In-orbit calibration

Geomagnetic cutoff

Use of the ionisation energy loss of cosmic-ray heavy ions
C, N, O, Mg, Si, Fe

CR energy spectrum

$E_{\text{loss}}(E)$

minimum of ionisation

“minimum-ionisation” peak

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Heavy-ion simulation Status
Elements of heavy-ion calibration

Source: cosmic rays
ACD: Trigger CNO
Tracker:
• trajectory selection
• identification of reactions
• Z identification (TOT)

Calorimeter:
• ion identification
• rejection of nuclear reactions
• selection & correction for trajectories (angle, hit position)
• feeding histograms, comparison to simulation results and extraction of calibration values
Heavy-ion simulation: where do we stand?

We currently use standalone GEANT4 v6.0 simulations for the GSI analysis.
Needed process: ionisation only.

Data allow models of nuclear interaction to be validated (or rejected).
Ex: JQMD

Ultimately, the heavy-ion package must be incorporated into Gleam, included in GlastRelease.

Gleam is currently based on GEANT4 v5.1:
There is a bug in the ionisation energy loss for ions in v5.x:
the ionisation energy loss is OK for primary ions
wrong for secondaries
Observed both in standalone and Gleam simulations.
The problem is fixed in v6.0.
Ion flux & spectrum

CREME 96

solar modulation

no change in resulting spectrum

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Heavy-ion simulation Status
Definition of valid trajectories

“No edges or glancing hits”

selection of trajectories with tracker /CAL:

• calculate the entrance-exit points for each layer
• compare these points against the crystals' face coordinates to figure if a crystal boundary was crossed
• deduce the length in each crystal: in principle, some trajectories can be recovered by multiplying $E_{\text{loss}} \times l_{\text{nocrossing}} / \text{length}$ with $l_{\text{nocrossing}} = \text{thickness}/\cos(\theta)$
• calculate $E = E_{\text{loss}} \times \cos(\theta)$
• calculate the closest distance to a face must be greater than 1 mm (delta electrons)
• fill flag-array (0,1,.....) of valid layers

A prototype of this package exists in root format.
Example: muons
20cmx20cm, $\theta$ between 0 and 30°

« Raw »

Valid hits

Corrected
(cos $\theta$)

« Recovered »

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Heavy-ion simulation Status
Example: Carbone

- «Raw»
- Valid hits
- Corrected \((\cos \theta)\)

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20cmx20cm

0° < θ < 30°
Nuclear reactions: simulation

« Central » reactions (high multiplicity of particles, high deposited energy) will be easy to eliminate.
Most annoying in our case are the « gentle » reactions where the ion fragment remains close to the incident ion.

Simulating nuclear reactions properly is much more difficult than simulating EM showers, and requires many fine-tuned parameters (nuclear equation of state, in-medium cross sections, level density parameter, fission widths…)

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JQMD

• Stands for Jaeri Quantum Molecular Dynamics

• Kindly provided to us by Tatsumi Koi (SLAC), who wrote an interface to GEANT4

• Limited to 3 GeV/nucleon

• Uses Tripathi total cross sections

• Runs with GEANT4 v6.0

• Deficiencies observed: too much excitation energy in fragments close to incident ion (Z-1,Z-2,Z-3) which decay into lighter fragments. Not easy to fix
Comparison between data and JQMD predictions ($Z=14$)

GSI data (1.7 GeV/nucleon)  Ionisation peaks  JQMD (1 GeV/nucleon)

Charge-changing events: $Z=11$  $Z=12$  $Z=13$

Heavy-ion simulation Status
Alternative: EPAX-based phenomenological model

The cross sections are *known* for charge-changing reactions. Empirical formulae exist: EPAX (Blank & Sümmerer) valid in the « limiting-fragmentation » regime (s independent of Ebomb)

EPAX only considers the projectile, neither the target nor the missing lighter fragments or particles (charged or neutrons). The number of these particles and their energies can be estimated from the literature: $N \sim 0.75 \times (Z_{proj} - Z_{final})$

These parameters can be tuned from the GSI data.
EPAX-based phenomenological model: comparison with data
Future plans

- iterate at least once more with JQMD;

- tune Epax-based model;

- incorporate this model into G4 v6-based Gleam (Tracy Usher has one running);

- code quenching factors;

- incorporate simple versions of different algorithms…

All this can be accomplished by DC2 (?)
CalSoft Face-to-Face Meeting April 15 – 16, 2004

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Heavy-ion simulation Status

Calibration with Heavy Ions

From Eric’s presentation at the SAS Software eMeeting Nov. 2001

Algorithms
- Physic inputs:
  - dE/dx for heavy ions. Code expressions from the literature.
  - dL/dE for heavy ions. Measure it than code it. Analytic expr. exist.

  - Elements of calibration events
  1. Extract multiMIP events.
  2. Identify likely GCRs, reject obvious junk
  3. Fit tracks.
  4. Accept events with clean track through log, no edges or glancing hits.
  5. Identify charges.
  6. Identify charge-changing interactions.
  7. Identify mass-changing interactions.
  8. Fit dE/dx
Rejection of high-E tail

- can be done if tail is mainly due to “logarithmic rise” instead of Landau fluctuations
- more effective on Fe than on C

Minimum ionizing ions

\[ \delta = \frac{\text{RMS}}{\langle E_{\text{loss}} \rangle} \]

\[ \varepsilon = \frac{N_{\text{cuts}}}{N_{\text{tot}}} \]

\begin{align*}
\text{Eloss} < 450 \text{ MeV} & \quad \delta = 3.6\% \quad \varepsilon = 0.27 \\
\text{Eloss} < 8 \text{ GeV} & \quad \delta = 1.2\% \quad \varepsilon = 0.15
\end{align*}

Distributions resulting from a cut on Eloss in the 7 other layers
Rejection of high-E tail

C: \( \delta=10\% \) cut at \( E_{\text{loss}} <450 \text{ MeV} \): \( \delta=3.6\% \) \( \varepsilon=0.27 \)
\( \Delta E/E <1\% \) 100 evts 13 evts 50 evts total
factor of 100/50= 2 improvement

Fe: \( \delta=9.6\% \) cut at \( E_{\text{loss}} <8 \text{ GeV} \): \( \delta=1.2\% \) \( \varepsilon=0.15 \)
\( \Delta E/E <1\% \) 92 evts 1.5 evts 10 evts total
factor of 92/10= 9 improvement

The resulting distributions are more gaussian-like: easily fitted.