Experimental Nuclear Physics
Structure, Reactions and nuclear Astrophysics

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NuPECC meeting
Madrid, March 2008

Layout

- ✓ Spanish research groups in experimental nuclear physics
- ✓ Use of Large Scale Facilities
- ✓ Fields of research
- ✓ Recent highlights
- ✓ Detector R&D activities

The experimental nuclear physics community

56 researchers, 37 PhD students and 16 technical staff

(from NuPECC survey 2006)

- 7 University groups
- 2 CSIC Institutes
- CIEMAT

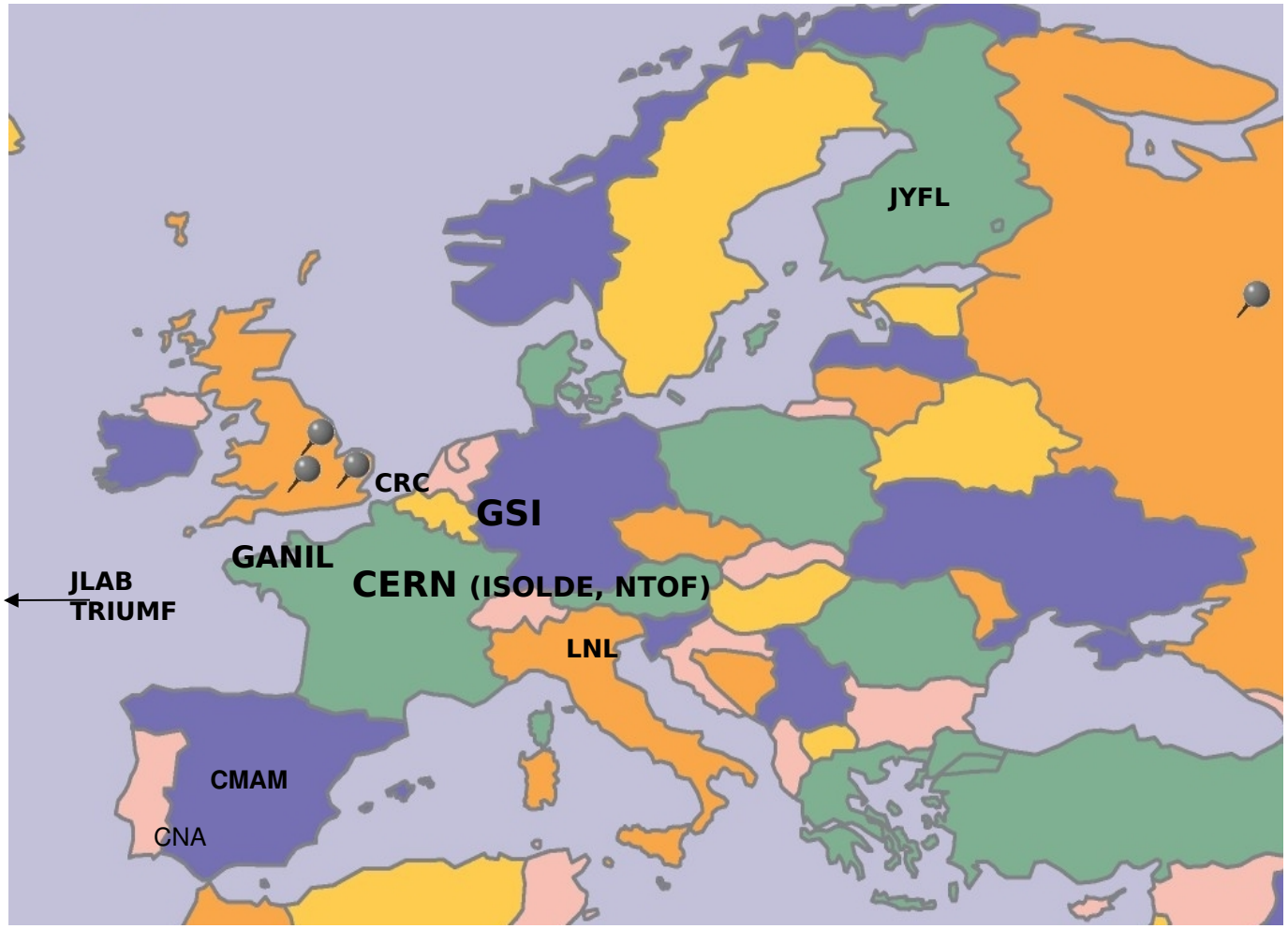
Funding

- National Funding Agency : MEC (Programa Nacional de Física de Partículas)
- UE FP
- Regional Funding Agencies

Additional information ific.uv.es/gamma/refinu

Madrid, March 2008

Scientific activity: International facilities



Activity developed in an international context: LSF and international collaborations

- 67 SCI articles in 2005
- 22 PhD thesis (02-06)

Fields of interest

Nuclear structure and dynamics

Reactions of astrophysycal interest

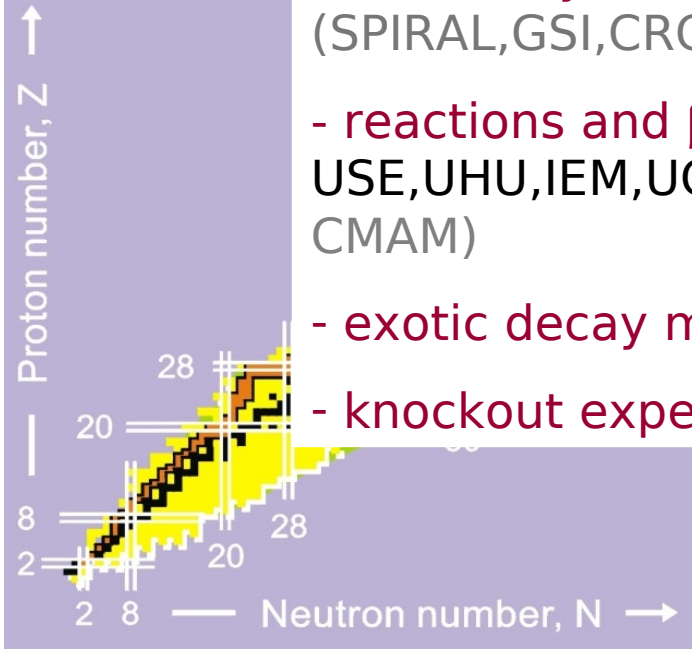
Light n-rich nuclei

- extremely n-rich systems IEM,USC,UHU (SPIRAL,GSI,CRC,ISOLDE)

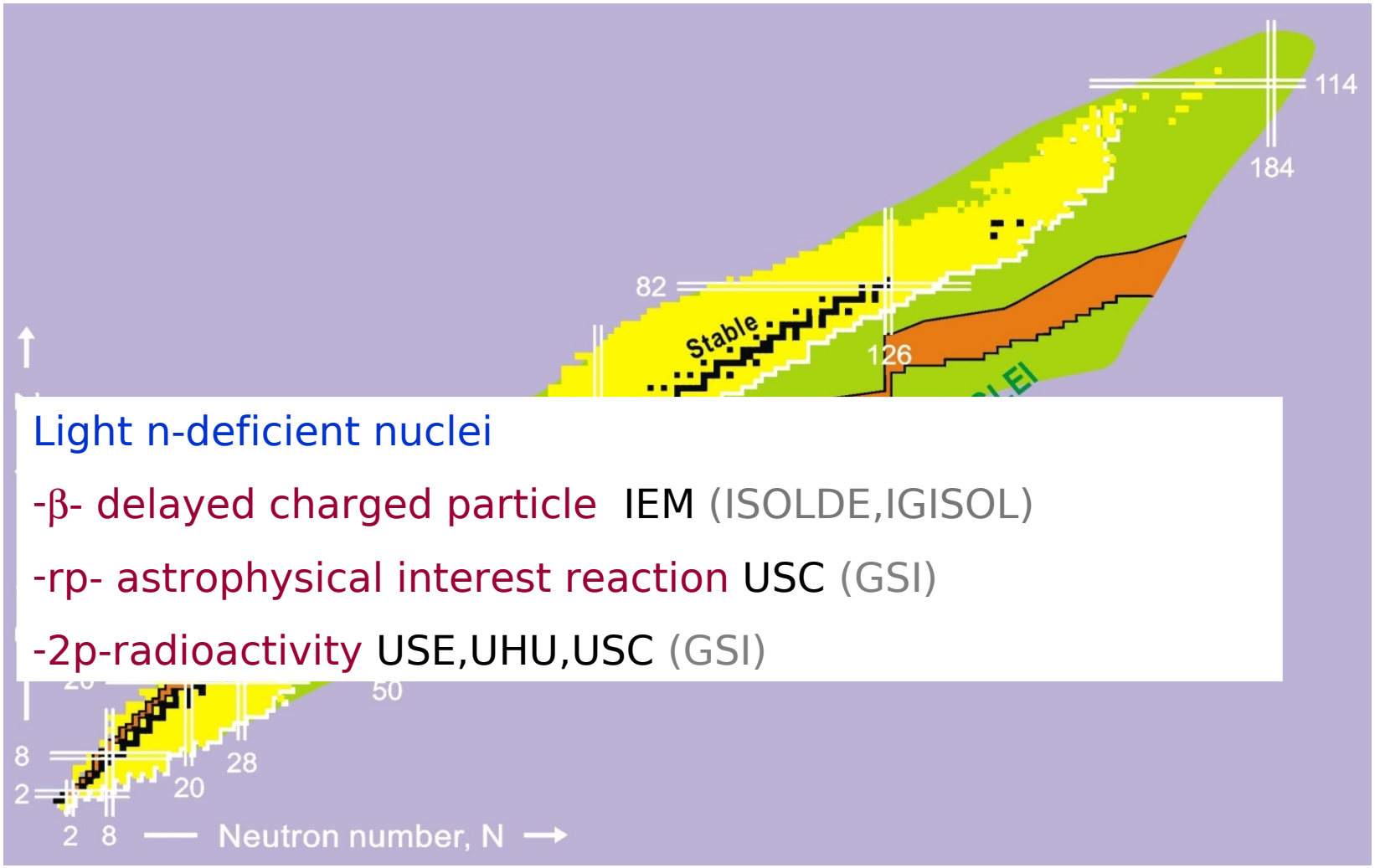
- reactions and β-decay experiments on exotic nuclei USE,UHU,IEM,UCM (ISOLDE, CRC,GSI,GANIL-SPIRAL, CMAM)

- exotic decay modes IEM,UCM (ISOLDE)

- knockout experiments in the sd-shell USC,IEM,UCM (GSI)



Fields of interest



Light n-deficient nuclei

-β- delayed charged particle IEM (ISOLDE,IGISOL)

-rp- astrophysical interest reaction USC (GSI)

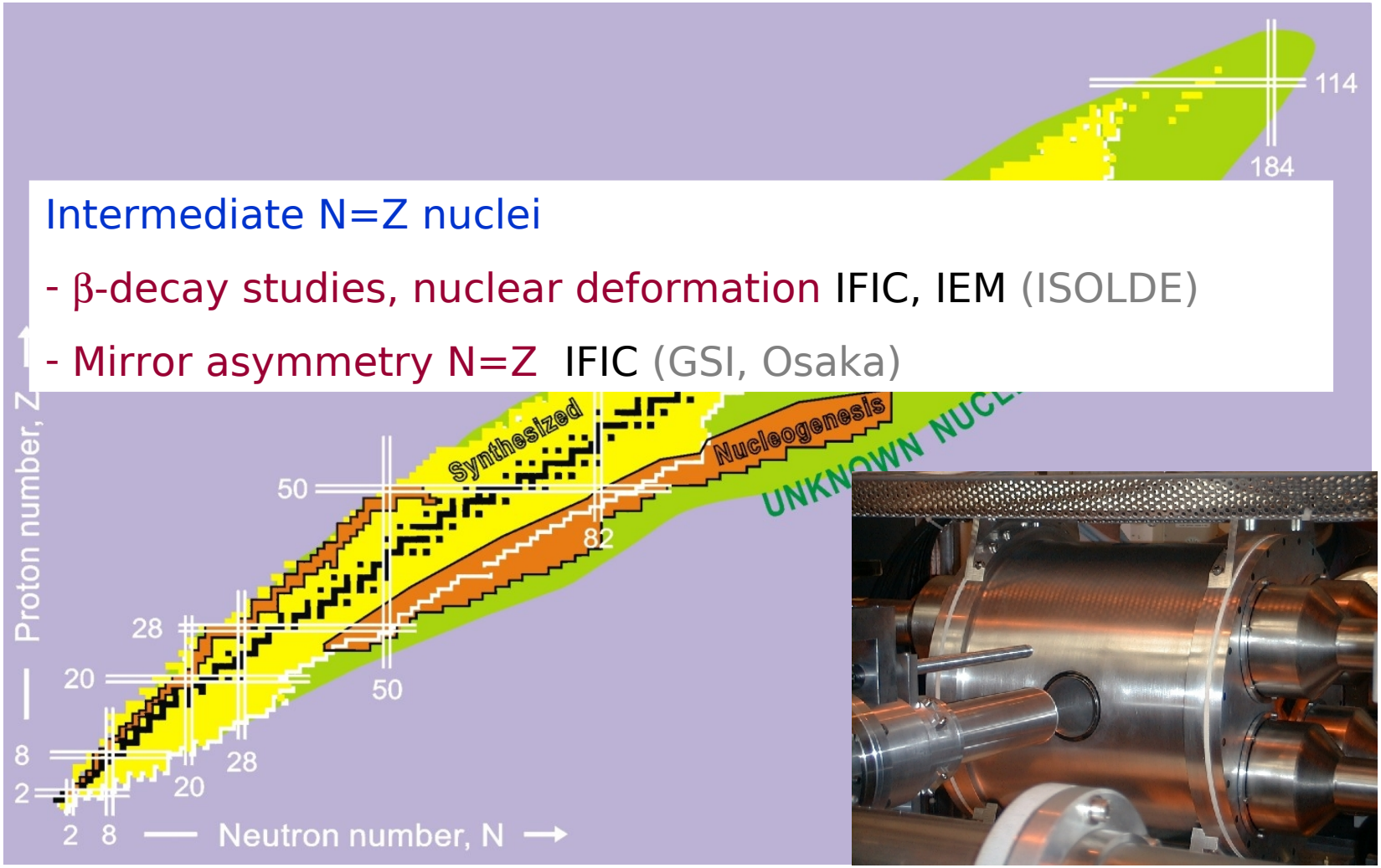
-2p-radioactivity USE,UHU,USC (GSI)

Fields of interest

Intermediate N=Z nuclei

- β-decay studies, nuclear deformation IFIC, IEM (ISOLDE)

- Mirror asymmetry N=Z IFIC (GSI, Osaka)



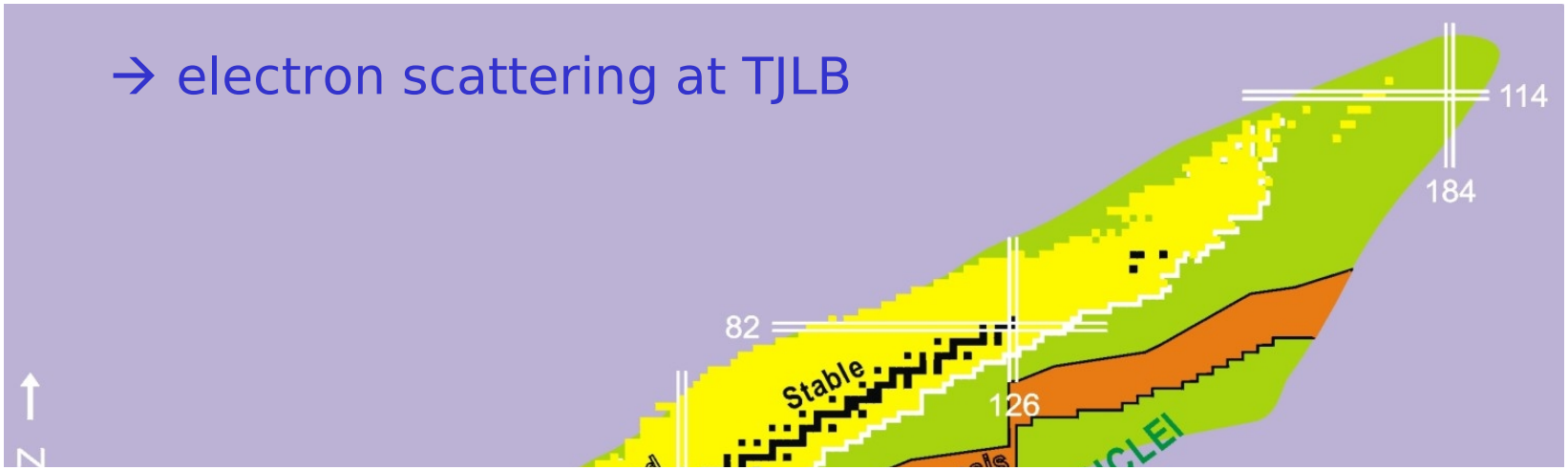
Fields of interest

Intermediate n-rich nuclei

- s-process (n,γ) reactions

IFIC,CIEMAT,UPC,USC,USE (n_ToF)

Fields of interest



Heavy n-rich nuclei

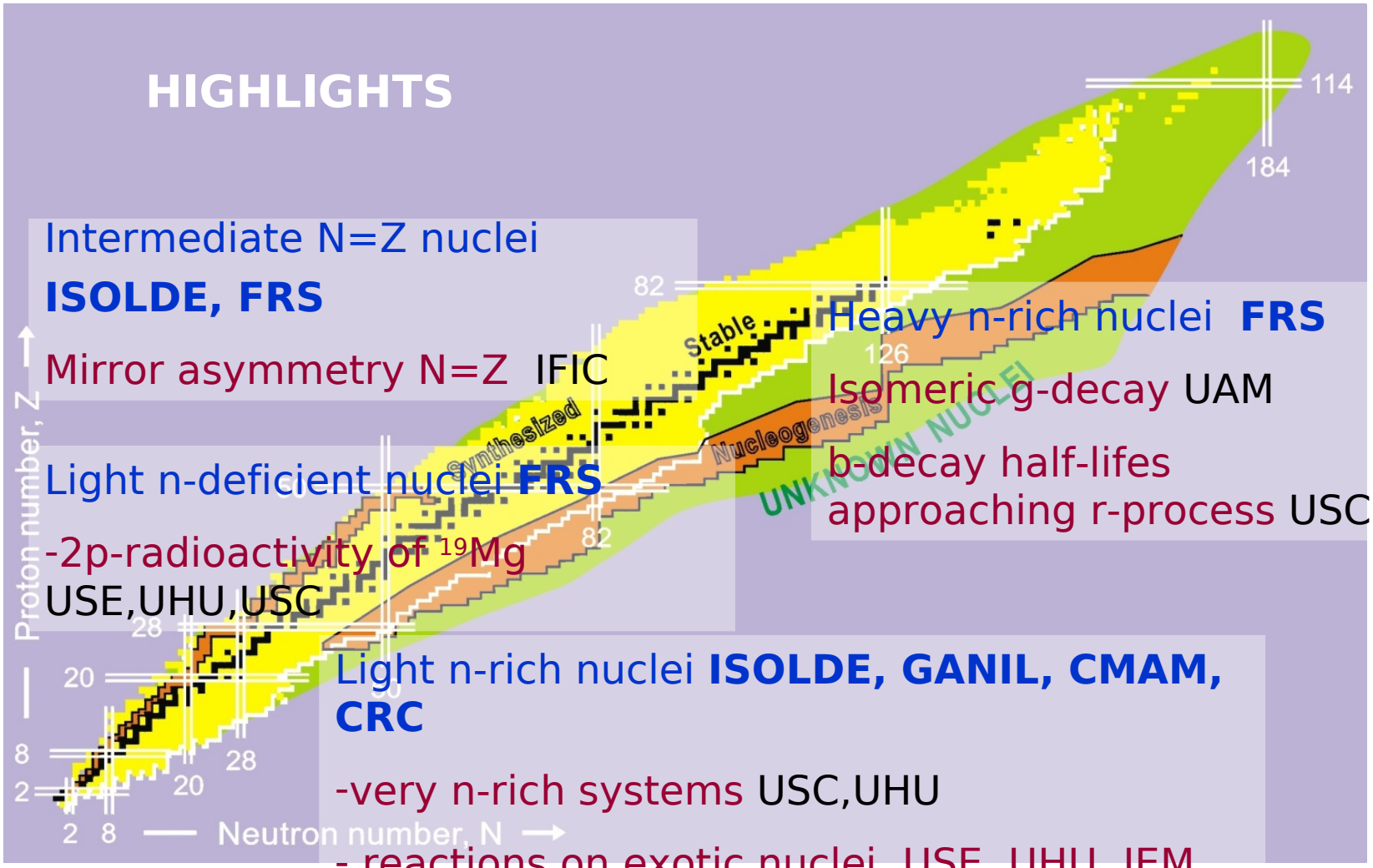
- n-induced fission IFIC,CIEMAT,UPC, USC,USE (n_ToF)

- Production of heavy n-rich nuclei USC, IEM, UCM (GSI, ISOLDE)

- Fission dynamics USC (GSI)

- Spectroscopy, Decay spectroscopy, Magnetic moments UAM,USC,IEM,IFIC (GSI, ISOLDE)

Fields of interest

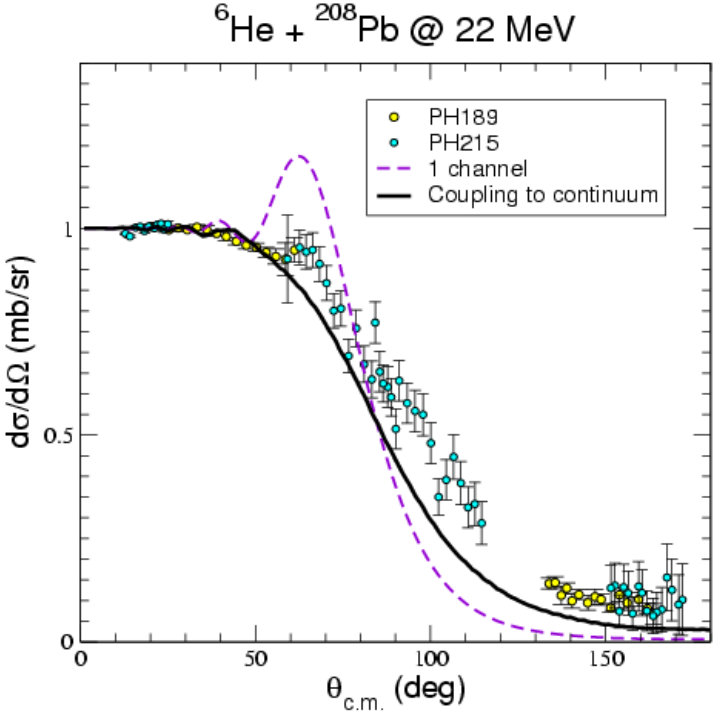


Dipole polarizability in the scattering of halo nuclei

Experimental program performed at CRC, Isolde and Triumf

J.G. Camacho USE
I. Martel UHU

Goal: distorsion of halo nucleus in the strong coulomb field (target)
new phenomena discovered: long range absorption of halo nuclei



➢ One channel calculations (- - -) unable to describe the scattering data

Coupling to the continuum needed (———) :

- Coulomb dipole couplings
- Nuclear couplings

} Contributions

D. Escrig et al., NPA 792(2007)2

A. Sanchez- Benitez et al, UHU PhD, NPA (2008) in press

Resonance State in ^{7}H

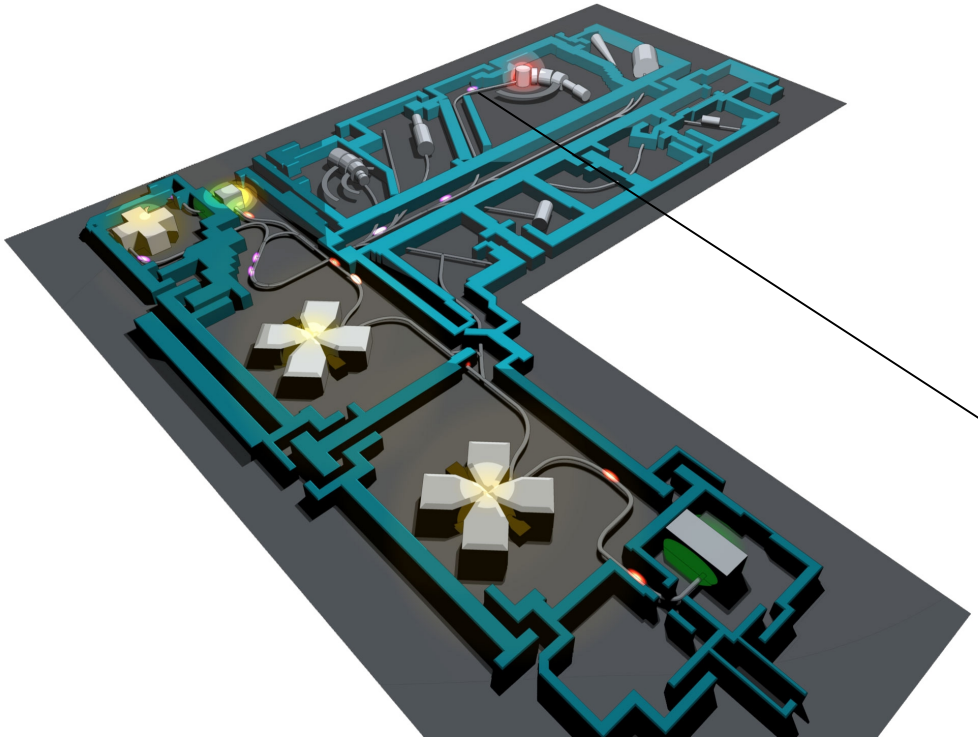
D.Cortina USC

Experimental study performed at SPIRAL

Goal: study of resonances beyond the neutron dripline
search for heavier hydrogen isotopes

Experimental technique: transfer reaction

8He beam @ 15.5 A. MeV

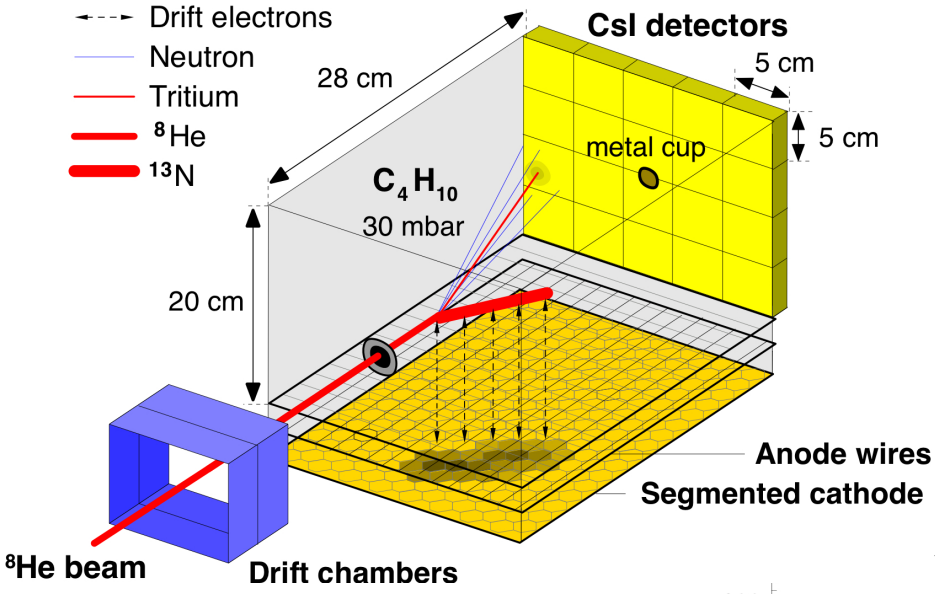


$^{8}He(^{12}C,^{13}N)^{7}H \rightarrow {}^{3}H + 4n$

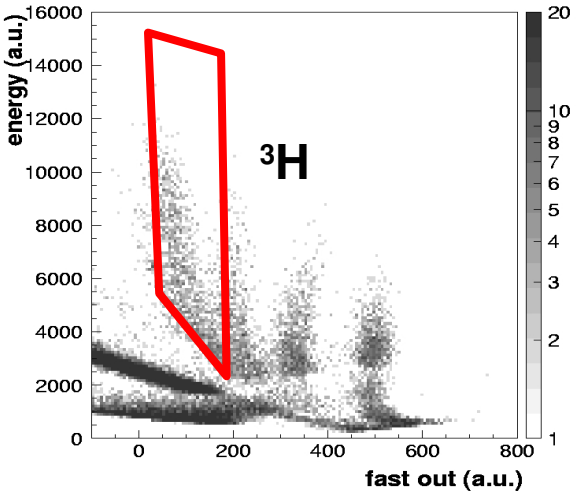
C_4H_{10} at 30 mbar ~6 10^{19} atoms/cm^2 of ^{12}C

MAYA ACTIVE TARGET

Resonance State in ^{7}H



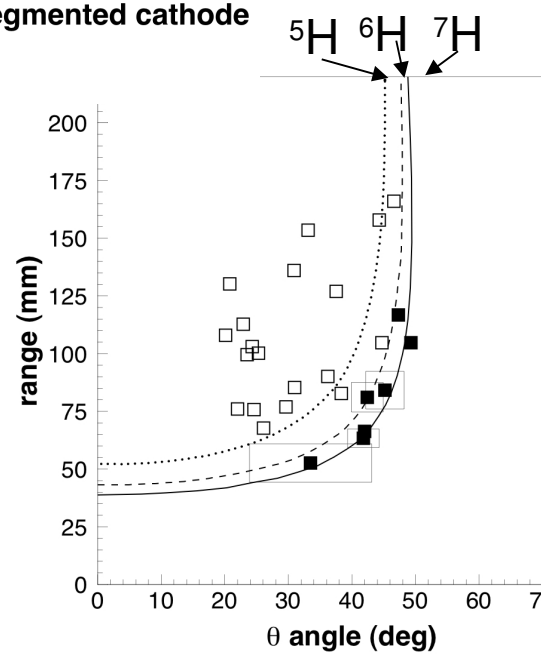
the light the gas traverse the gas volume and are stopped and identified in the CsI wall.

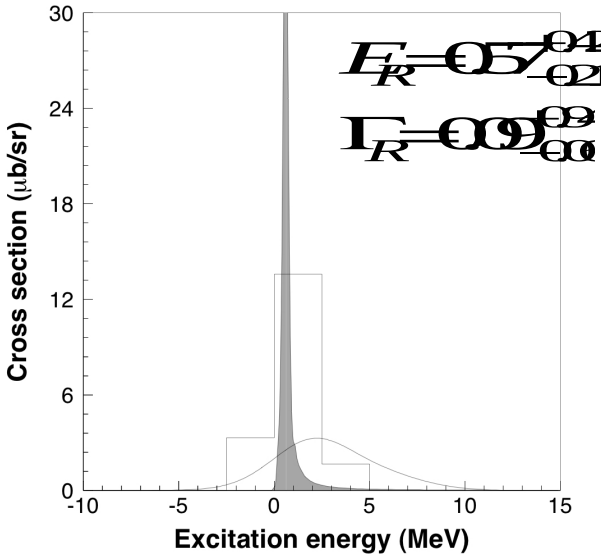


3D trajectrory reconstruction on

image of recoil trajectory in the segmented cathode.

the drift time →allows the determination of the reaction plane.





M. CaamaÒo, PhD USC, PRL 99(2007) 062502

Stellar triple-α process from measurement of ^{12}C nuclear resonances

Experimental study performed at ISOLDE & IGISOL

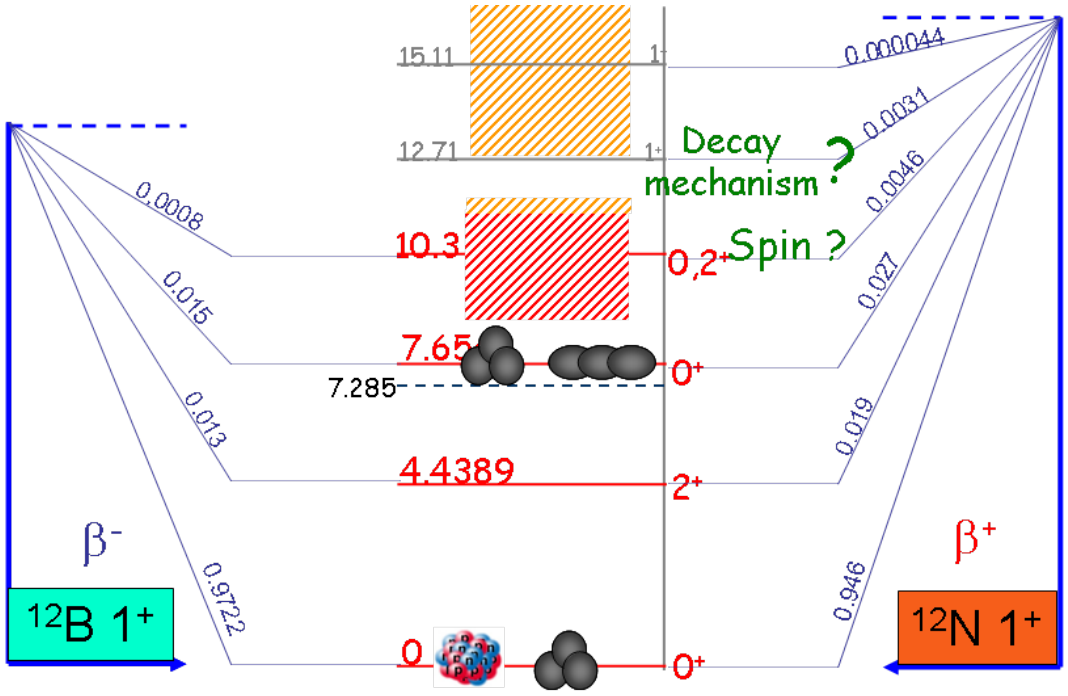
M.J.G. Borge IEM

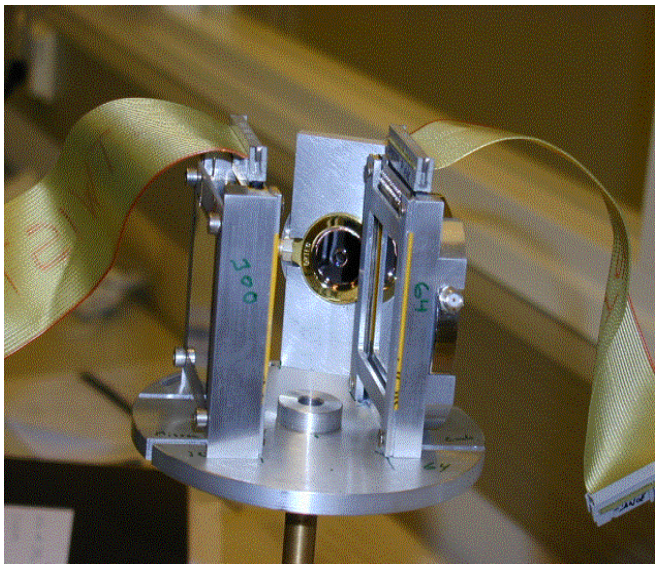
Goal: Multiple-decay mechanism

Revision of the triple-α process

astrophysical interest → observed abundances of ^{12}C and ^{16}O at the end of heliu

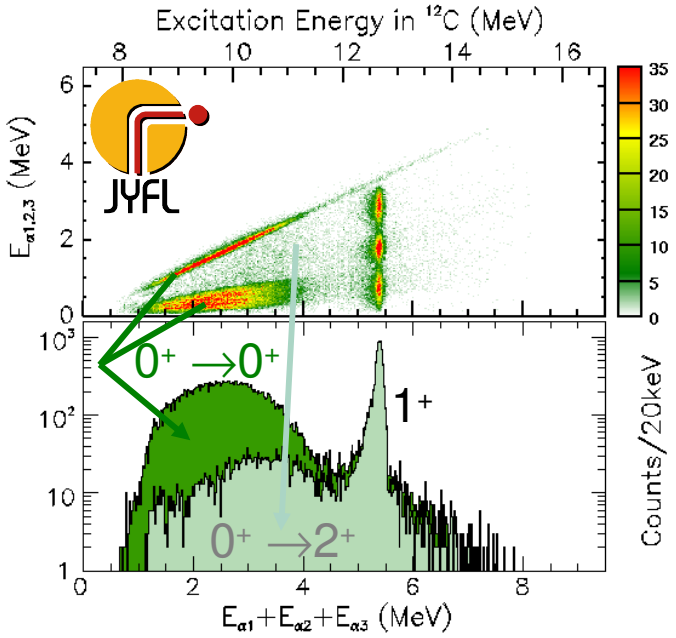
Experimental technique: β-decay of ^{12}N and ^{12}B





Windowless Si DSSSD, Tengblad et al, NIM A525(2004)458

Stellar triple-α process from measurement of ^{12}C nuclear resonances



Nuclear Structure Information

✓ Breakup of the 1^+ 12.7 MeV ⇒ mainly sequential .

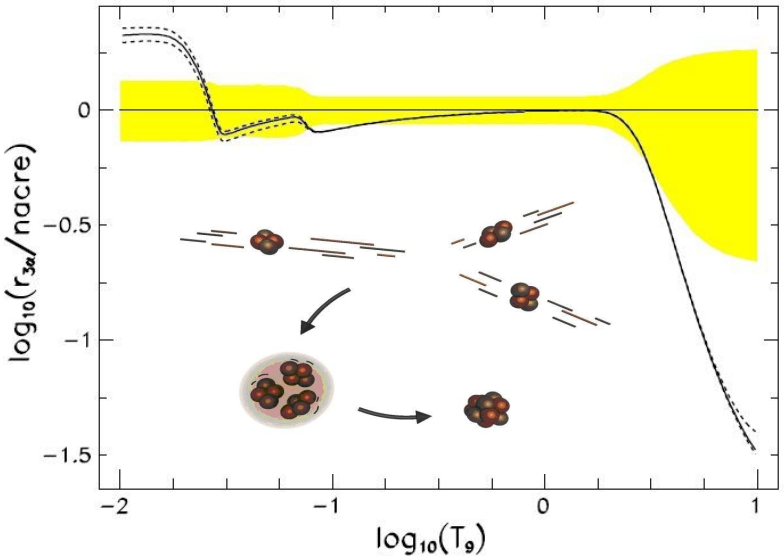
✓ Energy, width and $J^\pi = 0^+$ for the 10 MeV state.

✓ Decay channels of the 10 MeV state through 0^+ and 2^+ states in Be.

Nucleosynthesis: 3α-fusion rate (Hoyle + 10 MeV)

✓ T < 10^8K ⇒ Half time for primordial stars to reach ^{12}C abundance to ignite the CNO cycle.

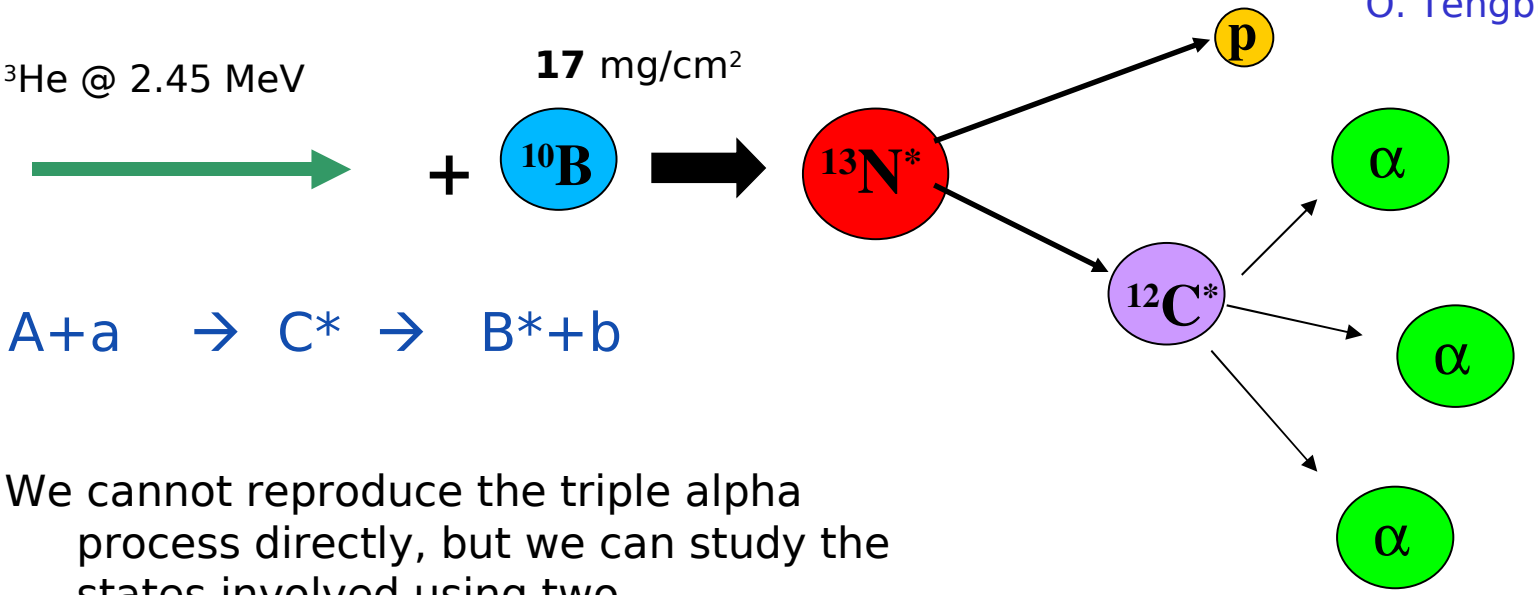
✓ At high temp (T>3x10^9) reduction (factor 2-3) in production ^{56}Ni and heavier elements in proton rich supernova.



H.O.U Fynbo et al., Nature 433 (2005) 13

Low energy reaction study @ Madrid Tandem accelerator – how to produce the $^{12}C^*$ states

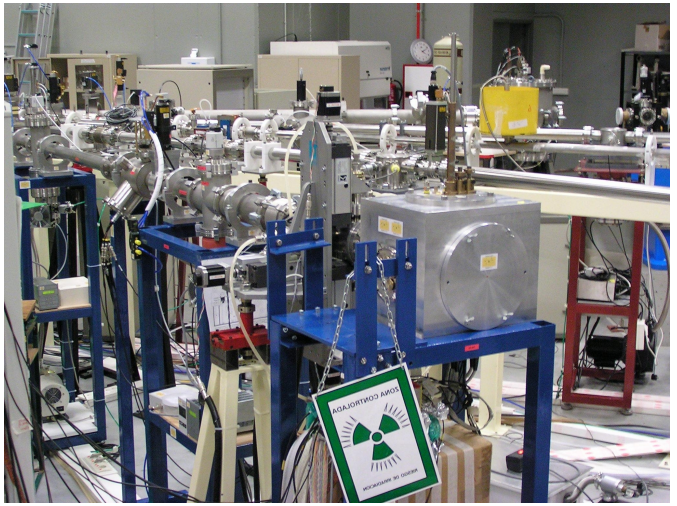
O. Tengblad IEM



A+a → C* → B*+b

We cannot reproduce the triple alpha process directly, but we can study the states involved using two complementary methods;

- In beta decay
- Via the ^3He + ^{10}B reaction, which allows us to gain complementary information on the ^{12}C resonances



O. Tengblad et al., INPC 2007

Observation of two-proton radioactivity of ^{19}Mg

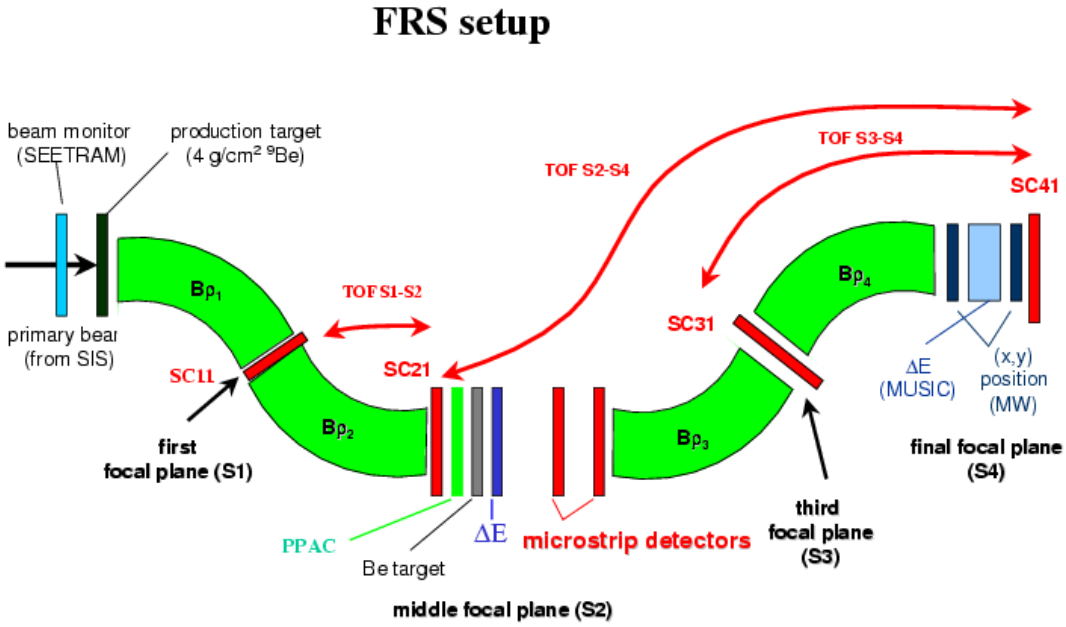
Experimental study performed at FRS

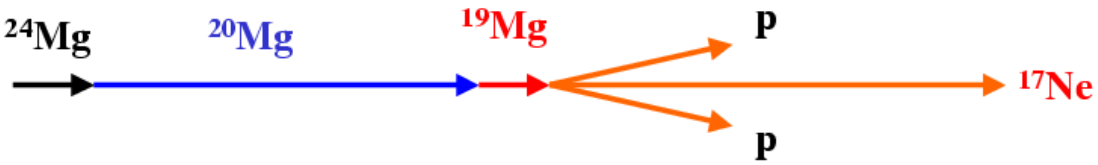
I. Muhka USE

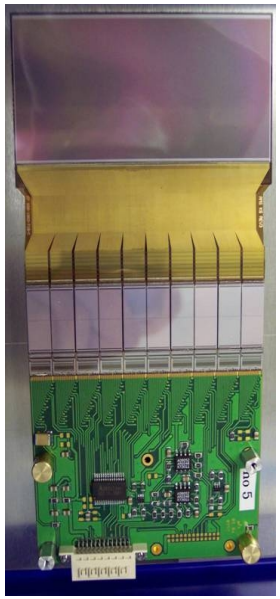
Goal: Observation of 2-p radioactivity of ^{19}Mg gs

^{24}Mg@591 A MeV 10^9 pps

Experimental technique: in-filght tracking of the decay products





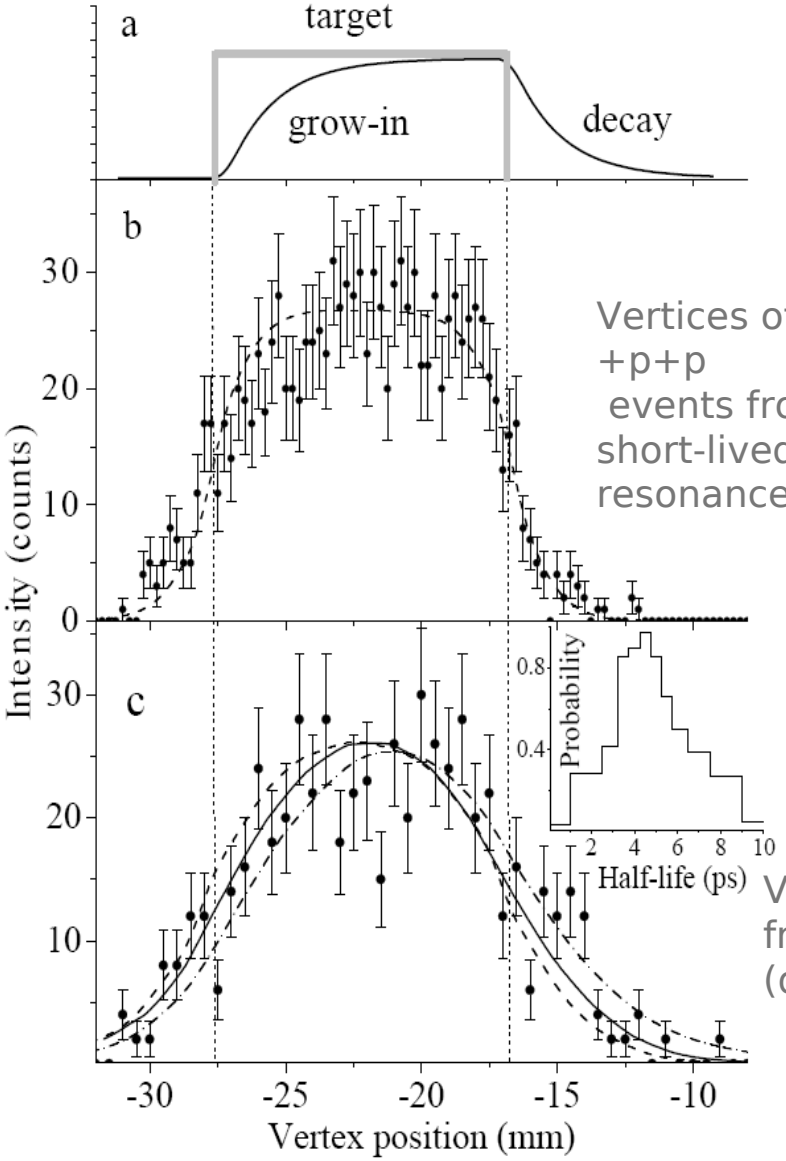


Dimensions 70x40 mm^2,

100μ strip, in total 4000 channels

http://dpnc.unige.ch/ams/GSItracker

Observation of two-proton radioactivity of ^{19}Mg



Vertices of ^{17}Ne +p+p events from short-lived resonances

Vertex distribution from ^{19}Mg (delayed activity)

- The unknown isotope ^{19}Mg is observed by using the novel tracking technique.
- Two-proton decay with $T_{1/2}$=4.1(1.5) ps and Q_{2p}=0.75(5) MeV was detected by measuring decay vertices and fragment correlations from coincident ^{17}Ne+p+p events.
- Three-body decay mechanism of 2p radioactivity has been confirmed.

I. Mukha et al., PRL99 (2007) 182501

Mirror symmetry for N=Z

Experimental study performed at RISING

B. Rubio IFIC

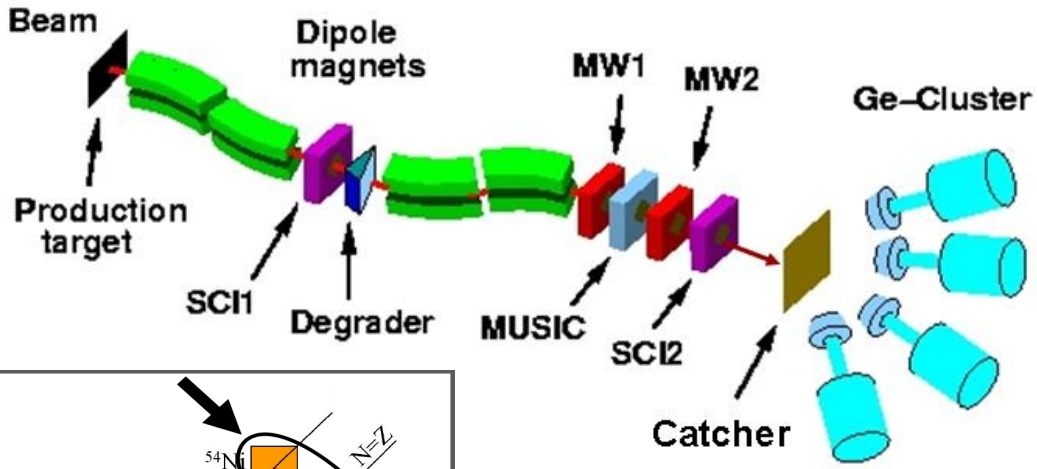
Goal: Study of mirror symmetry for N=Z

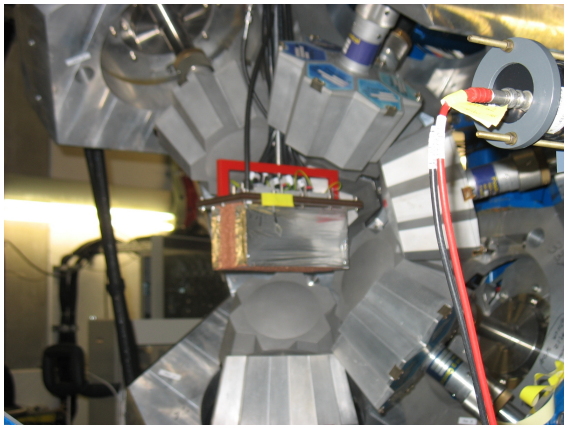
β–decay of ^{54}Ni→ complemetarity of b-decay and charge exchange

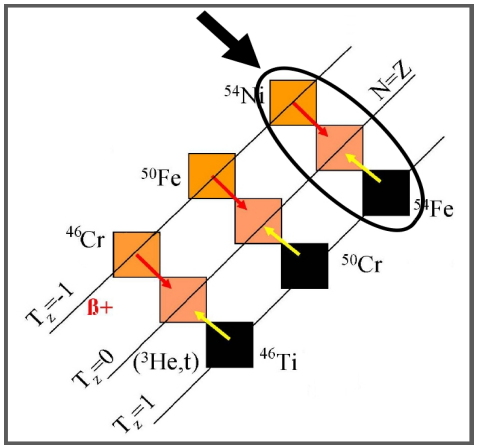
^{58}Ni@680 MeV/u 10^9 pps Target Be 400mg/cm^2

Experimental technique: β-decay of ^{54}Ni

delay γ detected in RISING

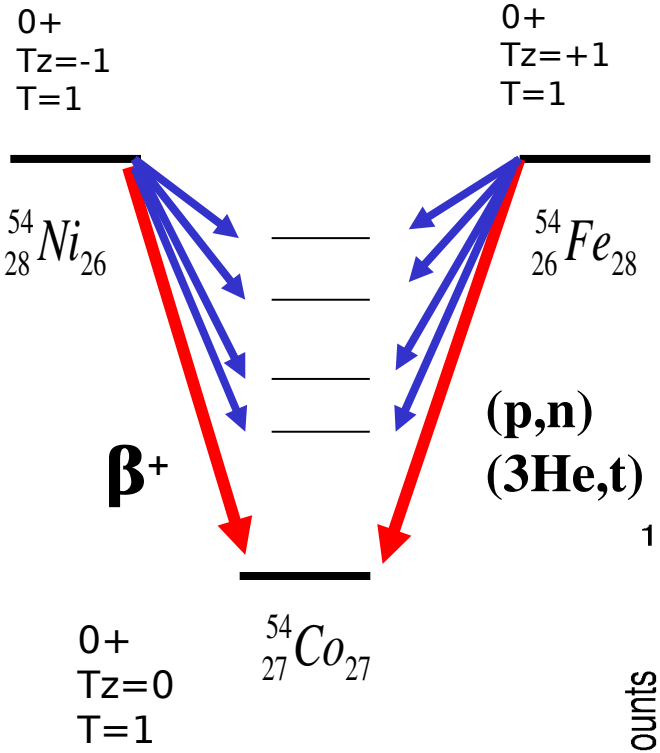


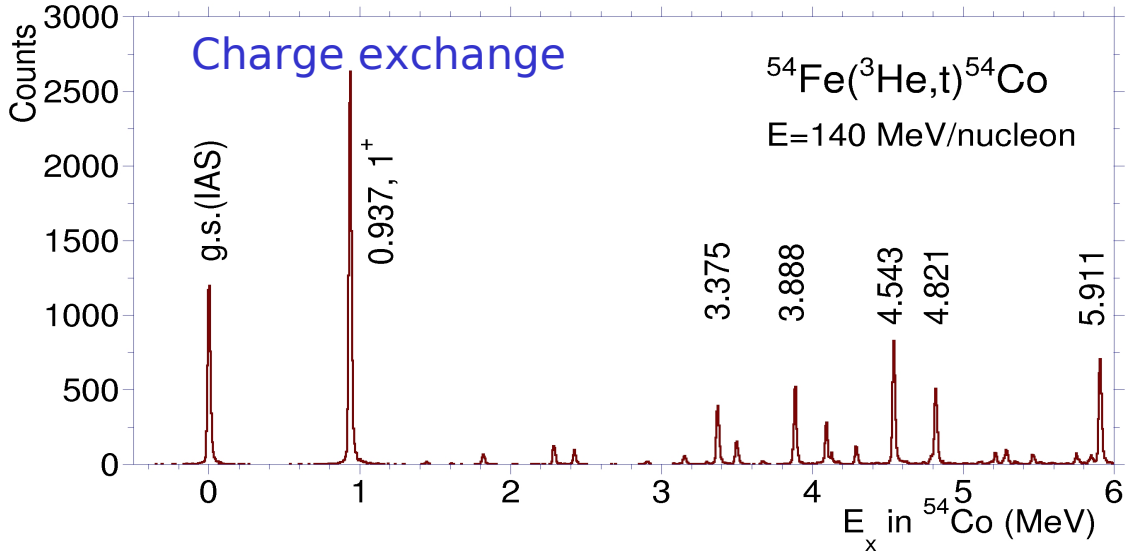


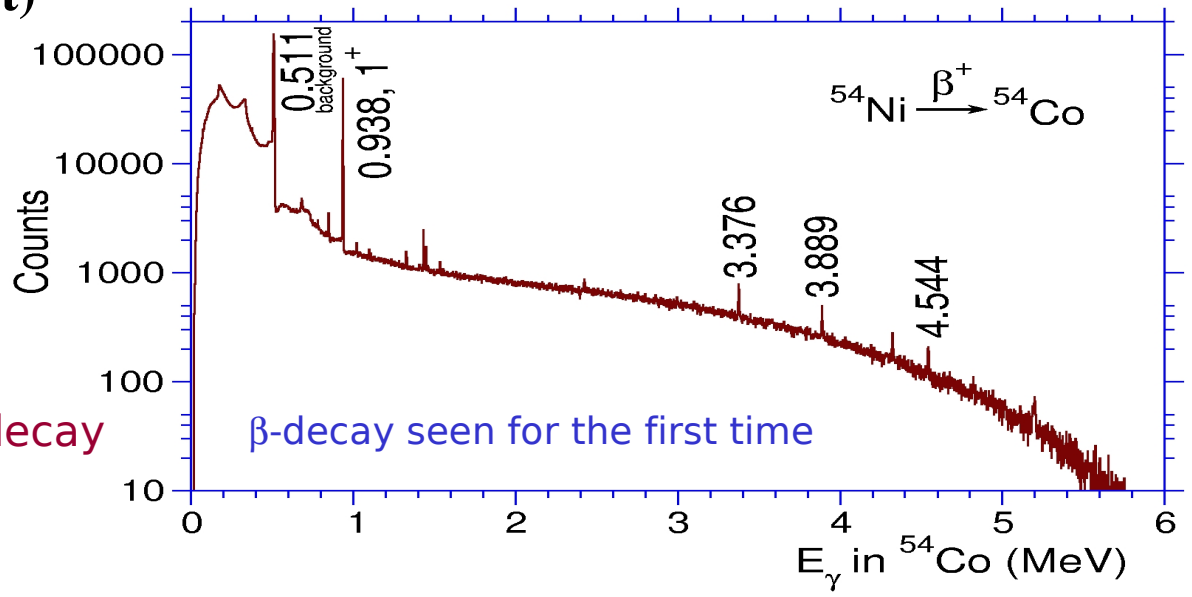


Y. Fujita et al., PRL95 (2005) 212501

Mirror symmetry for N=Z







β-delayed g-rays from ^{54}Ni decay

(GSI, RISING)

On going analysis …

Isomeric decays in the r-Process waiting point ^{130}Cd

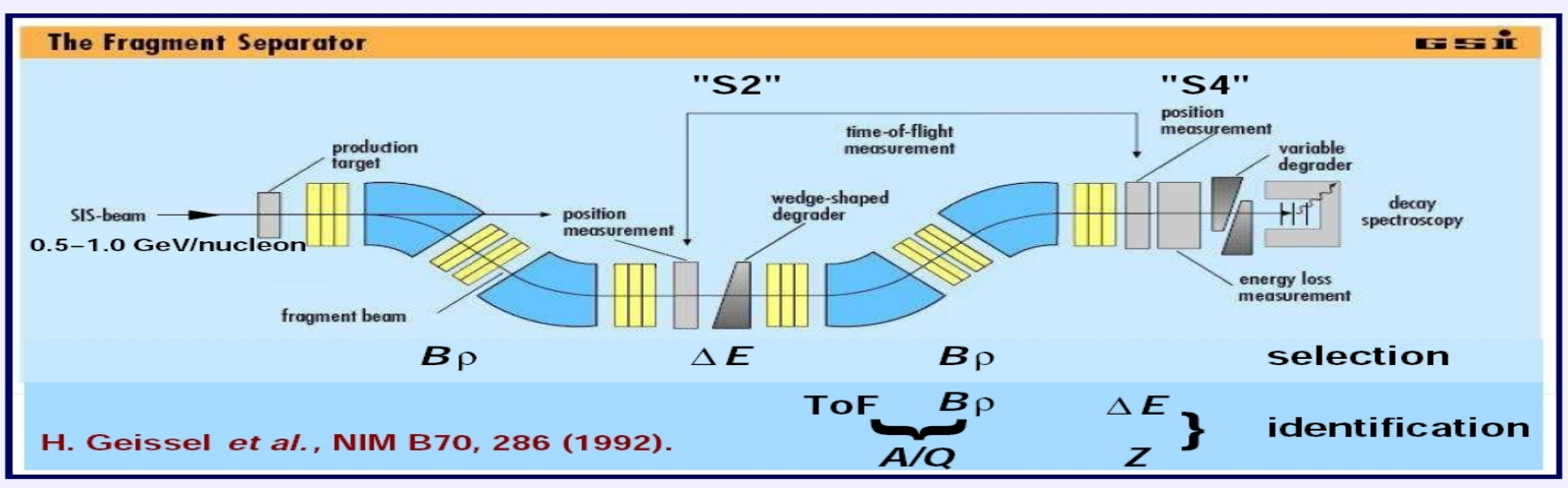
Experimental study performed at RISING

A. Jungclaus UAM

Goal: shell structure evolution
quenching of N=82 shell → peak r-process abundance A ~ 130
^{130}Cd is the most n-rich waiting

^{136}Xe fragmentation@ 750 MeV/u Target Be 4g/cm^2
^{238}U fission@ 650 MeV/u Target Be 1 g/cm^2

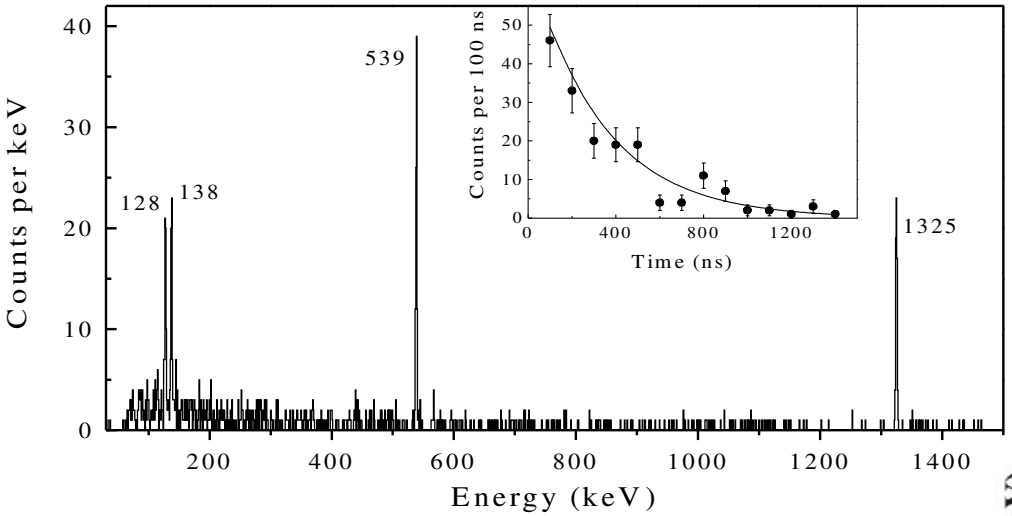
Experimental technique: implantation of excited isomeric states in a passive stopper



4000 identified ^{130}Cd ions in fragmentation (2300 in fission)

Isomeric decays in the r-Process waiting point ^{130}Cd

Singles γ-spectrum in delayed coincidence with implanted ^{130}Cd ions

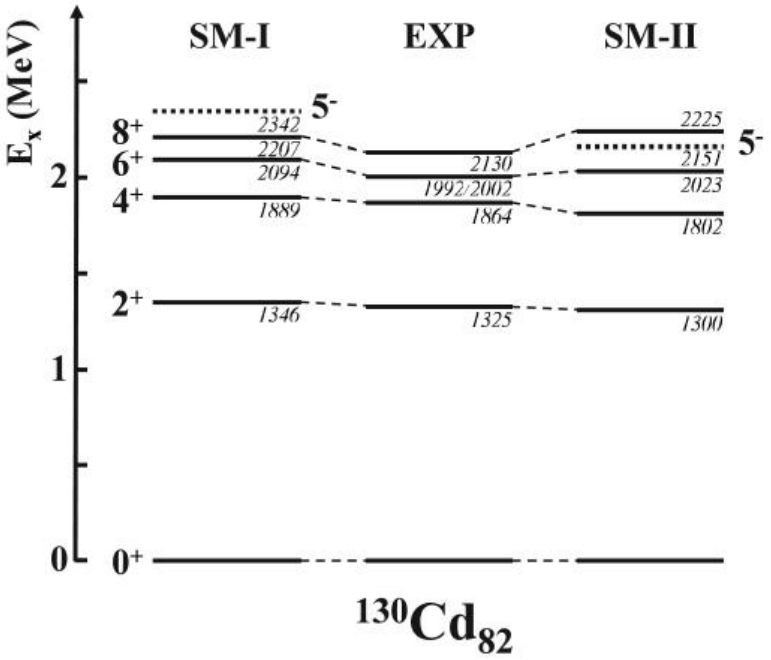


4 transitions in coincidence →

cascade from the isomeric state to the gs. → E2

$T_{1/2}$= 220(30) ns

summed time spectra of all transitions



Both SM calculations used modern interaction.

Very good agreement with experimental data →

No evidence for a quenching in the N=82 shell

A. Jungclaus et al., PRL 99 (2007) 132501

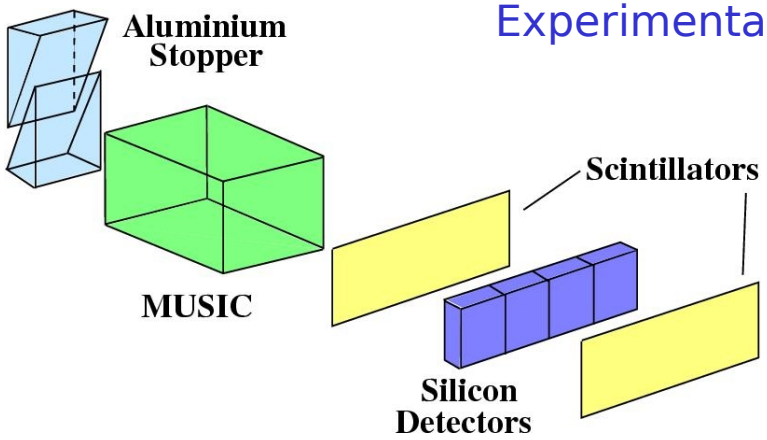
First access to β-half-lives close to r-Process path near N=126

Experimental study performed at FRS

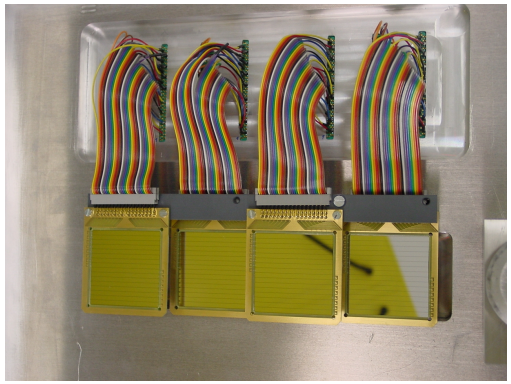
J. Benlliure USC

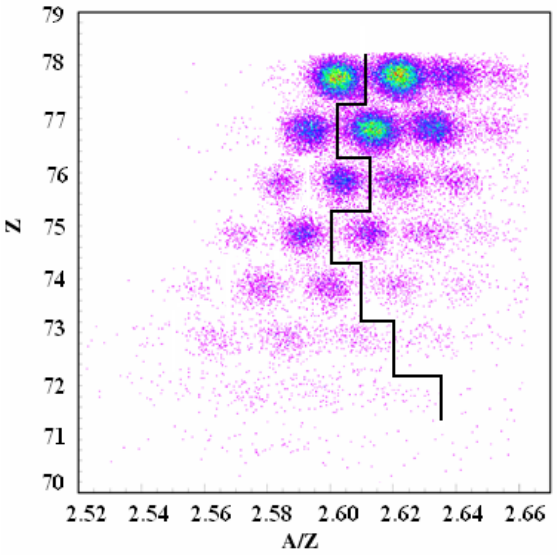
Goal: β- decay half lives of nuclei close to the r-path
first experimental access to N~126 south of lead → r-abundance A=195

^{208}Pb fragmentation@ 1000 A MeV

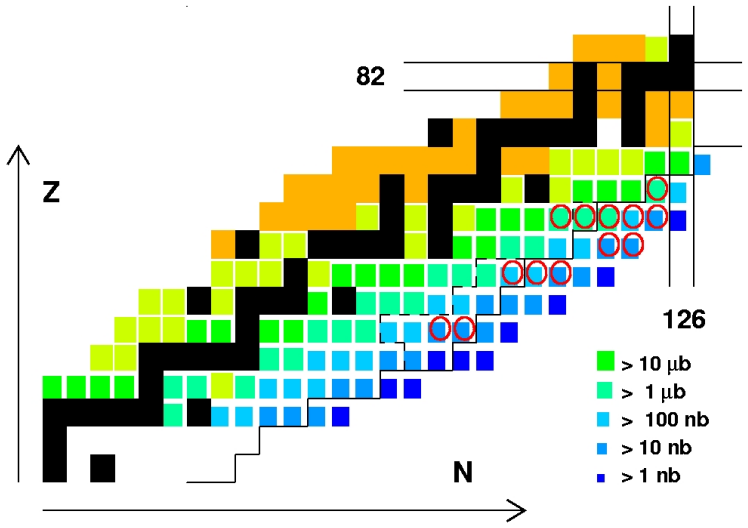


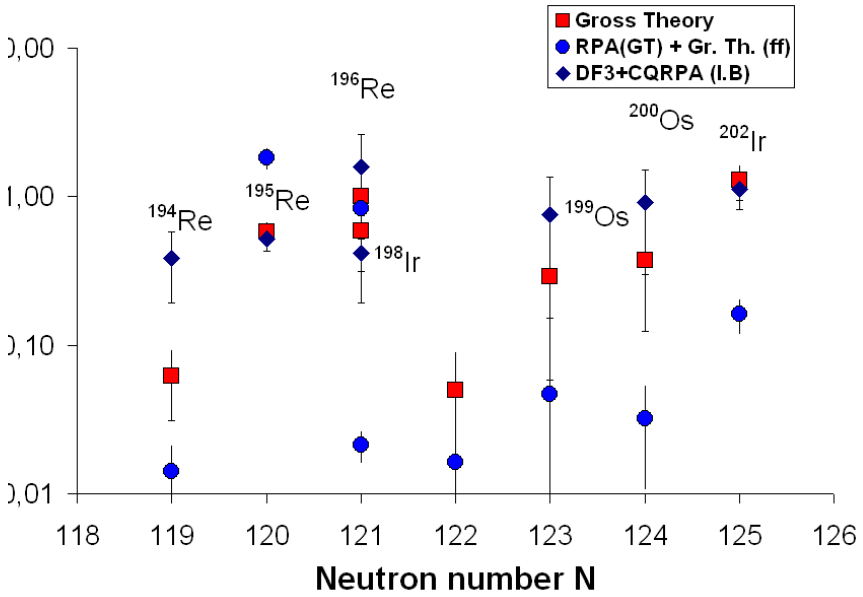
Experimental technique: implantation in an active stopper
β –decay half- lives





First access to β-half-lives close to the r-Process path near N=126





- 25 new isotopes identified
- Half lives measurement (or upper limit) for 13 isotopes
- Considerably shorter than predicted by different theories.
- This results in a faster r-process able to produce a larger number of heavy nuclei.

T. Kurtukian, PhD USC, submitted PRL arXiv:0711.0101

Electron scattering of nuclei

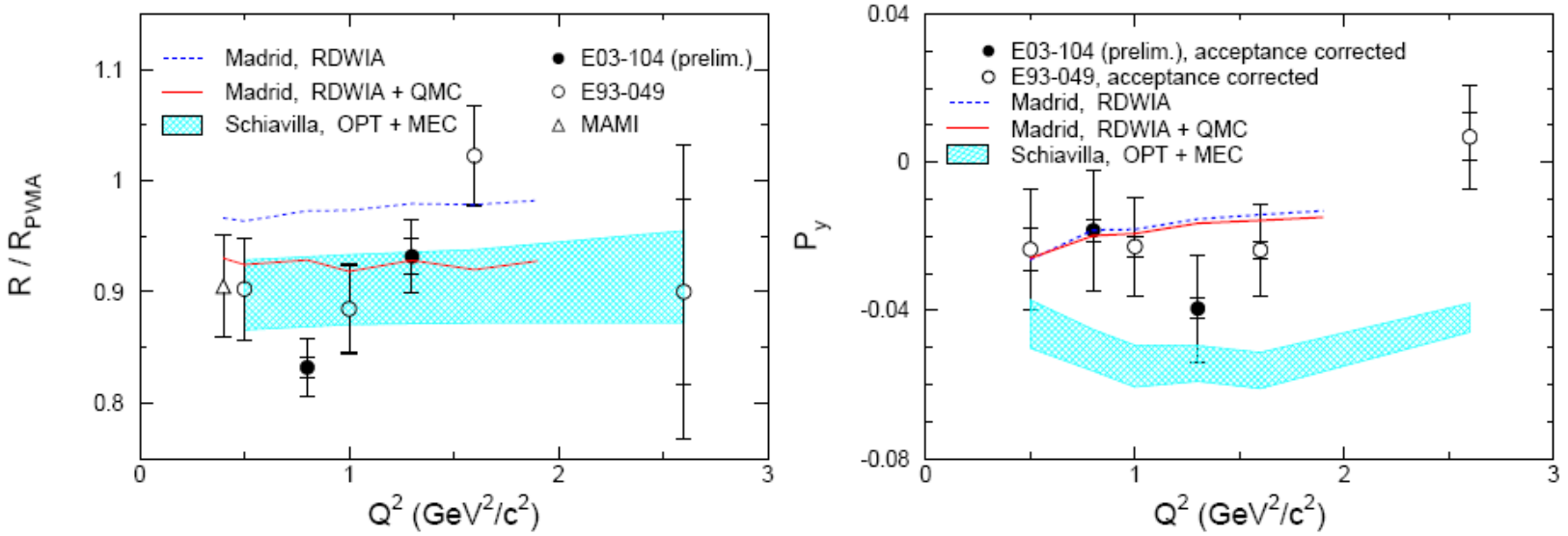
Experimental study performed at JLAB and MAMI

J.M. Udias UCM

Goal: Tests of nuclear structure, Coulomb Sum Rule experiment

(e,e'p) experiments: high precission spectroscopic factors and correlations in oxygen and lead

ratio of G_E/G_M form factors in bound nucleons



Data suggests the pressence of mild medium modifications of the form factors, like the ones implied in QMC model. Alternative (nonrleativistic) modeling (cyan area) is not compatible with data for induced (P_y) polarization

Polarization transfer in the ^{4}He((e,e 'p)^{3}H reaction PRL 91, 052301 (2003)

Detector tests at CNA

J. Gómez Camacho USE

Goal:

Development of tracking detectors for slowed down exotic beams at the low-energy branch of NUSTAR (FAIR)

Tracking detectors:

SeD, being constructed at Saclay. (Seville technician there)

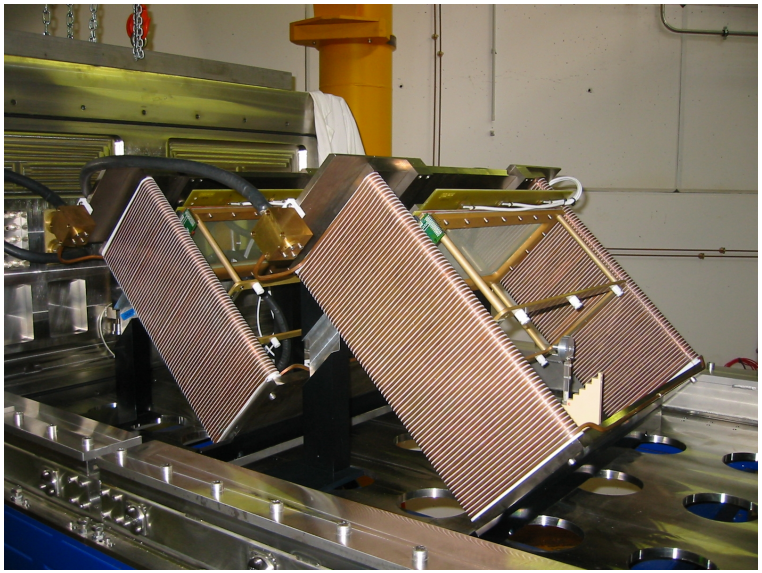
Test experiments:

Tracking of low energy stable beams in a dedicated Tracking chamber at CNA (planned for Sept 2008)

Sinergies Saclay-FAIR-CNA

Tracking chamber @ CNA

SeD @ Saclay



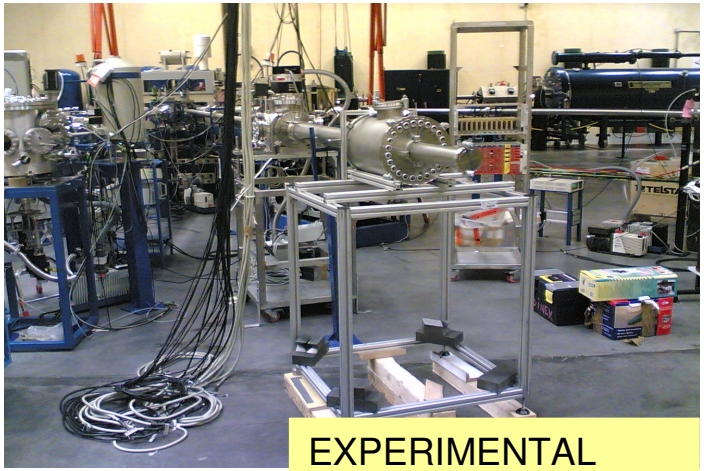
Detector tests at CNA

I. Martel UHU

Goal
- development of single crystal diamond detectors
- fast response (< 100ps) & good energy resolution

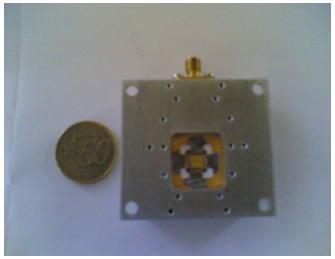
Used as: charged particle detectors, beam trackers and active targets for the new facilities at FAIR and SPIRAL2

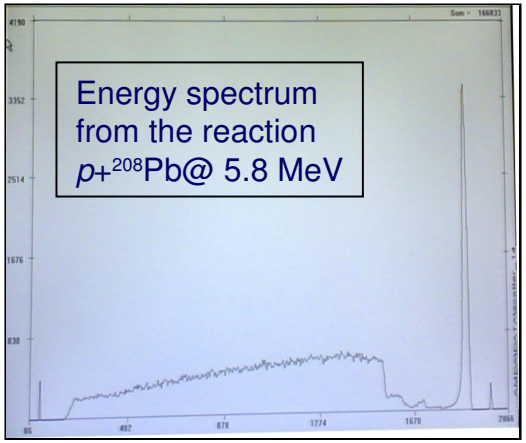
Collaboration with GSI-FAIR and GANI-SPIRAL2.
(for detectors HYDE & GASPARD)

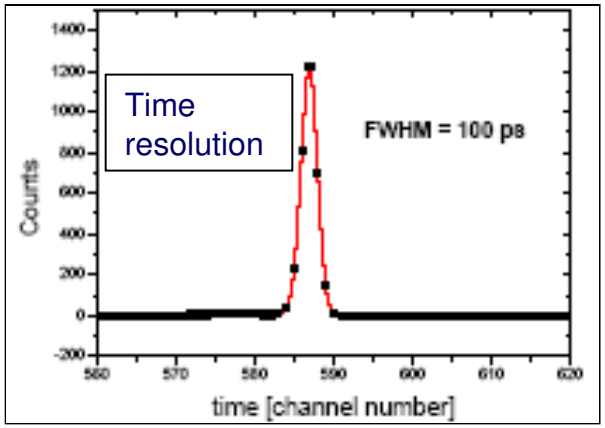


EXPERIMENTAL SETUP

DIAMOND DETECTORS







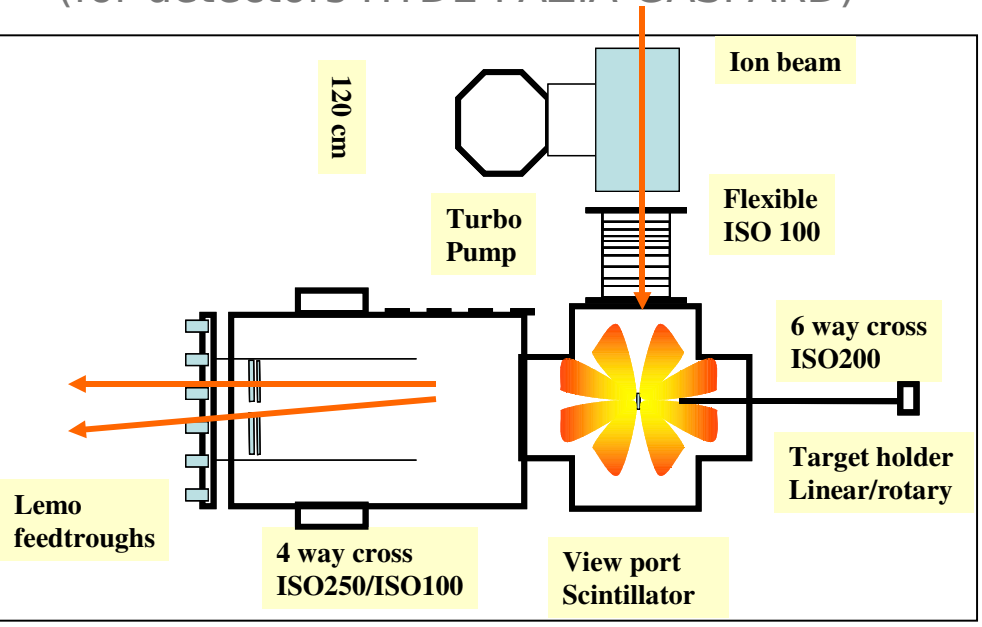
Detector tests at CNA

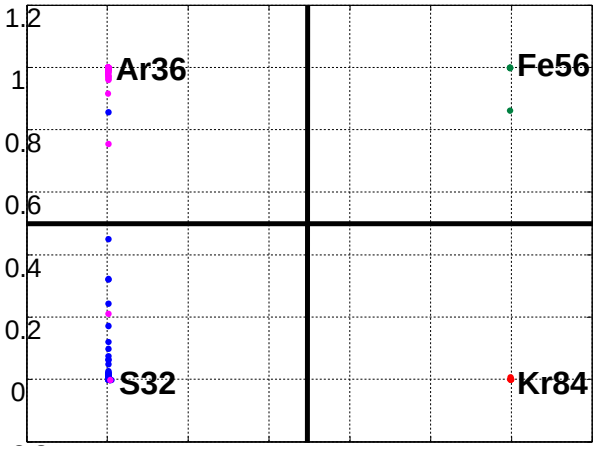
I. Martel UHU

Research on charged particle identification using Digital Pulse Shape analysis

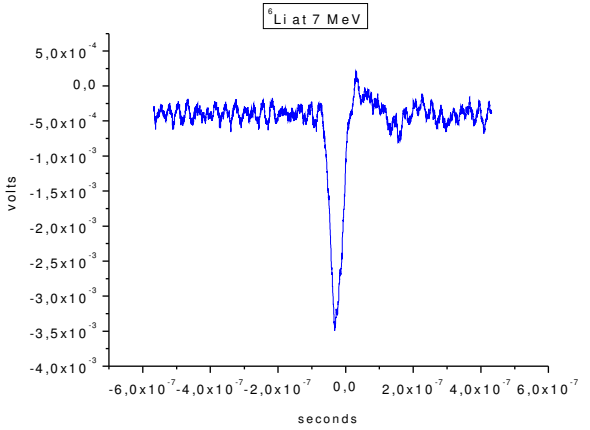
Goals : Study the limits of PSA with thin silicon detectors and DSSD detectors using low energy particles.

Collaboration with SPIRAL2, LEGNARO and FAIR
(for detectors HYDE-FAZIA-GASPARD)





Z identification witn NEURAL NETWORKS
@ about 5 MeV/u (JL. Flores, HUELVA)

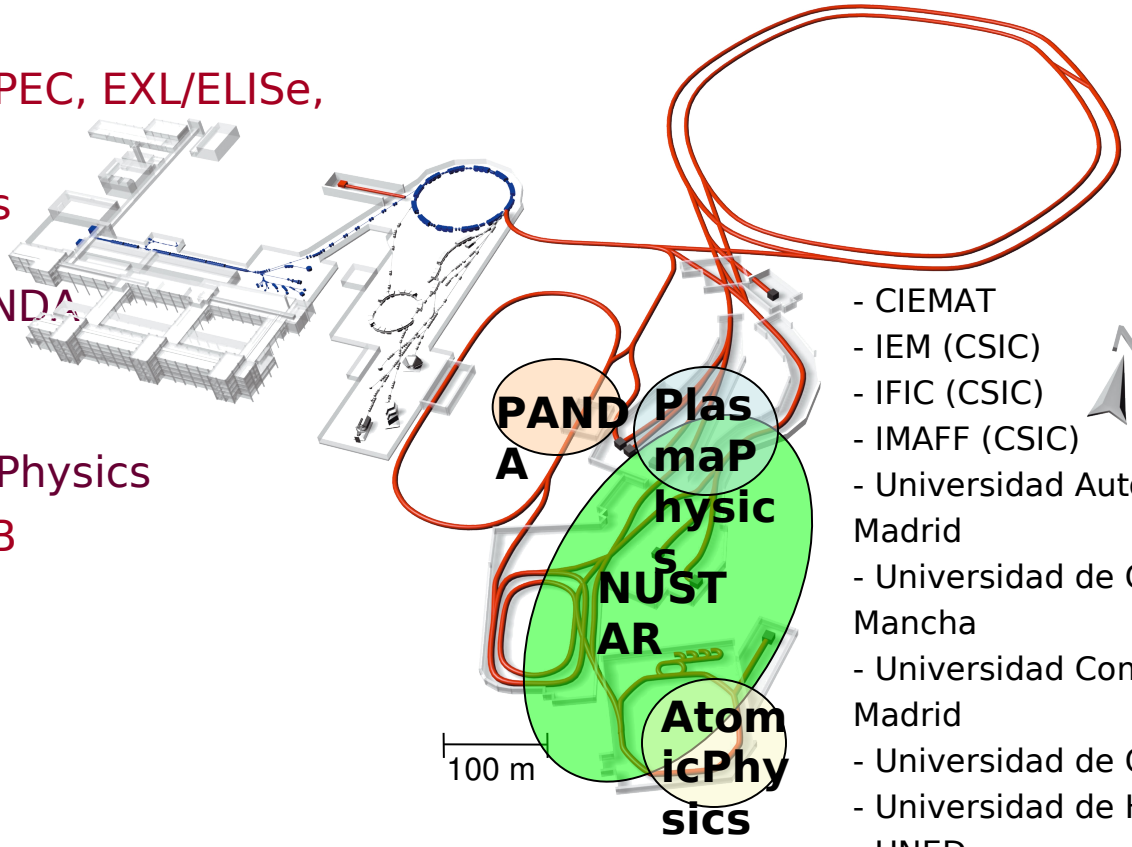


Spanish scientific contribution in FAIR

✓ Nuclear Structure and Astrophysics: NUSTAR
- R3B, HISPEC/DESPEC, EXL/ELISe, MATS
- 9 research groups

✓ Hadron Physics: PANDA
- 1 research group

✓ Atomic and Plasma Physics
- SPARC, HEDgeHOB
- 4 research groups

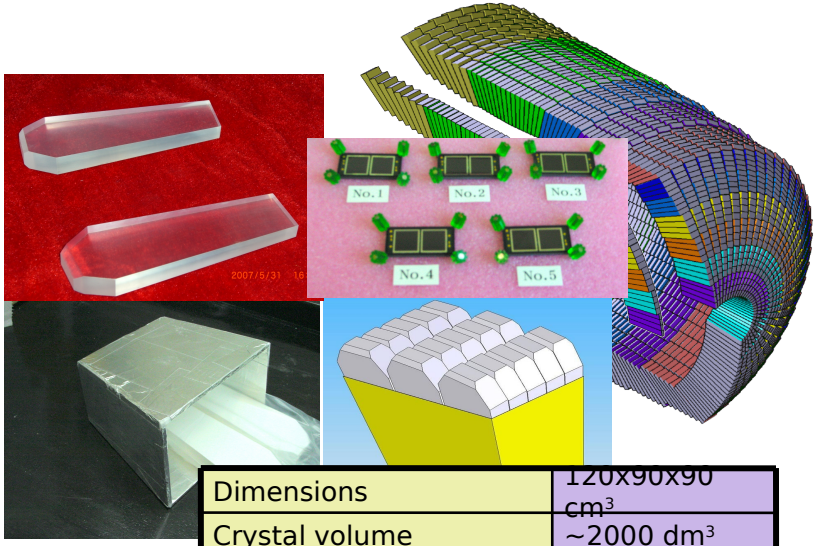


- CIEMAT
- IEM (CSIC)
- IFIC (CSIC)
- IMAFF (CSIC)
- Universidad Autónoma de Madrid
- Universidad de Castilla la Mancha
- Universidad Complutense de Madrid
- Universidad de Granada
- Universidad de Huelva
- UNED
- Universidad Politécnica de Cataluña
- Universidad Politécnica de Valencia
- Universidad de Salamanca

- All the spanish experimental groups participate in the project
- Active participation in 7 over 18 experiments

R&D for FAIR experiments

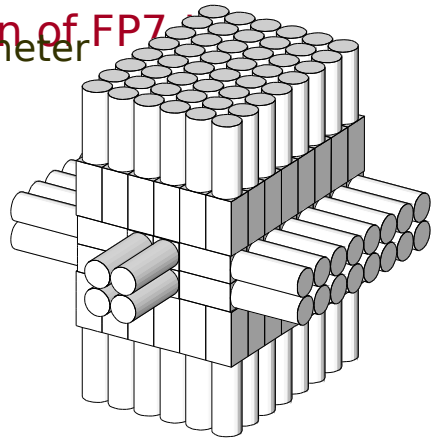
R3B calorimeter



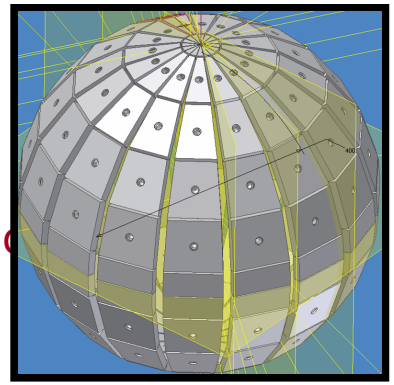
Dimensions	120x90x90 cm³
Crystal volume	~2000 dm³
Nº of crystals	~5000
Crystal dimensions	~1x2x18 cm³
Detector weight CsI(Tl)	~2500 Kg

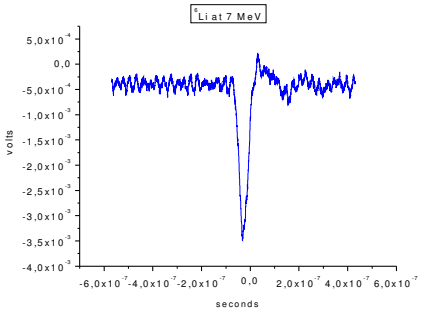
- ✓ γ calorimeters for R3B and DESPEC:
  - new scintillator materials $LaCl_3$:Ce and $LaBr_3$:Ce
  - new photo-sensors: APDs a silicon-PM
  - USC, IEM, UCM, IFIC
  - coordination of FP7

DESPEC calorimeter



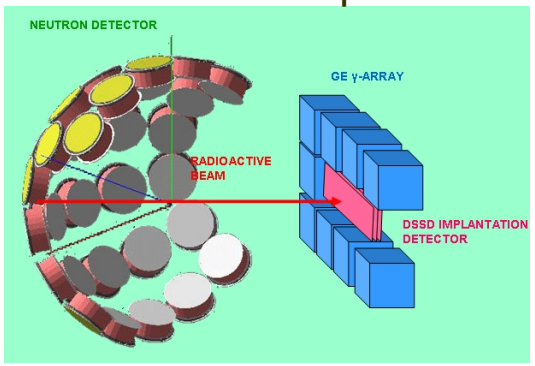
- ✓ Silicon Detectors for HISPEC:
  - micro- strip detectors
  - Digital pulse shape analysis techni
  - UHU, USE,IEM





R&D for FAIR experiments

DESPEC experiment



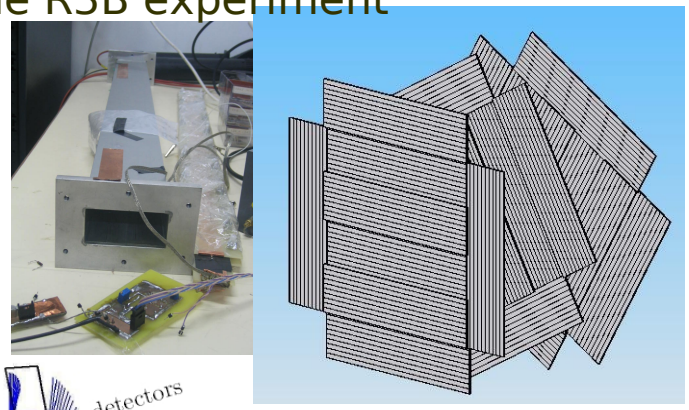
✓ Germanium Detectors for DESPEC experiment:

- planar technology
- position sensitive detectors
- IFIC, USAL, UAM

✓ Neutron detectors for DESPEC:

- new scintillation materials
- digital electronics
- CIEMAT, UPC

ToF-wall for the R3B experiment



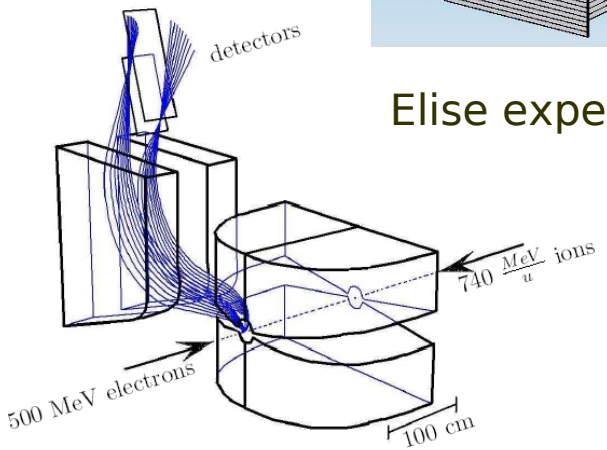
✓Time of fight Detector for the R3B experiment:

- resistive plate chambers gas detectors (RPC)
- USC, UVI

✓ Magnet separator in ELISE magnet spectrometer

- Field uniformity study
- UCM

Elise experiment



✓The Spanish experimental nuclear physics community concentrates on nuclear structure studies

✓ The number of scientists and groups has increased in the last years

✓ The funding has also increased

✓ Institutional support to these activities → Spanish contribution to FAIR