BRIKEN WORKSHOP:

"Opportunities with BELEN at RIKEN"

Beta dELayEd Neutron (BELEN) detector

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17 de desembre de 2012

València

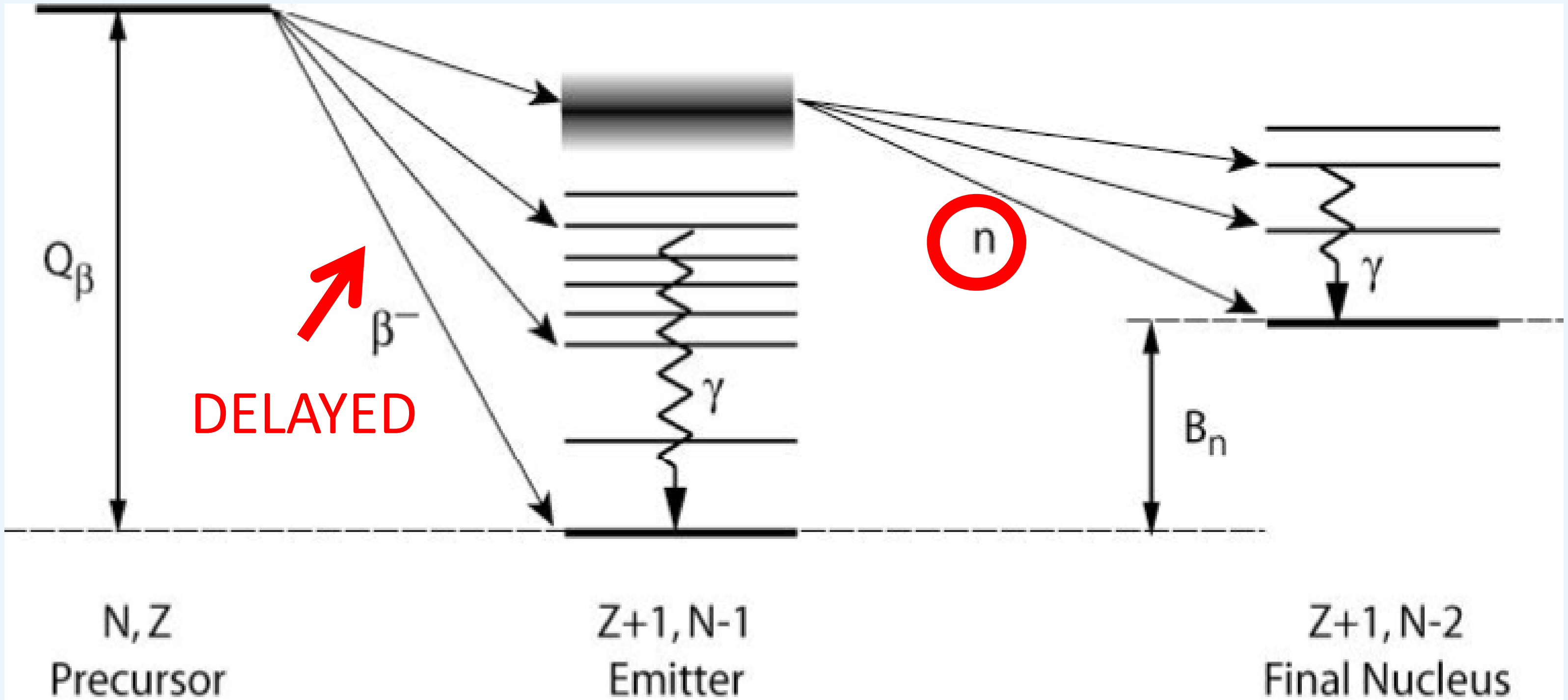
Contents

Contents

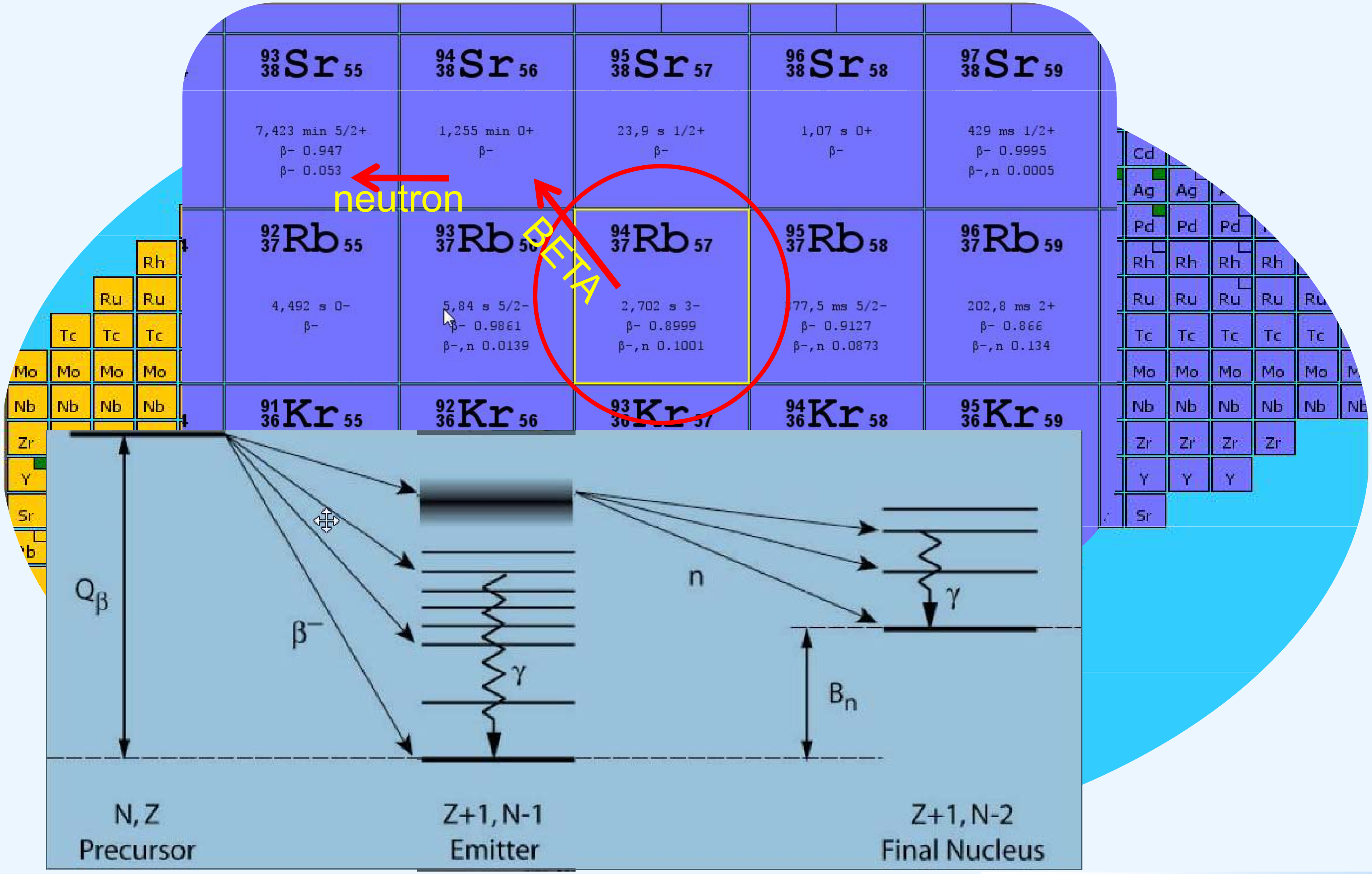
- **The concepts of β-delayed neutron emission**
- Detection system
- Previous versions used at JYFL and GSI
- New designs and conclusions

β-delayed neutron emission

Neutron emission after β⁻ decay scheme



Example of β⁻ delayed neutron emission

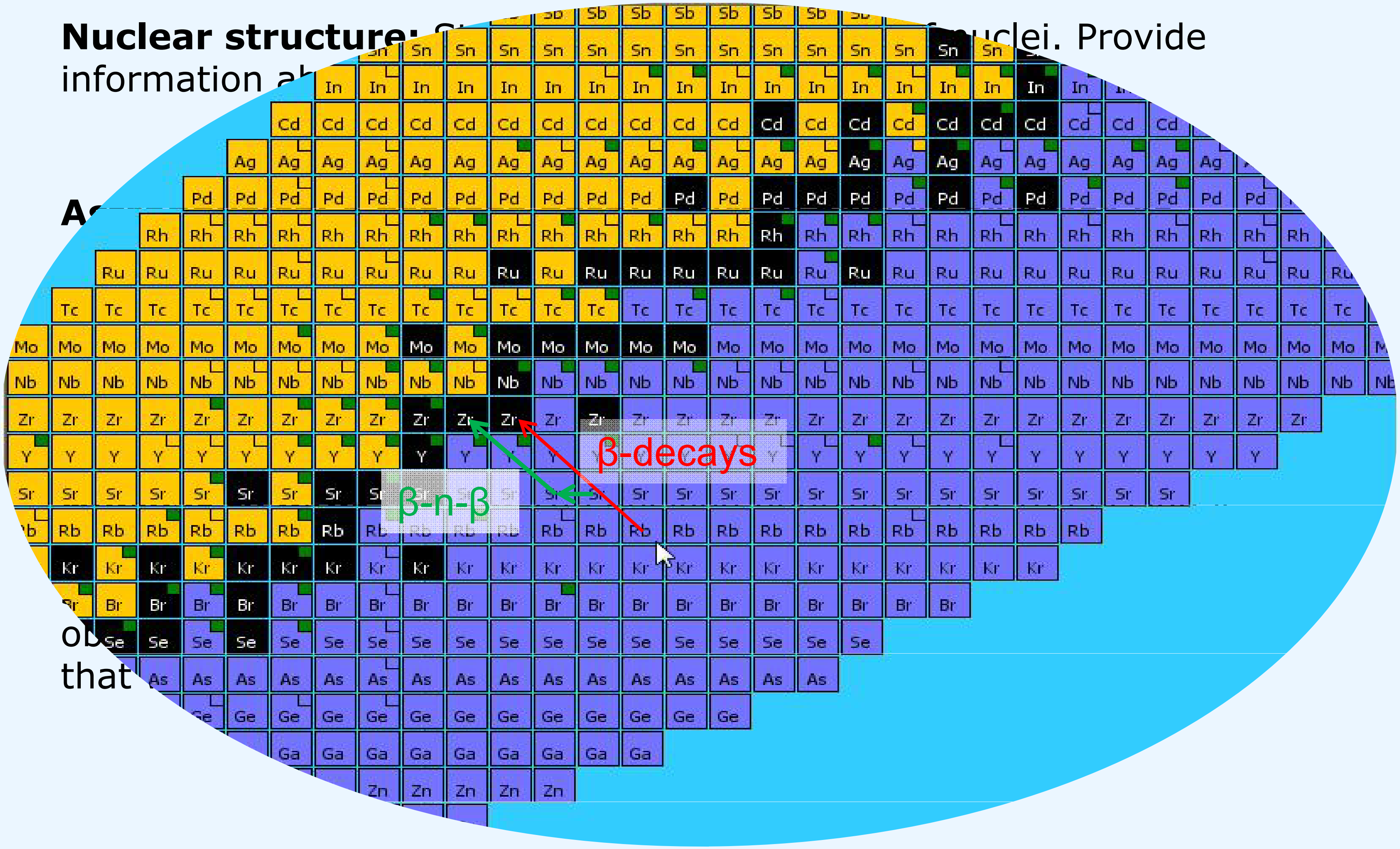


β-delayed neutron emission - Applications

Nuclear structure: S… f nuclei. Provide
information ab…

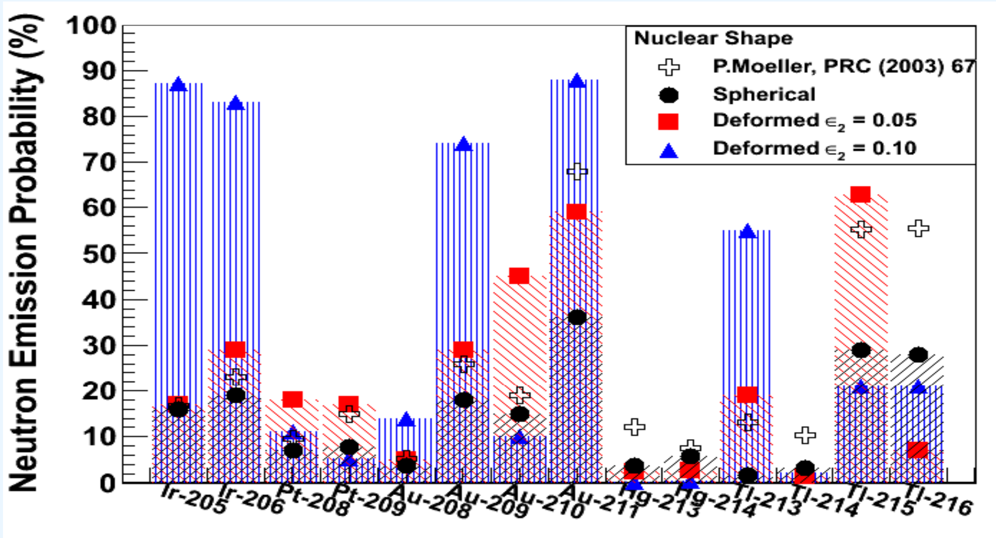
A…

ob…
that…



Theoretical predicitons with large uncertainty

Neutron emission probablity (Pn)



Information from K.-L. Kratz, (priv. comm. 2010)

- ✓ Predictions for P_n are also very different depending on the (unknown) nuclear deformation.

- ✓ Detector with large efficiency is needed due to the low production of nuclei of interest in actual facilities.

- ✓ RIKEN can be a unique opportunity to measure the most exotic nuclei.

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^{3}He counters as detector

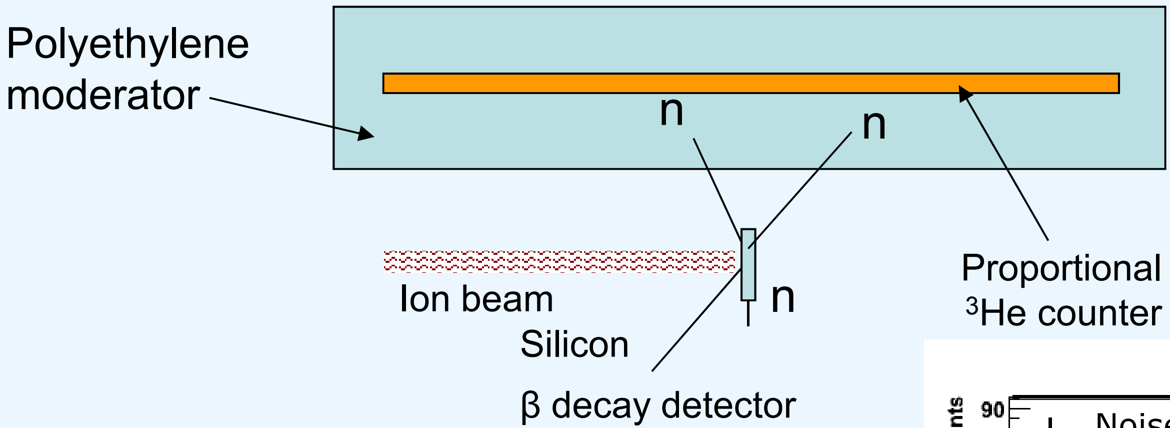
✓ The detection of the neutron is based on an indirect method: the detection of the products of the reaction of the neutron with ^{3}He counters:

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

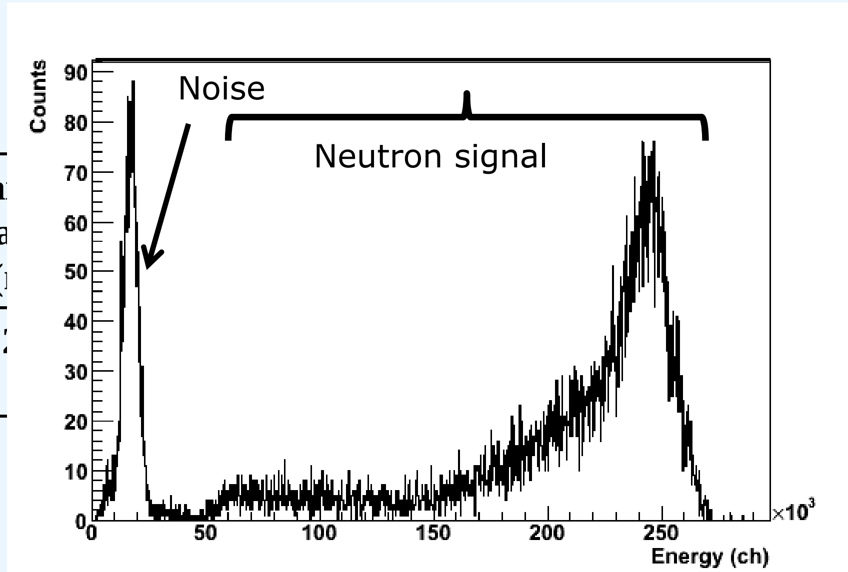
Other reactions:

$^{10}B + n \rightarrow {}^7Li^* + {}^4He + 2310\ keV$

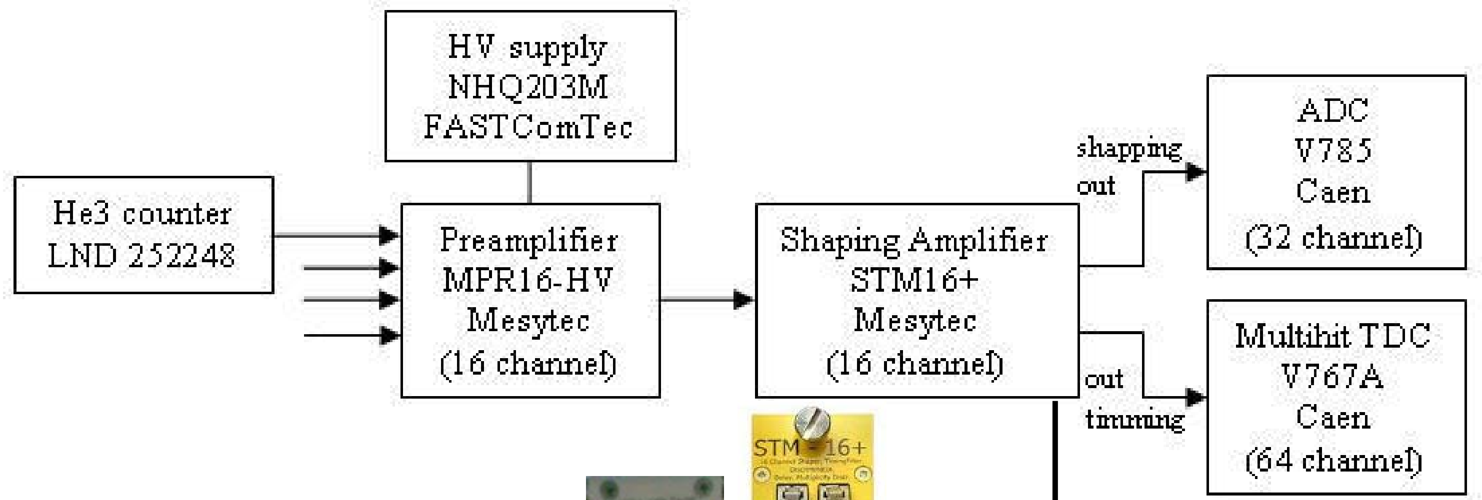
$^7Li^* \rightarrow {}^7Li + 480\ keV$



Counter	Gas	Maximum length (mm)	Effective length (mm)	Ma dia (
2527 LND inc	^{3}He	686.84	604.8	[illegible]



Electronic chain for data acquisition and signal processing



The electronic chain of the acquisition system operates independently of the other systems of the experiment and detectors along the beamline. It only needs to sinchronize the timestamp.

Analog system: Trigger

NEW Digital system: Triggerless

Digital Data Acquisition System (DDAS)

Talk of this part by J. Agramunt

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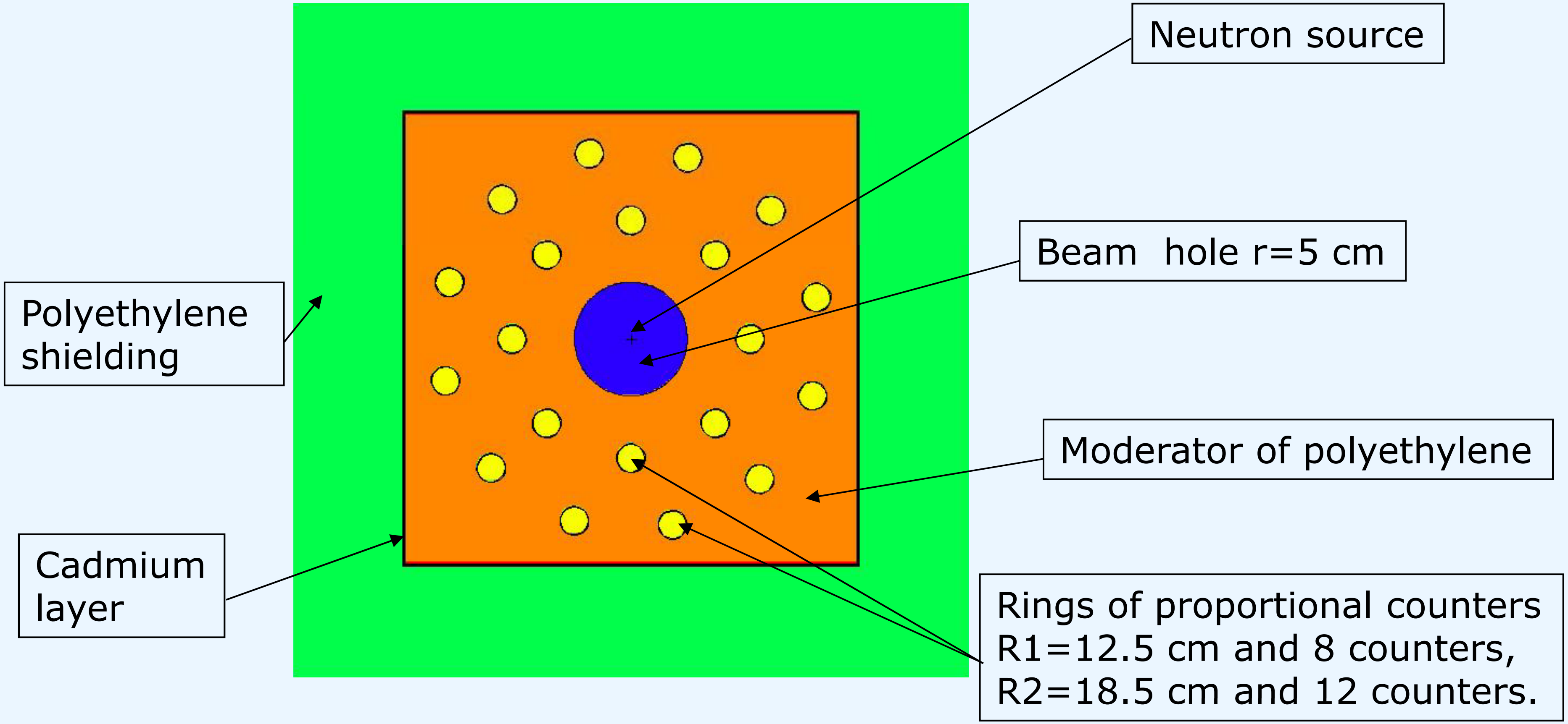
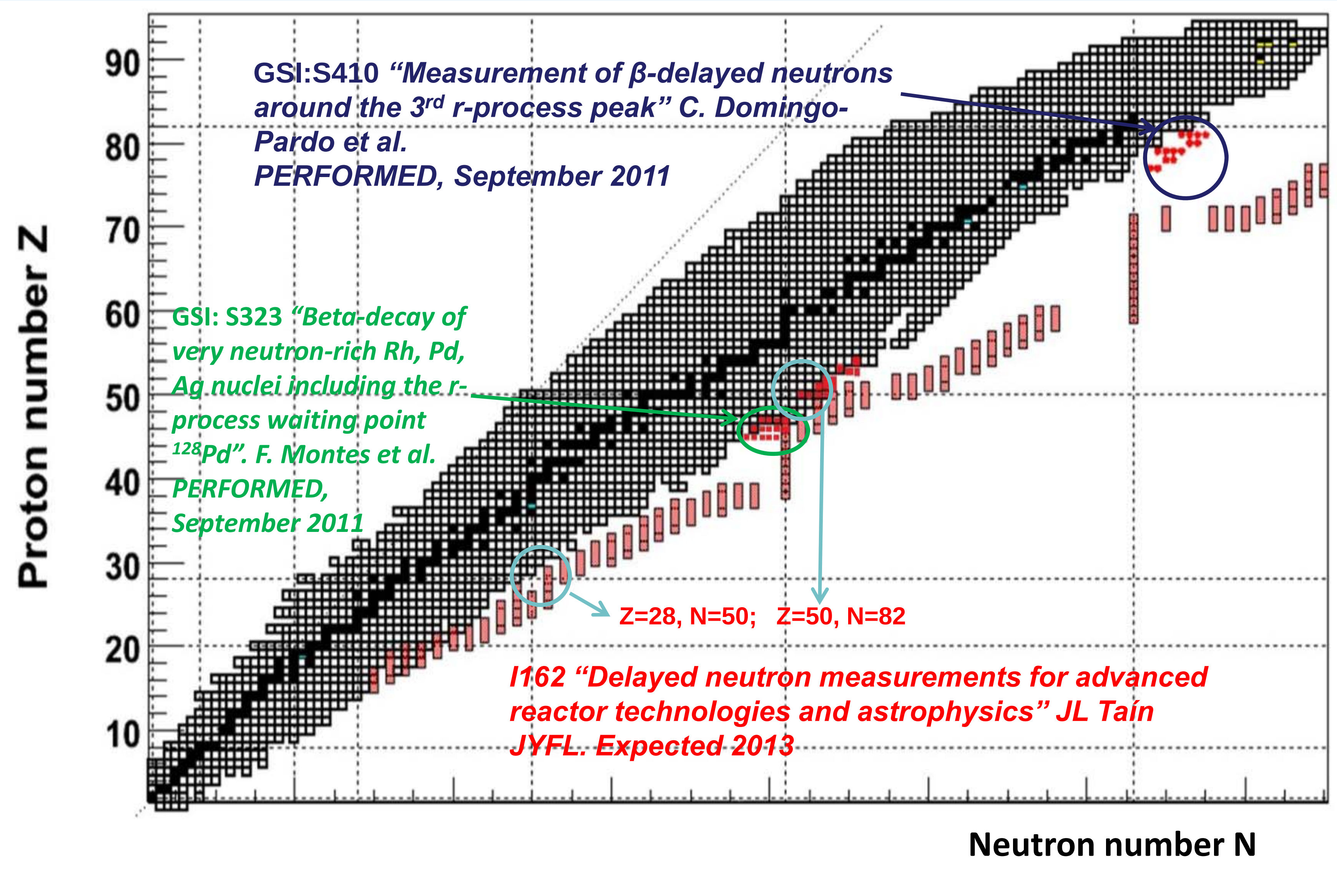
BELEN first designs and geometry



The geometry design is based in two crowns. The aim is to have a flat difference in efficiency in the energy range of interest (100 keV – 5 MeV).

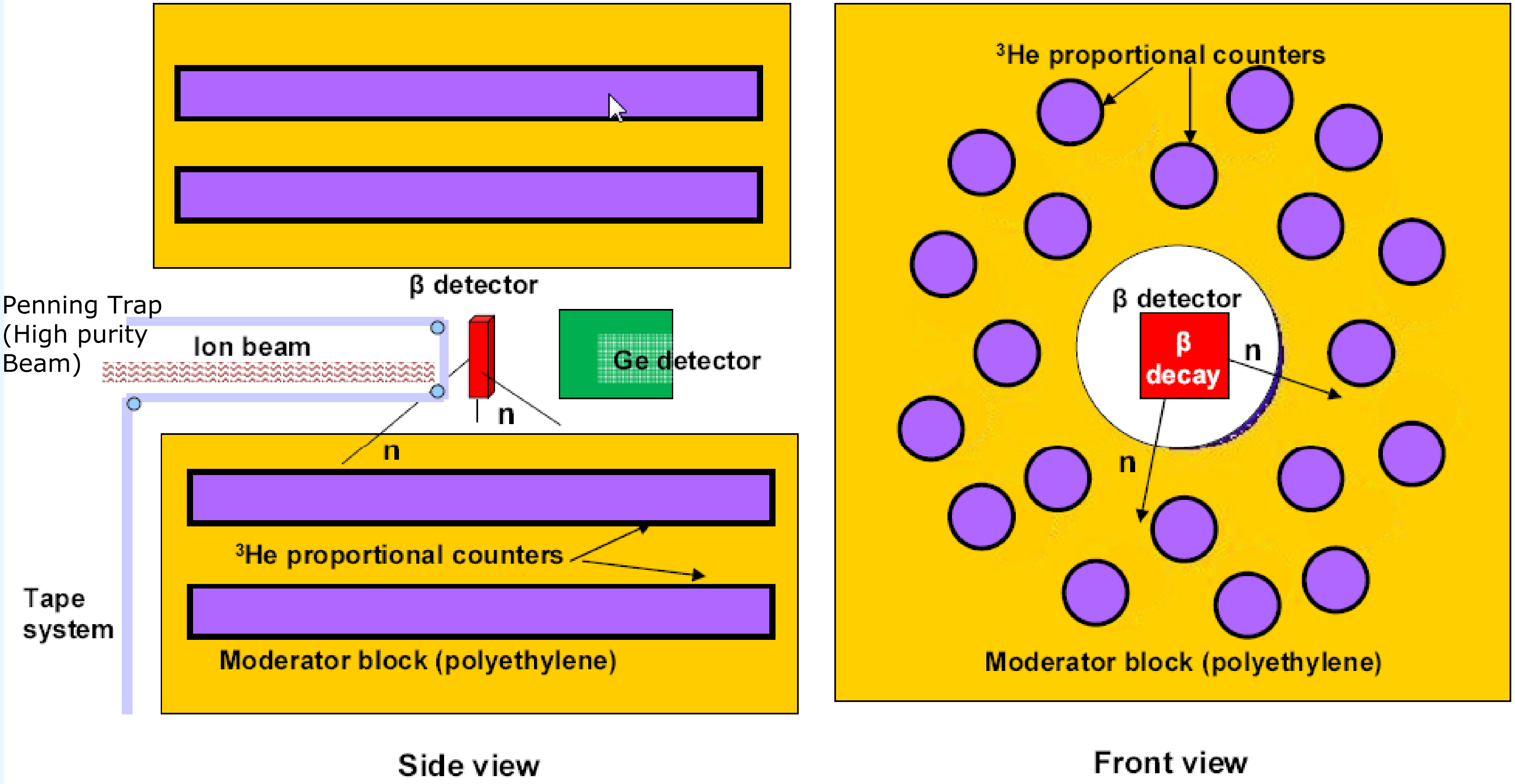
✓ **Developed by V.Gorlychev and B.Gomez at UPC-Barcelona**

Tests and experiments with **BELEN** detector

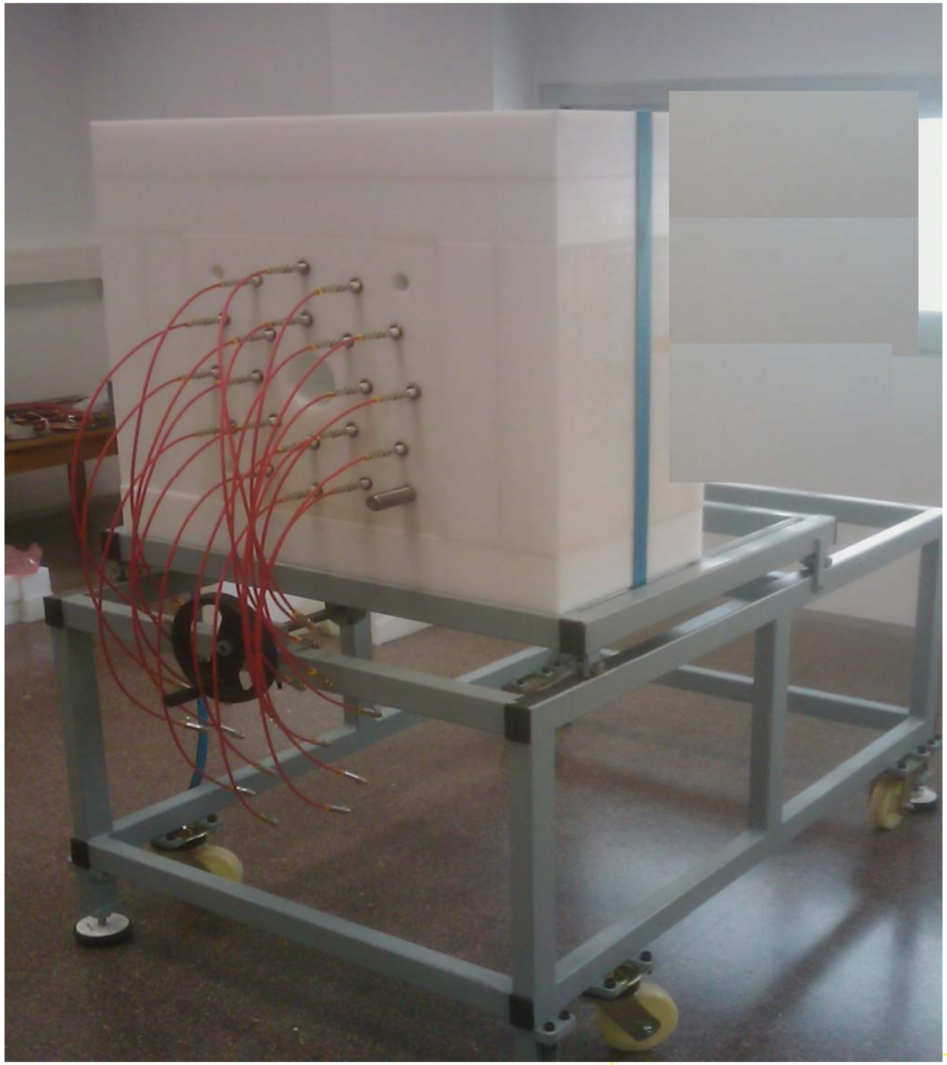


BELEN design for JYFL experiments

Prototype designed for JYFL 2009 with 20 counters



BELEN design for JYFL experiments



Support structure requirements:

Hold and transport 650 Kg

Allow access to the beam hole

Movable in Z for fine placement

Table + tray movable on "z" on rails

Polyethylene block hold together and can be lifted as a single unit.

Polyethylene: 10 cm thick vertical slices assembled => 90 x 90 x 80 cm3 ~650 Kg detector

JYFL experiment 2009 & 2010 - **BELEN-20**

20 ^{3}He counters at 20 atm

1ST ring: 8 counters at 11 & 9.5 cm

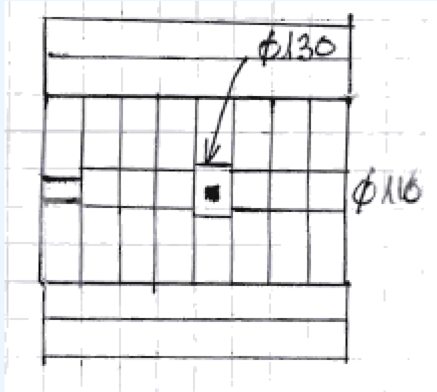
2nd ring: 12 counters at 20 & 14.5 cm

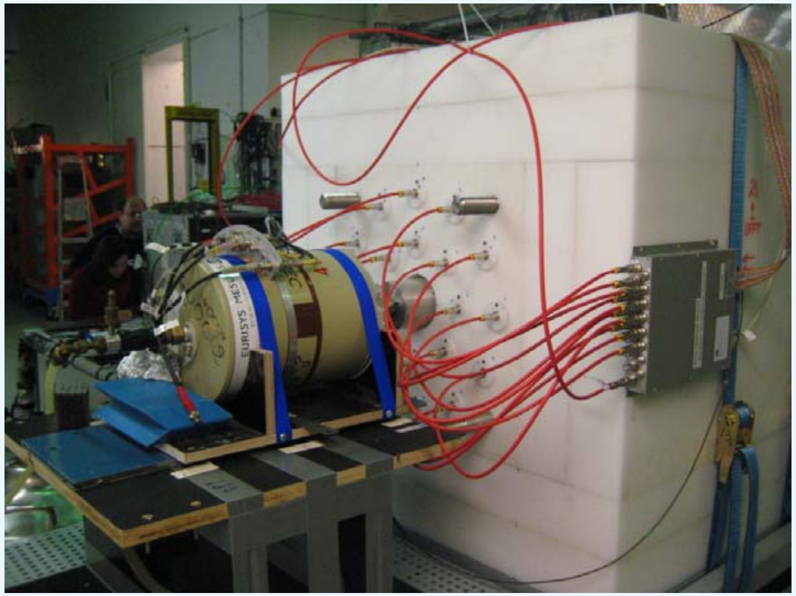
Average efficiency: 27% & 35%

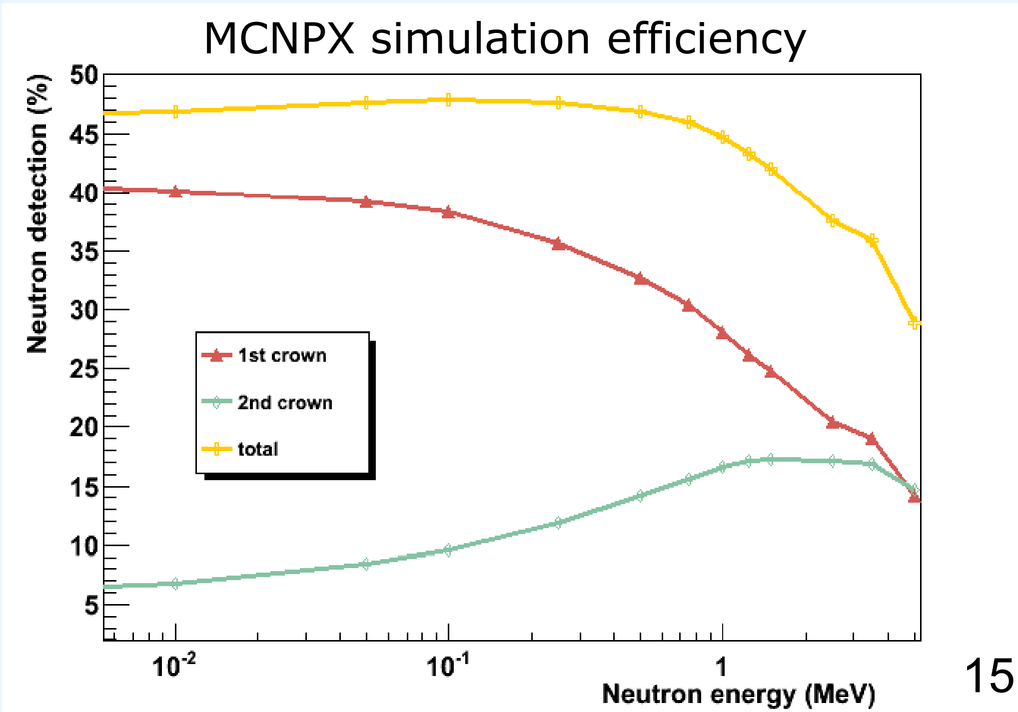
Dimensions: 50x50x80 cm^3 + shielding (90x90x80 cm^3)

Diameter holes: 2.75 cm

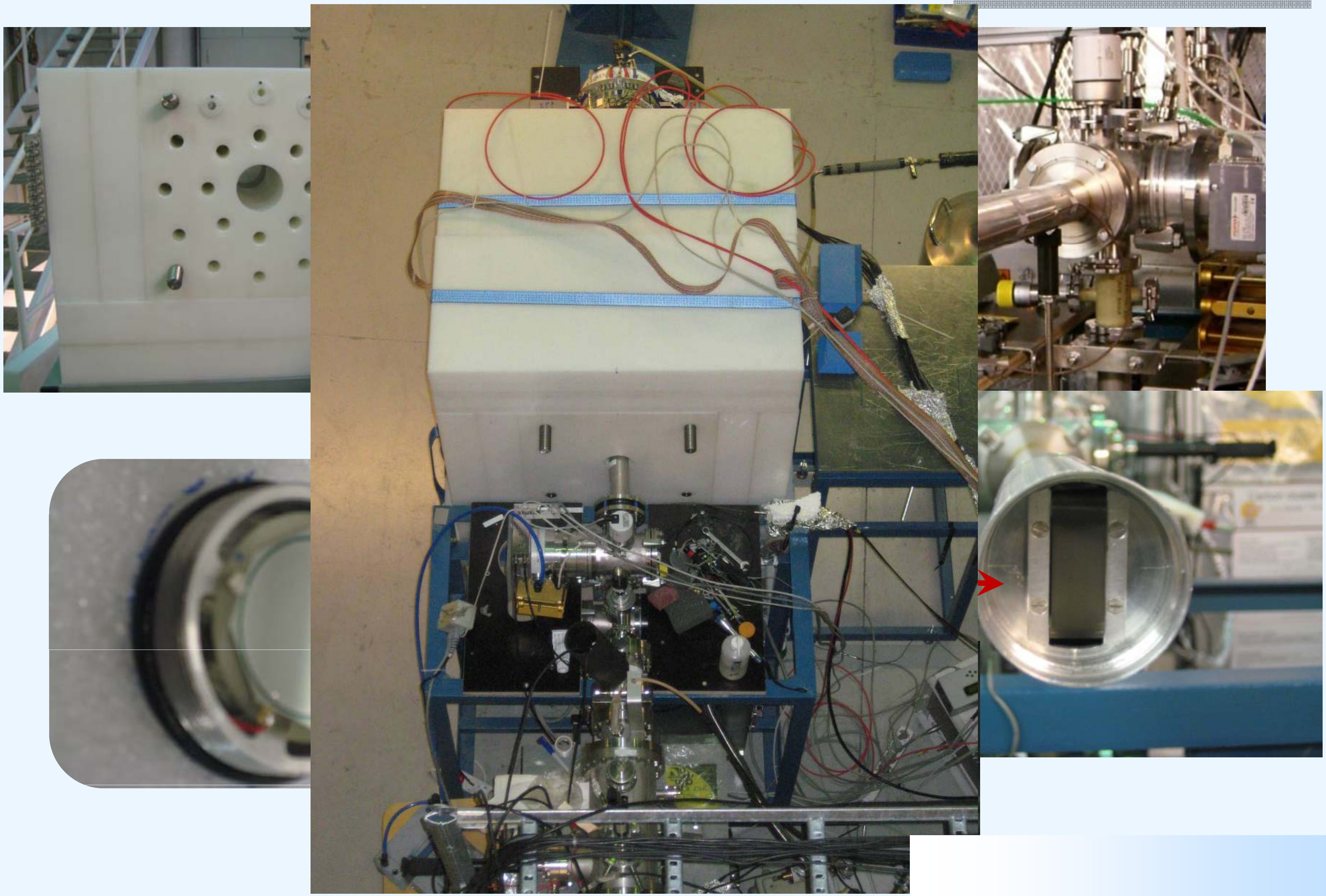
Central hole: 5.5 cm







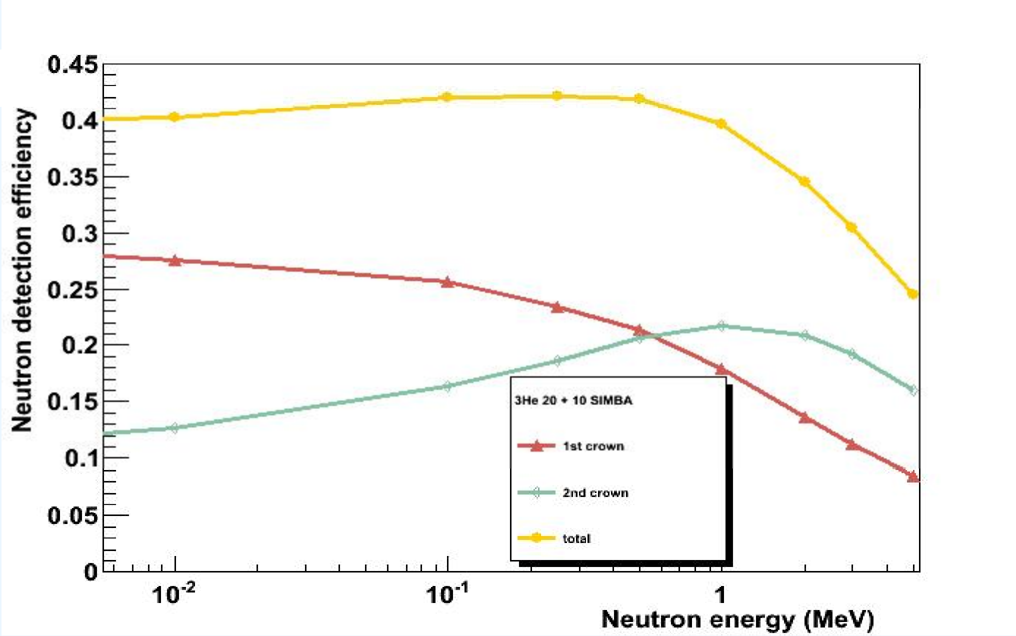
JYFL ion implantation system

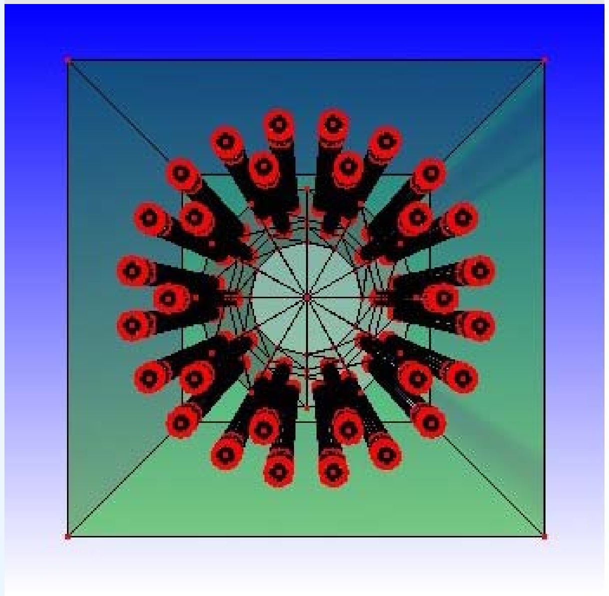


S410/S323 experiments at GSI (2011). Design & efficiency.

BELEN-30
20 ^{3}He (20 atm) + 10 ^{3}He (10 atm)
Inner ring (10 counters): 29 cm
Outer ring (20 counters): 37 cm

Efficiency (1keV-1MeV) ~40%
Average up to 5MeV ~ 35%





^{252}Cf neutron source detection efficiency (M.Marta):

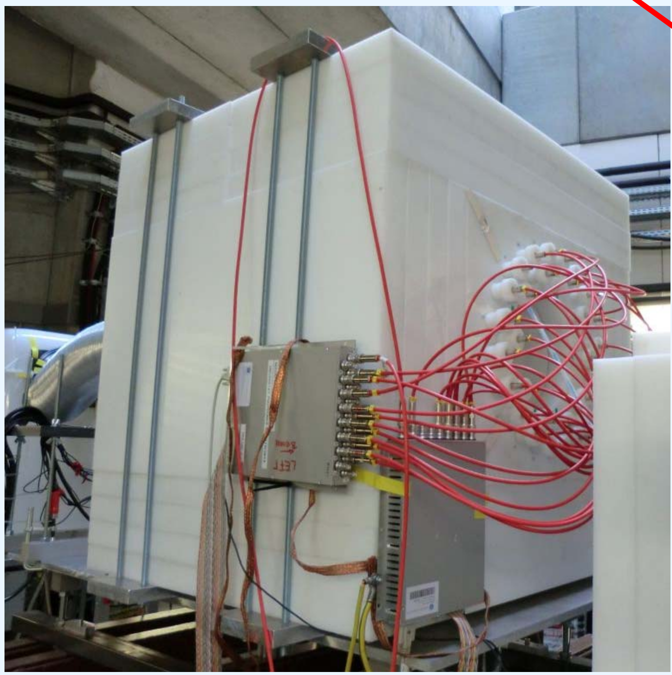
- MCNPX simulation: (34.5±0.2)%
- Triggerless DACQ (IFIC) in MBS : (35.4±0.8)%
- Analog branch: (25.5±0.9)% (electronics)

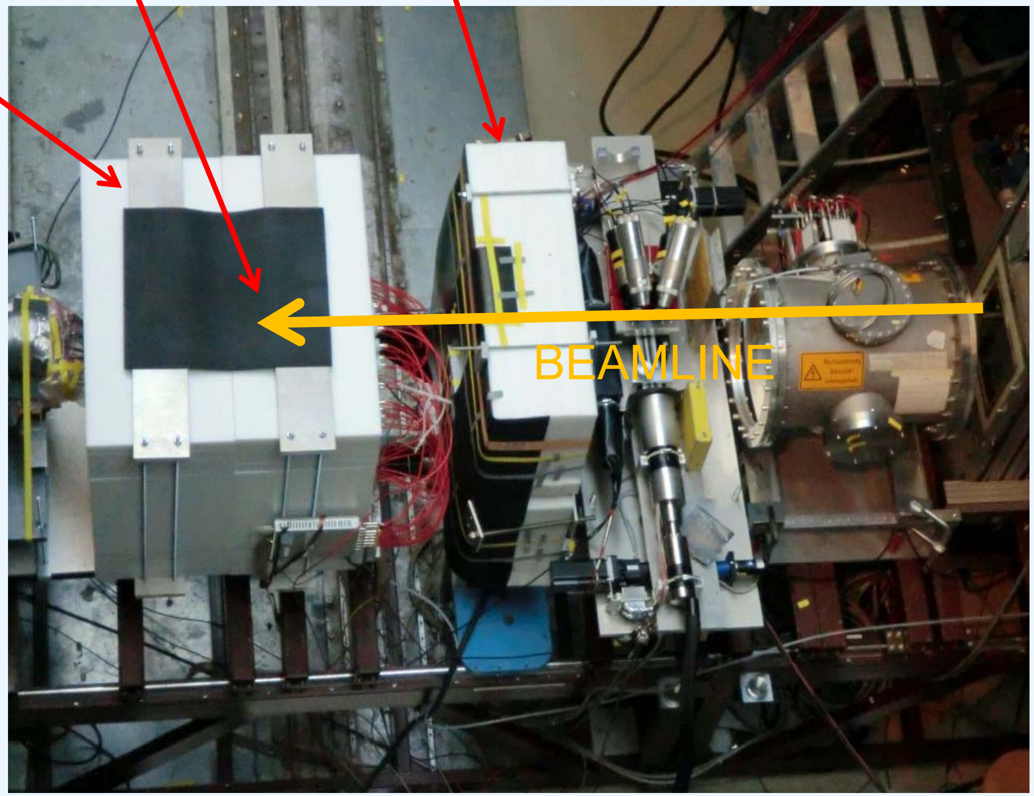
S410/S323 experiments at **GSI**. Setup.

BELEN-30 neutron detector

Neutron shielding

SIMBA inside
the matrix

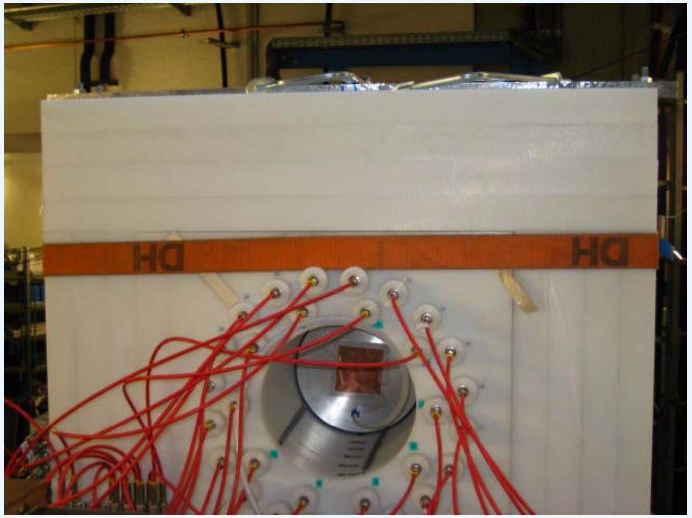


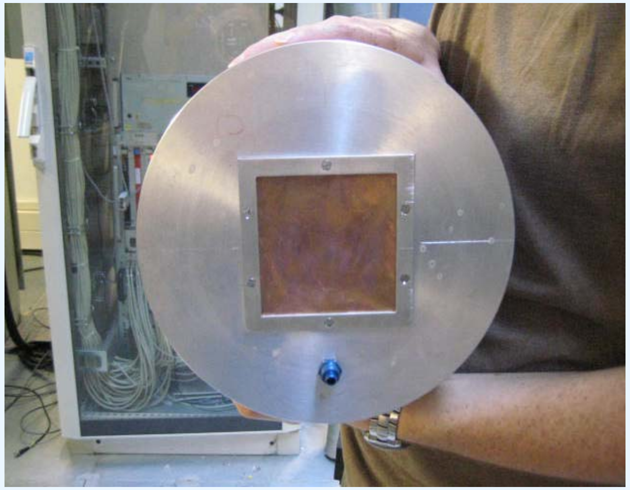


- ✓ Approx 700 kg weight
- ✓ Dimensions: 90 x 90 x 80 cm^3

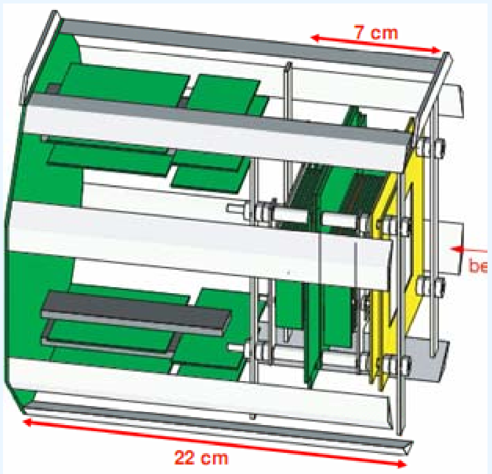
S410/S323 experiments at **GSI**. Ion implantation system.

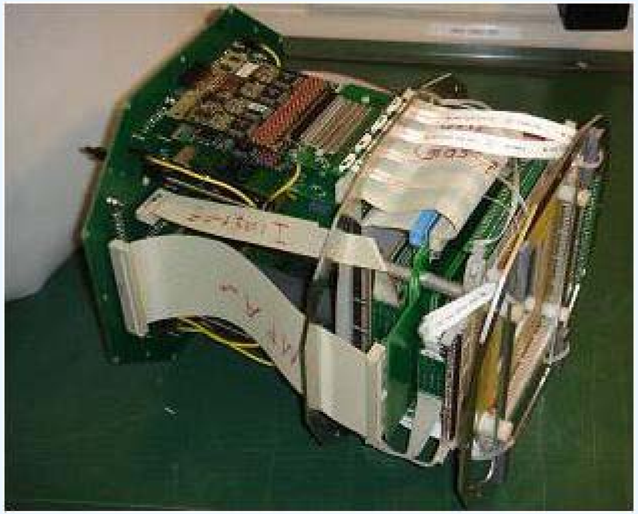
Silicon Implantation Beta Absorber (SIMBA)





Front view





Constructed and developed at TUM Technische Universität München

PhD thesis C. Hinke, TUM (2010)
Diploma thesis K. Steiger, TUM (2009)

SIMBA detector: (SSSD & DSSD) 60x40x1 mm^3

Summary of tests and experiments

BELEN-20 (20atm) for JYFL. Experiments at JYFLTRAP (Finland). Measurements of β delayed neutron emission of fission fragments (UPC, IFIC, CIEMAT):

A~80-95 with Nuclear structure and Astrophysics interest.

Background measurements at GSI (July 2010) and Canfranc underground laboratory (July 2011).

BELEN-30 (20 (20atm), 10 (10 atm)) for FRS-GSI. Two experiments at GSI with & SIMBA September 2011, nuclei of astrophysical interest:

S323 & S410 experiments, isotopes around regions of ^{128}Pd, ^{215}Tl, ^{211}Hg in collaboration with MSU and ND.

BELEN-48 (2013) Efficiency calibration measurements at PTB (Germany) and experiment at JYFL with ongoing design.

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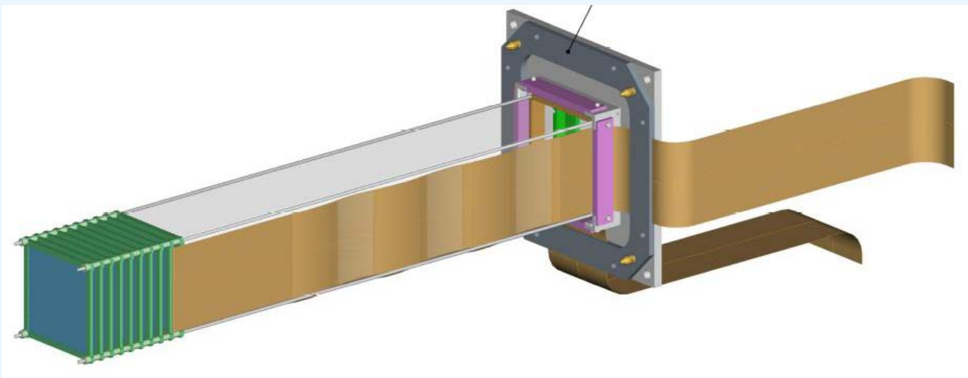
BELEN versions designed

Name	^{3}He counters	Pressure (atm)	Experiment	Average Efficiency	Central hole radius (cm)
BELEN-20	20	20	JYFL-2009	27%	5.5
BELEN-20	20	20	JYFL-2010	35%	5.5
BELEN-30	20+10	20 & 10	GSI-2011	35 %	11.5 (SIMBA)
BELEN-48	40+8	8 & 10	JYFL-2013	37%-52%	6
BELEN-48	40+8	8 & 10	RIKEN	34%-50%	8 (AIDA)
BELEN 48	40+8	8 & 10	RIKEN	???	Local imp. detector

See differences:

- Central hole
- Number of counters
- Distance of rings



BELEN design parameters

- ✓ Define the range of energy of the neutrons to be optimized
  - Efficiency Vs energy (flat efficiency in the energy range of interest: 100keV – 5MeV)
- ✓ Knowledge of the estimation neutron background to decide the shielding
- ✓ Radius of central hole → Implantation detector and beamsize

(see table at *Previous versions* section)

- ✓ Number of counters available → Polyethylene matrix

R1

Slide 24

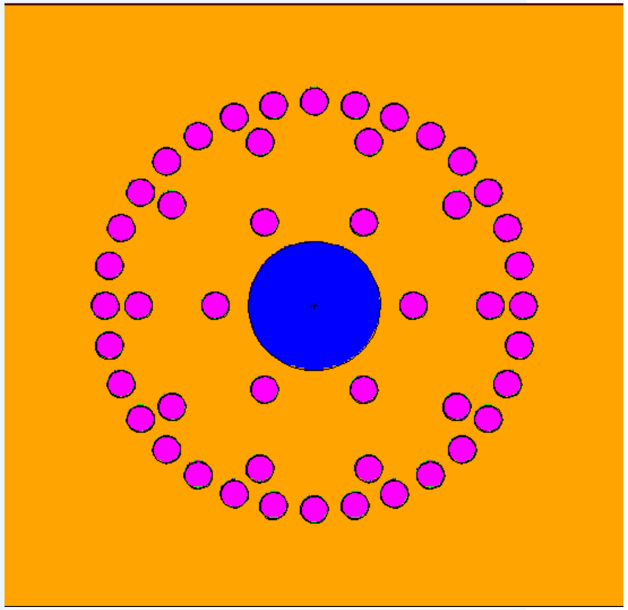
R1 Distribution of the energy of the neutrons. Levels between Qb and Bn

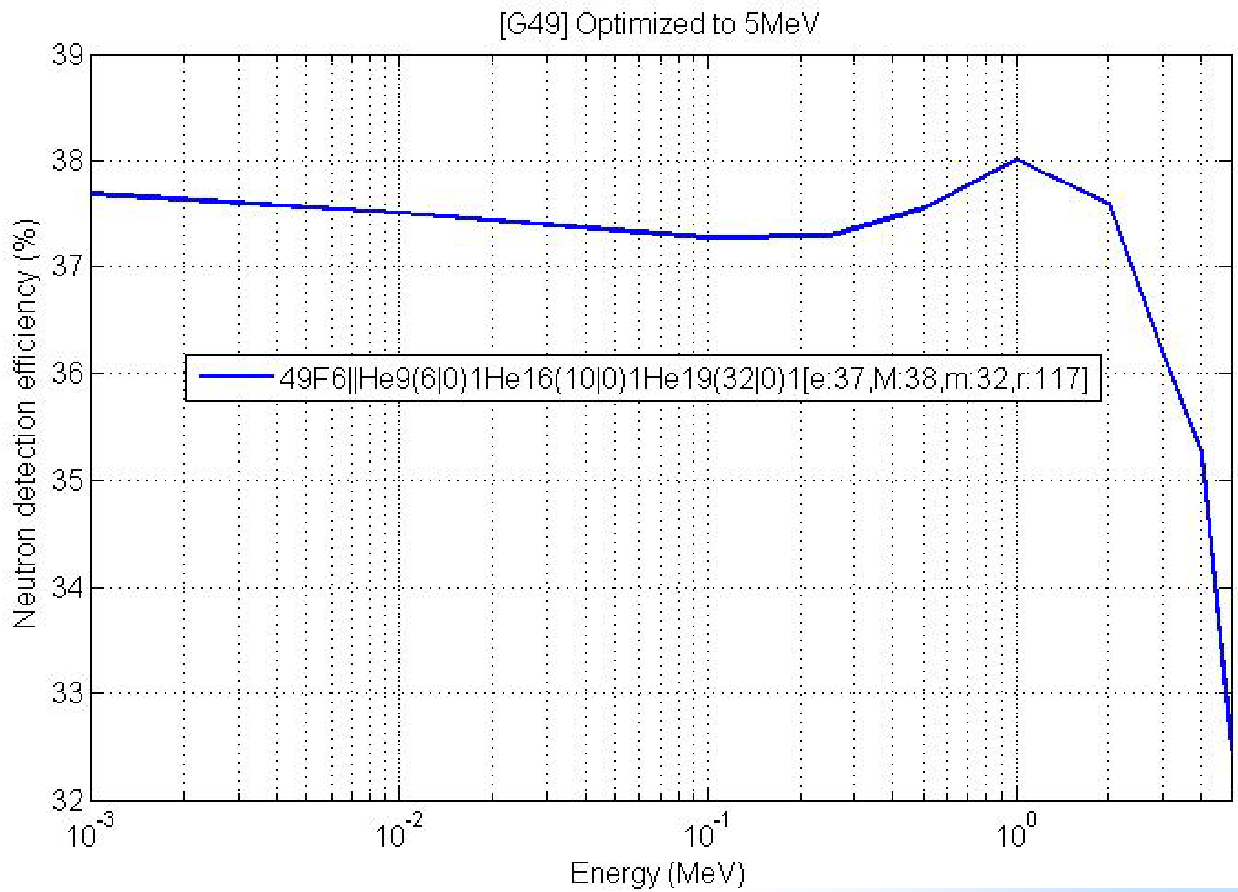
Roger; 14/12/2012

BELEN design in progress for **JYFL 2013**

Optimized for range 100 keV – 5 MeV

Radius 6 cm

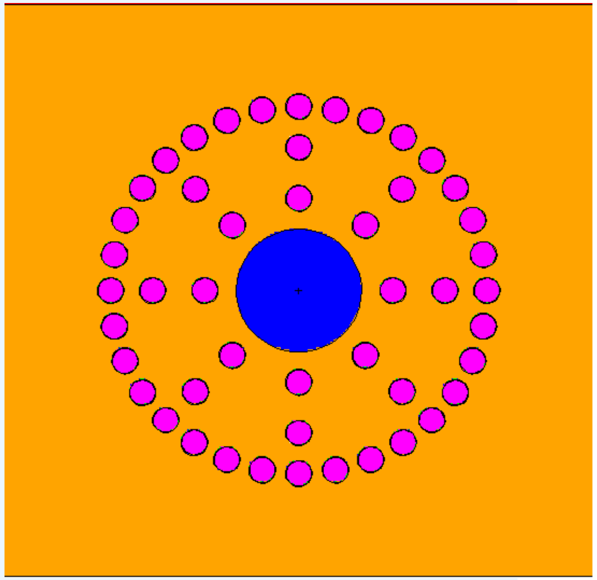


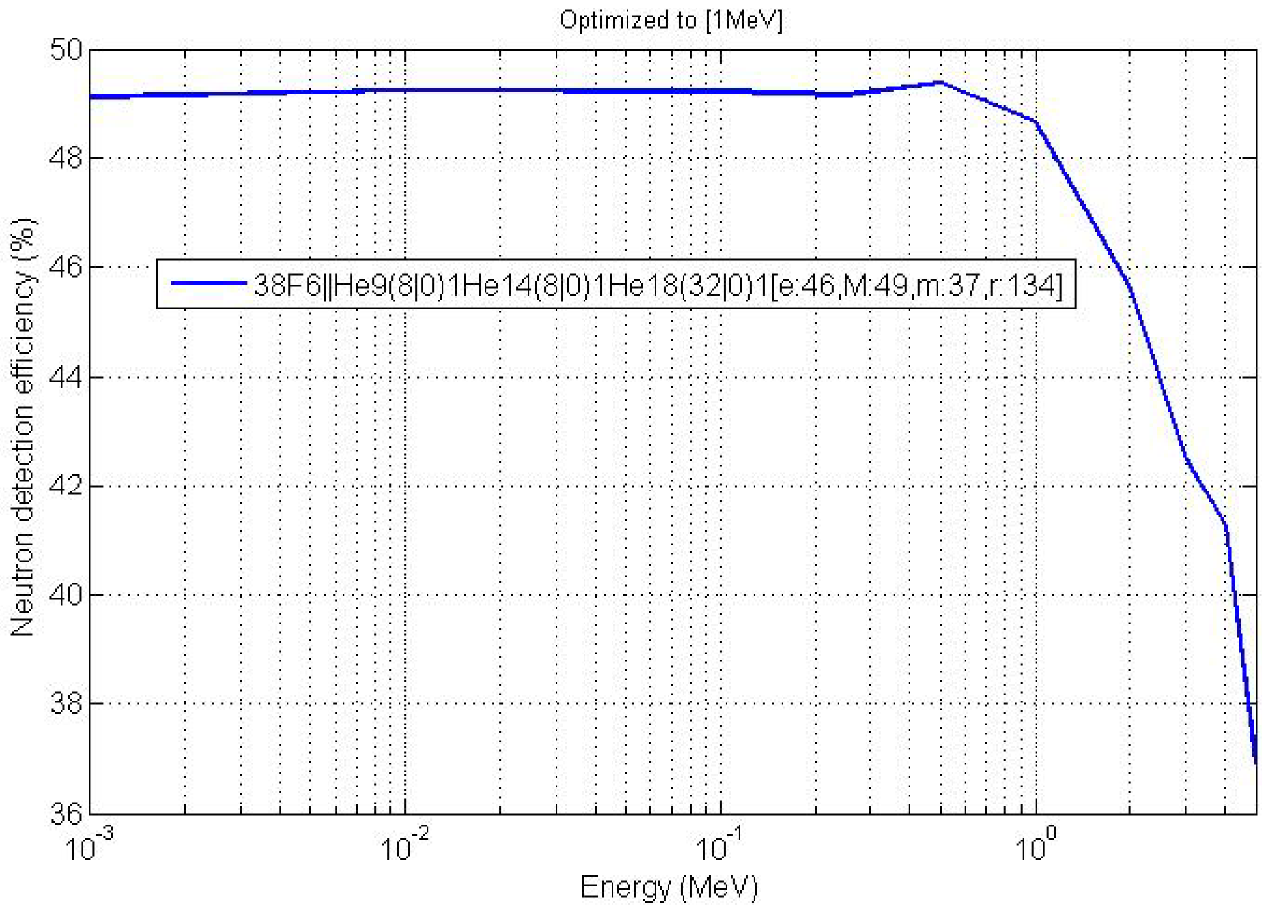


BELEN design in progress for **JYFL 2013**

Optimized for range 100 keV – 1 MeV

Radius 6 cm

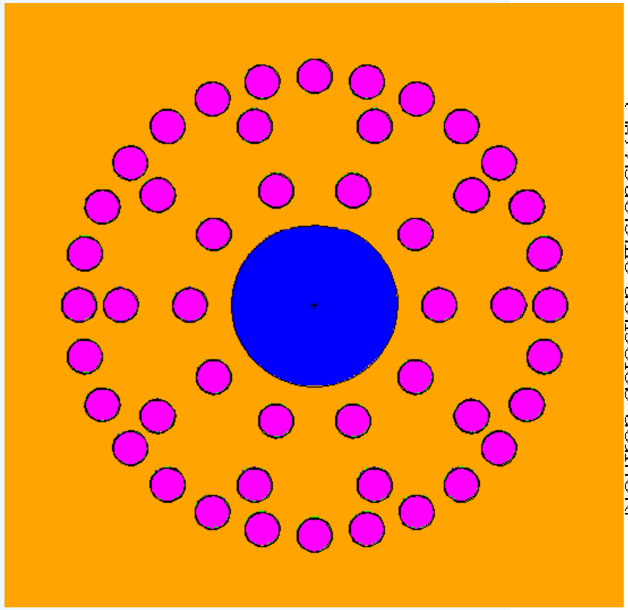


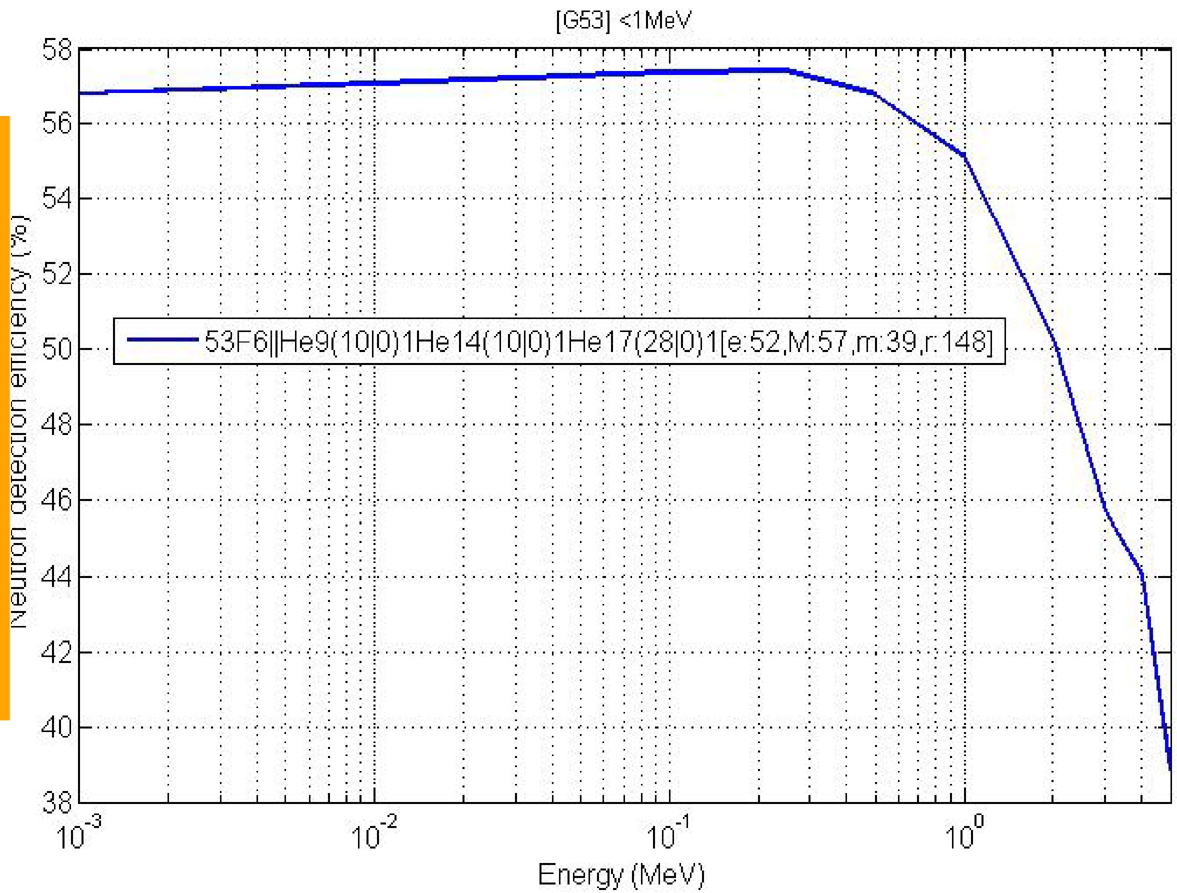


BELEN design in progress for **JYFL 2013**

Optimized for range 100 keV – 1 MeV

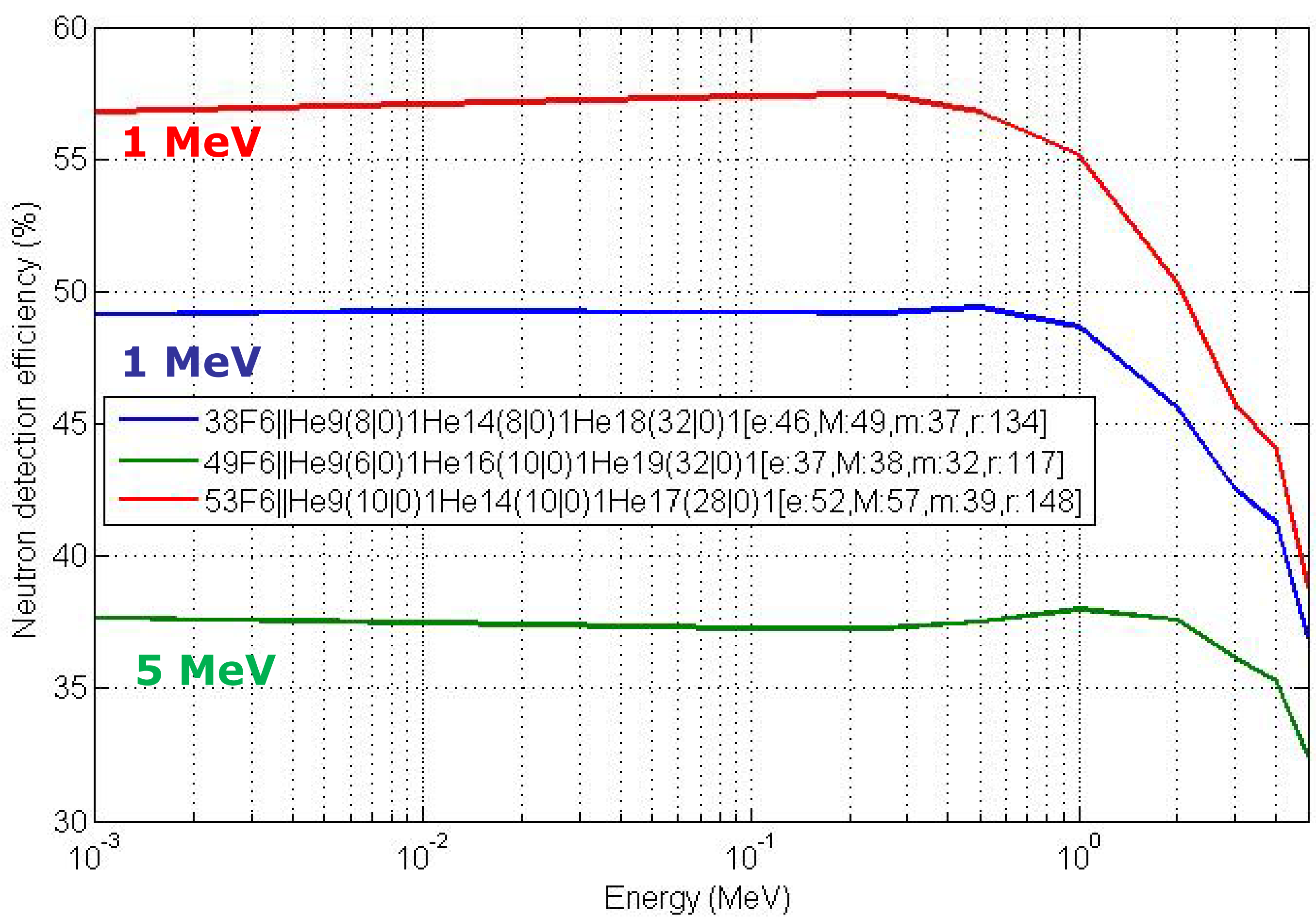
Radius 6 cm





BELEN design in progress for **JYFL 2013**

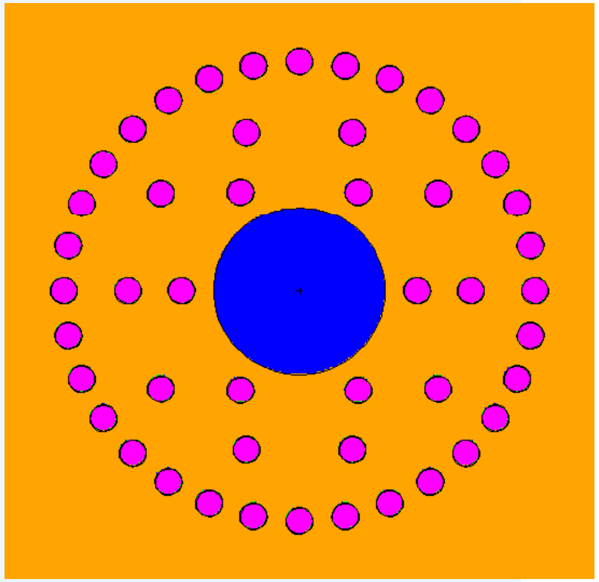
Efficiency comparison of three examples

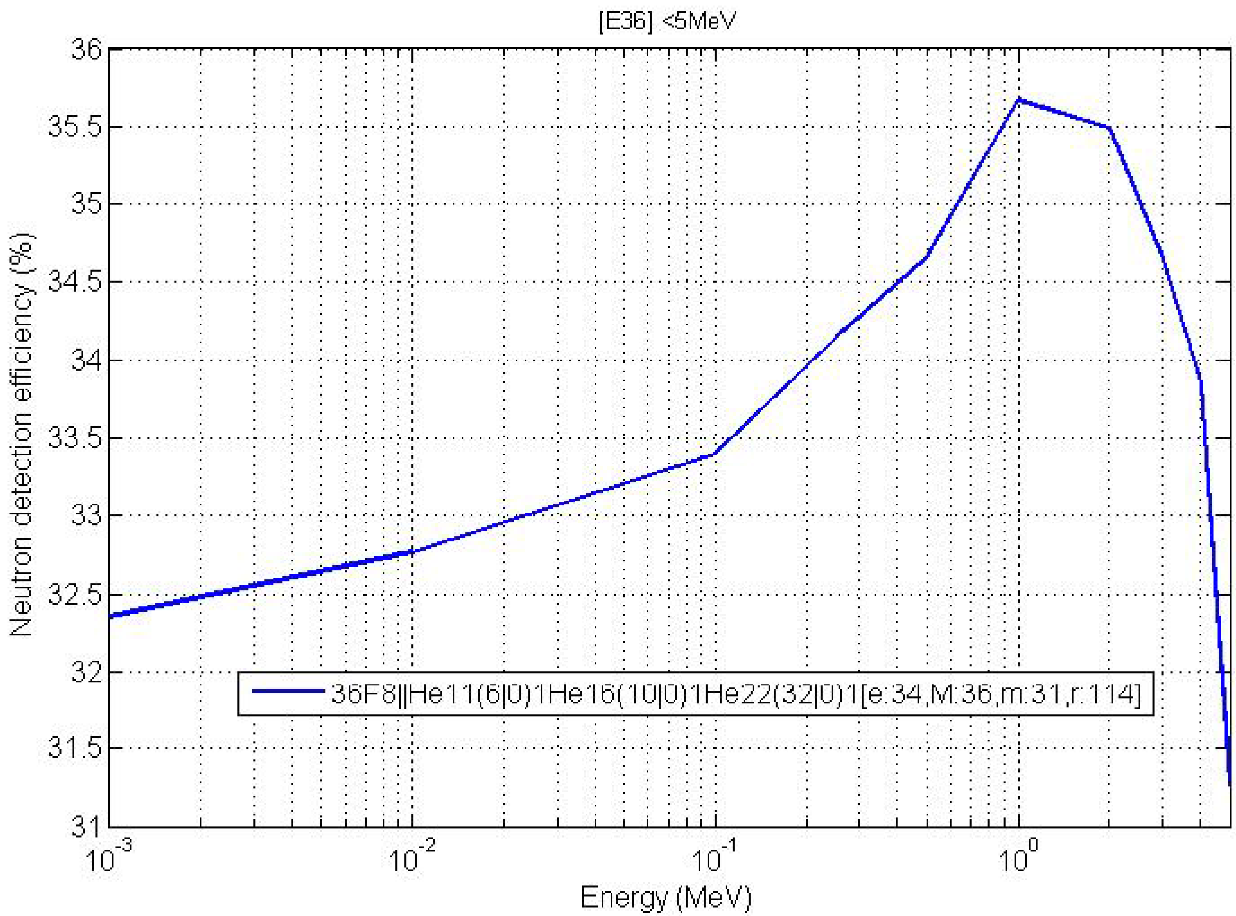


BELEN design in progress for **RIKEN** with **AIDA**

Optimized for range 100 keV – 5 MeV

Radius 8 cm

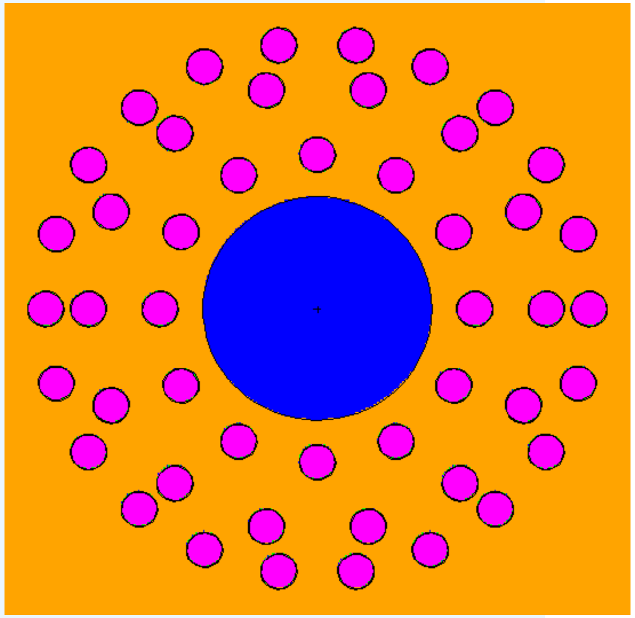


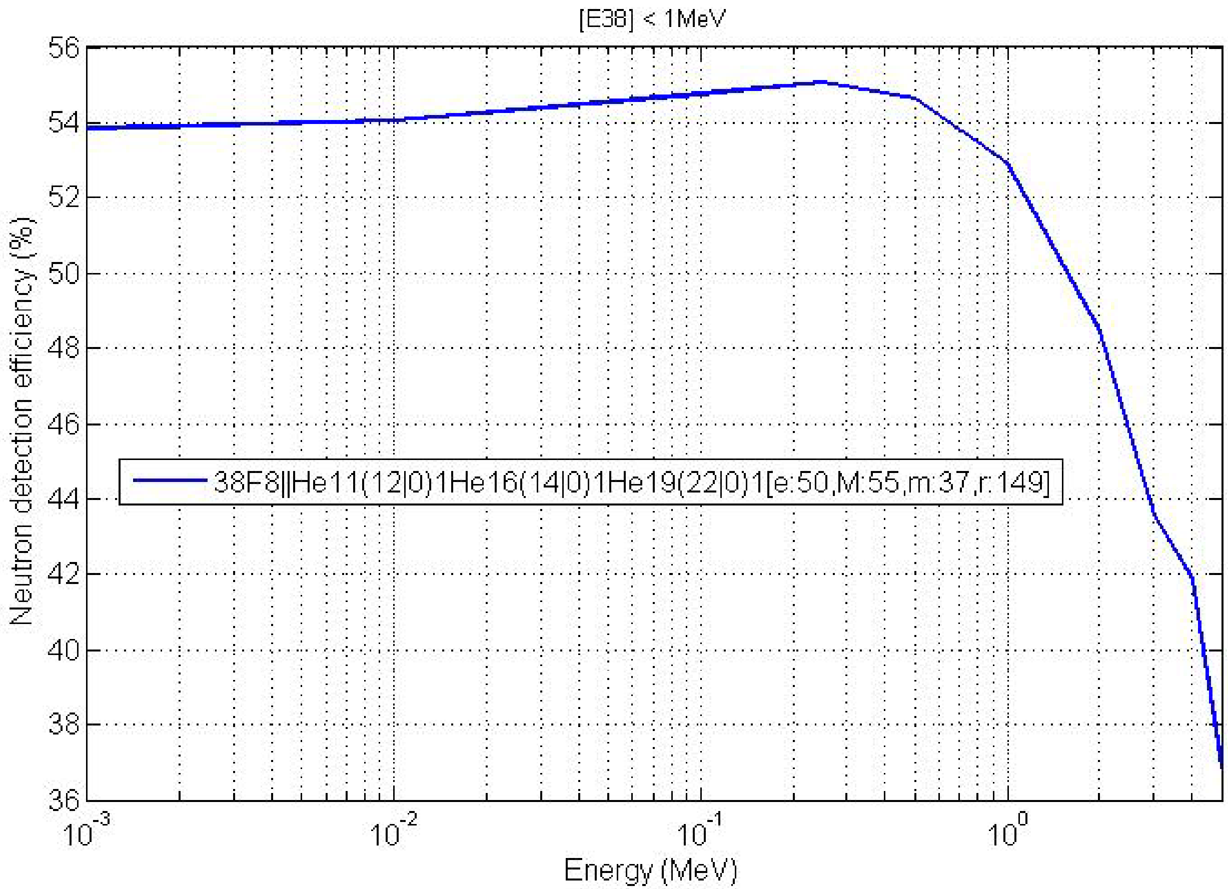


BELEN design in progress for **RIKEN** with **AIDA**

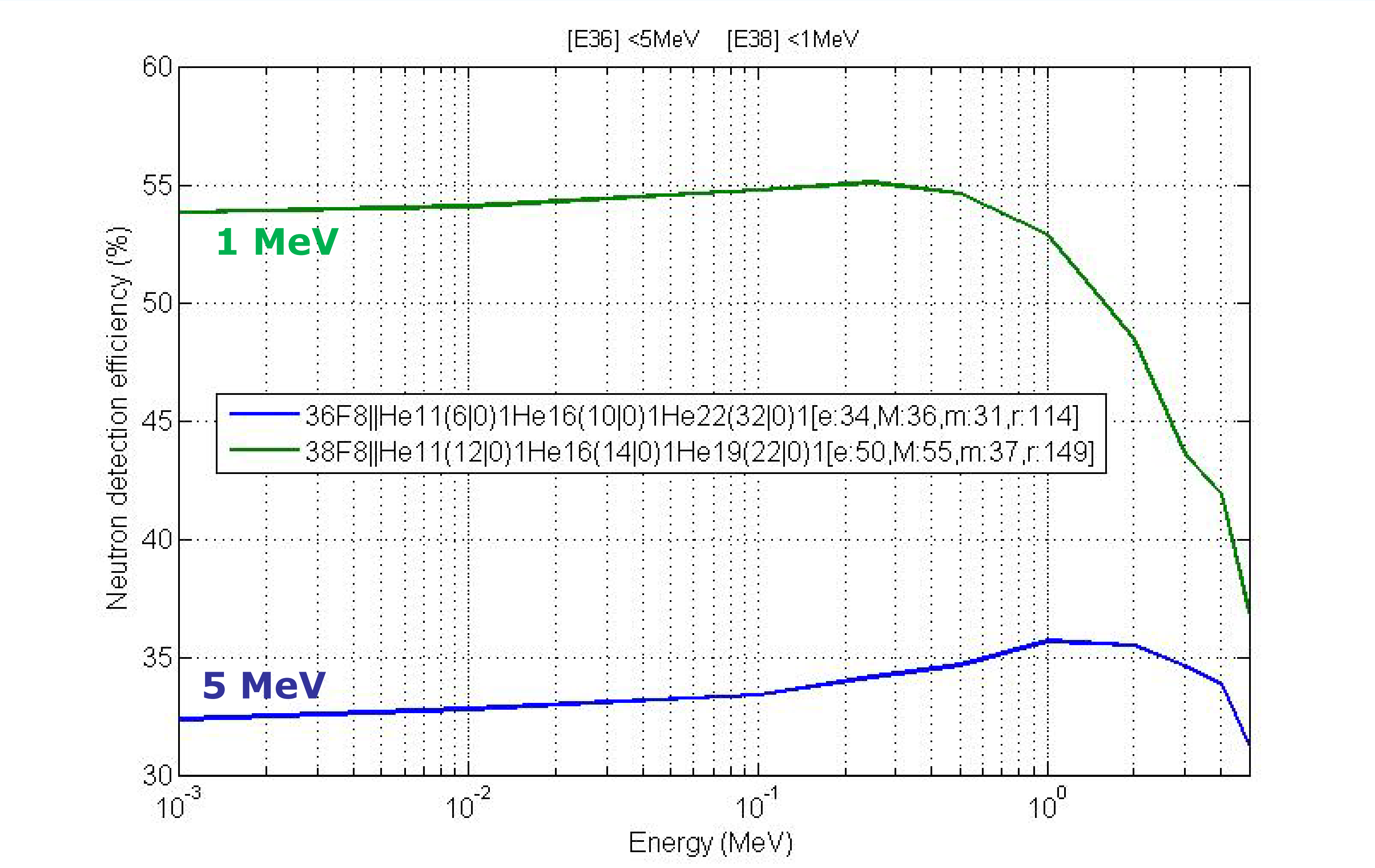
Optimized for range 100 keV – 1 MeV

Radius 8 cm





BELEN design in progress for **RIKEN** with **AIDA** (8cm central hole)



Summary & RIKEN management

- ✓ BELEN is a 4pi neutron detector designed to study beta delayed neutron emission.
- ✓Laboratory tests and several successful experiments performed.
- ✓The efficiency of the previous configurations has been validated experimentally with ^{252}Cf sources and some reference isotopes

- ➢ Logistics for measurements with BELEN at RIKEN→ TO DISCUSS tomorrow!
  - ✓Think about transportation of the detector (Counters & electronics).
  - ✓Which part can be built in RIKEN? (Polyethylene matrix, support).
  - ✓Design of the support structure. Adapted to the experimental hall.
  - ✓Possibility to commission BELEN at RIKEN.
  - ✓A campaign of measurements for optimizing resources?
  - ✓Availability of neutron sources to test/calibrate the detector.
  - ✓Integration of the acquisition system.
  - ✓Human resources.

BELEN detector team

UPC (Barcelona)
R.Caballero-Folch, F.Calviño, G.Cortès, A.Poch, C.Pretel, A.Riego, A.Torner
Old members: M.B.Gómez-Hornillos, V.Gorlychev

IFIC (València)
J.Agramunt, A.Algora, C.Domingo-Pardo, D.Jordan, J.L.Taín

GSI (Darmstadt – Germany)
I.Dillmann, A.Evdokimov, M.Marta

CIEMAT (Madrid)
D.Cano-Ott, T.Martínez, E.Mendoza, A.García

Work supported by the Spanish Ministry of Economy and Competitivity under contract ***FPA 2011-28770-C03-03***

Digital Data Acquisition System (DDAS)

Triggerless digital data acquisition system:

✓Struck digitizer modules (SIS3302): provide time-stamps very versatile for time correlations

✓Negligible dead-time when compared to analog systems

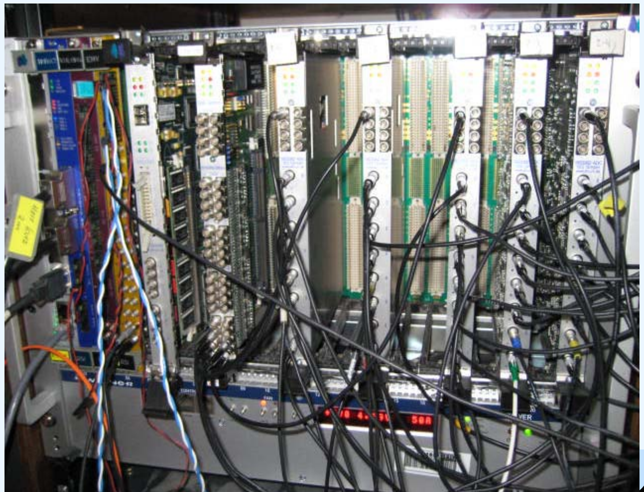
✓Increase the efficiency by about 8% (from 27 to 35%)

✓Flexibility for large time correlation (fundamental to obtain correlations with all neutron and to change the gates offline)

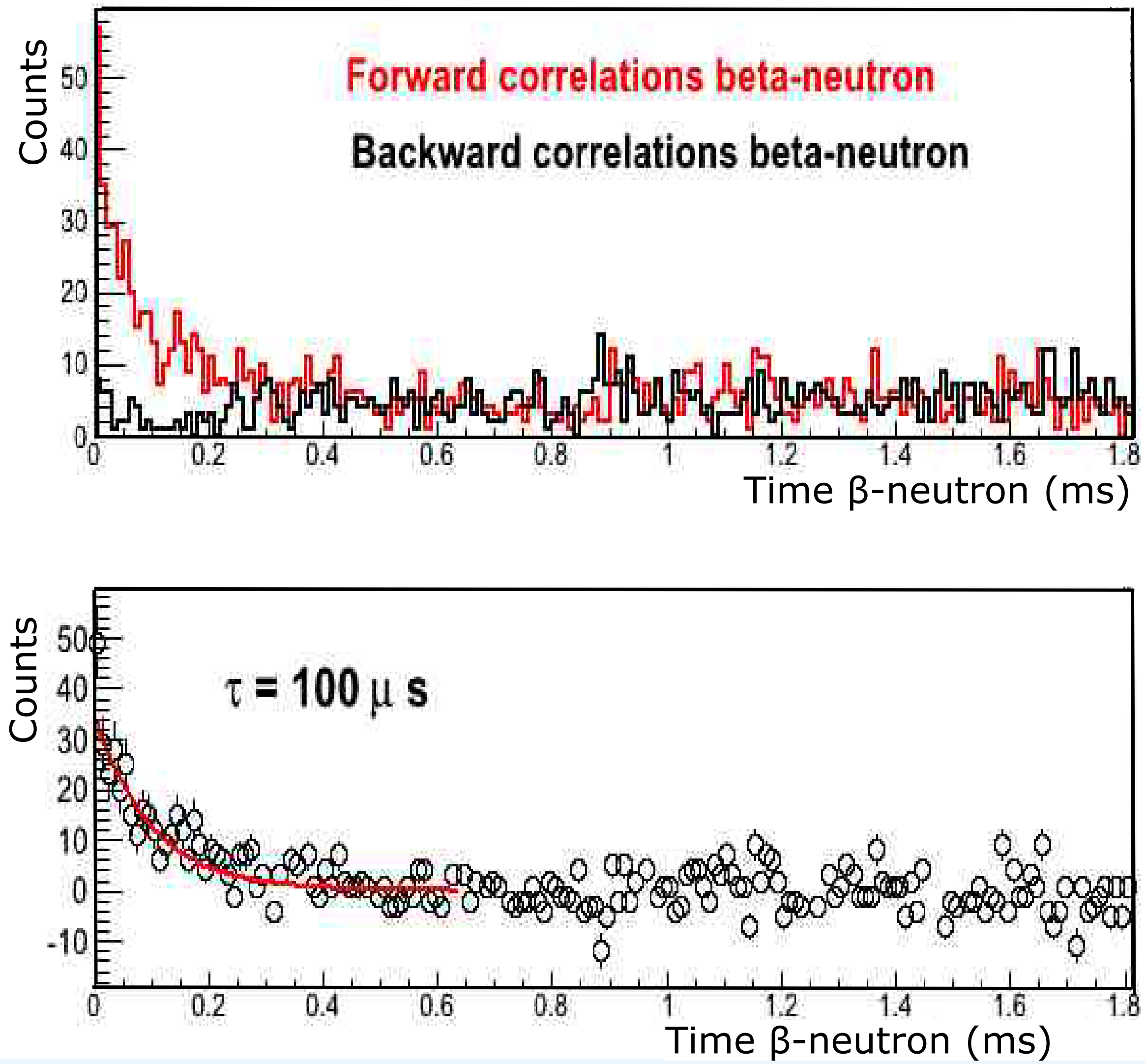
✓Allows to correct some experimental effects, e.g. To reduce neutron background from uncorrelated neutrons

✓Developed at IFIC (València-Spain)

Talk of this part by Jorge Agramunt



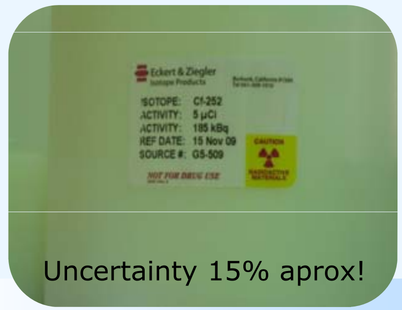
Performance test time correlation between neutron and β-decay for ^{213}Tl



$$P_n = \frac{1}{\varepsilon_n}\frac{N_{n\beta}}{N_\beta}$$

Source to test

the efficiency



Experimental hall for background measurements at GSI