GEANT4 simulations for the Castilla-La Mancha Neutron Monitor (CaLMa)

Space Research Group (SRG) Geant4 Space Developments

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Instrumentation area:

- Castilla-La Mancha Neutron Monitor (CaLMa)
- Solar Radio Telescope (e-Callisto standard)
- Detectors Development:
  - PESCA2
  - Scintillator Project (SciPro)
  - Radiation Shielding for Human Exploration of Space (RSHES)
- Energetic Particle Detector (EPD) Solar Orbiter

GEANT4 Simulations Planned

Energetic Particle Detector (EPD) Solar Orbiter:

The Geant4 models are produced by the sensor units teams for characterization of the instrument response.

The Geant4 models of the EPD instruments are needed to be available on the team for:

- Optimization of the data analysis SW tools
- Future troubleshooting during operations
- Integration with S/C model and mission *(TBC)*:
  - Orbit influence
  - S/C Background

Castilla-La Mancha Neutron Monitor (CaLMa):

- First project using Geant4 at SRG:
  - Simple Geometry
  - Stable environment (non orbital environment)
  - Well known physics
  - Geant4 is suitable for multiple physics process as the ones to be considered on a Neutron Monitor
  - Detector already on operation for comparison

- Student Final Degree Project as a precursor:

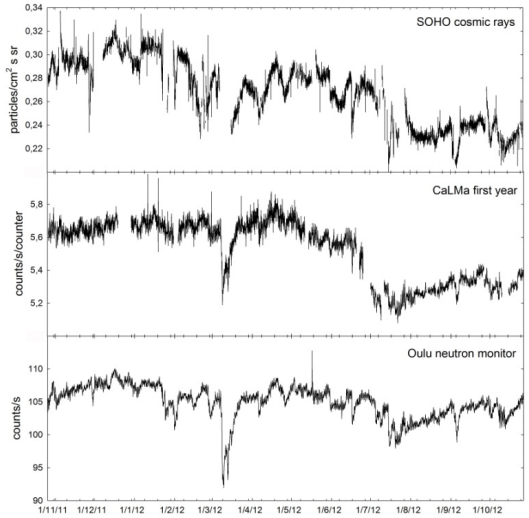
  Simulación del Monitor de Neutrones sobre Geant4, L. Gayarre
- Staff from the area is partially involved

CaLMa Neutron Monitor located in Guadalajara (Spain) the first installed in Spain.

The instrument is made up of fifteen proportional counter tubes. Three of them are standard BP28 and twelve are LND 2061.

CaLMa is operative from October 2011.

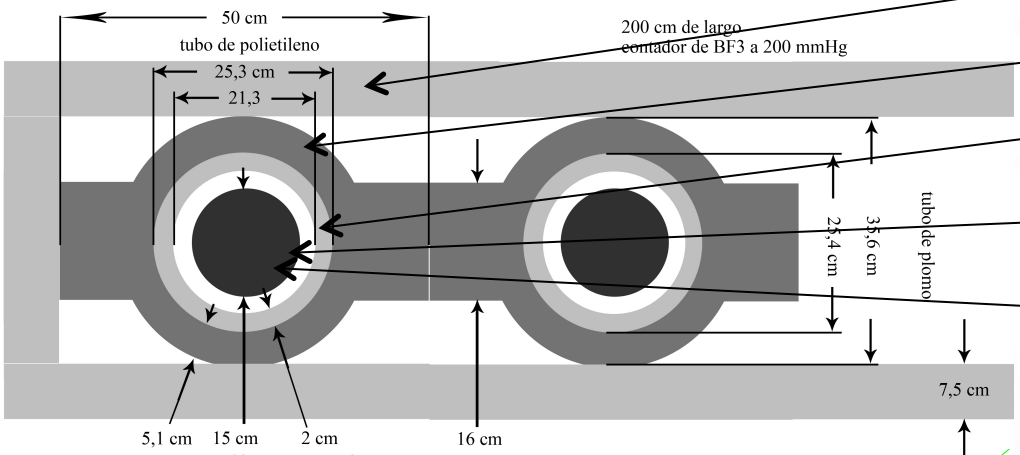
The magnetic rigidity threshold is near 6.95 GV, which implies that particles with energies over 6.07 GeV/amu can reach the monitor.



Source: Medina et al 2012

Castilla-La Mancha Neutron Monitor (CaLMa):

BP28 & LND2061 Configuration



Source: Medina et al 2012

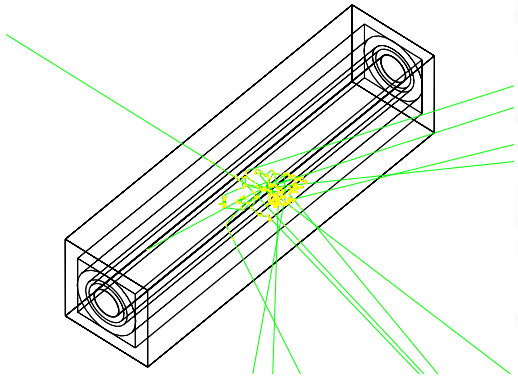
Reflector: Polyethylene

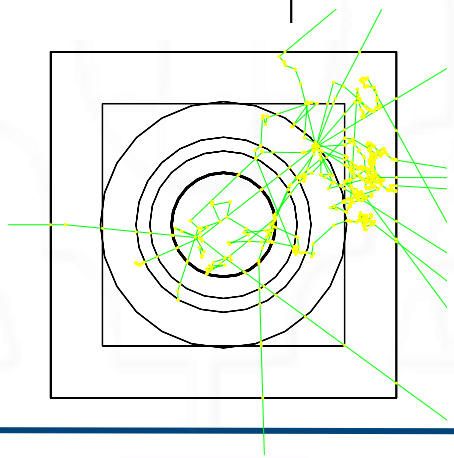
Productor: Lead

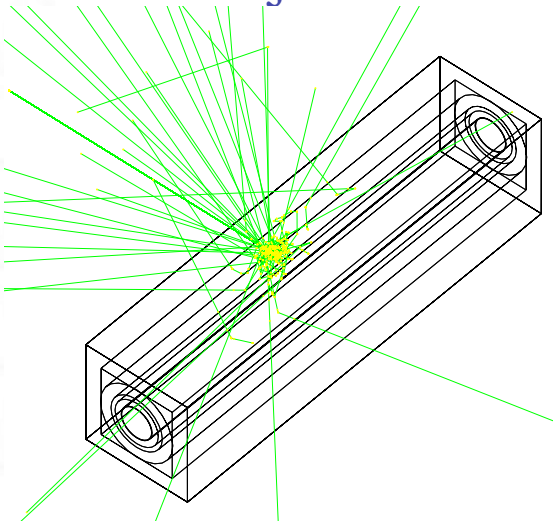
Moderator: Polyethylene

Detector Cylinder: INOX

Detector: $^{10}BF_3$







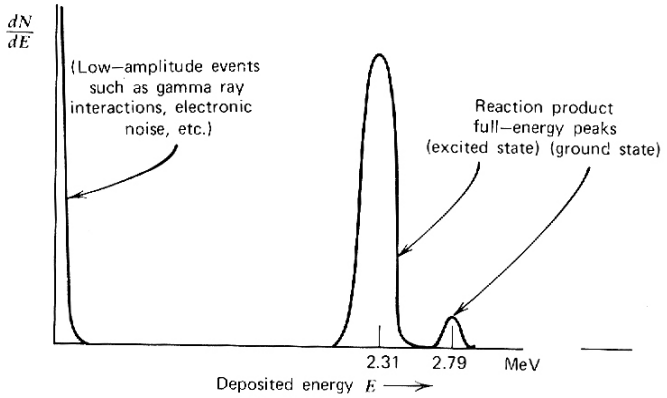
Castilla-La Mancha Neutron Monitor (CaLMa):

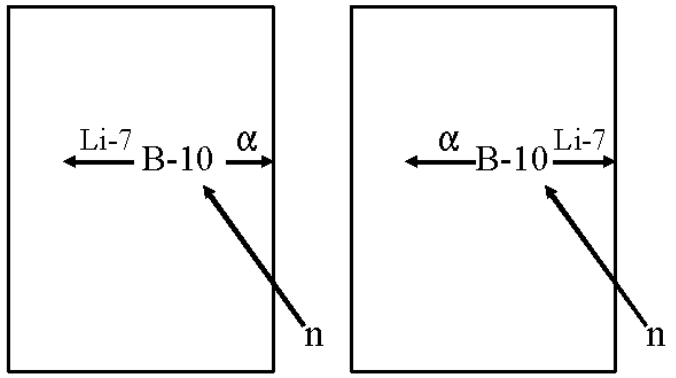
BP28 & LND2061

Proportional Counter

$$^{10}_{5}B + ^{1}_{0}n - > ^{7}_{3}Li + ^{4}_{2}\alpha + 2{,}792MeV$$

$$^{10}_{5}B + ^{1}_{0}n - > ^{7}_{3}Li^{e} + ^{4}_{2}\alpha + 2{,}391MeV$$





The Li-7 deposits all its kinetic energy in the gas while the alpha particle deposits only a fraction of its energy.

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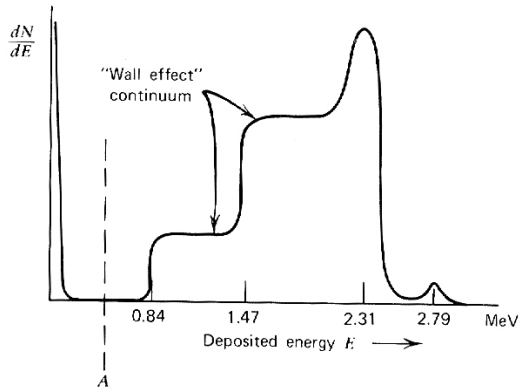


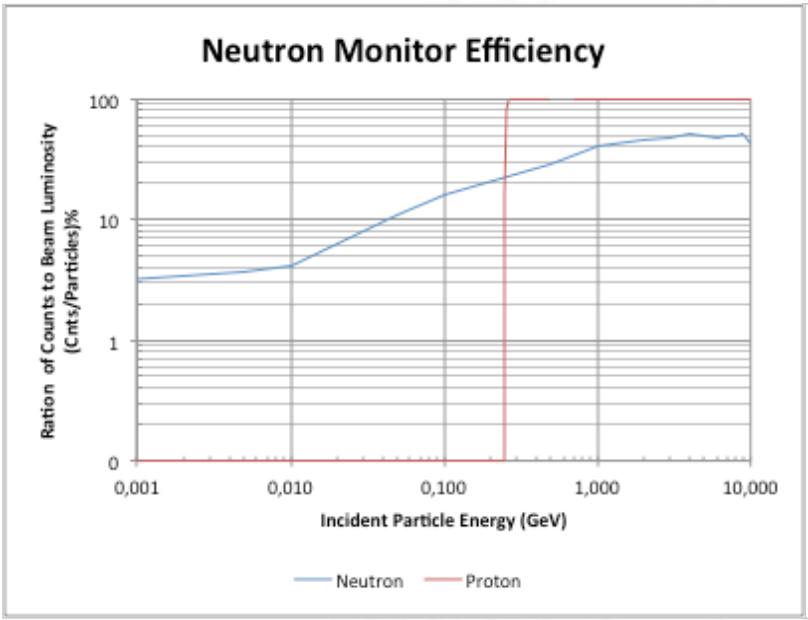
Castilla-La Mancha Neutron Monitor (CaLMa):

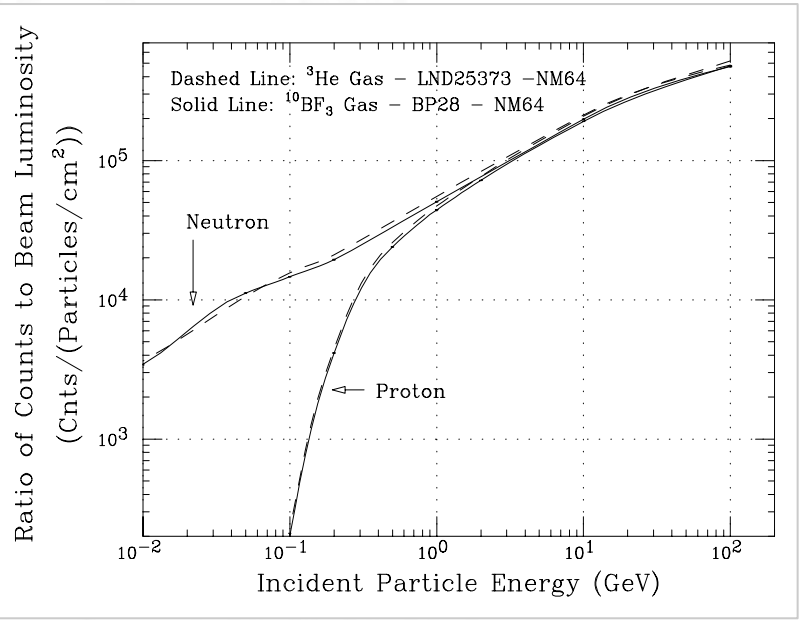
Status of the Simulation:

- Materials has been defined or NIST used, including $^{10}BF_3$ definition for variable pressure (He_3 also compiled)
- Unit Geometry defined and will be replicated
- ParticleGun used and will be upgrade to GPS
- PhysicsList is still very general and will be detailed to more accurate physics involved
- Event, step and run actions has been modified from example novice 3

Castilla-La Mancha Neutron Monitor (CaLMa):

Preliminary Results for the efficiency for Protons and Neutrons in accordance with J.M. Clem 2000 (right figure).



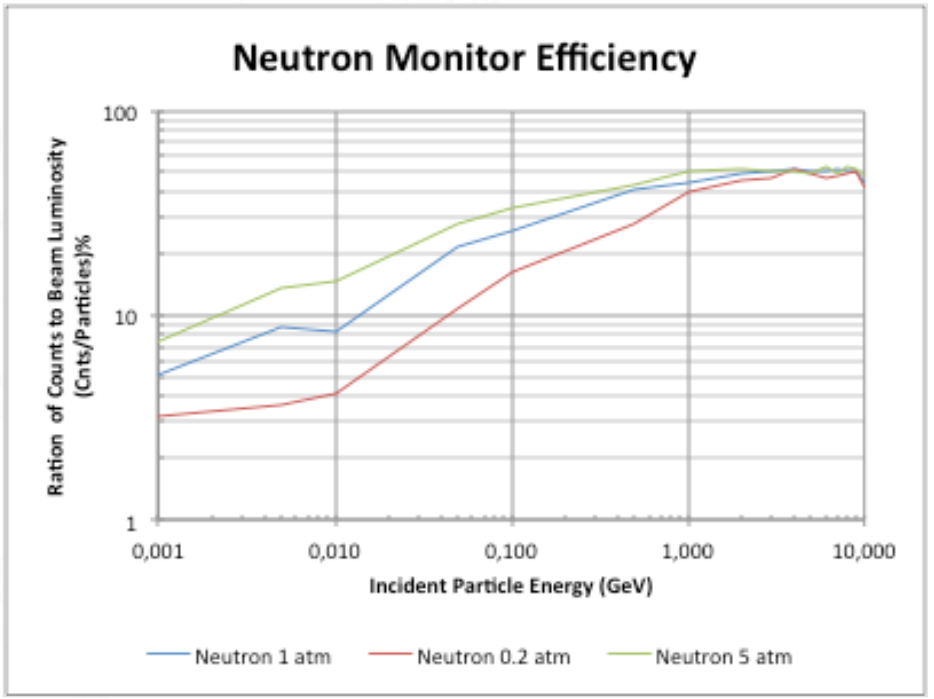


Castilla-La Mancha Neutron Monitor (CaLMa):

The release of a new governmental rule allows to increase the pressure of the BF3.

An analysis of the variation of the gas pressure has been done with gas at Room Temperature (298*kelvin).

The preliminary results are in accordance with Crane, T. W. and Parker, M. B., "Neutron Detectors," available online (accessed January, 2012).



Castilla-La Mancha Neutron Monitor (CaLMa):

Geant4 simulations Road Map

- Characterization of the system:
  - Efficiency
  - Response to different incident particles
  - ….
- Characterization of the “Wall Effect”
- Study of the different count rate with the two 3 BP28 and 12 LND2061 tubes used on CaLMa
- Study of parameters modification for the current facility as detector material, gas pressure,…

Summary and conclusions

- Novel developments on Space Instrumentation at SRG require Geant4 simulations
- The work is already in progress for CaLMa
- We have developments in the near future requiring Geant4 simulations as a design optimization tool for the new HE payloads
- Solar Orbiter Science Data Analysis SW requires a Geant4 model as a SW optimization tool

Acknowledgement

- This work is being supported by JCCM PPII10-0150-6529 and AYA2011-29727-C02-01

Back Up Slides

Detectors Development (Different stages):

- PESCA2 (on-going with last year students)
  - Si stacked detectors for a CubeSat mission
- SciPro (on-going with last year students)
  - Characterization of BGO scintilliators with PMT & PD
- RSHES (on-going under Univ. Zaragoza collaboration)
  - Si stacked detectors for a Lunar Lander

- SRG is an interdisciplinary group composed by researchers from the:
  - Computer Engineering Department
  - Physics and Mathematics Department
- Areas of interest:
  - Satellite subsystems
    - Hardware: space processors, FPGAs, MMUs, C&DH, etc.
    - Hardware/Software codesign (VHDL, SystemC)
    - High reliability software development (Ada, C/C++, Java)
    - Embedded systems
    - Real-Time Operating Systems
  - Instrumentation area (Space Payloads included)
  - Physical models of propagation
  - Solar and Heliospheric Physics
  - Space weather

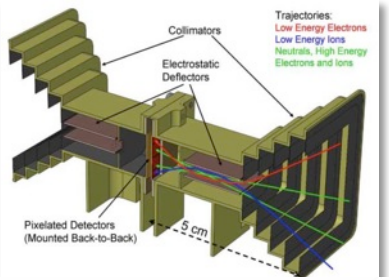
EPD Units:

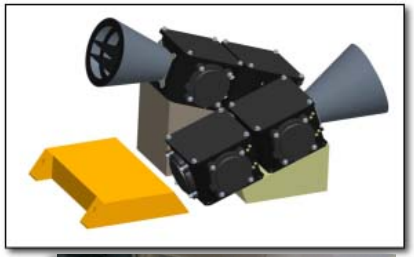
- **STEIN (Supra-Thermal Electrons Ions and Neutrals**

  Electrons & protons: 3 – 100 keV, neutrals: 4 – 20 keV

  Double-ended telescope utilizing passively cooled Silicon Semiconductor Detectors

  It uses an electrostatic deflection system to separate electrons and Ions

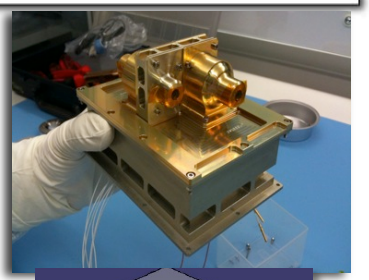




- **SIS (Supra-thermal Ion Spectrograph)**

  Elemental Composition He-Fe: 8 keV/n – 10 MeV/n

  Concept: time-of-flight mass spectrometer with a mass resolution of $m/\sigma_m \approx 50$



- **EPT (Electron and Proton Telescope)**

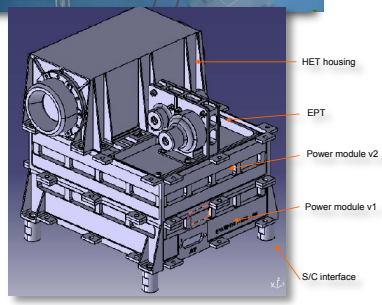
  Electrons: 20-400 keV, Protons: 20-700 keV

  ΔE-E technique telescope combined with magnet and foil, two units (two apertures each), one pointing 45° out of the ecliptic.

- **HET (High Energy Telescope)**

  Electrons 0.3 - 20 MeV, protons : 10 – 100 MeV and ions (He – Fe) 50 – 200 MeV/n.

  ΔE-E technique telescope, two units, two apertures each, one pointing 45° out of the ecliptic. EPT and HET share the same ebox.



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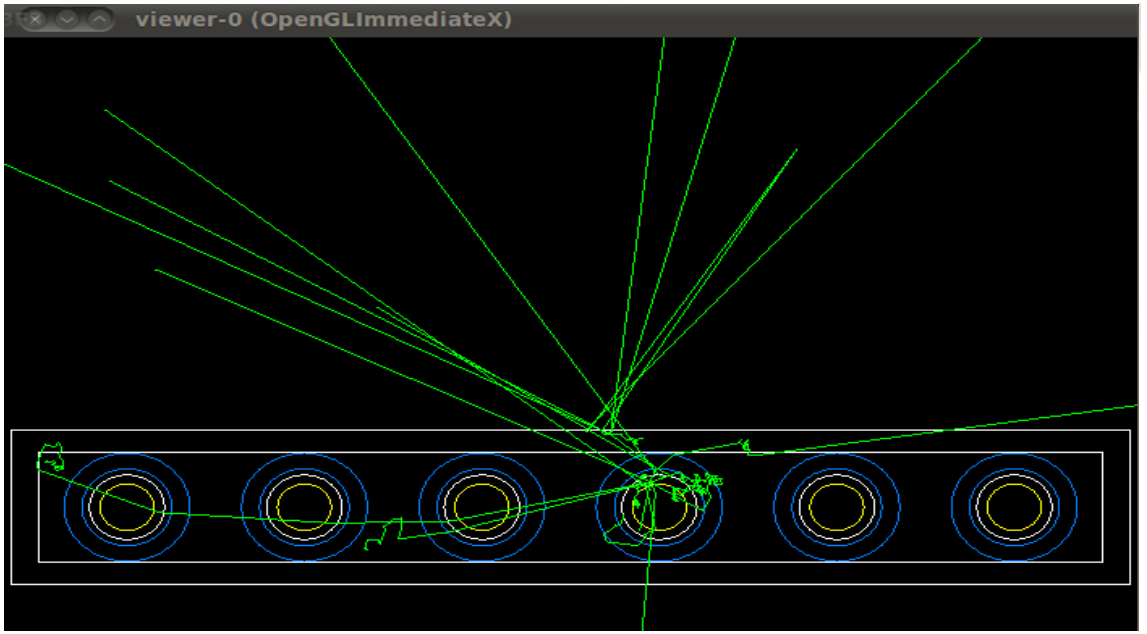
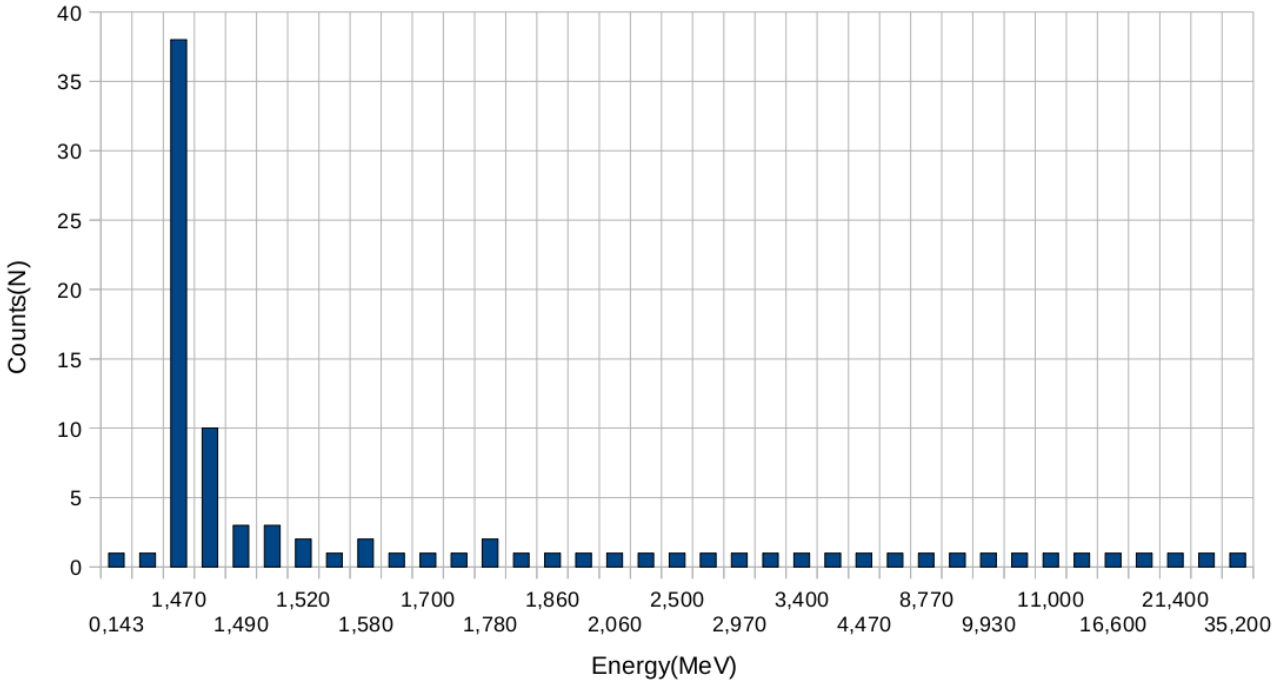


Source: EJ Catalán et al 2012

Castilla-La Mancha Neutron Monitor (CaLMa):

The energy deposited on the detector by the alpha particle, Gayarre&Catalán 2012. Most of the counts have an energy which corresponds to the alpha associated the excited state of the Li_7 as expected.



Source: L.Gayarre et al 2012