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Laboratory of Theoretical Physics

G.I.Kopylov

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A b s t r a c t

The formula which allows to diminish the spacing between limiting values for the momentum of the identified particle in star is derived. This equation contains besides masses of other particles the lower bounds of their momenta and the angles between the prongs.

The identification of particles in high-energy stars x) is often made by comparing measurements of the momentum p_1 of one of the particles, namely, particle 1 with its limiting values under certain assumptions about masses and quantity of other particles 2, 3, ..., n. These particles are united in an one compound-particle with some effective mass m_{eff}. The formula for the momentum of the particle 1 at the observed angle ϑ_1 under the assumption that the other particle has the mass m_{eff} yields limiting values of the momentum of the particle 1 [1 - 3]. Usually m_{eff} is taken equal to

$$\bar{m} = m_2 + m_3 + \ldots + m_n ;$$

here one assumes that velocities of the particles 2,3,....., n coincide with each other [2]. We shall show that the spacing between limiting values $p_{1\,\substack{min\\max}}$ of the momentum p_1 of the particle 1 can be diminished if one takes into account the angles ϑ_{ij} between the charged particles i and j (i,j = 2, ..., n') and if one estimates the lower bounds $\tilde{p}_i$ of their momenta p_i .

An attempt to take into account the information on angles and momenta of particles was made earlier [4]. In contrast to [4] in the method suggested here this information is directly included into m_{eff}. In this case we have to know lower momentum bounds only (in [4] it is necessary to know the values themselves of p_i what is difficult for large values of p_i and leads to the indefinity in $p_{1\,\substack{min\\max}}$).

1. The conservation laws for n particles

$$E_1 + E_2 + \ldots + E_n = E$$
$$\vec{p}_1 + \vec{p}_2 + \ldots + \vec{p}_n = \vec{P}$$

yield the equation for p_1

$$E E_1 - P p_1 \cos\vartheta_1 = \frac{(E^2 - P^2) + m_1^2 - (E_2 + \ldots + E_n)^2 + (\vec{p}_2 + \ldots + \vec{p}_n)^2}{2(E^2 - P^2)^{1/2}} . \qquad (1)$$

It coincides with the equation for p_1 when the particle with mass M, energy E and momentum P decays into two particles with masses m_1 and m_{eff} if we put

$$M^2 = E^2 - P^2$$

and take as m_{eff}^2

$$m_{eff}^2 = (E_2 + \ldots + E_n)^2 - (\vec{p}_2 + \ldots + \vec{p}_n)^2 . \qquad (2)$$

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x) i.e. the stars which have the relativistic prongs .

After the differentiation of the roots of Eq.(1) with respect to m_{eff} it is easy to see that the larger root always decreases with increase of m_{eff} ($dp_{1\,max}/dm_{eff} < 0$) but the smaller one (if it exists) increases ($dp_{1\,min}/dm_{eff} \geqslant 0$). Thus, any rise of the estimate of m_{eff} diminishes the distance between limiting values of the momentum p_1 of the particle 1.

To obtain such an estimation let us transform (2)

$$m_{eff}^2 = \sum_{i=2}^{n} m_i^2 + 2\sum_{2\le i<j}^{n}\sum^{n}(E_i E_j - p_i p_j \cos\vartheta_{ij}) =$$

$$= \sum_{i=2}^{n} m_i^2 + 2\sum_{2\le i<j}^{n}\sum^{n}(E_i E_j - p_i p_j) + 2\sum_{2\le i<j}^{n}\sum^{n} p_i p_j (1-\cos\vartheta_{ij}) . \qquad (3)$$

It is easy to prove that always

$$E_i E_j - p_i p_j \geqslant m_i m_j . \qquad (4)$$

Substituting into (3) in place of p_i its lower bound [x)] $\tilde{p}_i$ and in place of $E_i E_j - p_i p_j$ quantity $m_i m_j$ we obtain finally

$$m_{eff}^2 \geqslant \tilde{m}^2 \equiv \bar{m}^2 + \Delta^2 , \qquad (5)$$

where

$$\Delta^2 = 2\sum_{2\le i<j}^{n'}\sum^{n'} \tilde{p}_i \tilde{p}_j (1-\cos\vartheta_{ij}) \qquad (6)$$

and the summation is performed over all pairs of charged particles except for the particle 1.

So, taking instead of $\bar{m}$ the quantity $\tilde{m}$ for the effective mass one can dimi - nish the interval between limiting values of the momentum p_1 of the particle 1. The higher are the estimations from below the more narrow is the interval between limiting values. The use of (5) - (6) is not effective for narrow particle beams. The existence of the neutral particles is taken into account as before by simple inclusion of their masses into $\bar{m}$ in (5).

2. One may rise still more the estimation for m_{eff} if one can measure exactly momenta of N particles. Then, one obtains easily

$$\tilde{m}^2 = \bar{m}^2 + 2\sum_{k<\ell}^{N}\sum^{N}(E_k E_\ell - p_k p_\ell - m_k m_\ell) + 2\sum_{2\le i<j}^{n'}\sum^{n'} p_i' p_j' (1-\cos\vartheta_{ij}) . \qquad (7)$$

Here p_i' $(i=2,\dots,n')$ implies p_i for particles with exactly measured mo -

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x) For grey prongs, for instance, one may assume $\tilde{p}_i = m_i$. For neutral particles $\tilde{p}_i = 0$.

menta and $\tilde{p}_i$ for other particles. In the second term the summation is performed over all pairs of particles with exactly measured momenta.

The further rise of estimate for m_{eff} can be achieved by including into the last term of the expression (7) the summation over neutral particles . One can do it roughly replacing $\tilde{p}_i$ and ϑ_{ij} for neutral particles by their average values $\bar{p}$ and ϑ in the given event and assuming the number of neutral particles to be equal to the half of charged ones. Then, the existence of neutral particles will be taken into account by including into (7) the term

$$\frac{1}{4} n'(n'-2)\, \bar{p}^2 \left(1 - \cos \bar{\vartheta}\right) \tag{7'}$$

which represents the most probable neutral particle contribution to (7).

In using the given Eqs. (6) - (7) for the identification of stars obtained on an accelerator in the interaction NN or πN it is not necessary to calculate the limiting values for p_1 each time when we obtain next value of $\tilde{m}$. It is quite sufficient in this case to have a two-parametrical set of curves $p_{1\,\substack{min\\max}} = f(\tilde{m}, \cos\vartheta_1)$ for definite energy and character of the interaction and assuming that the particle 1 is either meson or nucleon. One finds from these diagrams the values of $p_{1\,\substack{min\\max}}$ by means of the interpolation. An example of such diagrams for pp - interaction at 10 Bev is given in the Appendix. The comparison of the limiting values obtained with due use of (6) and the formulas of the paper [4] shows that Eqs. (6) bound better p_i from above but the equations of [4] from below.

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