Wave Algorithm for Searching Track with Bremsstrahlung - Testing Abilities of the Method

Jiřina, Marcel

2002

Institute of Computer Science
Academy of Sciences of the Czech Republic

Wave Algorithm for Searching Track with Bremsstrahlung - Testing Abilities of the Method

Marcel Jiřina and František Hakl

Technical Report No. 873

September 2002

Pod Vodárenskou věží 2, 182 07 Prague 8, phone: (+4202)66053350, fax: (+4202)8585789,
e-mail: marcel@cs.cas.cz

Institute of Computer Science
Academy of Sciences of the Czech Republic

Wave Algorithm for Searching Track with Bremsstrahlung - Testing Abilities of the Method

Marcel Jiřina and František Hakl

Technical Report No. 873

September 2002

Abstract

Behavior and some parameters of the Wave algorithm are presented as well as its ability to identify tracks of electrons and positrons "broken" due to Bremsstrahlung effect.

Keywords:
particle track, track searching, b-physics, Bremsstrahlung

Contents

Introduction

(Short description of the method)

The Task

From physics point of view the B-physics studies include the search for and measurement of so called CP violation through decays $B_d^0 \to J/\psi\, K_S^0$, $B_d^0 \to \pi^+\pi^-$ and $B_S^0 \to J/\psi\,\phi$. The other decay $J/\psi \to e^+e^-$ produces electrons, which can be identified using transition radiation tracker (TRT) [1] [2]. There are several other b-physics decay processes which produce electrons and positrons. Thus the b-physics events are identified through identification of special electrons in TRT. One special interesting phenomenon is Bremsstrahlung of electrons (and positrons).

Standard algorithms as XKALMAN [3] or the one used in DELPHI detector [4] [5], as well as in ZEUS (DESY) [6] and ALICE detector [7], use a transform of circular TRT to polar coordinates. It changes the circular tracks going through the origin to straight lines. The algorithm searches these straight lines systematically in all possible directions and places or build the track starting from the initial hit search for next hit which can be a candidate and at the same time with filtering procedure the outliers are rejected. This procedure is not primarily suitable for searching tracks with Bremsstrahlung as such track consists of two circular part, the first - when electron has larger energy and then speed - with larger radius, and the second after loss of energy with lesser energy, i.e. speed and smaller radius. Because in Bremsstrahlung the electron loss energy but does not change direction, the both circular parts of the track are tangent one to another in point where the Bremsstrahlung arises. There is no disruption in this point.

In this report a new algorithm is proposed. It reminds a little Huygen's principle, but the wave spreads only in limited sector of possible directions. After a set of hits which may, but need not form a track, is found (so we get the <u>track set</u>), the track approximation is computed and outlier hits are deleted from the set to get track candidate (the <u>tracks found</u>). These track candidates are again tested with respect to other criteria and so we get <u>tracks accepted</u>. To find Bremsstrahlung tracks the tracks are tested whether it is possible that the track found in the TRT can be the second, slow part of some Bremsstrahlung track. For it, it is supposed that in each layer of material can be a Bremsstrahlung point. Thus set of 16 hypotheses are formed, each corresponding to seven layers of the silicon detector. At the same time, the continuous medium of lower layers of TRT is discretized into 9 discrete layers of radii equal to radii of the first, second, ... ninth layer of straws of the TRT. The 17^{th} hypothesis corresponds to track without Bremsstrahlung and going from the origin. These hypotheses are tested using hits in silicon detector and the best of them, i.e. the one having the most hits in the silicon detector, is acknowledged and accepted. Quality of a track thus found is measured simply by number of hits found in silicon detector - zero to seven. Of course, special cases, as Bremsstrahlung in the first layer of pixel detector cannot be acknowledged. Also, there are some tracks, for which no Bremsstrahlung hypothesis can exist. The best fit for part of track with hits in TRT as well as in silicon, is the weighted fit with weights inversely proportional to the pitch size of the corresponding layer and we use "circular" linear regression technique [8]. By rather artificial layers in TRT we only approximate otherwise practically continuous medium of TRT to get finite number of corresponding hypotheses to test as mentioned above.

Data at Hand

Data used for evaluation was generally data after reconstruction with old geometry. There were total 92 events with total 2194 tracks. The analysis was performed for all tracks, for hadrons and for electrons. Table 1 gives number of tracks under different conditions.

Type of data	All data saved after reconstruction without • Fake tracks • Multiplicity	All data saved after reconstruction without • Fake tracks • Multiplicity • too large error	All data saved after reconstruction without • Fake tracks • Multiplicity • too large error • nothing was identified in silicon layers
All tracks	2194	1762	1362
Electrons (+positrons)	207	155	107
Hadrons	1650	1335	1137

TABLE 1. Number of entries (tracks).

Fake tracks are reconstructed tracks, which cannot be assigned to any true track as they are formed by hits from several different true tracks.
Multiplicities are the cases of two or more tracks assigned to one true track.
Too large error means that error criterion was not fulfilled during reconstruction process (this is not a comparison with true track).

Efficiency

To evaluate efficiency there is necessary to know corresponding true tracks. There is the fact that not all tracks in the file correspond to elementary criteria to be reconstructed, especially they have mostly too small number of hits or more hits than the number of layers in TRT.
The set of TRT hits to be considered as a track candidate must

a. have sufficient number of hits (HitsCountMin = 10)
b. cannot have more hits than there is TRT layers (NumOfLayers= 73; max. one hit in a layer)
c. must not have gaps, i.e. the number of successive layers with no hits must not exceed a given number (MaxEmpty = 10). A derived condition of this condition is that the track must start sufficiently early and not end too early, i.e. it have the first hit not further than in layer No. MaxEmpty = 10, and the last hit in layer at least No. NumOfLayers - MaxEmpty = 63.

The such set of hits is the „track candidate“ not yet the track found. It may be a rather random set of hits not forming a circular track.
To become the „track found“ it must fulfill best-fit criterion more. The best fit is the weighted fit with weights inversely proportional to the pitch size of the corresponding layer and we use "circular" linear regression technique.

Reconstruction Efficiency

Reconstruction Efficiency is the percentage of tracks found in all tracks looked for.
To estimate number of true tracks fulfilling conditions a., b., c. above, we use all track candidates without multiplicity as the true tracks. Multiplicities are found using KINE number that prevails in hits of the track set or track found.

In fact we use the program to find all tracks fulfilling conditions a., b., c. and we suppress track multiplicities. Reconstructed tracks are only those which comply error criteria more. From it reconstruction efficiency less than one follows. The average value found is 80.31 % as ratio of 1762 and 2194 tracks.

Reconstruction Efficiency with respect to pT

ESSENTIAL: READ TEXT ABOVE!

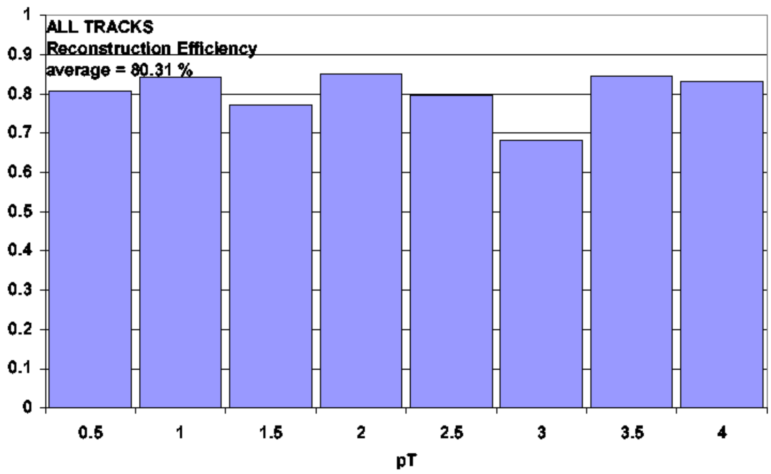

Fig. 1. Reconstruction Efficiency as function of pT, all tracks[1]

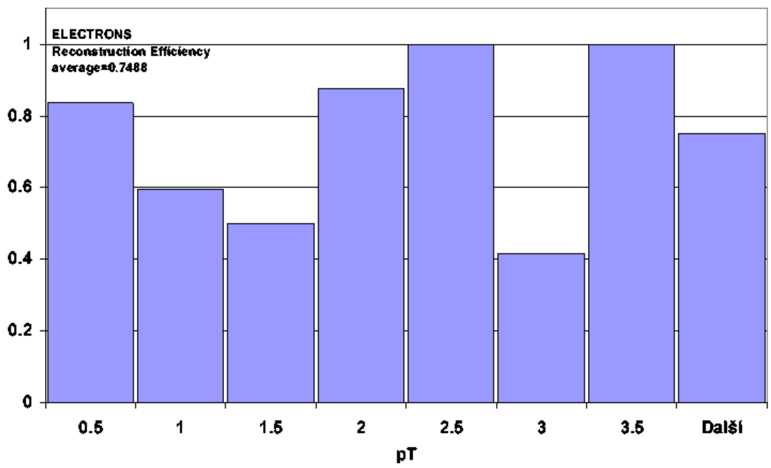

Fig. 2. Reconstruction Efficiency as function of pT, electrons

[1] Notation in histograms. Note that in histograms the numbers under individual bins are values of the left boundary of bins.

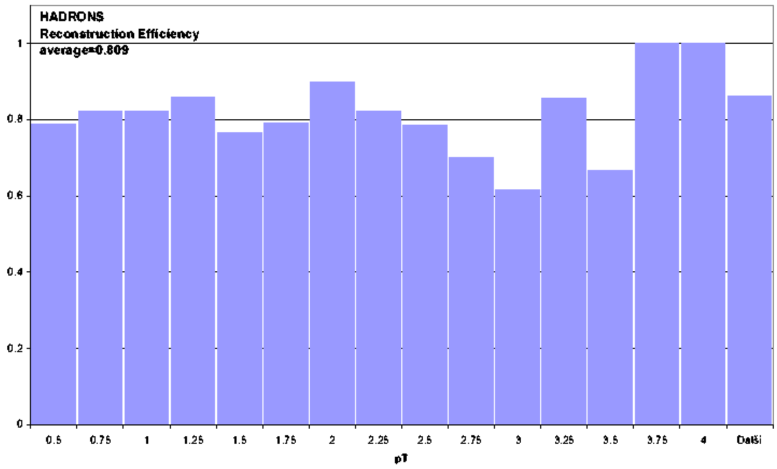

Fig. 3. Reconstruction Efficiency as function of pT, hadrons

Reconstruction Efficiency with respect to eta

ESSENTIAL: READ TEXT ABOVE!

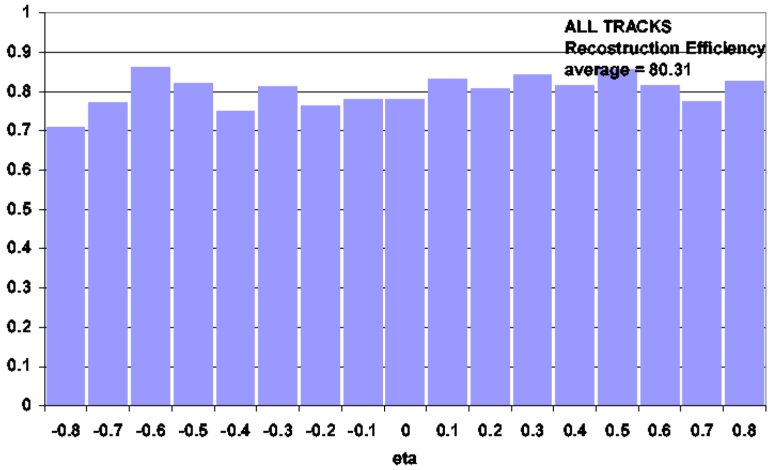

Fig. 4. Reconstruction Efficiency as function of eta, all tracks

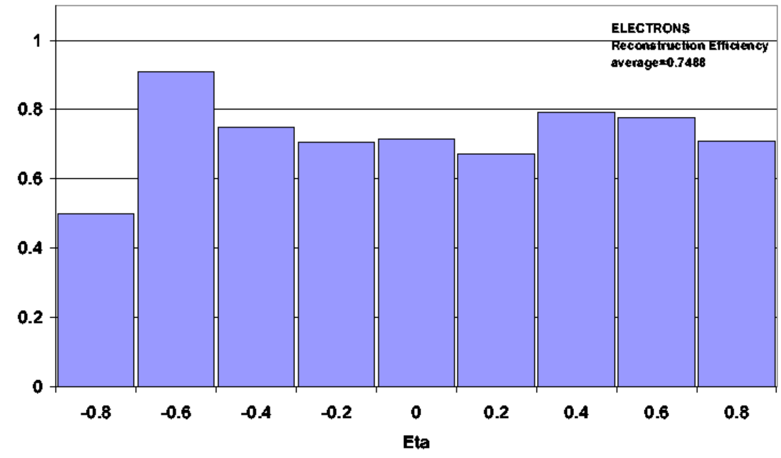

Fig. 5. Reconstruction Efficiency as function of eta, electrons

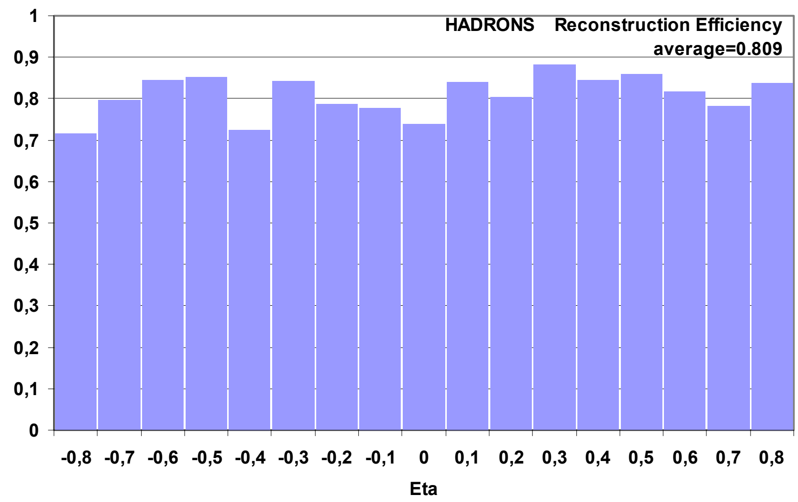

Fig. 6. Reconstruction Efficiency as function of eta, hadrons

Tracks Multiplication

Tracks multiplication is defined as the ratio of the number all tracks found over the number of all tracks found without multiplicities. Overall Tracks multiplication gives 2.60 %, 4.37 %, and 1.71 % rise above one for all tracks, electron tracks and hadron tracks, respectively.

Tracks Multiplication with respect to pT

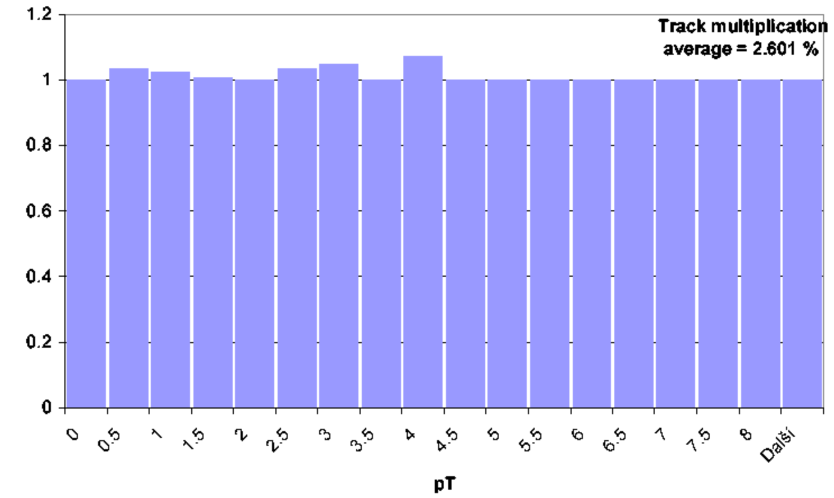

Fig. 7. Tracks Multiplication as function of Pt for all tracks

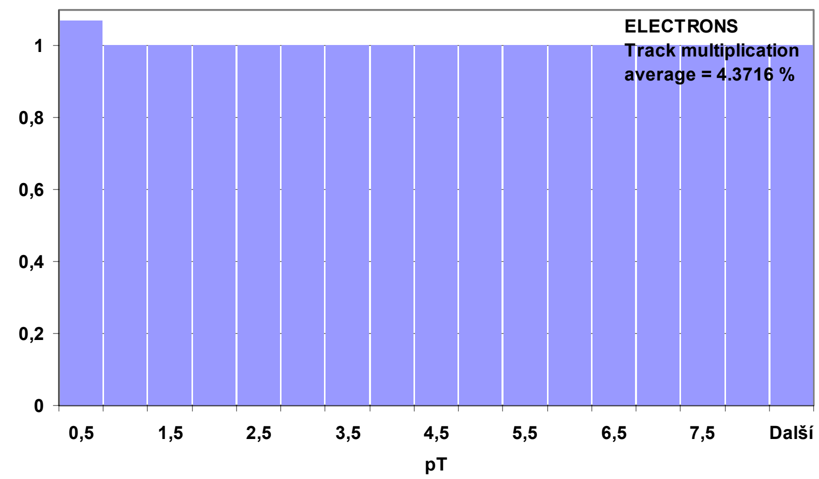

Fig. 8. Tracks Multiplication as function of Pt for electrons

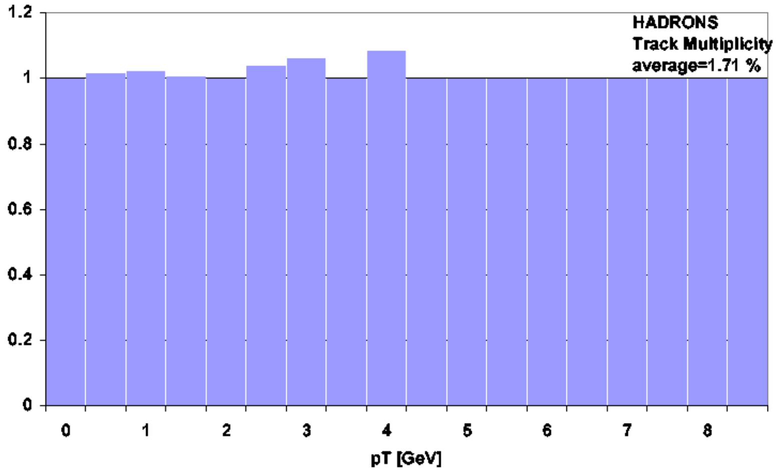

Fig. 9. Tracks Multiplication as function of Pt for hadrons

Tracks Multiplication with respect to eta

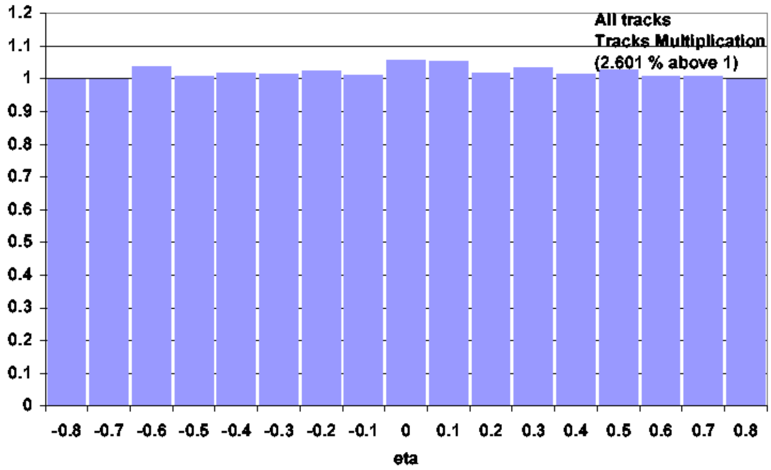

Fig. 10. Tracks Multiplication as function of eta, all tracks

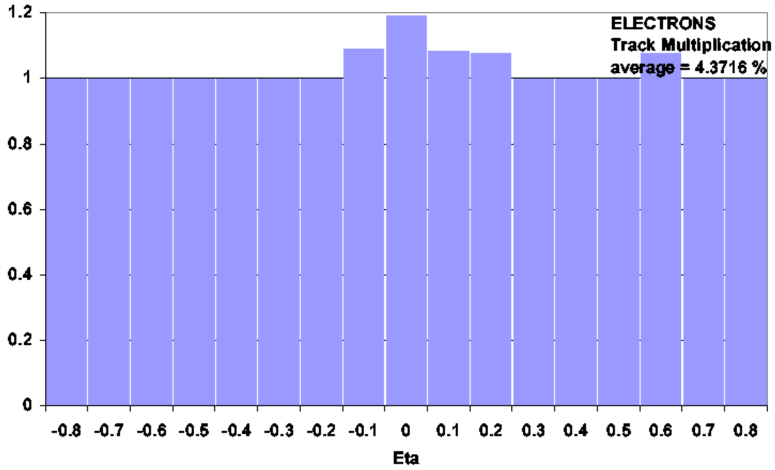

Fig. 11. Tracks Multiplication as function of eta for electrons

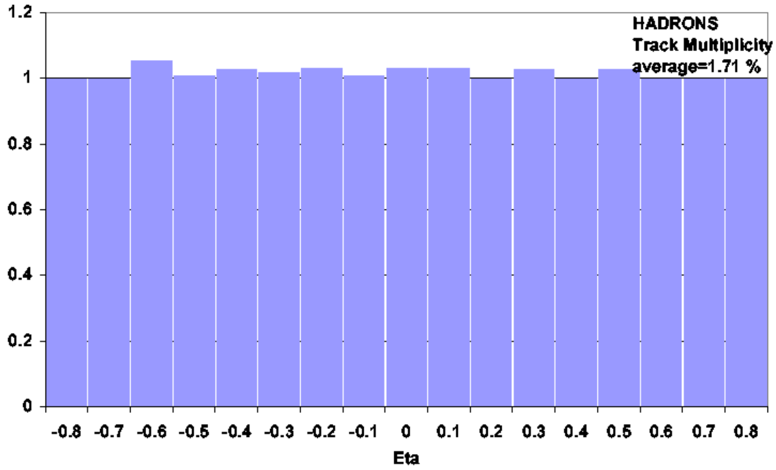

Fig. 12. Tracks Multiplication as function of eta for hadrons

Hits Finding Efficiency

Hits finding efficiency is defined as ratio of true hits found on the track by our algorithm with respect to true number of hits forming the track (i.e. true track). The tracks considered are the accepted tracks as defined in Introduction.

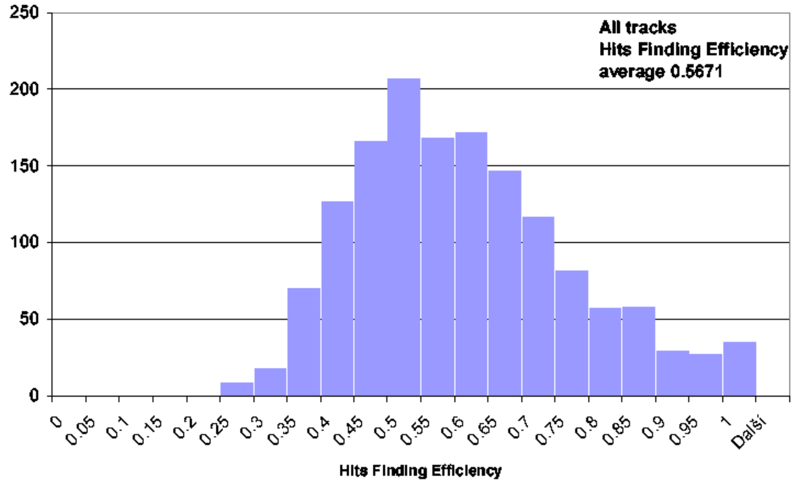

Fig. 13. Hits finding efficiency, all tracks

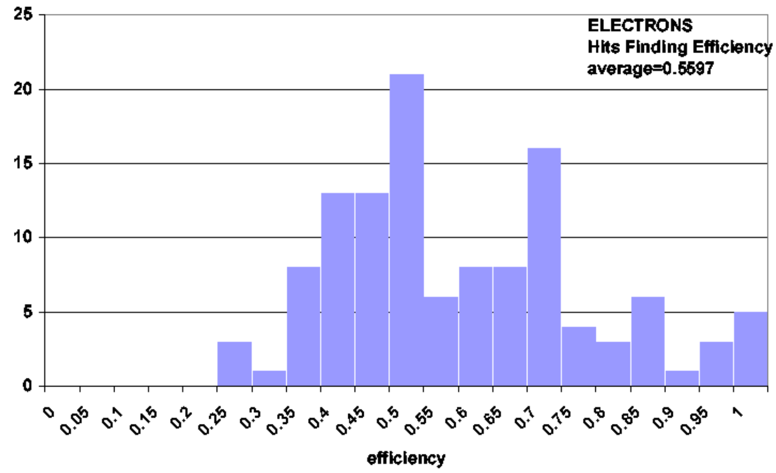

Fig. 14. Hits finding efficiency, electrons

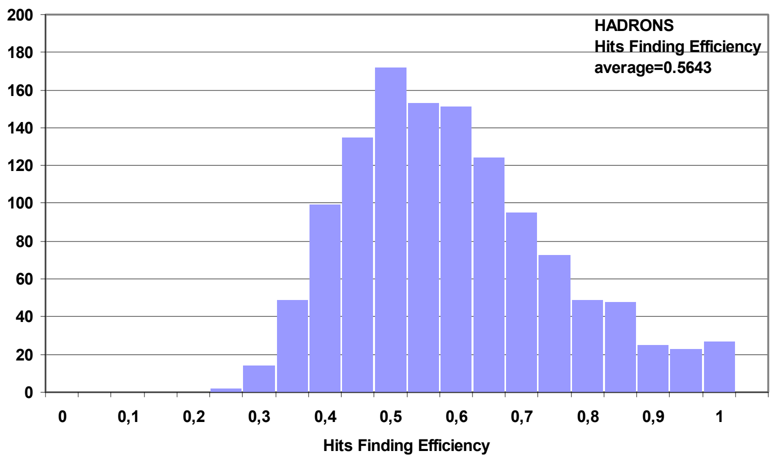

Fig. 15. Hits finding efficiency, hadrons

Quality

1/pTrec - 1/pTtrue

This is computed for tracks having at least one hit in silicon tracker. In the case of "Bremsstrahlung tracks" the first, fast part of the track is considered.

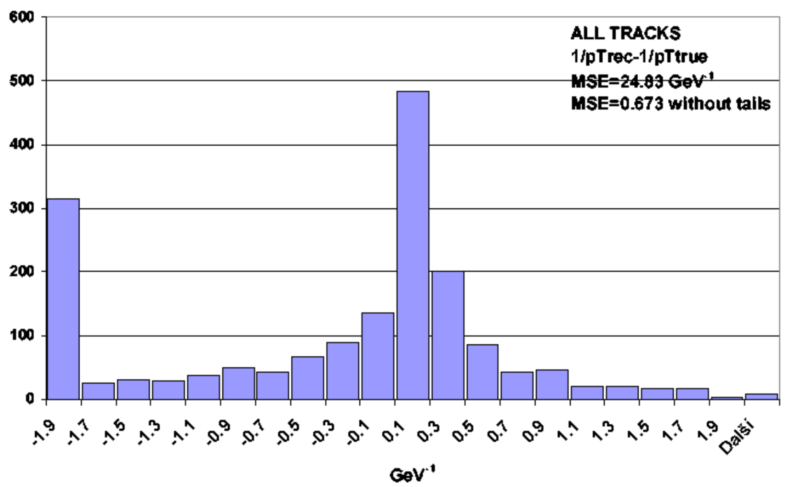

Fig. 16. Difference between 1/pT reconstructed and 1/pT true, all tracks

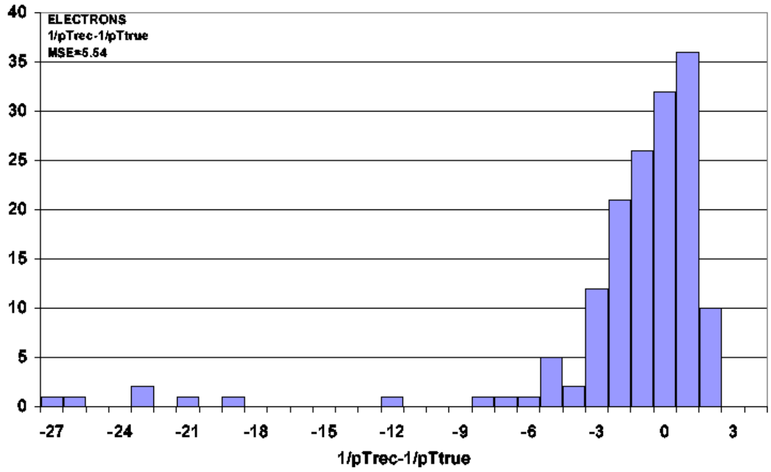

Fig. 17. Difference between 1/pT reconstructed and 1/pT true, electrons

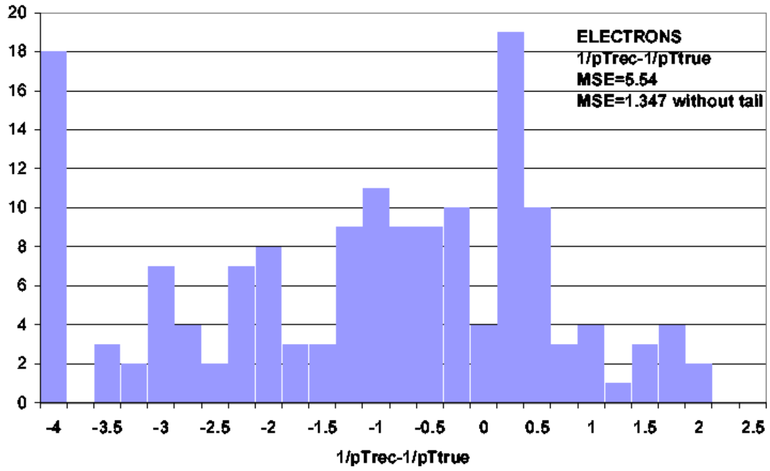

Fig. 18. Difference between 1/pT reconstructed and 1/pT true, detail, electrons

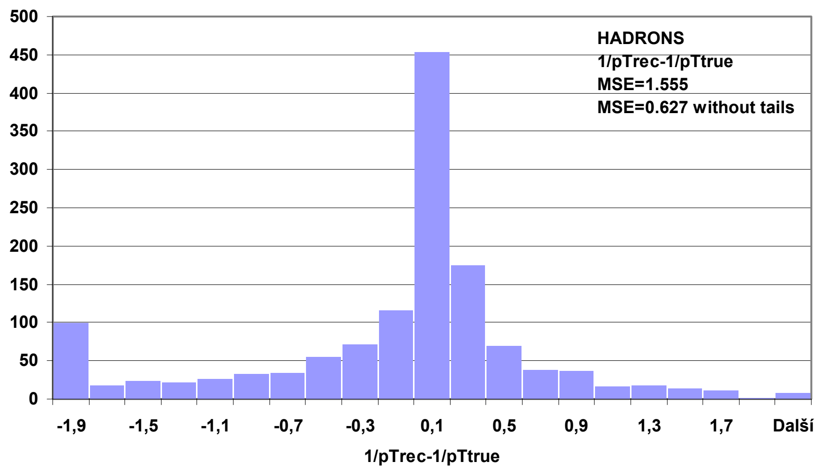

Fig. 19. Difference between 1/pT reconstructed and 1/pT true, hadrons

Impact Parameter Reconstructed

In this case the true impact parameter is computed the same way in which it can be established for reconstructed tracks, i.e. as the negative difference between the radius of the track and the distance of the circle center from the origin.

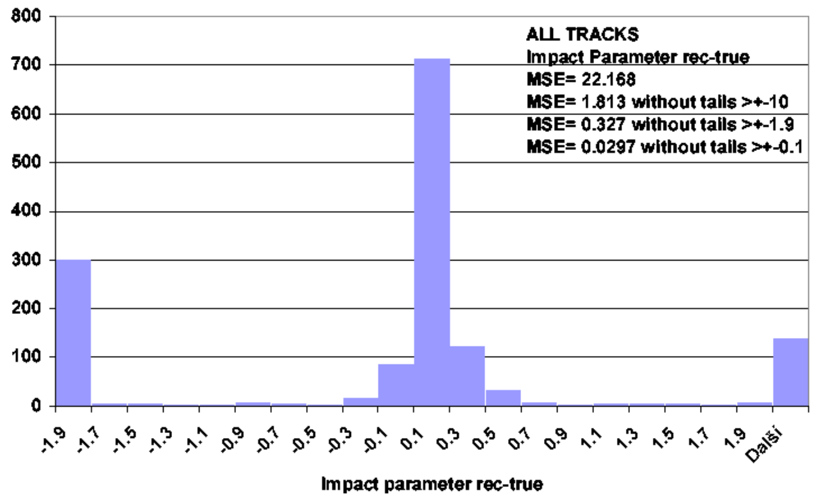

Fig. 20. The difference between Impact parameter Reconstructed and the Impact parameter True in cm, all tracks

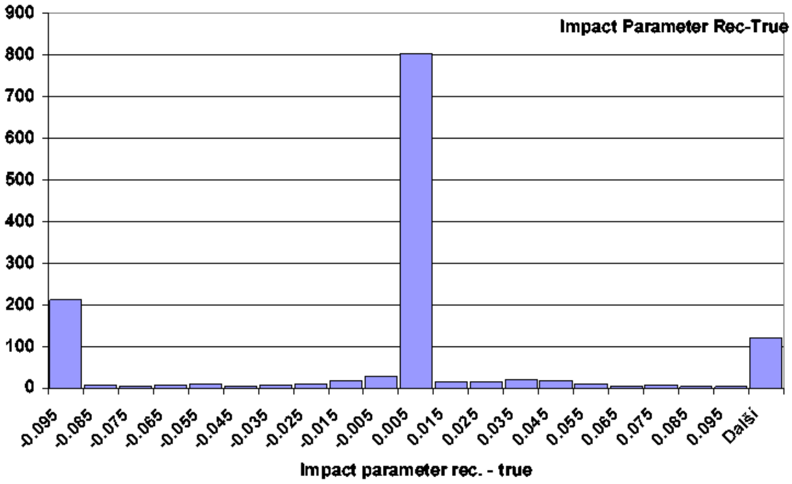

Fig. 21. The difference between Impact parameter Reconstructed and the Impact parameter True in cm, detail, all tracks

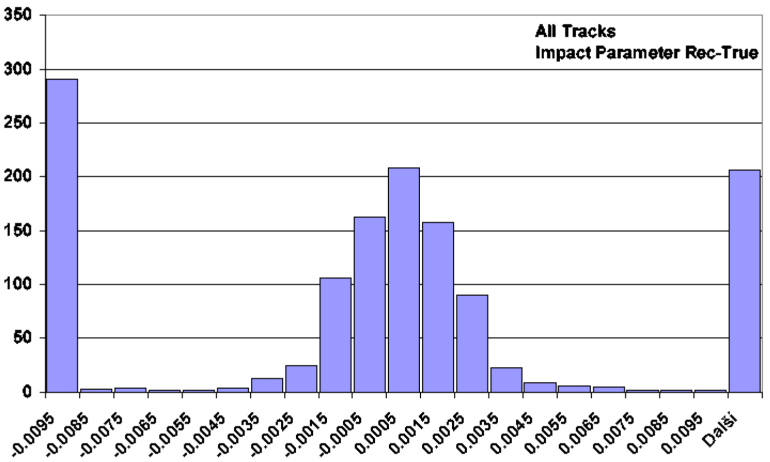

Fig. 22. The difference between Impact parameter Reconstructed and the Impact parameter True, all tracks - more detail

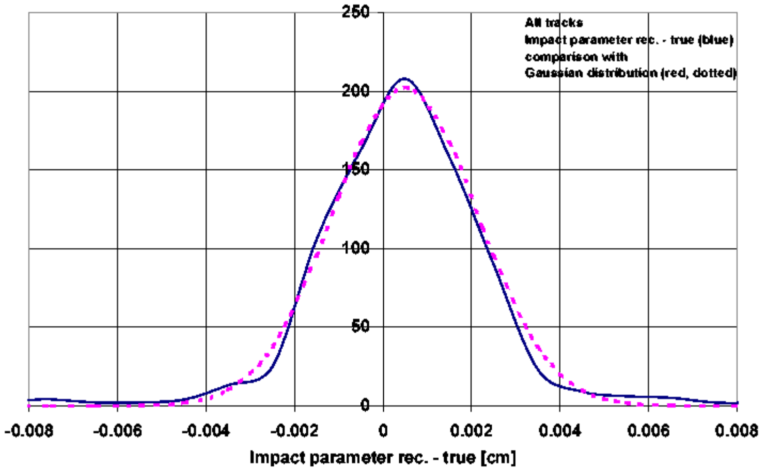

Fig. 23. The difference between Impact parameter Reconstructed and the Impact parameter True, all tracks - more detail - comparison with Gaussian distribution

It can be found that for all tracks but without outliers, i.e. for ABS(1/pTrec - 1/pTtrue) < 0.25 GeV^{-1}, there is shift of histogram peek to the right, i.e. systematic error of pT is 0.00410 GeV (not 1/pT).

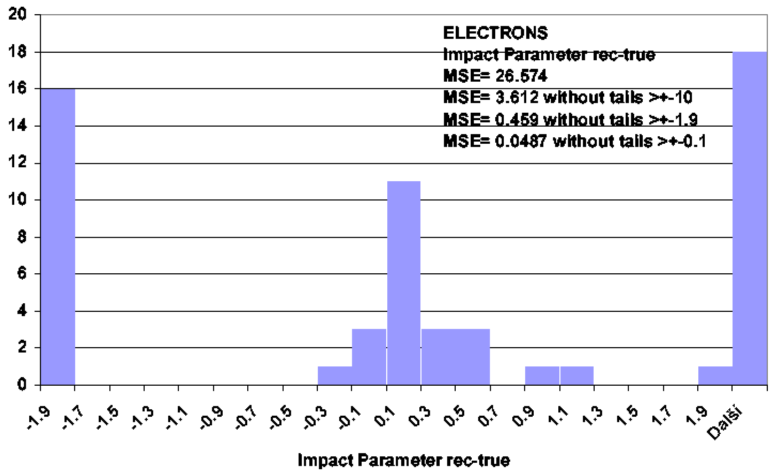

Fig. 24. The difference between Impact parameter Reconstructed and the Impact parameter True, electrons

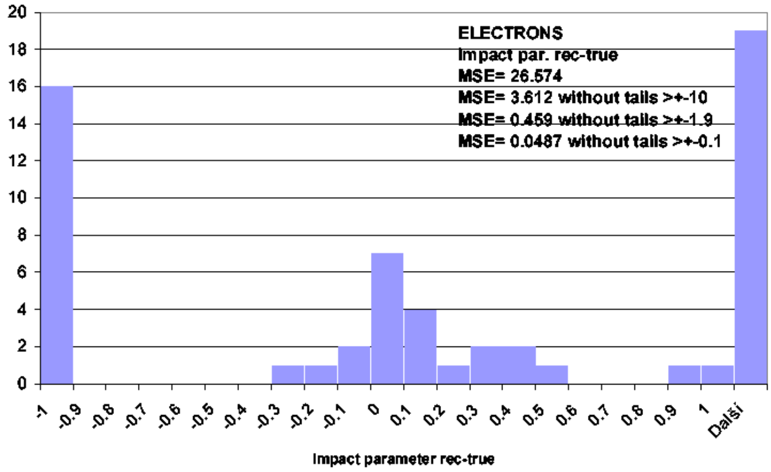

Fig. 25. The difference between Impact parameter Reconstructed and the Impact parameter True, electrons

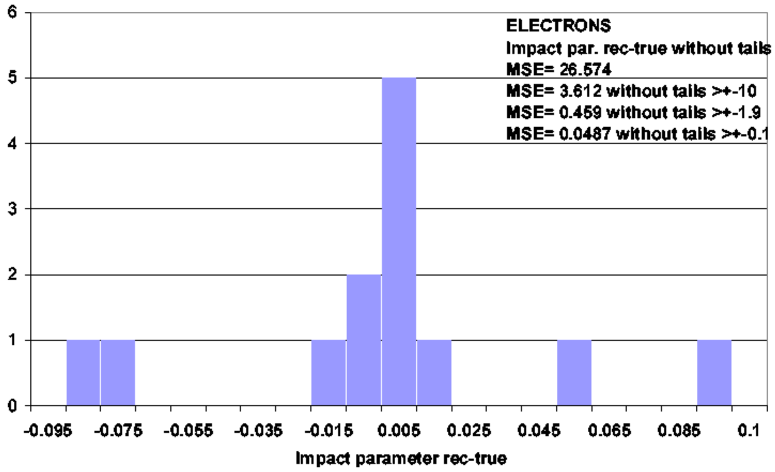

Fig. 26. The difference between Impact parameter Reconstructed and the Impact parameter True - detail, electrons

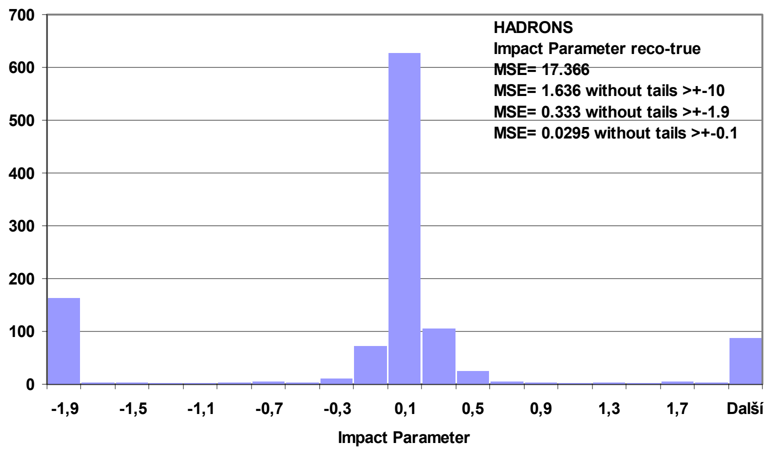

Fig. 27. The difference between Impact parameter Reconstructed and the Impact parameter True, hadrons

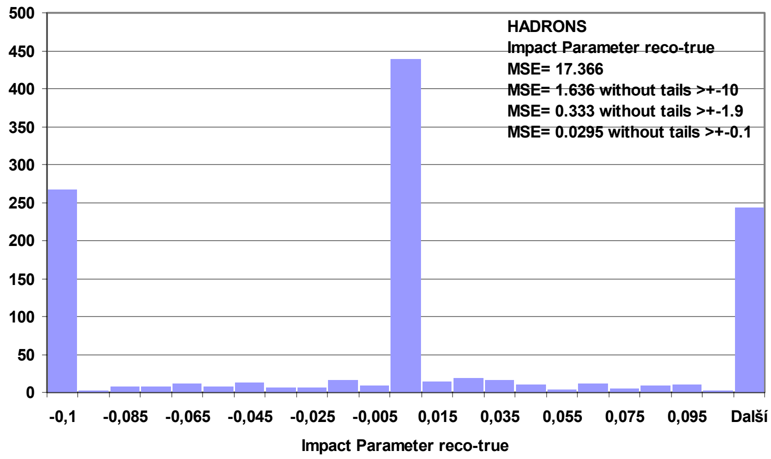

Fig. 28. The difference between Impact parameter Reconstructed and the Impact parameter True, hadrons

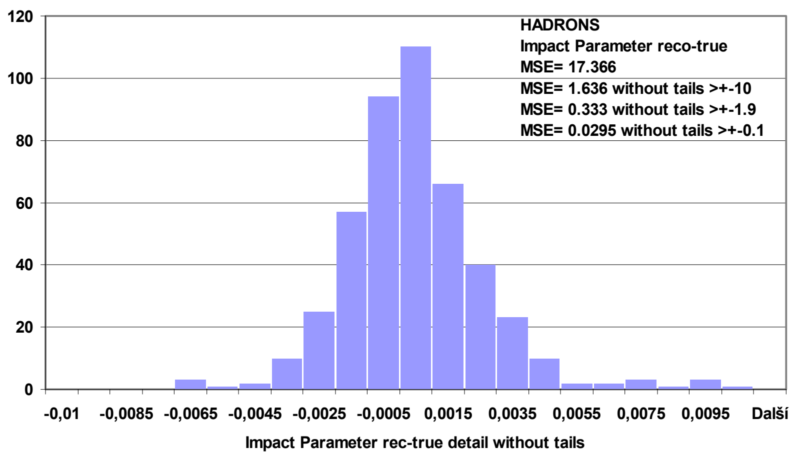

Fig. 29. The difference between Impact parameter Reconstructed and the Impact parameter True - detail, hadrons

Bremsstrahlung tracks

From all tracks found some are found to be "broken" and fulfilling geometrical condition that two circular parts of thus broken track touches each other, i.e. the particle continues in the same direction but with lesser energy and then lesser speed. For electrons (and positrons) this is due to Bremsstrahlung effect. For other particles it may be due to strong interactions, ionization loss and other phenomena.

In this part we used tracks of electrons only.

We found that there were 107 tracks of electrons and from them 16 with Bremsstrahlung where pT of the second part of the track has pT at least 0.36 GeV. Average pT before energy loss, after energy loss, and average loss of pT are shown in Table XX.

Tracks	No. of tracks	No. of BS tracks	% of tracks with en.loss	pT1 before energy loss	pT2 after energy loss	loss of pT GeV
electrons	107	16	14.95 %	2.160921	0.512724	1.648197

Table 2. Average pT before energy loss, after energy loss, and average loss of pT.

The values in the Table XX and for histograms was computed as follows:

1. of all 107 electron tracks was identified those consisting of two parts, slow and fast, and slow part was limited to be at least 0.39 GeV (R2 at least 60 cm). Thus we got 16 Bremsstrahlung tracks
2. radii R1 and R2 of both circular parts of the track was computed and from them pT1 before Bremsstrahlung, and pT2 after Bremsstrahlung,
3. loss of pT was computed as pT1-pT2,
4. average values are in Table XX, histograms in following figures.

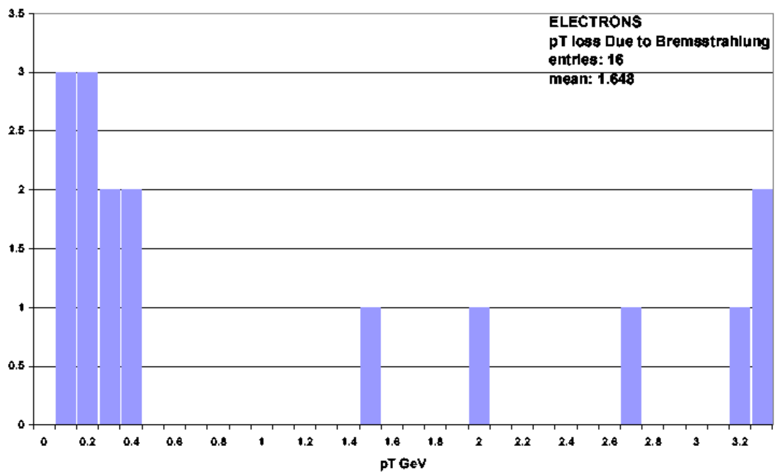

Fig. 30. The pT loss due to Bremsstrahlung effect, electrons

To this distribution of pT loss correspond the distribution of pT before and after the Bremsstrahlung shown in Fig. 31.

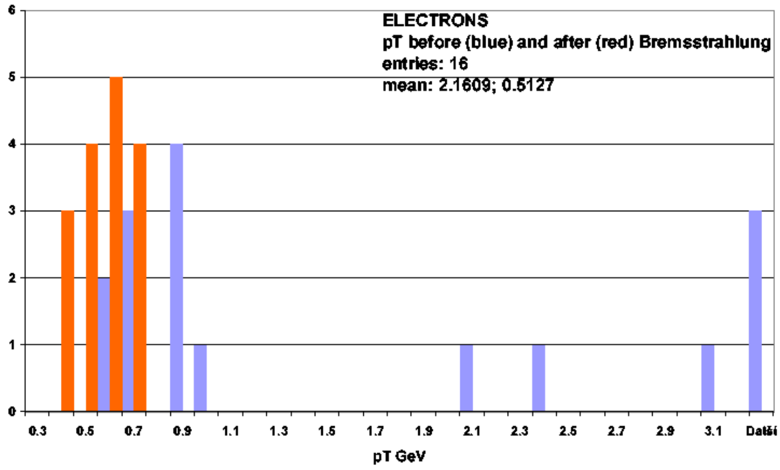

Fig. 31. The pT [GeV] before (blue) and after (red) Bremsstrahlung for electrons. The difference i.e. pT loss is shown in Figs. 30.

Distribution of the number of tracks with loss of energy arising in different layers of silicon tracker as well as in TRT is shown in Fig. 32. In silicon tracker loss of energy may arise only on individual layers of detector, but in TRT anywhere. To get some estimation for continuous medium of TRT we discretized it in nine layers. Each "layer" in TRT is in fact a layer of straws.
The position, or the layer on which energy loss arises for a particular track is given simply by the layer for which the best hypotheses was found as mentioned in Introduction.

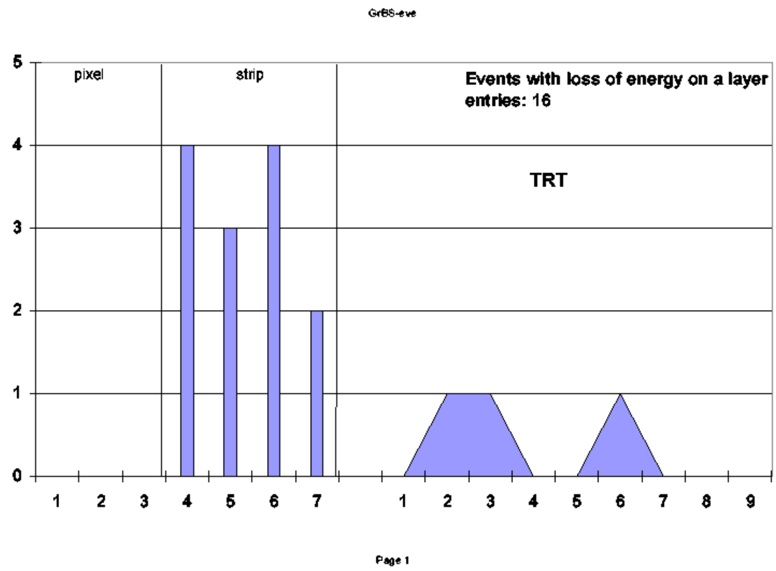

Fig. 32. Distribution of the number of tracks with loss of energy arising in different layers of silicon tracker and in bottom layers of TRT, all tracks.

In Fig. 33 an event is shown with one Bremsstrahlung track.

Fig.33 an event with one Bremsstrahlung track. "B" denotes Bremsstrahlung point, "S1" and "S2" are centers of the first and the second part of the track, respectively.

Conclusion

These results are preliminary from the following reasons:

1. data used are related to old geometry, but we mean that it does influence neither behavior of the tracking algorithm nor the algorithm itself,
2. statistics are rather small,

3. for tracks with loss of energy – Bremsstrahlung usually the first, fast part of track has hits in silicon detector. The second, slow part of the track is "seen" in TRT only or in TRT and one or two layers (hits) in silicon. As TRT has "pitch" 80 or 50 times larger than strip or pixel detector, respectively, the error is correspondingly large.

On the other hand the procedure can search for tracks with loss of energy (BS tracks) arising not only on layers of silicon detector but in also in lower part of TRT. For BS track finding the technique is used, first to approximate track in TRT, then extrapolate it back in lower part of TRT and in silicon detector either directly (the "central" track) or as a faster track going through the primary vertex and fulfilling the assumption of loss of energy arising on layers of material. Thus we are looking for set of (today) 17 possible tracks as mentioned in Introduction. These tracks correspond first to the central track and then to tracks with loss of energy arising in the first, the second, ... layer of the silicon detector and the first, the second,... till the ninth layer of straws in TRT. From these 17 track hypotheses the track having the best fit to hits in silicon detector and in TRT is selected as the accepted track. The best fit is computed using weighted LMS to take into account the fact that TRT has "pitch" (and then error) 80 or 50 times larger than silicon detector.

Using this algorithm we found that it is able to reconstruct all „standard“ reconstruction parameters as pT and impact factor. It is also able to find that track is „broken“ due to energy loss, in the case of electrons due to Bremsstrahlung effect. We also found that approximation error (not error reconstructed – true) when using set of hits finally selected (also in silicon detector) when supposing a „broken“ track is smaller than approximation error when the same set of hits in silicon detector and in TRT is „forced“ to approximate a single circular track without any break.

Acknowledgment

This work has been supported by the Czech Ministry of Industry and Business as a part of the project “Collaboration of the Czech republic with CERN” No. RP-4210/69/99.

References

[1] ATLAS Technical Proposal for a General-Purpose pp Experiment at the Large Hadron Collider at CERN. CERN/LHCC 94-43 LHCC/P2 15 Dec. 1994, Chaps. 11.11, 3.4.
[2] Sessler, Matthias, Smizanska, Maria: Global Pattern Recognition in the TRT for the ATLAS LVL2 Trigger . ATL-INDET-98-210 (ATL-COM-INDET-98-005) 25 Jun 1998.
[3] Gavrilenko, I.: Description of Global Pattern Recognition Program (XKalman). ATLAS Note-INDET-97-165 (ATL-I-PN-165), 25 Apr. 1997.
[4] Billoir Pierre: Progressive Track Recognition with a Kalman-like Fitting Procedure. Computer Physics Commnications 57 (1989) pp. 390-394.
[5] Frühwirth, R.: Applicaton of Kalman Filtering to Track and Vertex Fitting. Nucl. Instr. and Meth. in Phys res. A262 (1987), pp. 444-450.
[6] Billor, P., Qian, S.: Simultaneous Pattern Recognition and Track Fitting by the Kalman Filtering Method. Nucl. Instr. and Meth. in Phys res. A294 (1990), pp. 219-228.
[7] Badalá, A; Barbera, R; Lo Re, G; Palmeri, A; Pappalardo, G S; Pulvirenti, A; Riggi, F: Tracking inside the ALICE Inner Tracking System. CERN-ALI-2001-034 ; CERN-ALICE-PUB-2001-034. Geneva, CERN, 30 Jul 2001, 11 p.
[8] Jiřina, M.: Circular Regression for Particle Tracks Approximation. Technical Report No. 868, Institute of Computer Science of Acadeny of Sciences of the Czech Republic, 2002.