NEUTRON DETECTOR FOR SPIRAL2
MINUTES OF THE MEETING HELP AT WARSAW THE 5/10/2007

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Agenda:

Friday, 5 October 2007

Javier Valiente	New neutron detector for SPIRAL2
Andres Gadea	Coupling of the neutron detector with AGATA
Louise Stuttge	New neutron detection material (ANR project "Neutromania")
Franck Delaunay	Neutron detector developments at LPC Caen
Par-Anders Söderström	Digital pulse shape discrimination
Scott Williams	New neutron array at TRIUMF
Adam Maj	PARIS project and its synergy with neutron detectors
	Discussion

The goal of the meeting was to gather researchers interested in building up a future neutron detector for SPIRAL2.

The meeting started with a presentation of the “FP7 – INFRASTRUCTURES-2007-1” SPIRAL2 Preparatory Phase where the task 5.8 (Neutron Wall) within the WP5 (Instrumentation Spiral2) was described. The objectives of the task 5.8 is to build an ancillary neutron detector for AGATA and EXOGAM2 germanium array installed at the intense stable and radioactive ion beams from SPIRAL2. The Neutron Detector should be characterized by the highest possible neutron detection efficiency, excellent discrimination of neutrons and gamma rays, and a very small neutron-scattering probability. These properties are necessary in order to achieve a clean and efficient identification of gamma rays from the rare neutron-deficient nuclides produced in reactions in which only two or more neutrons are emitted.

It was emphasize that in three years time there should be ready a MoU (Memorandum of Understanding) where the future neutron array is defined in detail.

Andres Gadea (Coupling of the neutron detector with AGATA)

The Advanced GAmma-ray Tracking Array, AGATA, is proposed for high-resolution γ-ray spectroscopy with exotic beams. AGATA will employ highly segmented Ge detectors as well as fully digital electronics and relies on newly developed pulse-shape analysis and tracking methods. The structure of the AGATA data processing with an ancillary detector is done using an interface to the GTS (Global Trigger system) via a mezzanine. The data from AGATA and the ancillary detector, which is time-stamped, is merged into an event builder. There is a prompt local trigger available from digitizers.
Any ancillary detector can make part of the AGATA trigger, but in that case the system should be able to support a large latency time (6 microseconds). In this case it is required preprocessing of the signals. It was suggested a fully digital system, with an analog/digital buffering.

Louise Stuttgé (New neutron detection material (ANR project "Neutromania"))

A collaboration issued from the DEMON collaboration has been working for about two years on a project which aims to develop a new material for the neutron detection. This work which is done in the frame of the French ANR-programme, associates physicists and chemists from Strasbourg, Caen and Saclay. The goal of the project is to obtain a solid scintillator which presents at least the same good characteristics as the organic liquid scintillator (NE213) used in the DEMON detector (g-neutron discrimination, time resolution, efficiency,…). This new material could in particular be used in the construction of a new neutron detector for SPIRAL2.
Indeed it seems important to think about such a new material as with the evolution of the security regulation, it will become more and more difficult to use liquid scintillators at places like SPIRAL2 as they present all major inconvenience: the NE213 is toxic, corrosive, flammable, explosive and dangerous for the environment. No development has been performed in this detection field since the 1970s. Moreover the process which allows the g-

neutron discrimination, the fluorescence, is not well understood.
First results look promising although a lot of work has to be done before it can be claimed that the project succeeded. One more year may be enough to produce a prototype of such a detector.
Concerning the demand of such a material, the Fazia collaboration wants to use these solid detectors in vacuum for two purposes: neutron detection and energy measurement of light charged particles. The CORSET-DEMON collaboration has been investigating the capture dynamics at low energy in the heavy and superheavy mass region for many years. Both SPIRAL2 and DRIBS2 (Dubna) will allow to extend this investigation to neutron rich systems. Of course the neutron detection is essential and a new detector like DEMON will be necessary.

Frank Delaunay (Neutron detector developments at LPC Caen)

The desired characteristics for a future β-delayed neutron detector are the following:

- neutron-β discrimination (background rejection, β2n detection): liquid scintillators or new solid scintillators
- improved energy resolution: thin detectors, increased distance-of-flight
- efficient cross-talk rejection (β2n detection) : modular array, variable geometry
- lowest possible threshold in neutron energy: thin, small volume detectors, digital electronics, good neutron-β discrimination at low energy.

We plan on studying the feasibility of β2n detection with a test experiment in 2008 using existing thin liquid scintillator detectors (EDEN array).

An efficient cross-talk rejection points to a careful definition of the geometry of the detector, which can be addressed through simulations. We are testing Geant4 simulations by comparison to efficiency and cross-talk data from the DEMON detector. None of the Geant4 neutron interaction models appears to be fully satisfying. Results with our own data-based elastic scattering model are promising.
Digital electronics developments dedicated to neutron detectors are planned, such as a digital CFD for time-of-flight measurement, a digital trigger and a time stamping system. Important issues are the digital ADC sampling rate necessary to obtain a 500 ps time resolution, as well as the ability to improve n-β discrimination by using digital electronics and/or new algorithms.

Par-Anders Söderström (Digital pulse shape discrimination)

It was discussed digital methods to do pulse shape discrimination between neutrons and gamma-rays in a liquid scintillator. The goal has been to test the behavior of well known algorithms, charge comparison and zero cross-over, for different properties of the ADC, that is bit resolution and sampling frequency. To do this a NORDBALL detector was used together with a 100 MHz and 14 bits flash ADC, connected so that the frequency was increased to 300 MHz. The performance of the algorithms for maximum bit resolution and sampling frequency was compared to a standard Neutron Wall PSD unit. The performance of the separation was very similar for all the algorithms under these conditions. When the bit resolution was reduced it was noticed that the charge comparison was less sensitive to this. For a range of 0 to 700 (1650) keV electron (proton) energy, the separation quality for the zero-cross over started to be noticeably worse around 7 bits for charge comparison and 9 bits for zero cross-over. For reduction of sampling frequency, the zero cross-over started to degrade at 75 MHz, while it was difficult to draw any conclusions for the charge comparison. The effects on this is to be further investigated.

Scott Williams (New neutron array at TRIUMF)

The DEuterated SCintillator Array for Neutron Tagging (DESCANT) is a new neutron detector array presently being developed at the University of Guelph, Canada and TRIUMF. The array is based upon using deuterated benzene, BC537, for the scintillator material in order to increase the information contained in the pulse height resulting from a neutron induced scintillation. Fast neutrons interact in a scintillator primarily through elastic scattering processes. For a deuterated scintillator, scattering from the deuteron is peaked towards forward angles such that it is much more probable for the neutron to transfer it's full energy in a single scatter within the detector volume. This is in contrast to scattering from a proton in a normal scintillator, in which the scattering is largely isotropic in the centre of mass frame. Thus, for this novel scintillator, fewer interactions are required for the pulse height to reflect the full energy of the neutron. By recording the time of flight of each neutron, it's energy is therefore over-determined. This becomes useful when the event of interest requires more than one neutron to be detected. In a standard fusion-evaporation reaction, the overwhelming number of recorded events with a neutron multiplicity of two or more are from one neutron scattering between different detectors. By correlating the energy and time of flight of each neutron the background of scattered one neutron events can be removed from the true higher fold events.

The array will consist of seventy irregular hexagonal elements, tiled to cover ~90% of the forward 1.2π of the TIGRESS array, for a total angular coverage of ~1.1π. Each element will be 15 cm deep, which gives a total scintillator volume of ~190 litres.

A test can of the scintillator was subjected to a monoenergetic beam of neutrons at the University of Kentucky, and the response measured. A well defined peak was observed in the energy spectra from the detector, the position of which was determined empirically to depend on the neutron energy to the power of 1.6. The efficiency of the scintillator was measured to be ~75% of that of an equivalent volume of normal scintillator. This deficiency is largely due to a lower cross-section for n-d scattering below 1MeV, although in addition, this number was obtained with non-optimum low energy thresholds. The array is designed for fusion-evaporation reactions in inverse kinematics, and in this case the Lorentz boost will do much to compensate for this deficiency, as above 1 MeV the cross-sections are comparable.

These results were compared to the output of GEANT4 simulations, which reproduce the data satisfactorily. Further work will be done to model the full DESCANT array in GEANT4, and to develop algorithms to investigate the multiple scattering.

Digital electronics are being developed in parallel, by the University of Montreal. The modules will be based upon 1GHz digitistation of the signal coming from the PMT tube, and will be an upgrade to the existing TIG-10 standard which is presently used for the TIGRESS HPGe detectors. FPGA chips will be used to perform pulse-shape analysis on the digitized waveforms, to determine the risetime of the pulse, equivalent to the standard zero-crossover method of neutron-gamma discrimination. In addition, it is expected that the decay constant of the pulse can be fitted with a sensitivity of a few ns with these devices. As the ratio of fast/slow components in the light output of the scintillator is radiation dependent, this allows on-board pulse-shape discrimination of neutrons and gamma rays.

The assembly and testing of the array will begin with the first delivery of elements commencing in spring/summer 2008, and the array is expected to be ready for experiments by autumn/winter 2009. In addition, it is envisaged that the array will be available for campaigns in facilities other than TRIUMF, and could conceivably be coupled to AGATA/EXOGAM2 at SPIRAL2.

Adam Maj (*PARIS project and its synergy with neutron detectors)*

Fusion-evaporation reactions induced by high intensity neutron-rich beams from SPIRAL2 will allow us to populate exotic compound nuclei, transferring more initial angular momentum to them (up to 100 $\hbar$) than currently achievable with stable beams. This will be of great benefit for the study of vibrational and rotational collective phenomena at finite temperature, such as the Giant Dipole Resonance or exotic shape changes induced by fast rotation. Heavy-ion radiative capture and reaction dynamics studies will also benefit considerably from the availability of high intensity neutron-rich beams. There are also interests related to study weak isomeric decays produced after fission or fragmentation of relativistic beams from FAIR, within the HISPEC/DESPEC experiments within NUSTAR@FAIR. Studying very weak gamma branches are also of astrophysical importance.

Gamma ray detection constitutes an important experimental probe common to all these physics topics. Therefore the main aim of the PARIS (Photon Array for Radioactive Ion and Stable beams studies) collaboration (see www.paris.w.pl) is develop and to construct a dedicated gamma-calorimeter with dynamical range from 100 keV to 50 MeV. Such a device might partly consist of existing European detectors.

A clear plan for such new gamma-calorimeter PARIS can only arise from an intensive R&D program, with GEANT4 simulations being a key component of this work. One of the possibilities presently under consideration is to develop a 2-shell calorimeter, with inner (hemi-)sphere, highly granular, made of new short crystals (LaBr3(Ce), LaCl3, CeZnTe). The readout might be performed with APDs or with digital electronics which would offer the possibility of pulse shape analysis. The outer (hemi-)sphere, with lower granularity but with high volume detectors, could be made from conventional crystals (preferably of BaF2), or using existing detectors (Chateau de Crystal or HECTOR). The inner-sphere will be used as a multiplicity filter, sum-energy detector and will also serve as an absorber for the large detectors behind. The outer-sphere will measure high-energy photons. In addition to the spherical geometry there is also cubic geometry under consideration.

A very important issue is to find a synergy with other new detectors, especially those that will be used with SPIRAL2, as for example new neutron detector. Both collaboration might substantially benefit from it.

Discussion

The meeting finished by a discussion on the way to proceed efficiently. In this respect different working groups where created, which will take care of the following tasks:

- Detector characteristics (Report on physics of interest, this will help to define the detector specifications).
  - Responsible: B. Wadsworth
- Geometry (Make a full study of geometry to determine (materials) efficiency, reduce cross-talk, ... Comparison between different codes: Genat4, MCNP-X. Simulate effect of other ancillaries, neutron scattering.).
  - Responsible: M. Palacz
- Study New Materials (Exploring new materials, solid scintillators, deuterated liquid scintillators).
  - Responsible: L. Stuttgé
- Digital Electronics and PSA (Simulations of Pulse shapes, PSA algorithms, flash ADC, ...).
  - Responsible: J. Nyberg
- Synergies other detectors (Detectors that can be considered in synergy with the new neutron wall. EXOGAM2, PARIS, AGATA, FAZIA, GASPARD, DIAMANT, DESCANT, DESPEC/HISPEC, NEUTROMANIA, ...).
  - Responsible: A. Maj

It was also decided to:

a. have a parallel meeting during the SPIRAL2 week at GANIL, probably the 27th of November from 9.00-11.00.

b. send to the whole community a mail asking for the possible people interested in joining the different working groups

c. think about an acronym for the future neutron wall.