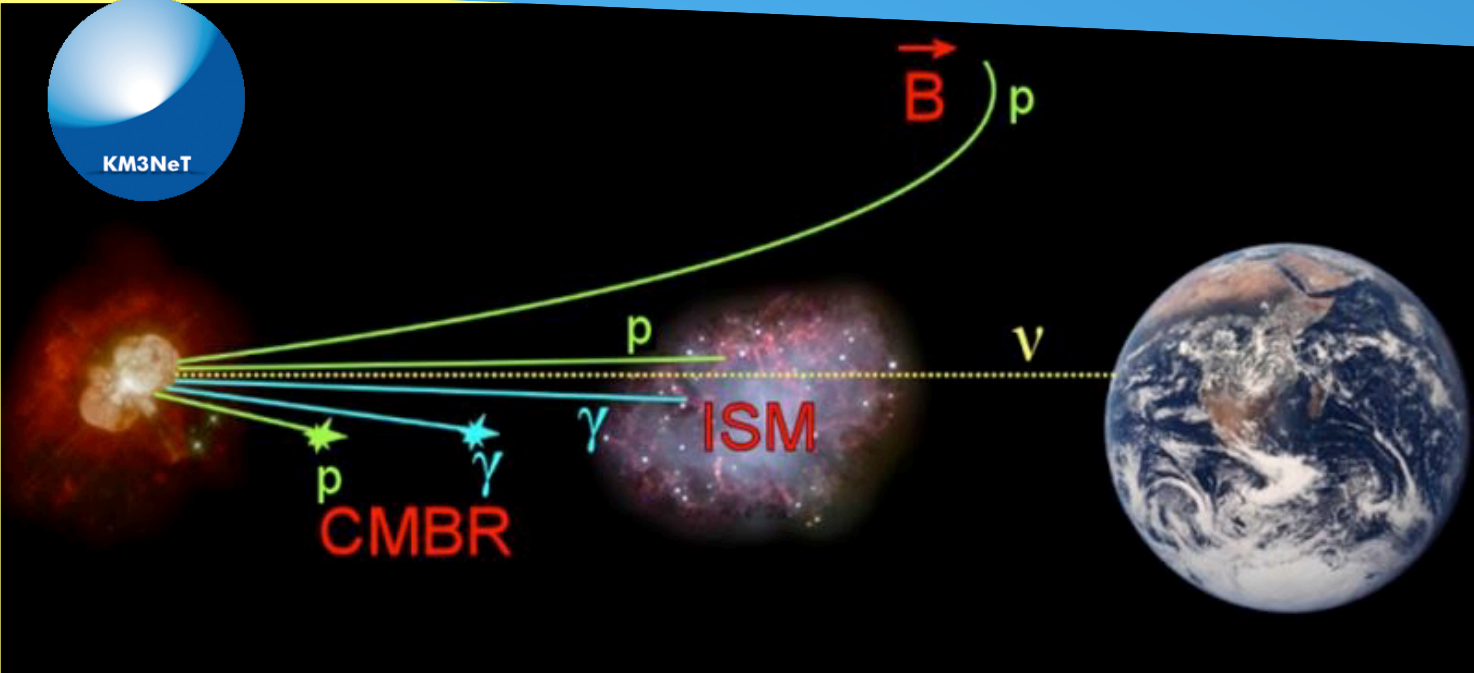


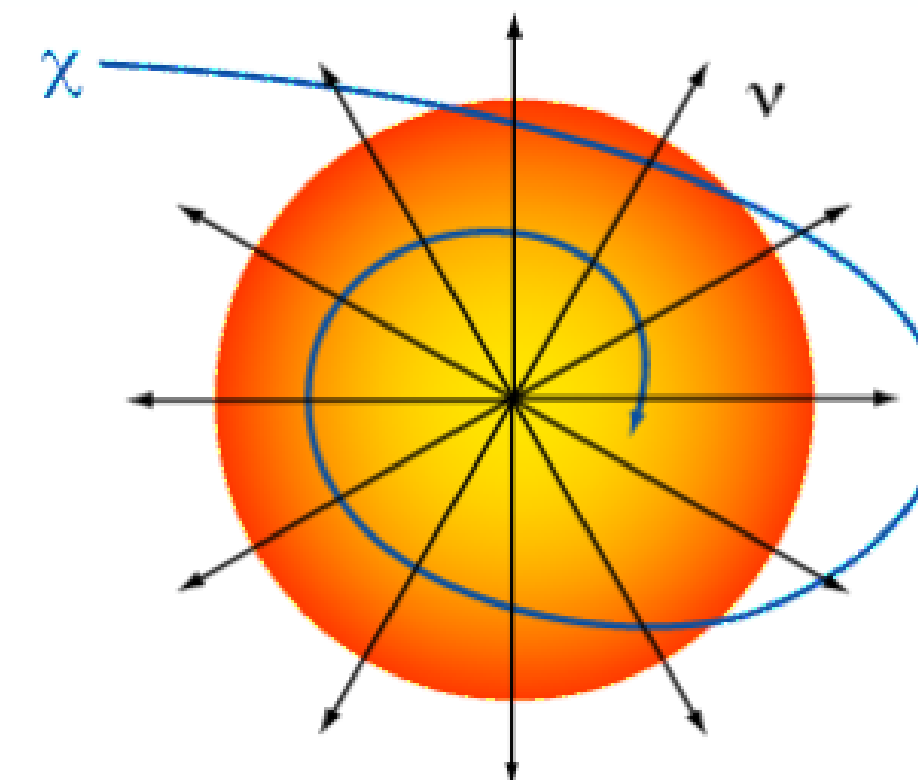
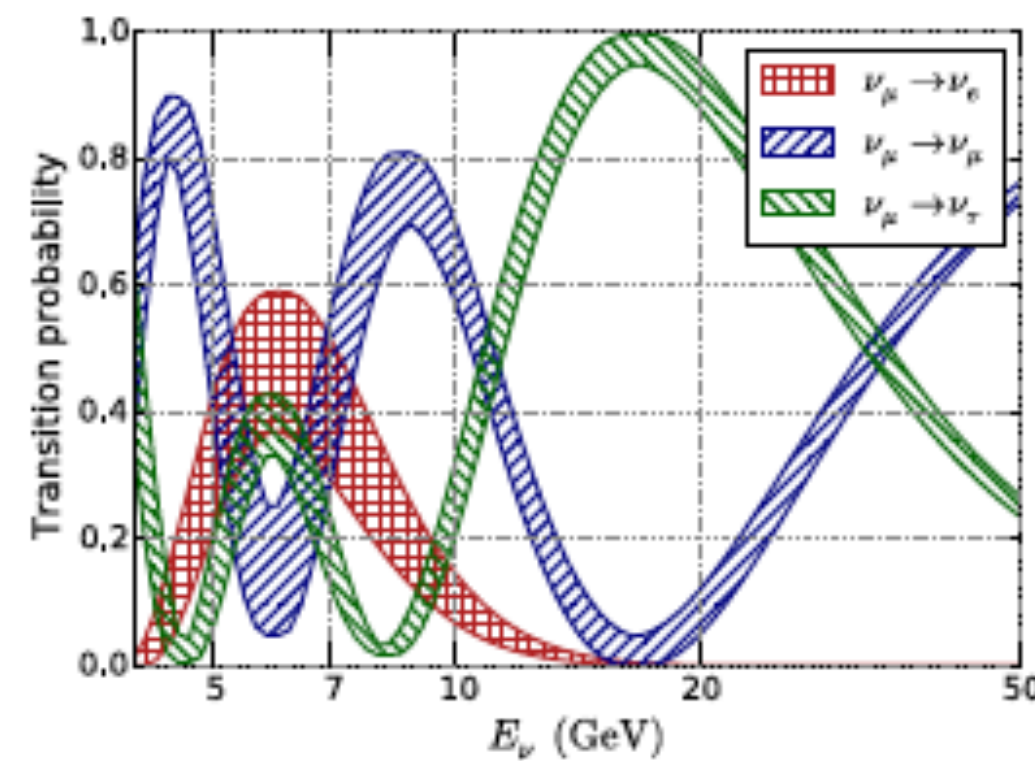
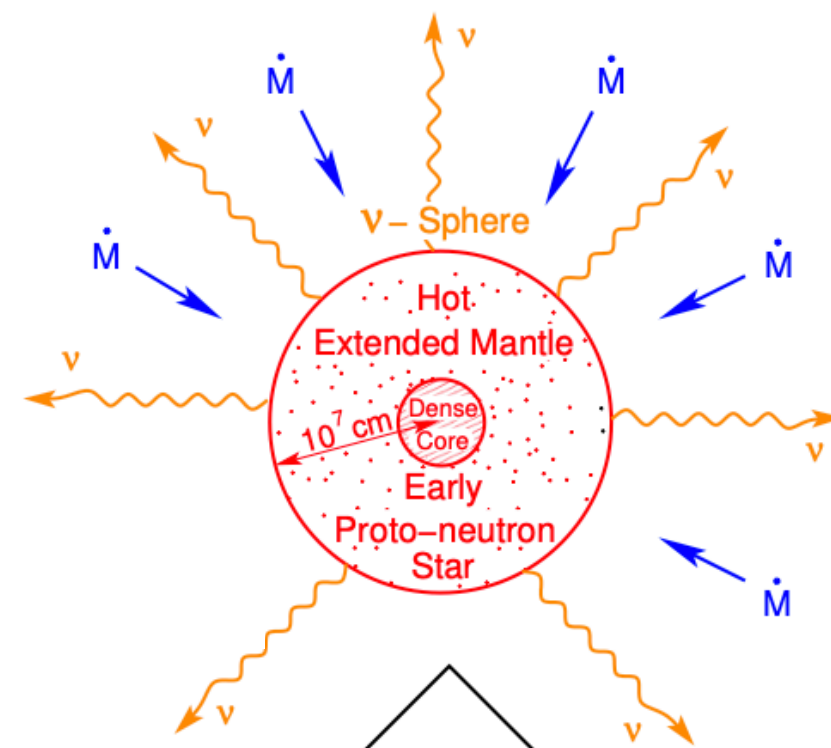
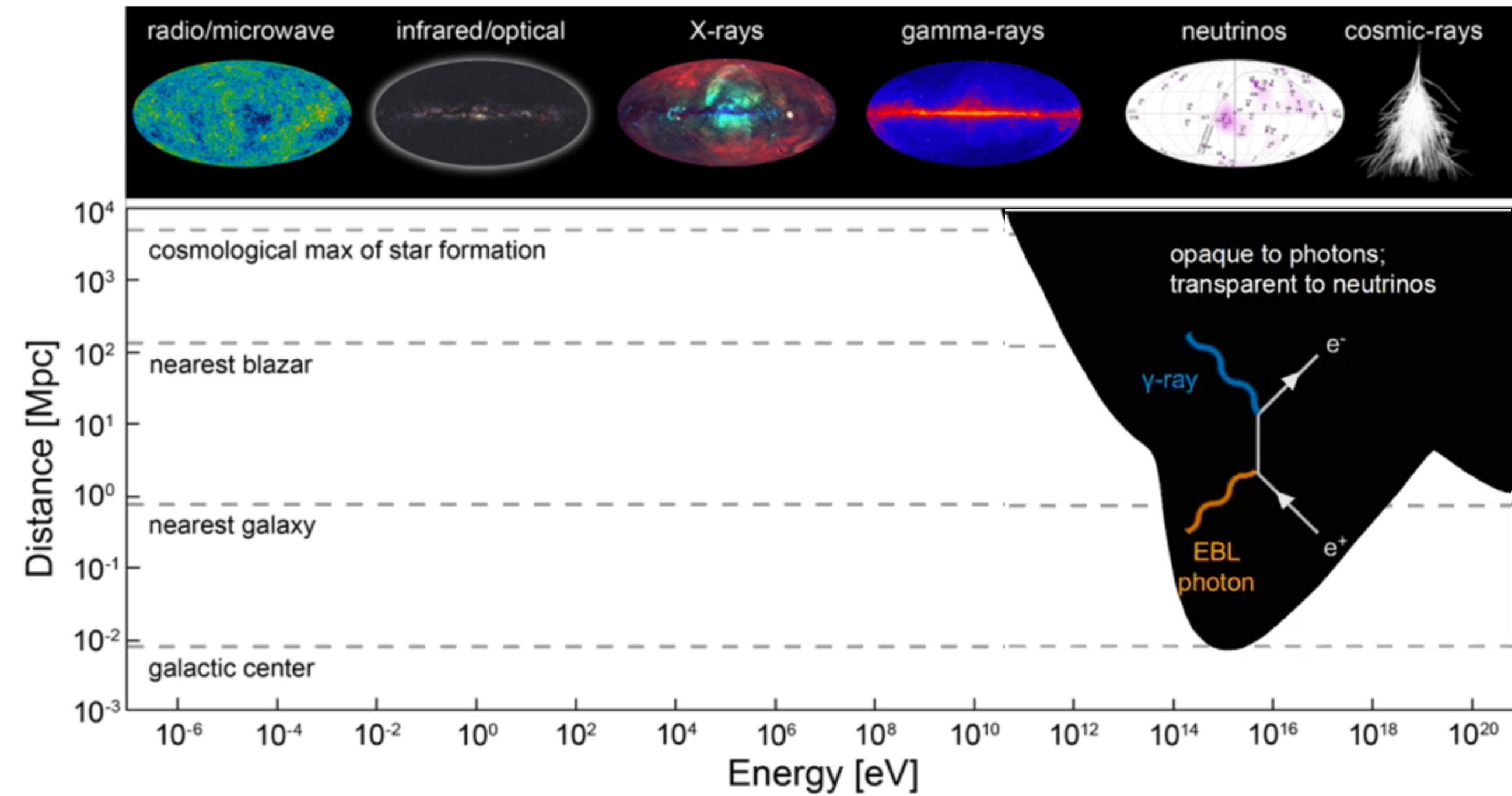
Recent achievements and scientific results of KM3NeT

Tommaso Chiarusi —



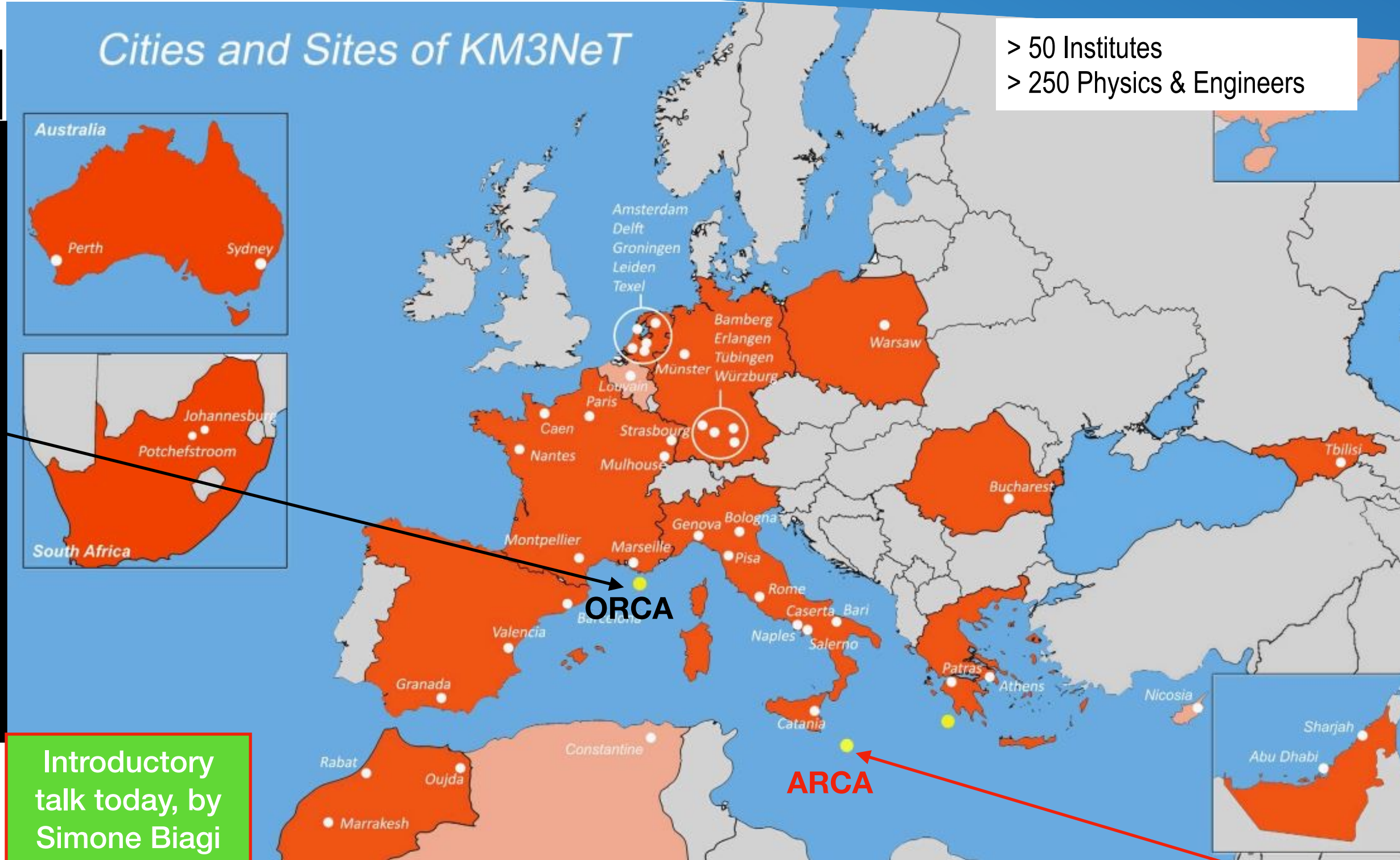
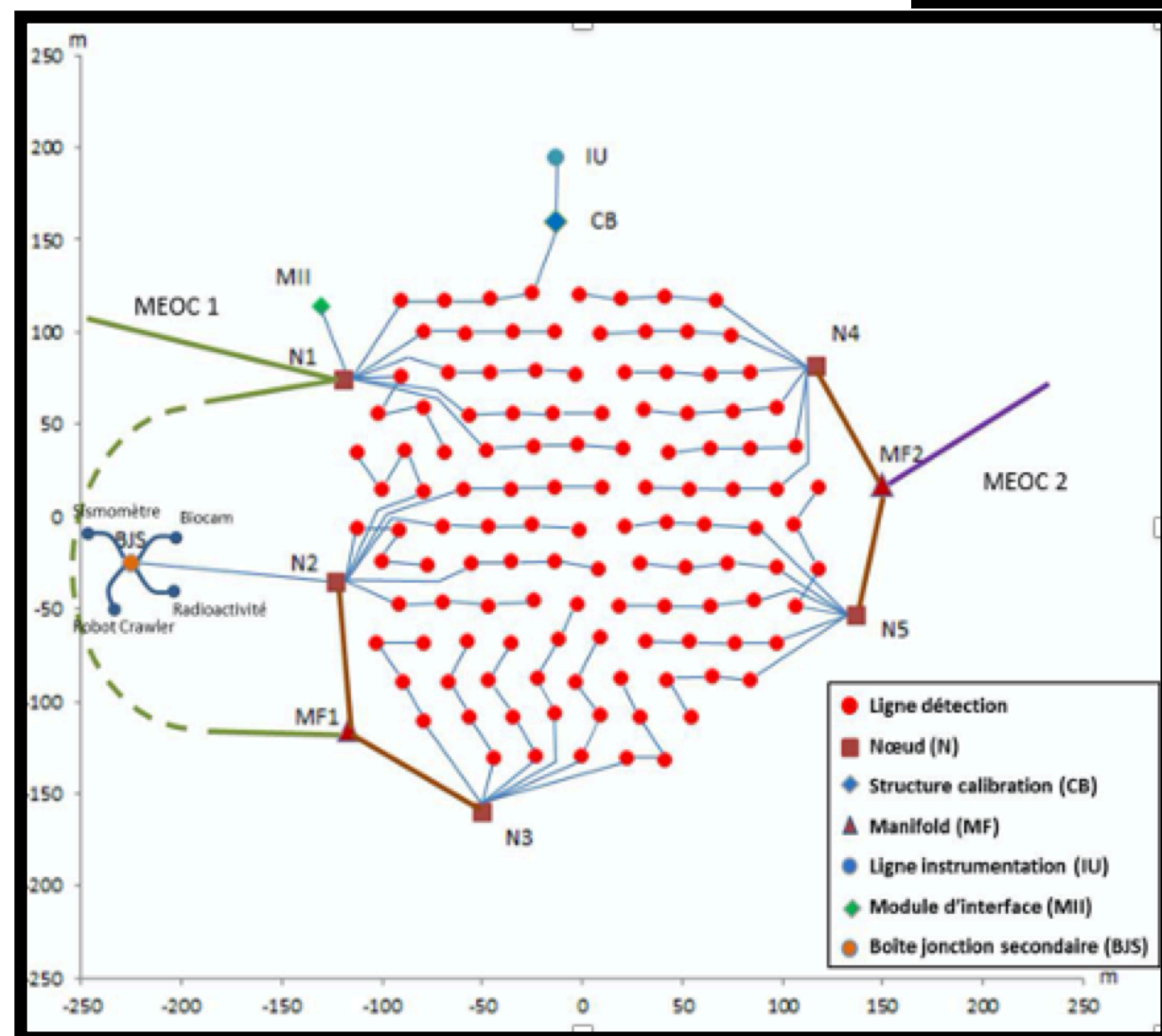


- Origin of Cosmic Rays
- Neutral messengers point back to their sources
 - Neutrons are short-lived, photons are likely to interact
 - ⇒ **Neutrinos as cosmic probe**
- Neutrinos are produced at sources via hadronic interactions
 - Cosmic diffuse flux
 - Point-like sources
 - Multi-messenger approach

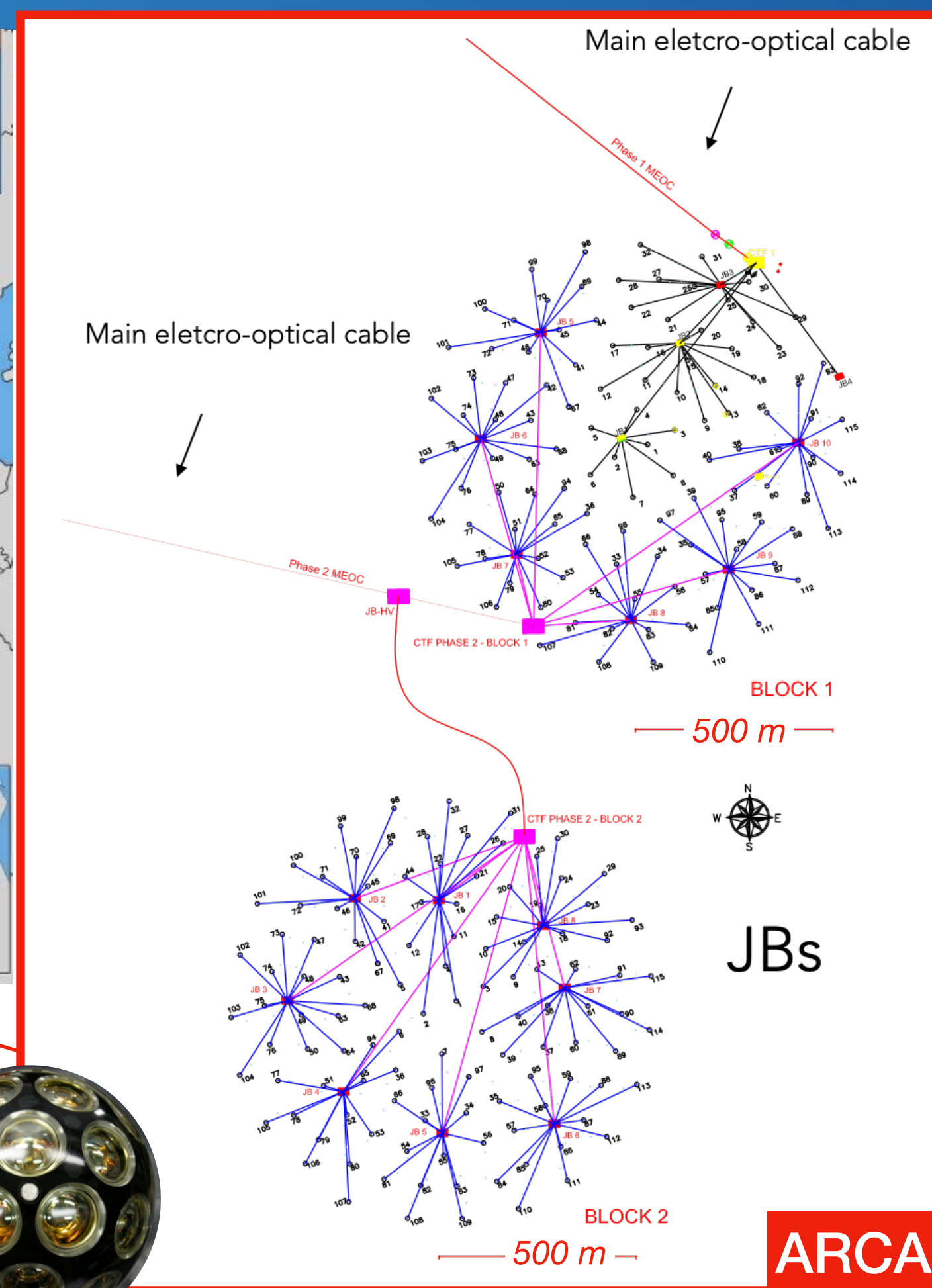


Super Novae explosion MeV	Neutrino oscillation GeV	Dark Matter GeV-TeV	HE neutrinos, CRs Multi-messenger program TeV-PeV
ARCA		ORCA	ARCA

ORCA

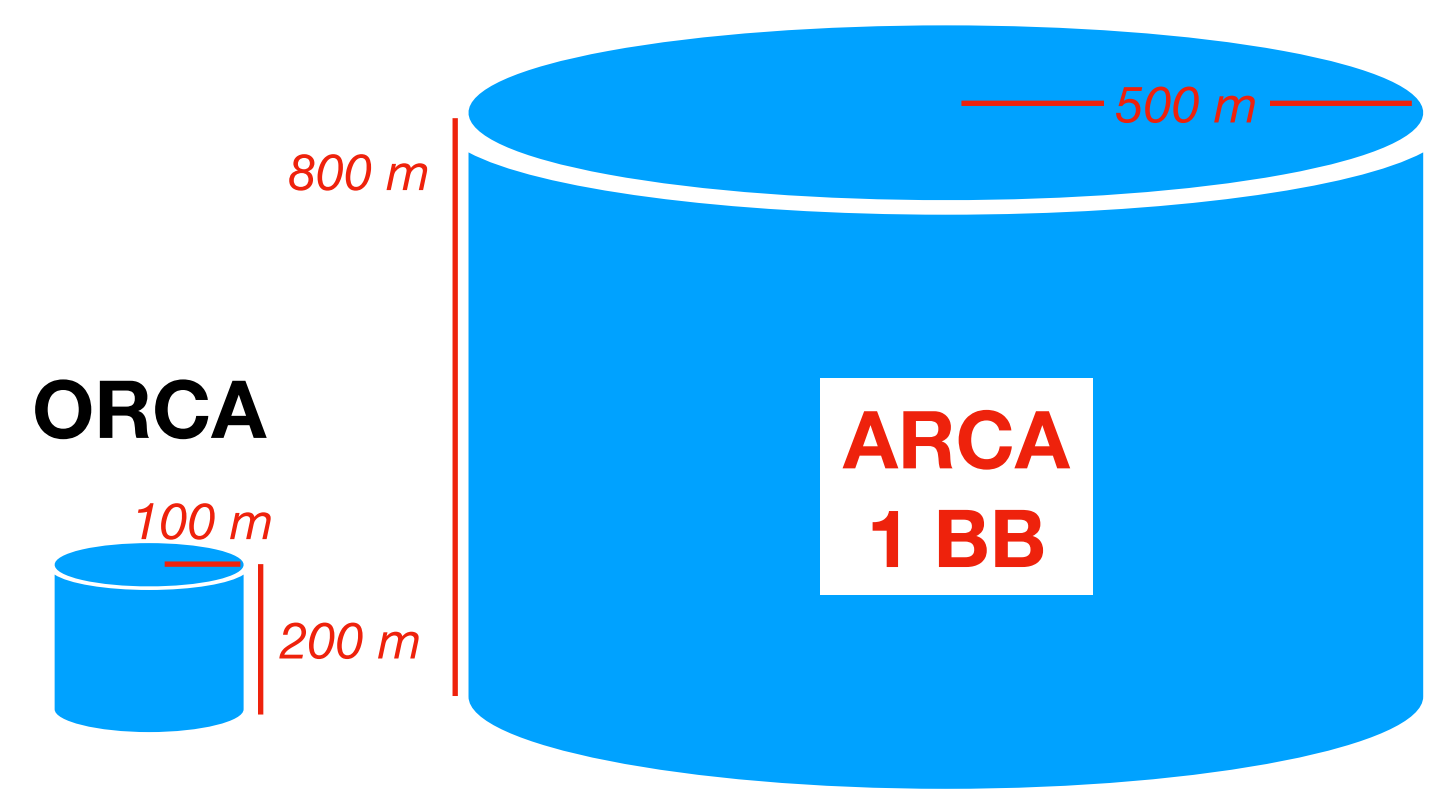


Introductory talk today, by Simone Biagi

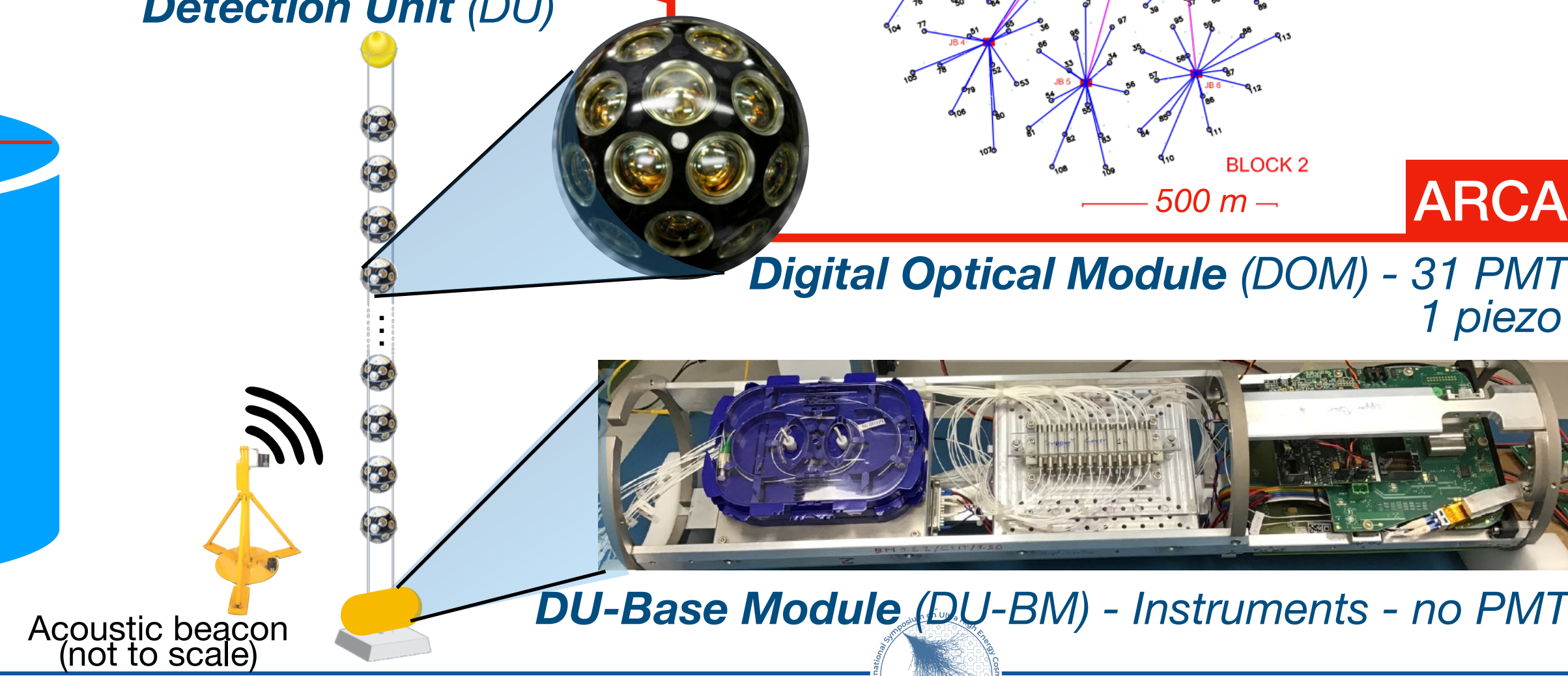


Two detectors, same technology, different layout and physics objectives

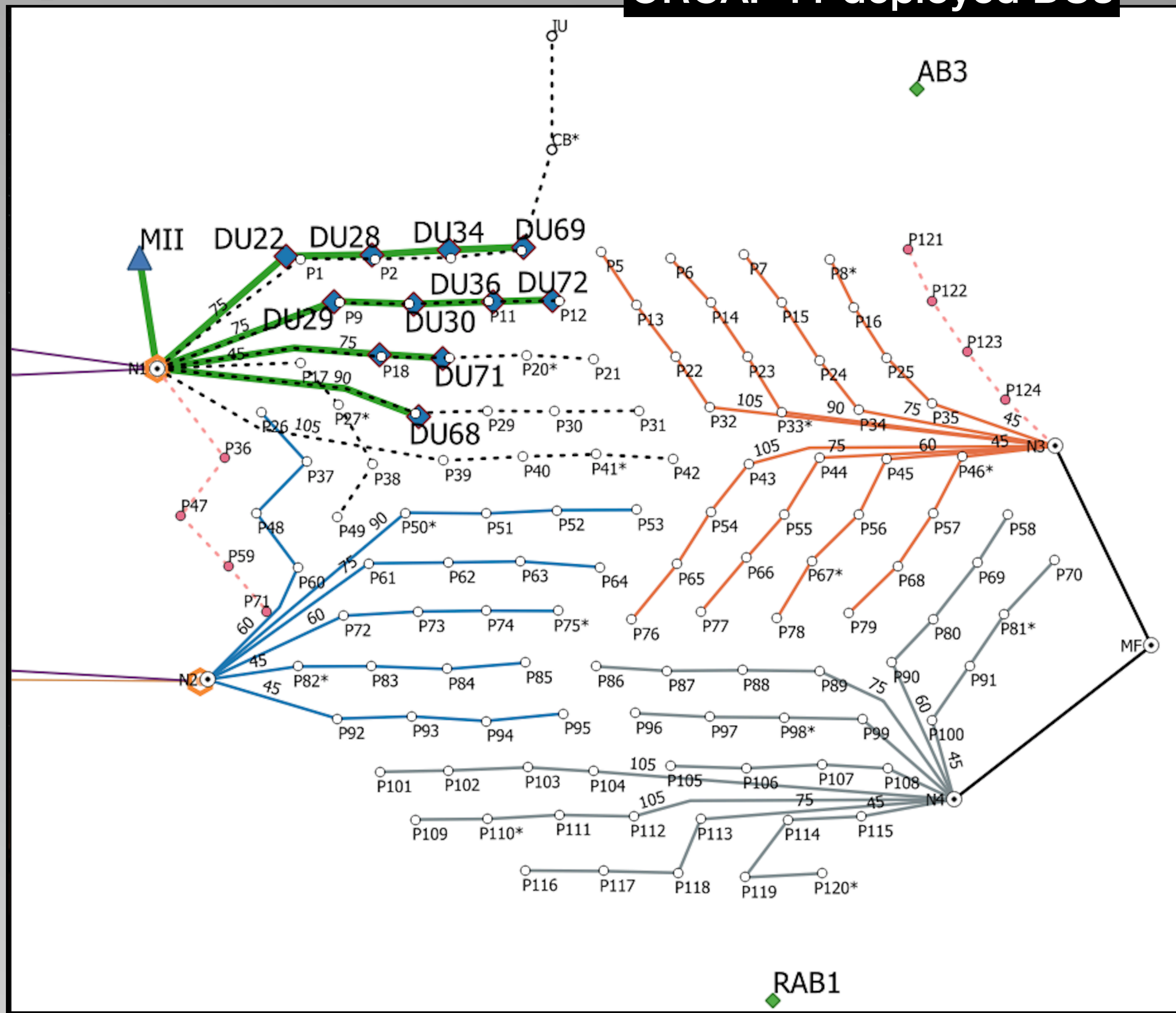
	ARCA	ORCA
Location	Italy	France
N. building blocks	2	1
N. DU per b.b.	115	115
DU distance	90 m	20 m
DOM spacing	36 m	9 m
DU height	~ 800 m	~ 200 m
Instrumented mass (Mton)	2*650	7
Depth	3500 m	2500 m



Detection Unit (DU)



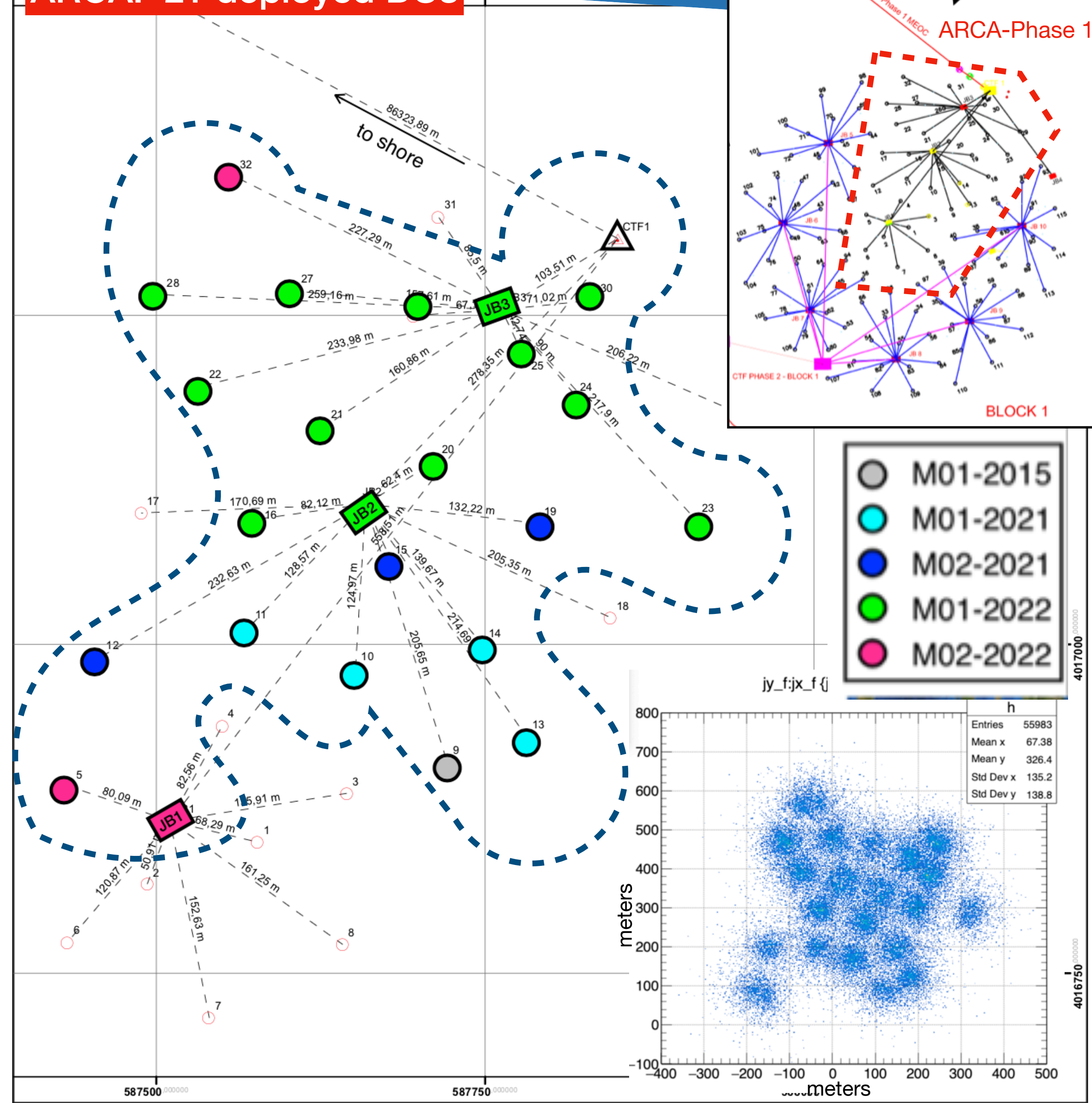
ORCA: 11 deployed DUs

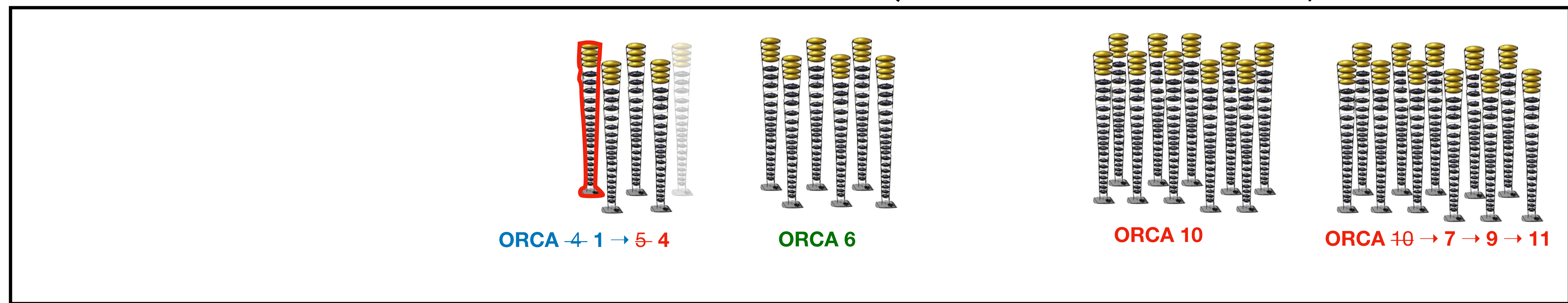
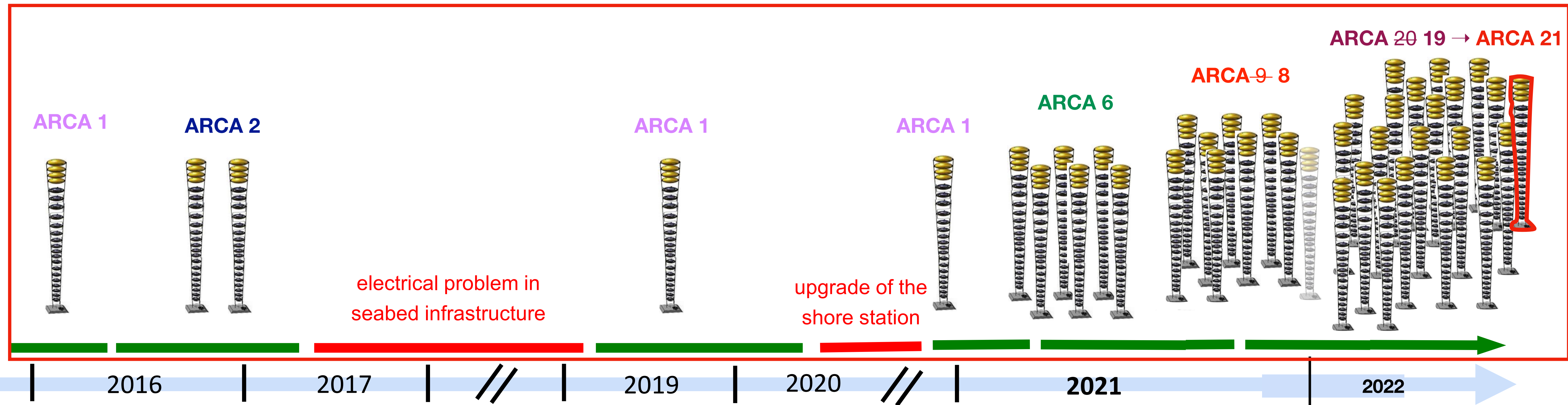


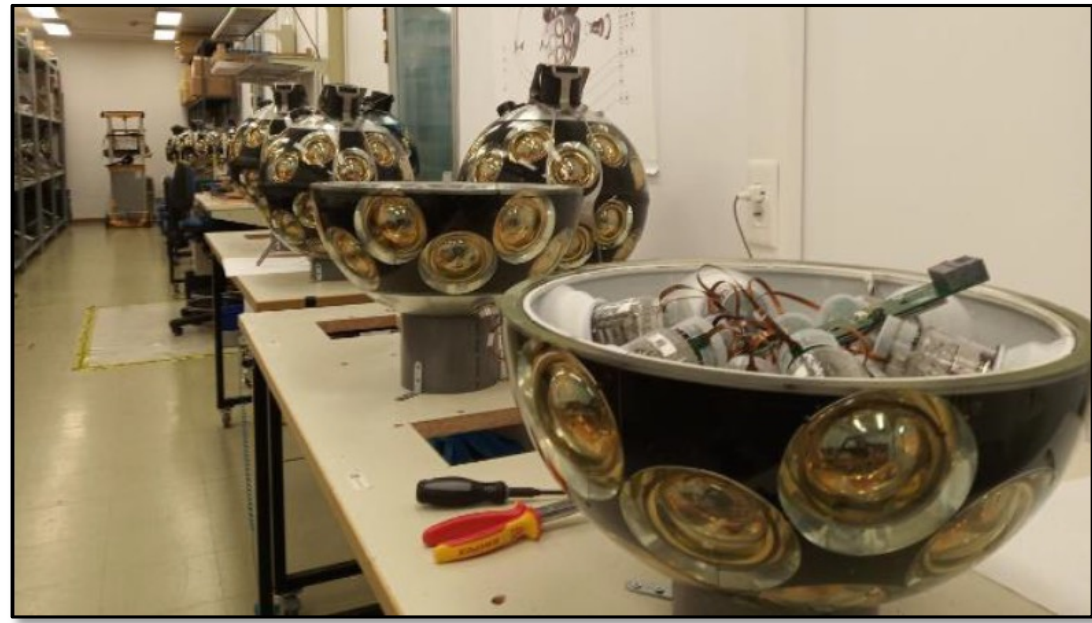
Latest Marine Operations in September 2022,
 new deployments for both ARCA and ORCA.
 Accumulating data with growing detector.

. ARCA/ORCA current layout .

ARCA: 21 deployed DUs

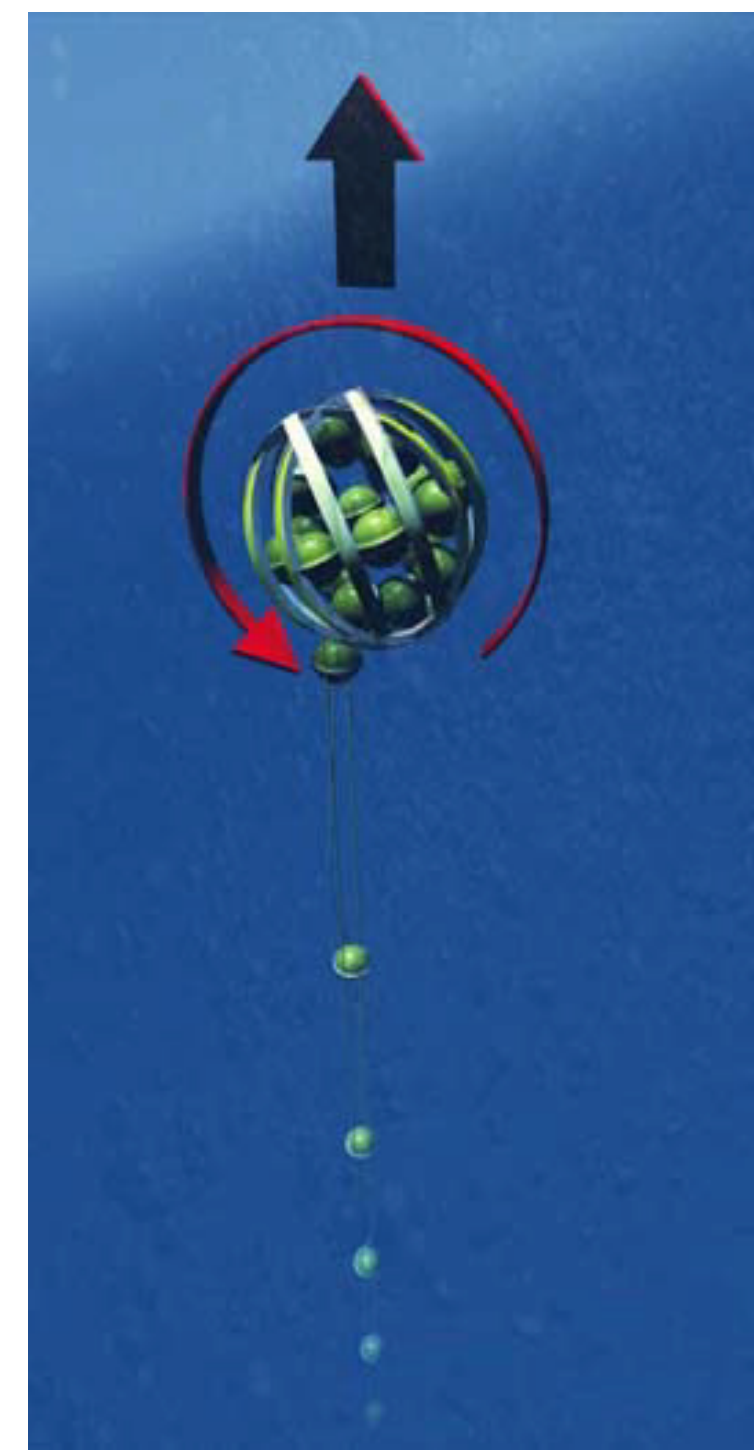
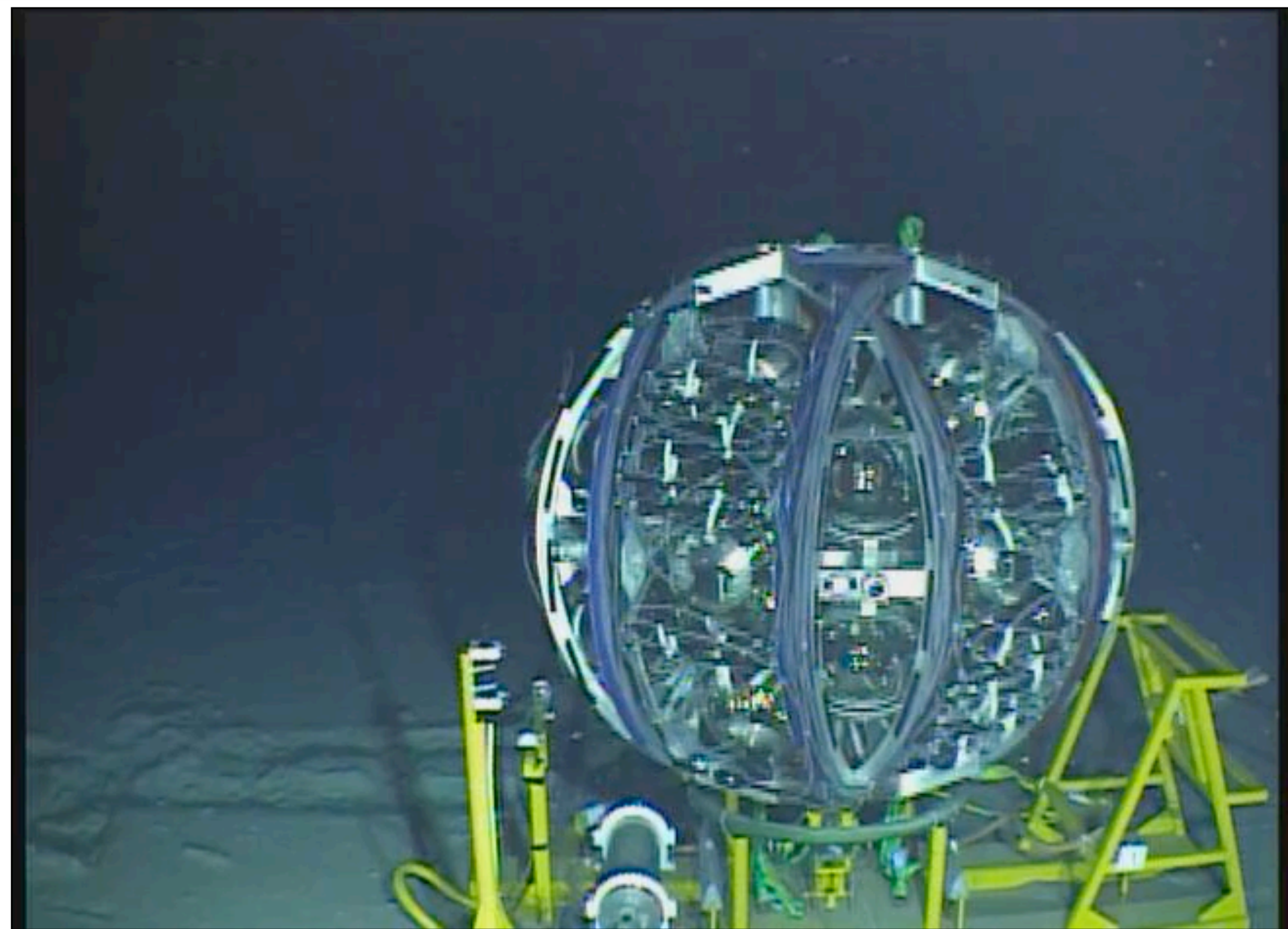




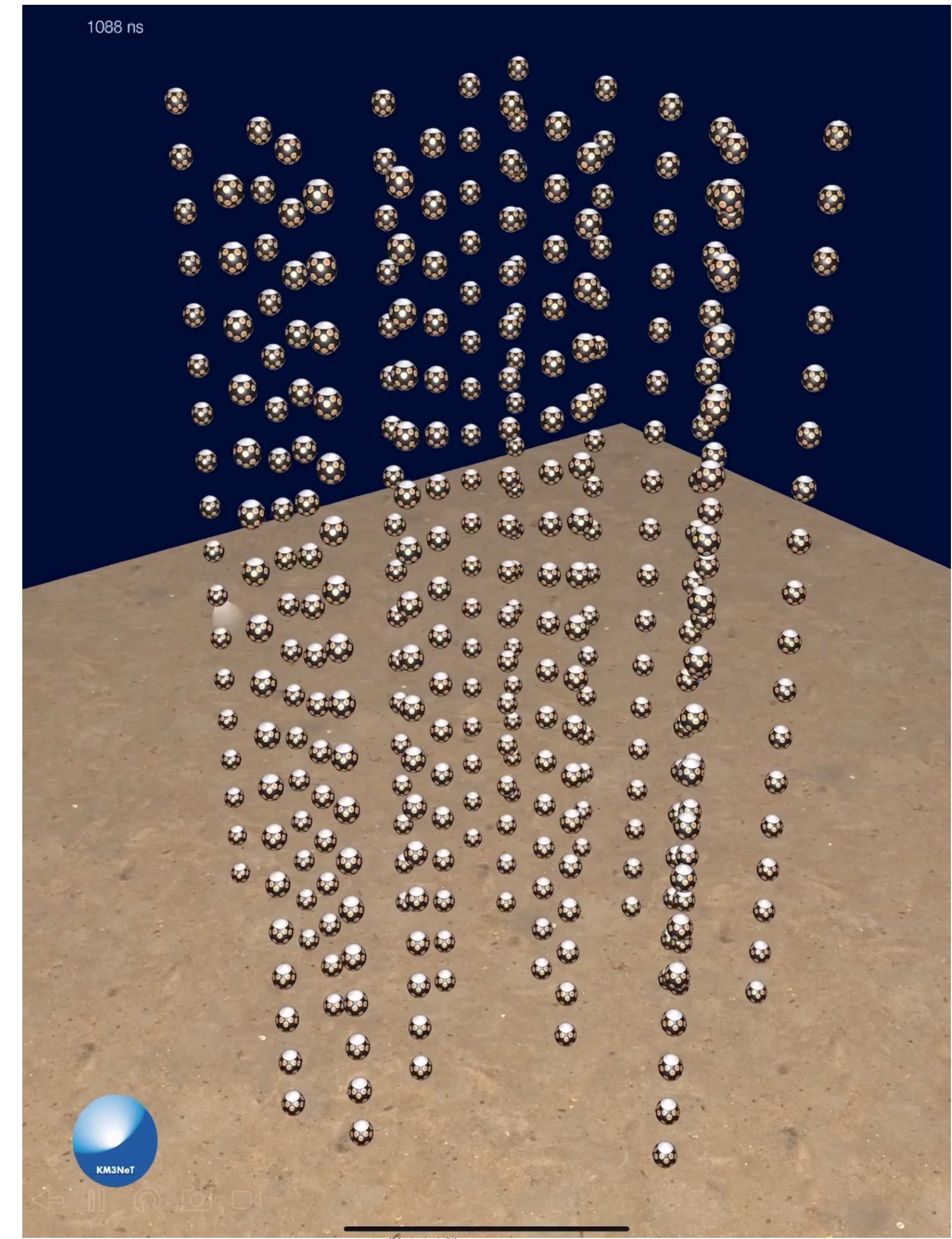


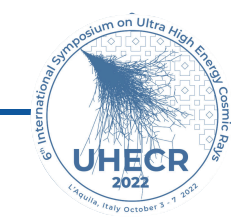
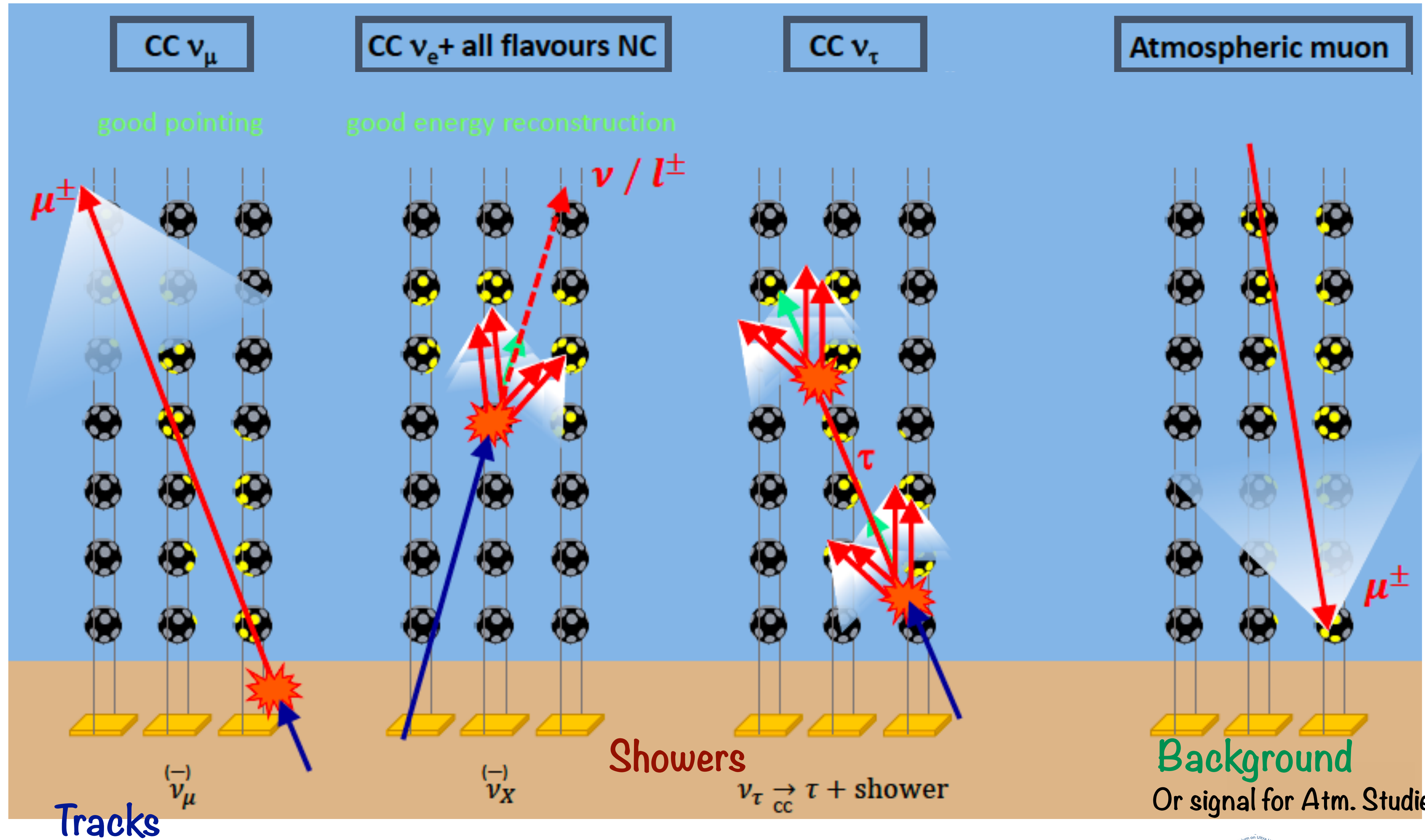
DOM: 8 sites
DU: 5 sites

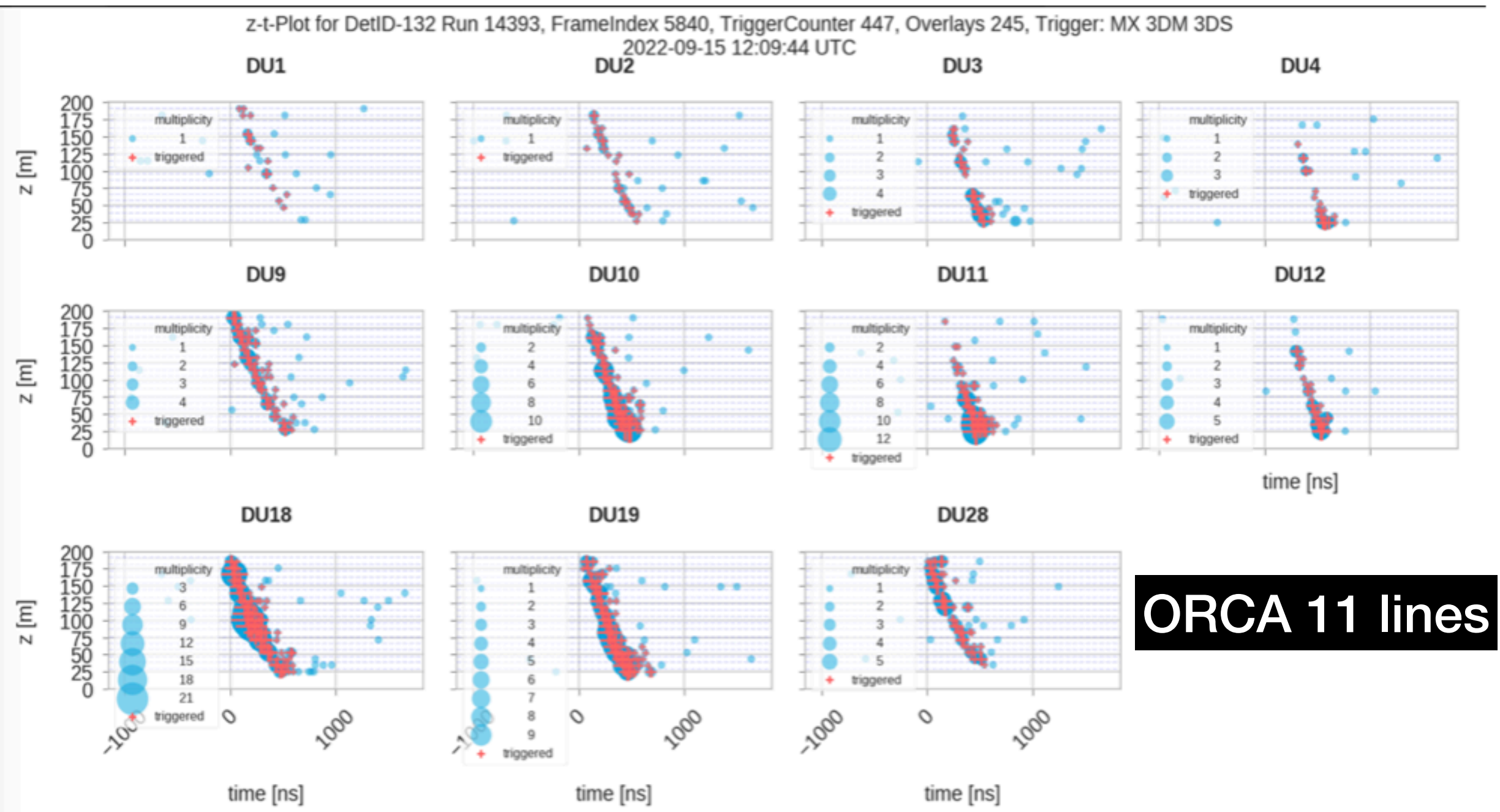
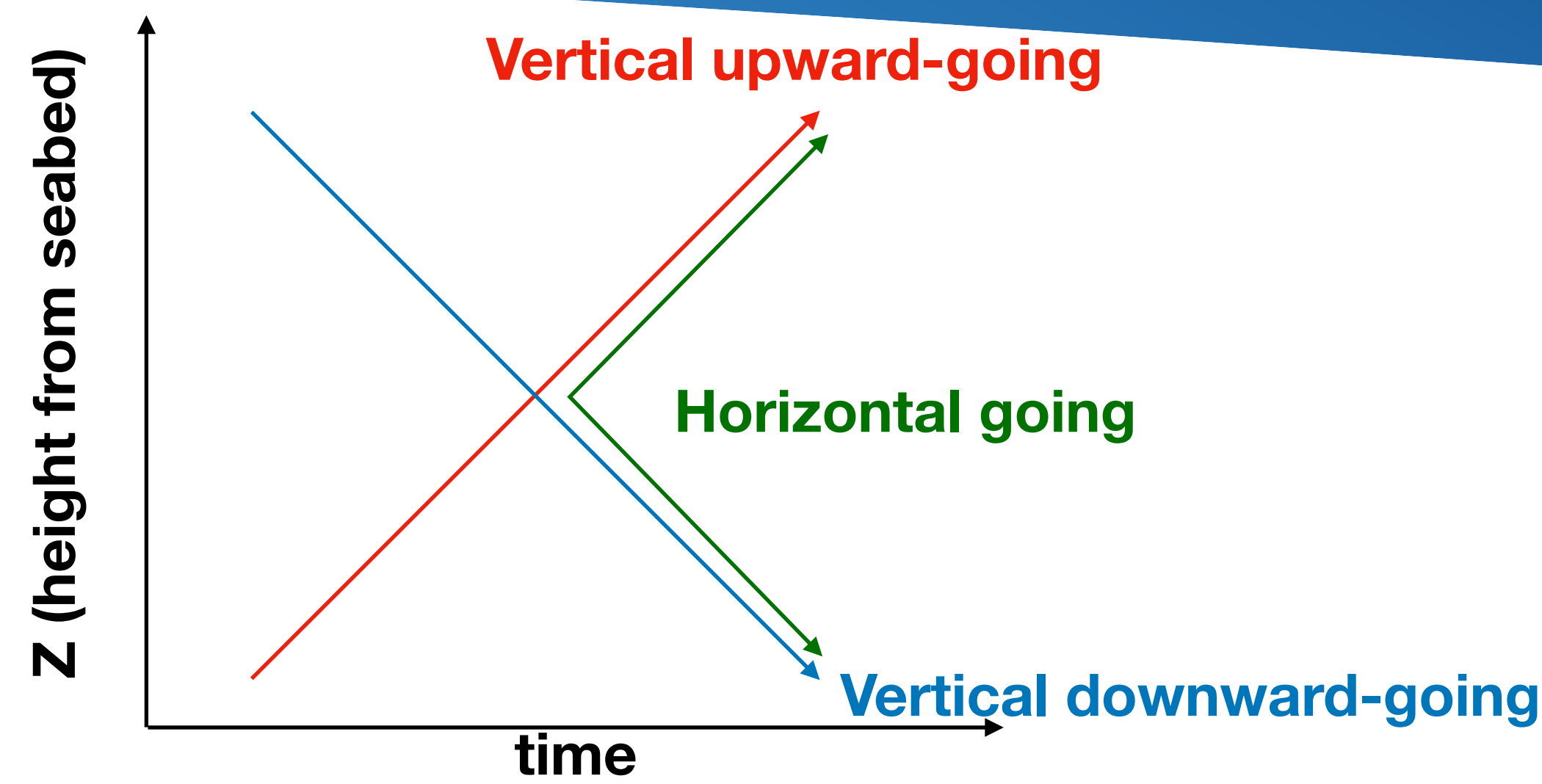
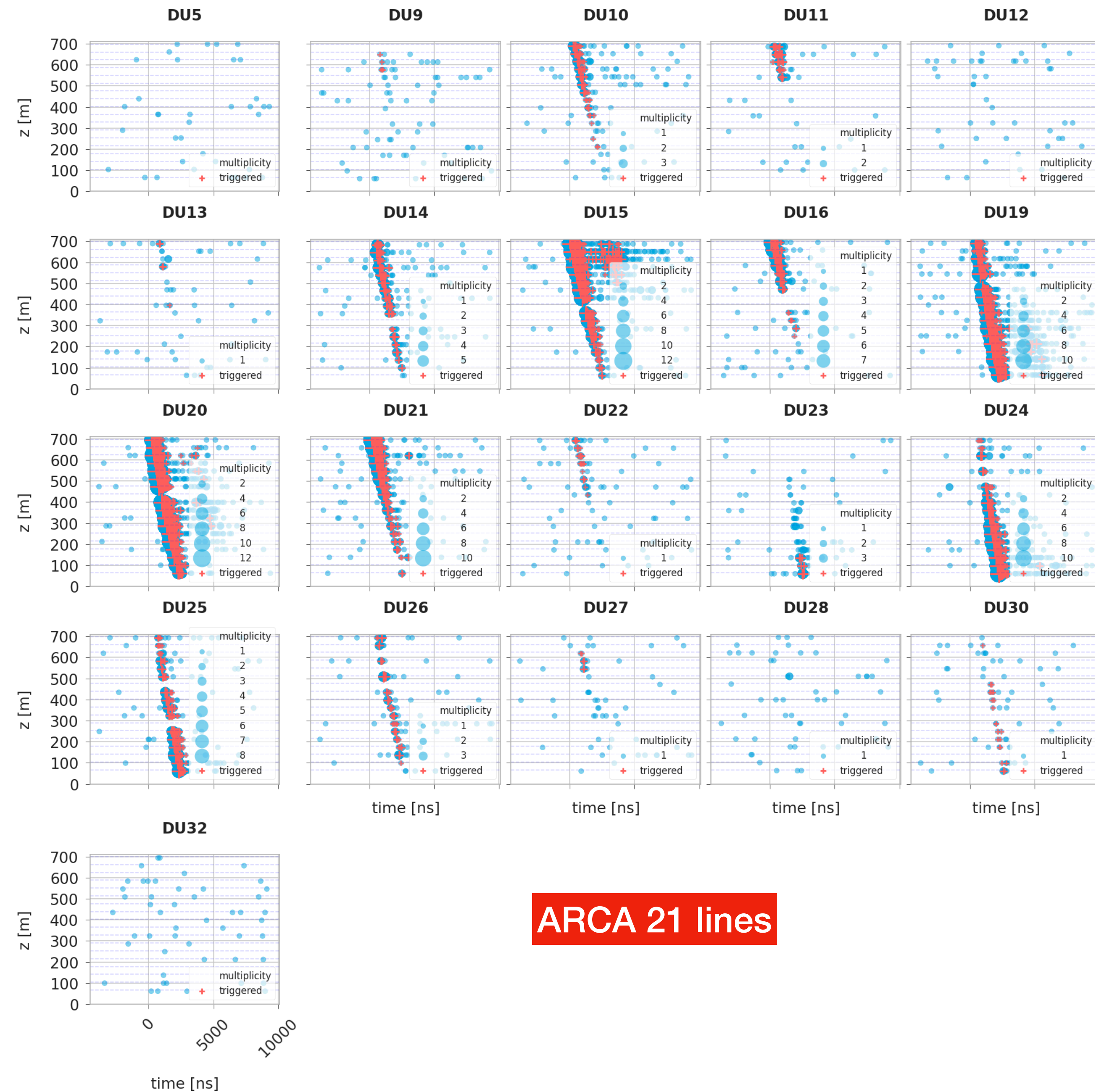
+ sites for
base containers,
electronics,
testing



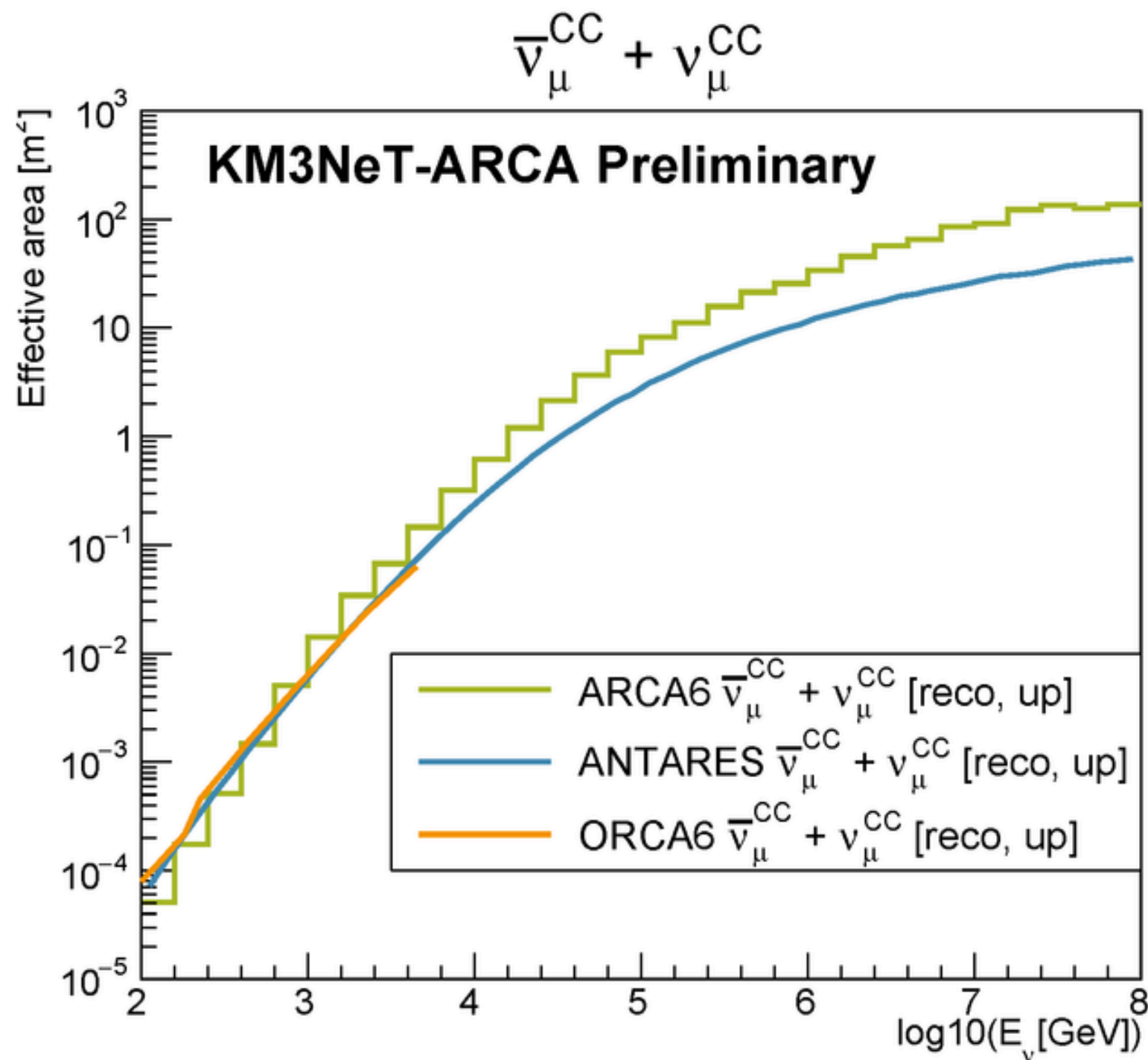
ARCA 19 reconstructed event display







ARCA6 + ORCA6 compared to ANTARES



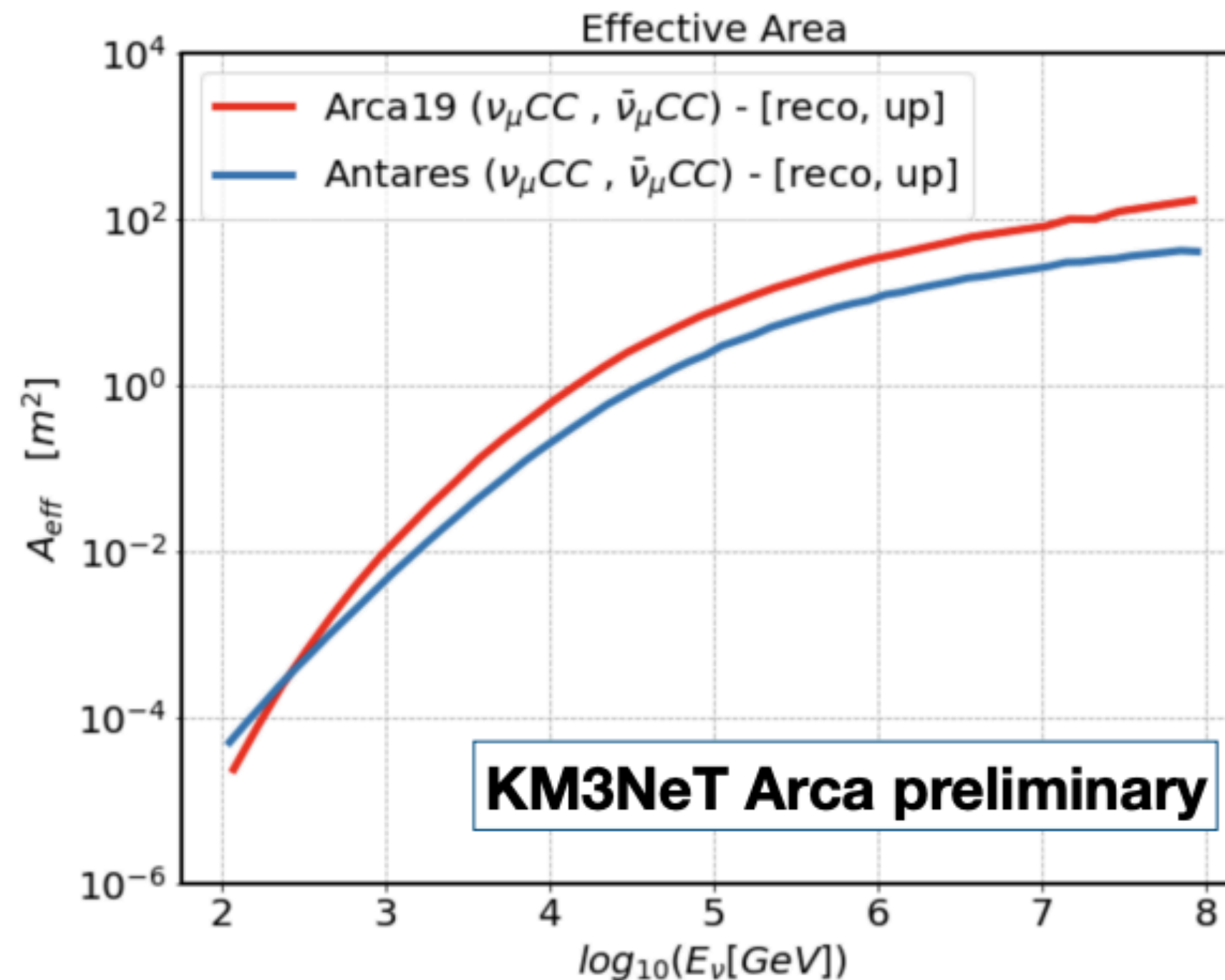
Effective areas \geq of ANTARES

Number of events per year for a cosmic diffuse flux

$$\Phi = 10^{-8} E^{-2} \text{GeV}^{-1} \text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$$

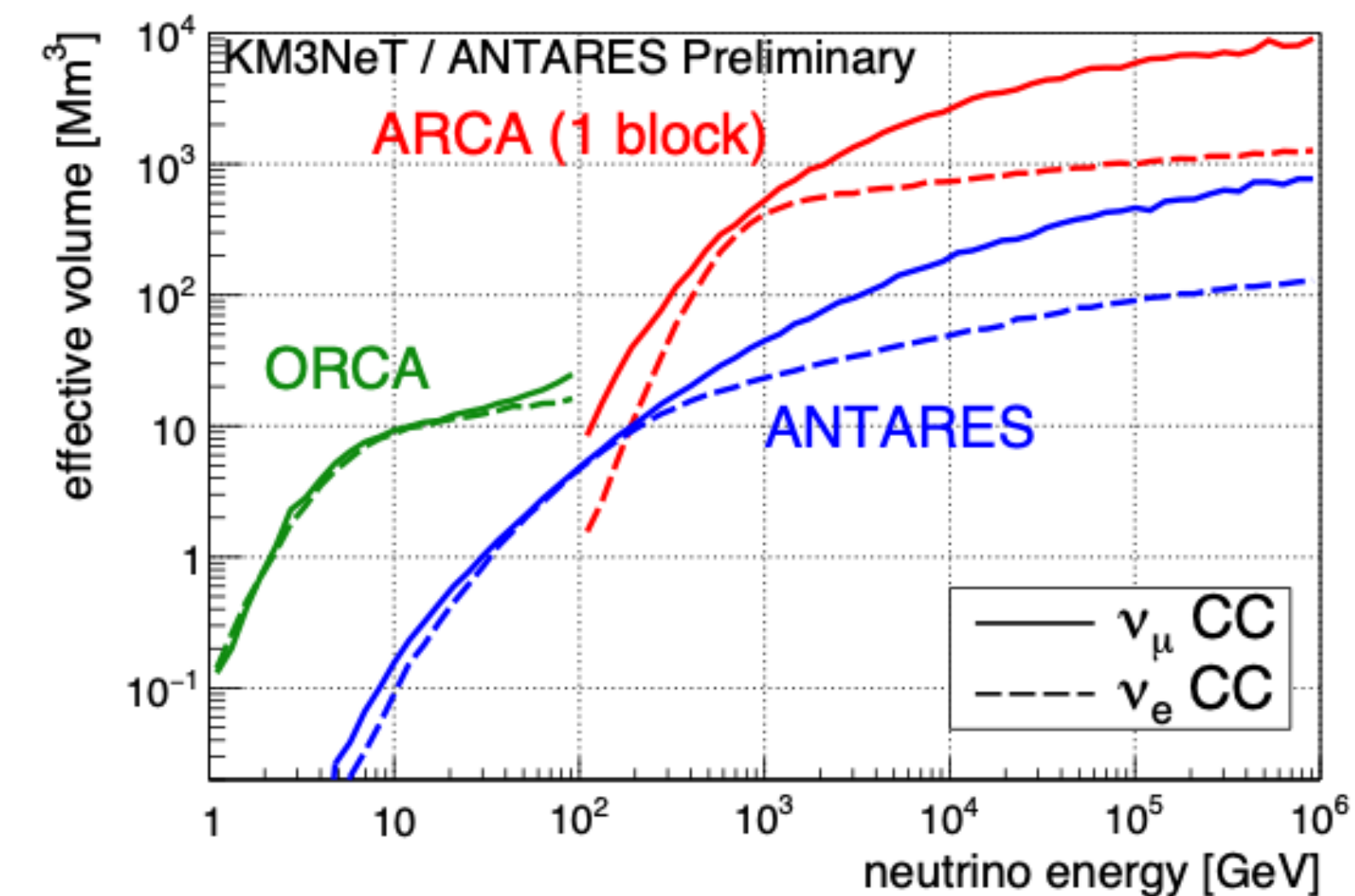
up going tracks **ARCA6 -> 6.8ev/year**
ANTARES 6.0 ev/year

ARCA19 compared to ANTARES



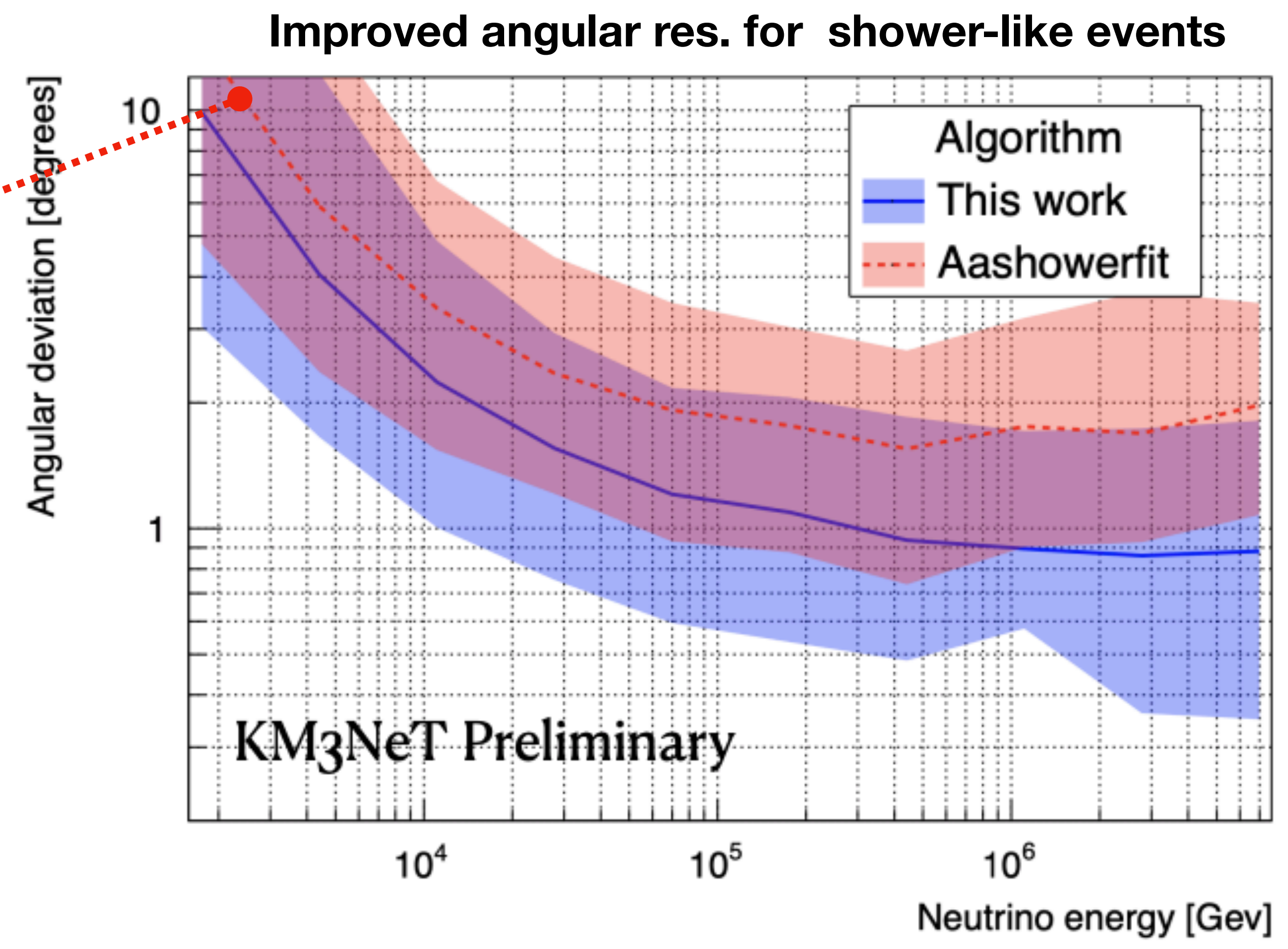
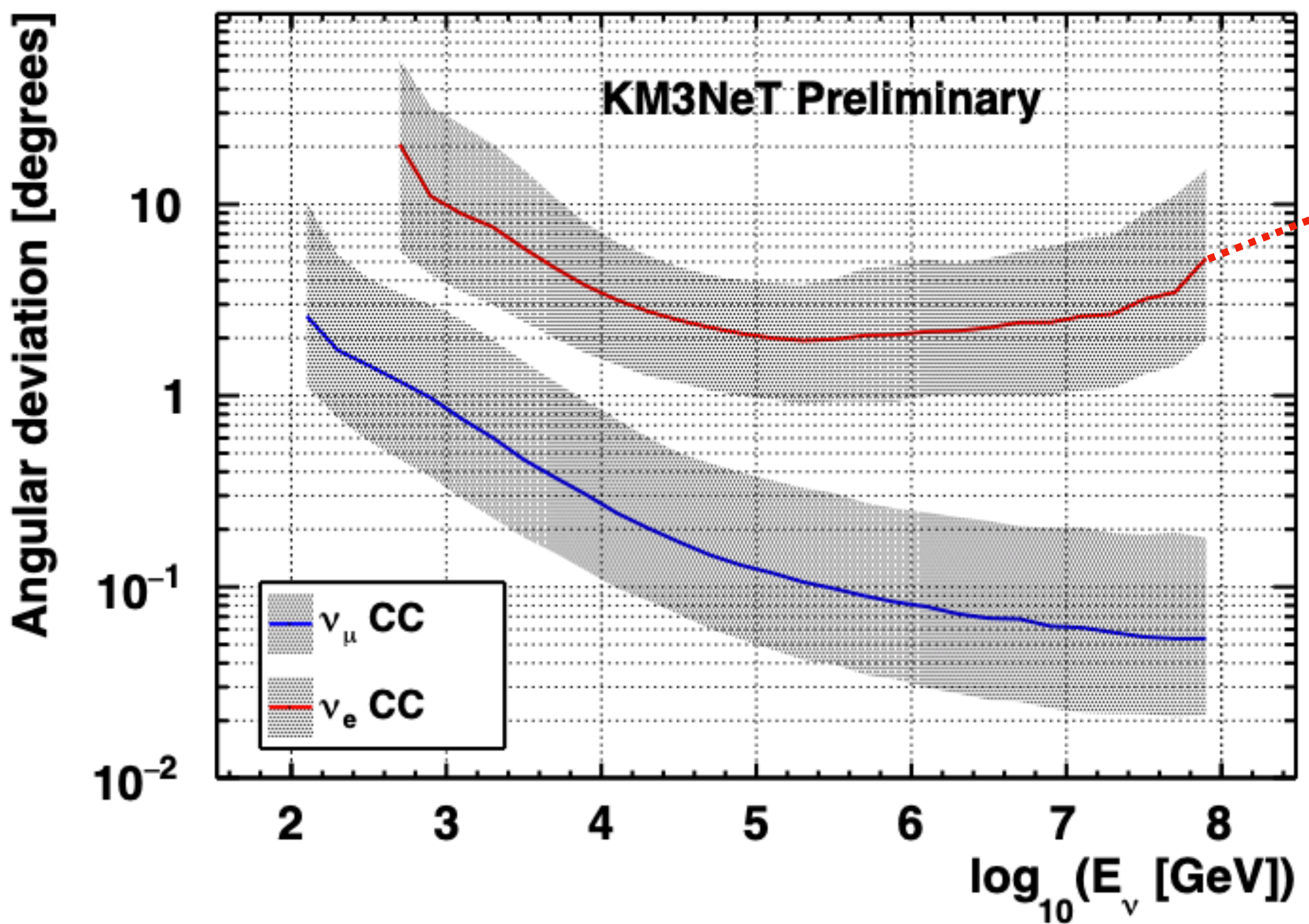
ARCA 19 3x ANTARES
 Same selections applied:
 reco, up-going cut

ARCA/ORCA (1BB) compared to ANTARES



Poster presented at Neutrino22

Track-like and **shower-like** events



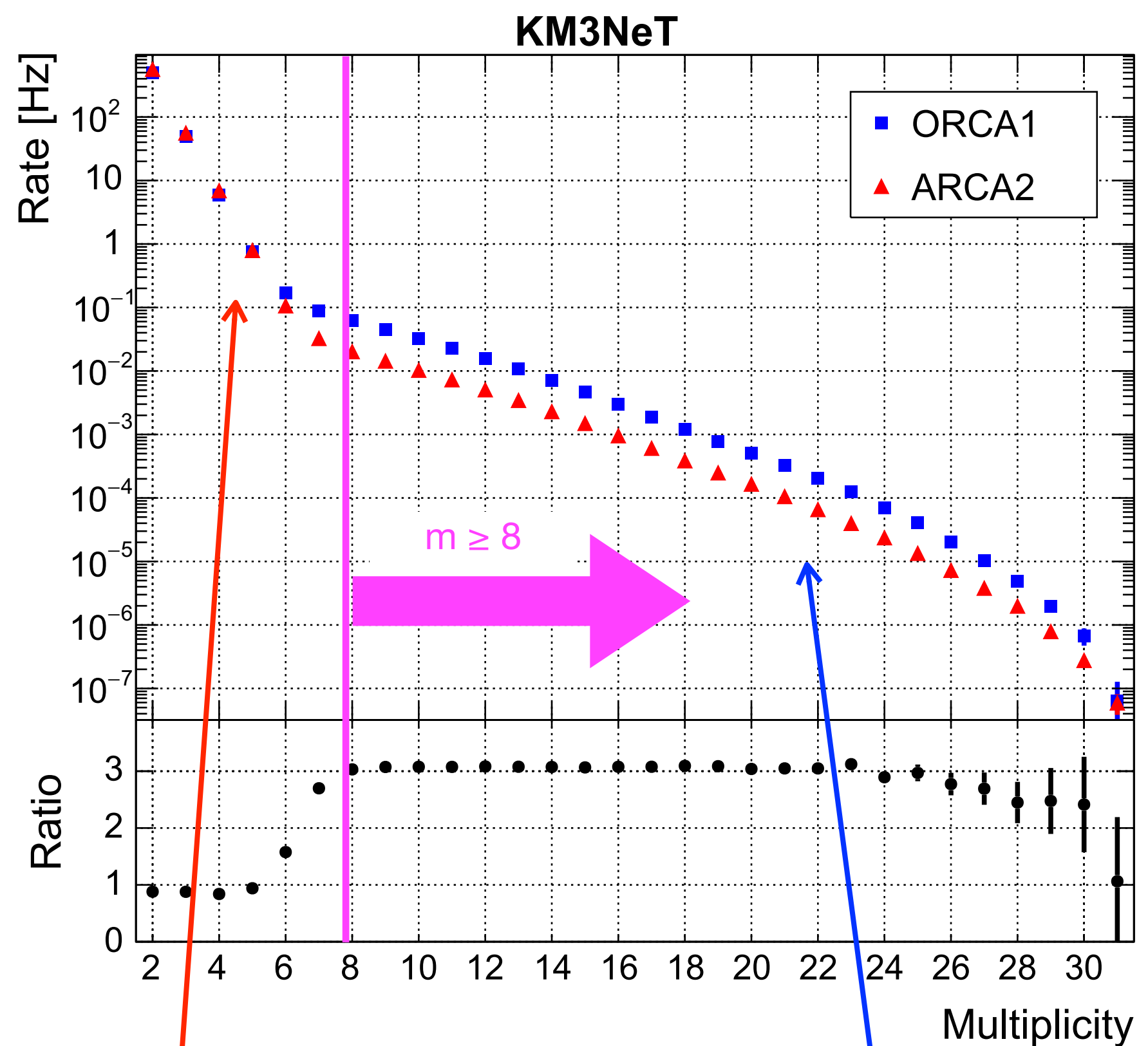
Track Energy Resol. ~ 0.27 in $\log_{10}\left(\frac{E_{reco}}{E_\mu}\right)$ ($10 \text{ TeV} < E_\mu < 10 \text{ PeV}$)

Shower (ν_x NC + ν_e CC) contained events above 50 TeV
Energy Resol. $< 5\%$

KM3NeT vs IceCube:

- Con: ^{40}K background, bioluminescence, need for real-time positioning, deep-sea operations, large throughput from the detector
- Pro: ^{40}K calibration, better view of the galactic center, no bubbles/dust \rightarrow better angular resolution

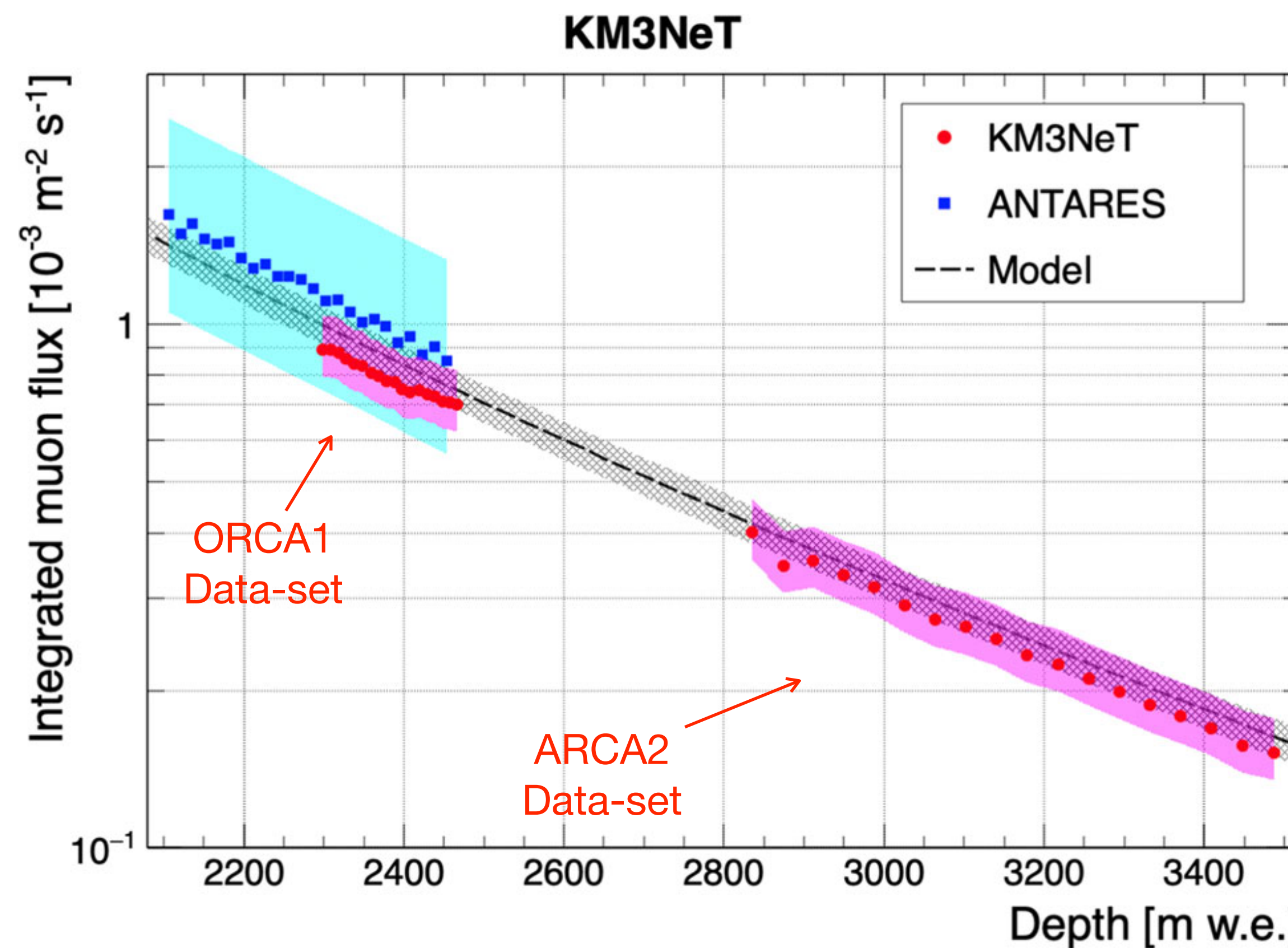
μ



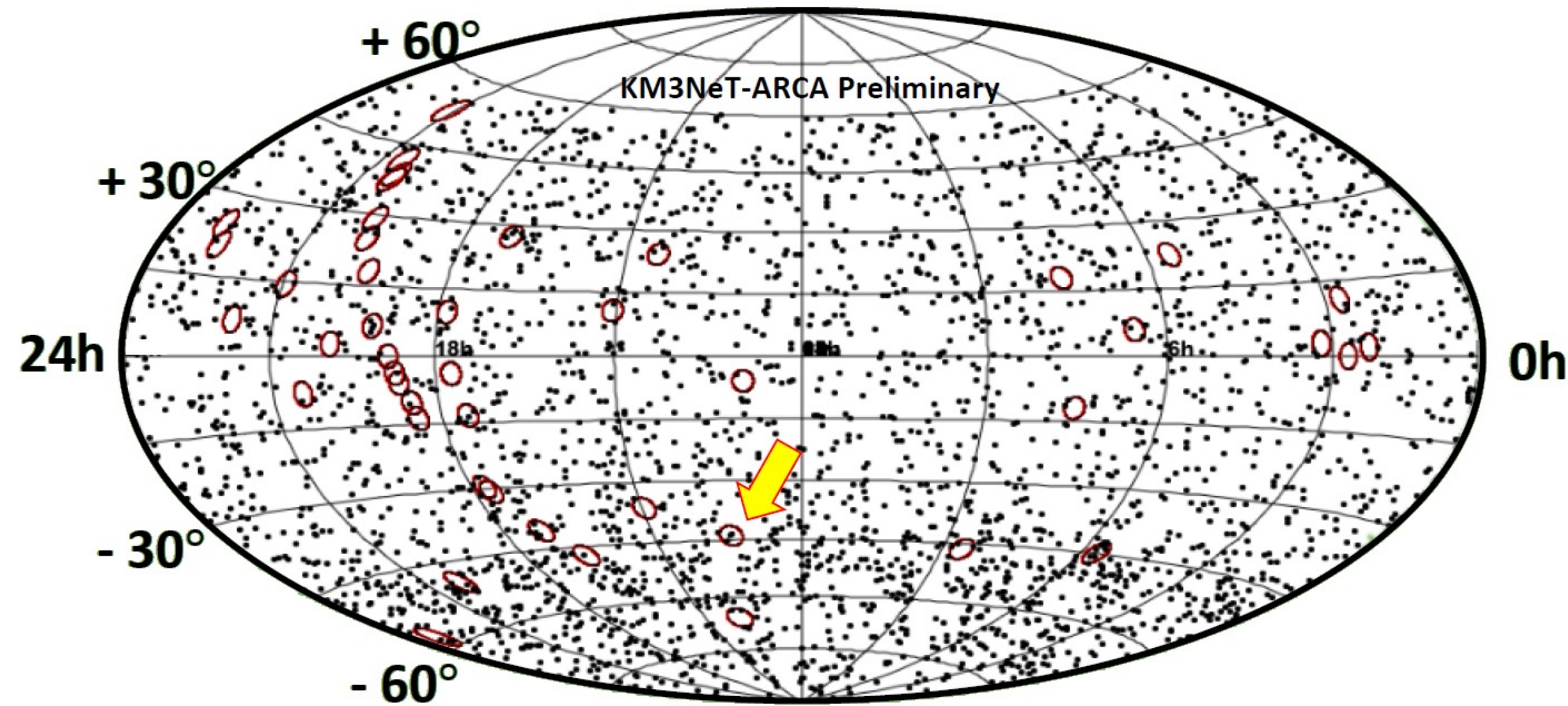
Optical background
(^{40}K decay)

Atmospheric muons

- Single-DOM measurement
- Useful to validate the calibration process
- Results compared with ANTARES and Bugaev model

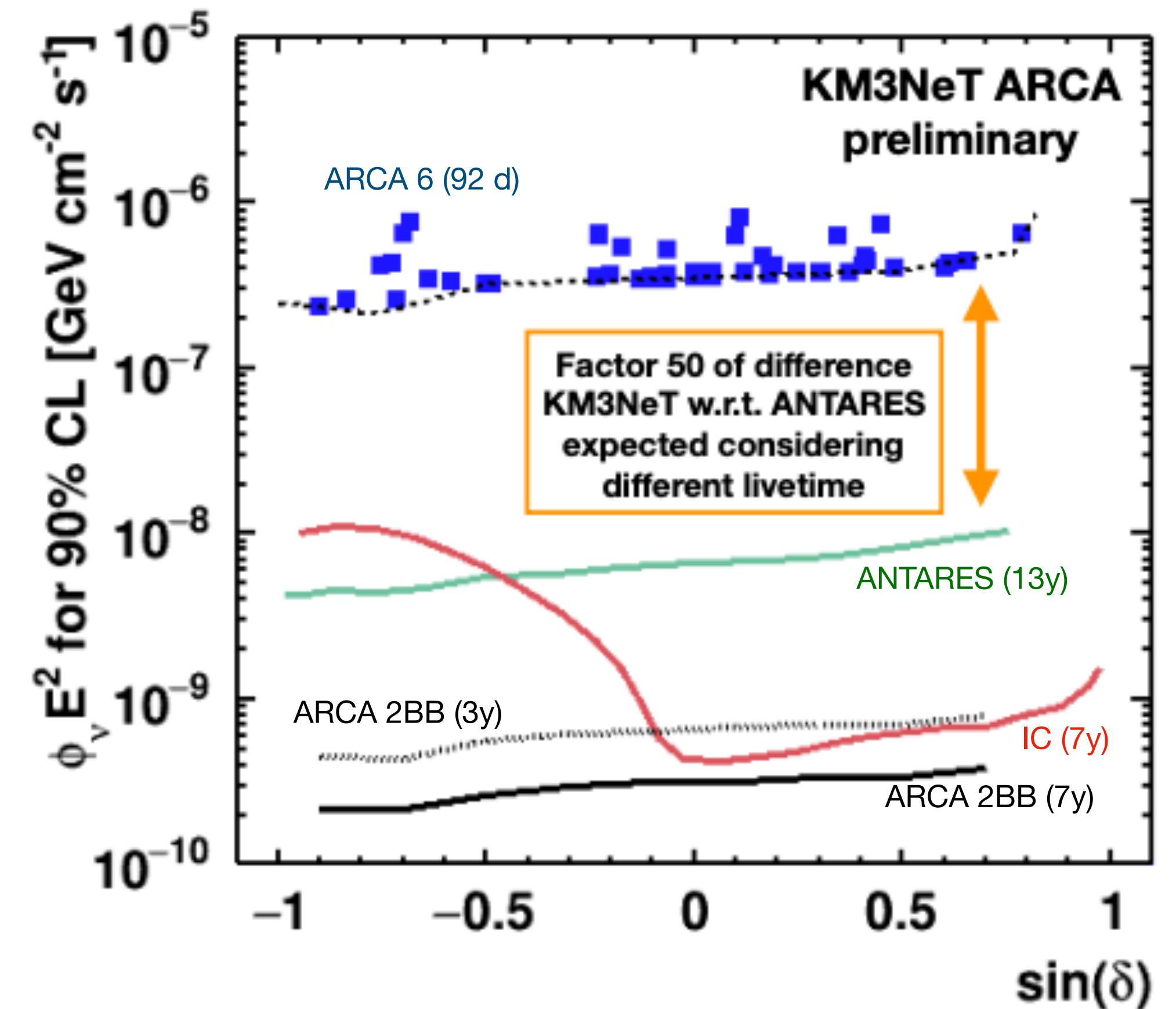


Poster P0745 @ Neutrino 22



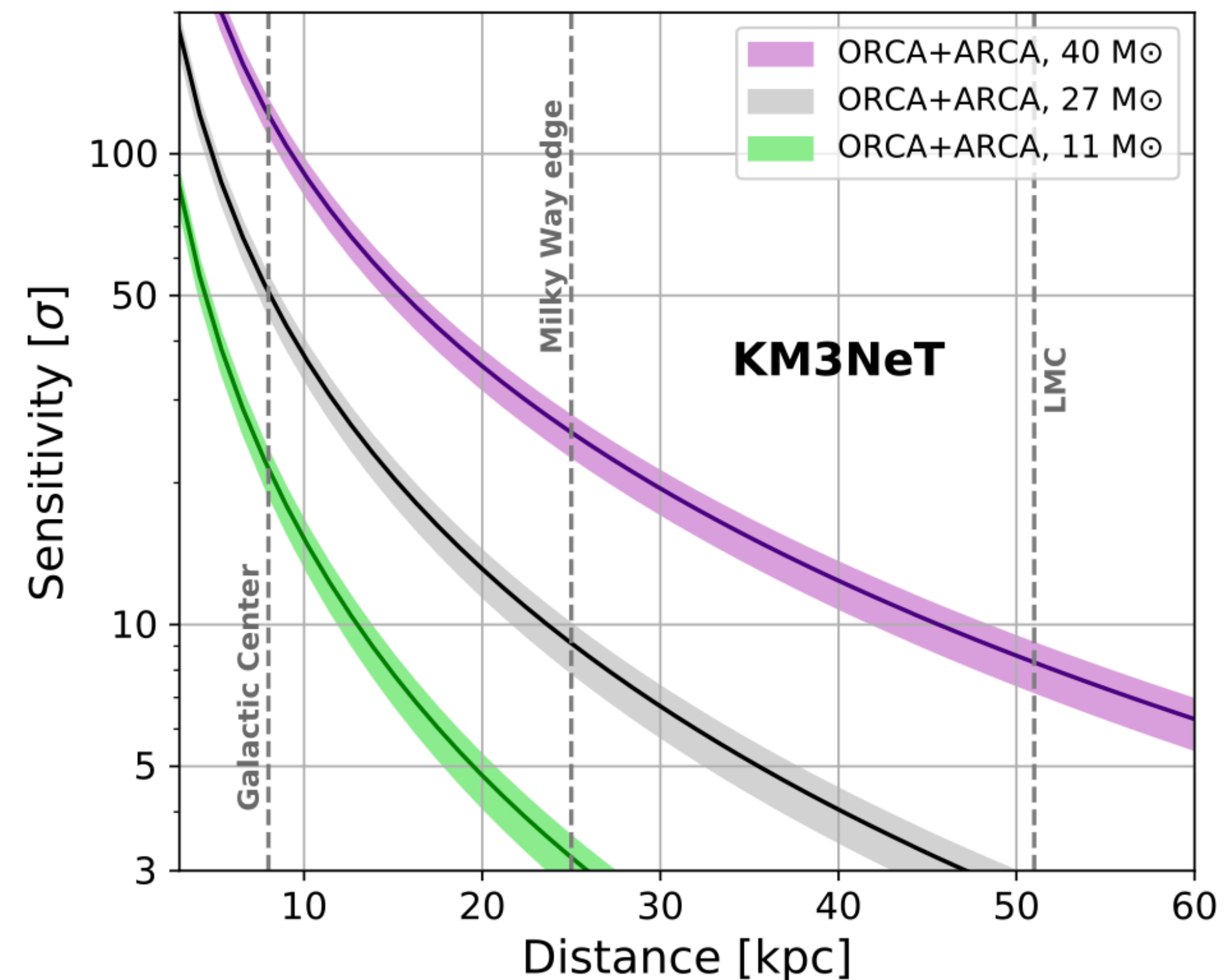
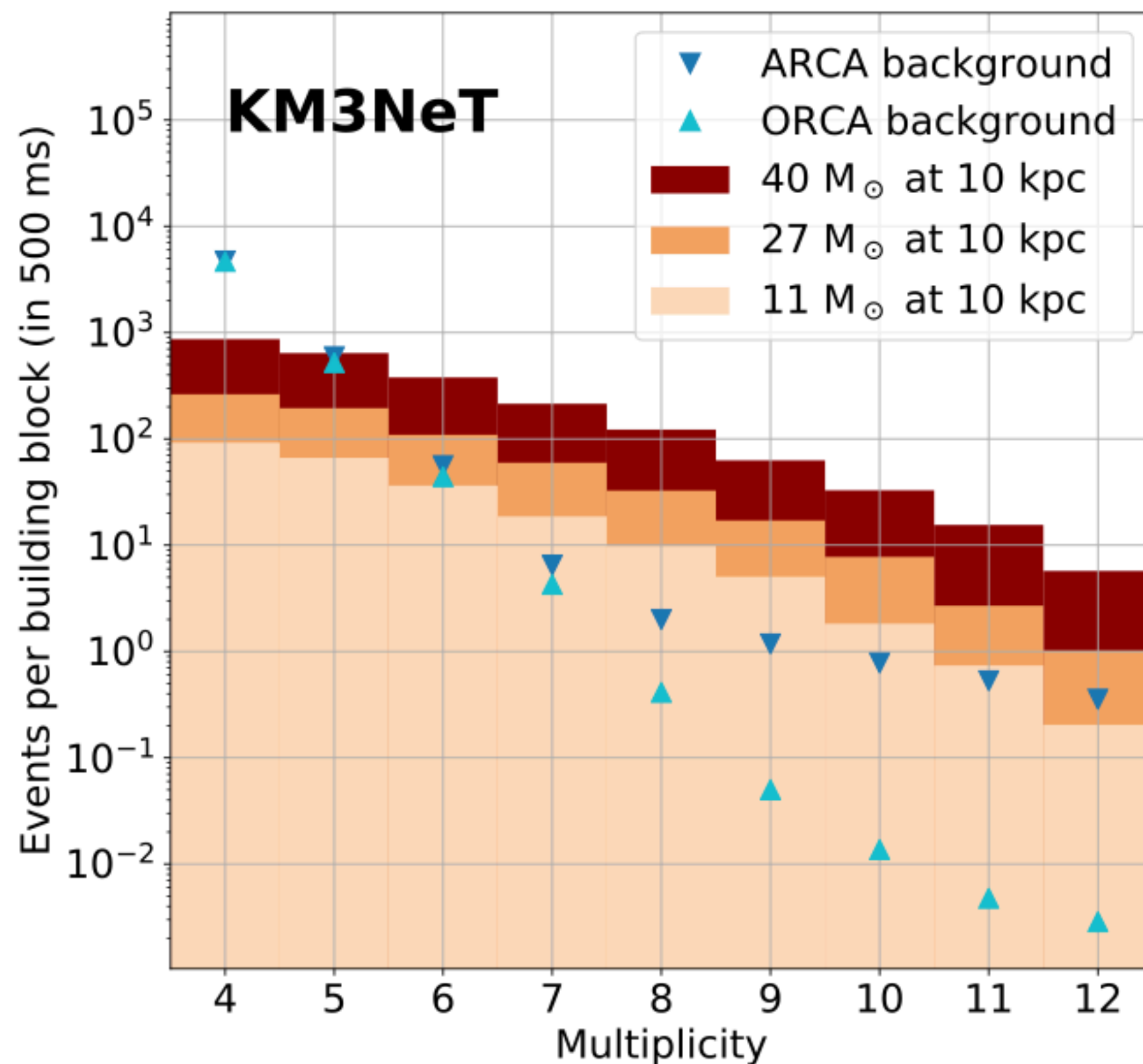
- *time*-integrated Point Source search
- 46 candidate sources -red circles - (6 are extended sources)
- Livetime: 92 days (May-Sep 2021)
- Binned likelihood search

- No significant excess — as expected
- Limits not (yet) competitive — as expected
- **Smallest p-value:** $p = 0.02$ for Centaurus A (radio galaxy, yellow arrow) - compatible with background





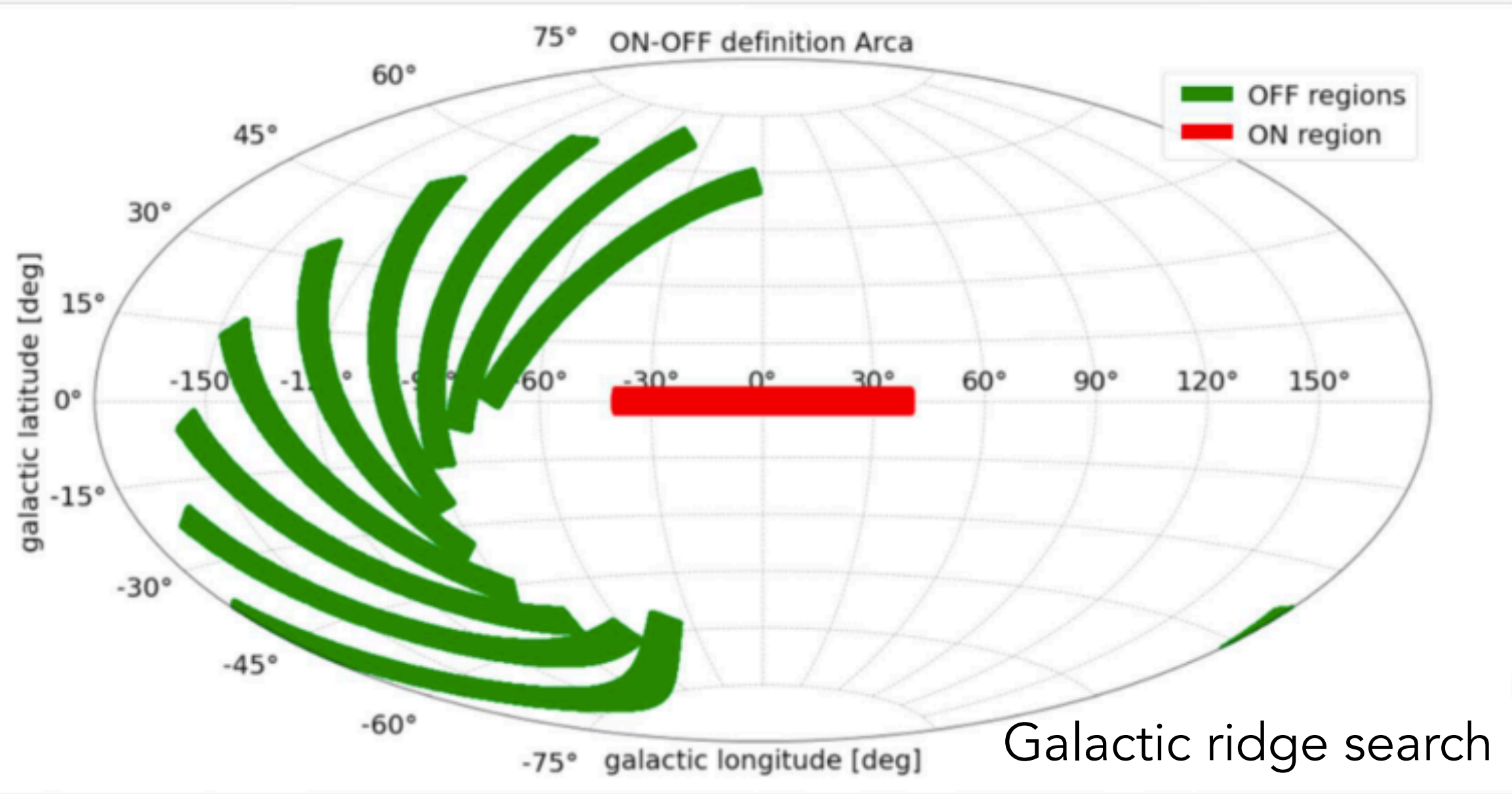
ORCA 1 BB + ARCA 1BB



ARCA6+ORCA6 already sensitive to 60% of Galactic CCSNe (<11 kpc)
 Joint real time trigger operational for SNEWS since early 2019

> 5 σ for ARCA+ORCA for
 27 M_{\odot} at a distance < 25 kpc

**ARCA 21: 1/3 w.r.t. the above
 sensitivity**



GALACTIC RIDGE search - 101 days live-time.

ON-OFF analysis

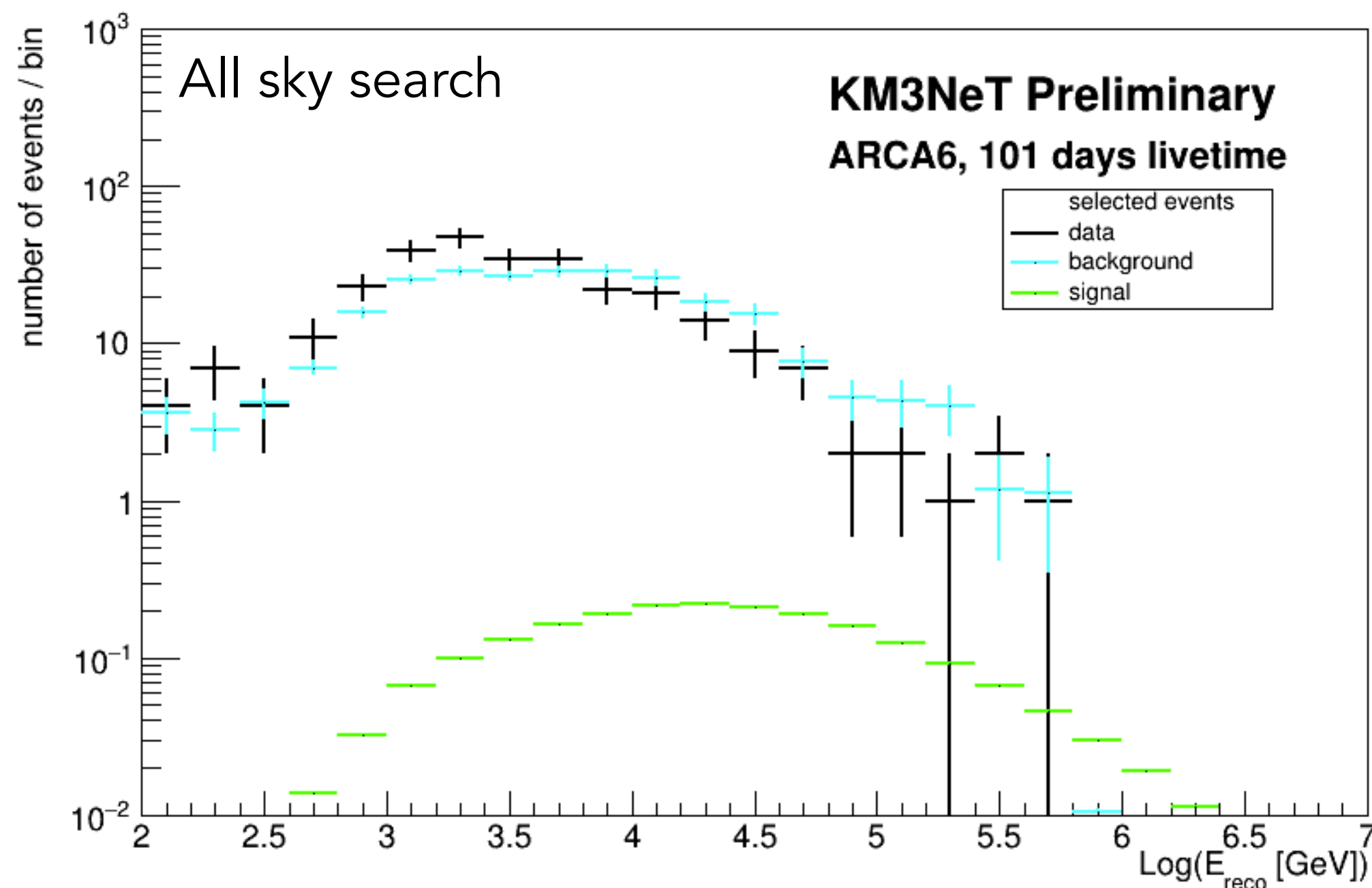
- ON region: $|L_{gal}| < 40^\circ$ and $|b_{gal}| < 3^\circ$
- OFF region: shift in time of the ON region, no FermiBubbles

Simulated signal flux:

$$1.2 \times 10^{-8} (E/GeV)^{-2.4} [\text{GeV}^{-1} \text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}]$$

NO statistically significant excess found

Upper limit (UL) : $6.2 \times 10^{-4} [\text{GeV}^{-1} \text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}]$



Privileged position of the KM3NeT detectors, looking at the Southern sky, and at the Galactic Centre

ALL SKY search 101 days live-time

Multi-variate (BDT) technique adopted

Simulated signal flux from IceCube (ICRC 2019) :

$$1.44 \times 10^{-18} (E/100 \text{ TeV})^{-2.28} [\text{GeV}^{-1} \text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}]$$

Obtained sensitivity for the corresponding flux :

$$17.3 \times 10^{-18} [\text{GeV}^{-1} \text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}]$$

ON - OFF technique used

- ON region: circular region with optimized ROI
- OFF region: declination band of 10 standard time-window of 1 day.

E^{-2} spectrum assumed Selection of up-going events

Up to now followed-up IC alerts:

- IC211208A (± 1 day),
- IC211208A (**31** days),
- IC220205B (± 1 day),
- IC220225A (± 1 day),
- IC220304A (± 1 day)

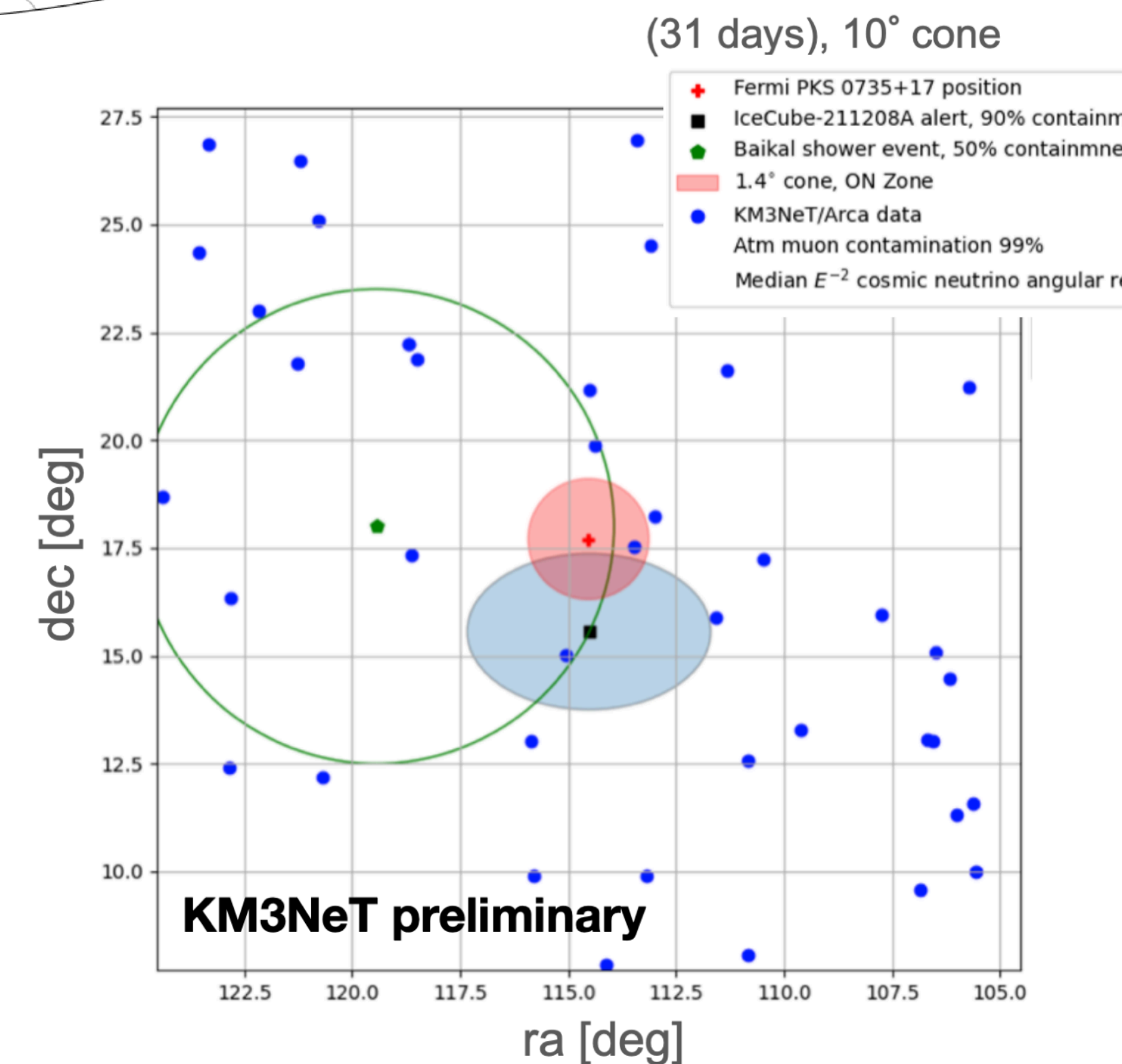
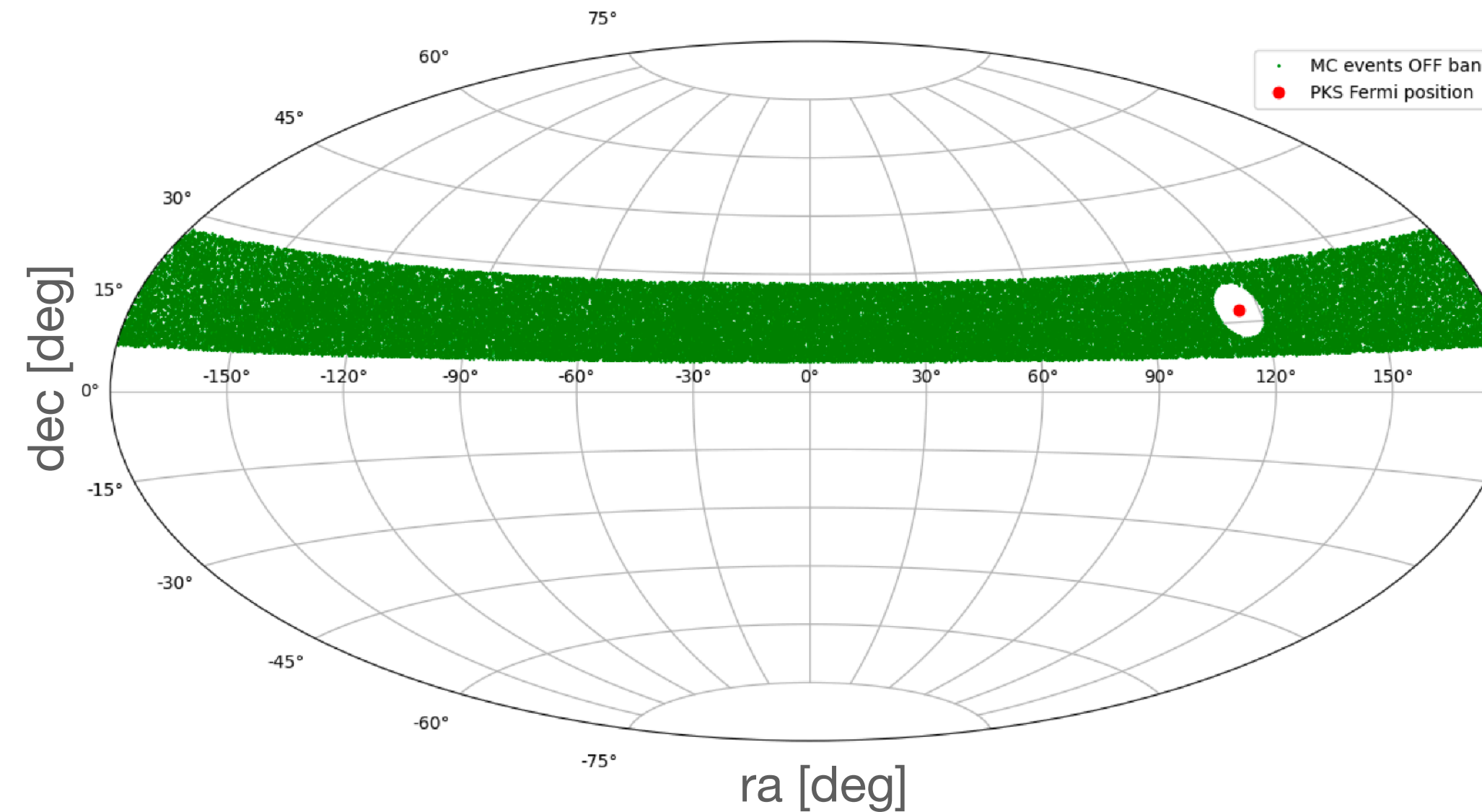
PKS0735+17

also enlarged time window of **1 month**

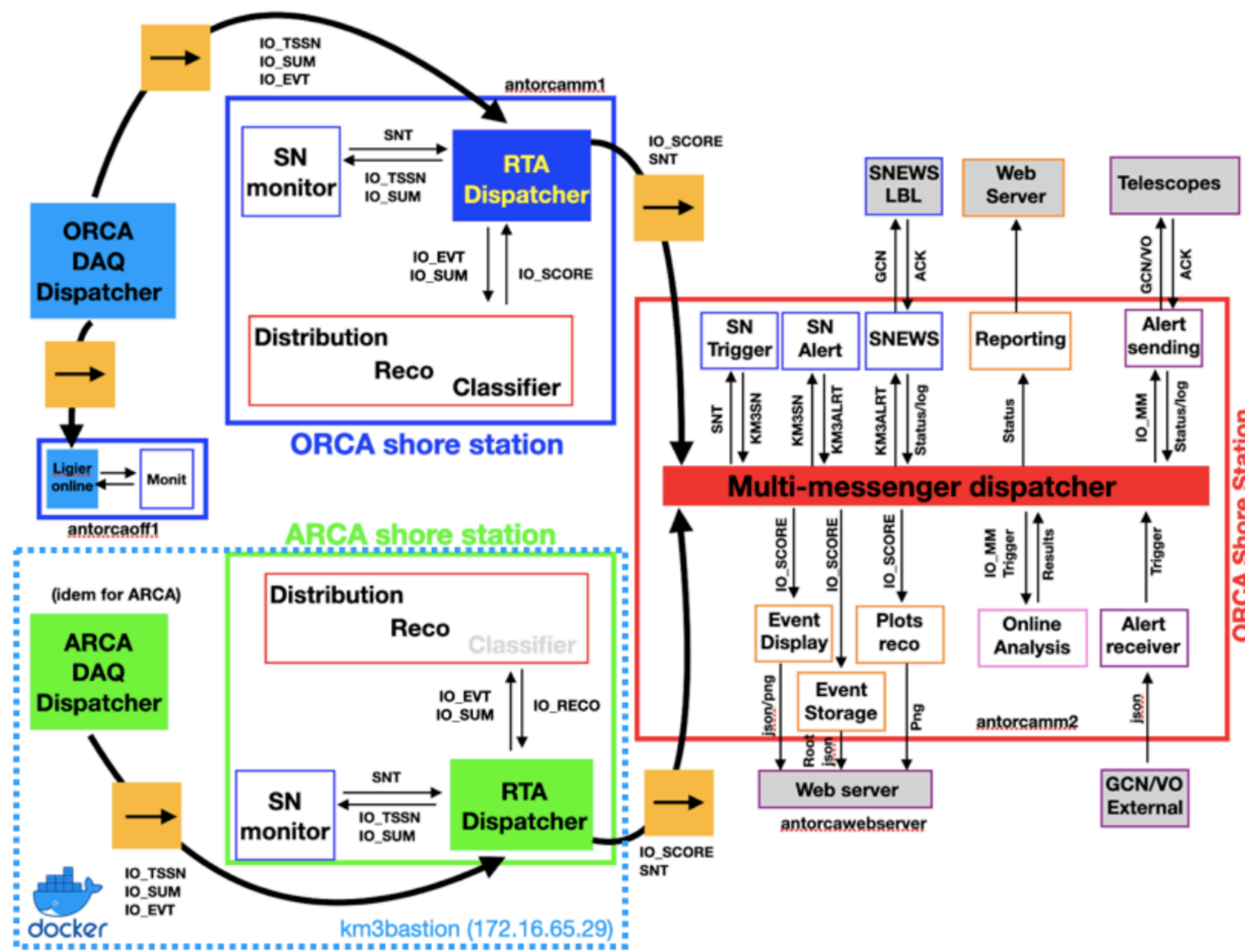
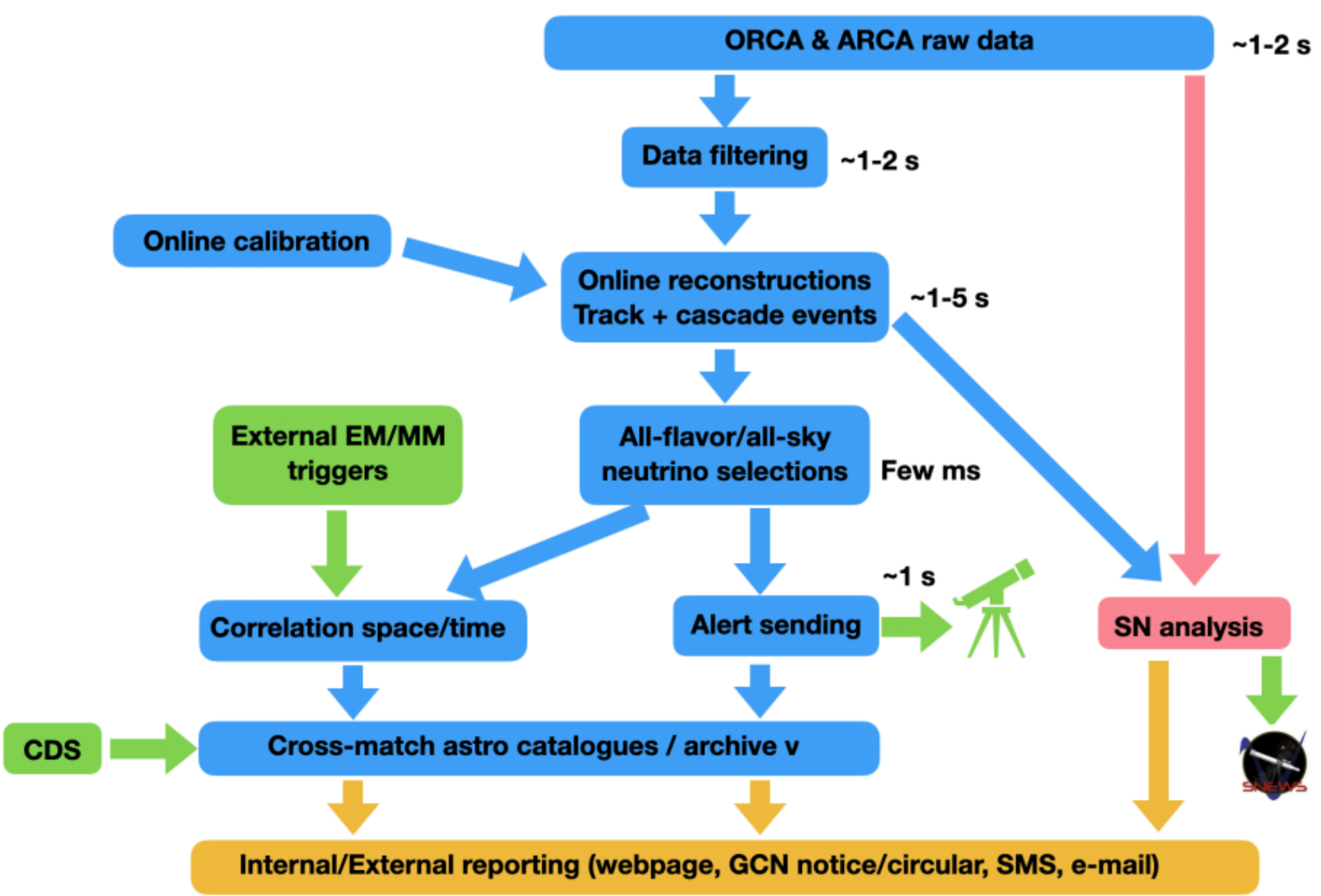
No significant discovery

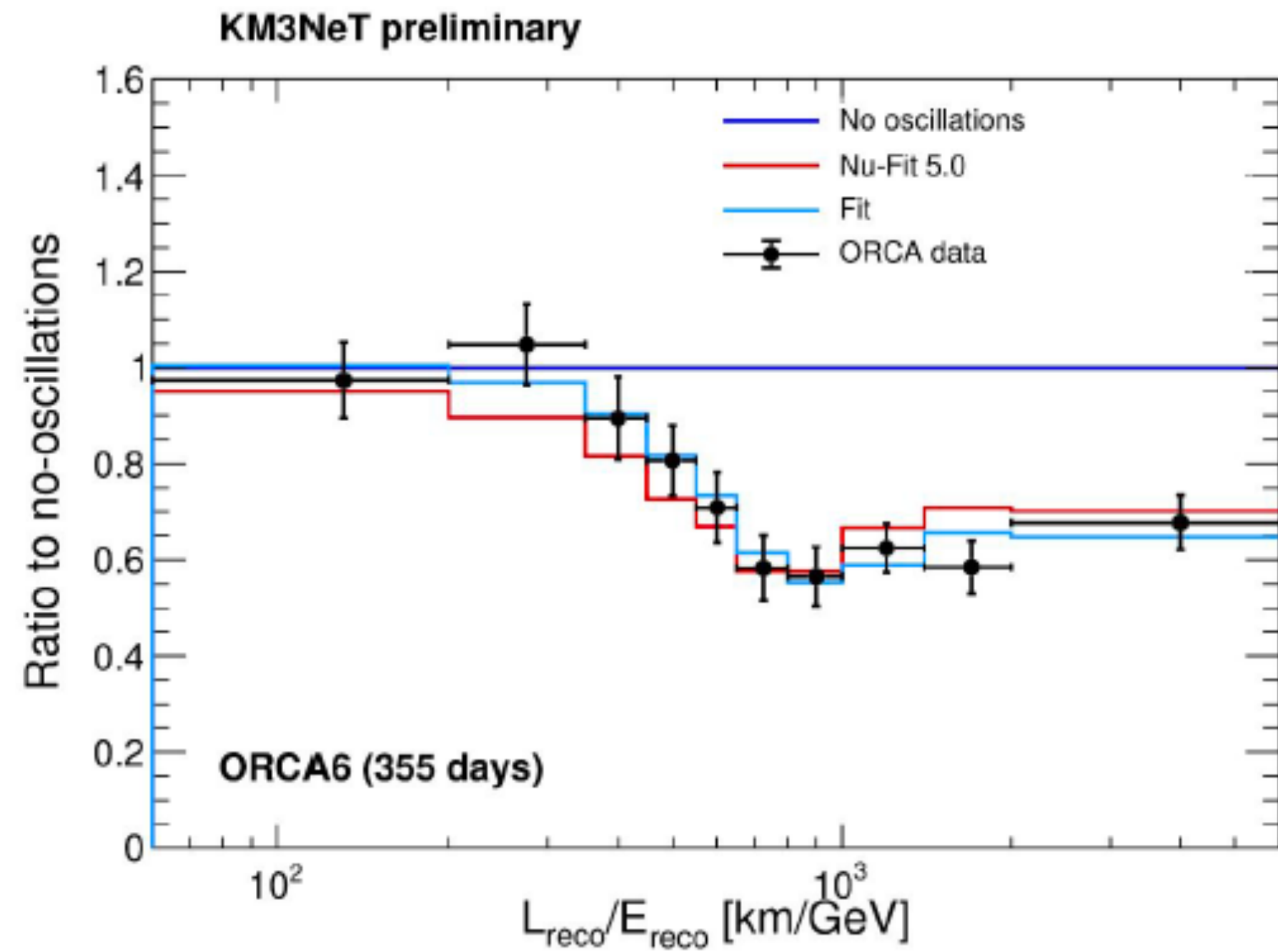
Only 1 event found in the 1 month search with E 18 TeV with associated **p-value: 0.14**

**These analyses were performed off-line,
They will be realised on-line within the Multi Messenger program**



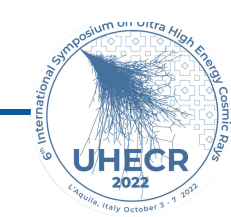
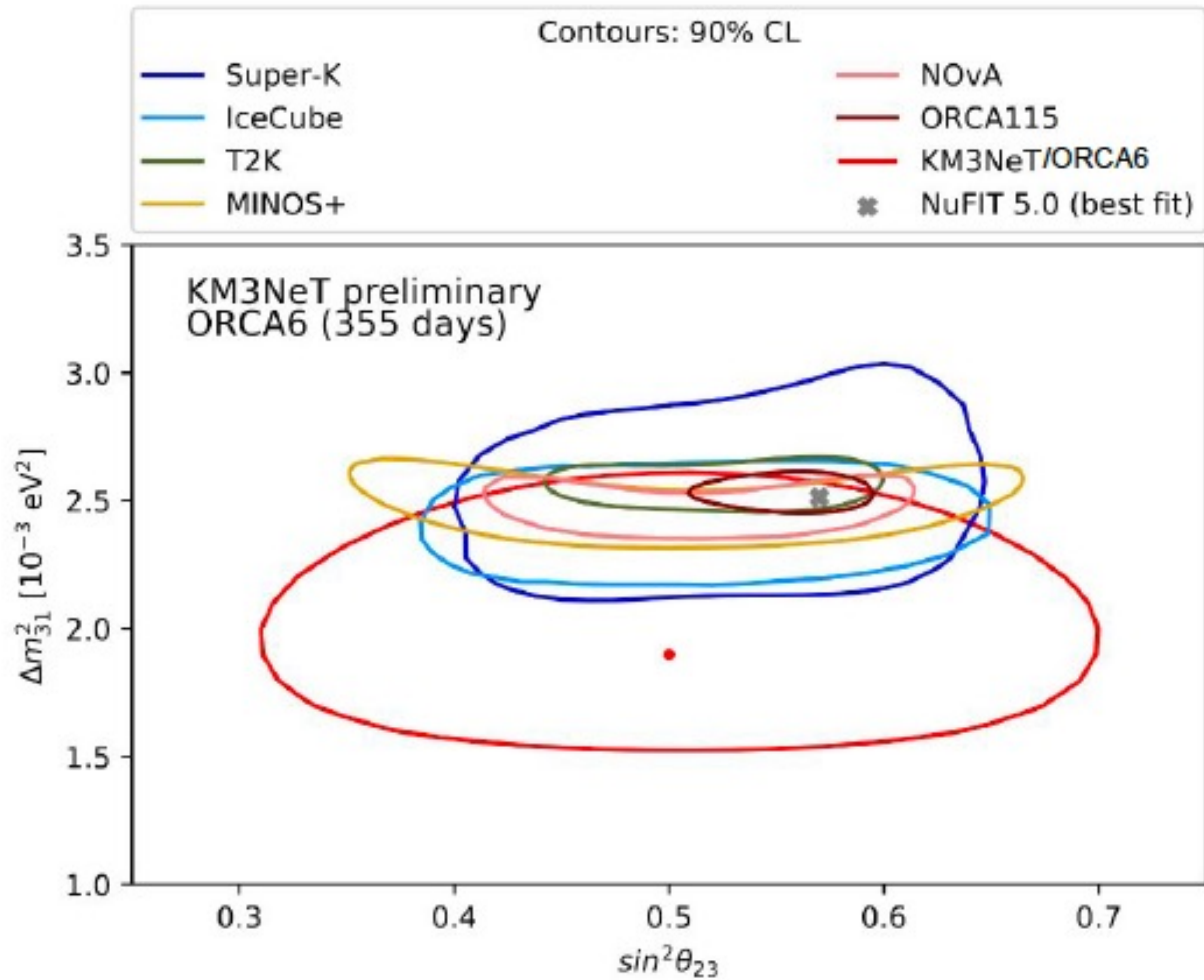
Real-time analysis framework





Oscillation fit, binned in E_{reco} , θ_{zenith}
 Normalization left free, various systematics on flux, energy scale, tau- and NC normalization

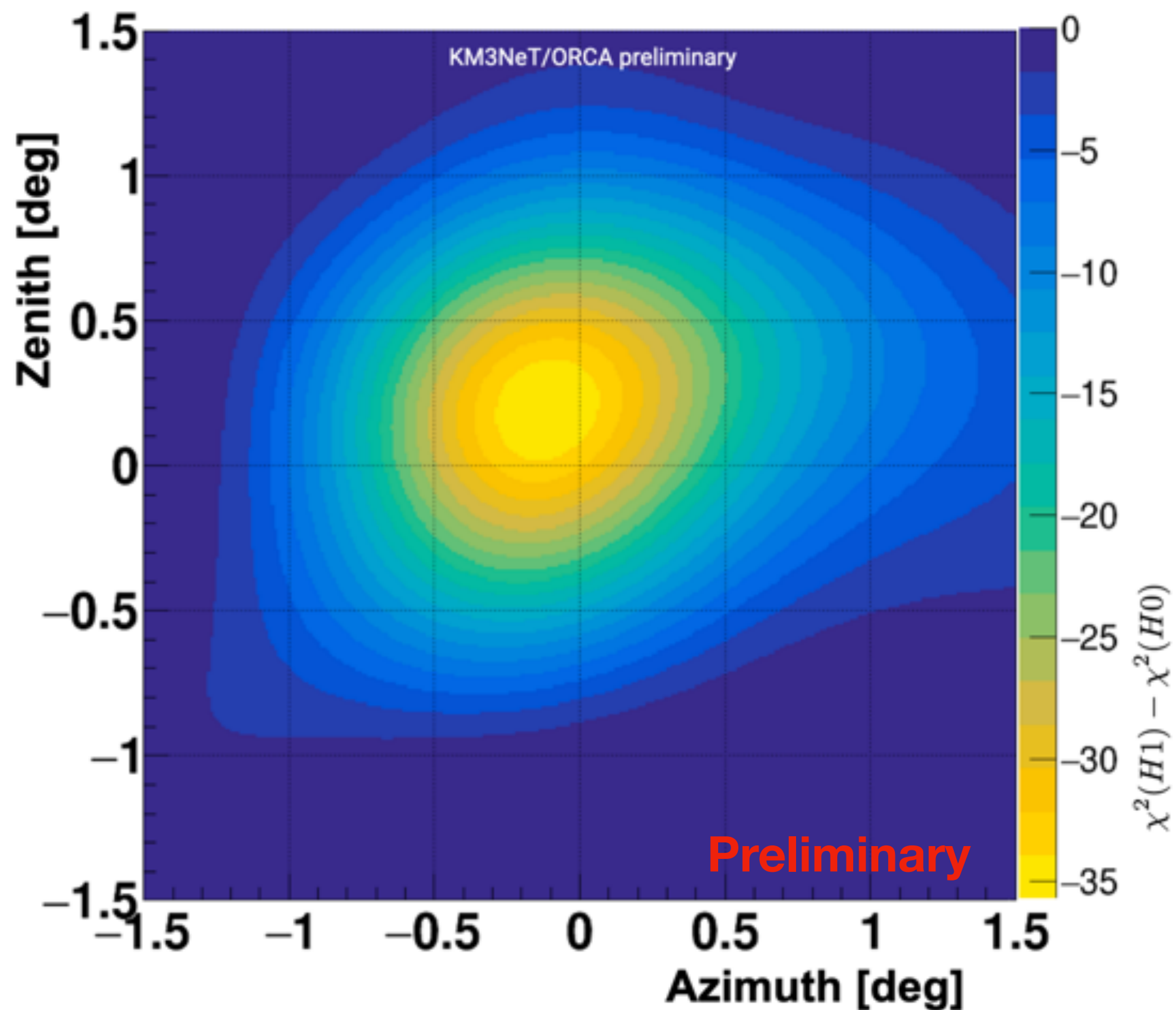
Parameter	Treatment	Fit value
Δm_{31}^2 [10^{-3} eV ²]	Free	$1.95^{+0.24}_{-0.21}$
θ_{23} [deg]	Free	$45.4^{+5.6}_{-5.7}$





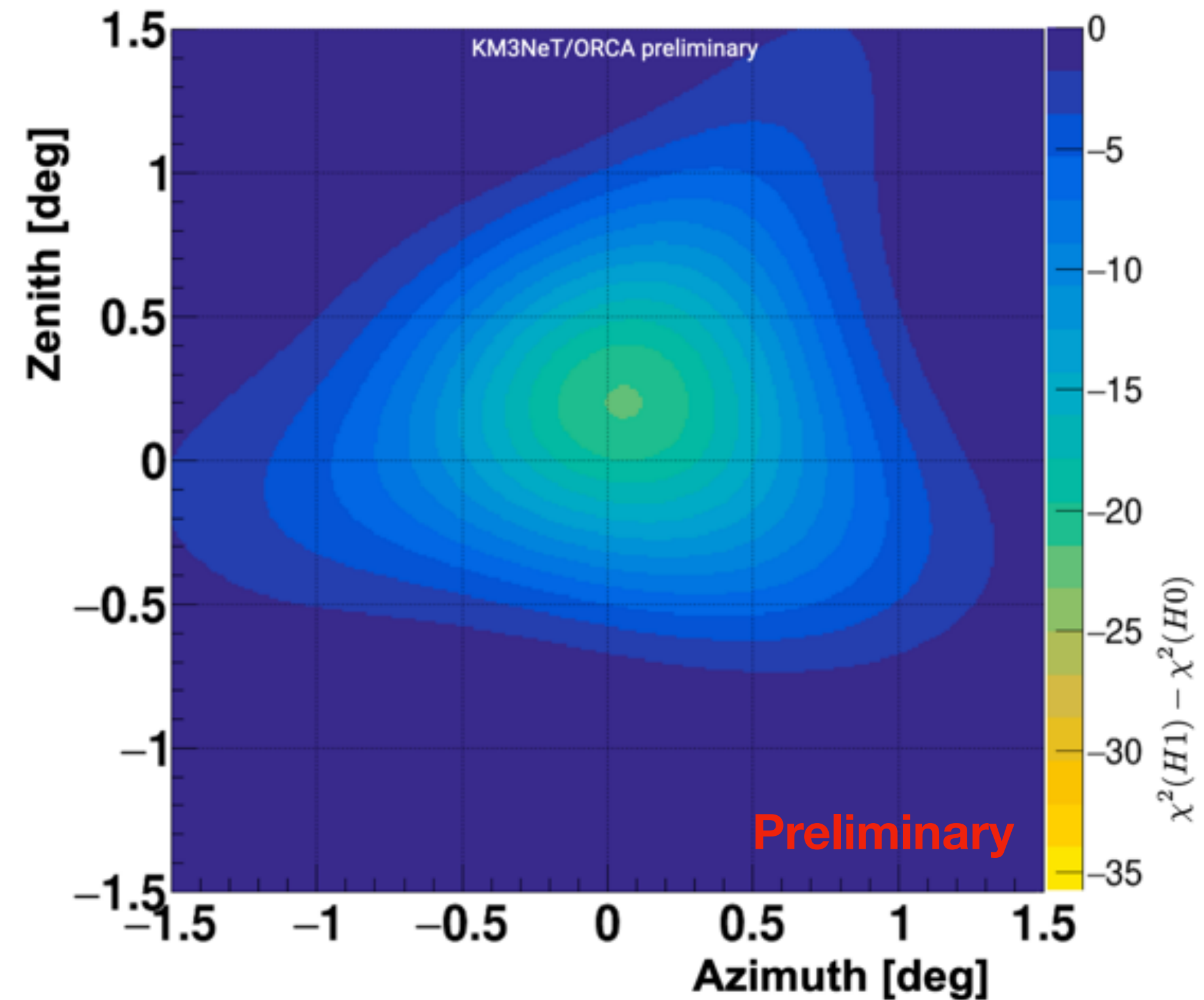
KM3NeT - ORCA6
13 months data taking

2D histogram data sun



Significance $> 6 \sigma$
Angular resolution = $0.8^\circ \pm 0.14^\circ$

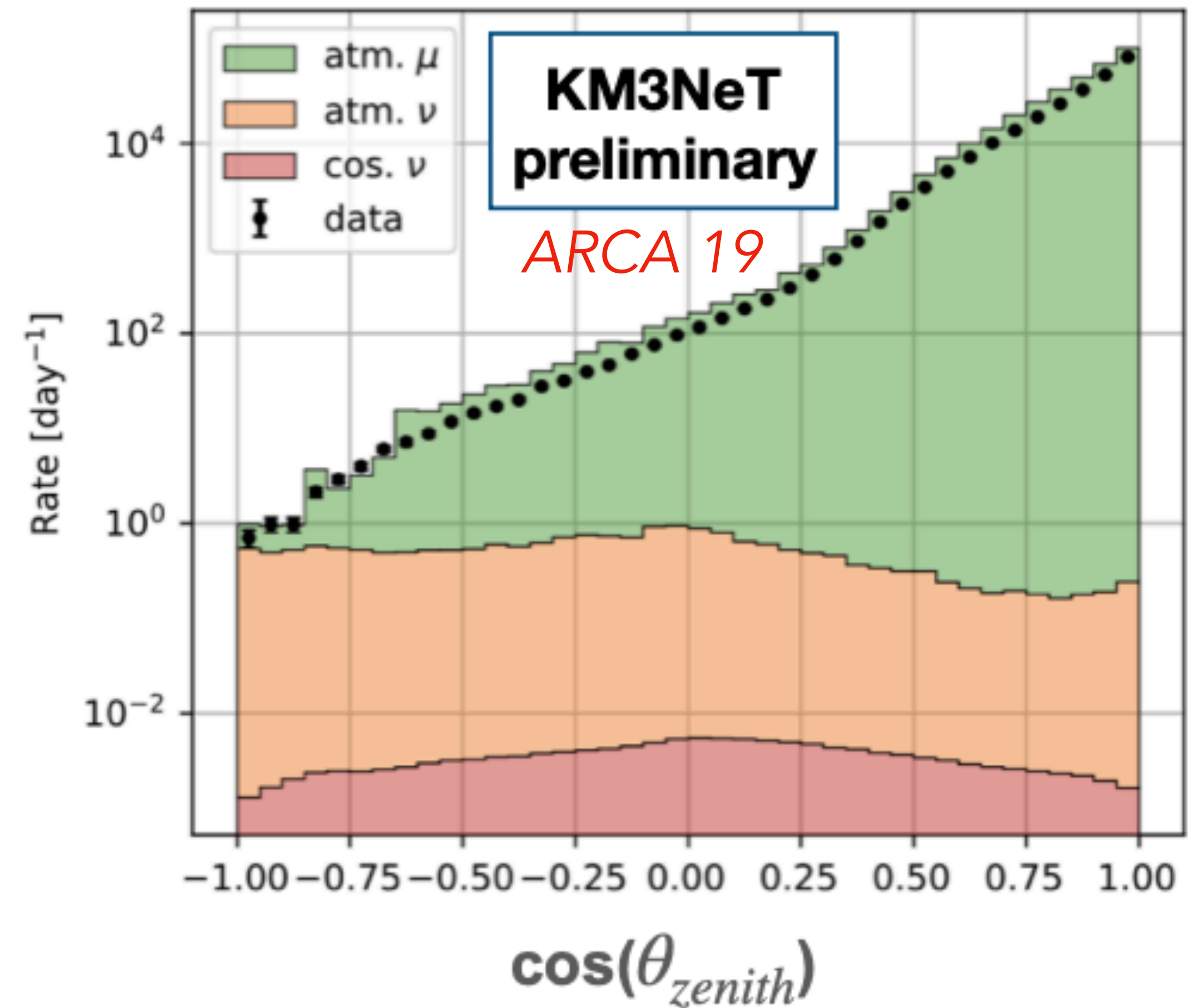
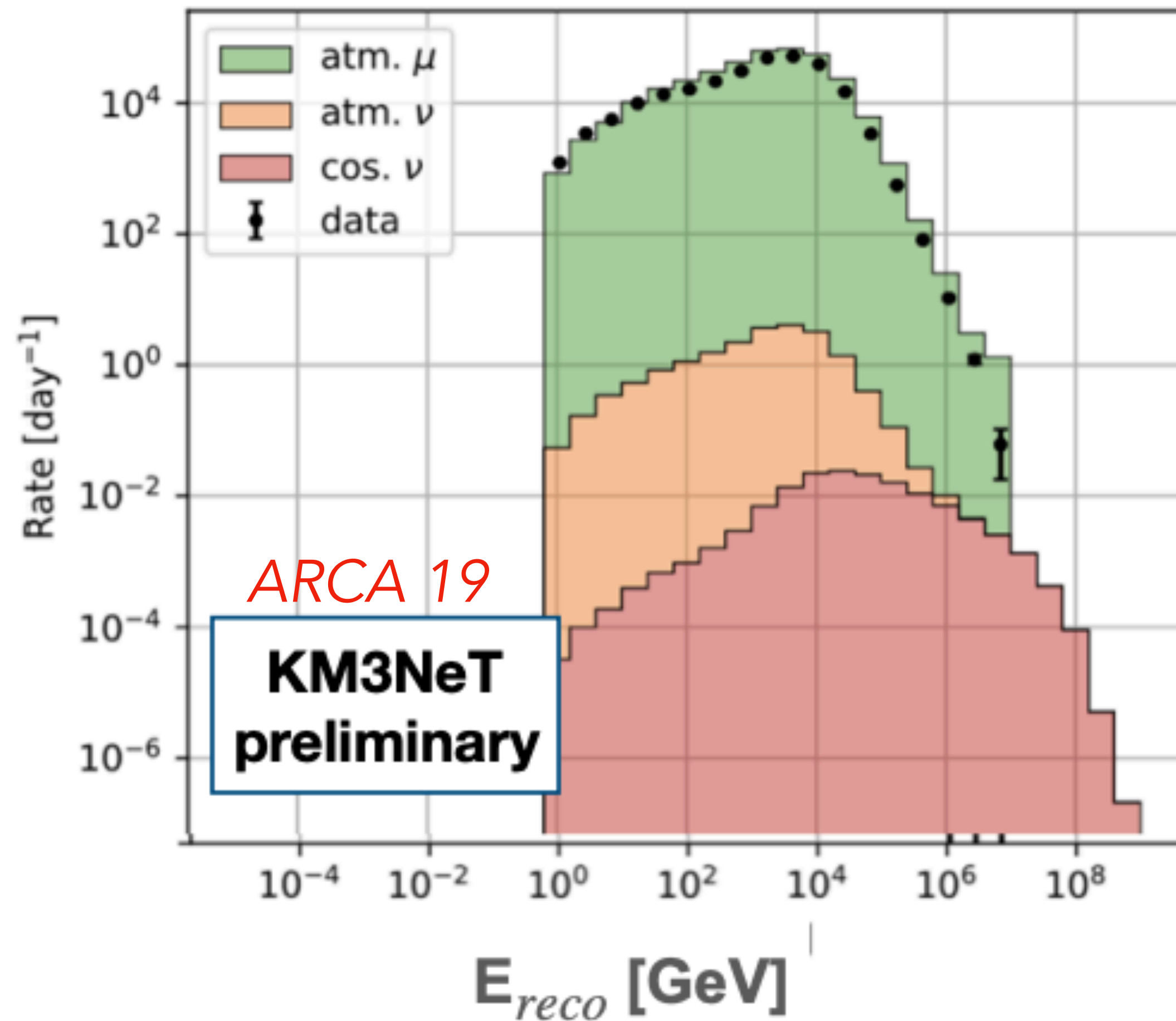
2D histogram data moon



Significance = 4.2σ
Angular resolution = $0.49^\circ \pm 0.15^\circ$

Moon-sun joint paper under finalisation - Ongoing the same analysis for ARCA => towards automatic performance checks

From ARCA 8 to **ARCA 19** (June '22) and then **ARCA 21** (September '22)
 Data have started to be analyzed soon after the end of the commissioning phase



New exciting results soon with ARCA 21 and so on...



- KM3NeT is active and taking data!
- Detector performance as good as expected. First science preliminary results (here shown only a selection).
- ORCA currently taking data with 11 lines.
~10 more lines ready for deployment late 2022, early 2023.
 - ◆ Funding assured, procurement and construction in progress, for ~50 strings.
- ARCA currently taking data with 21 lines.
 - ◆ Funding assured, procurement and construction in progress, for ~130 strings.
- Detector mass production in regime stage. Production rate will increase in the next years
- Interesting physics results and intense Multi-messenger program in the next years!

Thanks for your attention !

Email: tommaso.chiarusi@bo.infn.it

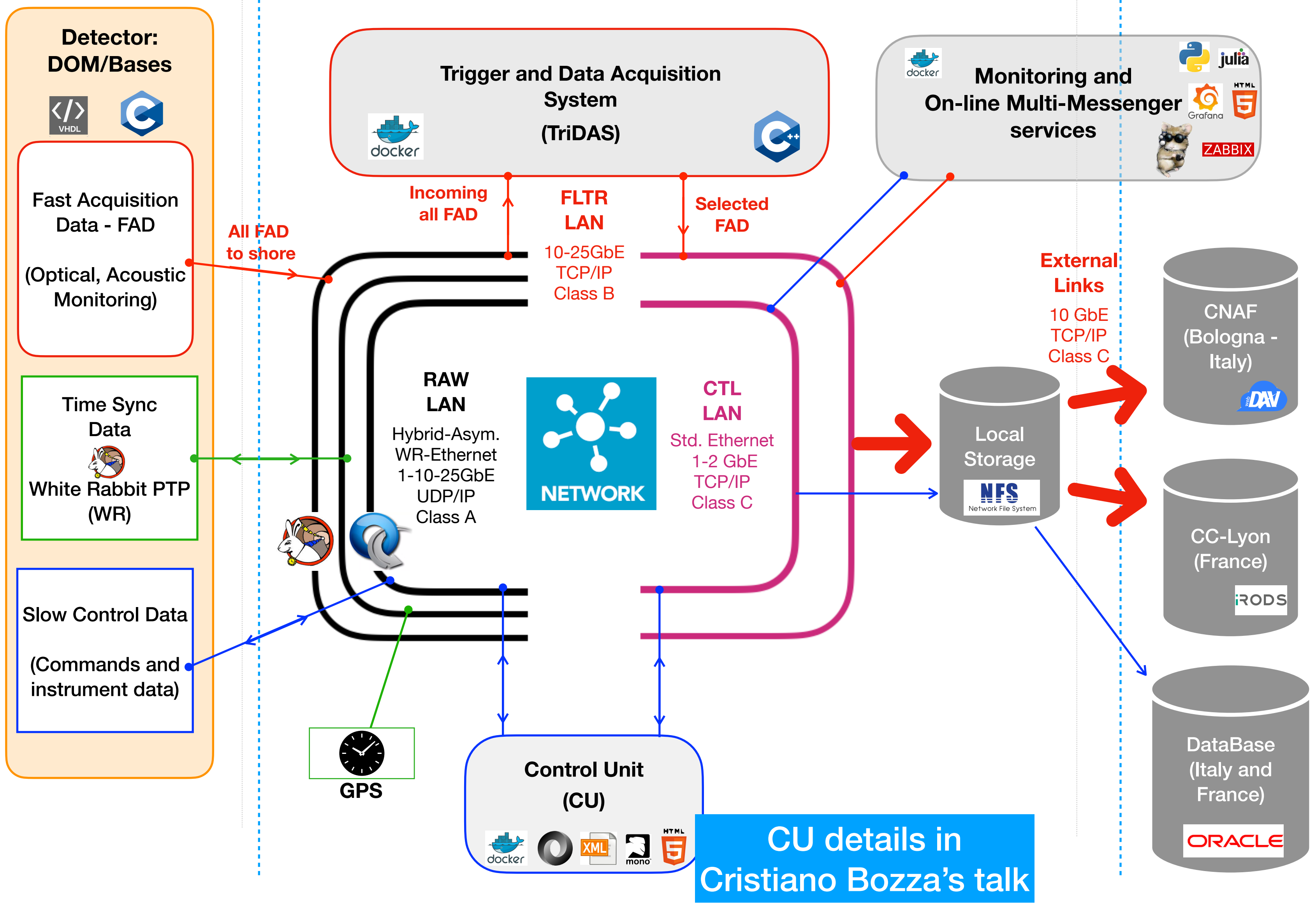
Backup Slides



Off-shore

On-shore
(shore station facility)

Remote facilities



CU details in Cristiano Bozza's talk

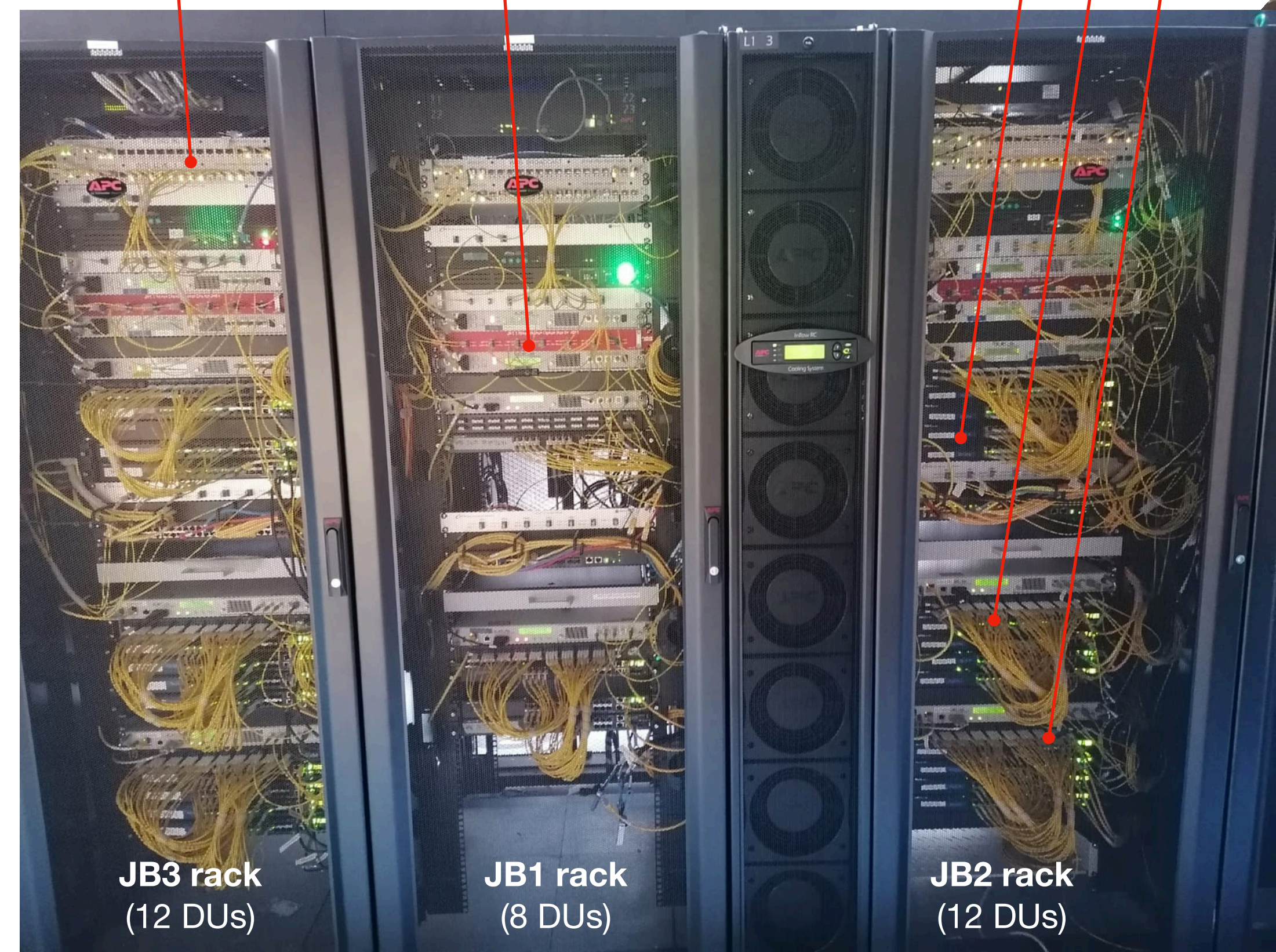
A collection of logos for various technologies and services used in the DAQ system:

- White Rabbit** (Time Sync)
- Openflow** (Network Management)
- ORACLE** (Database)
- HTML** (Markup Language)
- XML** (Markup Language)
- JSON** (Data Format)
- mono** (Library)
- C++** (Programming Language)
- VHDL** (Hardware Description Language)
- docker** (Containerization)
- python** (Programming Language)
- julia** (Programming Language)
- ANSIBLE** (Configuration Management)
- Grafana** (Monitoring Dashboard)
- ZABBIX** (Monitoring Service)
- NFS** (Network File System)
- CentOS** (Operating System)
- iRODS** (Data Management System)
- web DAV** (WebDAV)
- Observium** (Network Monitoring)



White Rabbit switch sector
Optical sector
(mux/demux/amplifier)

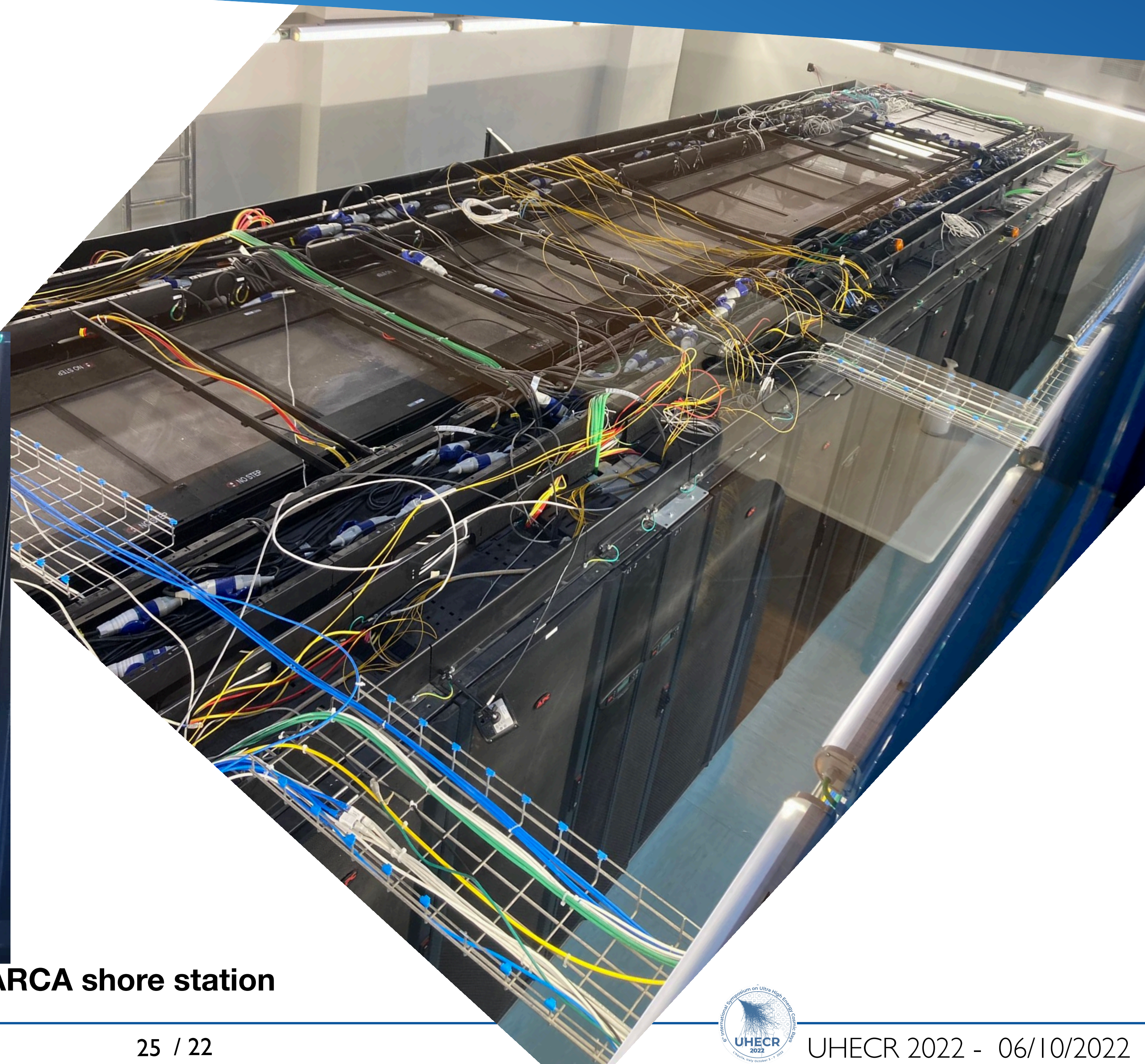
DOM Front End
Switch sectors



JB3 rack
(12 DUs)

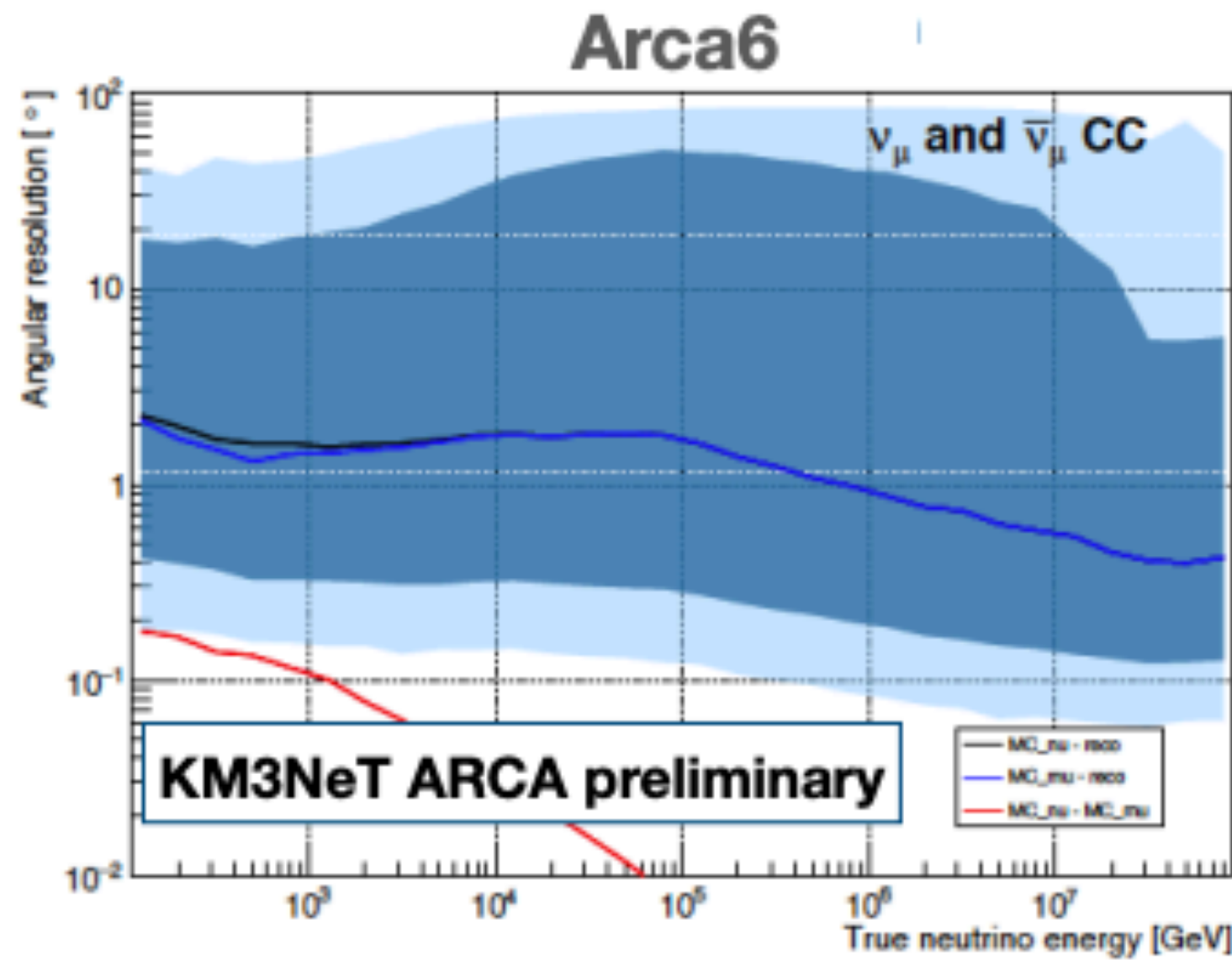
JB1 rack
(8 DUs)

JB2 rack
(12 DUs)



ARCA shore station

Angular resolution track channel

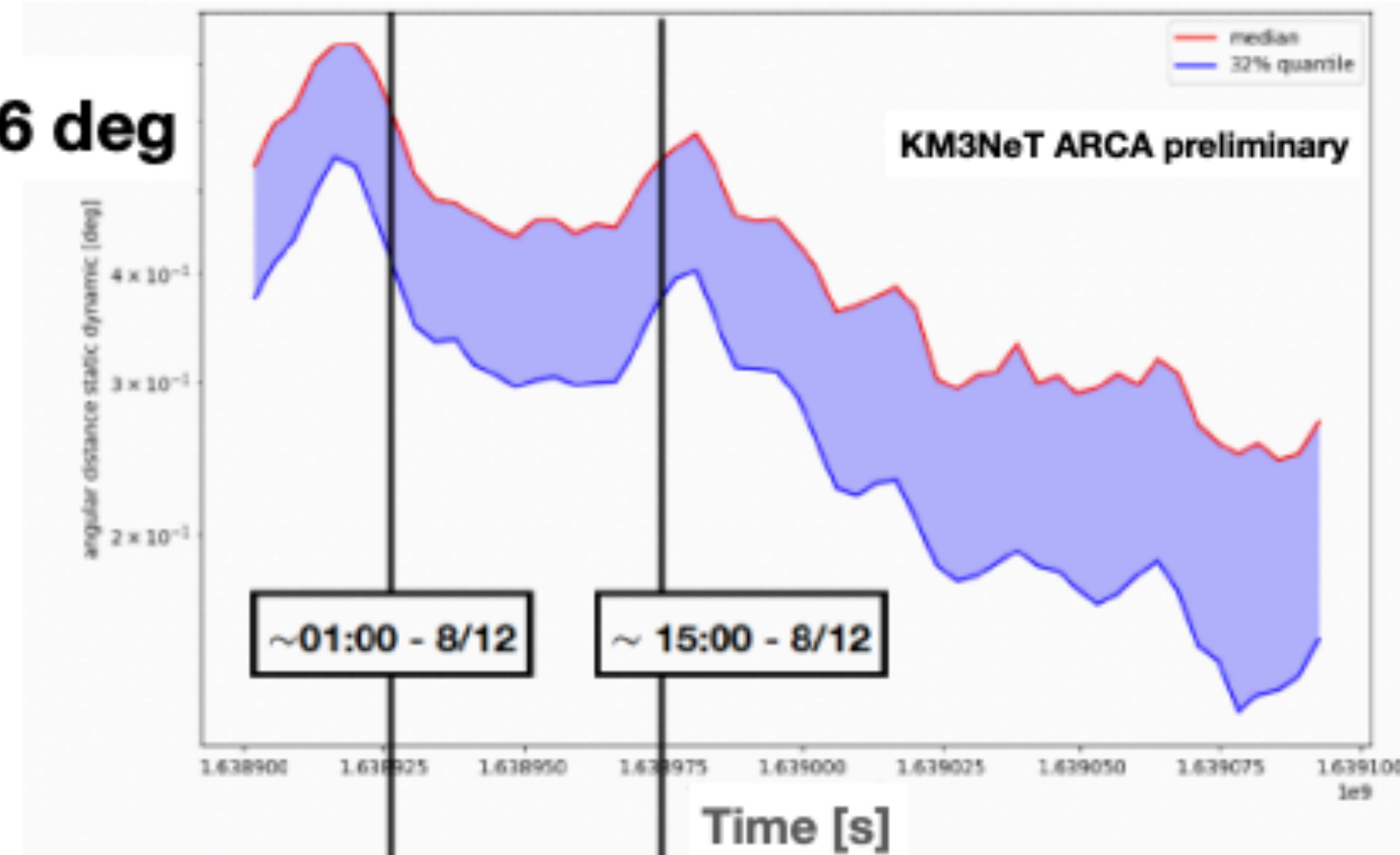


Angular resolution ARCA6 for track channel only (ν_μ , $\bar{\nu}_\mu$ CC)

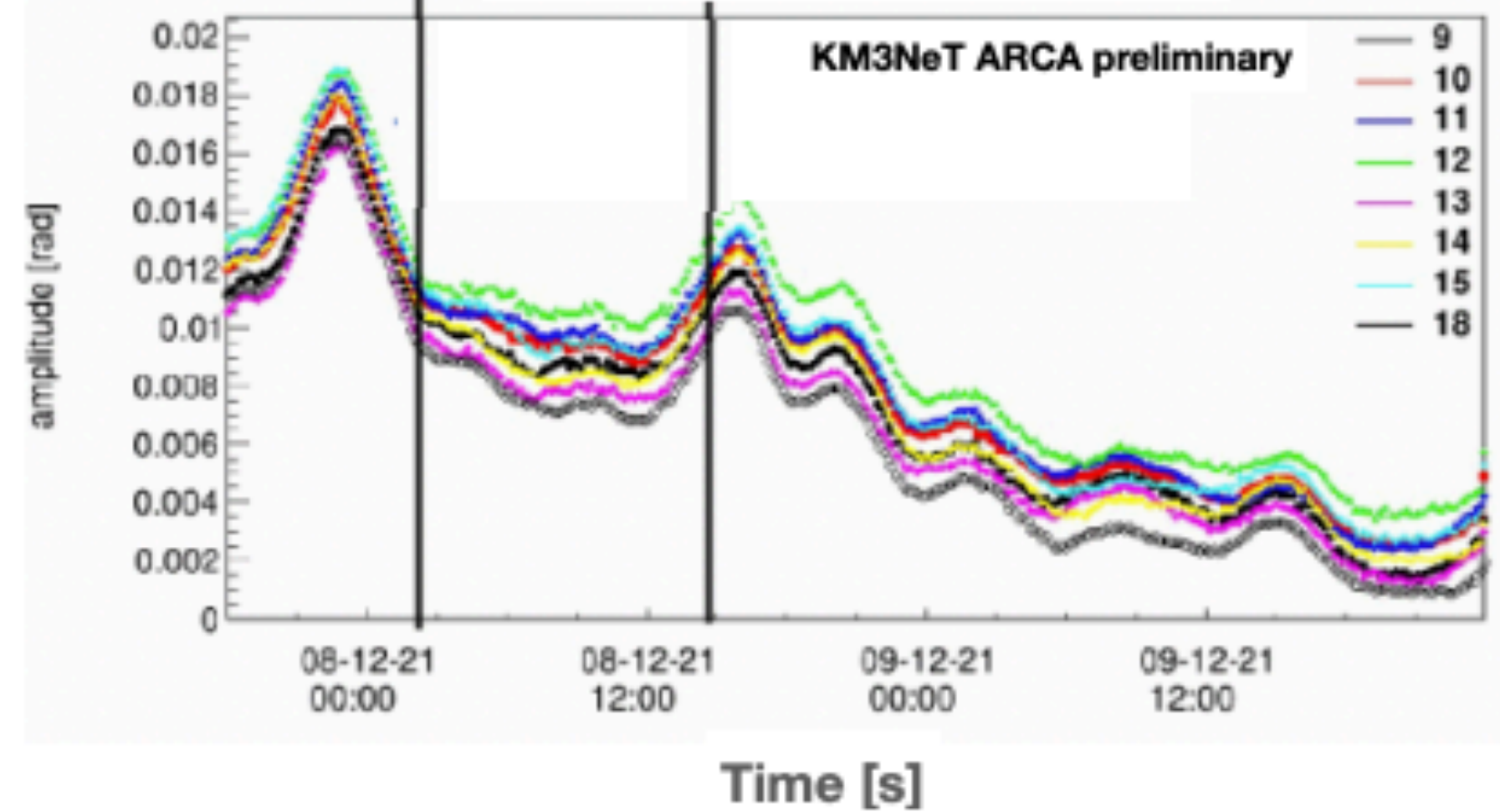
**Important understanding of systematic effects:
dynamic calibration applied on data,
updating position and orientation of the
DOMs in function of time**

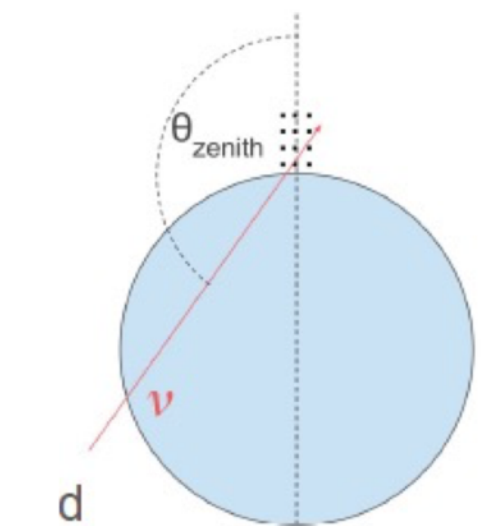
Median angular distance reco tracks dynamic vs static calibration [deg]

~ 0.6 deg

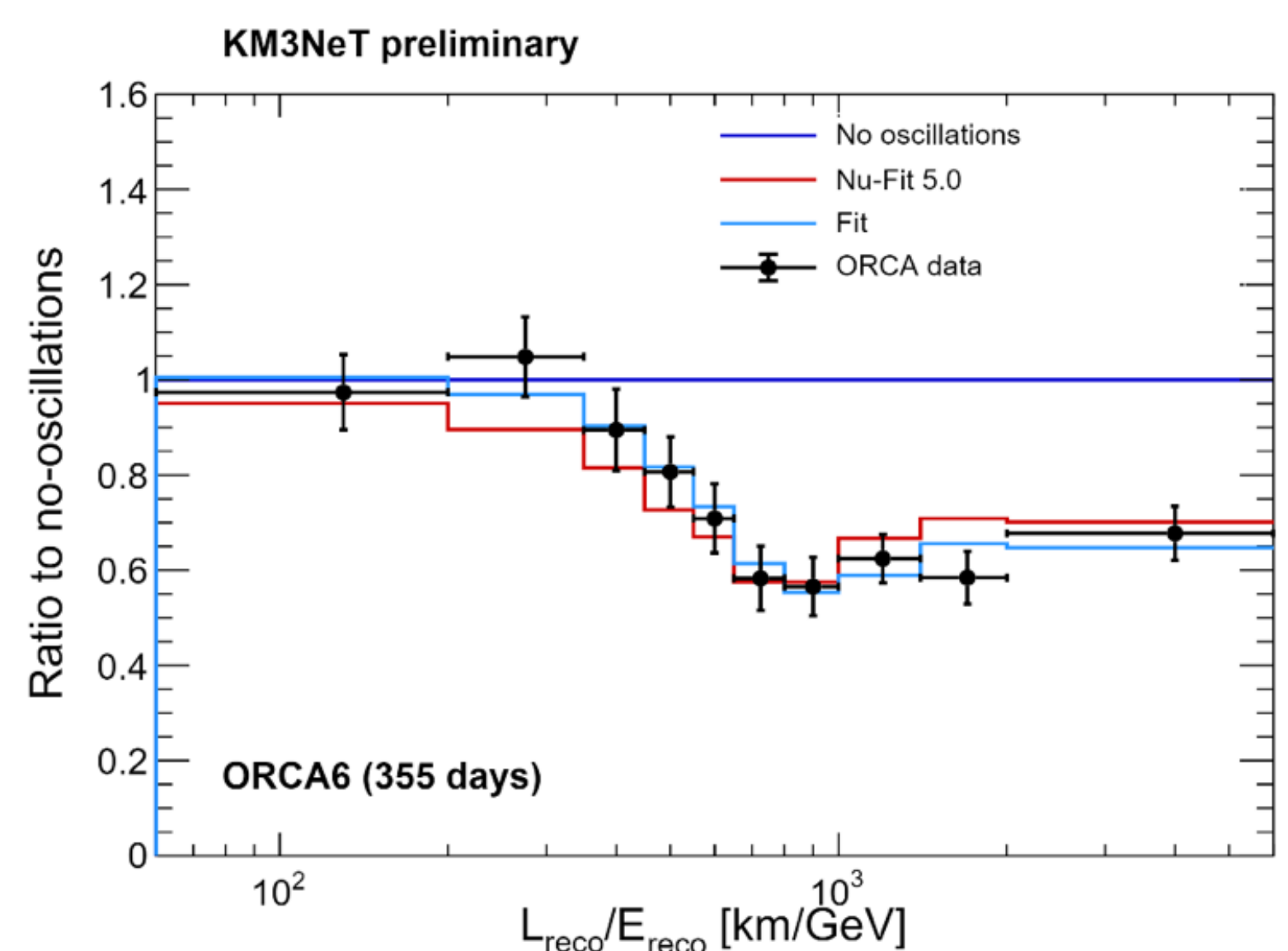
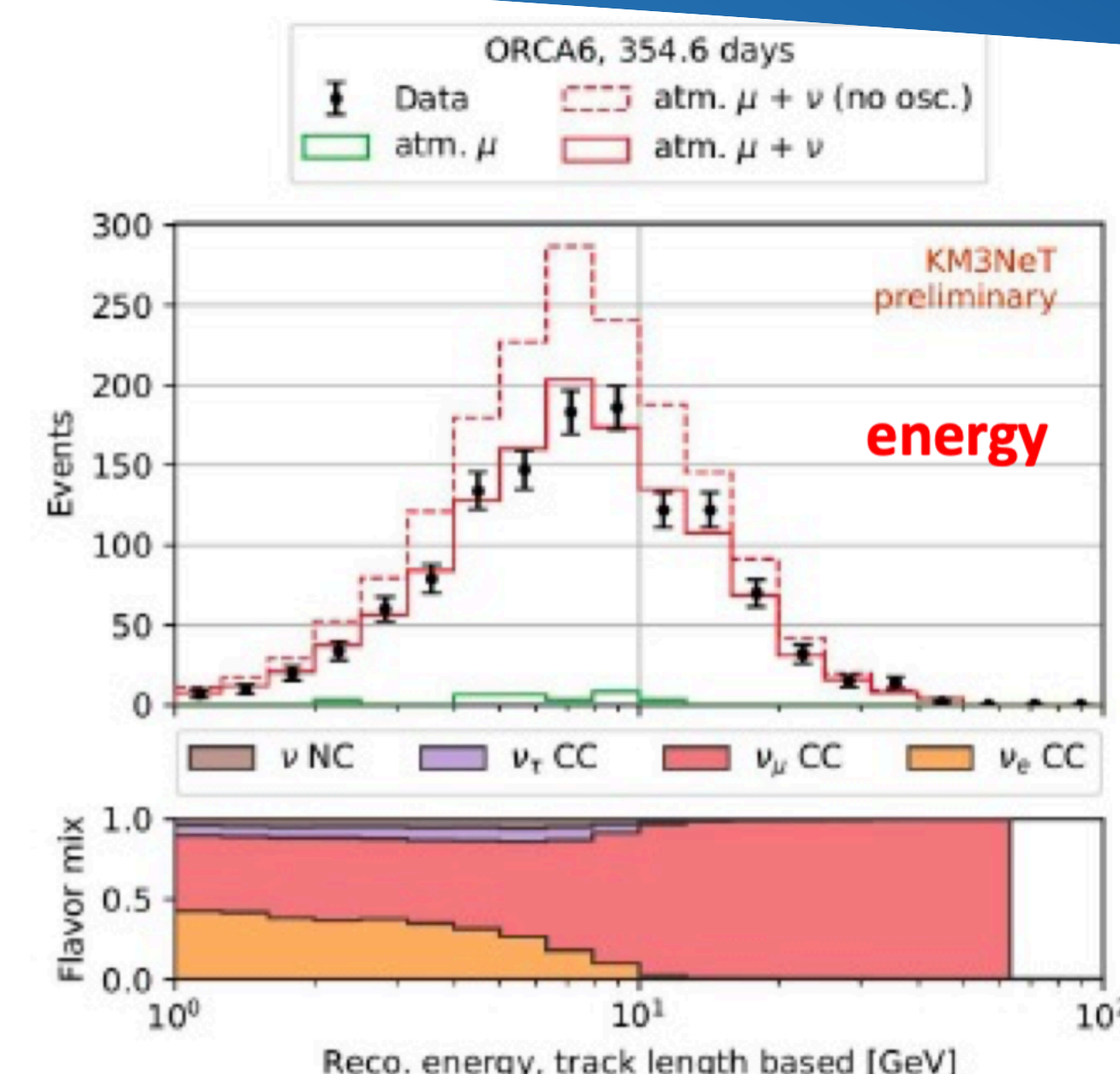
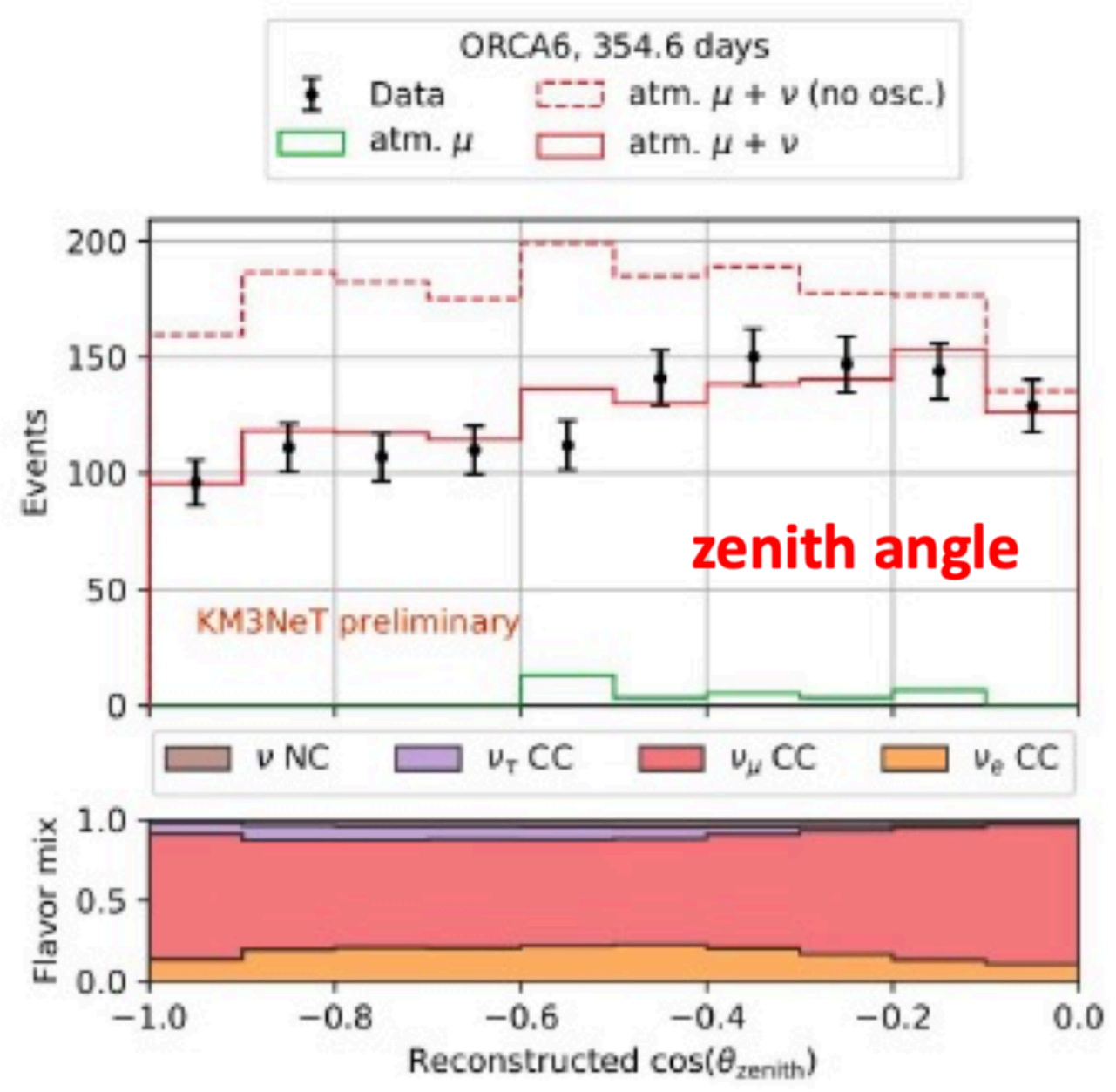
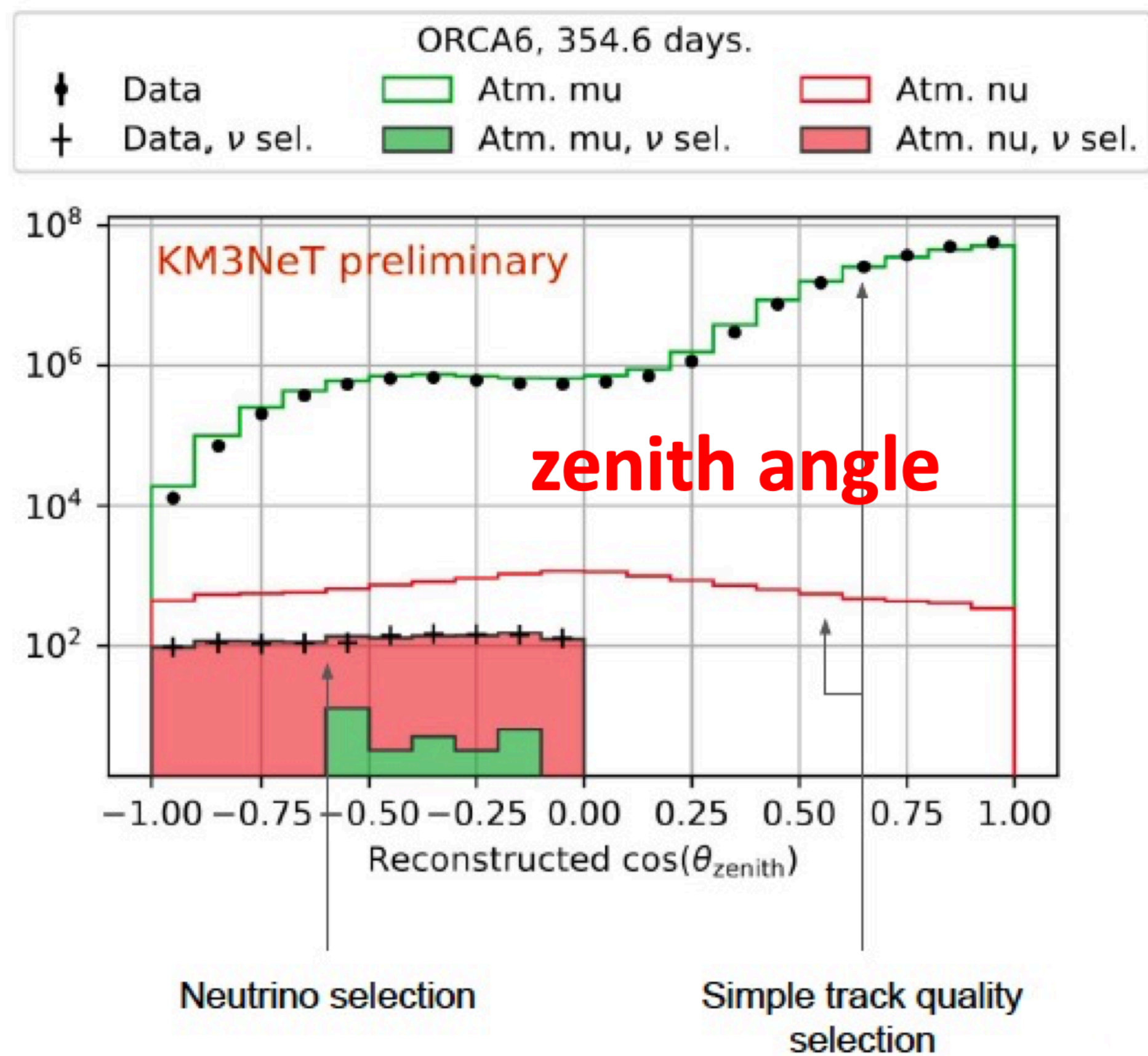


String tilt in function of time





- Selection based on track signature: mostly ν_μ
- Background: atmospheric muons
- Selection: vertex position, track fit quality, upgoing tracks
- 1237 ν candidates in 354.6 days, S/B~40



Parameter	Treatment	Fit value
Δm_{31}^2 [10^{-3} eV^2]	Free	$1.95^{+0.24}_{-0.21}$
θ_{23} [deg]	Free	$45.4^{+5.6}_{-5.7}$

- Oscillation fit, binned in E_{reco} , θ_{zenith}
- Normalization left free, various systematics on flux, energy scale, tau- and NC normalization

