Making neutrinos public - open data in KM3NeT
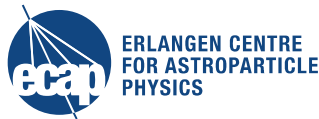
Jutta Schnabel

WP4 Technology Forum 1

Observatoire de Strasbourg

4-6 February 2020

KM3NeT

ECAP — ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

FAU — FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

ESCAPE — European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

What is going on in KM3NeT?

- multi-site neutrino telescope in the construction phase
  - Selecting first neutrino candidates from measurement
  - analysing statistical significance of neutrino sample through optimising model sensitivity through simulation

- Technical aspects
  - Integration into VO not staight-forward for full exploitation of the scientific potential
  - Simulation as inseparable part of data generation → control of data and simulation workflow integral part of open data

KM3NeT overview
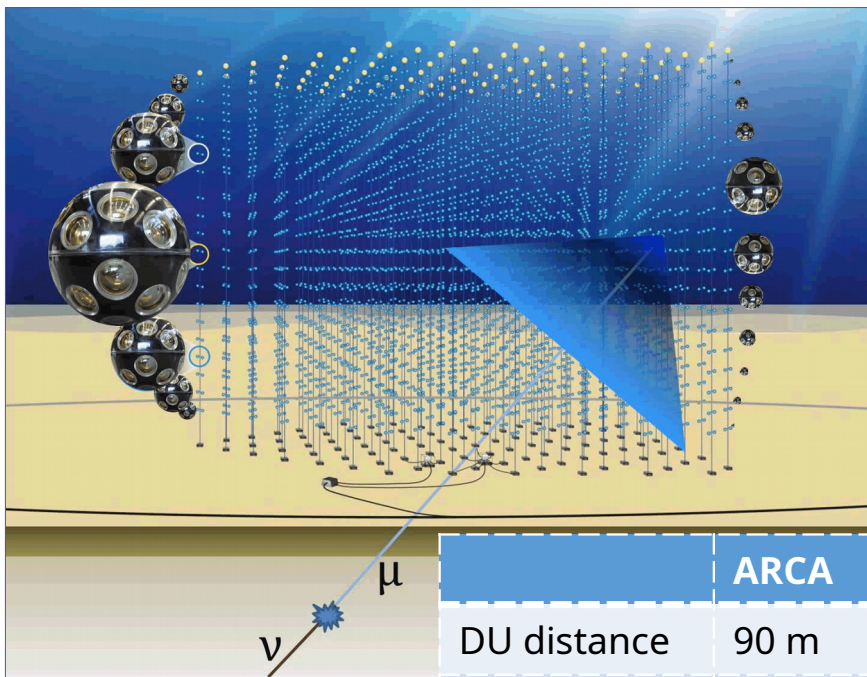
	ARCA	ORCA
DU distance	90 m	20 m
DOM spacing	36 m	9 m
Location	Italy/Greece	France

Water Cherenkov detector

- Multi-PMT modules
  (31 3"-PMTs in one sphere)

- 18 modules per string (DU)

- Building blocks of 115 DUs

- Science goals: astrophysics (ARCA) and neutrino oscillations (ORCA)

- Under construction
  - 1 DU working in ARCA
  - 6 DUs working in ORCA

- 24 **ARCA** + 6 **ORCA** strings

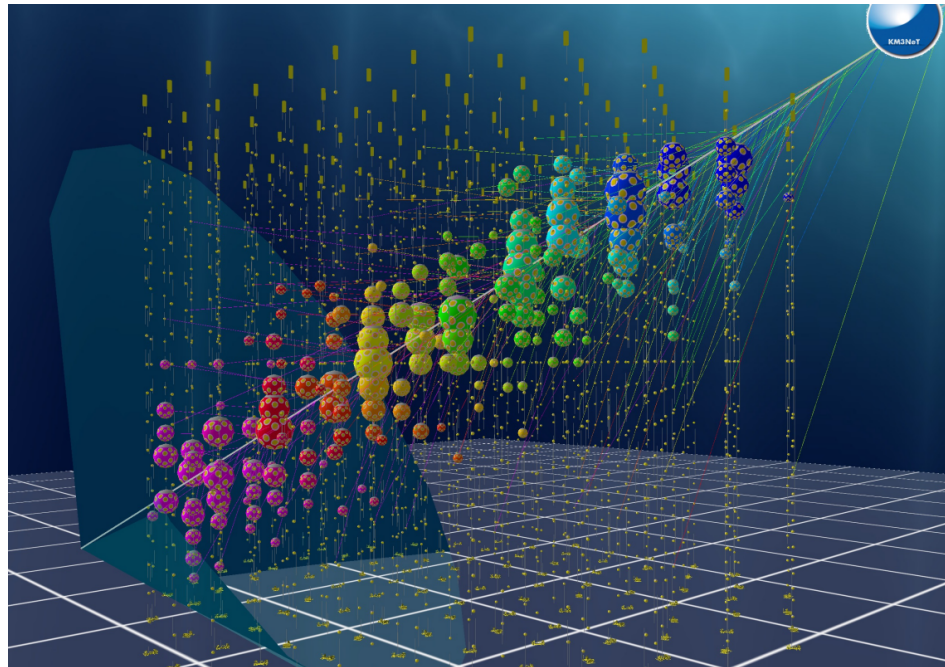KM3NeT 2.0 Letter of Intent: arXiv:1601.07459

KM3NeT data levels

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

event identification	detector status	<photon detections x̄, 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
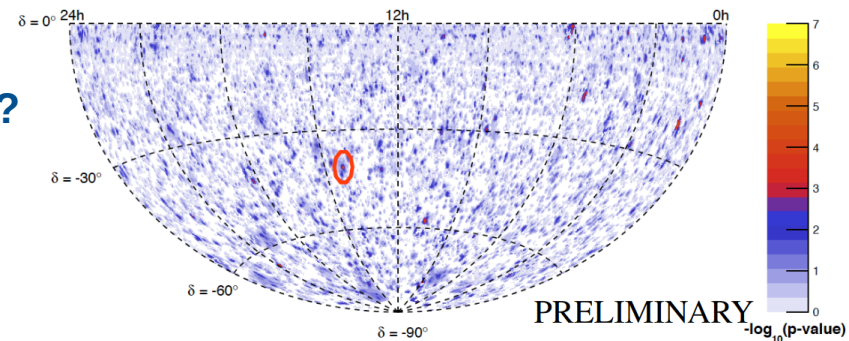
+ IceCube/ANTARES common analysis

Use case ANTARES / IceCube

„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?

PRELIMINARY

neutrino flux properties?

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

Spectrum	Φ_0	Γ	E_{cut}	β	$\hat{n}_s$	p-value	$\Phi_S^{90\%\text{C.L.}}/\Phi_0$	$\Phi_L^{90\%\text{C.L.}}/\Phi_0$
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	$\delta[°]$	$\alpha[°]$	$\hat{n}_s$	$\hat{\gamma}$	p-value	$\Phi_{E_\nu^{-2.0}}^{90\%}$	$\Phi_{E_\nu^{-2.5}}^{90\%}$
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 [astro-ph.HE]

Use case ANTARES / IceCube

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correlated neutrinos?

**needs
instrument response function
from simulations
for full sky**

PRELIMINARY

neutrinos from source?

neutrino flux properties?

**access to „full" event
to explore reconstruction
of event properties**

**needs specialized simulation
for position of source**

ANTARES and IceCube combined search for neutrino point-like and extended sources in the Southern Sky - arXiv:1908.07439 [astro-ph.HE]

Integration steps into VO

- Introducing catalogues of reduced events of neutrinos
  - Need to be linked to service for probabilistic interpretation according to source and research question
  - Underlying datamodel of data sets needs to be fully defined (between VOEvent and VOTable?)
  - Starting point: ANTARES/IceCube use case, perhaps data publications from commissioning phase

- Providing access to „full event"
  - Through data link → limited useability as single event, impractical for large data samples?
  - Through dedicated software in an ESCAPE-provided environment → linkage to VO?
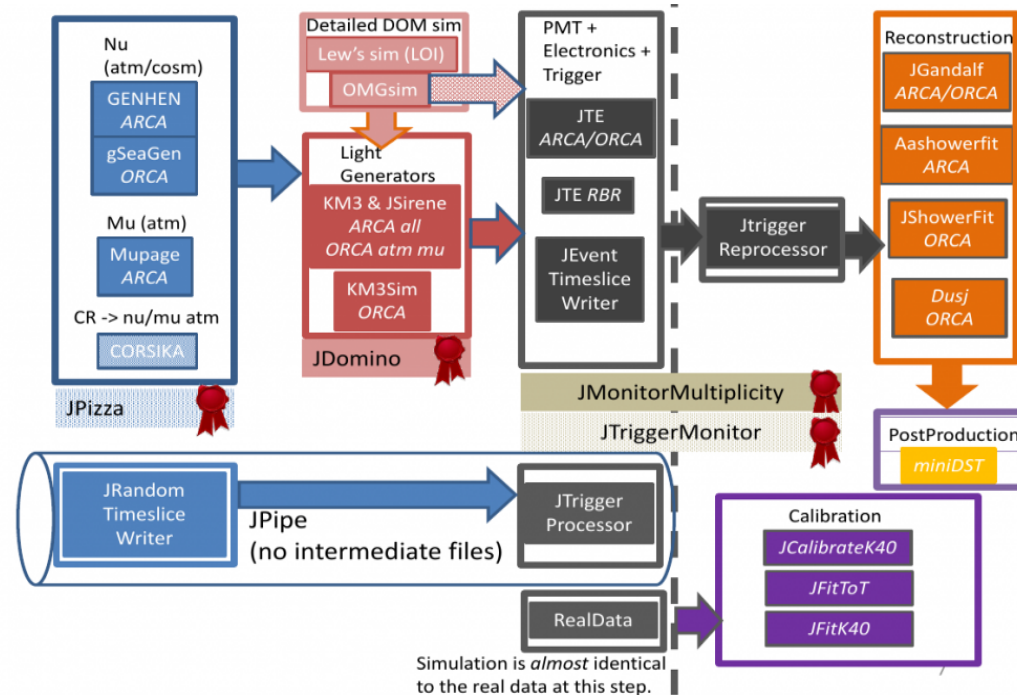
2 level data access?
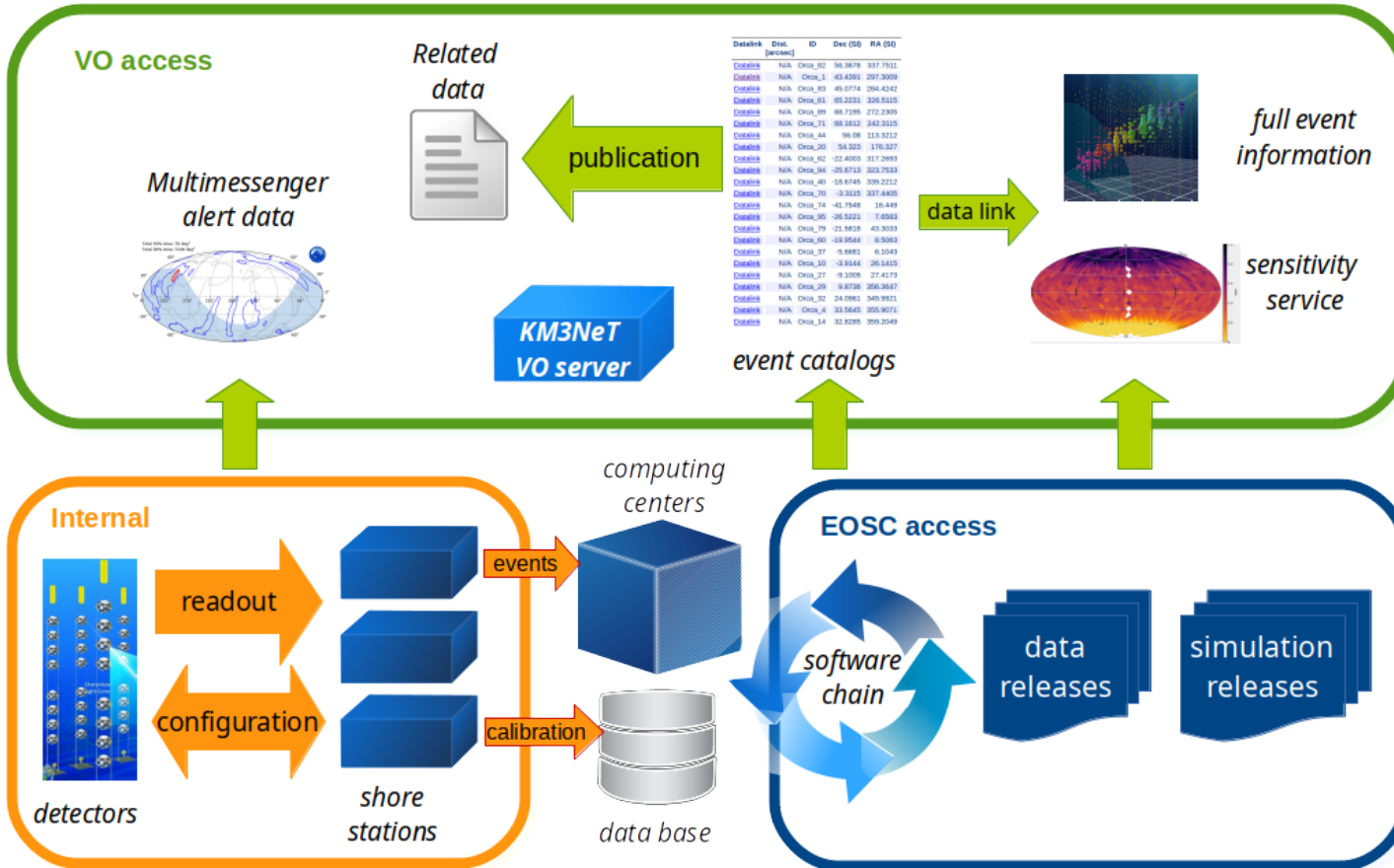
VO access

- Alerts
- Catalogues for reduced events
- Service for probability

EOSC access

- Simulation & dedicated software
- Full event data sets
- Simulation data sets

Requirement on workflows

Processing steps of current simulation chain

- Simulation as integral part of understanding of neutrino data
- Contains „physics" interpretation of the neutrino sample
- For quality management, needs clear handling of workflow and documentation

→ „provenance" not only for data, but also simulation

Open data in KM3NeT

… requires publication of software

- For data handling and event display: km3pipe, others to follow
- For simulation: under discussion

… needs workflow management for good provenance

- Exploring Common Workflow Language usage
- Could link well to development of underlying data model

… needs some thoughts about linkage to VO

- Starting point will be use cases of common analysis
  (here ANTARES/IceCube, or KM3NeT/CTA - under internal discussion)