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DAQT TDR

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for the PANDA collaboration

Technical Design Report for the:

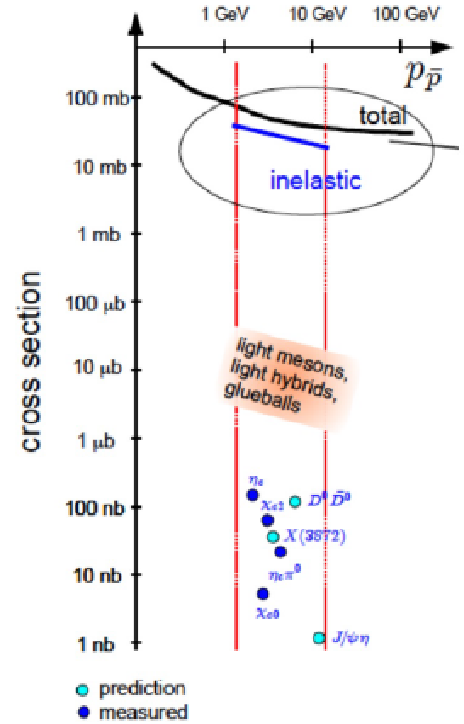
$\overline{\text{P}}$ANDA Data Acquisition and Event Filtring

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

$\overline{\text{P}}$ANDA Collaboration

November 7, 2018



Contents

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Event rates and pile-up situation for Phase 1 Physics

- What do we expect in terms of event rates?
- How to perform event building?

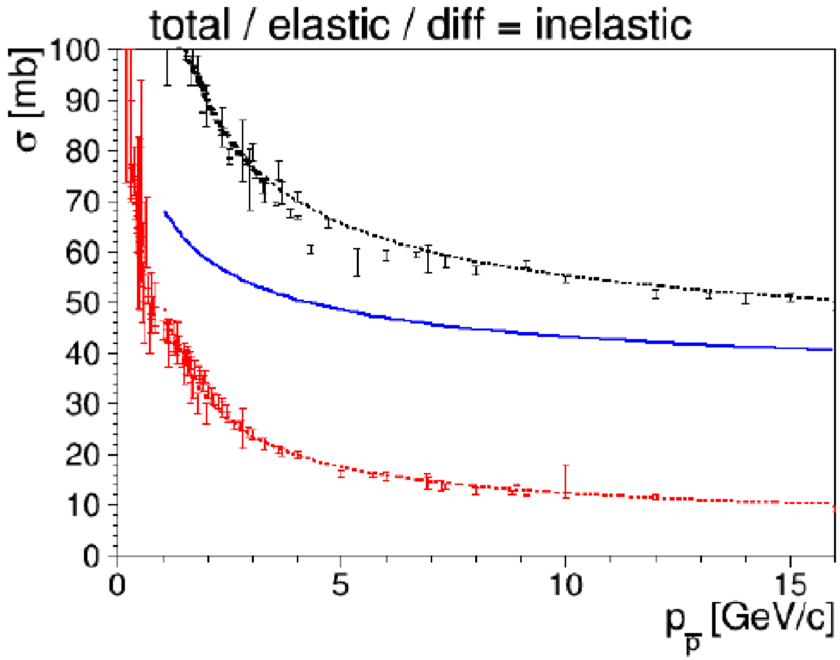


Figure 3.1: Measured antiproton-proton total (black) and elastic (red) cross section and calculated as the difference between the two the inelastic (blue) cross section in the momentum range of the PANDA experiment

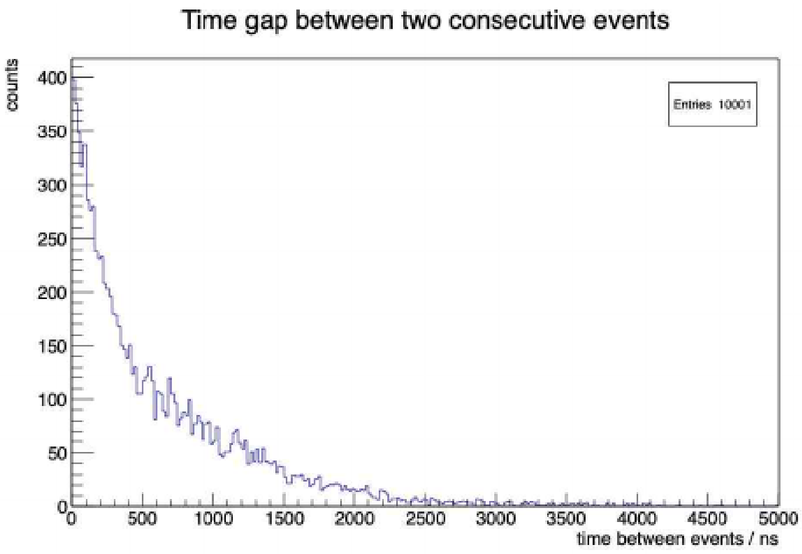
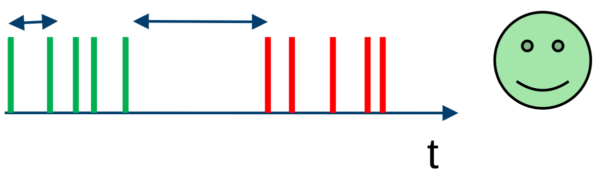
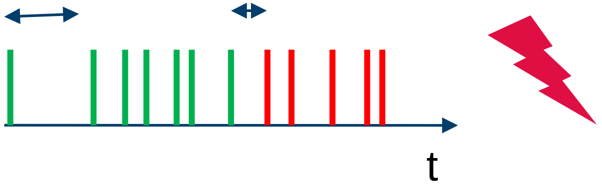


Figure 3.2: Simulated time between two consecutive anti-proton target interactions with a mean time between events of 500 ns, a continuous beam with 1600 ns and a gap of 400 ns

Event rates and pile-up situation for Phase 1 Physics





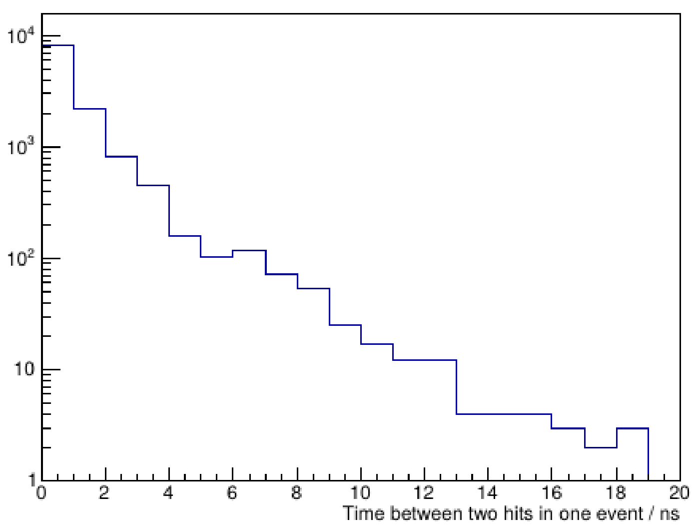


Figure 3.3: Time difference between two consecutive hits in the MVD for 1000 simulated background events

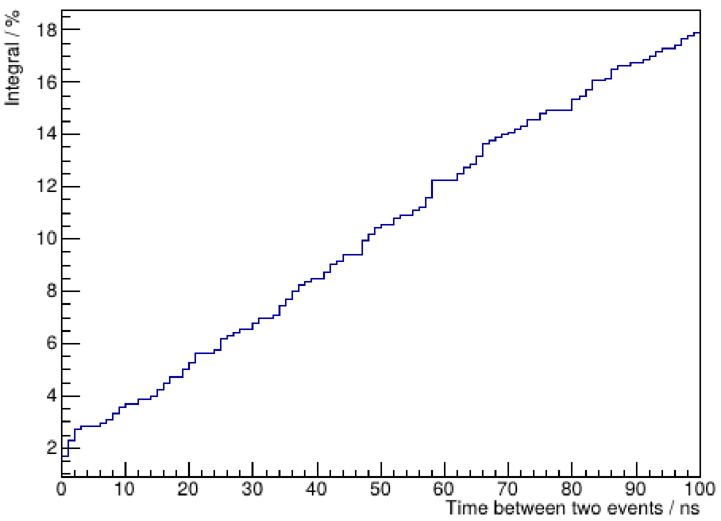
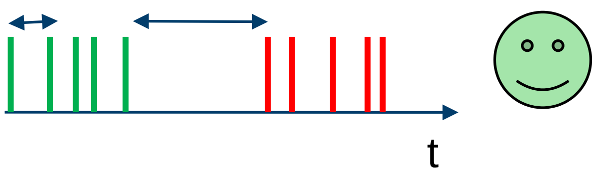
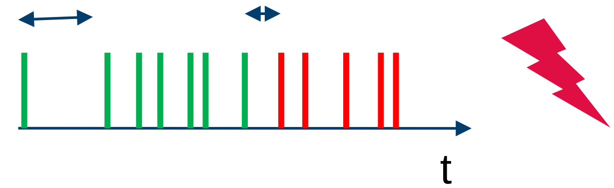


Figure 3.5: Integral of the time difference between the last hit of one event and the first hit of the next event as percentage value for all events.

Event rates and pile-up situation for Phase 1 Physics





With a time gap of 20 ns

~5 % of events which are merged together

Overlap for STT is ~60 %

which manageable for the online tracking

Gap event-building will work for the phase 1!

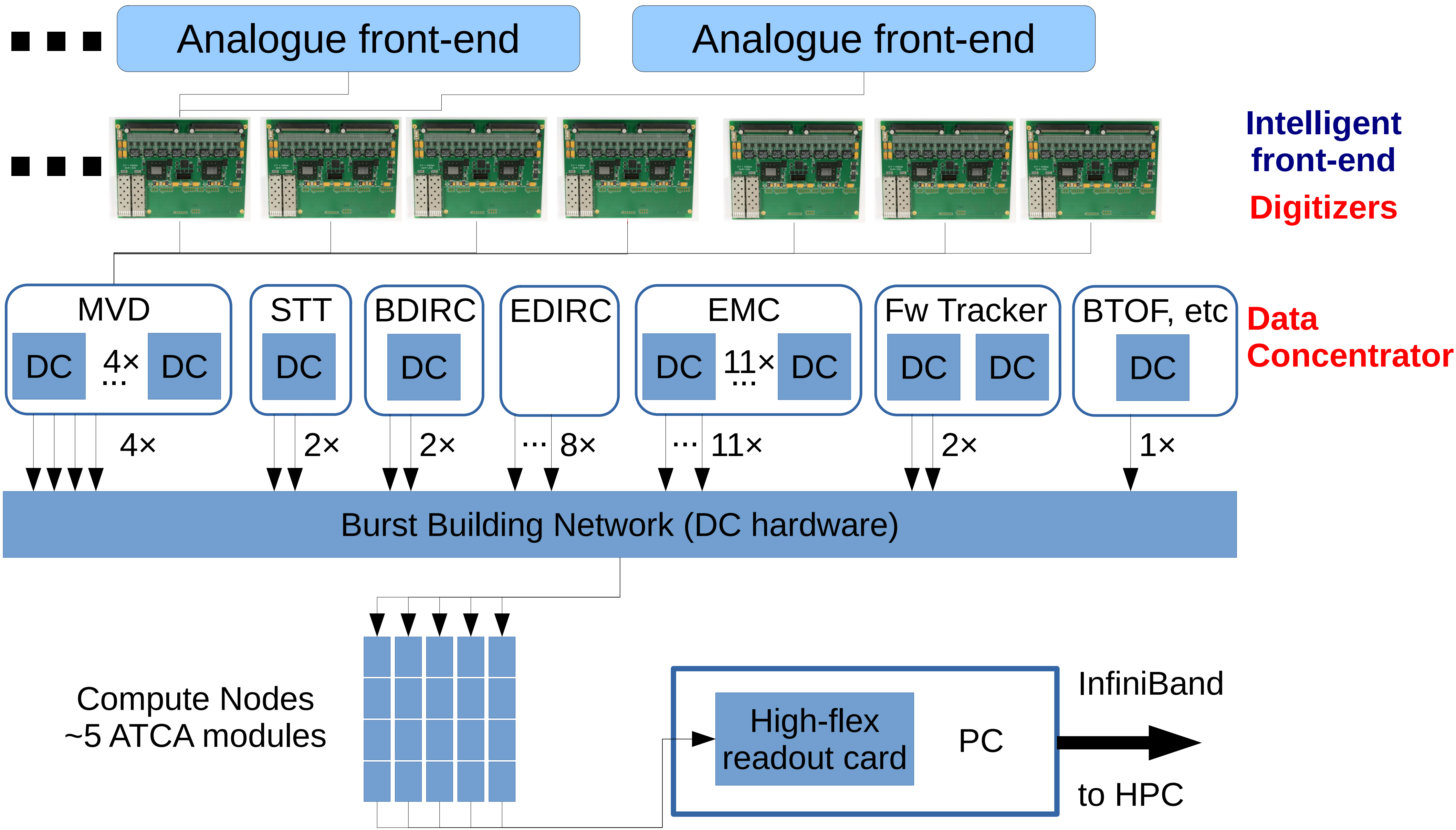
Figure 3.3: Time difference between two consecutive hits in the MVD for 1000 simulated background events

Figure 3.5: Integral of the time difference between the last hit of one event and the first hit of the next event as percentage value for all events.

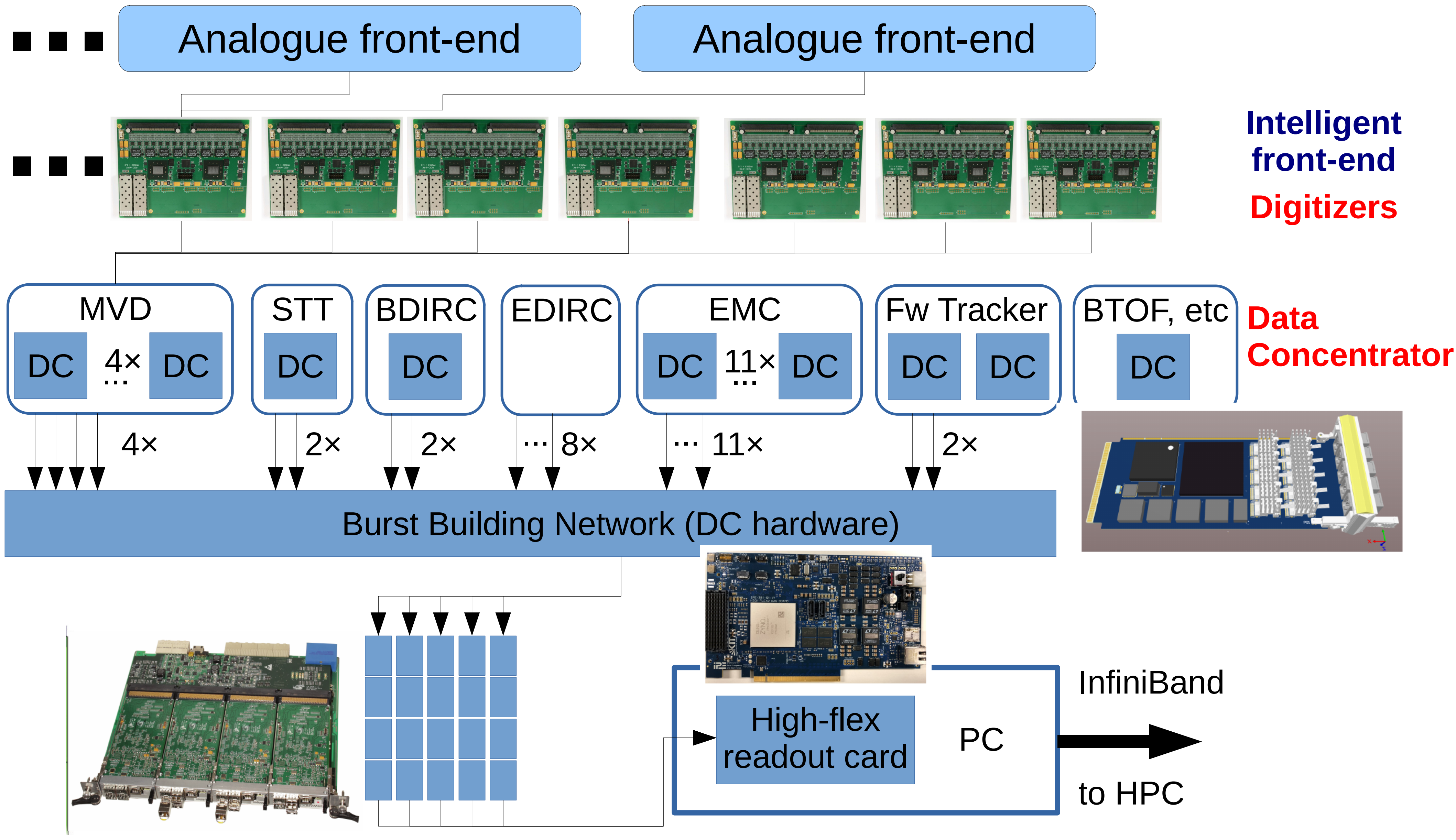
Contents

1. **Executive summary**
2. **The PANDA experiment**
   - Summary of physics goals of PANDA
   - Description of the PANDA detector
3. **Requirements**
   - Expectation for the event and data rates
   - Pile-up of events and event building
   - Requirements for on-line storage and DAQ partitioning
4. **System Architecture**
   - Architecture of the readout
   - Key components (hardware and protocols)
5. **Performance**
   - Monte Carlo simulations of the event filtering
   - Measurements with DAQ prototypes
6. **Project management and resources**

System Architecture



System Architecture

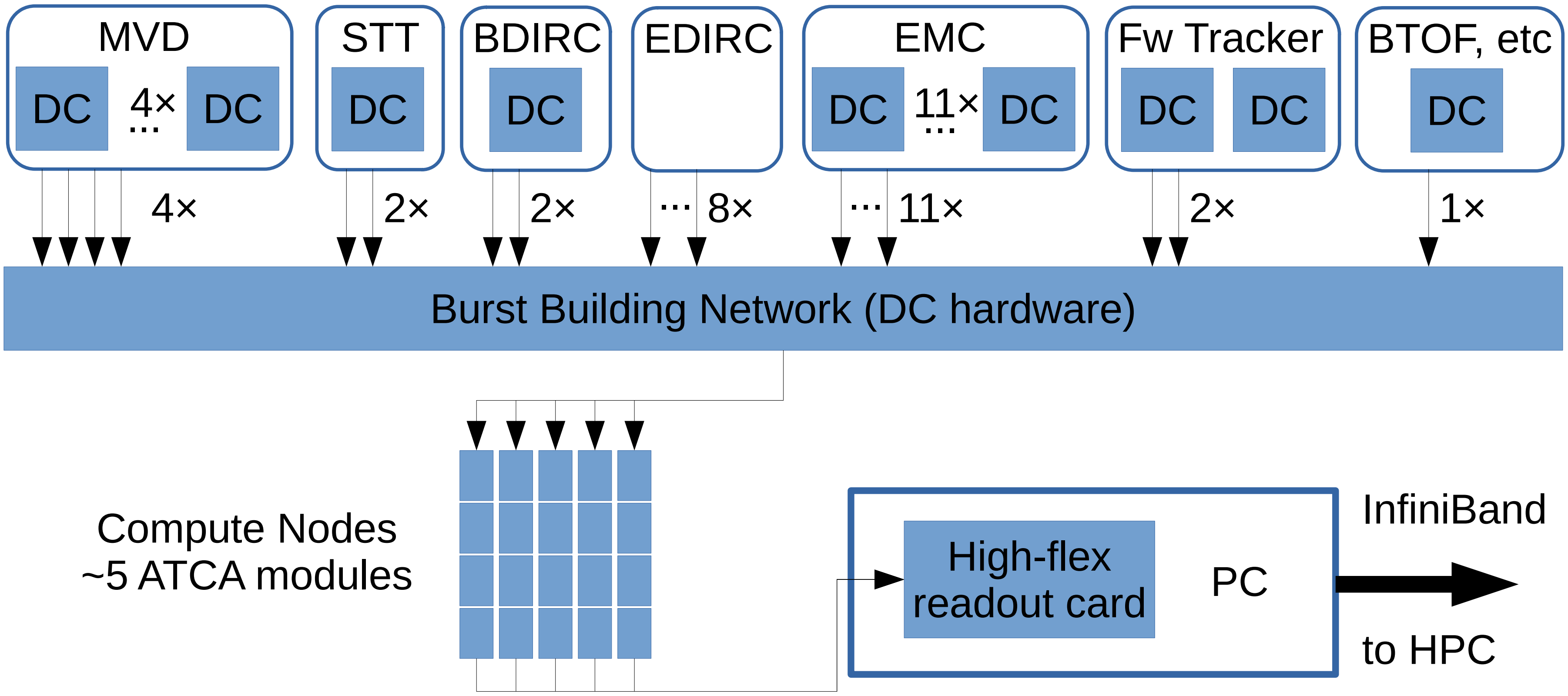


We have prototypes of all required hardware!

Data flow

4 (MVD) + 16 (STT) + 20 (BDIRC) + 9 (EDIRC) + 0.6 (BTOF) +

12.7(EMC) + 24(FwTracker) = **86.3 Gbit/s**



Developed hardware is able to process all expected data online.

Synchronization

Synchronization protocol SODANET

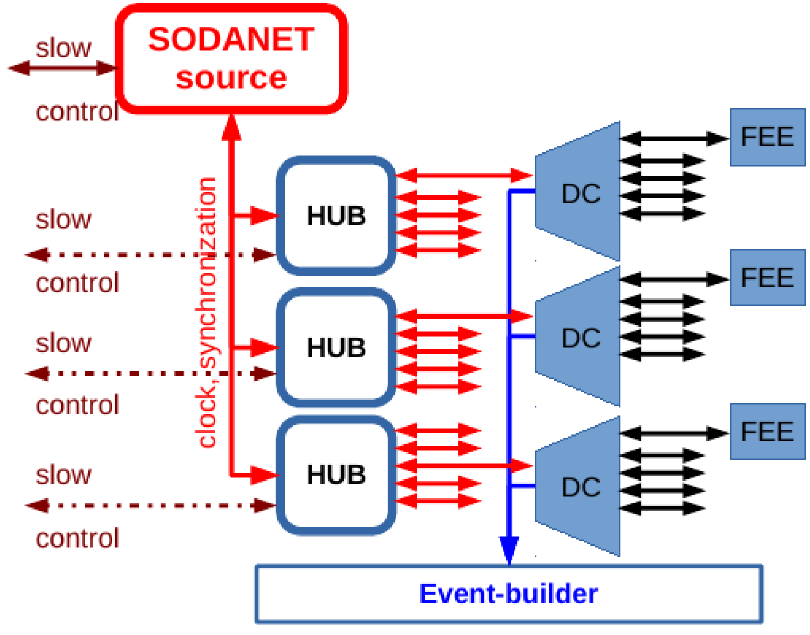


Figure 4.8: The topology of the SODANET network for the PANDA experiment.

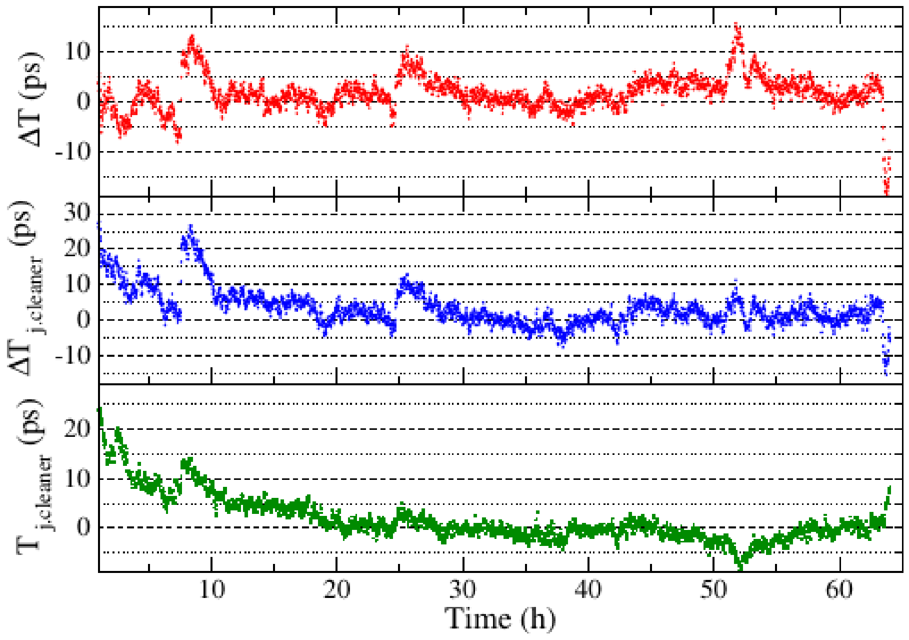


Figure 4.19: Stability of SODANET synchronization. The lower panel shows stability of the system once the hardware warmed up to the working temperature.

Crucial component, required for DAQ.

Developed for PANDA, tested under different conditions.

Online data-processing algorithms

In order to achieve required data-reduction factor of 100 online event-filtering algorithms rely on:

- time-ordered hit data
- tracking (possible with lower momentum resolution)
- EMC clustering (with lower resolution)

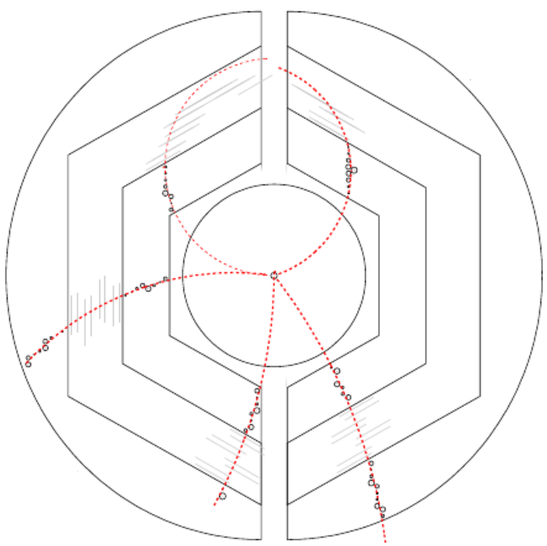


Figure 4.33: Example of a single event . The red circles represent the tracks found by the algorithm.

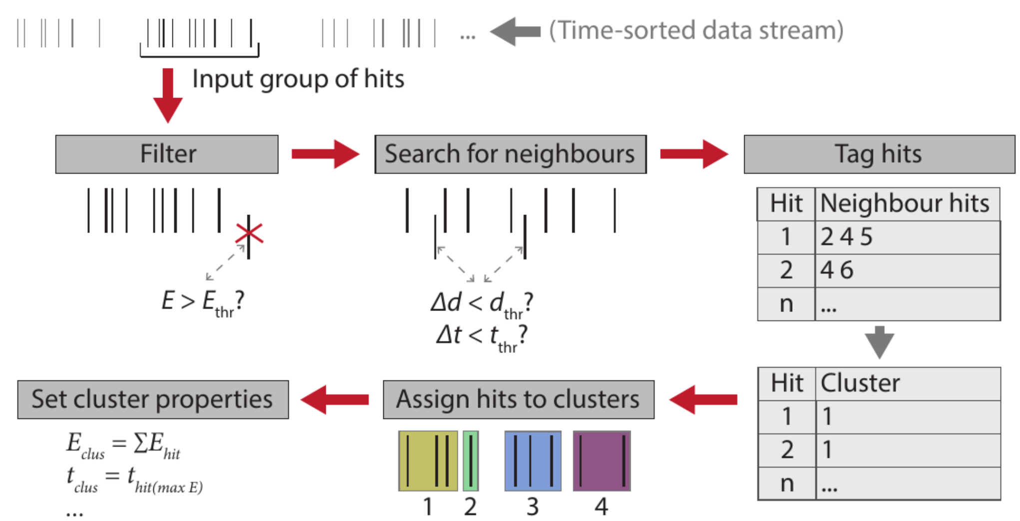


Figure 4.37: Flow chart of the online cluster-finding algorithm, describing each step taken by the algorithm. First, digis that have an energy below some threshold (in the current setting 3 MeV) are discarded. Then, a loop over all pairs of digis determines neighbourhood relations and creates the digi map in the top right of the Figure (in reality this has been flattened to a 1D array). The algorithm proceeds to assign digis to clusters using this map, creating the cluster map in the bottom right, and then uses this map to build the cluster objects. In the final step, the cluster properties are determined.

All crucial FPGA-based algorithms developed and tested.

Contents

Monte-Carlo Simulations

- Proof-of-principle benchmark channels
- Should cover various aspects of day-1 physics
- PhysCom decided on:

1. Small cross section case / charmonium:
   $\bar{p}p \rightarrow J/\psi(e^+e^- / \mu^+\mu^-)\ \pi^+\pi^-$ @ 3.872 GeV

2. Very small cross-section, exclusive / form factor physics:
   $\bar{p}p \rightarrow e^+e^-$ @ 2.254 GeV
   $\bar{p}p \rightarrow e^+e^-\ \pi^0$ @ 2.254 GeV

3. High cross section / hyperon physics:
   $\bar{p}p \rightarrow \Lambda\bar{\Lambda}$ @ 2.304 GeV

- Single trigger lines (although should be simultaneous for J/ψ)
- Use mainly simple quantities, probably easy to determine online

Monte-Carlo Simulations

Table 5.2: Efficiencies for signal and background events after combinatorics and additional filtering, and the background suppression factors. The numbers marked with * represent the lower border of the one standard deviation confidence interval.

No.	Channel	$\epsilon_S[\%]$	$\epsilon_B[\%]$	f_{sup} [×1000]
(1)	$\Lambda \to p\pi^-$	30.0	0.75	0.134
(2)	$J/\psi \to e^+e^-$	31.8	0.0001	$> 303^*$
(3)	$J/\psi \to \mu^+\mu^-$	56.6	0.0029	$> 28.2^*$
(4)	$\bar{p}p \to e^+e^-$	53.7	0.0013	$> 56.5^*$
(5)	$\bar{p}p \to e^+e^-\pi^0$	36.2	0.0269	3.72

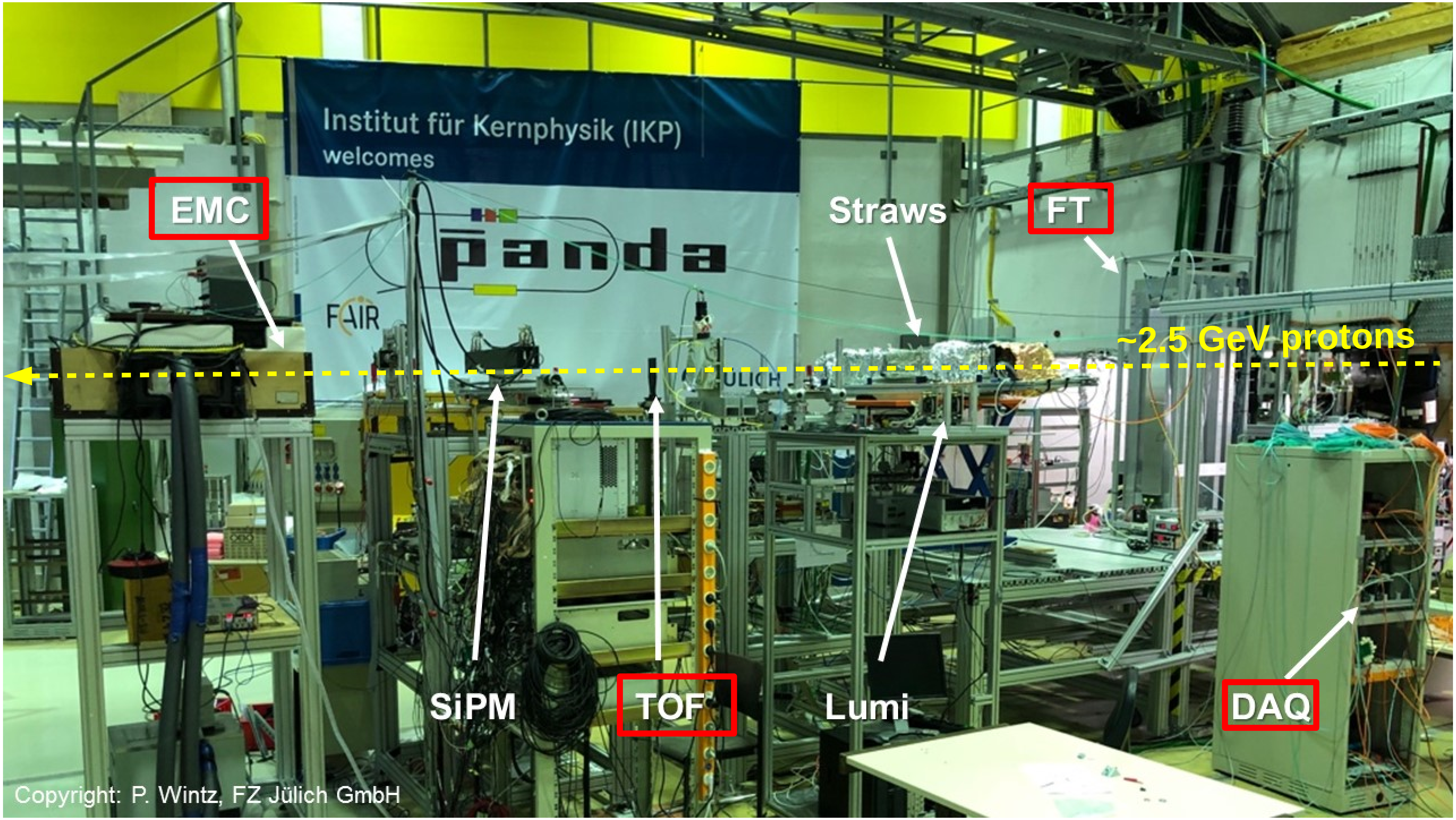
Table 5.3: Efficiencies for signal and background events after combinatorics and additional filtering, and the background suppression factors. The numbers marked with * represent the lower border of the one standard deviation confidence interval. (DAY1 scenario with 75% EMC).

Channel	$\epsilon_S[\%]$	$\epsilon_B[\%]$	f_{sup} [×1000]
$\Lambda \to p\pi^-$	30.0	0.82	0.121
$J/\psi \to e^+e^-$	24.7	0.0001	$> 303^*$
$J/\psi \to \mu^+\mu^-$	56.3	0.0038	$> 22.2^*$
$\bar{p}p \to e^+e^-$	40.9	0.0009	$> 76.3^*$
$\bar{p}p \to e^+e^-\pi^0$	16.5	0.0156	6.41

It is possible to achieve required data-reduction factor of 100 with

- **day-1 detector configuration;**
- **online tracking (worth resolution)**
- **not optimal EMC energy calibration and clustering (online data processing)**

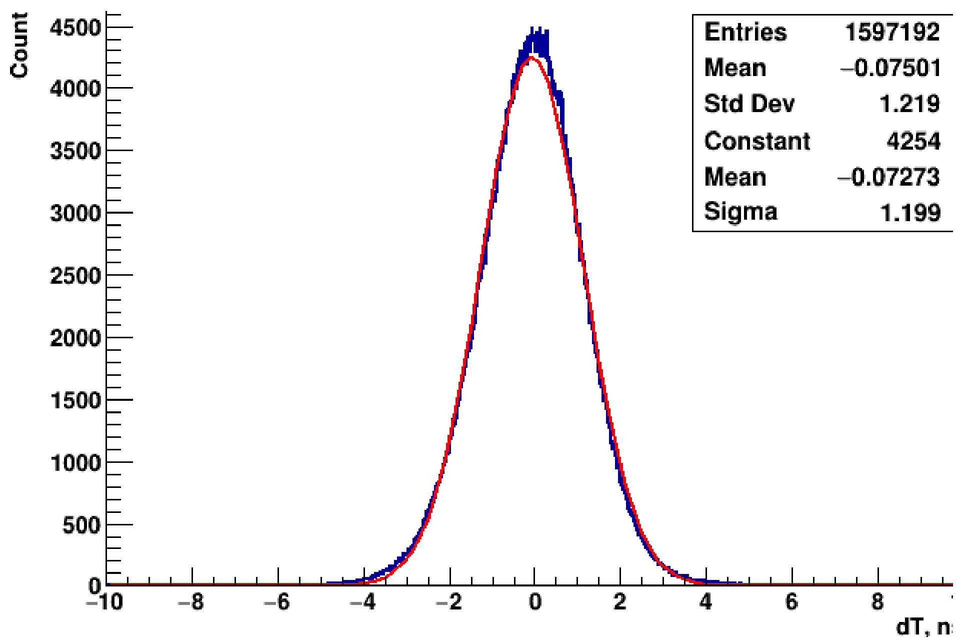
Measurements with prototype components



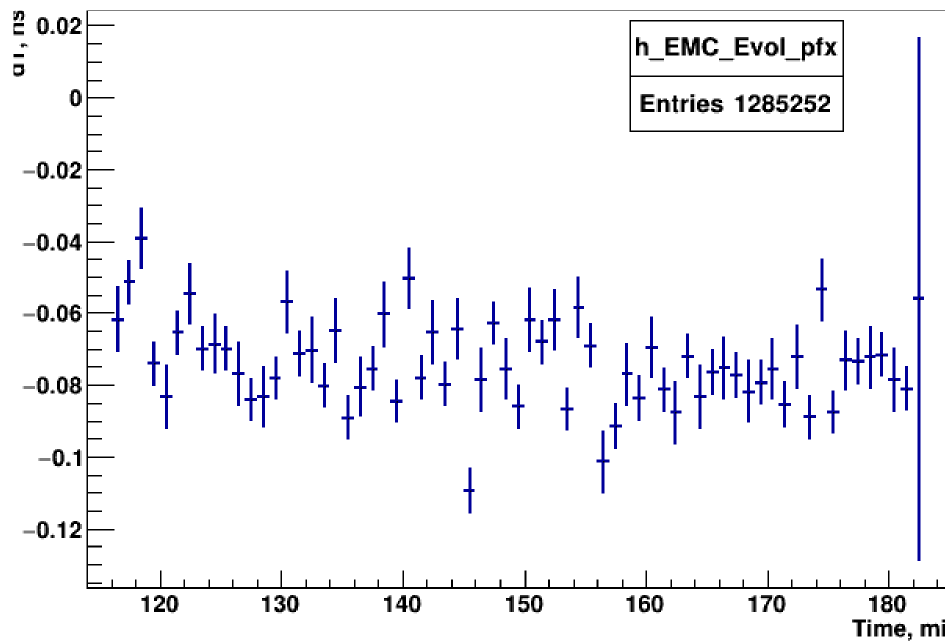
Joint readout of few subsystems – test of *event building* and *synchronisation* between different brunches.

Measurements with prototype components

EMC+TOF Results



EMC-TOF time difference in case of energy gate for cluster. Values in red square show Gaus fit parameters.



Evolution with time.

Joint operation of several subsystems has been demonstrated!

Summary

DAQ TDR:

- describes requirements of the PANDA experiment;
- demonstrates feasibility of online event building and filtering;
- shows that we have key components of required hardware and firmware and software.

We have required technology and knowledge to build the PANDA DAQ!