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Memo CP-E/052

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To: Distribution
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Subject: Effective mass correlation

"`,EMC`" (effective mass correlation) is a correlation quantity defined in EXFOR. In EXFOR, we have some codes for "effective mass squared" e.g. information identifier `EMS-SEC`, data heading `EMS`, `EMS1`, `EMS1-MAX`,…, quantity code "`,EMC`". Only one subentry M0035.028 uses these codes. I study the possibility of translating "`,EMC`" into "differential with effective mass squared" as done for "energy distribution for a correlated pair" in CP-C/350. Hereafter, I put light velocity *c* assuming effective mass *M* has the dimension of energy (e.g. MeV) in EXFOR, as done in M0035.028.

So far I did not know the definition of "effective mass squared" in EXFOR. Therefore I start with the clarification of the definition by checking the reference of M0035 (Yu. M. Arkatov, UFZ,25,933,1980), which studies p-n correlation in ^{4}He (γ, p+n+d). "Effective mass squared" M_{pn}^2 is given in Eq.(3) of this article:

$$M_{pn}^2 = s_{\gamma 4He} + (m_d c^2)^2 - 2 E_d \sqrt{s_{\gamma 4He}} \qquad \text{(in c.m.s. of beam and target pair)}$$

, where m_d is the mass of deuteron, $s_{\gamma 4He}$ is "c.m.s. energy squared" for this reaction system:

$$s_{\gamma 4He} = (E_\gamma + E_{4He})^2 - (c\,\boldsymbol{p}_\gamma + c\,\boldsymbol{p}_{4He})^2 = (E_p + E_n + E_d)^2 - (c\,\boldsymbol{p}_p + c\,\boldsymbol{p}_n + c\,\boldsymbol{p}_d)^2$$

From these equations, we obtain the definition of "effective mass squared" in this article,

$$M_{pn}^2 = s_{pn} = [\,(E_p + E_n)^2 - (c\,\boldsymbol{p}_p + c\,\boldsymbol{p}_n)^2\,]$$

, this is center-of-mass energy squared for proton-neutron pair.
Therefore I conclude that "effective mass squared" in EXFOR means center-of-mass energy squared in relativistic kinematics (= invariant mass squared) $[\,(\sum E_i)^2 - (\sum c\,\boldsymbol{p}_i)^2\,]$ for more than 2 particles. This quantity is Lorentz invariant. An example of LEXFOR entry is as follows:

<u>Effective (invariant) mass squared distribution for a correlated pair</u> : Probability that a particle *a* and a particle *b* will be emitted at effective (invariant) mass squared
$s = [(E_a + E_b)^2 - (c\,\boldsymbol{p}_a + c\,\boldsymbol{p}_b)^2]$, dσ / d*s* :
REACTION coding : `DS` in SF6; particles in SF7 as a+b (e.g., `P+A`).
Unit type: DE2 (e.g. `B/MEV2`)

The effective (invariant) mass squared is given under the data heading EMS.

I put "(invariant)" after "effective", because "effective mass" has various meanings in physics, for example mass of nucleon or other hadrons in nuclear matter is called as "effective mass" in nuclear physics, while the definition of "invariant mass" is probably unique.

Using ",DS,A+B", M0035.028 can be coded by ",DS,N+P,,REL" with ARB-UNITS.

Relations of invariant mass squared to other variables found in EXFOR are as follows:

1) $\sqrt{s}$ is the sum of energy (including mass energy mc^2) for particles in their center-of-mass system. This is a relativistic extension of "energy of relative motion" E_{rel} (=center-of-mass energy in non-relativistic kinematics) given in Eq.(1) of CP-E/051, and a relativistic extension of EN-CM for incoming channel.

2) The set of s, t (4-momentum transfer squared, given under -t in EXFOR) and u is called Lorentz-invariant Mandelstam variables. For reaction 1+2→3+4,

$$s = (E_1 + E_2)^2 - (\boldsymbol{p}_1 + \boldsymbol{p}_2)^2 = (E_3 + E_4)^2 - (\boldsymbol{p}_3 + \boldsymbol{p}_4)^2$$
$$t = (E_1 - E_3)^2 - (\boldsymbol{p}_1 - \boldsymbol{p}_3)^2 = (E_2 - E_4)^2 - (\boldsymbol{p}_2 - \boldsymbol{p}_4)^2$$
$$u = (E_1 - E_4)^2 - (\boldsymbol{p}_1 - \boldsymbol{p}_4)^2 = (E_2 - E_3)^2 - (\boldsymbol{p}_2 - \boldsymbol{p}_3)^2$$
$$s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2$$

using natural unit ($c = 1$).