



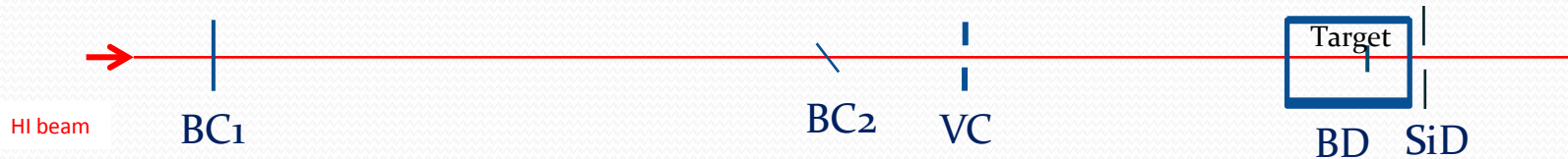
Trigger system of BM@N experiment

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Outline

- Requirements
 - Beam line + equipment
 - Architecture choice
- Hardware
 - Architecture
 - Motherboard and Mezzanine cards
- Software
 - Architecture
 - Control and monitoring

Requirements -> Beam line



Scintillation Detector	Photodetector	Scintillator	Operation in magnetic field
BC ₁	XP2020	Plastic scintillator D150x3 mm	No
BC ₂ (T ₀)	MCP-PMT PP2365E	Plastic scintillator D20x0.8 mm Angle 45°	Yes
VC	XP2020	Plastic scintillator D100x10 mm hole D27 mm	Yes
BD	SiPMs (Sensl) 6 x 6 mm	BC-418 plast. scintillator 150x7x7 mm 40 units	Yes
SiD	64 radial strips	Silicon D86x0.3 mm hole D32 mm	Yes

Requirements->Detectors I



To detector (BC2)

Photodetector
18mm MCP-PMT

TYPE
PP0365G



Barrel detector

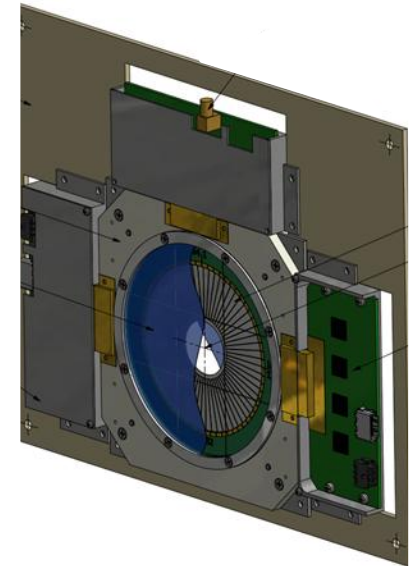
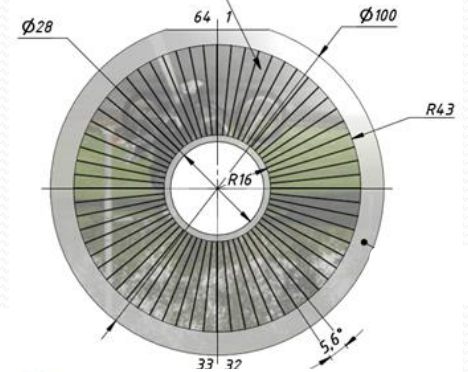
40 scintillation strips
with SiPM readout



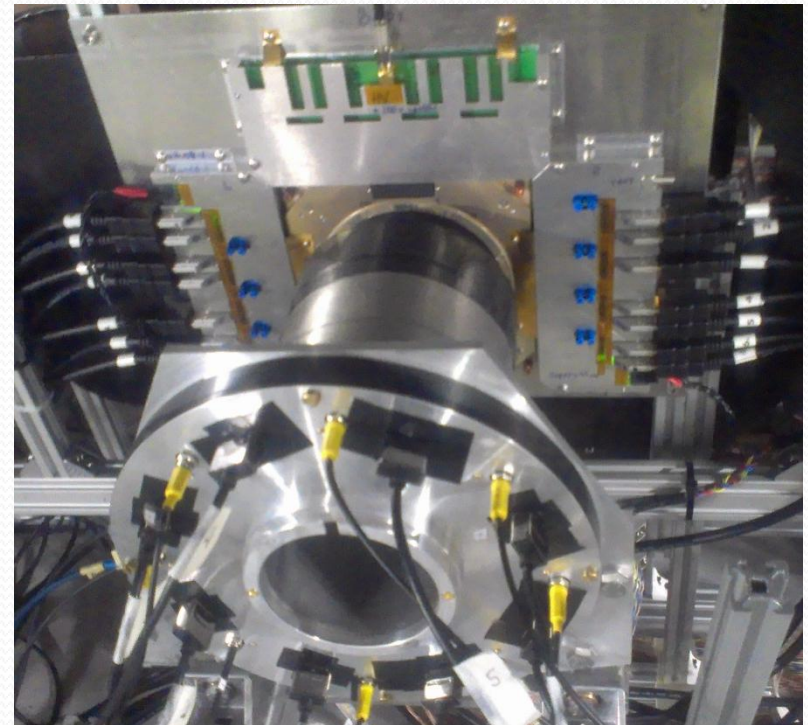
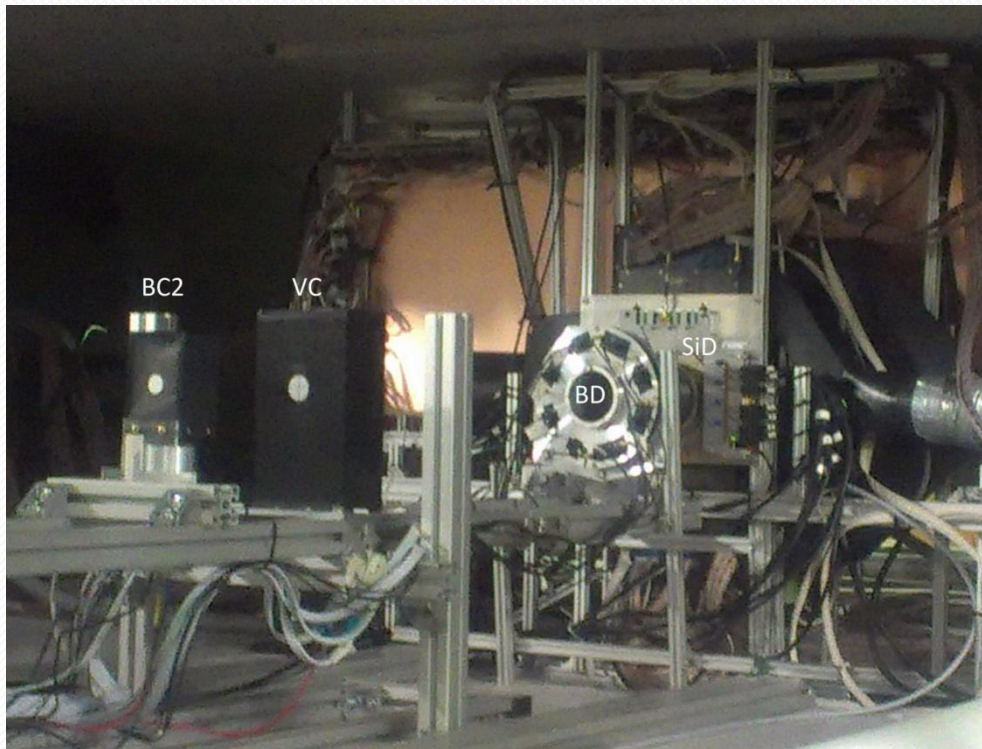
Si detector

64 radial strips

Active area



Requirements -> Detectors II





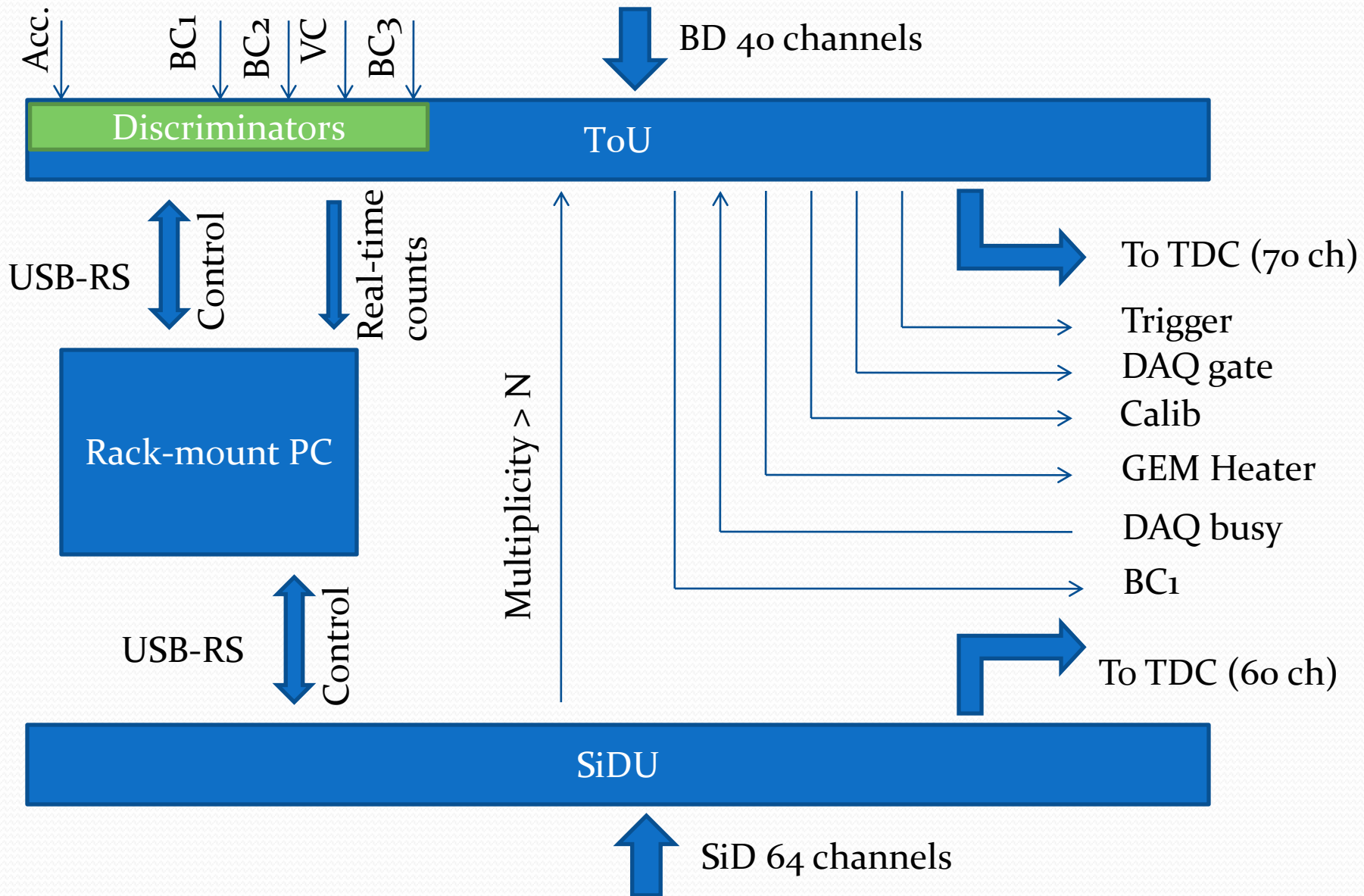
Requirements I

- We have to use short cables
- The trigger units should be installed in the restricted access area
- Adjustments and control should be done remotely
- Trigger system should generate a trigger signal based on particle multiplicity in the Barrel Detector and Si detector
- We should use two trigger units – ToU and SiDU connected by LVDS
- The rack contains NIM crate with extra equipment
- The control PC is a rack-mount industrial PC located in the trigger system rack

Requirements II

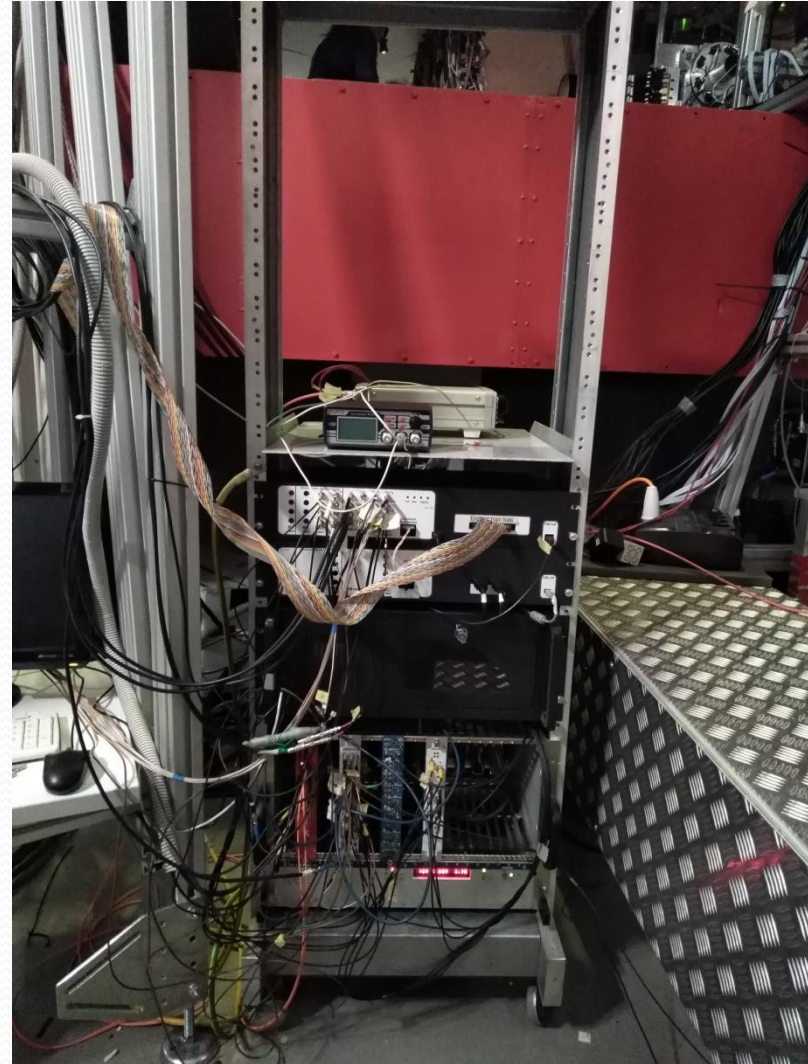
- All input signals should be sent to TDC to get event timing
- Trigger unit should generate gate and trigger signals to subsystems
 - Spill gate
 - LED calibration gate
 - LED flash signal
 - GEM Heating signal
- Trigger unit should generate beam/calibration event flag signal to DAQ
- Trigger system contains PMT HV power supply (by HVSys, Dubna) and SiPMT BV power supply (self-made)

Requirement->Architecture



Requirements->realization

- Trigger system rack located near the magnet
- No magnetic field influence observed
- No radiation damage or SEU observed

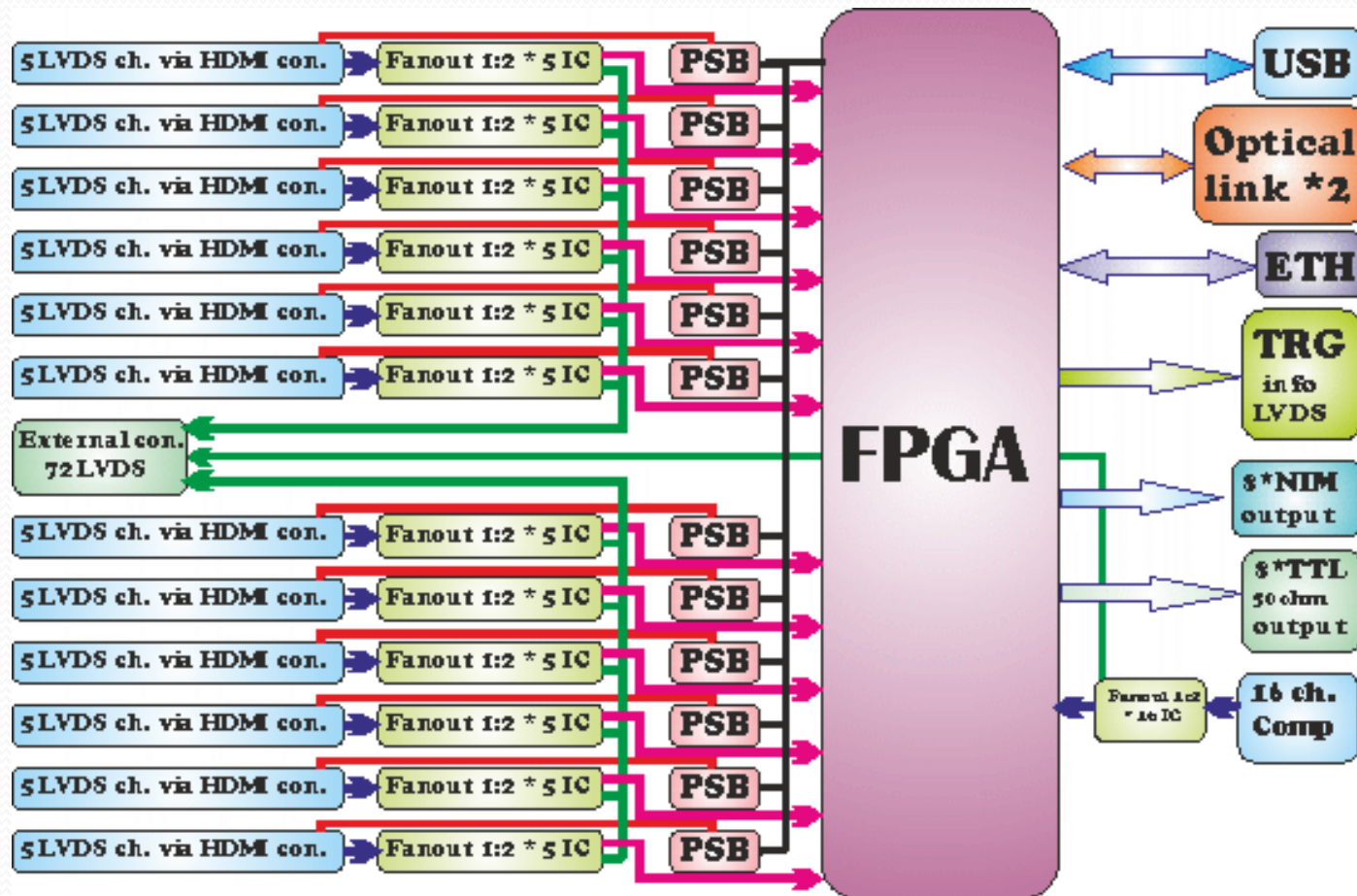


Hardware I

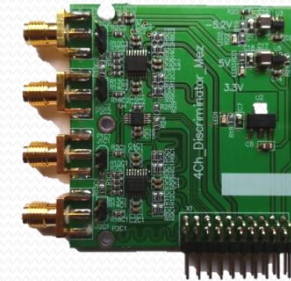
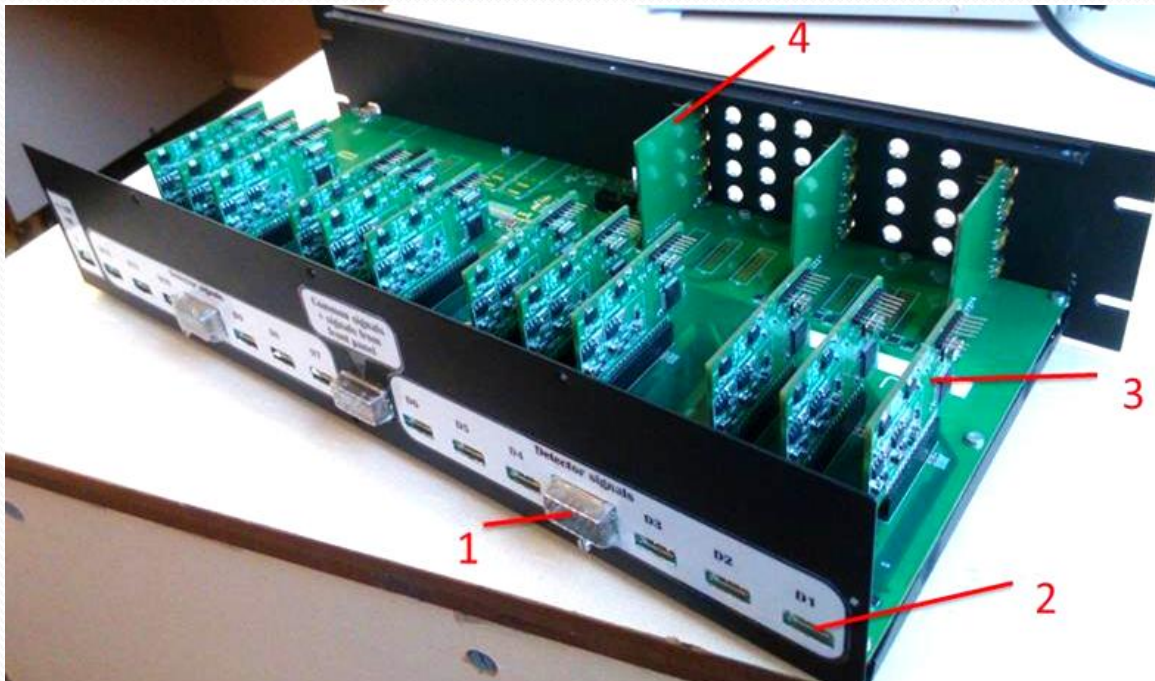


- Trigger unit consists of
 - Mother board containing
 - FPGA Altera Cyclon5
 - Low jitter signal splitters
 - USB, Ethernet and Optical link interfaces
 - Mezzanine boards
 - 4 Input boards with discriminators, 4 channels each
 - 4 Output boards – NIM signal, 4 channels or
 - 4 Output boards – 50 Ohm TTL , 4 channels
 - 12 LV power supplies, +8V adjustable ,+8V adjustable, -7.2V fixed
 - LVDS output buffer

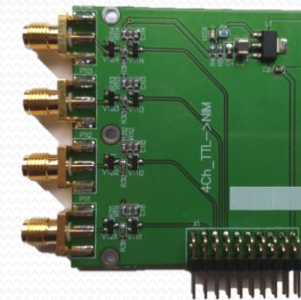
Hardware II



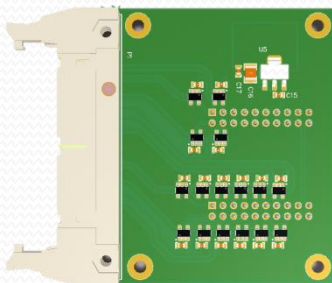
Hardware III



Input module



Output NIM module



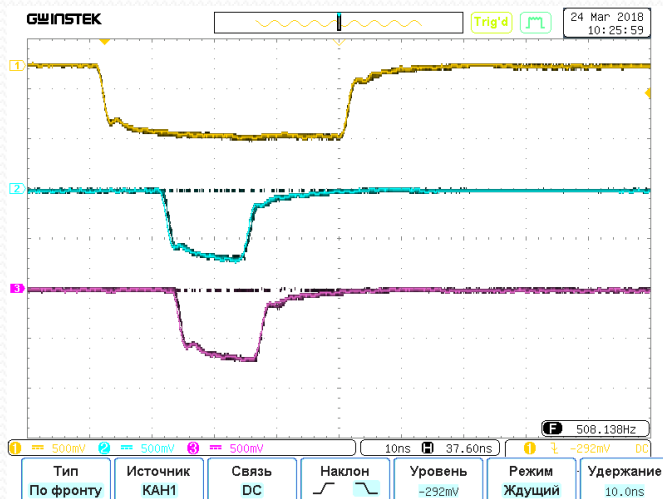
Output LVDS module



Output 50 Ohm TTL module

Hardware IV -> features

- ToU Logics contains up to 12 adjustable delay lines and shapers
- Delay and shaper settings could be adjusted with ~ 0.7 ns step
- ToU contains 4 multiplexers providing connection to the logics key points for simple trigger adjustment



BC₁, BC₂ and Beam_Trigger



BC₁, SiD and DAQ_Trigger

Hardware -> Summary



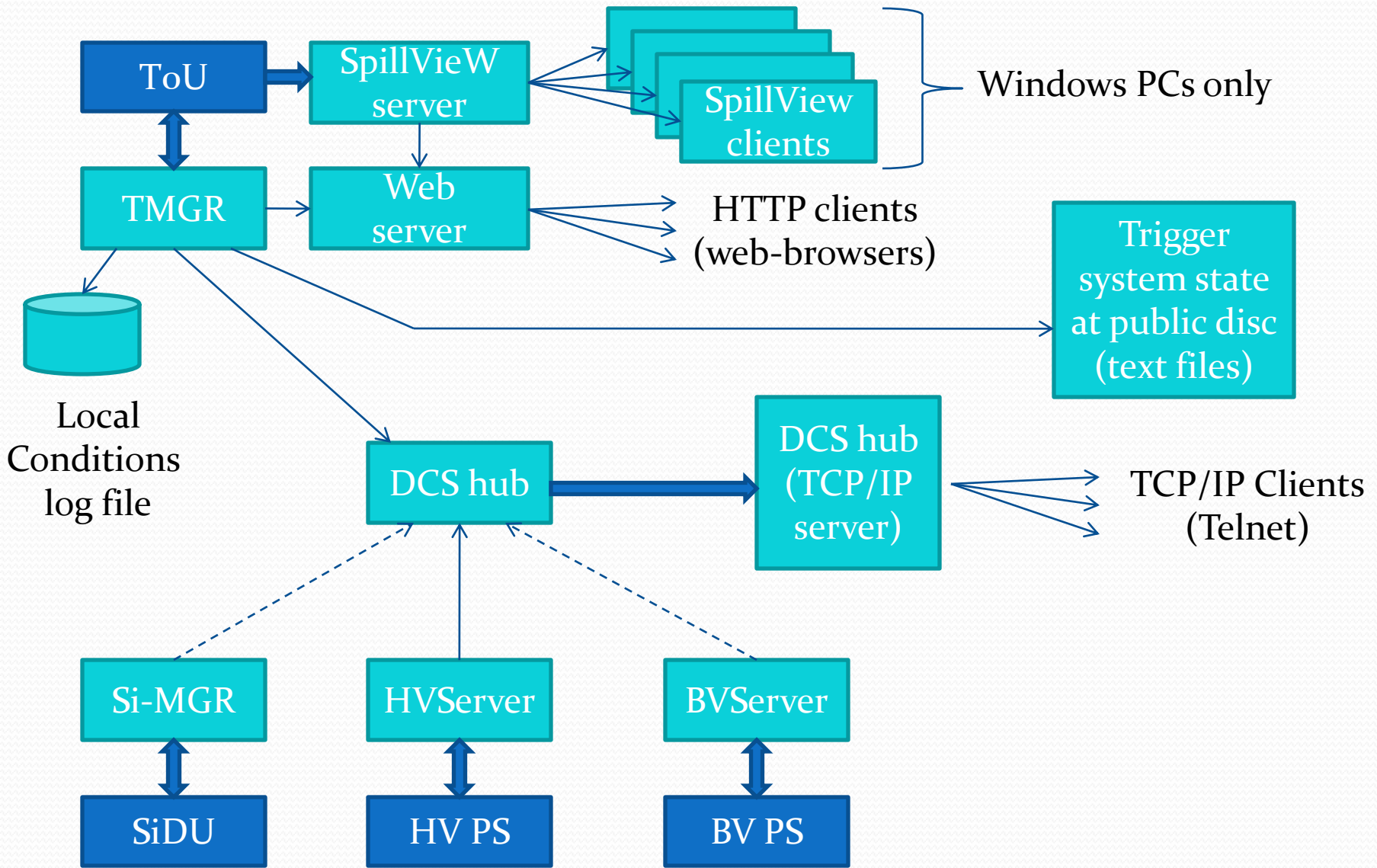
- Developed in 2015
- Used in experiments BM@N and SRC
- No electronics failures observed
- Mechanically damaged Molex connectors -> replaced

Software -> requirements

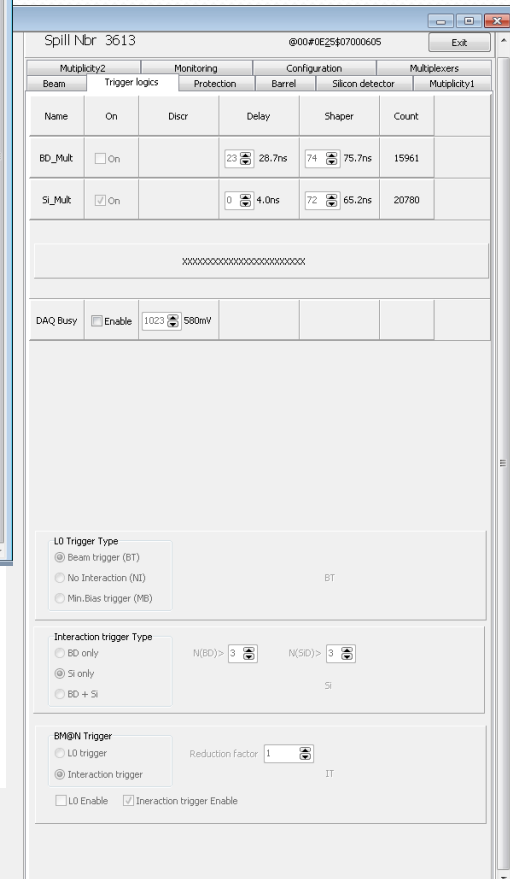
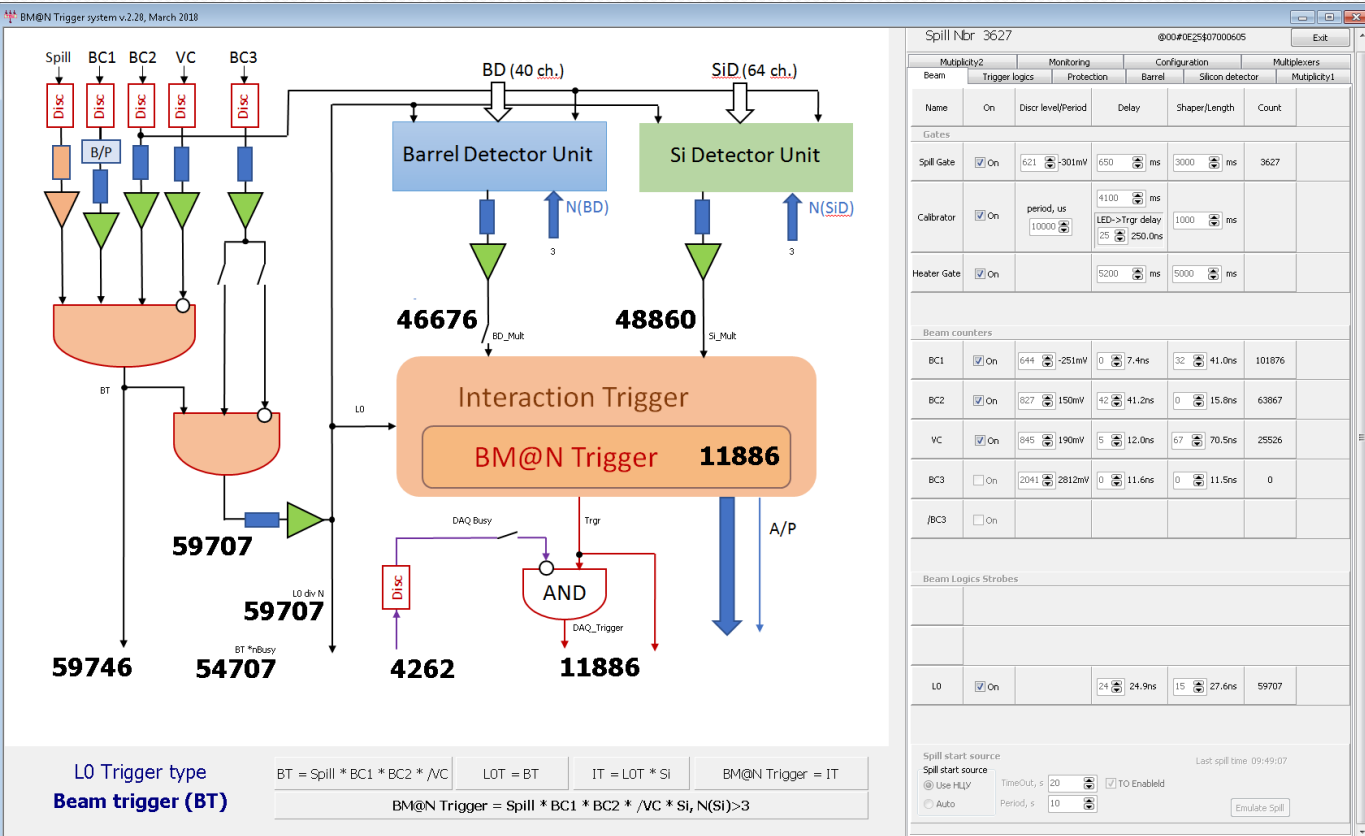


- Software should allow to the shifters to select a trigger type in a simple way
- ToU hardware has > 100 controls => software should have extended GUI
- The spill data information should be presented to the BM@N shifters and to the accelerator shifters => client/server architecture
- The actual trigger system state should be sent to the MN@N DCS

Software -> architecture



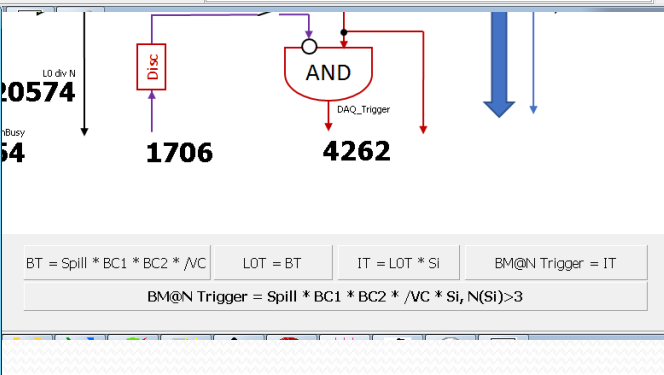
Software -> ToU manager I



LV Control

Configuration name: LV_Coolp_Luc2

	Settings	Read Back Settings	Actual Values
1 0-4	5.000	5.200	5.000 5.200
2 5-9	5.000	5.200	5.000 5.200
3 10-14	5.000	5.300	5.000 5.300
4 15-19	5.000	5.200	5.000 5.200
5 20-24	5.000	5.200	5.000 5.200
6 25-29	5.000	5.300	5.000 5.300
7 30-34	5.000	5.200	5.000 5.200
8 35-39	5.000	5.200	5.000 5.200
9 BC2	4.700	4.700	4.700 4.700
10 VC	5.000	5.000	5.000 5.000
11 BC3	5.000	5.000	5.000 5.000
12 ch12	4.000	5.000	4.000 5.000



Software -> ToU manager II



Spill Nbr 3624 @00#0E25407000605

Multiplicity2		Monitoring		Configuration		Multiplexers	
Beam	Trigger logics	Protection	Barrel	Silicon detector	Multiplicity1		
Barrel counts							
3806	4388	4118	3738	6685	4907	4263	4569
4956	3965	5575	5639	6347	6053	4652	6392
6664	9285	12892	6068	20247	28362	34664	29942
15272	42327	39325	32317	34702	41251	28744	25493
30188	19320	35950	17142	16903	9739	7962	22368

Channel # XXXXXXXX

Spill Nbr 3634 @00#0E25407000605

Ack. All Take last 20 spills as a reference Take as Ref

Beam intensity

BC1 **166585**

BC1_in **167816**

BT **98432**

Beam focusing

BT/BC1 **0.5908**

Beam background

VC/BC1 **0.2417**

Trigger monitoring

MinBias **98433**

No interaction **0**

Trgr **19643**

MinBias/BT **1**

noInteract/BT **0**

Trgr/BT **0.1995**

Trgr_Bsy/Trgr **1**

BT_Bsy/BT **0.8647**

Spill Nbr 3631 @00#0E25407000605

Beam	Trigger logics	Protection	Barrel	Silicon detector	Multiplicity1
Multiplicity2	Monitoring	Configuration			
MUX1					
<input type="radio"/> 0 BC1_inDelOS	<input type="radio"/> 8 BT	<input type="radio"/> 9 L0_inDelOS	<input type="radio"/> 10 BD_Mult_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 Min_Bias
<input type="radio"/> 1 BC2_inDelOS	<input type="radio"/> 9 L0_inDelOS	<input type="radio"/> 10 BD_Mult_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Bias	<input type="radio"/> 13 L0
<input type="radio"/> 2 VC_inDelOS	<input type="radio"/> 10 BD_Mult_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Bias	<input type="radio"/> 13 L0	<input type="radio"/> 14 BD_Mult
<input type="radio"/> 3 BC3_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Bias	<input type="radio"/> 13 L0	<input type="radio"/> 14 BD_Mult	<input type="radio"/> 15 SID_Mult
<input type="radio"/> 4 BC1	<input type="radio"/> 12 No_Bias	<input type="radio"/> 13 L0	<input type="radio"/> 14 BD_Mult	<input type="radio"/> 15 SID_Mult	
<input checked="" type="radio"/> 5 BC2	<input type="radio"/> 13 L0				
<input type="radio"/> 6 VC	<input type="radio"/> 14 BD_Mult				
<input type="radio"/> 7 BC3	<input type="radio"/> 15 SID_Mult				
MUX2					
<input type="radio"/> 0 BC1_inDelOS	<input type="radio"/> 8 BT	<input type="radio"/> 9 L0_inDelOS	<input type="radio"/> 10 BD_Mult_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Inter
<input type="radio"/> 1 BC2_inDelOS	<input type="radio"/> 9 L0_inDelOS	<input type="radio"/> 10 BD_Mult_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Inter	<input type="radio"/> 13 L0
<input type="radio"/> 2 VC_inDelOS	<input type="radio"/> 10 BD_Mult_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Inter	<input type="radio"/> 13 L0	<input type="radio"/> 14 BD_Mult
<input type="radio"/> 3 BC3_inDelOS	<input type="radio"/> 11 SID_Mult_inDelOS	<input type="radio"/> 12 No_Inter	<input type="radio"/> 13 L0	<input type="radio"/> 14 BD_Mult	<input type="radio"/> 15 SID_Mult
<input type="radio"/> 4 BC1	<input type="radio"/> 12 No_Inter	<input type="radio"/> 13 L0	<input type="radio"/> 14 BD_Mult	<input type="radio"/> 15 SID_Mult	
<input type="radio"/> 5 BC2	<input type="radio"/> 13 L0				
<input checked="" type="radio"/> 6 VC	<input type="radio"/> 14 BD_Mult				
<input type="radio"/> 7 BC3	<input type="radio"/> 15 SID_Mult				
MUX3					
<input checked="" type="radio"/> 0 BT	<input type="radio"/> 8 outOS_Pull1	<input type="radio"/> 9 DAQ_Busy	<input type="radio"/> 10 Busy	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt
<input type="radio"/> 1 L0_inDelOS	<input type="radio"/> 9 DAQ_Busy	<input type="radio"/> 10 Busy	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot
<input type="radio"/> 2 L0	<input type="radio"/> 10 Busy	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot	<input type="radio"/> 14 Trigger_Abort
<input type="radio"/> 3 Min_Bias	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot	<input type="radio"/> 14 Trigger_Abort	<input type="radio"/> 15 EvtK_Good
<input type="radio"/> 4 No_Inter	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot	<input type="radio"/> 14 Trigger_Abort	<input type="radio"/> 15 EvtK_Good	
<input type="radio"/> 5 BD_Mult	<input type="radio"/> 13 Prot				
<input type="radio"/> 6 SID_Mult	<input type="radio"/> 14 Trigger_Abort				
<input type="radio"/> 7 Pull_zdc_led	<input type="radio"/> 15 EvtK_Good				
MUX4					
<input type="radio"/> 0 BT	<input type="radio"/> 8 outOS_Pull1	<input type="radio"/> 9 DAQ_Busy	<input type="radio"/> 10 Busy	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt
<input type="radio"/> 1 L0_inDelOS	<input type="radio"/> 9 DAQ_Busy	<input type="radio"/> 10 Busy	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot
<input type="radio"/> 2 L0	<input type="radio"/> 10 Busy	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot	<input type="radio"/> 14 Trigger_Abort
<input type="radio"/> 3 Min_Bias	<input type="radio"/> 11 DAQ_Trigger	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot	<input type="radio"/> 14 Trigger_Abort	<input type="radio"/> 15 EvtK_Good
<input type="radio"/> 4 No_Inter	<input type="radio"/> 12 Trigger_inProt	<input type="radio"/> 13 Prot	<input type="radio"/> 14 Trigger_Abort	<input type="radio"/> 15 EvtK_Good	
<input type="radio"/> 5 BD_Mult	<input type="radio"/> 13 Prot				
<input type="radio"/> 6 SID_Mult	<input type="radio"/> 14 Trigger_Abort				
<input checked="" type="radio"/> 7 BT_Busy	<input type="radio"/> 15 EvtK_Good				

Software -> SiDU manager



BM@N Silicon detector manager v.1.6.1

Com port 16 Auto Open Port opened

Spill nbr 20112 Multiplicity 2 Data received 02.04.2018 14:42:08 Last command @10#0606

Counts Channel 22 Count 66

Multiplicity Channel 0 Count 64

Channel configuration

0 1 2 3 4 5 6 7

8 9 10 11 12 13 14 15

16 17 18 19 20 21 22 23

Self-Trigerring 24 25 26 27 28 29 30 31

32 33 34 35 36 37 38 39

40 41 42 43 44 45 46 47

48 49 50 51 52 53 54 55

56 57 58 59 60 61 62 63

@10#0E02\$FFFFFFFF
@10#0E03\$FE7FFFFFFF

Software->HV & BV managers



HV_Systems SM32_220 Control v1.3

Overheating = 0 Temperature, C = 30 Low voltage, V = 10.4 Base voltage, V = 242

Configuration file name: Config2.hvConfig

Control Configuration manager Service

ID	Label	On/Off	Uset, V	Status	Uout, V	Iout, uA	Ustby, V	RampUp	RampDn	Prot.delay(ms)	Imax, uA
1	BC1	On/Off	1600	On	1601	1079	328	100	100	0.0	2998
2	BC2	On/Off	1575	On	1575	85	326	100	100		
3	VC	On/Off	1450	On	1449	252	324	100	100		
4		On/Off	325	Off	6	0	325	100	100		
5		On/Off	327	Off	0	0	327	100	100		
6		On/Off	326	Off	0	0	326	10000	10000		
7		On/Off	-1	Rpg Dn	-1	-1	-1	65535	65535		
8		On/Off	-1	Rpg Dn	-1	-1	-1	65535	65535		
9		On/Off	-1	Rpg Dn	-1	-1	-1	65535	65535		
10		On/Off	-1	Rpg Dn	-1	-1	-1	65535	65535		
11		On/Off	-1	Rpg Dn	-1	-1	-1	65535	65535		
12	BCX	On/Off	-1	Rpg Dn	-1	-1	-1	65535	65535		

SIPM_LV_PS_x16_Manager, v8.1.1. Bogoslovskij Dmitriy. 12.05.2015 10:32

Unit	DAC_val	U set [0 ... 30.18 v]	U control [0 ... 30.18 v]	ADC_val [uA]
Ch1	57671	26.558 v	26.460 v	87%
Ch2	57671	26.558 v	26.524 v	87%
Ch4	57671	26.558 v	26.635 v	88%
Ch4	57671	26.558 v	26.405 v	87%
Ch5	57671	26.558 v	26.429 v	87%
Ch6	57671	26.558 v	26.325 v	87%
Ch7	57671	26.558 v	26.341 v	87%
Ch8	57671	26.558 v	26.532 v	87%
Ch9	57671	26.558 v	26.357 v	87%
Ch10	57671	26.558 v	26.548 v	87%
Ch11	57671	26.558 v	26.627 v	88%
Ch12	57671	26.558 v	26.849 v	88%
Ch13	57671	26.558 v	26.786 v	88%
Ch14	57671	26.558 v	26.444 v	87%
Ch15	57671	26.558 v	26.706 v	88%
Ch16	57671	26.558 v	26.476 v	87%

Broadcast U[1..16] set: 0

Time: 09:58:33 Run State: RUN EvN: 36385 Tack: 78 mS

COM_Port cfg: \\COM8 115200, n. 8. 1 Port_Status: Active Port_BPS: 115200 COM_Port_N: \\COM8

Transceive	Receive
T> 1 WDA 0xE147	R> .0x01>WDA \$0A 0xE147
T> 1 WDB 0xE147	R> .0x01>WDB \$0B 0xE147
T> 1 WDC 0xE147	R> .0x01>WDC \$0C 0xE147
T> 1 WDD 0xE147	R> .0x01>WDD \$0D 0xE147
T> 1 WDE 0xE147	R> .0x01>WDE \$0E 0xE147
T> 1 WDF 0xE147	R> .0x01>WDF \$0F 0xE147

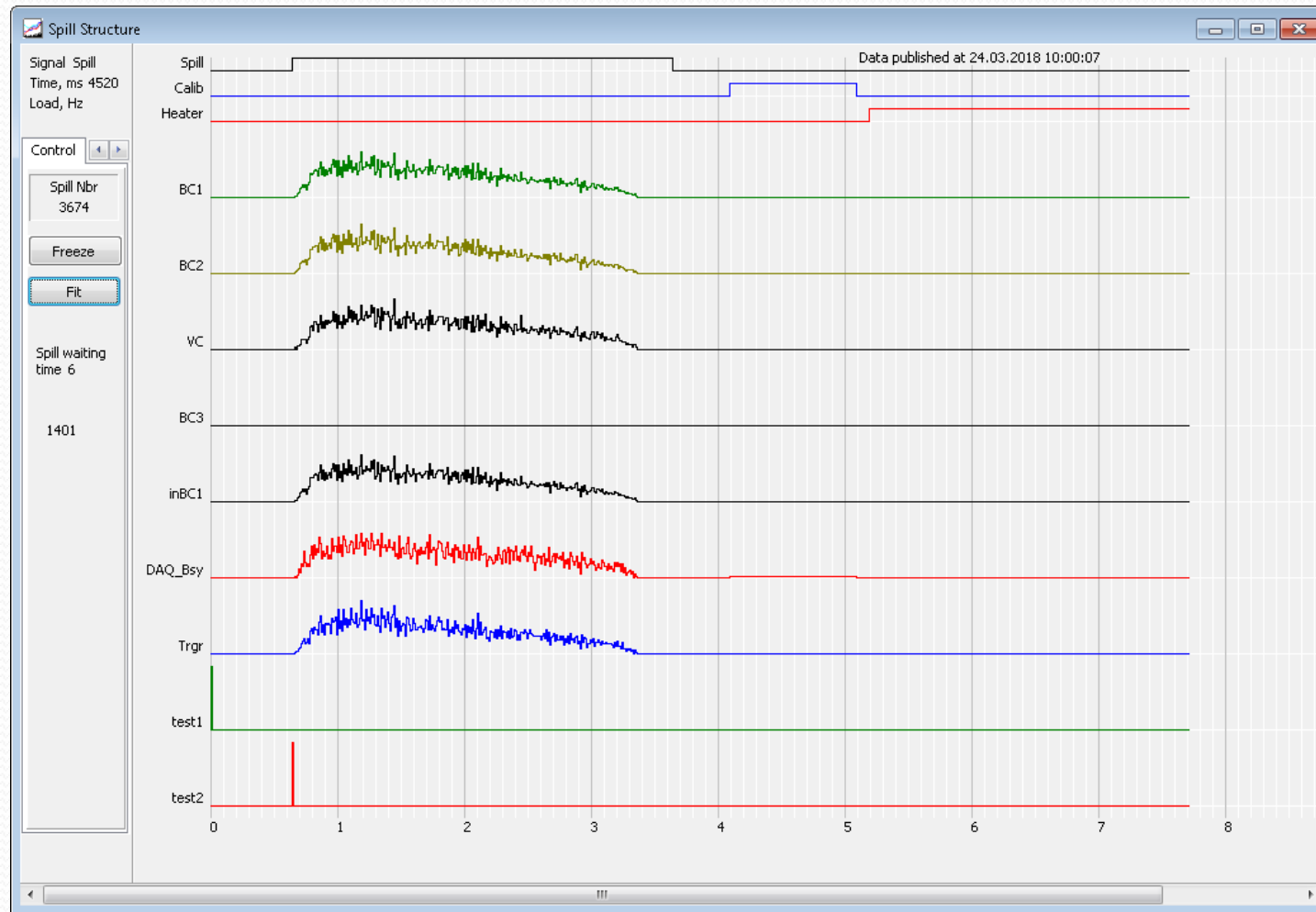
-Service

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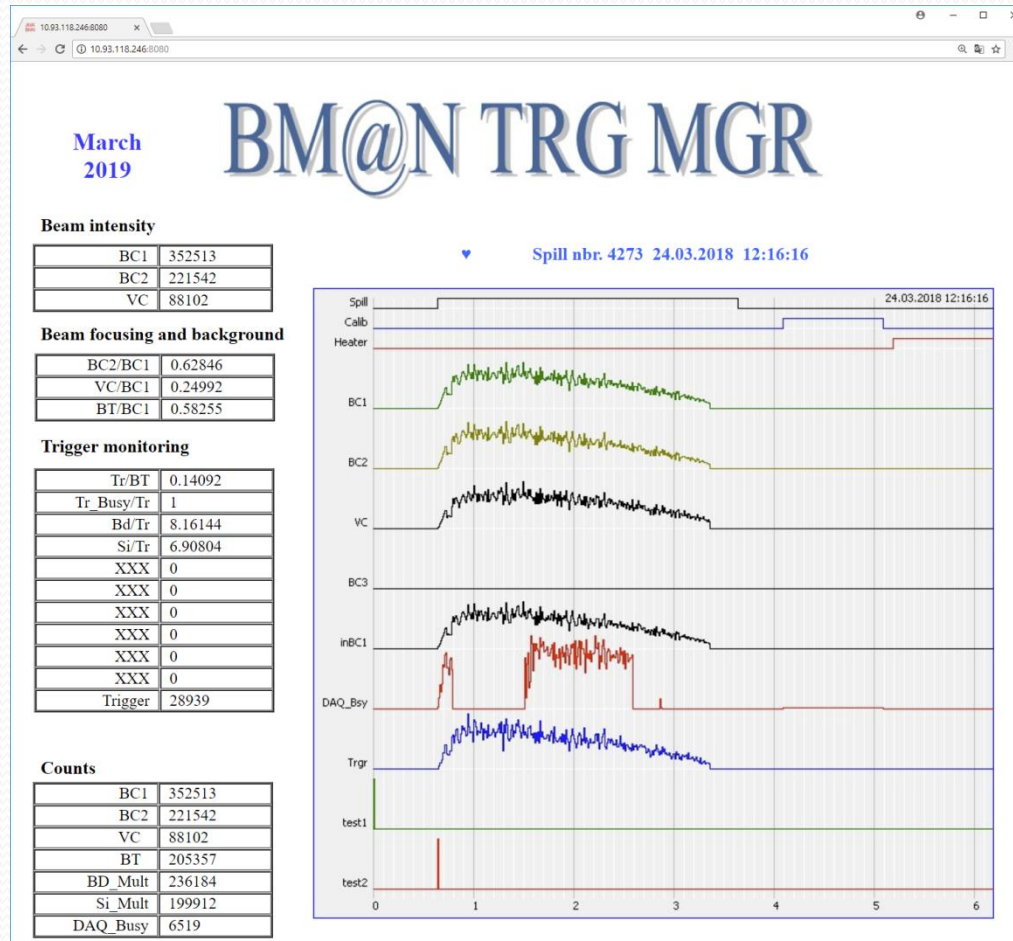
S> Comm32dim.Bits=8
S> Comm32dim.StopBits=1
S> Comm32dim.CommPort=\\COM8
S> Comm32dim.ReadInterval=50
S> Unit_1 detected
    
```

Buttons: RUN, END, Get ADC val, Get ID, File Name: LV_PS.cfg, Load Cfg, Save Cfg, Dialog Load Cfg, Dialog Save Cfg, Help, Graph, Clear, Tx: 1 ra*, Clear, Send_String, Hex: \$30, Send_Byte

Software -> SpillView server



Software -> Web server

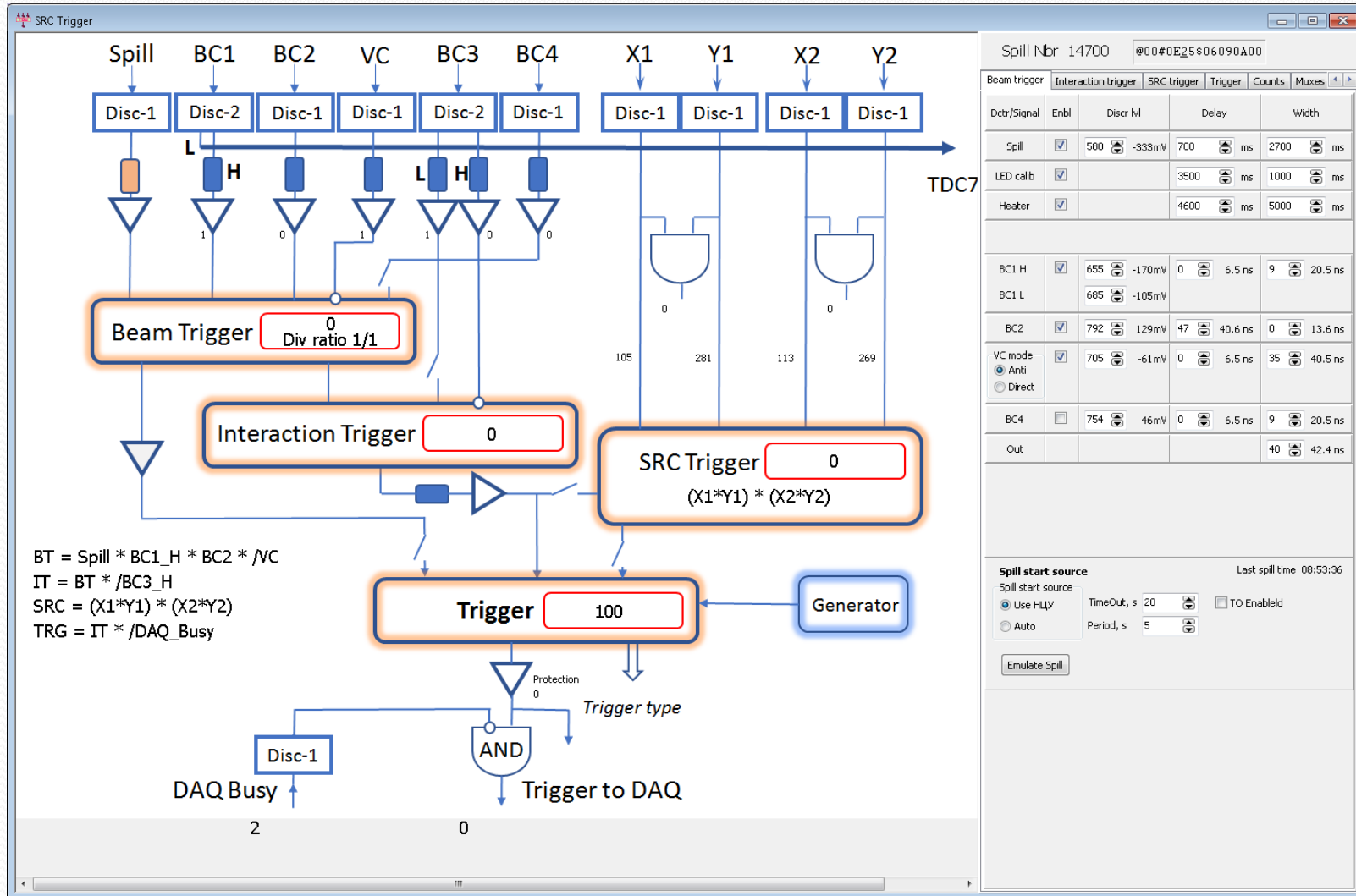


Conclusion



- Trigger system works since 2015. It provides comfortable and user-friendly GUI
- Five modules have been manufactured
- Used in two experiments – BM@N and SRC
- No electronics failure observed. We met only “external” problems – bad 220V power and mechanical damage of a Molex TDC cable connector
- The system has been interfaced to the DCS system (no DCS commands accepted, the Trigger State transfer only)
- Almost all FPGA recourses have been used. Further ToU extension requires a motherboard redevelopment

Software -> SRC experiment



Software -> SRC experiment

