S419: Umbrella proposal for commissioning of HISPEC/DESPEC detectors

Alejandro Algora / Alison Bruce

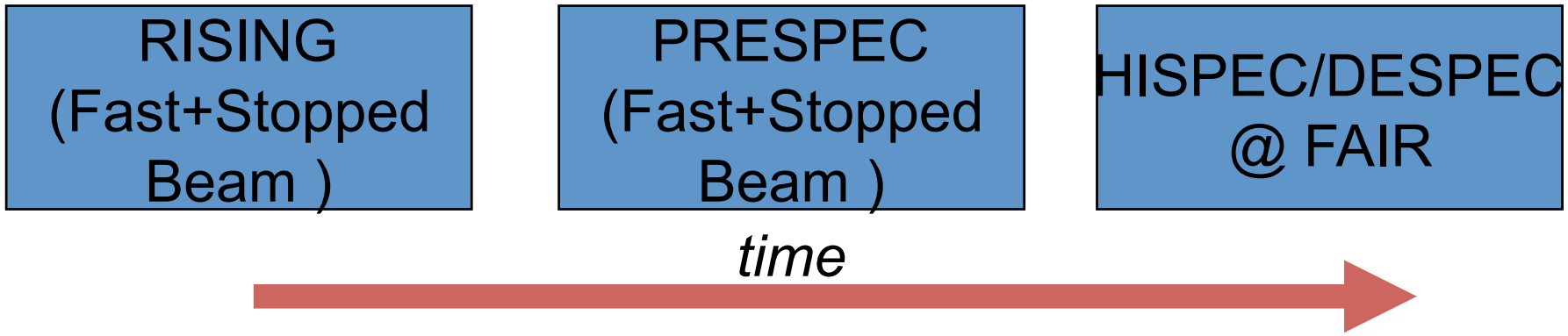
(for the PRESPEC collaboration)

What is PRESPEC?

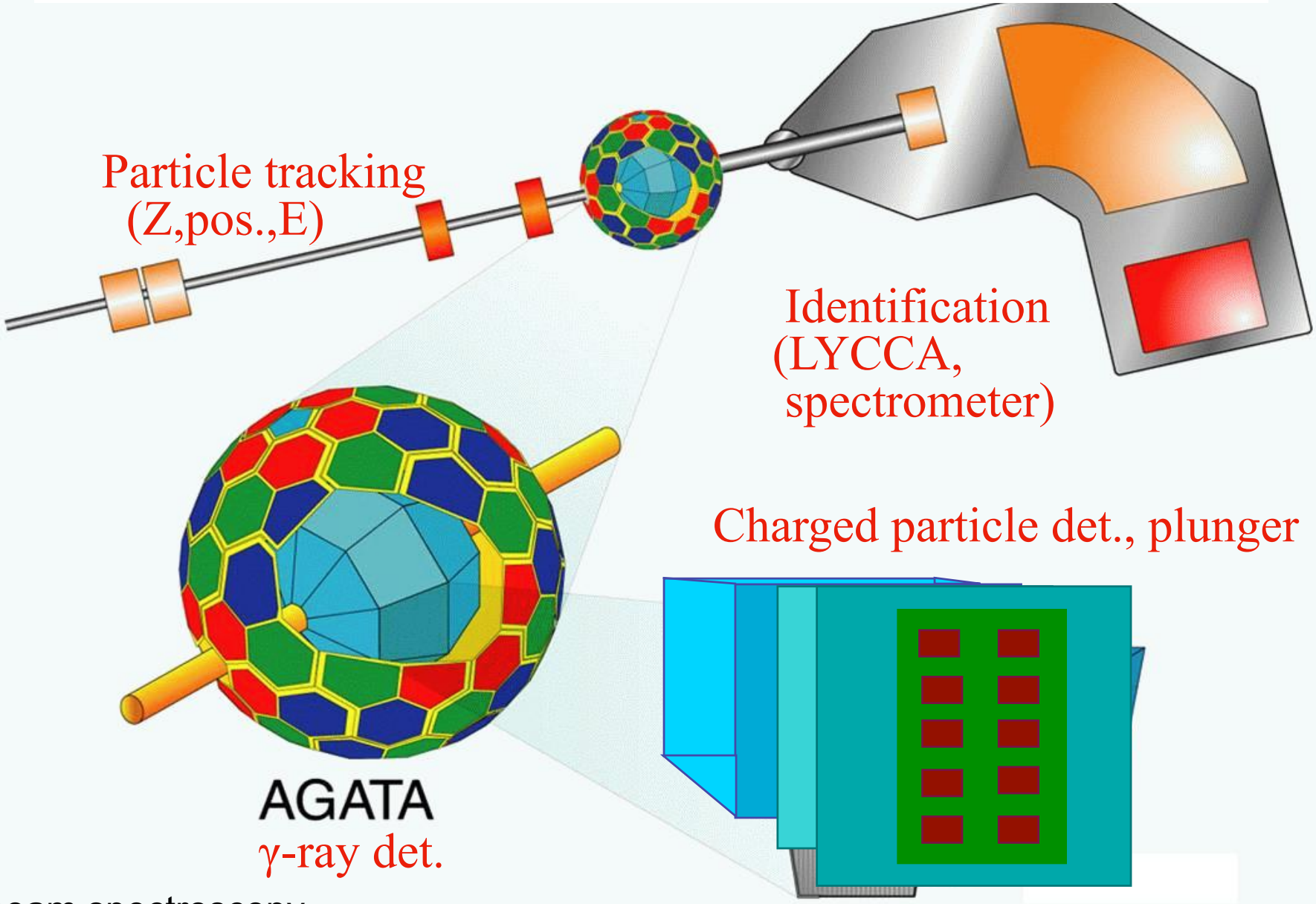
Open collaborative European scientific project that represents the transition from RISING to HISPEC/DESPEC at FAIR

Its goal is to perform nuclear spectroscopy experiments at the SIS/FRS facility at GSI exploiting *the uniqueness of the GSI/FAIR installations (in campaigns !)*

It is also aimed at preparing for the spectroscopy to be carried out with HISPEC/DESPEC at NUSTAR/FAIR by commissioning and employing components developed for HISPEC/DESPEC already at the SIS/FRS facility

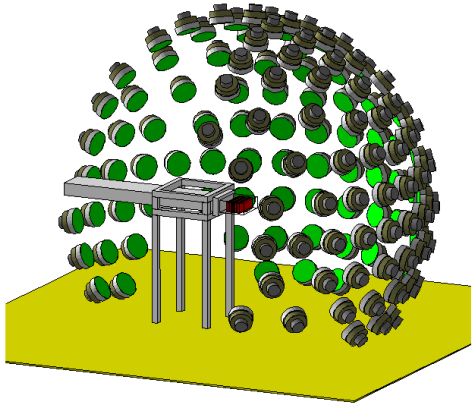


High-resolution In-flight SPECtroscopy (HISPEC)

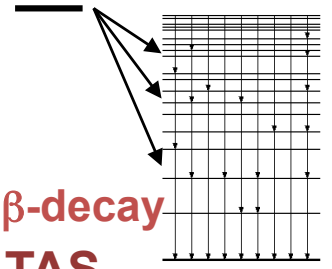


In-beam spectroscopy using radioactive beams

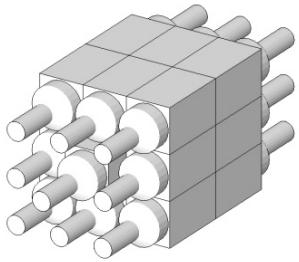
DEcay SPECtroscopy



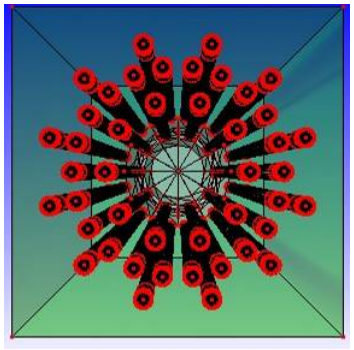
Neutron spectrometer with AIDA

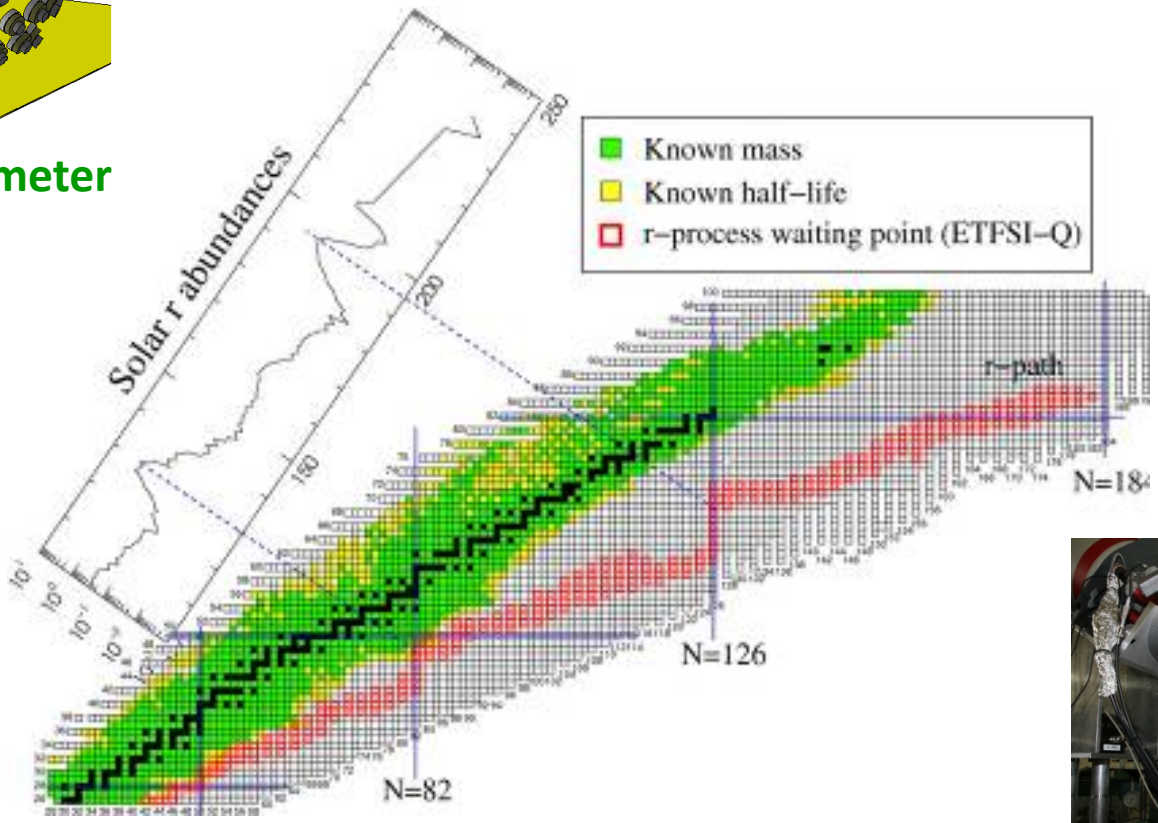


β-decay TAS

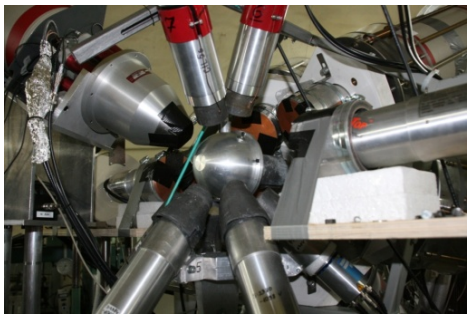


β−delayed neutron detector





γ-ray time measurements



β,n, γ-decay of exotic (neutron-rich) nuclei...
DESPEC requires different types of equipment to study the multiple aspects of the problem

Overview of request:

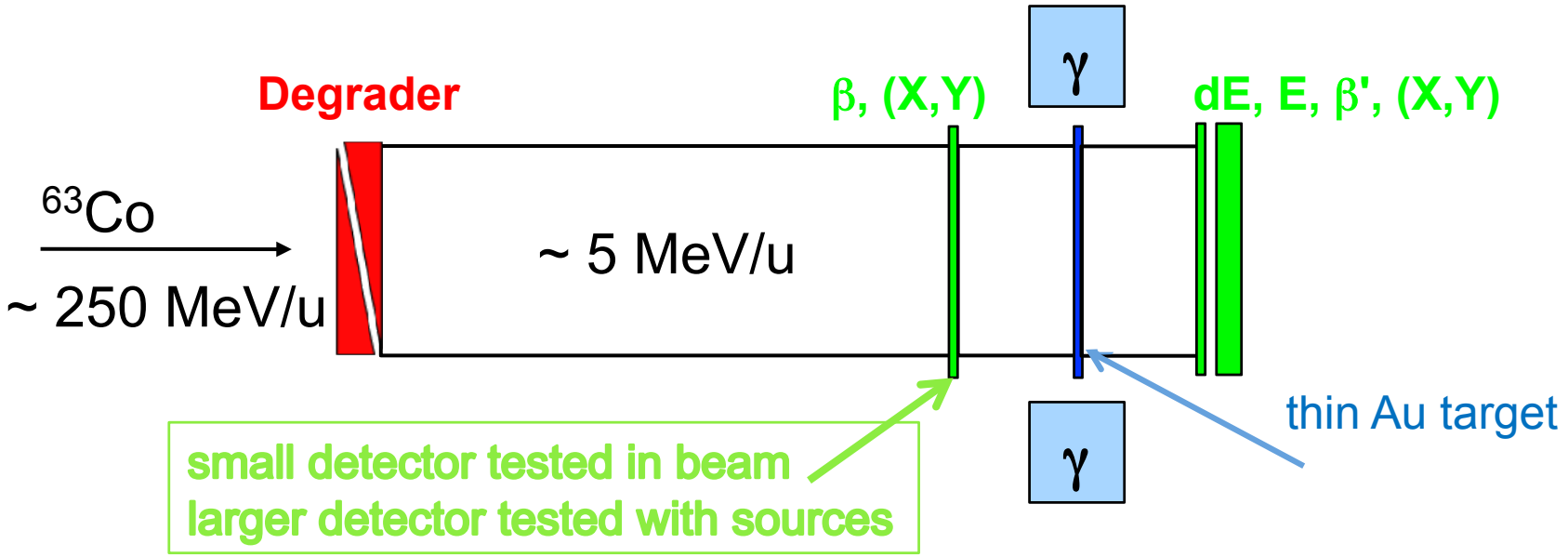
Purpose of test	Beam species	Number of shifts of parasitic beam	Lead investigator
Large-area tracking detectors and use of slowed-down beams	^{64}Ni, ^{63}Co	51	Plamen Boutachkov
Characterisation of the background for an AGATA capsule	e.g. ^{40}Ar, ^{64}Ni, ^{86}Kr	21	Cesar Domingo Pardo
Characterisation of the background for a MONSTER (neutron) detector	Many possibilities	21	Daniel Cano-Ott
Test beamtime request for BELEN	^{95}Rb	21	Belen Gómez Hornillos
Development of a TAS for DESPEC	Many possibilities	21	Jose Luis Tain
Testing and optimizing the fast-timing array.	^{24}Na,^{88}Rb,^{140}Ba	21	Luis Mario Fraile

+ evaluation of EDAQ and assure its continuous evolution

Plamen Botachkov

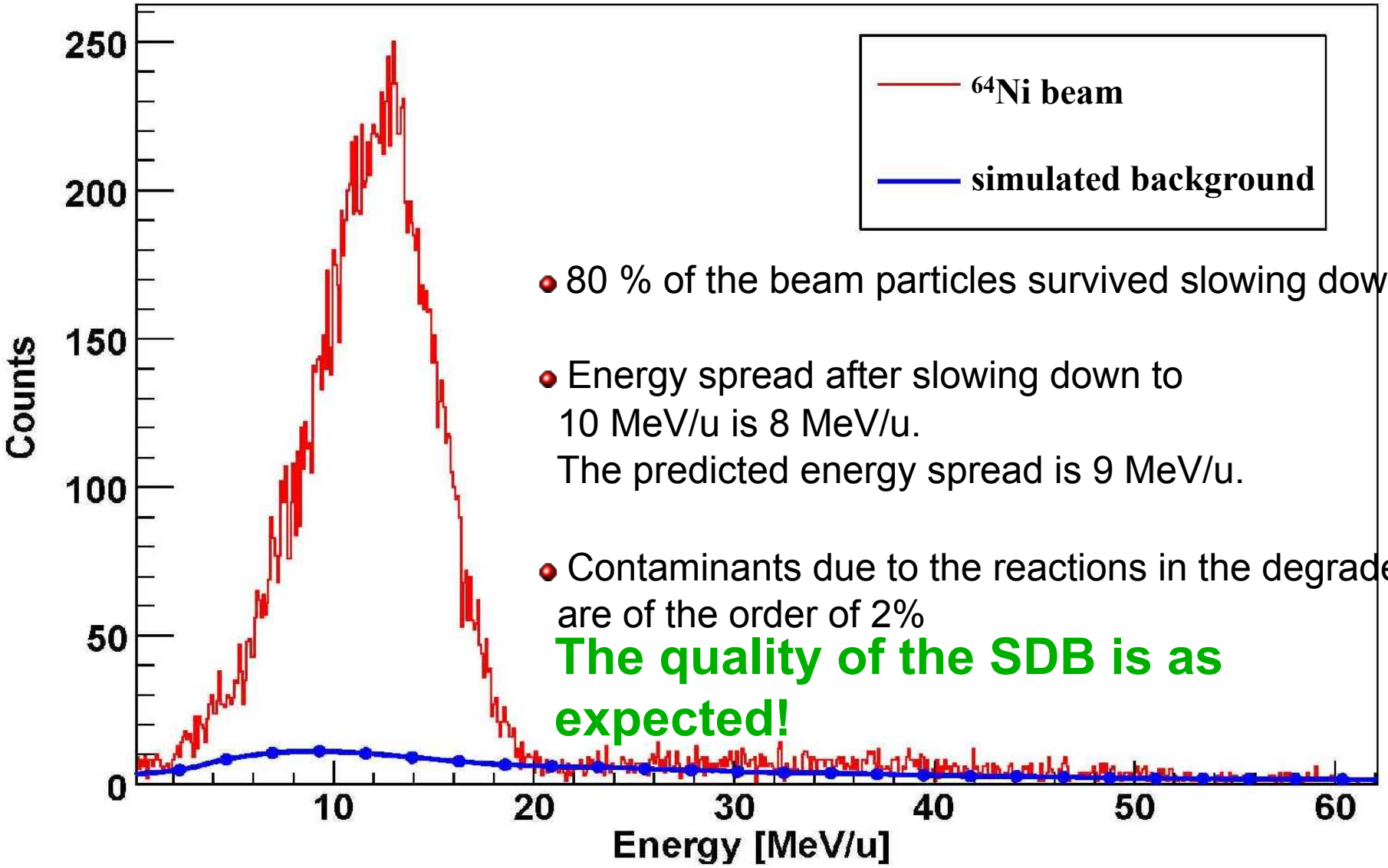
Slowed-down-beam setup:

Aim: Obtain *5 MeV/u* to *10 MeV/u* RIB to be used for secondary reaction studies at Super FRS



- Track and ID each particle before slowing down
- Track and measure velocity of each particle after slowing down

Results from the test performed in 2008:

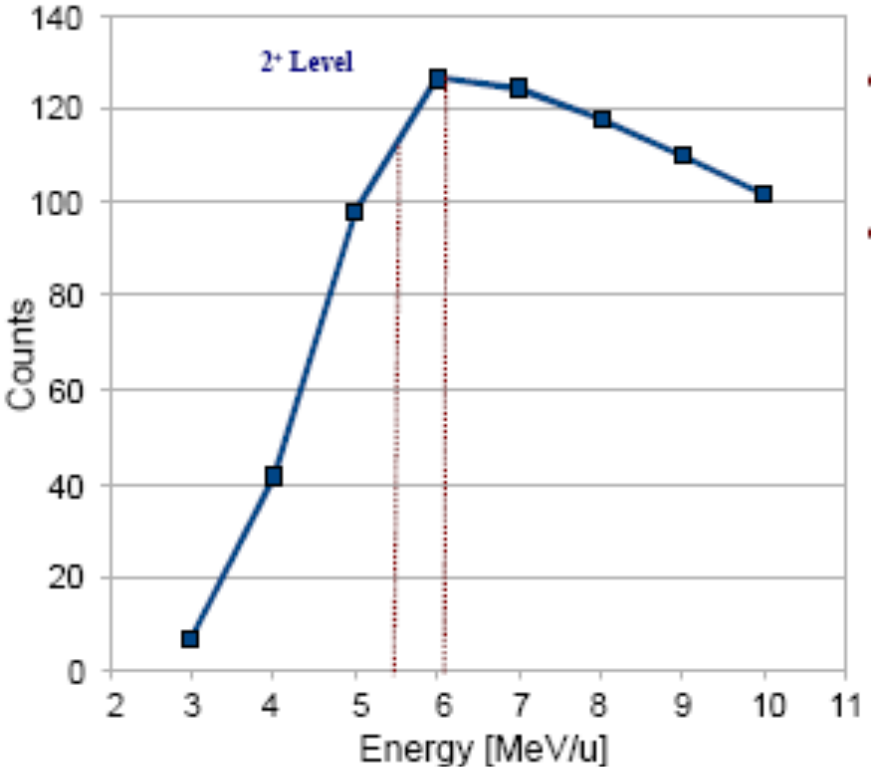


- 80 % of the beam particles survived slowing down.
- Energy spread after slowing down to 10 MeV/u is 8 MeV/u.
  The predicted energy spread is 9 MeV/u.
- Contaminants due to the reactions in the degrader are of the order of 2%

The quality of the SDB is as expected!

Plamen Botachkov

Coulomb excitation of ^{64}Ni and ^{63}Co and test of large tracking detectors



- Demonstrate that Coulomb excitation experiments can be performed with SDB at FRS
- Test new large area tracking detectors

New large area MCP detector developed at Cologne for SDB experiments

Counts in 10 days of parasitic beam time from the $2^+ \rightarrow 0^+$ transition in ^{64}Ni

Beam request: *17 days of parasitic beam time* to observe >100 counts in the Coulex peak of ^{64}Ni and ^{63}Co

Plamen Botachkov

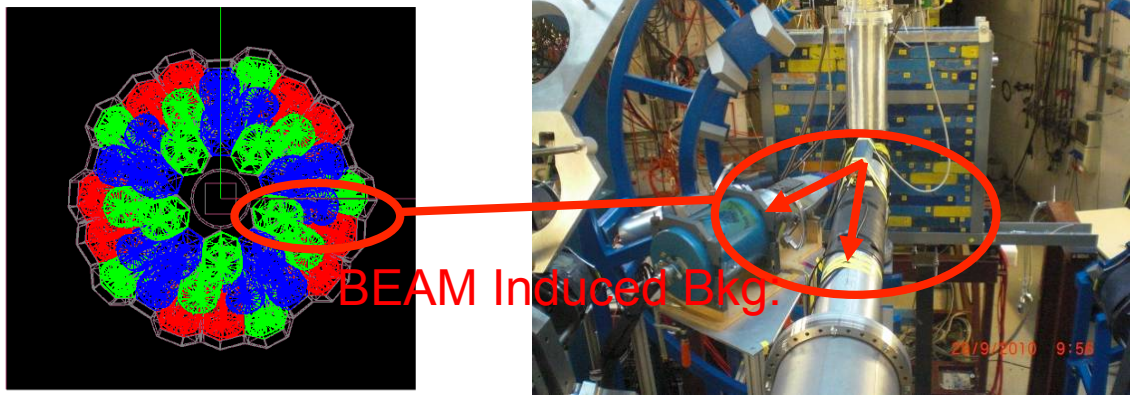
AGATA detectors:

Cesar Domingo

Tasks:

•**characterize the response and performance of AGATA in terms of gamma- and particle-background** at the FRS. These are features which are difficult to estimate in a MC simulation and need a dedicated experiment .

• measure the **background level and the peak-to-noise ratio** as a function of the reconstructed gamma-ray energy in order to calculate **realistic particle-gamma count rates.** Crucial to the preparation of experimental proposals for the next campaign of AGATA at GSI.



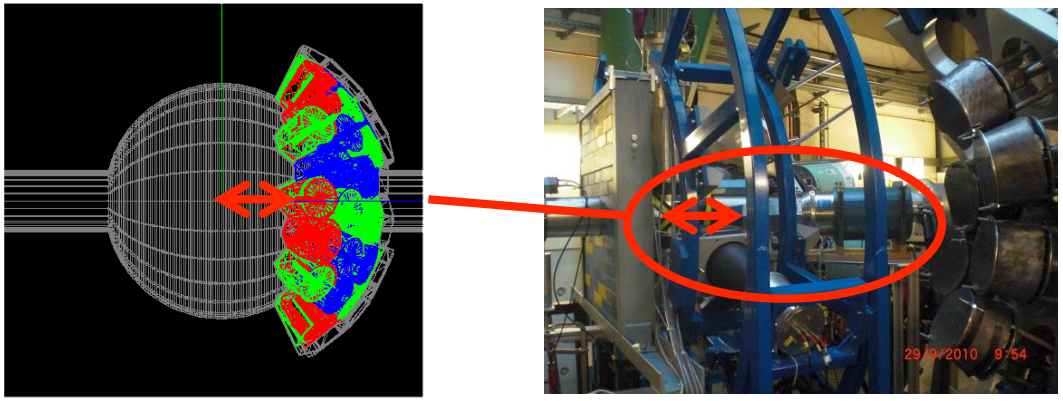
• Angular background dependence to characterize the bkgd in the whole array.

• Measurement with one AGATA capsule at 3 different angles covering the solid angle subtended by AGATA.

AGATA detectors:

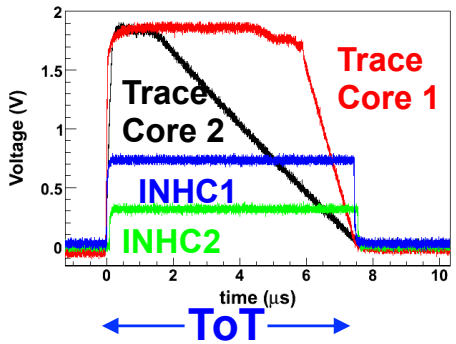
Cesar Domingo

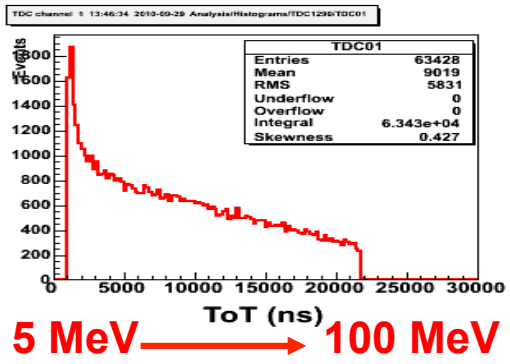
•Evaluate the **gamma-ray hit multiplicity** at a range of target-detector distances as it is foreseen to use the AGATA detectors (for some experiments) at a very short distance from the target (**10 cm**). Maximum rate accepted by the detectors (10 kHz).



- Characterize the background variation with the distance to the target.
- Measurement at 4 different target-detector distances between 8cm and 23cm.

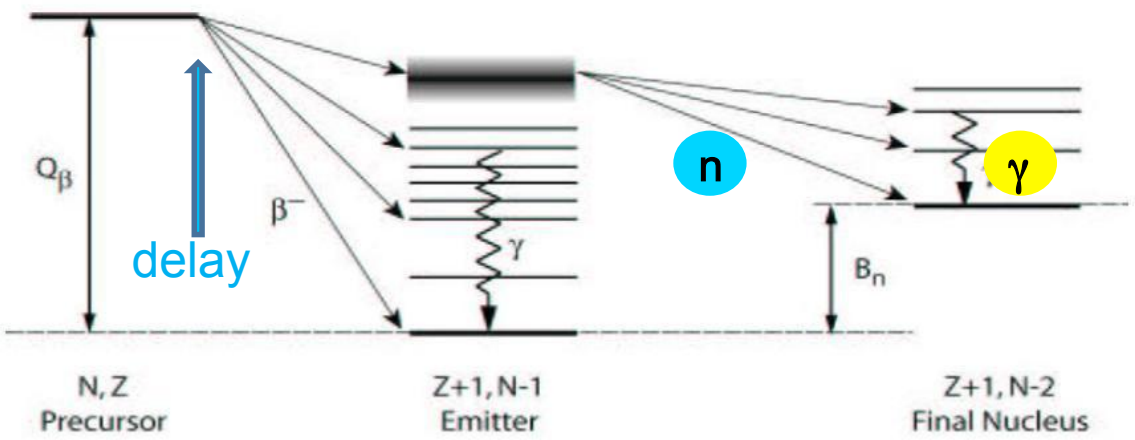
• Recently, a factor of 3 increase of the **high-energy background component**, commonly ascribed to light charged particles, has been observed when the S4-degrader is in the beam. This needs to be characterised and its origin understood.





- At the same time, the high-energy component of the background will be measured by using the time-over-threshold technique.

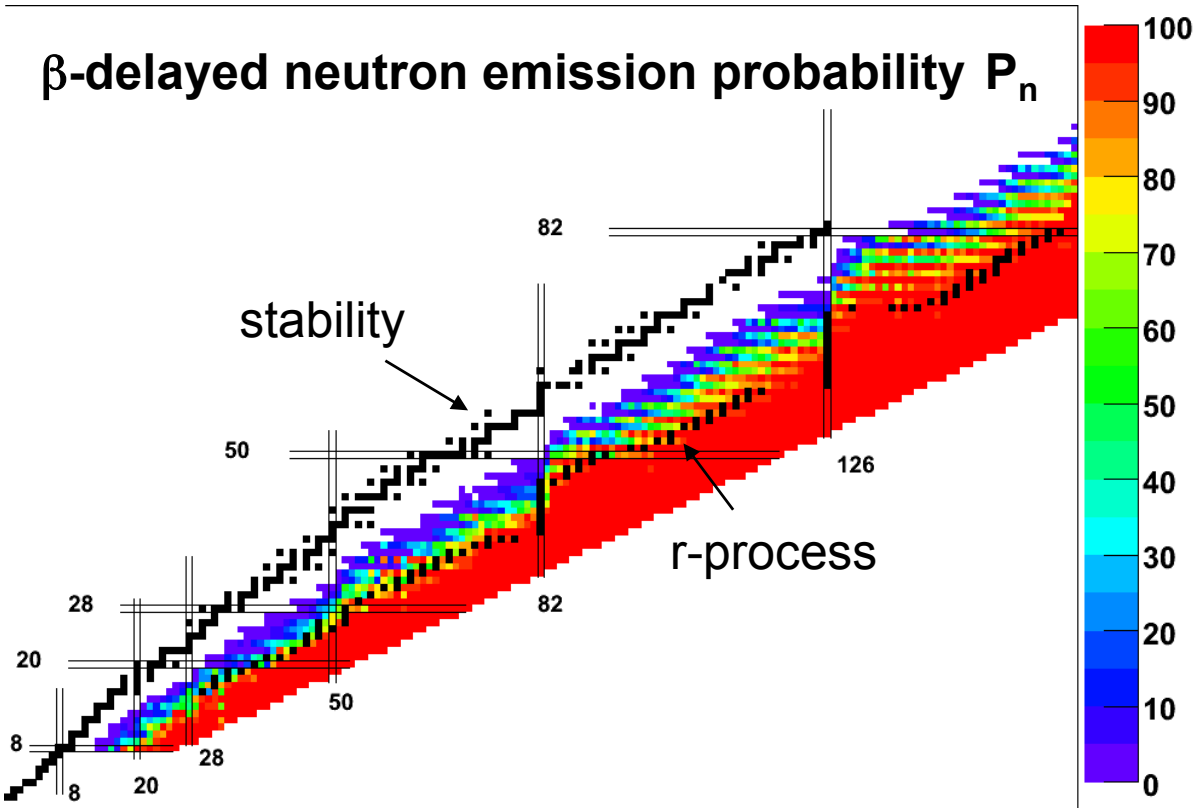
Beta delayed neutron emission of neutron rich nuclei



- Far enough from the stability, **β-delayed neutron emission** becomes the dominant decay process

Physic cases:

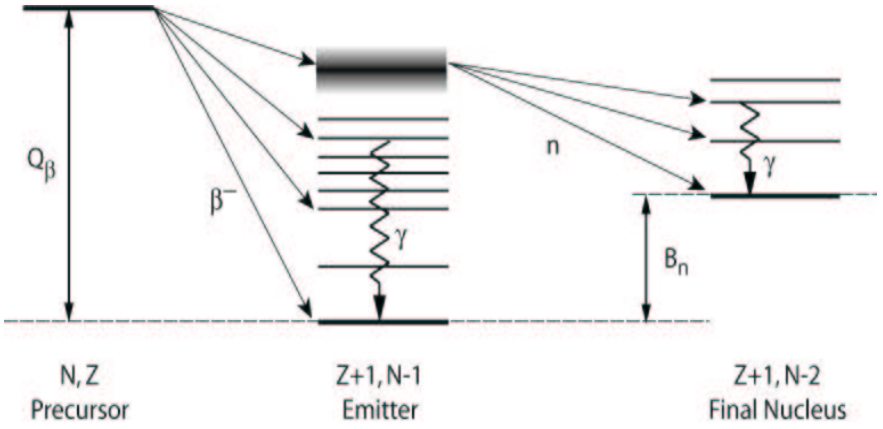
✓ ***Astrophysics r-process***: delayed neutron emission defines decay path and is a source of late neutrons.
✓ ***Nuclear technology***: delayed neutron emission in fission products.
✓ ***Nuclear structure*** in nuclei at the limits of existance.



Daniel Cano

MONSTER neutron detector:

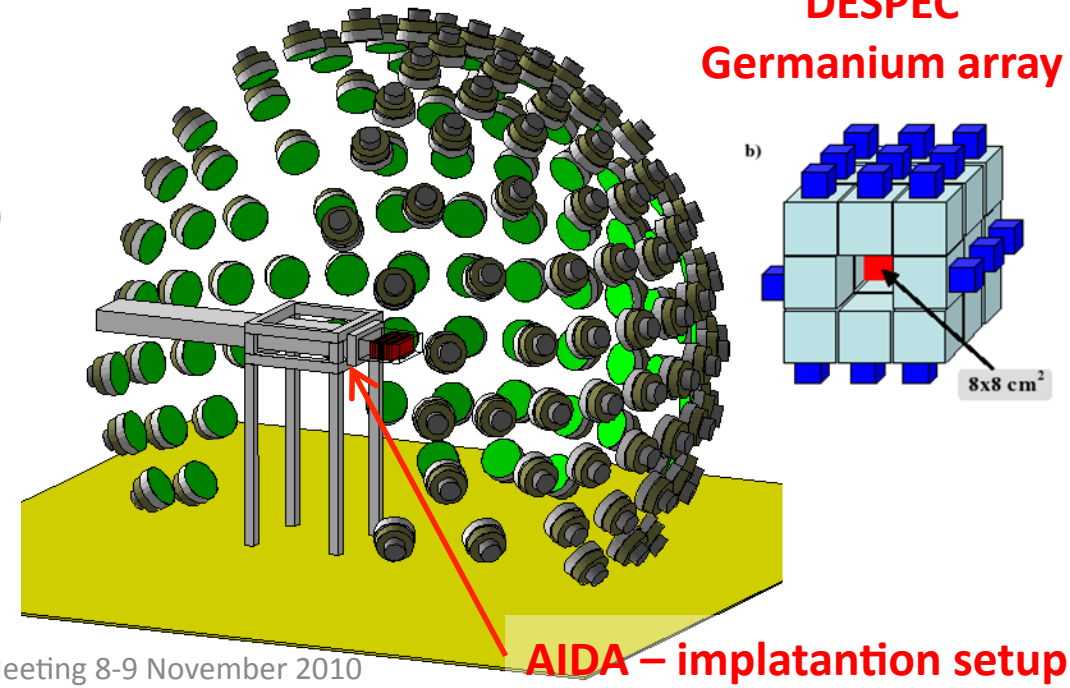
Measure the beta decay properties of neutron rich nuclei for nuclear structure, astrophysics and reactor technology applications (new FAST reactor design).



A powerful neutron spectrometer for b-decay measurements:

- Array of 150 – 200 detectors
- BC501A liquid scintillators
- High intrinsic efficiency
- Energy threshold ~ 30 keVee (E_n ~100 keV)
- Reasonable energy resolution < 10% up to 5 MeV:
- Good neutron timing ~1ns
- 3-4 m flight path

DESPEC Germanium array

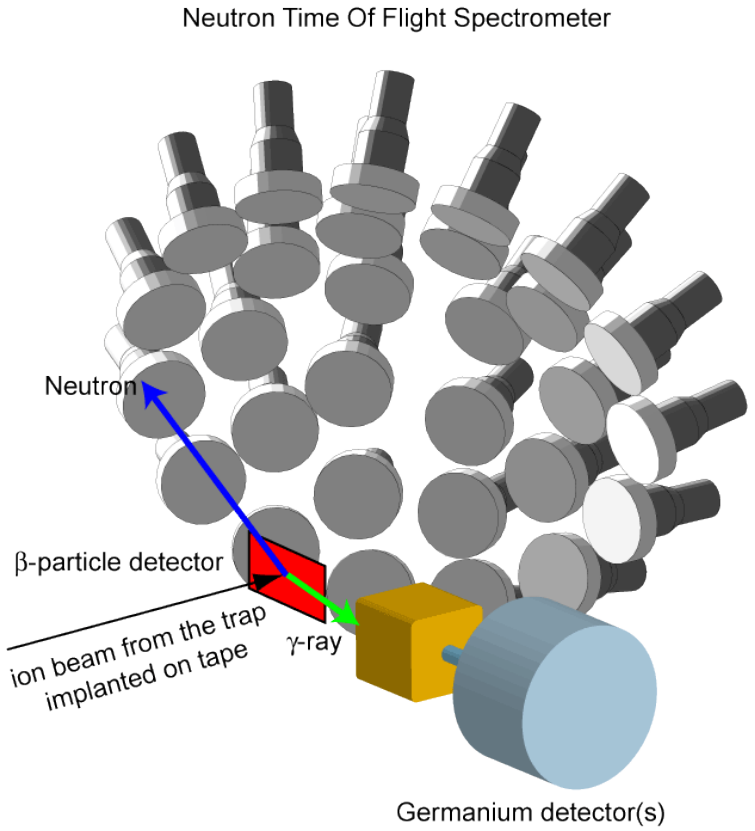


Combined β,γ,n information

AIDA – implatantion setup

The MONSTER demonstrator at the FRS (PRESPEC)

- To determine the **performance of the detector in real conditions**: degradation of the time resolution, electronic noise with and without beam, blinding of the detectors due to Bremsstrahlung radiation and other possible effects.
- To determine the **sources of neutron and γ-ray background** and its origin.
- To determine the **energy resolution** and the **energy threshold** of MONSTER in combination **with the implantation setup (AIDA)**.
- To determine the performance of a **new digital acquisition system** based on 12 bit & 1 Gsample/s digitizers.



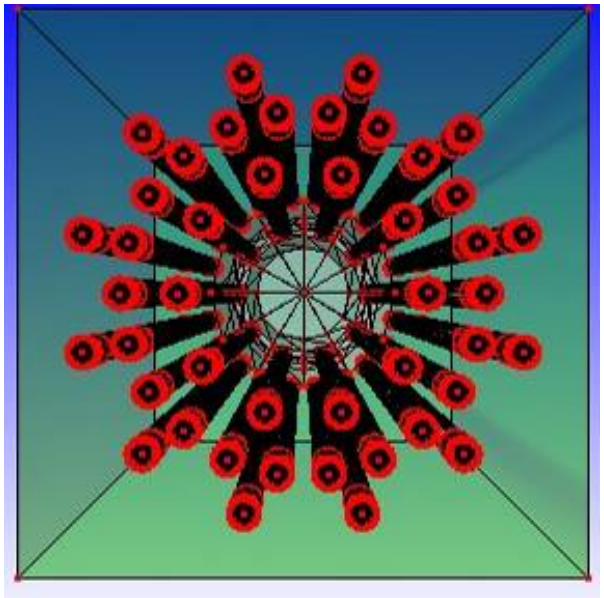
Test case: a **light nucleus** with a **high Pn** value and a **hard β-delayed neutron spectrum**.
Flexibility: various primary beams can accommodate the experimental needs.
Beam time request: 7 days of parasitic beam

Daniel Cano

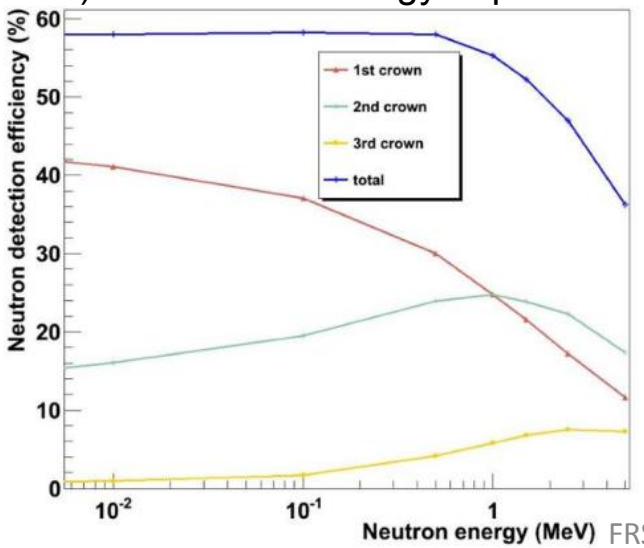
Features

BEta deLayEd Neutron detector

• BELEN detector consists of 44 ^{3}He counters arranged in 3 crowns around the beam hole.

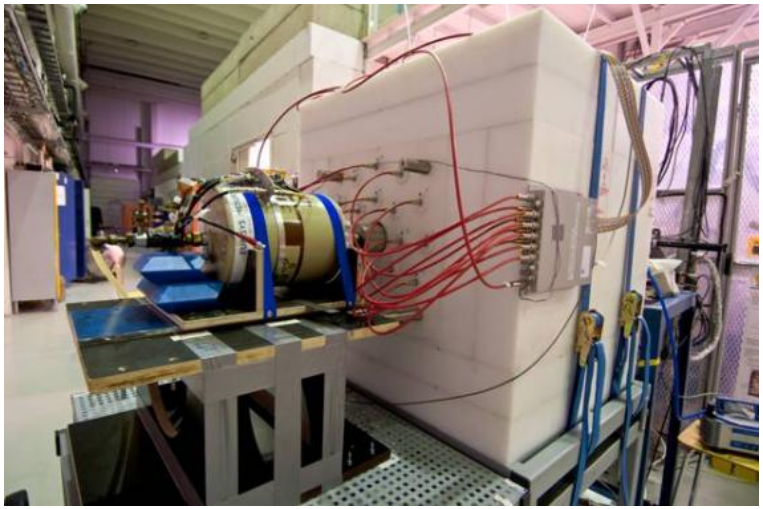


The detector has very high and flat efficiency (~60%) to minimise energy dependence

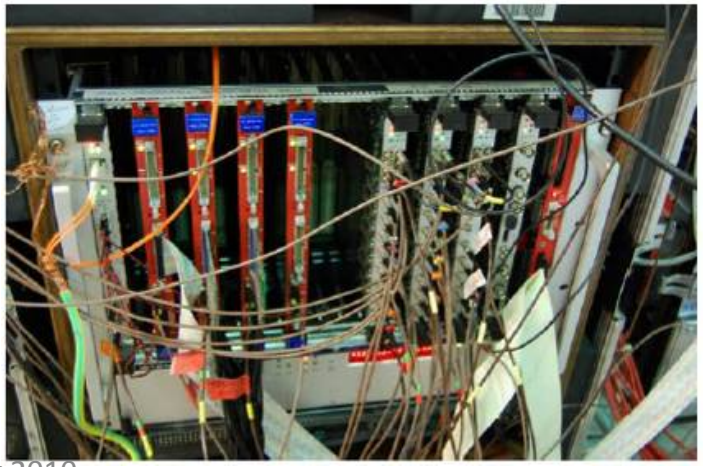


Prototype

A fully functional prototype with 20 ^{3}He counters has been successfully used in two experiments at JYFL



with a purpose built triggerless data acquisition system that allows long correlation times among data with minimum dead time



BELEN:

✓ Test time requested for:

- ***Background test*** of the whole BELEN setup at GSI
  Background has to be reduced as much as possible to allow measurements of very low yield nuclei. Test time under GSI realistic conditions is required to study shielding needs.
  2 days requested

- **Integration and callibration:**
  BELEN detector + Implantation detector (AIDA) + DACQ at GSI.
  5 days requested with a well known neutron emitter (e.g. ^{95}Rb).

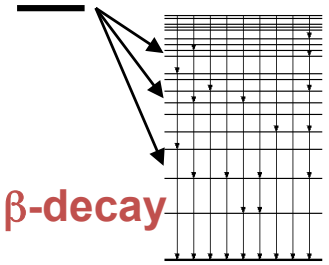
✓Two proposals approved at FRS-GSI will use the BELEN detector

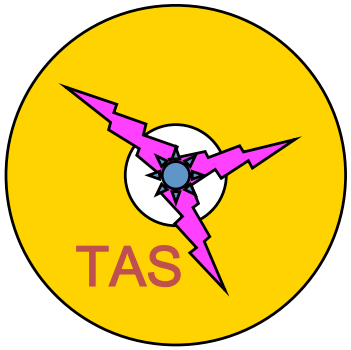
- S323 *"Beta-decay of very neutron-rich Rh, Pd, Ag nuclei including the r-process waiting point 128Pd".* F. Montes et al.
- S410 *"Beta-decay measurements of new isotopes near the third r-process peak".* C. Domingo et al.

Jose L. Taín

Total Absorption Spectrometer

• **Total Absorption Spectroscopy is the best method to measure beta strengths in β-decay for complex decay schemes because of the ability to detect the full cascade**



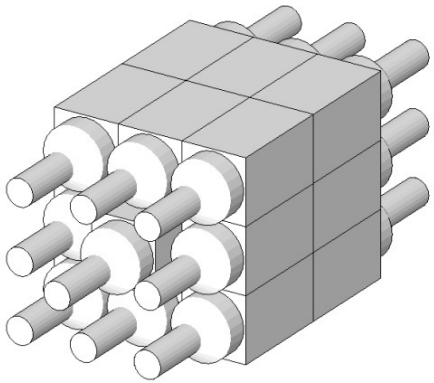


•**The main source of systematic error is contamination/background signals**

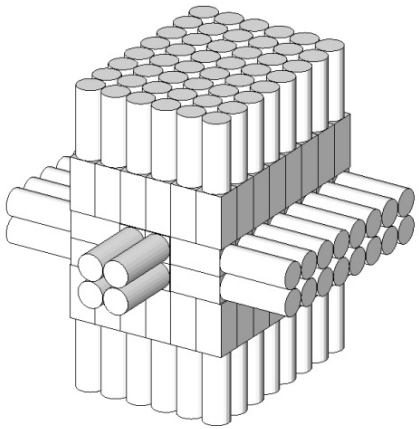
DESIGN CHOICES

16 + 1 modules:
15×15×25 cm^3 **NaI(Tl)**
+ 5" PMT (50% light col.)
V= 95 L, M= 351 kg

ΔE/E ~ 5%
(@1.3MeV)
Δt ~ 2 ns
τ ~ 230ns



128 + 4 modules:
5.5×5.5×11 cm^3 **$LaBr_3$:Ce**
+ 2" PMT (60% light col.)
V= 44 L, M= 223 kg



ΔE/E ~ 2%?
(@1.3MeV)
Δt ≤1 ns
τ ~ 26/160ns

- **×2 better energy resolution**
- **much increased cost**

Jose L. Taín

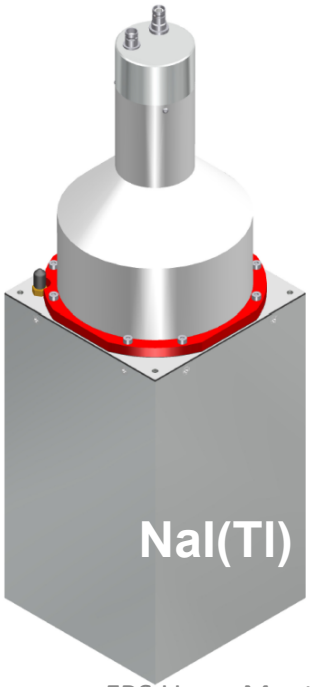
Total Absorption Spectrometer

TAS measurements have never been performed at an in-flight fragmentation facility

Therefore we propose to study:

1. **The response of the detectors to the particular background conditions associated with the implantation of high energy beams**

Test of NaI(Tl) and $LaBr_3$:Ce prototype modules response (recovery from saturation) close to a passive implanter at FRS S4 focal plane



- **changing detector position**
- **varying beam ^{A}Z, energy and intensity**
- **changing PMT-VD**

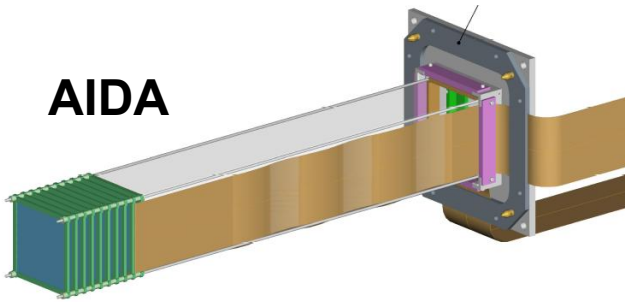
Total Absorption Spectrometer

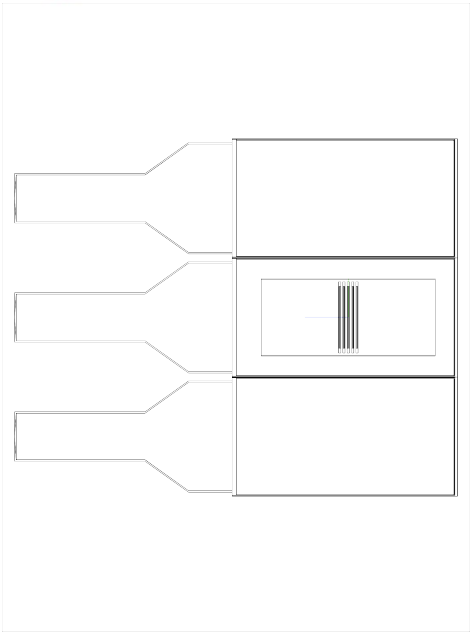
Jose L. Taín

2. Perform a measurement with a functional prototype (at least 8 NaI modules) and an active stopper (AIDA)

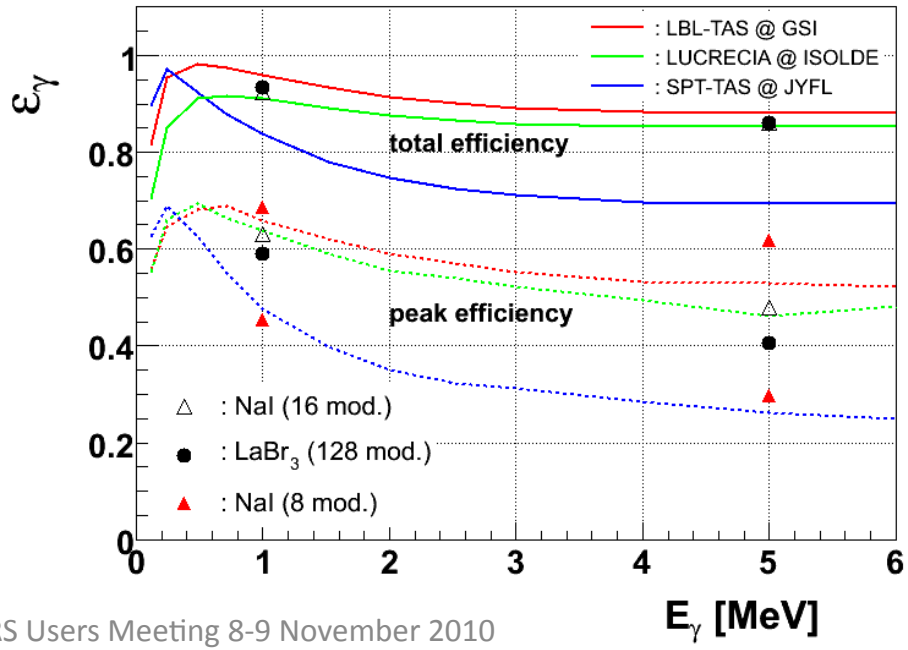
Test the event reconstruction performance and its ability to reject backgrounds

AIDA





- **use beams already measured with TAS at ISOL facilities**
- **use short/long half-lives to investigate on-spill/off-spill differences**



Luis Mario Fraile

Fast timing array for DESPEC:

✓ Physics goals at DESPEC

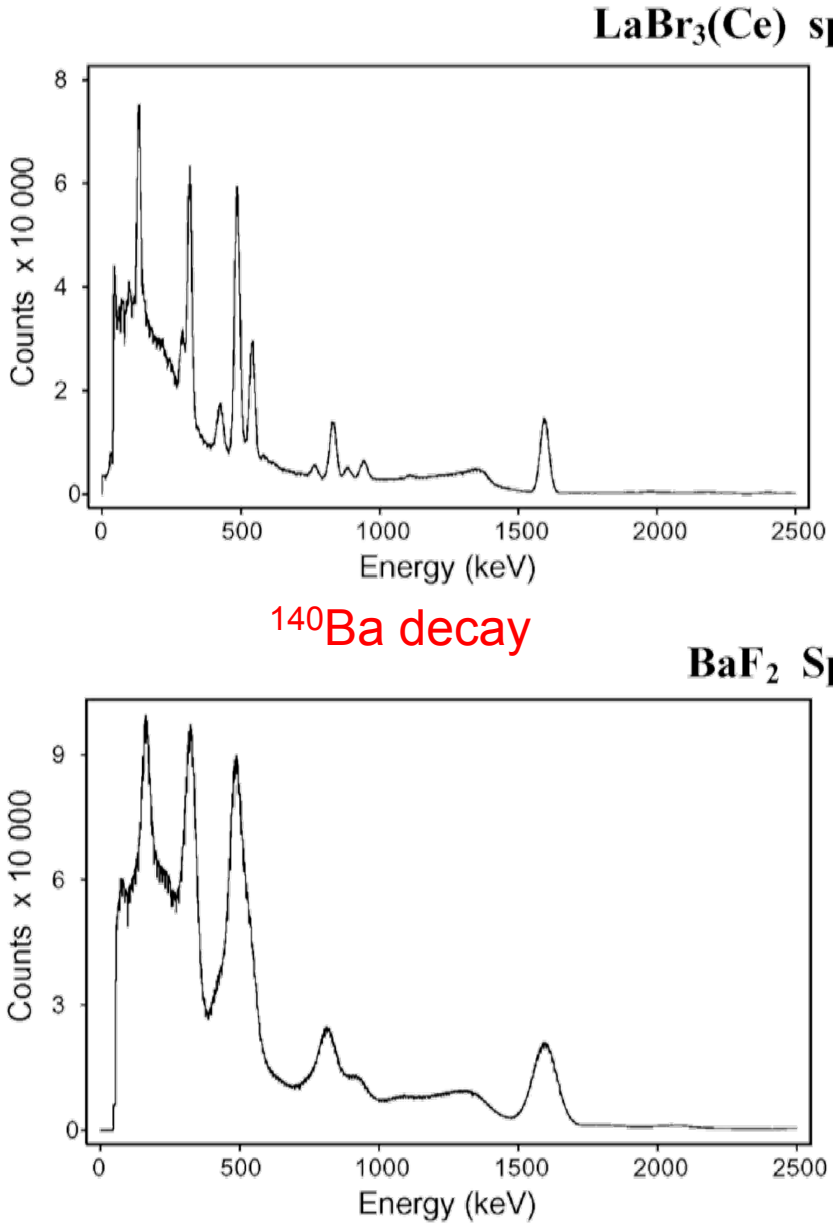
- In order to fully exploit possibilities at DESPEC the measurement of absolute transition probabilities is of paramount importance
- Absolute reference is required by other measurement for normalization
- The fast timing technique can measure level lifetimes:
  - ∵ Beta decay: βγγ, 5 ps precision with beams down to 20 counts/s.
  - ∵ Isomeric decay: γγ, 5-10 ps precision with 10 isomers/min.
  - ∵ In beam: γγγ and γγγγ, to be further explored.

✓ Commissioning within PRESPEC

- Demonstrate that fast timing experiments can be performed.
- Address the challenges derived from the integration in a slowed down beam setup
- This can be partially achieved with existing equipment

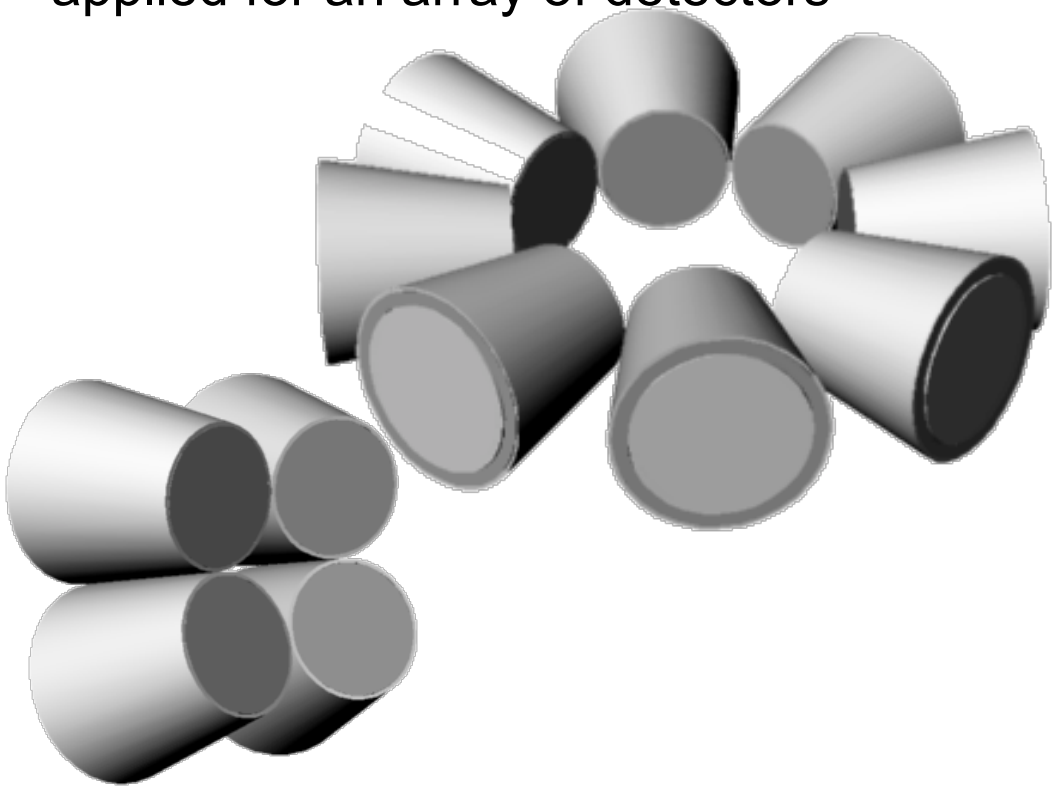
Luis Mario Fraile

Fast timing array for DESPEC:



^{140}Ba decay

- Beams of standard fast-timing sources, used in other facilities allow direct comparison to other experiment conditions: ^{24}Na, ^{88}Rb, ^{140}Ba
- Time resolution can be measured and time calibration procedures can be applied for an array of detectors



Luis Mario Fraile

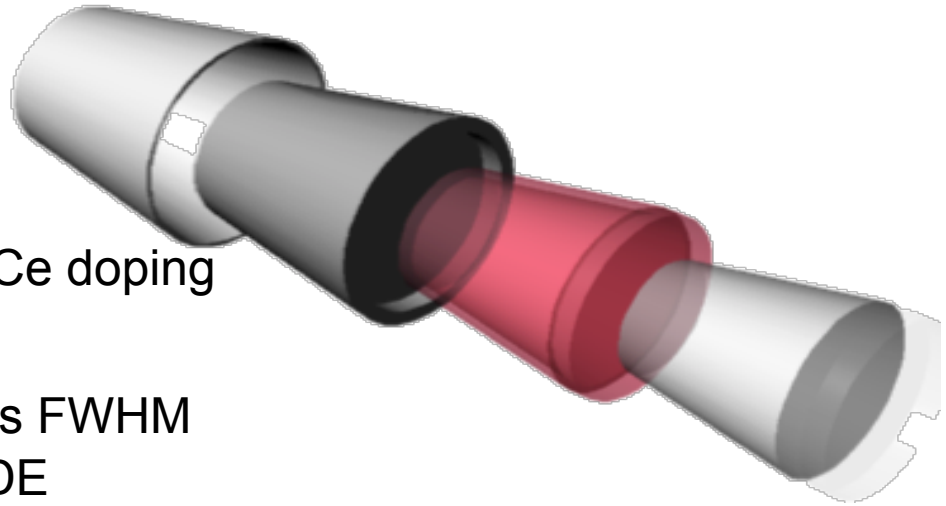
Fast timing array for DESPEC:

We would like to explore under realistic experimental conditions:

- Effect on energy and time resolution.
- Time response of the active stopper for timing studies.
- Impact of extended source and position resolution.
- Effect of shielding and scattering processes in a realistic arrangement at FRS: optimization of the setup.
- Impact of the FRS background conditions on the time calibrations.
- Possibilities of alternative photosensors in realistic conditions.
- Integration of front-end electronics and data acquisition.

38.1/25.4 x 38.1 mm 5% Ce doping (2009)

Time resolution 140-145 ps FWHM at 1.3 MeV - Tested ISOLDE



Overview of request:

Purpose of test	Beam species	Number of shifts of parasitic beam	Lead investigator	When??
Large-area tracking detectors and use of slowed-down beams	^{64}Ni, ^{63}Co	51	Plamen Boutachkov	Ready for 2011. Large detector has been tested with sources.
Characterisation of the background for an AGATA capsule	e.g. ^{40}Ar, ^{64}Ni, ^{86}Kr	21	Cesar Domingo Pardo	Fast-beam ~ 100 MeV/u LYCCA (preferable) 2011 PRESPEC experiment
Characterisation of the background for a MONSTER (neutron) detector	Many possibilities	21	Daniel Cano-Ott	Early 2012
Test beamtime request for BELEN	^{95}Rb	21	Belen Gómez Hornillos	ASAP in 2011
Development of a TAS for DESPEC	Many possibilities	21	Jose Luis Tain	1) Now 2) Needs AIDA 2012
Testing and optimizing the fast-timing array.	^{24}Na,^{88}Rb,^{140}Ba	21	Luis Mario Fraile	??