Friedrich-Alexander-Universität
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Neutrino data

Approach to high-level data formats

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KM3NeT Collaboration

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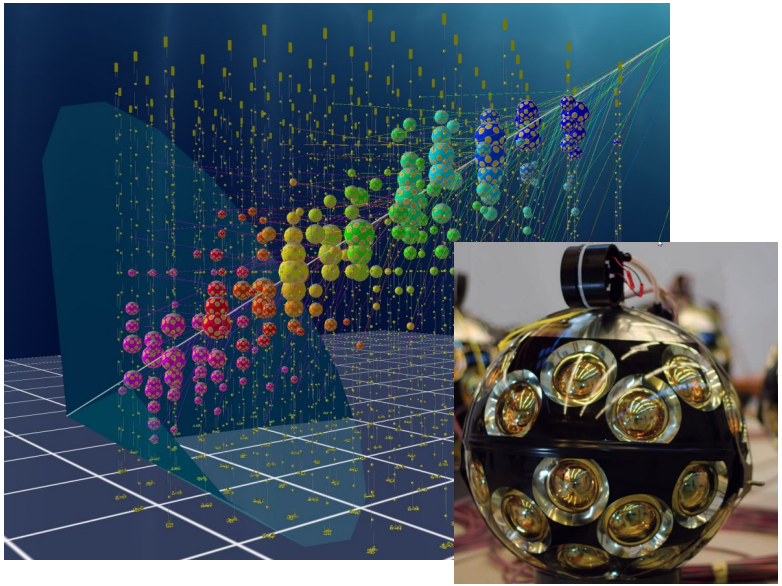
Neutrino experiment features

- Water Cherenkov detectors in water or ice
- Single photon detection to reconstruct particle direction, energy estimate by light gain
- Generally all-sky, continuous data taking, long-term (years …)
- Low-countrate particle detection with extensive Monte Carlo simulation for analysis
- High-level analysis products: event list & IRFs (or similar)
    - Or: single neutrino events as transient alert
- Example data from ANTARES & KM3NeT (broader introduction @IVOA Paris WS)



- Aside: radio neutrino (RNOG) coming up with EHE neutrino

Neutrino event lists

„Full“ event (i.e. particle detection!)

event identification	detector status	<photon detections $\vec{x}$, t, A>

„Reduced“ event

reconstructed particle properties	direction time energy, resolution ...

Decl [deg]	RA [deg]	Nhit [deg]	Beta	MJD [days]
19.5	68.2	21	1.0	54138.3105
-60.0	26.5	33	0.8	54138.5830
-29.8	82.1	34	0.3	54140.2299
-8.6	271.8	41	0.3	54140.6394
-32.3	261.4	45	0.5	54142.7042
-66.7	149.9	52	0.8	54159.4158
-13.0	93.6	25	0.7	54160.4830
-26.2	266.7	28	0.8	54160.6180
23.5	121.7	41	0.5	54161.4361
-70.7	47.1	30	0.9	54165.5838
-55.0	284.4	36	0.5	54169.0685

Event list requirements for neutrinos

Mandatory

- Time
- Direction (RA, Dec)
- Particle ID

Highly recommended

- Energy estimate
- Angular error estimate

Optional

- Particle type identifiers, classifiers, …

Example table data: ANTARES 2007-2017 event list @vo.km3net.de

MJD	MJD	Modified Julian Day
Beta	Beta	angular error estimate on reconstruction
Nhit	number of hits	number of discrete integrated light signals in photomultipliers
RA	right ascension	ICRS right ascension
Decl	declination	ICRS declination
ID	ID	Event identifier, continuous event number in the data set

Instrument response functions

Common source search with CTA and KM3NeT

- Available on Github and Zenodo

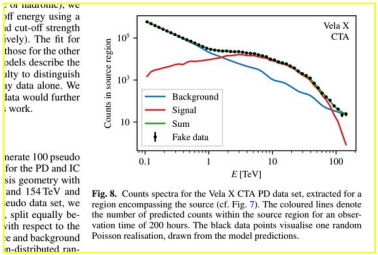
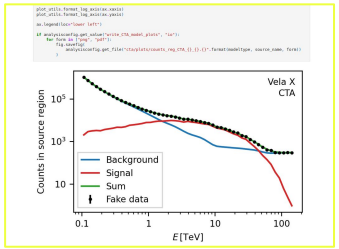


Fig. 8. Counts spectra for the Vela X CTA PD data set, extracted for a region encompassing the source (cf. Fig. 7). The coloured lines denote the number of predicted counts within the source region for an observation time of 200 hours. The black data points visualise one random Poisson realisation, drawn from the model predictions.

paper



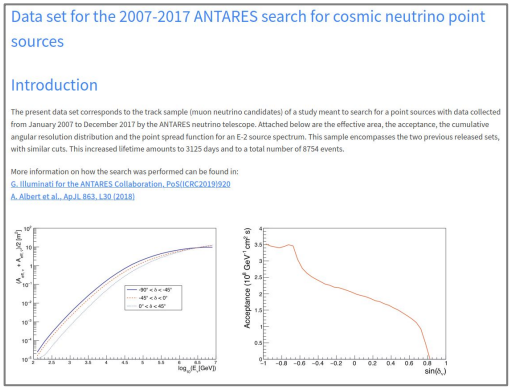
repository

Lessons learned: when using gamma IRFs, need to “fake” pointing to generate e.g. pseudo data

-> would natively come from all-sky and cut down

ANTARES 2007-2017

- On webpage (not nicely presented, but essentially what’s available)



Data set for the 2007-2017 ANTARES search for cosmic neutrino point sources

Introduction

The present data set corresponds to the track sample (muon neutrino candidates) of a study meant to search for a point sources with data collected from January 2007 to December 2017 by the ANTARES neutrino telescope. Attached below are the effective area, the acceptance, the cumulative angular resolution distribution and the point spread function for an E-2 source spectrum. This sample encompasses the two previous released sets, with similar cuts. This increased lifetime amounts to 3125 days and to a total number of 8754 events.

More information on how the search was performed can be found in:
G. Illuminati for the ANTARES Collaboration, PoS(ICRC2019)920
A. Albert et al., ApJL 863, L30 (2018)

-> no reproducibility, only approximation possible, as likelihood scans on MC simulations are required

Which analysis would the user do with the data?

Point-Source search

Example: neutrinos from the Crab nebula?

Access Cone Search
Energy > TeV
Duration 10+ years
IRFs

- background estimate
- det. acceptance for given flux

“Cut and count” analysis

Diffuse search

Example: neutrinos from the Fermi Bubbles?

Access TAP?
Energy GeV - TeV
Duration 10+ years
IRFs

- background estimate
- Energy dispersion, effective area?

Extended search area

BSM physics

Example: WIMP Neutrinos from the Sun?

Access ?
Energy GeV
Duration 10+ years
IRFs

- background estimate
- PSF, …

Lower energy, “moving” target

Transient event

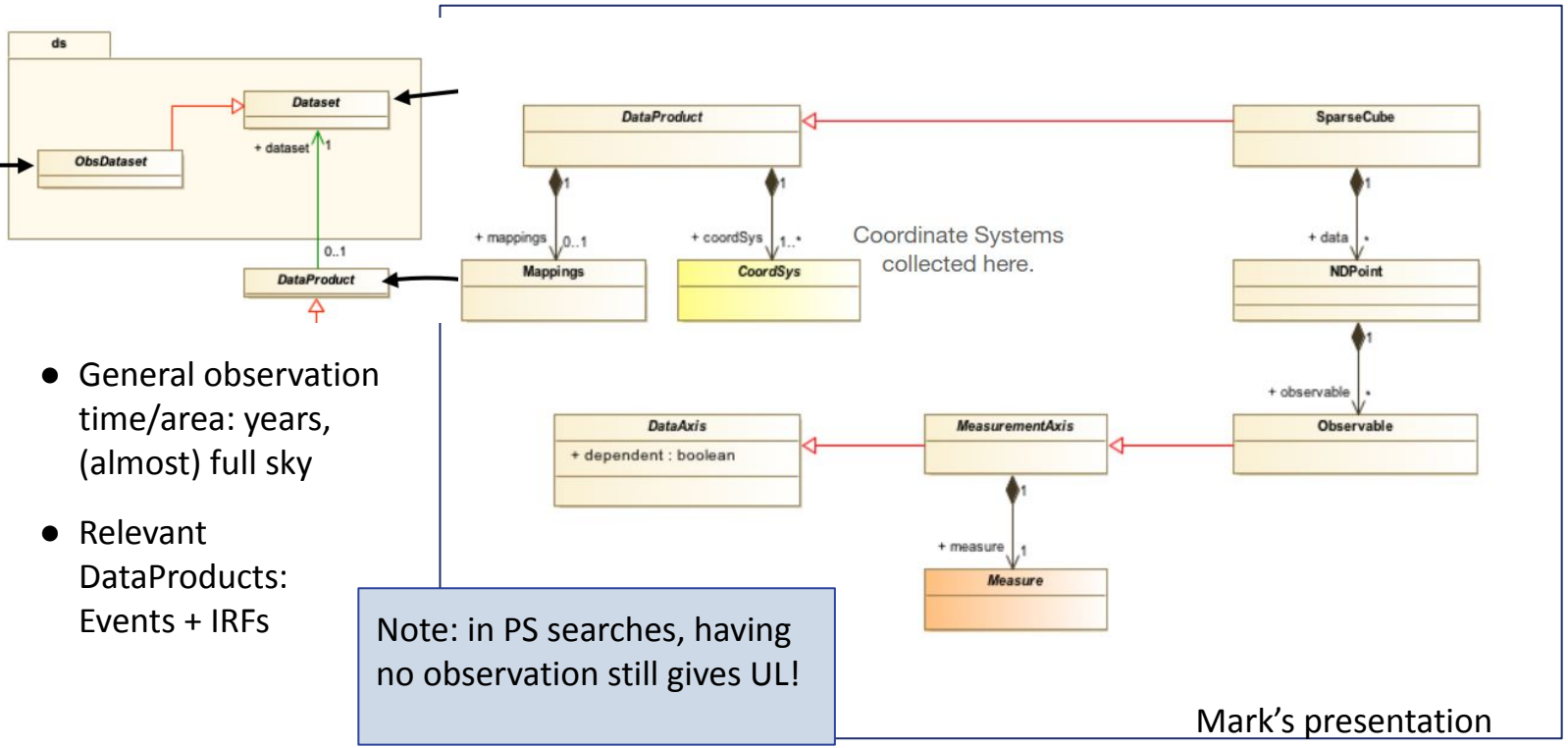
Example: GRB, source of VHE neutrinos?

Access VOEvent…?
Energy depends
Duration <hrs
IRFs

- p-Value, signal probability …

Result of online filtering or external alert

SparseCube for neutrino?



- General observation time/area: years, (almost) full sky
- Relevant DataProducts: Events + IRFs

Note: in PS searches, having no observation still gives UL!

Mark's presentation

For event lists alone, sparse cubes seem OK

BUT

only with additional "maps" and access functions

Summary & Questions

- Event lists as sparse cubes look OK
- Event list is meaningless without IRFs (always need the Dataset with both)
- Dataset with event list and IRF selection is dependent on the physics question & type of search
- Observations for data sets are generally years in duration and up to all-sky
- Searches with no resulting events can still give a physics results in form of flux upper limits
- Currently, application of IRF usually requires further processing of the information

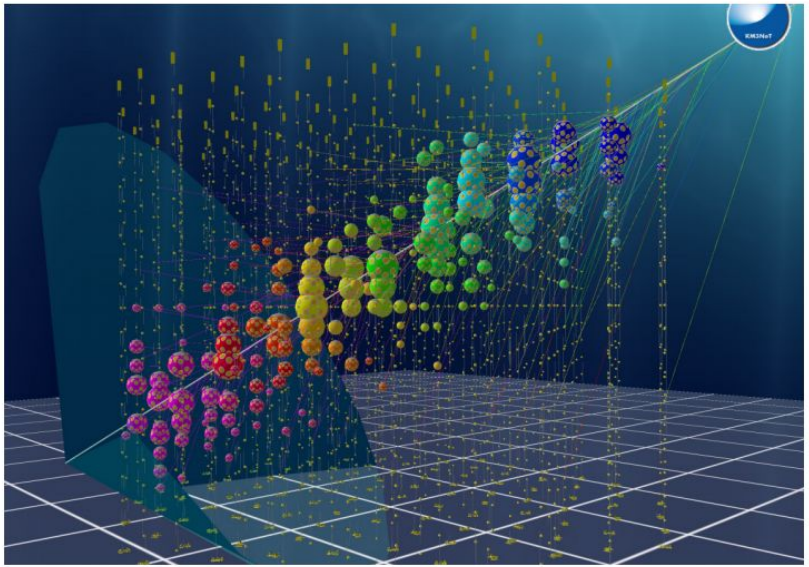
For further discussions: What are the analysis examples we are considering?

Backup

Neutrino data in VHE Cherenkov telescopes

„Full“ event (i.e. particle detection!)

event identification	detector status	<photon detections $\vec{x}$, t, A>



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Example files of KM3NeT ROOT files:
https://github.com/KM3NeT/km3net-testdata

Low countrate experiments!