Transition Radiation Detector for the CBM Experiment

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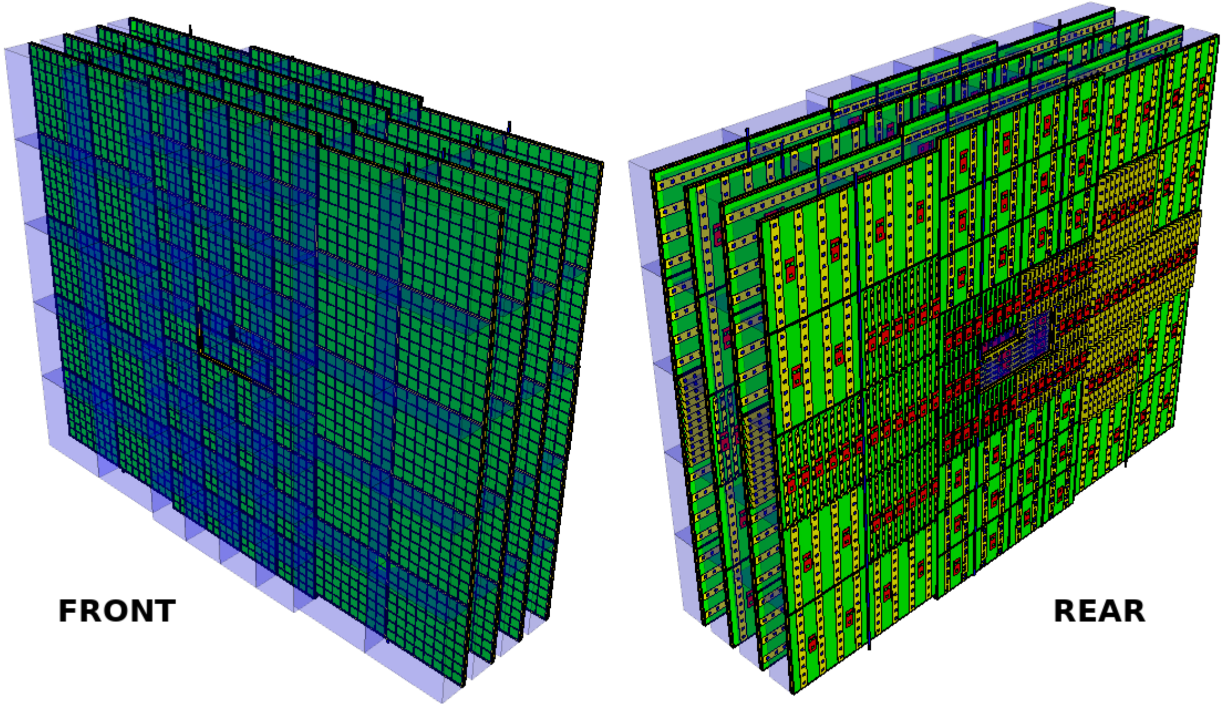
TRD in CBM

- 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

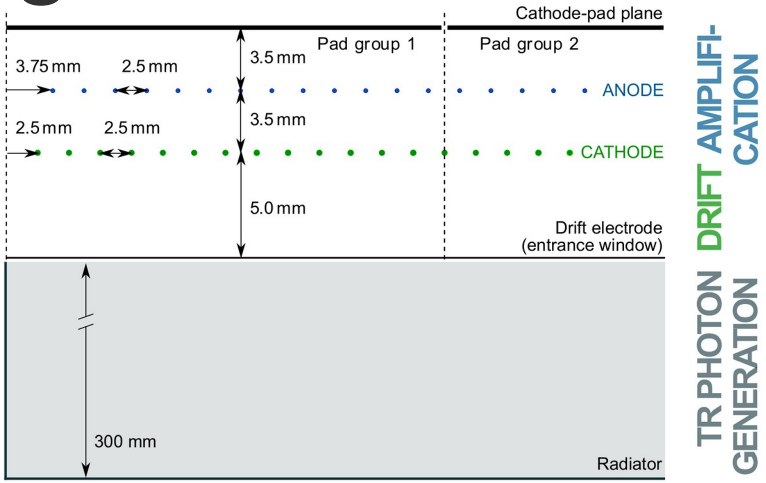


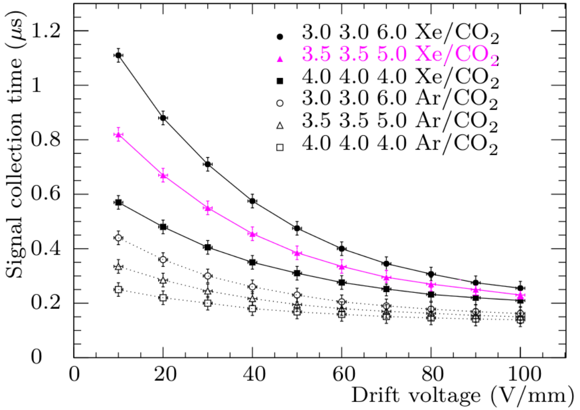
TRD MWPC design

- 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

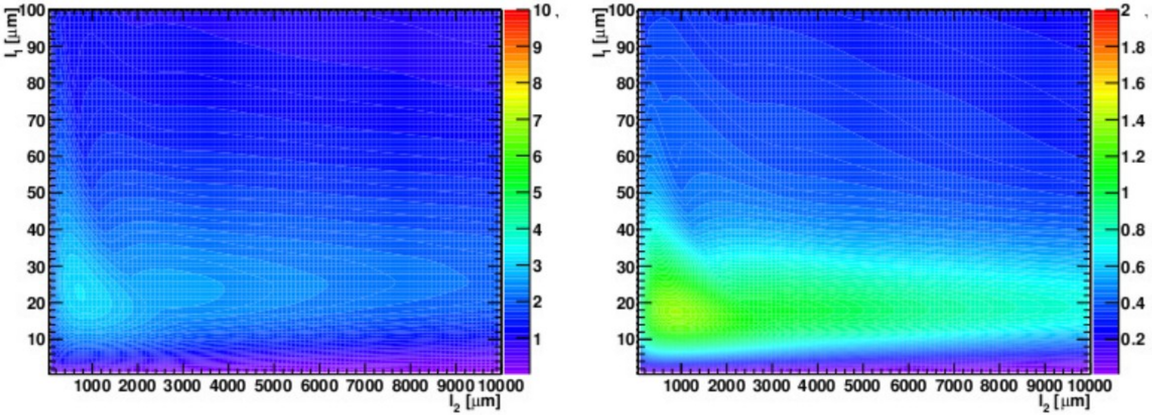




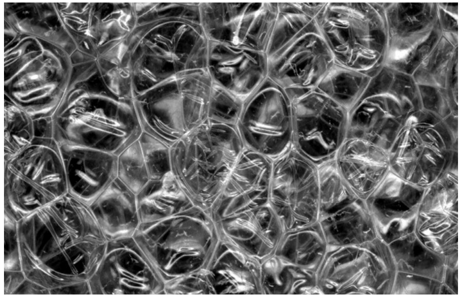
TR yield optimisation

- electron ID from integrated signal dE/dx+TR, fast design w/o drift time resolution

- maximise TR yield in detector
- simulation of irregular radiator configs with mean l_1 (material) and l_2 (air gap)
- realisation of radiator:
  - PE foam mats, mean $l_1 = 12$ µm, $l_2 = 900$ µm



Simulation of radiator spectrum, mean l_1 (material) and l_2 (air gap): emission yield RIGHT and Xe absorption yield LEFT, 2 GeV electrons

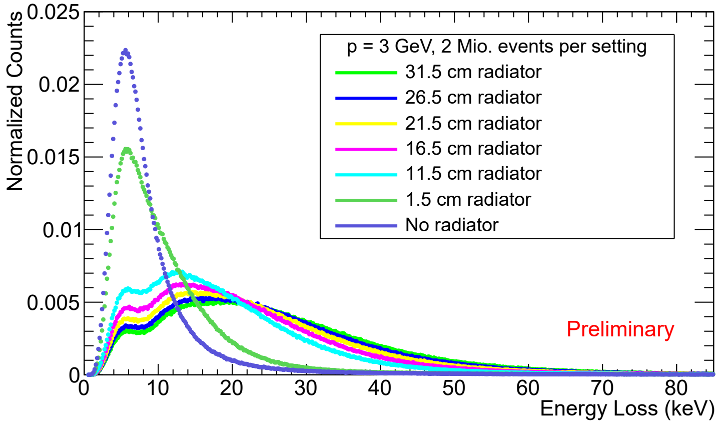


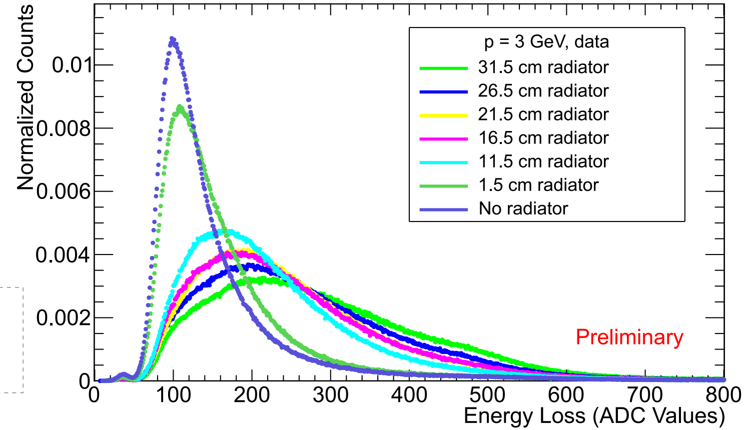
CBM TRD radiator, irregular type, PE foam mat stacks, mean 12 µm | 900 µm

TR measurements

- measurement of electron beam with distinct momentum at DESY
- direct comparison of radiator thicknesses
- simulation and measurement show still increase of TR for largest radiator size
- consider also geometry, layer spacing

- select 25 … 30 cm
- radiator $X/X_0 = 1.2 \dots 1.5$



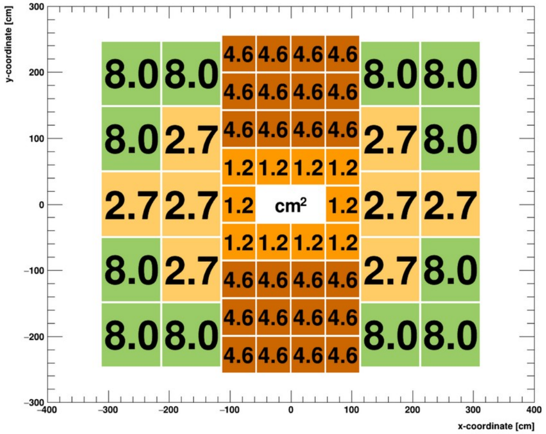


Simulation TOP and measurement in DESY electron beam BOTTOM, radiator spectra

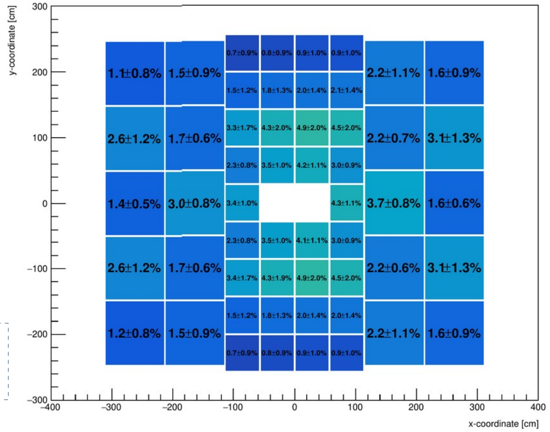
pad size scaling to local rate

- fixed-target setup with forward-focused particle rate
- adapt cathode pad length to local rate

- granularity: 4 pad sizes, in 2 chamber sizes



Module type	# Columns	# Rows	# Pads	Height (cm)	Width (cm)	Area (cm^2)
1	80	32	2560	1.75	0.68	1.18
3	80	8	640	6.75	0.68	4.56
5	144	24	3456	4.00	0.67	2.67
7	144	8	1152	12.00	0.67	8.00



Cathode pad sizes TOP and local FEE occupancies BOTTOM

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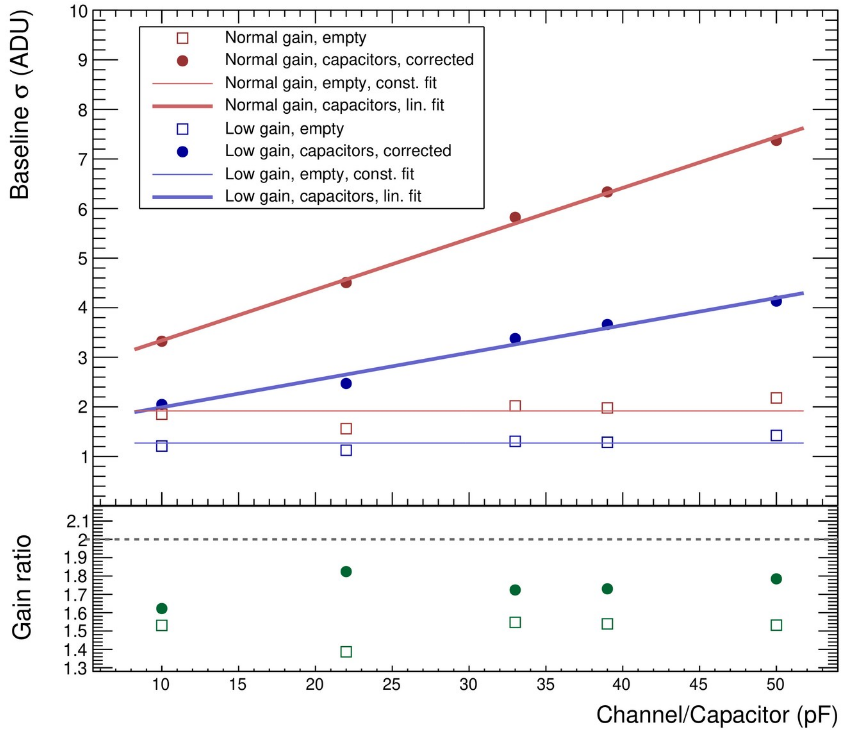


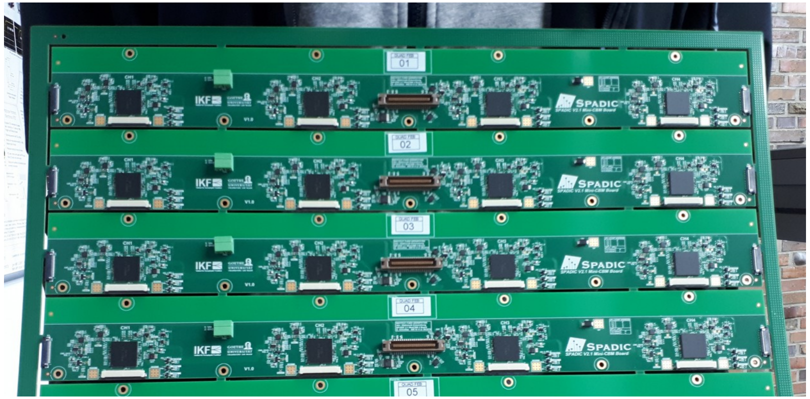
Spadic 2.2 ASIC: fluctuation level wrt. capacity, ongoing

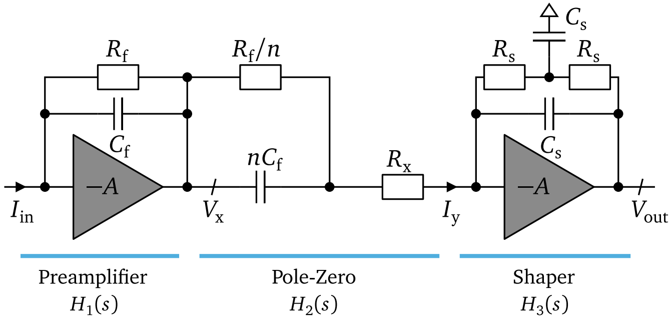
read-out electronics

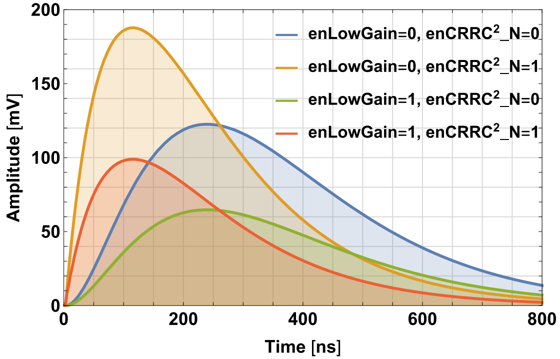
- SPADIC chip
  (Self-triggered Pulse Amplification and Digitization asIC)
- pre-amp, shaper and free-streaming digital messaging generation
- charge from MWPC: 0 … ~ 100 fC
- configurable front-end,
  typical: 1^{st} order shaper 120 ns, about 1000 e/ADU

- power consumption: 26 mW/channel @ 2.5 V layer

- 16 MHz sampling, 9 bit (pipelining/SAR)
- GBTx multiplexing boards on detector
- ADC values transmitted,
  extraction of charge and time
  in subsequent FPGA

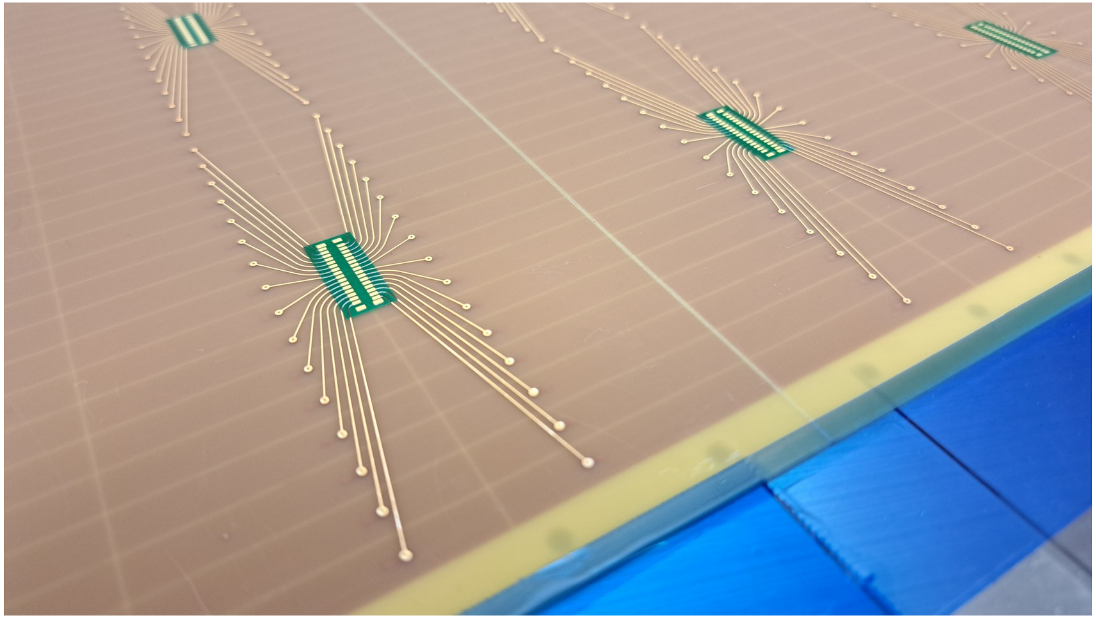






production: cathode padplane

- 4-layered PCB
  - intrinsic gas tightness by displaced vias
- 2 segments per (large) chamber
- *ENIG* surface, 50 to 100 nm Au
  - improved storage before operation
- transfer process to honeycomb carrier with vacuum table
  - < 20 µm flatness (segment edge), < 10 µm within segments
- external connector soldering & contact test



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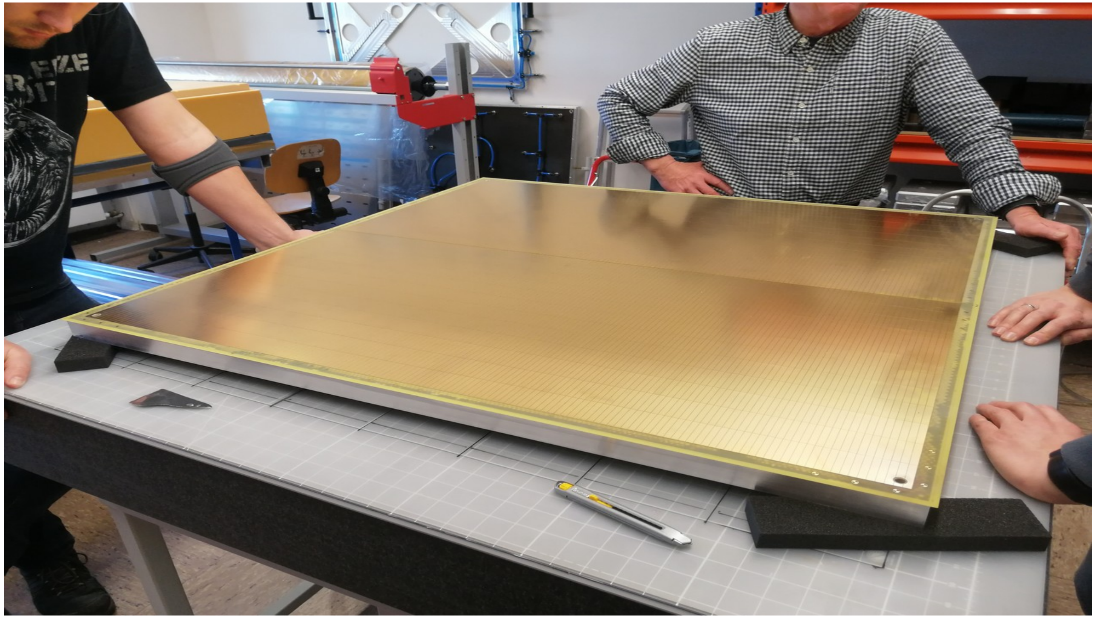
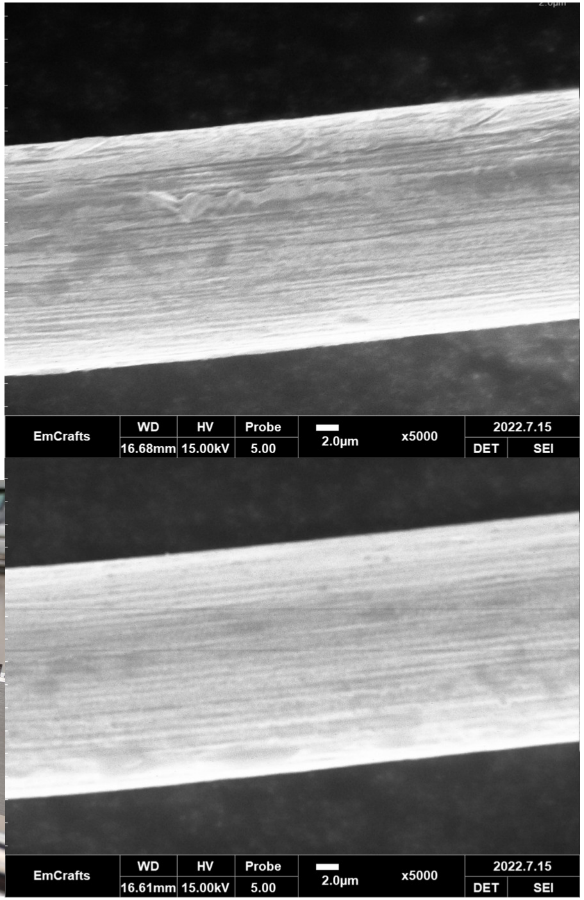


production: anode wires

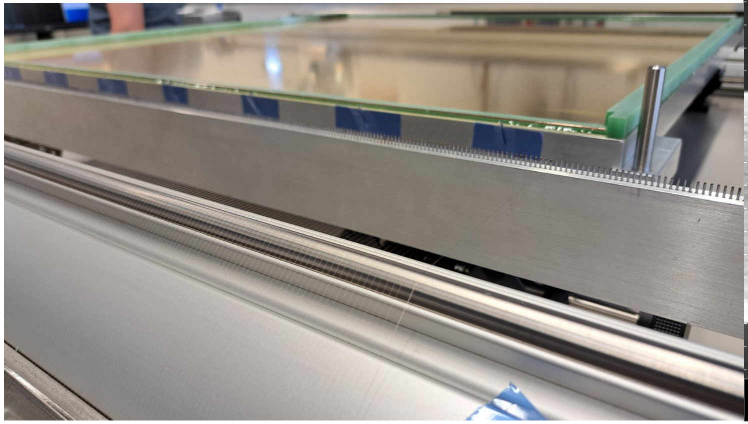
- WRe3 + Au coating 0.2 µm
- overall diameter: 20 µm
- tensile test at GSI detector lab
  - tensile strength 3305 N/mm²
  - yield point 1639 N/mm²
  - wire tension, OK for 50 cN (→ wire sag)
- SEM surface inspection



- reminder, wire sag

$$\Delta y = g \cdot \frac{\rho A l^2}{8 F}$$

- suppose $F = 50$ cN:
  $\Delta y = 13.7$ µm
  ... plus electrostatics!



ageing / accumulated current

- main influences for (wire-based) ageing
  - gas contaminants
  - wire surface

- comparison to Alice-TRD
  - chambers confirmed for > 10 mC/cm^2,
    i.e. > 20 mC/cm^2 for 2.5 mm wire pitch
  - check at changed/relevant materials wrt. Alice at GSI ageing setup

- estimate accumulated charge for CBM-TRD chamber
  - assume 100 kHz/cm^2, $\varepsilon_{MIP} = 6$ keV, $k_{particle} = 1.5$, $W_{XeCO2} = 22$ eV/e, $gain = 2000$
  - yields: 3.3 nA/cm for central region
  - x 60 days x 8 years x 50% $\rightarrow$ 68 mC/cm
  - … and by factor > 3 lower for all other chamber types

relevant components (gas contact) are being tested at GSI ageing setup

summary

the Transition Radiation Detector for CBM

- 216 high-rate MWPCs, 12 mm thick,
  2.5 mm anode wire pitch
- read-out at segmented cathode padplane
- 960 mm x 960 mm and 540 mm x 540 mm,
  pad size adapting to local rate

status

- start of (pre-)production
- PRR to follow on preproduction samples

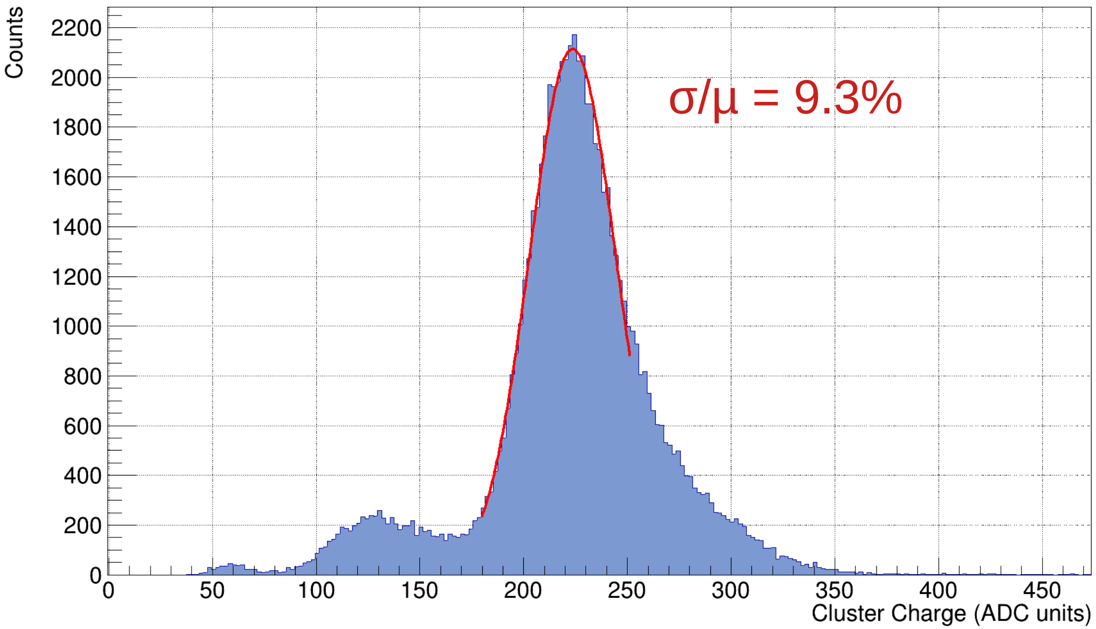
ressources and infrastructure

- keep & strengthen FAIR/GSI-based “services”,
  e.g. ageing tests, optical and tensile wire testing
- consider material database?
- Technical Notes as in CBM … shared?

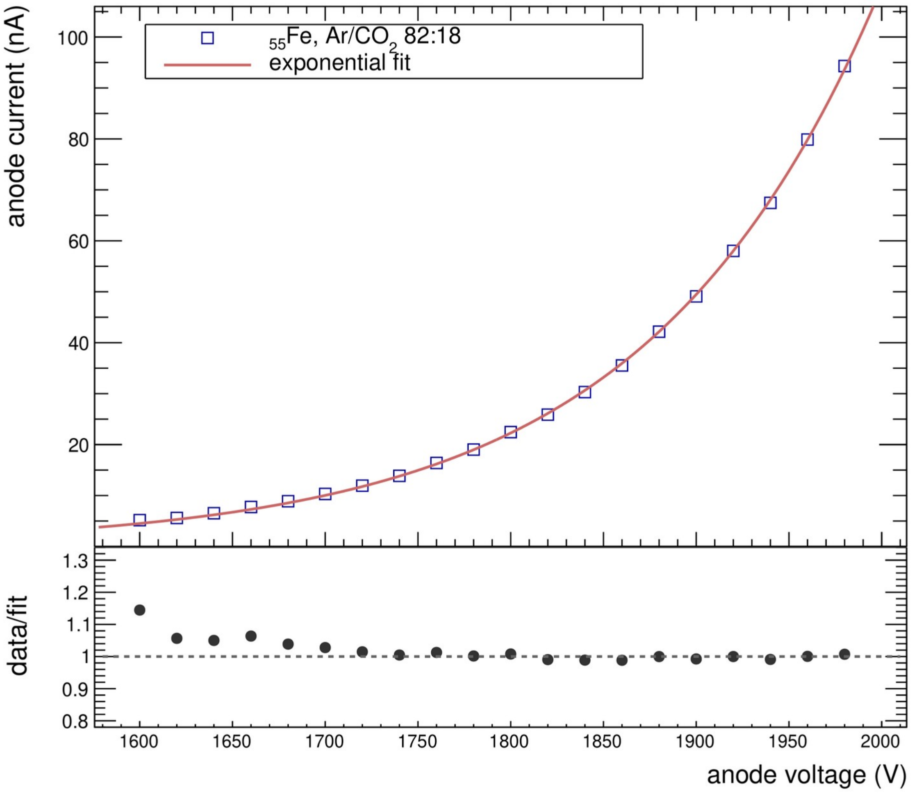
last slide ↑

backup ↓

- ^{55}Fe spectrum with Ar/CO_2 80:20
- K line fit, energy res: $\sigma/\mu = 9.3\%$



gain measurement, wip.



time resolution

- ongoing intervention / new version of FEE, new ADC
- high pick-up noise and fluctuation level in mCBM21, nevertheless: