

Groupe Neutrino

HCERES

Report 2013-17

Present Composition

•[9] permanents

- Stavros Katsanevas* (Prof), Antoine Kouchner* (Prof), Thomas Patzak* (Prof), Véronique Van Elewyck (MC), Alessandra Tonazzo* (Prof)
- Anatael Cabrera (CR), Jaime Dawson(CR), Davide Franco*(CR)
- Thierry Lasserre* (DR CEA) [*HDR]

•[4] postdocs

- Marco Grassi, LiquidO, Marie Curie,
- Anthony Onillon, Double Chooz, IN2P3, 15/09/2015 – 14/09/2018
- Christine Nielson, KM3NeT/ORCA, 09/2017 –
- Stefan Wagner, LiquidO, CDD, July. 2017 – June. 2018

•[5] PhD students

- Theodoros Avgitas*, CD , Antoine Kouchner, 11/2014 – 11/2017
 - Simon Bourret*, AMX, Veronique Van Elewyk (Eduoard Kaminski), 09/2015 –2018
 - Timothée Gregoire*, CDE , Antoine Kouchner, 10/2015- 2018
 - Yan Han, CSC, Anatael Cabrera, 09/2017 – 2020
 - Andrea Scarpelli, CD , Thomas Patzak & Alessandra Tonazzo, 10/2016 – 2019
- [*aussi membres du groupe Haute Energies – KM3NET]

Recent Evolution (last 5 years) - I

•Permanents

Christiano Galbiati, DarkSide, invited professeur UPSC, 03/2016 – 12/2016

Fumihiko Suekane, LiquidO, chair Blaise-Pascal , 04/2017 – 11/2018

Michel Cribier (CEA DR), emeritus 2009

Herve de Kerret (DR), emeritus 2014

Francois Vannucci (PR), emeritus 2012

Daniel Vignaud (DR), emeritus 2007

Didier Kryn (CR), retired 2013

Michel Obolensky (CR), retired 2015

•Postdocs

Hector Gomez, DoubleChooz/MuonTomography, labex UnivEarth (E4), 09/2014 - 09/2017

Joao de Abreu Barbosa Coelho, KM3NET ORCA, labex UnivEarth (E4), 12/2015 – 09/2017

Quentin Riffard, DarkSide, UnivEarth (E4), 11/2015 – 09/2017

Romain Roncin, Borexino/SOX, E4, 11/2014 – 11/2016

Marghertia Buizza Avancini, LBNO, 02/2012 – 05/2014

Jonathon Gaffiot, SOX, E4, 12/2012 – 11/2014

Pau Novela, Double Chooz, Marie Curie, 2012-- 2013

Recent Evolution - II

•Theses defended

- Adrien Hourlier, Double Chooz, ecole doctorale, 09/2016
- Thibaut Houdy, Borexino/SOX, CDE E4, 09/2017
- Paolo Agnes, DarkSide, CD E4, 09/2016
- Romain Roncin, Double Chooz/Borexino, 09/2014
- Alberto Remoto, Double Chooz, 09/2012
- Luca Agostino, Feasibility study of a new generation neutrino detector in the context of the LBNO experiment, 09/2014

•International co-supervision

- Thamys Abrahao, Double Chooz, PUC-Rio (Brazil),10/2017
- Luis Gomez, Double Chooz, CBPF (Brazil)
- Aldiyar Oralbaev, Double Chooz, Kurchatof Institute, 2018

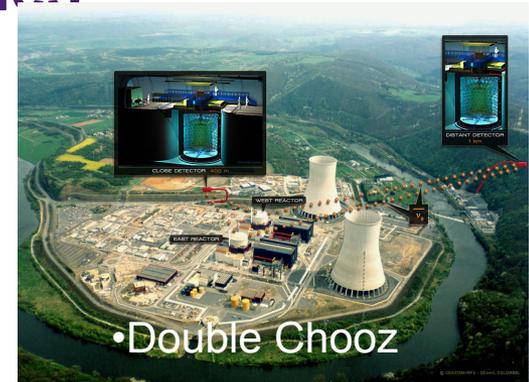
•HDR obtained or imminent

- Davide Franco, 2016
- Anatael Cabrera

The Neutrino Group

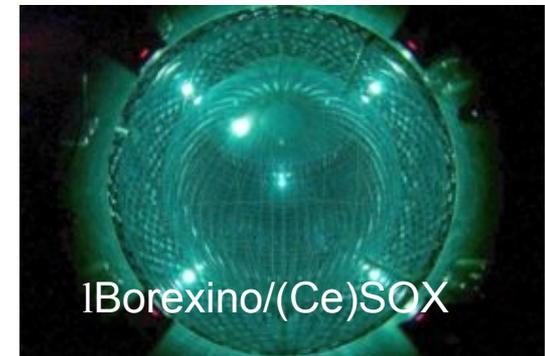
Fundamental Neutrino Properties

Oscillation parameters
Mass Hierarchy
Leptonic CP violation
Sterile Neutrinos



Neutrino Observatories

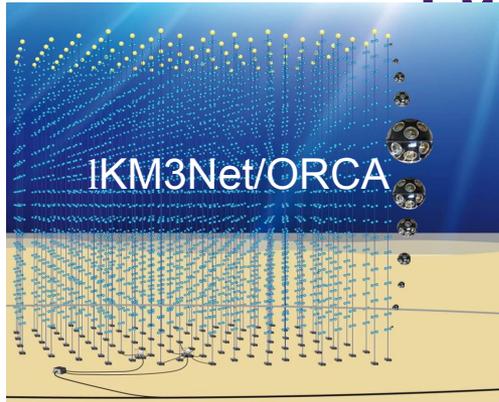
Solar Neutrinos
Geo-neutrinos
Atmospheric neutrinos
Supernova



Dark Matter

darkside

two-phase argon TPC for Dark Matter Direct Detection



upcoming experiments

Open Questions (not exhaustive)

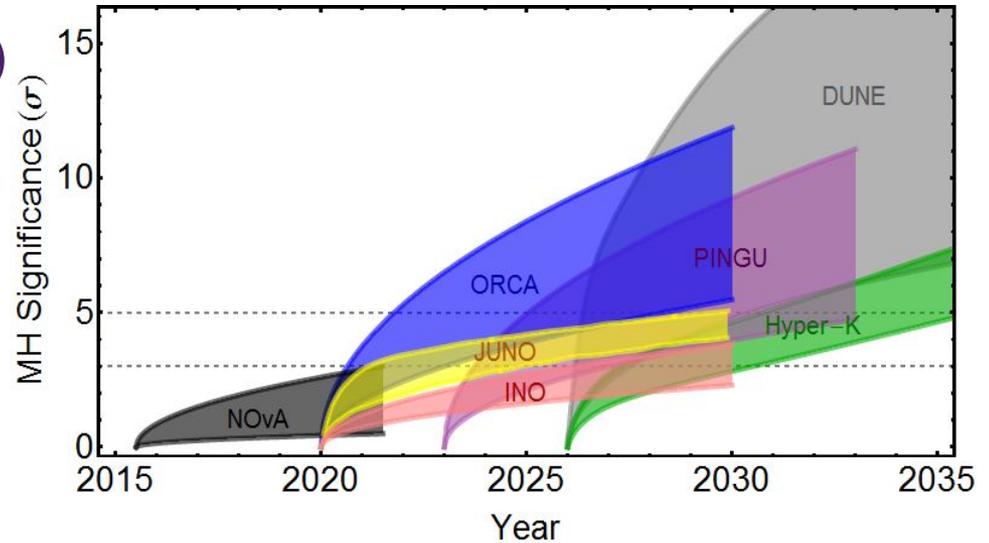
$\theta_{23} \sim 45$ degrees - Octant?

Mass hierarchy

CP violation δ_{cp}

Tests of 3ν paradigm

Sterile?



Mass Hierarchy -
ORCA JUNO DUNE

CP-violation - DUNE

Precision oscillation parameter measurements to
test 3ν paradigm - JUNO DUNE

Sterile neutrinos - Borexino/SOX

Organisation – I

- Group leader: rotation 2-3 ans
 - Alessandra Tonazzo : 2009 – 2012
 - Antoine Kouchner : 2012 – 2015
 - Jaime Dawson : 2015 – present
 - Adjoint – Antoine Kouchner
- Budget: ~18keuro (80%)
 - Conferences/schools for PhD students, postdocs, researchers
 - Neutrino 2016 – 8 people attended
 - Thesis defense (~2/year), HDR (~1/year)
 - laptops etc..
- Seminar organiser – Marco Grassi (prev, J. Coelho)
- Monthly meetings
 - Round table, News, Upcoming events, Short presentation by groupe member (new arrivals, post docs, students)
 - Attendance variable – Doodle, 6 - 15 people
 - Minutes on neutrino wiki <http://www.apc.univ-paris7.fr/APCMediaWiki/Neutrino>
- Leaving drinks, celebrations etc
- Collect Information/Presentations for: Biennale, HCERES, CSP (annual), Dialog, base indicateurs APC, NSIP, DAS visit, Conseil Scientifique (annual)

Organisation - II

- KM3NeT ORCA/ANTARES – **Veronique Van Elewyck** (100%), Antoine Kouchner (100%), Theodoros Avgitas (100%), Simon Bourret (100%), Timothee Gregoire (100%), Christine Nielson (100%)
- ProtoDUNE/WA105/DUNE – **Thomas Patzak** (100%), Alessandra Tonazzo (60%), Jaime Dawson(50%), **Andrea Scarpelli**(100%)
- DarkSide – **Davide Franco** (60%), Alessandra Tonazzo (20%)
- Borexino/SOX – **Davide Franco** (30%), Michel Cribier, Thierry Lasserre
- Double Chooz – **Anatael Cabrera** (40%), Herve de Kerret, **Anthony Onillon** (100%), Jaime Dawson (50%), Davide Franco (10%), Alessandra Tonazzo (20%), Fumihiko Suekane (25%)
- JUNO – **Anatael Cabrera** (20%), **Yan Han** (100%)
- LiquidO R&D – **Anatael Cabrera** (40%), **Marco Grassi** (100%), Stefan Wagner (100%), F. Suekane (75%)

	Double Chooz	Borexino/SOX	KM3NeT/ORCA	DUNE	JUNO	DarkSide	LiquidO
Anatael Cabrera	40%				20%		40%
Jaime Dawson	50%			50%			
Davide Franco	10%	30%				60%	
Antoine Kouchner *			25%				
Thomas Patzak*				50%			
Véronique Van Elewyck *			25%				
Fumihiko Suekane	25%						75%
Alessandra Tonazzo *	10%			30%		10%	
Michel Cribier		100%					
Thierry Lasserre	40%	60%					
Herve de Kerret	90%				10%		

FTE

* lecturers/professors 50% FTE for teaching

	Double Chooz	Borexino/SOX	KM3NeT/ORCA	DUNE	JUNO	DarkSide	LiquidO
Marco Grassi							100%
Christine Nielson			100%				
Anthony Onillon	100%						
Stefan Wagner							100%
Remy Le Breton			75%				
Alexandre Creusot			25%				
Theodoros Avgitas			100%				
Marta Colomert			50%				
Timothee Gregoire			100%				
Yan Han					100%		
Andrea Scarpelli				100%			

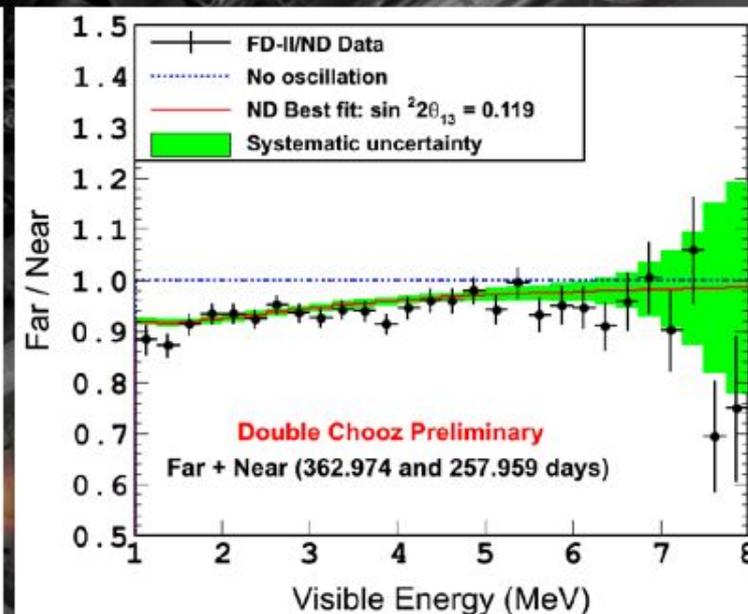
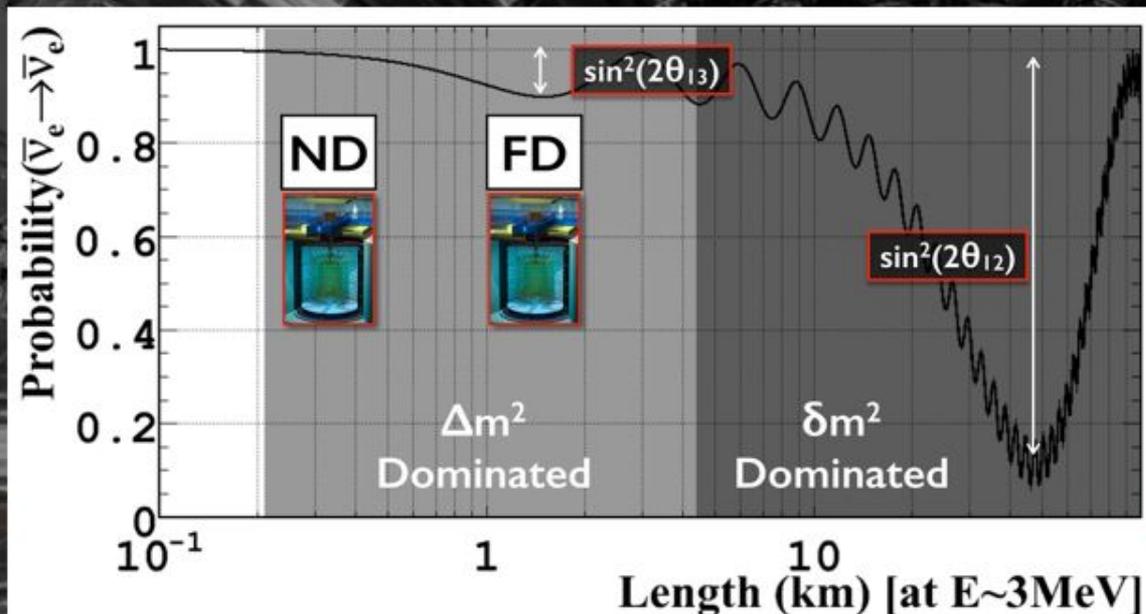
FTE

faites marquants — Double Chooz

APC DC-group (10 physicists) responsible: Anatael Cabrera

Spokesperson: Hervé de Kerret (APC)

IN2P3/CNRS national responsible: Anatael Cabrera (laboratories: APC, CENBG, SUBATECH)



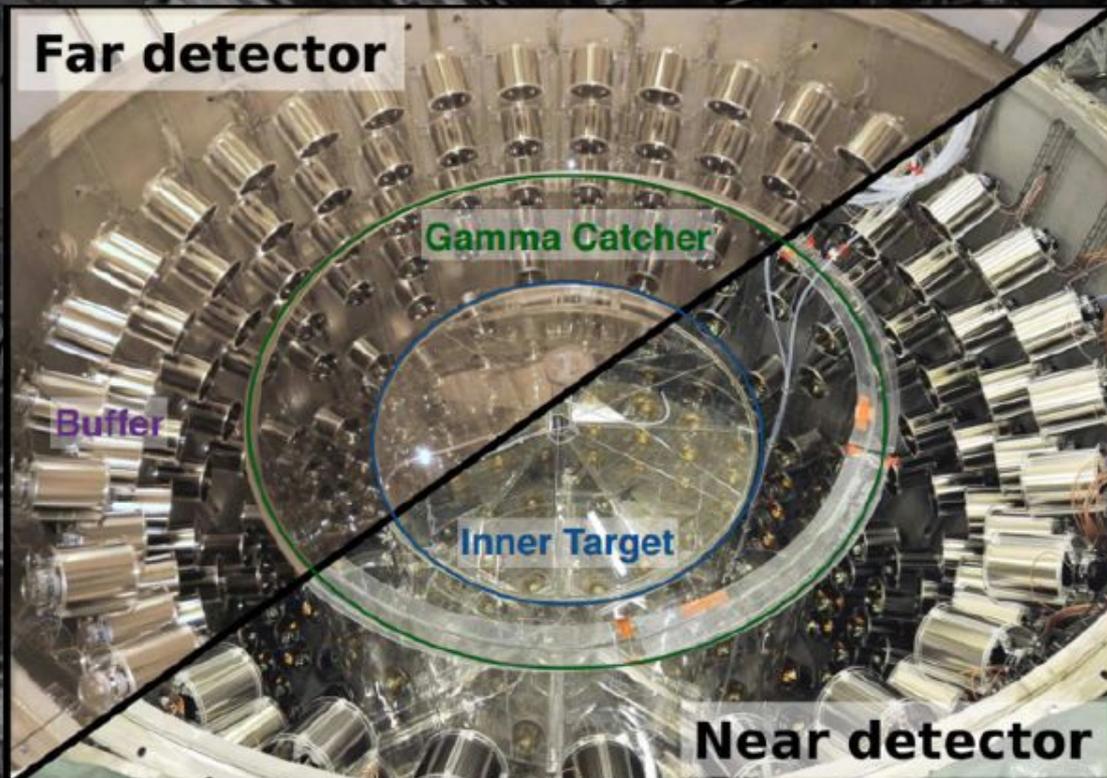
$\sin^2(2\theta_{13})^{R+S} = (0.119 \pm 0.016)$ — first multi-detector result

- **physics operations** (physics analysis coordination @ APC) ...
 - **detector:** selection, background/vetoes, detection systematics [past: energy]
 - **reactor:** prediction & systematics (Anthony Onillon **reactor coordination**)
- **detector operations** (detectors coordination @ APC) ...
 - **LNCA laboratory running** (director A. Cabrera) & reactor data collection
 - **detectors running & decommissioning preparation (2018)** [past: commissioning]

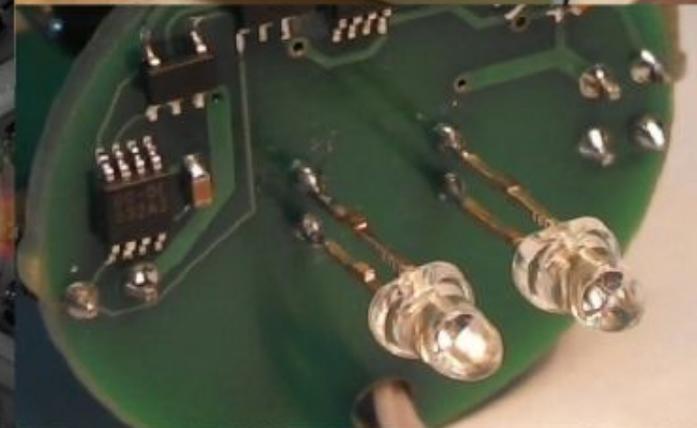
contributions techniques — Double Chooz

APC DC-group: ~9 physicists (1 emeritus) + ~6 engineers (past)

Far detector



new Cf-tag (2xLED's light) source



- **detector construction** (major mechanics & electronics contributions)...

- **mechanics:** shields, inner-veto tanks, electronics huts, bridges, etc
- **electronics/DAQ:** FADC electronics (w CAEN), DAQ, Trigger/FEE support, computing on site
- **calibration:** Cf-tag source (LIA collaboration with Kurchatov, Moscow, Russia) [PhD student]

- **detector operations** (detectors coordination @ APC)...

- FD and ND commissioning, running (weekly visits) decommissioning preparation (ongoing)

perspectives — Double Chooz

APC DC-group: ~9 physicists (1 emeritus)

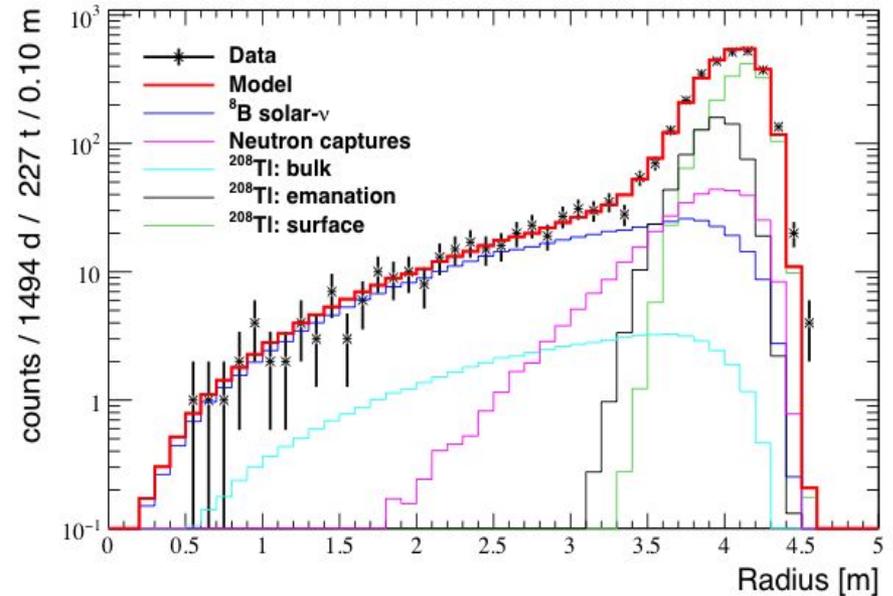
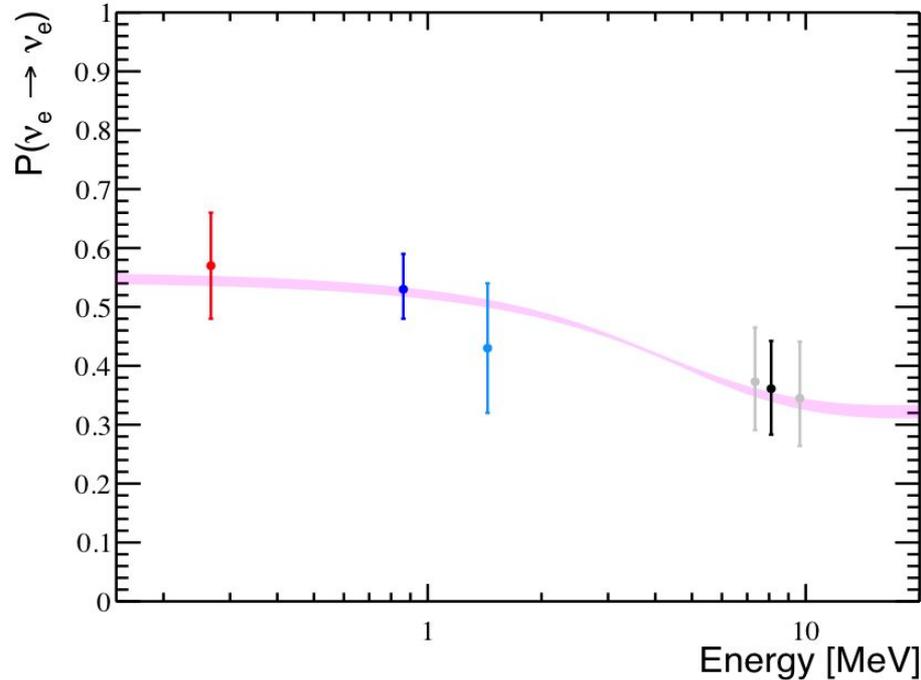
• detectors...

- de-commissioning detectors during 2018-2019 (schedule being prepared)
 - (by-product) re-measure the proton# composition of detection volumes
 - proton#: dominant systematic (accuracy & precision improvement)

• physics...

- **DC-IV result being write-up** (publishing within 2017)
 - first multi-detector θ_{13} measurement
 - most precise “**mean cross-section per fission**” supersede Bugey4 (best some 90's)
 - other results...
- **DC-V final publication** (likely all results)
 - ultimate θ_{13} precision (expected $\geq 2x$ wrt now)
 - rate+shape reactor shape prediction analysis
- **a few dedicated publications** (under discussion prior to DC-V)
 - energy, IBD-directionality (supersede CHOOZ), etc

Borexino/SOX



Activities at APC:

- measurement of the ^8B neutrino rate with 3 MeV energy threshold
(D. Franco and T. Houdy, PhD in 2017)
- determination of the backgrounds in the ^{144}Ce neutrino source with gamma spectroscopy
(APC-CEA collaboration: D. Franco and T. Lasserre)

^{144}Ce neutrino source (SOX) deployment in March 2018!

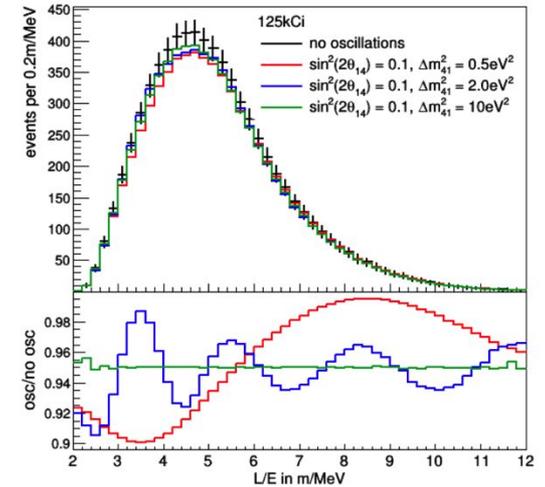
Borexino/SOX

150 kCi ^{144}Ce anti-neutrino source at 8.5 m from the detector center for test of sterile neutrino hypothesis

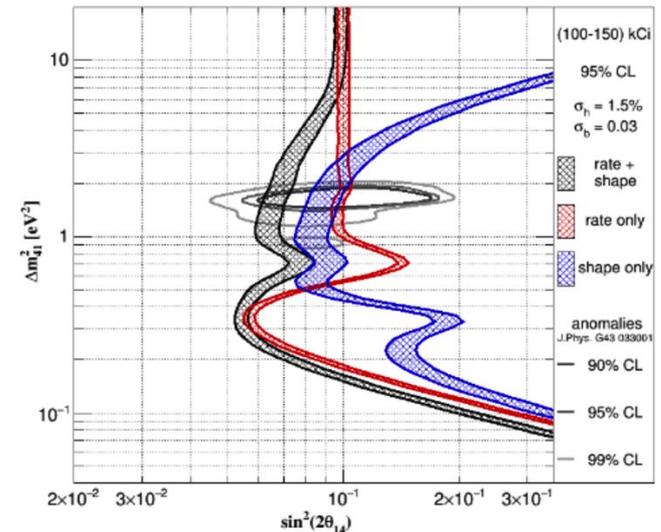
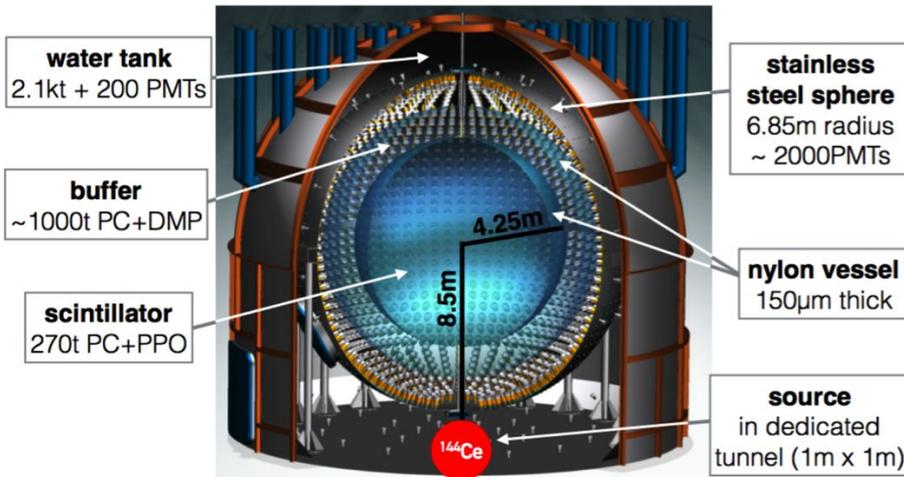
1.5 year of data taking from the deployment (scheduled for March/April 2018)

Rate measurement: activity at $\sim 1\%$ level, thanks two 2 calorimeters

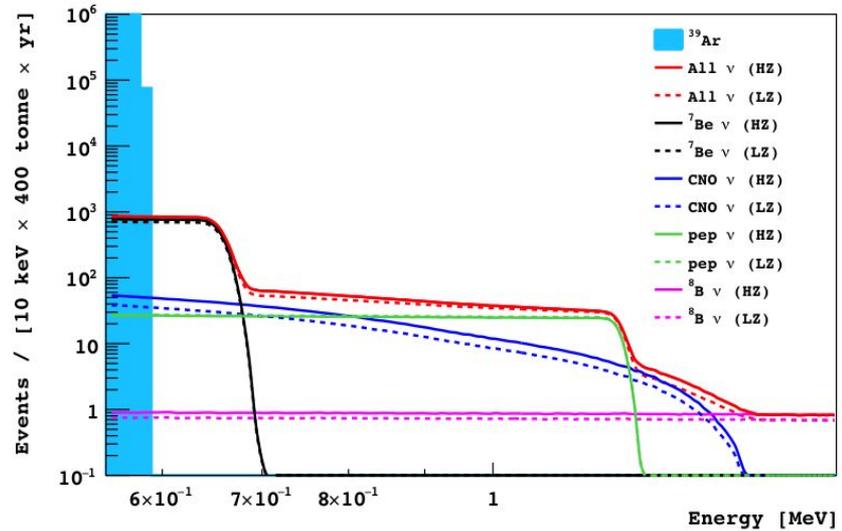
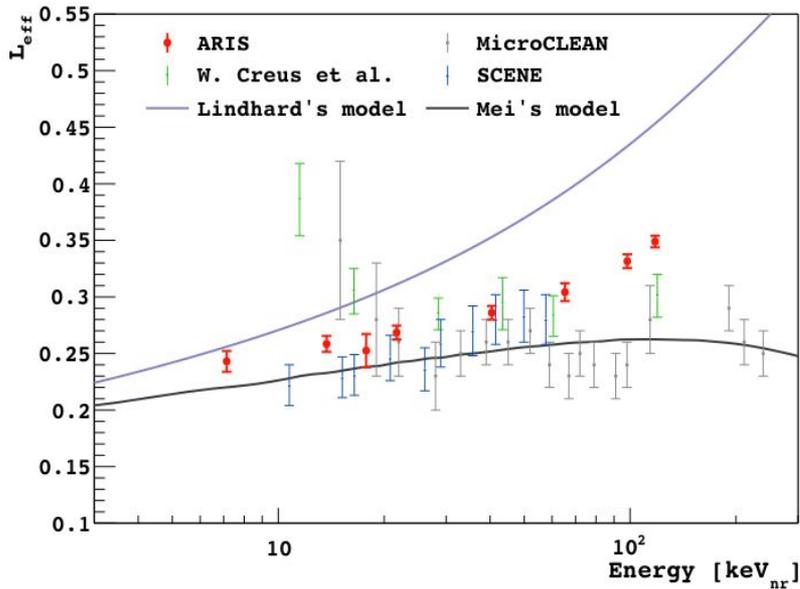
Shape measurement: new Borexino calibration campaign in January



The Borexino detector.



DarkSide



Activities at APC:

-sensitivity study to solar neutrinos in 400 t x y liquid argon exposure

(DarkSide Science and Computing coordinator: D. Franco)

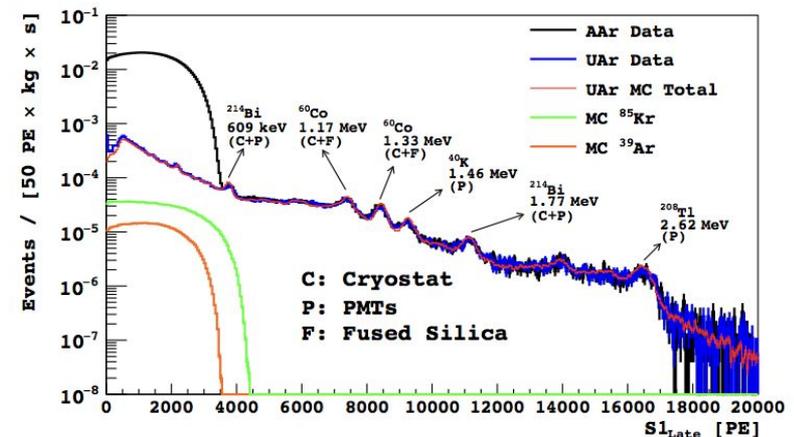
-measurement of the liquid argon response to nuclear and electron recoils with the ARIS setup

(D. Franco P.I., project funded by LabEx UnivEarthS)

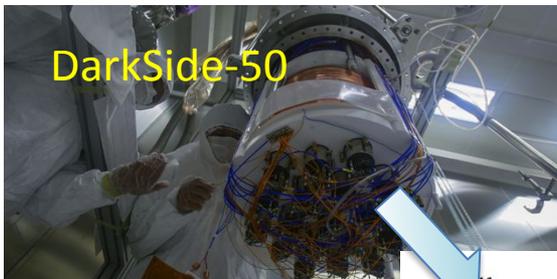
-measurement of the ^{39}Ar depletion factor in underground argon

(D. Franco with P. Agnes, PhD in 2016)

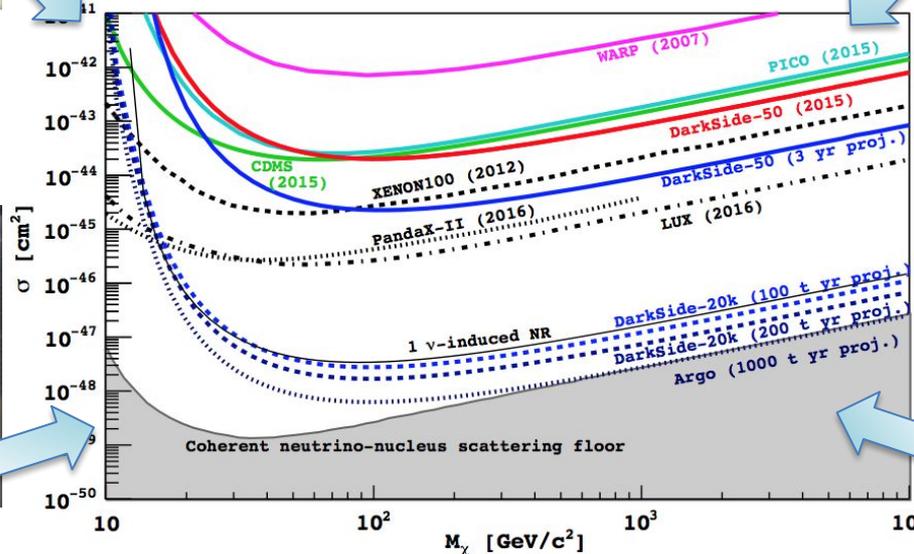
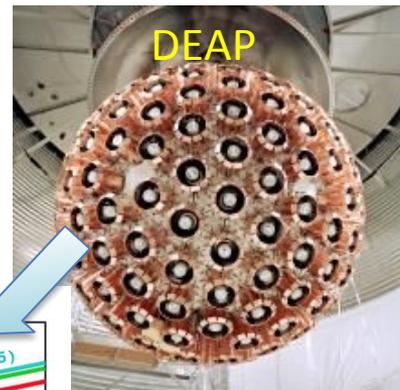
DS-50 filled with UAr in March 2015



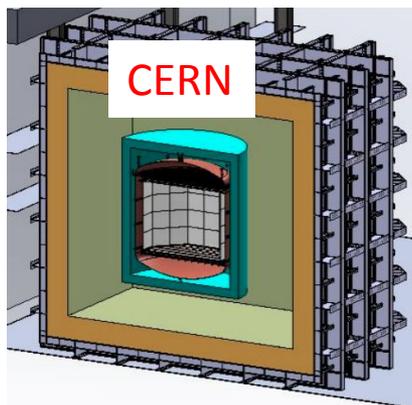
DarkSide-20K



Global effort from all liquid argon experiments looking for dark matter



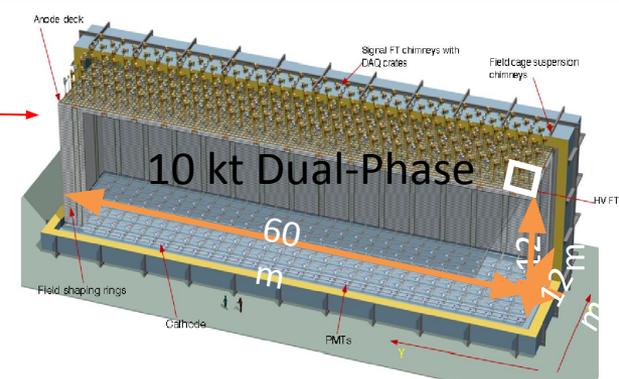
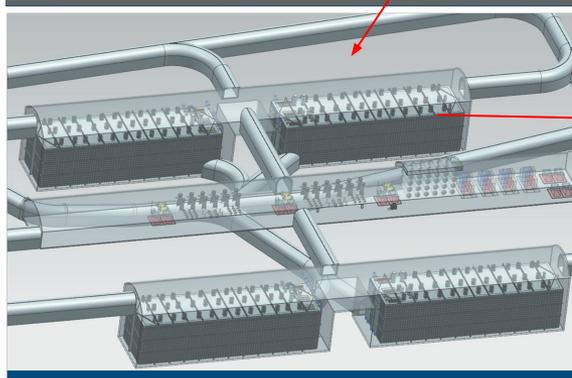
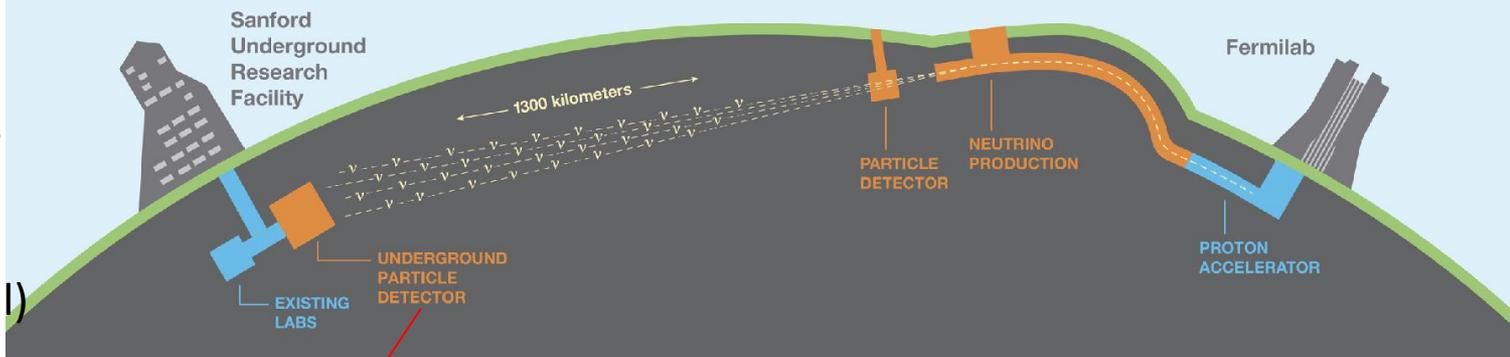
Access to current DEAP-3600 data



Discussion with CERN on going: interest in participating with the DUNE cryostat technology

Next generation long baseline experiment:

- 1000 scientists
- 30 Countries
- 160 Institutions
- 1,5 G\$
- 4 x 10 kt fiducial)
- 1 MW beam



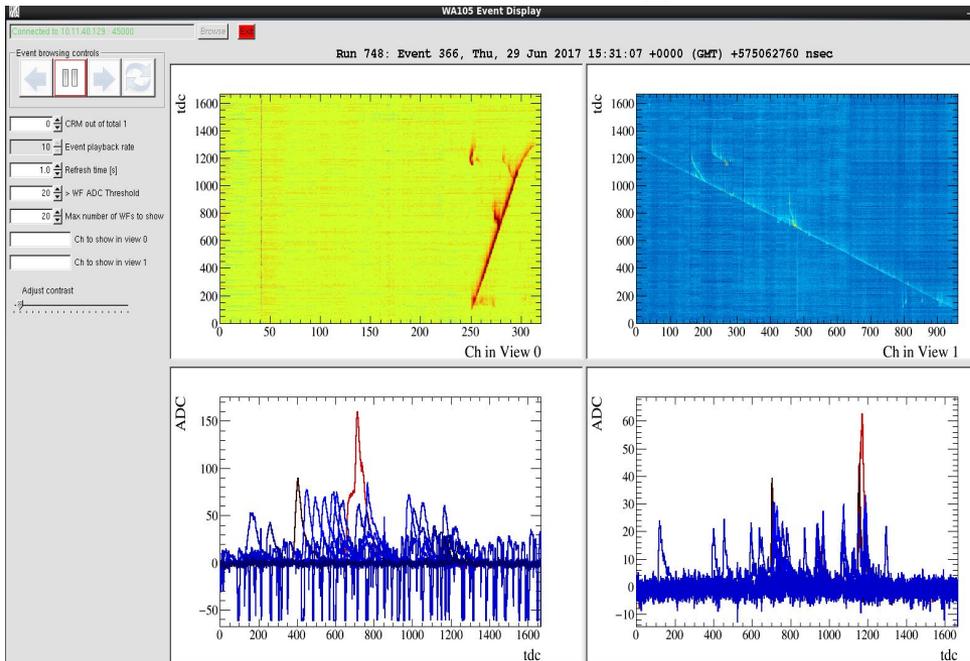
DUNE Science:

- 5 σ discovery of leptonic CP violation
- Measurement of CP phase
- 5 σ determination of mass hierarchy
- Proton Decay
- Supernova neutrinos (time and spectral)
- Relic supernova neutrinos
- Atmospheric neutrinos

Physics milestone	Exposure kt-MW-years (optimized beam)
1 σ Δ_{23} resolution ($\Delta_{23} = 42^\circ$)	45
CPV at 3 σ ($\theta_{CP} = +\pi/2$)	60
CPV at 3 σ ($\theta_{CP} = \neq \pi/2$)	100
CPV at 5 σ ($\theta_{CP} = +\pi/2$)	210
MH at 5 σ (worst point)	230
10 σ resolution ($\theta_{CP} = 0$)	290
CPV at 5 σ ($\theta_{CP} = \neq \pi/2$)	320
CPV at 5 σ 50% of θ_{CP}	550
Reactor Δ_{13} resolution ($\sin^2 2\Delta_{13} = 0.084 \pm 0.003$)	850
CPV at 3 σ 75% of θ_{CP}	850

ProtoDUNE - DualPhase

First events in the 3x1x1 prototype at CERN:



Ongoing effort

Activities at APC:

- development of analysis software
- data analysis
- shifts 3x1x1 running and debugging, 6x6x6 installation
- development of Light Read Out front-end electronics for protoDUNE-DP and DUNE

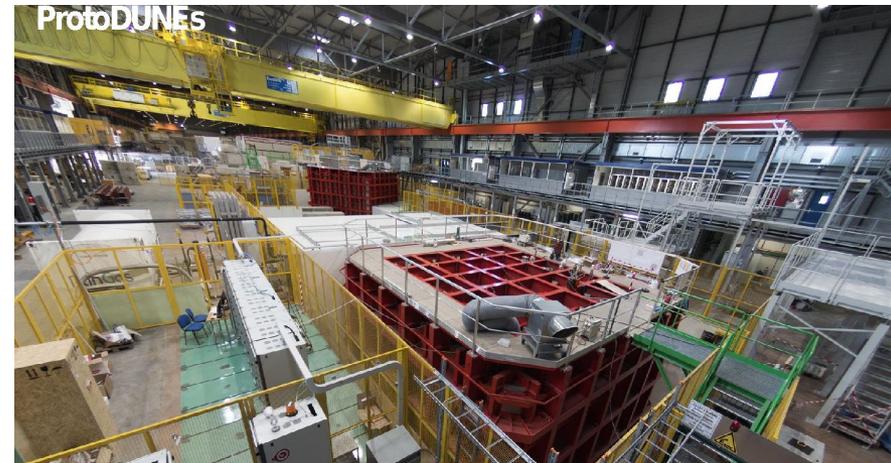
Alessandra Tonazzo: Co-coordinator of the atmospheric neutrino WG in DUNE 2015-2017

Alessandra Tonazzo: Member of the DUNE speakers committee since 09/2017

Thomas Patzak: Co-coordinator of the long-baseline neutrino physics WG of DUNE 2015-2016

Thomas Patzak: Chairman of the DUNE speakers committee since 09/2017

ProtoDUNEs (single phase and dual-phase at CERN):

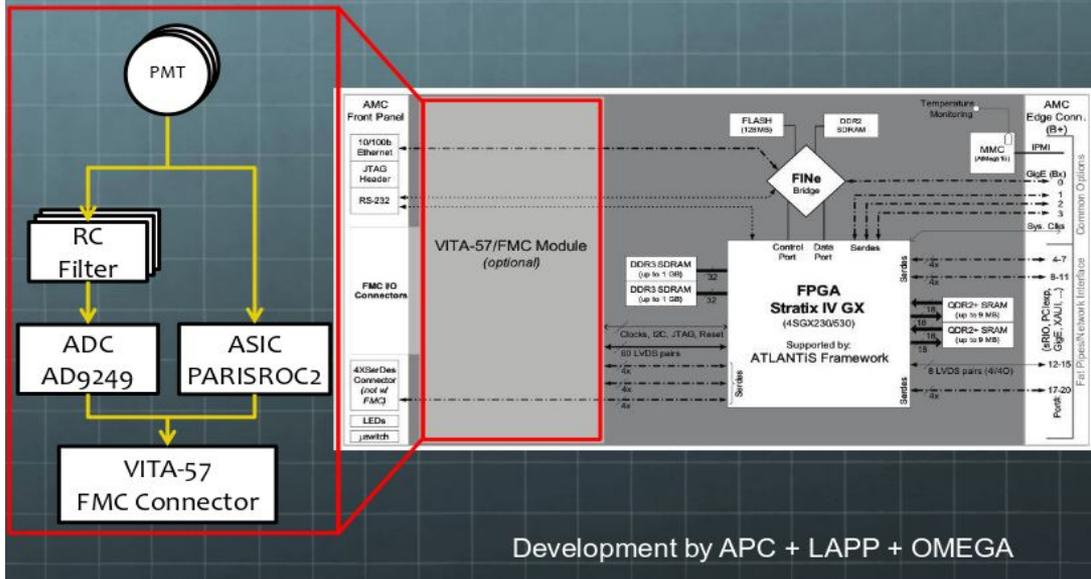


Technical Contributions

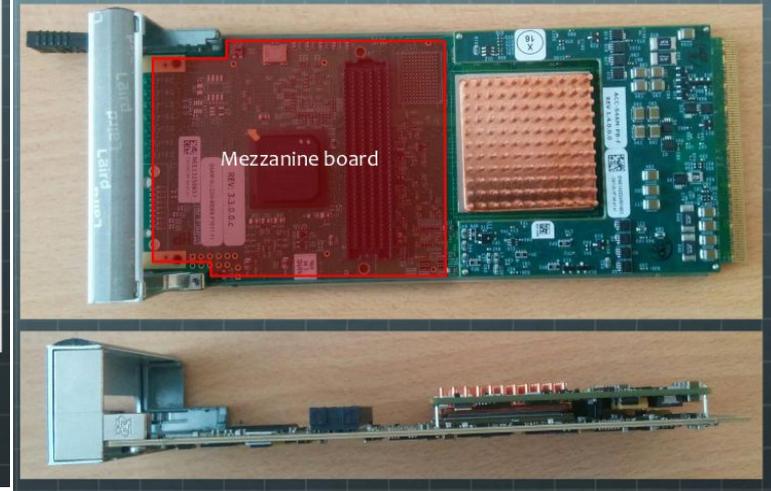
DUNE

- Electronique [C. Santos, A. Noury]
- Development Front-end Light Read Out card
- To be used for 6x6x6 ProtoDune Dual-Phase at CERN (2018) and proposed for DUNE Dual-Phase module (joint effort with LAPP, Omega, IPNL)
 - Light Detection provides the 3rd (Z) co-ordinate in the Dual Phase detector
 - Will provide trigger for SuperNova, Proton Decay and Atmospheric Neutrinos
 - Front-End is fully integrated in Global DAQ based on micro-TCA technology and synchronised by White Rabbit

LRO-FEB block diagram



Bittware S4AM μ TCA board



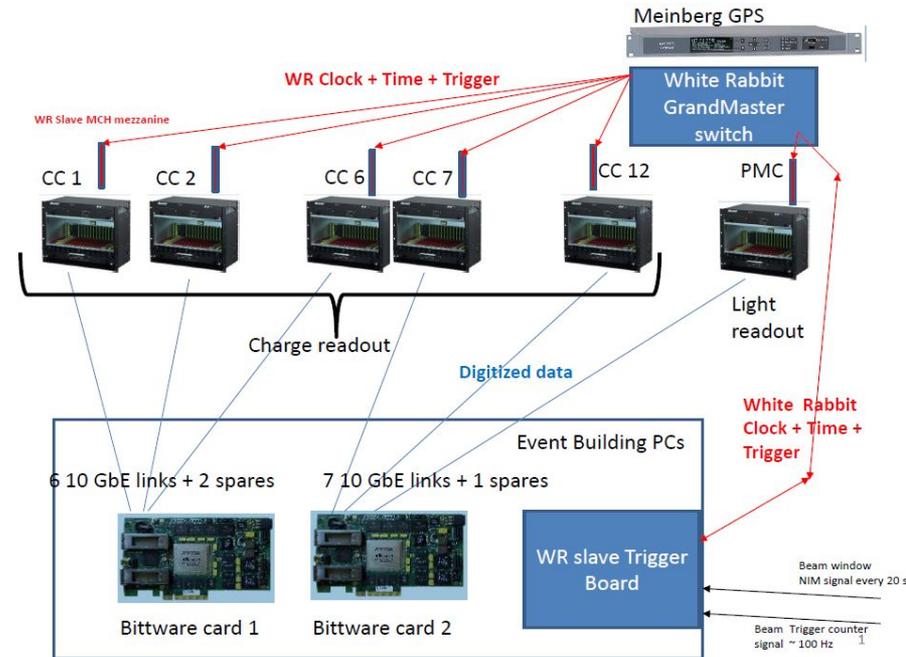
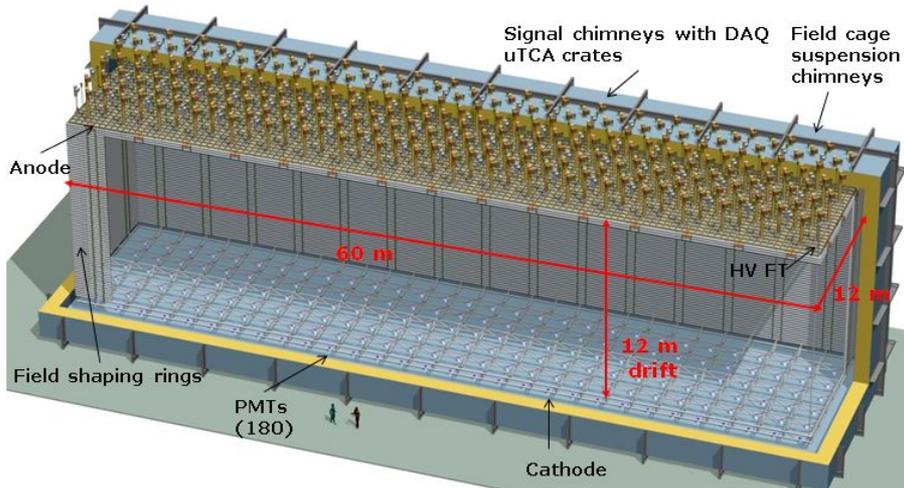
Towards DUNE

- Dual-Phase Electronics Consortium includes
- Analog cryogenic Front-End for Charge-ReadOut
 - micro-TCA digitisation system for Charge and Light ReadOuts
 - White Rabbit time distribution system

Charge ReadOut is already working 3x1x1 at CERN

Hardware proposed for DUNE, same as for protoDUNE

Dual-Phase DUNE FD: 20 times replication of Dual-Phase ProtoDUNE (drift 6m → 12m) DUNE Conceptual Design Report, July 2015
 Active LAr mass: 12.096 kton, fid mass: 10.643 kton, N. of channels: 153600



CRP - CEA

DAQ, cryogenic electronics -- IPNL

Light ReadOut -- APC, LAPP, Omega, IPNL

Future APC contributions

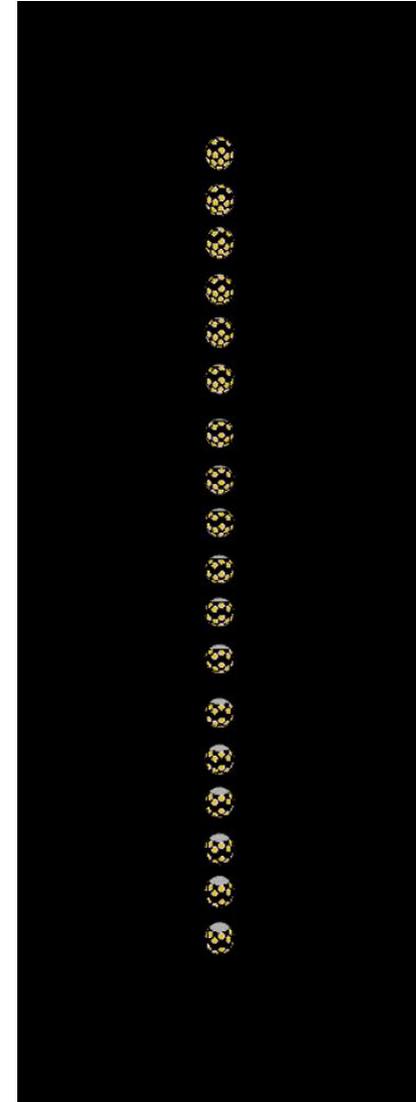
- contribute development of next LRO card
- develop trigger strategy and hardware for LRO triggers

Supernova, proton decay

KM3NeT/ORCA: Oscillation Research with Cosmics in the Abyss

MAIN AIM: measuring the neutrino mass hierarchy
(exploit matter oscillation effects with GeV atmospheric neutrinos)

September: Deployment of first ORCA line @ Toulon site !
Data taking ongoing... first neutrinos seen



Sept 2017:
1 string

End 2020:
full ORCA
(115 strings)

ORCA Construction

NMH Determination

2016 2017 2018 2019 2020 2021 2022 2023 2024 2025

A downward-going muon bundle

KM3NeT/ORCA: Oscillation Research with Cosmics in the Abyss

Activities at APC: present and future

- **sensitivity study for neutrino mass hierarchy (KM3NeT coordinator: A. Kouchner)**

expected $\sim 3\sigma$ in 3 years (worst case)

- **sensitivity to supernovae detection with ORCA (PhD co-advised APC/IFIC)**

- **neutrino oscillation tomography of the Earth**

- + **Technical contributions:**

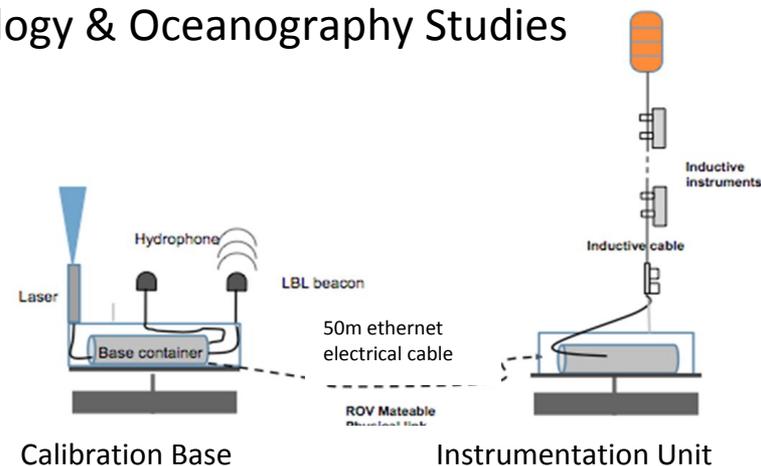
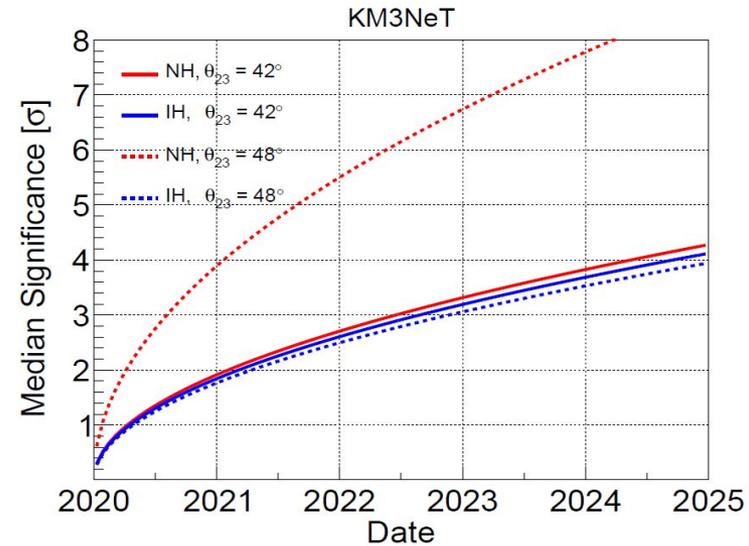
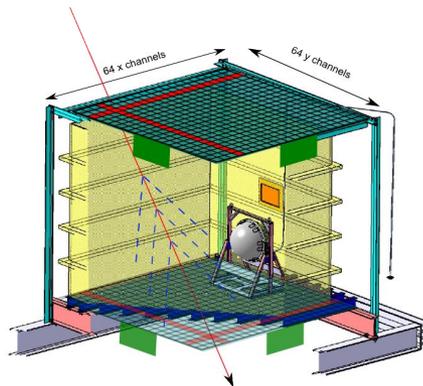
- **design and construction of the first Calibration Unit for ORCA**

→ Opportunities for Earth and Sea science:

project ARGOS: Astroparticle Physics, Research, Geology & Oceanography Studies

APC-IPGP, project funded by LabEx UnivEarthS

- **Test benches for KM3NeT Digital Optical Modules**



KM3NeT/ORCA: Team

Responsable scientifique local: Véronique Van Elewyck

Liste des chercheurs participants:

• 7 permanents (éq. 2,75 FTE recherche)

	ANTARES	KM3NeT	
• Antoine Kouchner (PR Paris 7; HDR; IUF 2015)	50%	50%	(Antares Spokesperson)
• Véronique Van Elewyck (MCF Paris 7; IUF 2016)	50%	50%	
• Alexandre Creusot (MCF Paris 7)	20%	80%	
• Bruny Baret (CR1)	80%	10%	(aussi sur SVOM)
• Corinne Donzaud (MCF Paris 11)	50%		
• C. Lachaud (MCF Paris 7)	10%		(aussi sur SVOM)
• S. Loucatos (CEA)	10%	10%	(dir. adjoint APC)

• 2 chercheurs associés (éq. 0,7 FTE recherche)

• Bertrand Vallage (CEA)	25%	25%	(aussi sur Gbar)
• Pascal Gay (PR U. Clermont-Ferrand; HDR)	10%	10%	(aussi sur LHC)

• 2 post-doctorants (éq. 3 FTE recherche):

• Alexis Coleiro (1/2 ATER P7 + CNRS)	100%		Oct 2014 → Oct 2016
• Joao Coelho (bourse IdEx USPC)		100%	Dec 2015 → Oct 2017

• 4 Doctorants (éq. 4 FTE recherche):

• Rodrigo Gracia (bourse Ile-de-France DIM ACAV)	100%		Oct. 2013 → Oct. 2016
Recherche de sources de neutrinos cosmiques avec ANTARES (directeur: A. Kouchner + B. Baret)			
• Theodore Avgitas (1/2 ED STEP'UP P7, 1/2 LabEx UnivEarthS)		100%	Nov 2014 → Nov 2017
Caractérisation des MO de KM3NeT et premières données (directeur: A. Kouchner + A. Creusot)			
• Simon Bourret (bourse Ecole Polytechnique)		100%	Oct 2015 → Oct 2018
Hiérarchie de masse et tomographie terrestre avec ORCA (codir.: V. Van Elewyck, E. Kaminski IPGP)			
• Timothée Grégoire (bourse ED STEP'UP P7)	100%		Oct. 2015 → Oct. 2018
Méthodes de reconstruction des cascades dans ANTARES (directeur: A. Kouchner + B. Baret)			

KM3NeT/ORCA Team

Responsable scientifique local: Véronique Van Elewyck

Liste des ingénieurs participants:

ANTARES

KM3NeT

• **4 permanents (éq. 1,7 FTE)**

- | | | |
|---|-----|---------------------|
| • Miles Lindsey Clark (IR Tech. Expérimentales) | 20% | (aussi sur TARANIS) |
| • Claude Boutonnet (IE électronique) | 20% | (aussi sur ??????) |
| • Stéphane Colonges (IR Qualité) | 30% | (aussi sur CTA) |
| • Cédric Champion (IE électronique) | 20% | (aussi sur CTA) |

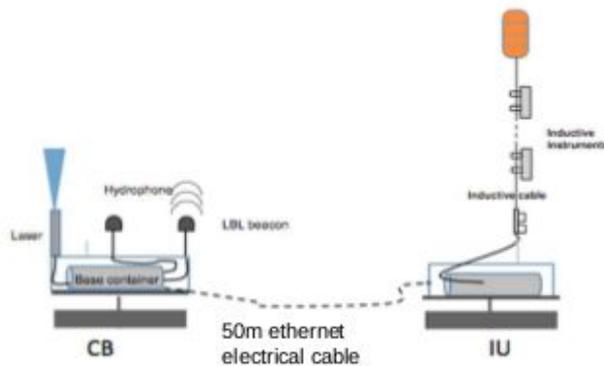
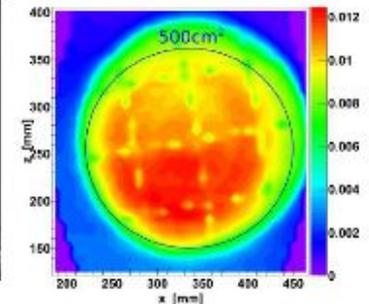
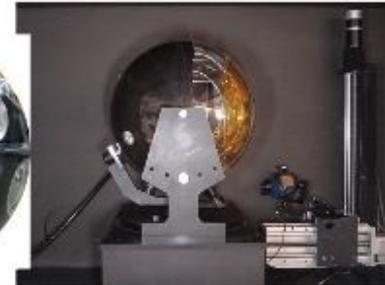
• **1 CDD (éq. 0.8 FTE)**

- | | | |
|-------------------------------|-----|---------------------|
| • Daniel Cobas (AI mécanique) | 80% | Fév 2016 → Fév 2018 |
|-------------------------------|-----|---------------------|
- financement LabEx Univ'EarthS (projet interdisciplinaire avec IPGP)

Technical Contributions

ORCA

- Instrumentation
 - Dark boxes for optical scans
 - Water Cherenkov Tank (T. Avgitas)
- Quality studies on electronics
- Design/Qualification and Construction of First Calibration Unit (deployment beginning 2019)



Calibration Base
Instrumentation Unit

Laser beacon



Claude Boutonnet	Electronics engineer CNRS - APC
Stéphane Colonges	Quality engineer - APC
Alexandre Creusot	Associate Professor Paris Diderot - APC
Miles Lindsey Clark	Research engineer CNRS - APC
Véronique Van Elewyck	Associate Prof. Paris Diderot - APC
Rémy Le Breton	ATER Paris Diderot/IN2P3
Mathilde Cannat	Senior Researcher (DR) CNRS - IPGP
Wayne Crawford	Junior Researcher (CR) CNRS – IPGP
Pascal Robert	Physicist IPGP
Eléonore Stutzmann	Professor IPGP
Daniel Cobas	Mechanical engineer - APC & IPGP

Water Cherenkov Test Bench

Originally built to test PMT read-out electronics for Memphys (M. Marafini, T. Patzak, A. Tonazzo)

PhD thesis, M. Marafini, 2011

<<Future large-scale water-Cherenkov detector>>PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 16, 061001 (2013)

- Large water tank (2mx2mx2m)
- Muon hodoscopes (above and below)
- Unique facility

Refurbished and developed by KM3NeT

- In water testing of Antares Optical Module and ORCA

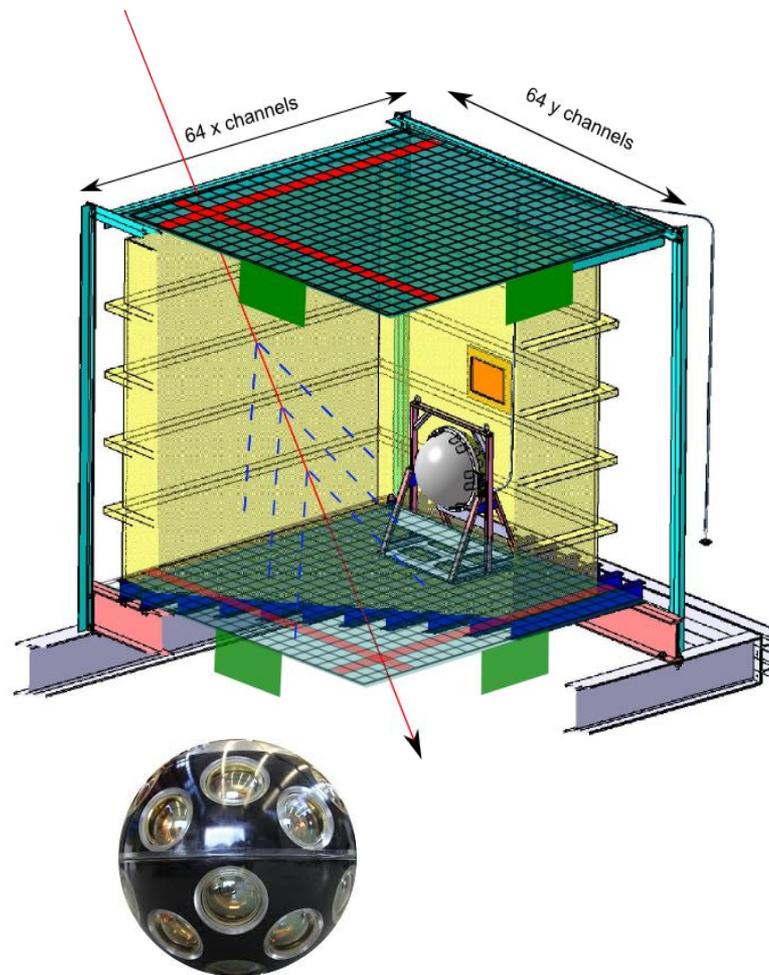
DOMs

• Calibration

• DOM response etc

• PhD thesis, T. Avgitas, Dec 2017

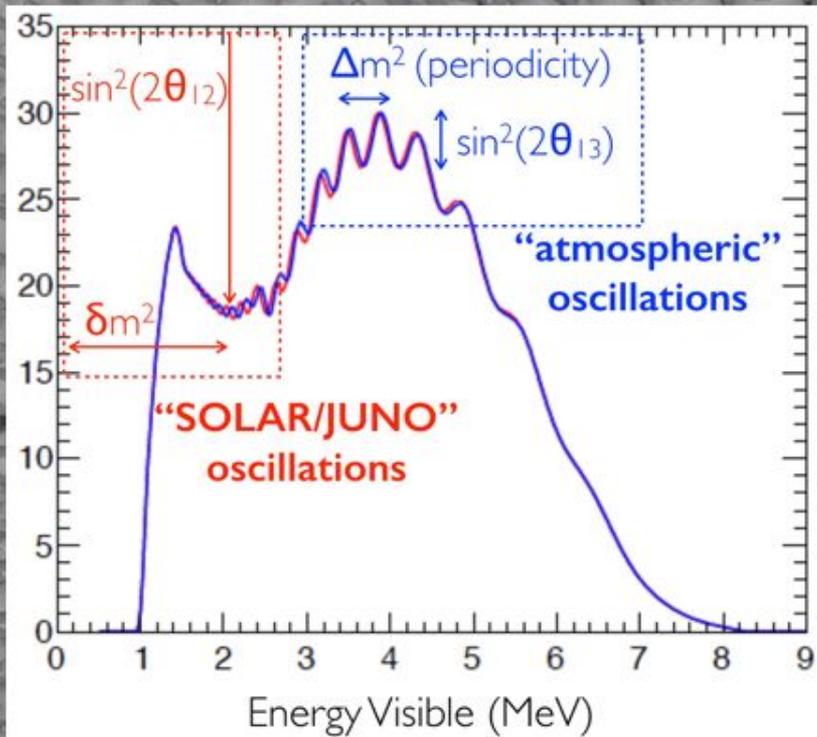
Interest from other institutes (LPNHE) for HyperK



faites marquants — JUNO

APC JUNO-group (3 physicists) responsible: Anatael Cabrera

IN2P3/CNRS SPMT responsible: Anatael Cabrera (laboratories: APC, CENBG, CPPM, OMEGA, SUBATECH)

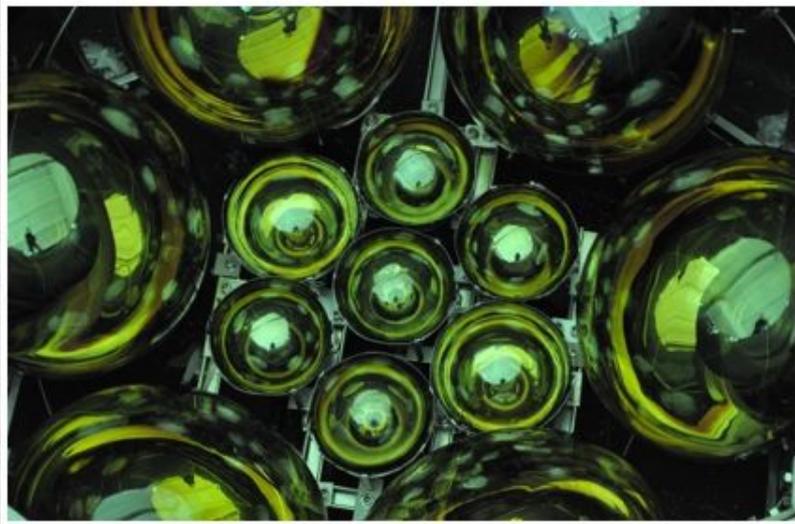


SN 1987

- **JUNO collaboration coordination SPMT system** (Anatael Cabrera + 2 deputies + 20 laboratories)
- **experiment start data-taking by 2021** (official schedule)
 - highest priority on hardware & detector (see “technical contributions”)
- **physics operations...**
 - neutrino physics: “solar” (θ_{12} , Δm^2) measurement & **supernova deadtime-less trigger/readout**
 - high precision calorimeter (Mass Hierarchy): stereo-calorimetry (SPMT \oplus LPMT)

contributions techniques — JUNO

APC DC-group: ~3 physicists (1 emeritus) + 2 engineers



JUNO prototype (testing SPMT system)



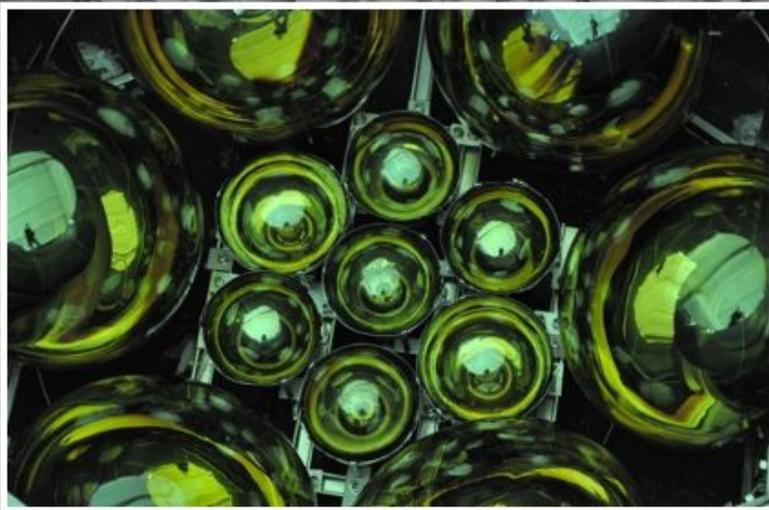
JUNO ABC card (first prototype 2017)

- **JUNO collaboration SPMT national/international technical coordination:** Cedric Cerna (CENBG)
 - **SPMT electronics technical coordinator @ APC:** Cayetano Santos
 - all sub-system built and ready to install within 2019: **production during 2018**
- **SPMT readout electronics @ IN2P3...**
 - conceived/designed @ APC (routed/building @ CENBG): **ABC card** (128 channels): prototype 2017
 - CatiROC ASIC readout (Ω laboratory: micro-electronics @ IN2P3)
- **SPMT 3" PMTs (design/test/production)...**
 - APC led much operation for 25,000 3" PMT (HZC company, China) system: production during 2018

perspectives — JUNO

APC DC-group: ~3 physicists (1 emeritus)

- **JUNO production (HW), construction & commissioning till 2021 (at least)...**
 - large involvement **electronics production (ASIC+ABC card) & ~26,000 SPMT testing**
 - evolution to launch 26,000 3" PMTs (right now in China)
 - a **few publications envisaged** for HW developments (CatiROC, ABC card, SPMT, etc)
 - **JUNO small prototype @ IN2P3** (validate integration and test performance)
- **physics analysis preparation** (few publications envisaged and 2 in preparation)
 - **double-calorimetry implementation** (towards MH measurement) — several groups within JUNO
 - **most precise measurement of θ_{12} - δm^2** with both SPMT and LPMT — cross-check systematics
 - studies of SPMT performance on **supernova measurements** (deadtime-less readout)



JUNO prototype @ IHEP (testing SPMT system)

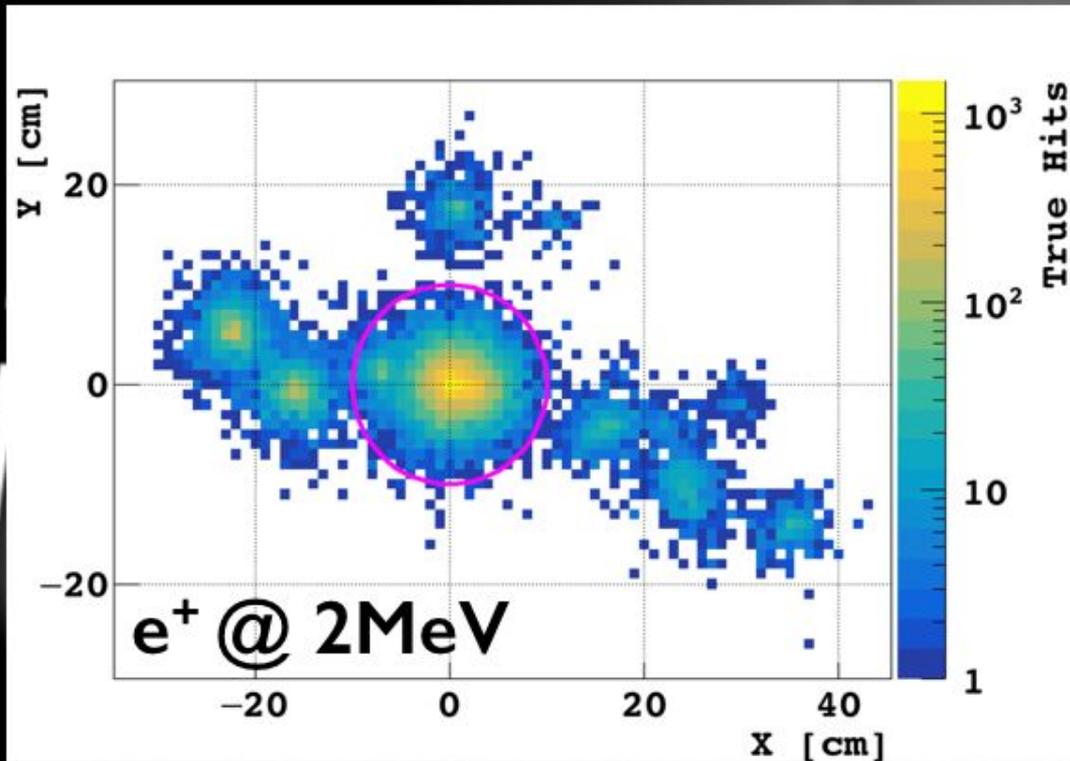
new prototype @ IN2P3

⇒ **test SPMT readout (integrated) with μ 's**

APC LiquidO-group (4 physicists) responsible: Anatael Cabrera

Proto-Collaboration responsible: Anatael Cabrera

IN2P3/CNRS team laboratories: APC, CENBG, CPPM, LAL, SUBATECH



- **physics operations** (physics exploration)...

- detector design for different source reactor/ π -decay@rest, $2\beta\pm$
- simulation full detector validation (almost finished) [publication in preparation]

- **detector operations** (prototyping)...

- 1st prototype to be exposed to e- beam @ CENBG during 2018 [technique validation]

Publications (2013-17)

- 71 publications during the evaluation period
- Selection of 16...

S. Adrián-Martínez et al., (B. Baret, S. Baron, C. Champion, S. Colonges, A. Creusot, C. Donzaud, V. Elewyck, S. Galatà, R. Gracia Ruiz, A. Kouchner, M. Lindsey Clark, B. Vallage). Deep sea tests of a prototype of the KM3NeT digital optical module. KM3NET Collaboration, Eur. Phys. J. C, 74 (2014) 3056

35 citations

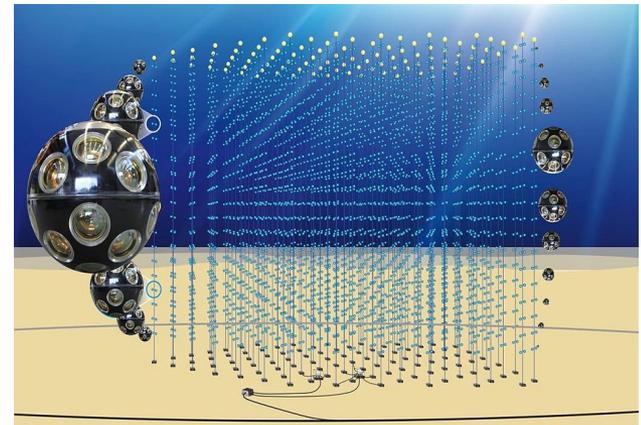
Multi-messenger Observations of a Binary Neutron Star Merger
ANTARES contribution
ApJL, 848:L12, 2017

53 citations

Mass hierarchy discrimination with atmospheric neutrinos in large volume ice/water Cherenkov detectors, D. Franco (APC, Paris), C. Jollet (Strasbourg, IPHC), A. Kouchner (APC, Paris), V. Kulikovskiy (APC, Paris & INFN, Genoa), A. Meregaglia (Strasbourg, IPHC), S. Perasso (APC, Paris), T. Pradier (Strasbourg, IPHC), A. Tonazzo, V. Van Elewyck (APC, Paris). Jan 2013. 23 pp. Published in JHEP 1304 (2013) .

36 citations

KM3NET/ORCA/ANTARES



General sensitivity study led
by
Neutrino group members

Publications (2013-17)

First Measurement of θ_{13} from Delayed Neutron Capture on Hydrogen in the Double Chooz Experiment, Double Chooz Collaboration (Y. Abe (Tokyo Inst. Tech.) et al.). Jan 2013. 6 pp. Published in Phys.Lett. B723 (2013) 66-70

127 citations

Reactor electron antineutrino disappearance in the Double Chooz experiment
Double Chooz Collaboration (Y. Abe (Tokyo Inst. Tech.) et al.). Jul 2012.
Published in Phys.Rev. D86 (2012) 052008

389 citations

Indication of Reactor $\bar{\nu}_e$ Disappearance in the Double Chooz Experiment
Double Chooz Collaboration (Y. Abe (Tokyo Inst. Tech.) et al.). Dec 2011. 7 pp.
Published in Phys.Rev.Lett. 108 (2012) 131801

961 citations



Publications (2013-17)

Neutrinos from the primary proton–proton fusion process in the Sun
BOREXINO Collaboration (G. Bellini et al.). 2014. 4 pp.
Published in Nature 512 (2014) no.7515, 383-386

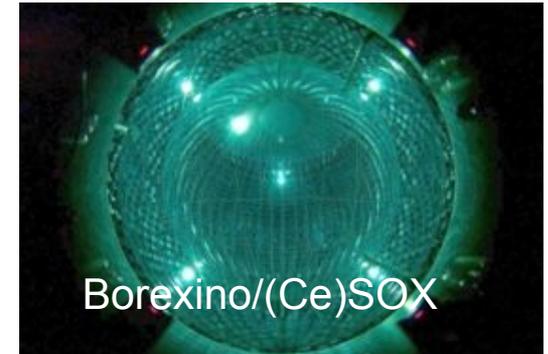
108 citations

Spectroscopy of geoneutrinos from 2056 days of Borexino data
Borexino Collaboration (M. Agostini (Munich, Tech. U.) et al.). Jun 15, 2015. 5 pp.
Published in Phys.Rev. D92 (2015) no.3, 031101

37 citations

SOX: Short distance neutrino Oscillations with Borexino
Borexino Collaboration (G. Bellini (INFN, Milan & Milan U.) et al.). Apr 29, 2013. 14 pp.
Published in JHEP 1308 (2013) 038

98 citations



Publications (2013-17)

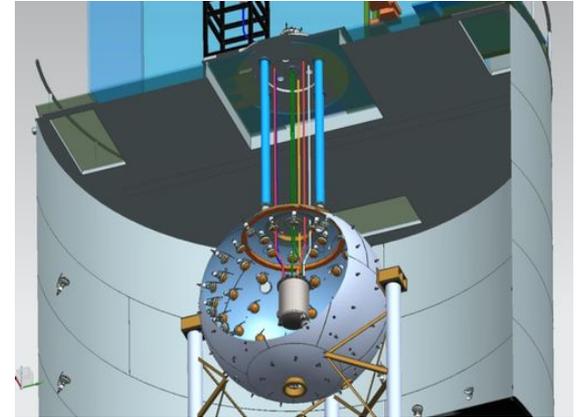
Results from the first use of low radioactivity argon in a dark matter search
DarkSide Collaboration (P. Agnes (APC, Paris) et al.). Oct 2, 2015. 7 pp.
Published in Phys.Rev. D93 (2016) no.8, 081101, Addendum: Phys.Rev.
D95 (2017) no.6, 069901

67 citations

First Results from the DarkSide-50 Dark Matter Experiment at Laboratori Nazionali
del Gran Sasso, DarkSide Collaboration (P. Agnes (APC, Paris) et al.). Oct 2, 2014.
11 pp. Published in Phys.Lett. B743 (2015) 456-466

104 citations

DarkSide



Publications (2013-17)

Optimised sensitivity to leptonic CP violation from spectral information: the LBNO case at 2300 km baseline, LAGUNA-LBNO Collaboration (S.K. Agarwalla (Bhubaneswar, Inst. Phys.) et al.). Dec 1, 2014. 25 pp.
e-Print: arXiv:1412.0593

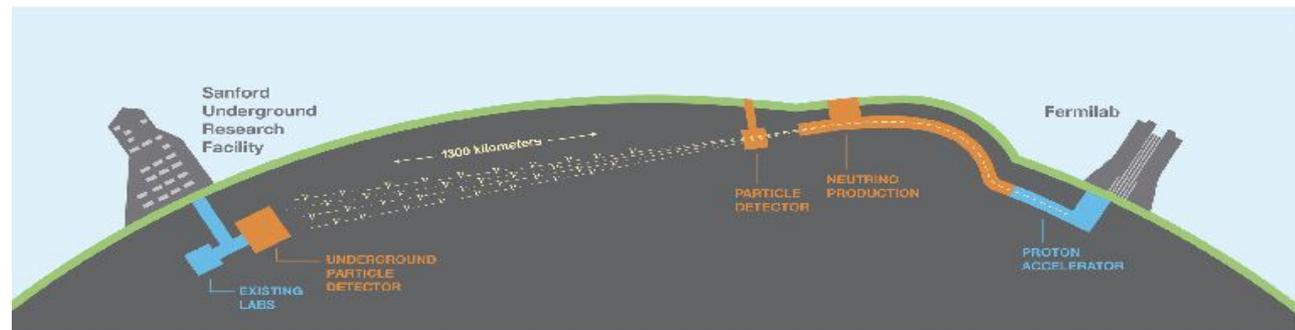
18 citations

Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) : Volume 2: The Physics Program for DUNE at LBNF
DUNE Collaboration (R. Acciarri (Fermilab) et al.). Dec 18, 2015. 127 pp.
FERMILAB-DESIGN-2016-02 e-Print: arXiv:1512.06148

156 citations

The mass-hierarchy and CP-violation discovery reach of the LBNO long-baseline neutrino experiment, LAGUNA-LBNO Collaboration (S.K. Agarwalla (Bhubaneswar, Inst. Phys.) et al.). Dec 23, 2013. 38 pp.
Published in JHEP 1405 (2014) 094

81 citations



Publications (2013-17)

Neutrino Physics with JUNO

JUNO Collaboration (Fengpeng An (East China U. Sci. Tech., Shanghai) et al.). Jul 20, 2015. 188 pp. Published in J.Phys. G43 (2016) no.3, 030401

132 citations

JUNO Conceptual Design Report

T. Adam, F. An, G. An, Q. An, N. Anfimov, V. Antonelli, G. Baccolo, M. Baldoncini, E. Baussan, M. Bellato, L. Bezrukov, D. Bick, S. Blyth, S. Boarin, A. Brigatti, T. Brugière, R. Brugnera, M. Buizza Avanzini, J. Busto, A. Cabrera, H. Cai, X. Cai, A. Cammi, D. Cao, G. Cao, J. Cao, J. Chang, Y. Chang, M. Chen, P. Chen, Q. Chen, S. Chen, S. Chen, S. Chen, X. Chen, Y. Chen, Y. Cheng, D. Chiesa, A. Chukanov, M. Clemenza, B. Clerbaux, D. D'Angelo, H. de Kerret, Z. Deng, Z. Deng, X. Ding, Y. Ding, Z. Djurcic, S. Dmitrievsky, M. Dolgareva, D. Dornic, E. Doroshkevich, M. Dracos, O. Drapier, S. Dusini, M.A. Díaz, T. Enqvist, D. Fan, C. Fang, J. Fang, X. Fang, L. Favart, D. Fedoseev, G. Fiorentini, R. Ford, A. Formozov, R. Gaigher, H. Gan, A. Garfagnini, G. Gaudiot, C. Genster, M. Giammarchi, et al. (325 additional authors not shown)

(Submitted on 28 Aug 2015 (v1), last revised 28 Sep 2015 (this version, v2))

The Jiangmen Underground Neutrino Observatory (JUNO) is proposed to determine the neutrino mass hierarchy using an underground liquid scintillator detector. It is located 53 km away from both Yangjiang and Taishan Nuclear Power Plants in Guangdong, China. The experimental hall, spanning more than 50 meters, is under a granite mountain of over 700 m overburden. Within six years of running, the detection of reactor antineutrinos can resolve the neutrino mass hierarchy at a confidence level of $3-4\sigma$, and determine neutrino oscillation parameters $\sin^2 \theta_{12}$, Δm_{21}^2 , and $|\Delta m_{ee}^2|$ to an accuracy of better than 1%. The JUNO detector can be also used to study terrestrial and extra-terrestrial neutrinos and new physics beyond the Standard Model. The central detector contains 20,000 tons liquid scintillator with an acrylic sphere of 35 m in diameter. $\sim 17,000$ 508-mm diameter PMTs with high quantum efficiency provide $\sim 75\%$ optical coverage. The current choice of the liquid scintillator is: linear alkyl benzene (LAB) as the solvent, plus PPO as the scintillation fluor and a wavelength-shifter (Bis-MSB). The number of detected photoelectrons per MeV is larger than 1,100 and the energy resolution is expected to be 3% at 1 MeV. The calibration system is designed to deploy multiple sources to cover the entire energy range of reactor antineutrinos, and to achieve a full-volume position coverage inside the detector. The veto system is used for muon detection, muon induced background study and reduction. It consists of a Water Cherenkov detector and a Top Tracker system. The readout system, the detector control system and the offline system insure efficient and stable data acquisition and processing.

Comments: 328 pages, 211 figures

Subjects: **Instrumentation and Detectors (physics.ins-det)**; High Energy Physics - Experiment (hep-ex)

Cite as: [arXiv:1508.07166](https://arxiv.org/abs/1508.07166) [physics.ins-det]

(or [arXiv:1508.07166v2](https://arxiv.org/abs/1508.07166v2) [physics.ins-det] for this version)

Citations -
Topcite

Visibility/Presence

2 chapitres de livres

77 symposia/meetings

29 invitations à des colloques (2013-2017)

Selection de présentations en conférence (permanents, postdocs et doctorants)

A. Cabrera: <<Double Chooz Results>>, CERN seminar, September 2016

J. Dawson: <<Organic Liquid TPCs>> 2014 Advances in Neutrino Technology (Los Angeles), invited speaker.

H. De Kerret: <<Double Chooz>> Invited speaker at the Neutrino 2014 conference Boston (2014)

D. Franco : Talk at Rencontres de Moriond (EW Interactions and Unified Theories): "First results from DarkSide-50", 2015.

T. Lasserre : <<sterile neutrinos and Dark Matter>> at NOW 2016 workshop, Otranto, 2016, invited speaker.

A. Tonazzo : "Statistical issues in future neutrino oscillation experiments", European Physical Society Conference EPS2015, Vienna, 2015, invited speaker.

V. Van Elewyck <<ANTARES, KM3NeT/ORCA: Astronomy and Fundamental Physics in the Abysses>> NNN2014 : 15th Next Generation Nucleon decay and Neutrino detectors, Paris (France), 2014.

A. Onillon <<Latest results of the Double Chooz experiment>>, 2017, La Thuile, Les Rencontres de Physique de la Vallée d'Aoste.

J. Coelho <<Status and Prospects of the KM3NeT-ORCA experiment>> 28th Rencontres de Blois 2016.

M. Grassi <<Status of Reactor Neutrino experiments>> PIC 2017 (Physics in Collision).

S. Bourret <<Measuring neutrino oscillations and the Mass Hierarchy in the Mediterranean with KM3NeT-ORCA>> WIN2017.

A. Hourlier <<First Double-Detector Results from the Double Chooz Experiment >> 12th Rencontres du Vietnam, NUFACT 2016.

Visibility/Presence

- Organisations de conférences, workshops, réunions de collaboration

S. Katsanevas:

- APPEC Town meeting 6-7 April 2016, Paris
- European and global Coordination on CMB, September 2015 and 2016 Florence
- International Conference for Large Neutrino Infrastructures: 1st conference : APC, Paris June 2014, 2nd conference : Fermilab April 2015, 3rd conference Tokyo May 2016
- Member of International Advisory Committees of international workshops and conferences: European Physics Society High Energy Physics Conference (2012-), International High Energy Physics (ICHEP) Conference (2013-), International Conference on Neutrino Physics and Astrophysics, Neutrino (2008-), Identification of Dark Matter (IDM), Neutrino Oscillation Workshop (NOW), Cosmology COSMO, Neutrino Factory NUFACT, NNN...

T. Patzak: Since 2013, Chairman of the organizing committee of the school of GiF.

Chairman of internationale conferences:

- NNN14 (Next Nucleon decay and Neutrino detectors), APC – Université Paris Diderot, November 4-6, 2014, Paris, France.

A. Kouchner, V. Van Elewyck:

- ORCA Workshop & perspectives in neutrino mass hierarchy measurements, APC (Paris), 17 - 18/04/2013 (~30 participants) (<https://indico.in2p3.fr/event/8261/>)
- KM3NeT and associated science workshop, Institut de Physique du Globe de Paris, 6/12/2016 (~30 participants)

D. Franco, A. Tonazzo

- 1ère Journée Matière Sombre France, Dec 2016 à APC.

D. Vignaud, M. Cribier

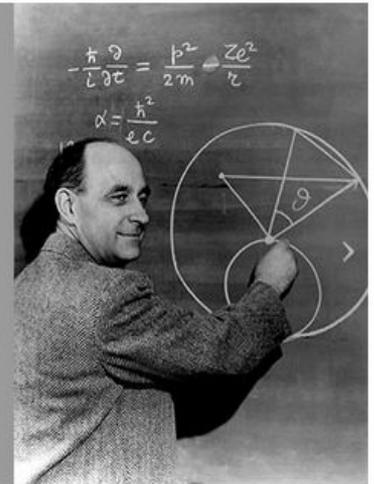
- History of the Neutrino, September 2018, <http://neutrinohistory2018.in2p3.fr/>

History of the Neutrino

September 5-7, 2018
Paris, France



Wolfgang Pauli
25 April, 1900 - 15 December, 1958
Nobel Prize in 1945



Enrico Fermi
29 September, 1901 - 28 November, 1954
Nobel Prize in 1938

D. Vignaud, M. Cribier

– History of the Neutrino, September 2018, <http://neutrinohistory2018.in2p3.fr/>

Visibility/Presence

- Awards/Prizes/Fellowships

- F. Suekane awarded chair Blaise Pascal 2017
- T. Lasserre awarded Hans Fischer Senior Fellowship (IAS, TUM) 2015
- T. Lasserre obtained 2012 ERC Starting Grant 4th-Nu-Avenue - Search for a 4th Neutrino State with a PBq neutrino source experiment
- M. Grassi awarded Marie Curie Fellowship 2016

Scientific Responsibilities

[*convenerships*, board memberships etc]

ANTARES, KM3Net

- Spokesperson (A. Kouchner) ANTARES
- Responsible of the Astronomy working group (~60 people, largest of the collaboration, divided into 4 subgroups): since 2008 (A. Kouchner)
- Responsible of the data quality (V. van Elewyck)
- Responsible of the working groups “Charge and Energy Calibration” and “Point-like sources” (up to 2008) (A. Kouchner)
- Coordination of the DAQ Front End Electronics Calibration group (since 2006) (A. Kouchner, then B. Baret)
- Member of the Steering Committee of the collaboration (since 2008) (A. Kouchner, B. Baret)
- Member of the collaboration’s Publication Committee (since 2011) (A. Kouchner, B. Baret)
- Working group leader of ORCA in KM3NeT (A. Kouchner)
- Members of the collaboration’s Publication Committees (since 2012) (B. Baret, V. Van Elewyck)
- Members of the collaboration Conference Committees (since 2012) (V. Van Elewyck: chair since Nov 2016)

Double Chooz

- Spokesperson (H. De Kerret),
- Three members of the Executive Committee (A. Cabrera, H. De Kerret, T. Lasserre)
- Physics Analysis Coordination (A. Cabrera, past T. Lasserre)
- Detector Coordination (A. Cabrera)
- Online and Data Acquisition coordination (A. Cabrera)
- Technical Board Members (A. Cabrera, H. de Kerret, A. Givaudan, T. Lasserre)
- Co-ordinator of electronics (J. Dawson)

Scientific Responsibilities

DUNE

- Collaboration board (T. Patzak)
- Co-coordinator of the atmospheric neutrino WG in DUNE 2015-2017 (A. Tonazzo)
- Member of the DUNE speakers committee since 09/2017 (A. Tonazzo)
- Co-coordinator of the long-baseline neutrino physics WG of DUNE 2015-2016 (T. Patzak)
- Chairman of the DUNE speaks committee since 09/2017 (T. Patzak)

– LAGUNA-LBNO

- Head of the Science Board (T.Pazak)
- Member of the Science Board (A.Tonazzo)

– DARKSIDE

- Work package co-ordinator “Science, simulations and computing” (D. Franco)

Teaching, Animation, Management

•Teaching:

- Antoine Kouchner (Prof), Thomas Patzak (Prof), Véronique Van Elewyck (MCF), Alessandra Tonazzo (Prof)
- Paulo Agnes, Simon Bourret, Timothée Gregoire, Adrien Hourlier: monitorat

•Laboratory/University

- Simon Bourret: Conseil des Enseignements
- Thomas Patzak: Conseil Scientifique LLR
- Véronique Van Elewyck: Conseil Du Laboratoire, membre du Conseil Scientifique UFR de physique
- Antoine Kouchner: Directeur Adjoint APC depuis 2016, Conseil Scientifique IPNO 2012-2016, membre du comité du pilotage Labex UnivEarthS, Conseil Scientifique UFR de physique, Conseil de l'Ecole Doctoral ED560 STEP'UP 2013-2016.
- Alessandra Tonazzo: Conseil des Enseignements, Directeur Adjoint APC 2012-2016, membre du comité du pilotage Labex UnivEarthS 2012-2016, Conseil de l'Ecole Doctorale ED560 STEP'UP
- Davide Franco: membre CSP APC

•National Responsibilities

- Davide Franco: Co-ordinateur in2p3 DarkSide and Borexino
- Anatael Cabrera: Co-ordinateur in2p3 Double Chooz, SPMT System in JUNO, Liquid R&D, director LNCA laboratory (prev. H. de Kerret)
- Alessandra Tonazzo & Antoine Kouchner: coordinateurs de GT du GDR Neutrino

Summary of Projects over next 5 years

- Double Chooz final results (2018/2019)
- R&D activity – LiquidO
- Borexino
 - Nature publication in preparation (PP to 8B solar neutrinos)
 - deployment of SOX March 2018, strong test for existence of sterile neutrinos
- Mass Hierarchy/Precision Oscillation
 - JUNO Under-construction, data-taking ~2020
 - ORCA Under-construction, data-taking (complete array) ~2021
- Longer term project – DUNE -
 - ProtoDUNE demonstrators (single and dual-phase) are under-construction at CERN
 - Beam tests begin at the end of 2018
 - Front-End development -- part of French electronics package -- contribution to DualPhase
 - DUNE module
- Dark Matter interest -- impact on design of 20k detector of DarkSide, and future liquid argon solar neutrino detectors (ARGO)
 - Continuing ARIS work on neutron beam measurements with noble liquids (2 weeks/year beam time at IPNO)

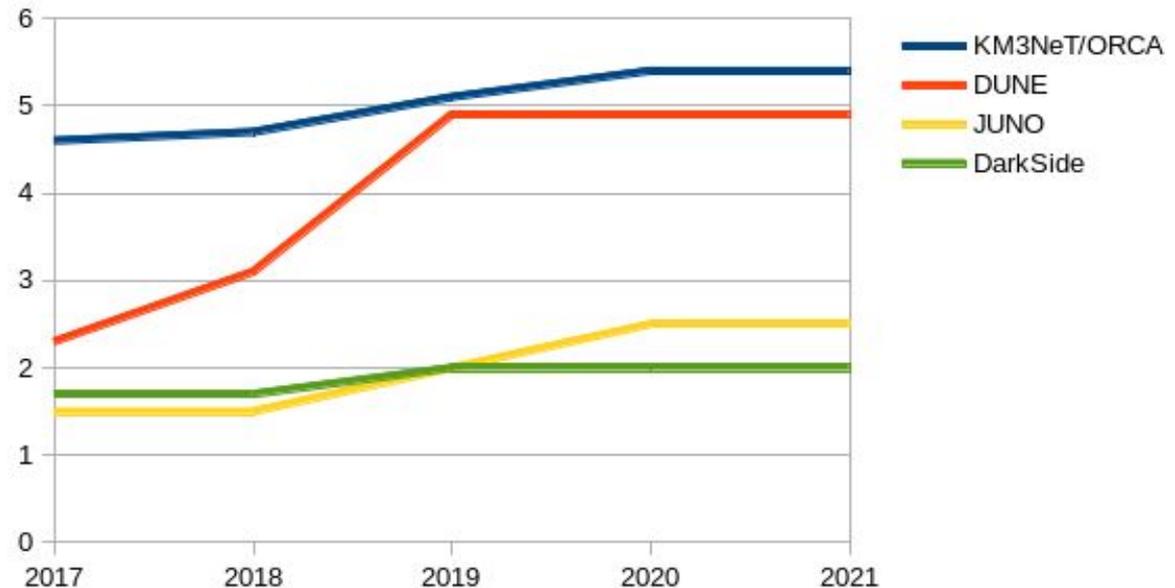
Estimated Effort over 5 years

Redeployment of permanents from ANTARES to KM3NeT/ORCA
Assuming postdocs and PhD students remain at least constant

Redeployment of 2 permanent members from Double Chooz to DUNE. Keeping 1 PhD student, and assuming addition of 1 postdoc in 2019.

Redeployment from Double Chooz to JUNO. Keeping 1 PhD student and assuming addition of 1 postdoc.

Current effort is at 1.7 FTE from two permanent members and 1 visiting postdoc, 1 PhD student begins shortly, and potential of a postdoc/PhD student from ANR/Labex.



Additional reinforcement could come from hiring of CNRS researchers (CR) and university lecturers (MCF).

Forseen Evolution (personnel)

Contrat Ends:

Stefan Wagner (LiquidO), June 2018

Anthony Onillon (Double Chooz), Sept 2018

Marco Grassi (Marie Curie, LiquidO), Oct 2018

Fumihiko Suekane (Blaise Pascal Chair, LiquidO), Nov 2018

- + Forseen at least 2 new research members (CNRS CR and/or MDC) in next 5 years

Auto-analysis SWOT

(aka SWOT = Strengths, Weaknesses, Opportunities, Threats)

•Strengths

- High visibility and internationally recognized expertise
- Diverse experiments
- Synergies between experiments
- Complementary measurements
- Future projects well defined

•Weaknesses

- Not enough resource given for the electronics development of the card for protoDUNE
- Need to recruit at least one young researcher in the next few years (CR ou MCF). Last CNRS recruitment 2012 and MCF in 2005.

•Opportunities

- Interesting opportunities related to joint analyses

•Threats

- Future projects ORCA, Darkside-20k, DUNE are not completely funded

Questions

Neutrino and DM questions:

- 1 Is it possible to see a table with the physicists involved in each of the different projects? [slides 9,10]
- 2 How the neutrino group is organized? [slides 7,8]
- 3 How do you anticipate efforts on the 4 major projects (JUNO, ORCA, DUNE and Darkside 20t) will evolve with time? [slide 45]
- 4 Beyond the prototype at CERN, what are the current prospects for French hardware contributions to DUNE, and what APC roles are foreseen? [slide 21]