



# Analysis Summary

**iihe**  
BRUXELLES BRUSSEL

Useful stuff:

12.9 fb<sup>-1</sup> [PAS](#)



35.9 fb<sup>-1</sup> [CADI](#)



ATLAS (36.1 fb<sup>-1</sup>) [Paper](#)



HppHmmLep [GitLab repository](#)



Santiago Paredes Saenz  
[santiago.paredes@cern.ch](mailto:santiago.paredes@cern.ch)

September 2022



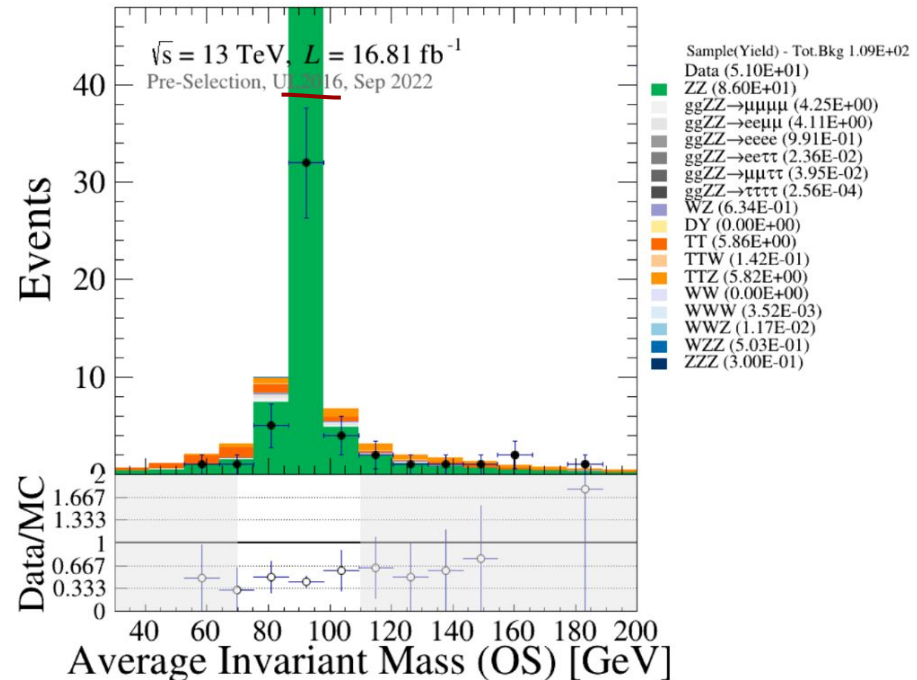
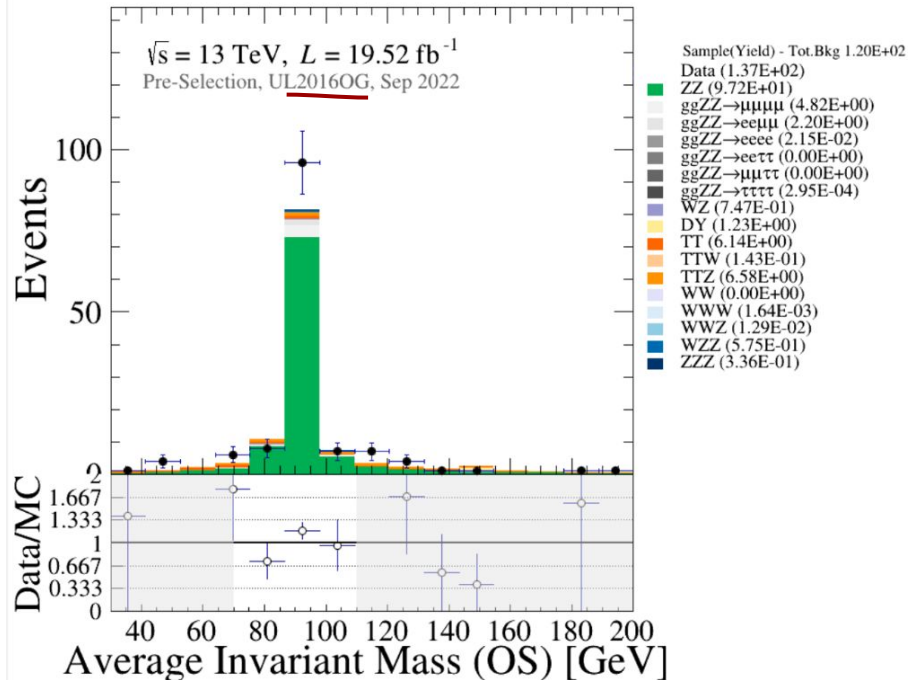
# New Stuff Since Last Week

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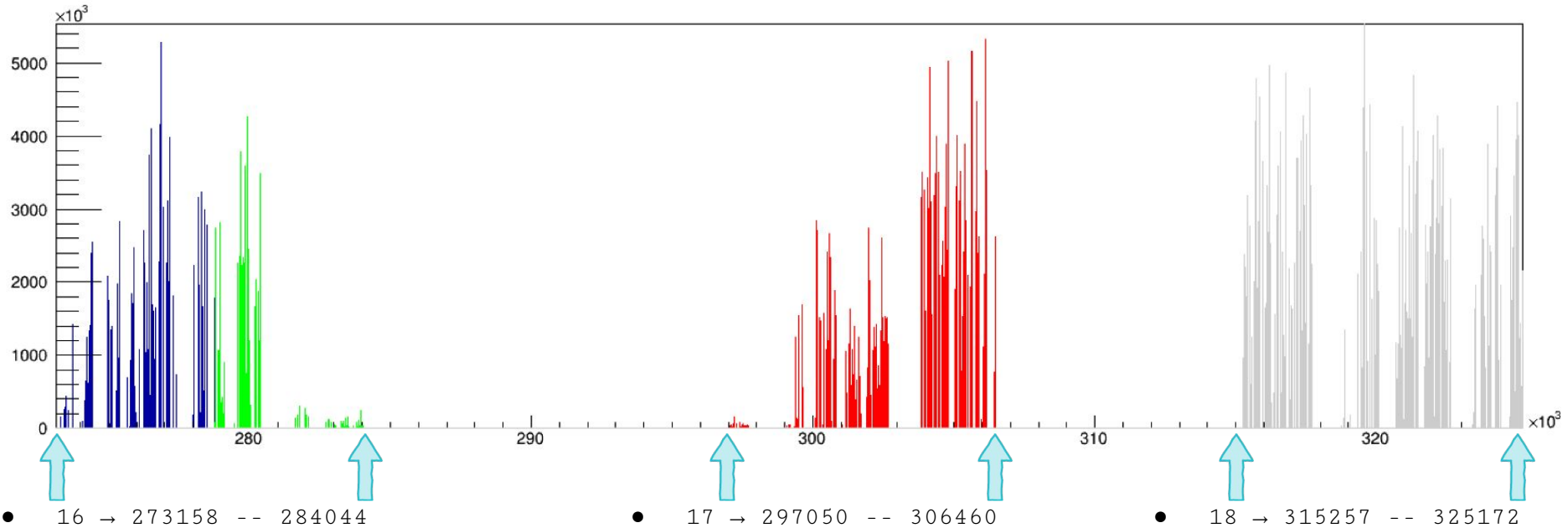
# Run numbers check

Only in late 2016, data < MC --> DOING SOME CROSS CHECKS



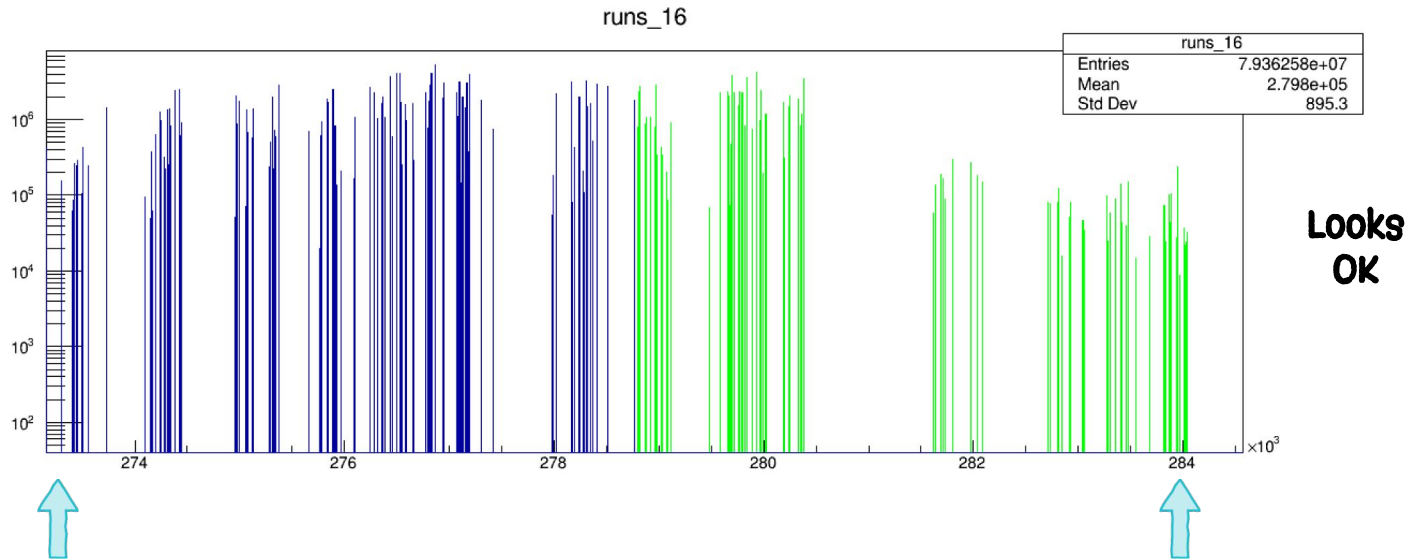
# Run numbers check

Only in late 2016, data < MC --> DOING SOME CROSS CHECKS



# Run numbers check

Only in late 2016, data < MC --> DOING SOME CROSS CHECKS



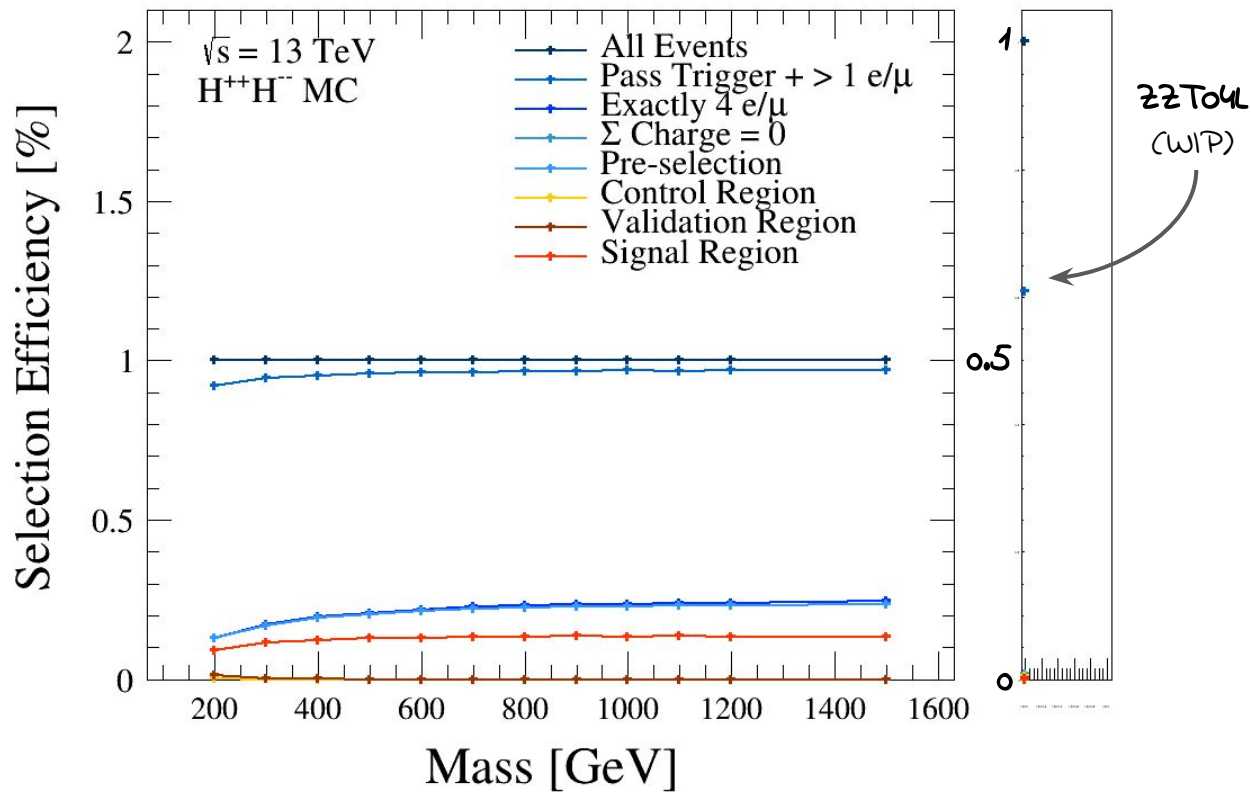
• 16 → 273158 -- 284044

• • •

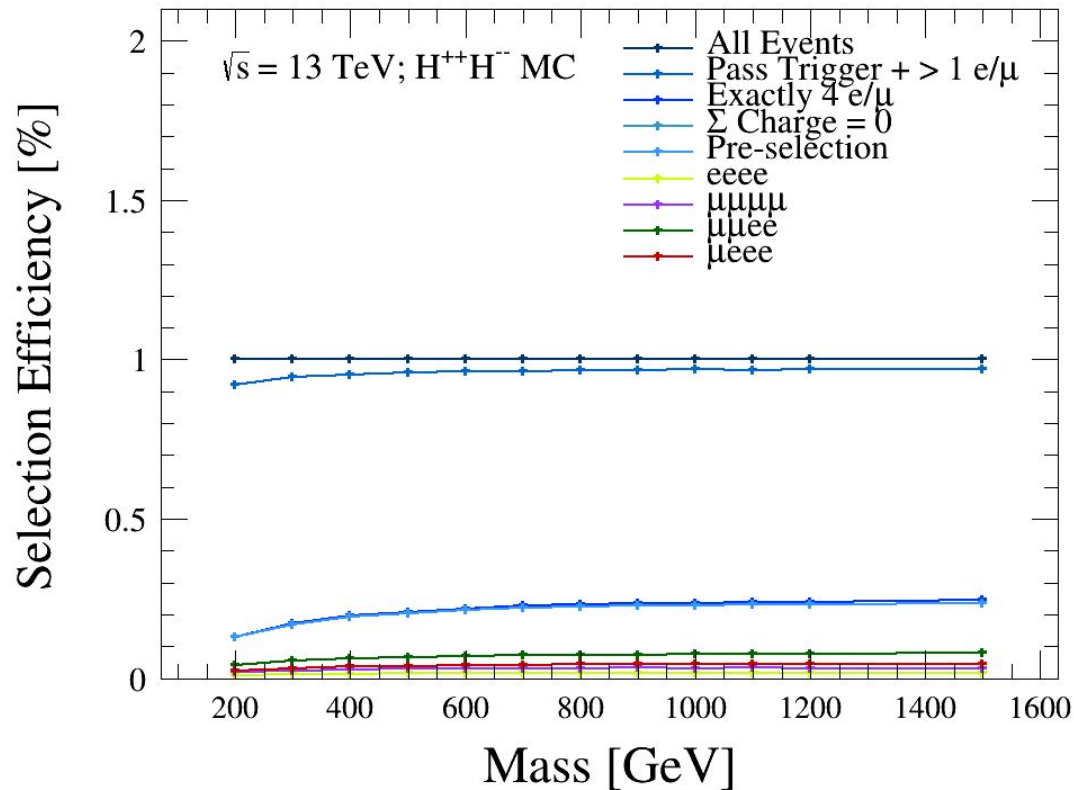
```
"280385": [[1, 519], [523, 2022]],
"281613": [[101, 903]],
"281639": [[1, 136]],
"281641": [[1, 319]],
"281693": [[1, 2191]],
"281707": [
  [99, 982],
  [1000, 1065],
  [1087, 1089]
],
"281726": [[1, 291]],
"281727": [[1, 1605]],
"281797": [[125, 2176]],
"281975": [[1, 215]],
"281976": [[1, 2166]],
"282033": [[82, 124]],
"282034": [[1, 35]],
"282035": [[1, 47]],
"282037": [[1, 457], [459, 1862]],
"282092": [[92, 222], [624, 2276]],
"282708": [[1, 8]],
"282710": [[1, 9]],
"282712": [[1, 1], [10, 68]],
"282730": [[89, 171]],
"282731": [[1, 176]],
"282732": [[1, 73]],
"282733": [[1, 178]],
"282734": [[1, 330]],
"282735": [[1, 1823]],
"282800": [[1, 382]],
"282807": [[1, 330]],
```

Data16  
Golden  
json

# Analysis Selection Efficiency








# Analysis Selection Efficiency



# Difference in trigger VS Laurent's lep trig. review

2016

'\_DZ' not available in NanoAOD 

1. "MuonEG" : "(HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL || HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL)" 
2. "DoubleMuon" : "(HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL || HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ)" 
3. "DoubleEG" : "(HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ)" 
4. "SingleElectron" : "(HLT\_Ele27\_WPTight\_Gsf)" 
5. "SingleMuon" : "(HLT\_IsoMu24 || HLT\_IsoTkMu24)" 

2016		
Description	Path	Comment
Isolated electron	HLT_Ele27_WPTight_Gsf	L1 threshold at $\approx 30$ GeV. L1 H/E inefficiency above 1 TeV for runs <.

2016

Description	Path	Comment
Isolated muon	HLT_Iso(Tk)Mu24	Should use both Mu and TkMu

2016

Description	Path	Comment
Isolated dimuon	HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL(.DZ)	DZ for 2016H. Low $\Delta\phi$ L1 inefficiency (runs $\leq 277166$ )
Isolated dielectron	HLT_Ele23_Ele12_CaloIdL_TrackIdL_IsoVL_DZ	/
Isolated $e\mu$	HLT_Mu23/8_TrkIsoVVL_Ele12/23_CaloIdL_TrackIdL_IsoVL_DZ	/



# Difference in trigger VS Laurent's lep trig. review

2017

1. "SingleMuon": "(HLT\_IsoMu27||HLT\_IsoMu24)" ❌ → 'Tk' not available in NanoAOD
2. "SingleElectron": "(HLT\_Ele35\_WPTight\_Gsf)" ❌ → HLT\_Ele32\_WPTight\_Gsf\_L1DoubleEG --> to be added soon!
3. "DoubleEG": "(HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL)" ✅
4. "DoubleMuon": "(HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ||HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ\_Mass3p8)" ✅
5. "MuonEG": "(HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL\_DZ||HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ)" ✅

2017

Description	Path	Comment
Isolated muon	HLT_Iso(Tk)Mu24	2017B
Isolated muon	HLT_IsoMu24/27	2017C-F. IsoMu24 only disabled for a small fraction of 2017

2017





Description	Path	Comment
Isolated electron	HLT_Ele32_WPTight_Gsf(_L1DoubleEG)	Use L1_DoubleEG for runs <302026, explicitly ask SingleEG seed to be fired.

2017

Description	Path	Comment
Isolated dimuon	HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ(_Mass3p8)	Mass3p8 (eras ≥ 2017C)
Isolated dielectron	HLT_Ele23_Ele12_CaloIdL_TrackIdL_IsoVL	DZ dropped. L1: Single or DoubleEG
Isolated $e\mu$	HLT_Mu23/8_TrkIsoVVL_Ele12/23_CaloIdL_TrackIdL_IsoVL_DZ	/

# Difference in trigger VS Laurent's lep trig. review

2018

1. "SingleMuon" : "(HLT\_IsoMu24)" 
2. "EGamma" : "(HLT\_Ele32\_WPTight\_Gsf || HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL)" 
3. "DoubleMuon" : "(HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ\_Mass3p8)" 
4. "MuonEG" : "(HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL\_DZ || HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ)" 

2018

Description	Path	Comment
Isolated electron	HLT_Ele32_WPTight_Gsf	/

2018

Description	Path	Comment
Isolated muon	HLT_IsoMu24	/

2018

Description	Path	Comment
Isolated dimuon	HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ_Mass3p8	/
Isolated dielectron	HLT_Ele23_Ele12_CaloIdL_TrackIdL_IsoVL	DZ dropped. L1: Single or DoubleEG
Isolated $e\mu$	HLT_Mu23/8_TrkIsoVVL_Ele12/23_CaloIdL_TrackIdL_IsoVL_DZ	L1: Single or DoubleEG

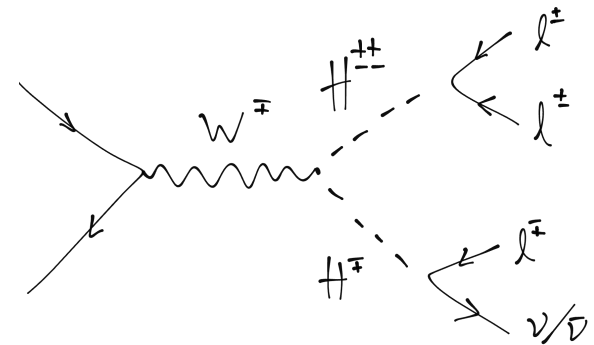
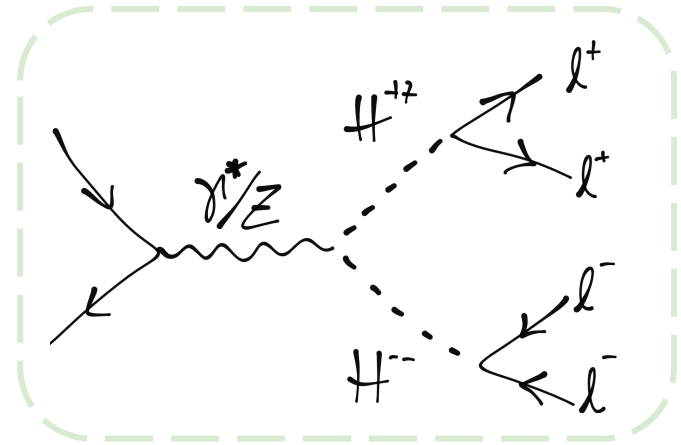
# Analysis Summary

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# Intro & General Idea

- **Search** for **doubly charged Higgs** bosons
  - ↳ Motivated by **extended Higgs** sector models,  **$\nu$  mass** models, others
- **Initially** focus on **4 lep** channel
  - ↳  **$e/\mu$**  channels



# Datasets

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## DATA 2016 PART-1 (eras B to F, B ver2 only)

- /MuonEG/Run2016\*-HIPM-UL2016\_MiniAODv2\_NanoAODv9-v2
- /SingleElectron/Run2016\*-HIPM-UL2016\_MiniAODv2\_NanoAODv9-v2
- /SingleMuon/Run2016\*-HIPM-UL2016\_MiniAODv2\_NanoAODv9-v2
- /DoubleEG/Run2016\*-HIPM-UL2016\_MiniAODv2\_NanoAODv9-v2
- /DoubleMuon/Run2016\*-HIPM-UL2016\_MiniAODv2\_NanoAODv9-v2

## DATA 2016 PART-2 (eras F to H)

- /MuonEG/Run2016\*-UL2016\_MiniAODv2\_NanoAODv9-v2
- /SingleElectron/Run2016\*-UL2016\_MiniAODv2\_NanoAODv9-v2
- /SingleMuon/Run2016\*-UL2016\_MiniAODv2\_NanoAODv9-v2
- /DoubleEG/Run2017\*-UL2016\_MiniAODv1\_NanoAODv9-v1
- /DoubleMuon/Run2016\*-UL2016\_MiniAODv2\_NanoAODv9-v2

## DATA 2017 (eras B to F)

- /MuonEG/Run2017\*-UL2017\_MiniAODv2\_NanoAODv9-v1
- /SingleElectron/Run2017\*-UL2017\_MiniAODv2\_NanoAODv9-v1
- /SingleMuon/Run2017\*-UL2017\_MiniAODv2\_NanoAODv9-v1
- /DoubleEG/Run2017\*-UL2017\_MiniAODv2\_NanoAODv9-v1
- /DoubleMuon/Run2017\*-UL2017\_MiniAODv2\_NanoAODv9-v1

## DATA 2018 (eras A to D, NanoAODv9-v1/2/3)

- /MuonEG/Run2018\*-UL2018\_MiniAODv2\_NanoAODv9-v\*
- /EGamma/Run2018\*-UL2018\_MiniAODv2\_NanoAODv9-v\*
- /SingleMuon/Run2018\*-UL2018\_MiniAODv2\_NanoAODv9-v\*
- /DoubleMuon/Run2018\*-UL2018\_MiniAODv2\_NanoAODv9-v\*

# Datasets

## BACKGROUNDS --> + NANOAOBSIM

/ZZTo4L\_TuneCP5\_13TeV\_powheg\_pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v2  
/GluGluToContinToZZTo2mu2tau\_TuneCP5\_13TeV-mcfm701-pythia8/RunIISummer20UL18NanoAODv9-106X\_upgrade2018\_realistic\_v16\_L1v1-v2  
/GluGluToContinToZZTo2e2mu\_TuneCP5\_13TeV-mcfm701-pythia8/RunIISummer20UL18NanoAODv9-106X\_upgrade2018\_realistic\_v16\_L1v1-v2  
/GluGluToContinToZZTo2e2tau\_TuneCP5\_13TeV-mcfm701-pythia8/RunIISummer20UL18NanoAODv9-106X\_upgrade2018\_realistic\_v16\_L1v1-v2  
/GluGluToContinToZZTo4mu\_TuneCP5\_13TeV-mcfm701-pythia8/RunIISummer20UL18NanoAODv9-106X\_upgrade2018\_realistic\_v16\_L1v1-v2  
/GluGluToContinToZZTo4tau\_TuneCP5\_13TeV-mcfm701-pythia8/RunIISummer20UL18NanoAODv9-106X\_upgrade2018\_realistic\_v16\_L1v1-v2  
/GluGluToContinToZZTo4e\_TuneCP5\_13TeV-mcfm701-pythia8/RunIISummer20UL18NanoAODv9-106X\_upgrade2018\_realistic\_v16\_L1v1-v2  
/WWTto2L2Nu\_TuneCP5\_13TeV-powheg-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v2  
/WZTo3LNU\_TuneCP5\_13TeV-amcatnloFXFX-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v2  
~~/WZTo3LNU\_mllmin01\_NNP31\_TuneCP5\_13TeV-powheg-pythia8/RunIISummer20UL17NanoAODv2-106X\_mc2017\_realistic\_v8-v1~~  
/WWW\_4F\_TuneCP5\_13TeV-amcatnlo-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9\_ext1-v2  
/WWZJetsTo4L2Nu\_4F\_TuneCP5\_13TeV-amcatnlo-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v2  
/WZZ\_TuneCP5\_13TeV-amcatnlo-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9\_ext1-v2  
/ZZZ\_TuneCP5\_13TeV-amcatnlo-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9\_ext1-v2  
/TTWJetsToLNU\_TuneCP5\_13TeV-amcatnloFXFX-madspin-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9\_ext1-v2  
/TTZToLLNuNu\_M-10\_TuneCP5\_13TeV-amcatnlo-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9\_ext1-v2  
/TTTto2L2Nu\_TuneCP5\_13TeV-powheg-pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v1  
/DYJetsToLL\_M-50\_TuneCP5\_13TeV-madgraphMLM-pythia8/RunIISummer20UL17NanoAODv2-106X\_mc2017\_realistic\_v8-v1

Exact files per year can be found in [nanoaod\\_location.py](#)

# Datasets

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SIGNAL → CUSTOM NANO AOD

/HPlusPlusHMinusMinusHTo4L\_M-\*\_TuneCP5\_13TeV\_pythia8/lathomas-NANO AOD\*/USER  
/HPlusPlusHMinusMinusHRTto4L\_M-\*\_TuneCP5\_13TeV\_pythia8/lathomas-NANO AOD\*/USER

Mass: 200 GeV - 1.5 TeV  
Parameters detailed in AN2017\_100

# Triggers

DATASET

TRIGGER CONDITION

2016

1. "MuonEG" : " (HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL || HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL) "
2. "DoubleMuon" : " (HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL || HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ) "
3. "DoubleEG" : " (HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ) "
4. "SingleElectron" : " (HLT\_Ele27\_WPTight\_Gsf) "
5. "SingleMuon" : " (HLT\_IsoMu24 || HLT\_IsoTkMu24) "

- MC  $\Rightarrow$  **OR** of all paths
- Data  $\Rightarrow$  **Per-dataset pass** condition + **fail all previous** datasets' conditions to avoid double counting  
 $\rightarrow$  Example of **actual trigger cut** for dataset 2 (DoubleMuon):

```
((HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL || HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ)) && (!( (HLT_Mu8_TrkIsoVVL_Ele23_CaloIdL_TrackIdL_IsoVL || HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL))
```



# Triggers

2016

1. "MuonEG" : " (HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL || HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL) "
2. "DoubleMuon" : " (HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL || HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ) "
3. "DoubleEG" : " (HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ) "
4. "SingleElectron" : " (HLT\_Ele27\_WPTight\_Gsf) "
5. "SingleMuon" : " (HLT\_IsoMu24 || HLT\_IsoTkMu24) "

- MC  $\Rightarrow$  **OR** of all paths
- Data  $\Rightarrow$  **Per-dataset pass** condition + **fail all previous** datasets' conditions to avoid double counting  
 $\rightarrow$  Example of **actual trigger cut** for dataset 2 (DoubleMuon):

```
((HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL || HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ) ) && (!( (HLT_Mu8_TrkIsoVVL_Ele23_CaloIdL_TrackIdL_IsoVL || HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL) ) )
```

# Triggers

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2017

1. "SingleMuon": "(HLT\_IsoMu27||HLT\_IsoMu24)",
2. "SingleElectron": "(HLT\_Ele35\_WPTight\_Gsf)",
3. "DoubleEG": "(HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL)",
4. "DoubleMuon": "(HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ||HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ\_Mass3p8)",
5. "MuonEG": "(HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL\_DZ||HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ)"

2018

1. "SingleMuon": "(HLT\_IsoMu24)",
2. "EGamma": "(HLT\_Ele32\_WPTight\_Gsf||HLT\_Ele23\_Ele12\_CaloIdL\_TrackIdL\_IsoVL)",
3. "DoubleMuon": "(HLT\_Mu17\_TrkIsoVVL\_Mu8\_TrkIsoVVL\_DZ\_Mass3p8)",
4. "MuonEG": "(HLT\_Mu8\_TrkIsoVVL\_Ele23\_CaloIdL\_TrackIdL\_IsoVL\_DZ||HLT\_Mu23\_TrkIsoVVL\_Ele12\_CaloIdL\_TrackIdL\_IsoVL\_DZ)"

# Lepton Selection

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## ELECTRONS

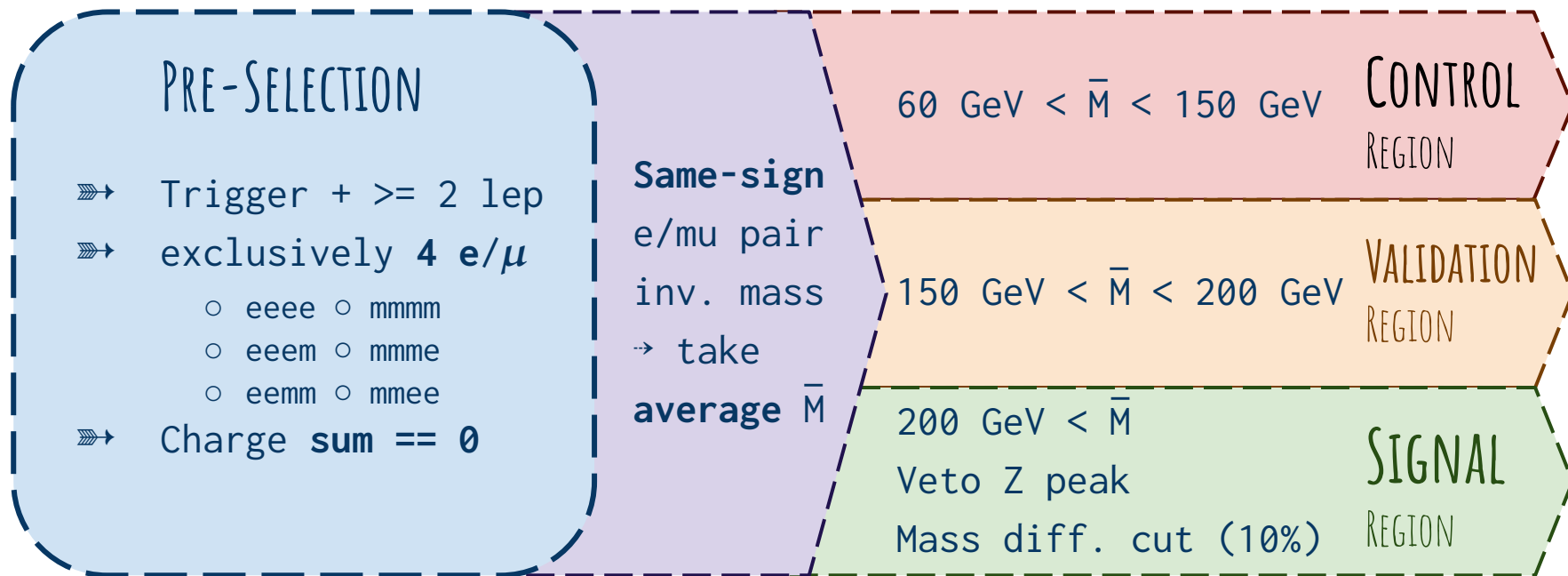
- ⇒  $p_T > 30$  GeV
- ⇒  $|\eta| < 2.5$
- ⇒ **Iso:** cutBasedHEEP  
pfRelIso03\_all  $< 0.4$
- ⇒  $|d_{xy}| < 0.05$
- ⇒  $|dz| < 0.1$

## MUONS

- ⇒  $p_T > 30$  GeV
- ⇒  $|\eta| < 2.4$
- ⇒ **ID:** mediumID
- ⇒  $|d_{xy}| < 0.2$
- ⇒  $|dz| < 0.5$
- ⇒ tkRelIso  $< 0.4$

# Event Selection

- Discriminating variable:  $\bar{M}$

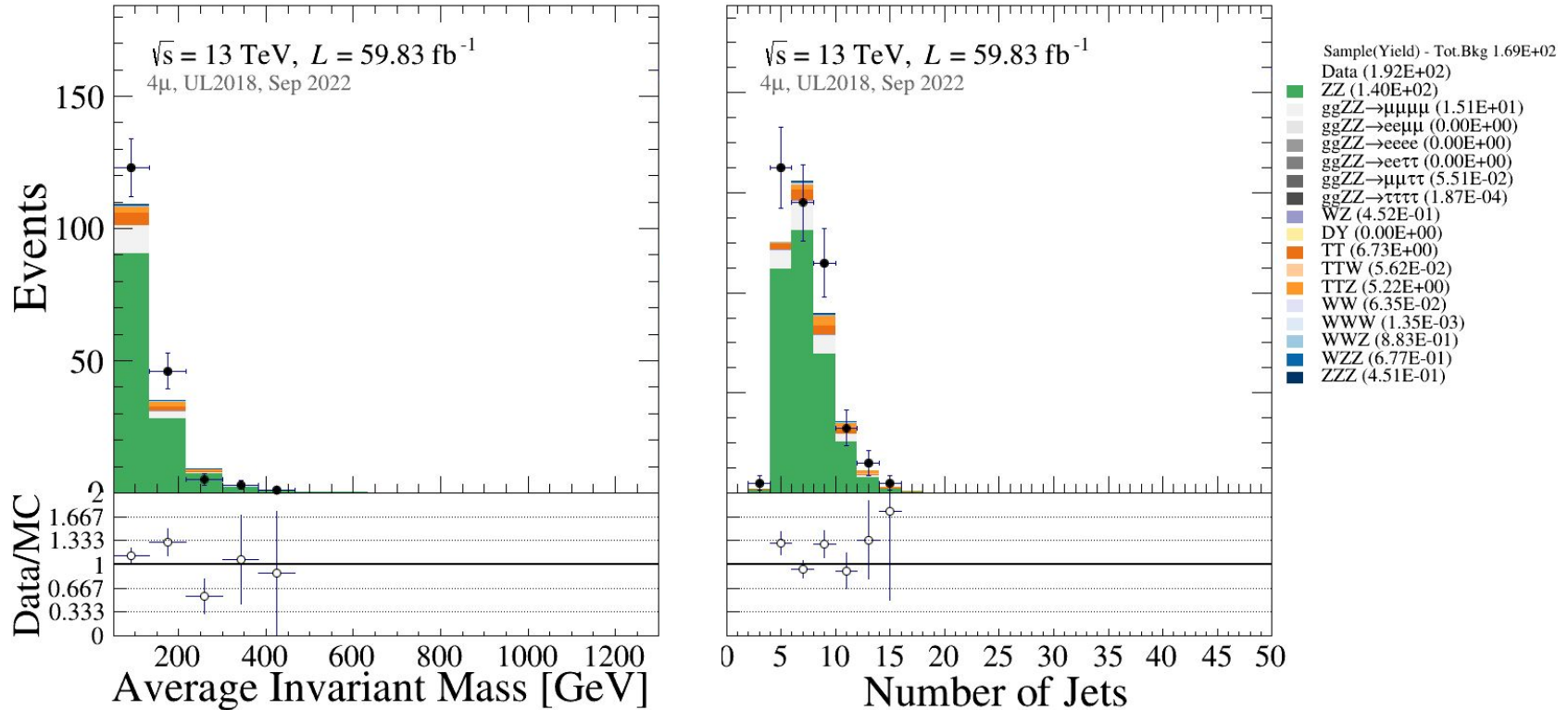


# Status

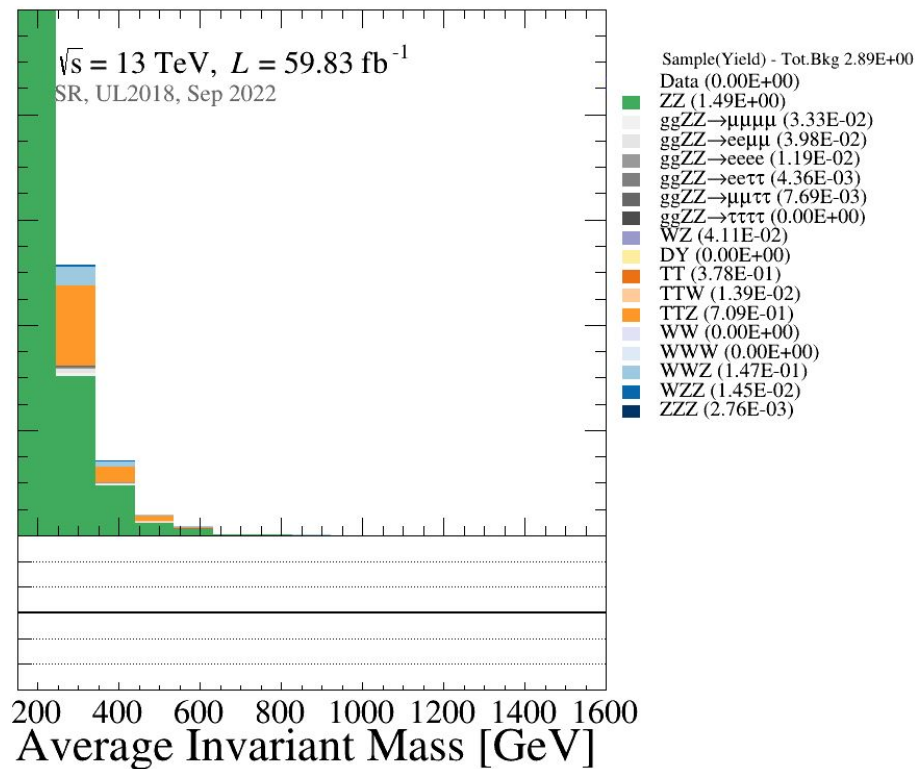
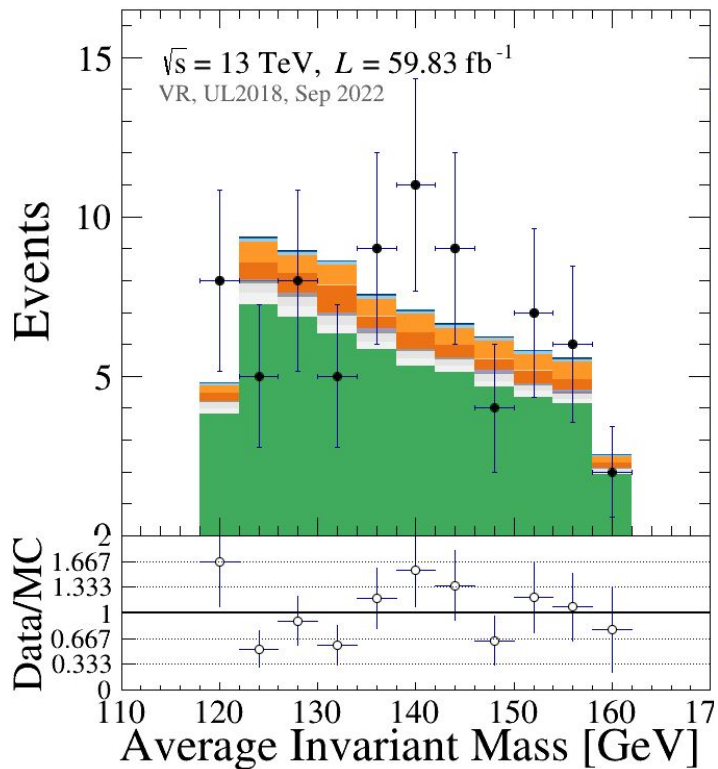
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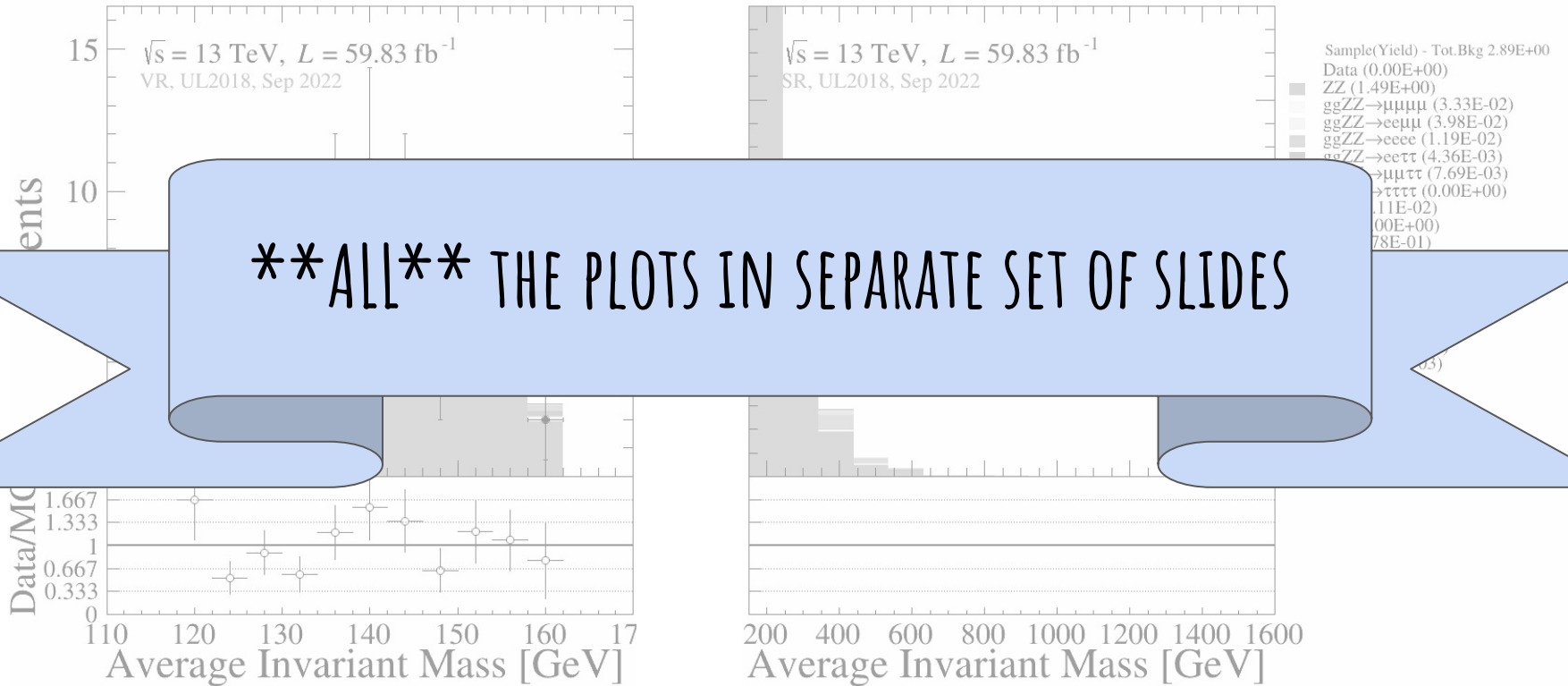
# Updated triggers, new variables plotted



# New CR/VR/SR definitions



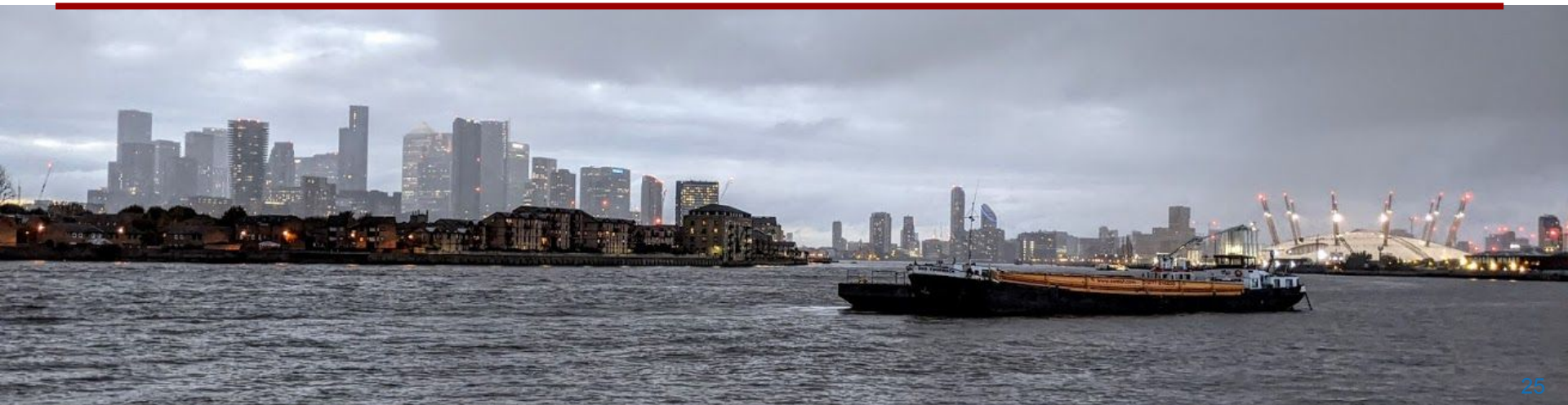
# New CR/VR/SR definitions





# Next Steps

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# Next steps

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- Add e charge misID scale factors
- Add missing systematic uncertainties
  - Background estimate non-closure
  - Charge flip
  - MC cross section
  - Lepton energy scale
- Start on Analysis Note
  - CADI line?

# Tracking Objectives + Progress

- Trello board to keep track of tasks and people responsible  
<https://trello.com/b/TunxYh1k/hh-analysis>

The screenshot shows a Trello board titled "H++H-- Analysis" in "Santiago Paredes's workspace". The board is organized into three columns: BRAINSTORM, TODO, and DOING. Each column contains several task cards with labels and descriptions.

**BRAINSTORM**

- Create new region by reversing signal region cuts
- No need to re-calculate `genWeightSum`` for each syst. variations? -- Doing it only once could save time!
- Make script to run a x-check of preprocessing (grep 'Done' in corresponding .out logs) during `./run_batch_mode`, and of the eventSelection during the hadd script (grep 'Have a lovely day' in corresponding .out logs)

**TODO**

- Background Estimation**: Are fakes negligible? Show this?
- Background Estimation** / **Systematics**: Implement Bkg Estimation Non Closure Uncert.
- Systematics** / **MC**: Implement Theory Uncert.
- Systematics**: Implement Charge Flip Uncert.
- Systematics**: Implement Lepton Energy Scale Uncert.
- Writing up**: Request Cadi line/ Get started on AN
- Data**: Make trigger efficiency plots for all years


**DOING**


- Background Estimation**: Implement QCD+EW Corrections for ZZ
- Analysis Optimization**: Change CR/VR definition to avoid 200 GeV mass point
- Analysis Optimization** / **MC**: Make signal efficiency plots




# Backup

Useful stuff:

12.9 fb-1 [PAS](#) 

35.9 fb-1 [CADI](#) 

ATLAS (36.1 fb-1) [Paper](#) 

HppHmmLep [GitLab repository](#) 

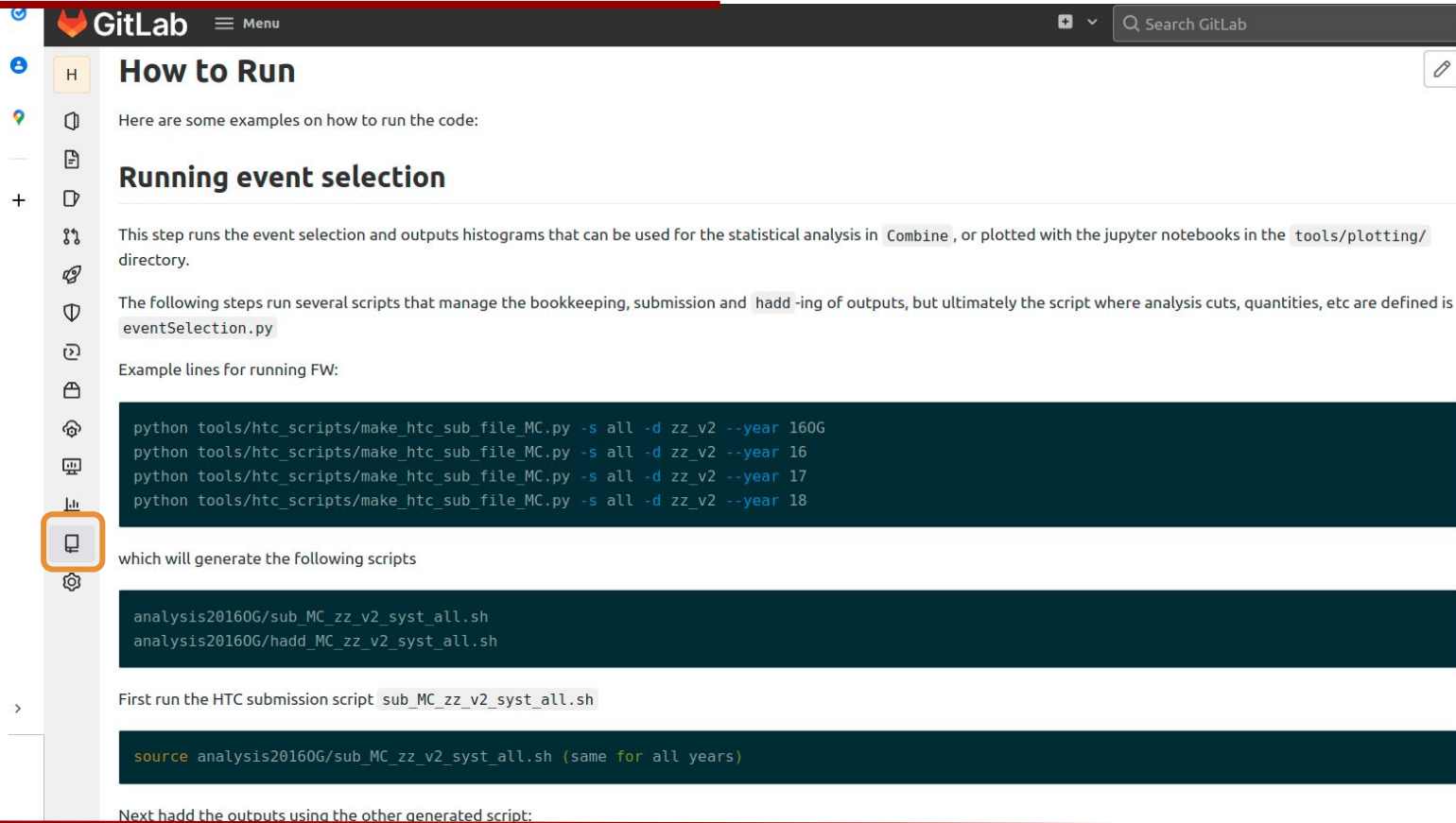
*iihe*  
BRUXELLES BRUSSEL

Santiago Paredes Saenz  
[santiago.paredes@cern.ch](mailto:santiago.paredes@cern.ch)

September 2022



# Added 'how to run' section to wiki



The screenshot shows a GitLab wiki page with a dark header bar containing the GitLab logo, a menu icon, and a search bar. The page title is 'How to Run' with an edit icon. The content includes a sub-section 'Running event selection' with explanatory text and code blocks. A sidebar on the left contains navigation icons, with the 'How to Run' icon highlighted by an orange box.

## How to Run

Here are some examples on how to run the code:

### Running event selection

This step runs the event selection and outputs histograms that can be used for the statistical analysis in `Combine`, or plotted with the jupyter notebooks in the `tools/plotting/` directory.

The following steps run several scripts that manage the bookkeeping, submission and `hadd`-ing of outputs, but ultimately the script where analysis cuts, quantities, etc are defined is `eventSelection.py`

Example lines for running FW:

```
python tools/htc_scripts/make_htc_sub_file_MC.py -s all -d zz_v2 --year 160G
python tools/htc_scripts/make_htc_sub_file_MC.py -s all -d zz_v2 --year 16
python tools/htc_scripts/make_htc_sub_file_MC.py -s all -d zz_v2 --year 17
python tools/htc_scripts/make_htc_sub_file_MC.py -s all -d zz_v2 --year 18
```

which will generate the following scripts

```
analysis20160G/sub_MC_zz_v2_syst_all.sh
analysis20160G/hadd_MC_zz_v2_syst_all.sh
```

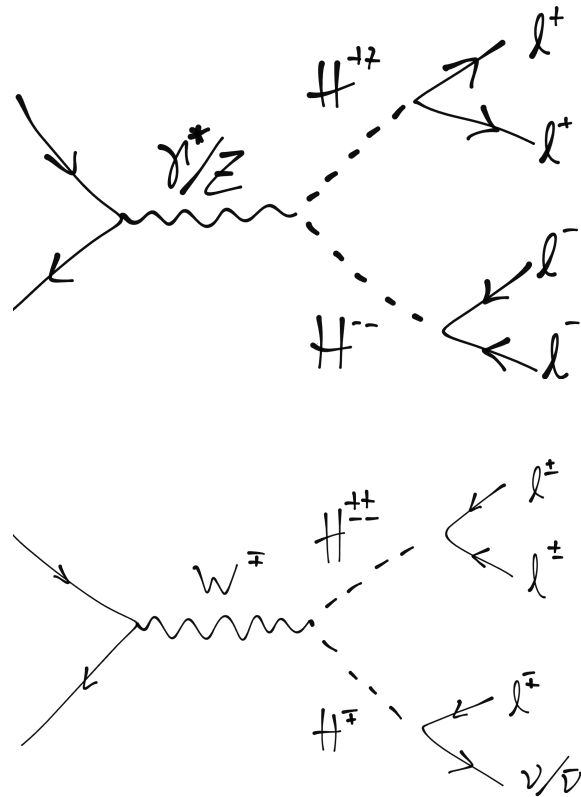
First run the HTC submission script `sub_MC_zz_v2_syst_all.sh`

```
source analysis20160G/sub_MC_zz_v2_syst_all.sh (same for all years)
```

Next `hadd` the outputs using the other generated script:

# Current Results

- [CMS-PAS-HIG-16-036](#) ( $12.9 \text{ fb}^{-1}$ )
  - **Draft** of update: [CMS-AN-17-100](#) ( $35.9 \text{ fb}^{-1}$ )
    - ↳ **Archived** since 2018
  - By **Devin N. Taylor** (UC Davis)
- [ATLAS Run 2](#) conf note
  - Only targets pair-production



# Datasets

## BACKGROUNDS → NANOADSIM

/ZZTo4L\_TuneCP5\_13TeV\_powheg\_pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v2  
/WZTo3LNu\_mllmin01\_NNPDF31\_TuneCP5\_13TeV\_powheg\_pythia8/RunIISummer20UL17NanoAODv2-106X\_mc2017\_realistic\_v8-v1  
/TTTo2L2Nu\_TuneCP5\_13TeV\_powheg\_pythia8/RunIISummer20UL17NanoAODv9-106X\_mc2017\_realistic\_v9-v1  
/DYJetsToLL\_M-50\_TuneCP5\_13TeV-madgraphMLM-pythia8/RunIISummer20UL17NanoAODv2-106X\_mc2017\_realistic\_v8-v1

## SIGNAL → CUSTOM NANOAD

/HPlusPlusHMinusMinusHTo4L\_M-\*\_TuneCP5\_13TeV\_pythia8/lathomas-NANOAD\*/USER  
/HPlusPlusHMinusMinusHRTto4L\_M-\*\_TuneCP5\_13TeV\_pythia8/lathomas-NANOAD\*/USER

ALSO (IN BACKUP)

VV  
VVV  
gg->ZZ  
...

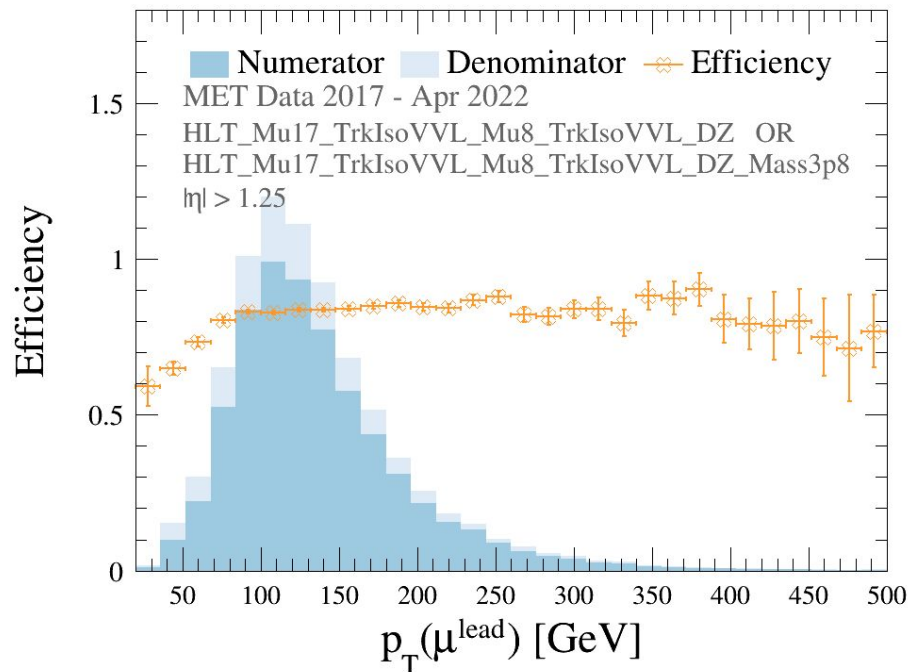
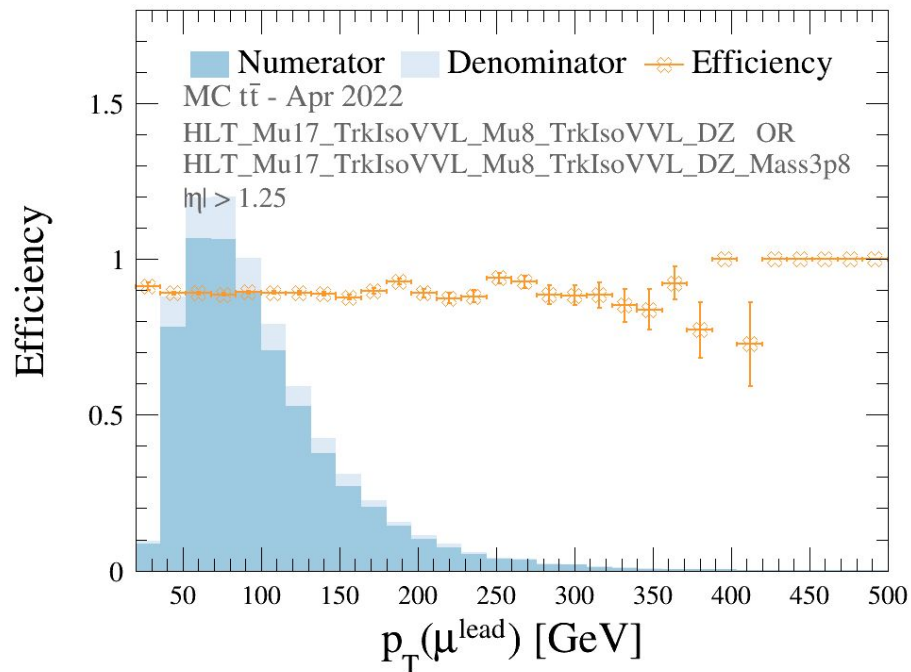
## DATA → NANOAD

/DoubleMuon/Run2017\*-UL2017\_MiniAODv1\_NanoAODv9-v1  
/DoubleEG/Run2017\*-UL2017\_MiniAODv1\_NanoAODv9-v1  
/MuonEG/Run2017\*-UL2017\_MiniAODv1\_NanoAODv9-v1  
/SingleMuon/Run2017\*-UL2017\_MiniAODv1\_NanoAODv9-v1  
/SingleElectron/Run2017\*-UL2017\_MiniAODv1\_NanoAODv9-v1

Mass: 200 GeV - 1.5 TeV  
Parameters detailed in  
AN2017\_100

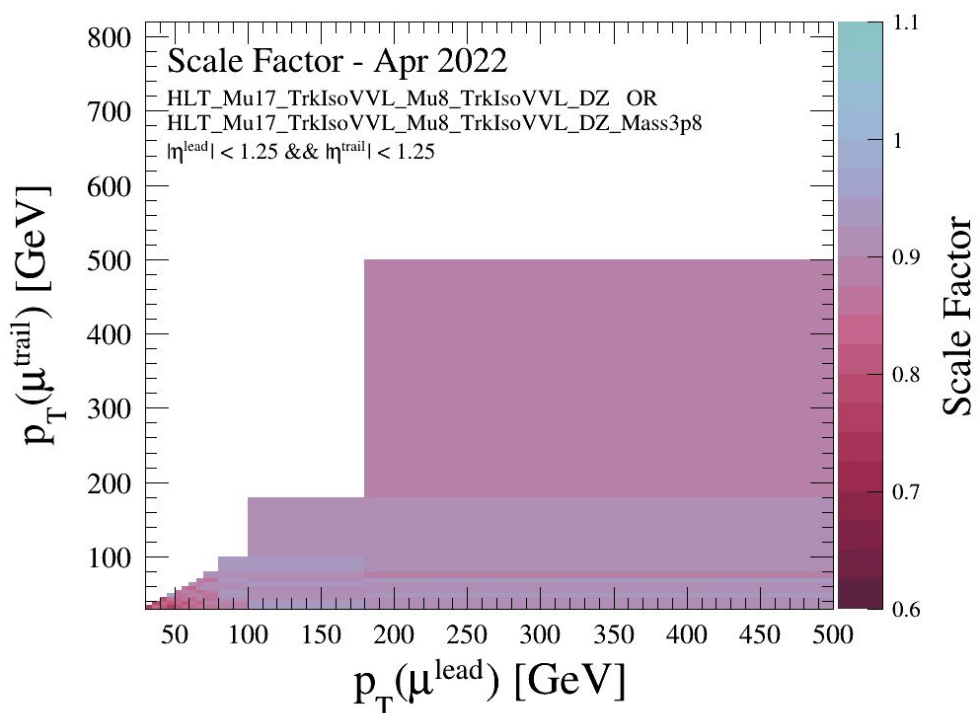
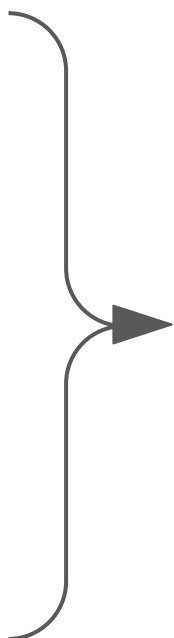
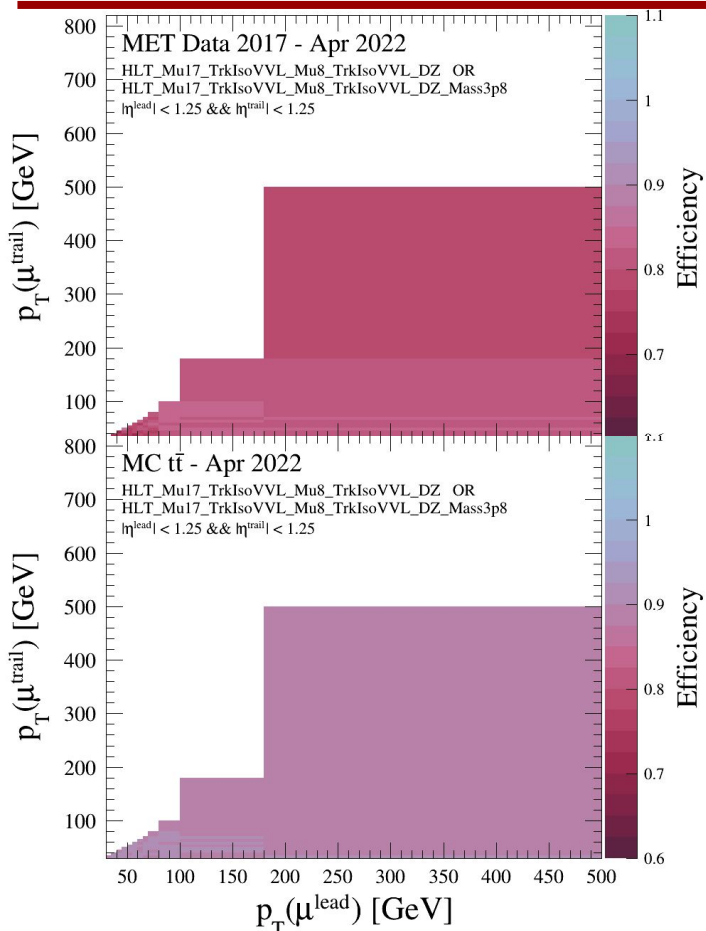
# Trigger Efficiency

- **Efficiency** vs  $p_T \rightarrow$  MC/Data differences @ low  $p_T$

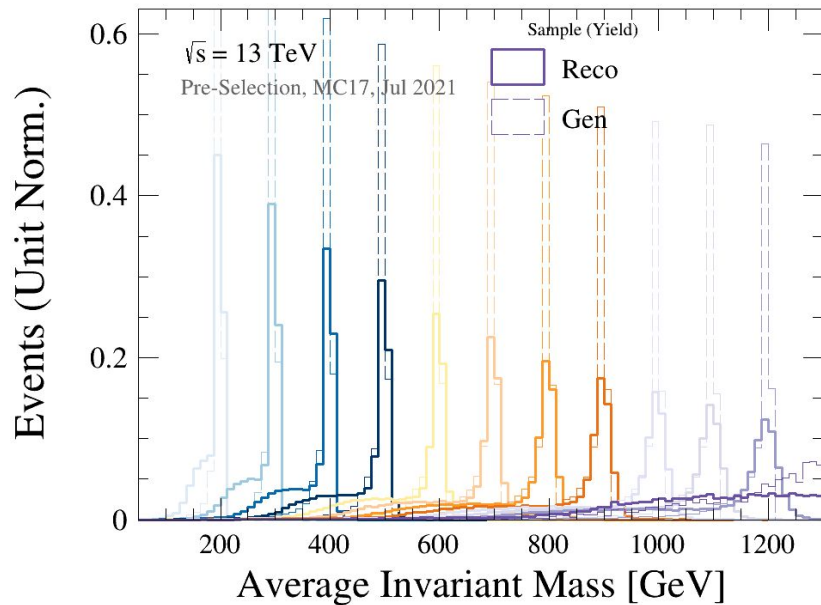
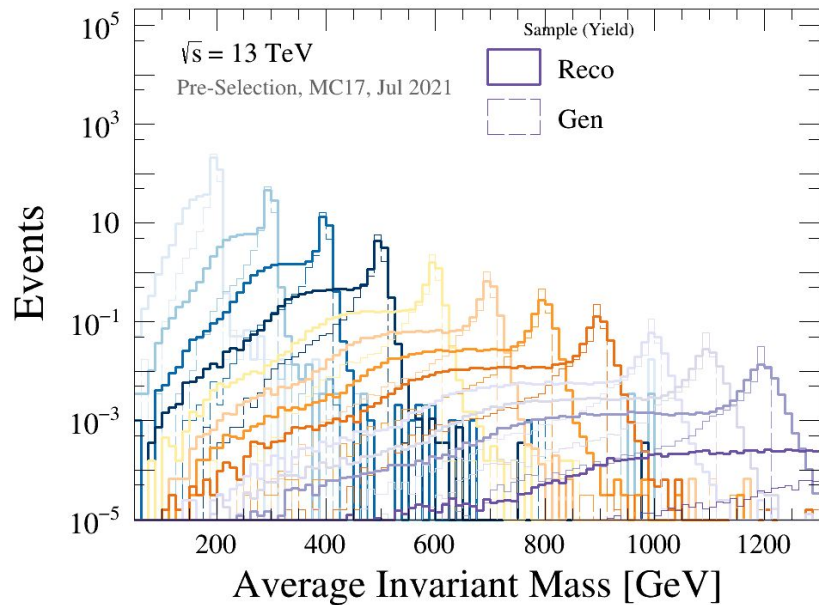




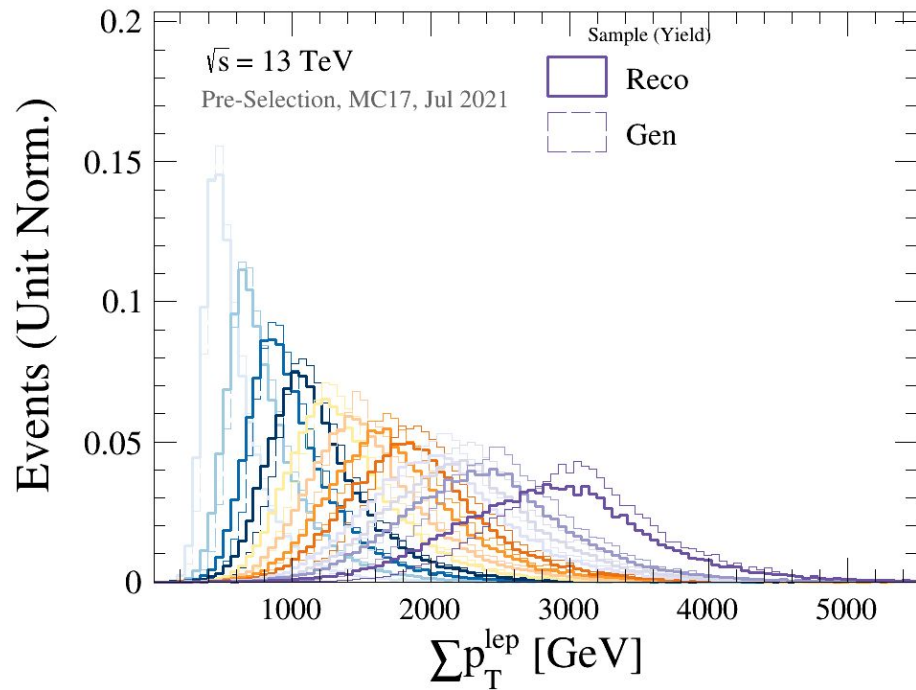
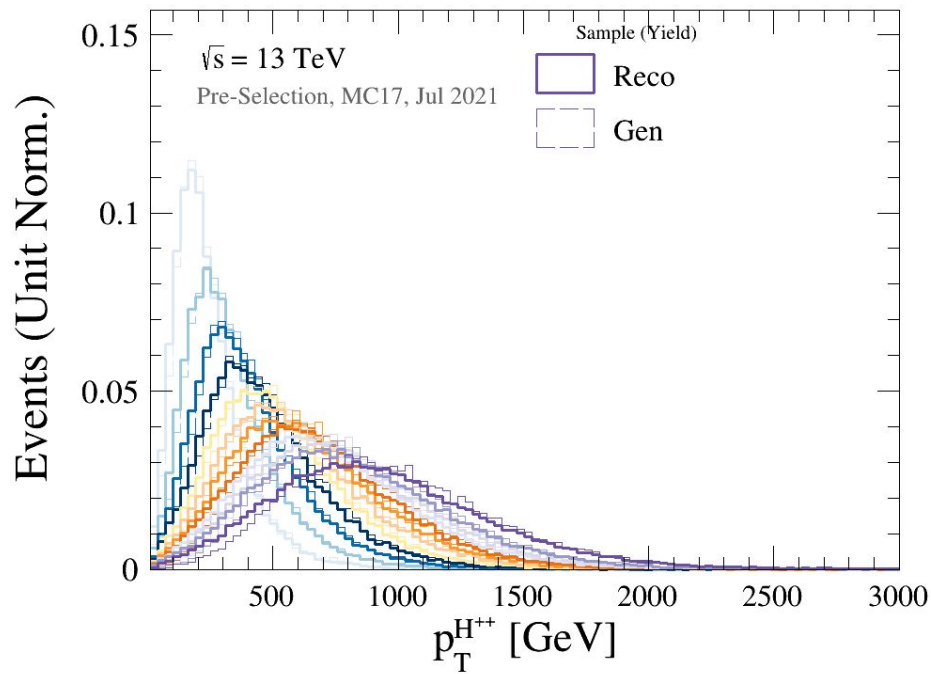
# Trigger Scale Factors



# New signal samples

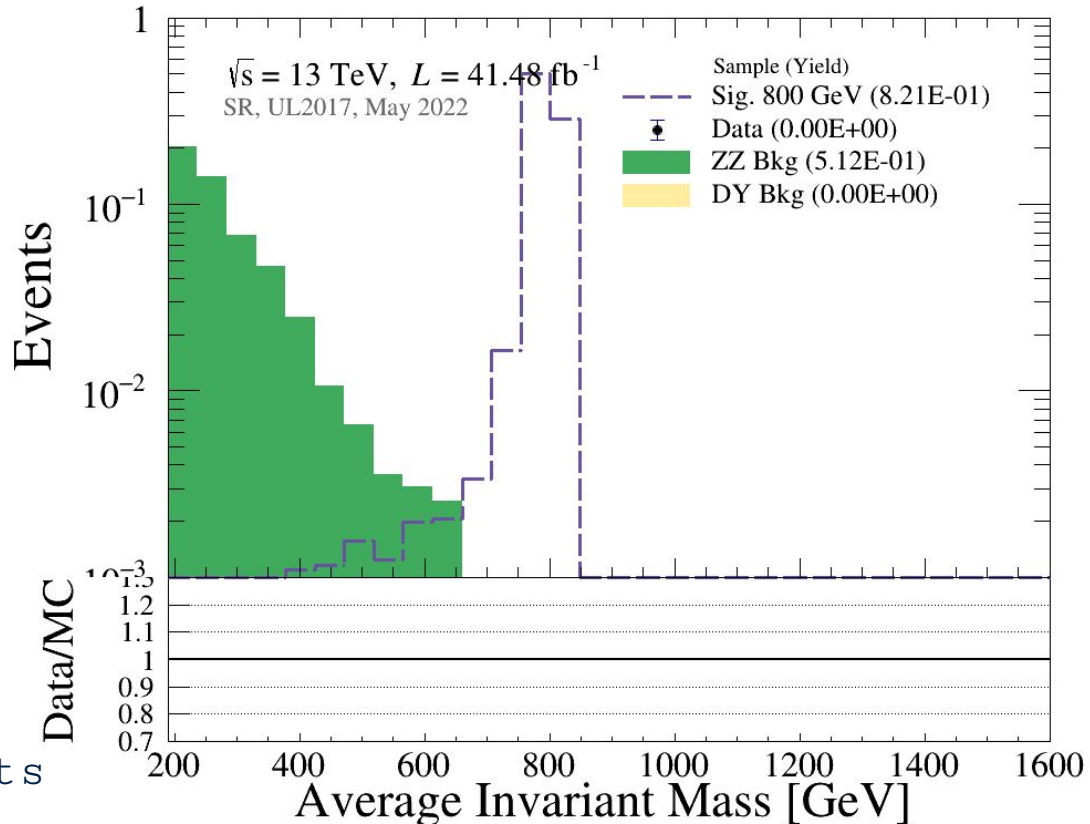


# New signal samples



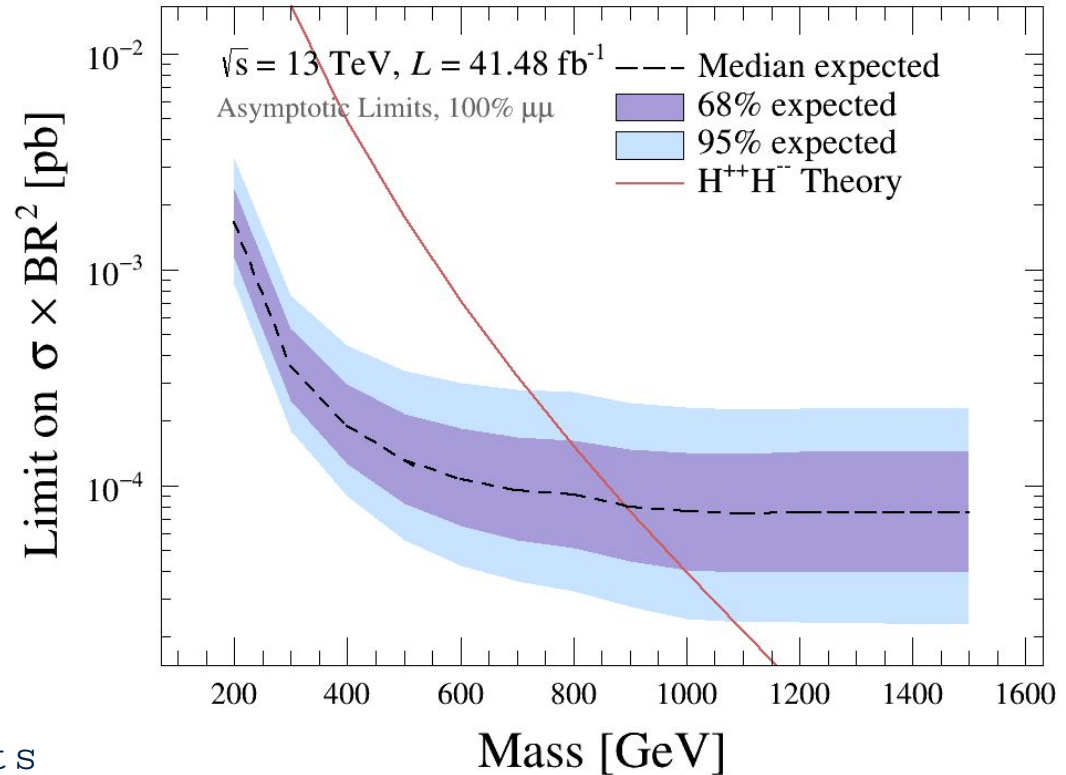
# Limits - first pass

- **First pass** combine statistical analysis
  - ↳ **Mass average** used
  - ↳ **No experimental data**
  - ↳ **ZZ** bkg only
  - ↳ Lep. ID+ISO **shape uncertainty**
  - ↳ **Lumi** uncertainty
- **Plan to use** HybridNew
  - ↳ **WIP** : AsymptoticLimits



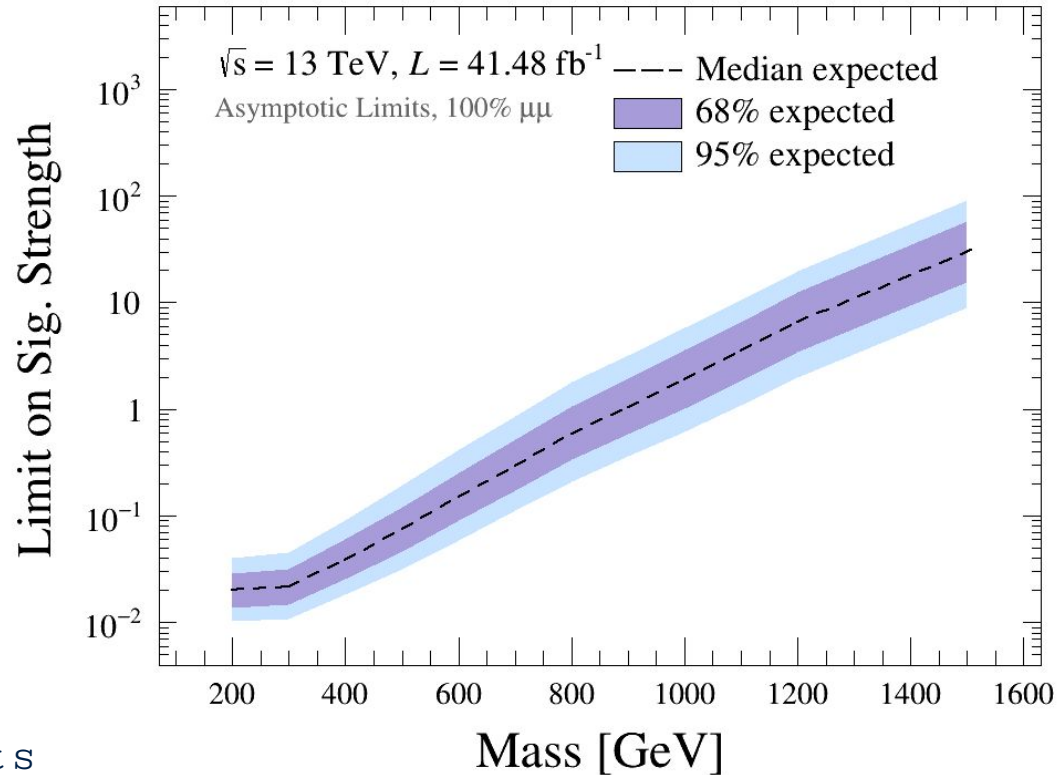
# Limits - first pass

- **First pass** combine statistical analysis
  - ↳ **Mass average** used
  - ↳ **No experimental data**
  - ↳ **ZZ** bkg only
  - ↳ Lep. ID+ISO **shape uncertainty**
  - ↳ **Lumi** uncertainty
- **Plan to use** HybridNew
  - ↳ **WIP** : `AsymptoticLimits`



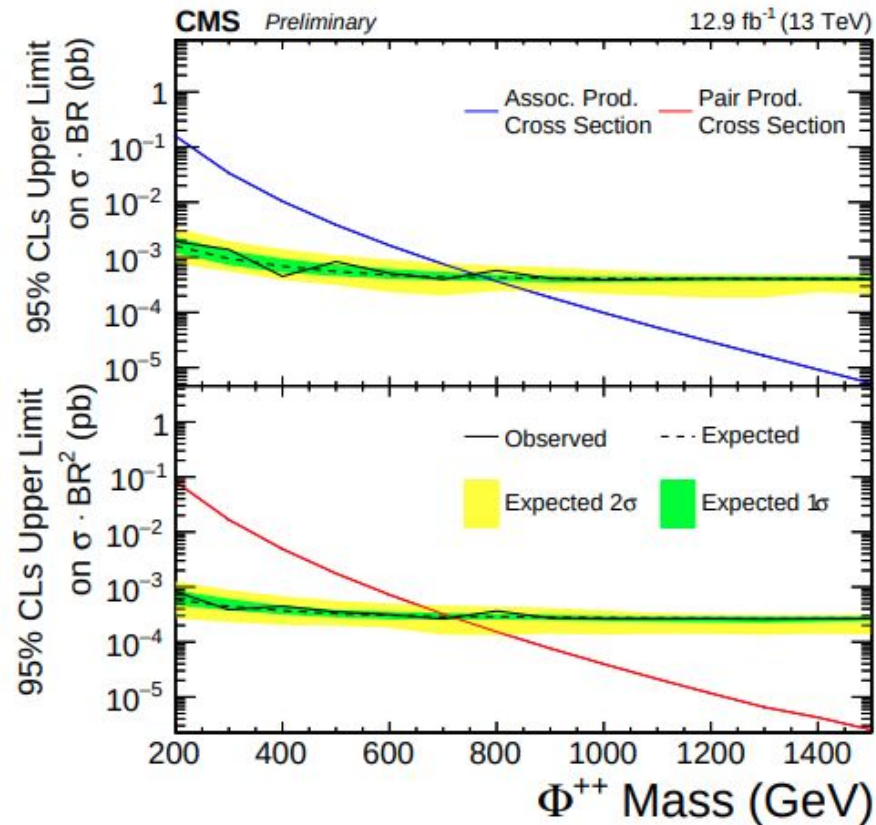
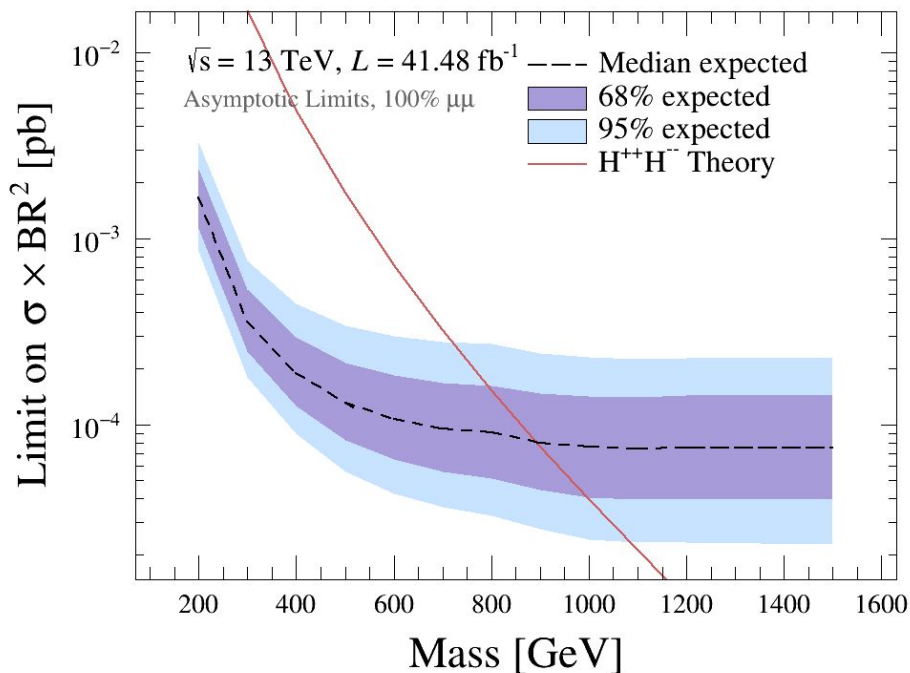
# Limits - first pass

- **First pass** combine statistical analysis
  - ↳ **Mass average** used
  - ↳ **ZZ** bkg only
  - ↳ **No experimental data**
  - ↳ Lep. ID+ISO **shape uncertainty**
  - ↳ **Lumi** uncertainty
- **Plan to use** HybridNew
  - ↳ **WIP** : `AsymptoticLimits`



# Limits vs past analysis

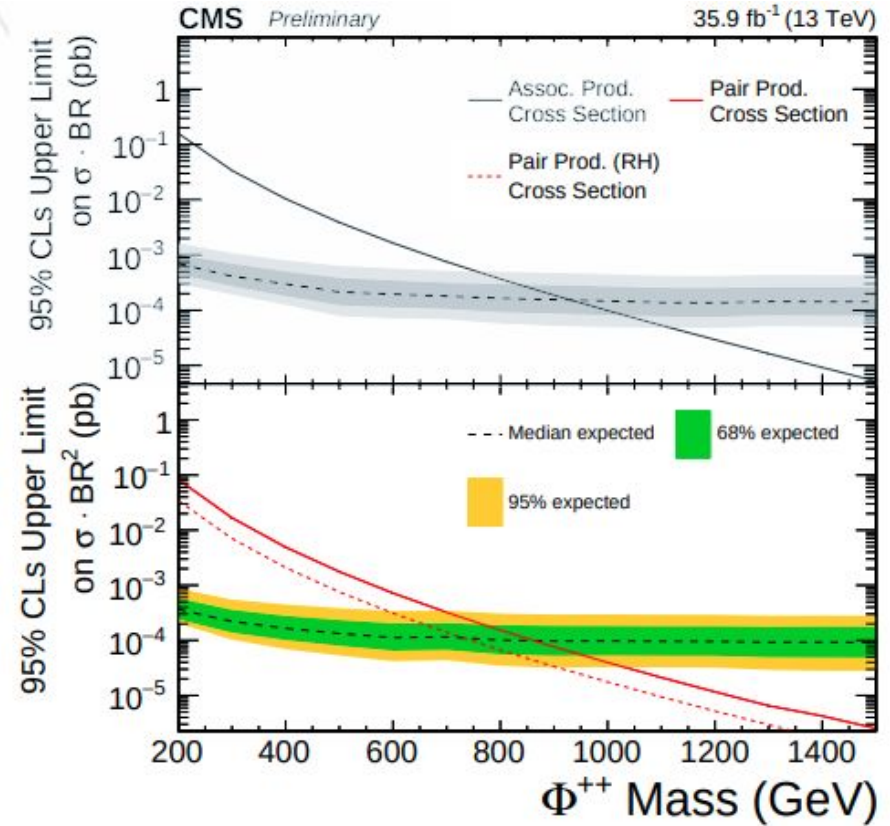
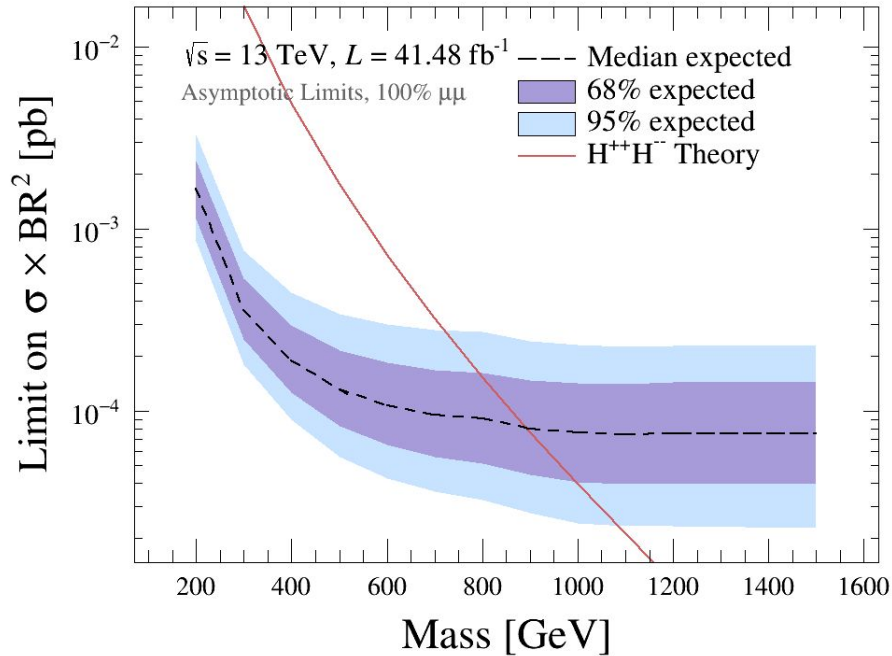
[HIG-16-036-pas](#)



(a) 100%  $\mu\mu$

# Limits vs past analysis

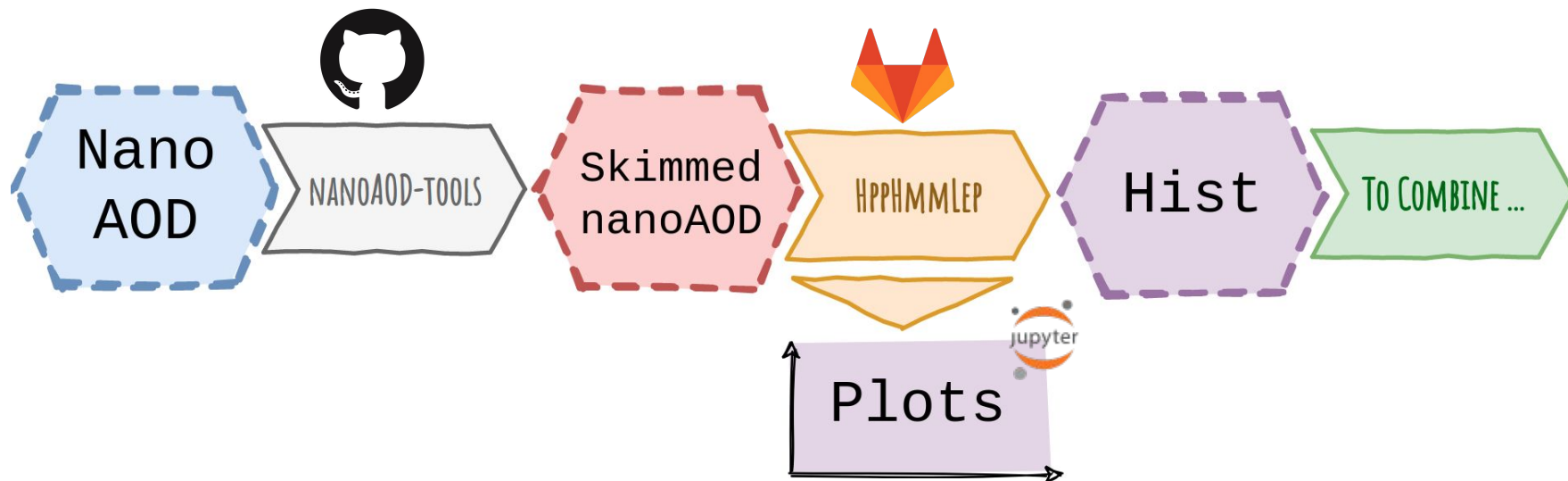
- **Similar results** to  $35.9 \text{ fb}^{-1}$  limits from analysis note draft

(e) 100%  $\mu\mu$



# Analysis framework

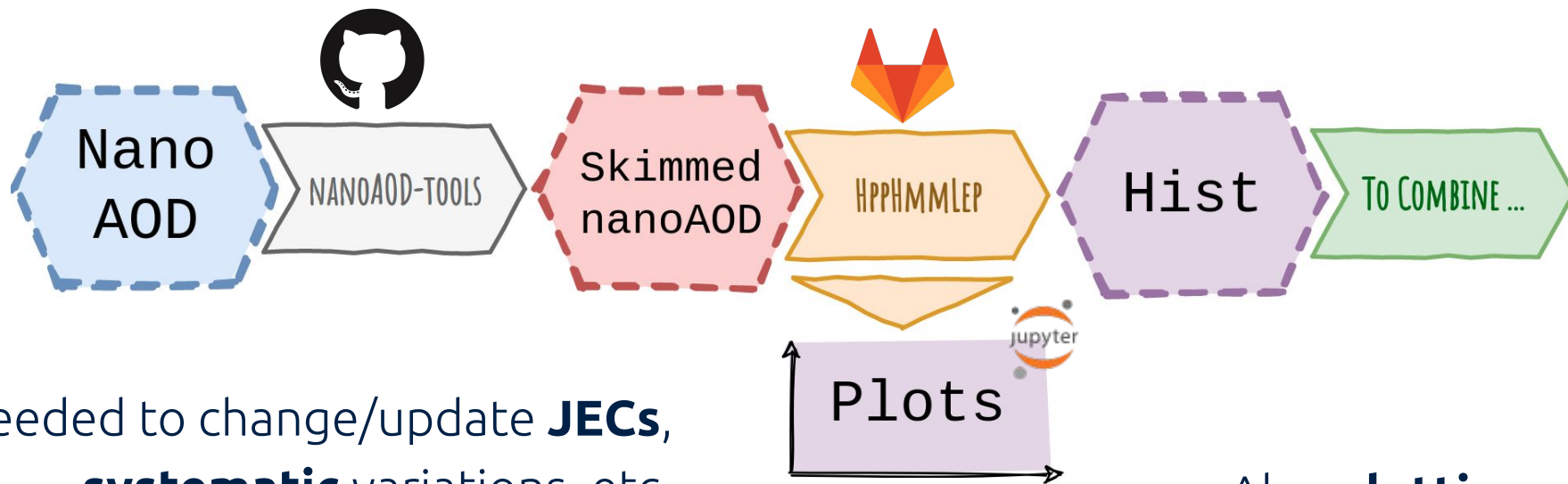
- Requirements: **Git**Lab/Hub , access to `/cvmfs`
- Mainly **pyroot** + ROOT::**RDataFrame**
  - + python/ bash scripts for automatization



# Status - software

- **Software framework**

Object & Event **Selection**,  
weighting, etc.



Needed to change/update **JECs**,  
**systematic** variations, etc.  
+ some **initial cuts**

Also **plotting**

# HppHmMLep Package

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- eventSelection.py
  - ↳ **Main** analysis **script** written in **python**
  - ↳ ROOT::RDataFrame and ROOT::VecOps::RVec for event and object selection
    - Efficient, readable code
    - Multi-thread friendly(`ROOT.EnableImplicitMT(1)`)
  - ↳ Easy **configuration** and **pipeline integration**

# Next Steps - checklist

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- **Next** steps:

- Run on more **MC bkg** (DY, WZ) samples 
- **Produce** more **signal** mass points 
- **Synchronize** SW Frameworks with  $\tau$  analysis 
- Finalize **MC background** estimate (UL2017) 
- **First pass of** statistical setup in **Combine** 
- **Explore** new **variables, cuts** on MC 
- Full **Run II, 3-lep** channel, optimization ... 

# Other Steps - checklist

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- **Other** steps:
  - ↳ Finalize **trigger** strategy + check **efficiency**
  - ↳ Finalize **selection** and **optimization**
  - ↳ Apply all **scale factors**
  - ↳ **Final background** estimation **CR+VR** and plots
  - ↳ **Unblind** small %tage of **SR**
  - ↳ **Run** analysis on **2016** and **2018**
  - ↳ **Finalize statistical** analysis + **Combine** setup

# Difference in trigger VS Laurent's lep trig. review

```
root [8] .ls
TFile**      /pnfs/iihe/cms/ph/sc4/store/data/Run2016B/MuonEG/NANOAOB/ver2_HIPM_UL2016_MiniAODv2_NanoAODv9-v2/40000/D83ED32C-B135-874E-872B-A13F855133A1.root
TFile*       /pnfs/iihe/cms/ph/sc4/store/data/Run2016B/MuonEG/NANOAOB/ver2_HIPM_UL2016_MiniAODv2_NanoAODv9-v2/40000/D83ED32C-B135-874E-872B-A13F855133A1.root
OBJ: TTree   Events Events : 0 at: 0x302a720
KEY: TObject tag;1 Collectable string class
KEY: TTree   Events;1 Events
KEY: TTree   LuminosityBlocks;1 LuminosityBlocks
KEY: TTree   Runs;1 Runs
KEY: TTree   MetaData;1 Job metadata
KEY: TTree   ParameterSets;1 Parameter sets

root [9] Events->Print("HLT*Mu23*Ele*TrackIdL_IsoVL")
*****
*Tree :Events : Events *
*Entries : 1544814 : Total = 7276586621 bytes File Size = 1511699251 *
* : : Tree compression factor = 4.81 *
*****
*Br 0 :HLT_Mu23_TrkIsoVVL_Ele8_CaloIdL_TrackIdL_IsoVL : *
* | Bool_t Trigger/flag bit (process: HLT) *
*Entries : 1544814 : Total Size= 1571315 bytes File Size = 166120 *
*Baskets : 193 : Basket Size= 9216 bytes Compression= 9.43 *
*.....*
*Br 1 :HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL : *
* | Bool_t Trigger/flag bit (process: HLT) *
*Entries : 1544814 : Total Size= 1571511 bytes File Size = 138141 *
*Baskets : 193 : Basket Size= 9216 bytes Compression= 11.34 *
*.....*
root [10]
```

# Difference in trigger VS Laurent's lep trig. review

2017

```

root [0]
Attaching file /pnfs/iihe/cms/ph/sc4/store/data/Run2017D/SingleMuon/NANOAOD/UL2017_MiniAODv1_NanoAODv2-v1/280000/CC462DA3-8404-8746-8501-F0513E88B97B.root
Warning in <TClass::Init>: no dictionary for class edm::Hash<1> is available
Warning in <TClass::Init>: no dictionary for class edm::ParameterSetBlob is available
Warning in <TClass::Init>: no dictionary for class edm::ProcessHistory is available
Warning in <TClass::Init>: no dictionary for class edm::ProcessConfiguration is available
Warning in <TClass::Init>: no dictionary for class __pair_base<edm::Hash<1>,edm::ParameterSetBlob> is available
Warning in <TClass::Init>: no dictionary for class pair<edm::Hash<1>,edm::ParameterSetBlob> is available
(TFile *) 0x2b4d1a0
root [1] Events->Print("HLT*Mu24")
*****
*Tree   :Events   : Events                                     *
*Entries : 286499 : Total = 1199072190 bytes File Size = 211875825 *
*       :         : Tree compression factor = 5.66           *
*****
*Br    0 :HLT_IsoMu24 : Bool_t Trigger/flag bit (process: HLT) *
*Entries : 286499 : Total Size= 290140 bytes File Size = 38969 *
*Baskets : 33 : Basket Size= 10240 bytes Compression= 7.42 *
* .....*

```

Description	Path	Comment
Isolated dimuon	HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ(_Mass3p8)	Mass3p8 (eras ≥ 2017C)
Isolated dielectron	HLT_Ele23_Ele12_CaloidL_TrackIdL_IsoVL	DZ dropped. L1: Single or DoubleEG
Isolated $e\mu$	HLT_Mu23/8_TrkIsoVVL_Ele12/23_CaloidL_TrackIdL_IsoVL_DZ	/