BELEN

A 4π **BE**ta de**L**ay**E**d **N**eutron counter

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Nuclear Astrophysics at the Canfranc Underground Laboratory

2nd CUNA Workshop   Canfranc, Huesca, Spain, 29 February – 1 March, 2016

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

IFIC INSTITUT DE FÍSICA CORPUSCULAR

GSI

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

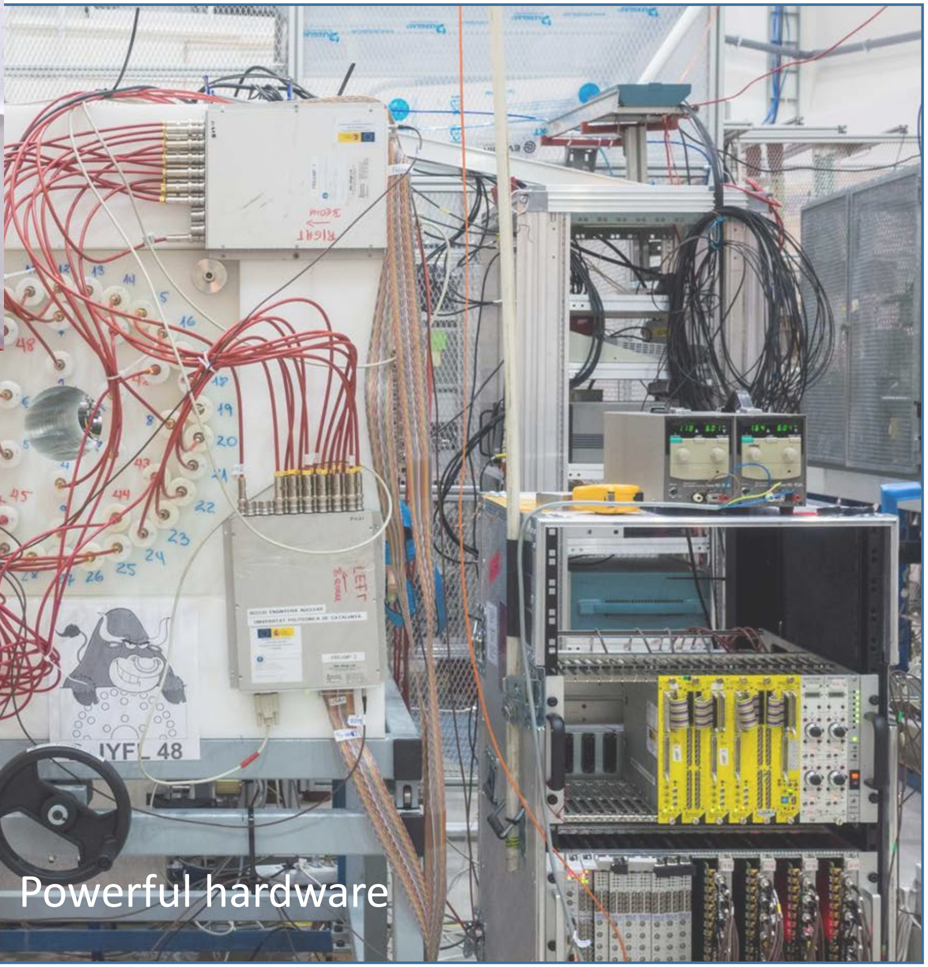
TRIUMF

OUTLINE

- Introduction
  - BELEN
  - BELEN evolution
  - Delayed neutrons
  - He-3 proportional counters
- Latest results with BELEN prototypes
  - BELEN-30: S410 experiment at GSI
  - BELEN-48: IGISOL-Jyväskylä in 2014
- **B**ELEN at **RIKEN** (BRIKEN collaboration)
- Concluding remarks.

What’s BELEN?

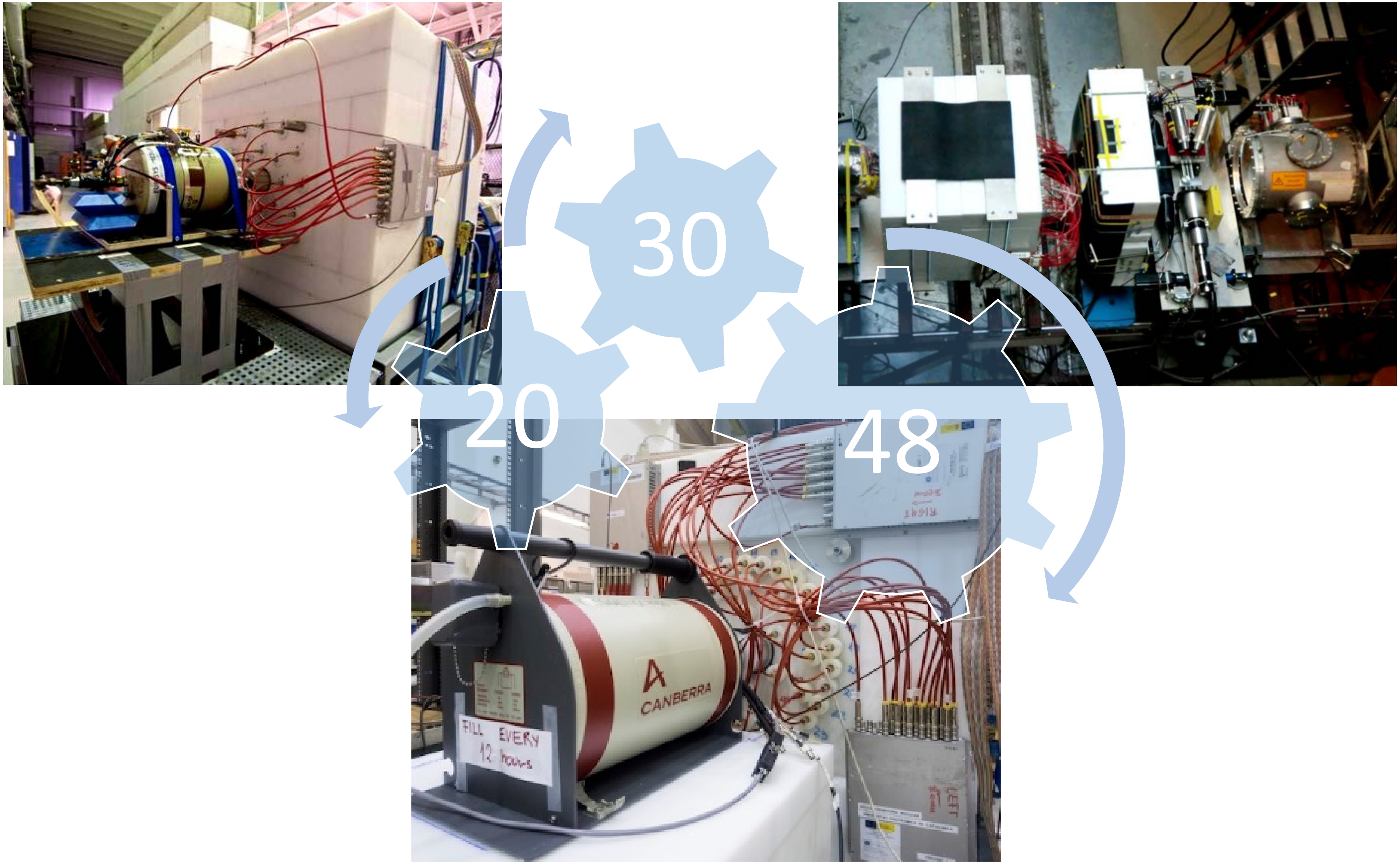
Nice and good group



Powerful hardware

- He-3 proportional counters
- HPPE
- Trigger-less DACQ

BELEN evolution



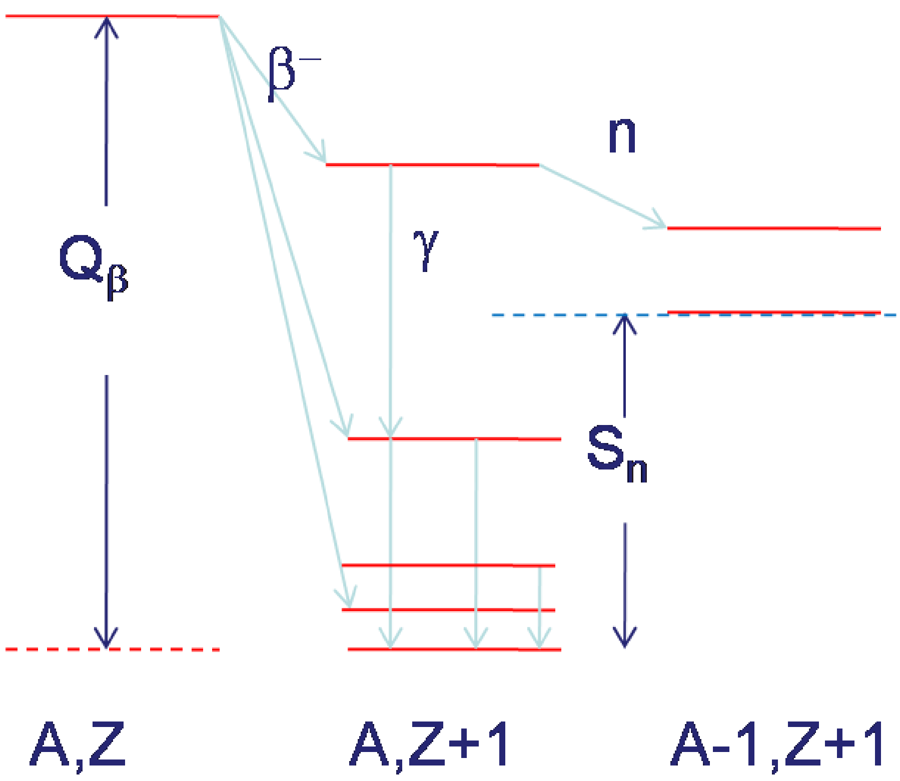
Developed within the DESPEC-NUSTAR collaboration for FAIR

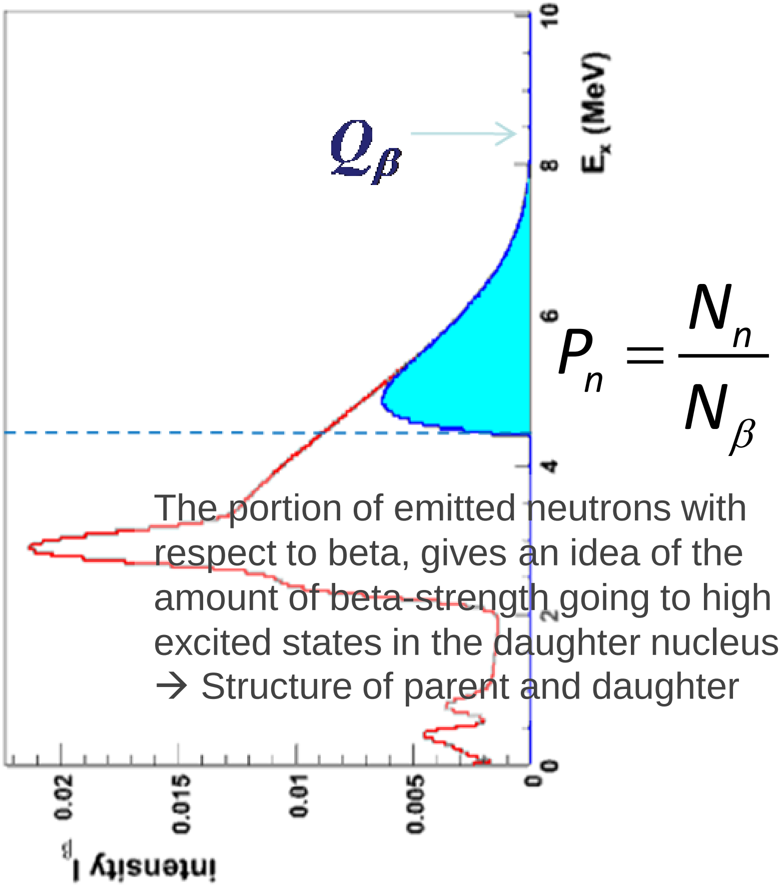
Delayed neutrons

If $S_n < Q_\beta$

and the β-decay proceeds to states above S_n, neutron emission competes and can dominate over γ-ray emission.

The process will dominate far from stability on the n-rich side.

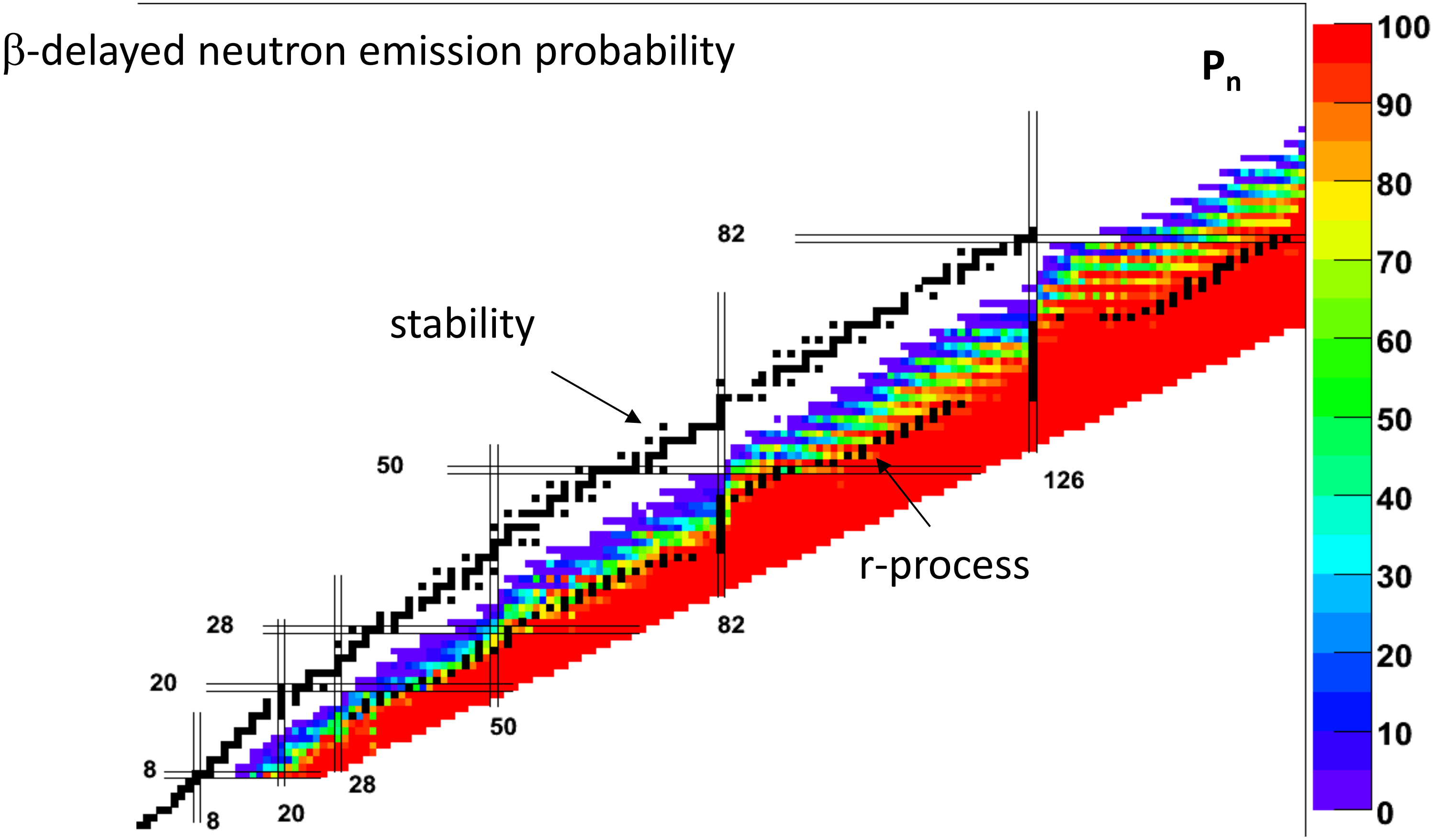




$$P_n = \frac{N_n}{N_\beta}$$

The portion of emitted neutrons with respect to beta, gives an idea of the amount of beta-strength going to high excited states in the daughter nucleus → Structure of parent and daughter

Beta decay in the neutron rich side



Importance of beta-delayed neutron emitters

Nuclear power safety:

NPP reactors are designed to be prompt-neutron subcritical. Criticality is controlled by delayed neutrons. Some FP are delayed neutron emitters.

Nuclear Energy Agency (NEA) highlights the importance of experimental measurements and data evaluation of delayed neutron emission in its working group 6 “Delayed neutron data” [WPEC-SG6].

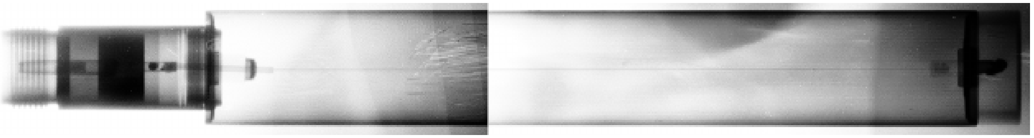
Rapid neutron-capture process of stellar nucleosynthesis:

Stellar abundances: delayed neutron emission probability (P_n) of r-process isobaric nuclei define the decay path towards stability during freeze-out, and provide a source of late time neutrons.

Nuclear Structure:

Additionally the measured half-lives ($T_{1/2}$) and β-delayed neutron-emission probabilities (P_n) can be used as first probes of the structure of the β-decay parent and daughter nuclei in this mass region.

Why He-3?



Detection reaction:

$$^{3}He + n \rightarrow {}^{3}H + p \qquad Q=0.764\ MeV$$

High Thermal cross section: **5330 barns!!!**

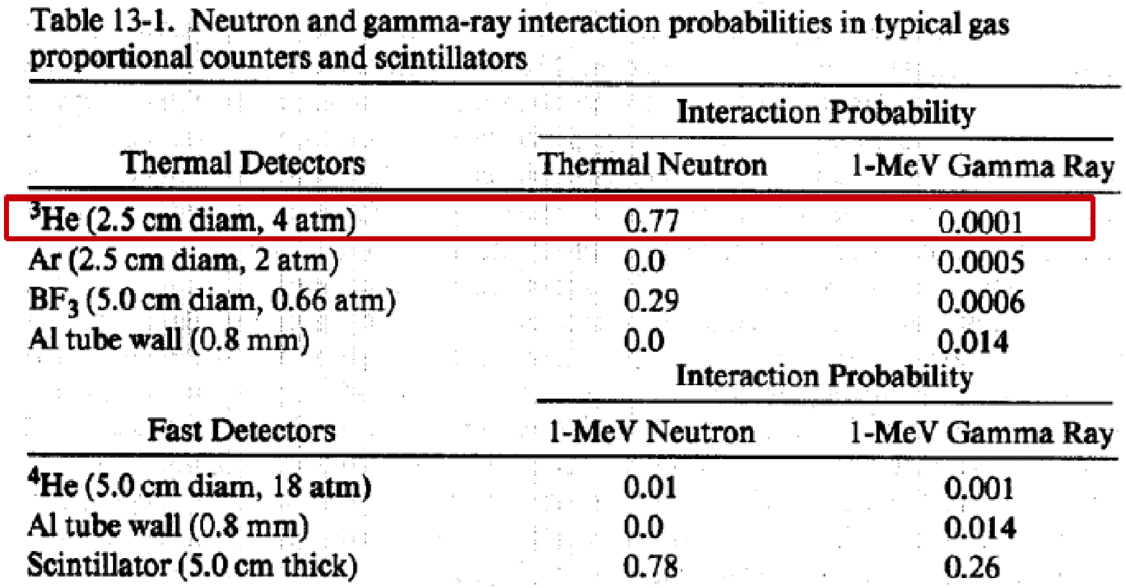
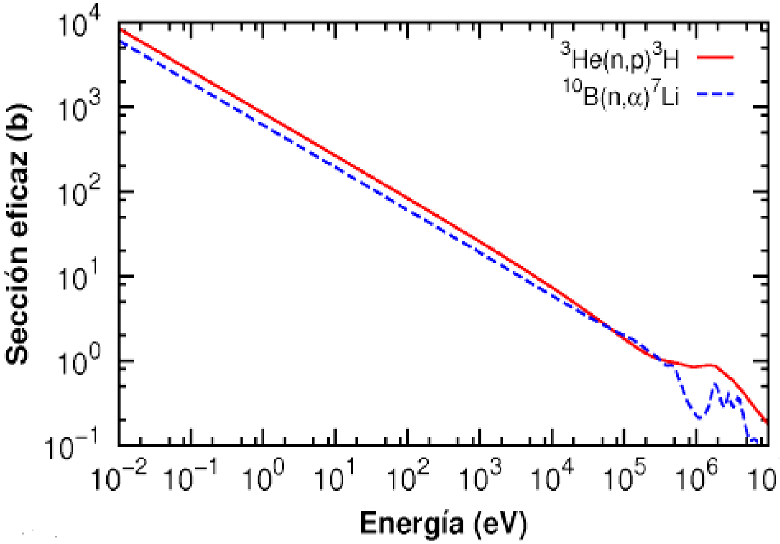


Table 13-1. Neutron and gamma-ray interaction probabilities in typical gas proportional counters and scintillators

	Interaction Probability	
Thermal Detectors	**Thermal Neutron**	**1-MeV Gamma Ray**
^{3}He (2.5 cm diam, 4 atm)	0.77	0.0001
Ar (2.5 cm diam, 2 atm)	0.0	0.0005
BF$_3$ (5.0 cm diam, 0.66 atm)	0.29	0.0006
Al tube wall (0.8 mm)	0.0	0.014
	Interaction Probability	
Fast Detectors	**1-MeV Neutron**	**1-MeV Gamma Ray**
^{4}He (5.0 cm diam, 18 atm)	0.01	0.001
Al tube wall (0.8 mm)	0.0	0.014
Scintillator (5.0 cm thick)	0.78	0.26

*Extracted from Neutron Detectors, T. W. Crane and M. P. Baker



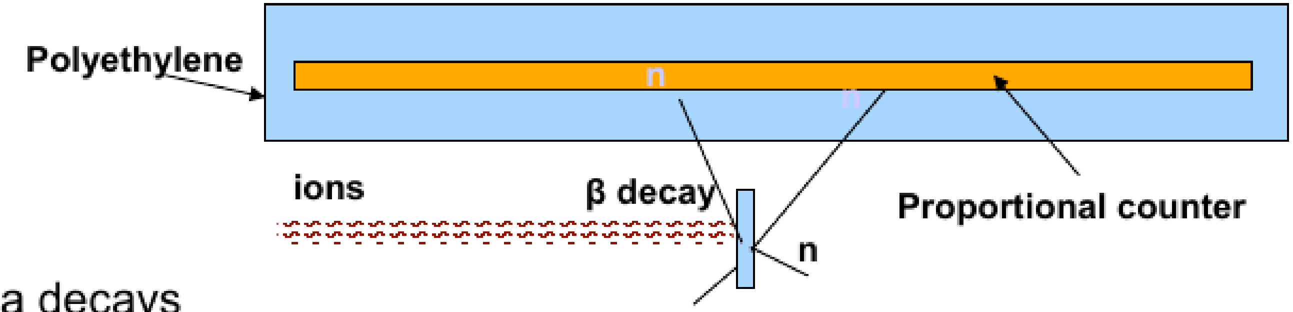
- These neutron counters are gaseous ionization detectors that use 3He as converting gas.
- Due to the high thermal capture cross section, 3He filled counters have a high neutron sensitivity.
- For non-thermal neutrons, the high efficiency can be exploited by using moderators.
- All these characteristics make 3He-filled counters very attractive for applications requiring high neutron efficiency and good neutron/gamma discrimination (thermal/fast neutron counting, spectroscopy, etc.).

Determination of P_n values

$$P_N = \frac{N_n}{N_\beta}$$

N_n is the number of beta decays going through neutron emission

N_β is the number of decays



$$n + {}^{3}He \rightarrow {}^{3}H + {}^{1}H + 765\ \text{keV}$$

$$n + {}^{10}B \rightarrow {}^{7}Li + {}^{4}He + 0.48\ \gamma + 2.3\ \text{MeV}$$

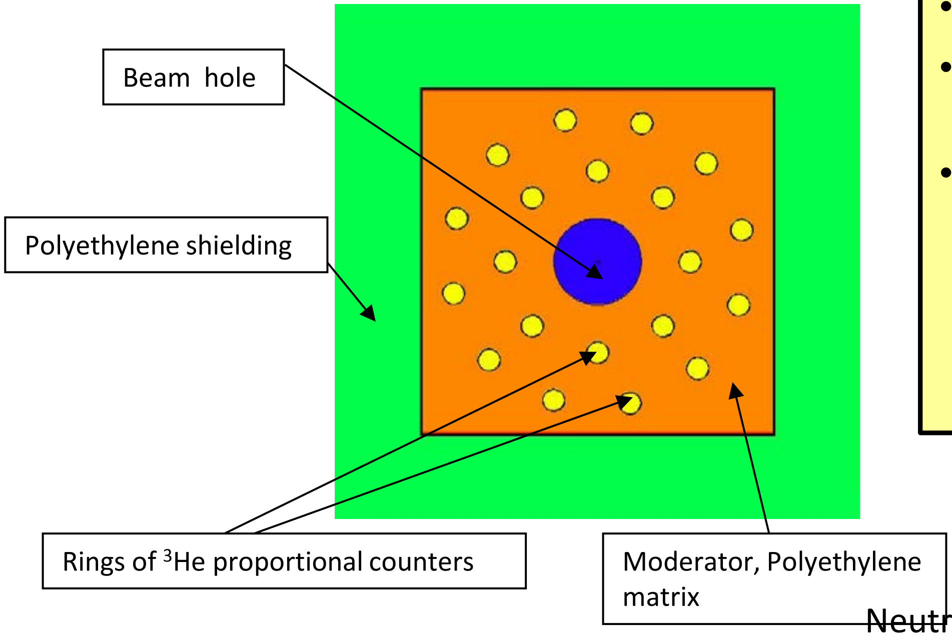
Some key issues concerning the technique:

- Moderation of the neutrons is required
- Purity of the sources → background issues
- High efficiency of the whole detector
- Flatness. The efficiency curve of the detector should be as flat as possible (no dependence on the E of the neutrons up to the highest possible energy).
- Much better if DACQ is trigger-less

Examples: “Krat’s long counter”, NERO, **BELEN**, 3Hen, LOENIE, TETRA, …

Detector design assisted by intensive MC simulations

Front view



Beam hole

Polyethylene shielding

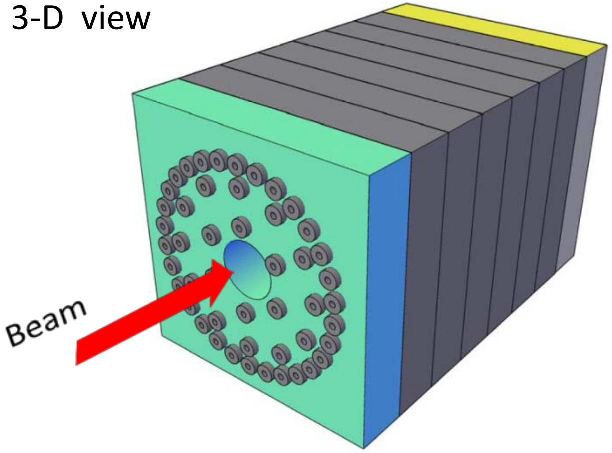
Rings of ^{3}He proportional counters

Moderator, Polyethylene matrix

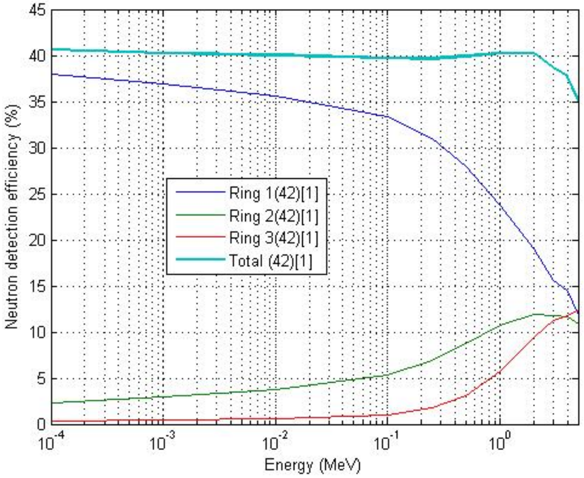
- Energy of beta-delayed neutrons not ~~well~~ known
- The neutron detection efficiency must be as flat as possible for a wide range of neutron energies
- The efficiency depends on many parameters:
  - Diameter of beam hole
  - Number of neutron counters
  - Distance of counters to the center of polyethylene matrix
  - Number of rings

Need to find the optimal configuration

3-D view



Neutron detection efficiency



UPC Design team:

V. Gorlychev, PhD thesis 2014

B. Hornillos (Until 2013)

A. Riego, PhD thesis 2016

G. Cortes

P. Calvino

Prototypes up to now:BELEN-20, BELEN-30 and BELEN-48

	Detector Name	**^{3}He counters**	**Pressure (atm)**	**Experiment**	**Ratio @ 2 MeV**	**Ratio @ 5 MeV**	**Mean efficiency**	**Beam hole radii (cm)**
[1]	BELEN-20	20	20	IGISOL: Jyväskylä - 2009 --- DONE	1.17	[1.60]	27%	5.5
[2]	BELEN-20	20	20	IGISOL: Jyväskylä - 2010 --- DONE	1.17	[1.60]	35%	5.5
[3]	BELEN-30	20+10	20 & 10	GSI: Germany – 2011 --- DONE	1.17	[1.70]	40%	11.5 (SIMBA)
[4]	BELEN-48	40+8	8 & 10	PTB: Germany-06/2013 (Detector calibration) --- DONE	1.02	1.16	45%	5.5
[5]	BELEN-48	40+8	8 & 10	IGISOL: Jyväskylä – DONE	1.02	1.16	45%	5.5
[5]	BELEN-48	40+8	8 & 10	IGISOL: Jyväskylä -- DONE	1.02	1.12	61%	**3**
[6]	BELEN-48	40+8	8 & 10	FAIR / DESPEC	1.07	1.18	45%	8.0 (AIDA)

[1] ***Paper: J. Agramunt et al, "New Beta-delayed Neutron Measurements in the Light-mass Fission Group"***, *Nuclear Data Sheets, Volume 120, June-2014, pages 74-77*

[2] Not yet finished data analysis. Distribution of neutron counters optimized to increase the mean efficiency.

[3] GSI: S410/S323. "Measurement of beta-delayed neutrons around 3rd r-process peak". (Phd.Thesis Roger Caballero) ***Paper: R. Caballero-Folch, et al. "β-decay and β-delayed Neutron Emission Measurements at GSI-FRS Beyond N=126, for r-process Nucleosynthesis",*** *Nuclear Data Sheets, Volume 120, June2014, pages 81-83*

[4] Measurements done on 24-28 June 2013. Preliminary experimental results agree with MC simulations

[5] Two experiments: **I162** "Delayed neutron measurements for advanced reactor technologies and astrophysics", and **I181** "Measurement of the beta-delayed 2-neutron emitter ^{136}Sb" were done on November-2014. Two matrix wereused: One with a beam hole of 3 cm radii, and other with a beam hole radii of 5.5 cm to insert a HPGe detector for gamma coincidence measurements.

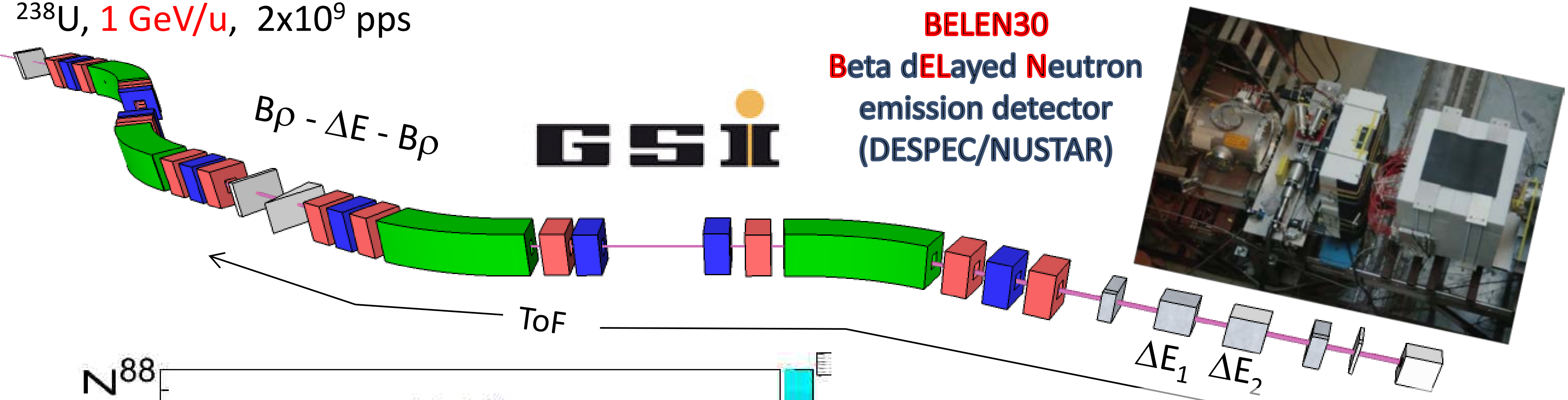
[6] Design for DESPEC / FAIR. Polyethylene matrix 80x80x90 cm^3. Beta particle detector: AIDA

Latest results with BELEN prototypes

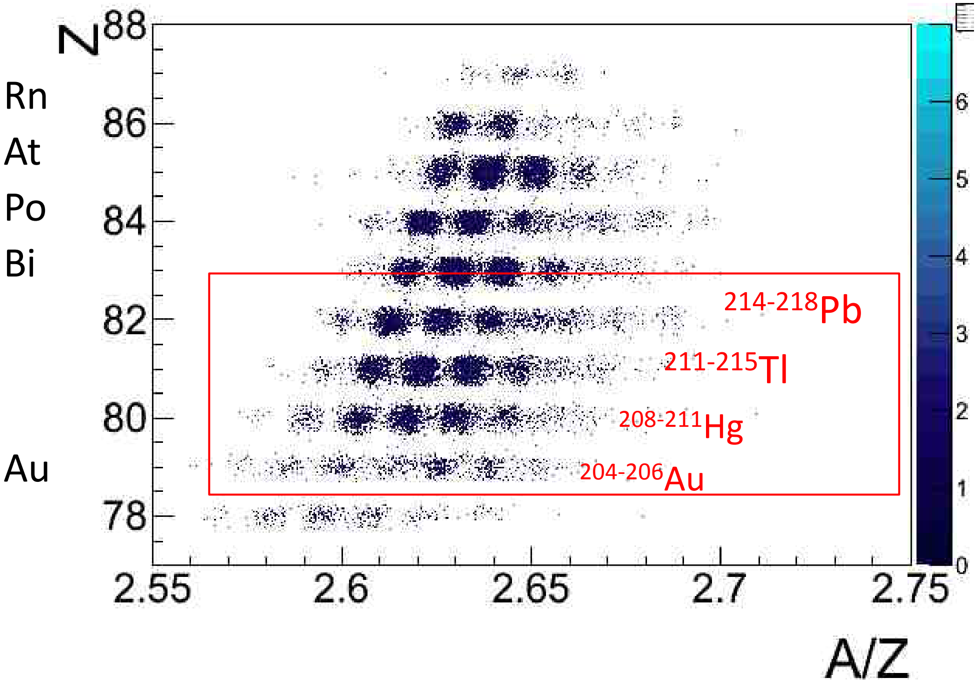
S410: First measurement of several βn-emitters beyond N = 126

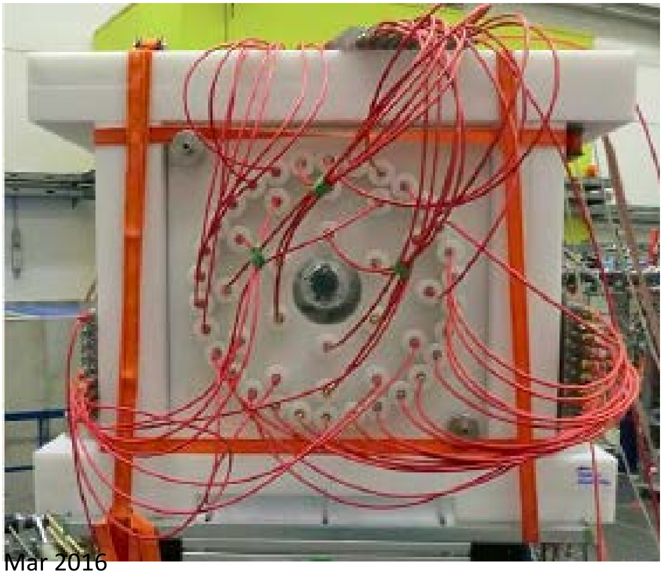
^{238}U, 1 GeV/u, 2x10^{9} pps

BELEN30
Beta dELayed Neutron emission detector (DESPEC/NUSTAR)

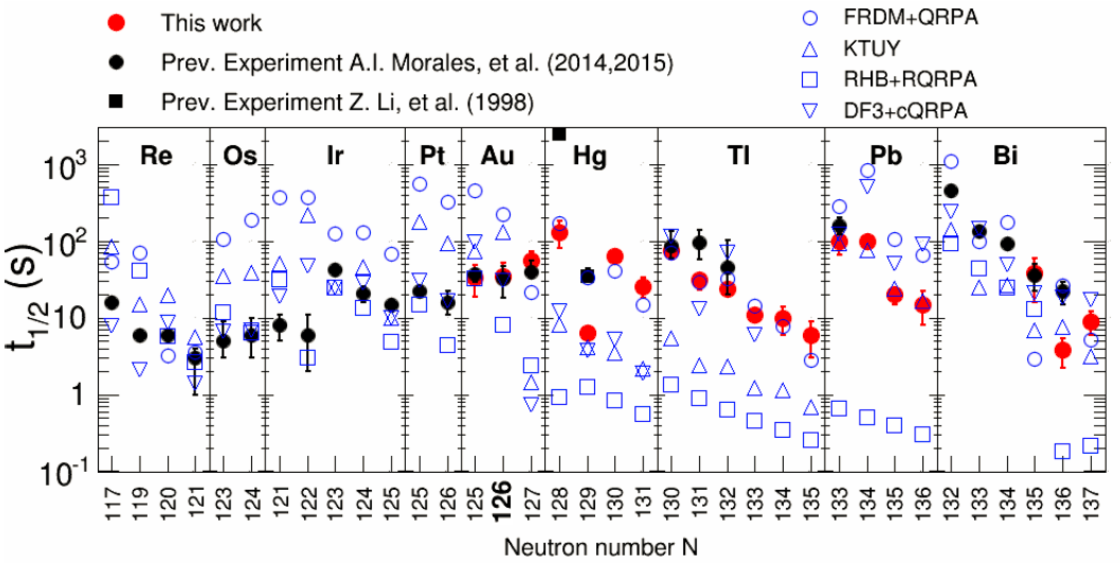


PhD Thesis: R. Caballero-Folch (2015)





S410: First measurement of several bn-emitters beyond N = 126

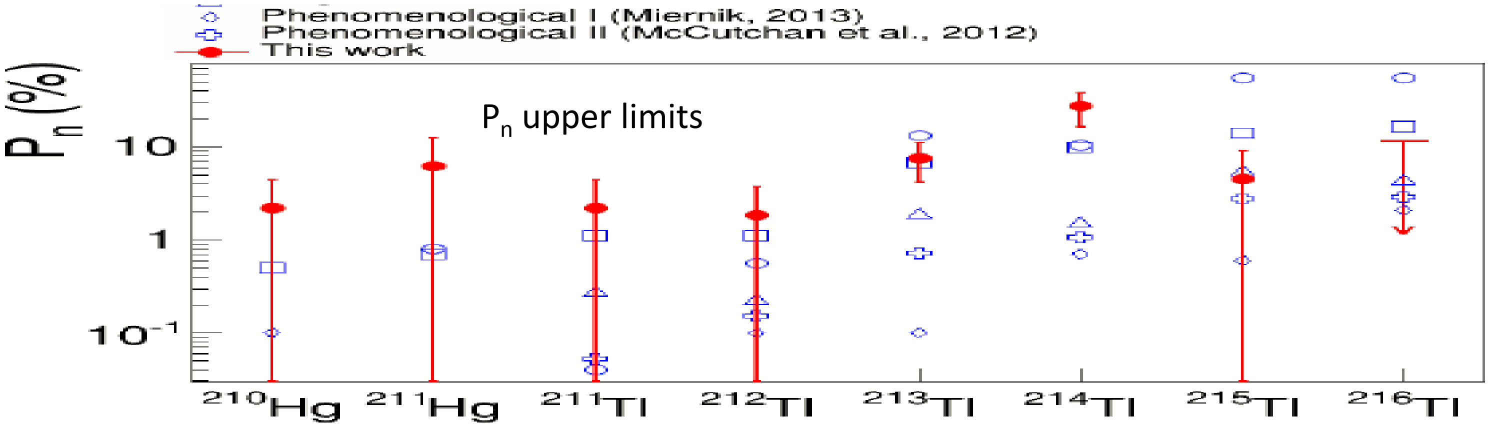


→ GSI-FRS Experiment (S410) using SIMBA + BELEN: precursor of AIDA+BRIKEN & AIDA + BELEN@NUSTAR

→ Demonstrates uneven performance of state-of-the-art global models on both sides of N=126 → Large uncertainties in r-process model calculations

→ Need of more experimental data around N=126 (Source: arXiv:1511.01296, submitted to Phys. Rev. Lett.)

PhD Thesis: R. Caballero-Folch (UPC)
C. Domingo-Pardo (IFIC)

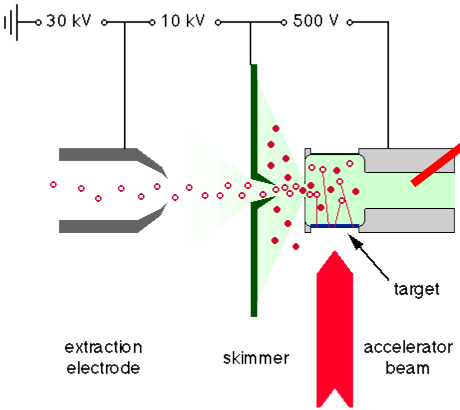


Experiments in JYFL 2014: Preliminary results

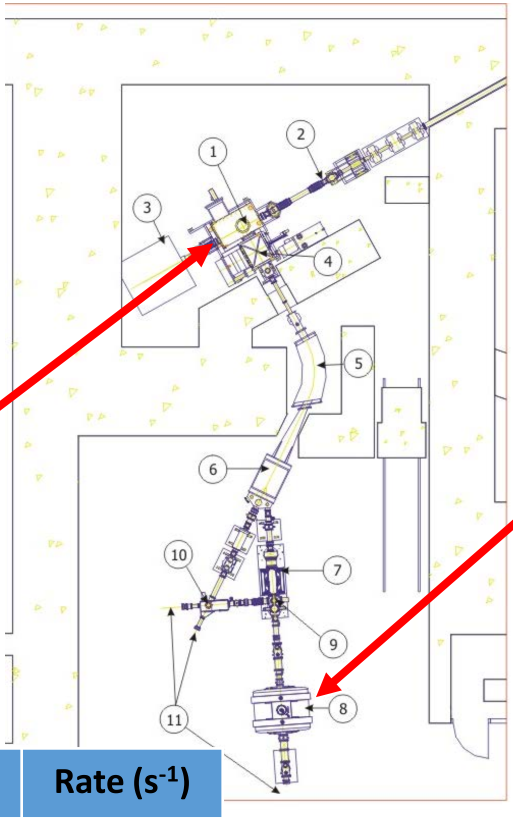
JYFL Accelerator Laboratory

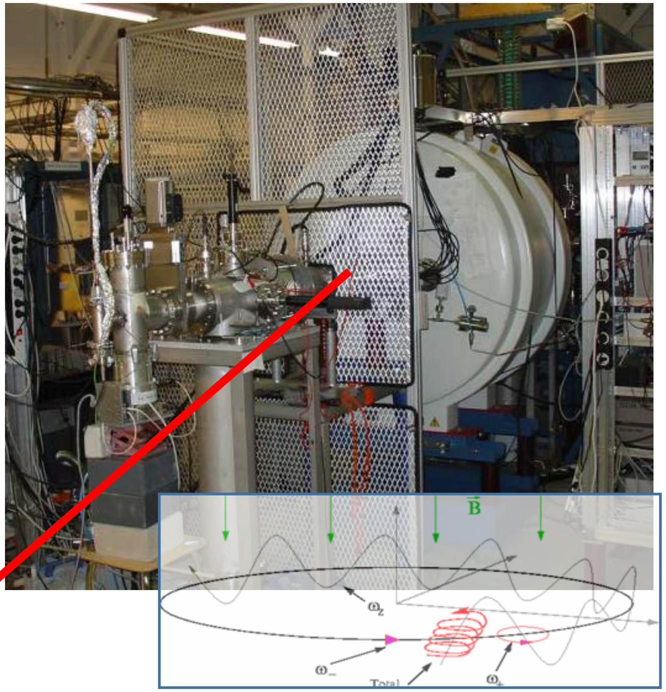
IGISOL separator **+ ion guide** source:
refractory elements

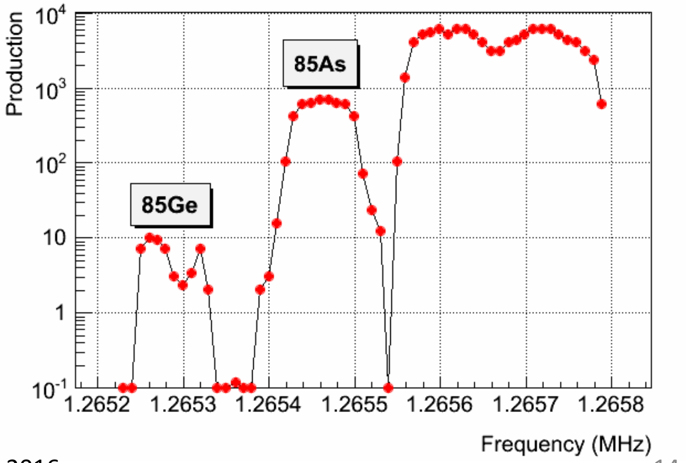
p(25MeV) + Th/U



Before relocation!







Isotope	Rate (s^{-1})	Isotope	Rate (s^{-1})
^{88}Br	1450	^{85}Ge	6
^{94}Rb	1030	^{85}As	175
^{95}Rb	760	^{86}As	30
^{137}I	100	^{91}Br	80

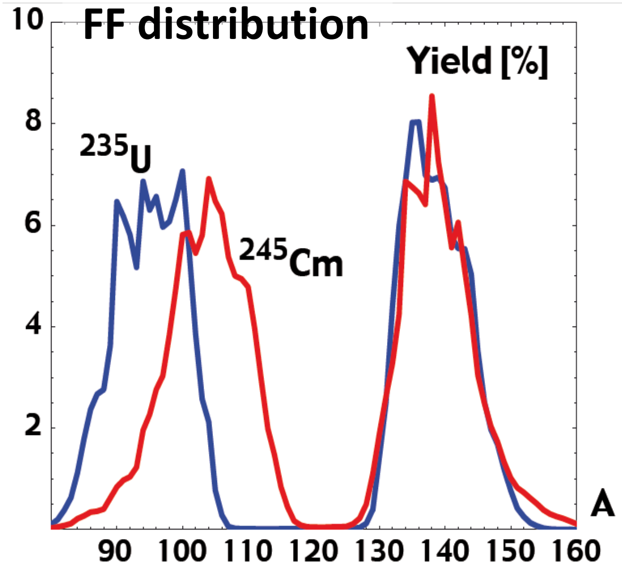
I162: Delayed neutron measurements for advanced reactor technologies and astrophysics* (J.L.Tain-IFIC, B.Gomez-UPC, et al.)

- The delayed neutron fraction β_{eff} is a key parameter in the control of reactor power
- Microscopic summation calculations lack still the accuracy of Keepin six-group formula
- Reason: **inaccuracies** in fission yields *Y* and **delayed neutron emission probabilities P_n**

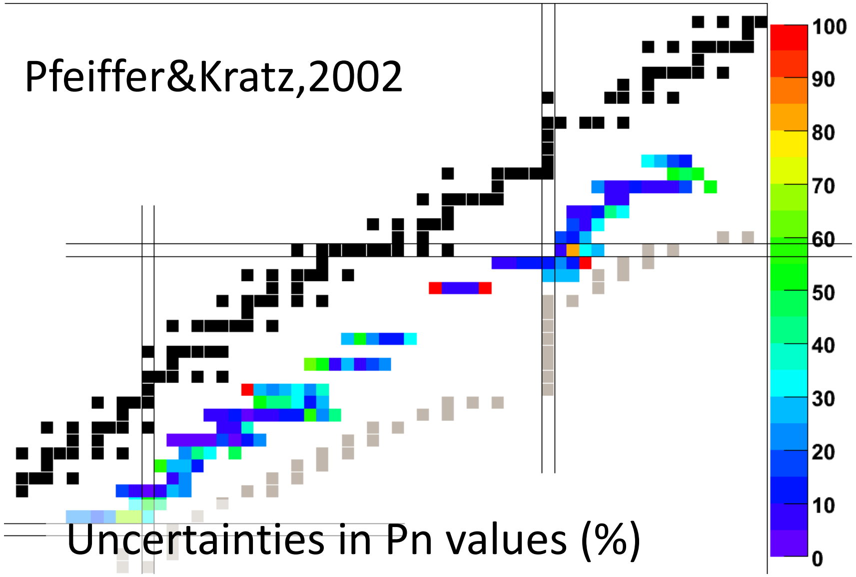
Number of delayed neutrons per fission

$$\overline{\nu}_d = \sum_i Y_i \cdot P_n^i$$

Used to identify P_n values that should be revisited (sensitivity study)



FF distribution



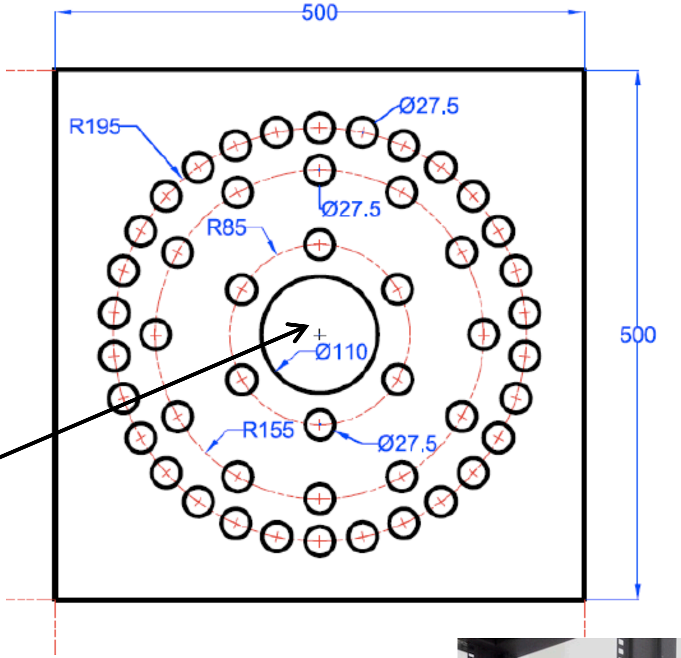
Pfeiffer&Kratz,2002

Uncertainties in Pn values (%)

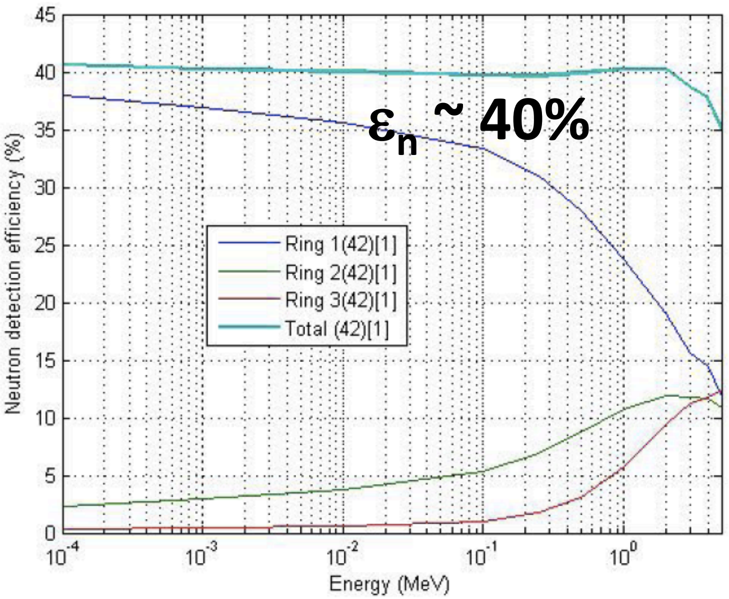
* Supported by FP7-EURATOM CHANDA Project

I162: BELEN-48a

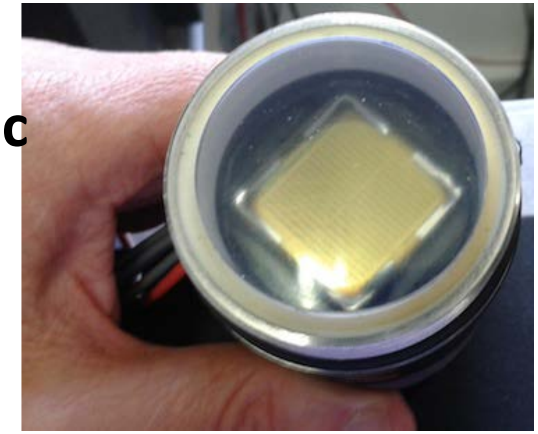
48x 3He tubes
@ 8 & 10 atm



Inner hole 11 cm
in diameter



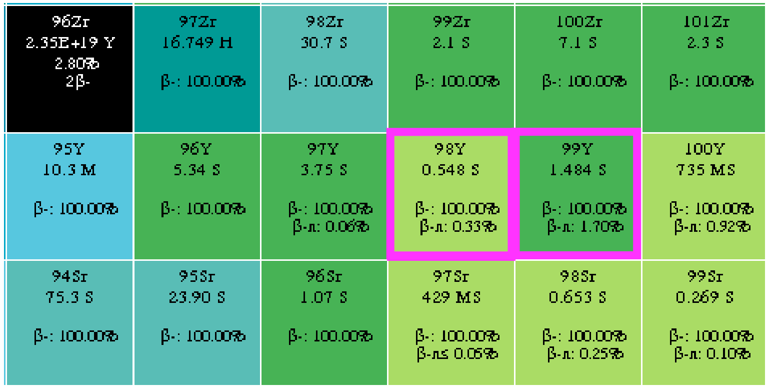
New Plastic Scint. Beta detector



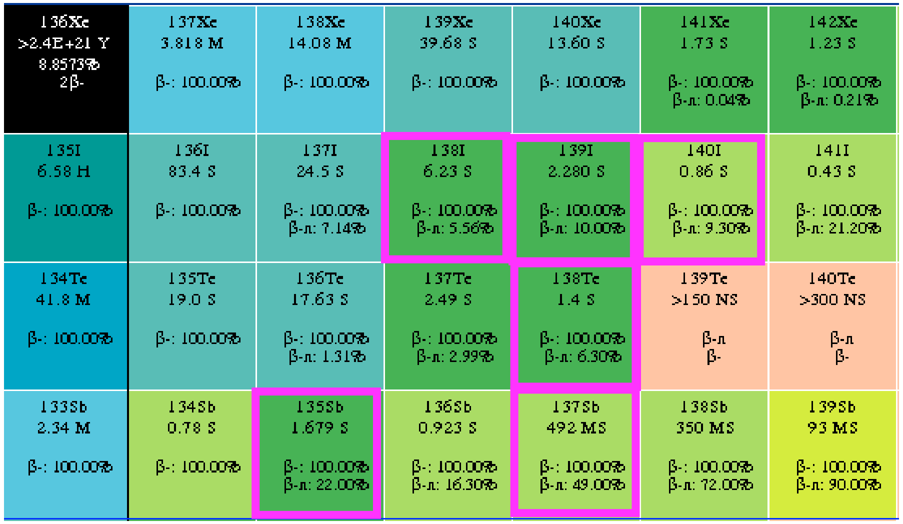
Setup with HPGe detector

Trigger-less DACQ

Data acquired for: ^{98,98m,99}Y, ^{135,137}Sb, ^{138}Te, ^{138,139,140}I

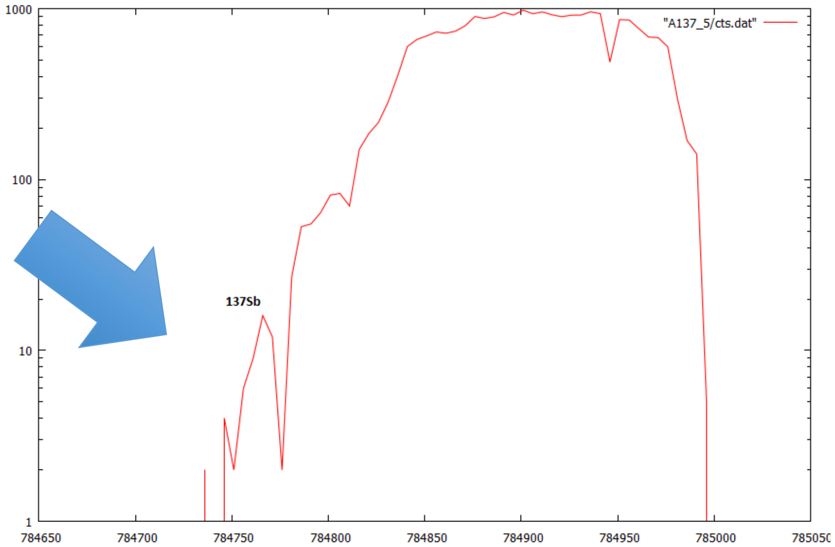


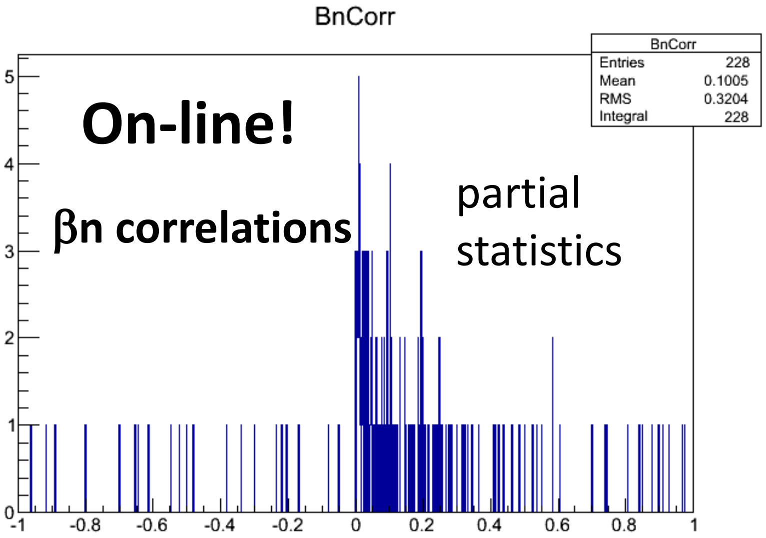
96Zr 2.35E+19 Y 2.80% 2β-	97Zr 16.749 H β-: 100.00%	98Zr 30.7 S β-: 100.00%	99Zr 2.1 S β-: 100.00%	100Zr 7.1 S β-: 100.00%	101Zr 2.3 S β-: 100.00%
95Y 10.3 M β-: 100.00%	96Y 5.34 S β-: 100.00%	97Y 3.75 S β-: 100.00% β-n: 0.06%	98Y 0.548 S β-: 100.00% β-n: 0.33%	99Y 1.484 S β-: 100.00% β-n: 1.70%	100Y 735 MS β-: 100.00% β-n: 0.92%
94Sr 75.3 S β-: 100.00%	95Sr 23.90 S β-: 100.00%	96Sr 1.07 S β-: 100.00%	97Sr 429 MS β-: 100.00% β-n≤ 0.05%	98Sr 0.653 S β-: 100.00% β-n: 0.25%	99Sr 0.269 S β-: 100.00% β-n: 0.10%



136Xe >2.4E+21 Y 8.8573% 2β-	137Xe 3.818 M β-: 100.00%	138Xe 14.08 M β-: 100.00%	139Xe 39.68 S β-: 100.00%	140Xe 13.60 S β-: 100.00%	141Xe 1.73 S β-: 100.00% β-n: 0.04%	142Xe 1.23 S β-: 100.00% β-n: 0.21%
135I 6.58 H β-: 100.00%	136I 83.4 S β-: 100.00%	137I 24.5 S β-: 100.00% β-n: 7.14%	138I 6.23 S β-: 100.00% β-n: 5.56%	139I 2.280 S β-: 100.00% β-n: 10.00%	140I 0.86 S β-: 100.00% β-n: 9.30%	141I 0.43 S β-: 100.00% β-n: 21.20%
134Te 41.8 M β-: 100.00%	135Te 19.0 S β-: 100.00%	136Te 17.63 S β-: 100.00% β-n: 1.31%	137Te 2.49 S β-: 100.00% β-n: 2.99%	138Te 1.4 S β-: 100.00% β-n: 6.30%	139Te >150 NS β-n β-	140Te >300 NS β-n β-
133Sb 2.34 M β-: 100.00%	134Sb 0.78 S β-: 100.00%	135Sb 1.679 S β-: 100.00% β-n: 22.00%	136Sb 0.923 S β-: 100.00% β-n: 16.30%	137Sb 492 MS β-: 100.00% β-n: 49.00%	138Sb 350 MS β-: 100.00% β-n: 72.00%	139Sb 93 MS β-: 100.00% β-n: 90.00%

Most challenging Sb-137: implantation rate: 0.5cps





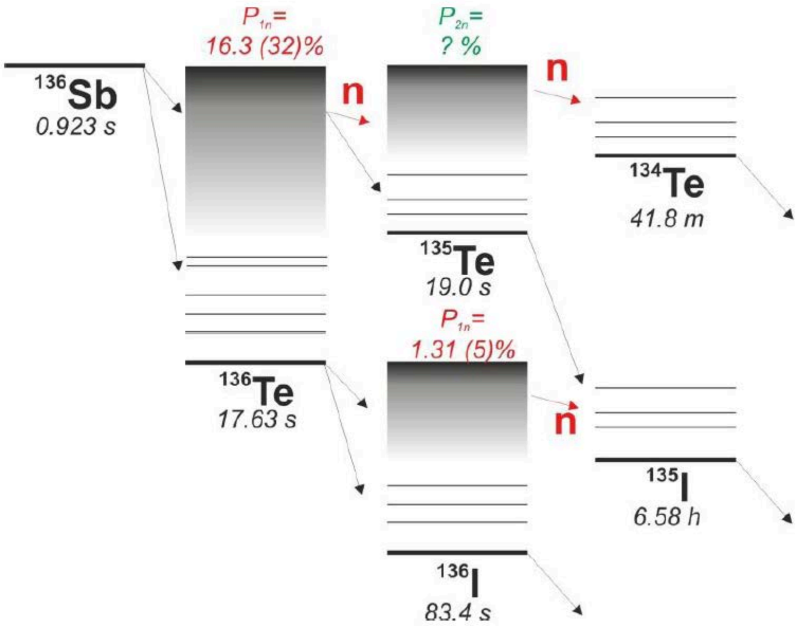
On-line!

βn correlations

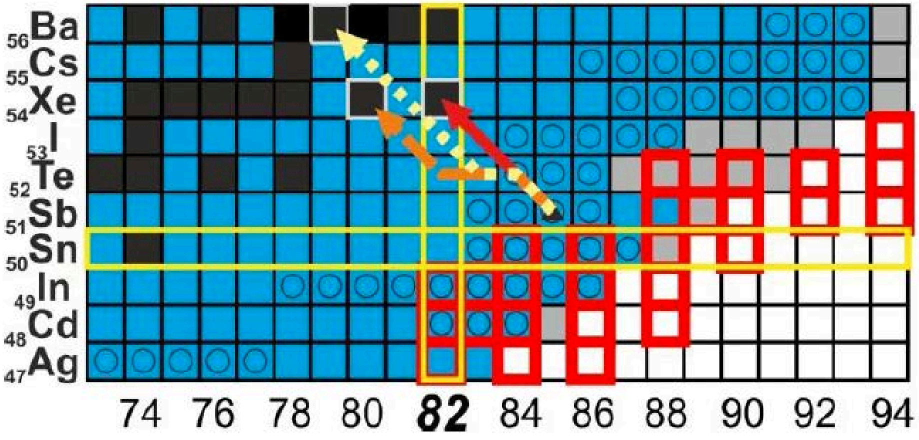
partial statistics

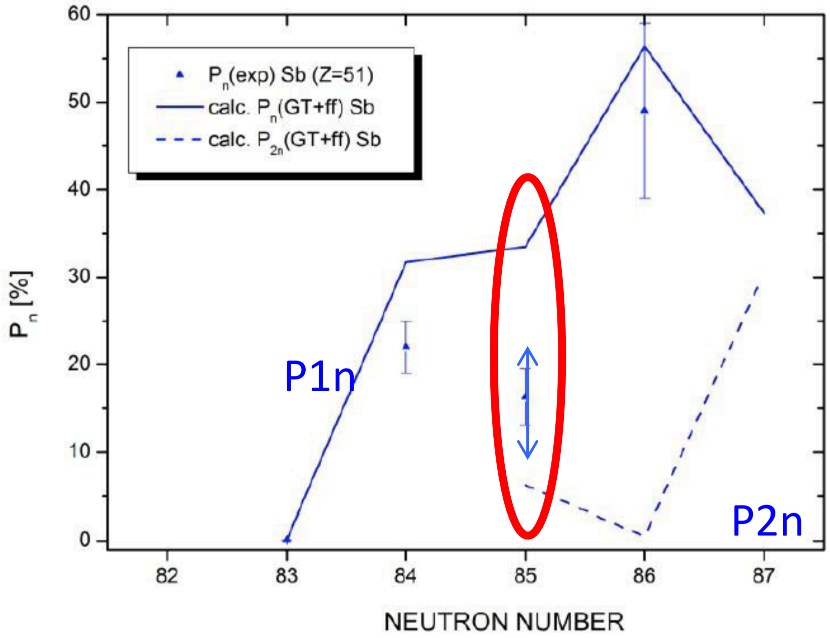
Off-line analysis in progress: PhD thesis J. Agramunt and A. Tolosa

I181: Measurement of the beta-delayed two-neutron emitter Sb-136 with the BELEN detector (I.Dillmann-TRIUMF, et al.)

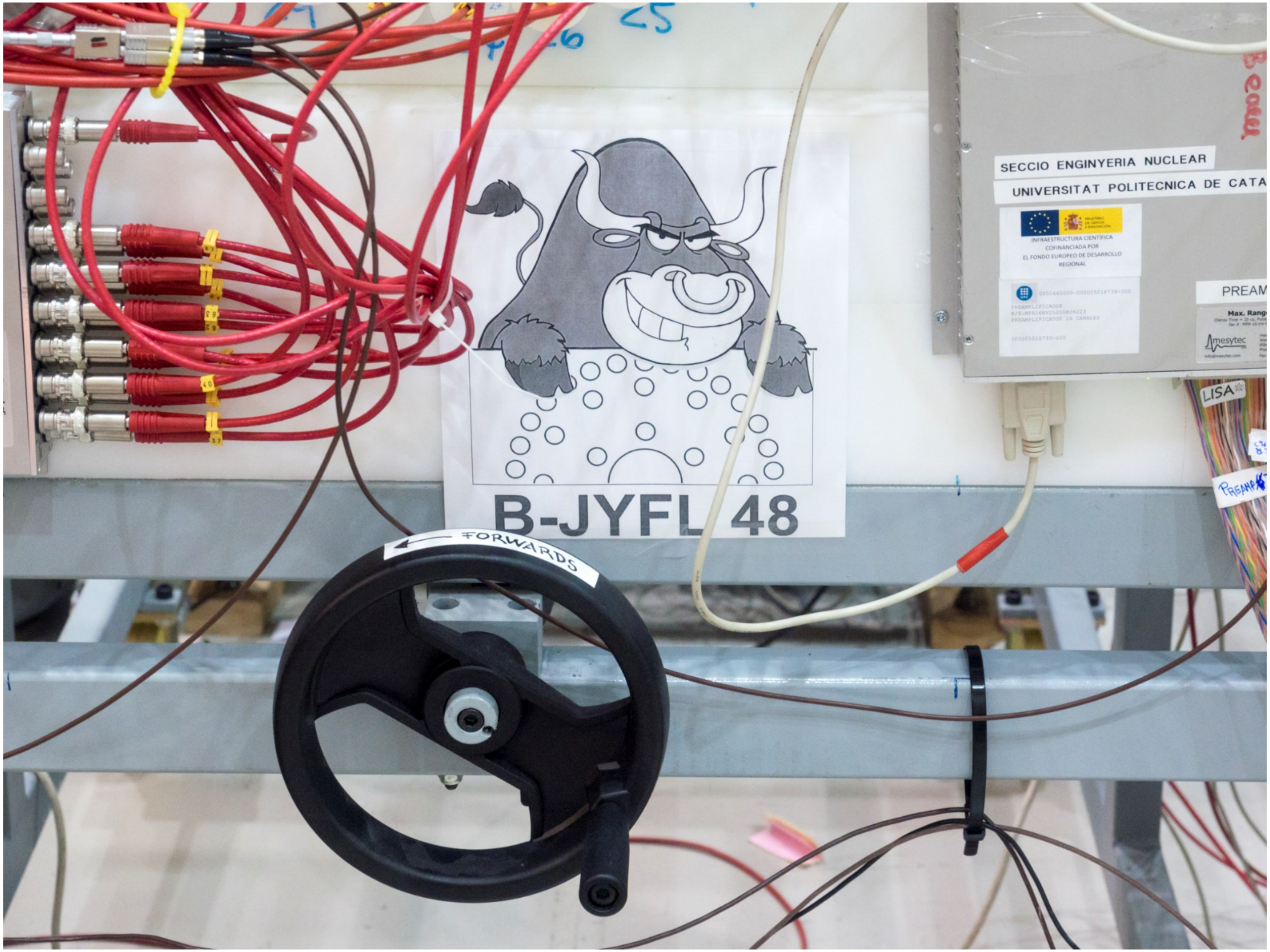


- Sizeable P_{2n} emission predicted
- Close to r-process path and 132Sn
- Accessible at JYFL as pure isotopic beam

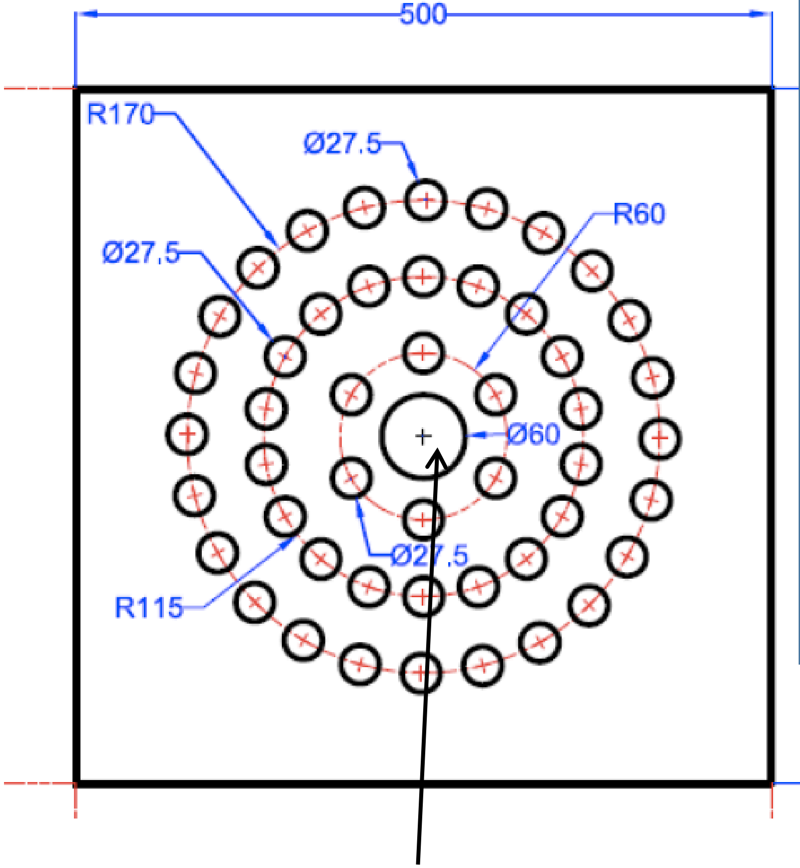




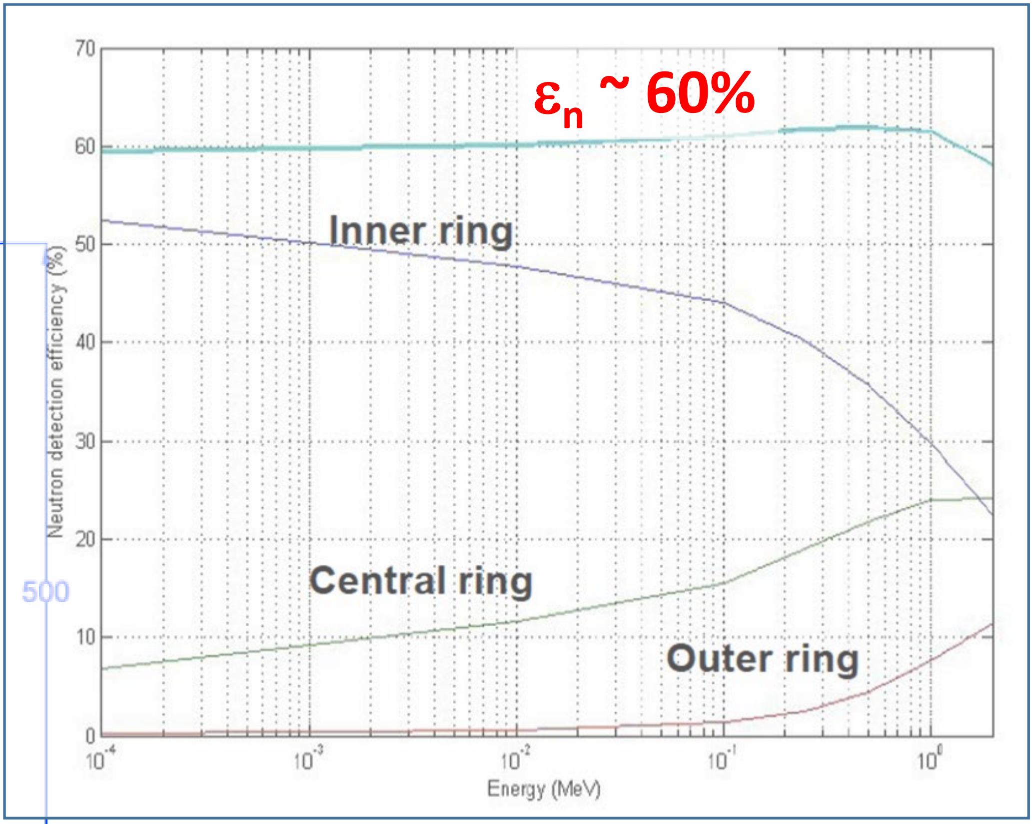
I181: BELEN-48b



I181: BELEN-48b

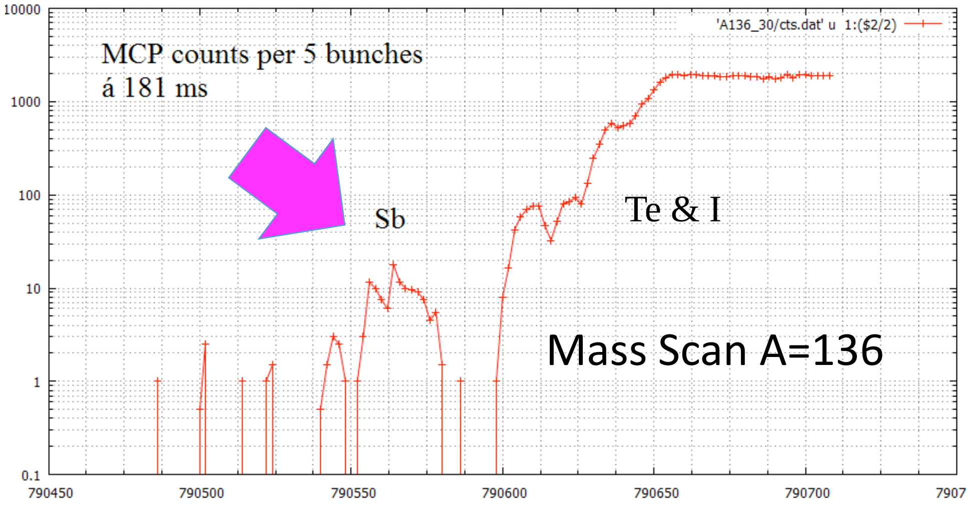


Inner hole 6 cm in diameter


ε_n ~ 60%

Configuration optimized for efficiency: 50% increase. Factor 2 for nn detection

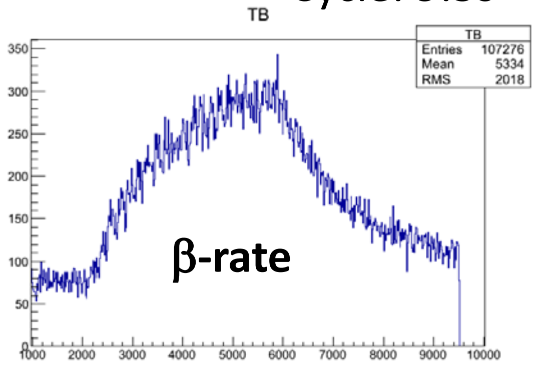
I181: BELEN-48b



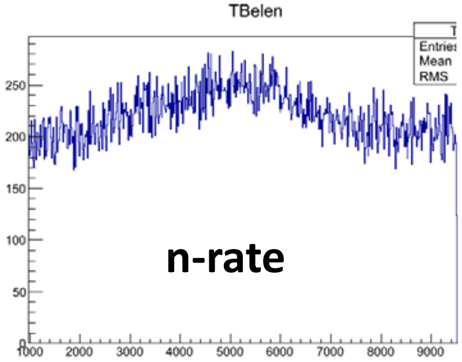
Mass Scan A=136

Implantation rate: 1.5cps

Cycle: 9.5s



β-rate



n-rate

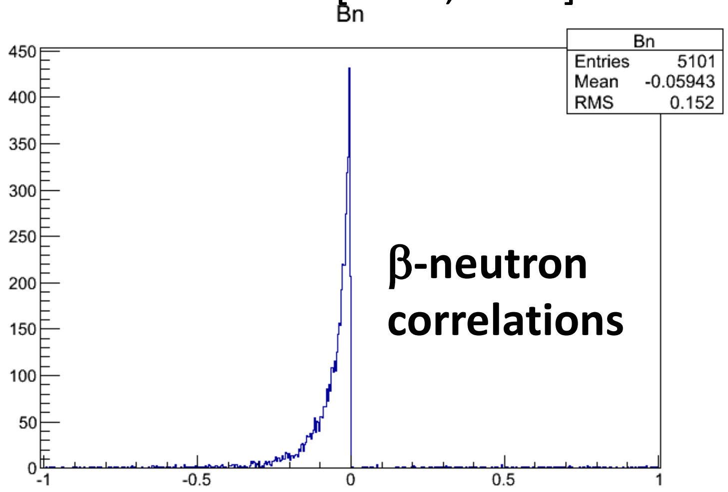
Analysis in progress:

R. Caballero-Foch (TRIUMF)

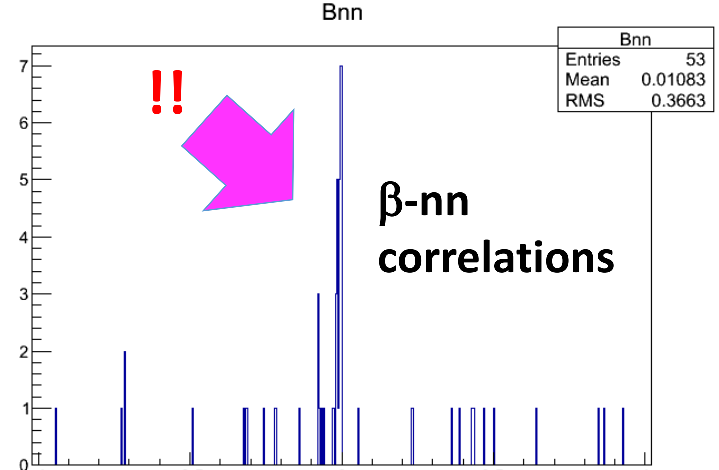
Some on-line plots !

(partial statistics)

Correlation time window: [-1ms,+1ms]



β-neutron correlations



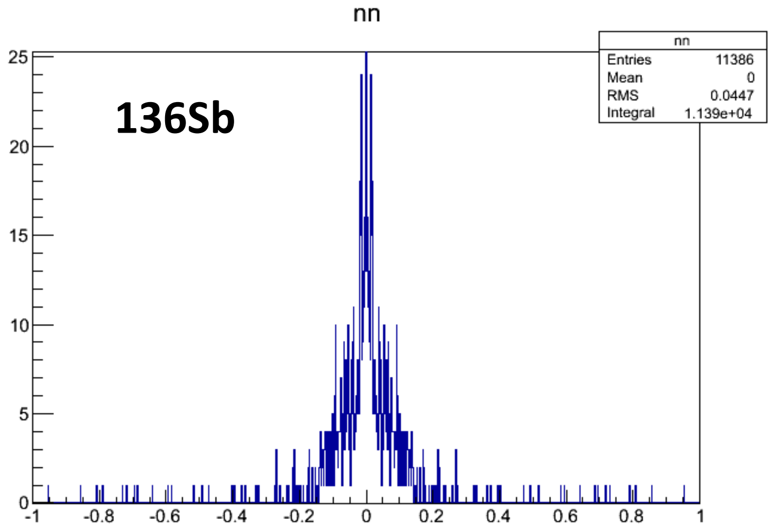
!!

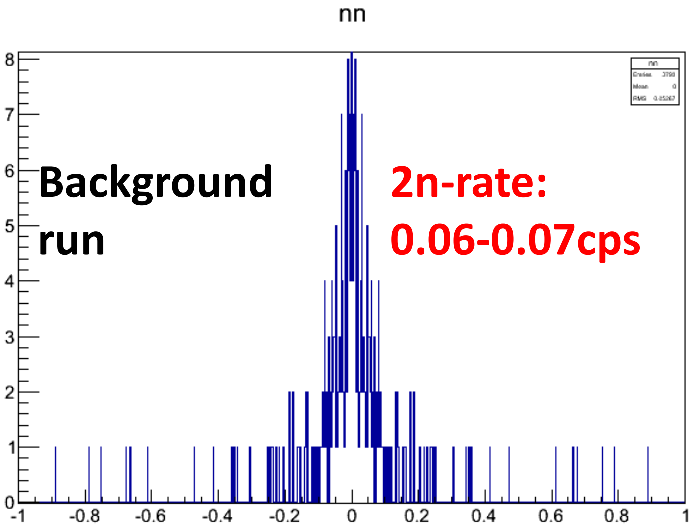
β-nn correlations

I181: BELEN-48b

2n correlated background:

window: [-1ms,+1ms]





Background run

2n-rate: 0.06-0.07cps

Bkg. n-rate: 1.5cps

Reeder et al PRL47(1981)483:

- Similar detector: 42x 8atm tubes, 3 rings, ε_n=59%,
  but PE: 50cmx50cmx50cm
- nn background rate: 0.012cps (5x lower!)
- Assume cosmic-ray origin: muon capture and spallation

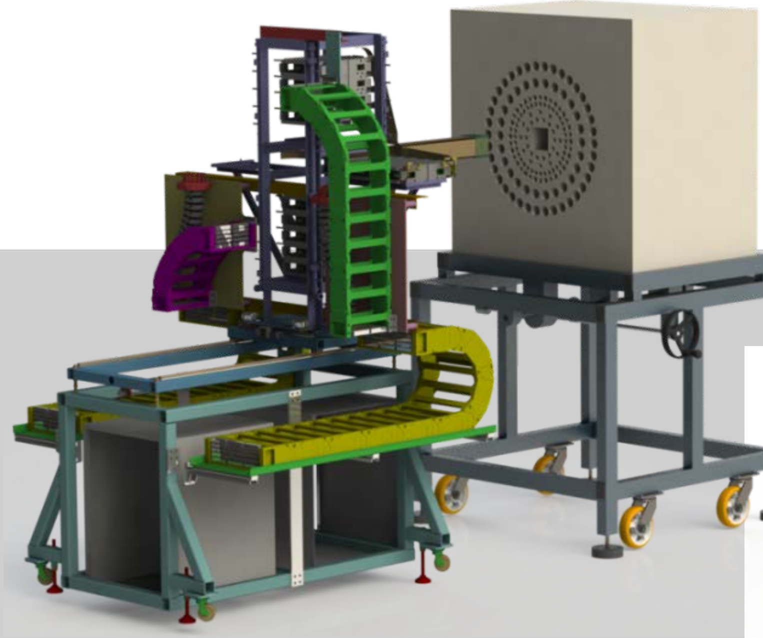
➔Limits measurements based on nn correlation (need of βnn corr.)

The BRIKEN Collaboration

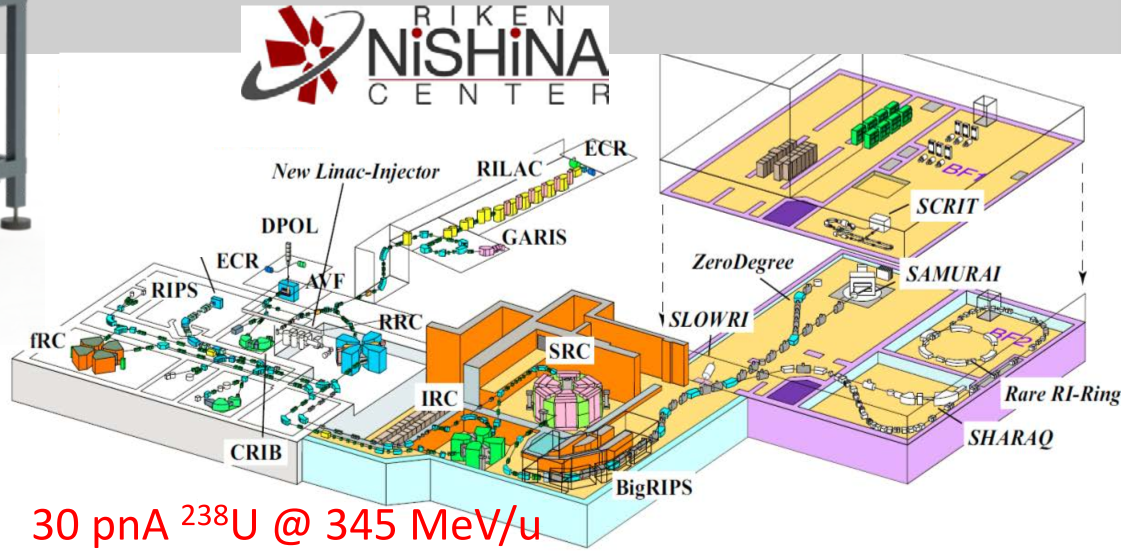
20 institutions, >50 participants

BELEN at RIKEN (BRIKEN)

Beta-delayed neutron measurements of the most exotic nuclei

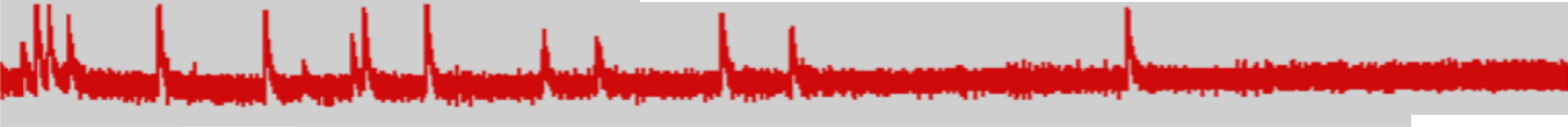


- **The largest beta-delayed neutron detector**
- **The AIDA implantation detector**
- **BigRIPS spectrometer @ RIKEN**

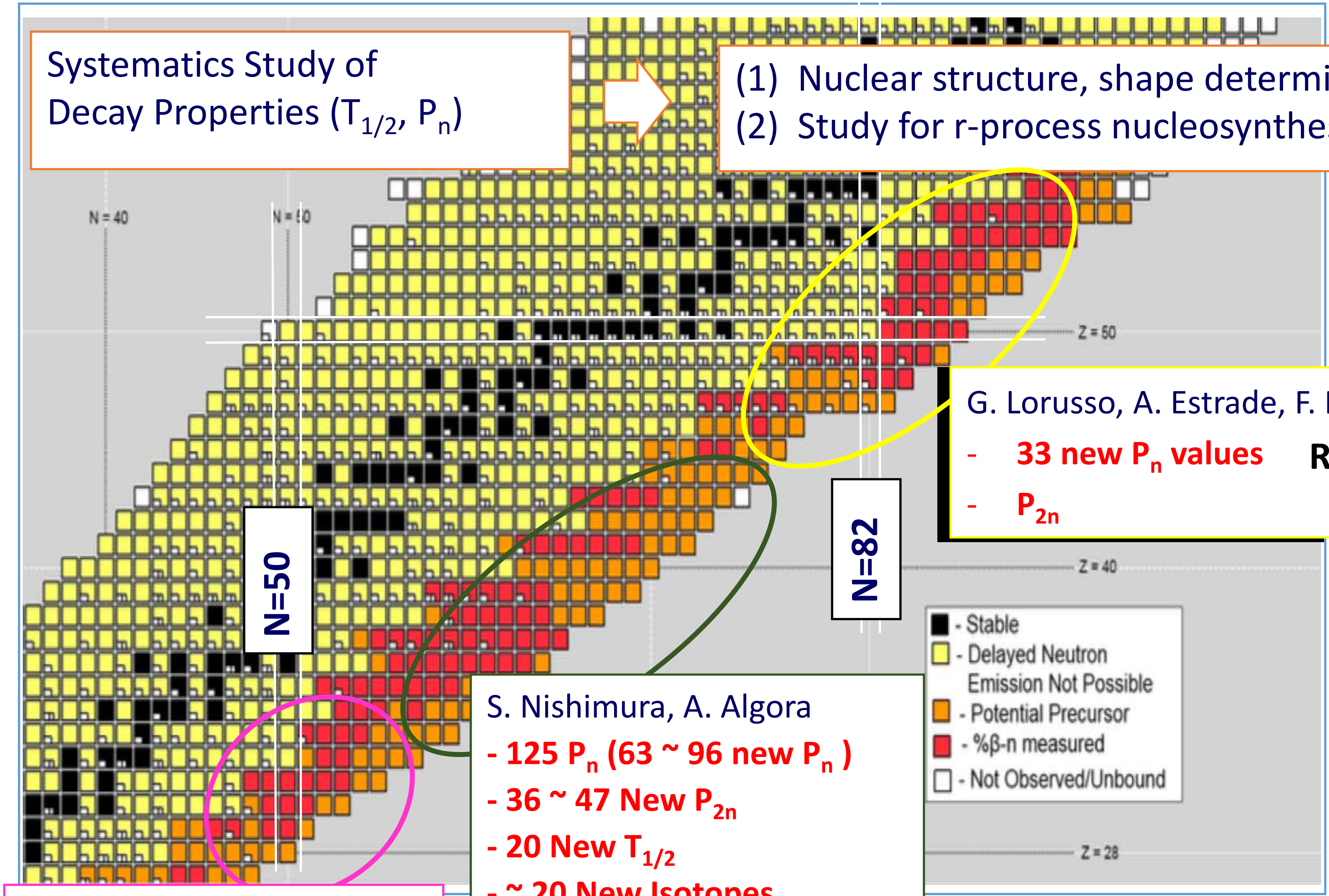


30 pnA ^{238}U @ 345 MeV/u

- **20 institutions**
- **50 participants**



Physics at BRIKEN: Accepted proposals for measurements



Systematics Study of Decay Properties ($T_{1/2}$, P_n)

(1) Nuclear structure, shape determination
(2) Study for r-process nucleosynthesis

G. Lorusso, A. Estrade, F. Montes
- **33 new P_n values** **RIB127**
- **P_{2n}**

S. Nishimura, A. Algora
- **125 P_n (63 ~ 96 new P_n)**
- **36 ~ 47 New P_{2n}**
- **20 New $T_{1/2}$**
- **~ 20 New Isotopes**

RIB139

K. Rykaczewski, J. Tain,
R. Grzywacz, I. Dillmann
- **20 new P_n values** **RIB128**

Status of the BRIKEN project

Design of a flexible neutron counter for BRIKEN

A. Tarifeño-Saldivia(IFIC & UPC), J.L. Tain(IFIC) and C. Domingo-Pardo(IFIC)

The BRIKEN detector is conceived to address measurements of very neutron-rich nuclei with astrophysical implications. The research will be focused on improvements of Pn uncertainties of known nuclei, measurements of multiple neutron emitters (2n, 3n, . . .) and study of the properties of very exotic unknown nuclei. To meet these research goals, regarding current production rates at RIKEN, the main requirements for the BRIKEN neutron counter are:

1. Neutron efficiency higher than 60% up to 1MeV.
2. Flat response up to 1MeV and small variations of the efficiency up to 5MeV.
3. Gamma-ray detection capabilities compatible with high neutron efficiency and flatness (hybrid mode).

How to do it?
Using 3He counter, but...

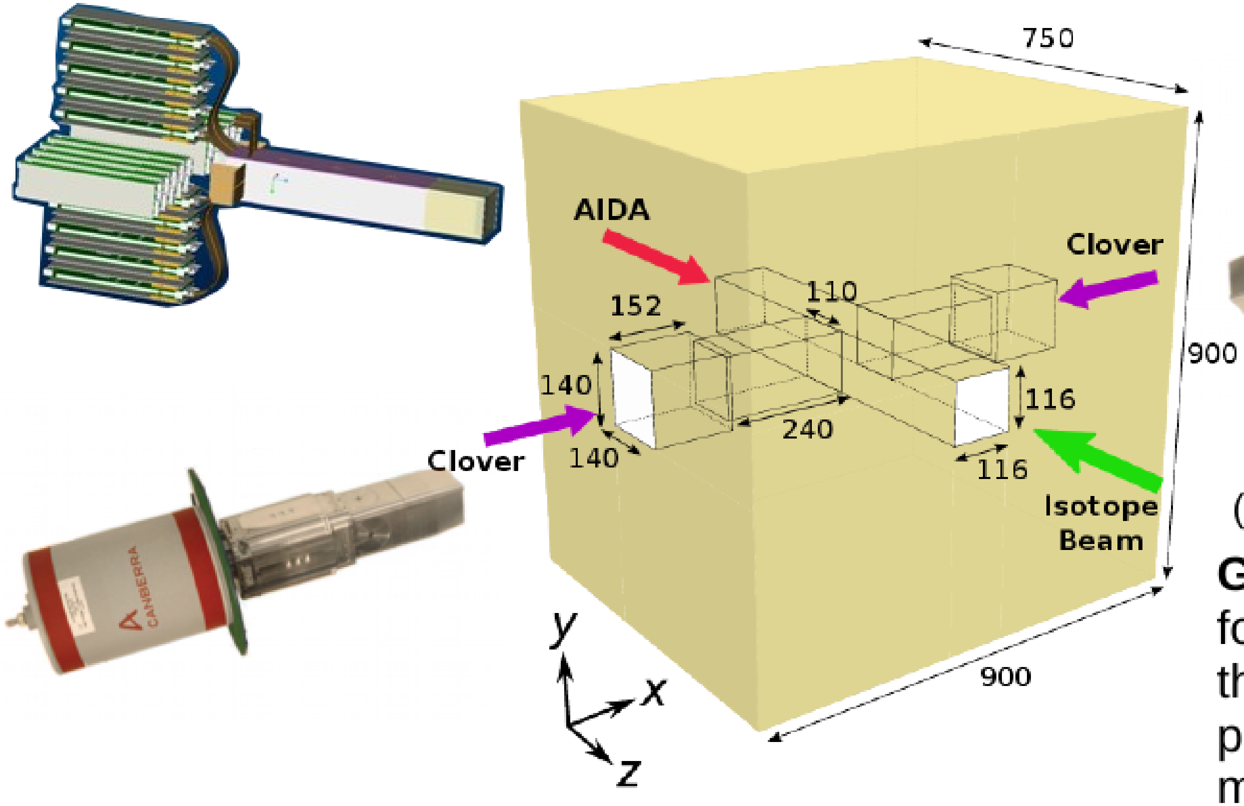
179!!

Hybrid detector using ORNL clovers			
Owner group	**Diameter (inch/cm)**	**Eff. Length (inch/mm)**	**Total counters**
UPC + GSI	1 / 2.54	23.62 / 600	52
ORNL	1 / 2.54	24 / 609.6	17
ORNL	2 / 2.54	24 / 609.6	64
RIKEN	1 / 2.54	118.1 / 300	26
JINR	1.18 / 3	~ 18.9 / 48	20
TOTAL			**179**

Status of the BRIKEN project

We have developed a parametrized Monte Carlo optimization algorithm for Geant4

Hybrid mode



Geant 4

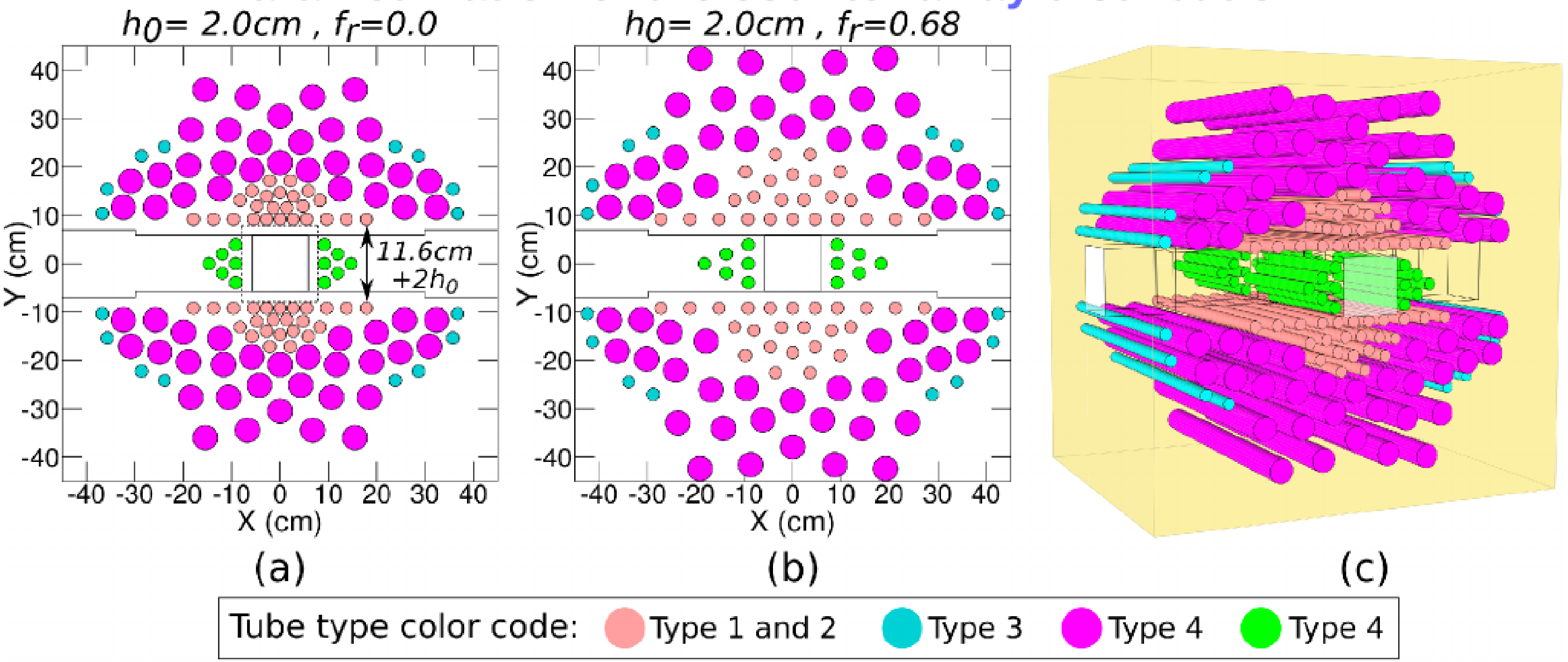
(**GE**ometry **AN**d **T**racking)

Geant4 is a toolkit for the simulation of the passage of particles through matter.

Problem:
How to place 179 counters to obtain the efficiency as high and flat as possible?

Status of the BRIKEN project

Parametrization of the counter array distribution



Parametrization hybrid mode:

P = $P(i, h_0, f_r)$

i: Group index

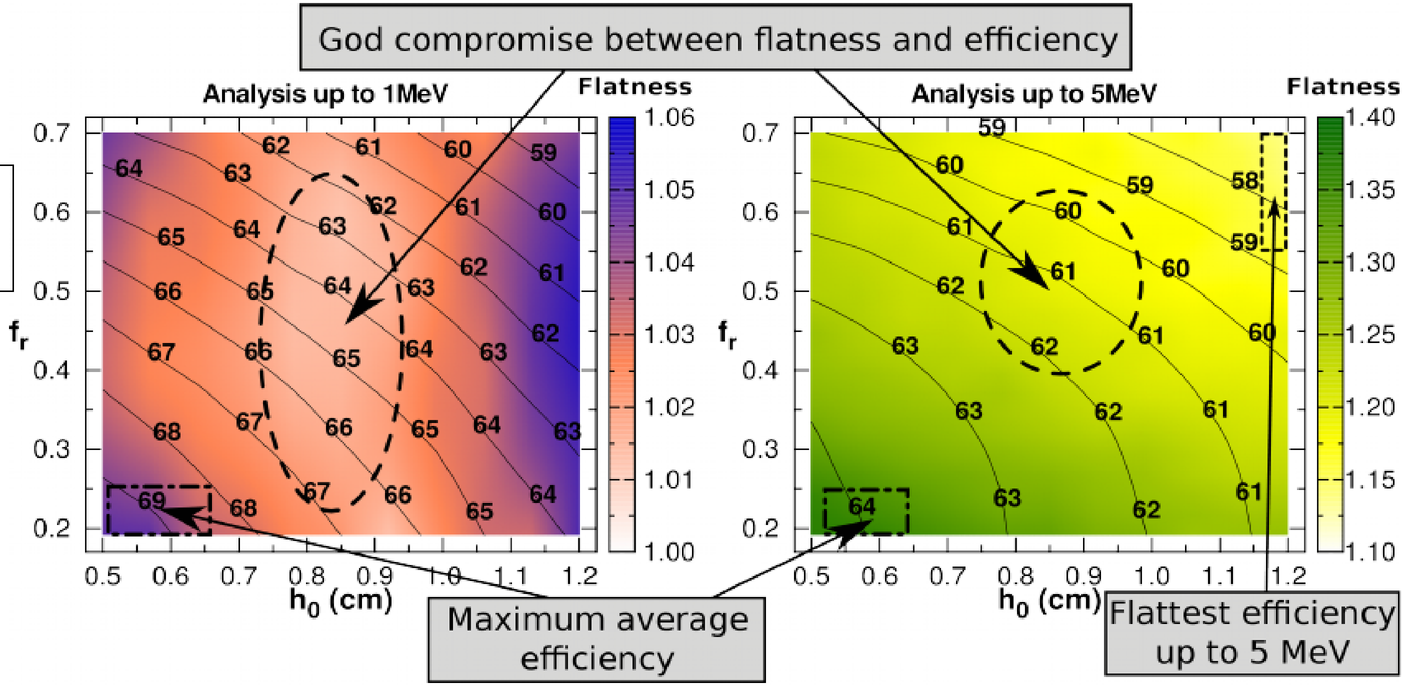
h_0: Separation from inner border

f_r: Separation between counters

Hybrid detector using ORNL clovers						
Owner group	Diameter (inch/cm)	Eff. Length (inch/mm)	Total counters	Used counters	Available	Color code
UPC + GSI	1 / 2.54	23.62 / 600	52	48	4	🟥
ORNL	1 / 2.54	24 / 609.6	17	16	1	🟦
ORNL	2 / 2.54	24 / 609.6	64	60	4	🟪
RIKEN	1 / 2.54	118.1 / 300	26	24	2	🟩
JINR	1.18 / 3	~ 18.9 / 48	20	0	20	🟧
TOTAL			179	148	31	

Status of the BRIKEN project

Monte Carlo simulation results



God compromise between flatness and efficiency

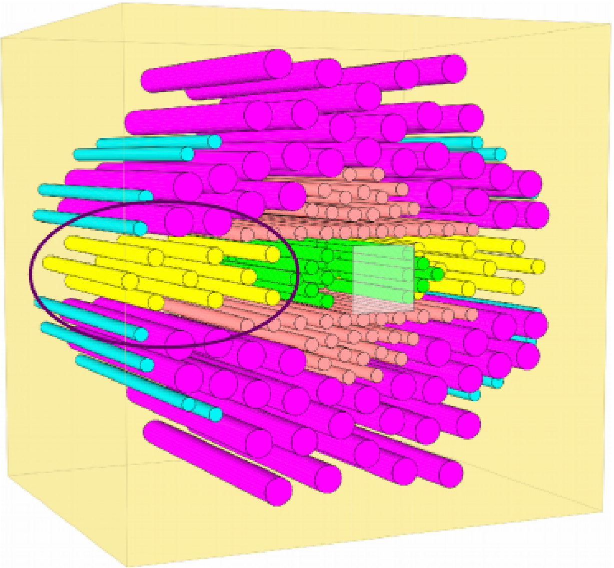
Maximum average efficiency

Flattest efficiency up to 5 MeV

FLEXIBLE design concept: Compact mode

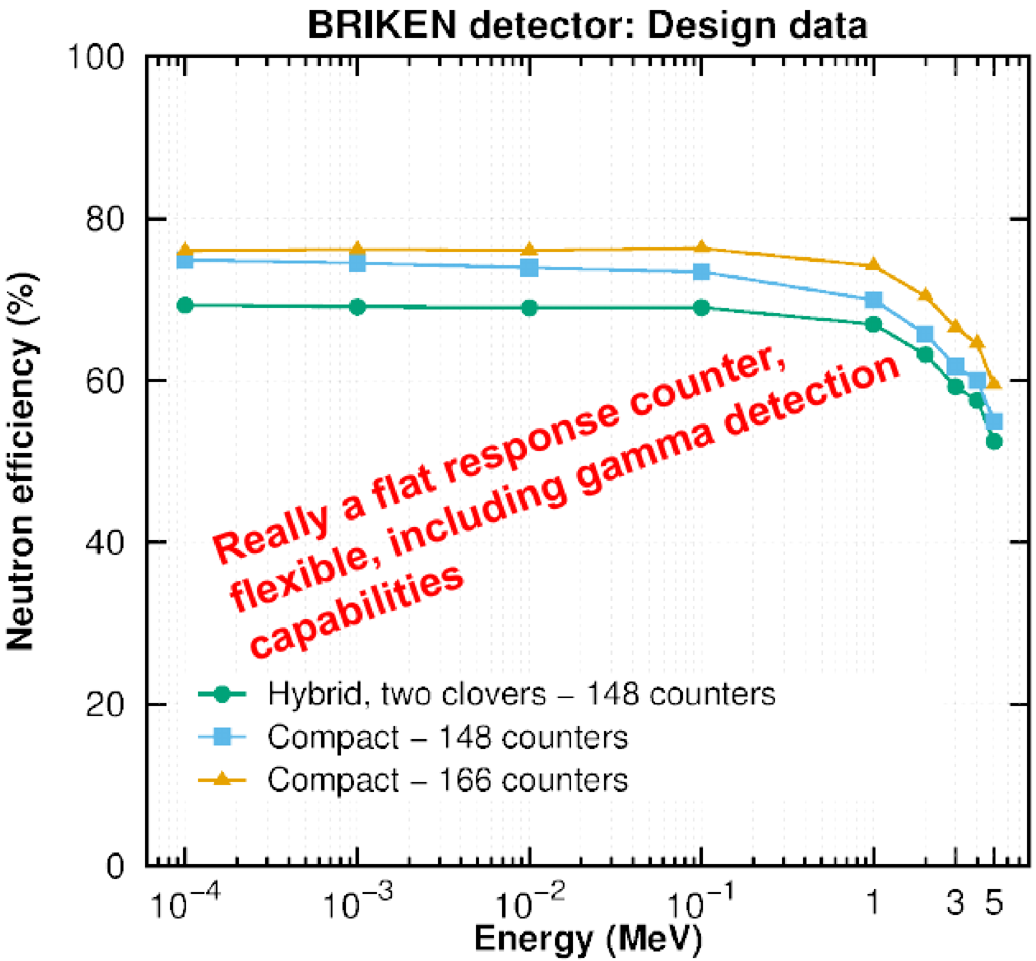
Removing clovers, insertion of a PE piece fitting the hole geometry. Using JINR counters. Thus, we have **148 + 18 =166** counters:

Hybrid detector using ORNL clovers						
Owner group	**Diameter (inch/cm)**	**Eff. Length (inch/mm)**	**Total counters**	**Used counters**	**Available**	**Color code**
UPC + GSI	**1 / 2.54**	**23.62 / 600**	**52**	**48**	**4**	🟥
ORNL	**1 / 2.54**	**24 / 609.6**	**17**	**16**	**1**	🟦
ORNL	**2 / 2.54**	**24 / 609.6**	**64**	**60**	**4**	🟪
RIKEN	**1 / 2.54**	**118.1 / 300**	**26**	**24**	**2**	🟩
JINR	**1.18 / 3**	**~ 18.9 / 48**	**20**	**18**	**2**	🟧
TOTAL			**179**	**166**	**13**	



Status of the BRIKEN project

The BRIKEN neutron counter



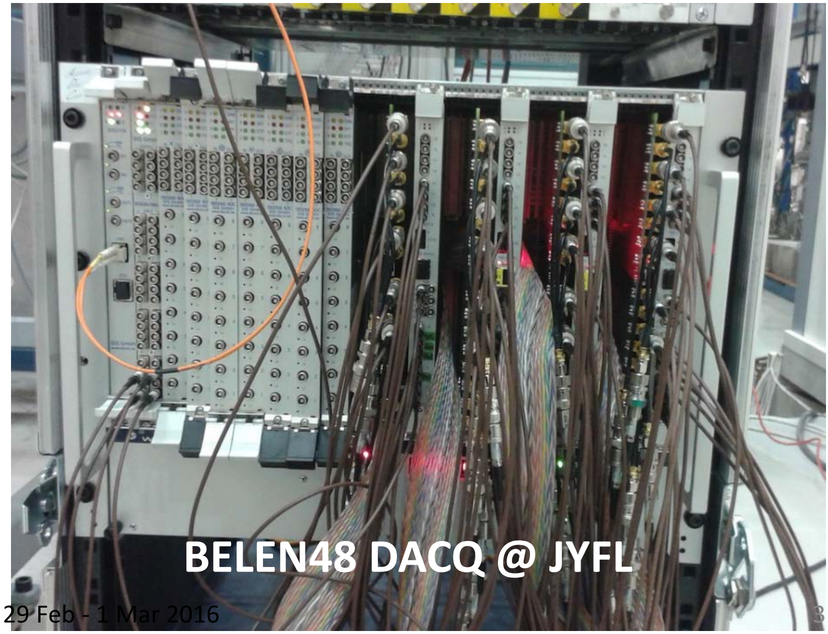
Really a flat response counter, flexible, including gamma detection capabilities

PE moderator already constructed.
It has just arrived at RIKEN! ☺

Development of the DACQ for the BRIKEN neutron detector

J. Agramunt and A. Tolosa (IFIC)

- Enhancement of our BELEN trigger-less DACQ
- New digitizers Struck SIS3316 (250MHz,16ch, 7modules) added to original SIS3302 (100MHz, 8ch, 8modules) dig.
- Multi-crate (VME)
- New differential-unipolar converter cards
- New DACQ control and on-line software
- **48 channel system tested at JYFL (Nov. 2014)**
- **First synchronization test with AIDA-DACQ and BIGRIBS-DACQ at RIKEN (Feb. 2015)**
- Ongoing tests at IFIC with BELEN-48



BELEN48 DACQ @ JYFL

Next

- BRIKEN!!!

- Spectrometric capabilities (Bonner spheres principle)
- New semiconductor n-detectors (?)
- New collaborations are welcome

Summary and Conclusions

- He-3 excellent for thermal n detection (50+ available)
- Different configurations tested
- Configuration is experiment dependent
- Expertise on optimization
- Trigger-less DACQ very important
- … can be used for background measurements (Felsenkeller, LSC, … → Tain)
- …

Backup slides

Development of the DACQ for the BRIKEN neutron detector

J. Agramunt and A. Tolosa (IFIC)

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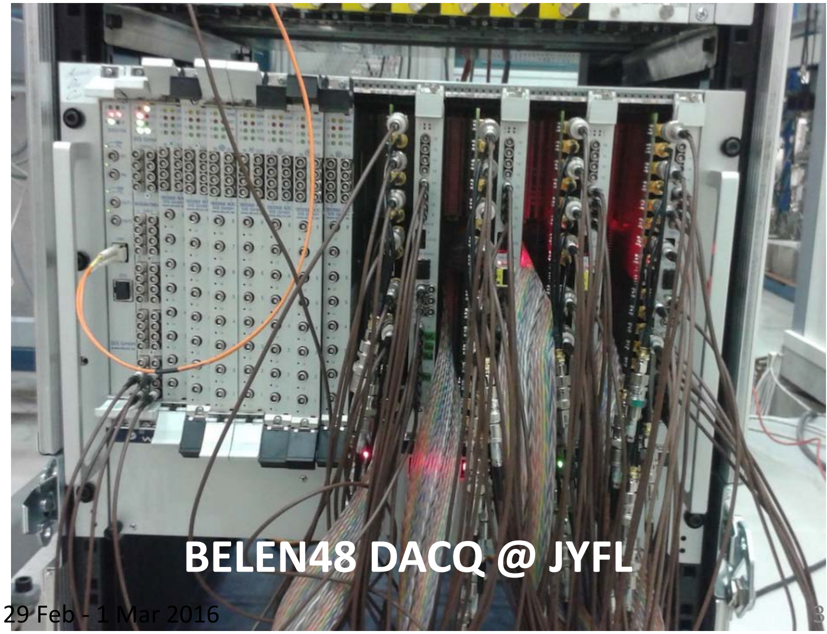
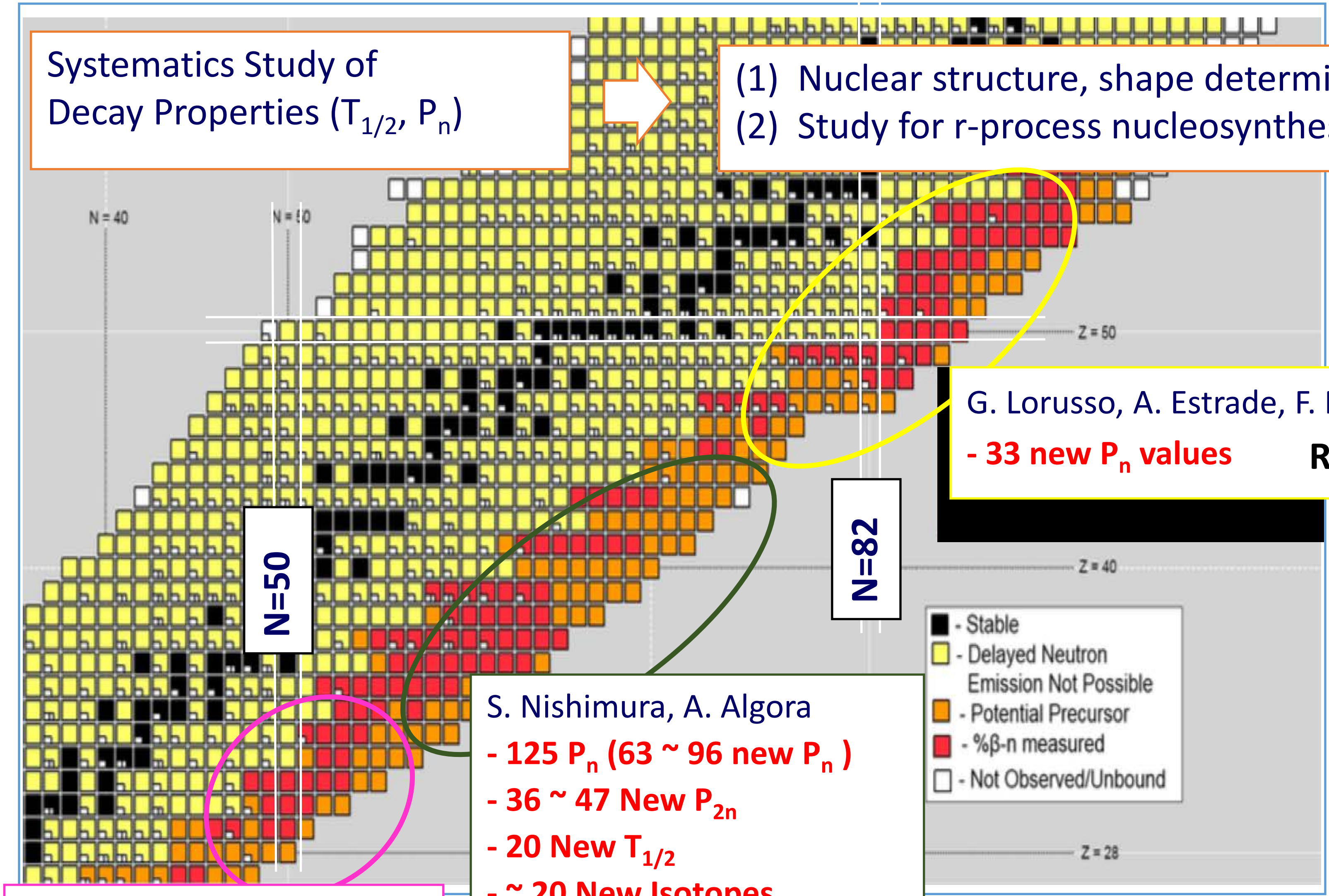


BELEN48 DACQ @ JYFL

Physics at BRIKEN: Accepted proposals for measurements



Systematics Study of Decay Properties ($T_{1/2}$, P_n)

(1) Nuclear structure, shape determination
(2) Study for r-process nucleosynthesis

G. Lorusso, A. Estrade, F. Montes

- 33 new P_n values **RIB127**

S. Nishimura, A. Algora

- 125 P_n (63 ~ 96 new P_n)
- 36 ~ 47 New P_{2n}
- 20 New $T_{1/2}$
- ~ 20 New Isotopes

RIB139

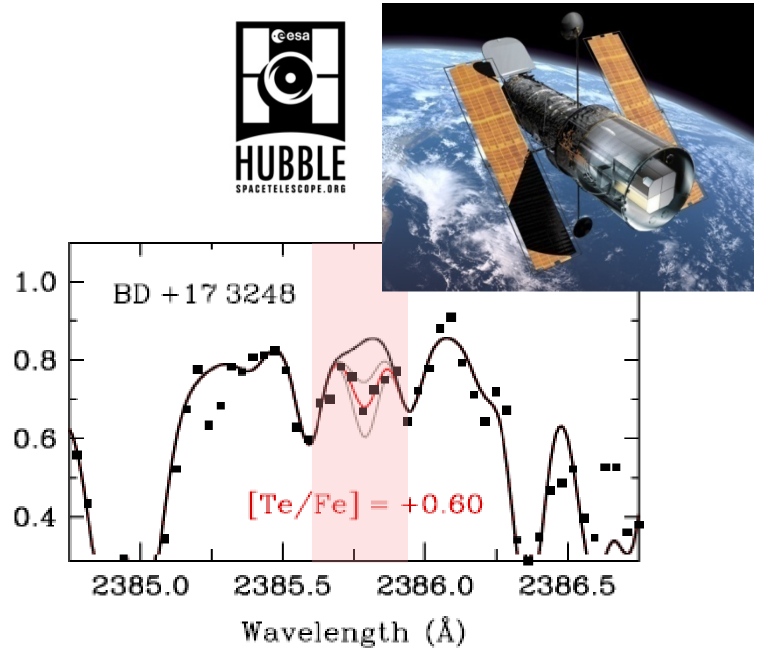
K. Rykaczewski, J. Tain,
R. Gryzywacz, I. Dillmann

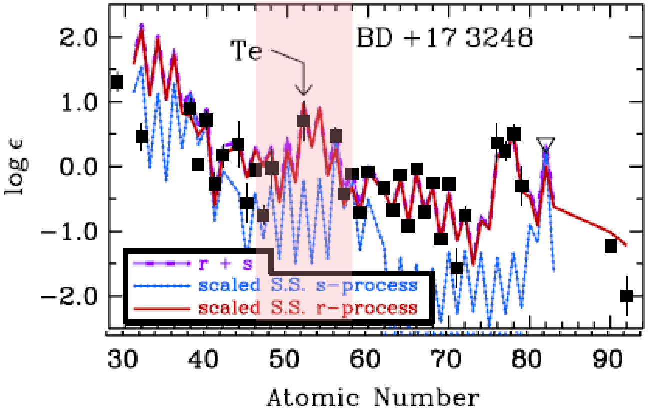
- 20 new P_n values **RIB128**

RIBF127: βn-relevant for the A = 130 r-process peak

Spokespersons: G. Lorusso(NPL), A. Estrade(Edinburgh), F. Montes(NSCL)

First observation of Te in metal poor stars (!!)



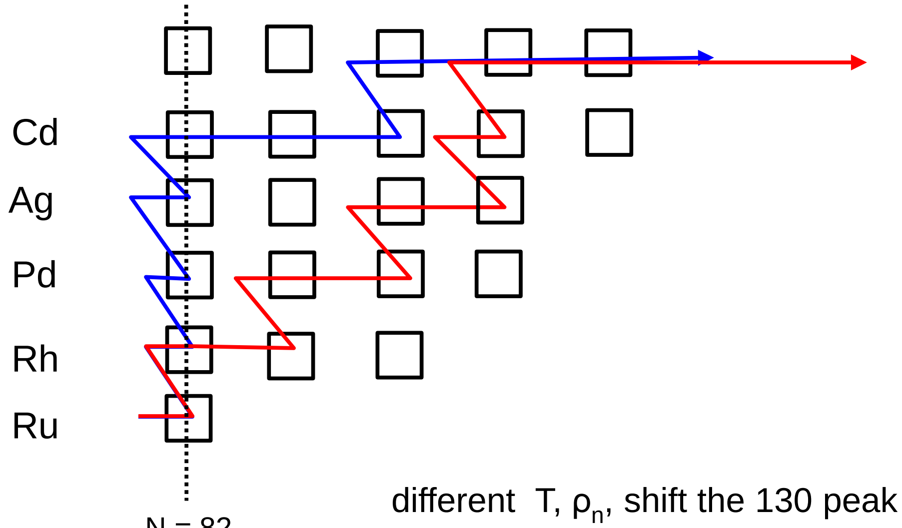


I. Roederer et al., The Astroph. Journ. Lett. 2012

- New Te observation (A ≤ 130) and Ba (A ≥ 140) highlight r-process conditions in single r-process events (!)
- Te-abundance in UMP-Stars offers and independent test on the predicted r-process abundance of Te in the S.S.
- Relevant to constrain the conditions of the r-process operating early in the Galaxy

(not averaged like in the solar)

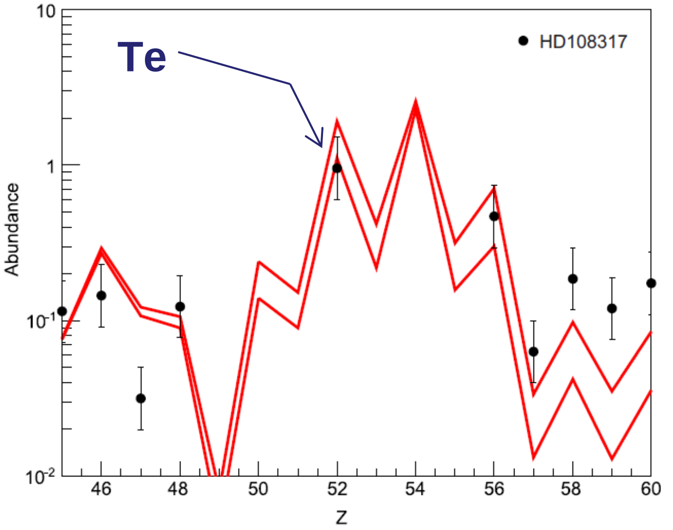
- Te/Ba ratio is sensitive to
  - + r-process conditions
  - + contribution of the weak r-process
- Pn is one of the important unknown affecting the ratio Te/Ba



different T, ρ_n, shift the 130 peak

RIBF127: βn-relevant for the A = 130 r-process peak

Elemental distribution in HD108317



Main Motivations

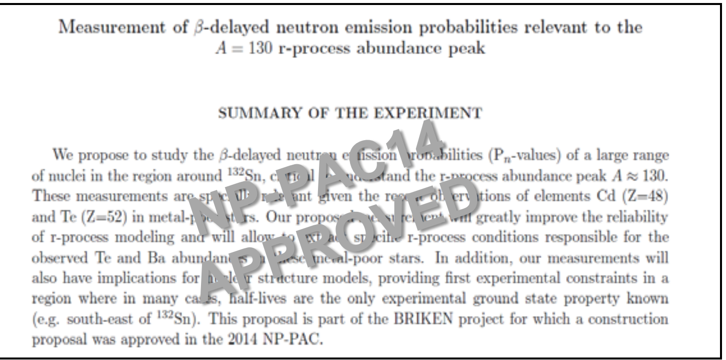
1) N = 82 nuclei (^{129}Ag, ^{128}Pd, ^{127}Rh)
   - possibly the most exotic probe of shell model
   - possibly the largest source of neutron during freezout

2) Rh, Pd, Ag are progenitors of Te (^{131}Ag, ^{129}Pd)
   Sb, Sn, In are progenitors of Ba

3) Candidate for b-2n, b-3n emission

Measurement of 33x$P_{\beta 1n}$, 11x$P_{\beta 2n}$ and 3x$P_{\beta 3n}$

All relevant to the A=130 peak



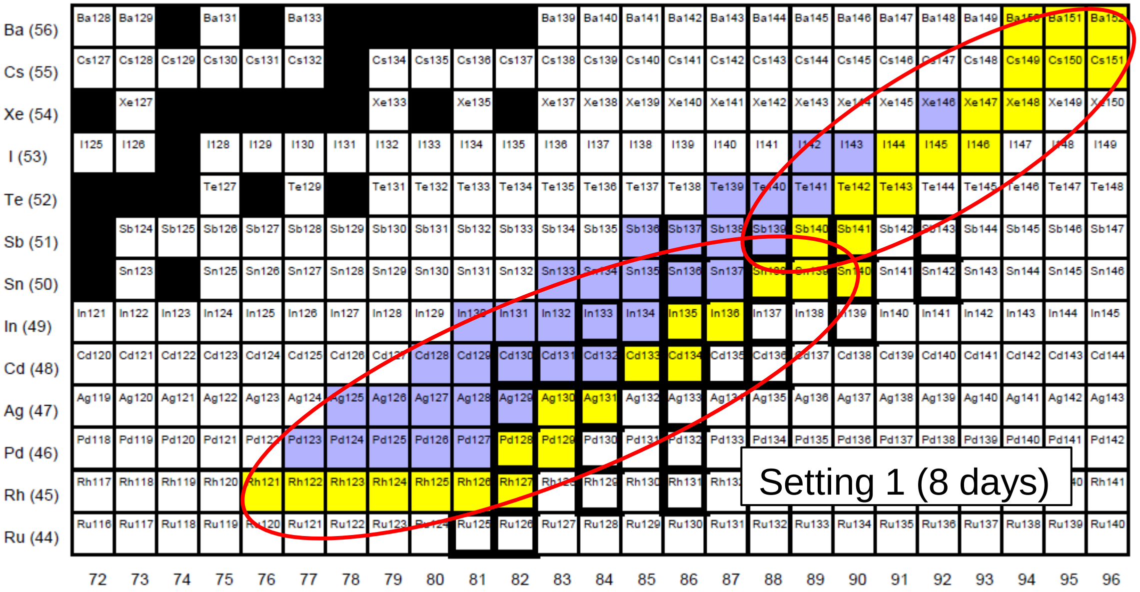
Measurement of β-delayed neutron emission probabilities relevant to the $A = 130$ r-process abundance peak

SUMMARY OF THE EXPERIMENT

We propose to study the β-delayed neutron emission probabilities (P_n-values) of a large range of nuclei in the region around ^{132}Sn, critical to understand the r-process abundance peak $A \approx 130$. These measurements are specially relevant given the recent observations of elements Cd (Z=48) and Te (Z=52) in metal-poor stars. Our proposed measurement will greatly improve the reliability of r-process modeling and will allow to extract specific r-process conditions responsible for the observed Te and Ba abundances in these metal-poor stars. In addition, our measurements will also have implications for nuclear structure models, providing first experimental constraints in a region where in many cases, half-lives are the only experimental ground state property known (e.g. south-east of ^{132}Sn). This proposal is part of the BRIKEN project for which a construction proposal was approved in the 2014 NP-PAC.

Spokespersons: A. Estrade, G. Lorusso, F.Montes

Setting 2 (2 days)



	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Ba (56)	Ba128	Ba129		Ba131		Ba133						Ba139	Ba140	Ba141	Ba142	Ba143	Ba144	Ba145	Ba146	Ba147	Ba148	Ba149	Ba150	Ba151	Ba152
Cs (55)	Cs127	Cs128	Cs129	Cs130	Cs131	Cs132		Cs134	Cs135	Cs136	Cs137	Cs138	Cs139	Cs140	Cs141	Cs142	Cs143	Cs144	Cs145	Cs146	Cs147	Cs148	Cs149	Cs150	Cs151
Xe (54)		Xe127						Xe133		Xe135		Xe137	Xe138	Xe139	Xe140	Xe141	Xe142	Xe143	Xe144	Xe145	Xe146	Xe147	Xe148	Xe149	Xe150
I (53)	I125	I126		I128	I129	I130	I131	I132	I133	I134	I135	I136	I137	I138	I139	I140	I141	I142	I143	I144	I145	I146	I147	I148	I149
Te (52)				Te127		Te129		Te131	Te132	Te133	Te134	Te135	Te136	Te137	Te138	Te139	Te140	Te141	Te142	Te143	Te144	Te145	Te146	Te147	Te148
Sb (51)		Sb124	Sb125	Sb126	Sb127	Sb128	Sb129	Sb130	Sb131	Sb132	Sb133	Sb134	Sb135	Sb136	Sb137	Sb138	Sb139	Sb140	Sb141	Sb142	Sb143	Sb144	Sb145	Sb146	Sb147
Sn (50)		Sn123		Sn125	Sn126	Sn127	Sn128	Sn129	Sn130	Sn131	Sn132	Sn133	Sn134	Sn135	Sn136	Sn137	Sn138	Sn139	Sn140	Sn141	Sn142	Sn143	Sn144	Sn145	Sn146
In (49)	In121	In122	In123	In124	In125	In126	In127	In128	In129	In130	In131	In132	In133	In134	In135	In136	In137	In138	In139	In140	In141	In142	In143	In144	In145
Cd (48)	Cd120	Cd121	Cd122	Cd123	Cd124	Cd125	Cd126	Cd127	Cd128	Cd129	Cd130	Cd131	Cd132	Cd133	Cd134	Cd135	Cd136	Cd137	Cd138	Cd139	Cd140	Cd141	Cd142	Cd143	Cd144
Ag (47)	Ag119	Ag120	Ag121	Ag122	Ag123	Ag124	Ag125	Ag126	Ag127	Ag128	Ag129	Ag130	Ag131	Ag132	Ag133	Ag134	Ag135	Ag136	Ag137	Ag138	Ag139	Ag140	Ag141	Ag142	Ag143
Pd (46)	Pd118	Pd119	Pd120	Pd121	Pd122	Pd123	Pd124	Pd125	Pd126	Pd127	Pd128	Pd129	Pd130	Pd131	Pd132	Pd133	Pd134	Pd135	Pd136	Pd137	Pd138	Pd139	Pd140	Pd141	Pd142
Rh (45)	Rh117	Rh118	Rh119	Rh120	Rh121	Rh122	Rh123	Rh124	Rh125	Rh126	Rh127	Rh128	Rh129	Rh130	Rh131	Rh13							40	Rh141
Ru (44)	Ru116	Ru117	Ru118	Ru119	Ru120	Ru121	Ru122	Ru123	Ru124	Ru125	Ru126	Ru127	Ru128	Ru129	Ru130	Ru131	Ru132	Ru133	Ru134	Ru135	Ru136	Ru137	Ru138	Ru139	Ru140

Setting 1 (8 days)

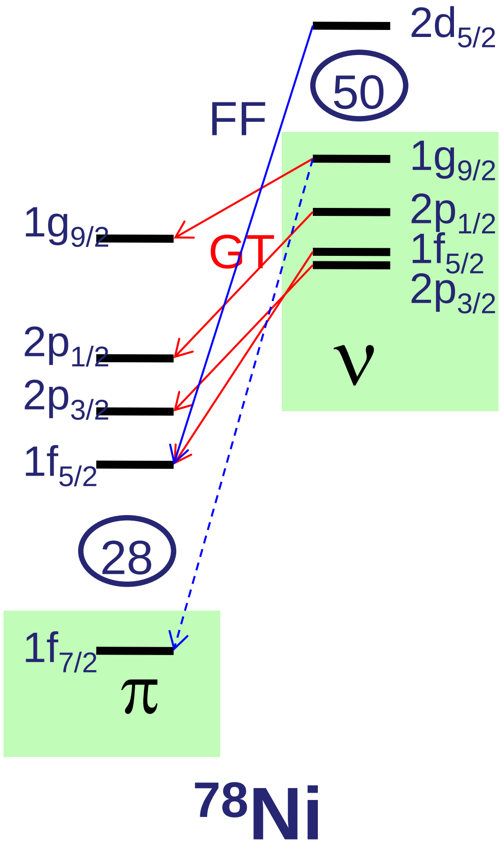
Neutron number

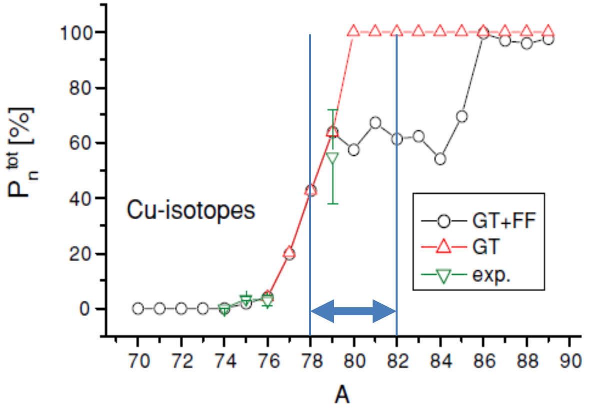
RIBF128: New βn-emission properties around doubly-magic ^{78}Ni

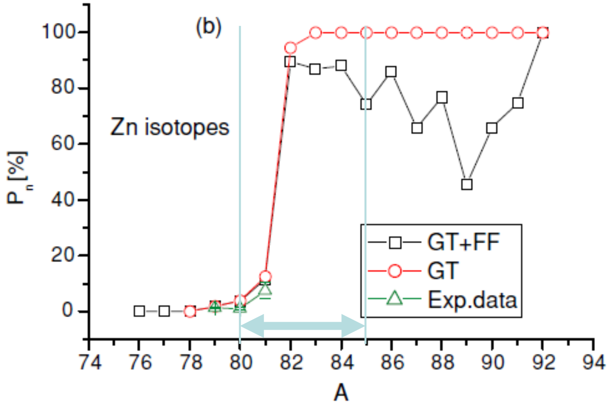
Spokespersons: K.Ryckazewscki (ORNL), J.L.Tain (IFIC), R. Grywacz(Tennessee) & I.Dillmann (TRIUMF)

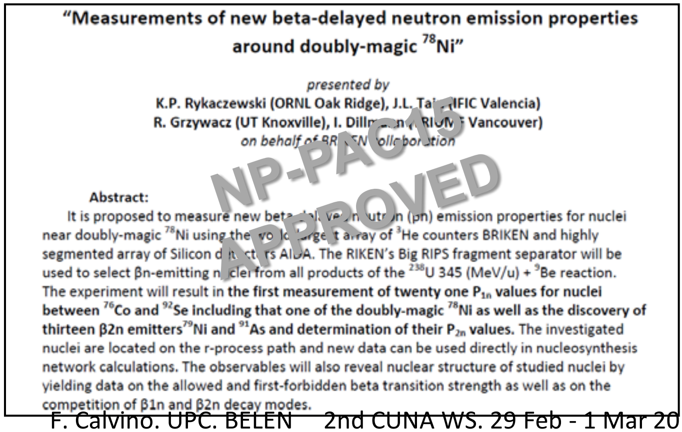
- Competition between GT- and FF-transitions reflects the underlying nuclear structure beyond Z=28, N=50.
- Decay properties of these nuclei are a direct imput for r-process abundance calculations.
- Several P2n and P3n candidates.

20 new $P_{\beta 1n}$ and 14 new $P_{\beta 2n}$ values









"Measurements of new beta-delayed neutron emission properties around doubly-magic ^{78}Ni"

presented by

K.P. Rykaczewski (ORNL Oak Ridge), J.L. Tain (IFIC Valencia)

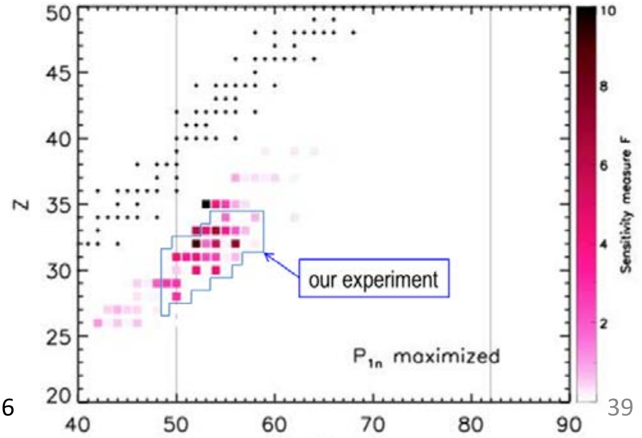
R. Grzywacz (UT Knoxville), I. Dillmann (TRIUMF Vancouver)

on behalf of BRIKEN collaboration

NP-PAC15 APPROVED

Abstract:

It is proposed to measure new beta-delayed neutron (βn) emission properties for nuclei near doubly-magic ^{78}Ni using the world largest array of ^{3}He counters BRIKEN and highly segmented array of Silicon detectors AIDA. The RIKEN's Big RIPS fragment separator will be used to select βn-emitting nuclei from all products of the ^{238}U 345 (MeV/u) + ^{9}Be reaction. The experiment will result in **the first measurement of twenty one P_{1n} values for nuclei between ^{76}Co and ^{92}Se including that one of the doubly-magic ^{78}Ni as well as the discovery of thirteen β2n emitters ^{79}Ni and ^{91}As and determination of their P_{2n} values.** The investigated nuclei are located on the r-process path and new data can be used directly in nucleosynthesis network calculations. The observables will also reveal nuclear structure of studied nuclei by yielding data on the allowed and first-forbidden beta transition strength as well as on the competition of β1n and β2n decay modes.



RIBF139: Decay properties of r-process nuclei in deformed region around mass A = 100 -125

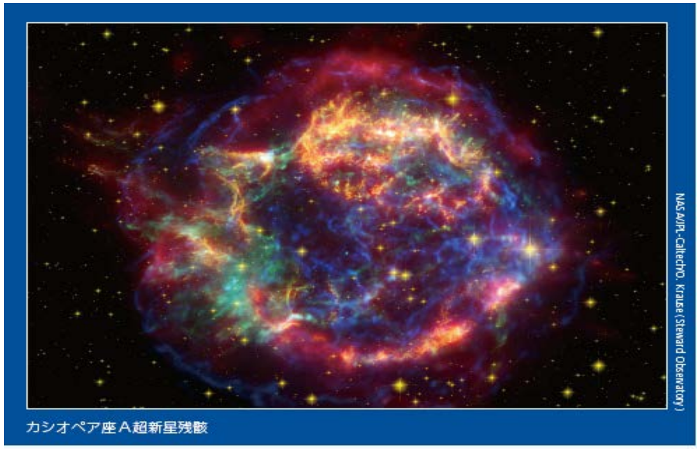
Spokespersons: S. Nishimura (RIKEN) and A. Algora(IFIC)

Primary Motivation: P_n and $T_{1/2}$ measurements of nuclei relevant for the r-process in the A~100 region

Measurement of the decay properties (T1/2 and Pn values) of very neutron rich isotopes from Se to Tc that are progenitors of the Rb to Cd elements

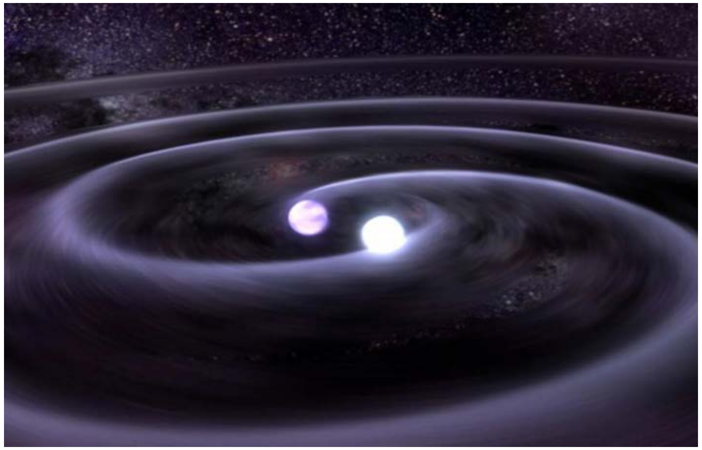
This data is an important input for modeling the weak r-process, in particular to interpret the recent observation of Mo, Ag, Pd, and Cd in metal poor stars

These elements are key indicators of the weak r-process and very sensitive to the r-process conditions



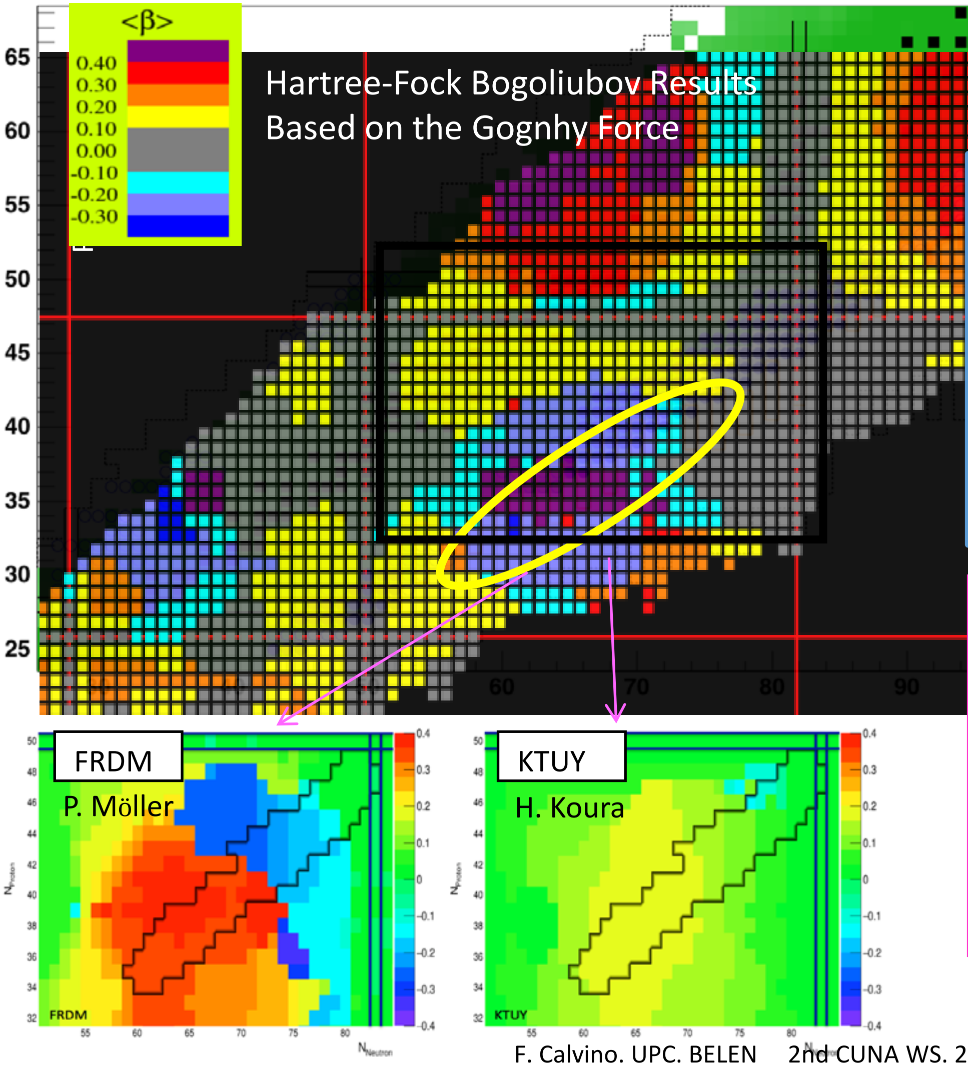
カシオペア座A超新星残骸

NASA/JPL-Caltech/O. Krause (Steward Observatory)



RIBF139: Decay properties of r-process nuclei in deformed region around mass A = 100 -125

Additional Motivations: nuclear structure aspects, shape determination, test of nucl. models



Hartree-Fock Bogoliubov Results Based on the Gognhy Force

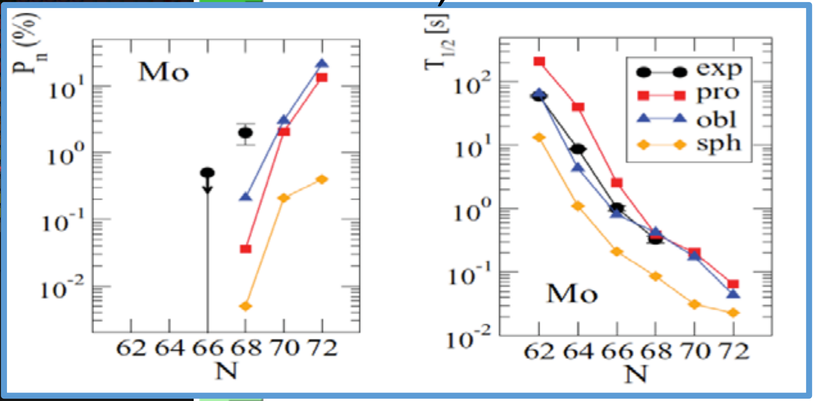
FRDM

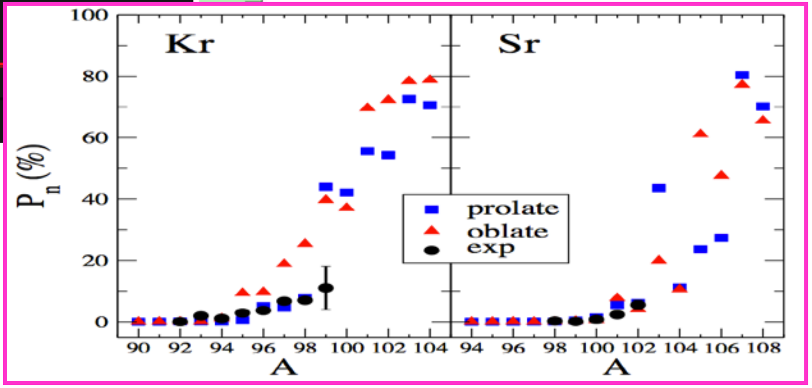
P. Möller

KTUY

H. Koura

Private com: P. Sarriguren and P. Sarriguen et al. PRC 89, 034311





Evolution of the BRIKEN project and plans

1st BRIKEN
Workshop, Valencia
2012

2nd BRIKEN
Workshop, Tokyo
2013

Construction
Proposal
Approved

3rd BRIKEN
Workshop, Valencia
2015

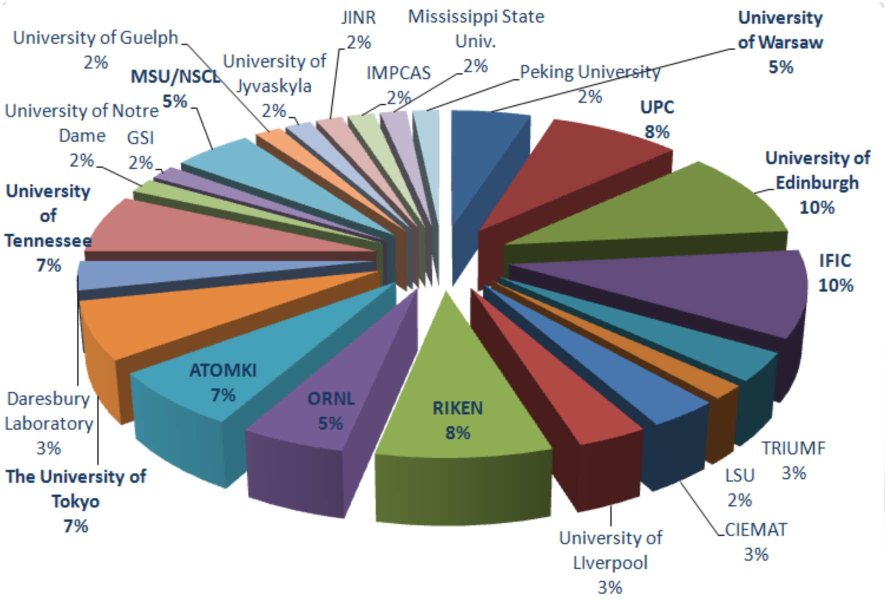
RIBF127, RIB128 and
RIBF139
Proposals Approved

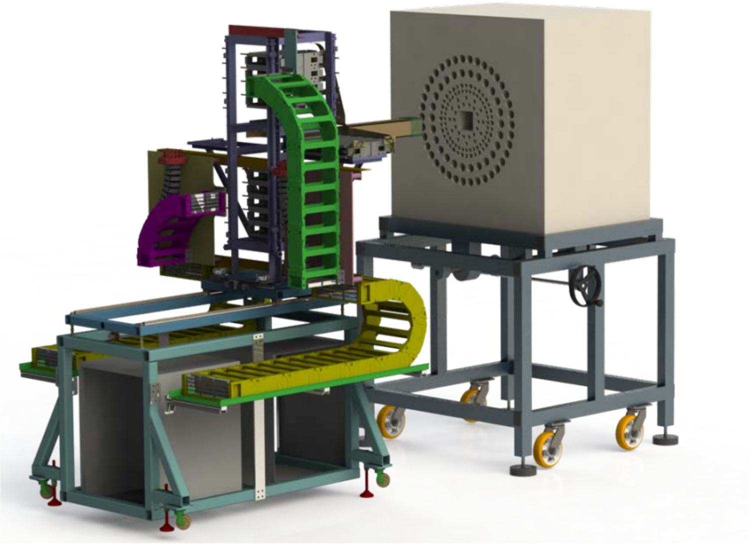
Summer
2016

Commission
Full system
@ RIKEN

Autum
2016

1st BRIKEN
Experiments





Open project, to join:

briken.project@gmail.com

http://indico.ific.uv.es/indico/event/briken 1st BRIKEN Workshop, Valencia 17-18 Dec. 2012

http://indico.ific.uv.es/indico/event/briken2 2nd BRIKEN Workshop, Tokyo, 30-31 July 2013

http://indico.ific.uv.es/indico/event/briken3 3rd BRIKEN Workshop, Valencia, 22-24 July 2015