MONSTER and BELEN

Beta delayed neutron detectors
at DESPEC

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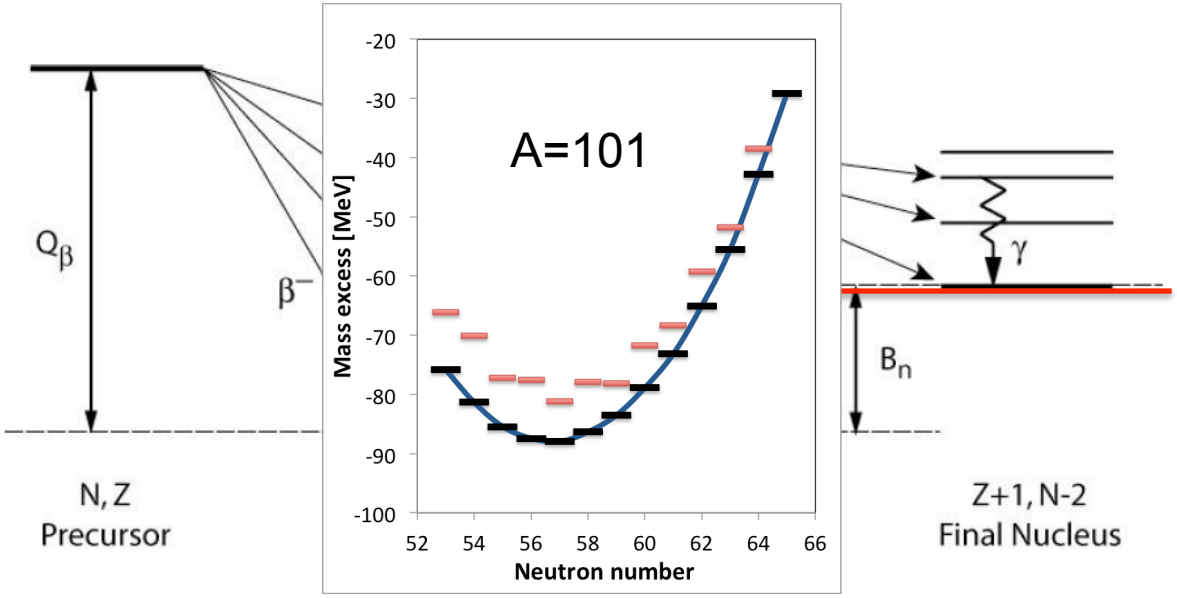
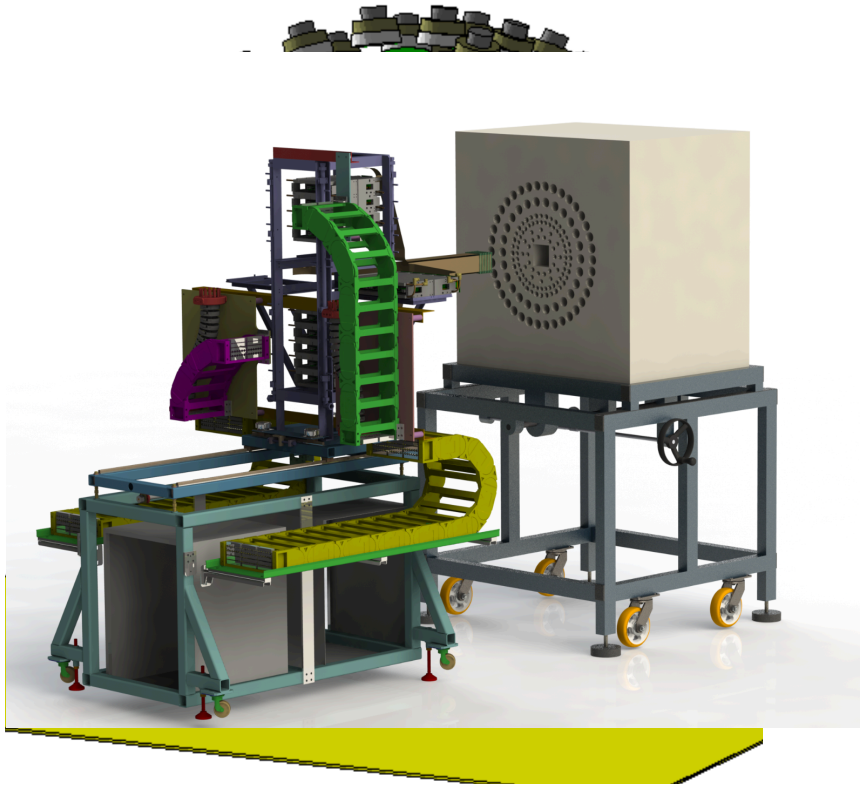
Beta delayed neutrons



- Far from stability energy window opens up for beta delayed neutron emission (β-1n, β-2n, …)
- P_n values important for the r-process final distribution, control of advanced reactors
- Information about unbound states via neutron energy measurement
- β-strength function $S_\beta(E)$ far from stability

Neutron detectors at DESPEC



- GOAL: To measure neutron emission probabilities and energies for neutron rich isotopes with relevance to *basic nuclear physics*, *nuclear astrophysics* and *nuclear technologies*.
- High production: TOF spectrometer **MONSTER** (in combination with a dedicated gamma ray setup)
- Low production, P_n values: 4π neutron counter **BELEN**

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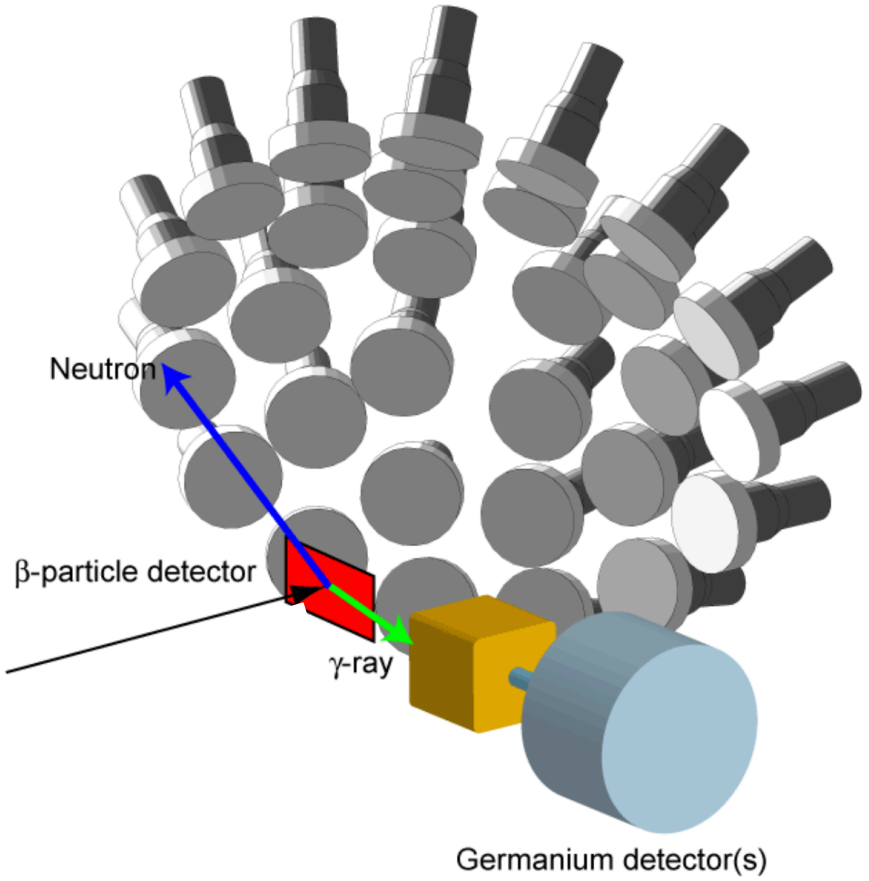
MONSTER

- Modular Neutron Time of Flight Spectrometer
- Array of 100 scintillator cells
- Different geometries possible
- Gamma-neutron separation from pulse shape
- Cross talk minimized; β-2n detection possible
- Possible to couple with other detector arrays (gamma detectors)
- Part of the array can be used as a detector itself



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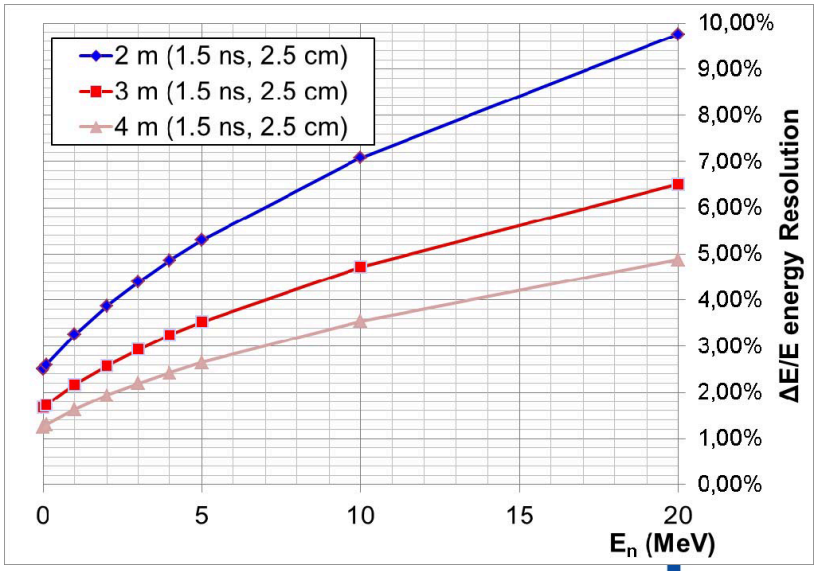
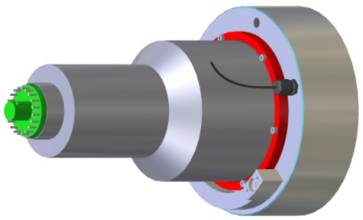
Neutron Time of Flight

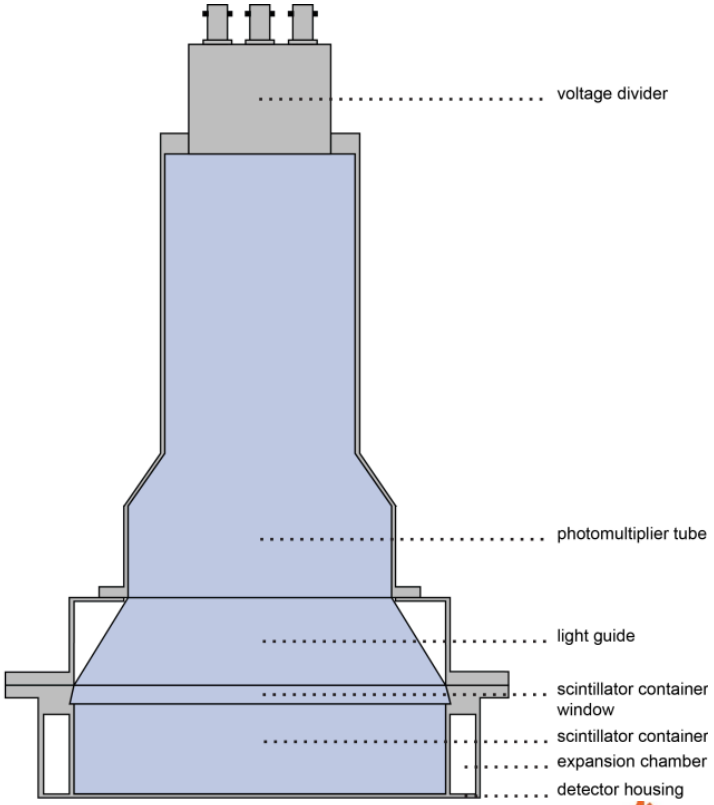
- Start from beta decay signal from AIDA
- Stop signal from one of MONSTER detector cells
- Relative energy resolution depends on timing resolution of both detectors, length of the neutron flight path and neutron energy
- Design values 2-4 m flight path, 1.5 ns timing resolution ΔE/E < 10%



Detector cell

- Liquid scintillator
  - BC501A/EJ301
  - Diameter 20 cm
  - Thickness 5 cm
- Hamamatsu R4144 PMT 5”
- PMMA light guide





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Pulse shape analysis

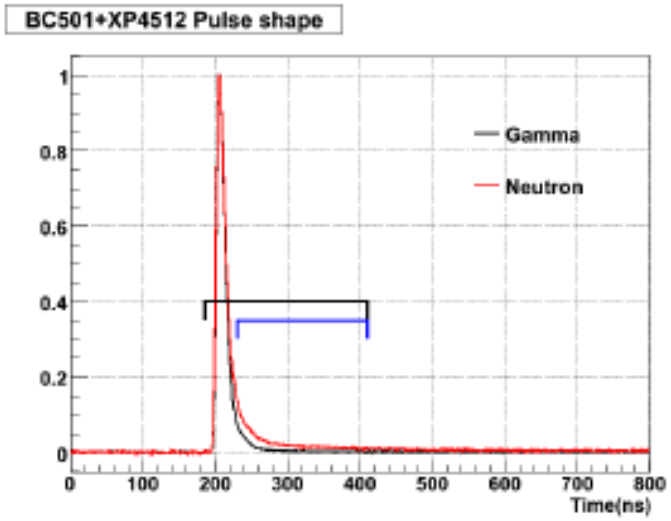
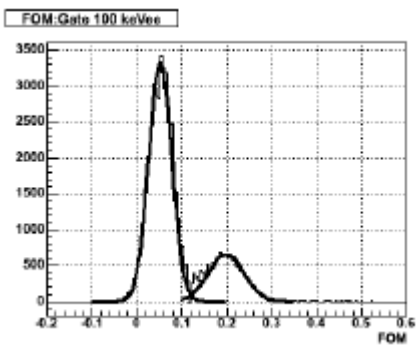
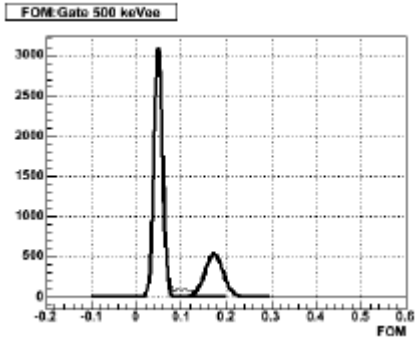


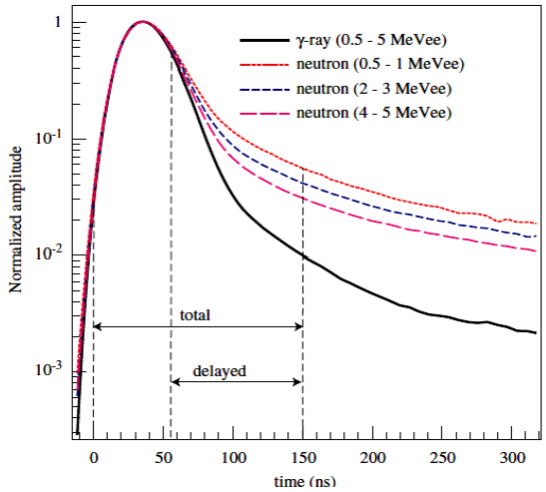
Figure of merit (FOM) plots

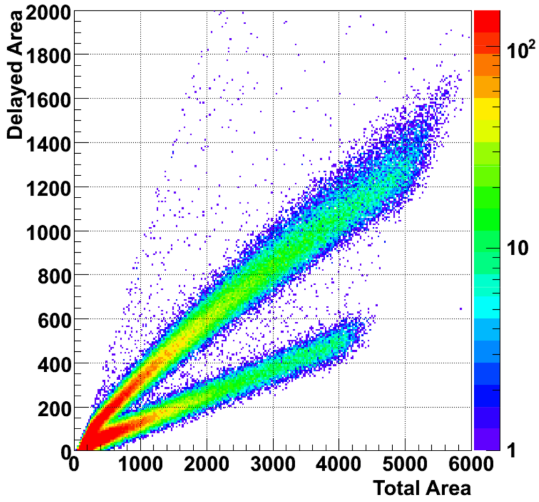


Low energy



Modest energy





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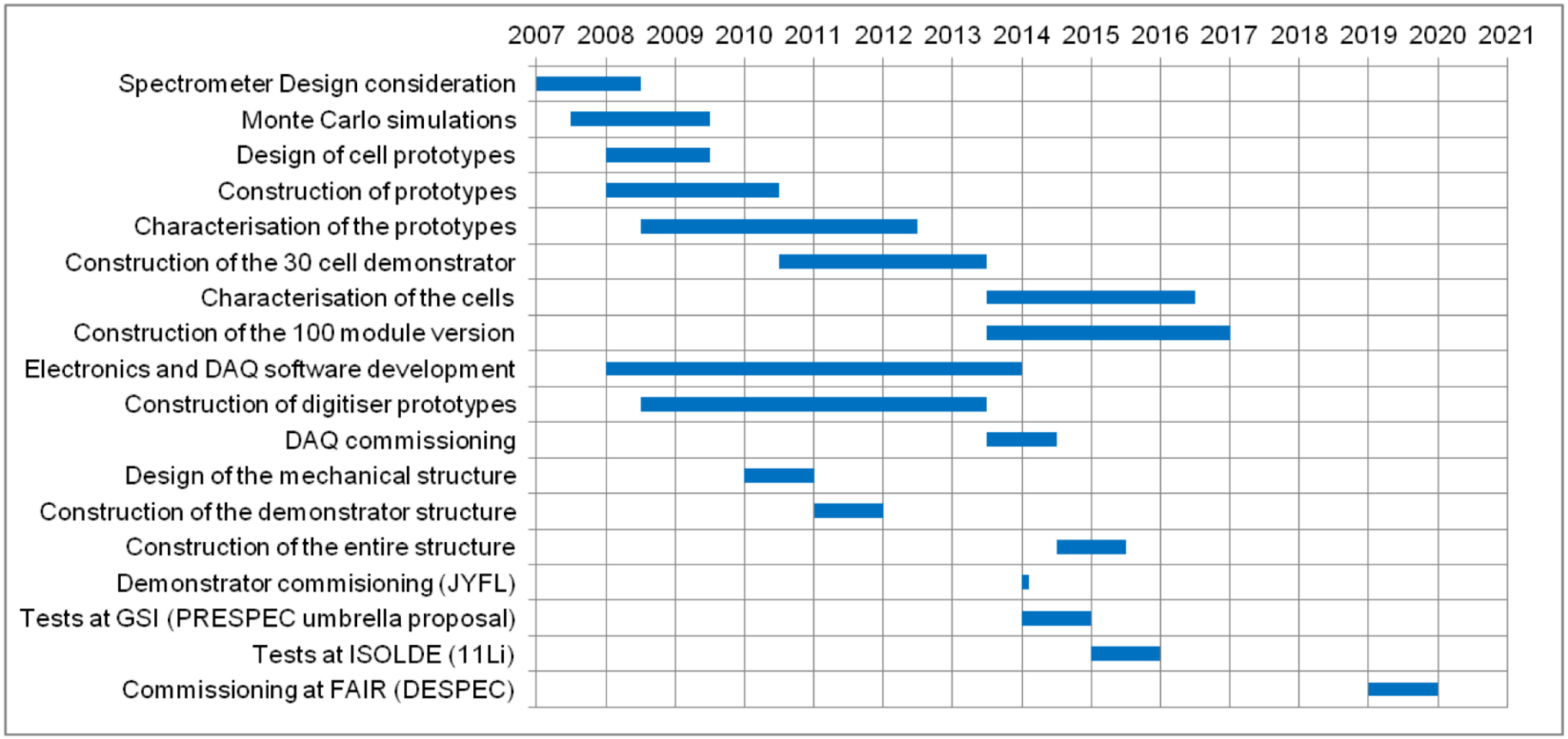
MONSTER Gantt chart



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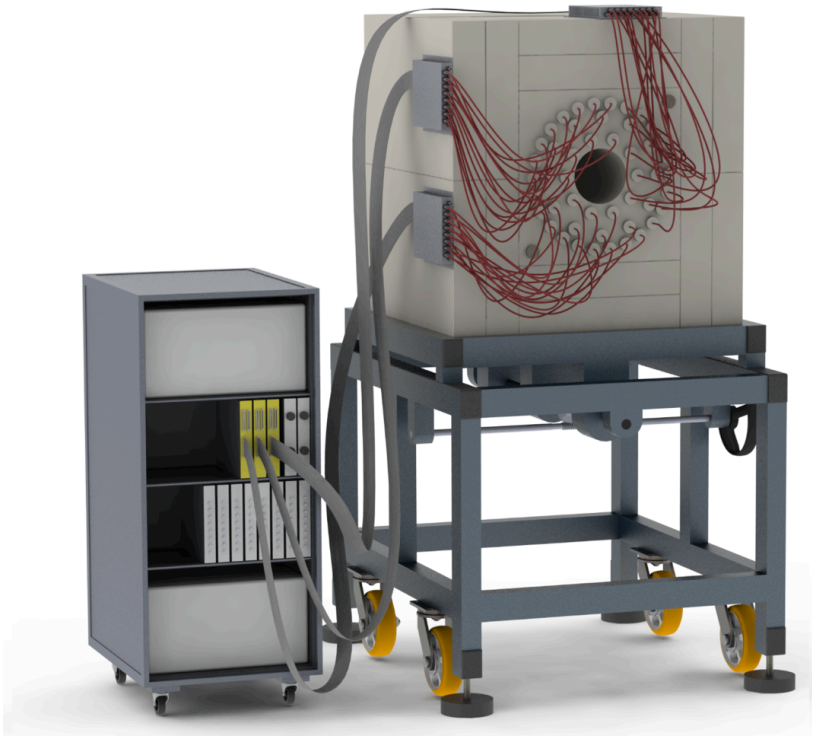
BELEN

- High-efficiency neutron counter
- P_n value determination
- AIDA 8x8cm^2 inside the central bore



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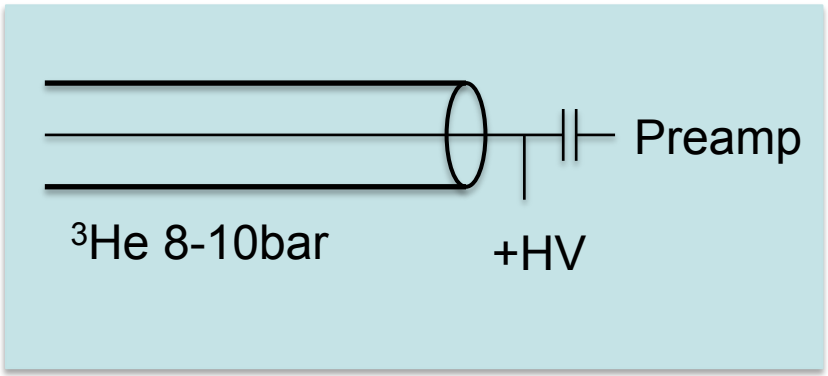
^{3}He proportional counter tubes

- Based on reaction

  $^3He + n \rightarrow$

  $^1H + {}^3H + 765\ keV$
- No information on neutron energy
- Cross section increases as energy decreases → moderator
- Not sensitive to gamma-rays



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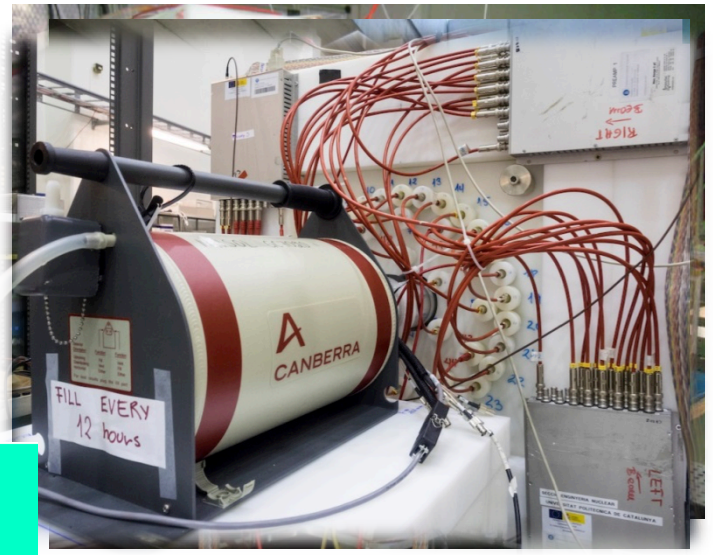
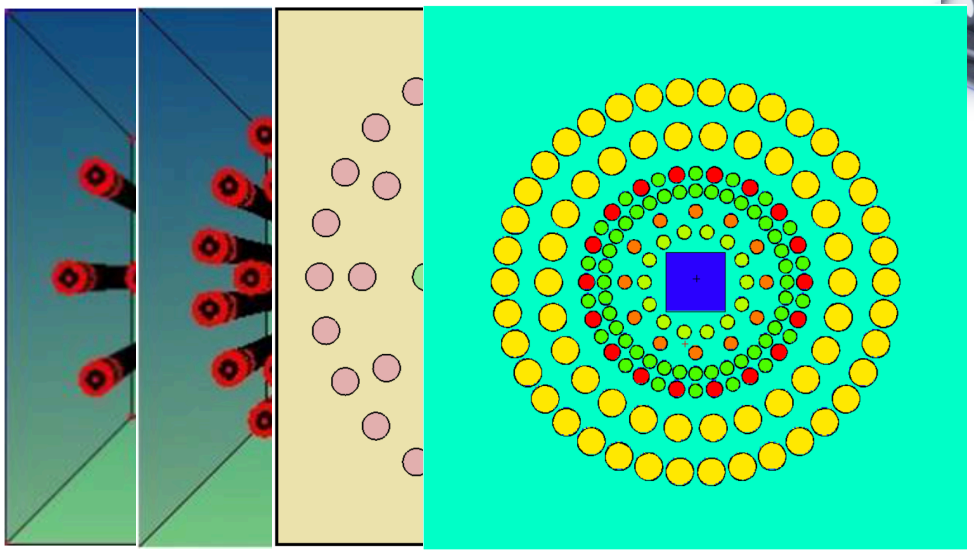
Evolution of BELEN

- BELEN-20A, 27%; JYFLTRAP 2009
- BELEN-20B, 35%; JYFLTRAP 2010
- BELEN-30, 40%; FRS@GSI 2011
- BELEN-48, 45% (61%); JYFLTRAP 2014
- BRIKEN-174, 66% (2016)





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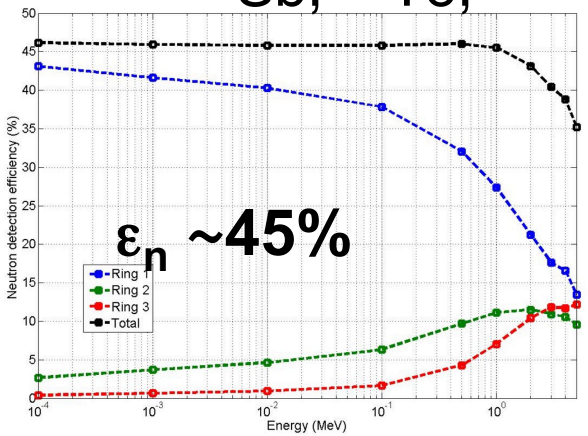
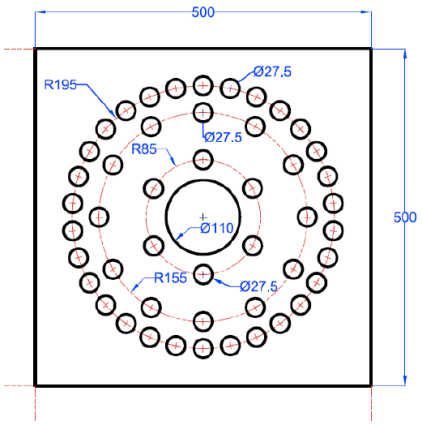
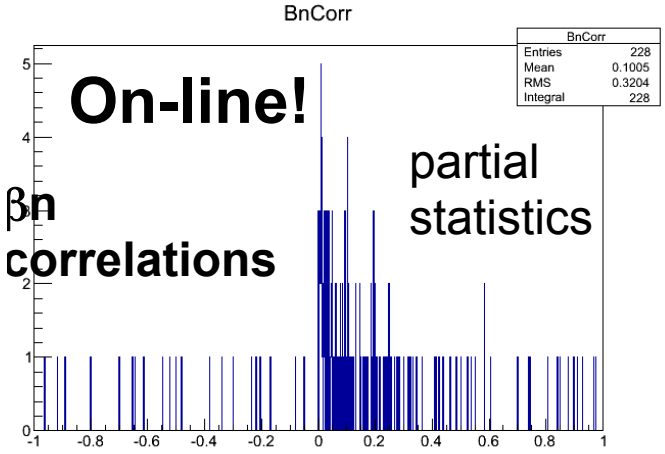
BELEN-48 for 1- and 2n emission

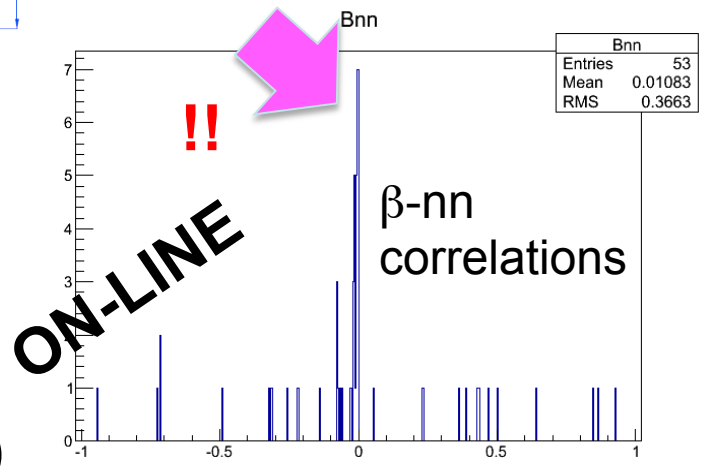
- Data acquired for: ^{98,98m,99}Y, ^{135,137}Sb, ^{138}Te, ^{138,139,140}I





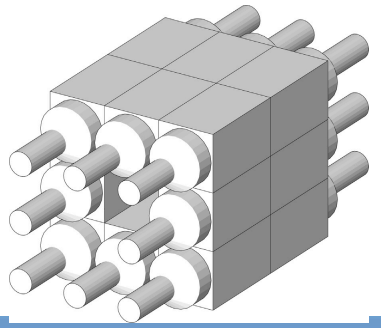


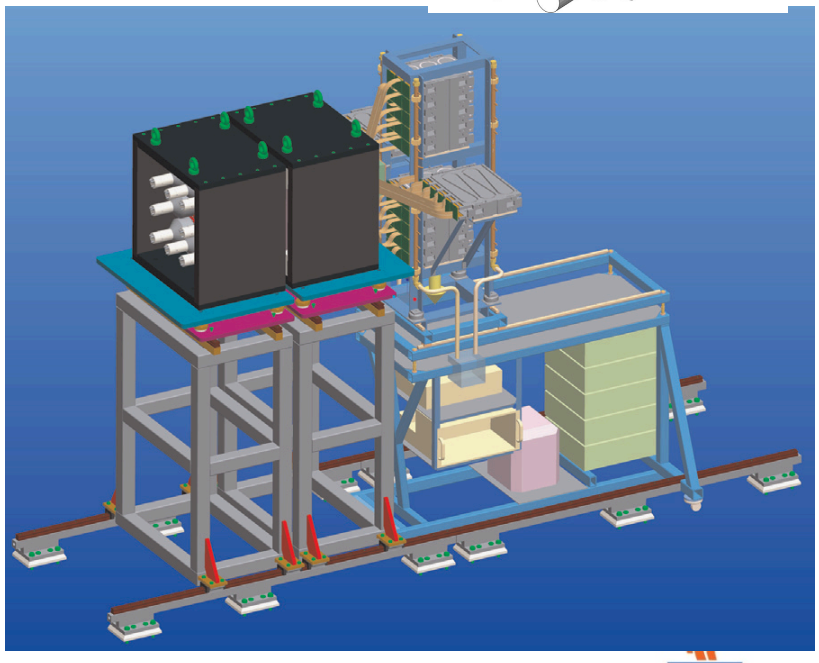
- Measurement of β-delayed 2n emitter ^{136}Sb (sizeable P_{2n} predicted, close to r process path and ^{132}Sn)
- Implantation rate 1.5 cps
- Data under analysis (Iris Dillmann)



DTAS

- This is **not** a neutron detector!
- Decay Total Absorption Spectrometer
- Pandemonium effect
- Instead of single discrete gamma-rays record the energy of the full gamma cascade at once
- Extract beta decay intensity to exited levels, β-strength function $S_\beta(E)$ below S_n





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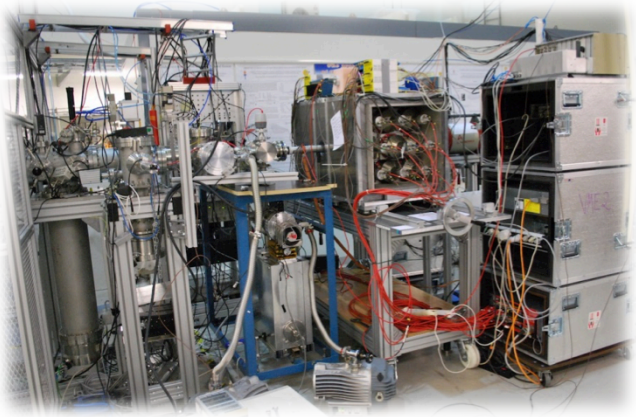
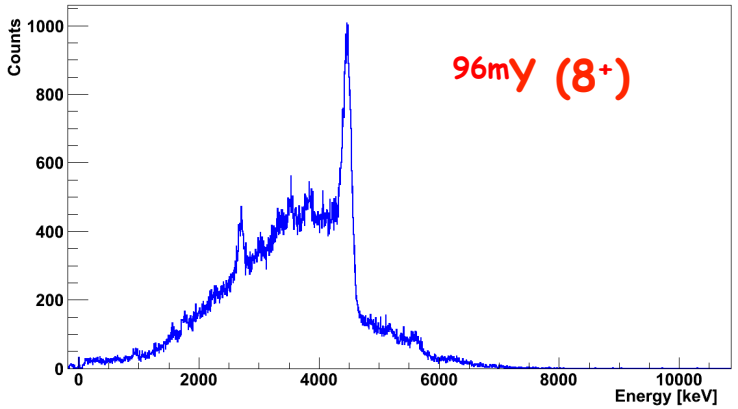
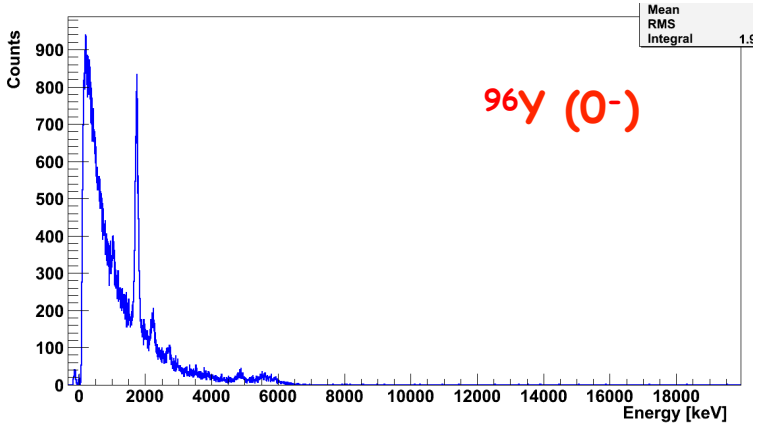
DTAS at JYFLTRAP

- 16 (+2) NaI(Tl) modules
- 5” PMT (50% light collection)
- Commissioning at JYFL (02-03/2014)
- PHASE 0 experiments for NUSTAR







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- I. Moore, H. Penttilä, JYFL

- References:
  - BELEN TDR
  - MONSTER TDR
  - DTAS: Nucl. Instrum. and Meth. Phys. Res. A803(2015)36–46