Performance of new Amplifier-Shaper-Discriminator chips for the ATLAS high-luminosity upgrade of the ATLAS muon chambers

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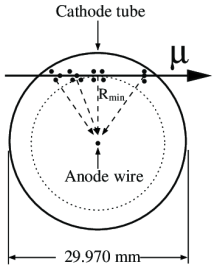
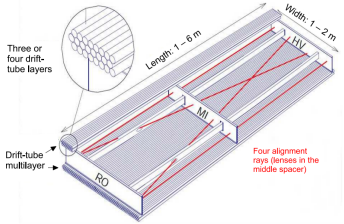
Monitored Drift Tube (MDT) spectrometer

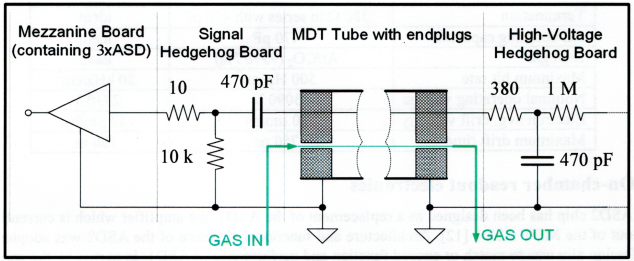


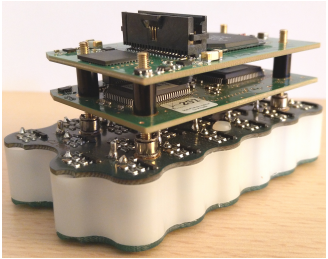


- Part of ATLAS Muon Spectrometer.
- Designed for precision tracking of charged particles.
- 1084 MDT and sMDT chambers comprised of 370.000 drift tubes.

- Scheduled High-Luminosity upgrade of the LHC requires complete replacement of the MDT readout electronics.

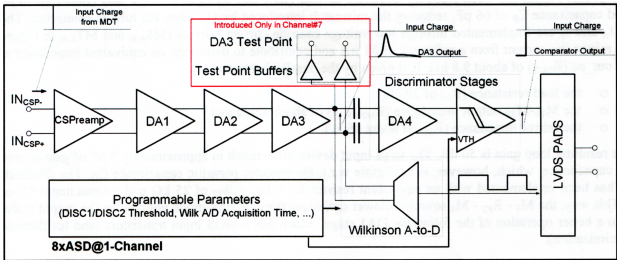
Readout circuitry





- Signal from 24 tubes are channeled to a readout board(mezzanine card) that contains:
  - 3 ASD Chips
  - Single 24-channel TDC
  - Control circuitry
- Chamber Service Module(CSM) reads the data from the up to 18 mezzanine cards per MDT chamber that is then transferred to the ATLAS DAQ.
- Communications with CMS using LVDS standard

Amplifier/Shaper/Discriminator Chips



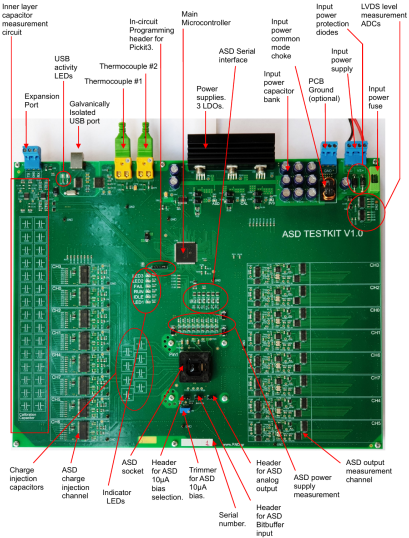
- Charge sensitive preamplifier - voltage gain > 100
- 3 Differential amplifiers used to amplify and shape the signal
- Discriminator Stage
- Conversion to LVDS
- Designed by Max Plank Institute for Physics

High-Luminosity Upgrade

MAX-PLANCK-INSTITUT FÜR PHYSIK

- New readout electronics have to designed, manufactured and tested which includes at least:
  - around 60000 ASD chips
  - around 20000 TDC chips
  - around 20000 Mezzanine boards
- 7000 preproduction chips were produced in 2019, then manually tested and classified in 2020.
- 80.000 production chips were produced and delivered in January 2021 and are to be tested by machines.

Testing board



- Designed by LMU
- Serial link to a computer
- Custom software and GUI created in order to:
  - Automate tests execution.
  - Store the data in a way to ease future analysis.
  - Help diagnose chips that ware not properly seated in the socket in real time.
- Used to test 2440 preproduction chips.

```
>VLV()
VA0=1115    VB0=1360    VD0=245 VC0=1228    D0=0
VA1=1111    VB1=1340    VD1=229 VC1=1221    D1=0
VA2=1101    VB2=1344    VD2=243 VC2=1229    D2=0
VA3=1111    VB3=1351    VD3=240 VC3=1221    D3=0
VA4=1107    VB4=1343    VD4=236 VC4=1236    D4=0
VA5=1109    VB5=1358    VD5=249 VC5=1225    D5=0
VA6=1102    VB6=1357    VD6=255 VC6=1229    D6=0
```

Testing methodology

MAX-PLANCK-INSTITUT FÜR PHYSIK

Operating point:

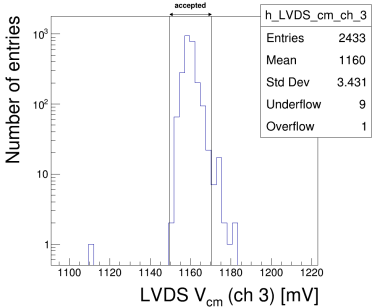
- Supply voltage: 3.0 V
- Bias current: 10 µA
- Rundown current: 3.1 µA

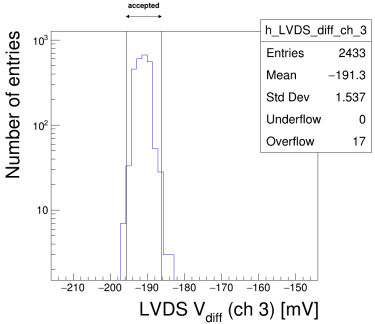
Test strategy:

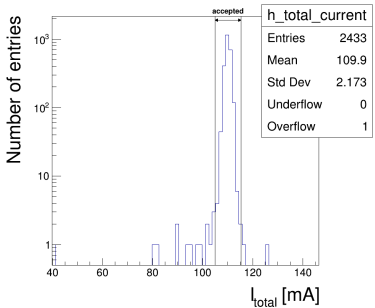
- Check if a chip can be powered on and operated.
- Reject chips that :
  - draw abnormal currents.
  - have wrong LVDS.
  - have dead channels.
  - have too large threshold spread.
  - have "abnormal" ADC counts for an input charge of 10 fC .

Basic Health Tests

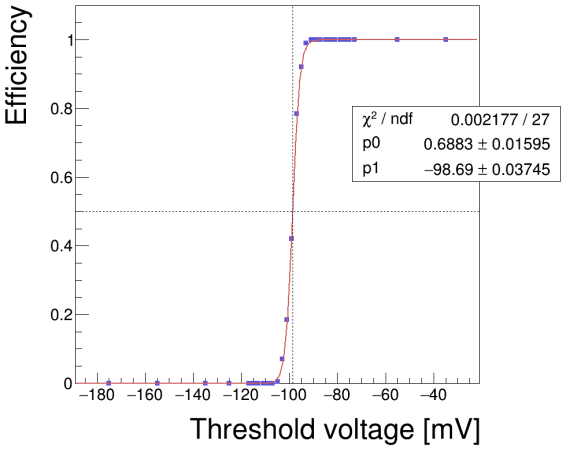
- 5 chips could not be powered on or operated
- Reject chips with values that lie outside the 3σ interval.
- 122 chips have bad common mode and/or differential LVDS levels in one or more channels
- 19 chips draw abnormal current





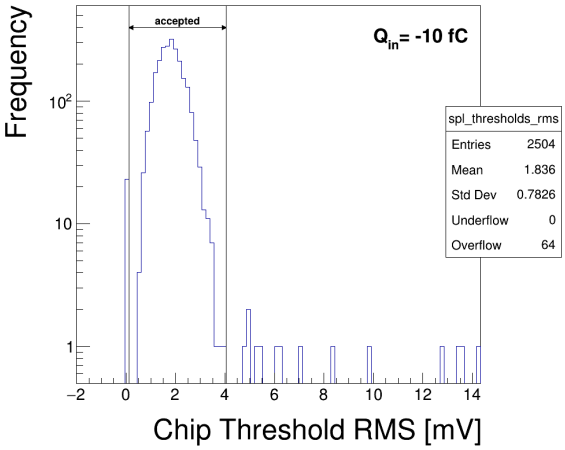


Threshold measurement



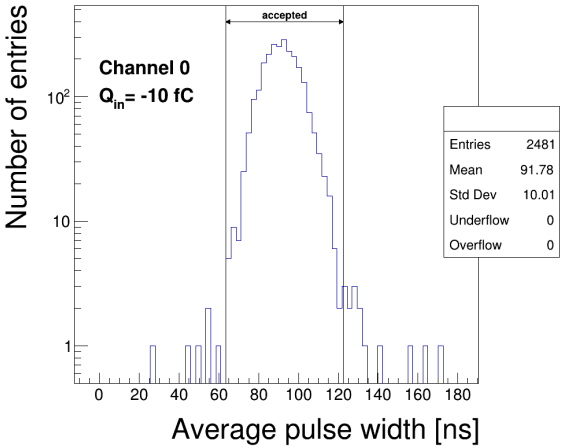
- 200 −10 fC pulses are injected in each 8 channels of the ASD.
- If the comparator threshold has been passed, a signal is sent out of the ASD.
- Count how many pulses are detected coming out of the ASD and record their width.
- Repeat the test for different threshold values.
- Measurement of the hit efficiency(percentage of all pulses detected) as a function of the threshold voltage.
- Fit a sigmoid function and take the

Threshold spread



- The threshold value can not be set each individual channel of the ASD chip.
- Chips with small threshold span are preferred.
- Chips with RMS of the thresholds outside the 3σ interval are rejected.
- Chips with threshold spread of 0 are rejected: no signals detected in all channels.
- 131 out of 2440 chips are rejected due to their threshold span.

Uniformity of ADC measurements

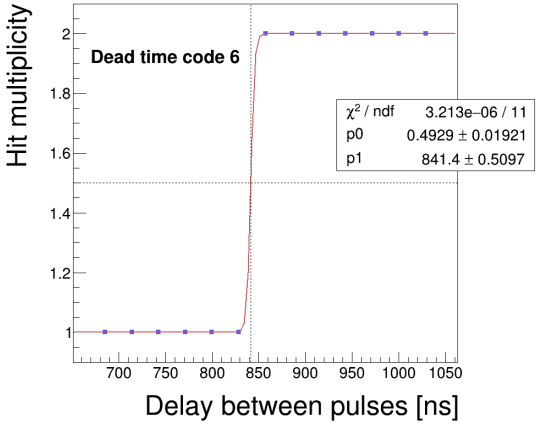


- Average width of the detected pulses coming out of the ASD, reported by the test board.
- Pulse width directly related to the Wilkinson ADC performance.
- Values found to be normally distributed.
- Reject chips with a pulse width outside the 3σ interval.
- 83 out of 2440 chips are outside the interval.

Dead-time test

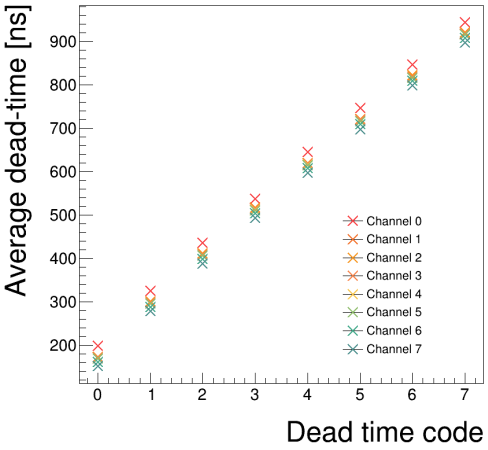
Goal:

- Check if the dead-time circuit is working properly.
- Identify dead channels.



- Inject two consecutive pulses with different delays.
- Measurement of the hit multiplicity as a function of the delay.
- Fit sigmoid function to the multiplicity points and take the inflection point as the measured dead time.
- 73 out of 2440 with at least one dead channel have been identified, i.e. chips that have channels with constant output

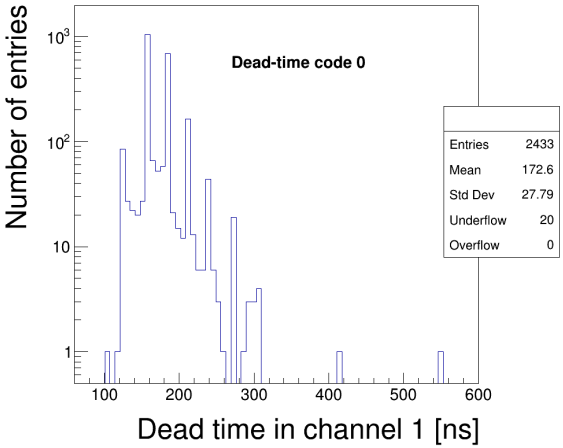
Dead-time test results



- Linear dependence of the average dead time on the programmed dead-time code.
- ~ 30 ns longer dead times in channel 0 than in other channels.

Dead-time spread

Minimum dead time



- Large dead-time spread
- No chips rejected due to their dead-time value in the present analysis.
- Exact dead-time is not critical, as long as the counting rates are moderate, as is the case at HL-LHC

Summary

- 2440 chips tested

Reason for rejecting the chip	# of chips identified
Chip not operable	5
Bad LVDS levels	122
Abnormal total current	19
Large threshold spread	131
Dead channels	73
Bad ADC value	83
Other	3
Total rejcetions	179

- Number of accepted preproduction chips: 2261
- Acceptance rate: 92.7%