HEP Software Installation

SERB SCHOOL ON EXPERIMENTAL HIGH ENERGY PHYSICS

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Summary

This document explains the procedure to install some of the analysis and simulation software's used in High Energy Physics. The commands are for Ubuntu OS. For Scientific Linux follow the instructions in the document serb_soft.pdf

Instructions for installation of

1. **Pythia8**
2. **Pythia6**
3. **GSL 2.5 (GNU Scientific Library)**
4. **ROOT-6**
5. **GEANT(CLHEP)**
6. **GENIE(LHAPDF6,log4cpp,libxml2)**
7. **EVTGEN(HepMC,PHOTOS,TAUOLA)**
8. **HIJING**
9. **RooUnfold**

- Working with GENIE

All the installations are done in the directory /<path>/products. Copy all the downloaded files to this installation directory.

How to copy a file :- $cp /<path of file> /<path of destination directory>
How to copy a directory :- $cp -R /<path of file> /<path of destination directory>

1 Pythia8 Installation

Download Site:- http://home.thep.lu.se/ torbjorn/pythia8/pythia8235.tgz

1.1 Compiling and installing

$tar -xvfz pythia8235.tgz
$mv pythia8235 pythia8235-source
$cd pythia8235-source
$./configure --enable-shared -fPIC --prefix=/<path>/products/pythia8235
Use the -fPIC configure flag only on 64bit systems
$make -j n
In the above command n stands for the number of cores(no space between j and n)
$make install

1.2 Post Installation - Set environment in ~/.bashrc

```
#Pythia 8
export PYTHIA8=/<path>/products/pythia8235
export PYTHIA8DATA=$PYTHIA8/share/Pythia8/xmldoc
export PATH=$PYTHIA8/bin:$PATH
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$PYTHIA8/lib
```

1.3 Running Examples which comes along with the package

$cd /<path>/products/pythia8235/examples
$make main01
$./main01

2 Pythia6 Installation

Download site :- http://neutrino.ift.uni.wroc.pl/files/pythia6.tar.gz
$tar -xvzf pythia6.tar.gz
Download the latest Pythia (pythia6428) from the site
http://www.hepforge.org/archive/pythiasix/pythia-6.4.28.f.gz
$gunzip -k pythia-6.4.28.f.gz

2.1 Compiling and installing

$mv pythia6/ pythia6428/
$rm pythia6428/pythia6416.f
$cp pythia6428.f pythia6428/
$cd pythia6428/
$./makePythia6.linuxx8664
It will create libPythia6.so in current folder.
$rm *.o
It will delete all object files from the directory.

2.2 Possible errors and workaround in ubuntu

2.2.1 workaround for g77 not found

$sudo -H gedit /etc/apt/sources.list
Add the following lines in the end $deb [trusted=yes] http://old-releases.ubuntu.com/ubunt
hardy universe
$deb-src [trusted=yes] http://old-releases.ubuntu.com/ubuntu/ hardy universe
$deb [trusted=yes] http://old-releases.ubuntu.com/ubuntu/ hardy-updates universe
$deb-src [trusted=yes] http://old-releases.ubuntu.com/ubuntu/ hardy-updates universe
$sudo apt-get update
$sudo apt-get install g77

2.2.2 workaround for cannot not find crti.o

export LD_LIBRARY_PATH=/usr/lib/x86_64-linux-gnu:$LD_LIBRARY_PATH

2.2.3 workaround for cannot find -lgcc_s

$sudo find /usr/ -name libgcc_s.so
$ld -lgcc_s --verbose
$sudo ln -s /usr/lib/gcc/x86_64-linux-gnu/4.8/libgcc_s.so /usr/lib/x86_64-linux-gnu/
It will create a hard link in the destination directory.

2.3 Post Installation - Set environment in ~/.bashrc

```
#Pythia 6
export PYTHIA6=/<path>/products/pythia6428
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$PYTHIA6428/lib
```

3 GSL Installation

Download site :- https://ftp.gnu.org/gnu/gsl/gsl-2.5.tar.gz

3.1 Compiling and installing

```
$tar -xvzf gsl-2.5.tar.gz
$cd gsl2.5
$./configure --prefix=/<path>/products/gsl25
$make -j n
$make install
```

3.2 Post Installation - Set environment in ~/.bashrc

```
#GSL-2.5
export GSLHOME=/<path>/products/gsl25/
export GSL_INC=$GSLHOME/include
export GSL_LIB=$GSLHOME/lib
export PATH=$GSLHOME/bin:$PATH
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$GSLHOME/lib
```

4 ROOT6 Installation

Version - 6.14.00
Download site :- https://root.cern.ch/download/root_v6.14.00.source.tar.gz

4.1 Installing Prerequisites

Check https://root.cern.ch/build-prerequisites to make sure you install correct prerequisites that matches your Operating System.

4.1.1 Required packages:

$sudo apt-get install git dpkg-dev cmake g++ gcc binutils libx11-dev libxpm-dev libxft-dev libxext-dev

4.1.2 Optional packages:

$sudo apt-get install gfortran libssl-dev libpcre3-dev xlibmesa-glu-dev libglew1.5-dev libftgl-dev libmysqlclient-dev libfftw3-dev libcfitsio-dev graphviz-dev libavahi-compat-libdnssd-dev libldap2-dev python-dev libxml2-dev libkrb5-dev libgsl0-dev libqt4-dev

4.2 Compiling and installing

$tar -xvzf root_v6.14.00.source.tar.gz
$mkdir root_v6.14.00-build
$cd root_v6.14.00-build
Use 'cmake' to create the makefile
$cmake -Dgdml=ON -Dbuiltin_gsl=OFF -Dmathmore=ON -Dpythia6=ON -Dpythia8=ON -Droofit=ON -DGSL_DIR=/<path>/products/gsl25/ -DGSL_CONFIG_EXECUTABLE= /<path>/products/gsl25/bin/gsl-config -DPYTHIA6_LIBRARY= /<path>/products/pythia6428/libPythia6.so -DPYTHIA8_DIR= /<path>/products/pythia8235/ -DPYTHIA8_INCLUDE_DIR= /<path>/products/pythia8235/include/ -DPYTHIA8_LIBRARY= /<path>/products/pythia8235/lib/libpythia8.so -DCMAKE_INSTALL_PREFIX= /<path>/products/root-6.14.00/ ../root-6.14.00/

$make -j n
$make install

4.3 Possible errors and workaround in ubuntu

4.3.1 fatal error:'vdt/vdtMath.h' file not found(at 89 %)

This happens if you use cmake itself to build
$cmake --build . --target install
In this case do
$cmake --build . --target VDT
$cmake --build .

4.4 Post Installation - Set environment in ~/.bashrc

```
#ROOT6
#export ROOTSYS=/<path>/products/build-root
source /<path>/products/root-install/bin/thisroot.sh
```

4.5 Running Examples which comes along with the package

$cd /<path>/products/root-6.14.00/tutorials
$root
$.X hsimple.C

The $ROOTSYS/tutorials/ directory include the following sub-directories:

fft: Fast Fourier Transform with the fftw package
fit: Several examples illustrating minimization/fitting
foam: Random generator in multidimensional space
geom: Examples of use of the geometry package (TGeo classes)
gl:Visualisation with OpenGL
graphics: Basic graphics

graphs: Use of TGraph, TGraphErrors, etc.
gui: Scripts to create Graphical User Interface
hist: Histograming
image: Image Processing
io: Input/Output
math: Maths and Statistics functions
matrix: Matrices (TMatrix) examples
mlp: Neural networks with TMultiLayerPerceptron
net: Network classes (client/server examples)
physics: LorentzVectors, phase space
pyroot: Python tutorials
pythia: Example with pythia6
quadp: Quadratic Programming
ruby: ruby tutorials
smatrix: Matrices with a templated package
spectrum: Peak finder, background, deconvolutions
splot: Example of the TSplot class (signal/background estimator)
sql: Interfaces to SQL (mysql, oracle, etc)
thread: Using Threads
tmva: Examples of the MultiVariate Analysis classes
tree: Creating Trees, Playing with Trees
unuran: Interface with the unuram random generator library
xml: Writing/Reading xml files

As a beginner you can use the document in the following site
https://twiki.ppe.gla.ac.uk/pub/ATLAS/WebHome/RootManual.pdf
It contains some basic worked out examples

5 GEANT4 Installation

5.1 Installing Prerequisites

- ROOT(version 6.14.00)
- CLHEP(version 2.4.0.4)
- libxmu-dev, libxi-dev, libconfig++-dev, libpq-dev

5.1.1 CLHEP installation

Download site:-
http://proj-clhep.web.cern.ch/proj-clhep/DISTRIBUTION/tarFiles/clhep-2.4.0.4.tgz
$cd /<path>/products
$mkdir CLHEP
$cd CLHEP
$tar -xzvf clhep-2.4.0.4.tgz
$mv 2.4.0.4 clhep-source
Renamed in order to avoid confusion between build and source directory
$mkdir clhep-build
$cd clhep-build
$cmake -DCMAKE_INSTALL_PREFIX=/<path >/products/CLHEP/clhep2404 /<path >/products/CLHEP/clhep-source
$make -j n
$make install

5.1.2 Post Installation - Set environment in ~/.bashrc

```
#CLHEP-2.4.0.4
export CLHEP_BASE_DIR=/<path>/products/CLHEP/clhep2404
export PATH= $PATH:$CLHEP_BASE_DIR/bin
export LD_LIBRARY_PATH=$CLHEP_BASE_DIR/lib:$LD_LIBRARY_PATH
```

5.1.3 Other prerequisites

$sudo apt-get install libxmu-dev libxi-dev libconfig++-dev libpq-dev

5.2 Compiling and installing

Version :- Geant 4.10.04 patch 02
Download site:-
http://geant4-data.web.cern.ch/geant4-data/releases/geant4.10.04.p02.tar.gz
You need a working internet connection during compiling, because the compilation will download data.

```
$cd /<path>/products
$mkdir GEANT4
$cd GEANT4
$tar -xvzf geant4.10.04.p02.tar.gz
$mv geant4.10.04.p02 geant4.10.04.p02-source
$mkdir geant4.10.04.p02-build
$cd geant4.10.04.p02-build
$cmake -DCMAKE_INSTALL_PREFIX=/<path>/GEANT4/products/
geant4.10.04.p02-install -DGEANT4_USE_SYSTEM_CLHEP=ON
-DCLHEP_ROOT_DIR=/<path>/products/CLHEP/clhep2404
-DGEANT4_USE_GDML=ON -DGEANT4_USE_QT=ON
-DGEANT4_USE_OPENGL_X11=ON -DGEANT4_USE_RAYTRACER_X11=ON
-DGEANT4_INSTALL_DATA=ON /<path>/products/GEANT4/geant4.10.04.p02-
source
$make -j n
$make install
```

5.3 Post Installation - Set environment in ~/.bashrc

```
#GEANT4
export G4INSTALL=/<path>/products/GEANT4/geant4.10.04.p02-install/
share/Geant4-10.4.2/geant4make
export G4WORKDIR=/home/user/G4WORK
source $G4INSTALL/geant4make.sh
source /<pat>/products/GEANT4/geant4.10.04.p02-install/bin/geant4.sh
```

5.4 Running Examples which comes along with the package

$cd /<path>/products/GEANT4/geant4.10.04.p02-install/share/Geant4-10.4.2/examples
$cd basic/B1
$cmake -DGeant4_DIR= /<path>/products/GEANT4/geant4.10.04.p02-install /share/Geant4-10.4.2/ /home/jim/G4WORK/examples/basic/B1

This command will create a executable in $G4WORK/bin/Linux-g++/

6 GENIE Installation

6.1 Installing Prerequisites

- ROOT(version 6.14.00)
- GNU Scientific Library (GSL)
- PYTHIA6
- LHAPDF5 or LHAPDF6
- log4cpp
- libxml2

6.1.1 LHAPDF Installation:

Download site:-
https://lhapdf.hepforge.org/downloads/?f=LHAPDF-6.2.1.tar.gz

```
$cd /<path>/products
$mkdir LHAPDF
$cd LHAPDF
$tar -xvzf LHAPDF-6.2.1.tar.gz
$cd LHAPDF-6.2.1
$./configure --prefix=/<path>/products/LHAPDF/lhapdf621
$make -j n
$make install
```

NOTE:
LHAPDF no longer bundles PDF set data in the package tarball. The downloadable PDF sets are packaged as tarballs, which must be expanded to be used. Here is an example of how to retrieve and install a PDF set from the command line:

```
$wget http://www.hepforge.org/archive/lhapdf/pdfsets/6.2/CT10nlo.tar.gz -O-
| tar xz -C /localhome/products/LHAPDF/lhapdf621/share/LHAPDF
```

6.1.2 Possible errors and workaround in ubuntu

6.1.3 Error: 'aclocal-1.15' is missing on your system

$sudo apt-get install automake

6.1.4 log4cpp Installation:

Download site:-
http://sourceforge.net/projects/log4cpp/

$cd /<path>/products
$mkdir LOG4CPP
$cd LOG4CPP
$tar -xvzf log4cpp-1.1.3.tar.gz
$mv log4cpp log4cpp-source
$./configure --prefix=/<path>/products/LOG4CPP/log4cpp
$make -j n
$make install

6.1.5 libxml2 Installation:

Download site:-
ftp://xmlsoft.org/libxml2/libxml2-2.9.8.tar.gz

$cd /<path>/products
$mkdir LIBXML2
$cd LIBXML2
$tar -xvzf libxml2-2.9.8.tar.gz
$cd libxml2-2.9.8
$./configure --prefix=/<path>/products/LIBXML2/libxml2
$make -j n
$make install

6.2 Pre Installation - Set environment in genie-env.sh

Make a source file and name it as genie-env.sh

Source it after creating the file -

```
export GENIEBASE=/<path>/products
export GENIE=$GENIEBASE/GENIE/genie
export PYTHIA6=$GENIEBASE/pythia6428
export ROOTSYS=$GENIEBASE/root-6.14.00
export GSLHOME=$GENIEBASE/gsl25
export GSL_INC=$GSLHOME/include
export GSL_LIB=$GSLHOME/lib
export LOG4CPP_INC=$GENIEBASE/LOG4CPP/log4cpp/include
export LOG4CPP_LIB=$GENIEBASE/LOG4CPP/log4cpp/lib
export LHAPATH=$GENIEBASE/LHAPDF/lhapdf621
export LHAPDF_INC=$GENIEBASE/LHAPDF/lhapdf621/include
export LHAPDF_LIB=$GENIEBASE/LHAPDF/lhapdf621/lib
export XSECSPLINEDIR=$GENIEBASE/data
export LD_LIBRARY_PATH=$LHAPDF_LIB:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=/usr/lib64:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=$LOG4CPP_LIB:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=$PYTHIA6:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=$ROOTSYS/lib:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=$GENIE/lib:$GSL_LIB/lib:$LD_LIBRARY_PATH
export PATH=$GENIE/bin:$ROOTSYS/bin:$GSLHOME/bin:$PATH
```

6.3 Compiling and installing

Create directory GENIE under products folder

$cd /<path>/products
$mkdir GENIE
$cd GENIE
$git clone https://github.com/GENIE-MC/Generator.git $cd Generator ; Make sure that GSL Path is exported

$./configure --prefix=/<path>/products/GENIE/genie --disable-profiler --disable-validation-tools --disable-cernlib --enable-lhapdf6 --enable-flux-drivers --enable-geom-drivers --disable-doxygen --enable-test --enable-mueloss

--enable-dylibversion --enable-t2k --enable-fnal --enable-atmo
--enable-nucleon-decay --disable-masterclass --disable-debug
--with-optimiz-level=O2
--with-pythia6-lib=/<path>/products/pythia6428/libPythia6.so
--with-lhapdf6-inc=/<path>/products/LHAPDF/lhapdf621/include
--with-lhapdf6-lib=/<path>/products/LHAPDF/lhapdf621/lib
--with-libxml2-inc=/<path>/products/LIBXML2/libxml2/include/libxml2
--with-libxml2-lib=/<path>/products/LIBXML2/libxml2/lib
--with-log4cpp-inc=/<path>/products/LOG4CPP/log4cpp/include
--with-log4cpp-lib=/<path>/products/LOG4CPP/log4cpp/lib

7 EVTGEN Installation

7.1 Installing Prerequisites

- HepMC Mandatory Package
  $curl -O http://lcgapp.cern.ch/project/simu/HepMC/download/HepMC-2.06.09.tar.gz
- Pythia8
- PHOTOS
  $curl -O http://photospp.web.cern.ch/photospp/resources/PHOTOS.3.61/PHOTOS.3.61.tar.gz
- TAUOLA
  $curl -O http://tauolapp.web.cern.ch/tauolapp/resources/TAUOLA.1.1.6c/TAUOLA.1.1.6c.tar.gz

Before installing external packages create a directory called external inside EVTGEN and install all packages here.

7.1.1 Installation of HepMC

$cd /<path>/EVTGEN/external ; tar -xzvf HepMC-2.06.09.tar.gz
$mkdir -p HepMC ; cd HepMC
$ cmake -DCMAKE_INSTALL_PREFIX=/<path>/products/EVTGEN/external/HepMC /<path>/products/EVTGEN/external/HepMC-2.06.09 -Dmomentum:STRING=GEV -Dlength:STRING=MM
$ make -j n ; make install

7.1.2 Installation of PHOTOS

$cd /<path>/EVTGEN/external ; tar -xzvf PHOTOS.3.61.tar.gz
$cd PHOTOS
$./configure --with-hepmc=/<path>/products/EVTGEN/external/HepMC
$make

7.1.3 Installation of TAUOLA

$cd /<path>/EVTGEN/external ; tar -xzvf TAUOLA.1.1.6c.tar.gz
$cd TAUOLA
$./configure --with-hepmc=/localhome/products/EVTGEN/external/HepMC
$make

7.2 Installation of EVTGEN

$cd /<path>/EVTGEN
$git clone http://phab.hepforge.org/source/evtgen.git
$cd evtgen
$./configure --hepmcdir=/<path>/products/EVTGEN/external/HepMC
--photosdir=/<path>/products/EVTGEN/external/PHOTOS
--pythiadir=/<path>/products/pythia8235
--tauoladir=/<path>/products/EVTGEN/external/TAUOLA

7.3 Post Installation - Set environment in ~/.bashrc

```
#EVTGEN
export HEPMC=/<path>/products/EVTGEN/external/HepMC
export PHOTOS=/<path>/products/EVTGEN/external/PHOTOS
export TAULO=/<path>/products/EVTGEN/external/TAUOLA
export PYTHIA8=/<path>/products/pythia8235
export PYTHIA8DATA=$PYTHIA8/share/Pythia8/xmldoc
export EVTGEN=/<path>/products/EVTGEN/evtgen
export LD_LIBRARY_PATH=$HEPMC/lib:$PHOTOS/lib:$PYTHIA8/lib:
$TAULO/lib:$EVTGEN/lib:$LD_LIBRARY_PATH
```

8 Installation of HIJING

Download Site :-
http://atomfizika.elte.hu/haladolabor/HEP/hijing1411.tgz

create directory HIJING under products folder

```
$tar -xzvf hijing1411.tgz
$cd HIJING/hijing1411
$make
```

9 Installation of RooUnfold

The latest version of RooUnfold is not compatible with any root version after 5.34/12
So here we will install the development version

Run the following command in the products directory

```
$svn co https://svnsrv.desy.de/public/unfolding/RooUnfold/trunk RooUnfold
$cd RooUnfold
$make
```

9.1 Post Installation - Set environment in ~/.bashrc

```
#RooUnfold
export ROOUNFOLD=/<path>/products/RooUnfold/
export LD_LIBRARY_PATH=$ROOUNFOLD:$LD_LIBRARY_PATH
```

10 Working With Genie

10.1 Introduction

We require $\sim 10^7$ differential cross section evaluations are required just in order to select an interaction channel for a given initial state. If we have been simulating in realistic detector geometry with $\sim 10^2$ different isotopes, the number of differential cross section evaluations, before even starting simulating the event kinematics, would rise to $\sim 10^9$. It is therefore advantageous to pre-calculate the cross section data. The event generation drivers can be instructed to to load the pre-computed data and estimate the cross section by numerical interpolation, rather than by performing numerous CPU-intensive differential cross section integrations. The cross section data are written out in XML format and, when loaded into GENIE, they are used for instantiating Spline objects.

- Generating cross-section splines is a CPU-intensive task as a large number of processes and numerical integration of steeply peaked differential cross-sections over extended, multi-dimensional kinematical phase spaces.
- When cross-section calculations are needed for multiple targets, it is often impractical to generate all splines in a single job. The task is typically split into smaller jobs which can be run on parallel in a batch farm.
- The multiple XML outputs of all the gmkspl jobs can be merged into a single XML file using GENIE's gspladd utility.

10.2 Generating cross-section splines

- gmkspl - A GENIE utility for generating the cross section splines for a specified set of modeled processes for a specified list of initial states. The cross section splines are written out in an XML file in the format expected by all other GENIE programs.

To calculate cross-sections for ν_μ (PDG code: 14) scattering off Fe^{56} (PDG code: 1000260560), and build splines with 10 knots in the energy range up to 0.1 GeV

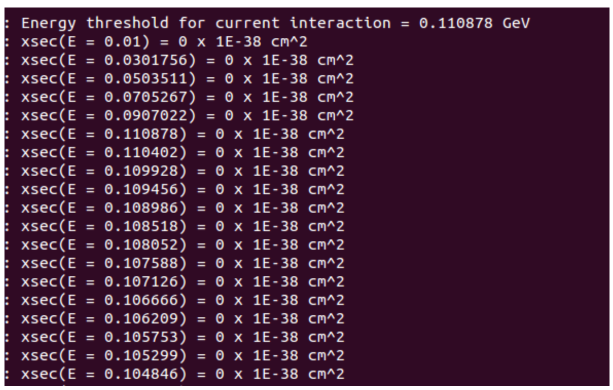
Listing 1: Generating cross-section splines

```
gmkspl -p 14 -t 1000260560 -n 10 -e 0.1
```

If we want for antineutrino also we can use -14 separated by a comma.

- **-p** Specifies the neutrino PDG codes.
- **-t** Specifies the target PDG codes.
- **-n** Specifies the number of knots per spline.
- **-e** Specifies the maximum neutrino energy in the range of each spline.

The spline creation in terminal looks like in the following figure.



You can download the xml file from `https://www.hepforge.org/archive/genie/data/2.12.8/`. The first option "DefaultPlusMECWithNC" contains both charged current and neutral current interaction cross-sections for muon neutrino with Fe^{56}.

https://www.hepforge.org/archive/genie/data/2.12.8/README_for_non-ups_use

```
What splines are available for R-2_12_6?

There are 4 pre-generated configurations:

${cfgname}                use w/ --event-generator-list
-------------------------------------------------------------------------------
DefaultPlusMECWithNC      "Default"           default set of models
                          "Default+CCMEC"          + CC-only Empirical MEC model
                          "Default+CCMEC+NCMEC"    + CC & NC Empirical MEC models
-------------------------------------------------------------------------------
DefaultPlusValenciaMEC    "Default"           default set of models
                          "Default+CCMEC"          + CC-only Valencia MEC model
-------------------------------------------------------------------------------
EffSFTEM                  "Default"           Effective Structure Function
                                              (replace FGMBodekRitchie)
                                              + Transverse Enhancement Model
-------------------------------------------------------------------------------
LocalFGNievesQEAndMEC     "Default+MEC"       Local Fermi Gas + Nieves (Valencia)
                                              model for QE + CC MEC
-------------------------------------------------------------------------------
AltPion                   "Default"           use BergerSehgal instead of
                                              ReinSehgal + add in DFR-CC + DFR-NC
-------------------------------------------------------------------------------
ValenciaQEBergerSehgalCOHRES "Default+CCMEC+1K" use BergerSehgal
                                                Valencia + add single Kaon

-------------------------------------------------------------------------------

using the command:

   cd ${TOPPATH}   # your chosen area in which to unpack the files
   tar xjf genie_xsec-2.12.8-noarch-${cfgname}.tar.bz2

results in the hierarchy:

genie_xsec
|__v2_12_8.version
|   |__NULL_${cfgname}
|__NULL
   |__${cfgname}
      |__ups
```

The xml file looks like the following figure.

```
<?xml version="1.0" encoding="ISO-8859-1"?>

<!-- generated by genie::XSecSplineList::SaveSplineList() -->

<genie_xsec_spline_list version="2.00" uselog="1">

<spline name="genie::AhrensNCELPXSec/Default/nu:-12;tgt:1000000010;N:2112;proc:Weak[NC],QES;" nknots="500">
        <knot> <E>    0.01000 </E> <xsec> 3.5935638244e-15 </xsec> </knot>
        <knot> <E>    0.01021 </E> <xsec> 3.7960303813e-15 </xsec> </knot>
        <knot> <E>    0.01043 </E> <xsec> 4.0068096158e-15 </xsec> </knot>
        <knot> <E>    0.01066 </E> <xsec> 4.2262367883e-15 </xsec> </knot>
        <knot> <E>    0.01089 </E> <xsec> 4.4546598821e-15 </xsec> </knot>
        <knot> <E>    0.01112 </E> <xsec> 4.6924400523e-15 </xsec> </knot>
        <knot> <E>    0.01136 </E> <xsec> 4.9399520870e-15 </xsec> </knot>
        <knot> <E>    0.01160 </E> <xsec> 5.1975848826e-15 </xsec> </knot>
        <knot> <E>    0.01185 </E> <xsec> 5.4657419317e-15 </xsec> </knot>
        <knot> <E>    0.01211 </E> <xsec> 5.7448418240e-15 </xsec> </knot>
        <knot> <E>    0.01237 </E> <xsec> 6.0353187615e-15 </xsec> </knot>
        <knot> <E>    0.01263 </E> <xsec> 6.3376230869e-15 </xsec> </knot>
        <knot> <E>    0.01290 </E> <xsec> 6.6522218255e-15 </xsec> </knot>
        <knot> <E>    0.01318 </E> <xsec> 6.9795992416e-15 </xsec> </knot>
        <knot> <E>    0.01346 </E> <xsec> 7.3202574083e-15 </xsec> </knot>
        <knot> <E>    0.01375 </E> <xsec> 7.6747167911e-15 </xsec> </knot>
        <knot> <E>    0.01405 </E> <xsec> 8.0435168461e-15 </xsec> </knot>
        <knot> <E>    0.01435 </E> <xsec> 8.4272166315e-15 </xsec> </knot>
        <knot> <E>    0.01466 </E> <xsec> 8.8263954332e-15 </xsec> </knot>
        <knot> <E>    0.01497 </E> <xsec> 9.2416534044e-15 </xsec> </knot>
        <knot> <E>    0.01529 </E> <xsec> 9.6736122182e-15 </xsec> </knot>
```

10.3 Event Generation in GENIE

- gevgen - A generic GENIE event generation application for simple event generation cases. The application handles event generation for neutrinos scattered off a given target (or 'target mix'). It doesn't support event generation over ROOT/Geant4-based detector geometries. It handles mono-energetic flux neutrinos or neutrino fluxes described in simple terms (either via a functional form, a vector file or a ROOT TH1D histogram).

Listing 2: Syntax for gevgen

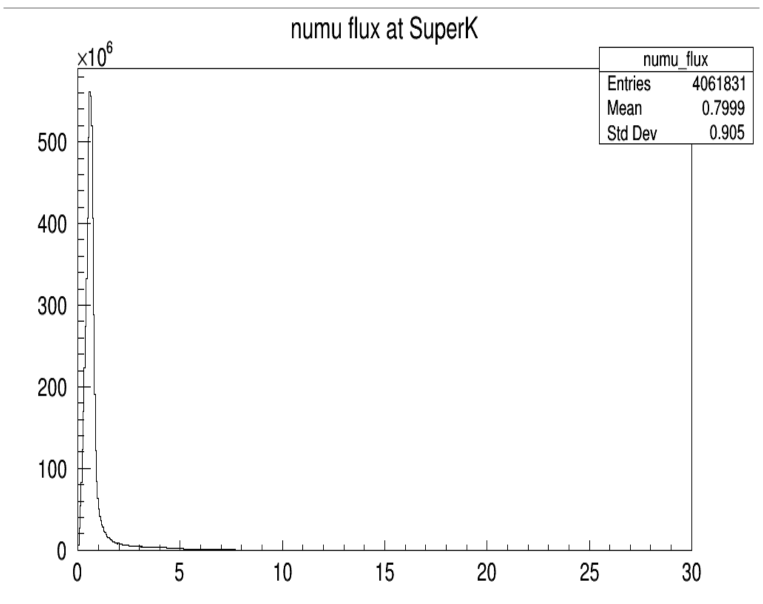
```
gevgen [-h][-r run#] -n nev -p neutrino_pdg -t target_pdg
 -e energy [-f flux][-w] [-seed random_number_seed]
 [--cross-section xml_file] [--event-generator-list
  list_name] [--message-thresholds xml_file] [--unphysical
  -event-mask mask][--event-record-print-level level]
[--mc-job-status-refresh-rate rate][--cache-file root_file]
```

The neutrino events generated was ν_μ (PDG code: 14) scattering off Fe^{56} (PDG code: 1000260560). This was done using the following command

Listing 3: Command for gevgen

```
gevgen -n 10000 -p 14 -t 1000260560 -e 0,10 --run 10 -f
/opt/GENIE-Generator_v2.12.8/data/flux/t2ksk.root,numu_flux --see
2989819 --cross-sections /home/jim/genie/genie_xsec/
v2_12_8/NULL/DefaultPlusMECWithNC/data/gxspl-FNALsmall.xml
```

The -f tag is for flux generator spectrum. Here t2ksk.root corresponds to the flux spectrum in superK which is as shown below.



The gevgen interaction summary is shown below. Also the same can be found in output status file.

```
------------------------------------------------------------------------------------------------
GENIE Interaction Summary
------------------------------------------------------------------------------------------------
[-] [Init-State]
 |--> probe        : PDG-code = 14 (nu_mu)
 |--> nucl. target : Z = 26, A = 56, PDG-Code = 1000260560 (Fe56)
 |--> hit nucleon  : PDC-Code = 2112 (neutron)
 |--> hit quark    : no set
 |--> probe 4P     : (E =     0.701141, Px =     0.000000, Py =     0.000000, Pz =     0.701141)
 |--> target 4P    : (E =    52.089777, Px =     0.000000, Py =     0.000000, Pz =     0.000000)
 |--> nucleon 4P   : (E =     0.927820, Px =    -0.196354, Py =     0.074695, Pz =    -0.109214)
[-] [Process-Info]
 |--> Interaction : Weak[CC]
 |--> Scattering  : QES
[-] [Kinematics]
 |--> *Selected* Bjorken x = 0.815494
 |--> *Selected* Inelasticity y = 0.281620
 |--> *Selected* Momentum transfer Q2 (>0) = 0.333974
 |--> *Selected* Hadronic invariant mass W = 0.938270
[-] [Exclusive Process Info]
 |--> charm prod.  : false |--> strange prod.  : false
 |--> f/s nucleons : N(p) = 0 N(n) = 0
 |--> f/s pions    : N(pi^0) = 0 N(pi^+) = 0 N(pi^-) = 0
 |--> resonance    : [not set]
------------------------------------------------------------------------------------------------
```

The status file shows the mother daughter information for each event the following shows the corresponding information for the event number 9950

```
|------------------------------------------------------------------------------------------------|
|GENIE GHEP Event Record [print level:   3]                                                       |
|------------------------------------------------------------------------------------------------|
| Idx |       Name | Ist |        PDG |   Mother  | Daughter  |     Px |     Py |     Pz |      E |      m |
|------------------------------------------------------------------------------------------------|
|   0 |      nu_mu |   0 |         14 |  -1 |  -1 |   4 |   4 |  0.000 |  0.000 |  4.591 |  4.591 |  0.000 |
|   1 |       Fe56 |   0 | 1000260560 |  -1 |  -1 |   2 |   3 |  0.000 |  0.000 |  0.000 | 52.090 | 52.090 |
|   2 |     proton |  11 |       2212 |   1 |  -1 |   5 |   5 | -0.179 | -0.090 | -0.124 |  0.928 | **0.938 | M = 0.897
|   3 |       Mn55 |   2 | 1000250550 |   1 |  -1 |  12 |  12 |  0.179 |  0.090 |  0.124 | 51.162 | 51.162 |
|   4 |        mu- |   1 |         13 |   0 |  -1 |  -1 |  -1 |  0.384 | -0.874 |  2.641 |  2.810 |  0.106 | P =
(-0.137,0.311,-0.940)
|   5 |   HadrSyst |  12 | 2000000001 |   2 |  -1 |   6 |   8 | -0.563 |  0.784 |  1.826 |  2.709 | **0.000 | M = 1.752
|   6 |     proton |  14 |       2212 |   5 |  -1 |   9 |   9 | -0.551 |  0.140 |  0.787 |  1.350 |  0.938 | FSI = 3
|   7 |        pi+ |  14 |        211 |   5 |  -1 |  10 |  10 | -0.124 |  0.611 |  0.982 |  1.171 |  0.140 | FSI = 1
|   8 |        pi0 |  14 |        111 |   5 |  -1 |  11 |  11 |  0.112 |  0.034 |  0.058 |  0.188 |  0.135 | FSI = 3
|   9 |     proton |   1 |       2212 |   6 |  -1 |  -1 |  -1 | -0.304 |  0.236 |  0.892 |  1.350 |  0.938 |
|  10 |        pi+ |   1 |        211 |   7 |  -1 |  -1 |  -1 | -0.124 |  0.611 |  0.982 |  1.171 |  0.140 |
|  11 |        pi0 |   1 |        111 |   8 |  -1 |  -1 |  -1 |  0.073 |  0.027 |  0.104 |  0.188 |  0.135 |
|  12 |   HadrBlob |  15 | 2000000002 |   3 |  -1 |  -1 |  -1 | -0.029 |  0.001 | -0.027 | 51.162 | **0.000 | M = 51.162
|------------------------------------------------------------------------------------------------|
|       Fin-Init:                                           |  0.000 |  0.000 |  0.000 |  0.000 |        |
|------------------------------------------------------------------------------------------------|
|       Vertex:        nu_mu @ (x =     0.00000 m, y =     0.00000 m, z =     0.00000 m, t =    0.000000e+00 s) |
|------------------------------------------------------------------------------------------------|
| Err flag [bits:15->0] : 0000000000000000    |  1st set:                                        none |
| Err mask [bits:15->0] : 1111111111111111    |  Is unphysical:    NO |   Accepted:   YES           |
|------------------------------------------------------------------------------------------------|
| sig(Ev) =      3.17399e-37 cm^2  | d2sig(x,y;E)/dxdy =      8.14213e-37 cm^2      | Weight =       1.00000 |
|------------------------------------------------------------------------------------------------|
```

The output root file gntp.0.ghep.root is converted into a readable file using the "gntpc" command. Here "gst" stands for the standard GENIE Summary Tree format.

Listing 4: Generating cross-section splines

```
gntpc -i gntp.0.ghep.root -f gst -n 10000 -o output.root
```