$\eta \to \pi^0\gamma\gamma$ with FCAL(2)

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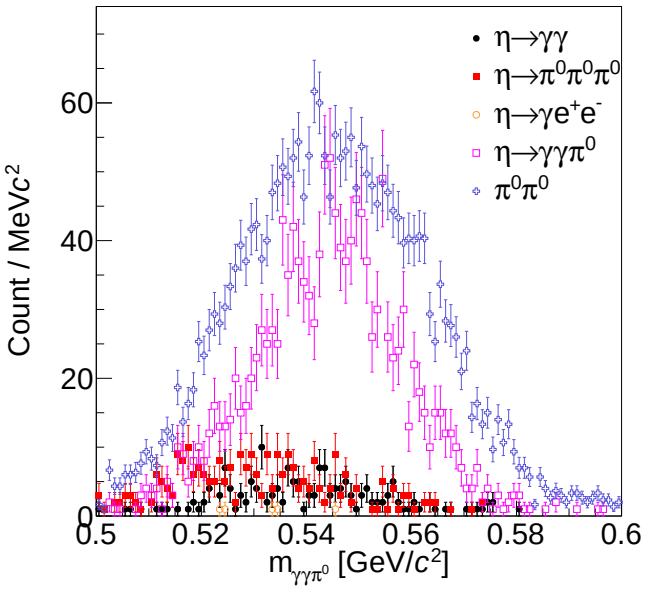
Introduction

Depending of the reaction choosen

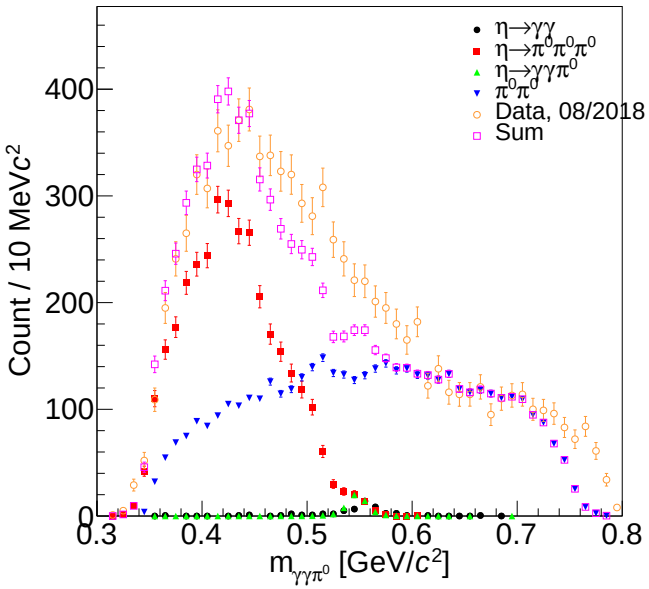
- $\gamma p \to \eta p$ and $\eta \to \pi^0\gamma\gamma$ with all masses constrained
- $\gamma p \to \eta p$ and $\eta \to \pi^0\gamma\gamma$ with π^0 mass constrained and η mass not constrained
- $\gamma p \to \eta p$ and $\eta \to \pi^0\gamma\gamma$ with no masses constrained
- $\gamma p \to \gamma\gamma\gamma\gamma p$

and number of neutral particle hypotheses, the results are changing

- All masses constrained



- π^0 mass constrained and η mass not constrained



And can produce fake bump ...

Combinational background

There can be up to 6 combinations of one π^0 and two bachelor photons, there are two possibilities

- Loop over all possible combinations
- Choose best combination

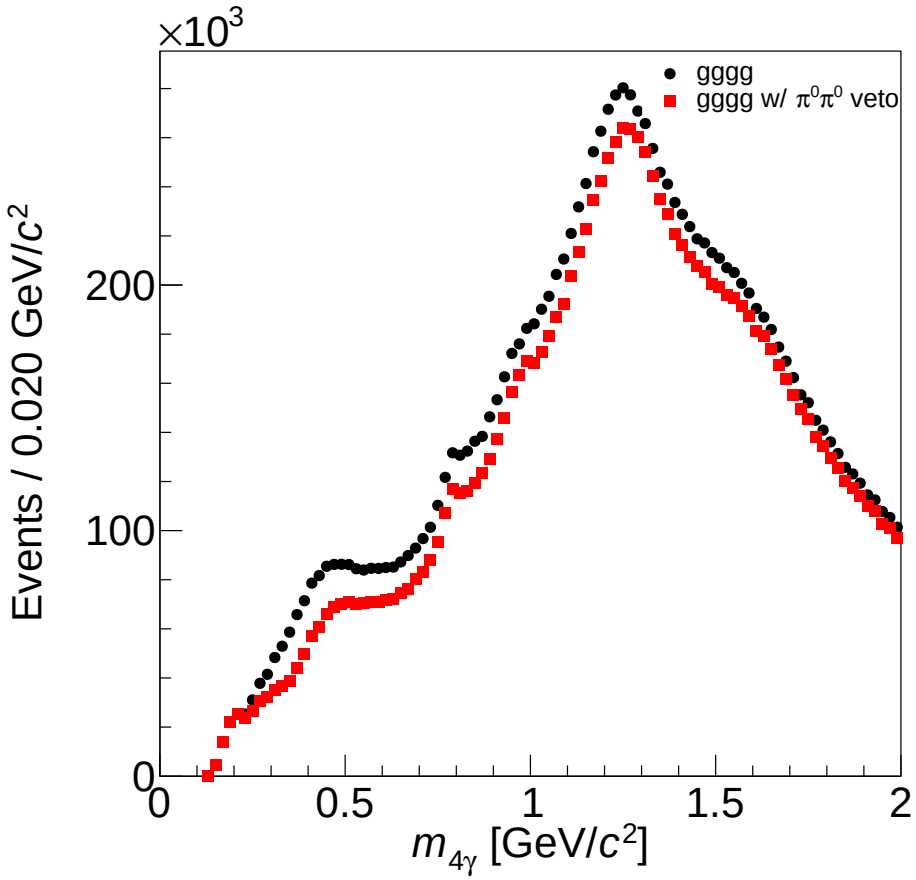
For a BSM search, "choose best combination", is the best option as it will reduce the background i.e. in this case can improve the limit by up to 40% ($1 / 6^{1/4}$)

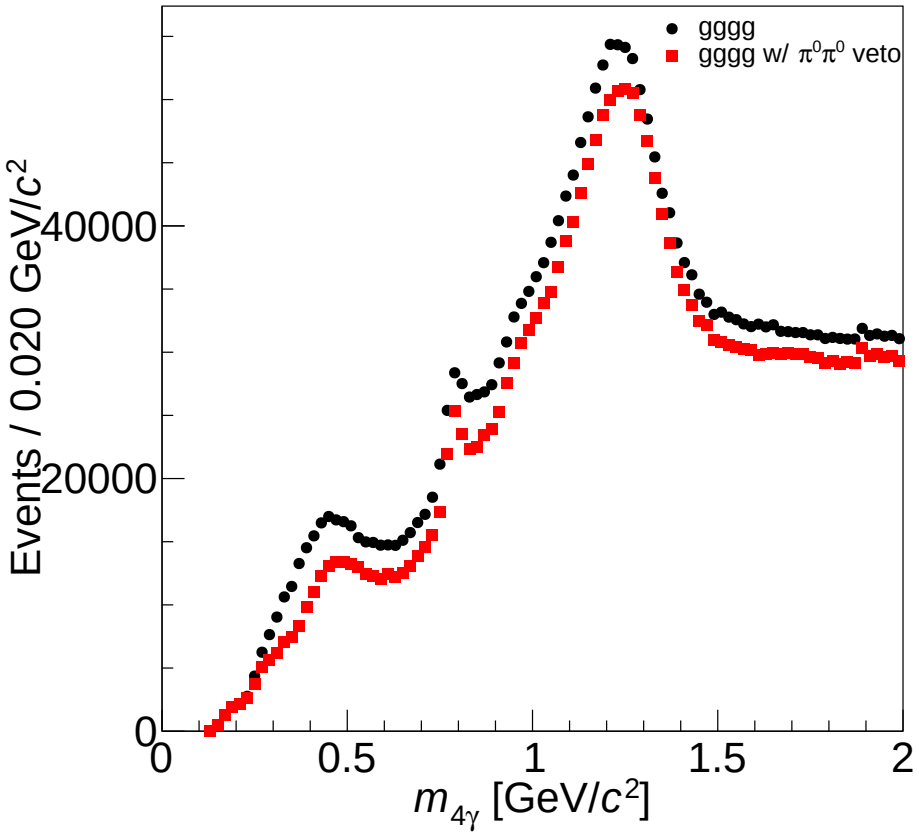
Reaction: $\gamma p \to \gamma\gamma\gamma\gamma p$ at this stage of the analysis is the best suited as it allows to have a better understanding of the non combinational background
π^0 and 2 bachelor photons selected by a χ^2-test

$\gamma p \to \gamma\gamma\gamma\gamma p$

For 1/3 of 2017-01 data set

- $3 \leq E_\gamma \leq 12$ GeV
- $8.3 \leq E_\gamma \leq 12$ GeV





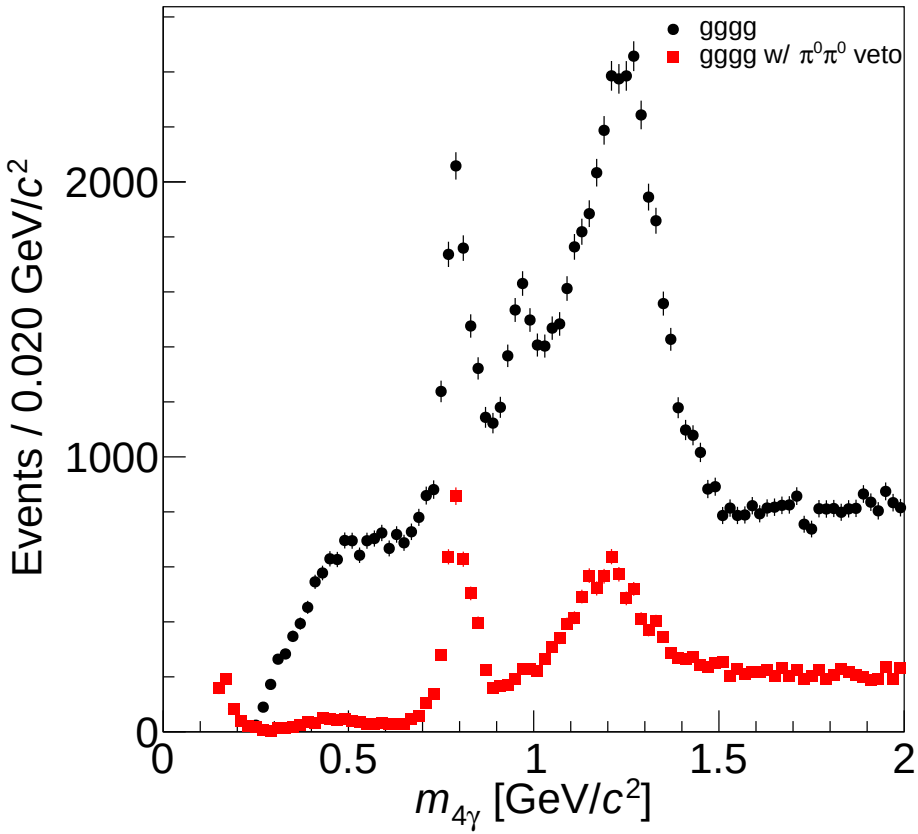
$\pi^0\pi^0$ veto = no diphoton invariant mass between 90 and 190 MeV/c^2

$\gamma p \to \gamma\gamma\gamma\gamma p$

With baseline selection applied

- $8.3 \leq E_\gamma \leq 12$ GeV

- Particle ID (standard)
- Kinematic fitter χ^2 (loose)
- Extra energy $= 0$
- Unused tracks $= 0$
- Missing mass square $\pm$ 0.2 $(\mathrm{GeV}/c^2)^2$
- Coplanarity (loose)
- Vertex: R and z (loose)

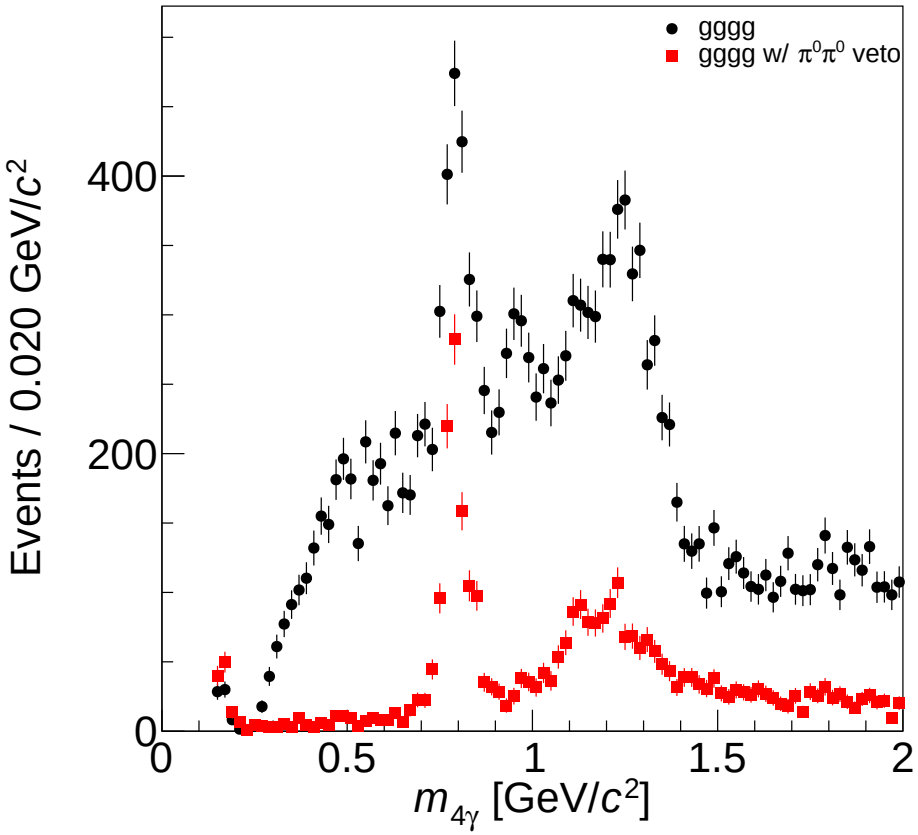


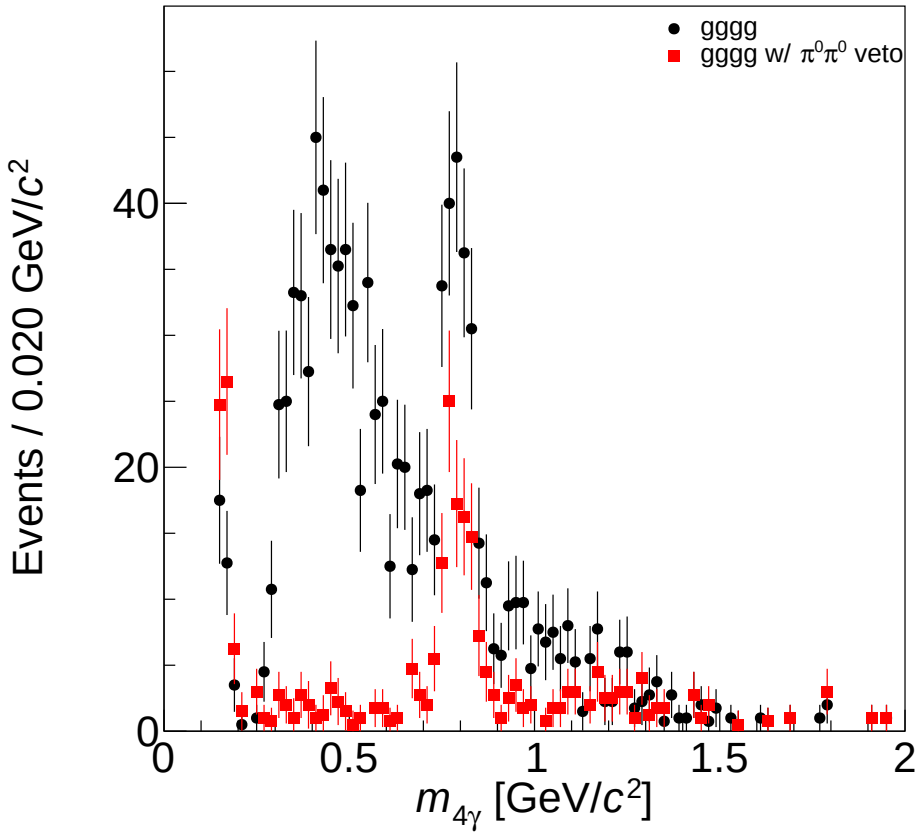
$\eta \to 3\pi^0$, $\omega \to \pi^0\gamma$, $\eta' \to \omega(\to \pi^0\gamma)\gamma$, and ...

$\gamma p \to \gamma\gamma\gamma\gamma p$

With baseline selection applied and number of cluster below 4.5^o

- $8.3 \leq E_\gamma \leq 12$ GeV and at least one cluster below 4.5^o
- $8.3 \leq E_\gamma \leq 12$ GeV and at least 3 clusters below 4.5^o



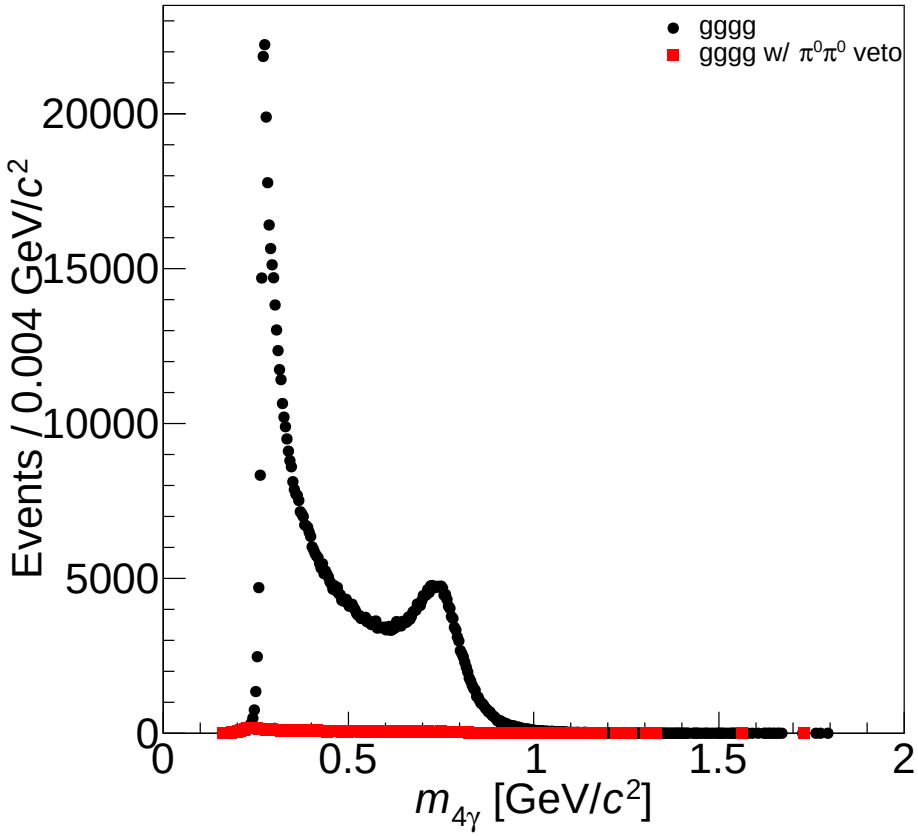


$\eta \to 3\pi^0$, $\omega \to \pi^0\gamma$, $\eta' \to \omega(\to \pi^0\gamma)\gamma$, and ...

MC simulation samples for TVMA training and studies

Used master branch, JEF geometry, and island cluster algorithm, baseline selection applied

- 1M Annika's $2\pi^0$



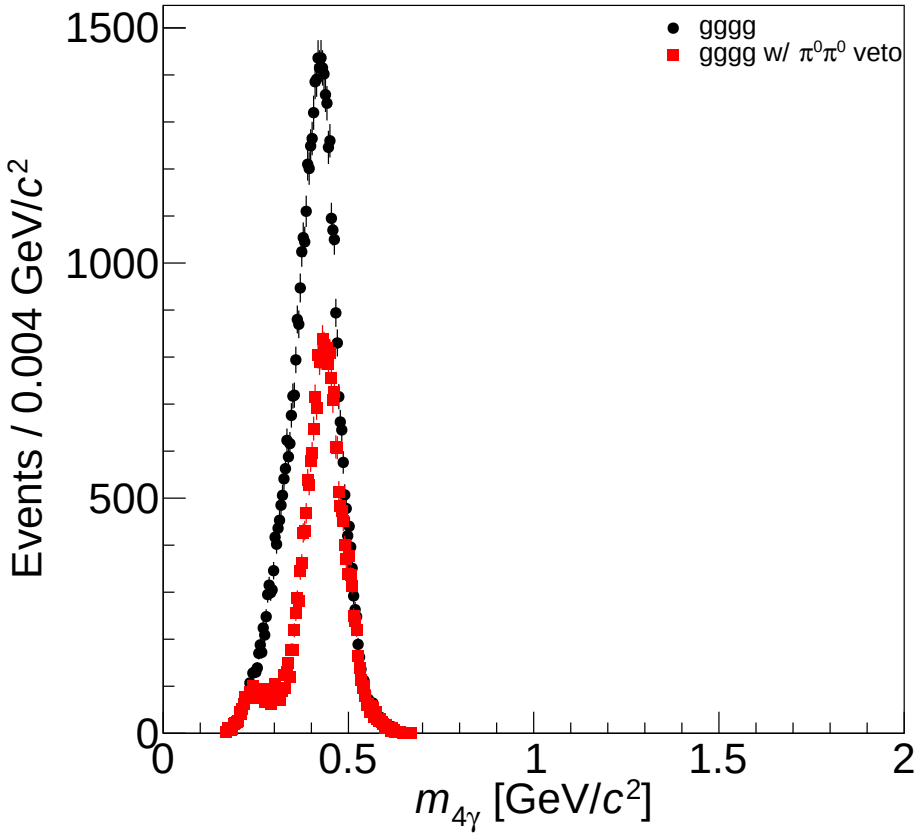
MC simulation samples for TVMA training and studies

Used master branch, JEF geometry, and island cluster algorithm, baseline selection applied

- 1M Annika's $2\pi^0$
- 40M η decaying into 10 different final states

```
#
Decay eta
0.393100000 gamma   gamma
0.325700000 pi0     pi0     pi0
0.227400000 pi-     pi+     pi0
0.046000000 gamma   pi-     pi+
0.007000000 gamma   e+      e-
0.000310000 gamma   mu+     mu-
0.000270000 gamma   gamma   pi0
0.000214200 pi+     pi-     e+      e-
0.000005700 mu+     mu-
0.000000100 pi0     e+      e-
Enddecay
```

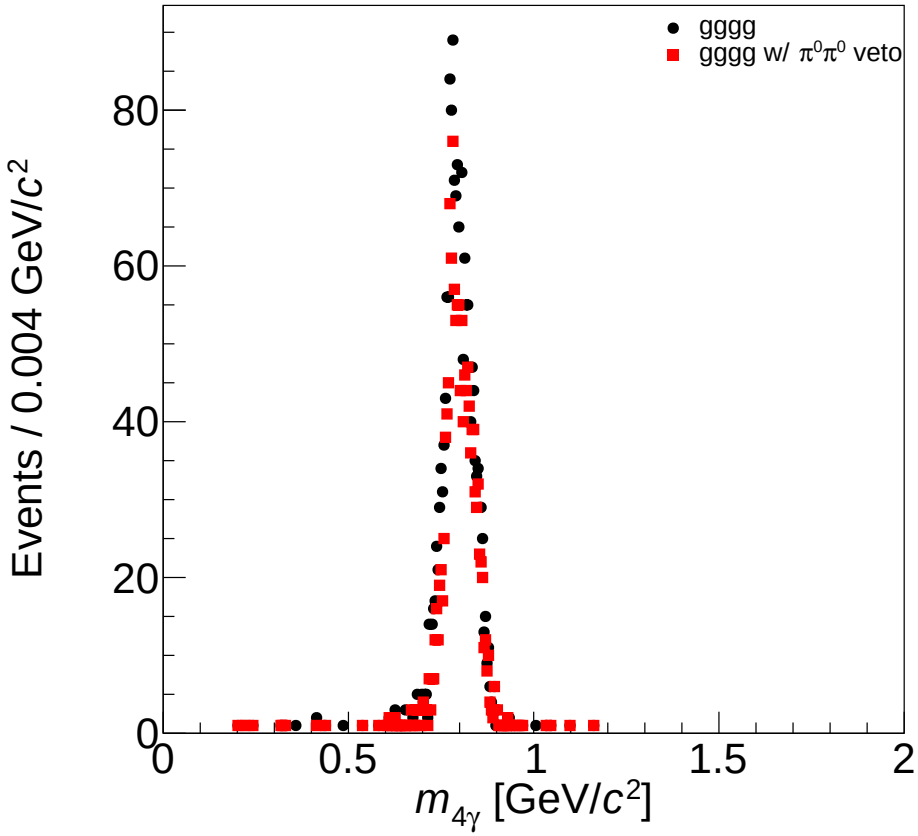
$\sim$10k $\eta \to \pi^0\gamma\gamma$
$\sim$40 $\eta \to \pi^0 e^+ e^-$



MC simulation samples for TVMA training and studies

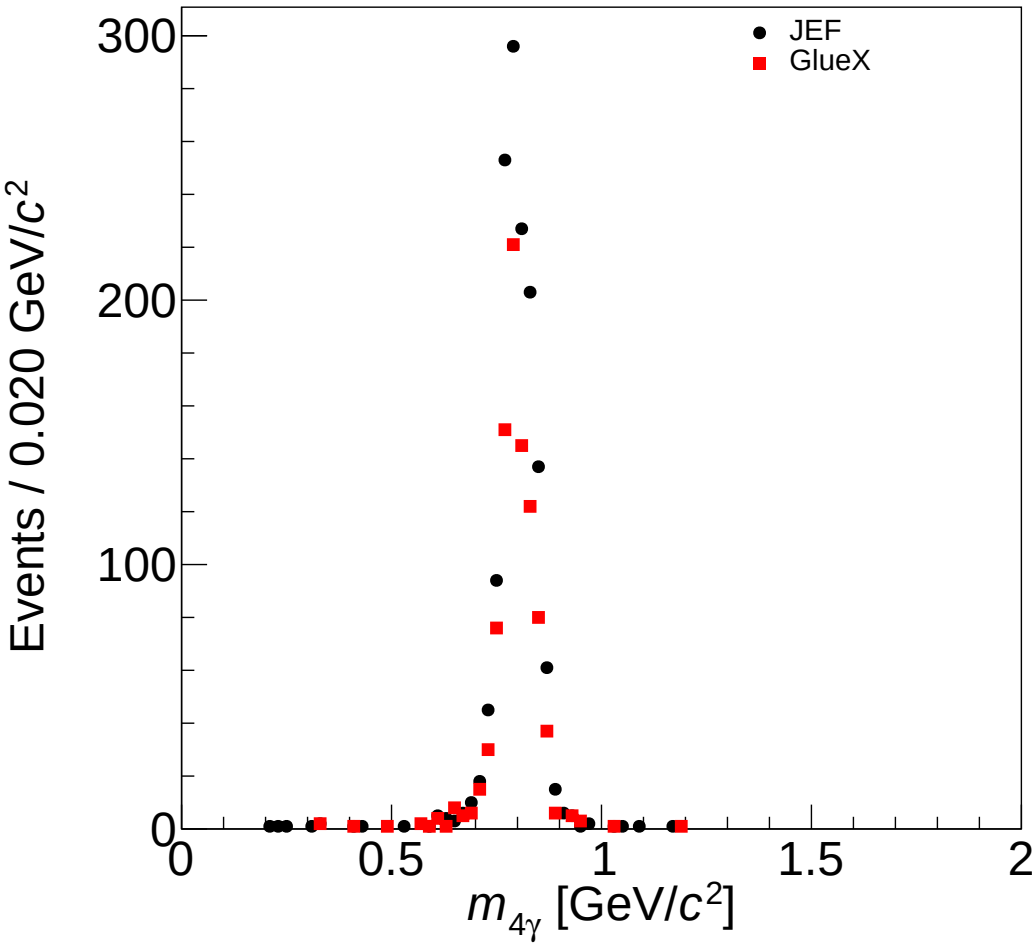
Used master branch, JEF geometry, and island cluster algorithm, baseline selection applied

- 1M Annika's $2\pi^0$
- 40M η decaying into 10 different final states
- 1M Mark D.'s $\omega \to \pi^0\gamma$



Side remark

Comparison between GlueX (run 30496) and JEF for $\omega \to \pi^0\gamma$



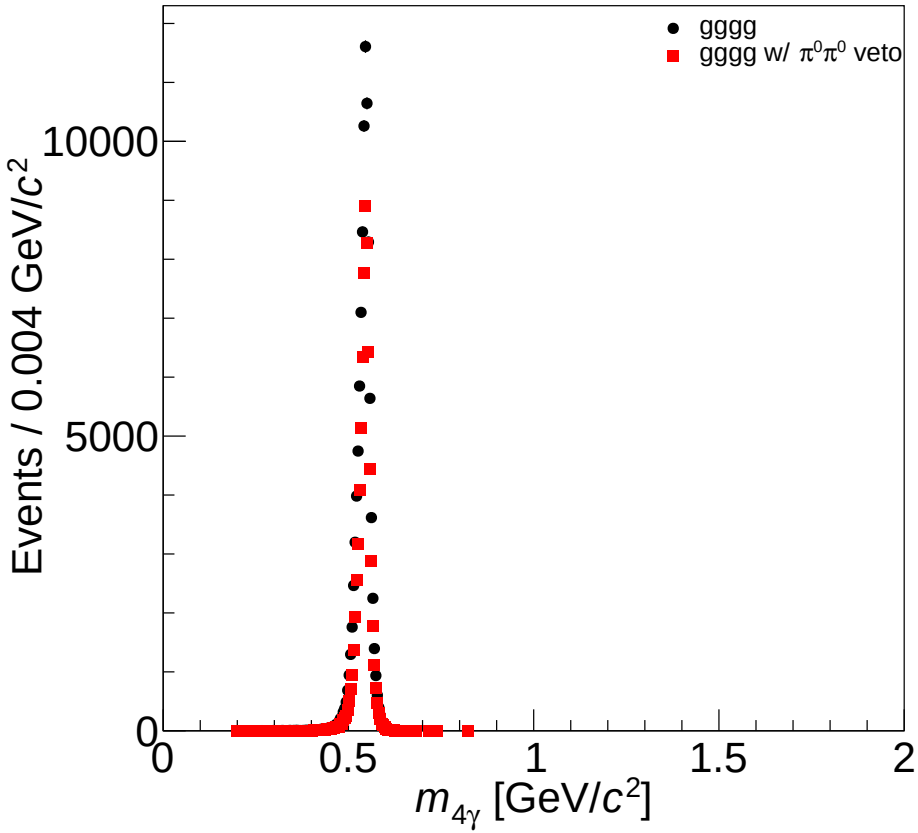
Island cluster algorithm too easily breakdown cluster?

MC simulation samples for TVMA training and studies

Used master branch, JEF geometry, and island cluster algorithm, baseline selection applied

- 1M Annika's $2\pi^0$
- 40M η decaying into 10 different final states
  $\sim$10k $\eta \to \pi^0\gamma\gamma$
  Expected to reconstruct $\sim$ 900 $\eta \to \pi^0\gamma\gamma$ w/ baseline selection
- 1M Mark D.'s $\omega \to \pi^0\gamma$
- 1M $\eta \to \pi^0\gamma\gamma$, $\epsilon \sim 9\%$ w/ baseline selection

```
m_chi2           = 0.428285
m_signal         = 1
m_background     = 1
m_invariantmass2g = 0.374542
m_invariantmass4g = 0.537575
m_missingmasssquare = -0.00012149
m_coplanarity    = 175.253
m_helicity       = -0.993825
m_insertnumber   = 0
m_mandelstam_t   = 1.15188
m_transversemomentum_eta = 1.34863
m_transversemomentum_pi0 = 0.365653
m_transversemomentum_2g = 0.661893
```



Conclusion

$\eta \to \pi^0\gamma\gamma$ revisited as promised

- 1/3 of 2017-01 data set analysed i.e. roughly 10% of JEF expected statistics
- $\gamma p \to \gamma\gamma\gamma\gamma p$
- π^0 and 2 bachelor photons selected by a χ^2-test
- Dominant backgrounds: $\eta \to 3\pi^0$ and $\omega \to \pi^0\gamma$ if $\pi^0\pi^0$ vetoed

MC simulation samples for TMVA training and studies are ready:

- 1M Annika's $2\pi^0$
- 40M η decaying into 10 different final states
- 1M Mark D.'s $\omega \to \pi^0\gamma$
- 1M $\eta \to \pi^0\gamma\gamma$

Chase & Joanna can easily check different combinations of input variables and MVA methods