ECOS 2012 Workshop
Loveno di Menaggio, 18-21 June 2012

Universidad de Huelva

Present status of the LRF facility

Ismael Martel
Department of Applied Physics
University of Huelva (Spain)

SPAIN

Map
Satellite
Corunna
Ferrol
Oviedo
Lugo
Santiago de Compostela
Ourense
Pontevedra
Leon
Bilbao
Vitoria
Pamplona
Burgos
Andorra
Vigo
Braga
Valladolid
Saragossa
Lerida
Sabadell
Porto
Salamanca
Reus
Barcelona
Viseu
Avila
Coimbra
Portugal
Spain
Valencia
Palma
Balearic Sea
Badajoz
Albacete
Cascais
Lisbon
Alicante
Cordova
Murcia
Sevilla
Huelva
Granada
Cartagena
Jerez de la Frontera
Malaga
Almeria
Gibraltar
Alboran Sea
Oran
Google

Huelva

Cristobal
Columbus
1492

Recreativo
Football Club
1889

1960's

1992

History:

→1492, the discovery of America: Shipbuilders, Caravels and the crew of Cristobal Columbus were from Huelva. Depart from a small port located at the village of Palos de la Frontera (Huelva).

→1889, first football team in Spain (soccer) founded by British workers at "Rio Tinto" mines (Rio Tinto Company, London, 1873).

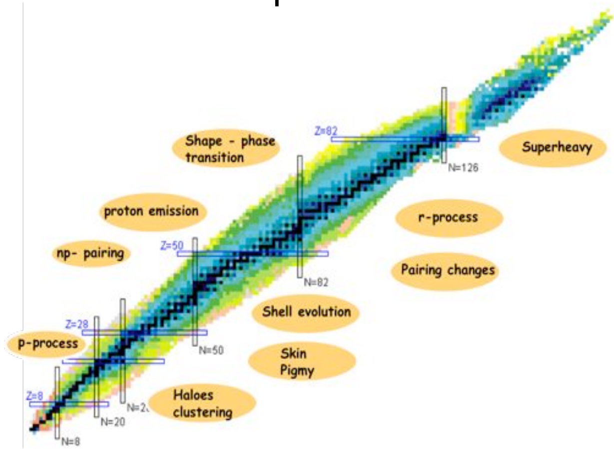
→1960's, one of largest industrial sites in Spain (Chemicals, Petrol & Mining industry)

→1992, University of Huelva was born, one of the youngest Universities of Spain. (15.000 students/150.000 habitants of Huelva) → Mainly Technical University/Engineering

→1999, the Nuclear & Particle Physics group ~ 20 staff (spec. + instrument.)

→ 2012, the Linac Research Facility

The Nuclear Landscape



The **Linac Research Facility (LRF)**

User oriented facility for producing intense HEAVY ION BEAMS for basic research on nuclear physics and applications. UNIVERSITY FACILITY (→students/masters/PhDs/etc).

→ OPEN INTERNATIONAL COLLABORATION ←

High intensity superconducting linac.

- Wide range of heavy ions
- Wide range of energies, from keV/u ~15 MeV/u
- Maximum intensity for HI (~100uA, ^{40}Ar)
- protons up to 30 MeV (~1 mA); up to 70 MeV (nA)

PROGRAM: Basic nuclear physics

- Nuclear reactions and spectroscopy with stable, high intensity, beams:
  →European ECOS initiative for high energy accelerators:

  Super-heavy & Nuclear astrophysics → long periods of beam time demanded
  Nuclear structure studies at low medium and high-spin
  Clusters and molecules in nuclei
  Ground-state properties
  Near barrier transfer and fusion

IGISOL type ion source: stopped beams (beta-decay, beta-particle, masses, etc).

APPLICATIONS

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→**Project driven by applications and industry: Science & Technology Park -PCTH**

-Modern radio-isotope production (heavies: Mo, I, Sc, Se, …)
-Medicine (branchiotherapy; proton therapy; dosimetry,…)
-Material research for energy (Fusion energy, solar cells, …)
-Aerospace
-Ion implantation

-Applications impose very demanding beam intensities and energies

→basic research

LINAC CONSTRUCTION

Interested companies:

ACS, France
ADEVICE, Spain
AIR LIQUIDE, France & Spain
ALTER TECHNOLOGY, Spain
APLICACIONES TECNOLÓGICAS, Spain
A-V-S, Spain
CIBERNOS, Spain
CRIOLAB , Portugal
EBS Group, Italy & Spain
ELYTT ENERGY, Spain
EMPRESARIOS AGRUPADOS, Spain
IBERDROLA, Spain
IDOM, Spain
I2FACTORY, Spain
INDRA, Spain
INGESER, Spain
JEMA, Spain
LINDE KRYOTECHNIK AG, Switzerland & Spain
PANTECHNIK, France
PRAXAIR, EEUU& Spain
SEVEN SOLUTIONS, Spain
THARSIS TECHNOLOGY, Spain
TTI NORTE, Spain

LINAC RESEARCH FACILITY: INDUSTRY & BASIC SCIENCE

FONDO EUROPEO DE DESARROLLO REGIONAL

PCTH Parque Científico y Tecnológico de Huelva

EUROPEAN UNION ERDF PROGRAM:

European Regional Development Funds

- UNDEVELOPED REGIONS OF EUROPE (HUELVA)
- EU: > 75 % COST SUPPORT OF INFRASTRUCTURE
- PARTICIPATION OF SPANISH INDUSTRY

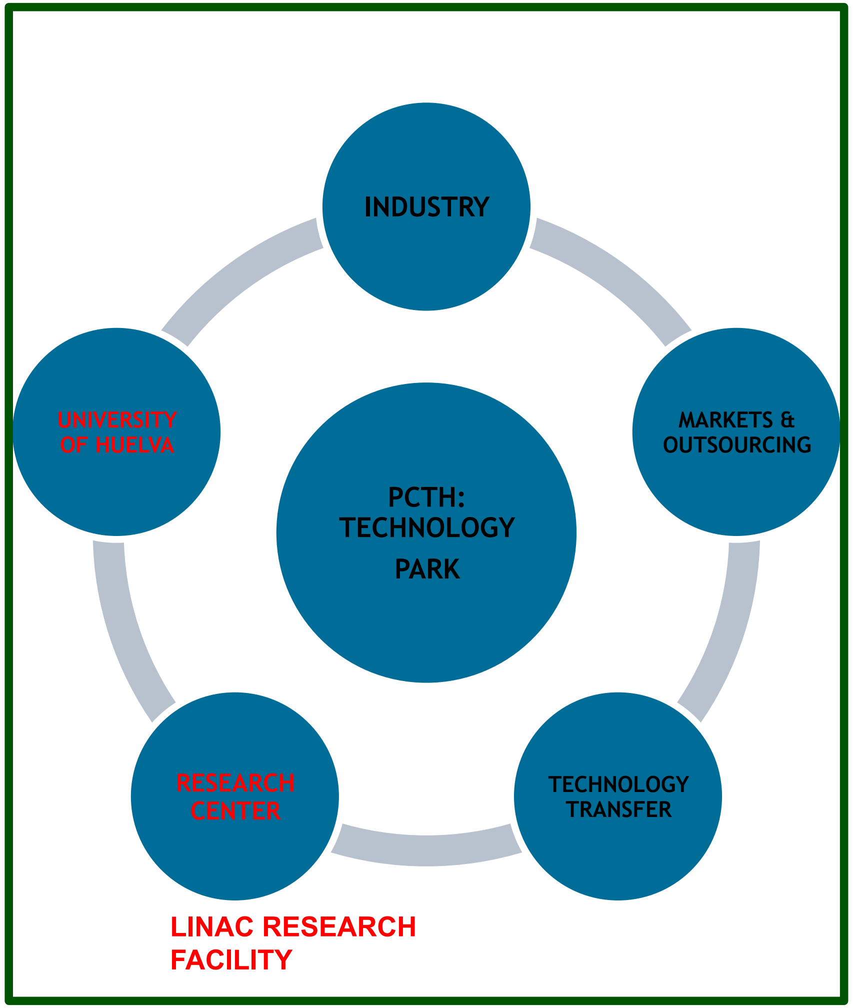
GOBIERNO DE ESPAÑA

CDTI
Centro para el Desarrollo Tecnológico Industrial

(MINISTRY OF ECONOMY & COMP.)

STATE OF ANDALUCIA (AUTONOMÍA)

JUNTA DE ANDALUCIA



INDUSTRY FUND.		Meur	2011	2012	2013	2014	2015	2016	2017
INNPLANTA	Buildings	10.8							
INNPLANTA	LINAC	15.4							
INNTERCONECTA	R&D	1.4							
?? 2012 ??	Commissioning +??	??							

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LRF ORGANIZATION (TODAY):

- PART of a Research Centre of the University of Huelva,
  "CENTER FOR ENERGY RESEARCH"

-Research groups (~ 60 staff)
-Technical staff (~ 6 staff)
- Also lecturing activity (Postgraduate)

- Participation of PCTH (State of Andalucía, industrial partners & other companies)

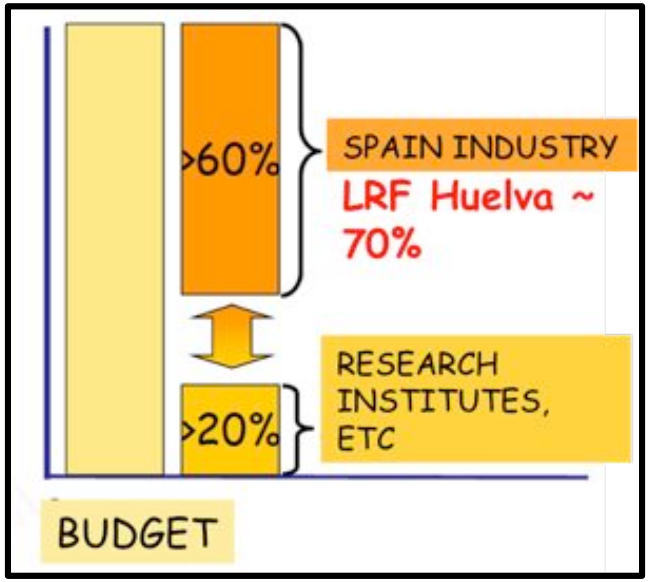
- Budget (Personnel, running costs, etc):
  - University (Staff + Project overheads)
  - Funding grants: Andalucía, Spain, European Union.

ENERGY RESEARCH CENTRE		
DIRECTOR OF THE RESEARCH CENTRE		
DEPARTMENT OF NUCLEAR TECHNOLOGY	DEPARTMENT OF RENEWVABLE ENERGIES	DEPARTMENT OF ELECTRIC POWER
Head of Department	Head of Department	Head of Department
Research groups: nuclear reactions, medical physics, particle detectors, theory	Research groups	Research groups
FACILITIES & LABS (LINAC RESEARCH FACILITY)	FACILITIES & LABS	FACILITIES & LABS

Budget @ June 2012

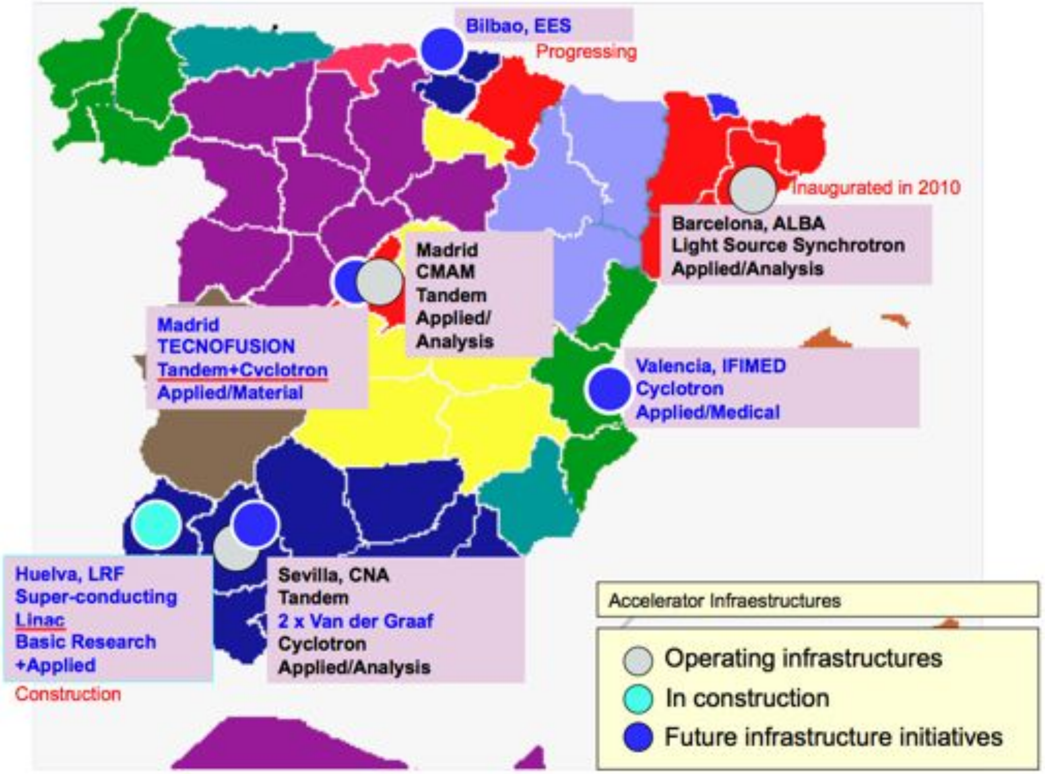
- Land is provided by university/PCTH
10.8 Meur building
15.4 Meur LINAC

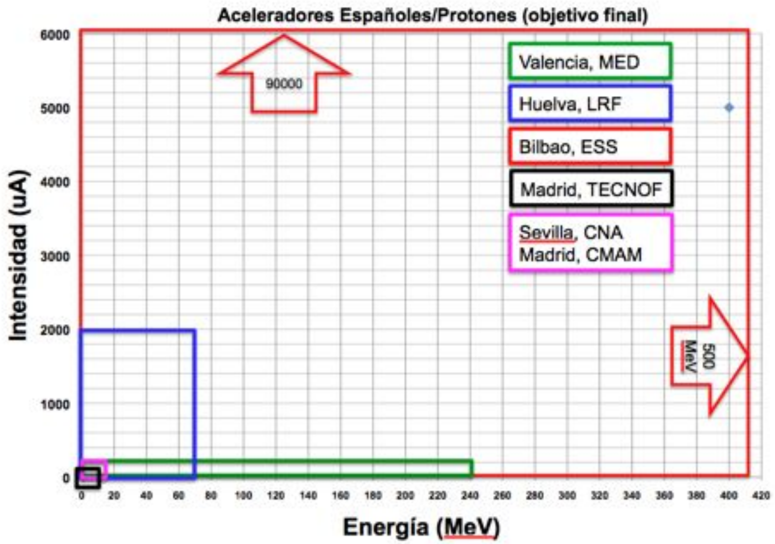
-3/4 years schedule for delivery (not commissioning)

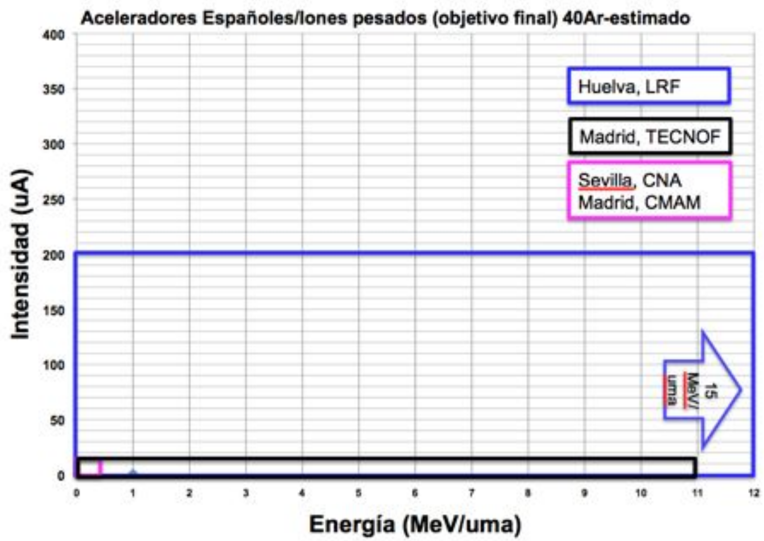


Panorama of accelerator facilities in Spain for basic research and applications.

Valencia: IFIMED
Bilbao: ESS
Madrid: TECNOFUSIÓN
Madrid: CMAM
Seville: CNA
Huelva: LRF







LRF-BASIC RESEARCH

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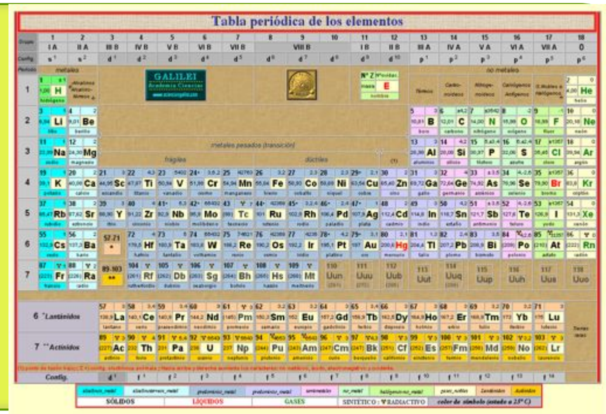
Main topics for a high intensity machine:

Superheavy nuclei are new elements of the Periodic Table which have been predicted to exist. They cannot be found in The Earth, but can be synthesized by heavy ion collisions like 48Ca+248Cm at high collision energies. One of the last elements accepted by IUPAC is the Darmstatium, given by the city name of Darmstadt (Germany) where the heavy ion laboratory GSI, where it was discovered, is located.



Astrophysics: The light of the stars come from the fusion reactions taken place in their core and the explosions occurring as novae and super-novae. In this way the elements of the Periodic Table are synthesized, the so called **nucleosynthesis**. The fusion reactions of this hot scenario with intense, high energy heavy ion beams, and therefore study the process of nucleosynthesis.

In-beam spectroscopy of exotic nuclei using thick-thin targets

Typical beams

40Ar ~ 14 MeV/u
86Kr ~ 8.5 MeV/u
84Kr ~ 10 MeV/u
136Xe ~ 7 MeV/u

Exotic isotope production:

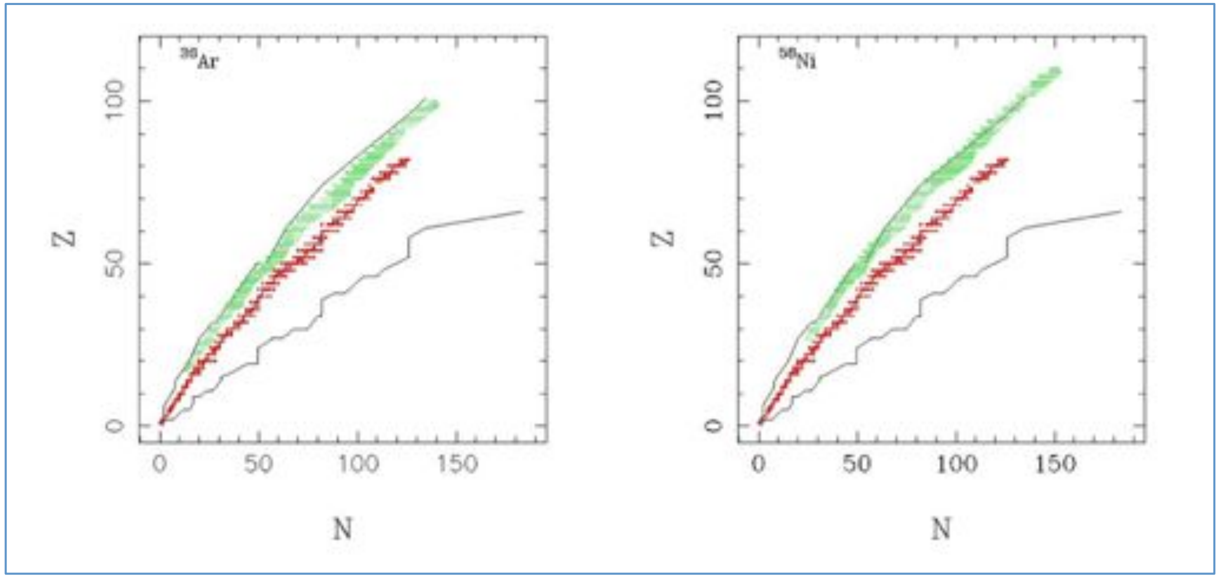
Height of the Coulomb barrier ~ 4 to 5 MeV/nucleon

→ compound nucleus/fus.evap reactions, E ~ Eb → proton rich
→ reactions of nucleon exchange, E>> Eb → neutron rich

Compound nucleus/fus. evap reactions → Basic mechanism for production of proton rich nuclei

de- excitation channels:
3-6n, p2-5n, a2-5n

M. Veselsky, Nuclear Physics A 705 (2002) 193;
M. Veselsky, G.A. Souliotis, Nuclear Physics A 765 (2006) 252;
A 781 (2007) 521.
G.A.Souliotis et al., PRC 84, 064607 (2011)
M. Veselsky,et al., Nucl. Phys. A 872 (2011) 1.



Accessible regions of the proton rich nuclei (green), which can be produced using proton rich ion beams such as 36Ar (left) and heavier ions 58Ni (right) in the compound nucleus reactions. Red region represents stable target nuclei. Lines represent the proton and neutron driplines.

Cortesy of M. Veselsky

Production of neutron rich nuclei

-preferably "cold" processes with minimum neutron loss. → Reactions of heavy ions with energies around > 10 MeV/u

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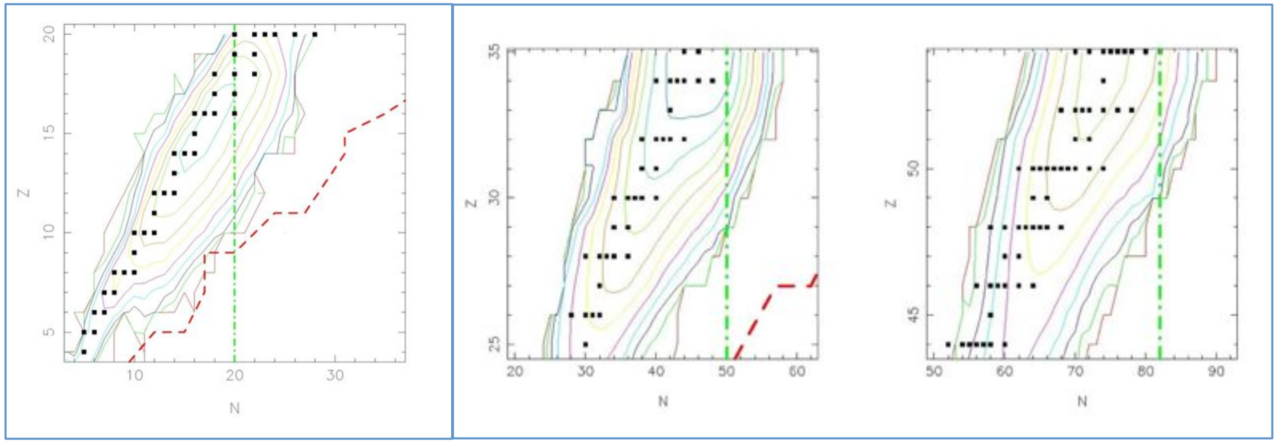
40Ar+238U @ 16 MeV/u 86Kr+90Zr@8.5 MeV/u 136Xe+124Sn@7 MeV/u



closed neutron shell N=20.

Cortesy of M. Veselsky

Example (Vamos, GANIL):

- intensity of 0.1 puA
- target thickness 50 mg/cm2

→ production around 10 nuclei per second

For present facility,

10 puA → 103 pps on target!!!**

Radioactive beam line: IGISOL

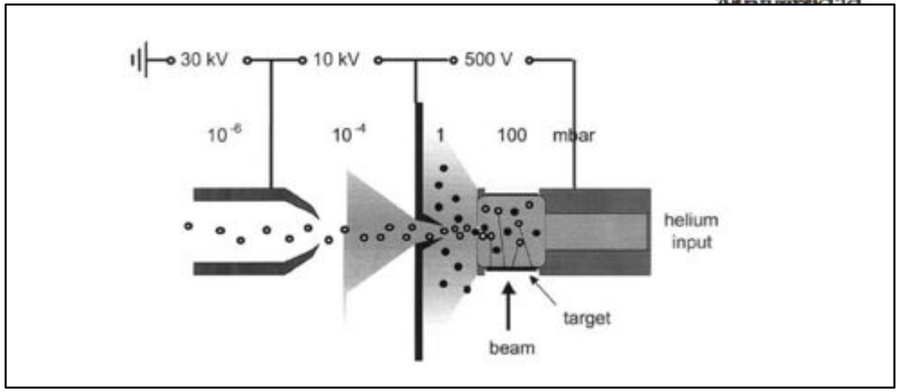
Isotope production and extraction pioneered at Jyvaskyla (J. Aysto et al.)

Ion source

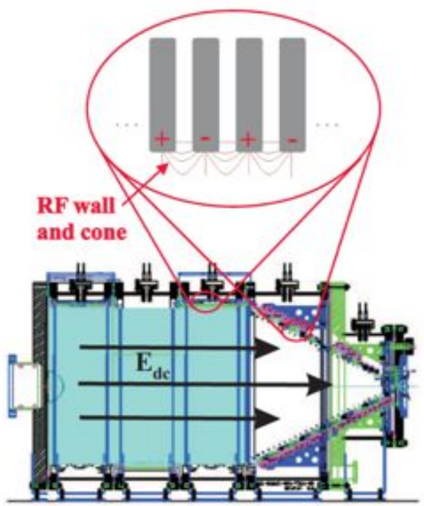
He gas jet
Ion guide
Acceleration voltage ~40 kV

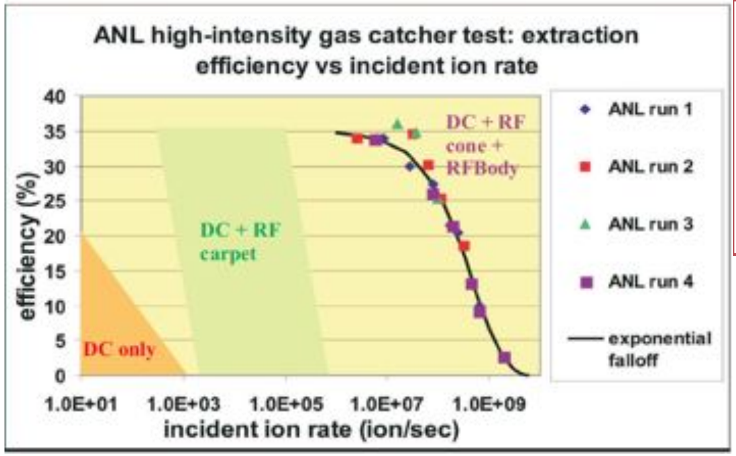
Mass separator

Detection setup: Tape station,
beta-gamma, gamma-gamma, (Ge, Si(Li), BaF2), →
traps , etc



→ GAS CATCHER: a large volume of high-purity helium gas surrounded by a guiding structure where the ions lose their energy and are extracted rapidly into a beam forming region



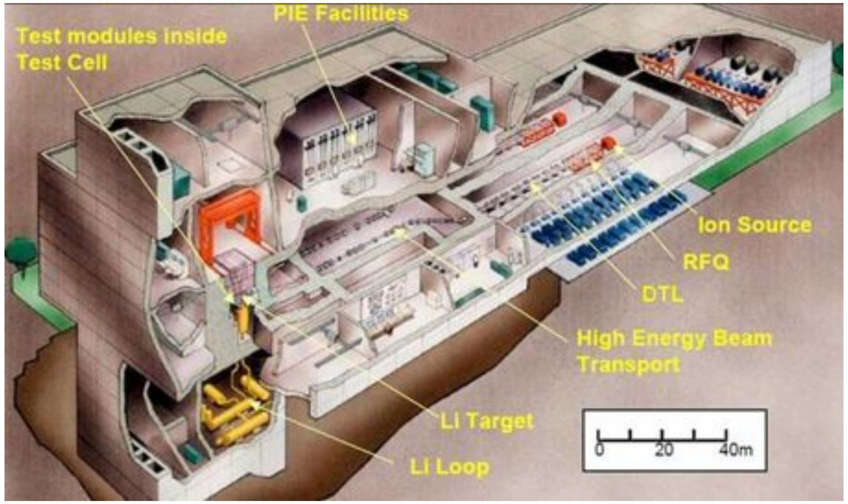


Physics program with radioactive beams:
- DECAY SPECTROSCOPY
- MASS MEASUREMENTS
- FUNDAMENTAL INTERACTIONS

G. Savart, Journal of Physics: Conference Series 312 (2011) 052004

LRF-APPLICATIONS

Material research for energy production



Fusion energy research: aiming at qualifying advanced materials resistant to extreme conditions, specific to fusion reactors like ITER. Intense ion beams of moderate energy are needed to simulate fusion reactor conditions. (CIEMAT)

IFMIF project: a 40 MeV, 125 mA deuteron + lithium target → neutrons to test materials for the first commertial fusion reactor :
the DEMO reactor

	A	Z	E (MeV)
C	12	4	146,7
Si	28	9	318,2
Fe	56	14	385,0
W	184	25	373,6
H	1	1	up to ~ 40

Why protons for cancer radiotherapy?

HOSPITAL JUAN RAMÓN JÍMENEZ -HUELVA

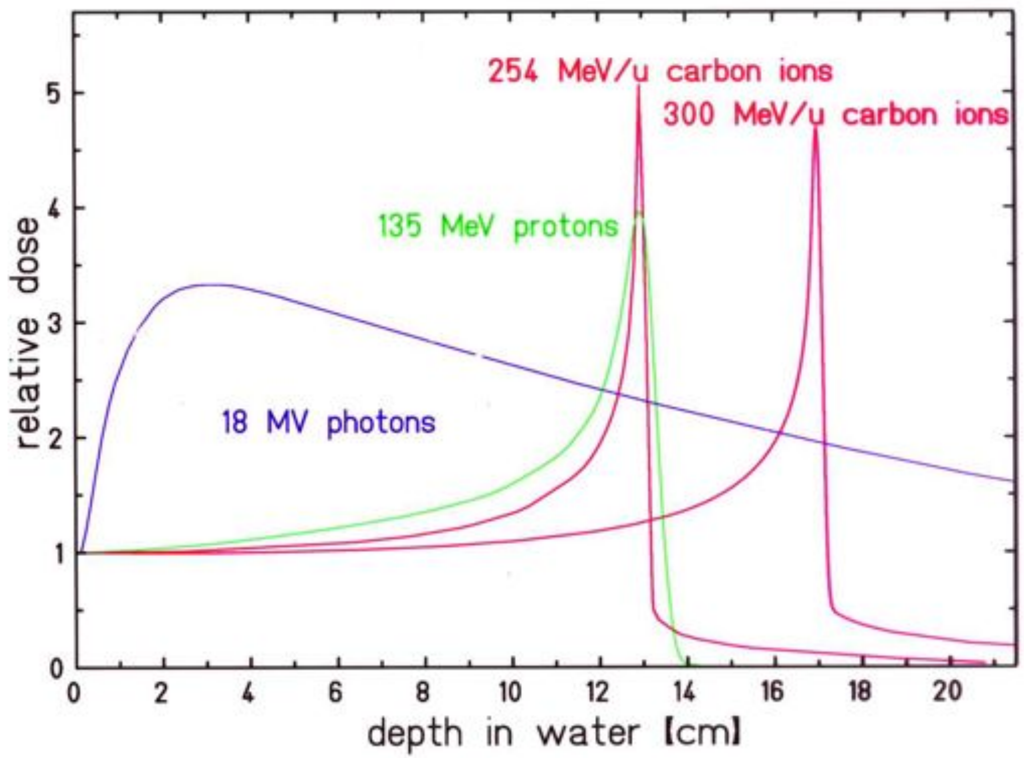
Universidad de Huelva

Proton Therapy is particularly appropriate in situations where conventional radiotherapy presents an unacceptable risk to the patient – cancer of the eye, brain and paediatric cases. Proton and carbon linacs are the most refined technique to cure tumours and cancer disease.

- **well defined range of proton beam**
- **very precise irradiation**

E (MeV)	Depth (mm)
10	1
20	4
50	22
100	76
120	105
150	155
200	256

Adapted from Pawel Olko, IEEE meeting, 30.06.2008



Material modification produced with intense ion beams are used for fabrication of new materials. Incipient diamond material industry for fabrication of microelectronic devices and hard radiation sensors for energy applications.

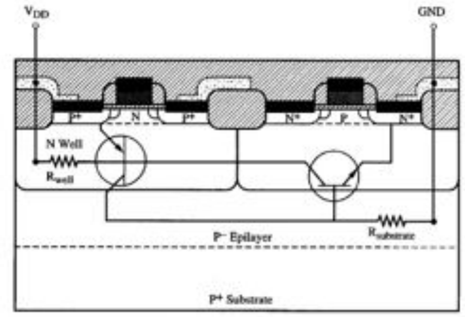
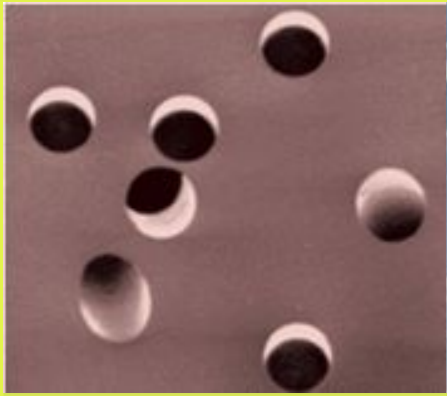
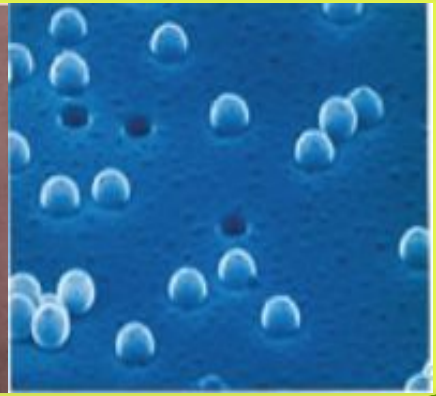


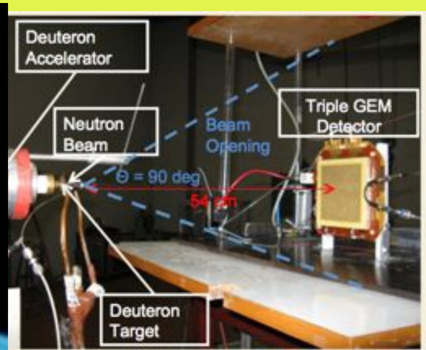
Figure 8–15 Schematic of latchup structure which occurs in a CMOS technology. The parasitic bipolar transistors are overlaid on the technology discussed in Chapter 2. The resistors are normally connected as shown in the schematic.

Microfiltration of membranes by heavy ions. Heavy ion beams are used to produce track-etched microfiltration membranes commercialized by various brands. In these membranes, tracks of slow, heavy ions crossing a sheet of polymer are chemically etched, giving cylindrical pores of very accurate diameter: Epifluorescence microscopy, Environmental analysis, Fuel testing, Parasitology, Air analysis and pharmaceuticals.



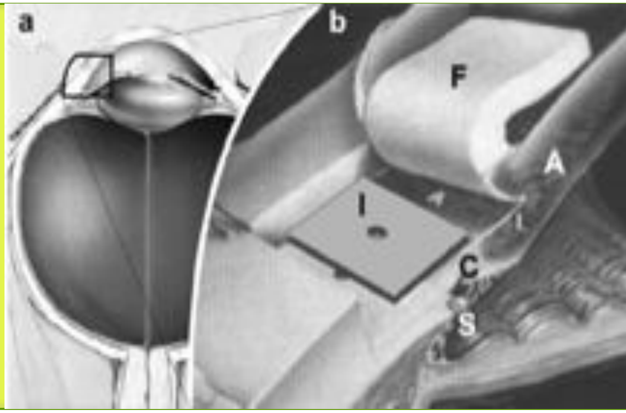


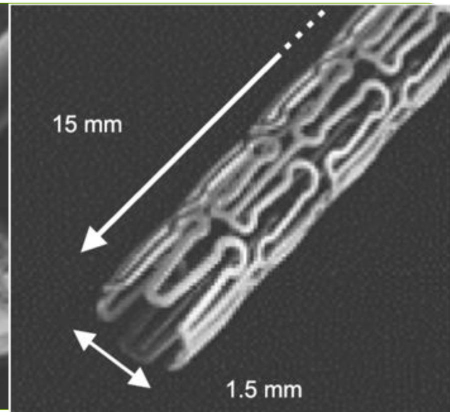
High intensity ion beams are used in **aerospace programs** for radiation resistant electronics and in nuclear energy applications. Quality tests are required in order to accomplish with UE safety regulations for energy control and aerospace on-board electronics. Research can be centred on the impact of radiation on the response of new device technologies and single-event effects in new technologies and ultra-small devices.



G. Croci, et al. 3rd RD51 mini-week

Brachytherapy techniques are developed in modern hospitals to treat tumours in eye (glaucoma), lungs and critical organs.
Ischemic heart disease is treated by radioactive ions implanted in foils. The activation process is carried out at accelerators.



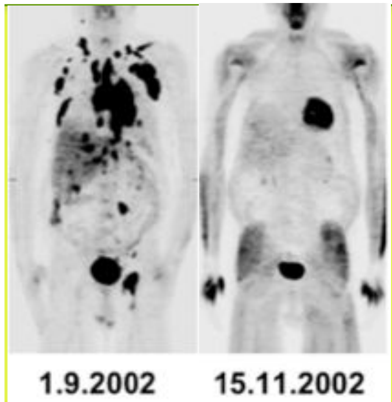


Modern radioisotopes are currently investigated to treat in a more efficient way the different tumours and cancer disease of our society. More than 1 million UE citizens die every year from cancer. New isotope production will be investigated at LRF-Huelva facility. An example is 177Lu for lymphoma therapy.

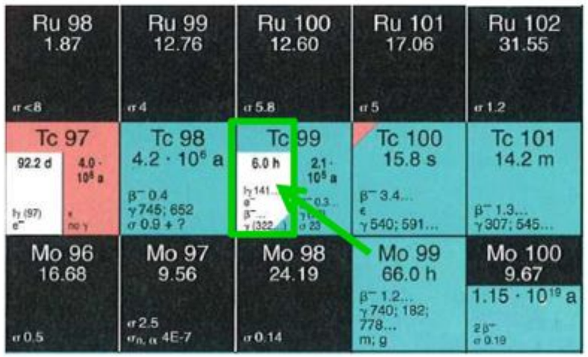
Radionuclides for radioimmunotherapy

Radio-nuclide	Half-life	E mean (keV)	Eγ (keV)	Range
Y-90	64 h	934 β	-	12 mm
I-131	8 days	182 β	364	3 mm
Lu-177	7 days	134 β	208, 113	2 mm
Tb-161	7 days	154 β 5, 17, 40 e⁻	75	2 mm 1-30 µm
At-211	7.2 h	5870 α	-	45 µm
Tb-149	4.1 h	3967 α	165,..	25 µm
Er-165	10.3 h	5.3 e⁻	-	0.6 µm

cross-fire
localized

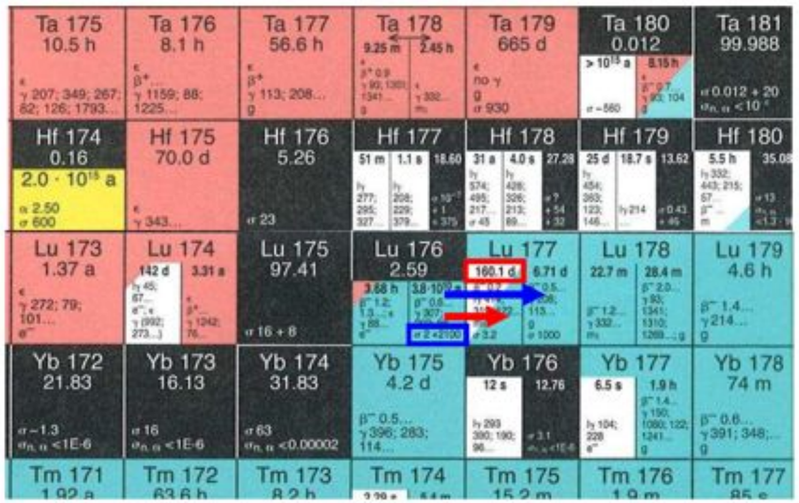


^{99m}Tc: ideal for SPECT and gamma cameras



- IT with 89% 140.5 keV gamma ray, $T_{1/2}$ = 6 h
- decays to quasi-stable daughter
- ^{99m}Tc fed in 88% of β^- decays of ^{99}Mo, $T_{1/2}$ = 66 h
- produces nearly carrier-free product

Production of ^{177}Lu



LOW ENERGY BEAM LINE: ION SOURCE AND 400 KV PLATFORM

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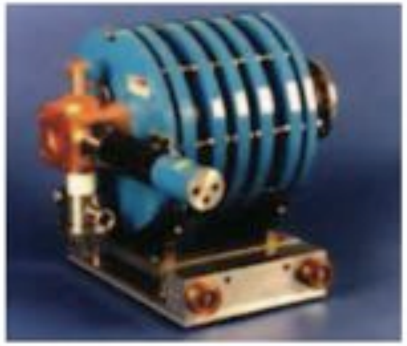
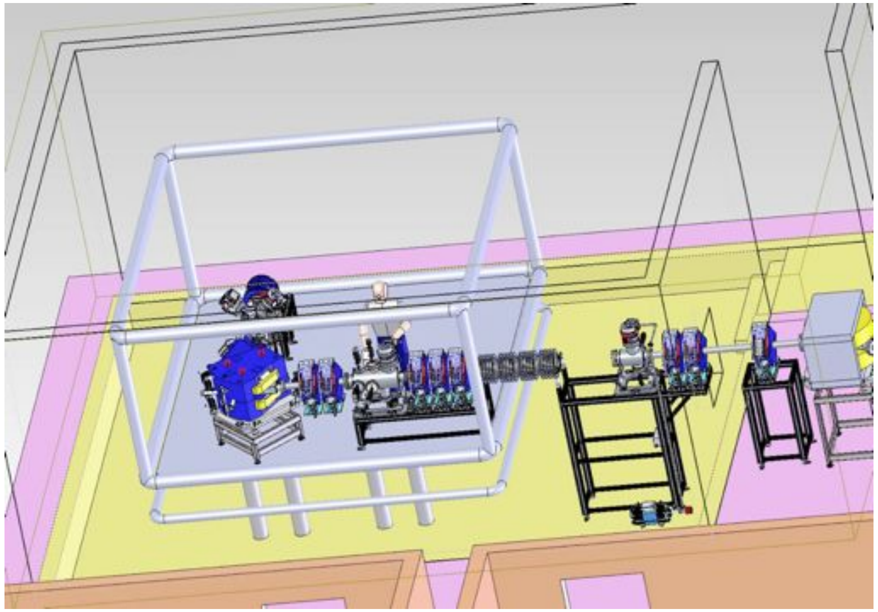
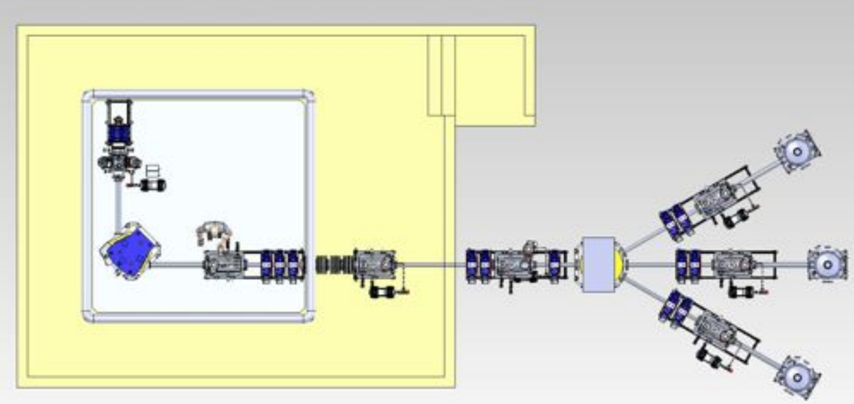
Wide range of ions 2 high intensity: Commercial options/ ECR ion source (Pantechnik).

Ions/Q	1+	2+	4+	6+	8+	9+	11+	14+	20+	23+	25+	26+	27+	30+	31+	32+
H	2000															
H_2	1000															
H_3	700															
He	2000	1000														
C	500	350	200	3												
N	1000	300	100	10												
O	1000	400	300	200												
Ne	1000	300	200	160	25											
Ar	1000	350	250	200	200	90	30	1								
Kr	1000						25	15								
Ag			250	250	200	90	30		4							
Xe	500				220				15	14	10	5				
Ta									4	0.8						
Au												10	6	1	0.7	0.2
Pb									10		5	3	1			



Preliminary arrangement of 400KV-HV platform and optics at LRF-Huelva (LNL, ANL, TRIUMF, etc).





→Low Energy Astrophysics
→Ion implantation

PRELIMINARY LINAC PARAMETERS AND CONFIGURATION

LRF-Huelva calculation (P. Ostroumov, ANL)

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Specifications:

- High intensity Heavy ion accelerator up to 15 MeV/u (40Ar 200uA, 130Xe 10 uA)
- H, D 1mA, 30 MeV; H, 1uA 72 MeV

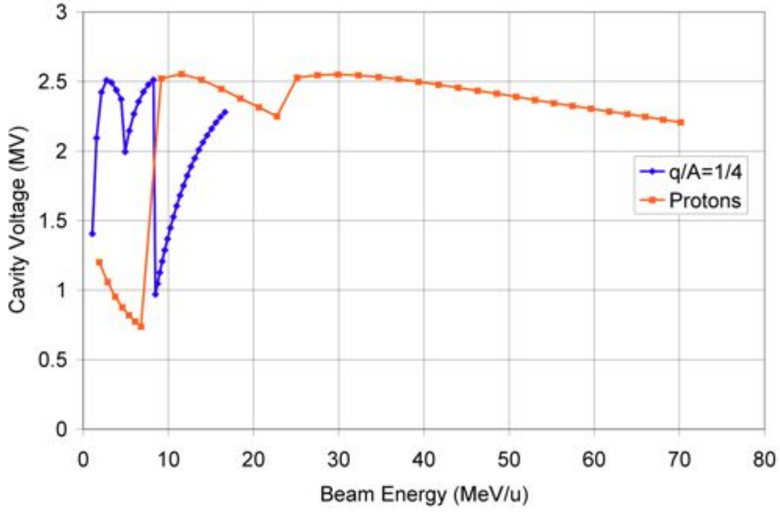
→ limited by ECR ion source

Possible configuration (still to be decided):

- Ion source + Low Energy Beam Line
- MBH: Multi Harmonic Buncher
- RFQ: "Radio Frequency Quadrupole" accelerator (injector)
- 35 SC cavities

Table 5. Main parameters of the Linac

	Frequency, MHz	β_{OPT}	Number of cavities	Comments
MHB*	36.375 (the 1st harmonic)	N/A	1	
RFQ	72.75	N/A	1	Based on ANL 60.625 MHz RFQ
QWR1	72.75	0.077	7	Design is available as ANL/ATLAS upgrade cryomodule
QWR2	109.125	0.15	7	Design is available as ANL/ATLAS upgrade cryomodule
HWR	181.875	0.25	14	Prototype cavity (f=170 MHz) was demonstrated at ANL



LRF- CONSTRUCTION PHASES

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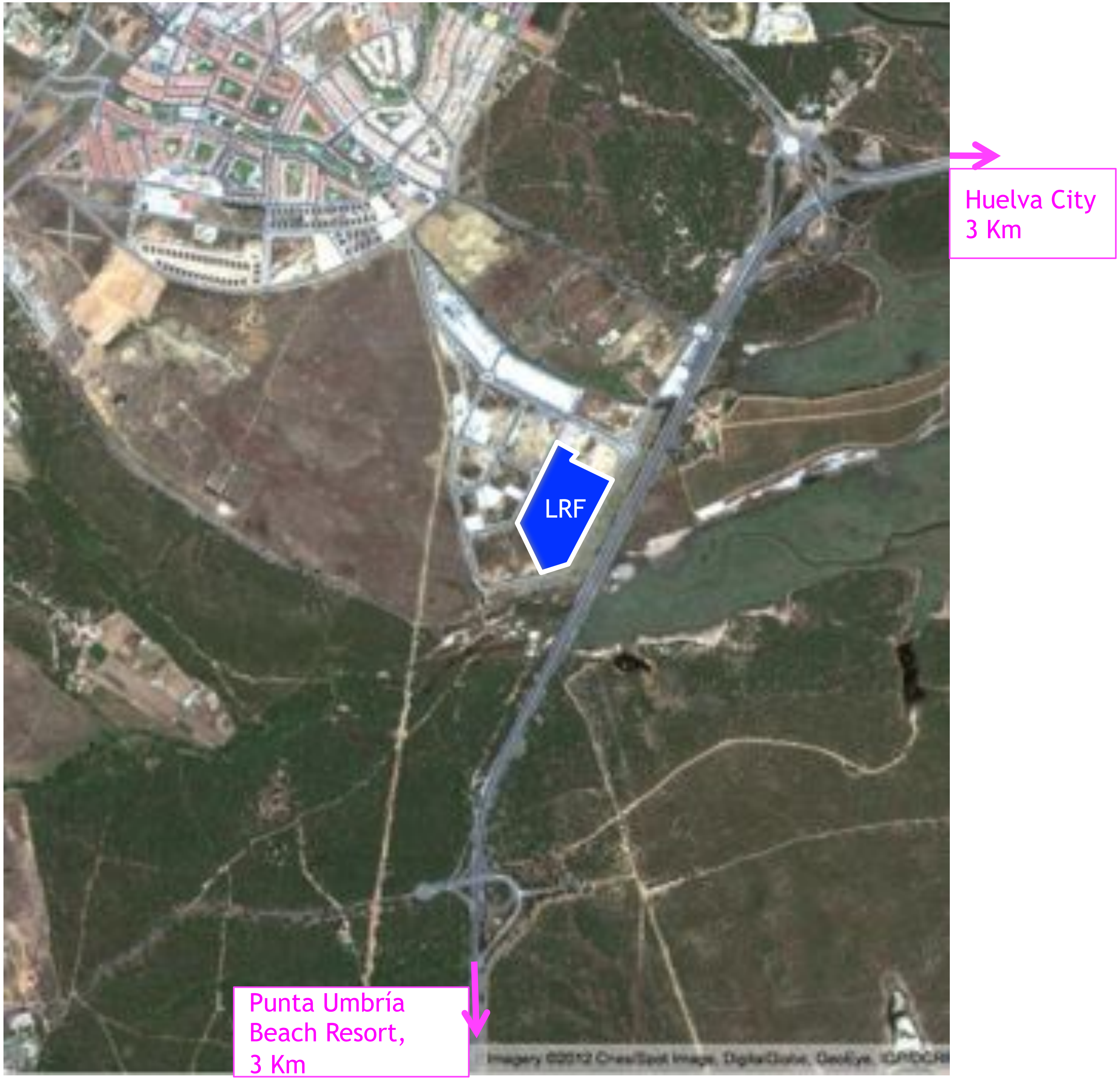
Parameter	Value	COST/Time	Comments
Ion Species	Heavy ions, protons		SCR ion source
Current Range	~1-2 mA (protons) ~ 500uA – 10 uA HI		HI intensities depends strongly on Q/A
PHASE 1	20 MeV protons 9 MeV/u HI	15.4 Meur ~3 years	Auxilliary, Cryogenics, Ion source, LEBT, RFQ, 2 x cryomodules (7 x SC), 2 beam lines
PHASE 2	55 MeV protons 15 MeV/u HI	5 Meur 2 years	2 x Cryomodule, Ext. Cryogenics, full experimental hall, IGISOL
PHASE 3	72 MeV protons 18 MeV/u HI	3 Meur 1 year	1 x Cryomodule, proton therapy line



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Barceló Punta Umbría Mar: LRF "Guest House"

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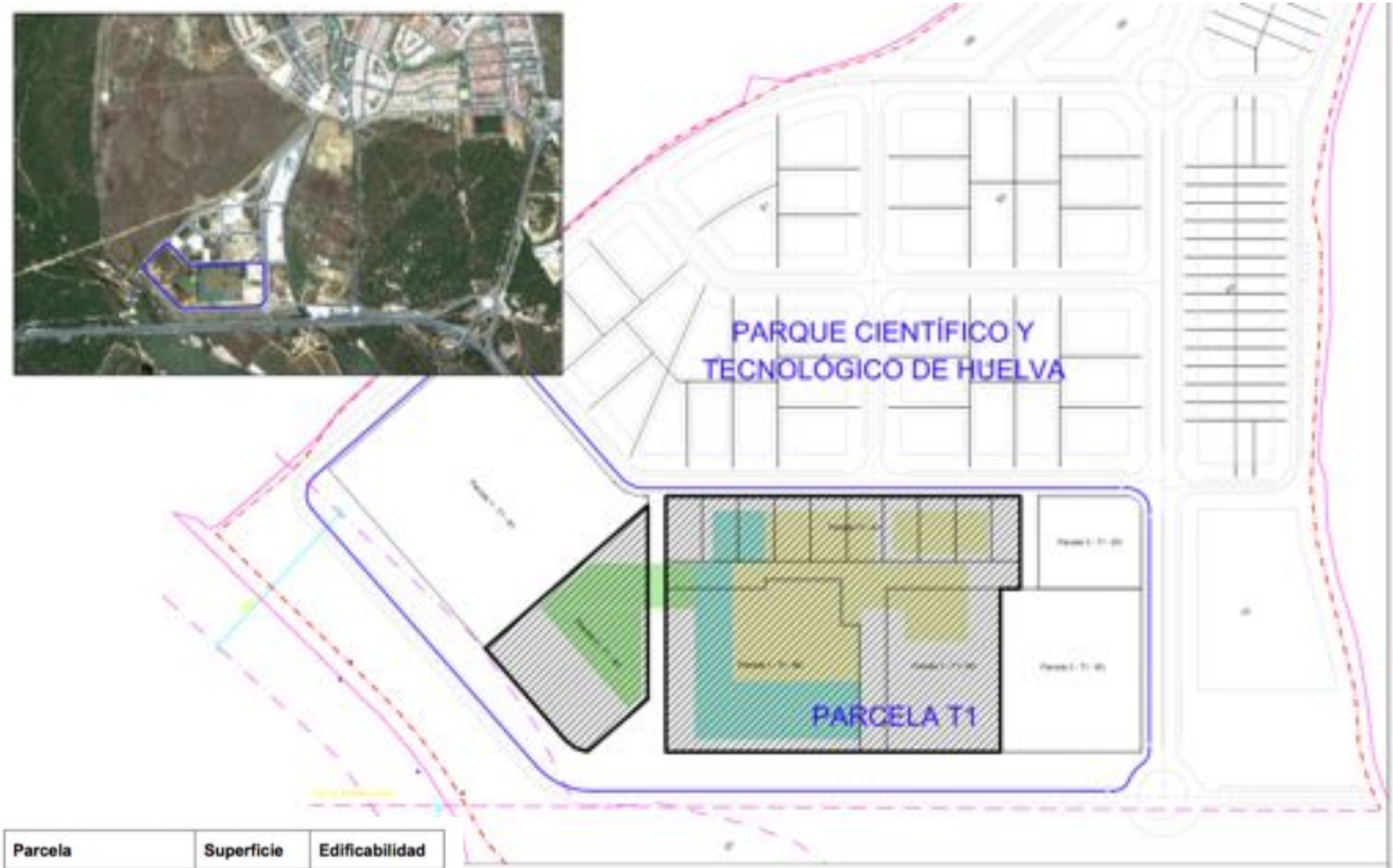
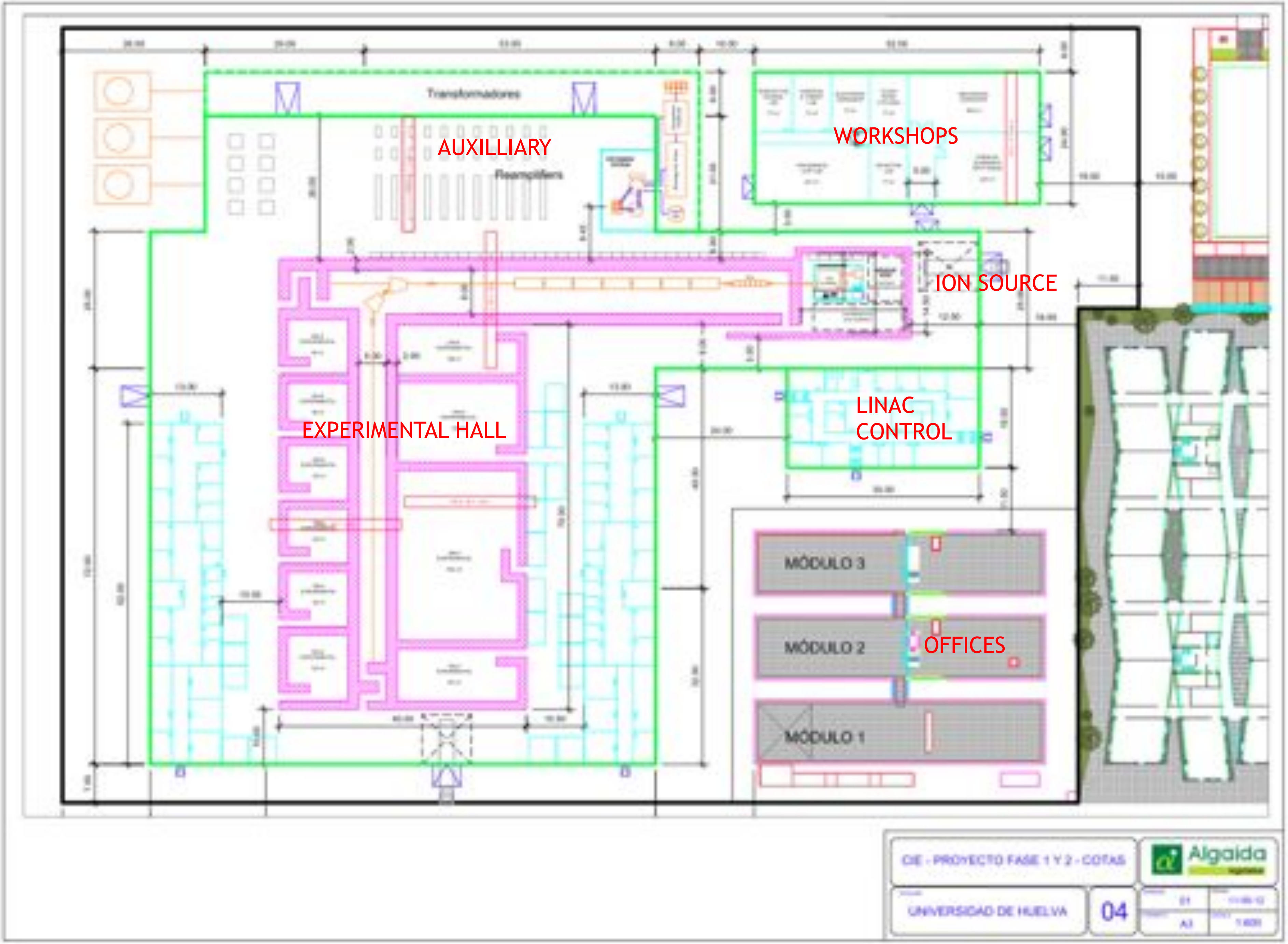


Parcela	Superficie	Edificabilidad
T1-B1 Parcela 2	6.765,65 m²	5.509,12 m²t
T1-B2 Parcela 1	9.640,00 m²	12.310 m²t
T1-B3 Parcela 1	5.670,00 m²	7.500 m²t
T1-A1 Parcelas 1 a 10	7.056 m²	10.744 m²t

CIE - PROYECTO GLOBAL EN PCTH
LOCALIZACIÓN

UNIVERSIDAD DE HUELVA

01


Transformadores
AUXILLIARY
Reamplifiers
WORKSHOPS
ION SOURCE
EXPERIMENTAL HALL
LINAC
CONTROL
MÓDULO 3
MÓDULO 2
OFFICES
MÓDULO 1
CIE - PROYECTO FASE 1 Y 2 - COTAS
Algaida
UNIVERSIDAD DE HUELVA
04

LRF Working group meeting at Hotel Barcelo Punta Umbría (March 2012)

Universidad de Huelva

-International Scientific Committee (ISC). Coord. Giuseppe Verde
→International User Group (IUG)
→ Must organize a meeting soon

-Working group for conceptual design study (CDS-WG)

1.Ion Beam Dynamics Group/IPNO (coordinated) + Bilbao-ESS
- SC & general IPNO - March
- RFQ/Bilbao - April
- first contact with industry participation

2.General Layout and Technical developments/GANIL+LNL+CMAN (coordination?)
- Visit of UHU + Industry to GANIL (May)
- Visit of UHU + Industry to LNL (July)
→ First proposal/economical estimation of building based on GANIL structure (IDOM, Algaida)
→ to be circulated to CDS.

3.Safety and Radioprotection
- Preliminary estimates by UNED-Madrid+UPV
- Meeting Friday-22 June UHU-UNED-GANIL(?)

-Technical Advisory Committee
-urgent advice on the choice of SC cavities → message sent to collaboration

-International Steering Committee: in progress

Actions:

Universidad de Huelva

1.Signature of MOU's between institutes:

- Already signed: UHU//ESS-Bilbao
- Sent: UHU//LNL & UHU//CIEMAT & UHU//UNED
- Rest of MOUs being prepared/ submit before end of June.

2. Local LRF staff at Huelva University + training programs

5 staff people:

Control
Safety
General infraestructure
Low energy + RFQ
High energy + SCC

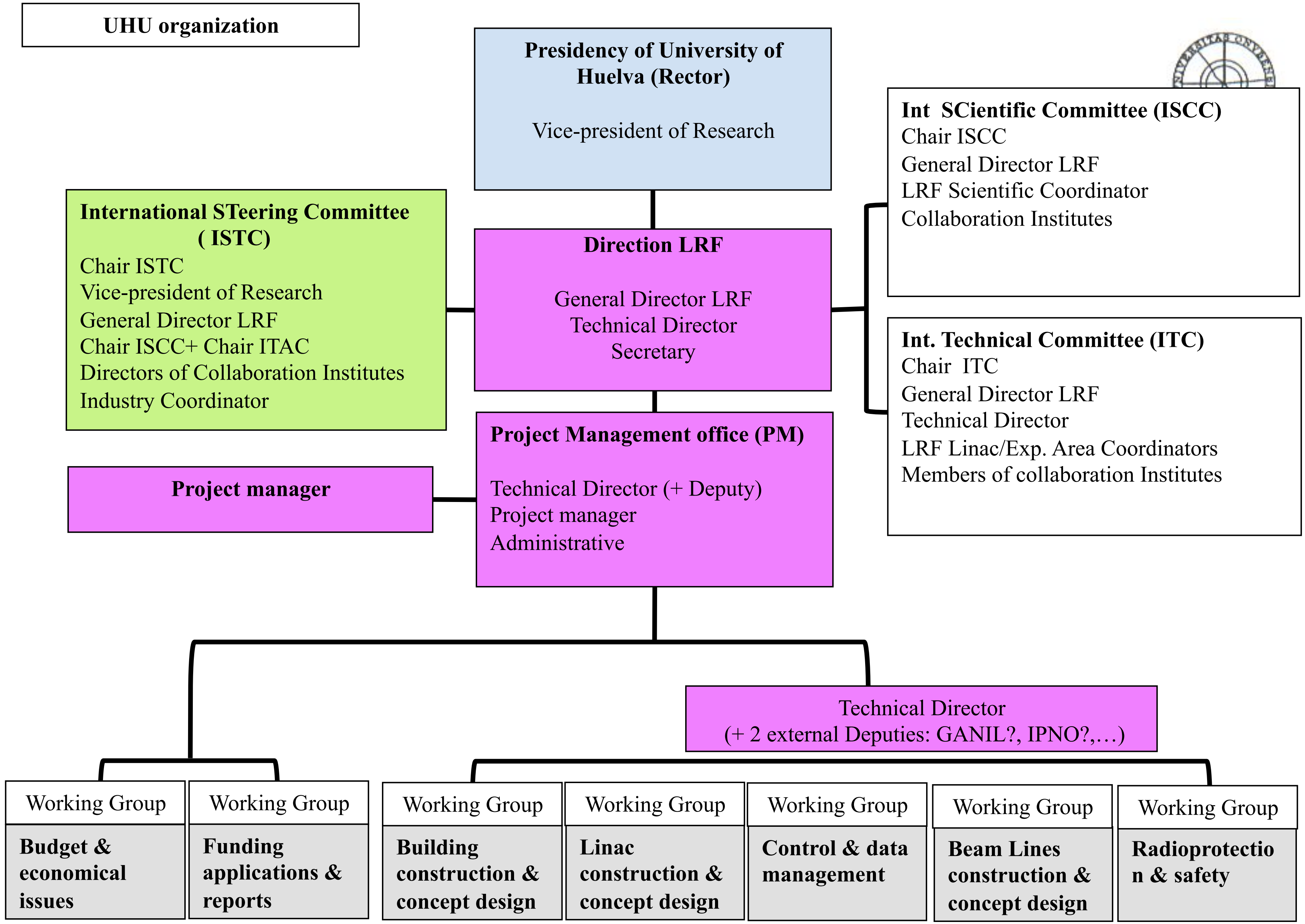
→ 2 staff sent to CERN school Ion Sources/Bratislava
→ 2 staff application for CERN School at Granada (Spain).

2 postdocs:

General LRF technical coordination
Auxilliary labs

1 mechanical engineer working at CERN trainning program /auxilliary systems (2 y +1 y)/ June 1st 2012.
1 Administrative

3. Funding for man power: OK, 6 specialized 3y contracts / expect call to be ready by end of June 2012.
4. Technical Director: accelerator expert at Huelva, in progress
5. Deputy Technical Director: LNL?, IPNO?, GANIL?... in progress


UHU organization
Presidency of University of Huelva (Rector)
Vice-president of Research
International STeering Committee (ISTC)
Chair ISTC
Vice-president of Research
General Director LRF
Chair ISCC+ Chair ITAC
Directors of Collaboration Institutes
Industry Coordinator
Direction LRF
General Director LRF
Technical Director
Secretary
Int SCientific Committee (ISCC)
Chair ISCC
General Director LRF
LRF Scientific Coordinator
Collaboration Institutes
Int. Technical Committee (ITC)
Chair ITC
General Director LRF
Technical Director
LRF Linac/Exp. Area Coordinators
Members of collaboration Institutes
Project manager
Project Management office (PM)
Technical Director (+ Deputy)
Project manager
Administrative
Technical Director
(+ 2 external Deputies: GANIL?, IPNO?,…)
Working Group
Budget & economical issues
Working Group
Funding applications & reports
Working Group
Building construction & concept design
Working Group
Linac construction & concept design
Working Group
Control & data management
Working Group
Beam Lines construction & concept design
Working Group
Radioprotectio n & safety

Summary & Conclusions

A new superconducting high-intensity heavy-ion linac is being build at University of Huelva:

- High Intensity Superconducting Linac as base design (from the beginning)
- Using most modern SC technology (ANL, Spiral2, LNL, …)
- Enormous Range of ions: from H up to Pb
- High intensities: 200uA 40Ar,

→ECOS facility for high intensity beams
→Test facility for future high intensity accelerators

HOT SPOTS

- Choice of SC cavities for an ECOS class facility
- Superconducting RFQs?
- High power target development
- Large scale detector arrays (CMS??)

International collaboration:

→OPEN COLLABORATION

Universidad de Huelva

ANL-USA
CENBG – Bordeaux, France
CIEMAT-Madrid, Spain
CMAM-Madrid, Spain
CSIC-Madrid, Spain
FLNR-Dubna, Russia
GANIL-Caen, France
GSI-Darmstadt, Germany
Hospital JRJ-Huelva, Spain
Heavy Ion Laboratory, Warsaw, Poland
ISOLDE-Geneva, Switzerland
IPN-Orsay, France
KU-Leuven-Belgium
LNL-Leñaro, Italy
LNS-Catania, Spain
UNED-Madrid, Spain
Univ. Huelva, Spain
Univ. Seville, Spain
Univ. UPV-Bilbao, Spain
(…)

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CDTI
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