

Draft Report from the committee to review the MINERvA Run-plan

Membership: K. Anderson, S. Brice, J. Hylan, M. Martens, C. Moore, S. Pordes (chair),
R. Zwaska

Charge to the committee as presented to us by Jeff Appel (Directorate):

MINERvA is preparing an Initial Run Plan for their experiment. The plan calls for a series of target-position-scan tests with various horn currents that may require specific planning and expense for the Laboratory, and coordination with other experiments. As input to decisions about this plan, the reviewers are asked to focus on two questions and to prepare a written report of their conclusions:

1. What would be the physics impact of the special target-scan data if it is obtained; what the implications of not having it, or of having a reduced amount of beam for this data?
2. What would be required of the Laboratory to allow the special target-scan running; what to assure the capability?

Of course, if other issues come up during the course of the review, these should be included in the written report of the review committee.

Pre-Review meeting held with Jeff - clarification of charge.

Charge item 1: 'physics impact' means the impact only on the MINERvA experiment.

Charge item 2: 'assure the capability' means to have the necessary infrastructure in place and equipment on hand.

Documentation

Pre-Review:

Proposed MINERvA Start-Up Run Plan *MINERvA note 1720 11/20/2009*

Constraining the Beam Neutrino MC Flux *MINOS-doc-2965 4/27/2007*

Review

Presentation by Sacha Kopp -kopp-review-slides-v2.ppt

Presentation by Jim Hylan -Hylan_NuMI Target Info for MINERvA Run Plan Review.pdf

Close-out Slides immediately after presentations S. Pordes

Post-Review:

Cost and schedule profile for the NT-06 Target

Answers to Committee Questions: replies to committee-3-26-10

MIPP status and comment on Answer to Committee Questions, Question 1

Review Report:

We believe it will be most useful to communicate our answer to the 2nd part of the charge first since our answer to this part of the charge is well-defined

On the second part of the charge:

Finding:

The key to making it possible for MINERvA to perform its beam studies - both during the MINOS era and during the NOvA era - is the construction of the target known as NT-06.

Recommendation:

There are independent reasons to build this target including the desire for the provision of a spare target for the end of the MINOS era running and the equally sensible desire to have an alternative target in case of the failure of the new NOvA era target. We have been told that the connections for the MINOS era target are fully compatible with the connections for the NOvA target. As such, the engineering effort for the NT-06 target is small and the costs are largely in materials and technician time. The committee is unanimous in recommending the funding of the construction of this target. A cost and manpower profile for this construction is included in the post review documentation.

On the first part of the charge:

Findings:

The aim of the target scan data is to allow the experiment to derive the neutrino flux and obtain absolute cross sections with an accuracy of 5%.

The document *Proposed MINERvA Start-Up Run Plan* gives the proposed run plan. The amount of beam requested is scaled from an existing analysis of NuMI beam data comparing near and far fluxes in MINOS, *MINOS-doc-2965 4* (presented in the pre-review documentation).

The amounts of beam requested are 0.9 E20 protons-on-target (POT) in the MINOS beam and 0.9 E20 (POT) in the NOvA beam. MINERvA will take data both in the MINOS and in the NOvA era.

Both sets of beam for the target-scans are requested with the MINOS target which is movable.

The MINOS target has a power limitation of about 400 kWatt while the NOvA target is designed to run at 700 kWatt.

It takes 2 weeks (+0.5 weeks / -0 weeks) to exchange targets if there are no problems; this assumes a single 10 hr shift 6 days/week for the second week. It takes a day or two to move the MINOS target to a different position.

The original MINERvA proposal proposed to use data from the MIPP experiment, which has taken data using an actual NuMI target (series number NT-02).

As of this review, the analysis of the data taken with the NuMI target has not been presented by MIPP. The MINERvA experiment further states that tertiary production, not reproduced in the MIPP data from the NuMI target, is responsible for much of the low (<1 GeV) neutrino flux.

After the presentations at the review, a set of questions was submitted by the review committee to MINERvA to try and further clarify the need for the beam-scan data. The response to these questions is given in the post-review documentation as *Answers to Committee Questions*. The MIPP spokesperson was invited to comment on the remarks about MIPP contained in the answer to question 1. The email exchange between the committee chair and the MIPP spokesperson is attached as *MIPP status and comment on Answer to Committee Questions, Question 1*

Comments:

The committee appreciates the work that the MINERvA collaboration devoted to this review, particularly at a time when the experiment is involved in completing the detector installation and commissioning.

The committee notes the variety of techniques given in the response to our questions for determining or checking the neutrino flux. These include the beam-scan data, the use of cross sections (known from other measurements) with known energy dependence, and measurements of the muon-flux.

The committee has not been convinced that any or all of these techniques will result in the desired accuracy. The committee does not, however, have an alternative technique to offer, and does not want to prevent the experiment from devoting its running time as it requests.

The committee, in particular, supports the argument that in-situ cross checks on the flux are essential to determine possible errors in alignment, horn-current, horn modelling etc.

The committee notes that MINERvA data from scans in the MINOS beam should be able to demonstrate the sensitivity and accuracy of the technique, including the usefulness of the individual run conditions proposed.

Recommendations.

Although the committee did not ask for a full Monte-Carlo simulation of the proposed beam scans at the time of the review, we believe such a simulation could eventually be useful to the experiment. It may help to establish the uncertainties that could be achieved and to indicate potential degeneracies in the analysis.

Proposed NT-06 Funding Profile

- The presentation indicated funds have been obligated for NT-06 target and baffle component procurement. Delivery from IHEP is expected January 2010.
- Procuring NT-06 target carrier in parallel with NT-05 (AD currently starting procurement phase of NT-05 carrier) will streamline procurement, save manpower, machining, and fabrication costs, and shorten a series procurement approach by 6-8 months.
- \$100k M&S plus \$100k SWF is necessary to complete NT-06 target carrier.
- The following funding profile approach is presented to complete NT-06 assuming funding is available:
 - \$85k M&S in FY2010 (85% procurement in parallel with NT-05)
 - \$20k SWF in FY2010 (SWF for procurement and technician time for QA)
 - \$15k M&S in FY2011 (final assembly hardware plus final machining allowance)
 - \$80k SWF in FY2011
 - \$80k M&S in FY2014 for coffin required to store assembly at TSB

MINERVA RUN PLAN RESPONSES TO REVIEW COMMITTEE'S QUESTIONS

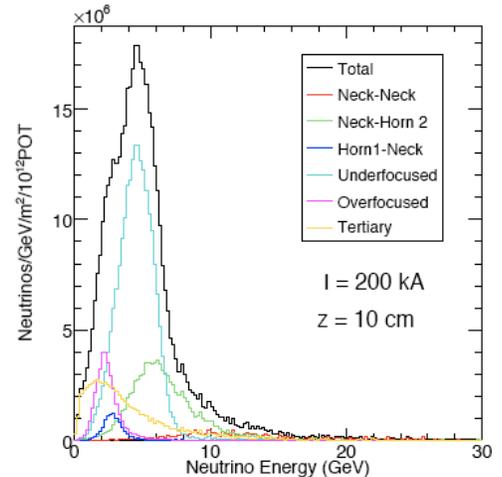
1. Please give a definite statement on the inadequacies of current external production data. Why has MINERvA abandoned statements made in its proposal about 5% flux uncertainties deriving from external data?

There are two important facts that form our reply to this question. These will emerge in our answers to questions 4-6 as well.

First, external production data has never been of sufficient accuracy to obtain the goals stated in the MINERvA proposal. The proposal was written taking at face value the projections of the MIPP experiment to make a full measurement of the (p_T, p_z) phase space of pions and kaons off the target to within 5%. This has not been realized, and on page 28 of our presentation we showed that the MIPP data was not even as constraining on particle production as was the fit to MINOS data. In fact, the preliminary measurements indicate less statistical power than anticipated and, more importantly, the presentation made at NuFact08 conveyed that the experiment done on thick targets was plagued by proton and electron backgrounds that were much higher than anticipated. That analysis is ongoing.

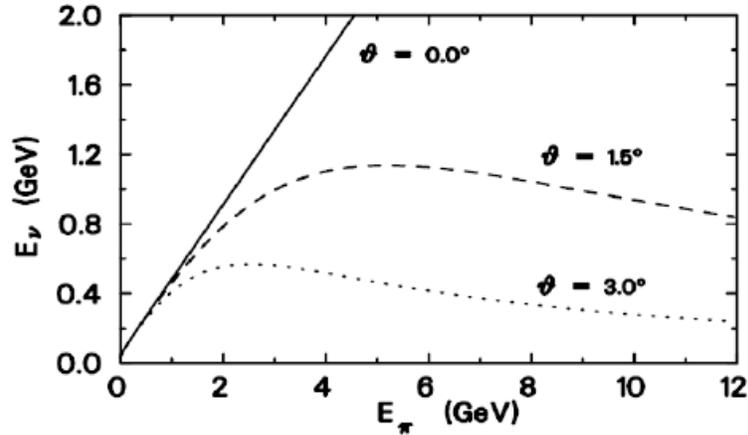
Second, we have come to understand a rather important over-simplification in the original proposal. It was assumed that if particle production off the target were to be understood to 5%, the neutrino flux would thus be understood. What we've since realized is that there are other effects that must be constrained, including tertiary production, that is, hadron interactions in downstream materials such as horns, windows, decay volume walls, which also contribute to the neutrino flux at the near hall 1040 m from the NuMI target. The MIPP data does not include production data across a variety of particle species and energies on these various nuclear targets. To begin a program of folding in all those cross sections on materials would result in substantial uncertainty, which we cannot easily quantify at this time because there is simply no current data to constrain it. If we take as a default the spread in current cascade models (MARS, Fluka, Geant), then we must accept a 30-40% uncertainty in this component (even assuming perfect measurements from MIPP on target production), which in some bins of neutrino energy is a significant flux uncertainty.

Therefore if we follow the model of MiniBooNE and attempt to fold in all these uncertainties, we will have a significantly larger uncertainty than the 5% in our proposal. Furthermore, we will have no checks on this method of estimating the flux. Since the cross section measurement goals of Minerva are considerably more ambitious than those of MiniBooNE, we wanted the ability to have our own independent checks on both of these effects.



2. *Could MINERvA explain how the kinematics of the special runs work such that MINERvA can disentangle the beam flux shape as a function of pion momentum from the cross section shape as a function of $E(\nu)$.*

As we understand the question, there is an impression (from Jim Hylen) that there is a one-to-one correlation between pion energy and neutrino energy, and hence there is no information available to fit for the shape in the (p_T, p_z) plane for pions. Such a view is understandable, because we often think that the focusing peak of neutrinos consists of those neutrinos coming from well-focused pions (nearly parallel rays), and hence there is a simple mathematical relationship $E_\nu = 0.43 E_\pi$. This misunderstanding is furthered by plots like the one at left (taken from the BNL886 proposal).

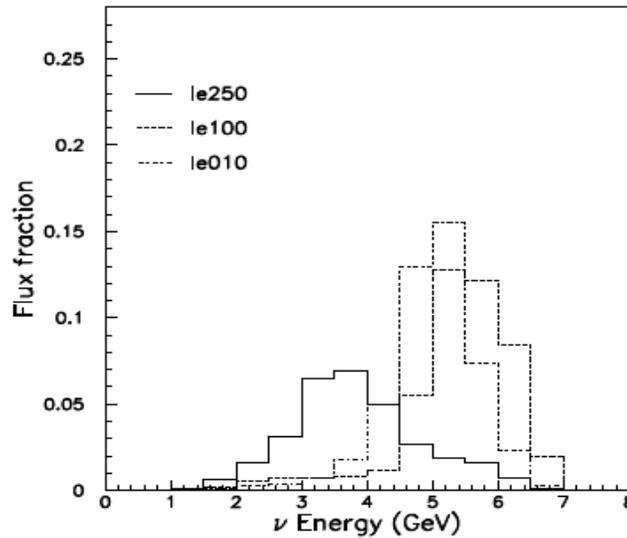
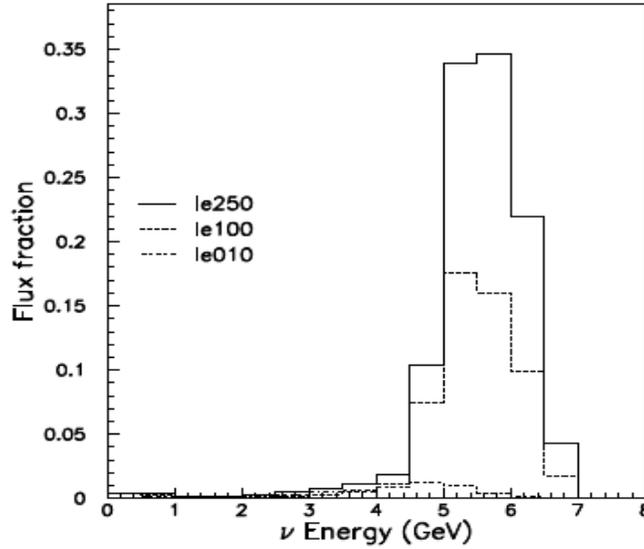


Actually, this is too simplistic a view and in fact the rich spread in (p_T, p_z) within any bin of E_ν is what allows the fit to constrain a hadron production model. The above assumptions all pertain to the *average* pion trajectory. *On average* the pion beam is collinear with the beam axis, and the horns reduce the divergence of the pion beam off the target within the focusing peak. There is still significant divergence, particularly for the low-energy beam. We only vaguely alluded to this in our presentation, where on page 33 we showed that the beam spectrum consists of 5 different categories of pion rays, and discussed the fact that the focused pion beam does have some angular divergence.

It is useful to see directly how the correlation between pion energy and neutrino energy is not exact. The plots below show what happens to two categories of pions, those with $p_T=(100-200)$ MeV/c (upper) and $p_T=(400-500)$ MeV/c (lower) (both have $16 < p_z < 20$ GeV/c). The vertical axis of each plot is the fraction of the neutrino flux in a given energy bin which comes from the particular bin of pion (p_T, p_z) . While the neutrino energy is related to the pion energy, the angular divergence of pions after the horns results in a rich cross-fertilization between E_ν and (p_T, p_z) . For example, in the upper plot, a value of 0.35 on the vertical axis indicates that 35% of the neutrinos of $E_\nu \sim 5.5$ GeV come from the pion bin chosen, while the remaining 65% of neutrinos at this energy would come from other pion (p_T, p_z) . The other pion bins comprising this 65% would be from those with lower p_z and p_T , or higher in p_z and p_T . Effectively, each bin of neutrino energy is derived from a diagonal stripe in the (p_T, p_z) plane). If the conjecture offered by the committee was correct, each bin in neutrino energy would be derived from a single bin in the (p_T, p_z) plane or a vertical stripe in the (p_T, p_z) plane (where p_z is along the

horizontal axis). Because we do our fit in bins of E_ν , each neutrino energy bin gives us information on pion kinematics across a rich spread in the (p_T, p_z) plane.

We therefore emphasize to the committee that the oft-held notion that pion and neutrino energy are linearly related is a *too-simplistic* view that only pertains to the the *average* pion trajectory. The actual ensemble in the beam requires kinematic (p_T, p_z) disentangling, particularly at low pion energy where focusing is never perfect. The fits to neutrino data therefore have significant power to disentangle the pion flux in the (p_T, p_z) plane.



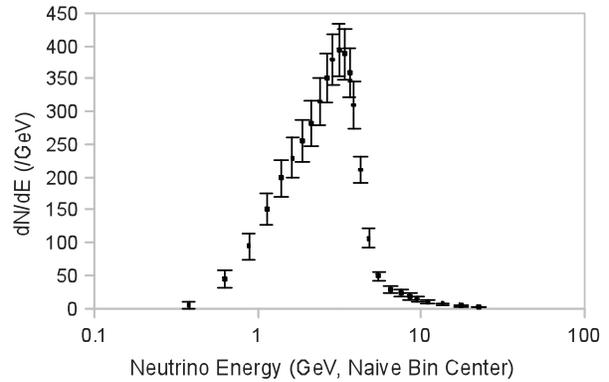
The plots show the fraction of the neutrino flux at a given neutrino energy which is derived from two particular bins in the plane of pion (p_T, p_z) . The upper plot shows the flux arising from those with $p_T=(100-200)$ MeV/ c and the lower plot shows the flux arising from pions with $p_T=(400-500)$ MeV/ c . The range $16 < p_z < 20$ GeV/ c is selected for both plots. The vertical axis of each plot is the fraction of the neutrino flux in a given energy bin which comes from the particular bin of pion (p_T, p_z) .

3. *Could MINERvA explain how 'standard candle cross sections' work over the whole energy range. Does this procedure in fact work over the whole energy range, and how would MINERvA be able to, for example, resolve the apparent MiniBooNE/NOMAD disagreement on the Quasi-Elastic cross section?*

This question suggests a measurement of both the relative energy spectrum and of the absolute flux. We will discuss each in turn since they are separate issues.

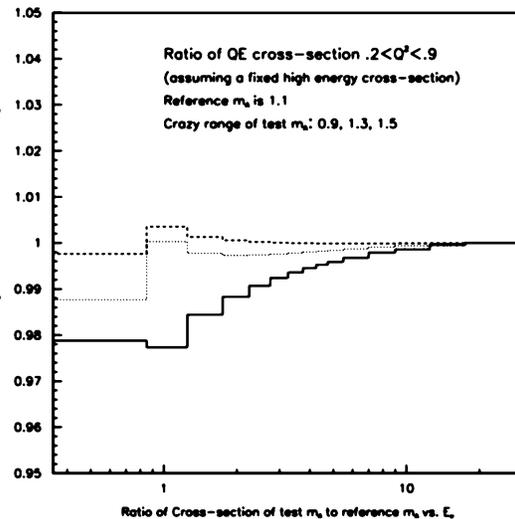
The proposed 'standard candle' cross-section for a spectral measurement is charged-current quasi-elastic scattering over a Q^2 range from 0.2 to 0.9 GeV^2 . Low Q^2 is not included because of uncertainties due to nuclear effects which have been observed in low energy experiments, and high Q^2 is not used primarily because of reconstruction difficulties and poor purity of the high efficiency samples and marginal statistical value. Reconstruction of the moderate Q^2 events proposed in this

MINERvA QE Statistical Errors
(LE beam $1E19$ POT, Q^2 between 0.2-0.9 GeV^2)



measured have been studied extensively in MINERvA. Statistical uncertainties, even for a relatively small number of protons on target, will be good as shown at right.

The cross-section in this region is approximately constant with energy because the quasi-elastic cross-section on nucleons is essentially a function of Q^2 , independent of neutrino energy. This does not depend on axial mass as illustrated by the figure at right in which an absurd range of axial masses are chosen to illustrate the continued independence of the energy dependence of the neutrino cross-section.



The primary sample for the analysis will be a one-track sample originating in the tracker (scintillator) target with limited additional activity away from the immediate region of the event vertex. This sample will

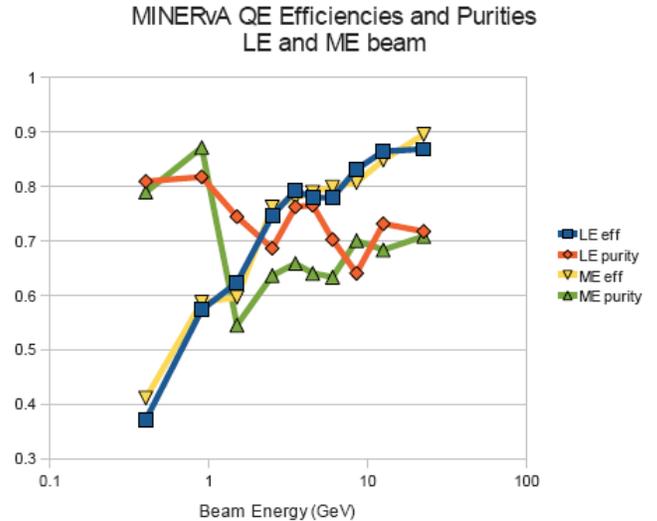
be one of the most easily understood samples, at least experimentally, and one of the simplest to study. The efficiency and purity for the construction of these samples is shown below. The purity is relatively constant as a function of energy, at least for the low energy beam. The efficiency is changing rapidly near the focusing peak. However, this effect is largely due to the efficiency of reconstructing the momentum of the muon in the MINOS near detector which is a geometric and kinematic effect that we should be able to understand with a fairly straightforward set of studies. The primary concern with this sample will be whether or not our purity as a function of energy, which includes irreducible backgrounds that must be

subtracted in simulation, is accurate. We will have to rely on models to some extent to make this determination. One of the advantages of MINERvA is that it should be capable of making a number of measurements which will help to constrain these models, e.g., pion production rates on a variety of nuclei, kinematic constraints to purify the quasi-elastic signal at sufficiently high Q^2 where the recoil nucleon can be reconstructed. As MINERvA gains experience with different nuclear models, that experience can be applied to the purity correction in this analysis.

We expect that we will have the statistics to determine the shape versus energy of the total quasi-elastic cross-section, including the low and high Q^2 regions which are not part of the “standard candle” cross-section, to good precision in an energy region that spans the MiniBooNE and NOMAD measurements. To “resolve” the discrepancy experimentally requires techniques to determine the absolute (as opposed to relative) flux. There are two techniques to measure the absolute flux that we plan to employ. As discussed with the committee during the review and after, we are not in a position to quantitatively defend the expected final uncertainties, although we can look at some limiting uncertainties and make plausibility arguments.

The first absolute flux extraction technique involves measuring the ‘standard candle’ described above as well as inclusive charged-current events in the high energy region, $E_\nu \gtrsim 20\text{GeV}$, with the full low energy (LE) data set of $4E20$ protons on target. The ‘standard candle’ events in the full LE data set provide a precision relative flux shape with a high energy anchor with an expected statistical uncertainty of 5%. The absolute flux in this same energy region can then be derived by measuring the total charged-current cross-section in the same high energy region and using the high energy measurements of CCFR, CCFRR and CDHSW which have a precision of 3% on the absolute cross-section in the high energy region.

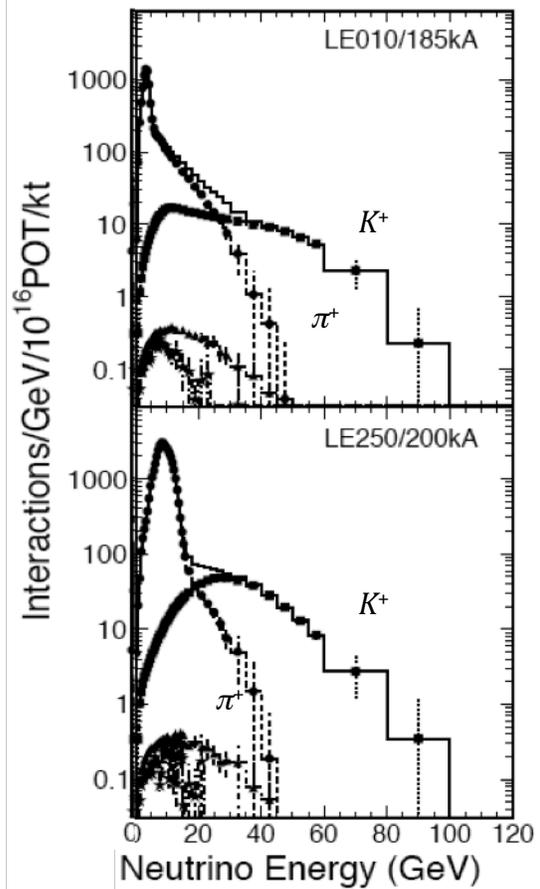
The second absolute flux technique involves tying the flux to measurements from the monitors in the muon alcoves. We plan to use the techniques pioneered at the CERN PS, SPS, and BNL neutrino beams to use the muon flux from pion decays to measure the neutrino flux (see AIP Conf.Proc.967:49-52,2007), and a preliminary demonstration of the technique to obtain a relative flux spectrum was presented by L. Loiacono at NuFact09. Although the present uncertainties are large, the major systematic uncertainties are understood and are being addressed for MINERvA to obtain an independent measurement of the flux shape to a precision estimated at 10%. An additional effort is being mounted to absolutely calibrate the NuMI muon chambers using auxiliary chambers to be placed in a test beam. We expect this program to permit an absolute calibration of the flux measurement from the muon chambers with an overall scale uncertainty of less than 10%.



4. What if MINERvA just used the standard beam running (no special runs) and defined a 'standard candle' (or some 'standard candles') to get the flux? How much better is it to use the special runs than just the normal running?

Although the standard candle techniques described in the previous question provide measurements of the absolute and relative muon neutrino fluxes for one beamline configuration for a given flux model, they provide no cross check of that underlying flux model. The non-zero divergence to the "focused" pion beam, tertiary production, and kaon production all contribute large uncertainties to that model (It should be noted that it is this model which is also used to predict the electron neutrino content in the beam, as well as any "off-axis" fluxes).

The purpose of this run plan is to constrain the flux model of our beam based on hadrons produced in the beamline. The successes of this type of run plan in MINOS, that used a less precise standard candle, were discussed extensively in the review. As another example, consider the procedure discussed in the response to Question #3 of constraining the absolute flux by measurements of the high energy tail of the beam. In that region $E_\nu > 20$ GeV, neutrinos originate almost entirely from kaon decay (seen at right). Kaon production off targets is also uncertain at the level of 40%, and is completely unrelated to the pion production which dominates the lower energy neutrino flux. As has been illustrated in similar special runs in MINOS, the special runs do provide measurements that give constraints on K/π ratios from the target to a significantly better precision than our *a priori* knowledge (see K/π ratio in review slides).



If this run plan is not pursued, we have no checks available to us in the experiment if we produce a cross-section result that is sensitive to flux uncertainties, and open ourselves to the same experience as MiniBooNE with its quasi-elastic cross-section. While MiniBooNE was successful in deriving a cross section, to the comparison to NOMAD revealed a significant difference between their highest energy points and the lowest energy points of NOMAD. As question #3 implies, there is currently no available resolution to this discrepancy.

This question and question #5 imply that it might be possible to use the standard candle process in the low energy beam to determine a flux that would then translate to the ME beam. The problem with such a conjecture is that the ME beam and the LE beam are largely unrelated. Each beam samples an entirely different

phase space in (p_T, p_z) , so it is possible to establish a beam flux model based upon one beam but not have measured enough to predict the flux in a second beam configuration. For example, the LE beam focusing peak at $E_\nu \sim 4$ GeV is derived from pion parents with $p_z \sim 10$ GeV and $p_T \sim 250$ MeV, while the ME beam at $E_\nu \sim 8$ GeV is derived from pion parents with $p_z \sim 20$ GeV and $p_T \sim 250$ MeV. While it is true that the LE beam has 8 GeV neutrinos, these are from unfocused pions which have $p_T < 100$ MeV. Also, as described in more detail in the answer to question #6, the tertiary production is different for different target positions. Thus, the adequate description of one configuration does not by itself translate to the prediction of other beams. Rather, the run plan we have proposed seeks to approximately smoothly vary the sampling of (p_T, p_z) , allowing a consistent description of hadron production across all the relevant phase space.

The goal of the MINERvA experiment is to provide definitive cross section measurements. That is a substantially more ambitious goal than the MiniBooNE cross-section program, and we are asking the lab to approve the only solid cross-check procedure we have been able to devise. This run plan would allow us to change the neutrino flux substantially and demonstrate to the world community that our flux is based on a model which is self-consistent under significant changes to the flux in these special runs. Without the special runs, we may find ourselves in a scenario in which (a) the flux is properly anchored at high energy yet (b) our poor understanding of pion and kaon production off the target still results in a flux miscalculation at lower energy, and thus (c) a cross section discrepancy emerges between MINERvA and NOMAD or even MINERvA LE and ME results.

5. Please make a distinction of what information is gained in the ME vs LE special runs. Can MINERvA get by in the ME case with just horn current variations? How much is the impact?

There are several points that must be emphasized with respect to the ME runs:

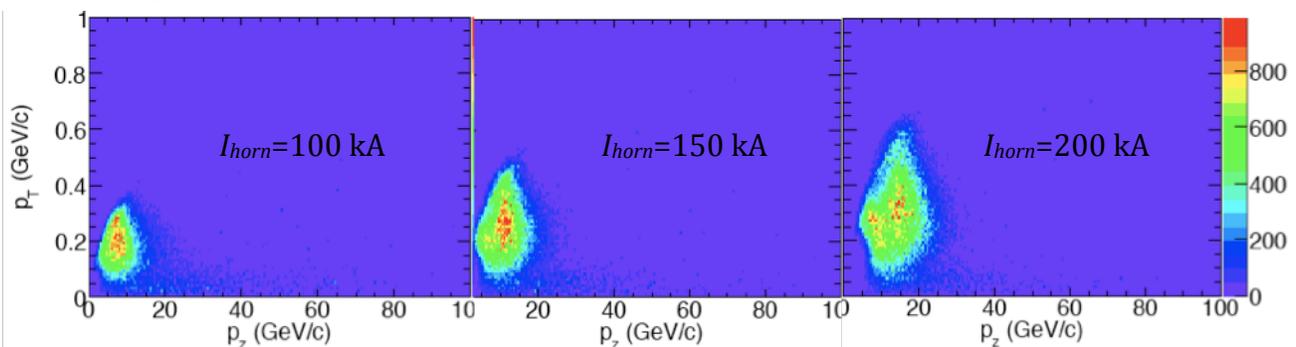
First, there are other beam flux uncertainties besides hadron production, and these special runs allow us to limit these uncertainties. As shown on page 34 of our presentation, there are a series of effects such as the alignment of the horns and target, the current in the horn, the modeling of magnetic field in the horn material, etc, whose uncertainties tend to pile up at the edge of the focusing peak. Such focusing errors will move along with the location of the focusing peak, but have calculable relative magnitudes at each beam configuration. By performing these special runs, we are able to limit these uncertainties from their current 10% (15-20% in the ME beam) to less than 5%. We will have an entirely new beam line in the ME era, and without these runs we will have to accept a substantially larger $\sim 15\%$ flux error at ~ 10 GeV in the ME beam.

Second, horn current alone is *not a sufficient knob* to determine the hadron flux off the target. The figures below show the (p_T, p_z) sampled for $z_{target}=100$ cm, for $I_{horn}=100, 150,$ and 200 kA. As can be seen, the distribution changes inappreciably in the p_z direction, so this is largely equivalent to asking us to not take any special runs at all, and just take our event rate in the standard candle process and divide by the standard candle cross section.

Third, tertiary production along the beam line (discussed further in response to Question 6) is more prominent in the ME configuration and will require extra data and checks to understand. When we change horn current alone, the $\langle p_z \rangle$ of pions from the tertiary interaction component is changing. If we want to understand this contribution, we really need some other running conditions to deconvolve this effect.

Fourth, and this is a somewhat philosophical issue, we want checks on the flux available to us in the NOvA era. An uncomfortable situation will arise if, at the same energy, we obtain different cross section results in the LE and ME beams. Performing these runs gives us an important check, and every indication is that it will be as successful as the set of runs taken in the LE beam by MINOS.

It was noted in the review that the NOvA experiment *may* request a modified width target compared to the original 6.4mm proposed for NOvA and utilized in the LE target. Far from arguing against our proposed run plan, this potential change argues further in its favor, because it means we have only one extrapolation to make (target width) rather than two (change in beam line and change in target width)

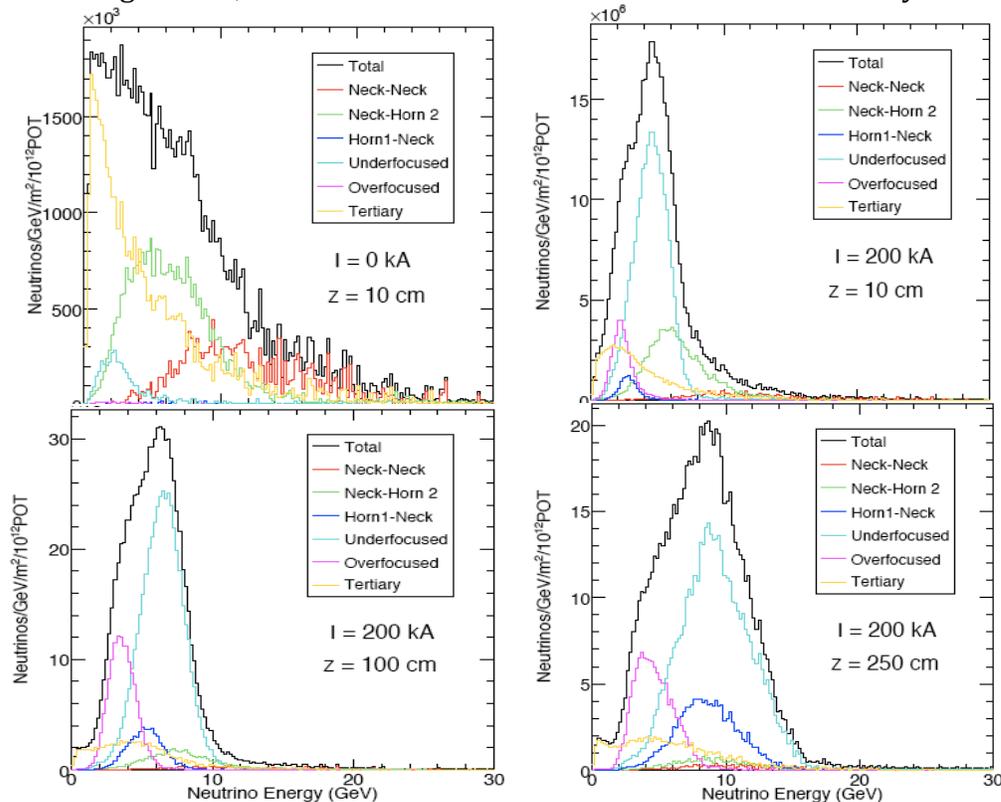


6. What is the level of tertiary production in the ME beam? Does this motivate the ME special runs?

The level of tertiary production in the ME configuration is indeed higher. The plots below show some of the horn current and target positions for the ME horn configurations. Note that tertiary production is nearly 100% of the neutrino flux in some energy bins, and even in the focusing peak during Nova running ($z=100$ cm), tertiary production is $\sim 20\%$ of the flux. The plots below show the breakdown of the various pion trajectories through the focusing, including tertiaries, in four configurations for the ME horn setting. The $(z_{target}, I_{horn})=(100$ cm, 200 kA) graph corresponds to standard running for NOvA.

Our presentation highlighted this issue as one of the reasons that MINERvA wants to perform the special test runs again in the ME configuration (it's not the only reason, see Question 5). In analyzing this ME data, MINERvA will have to include tertiaries as yet another component of the fit, accommodating the possibility that hadron production off of Aluminum (horns+windows) or Iron (decay volume) might differ from graphite (target). We have not done this analysis, and it is impossible/unreasonable to do so without the data in hand. Any mock/fake data study will be trivially successful because we will put in some model and fit it back.

However, we emphasize that these special runs in the ME configuration will only help us in our flux determination in the NOvA era. If the runs are denied in the ME configuration, we will be even *more uncertain* about the tertiary contribution.



Text of email exchange between S. Pordes (3/11) and R. Rajendran (3/19) to allow MIPP to give its status and comments on remarks made by Minerva.

Dear Stephen,

I have circulated the Minerva statement on MIPP capabilities to the MIPP analysis team. We are unable to understand the validity of the statements made and the conclusions drawn in the document you sent.

We have developed techniques to separate electrons and pions in MIPP using multivariate likelihood techniques. We enclose a recent note;
<http://mipp-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=993&version=1&filename=ElectronPionSeparation.pdf> on the topic. Based on this separating pions and electrons is not expected to be a problem. Separating protons from pions has never been a problem in MIPP. The TPC does an excellent job for momenta less than 1 GeV/c after which the TOF takes over. The CKOV and the RICH provide excellent separation for the remaining momentum range (till 120 GeV/c).

Minerva makes a good point of secondary neutrino production on nuclei of the surrounding material (horn etc) providing more uncertainty in the overall flux. MIPP has taken data on various nuclei. liquid H₂, Carbon, Be, Al, Bismuth and Uranium. (see http://ppd.fnal.gov/experiments/e907/RunPlan/Data_Summary.html for more detail)

This data will constrain Geant4 models once it becomes available. Further, MIPP Upgrade will produce much higher statistics and higher quality data on 30 nuclei which will constrain these models even further.

We will be available to provide more information if needed.

best regards
Rajendran Raja

Stephen Pordes wrote:

> Hi Raj,

> The Minerva people have presented a run plan to the laboratory to understand the beam flux for their measurement of Neutrino cross sections and I am chair of a committee that has been asked to review this plan. The original Minerva proposal was based on using results from MIPP data and analysis. I attach a response to a question we asked on how or whether they could use data from particle production experiments. It might be helpful to have an update on the status of the MIPP analysis of the NuMI target data beyond the reference to NuFact08. You should notice that 'even if the MIPP data were perfect' their thinking is now emphasizing the contribution of material outside the target at low energies.

> many thanks

> Stephen