The MIPP Trigger Document

0.1 Introduction

This document describes the MIPP trigger design. It is primarily intended to serve as a planning document for discussion and implementation of the trigger. Sec. 0.2 covers the basic physics goals of the experiment. Sec. 0.3 describes the characteristics of the MIPP beamline. Sec. 0.4 reviews the tools available for forming the trigger, including detectors and specialized trigger modules. The intended trigger layout in logic and timing is described in Sec. **??**. The final section (or more appropriately appendix) is reserved for the inevitable modifications that will occur in the design as we attempt to implement it.

0.2 Physics Goals for the MIPP Trigger

MIPP is a survey experiment, collecting data on hadron-nucleus interations over a wide range of projectile species, π, K, p of both signs, a wide range of energies and target masses. The data have a wide range of applications, from calibrating particle production from the NUMI target to measuring particle production backrounds for proton radiographs. Thus the requirements of the trigger are simple:

- Select beam particles with high probability for interaction and detction in the experiment
- Tag Particle identity
- Select nuclear interactions

The latter two requirements set the primary constraints for the definition of a good beam particle. Accurate particle identification with the Beam Cerenkov Counters a beam spot size of less than 1 cm and a dispersion of better then 0.5 mrad. The T00 and T01 counters will be used to to provide beam definition. A good beam focus is also needed to form a bullseye trigger that can detect the absence of an uninteracted beam particle.

The interaction trigger should be as general as is feasible, with the goal of including a significant fraction of the elastic cross-section, with an emphasis on including diffractive production. To achieve, we will try to combine a bulleye trigger with multiplicity threshold on one or more detectors.

0.3 Beamline Characteristics

0.3.1 The Fermilab Accelerator Complex

All beams at Fermilab start out in the Linac. The Linac injects into the Booster that accelerates protons to 8 GeV/c. The Booster feeds protons to the Main-Injector (MI) and to the MiniBoone experiment. The Main Injector accelerates the protons to 120 GeV/c and feeds the Tevatron (with most of the protons going to pbar production), the fixed target area experiments (Mtest and MIPP), and in the future will provide beam for Minos. Beam gets to the fixed target area through the Switchyard 120, where beam is split to the different fixed target areas.

From the Main Injector beam can be extracted in different modes, fast spill or slow spill. The pbar production and Minos need fast spill, meaning that the entire beam in the MI is extracted in one turn. MIPP needs slow extracted beam because the experiment wants only one beam particle per event, with one event following the next as fast as the MIPP detectors and the accelerator allow (to minimize running time).

0.3.2 Beam Time Structure

Sub-spill

The structure of the first stage of acceleration of the protons in the linac is lost when the protons get further accelerated in the Booster. However, the Booster structure is still visible and important when the secondary beam gets to the MIPP target.

The booster contains 84 rf buckets of 18.83 ns (53 MHz) separation. About 80 of these buckets are filled with beam, four buckets form the extraction gap to the MI. The width of the buckets is ca. 1.7 ns, but can vary from 1.3 to 2.8 ns depending on p-t phase rotation.

One booster turn extracted into the MI is called a booster batch, 80×19 ns long. The MI can hold multiple (up to six) bunches, but will have only one bunch for MIPP operation (even in double slow spill).

The 53 MHz clock from the Main Injector is available to the experiment.

Spill

The spill structure depends on the extraction mode. In 'fast spill' all the beam from the MI is extracted in one turn, i.e. the spill lasts for the duration of one booster batch, 1.52 μs.

In resonant extraction (aka 'slow spill') a fraction of the protons in the bucket circulating in the MI is extracted each time the bucket passes the extraction section. So the resulting structure looks like many low intensity fast spills separated by the cirulation speed in the MI. This is MI circumference, 3319.419 meters, times the speed of light or 10.89 μs. The entire slow spill takes (up to) one second.

http://www-fmi.fnal.gov/fmiinternal/MI_Technical_Design/index.html gives more details on the Main Injector.

Signals from the MI are available to tell the MIPP trigger the status of the extraction, e.g. when the flattop starts and ends. Beam is extracted between these signals.

The trigger can implement a veto for beam events outside the flattop time window.

0.3.3 Overall

The repetition rate of slow spills is limited technically by the MI and depends in practice on the operating scenario. Slow spills may be minutes apart at worst or follow each other with 3 second intervals. The administrative policy is that switchyard operations cannot impact the Tevatron by more than 5%. Testbeam and MIPP will share these protons. MTEST demands are low.

0.3.4 Beam Composition

In the primary MIPP target 120 GeV/c Main Injector protons are converted into the six secondary beam species. The beam momentum on the secondary target is selected in the MIPP secondary beam line. (The opening in the momentum collimator defines $\frac{\delta p}{p}$ and the field strength in the magnets defines the central secondary beam momentum.) The ratio of particle species depends on the selected secondary momentum and charge of the secondary beam. The primary intensity is set to optimize the yield of useful secondary interactions (with the constraint of 125 k particles per second or spill).

0.4 Hardware

0.4.1 Detectors

Each MIPP detector (TPC, BeamCkov, DCs, MWPCs, RICH, TOF, EMCAL, HCAL, ...) is listed below with the signals it can possibly provide to form a trigger (Multiplicity from TOF, etc.) and with the signals needed from the trigger electronics, including timing (adc gates, tdc common stops, etc.).

T00, T01 start counters

The T00, T01 counters are 1x6x6 cm quartz scintillator counters located approximately 60 m and 3 m upstream from the target, respectively. T01 is one of the beam definition counters. T01 also provides the start time for the Time of Flight (TOF) counter. In addition, the T01-T00 time difference is used to distinguish between pions and kaons at the lowest energy beam setting (5 GeV/c) outside the range of the BCKV.

The detectors are read out by ACME light guides and four BC408 phototubes, one on each side. The signals are split 90/10 into TDC and ADC components. The splitters provide an additional 250 ns delay for the ADC signals, which are read out by LRS 4300 ADCs. The TDC signals are discriminted by LRS 4415s, and then digitized in LRS2229s.

The trigger signals from these counters are formed from coincidence of three of the four discriminated PMT signals.

0.4.2 Beam Definition and Veto Counters

The beam definition is formed as the coincidence of T01 and a similar counter positioned just upstream of the first beam Cerenkov Counter. The upstream beam definition counter (Bdef) is not used for timing. This is left to T00 and T01. Bdef is used to ensure straight trajectories throught the beam Cerenkov detectors.

The area of Bdef and T01 is larger than the 2 inch diameter targets used for most of the MIPP data taking. Further the Beam Cerenkov counters can not work if two particles are radiating in the Cerenkov decay pipes. The Bveto counter addesses these two issues. It is a piece of scintillator mounted next to T01 with a 1.9 inch diameter hole in the center and a cross section area of the beam Cerenkov pipes.

Beam Cerenkov Counters

The beam Cerenkov counters are intended to provide mass identification of the incident particles, except at the lowest momenta. There are two counters each with two photomultiplier tubes: one tube denoted as "inner" and the other as "outer", according to the Cerenkov angular range covered. Coincidence relations may vary depending on momentum and polarity.

Output signals will tag the two minority particles, and these in anticoincidence with the T0 coincidence, for example, would identify the majority particle. All four, including T0, would be scaled. Amplified outputs from the four phototubes would be provided for ADCs. If the signals from the Cerenkov tubes, rather than the T0 signal, are the latest to arrive at the electronics rack, the outer tube of the upstream counter, BCKV1, would be the last. It would arrive 100ns after the particle traversed the primary mirror of BCKV1, or 60ns after traversing the primary mirror of BCKV2, i.e.T01. Processing time for the NIM circuitry will be approximately 70ns. All outputs should be scaled, event gated and beam gated.

Beam Wire Chambers

MIPP has three beam wire chambers used for offline beam definition. The chambers, BC1, BC2, BC3, are located 40.4, 16.0, and 3.3 m upstream of the target, respectively. See E690 NIM for details.

Target Wheel

TPC

Drift Chambers

Threshold Cerenkov Counter

The threshold Cerenkov counter consists of 96 PMT channels that are each read out via an analog (CAMAC ADCs) and digital (CAMAC TDCs) output. The analog output is delayed via 60 foot RG58 cables, which is approximately 100 ns. The ADCs are located in the RR12 rack, which is between the JGG and Rosie magnets. The digital outputs run along twisted pair ribbon cables of similar length, but can be delayed further with little additional work. Thus, the primary trigger requirement is a gate that comes in time to read out the ADCs.

Iowa Chambers

RICH

HCAL

ECAL

0.5 Trigger Design

0.5.1 Logic

The MIPP definition for a beam candidate particle (**BEAM**) is given by the Bdef and T01 coincidence vetoed by Bveto:

$$BEAM = Bdef \cdot T_{01} \cdot \overline{Bveto}. \tag{1}$$

Table 1: Summary of Detectors and Trigger Inputs.

Detector	Module	Gate	Timing
BC1-3	LRS 4291 TDC	$\geq$ 200 ns after signal	300ns dynamic range
BCKV	LRS 4300 ADC	50–500 ns, 20ns before	unknown cable delay
DC1-4	LRS 4291 TDC		300 ns dynamic range
PWC5&6	RMH TDC	unknown gate	unknown dynamic range
TPC	Clock Module	$\geq$ 50 ns duration	4μs to GG and clock
CKOV	LRS 4291 LRS 4300		300 ns dynamic range 300 ns from TOF splitter boards
TOF	LRS 2229 LRS 4300	unknown 50 ns	150 ns delay from cable 300 ns from TOF splitter boards
RICH	VME Latch		4μs pipeline delay
HCAL	LRS 2249	$\sim$ 200 ns gate	300 ns cable delay
ECAL	Nevis CAMAC		300 ns cable delay

These counters provide an active area of 6 cm, and their separation sets a maximum emittence of approximately 1 mrad.

Particle identification is achieved using the two differential Beam Cerenkov counters (BCKV). The standard particle definitions for most momenta are:

$$\pi = \overline{BCK1_{in}} \cdot BCK1_{out} \cdot \overline{BCK2_{in}}(\cdot BCK2_{out}) \quad (2)$$

$$K = BCK1_{in} \cdot \overline{BCK1_{out}} \cdot BCK2_{in}(\cdot BCK2_{out}) \quad (3)$$

$$p = \overline{BCK1_{in}} \cdot \overline{BCK1_{out}} \cdot \overline{B}CK2_{in} \cdot \overline{BCK2_{out}} \quad (4)$$

$$(5)$$

The interaction trigger is defined by the multiplicity in DC1. The E690 amplifier/discriminator cards produce 8 and 32-wire or'ed outputs that are fed into LRS 4352 modules to form analog sums of signals. The analog sum over threshold are then input into an LRS2365. An interaction is defined as greater than 2 hits on three out of 4 planes on DC1.

Other potential trigger signals are a multiplicity sum from the TOF, and the absence of beam particle in DC4. The logic for these signals has not yet been implemented.

Fig. 0.5.2 diagrams the full implementation of the MIPP trigger. The raw beam trigger signals are initially converted to ECL for further fast processing. The LRS 4418 is used to enable timing adjustments to be made remotely without breaking interlocks. All of the beam logic is implemented via a double cascade of pairs of LRS 2365s. All raw and processed triggers are read out by LRS 3777 multi-hit TDCs to provide a complete time history of all signals for a time window of 32 μs with 500 ps resolution approximately centered around the trigger signal.

The trigger signals are converted back to NIM logic in order to use the FNAL PD-22 scale-

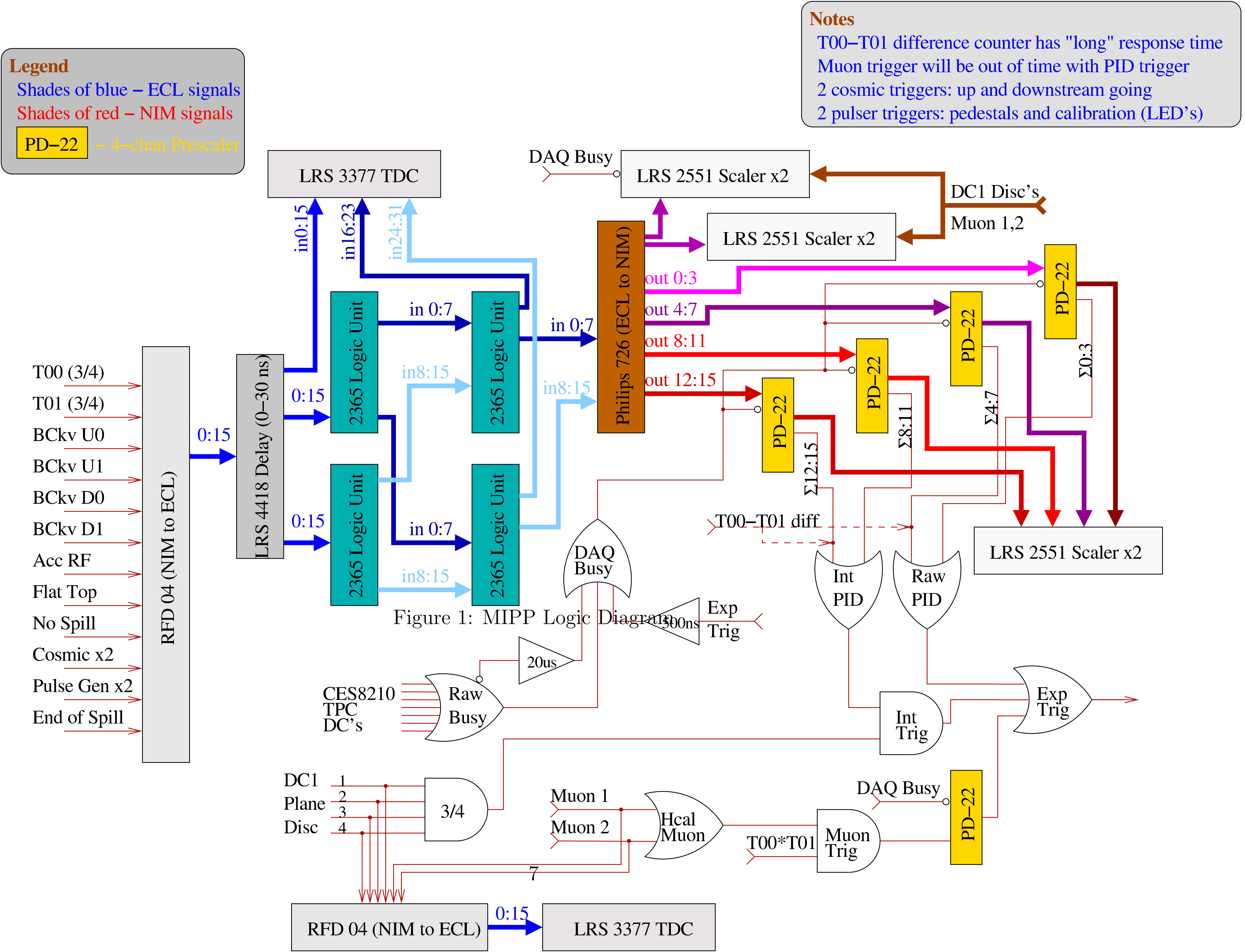

Figure 1: MIPP Logic Diagram