DE-FG03-93ER40773

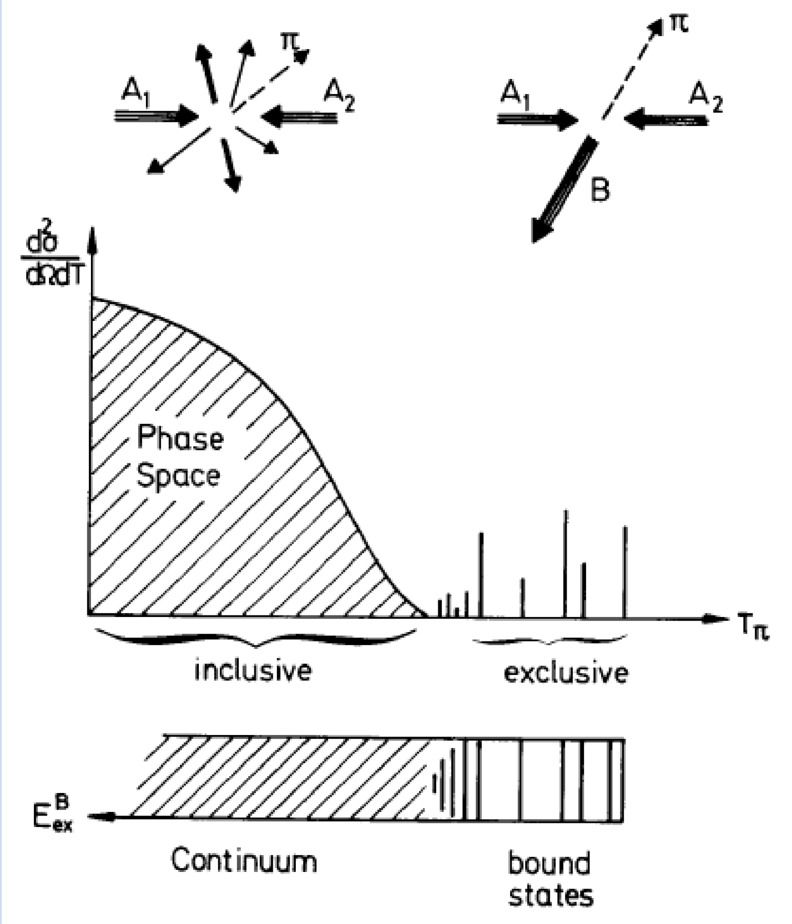
A-1266

Pionic Fusion of $^4He + ^{12}C$

Andrew Zarrella

Cyclotron Institute, Texas A&M University

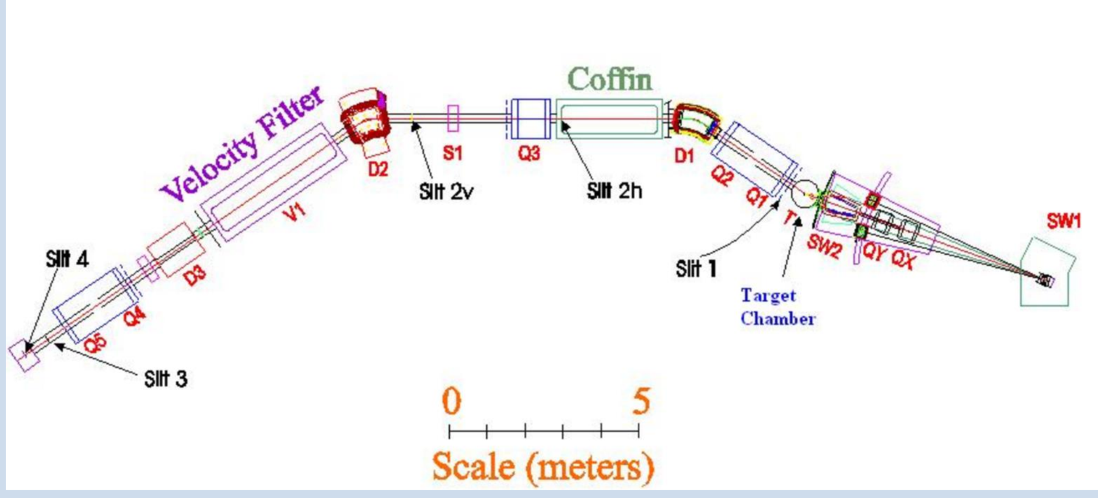
Background



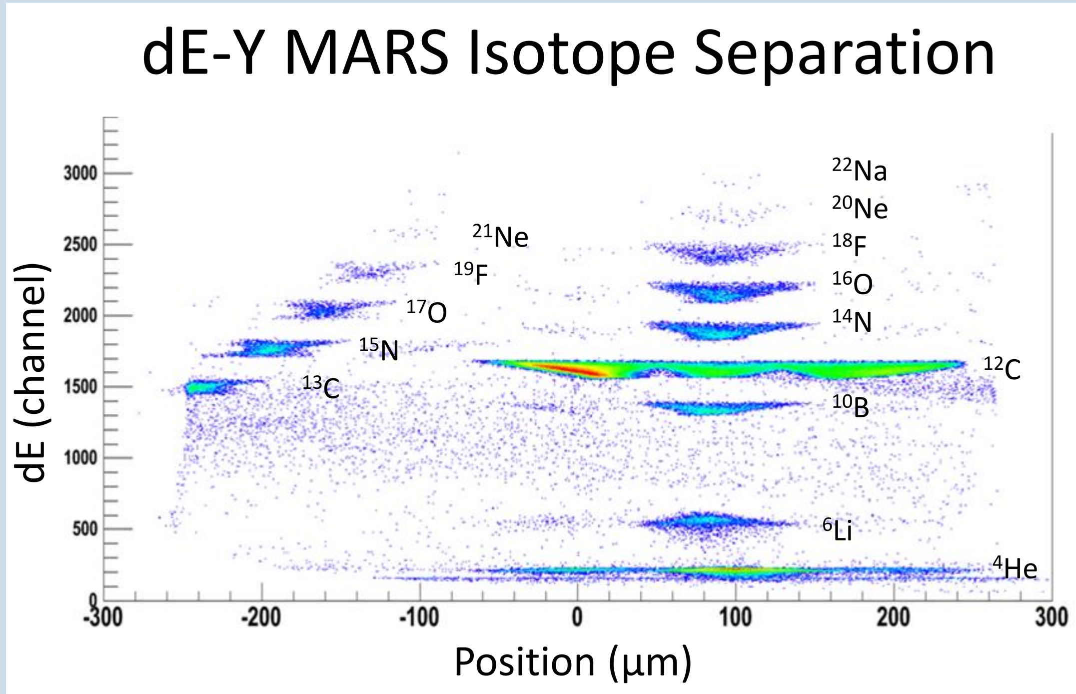
Pionic fusion is the process by which two nuclei fuse during a collision and then deexcite by the exclusive emission of a pion. The resulting compound nucleus is left in or near its ground state . The process requires that nearly all of the available kinetic and potential energy in the colliding system be concentrated into two degrees of freedom - the rest mass and kinetic energy of the emitted pion. Pionic fusion is typically studied for reacting systems in which the total available center of mass energy is just above the mass energy of the pion. This level of coherence in heavy ion collisions pushes traditional particle production mechanisms to their limit. Indeed, pionic fusion reactions may proceed through as yet unidentified or more complex mechanisms.

P. Braun-Munzinger and J. Stachel. Ann. Rev. Nucl. Part. Sci. (1987) **37** 97-131.

Momentum Achromat Recoil Spectrometer



MARS utilizes two dispersive planes to combine a momentum achromat with a recoil mass spectrometer. In our pionic fusion experiment, MARS will be used to separate and detect mass = 16 pionic fusion residues. The forward focused nature of the fusion process results in 100% angular efficiency of residues of interest entering the spectrometer. The transport efficiency of those residues through MARS has been measured at around 61%. The residues will be detected inside the detector chamber using a silicon stack consisting of a 30 μm single axis stripsilicon and a 1000 μm single element silicon.



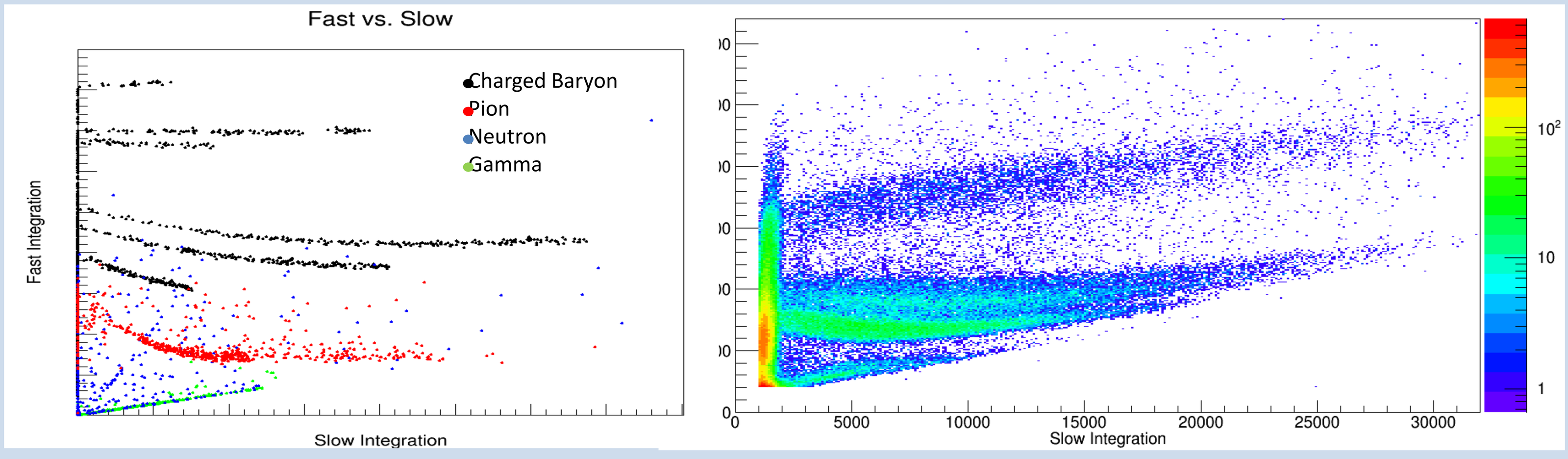
R. E. Tribble, *et al*. NIM A (1989) **285** 441-446.

Pionic Fusion in Literature

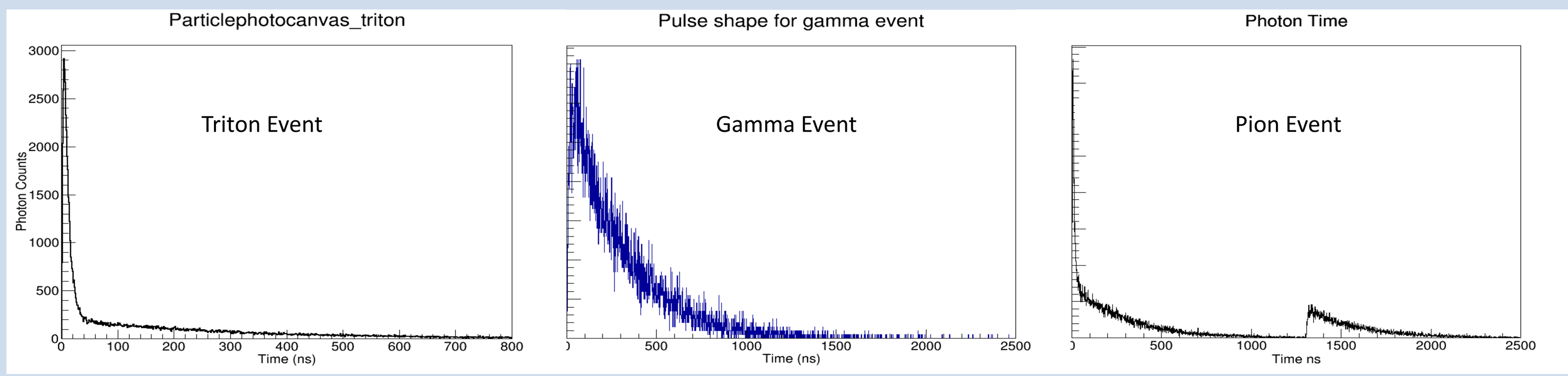
Reaction	Beam Energy (MeV)	$E^* - m_\pi c^2$ (MeV)	Cross section
$^3He(^3He,\pi^+)^6Li$	283	17	111 nb
$^4He(^3He,\pi^+)^7Li$	266.5	14	30 nb/sr @ 20° cm
$^4He(^3He,\pi^0)^7Be$	252	10	Unpublished
$^6Li(^3He,\pi^+)^9Be$	235	34	150 pb/sr @ 20° lab
$^7Li(^3He,\pi^+)^{10}Be$	235	41	≤ 60 pb/sr @ 20° lab
$^7Li(^3He,\pi^-)^{10}C$	235	38	≤ 28 pb/sr @ 20° lab
$^{10}B(^3He,\pi^+)^{13}C$	260	83	95 pb/sr @ 20° lab
$^{12}C(^3He,\pi^+)^{15}N$	235	62	102 pb/sr @ 20° lab
$^{12}C(^3He,\pi^-)^{15}F$	235	45	≤ 41 pb/sr @ 20° lab
$^{12}C(^3He,\pi^+)^{15}N$	170.2	10	< 0.03 nb
$^{12}C(^3He,\pi^+)^{15}N$	181.4	19	1.3 nb
$^{208}Pb(^3He,\pi^-)^{211}At$	130 - 270	20 - 130	1-10 nb

Pionic fusion cross sections have been measured for quite a few reacting systems since the mid 1980's. The list above represents all previous pionic fusion studies to this author's knowledge. Many of these measurements are quite limited in their angular coverage and in only one case ($^4He(^3He,\pi^0)^7Be$) was a coincidence measurement between the residue and pion attempted. In our experiment, we plan to measure coincident charged pions and residues, a first in the field. Our plan also has the potential to measure all three Pionic Fusion channels in the same experiment.

Pulse Shape Discrimination



Pions will be identified in phoswiches using fast vs. slow pulse shape discrimination. Prior to construction, the phoswiches were built inside a GEANT4 simulation to test their response to gamma rays, neutrons and charged particles. After construction, the phoswiches were tested in beam.

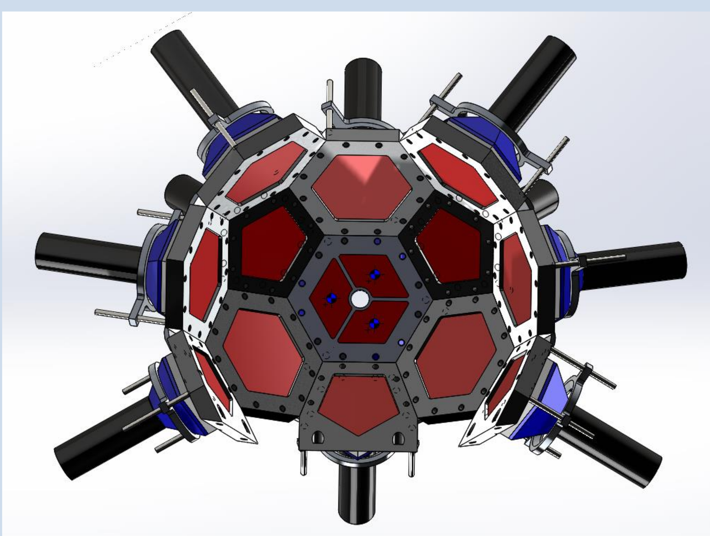


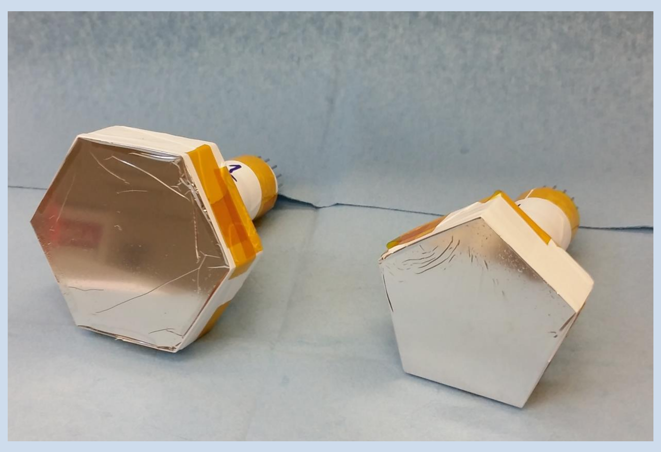
Pions will also be identified by the muon decay following the pion event. Fast sampling ADCs will be used to digitize the waveform with 12-bit resolution at 250 MS/s. ADC firmware was developed to analyze the waveforms in real time in order to look for the presence of the decay peak and trigger the system.

Partial Truncated Icosahedron (ParTI) Phoswich Array

- 15 phoswich detectors
- Hexagonal units 4.63" from target
- Pentagonal units 4.75" from target
- 3 partial hexes populate center frame
- Modular for use in future experiments
- Positioned backward of target

- 3 mm thick EJ-212 scintillating plastic
- 1 cm thick CsI(Tl)
- 1 in. thick plexiglass light guide
- 1924A Hamamatsu PMT
- Aluminized mylar over entrance face
- Teflon tape for diffusely reflective, light tight surface





Current Progress and Future Plans

To date, the phoswich detectors have been tested in beam, the transport efficiency of MARS has been measured for our residues of interest, the MARS beam line has been upgraded to accommodate increased signal density and the ParTI Array has been designed and built. We have performed an experiment in which we aligned the populated ParTI array inside the MARS production chamber and ran diagnostic beam tests on the 15 phoswich detectors. We have used MARS to create secondary beams of reaction products that were used to calibrate a phoswich unit located at the spectrometer focal plane. We expect to be measuring $^4He + ^{12}C$ pionic fusion cross sections by Spring 2016.