Digital Archives for Nuclear Emulsion Data

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Abstract. Digital archives for nuclear emulsion data of past experiments, such as in cosmic-ray and accelerator physics, is being studied and prepared. Significant progress of HTS, which is an automatic read-out system for tracks recorded in emulsion, is achieving a read-out speed of about 1 m²/hour and opens a possibility to read all tracks recorded in emulsion of past experiments. Current status of our first trial with RUNJOB emulsion plates is reported. Till now, the top-most 10 plates had been scanned by HTS and preliminary data is presented.

1 Introduction

Trajectories or tracks of charged particles are recorded in nuclear emulsion as series of silver grains as shown in Fig.1. The size of each grain is ∼1 micron and those tracks can be easily observed under optical microscope views. Automatic read-out systems for those tracks in emulsion had been playing an important role in elementary particle physics, for example, contributing in the first direct observation of tau neutrino charged current interactions in the DONUT experiment [1], and in the discovery of tau neutrino appearance in the CNGS neutrino beam with the OPERA experiment [2]. A most recent system called HTS [3] is achieving read-out speeds of ∼1 m²/hour making it possible to process 2000 m² of emulsion surface in one year. This value is similar to full emulsion surface of past experiments in accelerator and in cosmic-ray physics, such as ∼100 m² for DONUT, ∼120 m² for RUNJOB and ∼900 m² for JACEE.

In such past experiments, analysis or read-out speed of emulsion was limited and thus their analysis had to concentrate on events or phenomena of their major physics aims, with the help of supporting detectors such as scintillating fiber trackers, muon detectors and x-ray films.

Most events or phenomena recorded but not matching their major physics aims remained as not read-out nor analysed. As it is not so easy to have such events or phenomena recorded in emulsion again by performing new experiments, then it should be interesting and valuable to read full surface of such past emulsions and perform new physics analysis from our current physics knowledge. For such activities, a kind of archive for emulsion data, which is open to those who are interested, would be a suitable scheme. As a first such trial, one chamber in RUNJOB balloon experiment is being processed and the status of the trial is reported hereafter.

2 The RUNJOB Experiment

RUNJOB (RUssia Nippon JOint Balloon program) is a balloon experiment aiming to measure the chemical composition and energy spectra of the primary cosmic rays [4]. There were 4 balloon campaigns from 1995 to 1999 and a total of 10 balloons were successfully recovered. Each balloon flight was for ∼140 hours flight time at a mean altitude of ∼10 g/cm³ or 30–35 km. One of two chambers in the 1997 flight is being processed by HTS. The chamber has a cross section of 50 cm × 40 cm. An emulsion plate has two 60 µm thick emulsion layers poured on both sides of a plastic base, whose thicknesses are 500 µm or 800 µm. The chamber structure is composed of 5 modules as schematically shown in Fig.2. Emulsion plates are interleaved with materials selected, such as stainless plates in the target module, x-ray films and lead plates in the calorimeter module, according to their purposes.
3 Emulsion Data Process

3.1 Track Read-out by HTS

Before reading-out emulsion tracks by HTS scan, some treatments have to be applied. The size of a RUNJOB emulsion plate is 50cm×40cm, which is too large for the HTS stage, and it had to be cut into two pieces (two half-plates) of size 25cm×40cm. Then they have to be swollen to expand their emulsion layers thickness from ~30µm to ≥60µm, so that HTS could efficiently read-out emulsion tracks in them. An emulsion plate has two emulsion layers on both sides of a plastic base and HTS scans each layer separately. Track segments in those layers are called “micro-tracks”. Each RUNJOB half-plate is scanned divided into 9 zones, since one HTS scan is limited up to 13cm×9cm. So far, the top-most 10 plates of the chamber had been scanned with angular acceptance tan θ ≤ 1.4.

3.2 Emulsion Data Reconstruction

Fig.3 schematically shows an interaction induced by a charged particle entered from upside of the emulsion chamber. Track information that we can obtain for this event as a result of HTS scan looks as shown in Fig.4, since tracks of charged particles are recorded only in emulsion layers and relative positions among emulsion plates are lost after they were de-packed and developed. It means that connections among micro-tracks (i.e. information of which micro-track is to be attached to which charged particle) is more or less lost. Thus, simply speaking, the purpose of emulsion data processing is to reconstruct Fig.3 from Fig.4.

The first step is to reconstruct connections between micro-tracks in two emulsion layers of a plate. Distortion and shrinkage of emulsion layers are evaluated by searching for a set of those parameters that maximizes the number of connected micro-tracks within the tolerance defined by their position and angle accuracy. A connection between those micro-tracks is called a “base-track”. To keep high connection efficiency, all possible connections between micro-tracks are kept as base-tracks and thus one micro-track could be connected to multiple micro-tracks. To recover the inefficiency of base-tracks, linklets between non-consecutive plates are also used. Finally, connections among linklets in different plates are traced.
charged particle entered from upside of the emulsion

3.2 Emulsion Data Reconstruction

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layer separately. Track segments in those layers are called
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60 \( \times \) 40cm, so that HTS could e-
ciently read-out emulsion layers and relative positions among emulsion plates are evaluated by simply counting the num-
ber of missing base-tracks in a chain, using chains that
penetrate all scanned emulsion plates and are isolated from other chains. A result for plate \#5, zone=5 is shown in Fig.6. The recognition efficiency was \( \sim 0.82 \) for \( \tan \theta \leq 1.0 \), that would be acceptable for physics analysis. It must be noted that the efficiency varies depending on plate quality, which is not quite uniform.

3.3 Track Recognition Efficiency

The recognition efficiencies of base-tracks in RUNJOB emulsion plates are evaluated by simply counting the number of missing base-tracks in a chain, using chains that penetrate all scanned emulsion plates and are isolated from other chains. A result for plate \#5, zone=5 is shown in Fig.6. The recognition efficiency was \( \sim 0.82 \) for \( \tan \theta \leq 1.0 \), that would be acceptable for physics analysis. It must be noted that the efficiency varies depending on plate quality, which is not quite uniform.

4 Analysis Examples

4.1 Vertex Search

Vertices such as due to hadronic interactions could be selected using linklets. As a first step, all pairs of linklets,
each converge to a point called a “two-track vertex”, are picked up within the tolerance in a region where vertices are to be searched. Then, a 3D histogram of positions of those two-track vertices are made to select histogram bins, in which two-track vertices are concentrated.

As an example, this method is applied to all linkets between plate \#5 and \#6 in one zone to find vertices in stainless plate placed just upstream of plate \#5 (see Fig.7). All pairs of linklets having closest distance \( \Delta r \leq 10 \mu m \) and relative angle difference \( \Delta \phi \geq 50 \text{ mrad} \) are selected. The 3D histogram of positions of selected two-track vertices are made with a bin size \( 20 \mu m \times 20 \mu m \) in a plane parallel to emulsion plates and \( 40 \mu m \) in the vertical. A histogram of the number of two-track vertices in each 3D histogram bins is shown in Fig.7. Then linklets which belongs to two-track vertices in 3D histogram bins having \( \geq 300 \) entries are shown in Fig.8.
4.2 Shower Search

Shower topology could be better selected using chains. For example, in electro-magnetic showers, many tracks having similar angles are populated in a small region on each emulsion plate. In such circumstance, connection of base-tracks between two plates are more likely to be multiple to multiple due to insufficient angle accuracy of base-tracks. Then there are most likely to be many chains having same base-tracks in common, and those chains are to be grouped. Shower topologies could then be selected by choosing groups of chains having many chains and/or base-tracks in their members.

As an example, this method is applied for chains in plates from #5 to #10 (i.e. in the target module of the chamber). A distribution of the number of base-tracks in each group of chains is shown in Fig.9 and those groups having ≥200 base-tracks are then selected and shown in Fig.10.

5 Summary

Recent developments of HTS (an automatic read-out system for emulsion tracks) are achieving a speed of ~1m²/hour and it is being possible to process 2000m² in one year. This allows us to read the full surface of emulsion plates of past experiments in accelerator and in cosmic-ray physics. Since most of the events or phenomena recorded in those emulsion plates are not read-out and remain unused, and it is also not so easy to have them recorded in emulsion again by new experiments, it should be interesting and valuable to read them all to construct a digital archive of those emulsion data. As a first trial of such archives, one chamber of RUNJOB balloon experiment is being processed. Up to now, top-most 10 emulsion plates had been read-out by HTS. The recognition efficiency of base-tracks is evaluated to be ~0.85 for $\tan \theta \leq 1.0$, that would be acceptable for physics analysis. Relative slipping between emulsion plates was observed but could be treated properly without serious problem. As an analysis example, searches for vertices and showers are shown using a subset of obtained data.

After the conference, big efforts are being devoted to an HTS scan of the remaining emulsion plates of the chamber and will be completed in 2018.

References

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