Instrument Response Function Representation:
DC1 vs "testIrfs"

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Preliminaries and Open Issues

- Derived from AllGamma data
  - Will we have a single set of background cuts? or will cuts vary, e.g., as a function of geomagnetic latitude?
  - Will events always be only Front vs Back or should we partition more finely based on conversion layer?

If the higher level of granularity needed to satisfy the above can be handled by defining event types for each of the various cases, then the integration of more complex irfs with Likelihood and other Science Tools is straight-forward, i.e., a generalization of the two event scheme. If this is not possible, then we (I) need to know ASAP.

- For ScienceTools, IRFs need to have an interface that looks like this:

\[
R_i(E', \hat{p}'; E, \hat{p}) \quad (= A_i(E, \hat{p})P_i(\hat{p}'; E, \hat{p})D_i(E'; E, \hat{p}))
\]

(1)

where \(i\) is event type, \(E\) and \(\hat{p}\) are true photon energy and direction and \(E'\) and \(\hat{p}'\) are measured. (Here we assume a standard partitioning.)
For PSF and energy dispersion analyses, AllGamma events were partitioned into **four inclination ranges** (0–37, 37–53, 53–66, 66–78 degrees) and **eight energy ranges** (31.6–100, 100–316, 316–1000, 1000–3162, 3162–10000, 10000–31623, 31623–100000, 100000–316228 MeV) for a total of **32 bins**.

For PSFs, the angular deviation is scaled by

\[
\tilde{\theta} = 0.08 \left( \frac{\min(E, 10^4)}{10^2} \right)^{-0.8} \quad \text{front} \quad (2)
\]

\[
= 0.14 \left( \frac{\min(E, 10^4)}{10^2} \right)^{-0.8} \quad \text{back}, \quad (3)
\]

where \( E \) is the true photon energy in units of MeV, and the **scaled deviation** is defined as

\[
x \equiv \theta / \tilde{\theta} \quad (4)
\]
DC1 IRFs

- A comparison to GR v4r2 AllGamma data, using DC1 background cuts:

- In each of the 32 bins, the distribution of scaled deviations is modeled as

\[
\frac{dN}{dx} = x \left[ p_0 \exp\left(-\frac{x^2}{2p_1^2}\right) + p_2 \exp\left(-\left(p_3 x\right)^{p_4}\right) \right]
\] (5)
The parameters describing the PSF do not vary smoothly across the bins:

- PSF params: Front 0-37 deg
- PSF params: Front 37-53 deg
- PSF params: Front 53-66 deg
- PSF params: Front 66-78 deg
DC1 IRFs

PSF params: Back0-37 deg

PSF params: Back37-53 deg

PSF params: Back53-66 deg

PSF params: Back66-78 deg
Partitioning into 32 bins causes serious problems when trying to fit spectra since there are then large jumps in the PSF as a function of energy and inclination at a given angular deviation.
Goals:
- Behavior based on AllGamma data and DC1 cuts
- Find better energy scaling for angular deviations
- Use “hyper”-parameterization to ensure smooth transition across AllGamma bins
  ⇒ abandon detailed fit of the distributions

Implementation: use Toby’s proposed representations of
- $A_{\text{eff}}$, “logistic” function
- $P_{\text{sf}}$ (erred here however)
- $E_{\text{disp}}$, Gaussian function (as for DC1 irfs)
Fitting the energy scaling of the angular deviations

- In addition to Front/Back, consider ten $\mu = \cos i$ ranges covering $\mu = 1$ to 0.3
- Fit the profile for each $\mu$ with

$$\tilde{\theta}(\mu) = \theta_0(\mu) \left( \frac{1}{E} + \frac{1}{E_b} \right)^\delta$$

(6)

where $E_b$ and $\delta$ are found from fitting the profiles summed for all $\mu$, but still considering Front/Back separately.
- Hyper-parameterization for psf scale prefactor:

$$\theta_0(\mu) = p_0(\mu - 1)^2 + p_1$$

(7)
- Example profile fits:
Hyper-parameterization of psf scaling prefactor:

Front: psf scaling prefactor

Back: psf scaling prefactor
\[
\frac{dN}{dx} = p_2 x \left[ 1 + \frac{p_4 x}{p_3 - 1} \right]^{-p_3}
\]  

where \( x \equiv \theta/\theta_0 \). Using equations 6 & 7 in irfAnalysis, one finds more regularity in the parameter values, e.g., to a good approximation, can take \( p_4 = 2 \); and \( p_3 \) ranges from 10 to 4:

For testIrfs, I’ve arbitrarily set \( p_3 \equiv 9 \), but one could use an appropriate hyper-parameterization:

\[
p_3(E) = a \log E + b
\]
**testIrfs: Psf behavior**

- **testIrfs, Front**
  - sep=10 deg, inc=0
  - Energy (MeV) vs. psf graph
- **testIrfs, Front**
  - sep=10 deg, energy=300 MeV
  - inclination (degrees) vs. psf graph
- **testIrfs, Back**
  - sep=10 deg, inc=0
  - Energy (MeV) vs. psf graph
- **testIrfs, Back**
  - sep=10 deg, energy=300 MeV
  - inclination (degrees) vs. psf graph
• Use Logistic function:

\[ A(E) = \frac{p_0}{1 + \exp(-p_2 \log(E/p_1))} \]  

(10)
Conclusions

- Are the testResponse IRFs “better” than the DC1 versions? Not necessarily. I made no attempt to fit all details of AllGamma distributions.

- They are much better behaved, largely because of hyper-parameterizations so that the coarse binning in inclination and true energy is not imprinted on the output (also some amelioration from more careful assessment of psf scaling).

- However, we do need the details, so hyper-parameterizations, or even direct parameterizations (logistic for Aeff, Gaussian for Edisp), may not be sufficient.