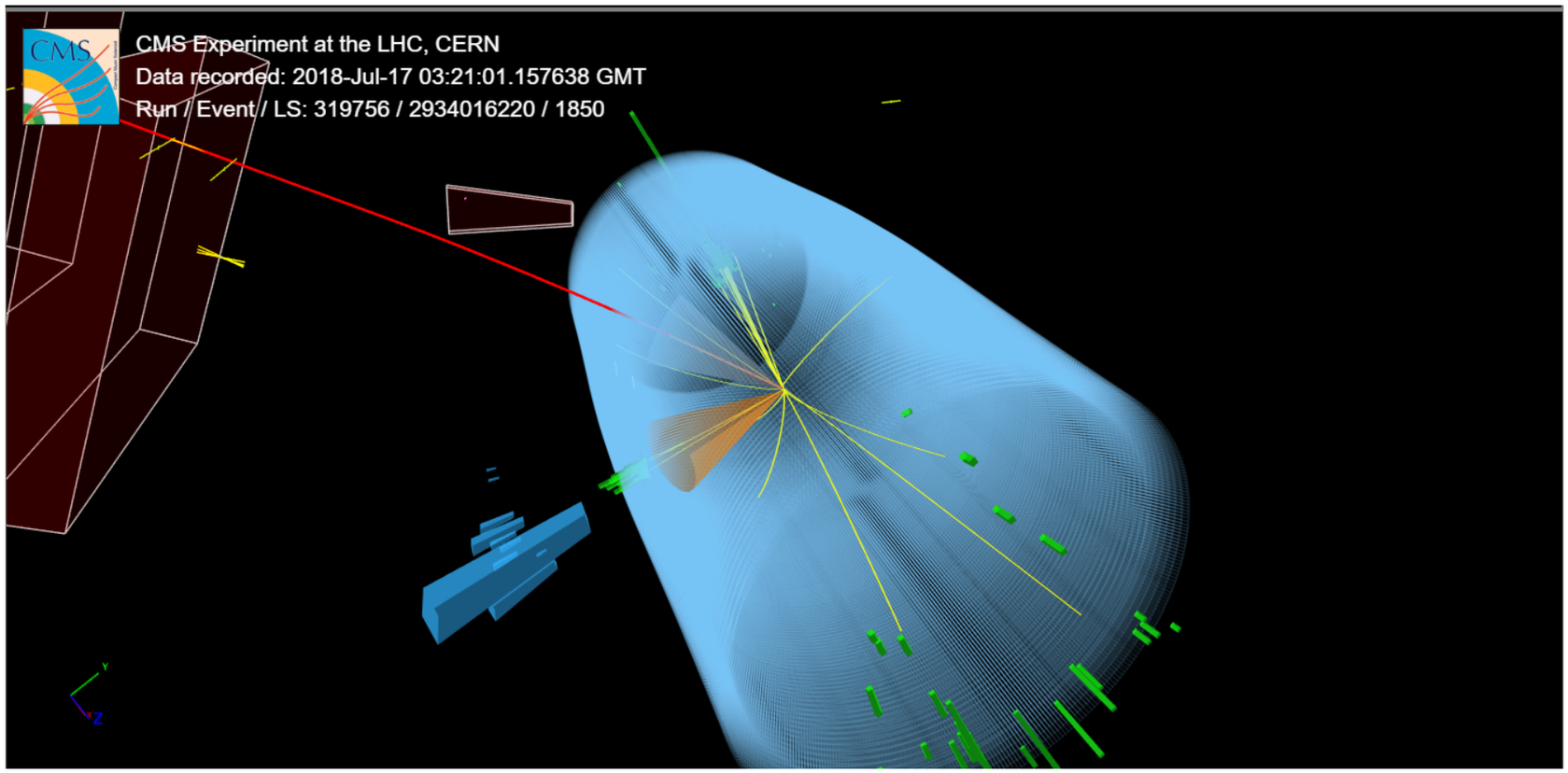
Imperial College London

IC plans for CP measurements in Run 3



Daniel Winterbottom
d.winterbottom15@imperial.ac.uk

Person power

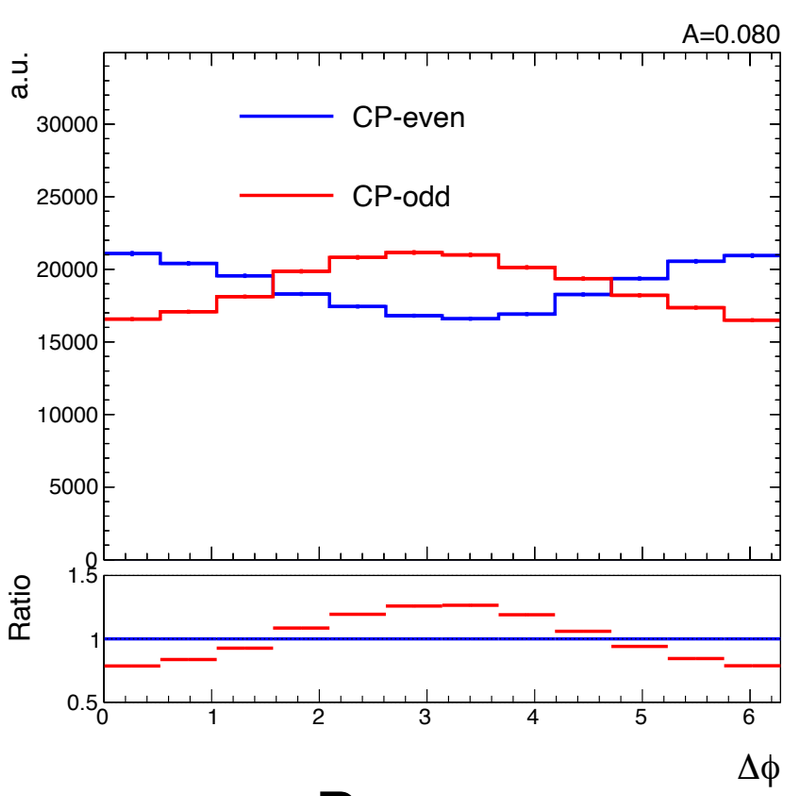
- Senior: David, Sasha
- Postdoc: Me
- PhD students:
  - Klitos (until March 25)
  - Would plan to get another PhD student overlapping with Klitos to take us to the end of the full Run 3 analysis
- MSc students:
  - Qintong (until Sep 22)
  - Possibility to get ~ 1 MSc student per year (masters projects related to HEP+ML)

General aims / plans

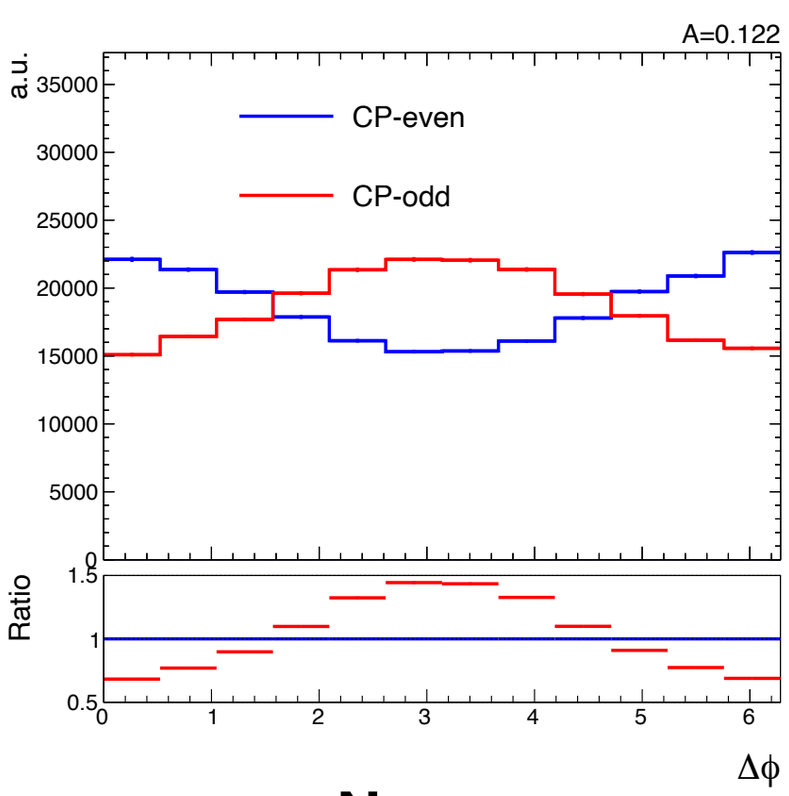
- Produce measurement of CP in HTT decays using Run 3 + Run 2 data
  - New analysis on Run 3 data + either re-analysis of Run 2 or combination with HIG-20-006
- Move analysis methods more towards polarimetric method for other channels
  - At least for a1 decays, and perhaps for other decay modes (i.e including additional information/ constraints e.g MET)
- Extract CP information in ggH production and decay simultaneously
  - Need appropriate MC samples for this
- Improve signal vs background separation
- Improve tau decay mode identification and reconstruction of π0
  - E.g Something similar to this interesting EGM paper about merged photons EGM-20-001

Moving to polarimetric vector method

- Tried very simple procedure to use polarimetric vector method for a1's in other channels
- We take the tau direction from SV-PV (+ a rotation for cases where GJ angle is > maximum)
- Absolute value of tau momentum from SV-fit
- Despite procedure being simple a significant improvement is observed in the separation e.f for ρ-a1 channel



Paper



New

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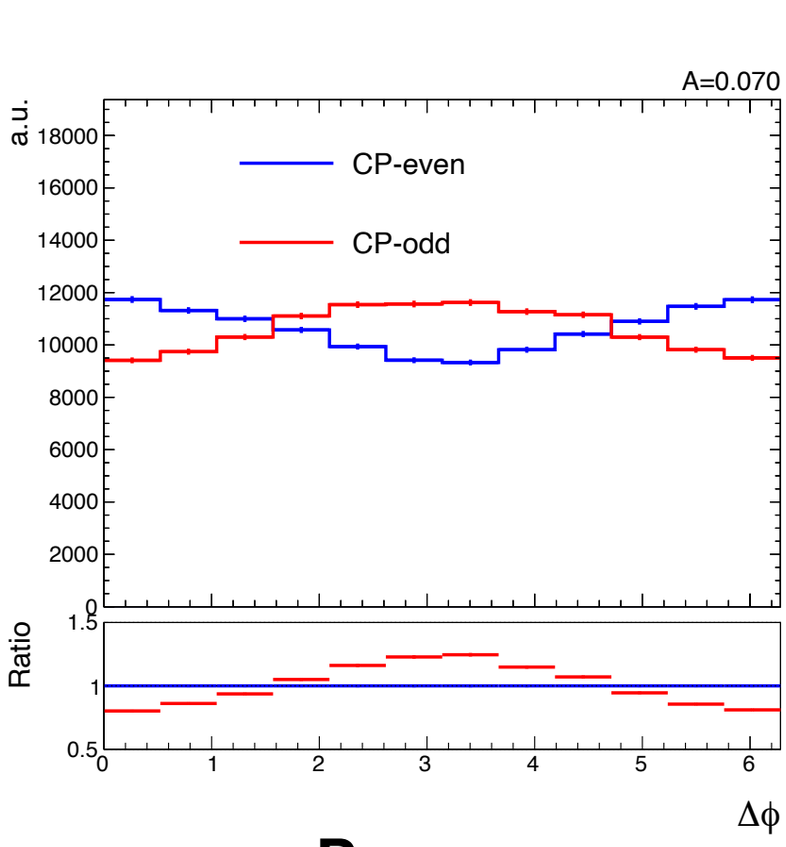

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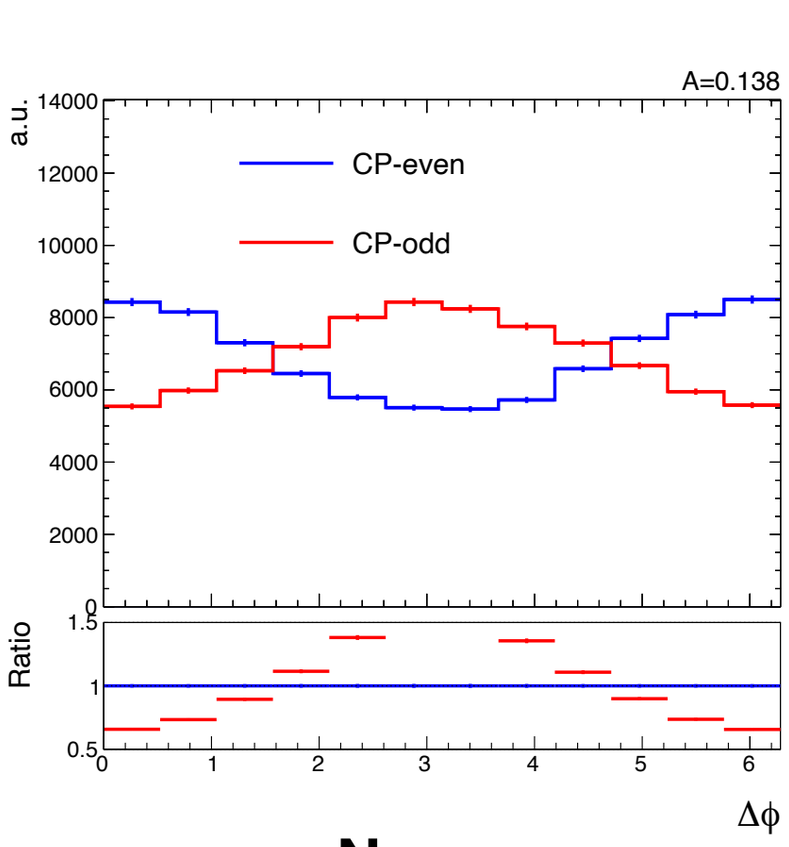


New

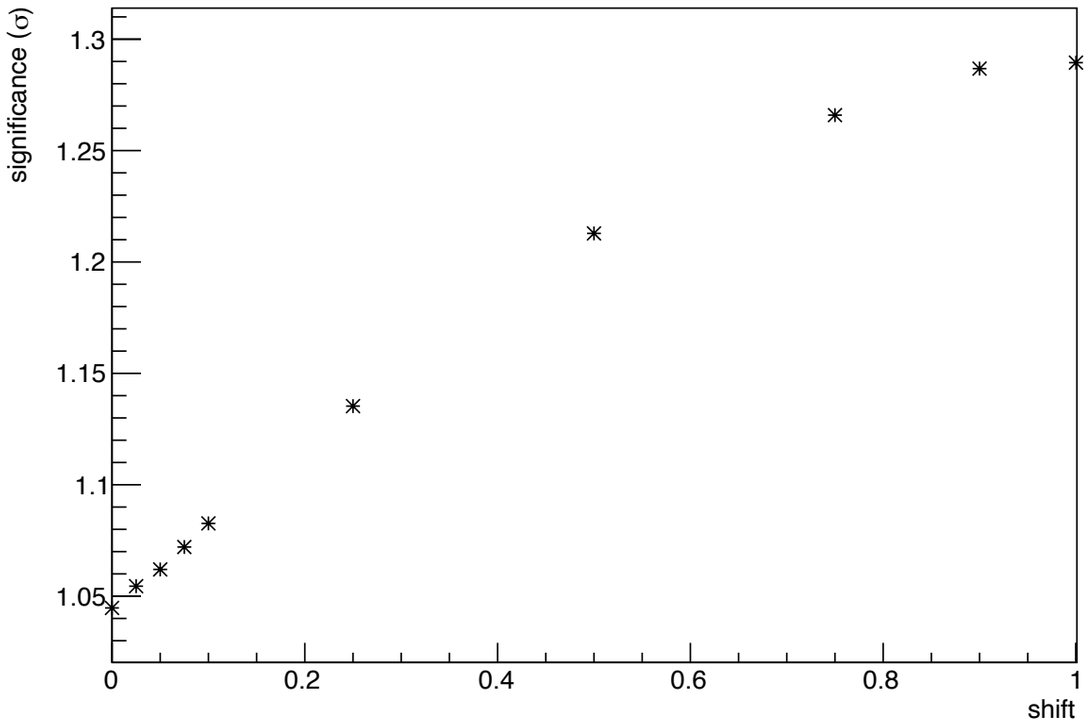
Improvements to significances

- Checked improvement in tt channel from using the police method for the a1's
- Significance with old method = 1.87σ
- Significance with new method = 2.06σ
- Gives ~ 8% gain overall
- Could do better if we can use finer binning for the a1 channels (we use 4 bins compared to 10 for most sensitive channels)
- Could also improve these channels further by rejecting more fake background events in SR

Improving tau decay mode identification and reconstruction of π0

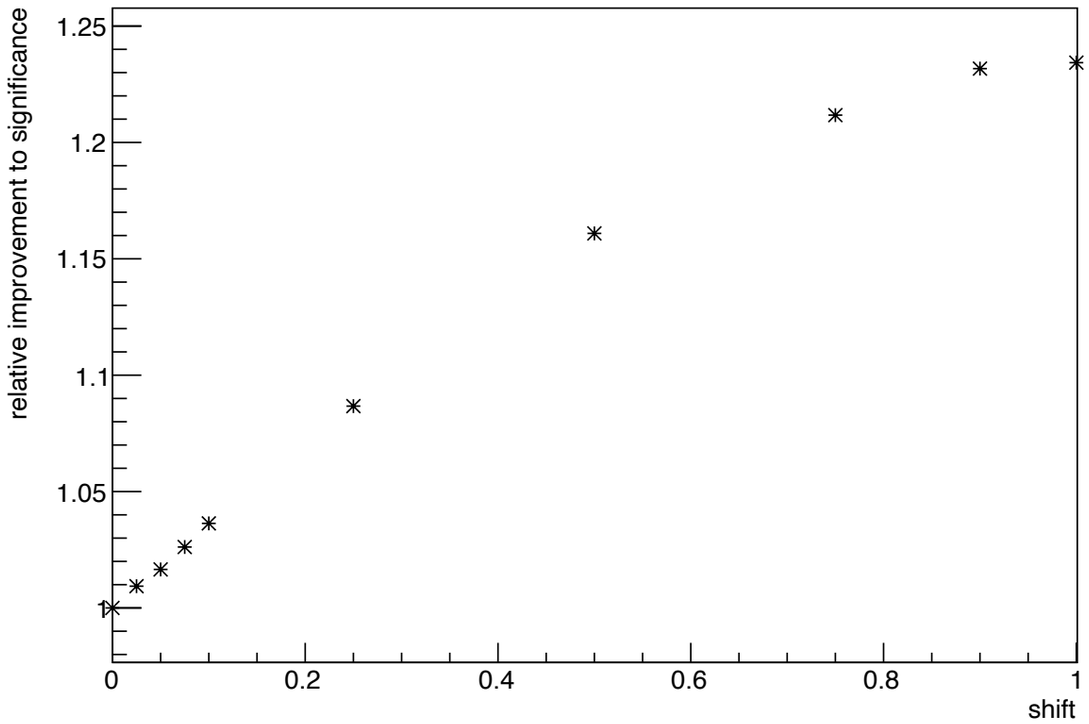
- Check how much improving angular resolution on pi0's will improve the CP-even vs CP-odd sensitivity
- Shift reconstructed pi0 ϕ and η closer to generator values
- $\phi' = (\phi_{gen}-\phi)*shift + \phi$; $\eta' = (\eta_{gen}-\eta)*shift + \eta$
- Current resolution: shift=0, perfect reconstruction: shift=1

ρρ



Absolute significance

ρρ



relative improvement

Improving tau decay mode identification and reconstruction of π0

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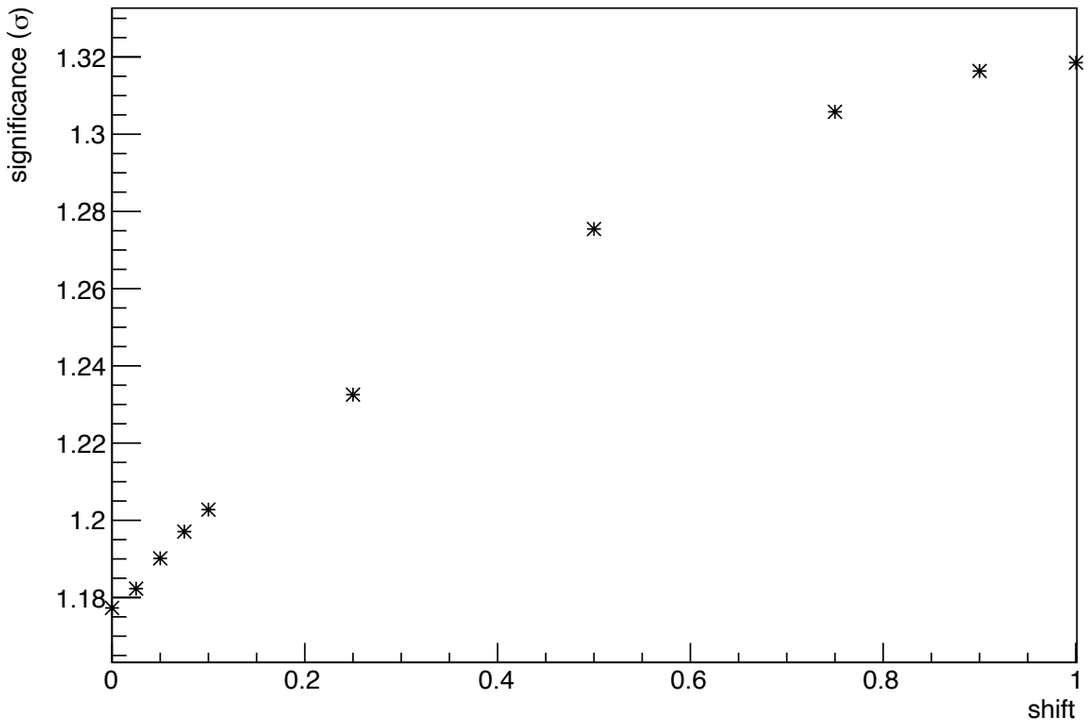
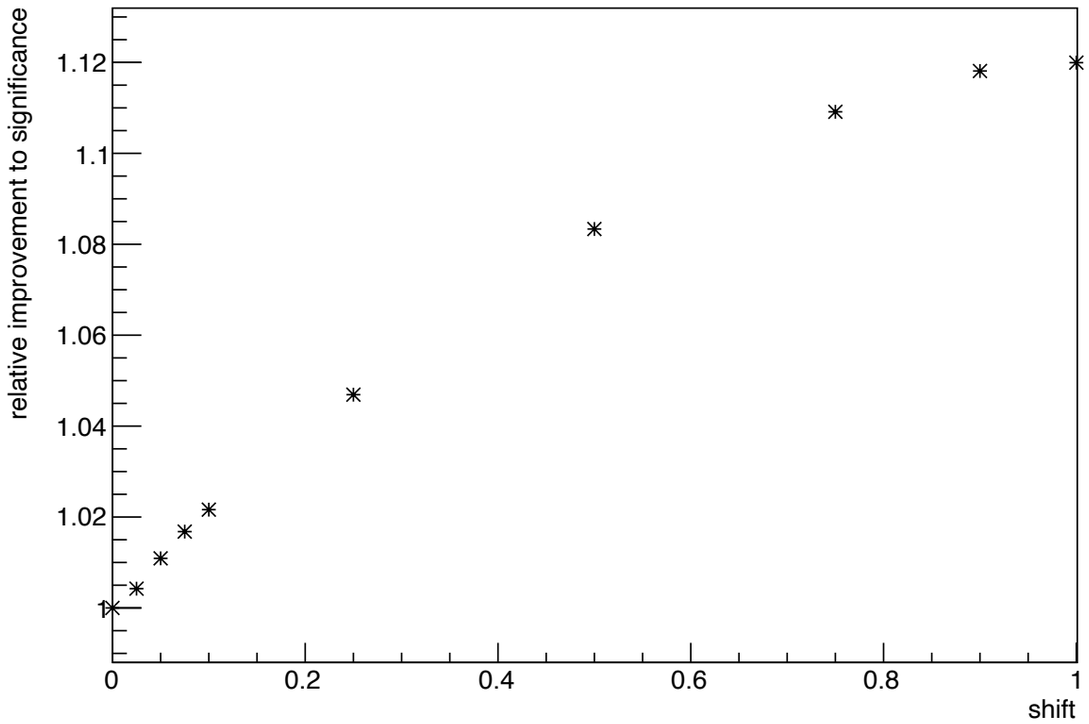
πρ



Absolute significance

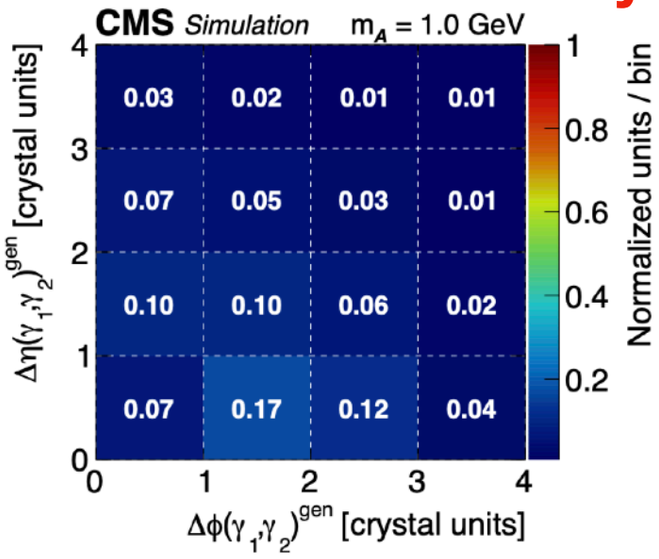
πρ

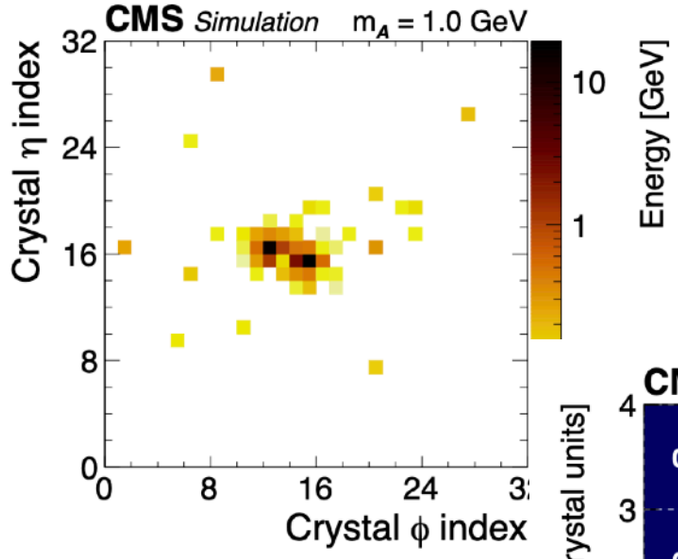


relative improvement

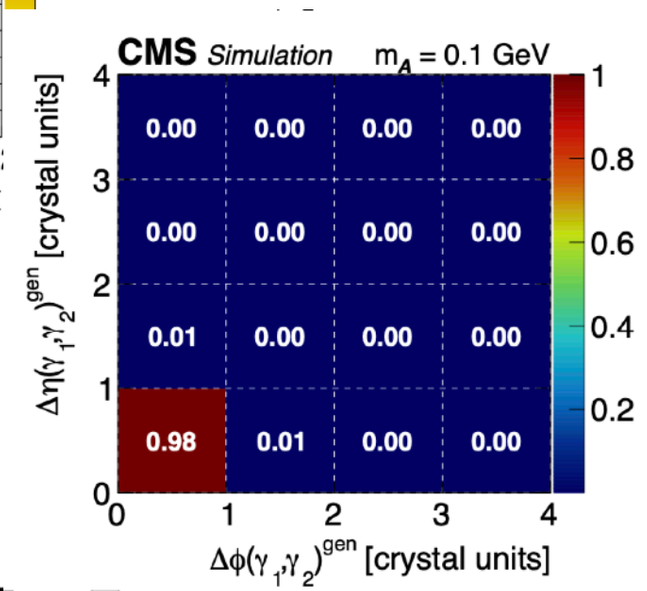
- Few plots taken from EGM-20-001

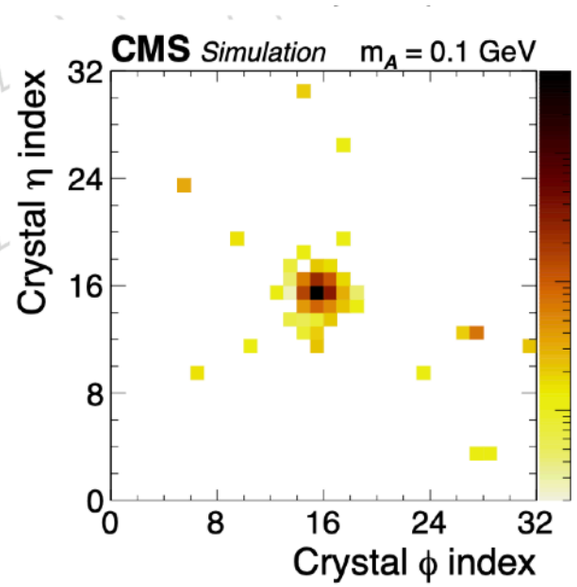
"Barley resolved"



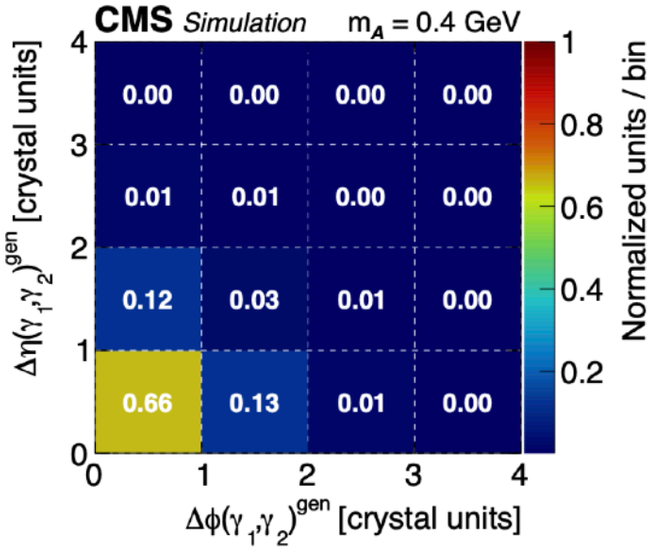


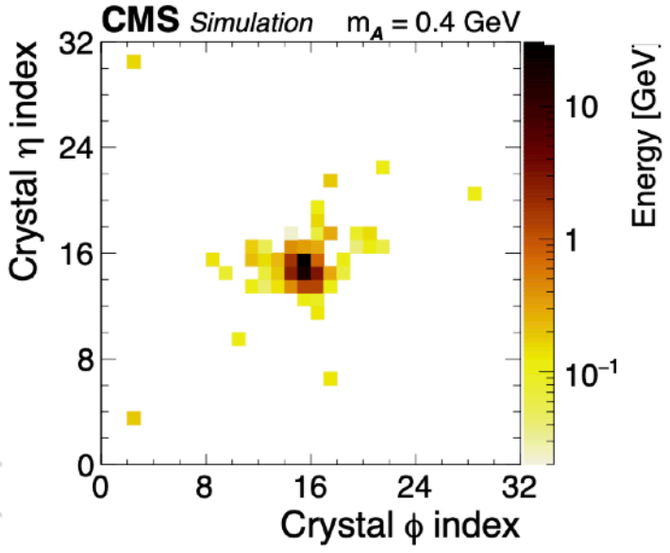
"instrumentally merged"





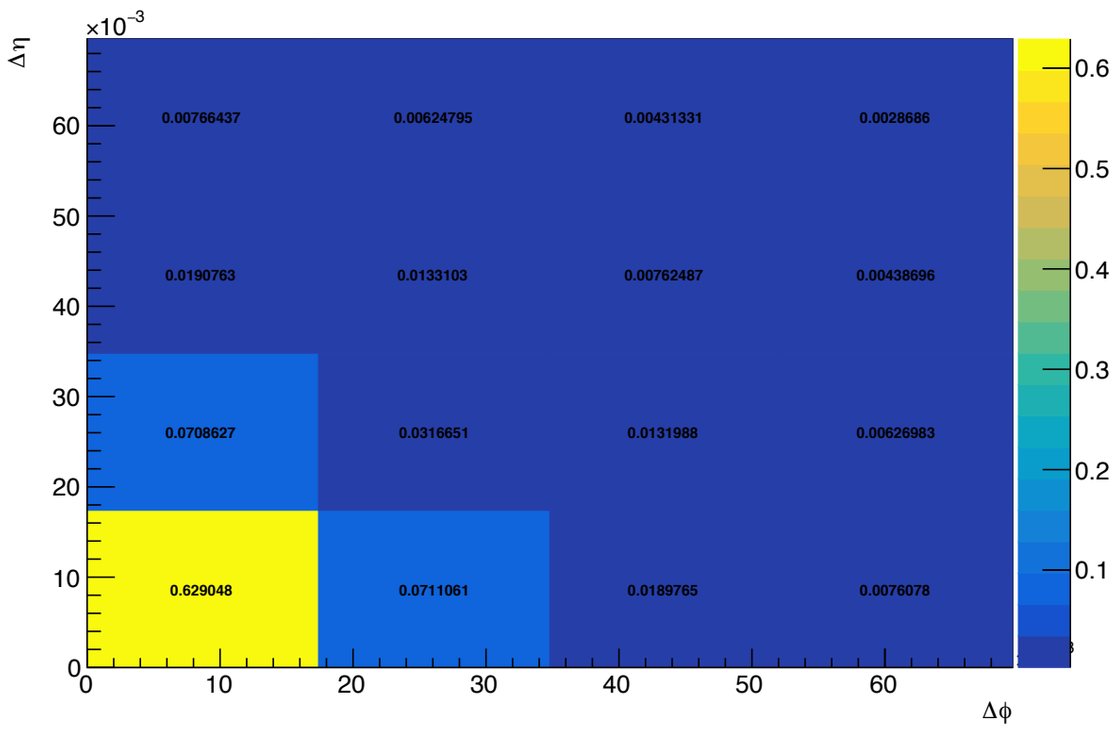
"Shower merged"



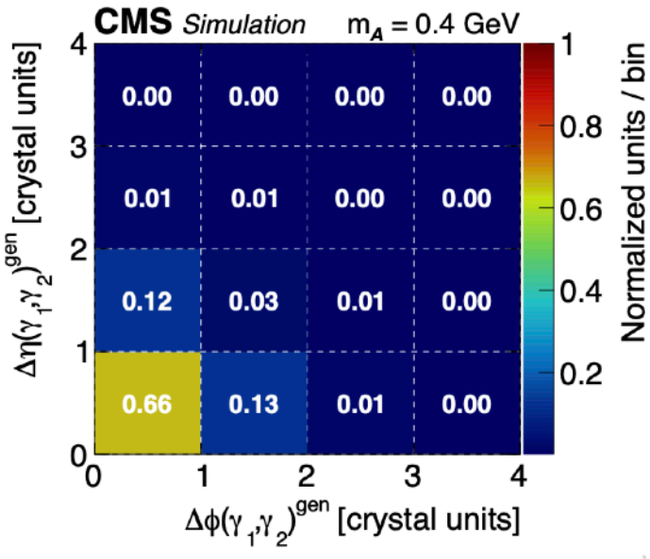


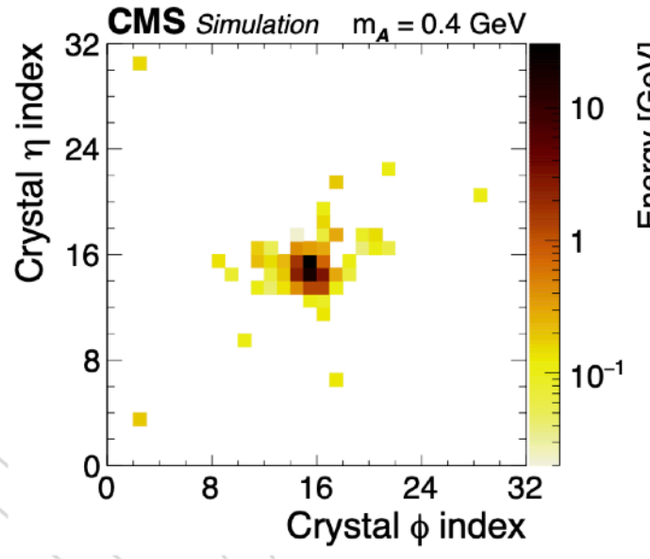
- From VBF MC sample of ρ decays our situation is closest to “Shower merged” scenario

- In the paper this is arguably the category where the largest improvement is observed



“Shower merged”

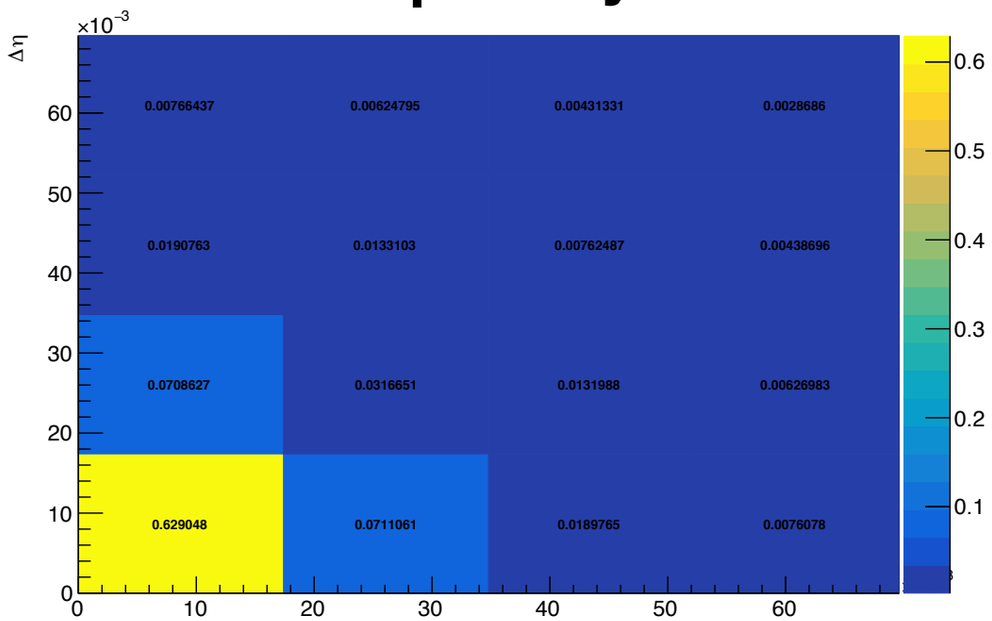




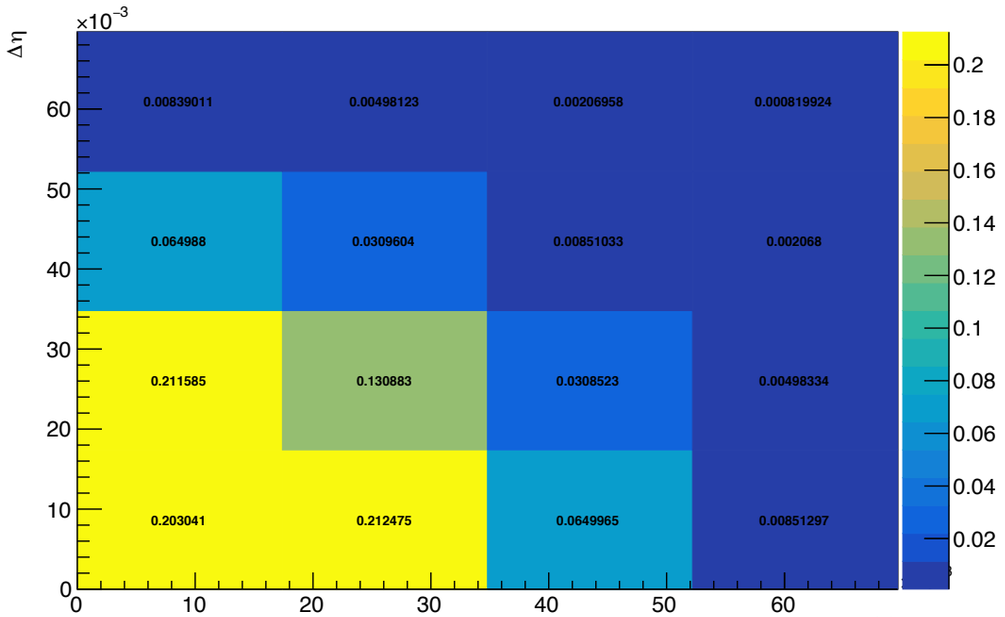
Other improvements of using ML for pi0s

- We will likely recover some events where HPS does not identify any pi0 (~20% of ρ decays fall into this category)
- We will likely be able to improve the decay mode identification accuracy
- We may be able to resolve 2 pi0's in some cases for a1 decays and may be able to define a more sensitive CP-observable in this case

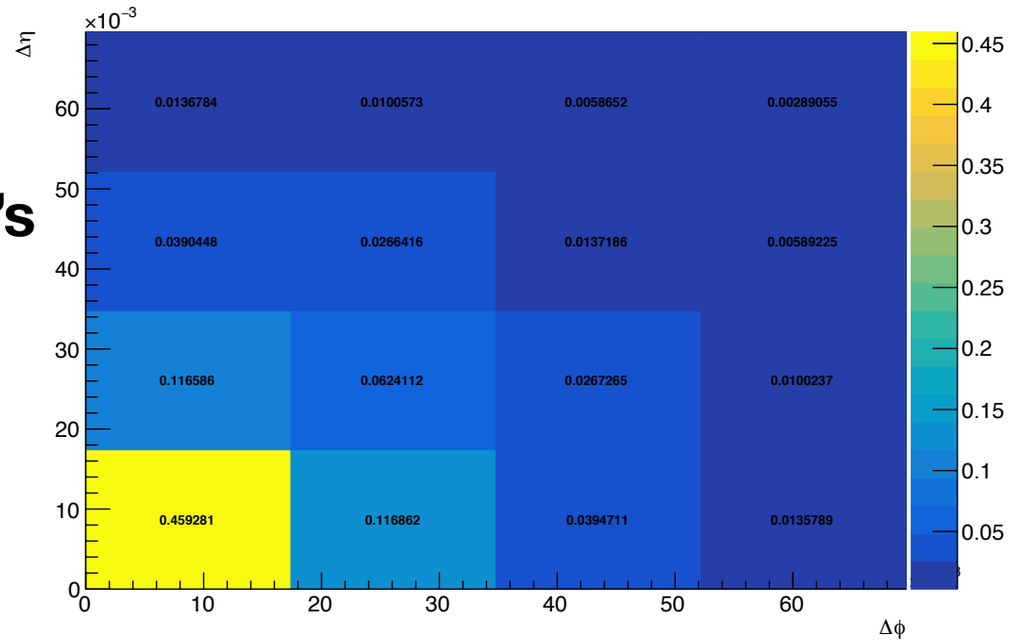
Separation between gammas for ρ decays



Separation between charged pi and pi0 for ρ decays



Separation between pi0's for a1 decays



MC samples

- VBF+VH: Plan to use same setup as for Run 2 but will m make requests for Run 2 UL samples + eventually Run 3

- For ggH if we want to measure CP in production and decay need samples that can model production side

  - For HIG-20-007 we used Madgraph for this but large number of negative weights made this tricky (~9x as many events needed for NLO vs LO)

  - However now possible to use a Madgraph+POWHEG interface (https://arxiv.org/abs/2008.06364) to reduce the number of negative weights (now need only ~ 1.5x as many events compared to LO)

  - Already tested this for a few events - see right

  - Update: preparing gridpack for Run2 SM case, generation seems very slow when using gridpacks compared to using standalone code - need to understand why