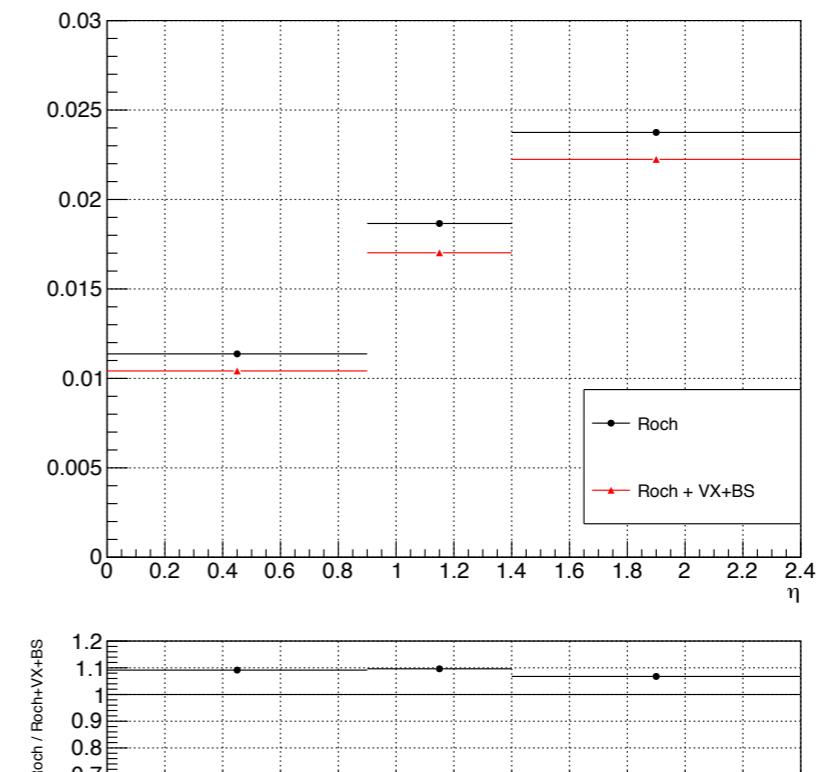
Legacy**2016
pre-VPF** η inclusive**2016
post-VPF****2017** η inclusive**2018**

muon pT resolution vs pT

UL

2016
pre-VPF η inclusive2016
post-VPF

2017

 η inclusive

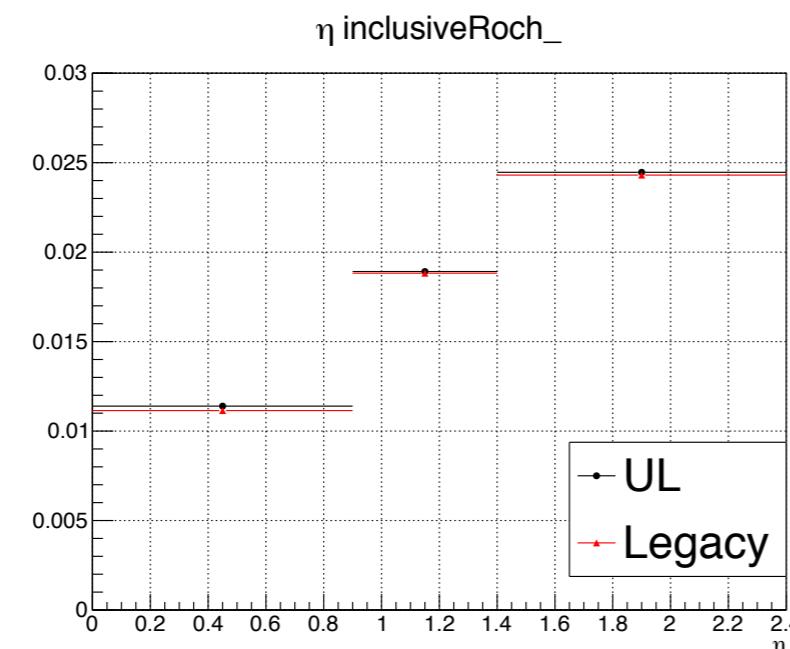
2018

muon pT resolution vs pT

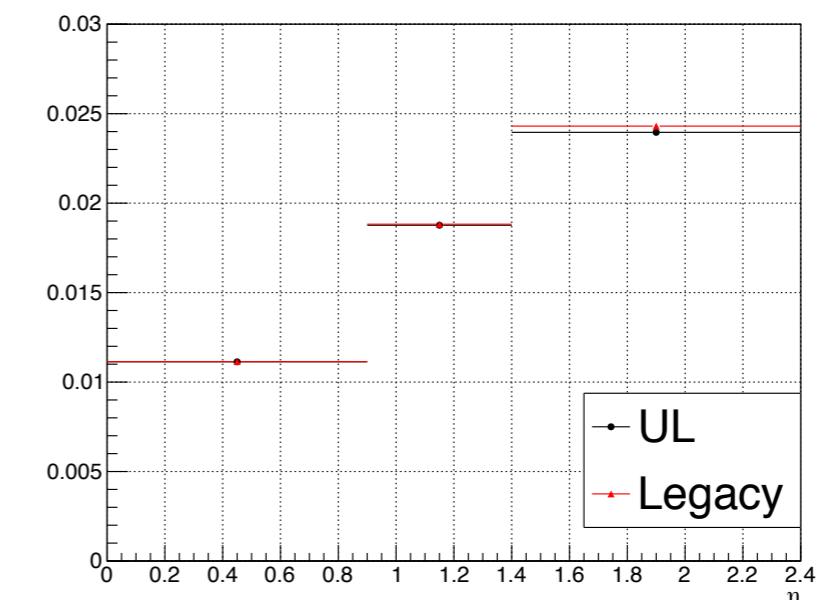


Rochester

2016
pre-VPF

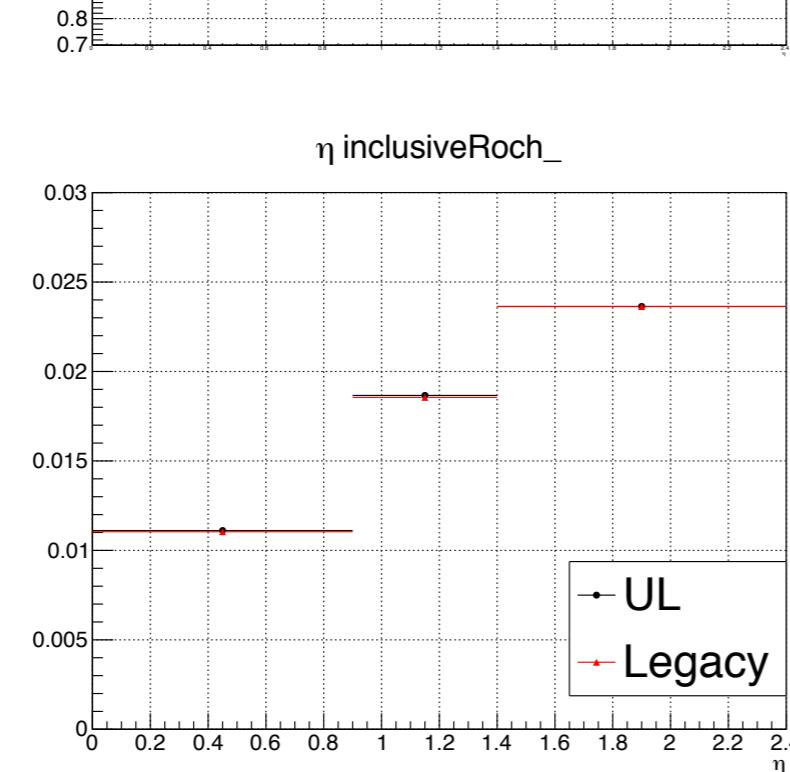


η inclusiveRoch_

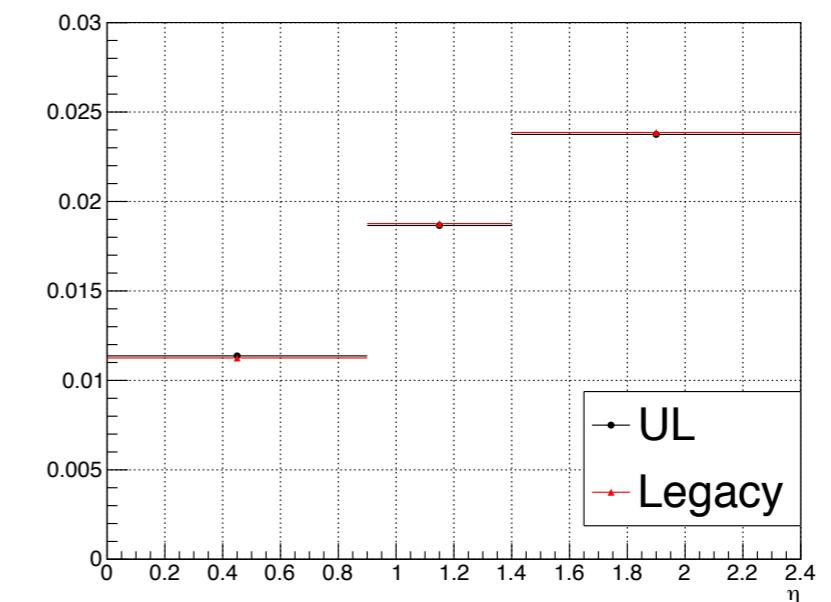


2016
post-VPF

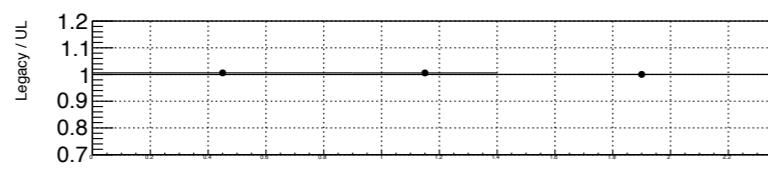
2017



η inclusiveRoch_



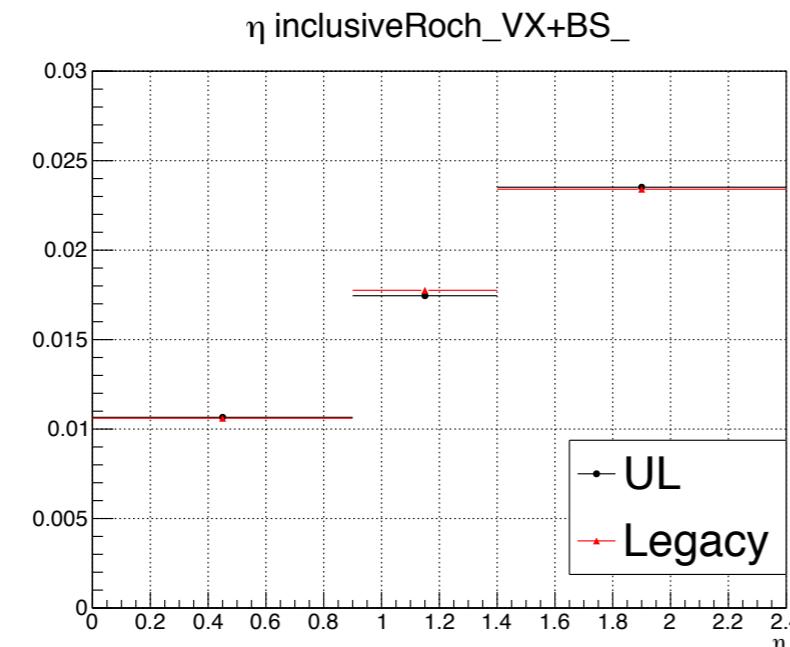
2018



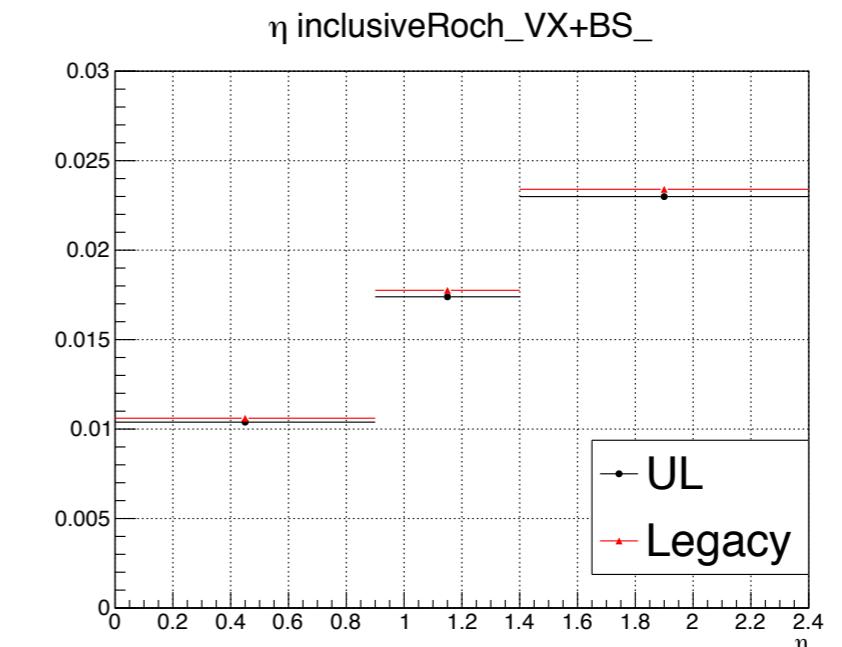
muon pT resolution vs pT

Rochester
+
VX+BS

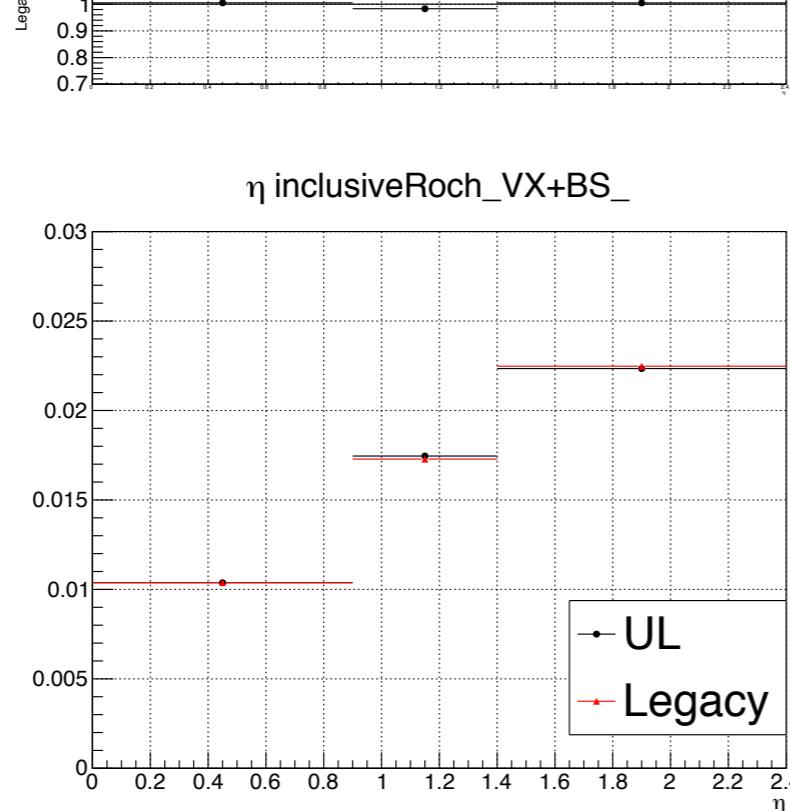
2016
pre-VPF



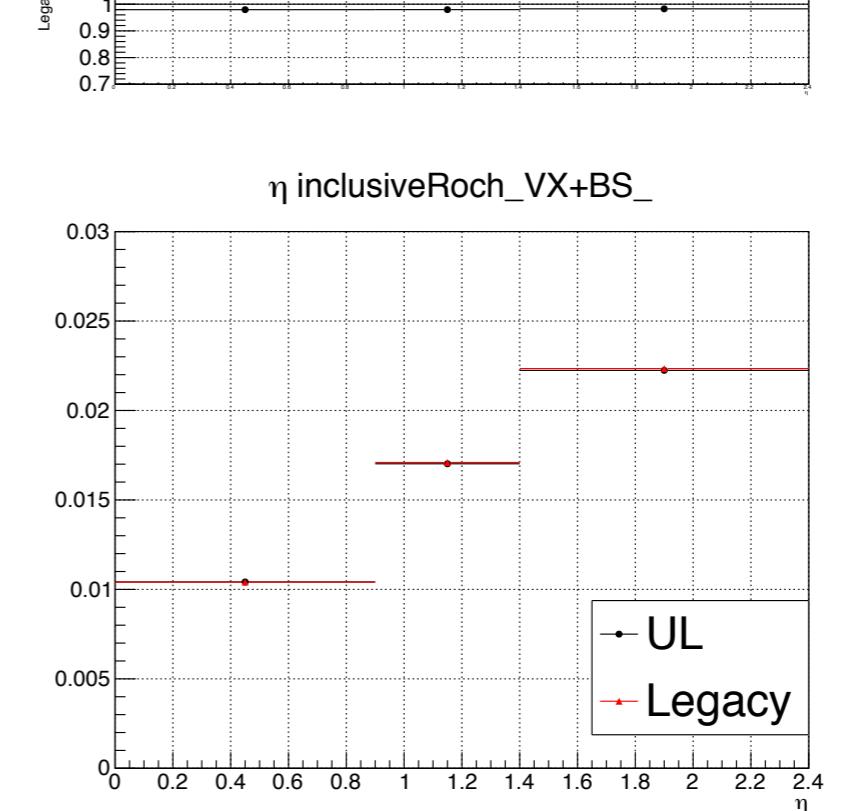
2016
post-VPF



2017

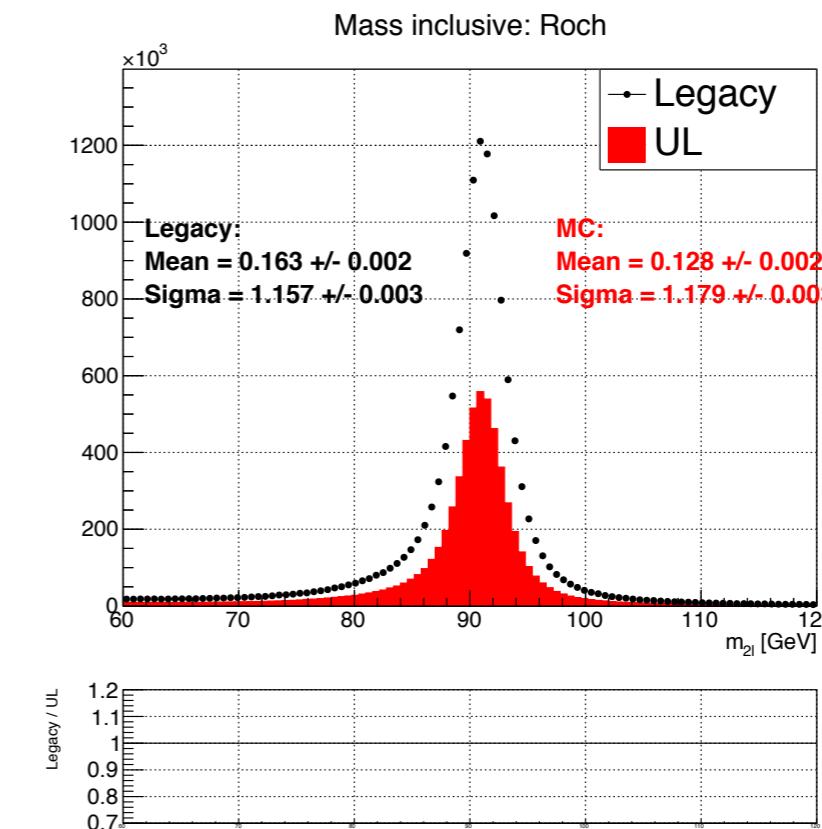
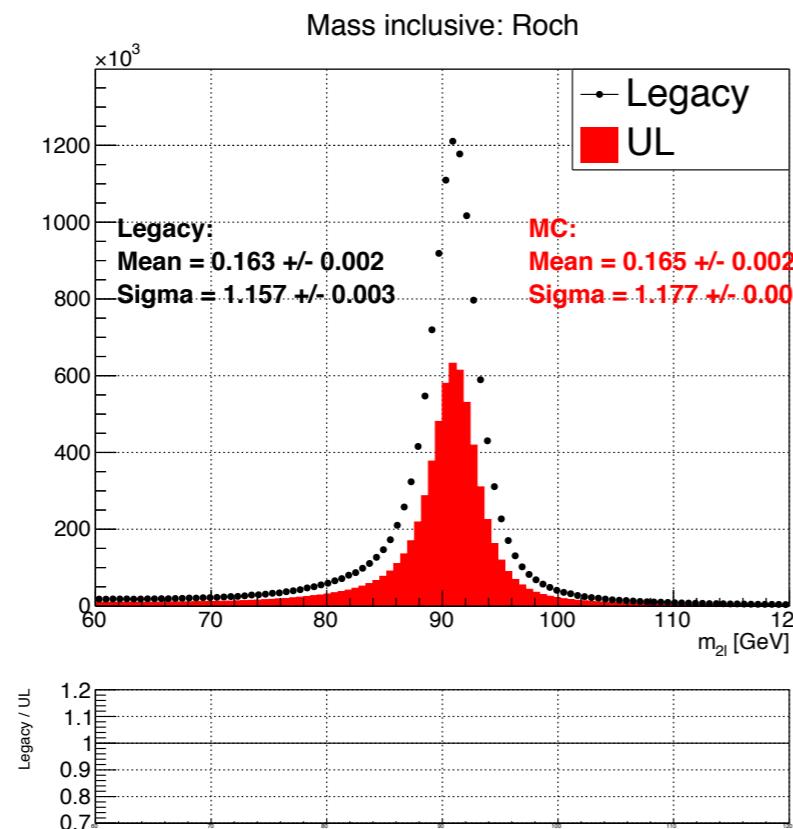


2018



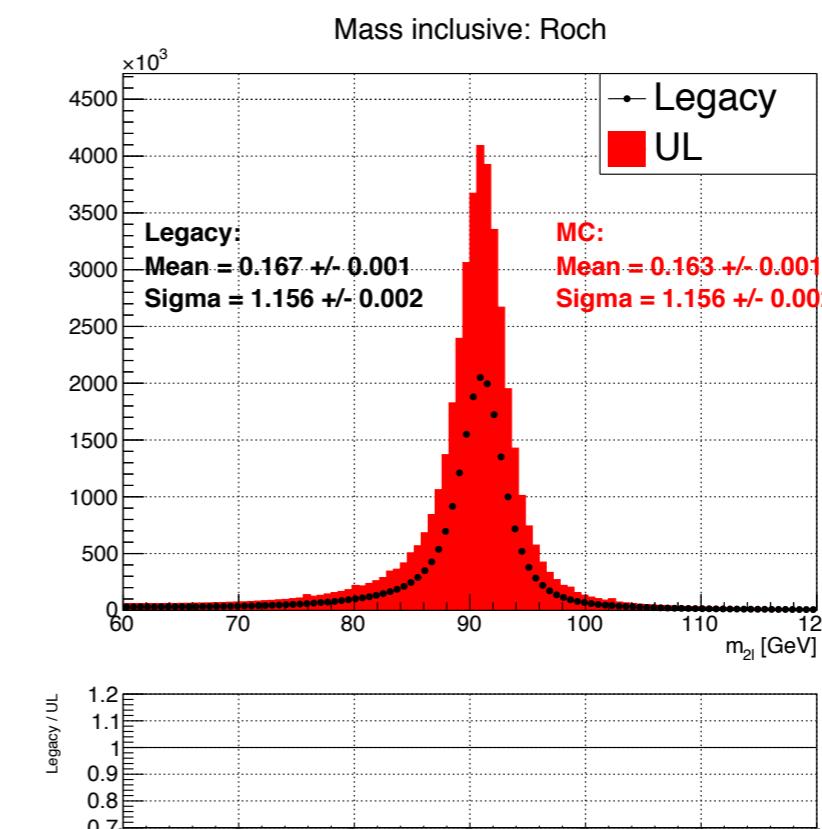
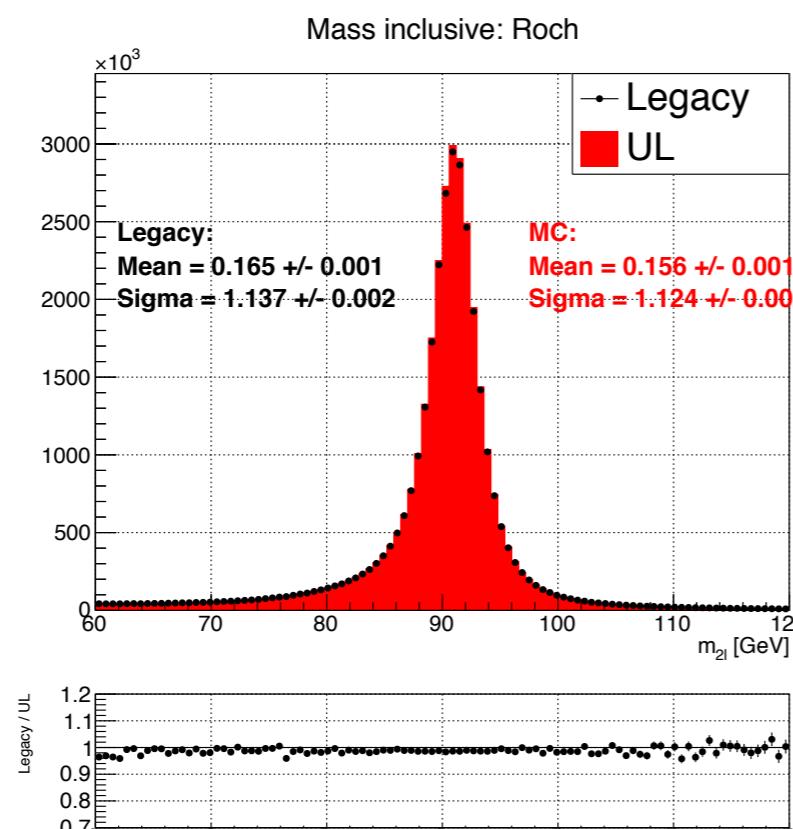
UE Dilepton mass distribution

2016
pre-VPF



2016
post-VPF

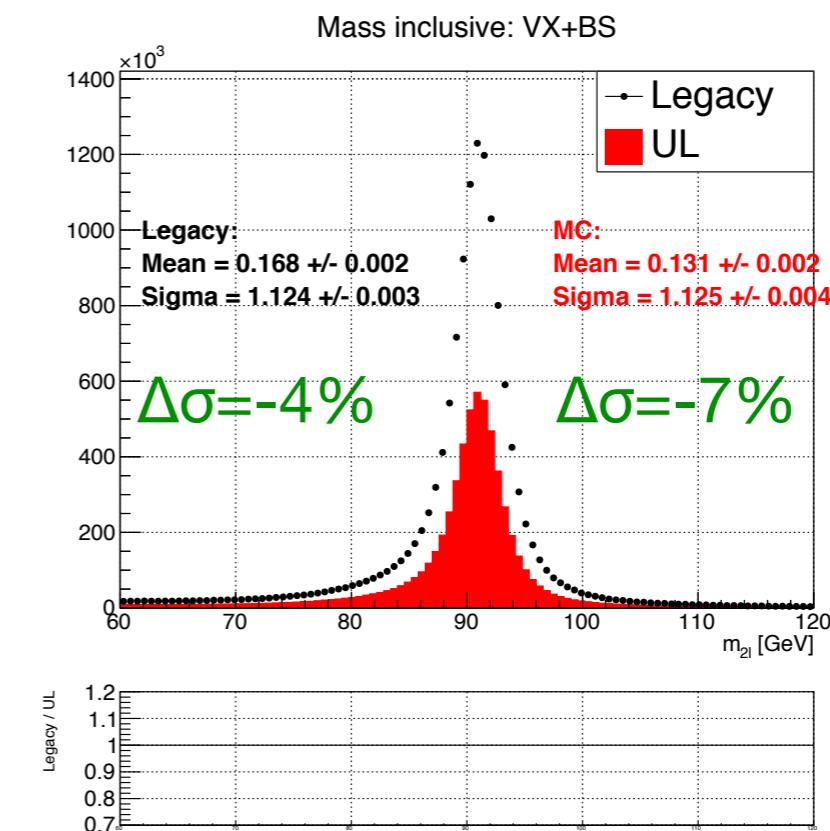
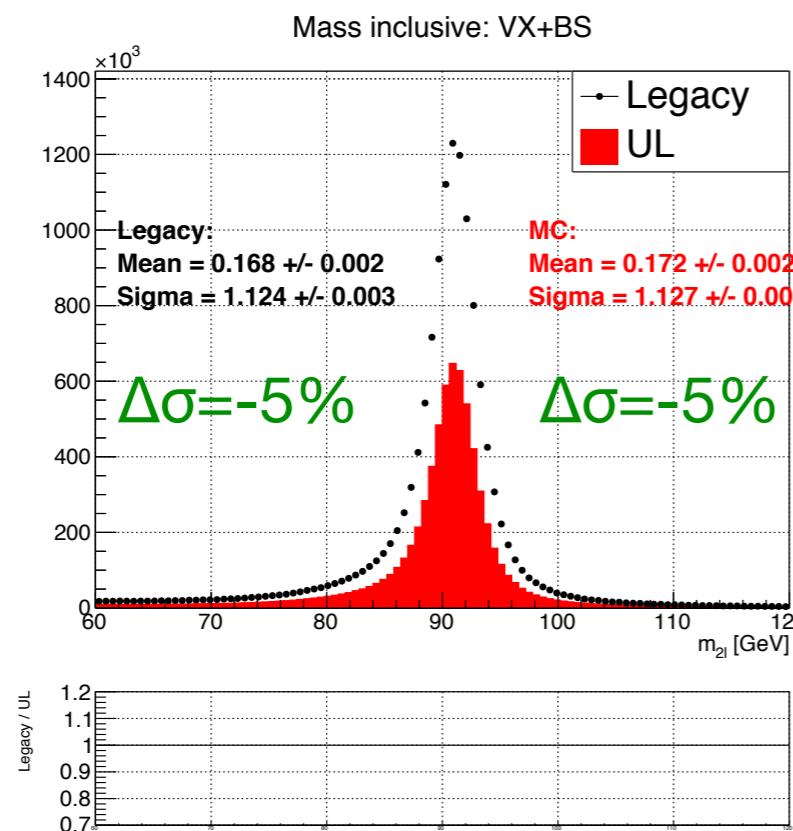
2017



2018

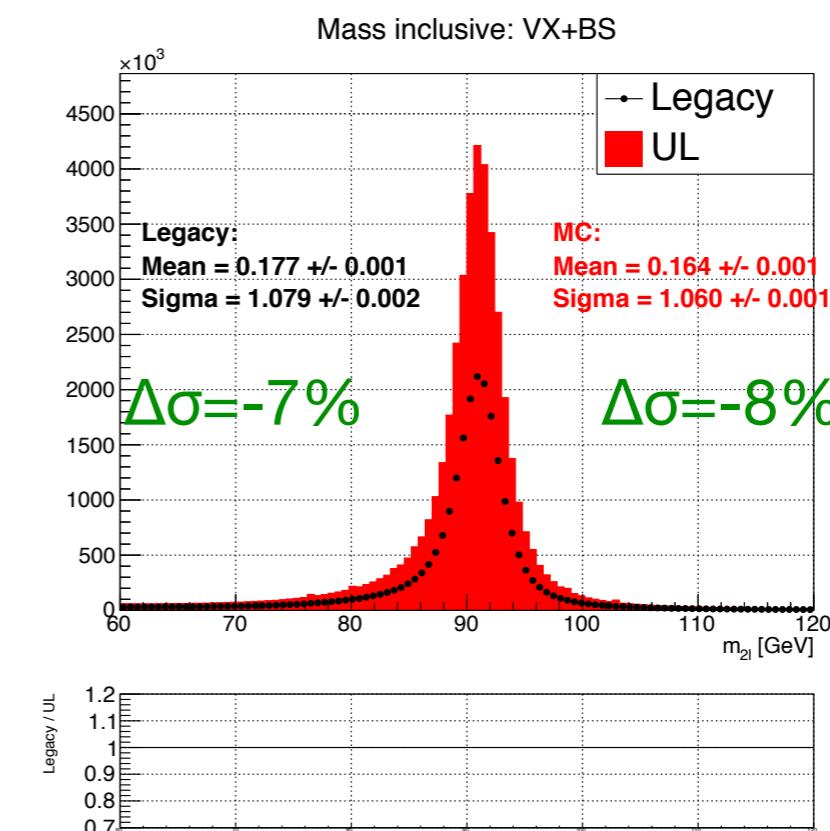
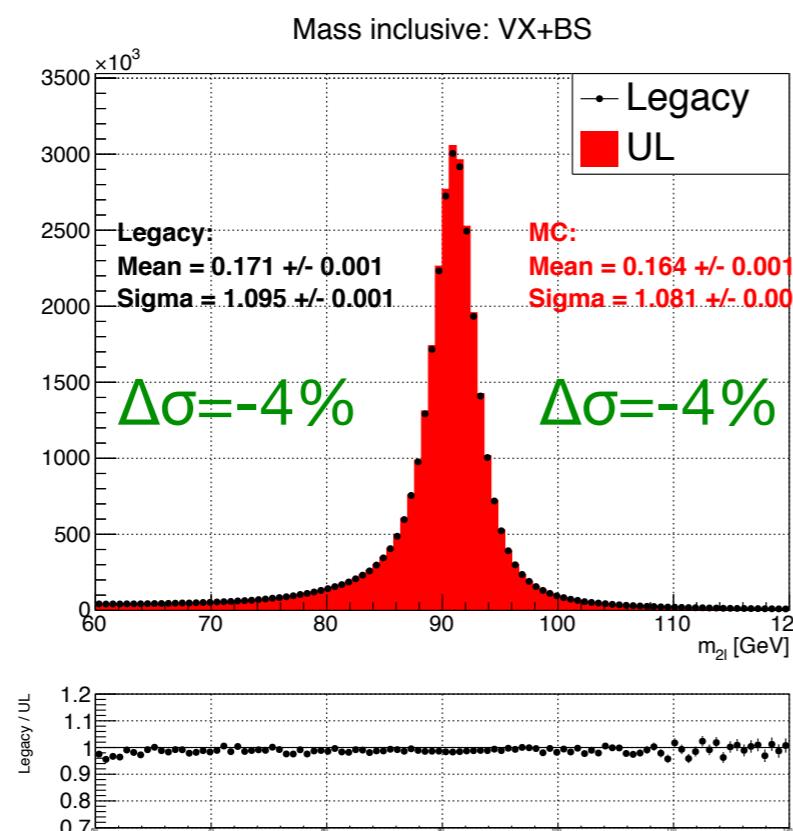
UE Dilepton mass distribution

2016
pre-VPF



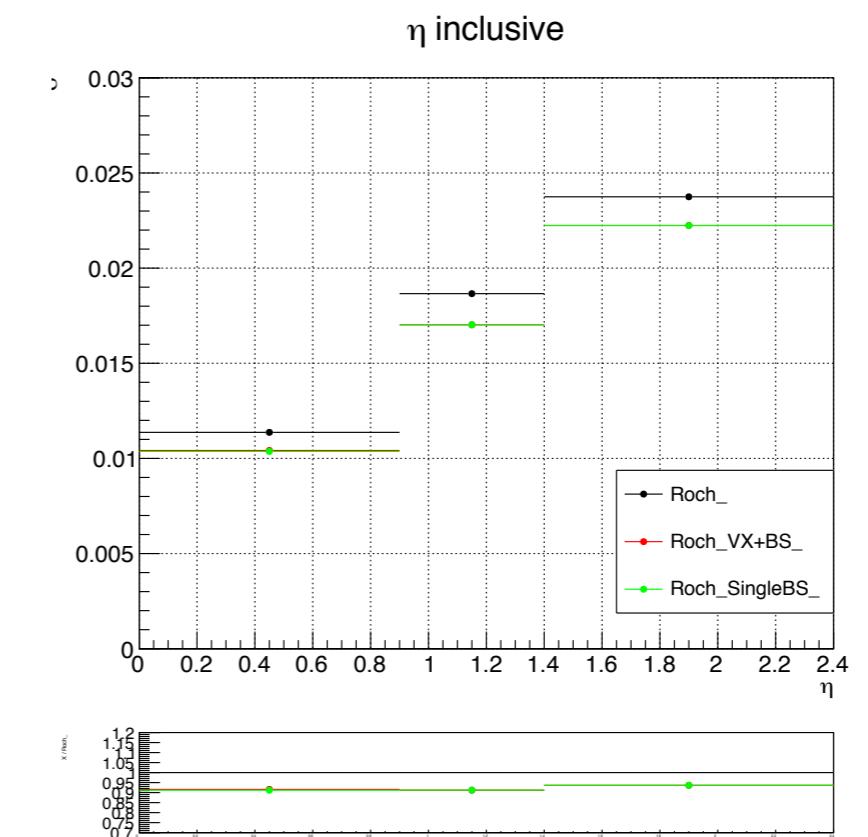
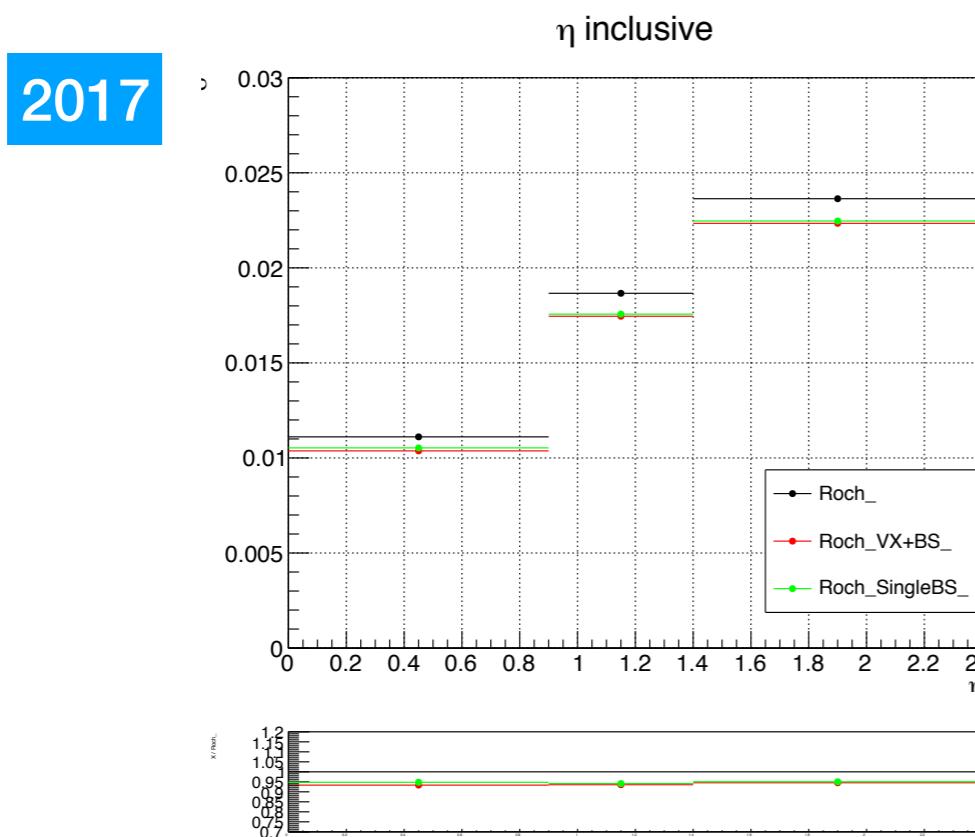
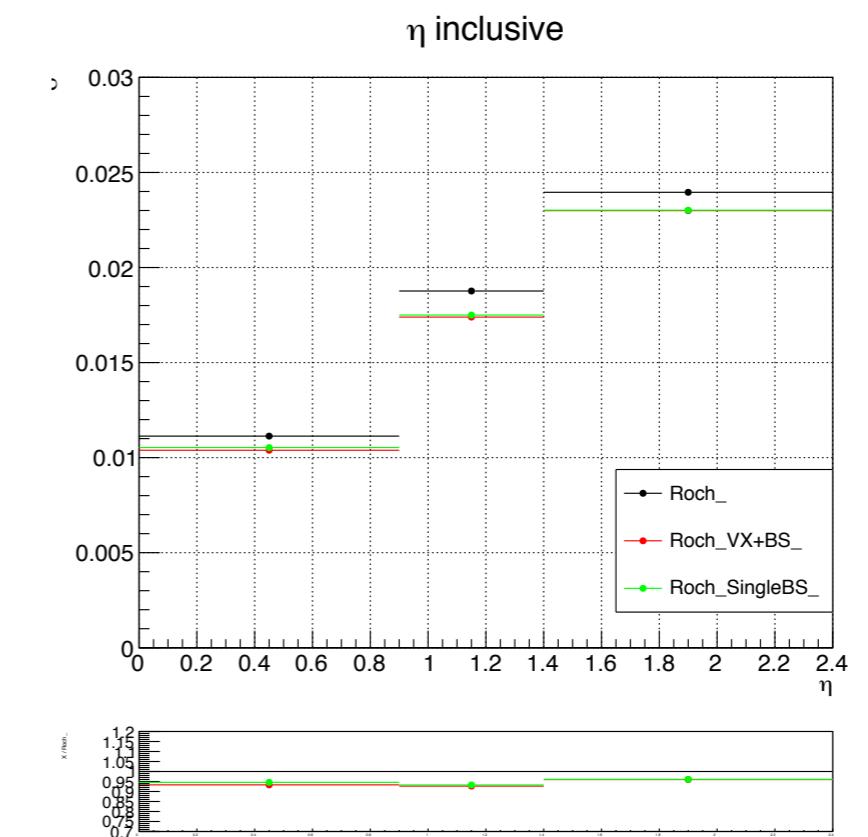
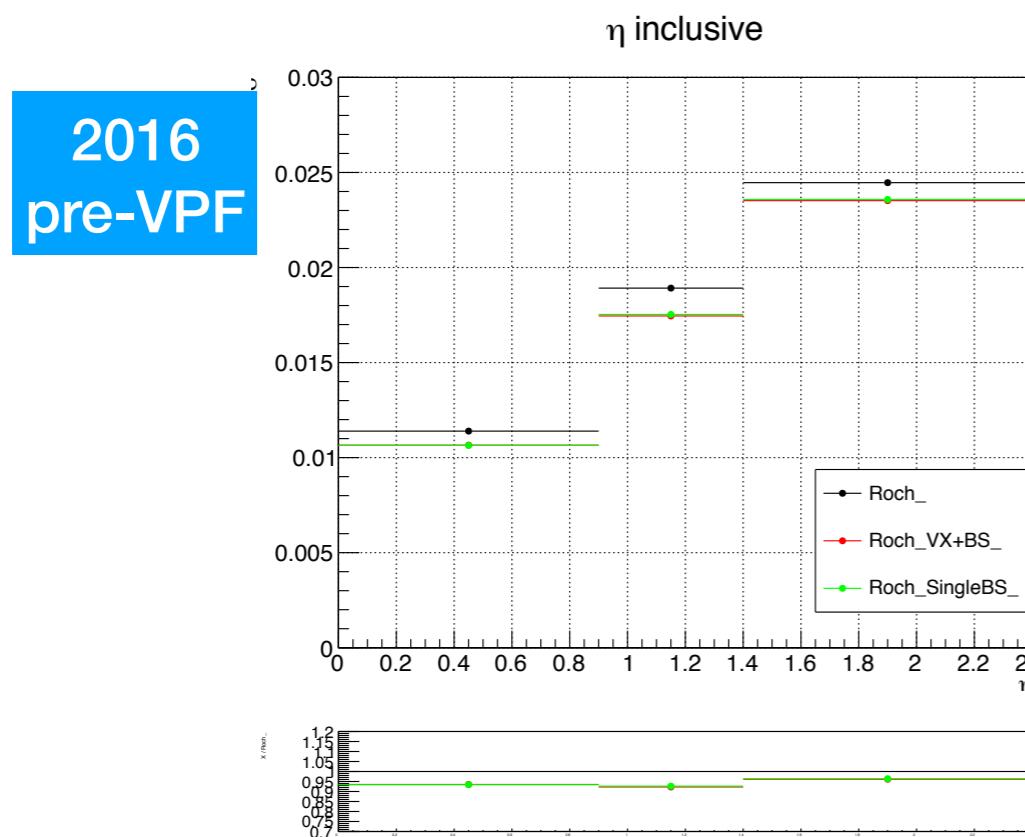
2016
post-VPF

2017

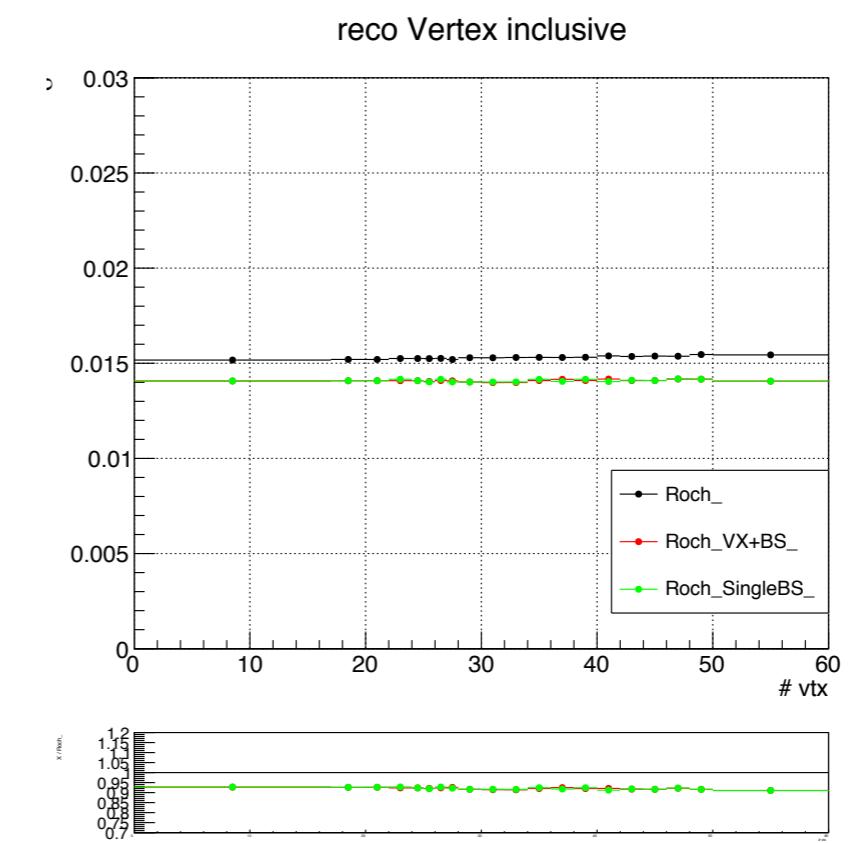
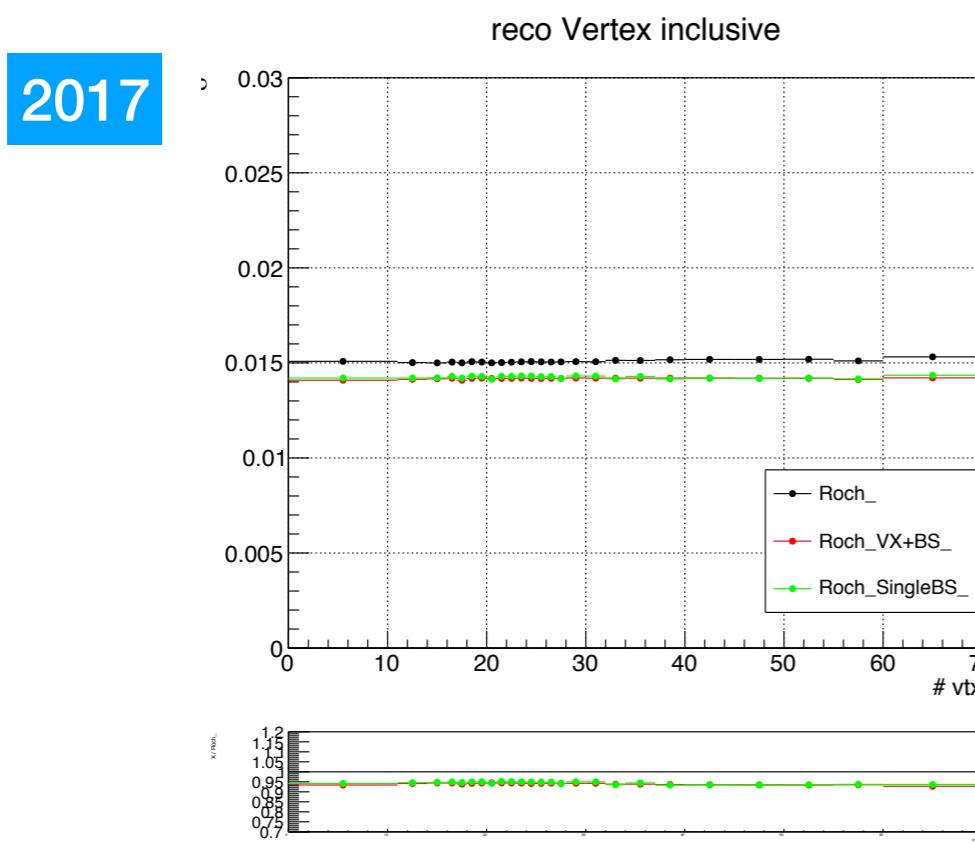
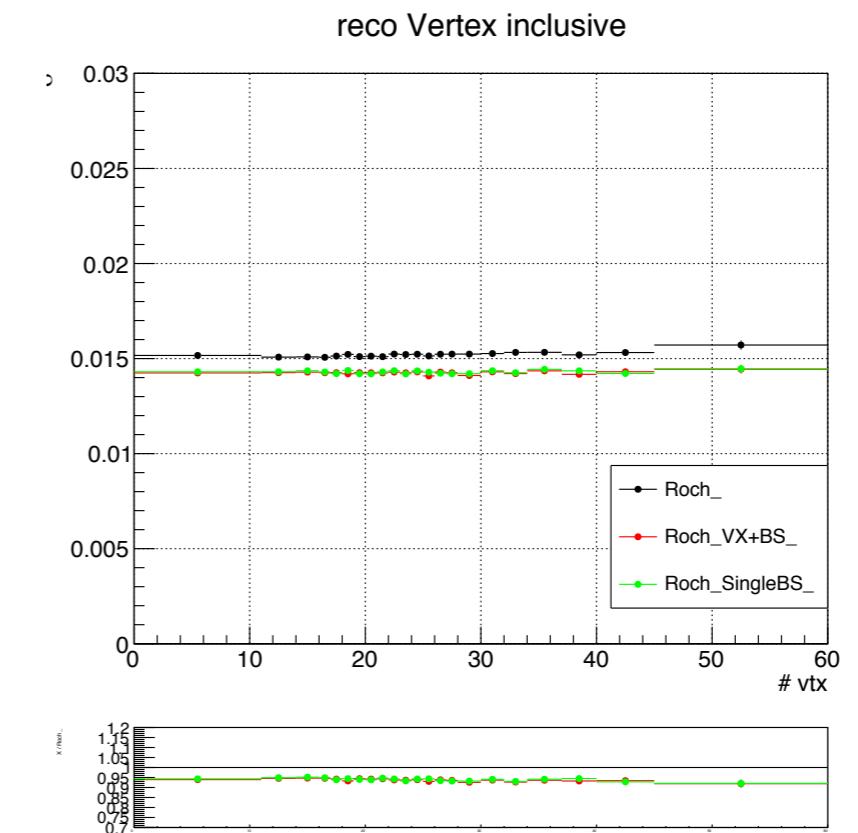
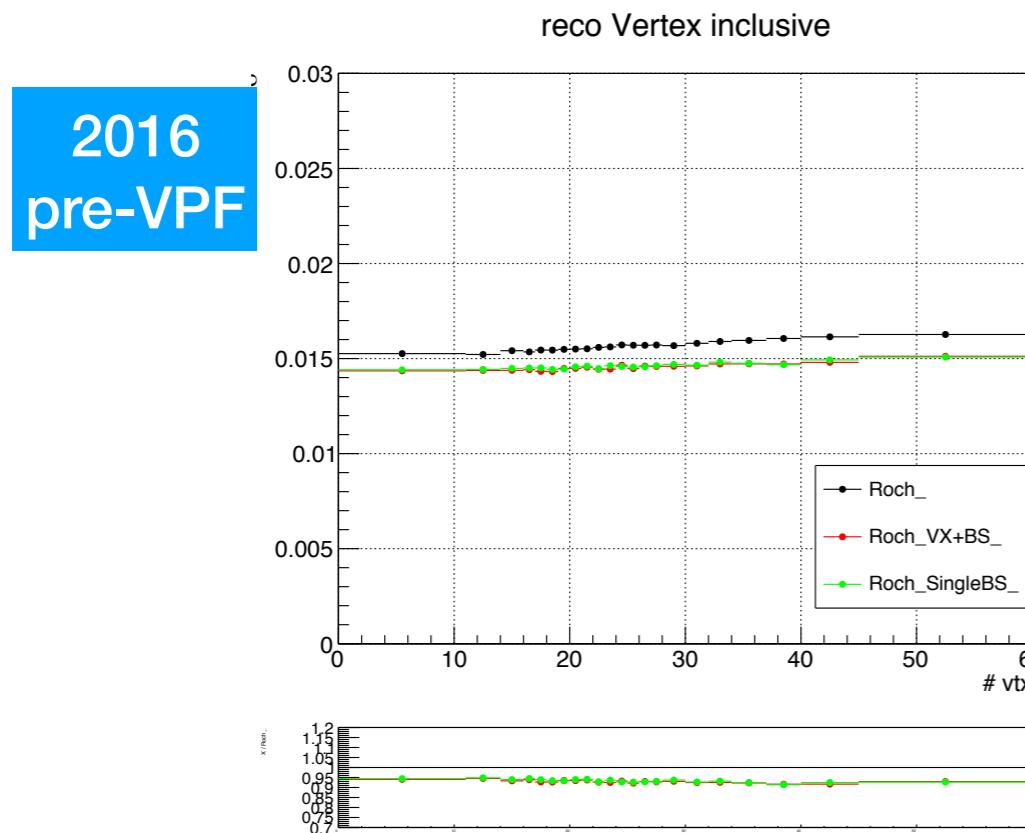


2018

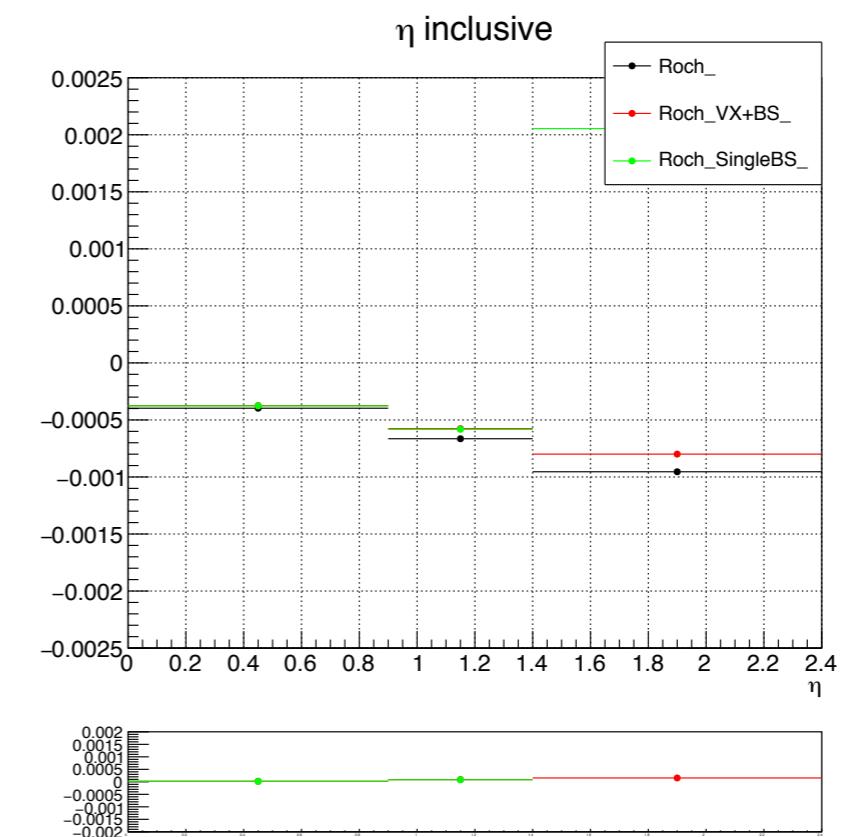
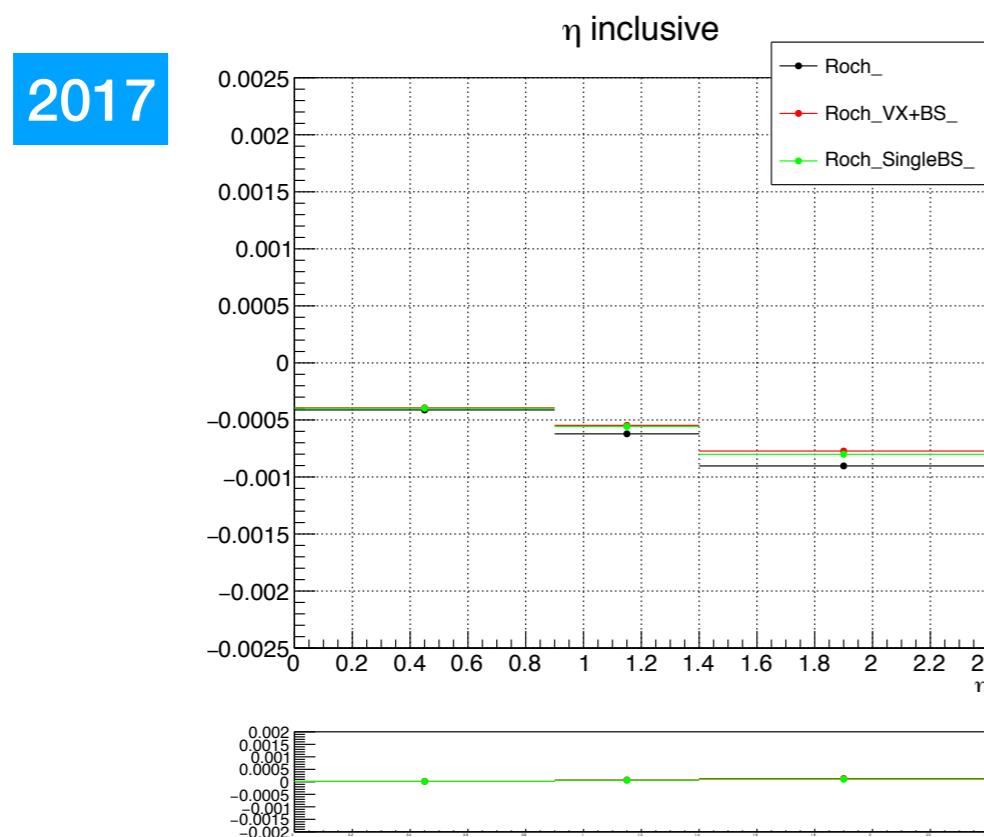
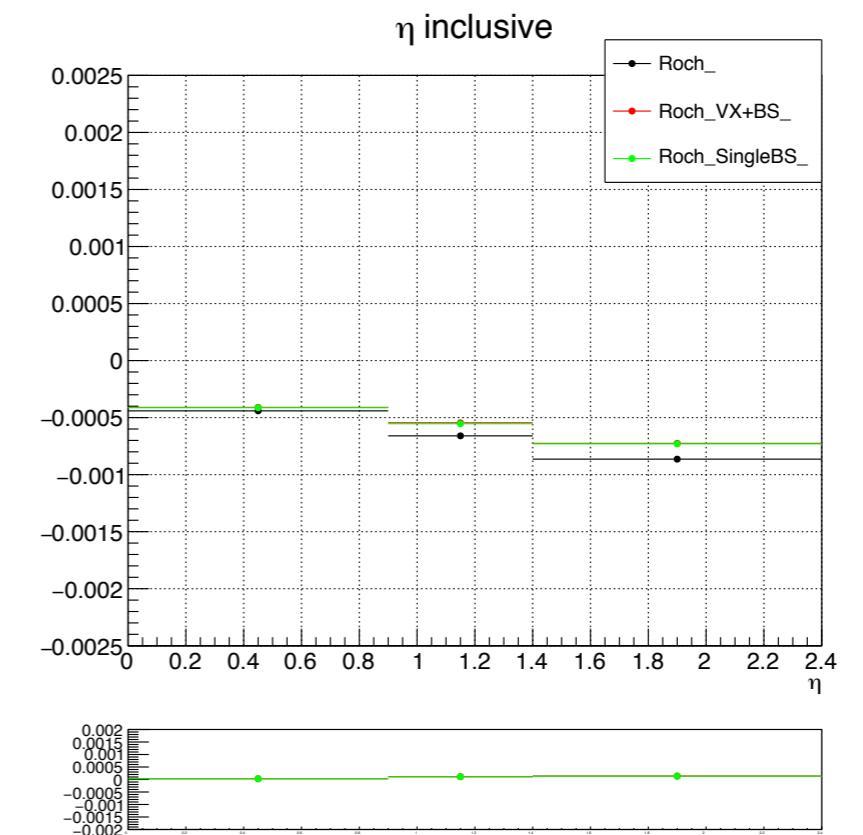
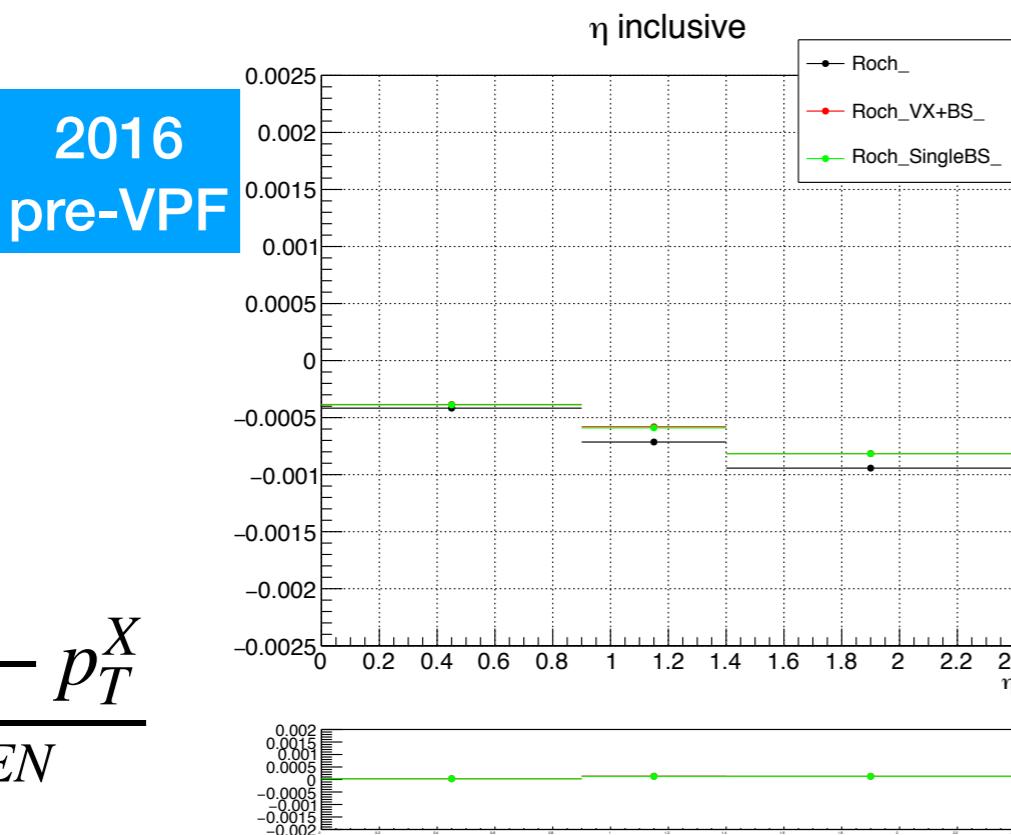
muon pT resolution



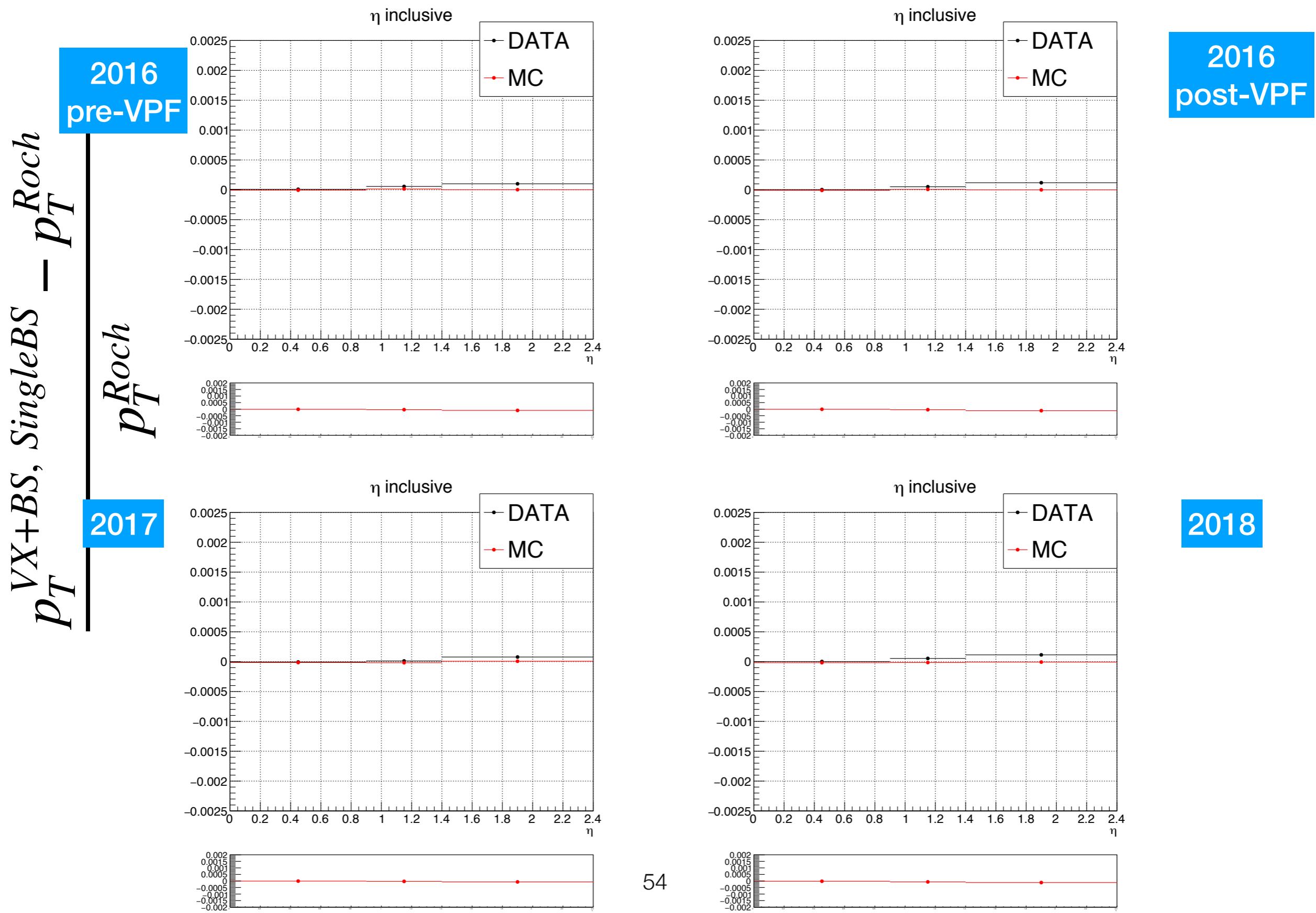
muon pT resolution



muon pT scale



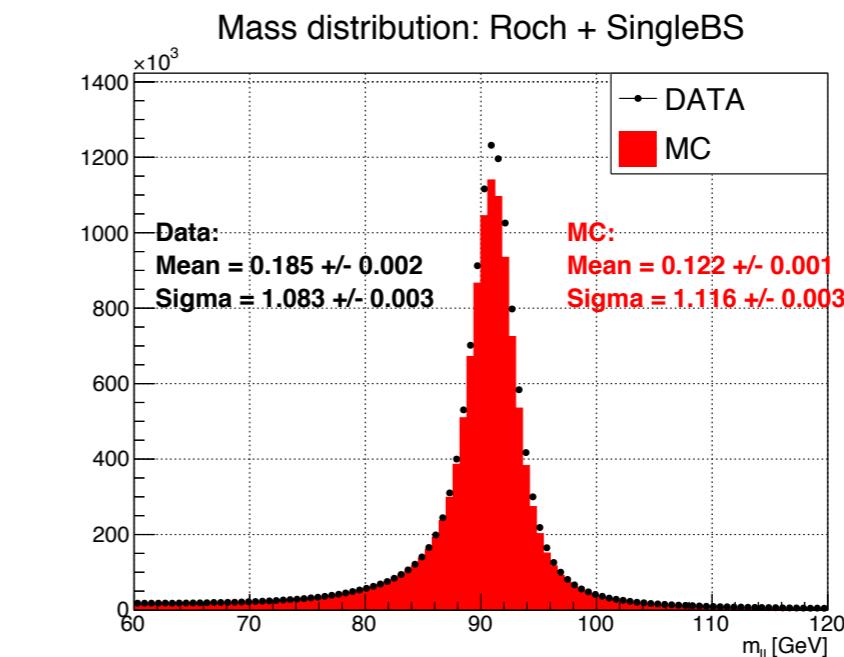
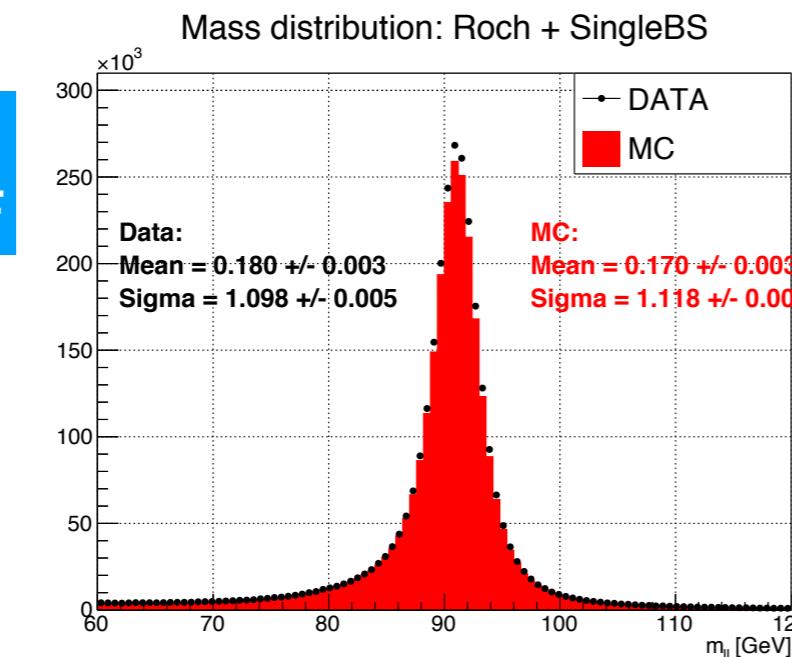
muon pT VX+BS scale



UE Dilepton mass distribution

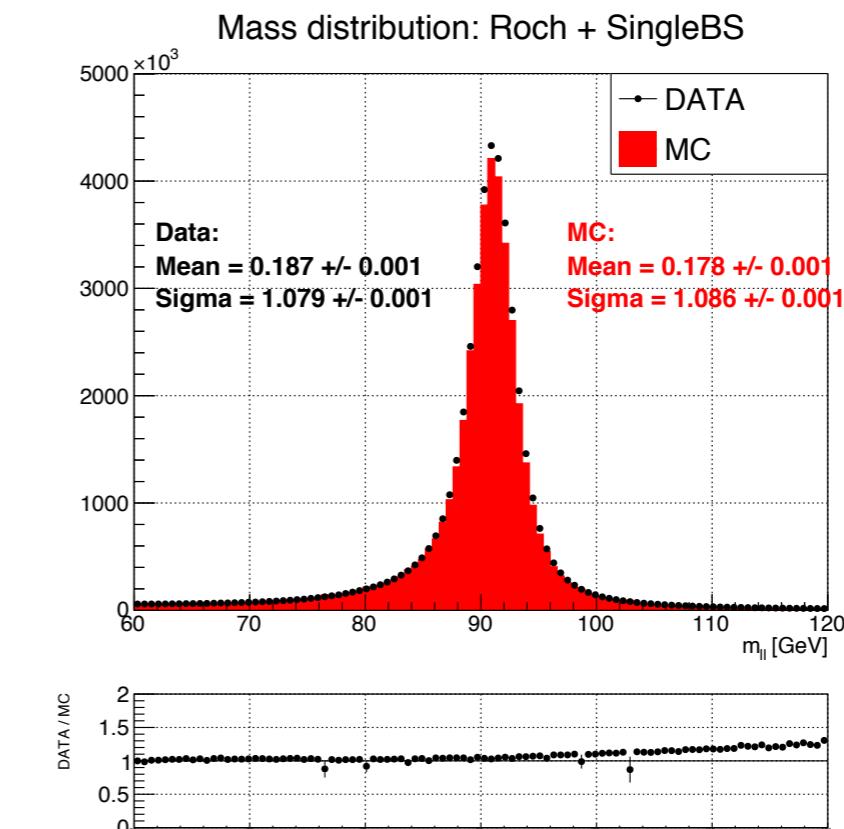
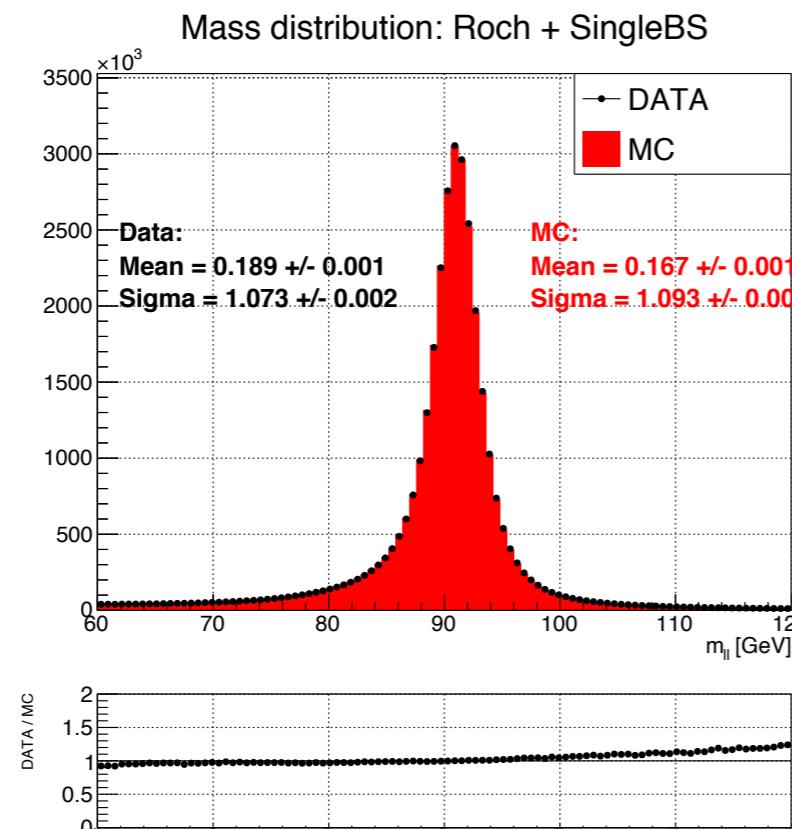
SingleBS

2016
pre-VPF



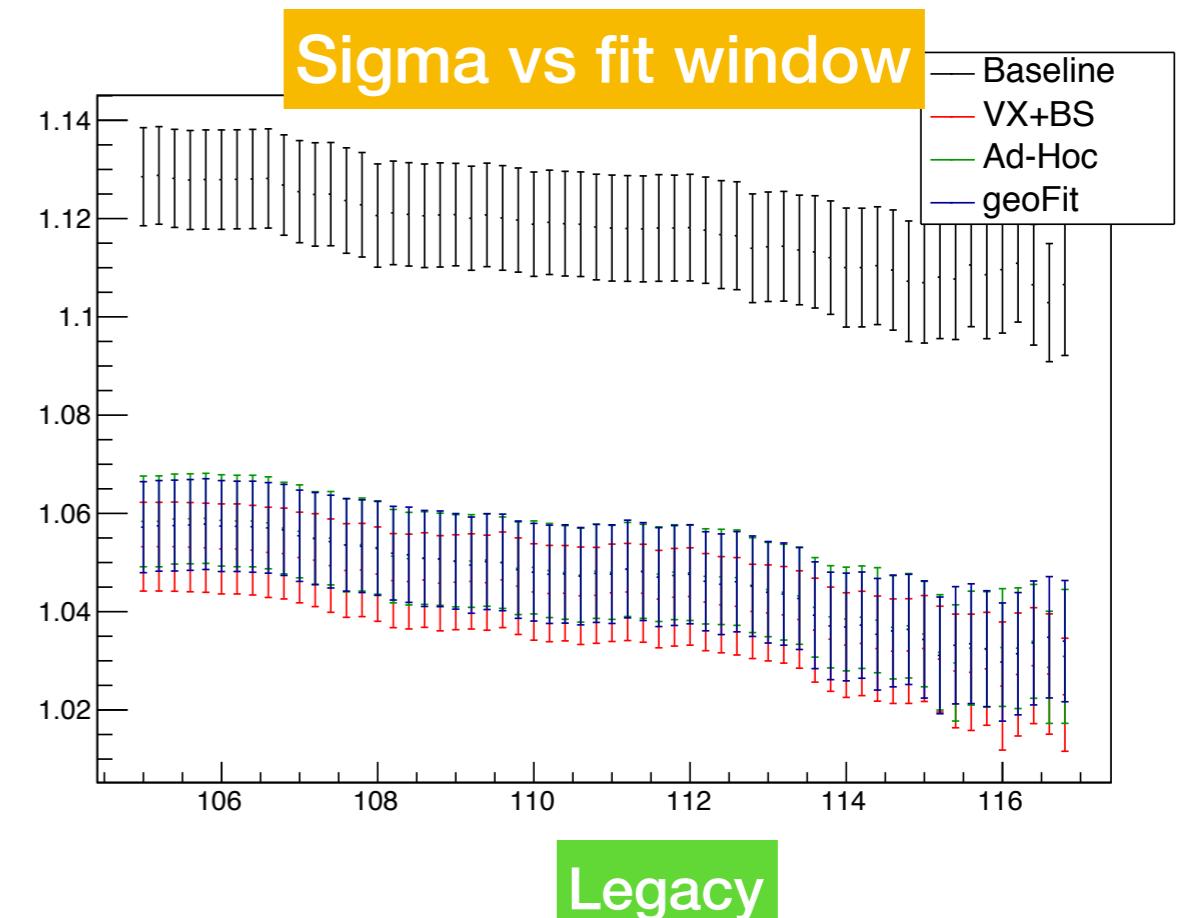
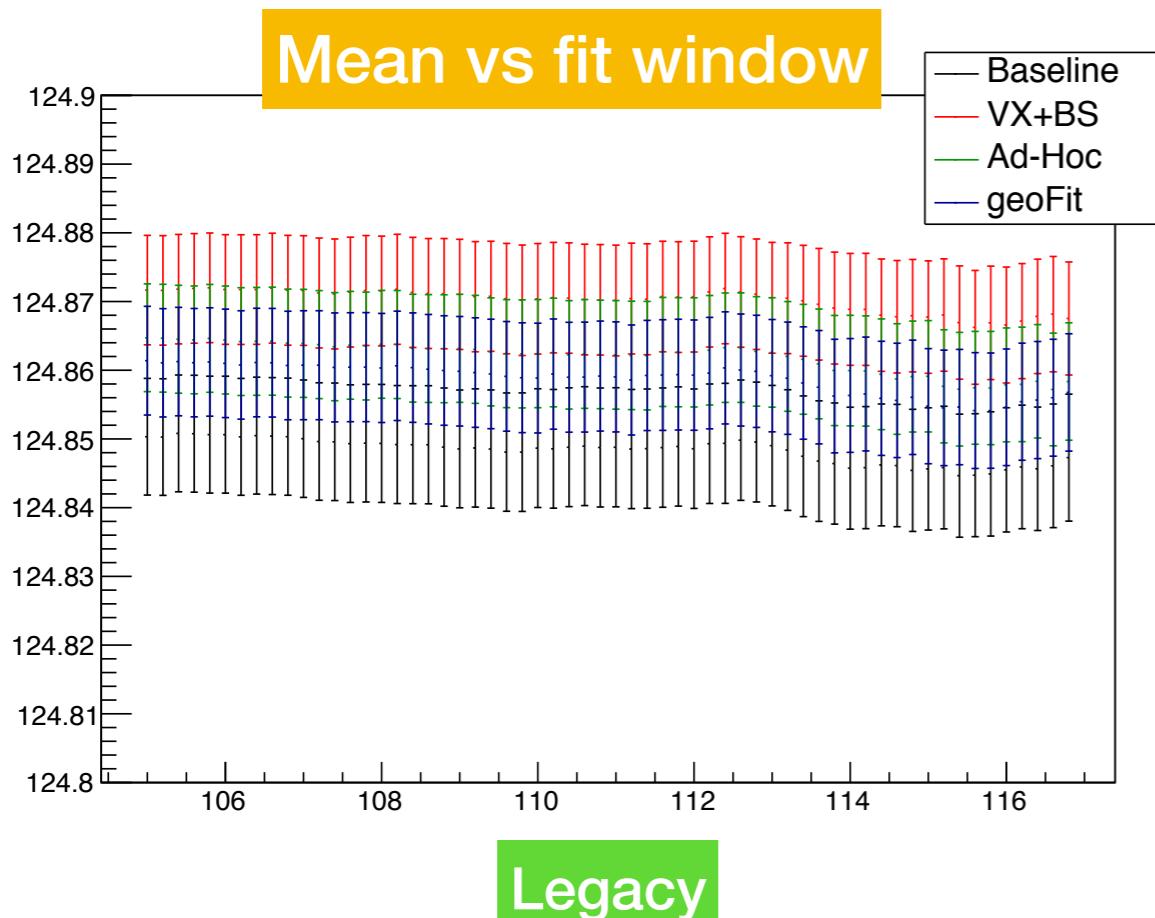
2016
post-VPF

2017



2018

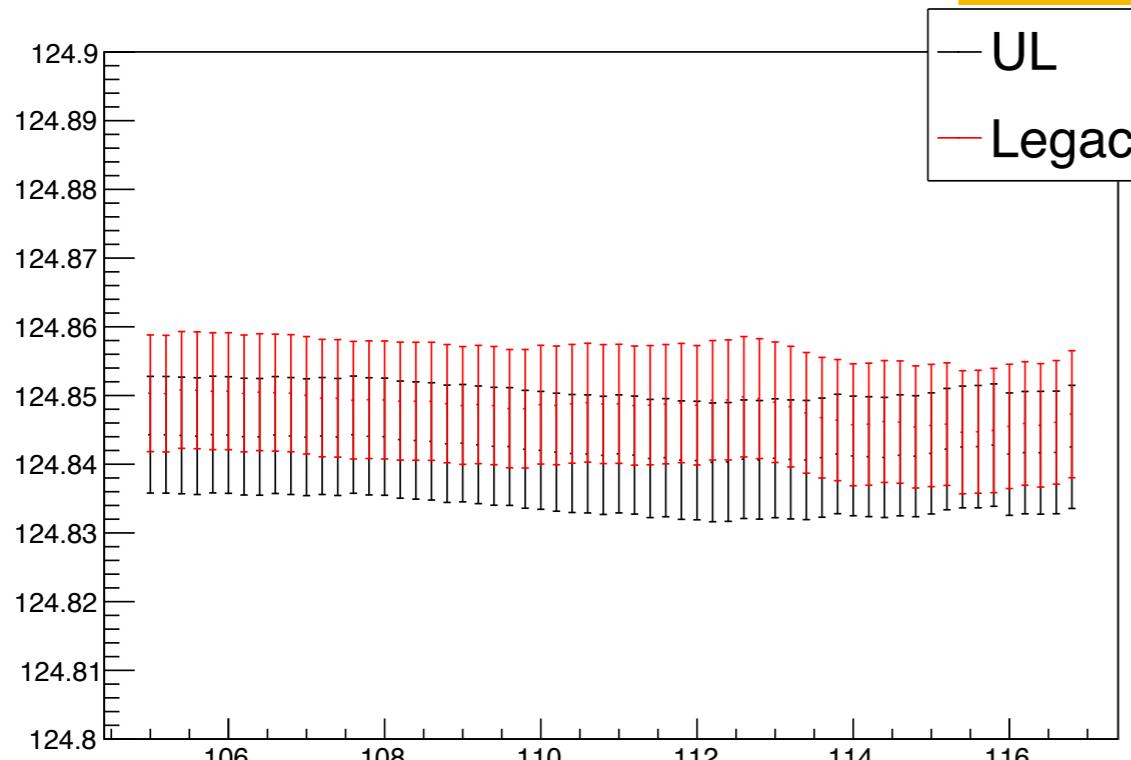
Moving to Higgs boson...



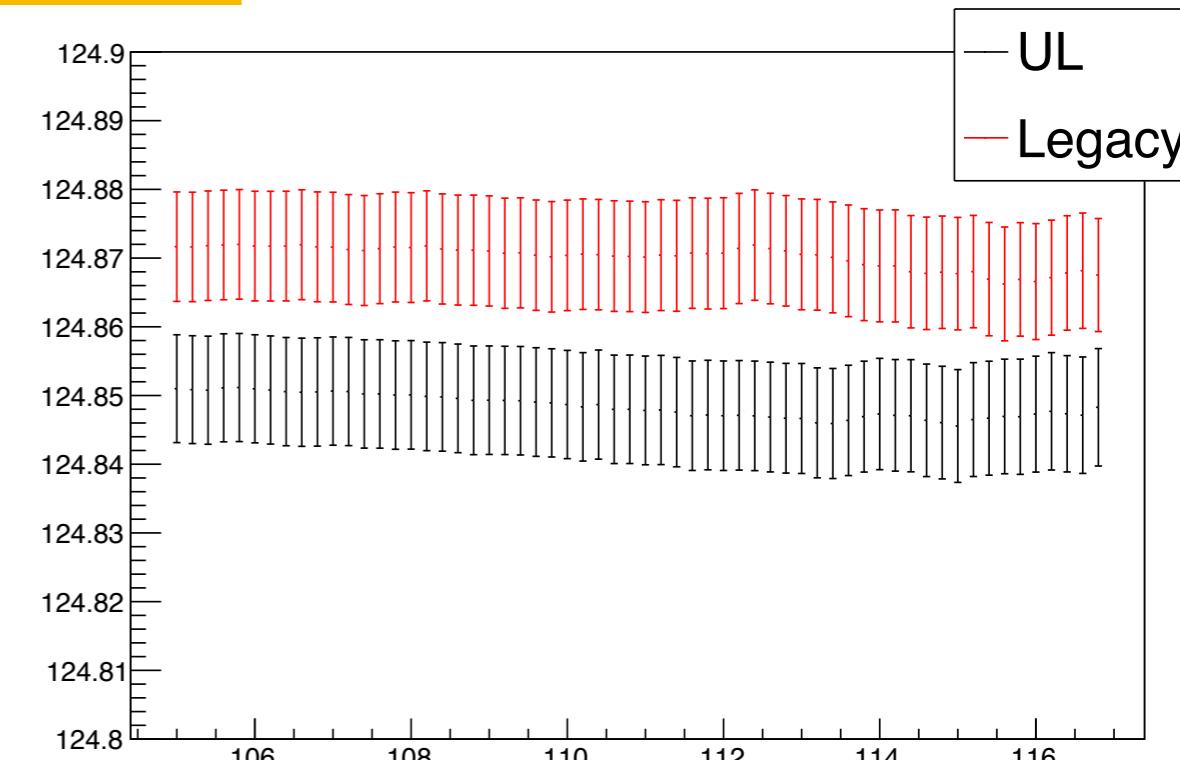
VX+BS has a bigger scale $O(10\text{MeV})$ and has a **bigger improvement on sigma**

Moving to Higgs boson: UL

Mean vs fit window



Rochester

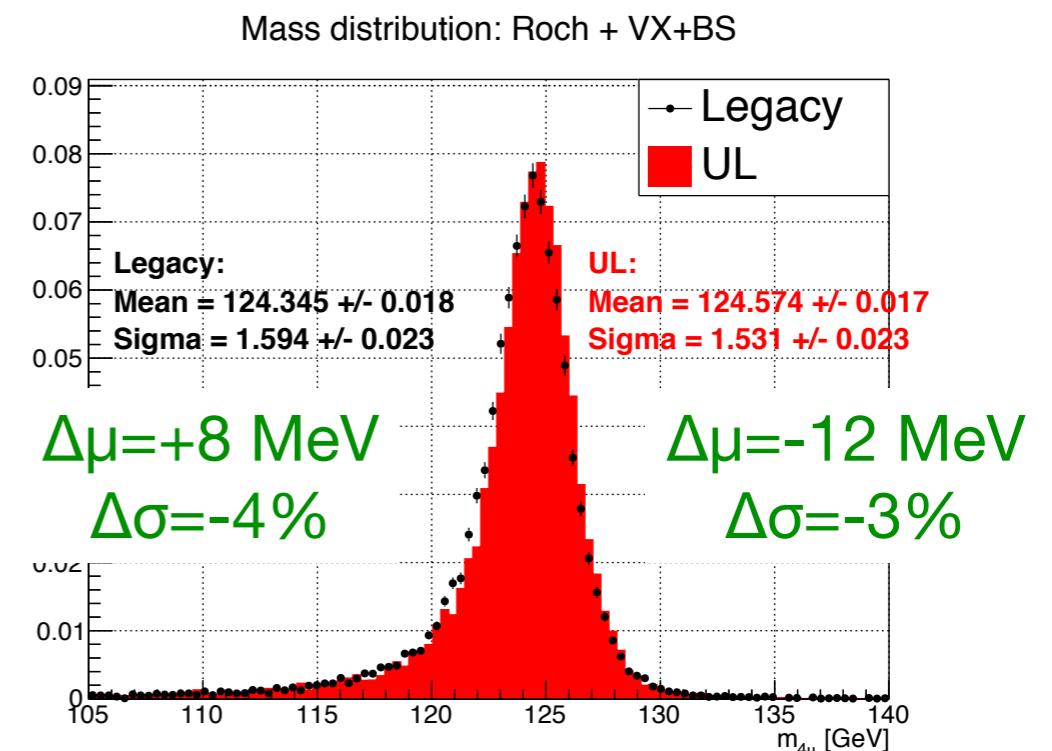
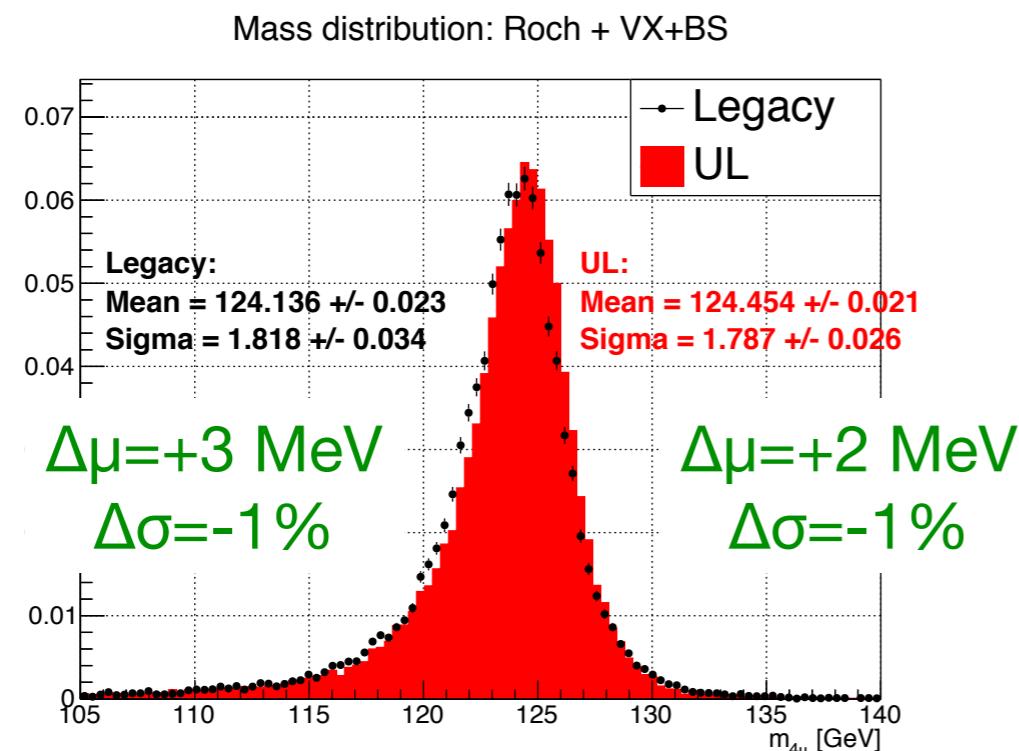
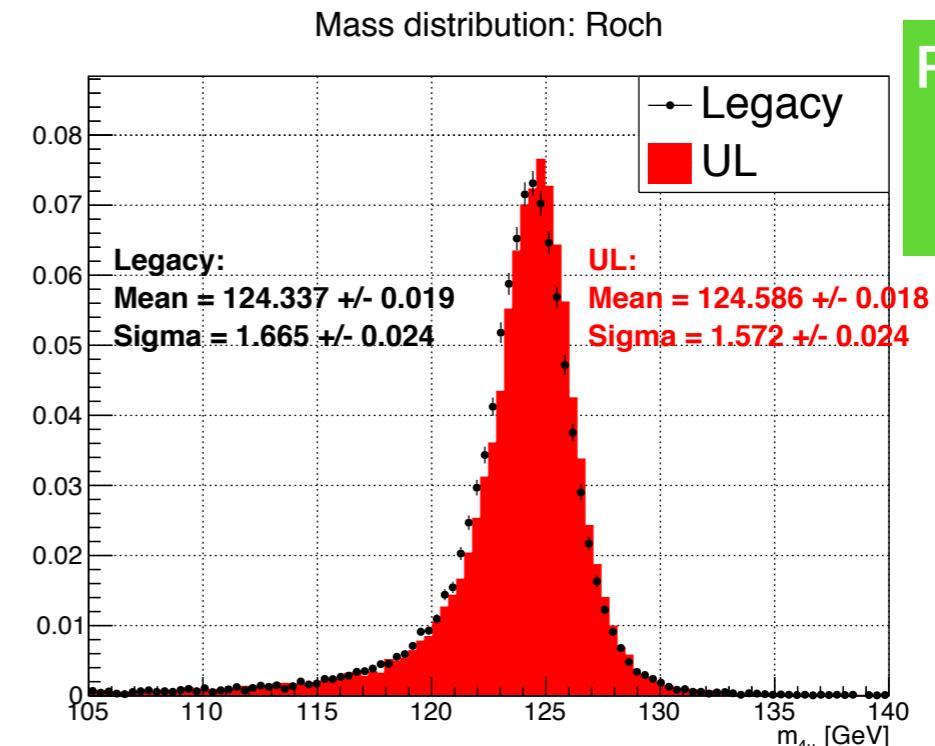
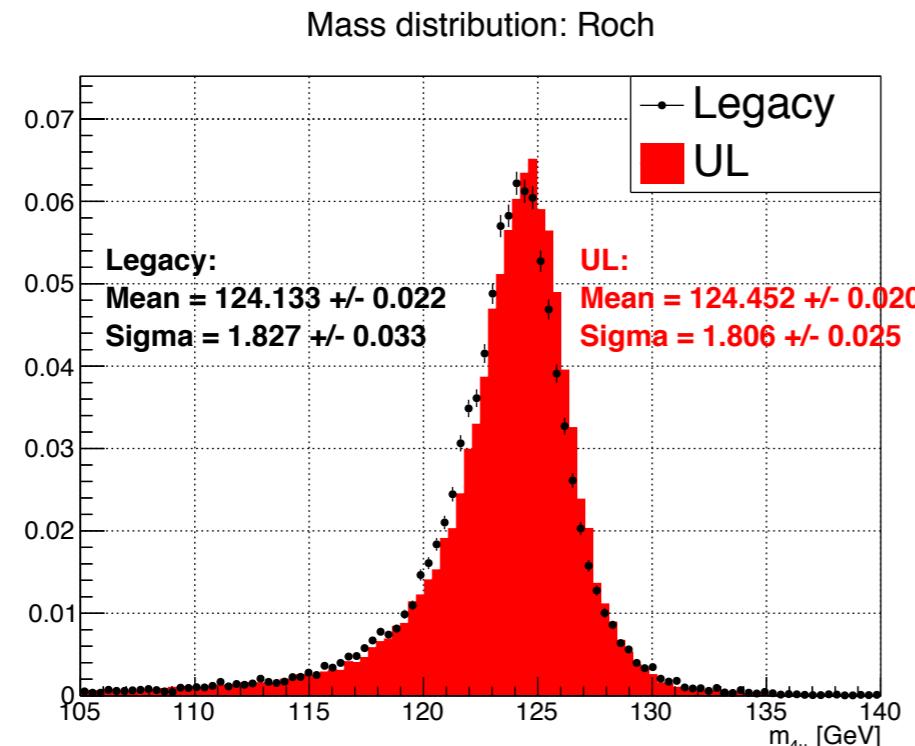


Rochester
+
VX+BS

In UL, Higgs mean shifts less than in Legacy.
Improvement in sigma is compatible.

Moving to Higgs boson...

Rochester



2e2mu

2mu2e