Introduction to Tutorials

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Sao Paulo, Brazil
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What is this all about?

• Lecturers and Organizers have composed a list of questions for you to answer that cover subjects across the school
• You will be split into groups of 3 or 4 and given time to prepare answers to these questions
• Roughly 2.5 hours per day for ~6 days
• Many of these questions are open-ended and have many possible correct answers
• Your group will present answers to your fellow students and lecturers on August 27
  – Everyone in the group needs to present at the end
Goal of the tutorial sessions

• Reinforce what you are learning in the lectures
• Give you a opportunity to work with other students from different specialties/ experiments
• Practice your skills in crafting concise presentations
• Fun and the opportunity to win fabulous prizes...
If no one in your group has a laptop

• You can still present your answer to a question, you can just use a whiteboard instead

• Please let us know in advance if this is the case
  – We have more whiteboards if needed!
Example Tutorial Question Response

Deborah Harris

Borrowing heavily from INSS 2012 problem presentation R. Castillo, M. Reeves, C. Sun, L. Yang

Advice: title slide with all the names of the people in your group
Advice: Plan for a 12 minute presentation, <10 slides if you can
Advice: state the question

• Imagine you were trying to set up a fast communications link using neutrinos to do insider trading between Sao Paulo and Hong Kong (see http://www.forbes.com/sites/brucedorminey/2012/04/30/neutrinos-to-give-high-frequency-traders-the-millisecond-edge/)

• What kind of neutrino detector and neutrino source would you need for this to work (imagine that money is no object)?

From INSS 2012 tutorials
Advice: start with the big picture

Take advantage of the fact that neutrinos can go through the earth directly, without the need for a satellite.

“... High-frequency traders are notoriously secretive about divulging trading times even to colleagues within their own firms, since any such time-dependent trading edge can be fleeting. But many programmed trades are now known to take place within milliseconds or less.

“Thirty milliseconds is a lot of time in high-velocity trading,” said former J.P. Morgan Chase options trader Espen Gaarder Haug, an expert in automated high-frequency trading, and a professor of finance at the Norwegian University of Life Sciences near Oslo. ...”

Communicating with neutrinos

• If you can turn on and off a pulsed neutrino beam then you can send a signal
  – A demonstration of this was done with the NuMI beamline in 2010

ASCII (American Standard Code for Information Interchange)
  - only use capital A (01000001) to Z (01011010)
  - A (01000001) to Z (01011010) and 0 (00110000) to 9 (00111001)
  - the word ’INSS’ is coded as 20 bits ’001001/ 001110/ 010011/ 010011’ and being encapsulated as 84 with control sequence

Assume need 100 bits to send the message: Which stock to trade

# Time differences

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<thead>
<tr>
<th></th>
<th>Distance Earth Surface</th>
<th>Distance Through Earth</th>
<th>Time Surface Fiber optics</th>
<th>Time Surface Air</th>
<th>Time Through Earth</th>
<th>Time saved Through Earth versus Fiber</th>
<th>Time saved Through Earth versus Air</th>
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<td>32.1</td>
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</table>

Distances in miles, time in milliseconds, calculations by professor Espen Gaarder Haug. Optical fiber assumed 66% speed of light. Neutrino speed assumed approximately speed of light.

Sao Paulo to Hong Kong: 11,271km by surface
Save 16msec with a neutrino interaction
Beam: Neutrino Factory

• Created by decays of muons that have been focused and accelerated and put into race-track like storage ring (Mahn advice: can quote professors here)

• Opening angle of neutrino beam: $1/\gamma$
  – Where $\gamma$ is the boost of the muon ($E_\mu/m_\mu$)
  – Show that flux is $\alpha$ to $(1/\gamma)^2$
  – Show that flux is $\alpha$ to $(1/L(\text{km}))^2$

• Average Neutrino Energy is $\alpha \gamma$
  – Can derive some version of event rate per muon decay
Neutrino Factory Event Rates:

\[ \mu^- \rightarrow e^- \nu_\mu \bar{\nu}_e \]

\[ \mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e \]

\[
N_\nu = 1.2 \times 10^{-14} \left[ \frac{(E_\mu, \text{GeV})^3}{(L, \text{km})^2} \right] \times C(\nu) \text{ events per kt}
\]

\[
N_{\bar{\nu}} = 0.6 \times 10^{-14} \left[ \frac{(E_\mu, \text{GeV})^3}{(L, \text{km})^2} \right] \times C(\nu) \text{ events per kt}
\]

\[
C(\nu_\mu) = \frac{7}{10} + P_\mu \frac{3}{10}, \quad C(\nu_e) = \frac{6}{10} - P_\mu \frac{6}{10}
\]

Assume Polarization \((P_\mu)\) is zero
Plugging in Numbers

• For 100GeV muons, 12,000km:

\[
N_{\nu} = 1.2 \times 10^{-14} \left[ \frac{(E_{\mu}, \text{GeV})^3}{(L, \text{km})^2} \right] \times C(\nu) \text{ events per kt}
\]

\[
N_{\overline{\nu}} = 0.6 \times 10^{-14} \left[ \frac{(E_{\mu}, \text{GeV})^3}{(L, \text{km})^2} \right] \times C(\nu) \text{ events per kt}
\]

\[
C(\nu_\mu) = \frac{7}{10} + P_\mu \frac{3}{10}, \quad C(\nu_e) = \frac{6}{10} - P_\mu \frac{6}{10}
\]

Assume: \(10^{24}\) muon decays/year, 
Or \(10^{17}\) decays per second 
\(10^{14}\) decays per ms 
and 100 kton: get

\[
N_{\nu} = 1.2 \times 10^6/(121\times10^6)*(7/10)*100 \quad \sim 0.7 \text{ CC } \nu_\mu /\text{ms}
\]

Advice: don’t need to show every step of math
Advantage of using Neutrinos only for communication

• Since this is not an oscillation or cross section measurement
  – We don’t care if it’s a neutrino or antineutrino
  – We don’t care if the interaction is charged current or neutral current
  – So 0.7 $\nu_\mu$ Charged Current/msec really means closer to 2 or 3 total neutral lepton interactions per msec

• But will need to reduce backgrounds if we accept all these kinds of events
  – Put detector underground, maybe use the new tunnel between Chile and Argentina?

Advice: can talk about other issues even if you didn’t calculate the effects precisely
Effects not considered in today’s example but could be considered

• Neutrino Absorption in earth
  – Interaction length of neutrino: $L_{int} = \frac{1}{\sigma \rho N_A} \sim 10^{15} m$
  – Conversion probability: $10^{-8}$

• Neutrino Oscillations
  – Would change muon neutrinos to tau neutrinos
  – Would change some electron neutrinos to $\mu/\tau$ neutrinos

• Earth’s matter effect
  – Would change electron neutrino transition probability

Advice: can mention effects that you didn’t calculate exactly and explain if they matter
Advice: end with Conclusion slide

- With neutrino factory beam
  - of 100GeV muons
  - With $10^{24}$ muon decays per year in straight section
- With neutrino detector of 100kton
  - 2x Super-Kamiokande
  - 20x MINOS
  - 7x NOvA
  - 5000 Daya Bay modules
- Can just get 3 $\nu$’s per msec in a communication link, to take advantage of the 16msec speed advantage of going from Hong Kong to Sao Paulo
- Moral of the story: Forbes magazine isn’t reviewed by physicists
Tutorial Schedule

• Today: split up into groups after last lecture of today
• Today: meet your group, discuss which question(s) you want to answer
• Tomorrow: sign up (by telling me)
• Rest of the time: work on questions (1st floor)
  – Professors/Tutors will be here during tutorial sessions if you have questions
• Give your slides to me by lunchtime, before presentation session starts
• Lecturers will be the jurors for presentations
• Tutorial session: Thursday afternoon August 27
• Thursday night: Award Ceremony at Banquet