DØ note ????

Tracking efficiency study

Alexander Rakitin
Lancaster University, Lancaster, UK

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We present study of the tracking in the forward region performed with the sample of di-electron events with one electron having matching track in the central region of the detector and another electron located in forward region and having no matching track. The proposed change in the algorithm diminishes tracking inefficiency in the forward region by 18%, while increasing the time per event by 5%. It is recommended to propagate the change of the algorithm into the official code repository.

1 Introduction

Understanding of tracking algorithms and high tracking efficiency are very important for any physics analysis. In this note we consider an addition to the current algorithm which increases the efficiency while keeping fake rate at practically the same level.

The algorithm currently used in D0 requires at least three hits in SMT barrels and SMT disks, but not in both of them. Further it uses these 3-hit seeds to construct a track hypothesis. Our idea is to allow three hits anywhere in SMT, while keeping the rest of algorithm the same. But since it leads to an unacceptably high timing increase, we only apply this changed algorithm to the limited number of hits. Namely, to the hits located nearby an imaginary track from primary vertex to EM cluster, which has no matching tracks found.

2 Data Sample

For our studies we are using $Z \rightarrow e^+e^-$ data sample (117 pb^{-1}) collected between September 2002 and June 2003 by Jan Stark. The following selection cuts are applied:

- id $= 10, \pm 11$
- iso < 0.15
- emfrac > 0.9
- $p_t > 25$ GeV/c
- HM8 < 20
- $m(ee) > 30$ GeV/c^2
- Fire at least one of cal. triggers: 2EM_2MD12, 2EM_2MD7, EM_HI
- No track triggers – to avoid bias
- One EM cluster in CC ("tag electron") – must have matching track
- Another EM cluster in end-caps ("probe electron") – does not have to have matching track

The resulting mass distribution is given in Figure 1 (© Jan Stark). The upper plots shows all events, the middle one – only events where the probe electron has matching track ($\sim$66%), and the lower one – events where the probe electron has no matching track ($\sim$34%). This sample is provides perfect setup for studying tracking issues, especially for studying non-reconstructed tracks in the forward region, because it has many electronic EM clusters without matching tracks in forward region. For this study we use 85 events from the last one-third of the sample.

3 Geometry

The distributions of different quantities, such as p_t, ϕ and η may be different for reconstructed (tag) and missing (probe) electrons in the last one-third of the sample. To check this we plot the distributions of p_t, ϕ and η in Figure 2. There is no difference observed, except for η, which is different by construction: tag electrons are located at the central calorimeter and have $-1 < \eta < 1$ and probe electrons are at the end-caps and have $|\eta| > 1$.

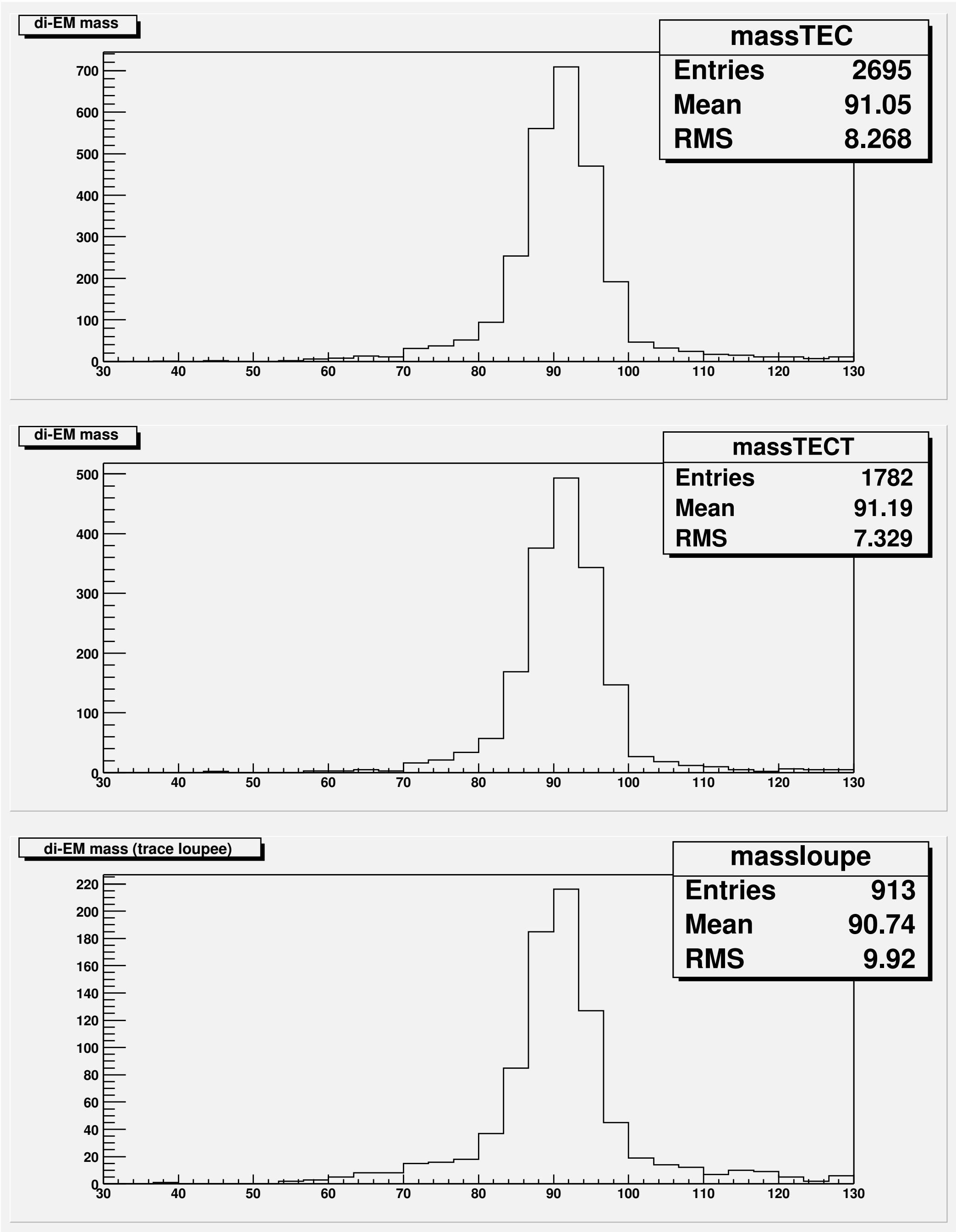

Figure 1: The plots of di-electronic mass (© Jan Stark). Upper: all events. Middle: probe electron has matching track (∼66%). Lower: probe electron has no matching track (∼34%).

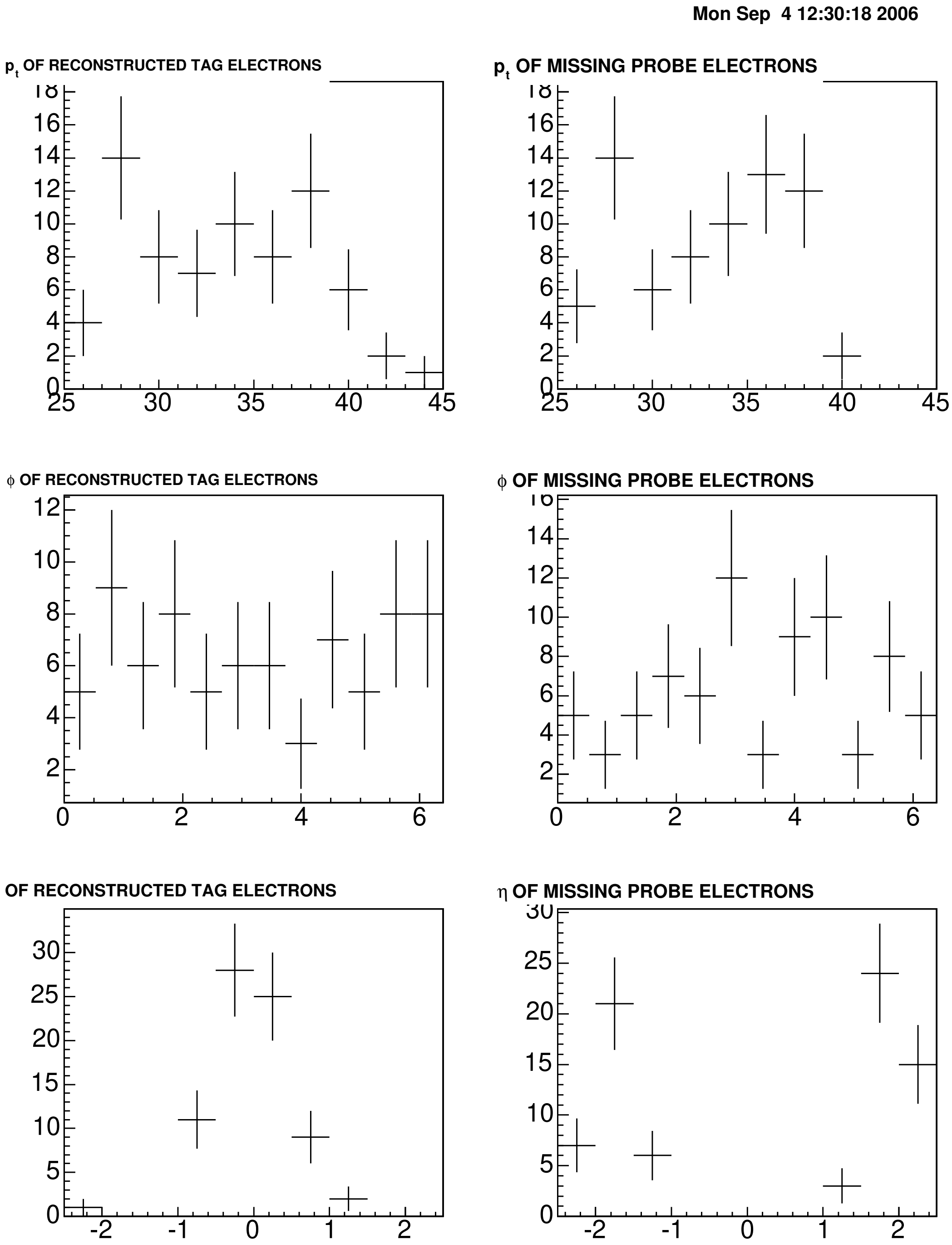

Figure 2: p_t, ϕ and η distributions

4 Tracking efficiency study

The current algorithm starts reconstructing tracks with 3-hit seed in SMT. The hits in that seed are required to be either in SMT barrels or in SMT disks. So, the tracks with 3+ hits in these parts of the detector are reconstructed. Eighty-five non-reconstructed tracks in our sample can be divided into 5 categories:

- ☞ Tracks with
  either 2 hits in SMT barrels and 1-2 in F-disks
  or 1-2 hit in SMT barrels and 2 in F-disks
  (24 tracks out of 85)
- ☞ Tracks with hits being further than "standard" 4σ window (12 out of 85)
- ☞ Tracks with 2 hits in SMT and 4+ in CFT (9 out of 85)
- ☞ "Invalid" tracks with too few axial or stereo hits (5 out of 85)
- ☞ Tracks with too few hits to be reconstructed (35 out of 85)

By changing the reconstruction algorithm (allowing 3 initial SMT hits to be in both barrels and disks) we can reconstruct a few tracks in first and second categories. See the details in Appendix A. The example of track with two SMT and two SMTD hits is given in Figure 3. This change decreases the inefficiency $\eta = 1 - \epsilon$ by 13%. Another change would be to increase "standard" 3σ window around track up to 4σ. This allows to reconstruct 8 more tracks out of 44 (inefficiency decreases by 18%). Further increase in the statistics (from 44 to 85 non-reconstructed tracks) diminishes the reduction in the inefficiency to 12%. This happens because the added sample of 41 track has lower fraction of reconstructed tracks.

A separate question which would need checking on Monte Carlo is whether the number of fake tracks increases. The total number of tracks per event increased by 37%, as shown in Figure 4. So, we presume that the fake rate should be quite high.

5 Timing study

An important characteristics of the reconstruction algorithm is its time performance. The tracks with hits in SMT barrels were checked for match in z only. The tracks with hits in SMT disks were checked for match in r only. Allowing the hits to be in any part of SMT leads to necessity to check them for both matches and, therefore, to significant timing increase. To measure this increase we fit ratios $\frac{\text{old time}}{\text{new time}}$ with horizontal line (Figure 5) and see that time increases by factor of ≈ 2.

6 Stage II tracking

One of the ways to diminish the timing per event and to avoid high fake rate is to use **two-stage tracking**. In the first stage we apply normal (current) tracking then find the EM clusters with no matching track, then shoot imaginary tracks from primary vertex to these EM clusters and find the hits in SMT close to these imaginary tracks. Then, in the stage II tracking, only these close hits are used, though no restrictions on their positions is imposed – they can be in either SMT

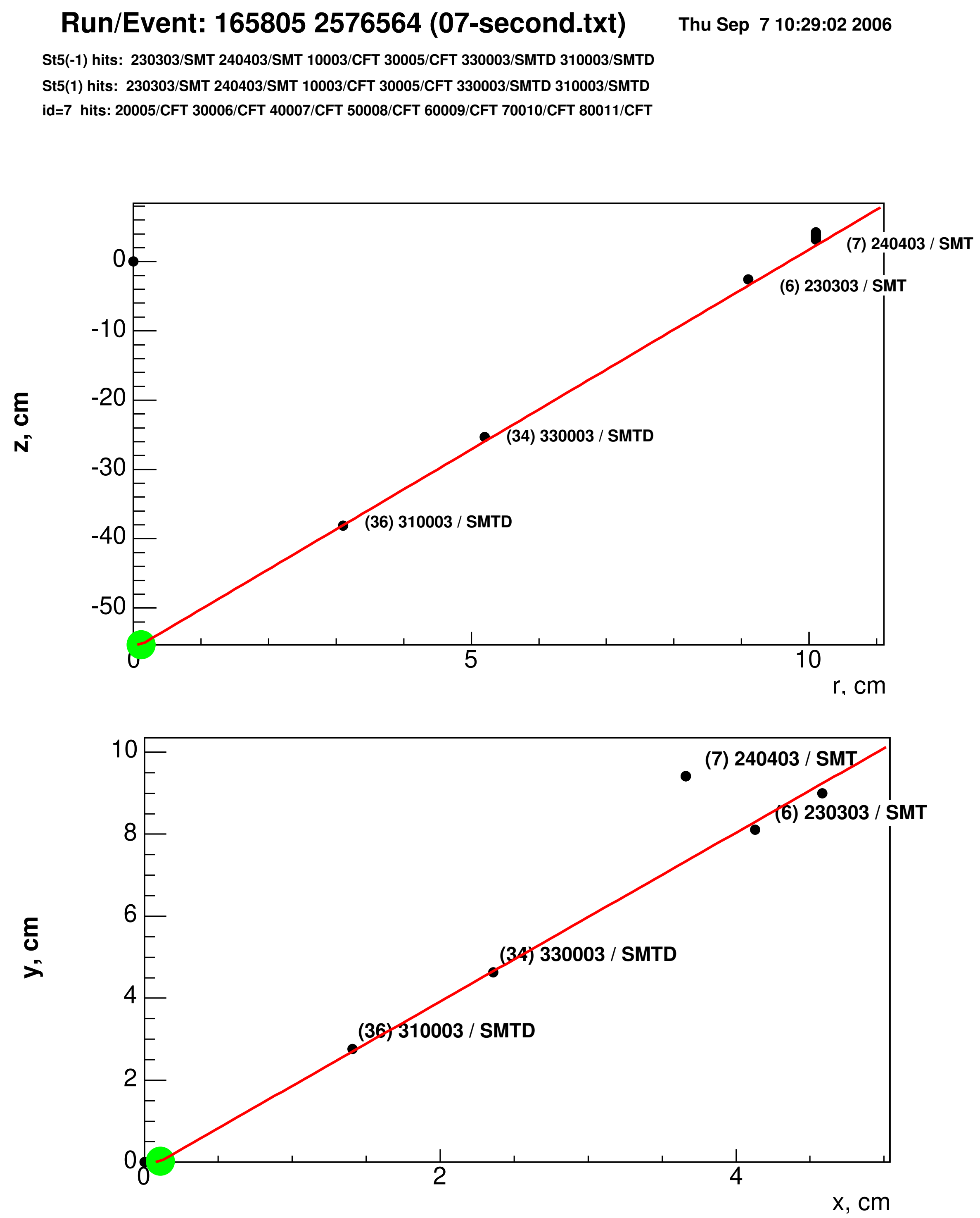

Figure 3: A track with two SMT and two SMTD hits.

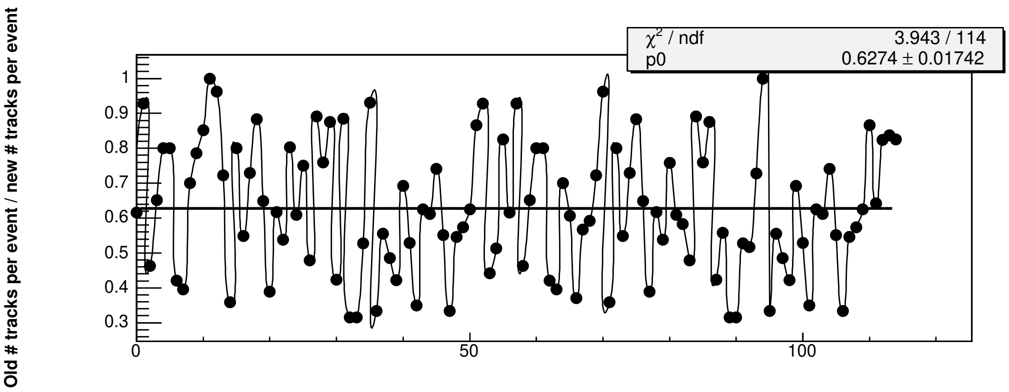

Figure 4: The fitted ratios of number of tracks per event.

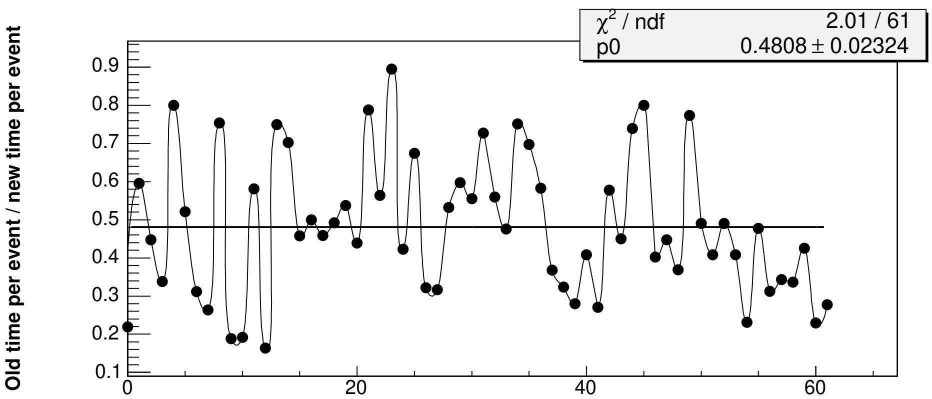

Figure 5: Fitted ratios of new time per event to old time per event.

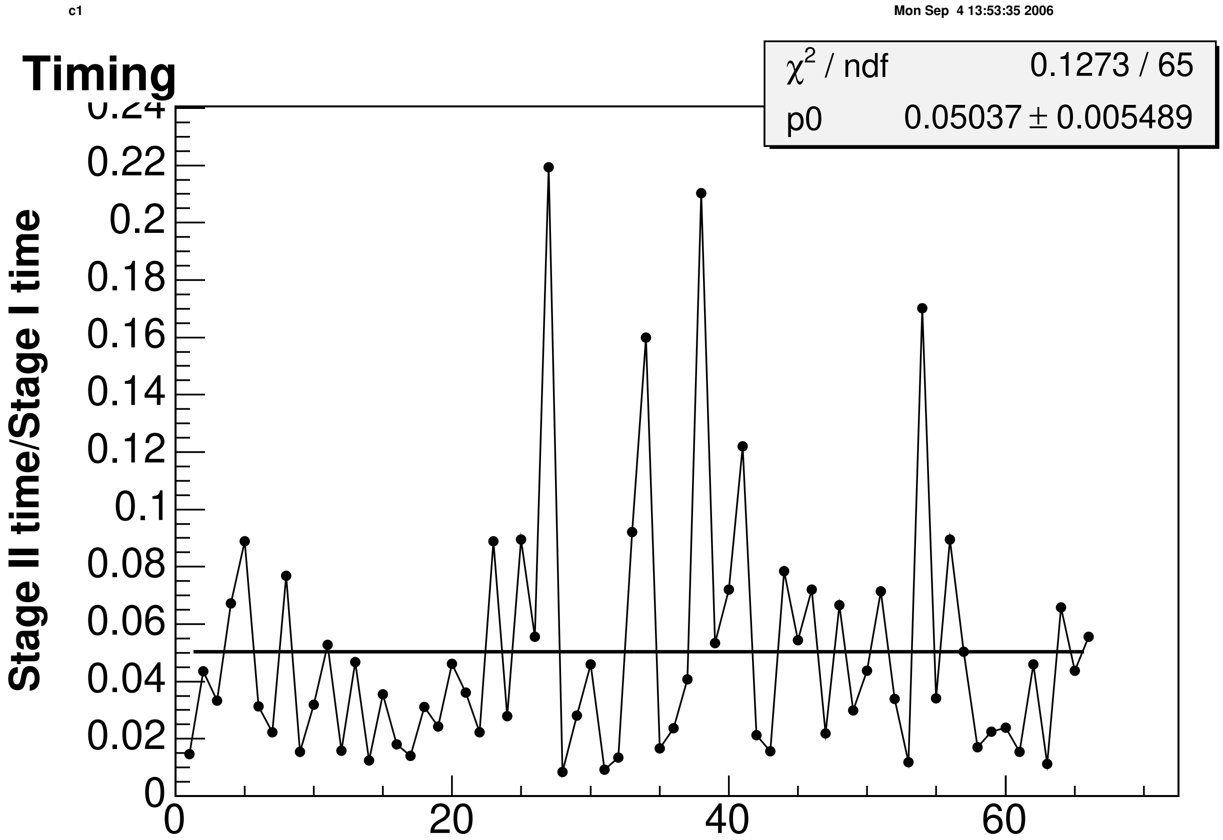

Figure 6: Fitted ratios of stage II time to stage I time.

disks or SMT barrels. This technique allows to find the tracks not found in the first stage, while keeping the fake rate at practically the same level. The stage II takes small time, on average 5% of the stage I's time. This number was obtained by fitting the ratios of stage II time to stage I time, as shown in Figure 6.

7 Conclusion

Several of the missing tracks from the "probe" electrons can be reconstructed by the "2nd stage" addition to the current tracking algorithm. It seems to be unreasonable to allow the hits in the 3-hit seeds to be anywhere in SMT, due to possible high fake rate and large timing increase. It is better to apply two-stage tracking which keeps the fake rate practically at existing level and increases the timing by only 5%.

A Appendix: Numbers of hits in CFT/SMT

The tables below display the numbers of hits in CFT and different parts of SMT for the missed (probe) and reconstructed (tag) electrons for each event. Often we see three or more hits in the different parts of SMT, but not in one part. This result inspired us to try to change the track reconstruction algorithm.

All the non-reconstructed tracks are divided into five categories, described in Section 4.

"2+1" or "1+2" or more SMT hits:

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
164605 10233199	Probe	2	3	2	0	YES	Yes
	Tag	6	7	0	0	Yes	Yes
165805 2576564	Probe	2	2	2	0	YES	Yes
	Tag	0	7	1	0	Yes	Yes
165906 6603711	Probe	2	3	1	0	No, hits too far	No
	Tag	4	7	0	0	Yes	Yes
166113 39215346	Probe	1	3	2	0	YES	Yes
	Tag	4	8	1	0	Yes	Yes
166295 20638511	Probe	1	0	2	1	No, invalid	No
	Tag	3	8	0	0	Yes	Yes
166302 24938931	Probe	2	3	2	0	No, hits 8 σ away	No
	Tag	3	8	0	0	Yes	Yes
166302 24109618	Probe	1	3	2	0	YES	Yes
	Tag	4	8	0	0	Yes	Yes
166506 46965463	Probe	2	4	1	0	YES	Yes
	Tag	2	8	0	0	Yes	Yes
164445 2159216	Probe	1	1	2	0	No, invalid	No
	Tag	2	8	2	0	Yes	Yes
166782 123665141	Probe	1	3	2	0	YES	Yes
	Tag	3	8	0	0	Yes	Yes
164605 7263701	Probe	1	3	3	0	No, hits too far	No
	Tag	2	8	0	0	Yes	Yes
164041 21879237	Probe	0	0	2	2	YES	Yes
	Tag	2	8	1	0	Yes	Yes
166835 18381547	Probe	2	1	2	0	No, hits too far	No
	Tag	4	8	0	0	Yes	Yes

"2+1" or "1+2" or more SMT hits:

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
166937 9714345	Probe	2	2	2	0	No, hits too far	No
	Tag					Yes	Yes
167325 3178494	Probe	1	1	2	0	No, hits too far	No
	Tag	5	7	0	0	Yes	Yes
166992 23278575	Probe	1	0	5	1	No, hits too far	No
	Tag	4	8	0	0	Yes	Yes
168562 3177272	Probe	1	3	2	0	No, hits too far	No
	Tag	3	8	0	0	Yes	Yes
168498 519484	Probe	1	2	2	0	No, hits too far	No
	Tag	2	8	0		Yes	Yes
168691 4204765	Probe	0	0	2	1	No, hits too far	No
	Tag	1	8	0	0	Yes	Yes
168973 5391969	Probe	2	2	1	0	No, invalid	No
	Tag	2	8	0	0	Yes	Yes
168733 20618630	Probe	2	2	2	0	No, hits too far	No
	Tag	4	8	0	0	Yes	Yes
168959 2815665	Probe	2	2	2	0	No, hits too far	No
	Tag	4	7	0	0	Yes	Yes
169224 3001153	Probe	0	1	2	1	No, hits too far	No
	Tag	0	8	0	0	Yes	Yes
169640 3952173	Probe	2	6	1	0	YES	Yes
	Tag	5	8	0	0	Yes	Yes

2 SMT hits and 4+ CFT hits:

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
165977 6659303	Probe	2	4	0	0	No, 3-hit req.	Yes?
	Tag	0	5	0	0	Yes	Yes
166313 32787929	Probe	0	4	2	0	No, 3-hit req.	Yes?
	Tag	2	8	0	0	Yes	Yes
163171 48542536	Probe	1	4	1	0	No, 3-hit req.	Yes?
	Tag	0	8	0	0	Yes	Yes
163171 46651698	Probe	0	4	2	0	No, 3-hit req.	Yes?
	Tag	1	8	0	0	Yes	Yes
164039 14995544	Probe	0	6	2	0	No, 3-hit req.	Yes?
	Tag	3	8	0	0	Yes	Yes
166869 37137074	Probe	0	5	2	0	No, 3-hit req.	Yes?
	Tag	0	8	1	0	Yes	Yes
166868 36065427	Probe	1	4	1	0	No, 3-hit req.	Yes?
	Tag	3	8	0	0	Yes	Yes
167662 67087731	Probe	0	5	2	0	No, 3-hit req.	Yes?
	Tag	2	8	0	0	Yes	Yes
169001 3373246	Probe	0	4	2	0	No, 3-hit req.	Yes?
	Tag	1	8	0	0	Yes	Yes

Hits too far from track (with non-changed algorithm):

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
165645 5273011	Probe	2	2	1	0	No	No, hits too far
	Tag	3	7	0	0	Yes	Yes
164636 16204878	Probe	0	0	1	2	No	No, hits too far
	Tag	0	8	1	0	Yes	Yes
165795 5443702	Probe	3	6	0	0	No	No, hits too far
	Tag	1	6	1	0	Yes	Yes
164385 4847391	Probe	0	4	2	0	No	No, hits too far
	Tag	3	8	0	0	Yes	Yes
163121 35154278	Probe	0	0	3	0	No	No, hits too far
	Tag	2	8	0	0	Yes	Yes
166892 1830713	Probe	3	6	0	0	No	No, hits too far
	Tag	3	8	0	0	Yes	Yes
167953 9317412	Probe	0	5	3	0	No	No, hits too far
	Tag	3	8	0	0	Yes	Yes
167951 1004617	Probe	0	0	4	0	No	No, hits too far
	Tag	1	8	2	0	Yes	Yes
168382 70911483	Probe	3	6	0	0	No	No, hits too far
	Tag	5	8	0	0	Yes	Yes
168618 1461725	Probe	2	4	1	0	No	No, hits too far
	Tag	0	8	0	0	Yes	Yes
168619 2445580	Probe	3	3	2	0	No	No, hits too far
	Tag	3	8	0	0	Yes	Yes
169521 3463103	Probe	1	2	2	0	No	No, hits too far
	Tag	3	8	0	0	Yes	Yes

Invalid tracks:

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
164216 83479647	Probe	0	1	3	0	No, invalid	No
	Tag	1	7	0	0	Yes	Yes
164018 11142735	Probe	0	1	4	0	No, invalid	No
	Tag	3	8	1	0	Yes	Yes
164040 18660971	Probe	4	5	0	0	YES	Yes
	Tag	2	8	0	0	Yes	Yes
164083 35308948	Probe	0	0	2	1	No, invalid	No
	Tag	1	8	0	0	Yes	Yes
168525 19495531	Probe	4	5	1	0	YES	Yes
	Tag	4	8	0	0	Yes	Yes

Too few hits to reconstruct track:

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
165765 36883677	Probe	0	3	1	0	No	No, too few hits
	Tag	3	8	0	0	Yes	Yes
165686 45005141	Probe	0	2	2	0	No	No, too few hits
	Tag	2	8	1	0	Yes	Yes
164382 3507437	Probe	0	2	0	0	No	No, too few hits
	Tag	0	7	0	0	Yes	Yes
166484 14657490	Probe	0	1	0	1	No	No, too few hits
	Tag	0	0	3	2	Yes	Yes
166483 3946198	Probe	0	0	0	1	No	No, too few hits
	Tag	0	7	0	0	Yes	Yes
166505 40748533	Probe	0	0	0	1	No	No, too few hits
	Tag	0	8	1	0	Yes	Yes
163172 49593518	Probe	0	0	1	1	No	No, too few hits
	Tag	0	7	0	0	Yes	Yes
166776 115353883	Probe	0	6	1	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
164605 6649931	Probe	0	0	2	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
164080 30329930	Probe	0	7	1	0	No	No, too few hits
	Tag	1	5	0	0	Yes	Yes
164080 30329930	Probe	0	7	1	0	No	No, too few hits
	Tag	1	5	0	0	Yes	Yes
164095 44036204	Probe	0	1	1	0	No	No, too few hits
	Tag	4	8	1	0	Yes	Yes
166872 41058810	Probe	0	5	1	0	No	No, too few hits
	Tag	2	8	0	0	Yes	Yes
166898 16826502	Probe	0	3	2	0	No	No, too few hits
	Tag	1	8	0	0	Yes	Yes
168732 17138782	Probe	0	4	1	0	No	No, too few hits
	Tag	1	8	0	0	Yes	Yes
167663 70873322	Probe	0	3	0	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
167663 71845529	Probe	0	3	0	0	No	No, too few hits
	Tag	0	8	1	0	Yes	Yes
167807 102734040	Probe	1	2	1	0	No	No, too few hits
	Tag	3	8	0	0	Yes	Yes
168149 3637743	Probe	0	0	2	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes

Too few hits to reconstruct track:

Run/Event	Electron	SMT Barrels	CFT	SMT F	SMT H	Reconstructed?	Reconstructible?
168153 21003252	Probe	0	1	0	1	No	No, too few hits
	Tag	0	5	0	0	Yes	Yes
168149 4360345	Probe	1	1	1	0	No	No, too few hits
	Tag	3	7	1	0	Yes	Yes
168152 20346262	Probe	0	1	1	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
168152 15671740	Probe	0	4	1	0	No	No, too few hits
	Tag	2	8	0	0	Yes	Yes
168640 1406155	Probe	0	0	0	1	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
168659 21057268	Probe	0	4	1	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
169183 11774110	Probe	0	5	1	0	No	No, too few hits
	Tag	2	8	0	0	Yes	Yes
168988 16788080	Probe	0	0	1	0	No	No, too few hits
	Tag	4	8	0	0	Yes	Yes
169247 16014181	Probe	0	5	0	0	No	No, too few hits
	Tag	0	7	0	0	Yes	Yes
169224 768975	Probe	1	3	1	0	No	No, too few hits
	Tag	3	7	1	0	Yes	Yes
169200 2352043	Probe	0	1	1	0	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes
169247 14340879	Probe	0	0	0	1	No	No, too few hits
	Tag	0	8	2	0	Yes	Yes
169261 9325069	Probe	0	4	0	0	No	No, too few hits
	Tag	2	8	0	0	Yes	Yes
169264 25341783	Probe	0	0	1	1	No	No, too few hits
	Tag	5	8	0	0	Yes	Yes
169640 6053332	Probe	0	0	0	2	No	No, too few hits
	Tag	0	8	1	0	Yes	Yes
169298 23688912	Probe	0	0	0	1	No	No, too few hits
	Tag	0	8	0	0	Yes	Yes