Epics Update: version 8.80(8.81)

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1 What's new

- dE/dx related stuff was updated.
- Using different densities for the one and the same material, the notation like "Air*0.95" is now possible without preparing special sampling tables for the density of 0.95×standard density.
- Plastic scintillator definition was changed, though no observable effect.

2 Some details

The energy deposit by a charged particle in media has been basically treated by Bethe-Bloch formula with Sternheimer's density correction and Urban's prescription of energy loss fluctuation. Epics empolyed rather old stuff for the density correction and related stuff. The stuff has been updated so many times by Sternheimer and others (Sternheimer wrote far more than ten papers on the density correction). This time, such stuff has been updated to be compatible with the standard. It is found that the formula used so far lacks some constant in e^-/e^+ case. For muon energy loss, one new term is added in the formula, which has some effect (∼2% increase of $< dE/dx >$) over 100 GeV.

3 Effect and validation

Epics validation in 2003 used the same contents as done for Glast(Fermi) by Kamae et al. Many other experimental data have been also compared. The agreement with Kamae et al was quite good; they compared Geant4 and EGS4 and also some few experimental data. They observed some discrepancy between Geant4 and EGS4; Epics was always consistent with EGS4[1].

However, I observed some deviation from experimental data for the electron or positron case when they enter a thin medium. Since the agreement with EGS4 was so nice, I didn't take the departure seriously[2].

[1] Geant4 at that time was suspected to give too narrow lateral spread as Kame et al pointed out and they could not figure out the cause. This problem seems to be solved when a new version of Geant4 was issued in early 2009 with a new class of multiple scattering treatment.

[2] Kamae et al's comparisons used mainly cascade showers, and was insensitive to the update stuff this time. Also pions injected to very thin Si were in complete agreement with the figure in PDG

3.1 Summary of effect

- For muons, the effect is small. In many cases, almost completely agrees with the old one except at high energies where the new added term works. However, depending on the material and new constants, some deviation from the old one is observed. E.g no change for PWO but some change for BGO.
- Casade shower development is little bit affected at the initial stage. However, the calorimetric energy will not be affected beyond statistical fluctuation.
- Most serious effect is seen for electron or positron when they enter into a thin medium.
- The agreement with experimental data for e^+ is now almost perfect as opposed to the 2003.

4 Figures

- Figures in BakETALcomp.pdf are comparison of ΔE in thin Si (32μ m to $\sim$1mm) The experimental data is from J.F. Bak et al. LARGE DEPARTURES FROM LANDAU DISTRIBUTIONS FOR HIGH-ENERGY PARTICLES TRAVERSING THIN Si AND Ge TARGETS. Nuclear Physics B288 (1987) 681-716.

  The dots are experimental data and colored histograms are Epics simulation. Each page contains the ΔE distribution for e^+, π^+ and p from the top. The solid lines are theoretical model calculation by Bak et al. The dotted line is the Landau distribution. Although there is some deviation at lowest ΔE region for very thin Si, the agreement is almost perfect.

- File "OldVsNew.pdf contains comparison of new (red line) and old (blue line) simulation data.
  - Fig.1 $\sim$4. Muons in PWO.
  - Fig.5, 6 Muons in BGO. Unlike PWO, there is some effect even at low energies.
  - Fig.7, 8 Muons in plastic scintillator.
  - Fig.9 $\sim$ 12. electrons in PWO. Large effect in thin case!
  - Fig.13$\sim$16. LHCf 2 cm$\times$ 2 cm configuration tower. Electrons of 100 GeV case. The numbers attached to the transition curve data points are difference between new and old in percentage.
  - Fig.17$\sim$ 21. The same for 100 GeV photons. Little bit larger effect than electron case is seen. However, the calorimetric energy is almost the same.
  - Fig.22$\sim$26. The same for 1.4 TeV photons. Less effect than at 100 GeV.
  - Fig.27$\sim$29. Calorimeter by PWO supposed in CALET. 1 TeV electron case.
  - Fig.30$\sim$ 33. Detector response of the Tibet air shower array. Ten proton primary showers of 100 TeV (zenith angle 0° and 30°) are generated and observed at the Yang Bajing altitude. To see the average effect, 10^4 to 3×10^4 particles are put in the detector (0.5 cm Pb + 3cm plastic scintillator) at a given core distance region. It is seen that $\sim$ 3% effect (smaller ΔE than old one) at near core region. At larger distances, $< 2\%$ is expected.

5 Air*0.505 type notation

Before the present version, if we want to use the same material with different densities, we must prepare the various tables by defining the material as different ones. This is somewhat inconvenient and the new version permits to use the notation like Air*0.5835 etc. This means, that the density of the Air is 0.5835 times the standard density. One example is below and the corresponding simulated result is in VaryingDensity.pdf. In the Fig. the new notation result is compared with the old method, i.e, using different tables for each different density.

```
#  type  matter  c    de maxpath  / x y z  a  b c
-------------------------------------------------------------------
1 box Air 0 2 0 / 0 0 0 10000.d2 10000.d2 300e2
2 box Air 0 2 0 / 0 0 + = = =
3 box Air 0 2 0 / 0 0 + = = =
4 box Air*2 0 2 0 / 0 0 + = = =
5 box Air*2 0 2 0 / 0 0 + = = =
6 box Air*2 0 2 0 / 0 0 + = = =
7 box Air*0.1 0 2 0 / 0 0 + = = =
8 box Air*0.1 0 2 0 / 0 0 + = = =
9 box Air*0.1 0 2 0 / 0 0 + = = =
10 box Air*0.5 0 2 0 / 0 0 + = = =
11 box Air*0.5 0 2 0 / 0 0 + = = =
12 box Air*0.5  0 2 0 / 0 0 + = = =
13 box Air*0.25 0 2 0 / 0 0 + = = =
14 box Air*0.25 0 2 0 / 0 0 + = = =
15 box Air*0.25 0 2 0 / 0 0 + = = =
---------------------------------------------------------
```

Note: The fordpmjet command in Version 8.80 cannot handle this notation; the bug was corrected in version 8.81; "foreach" in 8.80's Epics/Scrpt/fordpmjetGLB and fordpmjetINP should read

```
foreach f(`awk '$1 ~/[0-9]+/ && $2 !~/[0-9]+/ {l=index($3,"*"); \
     if(l>0) print substr($3,1,l-1);else print $3}' $1 | sort |uniq`)
```

.

6 Preparing a new matter

If one want to prepare a new material not listed in the Epics/Data/BaseM (or Epics/Data/Media/), one may prepare a file containing basic information in the BaseM directory. The format for the older one is format 1 and can be accepted in version 8.80 but one may prepare the data with format 2: like (this is new plastic scintillator definition)

```
#name   Format    NE102 etc are vinyltoluene C9H10;
#
SCIN  2
#
```

```
#  Elem  rho(g/cm^3) Gas/Solid(1/0)  refl.index  Birks c

2        1.032 0              1.581    13  9.6  0.5714
#  Z A   N
1 1 9
6 12     10
#  <Z/A>   I[eV]     a       k      x0     x1    Cbar  delta0
   0.54141 64.7   0.16101 3.2393 0.1464 2.4855 3.1997 0.00
```

"`SCIN  2`" part defines the format is 2. and new data must be supplied at the last line which is indicated by the comment above. This type of data can be found in ParticleData Group web page:
`http://pdg.lbl.gov/`.
Once connected there, go to
"Reviews, Tables and Plots"
"Constans, Units, Atomic and Nuclear Properies"
"Atomic and nuclear properties of materials (Rev.) PDF Interactive"
(Click "Interactive"). You will find a text file containing such data after choosing relevant material.

6.1 If material is not found

In some case, your material may not be listed in the web page (if not in the web page, probably it's difficult to find data in older literatures too;. E.g, D. E. GROOM et al., MUON STOPPING POWER AND RANGE TABLES 10 MeV—100 TeV; Atomic Data and Nuclear Data Tables 78, 183—356 (2001).

In such a case, you may use format 1. Even with format 1, the constant calculation routines in Epics has been updated and normally fairly accurate so probably there will be no problematic difference from those with format 2 case.

7 Annoying point

In some older version of Epics, the XCOM photon cross-section data have been available for use. It is supplied by NIST (National Institute of Standard and Technology, USA) and seems fairly reliable. It can be used below 100 GeV (down to 1 keV). In the 2003 validation, agreement with EGS4 is better with Nelson's pair creation cross-section than with XCOM. (Nelson is one of the authors of EGS4). At present, default value of Excom2 is set to 1 GeV (which mean below 1 GeV, pair creation cross-section by XCOM is used). If this is made to be 1 MeV (i.e, not use XCOM at all for pair creation), there will be some difference. At present, we are not sure which cross-section is really good.

8 Last but not least

The epicsfile in version 8.80's FistKiss contains wrong numerical value; althogh in many applications, the result will be OK. The value of RecoilKine there is 100, but this must read 0 or 100.0e-6 in normal applications. Never put this one less than 10 keV (i.e, 10.0e-6). It is better to define ElowerBndPair to be 1.022e-3 rather than 2.0e-3.