KM3NeT

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On behalf of the KM3NeT Collaboration

Lake Louise Winter Institute 2018, 18 - 24 Feb 2018, Lake Louise, Canada

Outline

- Physics motivation and Detection principles of neutrino detection
- KM3NeT
  - ARCA & ORCA Astroparticle & Oscillations Research with Cosmics in the Abyss
  - Design, architecture, and status
  - Science goals
  - Performances and Sensitivity
- Conclusions and Outlook

Physics with high-energy neutrinos

Charged Cosmic Rays

- ✓ Copiously produced
- ✗ Directions scrambled by magnetic fields

High Energy Gamma Rays

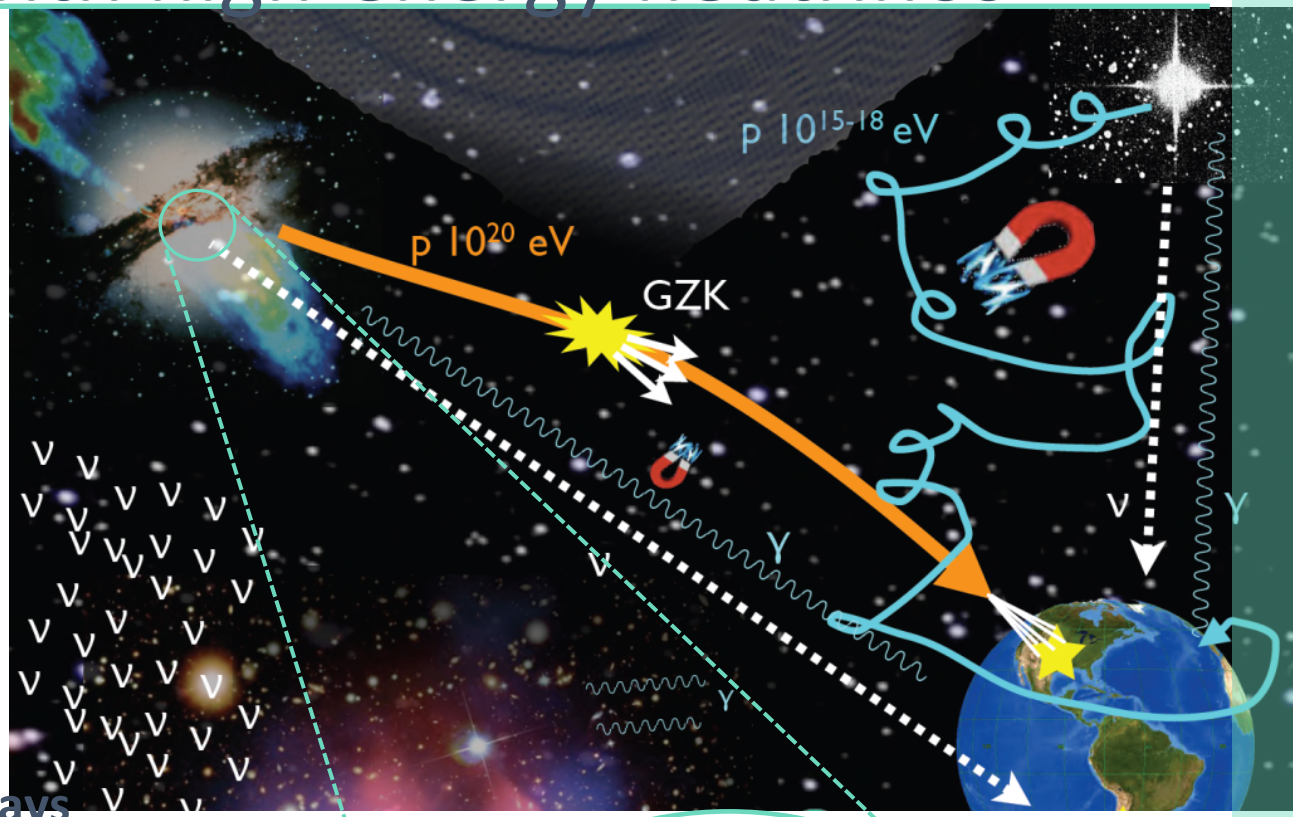
- ✓ Produced both by hadronic and leptonic mechanisms
- ✗ Absorbed by dust and radiation

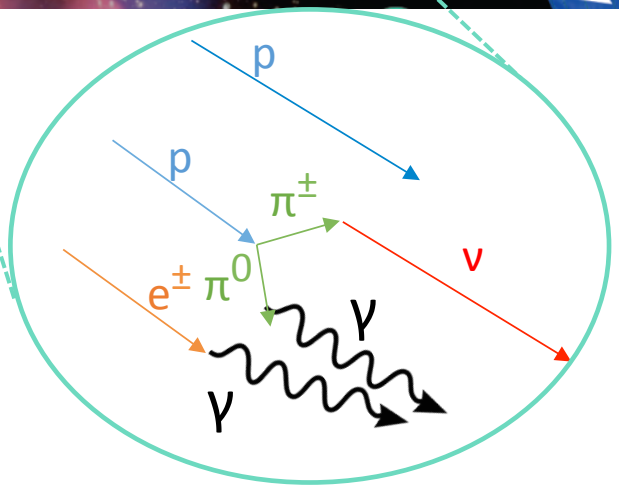
UltraHigh Energy Cosmic Rays

- ✓ Not strongly deflected by magnetic field
- ✗ Limited by GZK cut-off

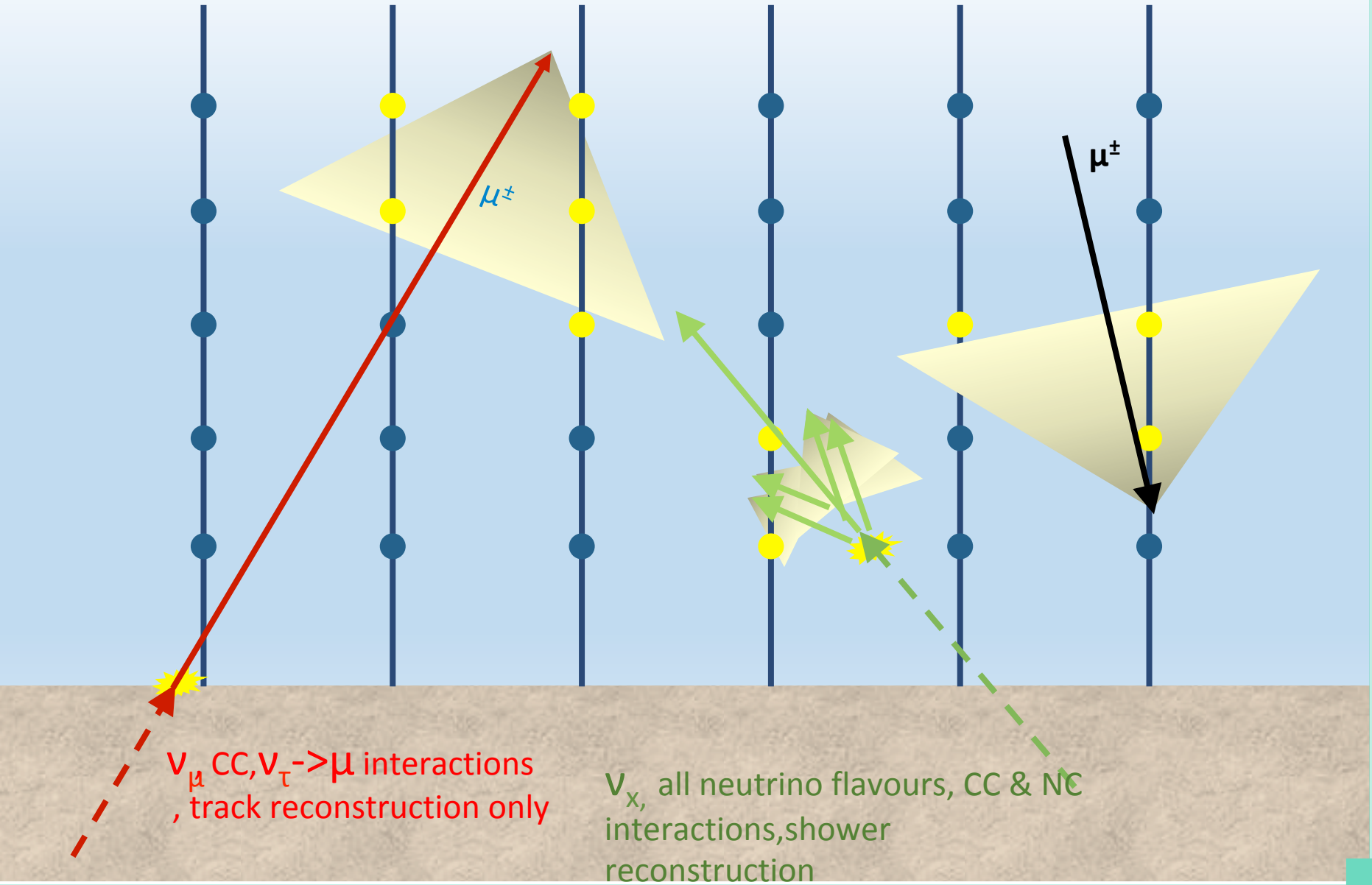
Neutrinos

- ✓ Produced only by hadronic mechanisms
- ✓ Not affected by magnetic fields and radiation
- ✗ Very low $\sigma_{interaction}$

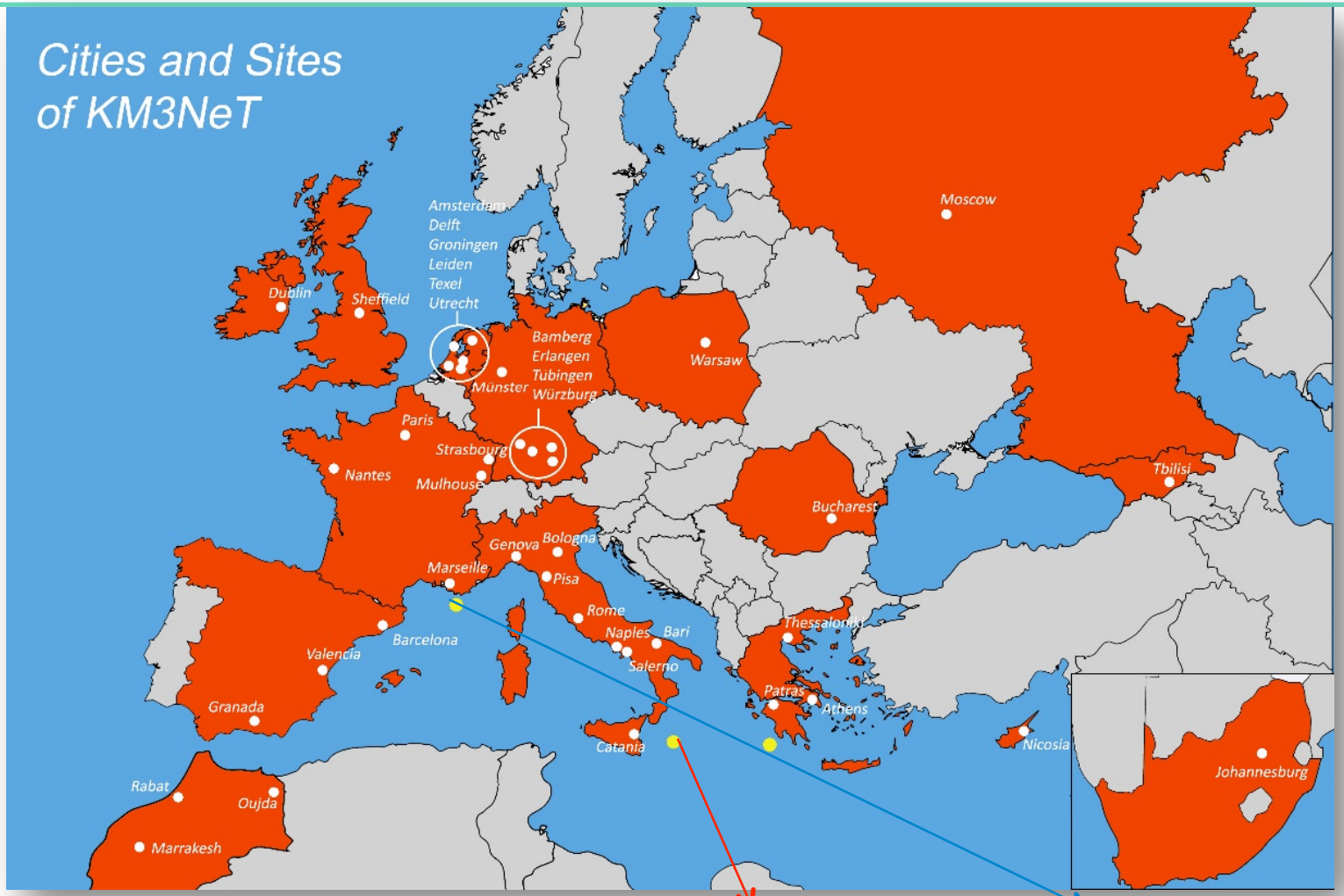




High energy neutrino detection



KM3NeT Collaboration



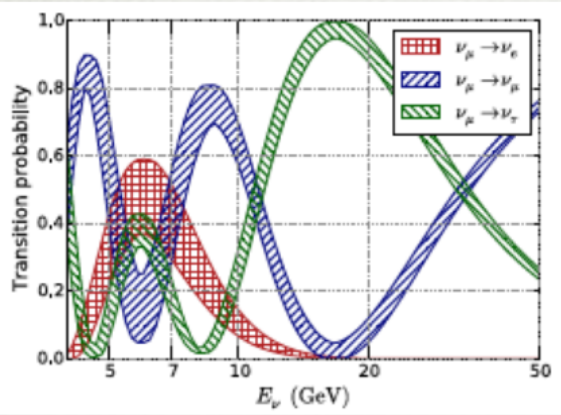
KM3NeT Letter of Intent:
J. Phys. G 43 (8), 084001, 2016

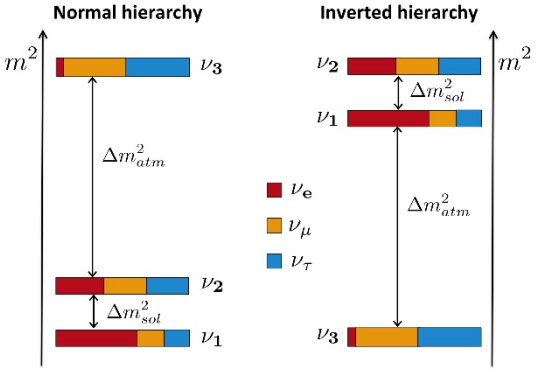
Astroparticle **R**esearch with **C**osmics In the **A**byss
High-energy (TeV-PeV) neutrino astrophysics

Oscillation **R**esearch with **C**osmics In the **A**byss
Low-energy (~GeV) studies of atmospheric neutrinos

KM3NeT science goals

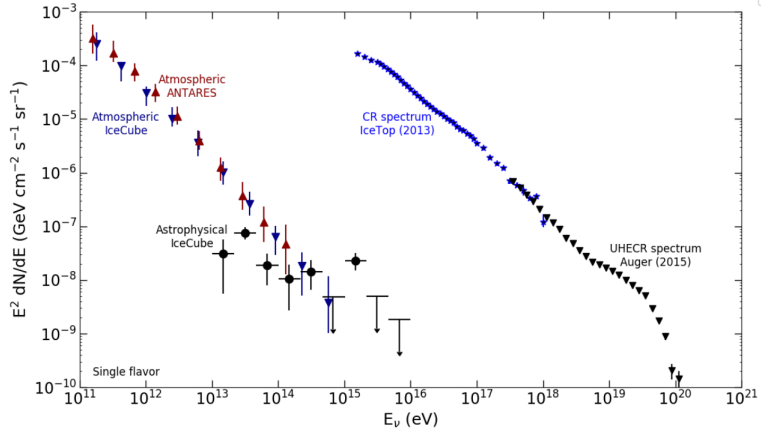
ORCA

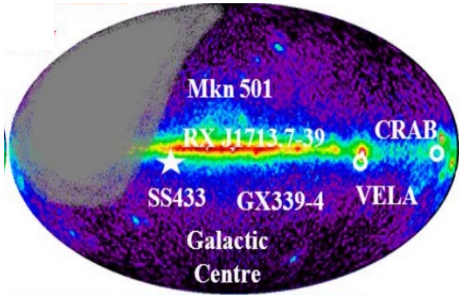




- Neutrino Oscillations
- Neutrinos Mass Hierarchy
- Sterile neutrinos
- Neutrinos from Supernovae

ARCA

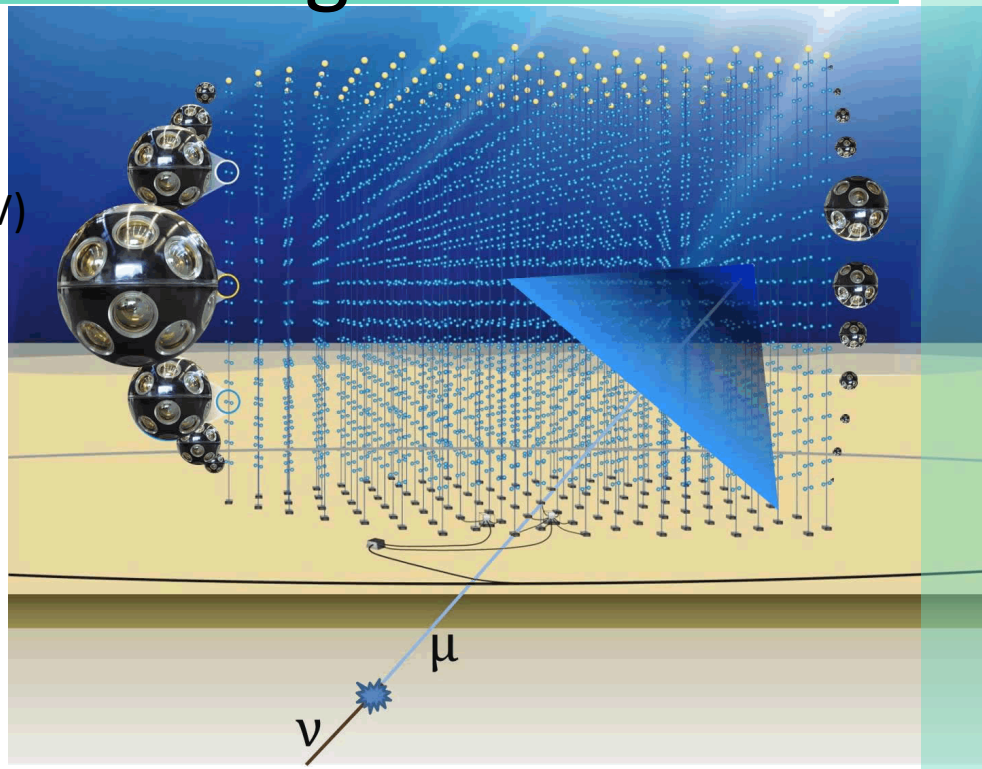




- Neutrinos from extra-terrestrial sources
  - Neutrinos from point-like sources
- Origin and production mechanism of HE CR

KM3NeT detector design

- Detection principle Optical Cherenkov radiation
- 6 orders of magnitude in energy (GeV-PeV)
- All flavour detection
- A 3D array built with a modular design
- **Optical sensor: multi-PMT (DOM)**
- **Detection units (DU): vertical slender strings host 18 DOMs**
- **Building blocks of 115 DUs each**
- Power and data distributed by a single backbone cable with breakouts at DOMs
- Sea network of submarine cables and Junction Boxes connected to shore via a main e/o cable
- All data to shore



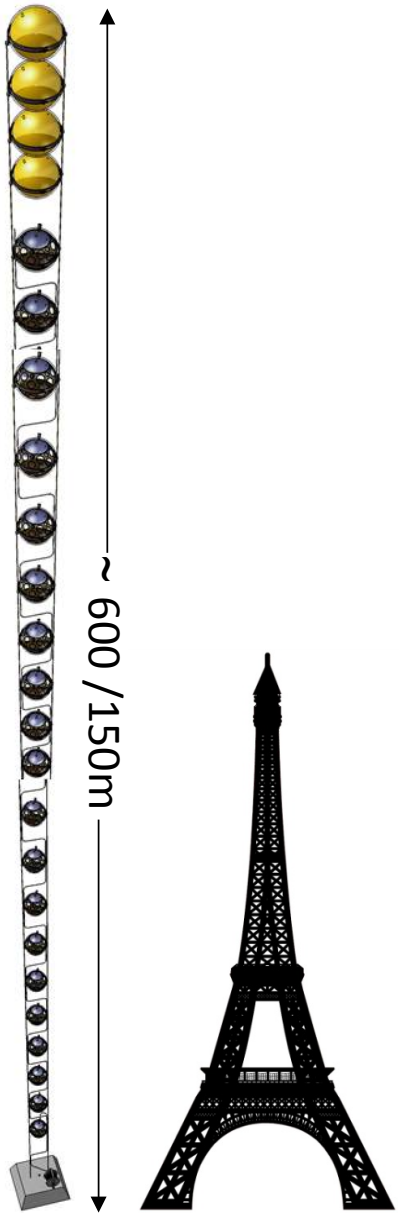
	ARCA	ORCA
Location	Italy	France
DU distance	90m	20m
DOM spacing	36m	9m
Instrumented mass	2*500Mton	5.7 Mton

KM3NeT DOM and DU

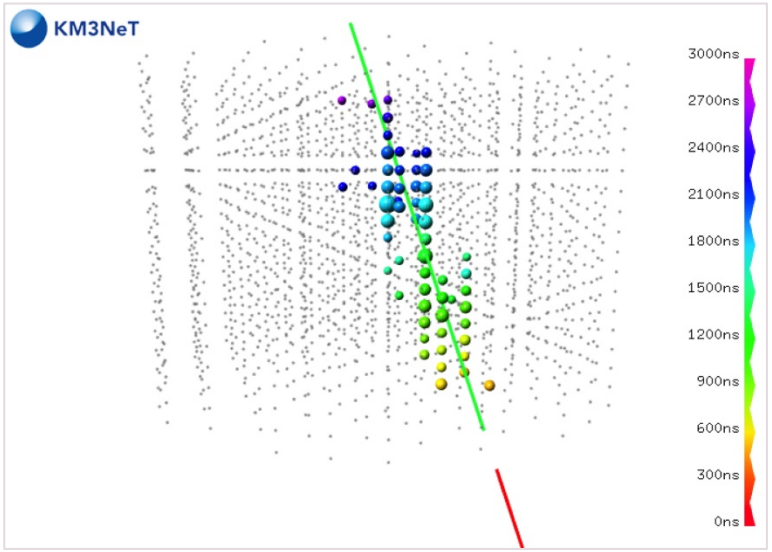
Optical module

- 31 x 3" PMTs
- Light reflector rings around PMTs
- LED & acoustic piezo inside
- Tiltmeter/compass
- Gbit/s fibre DWDM
- Hybrid White Rabbit

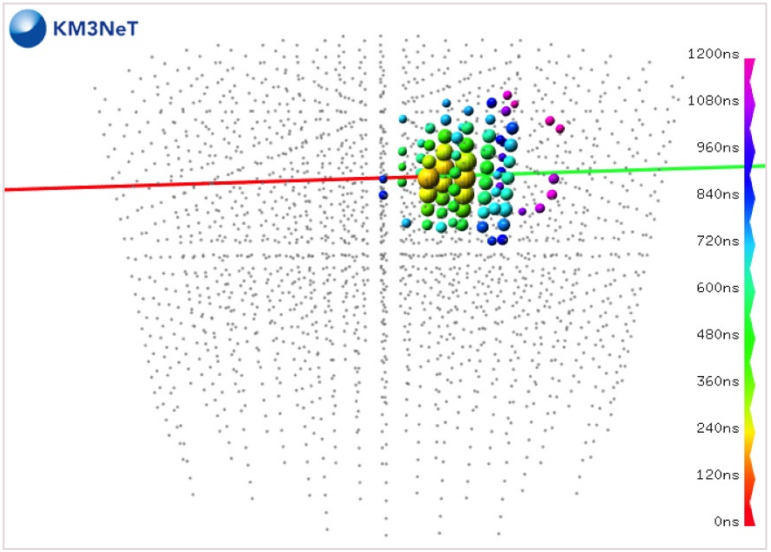
- Digital photon counting
- Directional information
- Wide angle of view
- Improved background rejection
- Compact and cost effective design:
  1 DOM equivalent to 3 Antares OMs



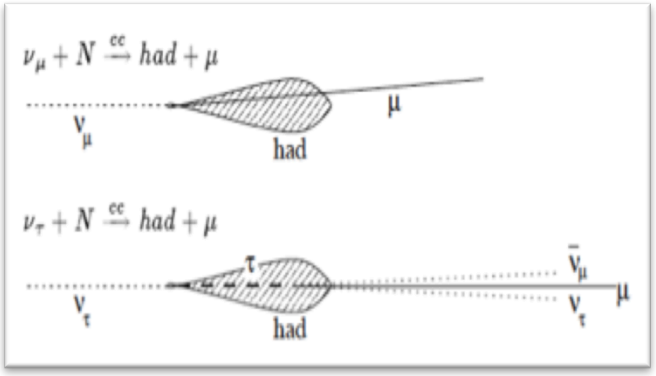
Event topologies

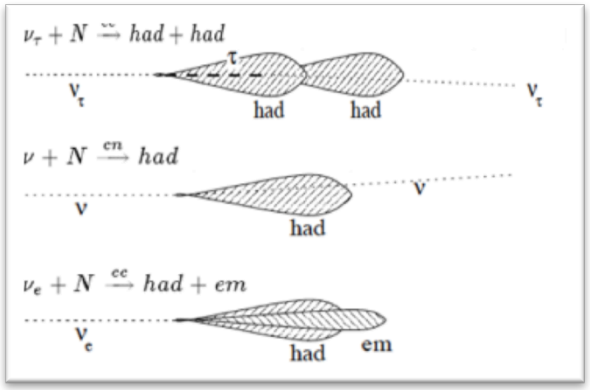


Upgoing ν_μ CC event or ν_τ->μ – "track like"
Interaction can occur far from the detector providing a large Effective Volume



Contained ν_x NC event – "shower"
Events contained in the detector: smaller Effective Volume

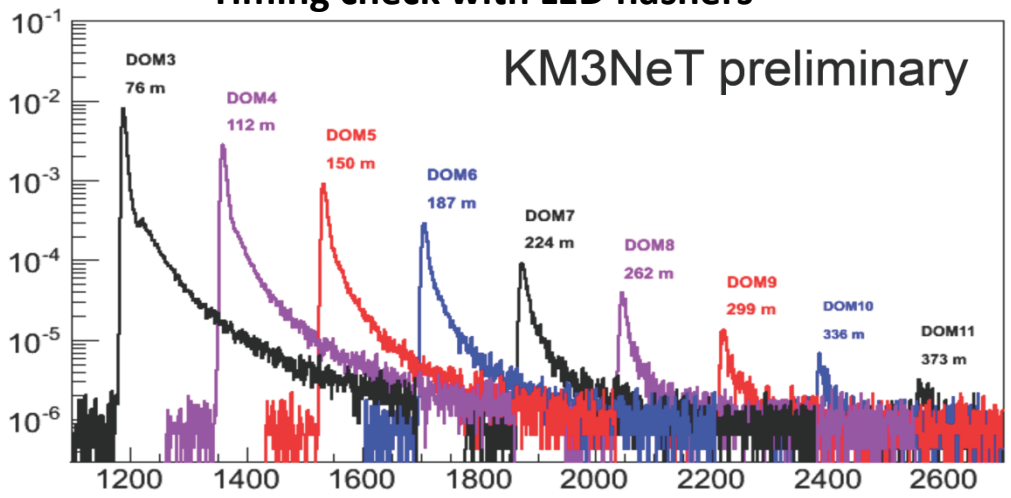




First ARCA DU preliminary results

Validation of technology

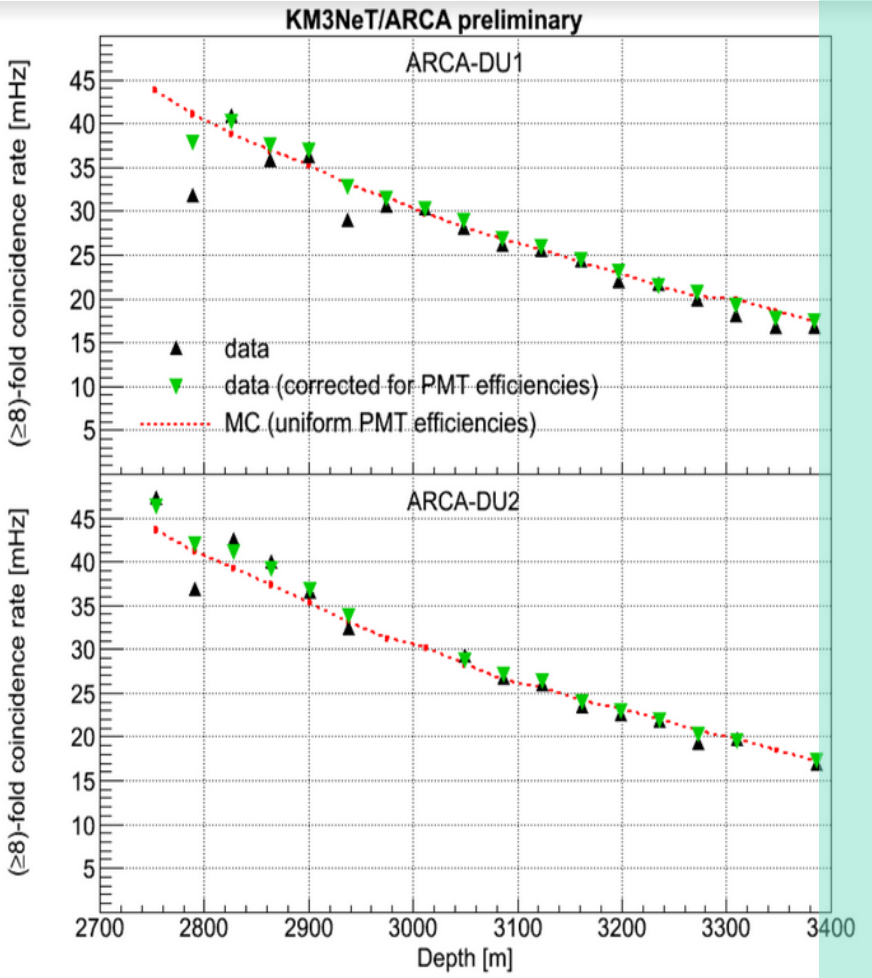
Timing check with LED flashers



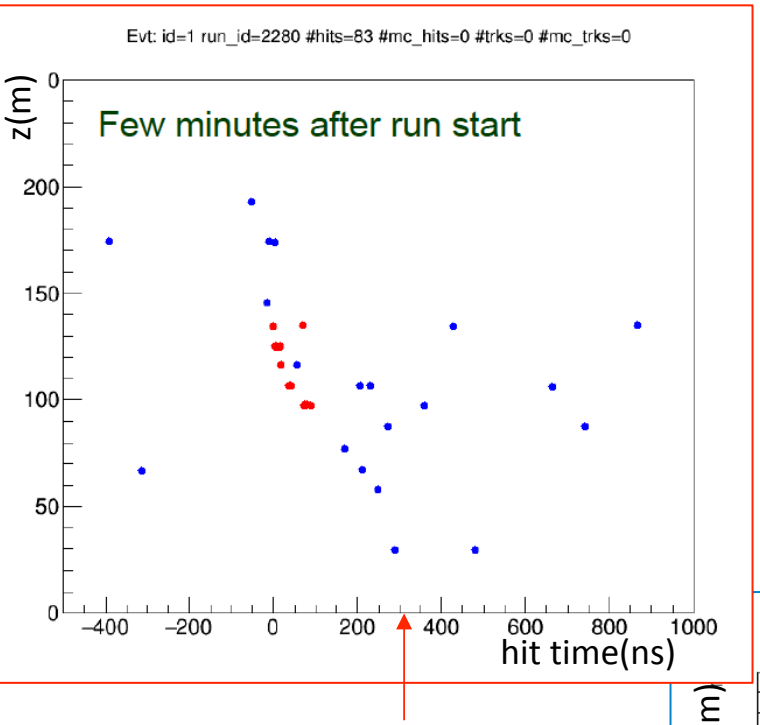
Count muons vs depth.

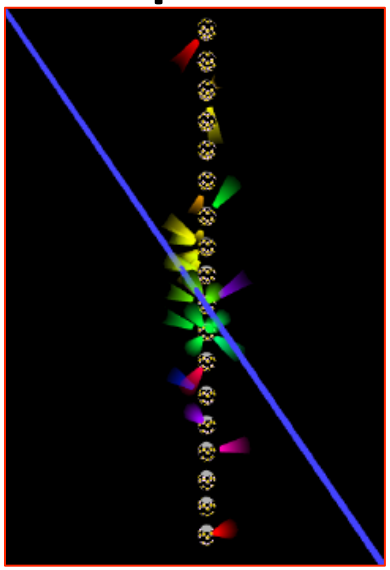
Test of in-situ per-PMT efficiency measurement

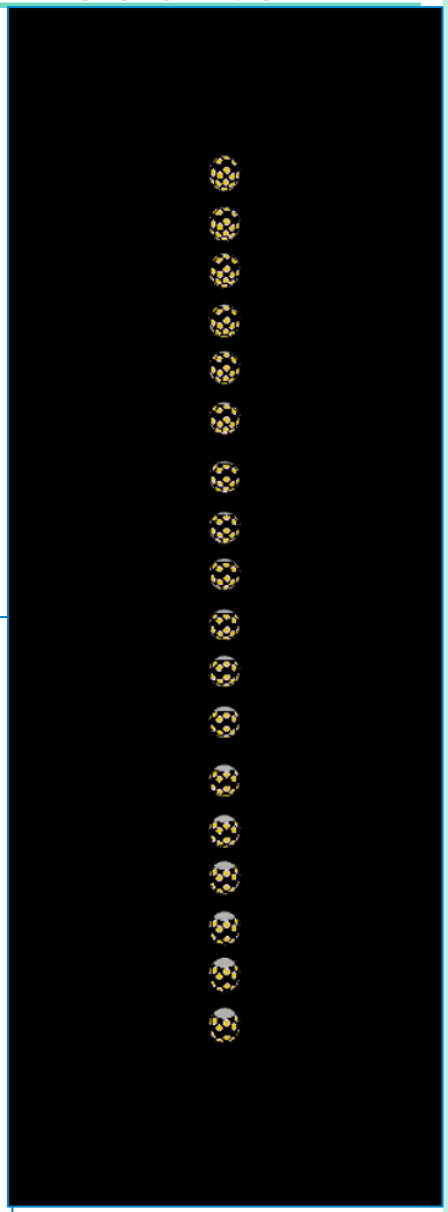
Muon flux measurement

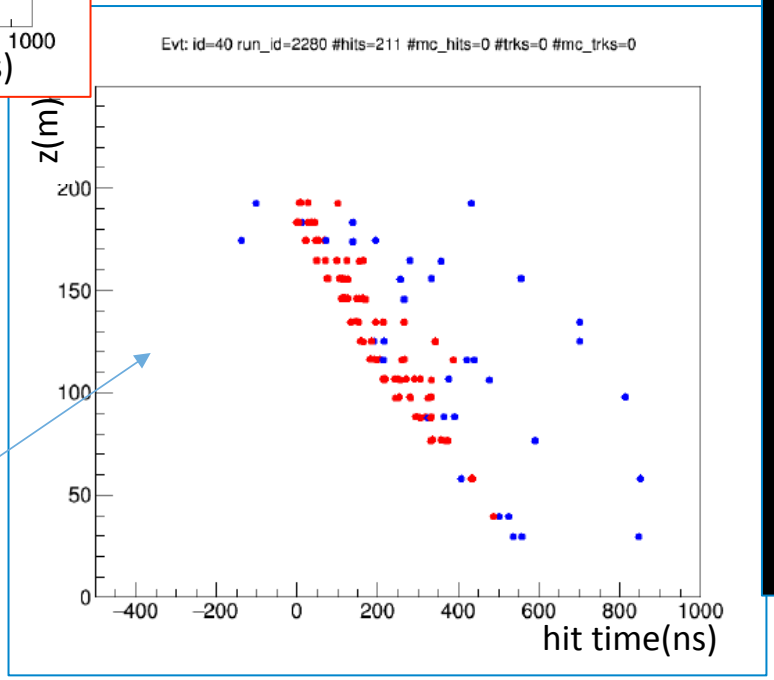


First ORCA DU preliminary results





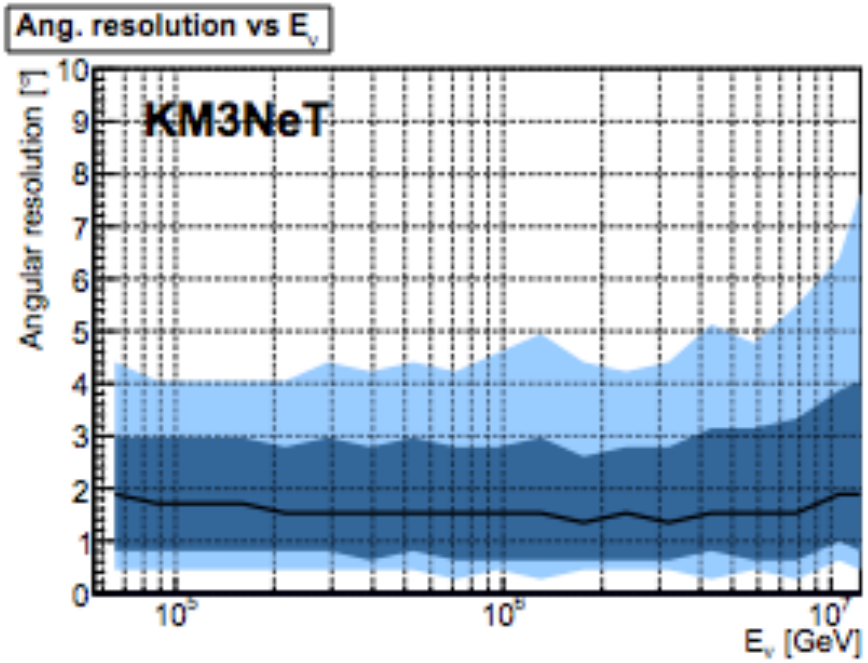




First event with recorded track reconstructed by ORCA (down-going muon)

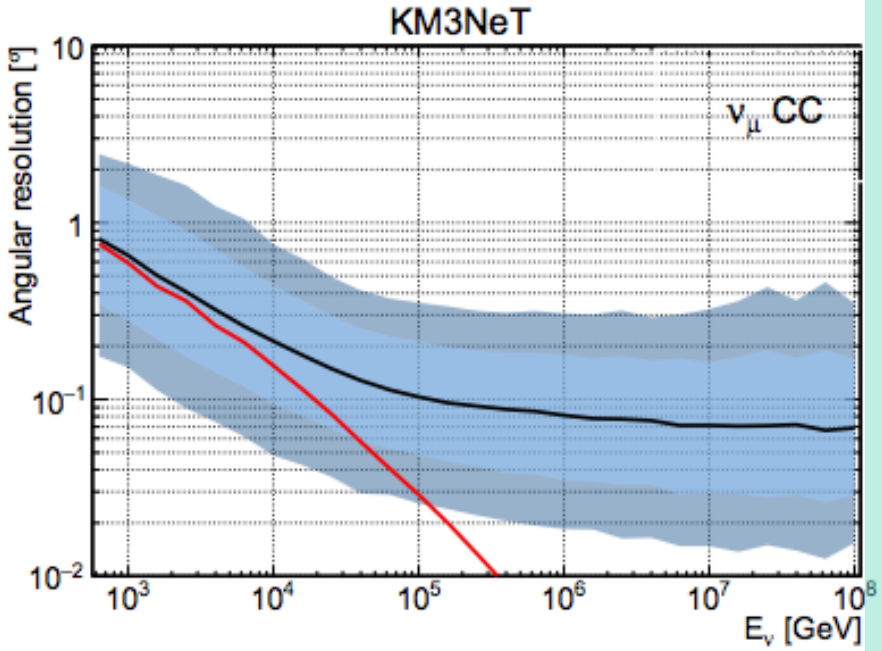
A bright muon bundle

KM3NeT/ARCA performance



Tracks events (ν_μ CC and ν_τ->μ)

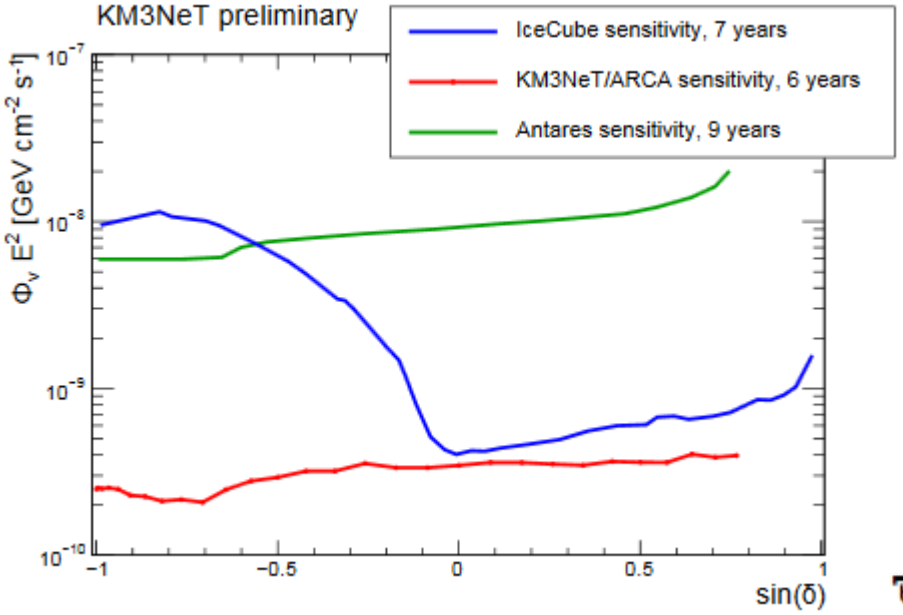
- Angular resolution <0.1° for E_ν>100TeV



Shower events (ν_e,ν_τ CC, NC)

- Angular resolution <1.5°
- Energy resolution ≈ 5%

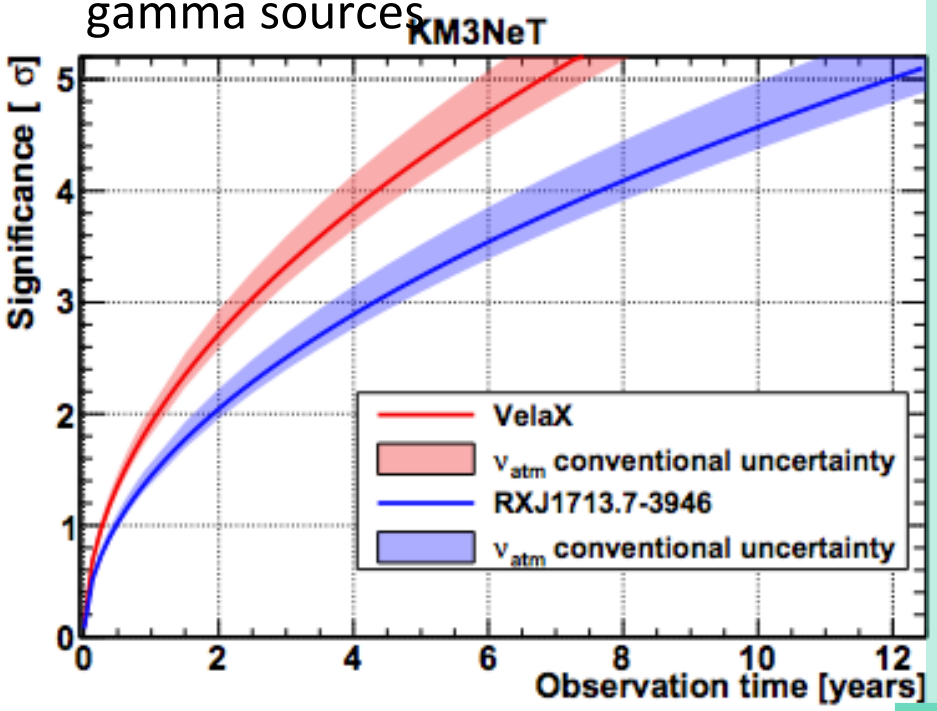
KM3NeT Pointlike source sensitivity



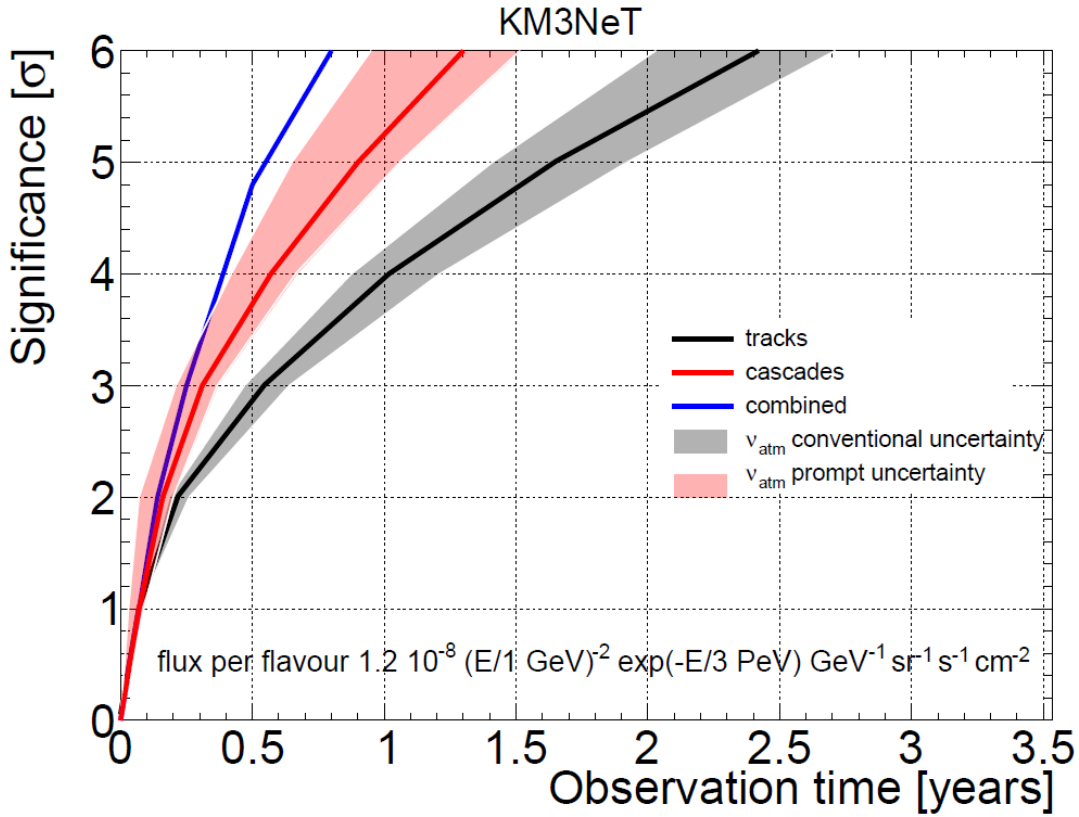
- Muon neutrinos still dominant in analysis
- More than order of magnitude improvement in Southern hemisphere
- Good acceptance in few-TeV range : Directly constrain (or discover) hadronic scenario in galactic TeV gamma sources

Directly constrain (or discover) hadronic scenario in galactic TeV gamma sources

2 Building Blocks



ARCA sensitivity to neutrino diffuse flux



Up-going track events events

Analysis based on Max. likelihood

Cuts on

θ_{zen} >80°

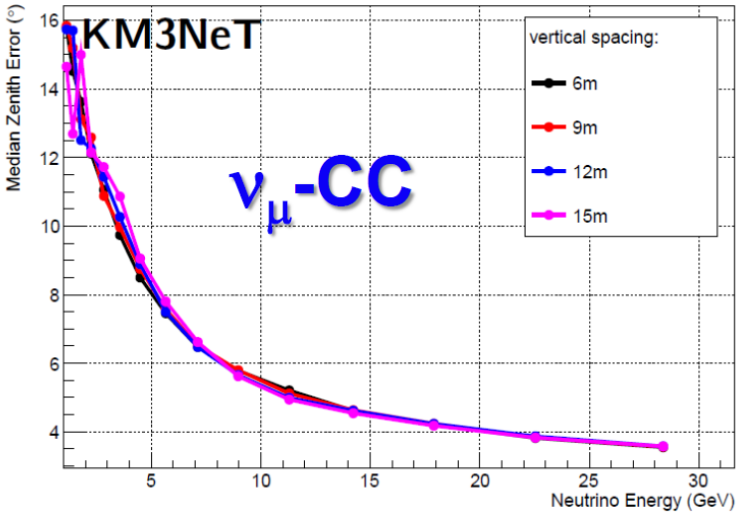
Λ (reconstruction quality parameter), N_{hit} (number of hits -> parameter related to the muon energy)

2 Building Blocks

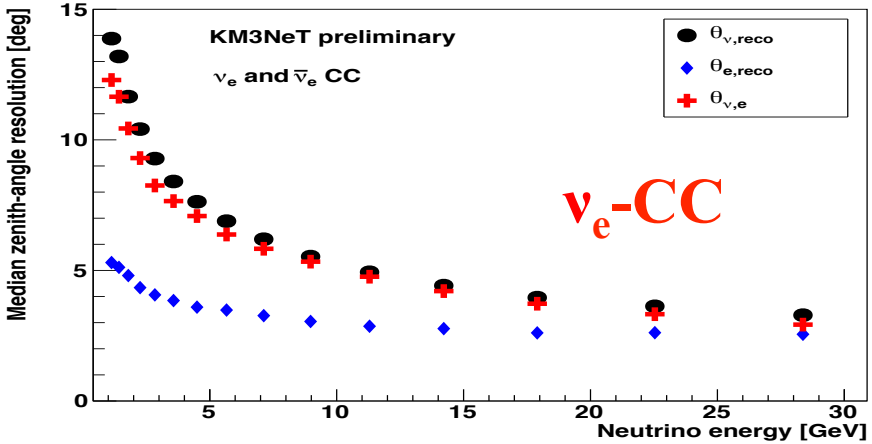
For combined analisys 5σ significance in less than 1 year

KM3NeT/ORCA performance

θ Res.

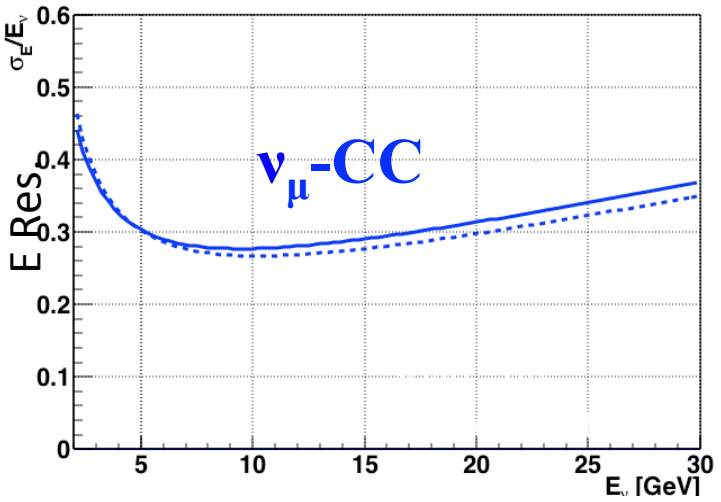


θ Res.

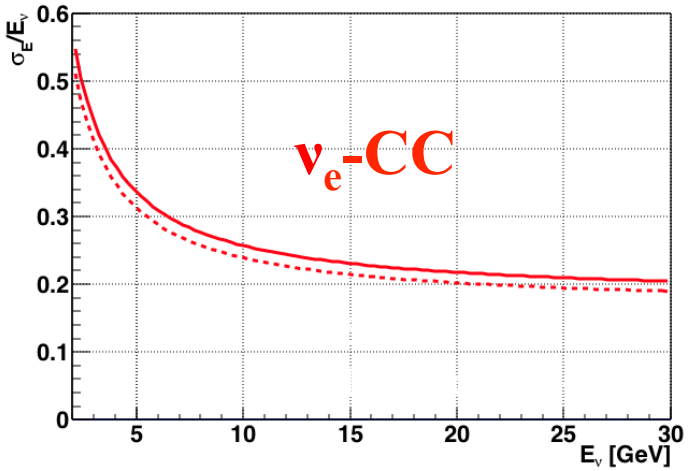


7°(5°) for 5(10) GeV for both channels

E Res.



E Res.

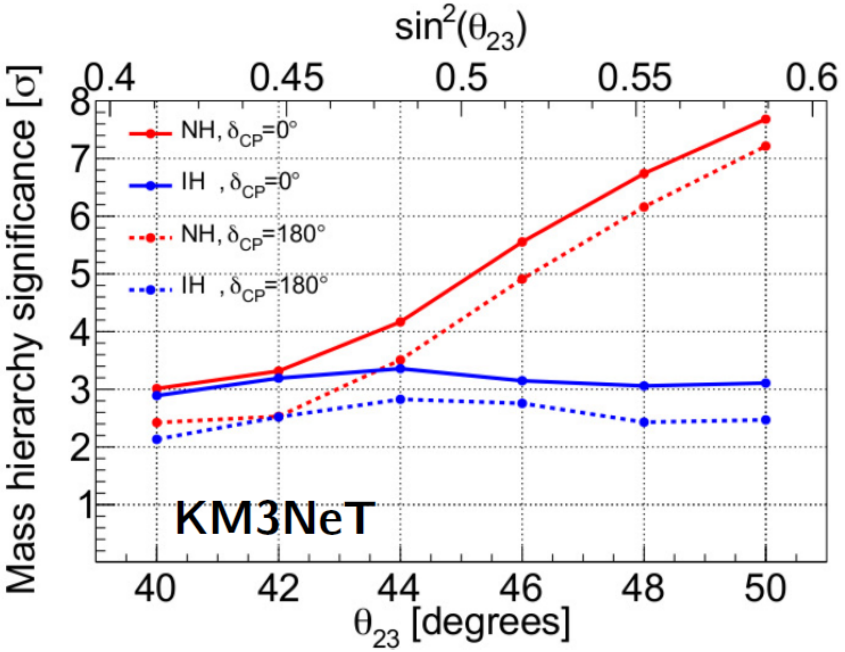


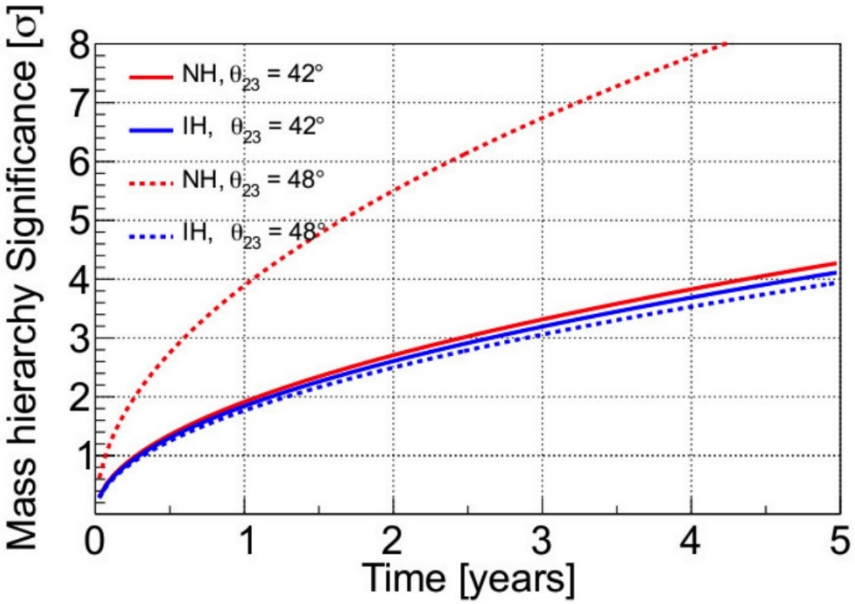
Energy resolution below 30%
in relevant energy range

ORCA: NMH sensitivity

KM3NeT LoI sensitivity

Median significance for the determination of NMH





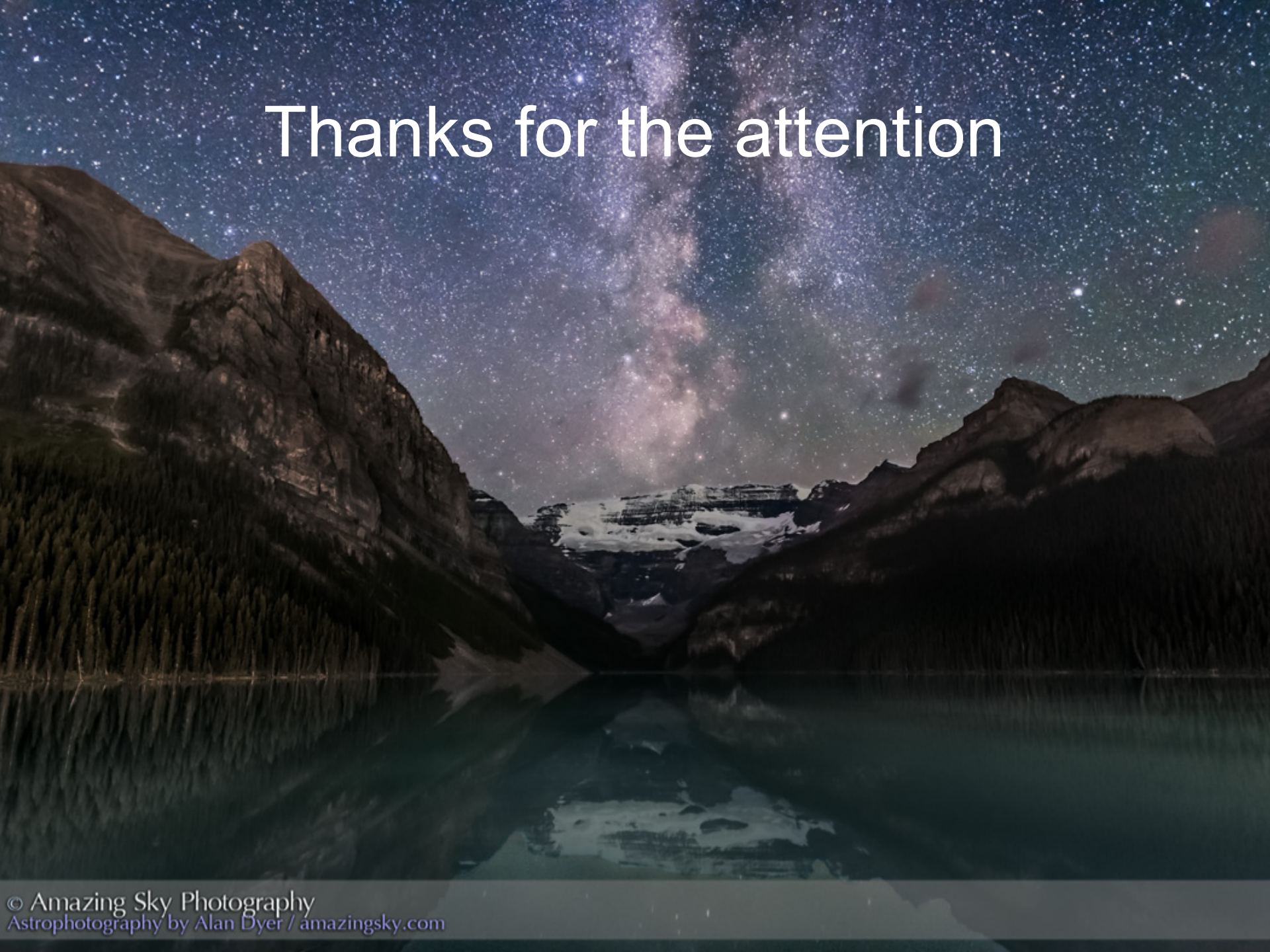
- Trigger simulation, track and shower reconstruction included.
- Expect an increase in sensitivity thanks to the improvements reached in the trigger and reconstruction
- At least 3σ sensitivity to NMH in ~3 years
- The combination of NH and upper octant of θ_{23} gives significantly improved sensitivity (>5σ in 3 years)

See KM3NeT Letter of Intent: *J. Phys. G 43 (8), 084001, 2016*

Conclusions and outlook

- KM3NeT will be the biggest detector in the Northern Hemisphere with the best angular resolution
  - ✓ Completion of both telescopes expected in 2020
- Exciting physics prospects:

  Investigate the neutrino sky with very good resolution and sky coverage with ARCA
  - Confirm IC flux in less than a year
  - Precise studies on potential HE neutrino sources
  - Constrain (or discover) hadronic scenario in galactic gamma sources
  - Allows for all flavour neutrino astronomy and spans with ARCA and ORCA a large energy window
- ORCA will be competitive with JUNO in time and performance
  - Determination of the neutrino mass hierarchy in ~3 years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Backup Slides

KM3NeT development

Phase	Blocks / DUs	Primary deliverables / site(s)	Funding Construction
1	0.2 / 31	Proof of feasibility and first science results KM3NeT-It + KM3NeT-Fr	Fully funded 2015-17
2.0	2 /230 1 / 115	Measurement of neutrino signal reported by IceCube All-flavor neutrino astronomy KM3NeT-It Neutrino Mass Hierarchy KM3NeT-Fr	Funding secured for 34 M€ in Italy and 8 M€ in France Applications ongoing in France, Italy and The Netherlands
3	6 / 690	Neutrino astronomy including galactic sources Multiple sites	t.b.d.