Convocatorias 2014

Proyectos de I+D "Excelencia" y Proyectos de I+D+I "Retos Investigación"
Dirección General de Investigación Científica y Técnica
Subdirección General de Proyectos de Investigación

a. RESUMEN DE LA PROPUESTA/SUMMARY OF THE PROPOSAL

a.1. DATOS DEL PROYECTO COORDINADO

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TÍTULO GENERAL DEL PROYECTO COORDINADO: Construcción puesta a punto y operación del experimento NEXT en el Laboratorio Subterráneo de Canfranc.

ACRÓNIMO DEL PROYECTO COORDINADO: NEXT.

RESUMEN DEL PROYECTO COORDINADO:

NEXT (Neutrino Experiment with a Xenon TPC) es un experimento para buscar desintegraciones doble beta sin neutrinos ($\beta\beta0\nu$), cuya detección demostraría unívocamente que el neutrino es una partícula de Majorana (es decir su propia antipartícula) y supondría un descubrimiento con profundas consecuencias en física de partículas y cosmología.

El isótopo escogido por NEXT es el ^{136}Xe. El experimento dispone de cien kilos de gas xenón enriquecido al 90 % en ^{136}Xe. La tecnología se basa en el uso de cámaras de proyección temporal operando a una presión típica de 15 atmósferas (HPXe). Las características principales de esta técnica experimental son: a) excelente resolución en la medida de la energía; b) capacidad de reconstruir la trayectoria de los electrones emitidos en la desintegración, lo que refuerza la capacidad del experimento para reducir el ruido de fondo; c) escalabilidad a grandes masa y d) la posibilidad de reducir el ruido de fondo hasta niveles despreciables mediante la técnica conocida como BaTa (de las siglas en inglés, *Barium Tagging*).

El experimento NEXT contempla cuatro fases: i) Demostración de la tecnología HPXe con prototipos que usan ∼1 kg de xenón natural; ii) Medida de los ruidos de fondo y de la señal del proceso permitido ($\beta\beta2\nu$) con un detector (NEW) basado en 12 kilos de xenón enriquecido y operando en el Laboratorio Subterráneo de Canfranc (LSC); iii) Búsqueda de desintegraciones $\beta\beta0\nu$ con el detector NEXT-100, una réplica a escala 2:1 (en tamaño) y 8:1 (en masa) de NEW, que usará por tanto 100 kilos de gas enriquecido; iv) Búsqueda de desintegraciones $\beta\beta0\nu$ con el detector BEXT (Barium-tagging Experiment with a Xenon TPC), con una masa de alrededor de una tonelada de ^{136}Xe, que introducirá la técnica de BaTa para reducir el ruido de fondo hasta niveles despreciables.

La primera fase de NEXT ha sido completada con éxito durante el periodo 2009-2013. Durante esta etapa se han construido los prototipos NEXT-DEMO (IFIC) y NEXT-DBDM (Berkeley) que han demostrado las características principales de la tecnología. El experimento se encuentra en estos momentos en su segunda fase. El detector NEW está siendo construido por la colaboración y operará en el LSC durante el año 2015. La financiación del detector NEW proviene de un Advanced Grant (AdG/ERC) concedido en 2013 al IP de este proyecto (operativo desde Febrero de 2014 a Febrero de 2018). El detector NEXT-100 supone la tercera fase del proyecto. Se construirá y pondrá a punto durante 2016 y 2017 e iniciará su toma de datos en 2018. La cuarta fase depende de los resultados de la fase tres, en la que se podría realizar ya un descubrimiento. Previsiblemente, BEXT podría funcionar en el LSC a partir del 2020.

NEXT es una colaboración internacional, liderada por grupos españoles y con una fuerte contribución de grupos norteamericanos. El desarrollo de la tecnología laser necesaria para el BaTa se realiza en colaboración con el Centro de Láseres Pulsados de Salamanca (CLPU).

Este proyecto de investigación requiere *cofinanciación* para desarrollar la fase tres del experimento. Concretamente, se requiere: a) fondos para adquirir una parte de los equipos y material fungible necesarios para la construcción del detector NEXT-100 (cofinanciado por el AdG y los fondos provenientes de la colaboración); b) fondos para una parte del personal científico y técnico; y c) fondos para cofinanciar el R&D dedicado al BaTa.

PALABRAS CLAVE DEL PROYECTO COORDINADO: neutrinos, TPC, HPXe, xenón, desintegración doble beta, Canfranc, alta presión, electroluminescencia.

TITLE OF THE COORDINATED PROJECT: Construction commissioning and operation of the NEXT experiment at the LSC underground laboratory.

ACRONYM OF THE COORDINATED PROJECT: NEXT.

SUMMARY OF THE COORDINATED PROJECT:

NEXT (Neutrino Experiment with a Xenon TPC) is an experiment to search neutrino less double beta decay processes ($\beta\beta0\nu$). The detection of such processes would demonstrate that neutrinos are Majorana particles (that is their own antiparticles) and would have deep consequences in physics and cosmology.

The isotope chosen by NEXT is ^{136}Xe. The collaboration has access to hundred kilograms of xenon enriched at 90 % in ^{136}Xe, owned by the Underground Laboratory of Canfranc (LSC). The NEXT technology is based in the use of time projection chambers operating at a typical pressure of 15 bar and using electroluminescence to amplify the signal (HPXe). The main advantages of the experimental technique are: a) excellent energy resolution; b) the ability to reconstruct the trajectory of the two electrons emitted in the decays, a unique feature of the HPXe which further contributes to the suppression of backgrounds; c) scalability to large masses; and d) the possibility to reduce the background to negligible levels thanks to the barium tagging technology (BaTa).

The NEXT roadmap was designed in four stages: i) Demonstration of the HPXe technology with prototypes deploying a mass of natural xenon in the range of 1 kg; ii) Characterisation of the backgrounds to the $\beta\beta0\nu$ signal and measurement of the $\beta\beta2\nu$ signal with the NEW detector, deploying 12 kg of enriched xenon and operating at the LSC; iii) Search for $\beta\beta0\nu$ decays with the NEXT-100 detector, which escales up the NEW detector by a factor 2:1 in size (8:1 in mass) and deploys, thus, 100 kg of enriched xenon. iv) Search for $\beta\beta0\nu$ decays with the BEXT detector (Barium-tagging Experiment with a Xenon TPC), which will deploy a mass in the ton scale and will introduce the technology of BaTa in order to reduce backgrounds to negligible levels.

The first stage of NEXT has been successfully completed during the period 2009-2013. The prototypes NEXT-DEMO (IFIC) and NEXT-DBDM (Berkeley) were built and operated for more than two years. These apparatus have demonstrated the main features of the technology. The experiment is currently developing its second phase. The NEW detector is being constructed during 2014 and will operate in the LSC during 2015. The funding for the construction and operation of NEW comes from an Advanced Grant (AdG/ERC) granted to the PI of this project in 2013. The NEXT-100 detector will be built and commissioned during 2016 and 2017 and will start data taking in 2018. NEXT-100 could discover $\beta\beta0\nu$ processes if the period of the decay is equal or less than 6×10^{25} year. The fourth phase of the experiment (BEXT) could start in 2020.

NEXT is an international collaboration, lead by spanish groups (the PI of this proposal is the spokesperson of the collaboration) and with a very significant contribution of US groups. The laser technology needed for the BEXT phase is being developed in collaboration with the spanish Center for Pulsed Lasers (CLPU).

This proposal requires *co-funding* to complete the phase three of the experiment. Specifically we request: a) funds to co-finance the construction of the NEXT-100 detector (which is being partially payed by the AdG as well as by the international collaboration, primarily US groups); b) funds to co-finance personnel; and c) a modest contribution of the R&D to develop the BaTa technology.

KEYWORDS OF THE COORDINATED PROJECT: neutrinos, TPC, HPXe, xenon, double beta decay, Canfranc, high pressure electroluminescence.

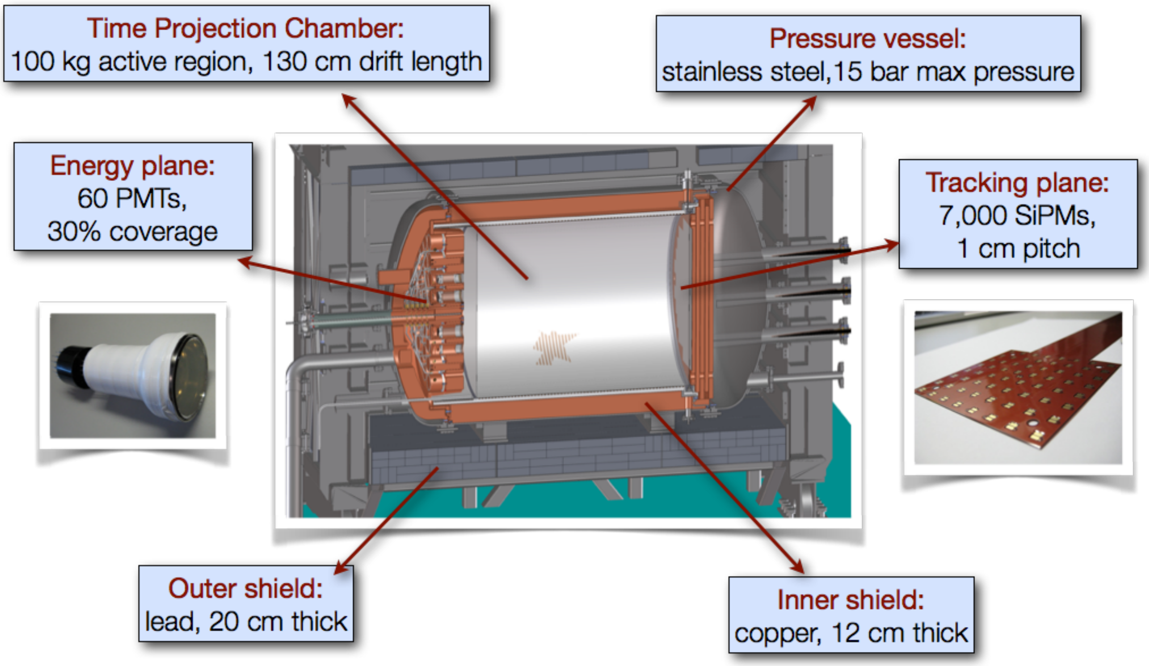

Figura 1: A drawing of the NEXT-100 detector showing its main parts. The pressure vessel (PV), (130 cm inner diameter, 222 cm length, 1cm thick walls, with a total mass of 1 200 kg) is made of a radio pure steel-titanium alloy. The inner copper shield (ICS), is made of ultra-pure copper bars, 12 cm thick, with a total mass of 9 000 kg.The electrical system includes the field cage, cathode, EL grids and HV penetrators. The light tube is made of thin teflon sheets coated with TPB (a wavelength shifter). The energy plane is made of 60 ultra radio pure PMTs housed in copper enclosures (cans). The tracking plane is made of SiPMs arranged into dice boards (DB).

b. Summary of the NEXT project

The NEXT experiment and its innovative concepts

The *Neutrino Experiment with a Xenon TPC* (NEXT)[1] is an experimental program to search for $\beta\beta0\nu$ in ^{136}Xe using high-pressure xenon gas time projection chambers (HPXe).

The design of the NEXT chambers is optimised for energy resolution by using proportional electroluminescent (EL) amplification of the ionisation signal. The detection process involves using the prompt scintillation light from the gas as start-of-event time, drifting the ionisation charge to the anode by means of an electric field ($\sim$ 0,3 kV/cm at 15 bar) where secondary EL scintillation will be produced in the region defined by two highly transparent meshes, between which there is a field of $\sim$ 20 kV/cm at 15 bar. The detection of EL light provides an energy measurement (in the energy plane, made of PMTs, located behind the cathode) as well as providing tracking through its detection a few mm away from production at the anode plane, via a dense array (1 cm pitch) of 1-mm^2 SiPMs (the *tracking plane*).

The design of the NEXT-100 detector (Figure **??**) has been described in a *Technical Design Report*.[2] NEXT-100 has the structure of a Matryoshka (a russian nesting doll). The outermost layer is a shield made of lead, which attenuates the background from the LSC rock by 6 orders of magnitude (e.g., the ^{208}Tl photons are attenuated from $\sim 10^{12}$ per year to $\sim 10^{6}$ per year). The pressure vessel, built out of steel, can hold 150 kg of xenon at 15 bar. Finally, an inner copper shield, 12 cm thick, constitutes the innermost and more radio-clean layer of the Matryoshka. In addition, all NEXT components have been selected and screened for low background. Of particular importance are the PMTs, whose activity is only 0.4 mBq of ^{214}Bi and 0.3 mBq of ^{208}Tl per unit. Our TDR included a detailed background model. A recent paper has validated these results from measurements in a extensive screening campaign carried out in the past year.[3] Currently, most of the major components entering the NEXT detector

[1] http://next.ific.uv.es/

[2] V. Alvarez y col. "NEXT-100 Technical Design Report (TDR): Executive Summary". En: *JINST* 7 (2012), T06001. arXiv: `1202.0721 [physics.ins-det]`.

[3] V. Alvarez y col. "Radiopurity control in the NEXT-100 double beta decay experiment: procedures and initial measurements". En: (2012). arXiv: `1211.3961 [physics.ins-det]`.

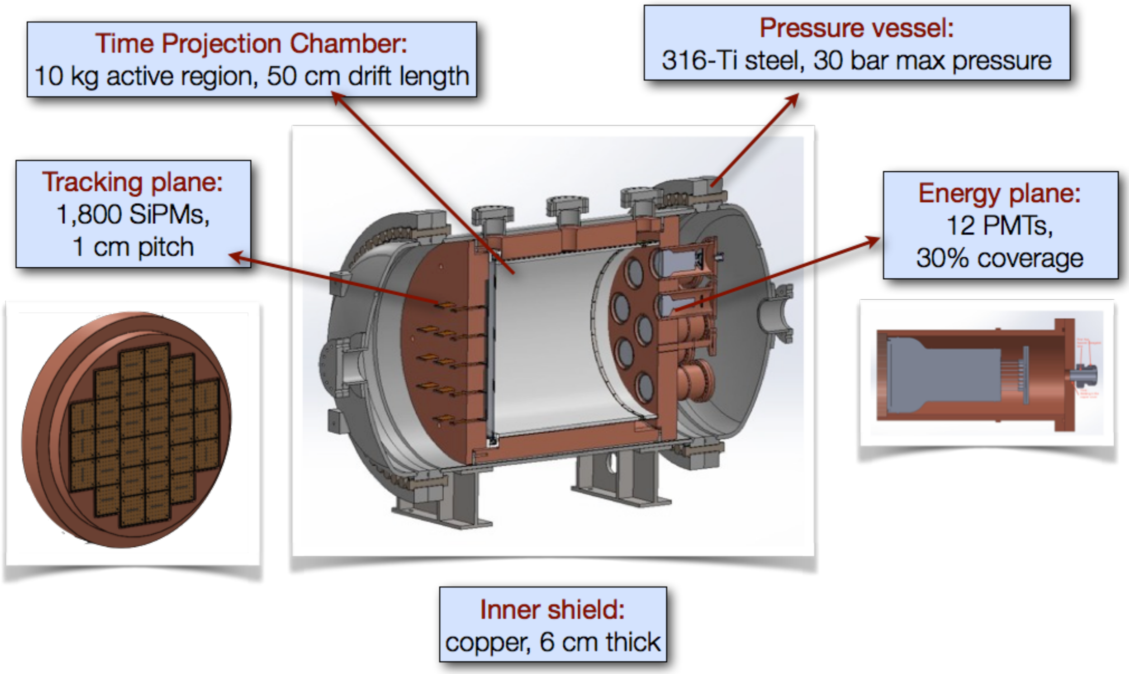

Figura 2: The NEW apparatus.

have been measured, and those numbers are incorporated in our background model.

The NEW detector

The NEW (NEXT-WHITE) apparatus[4], shown in Figure 2 is the first NEXT detector to operate underground. NEW has a triple goal:

1. **Technology**: it will validate the technological solutions adopted by NEXT-100.
2. **Radiopurity**: it will allow the NEXT collaboration an extra step in the implementation of a radiopure detector.
3. **Physics**: it will demonstrate with measurements of the ^{214}Bi and ^{208}Tl lines, as well as with the measurement of the $\beta\beta 2\nu$ spectrum, the physics capabilities of NEXT-100.

NEW is a scale 1:2 in size (1:8 in mass) of NEXT-100. The energy plane contains 12 radio pure PMTs of 3 inches diameter, isolated from the gas inside vacuum-tight copper enclosures (we refer to these as PMT cans). The tracking plane technology consists of 30 Kapton Dice Boards (KDB) deploying 1800 SiPMs. The field cage has a diameter of 50 cm and a length of 60 cm.

Construction schedule

The NEW detector is currently (September 2014) under construction. The detector will be assembled at IFIC for functional tests in December 2014, then dismounts and shipped to LSC for exhaustive cleaning (needed to eliminate any possible superficial radioactive contamination) before mounting it again, inside a clean tent in the second quarter (Q2) of 2015. NEW engineering run, needed to certify the technology will span Q3 and Q4 2015. In 2016, the construction of NEXT-100 will proceed in parallel with the operation of NEW at the LSC.

The construction of NEXT-100 will benefit of the methodology developed by NEW, since all their system are scaled-up versions of those in NEW. Taking into account that all sensors are currently acquired (the pressure vessel and infrastructures are also in hand) and adding the fact that the construction procedures needed for NEXT-100 are being developed and extensively tested during NEW construction, the project management plan of the experiment estimates one year for the construction of the large apparatus. NEXT-100, will, therefore, start operations in 2017.

[4]The name honours the memory of Professor James White, recently deceased and one of the key scientists of the NEXT Collaboration.

c. Costs of the NEXT project

c.1. Costs of the NEW detector

Table 1 summarises the total costs of the NEW detector as well as the funding sources. **AdG** refers to the Advanced Grant ERC granted to the PI of this proposal. **CUP** refers to the CONSOLIDER INGENIO grant of which the PI of this proposal is co-coordinator.

Each subsystem is costed in the subsequent tables. Table 2 summarises the costs of the pressure vessel, table 3 the costs of the inner copper shielding, table 4 the costs of the energy plane, table 5 the costs of the tracking plane, table 6 the costs of the field cage, table 7 the costs of the front-end electronics and table 8 the costs of the online and data acquisition. The NEW detector has been fully payed by CUP and AdG grants.

The costs detailed in the tables are very accurate, since most of the components have already been acquired.

System	Total €	CUP	AdG
Pressure vessel	186,668	12,6445	60,223
Inner copper shield	32,670	0	32,670
Energy plane	131,270	88,572	42,698
Tracking plane	82,318	0	82,318
field cage	78,009	0	78009
FE electronics	83,661	83,661	0
DAQ and online	70,391	0	70,391
Total NEW	**664,989**	298,678	366,311

Cuadro 1: Costs of the NEW detector.

Concept	€	Funding Source
Tools	2,144	AdG
Gaskets	24,200	AdG
Carts	12,100	AdG
Machining	21,780	AdG
Vessel	96,195	CUP
End-cups	15,730	CUP
Vacuum Pump	14,520	CUP
Total	**186, 669**	
Total CUP	126,445	
Total AdG	60.223	

Cuadro 2: Costs of the NEW pressure vessel.

Concept	€	Funding Source
Copper stock	18,150	AdG
Machining	14,520	AdG
Total	**32, 670**	
Total AdG	32,670	

Cuadro 3: Costs of the NEW inner copper shield.

c.2. Costs of the NEXT-100 detector

Table 9 summarises the total costs of the Next-100 detector as well as the funding sources. **FIS2014** refers to our proposal of co-funding submitted to the “Retos de la SociedadÏ+D+i program. **AdG** refers

Concept	€	Funding Source
Support plate	14,520	CUP
PMT cans	25,250	AdG
Feedtrhoughs	14,520	AdG
R11410-10 (12)	74,052	CUP
PMT Bases	2,928	AdG
Total	**131,271**	
Total CUP	88,572	
Total AdG	42,699	

Cuadro 4: Costs of the NEW energy plane.

Concept	€	Funding Source
SiPMs MicroFC-10035-SMT-GP	29,814	AdG
DICE-Boards SLK-1	4,356	AdG
LEDs & sensors	24	AdG
Connectors FX11	871	AdG
Inner Cables	4,840	AdG
Screws	3,630	AdG
Adapter Boards	4,840	AdG
External Cables	5,505	AdG
External cables shielding	847,00	AdG
SiPM Power Supply Components	2,420	AdG
SiPM Power Supply Cables	7,260	AdG
Support plate	12,100	AdG
Feedthrough PCB	2,178	AdG
Feedthrough mechanics	24,200	AdG
Total	**82.318,24**	
Total AdG	82.318,24	

Cuadro 5: Costs of the NEW tracking plane.

Concept	€	Funding Source
Light tube	12,877	AdG
Drift resistor chain	8,258	AdG
Buffer resistor chain	4,386	AdG
Poly body	19,844	AdG
Field shaping rings	4,451	AdG
Gate prototype	4,477	AdG
Gate	12,705	AdG
HVFT & meshes	11,011	AdG
Total	**78,009**	
Total AdG	78,009	

Cuadro 6: Costs of the NEW field cage.

to the Advanced Grant ERC granted to the PI of this proposal. **CUP** refers to the CONSOLIDER INGENIO grant of which the PI of this proposal is co-coordinator.**USA** refers to funds committed by the USA groups.

Each subsystem is costed in the subsequent tables. Table 10 summarises the costs of the pressure vessel, table 11 the costs of the inner copper shielding, table 12 the costs of the energy plane, table 13 the costs of the tracking plane, table 14 the costs of the field cage, table 15 the costs of the front-end electronics and table 16 the costs of the online and data acquisition. The NEW detector has been fully

Concept	€	Funding Source
PMT FEE	990	CUP
SiPM FE boards: components	43,337	CUP
SiPM FE boards: PCB manufacturing	4,374	CUP
SiPM FE boards: prototypes	2,815	CUP
SiPM FE boards: component mounting	4,704	CUP
Cables from FE to DAQ interface	493	CUP
SiPM FE power supplies	19,766	CUP
19çrates + fan cooling units	1,133	CUP
100 ft power supply cable AWG14	783	CUP
SiPM FE board design	5.263	CUP
Total	**83,6661**	
Total CUP	83,661	

Cuadro 7: Costs of the NEW front end electronics.

Concept	€	Funding Source
FECs + rear module vATCA	15,730	AdG
FEC v6 TRG module	2,420	AdG
ADC Cards vATCA	1,542	AdG
Digital Mezzanine vATCA	1,452	AdG
Chassis vATCA 6-slot	10,527	AdG
GbE CAT6 cables	145	AdG
Optic SFP Modules - GbE	1.319	AdG
GbE CAT6 cables	1,815	AdG
PCs (LDC/GDC)	16,940	AdG
Double port 10Gb	2,831	AdG
SAI APC	9,680	AdG
Swicth 1GbE	4,356	AdG
Rack SX 24U	1, 633,50	AdG
Total	**70,391**	
Total AdG	70,391	

Cuadro 8: Costs of the NEW DAQ.

payed by CUP and AdG grants.

The costs detailed in the tables are accurate, since the price of most of the components are estimated directly from the costs of the components already purchased for NEW.

Cost	Total	CUP	USA	FIS2014
Pressure vessel	277,332	102,850 0	174,482	0
Inner copper shield	187550	0	187550	0
Energy plane	625,317	265,353	123,420	236,544
Tracking plane	287,237	0	102,487	184,750
field cage	184,343	0	0	184,343
FE electronics	277,870	0	0	277,870
DAQ and online	142,775	0	0	142,775
Total NEXT-100	**1,982,426**	368,203	413,457	1,200,766

Cuadro 9: Costs of the NEXT-100 detector.

Concept	€	Funding Source
Tools	24,200	FIS2014
Carts	36,300	FIS2014
Vessel	102.850	CUP
Gaskets	27,104	FIS2014
Main flange	24,200	FIS2014
Bolts	8,470	FIS2014
Adaptor CF-DN	16, 940	FIS2014
Connexion Gas System	18.150	FIS2014
VCR gaskets	968	FIS2014
End-Cup	18,150	FIS2014
Total	**277, 332**	
Total CUP	102,850	
Total FIS2014	174,482	

Cuadro 10: Costs of the NEXT-100 pressure vessel.

Concept	€	Funding Source
Copper stock	158,510	USA
Machining	29,040	USA
Total	**187,550**	
Total USA	187,550	
Total FIS2014	0	

Cuadro 11: Costs of the NEXT-100 inner copper shield.

Concept	€	Funding Source
Support plate	58,080	FIS2014
PMT cans	108,216	FIS2014
Feedtrhoughs	60,000	FIS2014
R11410-10 (12)	388,773	CUP+USA
PMT Bases	10,248	FIS2014
Total	**625,317**	
Total CUP	265,353	
Total USA	123,420	
Total FIS2014	236,544	

Cuadro 12: Costs of the NEXT-100 energy plane.

c.3. Costs of the NEXT infrastructures

The operation of NEXT at the LSC requires extensive infrastructures. In addition to the xenon gas, owned by the LSC (100 kg enriched and 100 kg natural), the laboratory has built the working platform, seismic pedestal and lead castle needed to host the experiment. The NEXT experiment provides the gas system needed to recirculate and clean the gas. Such system is expensive, given the safety requirements, and has been purchased with AdG funds. The AdG also provides funds to buy the clean tent, radon suppression and monitoring system and miscellaneous expenses for a total of some 437 k€. Importantly, the infrastructures are fully funded with the contributions of the LSC, CUP and AdG. Table 17 summarises the total costs of the infrastructures. The costs detailed in the tables are very accurate, since most of the components have already been acquired.

Concept	€	Funding Source
SiPMs MicroFC-10035-SMT-GP	102,487	USA
DICE-Boards	15,246	FIS2014
LEDs & sensors	85	FIS2014
Connectors FX11	2,439	FIS2014
Inner Cables	16,940	FIS2014
Screws	14,520	FIS2014
Adapter Boards	16,940	FIS2014
External Cables	22,022	FIS2014
External cables	3,388	FIS2014
SiPM Power Supply Components	9,680	FIS2014
SiPM Power Supply Cables	14,520	FIS2014
Plate TP: copper stock	27,830	FIS2014
Plate TP: manufacturing	18,150	FIS2014
Plate TP: bolts	18,150	FIS2014
Feedthroughs	4,840	FIS2014
Total	**287,237**	
Total USA	102,487	
Total FIS2014	184,750	

Cuadro 13: Costs of the NEXT-100 tracking plane.

Concept	€	Funding Source
Light tube	20,570	FIS2014
Drift resistor chain	8,621	FIS2014
Buffer resistor chain	12,856	FIS2014
Poly body	44,700	FIS2014
Field shaping rings	17,182	FIS2014
Gate	45,980	FIS2014
HVFT & meshes	34,364	FIS2014
Total	**184,343**	
Total FIS2014	184,343	

Cuadro 14: Costs of the NEXT-100 field cage.

Concept	€	Funding Source
PMT FEE	5130	FIS2014
SiPM FE boards: front panels	1,332	FIS2014
SiPM FE boards: components	152,266	FIS2014
SiPM FE boards: PCB manufacturing	12,942	FIS2014
SiPM FE boards: mounting	18,728	FIS2014
Cat-6 RJ45 cables	1,731	FIS2014
SiPM FE power supplies	73,416	FIS2014
19çrates	5,666	FIS2014
100 ft power supply cable	2,663	FIS2014
Rack19"42U height x 600 mm deep	3,993	FIS2014
Total	**277,870**	
Total CUP	277,870	

Cuadro 15: Costs of the NEXT-100 front end electronics.

Concept	€	Funding Source
FECs v6	41,140	FIS2014
ADC Cards	5,082	FIS2014
CDTC16 v2	11,858	FIS2014
Crate Eurocard 19”	363	FIS2014
Cat-6 RJ45 cables	266	FIS2014
Fan cooling units	847	FIS2014
Power supply	16,456	FIS2014
Power supply connectors	242	FIS2014
Rack for Eurocard Crate	1,210	FIS2014
Optic SFP Modules	4,484	FIS2014
cables from FEC to PC	617	FIS2014
PCs (LDC/GDC)	33,880	FIS2014
Double port 10Gb DA/SFP	6,606	FIS2014
SAI APC	12,100	FIS2014
Swicth 1GbE	4,356	FIS2014
Rack SX 24U	3,267	FIS2014
Total	**142.775,16 €**	
Total FIS2014	142.775,16 €	

Cuadro 16: Costs of the NEXT-100 DAQ.

Cost	Total	CUP	AdG	LSC
Gas System	434,177	68,970	365,207	0
Platform and Castle	250,600	0	0	250,600
Xenon (100 kg + 100 kg) 1,056,000	0	0	1,056,000	
Lead cleaning	44,581	44,581	0	0
Cleaning equipment 18,150	18,150	0	0	
Clean tent	59878	0	59,878	0
Radon suppression	5,400	0	5,400	0
Radon monitoring 6,700	0	6,700	0	
Total Infrastructures	**1,875,486**	131,701	437,185	1,306,600

Cuadro 17: Costs of the NEXT infrastructures at the LSC.

c.4. Costs of computing, calibration and slow controls

Computing is estimated in 69,521 € that will be covered by the AdG grant. The costs of the slow control (18,271 €) and the calibration (60,700 €, cost dominated by the need to purchase special radioactive sources for calibration) are assigned to FIS2014.

c.5. Total costs equipment, NEXT construction

The total costs in equipment of NEXT construction are summarised in table 18. They totalise about 4.6 million € including the xenon gas (1.1 million €). The **external** contributions to the project (e.g, the money does not come from the spanish science system) add to 1,286,475m a figure slightly higher than the co-funding of 1,279,737 requested in this project.

Cost	Total	CUP	AdG	USA	LSC	FIS2014
	4,601,873	798,582	873,018	413,457	1,306,600	1,279,737

Cuadro 18: Total costs of the NEXT construction (equipment).

c.6. Costs of personnel for NEXT construction

The construction, commissioning and operation of the NEXT detectors require of a team of specialised physicists and engineers. This team comes from both national and international universities and research institutions. The contributions of the international collaboration, in particular of the USA groups during the period of R&D and design of NEXT have been very important for the development of the project. Currently, the spanish groups, in particular those participating in this co-ordinated project have absorbed the know-how brought to the collaboration by the crucial contributions of the Berkeley group (prof. David Nygren, the inventor of the TPC technology) and Texas group (the late prof. James White, who was the leading World expert in high pressure gas chambers).

The CUP grant have made possible the creation of a world class group at IFIC, which includes the PI, the technical coordinator (Dr. Igor Liubarsky, a renewed expert in the field), two R&C fellows, one of them senior (Dr. Sorel) and one of them junior (Dr. Novella, who starts this year in the group), six post-docs (Laing, Ferrario, López-March, Renner, Martin-Albo and Monrabal) and 4 Ph.D. students, 2 of whom will present their Ph.D. thesis in 2014 or early 2015. Last but not least, the group has formed several engineers. S. Cárcel is leading the development of mechanics (with the help of technical mechanics engineer A. Martínez) and J. Rodríguez leads the development of electronics (with the help of technical electronics engineer V. Alvarez).

The group at the UPV brings the essential expertise in front-end electronics and data acquisition. The group includes three experienced engineers, all of the professors at the UPV. Last, but not least, prof. J.A. Hernando, form the University of Santiago has taken the important role of calibration and reconstruction coordinator in NEXT.

We require co-funding to keep essential personnel for the project. A substantial contribution to personnel at IFIC will come from the AdG grant, which will provide funds for amount of 1,097,258 € over the period requested for this grant. This will cover the salary of the technical coordinator (Liubarsky) and 4 post-docs. We expect to obtain 4 post-doc years from national and international grants, in particular from the Marie Curie program (these are 2 years positions). Consequently, the IFIC group requires the equivalent to one full post-doc per for years to this grant.

IFIC also requests funding to keep our 2 senior engineers (Cárcel and Rodríguez), who are in charge of essential parts of the project and one technical engineer (external funds, from local agencies, such as the Generalitat Valenciana will be seek to fund the second technical engineer in the team).

The UPV is in charge of the full development of the electronics and brings in essential man power (with permanent positions). The personnel needed is: a technical engineer to help with the development of the front-end electronics, lead by the electronics coordinator of NEXT (prof J. Toledo), and a senior enginner/computer scientist to help with the dual task of DAQ development (task lead for the DAQ coordinator of NEXT, professor R. Esteve) and online computing.

Last but not least, we request a post-doc to reinforce the group at the University of Santiago. The group is lead by prof. J.A. Hernando, a renown physicist who has made major contributions to neutrino physics and to flavour physics. Hernando is now full time in NEXT and has taken the role of calibration and reconstruction coordinator. A post-doc to help in these tasks, essential for the performance of NEXT is requested. Santiago will seek for local support and international fellowships for a second post-doc.

The NEXT project is extremely well suited as a training ground for students and post-docs. The project involves the construction, commissioning, operation and data analysis of the most advanced HPXe in the World, and the possibility to participate in a major discovery. The teams are very experienced and well organised. At IFIC, four senior physicist (the PI, Dr. Liubarsky, Dr. Sorel and Dr. Novella) are looking forward to advise students. At UPV, students can work with two of the leading experts in front-end electronics and DAQ in the field. At the US, prof. Hernando is already working with two students in calibration and reconstruction.

At the same time, graduate students are very important for the future of the project and for its impact in science and society. Consequently, the groups in this coordinated project require 3 FPI grants, one per group (we will seek for other grants, such as FPU to enrol further graduate students).

Table 19 summaries the personnel requested. Table **??** details the standard salaries payed to post-docs and engineers. Finally, table **??** describes the personnel costs required to this project.

Notice that the total costs requested in this project are slightly below those provided by external fund sources such as the AdG.

Group	post-docs	engineers	technical engineers	FPI
IFIC	1	2	1	1
UPV	0	1	1	1
US	1	0	0	1
Total	2	3	2	3

Cuadro 19: Personnel requested.

Cost	post-docs	engineers	technical engineers
	40,000	40,000	30,000

Cuadro 20: Table of costs.

Group	post-docs	engineers	technical engineers	Total
IFIC	160,000	320,000	120,000	600,000
UPV 0	160,000	30,00	190,000	
US	160,000	0	0	160,000
Total	320,000	480,000	150,000	**950,000**

Cuadro 21: Personnel costs.

c.7. Travel to LSC

The NEW detector will be installed and commissioned at the LSC in mid 2015. In 2016, NEW will operate at the LSC, while the NEXT-100 detector will be constructed at IFIC, UPV and Texas, among other laboratories. In 2017, NEXT-100 will be commissioned at the LSC. Operation will proceed from 2018 onwards.

During commissioning, we foresee the constant presence at the LSC of one of our mechanical engineers and one of our electronics engineer (4 weeks a month). This is a must, because IFIC and UPV jointly coordinate the mechanics, electronics and computing of NEXT. In the operation periods, when the detector is stable, this presence can be reduced to one week per month. Concerning post-docs, a constant presence of 2 post-docs or students (4 weeks a month) from our groups is needed. In addition, one student or post-doc in charge of the detector shifts is needed. We also foresee the presence of the PI and technical coordinator for about one week per month during the span of the project.

Notice that the personnel at the LSC provided by the international collaboration will amply match the personnel provided by this project. The USA groups foresee to deploy at least two physicists to the LSC (4 weeks per month). The portuguese groups will deploy at least two more. Personnel from the university of Zaragoza, which is a part of NEXT will travel frequently to the LSC.

To minimise costs, we foresee to rent an apartment near Canfranc (probably at Jaca), and to organise travel car-pooling the teams. The daily expenses are computed conservatively (250 € per week).

Activities at LSC	2015	2016	2017	2018
Construction	NEW (6 months)	NEXT-100	-	-
Commissioning	NEW (6 months)	-	NEXT-100	-
Operation	-	NEW	-	NEXT-100

Cuadro 22: Activities at the LSC

Tables 22, 23, 24, 25 and 26 detail the calculation of costs. The total travel to LSC foreseen during the span of this project is 261,000 €.

Personnel at LSC	2015	2016	2017	2018
engineers	2 x 4 w/m per 6 months	2 x 1 w/m	2 x 4 w/m per 9 months	2 x 1 w/m
post-docs/students	2 x 4 w/m per 6 months	2 x 4 w/m	2 x 4 w/m	2 x 4 w/m
Technical coordinator	1 x 1 w/m	1 x 1 w/m	1 x 1 w/m	1 x 1 w/m
PI	1 x 1 w/m	1 x 1 w/m	1 x 1 w/m	1 x 1 w/m
Shifters	1 x 4 w/m per 6 months	1 x 4 w/m	1 x 4 w/m	1 x 4 w/m

Cuadro 23: Personnel at the LSC. w/m means week per month.

Weeks at LSC	2015	2016	2017	2018
engineer	48	24	72	24
post-docs/students	48	96	96	96
Technical coordinator	6	12	12	12
PI	6	12	12	12
Shifters	24	48	48	48
Total	132	192	240	192

Cuadro 24: Weeks at the LSC

Large apartment rental (month)	1200
car-pool trip	150
number of car-pool trips	1 per week
subsistence/week	250

Cuadro 25: Details of costs

Concept	2015	2016	2017	2018
Apartment	7,200	14,400	14,400	14,400
trips	3,600	6,000	6,000	6,000
Subsistance	33,000	48,000	60,000	48,000
Total	43,800	68,400	80,400	68,400

Cuadro 26: Costs travel to the LSC.

Subproject	Construction	Personnel	Travel	Total
COORD (IFIC)	859,091	600,000	181,000	1,640,091
ENG (UPV)	420,646	190,000	40,000	610,646
CALREC (US)	0	160,000	40,000	200,000

Cuadro 27: Costs of NEXT construction, personnel and travel to LSC.

c.8. Costs of construction, personnel and travel to LSC

The total costs of construction, personnel and travel to the LSC amounts to 2,450,737 €. The costs are distributed in three subprojects, called COORD (coordination, IFIC), ENG (engineering, UPV) and CALREC (calibration and reconstruction, US). The distribution of costs per subproject is detailed in table 27. Notice that the construction funds requested by IFIC are matched by those provided by the AdG, and the construction funds requested by the UPV are matched by those provided by the USA groups. All the personnel funds are matched by funds provided by the AdG. The personnel from the co-ordinated project at the LSC will be matched by personnel from the international collaboration.