MCNPX simulation for optimization of efficiency of a 4π neutron detector for beta delayed neutron emission measurements.

V. Gorlychev, M. B. Gómez, R. Caballero-Folch, G. Cortés, F. Calviño, A. Poch, C. Pretel

UNIVERSIDAD POLITÉCNICA DE CATALUÑA

D. Cano, T. Martínez and Nuclear Innovation Group
CIEMAT-Madrid

J.L. Taín, J. Agramunt and Gamma Spectroscopy Group
IFIC- Valencia

September 2009
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✓ FAIR
✓ DESPEC
✓ Delayed neutron emission
✓ Neutron detector for DESPEC
✓ Prototype of the neutron detector
✓ Test with Cf source
✓ Conclusions
INTRODUCTION

FAIR – Facility for Antiproton and Ion Research.
INTRODUCTION

OBJECTIVES:
• Nuclear structure study;
• Decay properties of exotic isotopes study;
• To study r-process;
• Beta delay neutron emission.

DECay SPECTroscopy.
INTRODUCTION

Beta delay neutron emission scheme
Mechanisms of detecting neutrons are based on indirect methods

\[ ^3\text{He} + n \rightarrow ^3\text{H} + ^1\text{H} + 765\text{ keV} \]

\[ ^{10}\text{B} + n \rightarrow ^7\text{Li}^* + ^4\text{He} + 2310\text{ keV (93\%)} \]

\[ ^{10}\text{B} + n \rightarrow ^7\text{Li} + ^4\text{He} + 2790\text{ keV (7\%)} \]
4π NEUTRON DETECTOR FOR DESPEC

Study of DEcay SPECtroscopy and associated emission

Front view

Ring A: 12 counters @ $R_A = 12$ cm
Ring B: 16 counters @ $R_B = 19$ cm

Beam hole radius: 8 cm
Dimensions: 50x50x80 cm$^3$ + shielding

Side view
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**EFFICIENCY FOR DESPEC DESIGN**

Configuration has been optimised in order to get the flattest efficiency possible.

Relative flat efficiency between 0.1MeV-2MeV (41%-44%)

<table>
<thead>
<tr>
<th>Counter</th>
<th>Gas</th>
<th>Max length (mm)</th>
<th>Effective length (mm)</th>
<th>Maximum diameter (mm)</th>
<th>Eff diam (mm)</th>
<th>Gas pressure (torr)</th>
<th>Cathode material</th>
</tr>
</thead>
<tbody>
<tr>
<td>2527 LND inc</td>
<td>$^3$He</td>
<td>686.84</td>
<td>604.8</td>
<td>25.4</td>
<td>24.38</td>
<td>15200</td>
<td>Stainless Steel</td>
</tr>
</tbody>
</table>

MCNPX simulation, 100 000 events
BACKGROUND SHIELDING

Outer layer of polyethylene and Cadmium added in order to shield detector from background neutrons.

Shield of polyethylene

Polyethylene moderator

Cadmium layer

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15 cm polyethylene shielding seems ok

- 2.5 % detection of 2 MeV neutrons
- No need to add Cadmium according to simulations

Unknown neutron background (!?)

MCNPX simulation, 100 000 events
NEUTRON FLUX AFTER POLYETHYLENE BLOCK

Neutron flux after polyethylene

Neutron flux after polyethylene + Cd
Polyethylene will be vertical slices of ~10cm, when assembled => 90 x 90 x 80 cm³ ~600 kg detector

Support structure requirements:
- Hold and transport 600 kg
- Allow access to the beam hole
- Movable in Z-axis for fine placement
- Adjustable height table + tray with bearing

Polyethylene

3He counters
A prototype with 20 counters is being designed to be tested at JYFL-Finland.

- Ring A: 8 counters @ $R_A = 11\text{cm}$
- Ring B: 12 counters @ $R_A = 20\text{cm}$

Beam hole radius: 5 cm
Dimensions: $50 \times 50 \times 80 \text{ cm}^3 +$ shielding
Relative flat efficiency in the range 0.1 MeV to 4 MeV (32% - 35%)

MCNPX simulation, 100 000 events
MODERATION TIME IN PROTOTYPE

MCNPX simulation, 100 000 events

Efficiency vs neutron propagation time. Neutron point source of 1 MeV. Detector: $R_1=11$ cm, $R_2=20$ cm.
NEUTRON SHIELDING

Shield of polyethylene

Polyethylene moderator

Cadmium layer
Efficiency of background neutron detection. Neutron source is a sphere around the neutron detector.

MCNPX simulation
100 000 events
Equipment:
- Neutron detector – UPC (Barcelona)
- DAQ – IFIC (Valencia)
- NaI(Tl) detector – CIEMAT (Madrid)

$^{252}$Cf neutron source. Activity:
- Dec. 2007 – 9.9kBq (1100 neutrons/second)
- July 2009 – 605 neutrons/second
Experimental efficiency (29±4)\% corresponds to simulation.

Block of polyethylene 60x50x80 cm\(^3\)
Beam hole \(R = 5\) cm (Shield =10 cm)
\(R_A = 11\) cm, 8 counters of 80 cm effective length
\(R_B = 20\) cm, 12 counters of 60 cm effective length
Counters with \(^{3}\)He, pressure = 15200 torr
Neutron point source
Date: 17.09.2009
Experimental propagation time corresponds to simulation
Decay properties of β delayed neutron emitters $^{87}\text{Br}$, $^{88}\text{Br}$, $^{94}\text{Rb}$, $^{95}\text{Rb}$, $^{137}\text{I}$

Three complementary setups to study three aspects: 15 days beam time

- Neutron emission probability (4π neutron detector, UPC)
- Neutron energy (ToF detector, CIEMAT)
- Beta decay energy (Total Absorption Spectrometer, IFIC)
CONCLUSIONS

✓ Prototype simulations were done
✓ Prototype construction was made
✓ First test with Cf source was performed in July 2009
✓ Experimental efficiency corresponds to simulation
✓ Moderation time corresponds to simulation
✓ Support structure was designed and constructed
✓ Test with prototype will be performed in November 2009 in JYFL
NEXT IN THE LIST: Test electronics and counters with a $^{252}$Cf source
TEST WITH Cf SOURCE @ UPC

PC DAQ

VME SIS3302 ADC

Preamp

HV

3He counter

3He counter

Amplifiers (STM-16 MESYTEC)
<table>
<thead>
<tr>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>4°</td>
<td>1°</td>
<td>2°</td>
<td>3°</td>
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<tr>
<td>Simulation of detector</td>
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<td>Definition of counters</td>
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<td>Electronics definition</td>
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<td>Electronics setup and test</td>
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<td>Prototype construction</td>
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<td>First tests of prototype</td>
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<td>Experiment JYFL</td>
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<td>Analysis of experiment</td>
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<td>Tuning of final design</td>
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<td>Construction of final detector</td>
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</table>
Efficiency of background neutron detection. Neutron source is a sphere around the neutron detector.
4π NEUTRON DETECTOR FOR DESPEC

Number of channels = 1
Rise time = 7 ns
Decay time = 140 µs
Gain = 1.4
Power Supply = +/- 12V

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UPC, Barcelona
- Detector overview
- Results of simulations with MCNPX
- Prototype design and first experiment
- Status of detector components
- Time planning
DESIGN OF 4π NEUTRON DETECTOR FOR DESPEC

V. Gorlychev, M. B. Gómez, G. Cortés, F. Calviño, A. Poch, C. Pretel

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December 2008
4π NEUTRON DETECTOR MATERIAL

Pre-amplifiers (CREMAT)

Pre-amplifiers (MPR-16 MESYTEC)

Amplifiers (STM-16 MESYTEC)
4π NEUTRON DETECTOR MATERIAL

TDC (V767 CAEN)

Power Supply (ISEG 203)
NIM crate (WIENER)

20 $^3$He counters (LND)
Delivery shortly
CREMAT PRE-AMPLIFIER TEST

Number of channels = 1
Rise time = 7 ns
Decay time = 140 µs
Gain = 1.4
Power Supply = +/- 12V
CABLE LENGTH TEST

Neutron spectrum for Mesytec pre-amplifier and amplifier chain for different cable length

It seems the cable length does not have large influence