Fermilab

Directorate

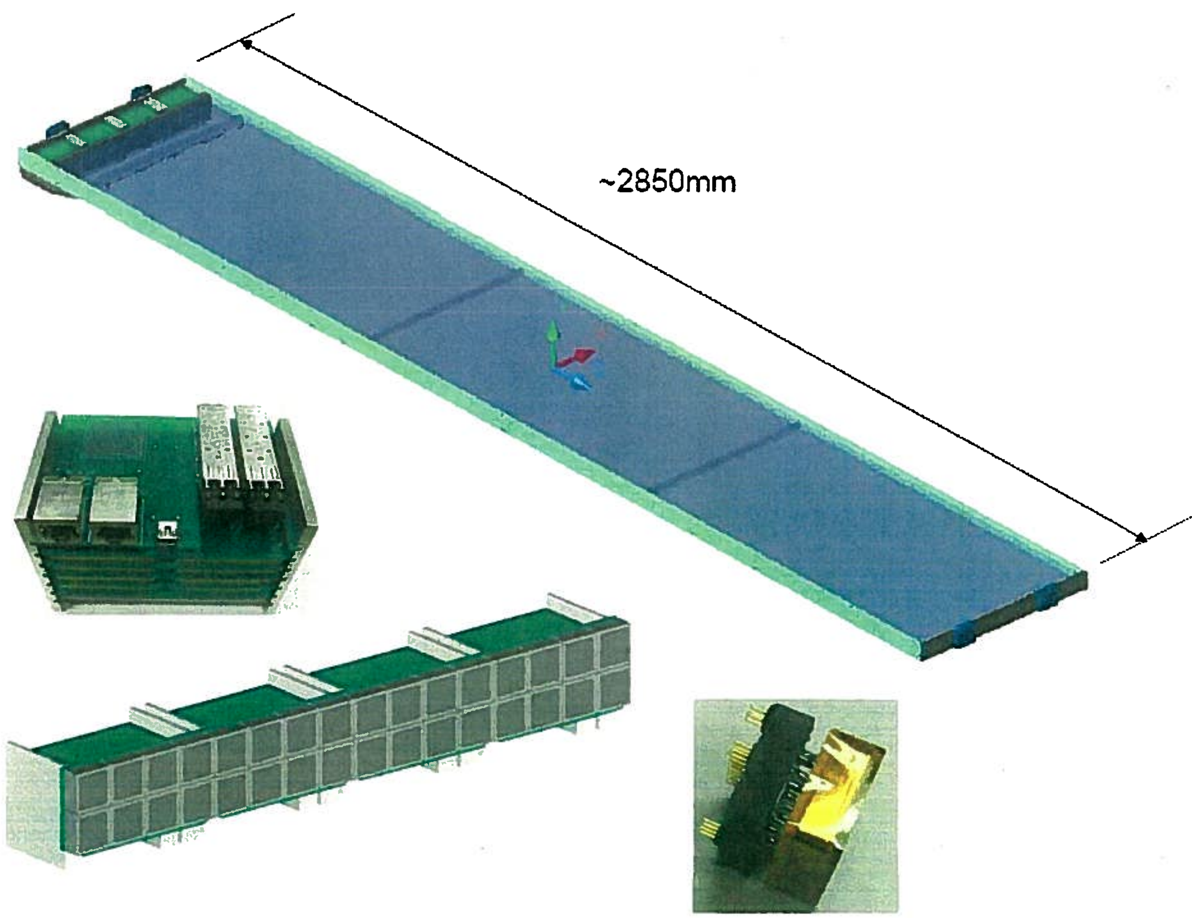
MEMORANDUM OF UNDERSTANDING

FOR THE 2011 – 2012 FERMILAB TEST BEAM FACILITY PROGRAM

T-1019

Performance confirmation of the Belle II imaging Time Of Propagation (iTOP) prototype counter

October 17, 2011



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INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of Nagoya University, Pacific Northwest National Laboratory, the University of Cincinnati, and the University of Hawaii who have committed to participate in beam tests to be carried out during the 2011 – 2012 Fermilab Test Beam Facility program.

The memorandum is intended primarily for the purpose of recording expectations for budget estimates and work allocations for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to modify this memorandum to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

Description of Detector and Tests:

The Belle Detector at the KEKB asymmetric-energy e^+e^- collider performed extremely well, logging an integrated luminosity an order of magnitude higher than the design baseline. With this inverse attobarn of integrated luminosity, time-dependent CP-violation in the 3rd generation beauty quarks was firmly established, and is now a precision measurement. Going beyond this to explore if the Kobayashi-Maskawa mechanism is the only contributor to quark-mixing, and to interrogate the flavor sector for non-standard model enhancements, requires a detector and accelerator capable of topping this world-record luminosity by more than an order of magnitude. The Belle II [1] detector at the upgraded Super-KEKB [2] accelerator has been designed to meet this highly ambitious goal of operating at a luminosity approaching 10^{36} cm^{-2} s^{-1}.

Such higher event rates and backgrounds require upgrade of essentially all detector subsystems, as well as their readout. Comparing the Belle composite (threshold Aerogel + Time of Flight) particle identification (PID) system with the DIRC employed by BaBar, quartz radiator internal Cherenkov photon detection proved to have higher kaon efficiency and lower pion fake rates. However, because the detector structure and CsI calorimeter will be retained, an improved barrel PID must fit within a very narrow envelope, as indicated in Fig. 1.

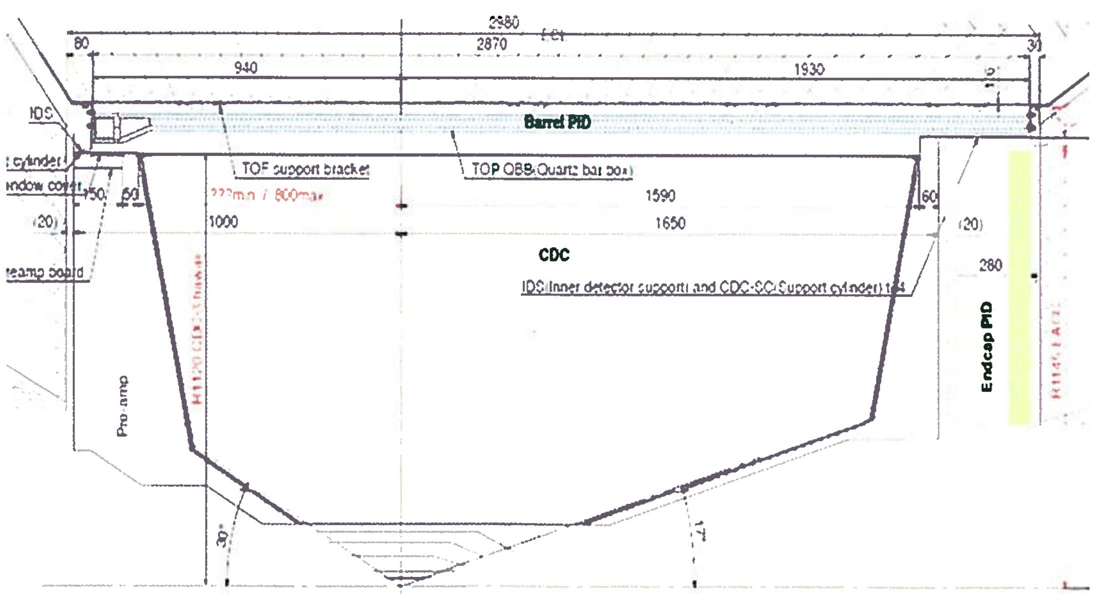


Figure 1: Cross-sectional view of the Belle II detector, where the restricted envelope available to the Barrel PID device is clearly seen.

To effectively utilize this space, a more compact detector concept based on the same quartz radiators, but primarily using photon arrival time was proposed. This Time Of Propagation (TOP) [3] counter was studied in a number of earlier prototype tests [4-5]. Key to the necessary 10's of picosecond single-photon timing has been the development of the so-called SL-10 Micro-Channel Plate Photo-Multiplier Tube (MCP-PMT) [6], which has demonstrated sub-40ps single photon Transit Time Spread TTS. Further simulation study of this detector concept [7] indicated that a focusing mirror in the forward direction, as well as a modest image expansion volume and more highly pixelated image plane improve the theoretical detector performance, since timing alone is limited by chromatic dispersion of the Cherenkov photons. This imaging-TOP (or iTOP) [8] counter is the basis of Belle II barrel PID upgrade. However a number of critical performance parameters must be demonstrated prior to releasing this prototype design for production manufacture. These include:

1. Demonstration of predicted photon yield for final detector geometry and optical components
2. Confirmation of the performance benefits of the forward mirror and backward expansion quartz optics elements
3. Operation of 32 SL-10 MCP-PMTs of the production 16-anode design (earlier tests all done with a 4-anode design and a different photocathode)
4. Confirmation of expected single photon and event timing using a highly integrated, 512-channel pico-second timing waveform sampling electronics
5. Matching photon timing and spatial probability density functions between detailed GEANT4 simulations and beam data
6. Demonstration of the ability to reconstruct events based on our K/π Likelihood studies, an example of which may be seen in Figure 2 below.
7. Exploration of multi-track event disentangling by overlaying beam event data from different tracks into a composite event, to confirm simulation-predicted reconstruction algorithm robustness

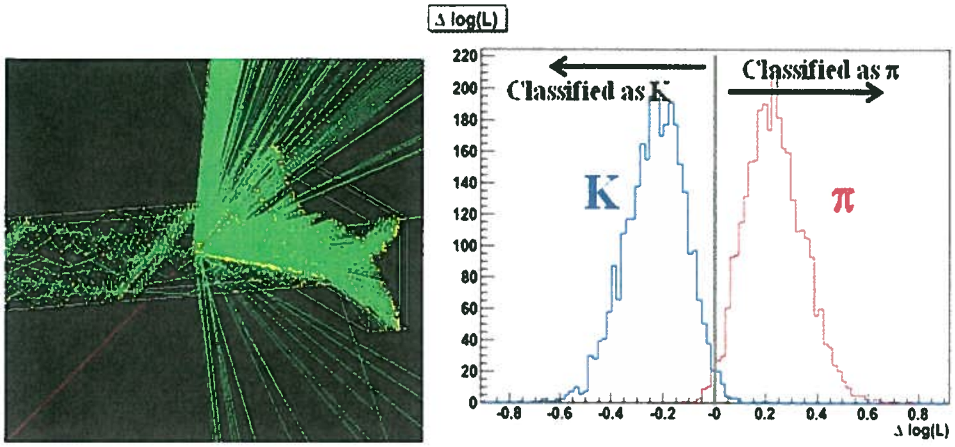


Figure 2: GEANT simulations (GEANT4 left) predict photon space-time Probability Density Functions to which photon data are compared to form a K/π Likelihood discriminator, as shown at right.

iTOP Building Blocks:

1) **Quartz Radiator --** While the contribution of modest imaging is important, the iTOP detector is primarily a TOP device. This is illustrated in Fig. 3, where K and π of the same momentum, but different relativistic velocity β, emit photons at different Cherenkov cone opening angles. While these differences are small (few mrad level at high momentum), the path-length, and thus the time-of-propagation to the end of the bar, differs.

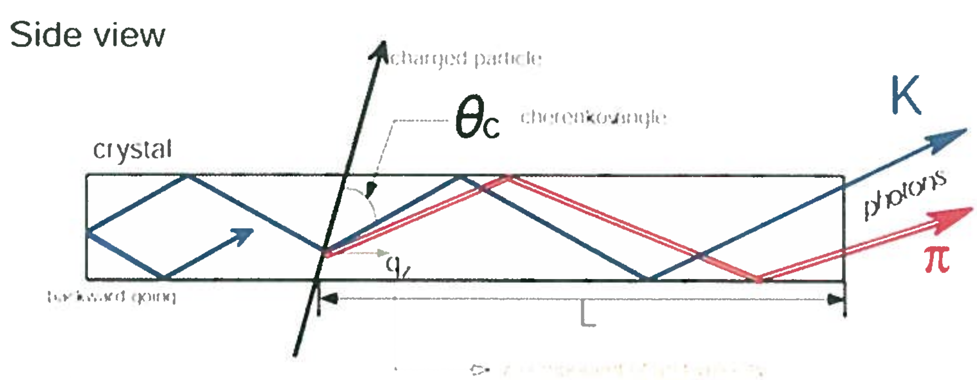
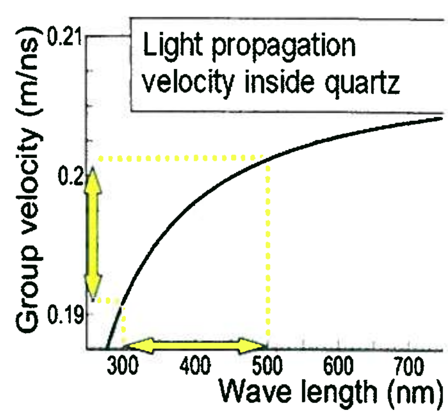


Figure 3: Illustration of the Time-Of-Propagation (TOP) concept. Particle identification is performed by precisely measuring the arrival time of the photons at the end of the bar.

2) **Wavelength cut-off filter --** Unfortunately this simple picture above is complicated by the wavelength-dependent velocity of propagation illustrated in Fig. 4 at the right. Applying a cut-off filter to the shortest wavelength photons reduces this timing dispersion. However this is at the cost of a reduced total number of photons, which impacts detector performance and robustness. In particular, since the Cherenkov emission itself is peaking in the blue, the loss of these photons due to the use of a filter is a major issue.



This is a major study item in this proposed beam test.

Figure 4: Deleterious impact on timing due to chromatic dependent velocity of propagation. Removing the shortest wavelength photons improves the timing but can degrade overall detector performance.

3) **Focusing and expansion optics** -- These two optical elements are, in principle, easy to understand. A focusing mirror in the forward direction provides a mechanism for taking photons following parallel rays and mapping them onto the same image plane pixel, thus reducing the imaging ambiguity due to the finite thickness of the quartz radiator bar. In reality the situation is more complex and having data to compare with simulation, including effects of misalignment for an actually glued mirror, will be extremely valuable. Similarly the benefit of the image expansion looks promising in simulation, though needs careful data-driven confirmation.

4) **Hamamatsu SL-10 MCP-PMT** -- Essential to realizing the TOP timing goals of this detector is a single photon detector with 10's of picosecond timing resolution, sufficiently high hit rate capability, adequate photocathode (total integrated charge) lifetime, and the ability to operate in a 1.5T magnetic field. Collaborators at Nagoya University worked with Hamamatsu to develop just such a PMT for the TOP detector. The original tube, being primarily for timing, had 4 anodes of readout for this roughly 1" square tube.

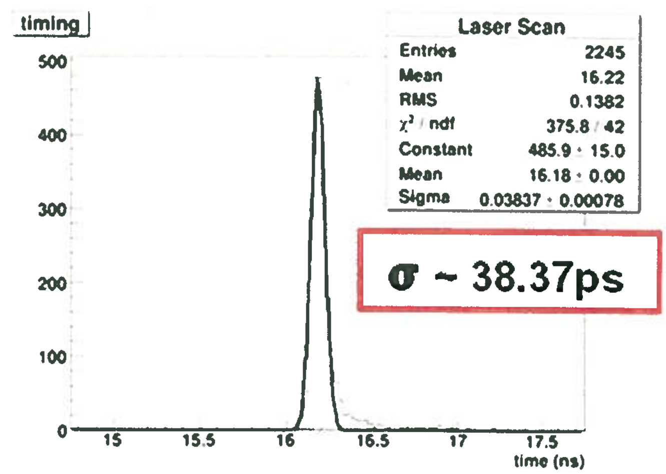


Figure 5: Measured single-photon timing resolution of the Hamamatsu SL-10 MCP-PMT.

Simulations demonstrated that finer pixelation is beneficial and the prototype detector will be instrumented with 32 16-anode tubes.

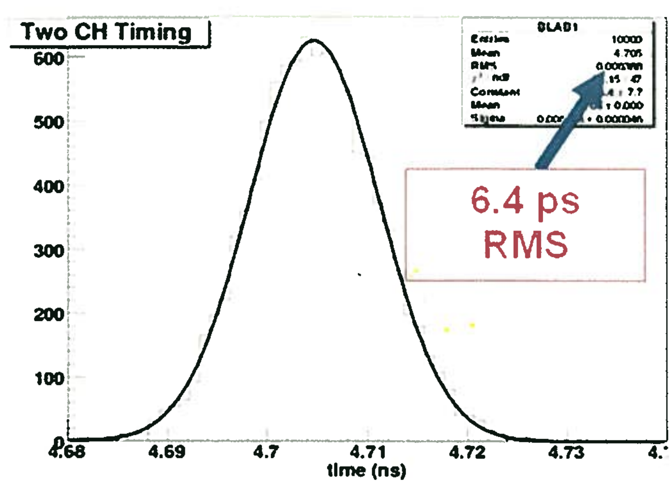


Figure 6: Measured timing resolution [10] for a prototype waveform sampling ASIC in the same architecture as that to be deployed in the beam test readout.

5) **Giga-sample per second, waveform sampling ASICs** -- high-density readout of the 45cm wide, 512 channel imaging plane requires a monolithic readout solution. As illustrated in Fig. 6 at left, prototypes of the Buffered LABRADOR (BLAB) [9] architecture ASIC have demonstrated the capability of making photo-detector limited single-photon timing measurements, while providing multi-hit capability and storage for the

5.2μs Level 1 trigger latency of Belle II.

A 400 channel system based on an earlier version of this readout has been operated at the SLAC focusing-DIRC detector prototype [11] cosmic-ray test for 2 years. However this will be the first test of high-rate data logging for the 32k sample deep, 8 channel (IRS2/BLAB3A) variant.

6) **Giga-bit fiber-optic data collection and timing control --** A major upgrade over Belle is the adoption of high-speed fiber optic serial links for data collection. Combining this with the pico-second level timing distribution system in a beam test environment will be a major demonstration of the maturity of these hardware and data handling protocols for the high trigger rates and volumes expected in Belle II. One complication is that this timing system is designed for measuring particles produced at a fixed phase offset with respect to the accelerator reference (bunch collision) clock. A particle-by-particle clock phase offset measurement, as described in Section II, is required.

I. Personnel and Institutions:

Spokesperson and physicist in charge of beam tests: Gary Varner

Fermilab liaison: Aria Soha

The group members at present and others interested in the test beam are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	University of Cincinnati	USA	Alan Schwartz	Professor	
			Yang Liu	Postdoctoral fellow	
			Matt Belhorn	graduate student	
1.2	University of Hawaii	USA	Thomas Browder	Professor	
			Gary Varner	Associate Professor	ANITA
			Matt Andrew	Electrical Engineer	
			Marc Rosen	Mechanical Engineer	
			Matthew Barrett	Postdoctoral fellow	
			Kurtis Nishimura	Postdoctoral fellow	
			Eric Anderson	graduate student	
1.3	Nagoya University	Japan	Toru Iijima	Professor	
			Kenji Inami	Associate professor	
			Kazuhito Suzuki	Research assistant professor	
			Yasuyuki Horii	Research assistant professor	
			Kodai Matsuoka	Research assistant	
			Yoshinori Arita	graduate student (D1)	
			Naoto Kiribe	graduate student (M1)	
			Shigeki Hirose	graduate student (M1)	
1.4	Pacific Northwest National Laboratory	USA	David Asner	Senior Staff Scientist	
			James Fast	Senior Staff Scientist	
			Lynn Wood	Staff Scientist	
			Mitchell Myjak	Staff Scientist	
			Gocha Tatishvilli	Research Scientist	

II. Experimental Area, Beams and Schedule Considerations:

2.1 Location

2.1.1 The beam test will take place on the remotely controlled motion Table #2 at MT6.2C.

2.1.2 Due to the extreme fragility of the precisely machined quartz optics, a foot-traffic restricted staging/cosmic check area is requested, to confirm detector operation after shipping and prior to installation in the MT6.2C area.

2.2 Beam

2.2.1 Beam Types and Intensities

Energy of beam: 120 GeV
Particles: protons
Intensity: 10k – 100k in units of particles/ 4 sec spill
Beam spot size: there is understood to be a compromise between spot-size and beam divergence: the experiment will trigger on $5mm^2$ trigger counters and will use scintillating fiber hodoscopes to measure particle-by-particle proton impact position and angle.

Ideally the divergence of the beam at the detector location should be 1 mrad or less. If necessary the experimenters will use the tracking system to correct for this, however the correction itself can lead to errors since the iTOP detector is sensitive to misalignment errors. Compromise between goals for spot size and divergence may be needed.

2.2.2 Beam Sharing

Upstream use of the beam is possible as long as the beam divergence isn't significantly increased, such as due to multiple-scattering in a thick detector. Downstream operation is compatible with any user accepting of 20mm of quartz radiator (and bar box support) in the beamline. Due to desire for large, continuous data sets, users requiring frequent or prolonged accesses are not compatible with the intended run plan.

2.2.3 Running Time

Since the experimenters would like to take as many quartz radiator particle impact-position-measurement points as possible, and anticipate that each fixed position will take of order 1 shift to acquire the requisite statistics, the experimenters would like to maximize the running time. The experimenters will have more than sufficient manpower to operate round the clock, if such an operating mode becomes available.

2.3 Experimental Conditions

2.3.1 Area Infrastructure

The iTOP module to be tested is approximately 2.85m long and 45cm wide. Figure 7 left provides a mechanical drawing of the structure being fabricated to hold the quartz radiator, forward mirror, expansion block, 32 photomultiplier tubes and 4 electronics readout modules, each consisting of 128 channels of Giga-sample per second waveform digitizing electronics. This completed module is then mounted into a support frame, as shown in the right of Figure 7, which provides protection of the fragile optical components, as well as a convenient mechanism for mounting the detector onto a movable stage or aligning/rotating the module.

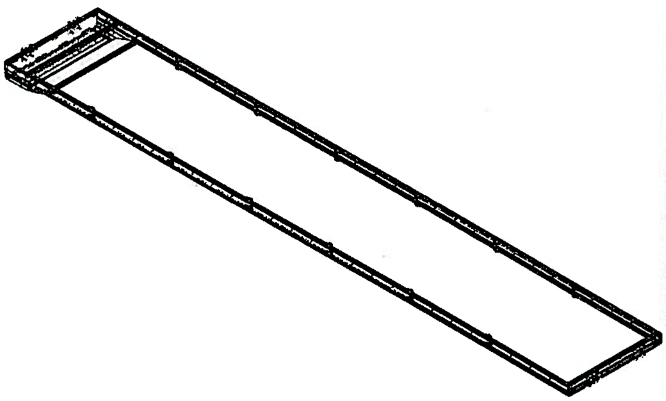
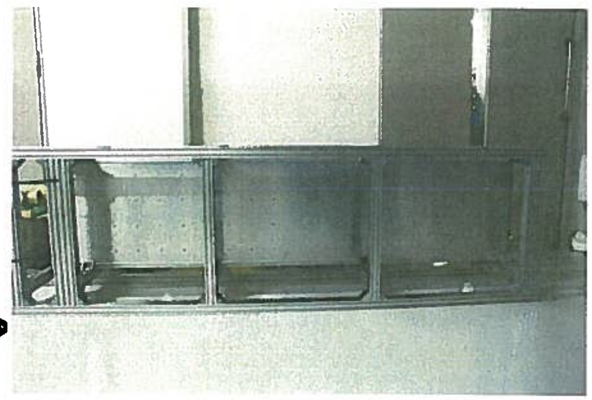



Figure 7: Detailed CAD drawing (left) of the iTOP module currently under construction. This module is mounted into a robust uni-strut type frame (photograph at right) for mechanical support and manipulation/positioning.

During PMT operation, the electronics and PMTs must be covered, as high voltage is present and exposed inside these enclosures. Moreover, the outer cases of the PMTs are at high voltage potential and care must be taken in their handling. Finally, it will be impossible to make the support box entirely light-tight. Therefore during operation the entire assembly with be covered with an appropriate light-shield (dark cloth material). Prior to installation of this assembly in the MT6.2C area, confirmation testing of the detector assembly after shipping will be performed. The assembly shown at right in Figure 7 will be mounted onto a rotating stage, provided by the experimenters, which will itself be mounted to the movable table. The detailed engineering design of these capture mechanisms has just started, but will be based upon an earlier design for a beam test at CERN. Once mounted on the beamline, and prior to taking beam, fast calibration laser pulse data will be taken and used to confirm detector/channel reference time offsets. Given the large, almost 1 minute pause between spills, the experimenters are also considering logging calibration data continuously, along with beam test data.

The other required components on the beamline are shown in Figure 8. A pair of small beam definition counters are used to trigger the readout system, which consists of CAMAC-based readout for basic beam definition and start timing, and custom cPCI module-based readout for the iTOP module and the tracking detectors, as explained in the next section.

Of particular importance are the pair of high-precision quartz-disk MCP-PMTs that determine the event start timing. Finally a veto counter is used to tag events with pile-up or anomalous off-axis energy.

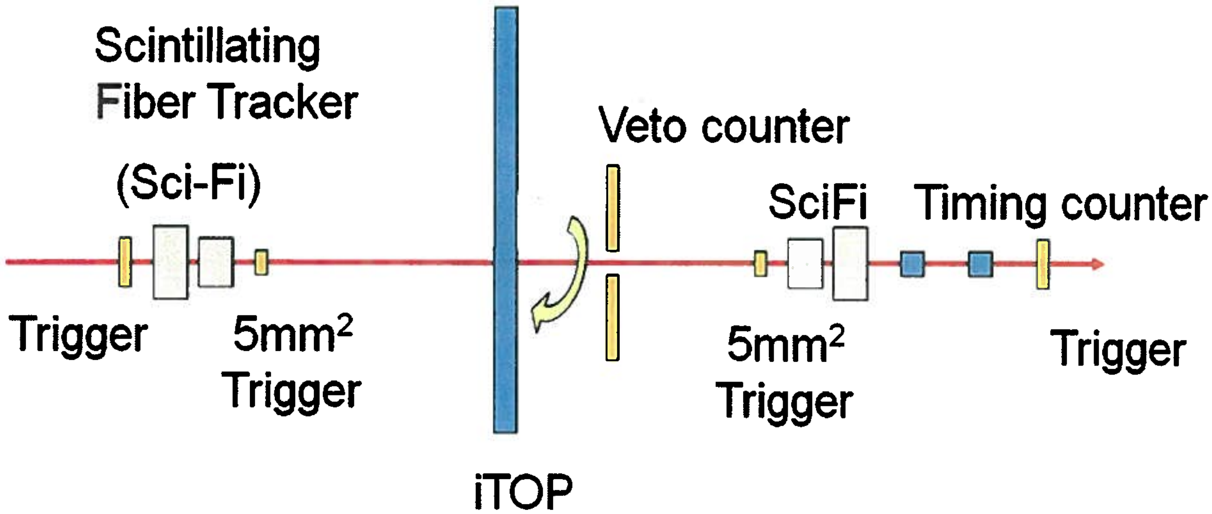


Figure 8: Schematic of the iTOP test counter configuration on the beamline. In addition to the usual beam-definition counters, dedicated start, tracking and veto counters are used to characterize charged particles incident on the iTOP counter. This stand-alone instrumentation will be fixed, with the iTOP counter translated and rotated to mimic various polar angle impact positions in the Belle II detector. This operation is not entirely trivial as the interaction point is offset from the geometric center of the detector due to the energy asymmetry of the Super KEKB beams.

In addition to the movable table for holding the iTOP detector, some additional structural supports/frames will be needed to hold these other elements shown in Figure 8. All of these component pieces will be verified with cosmic ray muons in advance of shipment to Fermilab for beam test. The start timing MCP-PMTs are single channel devices, each of which has measured time resolution of approximately 20ps. In combination, this reduces to more like 15ps, not quite obtaining a $1/\sqrt{2}$ improvement in measurement. This is adequate for the studies, since a comparable contribution due to the reference clock jitter is expected from testing in the lab.

Access is planned roughly once per shift to align the detector to a new polar angle position. During this time a dedicated large statistics calibration laser run will be taken, to allow monitoring of the channel-to-channel delays and overall system timing drifts/confirm timing stability.

Upon generation of a trigger, the waveforms corresponding to each of the readout channels for both the single photon signals from the MCP-PMTs and the scintillating fiber hodoscope are logged, using the electronics infrastructure described in the next subsection.

2.3.2 Electronics Needs

The detector under test readout electronics connections are seen at the center of the overall readout block diagram shown in Figure 9. In this figure the magenta signal lines are giga-bit optical fibers connections for data collection and event flow control. Light and dark blue lines represent pairs of Category-7 flat cables that are used for precision clock distribution, trigger distribution, and remote/in-situ JTAG programming/firmware monitoring. The larger green arrows represent bundles of 10x 34-conductor ribbon cables. Various other signal lines are power or USB connection (red) for reading out the CAMAC data into the event building embedded cPCI computer.

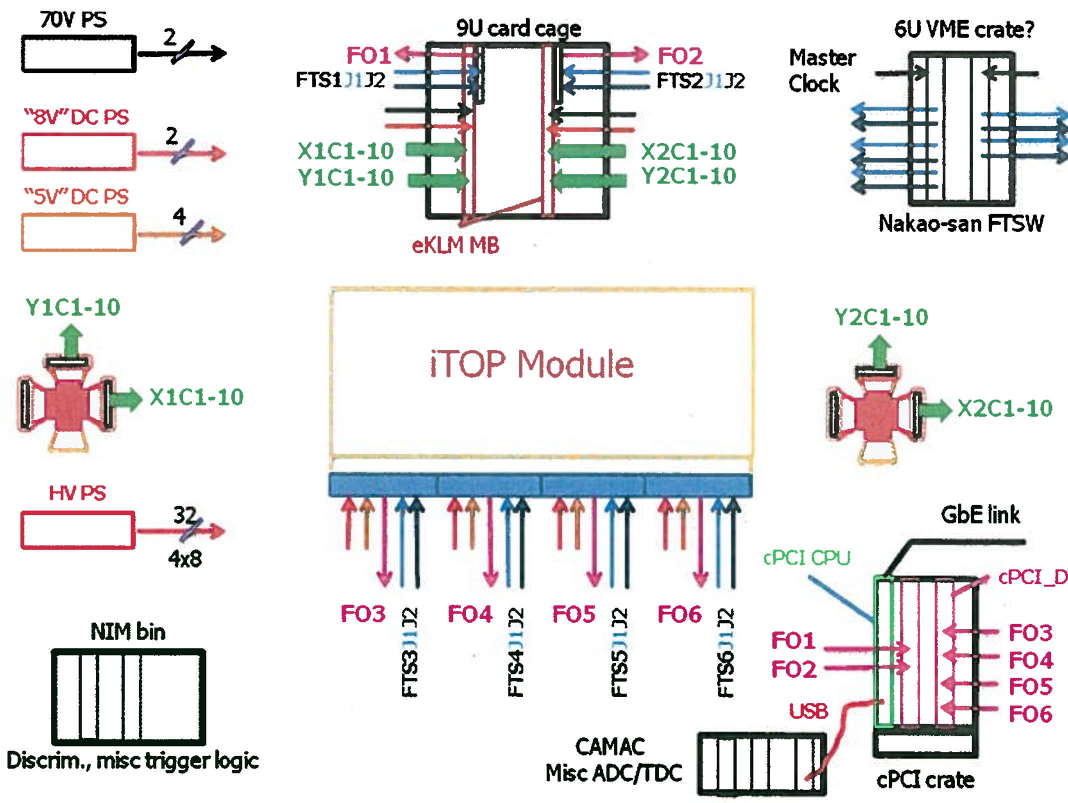


Figure 9: Block diagram of the iTOP readout electronics. Traditional NIM trigger electronics and CAMAC ADCs/TDCs are used for beamline trigger and timing instrumentation. Tracking detectors and the iTOP module readout itself are custom electronics developed for Belle II.

Upon generation of a trigger a Busy signal is issued until the entire data set is collected. Because the experimenters want to study waveform reduction algorithms, the experimenters plan to keep the full raw waveforms. This corresponds to an event size of approximate 0.25MBytes. Benchmarking of the cPCI backplane using the cPCI firmware and card drivers indicate a sustained acquisition rate of 25MBytes/s is possible. So during the spill a rate of 100Hz logging is possible. For a 4.2 second spill, this will permit the logging of about 25k events/hour. During an 8 hour shift, the experiment would be able to log 200k events, which is estimated to be sufficient for each polar angle measurement.

2.3.3 Description of Tests

The series of tests primarily consist of high-statistics runs at a few, fixed charged-particle impact positions on the iTOP counter. Moving to different locations is highly non-trivial since to mimic the polar angle/z-position of incident particles from the asymmetric interaction point in Belle II, both a pivot, as well as a translation is required. Also, the experimenters would like to measure this subsequent position as precisely as possible. To do so may involve theodolites and possibly photogrammetry. This operation should be done during periods when there will either be no beam, or minimized. Typical of the type of data the experimenters expect to see are the photo-detector pixel position-dependent timing plots, such as those shown at the right in Figure 10. Multi-path contributions to a given signal channel lead to a complex set of peaks in the timing distribution and are a very stringent test of the simulation code. Simulation needs also to reproduce any broad tail in the distribution seen in previous measurements, which the experiment expects to be less prominent when using a high momentum proton beam instead of a low energy electron beam as in this previous beam data. The experiment's minimum requirement is to map out the polar angle response of this iTOP module in 10 degree steps. At minimum statistics this would require 10 shifts. Additional running time would be used for a finer scan about the "photon minimum", located at a specific angle in the forward direction. Moreover, if more hours of beam operation are available, larger statistics will be taken at a few benchmark polar angles.

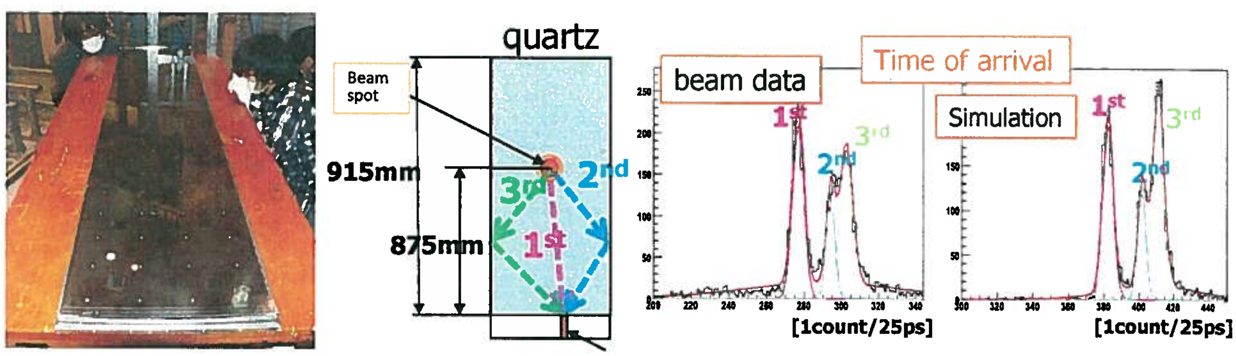


Figure 10: Overview of a sample measurement. At far left is a photograph of the highly polished quartz bar assembly to be used for this test. Charged particles traversing this quartz radiator emit photons at the Cherenkov angle characteristic of the relativistic velocity of the particle traversing the bar. For a given detector pixel, such as indicated in the next diagram over to the right, photons can reach either directly or after bounces of the near or far side walls, leading to 3 separate arrival peaks in the time spectrum. Confirming the timing resolution for somewhat degenerate peaks, including their relative amplitudes, is a very stringent test of the validity of the Monte Carlo.

2.4 Schedule

A specific request has been made for the run period at the end of December 2011, beginning of January 2012. This particular time is bounded by prototype detector readiness and the need to present these performance results to the DOE as part of the project approval process. It is possible a beam test would be desired of the first production iTOP module, though that timescale is likely to be in the planned accelerator shut-down.

III. Responsibilities by Institution – Non Fermilab

3.1 University of Cincinnati: (~15k$ total)

The primary Cincinnati responsibility will be analysis of the mirror and wavelength filter portion of the data taken.

- Develop simulation programs to compare with data for mirror and filter optical components
- Shifts and data analysis

3.2 University of Hawaii: (~325k$ total)

- Giga-sample/s waveform sampling electronics for iTOP and SciFi tracker readout, including custom ASIC development, readout electronics development, consisting of front-end and cPCI backend readout modules. Hardware, firmware and software development for these electronics (~200k$)
- SciFi tracker planes (~50k$)
- Develop simulation programs to compare GEANT4 expectations with data taken, including optimizing the statistics to be taken for a given number of polar angle test points and other configuration input
- Waveform processing algorithms for single photon time and charge extraction and SciFi tracker position reconstruction
- Shifts and data analysis

3.3 Nagoya University: (~725k$ total)

- Quartz gluing; quartz component assembly, bar box module and exoskeleton design and fabrication (~250k$)
- Beamline trigger and precision start counter counters and CAMAC modules (~50k$)
- Procure and characterize 32 production SL-10 MCP-PMTs (~350k$)
- High voltage and picosecond laser systems (~40k$)
- Develop simulation programs to compare previous data taking with completed module data taking (GEANT3 based)
- Shifts and data analysis

3.4 Pacific Northwest National laboratory: (~75k$ total)

PNNL will contribute primarily to real-time event sequencing firmware and to event reconstruction software

- Front-end timing-critical command and control firmware (~50k$)
- Develop simulation programs to compare reconstructed event data with MC predictions
- Shifts and data analysis

IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 FERMILAB ACCELERATOR DIVISION:

4.1.1 Use of MTest beam as outlined in Section II.
4.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.
4.1.3 Scalers and beam counter signals should be made available in the counting house.
4.1.4 Reasonable access to the equipment in the MTest beamline.
4.1.5 Connection to beams control console and remote logging (ACNET) should be made available.
4.1.6 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR). [1.5 person-weeks]
4.1.7 Position and focus of the beam on the experimental devices under test will be under control of MCR. Control of secondary devices that provide these functions may be delegated to the experimenters as long as it does not violate the Shielding Assessment or provide potential for significant equipment damage.
4.1.8 The integrated effect of running this and other SY120 beams will not reduce the neutrino flux by more than 5% globally, with the details of scheduling to be worked out between the experimenters and the Office of Program Planning.

4.2 FERMILAB PARTICLE PHYSICS DIVISION:

4.2.1 The test-beam efforts in this MOU will make use of the Fermilab Test Beam Facility. Requirements for the beam and user facilities are given in Section II. The Fermilab Particle Physics Division will be responsible for coordinating overall activities in the MTest beam-line, including use of the user beam-line controls, readout of the beam-line detectors, and MTest computers. [3.0 person weeks]
4.2.2 Conduct a NEPA review of the experiment.
4.2.3 Provide day-to-day ES&H support/oversight/review of work and documents as necessary.
4.2.4 Provide safety training as necessary, with assistance from the ES&H Section.
4.2.5 Update/create ITNA's for users on the experiment.
4.2.6 Coordinate the ES&H Operational Readiness Clearance Review or other required safety reviews. [0.2 person-weeks]

4.3 FERMILAB COMPUTING SECTOR

4.3.1 Internet access should be continuously available in the counting house.
4.3.2 See Appendix II for summary of PREP equipment pool needs.

4.4 FERMILAB ES&H SECTION

4.4.1 Assistance with safety reviews.
4.4.2 Provide safety training, with assistance from PPD, for experimenters. [0.2 person-weeks]

V. SUMMARY OF COSTS

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Particle Physics Division	0.0	3.2
Accelerator Division	0	1.5
Computing Sector	0	0
ES&H Section	0	0.2
Totals Fermilab	$0.0K	4.9
Totals Non-Fermilab	~$950K	750

VI. General Considerations

6.1 The responsibilities of the Spokesperson and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Researchers": (http://www.fnal.gov/directorate/PFX/PFX.pdf). The Spokesperson agrees to those responsibilities and to ensure that the experimenters all follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the Division's Safety Officer.

6.3 The Spokesperson will ensure at least one person is present at the Fermilab Test Beam Facility whenever beam is delivered and that this person is knowledgeable about the experiment's hazards.

6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.5 All items in the Fermilab Policy on Computing will be followed by the experimenters. (http://computing.fnal.gov/cd/policy/cpolicy.pdf).

6.6 The Spokesperson will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Sector management. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector management.

6.7 The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment. Fermilab will be responsible for repair and maintenance of the Fermilab-supplied electronics listed in Appendix II. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

At the completion of the experiment:

6.8 The Spokesperson is responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.9 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such a rigging, crane operation, etc.

6.10 The experimenters will assist Fermilab with the disposition of any articles left in the offices they occupied.

6.11 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters' Meeting.

VII. BIBLIOGRAPHY

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SIGNATURES:

____ 11/ 1 /2011
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____ 11 / 1 /2011
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____ 11/ 4 /2011
Roger Dixon, Accelerator Division, Fermilab

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Peter Cooper, Computing Sector, Fermilab

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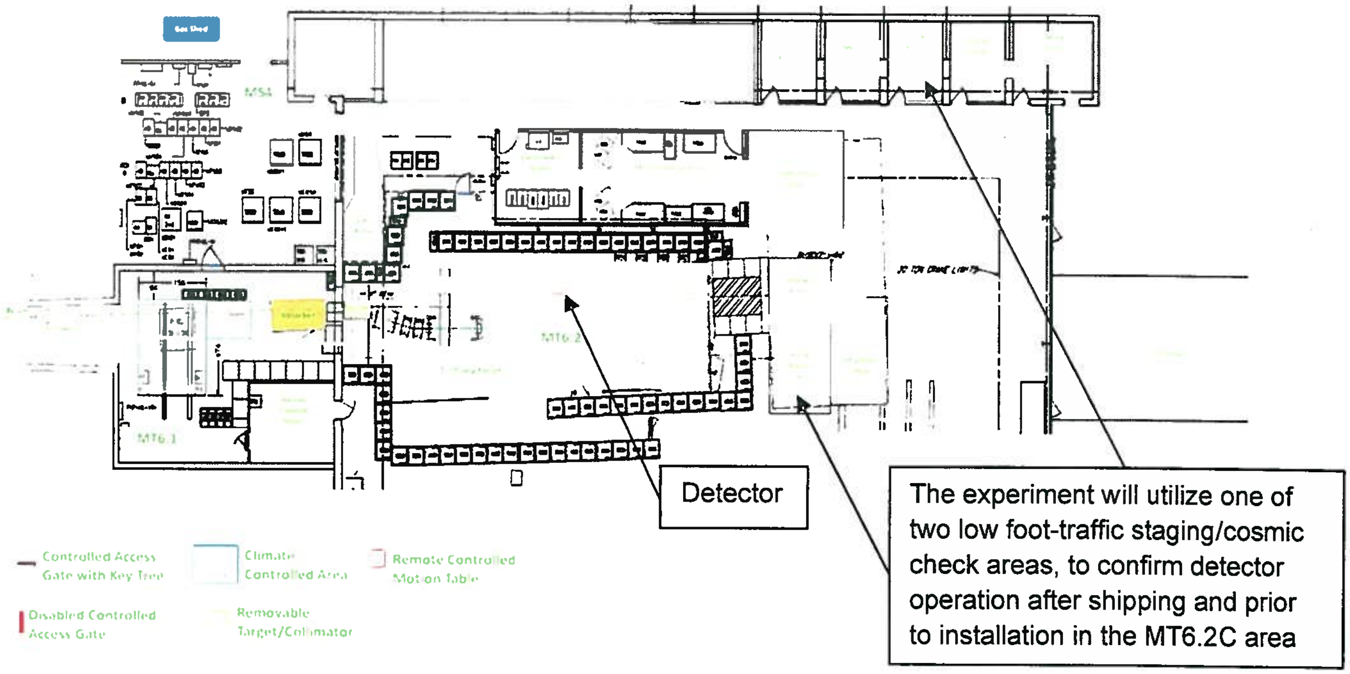
____ 11 /10/2011
Stuart Henderson, Associate Director for Accelerators, Fermilab

APPENDIX I: MT6 AREA LAYOUT

Given the girth of the iTOP module, and the desire to study different emulated Belle II polar angle impact positions on the detector, to the experiment will set up and operate from movable stage denoted Table #2 and located in MT6.2C.

MTEST AREAS



APPENDIX II: EQUIPMENT NEEDS

Provided by experimenters:

Delivered, tested cosmic ray prototype, including all detectors and electronics described in Figures 8 and 9 of Section II, except those specifically requested below.

Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup.

PREP EQUIPMENT POOL:

Quantity	Description
2	NIM bin with cooling fans
1	CAMAC crate, powered
1	6U VME crate, powered
1	9U Eurocard cage (backplane not used for signaling or power)

PPD FTBF:

Quantity	Description
N	random signal cables (e.g. RG-58) as needed

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked. See next page for detailed descriptions of categories.

Flammable Gases or Liquids		**Other Gas Emissions**		**Hazardous Chemicals**		**Other Hazardous /Toxic Materials**
Type:		Type:			Cyanide plating materials	List hazardous/toxic materials planned for use in a beam line or an experimental enclosure:
Flow rate:		Flow rate:			Hydrofluoric Acid	
Capacity:		Capacity:			Methane	
Radioactive Sources		**Target Materials**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:			Mercury (Hg)		TEA	
Strength:			Lead (Pb)		TMAE	
Lasers			Tungsten (W)		Other: Activated Water?	
	Permanent installation		Uranium (U)			
X	Temporary installation		Other:	**Nuclear Materials**		
X	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:	Solid state		Capacitor Banks	**Mechanical Structures**		
Wattage:	400mW peak pulsed	X	High Voltage (50V)		Lifting Devices	
MFR Class:	1 (635nm)	X	Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP		Scaffolding/ Elevated Platforms	
			Modified Commercial/PREP		Other:	
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:		Inside Diameter:			Beam line magnets	
Operating Pressure:		Operating Pressure:			Analysis magnets	
Window Material:		Window Material:			Target	
Window Thickness:		Window Thickness:			Bubble chamber	

NUCLEAR MATERIALS

Reportable Elements and Isotopes / Weight Units / Rounding

Name of Material	MT Code	Reporting Weight Unit Report to Nearest Whole Unit	Element Weight	Isotope Weight	Isotope Weight %
Depleted Uranium	10	Whole Kg	Total U	U-235	U-235
Enriched Uranium	20	Whole Gm	Total U	U-235	U-235
Plutonium-242[1]	40	Whole Gm	Total Pu	Pu-242	Pu-242
Americium-241[2]	44	Whole Gm	Total Am	Am-241	–
Americium-243[2]	45	Whole Gm	Total Am	Am-243	–
Curium	46	Whole Gm	Total Cm	Cm-246	–
Californium	48	Whole Microgram	–	Cf-252	–
Plutonium	50	Whole Gm	Total Pu	Pu-239+Pu-241	Pu-240
Enriched Lithium	60	Whole Kg	Total Li	Li-6	Li-6
Uranium-233	70	Whole Gm	Total U	U-233	U-232 (ppm)
Normal Uranium	81	Whole Kg	Total U	–	–
Neptunium-237	82	Whole Gm	Total Np	–	–
Plutonium-238[3]	83	Gm to tenth	Total Pu	Pu-238	Pu-238
Deuterium[4]	86	Kg to tenth	D_2O	D_2	
Tritium[5]	87	Gm to hundredth	Total H-3	–	–
Thorium	88	Whole Kg	Total Th	–	–
Uranium in Cascades[6]	89	Whole Gm	Total U	U-235	U-235

[1] Report as Pu-242 if the contained Pu-242 is 20 percent or greater of total plutonium by weight; otherwise, report as Pu 239-241.

[2] Americium and Neptunium-237 contained in plutonium as part of the natural in-growth process are not required to be accounted for or reported until separated from the plutonium.

[3] Report as Pu-238 if the contained Pu-238 is 10 percent or greater of total plutonium by weight; otherwise, report as plutonium Pu 239-241.

[4] For deuterium in the form of heavy water, both the element and isotope weight fields should be used; otherwise, report isotope weight only.

[5] Tritium contained in water (H2O or D2O) used as a moderator in a nuclear reactor is not an accountable material.

[6] Uranium in cascades is treated as enriched uranium and should be reported as material type 89.

OTHER GAS EMISSION

Greenhouse Gasses (Need to be tracked and reported to DOE)

- ☐ Carbon Dioxide, including CO_2 mixes such as Ar/CO_2
- ☐ Methane
- ☐ Nitrous Oxide
- ☐ Sulfur Hexafluoride
- ☐ Hydro fluorocarbons
- ☐ Per fluorocarbons
- ☐ Nitrogen Trifluoride