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# A PROPOSAL TO MEASURE NUCLEAR CALIBRATION CROSS SECTIONS FOR PROTONS WITH ENERGIES GREATER THAN 400 GeV

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## ABSTRACT

We propose to extend the measurement we made in Experiment 631 to Tevatron energies. That experiment measured the cross section for the production of $^{24}Na$ in copper by 400 GeV protons to three percent accuracy. In addition, we propose to measure this cross section as a function of energy from 30 GeV to the maximum energy currently available (800-900 GeV).

## Introduction

Use of 15 hour half-life $^{24}Na$ production in copper to determine the number of protons in an extracted proton beam from a high energy accelerator has several advantages over methods previously used:

1. The effective threshold of around 400 MeV makes the result less sensitive to beam quality than most other reactions, e.g., $^{24}Na$ production in aluminum.[1]

2. The determination is less sensitive to thickness corrections since gamma rays are counted rather than alpha particles. Formerly, alpha particles were counted from the production of $^{149}Tb$ in gold.[2]

3. The proximity of the gamma-ray energy (1.369 MeV) to that of $^{60}Co$ (1.332 MeV) makes accurate determination of detector efficiency possible.

4. Measurements to date indicate that the cross section rises only about 10% from 10 GeV to 400 GeV.

The development of the high resolution Ge(Li) gamma-ray detector made it easy to separate the $^{24}Na$ 1.369 MeV gamma ray from the multitude of others resulting from the spallation of copper. Such a separation required peak-stripping techniques using the NaI(Tℓ) detectors available earlier. That

precluded the routine use of the technique for beam intensity measurements.

Accurate determination of the number of protons incident on a target is a requirement for almost every experiment at a high energy accelerator. Toroids can be used when the current is high enough (typically $10^{11}$ protons or more in one millisecond). Individual protons can be counted up to almost $10^{7}$ per second. Outside these ranges foil activation is a valuable alternative since it can be used for calibrating instruments such as secondary emission chambers and ion chambers which monitor the number of protons. These instruments cannot be calibrated absolutely by passing a current through them as a toroid can. There are many experiments utilizing slow spill where such chambers are essential.

Experiment 631 measured the cross section for $^{24}$Na production in natural copper to 3% for 400 GeV protons.[3] This proposal would extend the measurement to Tevatron energies - 800 GeV or higher. In addition, measurement as a function of energy from 30 GeV to the highest energy available would yield information useful for interpolating between measurements and for extrapolating to 20 TeV, the energy proposed for the Superconducting Super Collider (SSC). One will also be able to compare the rise in the $^{24}$Na production cross section with the rise in the pp inelastic cross section. This could improve our understanding of the nuclear physics involved.

Location of Irradiation

As part of the upgrade of Fermilab to Tevatron energies, a new abort dump has been built near CØ in the Main Ring. This abort dump is outside the existing tunnel and separate beam pipes will be run to it. Thus, there is a unique opportunity to place foils in a region which is relatively free from scattered radiation and can receive energies from injection energy to the maximum the Tevatron can produce.

Since the cross section at 400 GeV has been measured to 3% by this group of collaborators, that measurement will be used as a reference for this experiment. This will greatly reduce the irradiation time and effort needed. A simple remotely controlled target wheel will suffice for positioning the foils in either the Main Ring or Tevatron beam (Fig. 1). The background will be low enough (based on a measurement already made - Appendix I) to permit placement and removal of foils during scheduled shutdowns.

We propose to make three irradiations at Fermilab at each of the following energies:

30 GeV (Typical extraction energy for BNL AGS)
76 GeV (Typical extraction energy for Serpukhov)
150 GeV (Typical extraction energy for Fermilab Main Ring)
400 GeV (Reference)
≥800 GeV (Typical extraction energy for Fermilab Tevatron)

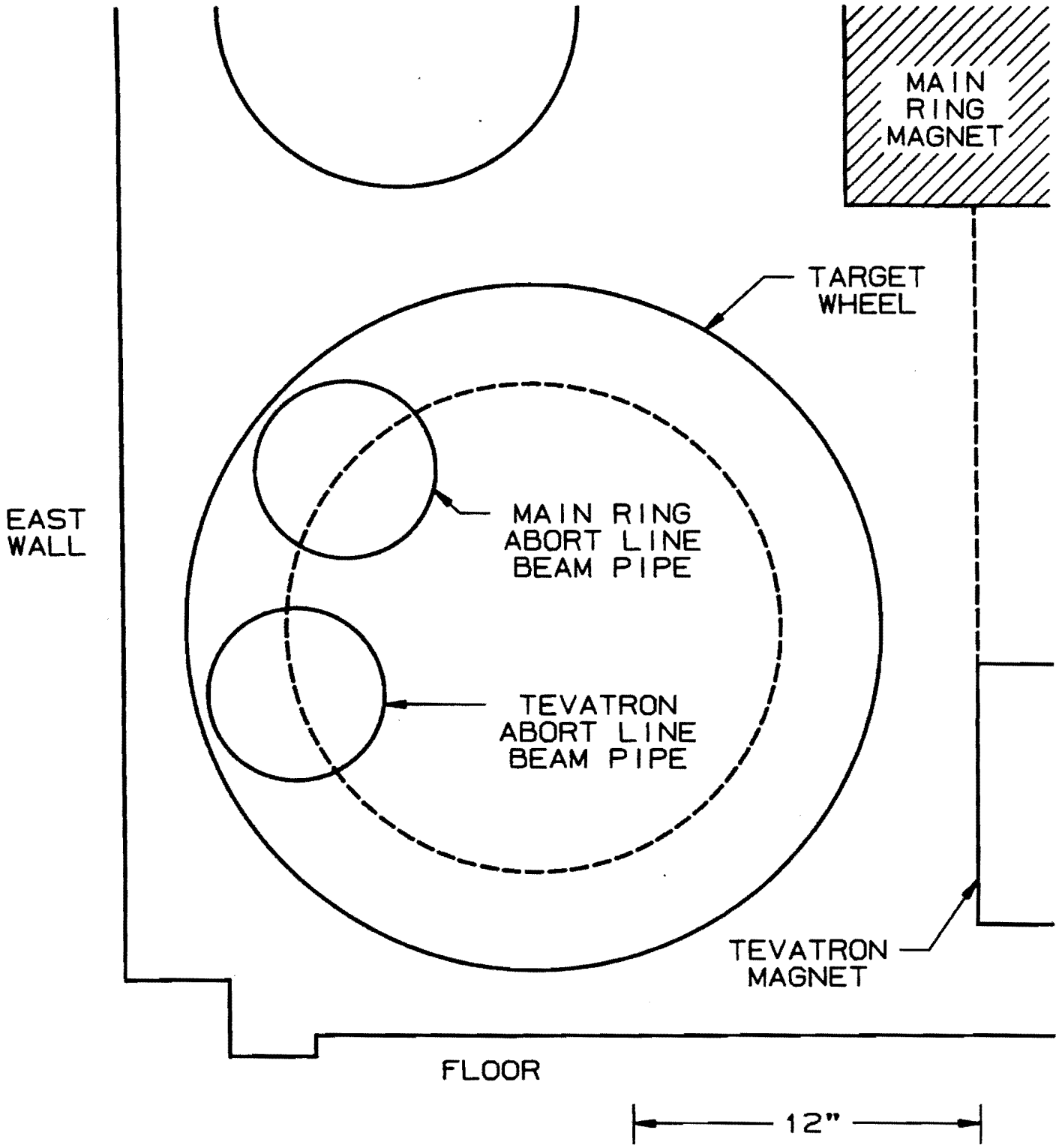


Figure 1. TARGET WHEEL LOCATION IN ABORT LINE NEAR CØ.

If desired, we could extend to 8 GeV (Booster). The beam spot is large, making losses higher. Thus, the accuracy would be poorer at 8 GeV.

The number of protons proposed for each irradiation would be $6 \times 10^{13}$ with two irradiations at different energies just before a given shutdown. See Appendix I. This typically would require four or five pulses (four or five minutes of accelerator operation). Because the abort system can be fired at any energy up to the maximum, no special ramps with "flat-tops" or "front-porches" at the desired energies would be necessary. Some of the irradiated foils will be sent to BNL and CERN to improve the cross calibration between high energy physics laboratories.

The cross section determination at 400 GeV will be used as a reference. In addition, the Main Ring and Tevatron toroids will be used to determine the number of protons entering the abort lines. We propose to add toroids in the abort lines to give measurements of the number of protons hitting the foils. Because the protons are extracted and sent to the abort dump in a single turn around the ring, the signal to noise in the toroids should be very high. Thus, the toroids and associated electronics do not need to be elegant, as was the case for Experiment 631. The toroids can easily fit with the target wheel in the available 7" longitudinal space between sections of beam pipe.

We anticipate that this experiment will run during the fixed target program. At that time Experiment 735 at CØ will not be in operation. The experiment should only have an impact on the fixed target high energy physics program during the irradiations in the Tevatron abort line (400 GeV and ≥800

GeV). The Main Ring line irradiations could be done under the "flat-top" for the Tevatron. To reduce the already small number of pulses lost to the rest of the program during the Tevatron irradiations, we propose to combine those irradiations with the needed abort dump muon measurements at the site boundary. The latter require at least ten pulses at the highest energy. In addition, a muon comparison at 400 GeV would be worthwhile.

## Conclusion

The needed nuclear cross section measurement at high energies can be performed with minimal disruption to the program.

REFERENCES

1. J. Hudis et al., Physical Review 129, 434 (1963).

2. J.B. Cumming et al., Physics Review C14, 1554 (1976).

3. S.I. Baker et al., Nuclear Instruments and Methods 222, 467 (1984).

## Appendix I. Background Measurement

An aluminum foil has been placed at the location where the target wheel for irradiating the foils would be installed. Its purpose was to measure the total number of protons sent to the abort dump at Tevatron energies. The foil was irradiated during the period from 7/8/85 to 10/14/85 with most of the irradiation occuring from 7/8/85 to 8/28/85.

The total number of protons incident was $3.6 \times 10^{16}$. The energies were in the range from 150 GeV to 800 GeV.

A small section of foil the size used for cross section determinations was punched near the outer edge of the aluminum foil which covered the end of the 6" diameter beam pipe. The small section was counted and had $1.5 \times 10^{13}$ protons incident on it. Thus, the background was approximately $2 \times 10^{12}$ per week at that location, assuming most of the irradiation occurred during an 8 week period.

Because the cross section was measured to 3% at 400 GeV, the background should be kept that low to get comparable results using the 400 GeV measurement as a reference. This gives $6 \times 10^{13}$ protons for each irradiation.

The number of protons for each irradiation was $1 \times 10^{14}$ in Experiment 631. Use of thicker foils can reduce the requirement to $6 \times 10^{13}$ because the effect of secondaries was studied in Experiment 631 and corrections can be made for

interactions of secondaries in the thicker foils. Decay corrections are easily made for 15 hour half-life $^{24}Na$. Background corrections can be made using additional foils, some stationary and some mounted at other locations on the target wheel.