Using Kinematics to Measure Nuclear Masses

For example, you want to study the nuclei created by alpha particle collisions with ^{28}Si. You set up an experiment

$^{4}He + ^{28}Si \rightarrow n + X$.

Here you have a ^{28}Si target at rest in the lab and use alpha particle kinetic energies of 12 MeV.

You have an exceptionally sensitive neutron detector which you can move around the ^{28}Si target at various angles. Besides outgoing neutrons you have other kinds of particles, X. However, you note that at the angles listed below there are groups of neutrons with certain well defined kinetic energies, T1 and T2, and TA and TB, at the two angles shown below. The angles are measured with respect to the incident alpha particle's momentum.

At 20 deg, T1 = 2.98 MeV and T2 = 1.58 MeV

At 40 deg, TA = 2.84 MeV and TB = 1.47 MeV

Develop a hypothesis about what X is. Is it a single nucleus or a collection of nuclei?

Questions to consider:
Is momentum conserved?
Is energy conserved?
Is baryon number conserved?
Is charge conserved?
What must be the energy E_X of system X?
What must be the vector momentum $\mathbf{P}_X$?
Is there a single nucleus X, of mass M_X, which is consistent with the data?

angle	High neutron kinetic energy	Low neutron kinetic energy
20 deg	2.98	1.58
E_X		
$\lvert P_X \rvert$		
M_X		
40 deg	2.84	1.47
E_X		
$\lvert P_X \rvert$		
M_X		