E10-2009-171

A. P. Jerusalimov

RECONSTRUCTION OF THE PARAMETERS OF V^0 PARTICLES

Submitted to «Particles and Nuclei, Letters»

Иерусалимов А. П. E10-2009-171

Реконструкция параметров V^0-частиц

Рассматривается задача реконструкции V^0-частиц на установке CBM, проектируемой для комплекса FAIR (GSI, Германия). Показано, что использование различных кинематических обрезаний позволяет существенно улучшить выделение V^0-частиц и увеличить отношение сигнал/фон. Использование процедуры кинематического фита дает еще более значительное улучшение точности параметров V^0-частиц. Также исследуется процедура выделения Ξ^--гиперона. Рассмотренный алгоритм может практически без изменений быть использован для реконструкции параметров V^0-частиц и Ω^-/Ξ^--гиперонов в установке MPD/NICA.

Работа выполнена в Лаборатории физики высоких энергий им. В. И. Векслера и А. М. Балдина ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2009

Jerusalimov A. P. E10-2009-171

Reconstruction of the Parameters of V^0 Particles

The procedure of reconstruction of the parameters of V^0 particles is considered for CBM setup that is planned to build up at the FAIR complex (GSI, Germany). It was shown that the use of various kinematic cuts permits one to improve essentially the selection of V^0 particles and to increase the signal/background ratio. The use of the kinematic fit procedure gives still more considerable improvement of the accuracy of V^0 parameters. The procedure of the selection of Ξ^- hyperons is also examined. The considered algorithm can be used practically without changes to reconstruct the parameters of V^0 particles and Ω^-/Ξ^- hyperons in MPD/NICA.

The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2009

1. FEATURES OF V^0 PARTICLE RECONSTRUCTION

The reconstruction of the parameters using ASME method was considered for charged particles in paper [1]. The determination of the parameters of neutral V^0 particles has some specific features.

As an example, let us consider the procedure of V^0 reconstruction for CBM setup [2]. STS (Si Tracking Station) CBM registers x and y coordinates of the tracks only at the certain z coordinates of Si planes (see Fig. 1). This leads to the fact that a true position of the vertex of primary interaction (primary vertex) is unknown. The position of V^0 decay (secodary vertex) is also unknown.

Therefore, during V^0 reconstruction it is necessary:
1) to determine the position of primary vertex,
2) to select secondary tracks (i.e., tracks from V^0 decay),
3) to determine the position of secondary vertex,
4) to reconstruct the parameters of found V^0 particles.

There were used 1K events (central Au–Au interactions at 25A GeV) simulated by GEANT to test the procedure of V^0 reconstruction.

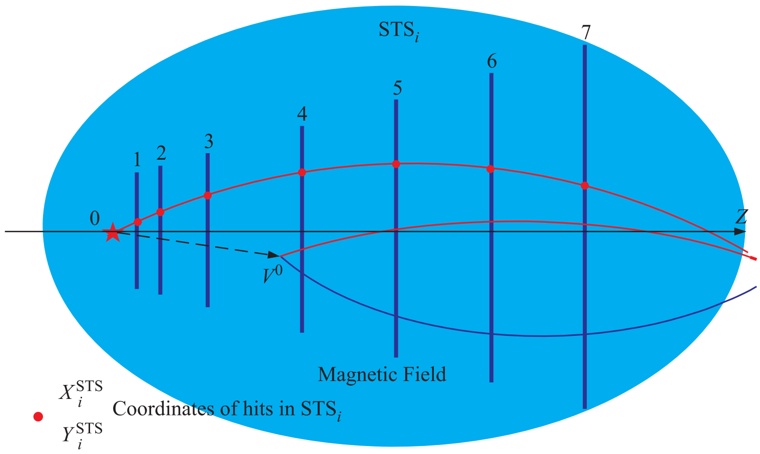

Fig. 1. Production and decay of V^0 particle in STS CBM

2. DETERMINATION OF PRIMARY VERTEX POSITION

To determine the primary vertex position the special track propagation procedure [3] based on the ASME method [1] was used. The analysis shows that this procedure ensures the accuracy of ~ 60 μm at the track propagation to $\Delta Z = 20$ cm.

For that the coordinates of the cross points with virtual planes $Z_k^{\rm Virt}$ were determined for the trajectory of each particle. Generally, 3 such planes are sufficient $(k = 1, 2, 3)$. It was desirable that the middle virtual plane $(k = 2)$ would be as close as possible to the supposed position of the vertex of a primary interaction. The tracks at the momentum of $P_i > 1$ GeV/c were used to get the larger accuracy.

Thus, there are sets of coordinates $x_i^{\rm CP}$, $y_i^{\rm CP}$ of the particle trajectories at the fixed $Z_k^{\rm Virt}$ (Fig. 2, *a*–*c*).

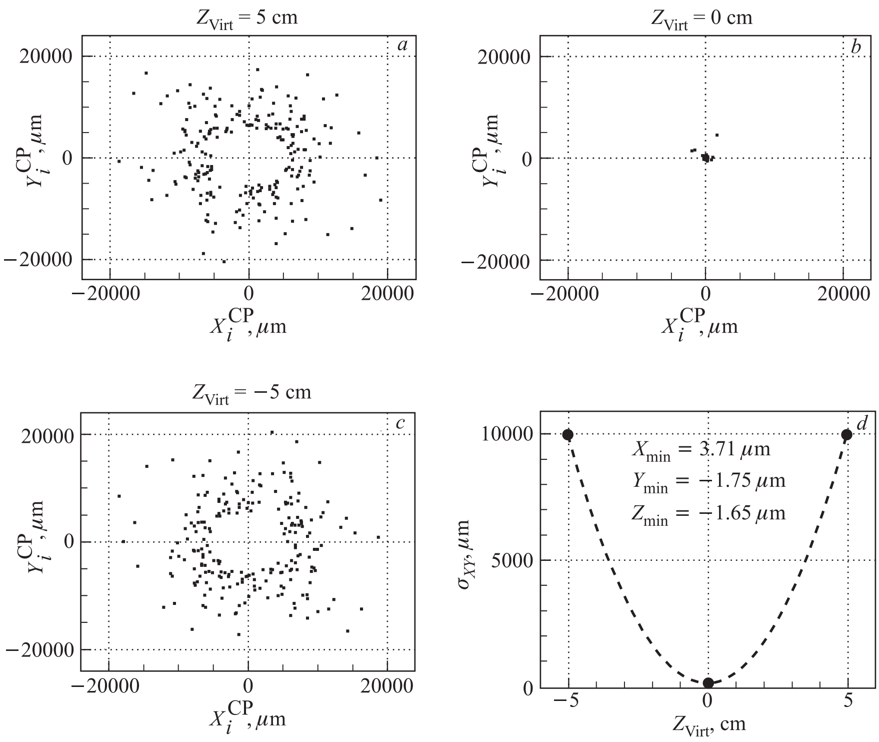

Fig. 2. *a*), *b*) and *c*) Plots of tracks cross points at various positions of $Z_{\rm Virt}$. *d*) The mean deviation of tracks from the center of tracks at various $Z_{\rm Virt}$. Dashed line — parabolic approximation

It is evident for the particle trajectories that the dispersion of the cross points relative to some mean position $\bar{X} = \sum_i x_i^{\mathrm{CP}}$ and $\bar{Y} = \sum_i y_i^{\mathrm{CP}}$ has to be minimal at the value of Z_k^{Virt} equal to the coordinate Z_0^{Vert} of the primary vertex. This dispersion is characterized by the value $\sigma XY = \frac{1}{N}\sum_i[(x_i^{\mathrm{CP}} - \bar{X})^2 + (y_i^{\mathrm{CP}} - \bar{Y})^2]$.

Then, the dependence of the value σXY on Z_k^{Virt} was approximated by the parabola and the position of primary vertex was found from the minimum condition for parabola (Fig. 2, *d*). The following coordinates of the primary vertex were obtained for 1K events of Au–Au interactions:

$$X^V = (0.7 \pm 2.2)\ \mu\mathrm{m},\ Y^V = (-0.3 \pm 1.4)\ \mu\mathrm{m} \text{ and } Z^V = (-1.9 \pm 4.1)\ \mu\mathrm{m},$$

that is in good agreement with GEANT data ($X^V_{\mathrm{GEANT}} = 0$, $Y^V_{\mathrm{GEANT}} = 0$, $Z^V_{\mathrm{GEANT}} = 0$).

3. V^0 FINDER

To reconstruct V^0 particles it is necessary at first to select the secondary tracks caused by V^0 decay. The analysis shows that 1K of processed events contains 94% of primary tracks (emitted from primary vertex) and 6% of secondary ones. The track propagation procedure is used to sort primary and secondary tracks and the impact parameter, i.e., distance between track and primary vertex position, is examined.

At that (5–7)% of secondary tracks were lost, i.e., falsely attributed as primary ones. The loss of the tracks produced by V^0 decay did not exceed 2%. (1.5–2)% of primary tracks were falsely attributed as secondary ones. But these false secondary tracks were excluded practically in full during next processing. All pairs of selected positive and negative secondary tracks (true and false) were tested to select the pairs of the tracks produced by V^0 decay.

The track propagation procedure in combination with virtual planes was used for the reconstruction of the position of secondary vertexes and parameters of V^0 particle.

There the following cuts to decrease the number of false («+», «–») combinations are used:

R2T: R2Tr $<$ R2Tr$_{\mathrm{lim}}$ — minimal distance between 2 tracks,
ZV: ZV $>$ ZV$_{\mathrm{lim}}$ — Z position of pair,
D00: D00 $<$ D00$_{\mathrm{lim}}$ — impact parameter for pair (to select primary V^0),
Rpp: Rpp $>$ Rpp$_{\mathrm{lim}}$ — ratio of positive momentum to negative one (for Λ^0 only!),
PID: particle identification, taken from data file produced by GEANT.

The results of application of these cuts are shown in Fig. 3.

One can see that the signal/background ratio increases from 0.83 (no cuts) to 31.2 and even up to 202.8 (all cuts used).

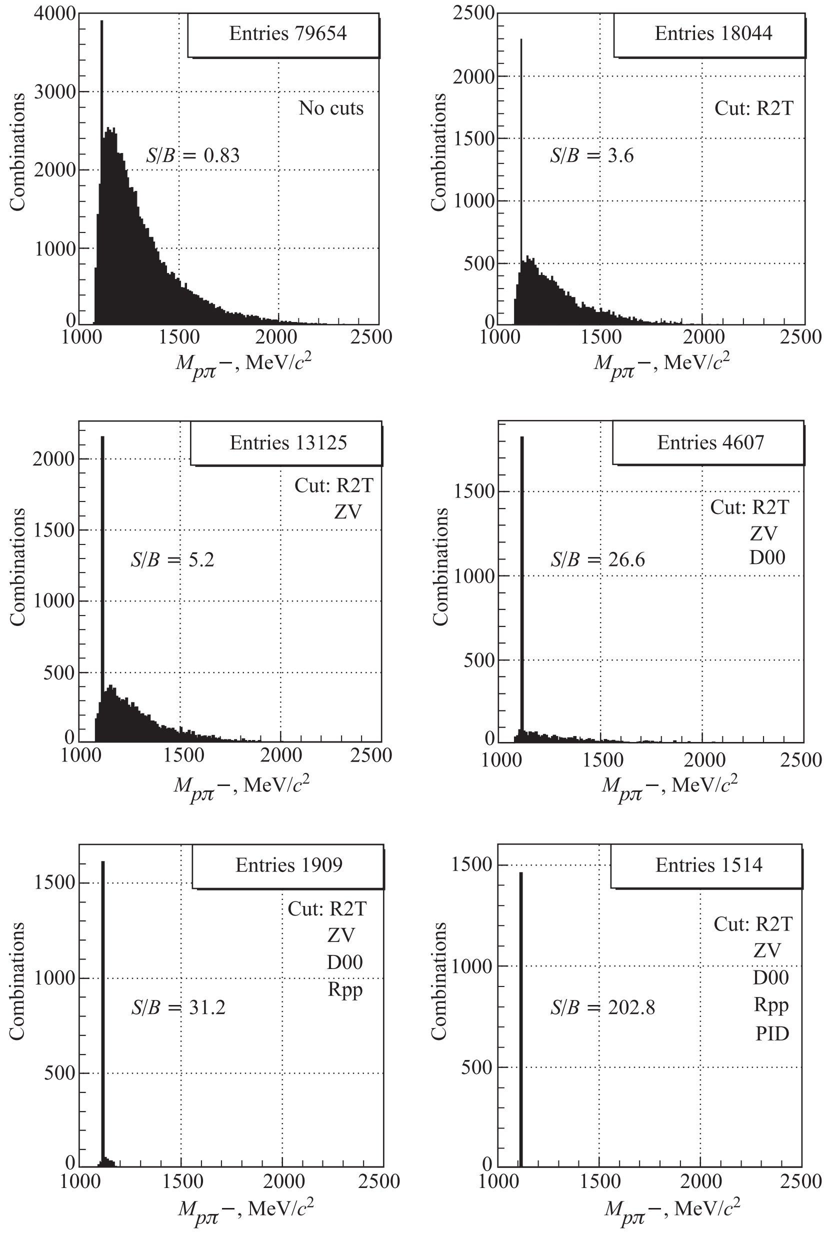

Fig. 3. The dependence of the signal/background ratio at various cuts for Λ^0

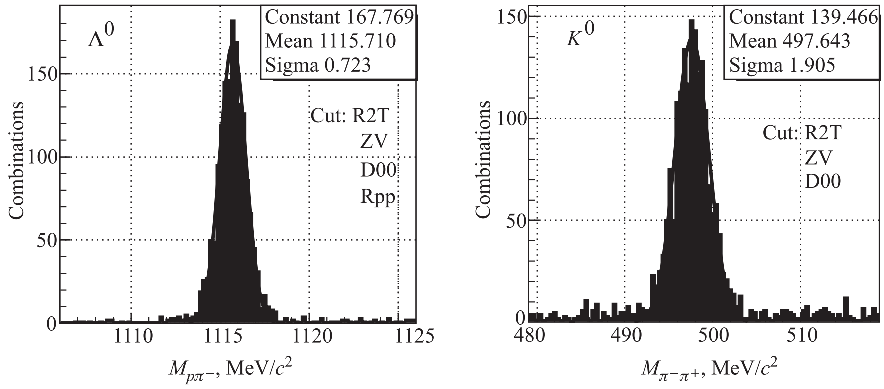

Fig. 4. Effective mass distributions for («+», «–») combination with corresponding cuts for Λ^0 and K^0 hypothesis of pair

Figure 4 shows the results of V^0 mass reconstruction. There were used R2T, ZV, D00, Rpp cuts for (p, π^-) combinations and R2T, ZV, D00 cuts for (π^+, π^-) combinations. The efficiency of the considered procedure of V^0 reconstruction is larger than 99%. The analysis has shown that the overlapping of Λ^0 and K^0 particles and the admixture of false V^0 are negligible.

The reconstructed parameters of V^0's are presented in Table for 7 and 8 Si planes of STS:

1st row — signal/background ratio,
2nd row — momentum resolution,
3rd and 4th rows — azimuth and deep angles (see Fig. 1 in [1]) resolution,
5th–7th rows — V^0 vertex position resolution,
8th row — mass resolution for Λ^0 and K^0.

One can see that all resolutions for 7 STS are better than for 8 STS. It can be explained by the fact that the total thickness of Si planes is equal to 1200 μm for 7 STS configuration and to 3500 μm for 8 STS configuration. Therefore, the effects of multiple scattering are much stronger for the case of 8 STS than for the case of 7 STS that results in a worsening of a resolution of reconstructed parameters.

4. V^0 FITTER

But the method of V^0 reconstruction described above takes into account the parameters of individual tracks. It does not consider the coordinates of the points of positive and negative tracks as the result of decay of V^0 particle emitted from the primary vertex.

Cuts*: R2T, ZV, D00, and Rpp for Λ^0

	Λ^0	Λ^0	Λ^0 fit	K^0	K^0	K^0 fit
	7 STS	8 STS	8 STS	7 STS	8 STS	8 STS
S/B^*	31.2	28.1	32.8	8.4	7.1	8.8
σP_{V0}, %	0.58	1.1	0.37			
$\sigma\beta_{V0}$, mrad	0.24	0.36	0.13			
$\sigma\tan(\alpha_{V0})$	0.28	0.33	0.13			
$\sigma X_{V0}, \mu$m	10.8	16.0	7.7	9.4	15.1	6.3
$\sigma Y_{V0}, \mu$m	12.8	17.1	7.7	9.5	14.6	6.7
$\sigma Z_{V0}, \mu$m	91.1	154.3	68.4	52.8	98.8	53.5
σM_{V0}, MeV/c^2	0.72	1.16	0.25	1.90	3.13	0.78

In order to get more precise parameters of V^0 particle, it is necessary to use the functional that includes the coordinates of both positive and negative tracks (see [1]) and the additional coordinates of vertex of found V^0 particle.
This functional is minimized taking into account the following constraints:

1) $(M_{\rm pair} - M_{V^0})^2 \to 0$, where $M_{\rm pair}$ — effective mass of («+», «–») pair,
2) D00V $\to 0$, impact parameter for V^0.

It needs 3 iterations to get minimum.

Figure 5 shows the effective masses of Λ^0 and K^0 particles obtained due to this fit procedure.

The other results of V^0 Fit are presented in Table. One can see that V^0 Fitter procedure increases considerably the precision of V^0 parameters.

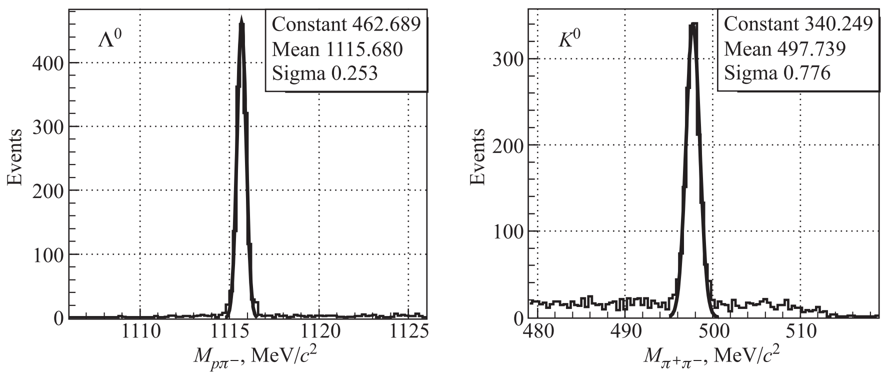

Fig. 5. Effective mass distributions for Λ^0 and K^0 hypothesis obtained due to the fit procedure

5. Ω^-/Ξ^- RECONSTRUCTION

Feature of Ω^-/Ξ^- decay is that this decay is two-stage process:

$$\Xi^-(\Omega^-) \to \pi^-(K^-) + \Lambda^0(K^0) + p + \pi^-.$$

Therefore, it is necessary to select secondary Λ^0's and to test (Λ^0, «–» track) pairs. In that way, the following cuts were used:

— cuts for Λ^0, i.e., («+», «–») pairs: R2T, ZV, anti-D00 (to select secondary Λ^0), Rpp,

— cuts for $\Xi^-(\Omega^-)$, i.e., (Λ^0, «–») pairs:

R2Tr $<$ R2Tr$_{\rm lim}$ — minimal distance between Λ^0 and «–» track,
D00h $<$ D00h$_{\rm lim}$ — impact parameter for (Λ^0, «–») pair.

1K events of GEANT simulated events were tested to find Ξ^- and Ω^- hyperons. The result is shown in Fig. 6.

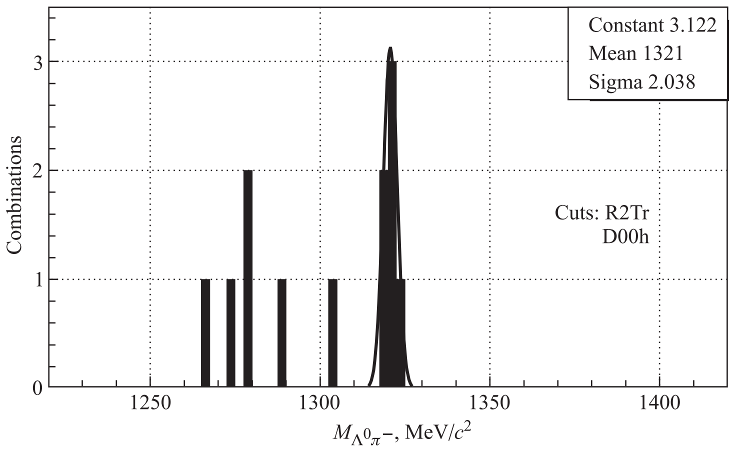

Fig. 6. Effective mass distribution of (Λ^0, π^-) combinations

There were 6 reference Ξ^- in GEANT data set, all 6 were found (in the peak). None Ω^- was found due to an insufficient statistics.

By the same way as V^0 Fitter it is possible to construct Ω^-/Ξ^- Fitter.

CONCLUSION

The presented algorithm of V^0 Finder gives good accuracies both for kinematical parameters and vertex position of V^0's and provides effective V^0 reconstruction. The algorithm of V^0 Fitter permits one to get an essentially better resolutions both for V^0 kinematical parameters and vertex position. V^0 Finder/Fitter algorithm can be also used for Ω^-/Ξ^- reconstruction.

V^0 Finder/Fitter algorithm of ASME can be used practically without changes to reconstruct the parameters of V^0 particles and Ω^-/Ξ^- hyperons in MPD/NICA.

Acknowlegements. The author is very grateful to Dr. O. V. Rogachevsky for helpful discussion and to Dr. V. P. Ladygin for continual interest to this work.

REFERENCES

1. *Jerusalimov A. P.* JINR Preprint E10-2009-157. Dubna, 2009.
2. *Friese V. et al.* The CBM Experiment at FAIR. GSI Sci. Report 2007. P. 3
3. *Jerusalimov A., Ladygin V., Rogachevsky O.* V^0 Reconstruction. https://www.gsi.de/documents/DOC-2006-May-30-1.pdf

Received on November 9, 2009.

Редактор *В. В. Булатова*

Подписано в печать 22.12.2009.
Формат 60 × 90/16. Бумага офсетная. Печать офсетная.
Усл. печ. л. 0,68. Уч.-изд. л. 0,93. Тираж 290 экз. Заказ № 56845.

Издательский отдел Объединенного института ядерных исследований
141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
E-mail: publish@jinr.ru
www.jinr.ru/publish/