cherenkov telescope array

Thoughts on DL3 for IACTs

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My favorite questions

- How to factorise the Instrument Response Function?
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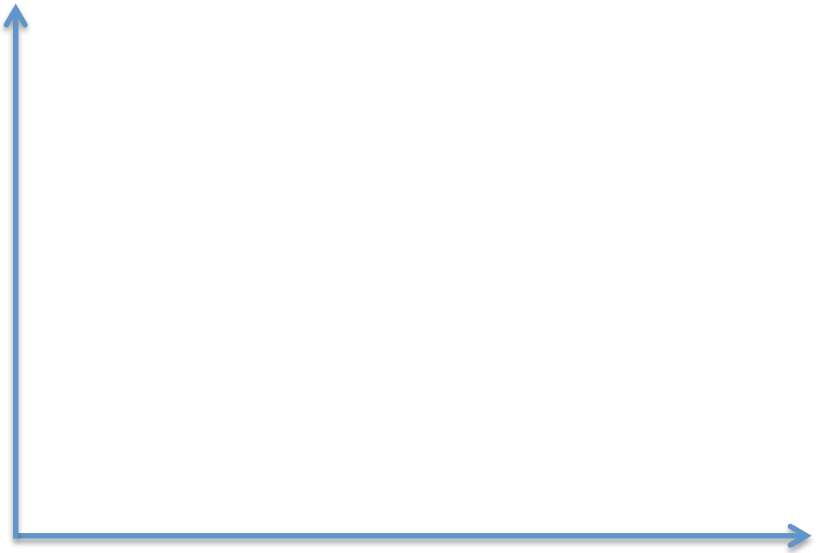
But before that …

- What information do we need in the event file?
  - is the minimal format that we implemented in GammaLib enough?
  - should there be redundant information?
  - Note: RA/DEC – DETX/DETY is not considered redundant as the transformation needs a pointing model and explicitly the time
  - should there be mandatory columns and optional columns? Should there be flexibility in implementing the format? (recall: the “F” in FITS stands for flexibility, maybe one of the reasons for its success)

Select / All / Invert	EVENT_ID	TIME	RA	DEC	ENERGY	DETX	DETY
	1J	1D	1E	1E	1E	1E	1E
		s	deg	deg	TeV	deg	deg
	Modify	Modify	Modify	Modify	Modify	Modify	Modify
1	1	3.596789240837E-01	8.362013E+01	2.197107E+01	1.570517E-01	-3.893483E-02	-9.149051E-03
2	2	9.667769908905E+00	8.360922E+01	2.195930E+01	1.137184E-01	-5.070112E-02	-1.927271E-02
3	3	1.314883381128E+01	8.365855E+01	2.205752E+01	1.149002E-01	4.752544E-02	2.645994E-02
4	4	1.550700747967E+01	8.362605E+01	2.206566E+01	1.719268E-01	5.566480E-02	-3.665101E-03
5	5	1.589011639357E+01	8.375288E+01	2.202609E+01	1.138880E-01	1.613743E-02	1.139171E-01

But before that ...

- How to partition the events?
  - can we use the logic of event classes and event types defined by Fermi/LAT?
  - inclusive or exclusive event files?
  - how to organise the response functions for the partitions?



event types (reconstruction quality)
Fermi/LAT: PSF, EDISP, FB (same file)
CTA: ? (multiplicity, xST)

event classes (background cuts)
Fermi/LAT: transient, source, clean, ultraclean (separate files)
CTA: South_0.5h, South_5h, South_50h

A possible DL3 format

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header | Image | Table
1	EVENTS	Binary	7 cols X 12121 rows	Header | Hist | Plot | All | Select
2	GTI	Binary	2 cols X 1 rows	Header | Hist | Plot | All | Select
3	EFFECTIVE AREA	Binary	6 cols X 1 rows	Header | Hist | Plot | All | Select
4	POINT SPREAD FUNCTION	Binary	10 cols X 1 rows	Header | Hist | Plot | All | Select
5	ENERGY DISPERSION	Binary	7 cols X 1 rows	Header | Hist | Plot | All | Select
6	BACKGROUND	Binary	7 cols X 1 rows	Header | Hist | Plot | All | Select

- Store information for one observation (aka run) in a single file
  - event list (for a given cut)
  - Good Time Intervals for the selected events
  - Instrument Response for the selected events (one per event type)
  - Background rate template for the selected events (one per event type)
- Science Users get for each observation a single, self contained file
  - simplifies data distribution
  - minimizes risk of improper usage

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- But …
  - assumes a given temporal granularity (IRF “fixed” over period)
  - eventually duplicates IRF and/or background information if their temporal variation is slower than the temporal granularity of the files
  - file size likely dominated by IRF
    - EVENTS & GTI: 406 kBytes / 325 kBytes (30 min, South_0.5h)
    - IRF: 2105 kBytes / 406 kBytes
    - Uncompressed / gzip compressed

Caveats

- Should an event file correspond to one run?
  - should we assume that the pointing direction is fixed?
  - how to deal with data for “slew” or “scan” observations?
  - CTA is considering to abandon “runs” at the low-level. Should we have a format that can do the same at the high-level?
- What if we want to support shorter runs (~ min)?
  - do we need that?
  - can we really measure IRF variations at such short time scales?
  - what about memory requirements?
  - can’t we achieve the same with a proper response factorisation?

Response formalism

- "Standard" response factorisation

$$R(\boldsymbol{p}', E', t'|\boldsymbol{p}, E, t) = A_{\text{eff}}(\boldsymbol{p}, E, t) \times PSF(\boldsymbol{p}'|\boldsymbol{p}, E, t) \times E_{\text{disp}}(E'|\boldsymbol{p}, E, t)$$

- Event probability

$$P_i(\boldsymbol{p}', E', t'|M_j) = \int_{\boldsymbol{p},E,t} R_i(\boldsymbol{p}', E', t'|\boldsymbol{p}, E, t) \times M_j^S(\boldsymbol{p}, E, t)\, \mathrm{d}\boldsymbol{p}\, \mathrm{d}E\, \mathrm{d}t$$

- Number of observed events (N_{pred})

$$e_i(M) = \int_{GTI} \int_{Ebounds} \int_{ROI} P_i(\boldsymbol{p}', E', t'|M)\, \mathrm{d}\boldsymbol{p}'\, \mathrm{d}E'\, \mathrm{d}t'$$

Can we factorise more?

- E.g. separate zenith angle from camera/array dependencies

$$A_{\mathrm{eff}}(\boldsymbol{p}, E, t) = A_{\mathrm{zenith}}(E|\boldsymbol{p}, t) \times A_{\mathrm{camera}}(\boldsymbol{p}, E)$$

compute zenith angle from sky direction and time

2D table (energy, zenith angle)

2D or 3D table (energy, offset angle, maybe azimuth angle)

both components vary probably only slowly with time

- Can we factorise other atmospheric parameters?
- Ultimate goal: separate atmosphere from array configuration

Preliminary conclusions

- Defining the DL3 format boils down to finding the proper factorisation for the Instrument Response Function
- Event file format will follow once the IRF format is fixed