DECTRIS
Next Generation X-Ray Detectors

USER MANUAL

PILATUS Detector Systems

Version 1.2

Table of Contents

1 Document History

Actual document

Version	Date	status	prepared	checked	released
1.2	6.2.2009	In Work	PS		

1.1 Changes

Version	Date	Changes
1.1	31.08.2007	Various improvements
1.2	06.02.2009	Various improvements

2 How to use this manual

Before you start to operate the PILATUS detector system please read this manual thoroughly.
This user manual has been especially designed for DECTRIS PILATUS detector systems.

The technical specification of the detector system is also part of this user manual. Read it thoroughly.

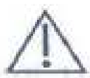
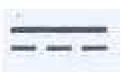
2.1 Address and support

DECTRIS Ltd.
Neuenhoferstrasse 107
Switzerland
Phone: +41 56 500 21 00
Fax: + 41 56 500 21 01

Email: support@dectris.com

Should you have questions concerning the system or its use, please contact us via phone, mail or fax.

2.2 Explanation of symbols

Symbol	Description
	Important or helpful notice
	Caution. Please follow the instruction carefully to prevent equipment damage or personal injury.
	DC-current
	AC-current
	Ground

2.3 Definitions of terms

Term	Description
MCB	Module control board
DCB	Detector control board
BCB	Bank control board
DAC	Digital to Analog Converter

3 Warnings

⚠ Please read these warnings before operating the detector

- Before turning the power supply on, check the supply voltage with the label on the power supply. Using the improper mains voltage will destroy the power supply and damage the detector.
- Power down the detector system before connecting or disconnecting any cable.
- Make sure the cables are connected and properly secured.
- Avoid pressure or tension on the cables.
- The air intakes and outlet for the detector fan should not be obstructed.
- The detector system should have enough space for proper ventilation. Operating the detector outside the specified ambient conditions could damage the system
- Do not touch the entrance window of the detector.
- The detector is not specified to withstand direct beam at a synchrotron. Such exposure will damage the exposed pixels.
- Replace the protective cover when the detector is not in use.
- On powering up the detector, the ammeter on the power supply should show a current of approximately 2 A. In operation the ammeter should not exceed a current of about 3 A. (where applicable)
  With any over-current condition, immediately shut the detector down and restart it.
- Opening the detector or the power supply housing without the explicit instructions from DECTRIS will void the warranty.
- The Linux-OS on the PC has a customized Kernel to improve data throughput.
  DO NOT UPDATE THE OS OR THE KERNEL

4 System Description

4.1 Overview

A PILATUS detector system consists of the following components:

- Detector
- Analysis PC with SuSE Linux, the data acquisition tool camserver and the data analysis tool TVX
- Power supply (where applicable)
- Connecting cables

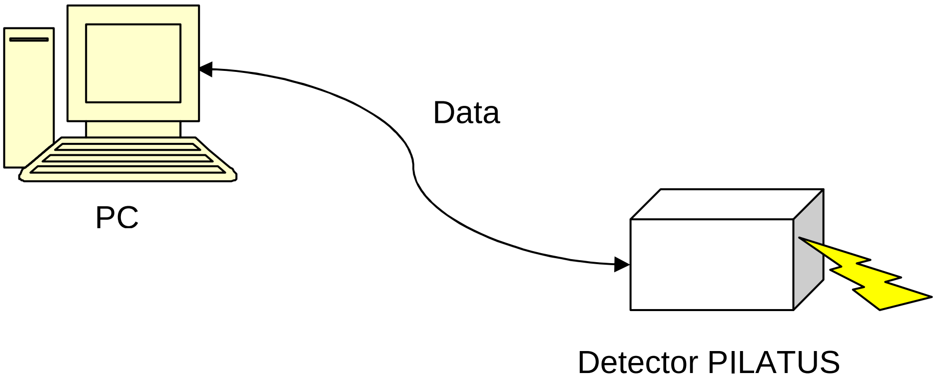


Figure 1 Overview of the PILATUS detector system setup.

4.2 Principle

DECTRIS X-ray detector systems operate in "single photon counting" mode and are based on the newly developed CMOS hybrid pixel technology. The main difference with respect to existing detectors is that the x-rays are directly transformed into electric charge (Figure 2) and processed in the CMOS readout chips. This new design has no dark current or readout noise, a high dynamic range of 1'000'000 (20 bits), a read out time of less than 3 ms, a framing rate of over 200 images/s and an excellent point spread function of < 1 pixel. The quantum efficiency of the 0.32 mm thick silicon sensor is optimal for experiments in the energy range from 3-12 keV; however the detectors can be used for energies of up to 30keV or more. The counting rate is more than $2x10^6$/s/pixel, enough to perform many experiments using the high flux of modern synchrotron light sources.

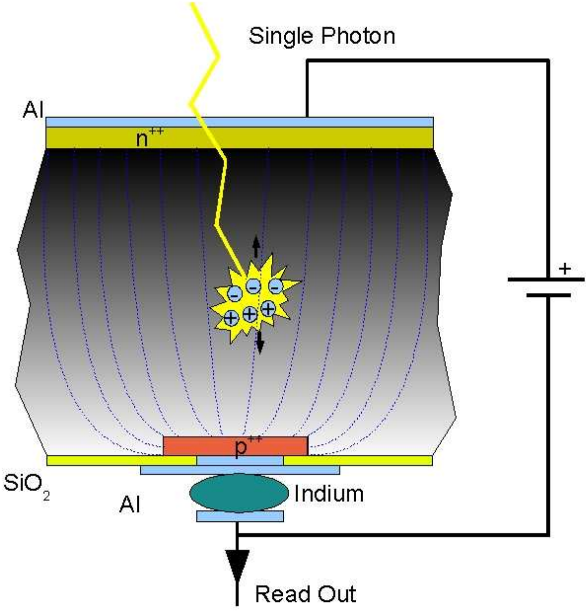


Figure 2 Principle of direct detection.

A DECTRIS hybrid pixel detector is composed of a silicon sensor, which is a two-dimensional array of pn-diodes processed in high-resistivity silicon, connected to an array of readout channels designed with advanced CMOS technology (Figure 3). Each readout channel is connected to its corresponding detecting element through a microscopic indium ball, with a typical diameter of 18 um. This connection process is called ‘bump-bonding’.

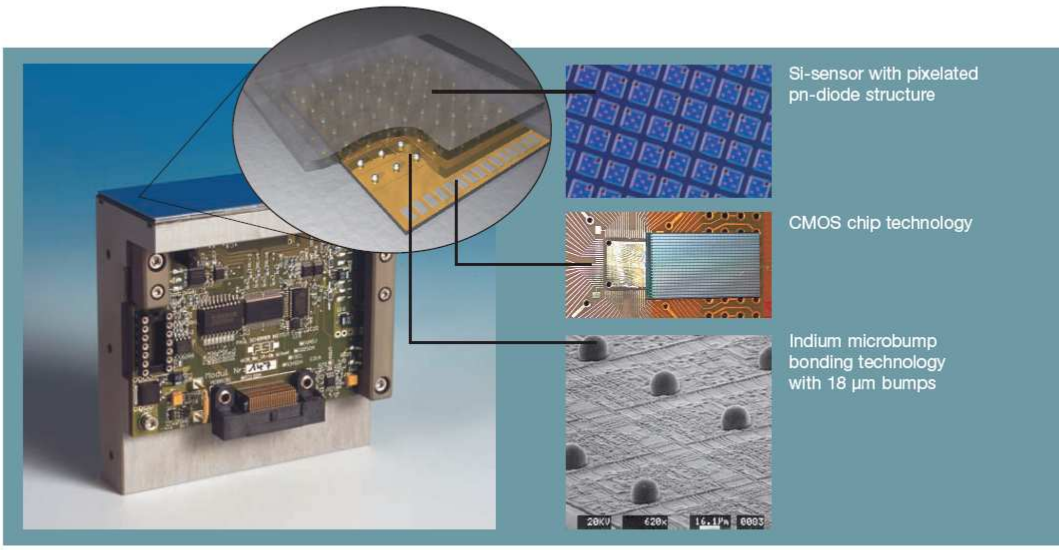


Figure 3 The detector module, the basic element of all DECTRIS detector systems

The great advantage of this approach is that standard technologies are used for both the silicon sensor and the CMOS readout chips, which guarantees highest quality. Both processes are optimized separately, as the best silicon substrates for X-ray detection and for high-speed/high-quality electronics are very different. Moreover, the small size of the pixel and of the interconnection results in a very low capacitance, which has the beneficial effect of reducing the noise and power consumption of the pixel readout electronics.

X-ray data collection can be improved with detectors operating in single photon counting mode. A hybrid pixel which features single photon counting comprises a preamplifier, which amplifies the charge generated in the sensor by the incoming X-ray, and a discriminator, which produces a digital signal if the incoming charge exceeds a pre-defined threshold. The discriminator feeds a 20 bit counter, which then leads to completely digital storage and noiseless readout of the number of detected X-rays in each pixel (Figure 4)

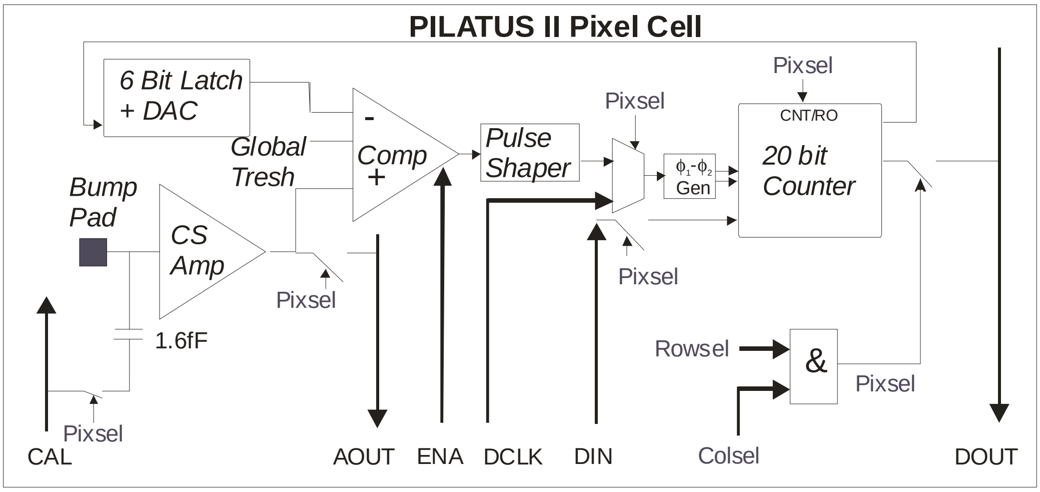


Figure 4 Block diagramm of the CMOS chip

The fundamental unit of the DECTRIS detectors consists of a single fully depleted monolithic silicon sensor with an 8 x 2 array of CMOS readout chips bump-bonded to it. Each sensor is a continuous array of 487 x 197 = 94965 pixels without dead areas and covers an active area of 83.8 x 33.5 mm^2. The readout chips are wire-bonded to the mounting bracket with its readout control electronics and forms the complete module (**Figure 3**).

5 Software

The operating software for the PILATUS detector system consists of two software components:

- **TVX**
  Data acquisition control and data analysis software

- **Camserver**
  Operating software for the detector

Those two software packages are normally installed on one PC and communicate with each other through an internal socket connection.

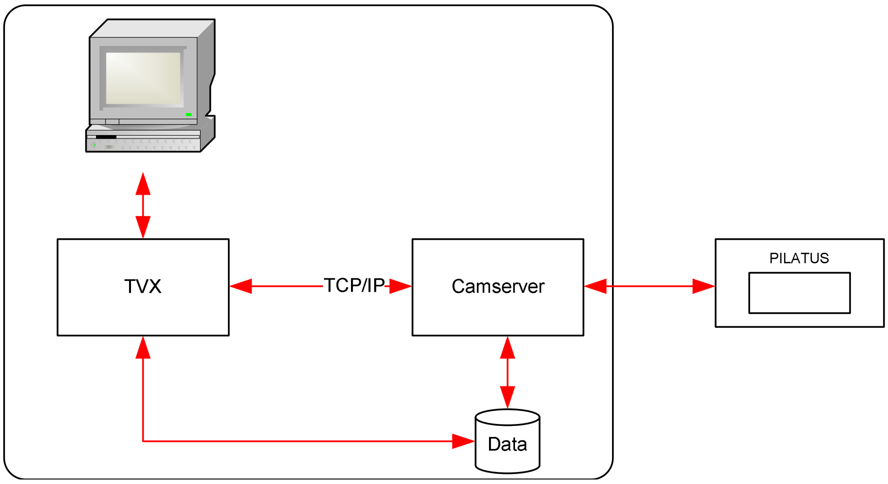


Figure 5 Normal operation with TVX and Camserver on one computer.

But it is also possible, to operate the detector without TVX and access Camserver directly via a socket connection from another PC.

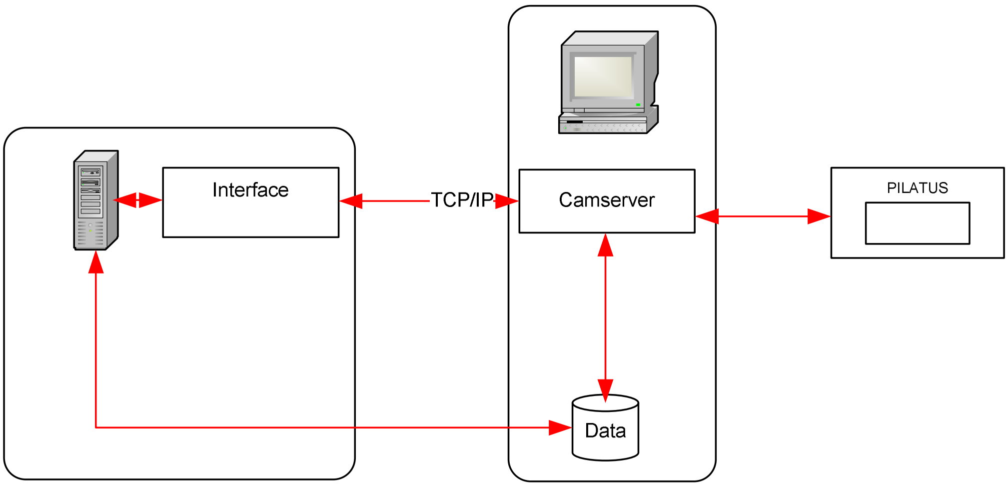


Figure 6 Operation with TVX and Camserver on separate computers.

5.1.1 Overview of TVX

TVX is a free, open source, data acquisition and control software suite tailored to X-ray science. TVX is an attempt to provide a flexible user interface that is easily adapted to control a broad range of 2-D X-ray detectors as well as a powerful collection of analysis tools.

TVX operates by distributing the tasks of data analysis and hardware control between two separate programs. The first program, which is most often referred to as TVX, contains the user interface and analysis tool suite. The other, which is referred to as the Camserver, is responsible for controlling the hardware of the specific data acquisition system. These two programs communicate over a TCP/IP connection, as shown in Figure 5, and thus do not need to run on the same machine, or even under the same operating system; see Figure 6.

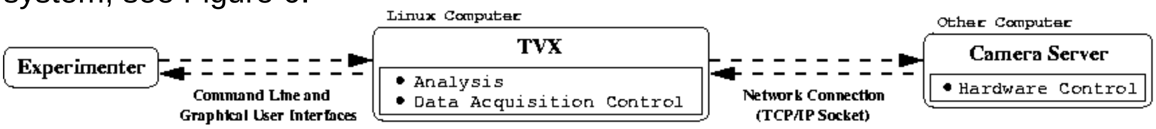


Figure 7 TVX communication scheme

Camserver bundles all of the details of the hardware control into a C program which can be ported across computer platforms. An added benefit of this model is that it allows the experimenters to do their analysis wherever and whenever it is most convenient from them, be it at the beam line while the data are being taken or back at their home institution or corporation.

TVX compiles and operates both on Linux and Mac OS X systems.

Camserver, except the demo version, requires specific camera hardware for operation.

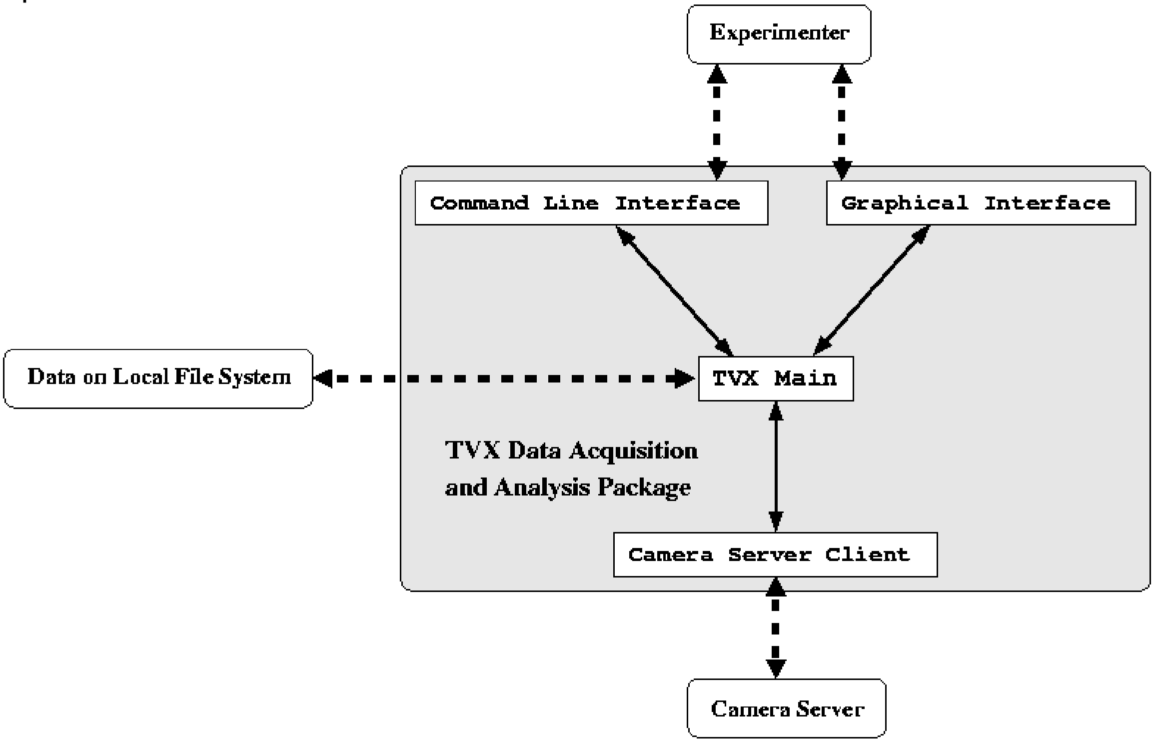


Figure 8. TVX control and analysis layout schematic.

5.1.2 Overview of Camserver

Camserver is a freestanding program that controls an x-ray camera and provides a simple user interface for "atomic" (single function) commands. It is intended to provide a spartan, but fully functional, low level interface to camera hardware.

On invocation, the program 'camserver' takes a single command-line argument, the path to its resource file, by default called 'camrc'. Camserver will also use the same path to open its debugging file, 'camdbg.out'.

A major function of camserver is to accept socket connections from a high level controller (e.g., 'tvx'), which can provide high level services to this or other cameras. The interface is a simple text-based message passing system. Images - the ultimate product of a working area x-ray detector - do not pass thru the socket interface, but are written to a configurable location (e.g., a nfs mount) where any program can access them. See more on 9.4

6 Getting started

See the appropriate chapter in the technical specification of your detector system.

7 How to operate the system

Before you turn on the system, make sure you have read this manual, the technical specification and connected the detector accordingly.

7.1 Login to the computer

Turn on the PC.

Log in procedure:
User:
PW:
Root PW:

7.2 Connect to a network

The IP address of the detector is identical to the IP address of the PC where Camserver is running on. In case TVX and Camserver are running on different machines the IP address and hostname should be adjusted in the following files:

/home/det/p2_det/tvxrc
/etc/hosts

See also 9.4 how to integrate the detector into other systems.

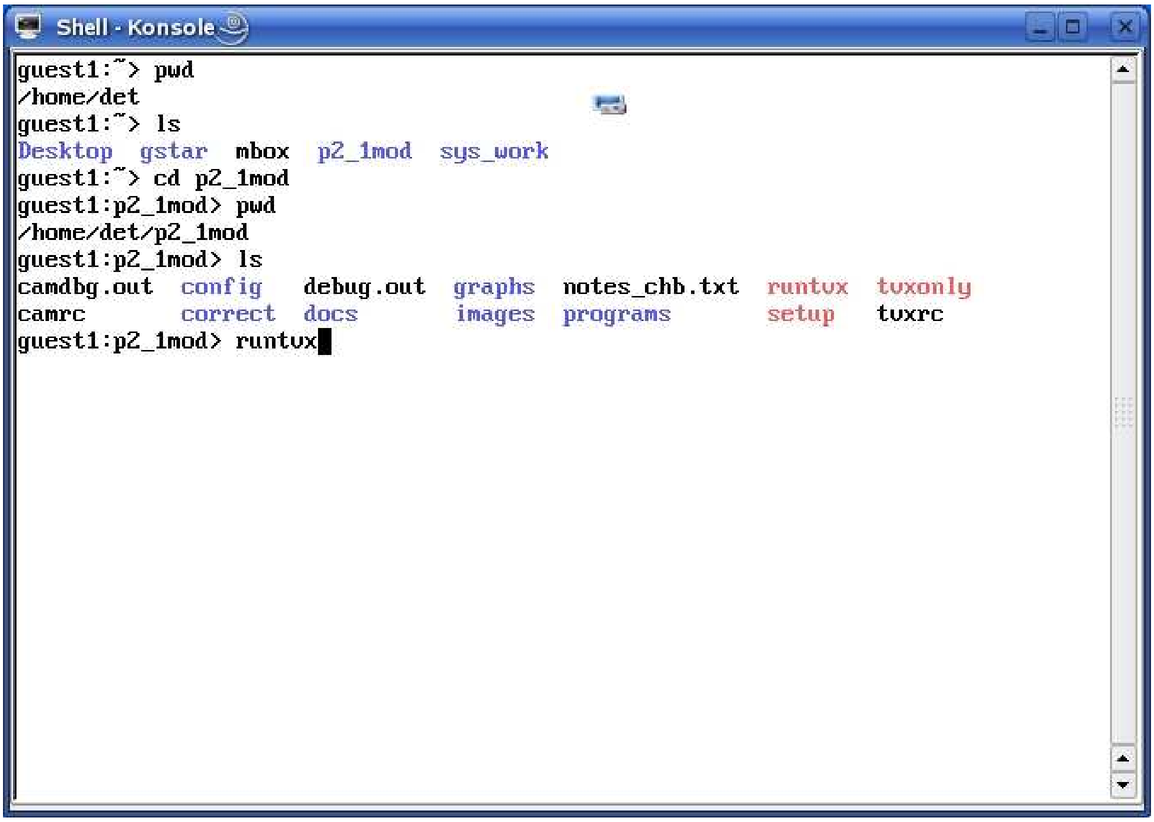


Figure 9 Shell showing the active path and the runtvx command.

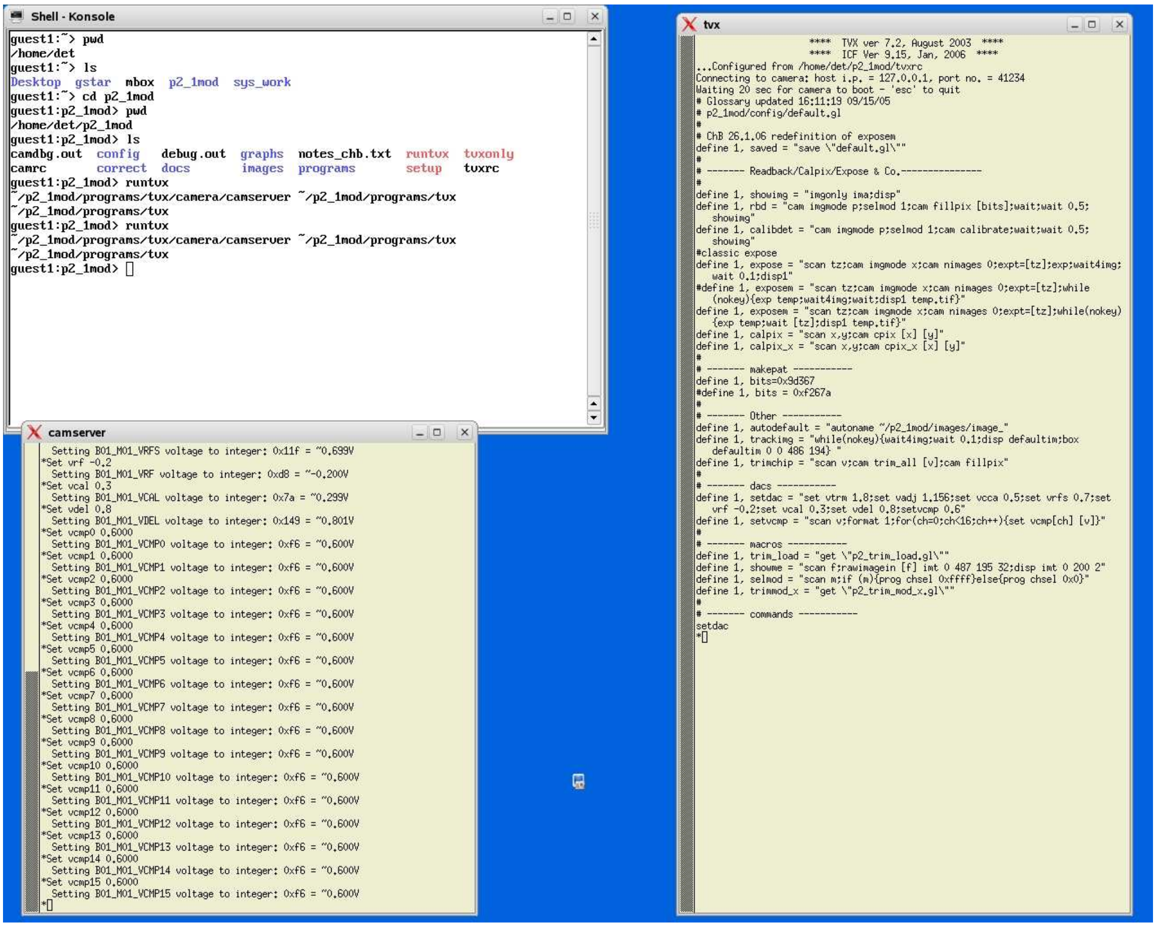


Figure 10 Screen after *runtvx* has initialized the detector and opened the Camserver and TVX window.

8 How to use TVX

8.1 Description of the directories

In the default setup, all data for the use of the PILATUS detector system is in the directory /home/det/p2_det.

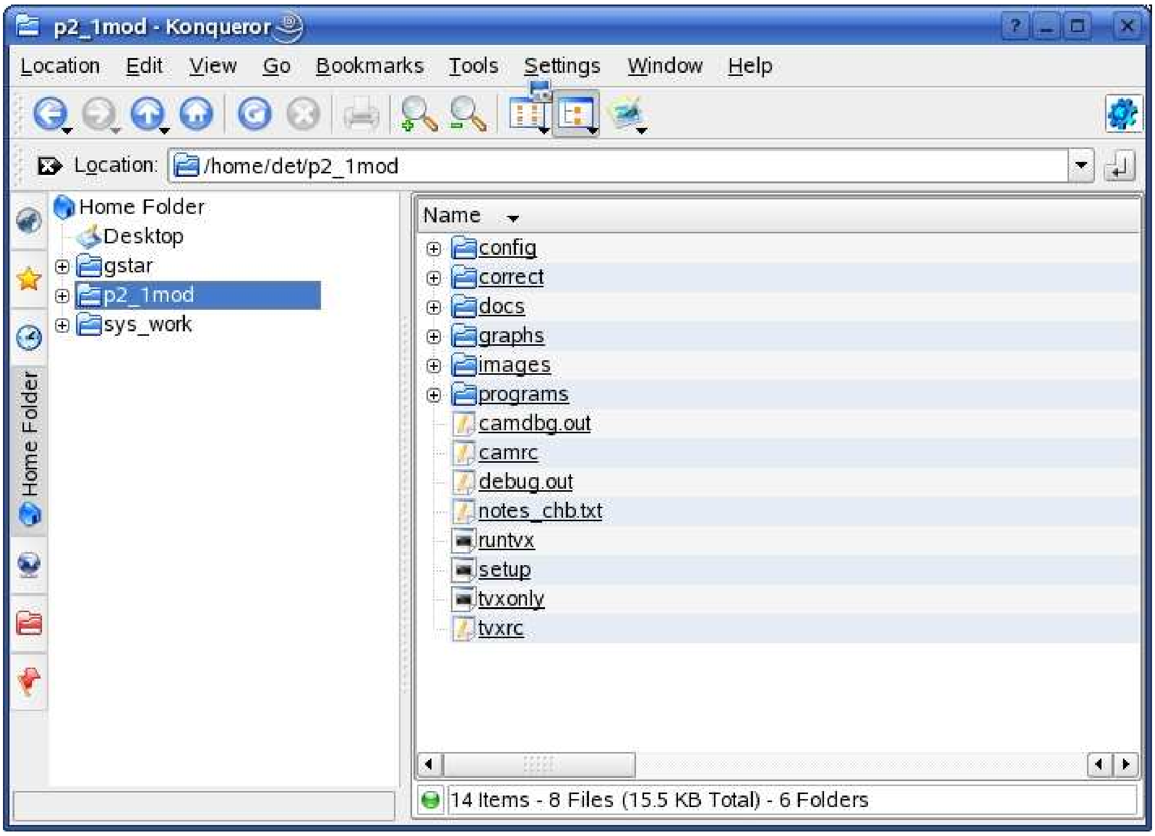


Figure 11 Relevant directories and folders.

Directory	Description
config	Glossary (.gl) files for the detector
correct	Detector specifications
docs	User manual, technical specification
graphs	Graphs are stored by default in this directory
images	Images are stored by default in this directory
programs	Program code for TVX and Camserver

8.2 Main commands

TVX is a powerful tool for data acquisition and analysis and has a complete description of all commands, which can be accessed through the *help* command.

This section describes only the most commonly used commands in TVX. All commands are case-insensitive; however, filenames are case-sensitive.

An ‘object’ in TVX may be an image or a graph. Many commands, such as *move*, will work on objects of either kind. Objects may combined with standard arithmetic operators (+, -, *, /, +=, etc.), logical operators (<, >, <=, >=, |, ||, &, &&) and special operators (<<, >>, !, :, <<=, etc.) in arbitrarily complicated expressions to perform sophisticated analyses and to construct custom scripts. In case of doubt, try it out you can’t hurt anything.

```
Reserved Words:
     clear_ICF   define      do          edit        else        for         forget
     format      get         goto        history     if          kill        menu
     monitor     nokey       save        scan        show        status      type
     while

External Procedures:
     reset       update

User Commands in current dictionary ('*')
     Add2Graf    AddToList   AnalyzeDiff AnnularAvg  AnnularInt  Aoutchk     AppendFile
     AreaFill    Autoname    Beep        Bin         Bkg         Box         Boxes
     Butterfly   ByteSwap    Calcomp     Cam         CamMenu     CamReset    CamStat
     CaptureGR   CaptureIM   CFFT        Circles     ClearFile   ClipImg
     CloseCamera CloseDisp   CloseGraf   ConfigPath* Connect     Convert
     CorrectionPath*         Cut         DeleteAllObjs           DeleteFile  DeleteObj
     DeTrim      DiffGraf    Disconnect  Disp        Disp1       DrawBox     DrawBoxes
     DrawCircle  DrawCircles DrawLine    DrawLines   DrawPlus    DrawPluses  DrawPoly
     DrawPolys   DrawTic     DrawTics    EditObj     Examine     Exit        Exp
     Expand      ExposePath* FFT         FinishGraf  Flatten     FVImg       GetVal
     gMouse      Graf        Graf1       GrafDemo    GrafLine    GrafPath*   GrafSet
     Help        Histogram   HistSet     HotFill     HotFill2    IFFT        ImagePath*
     Img         Imgonly     imMirrorH   imMirrorV   iMouse      imRotate180 imRotateL
     imRotateR   Integrate   ListObjs    Man         MaskImg     MaskList    Merge
     Mfilter     MkDistCorr  MkFlatCorr  MkImage     MkLowPass   MkMask
     MkNDistCorr MkNoiseImg  MMaccum     MMerge      ModTrim     Move
     NeighborFill            NeighborFill2           NoiseFill   NoOp        Oblique
     P2R         Paste       PasteRaw    Patcomp     PckImg      Peak        Pixl
     PixlFill    PixlScan    Pluses      Prog        Protect     PSF         QTrim
     Quit        R2P         RateCor     RawImageIn  RdimgB      RdimgM      RdPckImg
     RdPckImg32  ReadFile    Rectify     Regress     RegressSq   ResetETime  ReTrim
     Select      Set         SetDist     SetInt      Shell       ShowHots    ShowRes
     Smooth      SmoothGR    SmoothIM    Spot        StartGraf   Telemetry   Tics
     TimeStamp   Trunc16     Tscan       Tscan_ini   TypeHeader  TypeObj
     UndrawBoxes UndrawCircles           UndrawLines UndrawPluses
     UndrawPolys UndrawTics  vcmpScan    vcmpScanFit VImg        VImgRaw     vrfScan
     vrfsScan    vtrmScan    Wait        Wait4Img    WaitShowT   WriteFile   XDS_Tr16

Defined variables & strings:
     autodefault bits        boxall      calibdet    calpix      calpix_x    dispm
     expose      exposem     movie       qmt         rbd         selmod      set_th
     setdac      setvcmp     showimg     showme      trackimg    trim_load   trimchip
     trimdet

User Variables:
     area        bg          counts      d_space     dbglvl      det_dist    etime
     expt        intens      lambda      maximum     mean        minimum     pixel_size
     stdev       value       var         verbose     width       x1          x2
     xcen        y1          y2          ycen        zngcntrl    zngkut
*
```
Figure 12 The 'menu' of TVX.

Many commands in TVX or Camserver require an input value or argument. Without the declaration of a value, the currently set value is shown.

In this manual *input values* are shown in *Italic*.

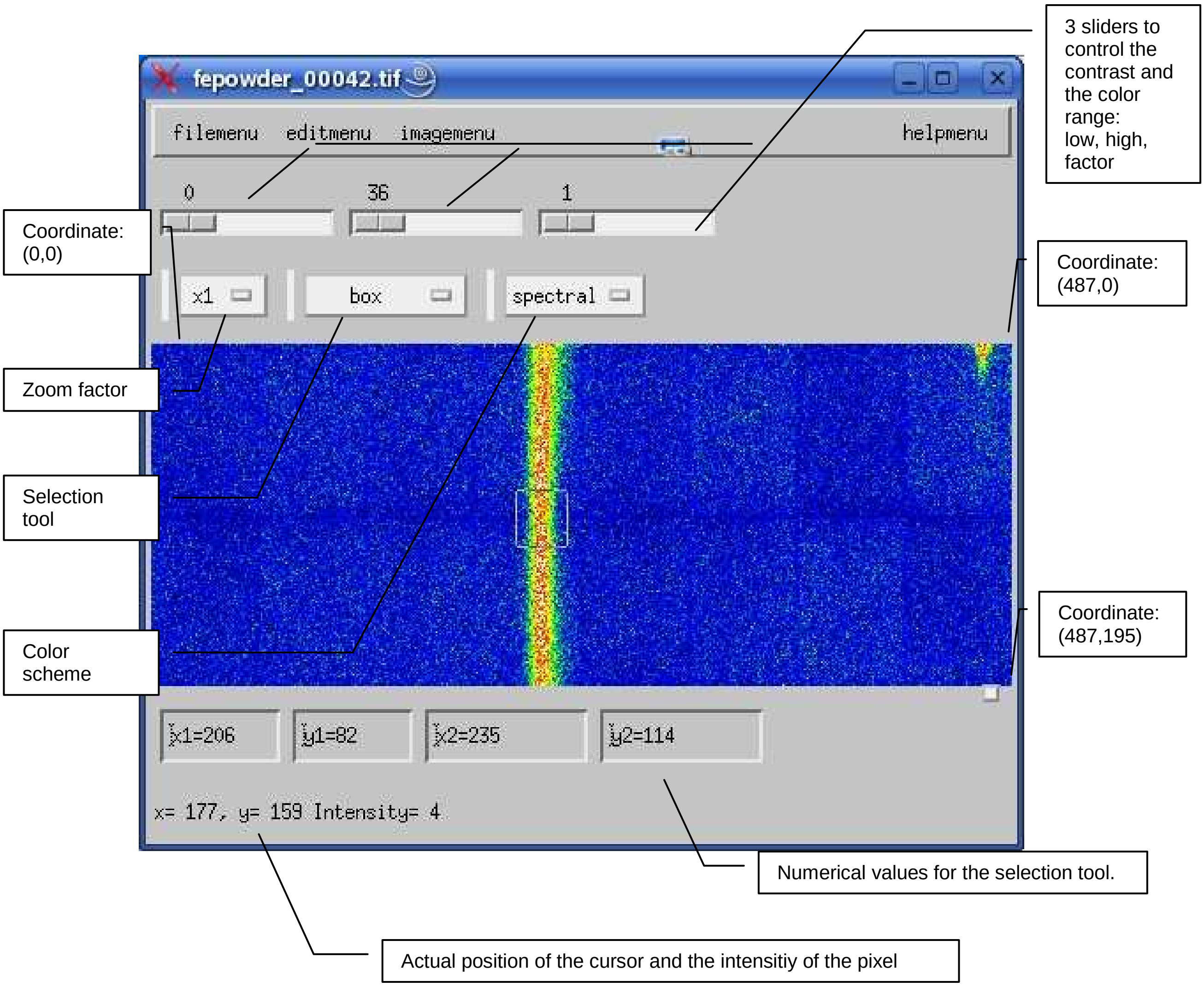
Command or Macro	**Description**
menu	Shows all commands It is divided in 4 parts: • TVX reserved words • TVX defined commands • Macros, saved in default.gl or typed by the user • Variables
help *command* -or- man *command*	Shows the help text for the *command*. Help *help* is a good way to start. Help “gr*” will show all commands beginning with ‘gr’; the quotes are required, else the system takes ‘*’ to mean multiplication.
ESC-button	Stop a running task and return to the TVX line interpreter
CTRL-C	Full reset of TVX
cam k	stops the running Camserver processes
rbd	Read Back Detector. Self test of the digital part of the detector. Sends a digital pattern to each pixel, reads it out and displays the image. Use this command always after a startup. Every pixel should show 1000 counts.
calibdet	Self test of the detector. Sends 100 calibrate pulses to the analog part of the detector, reads back the recorded values as an image and displays the result. Every pixel should show 100 counts. Use this command always after a startup. Should the pixels not show 100 counts in the absence of radiation, repeat the command. If the image is black, type setdac, then repeat the command. In case this tests fails, turn the power supply off, close the TVX and Camserver windows and start up again.
setdac	Sets all Digital Analog Converters (DAC) to the predefined values.
imagepath *path*	Image Path Without the input of a path it displays the current default path. With a declaration it changes the default

Command or Macro	Description
	path for images. The imagepath command also sets the autoname to the new path.
grafpath *path*	Display or change the default path for graphs. The keyword 'grafpath' can be used in expressions as [grafpath]
exp *filename*	Make an exposure. If filename is not given, TVX uses the next automatic filename. The files created are saved in the directory specified in imagepath.
expose *exposure time* (in seconds)	expose 1: makes an image with an exposure time of 1 sec. shortest exposure time: > 1 us, 0.000’001. Shows the exposed image immediately on completion.
Exposem *exposure time*	continuous camera mode without saving images. Takes images until any key is pressed. The last image is stored in temp.tif
disp *filename*	Display an image. Opens up to 3 windows for successive invocations.
disp1 *filename*	Displays an image reusing the last window. Useful in loops.
graf *fn1[fn2[fn3]]*	Graph up to 3 graphs in a window
show *variable* -or- show *string*	Shows the content of a variable or a string
define	DEFINE name="instruction1; instruction2;....." Defines user symbol name and value. E.g. define tpict="zpict; move imt=im3" defines symbol tpict as a comination of ‘zpict’, and the built-in move instruction.
CaptureIM *filename*	Capture the default image to filename captures a displayed image (and its zoom) as a .ppm (portable pixmap) file, including coloration and contrast adjustments.
CaptureGR *filename*	Capture the default graph to filename Captures a displayed graph (and its zoom) as a .ppm (portable pixmap) file.
connect [*ip_address]*	Connect the socket connection from TVX to the Camserver at [*ip_address]*
disconnect	Disconnect the socket connection from TVX to

Command or Macro	Description
	Camserver. E.g, so that a beamline operating system like EPICS can take control over the Camserver.

8.3 Description of the image display

After an exposure, the image will be shown in a separate window, the image window.



Display tools	Description
(sliders)	Define the color and the contrast of the image. For every value of a pixel a color from a lookup table will be displayed. With the two left sliders the cut off for the low and high values can be set. Values outside this range are displayed with the same color.. The third slider defines the contrast factor. The sliders can be moved with the mouse or by putting the mouse on the slider and adjust the value with the left and right cursor buttons. They can also be set from the command line using the *disp* command.
zoom	A magnification can be chosen and the enlarged area is shown in a new window. The zoom outline in the main window can be positioned by clicking or dragging with the mouse with the right button depressed.
Selection tools	
pointer	normal pointer
annulus	Allows analysis of circular areas. The sizes of the circles can be adjusted with the mouse or directly by the setting the values in the image window.
box	Allows analysis of rectangular areas. Move the box with the right mouse button pushed or put the center of the box with the left mouse button. The size of the box can be adjusted with the mouse or directly by setting the values in the image window.
butterfly	Allows analysis of special shaped areas. The shape of the area can be adjusted with the mouse or directly by the setting the values in the image window. The circle is only for alignment purposes.
Line	Distance measuring tool. Requires that the correct pixel size be set in detector setup file (name)
resolution	Resolution circles for crystallographic patterns. Calculates the resolution of the image. The correct parameters for the detector should be set in the detector setup file or from the command line, (det_dist, lamdba and pixel size)
Display mode	
greys	color lookup table with gray scale.
spectral	color lookup table with a spectral distribution (blue and

Display tools	Description
	black near zero, red fading to pink and white at the high end)
thermal	color lookup table going from blue through yellow and red, but no greens
decades	The values between Min and Max are displayed linearly, but with the scale wrapping around Scal number of time. Thus, Scal = 1 is linear, Scal = 5 covers the range Min to Max with 5 linear segments going from 0 to 255, 0 to 255, etc. This gives lots of artifical contrast that is good for smoothly-varying SAXS data, but is otherwise rather non-intuitive.

power	The image is displayed between Min and Max using the transfer function:
	
	(# grays)*((value - min)/(max - min))*(Scal/15)
	# grays is usually 256. Thus, a small value of Scal (~3) gives a very steep transfer function at low values, and very little contrast at high values.
	Scal = 15 is a linear transfer function; Scal > 15 is nearly useless.

reverse	The values are reversed - x-rays in the image become black rather than white. Useful for crystallographic images.

Several test images and graphs are included in the system.

Try the following:

imagepath examples
disp testimg.tif
disp gray20bit.tif

grafpath examples
grafdemo

More examples are in:
/home/det/p2_det/programs/tvx/test/images -and-
/home/det/p2_det/programs/tvx/test/graphs

Example: Butterfly selection tool

This selection tool is useful for straight line integrations (densitometer traces) and for integrating small angle scattering patterns from either a line or a point x-ray source.

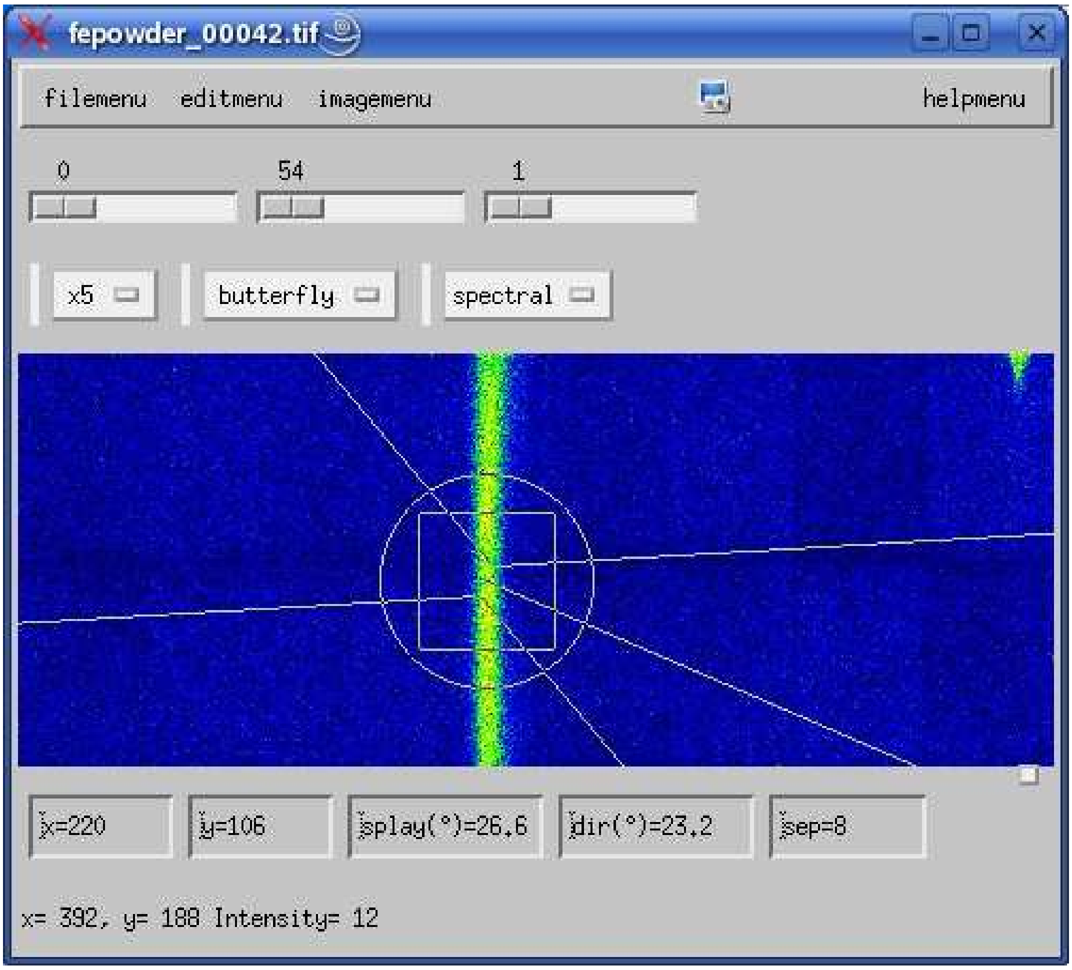


Figure 13 Example of a the butterfly selection tool

The size and position can be adjusted directly with the mouse or by typing the values directly into the boxes. The circle is used only as a positioning aid. Use the keyword *integrate* in the tvx window to display the result.

8.4 Image formats

Due to the high dynamic range of 20 bits (1’000’000) of the PILATUS detectors, images are stored as 32 bit (unsigned) integers. These images can be viewed and analyzed with TVX or other image viewers. Many viewers do not support 32 bit TIFF files; however these images may be read in IDL or MATLAB.

The default image file-type for TVX is set in tvxrc; however, any file-type can be specified explicitly. Camserver has no default, so the file type must be specified explicitly for each exposure.

TVX supports the following image formats:
.

Format	Description
.tif	32 bit TIFF files
.edf	ESRF data format
.cbf	Crystallographic binary format
.img	raw data format

8.5 Analysis commands

TVX offers a large variety of image analyzing and processing commands. The most important commands are described in this document.
All created data are stored in the graphs directory.

Command	Description
move *fn1=fn2*	The basic image manipulation command. In the simple form shown, this copies an image to a new name or directory. However, *fn2* can be any arithmetic expression of images and constants.
Integrate	integrate the pixels selected by the current selection tool - box, butterfly (includes straight-line case), or spot (annulus tool) - and show the resulting graph. Usage: integrate [IM] [graph_name]] For the butterfly, the graph name can be given as the second parameter; in this case the image name must be specified. In other cases, the default image is used if no image is specified.

histogram *lo hi int*	Histogram the pixels selected by the box tool on the image. Alternatively, specify the image and region-of-interest on the command line. Usage: histogram [IM] [lo hi int] [x1 y1 x2 y2]] [graph_name], where lo is the first value to use, hi is the last value, and int is the interval. If IM is not specified, the default IM is used. [x1 y1 x2 y2] are the coordinates of the box to be histogrammed. If no graph_name is specified, the histogram is placed in file 'hist[n].dat' in the default graph directory, where n rotates through the values 0…5. This file can be then be moved to a permanent file by a command such as "move myhist=hist1". The histogram parameters are remembered, so subsequent operations with the same parameters can be obtained by just typing 'histogram'. If the coordinates are specified on the command line, the parameters must also be specified. If the file name is specified, either the image name must also be given, or 3 (or 7) numeric parameters must be specified. In the integral mode, the integral is written to 'hist[n+1].dat'. if the name is specified, it is appended with "_i" for the integral. See also 'histset'
box	Print statistics from the current box selection tool on the image. Alternatively, specifiy image name and box coordinates on the command line. Usage: box [IM] [x1 y1 x2 y2] If IM is not given, the default IM is used. [x1 y1 x2 y2] are the coordinates of box to be examined. If not given, use the box selection tool on image. If given, the box selection tool is created or updated on the image, if it is displayed. If the box is set with the mouse, 'box' and 'integrate' give the same result. Several system variables are set: counts (total counts in box), area, mean, minimum, maximum, stdev (rms), var (variance), xcen & ycen (centroid), box_x1, box_x2, box_y1 & box_y2 (corners of box).
format *n1[.n2]*	Control the number of digits to be printed (n1) or the number of decimal places (n2).

deleteallobjs	Delete the TVX record of all objects – the objects themselves are untouched. Images are stored in the TVX memory up to the limit specified in *tvxrc,* which can consume significant resources; use this command to free up memory. In addition, one can create files with identical names in various directories. To avoid the necessity of always specifying full path names, use this command to clear the TVX memory.
deleteobj *filename*	Deletes the specified object from the TVX memory. The file on disk is untouched.
maskimg	Specify a mask image to be used by many TVX commands, such as box and histogram. See below.

8.6 Mask files

Setting a mask image is useful when you are looking at the statistics of images from the detector. Pixels in the detector that are either dead, too noisy or behave in a non-desirable manner can be masked out. After a pixel has been masked, it will no longer be considered when using statistical routines in tvx to analyse your image so that your results will not be distorted by pixels behaving incorrectly.

A mask file is an image file that uses only two distinct values for each pixel. Every pixel that is to be masked out is given a value of 0, every other pixel is given a value of 1. You can create a mask file from another image by using the command "mkmask".

Command	**Description**
mkmask	Make a mask from an image between two limits, inclusively. Usage: mkmask [IM] [IMout]] low high The result is a mask of 1's and 0's which can be used to select pixels of an image by multiplication. If no image is supplied, the default is used. Note that a float input object returns a 32-bit integer mask. Because the generated file is a normal image you can use any of the image manipulation tools supplied in TVX to alter your mask image if you wish.

maskimg	Declare, inquire about or turn off the current mask image. Usage: maskimg [im] -or- maskimg 0 If present, the mask is used to blank out bad pixels in statistical routines such as box, integrate, spot & histogram. Zeros in the mask are excluded from the analysis, non-zeroes are included. With no argument, displays the current mask image name, if any. With numeric argument (e.g. 0), turn off the mask image. You can also check the current mask image by using the command "maskimg" with no arguments, the path of the current mask image will be shown or a message saying "Mask image is not set" if there is no mask image being used.
pixlfill *[IM] value*	Set pixels in *IM* to *value* using the current box as a template. This permits you to manually alter a mask image based on observations on a different image.

If the command "deleteallobjs" is used after you have loaded a mask image your maskimg will be reset; of course, the stored image is untouched.

8.7 User defined commands

TVX supports complex C-like commands in the command line.

Example:
To display a series of images as a movie:

format 2; for (i=0;i<100;i++){disp1 image_000[i]; wait 0.5}

Displays image_00000 to image_00099 and waits 0.5 seconds between each picture. The brackets [ ] mean to substitute the enclosed argument as text with the number of digits specified by the format.

With *define* one can create custom commands for the current session and eventually save them for reuse.

Example:

define test1="format 2; for (i=0;i<100;i++){disp1 image_000[i]; wait 0.5}".

Command	**Description**
define *name=string* define *name=value*	Define a name (value or command) which can be used in the current session. They are not saved when tvx closes.
save *“myfile.gl”*	Saves the currently defined commands in *myfile.gl* as text. Such files are called glossaries. Glossaries my also have executable commands edited in following all the definitions; these are preserved when the file is overwritten.
get *“myfile.gl”*	Load the definitions from *myfile.gl*, and execute any commands appended after the definitions.

8.8 Glossary files

When TVX is started, a glossary is automatically started up called */home/det/p2_det/config/default.gl.*
In this glossary, the main commands for using the detector are defined. Three other glossaries are called from *default.gl* (all in config):

Glossary	**Description**
det_spec.gl	Detector specific definitions. In case of multi module detectors number of banks, modules, tools for adressing modules and analysing module specific data.
user.gl	User specific commands
startup.gl	Commands which are automatically loaded at startup, e.g. *setdac, rbd, calibdet*. For usage at the beamline, usually the last command is Disconnect, which allows remote control of camserver.

In case of multi-module detectors a file called *t.gl* is generated and used for automated trimbit calculation. Usually this file contains only a comment.

8.9 Various commands

To see the temperature and humidity log of the detector, do:
less $HOME/p2_det/config/camstat/TH.log

9 How to use Camserver

Camserver is a completely freestanding program that controls the detector and provides a simple user interface for "atomic" (single function) commands. It is intended to provide a spartan, but fully functional, low level interface to camera hardware.
To get help on the Camserver commands use the help facility of TVX.
All commands in camserver (unlike TVX) can be abbreviated to the minimum number of letters that make the command unambiguous; below we use only the full names for clarity.. As in TVX, commands are case-insensitive, but pathnames are case-sensitive.

We recommend that full command names be used in scrips for clarity as well

9.1 Main commands

Command	**Description**
menu	Shows all commands
exptime	Set the exposure time (10^{-6} to 10^{6} sec)
exposure *[filename]*	Make an exposure with the exposure time predefined with the command *exptime*. The format of the file is determined from the supplied extension – see above. The file is stored relative to the path defined by the *imgpath* unless an absolute path is given.
exttrigger *[fname]*	Start exposure with above define parameters after receiving an external trigger and store images [fname] (see section 13)
extenable *[fname]*	Start exposure defined by external exposure and store images in [fname]. (see section 13)
help *exposurenaming*	Type this in the TVX window for a discussion of how exposure series are named.
dcb_init	Re-initialize the DCB.

9.2 Variables

The following variables can be viewed just by typing them; all times are in seconds.

Variable	**Description**
exptime *[time]*	Query or set the exposure time
nimages *[N]*	Query or set the number of images in a sequence
expperiod *[time]*	Query or set the exposure period for serial exposures. The exposure period must be at least 3 ms longer than the exposure time.
imgpath *[path]*	Query or set the default imgpath
delay *[time]*	Query or set the external trigger delay. This is the time to wait after the external trigger before taking the first image (see section 13)
nexpframe *[N]*	Query or set the number of exposures per frame. This is the number of times to enable the detector before reading out the image (see section 13)

9.3 Exposure series

With PILATUS detector systems, it is possible to take image series with a frame rate of up to 300Hz (depending on the system) and a shortest exposure time of 1 µs. All timings are controlled by a crystal clock on the DCB.

Define the following variables in the Camserver window:

- ExpTime (expt)
- Number of images (ni)
- Exposure period (expp)

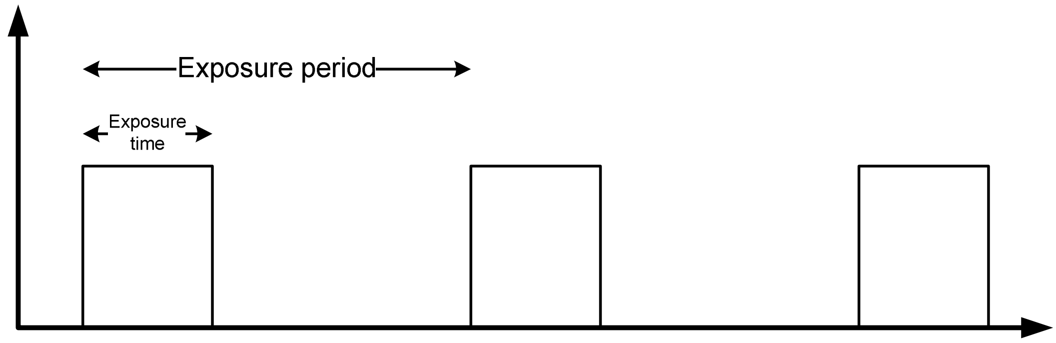


Figure 14 Timing diagramm

The exposure series can be started either from the Camserver window with 'exposure *filename*' or from the TVX window with 'expo' (a macro). The images are stored according the defined imagepath and filename; without a defined filename, the images are stored in the next automatic filename.

9.4 Integration into other systems

Basically, the client connects to camserver via a socket connection, and issues plain text commands to the camera. The command syntax over the socket is identical to the syntax to be typed directly in the camserver window. Thus, direct typing is helpful for testing.

The reply from camserver (acknowledgement) consists of a command index number, followed by a space and either "OK" or "ERR", followed by another space and possibly a message. The acknowlegement arrives after the requested action is completed, typically in 1-2 ms; some commands, such as SetThreshold, take longer, especially for a big detector. All acknowledgements end in 0x18 (ASCII 'CAN') without a linefeed; there may be internal linefeeds in long messages. (Since there is no terminating linefeed, MS Windows sockets must be opened in binary mode; this is not a consideration for unix-like systems.)

The command index number (see 'case_definitions.txt') may be generic or specific. Most commands have the generic response 'send' (case number 15) and, if the response is 'OK', can usually be ignored.

The exposure commands (Exposure, ExtTrigger, etc) operate a little differently. They give an immediate acknowledgement (case number 15, the generic response), followed by a second acknowledgement after the exposure series is completed (case number 7), carrying the full path name of the last completed exposure. Intermediate acknowledgements, e.g. every 100 images, can be requested as well via the 'SetAckInt' command.

Because of the socket connection protocol, the camera hardware and server can reside on a different machine from the high level controller.

Camserver implements a token mechanism to prevent more than one outside process from having control over the hardware. The camserver window has full control at all times.

There is a debug facility to help with setting up the interface. If you type "dbglvl 5", the file 'camdbg.out' will contain many messages, including the exact contents of socket messages. Be sure to set "dbglvl 1" (the default) before doing real work, else 'camdbg.out' can grow without limit. If there are difficult problems with the detector, a run with "dbglvl 6" reproducing the error can be helpful for diagnosis. Simply capture 'camdbg.out' and send it to DECTRIS.

The Camserver program of the PILATUS detector provides a simple to use interface for either EPICS or SPEC. Several clients for these protocols have been written at the Swiss Light Source (SLS) of the Paul Scherrer Institut (PSI). by Marc Rivers of the University of Chicago: http://cars9.uchicago.edu/software/epics/pilatusROIDoc.html

9.4.1 Steps to bring up a PILATUS detector in a new environment:

PILATUS detectors are shipped fully configured and ready to operate as stand-alone detectors. Some minor customization is required to integrate into a beam-line environment.

1) If needed, change the hostname to be compatible with the local network. This can be done conveniently in SuSE linux with YAST2, or directly with vi.

2) Set up the detector on the network, if needed. Note, that the detector does not require an external network.

3) Configure camserver, and the client tvx, as needed. Probably the defaults will be adequate, but many parameters can be adjusted in "camrc", and "tvxrc", both of which reside in the $HOME/p2_det directory.

4) Start the detector by "runtvx" in the $HOME/p2_det directory. This will show two images, the first with 1000 counts per pixel (produced by the command 'rbd'), the second with 100 counts per pixel (produced by the command 'calibdet'). If these images do not come up, there is a problem that must be resolved.

5) If you are using your own client for camserver (e.g., SPEC or EPICS) disconnect tvx. This will usually be done automatically in the startup script after the test images are shown. Connect your client and begin issuing commands.

Alternatively leave tvx connected. Tvx is a full-featured stand-alone controller and analyzer for detector work. Tvx is capable of executing almsot arbitrarily complex scripts for sequencing the detector, gathering data and analyzing data. See the numerous examples in "$HOME/p2_det/config/trim_gls", which are the glossaries used to set up and trim the detector.

There is a very simple test client, called "camclientt" in "p2_det/programs/tvx/camera" that can be used to issue commands to camserver and see exactly what the response is.

6) All commands are documented in the online help facility in "tvx"; camserver has no help facility of its own. Tvx does not need to be connected for this. Type "menu" in the camserver window, or in the tvx window to see what commands are available. Then, in tvx, type "help command_name".

Further sources of information:
$HOME/p2_det/tvxrc
$HOME/p2_det/camrc
$HOME/p2_det/programs/tvx/00README
$HOME/p2_det/programs/tvx/tvx/00README.SLS
$HOME/p2_det/programs/tvx/docs/*
$HOME/p2_det/programs/tvx/camera/camserver/00README
$HOME/p2_det/programs/tvx/camera/camserver/docs/case_definitions.txt
$HOME/p2_det/programs/tvx/camera/camserver/docs/README.camserver_commands
$HOME/p2_det/programs/tvx/camera/camserver/slsp2det_cam/docs/*
$HOME/p2_det/config/*
$HOME/p2_det/config/trim_gls/*

To see the details of the current configuration of camserver, do:
cat $HOME/p2_det/config/camstat/HWVersions

Further documentation of the system and of all commands can be viewed by:
konqueror $HOME/p2_det/programs/tvx/docs/html/index.html -or-
firefox $HOME/p2_det/programs/tvx/docs/html/index.html

10 Calibrating the detector

10.1 Principle

PILATUS detectors possess an adjustable threshold to suppress fluorescence, which can be useful in many experiments. The calibration of the PILATUS detector is necessary, because every pixel has a different characteristic, sensitivity and count rate due to voltage drops and nonlinearities in the analog amplifiers. To correct this irregularity, every pixel can be adjusted with 6 trimbits (6-bit DACs) which allow $2^6 = 64$ different values. In addition the magnitude of the influence of these trimbits can be adjusted by the voltage Vtrm.

Every detector is calibrated at our factory with at least 3 different energy levels. This is accomplished with macros (glossary files) that perform the steps described below.

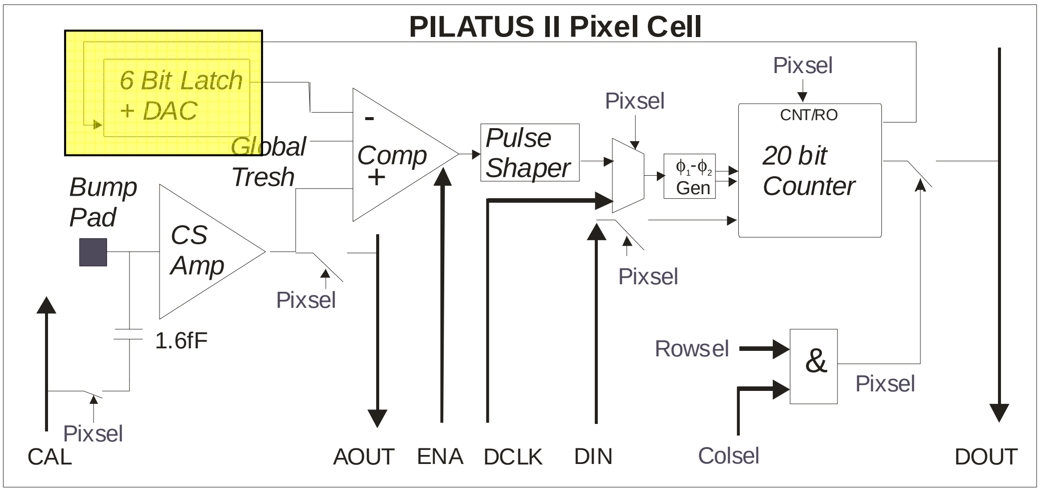


Figure 15. Block diagramm of the CMOS read out chip with high lighted 6 bit latch

The detector is calibrated as follows:

Irradiate the detector with a uniform field of x-ray's in a energy range between 4-18 keV.

Comparator (Vcmp) scan
Set all trimbits and Vtrm to zero and increase Vcmp from 0 to 0.8; recall that 0.8 corresponds to a low energy threshold, 0 to a high threshold. The result is a Vcmp calibration curve.
Set Vcmp to the value where the detector just begins to count fully, usually the inflection point plus the width of the S-curve.

Vtrm scan
Set all trimbits to high and increase Vtrm until all pixels are counting less than half of the value at trim=0; generally almost all pixels will be off at this point. Keep this value.

Trimbit scan
With these values, record images for every trim setting from 0 to 63. The result is a calibration curve for every single pixel. The trimbits are set to the value of the inflection point of this curve.

10.2 Calibrating the detector manually

As every detector is calibrated at least with 3 different energy levels before it leaves the factory, normally there is usually no need to create new trim files.
But in case you require a different setting at a special energy, you can trim the detector yourself.

The detector is irradiated with uniform x-ray illumination with a defined energy, the calibration is done and the result is stored in a trim file. For different energy levels and preamplifier setting, different trim files have to be created. Once a trim file is created, it can be loaded for the appropriate x-ray energy to achieve a uniform measurement.

All the glossaries and subroutines are in the directory:
config/trim_gls

To simplify the calibration, the script *p2_trim_det.gl* guides you through the whole calibration process for 1 energy.

Depending on the flux of the x-ray source this calibration may take several hours.

The first step is to create a good pixel mask for the use in the statistical comparisons. In the tvx window type get "trim_gls/p2_make_mask.gl".
Then to create a trim file for a detector module you should run the following command in the TVX window: get "trim_gls/*p2_trim_det.gl"* (the quotation marks are required).

You will be prompted to enter a name for the directory in which the trim files will be stored; this should be a directory that does not already exist. A format

is suggested but any valid directory is acceptable. This directory will be created in the images directory.
Example: newmod="m195_T5p9_vrf_m0p2__20070829"

Explanation:
- o m195: Preferably set the module number of the detector (for 1 module systems only)
- o T5p9: Energy of the illuminating x-rays, e.g. 5.9 keV
- o vrf_m0p2: Vrf = -0.2, Setting of the analog amplifier
- o yyyymmdd: Date of the calibration

The system will now run through the Vcmp scan. The next prompt will occur in about 5 minutes. Vcmp (comparator voltage) should be set such that all pixels are counting 100% of the incoming X-rays. The appropriate level of Vcmp can be determined from the "mean_vs_vcmp" graph (Figure 16). Set vc to a level well above the inflection point of the S curve: e.g. Vcmp = 0.65, where all pixels are counting.

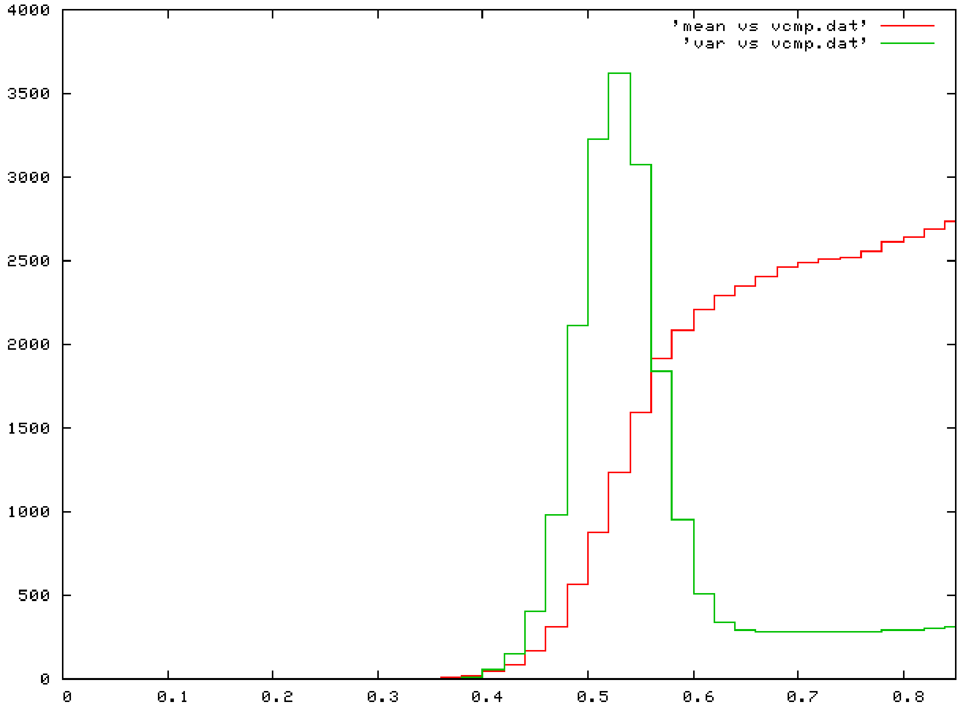


Figure 16 Result of the Vcmp scan.

The system will now run through a Vtrm voltage scan. All 6 trimbits are set to 63 and Vtrm is varied. You are now asked to enter a value of Vtrm such that all pixels are counting 0% of incoming X-rays. The appropriate level of Vtrm can be determined from the "mean_vs_vtrm" graph (Figure 17). Set Vtrm to a level well below the inflection point of the S curve, e.g. vt=1.35, where no pixels are counting. However the procedure suggests a value that is almost always correct.

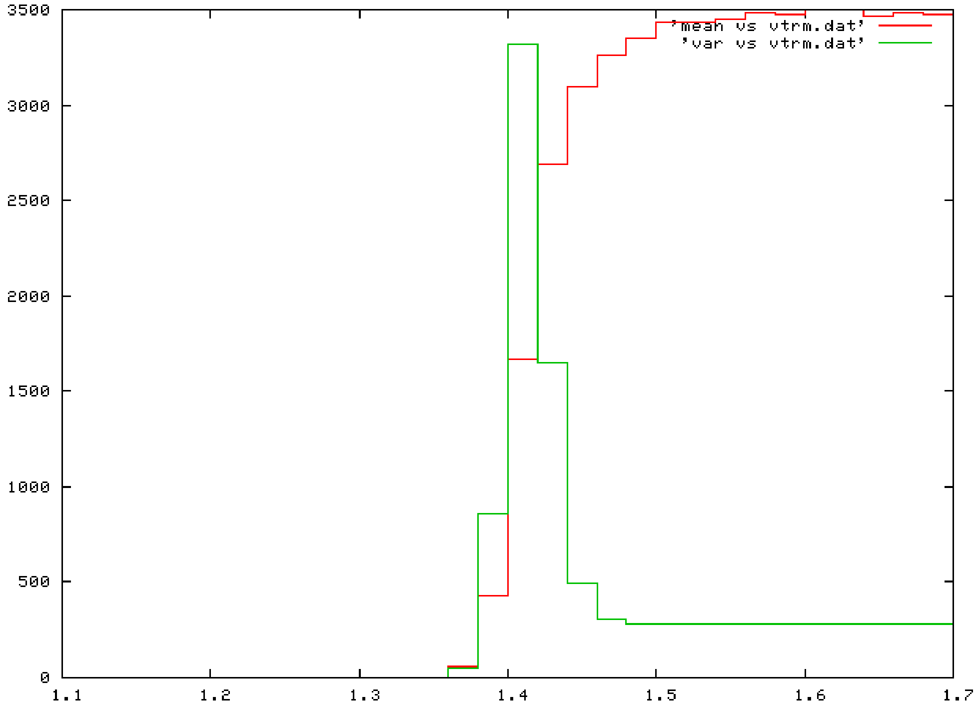


Figure 17 Result of the Vtrm scan.

The system will now run through a trim bit scan and vary all 64 possibilities of the trimbits. The next prompt will occur in a few hours depending on flux of the x-ray source.

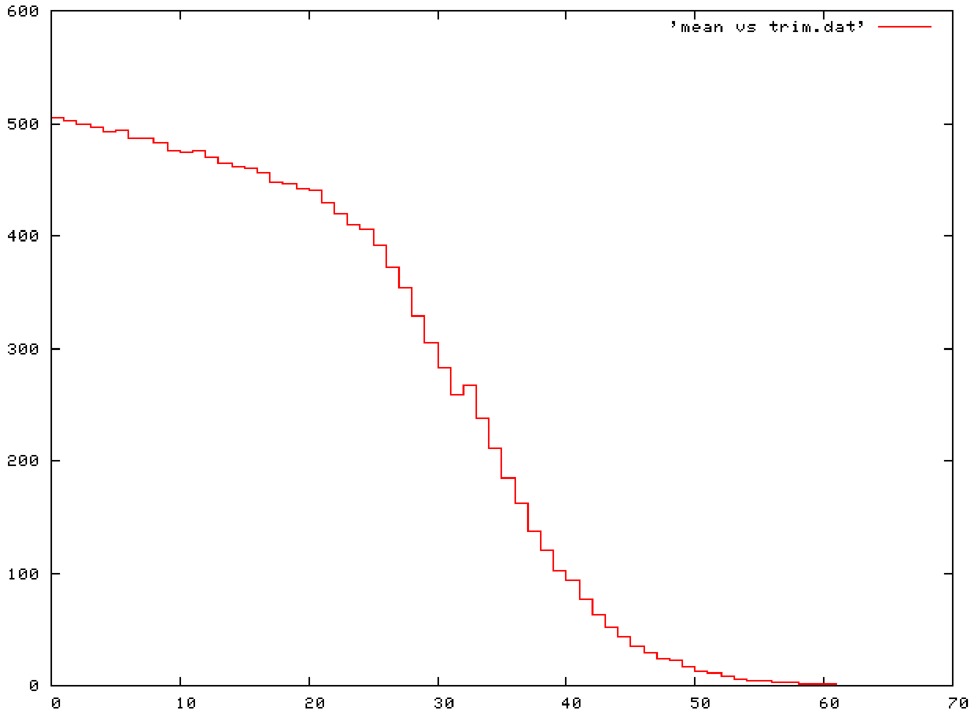


Figure 18 Result of the trimbit scan

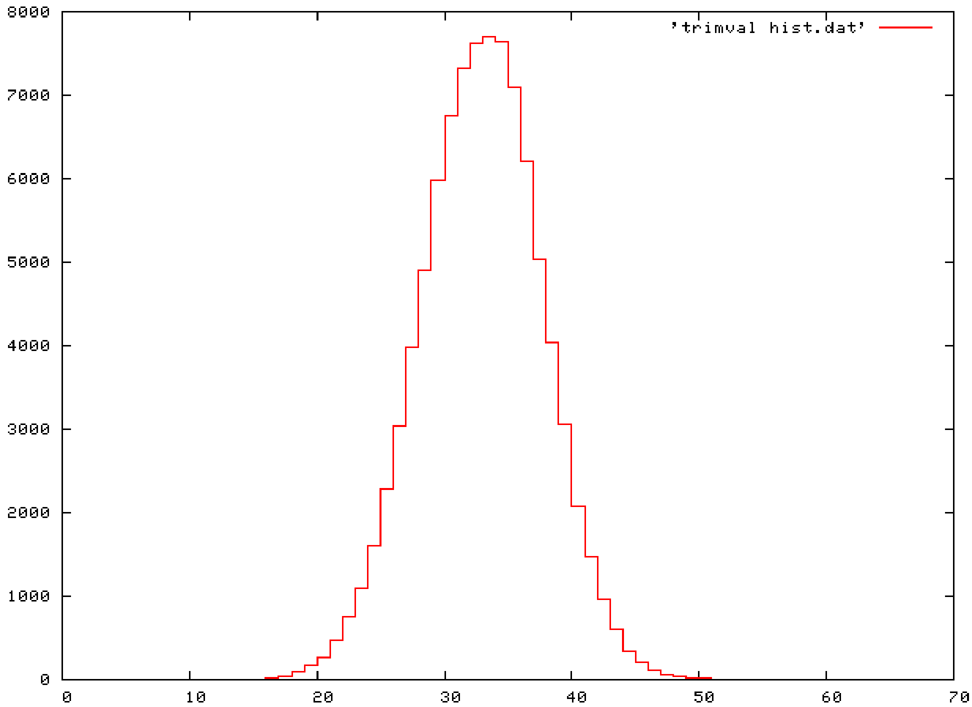


Figure 19 Distribution of the trimbit settings

Trimming of the module at the current X-ray energy is now complete. You are asked if you would like to load the trim settings you have just taken for this module. Set the variable flag to equal 1 to do this and the load trim glossary will be started: flag=1.

For standard settings, a faster way to generate trim-files is to use the following table for the recommended values for Vtrim and Vcmp

Settings for Vrf = -0.2		
E [keV]	**Vcmp0 [V]**	**Vtrim [V]**
6	0.75	1.38
8	0.6	1.37
10	0.44	1.36
12	0.3	1.35

Table 1: Recommended Values for Vcmp and Vtrim for standard settings and energies between 6 and 12 keV.

These values can be used together with the glossary *trimscan_only.gl,* where you directly enter Vtrim and Vcmp for the targeted energy.

10.3Loading trim files manually

After creating the trim files for a module and a specific x-ray energy you are able to load them at anytime. This can be done either after the trim scan glossary has finished or by executing the following command in theTVX window: get “trim_gls/p2_trim_load.gl”.

The trim files will be loaded and a comparison between loaded trims and assigned trims is made. If everything has worked correctly you should see exactly 100 counts per pixel.

Command	**Description**
trimdet *N*	Set all trimbits to *N*
show setdac	Shows the command used to set the DACs

10.4 Adjusting the threshold level manually

To avoid fluorescence radiation, the threshold of the detector can be adjusted. This adjustment is done in the TVX window.

Command	Description
setvcmp *value*	Values for setvcmp between 0 .. 0.8.

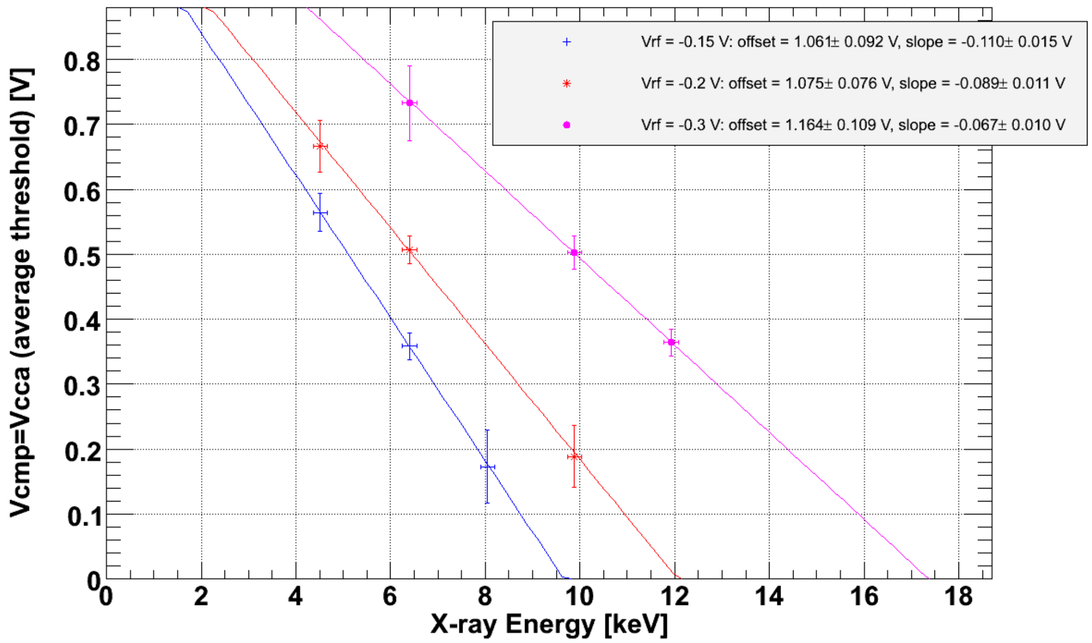


Figure 20 Value of Vcomp (x) for a specified energy

Zero sets threshold level very high and no x-rays are registered; 0.8 sets threshold level very low and all x-rays and some noise are counted.

10.5 Adjusting the analog amplifier manually

The frequency response and consequently the count rate of the analog amplifier can be adjusted.

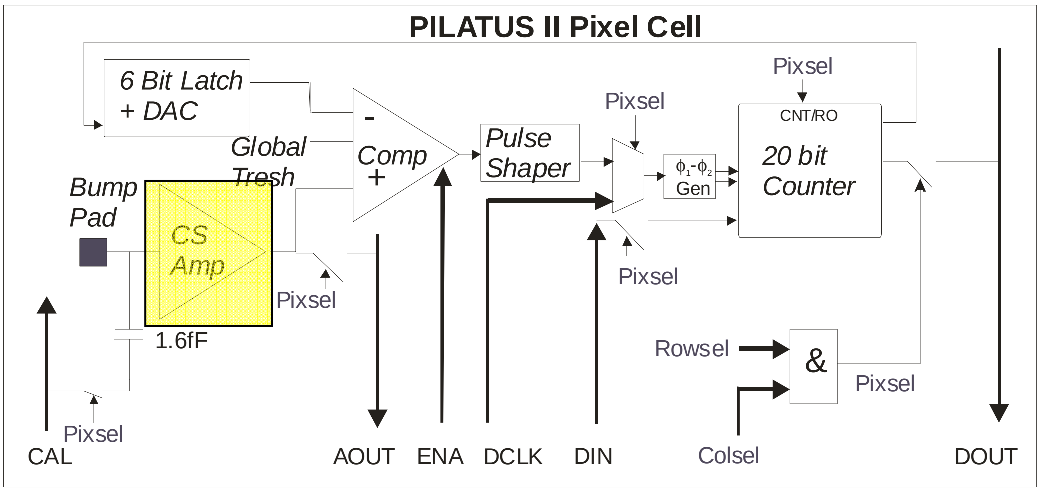


Figure 21: Block diagramm of the CMOS Chip with high lighted analog amplifier

Value Vrf	Description
-0.15	Slow settings with high gain for best resolution at low energies: 3 – 6 keV
-0.2	Standard settings for energies between 6 – 12 keV
-0.3	Fast setting with low gain for best performance at high energies: 12 – 20 keV

Command	Description
setvrf *value*	Values for setvrf between -0.15 and -0.3.

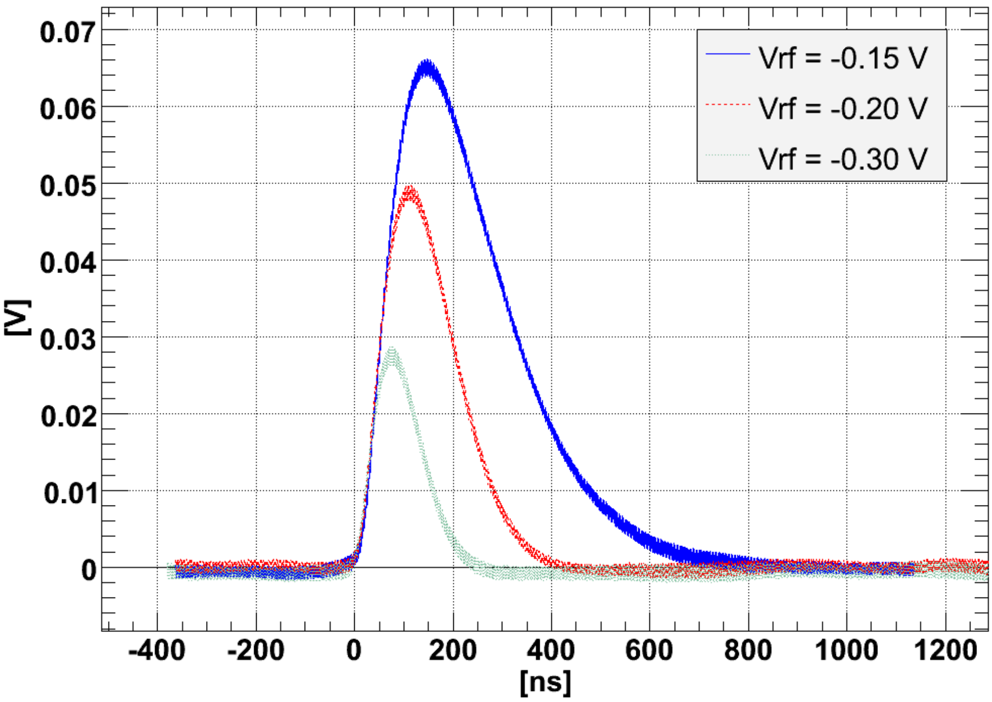


Figure 22 Step response at various Vrf settings

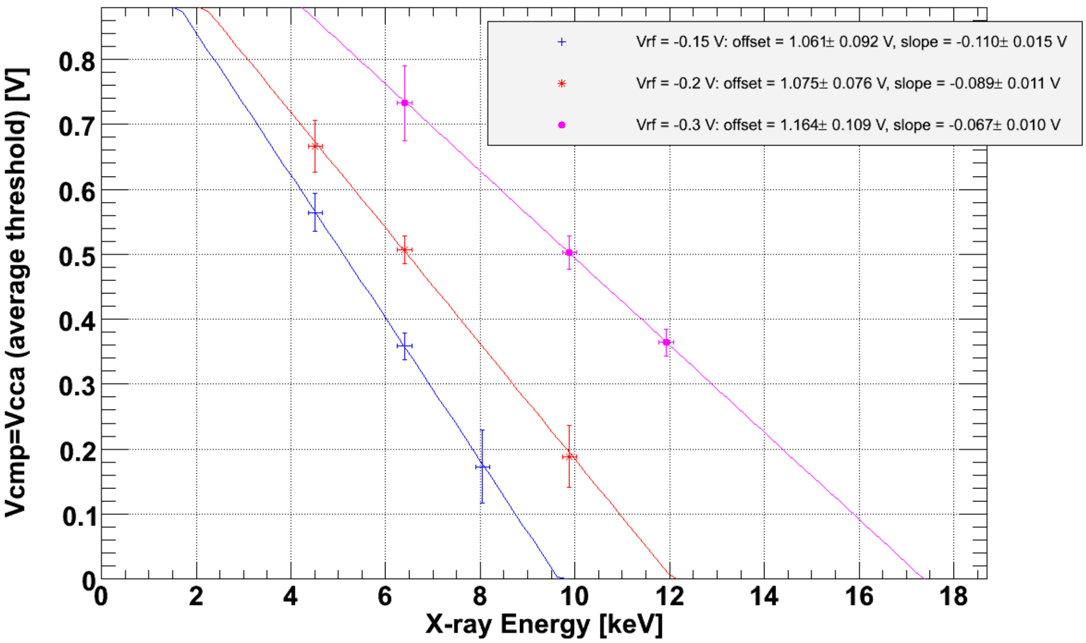


Figure 23 Calibration curves for different amplifier settings Vrf.

10.6 Loading trim files and setting the threshold automatically

In order set the trimfiles for an arbitrary treshold between 6 and 12 keV the camserver command *setthreshold* is used.
This simplifies the operation and makes sure that the detector is allways used trimmed.
For the target threshold T, the closest available trim_file is loaded and vcmp is calculated to match the target threshold T. In normal operation, the threshold should always be set to 50% of the energy of the incoming X-rays.
In cases where fluorescence radiation from a sample should be suppressed the threshold should be set about 0.5 keV above the energy of the emitted X-rays.

Command	**Description**
SetThreshold *gain threshold*	SetThreshold - set gain (energy range) and threshold energy T Usage: setthreshold [[gain] threshold] 1) if parameters are omitted, the current settings are shown 2) gain is 'uhighG', 'highG', 'midG' (standard) or 'lowG' 3) if gain is omitted, the previous setting is retained 4) threshold is in eV 5) this command builds a script in "/tmp/setthreshold.dat" and then loads it. The data for building the script are read, e.g., from p2_det/config/cam_data/m169_calibration.def.

gain	**Vrf**	**Description**	**Tau [ns]**
Uhighg	-0.1	Very slow settings with ultra high gain for best resolution at low energies: 2 – 5 keV	~2000
Highg	-0.15	Slow settings with high gain for best resolution at low energies: 3 – 6 keV	384
Midg	-0.2	Standard settings for energies between 5 – 18 keV	200
lowg	-0.3	Fast setting with low gain for best performance at high energies and high rates: 7 – 30 keV	125

The directories with the trim files are stored in:
/home/det/p2_det/config/calibration.

The information about the relevant trimfiles is stored in
/home/det/p2_det/config/cam_data/calibrations.def
In this file, the names of the trimfiles and the corresponding parameters are stored. In case new trim-files are generated, the directories should be copied to */home/det/p2_det/config/calibration* and the information should be entered in calibrations.def

11 Creating a flat field correction image

Intensity correction images are created with the glossary "trim_gls/p2_make_flat.gl" or using the TVX command: MkFlatCorr

First set up a very uniform x-ray illumination and verify that it is as flat as possible. This can very difficult, but is critical to success

Start this glossary in TVX by issuing the command get "trim_gls/p2_make_flat.gl".

Follow the instruction in the TVX window. You will be asked to supply a module number, this will create a directory under your images directory with the name you supply; ensure that this is a new directory.
A 'rbd' image will be taken followed by a 'calibdet' image, if these images are correct continue.
You are now asked to load the trim-files, start the load trim files procedure, set 'flag=1' and continue.
Now enter the trim file directory you wish to trim the module with, this procedure is described in 10.3 Loading trim files.
After the trim loading section has completed you will be given an opportunity to change the DAC settings if necessary.
The X-ray testing section will now begin, and you will be asked to turn on your X-ray source. A 1 second exposure will be taken and a mean count rate for the detector will be obtained. You are given the opportunity to redefine the area being used to obtain the mean value. Using this number an exposure time will be calculated to obtain a 10,000 X-ray count image. You are given the opportunity to change the exposure time if required.

The longer the exposure time, the better the statistics.

After the data has been taken you will be shown a histogram and asked if you would like to change the cutoff levels that have been set. These levels will be used to create a mask image. Both a mask file and a flat field correction image will be created and copied into the directory ~/p2_det/correct.
The final step will delete the working directory created under the images directory.

11.1Using the flat field correction image

To set the flat field correction image in TVX, issue the command "setint correction_image". By default the file is assumed to be in '~/p2_det/correct/'. By explicitly stating the path and image you can specify an image in a different directory. Issuing the command "setint" without any argument will list the currently used correction image, if any.

The flat field correction image is usually not automatically applied to the images that you take. To apply the correction to an image issue the command "move new_image=image!imi" . Where "new_image" is the new image that will be created and "image" is the image that is to be corrected.

Command	**Description**
LdFlatField *imagename*	The camserver command *“LdFlatField”* will cause camserver to apply a specified flat field correction to every image taken. The file specified (the same as in the abover paragraph) is a floating-point TIFF file with mean value near 1.0.

12 Factory Calibration and Correction

The following calibrations are done at our premises:

1) Threshold calibration
The PILATUS detector systems come fully calibrated. See the system information sheet in your user handbook for more information about the calibrated energies and settings.

The discriminator thresholds in the individual pixels are set by an automated procedure (described above). Ideally, the thresholds are set to 0.5 of the beam energy, and the procedure to reset them is activated automatically by the beamline software when the beam energy is changed. Special threshold settings may be employed, for example, to discriminate against specific fluorescence from the sample.
The threshold settings affect individual pixel sensitivity to some degree, so the threshold settings and the flat-field settings should be coordinated.

2) Rate correction
The counter in the pixels is a classical paralyzable counter with a dead time that depends on the voltage (Vrf) settings. The correction required is negligible up to 10^4 counts/sec for standard settings, but becomes quite significant approaching 10^6/s; above ~$2*10^6$/s (for standard settings) the conversion is cut off at a "saturation" value. This value is printed in the header and can be used as a flag in analysis software. Rate correction is optionally turned on in the control software, usually at startup.

Threshold setting, flat-field correction, rate correction and bad pixel tagging are all (optionally) handled by the detector software via a single command.

3) Distortion (only for multimodule systems)
A text file with a map of the offset in position and angle of each module with respect to some common origin will be provided.
The processing program must incorporate this information, using it as a lookup table to map sought reciprocal space positions onto detector positions.

4) Parallax
The silicon sensor is 0.320 mm thick. The parallax correction as a function of energy and angle of incidence has been well modeled and is about 1 pixel displacement at an angle of incidence of 45 deg. Parallax actually improves spatial resolution because a spot that is spread over a few of pixels can be localized better than a spot in just 1 pixel.

5) Flat-field
Different modules in a multi-module detector differ in sensitivity. This calibration needs to be done as a function of beam energy.
The flat field map can be loaded into the detector controller, and perform the correction as the data are read; however, once corrected it is difficult to go back.
Alternatively, crystallographic processing programs like XDS develop a flat-field calibration internally as they process. Giving such programs a good starting point for the refinement is presumably the better approach.

6) Bad pixels
The software permits reading of a bad pixel mask, which pixels are flagged as -2 in the data. This can be good or bad since once the pixel is flagged, the data are lost. It is also easy to incorporate these data as a post-acquisition step. The gaps between the modules can optionally be flagged with -1 (zero is the default). Both of these flags are used by XDS.

13 External Triggering

External triggering can be seperated into three different modes:

- External Trigger: triggers a predefined series of commands after the detector receives a positive edge
- External Multitrigger: triggers each exposure with an external pulse, but times the exposure using the internal timer
- External Enable: gates the detectors images on the positive signal coming to the detector

All these commands apply to camserver

13.1 Command list

Variables	Description
nimages	Number of images Sets the number of images to be taken after the trigger e.g. :“ni 2” for two images
exptime	Exposure time Sets the exposure time for each image e.g. “expt 1” for a one second exposure
expperiod	Exposure period Sets the period of time allocated to take an exposure and readout the image. e.g. “expp 2” for a one second period therefore readout time is (expp-expt), the minimum readout time is 3ms
delay	Delay Sets the time to wait after the trigger to take the first image. e.g. “delay 1” a one second delay between the trigger and first image
Exttrigger [image name]	External trigger Starts the external trigger mode and waits for the trigger
ExtMtrigger [image name]	External multi trigger Starts the external multi trigger mode and waits for the trigger
Extenable [image name]	External enable Starts the external enable mode and waits for the gate pulse

Variables	Description
nexpf	Number of exposures per frame This is a so called multi exposure mode. nexpf sets the number of exposures before the detector is read out e.g. “nexpf 3” exposes the detector 3 times before reading out an image of the 3 combined exposures.

13.2 External Trigger mode

External trigger mode is started with the command “extt *imagename.tif*” where *imagename.tif* is the name of the images you wish to be taken. The image name will be “imagename_00001.tif”. If ni > 1 the image number will be incremented for each image in the series.

The settings that are necessary for external triggering are:

- ni
- expt
- expp
- delay (optional)

After receiving a trigger on the positive edge, the module will wait a period of time defined by “delay”, take an exposure of length “expt”, readout the image and after a period defined by “expp” will repeat the cycle for “ni” images.

The image number is only incremented during the trigger mode, if you reissue the command “extt imagename.tif” the system will start writing images from “imagename_00001.tif” and overwrite existing data.

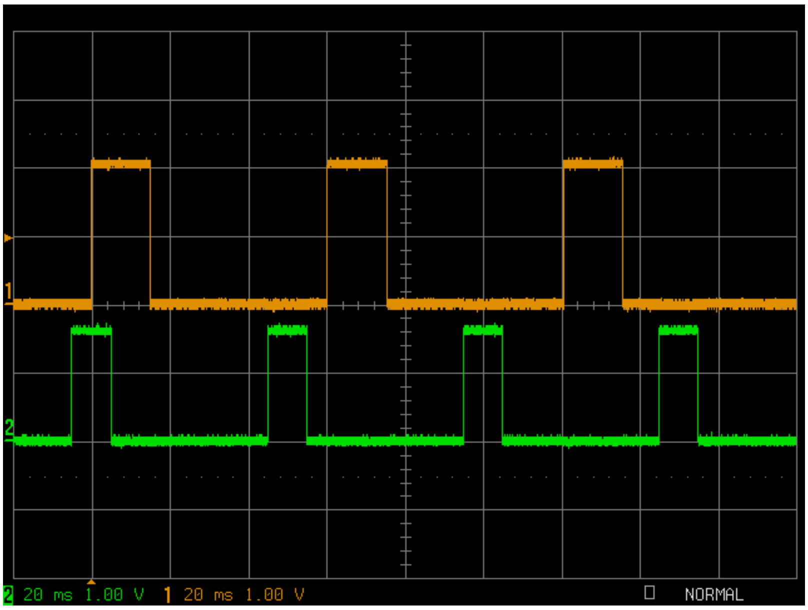


Figure 24. Oscilloscope trace of an external trigger. See text.

The upper trace is the exposure signal, the lower trace is from the pulse generator being used as a trigger. For this external trigger, “ni” is 3, the “delay” is 0.005 s, “expt” is 0.016 s and “expp” is 0.06 s. Only the first positive edge of the trigger is used.

Because the external trigger relies upon the module’s internal clock signal to start the timing of the exposure, there is a delay and jitter between the trigger signal and the start of the first exposure. The maximum jitter is ~15 ns with an average delay of 177 ns.

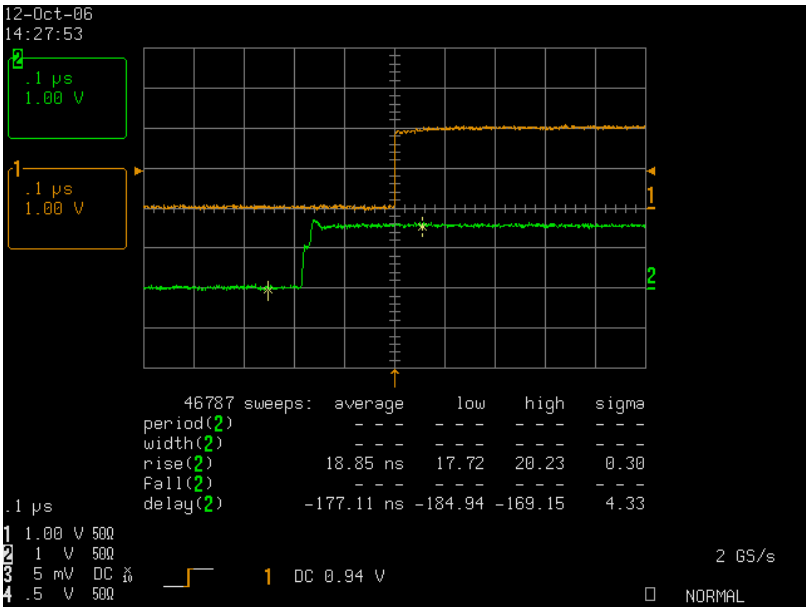


Figure 25. Delay and jitter.

13.3 External Multi Trigger mode

External multi trigger mode is started with the command “extMtrigger *imagename.tif*” where *imagename.tif* is the name of the images you wish to be taken. The image name will be *imagename_00001.tif*. If *ni* >1 the image number will be incremented for each image in the series.
After issuing the “extMtrigger *imagename.tif*” command the detector will monitor and take a number of images defined below, on the level of the trigger pulse.

The settings that are necessary for external multi triggering are:

- ni
- expt
- delay (optional)

After receiving a trigger on the positive edge, the detector will wait a period of time defined by “delay”, take exposures defined by “ni” of length “expt”, readout the images and will rearm to take another images.

The image number is only incremented during the exposure series; if you reissue the command “extt imagename.tif” it will start writing images from “imagename_00001.tif” and overwrite existing data.

Wait time ???

13.4 External Enable mode

External enable mode is started with the command “exte *imagename.tif*” where *imagename.tif* is the name of the images you wish to be taken. The image name will be *imagename_00001.tif*. If *ni* >1 the image number will be incremented for each image in the series.
After issuing the “exte imagename.tif” command the detector will monitor and take a number of images defined by *ni* gated on the level of the trigger pulse.

Variables “delay”, “expt”, “expp”, etc. are not used in external enable mode.

The image number is only incremented during the exposure series; if you reissue the command “extt imagename.tif” it will start writing images from “imagename_00001.tif” and overwrite existing data.

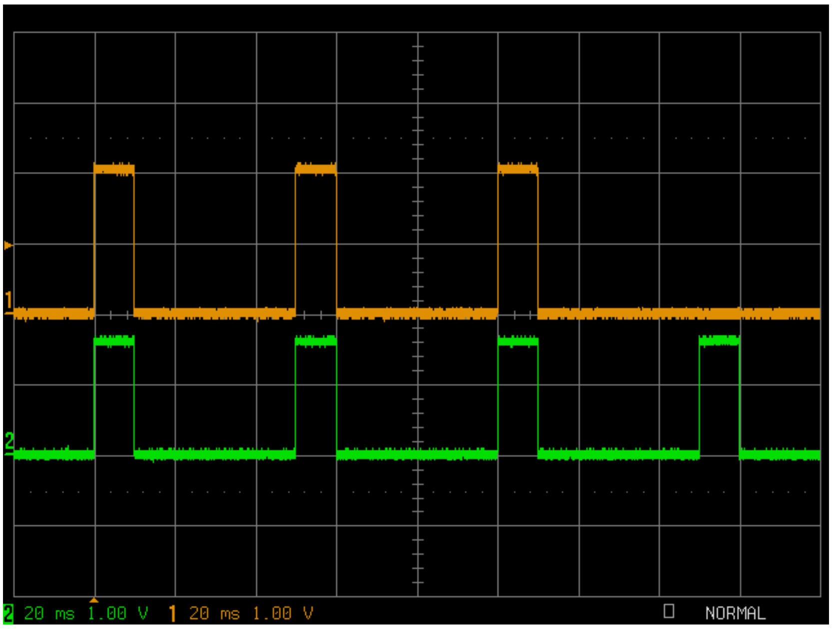


Figure 26. Oscilloscope image of an external enable.

For this external enable “ni” is set to 3.

Because external enable gates the counter directly, it does not rely upon the detector’s internal clock. This means that the delay between the enable and start of exposure is negligible and mostly given by the rise time of the enable provided to the detector. This can be seen in the oscilliscope image below.

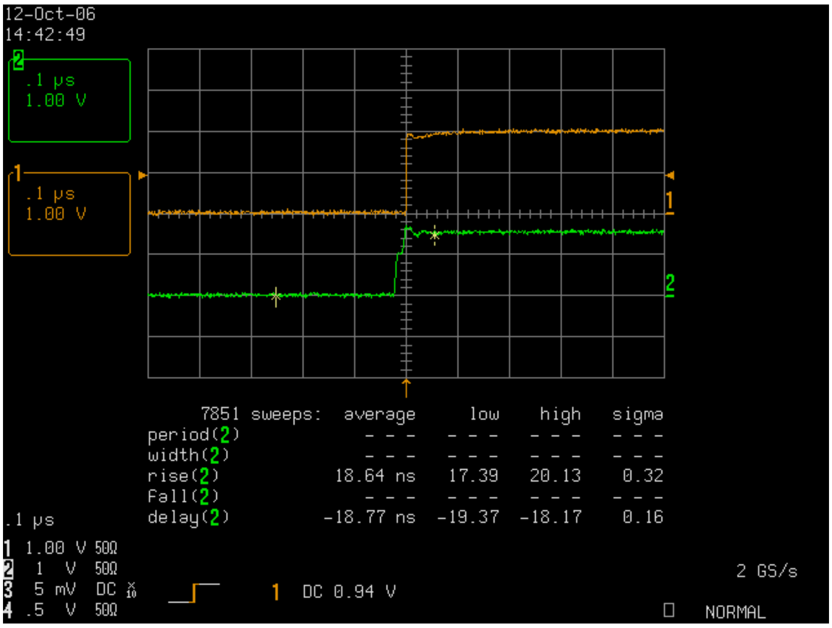


Figure 27. Oscilloscope trace of the typical delay between enable signal and exposure.

13.5 Multiple Exposure mode

It is possible to take multiple exposures in one image by setting the number of exposures with the variable *nexpf.* The default value is 1; all exposure modes use this variable. If '*nexpf 2'* is set, then the detector will take exposures in the same way as described for external trigger and external enable, but will additively bundle 2 exposures in each readout. If *ni* is defined to be 3 and *nexpf* is defined to be 4, then the detector will take 12 exposures and generate 3 images.

The advantage of this mode comes when you want to record a small number of x-rays at a repetitive fast rate e.g. at the Fempto project at the SLS. This also eliminate the need to wait 3 ms between exposures; however at least 3ms is needed for the image readout after *nexpf* eposures.

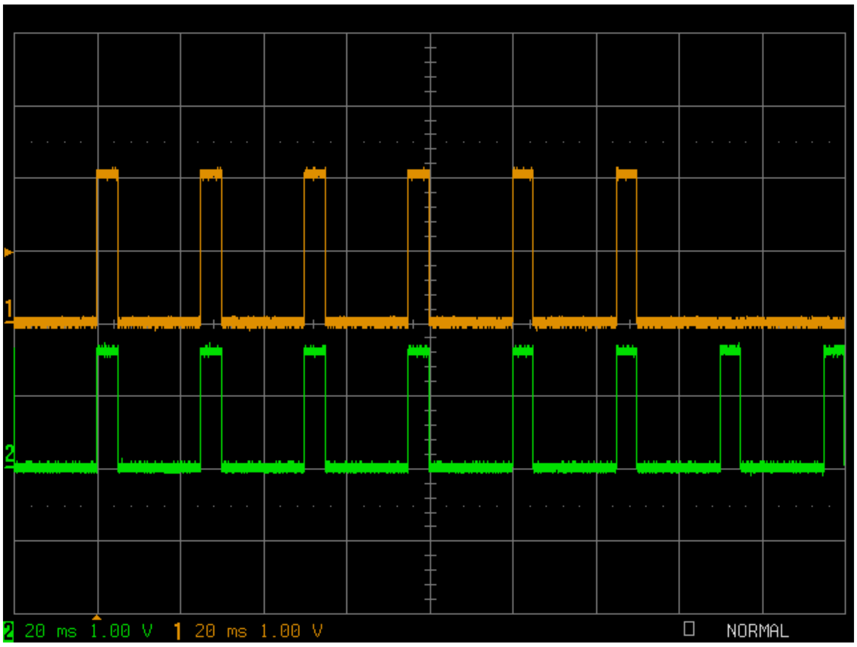


Figure 28. Osciloscope image of the multiple exposure mode.

14 Appendix

14.1Table of figures