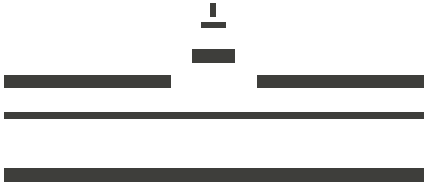

Westfälische
Wilhelms-Universität
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An instrumented analysis and supply gas system prototype for the CBM TRD

Bundesministerium
für Bildung
und Forschung

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Development of a Slow Control System

- As mentioned before, the CBM TRD F/MS prototype was tested at the CERN SPS in November of 2016.
- For this in-beam-test a new gas supply and analysis system was developed by F. Fidorra, and this system needed an electronic monitoring system.
- This monitoring system was developed from scratch and has certain requirements.

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Requirements of the Slow Control Software

- Many process variables are available and need to be recorded.
- The diverse interfaces need to be mapped to a common database format.
- The system should be as resilient towards network outages as possible.

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General Structure

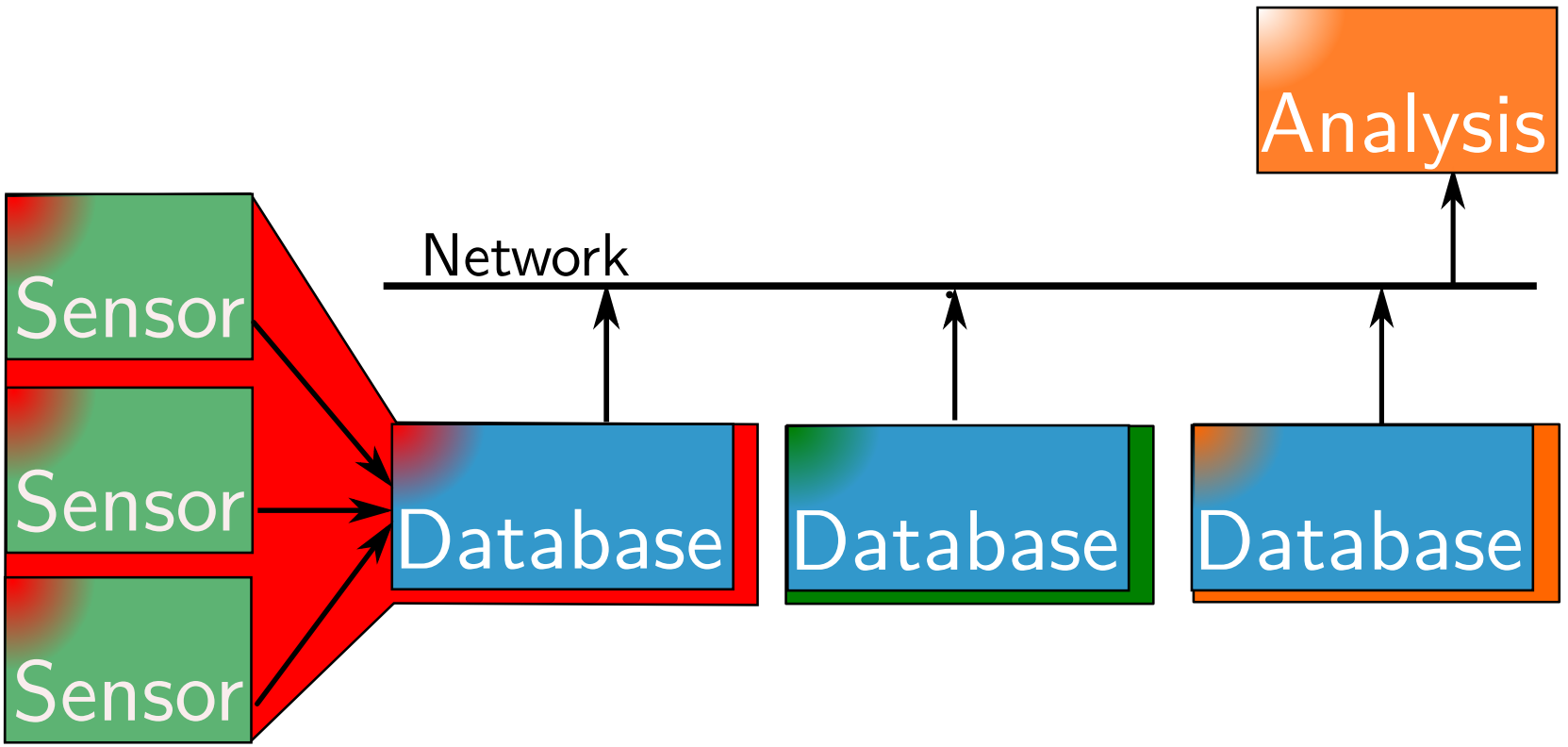

Figure: Structure of the developed slow control system

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Tooling

- Python
  - PyModbus3
  - PyMySQL
  - Python-Serial
- Pandas/NumPy
- MySQL
- plot.ly

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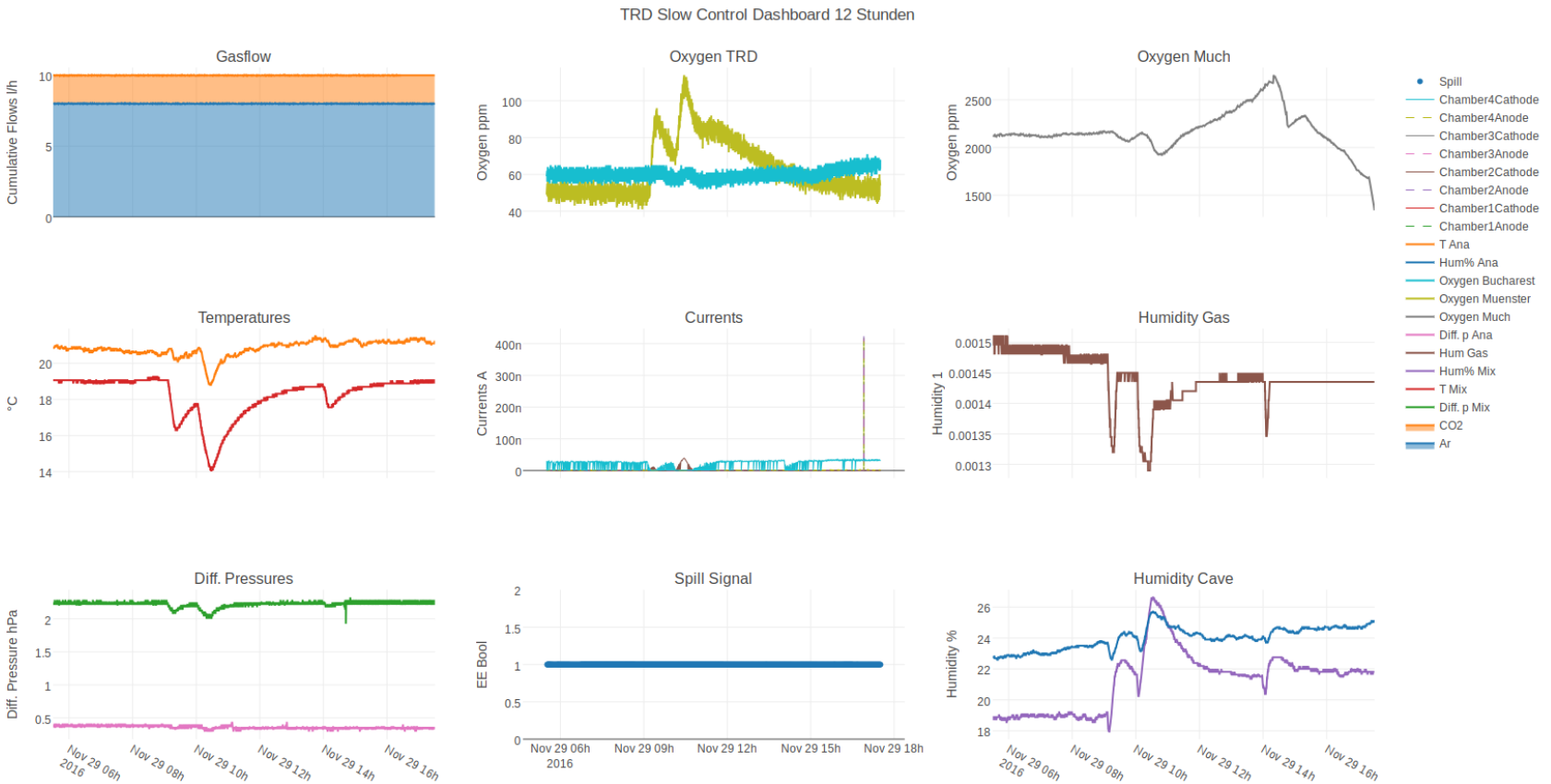

Figure: The monitoring dashboard employed during the in-beam test.

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Recorded Process Variables(1/2)

Observables	Channels	Frequency
Gas Flows Total	3: Ar, CO_2, Mix In(unused)	$1/1\,s^{-1}$
Gas Flows	4: 1 per Line	$1/2\,s^{-1}$
Differential Pressure	1: Line Mixing	$1/2\,s^{-1}$
	1: Line Analysis	$1/2\,s^{-1}$
Ambient Temperature	2: Mixing + Analysis	$1/10\,s^{-1}$
Ambient Humidity	2: Mixing + Analysis	$1/10\,s^{-1}$
Absolute Pressure	3: Analysis	$1/2\,s^{-1}$
Gas Temperature	3: TRD F/MS, Buch + MUCH	$1/2\,s^{-1}$
Oxygen Content	3: TRD F/MS, Buch + MUCH	$1/2\,s^{-1}$
Water Content	1: TRD F/MS	$1/2\,s^{-1}$

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Recorded Process Variables(2/2)

Observables	Channels	Frequency
HV Currents	8: F/MS Drift + Anode	$1/400\,\mathrm{ms}^{-1}$
HV Voltages	8: F/MS Drift + Anode	$1/400\,\mathrm{ms}^{-1}$
LV Currents	12: $2 \cdot$ SPADICs + SysCores	$1/400\,\mathrm{ms}^{-1}$
LV Voltages	12: $2 \cdot$ SPADICs + SysCores	$1/400\,\mathrm{ms}^{-1}$

$\Rightarrow$ In Total: 64 process variables

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Operation at CERN SPS in 2016

- The system was operated for the whole duration of the in-beam test of 6 weeks.
- It operated with only two major outages, both caused by a loss of power.
- The total amount of collected slow control data was 3.074 GiB.
- The bulk of this data were HV data, the rest of the data amounted to 149.6 MiB.

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Conversion process from MySQL to ROOT

1. Read the Data from MySQL using PyMySQL and Pandas.
   - If needed, split this step into smaller chunks and merge data using NumPy.
2. Convert the timestamps to an integer number of (nano-) seconds since $UNIX_EPOCH.
3. Convert the Pandas frame to a ROOT TTree using pandas_ROOT.

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Analysis: Gas Composition

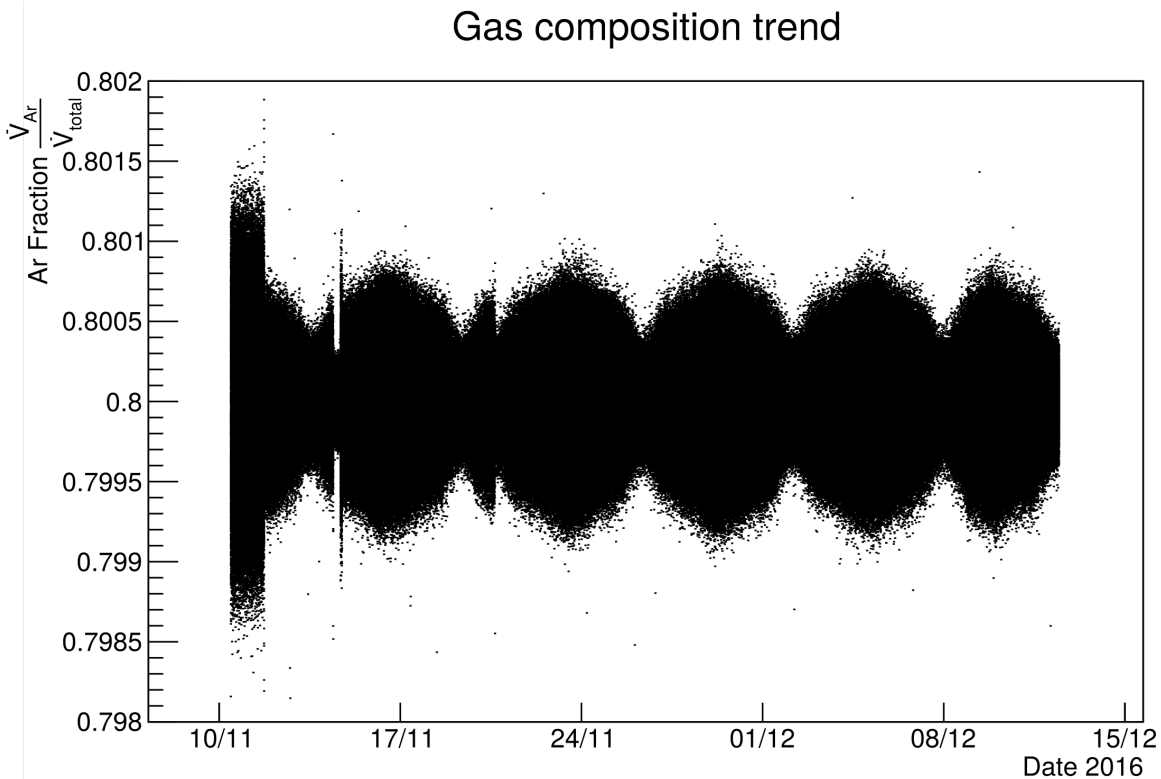

Figure: Gas composition in terms of added argon fraction over the whole in-beam test

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Analysis: Gas Composition

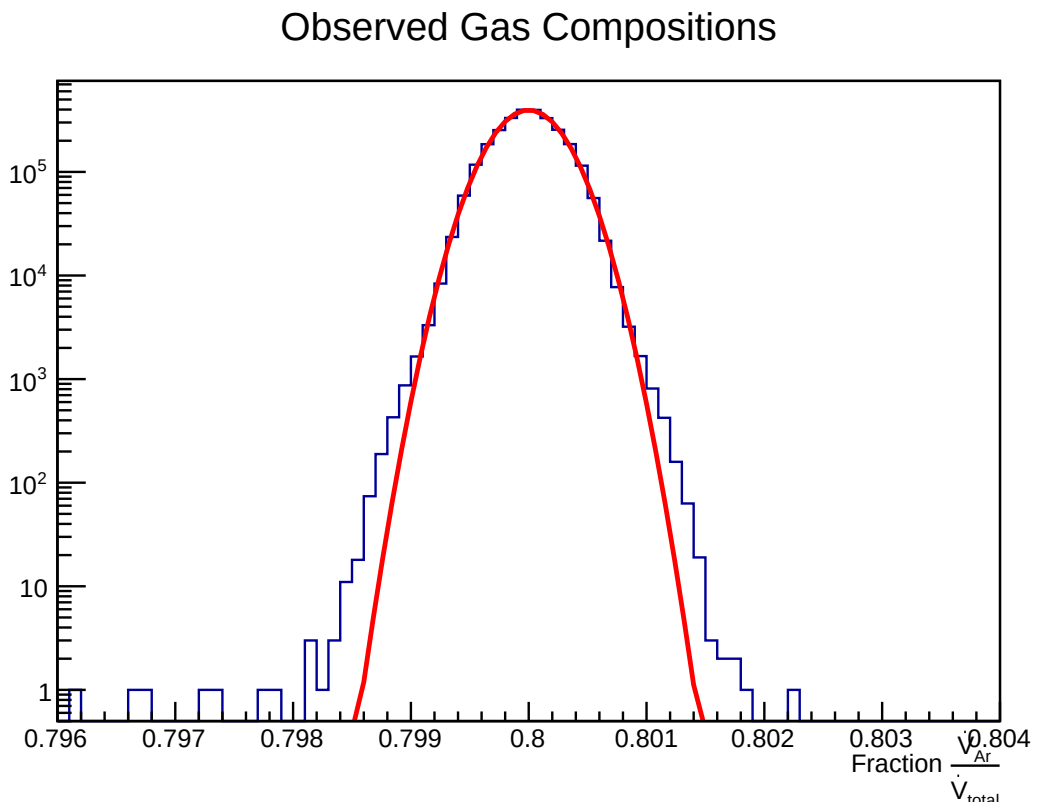

Figure: Distribution of added argon fractions (according to flowmeter), FWHM of 0.06 %.

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Analysis: Oxygen Content

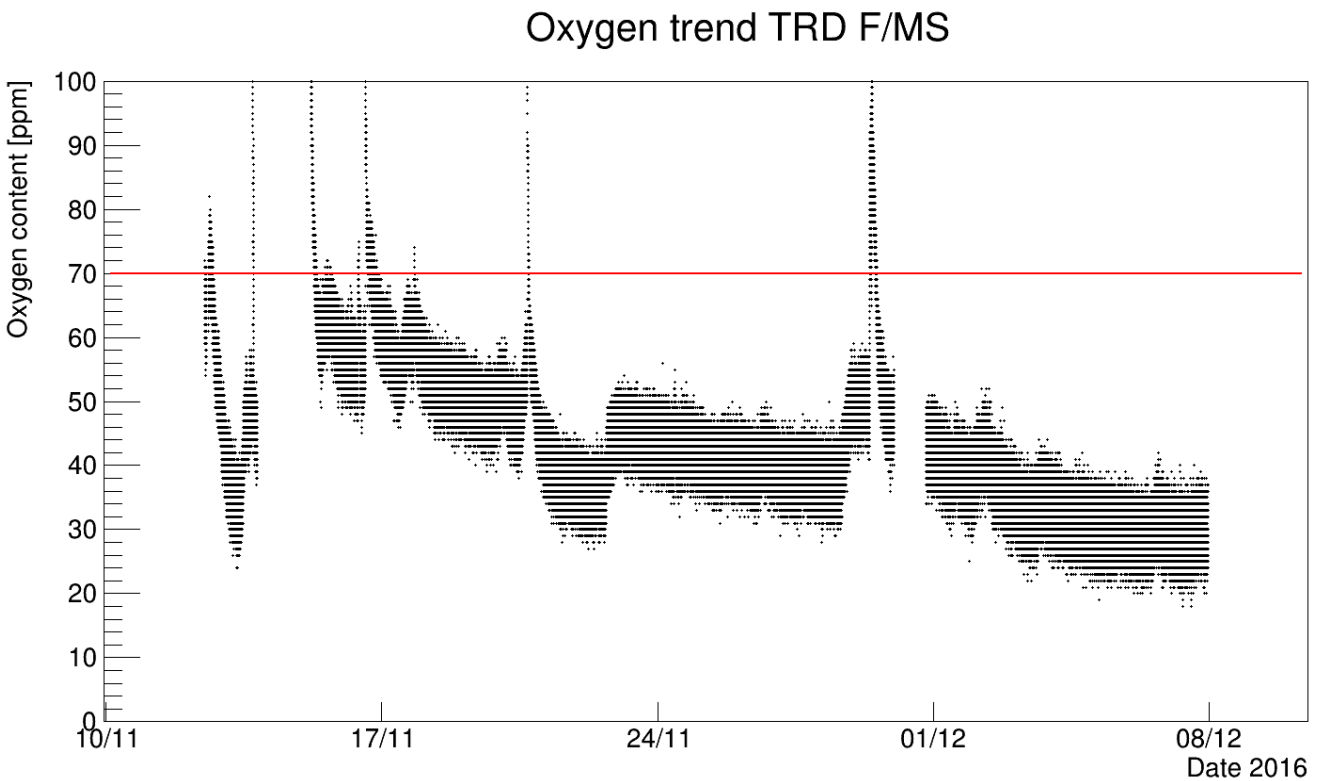

Figure: Oxygen content in exhaust gas of the 4 TRD F/MS prototypes.

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Outlook

- The analysis of the slow control data will continue and the results will be used to review and proceed with the full CBM-TRD support infrastructure.
- The slow control system will be further developed and will be used during the upcoming in-beam tests at DESY and GIF^{++} and for the eventual use at mCBM.

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Backup

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Analysis: Spillstructures

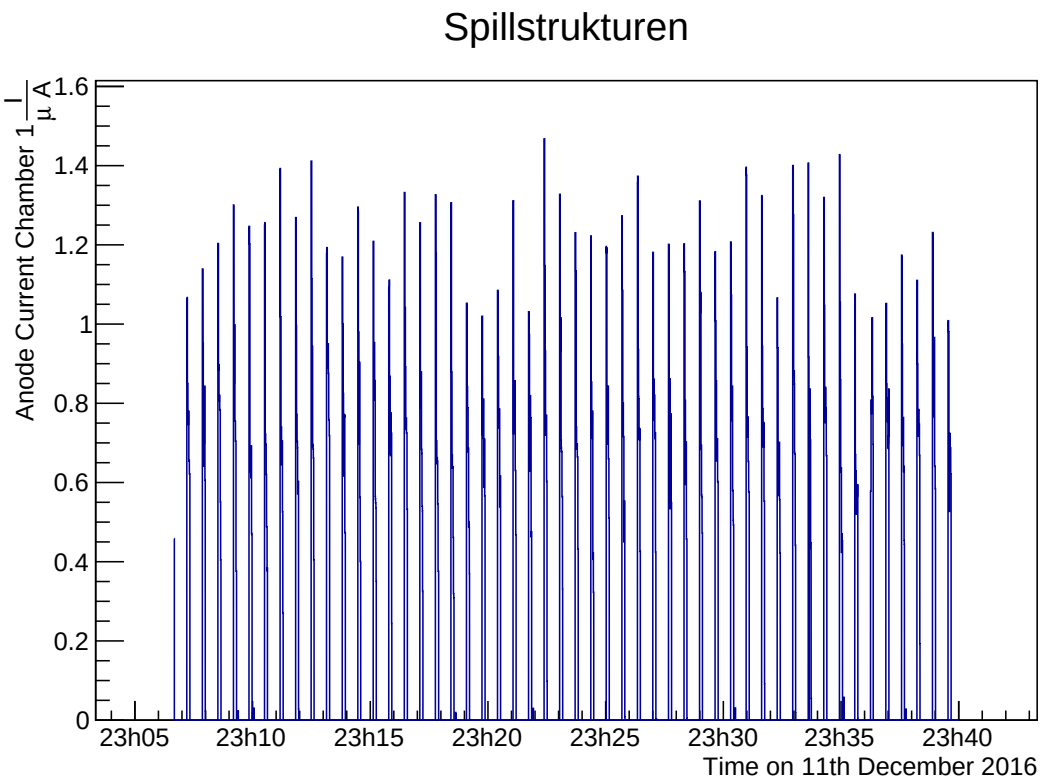

Figure: Spillstructures observed in HV-Data during In-beam test at CERN SPS 2016 pb-pb @150 AGeV.

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Analysis: Spillstructures

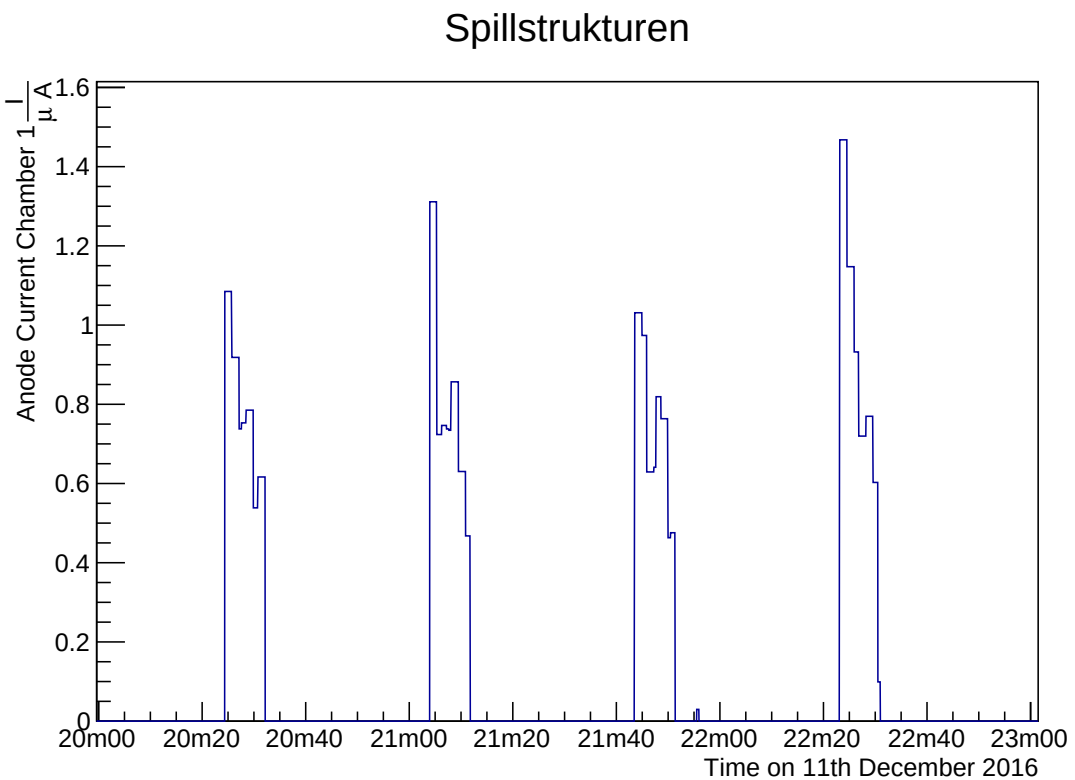

Figure: Spillstructures observed in HV-Data during In-beam test at CERN SPS 2016 pb-pb @150 AGeV.

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Analysis: Current Correllations

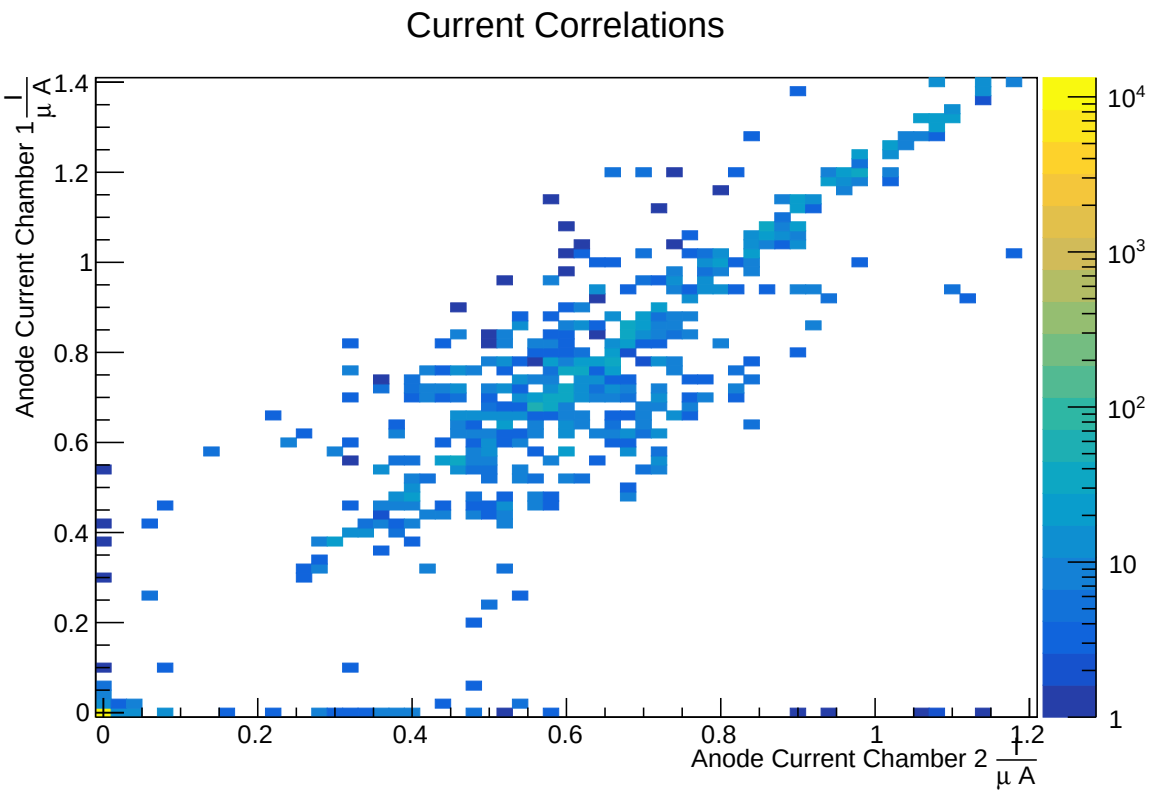

Figure: Correlations observed in HV-Data between Anode Currents of Chambers 1 and 4 during In-beam test at CERN SPS 2016.

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Analysis: Current Correllations

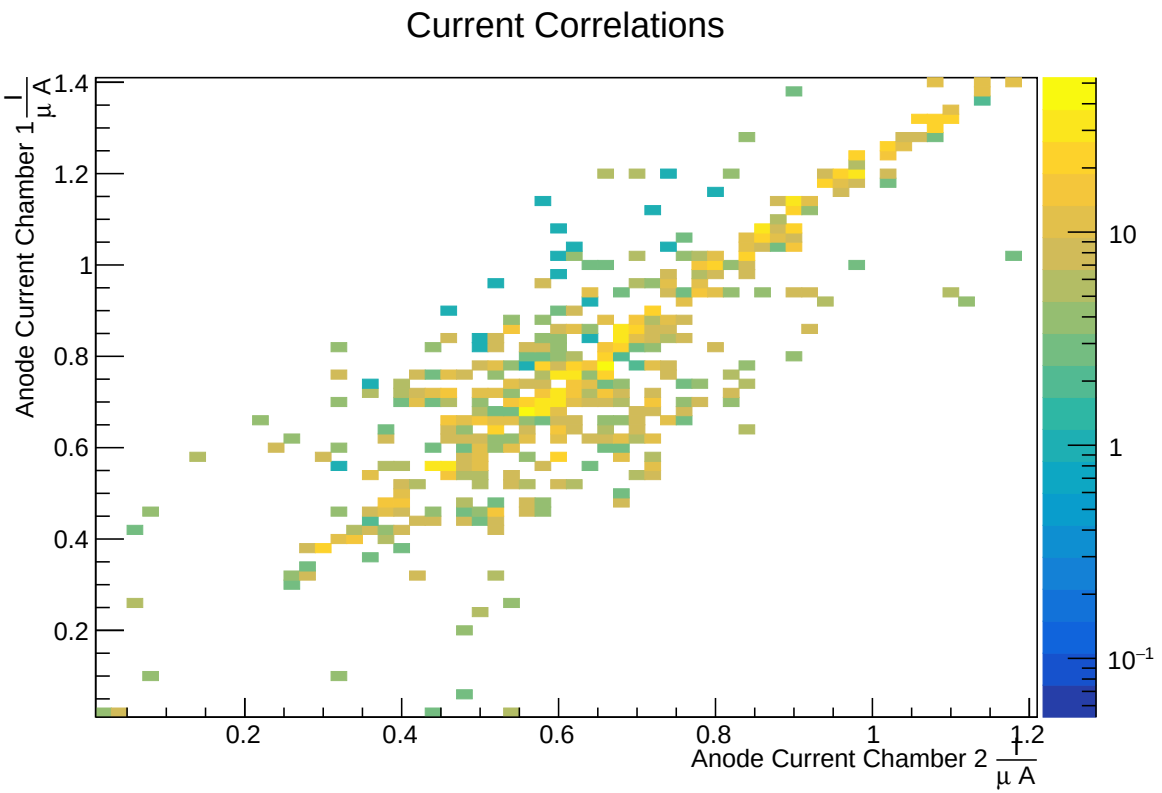

Figure: Correlations observed in HV-Data between Anode Currents of Chambers 1 and 4 during In-beam test at CERN SPS 2016.

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