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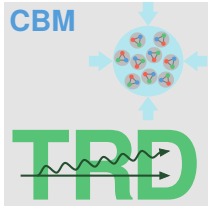
Status of the Transition Radiation Detector for the CBM Experiment

DPG-Frühjahrstagung 2018, Bochum

Bundesministerium
für Bildung
und Forschung

FAIR

GSI



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Philipp Kähler

26 February 2018

Overview

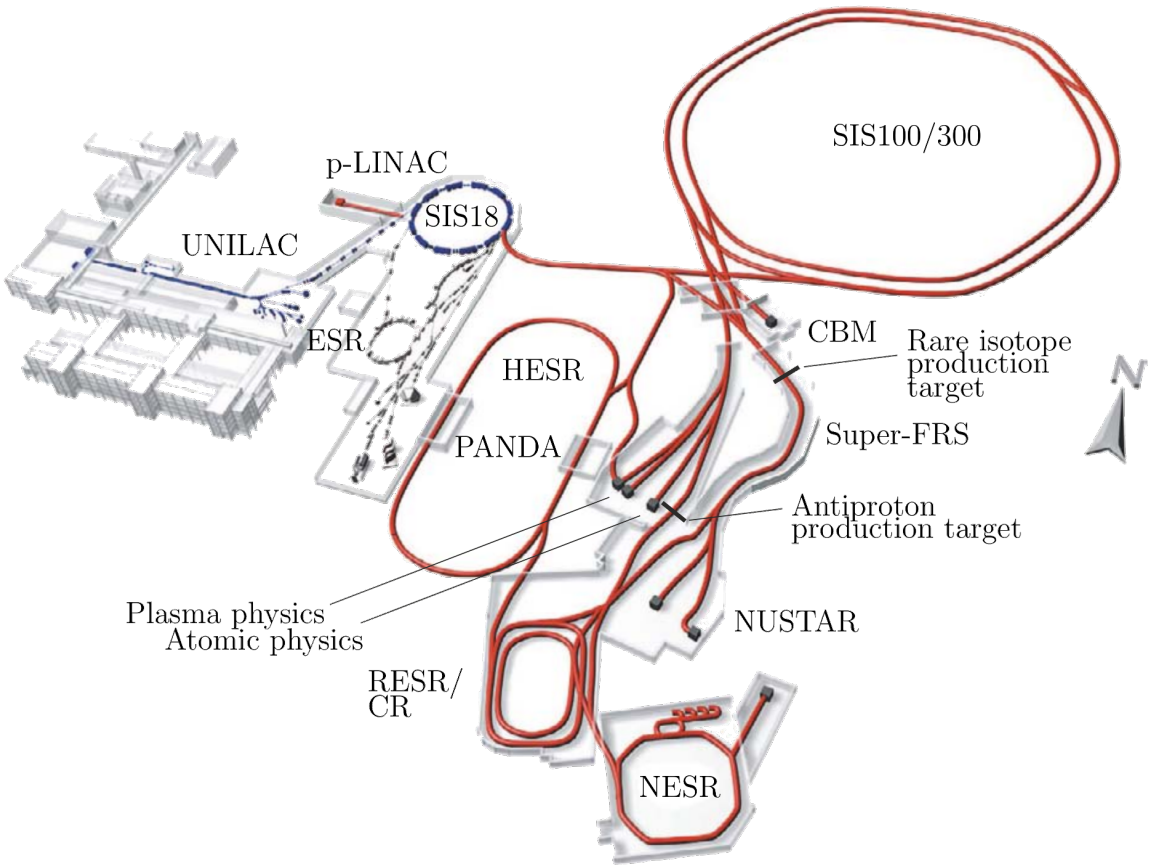
- The CBM experiment
- CBM-TRD requirements and design
- Data acquisition system status
- Lab and in-beam tests
- FAIR Phase 0: miniCBM
- Software status

The CBM Experiment

- FAIR Phase 1 / SIS100 currently in construction
- *Compressed Baryonic Matter* (CBM) experiment is one of the pillars of FAIR

SIS100 beam energies:

beam	Z	A	E (AGeV)
p	1	1	29
d	1	2	14
Ca	20	40	14
Ni	28	58	13.6
In	49	115	11.9
Au	79	197	11
U	92	238	10.7



The CBM Experiment

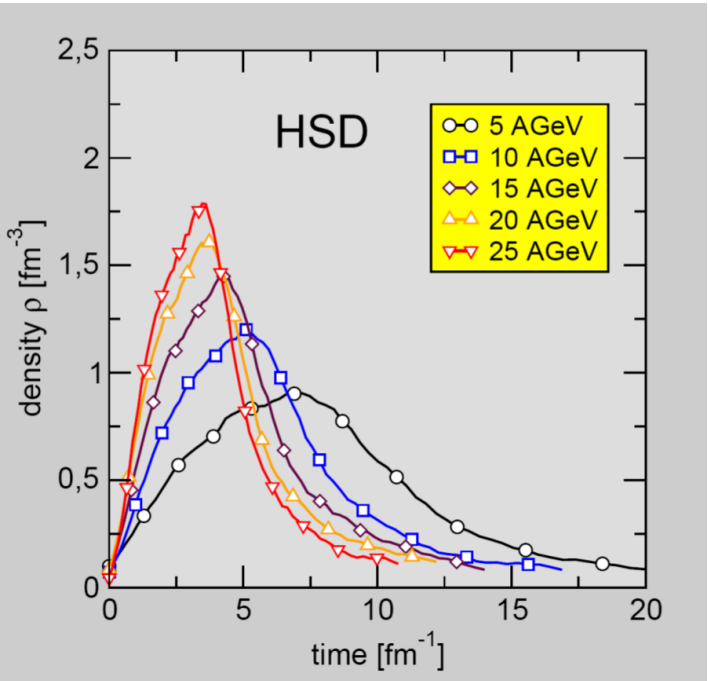


Figure: Baryon densities as function of elapsed time for central Au–Au collisions at different energies, HSD transport code, *Ehehalt, Cassing, Nucl. Phys. A602:449-486, 1996*

Exploration of the QCD phase diagram at highest net-baryon densities:

- Fixed-target experiment
- Heavy-ion interaction rates up to 10 MHz
- Neutron-star core net-baryon densities
- Access to rare medium probes in an unprecedented level of precision
- Vector mesons (by lepton pair reconstruction)
- Excitation functions of various observables as sensible probes
- Multi-strange hypereons and hyper-nuclei

The CBM Experiment

MVD+STS
Micro-Vertex Detector + Silicon Tracking Station
magnetic field

MUCH or RICH
MuonChambers/ Ring imaging Cherenkov Detector

TRD
Transition Radiation Detector

TOF
Time Of Flight

PSD
Projectile Spectator Detector

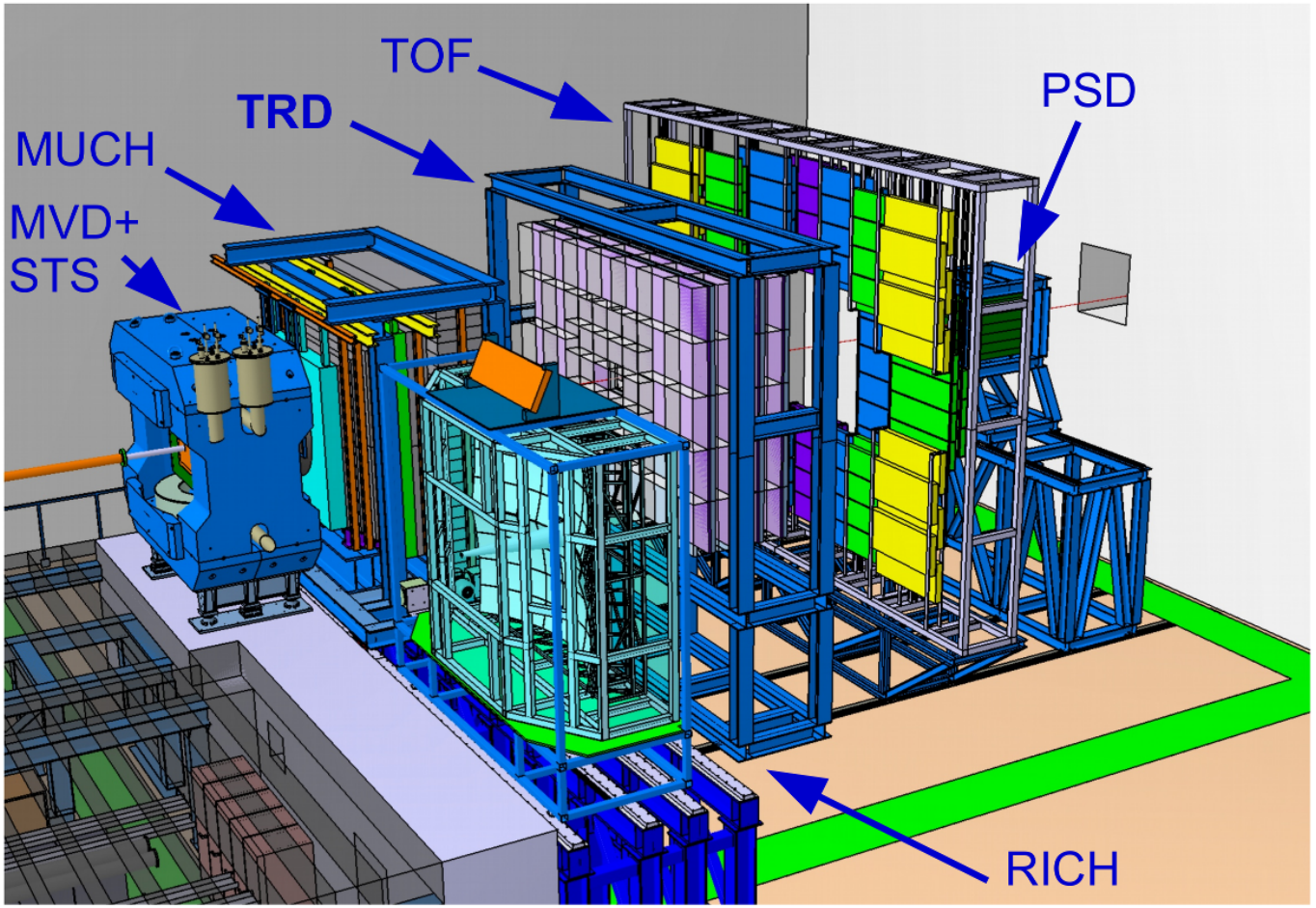


Figure: Rendering of the CBM experiment. A magnet is installed around MVD/STS. Three setups are foreseen: electron / muon / hadron measurements.

CBM-TRD: Requirements, Design

- Interaction rates leading to hit rates up to 100 kHz/cm² at the TRD
- Fast and radiation-hard detector design, signal collection times below 300 ns

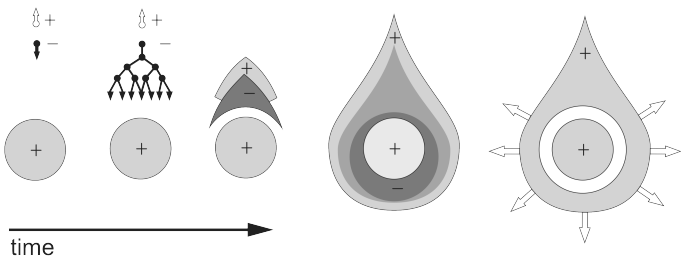


Figure: Gas amplification near anode wire, *Sauli, CERN lectures, 1977*

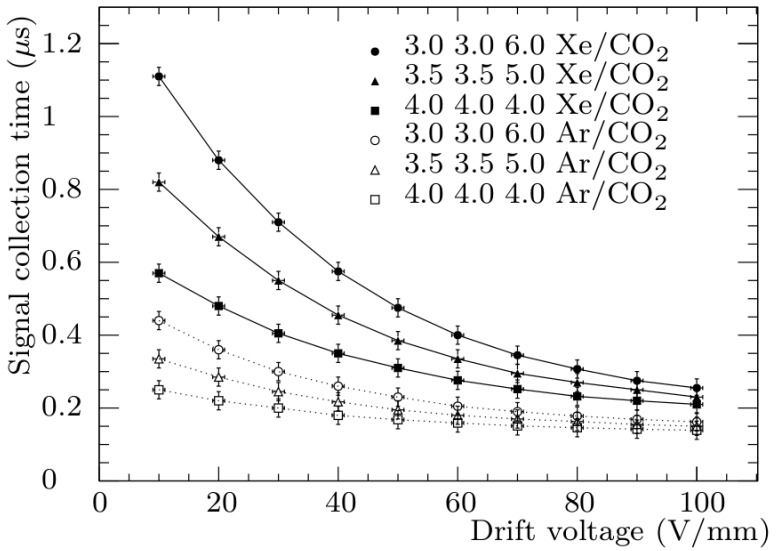


Figure: Signal collection time for simulated electron signal in symmetric amplification and drift, *Veenhof, NIMPR A, A419:726-730, 1998*

CBM-TRD: Requirements, Design

- Multi-wire proportional chambers,
  2.5 mm wire spacing
- Read-out: rectangular cathode-pad plane
- Symmetrical amplification region
  3.5 + 3.5 mm,
  5 mm drift region
- 30 cm irregular PE foam foil radiator,
  contacting directly to entrance window
- Xe-CO_2 80:20 as detector gas

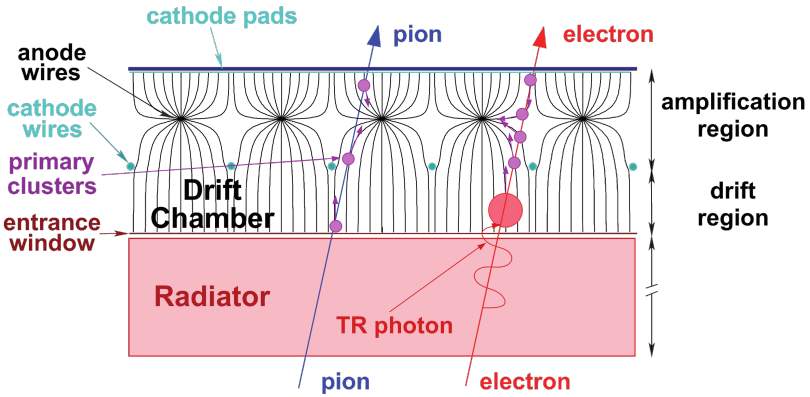


Figure: CBM-TRD geometry: Radiator and MWPC

Figure: Microscopic picture of PE foam foil

CBM-TRD: Requirements, Design

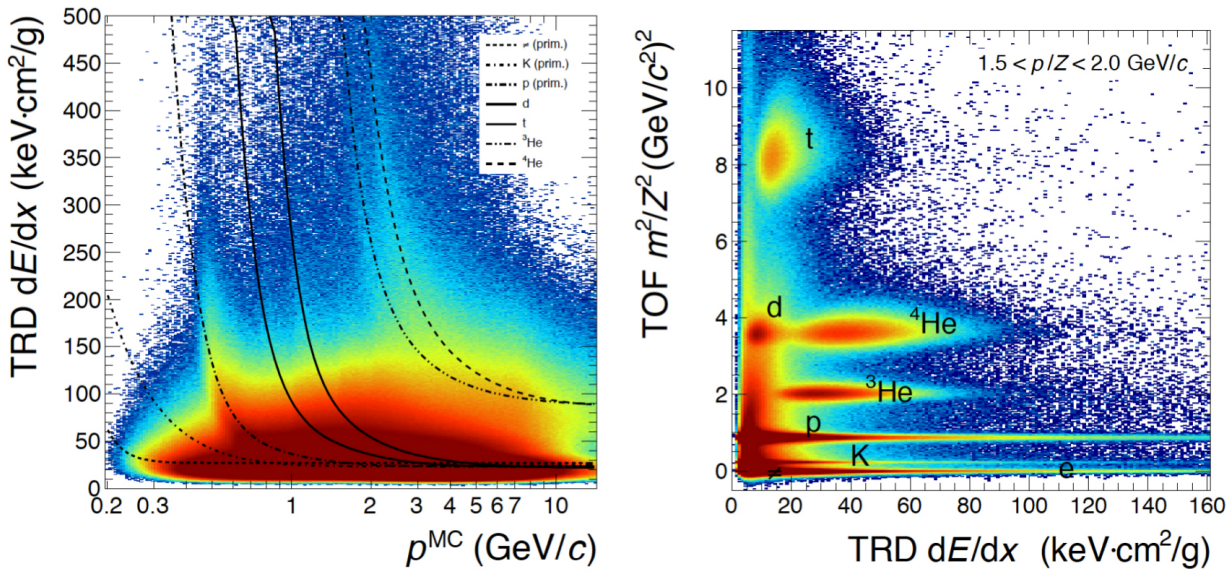


Figure: Left: averaged dE/dx signal as reconstructed in the TRD as function of the true momentum, right: TOF signal versus TRD energy loss, central Au+Au collisions at 8 GeV

Physics performance studies for the CBM-TRD at SIS100 energies

HK 31.3, Etienne Bechtel, Wednesday 14:45

Overall Detector Geometry

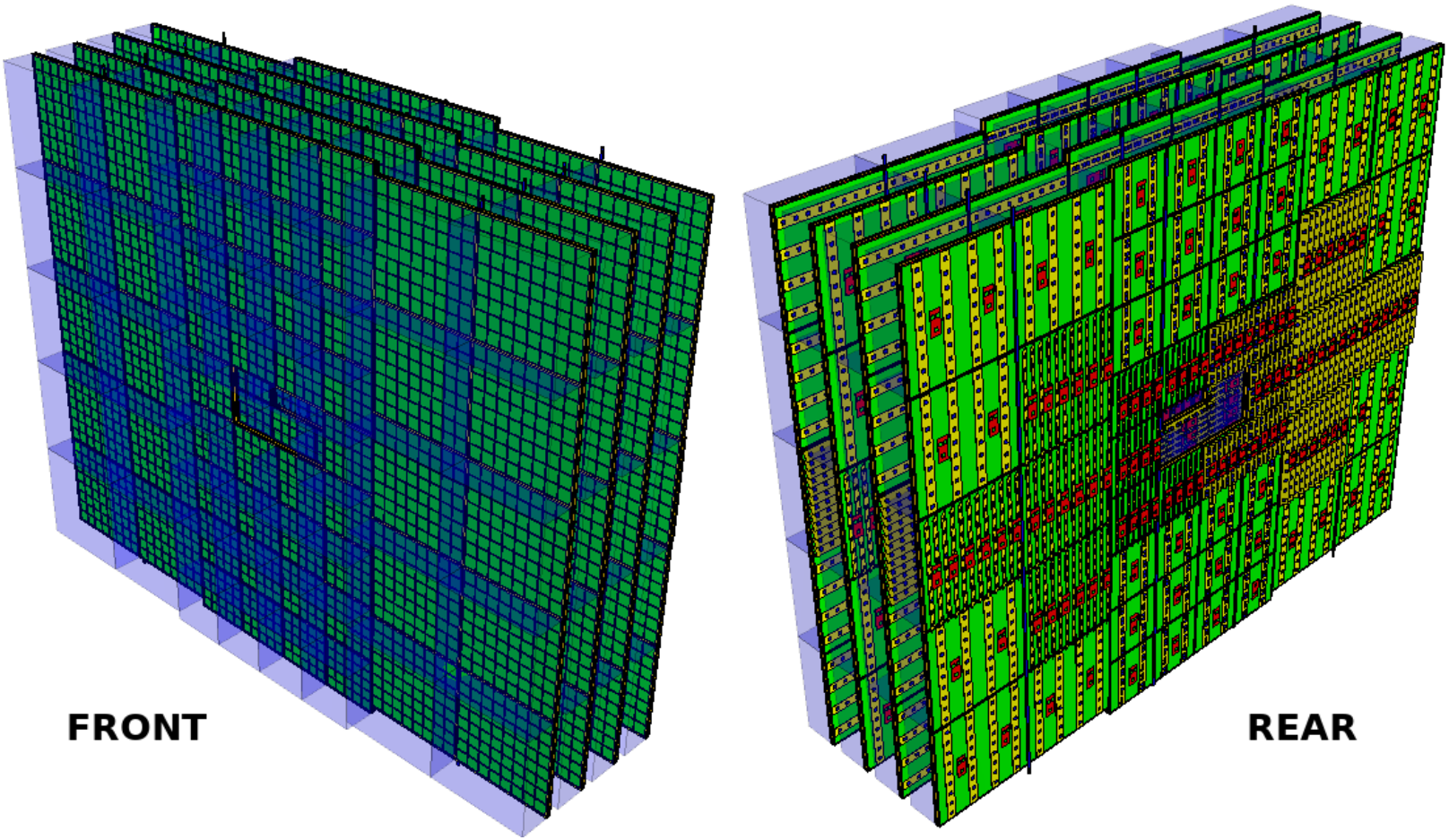


Figure: TRD station with four layers of radiator/MWPC. 6.25 x 5.15 m^2, four types of detector modules suiting the hit density distribution. Each 2nd layer rotated by 90 degree.

Read-Out and Electronic Status

- SPADIC front-end: 16 MHz/8 B sampling, self-triggered and free-streaming
- *Forced-Neighbour Read-Out* for efficient charge reconstruction
- Tail cancellation and multi-hit flagging
- e-link via GBTx (on module) to FPGA layer in entry nodes, feature extraction on-site

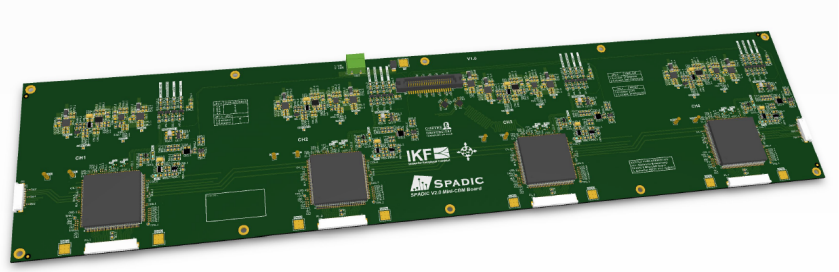


Figure: Quad-FEB, four SPADIC 2.0, 4 x 32 channel, inter-chip and inter-FEB neighbour-trigger (rendering)

Current integration branches:

- Quad-FEB based on SPADIC 2.0 with inter-chip neighbour-trigger
- Commissioning of SPADIC 2.1-based read-out: optimisation of protocol usage
- C-ROB ("Read-Out Board", GBTx) integration

Status of the Readout Chain for the CBM-TRD Experiment

HK 12.5, Cruz de Jesús Carcía Chávez, 17:45

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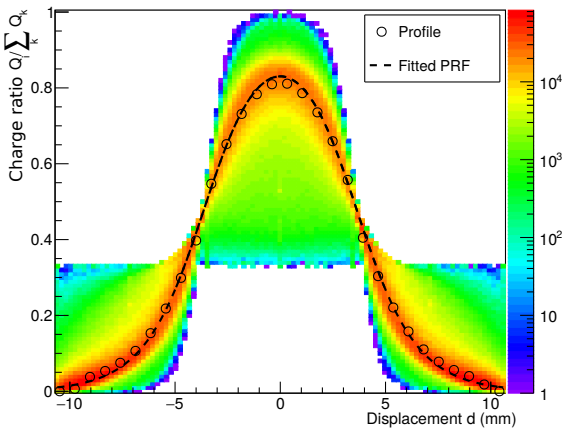

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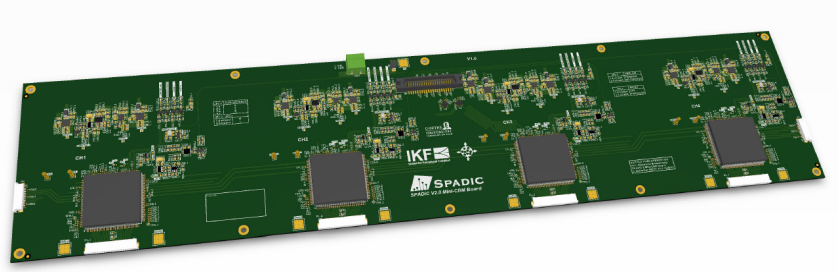

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HK 12.5, Cruz de Jesús Carcía Chávez, 17:45

Overview: Lab and In-Beam Tests

Lab measurements

- Electronic integration
- Front-end setting optimisation
- Oxygen/humidity levels in detector gas
- Gas gain confirmation

In-beam tests

- Earlier tests at SIS18, CERN-PS, CERN-SPS
- Electron testbeam at DESY II, 2017
- High-rate test at *Gamma Irradiation Facility* CERN-GIF^{++}, 2017
- High-rate test at CERN-GIF^{++} including muon beam, 2018
- miniCBM at SIS18, 2018 and 2019

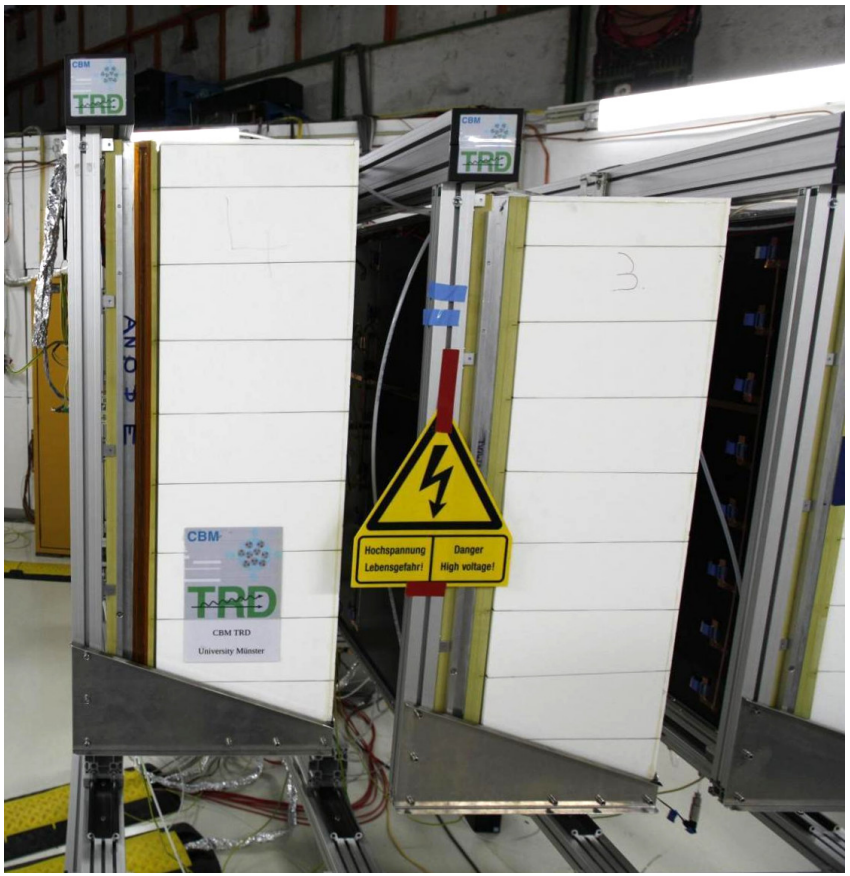

Figure: TRD prototypes at DESY, MWPCs + Radiators

DESY Electron Testbeam

- Electron beam (1 – 4 GeV), directly through detectors
- Full set of four MWPCs and radiators
- MWPC tracking station and scintillator coincidence reference
- Xe-CO_2 80:20 as detector gas
- Slow data recorded: e.g. HV, gas oxygen content, temperature, pressure

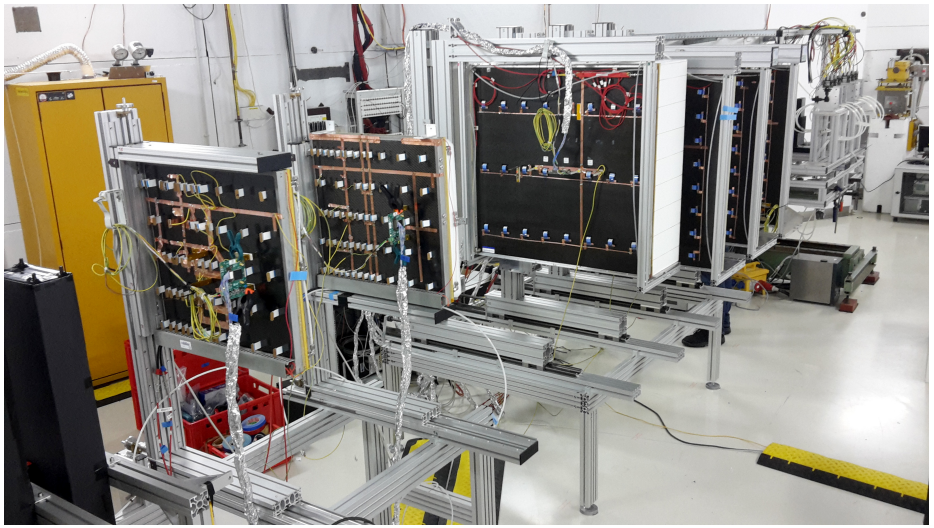

Figure: TRD testbeam campaign at DESY II

Measurement program:

- Detector response to electrons, TR spectrum
- Electron detection efficiency
- Track reconstruction
- *y*-position reconstruction, radiator contact to entrance window, ...

Test beam results of prototypes for the CBM-TRD at DESY and GIF++

HK 12.4, Florian Roether, 17:30

High-Rate Test at CERN-GIF

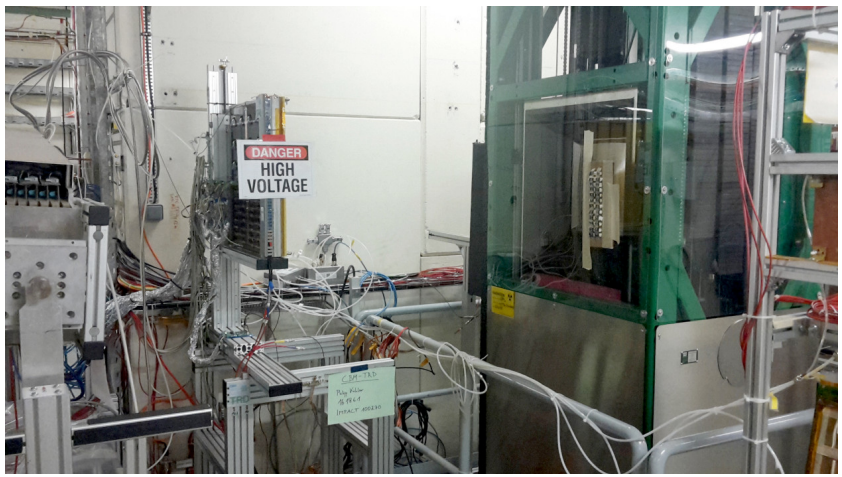

Figure: TRD testbeam campaign at CERN-GIF^{++}

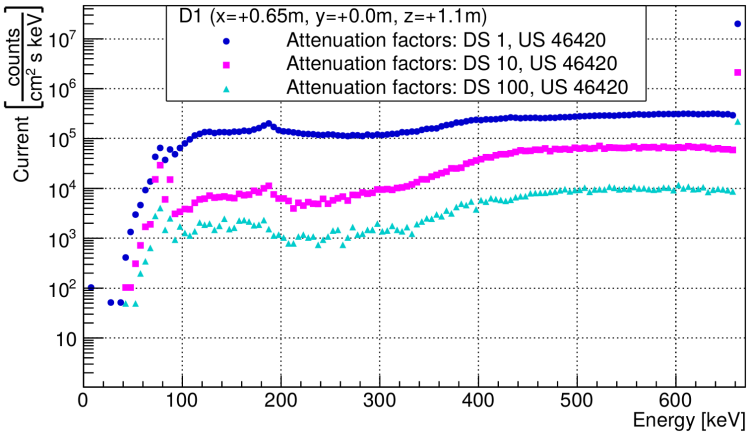

Figure: Simulated gamma spectrum in empty GIF bunker, three attenuator levels, *GIF*

- ^{137}Cs source, 13 TBq
- γ emission of 662 keV, interactions with material
- TRD prototype: 1 cm^2 cathode-pad size (equivalent: innermost TRD region)
- Xe-CO_2 80:20 as detector gas

High-Rate Test at CERN-GIF

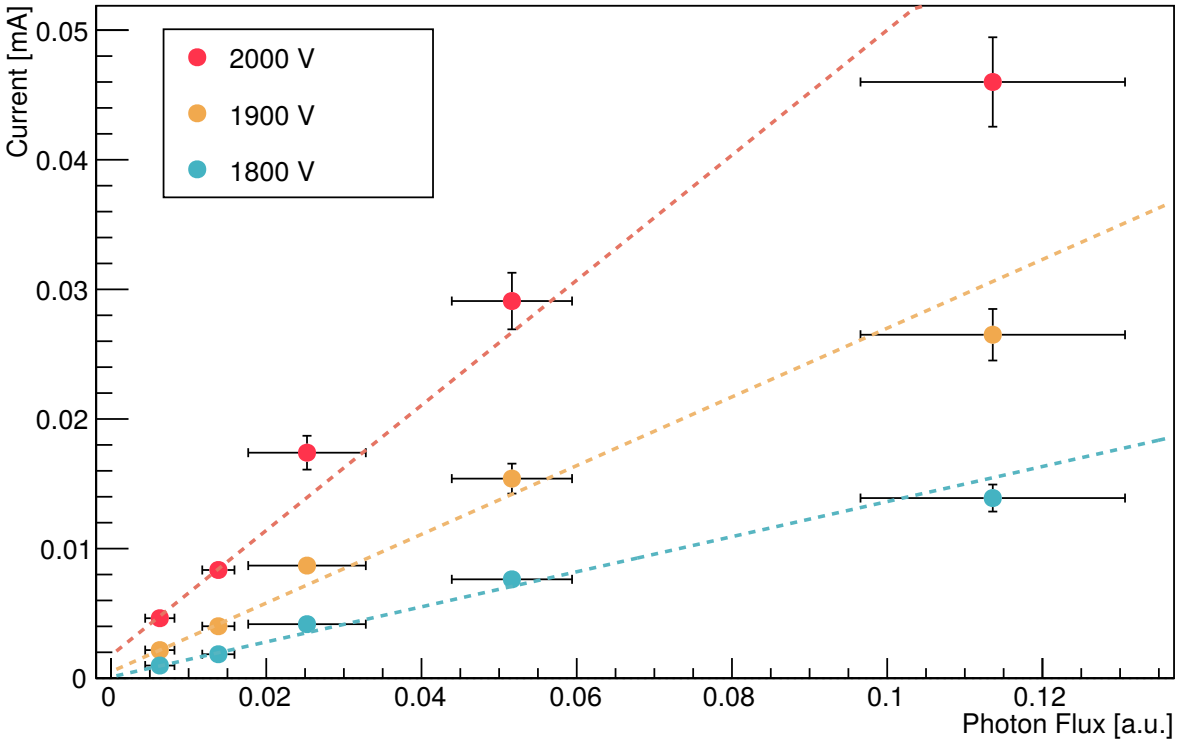

Figure: Measured anode currents with respect to photon flux

Measurement program:

- Detector load in the CBM domain and above: exclusion of space-charge effects
- DAQ chain at highest loads
- Homogeneity of detector

High-Rate Test at CERN-GIF

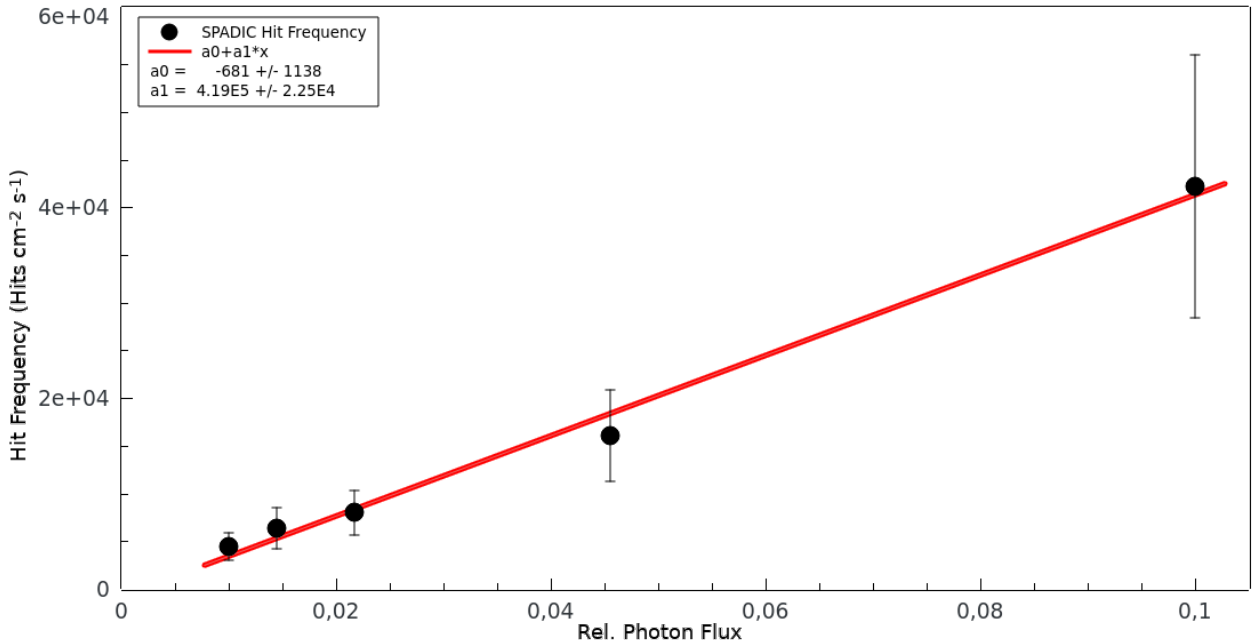

Figure: Reconstructed, self-triggered hit rates with respect to photon flux

Measurement program:

- Detector load in the CBM domain and above: exclusion of space-charge effects
- DAQ chain at highest loads
- Homogeneity of detector

FAIR Phase 0: miniCBM

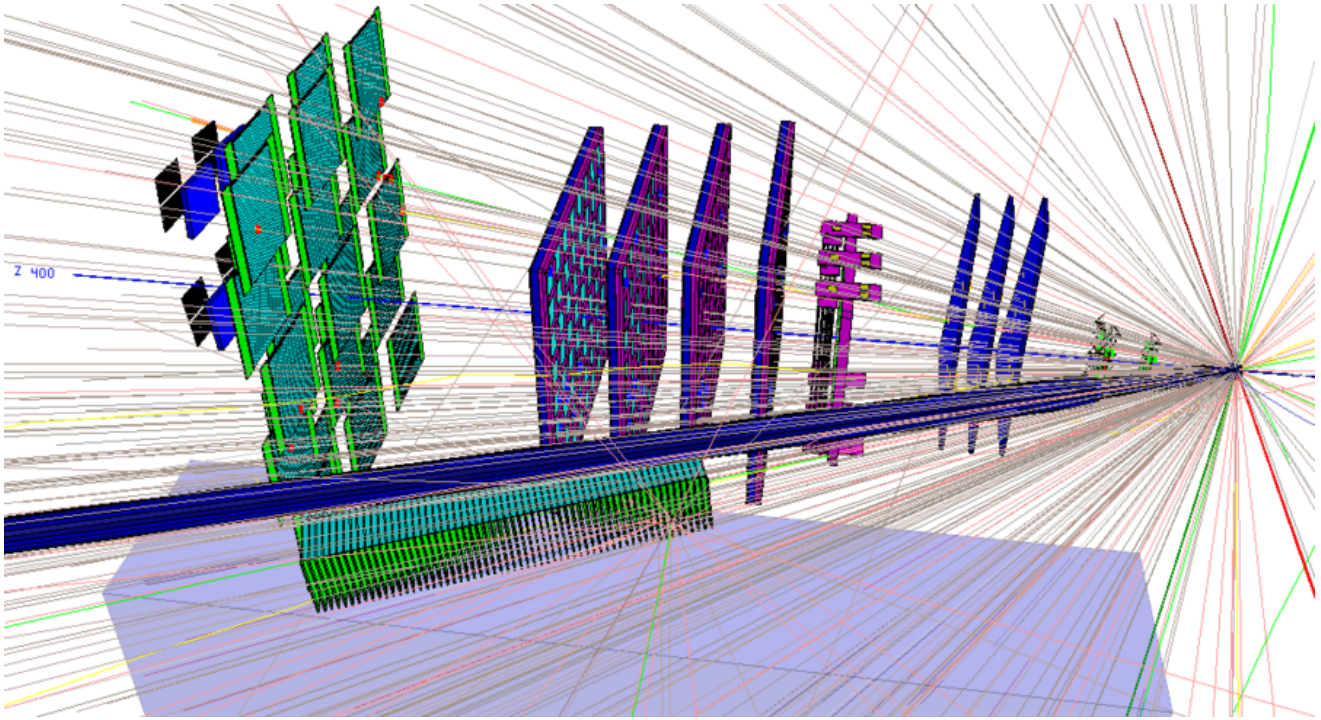

Figure: miniCBM setup at SIS18 (rendering)

- Separate detector read-outs well-tested and confirmed
- Common read-out chain launched at cosmic stand in Heidelberg (STS, TOF, TRD)
- Installation of miniCBM at SIS18 in 2018 and 2019
- Full event reconstruction

Software Status

- Reconstruction of free-streaming data requires new framework for reconstruction
- Digitisation, clusterisation, charge reconstruction, position reconstruction demonstrated
- Mechanismns for baseline correction established
- High-rate scenarios to be integrated
- Feature extraction launched, in development

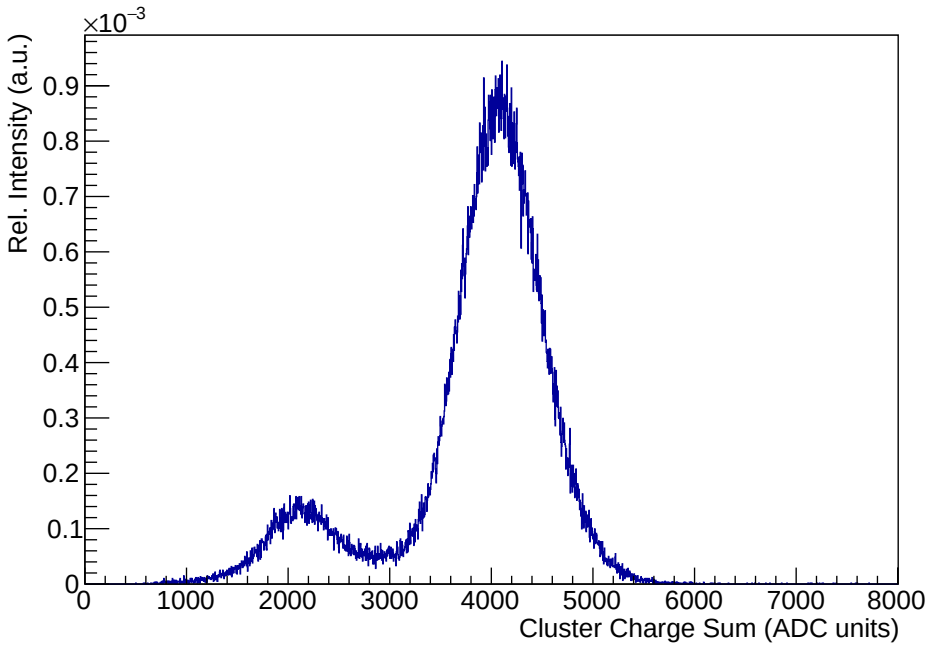

Figure: Cluster charge spectrum, ^{55}Fe source, *J. Beckhoff*

Hit reconstruction for the CBM-TRD

HK 13.2, Philipp Munkes, 17:00

Summary

- Key properties of the CBM-TRD:
  fast design, signal collection times below 300 ns
  pion suppression above 20
- Technical design finished
- Engineering tasks in progress

- Full event reconstruction currently developed
- Feature extraction in integration

- Read-out electronics near-to-final,
  used in many measurements
- Commissioning of joint CBM read-out ongoing
- FAIR Phase 0 to be started