Publishing multi-purpose data sets from KM3NeT

IV International Workshop
Data lifecycle in Physics 2020
8th – 10th June 2020

Jutta Schnabel for the KM3NeT collaboration

ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

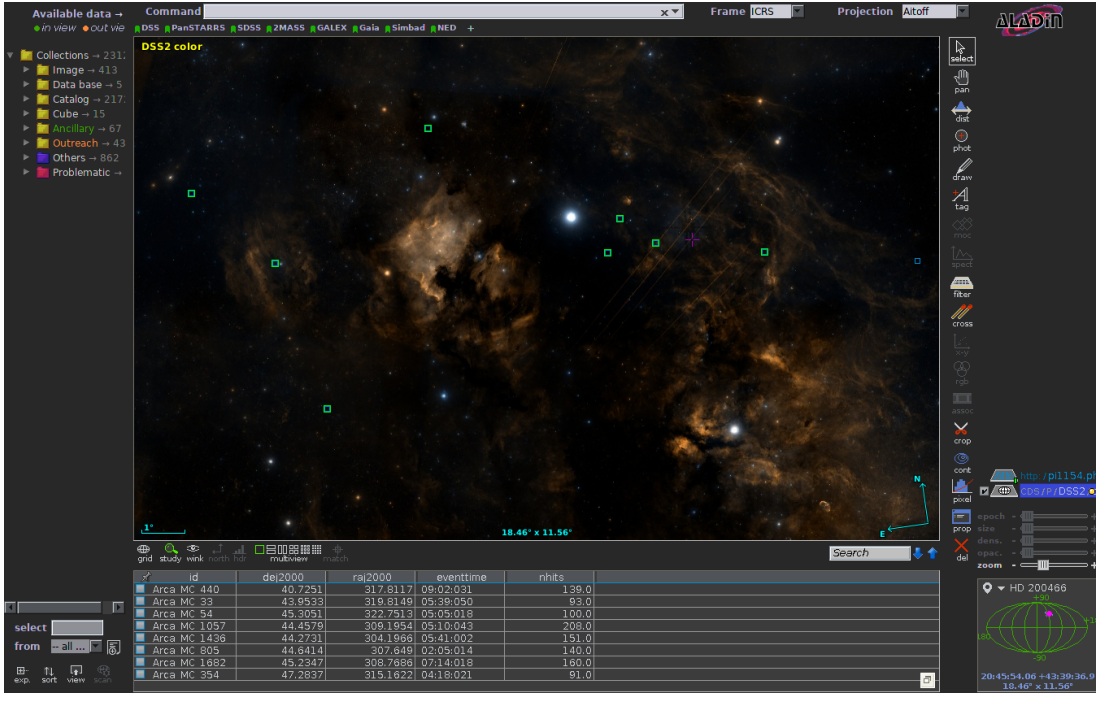
Overview

Moving towards Open Science

- KM3NeT - Science between astrophysics and particle physics
- Data taking and processing rooted in particle physics, requiring high performance grid computing

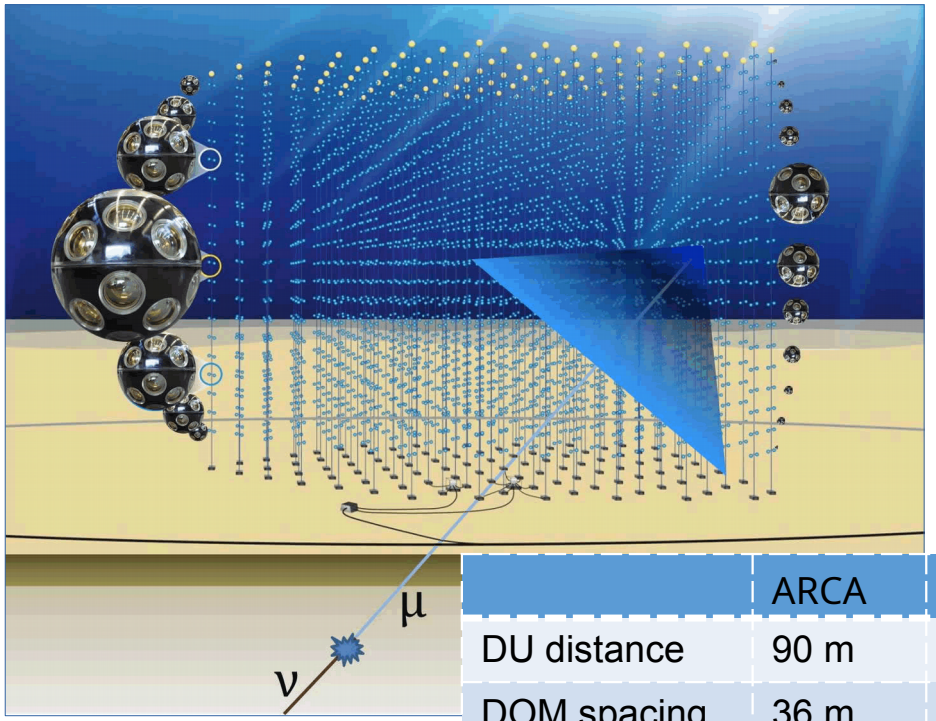
Data publication needs

- Interfaces to various community standards
- Services for statistical interpretation of data sets



Neutrino events in the Virtual Observatory

Detection principle and instruments



	ARCA	ORCA
DU distance	90 m	20 m
DOM spacing	36 m	9 m
Location	Italy /Greece	France

Water Cherenkov detector

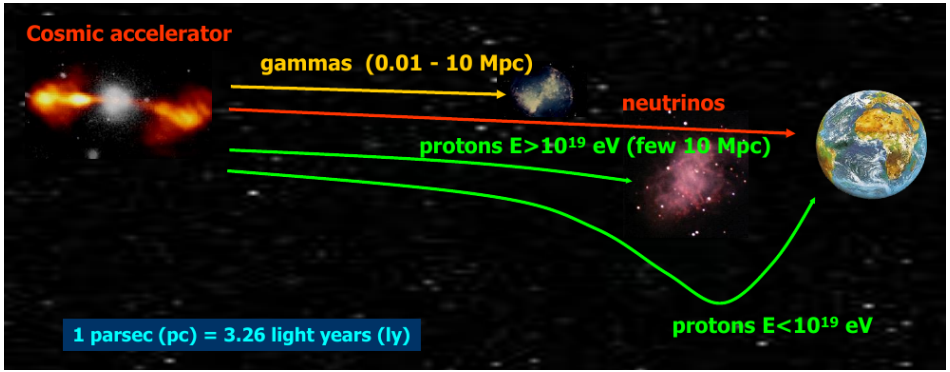
- Multi-PMT modules
- (31 3”-PMTs in one sphere)
- 18 modules per detection unit (DU)
- Building blocks of 115 DUs
- Under construction
  - 1 DU working in ARCA
  - 6 DUs working in ORCA

KM3NeT 2.0 Letter of Intent
J.Phys.G 43 (2016) 8, 084001
arXiv:1601.07459

Scientific targets

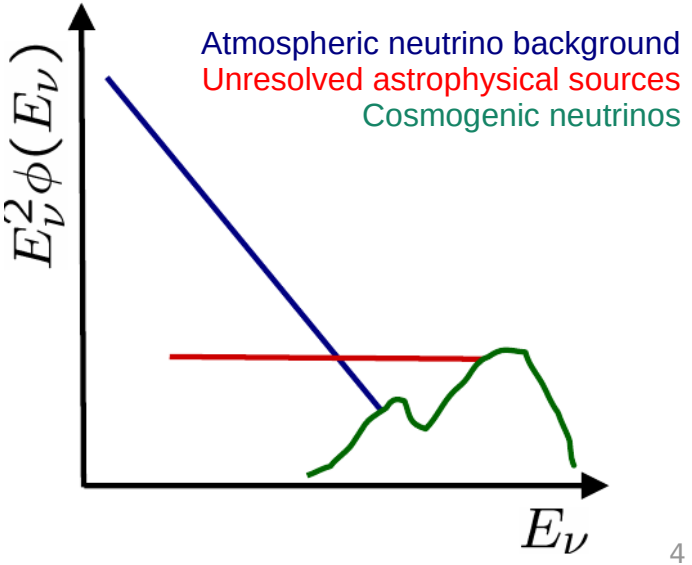
One concept – two detectors

- High-Energy neutrino Astronomy (ARCA)
- Neutrino Oscillation Research (ORCA)

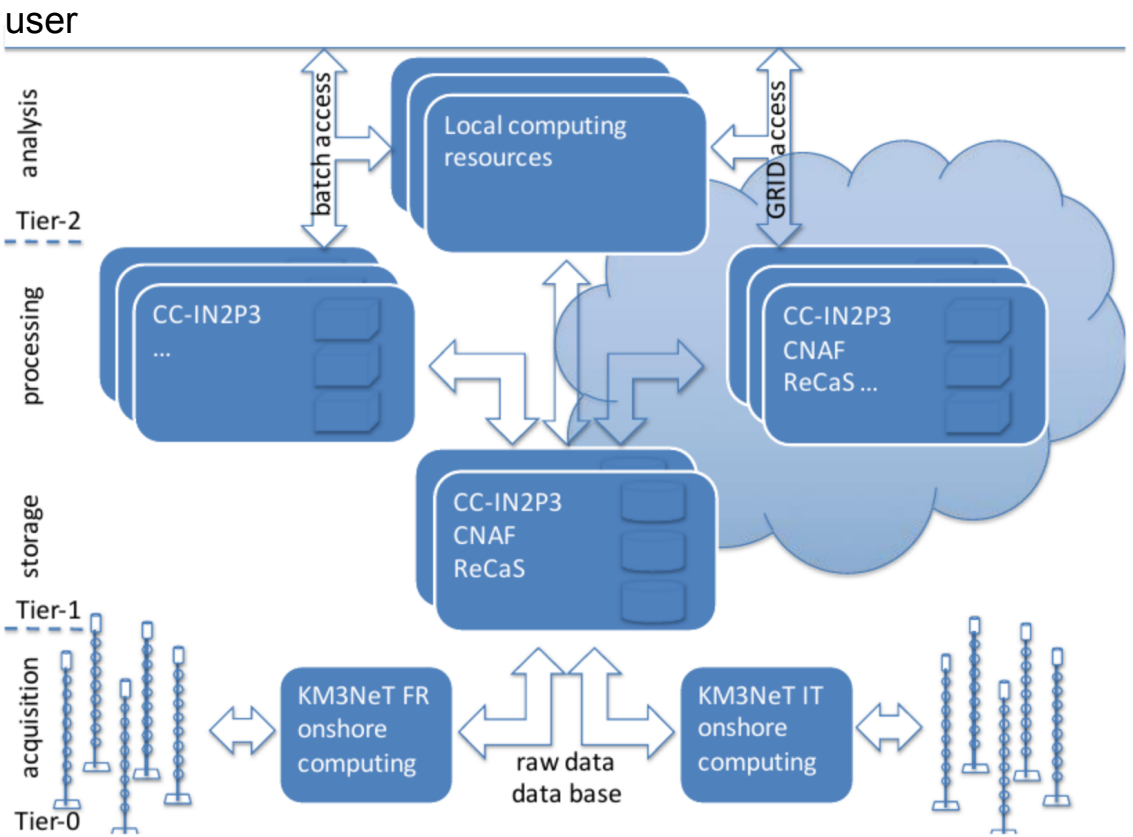


Two detectors – multiple targets

- Astrophysics: Galactic and extra-galactic neutrino sources, transients
- Dark matter & exotics: neutrinos produced e.g. by annihilation of WIMPs
- Neutrino physics: oscillation parameters, sterile neutrino searches etc.



Data taking and processing



Data processing

Typical for particle physics

- High-volume data taking
- Triggering
- Processing: reconstruction & filtering

Event simulation

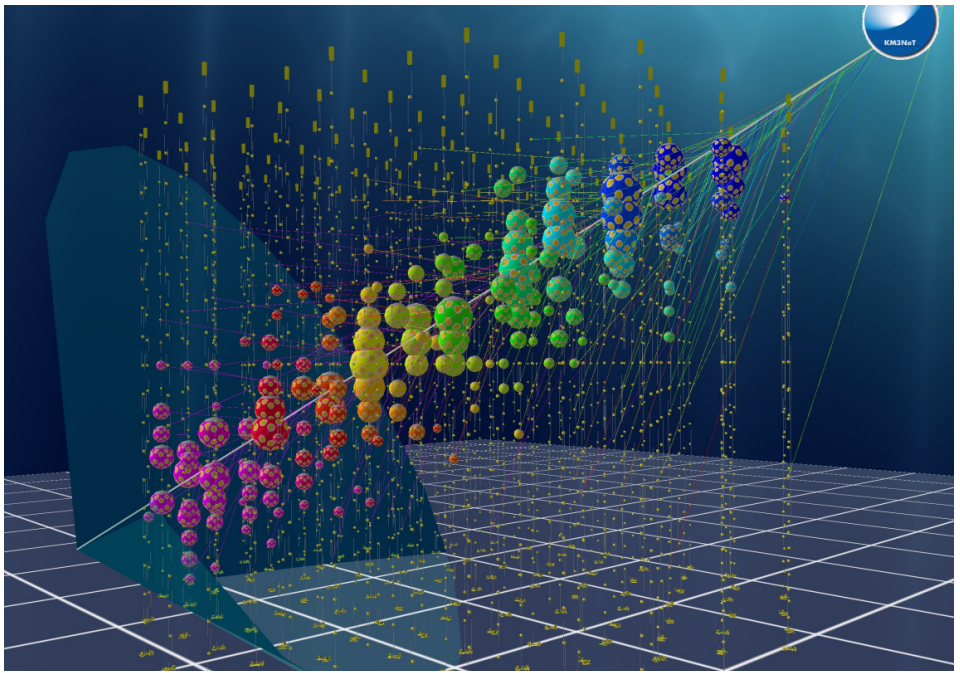
- Signal and background events
- Analogous processing to measurements

→ decentralized large data storage & processing needed

Data structure

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

event identification	detector status	<photon detections $\bar{x}$, 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

Use case

Test case for KM3NeT data publication

ANTARES 2007-2017 data catalogue

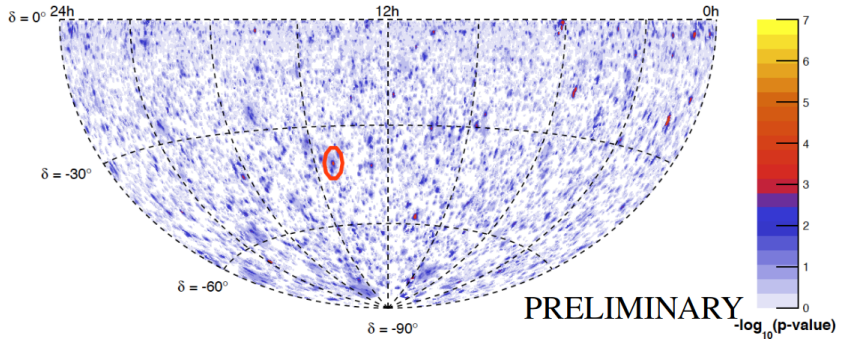
+ IceCube/ANTARES common analysis

Example: astrophysics study

„decades“ of events

ANTARES sample	Livetime [days]	# of events
Tracks	2415	5807
Showers	2415	102
IceCube sample	**Livetime [days]**	**# of events**
IC40	376	22779
IC59	348	64257
IC79	316	44771
IC86	333	74931
2012-2015	1058	119231

correlated neutrinos?



neutrino flux properties?

$$\Phi_\nu(E_\nu) = \Phi_0 \left(\frac{E_\nu}{1\,\mathrm{TeV}}\right)^{-\Gamma} \exp(-(E_\nu/E_{\mathrm{cut}})^\beta),$$

Spectrum	Φ_0	Γ	E_{cut}	β	$\hat{n}_s$	p-value	$\Phi_S^{90\%\mathrm{C.L.}}/\Phi_0$	$\Phi_L^{90\%\mathrm{C.L.}}/\Phi_0$
RXJ 1713.7-3946 (1)	1.55	1.72	1.35	0.5	0.3	0.40	10.7	13.2
RXJ 1713.7-3946 (2)	0.89	2.06	8.04	1	0.3	0.41	9.7	11.7

neutrinos from source?

Name	$\delta[^\circ]$	$\alpha[^\circ]$	$\hat{n}_s$	$\hat{\gamma}$	p-value	$\Phi^{90\%}_{E_\nu^{-2.0}}$	$\Phi^{90\%}_{E_\nu^{-2.5}}$
LHA120-N-157B	-69.16	84.43	-	-	-	3.6	0.9
HESSJ1356-645	-64.50	209.00	1.2	3.1	0.18	6.2	1.4
PSRB1259-63	-63.83	195.70	1.3	4.0	0.19	6.2	1.5
HESSJ1303-631	-63.20	195.74	-	-	-	3.7	0.9
RCW86	-62.48	220.68	1.0	1.6	0.20	6.3	1.5
HESSJ1507-622	-62.34	226.72	-	-	-	3.7	1.0
HESSJ1458-608	-60.88	224.54	3.7	3.6	0.036	9.3	2.0
ESO139-G12	-59.94	264.41	-	-	-	3.7	1.0
MSH15-52	-59.16	228.53	-	-	-	3.7	1.0
HESSJ1503-582	-58.74	226.46	-	-	-	3.7	1.0

ANTARES and IceCube combined search for neutrino point-like and extended sources in the Southern Sky - arXiv:1908.07439, The Astrophysical Journal, 892:92 (2020) (12 pp)

Statistical interpretation of data

„decades“ of events

ANTARES sample	Livetime [days]	# of events
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correlated neutrinos?

needs
instrument response function
from simulations
for full sky

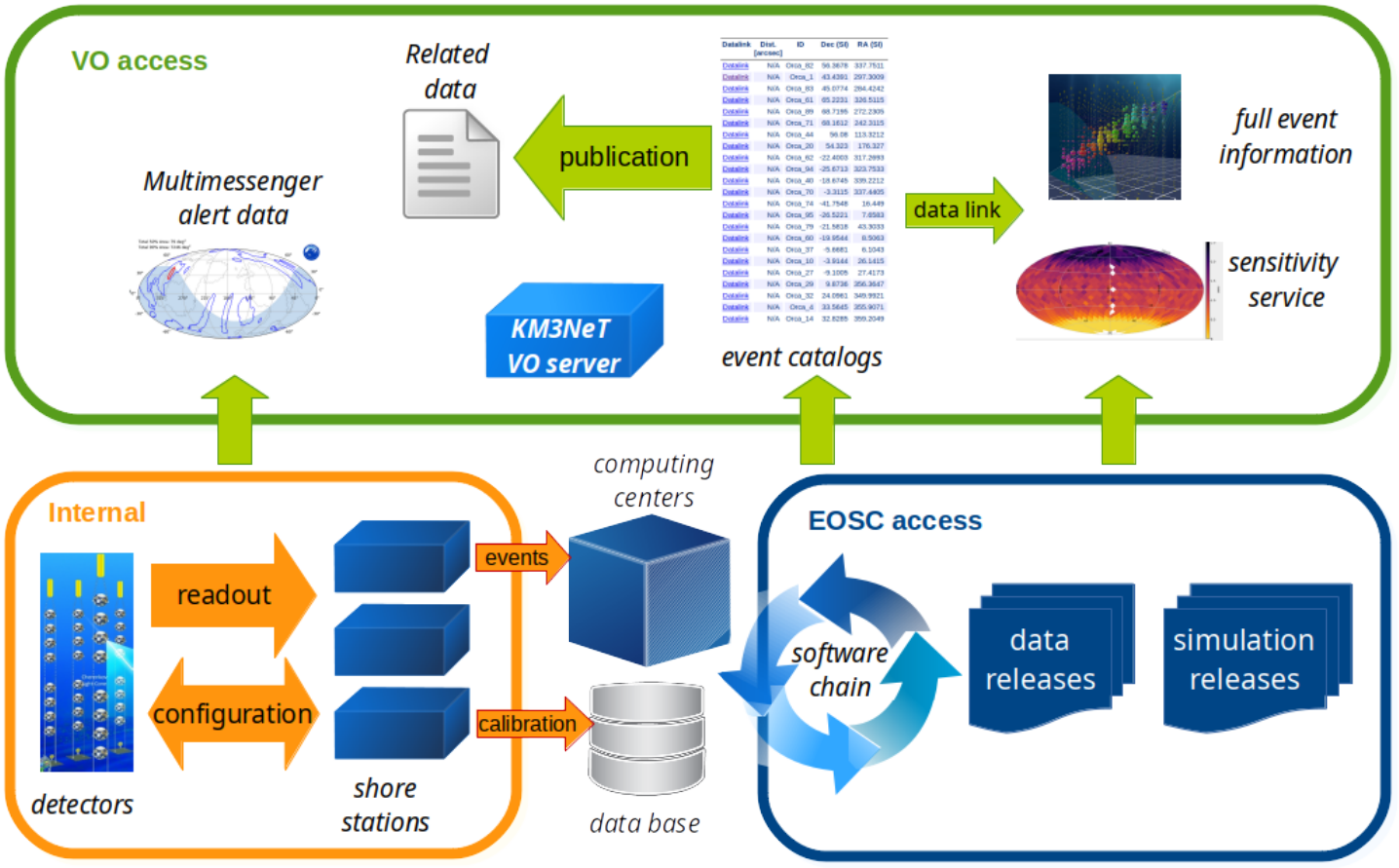
neutrinos from source?

needs specialized simulation
for position of source

neutrino flux properties?

might need „full“ event
to explore reconstruction
of event properties

Astrophysics standards: VO



Virtual Observatory standards

- Alerts as VO events
- Event catalogs as standardized table

BUT

- lacks standards for event data

→ process of model extension with the VO (ESCAPE project)

Beyond astrophysics

Background becomes signal

- Oscillation studies rely on atmospheric neutrinos → difficult scientific interpretation of data sets within the Virtual Observatory
- Dedicated simulations for dedicated analyses needed

  → providing high-level derivatives of full data sets in standard formats + services for scientific interpretation

Providing workflows and software

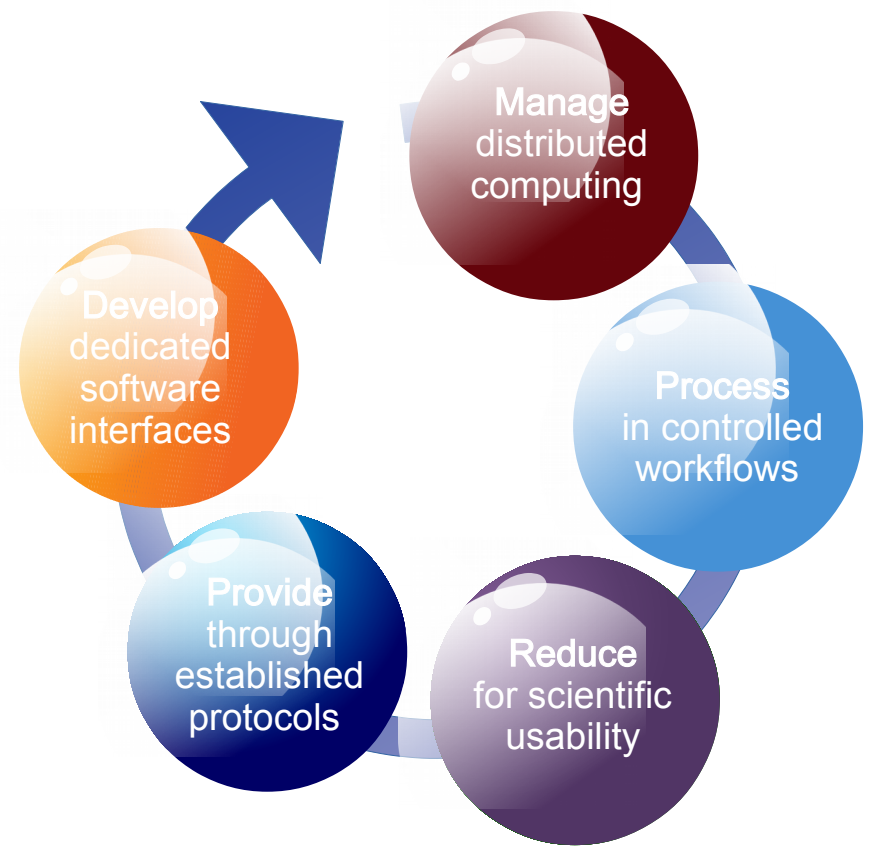
Need to facilitate common development of interfaces within the respective communities

→ sharing of software and implementation of use cases within the ESCAPE project (e.g. CTA+KM3NeT)

Working on the life cycle

Some upcoming software solutions

- Improving grid-computing capabilities (DIRAC)
- Implementing workflow management for data processing (CWL?)
- Developing standards for event data and interfaces for physics services (HDF5 for event data, docker containers)
- Integrating astrophysics data into the VO (DaCHS server suite)
- Providing example analyses (python-based, e.g. Jupyter-notebooks)



Thank you for your attention!

- More information on KM3NeT at www.km3net.org
- Virtual Observatory Server (test phase): http://vo.km3net.de/
- Dedicated software@git: https://github.com/KM3NeT
- ESCAPE project www.projectescape.eu