Determination of QP mass with measured neutrons

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A detailed analysis of the free neutron detection efficiencies in the TAMU Neutron Ball was performed using the reaction simulation models HIPSE-SIMON [1] and CoMD [2]. Recently, our group has published a number of papers whose results rely heavily on a precise reconstruction of the quasi-projectile (QP) source created in peripheral nuclear collisions [3-6]. The results of our neutron detection analysis were applied to this QP reconstruction process in order to determine the precision with which we can reconstruct the emitting sources. Equation 1 was developed in order to determine the actual number of QP-emitted free neutrons (N_{QP}) given the total detected free neutron multiplicity (N_{det}) measured by the Neutron Ball on an event-by-event basis.

$$N_{QP} = \frac{N_{det} - N_{background}}{\left(\varepsilon_{QP} - \frac{N_T}{N_P}\varepsilon_{QT}\right)\varepsilon_{Cf}}. \tag{1}$$

here, ε_{QP}, ε_{QT}, and ε_{Cf} correspond, respectively, to the effective detection efficiencies for neutrons originating from the QP, the QT (quasi-target) and an experimentally measured efficiency using a calibrated californium source. The N_T/N_P term is the ratio of the number of neutrons in the target and projectile. Symmetric reactions of ^{70}Zn, ^{64}Zn and ^{64}Ni were studied.

Fig. 1 and Table I relate the actual number of neutrons emitted from the QP and the number of neutrons calculated using Eq. (1) from events modeled by the two simulation codes. We see from Fig. 1 that the peaks of the distributions for the two simulation codes lies approximately on the black line corresponding to a 1-to-1 correspondence between the actual number of neutrons emitted from the QP and the number we calculate using Eq. (1). The HIPSE simulation code tracks the origin of fragments after the collision. Therefore, it is straight forward to compare the results of equation 1(N_{QP}) to the number of QP-tagged or actual free neutrons produced in the simulation (M_{QPn}^{raw}). For the CoMD simulation we calculated M_{QPn}^{raw} using a particle velocity cut which we describe in detail in Ref. [7]. This neutron velocity cut is similar to the experimental velocity cut for protons during QP reconstruction but corrected for the lack of Coulomb interaction.

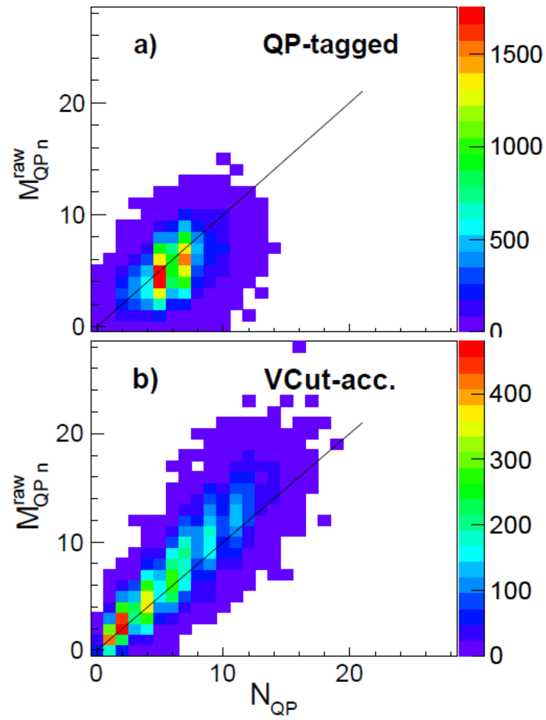

FIG. 1. The multiplicity of neutrons emitted from the QP (M^{raw}_{QPn}) versus the multiplicity of free neutrons assigned to the reconstructed QP (N_{QP}) for the reaction of ^{70}Zn + ^{70}Zn

Table 1 gives a numerical analysis of the information shown in figure 1. For a given number of

Table I. Average QP-emitted free neutron multiplicity and the width of that distribution for each value of reconstructed neutron multiplicity for CoMD and HIPSE-SIMON [7].

N_{QP}	$\langle M^{raw}_{QP_n}\rangle$	$\sigma(M^{raw}_{QP_n})$	$\langle M^{raw}_{QP_n}\rangle$	$\sigma(M^{raw}_{QP_n})$
	HIPSE		COMD	
0	1.46	1.10	0.51	0.74
1	2.13	1.21	1.47	1.08
2	3.02	1.64	2.69	1.34
3	3.67	1.68	3.76	1.58
4	4.06	1.75	4.66	1.78
5	4.72	1.88	5.88	2.03
6	5.28	1.97	6.81	2.16
7	5.94	2.04	8.44	2.52
8	6.59	2.14	9.61	2.49
9	–	–	10.63	2.73
10	–	–	11.58	2.65
11	–	–	12.49	2.77

calculated QP-emitted free neutrons (N_{QP}), the average number of actual QP-emitted neutrons is shown as well as the width of the distribution, σ. These results are shown for both simulations.

From these two figures we see that the calculated number of QP-emitted free neutrons corresponds very well with the actual number of neutrons emitted from the QP. The calculated multiplicities agree with the actual multiplicities to within 1.5 neutrons for about 92% of the analyzed events (N_{QP} = 1-8). The results of the study showed that our experimental procedure for determining the QP-emitted free neutron multiplicity was reasonably accurate and sufficiently precise as to allow for the study of well-defined QP sources [7]. Furthermore, the results suggest that our method of free neutron assignment during reconstruction is model independent.

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