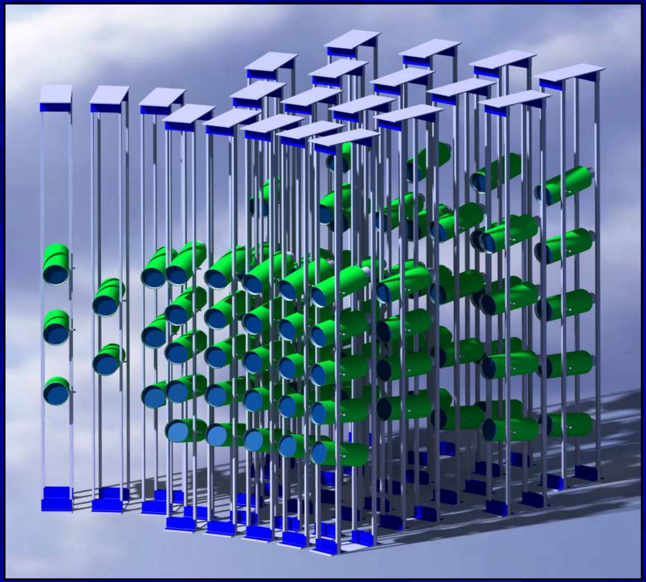
Progress towards a Low-Energy Neutron Array for DESIR

- Physics
- Current detectors
- Strategies
- Development status, timeline
- Day 1 experiment



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β-decay of exotic nuclei

β-decay of exotic nuclei important for

- Nuclear structure: level schemes, spins, parities…
- Nuclear astrophysics: r-process (successive n captures and β-decays)
- Nuclear technologies: decay heat, particle emission of nuclear fuels

β-decay of neutron-rich nuclei

Large Q_β and low S_n

$\rightarrow$ Unbound daughter states $\rightarrow$ delayed neutron emission

$\rightarrow$ Detect neutrons to build complete decay schemes

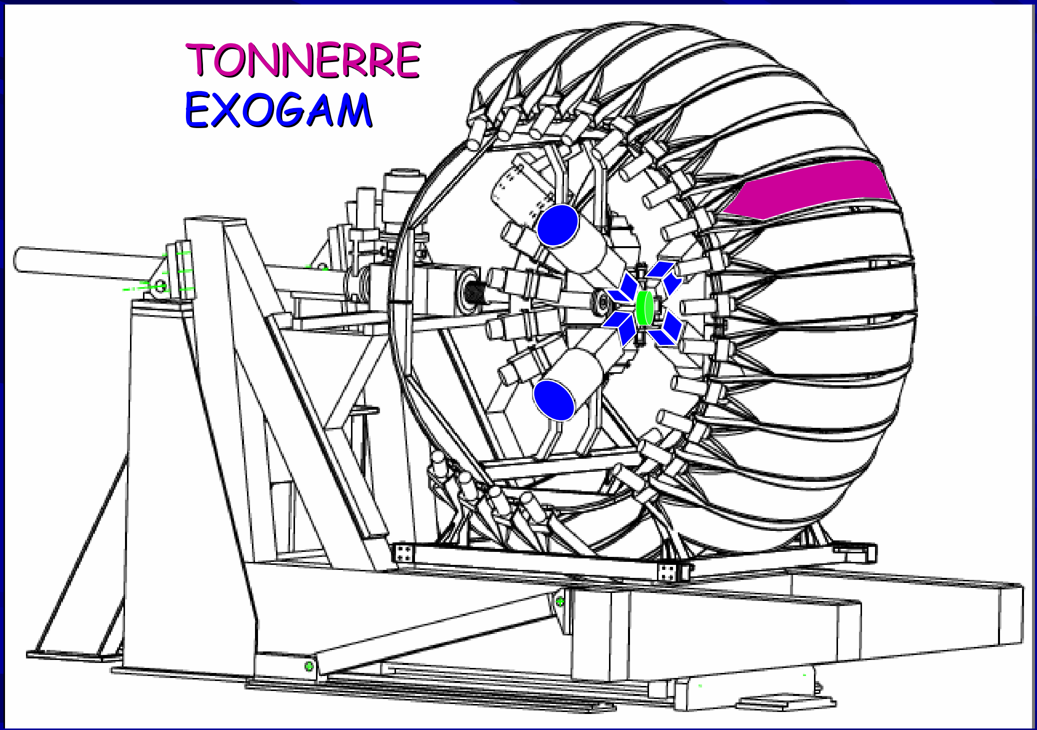
β-delayed neutron detection requirements

- Low energy neutrons (~0 to ~10 MeV)
- Energy from TOF: coupling to β detector ("start")
- Good energy resolution (intermediate mass nuclei)
- High efficiency (weak transitions and/or low intensity beams)
- Multiple neutron detection capability

  → nn correlations, sequential vs direct emission
- Coupling to γ detectors (β and β-n bound daughter states)
- Tape system (collection and evacuation of activity)

Current β-delayed neutron detectors @ GANIL

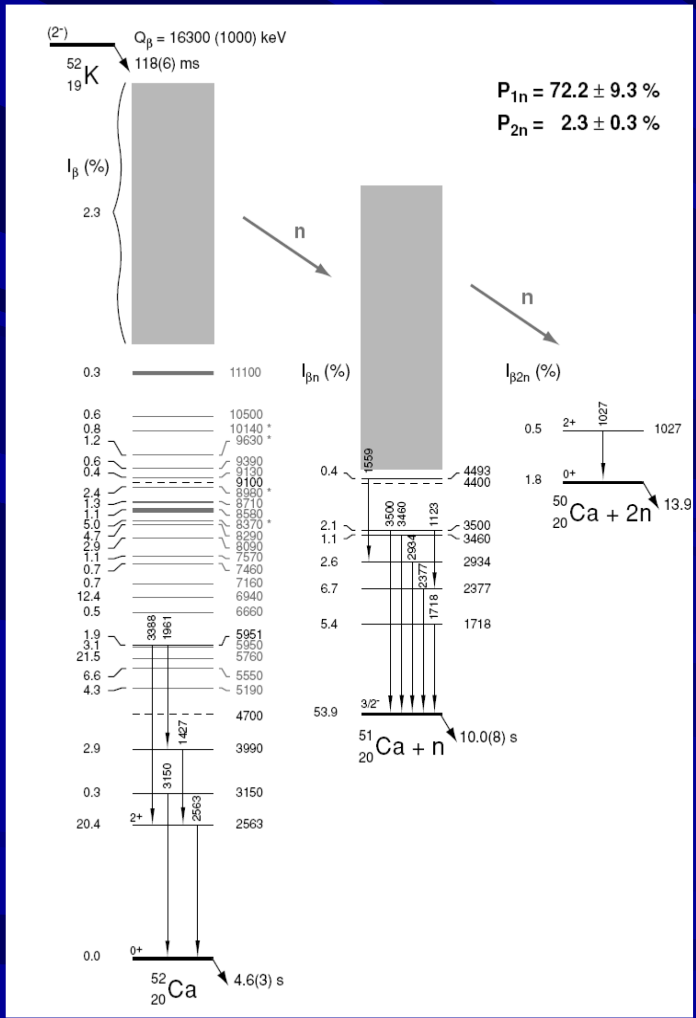
TONNERRE array (LPC Caen, IFIN-Bucharest)



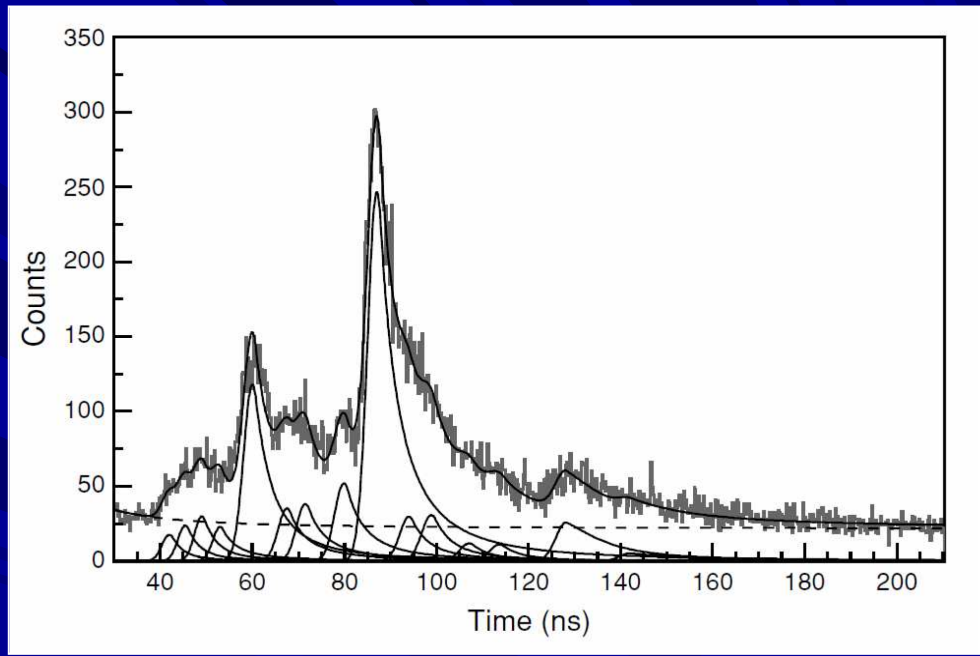
- 32 bars, 160 x 20 x 4 cm^3
- BC400 plastic
- Up to 45 % of 4π
- Intrinsic ε_n ~ 45 % at 1 MeV
- E_n from TOF (d=1.2 m)
- $\delta E_n/E_n$ ~ 10 %
- Threshold : E_n ~ 300 keV

A. Buta et al., NIM A455 (2000) 412

TONNERRE: limitations



F. Perrot et al., PRC 74,014313 (2006)



- No n-γ discrimination: random γ background
- $\delta E_n/E_n$ limited by thickness & d_{flight}
- Asymmetric lineshapes
- Relatively high threshold

Strategies for an improved neutron-TOF array

Reduce background

- n-γ discrimination: liquid scintillators

Improve energy resolution, reduce lineshape asymmetry

- thin, small volume detectors
- increase flight distance (~ 5 m or higher)

Lower threshold

- thin, small volume detectors
- digital electronics
- good n-γ discrimination at low energy

Multiple neutron detection

- background reduction
- cross-talk reduction: modular array, high granularity

Envisaged array

- Modular array with up to 100 modules
- Module design: similar to EDEN* module (IPNO, KVI)

  ⇒ 5 cm thick, 20 cm diameter

  ⇒ Liquid scintillator with n-γ discrimination capability (BC501A)

- Digital DAQ - DSP

Collaboration with D. Cano-Ott et al. (CIEMAT, Madrid) (JYFL, FAIR/DESPEC)

- ➢ Common proposal for DESIR TDR (Jan 2009)
- ➢ Common module concept
- ➢ Compatible support structures, DAQ…

* H. Laurent et al., NIM A326 (1993) 517

Development status

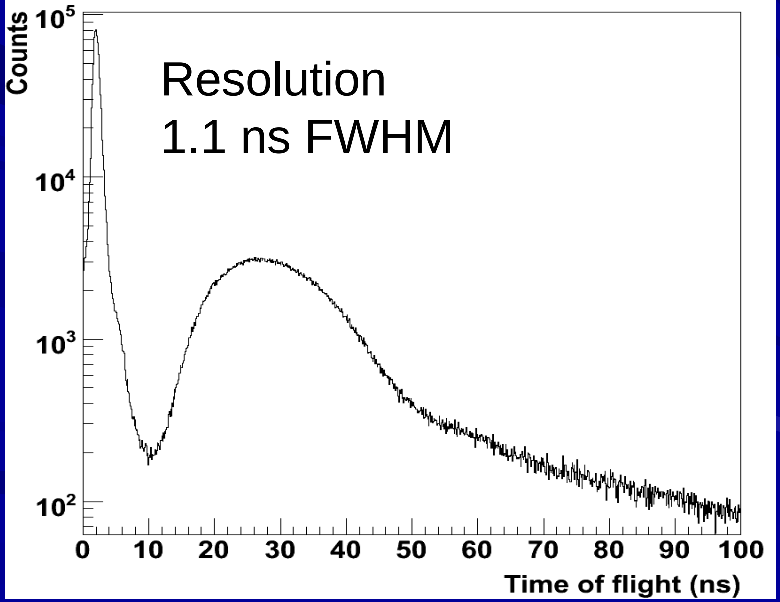
"Proof of principle" tests with EDEN modules and VME DAQ

- 2010: tests with sources
- 2011: test experiment @ GANIL/LISE

  ~40 modules + VME + ^{15}B (P_{1n}~94 %) and/or ^{11}Li (P_{2n}~5 %)

  + modules with digital DAQ

EDEN + $LaBr_3$ + VME + ^{252}Cf source



Demonstrate

- viability of liquid scintillators for β-n
- β-2n capability
- improved energy resolution
- reduction of lineshape asymmetry

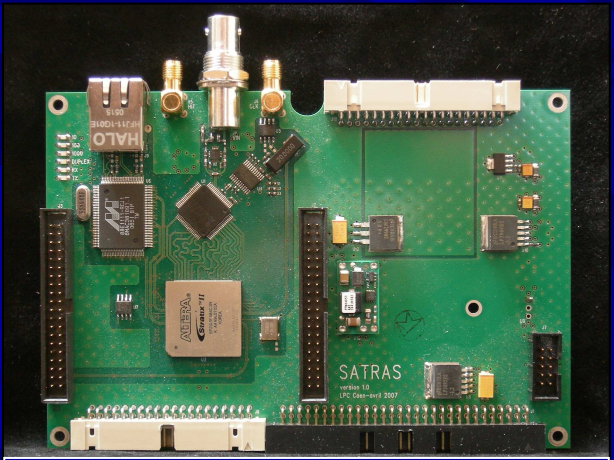
Masters project student: M. Sénoville (PhD thesis from Oct 2010)

Development status

Digital DAQ development @ LPC: FASTER project (D. Etasse et al.)

- 2005 - 2008: development of single-channel ADC, QDC, TDC functions
- 2009 - …: developing multi-channel capability

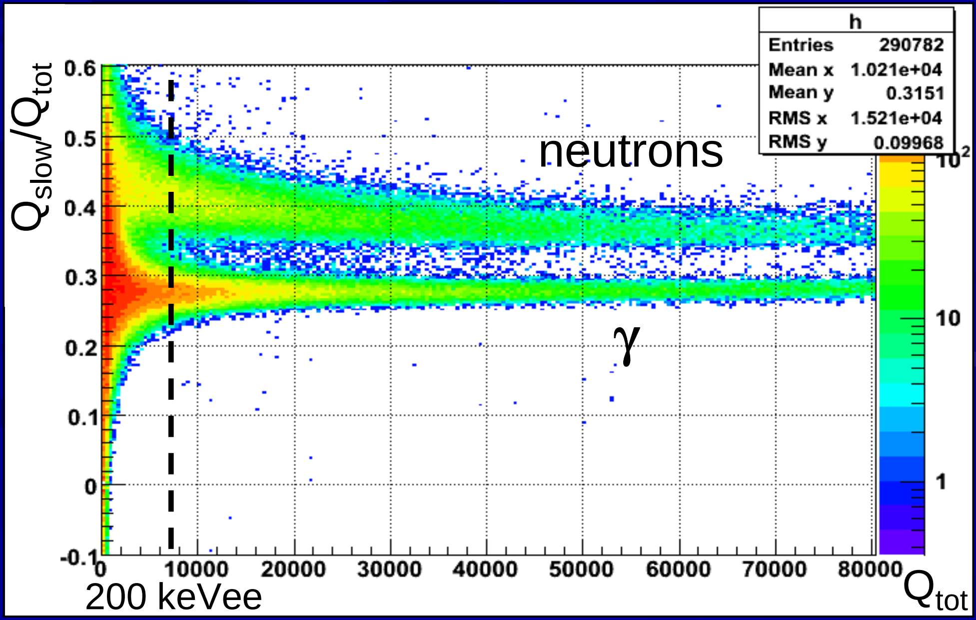
(2010: 10 channels, 2011: 30 channels, 2013: 100 channels)



ADC 14bit@100MHz (2007)

ADC 12bit@500MHz (2007)
QDC (2008)
TDC (2008)

DEMON + Digital QDC + AmBe source



Timetable

- 2010: tests with sources
- 2011: test expt @ GANIL/LISE + test of digital DAQ
- 2011 – 2013: assemble stepwise 100 channel digital DAQ
- 2013: expts with digital DAQ + EDEN + CIEMAT (SPIRAL1, LISE, ISOLDE, JYFL)
- 2013: begin stepwise acquisition of new modules (~6 k€ / module)
- 2014(?) - …: expts with digital DAQ + new dets + CIEMAT @ DESIR

Day 1 experiment: β-decay of n-rich Kr isotopes (A≥94)

⇒ Evolution of deformation around Z~40 and N~60

⇒ Heavy Kr isotopes expected to be waiting points in the r-process

- Decay schemes measured up to ^{93}Kr
- $T_{1/2}$ and P_n measured up to ^{99}Kr *

Intensities expected at SPIRAL2 (from FF yields after post-acceleration, Jan 2010):

^{95}Kr: 5.10^8 pps / 10 = 5.10^7 pps

^{99}Kr: 1000 pps / 10 = 100 pps

^{100}Kr: 150 pps / 10 = 15 pps

} βnγ, βγ, P_{1n}, P_{2n}, decay schemes…

^{101}Kr, ^{102}Kr, …: < 1 pps ? ⇒ $T_{1/2}$, P_n ?

* Bergmann et al., NPA 714 (2003) 21