# Pion Emission Close To Threshold

Bilal Ahmad Reshi* and Sugat V. Shende
*Department of Physics, University of Pune - 411007, INDIA*
**email: reshibilal@gmail.com*

## Introduction

Every observed physical phenomenon is governed by at least one of four types of interactions: Gravitational, Electromagnetic, Weak and Strong interactions. These interactions constitute the fundamental interactions, and are described by the exchange of fundamental particles: gravitons, photons, W, Z-bosons and gluons respectively. Hadrons are held together by the force called the strong interaction, with a specific strength, which is characterized by a coupling constant. The coupling constants cover many orders of magnitude and range from about $10^{-39}$ for the gravitational interaction to about 1 for the strong interaction. The strong interaction is carried by gluons which act between particles that carry color charge i.e. quarks and gluons. The pions ( i.e. mesons) are formed from a quark anti-quark pair and are created with a collision between energetic particles. The $\pi^+$, is made up of an up quark with charge +2/3 and an anti-down quark with charge +1/3 and it is written $ud^-$. The total charge of positive pion results +1. The aim of present work is to study the production of $\pi^+$ particle at electron accelerator facility Max-lab [1].

## Pions@Max-lab

An experiment has been carried out at electron accelerator facility Max-Lab, Lund University, Sweden to get a data on pion production. In this experiment, electron beam of energy upto 200MeV was incident on the radiator. It produces the photons moving in the forward direction. The energy of these photons were tagged by a tagger system. The forward moving photon hits the C12 target and it induces the nuclear reactions including pion production. The emitted particles were detected by Alpha and Beta RANGE Telescopes arranged at angles $30^0$, $60^0$, $90^0$ and $120^0$. The Alpha and Beta RANGE Telescope each consists of an array of five plastic scintillator namely α1,α2,α3,α4,α5 and β1,β2,β3β4,β5 respectively equipped with photomultiplier tubes. These detectors are used to collect the information from the reaction:

$\gamma + {}^{12}C \rightarrow \pi^+ + n + X$ [2,3].

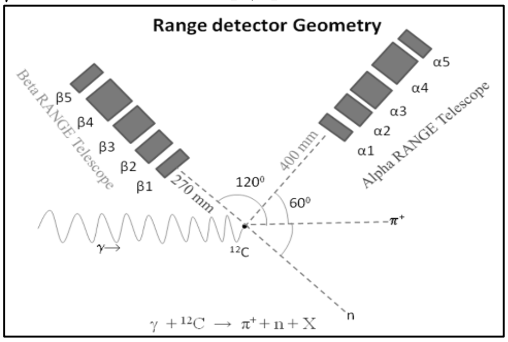


***Fig1**: Experimental set up of Alpha and Beta Range Telescopes.*

## Pion Identification

Some of these particles hit the RANGE telescope and stop there depending on their initial energy and thickness of the detector segment as shown in fig. 2A. Number of different particles ($e^-$, γ, π, protons, deuterons, etc.) are emitted during photonuclear reaction as shown in fig. 2B.. The number of pions were counted in α2,α3,α4 and β2,β3,β4 which gives us the possibility to determine the cross section as function of pion energy. The technique to identify $\pi^+$ in the experiment was based on probing the *26 ns* decay in Scintillator Range Telescopes. The charged pions have a mass of 139.6 MeV/$C^2$and positive and negative pions are considered a particle and anti-particle pair. The mean lifetime of the charged pion is 26.0 ns and it decays as follows:

$\pi^+ \rightarrow \mu^+$ (4.12 MeV) + $\mu\nu$, $\tau = 2.6\times10^{-8}$ s with a probability 99.99%.

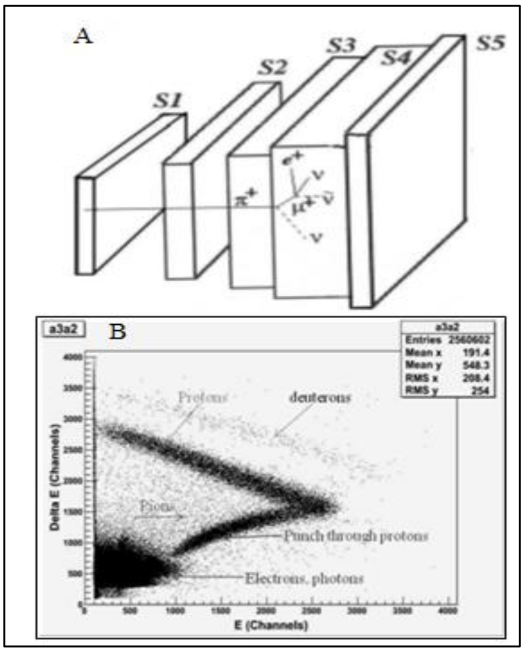


***Fig.2 (A):*** *$\pi^+$ detection process in the range telescope,* ***(B):*** *$\Delta E$ vs E plot for particles stopping in $\alpha 3$ detector of the $\alpha$ telescope.*

## Double differential cross section of pions

The experimental data presented in Fig 3 shows that the double differential cross section for pions. It increases gradually with increase in the detector angle. But after $60^0$ it starts decreasing again. The point to be noted here that the Alpha telescopes were kept at an angle of $30^0$ & $60^0$ at a distance of 400mm from target (C12) and the Beta telescopes were kept at $90^0$ and $120^0$ and more closer to the target ($^{12}C$) at a distance of distance of 270 mm as shown in fig. 1. The background contribution in Beta telescope is more as compared with the Alpha telescope, this may led to larger uncertainty in the detection of particles in Beta detector. Electrons, photons, protons and deuterons were observed and identified in the data set. The pions were identified/distinguished according to their mass. The double differential cross section for the pion at 30°, $60^0$, 90° and $120^0$ was observed to be 0.088μb/sr-MeV, 0.940μb/sr-MeV, 0.274μb/sr-MeV and 0.269μb/sr-MeV respectively with the photon beam energy between 169 to 180 MeV. The results obtained from the analysis of the pions recorded by the detector with respect to the angle as shown in Fig. 3.

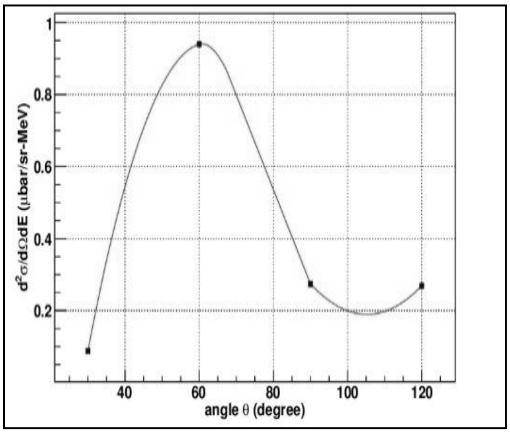


***Fig.3****: Angular distributions of pions produced on carbon by photons of the given energy 169 MeV to 180 MeV.*

## Conclusions

The photonuclear reaction experiment with photon energies from 169 to 180 MeV was conducted at Max-lab in order to collect data for π+, for the energy range near pion threshold. The pions (π+) were produced close to production threshold and were detected by Scintillator RANGE Telescopes. The double differential cross section for the pion was observed to have a strong angle dependence for the photon beam energy between 169 to 180 MeV.

## References

[1]. P.Golubev, et al., Nuclear Physics A 806 (2008) 216-219.
[2].G.V. O'Rielly et al., Charged Pion Photoproduction from Threshold up to the First Resonance Region, Proposal submitted to the MAX-lab, 2004.
[3] Ayaz Khan, Masters Thesis Project –II, Max-lab, Lund University (2012).