VX+BS for Higgs boson mass measurement

F. Errico,
on behalf of BBBF group

04/09/2021

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 beam spot constraint information in muon reconstruction.

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

As a remark, in the **VX+BS** approach, the system of 4 (2) tracks is constrained to the BS, profits from KalmanVertexFitter (already implemented in CMSSW) and is available at miniAOD level.

This method received **green light from Muon POG** this week [**].

In the following slides, first (very) preliminary results on VX+BS will be shown.

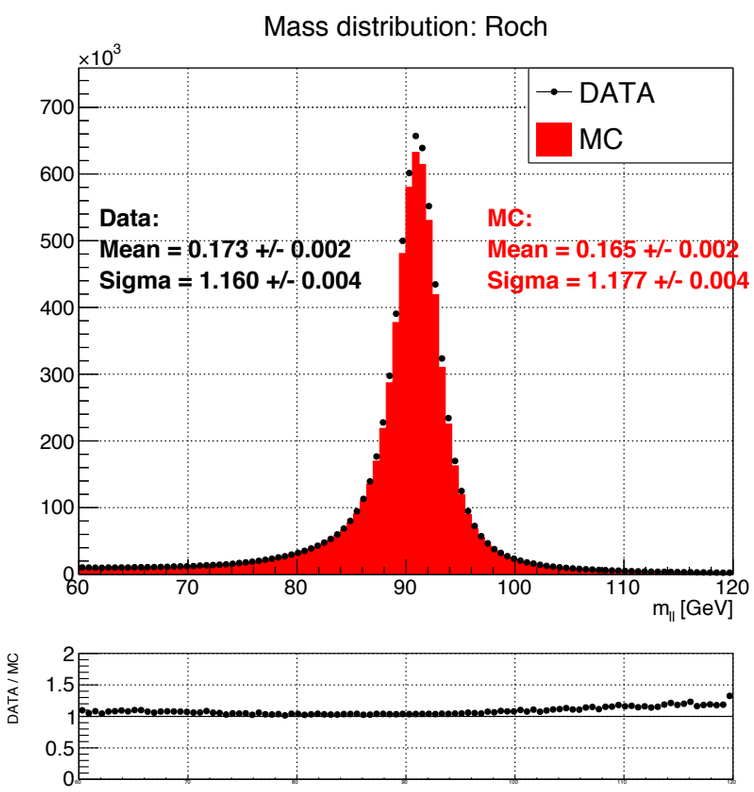
In parallel, also results using **UL** will be shown.

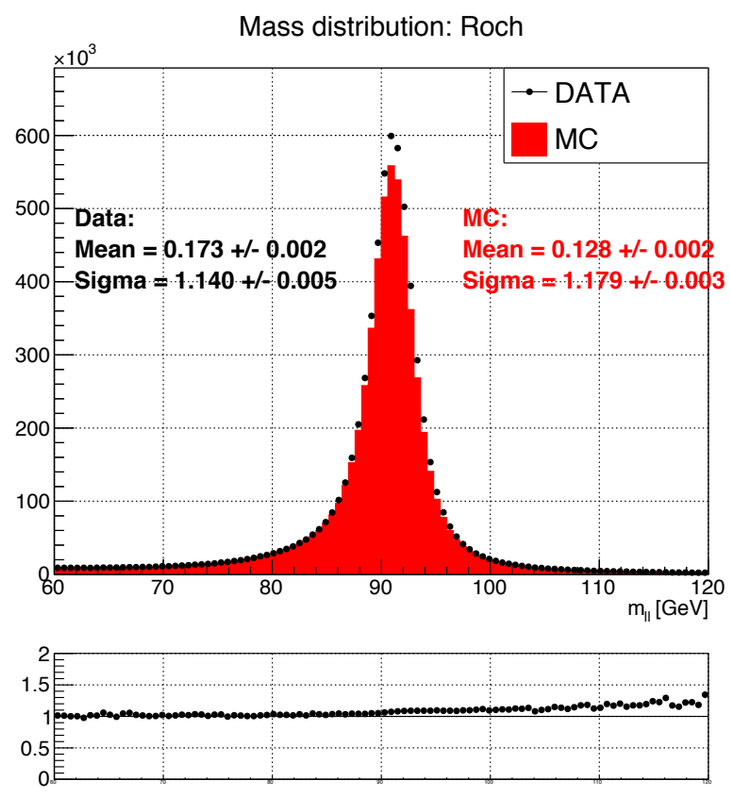
*Jake's slides
** Filippo's slides

Dilepton mass distribution

Baseline

2016 pre-VPF





2016 post-VPF

UL DY

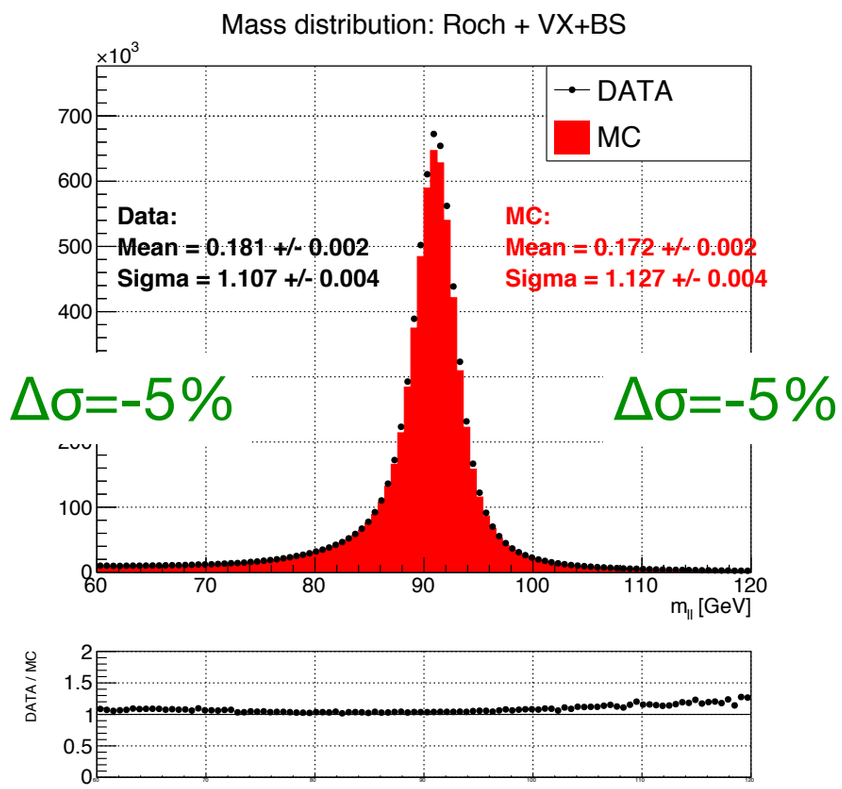
2017

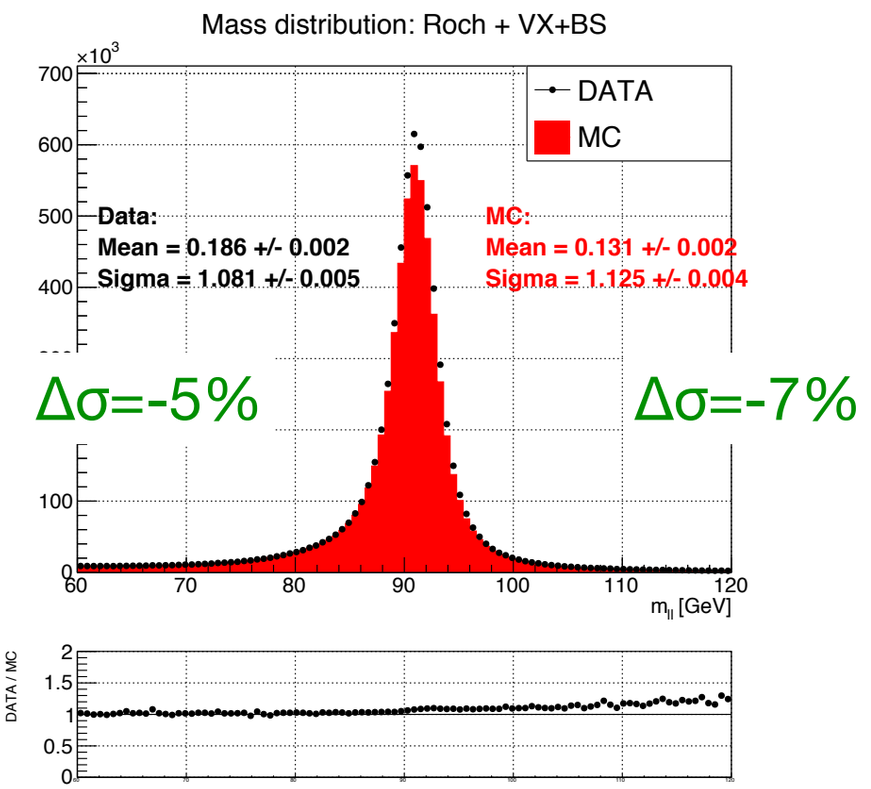
2018

Dilepton mass distribution

Baseline + VX+BS

2016 pre-VPF





2016 post-VPF

UL DY

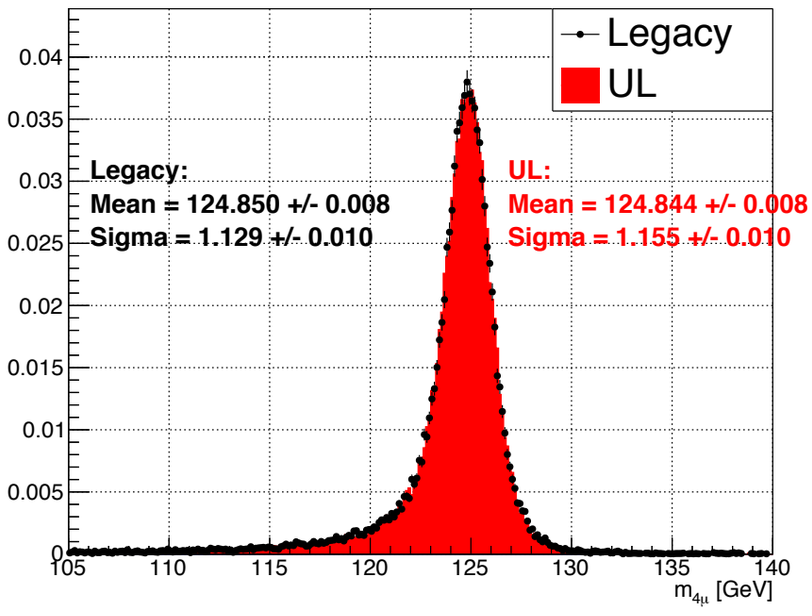
2017

2018

Moving to Higgs boson...

Baseline

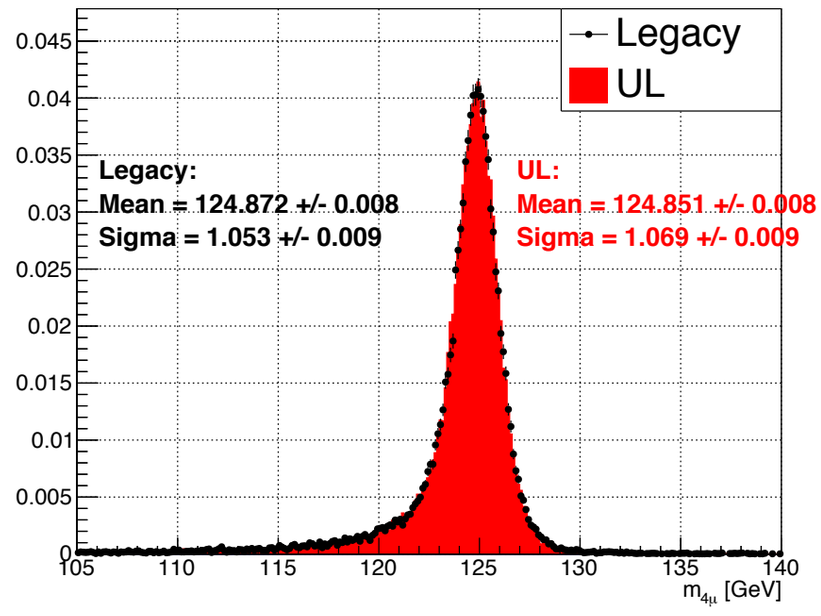
Mass distribution: Roch



Δμ=+22 MeV
Δσ=-7%

Baseline + VX+BS

Mass distribution: Roch + VX+BS



Δμ=+7 MeV
Δσ=-8%

ggH 2018 4mu

~8% improvement in sigma

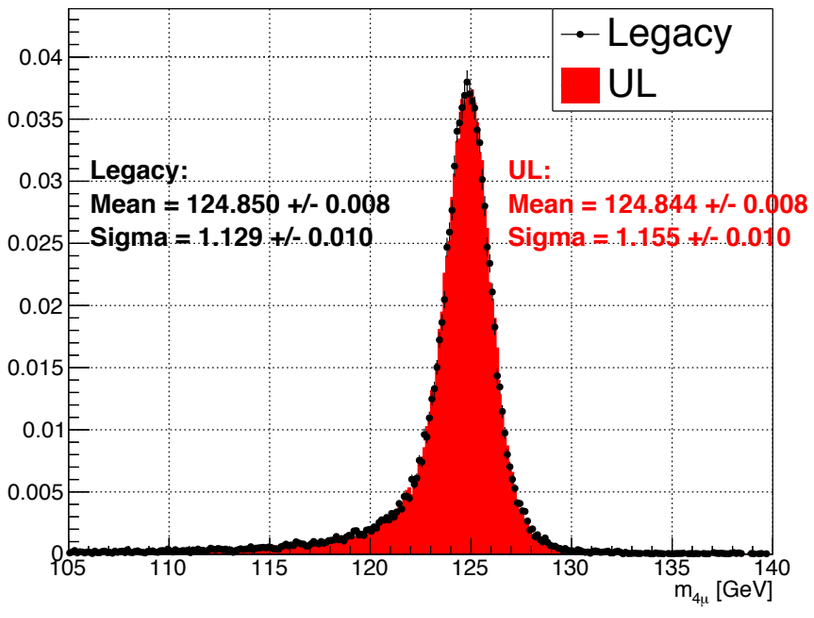
~10 MeV shift in peak position

2e2mu and 2mu2e in backup

Moving to Higgs boson...

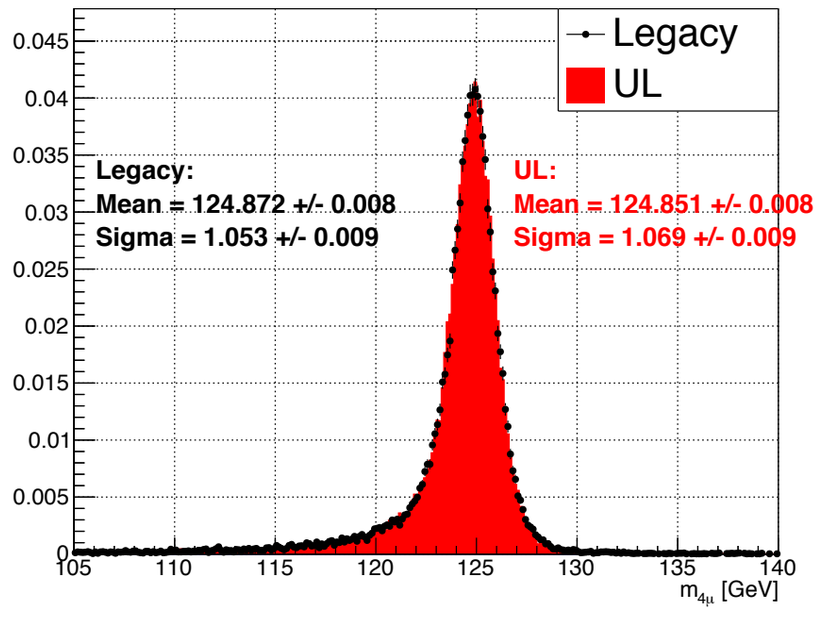
Baseline

Mass distribution: Roch



Baseline + VX+BS

Mass distribution: Roch + VX+BS



Δμ=+22 MeV
Δσ=-7%

Δμ=+7 MeV
Δσ=-8%

Legacy ggH samples 4mu final state

Legacy samples	Mean shift [MeV]	σ improvement [in ggH->4μ]
2016	15	4,6%
2017	6	5,1%
2018	22	6,7%

Higgs mass strategy

We have checked that VX+BS improves mass resolution.

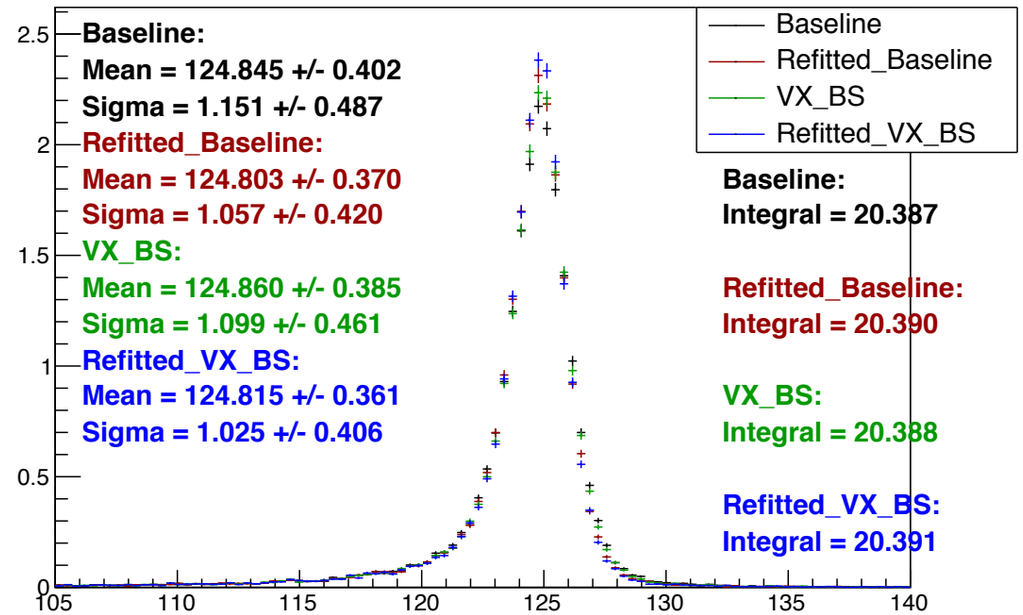
As a remark, the VX+BS is applied after Rochester correction and before any other treatment developed inside Higgs mass measurement.

In particular, **the Z1 constraint has been applied to the muons with VX+BS**.

Next results have been produced using Legacy samples.

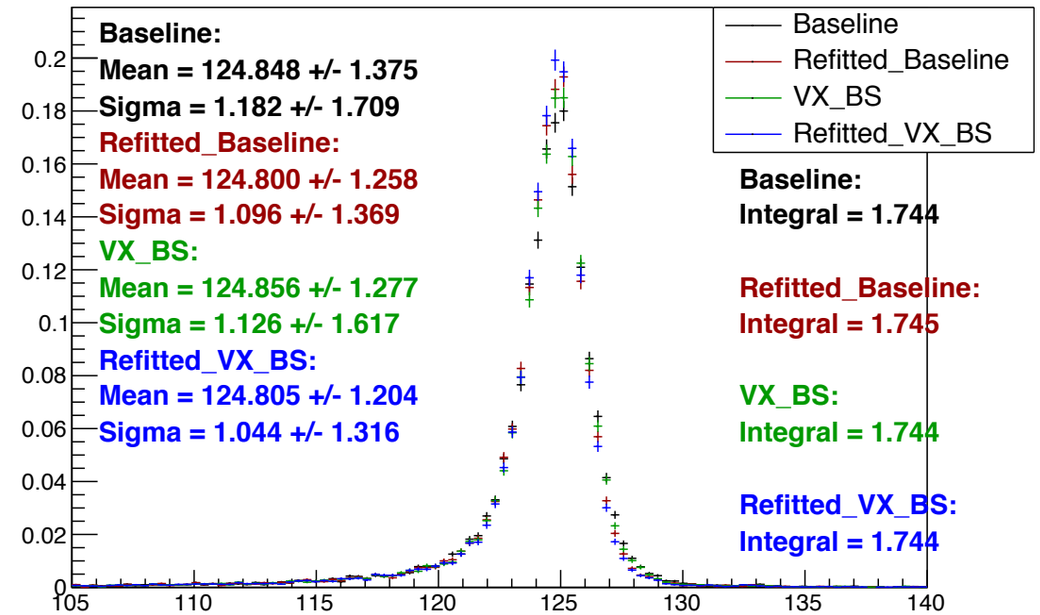
Higgs mass plots: signal

Signal_MassDistributon_125_ggH_4mu



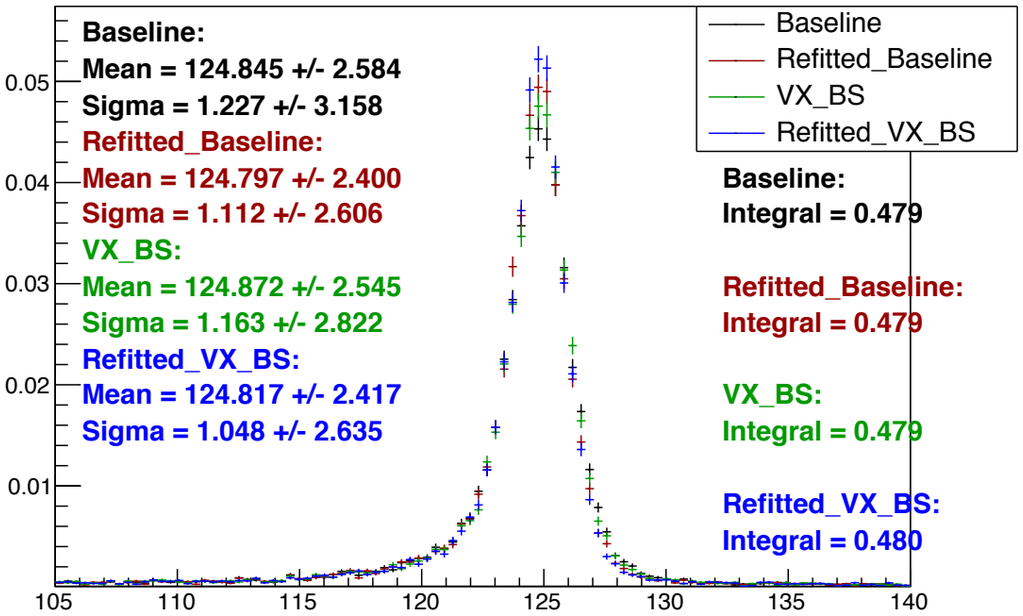
ggH 4mu

Signal_MassDistributon_125_VBF_4mu



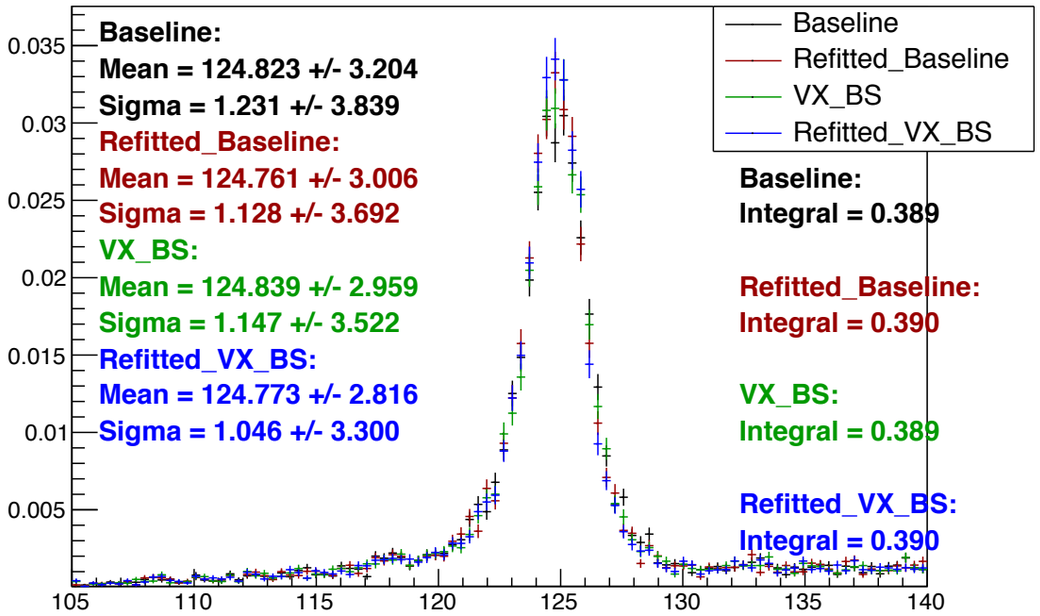
VBF 4mu

Signal_MassDistributon_125_WH_4mu



WH 4mu

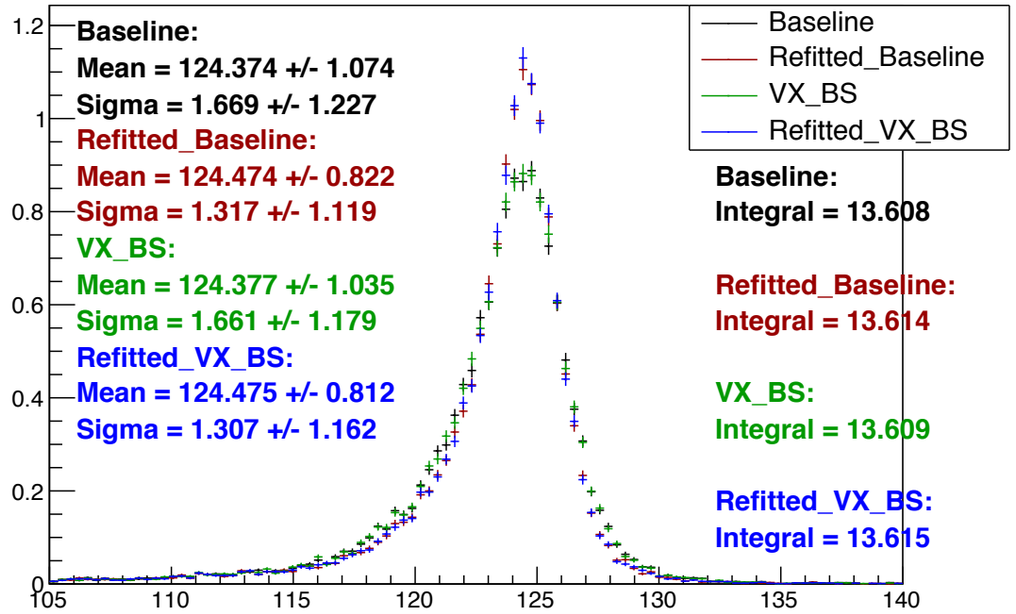
Signal_MassDistributon_125_ZH_4mu



ZH 4mu

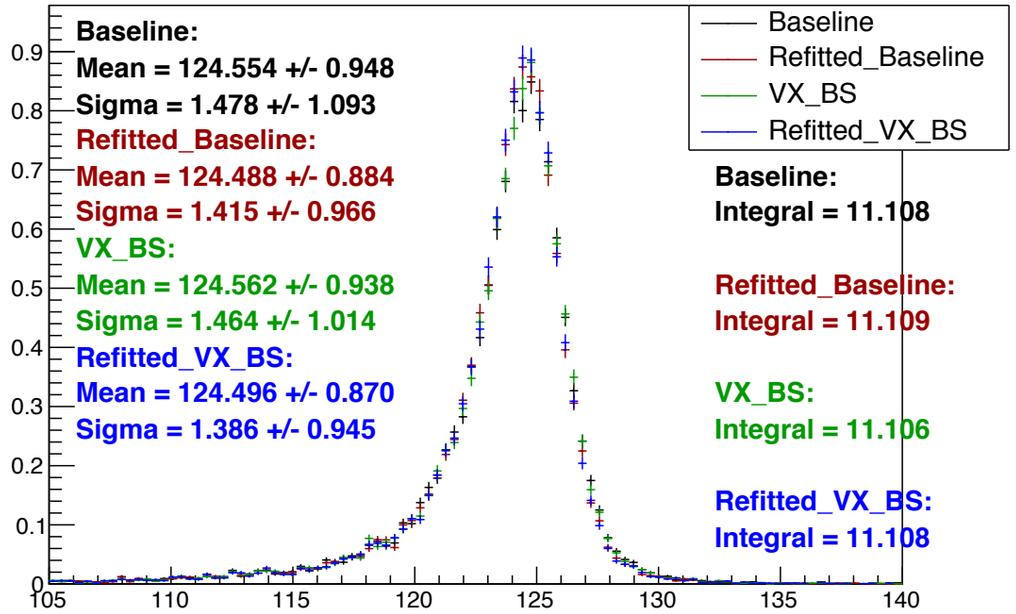
Higgs mass plots: signal

Signal_MassDistributon_125_ggH_2e2mu



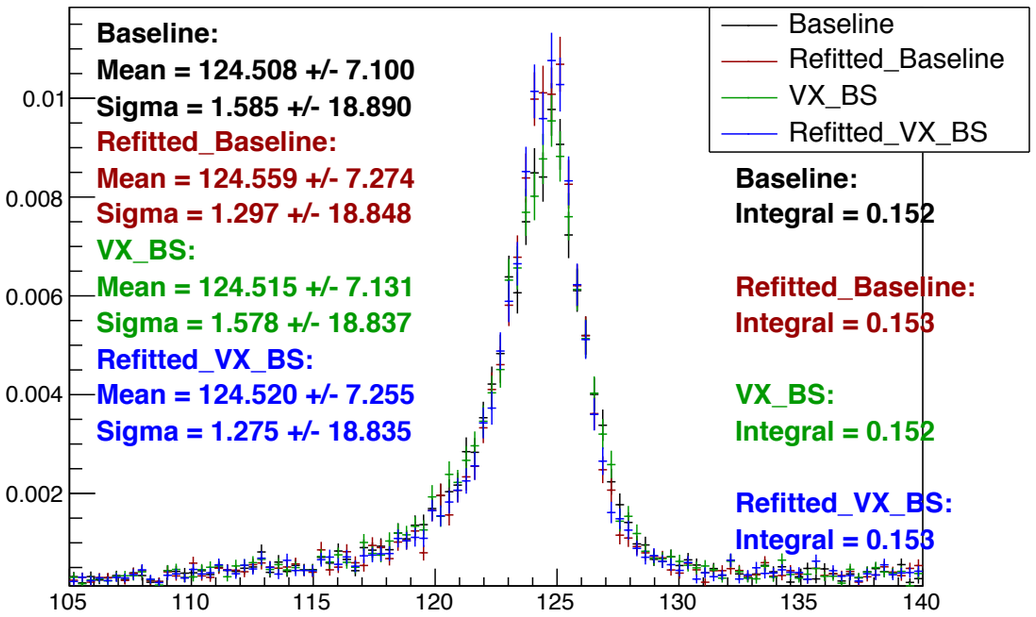
ggH 2e2mu

Signal_MassDistributon_125_ggH_2mu2e



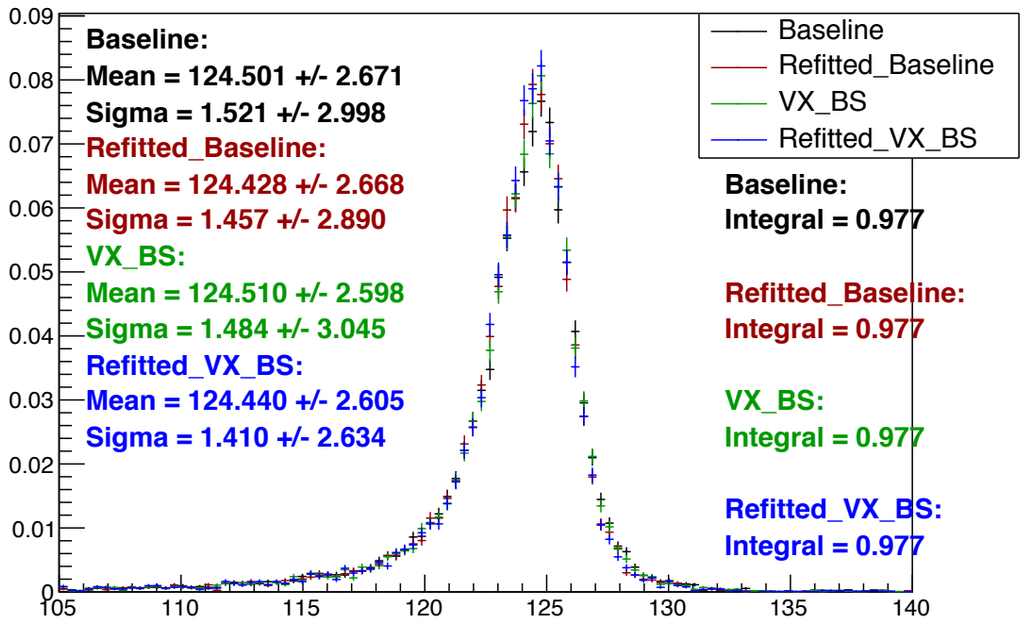
ggH 2mu2e

Signal_MassDistributon_125_ttH_2e2mu



ttH 2e2mu

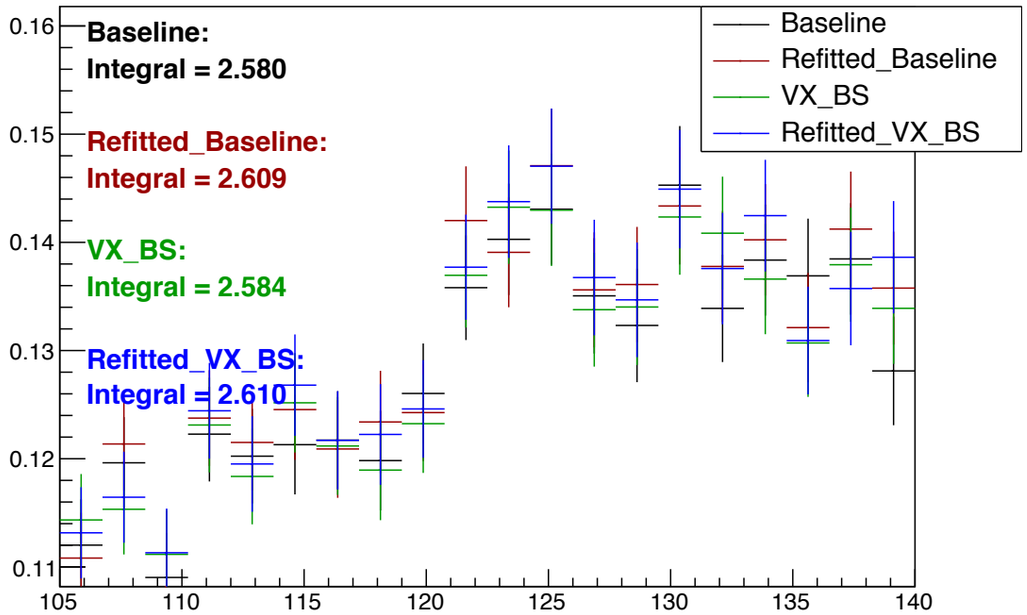
Signal_MassDistributon_125_VBF_2mu2e



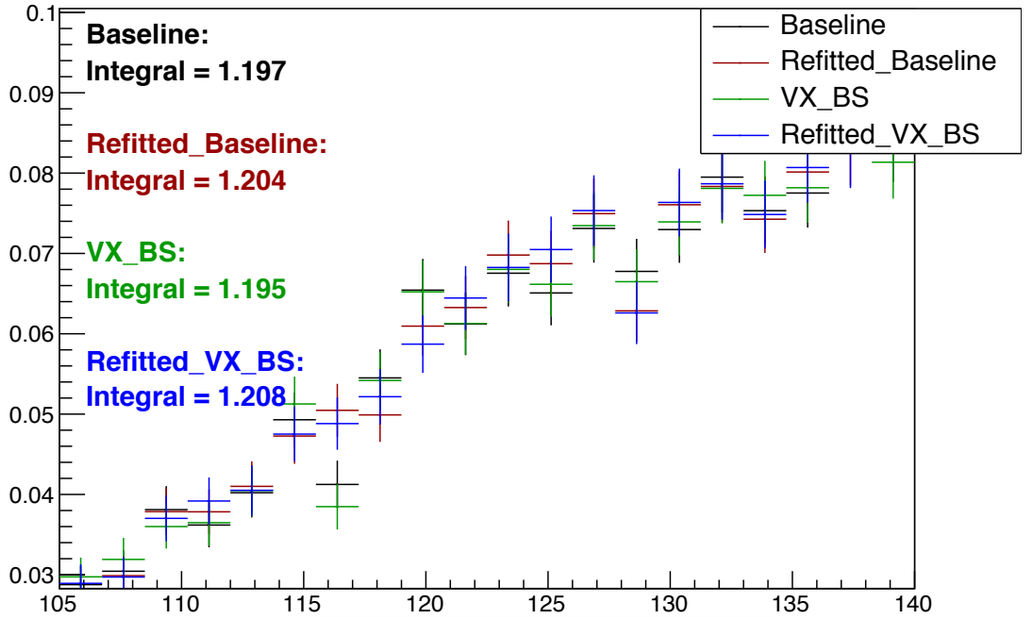
VBF 2mu2e

Higgs mass plots: bkg

ggZZ_MassDistributon_4mu



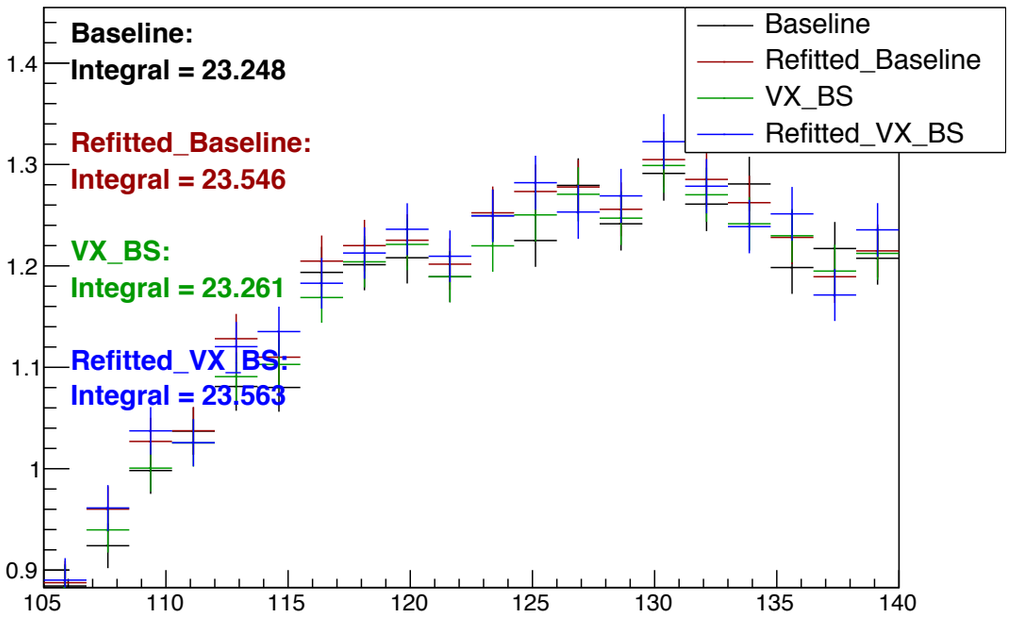
ggZZ_MassDistributon_2e2mu



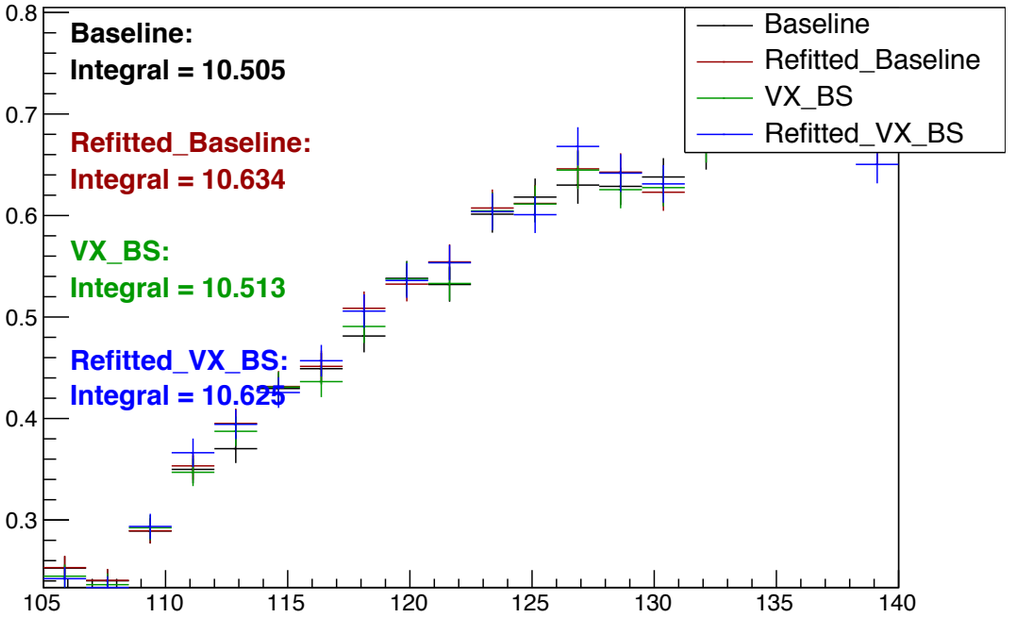
ggZZ 4mu

ggZZ 2e2mu

qqZZ_MassDistributon_4mu



qqZZ_MassDistributon_2mu2e



qqZZ 4mu

qqZZ 2mu2e

Results

Very preliminary expected **statistical** results on 1D method for 2016.

Full 2016 (Stat only)	4mu	4e	2e2mu	2mu2e	comb
BASELINE					
1D	-0.362/0.366	1.102/1.116	-0.738/0.756	-0.674/0.693	-0.282/0.285
2D (m + D_kin)	-0.335/0.34	-1.002/1.018	-0.687/0.708	-0.58/0.606	-0.257/0.259
REFIT					
1D	-0.331/0.335	-0.96/0.995	-0.585/0.597	-0.644/0.662	-0.254/0.256
2D (m + D_kin)	-0.307/0.311	-0.888/0.917	-0.53/0.544	-0.579/0.595	-0.23/0.232
VXBS					
1D	-0.344/0.349	-1.101/1.115	-0.734/0.751	-0.661/0.68	-0.273/0.276
2D (m + D_kin)	-0.319/0.323	-1.002/1.019	-0.682/0.702	-0.565/0.589	-0.248/0.25
REFIT+VXBS					
1D	0.318/0.322	-0.986/1.0	-0.584/0.595	-0.629/0.648	-0.246/0.249
2D (m + D_kin)	-0.295/0.298	-0.911/0.925	-0.531/0.546	-0.548/0.571	-0.224/0.226

Production mode considered: ggF, VBF, WH, ZH, ttH
Background considered: ggZZ, qqZZ

Results

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Ongoing debug on relative mass error (third variable used in the past for the fit: now will be used for categorisations)

Production mode considered: ggF, VBF, WH, ZH, ttH
Background considered: ggZZ, qqZZ

Conclusion

Very first preliminary results on VX+BS method on 2016 **Legacy** samples.

VX+BS approach **improves mass resolution**: **from 5% to 8%** depending on the year.

Approach already **blessed** by MuonPOG.

Looking only at 1D-2D methods, there is an **improvement of a few percent** (depending on the final states) in the expected statistical results.

First look also at **2018 UL ggH** samples: **nothing suspicious** has been found.

Pending works (for **Legacy** result):

- Z+X contributions (also for VX+BS)
- muon scale and resolution
- on-shell width
- categorisations

Conclusion

Very first preliminary results on VX+BS method on 2016 **Legacy** samples.

VX+BS approach **improves mass resolution**: **from 5% to 8%** depending on the year.

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Looking only at 1D-2D methods, there is an **improvement of a few percent** (depending on the final states) in the expected statistical results.

First look also at **2018 UL ggH** samples: **nothing suspicious** has been found.

Pending works (for **UL** result):

- samples [already pointed out]
- synchronisation among different groups

How to

Step 1: create the tracks collection.

```
#include "RecoVertex/KalmanVertexFit/interface/KalmanVertexFitter.h"
#include "RecoVertex/VertexTools/interface/InvariantMassFromVertex.h"
#include "TrackingTools/TransientTrack/interface/TransientTrackBuilder.h"
#include "TrackingTools/Records/interface/TransientTrackRecord.h"
#include "TrackingTools/TransientTrack/interface/TransientTrack.h"
edm::ESHandle<TransientTrackBuilder> ttkb;
iSetup.get<TransientTrackRecord>().get("TransientTrackBuilder", ttkb);

std::vector<reco::TransientTrack> ttv;
ttv.push_back(ttkb->build(“track of the Leptons”)
[muonBestTrack for muons]
```

Step 2: add Beam Spot (BS) information

```
KalmanVertexFitter KVfitter(true);
TransientVertex KVertex_BS = KVfitter.vertex(ttv, BS);
```

How to

Step 3: extract updated information

```
if(KVertex_BS.hasRefittedTracks())

TLorentzVector tmp;
std::vector <reco::TransientTrack> ttrks_BS =
KVertex_BS.refittedTracks();

reco::Track track_vtx_BS = ttrks_BS.at(0).track() [take the
new tracks one by one]

tmp.SetPxPyPzE(track_vtx_BS.px(), track_vtx_BS.py(),
…) [using the new info from track, create the TLorentzVector]
```

How to

Step 4: applied Rochester correction

```
float scaleFactor = ApplyRoccoR(year, isMC, charge(),
vtxLep_BS.at(0).Pt(), vtxLep_BS.at(0).Eta(),
vtxLep_BS.at(0).Phi(), gen_pt, n_layers);

updated_pt = vtxLep_BS.at(0).Pt() * scaleFactor;
```

Rochester correction is usually applied to the slimmed muons. For VX+BS, BestTrackMuon info are taken and these are not automatically corrected when applying Rochester correction.

How to

Step 5: update the TLorentzVector with the new pT

```
vtxLep_BS.at(0).SetPtEtaPhiM(updated_pt, vtxLep_BS.at(0).Eta(),
vtxLep_BS.at(0).Phi(), vtxLep_BS.at(0).M());
```

[If needed] Step 6: pT error and d0 info

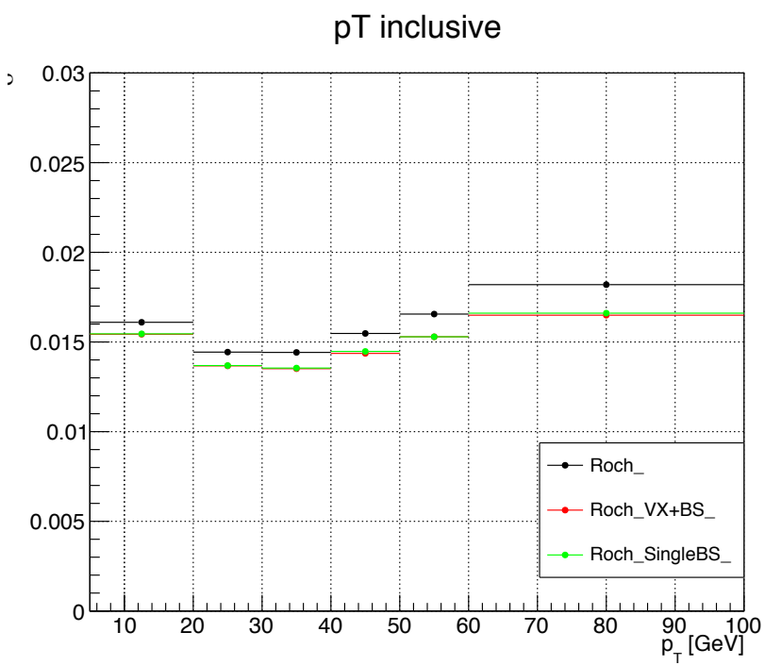
```
vtxLep_BS_ptError.push_back(track_vtx_BS.ptError());
vtxLep_BS_d0.push_back(track_vtx_BS.dxy(BS.position()));
```

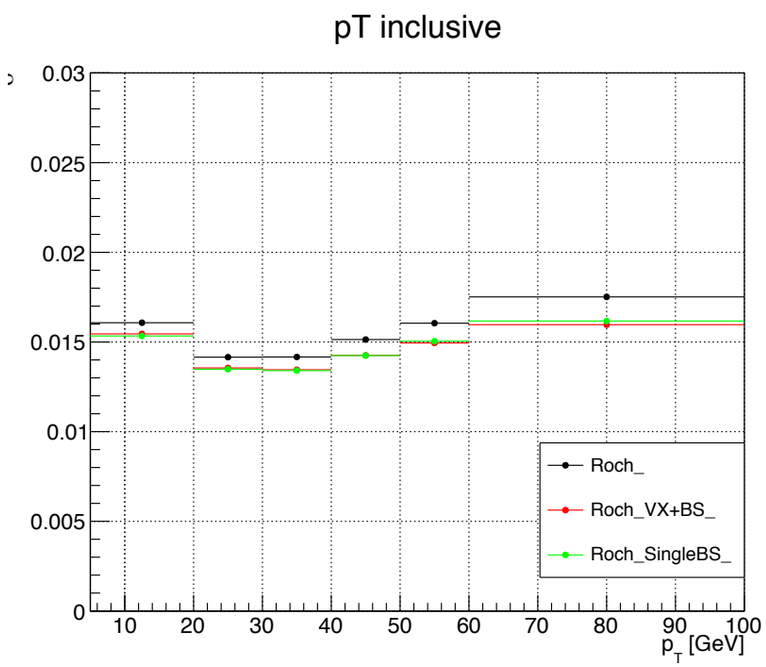
Backup

muon pT resolution

UL DY

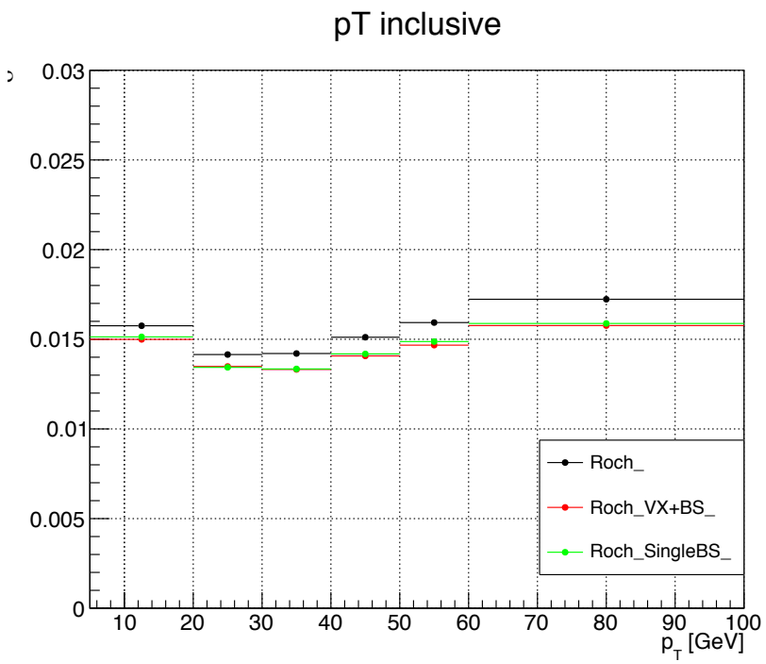
2016 pre-VPF

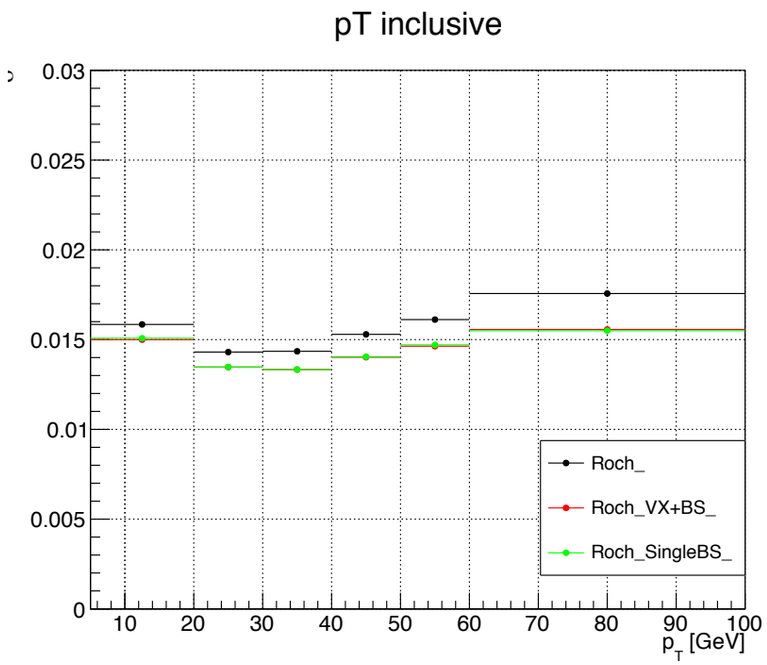




2016 post-VPF

2017



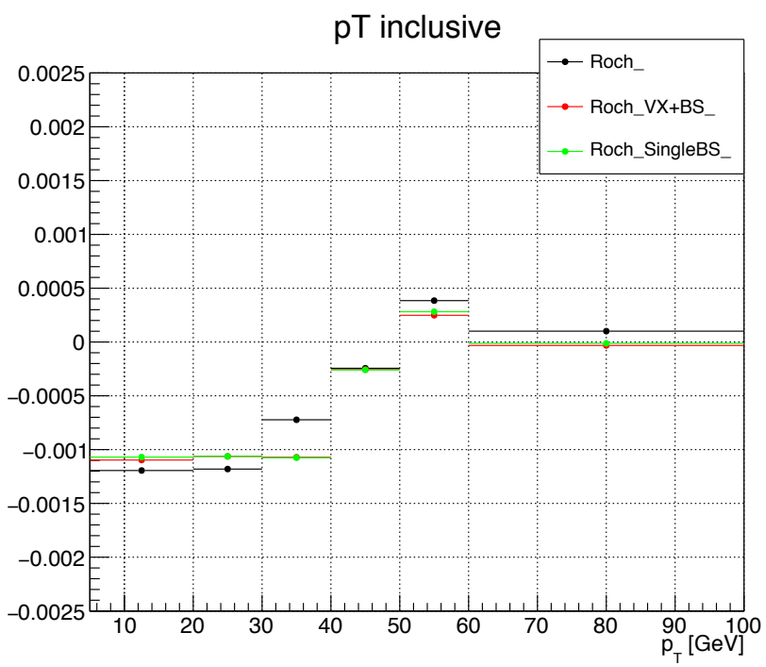


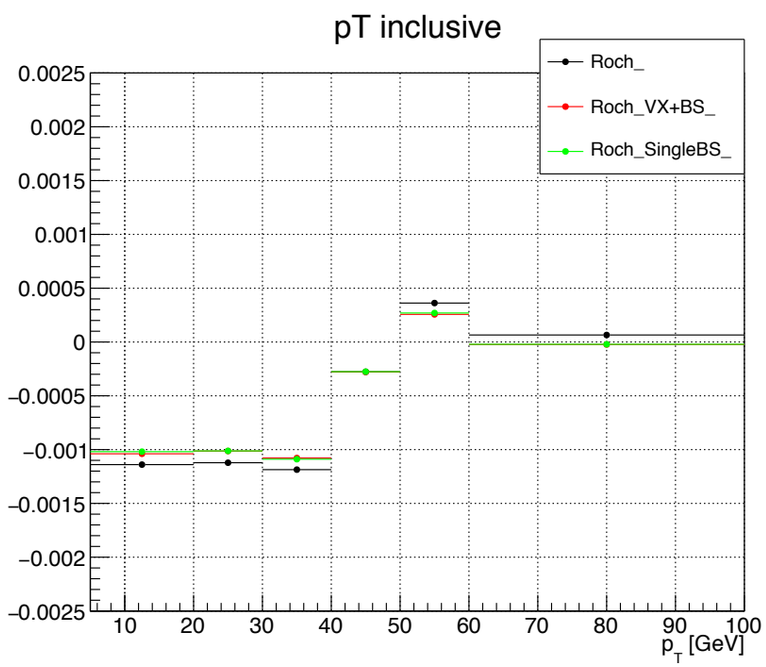
2018

muon pT scale

UL DY

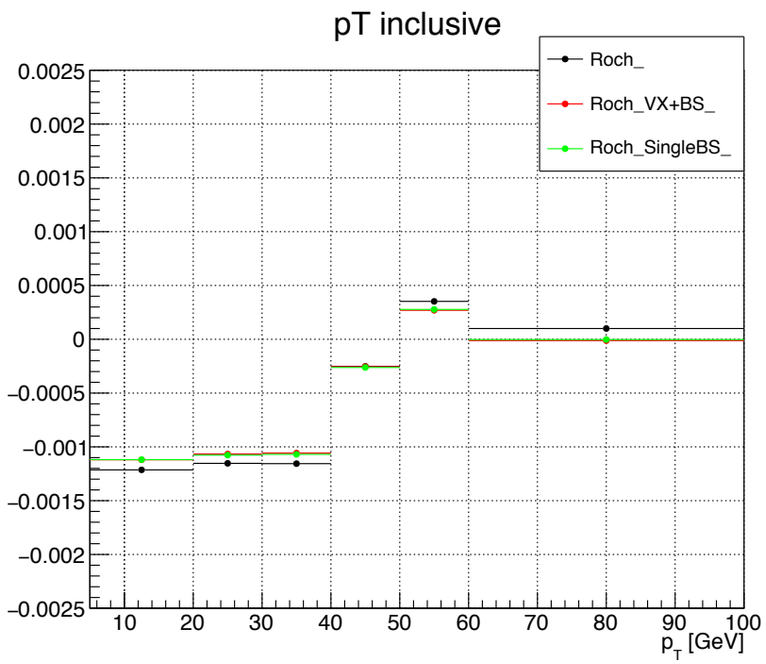
2016 pre-VPF

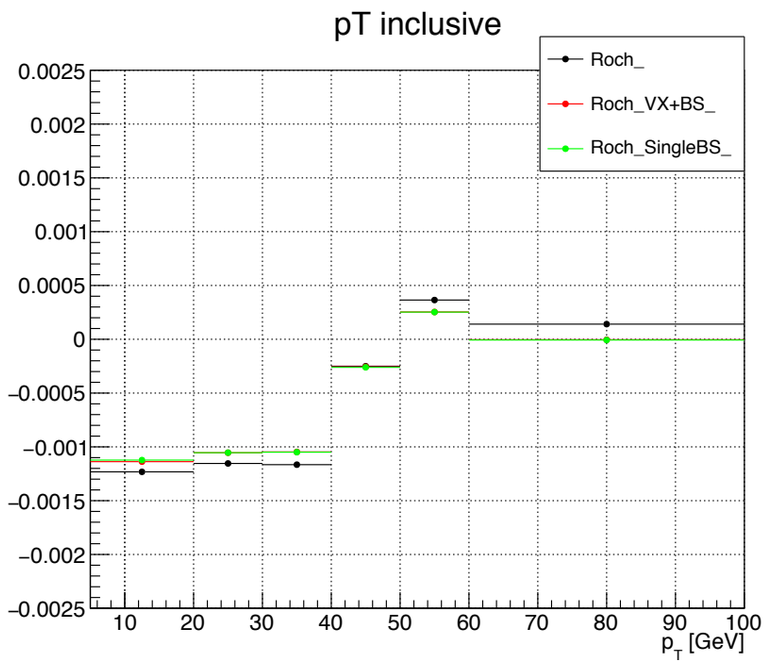




2016 post-VPF

2017



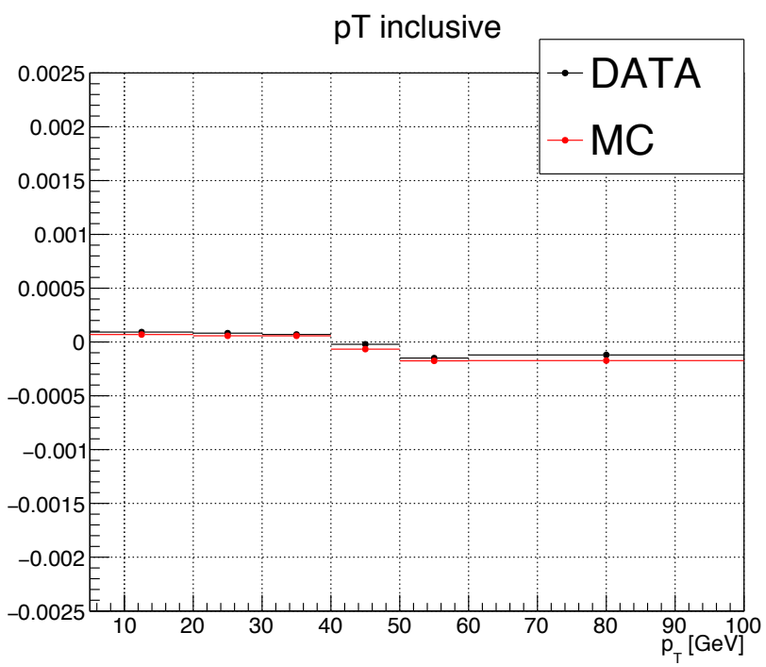


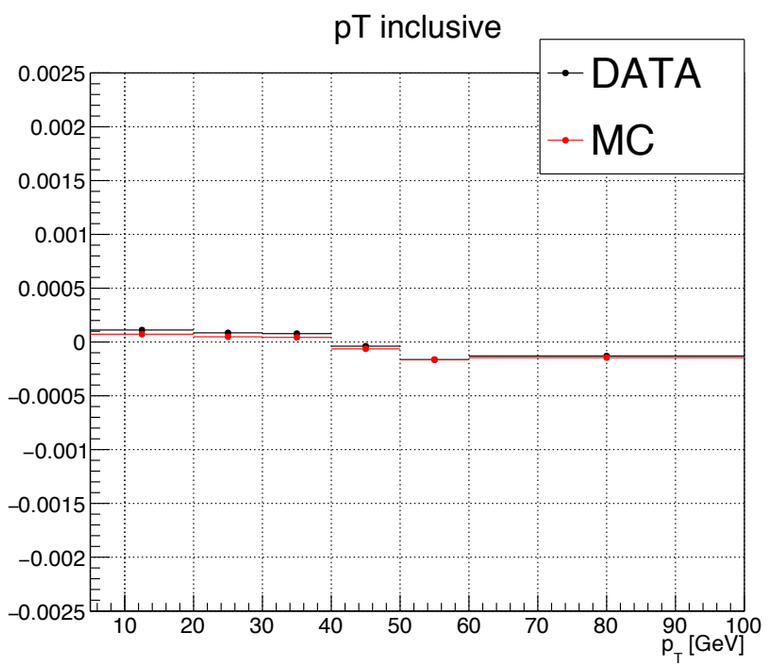
2018

muon pT VX+BS scale

UL DY

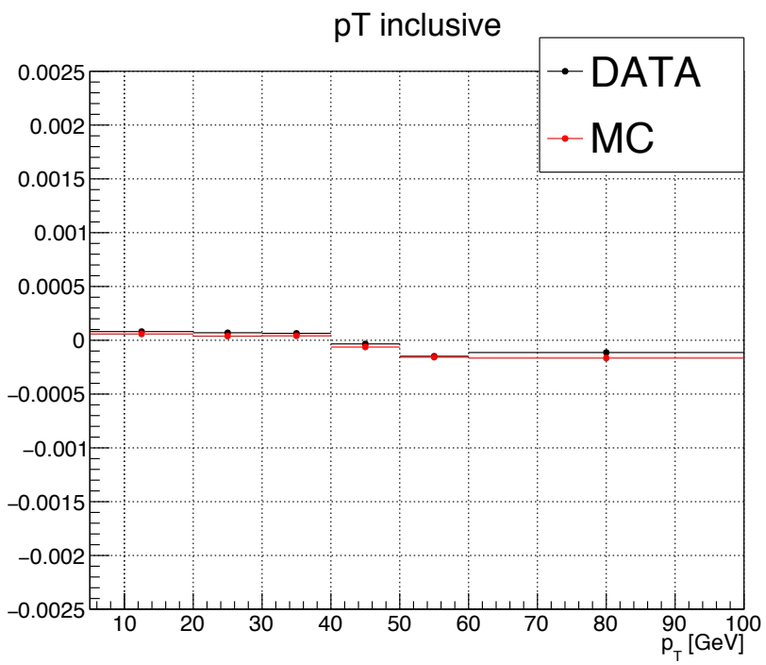
2016 pre-VFP

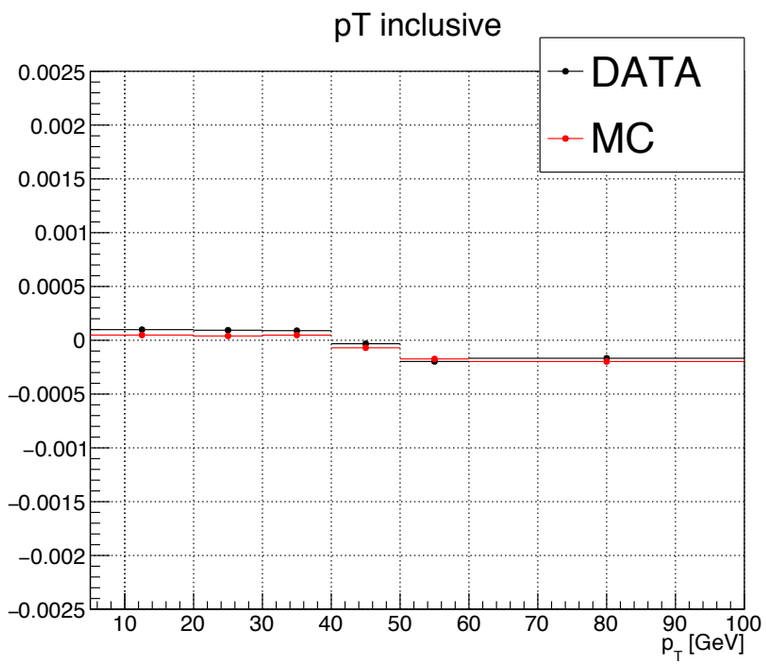




2016 post-VFP

2017

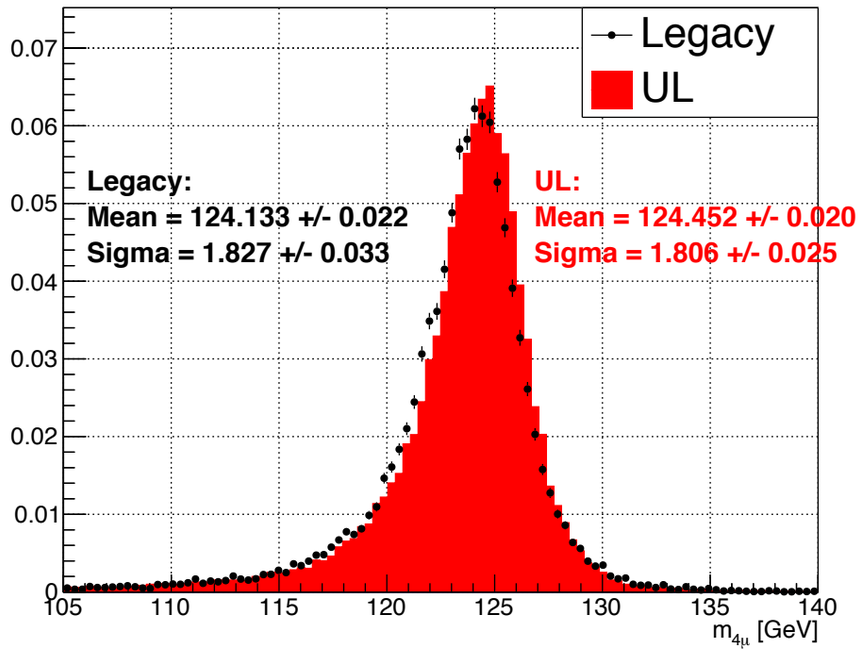


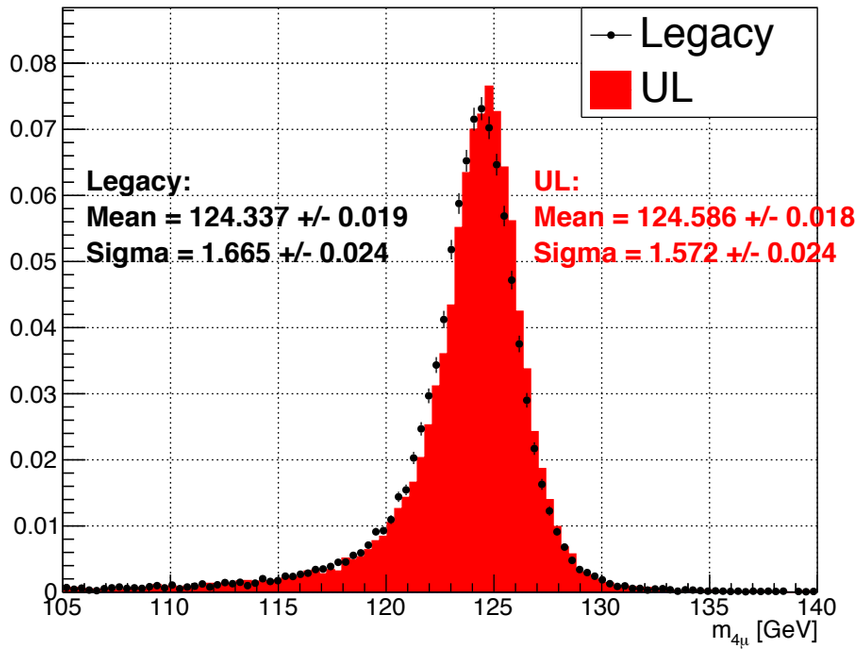


2018

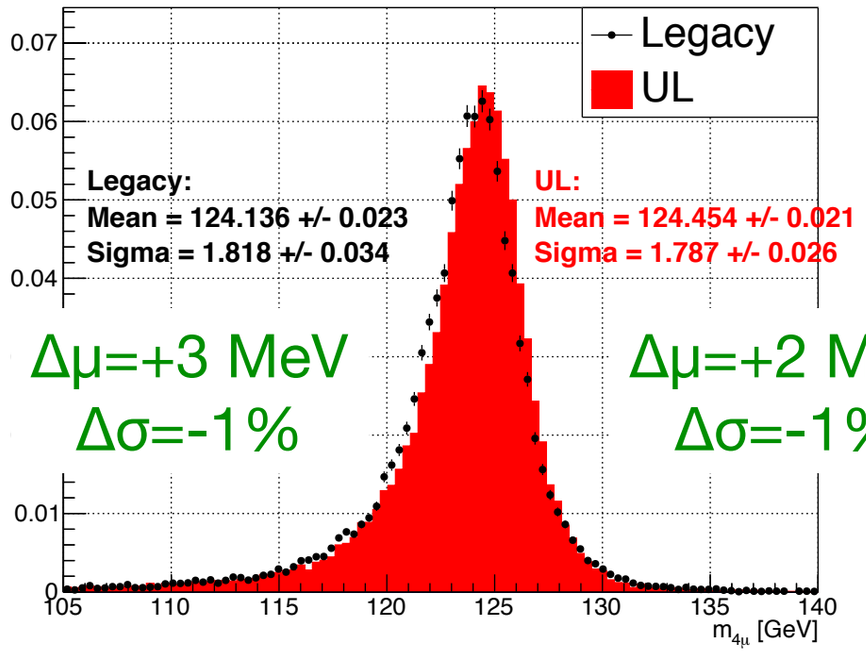
Moving to Higgs boson...

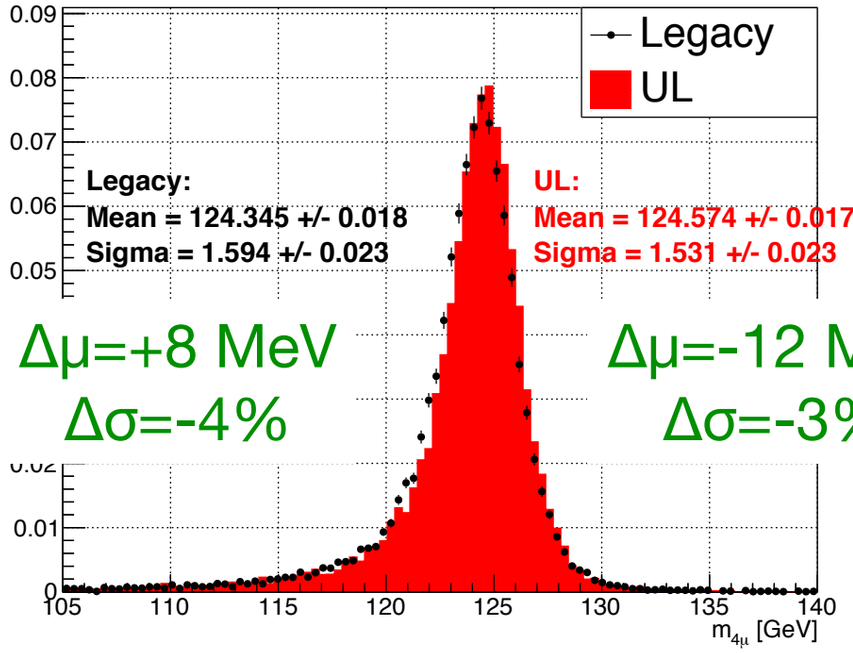
Rochester





Rochester + VX+BS



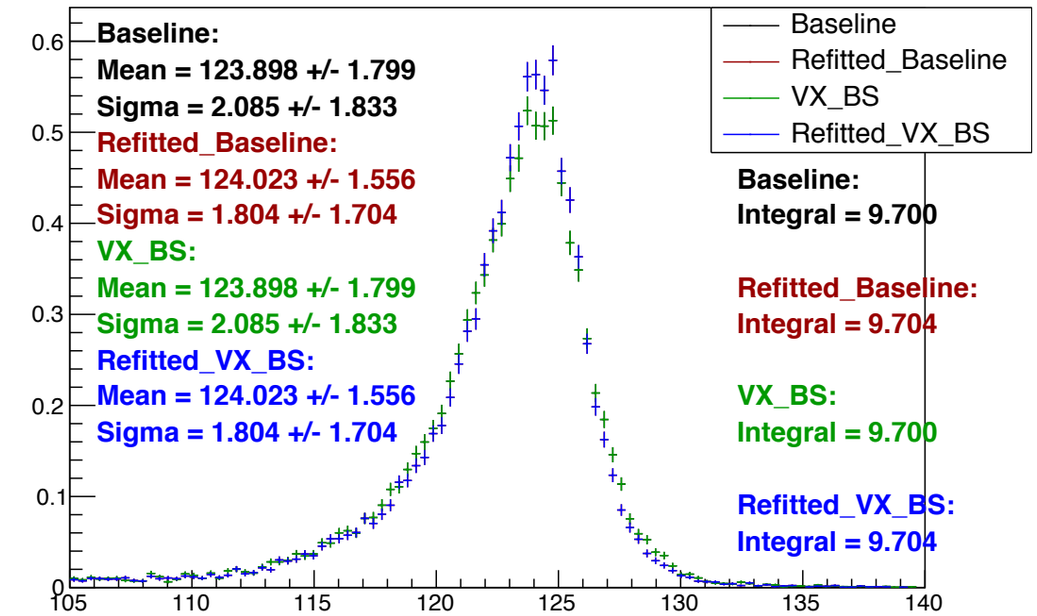


2e2mu

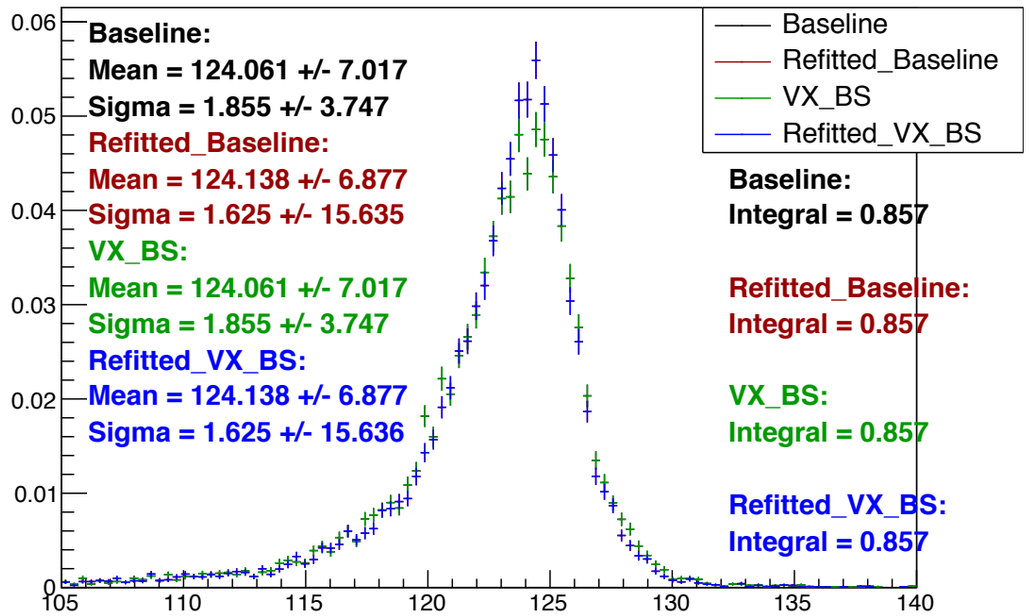
2mu2e

Higgs mass plots: signal

Signal_MassDistributon_125_ggH_4e

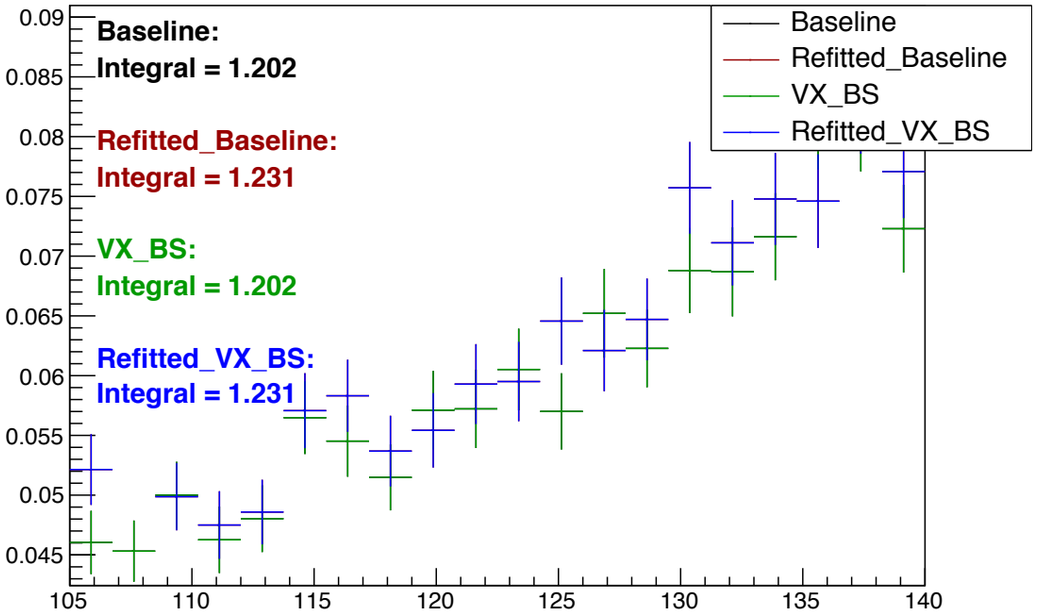


Signal_MassDistributon_125_VBF_4e



ggH 4e

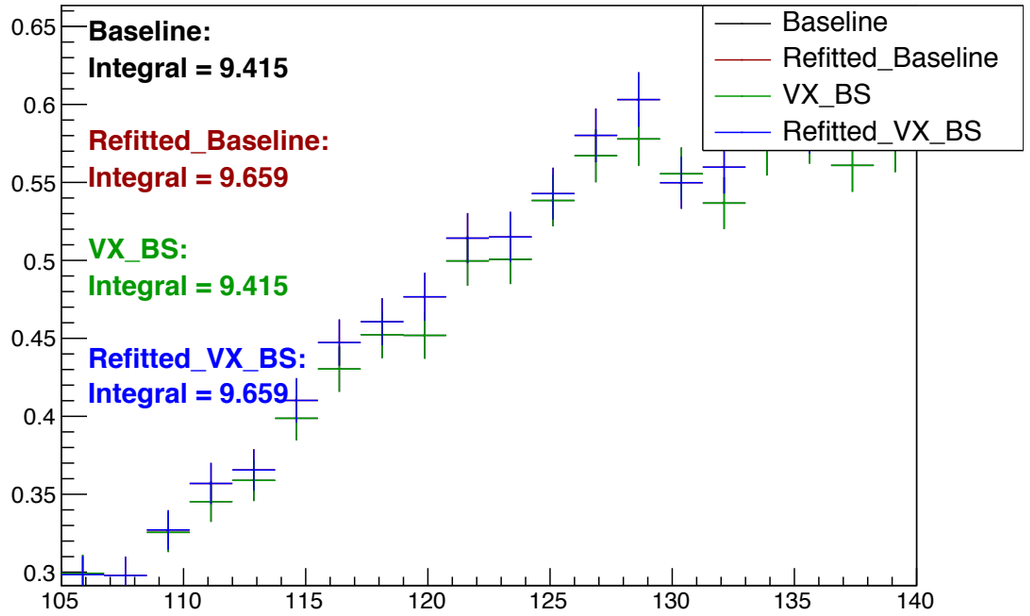
ggZZ_MassDistributon_4e



ggZZ 4e

VBF 4e

qqZZ_MassDistributon_4e



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