NMrena

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NMRENA, Universal Bern Unit

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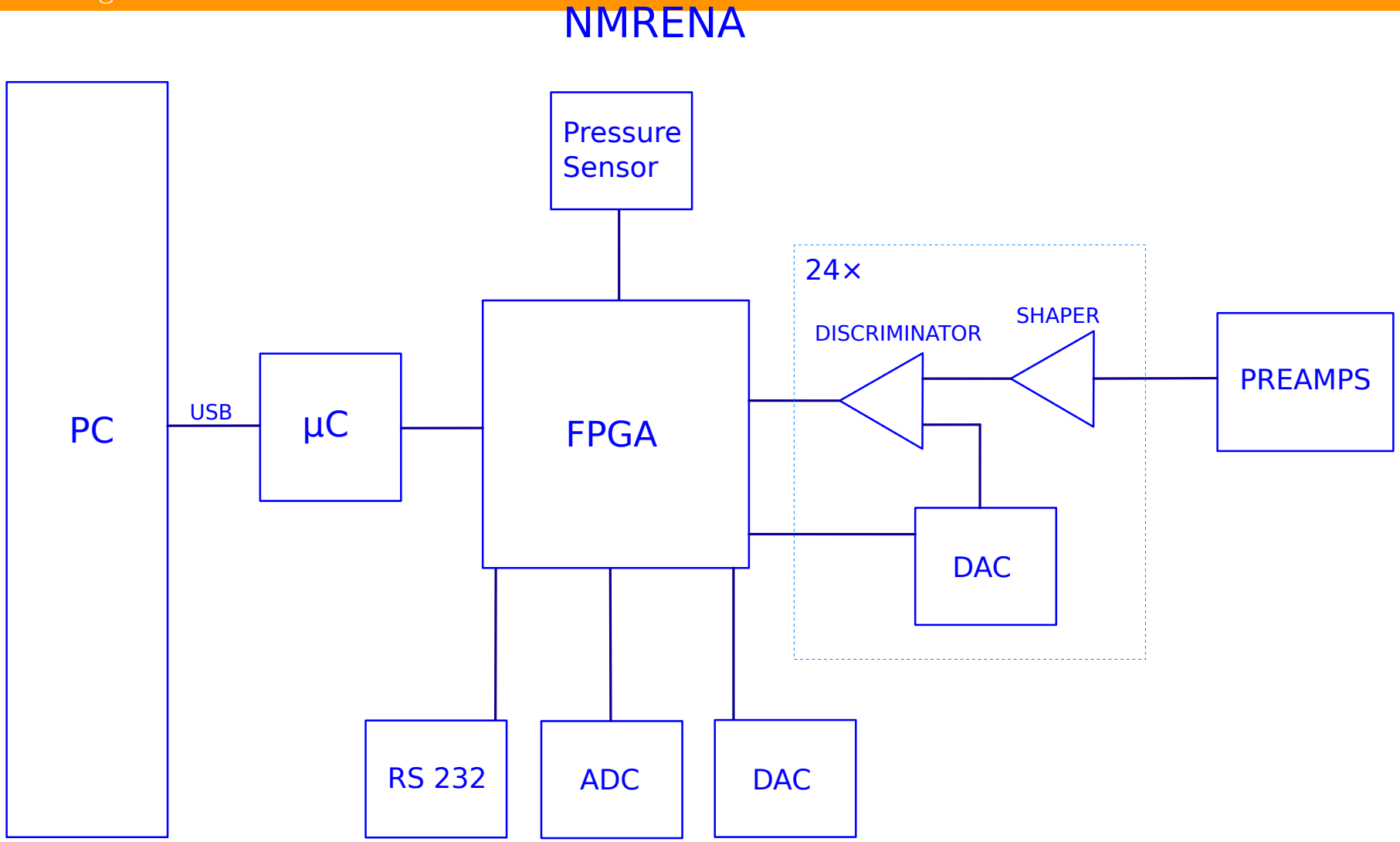
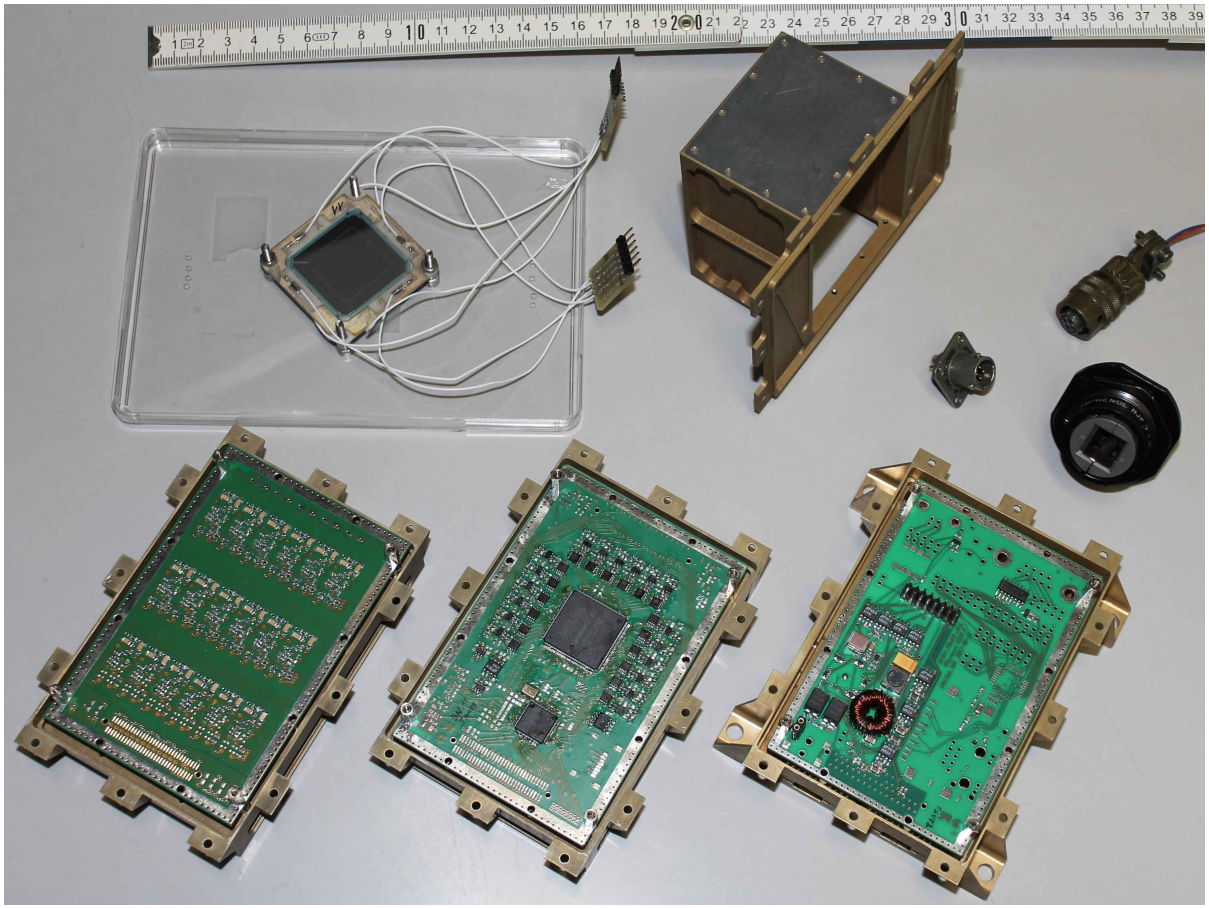

NMRENA
PC
USB
µC
Pressure Sensor
FPGA
24×
DISCRIMINATOR
SHAPER
PREAMPS
DAC
RS 232
ADC
DAC

The IRENA ist an 18-input multi channel analyser board, developed to fit into the flight housing that was designed to land on Mars with the ESA Exomars mission.

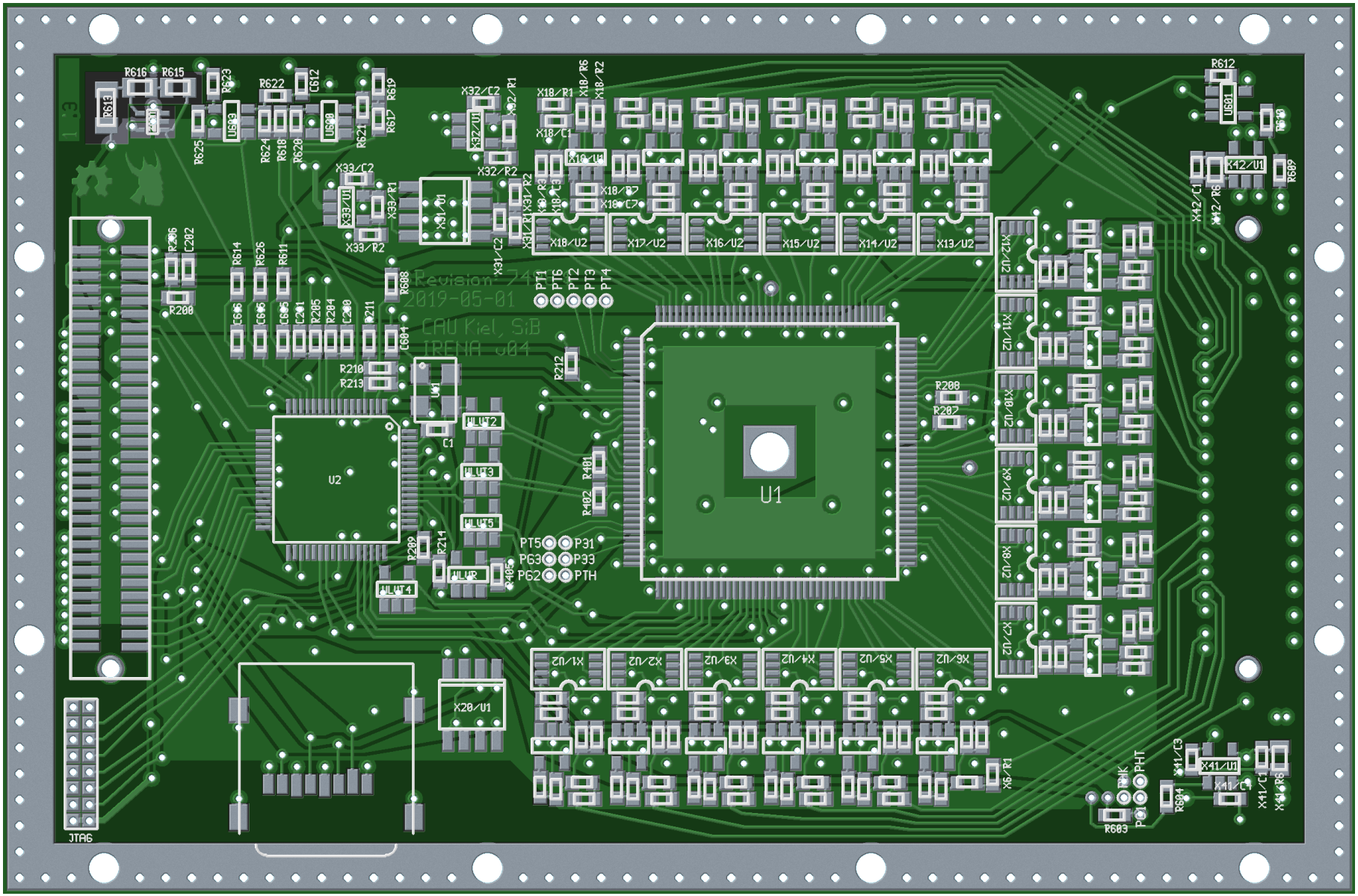


The IRENA is the origin of an expanding system of data acquisition systems developed at the CAU zu Kiel.

- Altera Cyclone III FPGA, EP3C25-E144,
- LPC2148 ARM7 microcontroller with USB 2.0,
- SPI flash, 2 MBytes,
- μSD-card slot,
- SPI interface,
- RS232 interface.

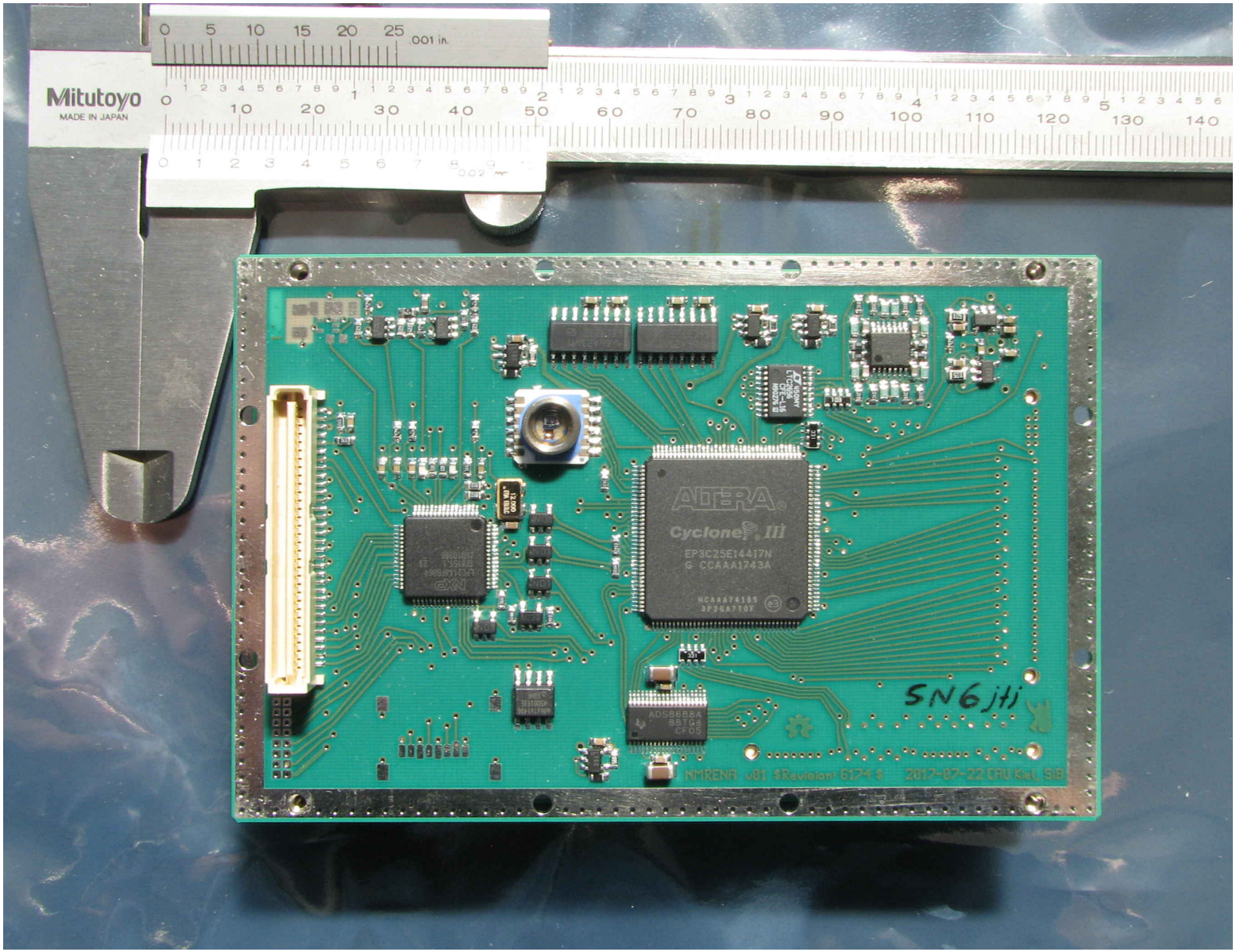
The prototypical IRENA hosts 18 ADCs and shapers for solid state detector readouts.

IRENA PCB



- Board size: $106 \times 70\,\mathrm{mm}^2$.
- Chassis ground frame and plane.
- Board separation: 10 mm Mezzanine connectors.
- Housing module for two boards.
- Four boards in two housings.
- Additional modules for sensors or connectors.
- Miscellaneous power board options.
- NM64_POWER board, 12 V input, DC/DC converters, optional Ethernet, or fullsize SD-card.

NMRENA board



Frontend connector:

- 24 counter inputs,
- 3 serial DAC output pins,
- $\pm 6\,\mathrm{V}$ power.

HK connector:

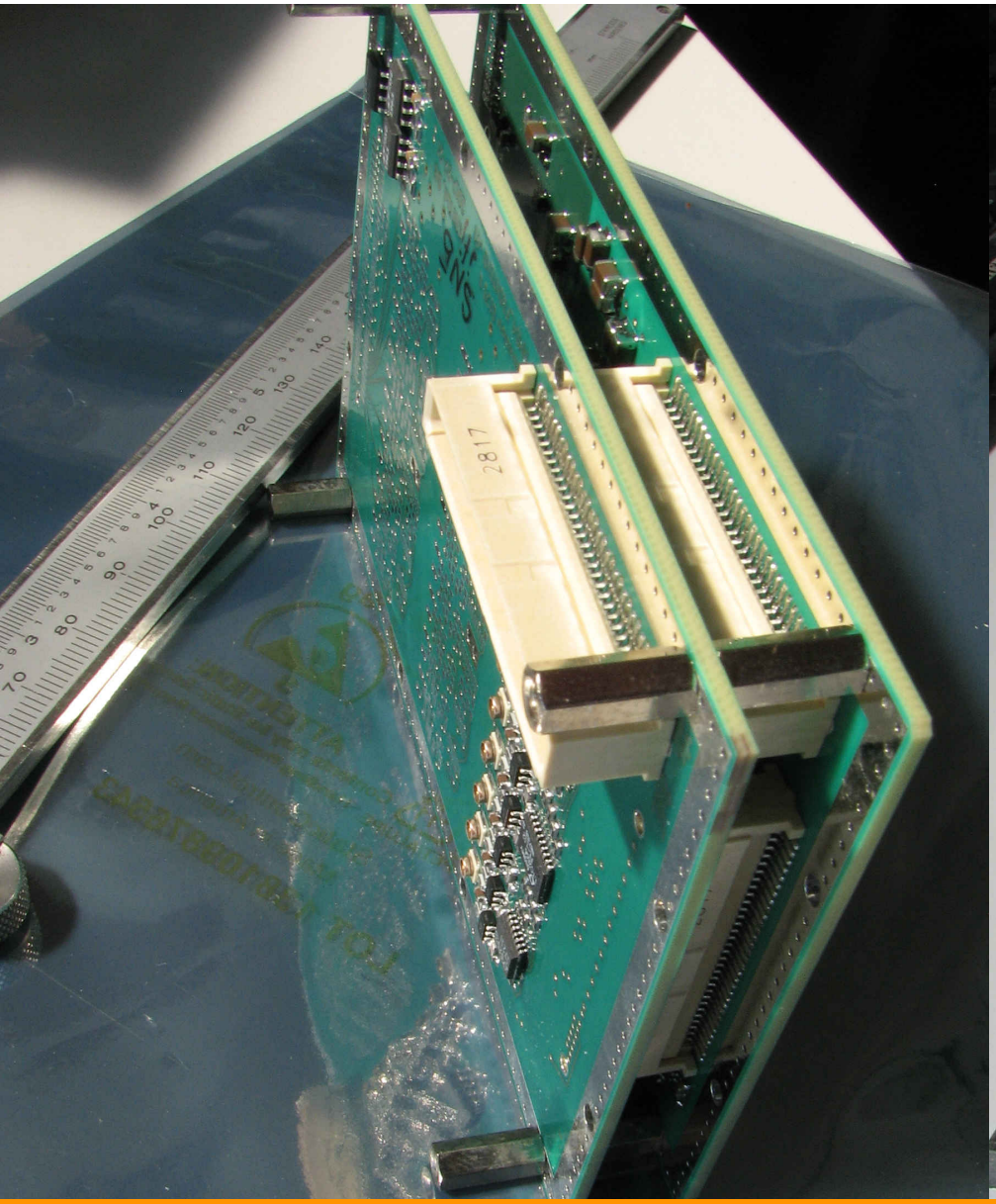
- 8 ADC inputs, ADS8688A, $\pm 10.2\,\mathrm{V}$, 16-bit.
- 4 (3) DAC outputs, LTC2656-L16, $\pm 11\,\mathrm{V}$ $(0 - 2.5\,\mathrm{V})$, 16-bit.
- RS232, 4 Tx, 4 Rx,
- 10 FPGA-IO, LVDS.

Pressure sensor.

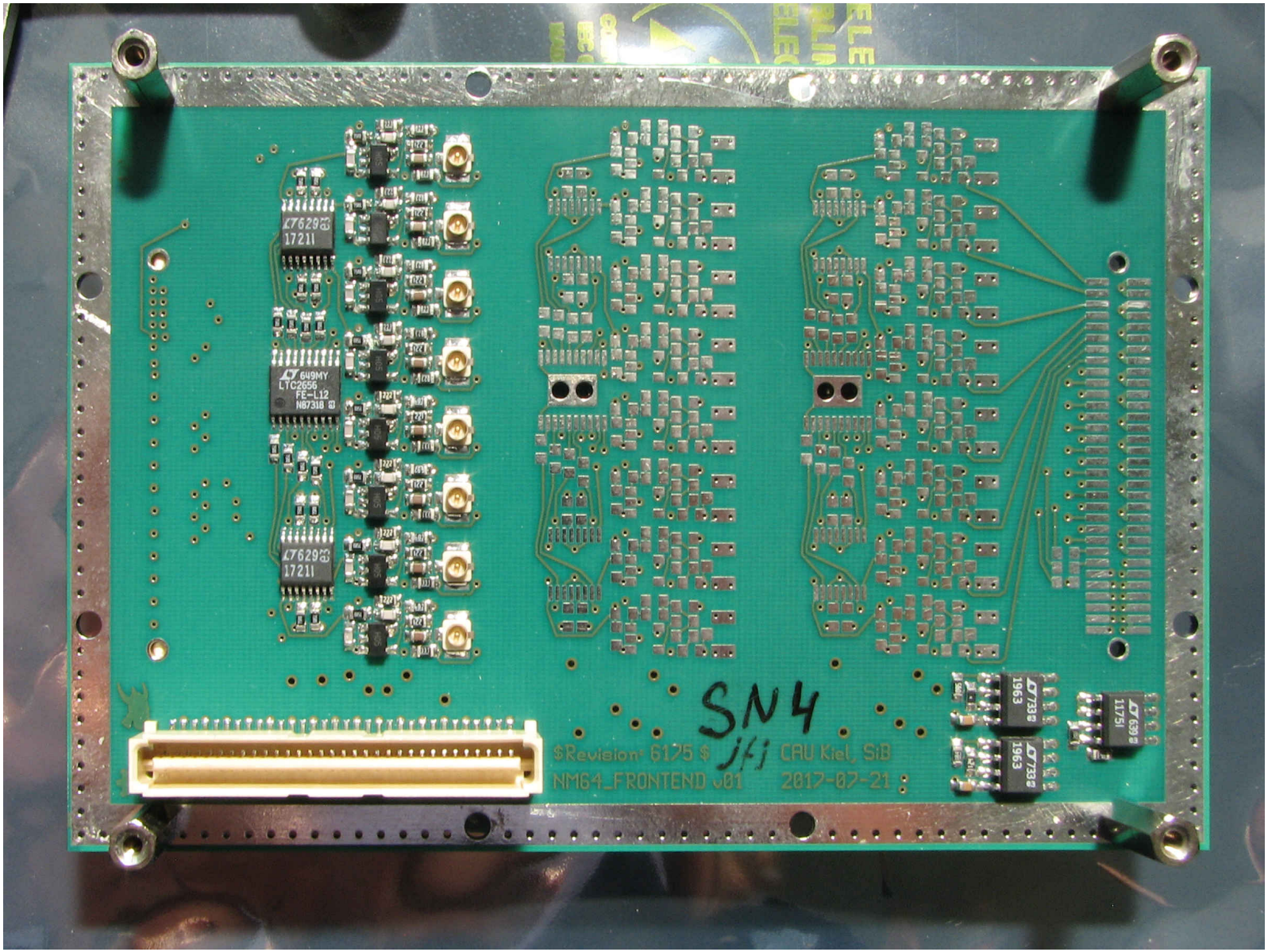
The latest member of the XRENA family is the NMRENA, specifically designed for the readout of neutron monitors. Although, for its primary function there is no infrastructure on the board. Just FPGA pins wired to a connector. That, and the auxiliary infrastructure is useful for a lot of different applications.

- 4-quadrand HV-supply for Langmuir probes and retarding potential analysers.
- Multi channel scaler.
- Readout of the muon telescope Mustang.

Board Stack



NM64_FRONTEND Board



The NM64_FRONTEND board receives and conditions the outputs from the counter tube preamplifiers.

24 channels, in three sections, each channel with

- SMA coax connector, or connected via Mezzanine,
- signal shaper, AD8005,
- comparator,
- threshold DAC, 12-bit.

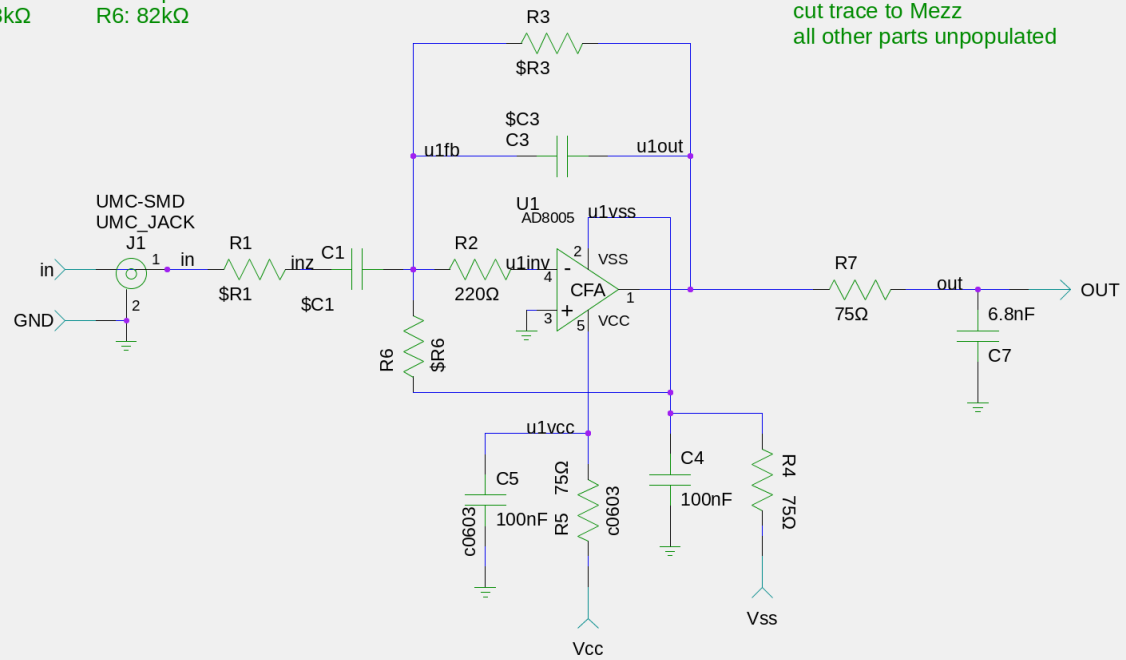
The output of the *shaper* amplifiers are connected to discriminators with a programmable threshold. The outputs of the discriminators go to the FPGA.

Signal Shaper Schematics

NM64:
R1: 330Ω
C1: 220nF
R3: 2.2kΩ
C3: 1.5nF
R6: 6.8kΩ

TTL:
R1: 82kΩ
C1: 220nF
R3: 22kΩ
C3: 10pF
R6: 82kΩ

MCS:
R7: 220Ω
C7: 220Ω
C5: 56Ω
wire: in - u1vcc - u1out
cut trace to Mezz
all other parts unpopulated



NM64 input conditioner

$Id: nm64_shaper.sch 7915 2020-02-17 19:31:50Z stephan $	
TITLE $Date: 2020-02-17 20:31:50 +0100 (Mo, 17 Feb 2020) $	
FILE: nm64_shaper.sch	REVISION: $Revision: 7915 $
PAGE OF	DRAWN BY: $Author: stephan $

The shapers need to be configured for the signal levels provided by the counter tubes. That requires selecting and soldering a suitable set of components to the NM64_FRONTEND board. We found three useful sets, for

- old NM64 preamps output, 300 mV, 20 μs, weak driver, AC-coupling. The shaper transforms the charge pulse from the leading edge into a shaped pulse.
- TTL-levels. The shaper is configured with a gain of 1/4 with AC-coupling.
- For the multi channel scaler, the board had to detect very short TTL pulses, 5 to 10 ns long. That was achieved with a piece of wire and three passive components in place of the shaper.

Verilog HDL.

- Counter module
  - Hit records with
    - pulse length,
    - channel pulse separation,
    - global pulse separation.
  - Counters for
    - pulses,
    - global pulse separation.
- Drivers for
  - threshold DACs,
  - HK DACs and ADCs,
  - pressure sensor,
  - UARTs,
  - GB1 barometer.

The NMRENA unit is driven by a Python script running on a Linux computer. The unit emits a binary data stream, that is written to disk by a background thread of the Python script. The REPL of the Python interpreter is available for commanding.

For the neutron monitor readout, we implemented a mode where the background thread opens a new data file at the beginning of each hour. The new file includes a copy of the last minutes of the previous file, so that each file allows for the analysis of the whole hour.

Offline, the data files are converted to an ASCII representation. A further script produces one minute summary records.

We have a script that reads the binary data files in real time and emits the 1 minute summary records on a network socket.

Raw data output

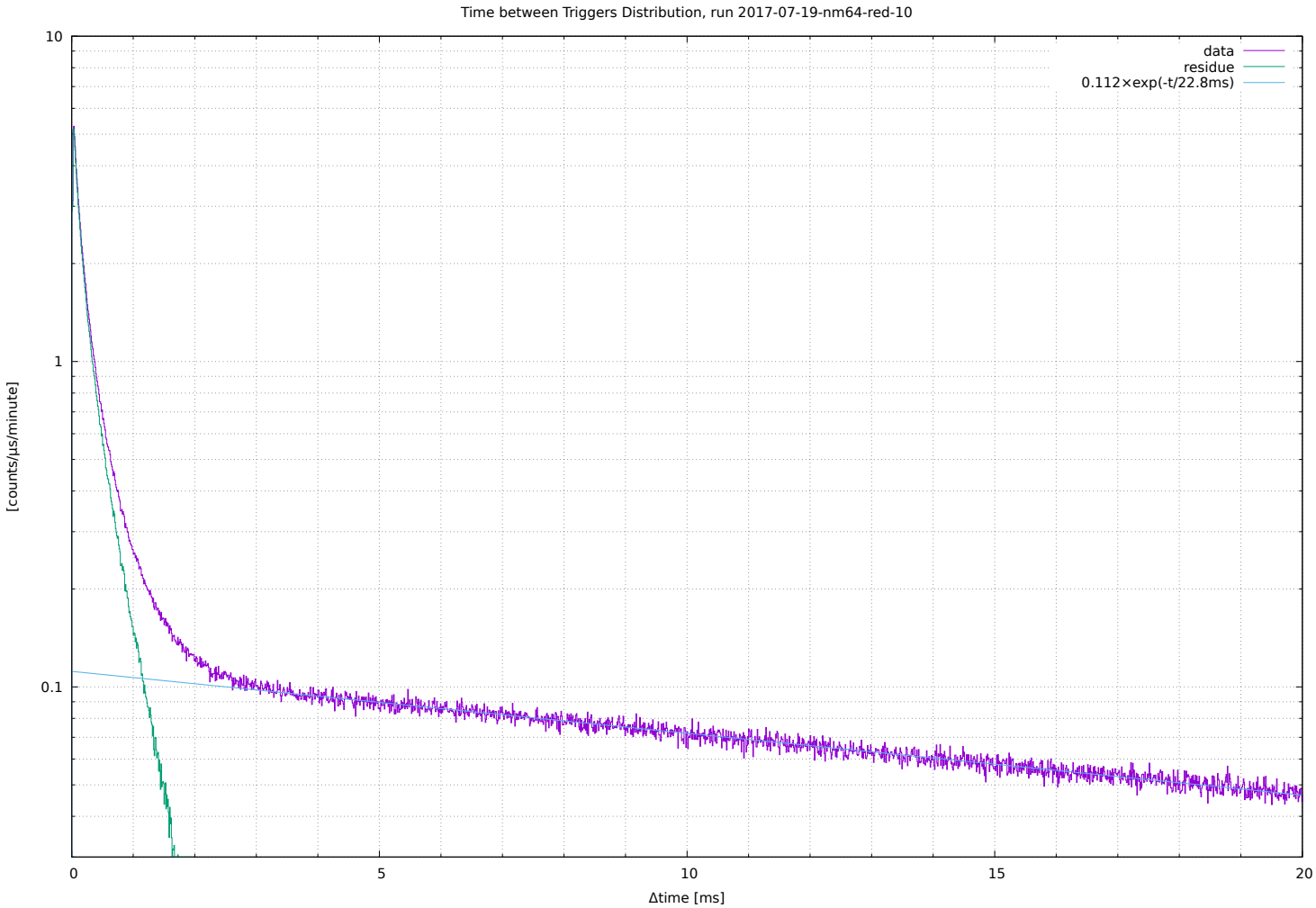
```
...
E64 12 492 45083 102
E64 22 489 65535 2152
E64 14 471 40245 5418
E64 2 704 65535 814
E64 19 489 65535 1055
E64 11 472 11662 2121
E64 2 705 16769 13593
...
C64 1  0 524 610 614 0 687 563 0 0 629 668 659 716 634 531 0 0 542 0 724 714 711 551 0
       12 12 29 66 207 416 631 723 803 756 938 1148 1707 1642 845 142  2265105978
...
ADC 0 0 0 10212726  256 2.22671 0.000173938
ADC 1 0 0 10211286  256 2.22495 0.000178287
ADC 2 0 0 10212314  256 2.2262 0.000183578
ADC 3 0 0 10212581  256 2.22653 0.000183578
ADC 4 0 0 10211680  256 2.22543 0.00018148
ADC 5 0 0 10211280  256 2.22494 0.000178287
ADC 6 0 0 10210935  256 2.22452 0.000176126
ADC 7 0 0 10212246  256 2.22612 0.00018148
...
UX 1 54 3d 31 35 39 33 32 30 38 36 38 33 0a
UT 1 T=1593208683
...
H 1593208685 0 64000 22144 24256 6016 28544 53440 21888 46080 30592 59200 60416
...
P 0xba7e 0xfff7 0xaed1 0x3559 0x9515 0xba88 0x4294 0x81c2
...
```

One Minute data output

```
2020-06-26T21:58:05Z 1593208685 60.000007 42.7 1006.02 1004.98 0.00
  0.000173938 0.000178287 0.000183578 0.000183578 0.00018148 0.000178287 0.000176126 0.00018148
  0 533 679 706 0 616 560 0 0 624 709 656 622 668 576 0 0 564 0 753 736 729 579 0
  15 13 35 68 211 445 658 799 872 768 880 1172 1723 1680 820 151
```

column	value
1	time UTC
2	time, seconds since Unix epoch
3	counting time, seconds
4	temperature reading of the internal pressure sensor
5	pressure reading of the internal pressure sensor
6	pressure reading of the BM35 barometer
7	pressure reading of the GB1 barometer
8...15	ADC readouts
16...39	tube count rate, per minute
40...55	global Δ-time spectrum

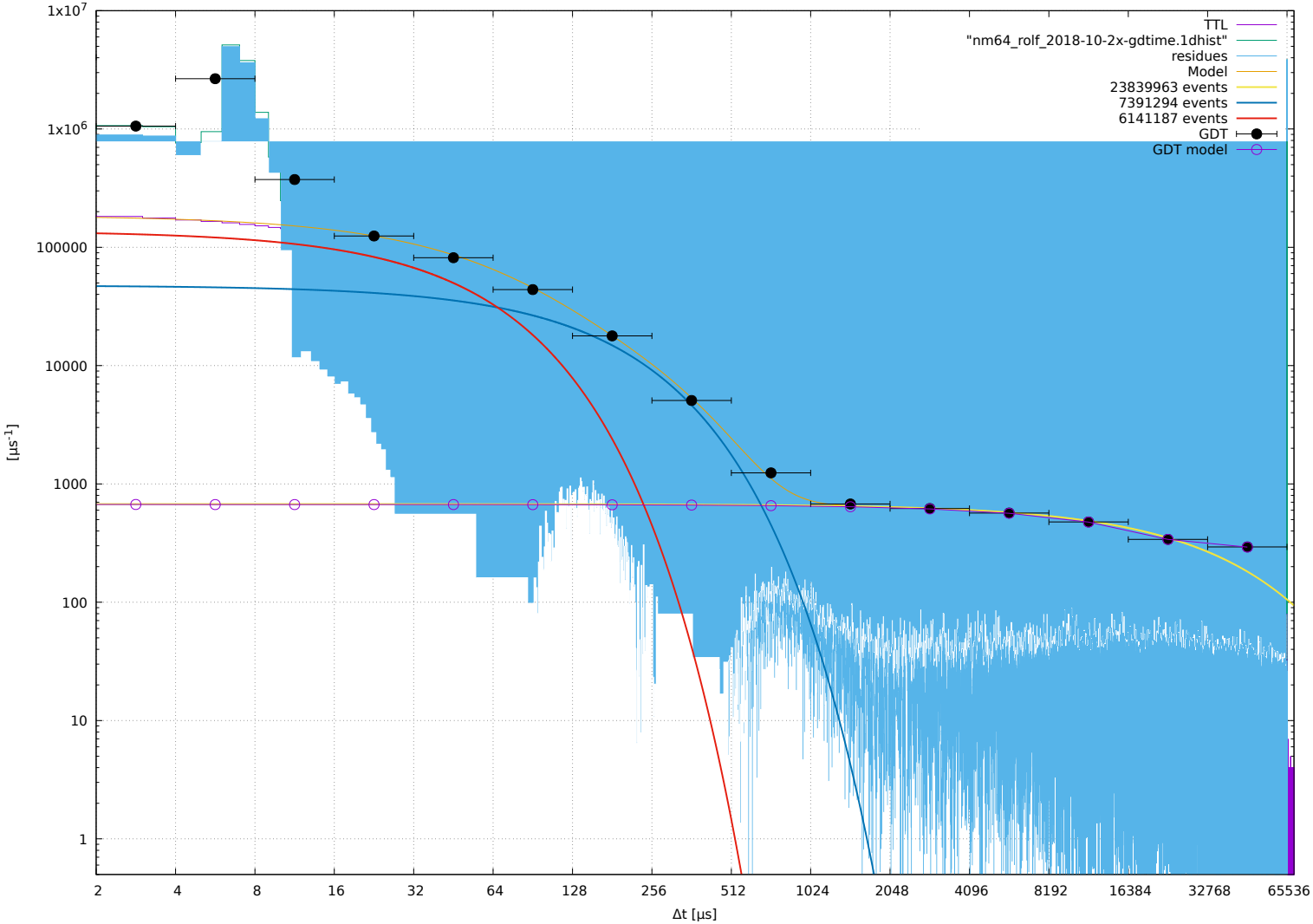
Δ-time distribution in the red section of the Kiel neutron monitor.



Fit of an exponential Δt distribution

$$
\begin{aligned}
f(\Delta t) &= a \exp\left(-\frac{t}{\tau}\right), && (1)\\
\tau &= 22.8\,\mathrm{ms}, && (2)\\
a &= 0.112/(\mu\mathrm{s\,min}), && (3)\\
a\tau &= \int_0^\infty f(\Delta t)\mathrm{d}\Delta t = 2550/\mathrm{min}, && (4)\\
\frac{1}{\tau} &= 2630/\mathrm{min}. && (5)
\end{aligned}
$$

Δ-time distribution in the Bern neutron monitor.



Analysis of the last six Δ-time counters may yield an alternative count rate value, independent of instrumental effects like pileup, multiple-hits.

Legend:

- green: Δ-time distribution,
- yellow, blue, red: fit, exponention components.
- cyan: residuals,
- black: Δ-time counters,
- purple: exponential model for the Δ-time counters.

Difference of three barometers readout by NMRENA in the lab.