Determination of inter-system timing for mCBM in 2020

vCHEP 2021

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CBM

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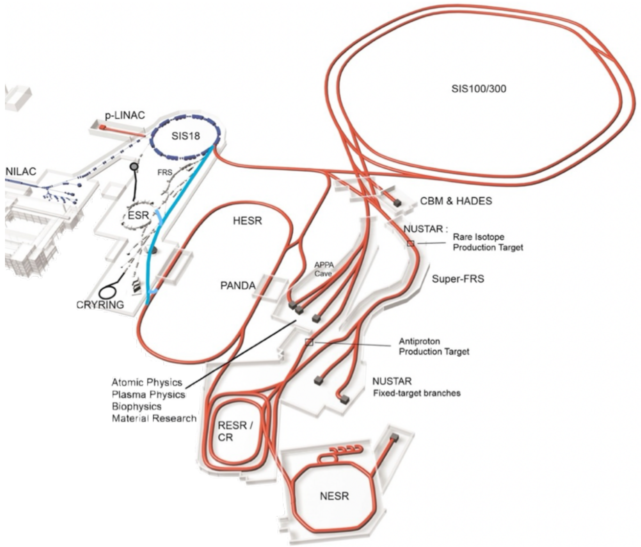
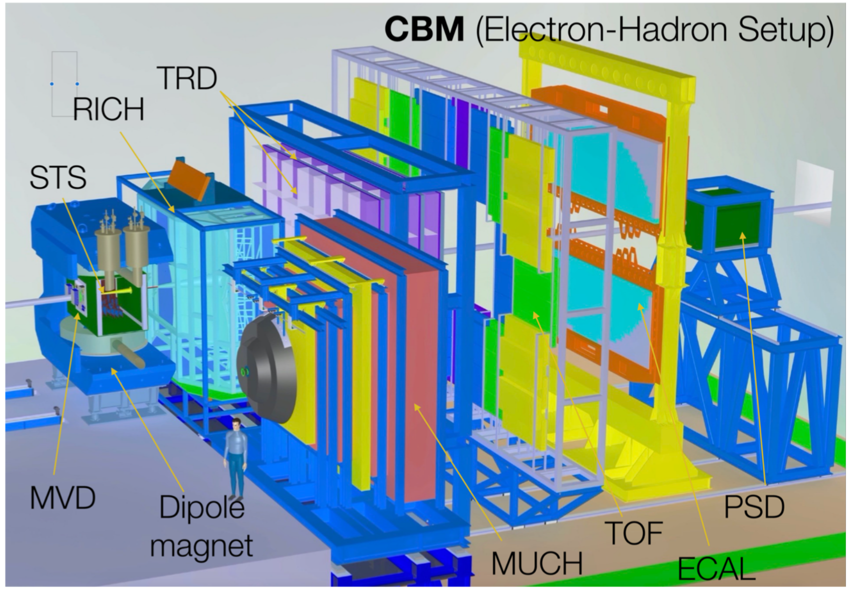
Overview

- mCBM as a prototype for full CBM experiment
- Algorithm for evaluation of inter-system time offsets
- Results
- Conclusions

Towards the CBM experiment



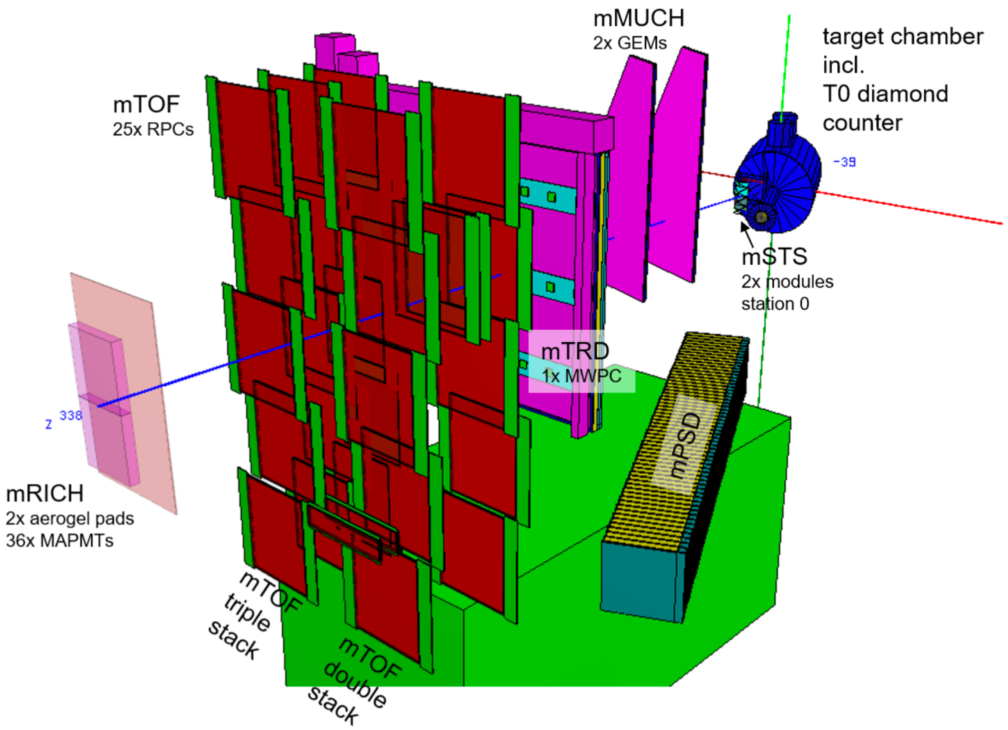


- Fixed target heavy ion experiment at FAIR
- Physics goal: exploration of the QCD phase diagram
- Complex trigger signatures
- Extreme reaction rates of up to 10 MHz and track densities up to 1000 tracks

Requirements for fast online processing / reconstruction:
→ Total input data rate of 1 TByte/s
→ Self-triggering free-streaming readout electronics

mCBM experiment as prototype for full CBM

CBM full-system test and precursor experiment



Components of all CBM subsystems (7 detector systems in 2020)

CBM full-system test-setup

- prototypes or pre-series productions of all CBM subsystems integrated incl. their triggerless-streaming read-out systems

- develop, test and optimize the online/offline software packages

Beamtimes for mCBM:

- Dec. 2018
- Mar. 2019
- Nov. 2019
- **Mar. – May 2020**
- Mar. - July 2021

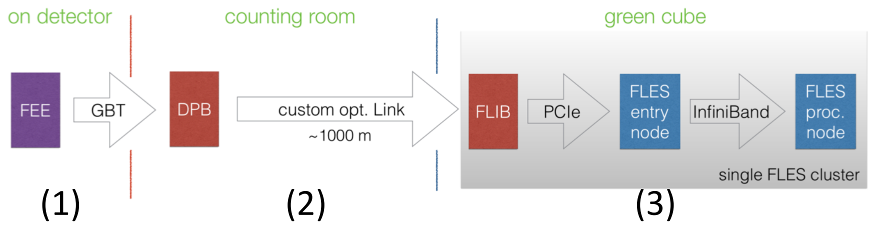
Additional beamtimes until start of full CBM

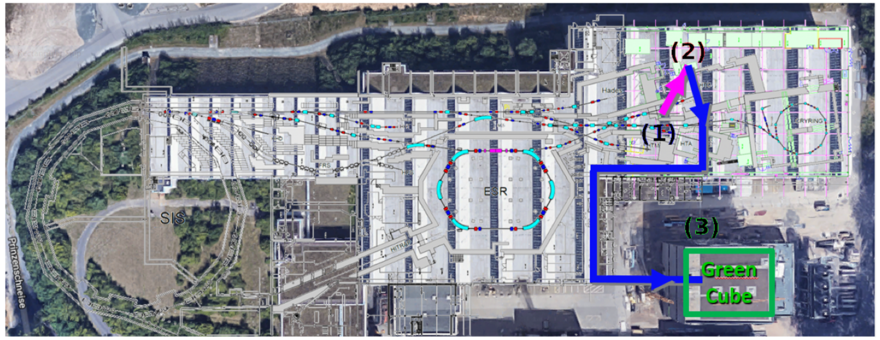
Beamtime applications of September 2017 and June 2020 fully granted by the GSI/FAIR G-PAC

→ test and optimize concepts of online reconstruction and selection

Details in CBM Progress Report 2020:
https://repository.gsi.de/record/237432/files/CBM%20Progress%20Report%202020.pdf

mCBM data aquisition and processing





Initial DAQ/FLES architecture 2020
→ basis for mCBM setup
→ long-haul interconnections

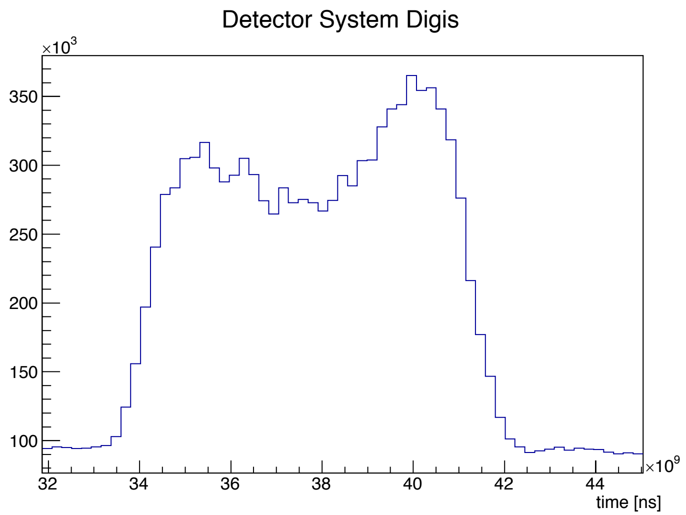
Detector front-ends:
- time-synchronized by timing and synchronization system
- digitize signals above threshold
- assign a time stamp to the hit

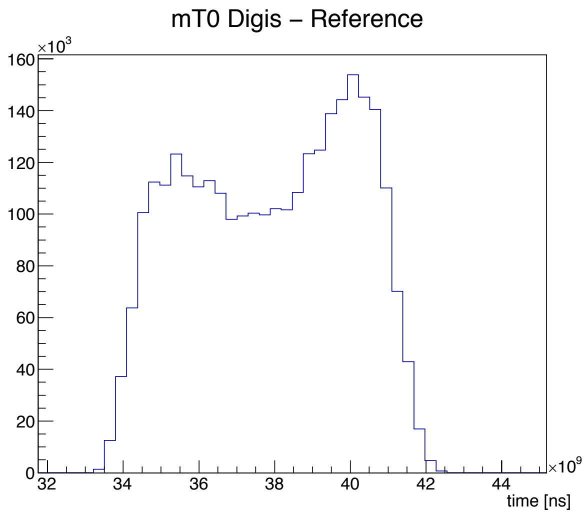
DAQ:
- ultra-fast and radiation-tolerant ASICs as front-end chips
- CERN GBTx-based data aggregation units
  → e-links converted and merged into an optical GBT link
- data streams handled by Data Processing Boards with FPGAs

FLES HPC computer farm:
- central system for online processing
- container data format to decontextualize time-stamped signal messages from detector systems

→ data segments of specific time intervals can be distributed on the farm and processed independently

Algorithm: Time differences



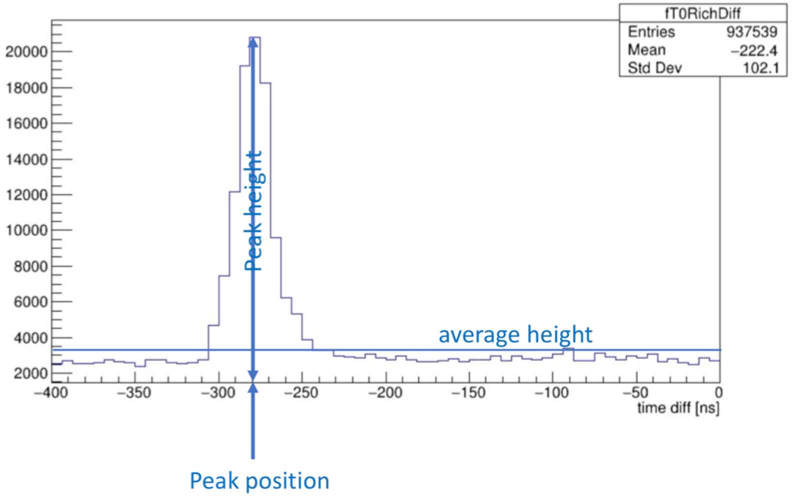


2-step approach:

1. From single time measurements (digis) to time differences

2. Fitting of peak in time differences

Example time differences



1. Processing of time differences wrt. reference time:

Input: Digi time measurements for readout channels

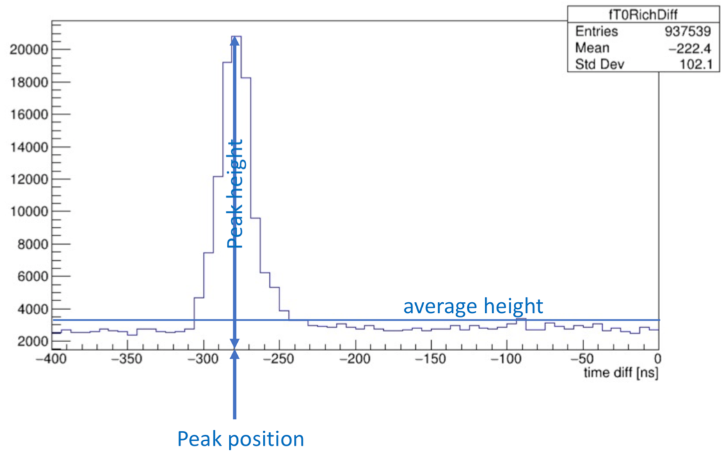
Relatively broad range of search windows

Output: Relative time distributions $t_{\text{system}} - t_{\text{mT0}}$

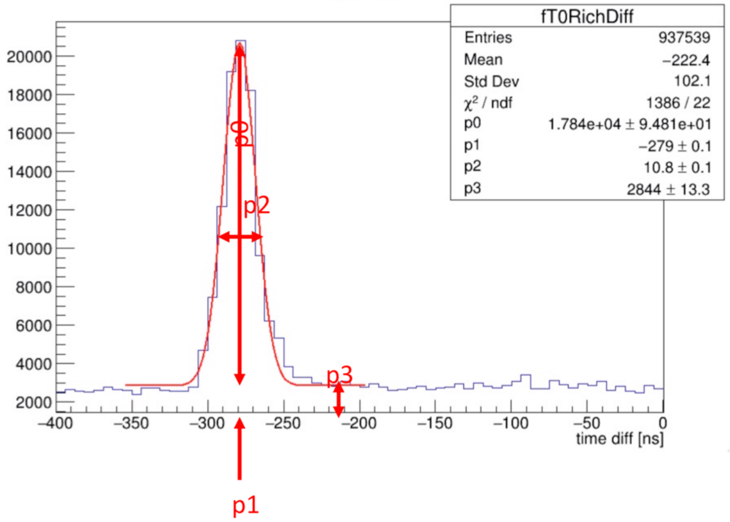
- peak height
- peak position
- average height

Algorithm: Fitting of peaks in time differences

Example time differences



Example fitting



2. Fitting:

Input: Relative time distributions of digis

Peak height, peak position, system-dependent width, average height

→ **input for fitting function**

Fitting of peak parameters and background level

Output: Fitting function in Root: **gaus(0)+pol0(3)**

→ **4 Parameters p0, p1, p2, p3**

Criteria for **stability**:

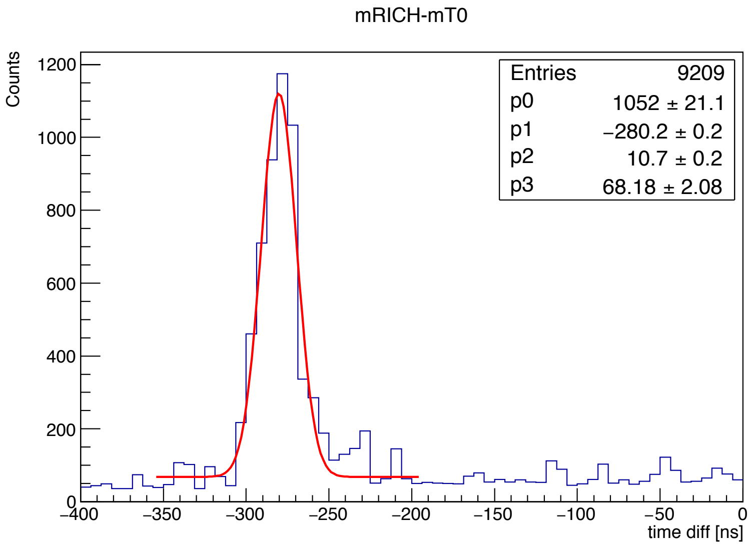
- Results from fitting
- Peak position and fitted peak position p1 within peak width
- Evaluation of extra time coincidences (with mTof detector)

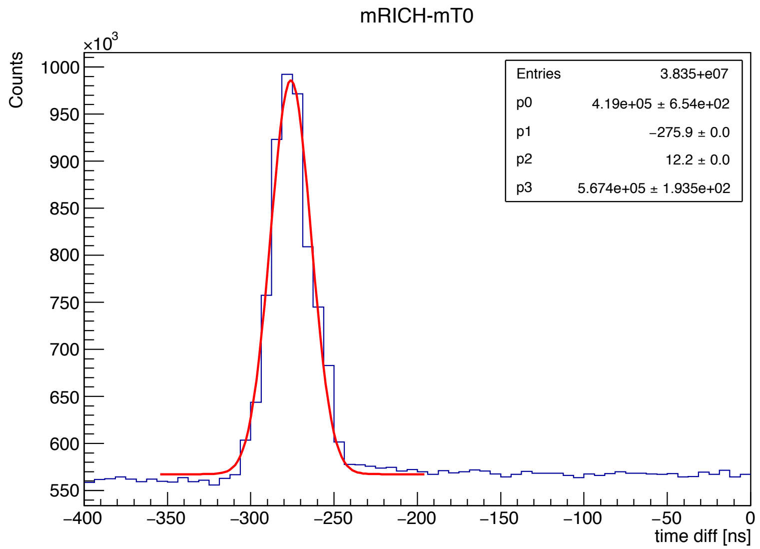
Stability of fitting

Results for runs:

831 (2*10^6 Ions, 2.5 mm Au Target)
836 (2*10^7 Ions, 0.25 mm Au Target)
852 (2*10^7 Ions, 2.5 mm Au Target)
855 (1*10^8 Ions, 0.25 mm Au Target)
856 (1*10^8 Ions, 2.5 mm Au Target)

Representative set of beam and runtime conditions in 2020





Example results for mRICH:
Fitting results overlaid for low statistics (run 831) and high statistics (run 836)

Application of algorithm for these runs

Summary of fitting results

Results for runs:

831 (2*10^6 Ions, 2.5 mm Au Target)
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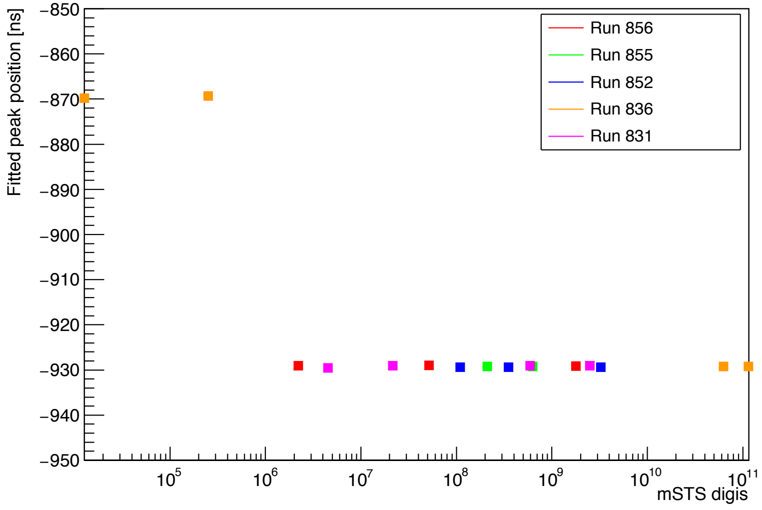
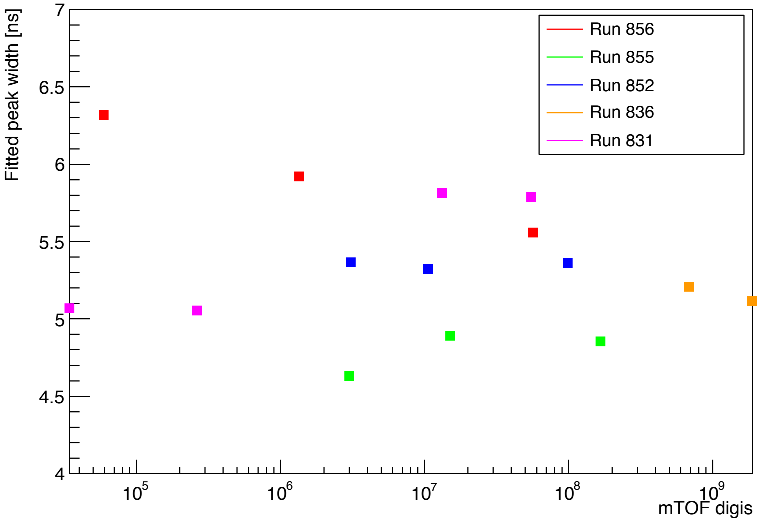


Fitted peak positions for mSTS



Fitted peak widths for mTOF

Systematic evaluation of algorithm:

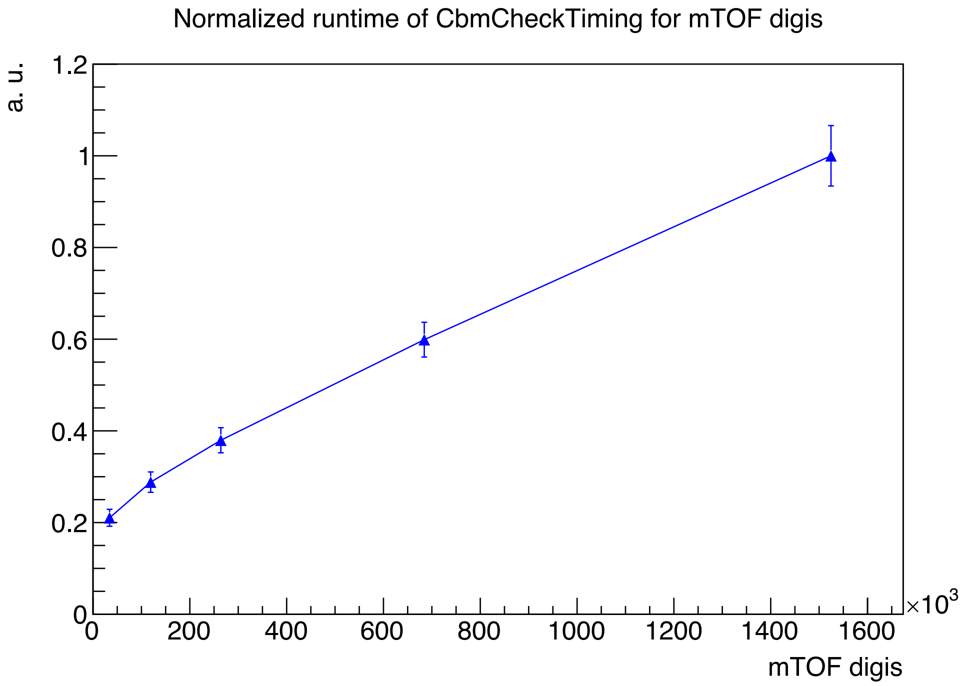
→ Stability of algorithm

→ Stability of time correlations

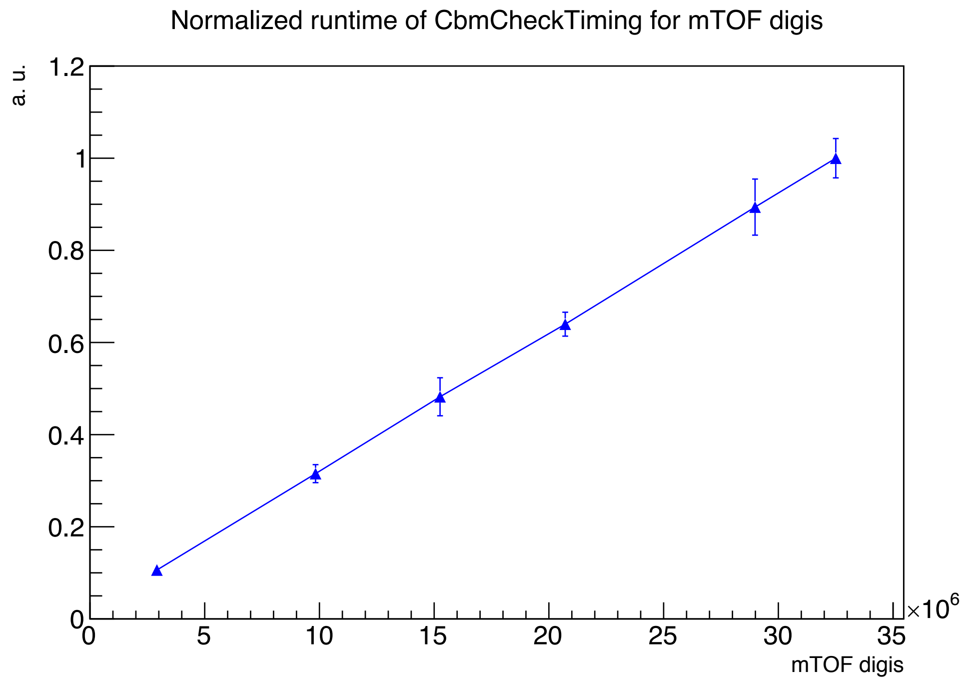
Scaling of runtimes

Execution of core algorithm of CbmCheckTiming

Processing broad time windows of digis



Lower range of mTof digis in run 831



Upper range of mTof digis in run 831

→ Linear scaling of runtimes with respect to number of (mTOF) digis

Runtimes normalized to corresponding maximum over the respective range
Measurements at a compute node of the GSI Virgo HPC cluster

Conclusions

- Basic functionality of algorithm demonstrated
- Stable time correlation between systems of mCBM in various runs
- Stable intersystem timing as indispensible requirement for future data taking
  - Fast and efficient approach
  - Application for online monitoring
  - Blueprint for other future online calibrations, also on ASIC level

- Dedicated statistical investigations for anomaly detection as a future option

BACKUP

Detector setup for mCBM 2020

mT_0	fast and radiation-hard time-zero (T_0) diamond counter, consisting of 8 vertical strips each of 2 mm width, mounted inside the target chamber, 20 cm upstream of the target, readout by TOF electronics (PADI and GET 4).
mSTS	2 6 x 6 cm^2 STS prototype modules mounted on a half-ladder, positioned on the 1st station (station 0). Each module contains 1024 channels on each sensor side, readout with 8 STS-XYTER v2.1 located on a FEB-8, interfaced to a GBTx ROB-3.
mMUCH	2 GEM prototype stations consisting of M2 modules with 2304 pads. Each module is equipped with 18 STS-XYTER v2.1 mounted on a single FEB each, interfaced to the GBTx ROB-3.

mTRD	1 TRD prototype module, type 8, 95 x 95 cm^2 large, with 768 rectangular pads, 6 FEB-4x1-2 per module interfaced to the GBTx ROB-3.
mTOF	5 TOF M4 prototype modules each containing 5 MRPC counters (32 x 27 cm^2). The readout is performed with PADI and GET 4 electronics interfaced to the GBTx ROB-1, in total 1600 read-out channels.
mRICH	2 aerogel radiators each with size 20 x 20 cm^2, equipped with 36 MAPMTs, connected to 72 DiRICH modules, readout with TRB3.
mPSD	a single PSD module, readout by a PANDA TDC board.

Time correlations of several systems

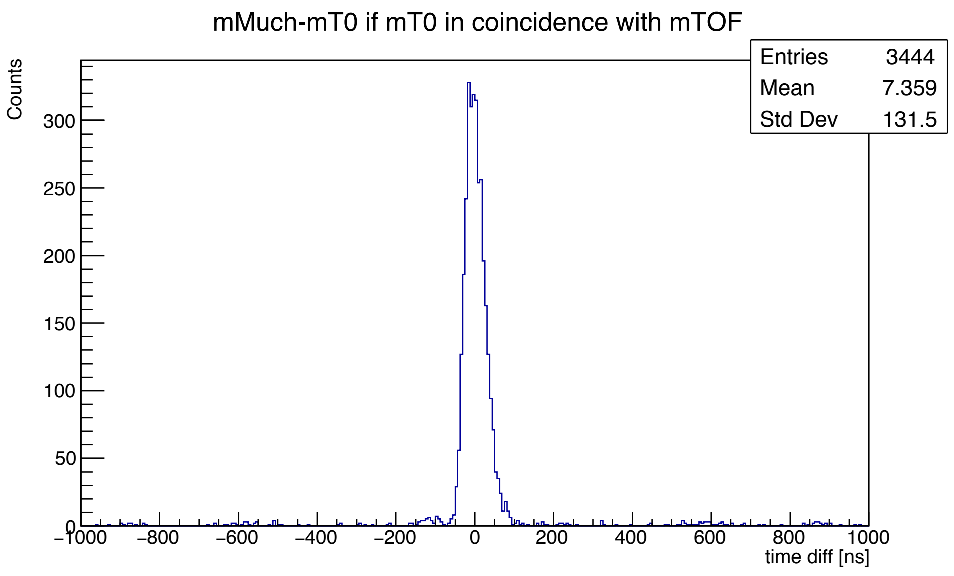
Requirement of an **additional time coincidence** of mT0 **with mTOF**:

Digis simultaneously in time correlation with mT0 and mTOF → potentially from common tracks

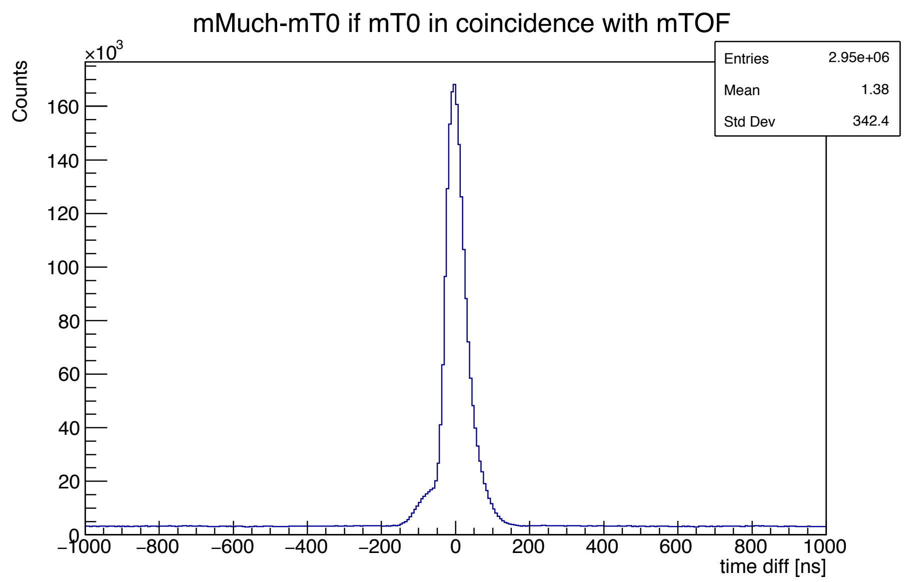
→ Stability of peak positions for low/high statistics

→ Stability of time correlations of e. g. mMUCH, mT0 and mTof

→ Reduction of background



Low statistics in run 831



High statistics in run 831

Time difference distributions for mMUCH (requiring additional time coincidence with at least 6 mTOF digis)
Synchronization of time offsets has been applied.