DL3 data model beyond the IACT community ?

Jaime Rosado and José Luis Contreras

Motivation

- Event lists [ID, energy, direction, time] are suitable for event-based, neutrino and cosmic-ray observatories.

- Applicable to large aperture γ-ray observatories (e.g., HAWC).

- Common formats (and tools) ease multi-messenger analyses.

- Openness (data, standards, software, mind…) also brings returns to experiments: larger impact of results, externally developed software, crosscheck analyses …

- Already happening: many astroparticle observatories are making available event sets (web, electronic journals).

Who are we and why are we proposing this?

H2020 project ASTERICS (Astronomy ESFRI and Research Infrastructure Cluster)

"Implementation and operation of cross-cutting services and solutions for clusters of ESFRI and other relevant research infrastructure initiatives".

Work package OBELICS (Observatory E-environments Linked by common ChallengeS):

- To enable interoperability and software re-use for the data generation, integration and analysis of ESFRI and pathfinder facilities.
- To create an open innovation environment for establishing open standards and software libraries for multi-wavelength/multi-messenger data.
- To develop common solutions for streaming data processing and extremely large databases, as well as studying advanced analysis algorithms and software frameworks for data processing and quality control.

Who are we and why are we proposing this?

• Within ASTERICS, we are in charge of surveying and testing existing data formats (all levels) and making proposals for standards.

Project	Field	Data
CTA	Gamma	Events
H.E.S.S.	Gamma	Events
MAGIC	Gamma	Events
KM3NeT	Neutrino	Events
IceCube	Neutrino	Events
ANTARES	Neutrino	Events
E-ELT	VNIR	Images

Project	Field	Data
LSST	Visible	Images
Euclid	Visible	Images
SKA	Radio	Signals
e-VLBI	Radio	Signals
LOFAR	Radio	Signals
LIGO	GW	Signals
Virgo	GW	Signals

• In CTA, we are in the Data Model sub-work package within the Data Management work package.

Strategy to make DL3 standards more general

- Keeping in mind other experiments/particles to name and define generic enough parameters.

- Making some parameters only related to IACTs optional (or allowing null values).

- Defining and grouping parameters and IRFs that cover the needs of a given type of experiment.

- Enriching this initiative of DL3 standards with contributions from the wide astroparticle community.

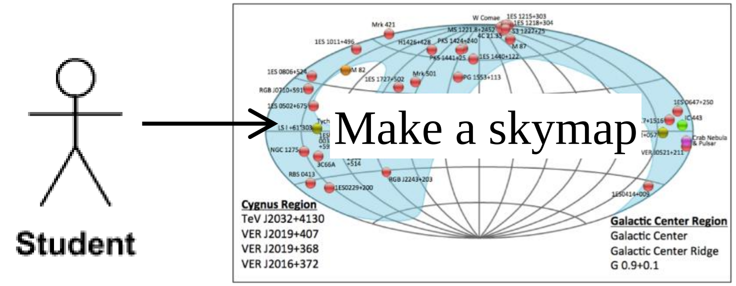
Some identified difficulties

- DL3-equivalent data level not necessarily defined in every experiment.
- Some essential variables not always given, e.g., energy is sometimes replaced by a related observable (proxy).
- Different concepts of operation, e.g., all-sky observation instead of source pointing. This even applies to IACTs (extended sources ?).
- IRFs will be different, e.g., exposure (km^2·sr·yr) instead of effective area. The very term "IRF" is not used in some experiments, but still applicable (at least for many high-level analyses ?).
- "Runs" make no sense for continuous observation.
May "observation periods" (months, years) be equivalent to "runs" ?

Simple use cases

One can think of many simple use cases involving data from one or more astroparticle observatories to test the approach:

- Making a skymap.
- Building a spectrum.
- Crosschecking a time series.
- Correlating events with GRBs, BL Lacs….

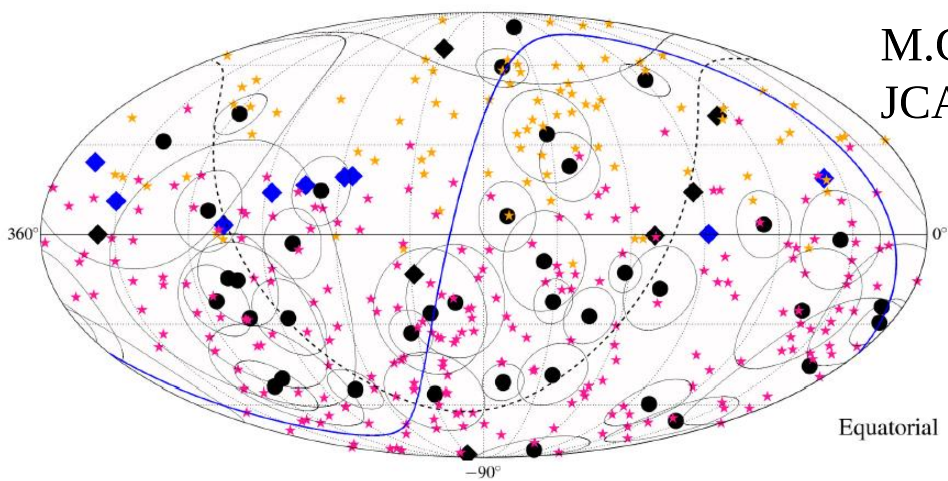


To be developed during the meeting ?

Complex use case

"Search for correlations between the arrival directions of IceCube neutrino events and ultrahigh-energy cosmic rays detected by the Pierre Auger Observatory and Telescope Array".

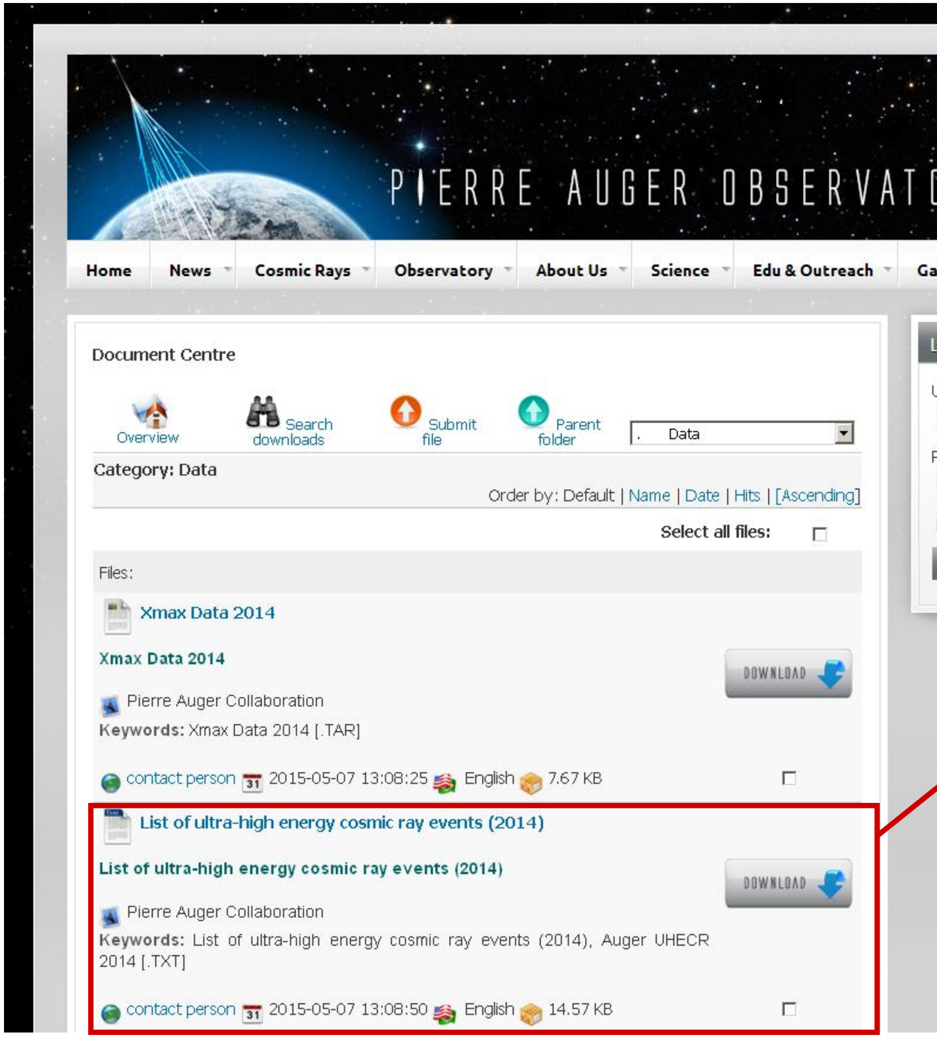
- HE event lists for selected observation periods.
- Angular resolutions: average values for Auger and TA, while event-dependent for IceCube.
- Model for an energy dependent Gaussian deflection of cosmic rays.
- Average relative exposures of Auger and TA as a function of declination.



M.G. Aartsen et al., JCAP01 (2016) 037

Complex use case

Auger Document Center: https://www.auger.org/index.php/document-centre




```
##################################################################################
##  (c) Copyright by Pierre Auger Collaboration 2014                            ##
##                                                                              ##
##  Publications using or referring to these data should cite the following     ##
##  reference:                                                                  ##
##                                                                              ##
##  A. Aab et al. (The Pierre Auger Collaboration), "Searches for Anisotropies in ##
##  the Arrival Directions of the Highest Energy Cosmic Rays Detected by the    ##
##  Pierre Auger Observatory", arXiv:1411.6111                                  ##
##                                                                              ##
##  Data are provided as is and might be subject to future changes.             ##
##                                                                              ##
##  These data are released under the Creative Commons Attribution-ShareAlike 4.0 ##
##  International License (CC BY-SA 4.0). For more details see                  ##
##  http://creativecommons.org/licenses/by-sa/4.0/                              ##
##                                                                              ##
##################################################################################
```

YYYY	DDD	Theta	E	RA	dec	Glon	Glat
2004	125	47.7	62.2	267.2	-11.4	15.5	8.4
2004	142	59.2	84.7	199.7	-34.9	-50.8	27.7
2004	177	71.5	54.6	12.7	-56.6	-56.9	-60.5
2004	239	58.3	54.0	32.7	-85.0	-59.1	-31.8
2004	282	26.3	58.6	208.1	-60.1	-49.5	1.9
2004	339	44.6	78.2	268.4	-61.0	-27.6	-16.9
2004	343	23.3	58.2	224.7	-44.0	-34.1	13.1
2005	50	67.5	60.2	29.0	-14.0	174.9	-70.0
2005	54	34.9	71.2	17.5	-37.8	-76.0	-78.6
2005	63	54.4	71.9	331.2	-1.3	58.7	-42.4
2005	81	17.1	52.1	199.1	-48.5	-52.8	14.1
2005	186	57.5	108.2	45.6	-1.7	179.5	-49.6
2005	233	65.4	61.9	278.4	-1.3	29.7	3.4
2005	295	15.3	54.9	333.0	-38.1	4.4	-55.0
2005	306	14.2	74.9	114.8	-42.8	-103.9	-10.0
2005	347	65.6	77.5	18.3	29.2	128.6	-33.4
2006	5	30.9	78.2	18.9	-4.7	138.3	-66.8
2006	35	30.8	72.2	53.6	-7.8	-165.9	-46.9
2006	55	37.9	52.8	267.6	-60.6	-27.5	-16.4
2006	64	66.6	64.8	275.2	-57.2	-22.6	-18.6
2006	81	34.0	69.5	201.1	-55.3	-52.3	7.3
2006	100	33.7	54.7	28.8	-16.4	-179.9	-71.8
2006	118	57.3	56.3	322.5	-2.0	51.6	-35.6
2006	126	65.2	82.0	299.0	19.4	57.6	-4.7

Complex use case

IceCube Public Data Access: https://icecube.wisc.edu/science/data

University of Wisconsin-Madison

Search Enter Topic or Name GO!

ICECUBE SOUTH POLE NEUTRINO OBSERVATORY

Principal | About Us | Science | Collaboration | Outreach | Life @ Pole | Photos & Video

IceCube in the Ne

Contact Us

Public Data Access (last release on 5 Jan 2016)

Featured release

A new release is available related to a dark matter search using data from 79-strings of the IceCube detector. The analysis is an improved event-level likelihood formalism for including neutrino telescope data in global fits for new physics. The code for applying this formalism to arbitrary dark matter models is also provided on the IceCube tools page.

Download: The 79-string IceCube search for dark matter

Data Use Policy

IceCube is committed to the goal of releasing data to the scientific community. The following links contain data sets produced by AMANDA/IceCube researchers along with a basic description. Due to challenging demands on event reconstruction, background rejection and systematic effects, data will be released after the main analyses are completed and results are published by the international IceCube Collaboration. During the construction phase of IceCube we expect that final data sets can be released within a few years after the data have been taken.

More Information

The following two links give more information about IceCube data formats and polcies.

IceCube Open Data

IceCube Policy on Data Sharing

Download Datasets

The pages below contain information about the data that were collected and links to the data files. We ask that you provide your contact information so that we may notify you if we revise the datasets in the future.

Dataset	Release Date
The 79-string IceCube search for dark matter	2016 Jan 05
Observation of Astrophysical Neutrinos in Four Years of IceCube Data	2015 Oct 21
Astrophysical muon neutrino flux in the northern sky with 2 years of IceCube data	2015 Aug 20
IceCube-59: Search for point sources using muon events	2015 Jun 19
Search for contained neutrino events at energies greater than 1 TeV in 2 years of data	2015 Feb 19
IceCube Oscillations: 3 years muon neutrino disappearance data	2015 Jan 27

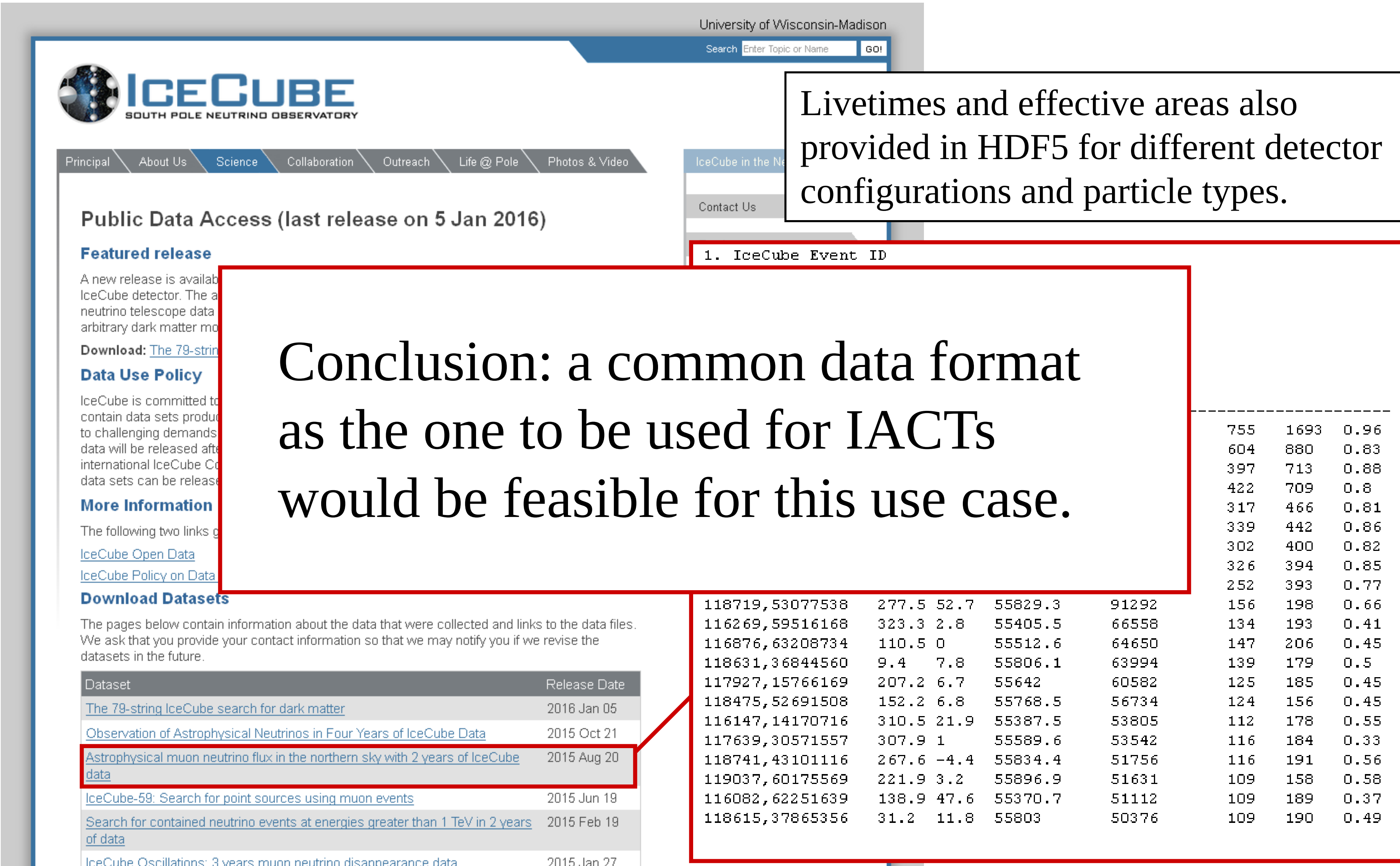
Livetimes and effective areas also provided in HDF5 for different detector configurations and particle types.

1. IceCube Event ID
2. Right Ascension, degrees
3. Declination, degrees
4. Modified Julian Day, days
5. Energy Proxy, arbitrary units
6. Most probable muon energy for best-fit, TeV
7. Most probable neutrino energy for best-fit, TeV
8. Signal Probability for best-fit

116357,6324295	254	16.3	55421.5	289916	755	1693	0.96
116807,9493609	88.5	0.2	55497.3	199981	604	880	0.83
119136,66932419	37.1	18.6	55911.3	157871	397	713	0.88
116883,17395151	285.7	3.1	55513.6	147002	422	709	0.8
116701,6581938	331	11	55478.4	140113	317	466	0.81
116026,44241207	346.8	24	55355.5	139728	339	442	0.86
116574,20123342	267.5	13.8	55464.9	131950	302	400	0.82
119739,41603205	238.3	18.9	55987.8	130382	326	394	0.85
118210,47538807	235.2	19.3	55702.8	106898	252	393	0.77
118719,53077538	277.5	52.7	55829.3	91292	156	198	0.66
116269,59516168	323.3	2.8	55405.5	66558	134	193	0.41
116876,63208734	110.5	0	55512.6	64650	147	206	0.45
118631,36844560	9.4	7.8	55806.1	63994	139	179	0.5
117927,15766169	207.2	6.7	55642	60582	125	185	0.45
118475,52691508	152.2	6.8	55768.5	56734	124	156	0.45
116147,14170716	310.5	21.9	55387.5	53805	112	178	0.55
117639,30571557	307.9	1	55589.6	53542	116	184	0.33
118741,43101116	267.6	-4.4	55834.4	51756	116	191	0.56
119037,60175569	221.9	3.2	55896.9	51631	109	158	0.58
116082,62251639	138.9	47.6	55370.7	51112	109	189	0.37
118615,37865356	31.2	11.8	55803	50376	109	190	0.49

Complex use case

IceCube Public Data Access: https://icecube.wisc.edu/science/data


University of Wisconsin-Madison

Search Enter Topic or Name GO!

ICECUBE SOUTH POLE NEUTRINO OBSERVATORY

Principal | About Us | Science | Collaboration | Outreach | Life @ Pole | Photos & Video

IceCube in the Ne

Contact Us

Public Data Access (last release on 5 Jan 2016)

Featured release

A new release is availab
IceCube detector. The a
neutrino telescope data
arbitrary dark matter mo

Download: The 79-strin

Data Use Policy

IceCube is committed to
contain data sets produ
to challenging demands
data will be released afte
international IceCube Co
data sets can be release

More Information

The following two links g

IceCube Open Data

IceCube Policy on Data

Download Datasets

The pages below contain information about the data that were collected and links to the data files. We ask that you provide your contact information so that we may notify you if we revise the datasets in the future.

Dataset	Release Date
The 79-string IceCube search for dark matter	2016 Jan 05
Observation of Astrophysical Neutrinos in Four Years of IceCube Data	2015 Oct 21
Astrophysical muon neutrino flux in the northern sky with 2 years of IceCube data	2015 Aug 20
IceCube-59: Search for point sources using muon events	2015 Jun 19
Search for contained neutrino events at energies greater than 1 TeV in 2 years of data	2015 Feb 19
IceCube Oscillations: 3 years muon neutrino disappearance data	2015 Jan 27

1. IceCube Event ID

					755	1693	0.96
					604	880	0.83
					397	713	0.88
					422	709	0.8
					317	466	0.81
					339	442	0.86
					302	400	0.82
					326	394	0.85
					252	393	0.77
118719,53077538	277.5	52.7	55829.3	91292	156	198	0.66
116269,59516168	323.3	2.8	55405.5	66558	134	193	0.41
116876,63208734	110.5	0	55512.6	64650	147	206	0.45
118631,36844560	9.4	7.8	55806.1	63994	139	179	0.5
117927,15766169	207.2	6.7	55642	60582	125	185	0.45
118475,52691508	152.2	6.8	55768.5	56734	124	156	0.45
116147,14170716	310.5	21.9	55387.5	53805	112	178	0.55
117639,30571557	307.9	1	55589.6	53542	116	184	0.33
118741,43101116	267.6	-4.4	55834.4	51756	116	191	0.56
119037,60175569	221.9	3.2	55896.9	51631	109	158	0.58
116082,62251639	138.9	47.6	55370.7	51112	109	189	0.37
118615,37865356	31.2	11.8	55803	50376	109	190	0.49

Livetimes and effective areas also provided in HDF5 for different detector configurations and particle types.

Conclusion: a common data format as the one to be used for IACTs would be feasible for this use case.

THANK YOU !

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 653477.