TRACKING OF THE HIGH p_t PARTICULES IN ITS STAND-ALONE DETECTOR.

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Tracking of the high p_t particles in ITS stand-alone detector

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Abstract

In this paper two new algorithms for ALICE ITS stand-alone tracking of high p_t particles are presented. They are based on hit grouping method, one of them uses also neural network predictions to connect the hits. Efficiency and purity results were estimated using Monte-Carlo simulated events.

1 Introduction

Two main parts of the ALICE detector (hadronic and dimuon) represent different needs and different possibilities in the question of their optimal physics performance. The hadronic part is rather slow, but gives an information on the huge number of tracks, while the dimuon one gives a fast information about small part of the particles. In order to make a di-muon arm fully operational and usable, it is required to use simultaneously the Inner Tracking System. It gives two very important informations: first it can indicate the event vertex with the very high precision, which allows measuring the angle between two muon tracks. Second, it allows studying the topology of the event and can be used as an extension of the di-muon arm. In order to increase the statistics (which means the requirement of the high event frequency) it is not reasonable to use TPC as a main tracking system (mainly due to relaxation processes in the TPC). ITS detector is much faster what makes possible to gain the higher statistics in shorter time - the price to pay is of course lower tracking efficiency.

The ITS as a stand-alone system requires a specific tracking algorithm. There are some existent codes, which can track the low-p_t particles, but there are assumptions that high-p_t particles are already tracked by TPC with 100% efficiency [7]. The aim of this note is to verify if we can track the high p_t particles in a stand-alone mode of ITS and in the enviroment of huge number simultanously registered hits coming from lower p_t particles. Here we present two independent algorithms, which deal with this problem. This note gives a short explanation of the idea and the current status of the work.

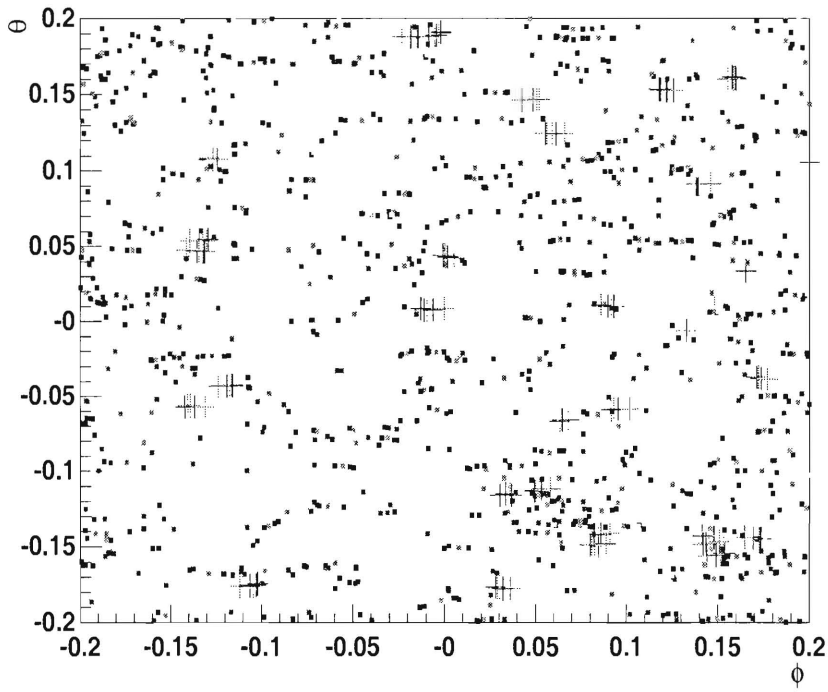

Figure 1: θ - ϕ map of hits. The crosses represent particles with $p_t > 1$ GeV/c, dots - other tracks. Note that the plot shows only a part of the space.

2 The grouping tracking algorithm

This method is based on searching for tracks in the (θ, ϕ, layer number) space, where θ and ϕ are the angles in the spherical coordinate system (θ is the angle between the beam axis and the line connecting hit and the vertex):

$$\theta = atan2(z/\sqrt{x^2 + y^2}) \tag{1}$$

$$\phi = atan2(y/x) \tag{2}$$

Since the high-p_t tracks are only slightly bent in ϕ and especially in θ, so in the chosen representation they form straight lines, almost perpendicular to the θ axis (fig.1).

In contrary to the Hough transform this algorithm is based on finding groups of points, when Hough transform tries to retrieve the parameters of a given pattern (like a straight line or a circle) - after the transition to the map built on the parameters space.

The first stage of the algorithm is the histogramming of the hits in θ-ϕ bins, thus boosting the scanning speed in the next steps (only a few hits - from the same bin and from the neighbours - have to be checked). All the space is divided in 4000 cells - 200 bins both in θ and ϕ. It was simulated that increasing number of cells doesn't improve the speed, which can even go down in case of low-memory system. It doesn't affect the efficiency, because the scanning area is small in comparison to the cell dimensions.

After this stage the scanning begins, starting from the innermost to the outermost layer. It is performed in five steps, with ascending scanning range (the highest momentum tracks are

found first). It means that not only straight tracks are found and some bending is also taken into account.

Scanning area ranges are obtained from simple Monte-Carlo minimalization (or rather maximalization) of the algorithm efficiency. These ranges have to be small, to allow finding the tracks with good purity - it means also a strict cut on transverse momentum (slow particles do not have a chance to get into very small cell since their ϕ is changing quickly). The distances were defined as follows:

$$d = \sqrt{\theta^2 + \phi^2} \tag{3}$$

Hits laying in the scanning area are taken to the buffer table and distances are calculated. The code is flexible enough to allow that each hit can be taken to the buffer more than once but now this feature is not used (doesn't give any improvement). After the loop over the hits from each layer, pairs of hits from neighboring layers are stored in the buffer table. They are sorted according to the distance and then the pairs with lowest distances are taken to make associations (fig.2). At this level of work no hit sharing is allowed, so the hit which was used is thrown out of the pool. The tendency of ϕ changes (positive or negative) is checked and the hits, which do not satisfy this condition (with some margin of error due to very little bending), do not make associations.

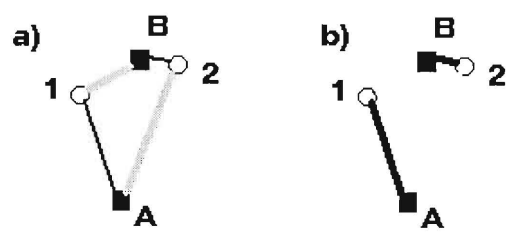

Figure 2: a) - Example of wrong association generated if there is no buffer table for pairs of hits. Hits marked '1' and '2' lay on the first layer, hits marked 'A' and 'B' are on the second layer of the ITS. One real track contains hits '1' and 'A', and the second one - '2' and 'B'. It means that hit '1' should be associated to 'A' (black line), but due to the fact that the 'B' was scanned first, the '1' was erroneously associated to 'B' (gray thick line). The hit '2' is then wrongly associated to 'A', because no other hits were left. b) - The associations are correct, due to storing the hit pairs in the table and then choosing the best pairs.

The main vertex position is assumed to be known, and the influence of the error of the vertex position was not included. The simulation of the detector resolution is included as a smearing of the hits with gaussian distribution, with dispersions for each direction taken from [5]. It should be also noted, that only those tracks, which leave at least one hit on each layer, can be reconstructed, and only these tracks are considered as "foundable".

The method presented above is related to the grouping algorithm, described in [8].

3 The combined tracking algorithm

The second algorithm is a combination of several methods based on creation of graphs, global approach and neural networks. The main point of this work is track reconstruction of high-p_t particles (p_t above 1 GeV/c) out of the high number of lower momentum particles (fig.3). Therefore we have applied strict cuts on lower p_t particles. This means that we expect the next hit in a very small ($\Delta\theta$ = 0.0020, $\Delta\phi$ = 0.0035) theta-phi bin. These numbers were obtained empirically to get the highest efficiency.

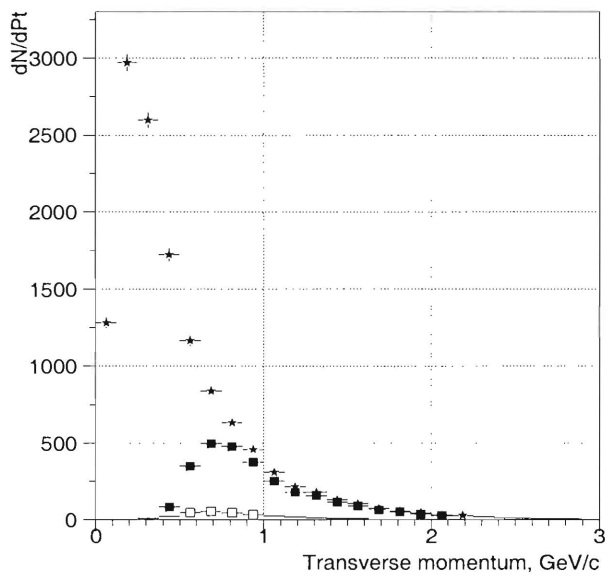

Figure 3: p_t distribution for real tracks (only these with six hits) - stars, well reconstructed - full boxes, and fake tracks - open boxes. The plot was done for 5 events reconstructed by the combined algorithm.

The structure of the code is as following:
1 - Creation of the assignment graphs for three inner layers.
2 - Track projection to the fourth layer using neural network prediction.
3 - Branching of track candidates (begin of the global method), projection of each candidate to outer layers, using neural network.
4 - Calculation of fit function.

1. Graph creation

This part is responsible for creating hit association for each layer. This information is used as a first rule of candidate selection. We assume that vertex can be found using ITS detector only (pixel layers in particular) as stated in [5], so we assume the vertex coordinates to be known.

This information is used for a first selection. Let us consider four arrays (fig. 4). They contain the number and indices of the nearest assigned hits from other layers. For example: array32 at position 30 contains indexes of hits from layer 2 nearest to the hit with index 30 on layer 3. array23 at position 20 contains the indices of hits from layer 3 nearest to the hit with index 20 on layer 2 (it is hit with index 30 in this case).

The method is similar for other arrays (array21, array12). After creation of these tables we obtain bi-directional associations between hits from pairs of layers.

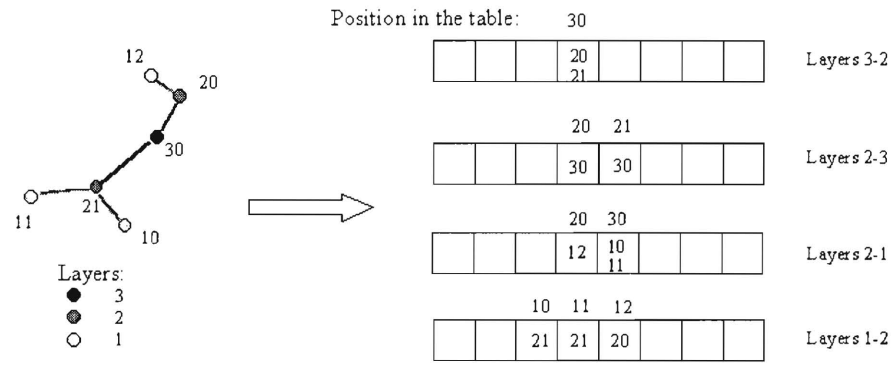

Figure 4: Scheme of candidate selection algorithm

2. Track projection

After creating reliable track candidates from three inner layers we make a projection of these triplets to layer 4. This is done using neural networks (for prediction of the ϕ angle) and linear extrapolation (for prediction of the θ angle). A three-layer feed-forward neural network (fig. 5) was used. As the inputs we give differences in the ϕ angle between hits on consecutive layers (fig. 6). There were two networks used. One for the prediction on the fourth layer (with two inputs - dphi12, dphi23) and one for prediction on the fifth layer(with three inputs - dphi12, dphi23, dphi34). The network has 2 hidden layers with 20 neurons each, and a single neuron output for giving the predicted ϕ angle. We use a sigmoidal activation function with β=0.8 The network was trained on simulated samples containing high p_t ($>$ 0.5GeV/c) tracks. As a training method we have used back-propagation algorithm with a variable training parameter η in the range: 0.1-0.7, which caused fast convergence to minimum error value (after about 200000 learning steps).

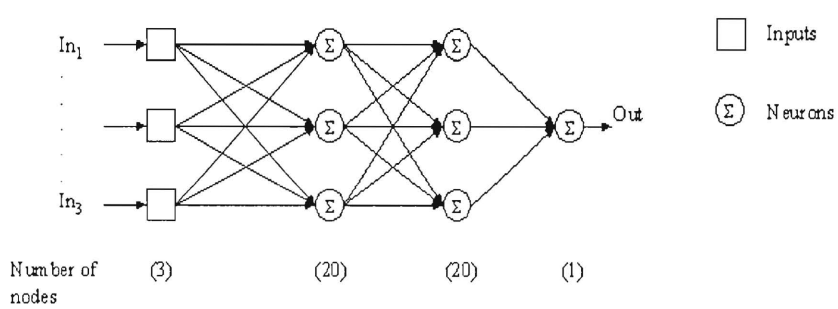

Figure 5: Scheme of the neural network architecture

3. Branching

From the previous step we obtain the predicted position of hit on layer 4. Then we search for

hits, which are close enough to that point. As "enough" we mean hits in some $\Delta\theta$, $\Delta\phi$ range. In some cases we find more than one hit, and then we apply branching of track candidate. After it we obtain several track candidates assigned to hits given by steps 1 and 2. For every hit from layer 4 we repeat projection steps to outer layers. This gives us a set of crossing assignments of track candidate from inner layers with hits from outer layers.

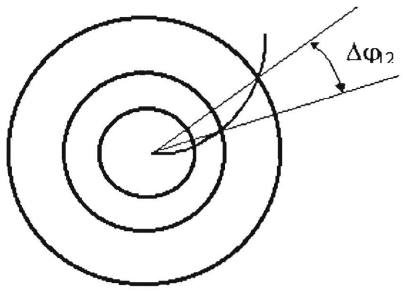

Figure 6: Definition of the ϕ angle between hits on consecutive layers

4. Fit function

The fit function in this version is simply the sum of squares of distances between projected point and found point. The value of fit function for each combination is stored in an array, so after processing all the possibilities, we choose the best fitted branch and release the others. We expect to increase the performance by replacing this formula with a neural estimation.

The simulation of the detector resolution was done in the same way as in the first algorithm.

4 Results

As stated above, the main goal was to reconstruct high-p_t ($>$ 1GeV/c) tracks. To reach high purity of the tracks we had to set very strict rules for choosing track candidates, so the number of found tracks with $p_t < 1$GeV/c appeared to be quite small.

The results of the first algorithm were obtained for 10 KINE4 events (simulated with AliRoot using HIJING parameterization for Pb+Pb reaction: around 80000 tracks ($|\eta|$ <6), which means 140000 hits in ITS). They are presented on the fig.7. Transverse momentum of good tracks is taken from AliRoot file, so momentum resolution effects are not seen on this plot. The momentum of fake tracks is estimated from the circle fitting.

The picture shows very strong dependence of the results on the transverse momentum in the region of low p_t and almost constant behaviour for high momenta. The efficiency is quite good for the high momentum tracks ($>$ 0.5 GeV/c), of course it's getting worse for lower p_t. The fake track efficiency is high for the lower p_t, but after reaching the minimum around 2 GeV/c it goes higher again. It is caused by the intrinsic feature of the algorithm - it chooses the points laying on a straight line, so sometimes it finds wrong associations which correspond to the very high momentum. The other explanation is the difficulty of momentum estimation for straight-lined fake tracks. It has to be stated here, that the number of bad tracks in this region is at the level of 5-6, but this number is high compared to the number of real tracks.

The average results for tracks with $p_t > 1$ GeV/c are at the level of 81% for efficiency and 15% for fake tracks. The execution of the tracking algorithm for one event took about 5 sec of CPU time on Pentium 200MMX with 40 MB RAM.

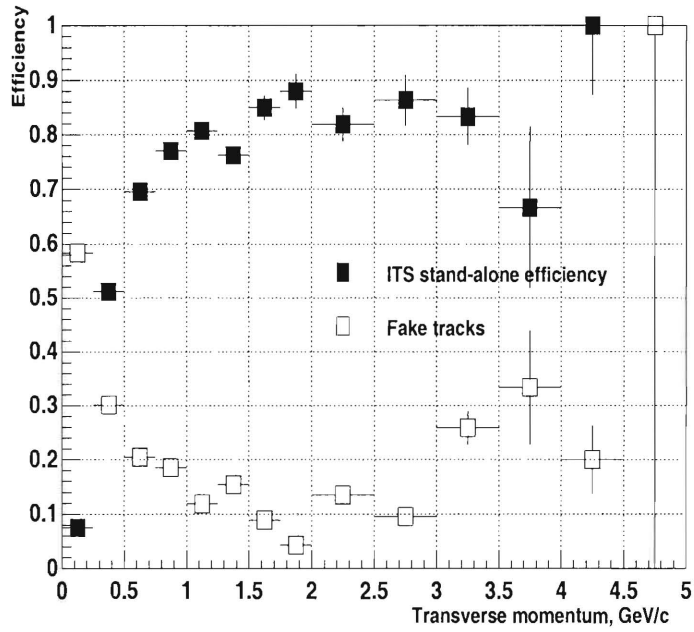

Figure 7: Results for grouping algorithm and AliRoot data

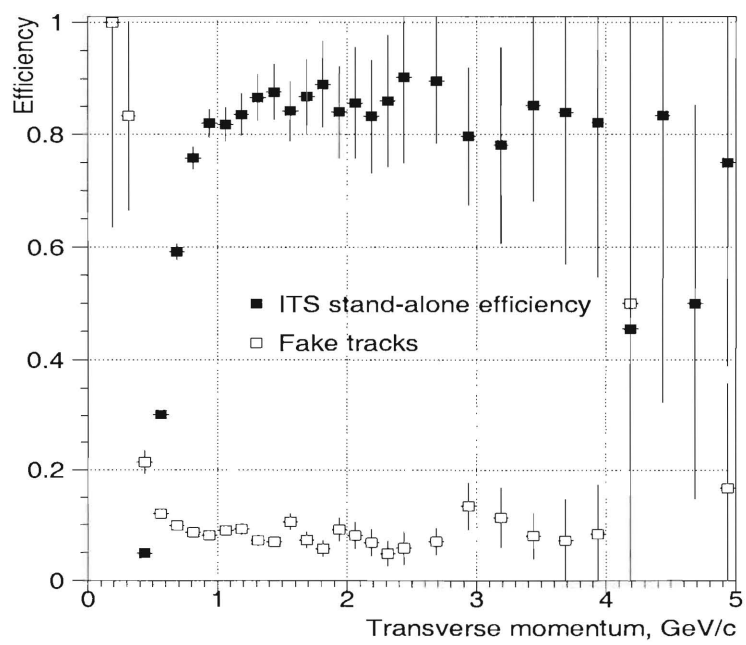

Figure 8: Results for combined algorithm and GAlice data

The second algorithm was tested on a slightly different set of data. Events were simulated using the same HIJING parameterization, but with older simulation package, GAlice. The results show a very similar p_t dependence (fig.8), but they are a little bit worse for lower p_t. The difference in the fake track efficiency (very high for low momenta and low for high p_t) comes from different way of estimation of the momentum for these tracks. The momentum of the fake track in this algorithm is equal to the momentum of the track, which gives the largest number of hits.

All these disadvantages are going to be solved in the very near future, after moving the code to ROOT environment.

The simulation was processed on 5 KINE4 events. The average efficiency for high p_t tracks is around 84% and fake track efficiency around 10% (which can be changed after improving the momentum calculation). The total execution time of the tracking program, including the reading data, processing and histogram creation is about 6 CPU seconds per event on a Pentium 200MMX and can be reduced after some optimizations.

It has to be stated that of course all physical effects were turned on while processing and a magnetic field of 0.2 T was present. The environment of all tracks, including those of secondary particles is taken into account in the tracking procedure. For both methods we identify track as a correct one if all of its hits are correctly identified and the track leaves at least one hit on each layer.

5 Future plans

The work is still in progress and we are going to improve both of our algorithms. The main things that have to be done are:
- Calculation of vertex position (currently we take it as known).
- More realistic simulation of the detector resolution.
- Calculation of particle momentum.
- Reconstruction tracks that have less than six hits.
- Increasing the range of transverse momentum (now we are interested mainly in p_t above 1GeV/c).
- In the combined algorithm - replacing of fit function with neural network (instead of sum of distances squares) and also hit sharing for all layers (now it is done only for the three inner layers).

6 Conclusions

This study has shown the feasibility to use the ITS as a stand alone tracking device, if one is interested in the high p_t part of the event (above e.g. 1 GeV/c). It seems to be possible to track the high momentum particles in the enviroment of a huge number of slow particles. This opens up the measurement and pattern recognition of jet quenching together with the detectors, which run at a high speed like the Dimuon Spectrometer and the PHOS.

References

[1] D.Kharzeev, H.Satz, Nucl.Phys., A 590 (1995) 1-2 (515c-518c)

[2] C.Lourenco, 12th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions (Quark Matter '96), Heidelberg, Germany, 1996

[3] K.Gallmeister et al., Phys.Rev. C57 (1998) 3276 6

[4] P.Braun-Munzinger et al., Eur.Phys.J.C. 1 (1998) 1/2. 123-130

[5] ALICE Technical Proposal, CERN/LHCC/95-71, 1995

[6] ALICE Addendum - The forward muon spectrometer, CERN/LHCC/96-32, 1996

[7] B.Batyunya, Yu.Belikov, A.Fedunov, A.Zinchenko, ALICE Note INT-95-50

[8] D.J.Prindle, STAR Note SN0153, 1994