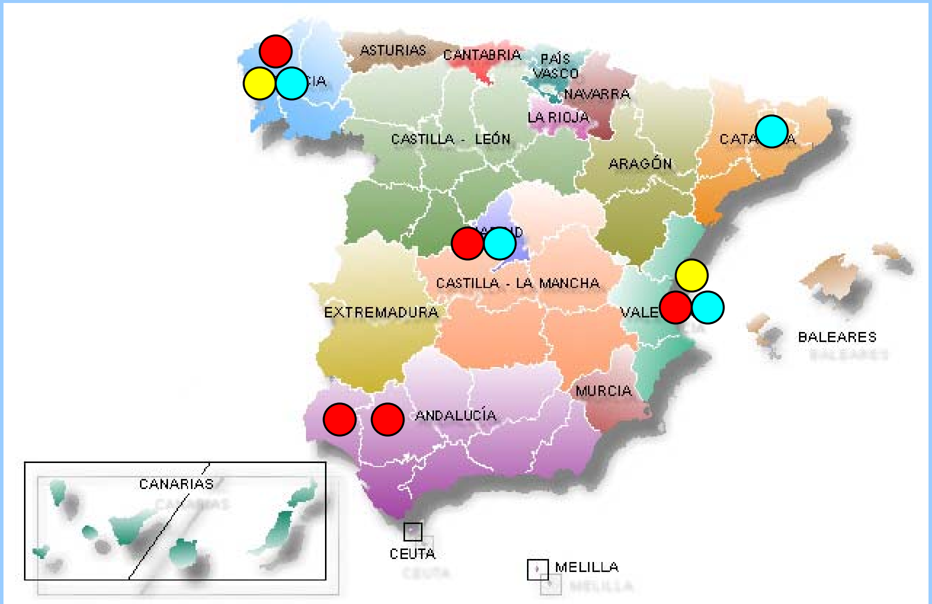
Experimental Nuclear Physics activity in Spain

(B. Rubio- IFIC Valencia)

Barcelona, Madrid, Santiago, Sevilla-Huelva, Valencia



- Exotic Nuclei
- Hadron reactions at intermediate energy
- Neutron Time of Flight

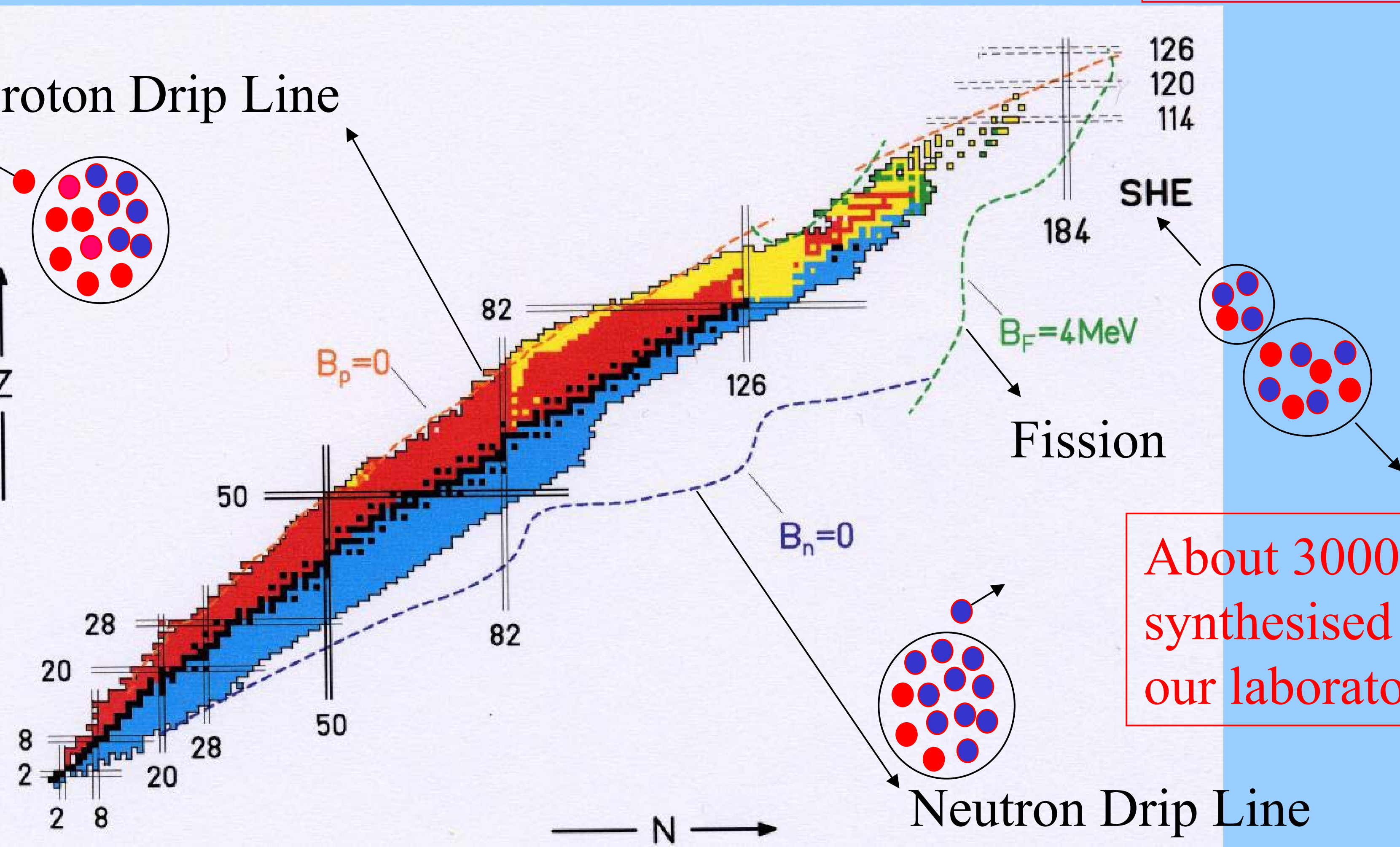
All projects supported by the Spanish “Particle and Large Accelerators National Programme”

EXOTIC NUCLEI

Madrid, Sevilla-Huelva, Santiago, Valencia

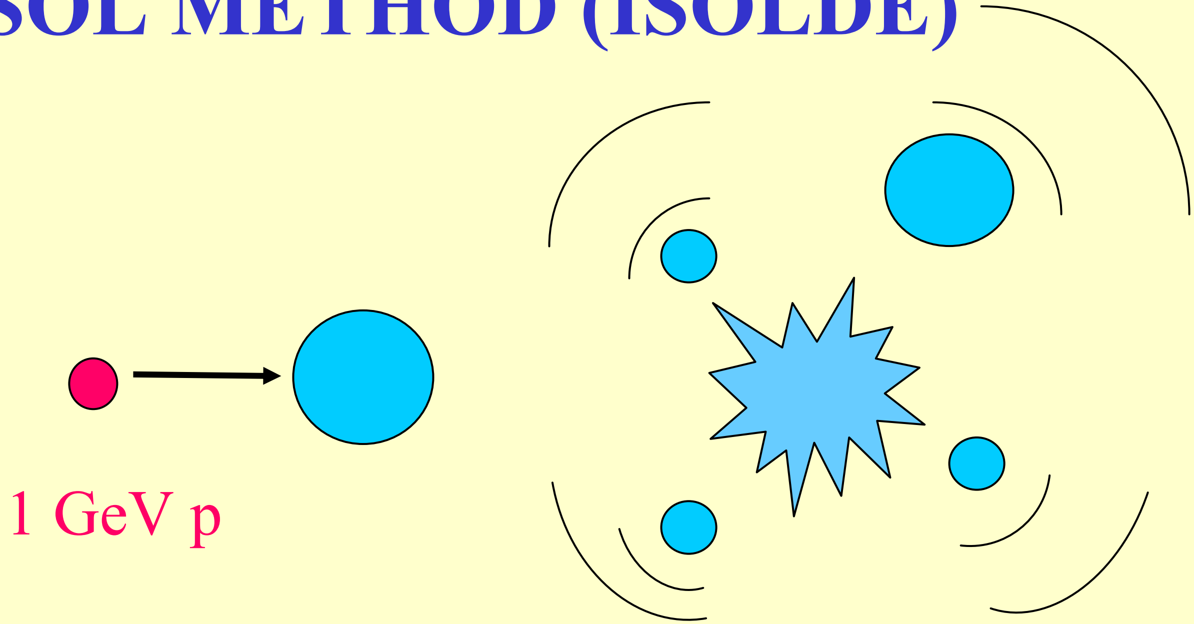
Proton emission, neutron emission and fission define an Island of about 6000 possible nuclei which might exist somewhere in our Universe

On our planet 265 stable plus 60 radioactive

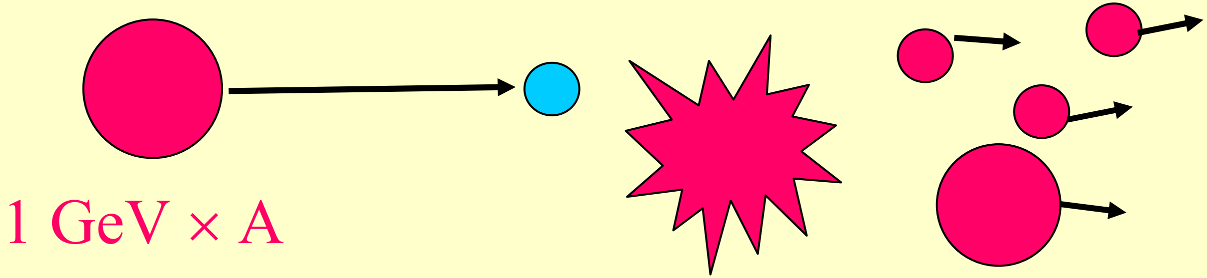


About 3000 synthesised in our laboratories

ISOL METHOD (ISOLDE)



IN FLIGHT METHOD (GSI)



IEM research programme (CSIC)

Grupo de Física Nuclear Experimental

- **REX-ISOLDE: study of halo systems**

  •Characterise the unbound nuclei ^{7}He y ^{10}Li

  study the transition from weakly bound systems to the continuum.

  (Aarhus-Darmstadt-Göteborg-Madrid-Moscow)

- Signatures of dipole polarizability in the halo nuclei ^{6}He and ^{11}Li.

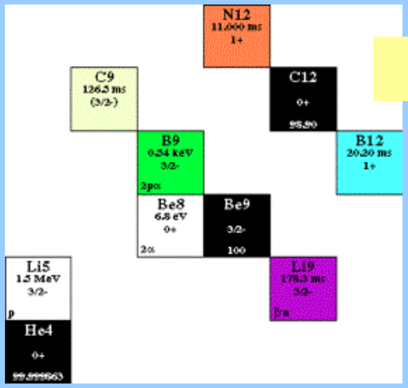
  (Huelva-Madrid-Santiago-Sevilla-Valencia)

- **In beam investigations** of nuclei around doubly-magic ^{100}Sn using stable and radioactive ion beams

  (Dresden-Köln-Madrid-Valencia)

- **β- delayed multi-particle breakup**

  (Aarhus-Göteborg-Jyväskylä-Madrid)



2 staff

3 postdocs

3 students

Example:

Multi particle breakup – IEM

- **β-delayed particle emission - ISOLDE**

$^{9}C \rightarrow {}^{9}B^{*} \rightarrow p + \alpha + \alpha$	CERN-IS361 *done*
$^{9}Li \rightarrow {}^{9}Be^{*} \rightarrow n + \alpha + \alpha$	(In preparation)
$^{12}N \rightarrow {}^{12}C^{*} \rightarrow \alpha + \alpha + \alpha$	CERN-IS404
$^{12}B \rightarrow {}^{12}C^{*} \rightarrow \alpha + \alpha + \alpha$	Jyväskylä *done*

- **Reaction studies - CMAM tandem**

$^{3}He + {}^{6}Li \rightarrow {}^{9}B^{*} \rightarrow \alpha + \alpha + p$

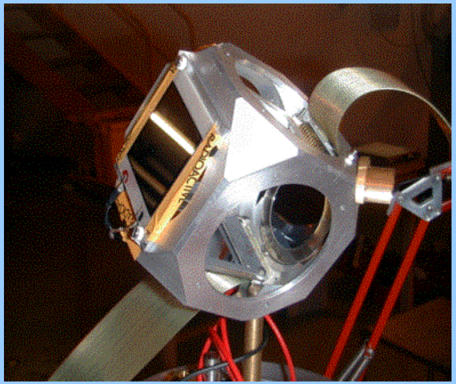
$d + {}^{7}Li \rightarrow {}^{9}Be^{*} \rightarrow \alpha + \alpha + n$

$p + {}^{11}B \rightarrow {}^{12}C^{*} \rightarrow \alpha + \alpha + \alpha$

$^{3}He + {}^{9}Be \rightarrow {}^{12}C^{*} \rightarrow \alpha + \alpha + \alpha$

eed states of definite spin & parity	⇐ **Selection rules** ⇒	Feeds many different states
efined by the Q-value	⇐ **Energy window** ⇒	Limited by the accelerator energy
lean the operator is known	⇐ **Feeding mechanism** ⇒	Not trivial, resonance or direct reactions
& GT transitions feed states of well defined spin	⇐ **Isospin** ⇒	Depends on beam and target chosen

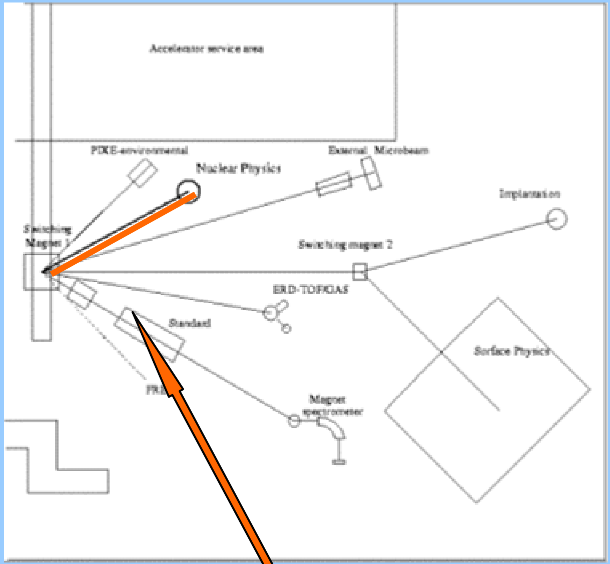
- ✓ **2 DSSSD telescope ultra thin window, design IEM**
- ✓ **64 +8 electronic channels**
- ✓ **Data acquisition system FERA-CAMAC**



Madrid Tandetron: 5MV electrostatic accelerator

Universidad Autónoma de Madrid

Terminal voltage V_T: 0,1 – 5 MV voltage ripple $\Delta V/V=10^{-4}$
Ion-sources: Duoplasma
Sputter → all elements available
Final energy: $V_T*(Q+1)$ Q=charge state
Beam current: 1-10 μA



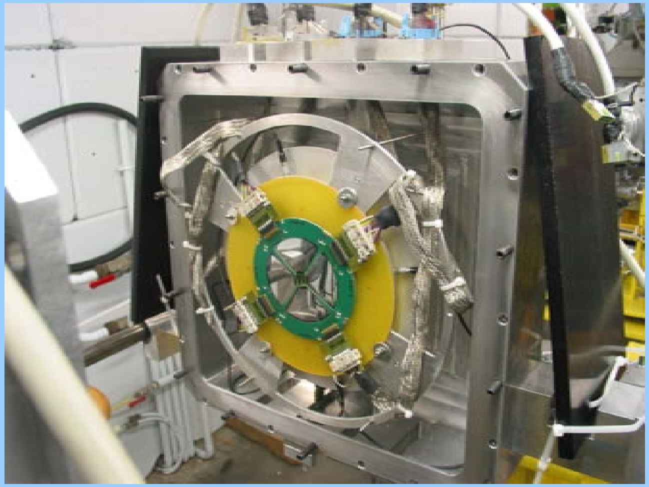
Accelerator working since september 2002.
Nuclear Physics beamline (CSIC-Madrid)
in preparation, foreseen for summer 2003.

Sevilla-Huelva research program

•EXPERIMENTS TO MEASURE DIPOLE POLARIZABILITY OF HALO NUCLEI 6He AND 11Li

EXPERIMENTS IN THE CNA 3MV TANDEM ACCELERATOR

•(THEORETICAL SUPPORT TO THE COLLABORATION)



2 staff } SEVILLA

2 staff
1 student } HUELVA

Strong involvement of the theory group

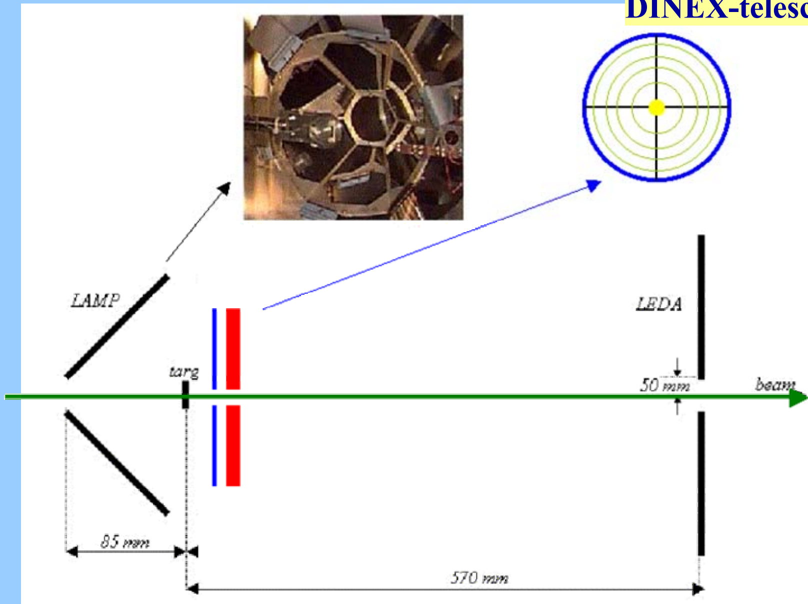
Reactions with radioactive nuclei:

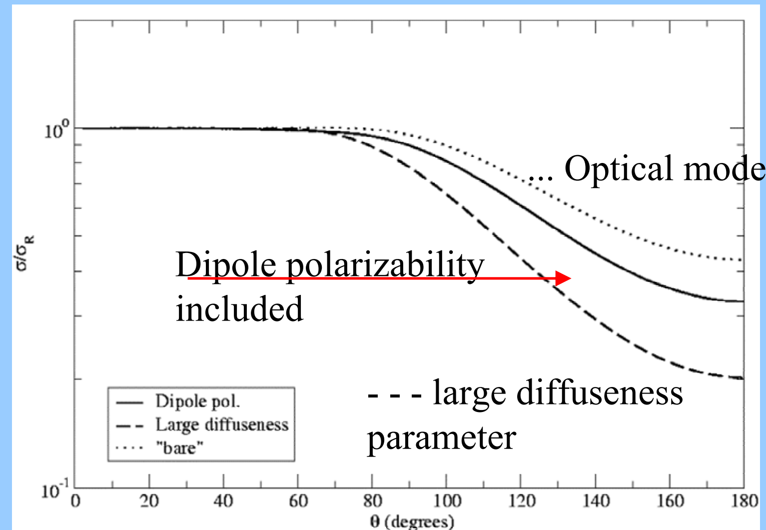
Dipole polarizability of halo nuclei

Huelva-Sevilla-Madrid

LEDA-Louvain Edingburgh Detector Array

DINEX-telescope





Elastic cross section of ^{6}He on ^{208}Pb divided by the Rutherford cross section at 19 MeV lab energy.

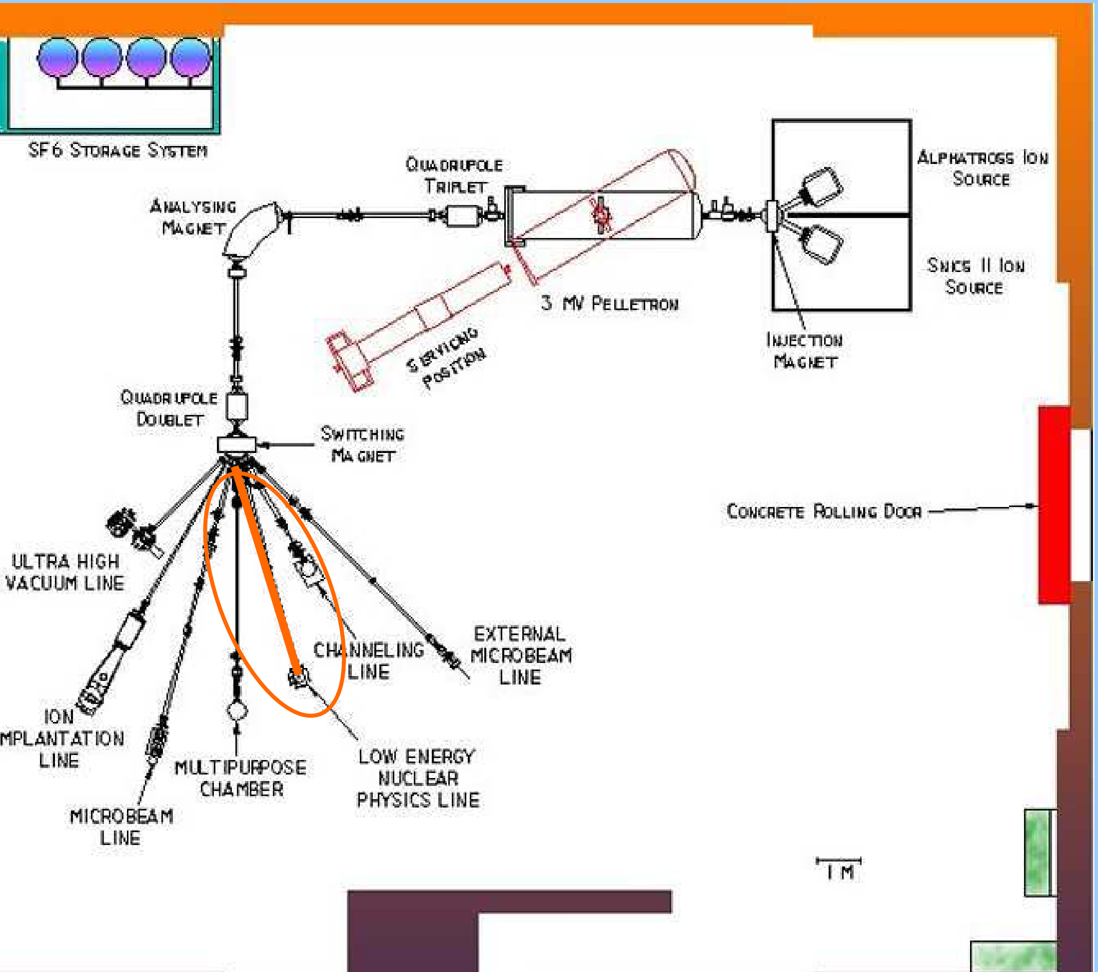
^{6}He Louvain-la-Neuve - PH189 **^{11}Li REX-ISOLDE - IS399**

One important aspect which differentiates *weakly bound nuclei* from normal is the Coulomb dipole polarizability.The strong Coulomb field of the target distort the ^{6}He (^{11}Li) projectile, so that the ^{4}He (^{9}Li) *core* is pushed away from the target while the *halo neutrons* remain unaffected by the Coulomb field.

CNA (Centro Nacional de Aceleradores) SEVILLA

Participants: University of Sevilla-CSIC(Research Council)-Junta de Andalucía (Local administration)

3 MV, 20 µA, operative since 1998



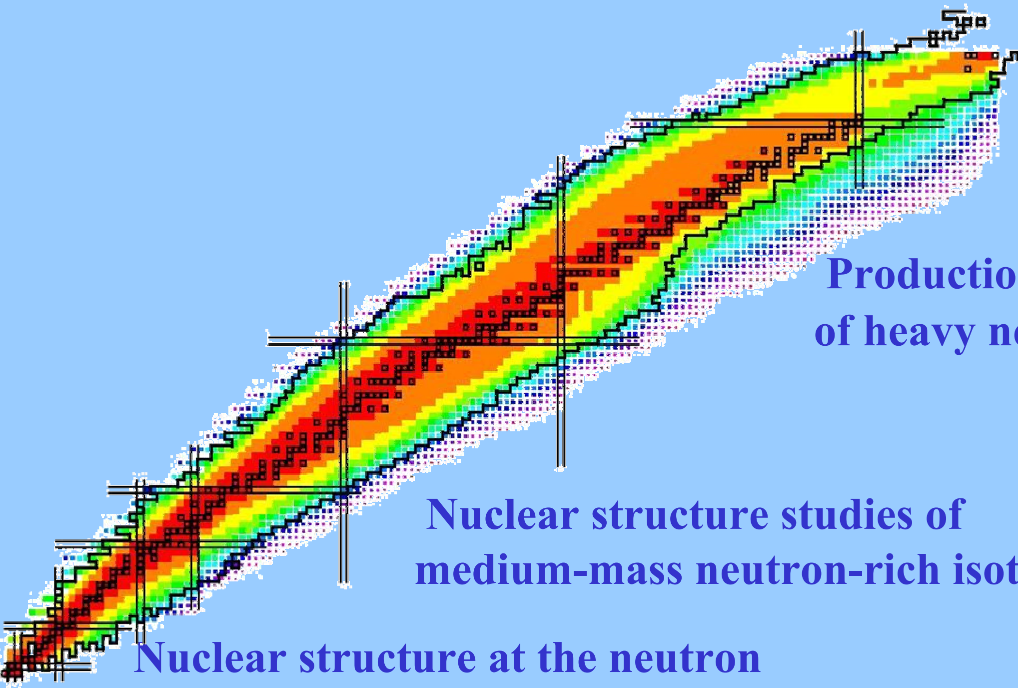
Ion beam analysis:
RBS, PIXE, NRA, Channeling, ERD

Material sciences
Archaeometry
Enviroment
Nuclear Physics
Nuclear Medicine

12 Investigators
5 Tecnicians
2 administ.

Univ. Santiago research programme

Production and structure of neutron-rich nuclei



Residual nuclei production in spallation reaction (GSI)

Production and β-decay investigation of heavy neutron-rich isotopes (GSI)

Nuclear structure studies of medium-mass neutron-rich isotopes (GANIL)

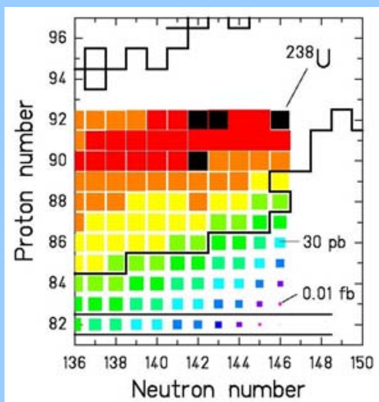
Nuclear structure at the neutron drip-line (light neutron-rich isotopes) (GSI)

1 staff
2 postdocs
4 students

Example:

Production and β-decay investigations of heavy neutron-rich isotopes

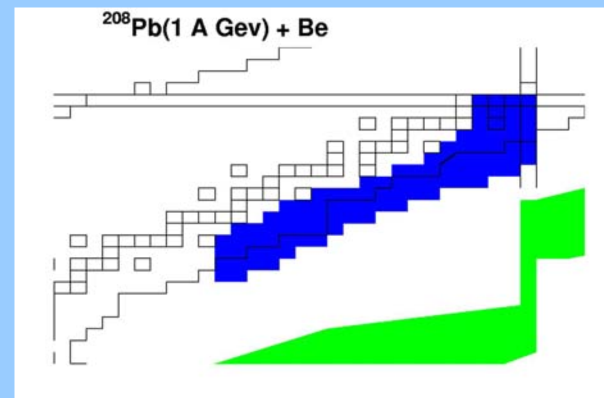
Collaboration: GSI, Santiago, Orsay, Bordeaux

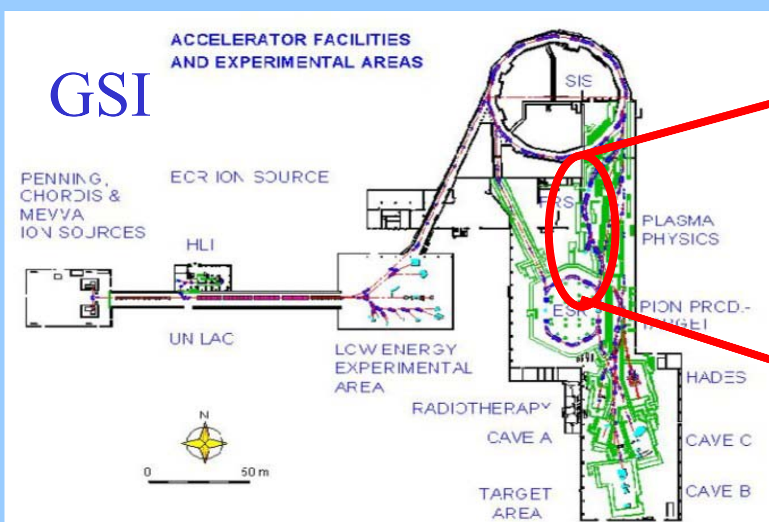


Production of heavy neutron-rich isotopes: Cold fragmentation

✓ only protons are abraded and no neutron evaporated

Approaching the r-process path





FRS

Gamma spectroscopy group at IFIC

2 staff
2 postdocs
2 students

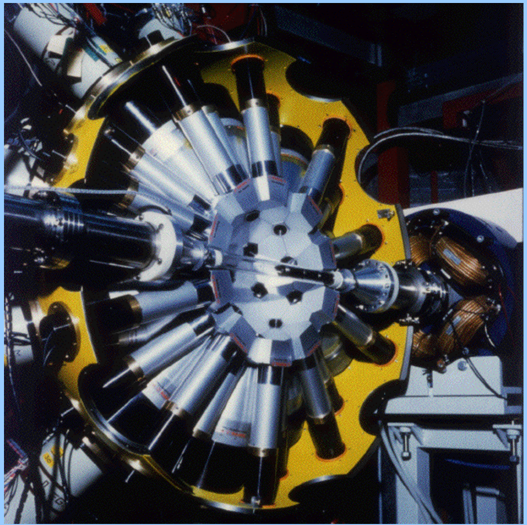
<u>Research</u>

Beta decay studies with Total Absorption Techniques (GSI,ISOLDE,Jyvaskyla)

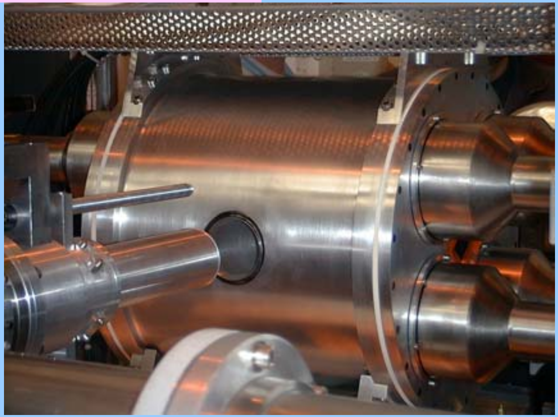
Nuclear structure at extreme values of spin and isospin (Legnaro, Strasboug)

Reactions with radioactive beams (Ganil)

Ge arrays

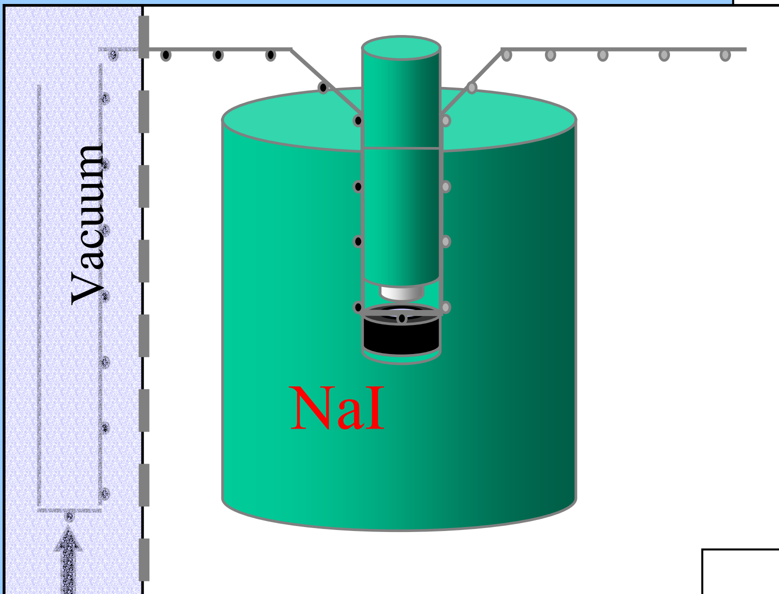


NaI, BaF



xample: Beta decay, far from stability, large energy window

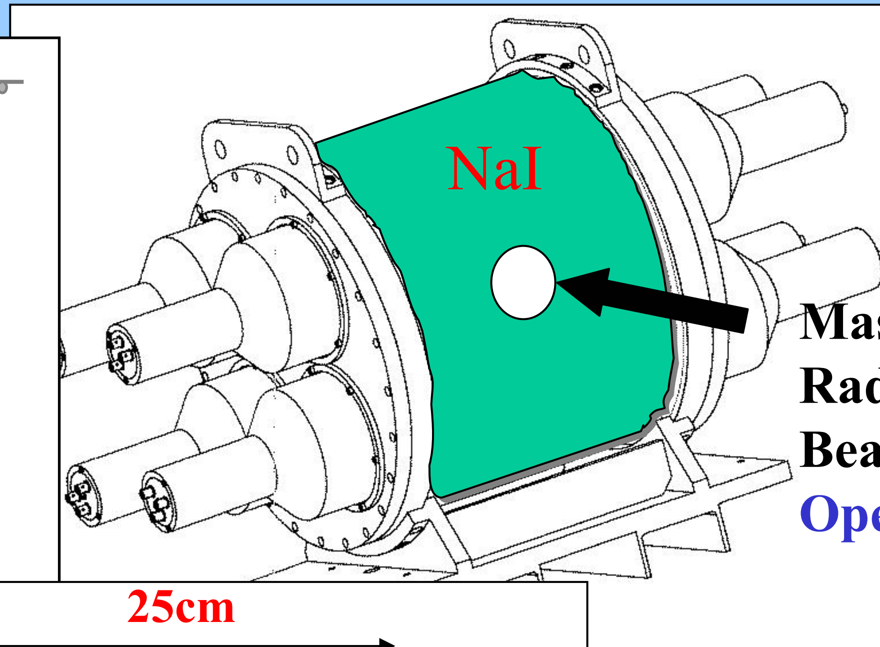
TAS at GSI

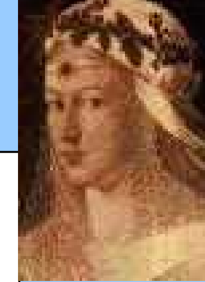


lass Separator beam
perating

(Warsaw,
GSI,
St. Petersburg,
Valencia)

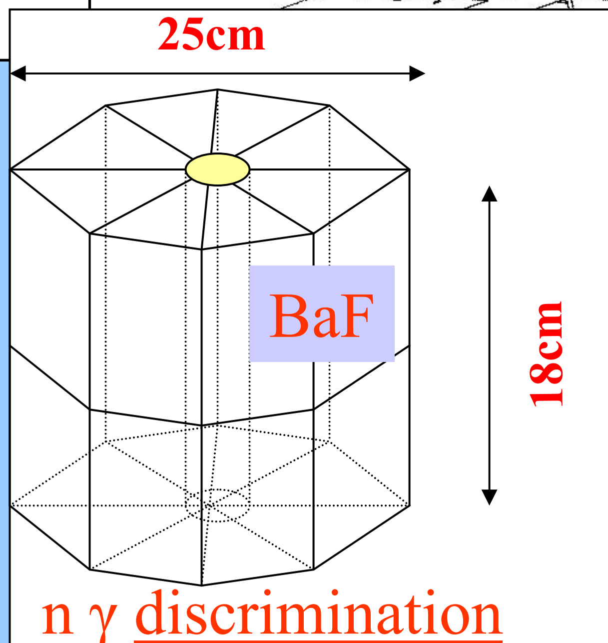
Lucrecia at ISOLDE





Mass sep.
Radioactive
Beam
Operating

(Madrid, Strasbourg,
Surrey, Valencia)



Under developemen
at IFIC

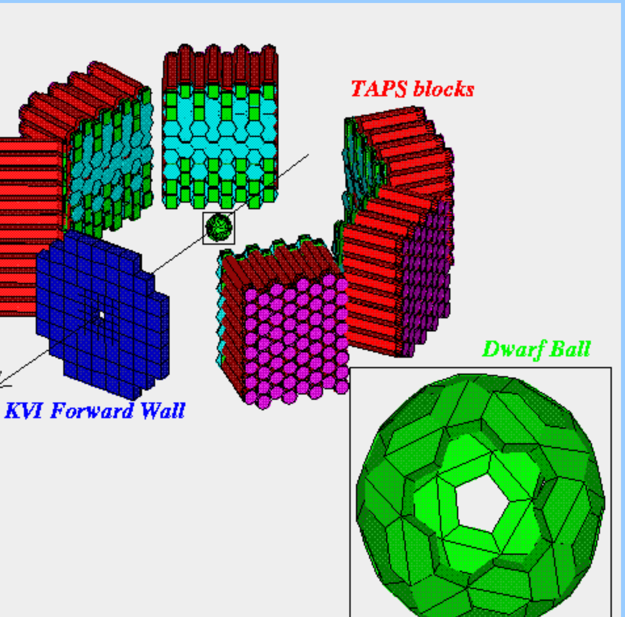
180 k€
(Valencia, Surrey)

Hadron Reactions at Intermediate Energy

IFIC

2 staff
2 postdocs
1 student

TAPS



Univ. Santiago

2 staff
2 student

HADES

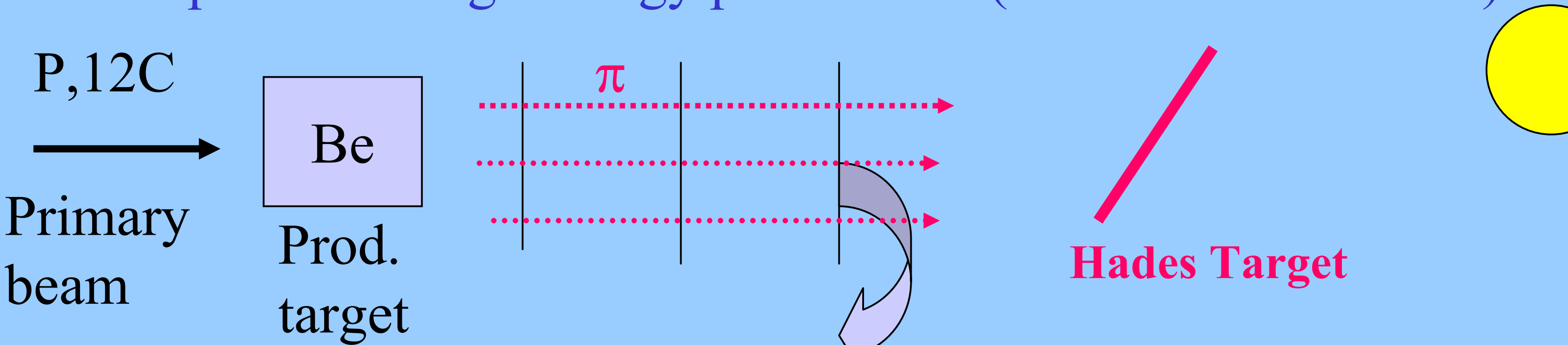
Collisions at intermediate energies

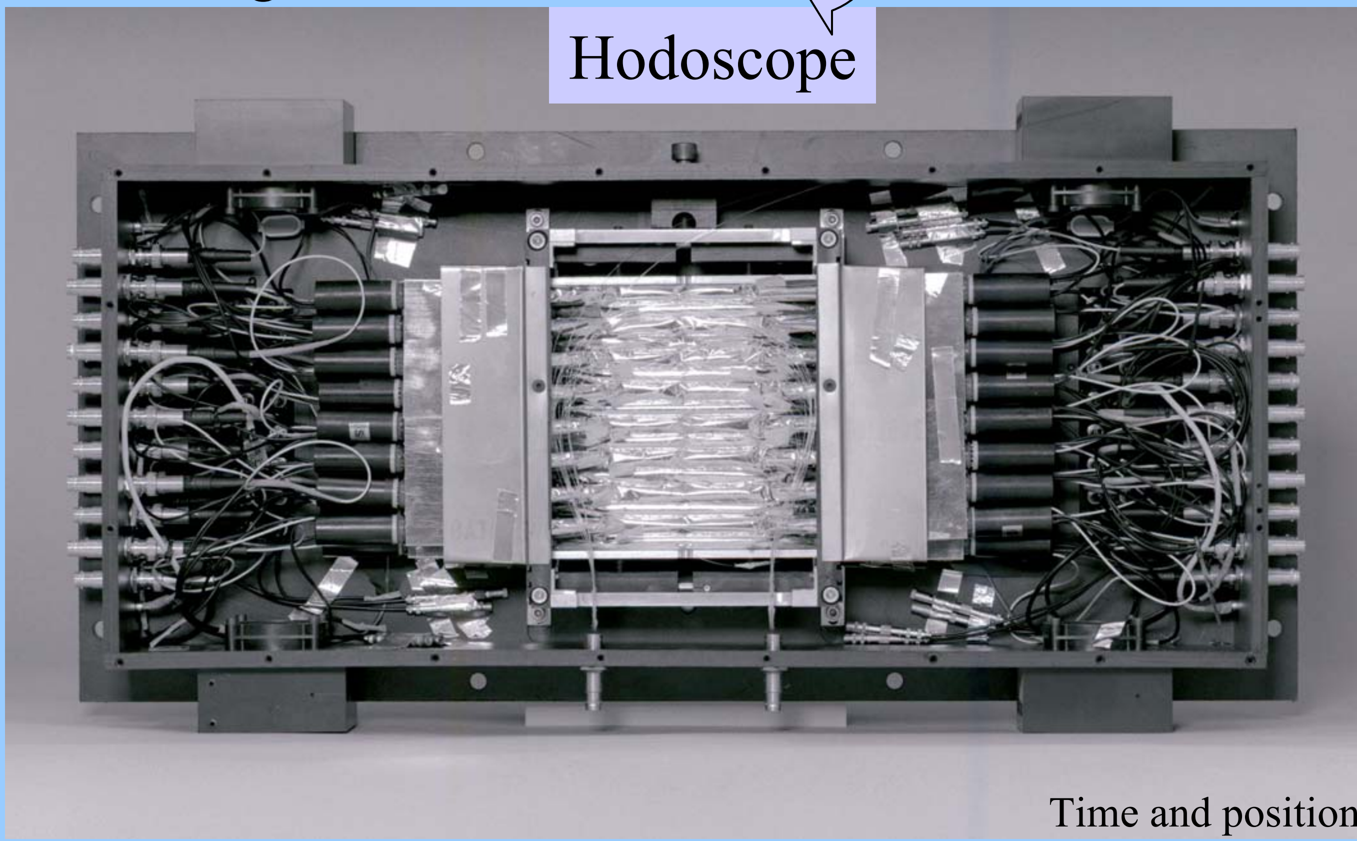
- Accelerators: KVI Groningen, GANIL (50, 200MeV/u)
- TAPS Collaboration (384 BaF)
- Measurements of hard photon and subthreshold pion production in heavy ion collisions (i.e. Ar + Au 25 MeV/U, Π^o)
- Dynamics of heavy ion reactions

Collisions at relativistic energies

- Accelerator: SIS (Darmstadt GSI) (1GeV/u)
- Measurement of particle production at relativistic energies (TAPS Collaboration)
- Hadron Properties in Nuclear Matter (Hades Collaboration: measuremt of ω, ρ, φ mass in the nuclear medium)
- Development of high energy pion beams (Hades Collaboration)

Development of high energy pion beams (Hades Collaboration)





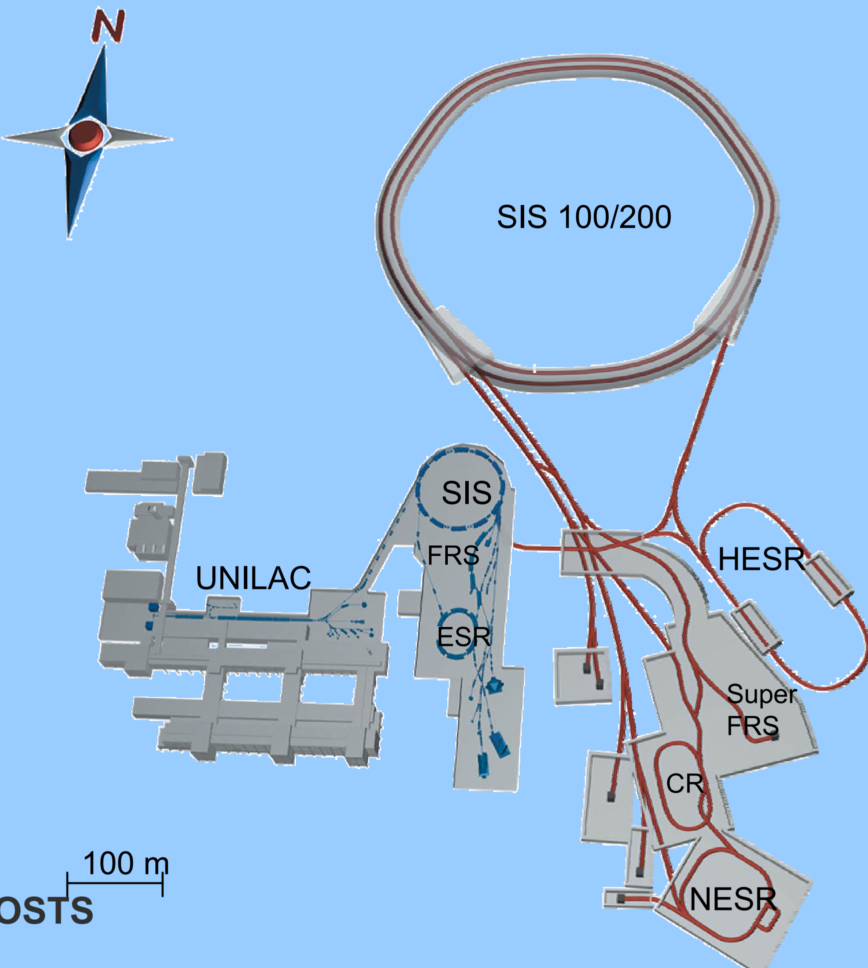
Time and position of the pions

Recent News:

Spain will (probably) enter the Isolde collaboration

GSI new project aproved in February 2003:
675 M€ if 25% of the cost by foreign partners

A New International Accelerator Facility for Research with Ion- and Antiproton Beams at GSI



Scientific program

- Nuclear Structure Physics and Nuclear Astrophysics
  - Structure of exotic nuclei far off stability;
  - Nuclear synthesis in stars and star explosions;
  - Fundamental interactions and symmetries
- Hadron Physics with Antiproton Beams
  - Quark gluon structure and dynamics of “strong” interacting particles;
  - Origin of the confinement and mass of hadrons
- Physics of Nuclear Matter
  - Studies of hadronic matter at high densities;
  - Phase transitions in quark matter;
  - Properties of neutron stars
- Plasma Physics
- Atomic Physics and Applied Science

OSTS

uildings and Infrastructure:	225 M €
ccelerator:	265 M €
xperiments / Detectors:	185 M €
otal:	675 M€

Special Properties

- Intense, fast cooled energetic beams of exotic nuclei
- Cooled antiproton beams up to15 GeV
- Internal targets for high-luminosity in-ring experiments

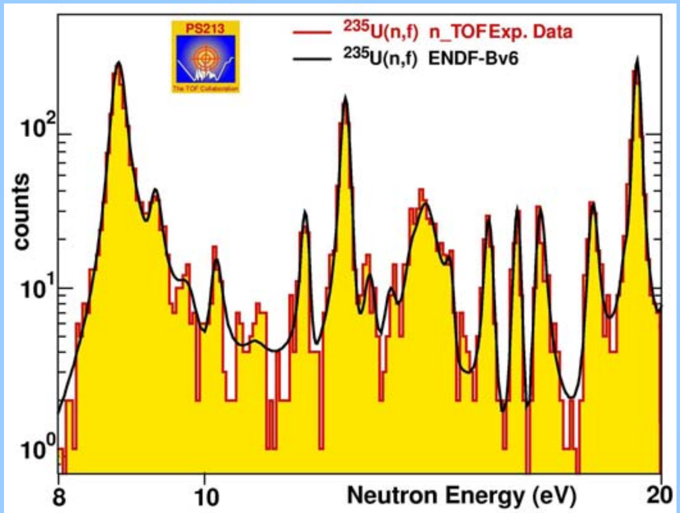
nTOF

n_TOF Collaboration

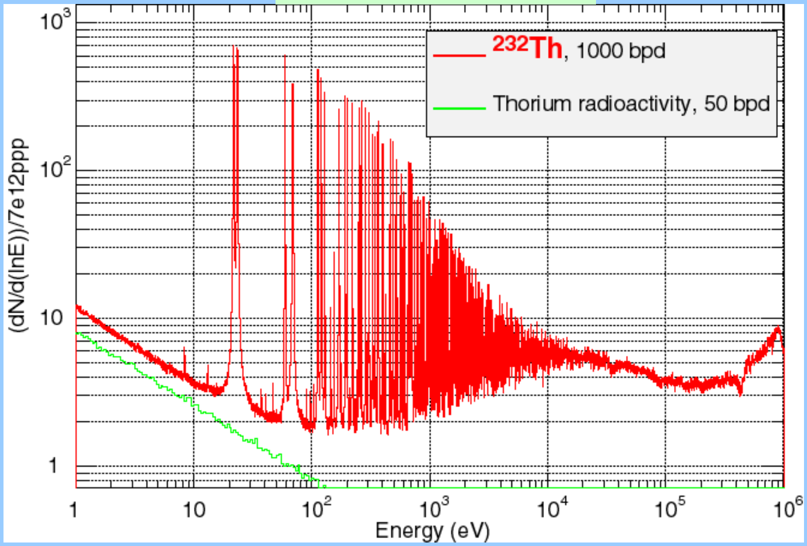
Spain: CIEMAT, CSIC-IFIC, U. Santiago, U. Sevilla, U.P. Cataluña, U.P. Madrid

- **Measurement of high quality neutron reaction cross sections: (n,f), (n,γ),(n,*x*n), ..., of key interest in Nuclear Technology (ADS, transmutation), Nuclear Astrophysics and Basic Nuclear Physics**

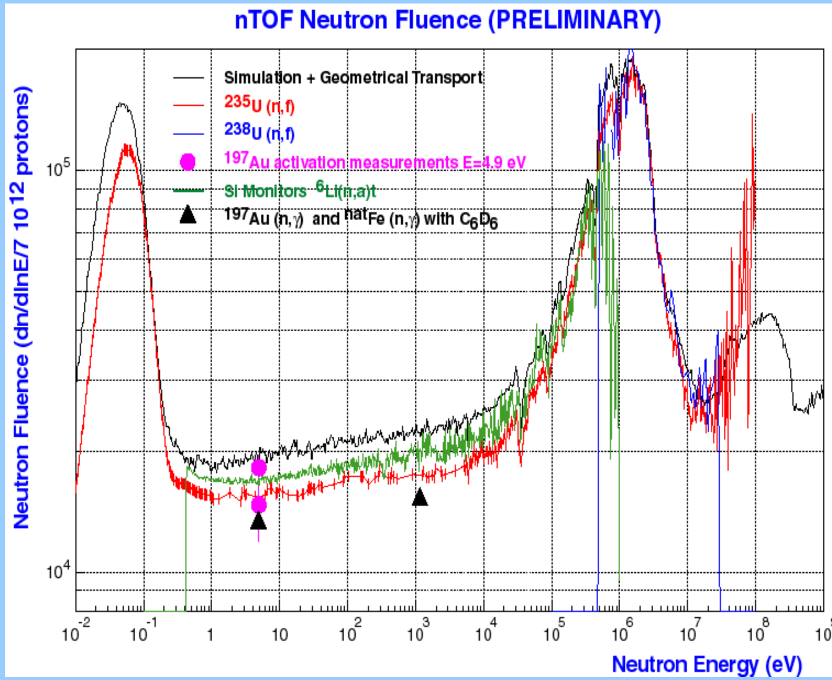
^{235}U(n,f)



^{232}Th(n,γ)



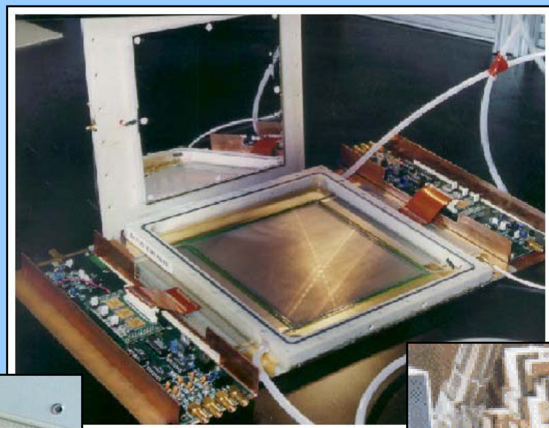
❒ Construction of a neutron Time Of Flight facility at CERN: high instantaneous flux (10^6 n/bunch), low duty cycle (10^{-8}), wide energy range (1eV-250MeV), (good resolution) long flight path (185m).



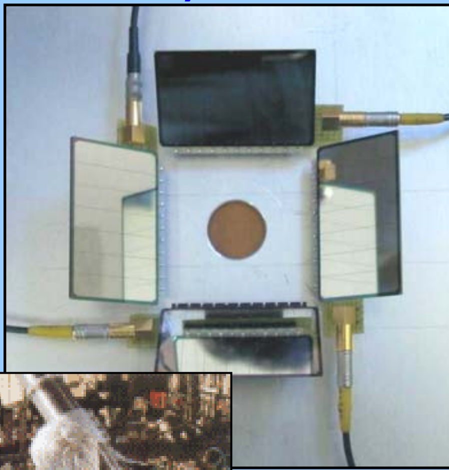
Operative since 2002

- Implementation of advanced instrumentation: fission (PPAC, Ionization Chamber), capture (C_6D_6 detectors, BaF_2 calorimeter), neutron multiplication (Ge detectors), monitoring (MicroMegas, Si detectors, BF_3 counters), data acquistion system (Flash ADC)

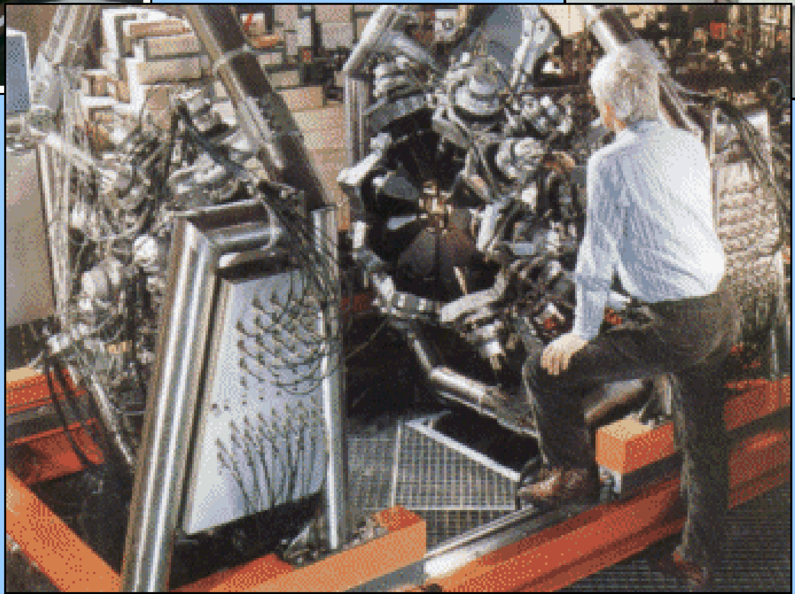
μM



SiMON



C_6D_6

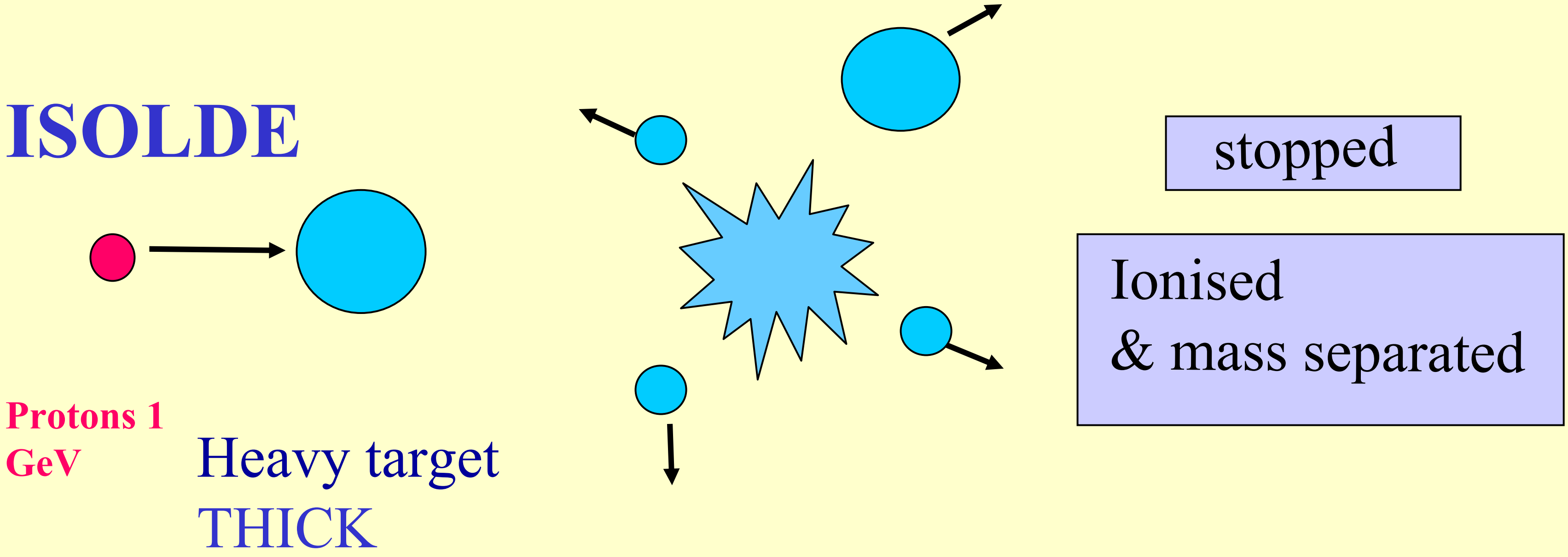


BaF_2

END

Producing nuclei far from stability

Isol method (from Isolde): spallation of target



In flight method: fragmentation of projectile