BELEN, a high efficiency neutron detector for (alpha,n) yield measurements

Or

What can we do with BELEN neutron detectors for (alpha,n) reaction measurements?

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Universitat Politècnica de Catalunya (UPC)

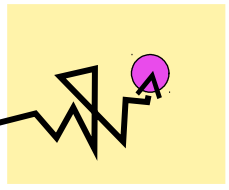
On behalf of MANY collaborators!

OUTLINE

- **BELEN detector**
- **BRIKEN detector**
- **Examples of neutron counters for (alpha, n)**
- **MANY project**
- **MANY neutron counters**

BELEN: Beta deLayEd Neutrons

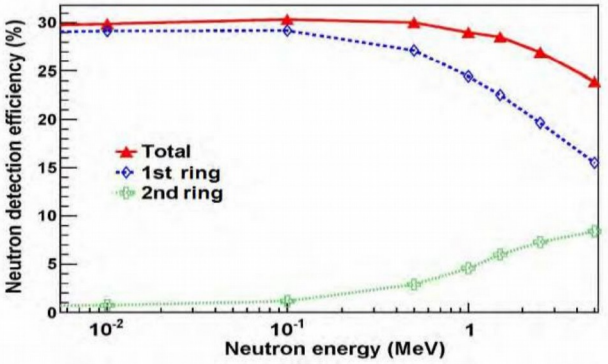
Huge efficiency 5330 b @ n_{th}



$$n + {}^{3}He \rightarrow p + {}^{3}H + 764keV$$

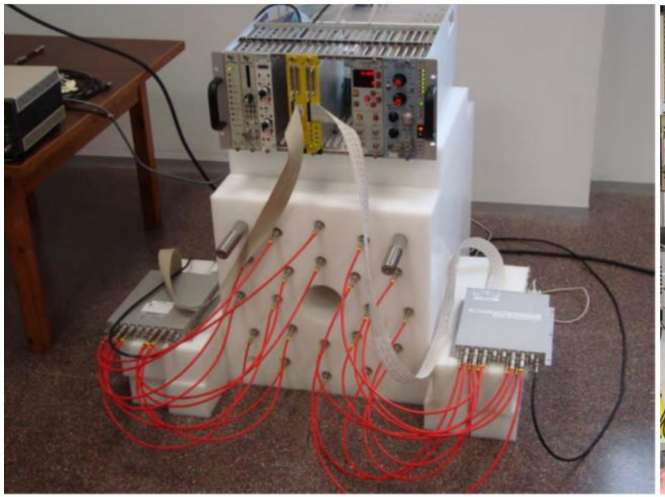
Neutron long counters based on 3He-filled tubes surrounded by HDPE moderator

Objetivo

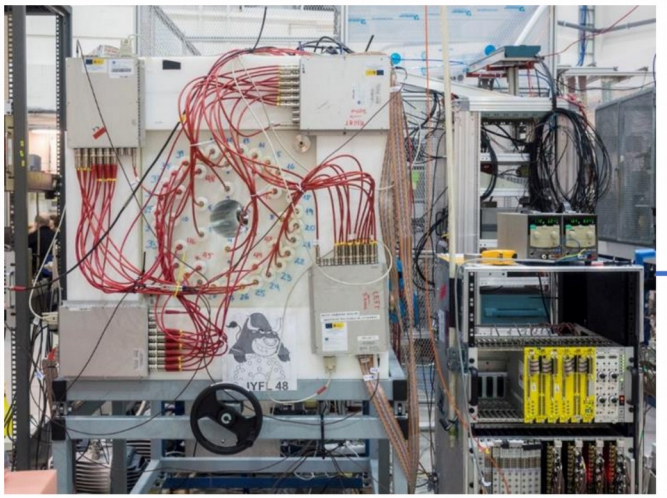


Nombre	Nº (p, atm)	Experimento	Efic. (<1 MeV)
BELEN-20M1	20 (20)	JYFL-2009	30%
BELEN-20M2	20 (20)	JYFL-2010	45%
BELEN-30	20 (20) + 10 (10)	GSI-2011	40%
BELEN-48M1	38 (8) + 10(10)	JYFL-2014	45%
BELEN-48M2	38(8) + 10(10)	JYFL-2014	60%

BELEN 20



BELEN 48



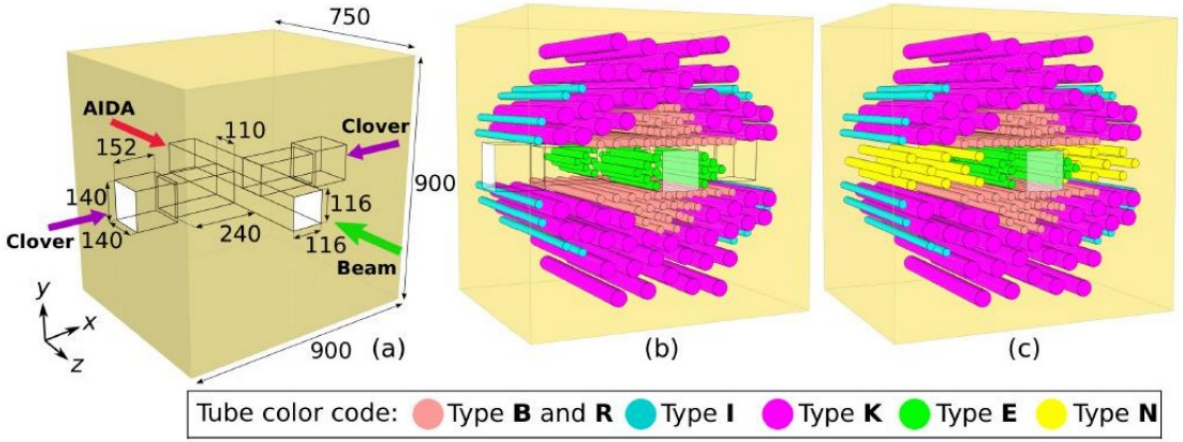
TDR → 2014

Futuro

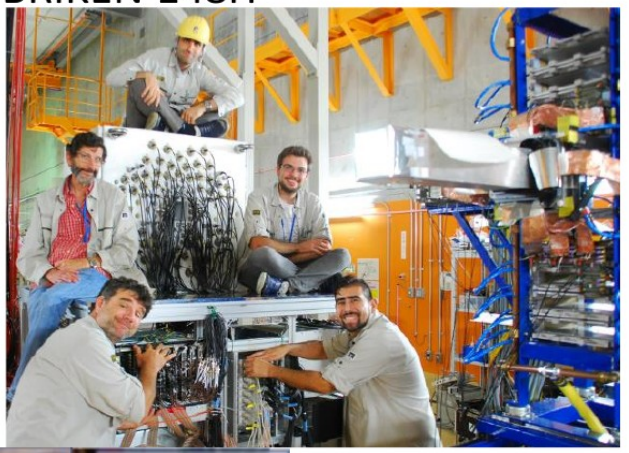
SANDA → 2020 → >2025? FAIR

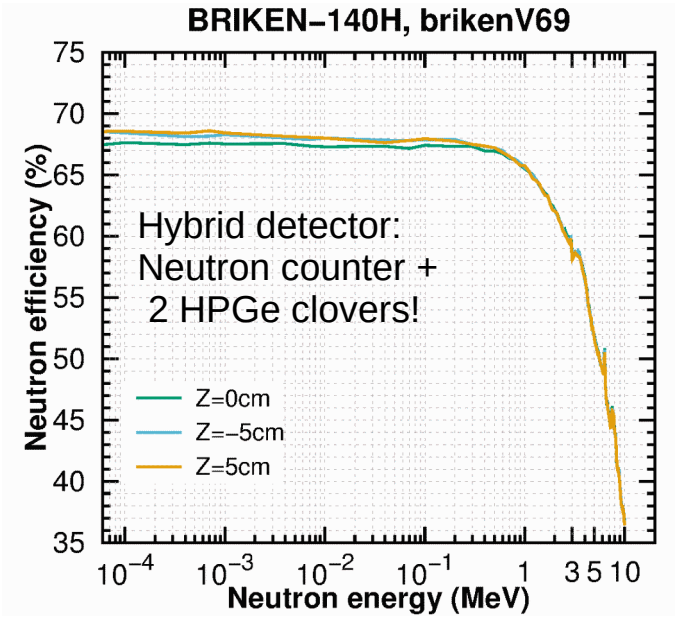
BRIKEN: Beta-delayed neutrons at RIKEN

MC iterativo



BRIKEN 148H





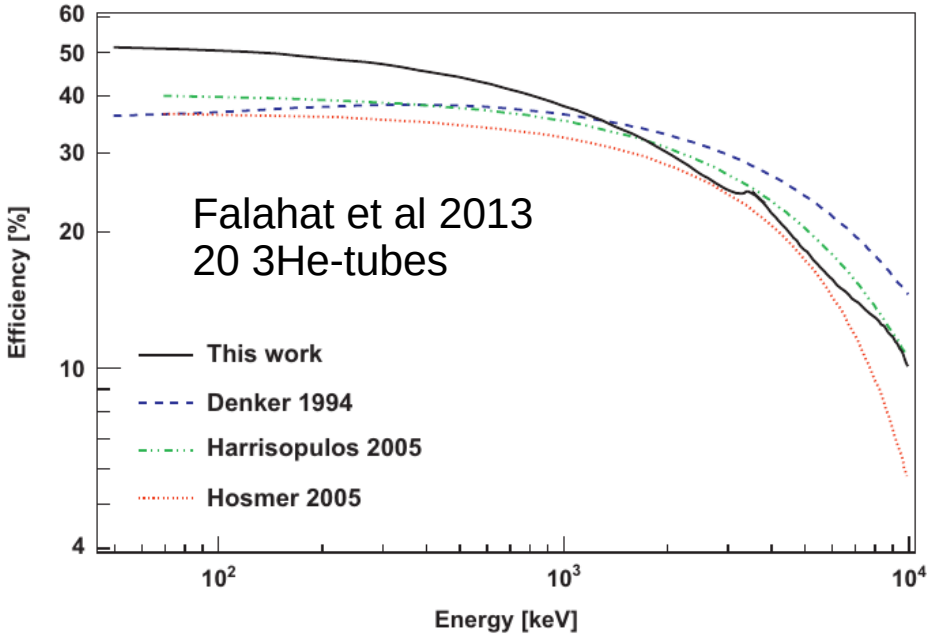
Futuro

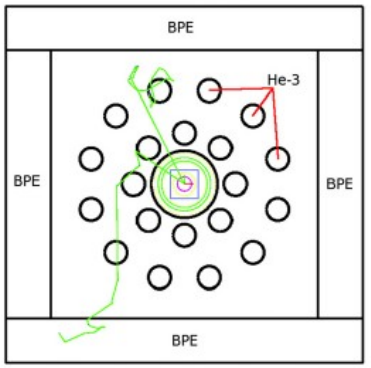
RIKEN

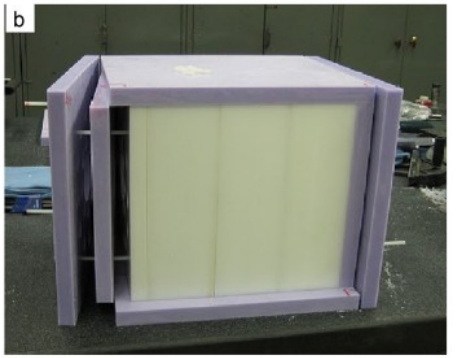
2021

World largest beta-delayed neutron counter:
140 3He-tubes in a "swiss cheese" configuration!

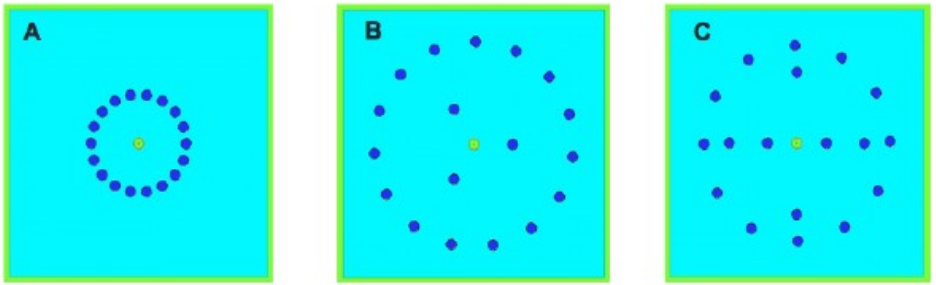
Some examples neutron counters for (alpha,n) reactions





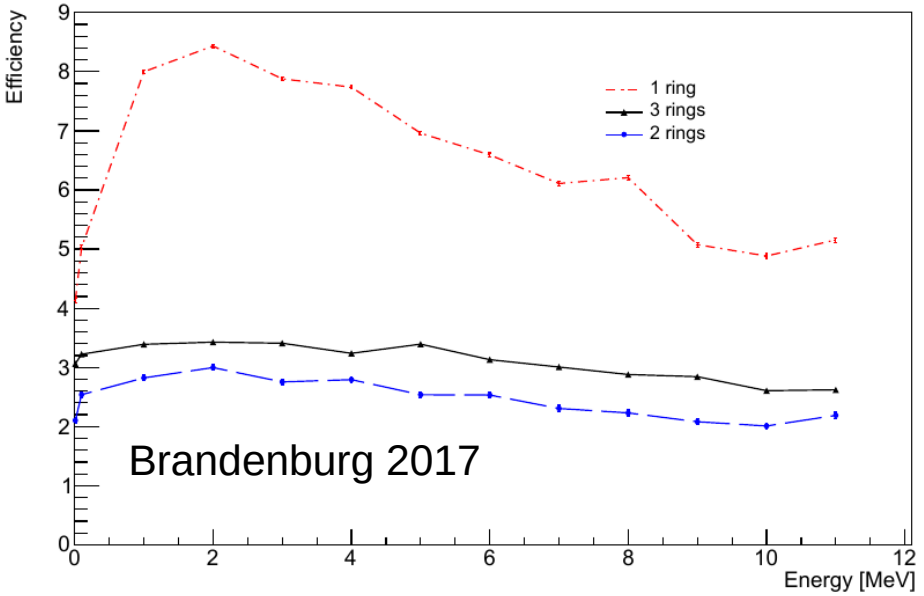


Focus on reactions of astrophysical interest:
- 18O(α,n)21Ne, PRC87 045806(2013)
- 17O(α,n)20Ne, PRC87 045805 (2013)
- 12C(12C,n)23Mg, PRL114 251102 (2015)



BB neutron counter, 18 BF3-tubes,
selected conf C.

Alpha-process:
Plans to measure 96Zr(α,n), 88Sr(α,n)

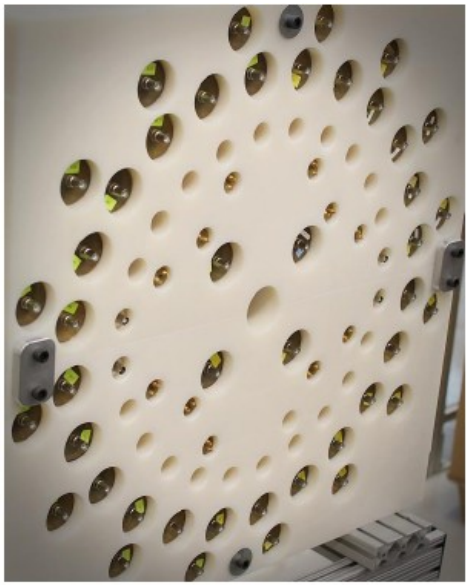


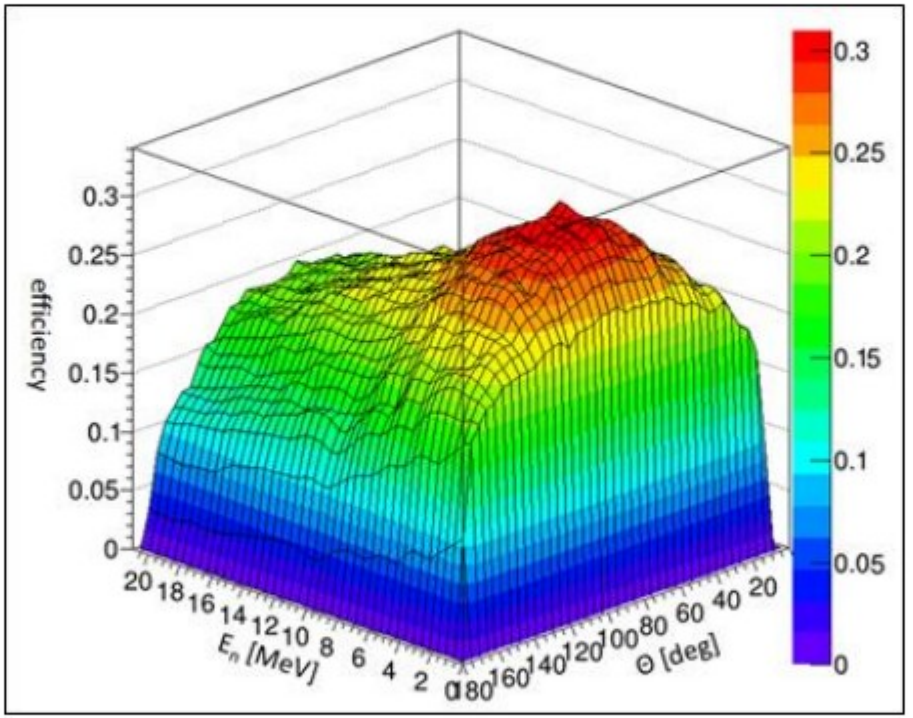
HABANERO: 36 3He long counter tubes and 44 BF 3 tubes (80 tubes total)

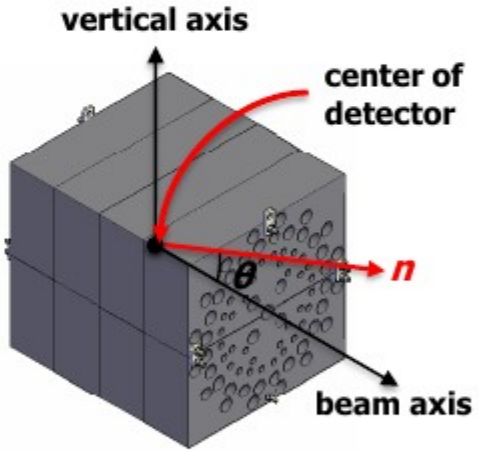
- HABANERO: Heavy ion Accelerated Beam induced (Alpha,Neutron) Emission Ratio Observer
- Properties:

  1) Relatively high and flat efficiency for large energy range

  2) For 0.1 MeV ≤ E_n ≤ 20 MeV, <ε>=22 %, ε_{max} = 27 %, ε_{min} = 17 %, δε = 5 %.







Neutron detection efficiency by MCNP simulation for neutrons having various theta angle

MANY project: Measurements of (Alpha,N) Yields

Measurement of (Alpha,N) Yields/ MANY neutron detector / 3He-tubes stock for 2020									
Detector	**Gas**	**Group**	**Units**	**Pressure (atm)**	**Total length (cm)**	**Tube length (cm)**	**Diameter (inch)**	**Gas length (cm)**	**Active length (cm)**
LDN 252266	3He, CO2	IFIC(10)/ CIEMAT(2)	12	10	67.59	63.72	1	63.3	60
LND 252231	He3, Ar, CO2	UPC(1)/ CIEMAT(3)	4	10.1	63.1	53.2	1	53.2	50
LND 252285	3He, CO2	UPC	1	8	67.59	63.72	1	63.3	60
LND 252303	3He, CO2	UPC	1	4	67.59	63.72	1	63.3	60
LND 252248	3He, CO2	UPC/IFIC	1	20	67.59	63.72	1	63.3	60
LND 252241	He3, CO2	UPC	1	20	38.65	33.97	1	33.97	30.48
LND 252251	3He, CO2	IFIC	1	20	15.35	20.7	1	15.43	13.1
LND 252250	3He, CO2	IFIC	2	10	12.75	7.06	1	7.46	5.13
Long tubes			**19**						
Small tubes			**4**						

Available in 2020

3He price: 20-25 €/cm/atm 3He!

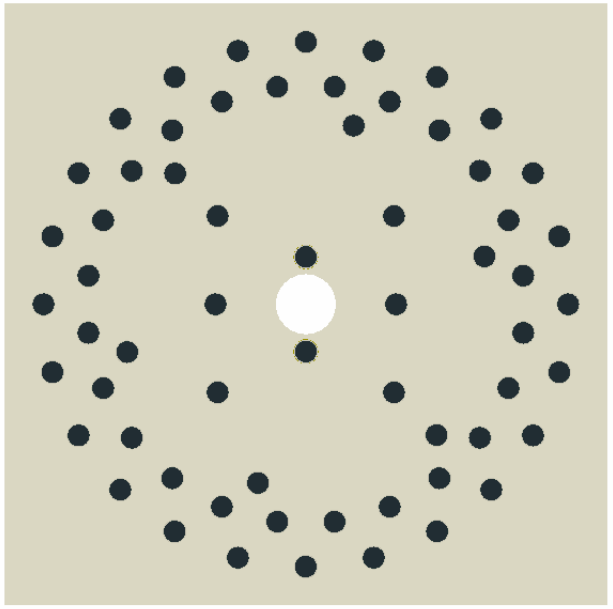
Expected during in 2021:
+ 48 tubes, 1”, 8 atm, 60 cm active length (coming from Japan)
+ 5-10 tubes, 1”, 4 atm, ~ 30cm, requested by UPC next grant.

Foreseen in 2021 60-65 tubes (~8atm, 60cm)

~700k€ just in 3He tubes...

What could be expected with such a 3He “budget”?

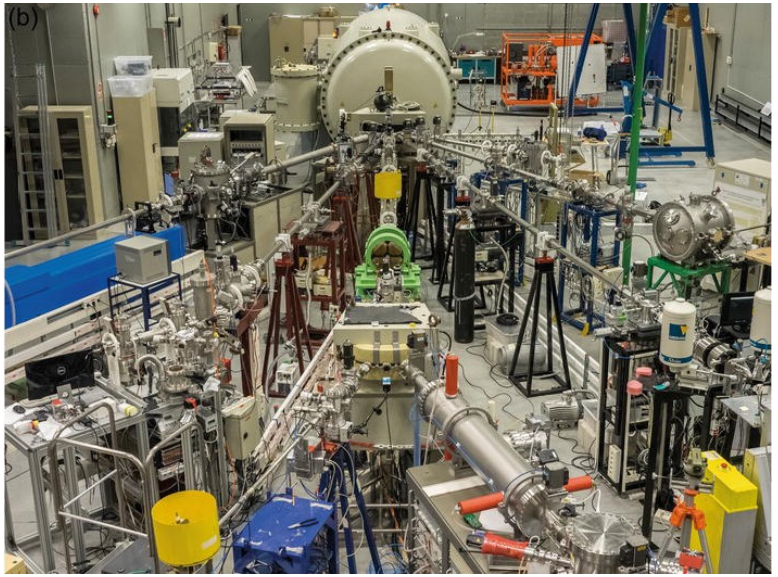
Neutron efficiency v/s flatness?



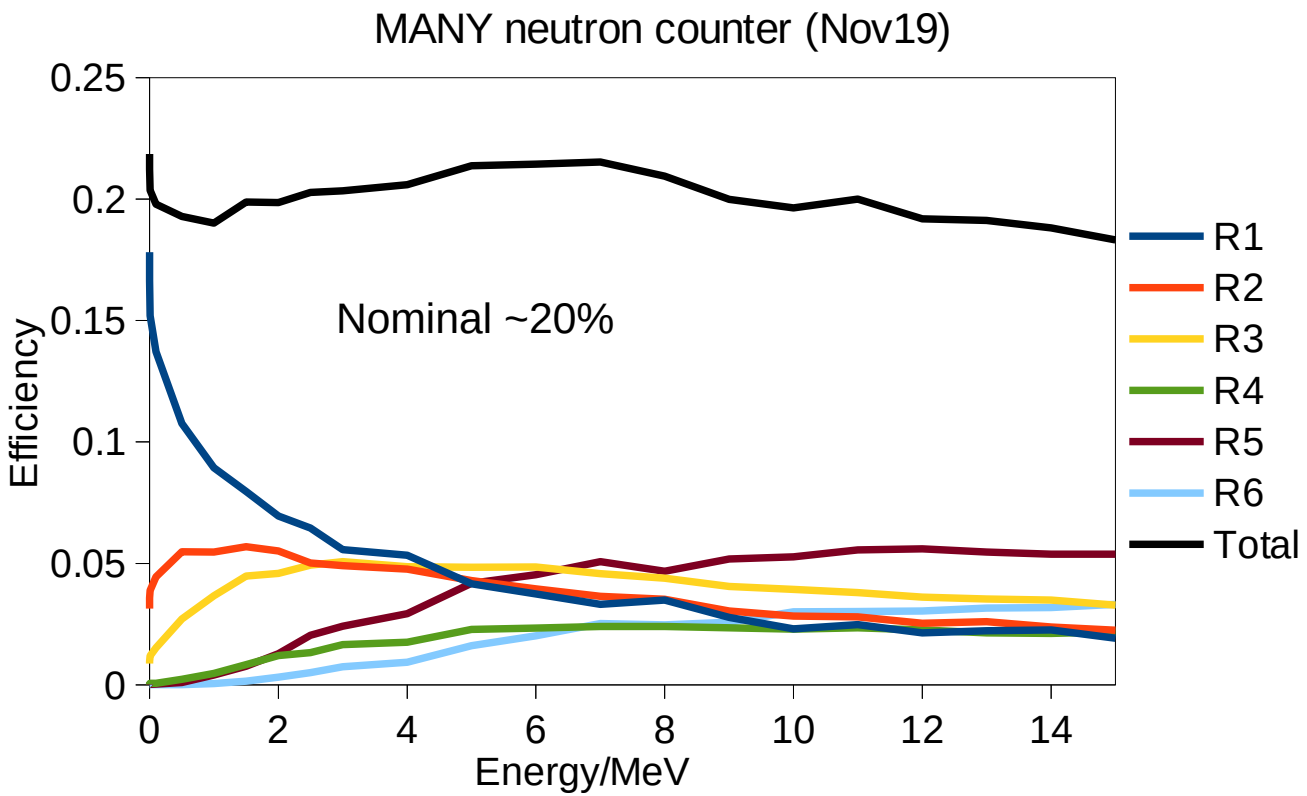
Proposal for MANY neutron detector

Preliminary optimization study (Nov2019)

+ HDPE moderator core 70x70x70cm3
+ Moderator central hole 7cm diameter
+ 62 3He-filled detectors
+ Six rings at 5.5cm, 10.5cm, 14.5cm, 21.5cm, 25.5cm, 30.5cm.
+ Design compatible for use of a HPGe detector (IEM).
+ Design use cadmium filters to compensate over efficiency at lower energies.
+ Beyond 2021. Experiments to be realistic in 2022...



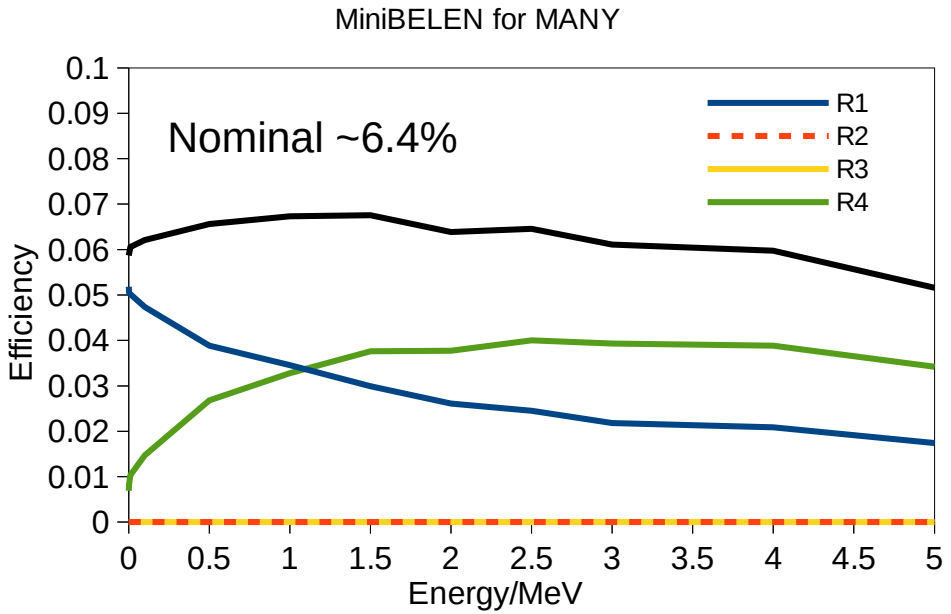
MANY_NC (Nov19)



E_low = 100 keV						
E_up/MeV	1	5	8	10	15	18
Average_eff	**19.36%**	**20.04%**	**20.36%**	**20.28%**	**19.97%**	**19.58%**
Flatness	**1.04**	**1.12**	**1.13**	**1.13**	**1.18**	**1.31**
Max_eff	19.79%	21.37%	21.53%	21.53%	21.53%	21.53%
Min_eff	19.01%	19.01%	19.01%	19.01%	18.32%	16.43%
Delta_eff	0.78%	2.36%	2.52%	2.52%	3.21%	5.10%

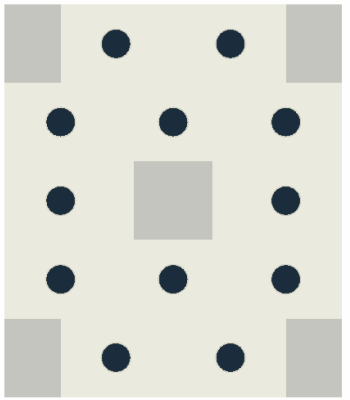
Do we need to wait until 2022?

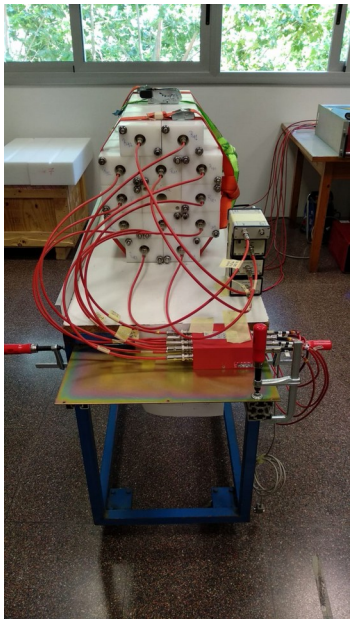
E_low = 100 keV					
E_up/MeV	1	2	3	4	5
Average_eff	**6.50%**	**6.53%**	**6.46%**	**6.40%**	**6.26%**
Flatness	**1.08**	**1.09**	**1.1**	**1.13**	**1.31**
Max_eff	6.73%	6.75%	6.75%	6.75%	6.75%
Min_eff	6.21%	6.21%	6.11%	5.97%	5.16%
Delta_eff	0.52%	0.54%	0.64%	0.78%	1.59%



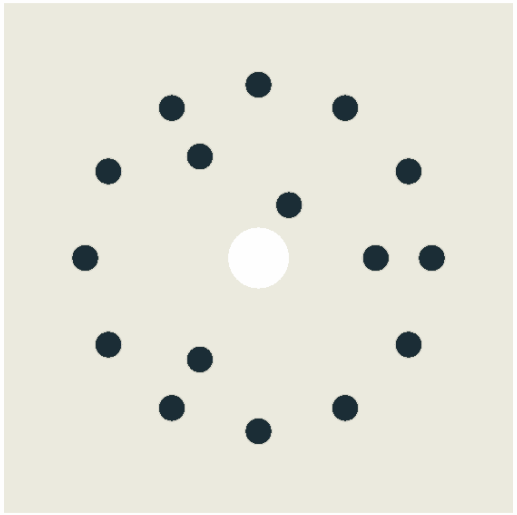
MiniBELEN for MANY

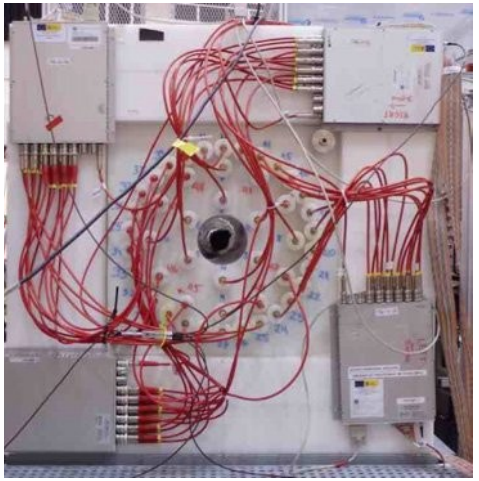
+ Highly modular HDPE moderator
+ Moderator central hole 7x7cm2
+ 12 3He-filled detectors
+ Two “efective” rings at 7cm and 14.87cm
+ Design compatible for use of a HPGe detector (IEM).
+ Cadmium and 3He counters (R2, R3) used to compensate over efficiency at lower energies.
+ Minor effort to prepare the detector!
+ Available at UPC. Experiments from ~March 2020.

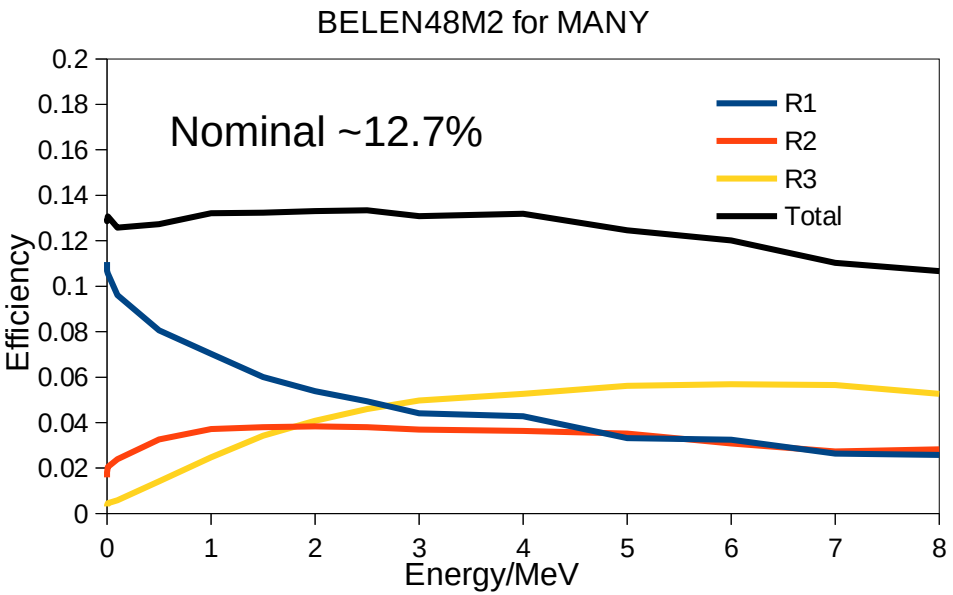




BELEN48 for MANY







BELEN48M2 for MANY

+ HDPE moderator 50x50x80cm2
+ Moderator central hole 6cm diam.
+ Adapted to use 16 from 48 3He-filled detectors.
+ Cadmium filter used to compensate over efficiency at lower energies.
+ Minor effort to prepare the detector!
+ Available at IFIC. Experiments from ~March 2020.

E_low = 100 keV					
E_up/MeV	1	3	4	6	8
Average_eff	**12.84%**	**13.07%**	**13.02%**	**12.75%**	**12.57%**
Flatness	**1.05**	**1.06**	**1.07**	**1.21**	**1.25**
Max_eff	13.22%	13.35%	13.35%	13.35%	13.35%
Min_eff	12.58%	12.58%	12.46%	11.03%	10.67%
Delta_eff	0.64%	0.77%	0.89%	2.32%	2.68%

Remarks

- Measurement program of (alpha,n) reactions can be achieved with BELEN detectors.
- Adapted detectors MiniBELEN (6.4% up to 5MeV) and BELEN48 (12.7% up to 8MeV) can be used in the short time. **~March 2020!**
- A dedicated detection system is under development. A preliminary optimization study shows that 20% efficiency up to 15MeV will be possible with ~60 3He-tubes.
- Impact of angular distribution on the detector design required.
- Feedback from the low background community is welcomed in order to adapt the detection system to specific requirements.

Thanks!

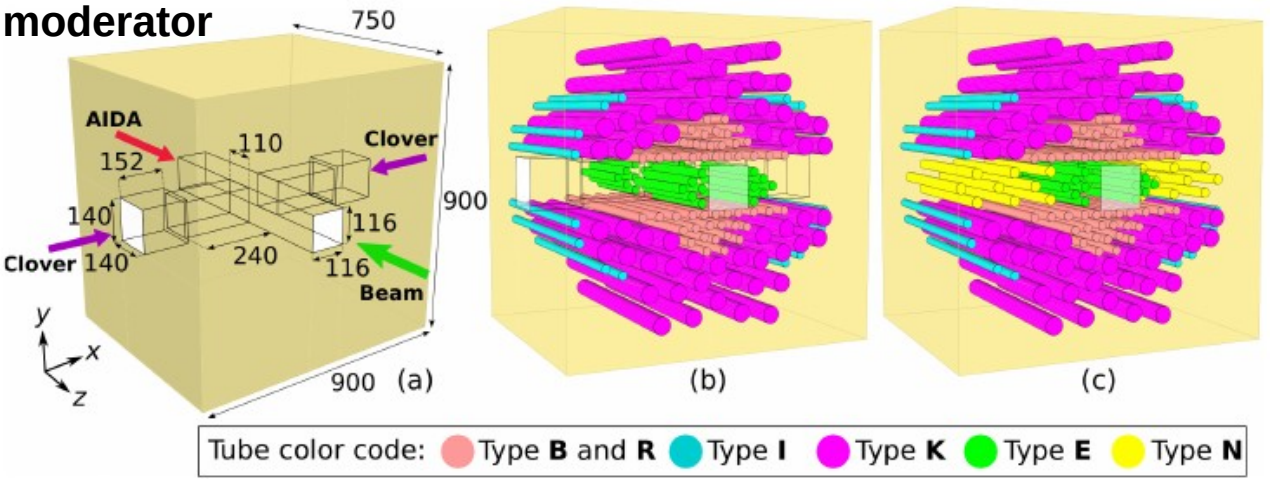
BACKUP

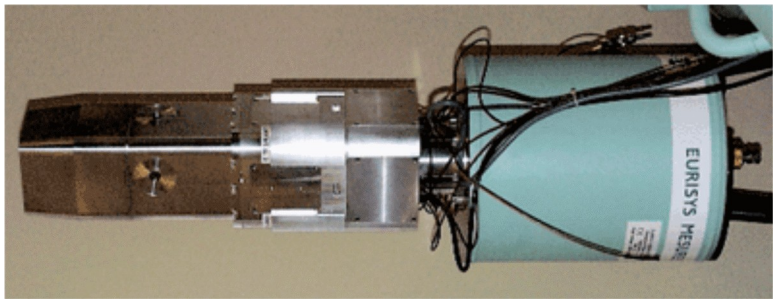
The BRIKEN neutron counter

Type	Owner group	Diameter (inch/cm)	Eff. Length (inch/mm)	Total counters
BR	UPC + GSI	1 / 2.54	23.62 / 600	52
I	ORNL	1 / 2.54	24 / 609.6	17
K	ORNL	2 / 2.54	24 / 609.6	64
E	RIKEN	1 / 2.54	118.1 / 300	26
N	JINR	1.18 / 3	~ 18.9 / 48	20
TOTAL				179

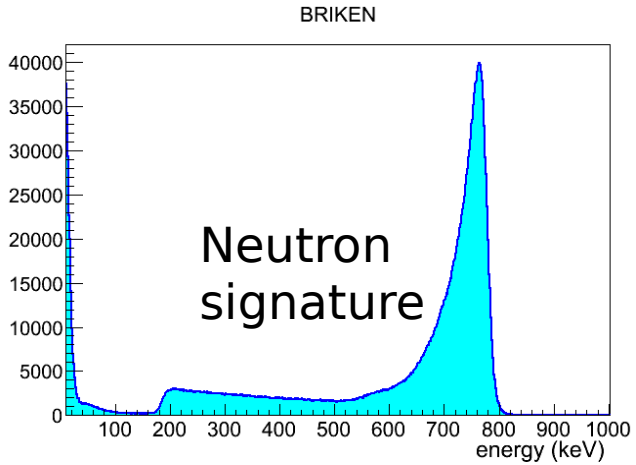
Topological Monte Carlo optimization Algorithm developed @UPC/IFIC

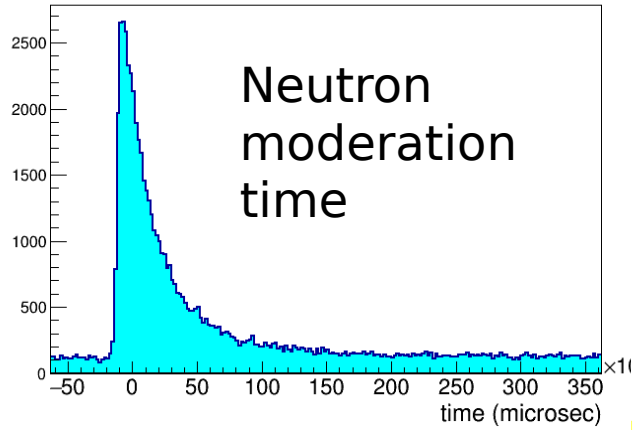
HDPE moderator **Hybrid (two clovers)** **Compact (4pi counter)**





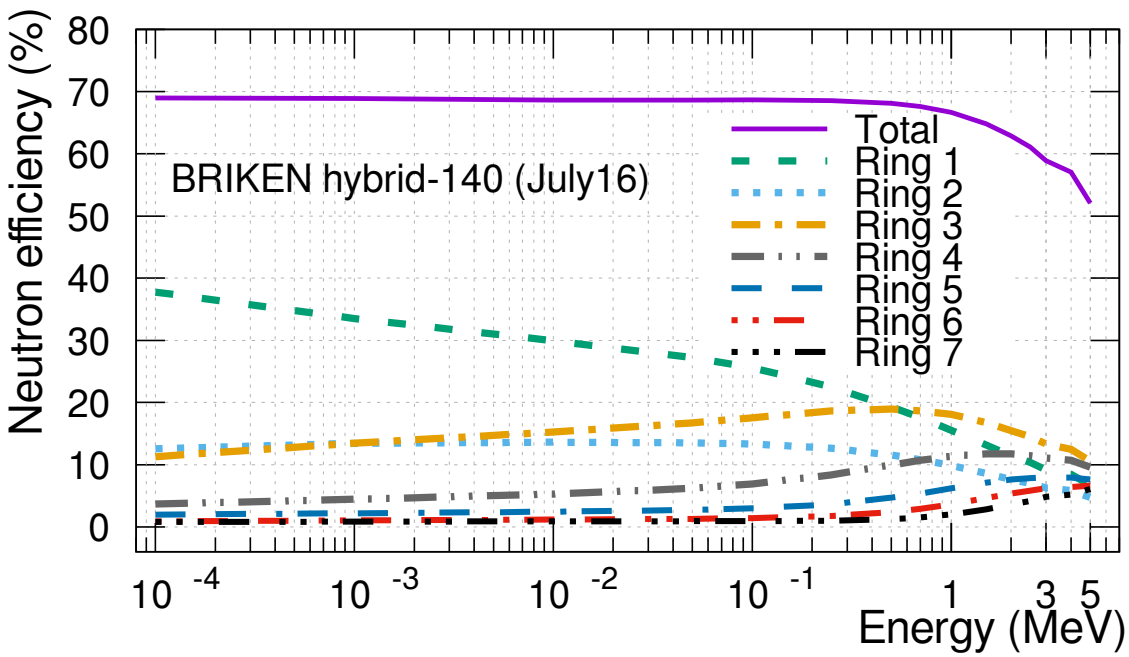
Two clovers (HPGe)
CARDS array type
~1% @ 1.33 MeV (BRIKEN)
UTK/ORNL

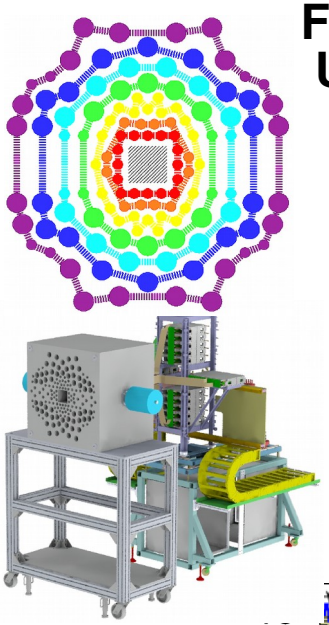




Tarifeño-Saldivia+, JINST 12 (2017) P04006

Performance of the BRIKEN neutron detector





Final hybrid configuration: Up to 148 ^{3}He tubes + two CLOVERS

Efficiency	Value
$Eff_{1n}(^{88}Br)$	68.4%
$\langle Eff_{1n} \rangle$ up to 1MeV	68.3%
$\langle Eff_{1n} \rangle$ up to 5MeV	63.6%
Eff_{2n}	~46.7%
Ratio $^{252}Cf/^{88}Br$	0.908