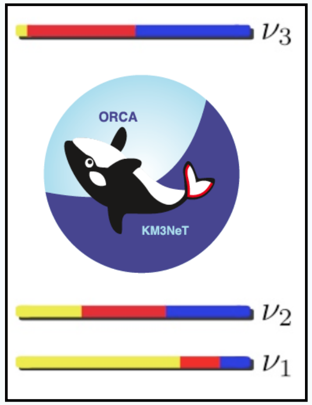
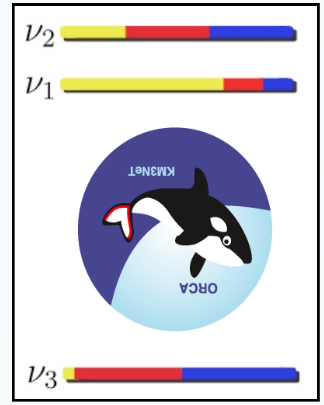
Oscillation Research with Cosmics in the Abyss



ORCA



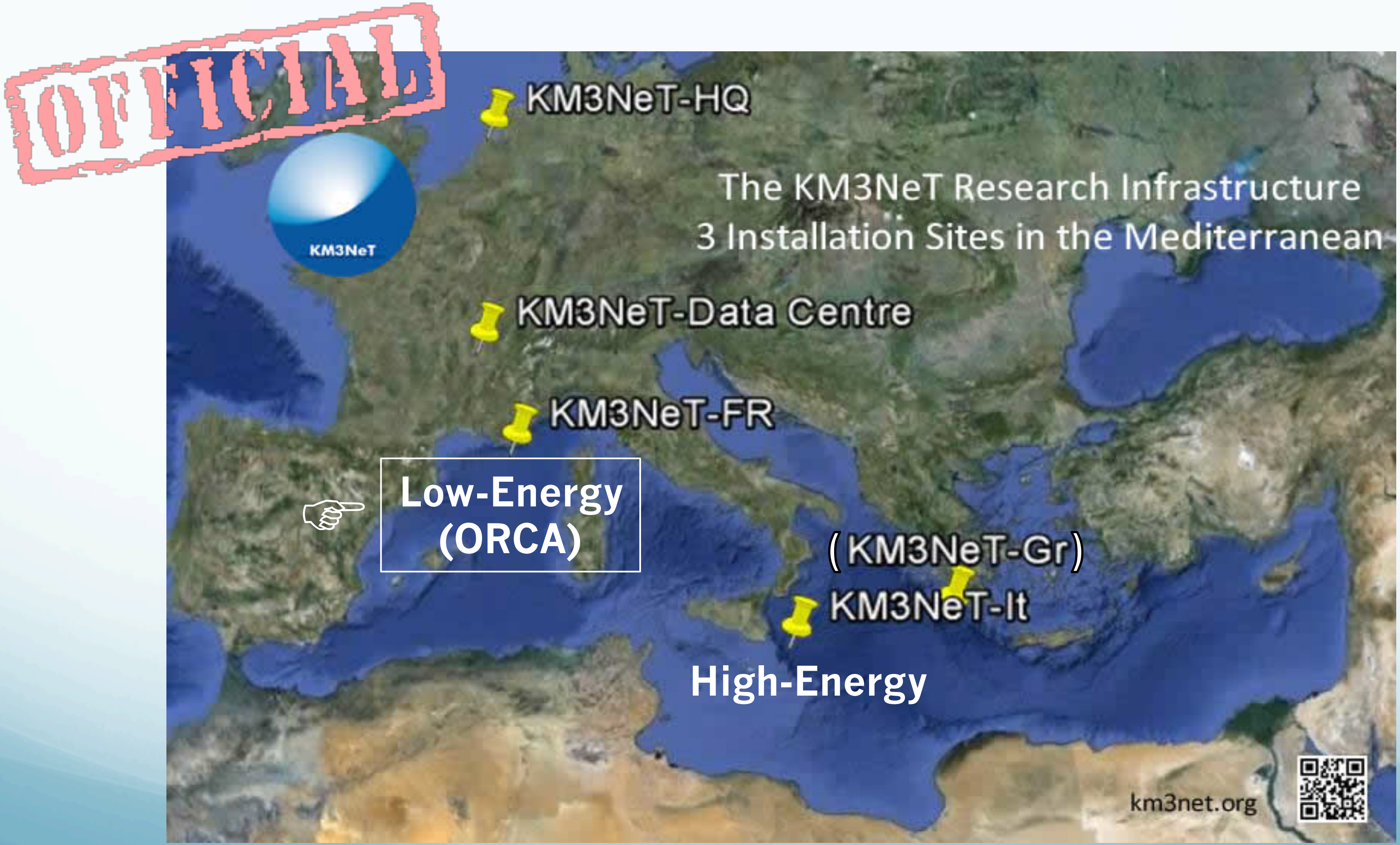
Status report on the feasibility of measuring the neutrino mass hierarchy with an underwater Cherenkov detector

Antoine Kouchner
University Paris 7 Diderot- AstroParticle and Cosmology

GDR Neutrino
Marseilles 26/11/2014

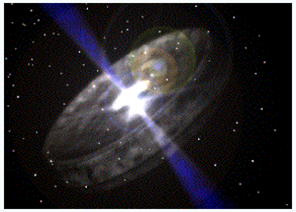
Forewords

KM3NeT is a distributed research infrastructure with 2 main physics topics:
Low-Energy studies of atmospheric neutrinos – High-Energy search for cosmic neutrinos



Many unofficial preliminary material shown today

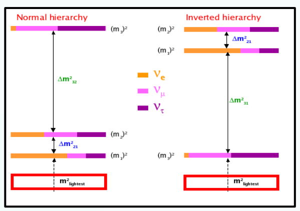
Outline



The High-Energy Physics Case

Today's context & KM3NeT sensitivity

Common Detector technology

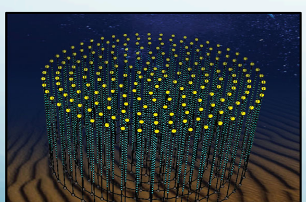


The Low-Energy Physics Case

Phenomenological reminder

Oscillations and matter effects

Electron vs Muon channels



ORCA (and comparison to PINGU)

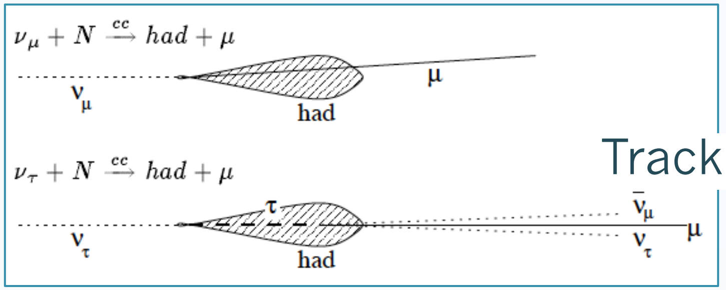
Proposed detector

Detector performances

Sensitivity study

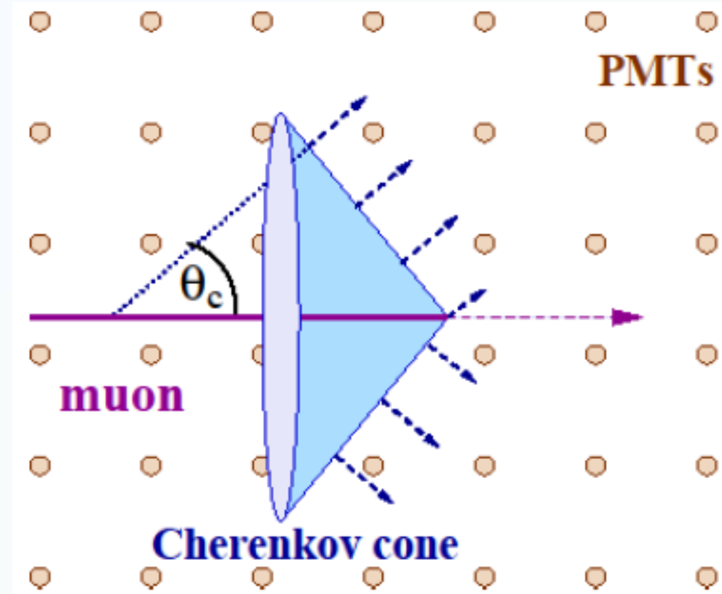
Planning

Event topologies

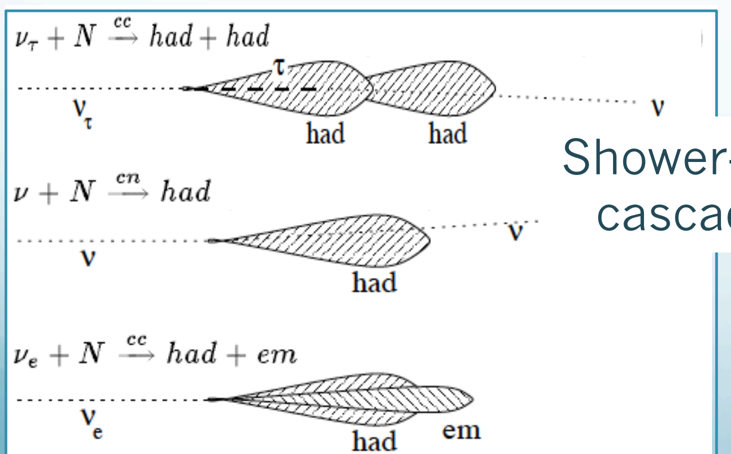


Track-like

Track-like contains both a cascade and one track

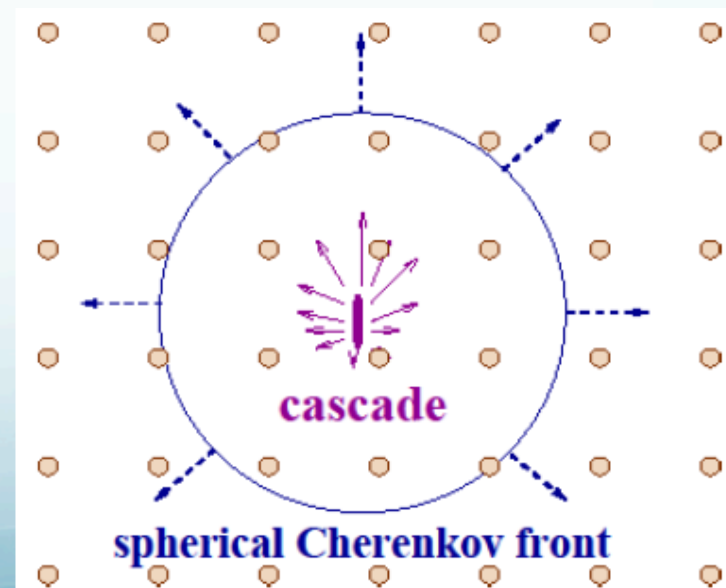


Not to scale



Shower-like
cascade

No track is identified



The IceCube HE cosmic signal

★ 2 year analysis:
28 events
4.1 σ
📖 Science 342, 2013

★ 3 year analysis:
37 events
5.7 σ
📖 PRL 113, 101101 (2014)

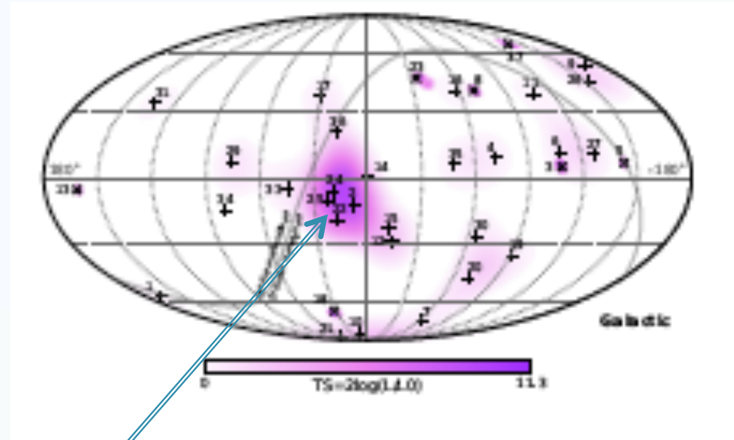
7 → 9 track-like events

1° angular resolution

21 → 28 cascade-like events

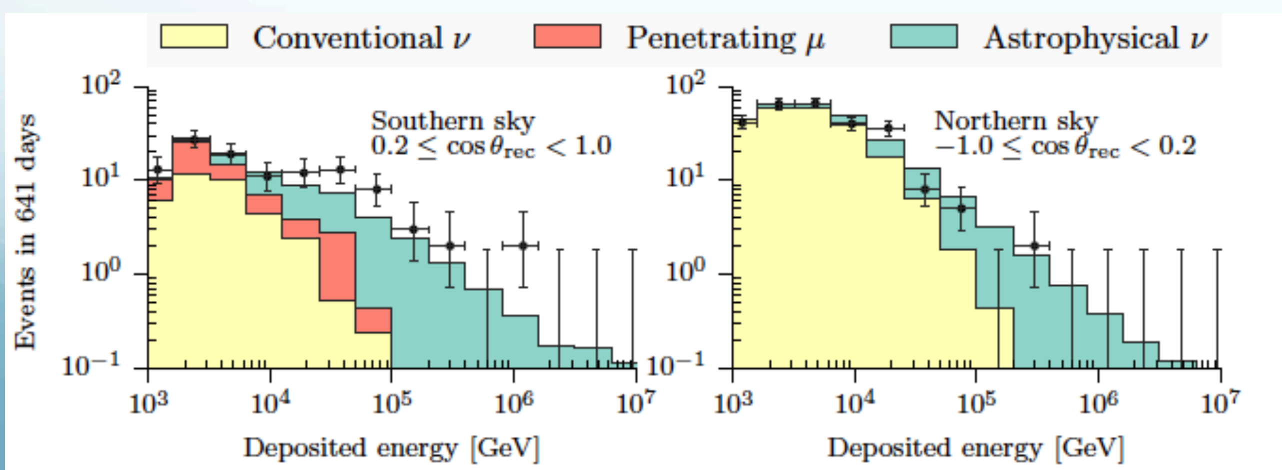
10° - 45° angular resolution

Flux intensity (per flavor): $\sim 10^{-8}\ E^{-2}$ GeV cm^{-2} s^{-1} sr^{-1}



ANTARES excludes single point source (E^{-2} spectrum) as origin of the cluster within 20° off GC
📖 Astrophys. J. Lett. 786:L5 (2014)

★ Most recent study lowering E threshold
📖 arXiv:1410.1749



M. Spurio's talk tomorrow

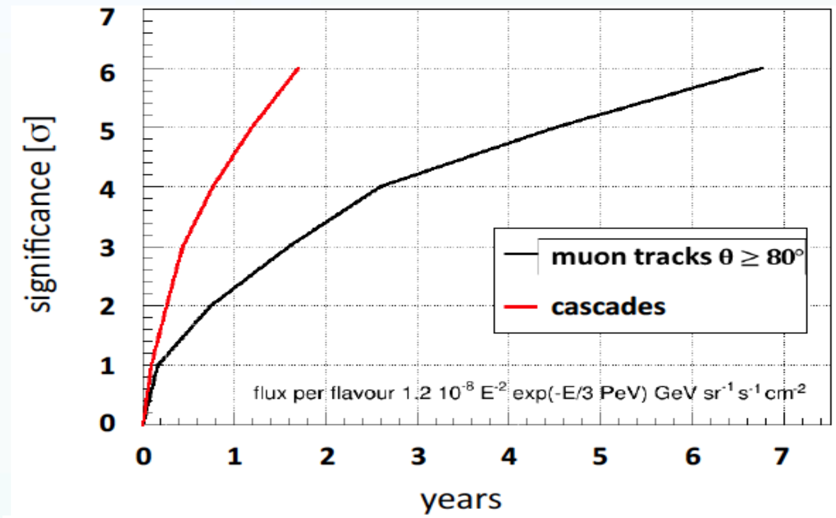
Excess in Southern sky?
Galactic contribution?
Constraints by ANTARES?

A phased implementation

Parallel to ORCA

PHASE 1:
Shore and deep-sea infrastructure at KM3NeT-Fr & KM3NeT-It
31 lines deployed by end 2016 (**3-4 x ANTARES sensitivity**)
Proof of feasibility of network of distributed neutrino telescopes

31 M€ FUNDED ONGOING



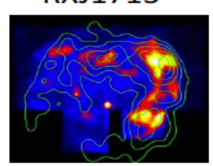
2016 PHASE 1.5:
230 lines (2 building blocks)
Investigation of IceCube signal

+ 50-60 M€ Letter of Intent In prep

2020 PHASE 2:
6 building blocks
Neutrino astronomy

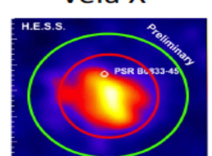
+ 130-170 M€ ESFRI Roadmap

RXJ1713¶

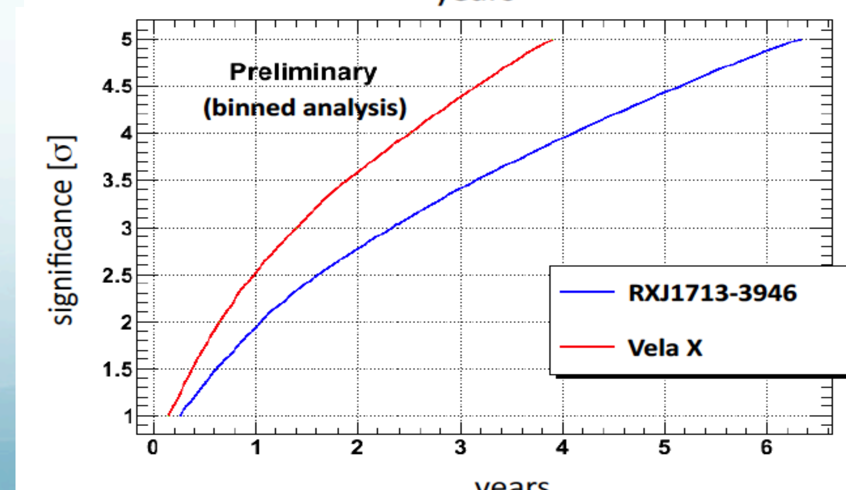


S.R. Kelner, *et al*

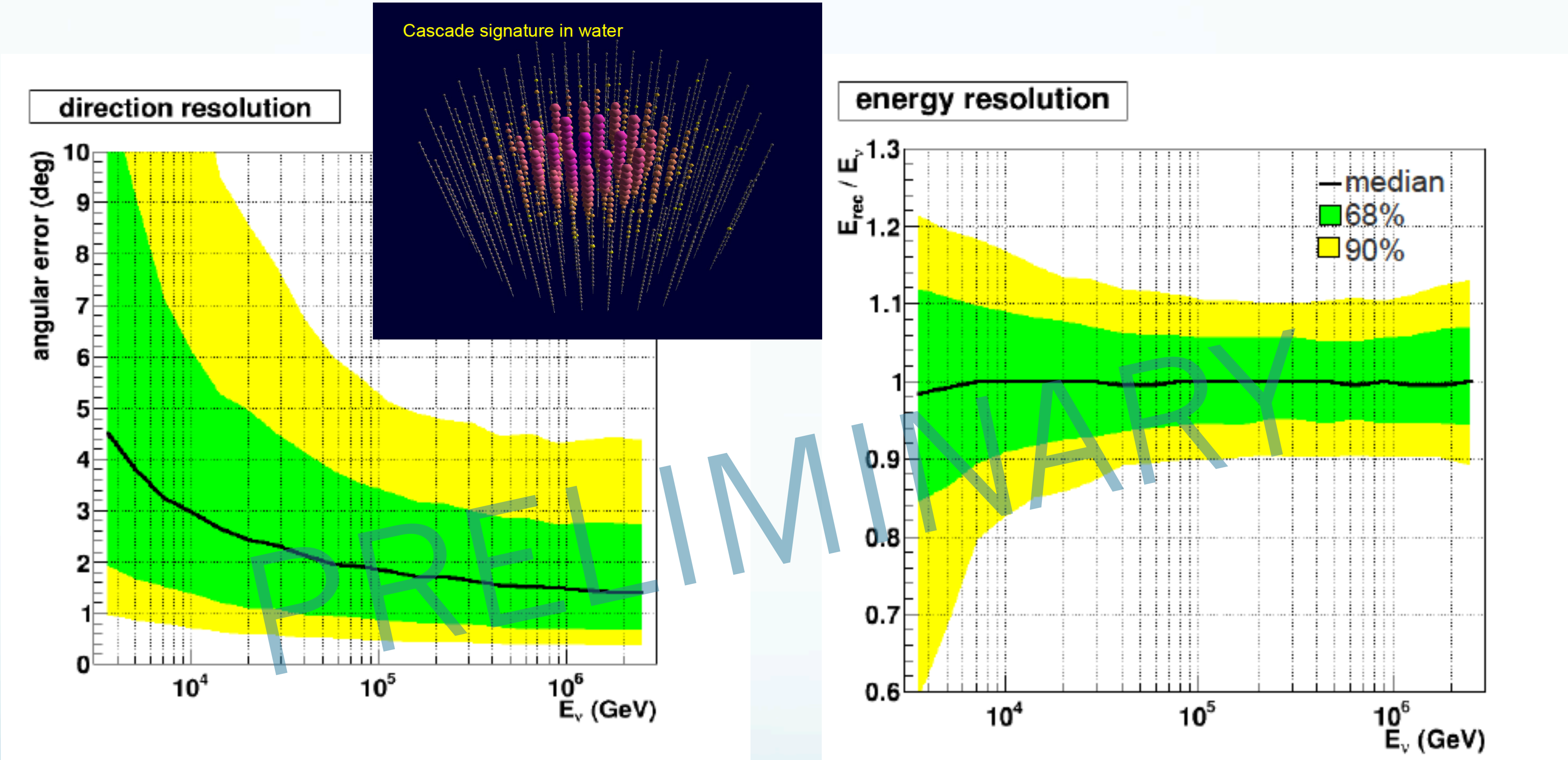
Vela X§



Villante & Vissani



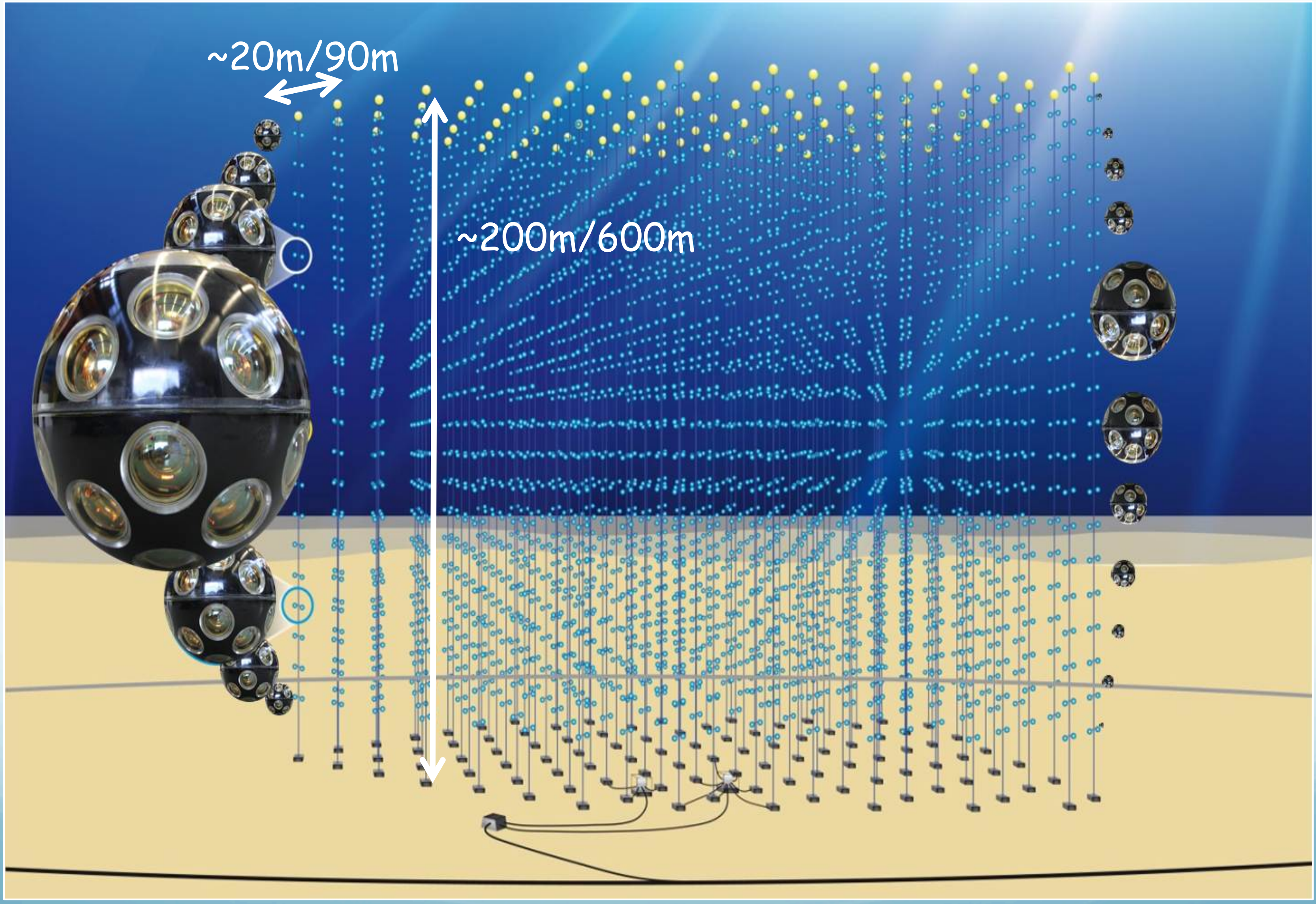
Towards an all-flavour astronomy



2° median angular resolution with ANTARES (10 times better than IceCube)

→ Actively being worked out for next year physics studies updates

Detector technology

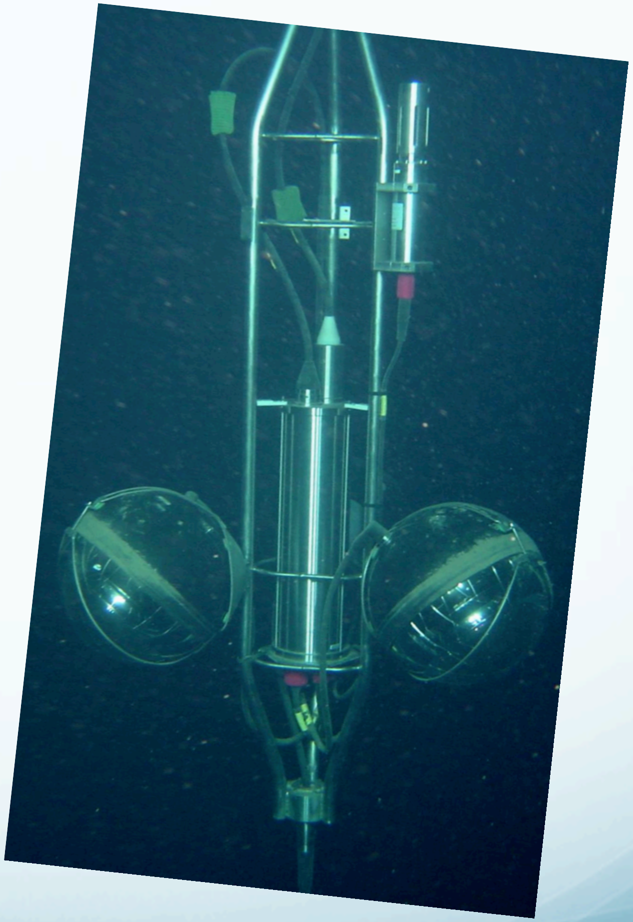


The Multi-PMT Digital Optical Module

17 inch

>

ANTARES Storey



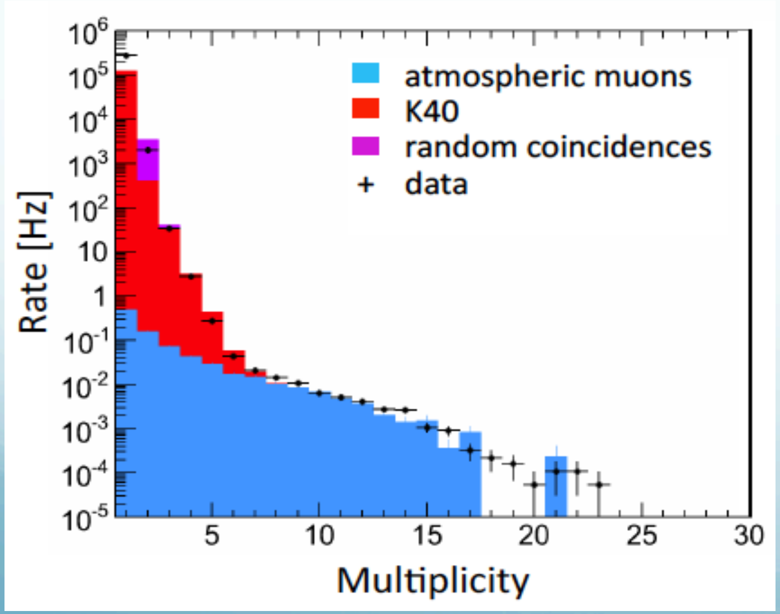
- Digital photon counting
- Directional information
- Wide angle of view
- Single pressure transition
- Cost reduction wrt ANTARES

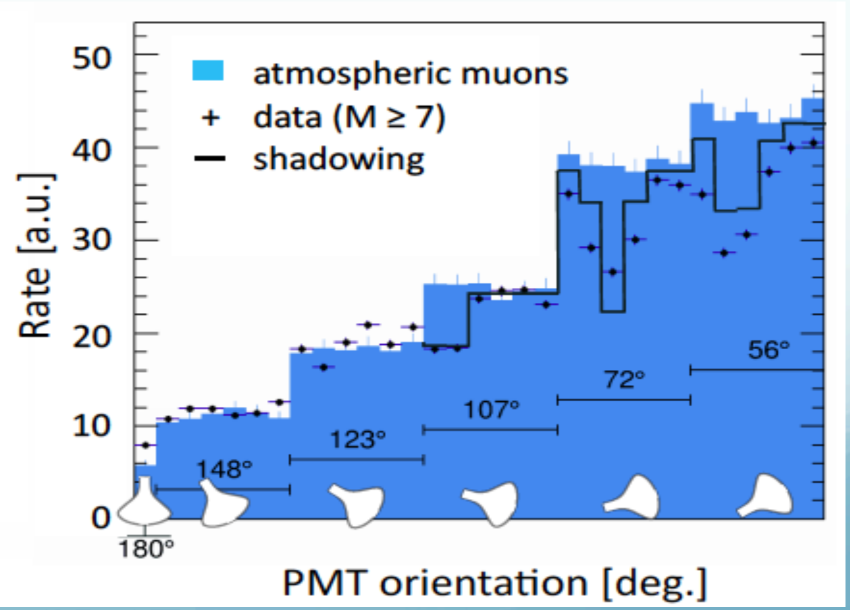
1st prototype @ ANTARES

April 2013: First DOM installed on ANTARES instrumented line

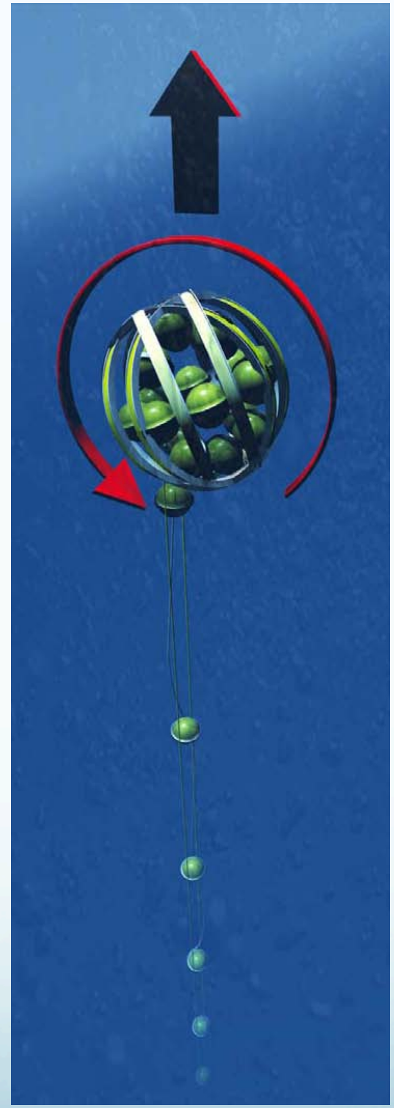
Validates photon counting and directionality performances

📖 Eur. Phys. J. C (2014) 74:3056

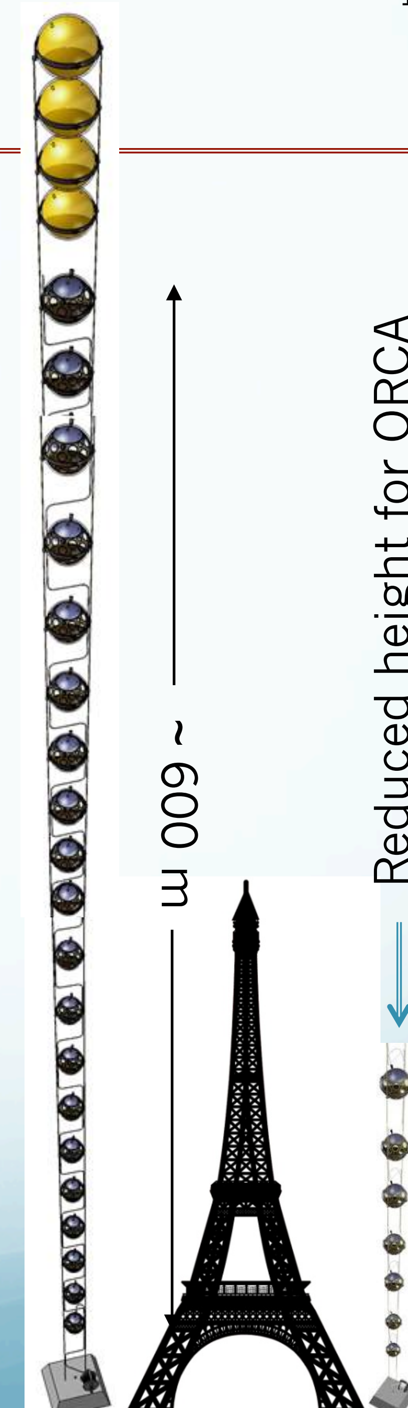




String deployment

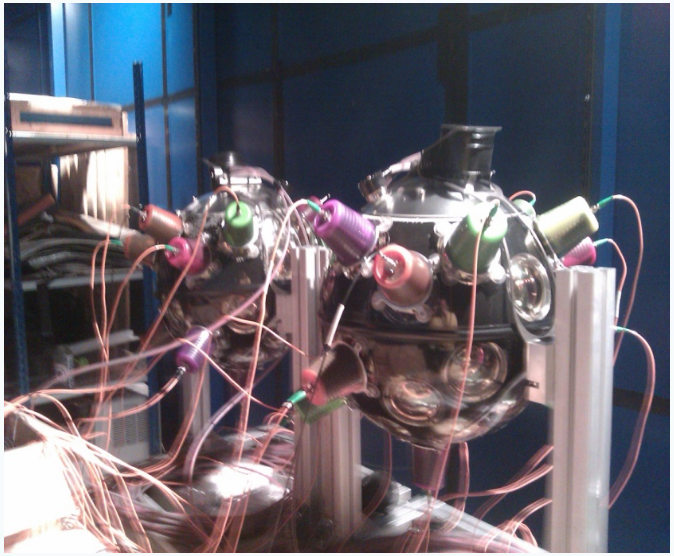


- Fast mounting of optical modules
- Rapid deployment
- Autonomous unfurling
- Recovery of launcher vehicle



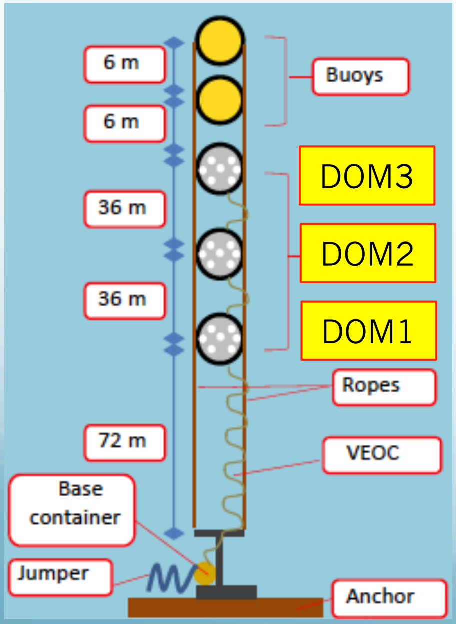
Multiple deployments with a single cruise

KM3NeT mini-line @ Capo Passero

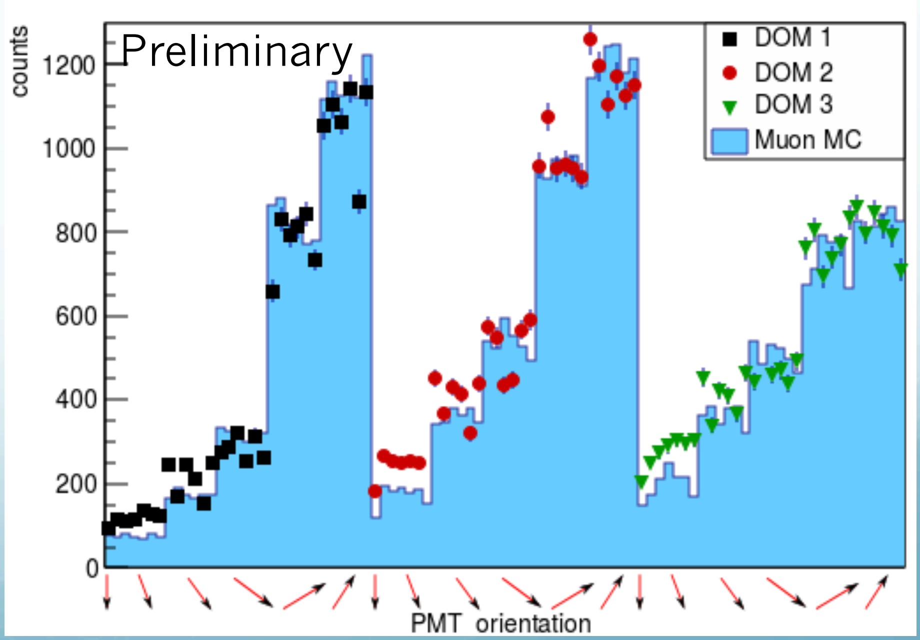


Integration
Nikhef & CPPM

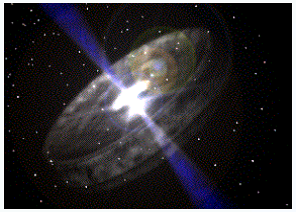
Deployment KM3NeT-It
May 2014



Smooth operation
and data taking



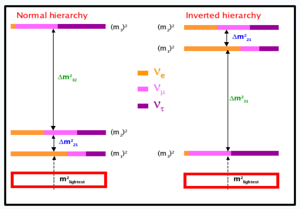
Outline

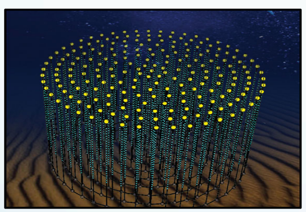


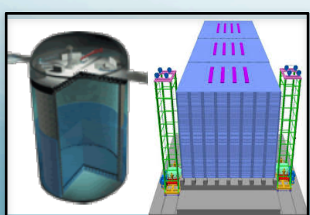
The High-Energy Physics Case

Today's context & KM3NeT sensitivity

Common Detector technology







The Low-Energy Physics Case

Introduction

Quick phenomenological reminder

ORCA (and comparison to PINGU)

Detector technology

Detector performances

Sensitivity study

Planning

Underground atmospheric detectors

Water/Ice Cherenkov

Magnetized Trackers

Oscillations of Massive Neutrinos

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \cdot \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta_{\mathrm{CP}}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{\mathrm{CP}}} & 0 & c_{13} \end{pmatrix} \cdot \begin{pmatrix} c_{21} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} e^{i\eta_1} & 0 & 0 \\ 0 & e^{i\eta_2} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Atmospheric
$\theta_A \sim 45°$

Reactor
$\theta_{13} \sim 9°$

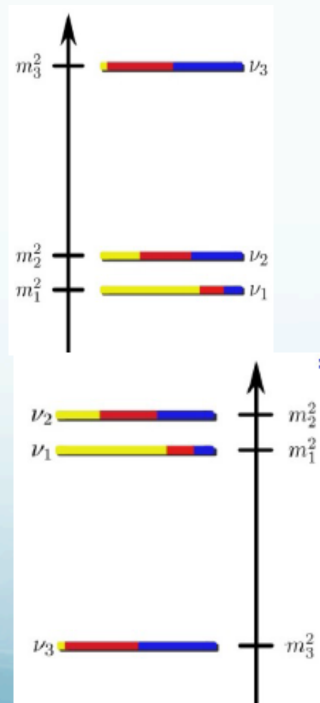
Solar
$\theta_\odot \sim 30°$

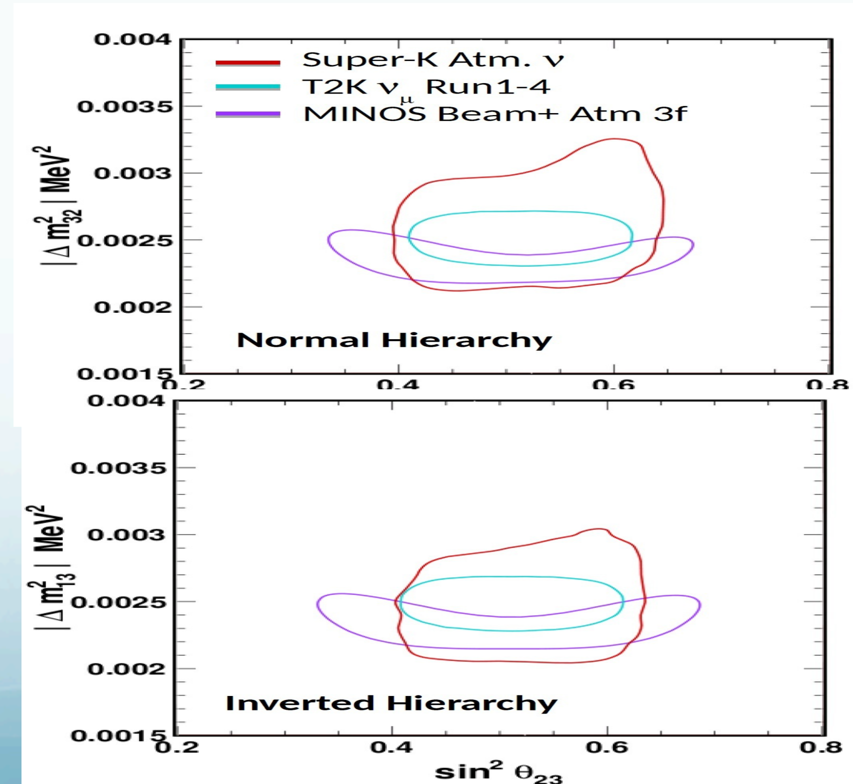
Majorana

↓
CP violating phase δ_{CP}

$$m_1^2 < m_2^2$$
$$m_2^2 - m_1^2 \ll |m_3^2 - m_{1,2}^2|$$

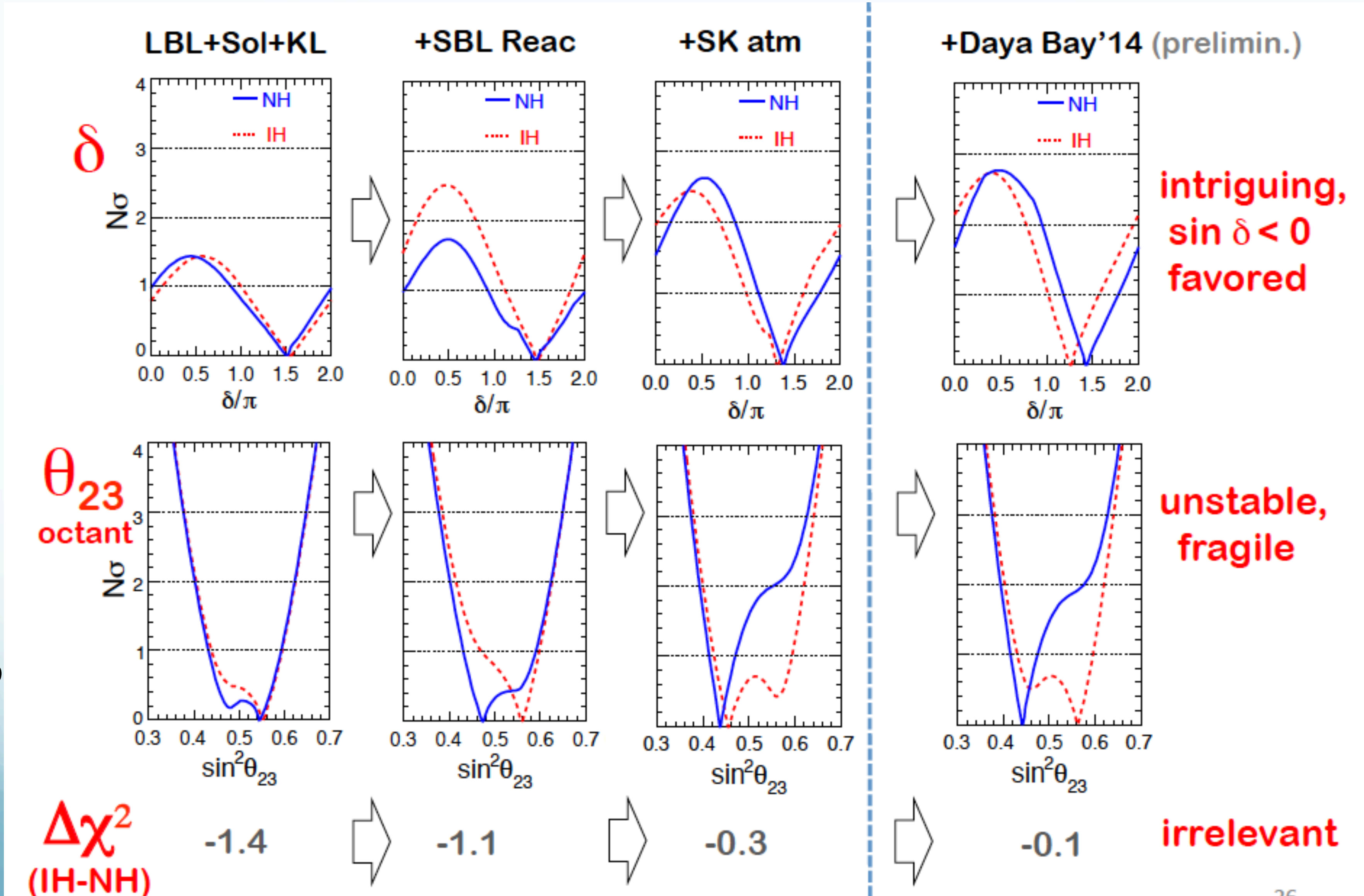
All parameters measured to fair precision except:
<u>mass hierarchy</u>
octant of θ_{23}
CP phase





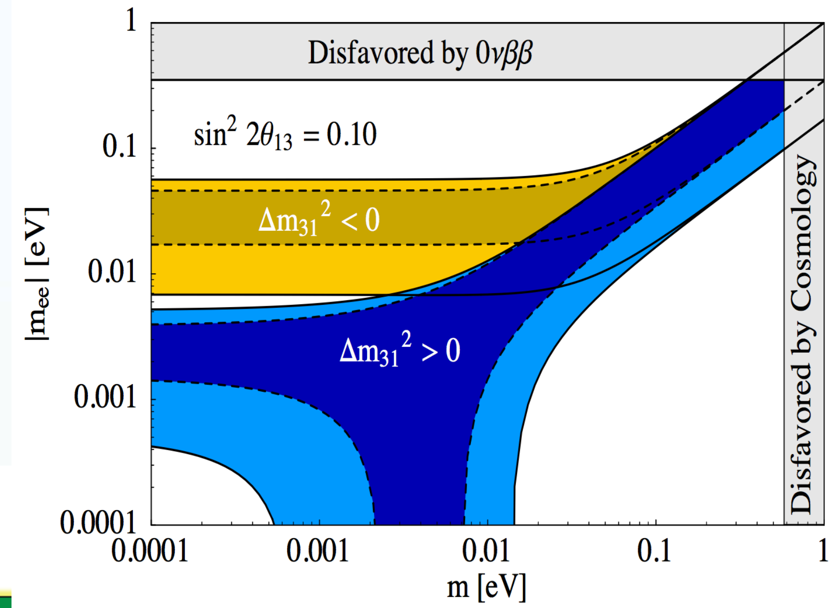
Current Status of unknowns

E. Lisi, Large Neutrino Infrastructure, Paris, June 2014

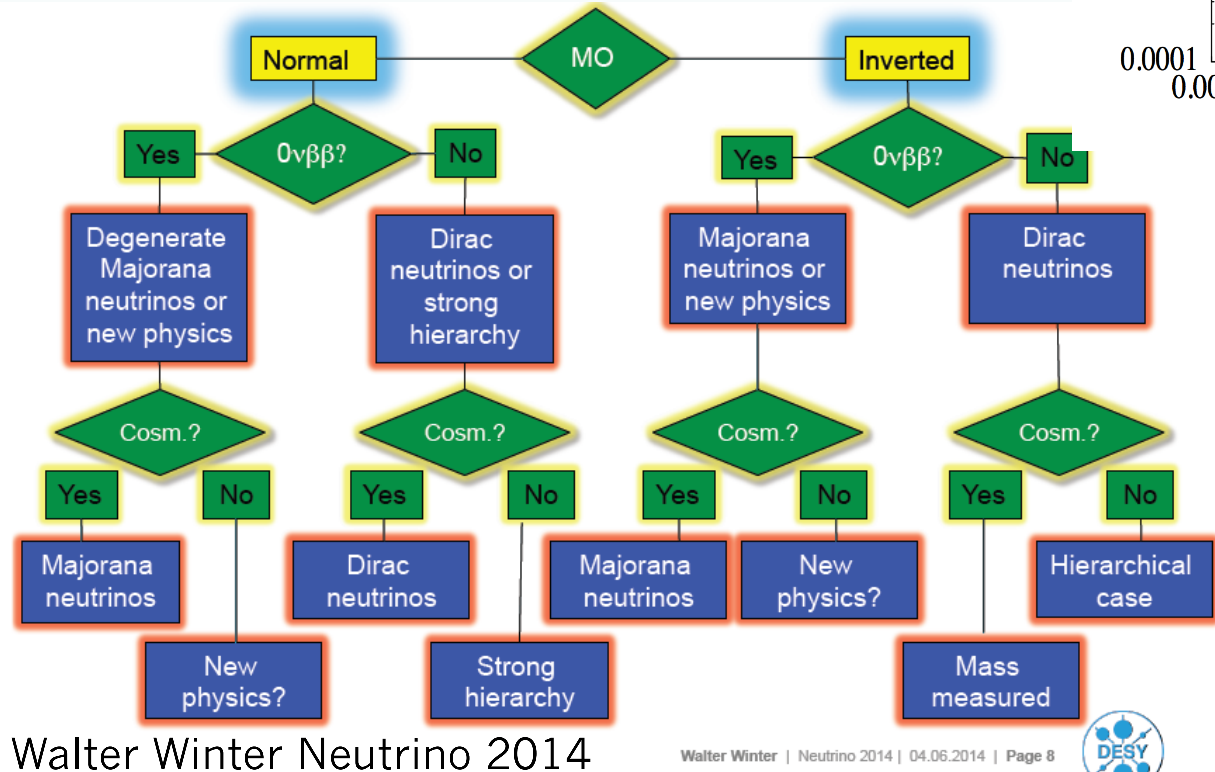


Why knowing the mass hierarchy?

- Help measuring the CP phase
- Absolute mass scale
- Nature (Dirac vs Majorana)
- Origin of neutrino mass and flavour
- Core-Collapse Supernovae Physics



Impact of direct mass ordering measurement



Walter Winter Neutrino 2014

A need for the Neutrino community
The sooner/cheaper the better

Neutrino Telescopes coll. owe a case study (consequence of large θ_{13})

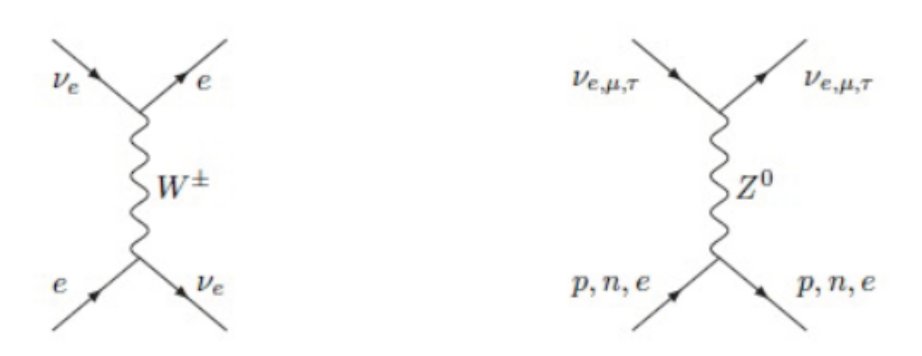
MH with LBL experiments

- « Standard approach » :probe $\nu_\mu \leftrightarrow \nu_e$ governed by Δm^2_{31}

$$P_{3\nu}(\nu_\mu \to \nu_e) \approx \sin^2\theta_{23}\, P_{2\nu} = \sin^2\theta_{23}\, \sin^2 2\theta^{m}_{13}\, \sin^2\left(\frac{\Delta m^{2\,m}_{31} L}{4E_\nu}\right)$$

[Neglecting solar (> a few GeV and >1000's km) and CP violation effects]

- Insensitive to the sign of Δm^2_{13} at leading order.
- Matter effects (MSW) come to the rescue



Through matter, neutrinos interact acquiring an effective mass (forward scattering)
Only electron neutrinos interact through CC with electrons
→ Additional potential A in the Hamiltonian

$A \equiv \pm\sqrt{2} G_F N_e$ (−)+ for (anti-)neutrinos

→ Modify the oscillation probability

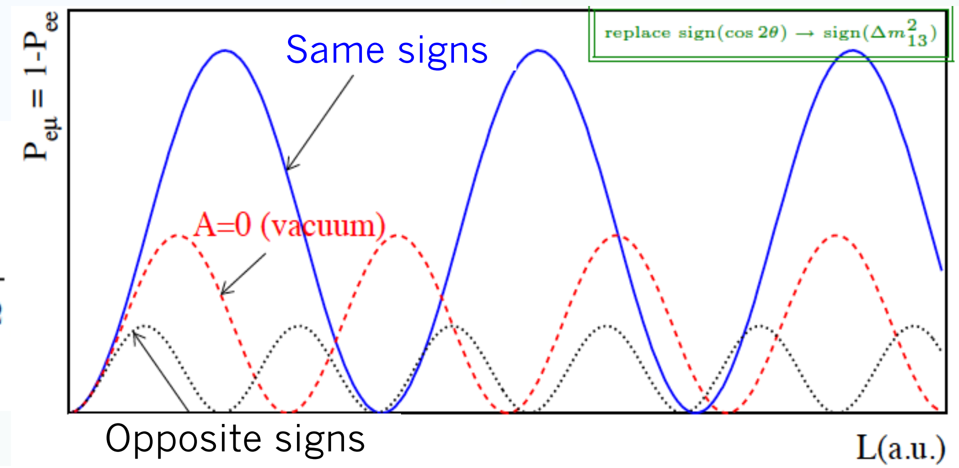
- Earth density variations (e.g. mantle-core) also affect the oscillations (*parametric resonance*)

(Constant Density) Matter Effects

$$P^m_{3\nu}(\nu_\mu \to \nu_e) \approx \sin^2\theta_{23}\sin^2 2\theta^m_{13}\sin^2\left(\frac{\Delta^m m^2_{31} L}{4E_\nu}\right)$$

$$\sin^2 2\theta^m_{13} \equiv \sin^2 2\theta_{13}\left(\frac{\Delta m^2_{31}}{\Delta^m m^2_{31}}\right)^2$$

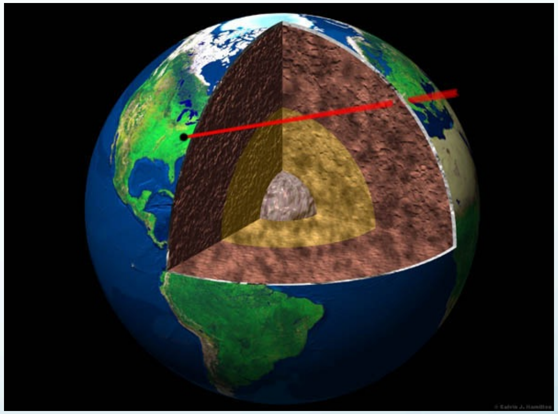
$$\Delta^m m^2_{31} \equiv \sqrt{(\Delta m^2_{31}\cos 2\theta_{13} - 2E_\nu A)^2 + (\Delta m^2_{31}\sin 2\theta_{13})^2}$$



$$E_{\rm res} \equiv \frac{\Delta m^2_{31}\cos 2\theta_{13}}{2\sqrt{2}G_F N_e} \simeq 7\,\mathrm{GeV}\left(\frac{4.5\,\mathrm{g/cm^3}}{\rho}\right)\left(\frac{\Delta m^2_{31}}{2.4\times 10^{-3}\,\mathrm{eV^2}}\right)\cos 2\theta_{13}$$

Matter resonance: A ➔ $\Delta_{13}\cos 2\theta_{13}$
- Effective mixing maximal
- Effective osc. frequency minimal

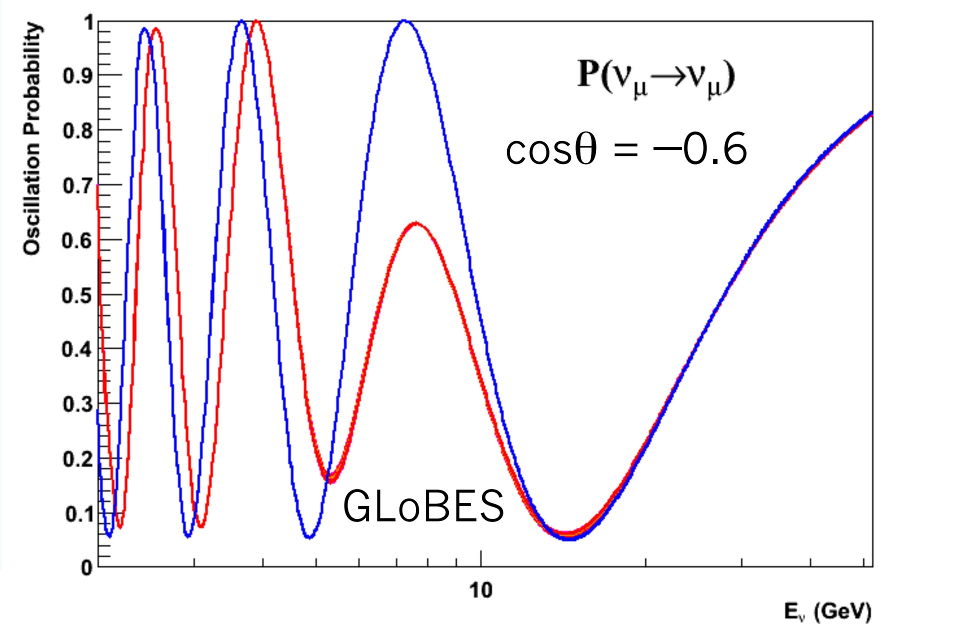
Resonance energy Earth:
- Mantle E_{res} ~ 7 GeV
- Core E_{res} ~ 3 GeV

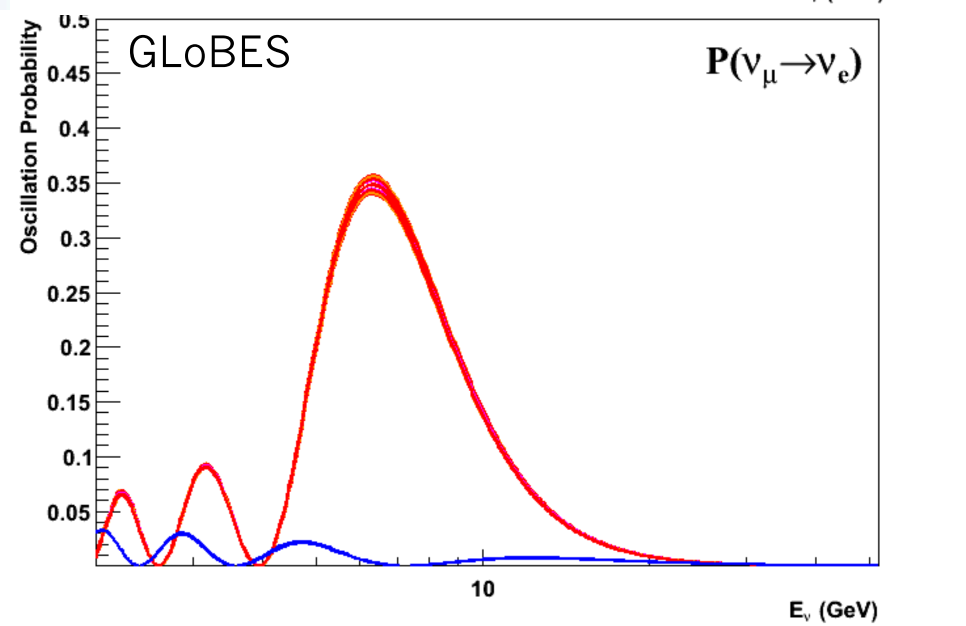


Requirements:
- Δ_{13} ~ A matter potential must be significant but not overwhelming
- L large enough – matter effects are absent near the origin
- Distinction between neutrinos and anti-neutrinos

→ different flux and cross-sections!

Phenomenological Summary



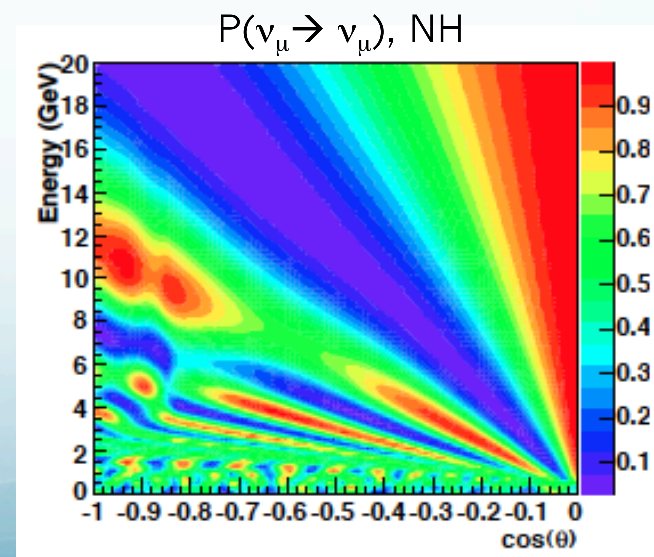


Inverted Hierachy

Normal Hierachy

In each case, CP-phase is varied in steps of 30 degrees

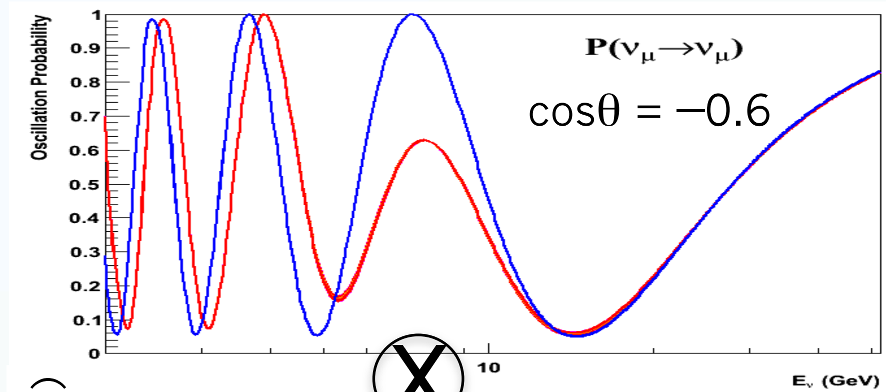
- Hierarchy differences disappear at around 15 GeV
- $P(\nu_\mu \to \nu_e) < 2\%$ at 20 GeV



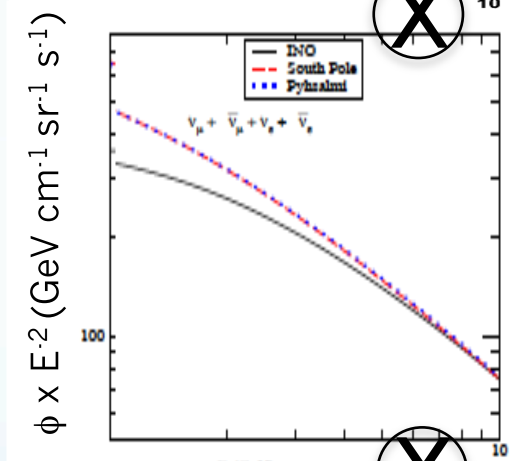
Fluxes and cross sections

$$\text{Cosmic Ray} + A_{air} \rightarrow \pi^+ + \ldots$$
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$$

A beam for free !



- Produce neutrinos and anti-neutrinos
- Broad energy range: Steeply falling spectrum
  → Requires good energy resolution
- Broad path-length range
  → Requires good direction resolution



📖 M.S. Athar et al. arXiv:1210.5154

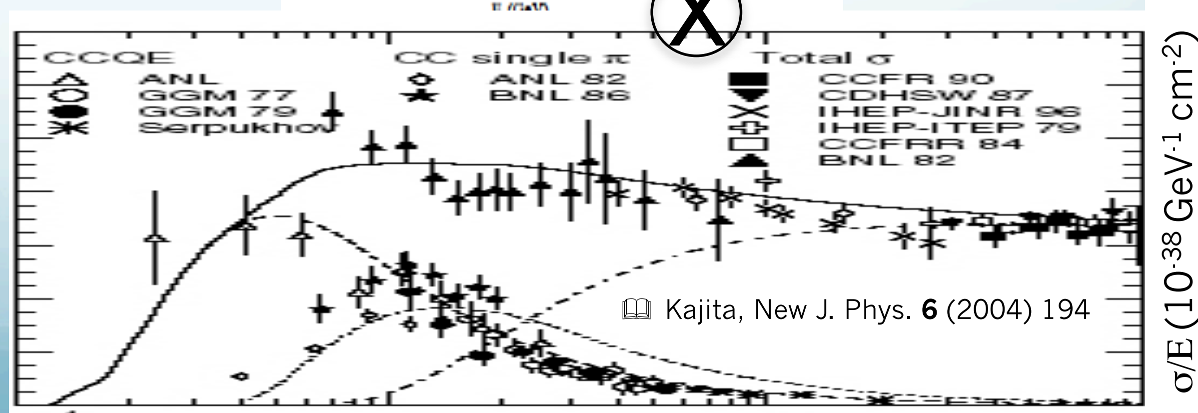
Calculations now made as a function of the position on Earth and the time in year

Different cross sections for ν and $\bar{\nu}$!

$$\sigma(\nu) \approx 2\sigma(\bar{\nu})$$

Three main contributions:
Quasi-elastic, Resonant, DIS

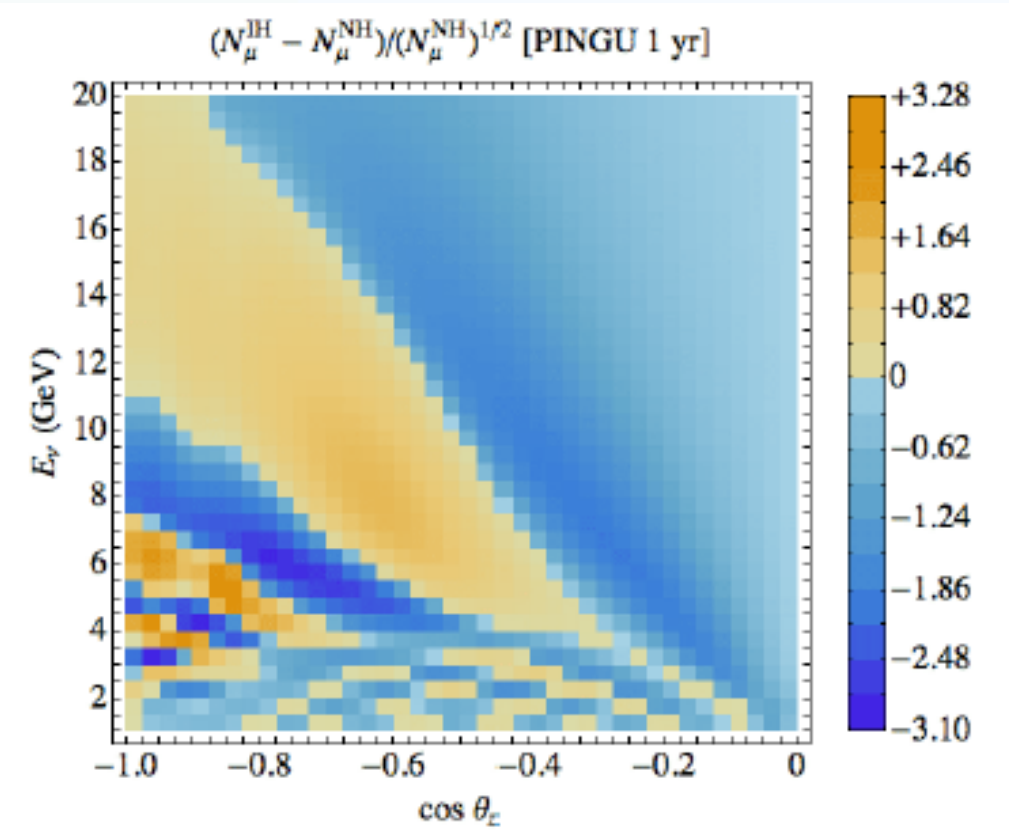
→ Use external measurements and regions without oscillations



📖 Kajita, New J. Phys. **6** (2004) 194

Oscillograms & sensitivity for NT

📖 Akhmedov et al. JHEP 02 (2013) 082



With exceedingly large PINGU effective volume

$$\boxed{\rho V_{\rm eff}(E_\nu) = 14.6 \times [\log(E_\nu/{\rm GeV})]^{1.8}\ {\rm Mt}}$$

$$S^{tot} = \sqrt{\sum_{ij} S_{ij}^2} = \sqrt{\sum_{ij} \frac{(N_{ij}^{IH} - N_{ij}^{NH})^2}{\sigma_{ij}^2}}$$

$$\sigma_{ij}^2 = N_{ij}^{NH} + (f N_{ij}^{NH})^2$$

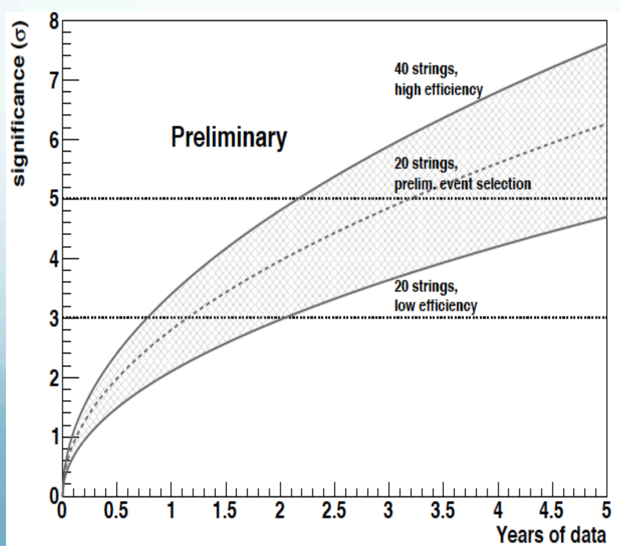
Uncorrelated systematics

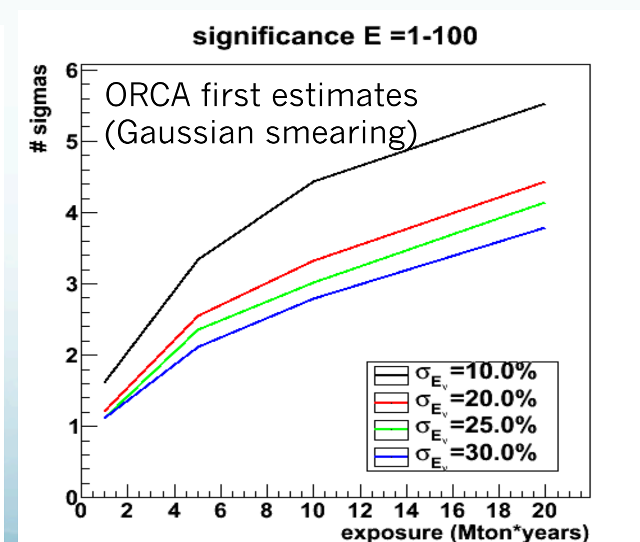
Perfect resolutions		σE=4 GeV, σθ= 22.5°	
S=45.5σ	(f=0%)	S=7.2σ	(f=0%)
S=28.9σ	(f=5%)	S=4.5σ	(f=5%)
S=18.8σ	(f=10%)	S=3.0σ	(f=10%)

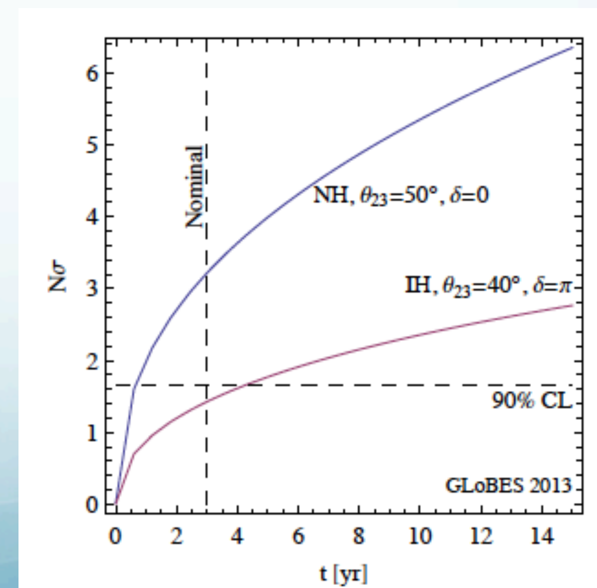
In 5 years

The ORCA feasibility study

- Launched in September 2012 (Coord. A. Kouchner)
- KM3NeT technology
- Regularly presented at GDR Neutrino since then
- First focus on neutrino muon channel
- Independent study
  - hard to reconcile with PINGU first studies
  - Consistent with other estimates





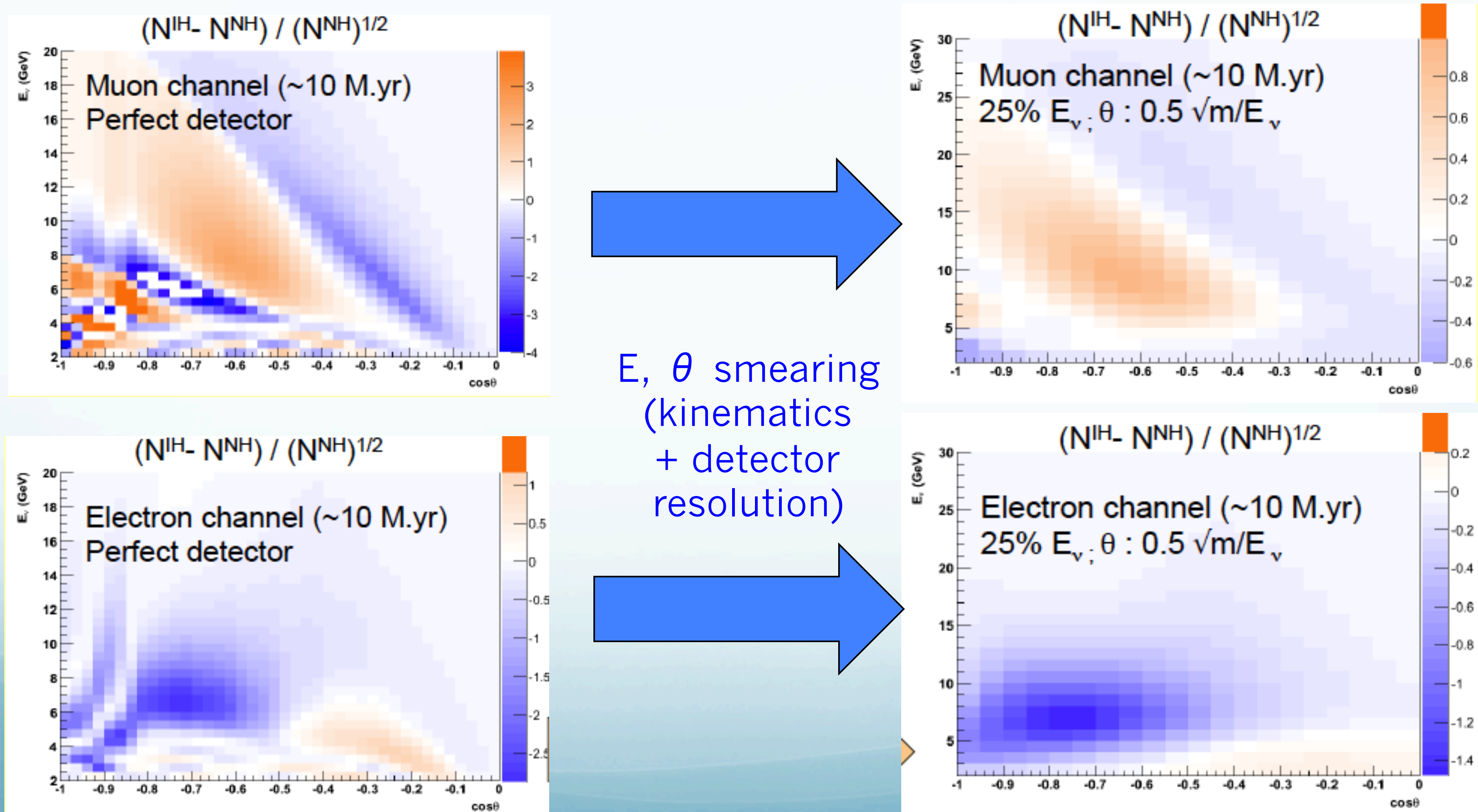


📖 PINGU collaboration, arXiv:1306.5846

📖 W. Winter, PRD.88.013013

Muon versus Electron channels

Both muon- and electron-channels contribute to net hierarchy asymmetry
electron channel more robust against detector resolution effects:



Additional ORCA physics topics

- Indirect Search for Dark Matter

- Sensitivity to CP phase (Threshold <1GeV, MH known)

    📖 Razzaque & Smirnov, arXiv:1406.1407

- Earth tomography and composition

    📖 Gonzales-Garcia et al.,Phys.Rev.Lett.100:061802,2008,
    📖 Agarwalla et al., arXiv:1212.2238v1

- Test NSI and other exotic physics

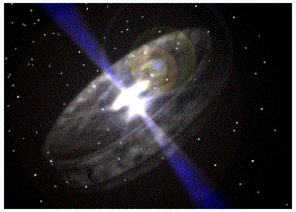
    📖 Ohlsson et al, Phys. Rev. D 88 (2013) 013001
    📖 Gonzales-Garcia et al., Phys.Rev. D71 (2005) 093010

- Supernovae monitoring (takes advantage on new DOM features)

- Low Energy Neutrino Astrophysics
    - Gamma-ray bursts, Colliding Wind Binaries

        📖 J. Becker Tjus, arXiv:1405.0471 ...

Outline

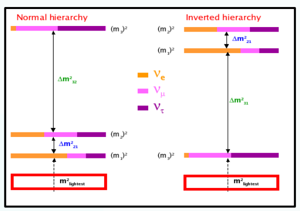


The High-Energy Physics Case

Today’s context & KM3NeT sensitivity

Common Detector technology

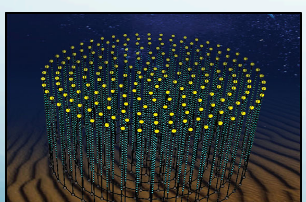
The Low-Energy Physics Case



Phenomenological reminder

Oscillations and matter effects

Electron vs Muon channels



ORCA (and comparison to PINGU)

Proposed detector

Detector performances

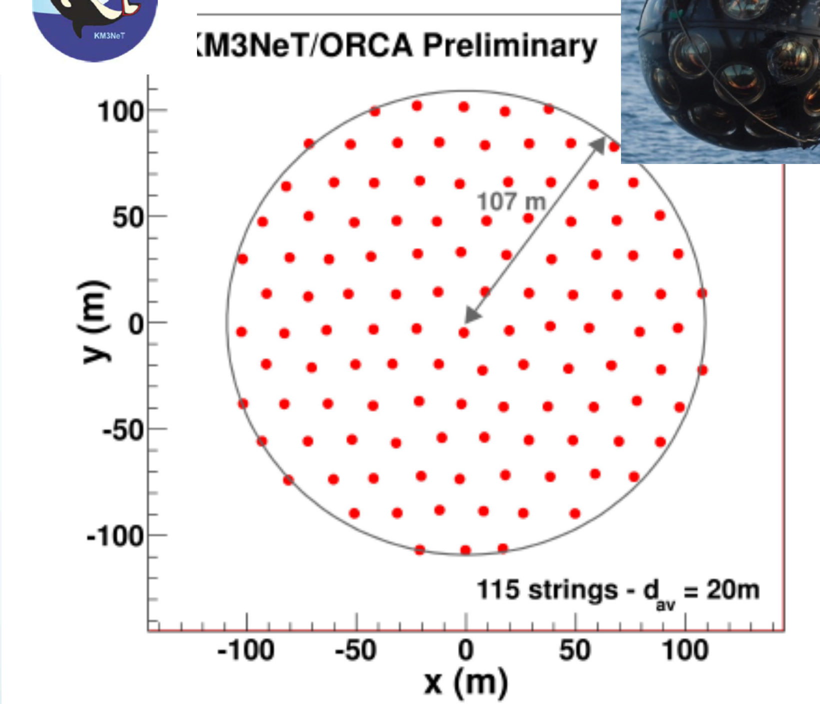
Sensitivity study

Planning

Proposed Low Energy Extensions

KM3NeT Collaboration

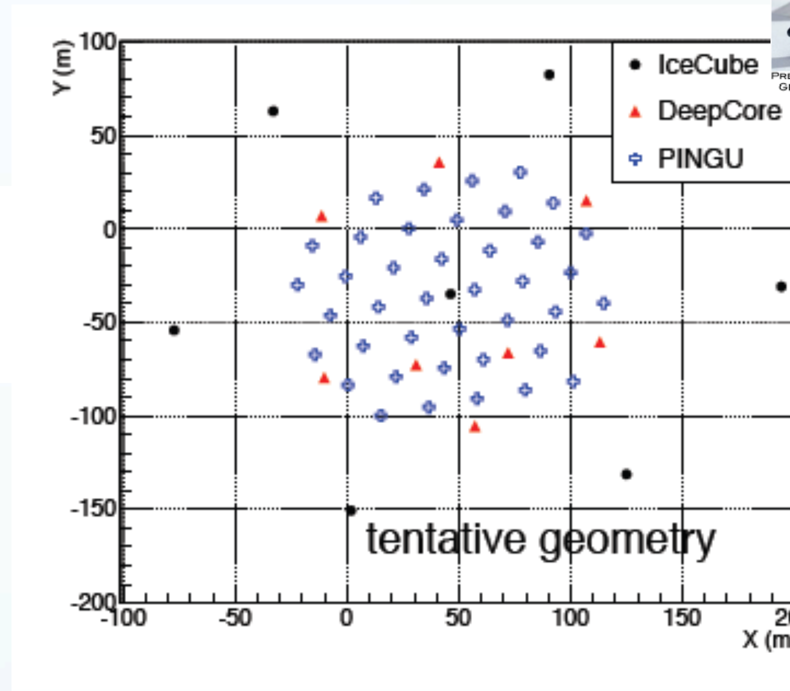
ORCA*



115 lines, 20m spaced,
18 OM/line 6m spaced
Instrumented volume ~3.8 Mt, 2070 OM

*First performances evaluated with a 50 string detector

PINGU#



Precision IceCube Next Generation Upgrade

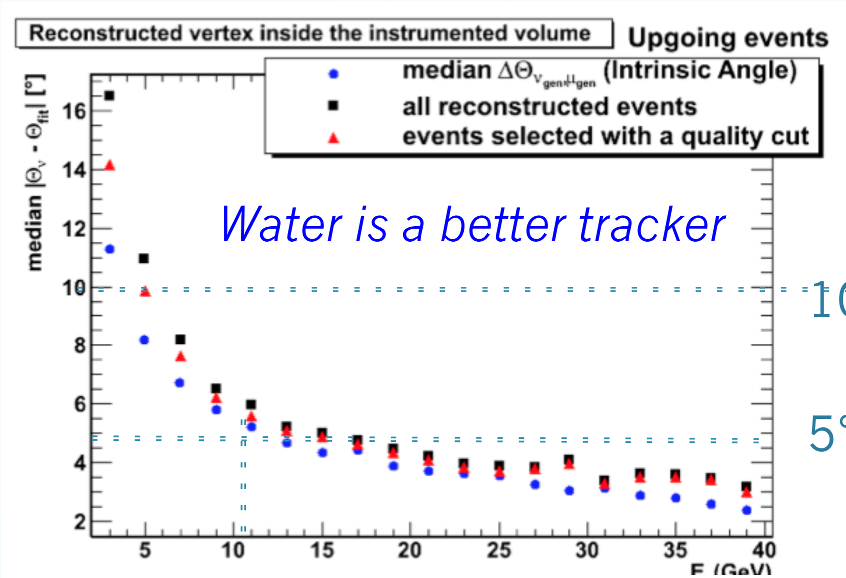
40 strings, 20-25m spaced,
96 OM/string 3m spaced
Instrumented volume ~ 6 Mt, 3840 OM

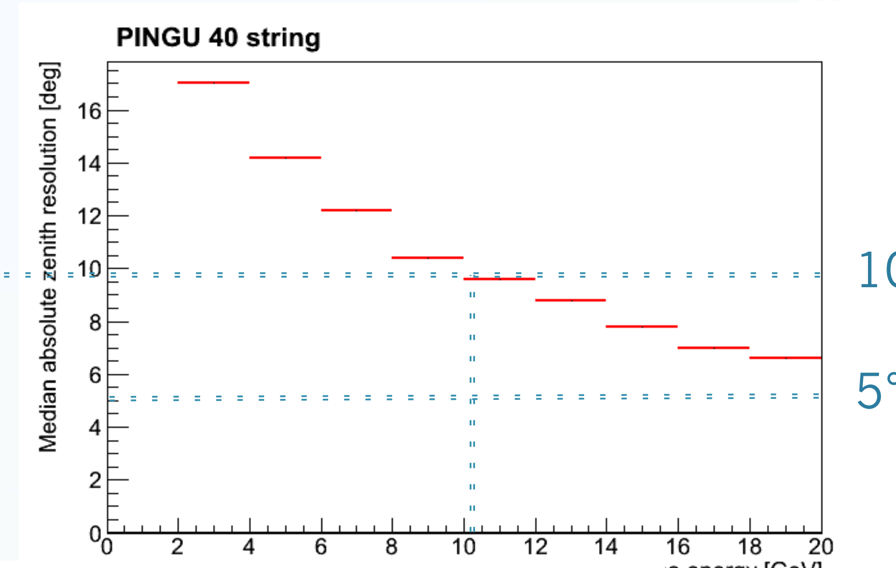
#First performances evaluated 60 OMs/string

Optimised layouts still under study

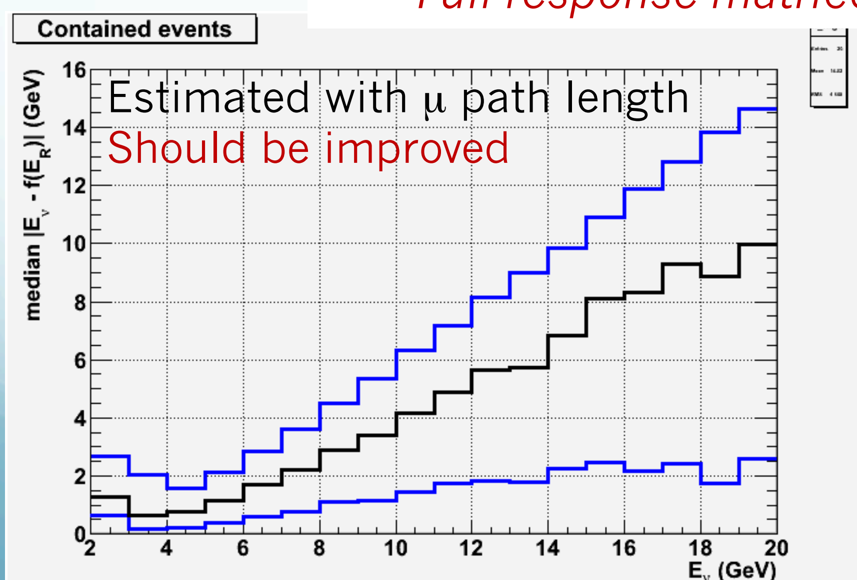
KM3NeT Collaboration

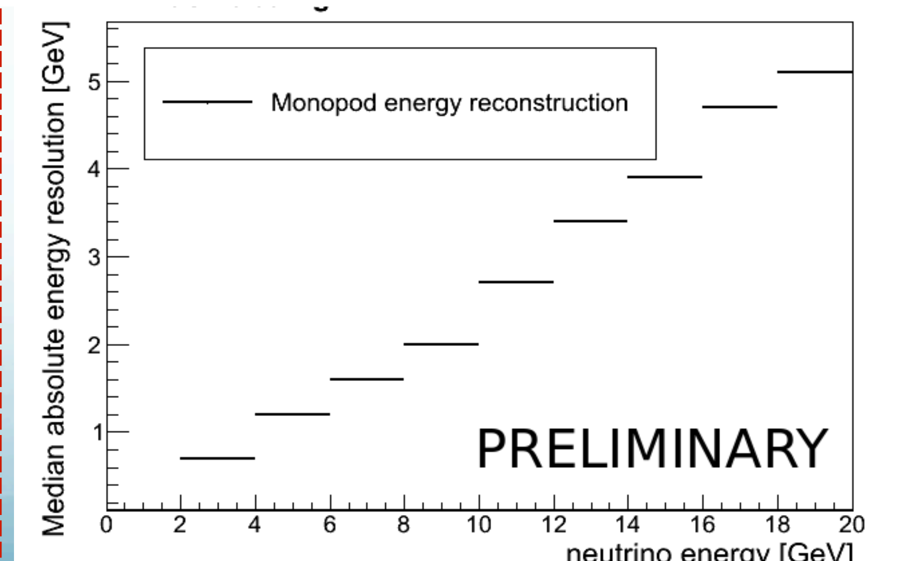
Preliminary performances (ν_μ)





Full response matrices used for sensitivity studies





Improvements in energy reconstruction

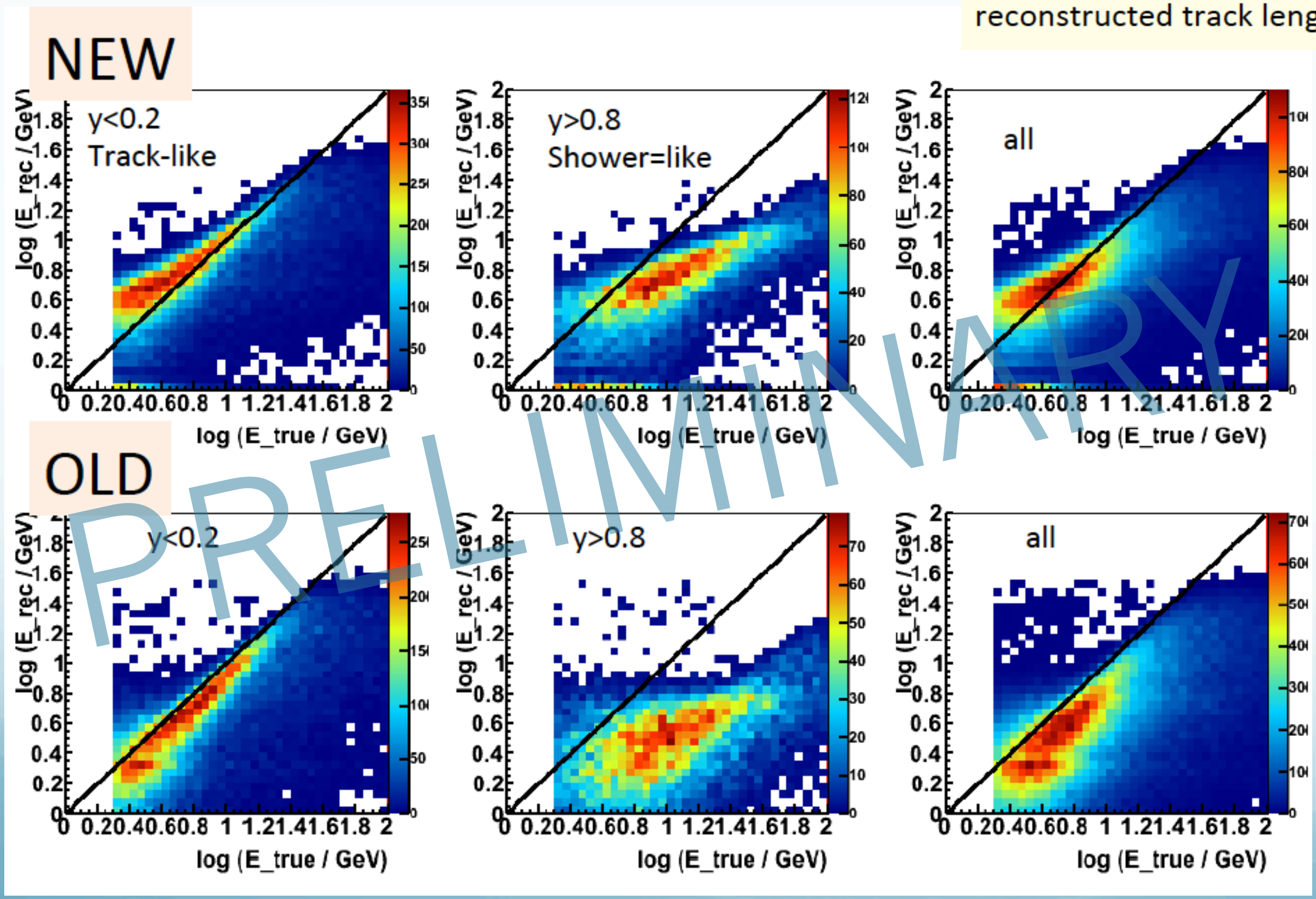
Work in progress

Old:

Energy reconstructed from reconstructed track length

New:

Energy reconstructed using a function dependent on reconstructed track length and #hits

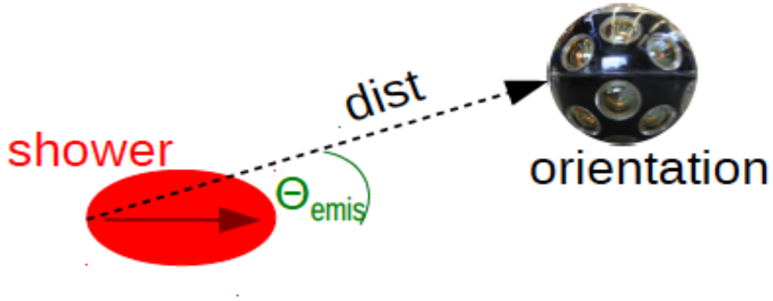


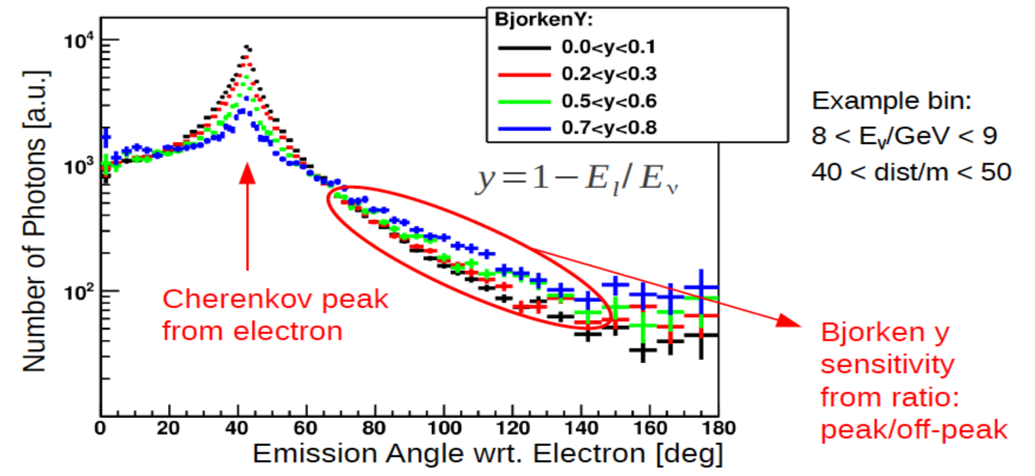
Knowledge of Bjorken-y ($1-E\mu/E\nu$) could boost the performances

Shower reconstruction (ν_e)

Work in progress

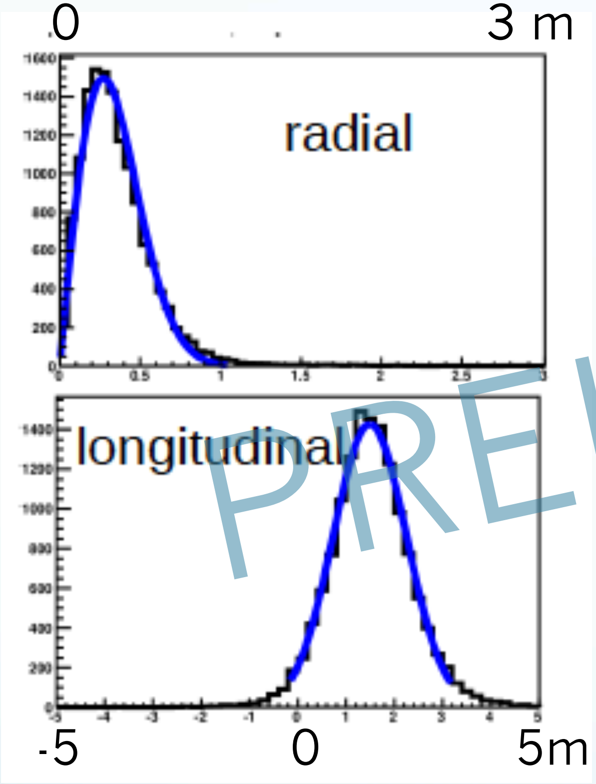
- 1. Vertex fit:
  - maximum likelihood method based on time residuals
  - two fits: first robust prefit then more precise fit
- 2. Energy + direction fit:
  - PDF for number of expected photons depending on: E_ν , Bjorken y, emission angle, OM orientation, distance(OM,vertex)
  - maximum likelihood method based probability that hits have been created by certain shower hypothesis (E_ν, Bjorken y, direction)

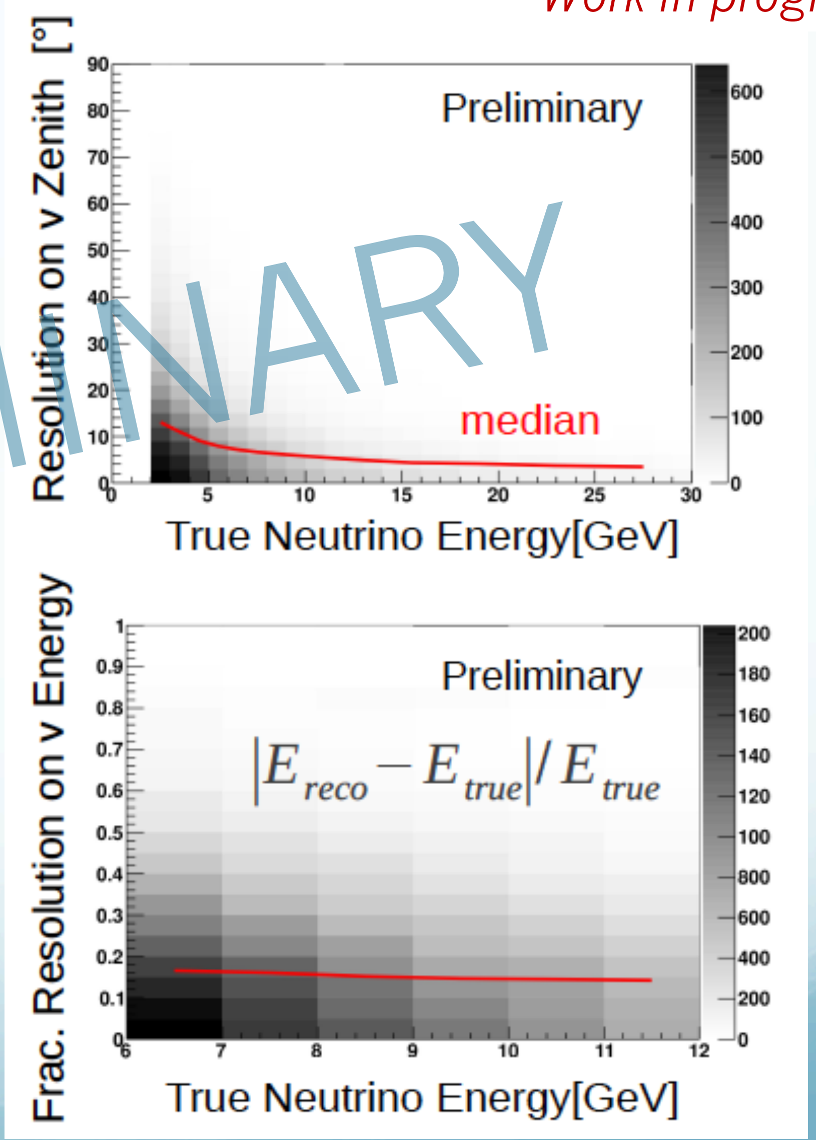




Shower reconstruction (ν_e)

Work in progress



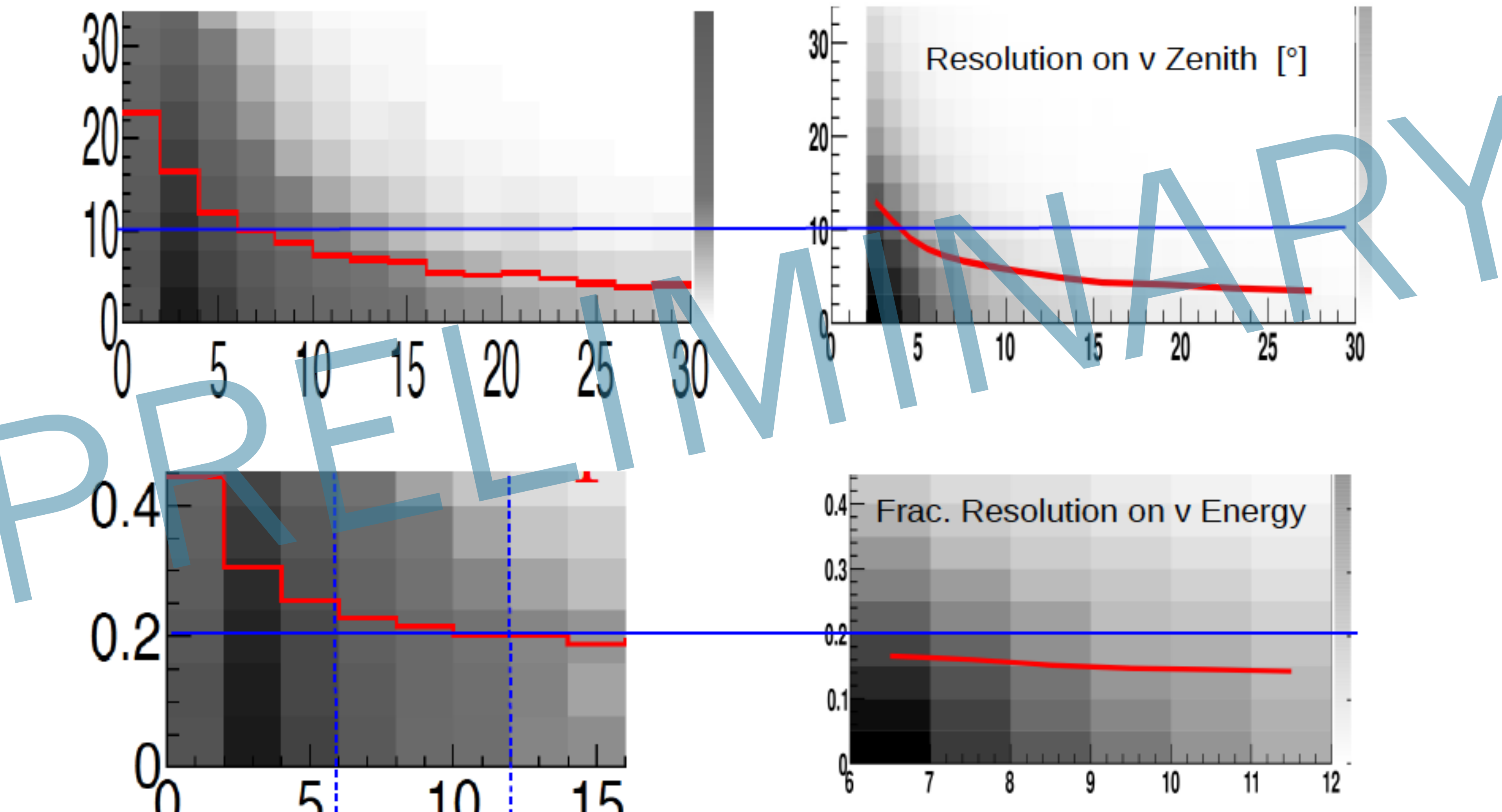


PRELIMINARY

Vertex resolution 0.5-1m
Zenith resolution 10°-5°
Energy resolution <20%

Shower reconstruction (ν_e)

PINGU (LoI, 2014) ORCA

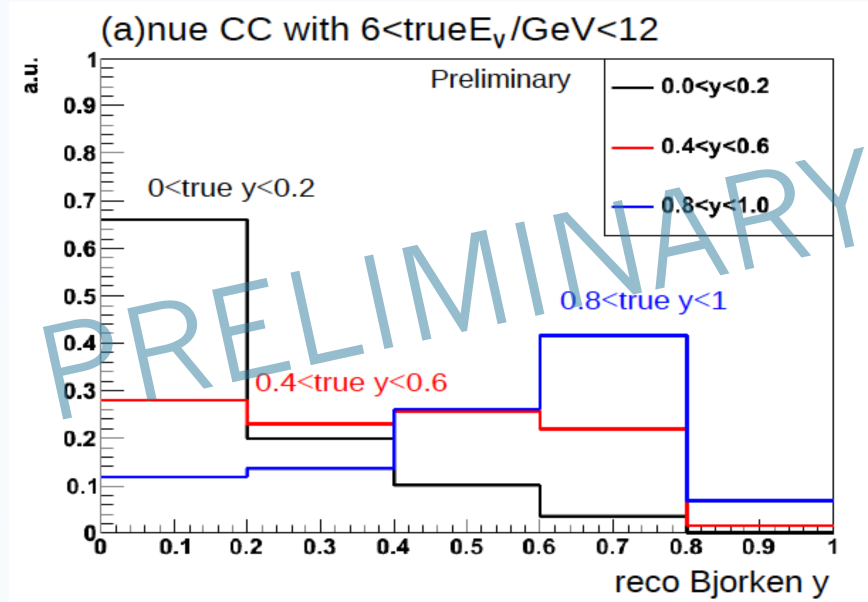


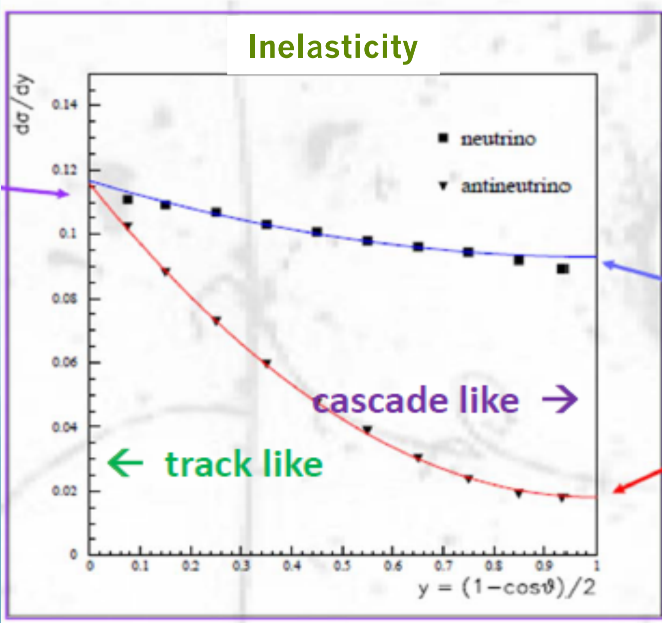
Towards a statistical separation of ν & $\overline{\nu}$

Work in progress

Shower reconstruction applied to electron ν has some sensitivity to Bjorken y

Should be studied on muon channel
Possible improvement in PID (flavour)





$$\frac{d\sigma(\nu q)}{dxdy} = \frac{d\sigma(\overline{\nu}\overline{q})}{dxdy} \propto 1$$

$$\frac{d\sigma(\nu \overline{q})}{dxdy} = \frac{d\sigma(\overline{\nu} q)}{dxdy} \propto (1-y)^2$$

y=1:

Neutrinos see only quarks.

Anti-neutrinos see only anti-quarks

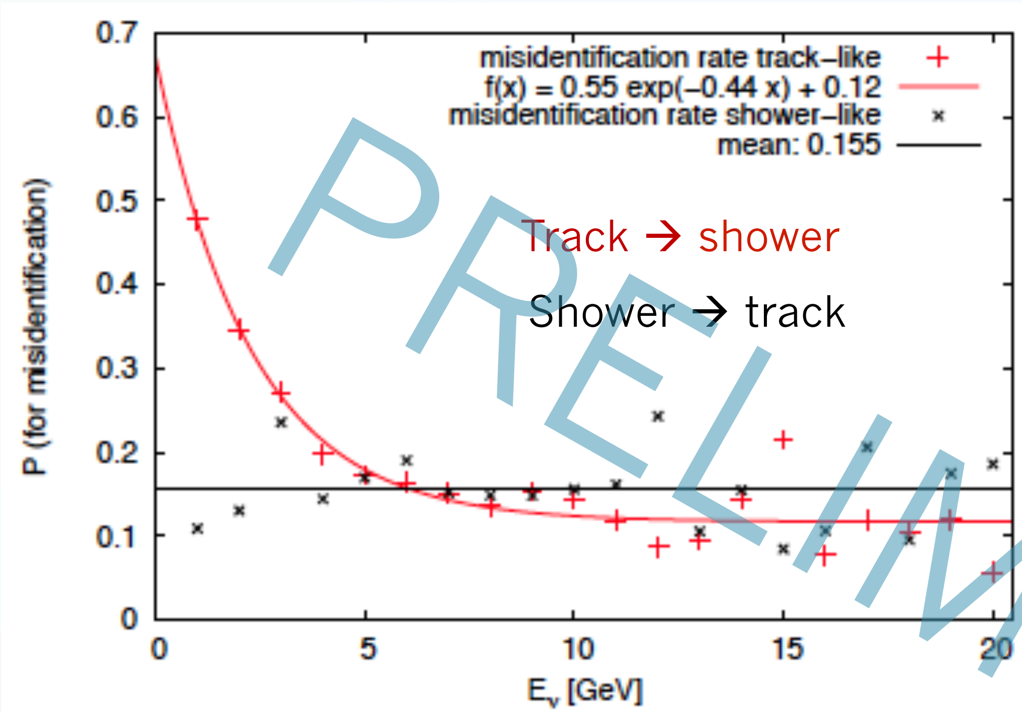
$$\sigma^{\overline{\nu}} \approx \frac{1}{2}\sigma^{\nu}$$

"With the inelasticity, the total significance of establishing mass hierarchy may increase by (20 - 50)%, thus effectively increasing the volume of the detector by factor 1.5 - 2"

📖 Ribordy & Smirnov PRD, 87. 113007 (muon channel only)

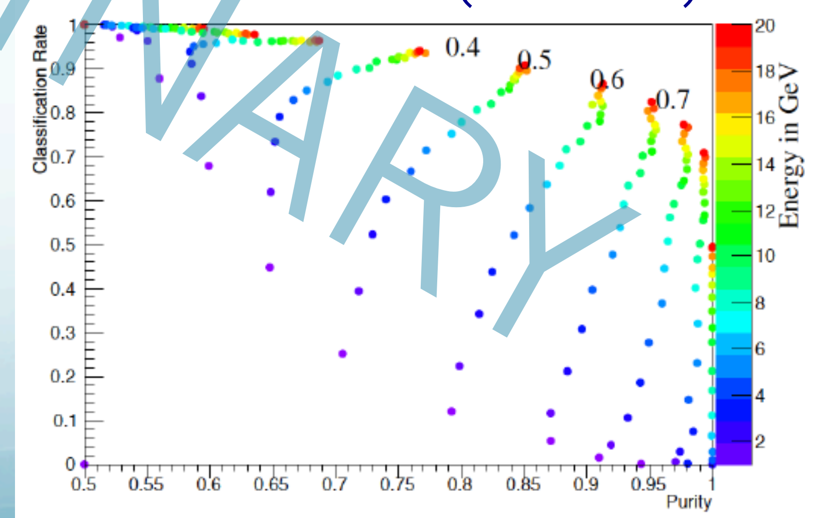
Flavour (mis)-identification

Work in progress



Used to evaluate the impact on the NMH sensitivity
(Probably optimistic?)

Goal discriminate between track-like and !(track-like)



Classification strategy

Use of machine learning algorithm based on decision trees, with 32 observables tested including: time residuals, tensor of inertia, hit distance to vertex…

Sensitivity studies

To optimally distinguish between IH and NH:
likelihood ratio test with nuisance parameters
→ *deal with degeneracies by fitting!*

$$\Delta \log(L^{\max}) = \sum_{\text{bins}} \log P(\text{data}|\hat{\theta}^{\text{NH}}, \text{NH}) - \log P(\text{data}|\hat{\theta}^{\text{IH}}, \text{IH})$$

$\hat{\theta}^{\text{H}} =$ maximum-likelihood estimates for the Δm^2's and angles using both data and constraints from global fit.
nb: constraints are different for H=IH and H=NH

1) fit mixing parameters assuming NH
2) fit mixing parameters assuming IH
3) compute ΔlogL = log(L(NH)/L(IH))

θ_{23} , Δm^2 and δ_{CP} can be fitted from data.

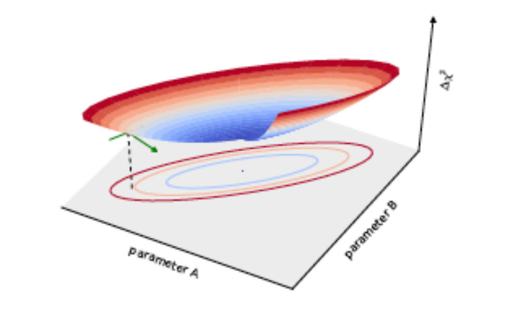
		with proposed detector (3.75Mton)		
Error on …	current	1.5 yr	2.5 yr	5 yr
θ_{23} [deg]	1.6*	0.6	0.4	0.3
Δm^2_{large} [10^{-5} eV^2]	8*	7.2	5.8	4.3

PRELIMINARY

The proper way to do ?

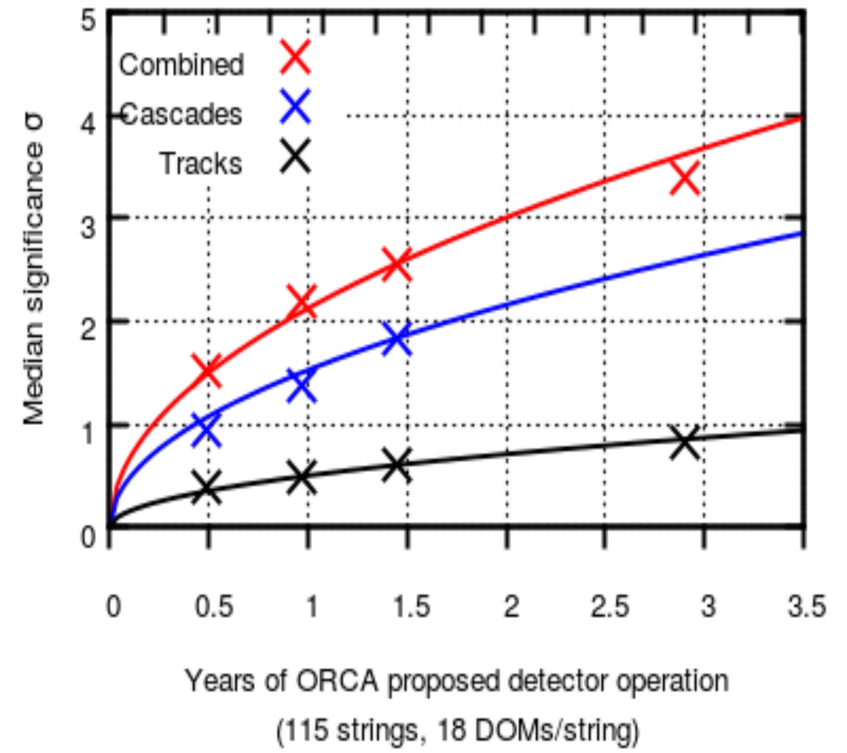
Fisher Information Matrix (FIM)

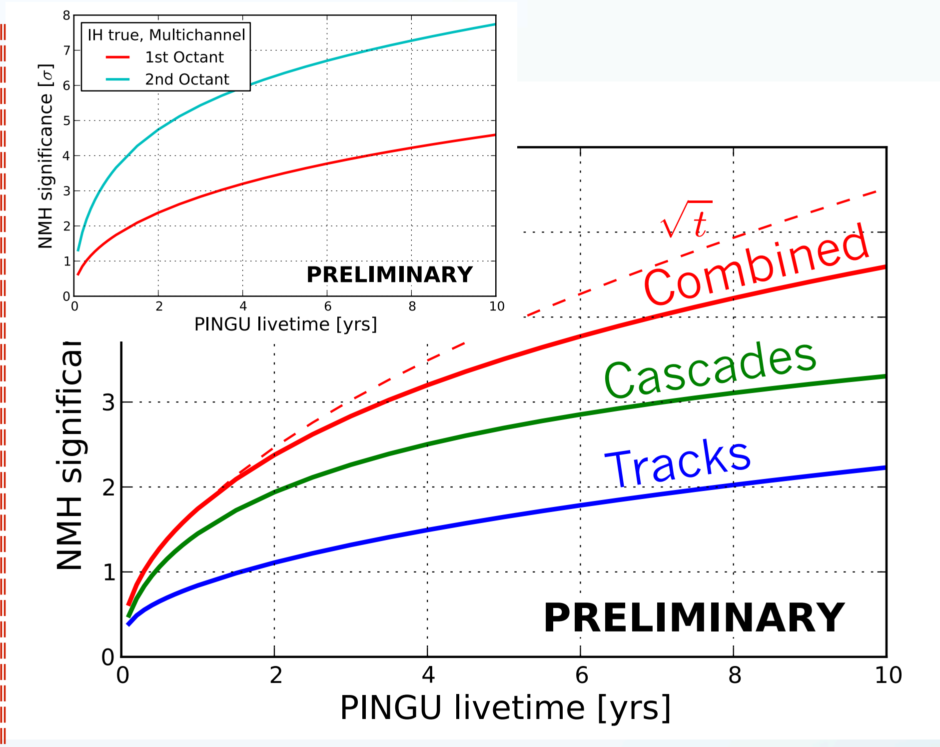
- Used in PINGU analysis
- Use 'fiducial' values (fixed true values)
- Evaluate bin-by-bin first-order derivatives of expected number of events
  ⇒ probe small region around fiducial values
- Covariance matrix from derivatives
- Yields individual and combined uncertainties



Runs much faster → easier for sys. studies

Current Sensitivities





Quite similar results

Both collaboration currently investigating details

Current ORCA Sensitivity

Pros & expected improvements

- Full correlations of osc. parameters
  ☞ *uncertainties will reduce in future*
- Most influential parameters fitted
- Improvement in the muon channel for energy
- Add reconstructed inelasticity (y)
- Try statistical separation of neutrinos (shower-like) from anti-neutrinos (track-like)
- Geometry optimisation

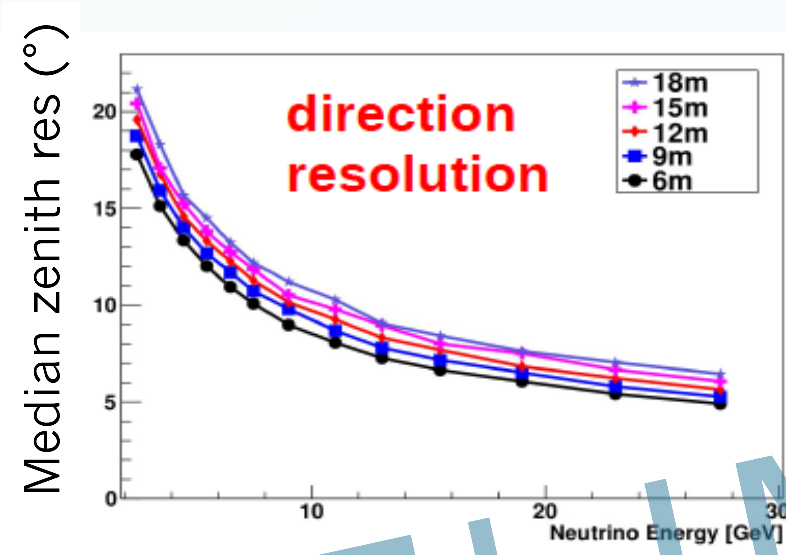
Cons & expected degradations

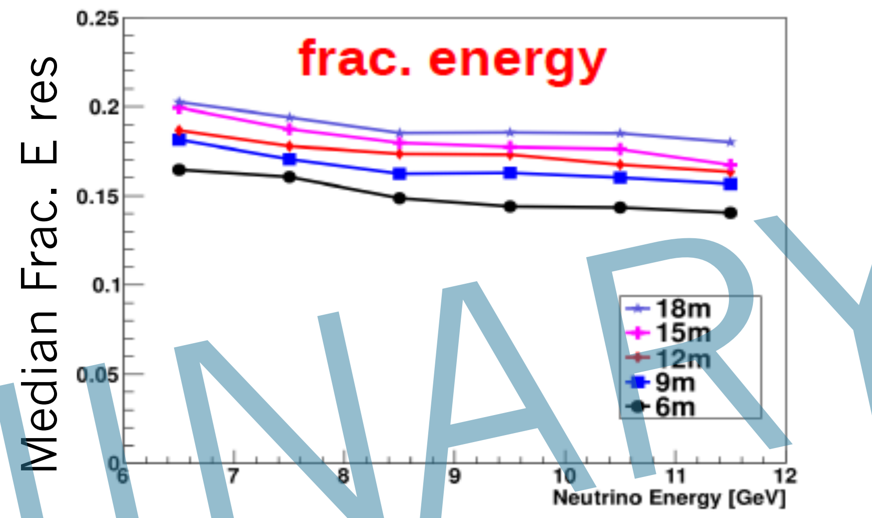
The sensitivity study does not yet account for:

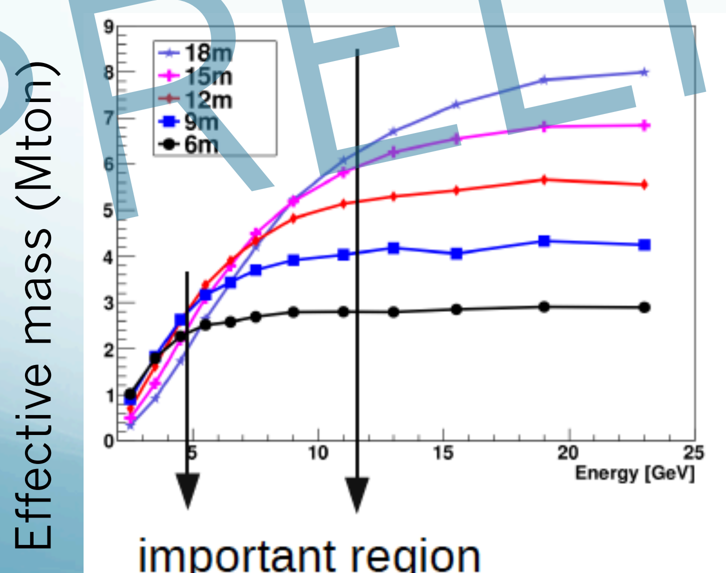
- The overall flux normalization
  ☞ *Use bins without physical affects*
- Neutral Currents and tau neutrinos
- Atmospheric muon background
- Other systematics
  - Flux polarity uncertainties
  - Flux flavour uncertainties
  - Cross sections
  - Energy scale
  - Exposure
  - Acceptance
  - …

Work in progress

Layout optimisation (ex. Shower)







All relevant quantities must be studied in details before adopting an optimum spacing

But substantial improvement possible

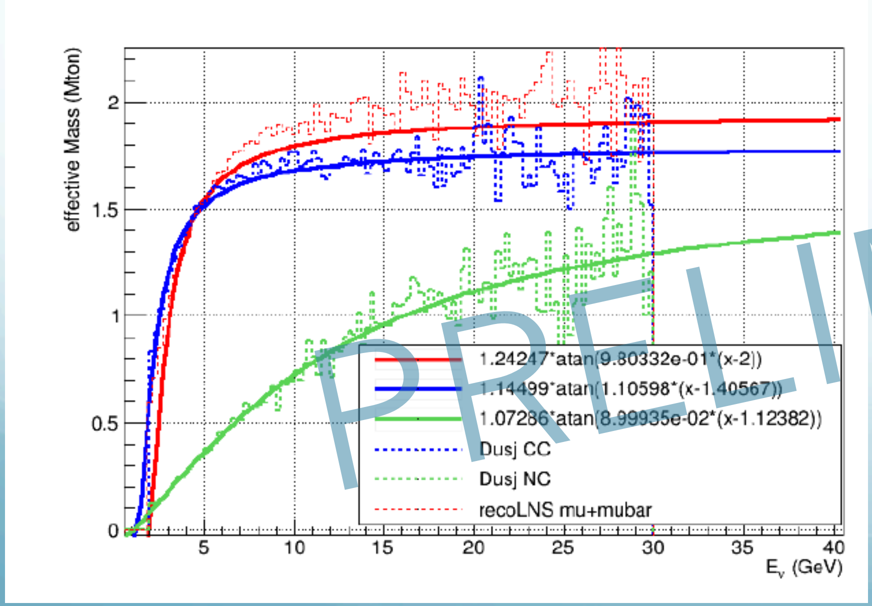
Other sensitivity studies

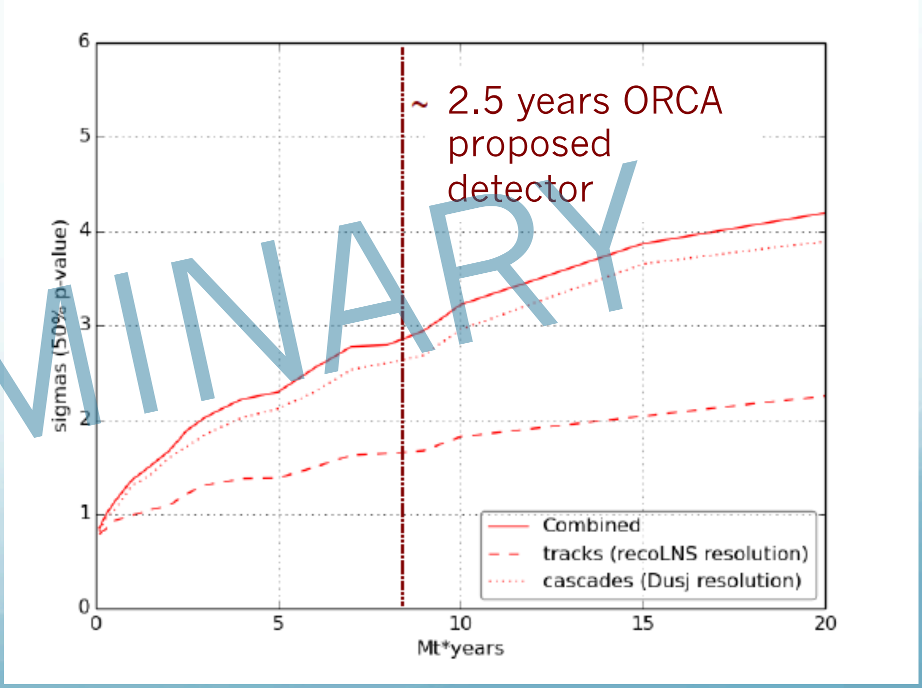
No fit

Extrapolated from 50 string detector

- Includes same reconstruction resolutions
- Same particle ID mis-identification
- Tracks includes muon and tau neutrinos (17%)
- Cascades includes NC, electron and tau neutrinos (83%)

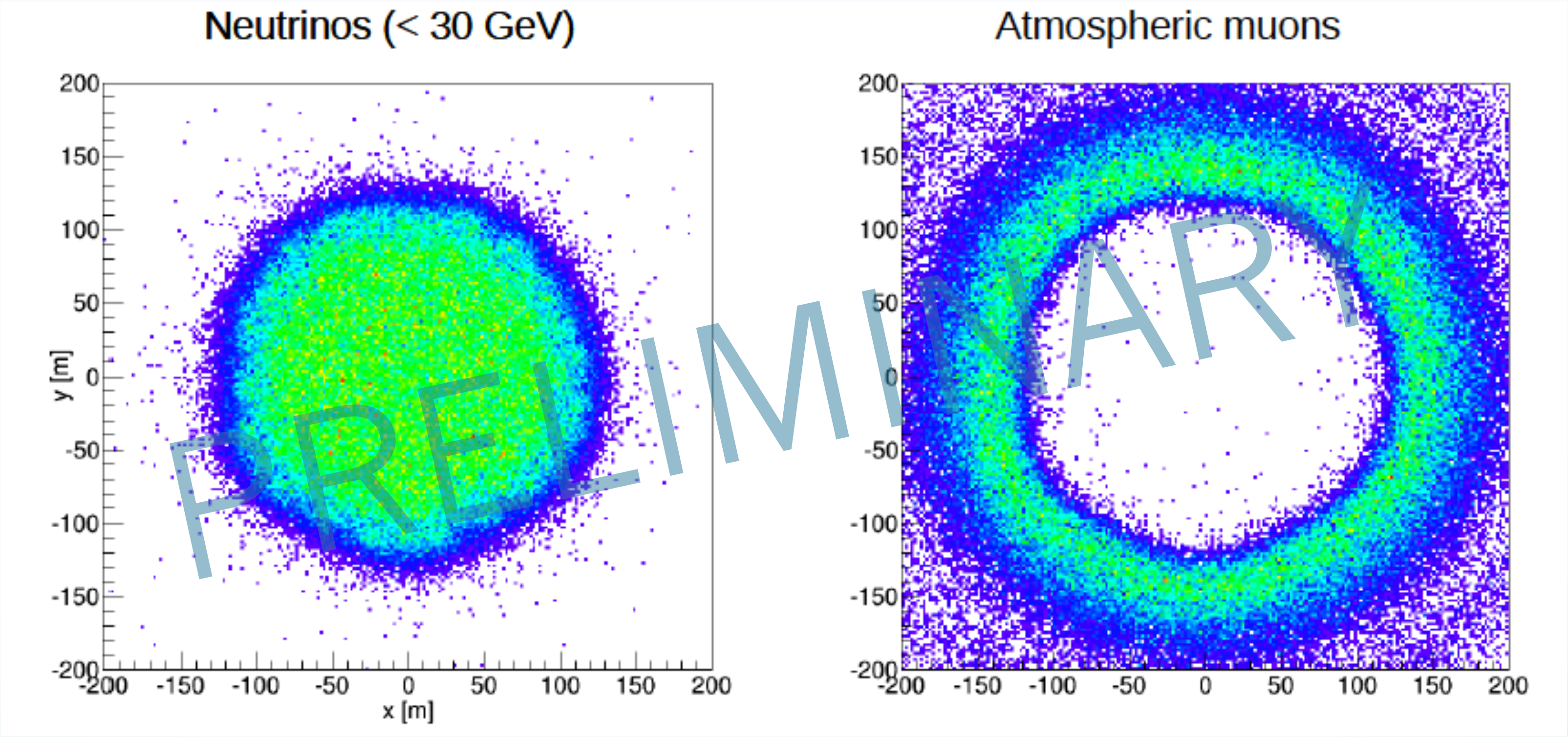
- Change hierarchy by $\Delta m^2_{13} \rightarrow -\Delta m^2_{13}+\Delta m^2_{12}$, with Δm^2_{12}=7.6E-5 eV^2
- Best fit osc. parameters from Fogli et al. (thus theta_23 ~ 38 deg)
- δ_{cp}=0





Atmospheric muon rejection

Cut on the reconstructed pseudo-vertex and quality parameters of reconstruction



Boosted Decision Tree

reconstruction quality,

vertex distance to center

Instrumental veto is not mandatory
(though not impossible)

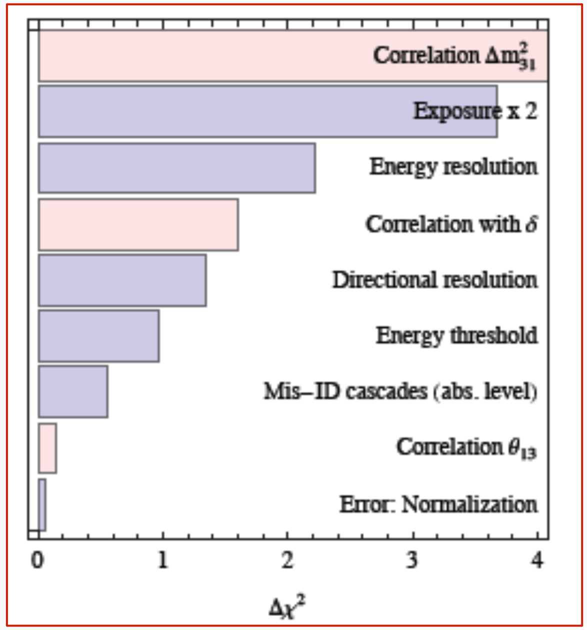
1% contamination achievable without strong signal loss

Room for improvement

Studies of systematics

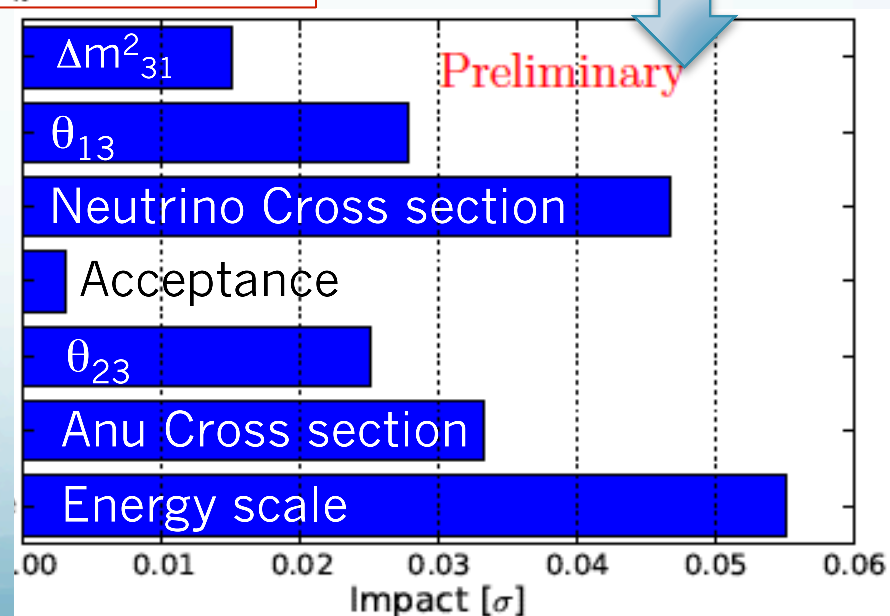
W. Winter, PRD 88 (2013) 013013

Systematics	Opt.	Def.	Cons.
Experiment properties:			
Fiducial mass and energy threshold	(*)	12/2012	12/2012
Energy res. $\Delta E/E$	0.15	0.25	0.35
Dir. resolution $\Delta\theta_z$	$0.5\sqrt{\frac{m_p}{E}}$	$0.6\sqrt{\frac{m_p}{E}}$	$\sqrt{\frac{m_p}{E}}$
Cascade mis-ID frac.	0.01	0.05	0.1
Systematical uncertainties:			
Normalization	0.10	0.25	0.35
mis-ID cascades	0.05	0.075	0.10
Cross sections (DIS)	0.05	0.075	0.10
Matter density	0.005	0.01	0.05
Uncertainties of atmospheric neutrino flux:			
Normalization	Included in "Normalization"		
Slope error (zenith bias)	0.01	0.04	0.10
Flavor ν_e/ν_μ	0.005	0.01	0.02
Polarity $\bar{\nu}_\mu/\nu_\mu$	0.01	0.02	0.03
Polarity $\bar{\nu}_e/\nu_e$	0.01	0.025	0.03
BG down-going	0.05	0.075	0.10



PINGU LoI arXiv1401.2046

Impact on 1year significance (total 1.75 σ)



Several other studies → same conclusions

e.g D. Franco et al, JHEP 04 (2013) 008

Project timelines

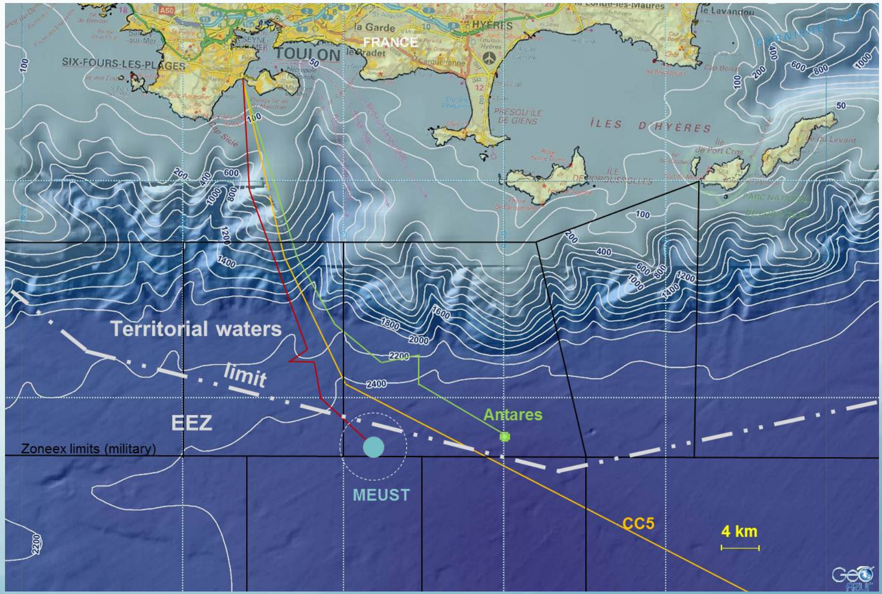
"Detector construction can be completed five years after funding starts, or as early as 2020."
"The PINGU share of the facility cost is roughly \$55M (US cost, including contingency) plus \$25M (foreign contribution) for a total of 80M\$."
📖 arXiv:1409.5755v2

P5 report:
"[...]cannot go forward as major projects at this time, due to concept maturity and/or program cost considerations. However, further development of PINGU is recommended [...]"
"...we encourage continued work to understand systematics. PINGU could play a very important role as part of a larger upgrade of IceCube, or as a separate upgrade, but more work is required."

ORCA is part of the KM3NeT program

Phase 1 (funded) : deploy a 6-7 string array In the ORCA configuration to demonstrate detection method in the GeV range.

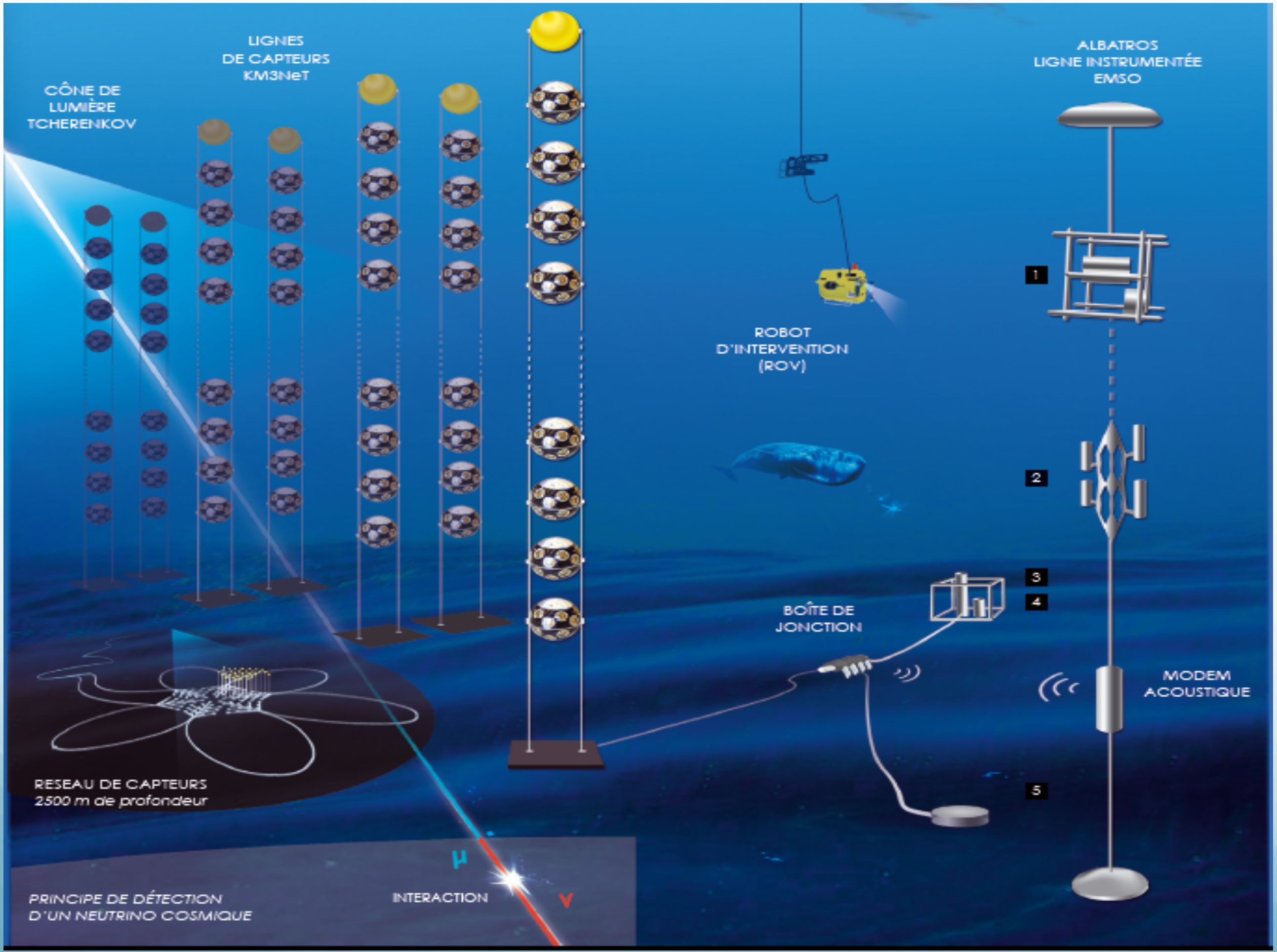
Phase 1.5 (+31 M€) : deploy 1 building block 115 strings in French KM3NeT site. Completion in 2019



ORCA can be first !

MEUST infrastructure

Submarine infrastructure of 2nd generation (wrt ANTARES) shared between the European neutrino (KM3NeT/ORCA) and Sea Science (EMSO) communities.

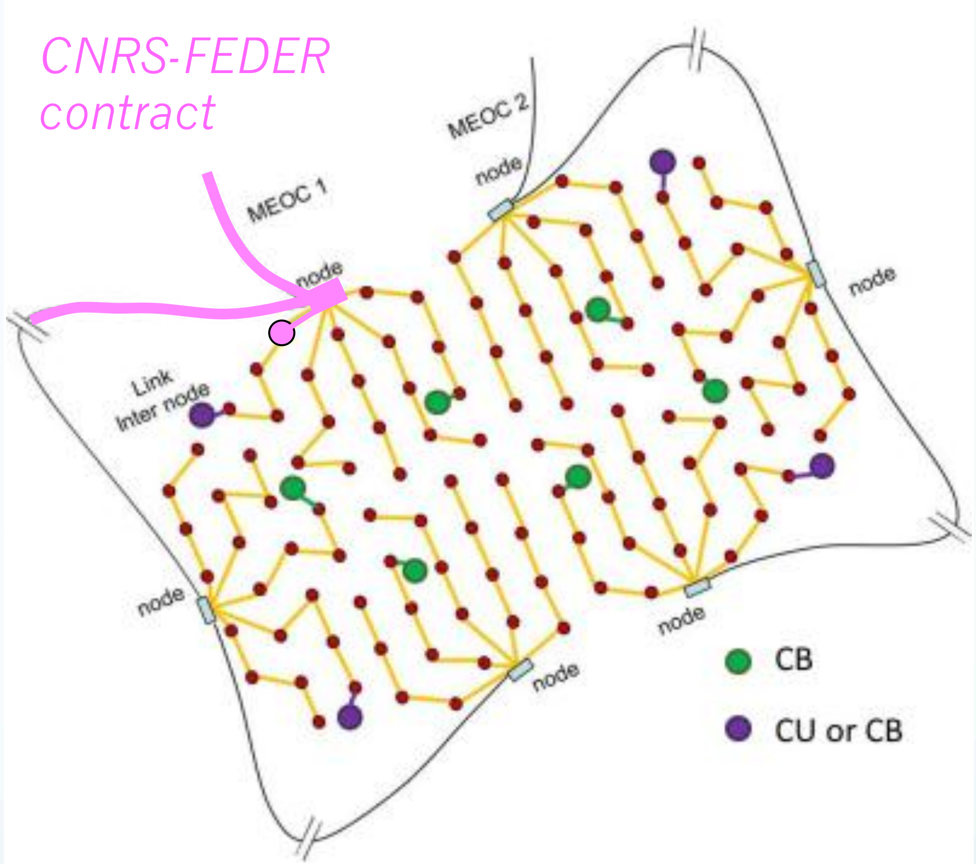


MEUST

MEDITERRANEAN EUROCENTRE FOR UNDERWATER SCIENCES AND TECHNOLOGIES

MEUST infrastructure

- Modular ring of up to 6 nodes with double connection to shore
- Up to 120 ν DUs
  + Sea Science instruments
- Electrical power in HV AC (as ANTARES) and data optical transfer with dense multiplexing (DWDM KM3NeT)

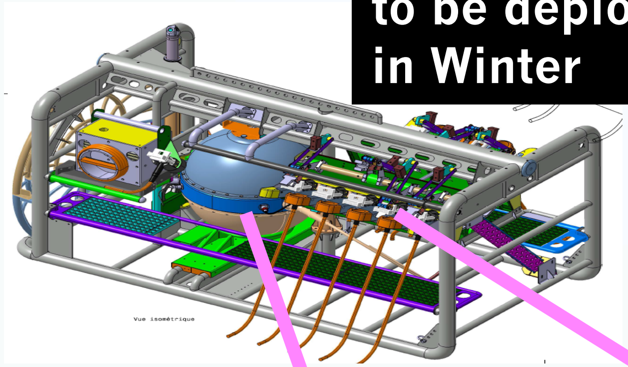


Possibility to redirect the ANTARES cable to MEUST as Main Cable 2.

CNRS-FEDER contract of 7 M€ (2011-15) for engineering of main components :
1 Main Cable, 1 node, 1 ν DU and SS devices

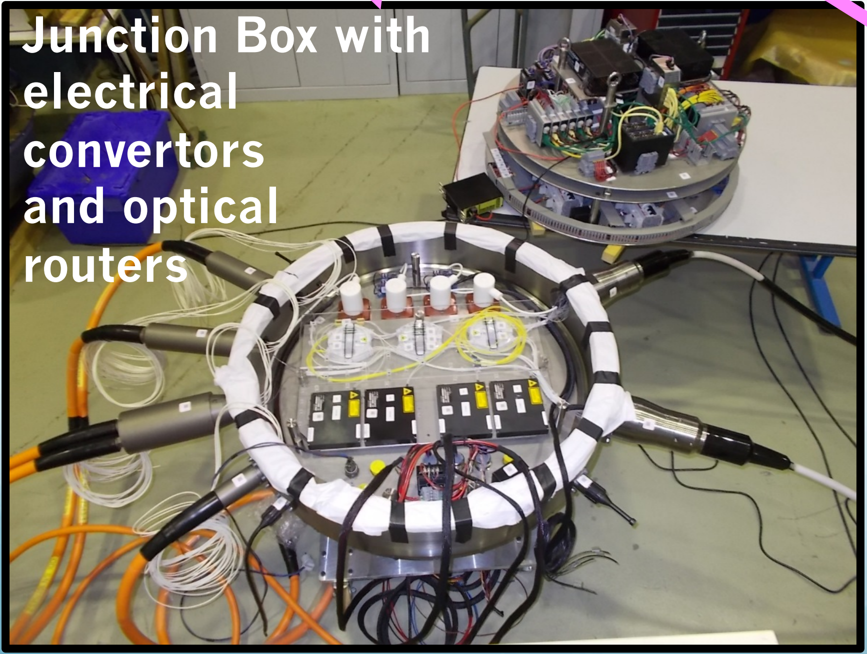
<u>New</u>: 6 more ν DUs financed by KM3NeT to be deployed in the ORCA dense configuration to exercise low E ν reconstruction !

MEUST components



Network node, to be deployed in Winter

Main Cable stored at La Seyne/ Mer, to be deployed in December



Junction Box with electrical convertors and optical routers

New connection tools for light ROV

Comex

Finance

Existing funds (Phase 1)

France:	7 M€ (MEUST-CNRS/FEDER, 4 yrs)
Italy:	16 M€ (PON-ERDF, 3 yrs)
The Netherlands:	8 M€ (FOM)
Germany:	0.15 M€ (Univ. Erlangen)

Requested funds (ORCA, high energy)

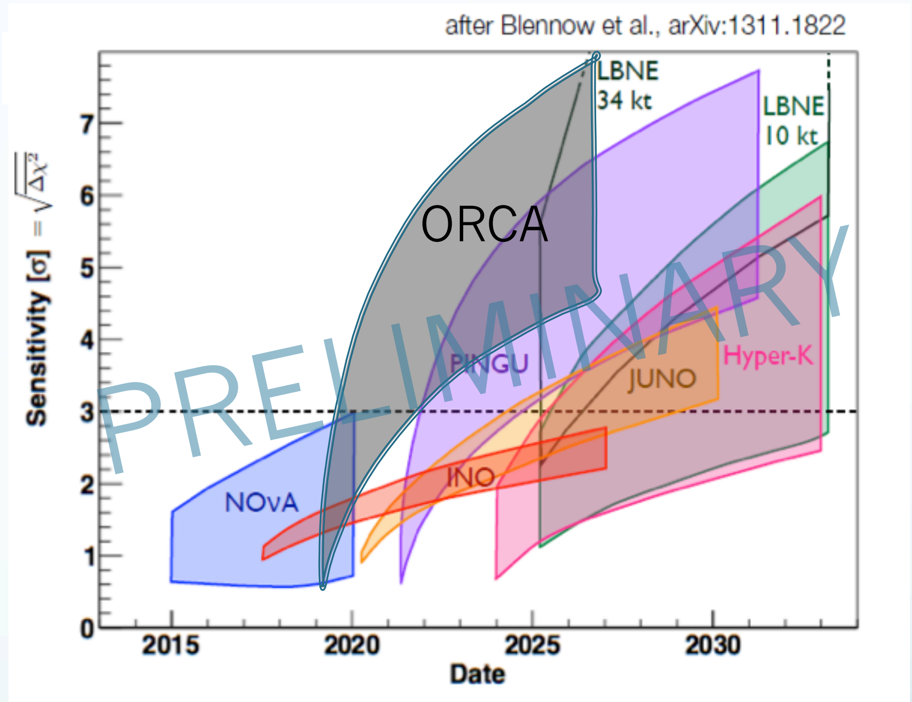
France:	12.4 M€ (NUMerEnv-CNRS/CPER/FEDER, 5 yrs)
	2.5 M€ (ERC-advanced grant: Coyle)
	1 M€ (ANR: Kouchner, Dornic)
Italy:	10 M€ (INFN, 5 yrs)
	? M€ (ERDF)
The Netherlands:	5+5 M€ (FOM, 5 yrs)

Greece, Germany, Spain, Romania, Poland, UK, …- under discussion

Summary

- Atmospheric Neutrinos have still a major role to play for precision measurements and determination of unknown parameters such as the mass hierarchy.
- Low energy (GeV) extensions of Neutrino Telescopes faster and cheaper than other alternatives...
- ...but challenging. So far no showstopper identified. ORCA will proceed with a demonstrator array.
- ORCA broadens the scientific scope of KM3NeT. Full support of the collaboration. LoI soon next year.
- Positive signals for funding requests

We need the support of the French Neutrino community!



KM3NeT/ORCA is a great opportunity for France (among IN2P3 priorities):

- Host a detector
- Provide a first measurement clearly identified as a need by the scientific community