"GASPHYDE particle detectors and the new superconducting linac facility LRF-Huelva"

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ASY-EOS 2012
International Workshop on Nuclear Symmetry Energy and Reaction Mechanisms

Outline:

→The research group at Univ. of Huelva

→ Recent developments on HYDE-GASPARD

→ The superconducting linac project at Huelva (LRF)

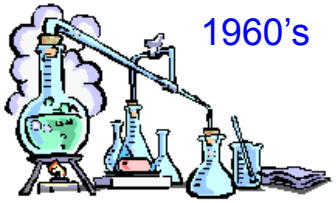
Huelva

Cristobal Columbus 1492

Recreativo Football Club 1889

Universidad de Huelva

1992



1960's

→1999, the Nuclear & Particle Physics group ~ 20 staff (th/exp/inst)

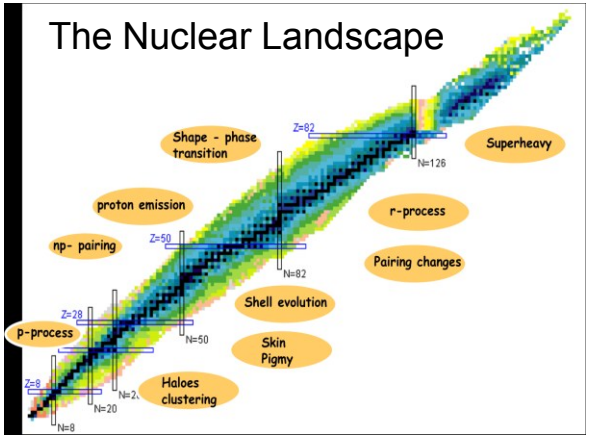
History:

→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)
→ Mainly Technical University/Engineering

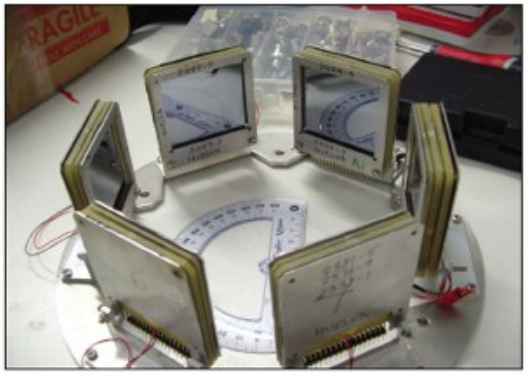


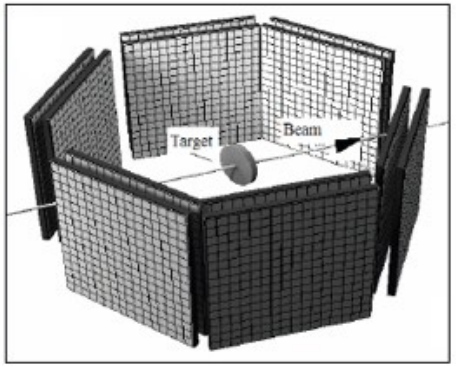
→ 2012, superconducting linear accelerator

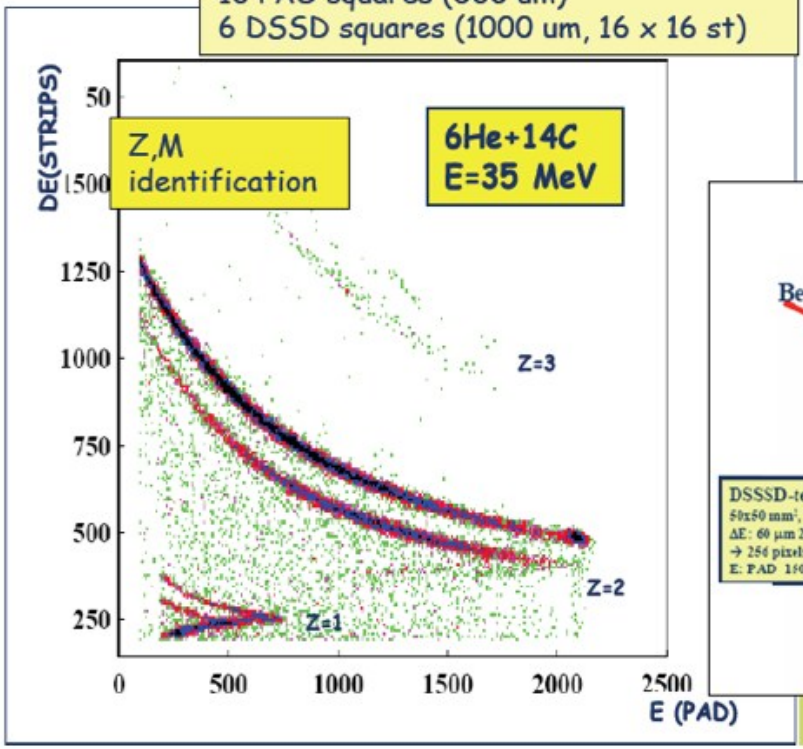
Detector arrays @ UHU

ARRAY of SILICON detectors
(University of Huelva, Spain)
- Detector array (42 Si detectors)
- Analog chain
- Data Acquisition (VME) ~ 300ch
- Reaction chamber

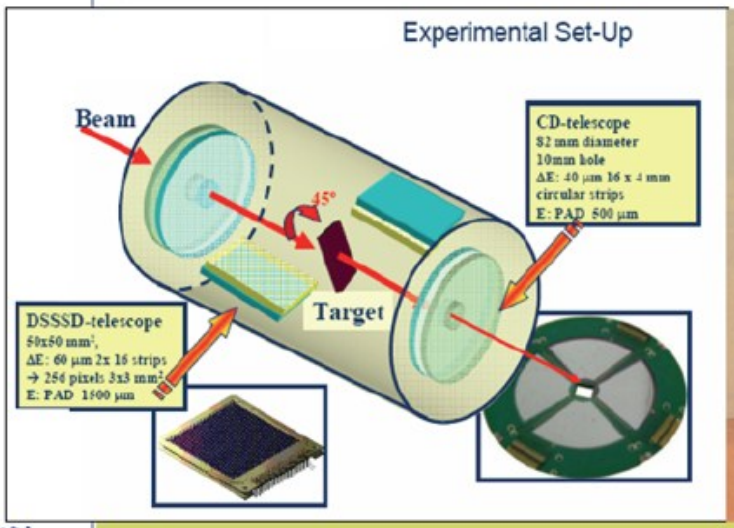
Large detector "POOL"
8 SSD - CD sectors (40um, 16 st)
8 PAD sectors (500um)
10 DSSSD squares (40 um, 16 x 16 st)
10 PAD squares (500 um)
6 DSSD squares (1000 um, 16 x 16 st)







SOME RECENT EXPERIMENTAL SETUPS:
DINEX (2005) & GLORIA (2010)

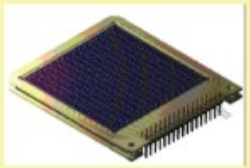


Detector arrays @ UHU

Universidad de Huelva

GLORIA

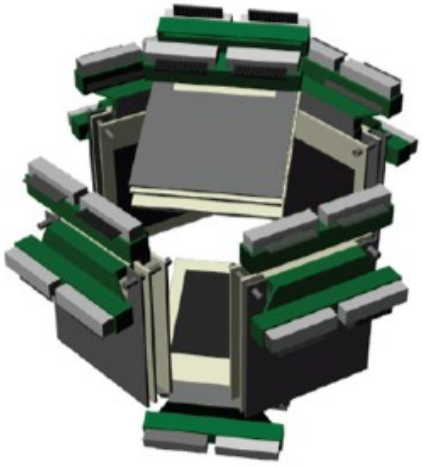
(Glogal Ion Reaction Array)

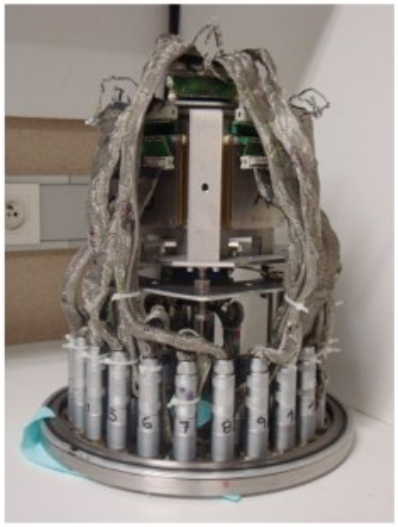


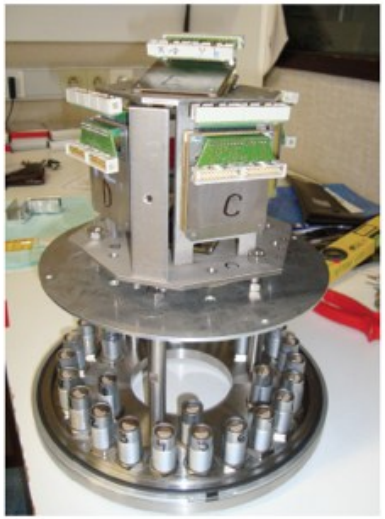
6 DSSSD-telescopes 50x50 mm2,
DE: 40 mm (16 x 16), 1000 mm (16 x 16)
Strip pitch: 3 mm, Solid angle ~25%

Distance to target (center square): 60 mm
Angular range: 15 -165 degrees Lab
Etotal_resolution ~ 150 keV

→ Mounted on a flange ISO250 LF





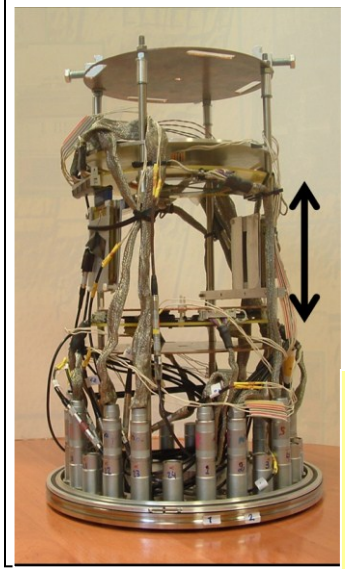


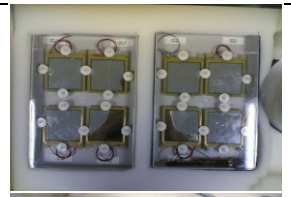
GLORIA at GANIL/SPIRAL

DETECTOR LABORATORY @ UHU

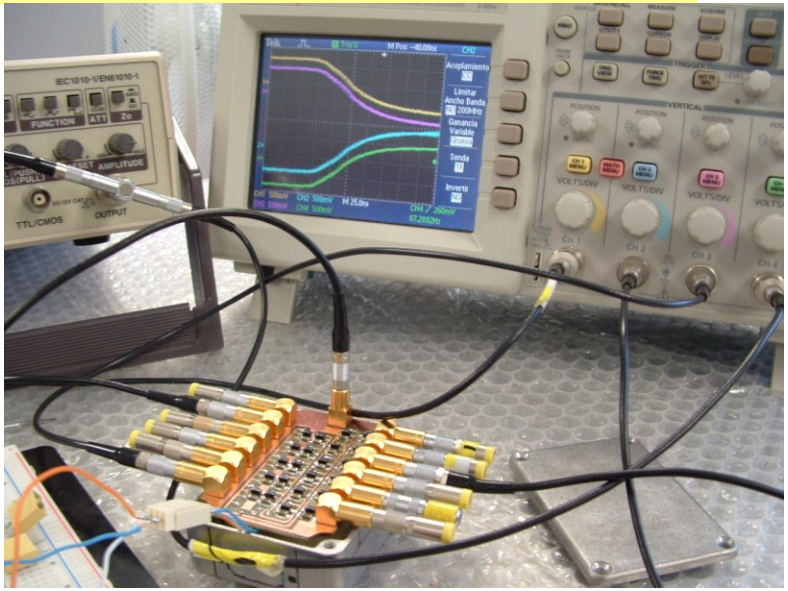
High vacuum chamber, DACQ's

Mechanical Workshop

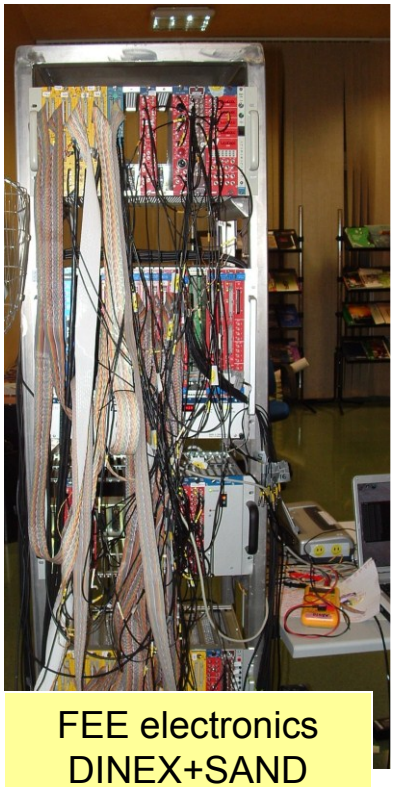




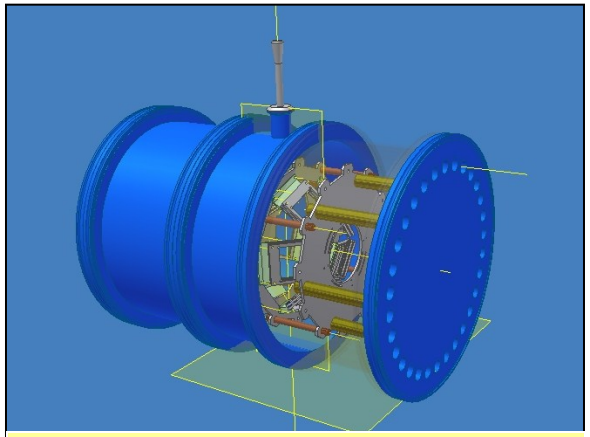
Detector test & Arrays → DINEX/3ST Prototype



Nuclear electronics lab: Electronics test bench, PCB design & developments…

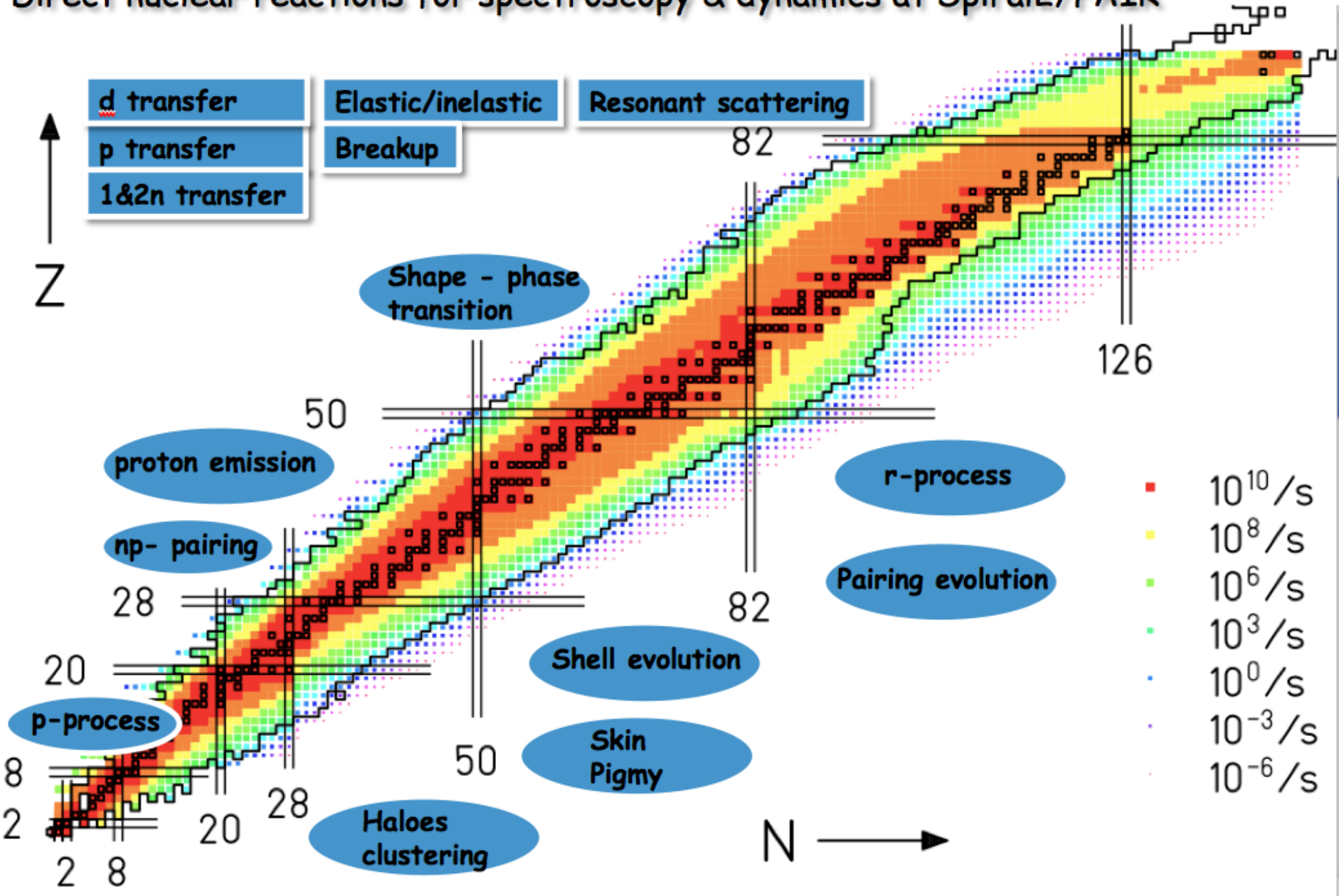


FEE electronics DINEX+SAND

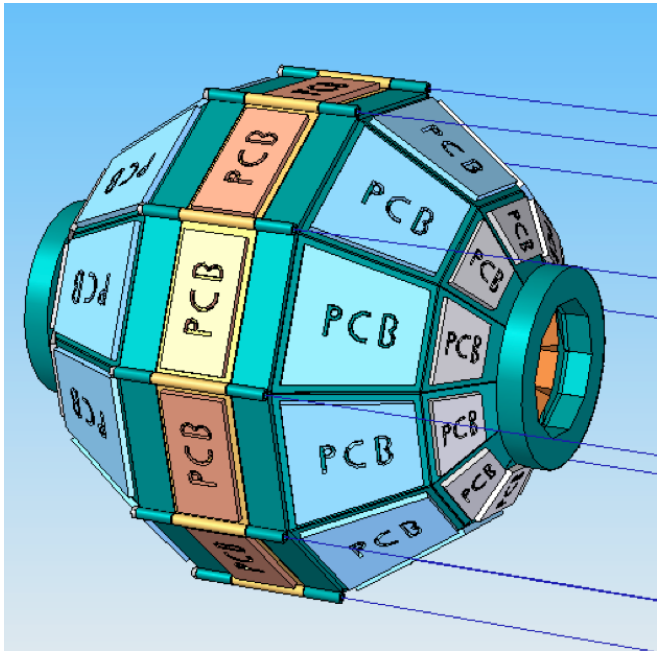


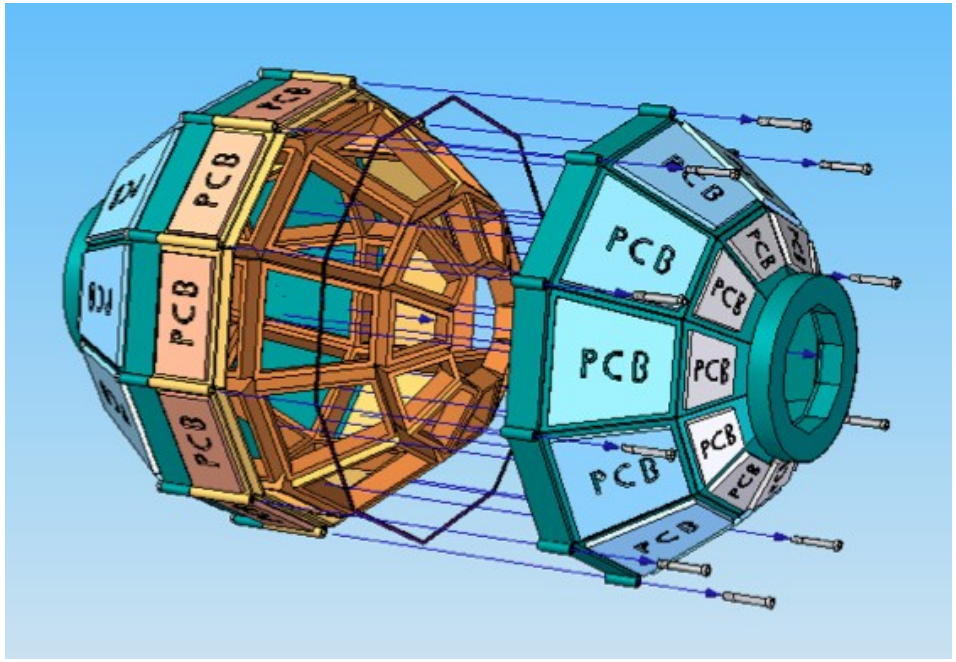
Mechanical design DINEX/3ST CHAMBER

Direct nuclear reactions for spectroscopy & dynamics at Spiral2/FAIR



Mechanical design of HYDE





Characteristics:
~ 4 PI ARRAY
- Detection of charged particles.
- Particle ID using PSA , DE/E and TOF.
- Energy & angular resolution (< 150 keV, 1°/0.1°).
- Large multiplicity (> 3)

Construction:
- Chamber < 380 mm diameter
- 49 DETECTOR CELLS
- 3 different shapes: square + 2 trapezoids fitting 4" wafer.
- Cylindrical symmetry/10 sides

Mechatronics
- FFE on air
- 31.360 channels
- High density feedthroughs
-Multiplexing.

Detector cell (Silicon)
- 4 inches, NTD silicon wafers
- Strip size 0,4 mm, Multilayer (5 layer)

Design constraints:
- Subsystem of AGATA array
- Use at other RIB facilities (SPIRAL2, HIE-ISOLDE, LEGNARO-SPES)
-Modularity and portability

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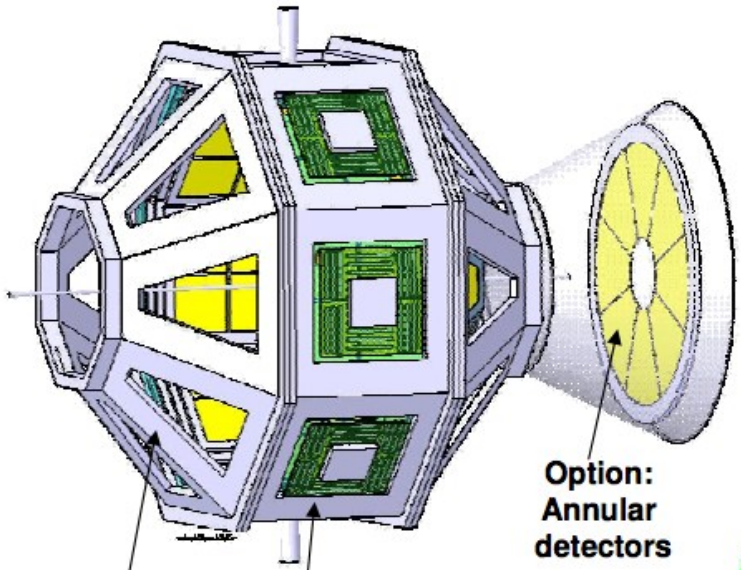
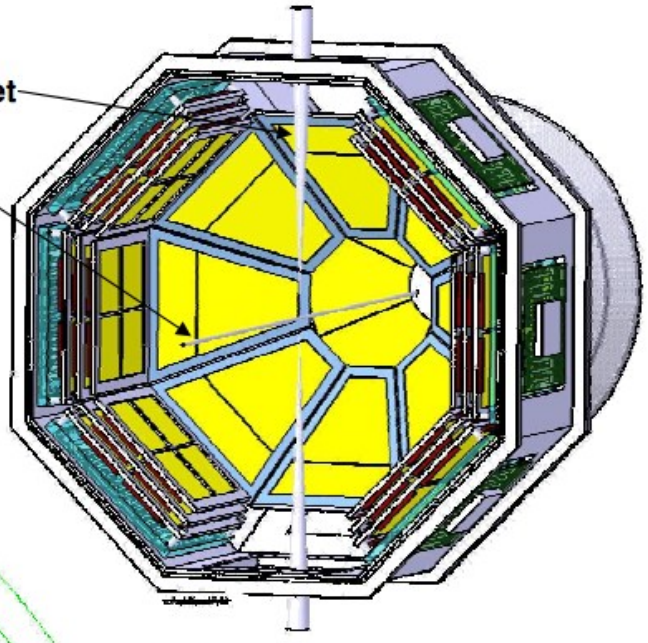
Towards a "GaspHyde" proposal

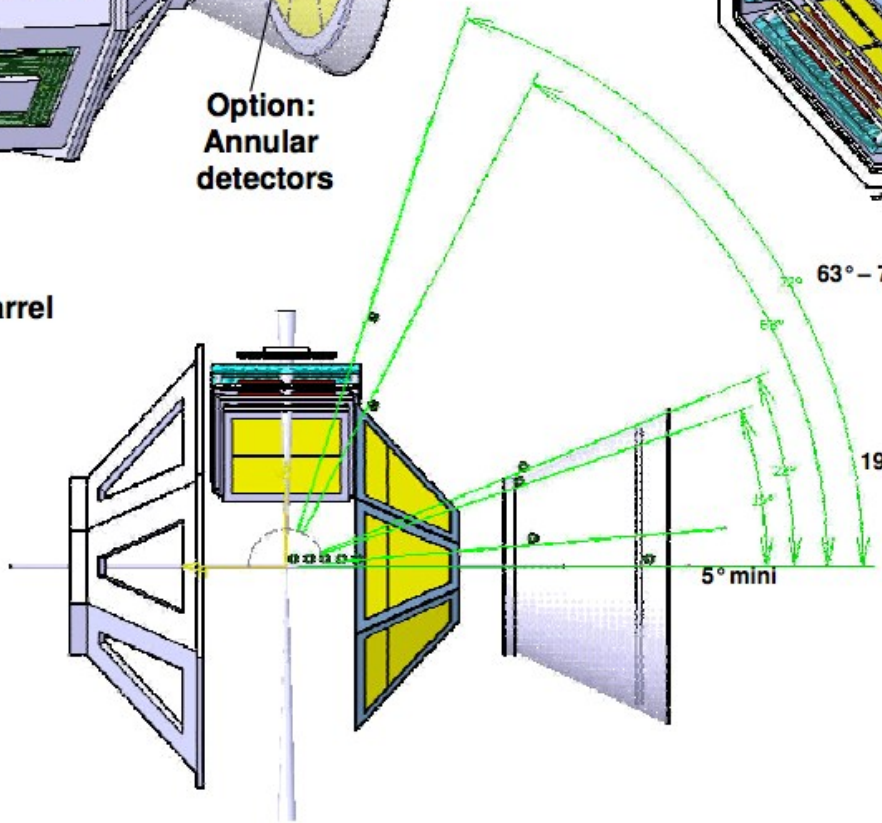


Option:
Annular
detectors

Same barrel

Trapezoidal
shapes for
end-caps





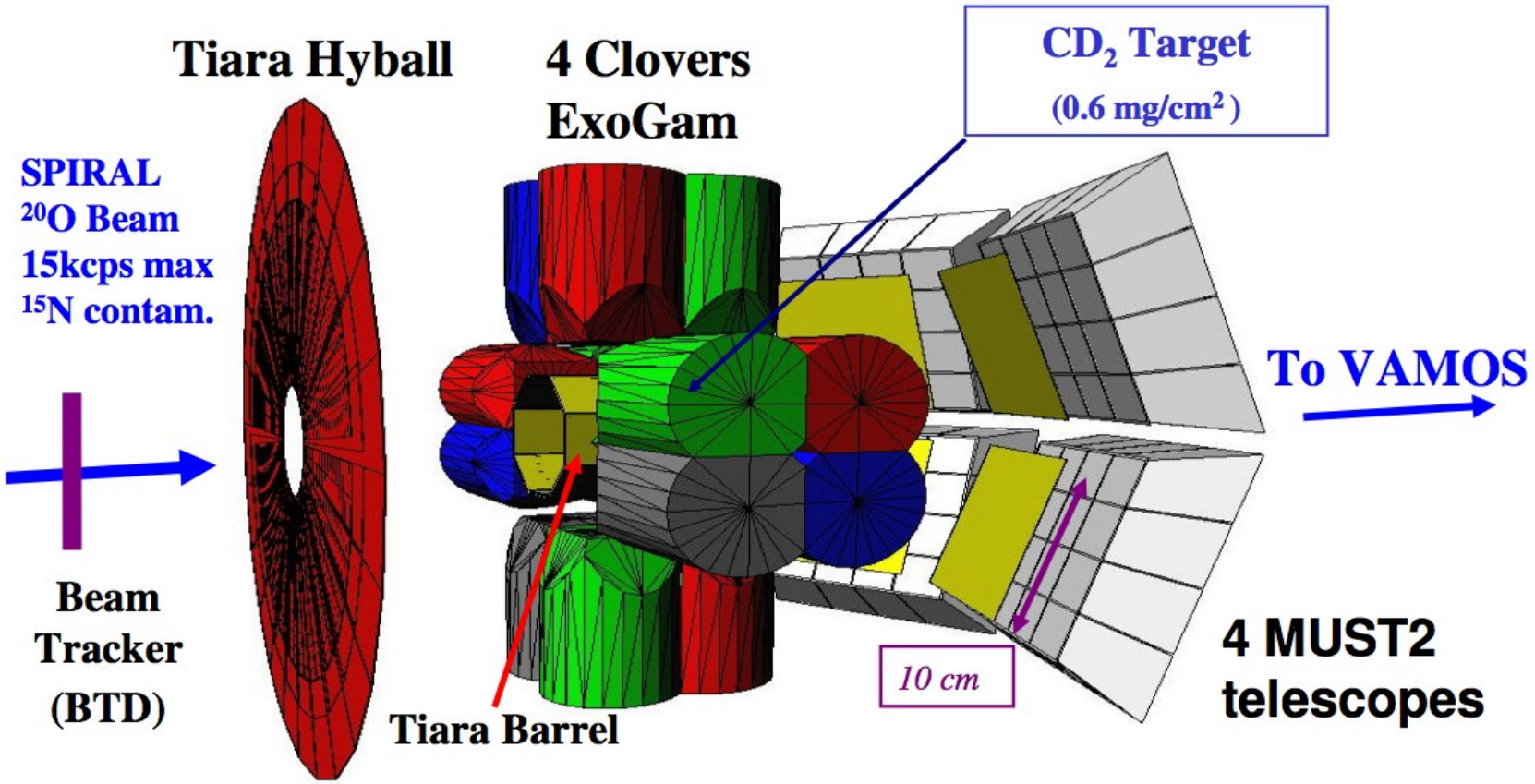
Interval angle with
dead zone due to supports

+ target in 2 squares

Ph. Rosier, IPNO

Limitations of the combined setup

A currently used combined setup:



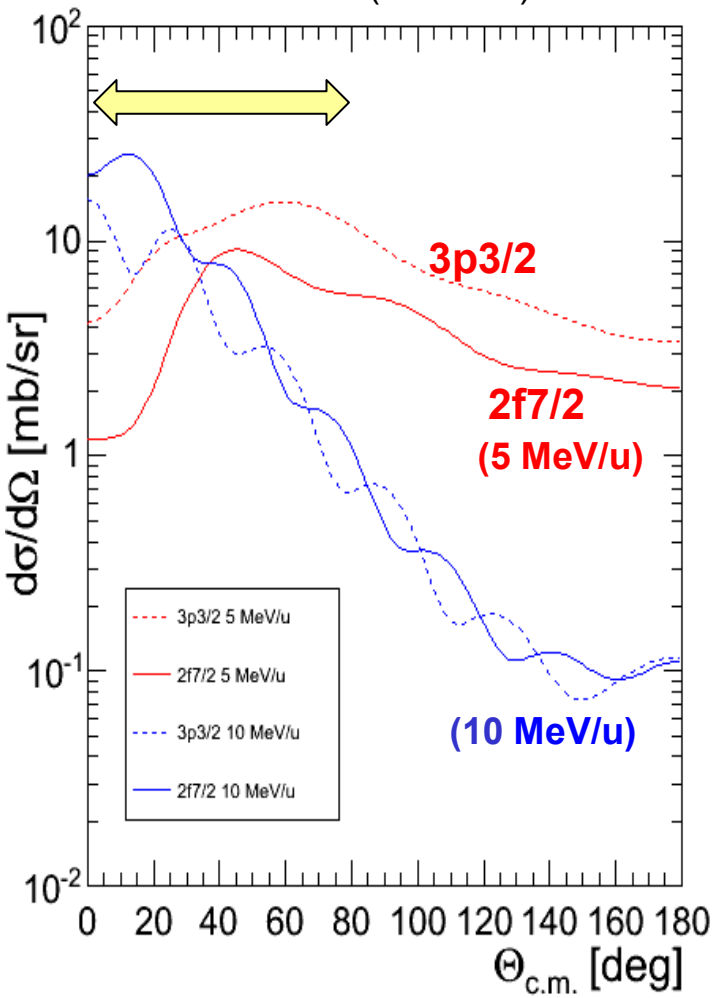
- Low efficiency for gamma-rays (5-10%)
- No flexibility to insert cryogenic target

Importance of angular coverage

Simulations for $^{132}Sn(d,p)^{133}Sn$

CROSS-SECTIONS

FRESCO (ZR-FRC)

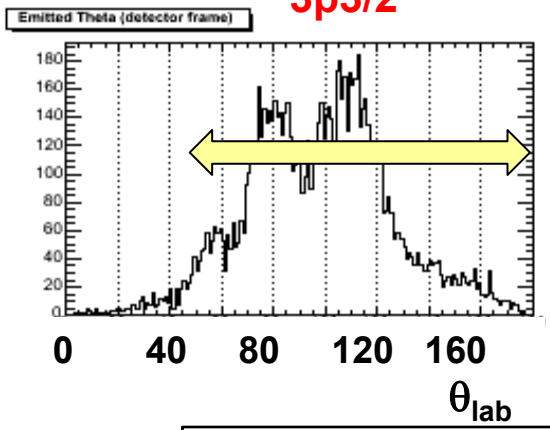


YIELDS

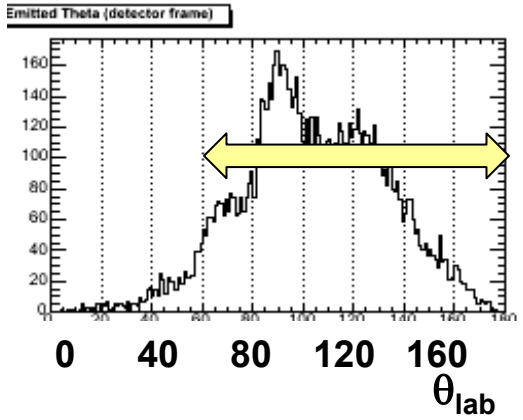
N. de Séréville, IPNO

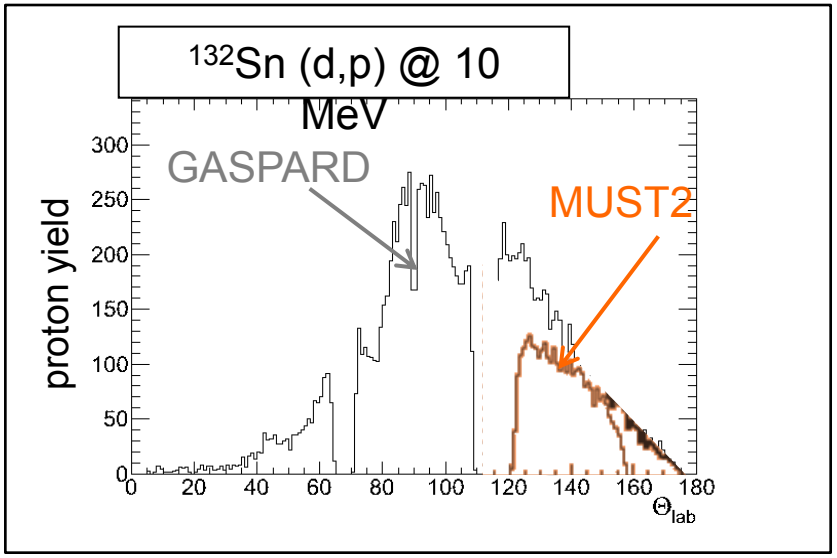
10 MeV/u

3p3/2



2 f7/2



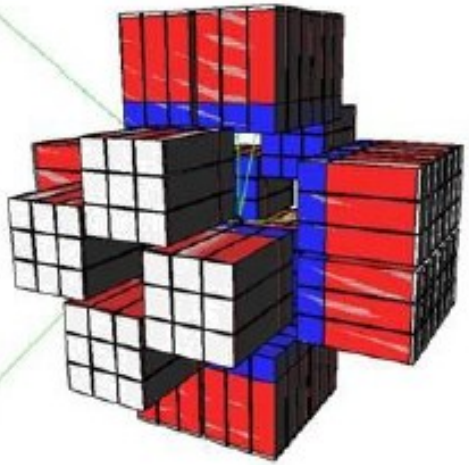


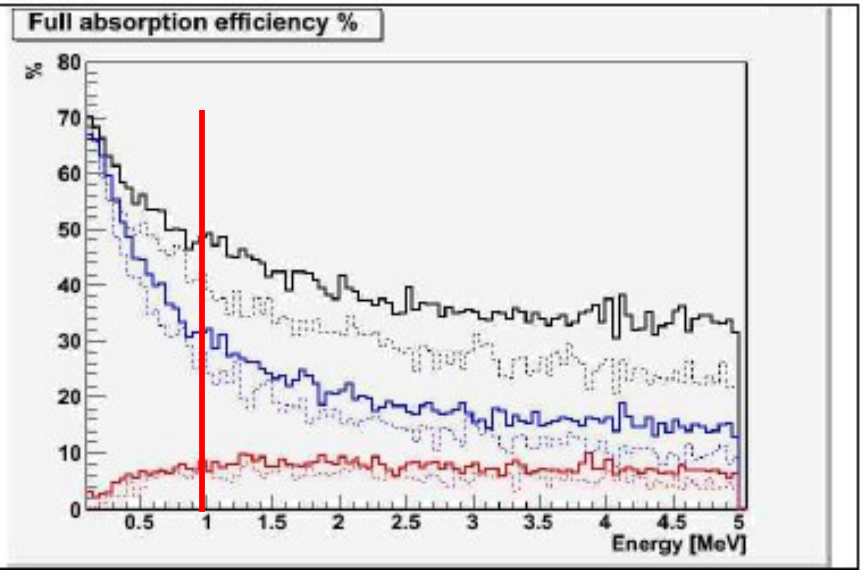
The GASPARD array : Gain in efficiency

GAmma SPectroscopy and PArticle Detection

4π silicon array fully integrable in PARIS, AGATA

4π PARIS configuration



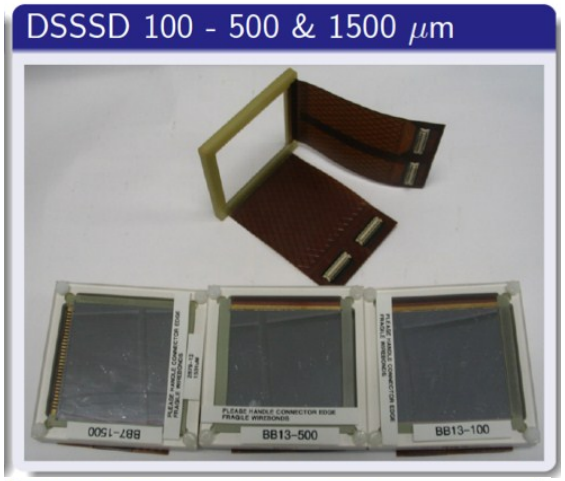


Efficiency gain ~20 for p-γ coincidences for ^{132}Sn(d,p) @ 10 MeV/u w/r to previous MUST2 + EXOGAM setup

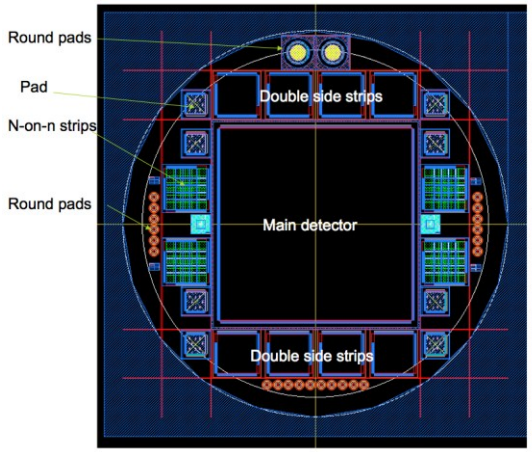
Resolution: ~40 keV at 10 MeV/u with 2mg/cm^2 CD2 target

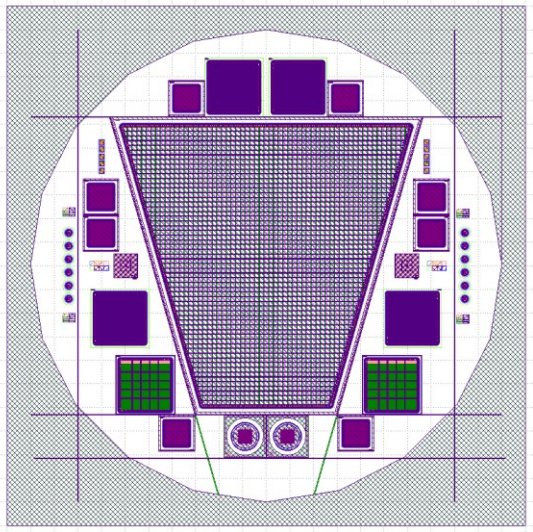
Large improvement in particle/gamma efficiency

HYDE-GASPARD - DETECTOR CELL – Prototype



Micronsemiconductors Ltd.





Centro Nacional de Microelectrónica (CNM), Barcelona (Spain)

•DSSD production

- NTD 500um
- Interstrip gap: 90um
- Strip pitch: 390um
- DC coupled
- 128 strips on each side
- Electrode strip material: Al (100nm).
- Biased guard ring: 300um wide
- Floating rings: 3
- P-stop isolation for n-side strips.
- Strip length: 49830um
- Angle between n and p strips 90º.

SQUARE: 54.2 x 54.2 mm

TRAPEZODIAL: 96.4 x 61.5 x 96.7 mm/ strip pitch 1mm

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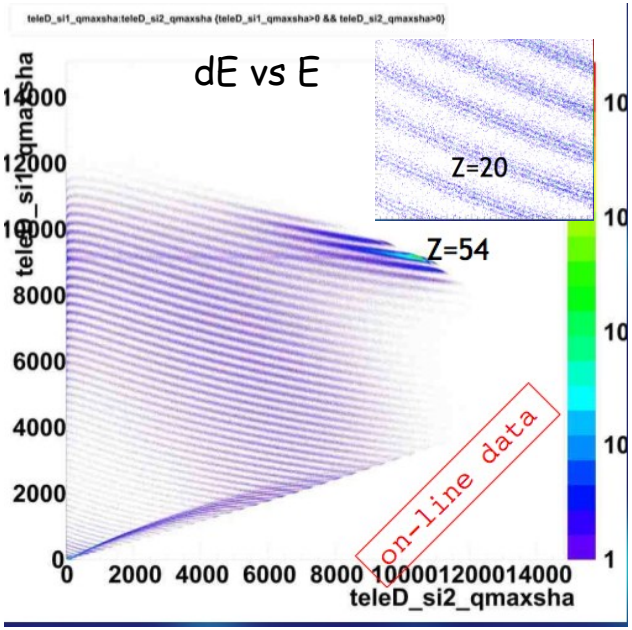
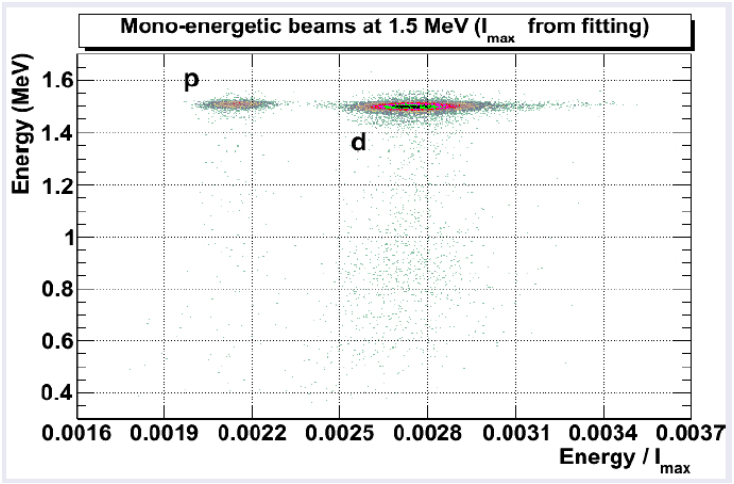
PARTICLE IDENTIFICATION: DE-E vs PSA

Results **from FAZIA** collaboration



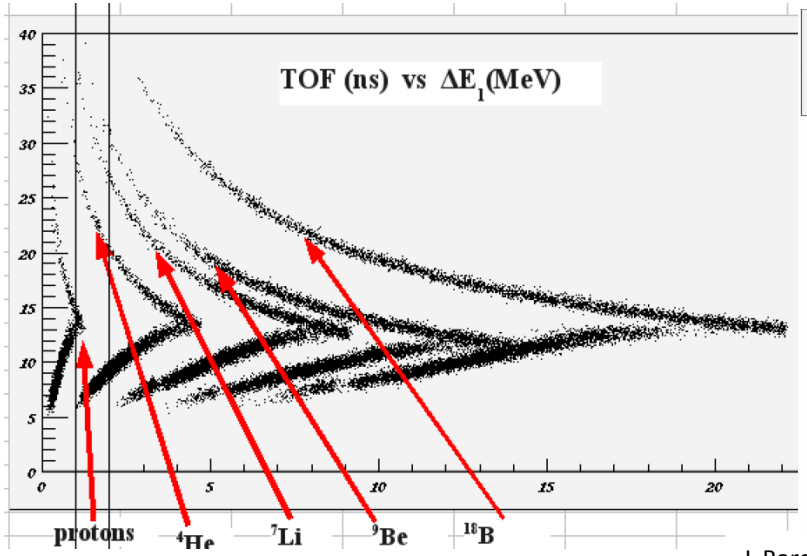
Carboni S., et al., NIMA 662(2012)251

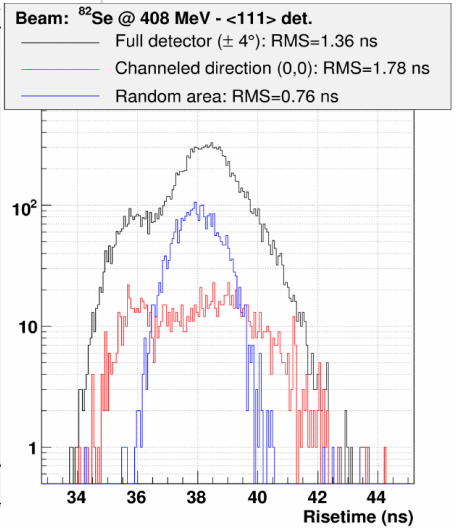
- Good identification up to Z~25 with ~5GeV
- 100MS/s 14 bit digitizer
- Highly uniform Si: NTD
- Silicon doping uniformity ~1% (TOPSIL)
- Channeling
- Voltage stability



Duenas J. A.; NIMA 676 (2012) 70

- HYDE-GASPARD PSA test at Orsay Tandem for light particles/500um NTD looks promising → test thin silicon (20um/100um)





TOF simulation for HYDE/A. Sánchez-Benítez) Limited by Si response ~1ns

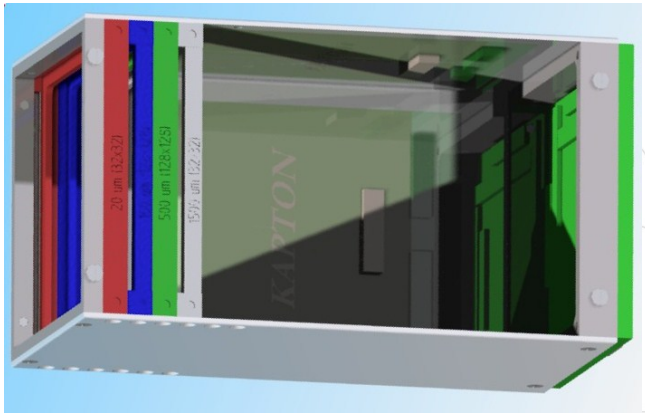
L.Bardelli et al, NIM A605 (2009) 353

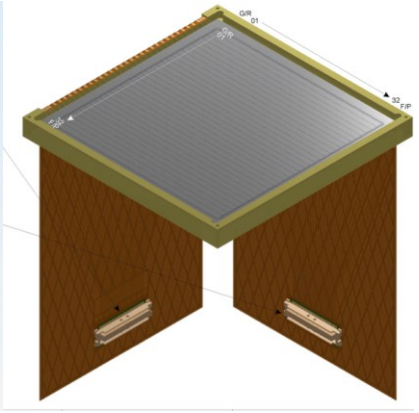
HYDE – GASPARD DETECTOR CELL – Prototype

4-Layer prototype (~62 x 62 mm2)

- NTD-20 µm 32 strip/side (*PSA*, *ΔE*, *E*).
- NTD-100 µm 128 strip/side (*PSA*, *ΔE*, *E*).
- FZ-500 µm 128 strip/side (*PSA*, *ΔE*, *E*).
- FZ-1.5 mm stack 32 strip/side (*ΔE*, *E*).
- 640 electronic channels/cell.

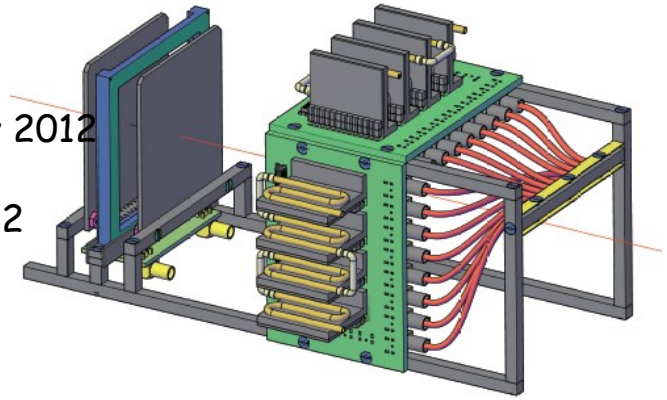
(128 x 128, 0.4 mm pitch, $\delta\theta \sim 0.1^{o}$)





DE/E
TOF & PSA: on the 20 or 100 um layer.

HYDE-GASPARD Test bench



TEST program TRACE-HYDE-GASPARD:
LNS (Catania, Italy) ~ 4He & 12C + CH/Au @ 60 AMeV
9-13 July 2012

LNL (Legnaro, Italy) ~ 16O+32Si@150MeV
October-December 2012

PSA: PACI + MATACQ (2 GS/s, 12-14 bits)
UHU-CEA-GANIL
Identification of particles (Z & A) for $1 \leq Z \leq 21$.
Detectors thickness: 20, 100 µm.
Optimum sampling rate.

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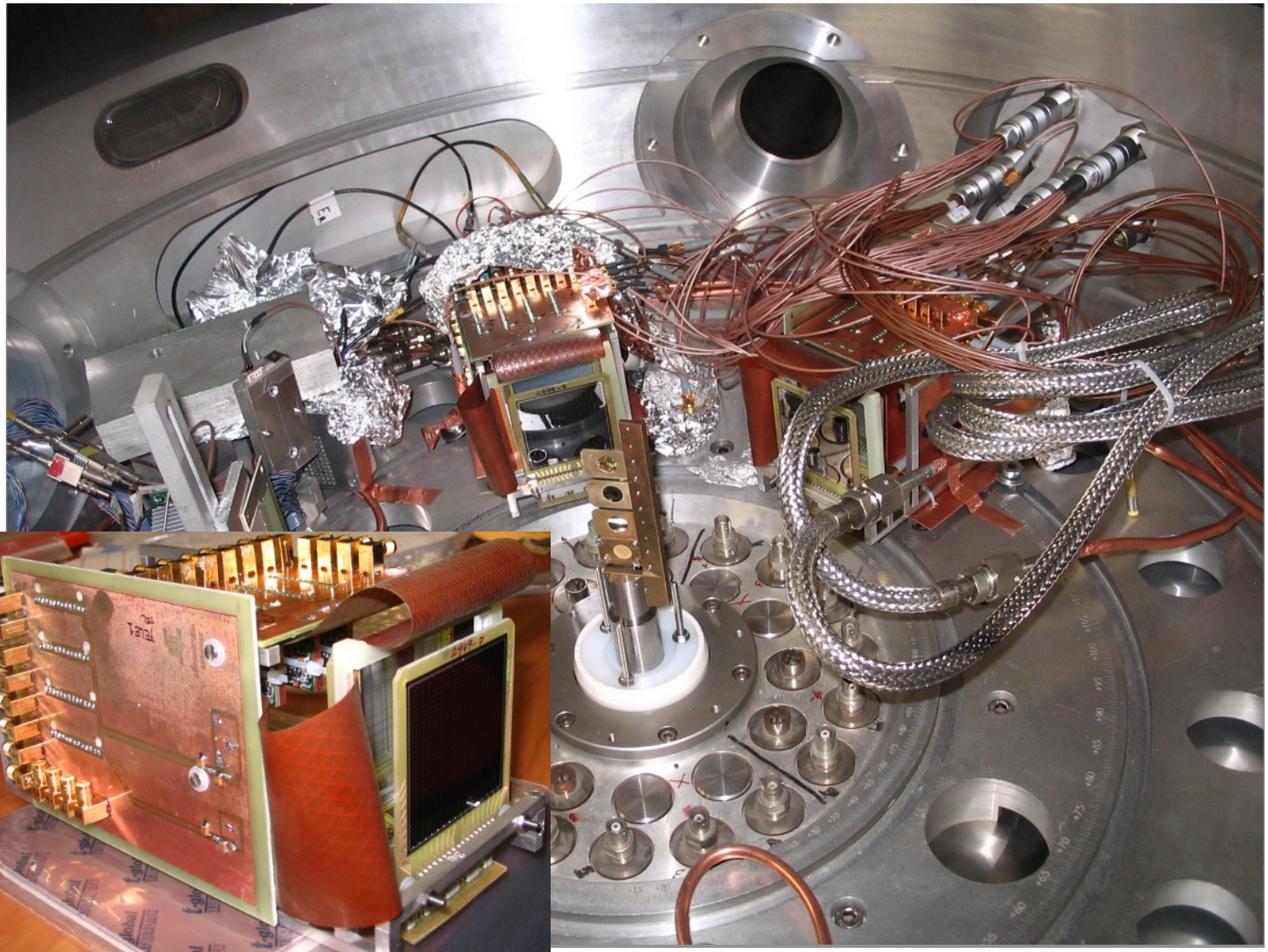
TANDEM/ALTO (Orsay, France) ~ 1H, 2H & 12C + CH/Au , February 2012



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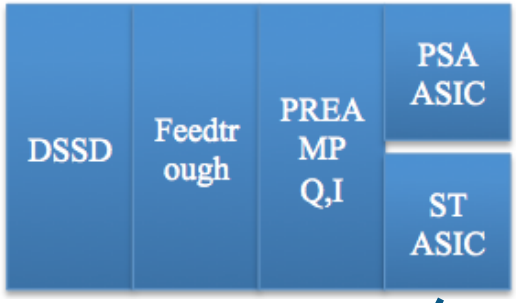
Front-end electronics



HIGH DENSITY FEE//KRAKOV-UHU

- First test board with VA-TA chips (IDEAS-Norway)
- Hybrid equipped with Readout board (ADC and dedicated XILINX SPARTAN FPGA).
- Readout frequency, 4 MHz clk. (8 μs for 32 channels)
- Dead time for 1 KHz event rate per detector is estimated to be around 0.8%.
- Power dissipation is around 100 mW per hybrid.
- However Eres~130 keV → design dedicated ASICs

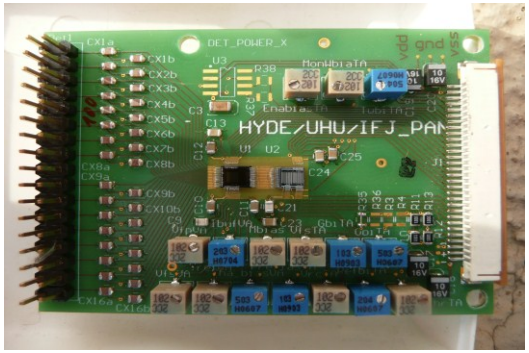
FPGA implementation of PSA using neural networks

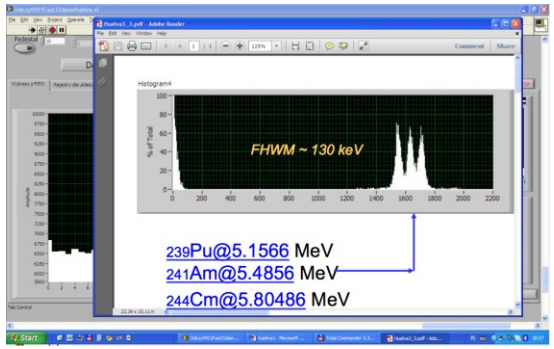
Configuration parameters

Neurons per MLP: 2
Architecture: 8x8x2 layers
Data size: 14 bits

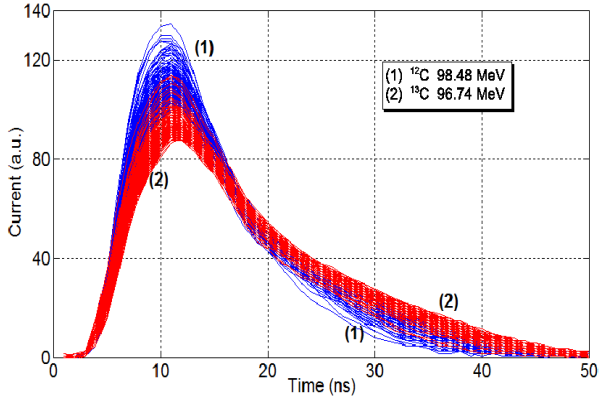
No. MLP in FPGA: 8
Device: Spartan3AN-700

Maximum operation frequency: 74 MHz





R. Jímenez-Naharro et al., NIMA 54210



The **Linac Research Facility (LRF)**

Universidad de Huelva

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 ←

http://www.uhu.es/gem/LRF/

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).

LINAC RESEARCH FACILITY

Radioactive beam line: the IGISOL beam production with low radioactive waste

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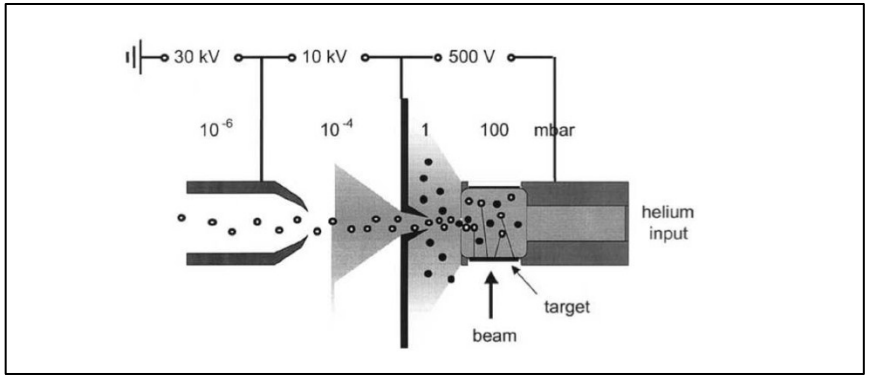
Isotope production and extraction pioneered at Jyvaskyla (J. Aysto et al.)

Ion source

- He gas jet
- Ion guide
- Acceleration voltage ~40 kV

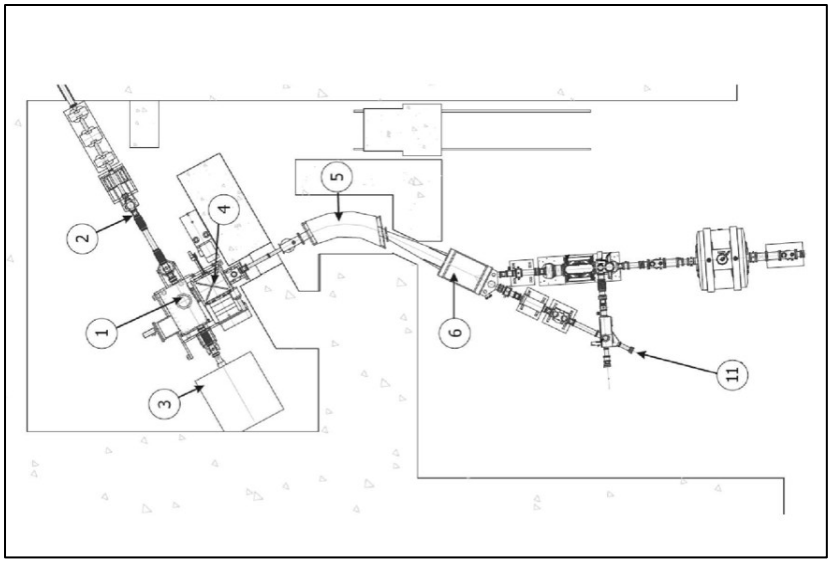


Mass separator

- Analyzing magnet
- Mass resolving power: ~700

Detection setup

- Tape station
- beta, gamma-gamma, Ge, Si(Li), BaF2



Physics program with radioactive beams:

- DECAY SPECTROSCOPY
- MASS MEASUREMENTS
- FUNDAMENTAL INTERACTIONS

LINAC RESEARCH FACILITY

Exotic beams: possibilities

Typical beams

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

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

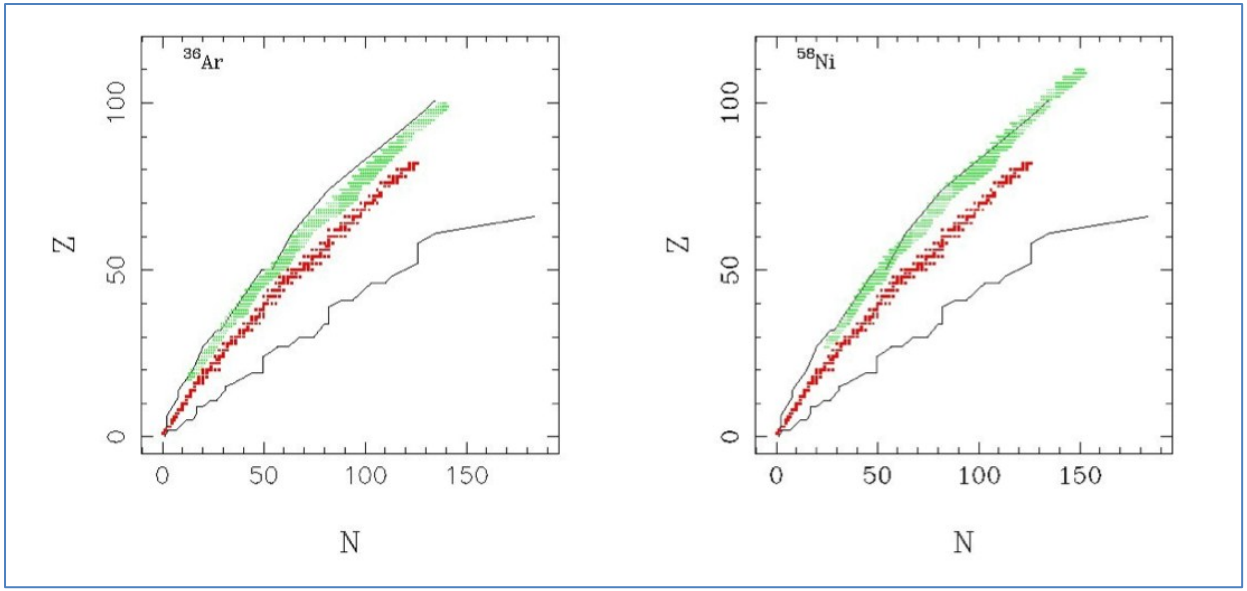
Exotic isotope production:

→ compound nucleus reactions ~ Eb → proton rich
→ reactions of nucleon exchange › Eb → neutron rich

Compound nucleus reactions ~ Eb → Basic mechanism for production of proton rich nuclei

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

Example: Cyclotron at JYFL Jyväskyla



M. Veselsky, Nuclear Physics A 705 (2002) 193;
M. Veselsky, G.A. Souliotis, Nuclear Physics A 765 (2006) 252;
A 781 (2007) 521.

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

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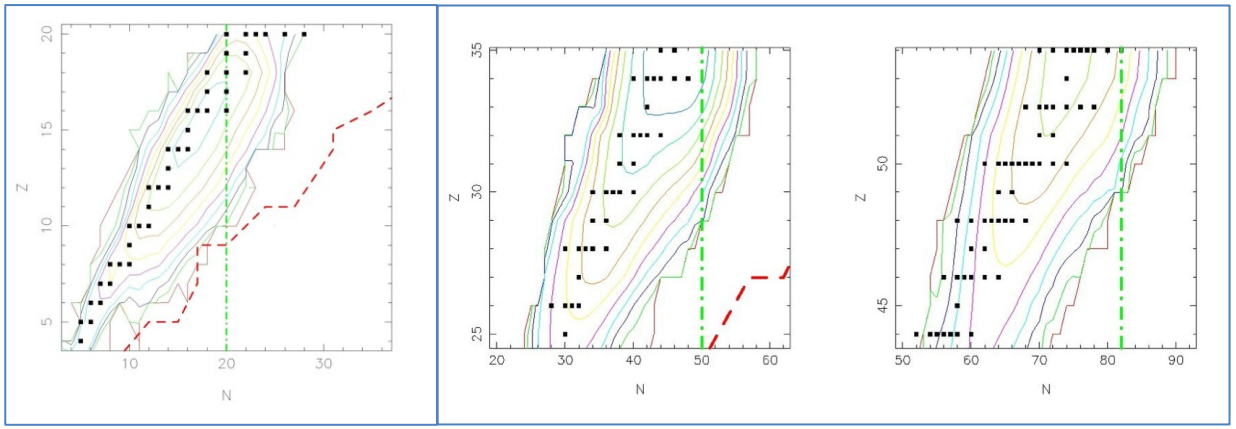
Production of neutron rich nuclei

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

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!!!**

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; dosimetry, proton therapy)
-Material research for energy (Fusion energy, solar cells, …)
-Aerospace
-Ion implantation

-Applications impose very demanding beam intensities and energies

→basic research

LRF ORGANIZATION (TODAY):

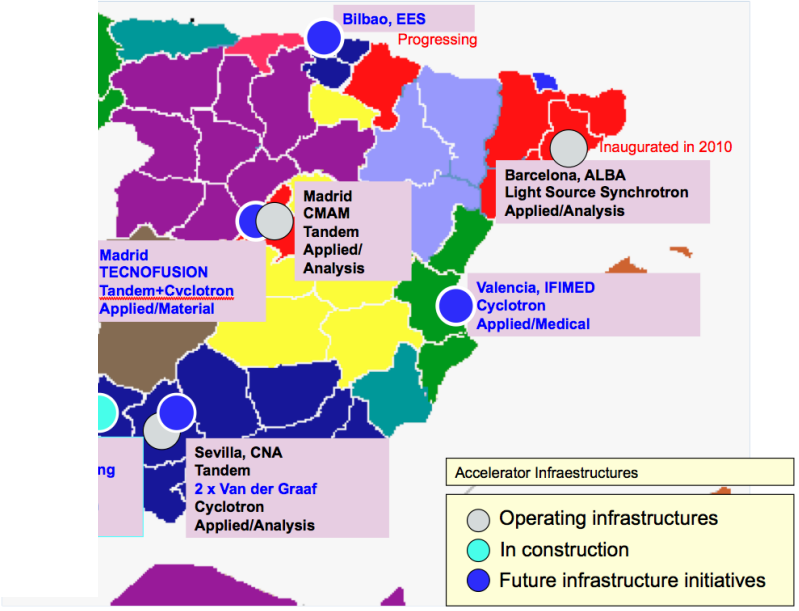
- **PART of a Research Centre** of the University of Huelva,
"CENTER FOR ENERGY RESEARCH"

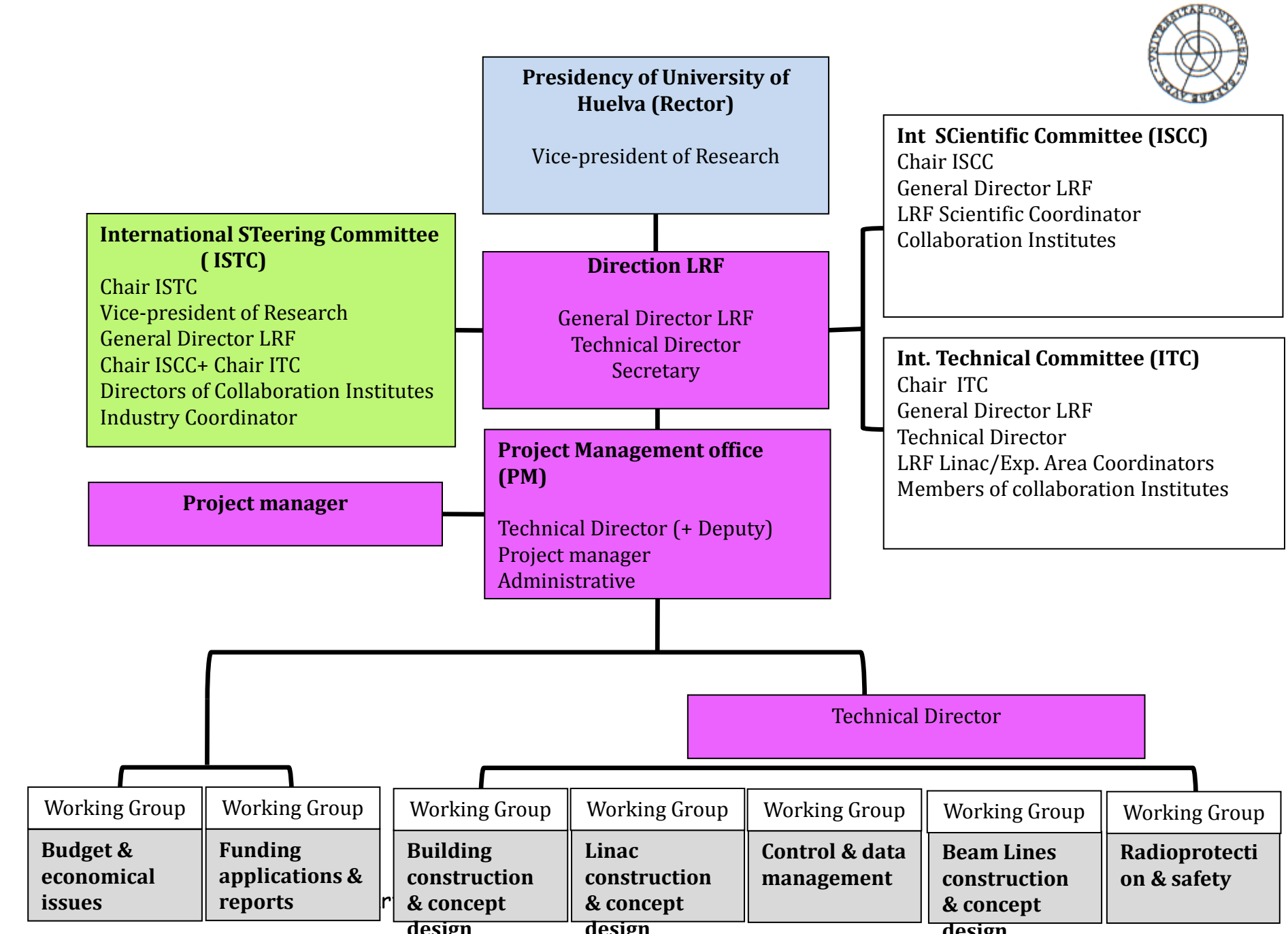
-Research groups (~ 60 staff)
-Technical staff (~ 6 staff)
- Also lecturing activity (Postgraduate)

- 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.

Facilities in Spain




Presidency of University of Huelva (Rector)
Vice-president of Research
Int SCientific Committee (ISCC)
Chair ISCC
General Director LRF
LRF Scientific Coordinator
Collaboration Institutes
International STeering Committee (ISTC)
Chair ISTC
Vice-president of Research
General Director LRF
Chair ISCC+ Chair ITC
Directors of Collaboration Institutes
Industry Coordinator
Direction LRF
General Director LRF
Technical Director
Secretary
Int. Technical Committee (ITC)
Chair ITC
General Director LRF
Technical Director
LRF Linac/Exp. Area Coordinators
Members of collaboration Institutes
Project Management office (PM)
Technical Director (+ Deputy)
Project manager
Administrative
Project manager
Technical Director
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
Radioprotection & safety

EUROPEAN UNION ERDF PROGRAM: European Regional Development Funds

Universidad de Huelva

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

INDUSTRY FUND.		Meur	2011	2012	2013	2014	2015	2016	2017
INNPLANTA	Buildings	10.8							
INNPLANTA	LINAC	15.4							
INNTERCONECTA	R&D	1.4							
INNPLANTA	Fusion technology	7.1 ??							
?? 2012 ??	Commissioning +??	??							

LRF- CONSTRUCTION PHASES

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 ~3-4 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

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

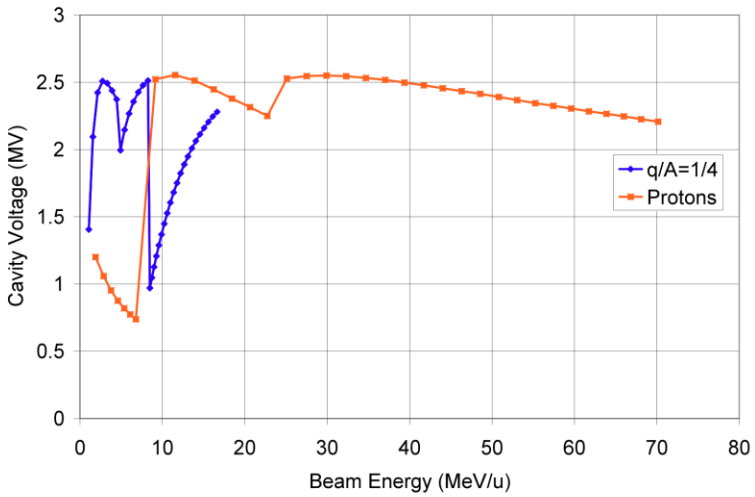
→ limited by ECR ion source

Configuration :

- Ion source + Low Energy Beam Line
- 400 kV HV platform → (ion implantation & LE astrophysics)
- 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



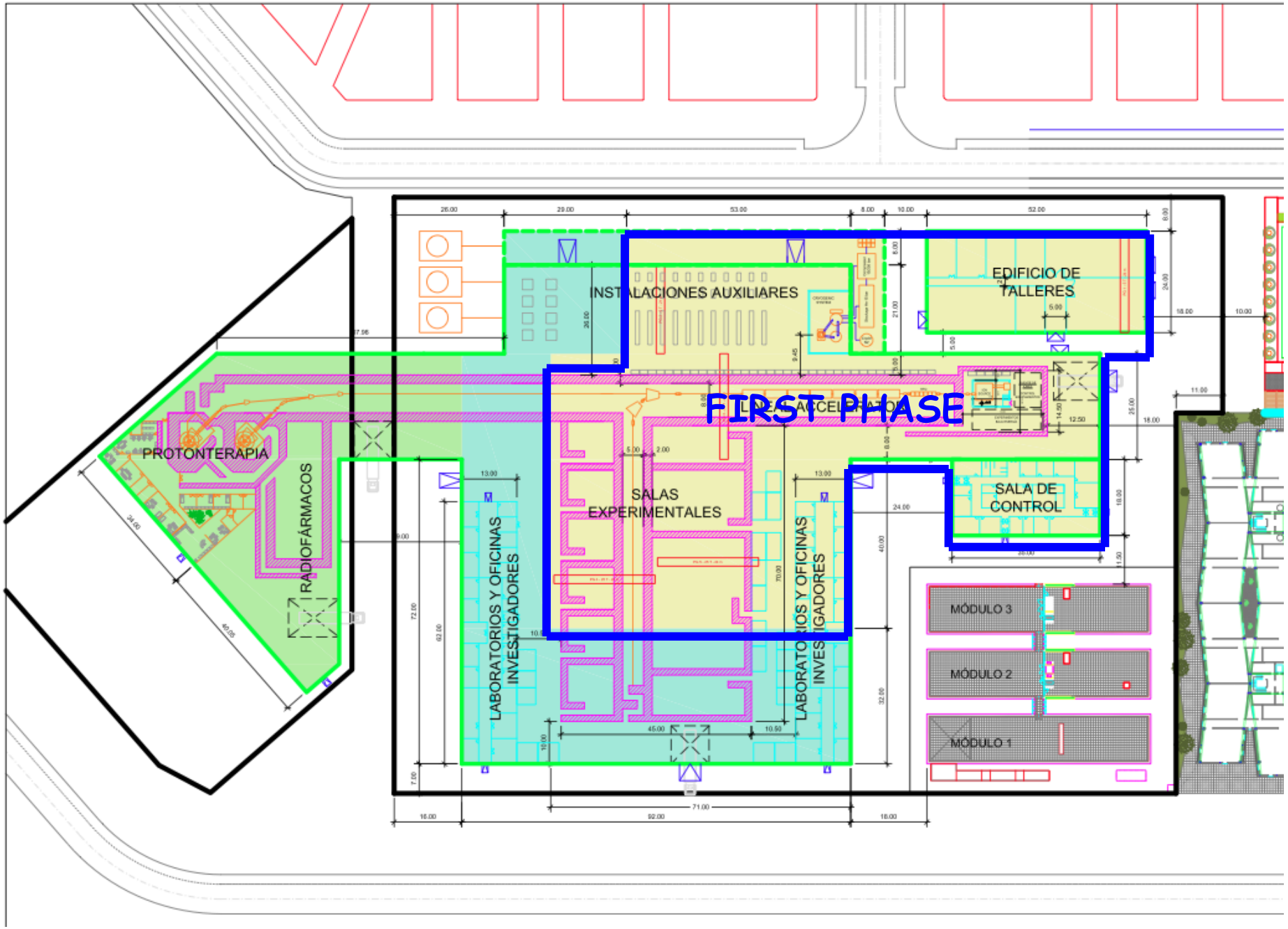
ION INTENSITIES

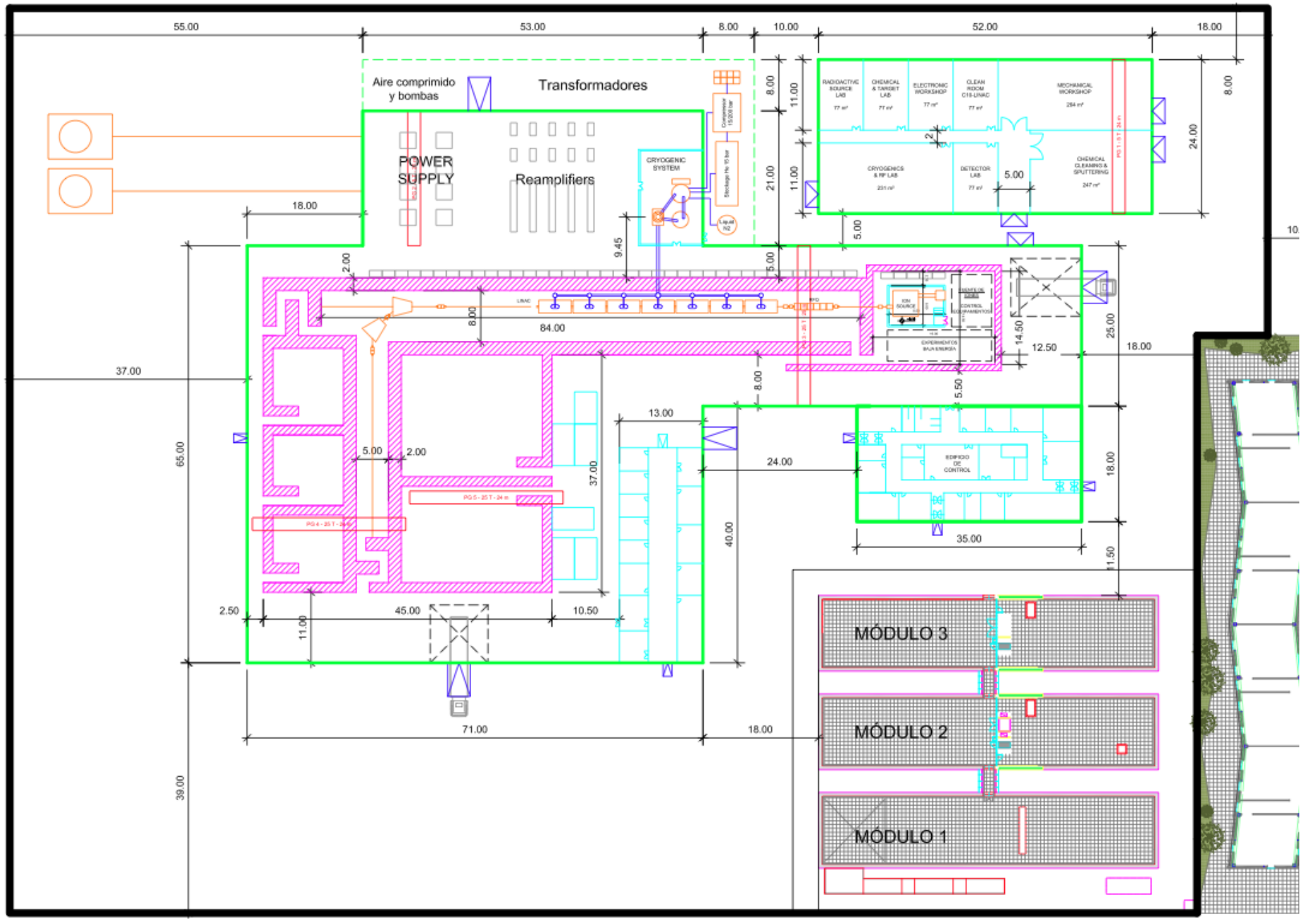
Wide range of ions 2 high intensity: Commercial options/ ECR ion source (Pantechnik).

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			

Huelva City
3 Km

Universidad de Huelva


FIRST PHASE
PROTONTERAPIA
RADIOFÁRMACOS
INSTALACIONES AUXILIARES
EDIFICIO DE TALLERES
SALAS EXPERIMENTALES
SALA DE CONTROL
LABORATORIOS Y OFICINAS INVESTIGADORES
LABORATORIOS Y OFICINAS INVESTIGADORES
MÓDULO 3
MÓDULO 2
MÓDULO 1


Aire comprimido y bombas
Transformadores
POWER SUPPLY
Reamplifiers
CRYOGENIC SYSTEM
RADIOACTIVE SOURCE LAB
CHEMICAL & TARGET LAB
ELECTRONIC WORKSHOP
CLEAN ROOM C16-LINAC
MECHANICAL WORKSHOP
CRYOGENICS & RF LAB
DETECTOR LAB
CHEMICAL CLEANING & SPUTTERING
LINAC
ION SOURCE
EXPERIMENTOS BAJA ENERGÍA
EDIFICIO DE CONTROL
MÓDULO 3
MÓDULO 2
MÓDULO 1
55.00
53.00
8.00
10.00
52.00
18.00
8.00
11.00
21.00
24.00
5.00
9.45
2.00
84.00
14.50
12.50
25.00
37.00
65.00
5.50
13.00
24.00
40.00
35.00
11.50
2.50
45.00
10.50
71.00
39.00

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, …)
- Large 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 →OPEN COLLABORATION

International collaboration:

ANL - Chicago, USA
CEA-Saclay, France
CENBG – Bordeaux, France
CIEMAT-Madrid, Spain
CMAM-Madrid, Spain
CNA-Seville, Spain
CSIC-Madrid, Spain
FSU-Tallahasee, USA
FLNR-Dubna, Russia
GANIL-Caen, FranceGSI-Darmstadt, Germany

Hospital JRJ-Huelva, Spain
HIL-Warsaw, Poland
IFIC-Valencia, Spain
ISOLDE/CERN-Geneva, Switzerland
IPN-Orsay, France
KU-Leuven, Belgium
LNL-Leñaro, Italy
LNS-Catania, Italy
ORNL-Tenneesee, USA
RBI-Zagreb, Croatia
Univ. Birmingham, UK
Univ, Complutense-Madrid, Spain

Univ. Edimburg, UK
Univ. Granada, Spain
Univ. Huelva, Spain
Univ. Ioannina, Greece
Univ. Jyväskylä - JYFL, Finland
Univ. Padua, Italy
Univ. Salamanca, Spain
Univ. Seville, Spain
Univ. UNED-Madrid, Spain
Univ. UPV-Bilbao, Spain
Univ. Surrey, UK
Univ. York, UK
(...)