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D–mesons in STAR : an Update

1 Introduction

In this document we summarize the work done as of today on the reconstruction of D-mesons. Various techniques were used in simulations to approach this delicate problem. All of them relied on the SVT detector and its current design specifications and performance [1]. After processing a reasonable sample of events, which in this study assumed to be about 10^5 central Au+Au events, none of them could reliably recover the signal used as the input.

We will close this document with a list of some new ideas that are still in the process of being tried out in simulations.

2 D-mesons in STAR environment

Extracting information about D-meson production at RHIC with the current STAR detector (TPC + SVT) is an extremely difficult and challenging task to perform. We summarize below the main reasons (see also [2]):

- The mean life-time of D-mesons is very short, i.e. $D^+ = 318\mu m$, $D^0 = 126\mu m$. In a collider experiment like STAR and around mid-rapidity, there is no significant Lorentz boost as there is no motion of the c.m. system relative to the lab. Thus most of the D decay vertices are within a millimeter from the main vertex! In addition, since the mean momentum of the particles and the decay products is of the order of a couple of hundreds of MeV/c, the multiple scattering is substantial. During track reconstruction, very often tracks which came originally from the main vertex will appear to have a finite impact parameter. Since the D-meson decay distance is expected to be comparable to the extrapolation accuracy to the vertex, the task of finding the true secondary vertices is expected to be very difficult.

- The branching ratios of the potentially reconstructible decay modes are very small, e.g. $D^0 \rightarrow K^- + \pi^+$ is 3.71%. This coupled to the low production rate (assumed to be about one D-meson of each kind per event), plus the finite acceptance of the detector, gives rise to a marginally small signal per event ratio (around 10^{-3}).

- The high multiplicity environment (about 2000 particles per event in the detector acceptance for a central Au+Au event) gives rise to a large combinatorial background. This background scales as N^a where N is the multiplicity of the particular particle species per event and a is the number of the daughter particles. In other words the background per event drastically increases with N (going from p-p to A-A) and/or a ($a = 2$ in $D^0 \rightarrow K^-\pi^+$ and $a = 4$ in $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$). As a increases (more particles in the final state) the lab momentum of the decay products decreases, which makes it more difficult to reconstruct them and more severe the effect of multiple scattering. For these reasons we preferentially investigated the decay modes with only two particles in the final state.

3 Reconstructing D vertices

Despite the difficulties in reconstructing the individual D vertices in STAR mentioned in the previous section, several people within the collaboration tried independently through simulations some novel ideas. We summarize below some of them:

- **D vertex finding and mass reconstruction**. This is a straight-forward analysis (like for K_s^0 or Λ). In this method secondary vertices are reconstructed by combining pairs of tracks and a n invariant mass is calculated through a mass hypothesis wherever PID is not provided for the daughter particles. A set of cuts is usually used in order to optimize the signal to background ratio. Two different SVT configurations were tried out. In the first one the SVT was three layers of more or less bare 300 μm thick Silicon at a radius of 5, 8 and 11 cm. From now on we will call this 'the standard configuration'. With rather idealistic assumptions and an optimized set of cuts the necessary number of events (for just one standard deviation difference between the fluctuations of the background and the signal) was found to be of the order of ten million.

  The second SVT geometry had also just three layers of Silicon but this time two layers were placed inside the beam-pipe in order to avoid the multiple scattering in the beam-pipe. The layers were placed at 3, 5 and 11 cm. With the same assumptions as before and the optimized set of cuts the minimum number of events needed dropped down to a few hundreds of thousands. Although this might seem to be a good number an additional factor of ten more in the number of events should be accounted for, if various efficiency factors (tracking, matching, pid and detector mass) are included in the simulations.

- **Statistical selection**. In this method, fully described in [3], one does not attempt to reconstruct the decay vertex of the D meson, or apply any cuts directly related to spatial or kinematic properties of the particle; instead the cuts are made in the multi-dimensional space of a set of generic cut–variables which are independent of the kinematical properties of the particle, the experimental resolution and other physically important quantities such as rapidity or transverse momentum. After the construction and search in this multi-dimensional space for the anticipated signal as well as the background, the authors found that, in the best case, many millions of central Au+Au events should be analysed for the standard SVT configuration, and many hundreds of years of CPU–time are needed in order to be able to make a substantial statement about D-meson production with STAR. They concluded that with this method and the current STAR equipment *D-meson detection will be impossible.*

- **Secondary Kaon impact parameter**. Since this method is presented for the first time here, we will describe it in some detail in the next section.

4 Kaon impact parameter

At RHIC energies, only Ω and D particles can decay into secondary non-vertex kaons, if we neglect contributions from charm baryon decays (e.g Λ_c). The relevant decays and the branching ratios are: $\Omega^- \rightarrow \Lambda K^-$ (67.8%), and $D \rightarrow K^- +$ anything (20.8%), $D \rightarrow K^+ +$ anything (5.8%). Kaons can be identified through dE/dx in the SVT in the momentum range 200–450 MeV [6], and one of the recent ideas [4] is to separate the primary from the secondary Kaon tracks in order to finally be able to extract D meson production cross–sections[1]. This could be done by looking at the track impact parameter distribution and searching for regions where secondary kaons dominate. As already mentioned, a problem in this method could be a large multiple Coulomb scattering effect which will give to any vertex track a large effective impact parameter.

In our simulations we used the standard SVT geometry (without the extra mass due to FEE and water cooling) plus a 1 mm thick berillium beam pipe. We have considered the following set of impact parameter definitions:

- $\mathbf{r0(x, y)_{min}}$: this is the 3-D distance of the back-projected track from the main vertex where closest approach only in the bending plane (x–y) has been considered.

- **z**: this is the z-coordinate distribution of the back-projected point when closest approach in the bending plane is considered.

- **r0**: this is the 3-D distance of the back-projected track from the main vertex. This is the real (3-D) impact parameter.

- **b**: this is the impact parameter in the bending plane. This variable is often used in high energy experiments.

The following different approaches have been adopted for the calculation of the impact parameter distribution:

[1]In this approach we ignore the background coming from Ω decays since only one Ω is produced in every ten central Au+Au events (as opposed to about 1–5 Ds per event) and they have a much longer life-time.

- **Ideal reconstruction**; we take from GEANT both the particle hit position and the momentum at the first SVT layer, project it back to the main vertex and calculate the impact parameter.

- **Fit without the main vertex**; we take from GEANT the coordinates of the three SVT hits for each track (assuming perfect detector position resolution) and we fit the momentum. Then extrapolate back to the vertex and calculate the impact parameter.

- **Fit with the main vertex**; same as above but include the main vertex position and its error as an extra space point in the fit. Then we perform a parabola fit [7] to the 4 points (3 SVT hits plus the main vertex). This also returns the impact parameter (b) as one of the fitted parameters.

- **Linear four point fit**; this is the same as above but the particle is forced to pass through the main vertex (known from GEANT) which linearizes the fit.

We processed with GEANT the vertex kaons produced in one thousand FRITIOF events. Only kaons with momentum in the range of 200–450 MeV were considered since for them PID through dE/dx is found to be close to 100% as we mentioned above[2]. The results, for all four approaches, are presented in figures 1 through 4 correspondingly. We observe that in all cases, 'idealized' or more real, the severe multiple scattering in the beam pipe and the detector itself of the relatively slow kaons considered in this method gives a large apparent impact parameter distribution. The anticipated D-meson signal in the same histograms ranges from 0.1 to 1 per bin (for a D-meson multiplicity of about 1 to 10 per event correspondingly). In order to achieve a distribution where the signal has the size of few standard deviations of the fluctuations on the background, many millions of events have to be processed. This combined with the difficulty to reliably model the systematic uncertainties in the track impact parameter distributions leads us to the conclusion that it will be impossible to disentangle the D signal from its very high background.

5 Future perspectives

We briefly discuss two other methods that could be used in the simulations.

The first relies on the fact a large fraction of the D^0 production comes from $D^{*+} \to D^0\pi^+$ and that there is a small mass difference between the D^{*+} and the D^0 which gives the so called 'bachelor' pion peculiar kinematical properties (soft pion with a zero degree angle opening between itself and the D^0).

The other uses the Lorentz boost effect for particles of high momentum (or high pseudorapidity) which might separate the decay vertex from the main vertex. Preliminary simulations showed that the pseudorapity interval $2 < \eta < 3$ is the ideal place to cover since it has the highest particle density[3] (dn/dη according to HIJING)

[2] For simplicity we ignored all possible miss-identified pions

[3] The distribution peaks at y=0 but not in η mainly due to the mass of the D.

and a reasonable Lorentz factor. There are several points to consider before pursuing further this idea:

- The current design of the STAR SVT is inadequate for this as it only covers $|\eta| \leq 1$. A small side detector of excellent position resolution is needed.
- Pseudorapidity 2 to 3 corresponds to angles of about 40 to 20 degrees relative to the beam. Since the side detector has to be as close to the main vertex point as possible, this calls the detector to be placed inside the beam-pipe.
- Although the Lorentz boost is extending the decay distance from the vertex by a factor $\beta\gamma$, the opening angle of the decay products becomes smaller by about the same factor due to the strong kinematic focusing. This, for a given detector resolution, means that there is no overall gain in the secondary vertices resolving power of the detector. On top of this, at large pseudorapidities, the tracks are traveling at shallow angles relative to the STAR magnetic field which makes it difficult to determine the momentum of the particles.

  One possible extra modification to STAR which will solve both of these problems, will be the introduction of a relatively strong magnetic field on one side of the interaction point, localized and normal to the beam (and the existing central magnetic field). Because of these technical modification these simulations were not further pursued.

6 Acknowledgement

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References

[1] STAR–CDR, PUB–5347

[2] S. Margetis, SVT note, Sep. 91

[3] M. Gazdzicki, W. Retyk, J. Pluta, Warsaw University Report IFD/3/92
J. Grebieszkow, Warsaw University Report IFD/3/93

[4] R. Bellwied, STAR note # 108, April 93

[5] W.K.Wilson, Unpublished SVT notes.

[6] E. Paganis and S. Margetis, 'dE/dx with the SVT', STAR note # 126, Sep. 93

[7] M. Hansroul et al.,'Fast circle fit with the conformal mapping method', NIM A270(1988)498.

[8] Particle Properties Data Booklet, AIP (1992).

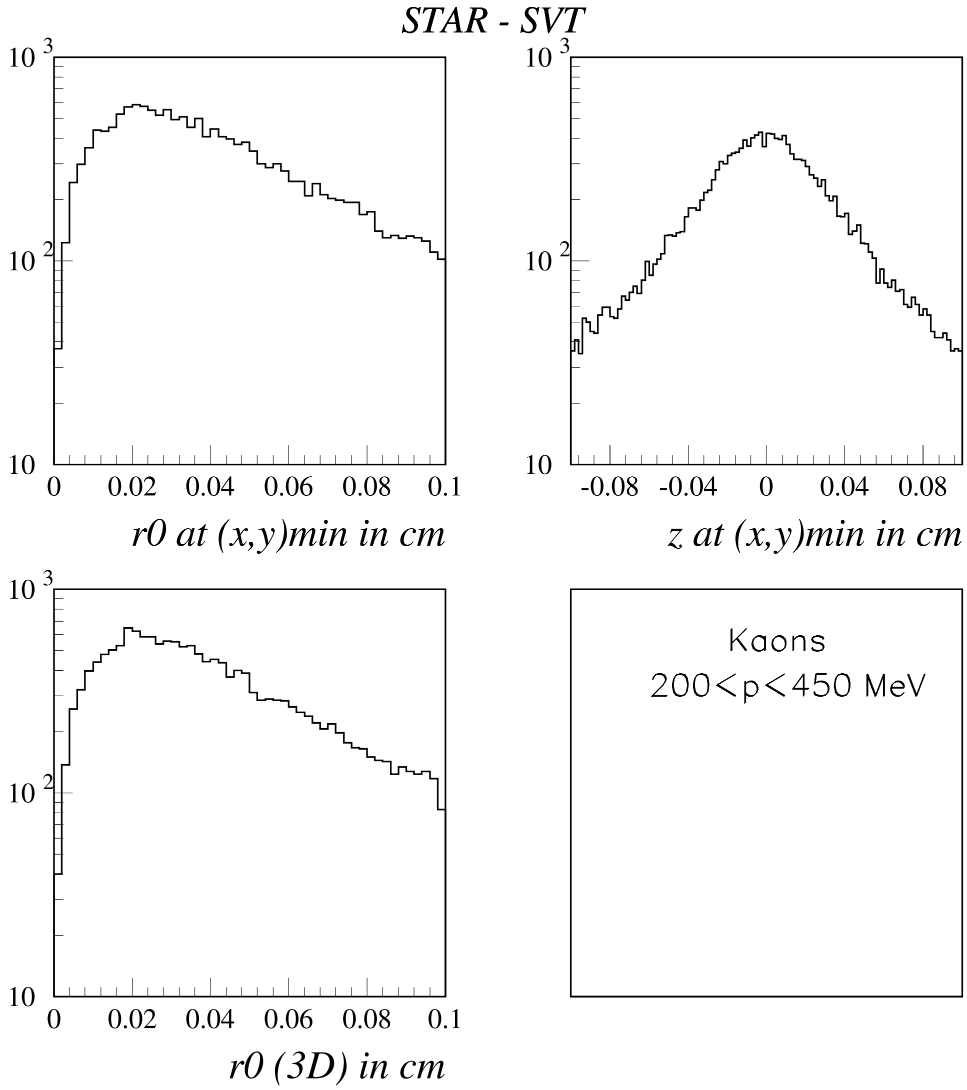

Figure 1: Impact parameter distributions for vertex kaons. One thousand FRITIOF events were processed with GEANT. The different variables are explained in the text. The momentum vector was taken from GEANT information at the first SVT layer.

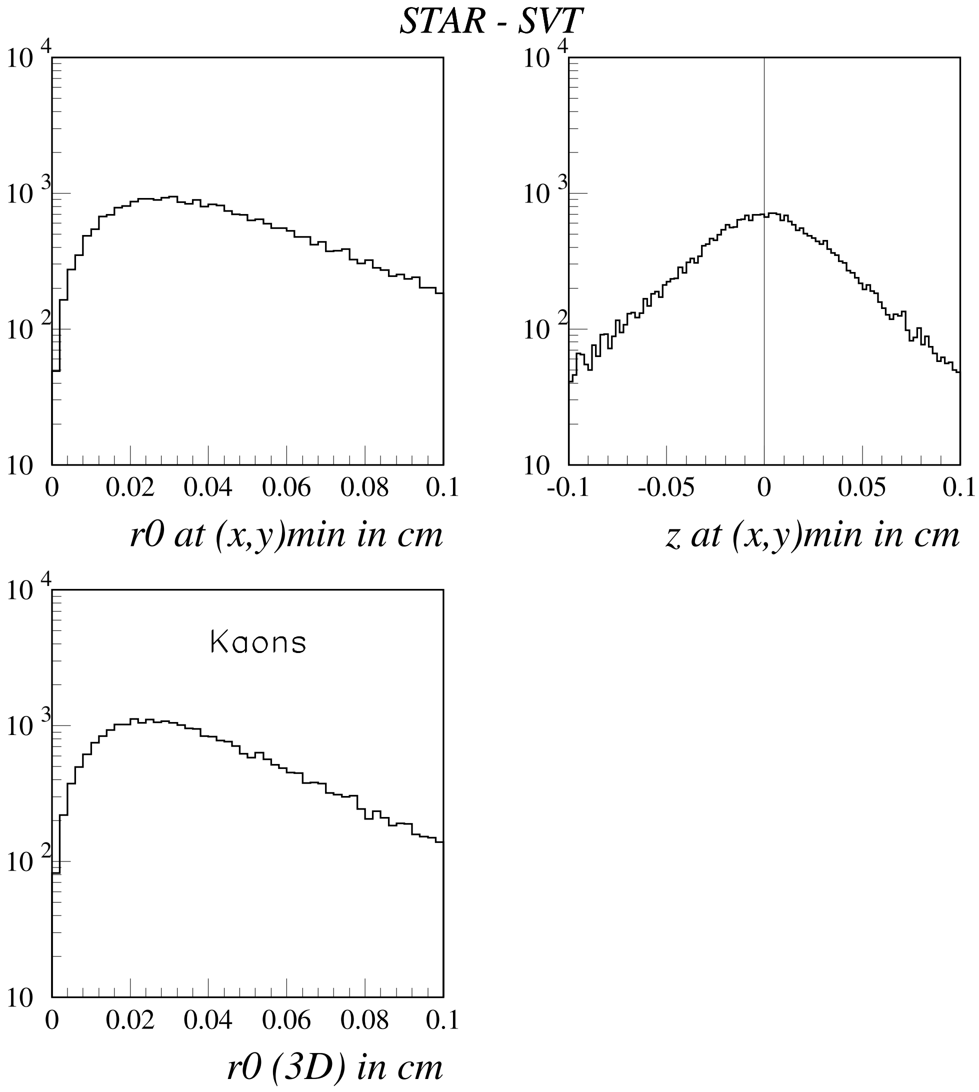

Figure 2: Impact parameter distributions for vertex kaons. To determine the momentum vector only the 3 points in the SVT layers were used without the main vertex.

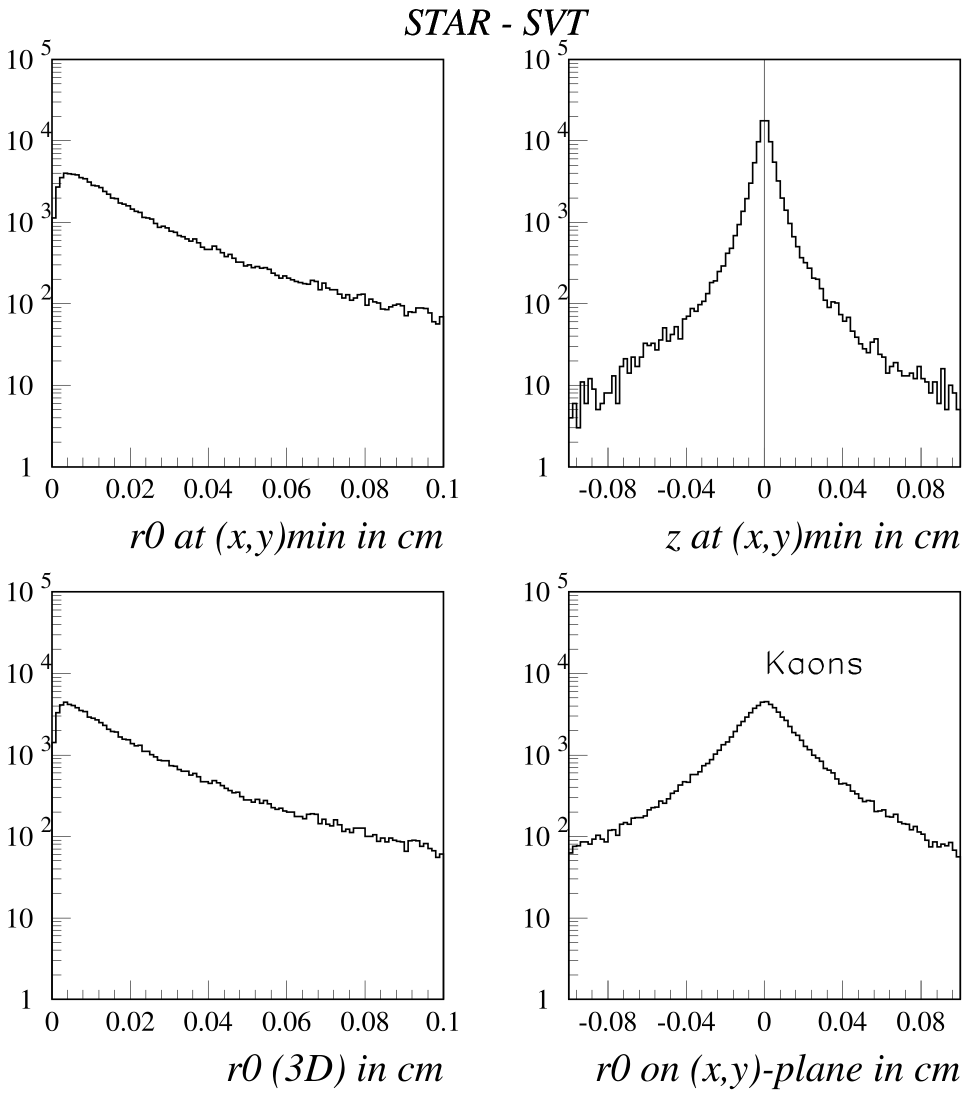

Figure 3: Impact parameter distributions for vertex kaons. The main vertex position and its error was used as a fourth space point in the track fitting.

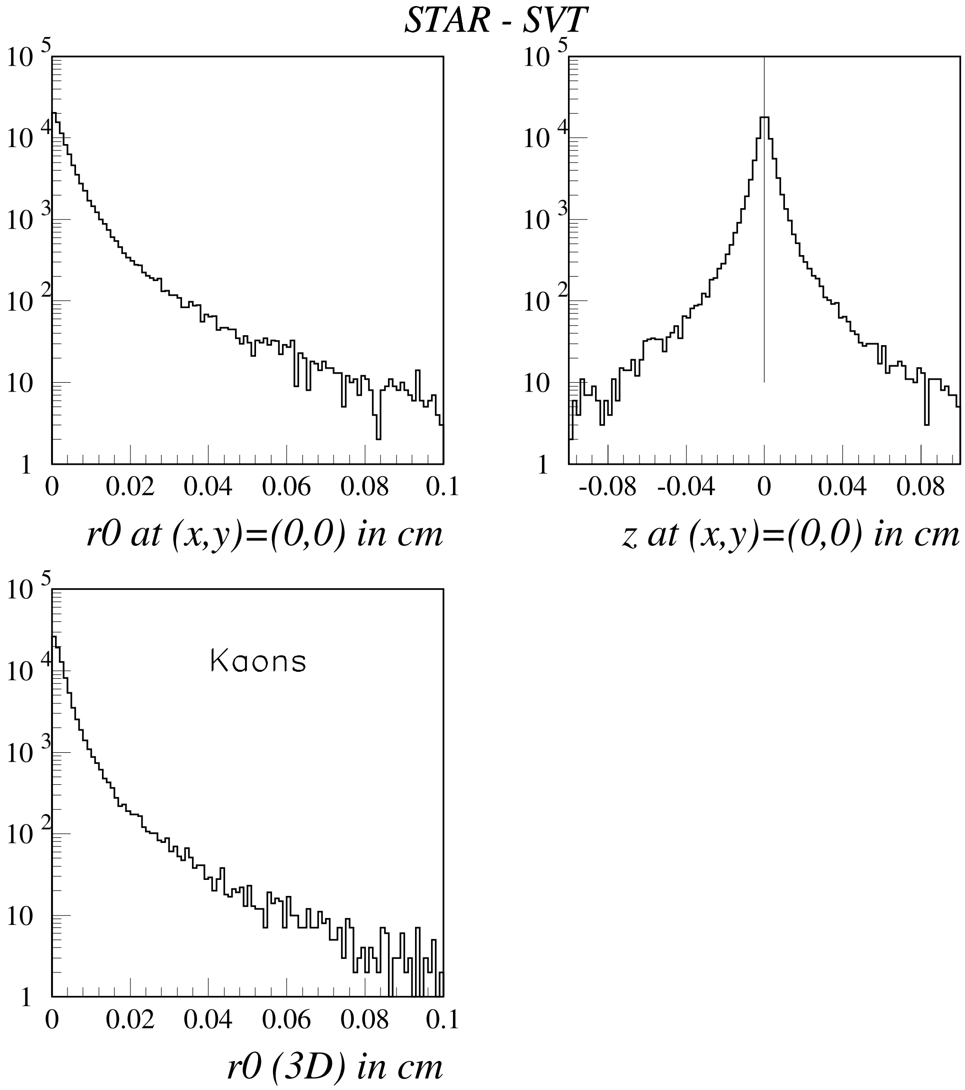

Figure 4: The same figure as before with the only difference that the fitting procedure was forcing the track to pass through the GEANT vertex in the bending plane.