A digital data acquisition system for Briken neutron detector

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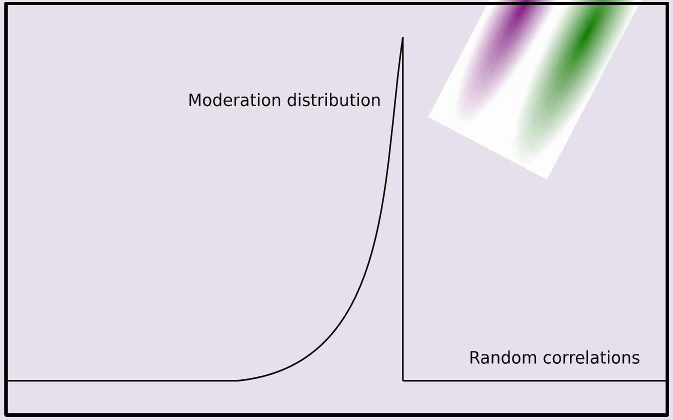
CSIC
Consejo Superior de Investigaciones Científicas

IFIC
Institut de Física Corpuscular

β-n correlation in β delayed neutron detector

- Neutron moderation time up to 300μs
- Time difference Beta-neutron in the moderation distribution if correlation exists
- Time differences between particles from different nuclei are random
- Moderation time distribution appears over the random background



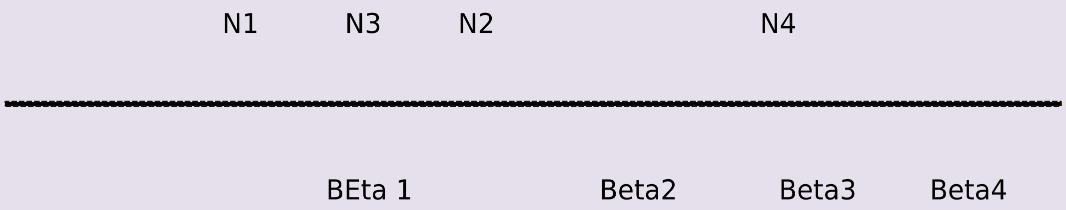
$$N_{\beta} = \varepsilon_{\beta} p_{\beta}^{alive} N_{dec}$$

$$N_{n} = \varepsilon_{n} p_{n}^{alive} P_{n} N_{dec}$$

$$N_{\beta n} = \varepsilon_{\beta} p_{\beta}^{alive} \varepsilon_{n} p_{n}^{alive} P_{n} N_{dec}$$

$$P_{n} = \frac{p_{\beta}^{alive}}{p_{n}^{alive}} \frac{\varepsilon_{\beta}}{\varepsilon_{n}} \frac{N_{n}}{N_{\beta}}$$

$$P_{n} = \frac{1}{p_{n}^{alive}} \frac{1}{\varepsilon_{n}} \frac{N_{\beta n}}{N_{\beta}}$$



Beta1 to n1	Exp distribution	Beta3 to n1	Random
Beta1 to n2	Random	Beta3 to n2	Random
Beta1 to n3	Random	Beta3 to n3	Exp distribution
Beta1 to n4	Random	Beta3 to n4	Random
Beta2 to n1	Random	Beta4 to n1	Random
Beta2 to n2	Exp distribution	Beta4 to n2	Random
Beta2 to n3	Random	Beta4 to n3	Random
Beta2 to n4	Random	Beta4 to n4	Exp distribution

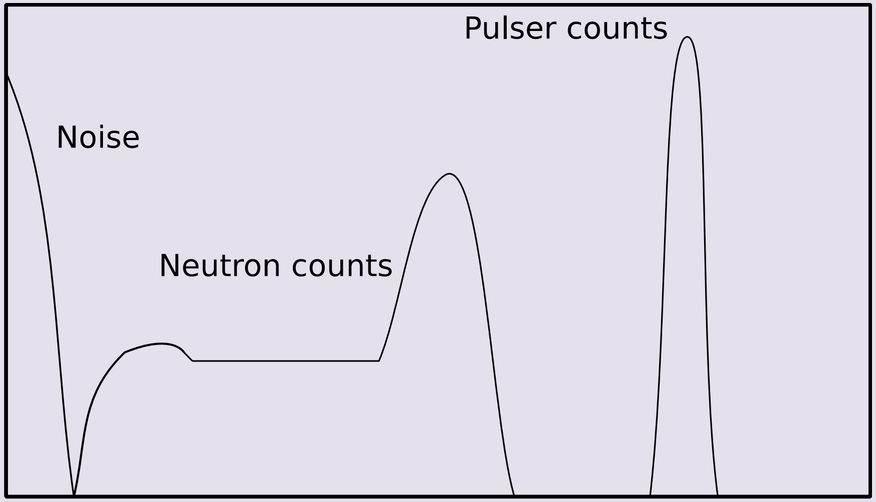
Possibilities

Classical (triggered) solutions

- ADC + long duration TDC Long dead time (more than 500µs)
- Multihit TDC
  - Long window duration, up to 1 ms
  - Multiple time data in one Window
  - No energy information from time data

Self Trigger solution

- New sampling modules available in the market with self trigger in each Channel
- Dead time reduced to the conversion dead time
- Correlation made by software



SIS3302 ADC digitizer

SIS3302 Characteristics:

- 100MHz sampling digitizer 50MHz Band width
- 32 MSamples memory/channel (in two swap pages)
- Readout simultaneous to acquisition
- 16-bit resolution (13 effective bits)

8 modules available

31 … 16	15 … 0
Timestamp [47:32]	Event header and ADC_ID
Timestamp[31:16]	Timestamp[15:0]
Raw samples (0 to 65532)	
Energy filter output (0 to 512)	
Energy max value	
Energy ofset	
Configurable registers	
Trailer (0xDEADBEEF)	

Data stream

- Each channel has a trigger
- Time-stamp at trigger
- Up to 65532 samples
- FIR (Finite Impulse Response) filter to determine signal energy

SIS3316 ADC digitizer

SIS3302 Characteristics:

- 250MHz sampling digitizer
  125MHz Band width
- 64MSamples memory/channel (in two swap pages)
- Readout simultaneous to acquisition
- 14-bit resolution (12 effective bits)

8 modules available

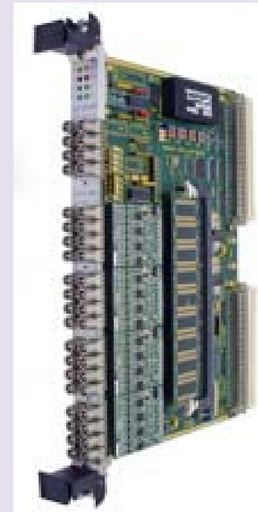
31 … 16	15 … 4	3 … 0	
Timestamp [47:32]	Channel ID	Format bits	
Timestamp [31:16]	Timestamp [15:0]		
Index of Peakhigh value [15:0]	Peakhigh value [15:0]		If Format bit 0 = 1
Information [7:0]	Accumulator sum of Gate 1 [23:0]		If Format bit 0 = 1
"0000"	Accumulator sum of Gate 2 [27:0]		If Format bit 0 = 1
"0000"	Accumulator sum of Gate 3 [27:0]		If Format bit 0 = 1
"0000"	Accumulator sum of Gate 4 [27:0]		If Format bit 0 = 1
"0000"	Accumulator sum of Gate 5 [27:0]		If Format bit 0 = 1
"0000"	Accumulator sum of Gate 6 [27:0]		If Format bit 0 = 1
"0000"	Accumulator sum of Gate 7 [27:0]		If Format bit 1 = 1
"0000"	Accumulator sum of Gate 8 [27:0]		If Format bit 1 = 1
"0000"	MAW maximum value [27:0]		If Format bit 2 = 1
"0000"	MAW value after Trigger [27:0]		If Format bit 2 = 1
"0000"	MAW value before Trigger [27:0]		If Format bit 2 = 1
Start Energy value (Energy value from first value of Trigger Gate)			If Format bit 3 = 1
Max. Energy value (during Trigger Gate active)			If Format bit 3 = 1

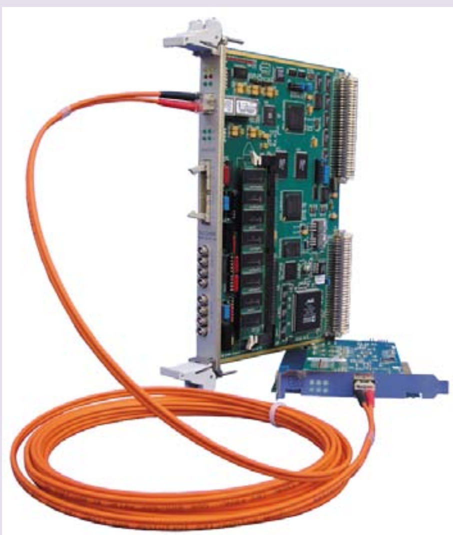
Data stream

- Each channel has a self trigger
- Time-stamp at trigger
- Up to 65532 samples
- FIR (Finite Impulse Response) filter to determine signal energy
- Up to 8 gate integration

SIS3100 SIS1100 and SIS3700

Features/Pproperties:
- 32 clock outputs or
- 16 clock and 16 start/stop/gate outputs
- NIM LEMO outputs (others on request)
- In field firmware upgrade capability

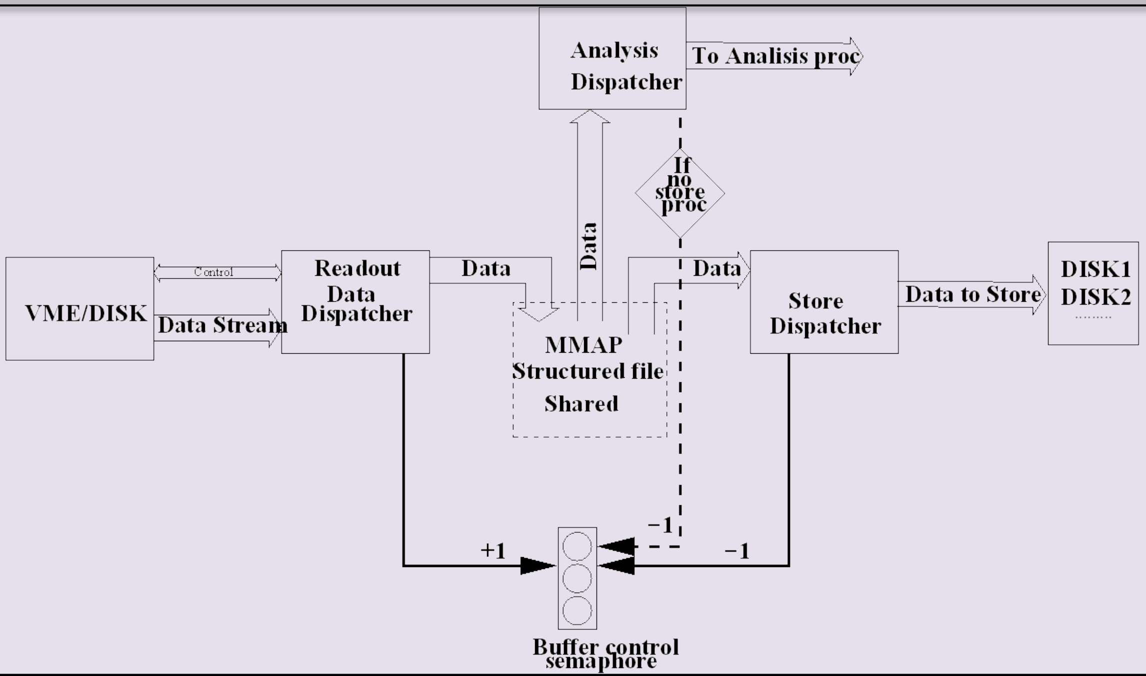




Features/Properties:
- Mapping table with 64 entries
- VME master A16/A24/A32/A40 D8/D16/D32/BLT32/MBLT64/2eVME
- VME slave A32/D32/BLT32/MBLT64
- Block transfer address auto increment on/off (for FIFO reads)
- System controller function (can be disabled by jumper)
- up to 450 m link distance (up to 20 km with long distance option)
- EMC front panel in field JTAG firmware upgrade capability

GasificTL readout: Flux Diagram

- Several processes run in parallel
- Data shared in the same memory space
- Several semaphores synchronize the processes
- Readout dispatcher: Get Data from Hardware and put it in the shared memory
- Store dispatcher: take data from the shared memory and send it to storage
- Analysis dispatcher: Copy a data block from the shared memory and send it to analyze



Asynchronous data readout

- As there are not a common trigger, event structure does not exist
- Each channel is readout independently
- Readout does not interrupt the data acquisition, as the ADC memory is swapped before the readout
- Analysis conditions are set by the common timestamp in each data

Data for each ADC

Last block read: LastBlockStack

t 0	Energie	Time
t-1	Energie	Time
t-2	Energie	Time
	....	....
t-n	Energie	Time

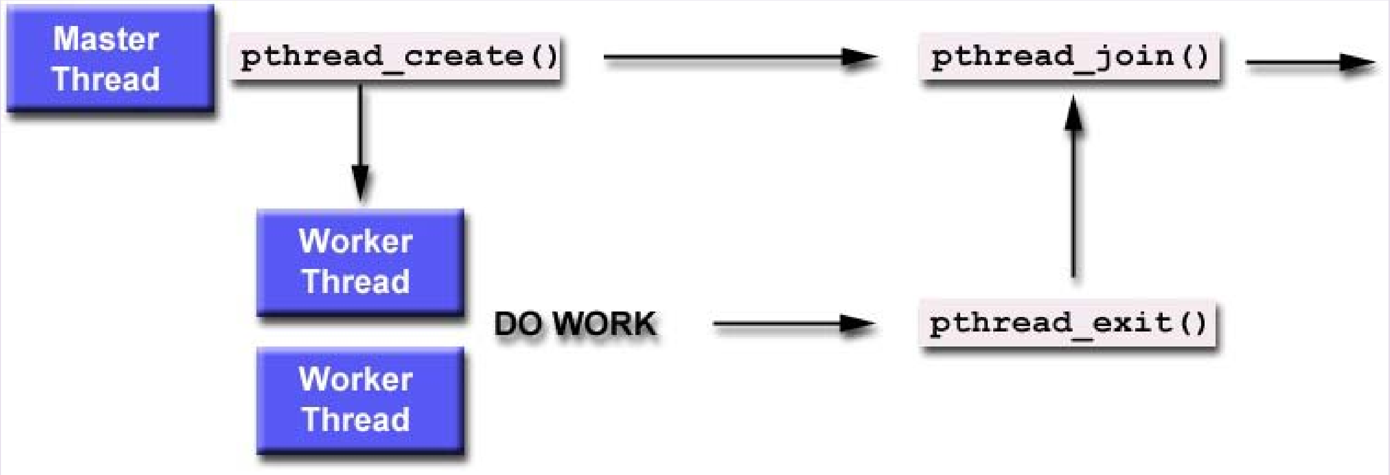
Data Stack

t 0	Energie	Time	
t-1	Energie	Time	
t-2	Energie	Time	Last Block
	....	....	
t-n	Energie	Time	
t 0	Energie	Time	
t-1	Energie	Time	
t-2	Energie	Time	
	....	....	Old Block
t-n	Energie	Time	
t 0	Energie	Time	
t-1	Energie	Time	
t-2	Energie	Time	Older Block
	....	....	
t-n	Energie	Time	

GasificTL Online: Parallel processing

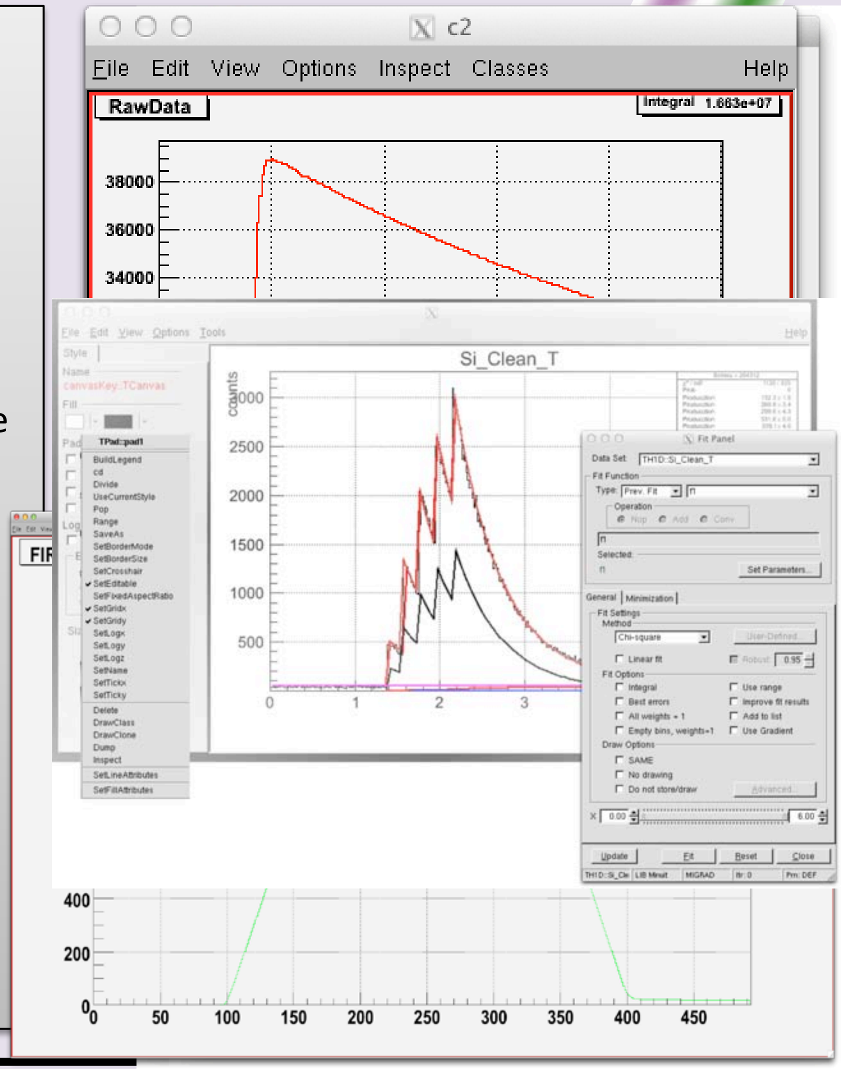
Parallel processing

- Unpacking data and making correlation is a repetitive process ideal for parallel processing
- Optimized for multi processor CPU
- The program sends several tasks to the operating system as independent threads without waiting for them
- The main thread waits for all tasks to be finished



GasificTL GUI: Control window

- To control the system, a graphical user interface was programmed using Qt libraries
- The main window is divided in four tabs with the different functions
- ACQ tab: From this tab it’s possible to control the DAQ: start, stop, save in disk...
- Online tab: From this tab the user can display all the defined spectra and define new correlations
- HV tab: GasificTL is also prepared to control some High Voltage units
- Digi tab: This tab is prepared to write and read VME commands, and has some special fields to configure the SIS3302 FIR filter
- Scope function: Show a window with input signal
- Filter output: in order to optimize the filter parameters we can see also the filter output
- Using ROOT libraries, linked with Qt in the GSI compilation, QtRoot, we have in the same program Qt buttons environment and ROOT displays with all the ROOT analysis tools

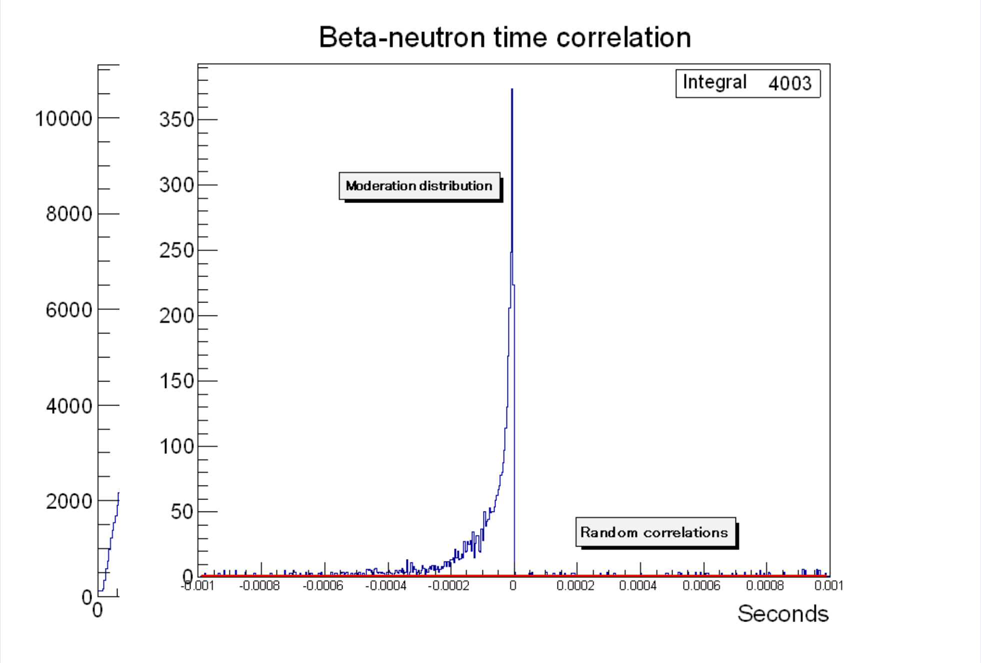


GasifcTL at BELEN 20 detector

- Standalone system already use in experiments
- Preamp signals connects directly to the digitizer
- Connect a shaper between the preamp and the digitizer is a “triki” way to filter noise , but increase the cost of electronics.
- Is convenient for a large number of channel to connect directly to preamp.

GasifcTL at BELEN 20 detector

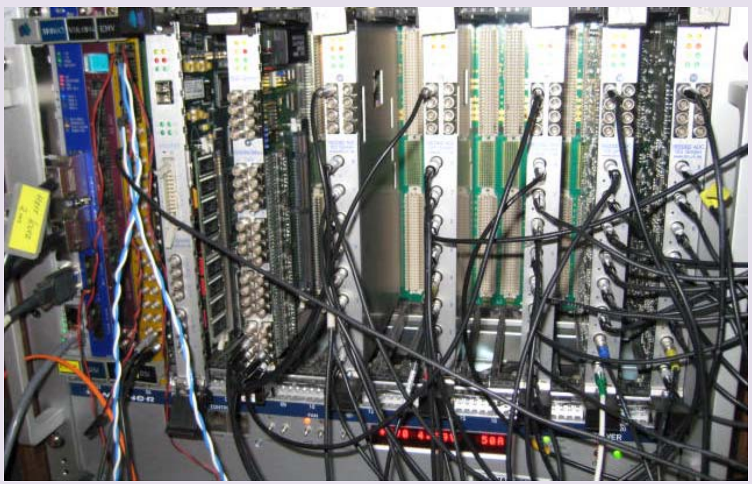
- The life time determine with a precise frequency pulser, is around 99%
- Amplitud (energy) information of each data
- Grow and decay activity curves
- The B-n correlation could be obtained online during the experiment



MBS integration

How to mix a trigger less system in a triggered data acquisition:

- Made a relation between times tamp and trigger
- Use a channel with a fixed signal in the event to to has a time stamp of the event
- Read the asynchronous data systematically (i.e. in each trigger)



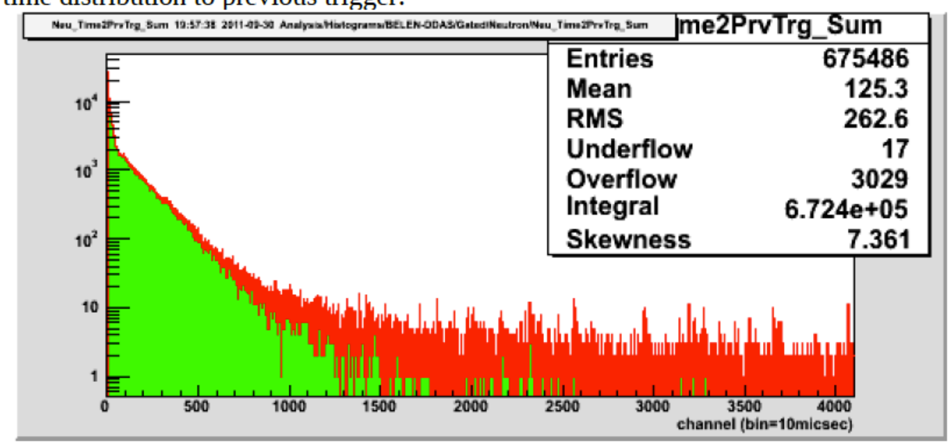
The DDAS at MBS

- Each accepted trigger signal
  - Introduced in the DADC
  - Made DADC read out
  - Reset the time stamp
- A fixed clock at 10Hz was add to the master trigged to avoid big memory length that increment the MBS dead time

Self-triggered vs triggered with MBS at GSI FRS

Advantages of DDAS vs Multihit TDC
- Better efficiency
- Information of neutron coming out of trigger
- Accurate information of life time from pulser

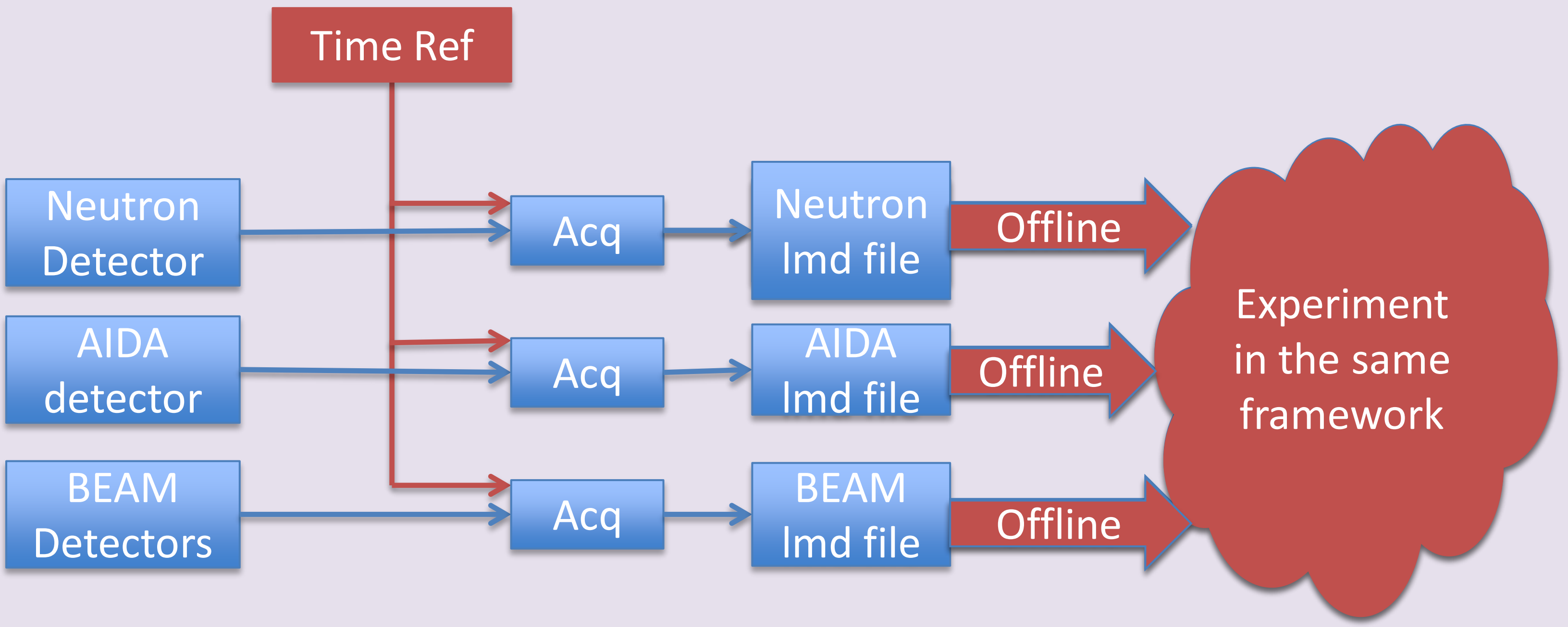
Neutron time distribution to previous trigger:



^{252}Cf neutron source detection efficiency (M.Marta):
- MCNPX simulation: (34.5±0.2)%
- Triggerless DACQ (IFIC) in MBS : (35.4±0.8)%
- Analog branch: (25.5±0.9)%

Next achievement: BRIKEN acq integration

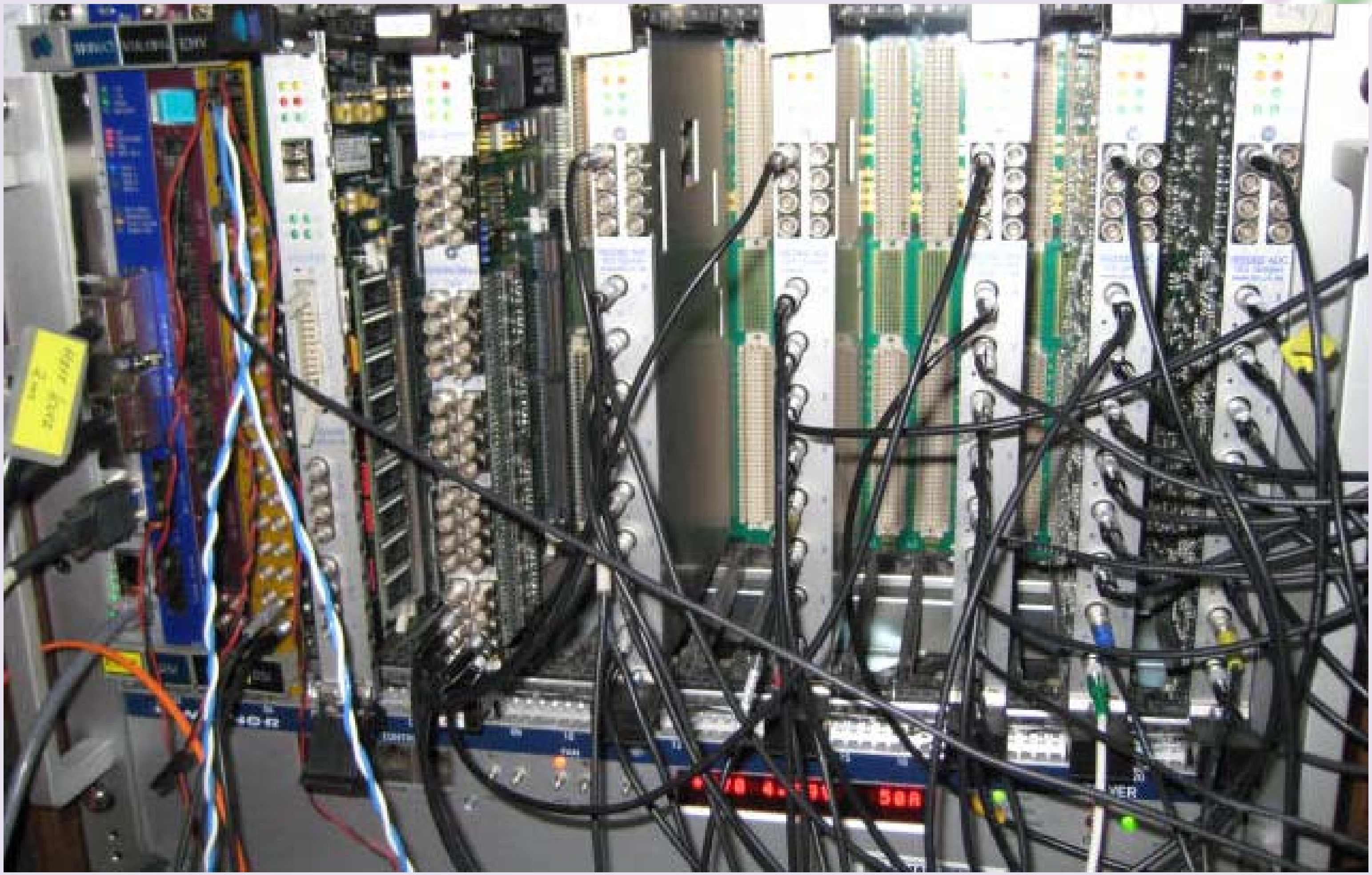
- We have three independent setups.
- Independent acq hardware
- Independent acq software
- Three different data files
- Common time reference, a possible solution.



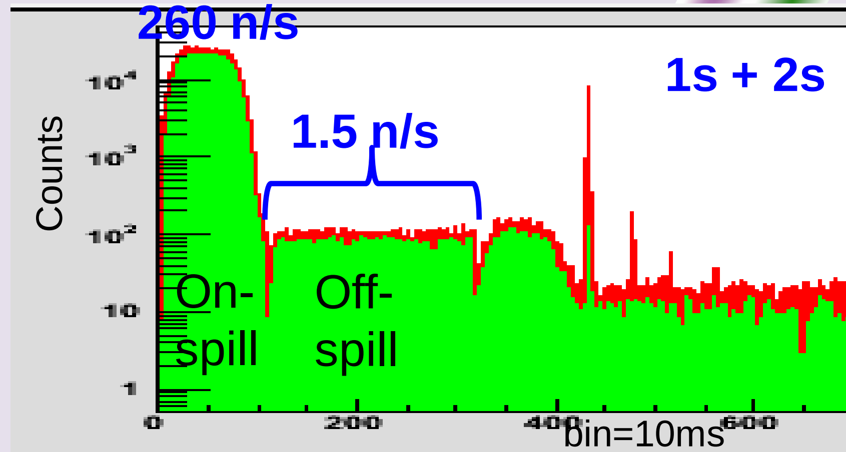
Conclusions

- Self trigger is the optimum way to read β delay neutrons
- He have 192 (8x8+8x16) channels available
- 20 to 40 free channels to ancillary detectors or synchronization signals
- GasificTL software fully developed at IFIC by our group
- GasifiTL is a modular package
- GasificTL is an acquisition system successfully use with the neutron detector BELEN and results presented at ND2013
- Already integrated with FRS
- Integration of the tree systems is needed

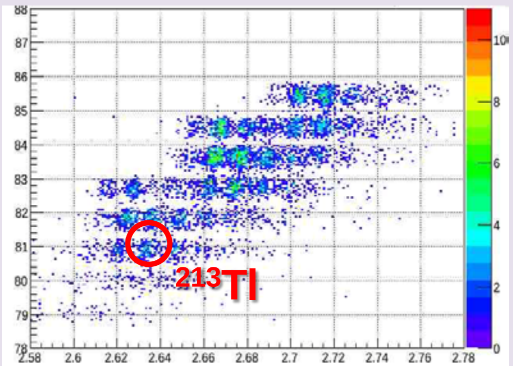
THANK YOU

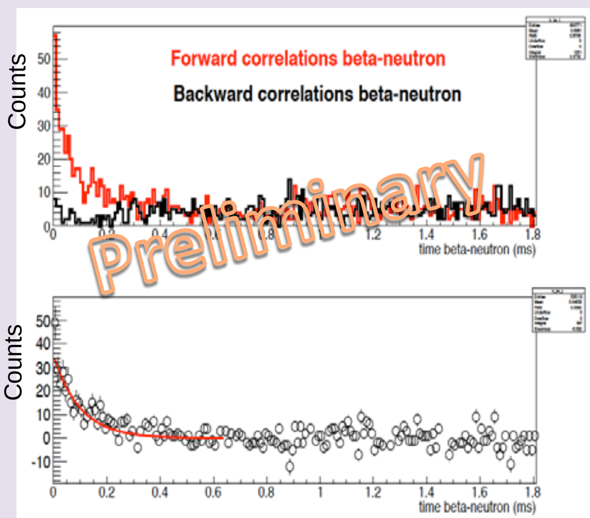


First Beta delayed neutrons identify

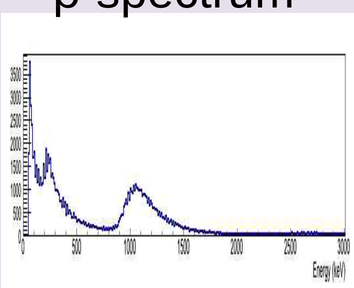


Beta- delayed neutrons have been identified in spite of the large beam-induced neutron background!

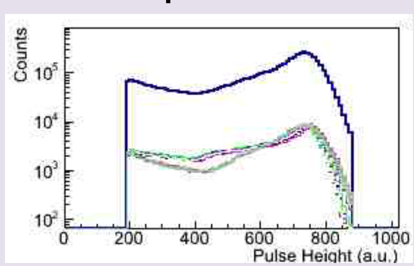




β-spectrum



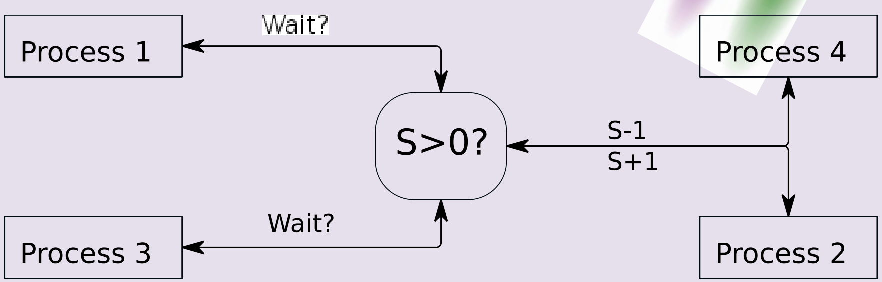
n-spectrum

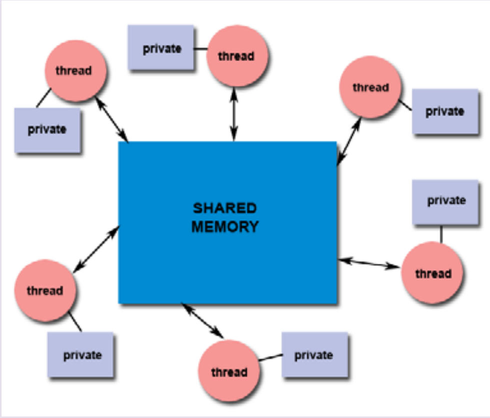


GasificTL readout: Inter Process Communication IPC

Shared Memory/Mapped files

- Same memory space for several processes
- Good way to share information
- No control over read and write
- "Critical section" must be previewed





Semaphores

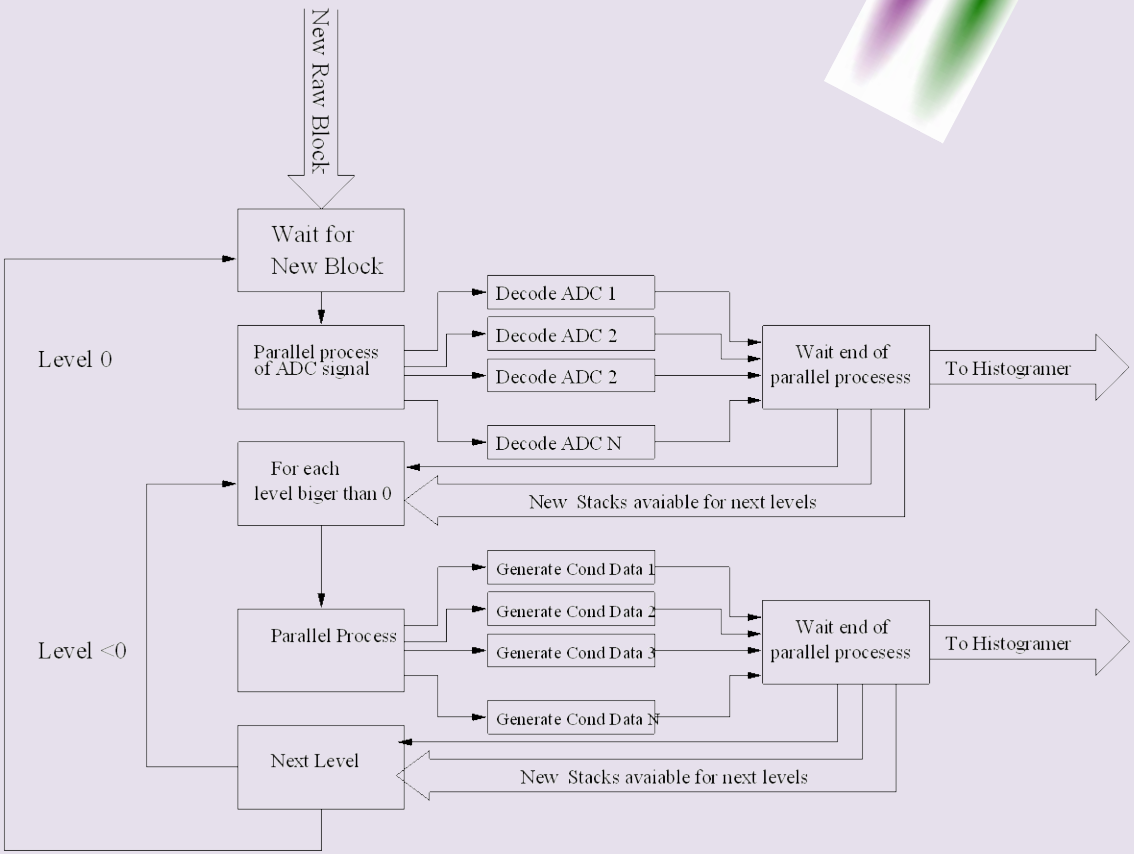
- All processes can increase or decrease the semaphore counter
- Processes go to sleep when his semaphore is "red"
- Sleepy processes don't use CPU time
- Easy way to implement circular buffers

Pipes: Connect stdout of a process with stdin of the next one, easy to implement, lineal process
Sockets: Powerful tool to transmit data through the net
Signal, message ...

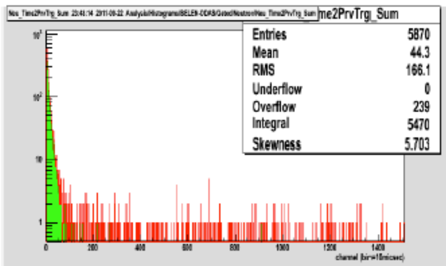
GasificTL Online: Parallel processing

Layered structure

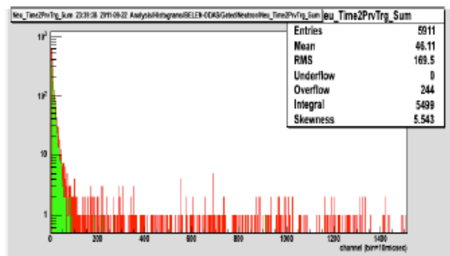
- The analysis program is CPU consuming
- Runs sending tasks in parallel
- Care should be taken because of task interdependencies
- Tasks are organized in layers according to dependencies
- Layer N include tasks which need data from layer N-1, layer 0 are unpacking data



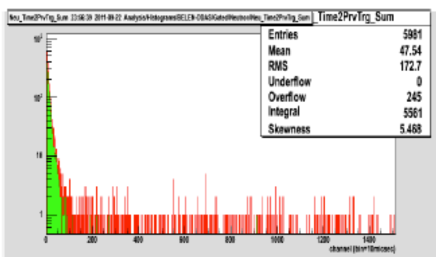
Prompt neutrons TPC veto



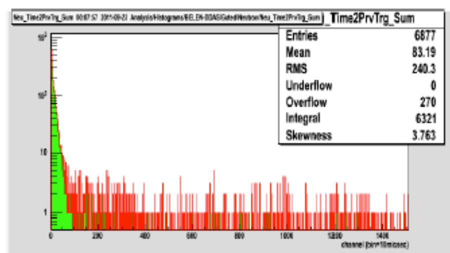
ΔT=40ms



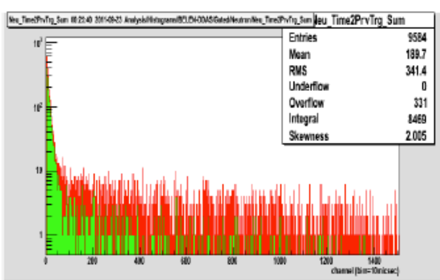
ΔT=500μs



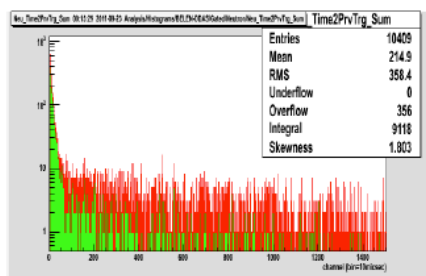
ΔT=200μs



ΔT=10μs



ΔT=1μs



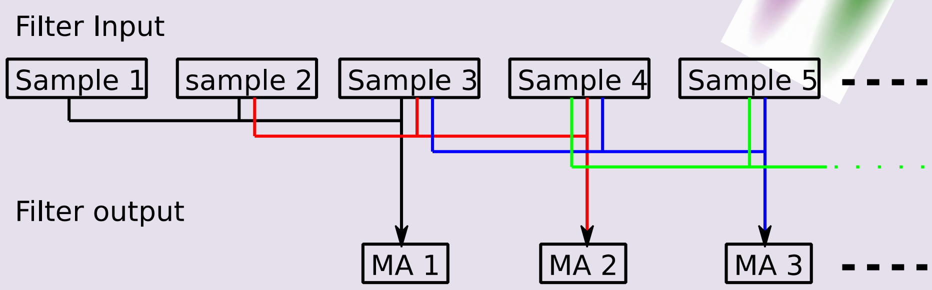
ΔT=100ns

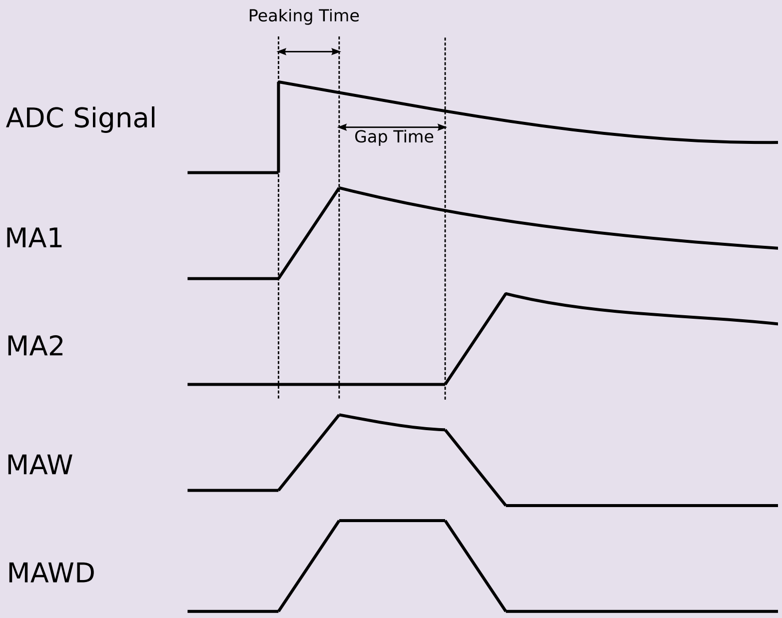
- Time stamp of digital system allow us to made any time condition
- Veto for the initial ΔT after the beam
- We reduce the contribution of prompt neutrons

FIR filter of SIS3302

Moving Average:

- Average during a configurable number of samples
- The average is shifted towards higher values



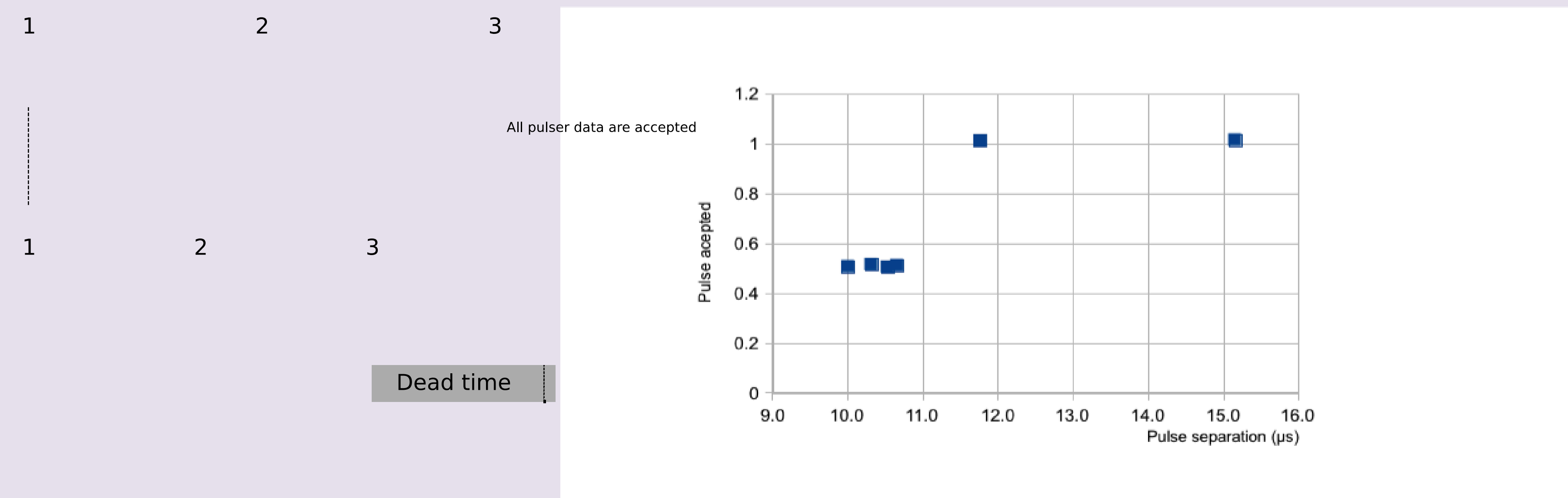


FIR filter:

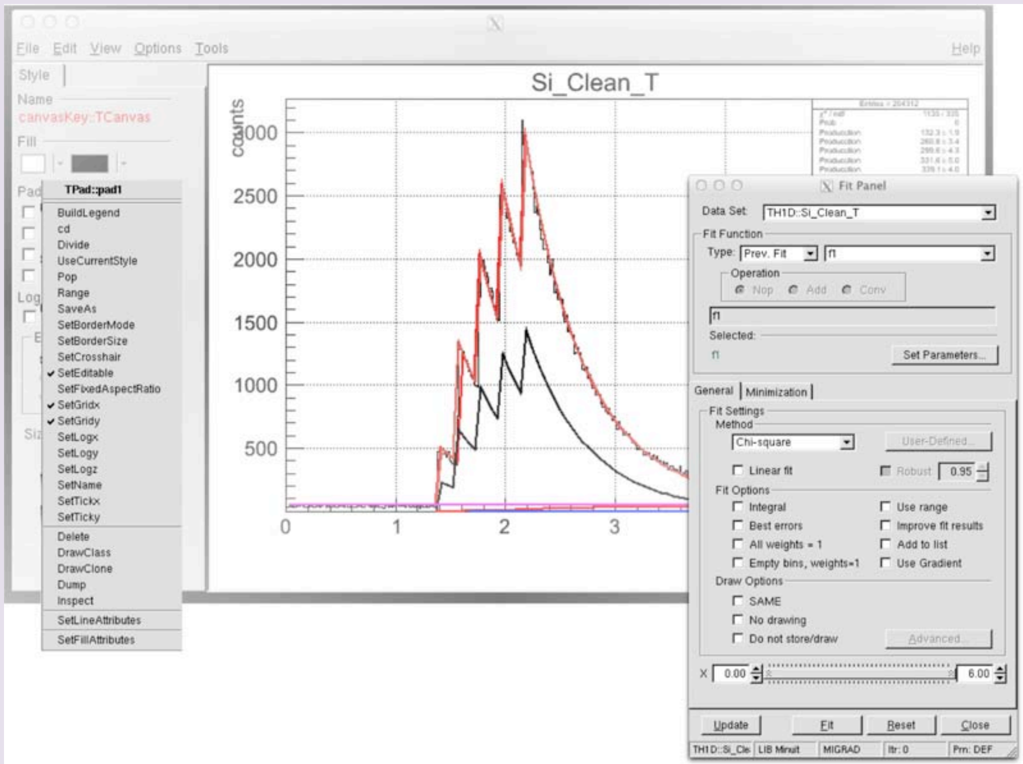
- Finite Impulse Response filter
- Applied over the subtraction of the input signal and the delayed input signal
- The window length of the filter correspond to the peaking time of the classical amplifiers
- The delay between signals is the gap time
- Filter length define the conversion dead time

Dead time

- The conversion dead time is measured with only a pulser in the preamp. Without real signal, as the pulser is periodic, when the pulse separation is similar to dead time, the acceptance falls to 1/2
- The conversion dead time when filter is configured to be used for the 3He counters is 11.5s. For different filter parameters this value could be decreased about 2s using shorter filter length

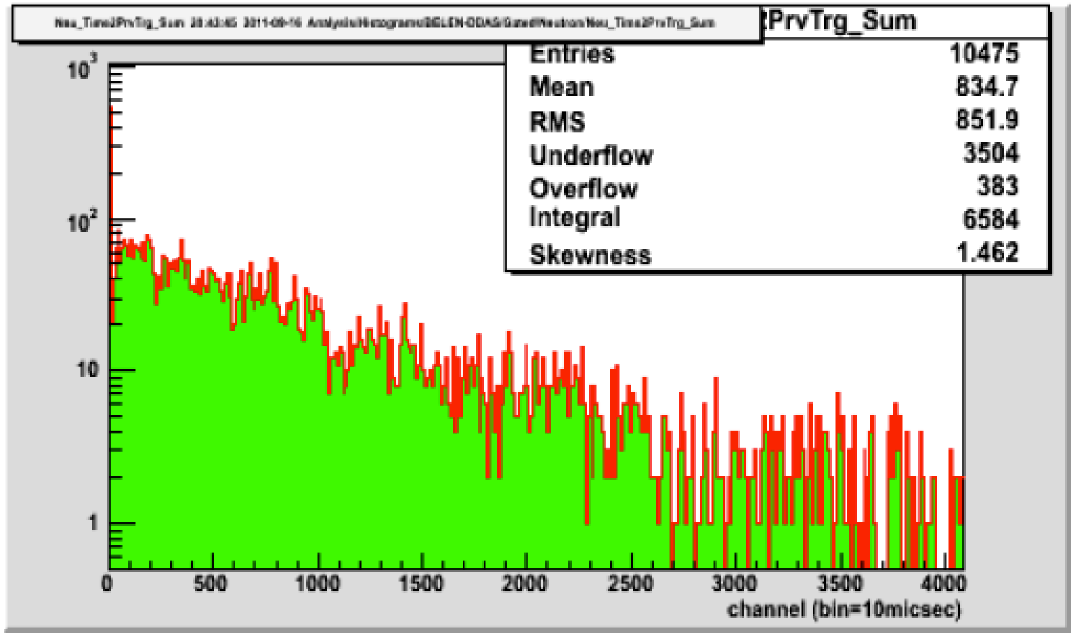


ROOT interface



- Using ROOT libraries, linked with Qt in the GSI compilation, QtRoot, we have in the same program Qt buttons environment and ROOT displays with all the ROOT analysis tools
- The Online displayed spectra can be added, overprinted, re binning, fitted... all the possibilities that ROOT gives to the user

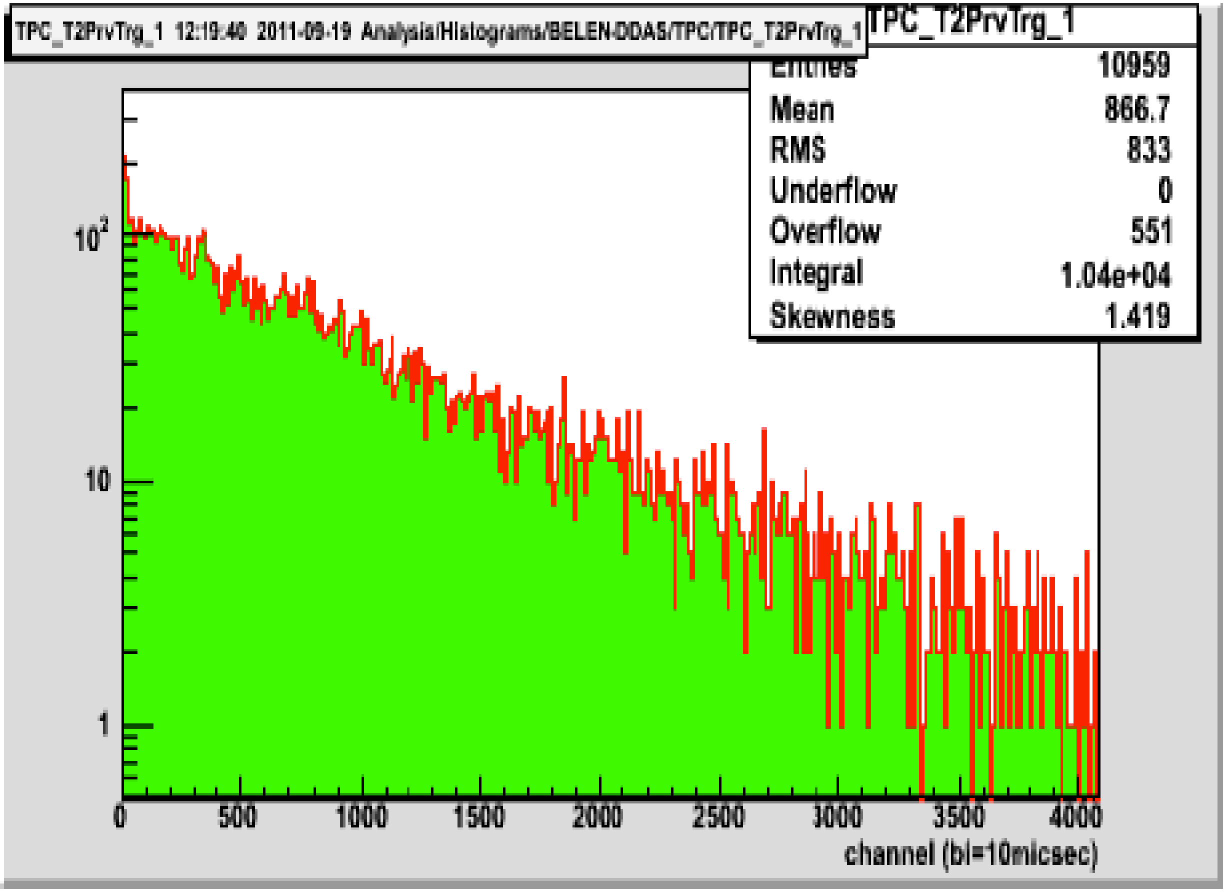
Neutrons coming from beam



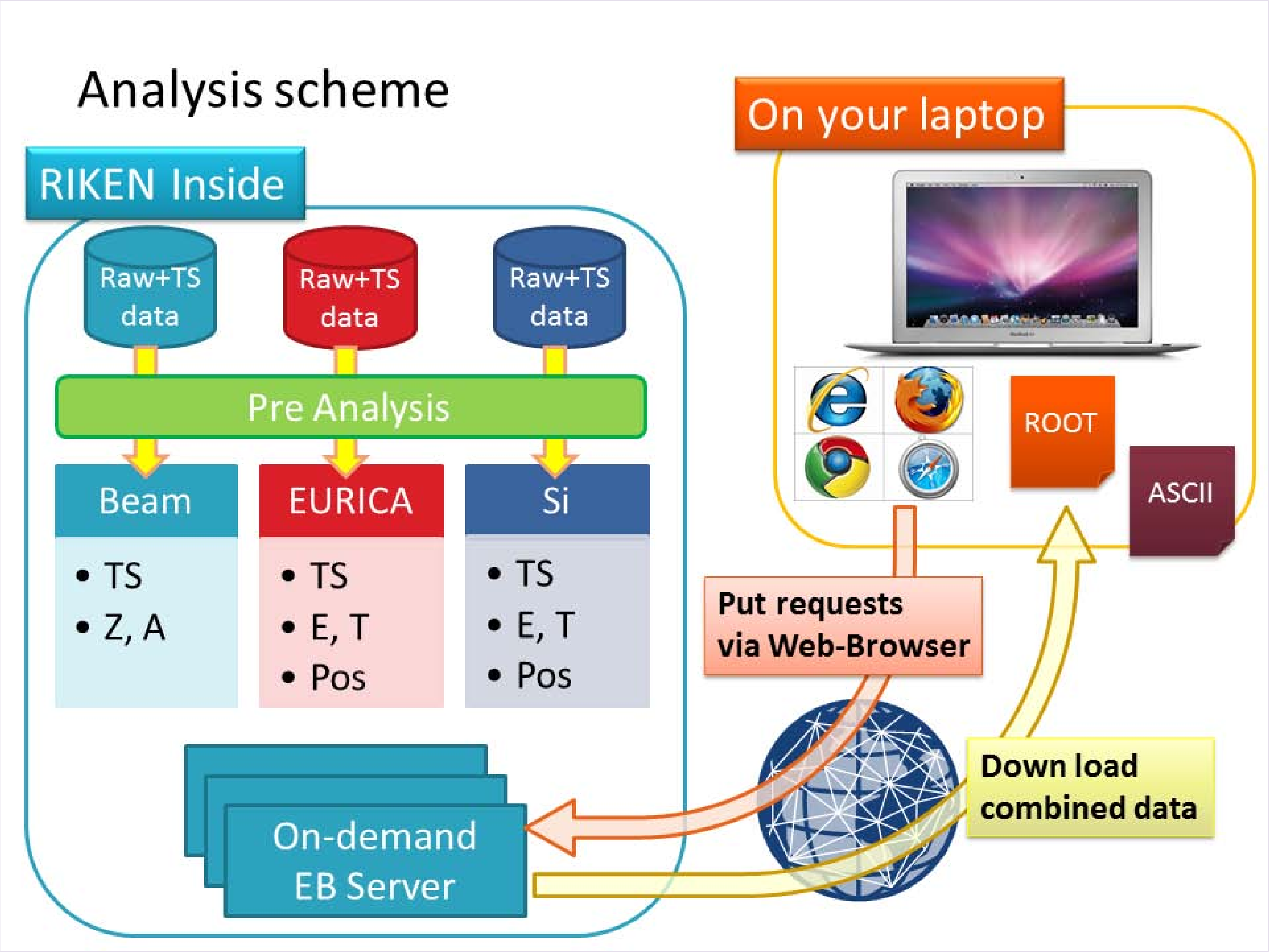
Time constant from fit: **τ=** 1/0.120= **8.33 ms**

TPC

TPC time distribution after previous trigger



Eurica: Starting point



From Eurika web page