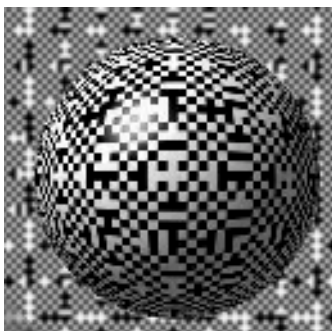# RasNiK, an Alignment System
for the ATLAS MDT Barrel Muon Chambers

Technical System Description

Artist Impression of RasNiK Alignment Mask (HG)

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Amsterdam, April 2000.

Abstract:

This paper gives a full description of the RasNiK alignment system and components to be installed in the ATLAS Muon Chamber environment. These include the 'On-Chamber' parts like RasCaM, RasLeD and RasMuX, the 'Off-Chamber' MasterMuX, the Counting Room electronics in USA15 and cabling aspects.

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Our work has been presented in "The third international workshop on accelerator alignment", September 1993. The paper presented there was: The RasNiK/CCD 3-dimensional alignment system.Authors: H.Dekker, H.vd.Graaf, H.Groenstege, F.Linde, S.Sman, R.Steensma. From: Nikhef-H, Kruislaan 409, 1098 SJ Amsterdam, the Netherlands. Since than, a lot of work has been done on improving the mask and on the reconstruction software. Also systematical errors were investigated and methods were developed to minimize the effects. The code is explained in The coding of the mask for CCD_Rasnik by H.L.Groenstege from NIKHEF. This is a NIKHEF paper, registered in 1994, numbered ETR_94-10. This paper can be obtained from NIKHEF or can be downloaded as a .pdf file. We claim all rights on using the principle and methods, especially on the coding of the mask (lightsource).

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Index

Acknowledgement

Glossary

Abbreviations used in this document: (alphabetical)

Underlined items are specific NIKHEF/RasNiK names.

AWG	American Wire Gauge; copper wire cross-section index.
Buck Regulator	Switching Voltage Regulator where Vin>Vout.
CAT5	FCC network designation; Category 5 network speed.
EIA/TIA 568B	Connection scheme for RJ45 connector.
EMI	Electro-Magnetic Interference.
ESD	Electro Static Discharge.
FCC	Federal Communications Commission.
I^2C-Bus	Philips two wire serialbus for ICs and/or boards.
Icaras	RasNiK Analyses and Control Software.
IR-Filter	Infrared pass filter.
IR-LED	Infrared Light Emitting Diode.
JTAG	Joint Test Action Group, IEEE-1194.1; 4 wire serial test bus.
LVDS	Low Voltage Differential Signaling; ANSI/TIA/EIA-644-1995.
MasterMuX	RasNiK Multiplexer: acting master for RasMuXs.
PCI	Peripheral Component Interconnect; PC slot.
RasCaM	RasNiK camera or image source.
RasLeD	RasNiK LED or lightsource.
RasMuX	RasNiK Multiplexer.
RasNiK	acronym: Red alignment system NIKhef.
RJ11	Network connector designation 4w/6p.
RJ45	Network connector designation 8w/8p.
RS485	Electrical specification Differential Serial Bus; EIA Standard.
SacLeD	Lightsource used for Saclay Reference System.
USA15	Underground Service Area 15; ATLAS 'counting room'.
USA15-MuX	RasNiK Multiplexer in USA15.
UXA15	Underground Experimental Area 15; ATLAS experiment hall.

Overview of RasNiK Components, Numbers and Locations.
(A5_MuX_Geo.wmf)

Location	Chambers	Magnet Support		RasNiK Components & Numbers

RasMuX 768x

MasterMuX 16->1 48x

RasCaM 8->1

RasCaM 5452x

RasMux I/O:
8 x RasCam
16 x RasLeD

USA15 Rack

USA15-MuX 48->8 Crate

Video Digitizers 8x

4 x PC

UXA15 -to- USA15

100m

RasLeD 6672x

RasLeD 1->16

Control PC

Power
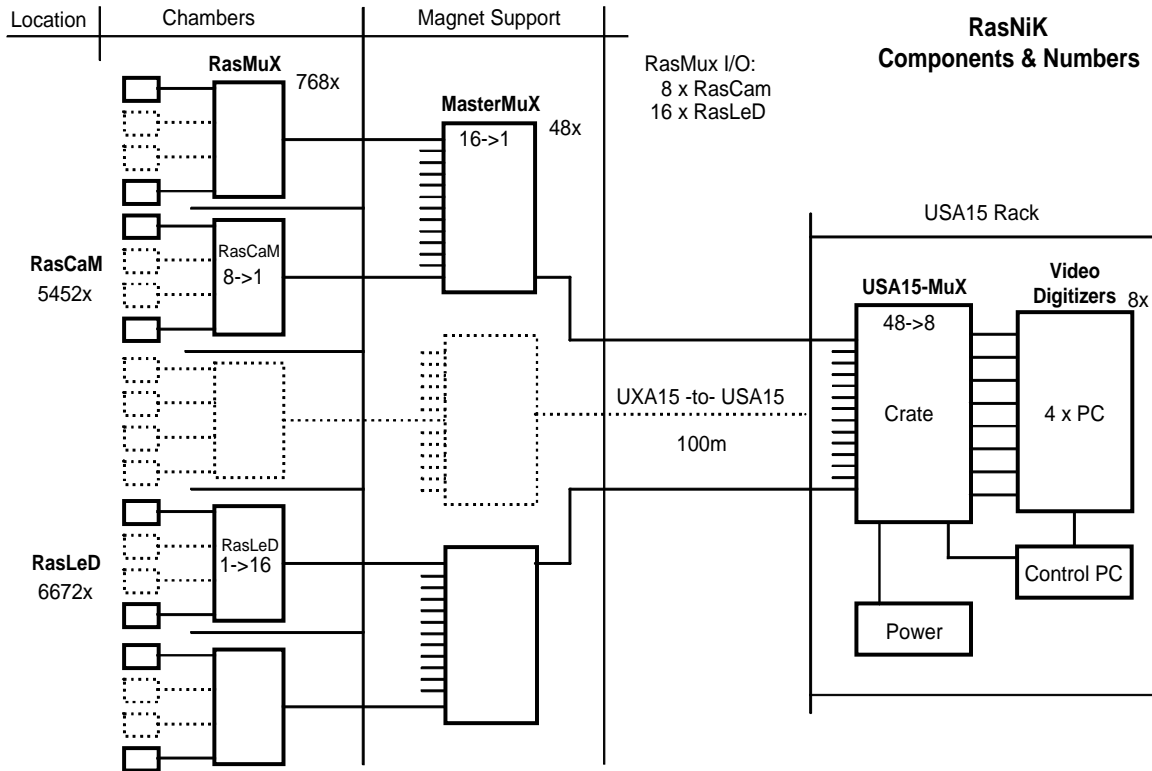
A5_MuX_Geo.drw

Light Source   -> Lens ->   Image Source
Mask   ->   Image
RasLeD   ->   RasCaM

RasNiK Components, Numbers and Locations

UXA15
<u>On Chamber:</u>

RasLeDs	6672x	
RasCaMs	5452x	
RasMuXs	768x	I/O: 16 x RasLeD and 8 x RasCaM

UXA15
<u>Off Chamber:</u>

MasterMuXs	48x	I/O: 16 x RasMuX

USA15
<u>RasNiK Rack:</u>

USA15-MuX Crate	1x	
USA15-MuX Units	8x	I/O: 48 x MasterMuX
Video Digitizers	8x	
PCs	5x	

RasNiK, an Alignment System for the ATLAS MDT Barrel Muon Chambers

Technical System Description

1. Scope:

Alignment: Introduction (from 7/7.1 from Atlas Technical Design Report, 5 June 1997)

The momentum measurement in the ATLAS muon spectrometer aims at a precision of the order of 10% for muons of transverse momentum $P_T = 1$ TeV by a sagitta measurement in triplets of precision chambers. The target level of accuracy for the precision chamber alignment is such that the alignment contribution to the final measurement error stays well below the intrinsic precision chamber measurement error.
On the scale of the measuring accuracy of 50 µm it will not be possible to keep stable the geometry of the chambers and their position in the spectrometer. The approach chosen to cope with movements is to measure their effect on the sagitta measurements of tracks and to correct for them off-line using the information from the optical alignment system; no attempt is made at physical chamber repositioning. Owing to geometrical constraints, the alignment schemes are different in the barrel (pseudorapidity below 1.0) and end-cap regions. Both are based on optical straightness monitors. It is proposed to achieve the target precision on the alignment corrections through a very precise mechanical mounting of the optical elements (typically better than 20 µm in the relevant coordinates) on the precision chambers and on any of the intermediate precision mechanical elements. A control of the positioning accuracy of the optical sensors can be achieved by using straight muon tracks. In order to save on the cost of the alignment system in the barrel, only the triplets of large chambers will be equipped with optical systems. Triplets of small chambers will be aligned by using tracks overlapping two neighboring triplets.

RasNiK is used for the alignment of the large muon precision chambers in ATLAS. The basic electronic components of this system are an image sensor called RasCaM and a light source called RasLeD. The RasNiK system for the MDT Barrel chambers needs 5452 RasCaMs and 6672 RasLeDs. The system can be divided into Inplane, Projective, Proximity, Axial, Bar and the BOG-BOH alignment. Table 1. shows a per system breakdown of the numbers of basic RasNiK components to be installed.

Table 1.

**RasLeD and RasCaM Distribution for 748 Locations
(Chambers and Reference Bars)**

Institute	System Type	# RasLeDs	# RasCaMs
Saclay			
●	Praxial	2264	2264
●	Axial	1164	1164
●	Ref. Bar	664 [*]	608
●	BIL-BIR	32	16
NIKHEF			
●	Inplane	2406	1240
●	Projective	124	124
Freiburg			
●	BOG-BOH	18	36
Totals #		6672	5452

[*] = SacLeD

2. Technical Introduction

The basic alignment idea is to create an image of a coded mask on an optical sensor by means of a lens. The mask is lit by an infrared light source. In this set up the relative position in X and Y directions are measured perpendicular to line connections of the mask, the optical center of the lens and the sensor. Also the (relative) rotation of the mask or the sensor can be measured. By calculating the actual image spotsize and comparing this with the mask spot size, the position of the lens along the Z-axis is calculated.
Also the relative rotation around the X- and Y-axis of the mask with respect to the CMOS image sensor can be calculated.
The system can be split into three major components: (see figure 1.)
- The optical system, with:
  · a light source with coded mask
  · a lens
  · an optical sensor
- The sensor and video digitizer combination:
  The optical sensor is a commercially available monochrome observation CMOS video camera, without lens. (i.e. like the VLSI Vision VV5430)
  The video digitizer can be any commercially available pixel synchronous 8 bit grayvalue type (i.e. like the Data Translation DT3152).
- The analyses software Icaras.

Figure 1: **Components of the Basic RasNiK System**. (A5M_RasNiK1)

Basic RasNiK System

CMOS Video Sensor = VV5430
IR-LEDs = HP-HSDL-4420-#011

A5M_RasNiK1.drw
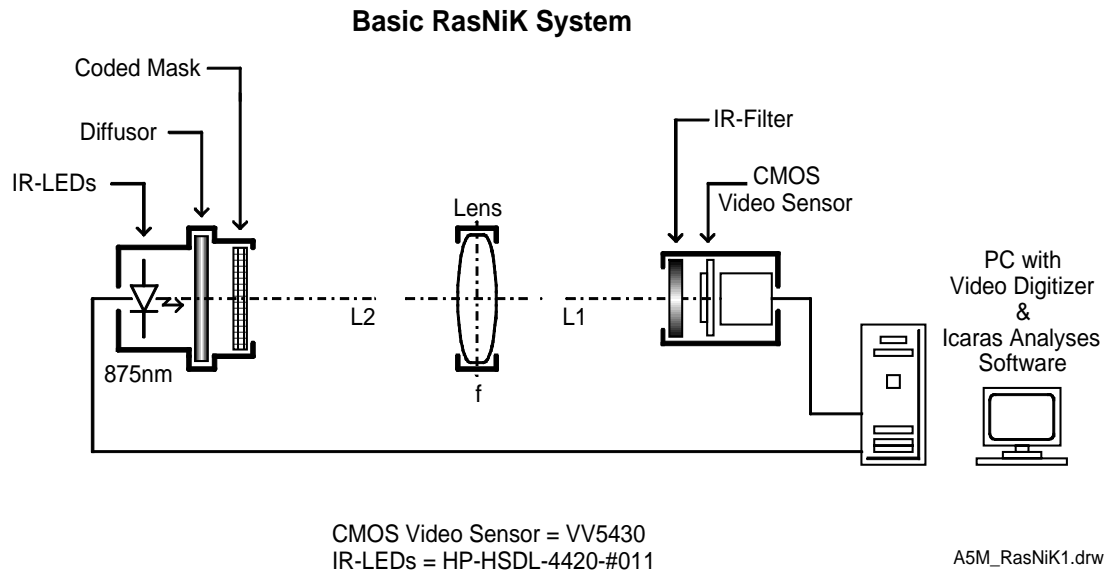
3. RasNiK Components

The RasNiK components -apart from lenses- installed in the experiment are :
* RasCaMs = sensors
* RasLeDs = light sources
* RasMuXs = chamber multiplexers
* MasterMuXs = multiplexers

The actual alignment components as outlined in the introduction are the RasCaMs and the RasLeD and of course the lens, which in the case of the Inplane Alignment scheme, are mounted on the MDT Chambers. As said, 5000 to 6000 thousand of these basic components will be installed.

Handling this large amount of basic components within the confined space of the MDT chambers is done with progressive layers of multiplexers, much like telephone subscriber lines to an exchange. The first level of multiplexing is the RasMuX. This RasMuX combines the limited number of RasNiK components (ex: for BOL-B: 8 RasCaMs and 12 RasLeDs) of just one chamber. The second level of multiplexing will be the MasterMuX, which combines the signals of 12 RasMuXs. The MasterMuXs connect to USA15, the location where more multiplexers will finally deliver the signals to the PC-Based Video Digitizers. This 'tree' structure also distributes power and control from USA15 upwards into the system to the RasCaMs and RasLeDs. The RasCaM video signals from the chambers are send downwards to USA15 over single cable connections to/fro the various RasNiK subcomponents. See also figure 2.

Figure 2: **RasNiK Components in the Experiment, with cable lengths**. (A5_Sys1a.wmf)
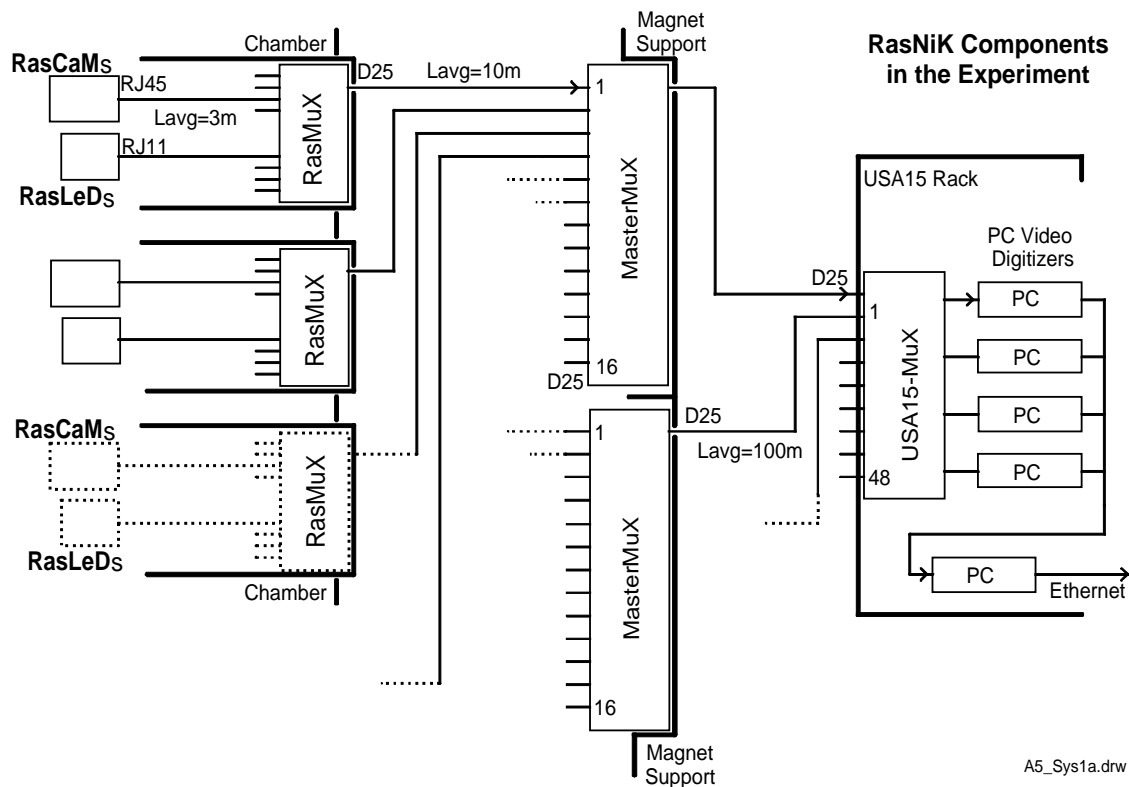
In this system with RasMuXs, MasterMuXs and the USA15-MuX we get an end-modularity of only eight video output lines. This number is considered to be a balanced compromise between cost and reliability.

Note that RasCaMs, RasLeDs and RasMuXs are 'On Chamber' components and MasterMuXs are 'Off Chamber' components

The RasNiK components installed in USA15 are :
- USA15-MuXs
- PCI Video Digitizers
- PCs with Control & Analyses Algorithm (Icaras)

3.1 The Light Source with Coded Mask (RasLeD)
The mask is a high accuracy (<0.5µm) thinfilm chromium/glass slide of the same type as used in the semiconductor industry. The mask has a modified 'chessboard pattern' with a grid optimized to produce as many 'redundant' black/white transitions on the optical CMOS sensor, within the limitations of the pixelsize. The projected black/white transitions cover several pixels, making a fine interpolation of the transition possible that is an order of magnitude more accurate than the pixelsize. At selective places in the 'chessboard pattern' of the mask, a code field is inserted, matched to the total pixel array size of the sensor, such that the range of RasNiK can be extended to several times the sensitive surface of the CMOS sensor. The mask used for the Inplane Alignment is 20mm x 20mm with a grid of 120µm. The mask is mounted in a die-cast housing with a diffuser (Opaline glass 3mm) and an

infrared light source. The infrared lightsource (875nm) has 9 high intensity IR-LEDs in a 'pokerdot' pattern. The diffuser assures a more even distributed overall surface intensity of the radiated maskpattern. See figure 3.

Figure 3: **RasNiK Coded Mask showing modified 'Chessboard Pattern'**. (mask.gif)
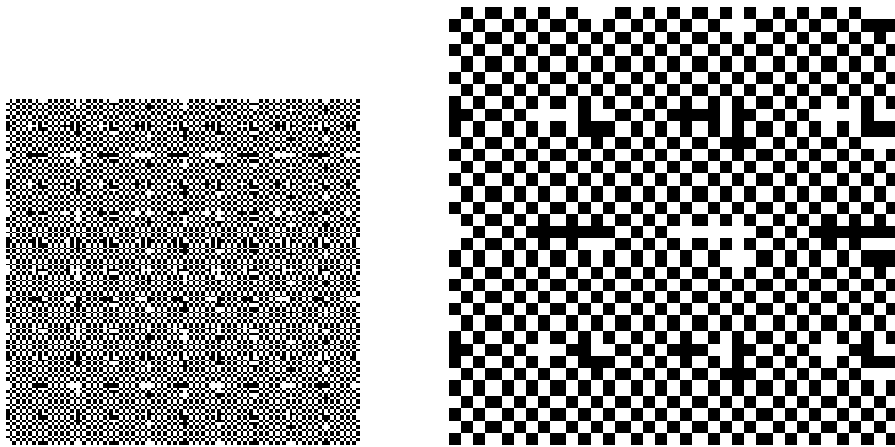
Full Mask & Detail

The field size (basic square) depends on the system: InPlane □ = 120μm

Projective □ = 120μm	Axial □ = 170μm	BOG-BOH □= 120μm
Praxial □ = 170μm	Bar Ref □ = 120μm	BIR-BIL □ = 120μm

The Projective System uses a 40mm x 40mm mask, all others use 20mm x 20mm masks.

The electrical connection to the RasLeD printed circuit board is an RJ11 connector. The RasLeD printed circuit board plugs into the mask housing with 3 brass Stand-offs, which are electrically isolated from the circuitry. The circuit is voltage driven (24V). There are nine IR-LEDs in series with a 165 Ohm resistor (8 x 330Ω/1206). The circuit has a power indication - Green LED- and ESD protection. See also figure 4.

SacLeD
Lightsource used in the Reference Bar System.

The lens
The lens and lens mounting mechanics are not covered here.

3.2 Optical Sensor (RasCaM)
The optical sensor is a monochrome CMOS Image Sensor from VLSI Vision. This VV5430 sensor has a pixel array size of 384 x 287 of 12μm x 12μm pixels. The array size itself is 4.66mm x 3.54 mm. The minimum useful sensor illumination for the analyses algorithm is ~0.5 lux. For the Inplane system with a length of 6 meters, a lens with diameter of only 40mm can be used. Here the illumination is then in the range of 1 to 2 lux.
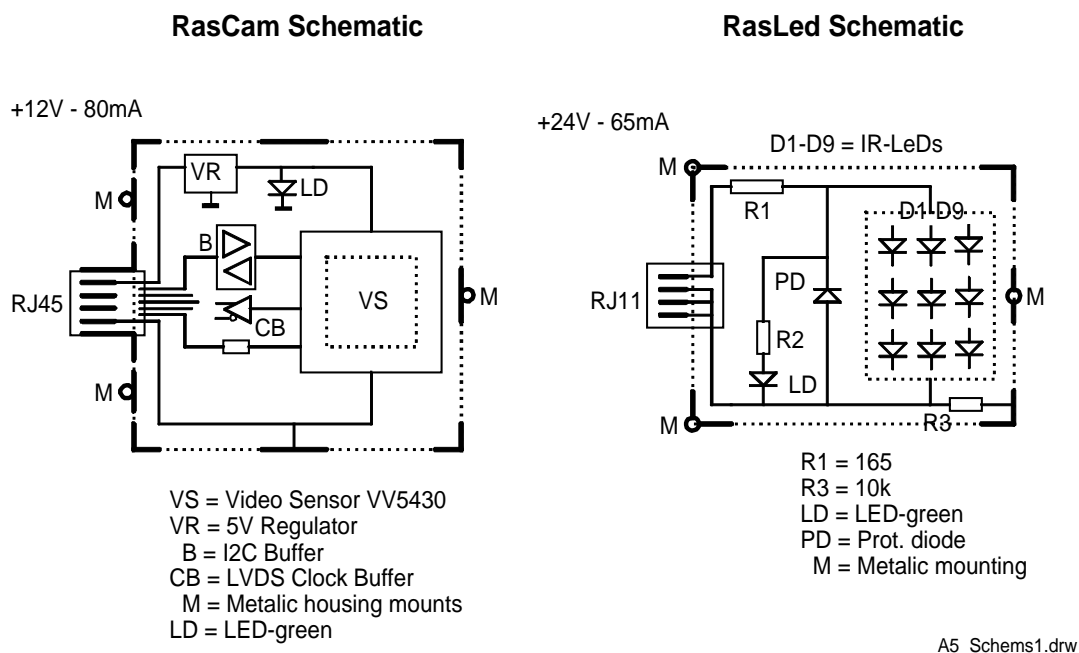
The spectral sensitivity peaks in the infrared range (820nm). The image sensor (lcc40 package) is mounted on a small printed circuit board (42mm x 53mm). The output is a standard, semi-differential CCIR composite video signal. The auxiliary circuits on the RasCaM board provide I/O protection, voltage regulation, control -I^2C- buffering and Pixel

Clock extraction. The synchronous output pixelclock frequency is 7.37 MHz, signal level is LVDS. The video, power, pixelclock and I^2C I/O lines are all on a shielded RJ45 (CAT5) connector.

Normally the RasCam will operate in the auto-gain/auto-exposure mode. The I^2C control however allows fixed video gain and exposure time settings when needed. For extreme low light intensity applications the exposure time can be set as high as 160ms (8x the normal video maximum). This of course at the expense of a reduced video frame rate.
Digitizing this low frame rate video signal is enhanced by using the synchronous pixel clock. Video digitizing with use of the pixelclock also reduces pixel timing jitter, resulting in a higher alignment resolution. It also eliminates systematic errors in the X-direction. For point sources like with the Bcams a fixed video gain should be selected.

The RasCaM board is mounted in an aluminum die-cast housing, 5cm x 6cm x 3cm (WxLxH). The optical window of the housing is covered with an infrared pass filter (Schott RG830). This to prevent day- and/or artificial stray light from entering the sensor and upsetting the infrared image contrast ratio. Furthermore, the housing has an outside 5mm ridge around the optical window for further stray light shielding. A neoprene gasket seals the housing to the sensor, thus preventing dust from gathering on the sensor surface focal plane. Electrically the housing is connected to the sensor board ground to prevent capacitive noise coupling into the sensitive pixel-area of the sensor. See also figure 4.

Figure 4: **RasCam and RasLeD Schematic; Functional Outlines**. (A5_Schems1.wmf)

RasCam Schematic

+12V - 80mA

VS = Video Sensor VV5430
VR = 5V Regulator
 B = I2C Buffer
CB = LVDS Clock Buffer
 M = Metalic housing mounts
LD = LED-green

RasLed Schematic

+24V - 65mA

D1-D9 = IR-LeDs

R1 = 165
R3 = 10k
LD = LED-green
PD = Prot. diode
 M = Metalic mounting

A5_Schems1.drw

Note: the Power ON indication Green LEDs are not neutron radiation tolerant, but can be very useful during the chamber assembly phase and mounting/testing phase.

As can be seen in the above schematics, the RasLeD circuit boards is electrically isolated from the die-cast maskhousing to be mounted on the chamber aluminum support. Resistor R3 -10kΩ- is used to prevent static charge build-up. The RasCaM circuit board however is not electrically isolated from its housing. The housing must be on the same potential as the video

sensor to prevent electro-magnetic interference (EMI) due to capacitive coupling between housing and sensor. Therefore the RasCaM housing must be mounted electrically isolated from the chamber.

RasCam: RasNiK Image Sensor < Shortform >

- CMOS Image Sensor; VVL type VV5430.
- 384 x 287 (CCIR) pixels.
- analog video output.
- pixelclock output (7.37 MHz / LVDS).
- I^2C control for exposure-time, video-gain and various other settings.
- die-cast housing with output on RJ45 I/O connector for S-FTP cable. (8 wires)
- internal circuits electrically connected to housing.
- power consumption: 12V at 80mA (1W)
- Neutron radiation Tolerant. [3]

RasLeD: RasNiK Light Source < Shortform >

- maskhousing with Mask, Diffuser and 3-point click-on printed circuit board.
- pcb with 9 IR-Emitters; HP type HSDL-4420-#011.
- I/O on RJ11 connector for non-shielded 4Wire cable ('Extension Cord' type).
- driven by RasMuX slewrate limited drivers; Tr = 500 us [max]
- die-cast maskhousing is electrically isolated from circuit.
- power consumption: 24V at 65mA (1.5W)
- Neutron radiation tolerant. [3]

[3] see Addendum 1, page 26.

3.3 RasMuX

The RasMuX is a video and pixelclock multiplexer and controller for RasCaMs and RasLeDs. It is the first level of multiplexing in the RasNiK system.
The prototype RasMuX, now as used with various Chamber Assembly Stations, was designed and build to fit on the chambers. This first version has I/O for 12 RasLeDs and 8 RasCaMs.

After several iterations of rearranging RasCaMs and RasLeDs over locations and systems, the final RasMuX version to be designed will have I/O for 16 RasLeDs and 8 RasCaMs. These numbers are optimized such that when one RasMuX is mounted on each Chamber, all RasCaMs and RasLeDs on that Chamber can be connected. Only the Bar Reference System will need 64 RasMuXs which are not mounted on Chambers.

The 16 RasLeD I/Os are driven in groups of 2 by 8 drivers only.

The RasMuX is controlled from the MasterMuX with JTAG control signals. At this level the JTAG control signals are LVDS. Also the power for the RasMuX is provided via its MasterMuX cable.

The RasMuX selects RasCaM and RasLeD sets - out of the 8 RasCaM and 16 RasLeD connections- for operation under JTAG control by switching on the appropriate power lines and multiplexing the incoming RasCaM video and pixelclock signals to the MasterMuX. The video signals from the RasCam is semi-differential; in the cable pair used only one wire is driven. The analog input multiplexer of the RasMuX is differential- both wires of the incoming pair are switched- and has a single differential receiving amplifier for noise and common mode rejection. In addition all incoming analog lines on the RasMuX are filtered. (Low Pass at 8MHz). This filter – with a 510Ω series resistor- also acts as ESD input protection. RasCaM settings are transmitted with I^{2}C (single ended). For the relative short length of RasCaM cable (RJ45/S-FTP Lavg=3m) this is acceptable. Power switching of the RasCaMs (+12V) and RasLeDs (+24V) is done with industrial short-circuitproof powerdevices. See also figure 5: RasMuX Schematic

The video standard used is CCIR. The video signals from the sensors are semi-differential. The output to the MasterMuX is fully differential. For test set-ups a BNC connector can be mounted to interface to a monitor directly (1Vpp video).

The pixelclock output of the RasCaMs is LVDS (Low Voltage Differential Signaling). The output to the MasterMuX is also LVDS . For test set-ups a LEMO connector can be mounted to obtain a TTL compatible pixelclock output. The RasMuX converts JTAG instructions to I^{2}C commands. The I^{2}C bi-directional bus is used to control and monitor various settings - like exposure time and video gain- in the RasCaMs.

The module requires four supply voltages, +28V, +15V, +8V and -8V, which are all supplied by the MasterMuX. Series regulators convert these voltages into +24V for the RasLeDs, +12V for the RasCaMs and +5V/-5V for internal analog & digital circuits. The series regulators also act as RasMuX input 'fuse-like' protection devices. The power outputs to the RasCaMs and RasLeDs are short-circuit proof, continuously monitored and flagged when outside nominal conditions.

The control and multiplexing functionality of the RasMuX is completely handled by standard ICs (for the logic circuits mostly lowpower HC/HCT types).

The physical appearance of the RasMuX will be a chromated aluminum box of appr. 16cm x 16cm x 4cm (WxLxH). This box will contain one board for control of 8 RasCaMs and 16 RasLeDs each. The RasMuXs are 'On Chamber' components and must be mounted electrically isolated from the Chamber. Each Chamber will have its own RasMuX. See also figure 7.

Figure 5: **RasMuX Functional Schematic**. (A5_RasMuX1a.wmf)
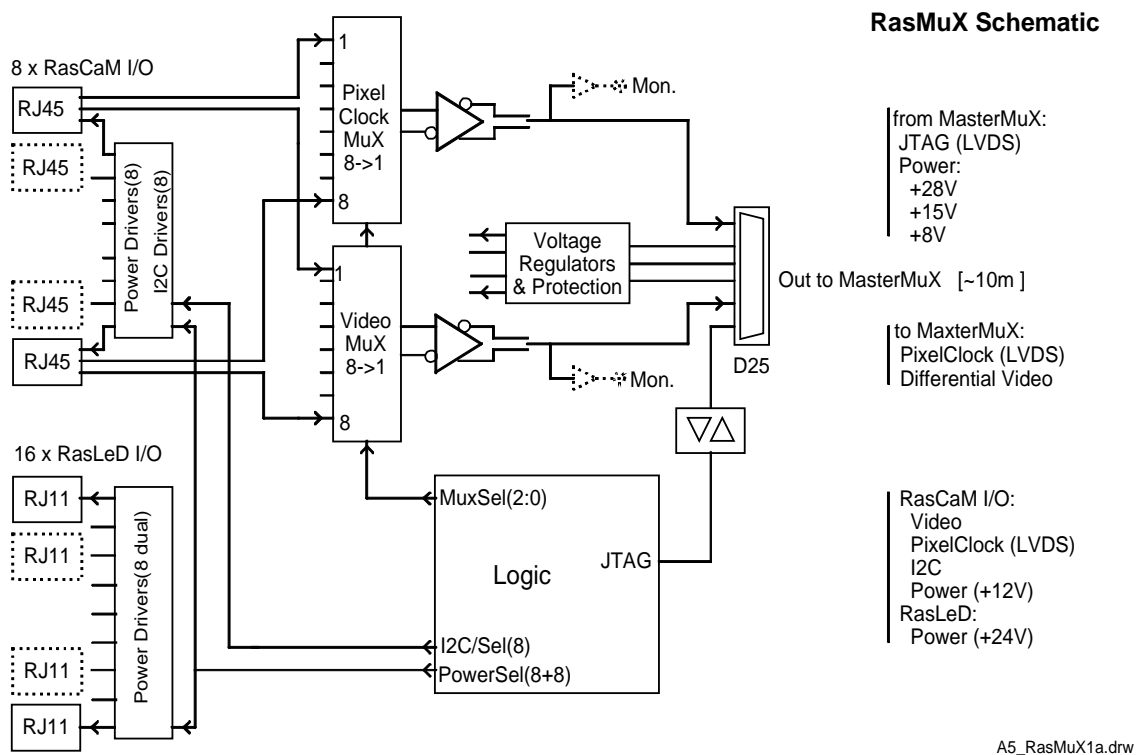
The 'On Chamber' RasMuX drives 16 RasLeDs and 8 RasCaMs.

3.4 MasterMuX:

The MasterMuX is the second level of multiplexing within the RasNiK system. It multiplexes the incoming video and pixelclock signals to USA15 and distributes power and JTAG control signals to the RasMuXs. See figure 8. The analog and digital multiplex schemes are more or less identical to the ones used in the RasMuX, but here for 16 signal sources.

A MasterMuX connects to 16 RasMuXs. This gives a total of 48 MasterMuXs or 24 MasterMuXs per side in the experiment. (for 768 RasMuXs)
With 48 MasterMuXs, the RasNiK components in the experiment are connected with 48 cables to USA15. This number is considered to be a balanced compromise between cost and reliability.

The MasterMuX is the central entry of the RasNiK system into the experiment. It is connected with long (100m) cables to the RasNiK rack in USA15. We have therefore opted for a single +28V(+/-10%) supply source from USA15. The MasterMuX acts as power converter station for the connected RasMuXs.

The incoming +28V from USA15 is converted with 'buck' regulators to +15V, +8V and –8V. These 250kHz switched mode regulators use toroide conversion aircoils. These voltages are used to supply the RasMuXs. The power outputs to the RasMuX will be made switchable to reduce overall power dissipation. Only the necessary RasMuX(s), RasCaMs and RasLeDs

will be powered upon a system request for alignment information. The internal +5V and -5V power for the MasterMuX is obtained with a linear regulators (from +8V and -8V).

The input JTAG control signals (RS485) from USA15 are buffered, used internally for multiplexer settings and re-transmitted to the RasMuXs as LVDS. The JTAG buffer scheme allows both single cast as well as broadcast JTAG messages to the RasMuXs.

The outgoing Pixelclock signals are RS485. The outgoing video signal is fully differential and has pre-emphasis –high frequency peaking- to compensate for bandwidth losses in the 100m cable to USA15.

The control and multiplexing functionality of the MasterMuX is handled by standard ICs (for the logic circuits mostly lowpower HC/HCT types).

The physical appearance of the MasterMuX will be a box of appr. 24cm x 18cm x 4cm (WxLxH). This box will contain 16 D-Sub25 connectors for RasMuX I/O and a single D-Sub25 connector for cabling to the USA15-MuX.
This single D25 connection to USA15 carries JTAG control signals (RS485) and power (+28V) from USA15 and Video an Pixelclock signals to USA15.

The MasterMuXs are 'Off Chamber' components and will be mounted on the magnet support structure, most likely at Z~0,5m, in 8 clusters in Rphi of 3 MasterMuXs each. See also figures 7 and 8.

Figure 6: **MasterMuX Functional Schematic**. (A5_MasterMuX1a.wmf)
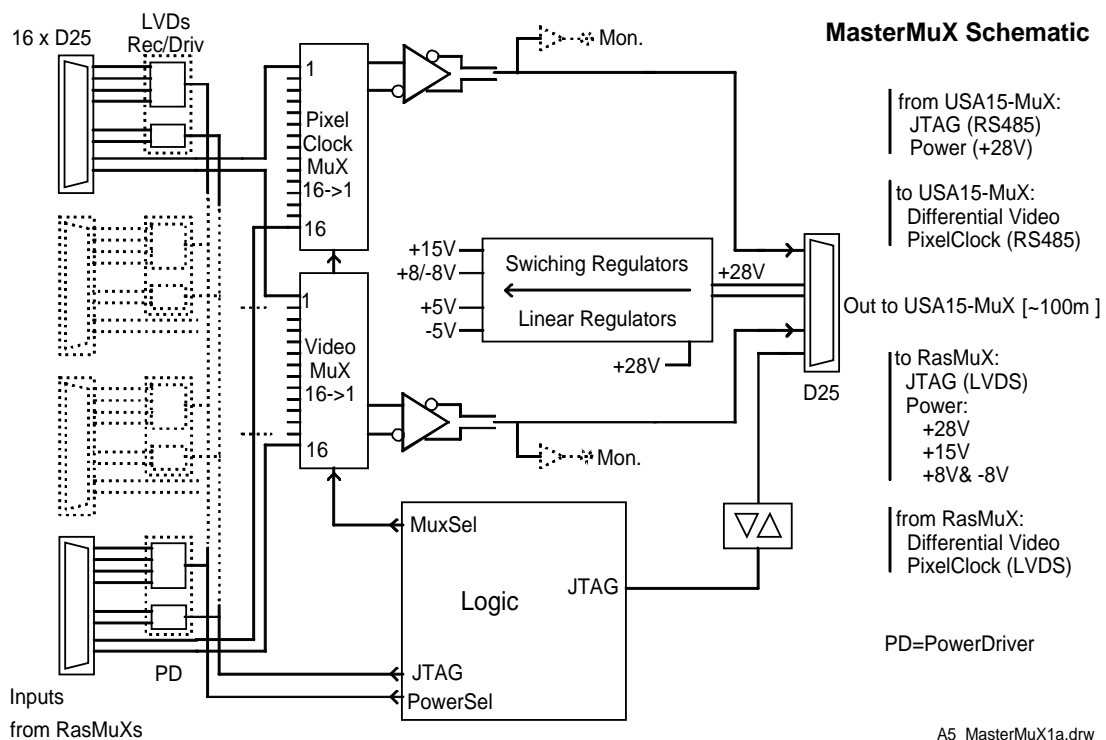
The MasterMuX drives 16 RasMuXs.

4. Locations

Figure 7: **Proposed Locations of RasMuXs and MasterMuXs**.
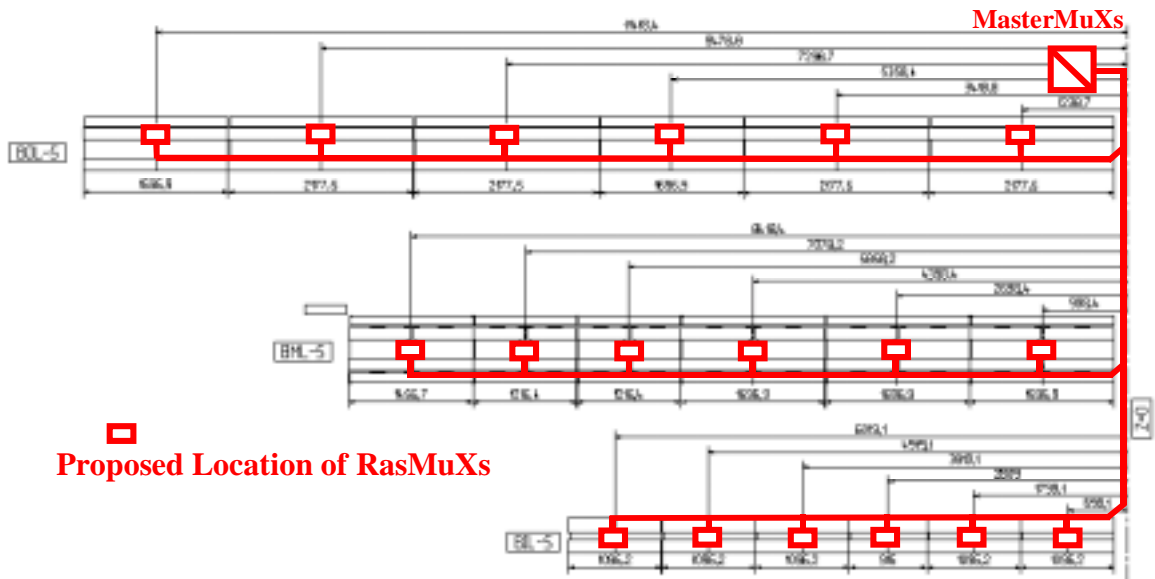
Each Chamber has its own RasMuX mounted on that Chamber.

Figure 8: **Proposed location of MasterMuXs**.
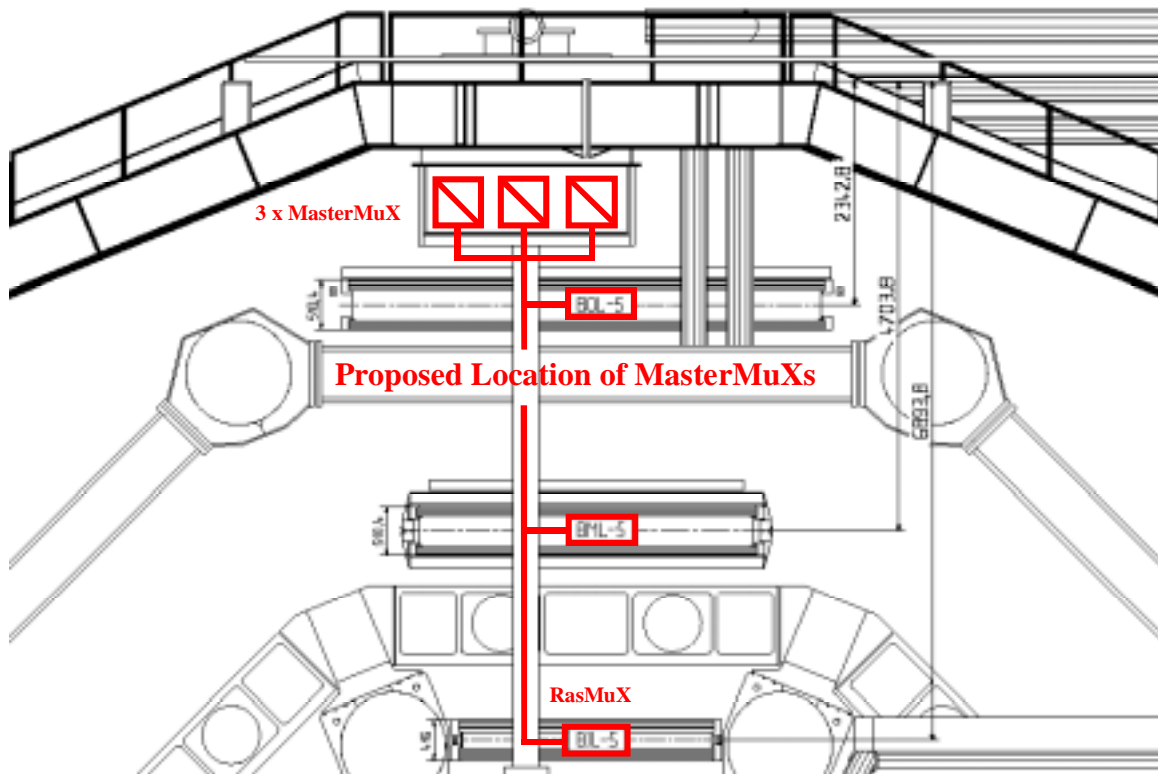
In Rphi: 8 x Triple MasterMuX Cluster = 24 MasterMuXs per Side, 48 Total.

Original drawings by S.Sidorov CERN 02.03.00

5. RasNiK in USA15

In USA15 the RasNiK video signals are digitized and analyzed to obtain system X, Y, Z translation and rotation information of the various alignments. This X, Y, Z info is then passed on to a higher system level. Also JTAG control and the power supplies will be housed in USA15.

For RasNiK in USA15 we foresee a 19inch Electronics Rack with:
- USA15-MuX.
- PCs with:
  • Video Digitizers.
  • Analyses Software (Icaras).
  • JTAG Control (Parallel I/O & Icaras).
  • Power Control/Monitor (Parallel I/O & Icaras).
  • Ethernet.
- Keyboard & Monitor for PC.
- Video Monitor.

See figure 9: RasNiK in USA15.

## 5.1 USA15-MuX

The USA15-MuX connects to the 32 MasterMuXs in the experiment with D25 cables of appr. 100m length.
These cables carry JTAG control signals (RS485) and power (+28V) to the MasterMuXs and receive video an pixelclock signals from the MasterMuXs.

The USA15-MuX will in effect be a Euro-Crate with 8 plug units for multiplexing, power and JTAG signal fanout. This third level of multiplexing will reduce the number of video and pixelclock lines to 8. (4 -to- 1 MuX units).

The 8 MuX units in the crate will be JTAG controlled in a tree type scheme. The power supplies in the USA15-MuX crate will be monitored/controlled from a PC, like the JTAG control.

With 8 Video Digitizers and an estimated analyses/cycle-time of 1s per RasCam, the 5452 installed RasCaMs will each be served at an average scanrate of once every 10 minutes. For RasCaMs at more sensitive locations the scanrate can of course be speeded up at the cost of a lower scanrate for the remaining RasCaMs.
The estimated overall analyses/cycle-time of an image source includes settling-time of the RasCaMs [*] when they are powered ON, the settling/synchronization-time of the Video Digitizer- up to ten video frames (20ms each)-, various system delays (10μs -100μs range), data transfer-times (1ms -10ms range) and the time needed for the analyses algorithm to extract X, Y, Z information from the digitized video frame . The analyses/cycle-time is largely determined by the execution time of the analyses algorithm, now 4s, but will be speeded up to <1s with future faster processors in the PCs and software optimization.

[*] The RasCaMs are sequentially powered-up and scanned.

After power-up the RasCaM normally requires a rather large number a video frames (20ms each) for finding its auto-gain and auto-exposure settings, this process can take up to a full second. By pre-powering and/or preloading the 'next' RasCaM in advance, the effective power-on settling time of the RasCaM can be reduced to zero.

The extracted X, Y, Z information is passed to a higher level system via Ethernet.

5.2 Power Supplies

The Power Supplies in the USA15-MuX crate are for both local crate use and for powering of the RasNiK components in the Experiment. These 28V power supplies will be of limited power (estimate <1kVA) because of the intelligent power switching scheme of RasCaMs, RasLeDs and RasMuXs, which are switched 'ON' when needed only. This limits the amount of power dissipated by the complete RasNiK system in the experiment to appr. 525W. See table 2.

Power Switching Scheme:
The MasterMuX power is always ON. From the 16 RasMuXs controlled by a MasterMuX only one in powered. The RasMuX powers only one RasCaM and two RasLeDs at the time. This means that per MasterMuX only one RasCam and two RasLeDs can be active.

Table 2: RasNiK total Power dissipated for components installed in UXA15:

Item	Total #	Power/p/c	# ON	Total Power
	Installed		(max)	
RasCaMs	5452	1.0W	48	~ 50W
RasLeDs	6672	1.5W	96	~ 150W
RasMuXs	768	2.5W [*]	48	~ 125W
MasterMuXs	48	4.0W [*]	48	~ 200W
All				~ 525W

[*] estimates, design not completed .

In the MasterMuXs the 28V primary supply voltage is converted with 250 kHz switching 'buck' regulators to +15V, +8V and –8V. As the MasterMuXs are 'Off Chamber' units possible EMI on the 'On Chamber' electronics is very unlikely.
Power return currents are forced back over the intended cable wires. The 100Ω resistor connected between the printed circuit grounds and the housings for ESD protection, prevents these currents from running back in/over the cable shields. See also figure 10.

5.3 PCs

with Video Digitizers, Analyses Software, JTAG Control and Supply Control/Monitor.

The RasNiK proto type system with Icaras Analyses & JTAG Software is PC based and uses PCI Video Digitizers (Frame Grabber DT3152 from Data Translation). The video digitizer could be any commercially available 8 bit grayvalue type. The Data Translation DT3152 however does a pixelsynchronous digitization and reduces the video frame to pixel (384 x 287) data, producing an output file of 128kB only.

For the final installation of RasNiK components in USA15 we foresee 5 PCs, i.e.

- 4 PCs with 2 PCI Video Digitizers each, w/o keyboard & monitor.
- 1 PC with keyboard & 19inch monitor for supervising and general communication (Ethernet) to the 4 Digitizer PCs (Local Hub) and the higher system level.

The 4 Digitizer PCs will use their abundant Pentium III (or higher) processing power for image analyses. Only the analyses results will be outputted on Ethernet. They will also provide JTAG control (4x) from the Icaras software via the Parallel I/O port to the USA15-MuX for the RasNiK components in the Experiment.

The Supervisor PC will provide JTAG control for the settings in the USA15-MuX crate and control/monitor the power supplies in this crate with JTAG (Icaras software) via its Parallel I/O port.

Video Monitor

This video monitor will be used for general purposes, like visual checks on RasCaM image quality. The video monitor is connected to the USA15-MuX.

Figure 9: **RasNiK 19inch Rack with Multiplexers and Digitizers in USA15** (A5_Sys2a.wmf)
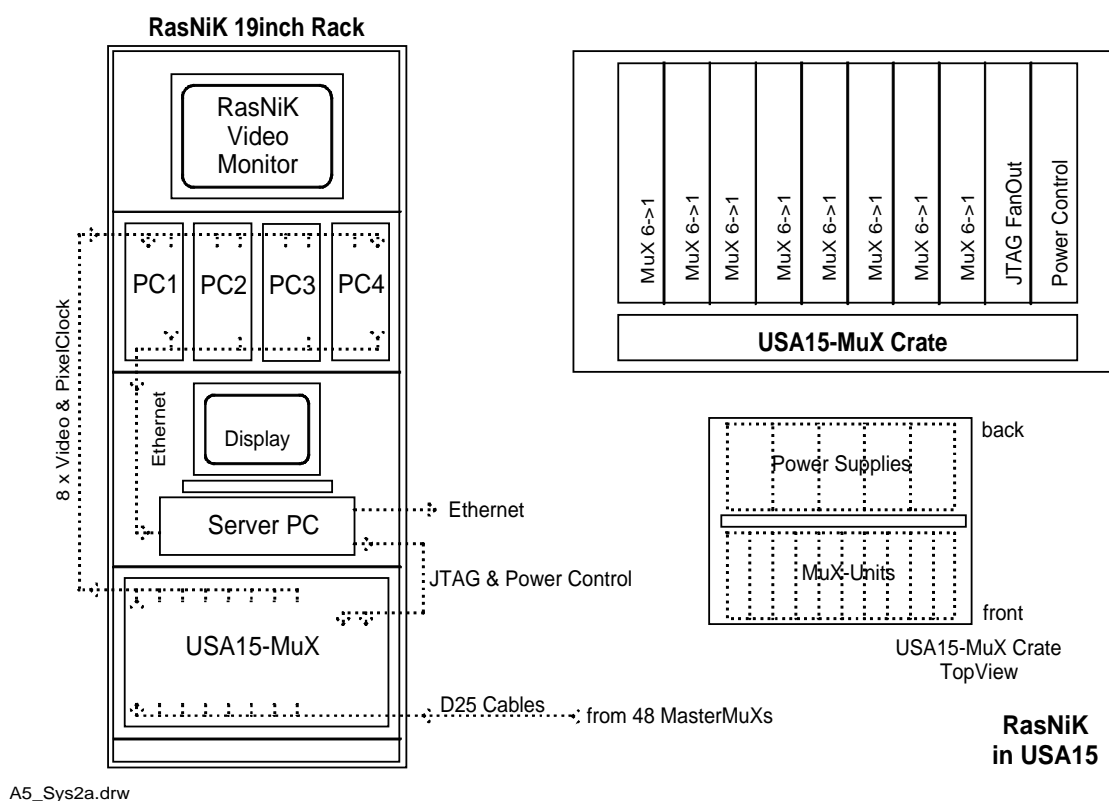
The 48 MasterMuX cables are routed to the USA15 6->1 MuX units in a Euro crate. This crate also provides al the power needed by the RasNiK components in UXA15. From the USA15-MuX crate 8 Video and Pixelclock connections are made to the Video Digitizers- of which there are two in each of the four PCs.

6. Cable Details and Specifications:

1. RasCam -to- RasMuX:
> Average length: 3m
> Cable type: FCC-68 CAT5 S-FTP LSFROH - IEC332-3C (conform CERN IS-23)
> Connector type: RJ45 shielded
> For 5500 RasCaMs at an average length of 3m, ~17 km of this cable is needed.

2. RasLeD -to- RasMuX:
> Average length: 3m
> Cable type: 4Wire 'extension cord' LSFROH - IEC332-3C (conform CERN IS 23)
> Connector type: RJ11 unshielded
> For 6700 RasLeDs at an average length of 3m, ~20 km of this cable is needed.

3. RasMuX -to-MasterMuX
> Average length: 10m
> CERN cable type MCA24P, 12 pairs, shielded, (conform CERN IS 23) for D-sub 25
> For 768 RasMuX cables of 10m average length, ~ 8 km of this cable is needed.

4. MasterMuX -to- USA15-MuX
> Average length: 100m
> CERN cable type MCA24P, 12 pairs, shielded, (conform CERN IS 23) for D-Sub 25
> For 48 MasterMuXs, ~5km of this cable is needed.

Summary of cables and cable lengths needed: (rounded figures)

RJ45 type	5500x	CAT5 S-FTP	17 km	[*]
RJ11 type	6700x	4Wire	20 km	[*]
D25 type	820x	MCA24P	13 km	

[*] For the RasCaM and RasLeD cables -RJ45 and RJ11 types- NIKHEF will tender for the full cable lengths needed.

Notes:
- CERN cable type MCA24P: SCEM Nr: 04.21.48.324.9

- LSFROH = Low Smoke - Fire Retardant – Zero Halogen

- CERN IS-23:
> CRITERIA AND STANDARD TEST METHODS FOR THE SELECTION OF ELECTRIC CABLES, WIRES AND INSULATED PARTS WITH RESPECT TO FIRE SAFETY AND RADIATION RESISTANCE

> Can be found at:
> http://www.cern.ch/CERN/Divisions/TIS/safdoc/IS/is23/is23_en.html

- RJ45 connected according to TIA/EIA T568B

7. Grounding and Shielding

The ATLAS Muon Grounding Policy [1] states that [….] alignment devices mounted directly on the Faraday enclosure represent a potential source of groundloop difficulties that must be prevented by mounting these devices electrically isolated.
For RasNiK these devices, although not directly mounted on the Faraday cage, are the RasCaMs, RasLeDs and RasMuXs, which are all 'On Chamber' components.

Grounding of the RasNiK devices:
See also figure 10, RasNiK Grounding and Shielding Schematic

- RasCaM: housing electrically coupled with internal circuits for shielding, housing must be mounted electrically isolated from the chamber mechanics.

- RasLeD: mounting is electrically connected to chamber mechanics, stand-offs are electrically isolated from RasLeD printed circuit board.

- RasMuX: housing electrically coupled with 100 Ω resistor to internal circuits, housing must be mounted electrically isolated from the chamber mechanics.

- MasterMuX: housing electrically coupled with 100 Ω resistor to internal circuits, housing must be mounted electrically isolated from the magnet support structure.

For all RasNiK components the cable shields are connected to the various housings and mountings.

7.1 Shielding:

All housings, mountings and covers are die-cast zinc/aluminum (Zamak) or chromated aluminum plate.

All cables are shielded with both foil and braiding, except for the RasLeD cable; this is an unshielded RJ11 cable. The RasLeDs are switched on with 24V at 60mA. The powerswitch used –in the RasMuX- has a rise-time of 500 us [max]. This limits the radiated EMI. Also in the –flatcable like- RJ11 cable the two inner wires are used for 24V currentfeed to the RasLeD and the two outer wires for current return. This has a shielding effect.

[1] ATLAS Muon Grounding, 2 December 1997, John Huth, John Oliver

Mounting of RasNiK Components: Locations & Type

Component	Location	Mounting Type	Cable I/O to
RasCaM	On Chamber	Isolated	RasMuX
RasLeD	On Chamber	Isolated	RasMuX
RasMuX	On Chamber	Isolated	MasterMuX
MasterMuX	Off Chamber	Grounded	USA15

7.2 Signals and Cable types

All cables are shielded with both foil and braiding except for the RasLeD cable.
The choice for both foil and braid shielding for the RasCaM, RasMuX and MasterMuX cables guarantees a 100% closed cable shield with low inductance and low resistance.

Digital signals on the short cables; RasCaM and RasMuX, are LVDS. LVDS was chosen because of the low power dissipation of the associated driver and receiver circuits. The low common mode range - +1V/-1V- of the LVDS circuits is sufficient for 'On Chamber' and short cable distances in the experiment, where large common mode voltage are not expected.

For the long cable distance -100m- between UXA15 and USA15 -MasterMuX to USA15-MuX- LVDS is not an option. Here RS485 is used for the digital signals. The common mode voltage range of RS485 is +12V/-7V which should suffice for a UXA15-USA15 cable connection.

Mounting of RasNiK Components: Signal and Cable types.

Item	Cable	Type	Signals		
			Analog	Digital	Power Input
RasCaM	CAT5 S-FTP	Shielded	Video SE	PixelClock LVDS I^2C TTL SE	+12V/80mA
RasLeD	4Wire RJ11	Unshielded	SE Tr = 500 us		24V/60mA
RasMuX	MCA24P [*1]	Shielded	Video DS	PixelClock LVDS JTAG LVDS	+28V +15V +8V -8V
MasterMuX	MCA24P [*1]	Shielded	Video DS	PixelClock RS485 JTAG RS485	+28V

SE = Single Ended   DS = Differential Signals

Video: BW < 2.5 MHz, Vpp=1V [max.]
Pixelclock frequency = 7.37 MHz [typ.]

 [*1] SCEM: 04.21.48.324.9, 12 pairs, 24AWG, shielded.

Signal Levels:
LVDS: ~350mV, differential, 100Ω, rise-time ~1ns.
RS485: ~2.5V, differential, 100Ω, rise time ~20ns.

Figure 10: **RasNiK Grounding and Shielding Schematic** (A5_GN_Shield.wmf)
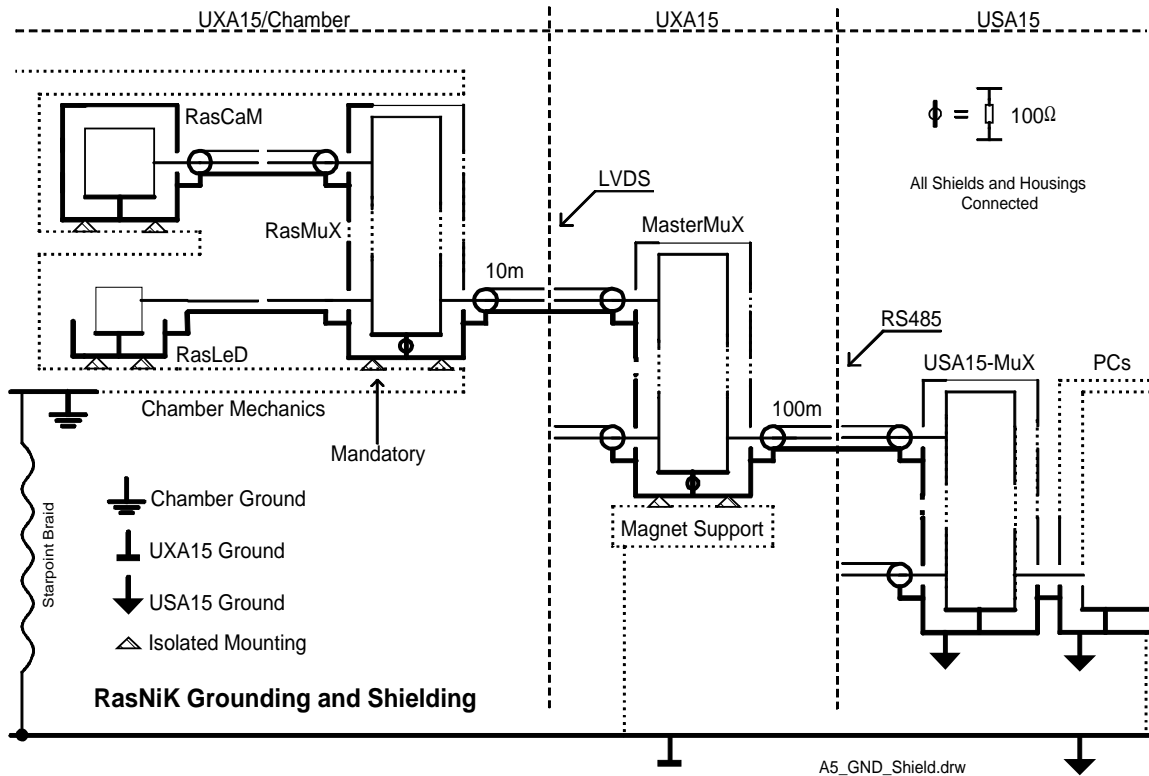
All cable shields are connected to the housings. All UXA15 RasNiK components are mounted electrically isolated to prevent unwanted groundloops. Ground reference is derived from the RasNiK rack in USA15. Power return currents are forced back over the intended cable wires. The 100Ω resistor connected between the printed circuit grounds and the housings for ESD protection, prevents these currents from running back in/over the cable shields.

8.

Picture 1: **RasCaM printed circuit: Board sensor side**.
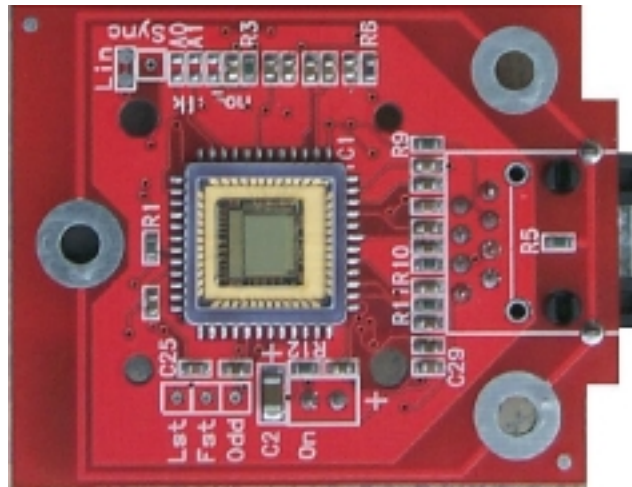
ET38110.04.01.v1
Boardsize: 42mm x 54mm
Sensor: LCC40 (14mm x 14mm)

Picture 2: **RasLeD printed circuit board LED side**.
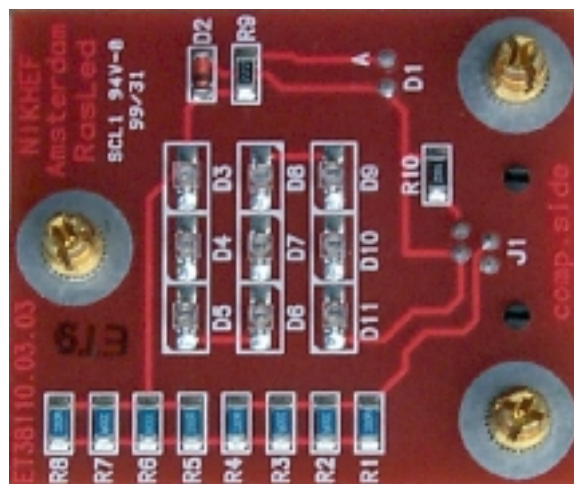
ET38110.03.03.v2
Boardsize 42mm x 52mm
LEDs: HP HSDL-4420#011

Picture 3: **Proto-type RasMuX printed circuit board**.
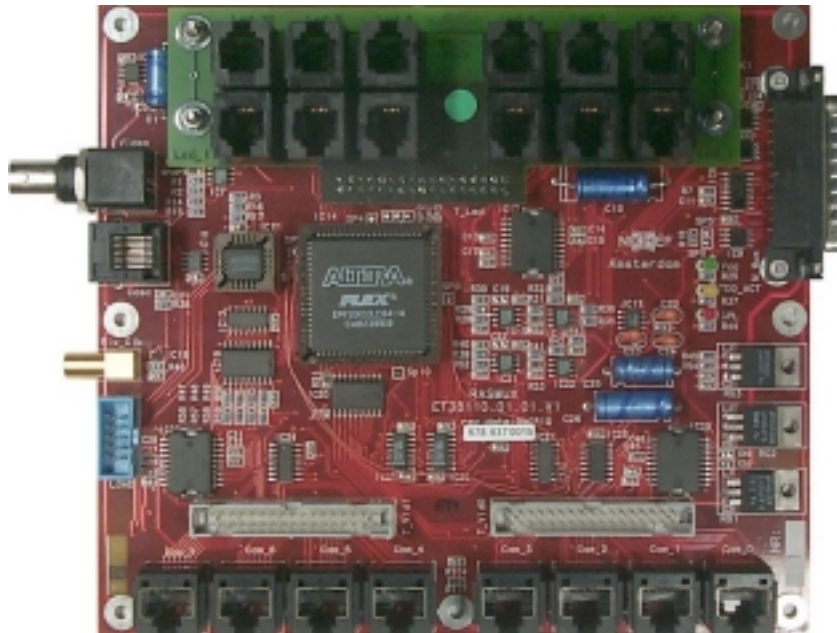
ET38110.01.01.v1
Boardsize: 160mm x 180mm
I/O for 8 x RasCam & 12 x RasLeD

The final RasMuX version to be installed on all Chambers will be sligthly smaller.
Complete with housing the estimated size is 16cm x 16 cm x 4cm (WxLxH).

9. Addendum: extract from:

The Radiation Hardness
of
RasNiK components

H. van der Graaf
NIKHEF, Nov 8, 1999

Abstract

Components for the RasNiK alignment systems, to be applied in the ATLAS muon spectrometer, have been irradiated by neutrons. We found that the performance of essential components within RasNiK, notably LEDs and CCDs or CMOS multi-photodiode arrays, is significantly affected. The reduction of the light output of most of the irradiated LEDs was the most dramatic effect. The CCDs and CMOS diode-arrays could stand the radiation better.

Fortunately, LEDs from Hewlett Packard survived the radiation good enough. The combination of a CMOS diode array and the HP-LEDs has shown to be sufficiently radiation hard for application in the ATLAS Muon Spectrometer. Based on the present knowledge of maximum radiation levels to be encountered, such a RasNiK system can withstand the dose equivalent of 30 years LHC at full luminosity, in the worst region of the muon spectrometer, including a safety factor 5.

[…..]

Conclusions

We conclude that a RasNiK made from LEDs from HP, and the CMOS image sensor VV5430 is sufficiently radiation hard to be applied in the ATLAS Muon Spectrometer: a test in which both components will form a RasNiK system has been carried out, in the meantime, on October 20, 1999, confirming this conclusion. Future tests are planned to measure the radiation hardness of less essential components, to be applied in the image sensor card and the readout circuitry, located in the zone of radiation. Tests with 50 MeV neutrons are due to take place in 2000, and a test with gammas will be performed at CERN.

RasLeD & RasCaM Distribution — **10. Table 3**

HvdG, NIKHEF
1/20/00
CG,Saclay
2/18/00

PR
3/3/00

Chamber Type	# Chambers	InPlan # RasCaM	InPlan # RasLeD	Praxial # RasCaM	Praxial # RasLeD	Axial # RasCaM	Axial # RasLeD	Projective # RasCaM	Projective # RasLeD	Reference Bar System # RasCaM	Reference Bar System # RasLeD	Reference Bar System # SacLeD	BIL-BIR # RasCaM	BIL-BIR # RasLeD	Remarks	Total # RasCaM	Total Ras/SacLeD
BIS-E1-Bc	8	1	1	2	2	2				2					2),6)	7	3
BIS-E2-Bc	8	1	1	2	2		2			2					2),6)	5	5
BIS	32	1	1	4	4	2	2								3)	7	7
BIS	80	1	1	4	4	2	2									7	7
BIL-E1-P-Bs	12	2	4	2	2	2			2			2			2),3)	6	10
BIL-E2-P-Bs	12	2	4	2	2		2		2			4			2),3)	4	14
BIL-P	12	2	4	4	4	2	2		2						3)	8	12
BIL	12	2	4	4	4	2	2								1),3)	8	10
BIL-Bs	12	2	4	4	4	2	2					2			1),3)	8	12
BIL-P-Bs	12	2	4	4	4	2	2		2			2			1),3)	8	14
BIL/R-E1-P-C	4	2	4	2	2	2			1					2	2),3)	6	9
BIL/R-E2-P-C	4	2	4	2	2		2		1					2	2),3)	4	11
BIL/R-Bs	4	2	4	4	4	2	2					1			1),3)	8	11
BIL/R-C-Bs	4	2	4	4	4	2	2					1		2	1),3)	8	13
BIL/R-P-Bs	4	2	4	4	4	2	2		1			2			1),3)	8	13
BIL/R-P-C	4	2	4	4	4	2	2		1					2	3)	8	13
BIR-E1	2	2	4	2	2	2									2),3)	6	6
BIR-E2	2	2	4	2	2		2								2),3)	4	8
BIR	4	2	4	4	4	2	2									8	10
BIR-Bs	4	2	4	4	4	2	2					1			1),3)	8	11
BIR-P-C	4	2	4	4	4	2	2		1				1		3)	9	11
BIR-C-Bs	4	2	4	4	4	2	2						1	1	1),3)	9	11

BIR-P-Bs-C	8	2	4	4	4	2	2		1			1	1	1),3)	9	12
BMS-E1	6	2	4	2	2	2								2),6)	6	6
BMS-E2	6	2	4	2	2		2							2),6)	4	8
BMS-Bs	24	2	4	4	4	2	2					2		1),3)	8	12
BMS	36	2	4	4	4	2	2								8	10
BMF-E1	4	2	4			2	2								4	6
BMF-E2-Bs	4	2	4			2	2					2		1),3)	4	8
BMF-Bs	4	2	4			4	4					2		1),3)	6	10
BML-E1-P-Bc	16	2	4	2	2	2				2				2),3)	8	6
BML-E2-P-Bc	16	2	4	2	2		2			2				2),3)	6	8
BML-P	16	2	4	4	4	2	2							3)	8	10
BML-Bs	16	2	4	4	4	2	2					2		1),3)	8	12
BML-P-Bs	16	2	4	4	4	2	2					2		1),3)	8	12
BML	16	2	4	4	4	2	2								8	10
BOS-E1-Bs	6	2	4	2	2	2						2		2),6)	6	8
BOS-E2-Bs	6	2	4	2	2		2					2		2),6)	4	10
BOS-Bs	12	2	4	4	4	2	2					2		1),3)	8	12
BOS	48	2	4	4	4	2	2								8	10
BOL-E1-P-Bc	16	2	4	2	2	2		2		2				2),3)	10	6
BOL-E2-P-Bc	12	2	4	2	2		2	2		2				2),3)	8	8
BOL-E2-P*-Bc	4	2	4	2	2		2	1		2				2),3),5)	7	8
BOL-P	16	2	4	4	4	2	2	2						3)	10	10
BOL-Bs	16	2	4	4	4	2	2					2		1),3)	8	12
BOL-P-Bs	16	2	4	4	4	2	2	2				2		1),3)	10	12
BOL	16	2	4	4	4	2	2							3)	8	10
BEE	32	2	4												2	4
BOF	16	2	4	4	4	2	2								8	10
BOG-E1-Bs	2	2	8	2	2	2						1		4),6)	6	11
BOH-E1-Bs	2	4	4	2	2	2						1		4),6)	8	7
BOG-E2-Bs	2	2	8	2	2		2					1		4),6)	4	13
BOH-E2-Bs	2	4	4	2	2		2					1		4),6)	6	9
BOG	10	2	8	4	4	2	2							4)	8	14
BOH	10	4	4	4	4	2	2							4)	10	10
BOG-Bs	4	2	8	4	4	2	2					1		1),4),3)	8	15

BOH-Bs	4	4	4	4	4	2	2					1			1),4),3)	10	11
Ref-plate do	32									8		4			1)	8	4
Ref-plate up	32									6		4			1)	6	4
Total:	748	1276	2424	2264	2264	1164	1164	124	124	608	0	664	16	32			

Total RasCaM:	**5452**
Total Ras/SacLeD:	**6672**
Total RasCaM without In-plane:	**4176**
Total RasLeD without In-plane:	**3584**

Notes:
1) SacLeD = Led doublet. RasMuX RJ 11, 24 V, required.
2) 'E1' : chamber at the left end of a layer, 'E2': chamber at the right end of a layer.
3) 'P': chamber with projective alignment platform, 'Bs': chamber with Ref. System image source, 'Bc': chamber with ref system RasCaM.
   'C': chamber with a BIL-BIR connection.
4) Sensors for BOG-BOH connection added to the In-plane list.
5) One missing projective ligne in the rail sector.
6) Continuous layer without interruption at Z=0.