Proposal to Measure Muon-induced Neutron Background at CERN

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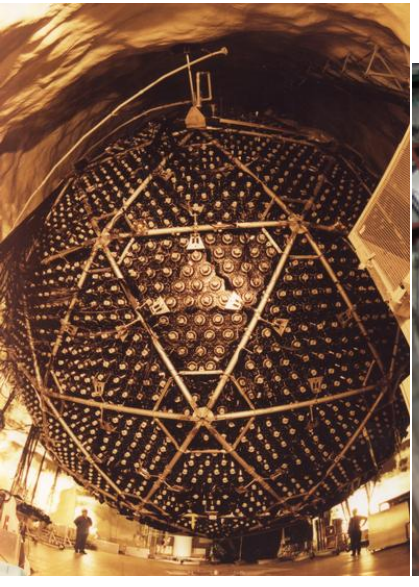
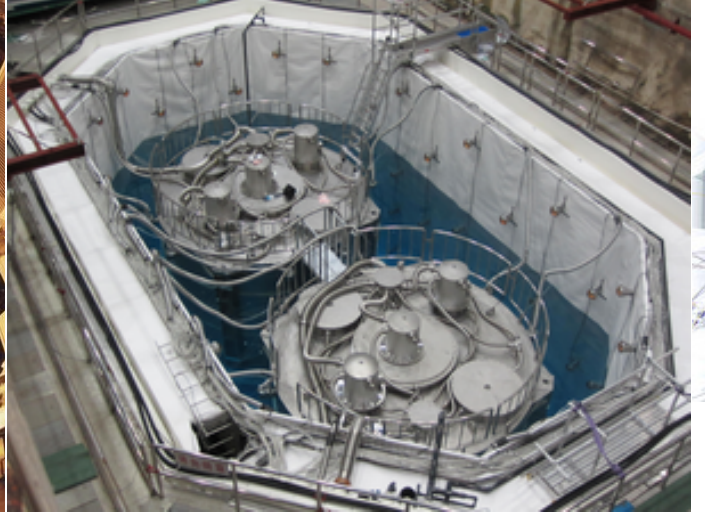
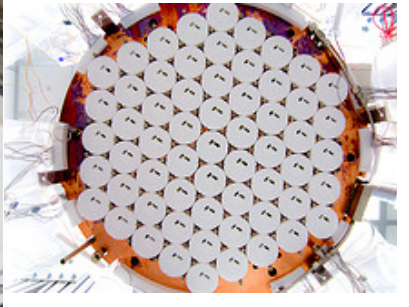
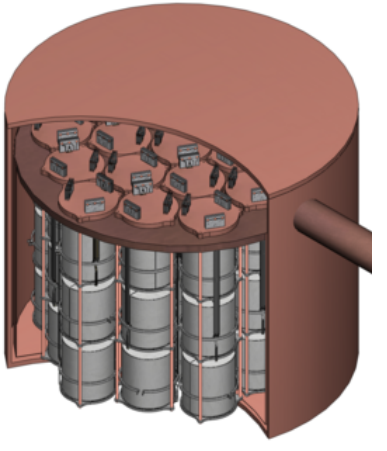
AARM Workshop @ U. Minnesota

June 23, 2012

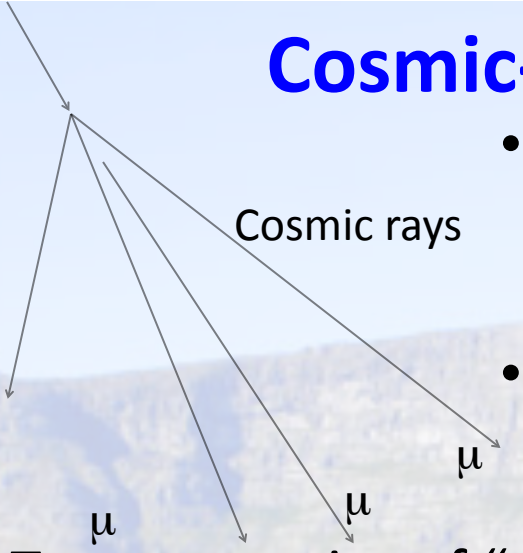








Cosmic-Ray Muon-Induced Backgrounds



- Rare searches need to go deep underground to shield detectors from cosmogenic backgrounds
- Mean muon energy at some of the deep underground labs is around 300 GeV

- Two categories of "problematic" muon-induced backgrounds:
  - Fast neutrons
  - Radioactive isotopes, such as ^{9}Li, ^{8}He, ^{11}C, ^{7}Be, etc. (isotope production is linked to neutron flux)

- Fast neutron is difficult to shield and is one of the most serious backgrounds for dark matter, $0\nu\beta\beta$, and other searches

- Modeling of these backgrounds has proven to be very challenging

- Underground sciences would greatly benefit from more comprehensive set of muon-induced neutron production data

- Complementary approaches to study muon-induced neutron production:
  - In situ measurements in underground labs
  - Dedicated measurements in a controlled environment (e.g. beamline)

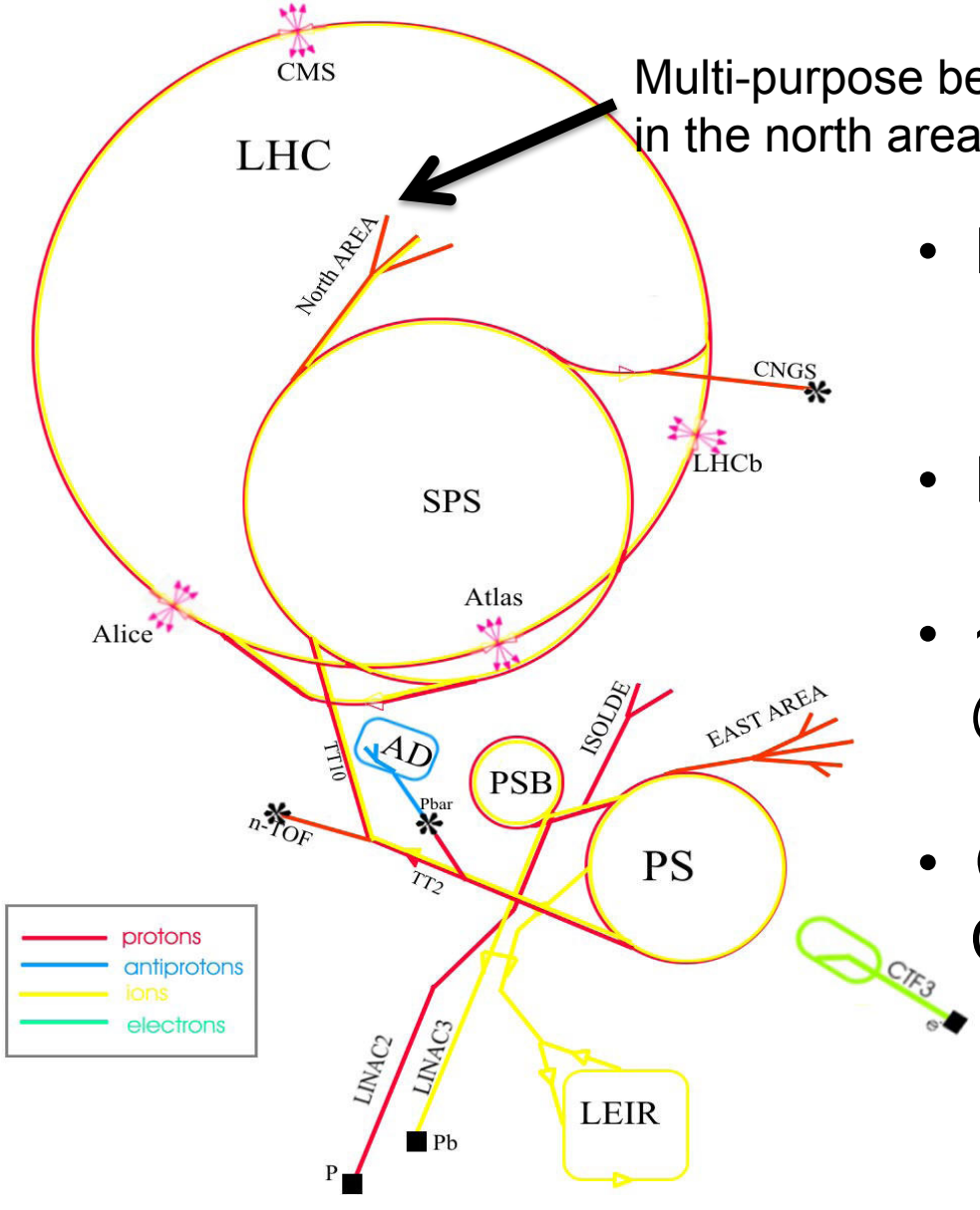
- Looking at the same problem from two different ends. Very different systematic issues

- Limited data available from dedicated muon-beam experiment. The primary source of information is from NA55 (~15 years ago)

- We propose to carry out a new experiment using the muon beam at CERN to systematically measure neutron production

- The purpose of this presentation is to solicit feedback from experts in this workshop

CERN ACCELERATOR COMPLEX



Multi-purpose beamlines in the north area

- M2 beamline in the North Area provides high intensity muons
- Muon energy up to 280 GeV
- ~10^8 muons per spill @ 160 GeV (45 sec duty cycle)
- Currently being used by the COMPASS experiment

Proposal

- M2 beamline is an ideal place to study the production properties of muon-induced neutrons

- We would like to mount a small fixed target experiment to systematically measure neutron production:

    - rates, angular distributions, and energy spectrum

    - for different targets (solids and liquids?)

    - from thin to thick targets

    - scan the muon energy from ~100 GeV to 280 GeV

- Anything else we should measure?

Interested Parties in this Proposal

University of Houston, Houston, Texas

- Toni Empl
- Ed V. Hungerford
- Kwong Lau

University of Sheffield, UK

- Vitaly Kudryavtsev

LBNL- Physics Division

- Cheng-Ju Lin
- Kam-Biu Luk
- Yasunori Nakajima
- Herbert Steiner
- Patrick Tsang
- Pedro Ochoa

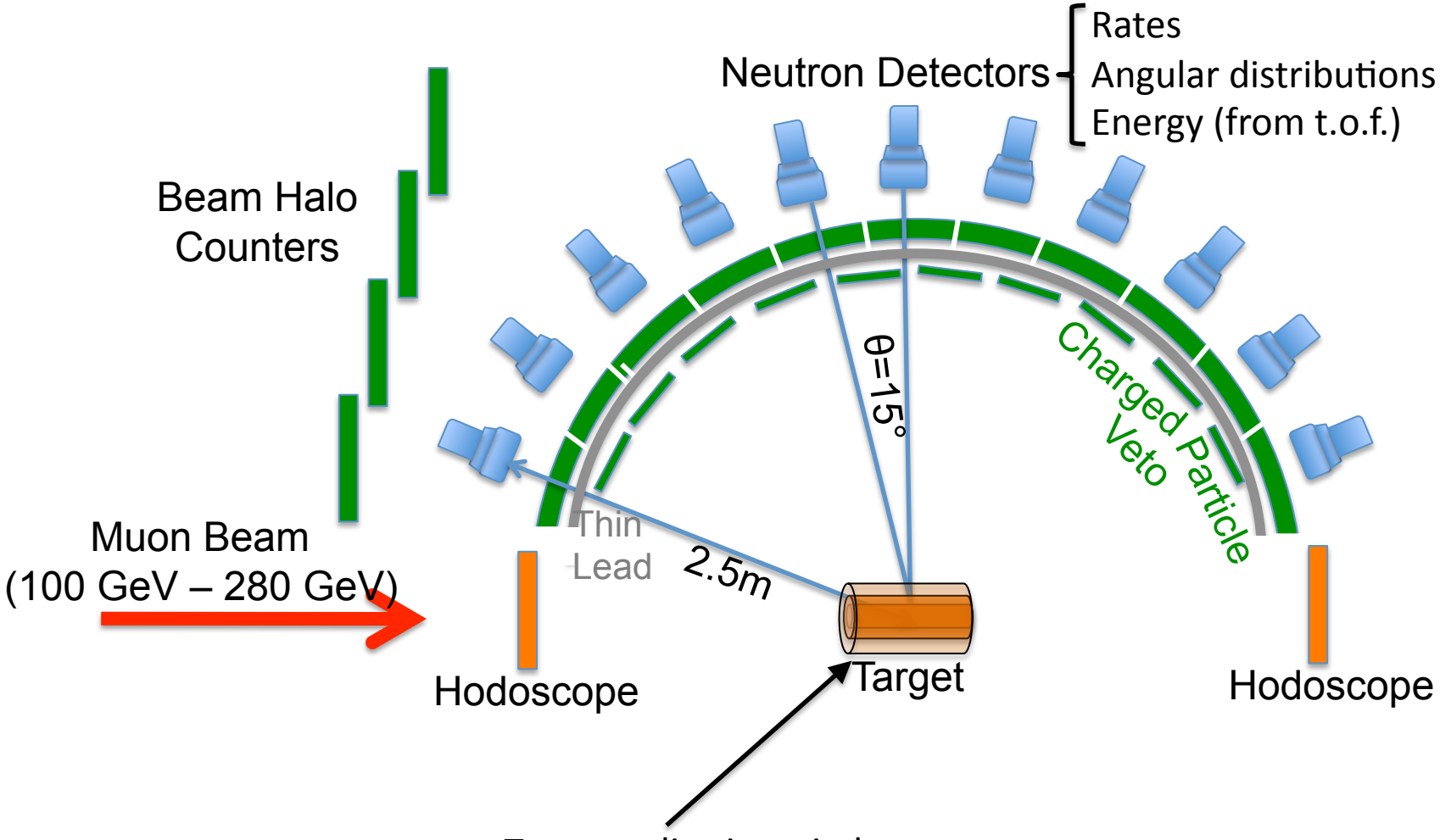
LBNL- Nuclear Science Division

- Yuen-Dat Chan
- Jason Detwiler (U. Washington)
- Brian Fujikawa
- Gabriel Orebi-Gann
- James Loach
- Ryan Martin
- Alan Poon

We welcome new members!!

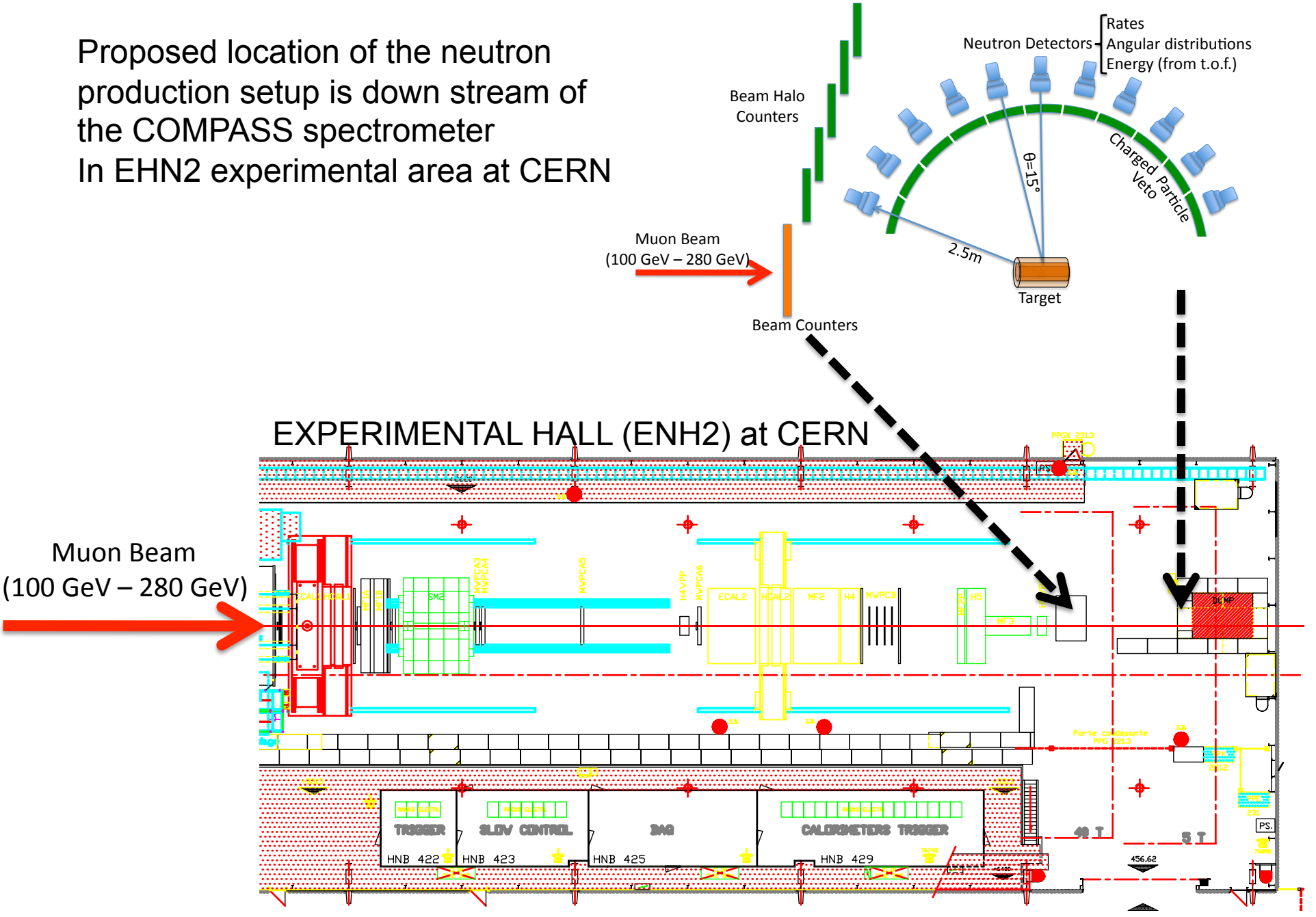
Lawrence Berkeley National Laboratory

Cartoon Sketch of the Neutron Production Experiment



- Target radius is varied to measure neutron production vs. target thickness.
- Potential targets: graphite, copper, lead, H_20, liquid scintillator, etc.

Proposed location of the neutron production setup is down stream of the COMPASS spectrometer
In EHN2 experimental area at CERN



- Met with both COMPASS spokespeople this past winter at CERN and discussed the proposal to place our setup downstream of the COMPASS spectrometer

- Presented the preliminary proposal at one of their Collaboration meetings as well

- Technical details need to be worked out, but no major logistic hurdles to run parasitically with COMPASS

- COMPASS has been approved to run in 2012, 2014-2016. The latter two years will be mostly muon runs

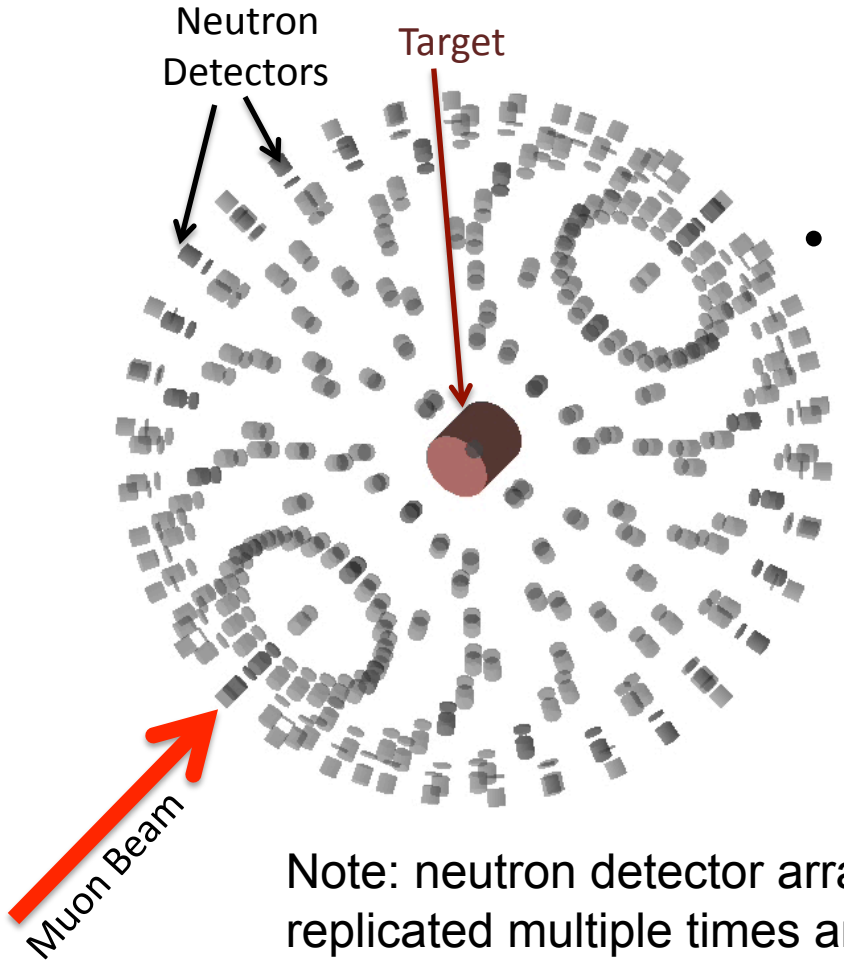
- COMPASS is only interested in muon beam < 200 GeV. Will need to negotiate with COMPASS and get approval from CERN for some dedicated higher energy runs

Current Hardware R&D Efforts

- Will use off-the-shelf technology for most pieces of the experimental setup to expedite the construction and keep the cost down
- Commercial HEP VME/CAMAC based DAQ system
- Liquid scintillator (e.g. BC501A/NE213) based neutron detector. Can be purchased commercially. Also collaborating with Sandia and LLNL neutron detector experts on the option of building them in-house
- Good understanding neutron detection efficiency is a critical component of the program. Looking at various neutron beam facilities to calibrate the neutron detectors

Simulation Efforts

- Jason Detwiler has implemented a simple GEANT4 model
- Toni Empl plans to perform similar studies in FLUKA



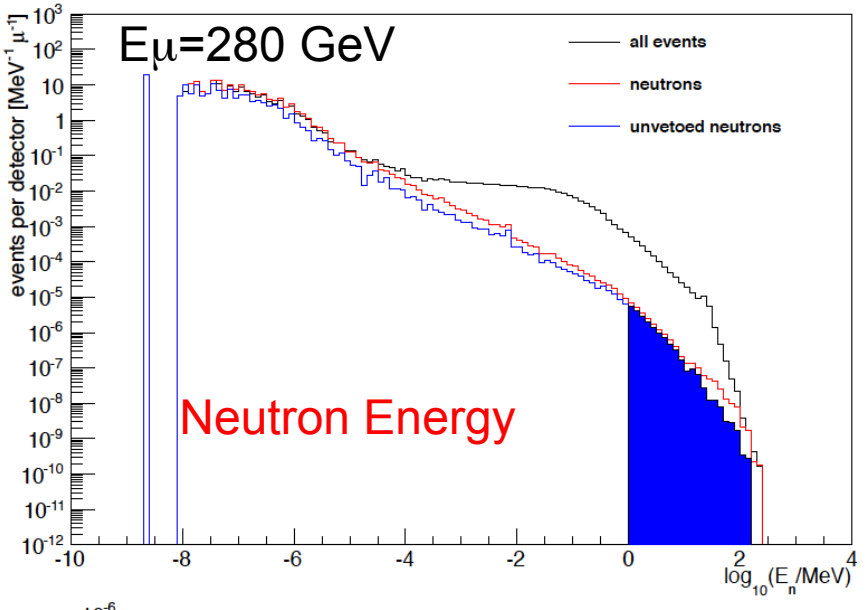
- Current GEANT4 model is sufficient for the purpose of detector optimization and sensitivity estimates
- Also using simulation to study issues relating to muon pile-ups
  - Need to implement a more detailed neutron detector model when the neutron detector choice and design are finalized

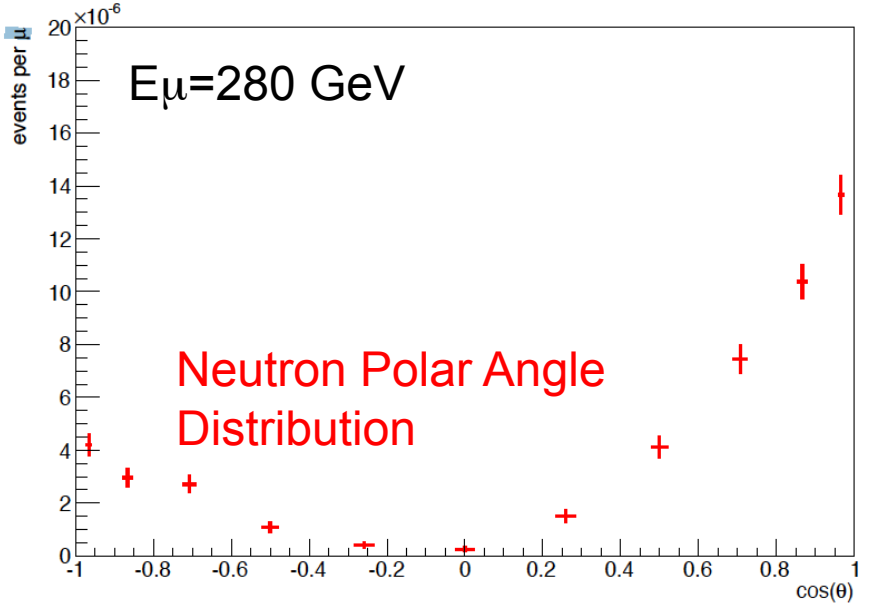
Note: neutron detector array in GEANT4 model is replicated multiple times around phi for study purposes

Sample GEANT4 Studies

(From J. Detwiler)

G4.9.5.b01 Shielding Physics List
Cylindrical copper target with radius of 50cm





Average # of "Counts" per Neutron Detector per 1M muons on target

Eμ (GeV)	Radius (cm)	All Events	Neutrons	Neutrons (unvetoed)
100	12.5	246	5.4	4.6
100	25	235	3.0	2.4
100	50	233	2.8	2.2
190	12.5	375	8.2	6.6
190	25	367	5.2	3.9
190	50	365	4.6	3.4
280	12.5	501	11.1	8.7
280	25	492	7.1	5.2
280	50	485	6.2	4.4

Tentative Timeline

Calendar Year	Plans and Milestones
2012	Simulation: detector optimization and sensitivity studies Milestone: survey "environmental" backgrounds in EHN2 while COMPASS is running in muon mode (November)
2013	No beam at CERN Milestone:Finalize experimental design and submit formal proposal to CERN SPSC for approval
2014	Construct and commission experimental setup COMPASS plans to run mostly in hadron mode this year Some limited opportunity to test and commission setup with muon beam
2015	Take data parasitically with COMPASS
2016	Take data parasitically with COMPASS Dedicated high energy scans

SUMMARY

- We propose to carry out an experiment to systematically measure muon-induced neutron production at CERN
- Results would greatly benefit many current and future underground experiments
- Discussion is ongoing with COMPASS. So far, no major obstacles in running parasitically with COMPASS
- Plan to survey backgrounds in EHN2 later this year to get a more quantitative estimate of the “environmental” background
- Target to have a comprehensive proposal ready early next year for CERN SPSC
- Look forward to productive discussions with participants here!