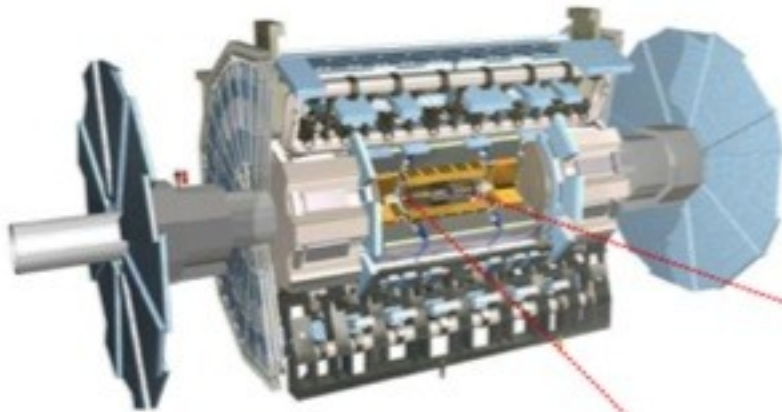


# ***TRT Introduction***

- TRT in ATLAS p. 2-4
- TRT design p. 5-7
- TRT operation principles p. 8-9
- TRT electronics p. 10-11
- TRT read-out information p. 12-15
- TRT test set-up p. 16-18
- TRT DCS tools p. 19-22
- TRT DAQ graphic user interface p. 23-24
- Tasks:
  - a) Noise Characterization p. 25-26
  - b) Operation with cosmic particles p. 27

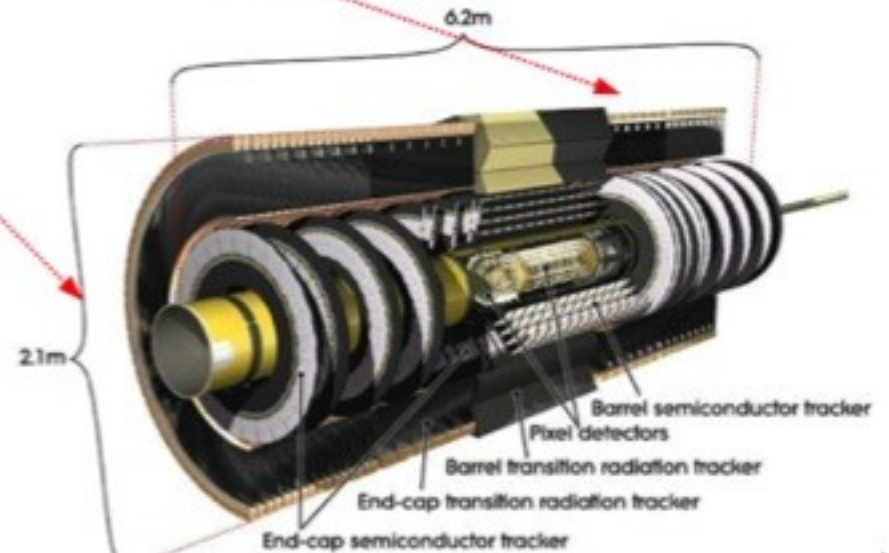


The Inner Detector consists of:

- Pixel detector
- Semiconductor Tracker (SCT)
- **Transition Radiation Tracker (TRT)**
  - All in a 2T solenoidal field

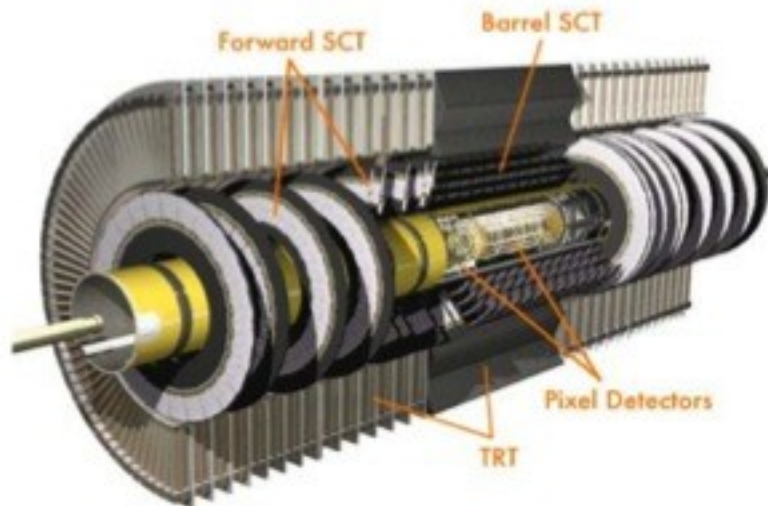
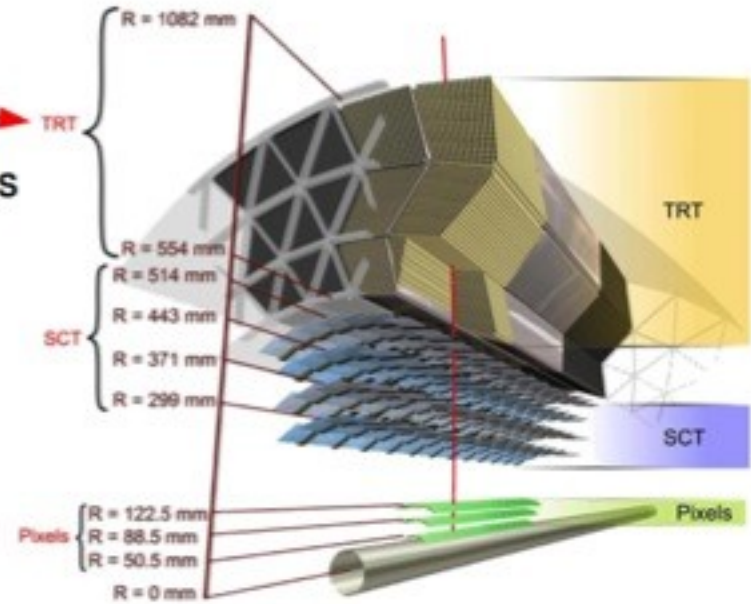
Performance goals:

- **Tracking** for charged particles:
  - $p_T > 0.5$  and  $|\eta| < 2.5$
  - $\sigma(p_T)/p_T = 0.05\% p_T \oplus 1\%$
- **Electron ID (TRT):**
  - $0.5 < p_T < 150$  GeV and  $|\eta| < 2.0$



## TRT Barrel:

- 3 layers \* 32  $\phi$  modules
- 1.44m long straws, parallel to beam axis
- Wires electrically split in middle
  - ~1.5cm dead region
  - Read out on both sides
- 105,088 readout channels

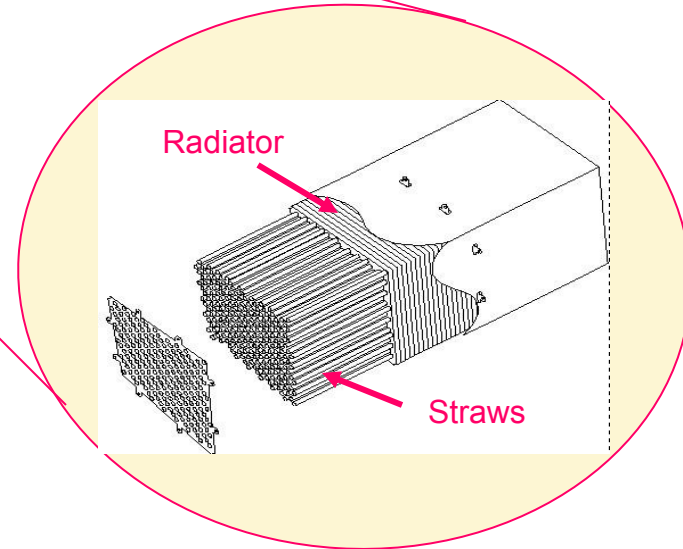
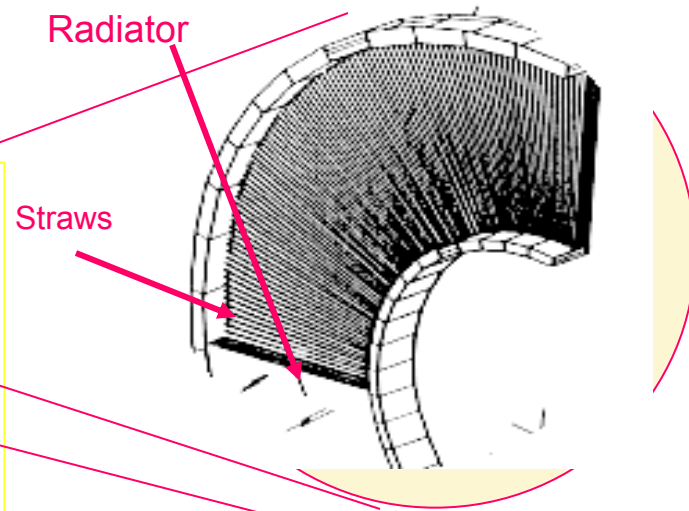
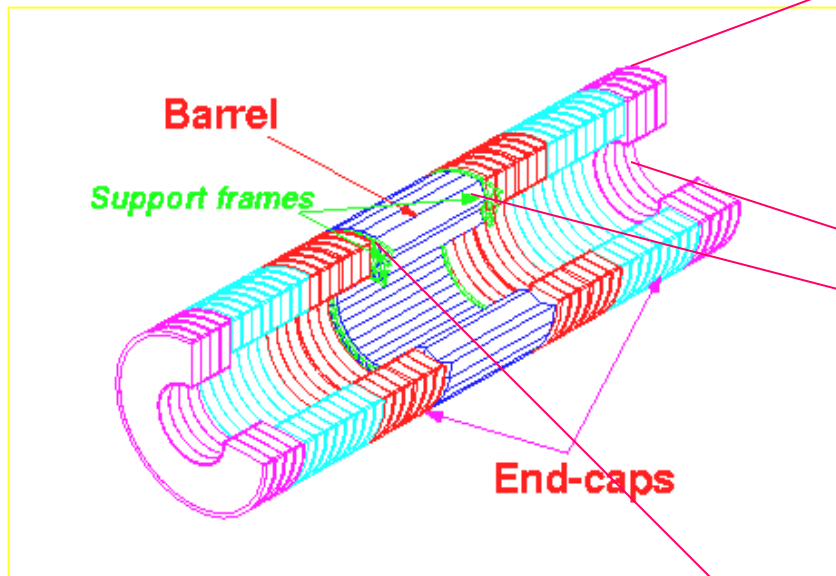


## 2 TRT Endcaps, each with:

- 20 wheels with 8 straw layers each
- 39cm long radial straws
- 120,880 readout channels

# Introduction: TRT concept

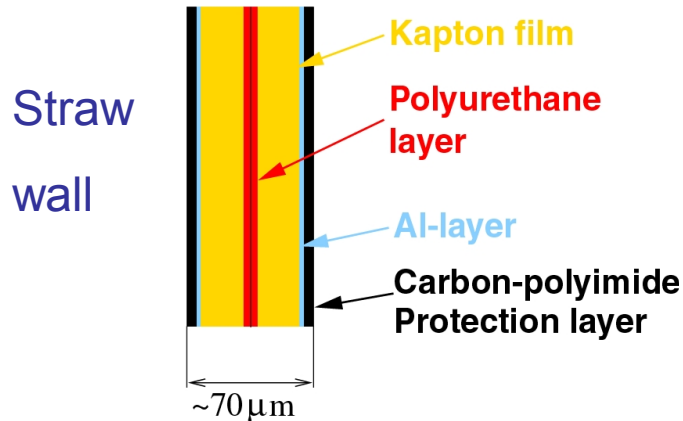
## TRT global parameters



Length: Total	6802 cm	N straws: Total	372032
Barrel	148 cm	Barrel	52544
End-cap	257 cm	End-cap	319488
Outer diameter	206 cm	N electronics channels	424576
Inner diameter	96-128 cm	Weight	~ 1500 kg

# Straw - the main detector element

## Straw design



## Straw cathode – 4mm

TR optimization:

*the larger diameter the better*

Wire offset  $\sim 300 \mu\text{m}$ :

*the larger diameter the better*

Self limited streamer length  $\sim 1 \text{ mm}$

*the larger diameter the better*

Max electron drift-time

*the smaller diameter the better*

## Reinforced straw

In order to make straw rigid 4 C-fibres are attached along the straw

## Wire diameter – 30 $\mu\text{m}$

Max electron drift-time

*the larger diameter the better*

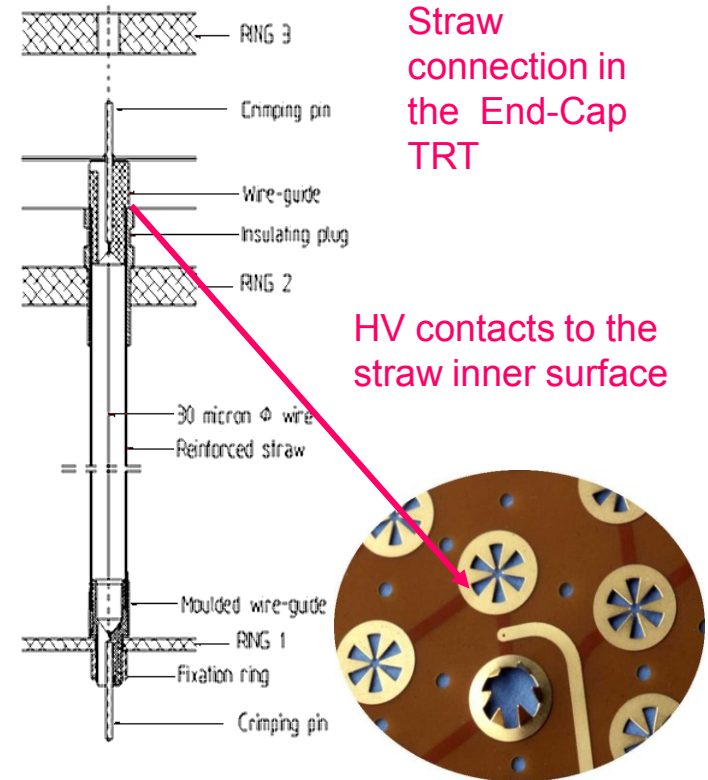
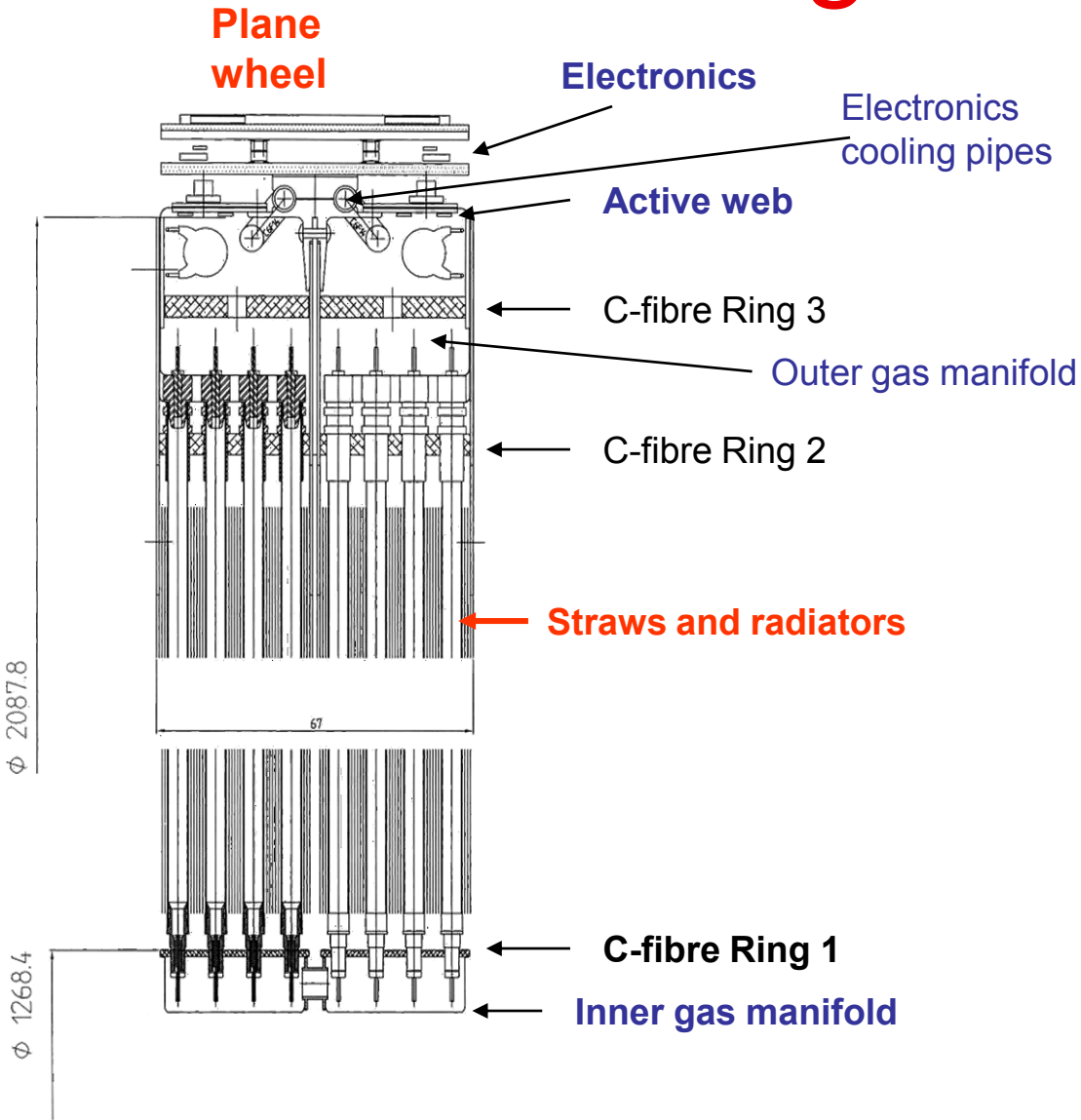
Operation stability

*the smaller diameter the better*





# TRT design: End-Cap

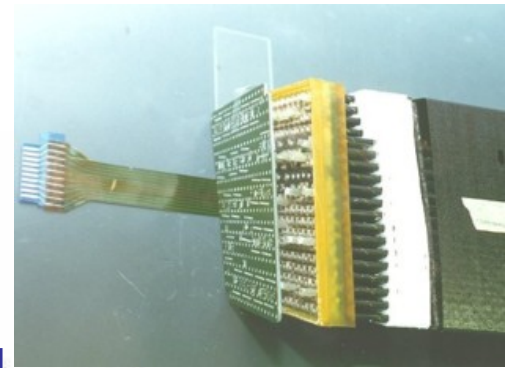
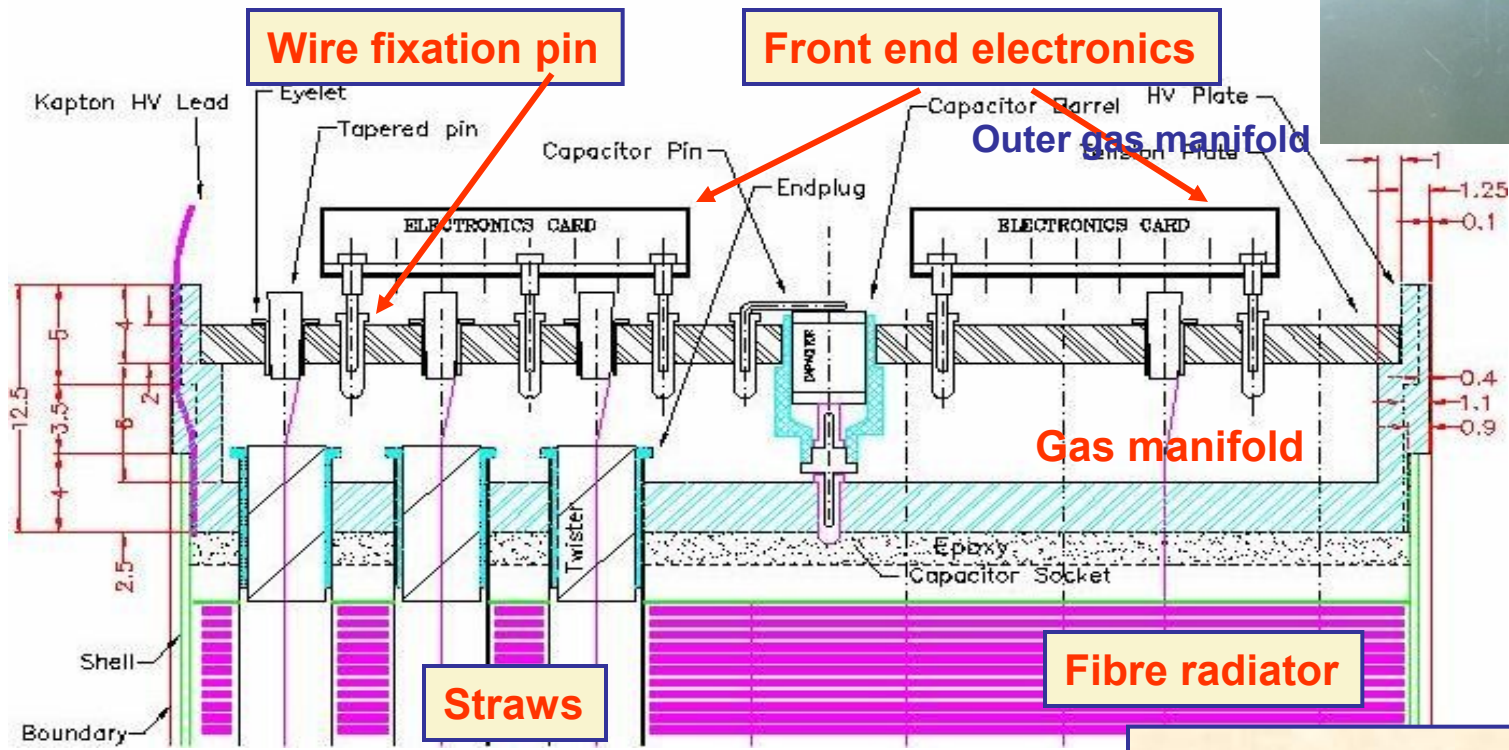


**One 8-plane wheel:**  
 $2 \times 4 \times 768 = 6144$  straws

**End-Cap:**  
 $40 \times 8$ -plane wheels

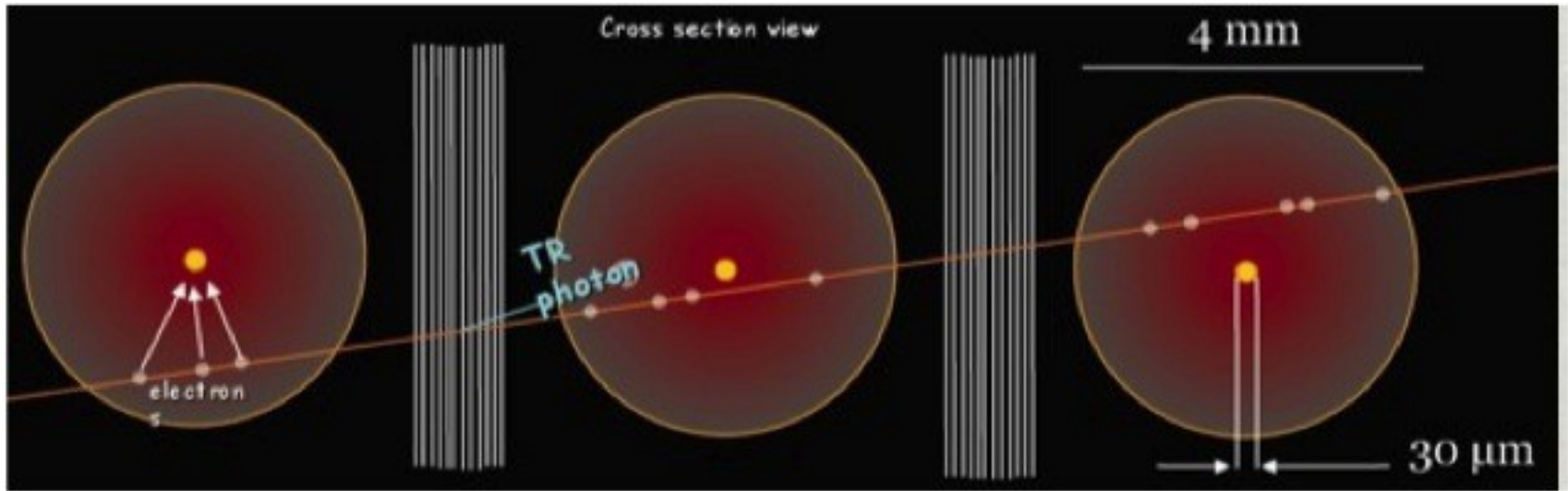
# TRT design: Barrel

TRT BARREL CONNECTIONS



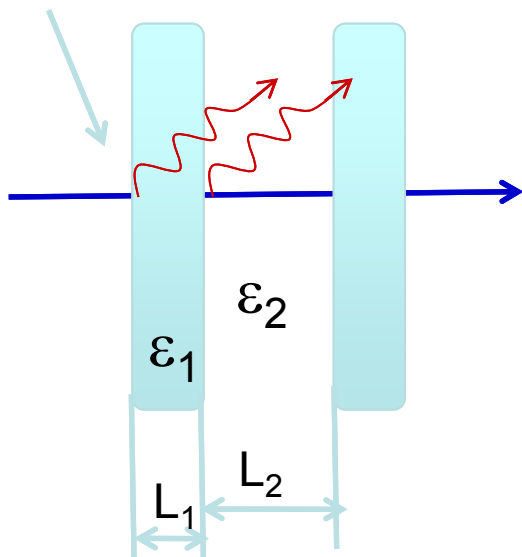
**52544 straws**  
**Wire split in two parts at the middle**

# Transition radiation detectors: principle



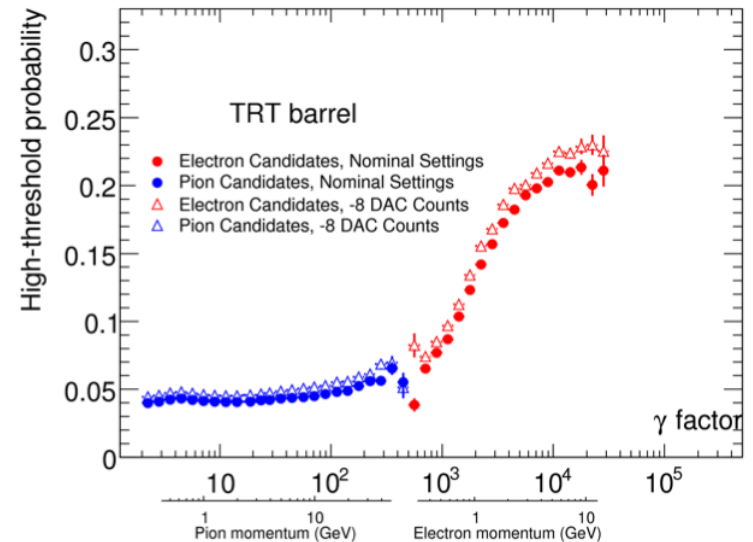
## Radiator.

Photon irradiation probability  $\sim 1/a$  (1/137)



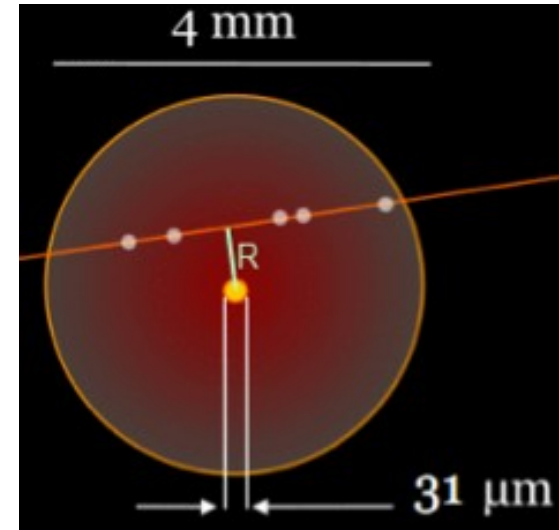
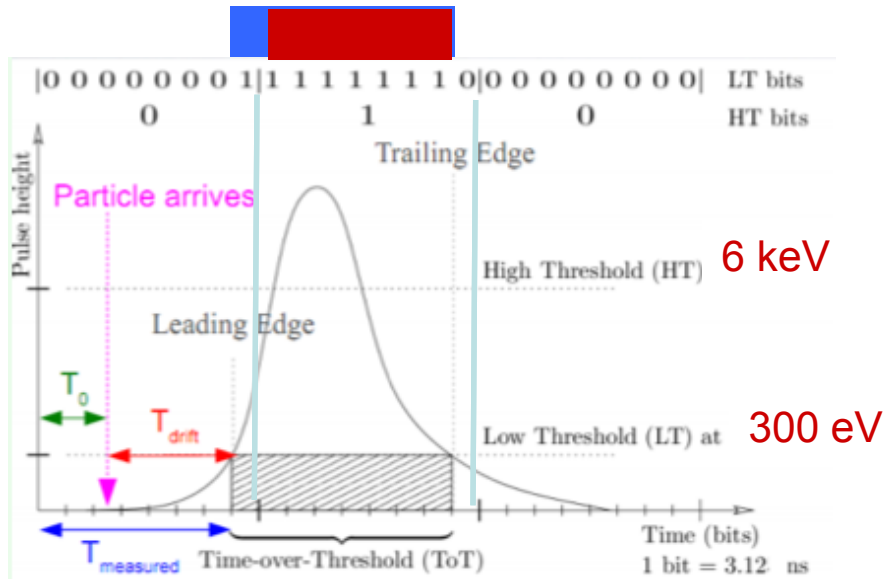
## Requirements:

- Maximum  $\epsilon_1/\epsilon_2$
- Minimum  $Z$
- $L_1$  &  $L_2$  compatible with the formation zones in corresponding media

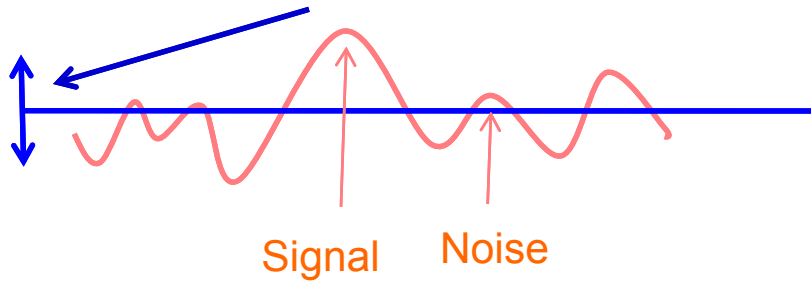




# Choice of the thresholds

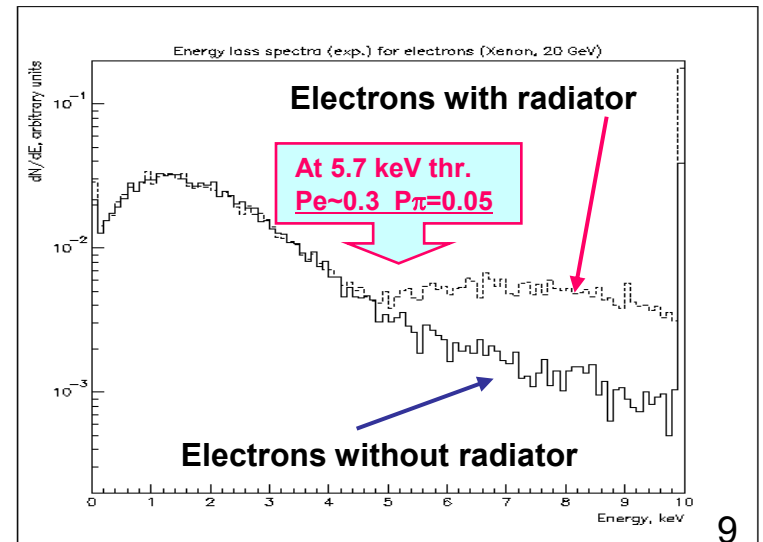


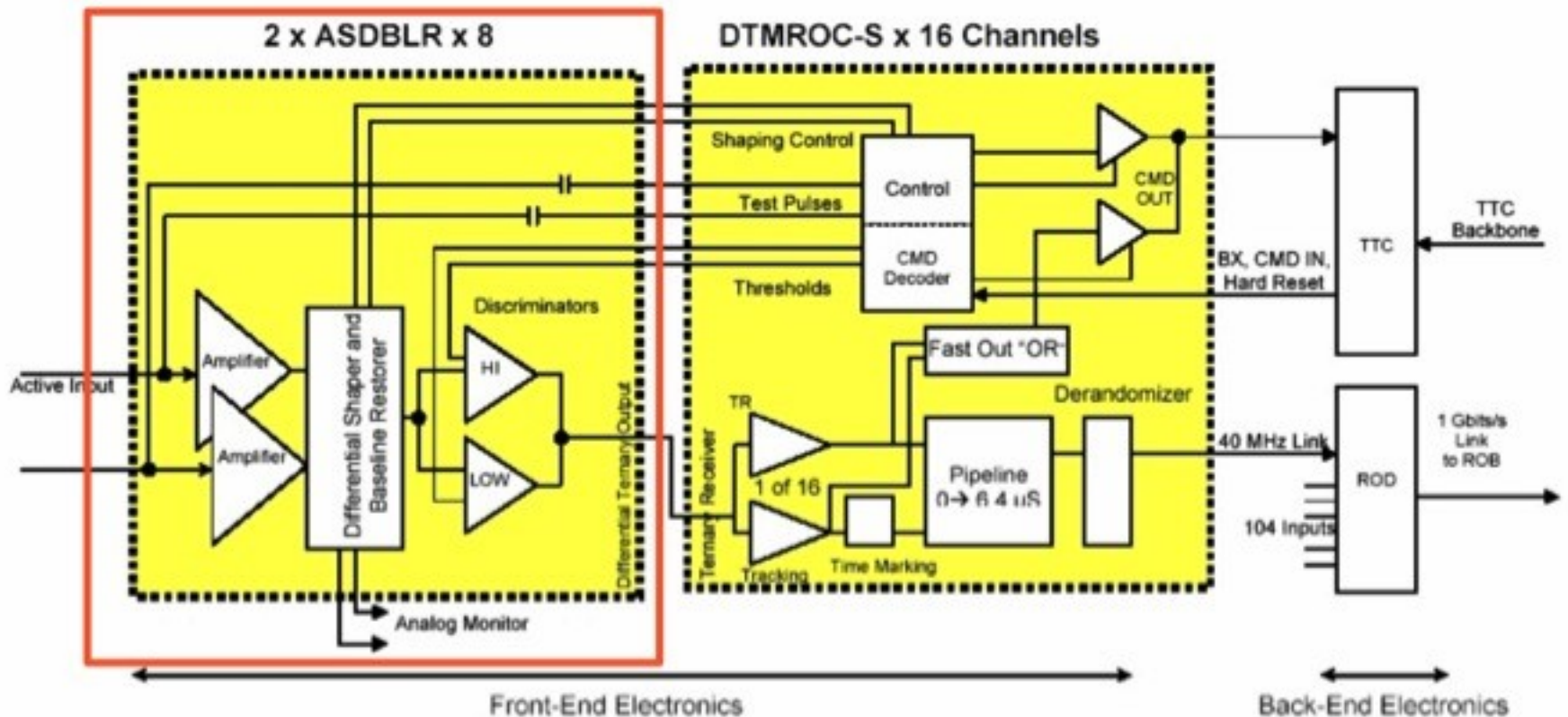
## Low level threshold



The *less* threshold  
 the *better* drift-time accuracy and efficiency  
 The *higher* threshold  
 the *less* noise

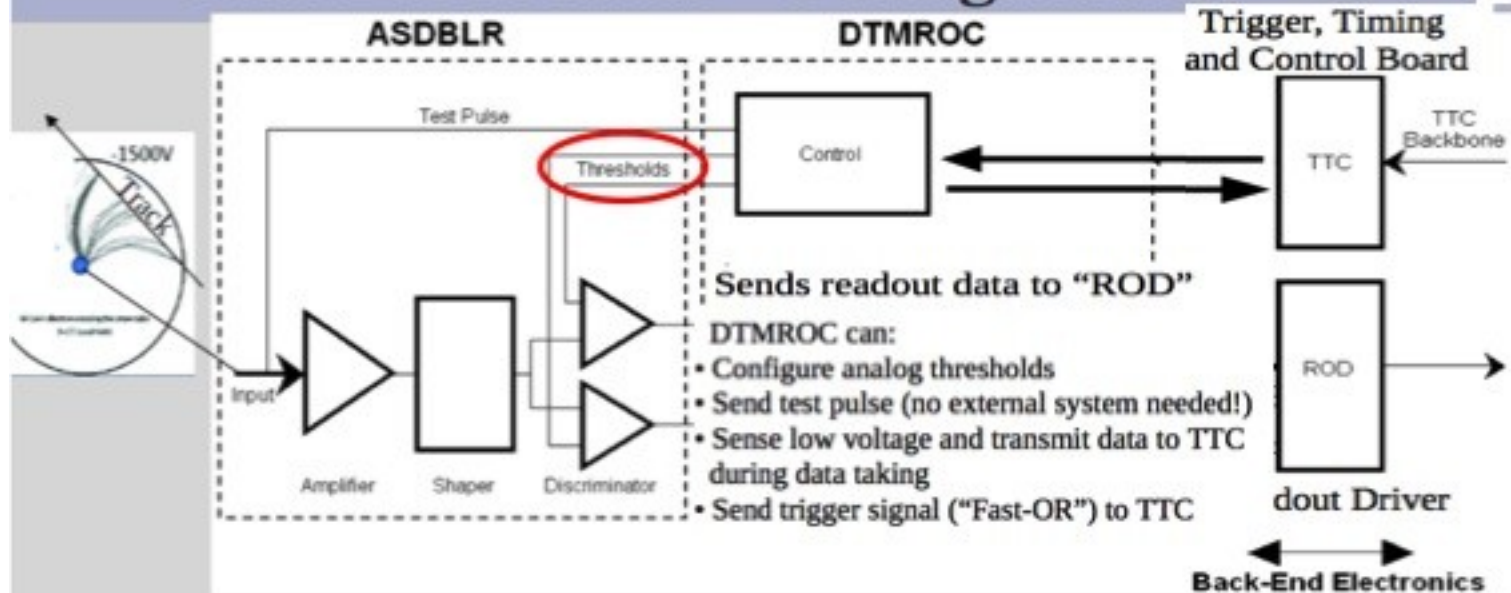
## High level threshold





- Amplifier, shaper, discriminator, baseline restorer (**ASDBLR**)
  - Analog chip, receives input from **8 channels**
- 2 discriminators, for **low** and **high** thresholds
  - **Ternary output** to DTMROC

# TRT Electronics - Configuration

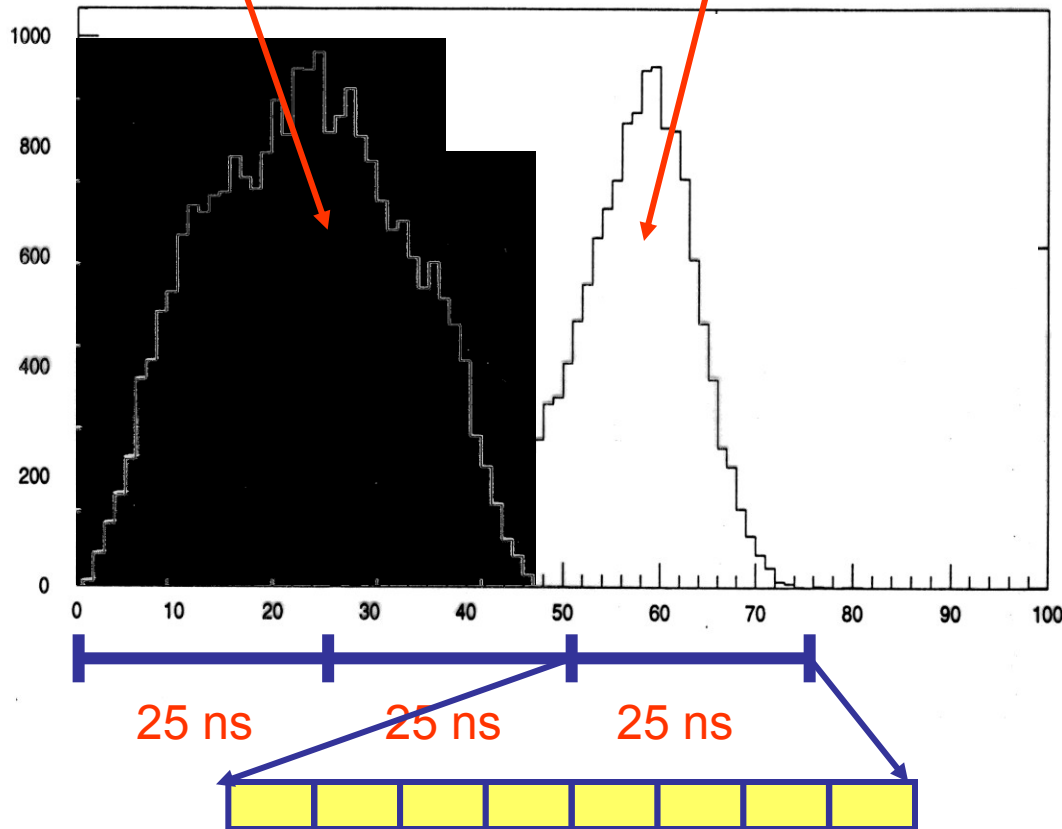


- Analog and digital boards powered separately (in barrel: grounds separated by impedance)
- Inaccurate board powering (low voltage) can have an effect on thresholds

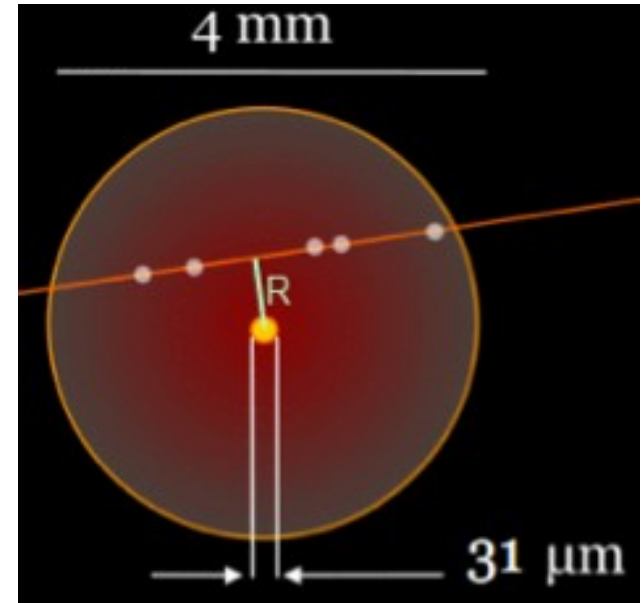
# Tracking

Leading edge distribution

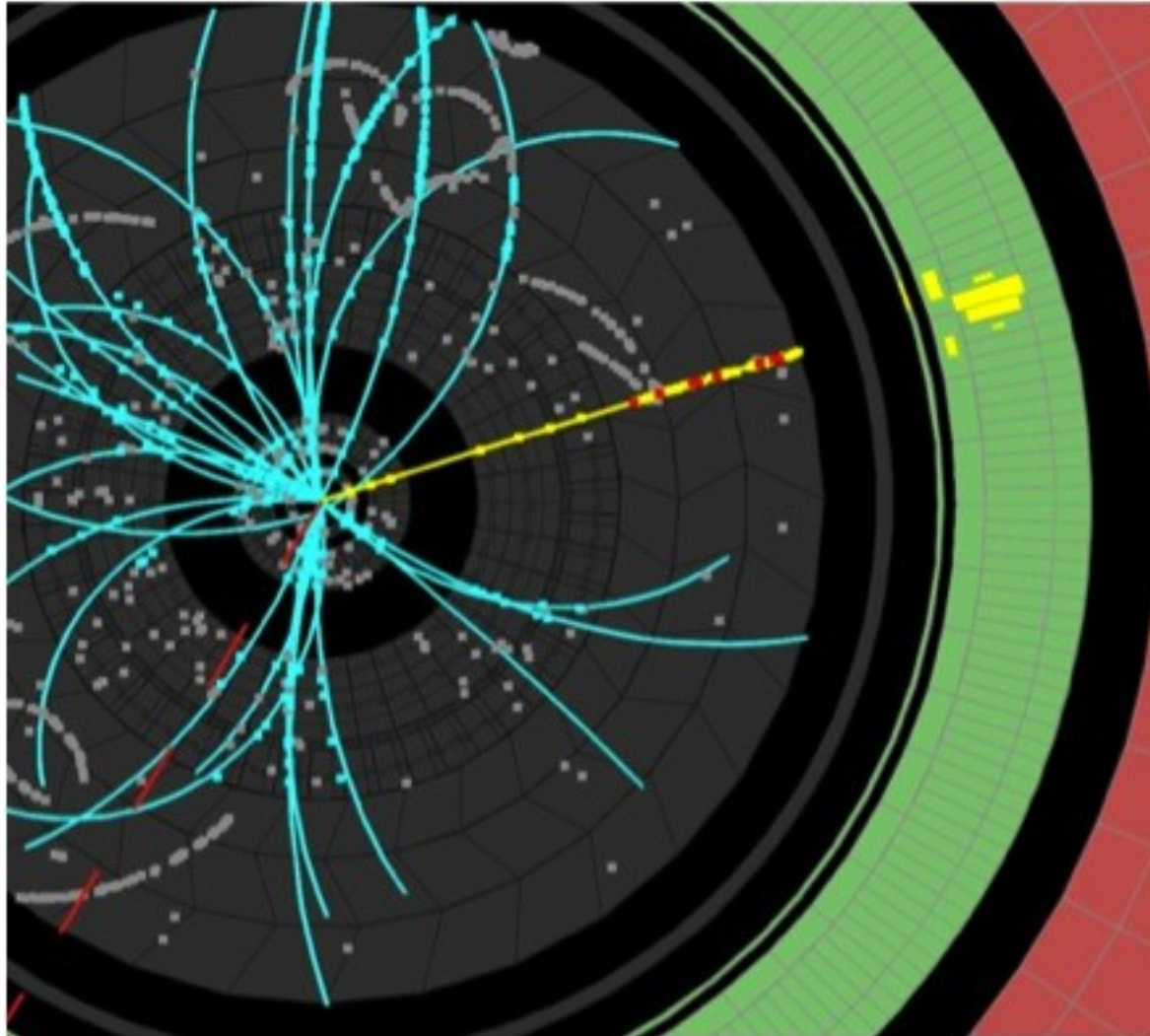
Tailing edge distribution



For low level discriminator bit status each 3.125 ns

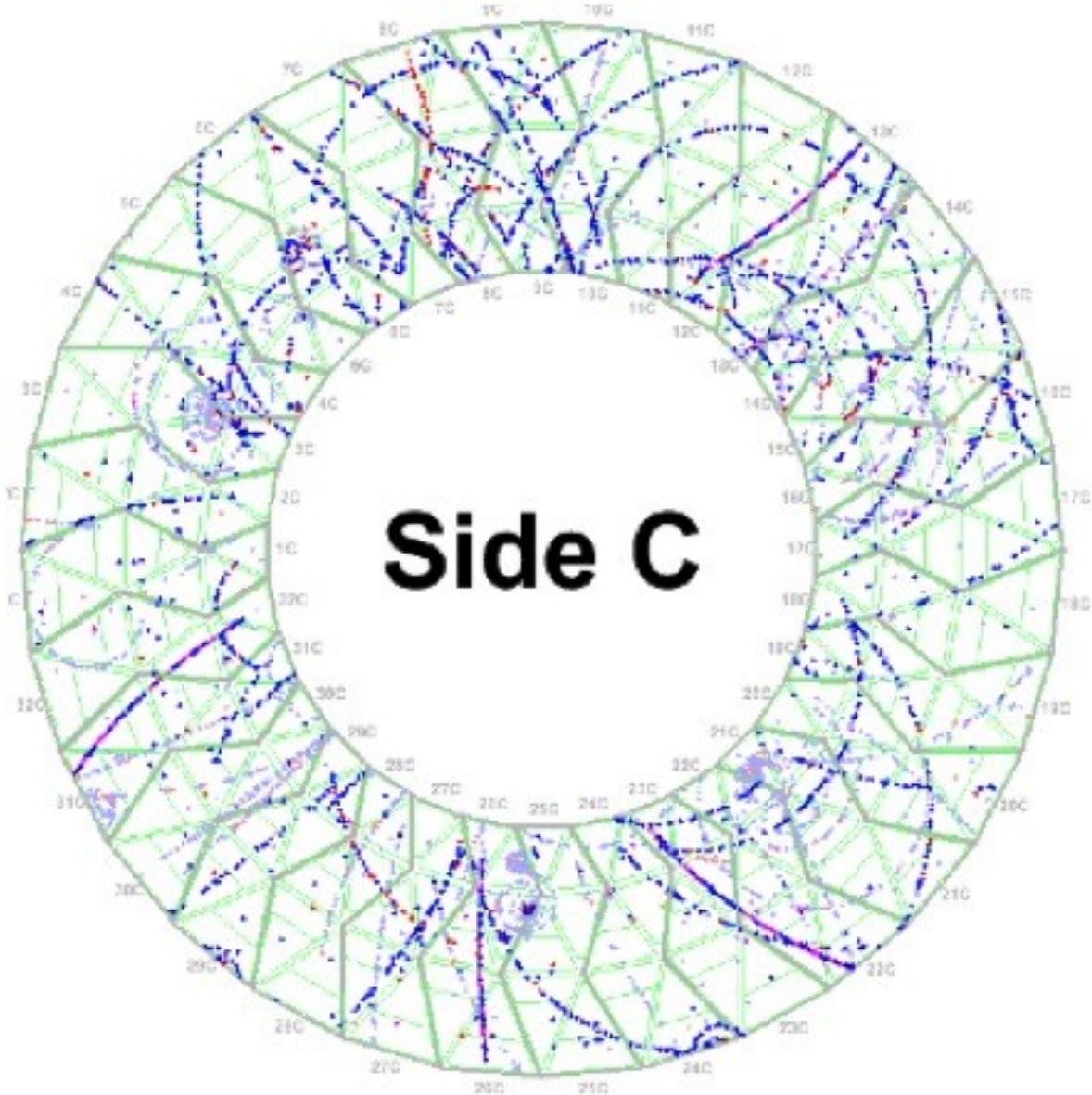


# ATLAS event display: electron from Z decay

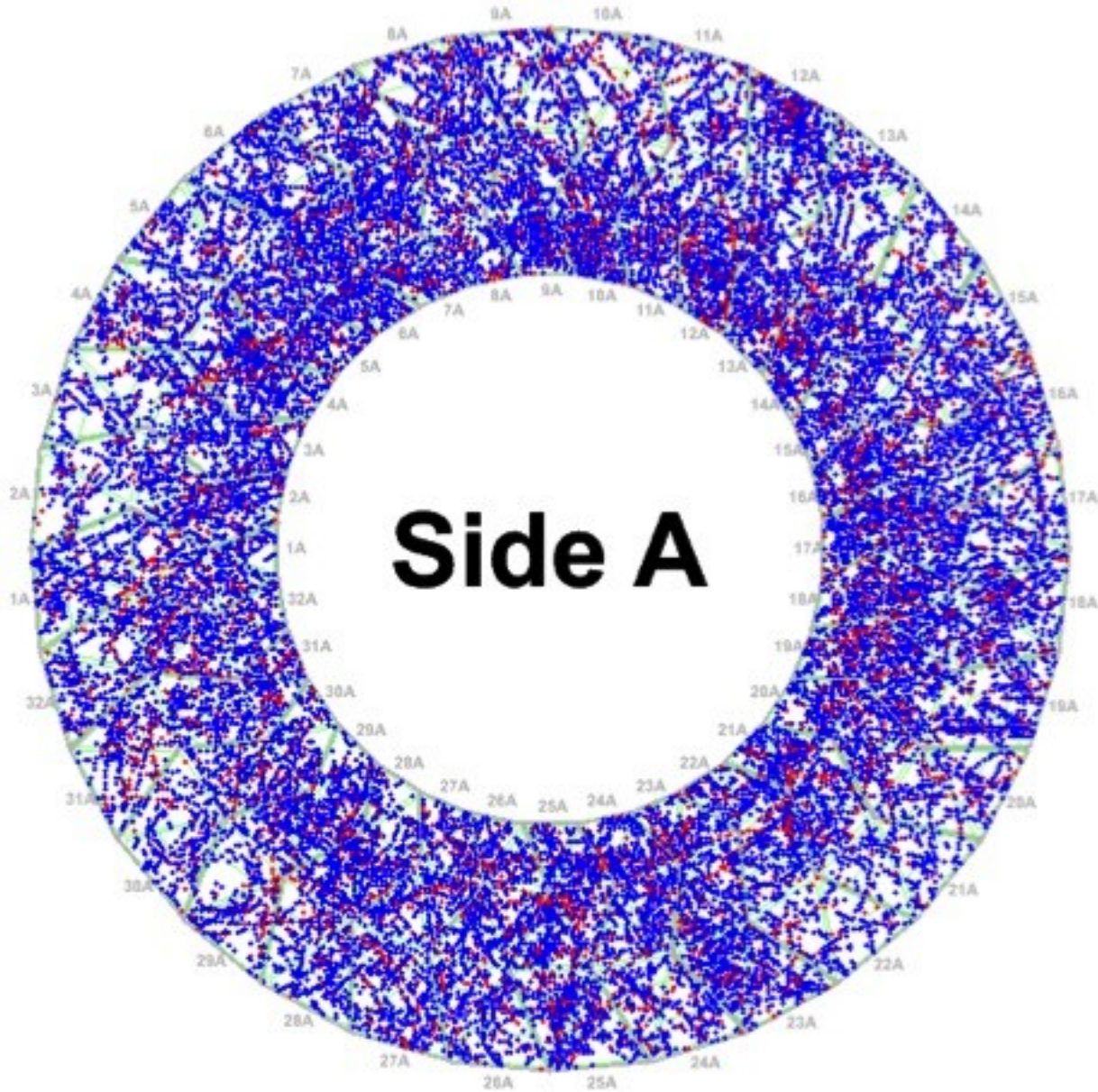




# Real event display: Heavy Ions non-central collisions

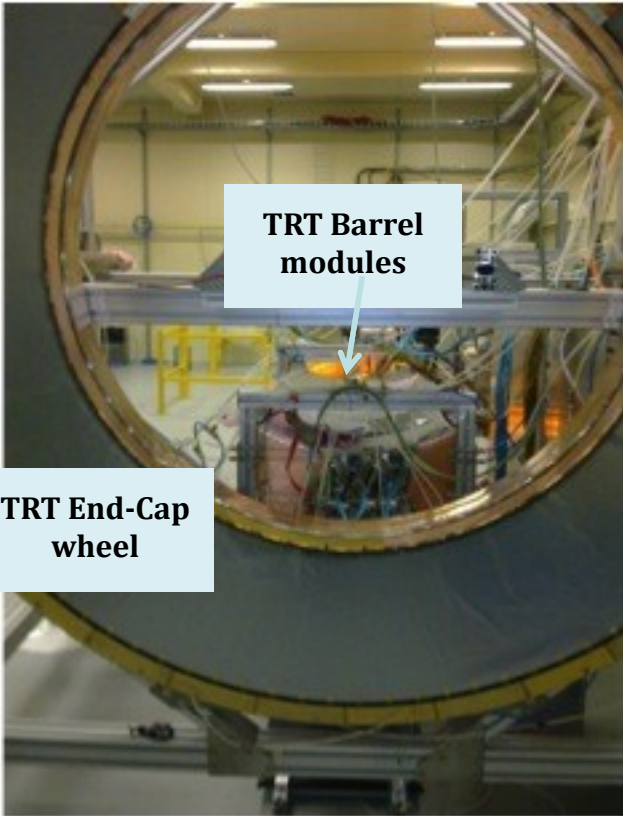


## Real event display: Heavy Ions central collisions





# Test set-up

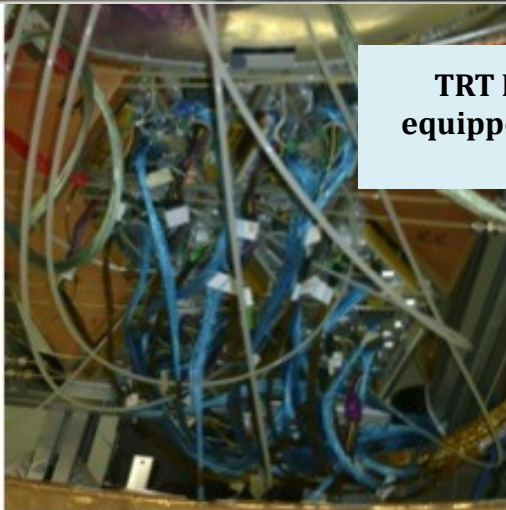


TRT End-Cap wheel

TRT Barrel modules



TRT Barrel module



TRT Barrel modules equipped for the readout



TRT Barrel modules assemblies in the support structure

# Service racks

**TRT Envelope  
ventilation**

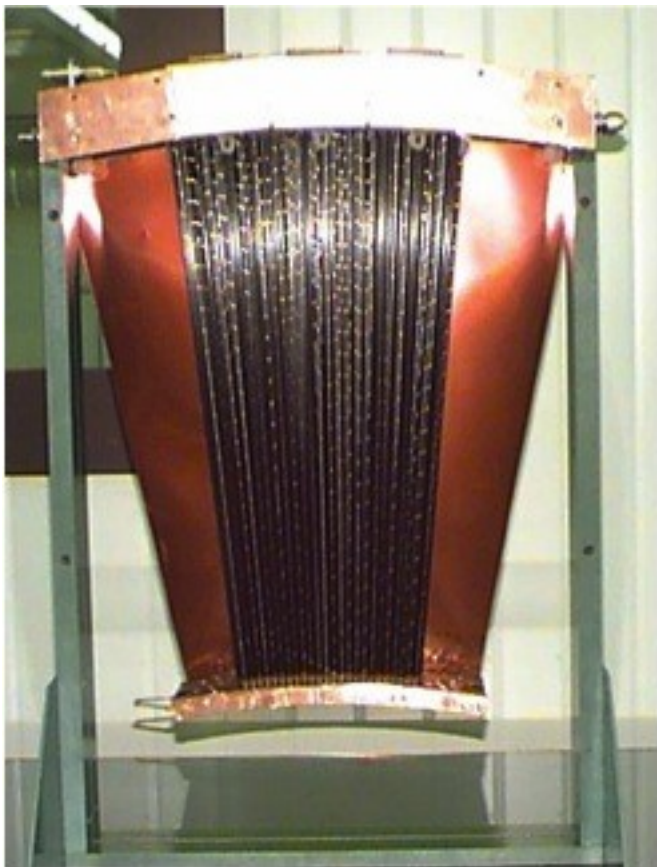
**Active gas rack**



**HV system rack**

**Front-End  
electronics  
Cooling Rack**

## Straw-electronics connectivity



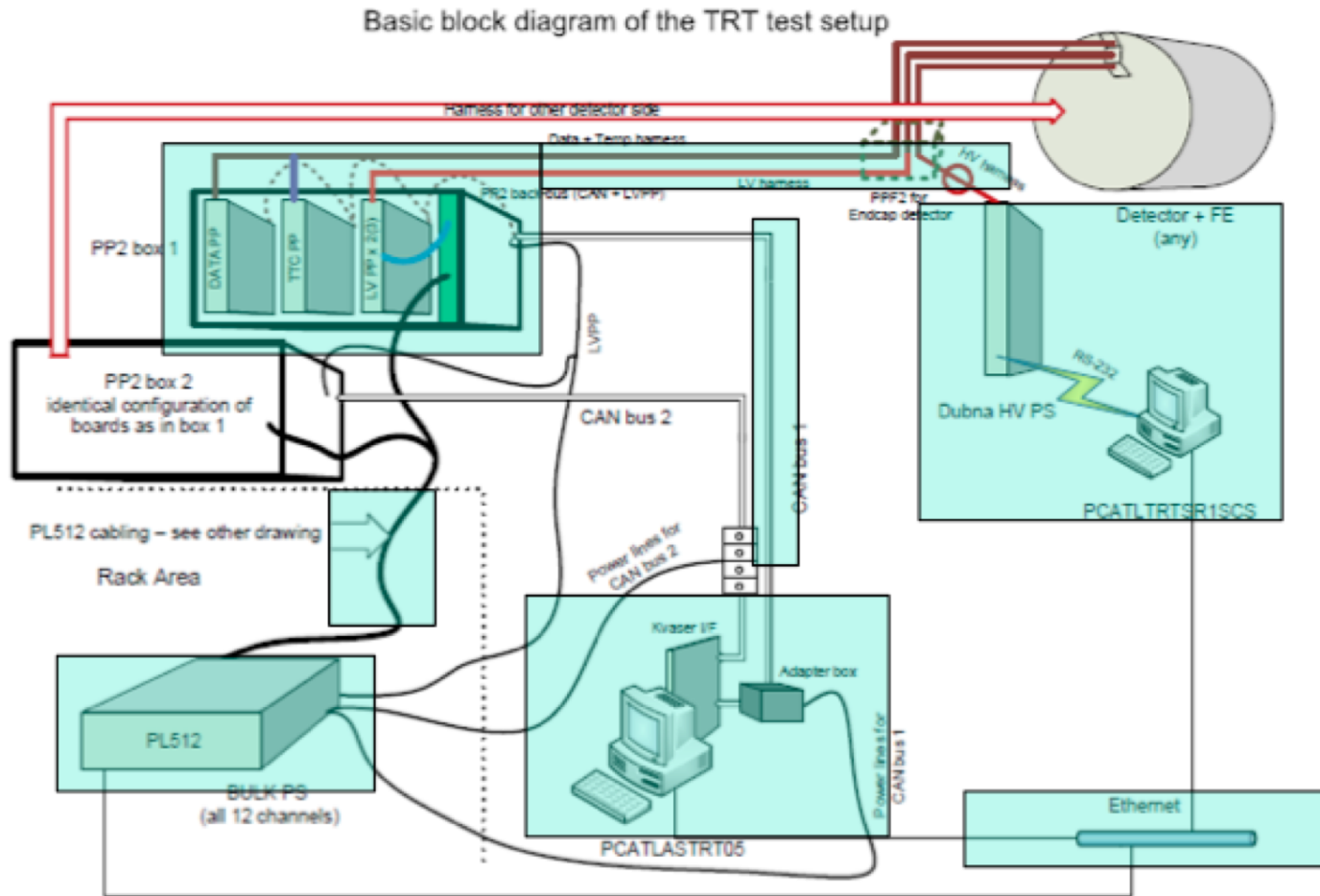
**End-Cap Wheel prototype:  
Front-End Electronics  
connections**



**End-Cap Wheel prototype:  
Straw-electronics connectivity**



# TRT test stand DCS.



# Test stand DCS

ATL\_TRT: fwUiAtlasFrame

roman 14-01-2011 18:39:14

Back Home

TRT BARREL A

HV	READY	OK
HVB	READY	OK

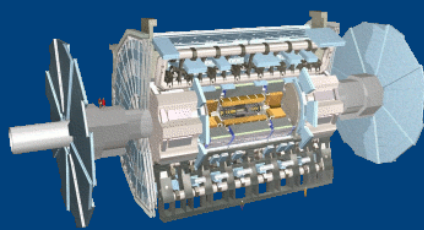
Barrel C: HV OK, LV OK, TEMF OK

Barrel A: HV OK, LV OK, TEMF OK

EndCap A: HV W, LV OK, TEMF OK

Infrastructure: COOL OK, BULK OK, HVI OK, CAN OK, GAS OK

S	Object	Time	1
W	TRT BARRELA	2011.01.14 15:33:3	W E F D



Zoom: 100

3D View All connected

TRT

INFRASTRUCTURE: READY OK

COOL OK GAS OK BULK OK CAN OK HVI OK

BARREL A	READY	W	HV	READY	OK
			LV	READY	OK
			TEMF	READY	OK

BARREL C	READY	W	HV	READY	OK
			LV	READY	OK
			TEMF	READY	OK

### TRT SR1 High Voltage

Active Gas Interlock Triggers: Gas Flow 12 l/h

Humidity Interlock Triggers: HV, HVI, HVC

Expert Actions: Disable Flow

Software Interlock Status: GasNot Safe FALSE, HumNotSafe FALSE, LockTriggered FALSE, ActionsEnable TRUE

Expert Actions: Force ILock, Disable Actions

Software Interlock Actions: SAFE\_HV Delay 5 min, CountDown 0, StartAction FALSE

PREPARED: Delay(Gas) 29 min, Delay(Hum) 5 min, CountDown 0, StartAction FALSE

CRATES SHUTDOWN: Delay 5 min, CountDown 0, StartAction FALSE

#### HVA

GGSStoHV DISABLED W

Software Interlock Activity: SAFE\_HV FALSE, PREPARED FALSE, SHUTDOWN FALSE


#### HVB

GGSStoHV DISABLED W

Software Interlock Activity: SAFE\_HV FALSE, PREPARED FALSE, SHUTDOWN FALSE

LCS1 disconnections allowed

Expert Action: Not allow LCS1 disconn



Crate 7

# Test stand DCS

Back roman 14-01-2011 18:35:33

Barrel C	HV OK	LV OK	TEMI OK
Barrel A	HV OK	LV OK	TEMI OK
EndCap A	HV W	LV OK	TEMI OK
Infrastructure	COOL OK	BULK OK	HVI OK CAN OK
	GAS OK		

S	Object	Time	1
W	TRT_BARRELA	2011.01.14 15:33:33	W E F D

BARREL A	READY	WARNING
HV	READY	OK
LV	READY	OK
TEMPERATURE	READY	OK
TRT_BARRELA_DDC	DEAD	(/INITIALIZE/)

Zoom: 100 All connected

INFRASTRUCT	READY	OK			
COOL	OK	GAS OK	BULK OK	CAN OK	HVI OK
BARREL A	READY	W	HV READY OK	LV READY OK	TEMI READY OK
BARREL C	READY	W	HV READY OK	LV READY OK	TEMI READY OK
ENDCAP A	NOT_READY	W	LV READY OK	TEMI READY OK	HV SHUTDOWN W

### TRT Partition: BARRELA

#### HV

HVB

READY

OK

Minimum and maximum values of voltages and currents

HV min. 1507.89 V	HVB/S24/M3/A2	I min. 0.00 µA	HVB/S24/M1/A3
HV max. 1511.78 V	HVB/S24/M3/A3	I max. 0.00 µA	HVB/S24/M1/A3

Number of cells where HVmax-HVout > 1000: 0 Show list

AutomaticTripRecoverySummary

Guarded Cells	<span style="border: 1px solid gray; padding: 2px;">0</span>	TripCount>0	<span style="border: 1px solid gray; padding: 2px;">0</span>
---------------	--	-------------	--

Software Interlock

Status:	GasNot Safe	FALSE	Activity:	SAFE_HV	FALSE
	Hum.NotSafe	FALSE		PREPARED	FALSE
	ILockTriggered	FALSE		SHUTDOWN	FALSE
	ActionsEnable	TRUE		<b>LC51 disconnections allowed</b>	

#### LV

LV

READY

OK

#### Temperature

Minimum and Maximum temperatures

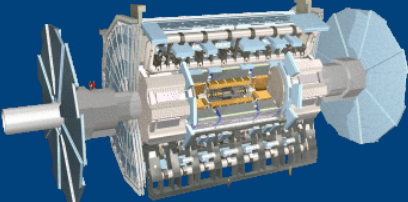
	Minimum	Maximum
FE Electronics	34.6 C	46.7 C
FE 2BS Stack24		FE 3BS2 Stack25
Cooling Plates IN	0.0 C	0.0 C
Cooling Plates OUT	0.0 C	0.0 C
Detector	0.0 C	0.0 C
CO2 Ventilation	0.0 C	0.0 C

# Test stand DCS

Back Home roman 14-01-2011 18:32:49

TRT BARREL A HV

HVB	READY	OK
HVB_S24	READY	OK
HVB_S25	READY	OK
HV_GGSS_MODE	DISABLED	WARNING



Zoom: 100 All connected

3D View

Barrel C	Barrel A	EndCap A
HV OK	HV OK	HV W
LV OK	LV OK	LV OK
TEMP OK	TEMP OK	TEMP OK
Infrastructure		
COOL OK	HVI OK	GAS OK
BULK OK	CAN OK	

GET SUMMARY 2011.01.14 18:31:31.903

HV min. 1508 V HV max. 1512 V

HVB/S24/M3/A2 HVB/S24/M3/A3

HVmax-HVout>1000V

NumberOfCells 0

I min. 0 µA I max. 0 µA

HVB/S24/M1/A3 HVB/S24/M1/A3

ATLAS

S	Object	Time
1	W TRT.BARRELA	2011.01.14 15:33:3

W E F D

### HVB TRT Barrel (side A view)

GGSS

Ref. HV 0 V Trust GGSS

Gas temp 0 C

GGSS to HV

IO T TRUSTED

DISABLED

HV Limits HV max. 1550 V HV min. 1400 V

**SOME ABOVE SAFE VOLTAGE**

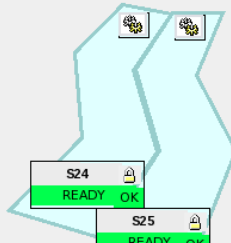
Safe HV level 1350

Infrastructure READY OK

Crate7	Branch0	Branch1	Branch2	Branch3
ON	ON	ON	ON	ON
OK	OK	OK	OK	OK

SHOW DEFAULT HV

Change default



S24 READY OK

S25 READY OK

HV Software Interlock

LCS1 conn. not guarded

Active Gas Safe for HV

Rack Humidity Safe for HV

Software Interlock enabled

SAFE\_HVafter 0 min

PREPAREafter 0 min

Automatic Trip Recovery Summary

Guarded Cells 0

TripCount>0 0

# Test stand DAQ GUI

ATLAS TDAQ SOFTWARE - Partition TRTSR1

File Commands Access Control Settings Logging Level Help

Commit & Reload Load Panels

MRS IS DVS ED OQS LM OH

**RUN CONTROL STATE** RUNNING

Run Control Commands

SHUTDOWN BOOT

TERMINATE INITIALIZE

UNCONFIG CONFIG

STOP START

HOLD TRG RESUME TRG

Beam Stable ● Warm Start Warm Stop

Run Information & Settings

Lumi Block

	Number	Rate
Level 1	<input type="text" value="0"/>	<input type="text" value="0"/>
Level 2	<input type="text" value="0"/>	<input type="text" value="0"/>
Event builder	14515	32.00 Hz
Event filter	<input type="text" value="0"/>	<input type="text" value="0"/>
Recorded	14515	32.00 Hz

Information Counters Settings

Run Control Segments & Resources Dataset Tags TRT Config Actions

**RUNNING** RootController

- RUNNING** EventBuilder
- RUNNING** TRT

RootController

- HW
- PMG
- Infrastructure

Infrastructure Advanced

Show Online Segment Find:   Match Case  Repeats

Subscription criteria  WARNING  ERROR  FATAL  INFORMATION  Expression Subscribe

TIME	SEVERITY	APPLICATION	NAME	MESSAGE
18:22:27	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
18:22:26	WARNING	RootController	rc:MiscWarning	No Run Number Server provided: check the TDAQ_RUN_NUMBER_CONNECT Variable in the DB. A dummy run number will be provided.
18:22:26	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
18:22:14	WARNING	TRTBarrelA_B-01	TRT::VTScan	TTC 350108: Could not find DDC object TRTDDC_DT in ISI! Skipping VT scan for TTC in slot 8
18:21:49	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
18:21:48	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
18:20:03	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.

Clear  Message format   Number of visible rows  Current MRS subscription WARNING|ERROR|FATAL



# Test stand DAQ GUI

ATLAS TDAQ SOFTWARE - Partition TRTSR1

File Commands Access Control Settings Logging Level Help

Commit & Reload Load Panels

MBS IS DVS ED OMS LHM OH

RUN CONTROL STATE **RUNNING**

Run Control Commands

SHUTDOWN BOOT

TERMINATE INITIALIZE

UNCONFIG CONFIG

STOP START

HOLD TRG RESUME TRG

Beam Stable  Warm Start Warm Stop

Run Information & Settings

Lumi Block 0

	Number	Rate
Level 1	0	0
Level 2	0	0
Event builder	16233	34.00 Hz
Event filter	0	0
Recorded	16233	34.00 Hz

Information Counters Settings

Run Control Segments & Resources Dataset Tags TRT Config Actions

TRT Config Panel

Select trigger:

TestTrigger1 (Scintillator) Choose TDM delay (0,255):

TestTrigger2 (Fast-Or)

TestTrigger3 (Random)

Change all low thresholds by (-255, 255):

Change all high thresholds by (-255, 255):

Current Trigger in Database: TestTrigger2  
Current TDM Delay: 11

Status:

must be in state INITIAL or lower to update settings

Subscription criteria  WARNING  ERROR  FATAL  INFORMATION  Expression

TIME	SEVERITY	APPLICATION	NAME	MESSAGE
-18:22:27	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
-18:22:26	WARNING	RootController	rc:MiscWarning	No Run Number provided: check the TDAQ_RUN_NUMBER_CONNECT Variable in the DB. A dummy run number will be provided.
-18:22:26	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
-18:22:14	WARNING	TRTBarrelA_B-01	TRT:VTScan	TTC 350108: Could not find DDC object TRTDDC_DT in ISI Skipping VT scan for TTC in slot 8
-18:21:49	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
-18:21:48	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.
-18:20:03	WARNING	RootController	rc:MasterTrigger...	Master Trigger not defined.

Clear  Message format   Number of visible rows  Current MRS subscription

ATLAS TDAQ SOFTWARE - Partition TRTSR1

File Commands Access Control Settings Logging Level Help

Commit & Reload Load Panels

MBS IS DVS ED OMS LHM OH

RUN CONTROL STATE **INITIAL**

Run Control Commands

SHUTDOWN BOOT

TERMINATE INITIALIZE

UNCONFIG CONFIG

STOP START

HOLD TRG RESUME TRG

Beam Stable  Warm Start Warm Stop

Run Information & Settings

Lumi Block 0

	Number	Rate
Level 1	0	0
Level 2	0	0
Event builder	35093	0.00 mHz
Event filter	0	0
Recorded	35093	0.00 mHz

Information Counters Settings

Run Control Segments & Resources Dataset Tags TRT Config Actions

INITIAL RootController

INITIAL EventBuilder

INITIAL TRT

RootController

HW

PMG

Infrastructure

Infrastructure Advanced

Show Online Segment Find:     Match Case  Repeats

# Tasks1: Noise characterization

## 1. Sources of the noise

- Thermal noise
- External pick up noise
- Internal pick up noise

## 2. Dependence on threshold

- The less threshold
  - the better accuracy
  - the larger noise
- Particle loses  $\sim 1$  keV in Ar-mixture
- One primary ionization cluster  $\sim 80-100$  eV (3-4 el)
- Electronics noise with the detector  $\sim 3000$  el
- Nominal threshold should be  $>4$  sigma above the noise (now  $\sim 14000$  el)
- 
- Phys. Threshold =  $EI.Thr * W / (Gas\ gain * Signal\ fraction)$
- In our case  $\sim 14000\ el * 27/5 * 10^4 * 0.12 = 63\ eV$
- We are sensitive to a 1 primary ionization cluster!

## 3. Threshold are set in DAC counts

10 DAC counts  $\approx 1400$ el or 6.3 eV

# Tasks1: Noise characterization

Identify problematic channels and choose the operating threshold.

## 1. Misbehaving channels

- Requirements
- Analysis noise maps at different thresholds
- Dead channels
- Readout problem
- Large noise
- Too high or too low thresholds

## 2. Methods of the noise source identification and noise signal suppression

- Signal shape.
- Time distribution.
- Noise rate estimate.

## 3. Operating threshold

- What noise occupancy is allowed to be?
- Noise scan

**Analysis Tool:** TRTViewer (see test manual)

## Task 2: Operation with cosmic particles

Identify detector problems, straw efficiency, tracking accuracy as a function of the electronics threshold

### 1. Signal from particles

- Signal shape
- Drift-time distribution (hit arrival time, trailing edge)
- Method of timing of the signals from particles
- Cosmic particle track characterization.

### 2. Misbehaving channels

- Dead
- HV problems
- Straw mapping with particles

### 3. Straw efficiency and drift-time accuracy

- Straw efficiency as a function of threshold
- Drift-time accuracy as a function of threshold
- Tracking at high occupancy and noise suppression

### 4. Basic principles of the particle Identification

- Compare HL threshold distributions at different conditions
- Choice of the correct representation of the results

**Analysis Tool:** TRTViewer (see test manual)