Validation of the UFS Bonner Sphere Spectrometer and Monte Carlo Methods at the CERN-EU high energy Reference Field (CERF)

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Motivation

• CERF provides a high energy reference neutron field similar to secondary cosmic ray neutrons
  • CERF provides reference neutron spectra, calculated with FLUKA

• Well defined geometry and beam intensity

• Quality assurance of measurements and Monte Carlo methods used at UFS
**Cosmic Radiation in the Earth’s Atmosphere vs. Simulation at CERF**

- Primary cosmic rays
  - galactic and solar component
  - about 85% p, 12% α
- Interact with atmosphere
- Secondary cosmic particles are produced (e.g.: p, n, π⁺⁻⁻⁻, μ⁺⁻⁻⁻, e⁺⁻⁻⁻, γ)

- High energy (120 GeV/c) hadron beam (about 2/3 π⁺, 1/3 p) hits copper Target
- Behind 80 cm lateral concrete shielding secondary cosmic ray neutron field is simulated

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The CERF Facility

- Beam intensity is monitored with a High Precision Ionisation Chamber (PIC)
- 1 PIC-cnt=22,000 incoming particles (+/- 10 %)
MC Simulation

- Using GEANT4 with two Physicslists:
  - QGSP_BERT_HP & QGSP_BIC_HP
  - QGSP: Quark gluon string model for HE interactions of p, n, π, K
  - HP: High precision neutron package for \( E_n < 20 \) MeV
  - BERT: G4 Bertini cascade for primary p, n, π and K below 10 GeV
  - BIC: G4 Binary cascade for primary p & n for energies below 10 GeV
- 3.2 m primary particles
  - 2m π⁺, 1m p, 0.2m K⁺
  - Normalized to 61% π⁺, 35% p, 4% K⁺
  - 120 GeV/c
- Reference calculated with FLUKA¹
  - Rebinned to 10 bins per decade

Spectrometry of Neutrons

Extended Range Bonner Sphere Spectrometer (ERBSS)

• spherical $^3\text{He}$ proportional counters (SP9, Centronic Ltd)
• 1 bare detector for thermal (low energy) neutrons
• 15 PE moderation Spheres (2.5“-15“)
• 2 9” PE Spheres with additional lead shell (0.5“ & 1”) for high energy neutrons

[Graph and images of detectors]
**Results: Top of Concrete Pos. 06 - Fluence**


Note: FLUKA spectra rebinned to 10 bins per decade

Fluence $\Phi$ [cm$^{-2}$ Pri$^{-1}$]

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>E&lt;0.4eV</th>
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</thead>
<tbody>
<tr>
<td>G4-BIC</td>
<td>5.28E−5</td>
<td>1.07E−5</td>
<td>6.02E−6</td>
<td>1.42E−5</td>
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<td>G4-BERT</td>
<td>7.42E−5</td>
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<td>FLUKA</td>
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<td>6.09E−6</td>
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<td>BSS-BIC</td>
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<td>9.82E−6</td>
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<td>2.39E−5</td>
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</tbody>
</table>

FluKa reference spectra from: [http://tis-div-rp-cerf.web.cern.ch/tis-div-rp-cerf/] Note: FLUKA spectra rebinned to 10 bins per decade
Results: Top of Concrete Pos. 06 - H*(10)

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<tr>
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<td>BSS-BERT</td>
<td>340</td>
<td>2.4</td>
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Results: Top of Iron Pos. 06 - Fluence

Fluence $\Phi$ [cm$^{-2}$ Pri$^{-1}$] :  

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<tbody>
<tr>
<td>G4-BIC</td>
<td>4.52E-4</td>
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<td>2.02E-4</td>
<td>3.08E-4</td>
<td>2.60E-5</td>
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<tr>
<td>BSS-FLUKA</td>
<td>5.42E-4</td>
<td>5.34E-6</td>
<td>2.17E-4</td>
<td>2.94E-4</td>
<td>2.55E-5</td>
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Note: FLUKA spectra rebinned to 10 bins per decade.
Results: Top of Iron Pos. 06 - H*(10)


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<table>
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<tr>
<th>H*(10) [pSv PIC⁻¹]</th>
<th>Total</th>
<th>E&lt;0.4eV</th>
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<td>2100</td>
<td>1.1</td>
<td>118</td>
<td>1800</td>
<td>182</td>
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Fluence Ratio of Simulations and Measurements

Ratio of MC Simulations & BSS Measurements to FLUKA Reference

Iron Top Shielding

Concrete Top Shielding
Fluence Ratio of Simulations and Measurements

Ratio of MC Simulations & BSS Measurements to FLUKA Reference

Ratio of MC Simulations to BSS Measurements

HelmholtzZentrum münchen
German Research Center for Environmental Health

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Conclusion

• The neutron field at CERF is eminently suitable for testing neutron detectors and Monte Carlo methods used at UFS

• It was shown that the ERBSS measurements are a proper method for validate MC calculations (influences of differences in input spectra eliminated after unfolding)

• No favourite of physicslist can be identified (QGSP_BERT_HP is overestimated and QGSP_BIC_HP is underestimated compared to ERBSS measurements)
  • Both models are currently in use for MC calculation of cosmic rays at UFS
Thank you for your attention!

S. Trink, M. Wielunski, T. Brall, M. Dommert, V. Mares

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