Comments on a Review of Specifications for Primary Beamline Instrumentation
July 26, 2001

Responses by Bruce Baller
May 6, 2004

Beamline Designer's Perspective on Instrumentation
Presenter: P. Lucas

1. (Reviewer: J. Crisp) I would like to see as much detail as possible for the following systems:
    a. auto-tune
    b. beam extraction permit
    c. beam loss budget monitor

    I understand these systems will be discussed Aug 17. Are there engineers assigned to these systems? Is there sufficient engineering support to insure success with these systems?

Peter Lucas is working on autotune. Bob Ducar is working on the BPS. The BLBM is a minor modification to an existing application (Bill Marsh). Resources are adequate.

2. (Reviewer: P. Czarapata) The specifications for the instrumentation are clearly tied to one of two types of need, regulatory or operational. Without showing an overall system that was being used to address these two areas, it was impossible to determine the specifications.

    a. Derive a "system" view of the instrumentation that addresses which of the two needs the system is intended to serve. Describe it's "primary" mission and it's "secondary" mission. For example: If the torroid is used to satisfy regulatory or safety requirements it must have an accuracy of x.x% and be auto-calibrating. If it is also used for monitoring the primary beam to the experiment it needs a second output with an accuracy of x.x and long term stability of xx ppm.

    b. Develop the real specifications for the instrumentation including environmental.

    c. Postpone the implementation review until the specifications are written and understood by the engineers and consider re-reviewing them with this group.

Done. Specs are all defined and maintained by the Instrumentation Coordinator, Debbie Harris.

3. (Reviewer: R. Ford) A non-trivial effort will be required to design a BLM system which is foolproof to use for groundwater protection. Not only must the long BLM system have a heartbeat, but you must able to show that it is working all along the length of the monitor.

The TLM/BPS system does not need to be fool-proof since it is not a safety system. Suitable controls are being engineered into the system to ensure reliability. The TLM will have a radioactive source heartbeat. HV and gas will be monitored in the BPS.

4. (Reviewer: R. Ford) The long BLMs or Total Loss Monitors (TLMs) as we use to call them should be used for the entire length of the beamline on a separate system from the standard BLMs in case some part of the control system goes down. One percent of the beam continuously lost would not be noticed by a toroid or eberm but could create a no-man's land in the beamline. This is also a concern for Miniboone.

Four TLM's will cover the entire length of the NuMI line.

5. (Reviewer: R. Ford) All of the concerns about the autotune program will likely be resolved well in advance of NuMI operation. Autotune is a non-trivial project that will be of great concern to Miniboone.

OK

6. (Reviewer: R. Ford) I hope that someone actually calculated the wire heating and shock on the multiwires where the beam is small.

Done by UT-Austin.

7. (Reviewer: R. Ford) How many pulses does it take to burn a hole in something? Even though NuMI claims they don't need an eberm system, they will need something similar. Lucky for them, Miniboone's design should be almost plug and play for NuMI.

Study done and published in a NuMI note.

8. (Reviewer: R. Ford) NuMI should investigate whether they need an Rf monitor like a resistive wall monitor. It may be used for gating events in the near detector and/or as a beam present detector to tell the toroids when to be active.

We have included a RWM.

9. (Reviewer: R. Ford) A better understanding of the Rf gymnastics required for bunch rotation between NuMI and PBar production. Considering the dispersion requirements, this must be monitored and automated.

Being studied by Alberto Marchionni

10. (Reviewer: M. Gerardi) Potential loss points and allowable limits should be specifically identified, and the mechanism for monitoring and reacting defined. There is an approval process for systems considered interlocked which takes some time to approve especially for unproven schemes.

Included in the shielding assessment.

11. (Reviewer: M. Gerardi) The BBM aspects of the system should be dedicated to avoid timing problems and inadequate data taking. Protons delivered whether they appear lost or not will need to be clearly and accurately logged.

Using the standard BBM system and procedures.

12. (Reviewer: M. Gerardi) How close to the groundwater limit is the requested yearly intensity ?

See the shielding assessment.

13. (Reviewer: M. Gerardi) Do we have a commissioning plan ?

Done.

14. (Reviewer: M. Gerardi) BPM's have never been proven to work efficiently with an auto-tune system.

The NuMI BPM electronics are a new designed and should provide excellent reliability and stability.

15. (Reviewer: M. Gerardi) The radiological and environmental issues associated with the monitoring systems for accessability and maitenance do not appear to have been addressed.

All such issues have been addressed by including ES&H in NuMI internal reviews.

16. (Reviewer: M. Gerardi) Has any of the proposed instrumentaion been designed ?

Done.

17. (Reviewer: M. Gerardi) How do we get gas to the loss monitors, or maintain the distribution system ?

We will use the MI gas system for the TLM's.

18. (Reviewer: W. Kissel) My main concern continues to be "auto tune". It has been recommended by earlier reviews to establish a prototype for auto tune in a similar

operational area. (pbar production - rapid duty cycle, hi intensity, MI era operation) Of examples stated, KTev auto tune worked well but all other auto tune efforts in the BD have had serious operational problems. Given the demands of NuMI operations and in the event that power supply stability is less than desired, auto tune must function reliably and accurately. We really need existence proof in the hi duty cycle, hi intensity, low loss environment.

We agree but the NuMI BPM electronics and Auto-tune will not be available until commissioning begins.

19. (Reviewer: P. Martin) The toroids were requested to have an absolute accuracy of 3%. The issues of definition need to be clarified. If the statement is that the absolute accuracy must be better than 3% of full scale, that is probably not adequate for low intensity tune-up. But 3% accuracy at all intensities is not achievable. This issue needs to be better understood. Additionally, since the toroids will be used for the beam budget monitor and for numerous other purposes, details of buffering of the outputs needs to be specified, so that one user cannot affect the others. Datalogging of the signals needs to be specified…how and where will this be done? Reliability should be specified.

Done. Standard AD toroid readout electronics is adequate. Data-logging list generated.

20. (Reviewer: P. Martin) The multiwires that will be used for beam profile measurements cannot remain in the beam 100% of the time due to the unacceptable beam losses that occur from the wires themselves. Since the frames are much thicker, even a few pulses of beam could be disastrous, and therefore the provisions need to be implemented to prevent beam from being extracted (the *beam extraction permit system*) if the multiwires are in an intermediate state, and to inhibit NuMI beam at the ion source (the *beam permit system*) prior to software commands to insert or retract the wires. The permit can only be restored once every multiwires reads fully in or out of the beam and will require operator intervention.

Done. Using UT-Austin profile monitors that eliminate this problem.

21. (Reviewer: P. Martin) The BPMs are known to be sensitive to beam striking the plates. False signals could lead to auto-tune diverging. While it was stated that the low levels of loss that can be tolerated shouldn't be a problem, I would recommend this be studied further as part of the P1 line studies.

No P1 line studies are planned.

22. (Reviewer: C. Moore) It was good to see redundant long loss monitors in the carrier region. I would like to see at least one long loss monitor just upstream of the carrier pipe region, in fact if the monitors have not been ordered one could consider just making these two longer.

Done.

23. (Reviewer: C. Moore) I asked the question if Multiwires could be inserted at high intensities. The answer was yes based on MARS studies. I assume that runs were made for the insertion of each wire and the pattern of radiation was examined to see if the losses in the most crucial regions were too high. A question which I did not ask is " Were the wires studied individually or was there one run with all the wires inserted". The effect of multiple scattering with all the wires in might lead to more losses than would be apparent from studying the wires one by one.

Using UT-Austin profile monitors that eliminate this concern.

24. (Reviewer: C. Moore) Slip stacking is not on the agenda for NuMI at least in the beginning. If it were the question of momentum spread would have to be carefully studied.

We agree.

25. (Reviewer: C. Moore) The requirement on toroid accuracy for the beam-based input was not mentioned on the slide but 5% was deemed sufficient.

OK.

26. (Reviewer: C. Moore) Peter will have SY120 and MiniBooNE to practice on in terms of debugging Autotune.

Done.

27. (Reviewer: R. Pasquinelli) The sensitivity to momentum spread due to vertical dispersion was presented. Due to the multi use of Main Injector beam in the future, it will be very important to understand the longitudinal dynamics planned for the Main Injector. Pbar production requires high momentum spread, NuMI requires low. Currently there is difficulty with Pbar beam lines; hence, bunch rotation is manipulated frequently. Operational conflicts could result. Consultation with Beams Division RF and longitudinal dynamics experts is suggested.

Done.

28. (Reviewer: R. Pasquinelli) The specifications must include all dynamic range requirements. Beam loss tolerances of 10^{-4} to 10^{-6} were presented. The locations of such tolerances must be part of the specification. What will be expected of all diagnostics over the dynamic range of commissioning? It is unlikely the experiment will be commissioned with full beam current. At what level of

accuracy will the instrumentation be expected to perform at low beam current levels?

Done. In the instrumentation specs.

29. (Reviewer: R. Pasquinelli) While "auto tune" features of the NuMI beam line are being planned, the amount of effort to build a real system is beyond that of one or two individuals currently assigned to the task. If auto tune is indeed necessary, a re-evaluation of system requirements, dynamics, and available resources is required. This is a real time beam feedback system with many elements over considerable distances, not a trivial task.

Resources assigned to this effort are considered adequate.

30. (Reviewer: R. Pasquinelli) An understanding of reliability of instrumentation channels should be investigated. How many loss monitor, BPM, or profile channels can be lost and still provide adequate operational performance?

This is a task in the commissioning plan.

31. (Reviewer: B. Webber) Unless the present embryonic state of instrumentation requirements and specifications determination and definition is consistent with the project schedule, this effort needs immediate attention from additional resources!

We agree. Regular coordination meetings are held with the Instrumentation Department to understand resource needs and constraints.

32. (Reviewer: B. Webber) My perception is that the success of whole general operational scheme as described in the review will depend critically on the detailed interfaces and interactions among the various systems including beam instrumentation. The review was devoid of substance in this important area; specifically details of beam instrumentation outputs and interfaces have not and need to be defined.

Done.

33. (Reviewer: B. Webber) Quantitative analysis of the requirements and failure analyses need to be completed and documented (what is really required to guarantee safe regular NUMI operation and can/how will we operate with system X broken?). Top down systems designs and interfaces must be defined. Only after this structure is in place can the feed-downs into individual instrumentation systems, including required reliability, need for automatic on-line remote calibration, required output signals, etc., be understood.

This is a task in the commissioning plan.

34. (Reviewer: B. Webber) It was mentioned at the review that there are plans to implement autotune features in the P1 line as "proof of principle" of those features identified as "integral to [NUMI] beamline operation." Apparently, these plans were identified over 16 months ago at a March 2000 review. There was little indication at this review of progress in that direction other than a statement that Bob Ducar is "building a box." I would urge this demonstration enterprise be given the highest priority below Run II operation and MiniBooNE preparations (isn't that where NUMI is in the priority of the Beams Division?). Only by attempting application of these ideas within the framework of an operational system and the present control system will the real problems be recognized and faced. And when it works, Run II will benefit!! If it's too much effort to do now and NUMI really requires this functionality, then the NUMI schedule will suffer later.

Done.

Beam Instrumentation Specifications
Presenter: S. Childress

1. (Reviewer: R. Ford) A plot showing beam size, with dispersion versus aperture size would be useful for determining locations of instrumentation and other things.

Done.

2. (Reviewer: P. Martin) Since the BLMs are critical for protecting the groundwater, some means of calibration and verification needs to be developed. One solution might be a combination of electrical pulsers for the ones in the carrier tunnel, together with radioactive sources on similar but short BLMs, supplied by gas that has flowed through the active ones, placed in an area shielded from beam losses and from the groundwater.

The TLM cable has been calibrated at the RTF. A heartbeat system using an embedded source is being designed.

3. (Reviewer: C. Moore) The instrumentation will have to work over a dynamic range of one hundred. This will require attention

Agreed.

4. (Reviewer: C. Moore) The question of the accuracy of the toroids is an issue since page 25 of the TDR states that the toroids will be used to inhibit beam. It was previously mentioned that a 5% relative difference would be used to inhibit beam. Jim Crisp said that in fact he could calibrate the toroids to less than 1%.

The standard AD toroid readout electronics is adequate.

5. (Reviewer: C. Moore) The high voltage on the loss monitors will be monitored but this is not sufficient to ensure that the monitor is working.

A heartbeat system using an embedded source is being designed.

6. (Reviewer: C. Moore) There is not redundant loss monitor coverage over the full longitudinal range. There is redundant loss monitor coverage in the carrier pipe. MARS studies have been used to judiciously place the short loss monitors at possible loss locations. Although MARS is a very useful program it depends on the ability of the user to model every possible loss scenario. I would recommend that there be long loss monitor coverage of the entire range of the beamline, this would provide some redundancy for the short loss monitors. Of course one could just double up the short loss monitors but then one is relying on the MARS studies having covered every possible loss scenario.

Done

7. (Reviewer: C. Moore) The development of a heartbeat for the loss monitors is imperative.

Done

8. (Reviewer: C. Moore) Solving the stale data problem for Multiwires and BPMs is an urgent problem for every project that intends to use Autotune and in fact it can even fool experienced tuners.

This is a generic problem that cannot be solved by NuMI.

9. (Reviewer: R. Pasquinelli) It must be made very clear exactly what hardware is incorporated in system diagnostics that is not critical to personnel or environmental safety. The loss monitor system presented clearly has safety considerations, but the level of detail presented did not make that distinction.

There is no NuMI specific hardware that is part of the safety system. There are no safety considerations with the loss monitors.

10. (Reviewer: R. Pasquinelli) The TESLA test facility is utilizing a fiber optic based beam loss monitoring system that can not only localize the dose rate but also provides an integrated loss indicator. The contact at DESY is Kay Wittenburg (kay.wittenburg@desy.de). This technique could be valuable to the NuMI project

This is outside the scope of the NuMI project.

11. (Reviewer: R. Pasquinelli) The environment in the NuMI tunnels looks to be inhospitable from radiation, moisture, and temperature. These details must be included in the specifications. It may also be necessary to utilize hermetic enclosures and connectors, which will add considerable expense to the installation.

Done.

12. (Reviewer: R. Pasquinelli) The need for auto calibration of torroids is not well understood. If it were available, it would be useful. NuMI needs to establish if it is indeed necessary to the success of the experiment.

No auto-calibration is necessary.

13. (Reviewer: R. Pasquinelli) At the next review, the number of channels, locations, and distances for data collection for all primary beam diagnostics should be listed along with the specifications.

Done.

14. (Reviewer: R. Pasquinelli) How much of the proposed instrumentation is already designed (or has past proven performance), needs further R&D, or has no resources allocated. This information is critical to get priority for resources from the Laboratory management.

Done.

15. (Reviewer: S. Pruss) I disagree with the philosophy of accepting whatever the instrumentation group can supply "off the shelf". Especially for Beam Loss Monitors, I think Scarecrows from the Radiation Protection Group would be much more appropriate.

LM's are used in the NuMI BPS. Scarecrows will be used in the safety system.

16. (Reviewer: S. Pruss) I just read the PAC2001 paper "Modeling of the Primary Proton Beamline of the Fermilab Numi Project" by S. Childress et.al. This states that "The nominal phase space considered is 15π mm-mrad 95% emittance *with a 40π cut on beam tails*." Italics are mine for emphasis. The Main Injector Department does not support the concept that the beam extracted from the Main Injector will not have tails extending out beyond 40π. I suggest the beamline should have movable scattering targets in the upstream end of the beamline shortly after extraction to monitor the beam halo. These should also be located at a large dispersion point since the $\partial p/p$ limit of 10^{-4} is also not assured.

The UT-Austin profile monitors include halo foils.

17. (Reviewer: B. Webber) The review panel noted several important instrumentation equipment specification/design criteria as absent from the presentations, e.g. environmental conditions, reliability, and tie-ins to safety systems. These must be included within a complete specification since they may drive significant departures from existing designs.

Done

18. (Reviewer: B. Webber) It was recommended that instrumentation specifications be classified according to the priority of the function served: personnel safety, regulatory performance monitoring and documentation, equipment protection, integral real-time operational support (e.g. part of autotune), and non-critical beam monitoring and diagnostics.

There is no instrumentation supplied by the Instrumentation Dept which is used for personnel safety or regulatory performance monitoring.

19. (Reviewer: B. Webber) The "Technical Design Handbook", Revised July 2001, states that there are conditions, including "extraction to antiproton has failed to occur or has indicated problems" and "internal measures of MI beam quality are off nominal," that can prevent beam from being extracted from Main Injector. No details were provided and no comprehensive answer was offered to the question as to what impact this application has for existing MI/Pbar diagnostics. It is not obvious that the data and interface provided by the existing MI and antiproton instrumentation systems satisfy the requirements for application to the NUMI problem.

The specifications for the MI quality beam inputs to the BPS are being finalized (in May 2004). The Instrumentation Department will be requested to provide transition electronics to provide inputs to the BPS.

20. (Reviewer: J. Zagel) I'm concerned about which instrument is used for what purpose. We have typically isolated machine/personnel protection from operational instruments. It looks like this will not be possible.

There is no instrumentation supplied by the Instrumentation Dept which is used for personnel safety or regulatory performance monitoring.