Development of neutron detectors for MONSTER collaboration

Gopal Mukherjee
Variable Energy Cyclotron Centre
1/AF Bidhan Nagar
Kolkata, INDIA

On behalf of MONSTER Collaboration
MONSTER ➔ MOdular Neutron Spectrometer array

- is being developed for DESPEC (DEcay SPECTroscopy) experiments

- Will consist of 100 liquid scintillator based fast neutron detectors

- Will be useful for the investigation of β-decay properties of neutron rich nuclei

- As a part of the collaboration 42 detectors will be developed by Indian collaborators
β-delayed neutron emission

- Practical application in reactor control
- Importance in basic nuclear structure physics
- Important measured quantities are:
  - delayed neutron emission probability, Pn
  - Neutron energy spectra

![Diagram showing fission and delayed neutron emission](image)

![Graph showing neutron energy spectra](image)
The design of the MONSTER detector has been finalized after detailed technical simulation.

**Cell Size:** 200 mm dia, 50 mm length  
**Material:** Aluminium alloy (6061T6)  
**Scintillator:** BC501A or equivalent  
**PMT:** 127 cm HAMAMATSU R4144  

MONSTER: a TOF Spectrometer for β-delayed Neutron Spectroscopy  
T. Martinez et. al, Nuclear Data Sheets 120 (2014) 78
Development of the proto-type detector at VECC: Different steps

1. Cleaning (removal of any suspended particles)
2. de-oxygenation
3. Liquid filling (vacuum suction technique)
4. Different components
5. Coupling of light guide
6. Sealing of liquid scintillator cell
7. Proto-type detector
The pulse height response of the detector has been studied using a $^{137}\text{Cs}$ $\gamma$-ray source.

The response has also been estimated using Monte Carlo simulation.

The pulse height resolution at the Compton edge (471 keV), was found to be around 10% in the present case.
The pulse shape discrimination were studied through the zero-crossover technique using the Mesytec-MPD4 module.
The time resolution has been determined with reference to a fast BaF$_2$ detector (1 inch), having time resolution $\approx 400$ ps (determined separately)

$(\Delta t)_{\text{mon}} \approx 0.90 \pm 0.07$ ns
The detector efficiency was measured using $^{252}$Cf source with fission trigger taken by direct fission fragment detection by small ionization chamber with the $^{252}$Cf source mounted on one of the electrodes.

$^{252}$Cf reference spectra

$N(E) = \frac{2\sqrt{E} \exp(-E/T)}{\sqrt{\pi} (T)^{3/2}}$

Measured efficiency is in good agreement with the Monte Carlo simulation (NEFF).
Based on the proto-type development, 10 detector modules for the MONSTER have already been fabricated and tested at Kolkata.

The MONSTER modules are being successfully used for neutron spectroscopic measurements at VECC

The detector pulses will be digitized using four channel, 14 bit, 1 GSPS digital ADC cards (ADQ-14 by SP Devices or equivalent).

Total data acquisition system can be divided into four streams having 7/8 digitizer boards placed inside a PCIe expansion box connected with a high end PC having Xeon Phi processor.

A MONSTER Master Controller (MONSTER MC) is to be designed as the master application to control, monitor and data logging for all the MONSTER DAQ Stations.
Total system consists of 4 units total 128 channels. Each unit can work independently.
Each unit (stream) consists of

• 8 digitizer boards
• each having 4 channels.
**DAQ system specification**

**Digitizer board ADQ14**
- 14 bit, quad channel
- 1 Gsamples/sec
- PCIe interface
- Xilinx Kintex 7 FPGA (user prog)

**Server Specification**
- 2 × 12 core Xeon Processor
- 2 × Intel Xeon Phi processor
- 128 GB RAM
- HDD 6 × 4 TB
- 2 × 24 inch LCD Display
- High end graphics card
- 4 PCIe slot

**PCIe expansion box**
- 18 slots

**White Rabbit System**
- White Rabbit Master module
- White Rabbit slave module
Indian Contribution on DAQ

Stand alone setup for 32 channels planned to be developed by Indian collaboration
- Digitizer board ADQ14 and firmware
- PCIe bus expansion box
- High end PC
- White Rabbit Board for Synchronisation

Software and Control Program
- Development of online monitoring software for the DAQ on a ROOT platform
- Control program for the Master PC for the synchronisation of streams, sharing of the configuration file etc
- Analysis program
Present status of the digital DAQ

- The digital DAQ is being developed in close collaboration with CIEMAT, Madrid.

- Preliminary acquisition and analysis software (DAISY) for data taking using one ADC card has been developed by the CIEMAT group.

- Program for the Master controller and online visualization is being developed by VECC.

- The online DAQ is being developed completely using ROOT classes.

- The control software part is being developed using QT 5.8. So far the network interface part is being developed. The performance of queues for concurrent data handling at high rate is being tested.
Ten detector modules have been fabricated and tested in Kolkata. A few other detectors are also ready at CIEMAT.

The digital DAQ is ready for stand alone use. Another DAQ is being developed in Kolkata in collaboration with CIEMAT.

The Indian part of the in-kind contract with FAIR for MONSTER has been finalized and ready for signatures.

Draft MOU between VECC and Bose institute has been prepared and send for DAE approval.
Thank You