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CBM

TRD

# Spectra and Position Reconstruction on CBM-TRD Data from CERN-SPS 2016

*(or the way to this)*

CBM-TRD TDR Review
2017, March 27th–31st

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Bundesministerium für Bildung und Forschung

GSI

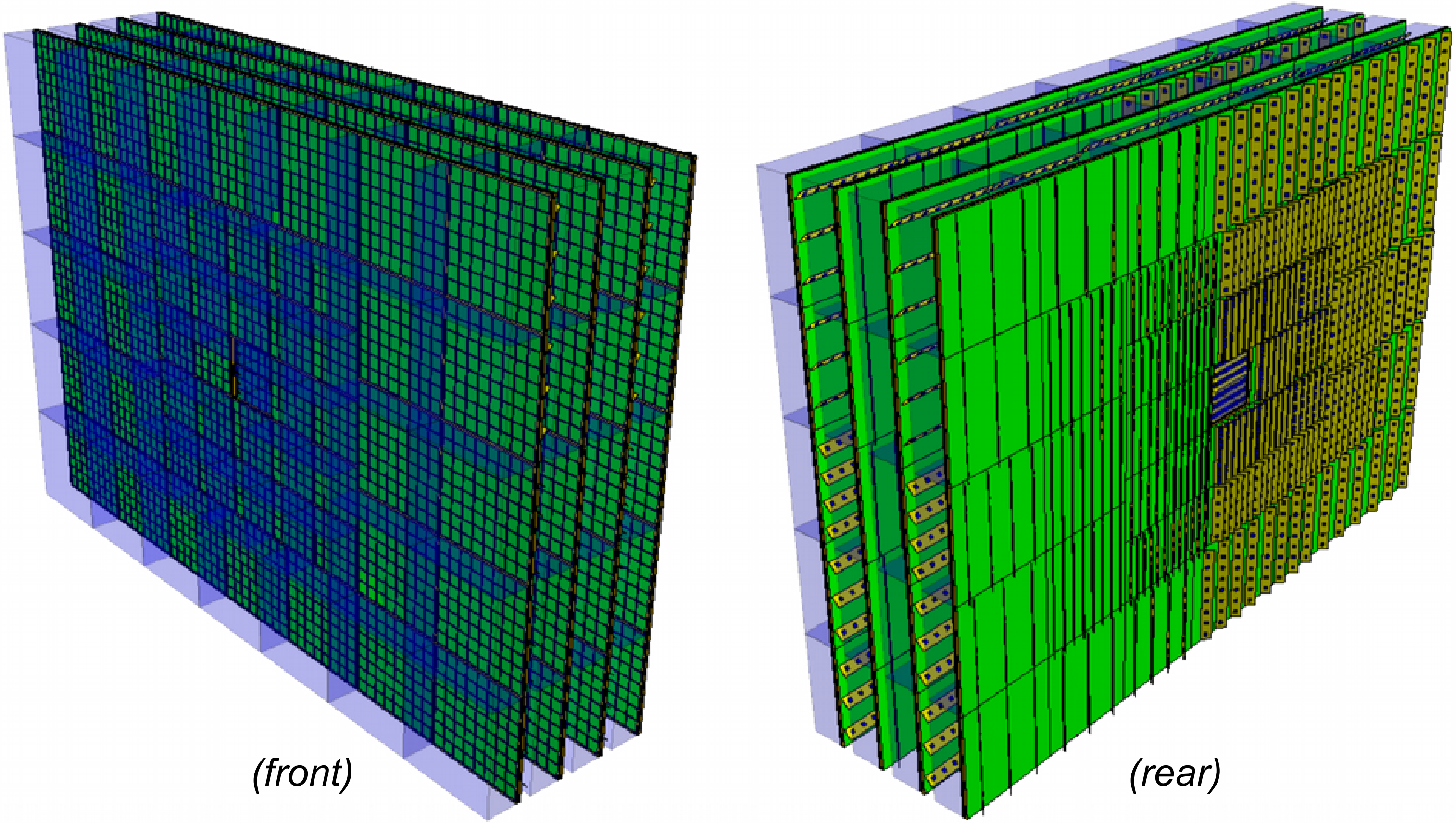
FAIR

Seventh Framework Programme

Study of Strongly Interacting Matter
HadronPhysics

# The TRD in CBM

- CBM-TRD in 4.1 m < $z$ < 5.9 m from target
- Two chamber sizes to cover 6.65 x 4.75 $m^2$ (0.89 < $\eta$ < 3.74)



# Test Beam Overview



- CBM-TRD test beam measurements

| Year | Beamline | Beam / Set-up | Prototypes | Read-out |
|---|---|---|---|---|
| 2006 | GSI-SIS18 | p, e, π (up to 2 GeV) / direct | dual-sided pre-types | ALICE-PASA * |
| 2010 | CERN-PS/T10 | e, μ, π (up to 5 GeV) / direct | pre-types | SPADIC 0.3, Susibo * |
| 2011 | CERN-PS/T9 | e, μ, π (up to 10 GeV) / direct | pre-types | SPADIC 0.3, Susibo * |
| 2012 | CERN-PS/T9 | e, μ, π (up to 8 GeV) / direct | 2012-style ($57x57\ cm^2$) | SPADIC 0.3, Susibo * |
| 2014 | CERN-PS/T9 | e, μ, π (up to 6 GeV) / direct | 2012+2014-style ($57x57\ cm^2$) | SPADIC 1.0, SysCore |
| 2015 | CERN-SPS/H4 | $^{208}$Pb (30 *A*GeV) / Pb target | 2012-style ($57x57\ cm^2$) | SPADIC 1.0, SysCore |
| 2016 | CERN-SPS/H4 | $^{208}$Pb (13, 30, 150 *A*GeV) / Pb target | Type 8 ($95x95\ cm^2$) | SPADIC 1.1, SysCore |

- Scheduled measurements

* triggered

| Year | Beamline | Beam / Set-up | Prototypes | Read-out |
|---|---|---|---|---|
| 2017 | DESY II/TB24 | e (variable) / direct | Type 8 | SPADIC 2.0, AFCK |
| 2017 | CERN-GIF++ | γ from $^{137}$Cs + μ beam | 2012-style | SPADIC 2.0, AFCK |

# CERN-SPS 2016 Campaign

- Four type 8 chambers ($95x95\ cm^2$)
- 4 chambers projective on target (tracking), each $2^{nd}$ rotated
- SPADIC 1.1 read-out: operated multi-SPADIC setup, developed live-monitoring (self-triggered, free-streaming)
- SPADIC 2.0 + AFCK commissioned (near-to-final)

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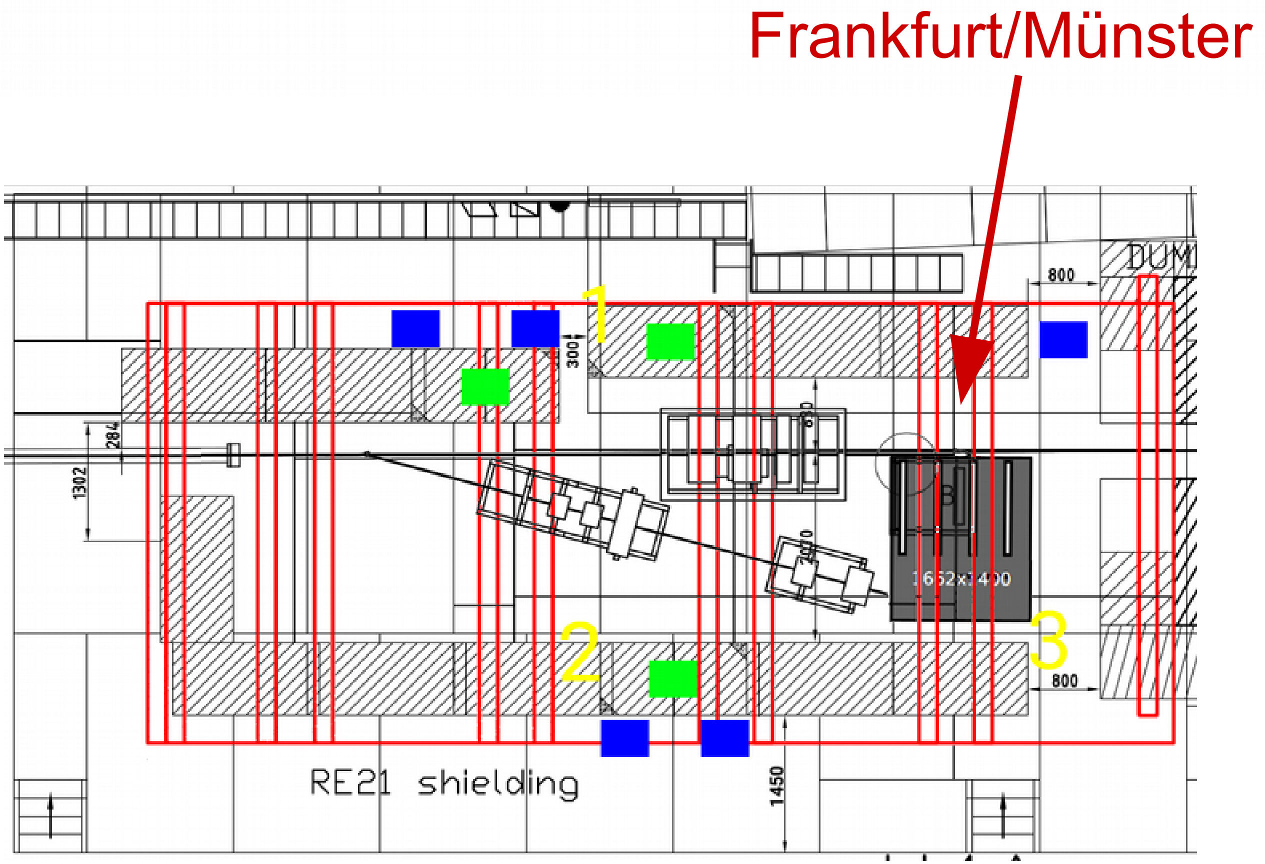

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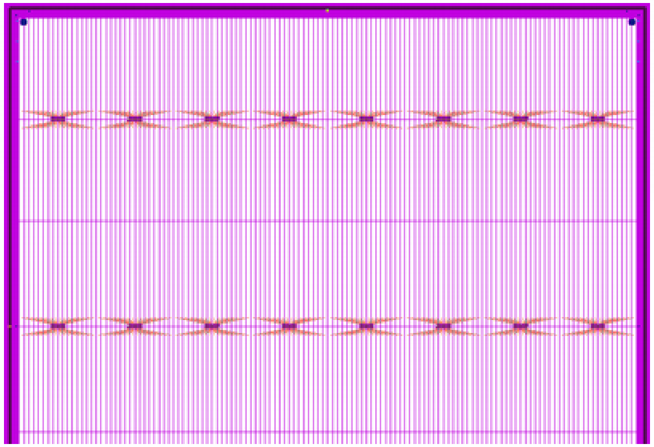
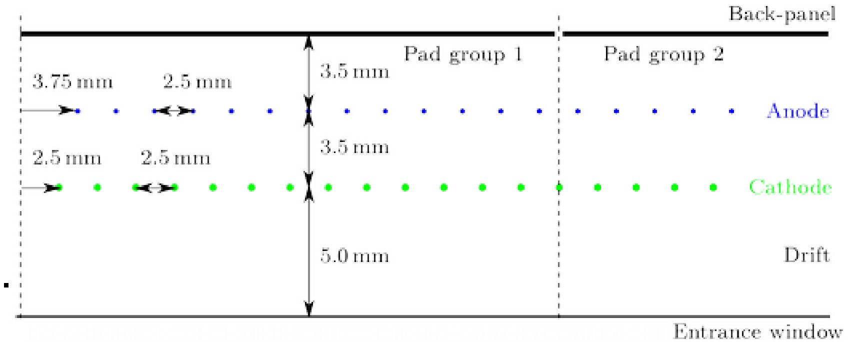
# Detector: Type 8 MWPC for CBM-TRD

- Full-size, 95 x 95 cm² MWPC prototype:
  - Read-out areas on pad-plane are each 48 x 2 pads
  - Pad sizes: 155 x 7.2 mm²
- Active volume spacing:
  - 3.5 / 3.5 / 5 mm
  - Nominal 1850 V on anode wires, -500 V on entrance window
- Charge distribution on pad-plane:
  - According to Pad-Response Function (PRF).

    Altern. Position of 3-pad cluster:
    (hyperbolic secant squared method)






$$\mathrm{PRF}(d/h) = \int_{d/h-W/2}^{d/h+W/2} \rho(d'/h)\; d(d'/h)\; \mathrm{d}d'$$

$$\Rightarrow \mathrm{PRF}(d/h) = -\frac{\arctan\left(\sqrt{K_3}\tanh\left(\pi\left(\sqrt{K_3}-2\right)\cdot\frac{W-2\cdot d}{8\cdot h}\right)\right)}{2\arctan\left(\sqrt{K_3}\right)} - \frac{\arctan\left(\sqrt{K_3}\tanh\left(\pi\left(\sqrt{K_3}-2\right)\cdot\frac{W+2\cdot d}{8\cdot h}\right)\right)}{2\arctan\left(\sqrt{K_3}\right)}$$

$$d = \frac{a_3}{\pi}\tanh^{-1}\left(\frac{\sqrt{Q_i/Q_{i-1}}-\sqrt{Q_i/Q_{i+1}}}{2\sinh\left((\pi W)/a_3\right)}\right)$$

$$a_3 = \frac{\pi W}{\cosh^{-1}\left(0,5\cdot\left(\sqrt{Q_i/Q_{i-1}}+\sqrt{Q_i/Q_{i+1}}\right)\right)}$$

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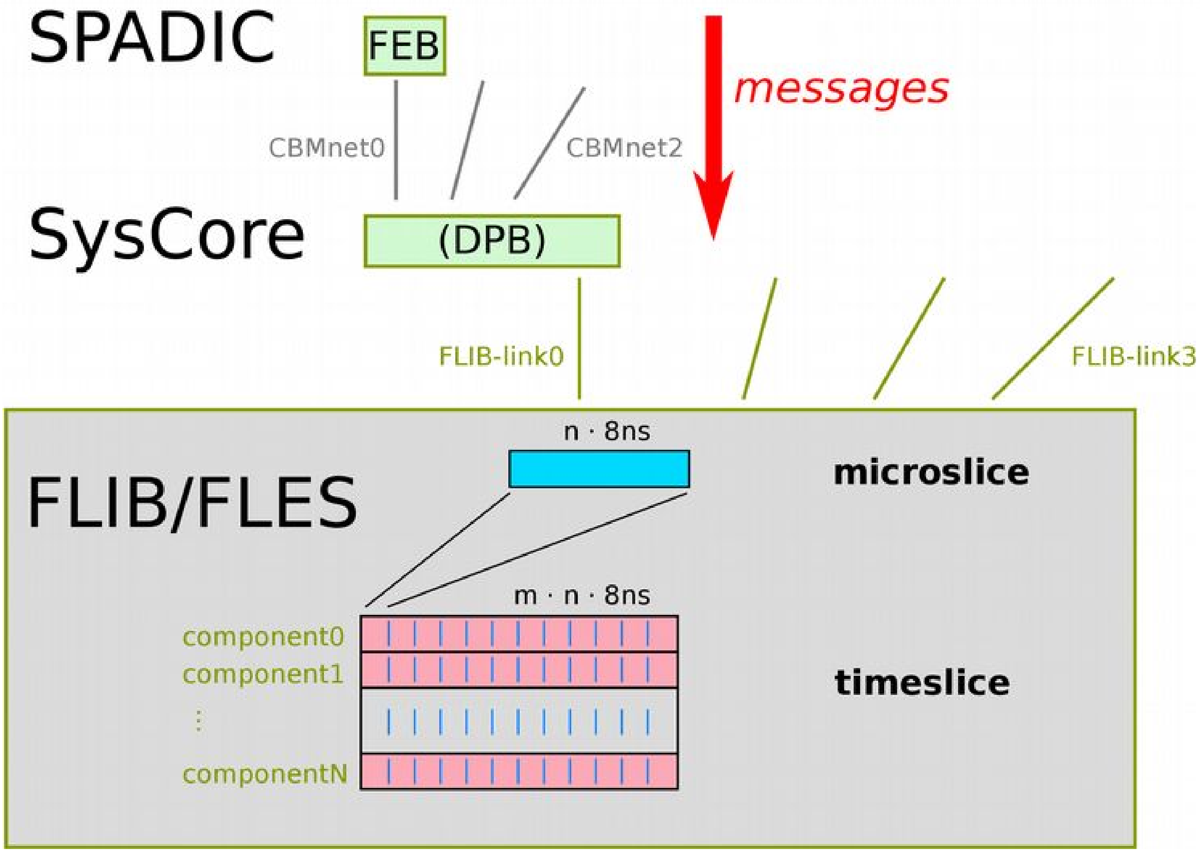
# Free-Streaming DAQ Chain




- Self-triggered FEE
- Principle allows various microslice sources
- Ringbuffers minimize memory consumption, maximize throughput

(Shown here: CBMnet-based chain instead of STS-XYTER/e-link)

# Free-Streaming DAQ Chain

*free-streaming data recording*

*offline/online analysis*

SPADIC

CLOCK

DPB

| | | |
|---|---|---|
| *timestamp* | *(12 bit)* | 66 ns x 4096 = 273 µs |
| overflows in *epoch* | *(12 bit)* | x 4096 = 1118 ms |

FLIB/FLES

**Storage**

Towards event-building:

- The unpacker *extracts SPADIC messages* from container archives
- Full-time calculated on system-side

Container Unpacking

Message Extraction

| | | |
|---|---|---|
| overflows in *super-epoch* | *(12 bit)* | x 4096 = 4581 s |

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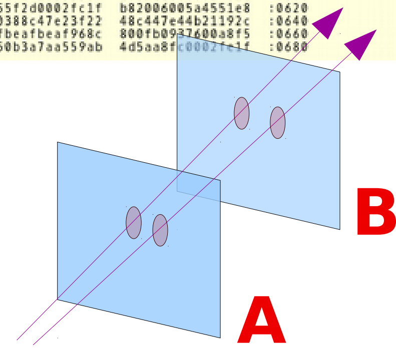
# Charge Cluster Reconstruction

- Offline event-building by reconstruction of charge-clusters from single hit messages



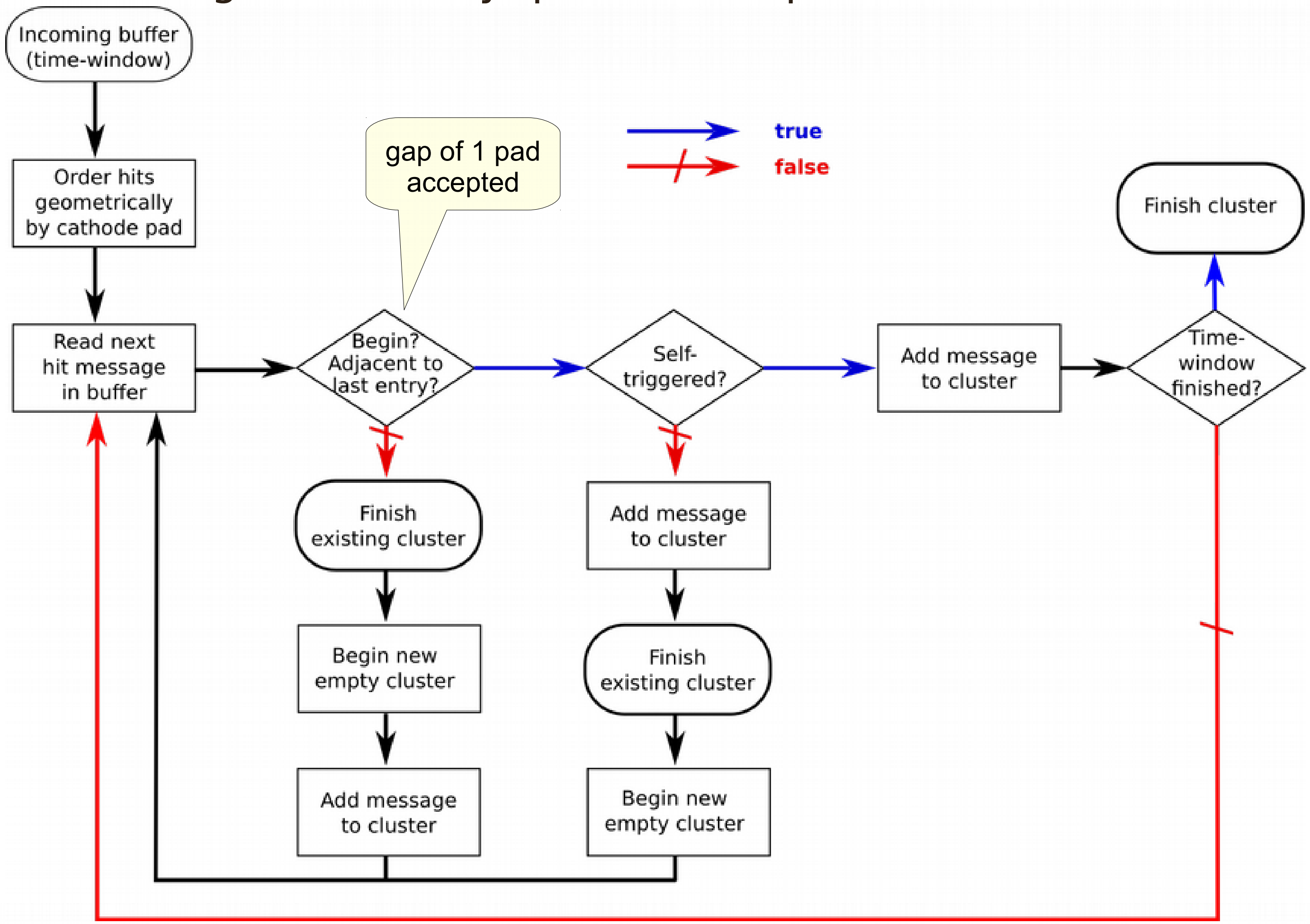



- Therefore, first: free-streamed hits to be sorted wrt. time (1 timestamp = 67 ns)

# Charge Cluster Reconstruction



- <u>Second</u>: order hits geometrically, process in spatial clusteriser



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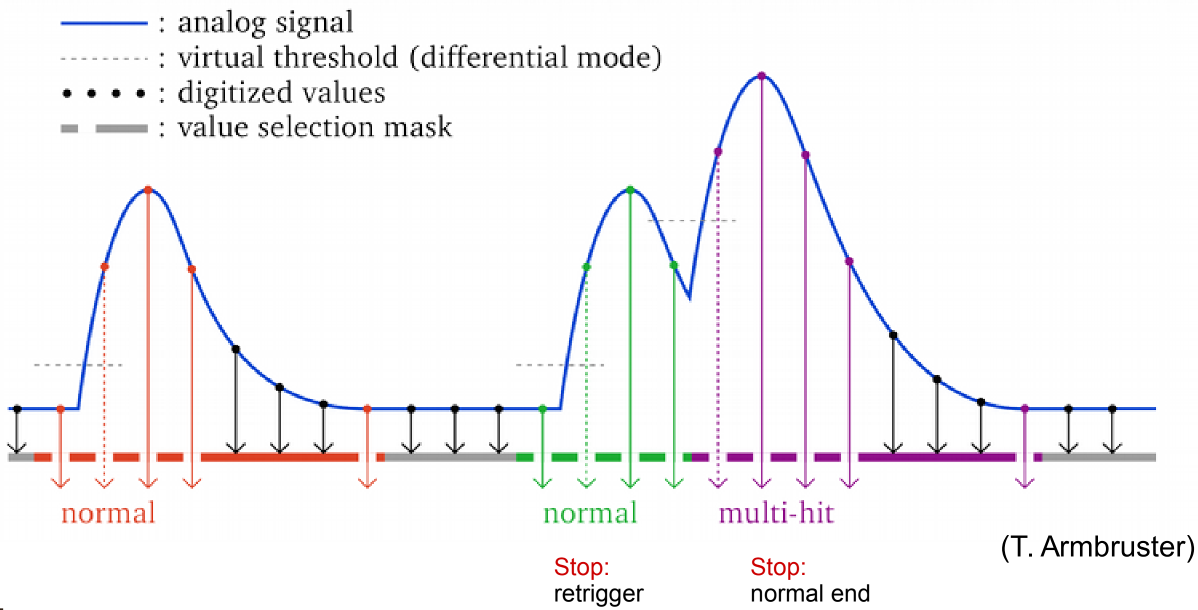
# High-Load Environment

- Chip response
  on delta pulse known

- Multi-hit concept
  of SPADIC:
  new message
  for newly fulfilled
  trigger condition

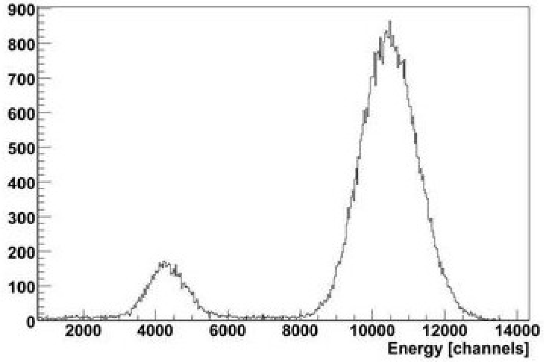



(T. Armbruster)

- Hit messages are flagged:
  - Channel and timestamp
  - TriggerType: self-triggered, neighbour-triggered, …
  - StopType: normal end (e.g. 32 samples), stop due to retrigger

# $^{55}$Fe Calibration Measurement

- $^{55}$Fe source for calibration: K lines and escape peak




(example spectrum)


- 227 MBq (assume 10% in chamber) → 23 MHz, or 1 γ every 43 ns
- Sampling with 15 MHz → 1 timebin = 67 ns

# $^{55}Fe$ Calibration Measurement

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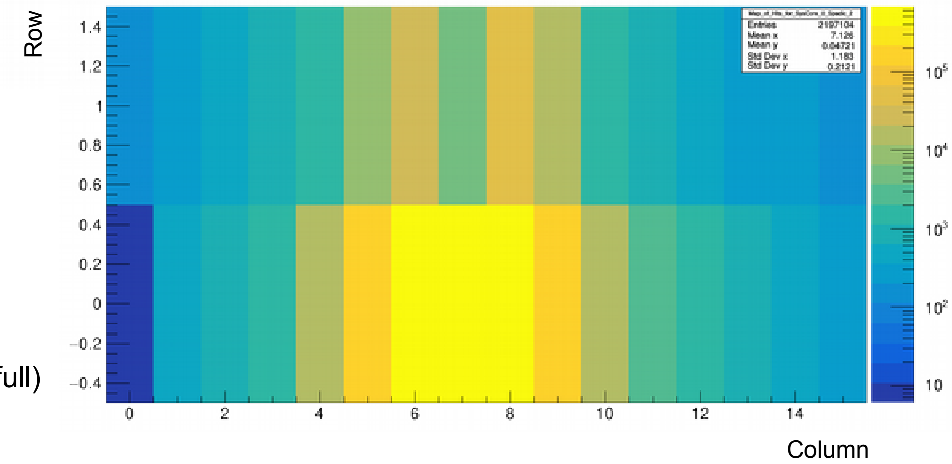
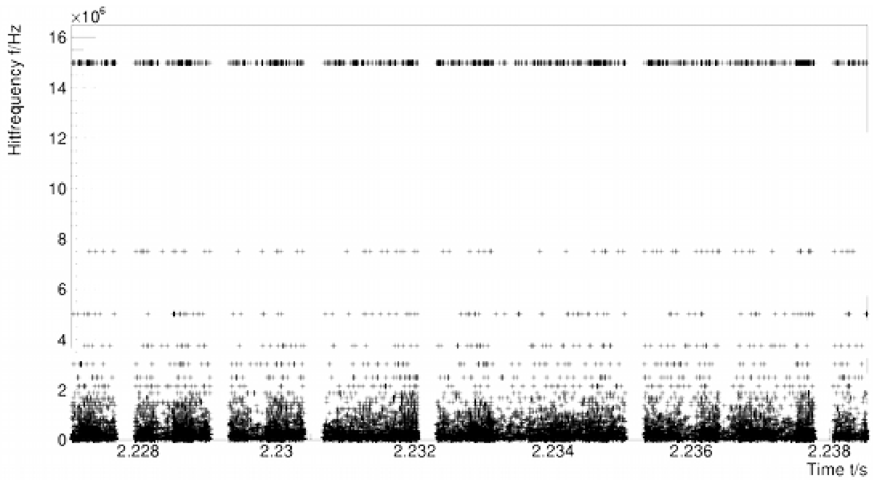
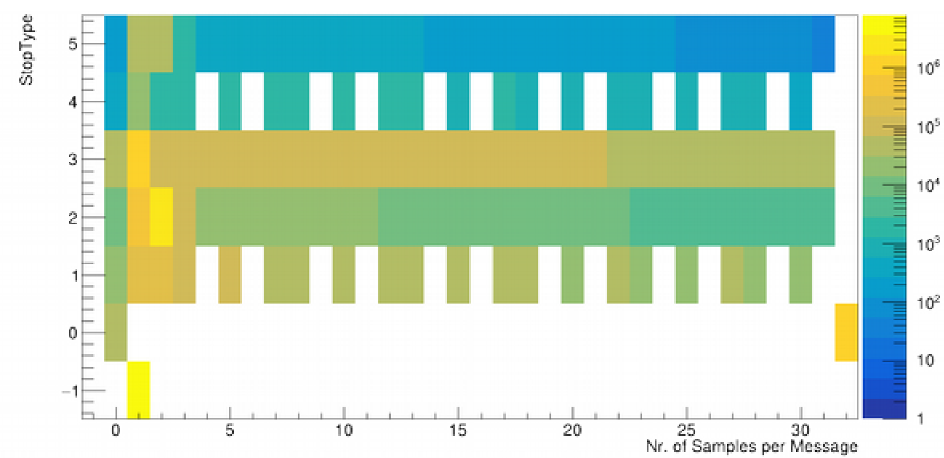
- Effects of high load clearly found.
- Investigate StopTypes:
  - 0 : 1.5M (single trigger, buffer ok)
  - 1 : 1.2M (single trigger, but channel buffer full)
  - 2 : 3.0M (single trigger, but total buffer full)
  - 3 : 3.5M (stop due to retrigger, buffer ok)
  - 4 : 50k (stop due to retrigger, simultan. channel buffer full)
  - 5 : 71k (stop due to retrigger, simultan. total buffer full)



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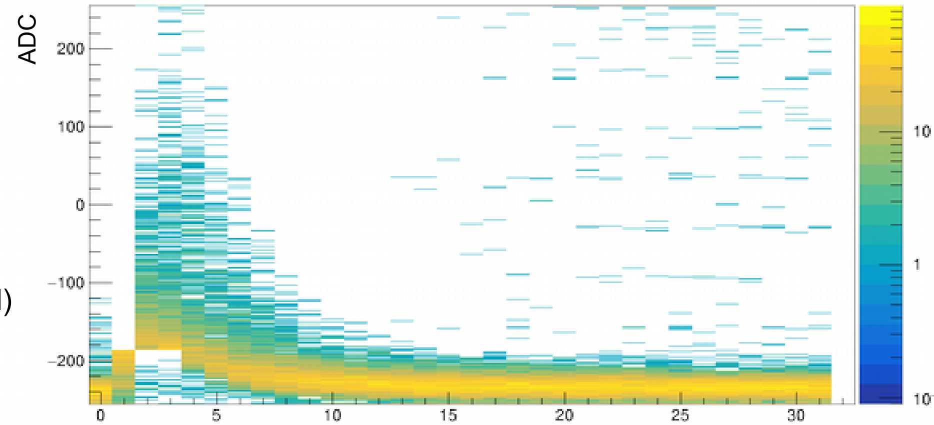


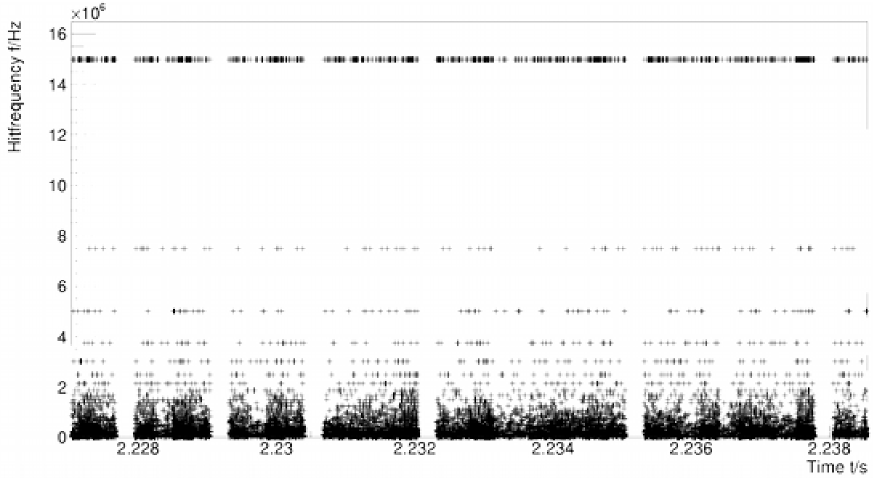


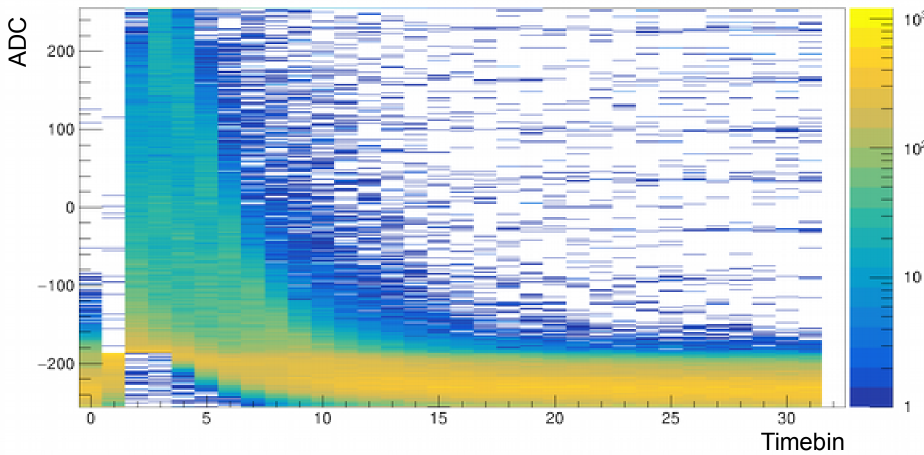

# Summary for TRD and Conclusions

- Position determination:
  - Established, by fit of PRF or hyperbolic secant squared method
  - 2-dimensional position reconstruction demonstrated earlier, can help in track-matching
- High-rate, secondaries behind fixed-target:
  - Charge distribution in chamber verified to follow the expected behaviour (Mathieson description)
  - Energy loss determined by maxADC, integral or pulse fit
- Shown here:
  - $^{55}Fe$ calibration during beam test campaign challenging due to high load
  - Concentrate on full event reconstruction now

# BACKUP

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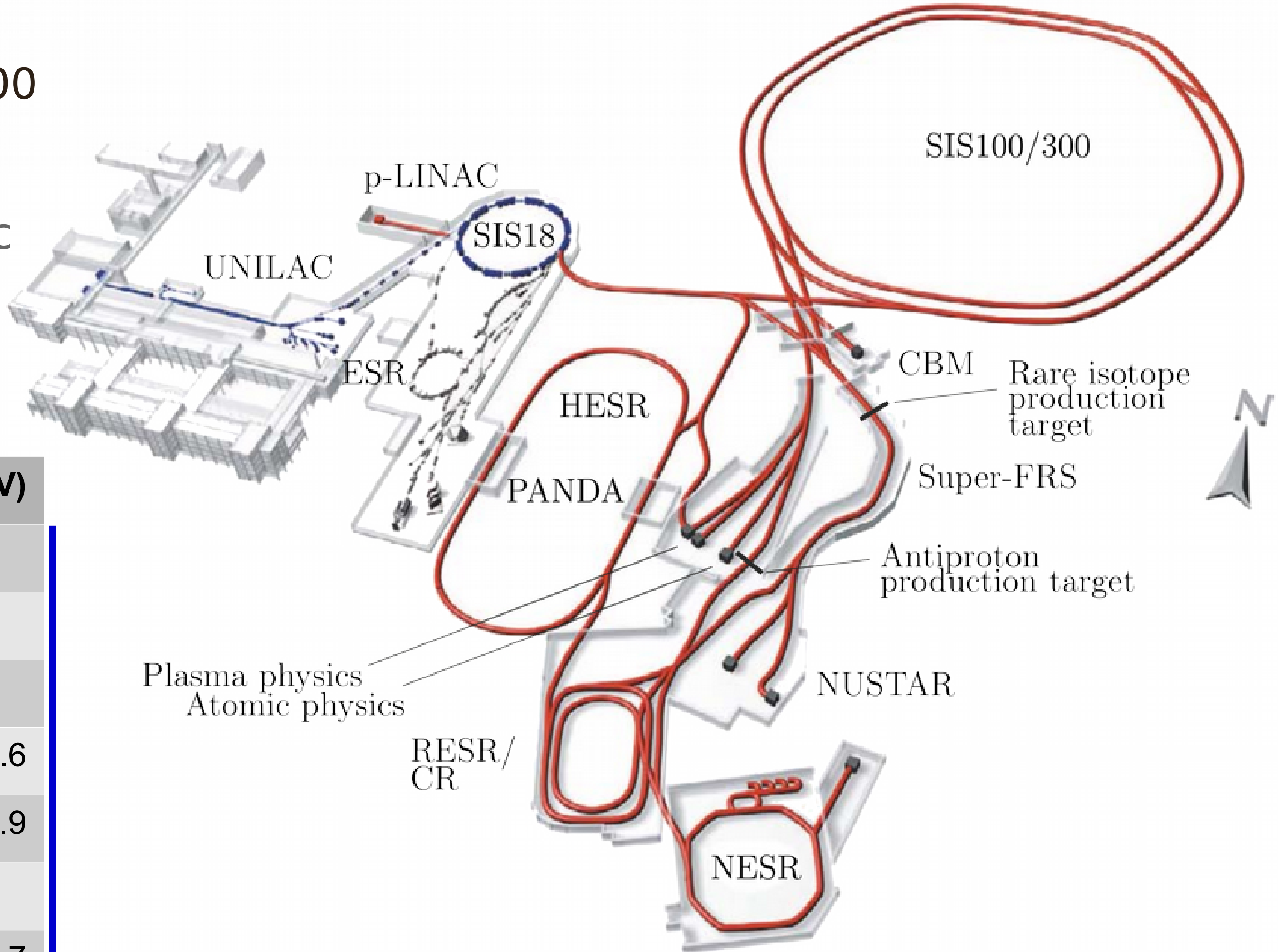
# The CBM-TRD in FAIR

- In construction: SIS100 (magnetic rigidity of 100 Tm)
- **C**ompressed **B**aryonic **M**atter as one of the four pillars of FAIR
- Upgradeable: SIS300

| 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 |

SIS100 energies



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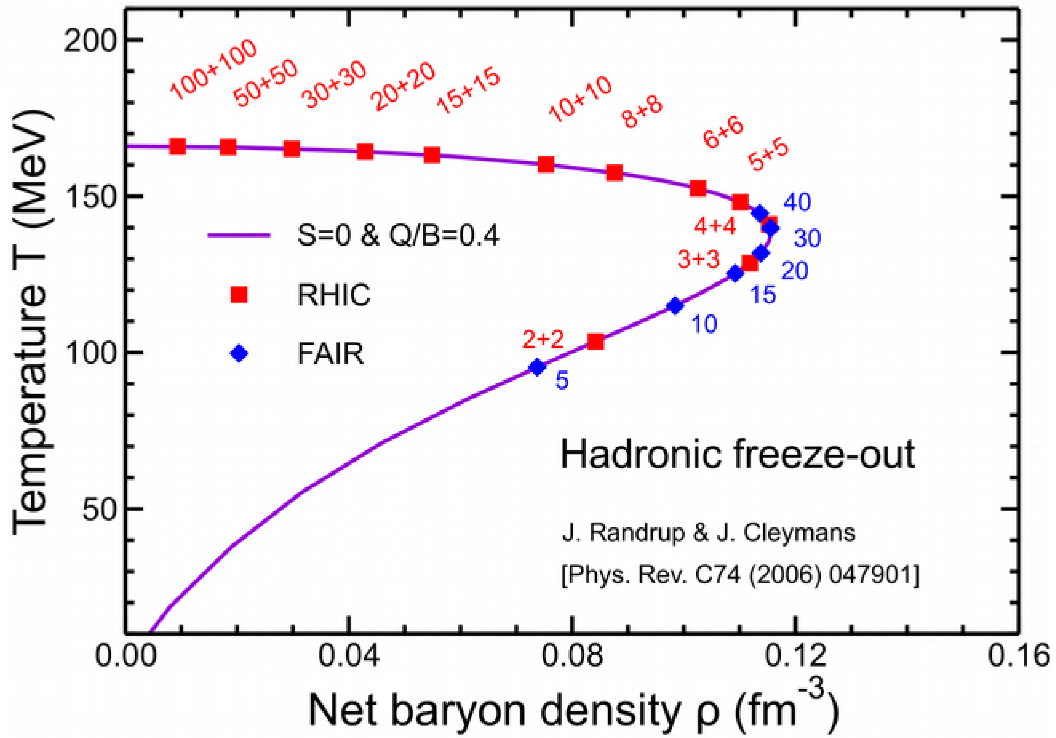
SIS100 energies



# The CBM-TRD in FAIR



- Physics objectives
  - Intermediate mass di-leptons … continuum from thermal sources (1…3 GeV)
  - Fragments … hyper- and anti-nuclei
  - Quarkonia … are probes for deconfined matter
  - Low mass vector mesons … medium-modified spectra
  - Direct Photons … inverse slope fits as thermometer
- Design considerations
  - Pion rejection capability … pion suppression up to 50 and $10^4$ with RICH
  - (Charged) Particle identification … dE/dx resolution below 30%
  - Tracking capabilities … track resolution below 300 µm (pad granularity)
  - High interaction rates … optimised: 5 x $10^6$ Hz & realistic multiplicities
  - Tracking of muons … high track matching with the MUCH

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- Physics objectives
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  - Fragments
  - Quarkonia
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  - Direct Photons
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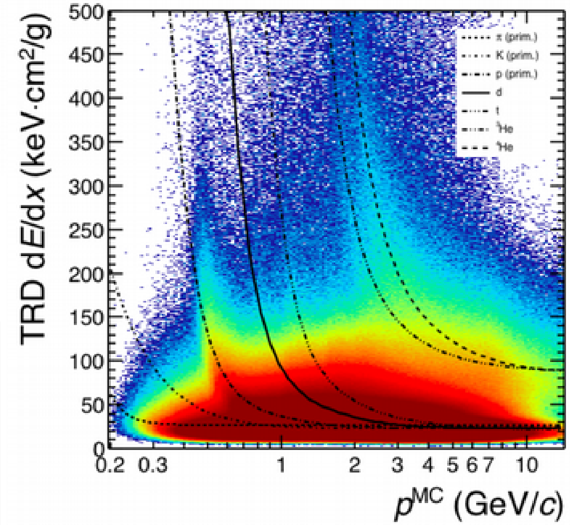
  - Tracking capabilities
  - High interaction rates
  - Tracking of muons

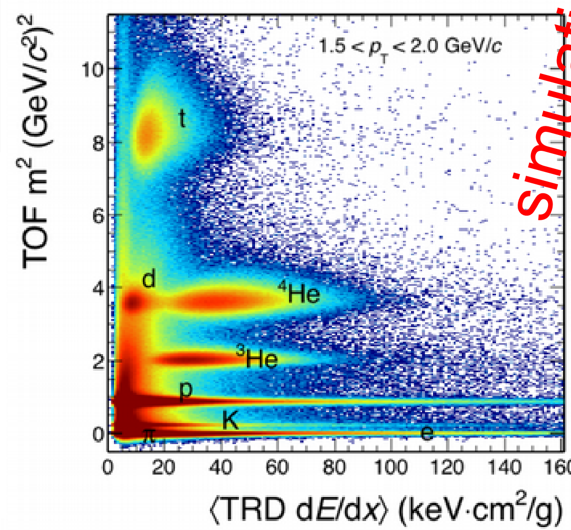
$_{\Lambda\Lambda}{}^{6}He \rightarrow {}_{\Lambda}{}^{5}He + p + \pi^-$

$_{\Lambda}{}^{5}He \rightarrow {}^{4}He + p + \pi^-$

*or*

$_{\Lambda}{}^{3}He \rightarrow d + p + \pi^-$

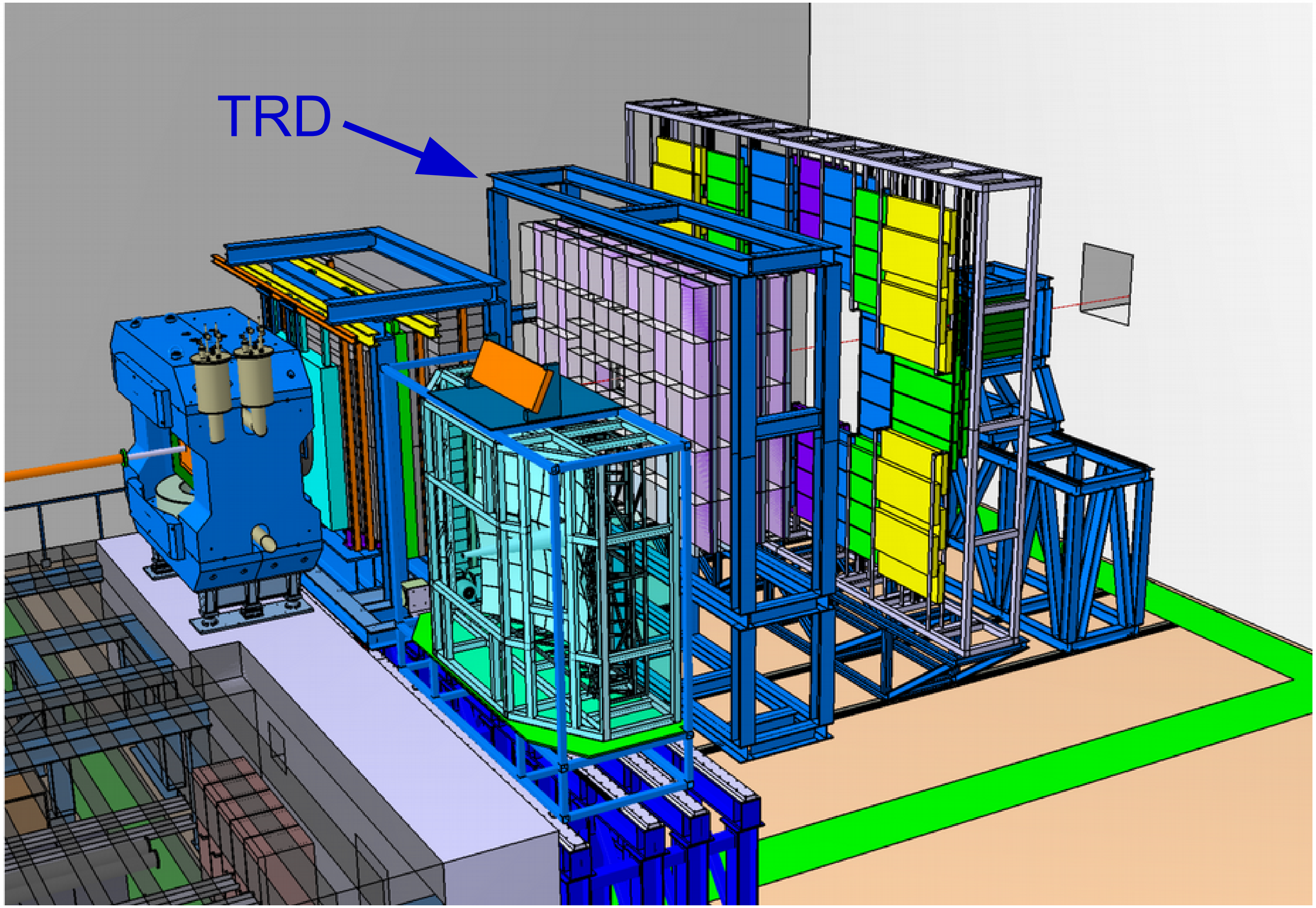



simulation, Au + Au, 8 GeV

# The CBM-TRD in FAIR

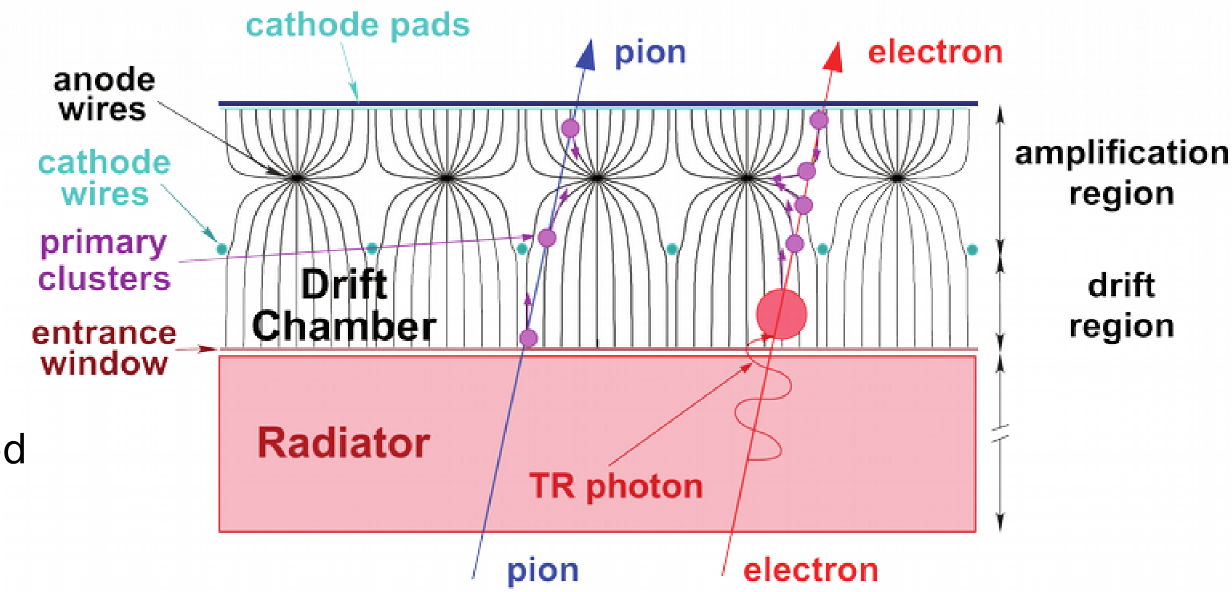
- MVD+STS
  Micro-Vertex Detector + Silicon Tracking Station
  *magnetic field*
- MUCH or RICH
  MuonChambers/ Ring imaging Cherenkov Detector
- TRD
  Transition Radiation Detector
- TOF
  Time Of Flight
- PSD
  Projectile Spectator Detector

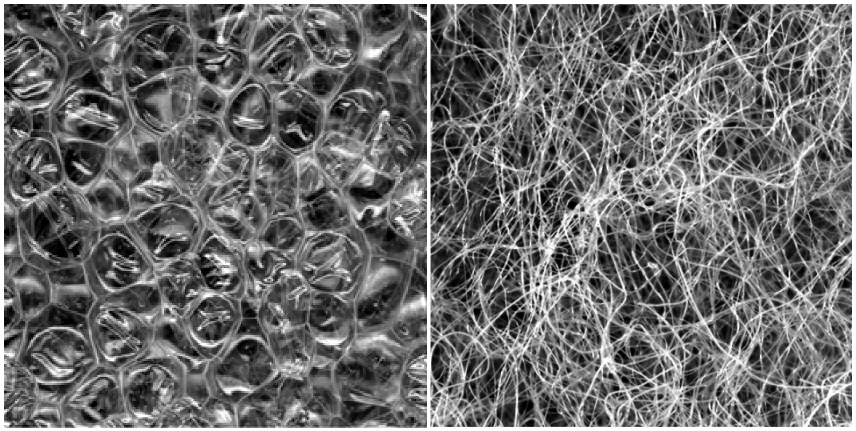


# The TRD in CBM



- TRD in principle:
  - Multi-wire proportional chamber-based
  - Transition radiation emitted at ε-transitions
  - Intensity of TR is ~ γ (idealised)
  - e/π-sep. e.g. by likelihood
- Regular and irregular radiators: foil, foam, fibers



Transition radiation at <u>one</u> ε-interface:

$$\left(\frac{d^2 N}{d\omega\, d\vartheta}\right)_{\text{interface}} = \frac{\alpha}{\pi}\cdot\left(\frac{\vartheta}{\gamma^{-2}+\vartheta^2+(\omega_{P,1}/\omega)^2} - \frac{\vartheta}{\gamma^{-2}+\vartheta^2+(\omega_{P,2}/\omega)^2}\right)^2$$

$\omega$: photon frequency

$\omega_{P,i}$: plasma frequency of material i

$\alpha$: fine structur constant

$\vartheta$: emission wrt. particle motion

$\gamma$: Lorentz factor

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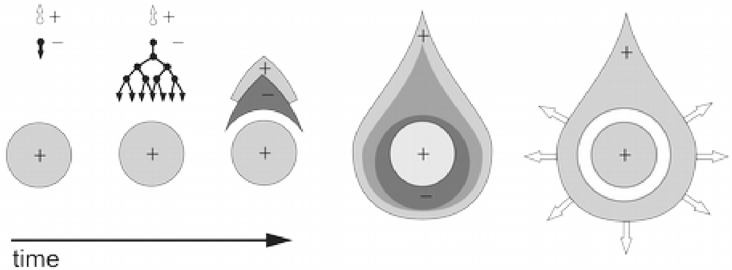
# The TRD in CBM

## Design principles

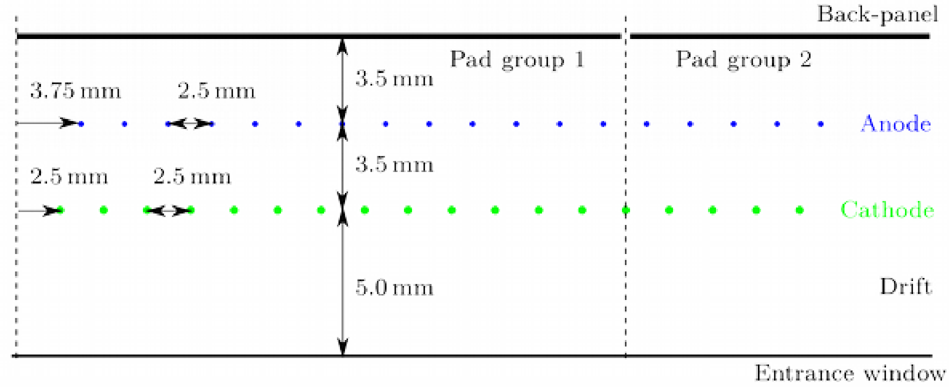
- High-voltage wire geometry: drift zone + two symmetrical amplication zones
- Proportional chamber: rate limits



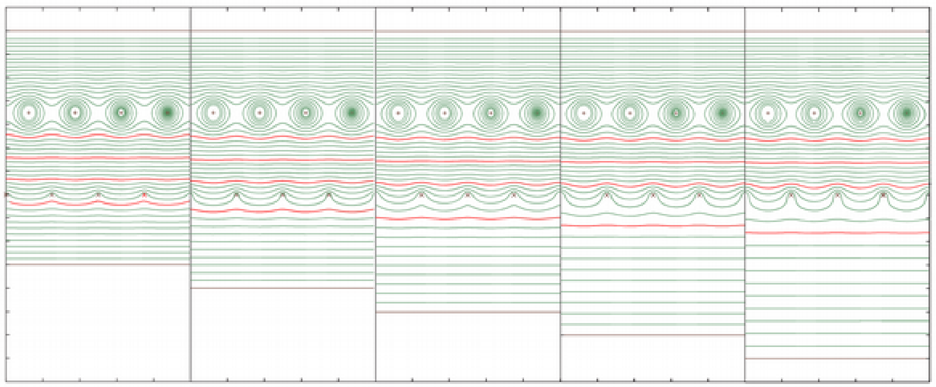

**from F. Sauli, CERN lectures 1977**

→ short ion drifts (3.5/3.5+5 mm)

- Special conditions: flexible cathode (entrance window)




Anode+Drift HV geometry



Example: Field distortion by entrance window stretching (Garfield sim.)

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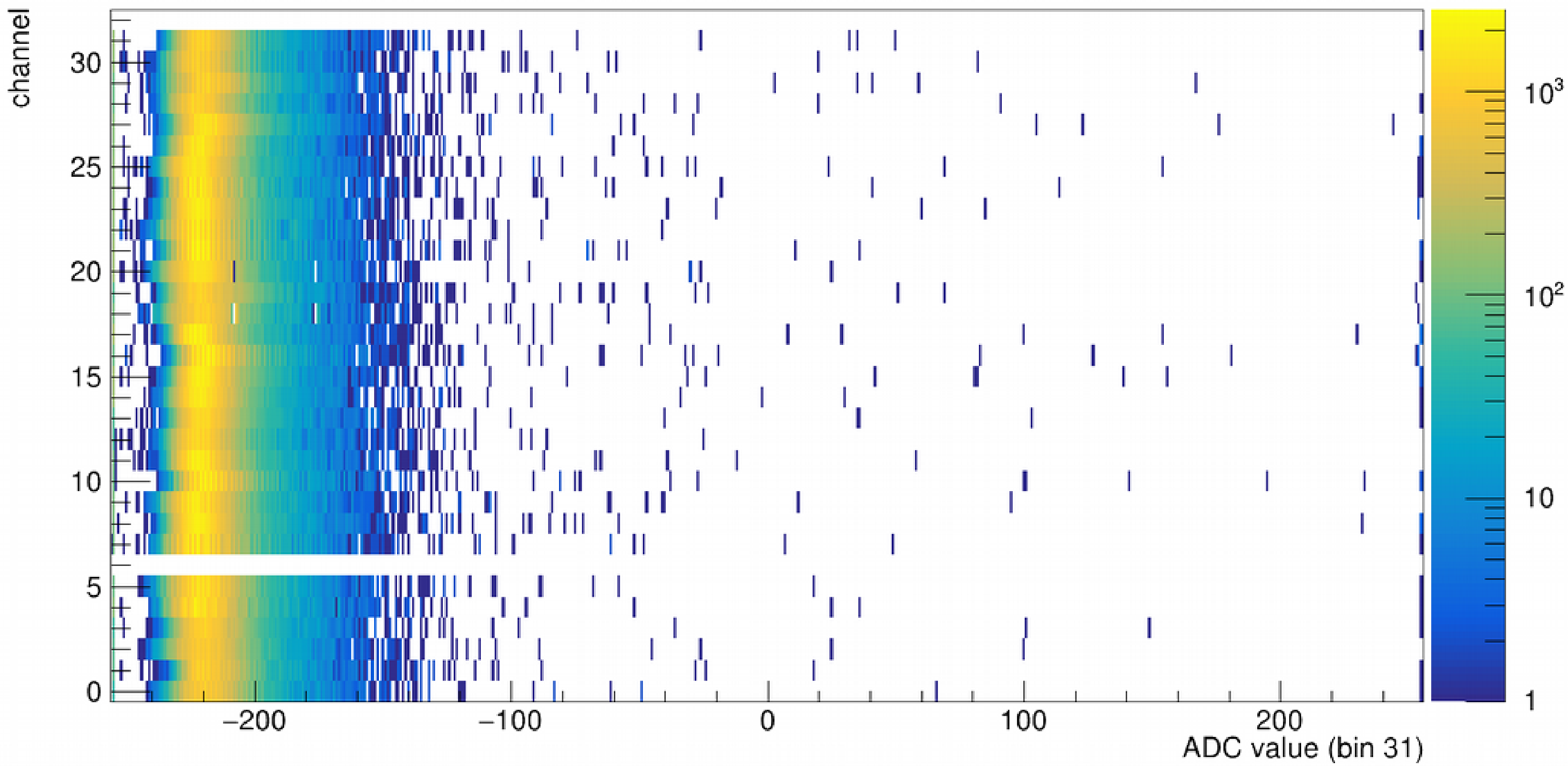
# CERN-SPS 2015 Campaign: Pad-Response Function

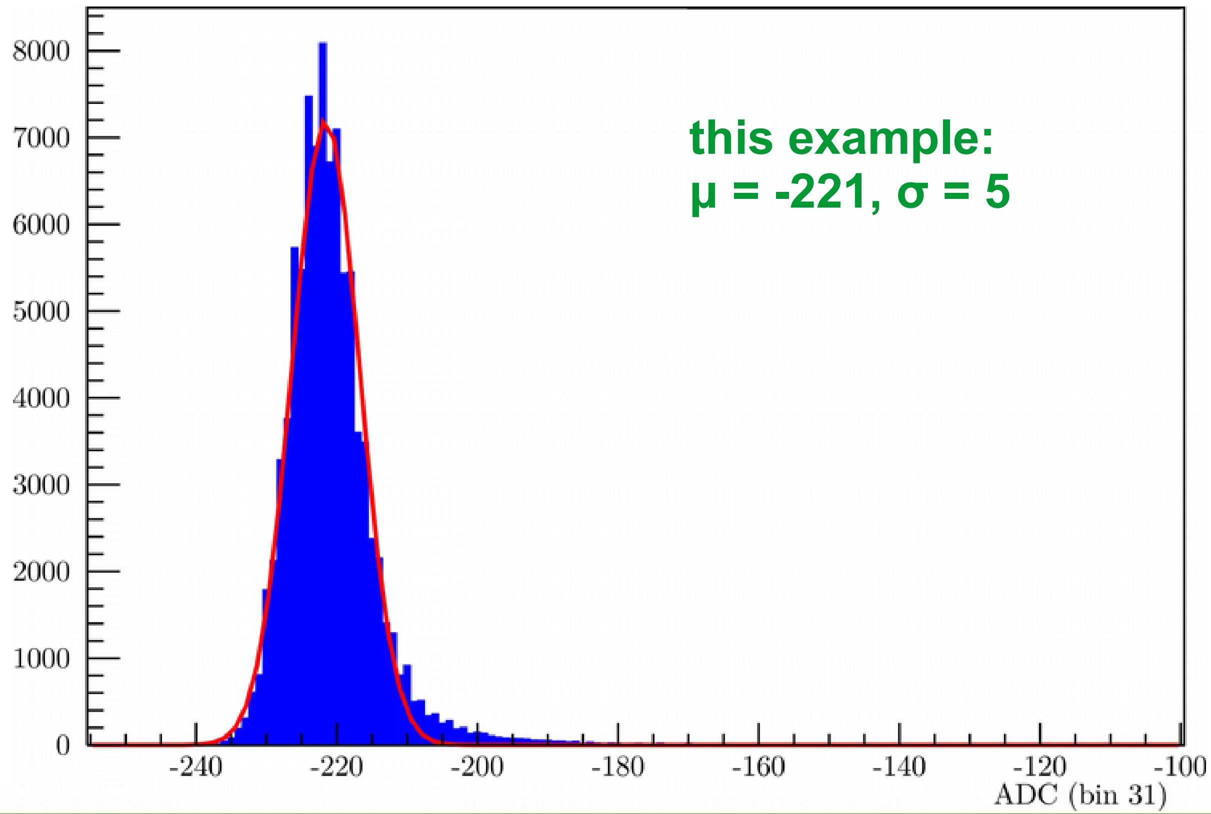
- Determination of a channel-wise baseline
  - Use ADC value of last timebin from all complete, self-triggered hit messages
  - Collect this baseline distribution separately for every channel



# CERN-SPS 2015 Campaign: Pad-Response Function



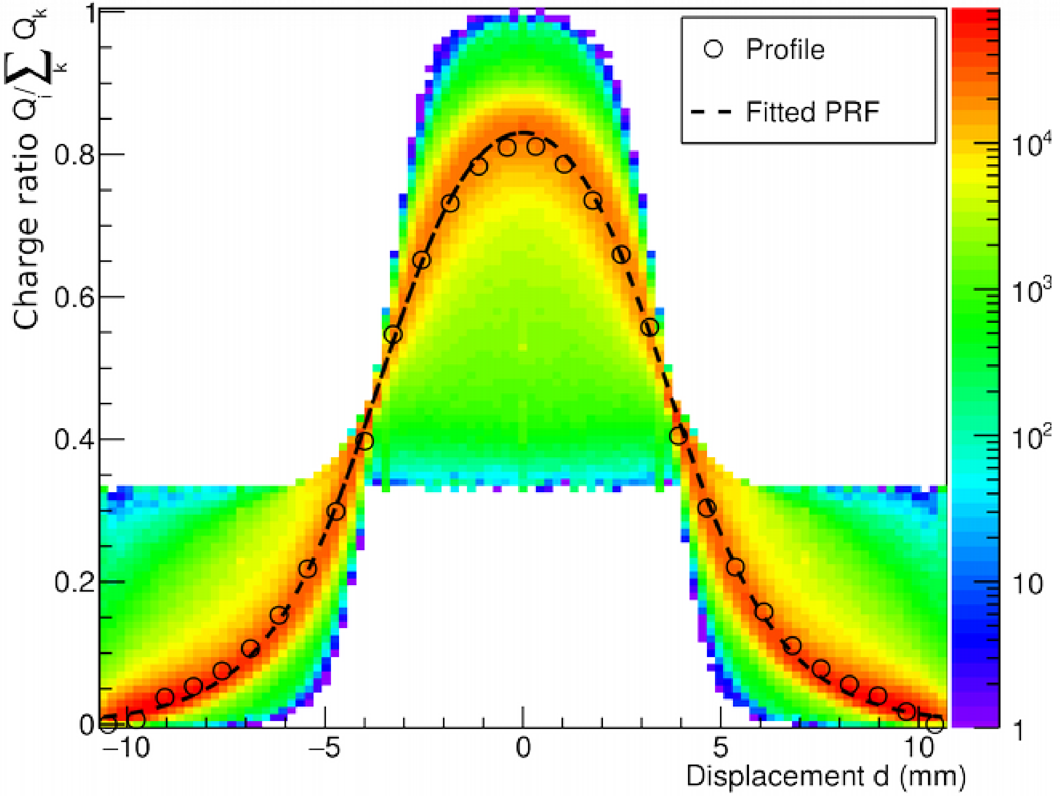
- Determination of a channel-wise baseline
  - Use ADC value of last timebin from all complete, self-triggered hit messages
  - Extract baseline value for each channel by Gaussian fit



# CERN-SPS 2015 Campaign: Pad-Response Function



- Resulting Pad-Response Function from 3-pad clusters, type 0:




- From fitting: $K_3$ = 0.388 ± 0.008 (expectation for this geometry: 0.38)

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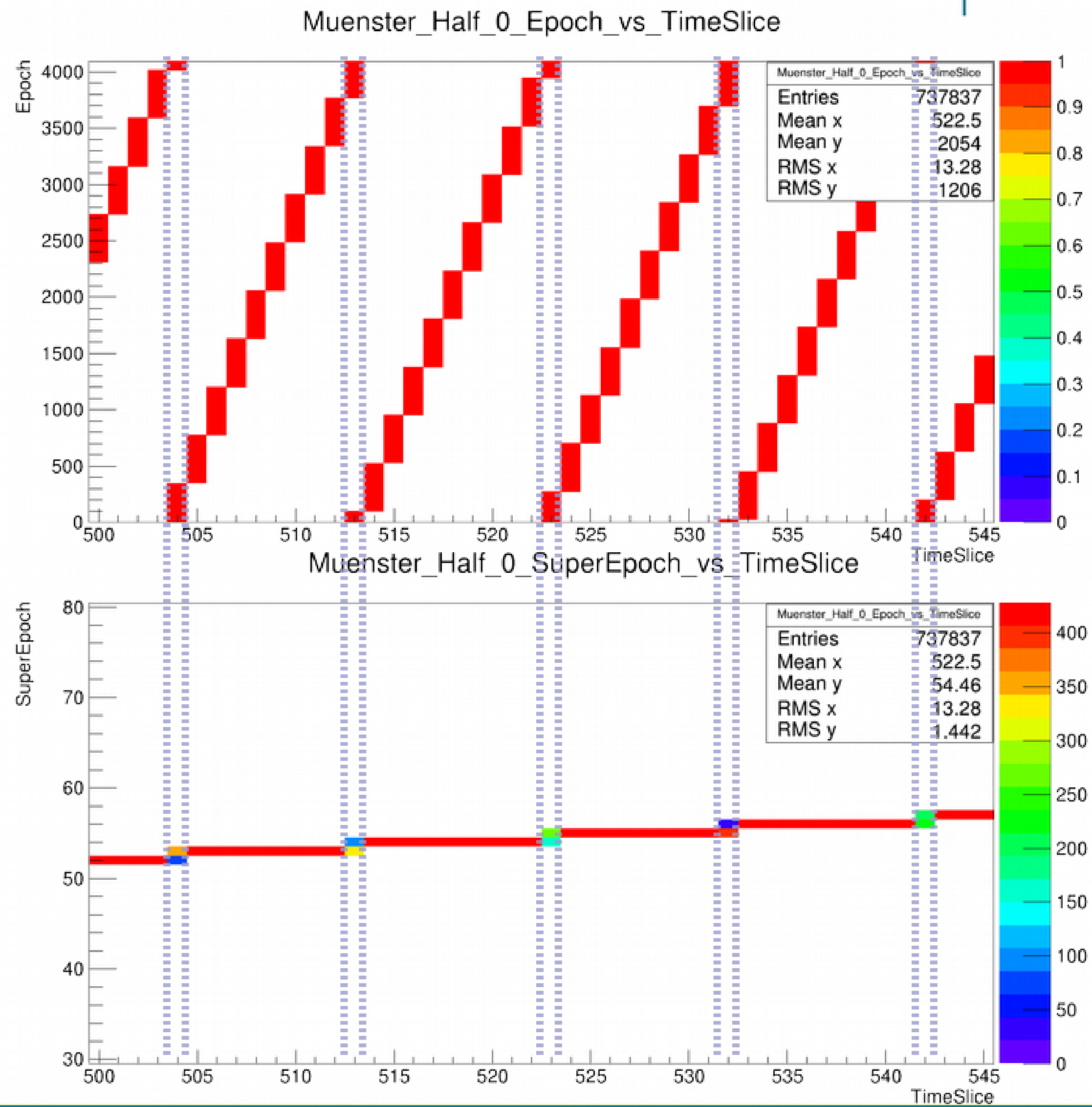
# CERN-SPS 2015 Campaign: Time Record Validation

- Validation of time records in their three single layers

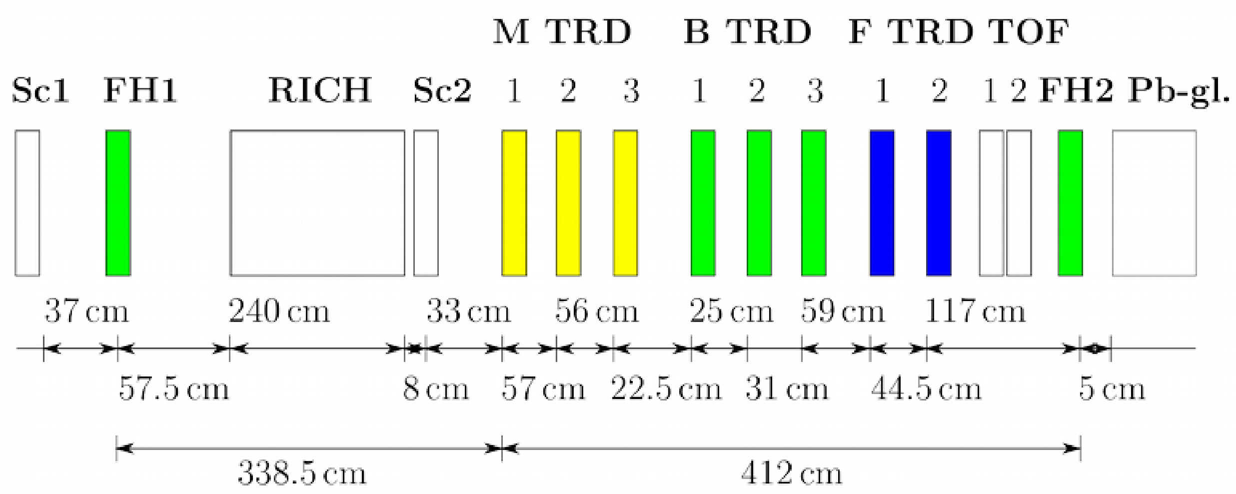



- *Super-epoch* and *epoch* are reconstructed dense, monotonously and synchronously as expected
- Last exceptions in *epoch* are currently under investigation

# CERN-PS 2012 Campaign: Position Resolution



- CERN-PS/T9
- Mixed e, μ, π beam
  with particle momenta between 1 and 10 GeV
- Read-out with SPADIC 0.3 Rev3 and SUSIBO
- Triggered using the fibre hodoscopes
- Test radiators mounted also on MWPC used here
- Xenon/$CO_2$



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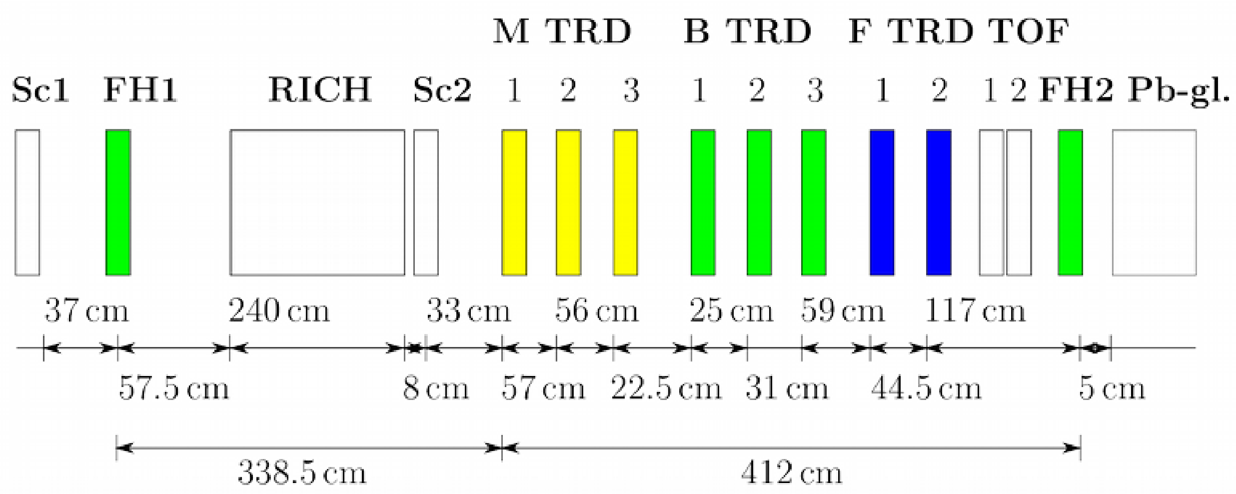
# CERN-PS 2012 Campaign: Position Resolution

- Small-angle scattering assumed following Highland-Lynch-Dahl with Gaussian distribution for e, μ, π beam (1:1:1)

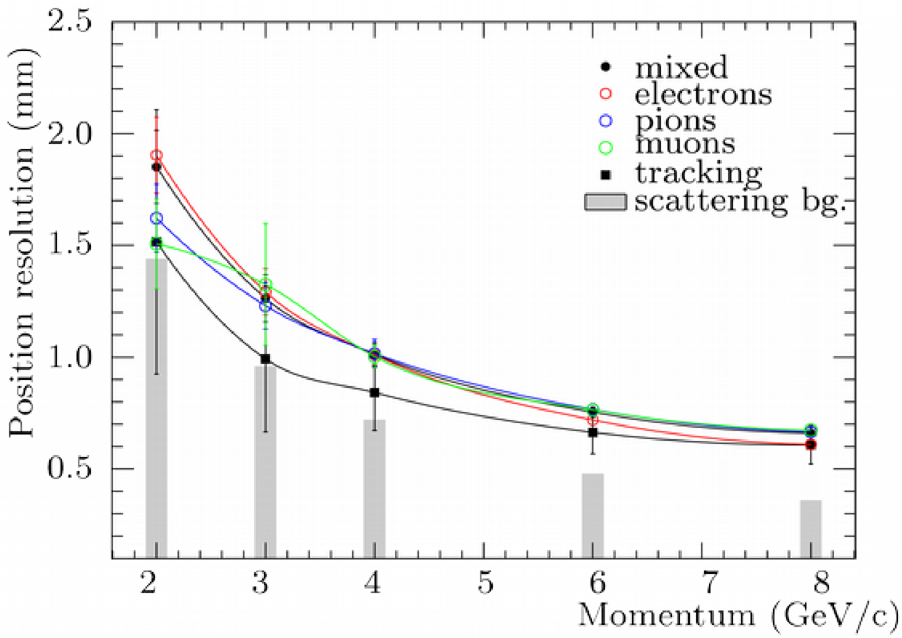
$$\theta_{proj}^{rms} = \frac{13.6\,\mathrm{MeV}}{\beta pc} z \sqrt{\frac{X}{X_0}} \left[1 + 0.038 \ln\left(\frac{X}{X_0}\right)\right]$$

- Material budget: Scintillators ($X/X_0$ = 2x 3.0%), Fibre hodoscope 1 ($X/X_0$ = 2.0%), RICH 2 mm PMMA ($X/X_0$ = 2x 0.58%) and SIMAX ($X/X_0$ = 5.1%), TRD M1 ($X/X_0$ = 1.54%), Radiators ($X/X_0$ = 1.5% and 3.1%) – simulated each at the known position

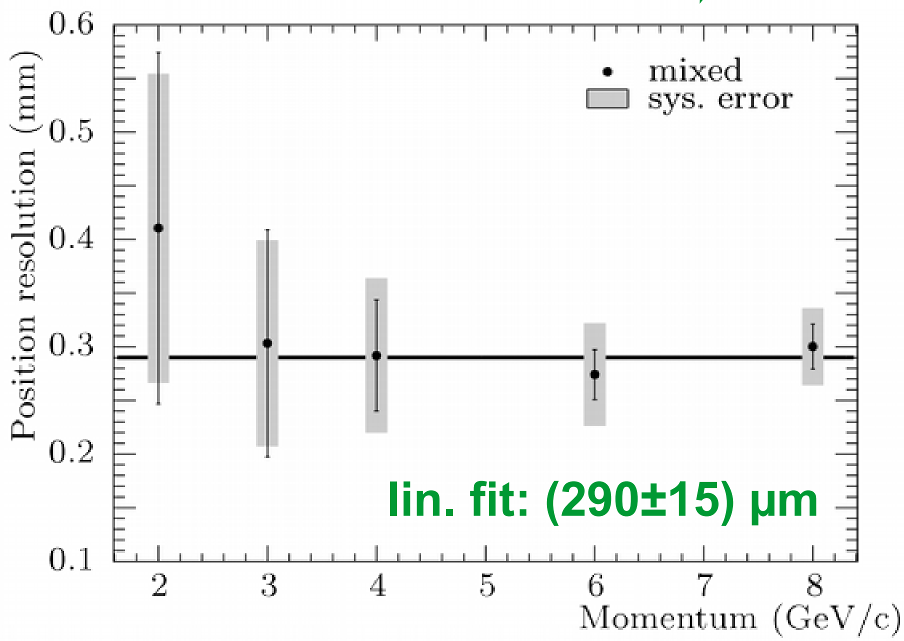


# CERN-PS 2012 Campaign: Position Resolution

- Misalignment compensation for parallel displacement along wire direction & rotation of the chambers
- Position determined by pad-response function fit
- Resolution as Gaussian fit to residual distributions: positions from detectors // checked by lin. tracks between hodoscopes




after scattering compensation



# GSI-SIS18 2006 Campaign: 2-Dim. Position Reconstruction

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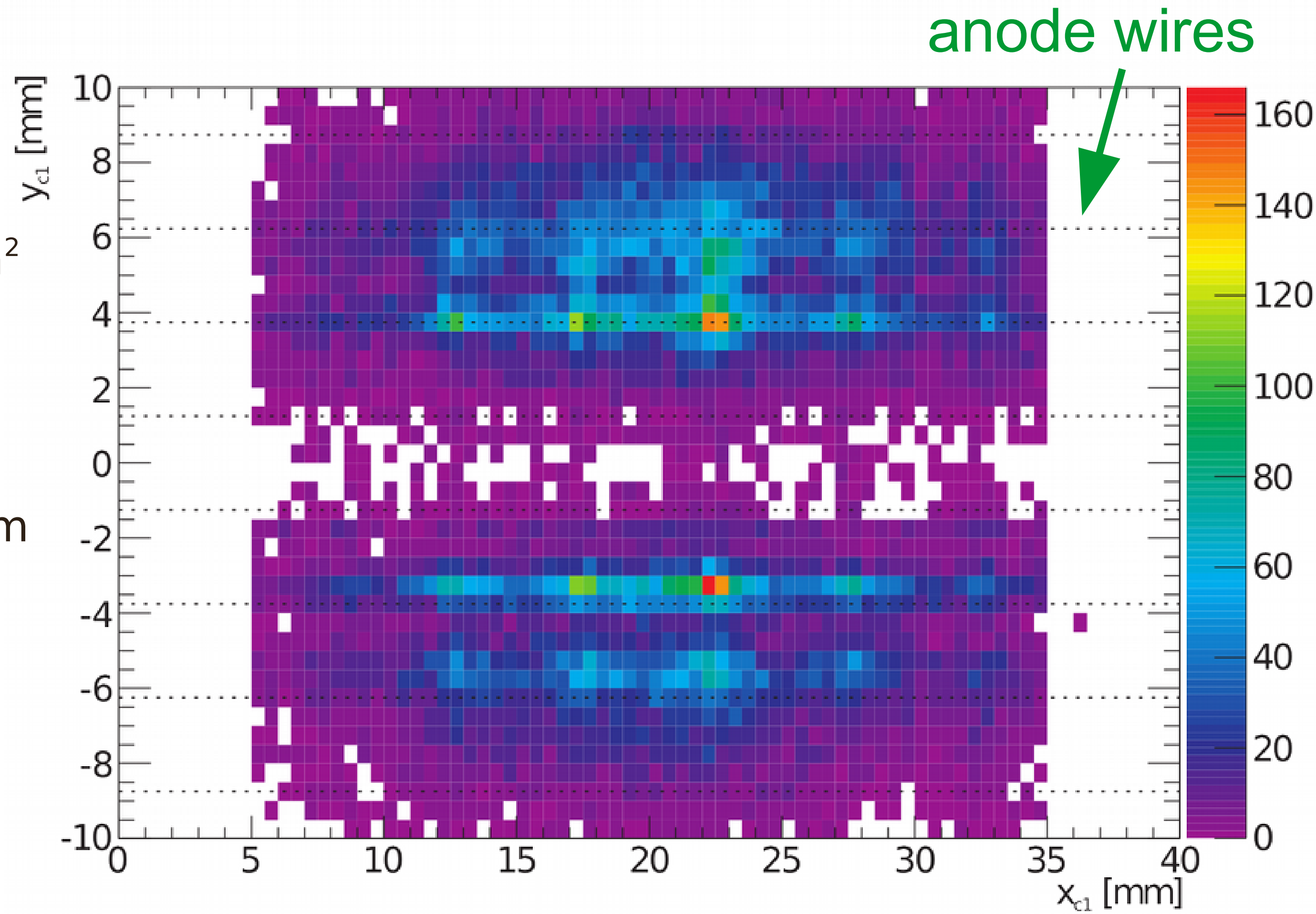
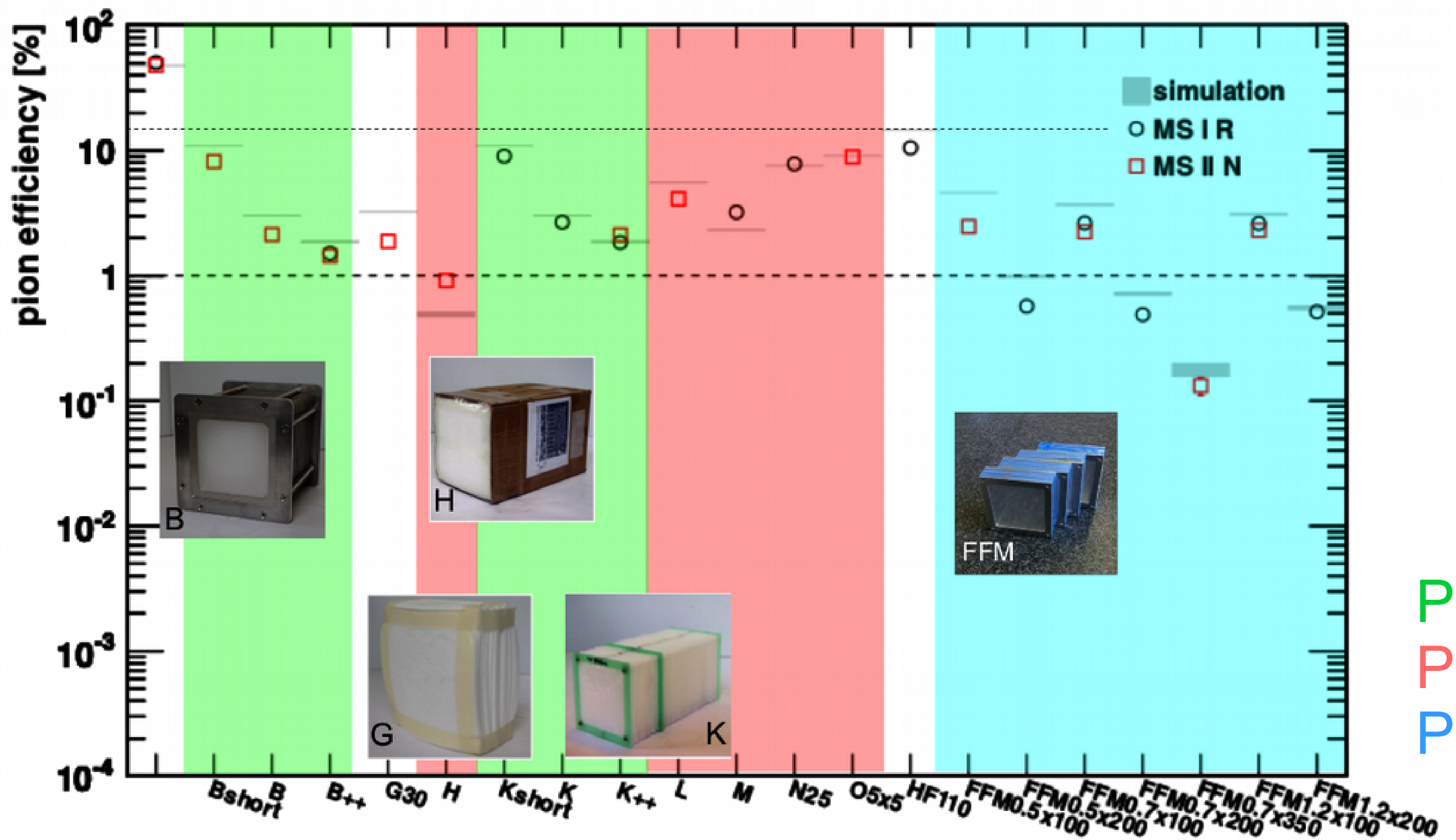
- Data from SIS18, test beam 2006
- Dual-sided MWPC, pad size 5 x 10 $mm^2$ ($Xenon/CO_2$)
- Protons, positrons (2 GeV), direct beam
- Gaussian fit for *y*-position reconstr.
- Wire spacing: 2.5 mm



# CERN-PS 2012 Campaign: Particle Identification




Pokalon
PE foam
PE foil

- Approximated pion efficiency with 4 detector hits per track (@ 90% electron efficiency)