BNL-CAP No.xxx/99

Geographic positioning of Possible Neutrino Beam Sources and Detectors

R. B. Palmer and Juan C. Gallardo†
Physics Department
Brookhaven National Laboratory

(Received October 27, 1999)

Abstract

A first order calculation of relevant distances and angles of potential high-intensity neutrino sources at FNAL or BNL aiming to detectors located at Gran Sasso (Italy), Soudan (MN, USA) and SLAC (CA, USA)

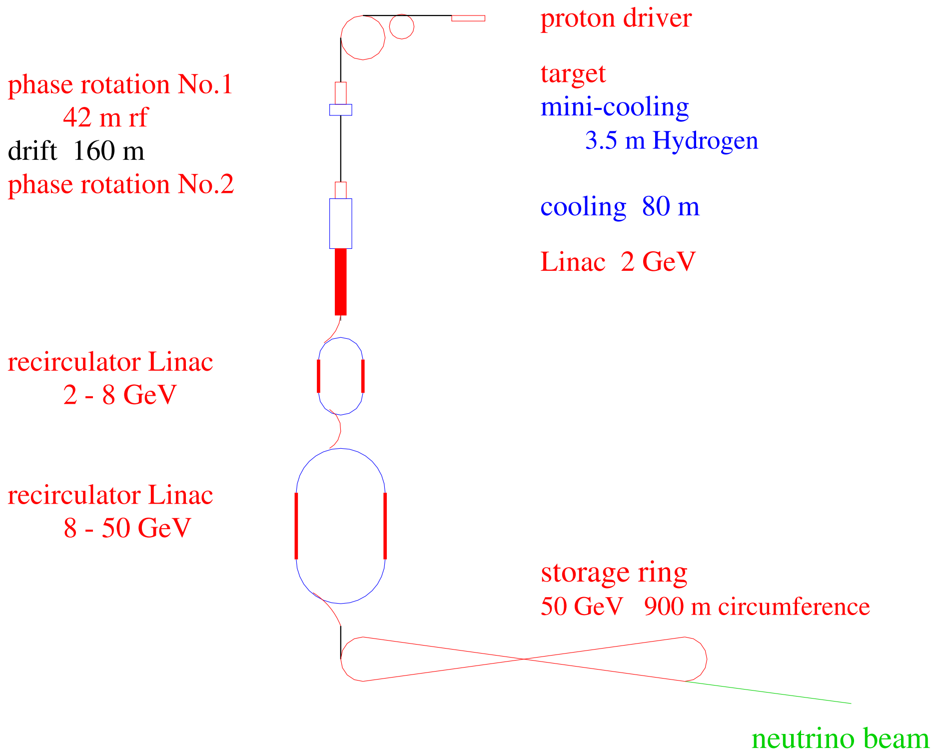

FIG. 1: Schematic displaying the main components of a neutrino factory

I. INTRODUCTION

The latest results from SK[1] has created a commotion in High Energy Physics [2]. A number of studies are being carried out to construct and utilize the superb neutrino beams that could be produced at suitable muon storage rings[3] A first attempt to compile a set of plausible parameters for a neutrino factory is being carried out by one of the authors [4]. Figure 1 is an schematic of a possible neutrino factory. In this note we document some of the geographic coordinates of the laboratories used in the tables presented in the mentioned work (see Fig. 2).

II. CALCULATIONS

There are several model of the earth with various degree of accuracy.

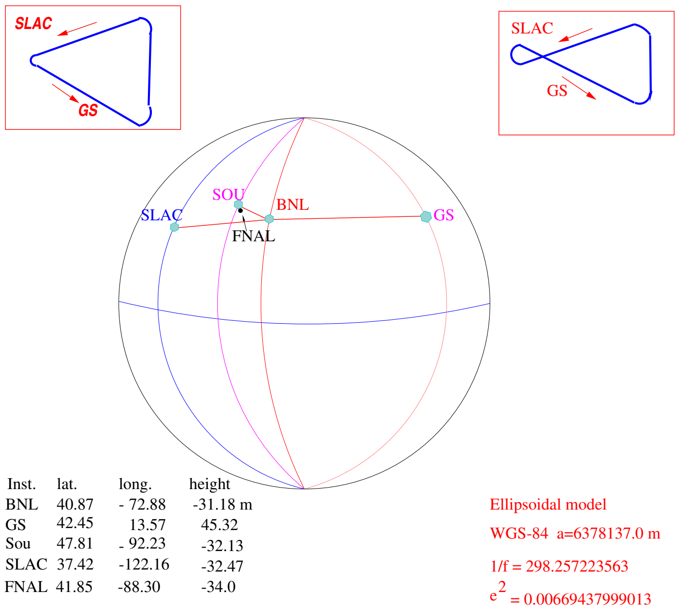

FIG. 2: Location of different laboratories in Europe and the US.

A Spherical Earth Model

First we assume a highly idealize spherical model to calculate the relevant angles and distances from the possible high-intensity neutrino sources at BNL or FNAL to the hypothetical location of detectors at Gran Sasso, Soudan and SLAC. Following the notation of Tb. I we obtain (distances in km and angles in degrees),

- For GS-SLAC at BNL

  1. tild angle = 51.30
  2. pseudo dip angle= 40.97 155.42
  3. opening angle (GS,SLAC) at BNL= 65.55

- For GS-SOU at BNL

  1. tild angle= 35.85
  2. pseudo dip angle= 119.09 13.24

3. opening angle (GS,SOU) at BNL= 74.15

- For SLAC-SOU at BNL

1. tild angle= 30.94
2. pseudo dip angle= 39.15 15.13
3. opening angle (SLAC,SOU) at BNL= 155.98

- For GS-SLAC at FNAL

1. tild angle= 53.36
2. pseudo dip angle= 148.09 30.39
3. opening angle (GS,SLAC) at FNAL= 62.30

- For GS-SOU at FNAL

1. tild angle= 35.70
2. pseudo dip angle= 92.95 18.08
3. opening angle (GS,SOU) at FNAL= 105.131586107836

- For SLAC-SOU at FNAL

1. tild angle= 13.40
2. pseudo dip angle= 83.39 18.82
3. opening angle (SLAC,SOU) at FNAL= 115.42

- Distance and angle BNL to other sites

1. BNL to GSAS = 6528.19 30.78
2. BNL to SOUD = 1711.77 7.71
3. BNL to SLAC = 4141.15 18.94

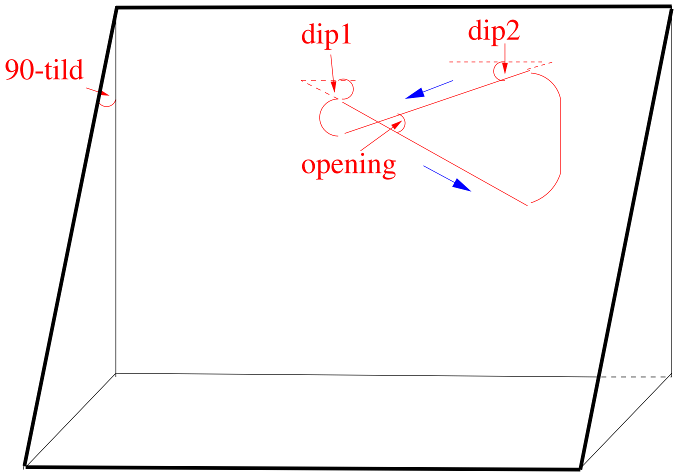

FIG. 3: Angles definitions usede in the text.

4. BNL to FNAL = 1289.09 5.79

- Distance and angle FNAL to other sites

1. FNAL to BNL = 1289.09 5.79
2. FNAL to GSAS = 7343.12 35.14
3. FNAL to SOUD = 731.70 3.28
4. FNAL to SLAC = 2901.20 13.14

where the different angles are defined in Fig. 3

The USA sites coordinates were obtained from the National Geodesic Survey at the URL . The datasheets are retrieved for areas as smaller as $2x2$ degrees. The data for Gran Sasso were provided by Andrea Donati.

B Ellipsoidal Earth Model

An idealize ellipsoidal earth model is used for a more accurate range and bearing calculations over long distances; in particular, Global Positioning System (GPS) navigation receivers use this model to compute position information.

TABLE I: Latitude, longitude and Height coordinates of different laboratories.

Laboratory	latitude	longitude	height
	degree	degree	m
BNL (1)	40.87 N	-72.88	-31.18
GS (2)	42.45 N	13.57	45.32
SOU (3)	47.81 N	-92.23	-32.13
SLAC (4)	37.42 N	-122.16	-32.47
FNAL (5)	41.85 N	-88.30	-34.0

There are many reference ellipsoids; the best of these models can represent the shape of the earth to within 100 meters. In addition, there are hundreds of geodetic datum tables that assign numerical values to latitude and longitude of known geographic points. Literally, different nations and agencies use different datum sets; this fact make mandatory to exercise care in the selection of the datums to use as well as in the conversion between coordinates of different datums. The relevant angles (degree) and distances (km) are:

- For GS-SLAC at BNL

  1. tild angle= 51.49
  2. pseudo dip angle=40.99 155.42
  3. opening angle (GS,SLAC) at BNL= 65.57

- For GS-SOU at BNL

  1. tild angle= 36.013
  2. pseudo dip angle= 119.19 13.22
  3. opening angle (GS,SOU) at BNL= 74.03

- For SLAC-SOU at BNL

1. tild angle= 31.07
2. pseudo dip angle= 39.09 15.11
3. opening angle (SLAC,SOU) at BNL= 156.01

- For GS-SLAC at FNAL

1. tild angle= 53.54
2. pseudo dip angle= 148.06 30.41
3. opening angle (GS,SLAC) at FNAL= 62.34

- For GS-SOU at FNAL

1. tild angle= 35.81
2. pseudo dip angle= 93.13 18.09
3. opening angle (GS,SOU) at FNAL= 104.97

- For SLAC-SOU at FNAL

1. tild angle= 13.44
2. pseudo dip angle= 83.35 18.84
3. opening angle (SLAC,SOU) at FNAL= 115.49

- Distance and angle BNL to other sites

1. BNL to GSAS = 6540.41 30.88
2. BNL to SOUD = 1713.52 7.73
3. BNL to SLAC = 4149.34 18.99
4. BNL to FNAL = 1291.48 5.81

- Distance and angle FNAL to other sites

1. FNAL to BNL = 1291.48 5.81
2. FNAL to GSAS = 7356.67 35.26
3. FNAL to SOUD = 730.93 3.29
4. FNAL to SLAC = 2906.63 13.18

ACKNOWLEDGMENTS

We thanks Andrea Donati for the Gran Sasso geographic coordinates.

REFERENCES

† `gallardo@bnl.gov`; `palmer@bnl.gov`

[1] The Super-Kamiokande Collaboration, *Evidence for Oscillation of Atmospheric Neutrinos*, Phys. Rev. Lett. xxx xxx, 1999.

[2] http://neutrino.kek.jp; also see *The Neutrino Oscillation Industry*, http://www.hep.anl.gov/NDK/Hypertext/nuindustry.html.

[3] http://muonstoragerings.cern.ch/Welcome.html/; http://www.hep.princeton.edu/mumu/nuphys/; http://www.fnal.gov/projects/muoncollider/nu/study/study.html; http://www.hep.princeton.edu/mumu/NSFLetter/; S. Geer, *Neutrino beams from muon storage rings: Characteristics and Physics Potential*, Phys. Rev. **vol. D 57**, 6989 (1998) and Erratum Phys. Rev. **vol. D 59**, 039903 (1998); B. Autin, A. Blondel and J. Ellis (eds), *Prospective Study of Muon Storage Rings at CERN*, CERN-99-02 (1999), http://preprints.cern.ch/yellowrep/1999/99-02.pdf.

[4] Robert B. Palmer, *Neutrino Factory: Draft Parameters*, unpublished; http://pubweb.bnl.gov/people/palmer/nu/.

[5] R. B. Palmer, C. Johnson and E. Keil, *A Cost-Effective Design for a Neutrino Factory*, unpublished.