TRD STD / outer modules status

46^{th} CBM week, CAS/IMP Lanzhou (PRC), 22^{nd} October 2025

Philipp Kähler

Institut für Kernphysik, Universität Münster, Germany

Bundesministerium für Bildung und Forschung

Universität Münster

CBM

CBM TRD

GSI

FAIR

TRD mainframe

detector layer spacing

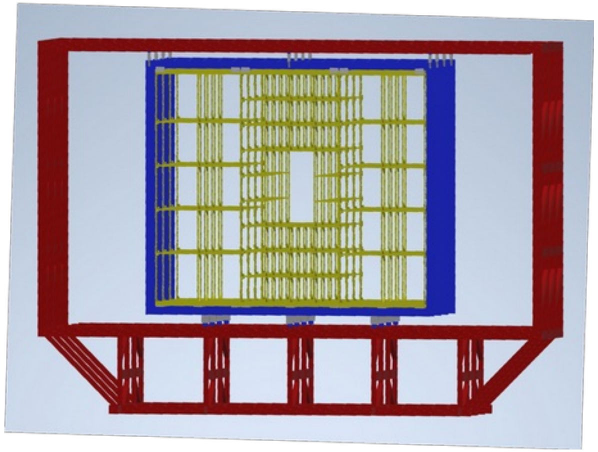
TRD production status

QA: new developments

QA reporting

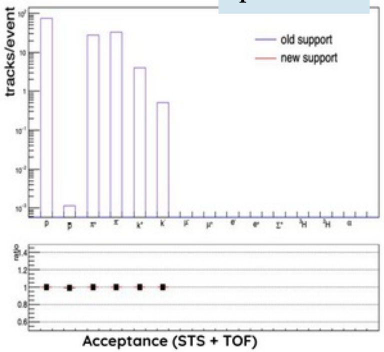
detector mainframe

- TRD mainframe now generated in Root primitive solids
  reviewed & merged in MR302 (**TRD v24c**, full TRD)
  `(cbmroot_geometry)/MR302`
  inlcluded: additional *y* clearance, top & bottom of primary frame
  - CPU time: 1.46 s/event with support,
    (“detector only” v20b: 1.23 s/event), only 18% increase
  - comparative simulations conducted, full STS acceptance
- v24c (full TRD) set as new TRD default geometry, also
  v24d (CFV) available

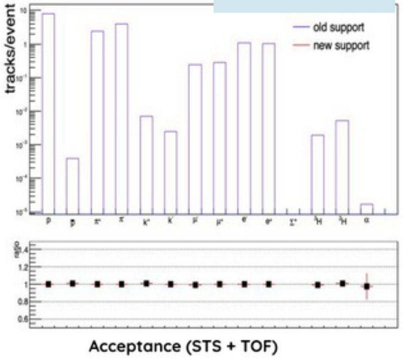


TRD frame with enlarged clearance, primary frame > 25°

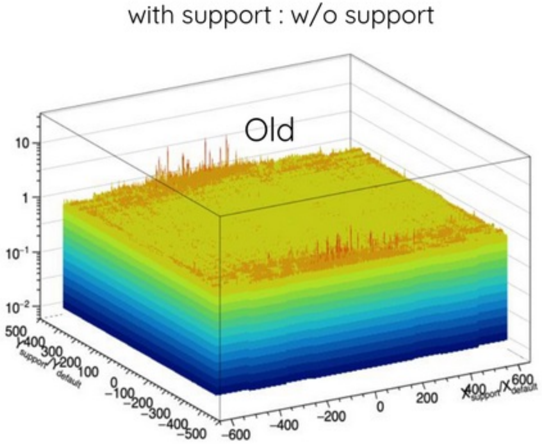
primaries

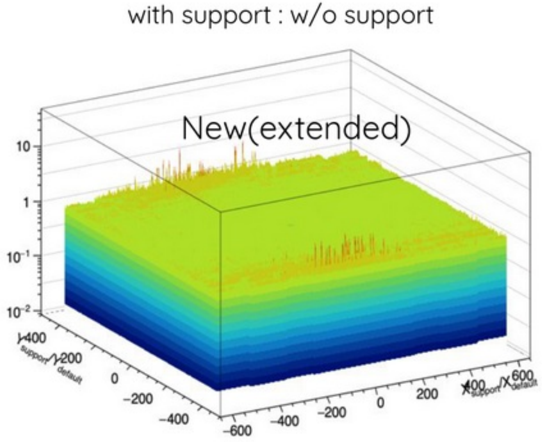


secondaries



Omveer





TOF hit distribution (no further systems affected)

TRD mainframe

detector layer spacing

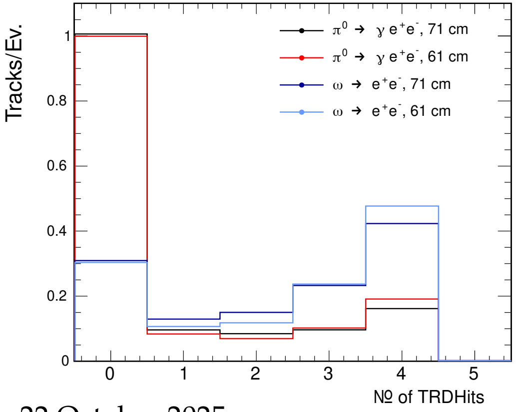
TRD production status

QA: new developments

QA reporting

TRD layer-to-layer distance

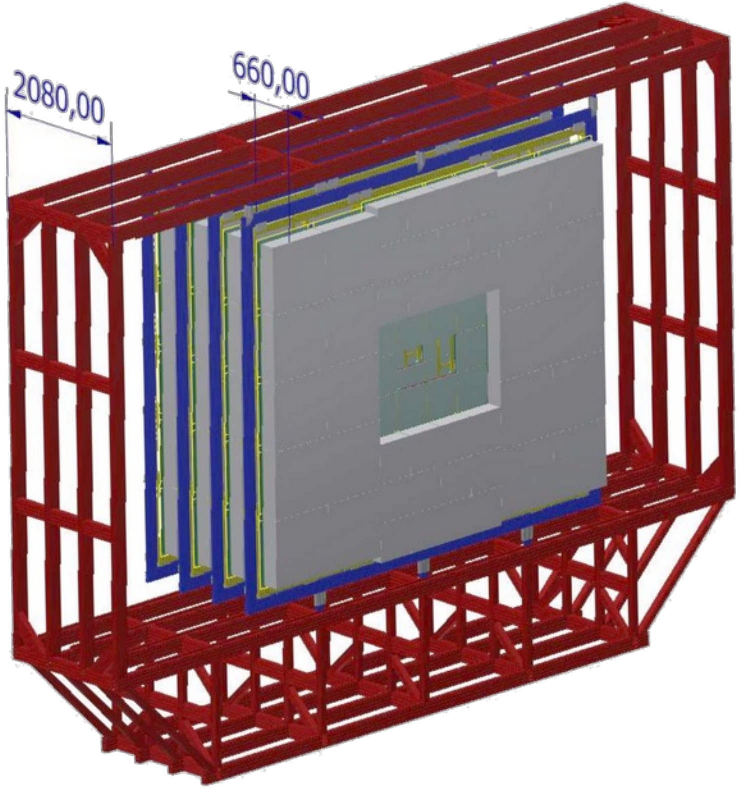
- reminder: TRD will consist of four equal layers, each layer of radiator (PE foam mats) and MWPCs
- full electron ID performance reached for electron hit in 4 layers
- current TRD design / TDR version – optimised TR yield: 30 cm radiator (+1.5 cm in entrance region)
  - with realistic detector design: current TRD geometries have layer repitition distance 71 cm
  - acceptance losses at large angles due to distance of rear layers
- system optimisation of radiator & layer spacing, compare these versions:
  - 71 cm layer repitition, 30 cm radiator (TDR, current geometries)
  - 66 cm layer repitition, 25 cm radiator ← **appears preferrable**
  - 61 cm layer repitition, 20 cm radiator



hits in TRD layers for electron tracks, different layer spacings

→ compact 66 cm geometry prepared, TRD v25a, MR324 to the geom. git

→ physics review ongoing, 1st positive feedback received



4 TRD layers, this rendering: layer repitition distance reduced to 66 cm (current default: 71 cm)

TRD mainframe

detector layer spacing

TRD production status

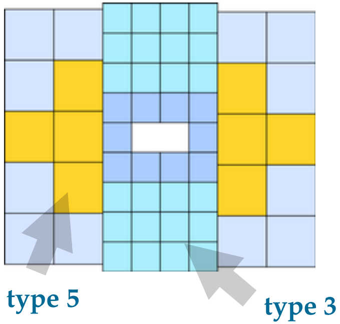
QA: new developments

QA reporting

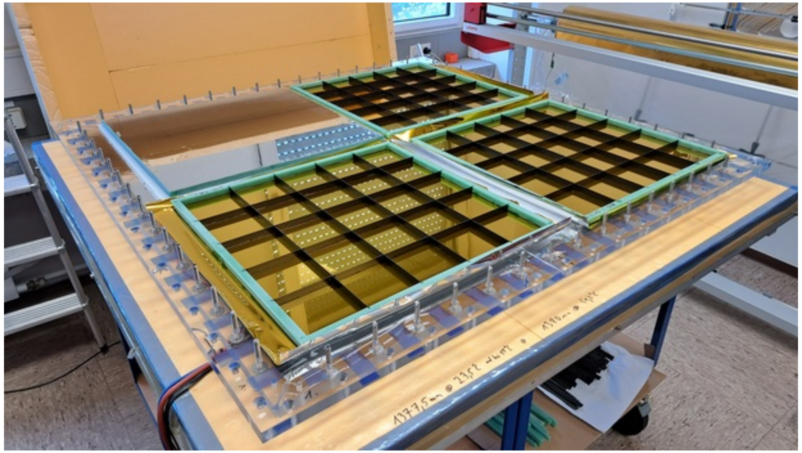
TRD pre-production

- components for chamber type 5:
  - 32+3 chambers, 990 mm x 990 mm, 144 x 24 pads
  - production of backpanels (with cathode-pad plane): established full QA for electrical connections, cathode surface planarity, connectors
  - 35 backpanels finished
  - 35 entrance windows to be finished in next weeks

- components for chamber type 3:
  - 64+6 chambers, 570 mm x 570 mm, 80 x 8 pads
  - started with entrance window production
  - parallelisation in frame preparation and entrance foil stretching reached: 4 windows in 1 production step



(this sketch: 1 of 4 TRD layers)

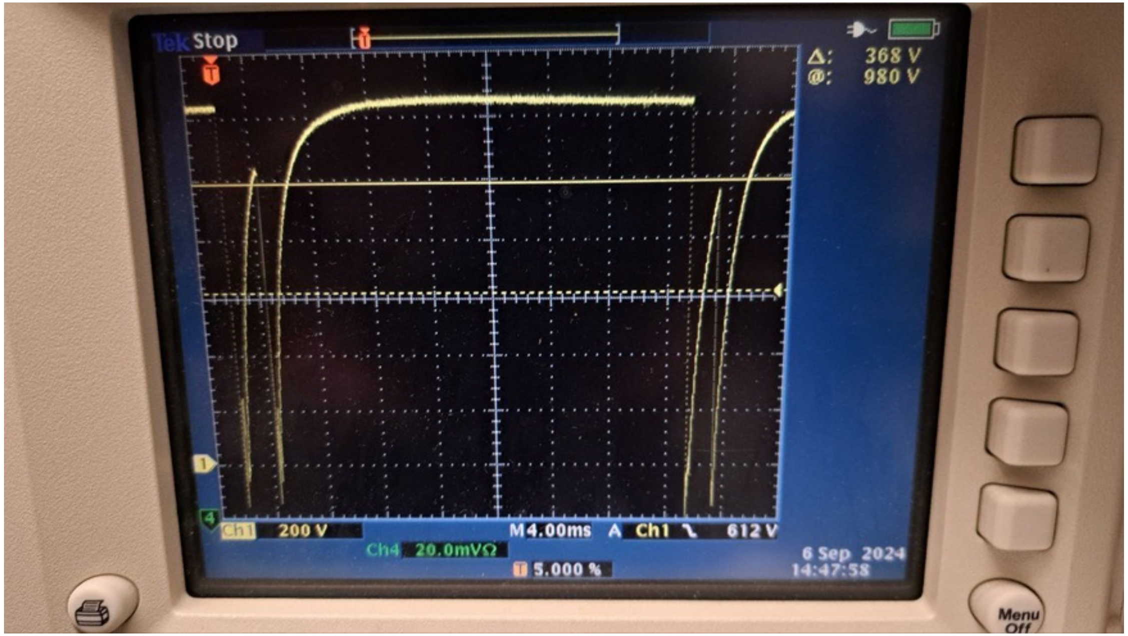


reminder: wiring, observed trip behaviour

- both pre-series chambers (serial BP5-003 and BP5-004)
  - 7 out of 8 anode wire layer segments confirmed to nominal voltage + 10%
  - 1 segment trips at 1140...1200 V
  - “ignition”: see scope picture, repetitive onset

- after trip (and completed onset): Ohmic resistance of ~ 200 Ω
  - “removable” → disappearance (“burning”) at ~ 6 V, 30 mA
  - **switchable – reproduced > 10 times with BP5-003**
  - during mCBM operation of the chambers, no further localisation achieved (as mounted FEE hinders)

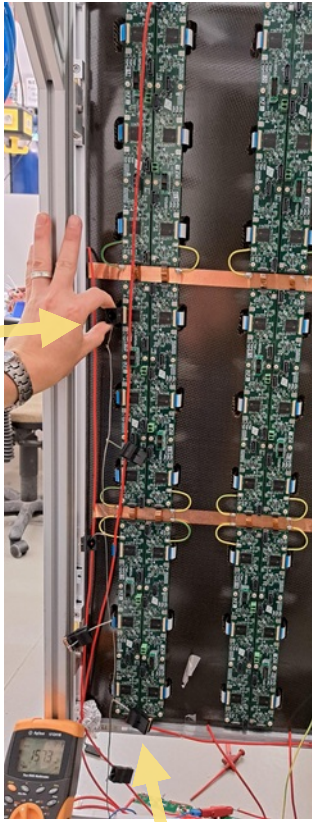
- trip avoided with floating cathode padplane
  - in chamber BP5-004: identified <u>one cathode pad</u> as trip partner



onset of trip, seen on chamber BP5-003, still in mCBM: trigger on breakdown of anode HV

trip/conductivity localisation

- in BP5-003 was possible to localise the connection (with chamber in conductive state) to exactly 1 cathode pad
  - 2^{nd} pad “row” from left (next-to border row), 6^{th} (of 9) pad group, close to centre-of-wire
- measured conductivity between anode segment and cathode pad: 157 Ω
- pad position is in about 54 cm distance from anode layer contact ledge (bottom in photo, this slide)
  - calculate resistivity of 54 cm anode wire:
    $R = \rho \times A / l$
    $= 0.092\ \Omega\ mm^2/m \times 0.54\ m\ /\ 0.0003173\ mm^2$
    $= 156.6\ \Omega$
- **hypothesis: contact via anode wire**



chamber in conductive state: contact localised exactly to 1 cath. pad, 2^{nd} row, 1^{st} of group

157 Ω

tripping/conductive: 1^{st} anode wire layer segment

chamber opening & winding log enquiry

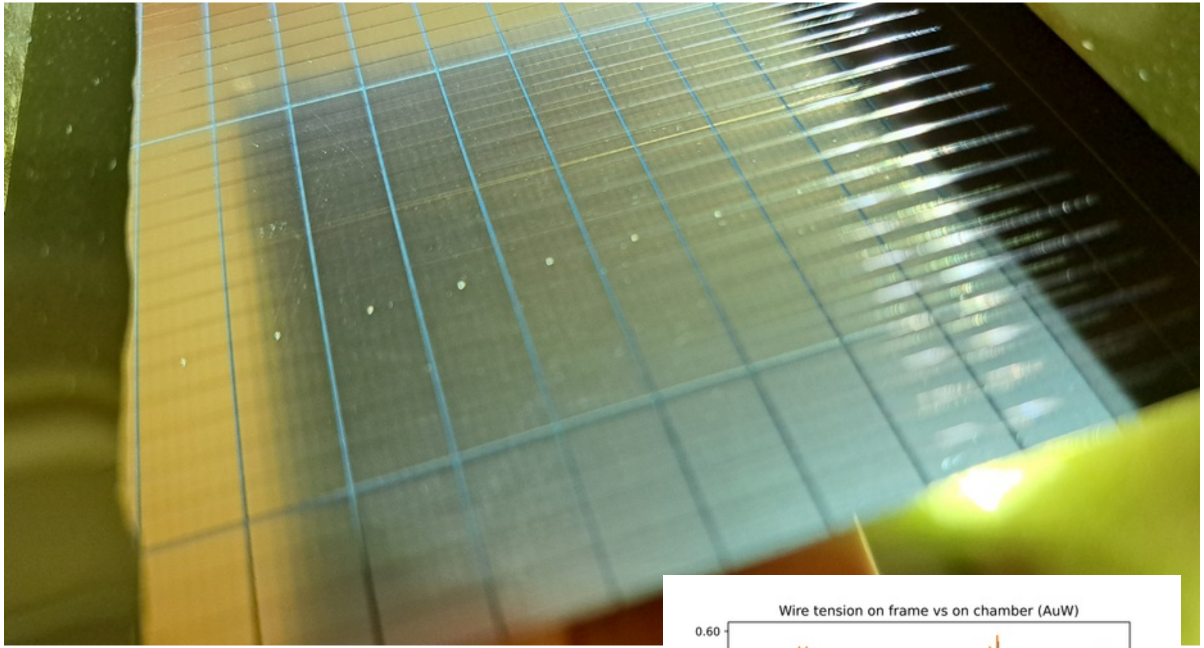
- **BP5-003** was opened
  by cutting the entrance window

- one anode wire found touching a cathode pad,
  while its ends appear properly glued
  in the wire ledge stacks

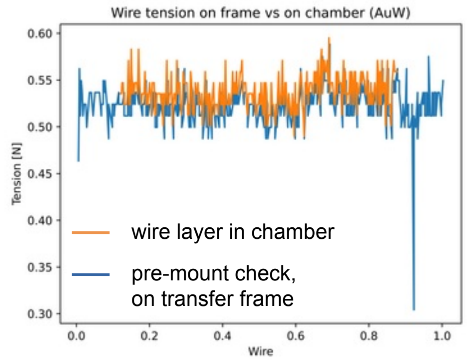
- new enquiry of wire tension measurement data
  in the winding log of this chamber production:
  insufficient tension
  already on winding (transfer) frame,
  routine failed to identify

- w.i.p.: inspect also chamber
  BP5-004 with same tripping behaviour
  – would suit tension error still in backside/
  "sibling" of same wire winding run,
  but not yet found in tension measurement,
  should exclude wire-to-ledge glueing

- **general, possible sources of insufficient tension:**
  - in tension regulation during winding (*Meteor*)
  - in wire glueing on transfer frame (*Technicoll*)
  - in wire ledge glueing in chamber (*Araldite*)



opened chamber BP5-003, view through remaining entrance window (surrounding), wire layers, cathode pads – one anode wire with insufficient tension



winding log data of same chamber, anode wire tension – see outlier

chamber opening & winding log enquiry

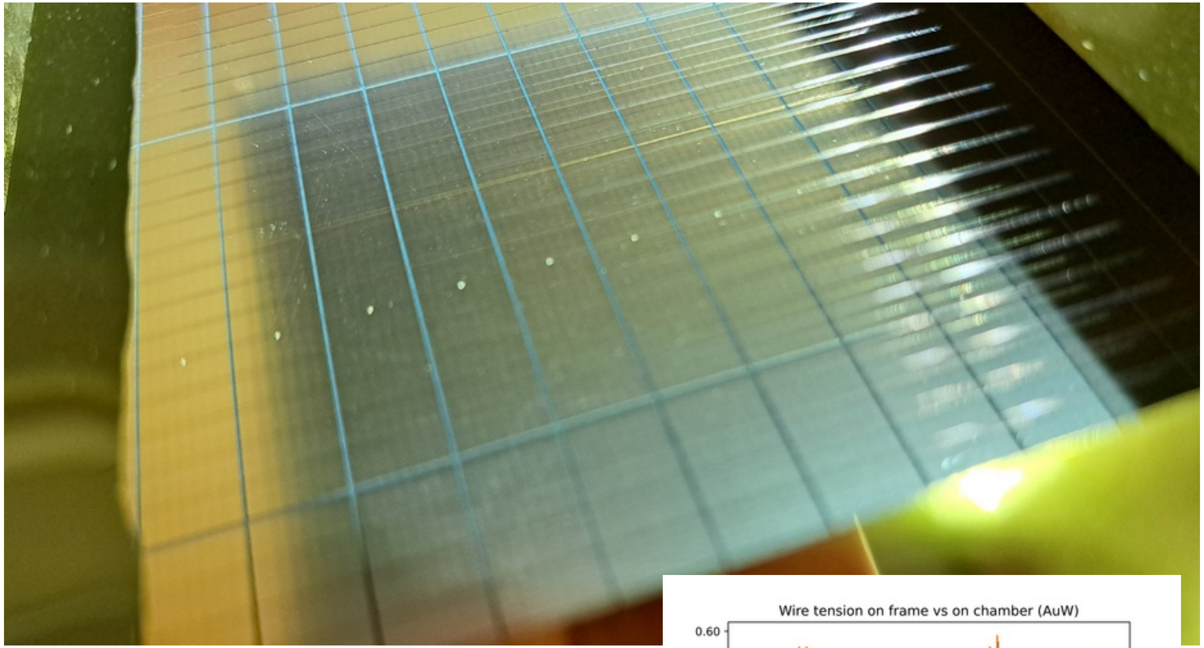
- **BP5-003** was opened
  by cutting the entrance window

- one anode wire found touching a cathode pad,
  while its ends appear properly glued
  in the wire ledge stacks

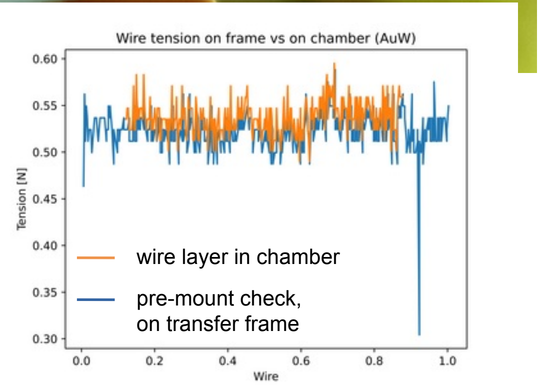
- new enquiry of wire tension measurement data
  in the winding log of this chamber production:
  insufficient tension
  already on winding (transfer) frame,
  <u>routine failed to identify</u>

- <u>w.i.p.:</u> inspect also chamber
  BP5-004 with same tripping behaviour
  – would suit tension error still in backside/
  "sibling" of same wire winding run,
  but not yet found in tension measurement,
  should exclude wire-to-ledge glueing

- **general, possible sources of insufficient tension:**
  - in tension regulation during winding (*Meteor*)
  - ~~in wire glueing on transfer frame (*Technicoll*)~~ – ruled out
  - ~~in wire ledge glueing in chamber (*Araldite*)~~ – ruled out



opened chamber BP5-003, view through remaining entrance window (surrounding), wire layers, cathode pads – <u>one anode wire with insufficient tension</u>



winding log data of same chamber, anode wire tension – see outlier

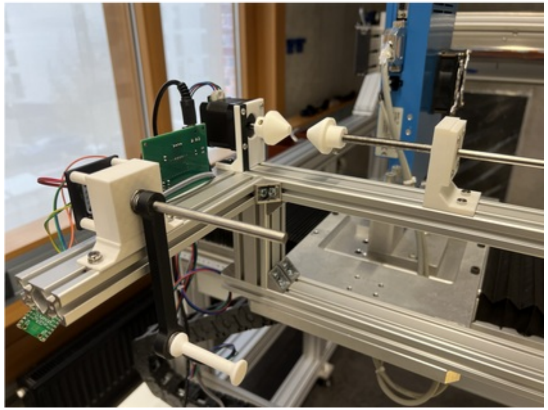
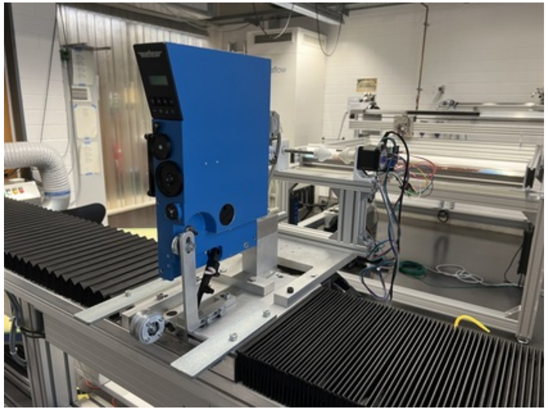
chamber wiring: stabilisations & restart

- full revision of *Meteor* wire tension device performed
  - breaking wheel exchanged
  - commissioned new active pre-tension regulation
  - next step: confirm calibration of tension meter

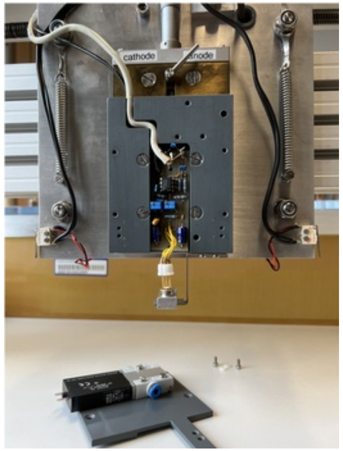
- rework of automated wire tension measurement device
  - modified sensor mounting to reach edges of wire layer also in 2nd run (wires in chamber)

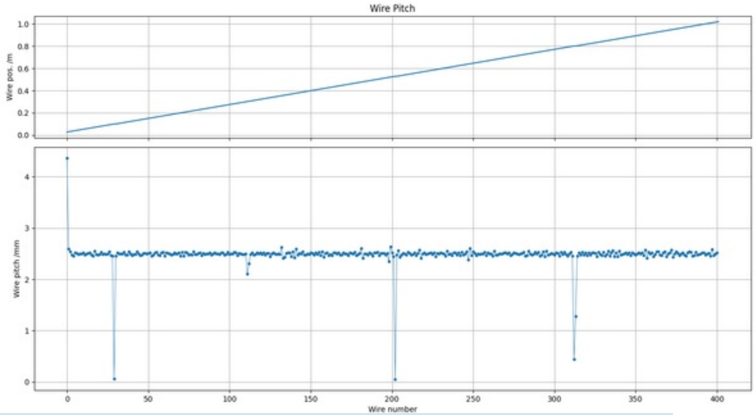
- activated pitch control to ensure <u>every wire</u> is measured

- test winding of anode wire layer completed, expecting to resume wiring of chambers soon

wire tension device: new active pre-tension regulation & *Meteor* revision





wire tension measurement: rework to reach edges in chamber and activated pitch evaluation

IKF team

TRD mainframe

detector layer spacing

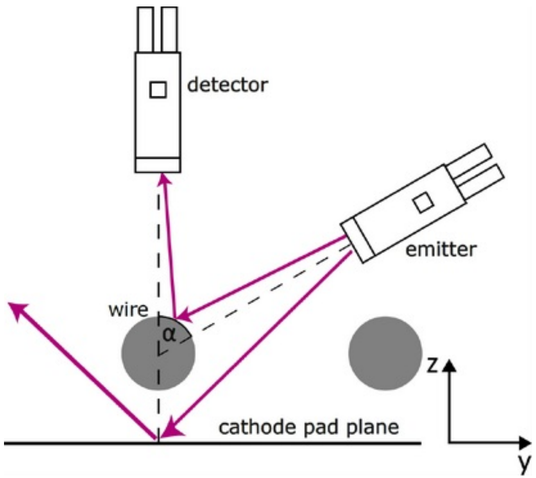
TRD production status

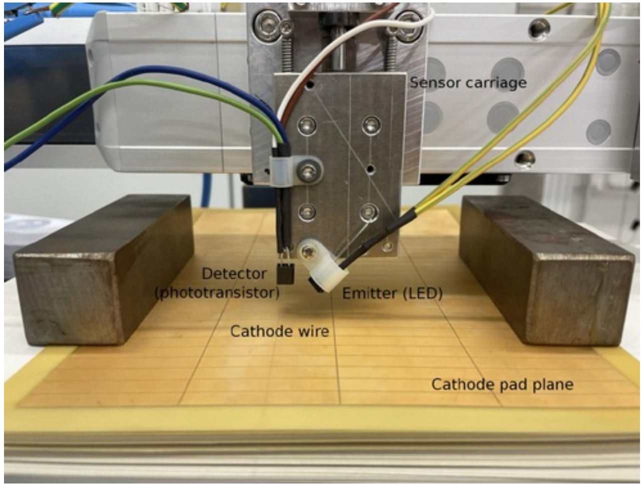
QA: new developments

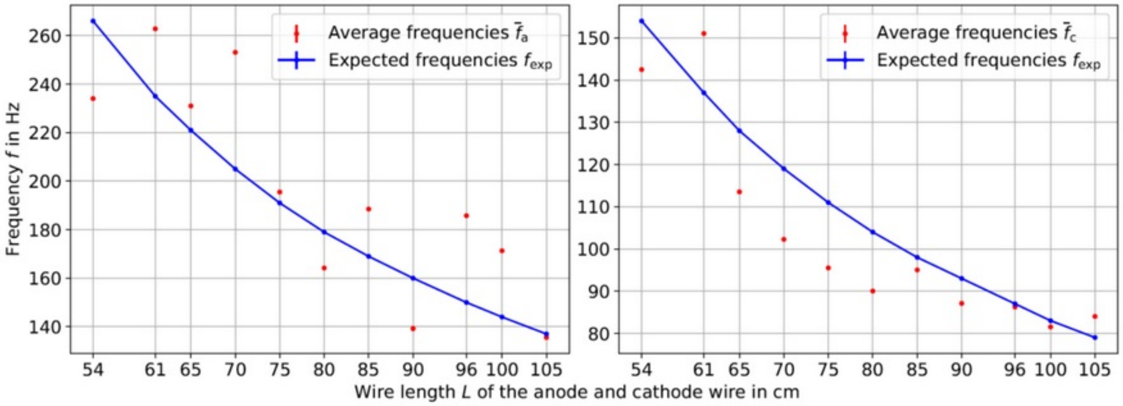
QA reporting

WIP: a new wire tension measurement

- automatised wire tension measurements
  for anode and cathode layers as inevitable check
- performed so far with well-established device,
  Gottschlag 2005, as used for all ALICE-TRD chambers
  - service demands increasing,
    replacement components partially unavailable
- started design of *up-to-date* tension measurement
  in collaboration with Bucharest/2D team
  - bus-based control
  - linear drive identified and purchased,
    confirmed reproduction precision < 10 μm
  - ADC identified
  - optical LED & phototransistor sensor setup
    being tested
- first promising results, oscillations measured, next step:
  - testing infrared laser diode instead of LED







Konstantin

TRD mainframe

detector layer spacing

TRD production status

QA: new developments

QA reporting

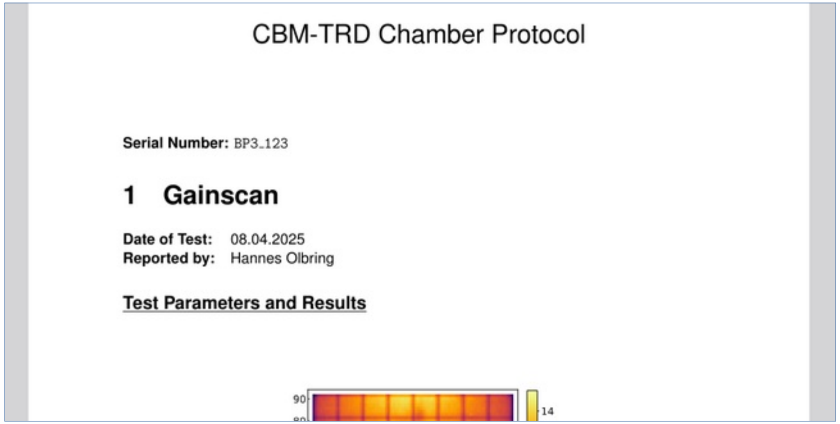
WIP: TRD chamber QA report generator

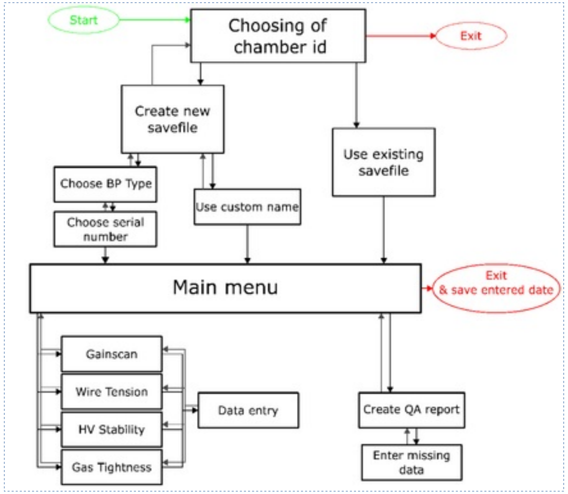
- Python-based programme to collect and store QA data of TRD chambers has been developed
  (gsi-git)/trd/software-extra/trd-qa-reporting
  - using *blessed* package as user interface
  - held 1st internal review, aiming for longterm software stability
  - structure: programme and data/report storage decoupled

- centralised generation of plots and QA report per chamber, current content:
  - gain scan
  - gas tightness / gas loss measurement
  - wire tension per wire (anode/cathode, pre/after layer install)
  - HV stability

    … observables can be added, backward compatibility
  - handover from test places via defined JSON format

- involving all 3 production places
  - to come: for data, considering separate git project / common cloud storage





Hannes

summary

- TRD geometries v24c (full TRD) and v24d with TRD mainframe merged
  - set as TRD default geometries
  - enlarged y clearance reached

- suggesting compact TRD layer spacing “66 cm”
  - comparative simulations conducted
  - technical review concluded, 1st positive comments in physics review
  - MRs to the geom. git set, aiming for November tests

- TRD chamber production
  - type 5 readout backpanels finished, windows finishing soon
  - type 3 window production started, improved parallelisation
  - wiring of chambers: issues identified, tools and routines reworked, restarting now

- chamber production QA processes
  - successor device for automatised wire tension measurement in development
  - new TRD QA report generator software being commissioned

last slide ↑

backup ↓

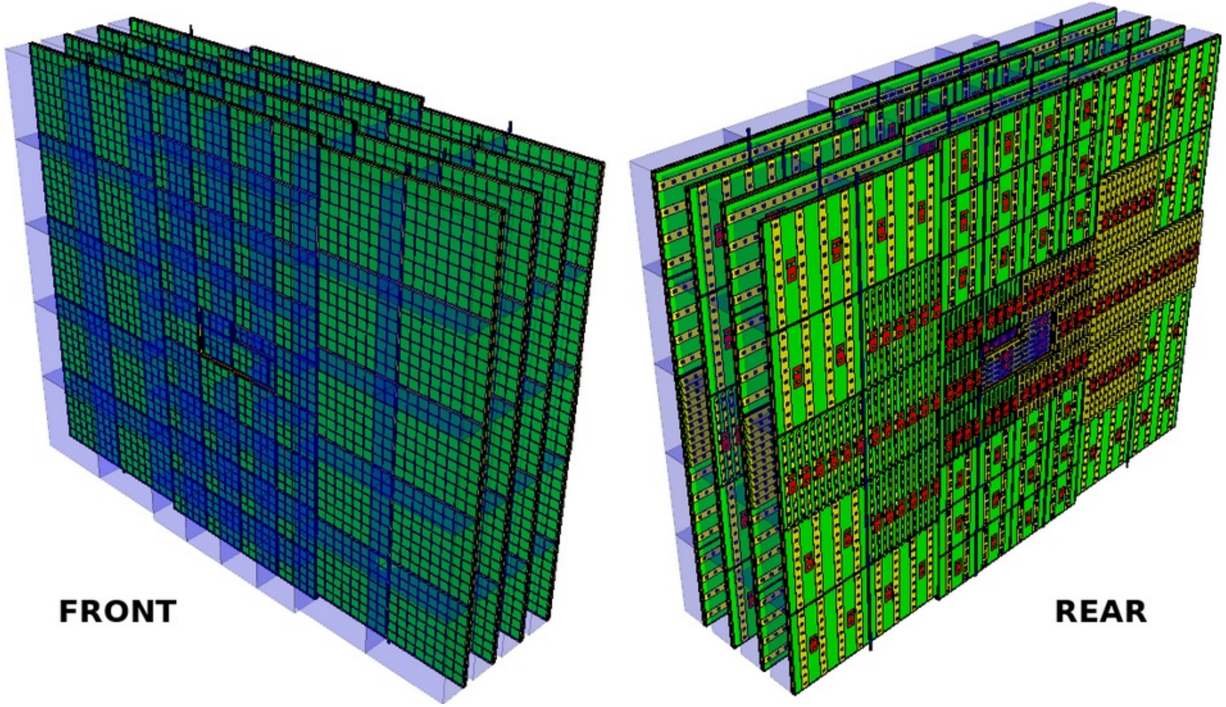
TRD in CBM

- 216 MWPCs & radiator
- 6.25 m x 5.15 m max. width/height
- alternating x- and y-layers (90° rotation)
- read-out at the segmented cathode plane
- 2D inner zone, triangular cathode pads
- 4.1 m behind centre-of-magnetic field
  - $1.15 < \eta < 3.65$ pseudo-rapidity coverage

PURPOSE

- electron identification above 1 GeV
  - design value: π supp. > 20 @90% e^- eff.
- intermediate tracker, 300 μm pos. res.
- hadron identification via dE/dx

- FPGA extraction: charge and time after CRI layer

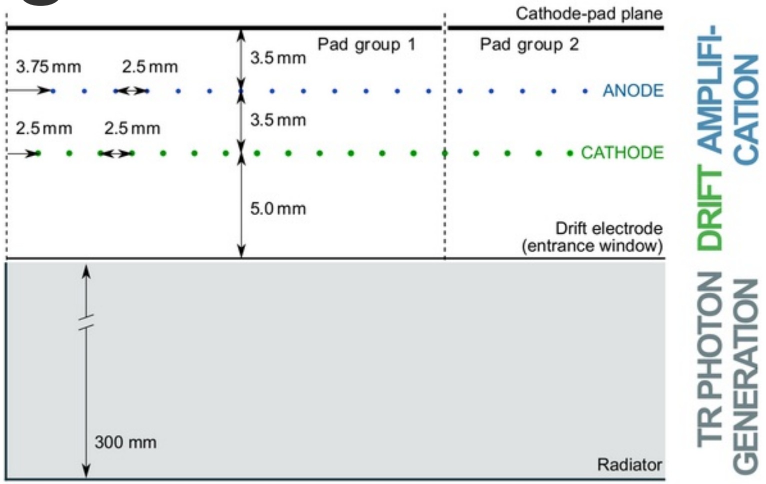


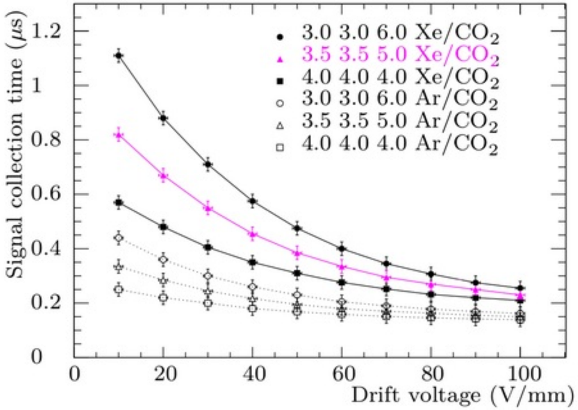
TRD MWPC design

- up to 100 kHz particle rate at 10 MHz interaction rate
- operated with Xe/CO_2 85:15,
  0 … 0.7 mbar (relative)
- thin *Kapton* entrance window (TR transmission)
- symmetrical amplification plus drift
- 3.5+3.5 / 5 mm: optimisation,
  rate capabilities vs. TR absorption
- pad width: 6.7 mm (PRF ~ 10/80/10)

- gain 2000, short signal collection time
  → U_{anode} = 1850 V, U_{drift} = -500 V

- Andronic et al.: *A comprehensive study of rate capability in Multi-Wire Proportional Chambers*, arXiv:0909.0242





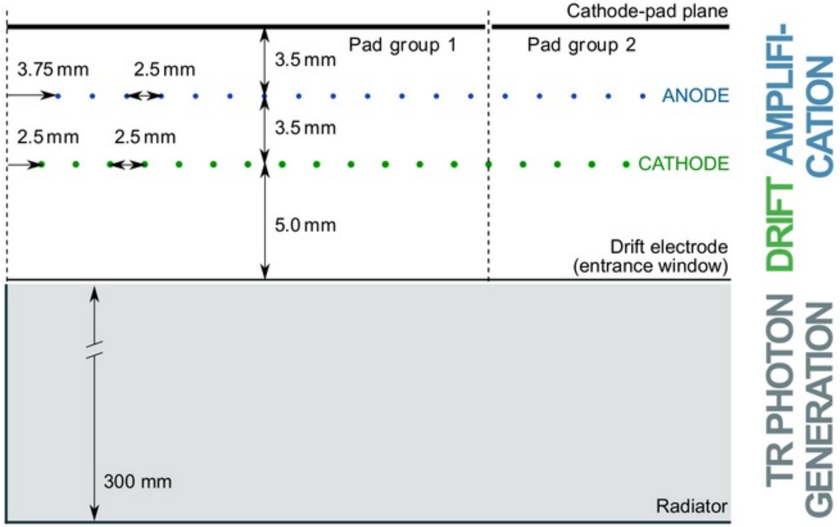
TRD HV geometry

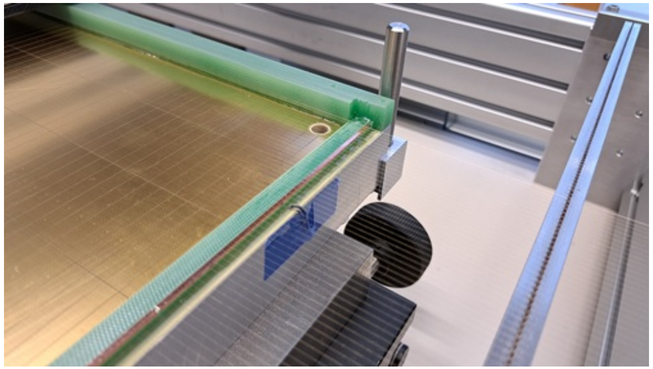
- wire spacing 2.5 mm (anode & drift layer)
- amplification region 3.5 mm x 2 (symmetrical)
- drift region 5.0 mm

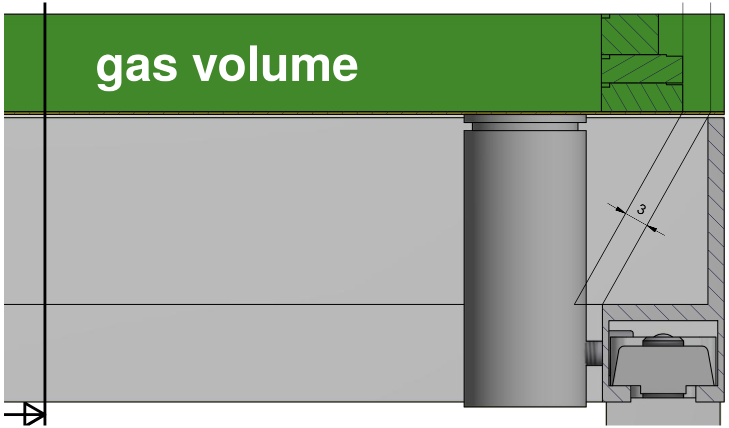
- wire diameters 20 µm anode (+ 75 µm outermost)
  75 µm cathode

- wire tension 45 … 50 cN anode
  100 … 110 cN cathode

- nominal voltages ~ 1800 V anode for gain 2000…3000 (Xe/CO_2 85:15)
  -100 V/mm drift for < 300 ns signal collection time

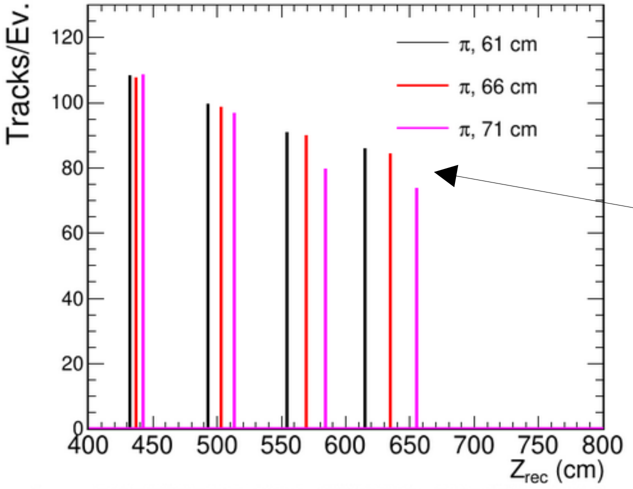






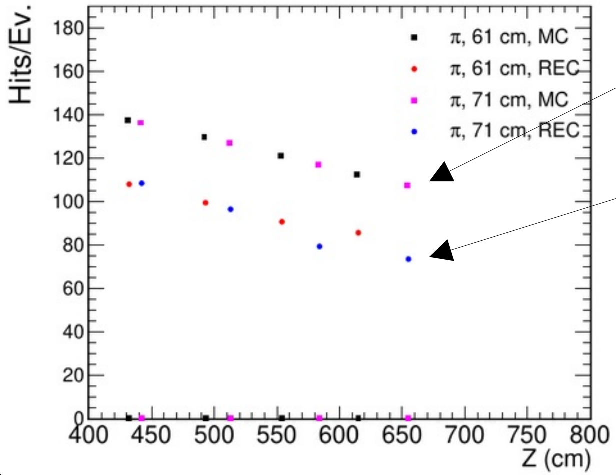
anode layer
is electrically split
into 8 segments

layer spacing, di-electrons, hit counts



71 cm (current default version, pink) shows unexpected count depression in 3rd and 4th layer

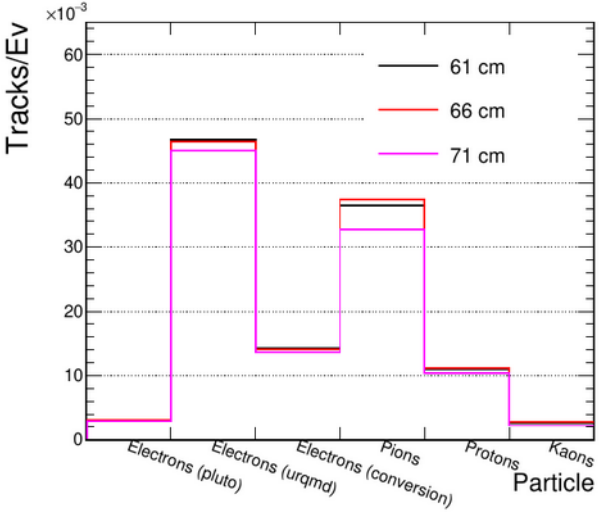
pions, hits per layer



upper "line", Monte Carlo 71 cm (pink) and 61 cm (black): expected geometrical effect, more hits for more upstream position in compact version

lower "line", reconstructed, 71 cm (blue) and 61 cm (red): additional suppression for 71 cm, assuming an effect in the tracking of that time

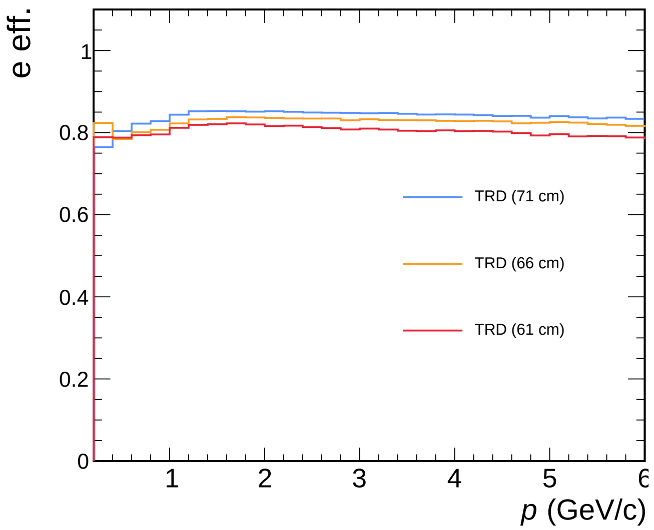
pion hits per layer, MC and rect'd/assigned to track

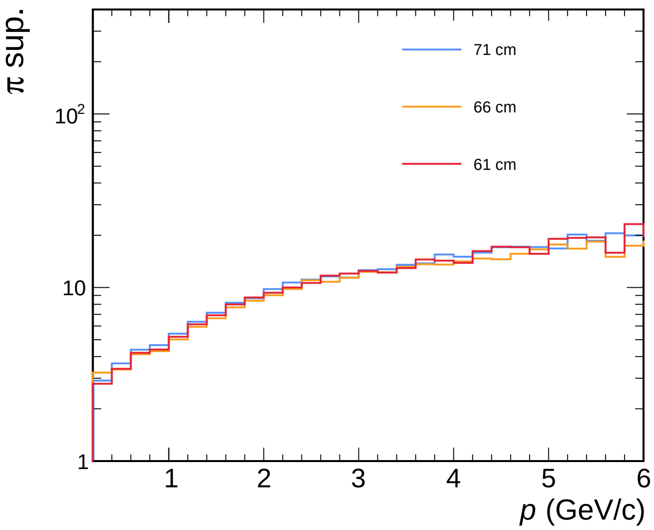


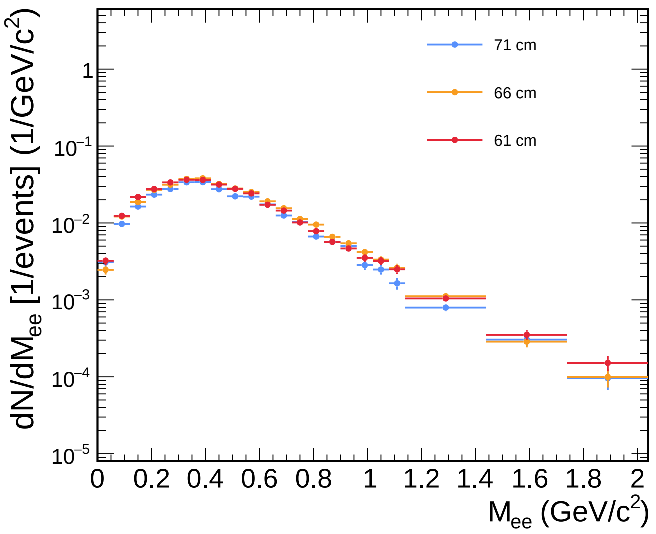
particle species and sources

simulations: Adrian

layer spacing, electron efficiency & π supp.







slightly reduced electron efficiency, as consequence in case of shorter radiators

simulations: Adrian

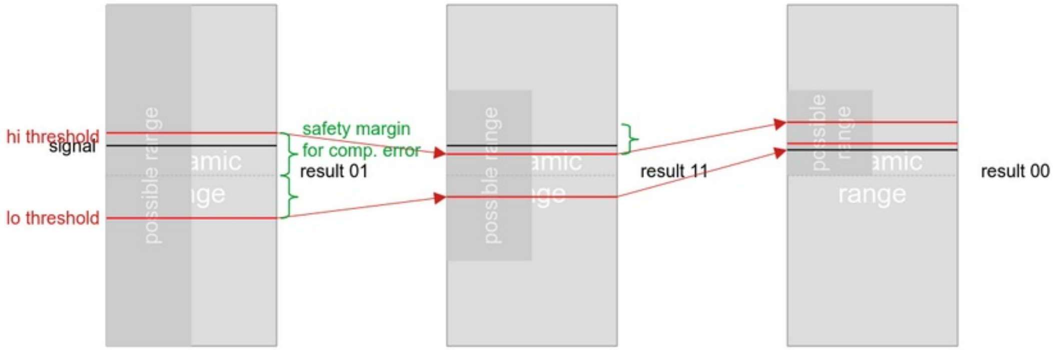
SPADIC version 3.1

- current version: SPADIC 2.2, working in mCBM
  - ~~hit to track residuals down to ~300 µm shown~~
  - few channels of each chip with unsatisfying ADC working point ("line effects")
  - internal ref. level generation
- SPADIC 3.1 submitted and received
  - dies in delivery, test setup available at ZITI
  - tests to be started
- design based on
  redundant successive approximation ADC

- -> 6.25 ns are available per conversion step:

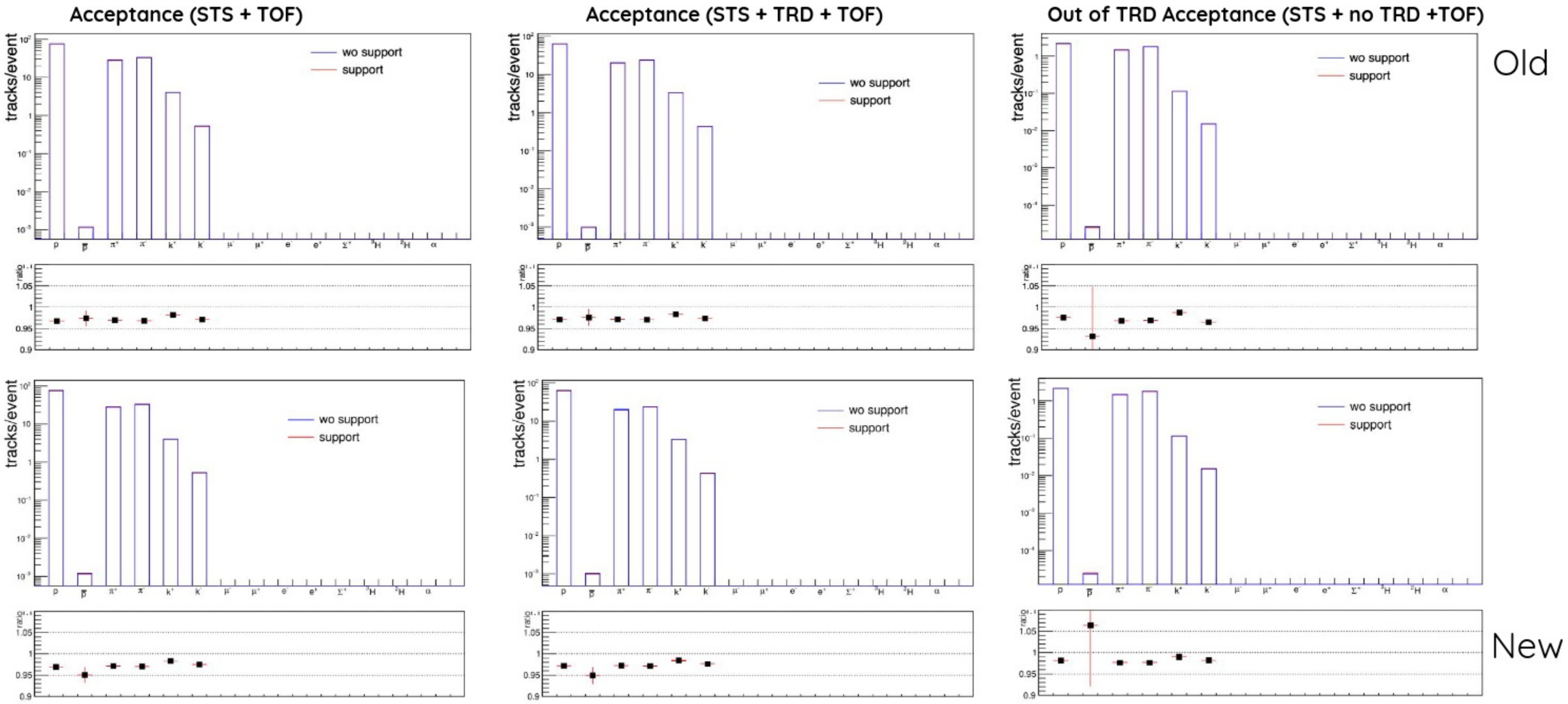
  CLK ->
  - Logic sends new DAC values
  - DACs logics decode values
  - DACs generates output voltages
  - Comparators compare
  - Results are sent to logic
  - Logic calculates next DAC values
    -> CLK

  6.25 ns



If we cannot adjust the input signal, we have to adjust the comparator threshold for the same effect.
The possible range is halved in each step. The thresholds are at ⅜ and ⅝ of this range.

Particle composition of reconstructed primary tracks



In all scenarios, up to 4% of primary tracks are reduced as a consequence of the TRD support structure.

8

Omveer