Heavy isotopes cosmic ray spectrometer (HICRS) for the NUCLEON-2 mission

D. Karmanov, I. Kovalev, A. Kurganov, M. Panasyuk, A. Panov, D. Podorozhny, G. Sedov, L. Tkatchev, A. Turundaevskiy

Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow

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Isotope composition and scientific problems

- Local environment of the sun: diffusion coefficient, radioisotope clocks, local sources
- Isotopes anomalies in supernova explosions in a heavy elements-enriched medium
- Reverse shock wave cosmic ray acceleration
- Features of various nuclei injection process in cosmic ray acceleration
Existing data

- **LDEF**: $Z = 70-103$, 1-2 GeV/N, no isotope composition measurements
- **HEAO-3-C3**: $Z = 17-120$, no isotope composition measurements, low statistics in $Z=44-60$
- **SuperTIGER**: $Z = 10-60$, 2-3 GeV/N, no isotope composition measurements
- **ACE/CRIS**: isotope composition up to $Z=32$, $\sim 10^2$ MeV/N

Conclusion:
- $Z>40$: Low charge composition measurement statistics
- $Z>32$: No isotope composition data at all
- An experiment with exposure several orders of magnitude larger than of the CRIS ACE experiment is needed
The NUCLEON-2 Mission

- Satellite experiment project for direct measurements of cosmic rays for the investigation of charge and isotope composition
- Energy range: 0.1-1GeV/N (depends on the charge)
- Z range (charge composition): 7-94
- Z Range (isotope composition): 7-66
- Exposition time: 5 years
- E-dE telescope technique
Supposed NUCLEON-2 construction and arrangement

Single HICRS

To zenith
HICRS construction

Tracker strip detectors

2mm detectors
**Expected results**

<table>
<thead>
<tr>
<th>Nucleus, Z</th>
<th>( N )</th>
<th>Nucleus, Z</th>
<th>( N )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe 26</td>
<td>( 3 \times 10^7 )</td>
<td>Zr 40</td>
<td>500</td>
</tr>
<tr>
<td>Co 27</td>
<td>( 1.4 \times 10^5 )</td>
<td>Nb 41</td>
<td>150</td>
</tr>
<tr>
<td>Ni 28</td>
<td>( 1.1 \times 10^6 )</td>
<td>Mo 42</td>
<td>230</td>
</tr>
<tr>
<td>Cu 29</td>
<td>( 1.6 \times 10^4 )</td>
<td>Ru 44</td>
<td>100</td>
</tr>
<tr>
<td>Zn 30</td>
<td>( 1.6 \times 10^4 )</td>
<td>Ag 47</td>
<td>140</td>
</tr>
<tr>
<td>Ga 31</td>
<td>2000</td>
<td>Cd 48</td>
<td>120</td>
</tr>
<tr>
<td>Ge 32</td>
<td>2300</td>
<td>Sn 50</td>
<td>120</td>
</tr>
<tr>
<td>As 33</td>
<td>350</td>
<td>Te 52</td>
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<tr>
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<td>1400</td>
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<td>80</td>
</tr>
<tr>
<td>Br 35</td>
<td>200</td>
<td>Ba 56</td>
<td>180</td>
</tr>
<tr>
<td>Kr 36</td>
<td>830</td>
<td>Ce 58</td>
<td>50</td>
</tr>
<tr>
<td>Rb 37</td>
<td>250</td>
<td>Nd 60</td>
<td>40</td>
</tr>
<tr>
<td>Sr 38</td>
<td>1000</td>
<td>Dy 66</td>
<td>180</td>
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<tr>
<td>Y 39</td>
<td>250</td>
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</tr>
</tbody>
</table>

**Graph**

- **NUCLEON-2**
- **ACE/CRIS**

**Axis labels**

- Atomic number
- Kinetic energy (MeV/N)
The prototype

32-channel 16-bit ADC

Trigger control board based on the FPGA devboard Spartan-3E
The prototype
CERN Test results: Z separation
Monte-carlo simulation model construction

Simulation in GEANT4, FLUKA and GEANT3
Isotopes separation in monte-carlo simulation
Isotopes separation in monte-carlo simulation (Mo, 0MeV noise)
Isotopes separation in monte-carlo simulation (Mo, 5MeV noise)
Isotopes separation in monte-carlo simulation (Sn, 0MeV noise)
Isotopes separation in monte-carlo simulation (Sn, 5MeV noise)
Conclusion

• The isotope spectra is one of the recent considerable interests in the field of cosmic rays origin physics and astrophysics in general
• No isotope composition data was measured above Z>32
• Statistics in the Z>40 range is low
• The NUCLEON-2 mission is proposed as a solution
• The monte-carlo simulation of the HICRS prototype and preliminary analysis methods confirm the proposed experiment’s isotope and charge measurement range and resolution
• The project is still in development and will be launched in the year ~2020-2022
Thanks for your attention!
Isotopes separation in monte-carlo simulation
Isotopes separation in monte-carlo simulation (Dy, 0MeV noise)
Isotopes separation in monte-carlo simulation (Dy, 5MeV noise)
Isotopes separation in monte-carlo simulation (Dy, 0MeV noise)
Isotopes separation in monte-carlo simulation (Dy, 5MeV noise)