Status of the Neutron Production Experiment Proposal

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COMPASS Collaboration Meeting
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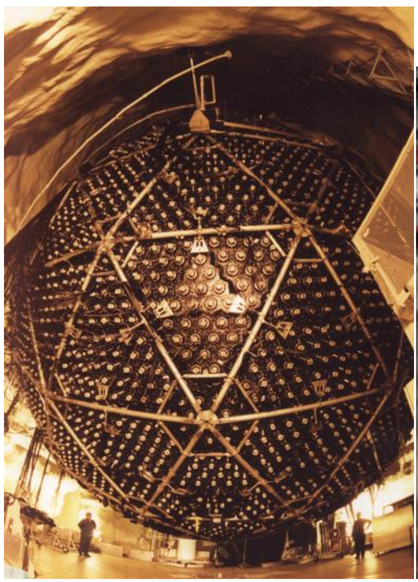
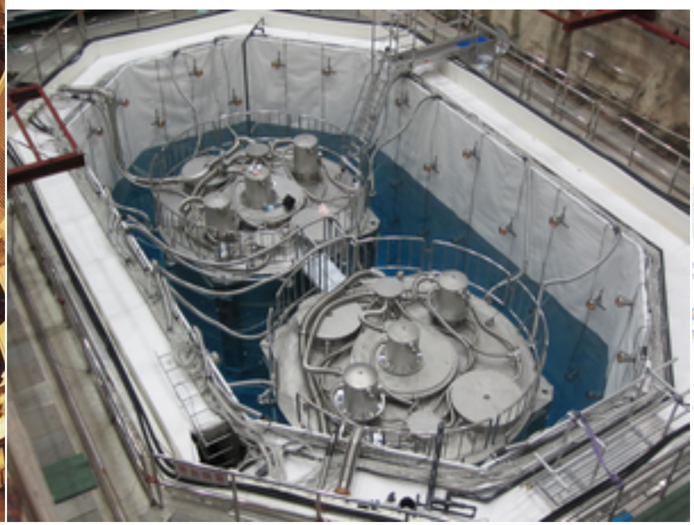
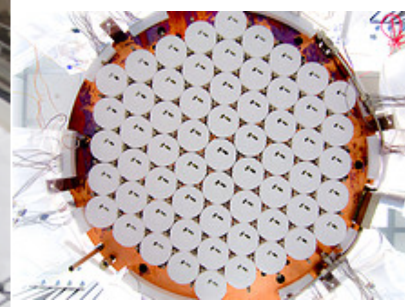
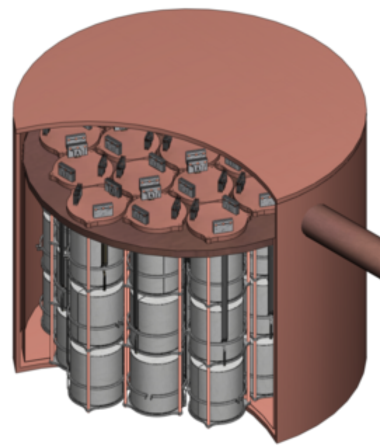


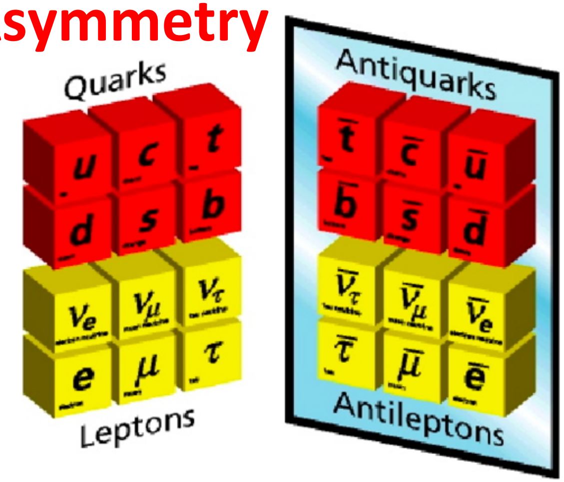




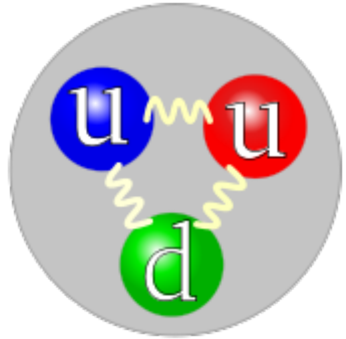


SOME OPEN QUESTIONS IN PARTICLE PHYSICS

Matter vs Anti-Matter Asymmetry

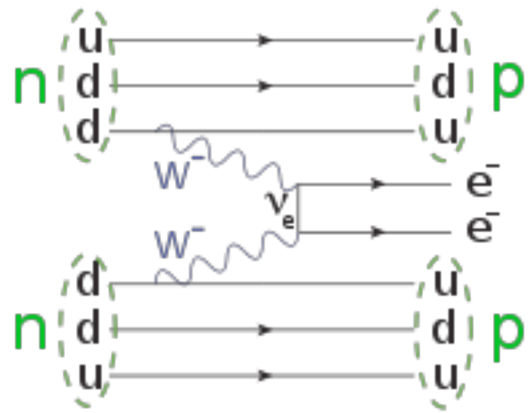


Nature of Dark Matter

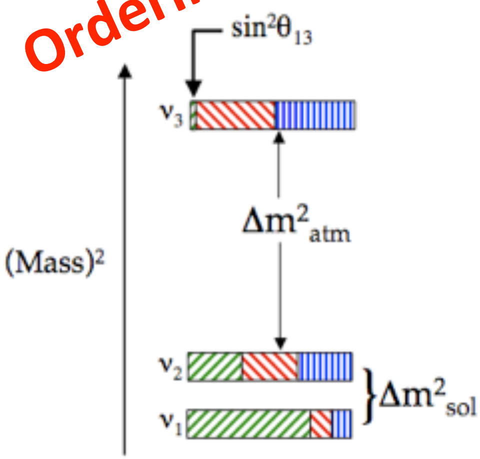


Proton Decay

ν (Dirac or Majorana)



Ordering of ν mass

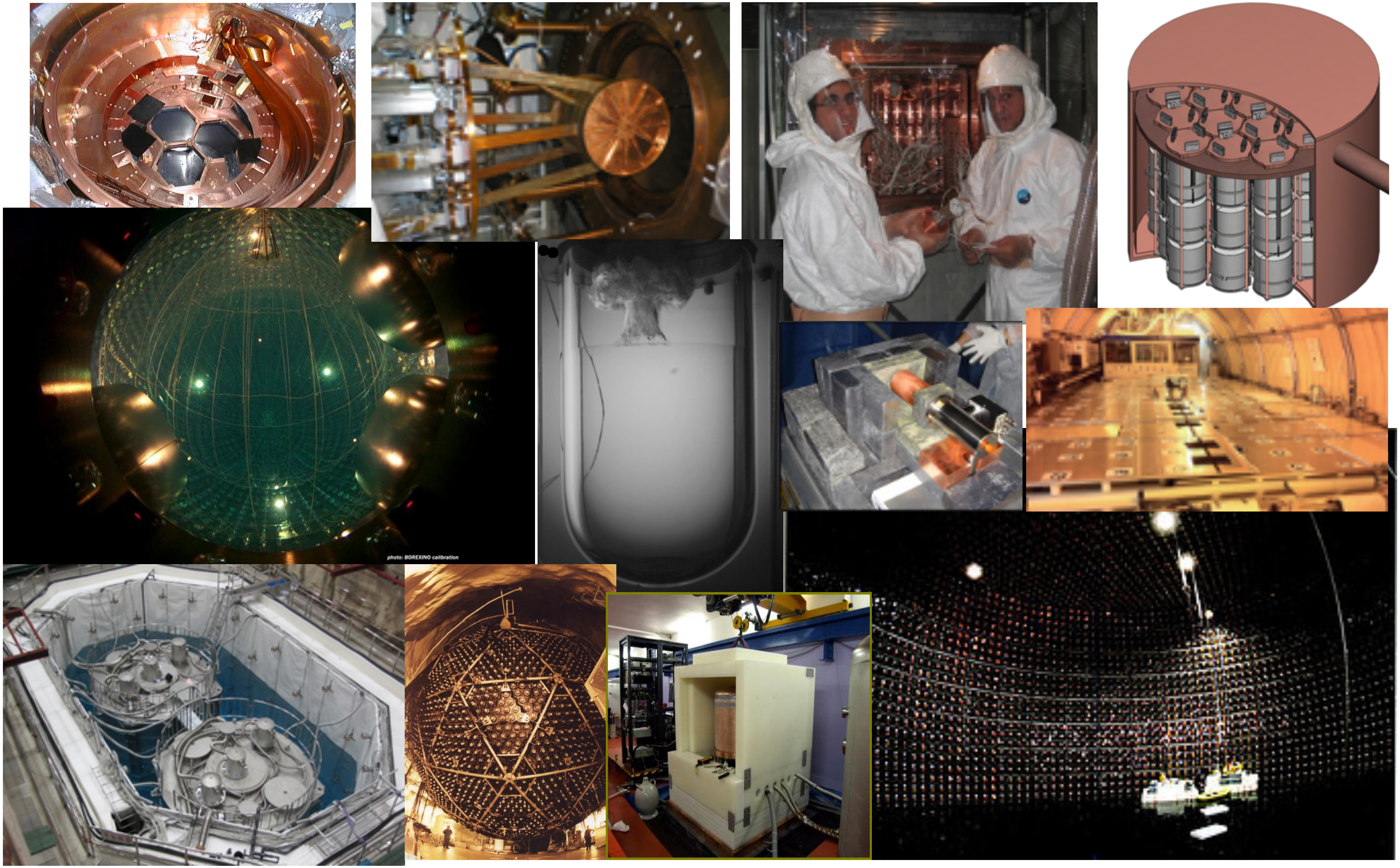


CP Violation in ν

θ_{13}

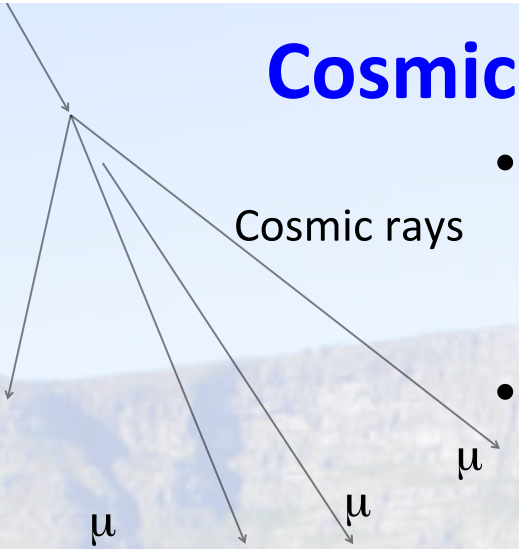
$$\begin{pmatrix}\cos\theta_{12} & \sin\theta_{12} & 0\\ -\sin\theta_{12} & \cos\theta_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13}\end{pmatrix}\begin{pmatrix}1 & 0 & 0\\ 0 & \cos\theta_{23} & \sin\theta_{23}\\ 0 & -\sin\theta_{23} & \cos\theta_{23}\end{pmatrix}$$

Plethora of Experiments to Tackle Those Mysteries



THEY ARE ALL UNDERGROUND EXPERIMENTS !!

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)

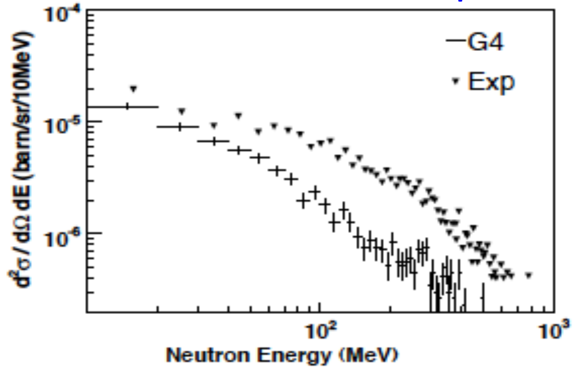
- Modeling of these backgrounds have proven to be very challenging

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

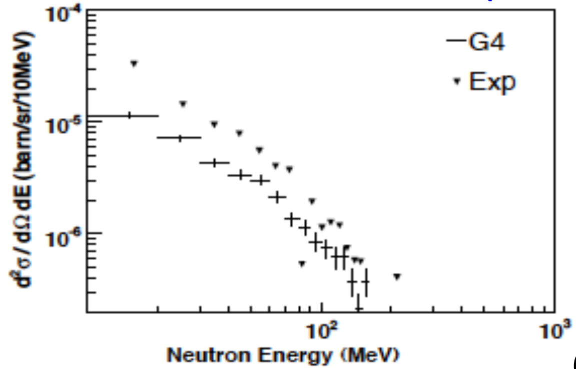
- We would like to measure muon-induced neutron production in a controlled environment → beamline

- NA55 took data at M2 ~15 years ago was the last (and only?) expt that measured fast neutron productions at a muon beamline
- However, they used a "thin" target for spallation studies and only one muon beam energy (190 GeV)
- After all these years, differences between data and simulation (GEANT4, FLUKA) are still not fully understood

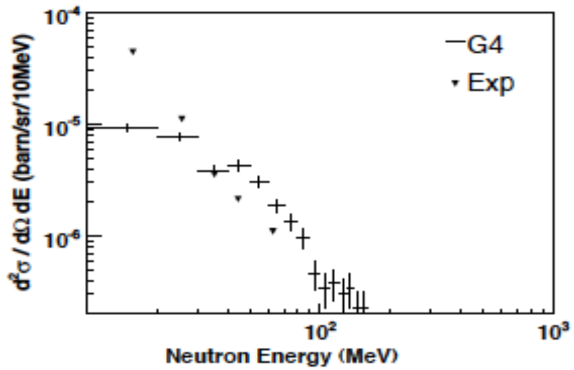
GEANT4 and NA55 Comparisons (Marino *et al.*, NIM A582, (2007), 611)



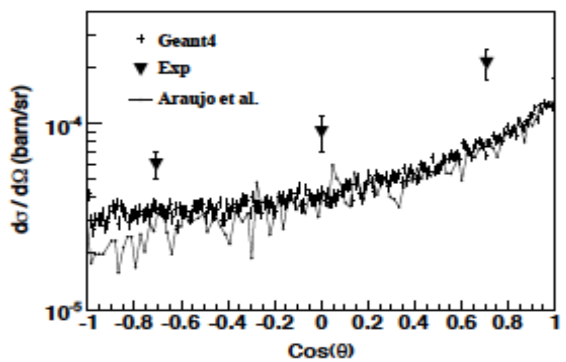
(a) $\theta = 45°$



(b) $\theta = 90°$



(c) $\theta = 135°$



(d) Angular distribution.

Other references:
NIM A545 (2005), 398
Astropart. Phys. 31 (2009) 366

GOAL of the Experiment

Provide a systematic set of data that can be used to better model fast neutron production for underground experiments

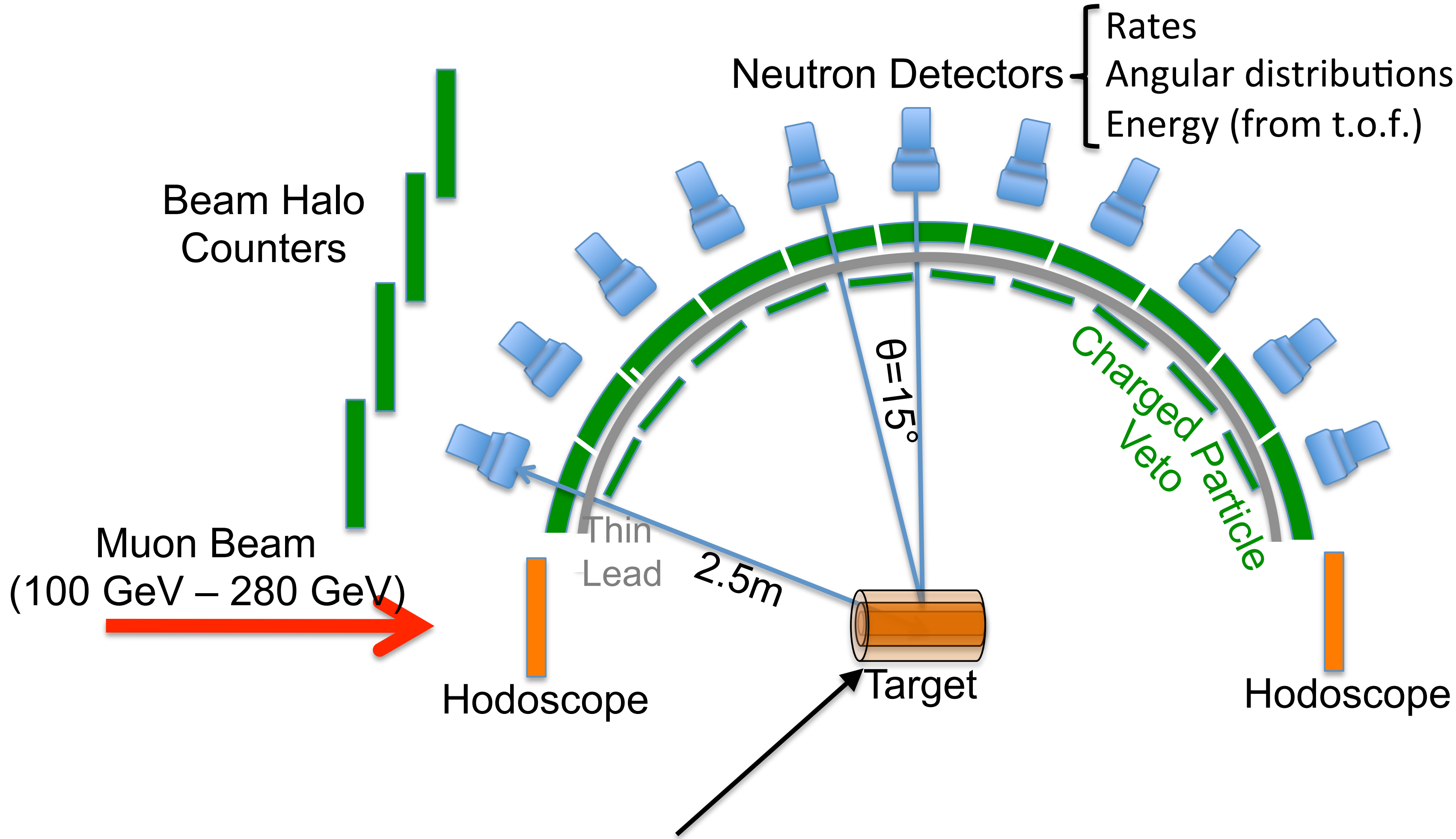
We want to measure neutron production properties:

- Rates and multiplicity
- Neutron energy spectrum
- Neutron angular distribution

We also want to make the measurements for:

- Different targets (lead, copper, graphite, H_2O, etc.)
- Target thicknesses (probe different aspect of neutron production)
- and a range of muon beam energies (100 to 280 GeV)

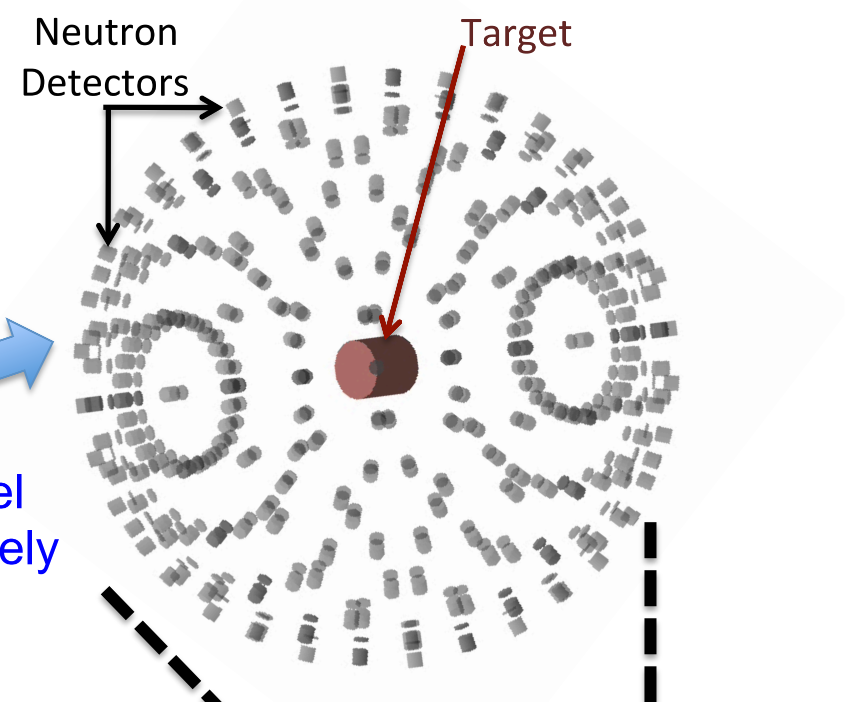
Cartoon Sketch of the Neutron Production Experiment



- Target radius is varied to measure neutron production vs. target thickness.
- Potential targets: graphite, copper, lead, H_2O, liquid scintillator, etc.

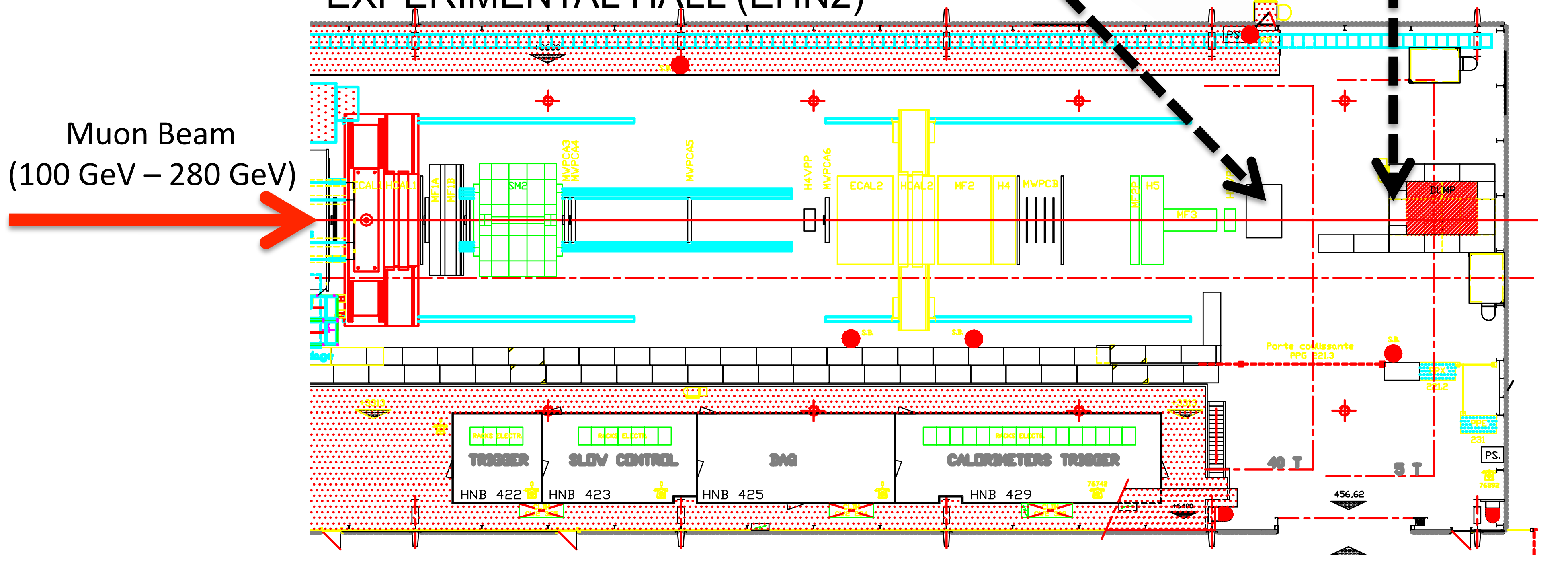
Potential locations:

- Behind the COMPASS spectrometer in EHN2
- In Bat. 906 (downstream of EHN2)



Our current GEANT4 model for studies. Final design likely to have fewer detectors

EXPERIMENTAL HALL (EHN2)



Beam Test at M2 (2012)*

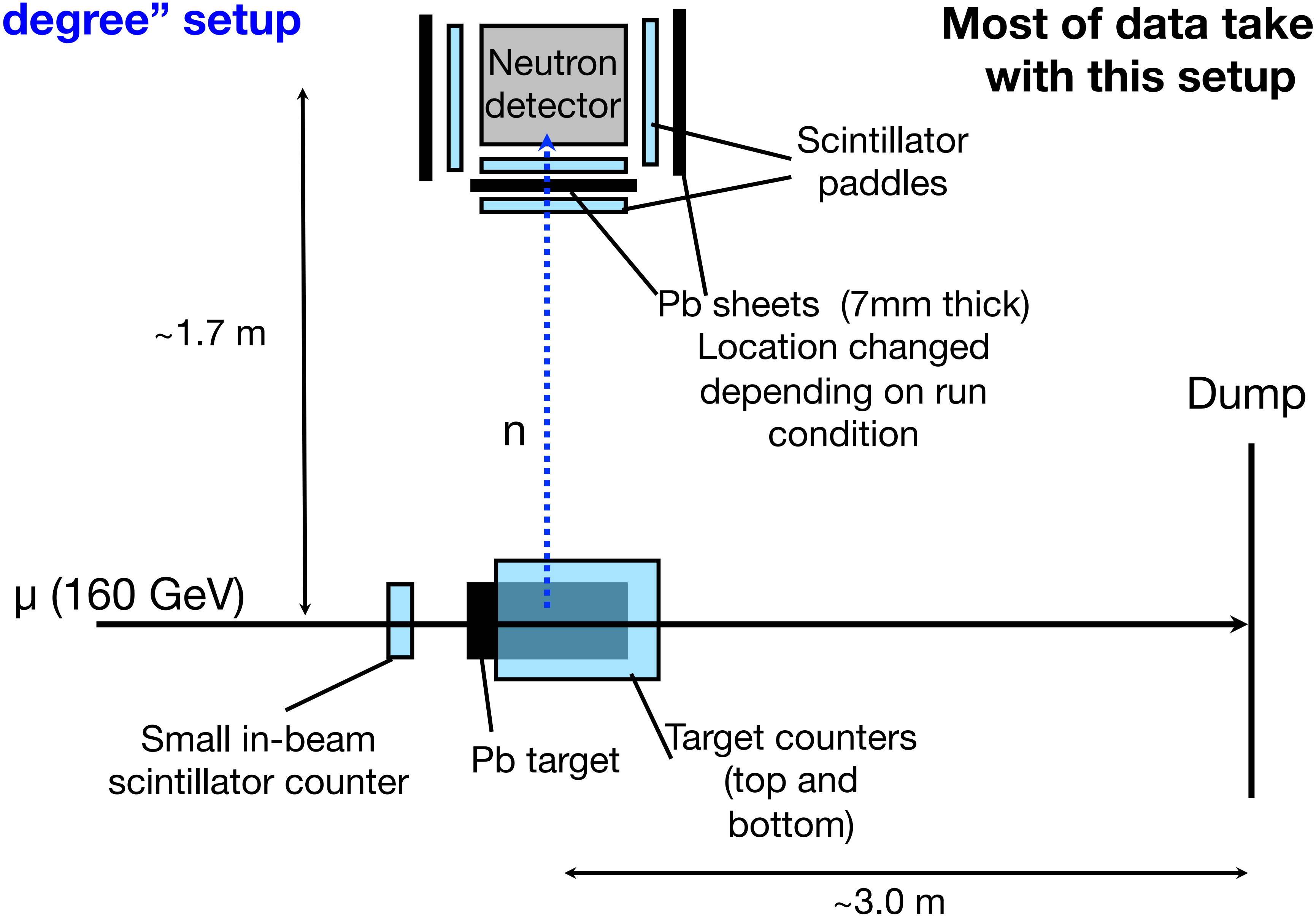
- At last my presentation back in 2011, Alain and others strongly recommended that we take some measurements first to look for potential problems
- Conducted a beam test this past fall at M2 to study the feasibility of using the beamline to measure neutron production properties
- Surveyed beam backgrounds and evaluated neutron detector performance in beam environment
- Lau Gatignon also conducted a short test to demonstrate the feasibility and stability of running M2 at 280 GeV
- The beam test was very successful and addressed many technical concerns. Initial goal was just a feasibility study, but now trying to extract some physics results from the data

* **Many thanks to the COMPASS collaboration and CERN accelerator group**

Beam Test Setup

“90 degree” setup

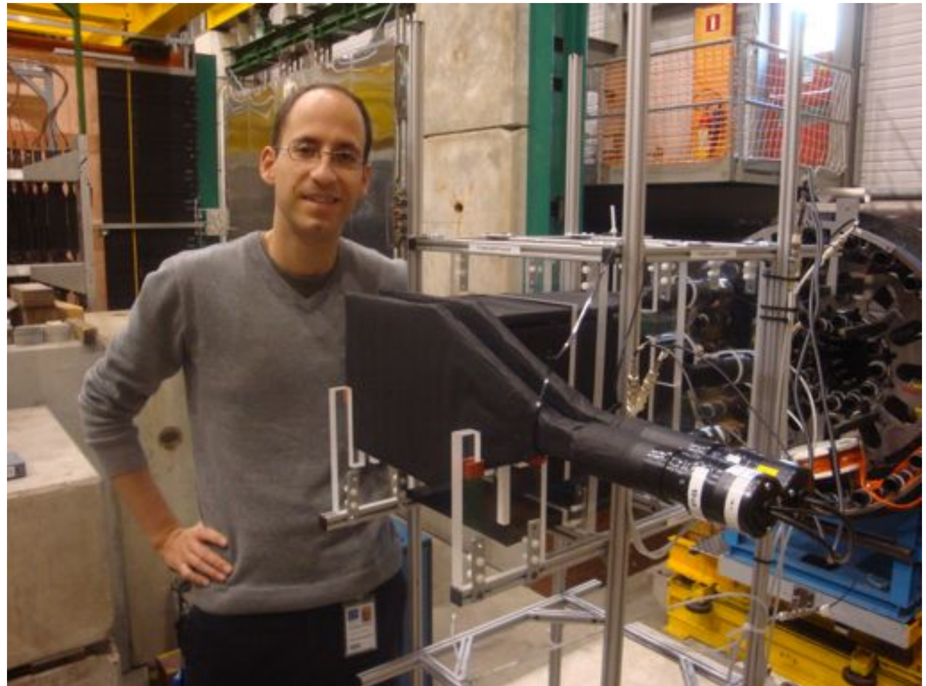
Most of data taken with this setup



Beam Test Installation and Commissioning Photos

Installing the Neutron Detector Assembly

Close-up of detector assembly



DAQ rack

Looking at initial beam data

Sample list of Data

Physics Runs (~0.1 MeV trigger threshold)

ND Location	Beam	Run #	Comment
90 degree	160 GeV μ^-	1181-1193	2 Pb target
90 degree	160 GeV μ^+	1203-1213	1 Pb target
90 degree	160 GeV μ^+	1215-1227	2 Pb target
90 degree	160 GeV μ^-	1234-1244	2 Pb target

Physics Runs (1.0 MeV trigger threshold)

ND Location	Beam	Run #
90 degree	160 GeV μ^-	1289-1297
45 degree	160 GeV μ^+	1368-1391
45 degree	160 GeV μ^-	1418-1440
135 degree	160 GeV μ^-	1441-1443

Trigger Efficiency Study Sample

ND Location	Beam	Run #	Trigger Condition
90 degree	160 GeV μ^- (low intensity)	122-1231 1232-1233	ND+small paddle
90 degree	160 GeV μ^-	1299-1303	ND + target top
90 degree	160 GeV μ^-	1304-1329	ND + target bot
90 degree	160 GeV μ^-	1330-1332 1333-1334	ND only. High and low intensity
135 degree	160 GeV μ^-	1444-1453	ND only

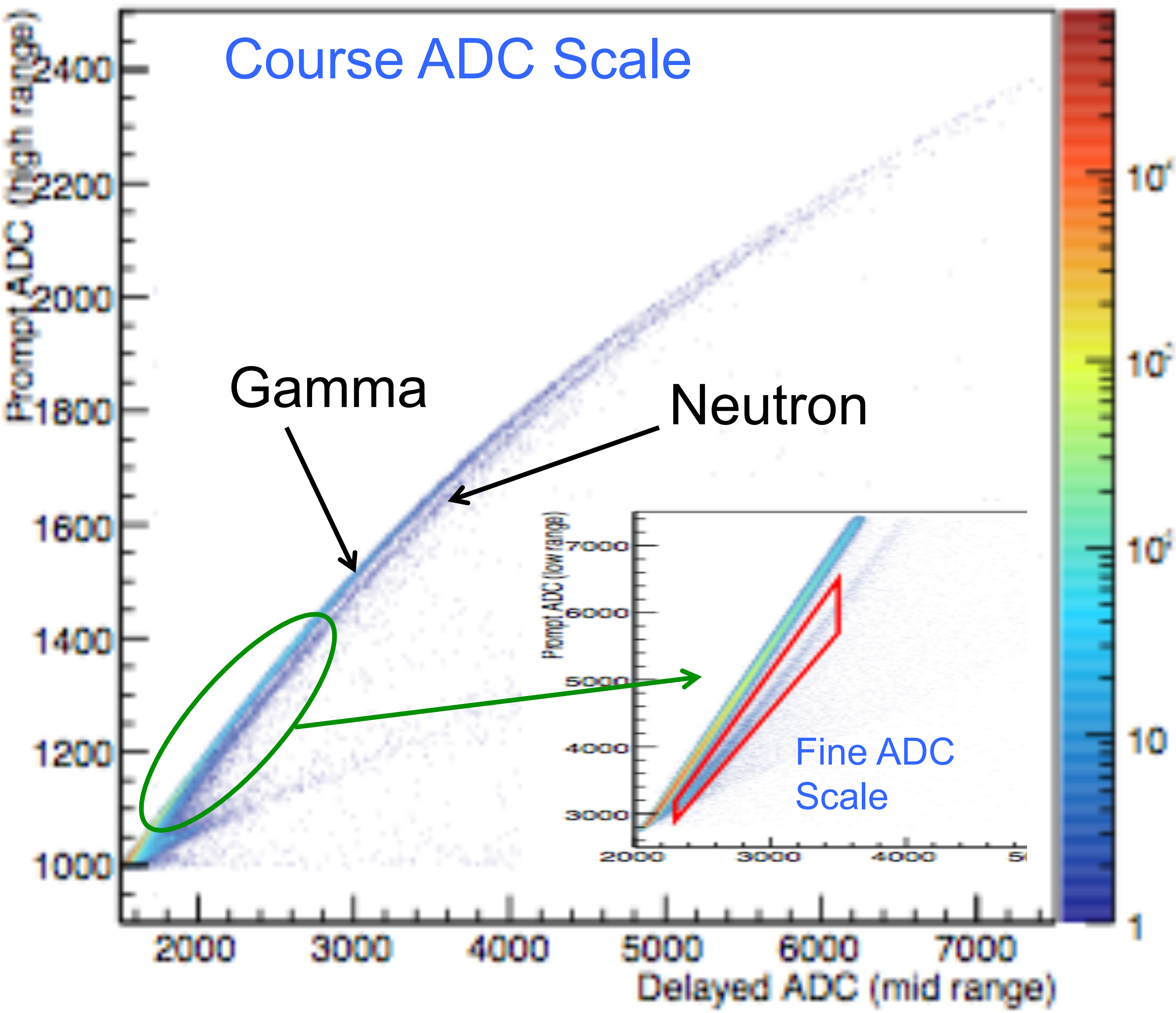
Source Calibration

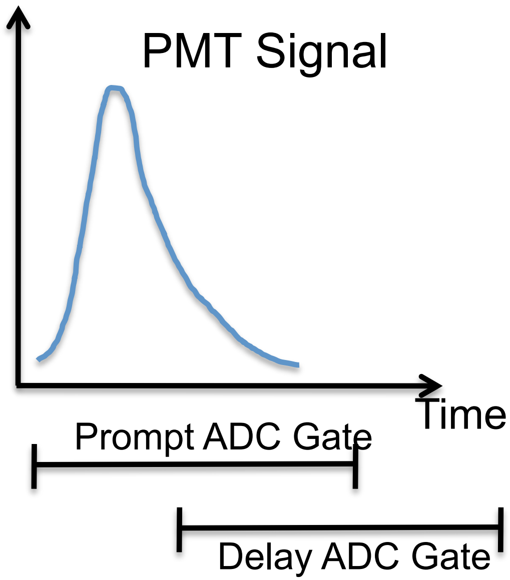
Source Type	Run #	Comments
Cf^{252}	1194, 1197	HV=-1.3KV
Cf^{252}	1199	HV=-1.4KV
Cf^{252}	1202	HV=-1.5KV
Co^{60}	1352-1362	----
Cf^{252}	1368-1391	----

+ other running configurations (e.g. target in/out, different target materials, etc.)

Preliminary Results

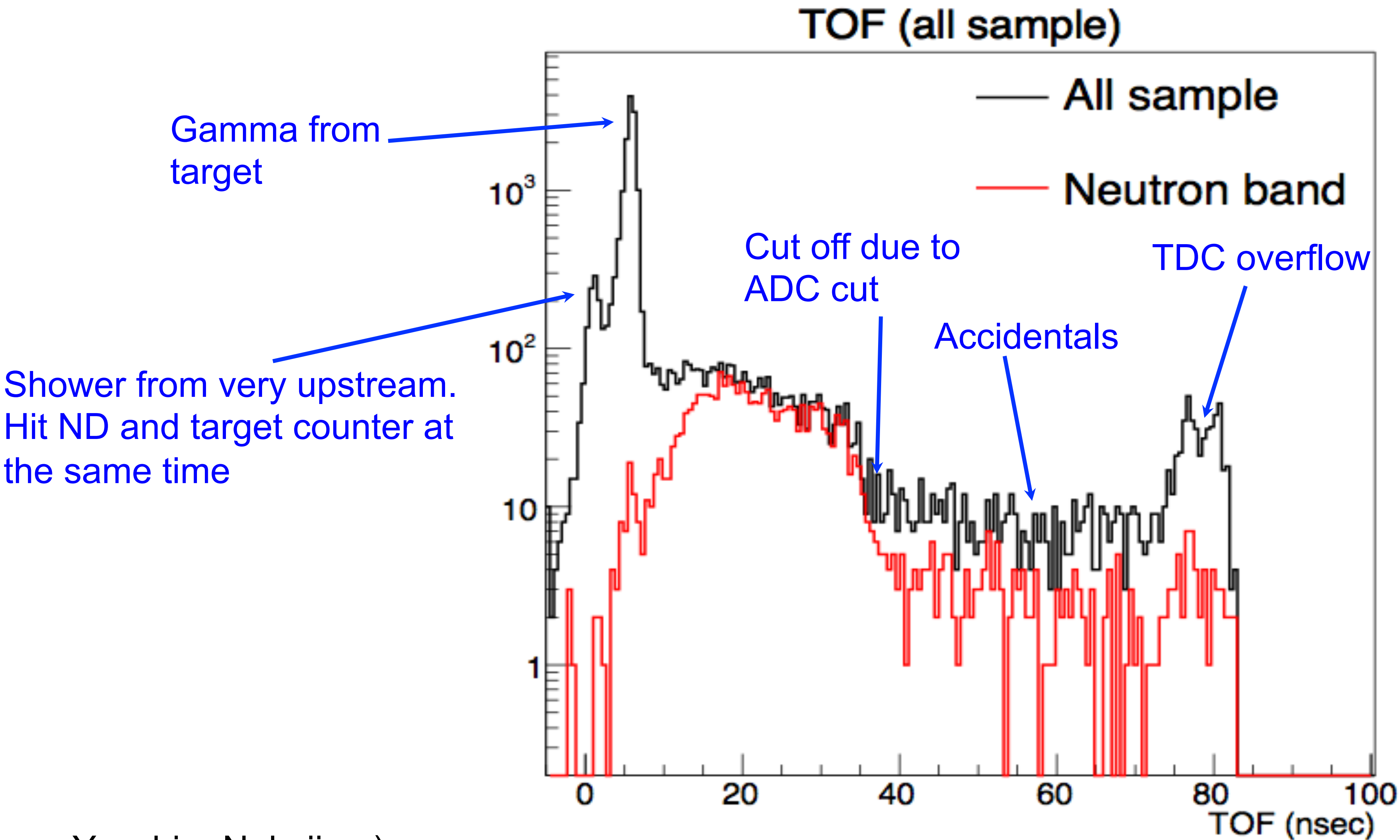
Data analysis is still ongoing, showing some highlights today





Good gamma-neutron separation over a wide energy range

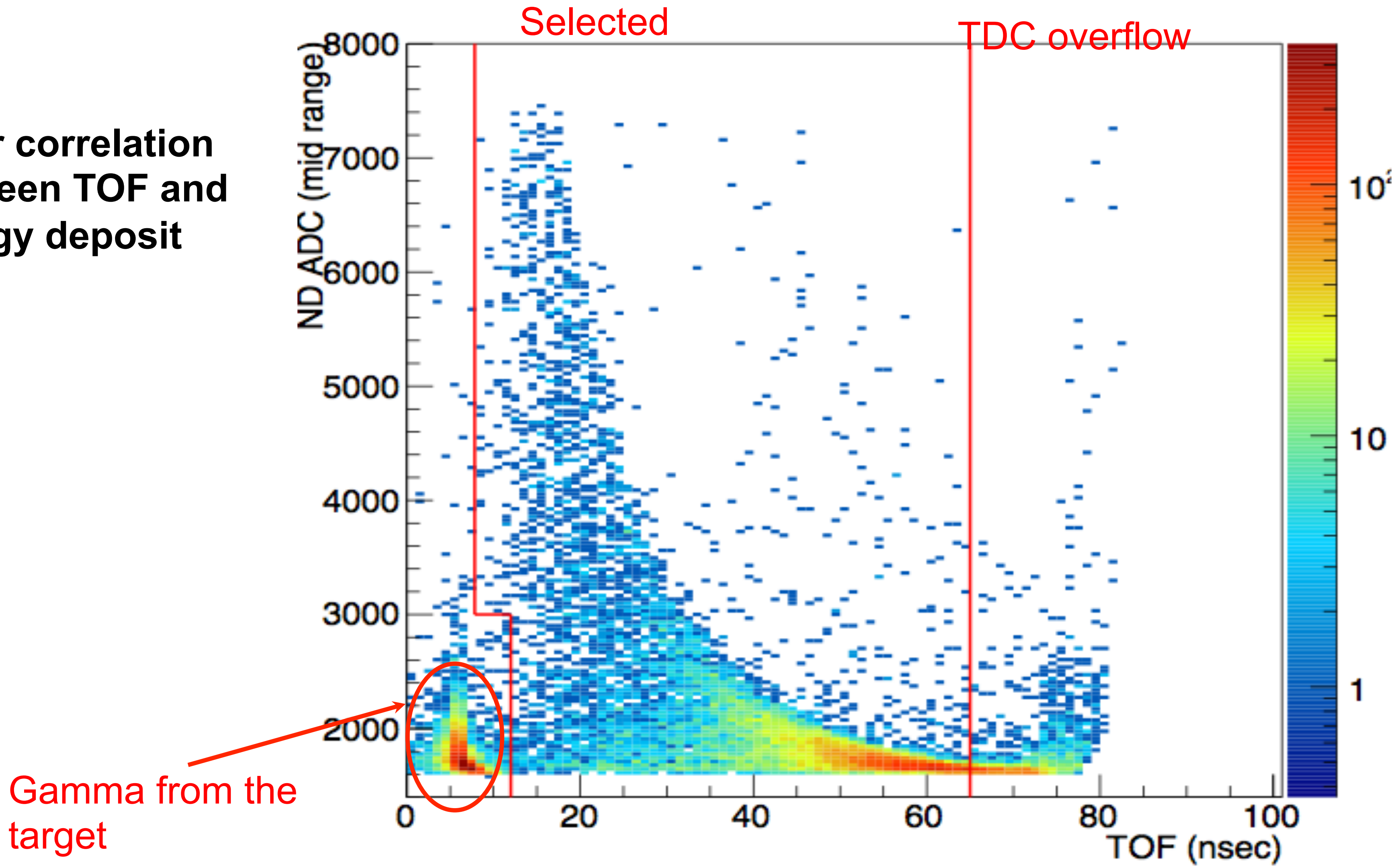
TOF Distribution



(From Yasuhiro Nakajima)

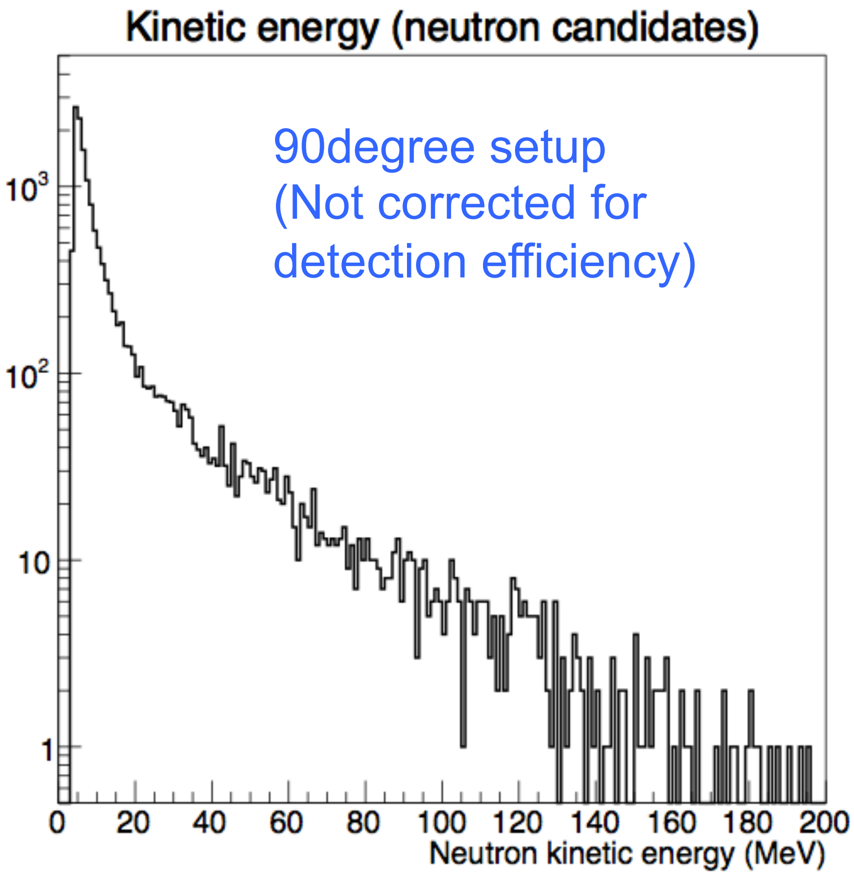
TOF vs. Energy Deposit

Clear correlation between TOF and energy deposit



Beam Test Data Analysis

Reconstruct kinetic energy assuming neutron mass



- Plan to complete data analysis (90deg, +45deg, -45deg) by this summer
- Working on extracting the neutron production rates now!
- One of the main systematic uncertainty is neutron detection efficiency. Plan to use 88" cyclotron at LBNL to constrain the efficiency
- GEANT4 and FLUKA simulation efforts are underway

Schedule (one possible scenario)

Our plan follows closely to COMPASS' schedule

YEAR	COMPASS	Neutron Production Measurement
2012	Hadron and 160 GeV muon beam	Feasibility study
2013	CERN shutdown	R&D
2014	6 weeks of low intensity hadron beam?	R&D Construction
2015	hadron beam?	Onsite installation and commissioning
2016	160 GeV muon beam	Take data parasitically
2017	160 GeV muon beam?	Take data parasitically + some short runs with muon energy > 200 GeV???

Discuss with COMPASS to see if it is possible for us to have one month of high energy scan to complete our measurements in either 2017 or 2018

Summary

- We propose to carry out an experiment to systematically measure muon-induced neutron production at CERN
- Feasibility study at CERN was very successfully. Have addressed main technical concerns of the “full experiment” (e.g. neutron detector performance, background level in the hall, systematic studies, etc.)
- Now trying to extract some physics (neutron production rates, neutron energy spectra and angular distributions) from the data
- Need to secure approval from the CERN SPSC and D.O.E. (in U.S.) and perhaps other agencies in Europe
- Continue to work with COMPASS to minimize interference with COMPASS physics program