Monte Carlo simulations of BRIKEN detector configurations

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- Simulation framework
- Some preliminary facts
- Geometries without clovers
- Geometries with clovers
- Reliability of simulations
- Shielding
- $\beta n \gamma$ coincidences
- Conclusions

Second BRIKEN Workshop, RIKEN, July 29-30, 2013

- Simulation codes:
  - Geant4 version 9.4.p02, neutron data file: ENDF/B7.0*, thermal scattering data for H in PE
    - Slightly different results than G4NDL3.14
    - Uncorrected bug found by A. Garcia (CIEMAT)
  - MCNPX version 26.d, neuntron data file ENDF/B6.1

- PE density = 0.95g/cm^3 (measured)
- 3He active volume inside a vacuum mother volume but no additional materials

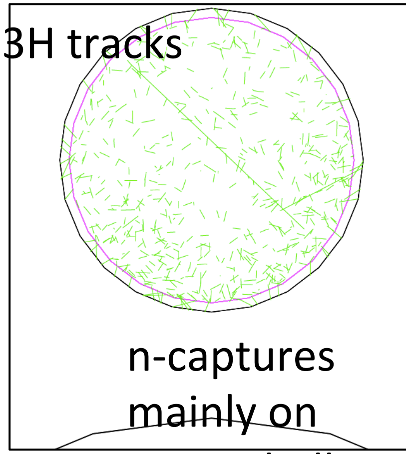
Typ	LAB	Number	Pressure	Active d	Active l	Mother d	Mother l
1	UPC	42	8	2.44	60.0	2.75	64.4
2	GSI	10	10	2.44	60.0	2.75	64.4
3	ORNL	16	10	2.44	61.0	2.75	67.3
4	ORNL	58	10	4.98	61.0	5.30	65.4
5	RIKEN	26	5	2.44	30.0	2.75	34.4
6	JINR	20	4	3.00	50.0	3.20	55.0
		172					

* Mendoza et al. (CIEMAT), http://www-nds.iaea.org/geant4/

Some facts:

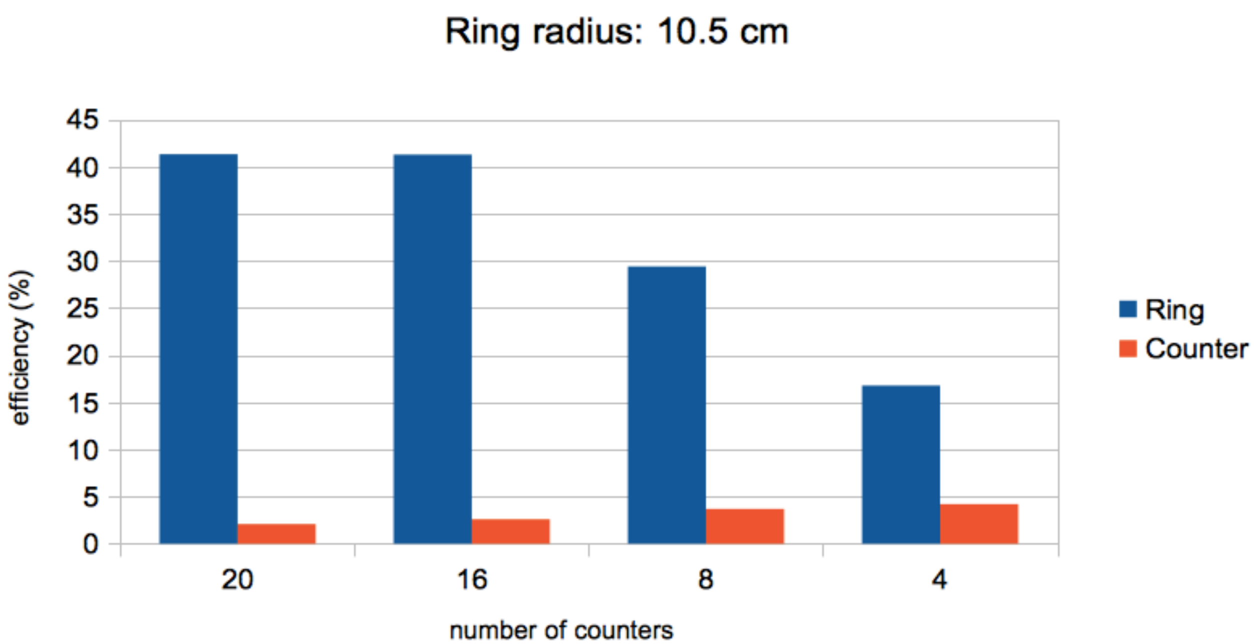
Fact: efficiency does not scale linearly with volume or pressure

	eff	PV
UPC	1.000	1
GSI	1.024	1.25
ORNLs	1.039	1.27
ORNLl	1.967	5.29
RIKEN	0.909	0.63
JINR	0.897	0.63



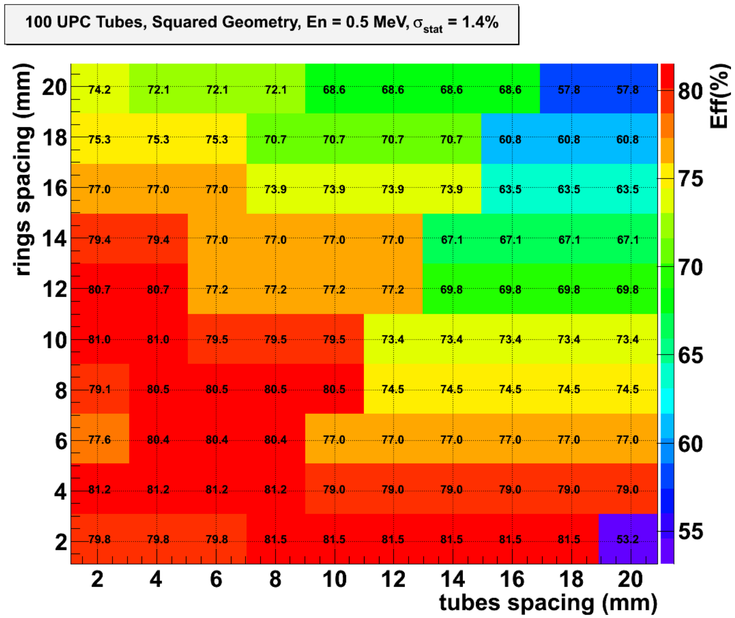
n-captures mainly on outer shells

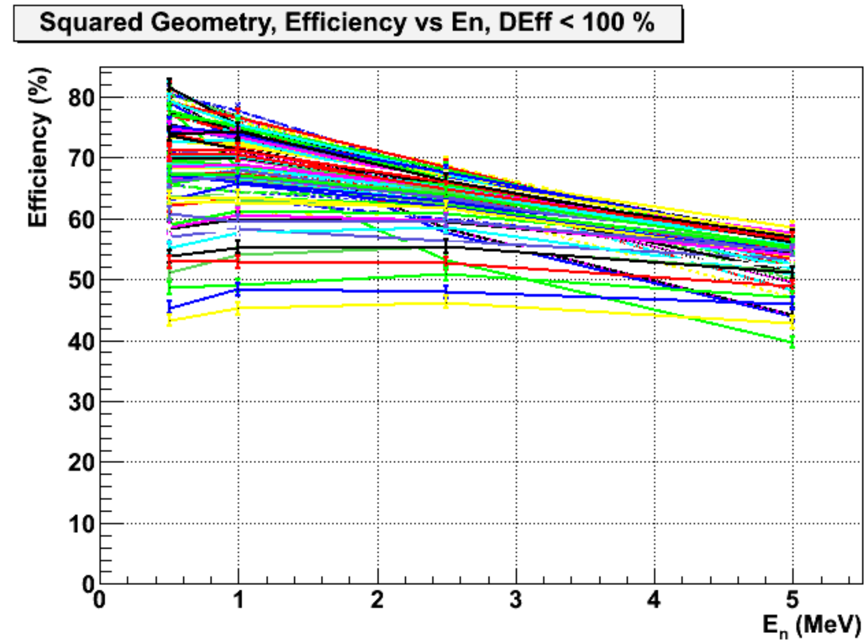
Fact: the efficiency is altered significantly by the proximity of other tubes both through removal of neutrons and decrease in moderation



Fact: large efficiency is in conflict with flat efficiency.
Here we concentrate in large efficiency.

1st approach: an automatic procedure to optimize the the distance between tubes in order to maximize efficiency



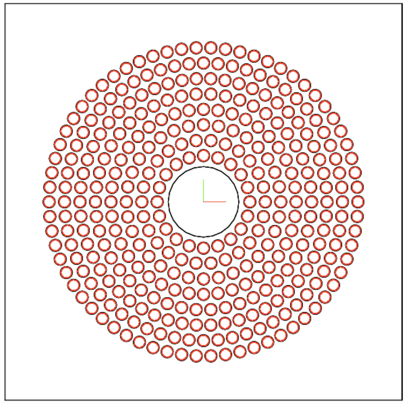


Example for 100 UPC tubes: **optimal spacing about 5mm**

However due to geometrical constraints and the different tube dimensions it was decided to take a

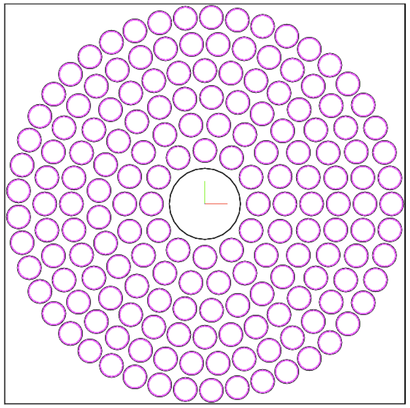
2nd approach: systematic variations based on educated guesses

What maximum efficiencies should one expect?



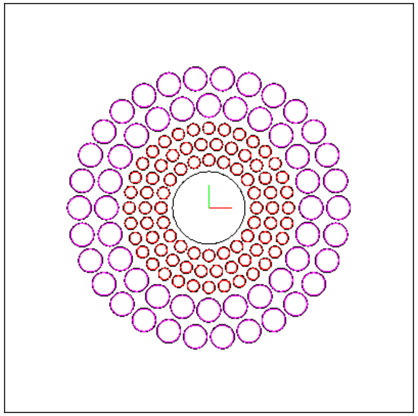
UPC

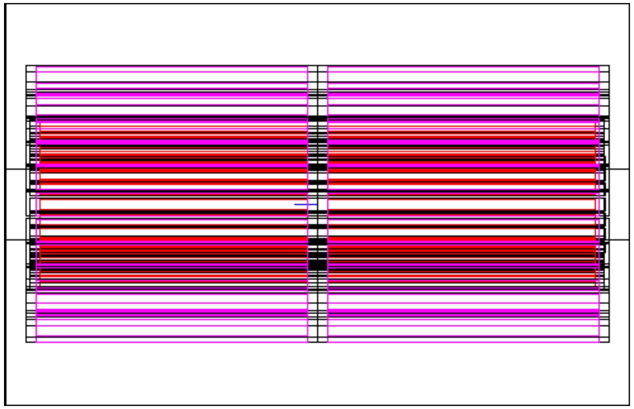
	N	% (0.5 MeV)	% (2.5 MeV)
Ring 1	20	27.2	13.2
Ring 2	26	21.3	13.2
Ring 3	32	15.4	12.0
Ring 4	40	8.9	10.8
Ring 5	46	5.1	8.6
Ring 6	54	2.2	6.8
Ring 7	60	1.4	4.7
Ring 8	66	0.6	4.9
Total	**344**	**82.2**	**74.2**



ORNLl

	N	% (0.5 MeV)	% (2.5 MeV)
Ring 1	12	36.6	18.9
Ring 2	18	23.7	17.2
Ring 3	25	12.2	13.4
Ring 4	32	5.6	9.9
Ring 5	38	2.4	6.9
Ring 6	45	1.0	5.1
Total	**170**	**81.4**	**71.2**

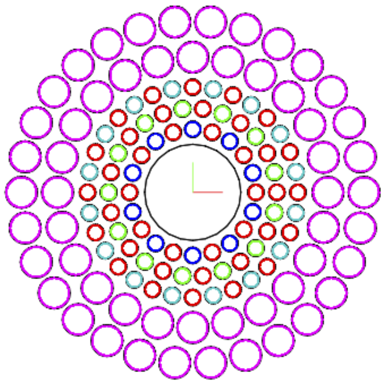




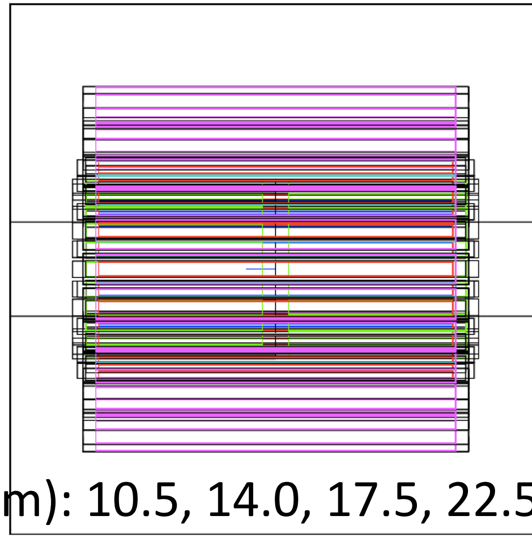
UPC+ORNLl

N	% (0.5 MeV)	% (2.5 MeV)
78+54	81.5	67.1
156+108	85.3	72.7

Two reasonable **configurations without CLOVERS**:



R(hole): 8cm



R(cm): 10.5, 14.0, 17.5, 22.5, 28.5

Ndet: 20, 26, 32, 24, 30

UPC: 39

GSI: 10

ORNLs: 16

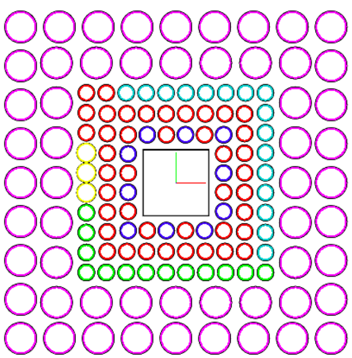
ORNLl: 54

RIKEN: 26

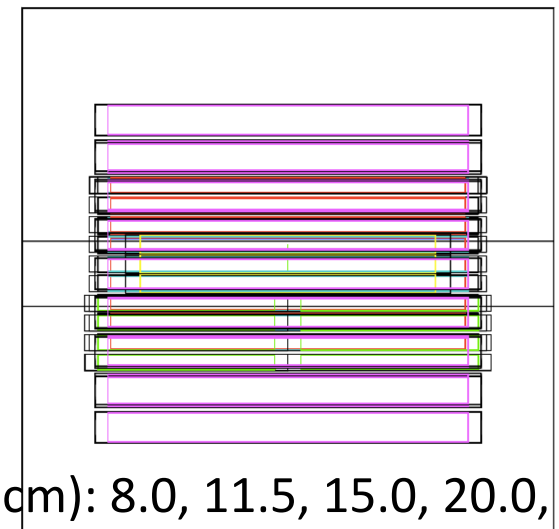
Eff(0.5MeV)=81.5%

Eff(2.5MeV)=67.3%

Ratio=0.83



R(hole): 5.5cm



R(cm): 8.0, 11.5, 15.0, 20.0, 26.0

Ndet: 20, 28, 36, 24, 32

UPC: 42

GSI: 10

ORNLs: 16

ORNLl: 56

RIKEN: 26

JINR: 3

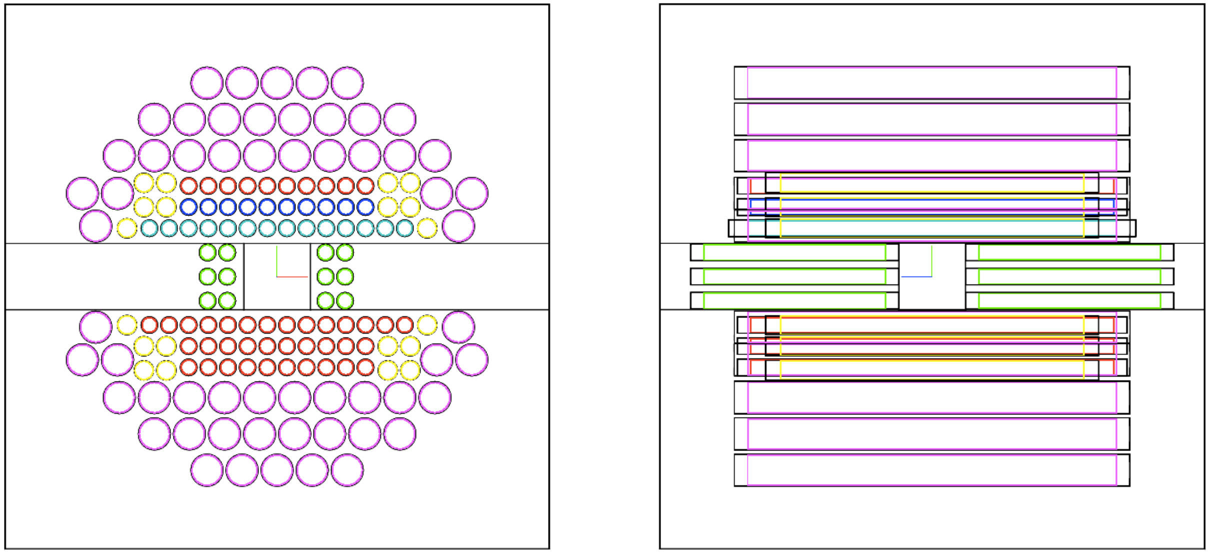
Eff(0.5MeV)=84.4%

Eff(2.5MeV)=73.0%

Ratio=0.86

Increasing PE from 90cm x 90cm x 90cm to 90cm x 90cm x 140cm does not change significantly the efficiency

A reasonable **configuration with 2 CLOVERS**:

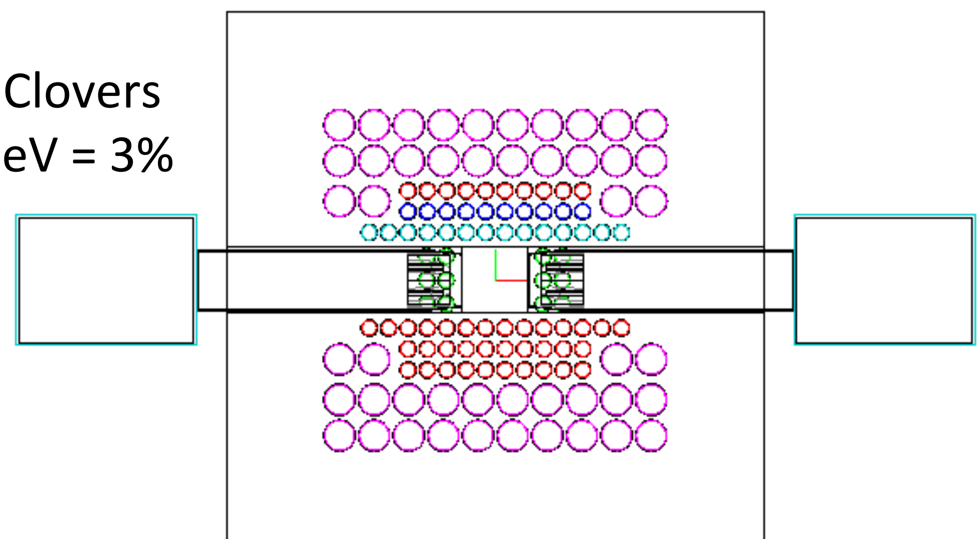


UPC: 42
GSI: 10
ORNLs: 16
ORNLl: 58
RIKEN: 24
JINR: 20
Eff(0.5MeV)=74.5%
Eff(2.5MeV)=62.5%
Ratio=0.84

PE: 90cm x 90cm x 90cm

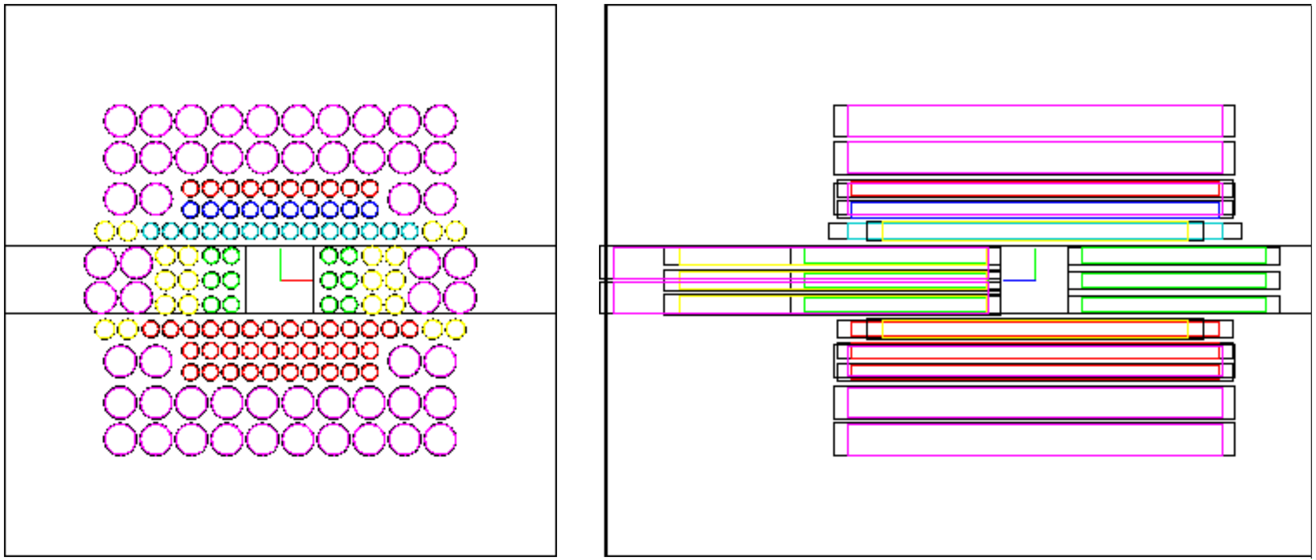
Another configuration with 2 CLOVERS:

2 EXOGAM1 Clovers
γ-effic. @1MeV = 3%



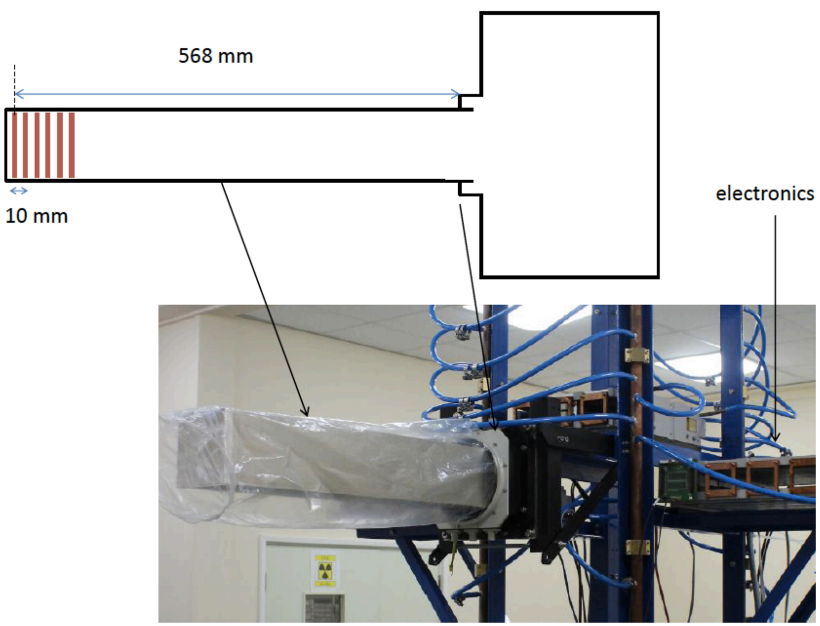
UPC: 42
GSI: 10
ORNLs: 16
ORNLl: 48
RIKEN: 24
Eff(0.5MeV)=71.7%
Eff(2.5MeV)=61.3%
Ratio=0.85

Another configuration with 2 CLOVERS:



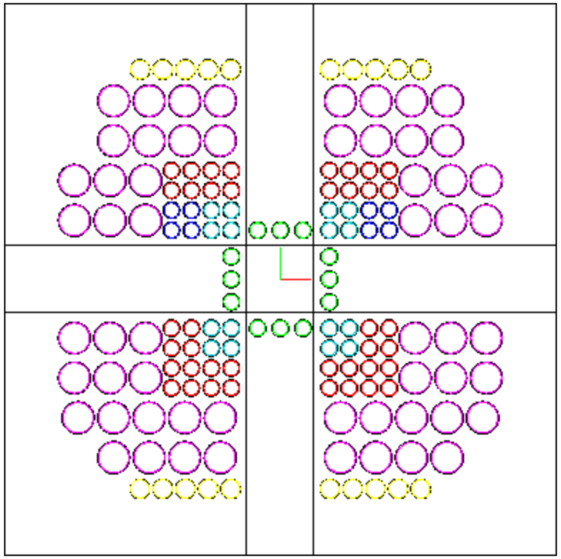
UPC: 42
GSI: 10
ORNLs: 16
ORNLl: 56
RIKEN: 24
JINR: 20
Eff(0.5MeV)=75.6%
Eff(2.5MeV)=66.5%
Ratio=0.88

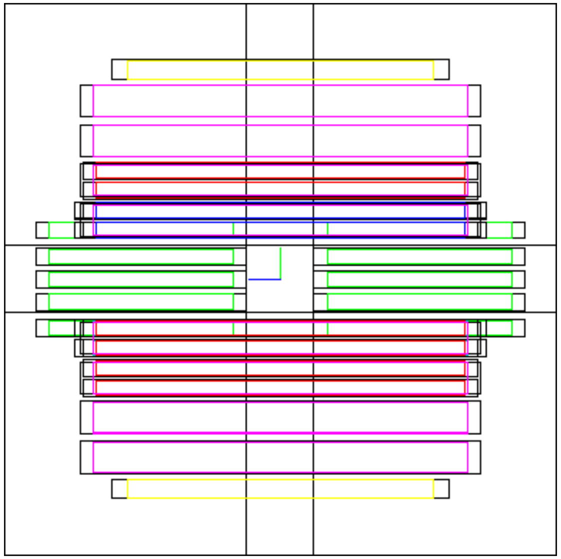
PE: 90cm x 90cm x (70+45)cm



- AIDA is designed to fit a PE block of up to 45-50cm half-length
- Possible problem: location of cables/length of cables

A configuration with 4 CLOVERS:

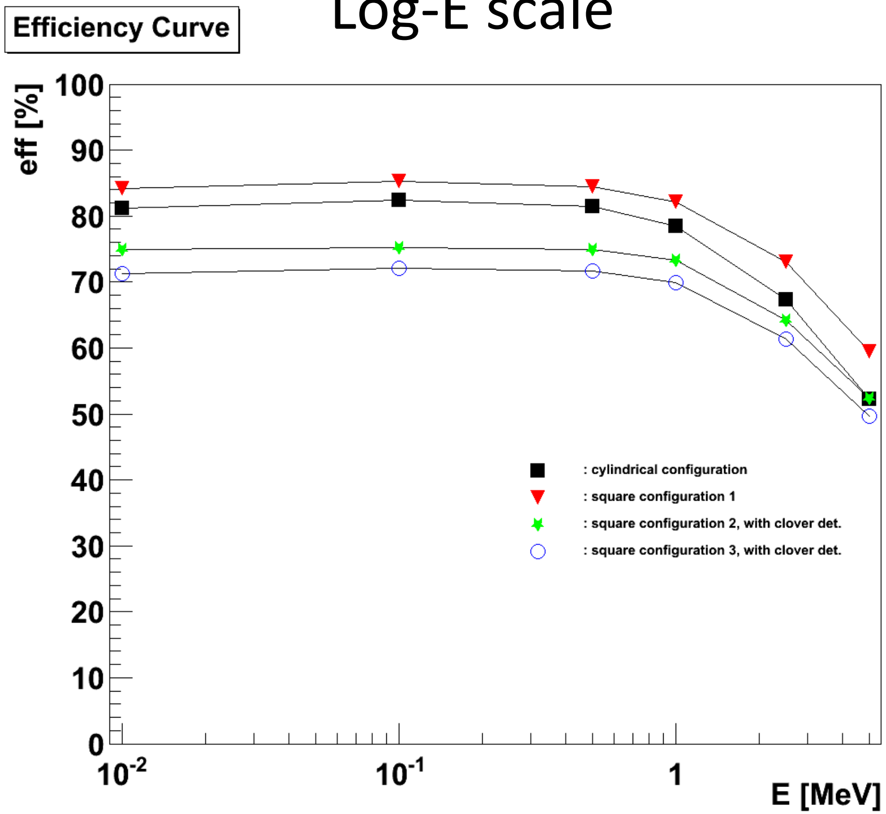




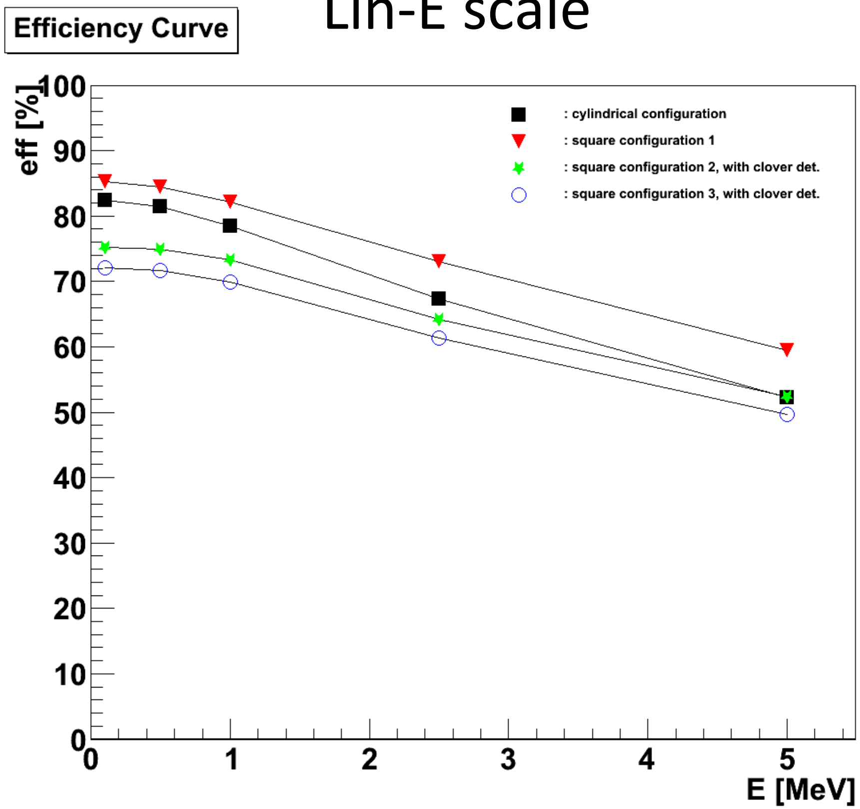
UPC: 40
GSI: 8
ORNLs: 16
ORNLl: 58
RIKEN: 24
JINR: 20
Eff(0.5MeV)=58.3%
Eff(2.5MeV)=51.9%
Ratio=0.89

Evolution of the efficiency with energy:

Log-E scale



Lin-E scale



(incomplete)

The effect of an extended source is marginal:

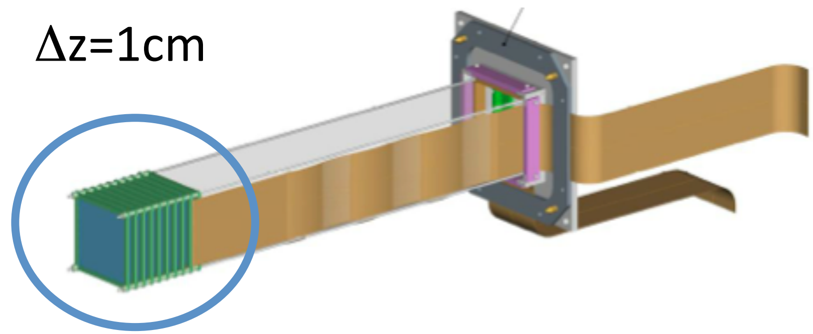
- Comparing a point source with a 8cm x 8cm x 8cm source:

  81.5% -> 81.7% @ 0.5MeV

  67.3% -> 67.5% @ 2.5MeV

Up to 8 DSSSDs
8cmx8cm
Δz=1cm

AIDA



Simulations performed with MCNPX gave very similar results:

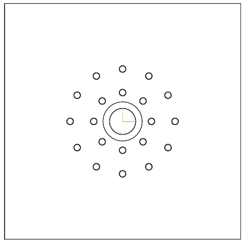
- For example, G4: 81.3%/68.0%, MCNPX: 81.2%/66.9%

NOTE: it is not clear how the inclusion of ancillary detectors (AIDA, CLOVERS) affect the reliability of MC predictions.

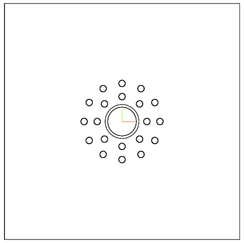
- Experimentally SIMBA decreased efficiency by 3% for 252Cf

How reliable are MC simulations?

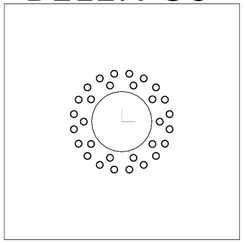
BELEN-20a

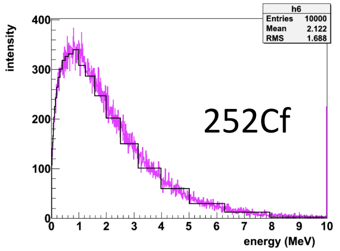


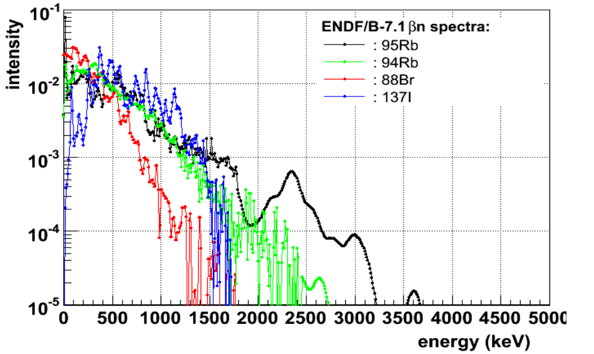
BELEN-20b



BELEN-30







BELEN-20a — **Efficiency**

Isotope	Mean E	Exper.	MCNPX	G4	G4 (bug)
94Rb	437	0.302(8)	0.298	0.300	0.319
95Rb	525	0.301(16)	0.296	0.298	0.317

BELEN-20b — **Inn/out ratio**

Isotope	Mean E	Exper.	MCNPX	G4	G4 (bug)
88Br	247	3.04(2)	3.27	3.32	3.25
94Rb	437	2.51(2)	2.66	2.71	2.66
95Rb	525	2.52(3)	2.62	2.63	2.60
137I	625	2.20(2)	2.22	2.24	2.21
252Cf	2200	1.50(1)	1.56	1.57	1.56

BELEN-30

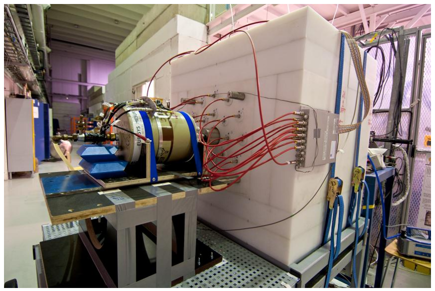
		Efficiency				Inn/out ratio			
Isotope	Mean E	Exper.	MCNPX	G4	G4 (bug)	Exper.	MCNPX	G4	G4 (bug)
252Cf	2200	0.351(8)	0.348	0.350	0.363	0.726	0.758	0.764	0.756

BELEN-48: New measurement at PTB (Dillmann/Marta)

Shielding:

Ambient background

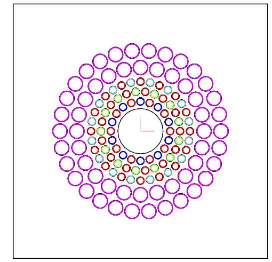
BELEN-20b @ JYFL-IGISOL



Beam-off: 0.7 cps
Beam-on: 0.9 cps
MC = 2 cps

Simulation with ambient background shape and Φ=5E-3 cm^{-2}s^{-1}

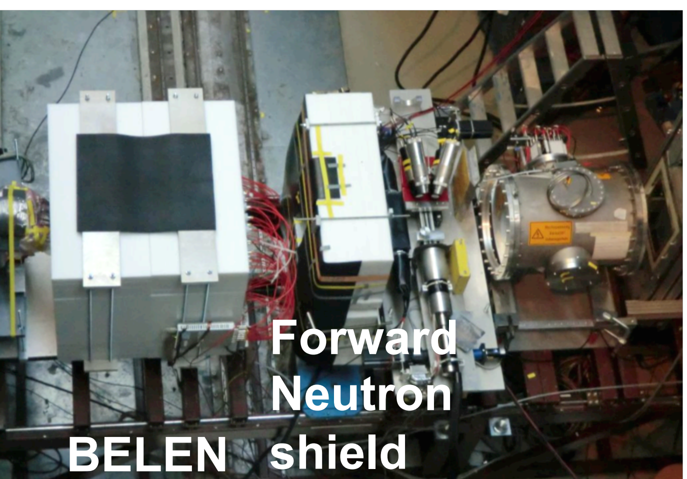
BRIKEN geometry:

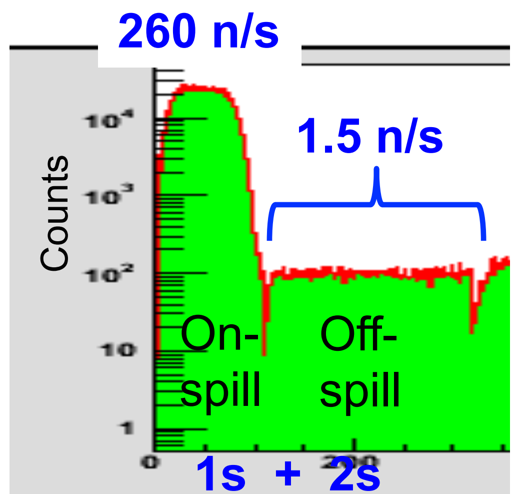


MC = 5.7 cps

Beam induced background:

BELEN-30 @ GSI-FRS





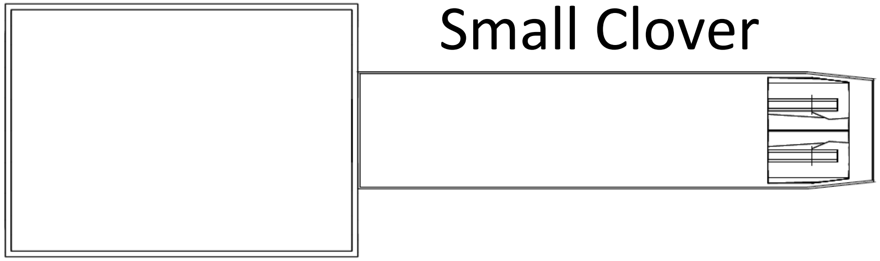
Should be reduced by passive shielding and active vetoing

(Secondary) beam induced background depends on settings and devices

Contribution to beta-n correlations: 250 cps ➔ 0.12 counts in 500 μs moderation time ➔ equival. to P_n=12%

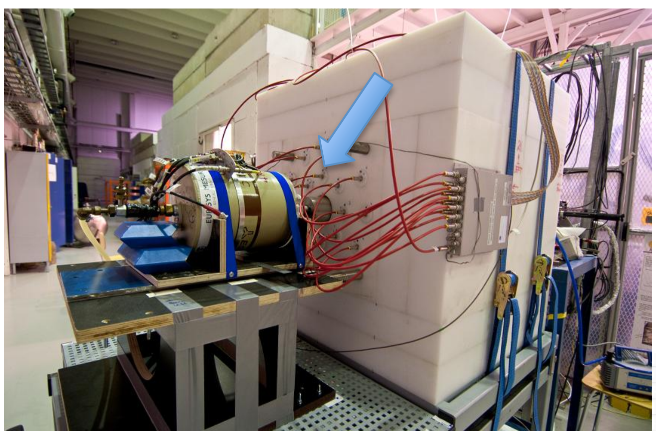
Sensitivity of the setup to βnγ branches

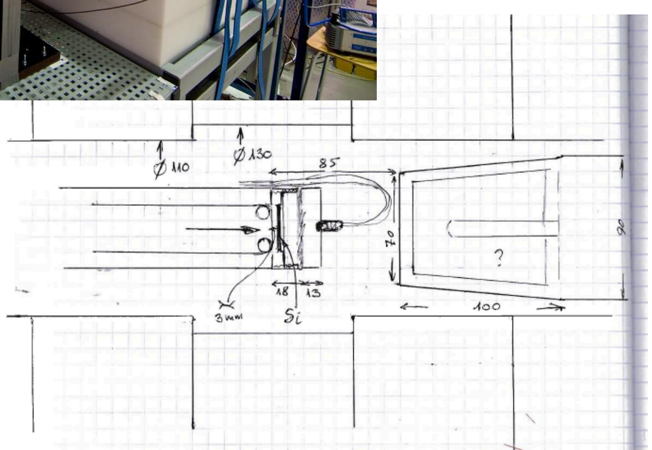
Small Clover



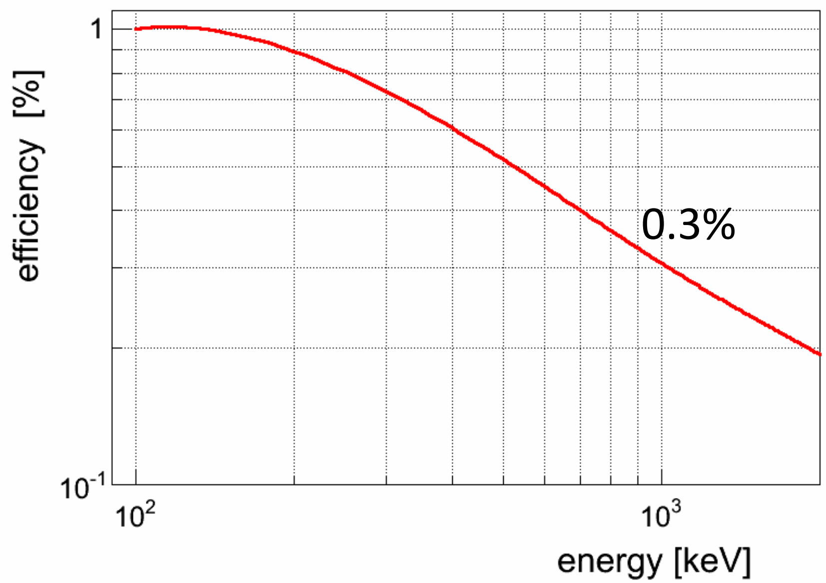
Distance 5.5cm:
Effic(200keV)=4.5%
Effic(1MeV)=1.4%

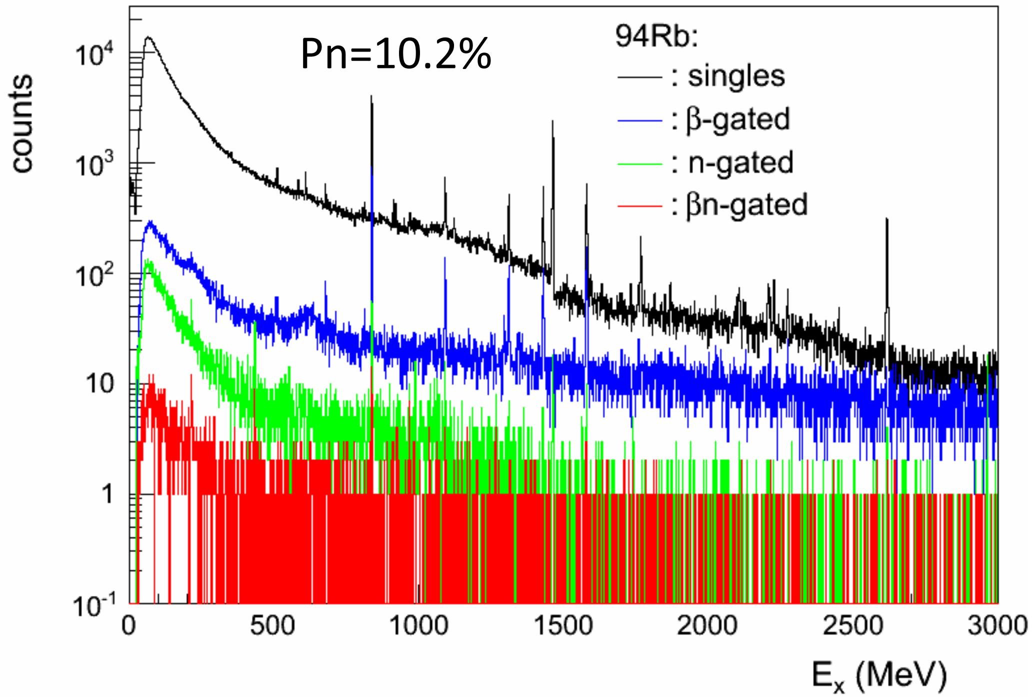
Results from JFYL 2010 BELEN-20b experiment:





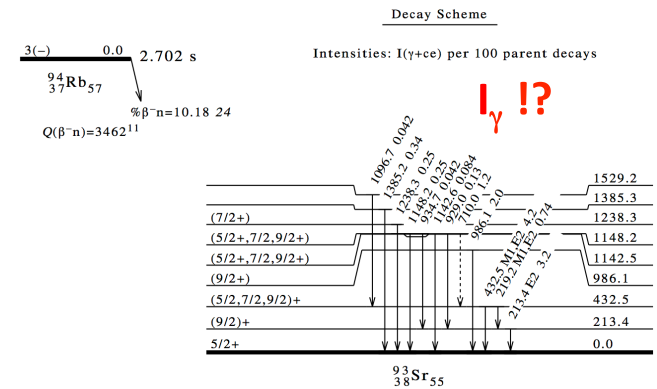
n-effic. = 50%
β-effic. = 24%
γ-effic. :





Effective rate=310 pps

Tmeas= 3.3h

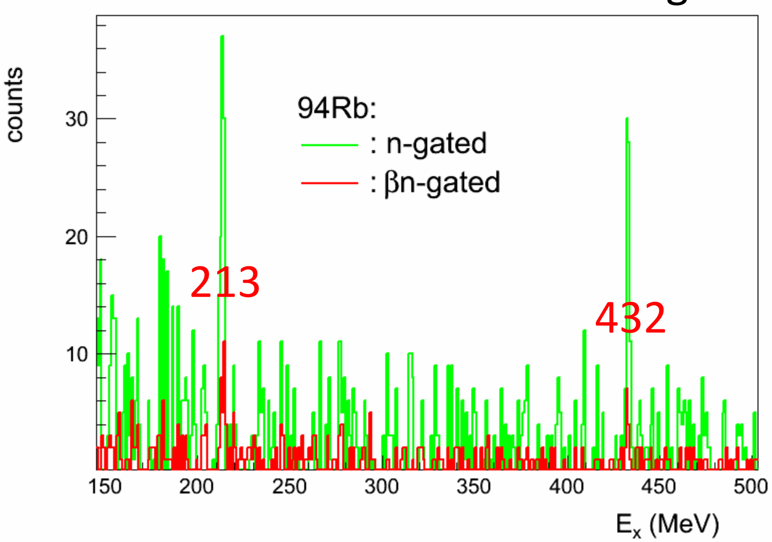


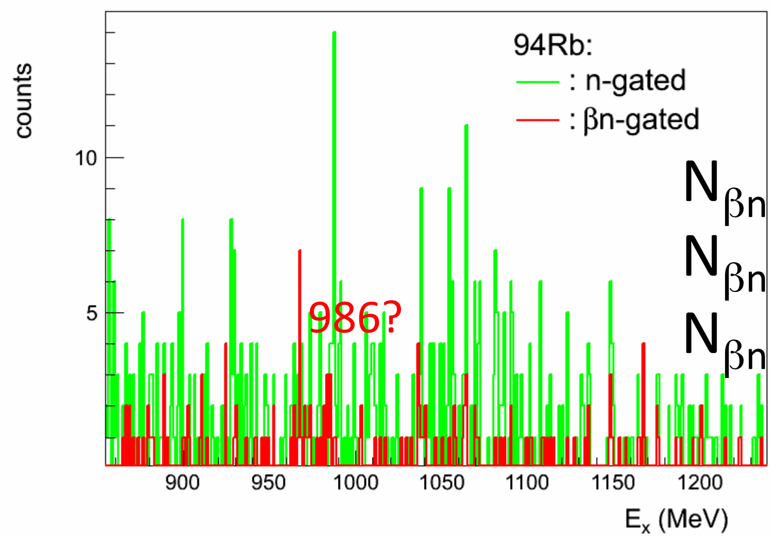
I_γ(213KeV)=0.82%

I_γ(432keV)=1.13%

I_γ(986keV)=0.54%

Background subtracted



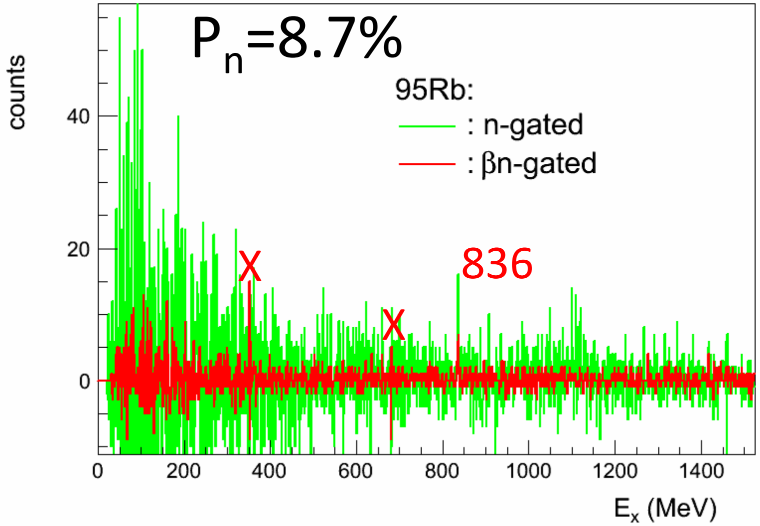


$N_{\beta n}$(213KeV)=30

$N_{\beta n}$(432keV)=17

$N_{\beta n}$(986keV)=?

(expec. 7)

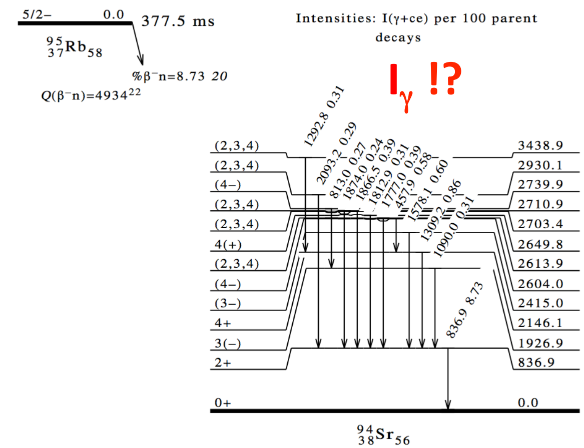


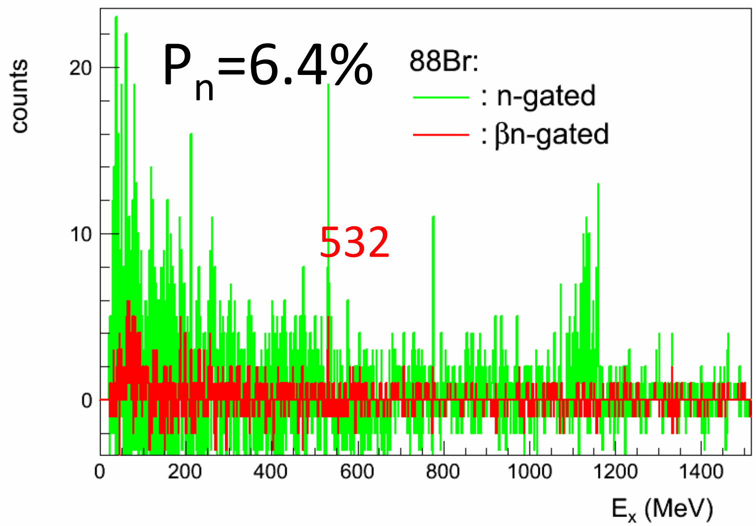
Effective rate=110 pps

Tmeas= 2.2h

Iγ(836keV)=2.83%

$N_{\beta n}$= 17 counts



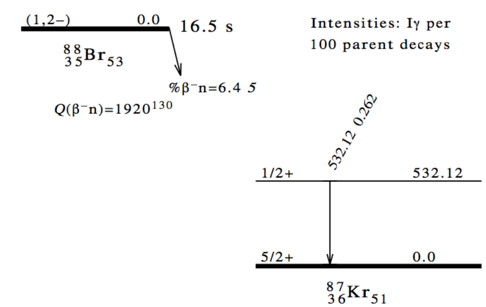


Effective rate=435 pps

Tmeas= 4.2h

I_γ(532keV)=0.28%

$N_{\beta n}$=10 counts



At RIKEN:

β-effic=50%

n-effic=70%

γ-effic=5%

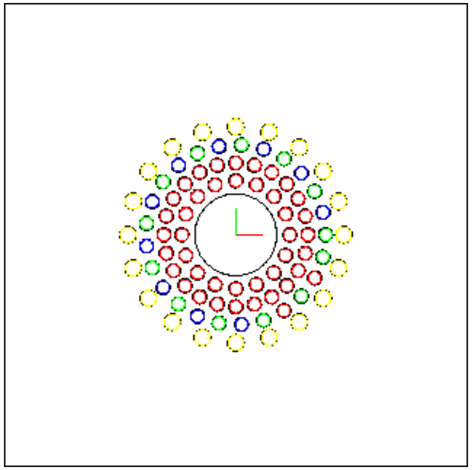
βnγ-effic=1.75%

Counts=implant-rate x time x γ-branch x βnγ-efficiency

For 1 pps in 1 day we would collect 15 counts for a 1% γ-branch

Conclusions:

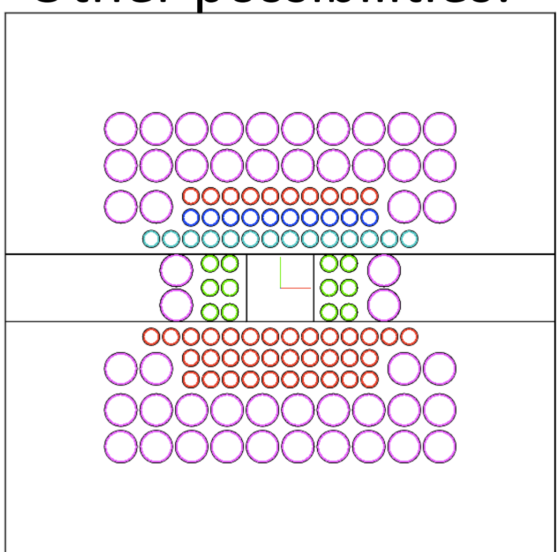
- Without CLOVERS:
  - Efficiencies (in the flat region): 80-85%
  - Ratio (2.5MeV/0.5MeV): 0.83-0.86
- With 2 CLOVERS:
  - Efficiencies of the order of 70-75%
  - Ratio: 0.84-0.88
- With 4 CLOVERS:
  - Efficiencies: 58%
  - Ratio: 0.89

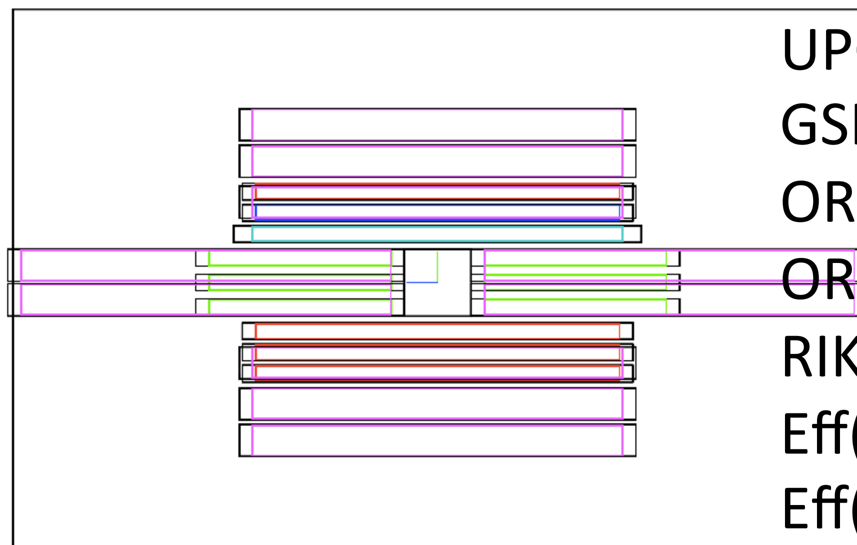


UPC: 42
GSI: 10
RIKEN: 26
JINR: 20
Eff(0.5MeV)=73.4%
Eff(2.5MeV)=56.0%
Ratio=0.76

PE: 90cm x 90cm x 90cm

Other possibilities:





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