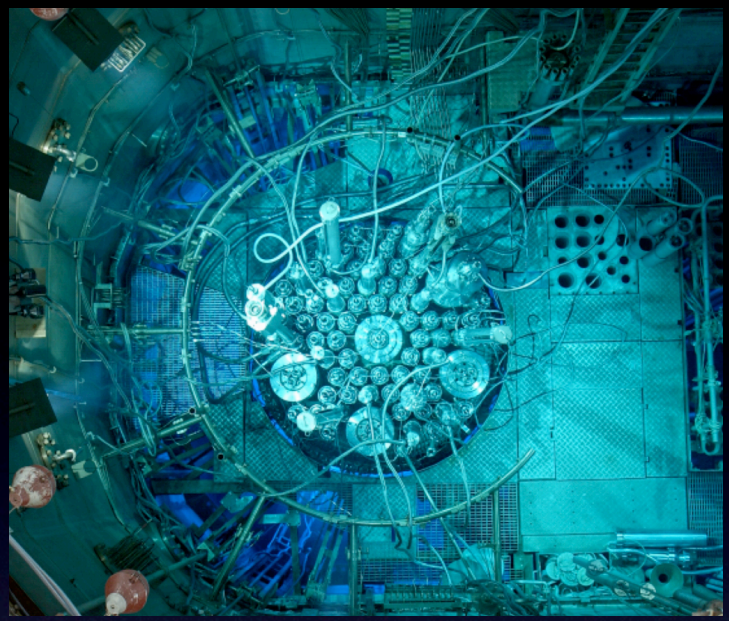
SoLiD



Search for Oscillation with Lithium-6 Detector at BR2
Prototype Update and short perspectives

A. Baird, N. Ryder, P. R. Scovell, A. Vacheret, A. Weber (Oxford, UK)
G. Barber, J. Nash, A. Rose (Imperial College London, UK)

S. Bouvier, J. M. Buhour, A. S. Cucoanes, M. Fallot, L. Giot, G. Guilloux, G. Pronost, F. Yermia (Subatech, France)
G. Ban, D. Durand, B. Guillon (LPC Caen, France)

X. Janssen, N. Van Remortel (Antwerp, Belgium)
D. Rychbosh (Gent, Belgium)
P. Van Mulders (Brussels, Belgium)

B. Coupé, S. Kalcheva, E. Koonen (SCK•CEN, Belgium)

SoLid - Reminder

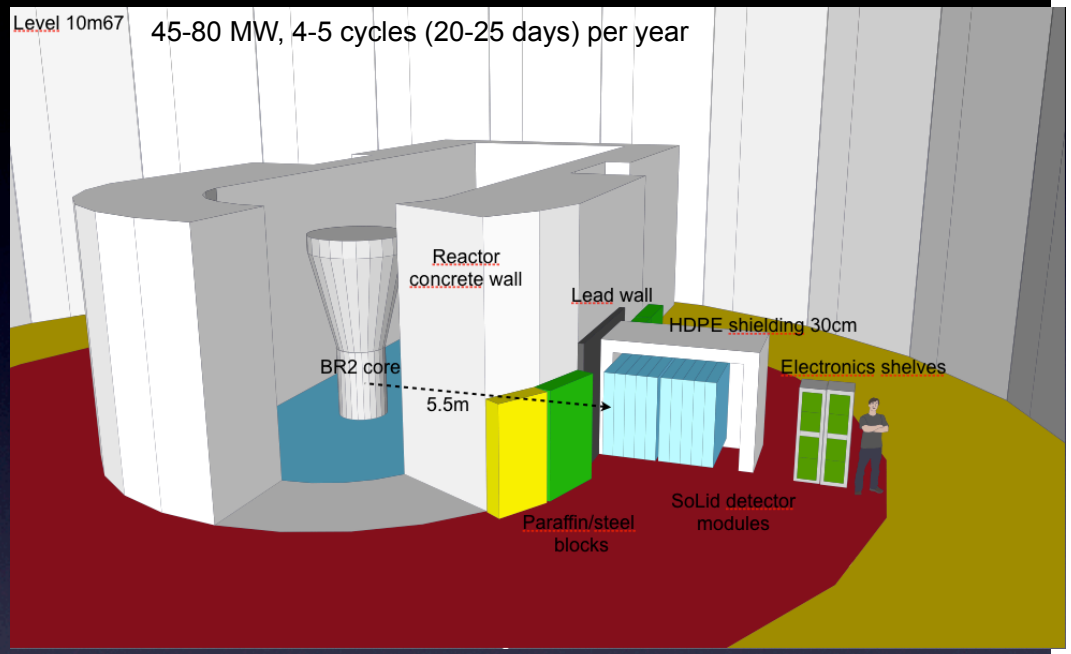
Search for Oscillations with ^{6}Li Detector

PHYSICS MOTIVATION

- Search for short distance oscillation & Non proliferation

RESEARCH REACTOR

- SCK•CEN BR2 Mol, Belgium

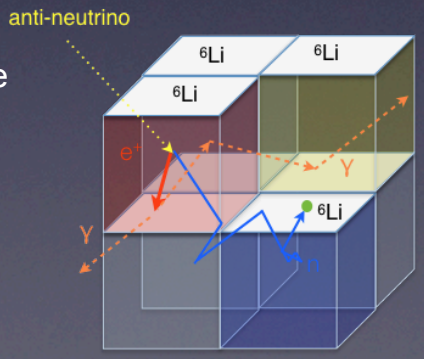


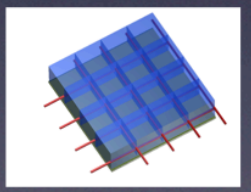
DETECTOR

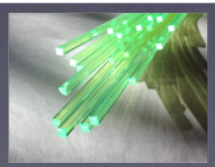
- 2.88t fiducial volume
- Novel type of composite solid scintillator detector (PVT + 6LiF:ZnS)
- detection element: 5cm x 5cm x 5cm
- read out by WLS fibres and Geiger-mode APDs (MPPC)
- digitizer electronics
- Physics Trigger : neutron events to limit data rate

Detection Principle and background

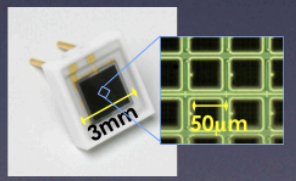
- Detection: Inverse Beta decay (IBD)
- Soft Gamma-rays (< 3 MeV)
- No reactor neutrons





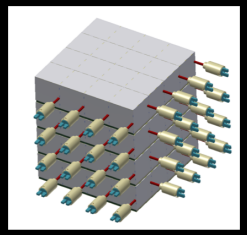


BCF-91A fibre



MPPC
S10362-33-050C
3mm x 3mm
50 um pixel pitch
60-65% active area
Pixel RC const~13 ns
PDE ~ 30-40%

Prototype aims



✓ Better understand the detection technology
✓ Check the expected response of the system
✓ Validation of the technology

✓ Characterize the level 10 BR2 environment (reactor on/off data)

✓ Demonstrate background suppression method

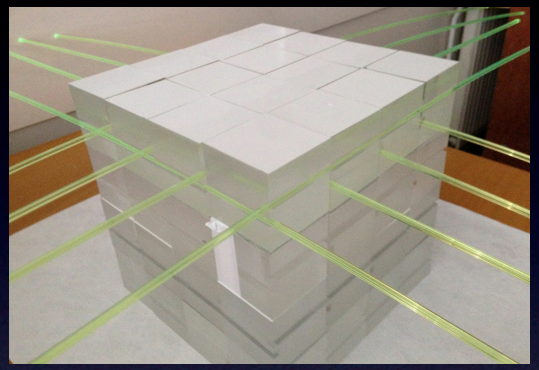
✓ Demonstrate practicality and safety of the technology of SoLid for non proliferation purpose

NEMENIX : 8 kg prototype

20cm x 20 cm x 20cm

4x4x4 cubes detector system
(without specific funding)

smallest anti-neutrino detector ?

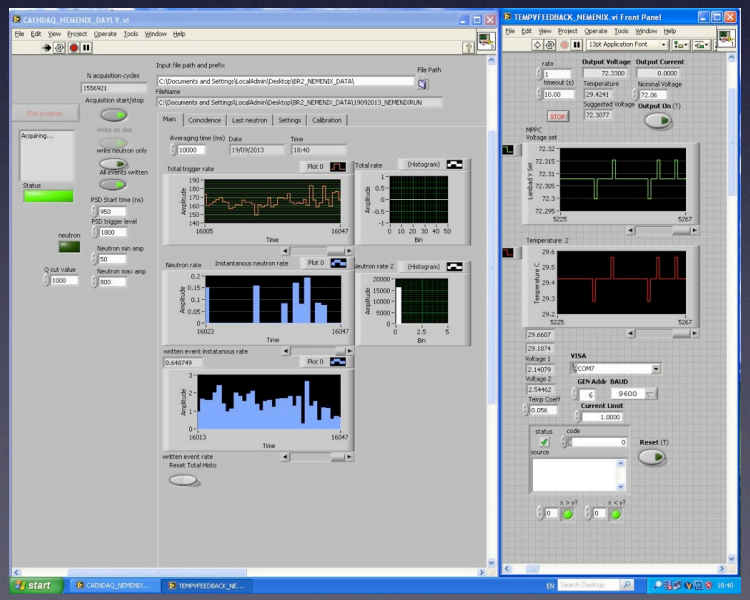


Electronics and DaQ:

32 read out channels, PHOBOS amplifier cards, Caen DT5740 desktop digitiser 62.5MS/s

custom Labview front-end

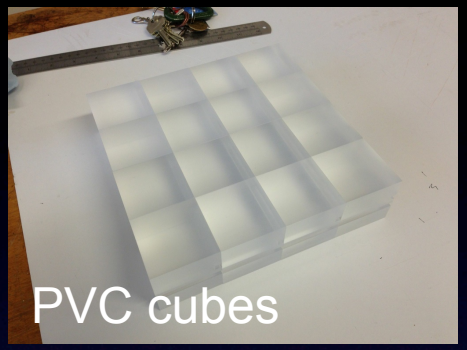
➔ Physics trigger: pulse amplitude ≠ SOLiD

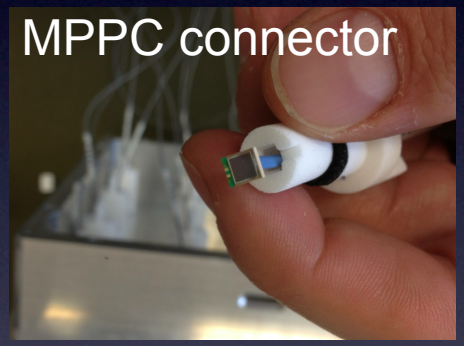


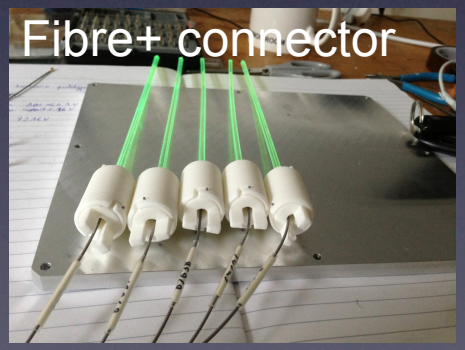
had to compromise efficiency/sensitivity with DAQ rate and data storage

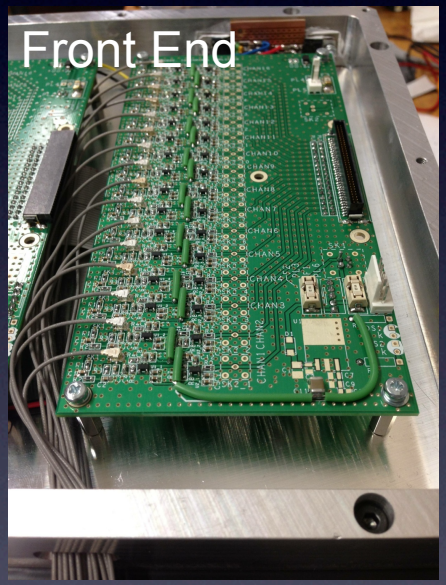
Expected target efficiency ~ 15% (no threshold)

NEMENIX Construction


PVC cubes


MPPC connector

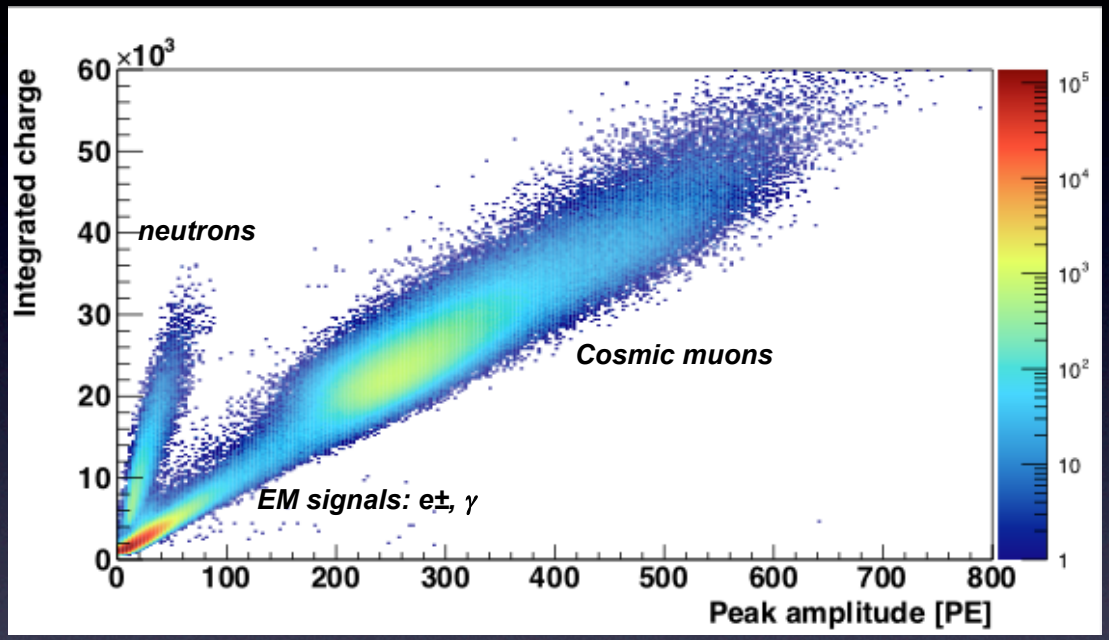

Fibre+ connector


Front End


Final stage

Detector response

Reconstructed waveform amplitude
vs integral charge

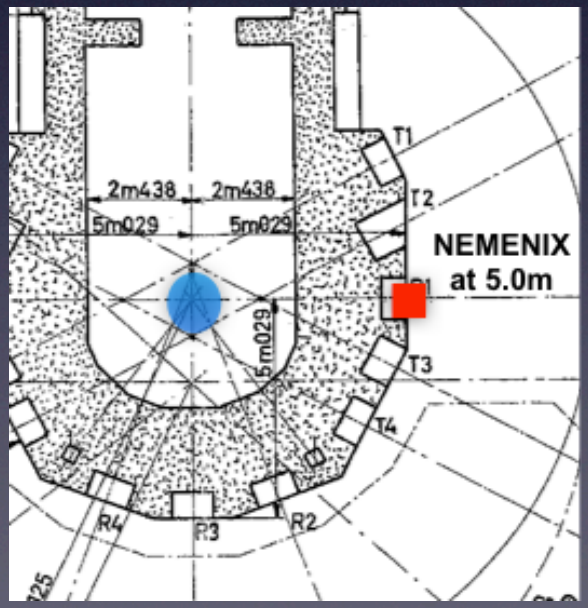


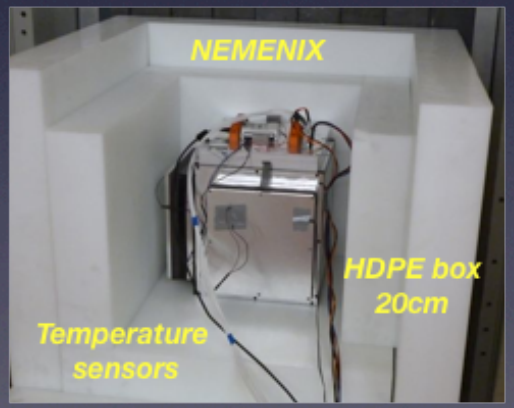
1PE= 80 keV

- Prototype response as expected
- Energy calibration with cosmic muons

Deployment at BR2 Reactor

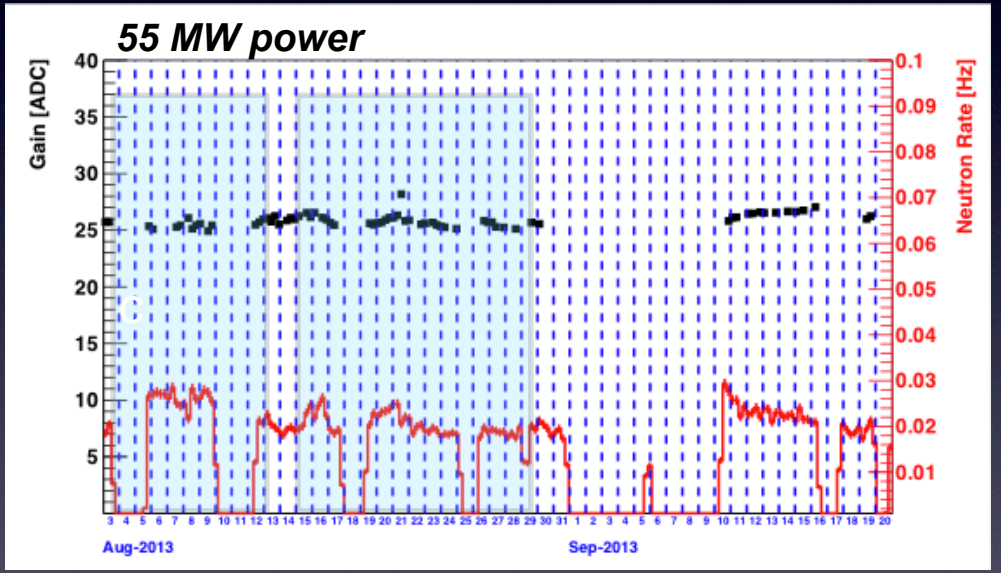
- NEMENIX prototype moved to BR2 at 5.0m from core (level 10 at R1 position) at end of July 2013
- very short commissioning period
- Detector shielding provided and installed by BR2 staff, Used similar shielding envisioned for SoLid (lead wall, HDPE box)
- No muon veto
- Manual temperature feedback loop on sensor bias voltage to maintain stable gain





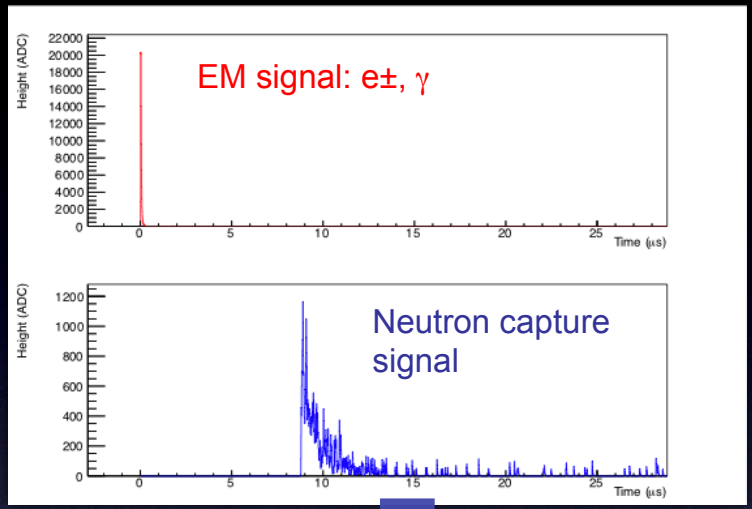
Summer run data

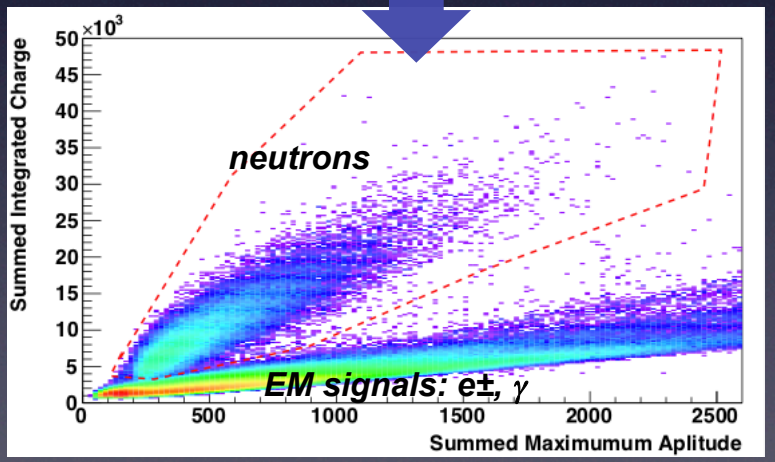
- 55 MW August cycle
- Reactor ON : 17.7 days recorded / 22.8
- Reactor OFF : 13.5 days
- good gain stability with manual temperature correction
- average temperature 30º C
- < 5% variation
- can be improved with automated feedback loop



IBD candidates identification

- Selection:
  - positron : X & Y cube highest prompt signal
  - neutron selection using 2D cuts
  - IBD = 200 μs Δt coincidence between EM signal and n capture + no crossing μ (no μ cut)
- Rate analysis:
  - Comparison Reactor ON / OFF
  - Off time window analysis for accidentals rejection

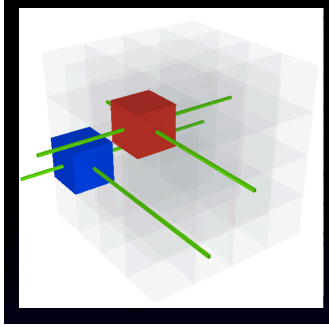


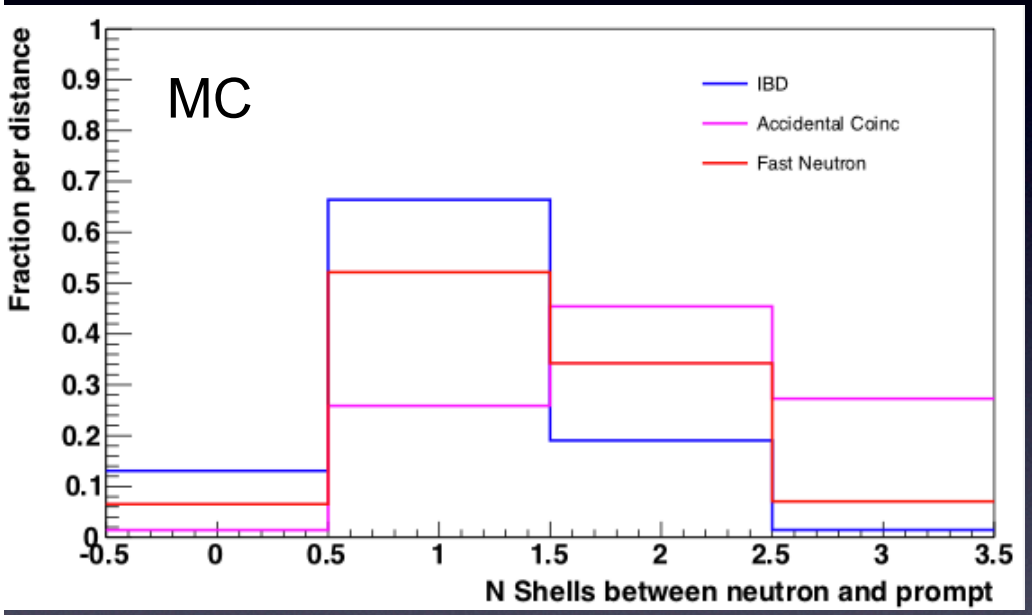


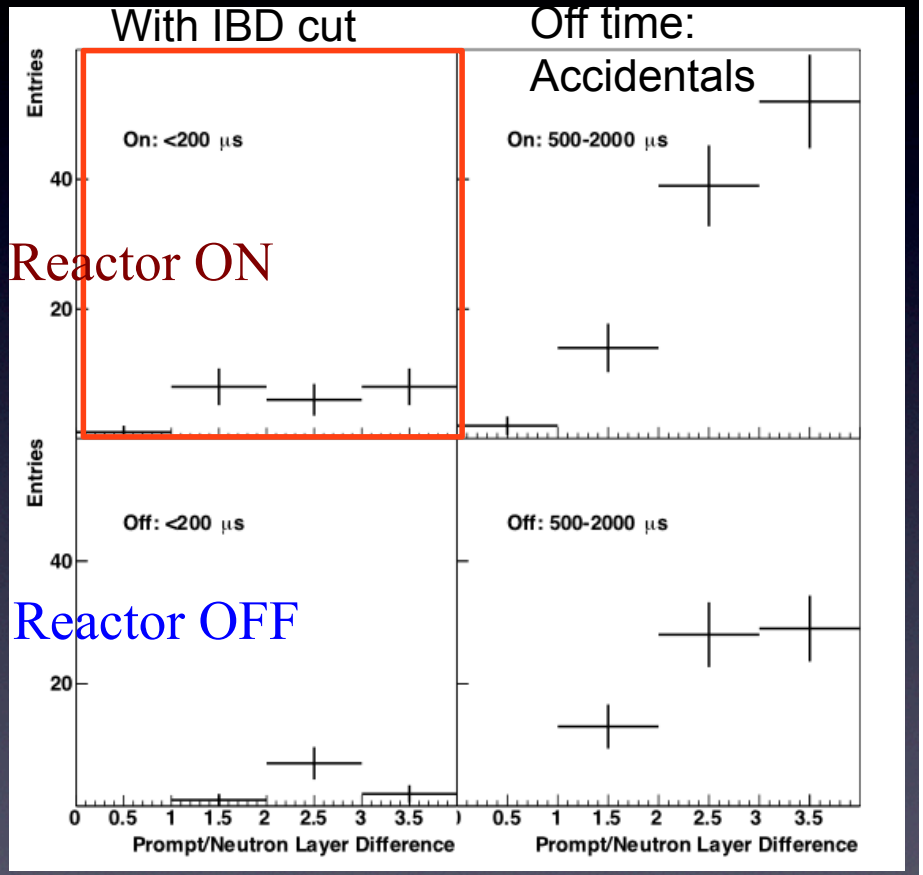
Rejection Power

selection cut	coincidences
no cut	2883919 ± 1698
delay n	31751 ± 178
em - n	30749 ± 175
em - n & no μ	18940 ± 138
em - n & no μ - 200us	23 ± 5

Adding topological cut

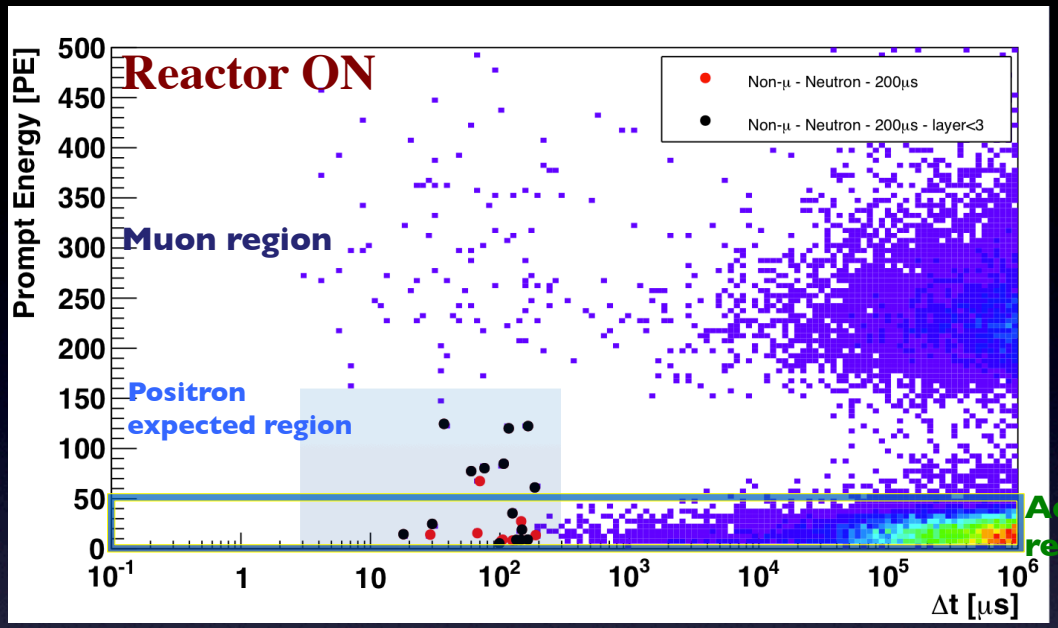




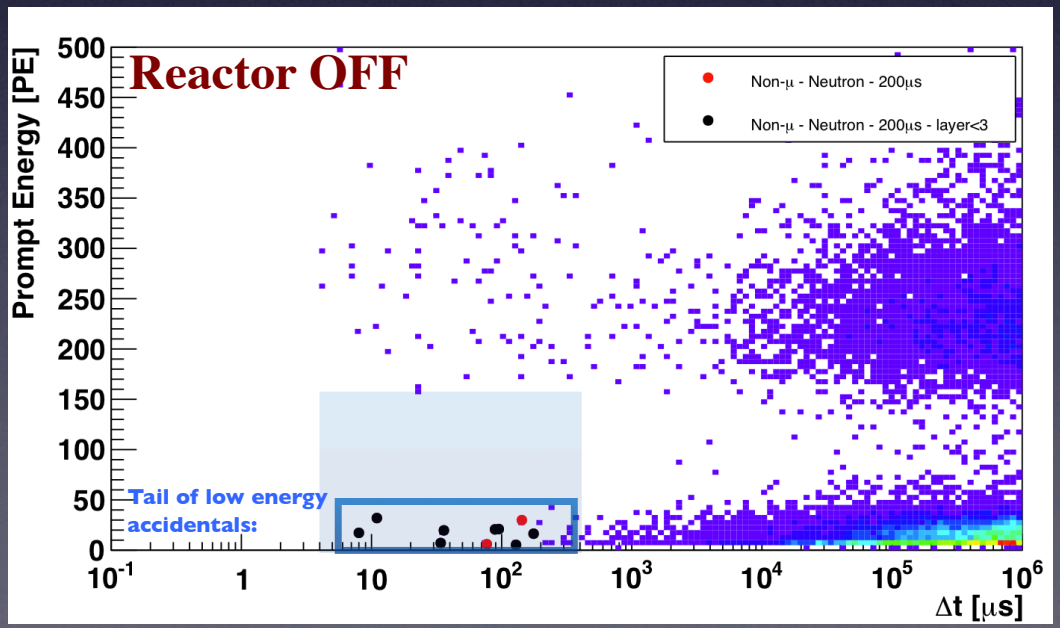


- cut > 2 layers
- indication for reduction of accidentals

Energy-Time correlations – signal excess



Blue shaded region:
expect to see a positron signal, in between both accidental regions & contains **15 events after topological cuts**



Blue shaded region:
Most of the events seem to be consistent with the tail of low energy accidentals

➔ For determining the significance of the excess, estimate the probability of events away from the signal region: off time window analysis

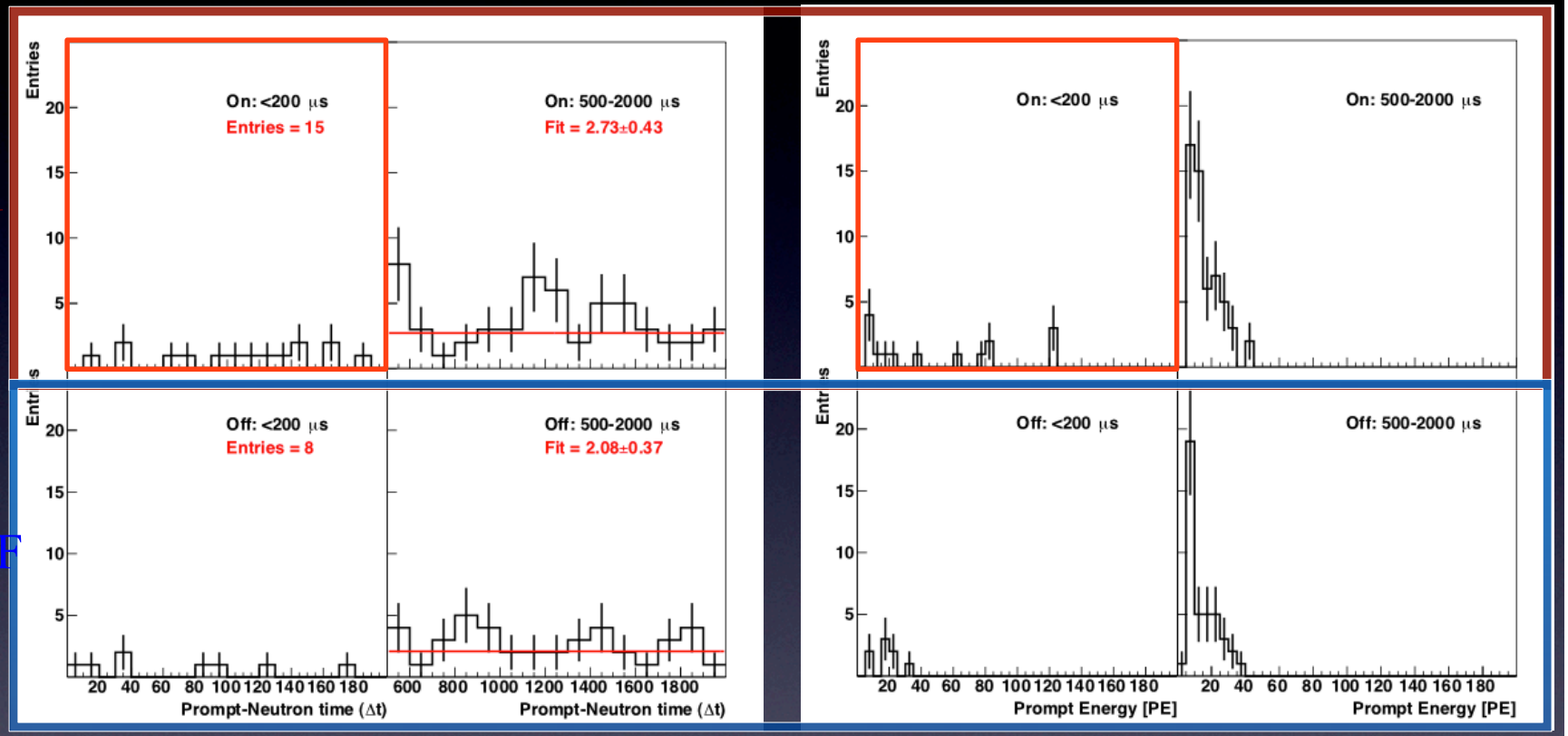
Time & Energy

Prompt-neutron time

Prompt Energy

Reactor ON

Reactor OFF



➔ Consistent with flat distribution and low energy for off time window events

➔ low entries number difference between ON/OFF for off time window analysis

➔ Expected number of accidentals in the signal window: 5.5 ± 0.9 events

Results

- Reactor ON excess compatible with signal : 9.54 ± 3.9 candidates (BKG subtracted)
- 5.46 ± 0.87 expected background events
- 2.44σ reactor ON signal excess

- efficiently reduced using spatial topology

- Low energy accidental background present (combination of muon and neutron induced)
- Need more statistics to increase significance of result
- develop more sensitive analysis

Short Perspectives

- Prototype: very encouraging results
- increase statistics and efficiency:
  - upgrade DaQ Nemenix
  - Installation of a Muon Veto

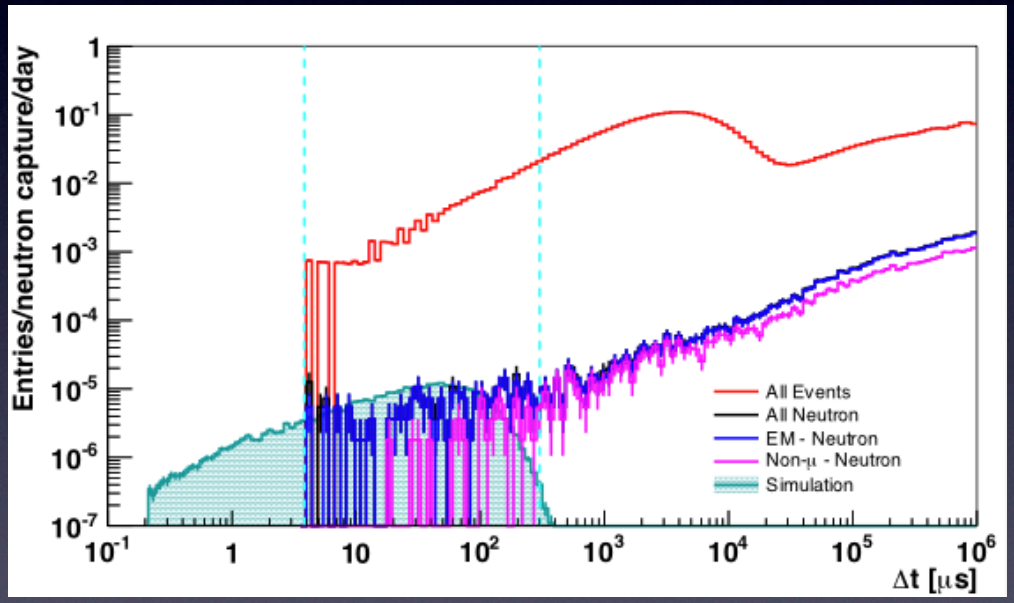
- Carnot Mines Funding for one sub module @ SUBATECH (280 kg)
  - Mechanical Design and Mock up 3 x 24 cubes
  - Commissioning at the end of the year
  before the 2015 BR2 stop

- Reactor Flux Calculations, Working Group created between SCK-CEN, Subatech and LPC-Caen

- SUBATECH-LPC CAEN: ANR “Projet international” for 2 sub-modules funding

Backup

Rejection Power

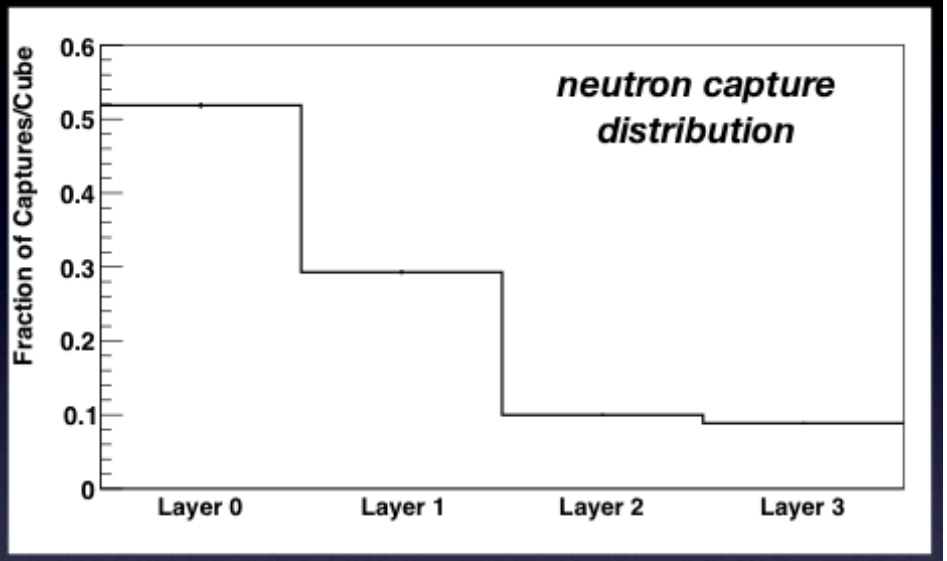


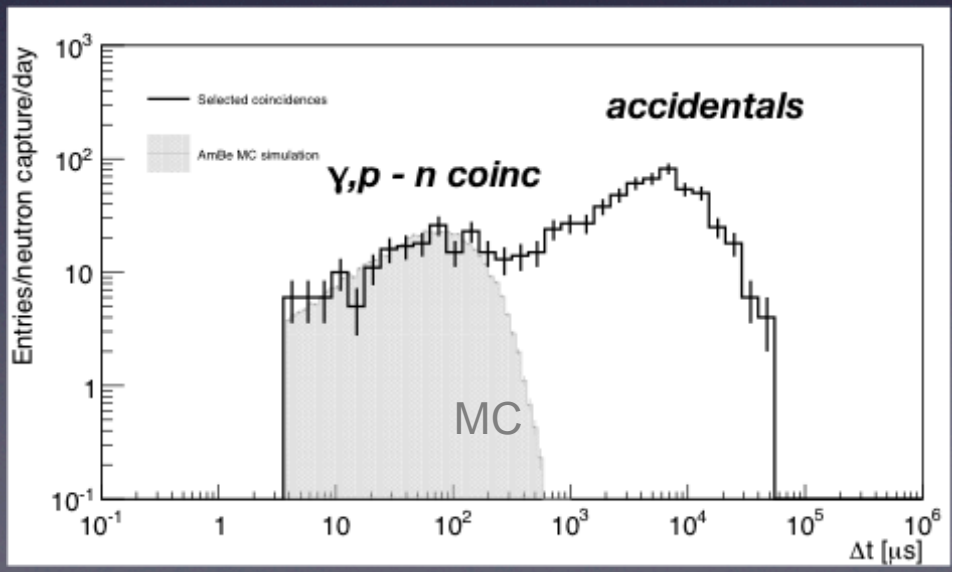
Timing between 2 events

selection cut	coincidences
no cut	2883919 ± 1698
delay n	31751 ± 178
em - n	30749 ± 175
em - n & no μ	18940 ± 138
em - n & no μ - 200us	23 ± 5

Correlation signal with neutron : AmBe source test

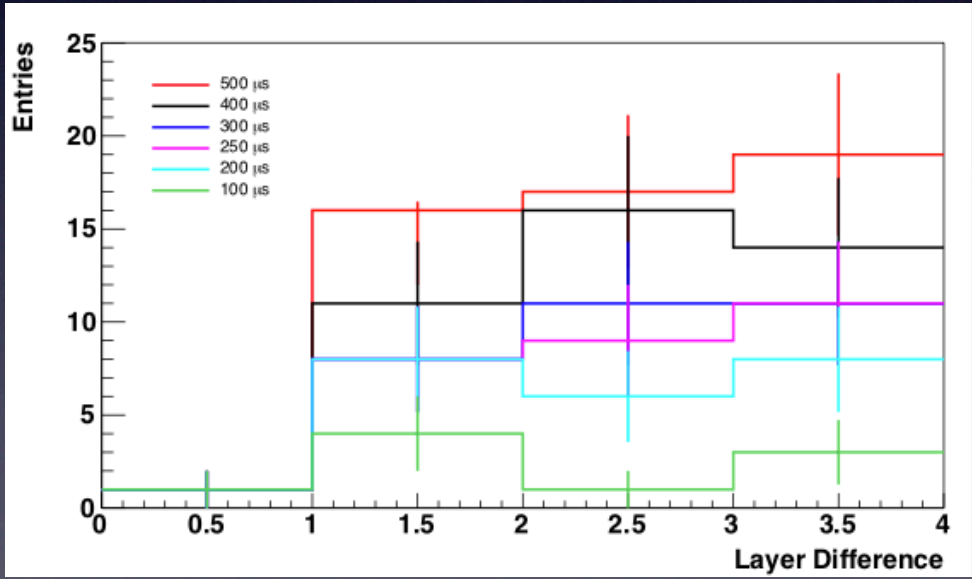
- AmBe emits gamma-rays in coincidence with neutrons
- coincidence also possible from proton recoil
- Prompt-delay time coincidence verified

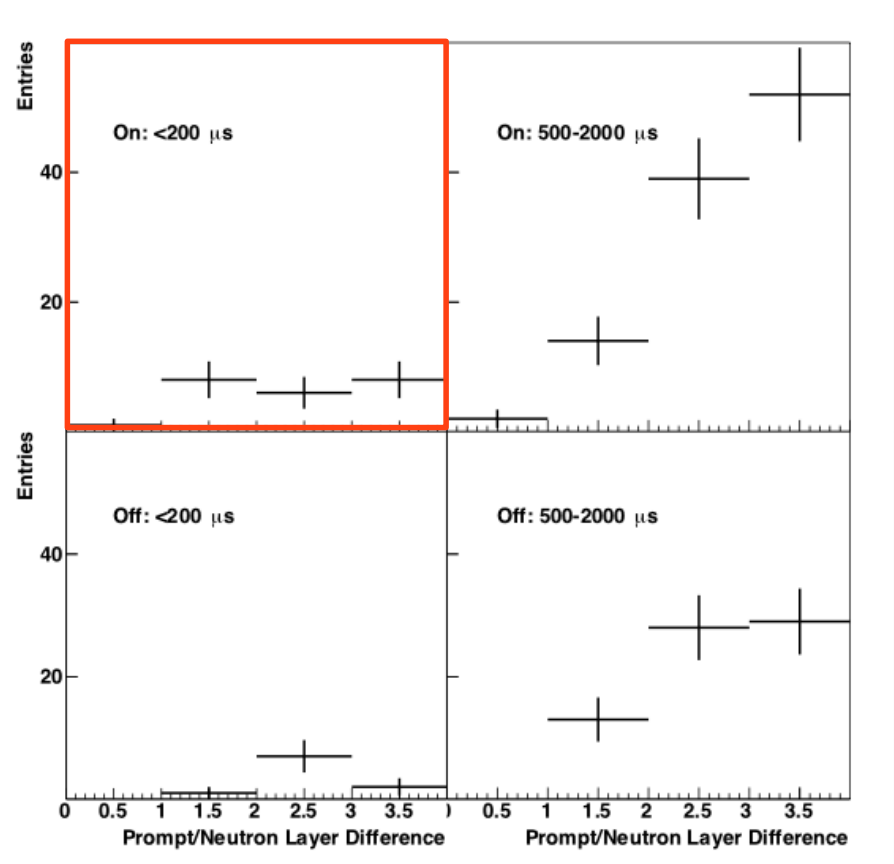




Adding topological cut

- cut > 2 layers
- evidence for reduction of accidentals

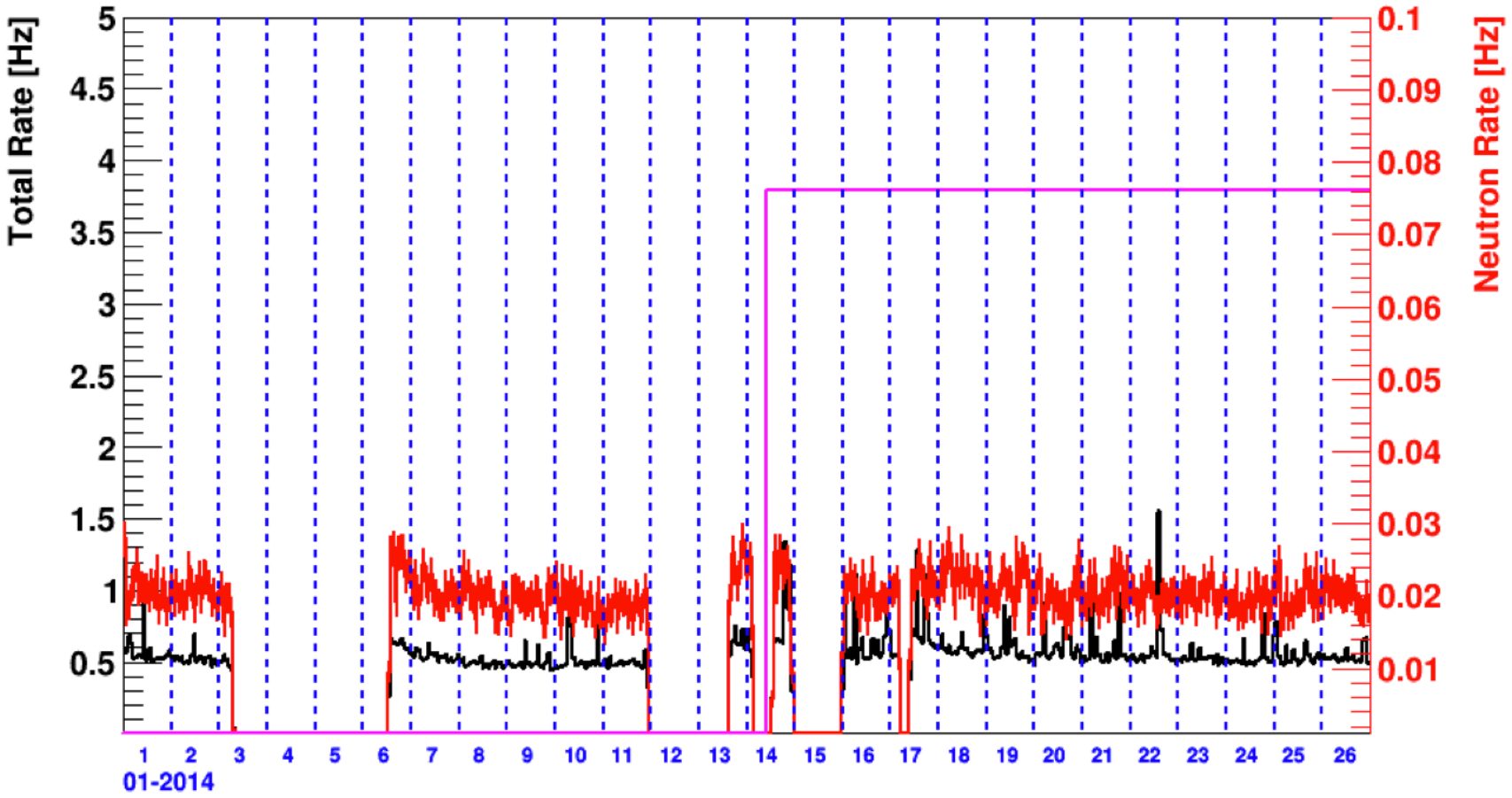




DAQ Comparison

Parameter	Desktop	VME
Module(s)	DT5740	V1724
Channels	32	56
Sampling rate (MS/s)	62.5	100
ADC bits	12	14
Data transfer	USB	CONET optical
Data rate (MB/s)	30	70
Input	68 pin	MCX
input range (Vpp)	2	2.25
DC offset (V)	± 1	± 1.125
buffer (kS/ch)	192	512
trigger thresholds	per group	per channel
DC offsets	per group	per channel

Rate


Total Rate [Hz]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Neutron Rate [Hz]
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
01-2014