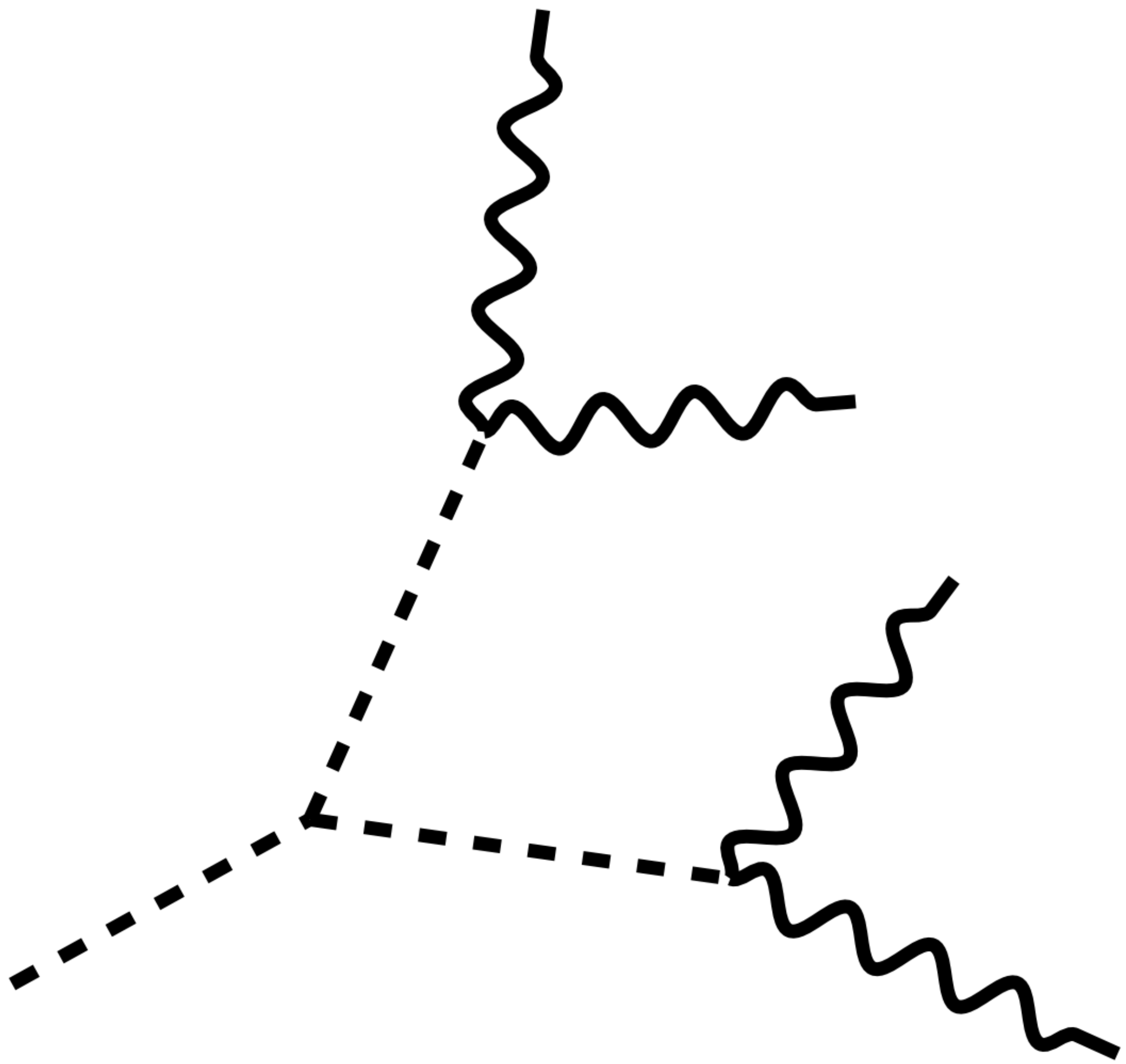

$h(125) \rightarrow aa \rightarrow \gamma\gamma\gamma\gamma$

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5th October 2017
Northeastern Meeting

KINEMATIC ANATOMY

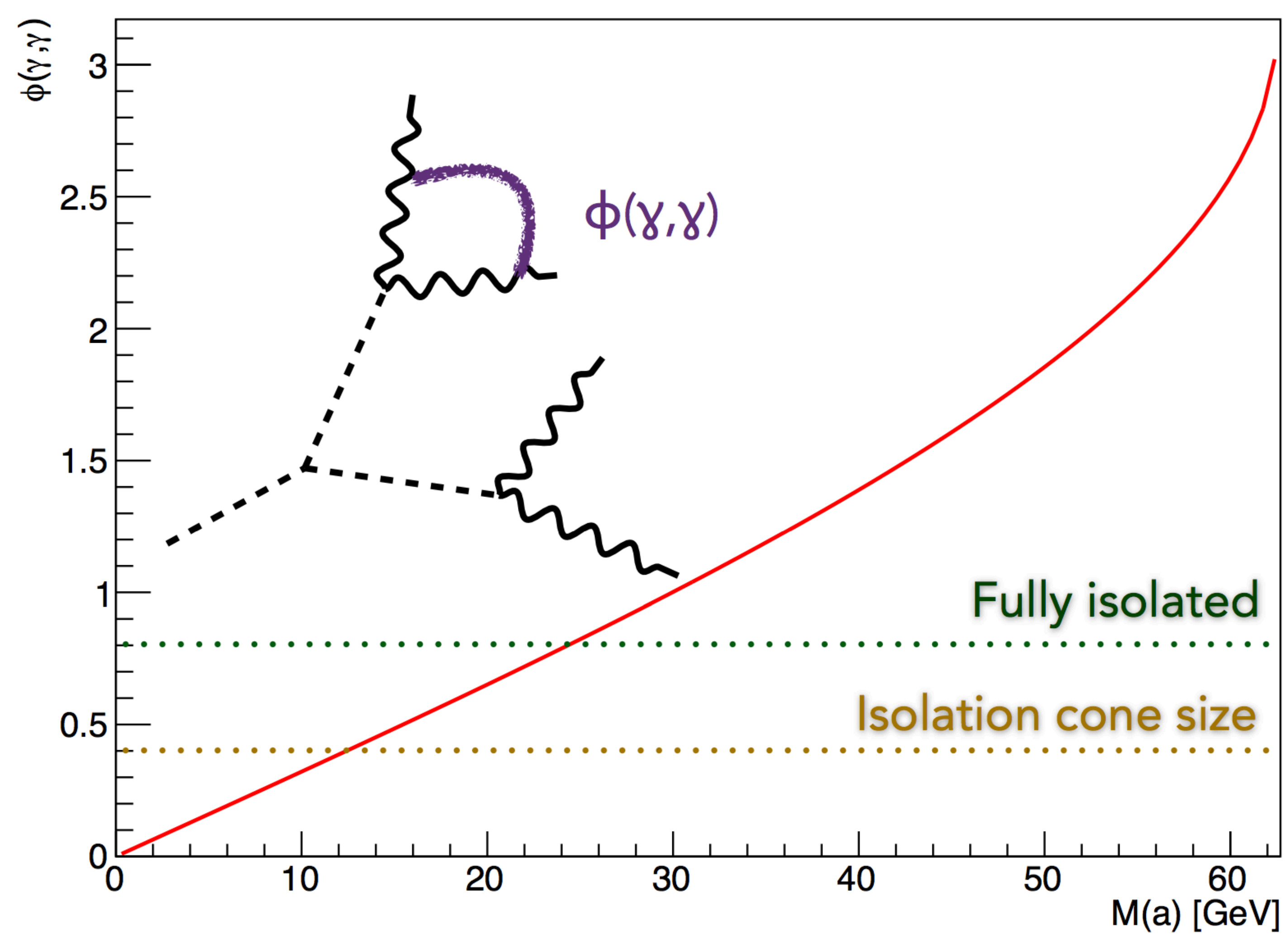
Low Mass: M(a) < ~ 10GeV — Merged Photons

Medium Mass: ~10GeV < M(a) < 25 GeV — Isolation problems are possible

High Mass: M(a) > 25GeV — Photons are expected to be well isolated

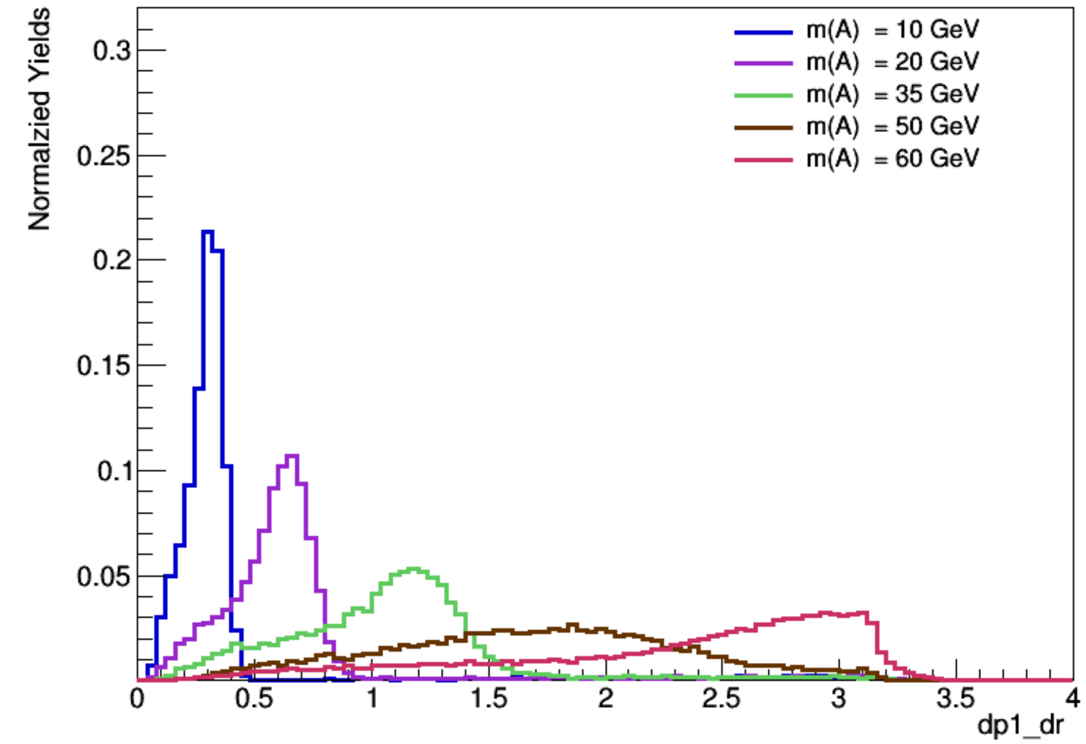
Φ: Angle between photons coming from the same "a"

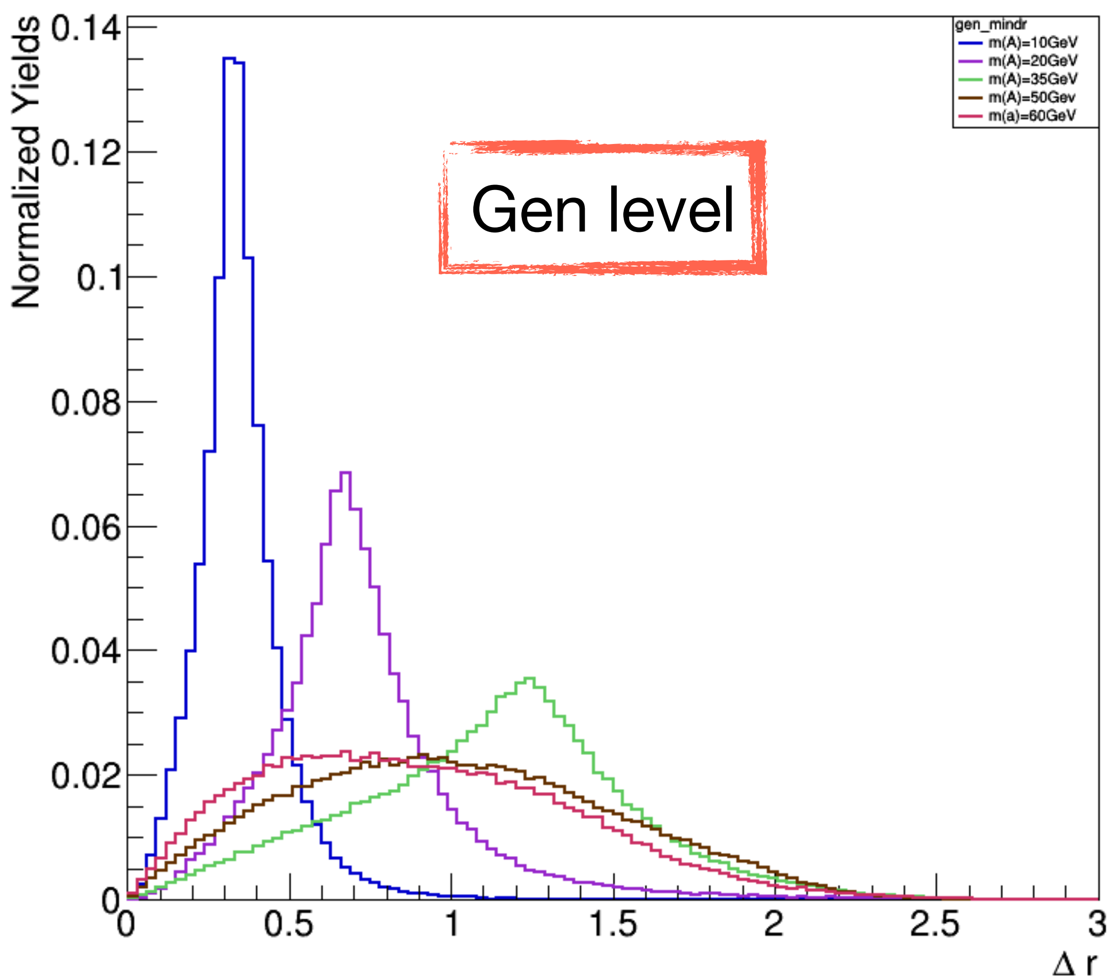
Assuming "h" at rest and decay to be on the transverse plane

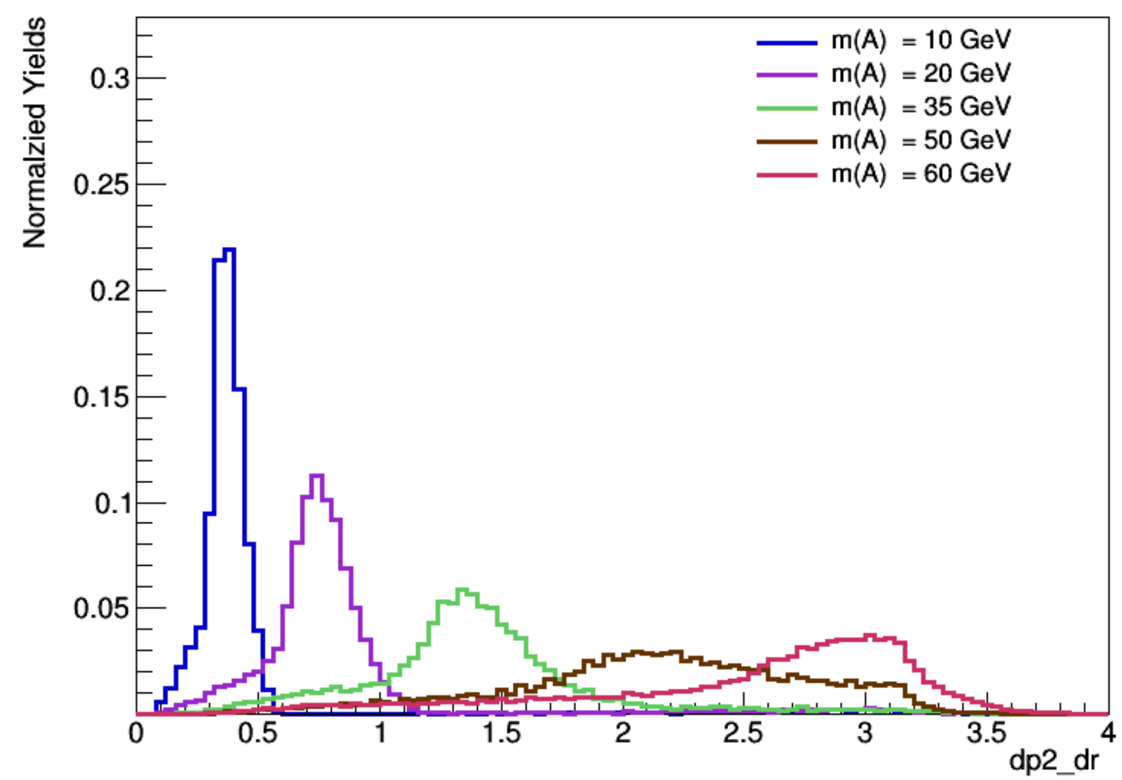


RECO-LEVEL DISTRIBUTIONS

- As expected, for M(a) < 20 GeV :
  ΔR(γγ) for same "a" < 0.4
- For high M(a) there are overlaps from γ's of different a's
- Since we are requiring at least 4 isolated photons, this is one possible cause of reduction in signal efficiency for M(a) < 20 GeV







CATEGORIZATION STRATEGY

- For low mass “a”, two γ’s could be merged enough to mimic a single γ
- In that case our current requirement of at least 4 γ is not efficient

All Events

At least **4 γ’s** ? — YES → Framework exits!

NO ↓

At least **3 γ’s** ? — YES →

NO ↓

At least **2 γ’s** ? — YES →

For the single Photon(s) -> apply different ID
Instead of R9 > 0.85 , lower the requirement
(0.5 < R9 < 0.85)

NO ↓

~~Not interested~~

UNBINNED SHAPE ANALYSIS

- **h(125)→aa→γγγγ** - Unbinned, parametric analysis
  - Signal is apparent as a narrow peak over a smooth continuum background
  - Expected Signal and Background shapes are described in terms of analytic functions rather than templates
- Implemented by RooFit package
  - Allows to use generic PDF's, for e.g : Gaussians, Polynomials, etc. or can also form more complex functions
- Creation of a Datacard
  - Plain ASCII file
  - Contains information like Number of channels, number of backgrounds, rate, systematic uncertainties
  - For unbinned, parametric analysis - Datacard contains name of RooWorkspace (contains the pdf's) + name of RooAbsPdf or RooAbsData for the observed data

Preliminary Workspace

```
RooWorkspace(Analysis2D) Analysis2D contents

variables
---------
(Bern2_tp_mass_norm,Bern3_tp_mass_norm,PowL_tp_mass_norm,b2_p0_mgg_bb,b2_p1_mgg_bb,b2_p2_mgg_bb,b3_p0_mgg_bb,b3_p1_mgg_bb,b3_p2_mgg_bb,b3_p3_mgg_bb,fr2,mH,meanG1,meanG2,meanG3,ng1,n
g2,power,power2,roomultipdf_norm,sigmaSigCB1,sigmaSigCB2,sigmaSigCB3,tp_mass)

p.d.f.s
-------
RooBernstein::Bern2_tp_mass[ x=tp_mass coefList=(mod_b2_p0_mgg_bb,mod_b2_p1_mgg_bb,mod_b2_p2_mgg_bb) ] = 0.00627863
RooBernstein::Bern3_tp_mass[ x=tp_mass coefList=(mod_b3_p0_mgg_bb,mod_b3_p1_mgg_bb,mod_b3_p2_mgg_bb,mod_b3_p3_mgg_bb) ] = 0.00709391
RooAddPdf::Gaus12_tp_mass[ ng1 * Gaus1_tp_mass + [%] * Gaus2_tp_mass ] = 0.83644
RooGaussian::Gaus1_tp_mass[ x=tp_mass mean=meanSigCB1 sigma=sigmaSigCB1 ] = 1
RooGaussian::Gaus2_tp_mass[ x=tp_mass mean=meanSigCB2 sigma=sigmaSigCB2 ] = 0.606531
RooGaussian::Gaus3_tp_mass[ x=tp_mass mean=meanSigCB3 sigma=sigmaSigCB3 ] = 0.292787
RooGenericPdf::PowL_tp_mass[ actualVars=(tp_mass,power,fr2,power2) formula="pow(tp_mass,power)+fr2*pow(tp_mass,power2)" ] = 0.374455
RooAddPdf::SigGaus123_tp_mass[ ng2 * Gaus12_tp_mass + [%] * Gaus3_tp_mass ] = 0.484182

functions
--------
RooFormulaVar::meanSigCB1[ actualVars=(meanG1,mH) formula="meanG1*mH/125.09" ] = 120
RooFormulaVar::meanSigCB2[ actualVars=(meanG2,mH) formula="meanG2*mH/125.09" ] = 128
RooFormulaVar::meanSigCB3[ actualVars=(meanG3,mH) formula="meanG3*mH/125.09" ] = 123.651
RooFormulaVar::mod_b2_p0_mgg_bb[ actualVars=(b2_p0_mgg_bb) formula="b2_p0_mgg_bb*b2_p0_mgg_bb" ] = 1.01283e-10
RooFormulaVar::mod_b2_p1_mgg_bb[ actualVars=(b2_p1_mgg_bb) formula="b2_p1_mgg_bb*b2_p1_mgg_bb" ] = 0.00777101
RooFormulaVar::mod_b2_p2_mgg_bb[ actualVars=(b2_p2_mgg_bb) formula="b2_p2_mgg_bb*b2_p2_mgg_bb" ] = 0.00957251
RooFormulaVar::mod_b3_p0_mgg_bb[ actualVars=(b3_p0_mgg_bb) formula="b3_p0_mgg_bb*b3_p0_mgg_bb" ] = 1.34031e-05
RooFormulaVar::mod_b3_p1_mgg_bb[ actualVars=(b3_p1_mgg_bb) formula="b3_p1_mgg_bb*b3_p1_mgg_bb" ] = 0.00371506
RooFormulaVar::mod_b3_p2_mgg_bb[ actualVars=(b3_p2_mgg_bb) formula="b3_p2_mgg_bb*b3_p2_mgg_bb" ] = 0.0122119
RooFormulaVar::mod_b3_p3_mgg_bb[ actualVars=(b3_p3_mgg_bb) formula="b3_p3_mgg_bb*b3_p3_mgg_bb" ] = 0.00895699

datasets
--------
RooDataSet::data(tp_mass)
```

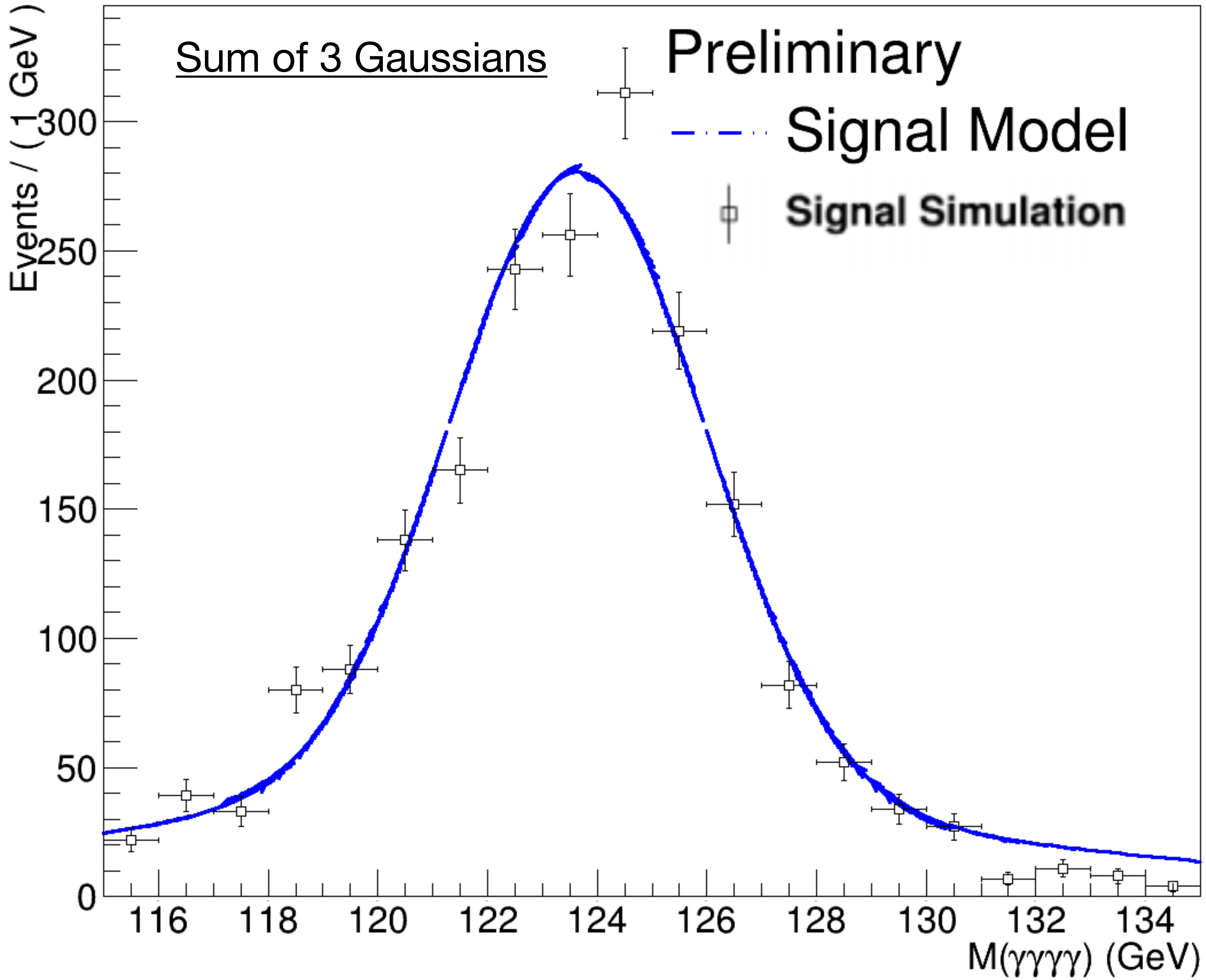
First Look at Signal Fits

Fit of Signal Shape (MC)

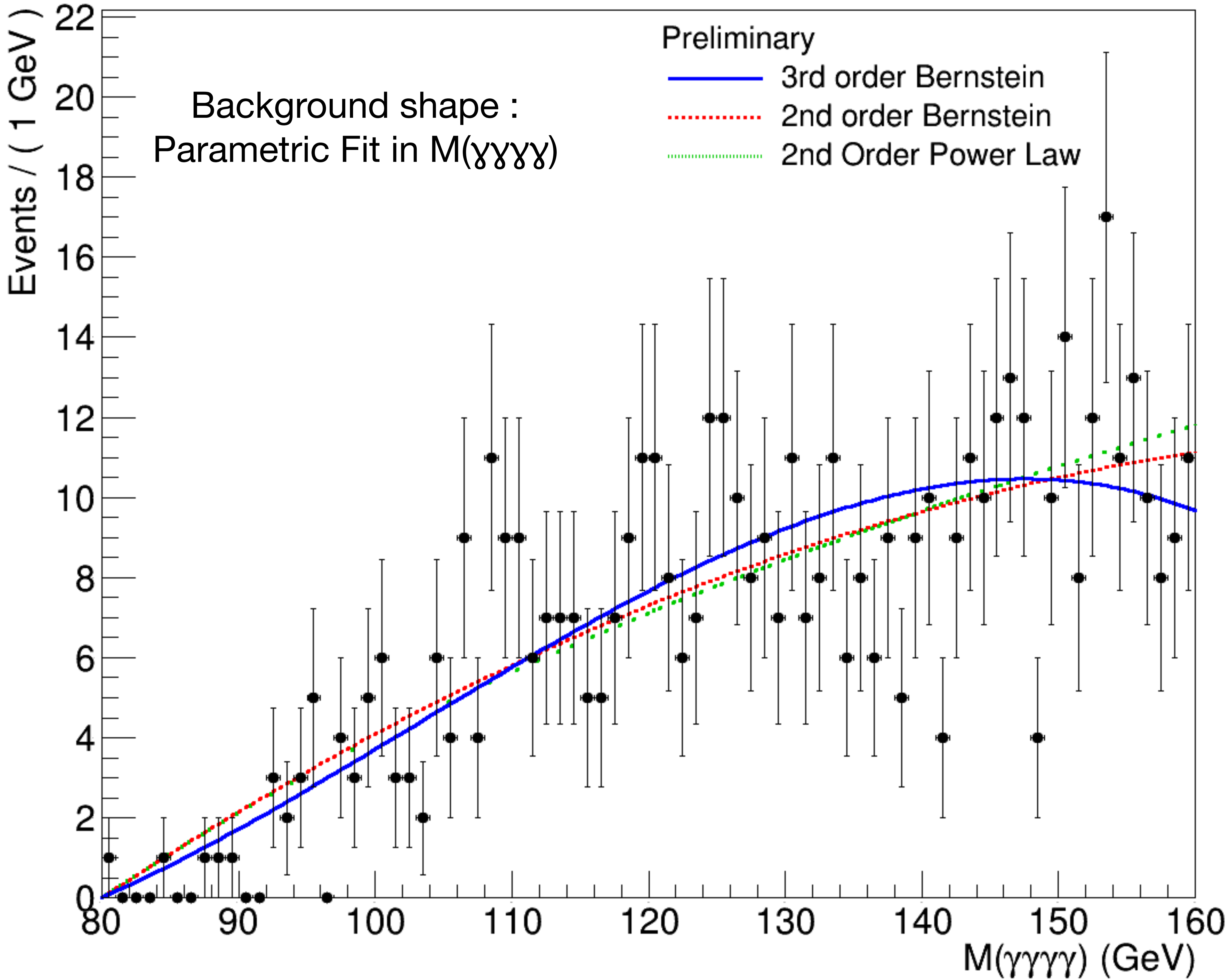
h(125)→aa→γγγγ

m(a) = 60GeV

- Next step:
  Consider a Double Sided Crystal Ball function-> could be more suitable since the two independent tails are expected to model the high and low mass categories



First Look at Background Fits



EVENT MIXING - PRELIMINARY

- To perform closure tests on the background model - require a dataset similar to our expected background in terms of kinematics + statistics
- Control Region - Event with 2 good γ's + 2 good γ's that fail the Photon ID
- Artificially create combinatronics background by exchanging γ's between events - MIXING
- Mixing Concept - After doing full event selection, replace 3 out of the 4 selected photons by those in other events

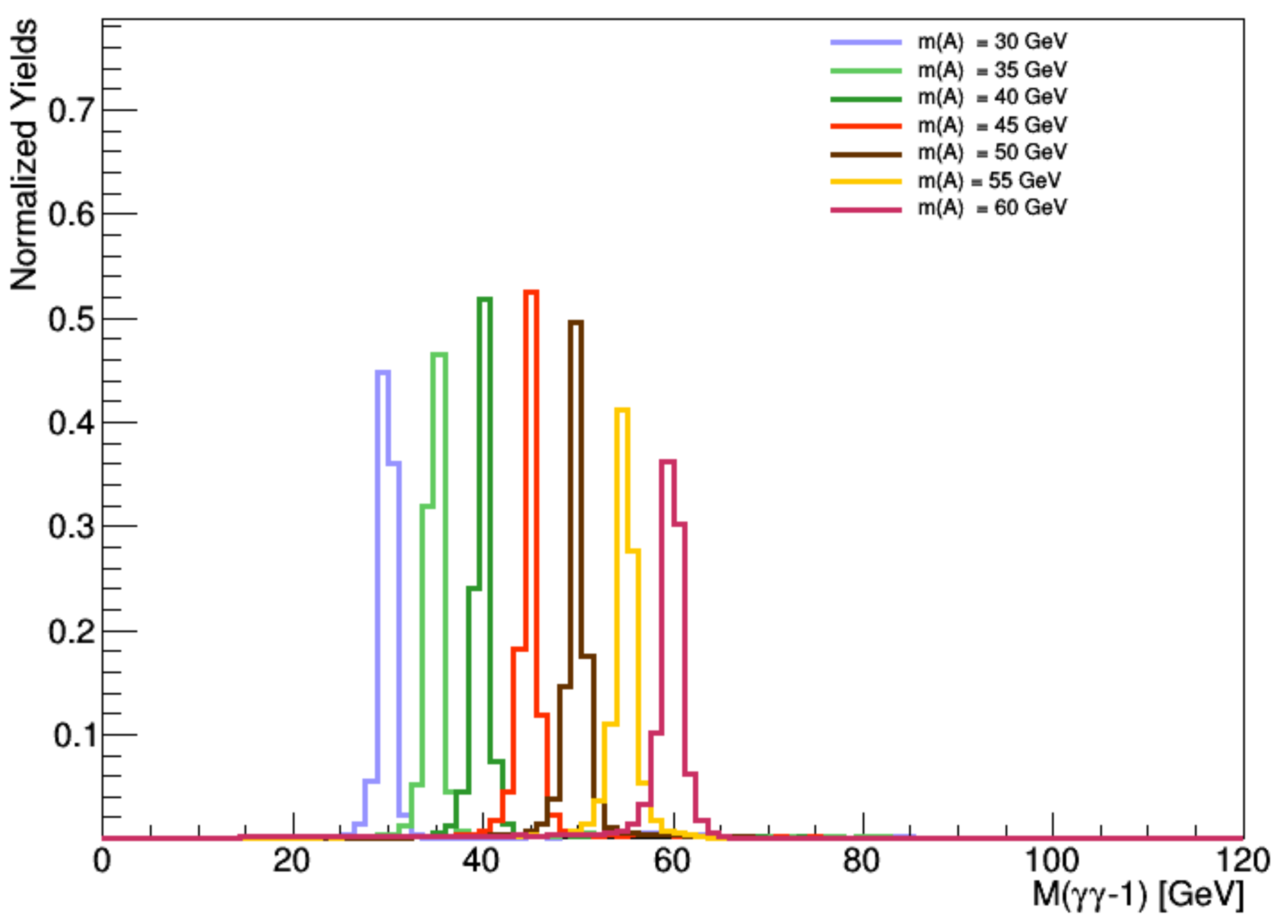
Pre - Mixing				Post - Mixing
Event # 1	**Event # 2**	**Event # 3**	**Event # 4**	**Event # 1**
γ1	γ1	γ1	γ1	γ1
γ2	γ2	γ2	γ2	γ2
γ3	γ3	γ3	γ3	γ3
γ4	γ4	γ4	γ4	γ4

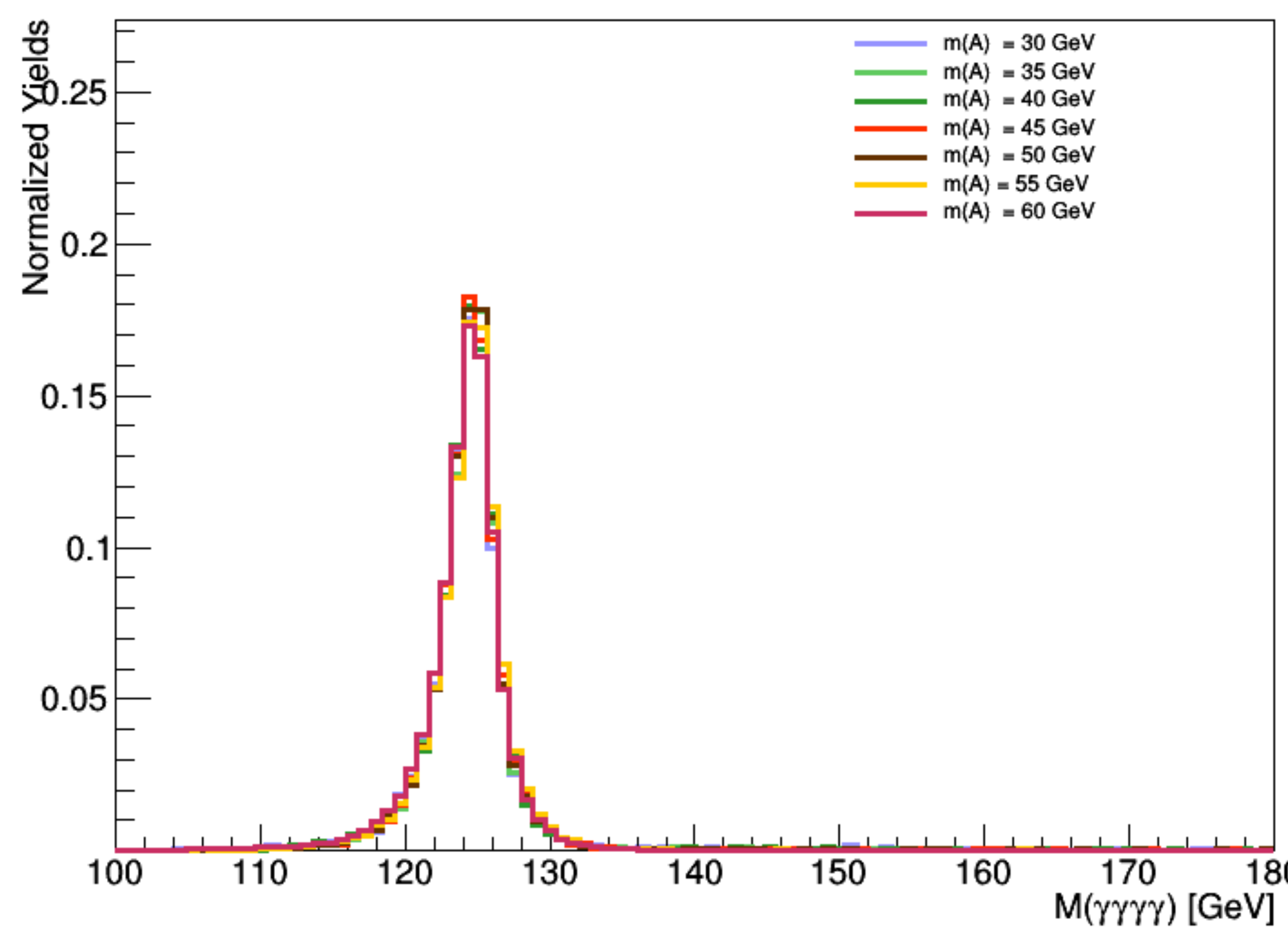
Expected Result of Event Mixing:

- Signal - M(γγ) and M(γγγγ) peaks should be smeared away
- Control region - Both mixed and unmixed distributions should appear same

Being Checked!

Pre - Mixing



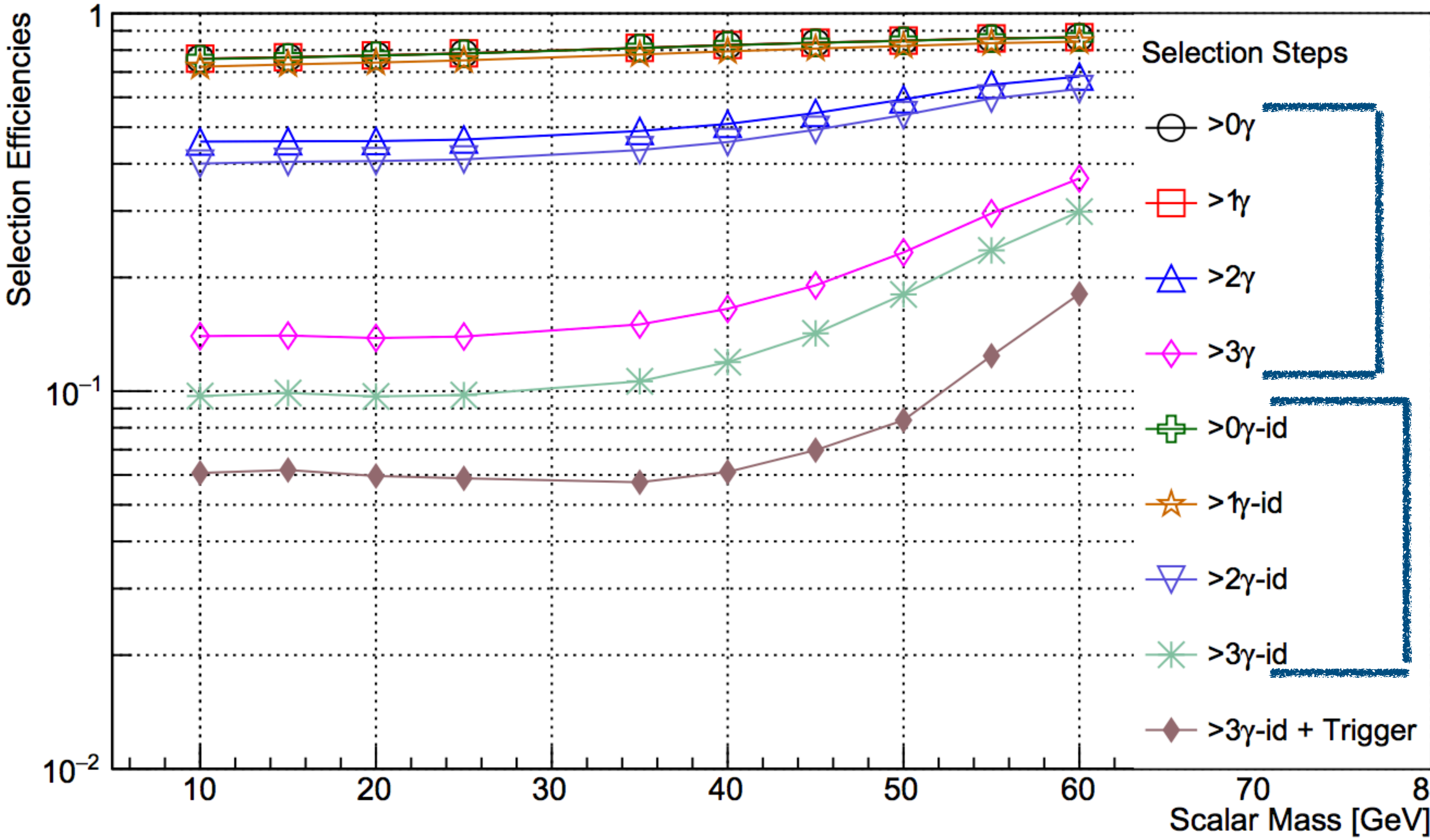


To-Do List

- Validate Event Mixing and use it to perform closure test on background modeling
- For Background modeling - find the best fitting function and perform bias studies
  <u>2ΔNLL test</u>
- Create Workspace for other categories + obtain Signal and Background fits for them
- Follow that by creating a Datacard inclusive of all categories and workspaces
- Datacard to be given as input to Combine to get preliminary/first look at limits
  - Combine provides a command line interface to various statistical techniques available in RooFit/RooStats

BACK UP

SIGNAL EFFICIENCIES



At least N γ's with Et > 15 GeV and |η| < 2.5

Good γ's

Good γ's + Photon MVA requirement

ID'ed 4γ's + Trigger