COMET-NARVAL ACQUISITION notice

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Translated by Anne Marie Dujardin

Institut de Physique Nucléaire, 91406 Orsay Cedex, France
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b Service Informatique de l'Institut
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February, 20, 2006

COMET-NARVAL ACQUISITION

1 – Overview

The COMET cards (COMET = Codage et Marquage En Temps : Encoding and time marking.) serve to determine the energies and the time correlations of radiations detected during a multiparameter experiment while avoiding any extra specific module (coincidence circuits, delays) to set up this time correlation.
For each detected radiation, the arrival time information as well as the amplitude of the detected signal, are encoded. The results of these amplitude and time codings are associated to create an event. In this way, each detector is an independent source which provides a building block of the general information obtained by all the detectors.
A COMET – 6x card is composed of 6 channels. The use of n COMET – 6 x cards allows us to process the data coming from the n x 6 detectors.
This method has the advantage of preserving all information of every event. Its disadvantage is that the data-acquisition bandwith sets a hard limit on the data transfer rate.
Its operational mode permits the extraction of several types of information with only one data sampling : for instance, coincidence relationships between radiations seen by different detectors and this, for several widths of the coincidence window, as well as the time variation, either of the spectrum in energy of detected rays, the radiation in a given energy or the coincidences of a given type.
Part of the processing is done in the card itself using a 32 bits DSP, 40 MhZ. The built event includes the time, coded on 47 bits (15.6 h), the amplitude on 13 bits (8192 cx) and the event's source. Data are transferred in an event by event mode to a concentrator, then to the VXI rack "Resource Manager" unit and finally to the acquisition computer via a 1 Gbit Ethernet link.
The control and command of the COMET card is done on the VXI rack's bus using the "Resource Manager" unit via the network. The embedded cpu is accessible through a serial console link via the network.

2 – Main technical characteristics

2-1 – Standard : C size VXI

2-2 – Energy/time (E/T) channel : magnitude encoding by peak detection and time tag

- number of E/T channels : 6
- amplitude encoding :
  - SMA plug
  - Energy-detector signal input
  - Amplitude scale : 0 – 10V, on 13 bits (8192 channels)
  - Energy resolution : 0.4 LSB (channel)
  - Differential non-linearity, obtained by a sliding scale with an automatic fit, < 2×10^{-3}
  - Encoding time : 5μs
- time encoding :
  - SMA plug
  - Time-detector signal input
  - Time scale on 47 bits (15.6h)
  - Encoding step : 400ps
  - Differential non-linearity: about 3%

- dead time : the dead time for the encoding and the E/T treatment is : 8±0.5μs without taking into account the filtering time constant of the amplifier.

2-3 – Data output

- VME standard bus
- link port serial output of the 21062 DSP (Analog Devices)
- number of independent links : 2
- transfer speed : 20Mb/s
- data collection from several cards :
  - Star shaped
  - Serial type, daisy-chain mode (not available)

3 – Directions for use and functions

3-1 – Card associations

Several cards plugged in contiguous slots of the rack form a group. The first card on the left is the ANCHOR card. The others are the slave cards. The rightmost card is the LAST CARD.
Two groups of independent cards are separated by at least one empty position.

3-2 – Available functions

- CODEN, encoding authorization :
  - 00 lemo plug
  - TTL signal (0, +3V to +5V)
  - 1kΩ input impedance
  - The presence of the "CODEN" signal or the unconnected input takes into account the T time signals coming in every channel of a group. The detection of this signal's rising edge initializes the time reference of every event which arrives during the signal's duration. If no cable is connected to the CODEN input, the time reference associated with events is then the start up of the data acquisition.
- PGATE module and PGATE crate, acquisition authorization :
  - 00 lemo plug
  - NIM signal (0, -0.8V)
  - 50Ω input impedance
  - "PGATE module". The (-0.8V) signal presence authorizes the taking into account of the time signals which arrive on every card channel. The current processing of an event for which the time signal arrived just before the PGATE module signal stop is however assured.
  - The PGATE crate signal has exactly the same function as the PGATE module signal but the authorization applies to every channel of a group and not only to the card channels. In the case of using a PGATE crate function for a group made of several cards, it is possible to enter a signal on each card of the group. The acquisition is then authorized for every group card when only one of the authorization signals is on. The stopping corresponding to the absence of the authorization signal behaves as an "And".

- Time-Energy coupling :
  - Time :
    - SMA plug
    - (0, -0.8V) NIM signal, 10ns to 2 or 3μs signal width
    - 50Ω input impedance
  - Energy :
    - SMA plug
    - receives an analog signal (output of an amplifier of a measurement chain).
    - 2kΩ input impedance
    - rise time t_m : 500ns< t_m <15μs
  - The front edge of the T time signal :
    - determines the time associated with the event with regard to the reference
    - opens a PT adjustable width gate
    - activates the energy measurement using the search of the maximum amplitude of the energy signal and memorization of this maximum (PDS : Peak Detection and Stretcher).

The maximum amplitude of the energy signal must be included in the width of the PT gate

- M channel, MRQ module and MRQ crate, event marking :
  - 00 lemo plug
  - (0, -0.8V) NIM signal
  - 50Ω input impedance
  - M channel : the presence of this signal during the opening or the closure of the gate allows the tagging of the event currently being encoded in a given channel
  - "MRQ module". the presence of the signal during the opening or the closure of the gate allows the tagging of the event currently being encoded whatever the channel of the board
  - "MRQ crate". It enables the tagging of events currently being encoded in every channel of a group. When using the MRQ crate function for a group made of several cards, entering a tag signal on each card of the group is possible. Then, only one tag signal has to be present to tag the currently encoded events in every channel of the group ; the tagging therefore behaves as an "OR"
- TOV, occupancy time of the channel : this function is implemented in the DSP program. By periodic polling of the occupancy (BUSY) of the channel,

the dead time of the actual data acquisition is statistically estimated. The obtained tov value does not take into account the dead time before the card. The inquiry is made at a 1kHz frequency and the result is transmitted to the data acquisition every 0.512s.

3-3 – Visualization

- BUSY module, BUSY crate :
  - 00 lemo plug
  - (0V to +5V) TTL output
  - The "BUSY" signal allows the visualization of the occupancy of channels shown by the (zero V) low level. The BUSY module signal is the logical "OR" signal of the card channels. The BUSY crate signal is the logical "OR" of every channel of a group
- warning (indicator) lights :
  - *GO* : this LED is on when the card is turned on by the data acquisition
  - DSP1 : this LED blinks at 1 Hz when the COMET card DSP operates. If the LED is continuously on, this indicates that the COMET card DSP stopped working. The main possible reasons are :
    - non correlation between time and energy
    - no data transfer by the link port link
  - DSP2 : this LED switches on when the word "END" generated by the stopping of the data acquisition has not been emitted by the COMET card DSP
  - V : this LED associated with each channel switches on when the channel processes an event
- PT Time gate :
  - Test point
  - (0V, +5V) TTL output. It enables the visualization of the opening time of the gate. Because of the synchronization of the energy encoding commands, the rear edge of the opening signal fluctuates by ± 0.5μs in time.
  - Gate width adjustment. The gate opening time which is simultaneously visualized with the E energy pulse must be adjusted for the gate to be closed about 1.5μs after the maximum of the energy pulse.
  - Adjustment of the tag signal "M Channel" , "MRQ module" or "MRQ crate". The arrival time of the tag signal must be adjusted for the signal to be roughly centered either on the rear edge or on the

front edge of the PT gate opening signal. This function may be equivalent to a coincidence. If the signal width is T, then the coincidence resolution is 2T.

3-4 – Data transfer

The data transfer can be made through two " link port" of the DSP which are configured one in input, the other one in output.
The daisy chain transfer mode has never been set up. It would require other programs in DSP.

3-5 - Event format

Two types of events are sent by the DSP : physical events and service data.
All events are made of 4 words of 32 bits which will afterwards be transformed into 8 words of 16 bits. They are emitted on the link port bus and therefore serialized by nibble (4 bits). The physical event format is given in Table 1, and the service data in Table 2. The 16-bit word made of the fields ranging from "group number" to "channel number" is also called "a descriptor".

Table 1 – Physical data format :

<table>
<tr><td colspan="6">OX FFFF header (16 bits)
(a)</td><td>WC number of 16 bit words (16 bits)
(b)</td></tr>
<tr><td>Group number (4 bits)
(c)</td><td>Position number (slot) (4 bits)
(c)</td><td>Rack number (2 bits)
(c)</td><td>Service S=0 (1 bit)
(d)</td><td>M (1 bit)
(e)</td><td>Channel number (4 bits)
(c')</td><td>ENERGY
(16 bits) (f)</td></tr>
<tr><td colspan="6">mid-order TIME
(16 bits)
(g)</td><td>Low-order TIME
(16 bits) (g)</td></tr>
<tr><td colspan="6">PARITY
Control
(16 bits)
(h)</td><td>High-order TIME
(16 bits)(g)</td></tr>
</table>

(a) The header indicates the beginning of the events (the 16 bits are set to ones)
(b) WC (word count) indicates the number of 16 bits words which constitutes the event
(c) The origin of the event is determined by the rack number, the position of the card in the rack, the number of the channel (c') and the group to which the card belongs
(d) S indicates if it is a physical event (S=0) or service data (S=1)
(e) M relates the physical tag of the channel, of the card or of the group
(f) The energy is transmitted in 16 bits including a sign bit
(g) The time is transmitted in 48 bits including a sign bit
(h) The parity is transmitted in 16 bits
(c) + (d) + (e) + (c') constitute the event descriptor

Table 2 – Service data format :

<table>
<tr><td colspan="5">OX FFFF header
(16 bits)
(a)</td><td>WC
number of 16 bit words
(16 bits)
(b)</td></tr>
<tr><td>Group number
(4 bits)
(c)</td><td>Position number
(slot)
(4 bits)
(c)</td><td>Rack number
(2 bits)
(c)</td><td>Service
S=1
(1 bit)
(d)</td><td>Type of service data
(5 bits)
(e)</td><td>FEFE or number of tov emission counting
(16 bits)
(f)</td></tr>
<tr><td colspan="5">mid-order TIME
(16 bits)
(g)</td><td>Tov value (9 bits) or low-order TIME
(16 bits)
(h)</td></tr>
<tr><td colspan="5">PARITY
Control
(16 bits)
(i)</td><td>high-order TIME
(16 bits)
(j)</td></tr>
</table>

(a) (b) (c) see table 1
(d)+(e) indicates the type of service data by the following codes expressed in hexadecimal :
0 x 20 to 0 x 25 : number of tov channels
0 x 26 : coden, raw time on 48 bits including a sign bit
0 x 27 : start, raw time on 48 bits including a sign bit
0 x 2a : correlation control
0 x 2F : end of acquisition information to the concentrator
(f) FEFE is the code corresponding to the "acquisition end" service data which indicates the tov number already emitted since the "run" acquisition start
(h) gives the average-tov value calculated on 0.512s, for a 1kHz query frequency on the channel indicated in (e)
(h)(g)(j) indicate the raw time on 48 bits including 1 sign bit in the case the type of data (coden, start, correlation control) transmits a time value
(i) the parity is transmitted on 16 bits

3-6 – Data flow

The association of cards in a group requires the use of a "concentrator" to avoid too much scattering of neighbor events in time.
The "concentrator" receives data event by event, each described by four words of 32 bits. To minimize the acquisition time, data are stored in 3 buffers. They are then transferred to the memory of the "Resource Manager". Then the data are transferred to a PC by a 1 Gbit Ethernet network.
In the case of coincidence search, events are chronologically ordered in arrays, then associated to form new events. These events are said to be in coincidence for a previously-defined programmable coincidence window. For an n-order coincidence, the event in coincidence will be made of (1+3n) words of 32 bits (WC=1+3n). During the acquisition, the coincidence search permits the display of some control-spectra for observation during the experiment. Those events are not written to disk.

Table 3 – Event format in n-order coincidence

HEADER	WC = 1 + 3n
DESCRIPTOR (1)	ENERGY (1)
mid-order TIME (1)	low-order TIME (1)
PARITY (1)	high-order TIME (1)
DESCRIPTOR (2)	ENERGY (2)
| | | |	| | |
DESCRIPTOR (n)	ENERGY (n)
mid-order TIME (n)	low-order TIME (n)
PARITY (n)	high-order TIME (n)

Each type of event is put back in the buffers after transformation to 16 bit words.

Table 4 – Physical event format in 16 bit words.

HEADER
WC
DESCRIPTOR
ENERGY
mid-order TIME
low-order TIME
PARITY
high-order TIME

3-7 - Throughput

To determine the throughput of the whole acquisition system made of the COMET cards associated with a NARVAL data acquisition system, the loss rates have been measured using 6 generators with adjustable frequency. Measurements have been made for a set of 3 cards divided into 2 groups that is to say, a total of 18 channels. The loss rates are determined by comparing the number of events processed in the card's DSP and the number of events processed in the PC and visualized. It is obvious that the loss rate will depend on the opening width of the peak detection PT gate because during this opening time and the encoding time, the channel is not available to accept a new event. Measurements have been made for a gate width of 6.3 μs, which is a necessary value for the pulse encoding coming from Ge detectors via shaper amplifiers whose time-constant is 2 μs. For counting-rates lower than 20 000 events/channel/s., therefore lower than 360 000 events on the 3 cards, no loss has been observed. The loss rates measured for 20 000, 25 000 and 30 000 events/channel/s., that is to say for a total of 360 000, 450 000 and 540 000 events/s. on the 3 cards are reported in table 5.

Table 5 – Loss rates measured with 3 cards distributed into 2 groups for a time gate opening width of 6.3μs.

Events/ channel/s events/s	20 000 360 000	20 000 360 000	25 000 450 000	30 000 540 000
Cards 1 Cards 2 Cards 3 On 3 cards	4.4% 3.3% 5.5% 4.4%	0.5% 1.2% 2.1% 1.3%	23.2% 25.1% 28.6% 25.6%	37.8% 39.7% 43.3% 40.3%

The results of the 2nd and 3rd columns are different in spite of identical counting rates. This difference is due to the plugging order of the link-port cables. The losses are less important when the cards are connected to the "Resource Manager" unit in order (column 3 results) than when they are linked in disorder (column 2 results).
The measured loss rates are identical if the data are being written to disk or not, which means that the data writing involves no additional loss.
In our measurement conditions, the data rate is obviously limited by the COMET DSP speed.

NOTE : These data measurements have been made using generators which emit regular gap-time signals. Therefore, they do not take into account the stacks during the measurements of events which occur at random.

4 – Software task allocation

In NARVAL data acquisition, a "producer" is an actor which gathers data from the electronic system, a "consumer" uses data.
The software tasks are implemented in the COMET card DSP, in the resource manager or in a PC. The following sections describe the distribution of those tasks.

4–1 – DSP code of the COMET card

It has to perform the following tasks :

- time and amplitude data reading
- absolute time calculation. Time is coded on 15 bits with 400 ps step, the 48 bit time word is obtained from folding counters (see SEP REF. 97/146/RS/AH).
- determination of sliding scale coefficients used for the amplitude encoding
- constitution of physical events by association of the absolute time, of amplitude encoding and of topology (group number, rack, channel…)
- calculation of channel occupation time (tov) by statistical query
- constitution of service events which give acquisition information : start, stop, tov…
- writing of events built up in the emission stack of the link port. (see Data sheet Analog Devices ADSP 21062)
- constitution of a control table, by event, mistake, and fold counting, accessible by the VXI rack bus
- channel reset
- electronic administration using data sent by the "Resource Manager" unit

4–2 – "Resource Manager" tasks

The "Resource Manager" unit is made of a VME-VXI adaptator card, of a VME G4 1 GHz processor (MVME 5500, Motorola) and of a PCI mezzanine card (ASPC2, vmetro transtech).

The G4 processor tasks through the VXI bus are :

- VXI rack self-configuration : occupied slot identification and group determination
- pre-configuration of the COMET card registers
- COMET DSP program loading
- COMET card graphic administration

The G4 task through the ethernet link consists in executing a NARVAL data producer. Data are sent by the ethernet link as buffers whose dynamic size is automatically optimized by NARVAL.
The G4 processor also performs command and control tasks of the ASPC2 "concentrator".

ASPC2 DSP tasks are :

- concentration of link port data from the COMET cards (a maximum of 5 link ports) in one of the 3 buffers working as a flip-flop.
- DMA-mode data transfer to the RAM of the G4 processor via the PCI bus of the MVME 5500 card.
- "DMA end" interrupt sending to the NARVAL producer.

4–3 – PC tasks

The different tasks of the acquisition PC are the following :

- dividing of the data flow
- sending the buffers of one of the data flow to the storage disks
- chronologically ordering the data of the other data flow in tables whose sizes are automatically optimized by NARVAL
- double coincidence event search from these tables
- double coincidence event and single event constitutions
- incrementing the PC random acces memory of the experimental control spectra
- refreshing the spectra visualized by the CVISU visualization software by reading this memory

5 – Graphic user interface for control & command

The control & command allow us to define the experiment to be done. All functions of a card are defined in the programmable registers. The configuration of each card is downloaded thanks to a « comet6x.aspc2 » graphical interface.

A second graphical interface "CVISU consumer settings" defines the data processes : coincidence event search in a given time window and/or multispectrum constitution.

5-1 – Card configuration

On the "comet6x.aspc2" graphical interface, each card is identified by its rack position number. The running parameters of each card have to be defined in the associated window :

- running in "gate" mode or "non gate" mode : in the "gate" mode, the data acquisition is authorized by a NIM signal presence either on the PGATE module or PGATE group.
- running in an "mqr" tag mode. The module tag mode or the group tag mode can be chosen. If none of these commands is validated, the card works in channel tag mode, the signals sent to the channel tag inputs are then taken into account.
- tag action edge choice. The event tag is either on the "f" front edge or on the "r" rear edge of the PT gate. One has to take into account that the front edge is perfectly synchronous with the input of the event time signal, the tag signal has to enclose the gate front edge. On the other hand, for the rear edge the time fluctuations due to the synchronization of the energy encoding commands are of +/- 0.5 μs, the signal to be put on the tag input has to be larger by at least 1 μs and enclose the gate rear edge and its fluctuations.
- opening and closing of the card channels individually.
- adjustment of the PT time gate width or Lpds for each card channel.
- "Time offsets" adjustment, a value that it is possible to add to the raw time of the time encoding of an event. This adjustment has to be made for each card channel : it permits the centering of the time curve in the coincidence window.

- "Energy thresholds" adjustment for each card channel. All events with amplitudes smaller than the threshold are not sent to the acquisition.
- change of the sliding scale coefficients obtained by the training method. "Learn new coeffs" permits recalculation of the sliding scale coefficients. *Command strictly reserved to experts, use only if the acquisition is off.*
- "Use default coeffs" reloads the sliding scale coefficients determined by the manufacturer. *Use only if the acquisition is off.*
- coding enable « CodEn » : either it is a TTL signal set on the CodEn plug of the anchor card "hardware" or it is a software programmed command (not available). The CodEn inhibits the input channel as soon as its level is low. The rising edges of the "CodEn" signals authorize the data acquisition. They are time encoded and used as a time reference for every event which arrives during the signal duration. It's the anchor card which spreads the CodEn to the other group cards via the local bus.
- on/off : the on function is activated by the data acquisition start : "démarrer" command. A program attributes this function to a TTL TRIG lines of the VXI bus, which allows the synchronization of the on/off card group. Only one line of the rack is used. Its choice is automatic and transparent to the user. To be on, a card or a group has first to be authorized thanks to the graphic interface by :

    - Enable Run : module start up authorization
    - Enable Run : group start up authorization

The card configuration can be saved in a "save" file then reloaded by "load" if needed.

5-2 – Experiment configuration

The graphic interface « Réglages consommateur CVISU » is used to define the experiment parameters :

- multispectrum built up or not
- search of coincidence events or not

- **Multispectrum mode** : it is the successive acquisition of several spectra during a CodEn duration. The parameters are :

  - "Durée des tranches" or slice duration in μs, ms, s or minutes. It is a data acquisition duration of a spectrum.

  - "Durée CodEn" or CodEn duration. It is the measurement duration defined by the time which separates two successive CODEN signals.

- **Coincidence mode** : used to build coincidence events in a determined time window and delayed coincidence events. The parameters are :

  - "Fenêtre de coincidence" or coincidence window in ns, μs, ms. Two events are in coincidence when their time gap is lower or equal to the given value in the coincidence window. The coincidence time resolution is therefore : 2 x "the coincidence window".
  - "Décalage du plateau" or coincidence time shift. It shifts the zero time of the coincidence curve to allow its visualization. If events arrive at the same time on the COMET card, the coincidence time shift value will be at least close to that of the coincidence window.
  - "Seuil retardé" or delayed threshold used to select in the time curve, the events associated with a time difference greater than the threshold.
  - "Borne inférieure" or lower boundary and "Borne supérieure" or higher boundary serve to select, in the time curve, the events with a time gap between the 2 chosen boundaries.

  Both modes can be chosen simultaneously.

  The experiment configuration can be changed only when the acquisition is stopped.

6 – Start up of an experiment

6-1 - Opening of the Narval web page

In an xterm window enter the instruction : "lancement-narval".

The narval window shows :

- acquisition state
- enter the configuration file name

All available files appear by clicking on the configuration file list.
Select the desired file's name in the list.
For instance, as far as the IS407 experiment is concerned :
Select « Isold05.conf » for acquisition with data storage on the disk.
Select « Isold05_nodisk.conf » for acquisition without data storage on the disk.

6-2 – Narval configuration

To configure the Narval operation by clicking on " Configurer".

Then two windows appear :

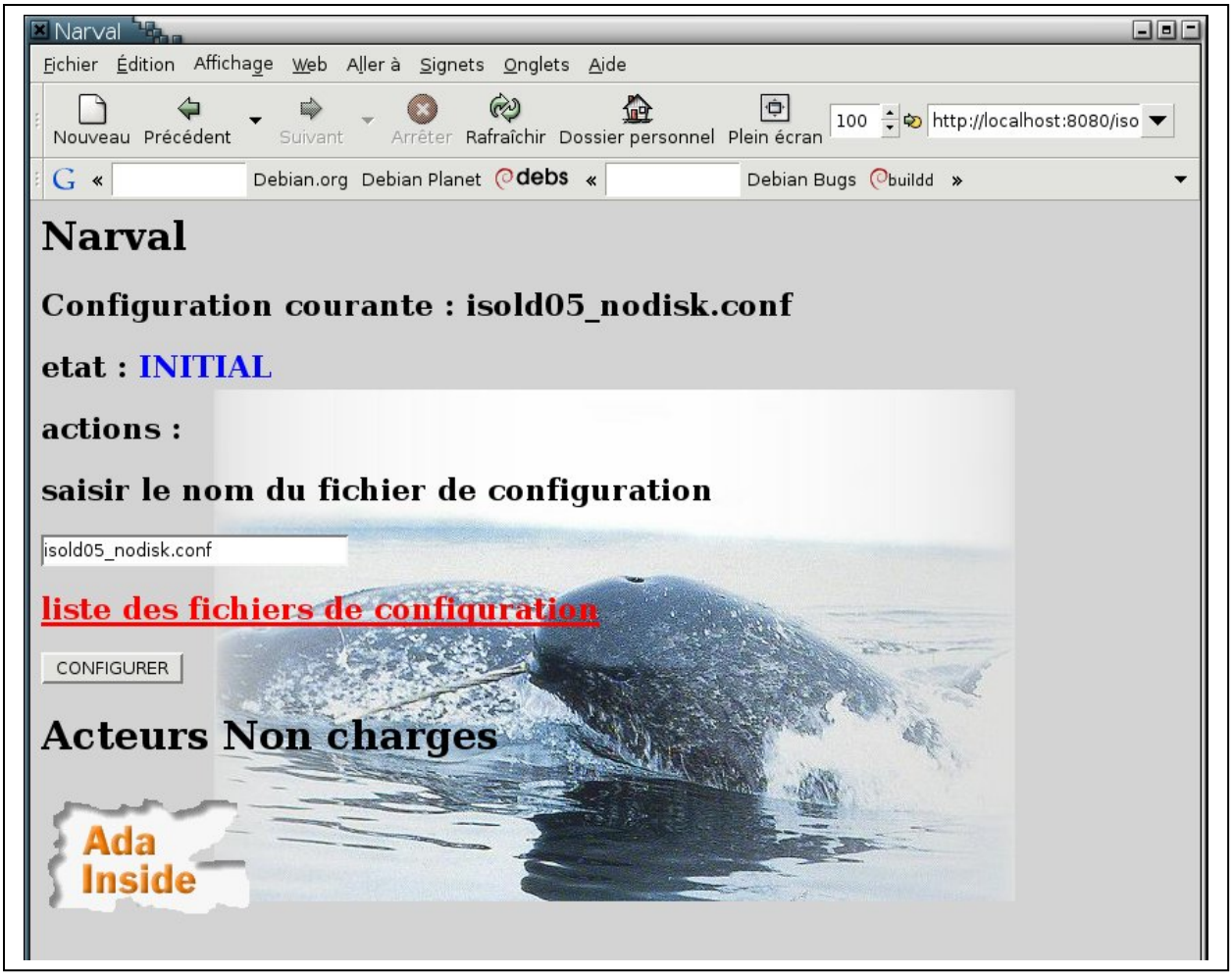
- power-pc root launcher
- pc root

They display possible mistakes written in red as well as the progession of the system in blue or in black.

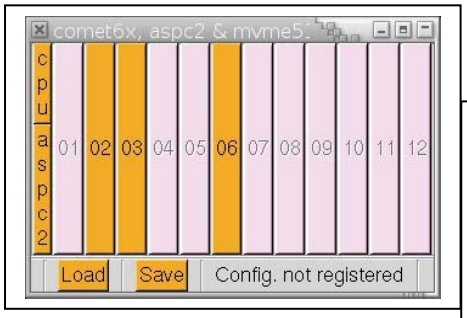
6-3 – Program loading

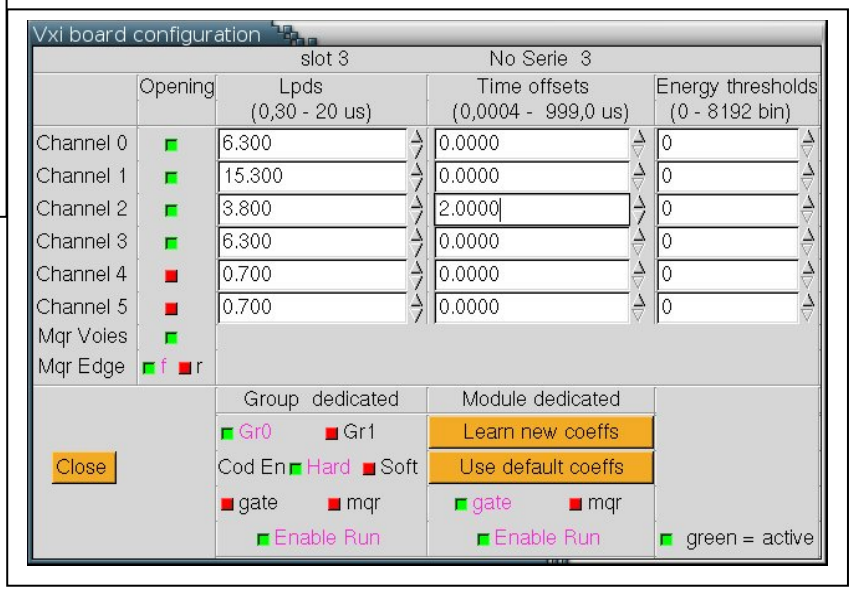
Click on « Charger» :

- loads the programs in COMET card DSP.
- opens the configuration interface of the COMET cards "comet6x.aspc2".
- runs the spectrum visualization program "cvisu ".
- opens the spectrum visualization window.
- opens the window reset spectrum button "RAZ ALL SPECTRA" .



« Narval » web page





Graphic configuration interface of COMET cards.

6-4 – Card configuration

Click on "Load" reloads a previous configuration.
A window opens : select by a double click the "configuration-interface" directory. Then select by a click the desired configuration file and lastly validate this choice.
The parameters of a card are accessible by clicking on the desired card number. This opens the configuration window associated with this card (see 5-1).
After having parametrized every card, do not forget to save the new configuration in a file by clicking on « save » in order to be able to find it again afterwards. If the file is not saved with a new filename, then the new configuration keeps the previous file name.

Parameters must not be modified while the acquisition is running.

6-5 – Experiment configuration

Type the "coinc" command in a terminal window. The graphic interface "Réglages consommateur CVISU " opens.
Activate the desired modes and enter the associated parameter values. Then click "save" for the new configuration to be active. (See 5-2)

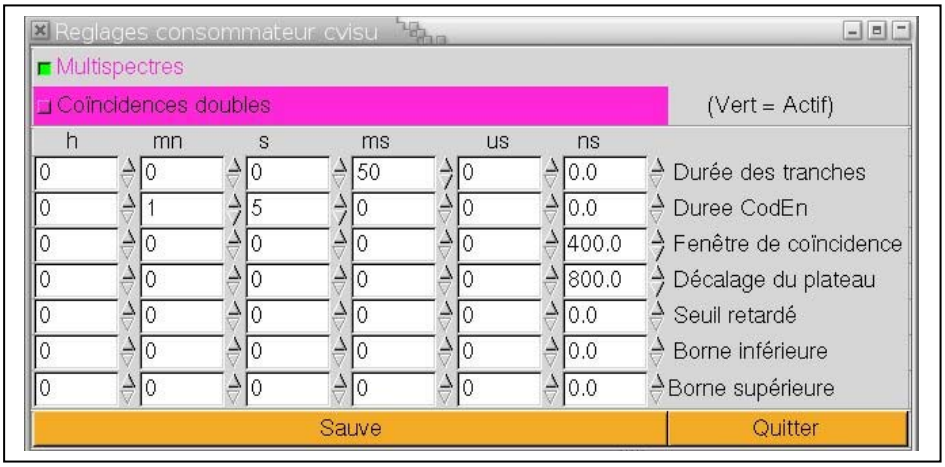
6-6 – Acquisition start up

- enter a run name and a comment in the case of acquisition with data stored on disk
- click on "préparer"
- click on "démarrer"

If the chosen configuration includes the storage of data on disk, one must enter a run name and a comment.

Spectrum visualization

Reset button of all spectra



Experiment configuration interface

6-7 – Other orders and controls

- Use the "nettoyage_all" command to kill running programs in case a problem occurs.

It is possible to check the good running of an experiment by looking at the COMET card DSP counter contents in the root window at the end of a run.

6-8 – Acquisition stop

Click on "arrêter".

For a configuration change :
- click on "décharger".
- click on "déconfigurer".
- restart from 6-1 paragraph to select a new configuration file.