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Mc Rc association comparison:

First of all, initial associations are made by `StAssociationMaker`, which generates maps that contain associations between Monte Carlo (Mc) and reconstructed (Rc) tracks that satisfy certain number of hits proximity. Each Mc and Rc track can be associated to more than one Rc and Mc tracks, respectively.

The next step in the association was done by my `StPkSimTreeMaker`. At minimum, we want a single Mc track associated to an Rc track (for particle id purpose). Ideally, we want a one-to-one association between the Mc and Rc tracks. However, that is not always the case. There are different ways to determine which Mc track is to be associated to a given Rc track. In this study, I included four 'methods' of associating Mc and Rc tracks.

1. **McRcSingle**

   Each Mc track is matched to the *unmatched* Rc track with the highest percent of TPC hits paired between the two tracks.The *unmatched* requirement means this method gives one-to-one association. It also means that there is a possibility that the associated Mc-Rc tracks pair is not the pair with the highest percent of paired TPC hits for the given Mc track (because that Rc track is better paired with another Mc track).

2. **RcMcSingle**

   Each Rc track is matched to the *unmatched* Mc track with the highest percent of TPC hits paired between the two tracks. The *unmatched* requirement means this method gives one-to-one association. It also means that there is a possibility that the associated Rc-Mc tracks pair is not the pair with the highest percent of paired TPC hits for the given Rc track (because that Mc track is better paired with another Rc track).

3. **McRcMulti**

   Each Mc track is matched to the Rc track with the highest percent of TPC hits paired between the two tracks. This method does not give a one-to-one association, as it is possible for a single Rc track to be associated to more than one Mc track(s). However, unlike in the McRcSingle method, in this method every Mc track is associated to the Rc track with which it has the highest percentage of paired TPC hits.

4. **RcMcMulti**

   Each Rc track is matched to the Mc track with the highest percent of TPC hits paired between the two tracks. This method does not give a one-to-one association, as it is possible for a single Mc track to be associated to more than one Rc track(s). However, unlike in the RcMcSingle method, in this method every Rc track is associated to the Mc track with which it has the highest percentage of paired TPC hits.

Since we need each Rc track to only be associated to one Mc track, McRcMulti is not a viable option to use as the final method to determine Mc-Rc association. The other three methods, however, all give one Mc track to an Rc track. Now the question is, which of the three is the best option?

McRcSingle and RcMcSingle agreement Does the two Single methods of association agree with each other? I did a check of every Mc-Rc pairs obtained via McRcSingle and RcMcSingle to see if the same Mc track is paired with the same Rc track. The results is that out of about 19 million pairings (19,203,119), only roughly 3% (581,539) pairs show disagreement between the two methods.

McRcMulti and RcMcMulti agreement Does the two Multi methods of association agree with each other? Each Mc (Rc) track has the potential of being associated to multiple Rc (Mc) track(s) via RcMcMulti (McRcMulti). To see how well the two methods agree, I counted how many Rc-Mc (Mc-Rc) pairs from RcMcMulti (McRcMulti) are also found in the alternate method.

First, let's take a look at how many tracks have multiple associations. Over 95% (18,298,724/19,160,692) Mc tracks only have a single Mc-Rc associated pair from the RcMcMulti method. For Rc tracks, over 99% (18,892,544/18,930,580) only have a single associated Mc track. The percentages are detailed in Table 1 below.

Table 1: Number of Mc-Rc and Rc-Mc pairs from RcMcMulti and McRcMulti.

Number of pairs, n	% of Mc tracks w/ n Rc tracks (RcMcMulti)	% of Rc tracks w/ n Mc tracks (McRcMulti)
1	95.5	99.8
2	2.57	0.20
3	0.80	< 0.01
4	0.34	< 0.01
≥ 5	0.80	0

Next, I checked how many Rc-Mc associated pairs from RcMcMulti can also be found using the McRcMulti method, and vice versa. Of the $\sim$19.2M ($\sim$18.9M) Rc-Mc (Mc-Rc) pairs from RcMcMulti (McRcMulti) method, almost 95% (over 99%) have complete agreement, i.e. all Mc-Rc (Rc-Mc) pairs for a given Mc (Rc) track can also be found as its inverse, Rc-Mc (Mc-Rc) pair via the opposite method.

Percent of TPC Hits Paired Checking if the percent of TPC hits paired between Mc and Rc tracks are consistent across the different methods. It looks like it's fairly consistent between McRc both Single and Multi, and similarly for RcMc (which I find rather surprising); however, there's a slight difference between McRc and RcMc methods as shown in Figure 1 below. RcMc methods, which give priority to the Mc track having its best Rc track (instead of the other way

Table 2: RcMcMulti agreement: n = number of Rc tracks from RcMcMulti method, m = number of Rc tracks out of n that are matched to the same Mc track using McRcMulti method.

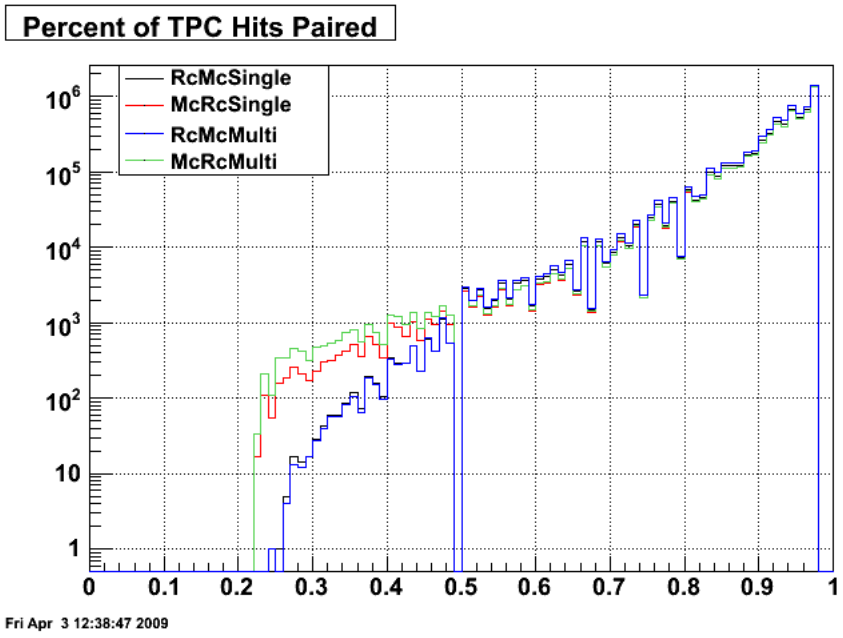
	m = 0	m = 1	m = 2
n = 1	0.99%	94.5%	0
n = 2	0.09%	2.47%	<0.01%
n = 3	0.04%	0.76%	<0.01%
n = 4	0.02%	0.32%	<0.01%
n $\geq$ 5	0.10%	0.69%	<0.01%

Table 3: McRcMulti agreement: n = number of Mc tracks from McRcMulti method, m = number of Mc tracks out of n that are matched to the same Rc track using RcMcMulti method.

	m = 0	m = 1	m = 2
n = 1	0.02%	99.8%	0
n = 2	<0.01%	0.20%	<0.01%
n = 3	0	<0.01%	0
n = 4	0	<0.01%	0

around), has slightly better agreement between the Mc and Rc track TPC hits (more with higher percent paired, fewer with lower percent).

Figure 1: Percent of TPC hits paired.



Single or Multi? While one-to-one association is ideal, the Single method is likely to reduce the number of Rc tracks successfully associated to an Mc track. To check how big an effect it is, I'm counting the number of Mc-Rc pairs obtained using the different methods (Table 4). It seems a bit strange that McRcMulti yields about the same number of unique Rc track pairs as McRcSingle, whereas there's roughly a 10% difference between RcMcSingle and RcMcMulti. However, it should be noted that the increased number of associated Rc tracks likely stems from cases where multiple Rc tracks are associated to the same Mc track. While that situations still gives particle identification to the Rc tracks, it's certainly not ideal.

Table 4: Number of associated Rc tracks, N_{Rc}^{assoc}.

	RcMcSingle	McRcSingle	RcMcMulti	McRcMulti
N_{Rc}^{assoc}	19.0M	18.9M	20.8M	18.9M

Charge Agreement We'll compare the charge agreement between Mc and Rc track as a way to measure and compare the 'goodness' of the track association between the different methods.

Table 5: Charge agreement

	RcMcSingle	McRcSingle	RcMcMulti	McRcMulti
Agree	95.3%	95.5%	92.3%	95.5%
Mc = -1, Rc = 1	1.40%	1.34%	2.99%	1.35%
Mc = 0, Rc = -1	0.04%	0.04%	0.05%	0.04%
Mc = 0, Rc = 1	1.50%	1.50%	1.41%	1.50%
Mc = 1, Rc = -1	1.80%	1.65%	3.22%	1.66%

Conclusion There is little (less than 5%) difference between the different association methods. As stated earlier, the choice is between RcMcSingle, McRcSingle and RcMcMulti. Considering the difference in the percent of TPC hits paired, either RcMcSingle or RcMcMulti seem the better choice. Considering what little difference between the two, choosing the one-to-one association of RcMcSingle seems reasonable.