# Introduction to Tutorials

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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*

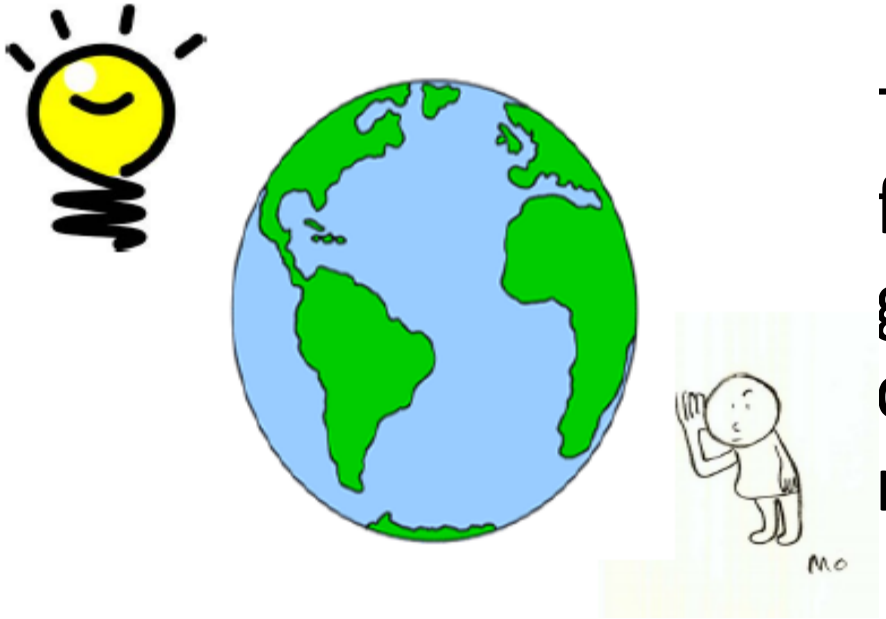
Advice: title slide with all the names of the people in your group
Advice: Plan for a 12 minute presentation, <10 slides if you can

# 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. ..."* http://www.forbes.com/sites/brucedorminey/2012/04/30/neutrinos-to-give-high-frequency-traders-the-millisecond-edge/2/

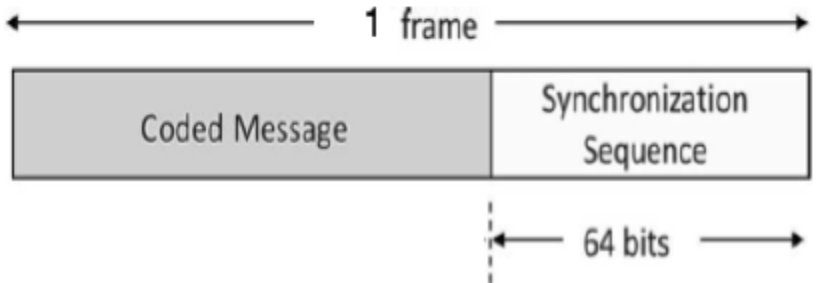
# Communicating with neutrinos

- 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 (~~01~~000001) to Z (~~01~~011010)
- A (Ø1000001) to Z (Ø1011010) and 0 (Ø0110000) to 9 (Ø0111001)
- 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




refer to 'Demonstration of Communication Using Neutrinos', (arXiv: 1203.2847v2 [hep-ex])

# Time differences

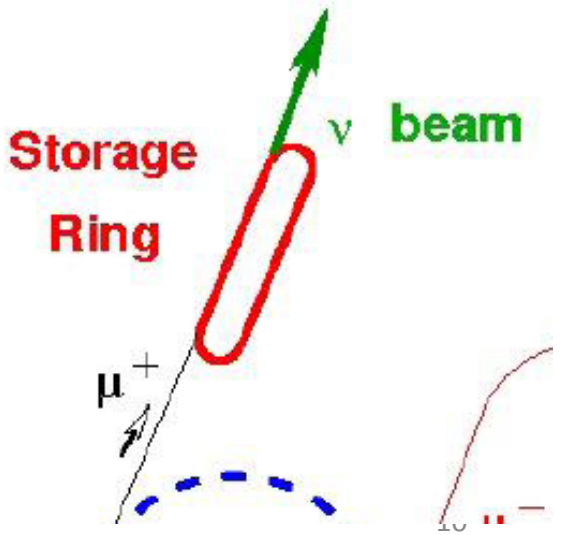
| | Distance Earth Surface | Distance Through Earth | Time Surface Fiber optics | Time Surface Air | Time Through Earth | Time saved Through Earth versus Fiber | Time saved Through Earth versus Air |
|---|---|---|---|---|---|---|---|
| New York London | 3,465 | 3,337 | 28.2 | 18.6 | 17.9 | 10.3 | 0.7 |
| New York Tokyo | 6,749 | 5,817 | 54.9 | 36.3 | 31.2 | 23.7 | 5.0 |
| London Tokyo | 5,946 | 5,394 | 48.4 | 31.9 | 29.0 | 19.4 | 3.0 |
| New York Hong Kong | 8,054 | 6,630 | 65.5 | 43.3 | 35.6 | 29.9 | 7.7 |
| London Hong Kong | 5,979 | 5,423 | 48.6 | 32.1 | 29.1 | 19.5 | 3.0 |
| London Sydney | 10,572 | 7,691 | 86.0 | 56.8 | 41.3 | 44.7 | 15.5 |
| New York Sydney | 10,377 | 7,487 | 84.4 | 55.7 | 40.2 | 44.2 | 15.5 |

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

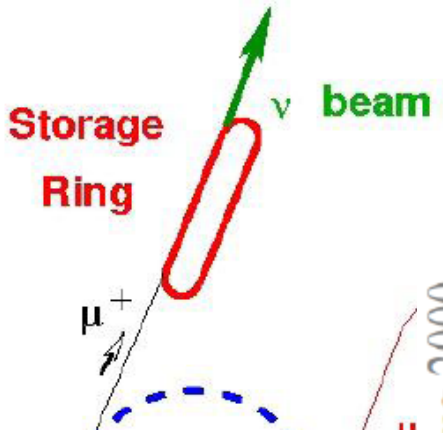
- Created by decays of muons that have been focused and accelerated and put into race-track like storage ring (Mahn advice: can quote professors here)
- Opening angle of neutrino beam: $1/\gamma$
  - Where $\gamma$ is the boost of the muon ($E_\mu/m_\mu$)
  - Show that flux is $\alpha$ to $(1/\gamma)^2$
  - Show that flux is $\alpha$ to $(1/L(km))^2$
- Average Neutrino Energy is $\alpha\ \gamma$
  - Can derive some version of event rate per muon decay



# Neutrino Factory Event Rates:

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

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




Total neutrino and anti-neutrino interaction rates per muon decay:

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

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

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



Assume Polarization ($P_\mu$) is zero

# Plugging in Numbers

- For 100GeV muons, 12,000km:

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

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

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

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

Advice: don't need to show every step of math

$N_\nu = 1.2 \times 10^6/(121 \times 10^6) * (7/10) * 100$ ~0.7 CC $\nu_\mu$/ms

# 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: $L_{\text{int}} = \frac{1}{\sigma \rho N_A} \sim 10^{15} m$
  - 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