# The *r-process* and the Universe nucleosynthesis New measurements for relevant data around N=126

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## The quest for the origin of the elements...

- What are the limits of the nuclear existence?
- Which is the heaviest element that can be produced?
- How have been the elements and isotopes in the Universe synthesized?
- What is the site(s) in the Universe for the r-process nucleosynthesis?



The nucleosynthesis of light elements is produced in common stars via

nuclear fusion processes Fusion up to iron is possible according to binding energy per nucleon Nuclei beyond iron (Fe) are produced by means of neutron capture reactions, s-process (slow) and r-process (rapid), and beta decays

89 90 91 92 93 94 95 96 97 98 98 89 8 Rh Rh

- Slow neutron capture process 
   87
   88
   89
   90
   91
   92
   93
   94
   95
   96

   Ru
   Ru</ produces the elements between iron and bismuth by means of
- The r-process takes place in environments with high neutron fluxes such as Super Nova



Site of s-process has been clearly identified as the asymptotic Giant Branch stars

## **EXPERIMENT:** Measurement of $\beta$ -delayed neutrons around the third r-process peak (2011)

The aim: to obtain half lives  $(T_{1/2})$  and  $\beta$ -delayed neutron emission probability  $(P_n)$  of nuclei around the region N=126

The delayed neutron emission modulates the abundance curve in stellar nucleosynthesis. New experimental data will give an important input to r-process model calculations and will extend limits of nuclei chart

#### **Beam characteristics**

**RIB facility of GSI - Darmstadt (Germany)** 

| Ducalization |
|--------------|

#### **Separation method:**

Bρ - Time of Flight - Bρ

Production Target







#### **β** delayed neutron theory

Emitter



| 126          | <sup>209</sup> 82 <b>Pb</b> 127 | <sup>210</sup> 82 <b>Pb</b> 128           | <sup>211</sup><br>82 <b>Pb</b> 129          | <sup>212</sup> 82 <b>Pb</b> 130  | <sup>213</sup> <b>Pb</b> 131    |
|--------------|---------------------------------|---|---|----------------------------------|---------------------------------|
|              | 3,253 hr 9/2+<br>β-             | 22,20047 yr 0+<br>β- 100 €<br>∝ 0.000001. | 36,1 min 9/2+<br>β-                         | 10,64 hr 0+<br>β-                | 10,2 min 9/2+<br>β-             |
| 126          | <sup>208</sup> <b>T 1</b> 127   |   | 210 <b>TL</b> 129                           | <sup>211</sup> 81 <b>TL</b> 130  | <sup>212</sup> 81 <b>TL</b> 131 |
| in 1/2+<br>- | 3,053 min 5+<br>β-              | 2,2 min 1/2+<br>β-                        | 1,3 min 5+<br>β- 99.9915 %<br>β-,n 0.0085 % | l min Unkn<br>β-                 | l,ll667 min Unkn<br>β-          |
| 126          | <sup>207</sup> 80 <b>Hg</b> 127 | <sup>208</sup> <b>Hg</b> <sub>128</sub>   | <sup>209</sup> 80 <b>Hg</b> 129             | <sup>210</sup> Hg <sub>130</sub> |                                 |
| +            | 2,9 min 9/2+<br>β-              | 41,5 min 0+<br>β-                         | 36,5 s Unkn<br>β−                           | 2,43333 min 0+<br>β-             |                                 |
| 126          |                                 |   |   |                                  |                                 |

#### Example of 6 delayed neutron decay

### **Implantation and B detector**

Based on DSSD silicon layers



#### **SIMBA** detector





**Neutron spectra obtained** 

#### **Beta deLayEd Neutron detector (BELEN)**

**Final Nucleus** 



UPC

Precursor

Designed by GRETER research group (UPC) 
 Mean
 570.3

 RMS
 230.6

 Integral
 1.035e+005
Neutron detector efficiency S1400 Based on <sup>3</sup>He counters with the reaction:  $N_{n\beta}$ D 01200  $^{3}$ He + n  $\rightarrow$   $^{3}$ H +  $^{1}$ H + 765 keV  $\mathcal{E}_n$ Noise 1000 Neutron signal 0.35 0.3 800 Pulser 0.25 600 0.2 30 <sup>3</sup>He counters 0.15 He 20 + 10 SIMB/ for this experiment 400 tst crowr 0.1 200 10-2 10<sup>-1</sup> Neutron energy (MeV 1000 1100 Energy (ch) 500 600 700 800 900 200 300 400 Work supported by the Spanish Ministry of Ciemat MICHIGAN STATE **GSJ** MINISTERIO Economy and Competitivity under contract **DE CIENCIA** Centro de Investigacion Energéticas, Medioambientales UNIVERSITY E INNOVACIÓN FPA 2011-28770-C03-03 y Tecnológicos