# 28 GeV/c BEAM DUMP EXPERIMENTS

John M. LoSecco
University of Michigan, Ann Arbor, Michigan 48109

## ABSTRACT

Three experiments that were run concurrently at the Brookhaven AGS are reviewed and compared. The experiments searched for prompt neutrinos and penetrating neutral particles from a beam dump exposed to $4.2\times10^{18}$ 28 GeV/c protons. Some indications of unusual production mechanisms have been reported.

## INTRODUCTION

Beam dump experiments are a good way to search for evidence for new particle states. The initial proton beam is incident on a dense large block of material. The beam produces large numbers of conventional hadrons, such as $\pi$'s and K's. The high density of the dump rapidly absorbs these before they can decay and produce neutrinos. The prompt signal can come from the decay of short lived states, such as charm, or from the production of penetrating neutral states such as the hypothetical axion. The advantage of beam dump studies at 28 GeV/c is that charm production is known to be highly suppressed, by $10^3$ or more, over its production rate at 400 GeV/c. So this interesting, but known, background is removed. Another advantage is the high sensitivity that can be obtained since the accelerator can produce more protons and the experiments can be located much closer to the dump.

The three experiments to be considered are: the Rutgers, Stevens, Columbia group[1] that made use of the 7' bubble chamber situated 43 meters from the dump (Figure 1), the Columbia, Illinois,

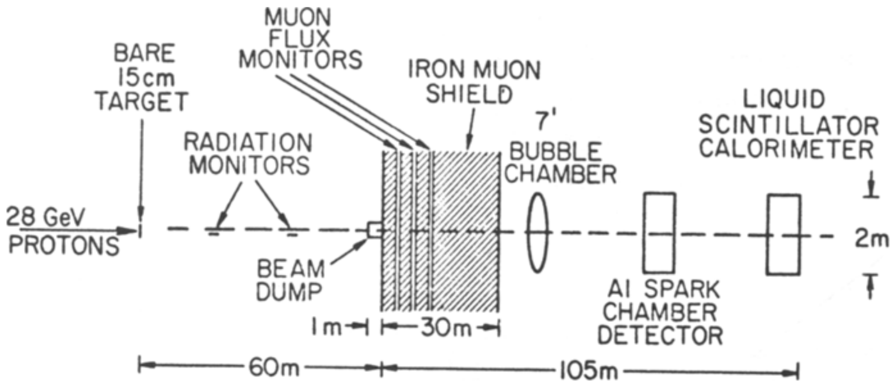


Fig. 1. The experimental layout indicating the relative position of the experiments.

Brookhaven group[2] that made use of an aluminum spark chamber detector situated 76 meters from the dump and the Harvard, Pennsylvania, Brookhaven, Oak Ridge group[3] that made use of a liquid scintillator detector situated 105 meters from the dump.

In addition to the dump two other targets were studied. A sample of conventional neutrino interactions were generated from a 15 cm thick bare target followed by a 60 meter decay space. Losses were studied with a series of transmission targets positioned at 5 points along the beam transport system.

## THE EXPERIMENTS

The bubble chamber has reported on a sample of 147,000 pictures randomly selected from 700,000 taken during the dump. This represents an exposure of $1.3\times10^{18}$ protons. The chamber was filled with 62% neon hydrogen mixture and had an effective fiducial mass of 2.8 tons. The scanning efficiency was 75 ± 10%.

The pictures were scanned for $\mu^-$, $\mu^+$, $e^\pm$, neutral current and $e^+e^-$ candidates. To remove cosmic ray background the events were required to have $E_{visible} > .5$ GeV and a total momentum within 30° of the beam axis. Their experience with wide band neutrino beam exposures suggests that these cuts retain 98% of the beam associated signal. Their results after background subtraction and correction for scanning efficiency and misidentification are reported in Table I. The expected rate is calculated from wide band running correcting for the decay space and the effects of focusing. The event candidates have the expected properties of muon neutrino induced events.

Table I

7 Foot Bubble Chamber Event Summary

| | Observed | Corrected | Expected |
|---|---|---|---|
| $\mu^-$ | 10 | 12 | 11 |
| $\mu^+$ | 6 | 4 | 2 |
| N.C. | 6 | 6 | 4 |
| $e^\pm$ | 0 | 0 | 0.1 |
| Total | 22 | 22±6 | 17±6 |

The Columbia, Illinois, Brookhaven group used their 4.5 ton detector to study neutrals from the dump and compared them with events observed from the bare target. Timing was used to eliminate background and indicated that cosmic ray induced or beam associated background was very small.

Their results are reported in Table II. A 15 to 20% correction for detection efficiency of low multiplicity events is needed, but has not been applied.

Table II

Columbia, Illinois, Brookhaven Event Summary

| | Bare Target | Dump |
|---|---|---|
| Protons | $1.9\times10^{17}$ | $4.7\times10^{18}$ |
| C.C. | 53 | 49 |
| N.C. | 9 | 14 |
| C.C. > 3 Prong | 24 | 29 |
| N.C. > 2 Prong | 9 | 14 |
| $e^{\pm}$ | 1 | 1 |
| $\mu^{+}$ | 4 | 6 |
| $\mu^{-}$ | 19 | 19 |
| N.C./C.C. > 2,3 Prong | .38 ± .15 | .48 ± .16 |
| Total | 62 ± 8 | 63 ± 8 |

The observed suppression factor for the dump is Target Rate/Dump Rate = 24±4. The group concludes that there are no obvious differences between dump and bare target events.

The Harvard, Pennsylvania, Brookhaven, Oak Ridge group used an 11 ton liquid scintillator detector to study dump and bare target events. The timing technique previously mentioned was also used. Background was very small. Their results are reported in Table III.

Table III

Harvard, Penn, BNL, ORNL Event Summary

| | Bare Target | Dump |
|---|---|---|
| Protons | $1.97\times10^{17}$ | $4.87\times10^{18}$ |
| C.C. | 115 | 90 |
| N.C. | 24 | 14 |
| N.C./C.C. | 0.21±0.05 | 0.16±0.04 |
| Total | 139 | 104 |
| Event Rate | $70.6\times10^{-17}$ | $2.14\times10^{-17}$ events/proton |

The Rate Target/Rate Dump = 33±4. No major differences between dump and bare target events were reported. This group also reported an analysis of the transport loss study. Less than 21 of their 104 beam dump events are attributable to beam losses at 90% confidence level.

## COMPARISON

In Table IV we compare the 3 experiments. We have standardized by scaling all experiments to an exposure of $10^{19}$ protons and a 10 ton detector at 100 meters.

Table IV

Comparison of Different Experiments

| Group | 7' | CIB | HPBO |
|---|---|---|---|
| Mass (tons) | 2.8 | 4.55 | 11 |
| $\ell$Dump (m) | 43 | 76 | 105 |
| Protons | $1.3\times10^{18}$ | $4.7\times10^{18}$ | $4.87\times10^{18}$ |
| Events | 22±6 | 63±8 | 104±10 |
| Standard Events | 112±21 | 204±26 | 214±21 |

The CIB group standard value has been corrected (+20%) for detection efficiency. The difference between the 7' group and the HPBO group is statistically significant.

$$\text{HPBO} - 7' = 102\pm30 \qquad (1)$$

Since the HPBO detector can only see events out to 10 mrad and the bubble chamber extends out beyond 20 mrad a flux fall off with angle could explain the difference since the standard value was obtained by scaling by $\ell^2$. Such a rapid fall off is not typical of hadronic showers at this energy.

## CONCLUSIONS

All groups agree that there is no striking and unique signal coming from the dump. An analysis of the conventional $\pi$ decay signal from the dump can be done and an excess searched for. This has been done by each group.

As seen from Table I the 7' bubble chamber group claims agreement between their predicted and observed event rate. The CIB group has done two calculations. One predicts half of the observed rate and the other predicts the rate observed. They do not trust the calculations to within a factor of 2 and do not draw any conclusions.

The HPBO group has done two separate calculations with different systematic errors. The first calculation scales the bare target event rate so it is insensitive to questions of absolute flux normalization or detection efficiency. The most critical parameter in the extrapolation is the effective pion absorption length in the dump. An absorption length of 29cm is indicated by experiments and includes the effect of hadron showers and secondary interactions.

The second calculation is a detailed hadron cascade Monte Carlo that follows the protons and secondaries in the dump. As a check on the Monte Carlo it was used to calculate the bare target rate and gave the observed value.

The detailed Monte Carlo calculation and the scaling calculation are in agreement. They predict 56 events for the HPBO group. The group has concluded that they have an excess of 48±10 events with a systematic error of ±12 events. Their studies indicate that it is unlikely that transport losses could account for the excess.

The calculations can be applied to the other two experiments. They indicate that the CIB group has a 45% excess. No excess is indicated for the 7' bubble chamber since it has a lower observed event rate.

I would like to thank M. Kalelkar and R. Fine for discussions and clarification of their experiments.

REFERENCES

1. P. F. Jacques, M. Kalelkar, P. A. Miller, R. J. Plano, P. Stamer, E. B. Brucker, E. L. Koller, S. Taylor, C. Baltay, H. French, M. Hibbs, R. Hylton, K. Shastri, and A. Vogel, Phys. Rev. D21, 1206 (1980).

2. P. Coteus, M. Diesburg, R. Fine, W. Lee, P. Sokolsky, R. Brown, S. Fuess, P. Nienaber, T. O'Halloran, and Y. Y. Lee, Phys. Rev. Lett. 42, 1438 (1979).

3. A. Soukas, P. Wanderer, W. T. Weng, M. Bregman, M. Claudson, J. LoSecco, L. Rivkin, J. Roeder, S. Russek, L. Sulak, P. Timbie, M. Yudis, T. A. Gabriel, R. S. Galik, J. Horstkotte, J. Knauer, M. Levine, and H. H. Williams, Phys. Rev. Lett. 44, 564 (1980).