Uniqueness Tracking Revisited

Tests conducted on MC for the reaction:

$\gamma p \rightarrow a_0(980)\ p \rightarrow \pi^0\ \eta\ p \rightarrow 4\gamma\ p$

$\gamma p \rightarrow a_2(1320)\ p \rightarrow \pi^0\ \eta\ p \rightarrow 4\gamma\ p$

Overview

Using Thrown information to determine performance of {Accidental Subtraction, Combination Tracking} weighting

- Probability Weights as an alternative to Best $\chi 2$ and Equal Weights
- Performance of accidental subtraction
- How to combine accidental weights with combination tracking weights?
- How to include sideband subtraction (on the masses)?

Methods of doing combination tracking

Best χ2

vs

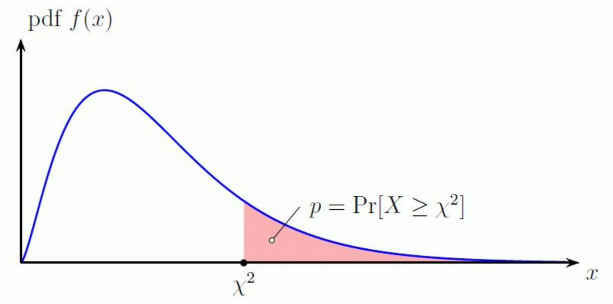
Weight by #combos passed selections in event

Both are limits of another approach. We cannot easily compare two χ2 values but given:

χ_1^2, χ_2^2, χ_3^2. We can convert all χ^2 into probabilities p_1, p_2, p_3. Then the weight for each combo would be $\frac{p_i}{\sum p_i}$

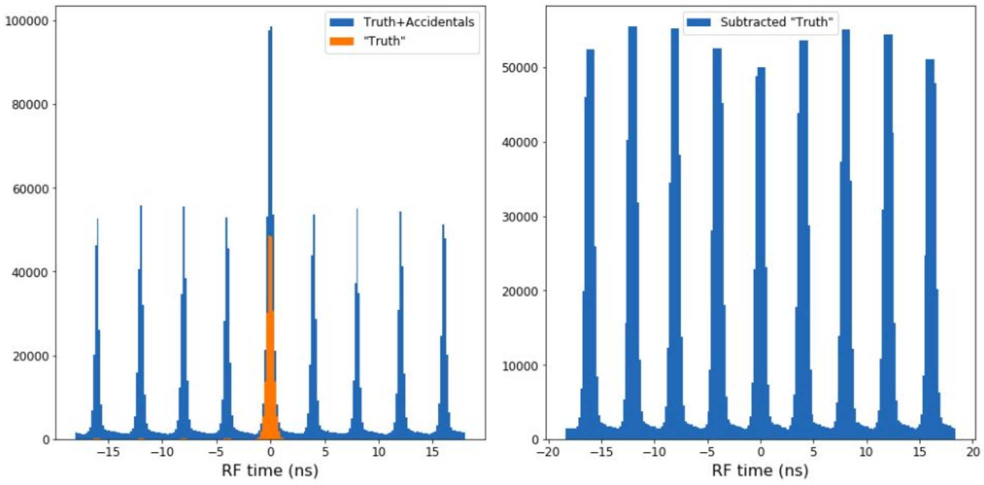
Best χ2 is when $\chi2_i << \{\chi2_j\}$ for $i \neq j$
Weighted approach is when $\chi2_i = \chi2_j$ for all i,j

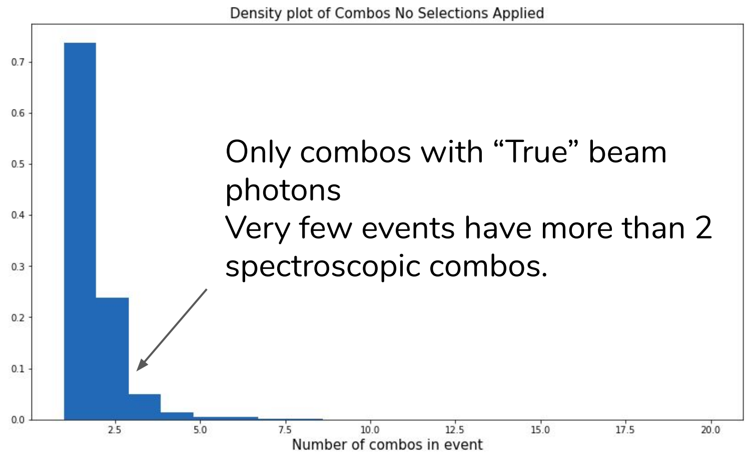
- At first glance it would seem that Best χ2 has high bias, weighting scheme has low bias but omits useful information. Compromise?
- Does not matter that the bottom sum can be > 1 since we really care about how much more likely one combo is than another

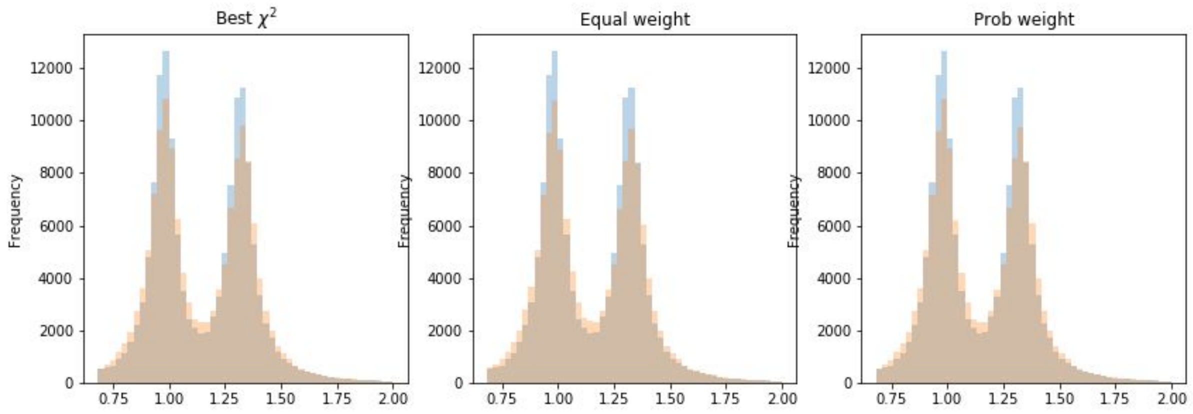


Removing Accidentals Before checking Spectroscopic combinatorics

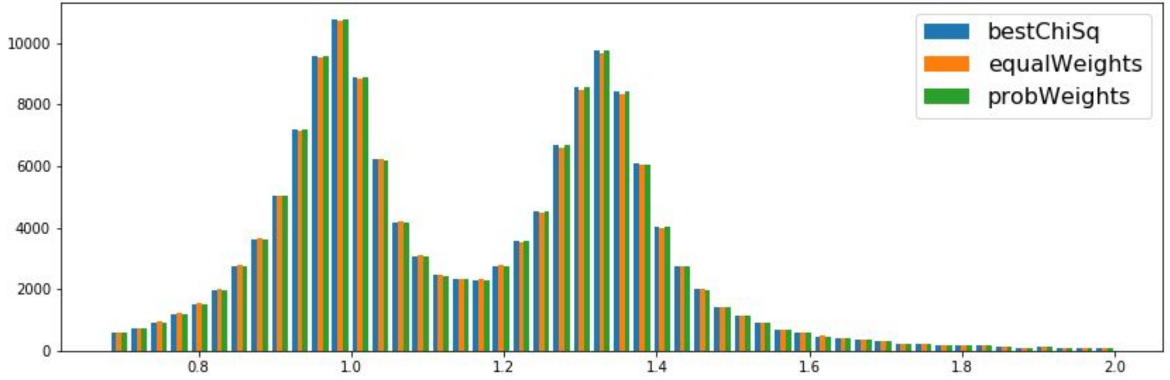
- Jon suggested to equate the photon beam energies (rare to have accidentals hit the same tagger counter) to get the "True" beam photon.
  - (LEFT) RF time histogram plotted with all the combos (blue) and just the "True" Beam photon (Orange)
  - (MIDDLE) The subtraction of the Orange from the Blue histogram. Looks okish for now
- (RIGHT) Density plot of the number of combos in event with only "True" beam photons







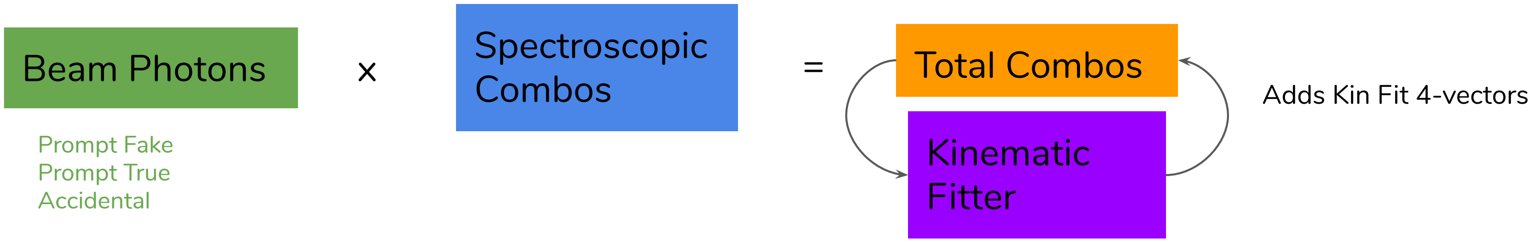
Blue - Thrown M(pi0eta) where at least one combo passed CUT
Orange - Combination tracking passing same CUT with different tracking schemes



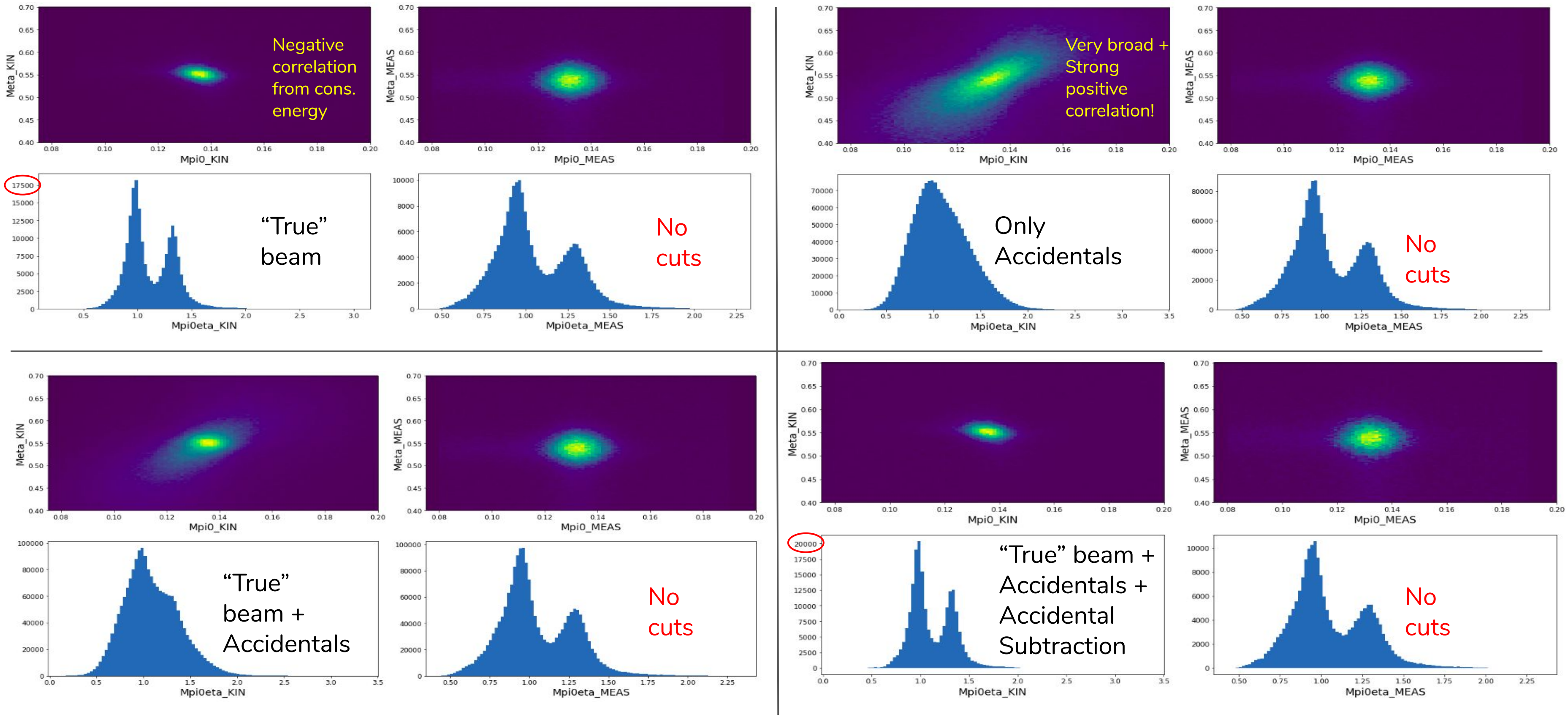
Overlaying the results from the 3 different tracking schemes

CUT = None

Only “True” beam photons



- If we include Accidentals we get a lot more total combos. Kinematic fitter will modify all the measured $M\pi\eta$. Thus, if we include accidental photons and depending on the selections we will see big differences between "equal weights" approach and the others since it does not use any additional information
  - A selection on the invariant masses M(pi0) and M(eta) is going to remove a lot of accidentals (as can be inferred from the next slide), and so will a selection on the ChiSq



- These are all recon values, not thrown. “True” would consist of all the reconstructed combos that have the correct beam photon. Accidentals would consist of all the combos that does not contain the correct beam photon (I include other prompt photons also). Will show a small comparison with Thrown later after I introduce another idea

* Binning is different

“True” beam

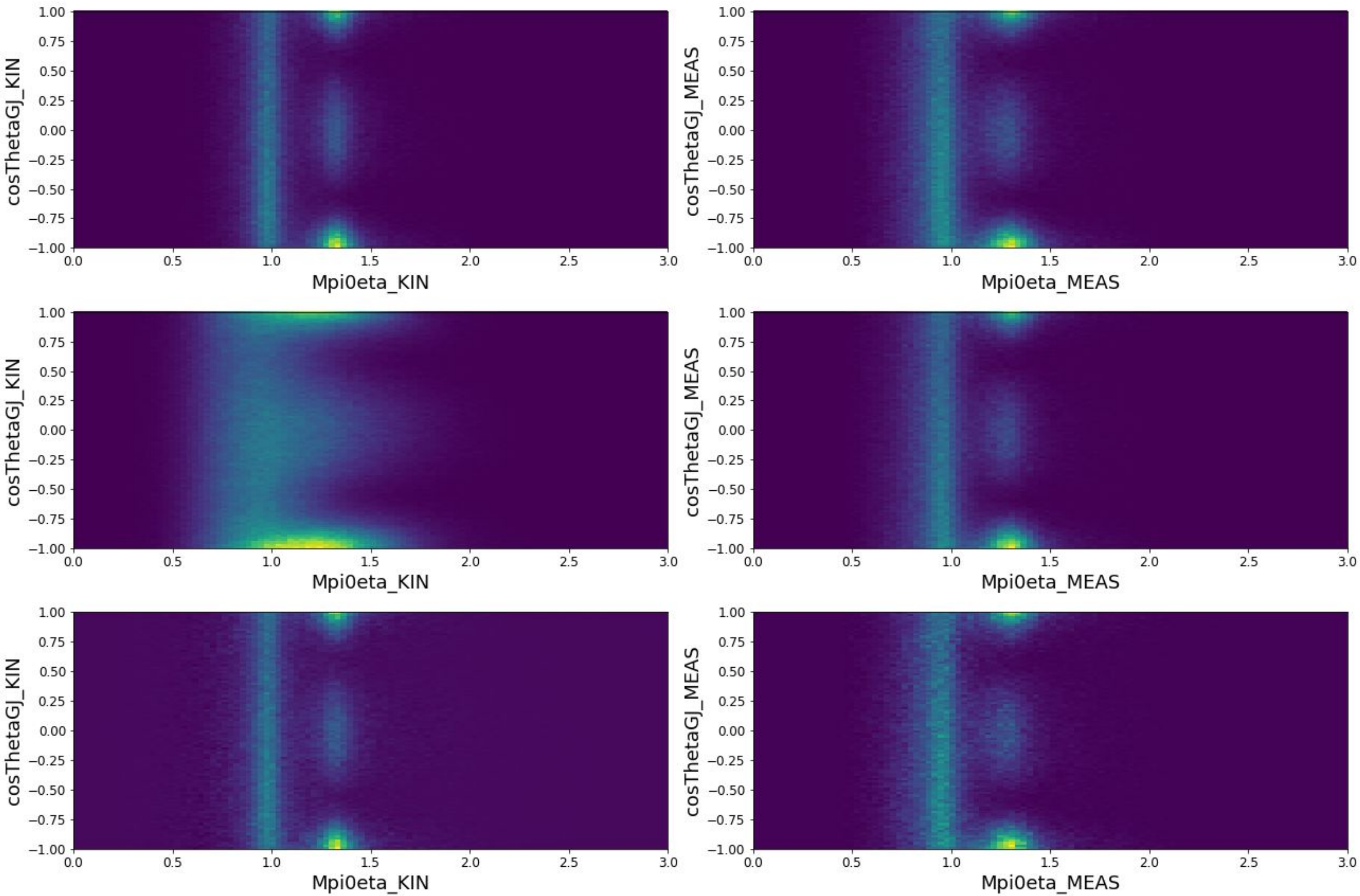
No cuts

Only Accidentals

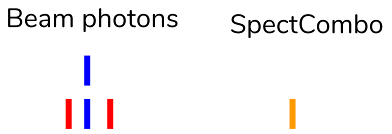
No cuts

Accidental Subtracted looks like “True” - Good!

No cuts



Working through a very specific ideal example to highlight the problems



OVERALL GOAL: We want a total integrated amount of 1 in our histogram per event.

Propose:

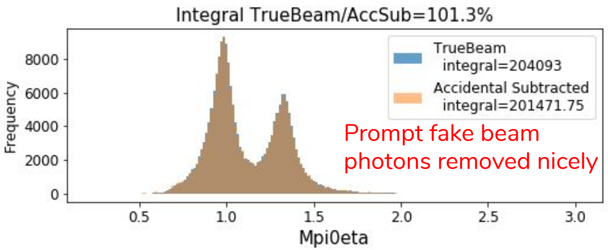
$$W_{ij} = \frac{p_{ij}}{\sum_{j \in spect} p_{ij}}$$

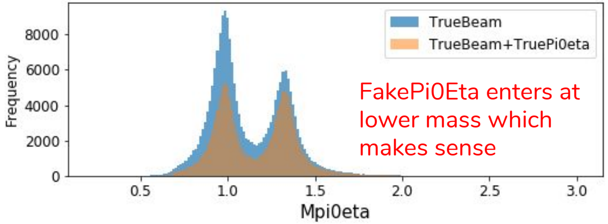
$$\sum_{j \in spect} W_{ij} = 1$$

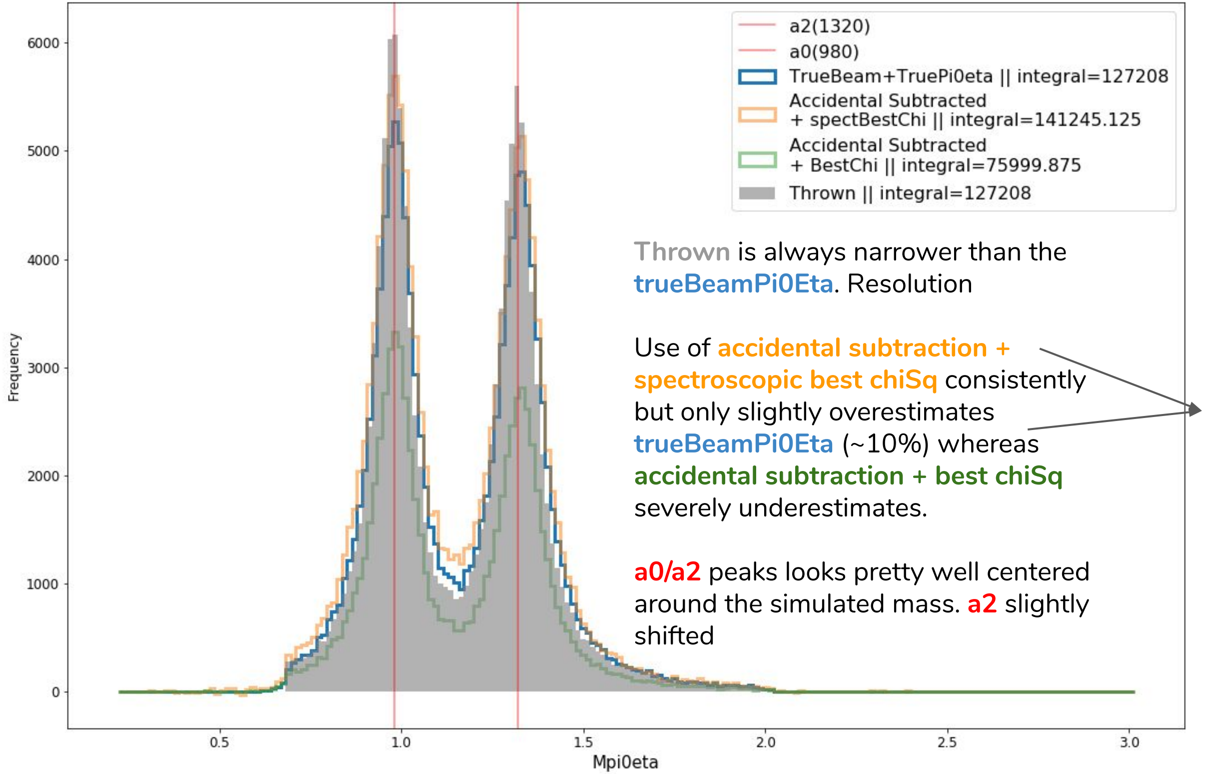
$$\sum_{i \in beam} \sum_{j \in spect} W_{ij} = N_{Beam}$$

Given 2 prompt photons, 2 accidentals, 1 spectCombo:

- If no combo tracking: accidental subtraction would make it seem like we have 1 prompt and 1 spectCombo. i.e. the two accidentals will cancel the effects of one of the prompt photons. In total this would have a weight of 1 for this event. This is what we want.
- Since we know all 3 tracking schemes are related we will look at "equal" weights first. If we use "equal" weights then we would basically have the same situation as above but scaled by ¼ since each combo is scaled by ¼. This is not what we want since the total event weight is now ¼.
- The combo counting and accidentals are not independent and in some ways double counts. When doing combo tracking, we need to ignore extra beam photons. How can we do this?
  - For "equal" weight each combo weight should then be $1/N_{Spect}$ where N_{spect} is the number of unique spectroscopic combos for a **given** beam photon. In this case there is only one spectCombo and thus one value of j. Then, W_{ij} = 1 for all i,j.
  - "BestChiSq" would then be related to the best chiSq among the spectroscopic combos for **each** beam photon i. Then, W_{ij} = {1,0} for every j.







No cuts used anywhere

With some selections (i.e. unused energy or shower quality...) hopefully they look more similar.

The goal probably is not to compare to the Thrown but to the trueBeamPi0Eta

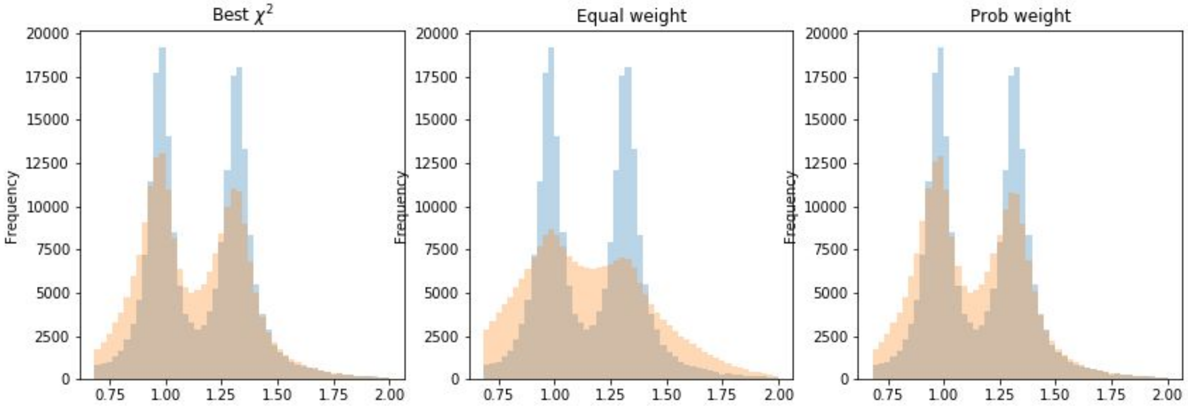
Extra thoughts

- Event counting vs signal counting: Sideband subtraction (on Mpi0 vs Meta) can be included independently at this point. **It is not a way of counting combos to try and enforce the goal of adding an integrated amount of 1 to the histogram per event but rather a way of handling backgrounds.** I think this distinction is important. i.e. we do not know that for every event we have a signal we just know we have an event (technically we kind of do in this case since this is MC).

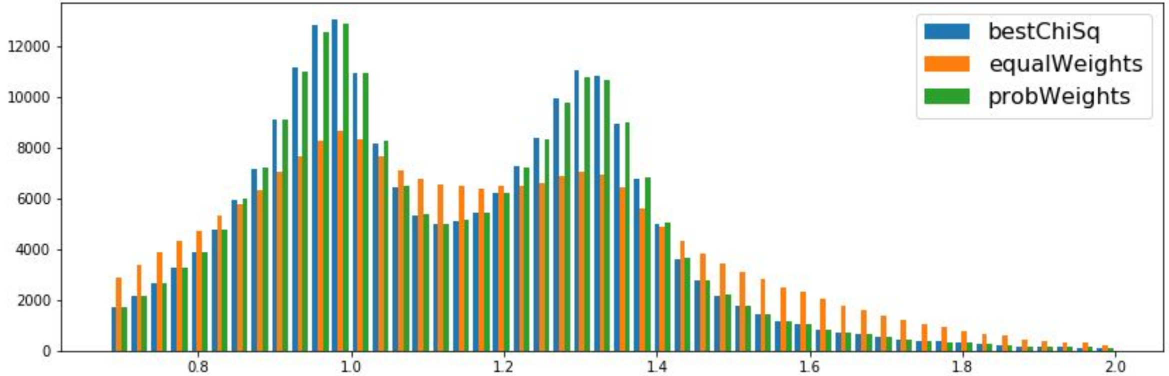
Next Steps

- Does including extra selections like Unused energy, FCAL shower, etc improve the similarity between the blue and orange curves from previous slide?
- Think about whether I should/shouldn't add a global selection on $\chi2$.
- Look into sideband subtraction
- Final comparison is made only with best $\chi2$ tracking. Need to implement "equal" and "probability" weighted tracking schemes

Backup Slides/Old
+
What if Accidentals are not removed?

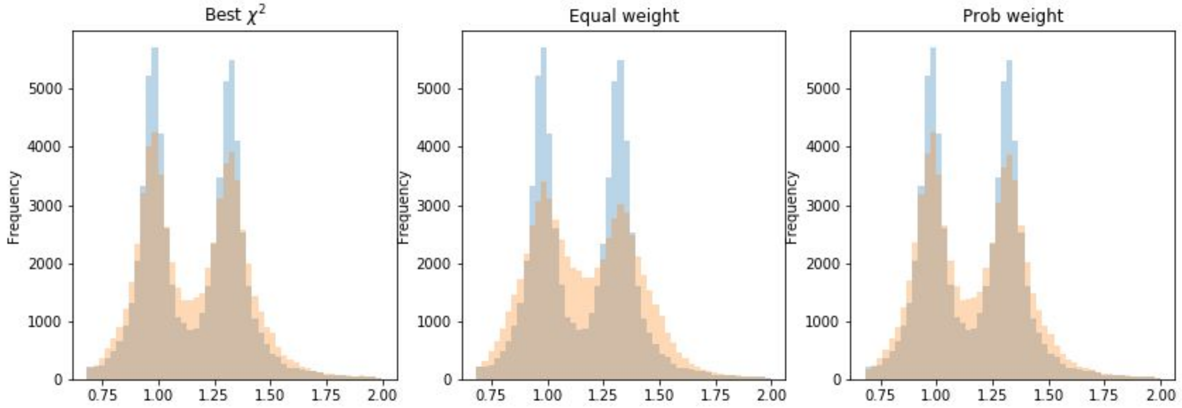


Blue - Thrown M(pi0eta) where at least one combo passed CUT
Orange - Combination tracking passing same CUT with different tracking schemes



Overlaying the results from the 3 different tracking schemes

CUT = None



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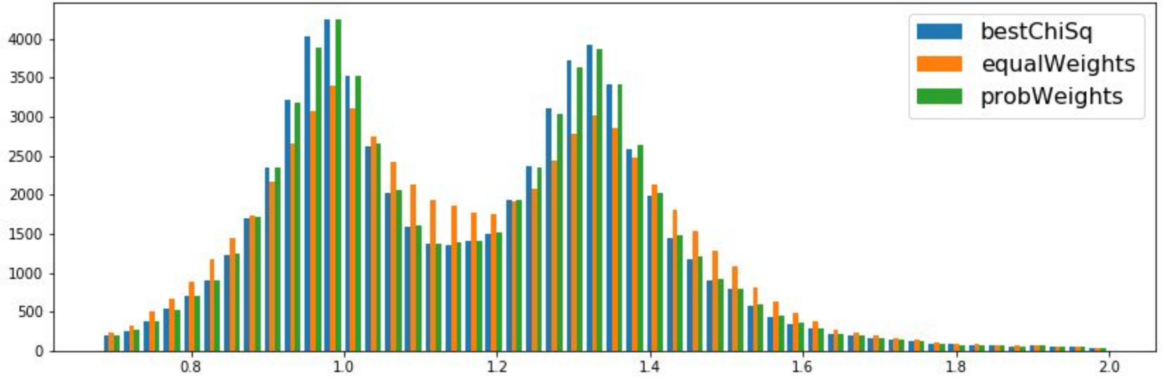
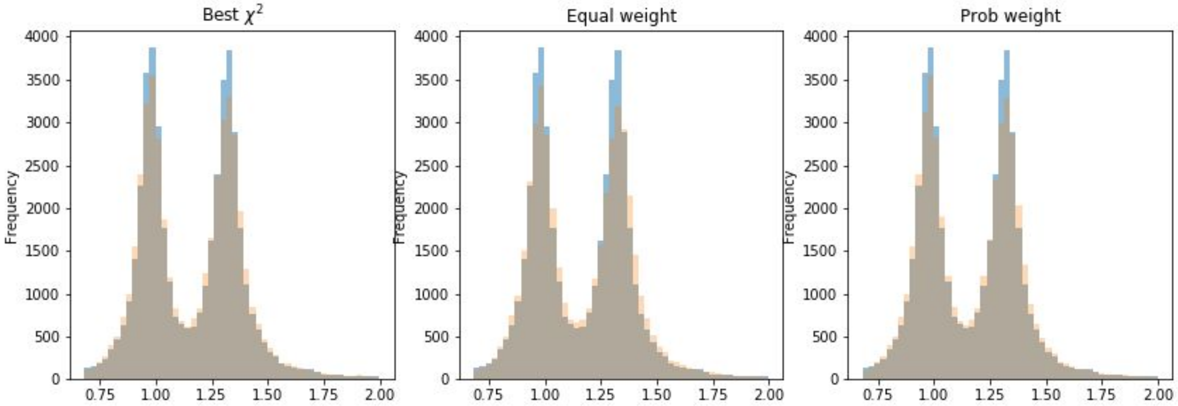


Overlaying the results from the 3 different tracking schemes

CUT = No selection on M(pi0) and M(eta). Has loose chiSq and Unused Energy cut

- + Some basic cuts (like proton from target, FCAL shower, MMSq …)



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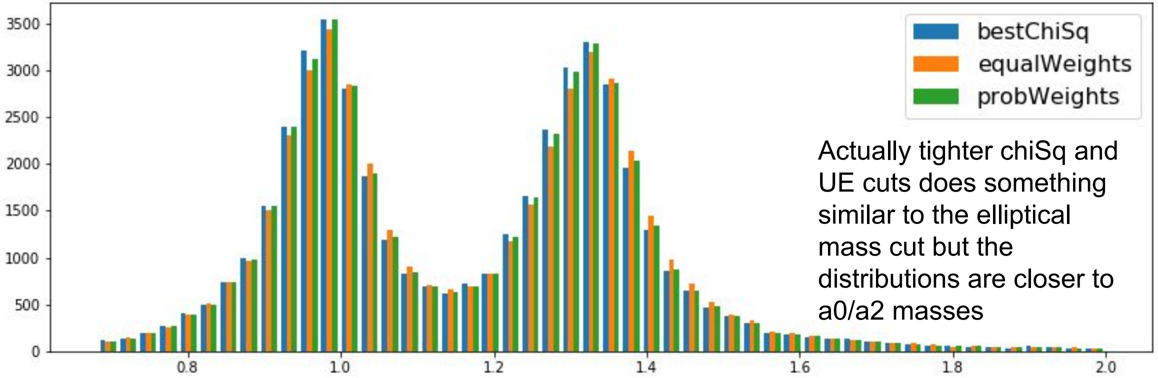
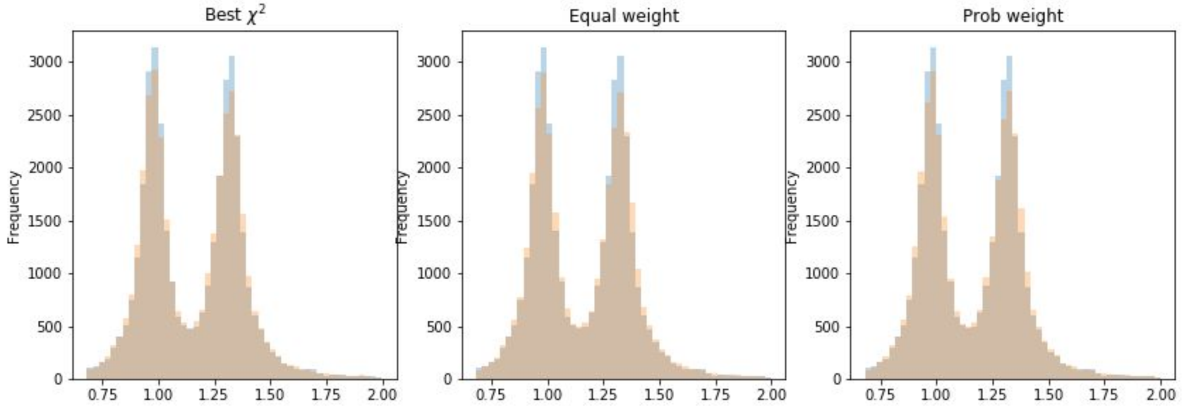


Actually tighter chiSq and UE cuts does something similar to the elliptical mass cut but the distributions are closer to a0/a2 masses

Overlaying the results from the 3 different tracking schemes

CUT = elliptical mass selection on M(pi0) and M(eta)

- + Some basic cuts (like proton from target, FCAL shower, MMSq …)



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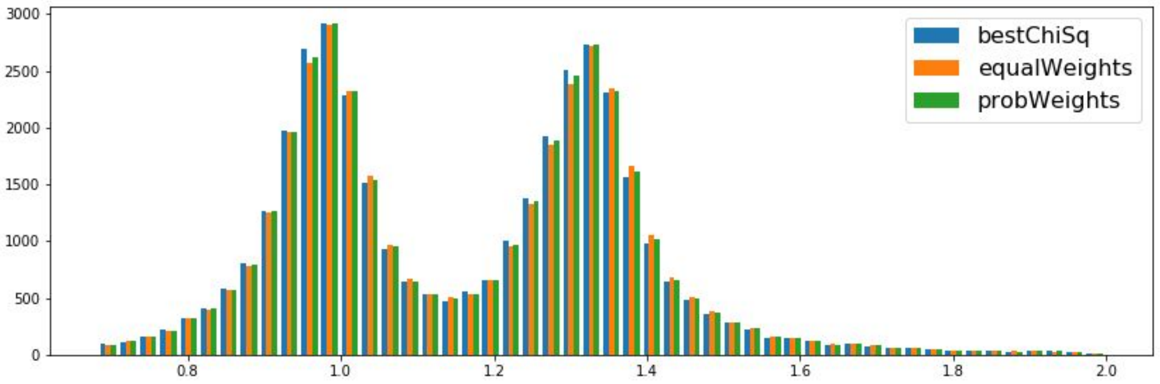


Overlaying the results from the 3 different tracking schemes

CUT = elliptical mass selection on M(pi0) and M(eta) + tighter chiSq and unused energy cut

- Some basic cuts (like proton from target, FCAL shower, MMSq …)

What does this tell us?

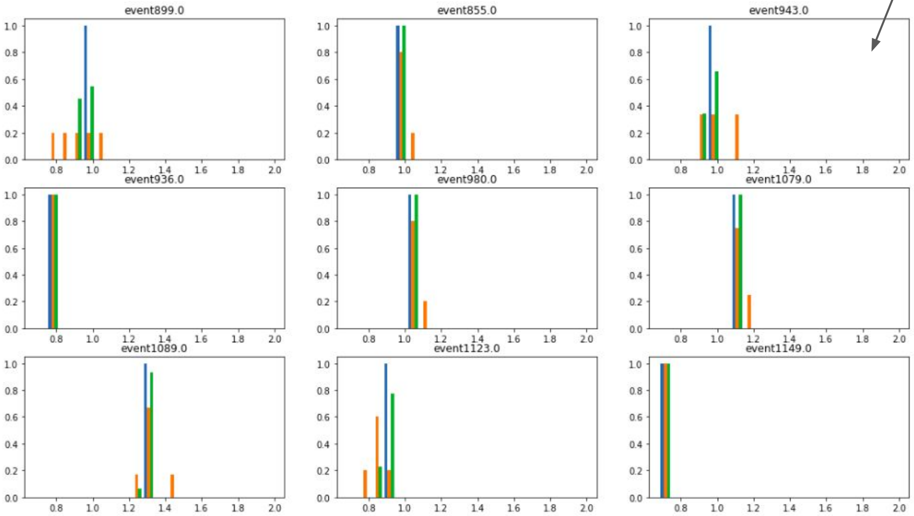
- Yields of Mpi0eta averages out pretty nicely even though there are significant differences between equalWeights and probWeights in the last case with tighter chiSq/UE/Mpi/Meta/etc cuts applied. Not so much with no cuts.

- Best ChiSq tracking scheme is very similar to the probability weighted tracking scheme even with NO selections applied. We can see differences on an event-by-event case but the Mpi0eta distribution avgs out nicely as an ensemble very quickly. Even with a few dozen events
  - Does this extend to other analyses? Should it?
  - It is too early to say but it seems like the choice of tracking scheme does not matter as much for cross sections but will for combo based analysis techniques like Q-factor sideband subtraction. Should probably check GJ angles to see how PWA might be affected

	Mpi0etas	bestChiWeights	chiSqs	equalWeights	eventNumber	probWeights
6	1.143075	1.0	2.204685	0.125	5334.0	0.216530
7	1.202340	0.0	10.358332	0.125	5334.0	0.010795
8	1.128230	0.0	3.966017	0.125	5334.0	0.127351
9	1.142028	0.0	2.279526	0.125	5334.0	0.212290
10	1.122824	0.0	4.980085	0.125	5334.0	0.089738
11	1.121735	0.0	5.208148	0.125	5334.0	0.082683
12	1.120645	0.0	5.444733	0.125	5334.0	0.075869
13	1.169166	0.0	2.777716	0.125	5334.0	0.184745

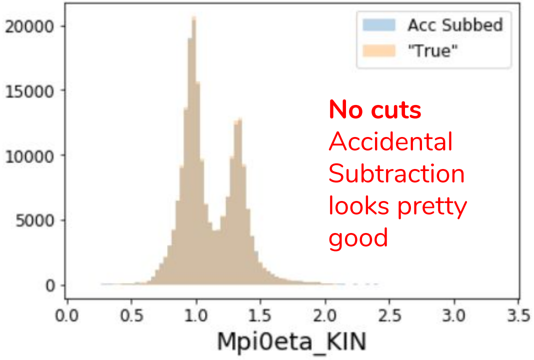
One event sample

Mpi0eta for multiple events with selections from slide 4



How should we go about incorporating other weights?

- We have basically 3 different weights to think about
  - Accidental, Sideband, Combo (tracking)
- It is because we do not know which beam photon was the “truth” so we include accidentals and do accidental subtraction. It works well as we have seen and there really isn’t an event by event alternative to use with combo tracking schemes as it works using the full ensemble. AccSub is also pretty well understood so how to incorporate it?
- We can also get the “True” pi0eta combination if we require the neutral hypotheses to have a parent with PID 7 and 17 for the pi0 and eta respectively. Done using Get_PID() on the result of Get_ParentIndex()
- Since the probability weighting scheme is the most general so far can we extend it?
  - Propose:



$$W_{ij} = \frac{p_{ij}}{\sum_{j \in spect} p_{ij}}$$

$$\sum_{j \in spect} W_{ij} = 1$$

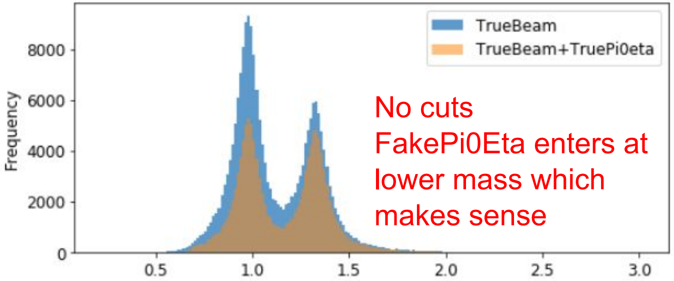
→ Redistribution of weights among spectroscopic combos

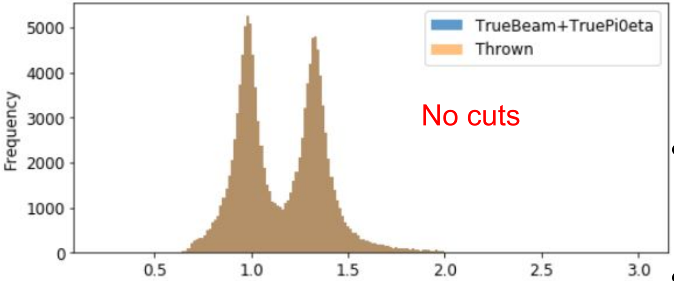
$$\sum_{i \in beam} \sum_{j \in spect} W_{ij} = N_{Beam}$$

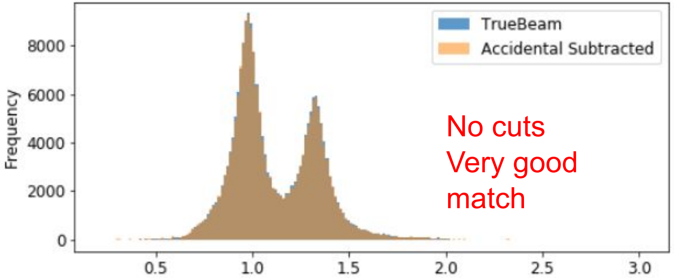
→ This equation tells us that the number of beam photons are left unchanged and thus accidentals can be properly applied

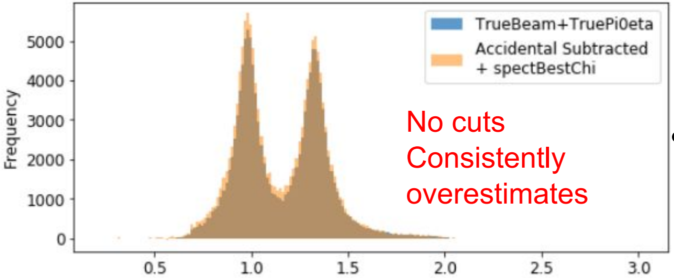
Splitting the weights into parts related to the set of beam photons and the set of spectroscopic combos (i,j respectively).
An example will motivate why we need to do this.
WHAT I THINK OUR OVERALL GOAL IS: We want a total integrated amount of 1 in our histogram per event.

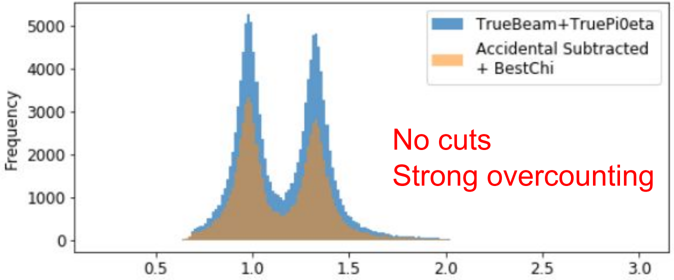
Beam Photons × Spectroscopic Combos











- **(Top Left)** Comparing combos with the “True” beam photon and combos with the “True” beam photon AND “True” pi0eta.
- **(Top Right)** compares combos with “True” beam+pi0eta with the thrown Mpi0eta. Thrown contains events where at least 1 combo has a “True” beam+pi0eta.
- **(Mid Right)** compares combos with “True” beam+pi0eta and all combos with accidentalSub + spectroscopic bestChiSq . They look similar to each other and thus also look similar to Thrown, as shown in top right.
- **(Bot Left)** Is basically the Mid Right plot but compares to using the bestChiSq tracking scheme (not restricted to spectroscopic combos)
- **(Mid Left)** compares combos with the “True” beam photon and all combos with Accidental subtraction.

ChiSq probably not good indicator of truePi0Eta and thus not implicitly doing sideband subtraction

1. For each event we can look at the minimum χ2 for all the fakePi0Eta combos and the χ2 for the truePi0Eta combo. Plot on the right. Vast majority at 0. It looks symmetric, suggesting true χ2 falls short and long equal amounts. We also know equal weights performs similarly with this MC sample. Then, the similarity of spectroscopic combo tracking to sideband subtraction should somehow be related only to the counts. It is not clear how it actually works...