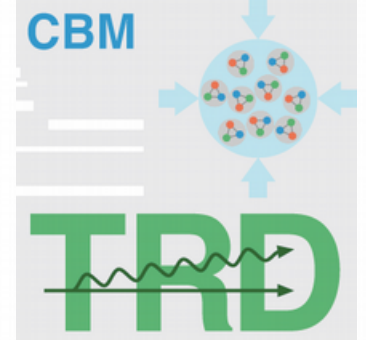


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Spectra and Position Reconstruction on CBM-TRD Data from CERN-SPS 2016

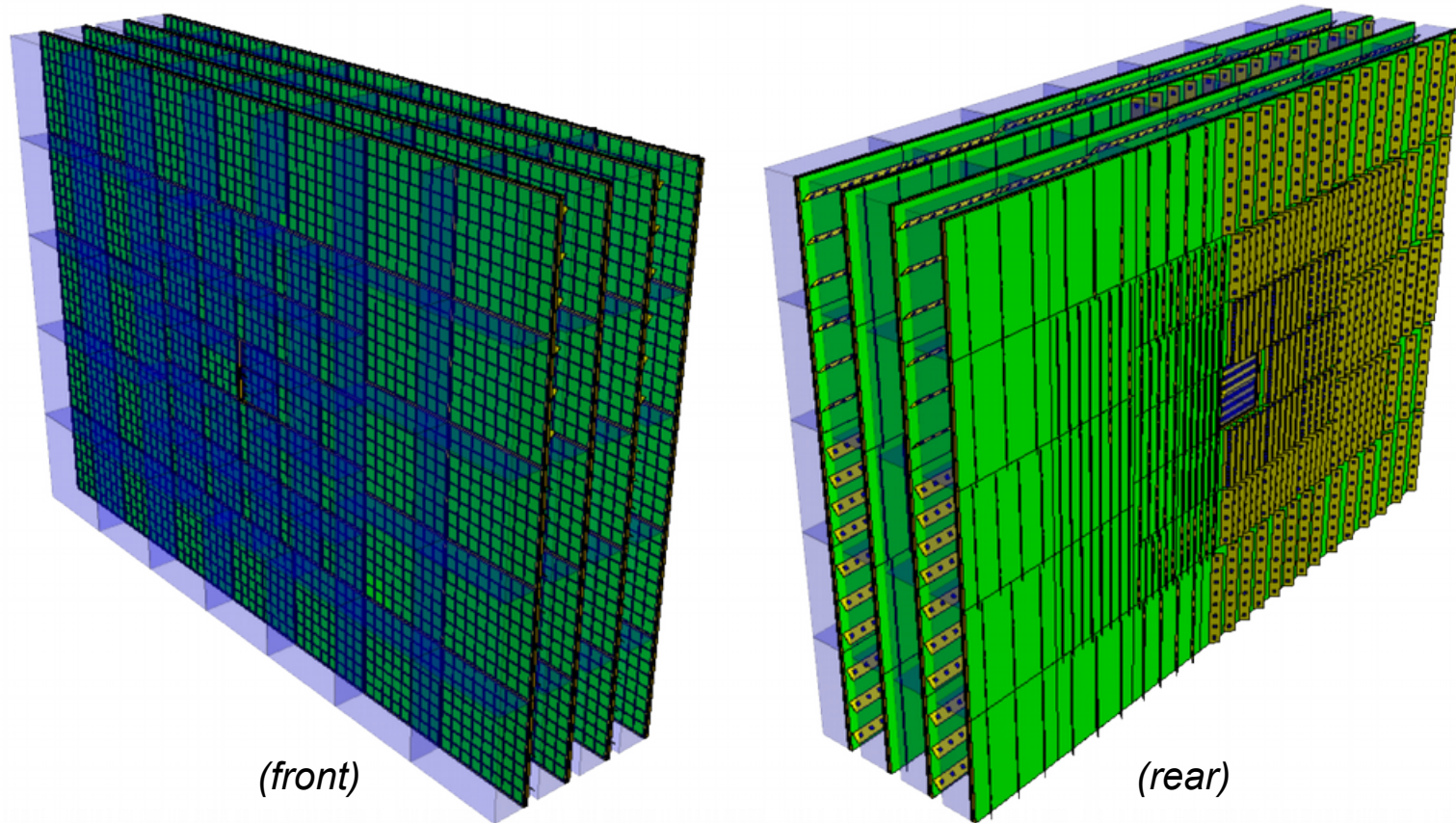
(or the way to this)

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

Philipp Kähler
WWU Münster, Germany
p.kaehler@uni-muenster.de



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



- 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 AGeV) / Pb target	2012-style (57x57 cm ²)	SPADIC 1.0, SysCore
2016	CERN-SPS/H4	²⁰⁸ Pb (13, 30, 150 AGeV) / Pb target	Type 8 (95x95 cm ²)	SPADIC 1.1, SysCore

- Scheduled measurements

* triggered

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

- Four type 8 chambers (95x95 cm²)
- 4 chambers projective on target (**tracking**), each 2nd 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)



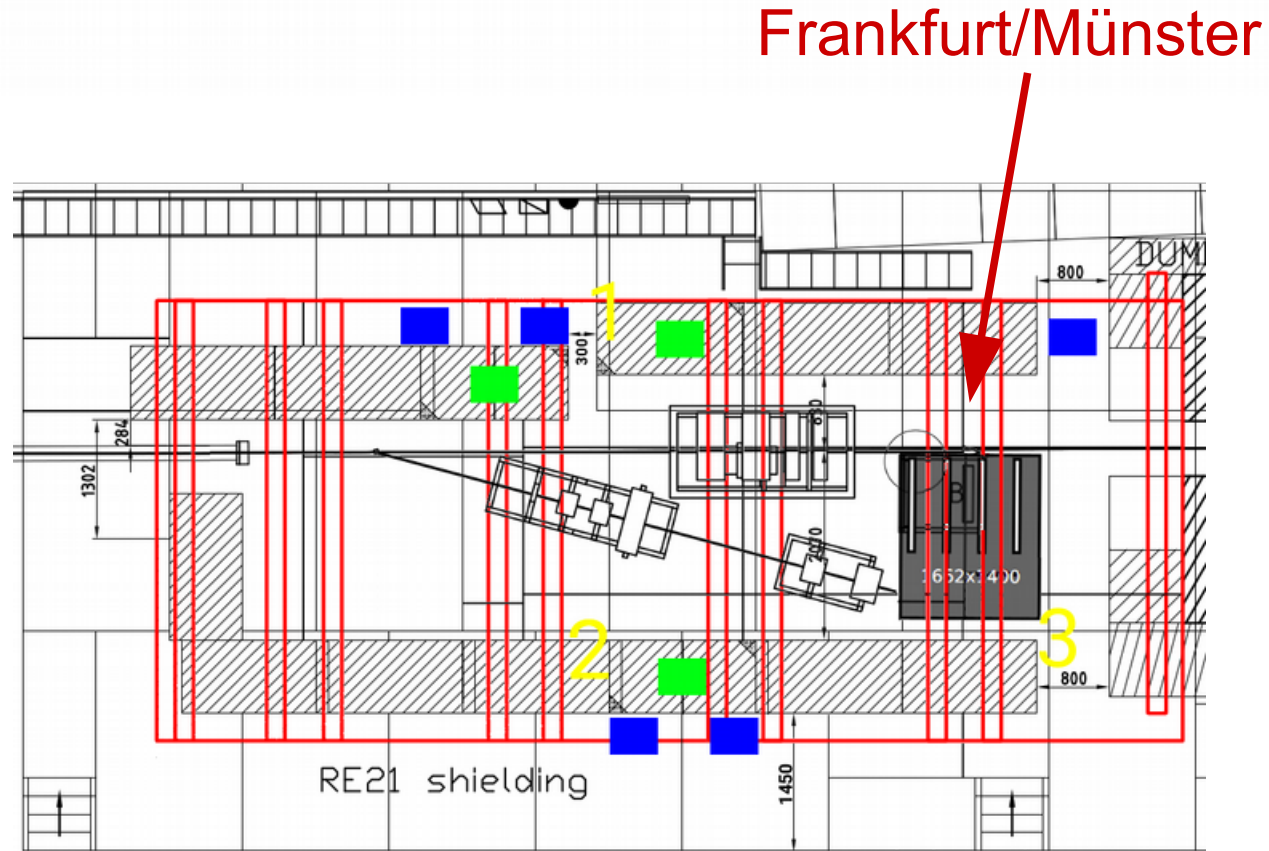
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Detector: Type 8 MWPC for CBM-TRD

- 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:

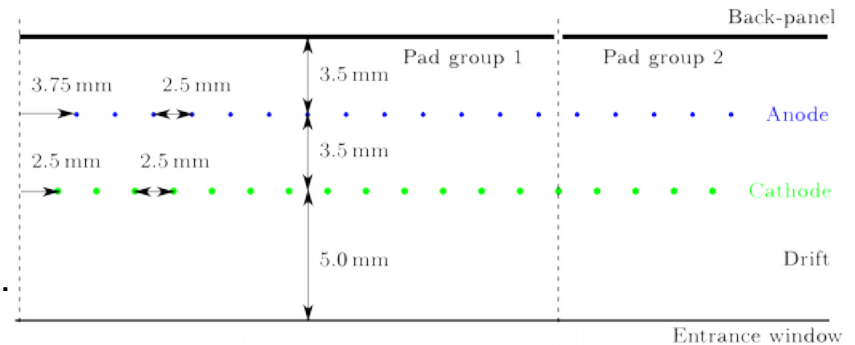
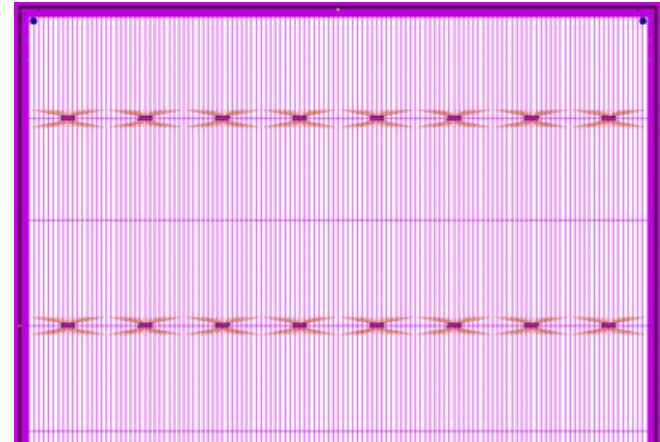
- According to Pad-Response Function (PRF).

Altern. Position of 3-pad cluster:

(hyperbolic secant squared method)

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

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

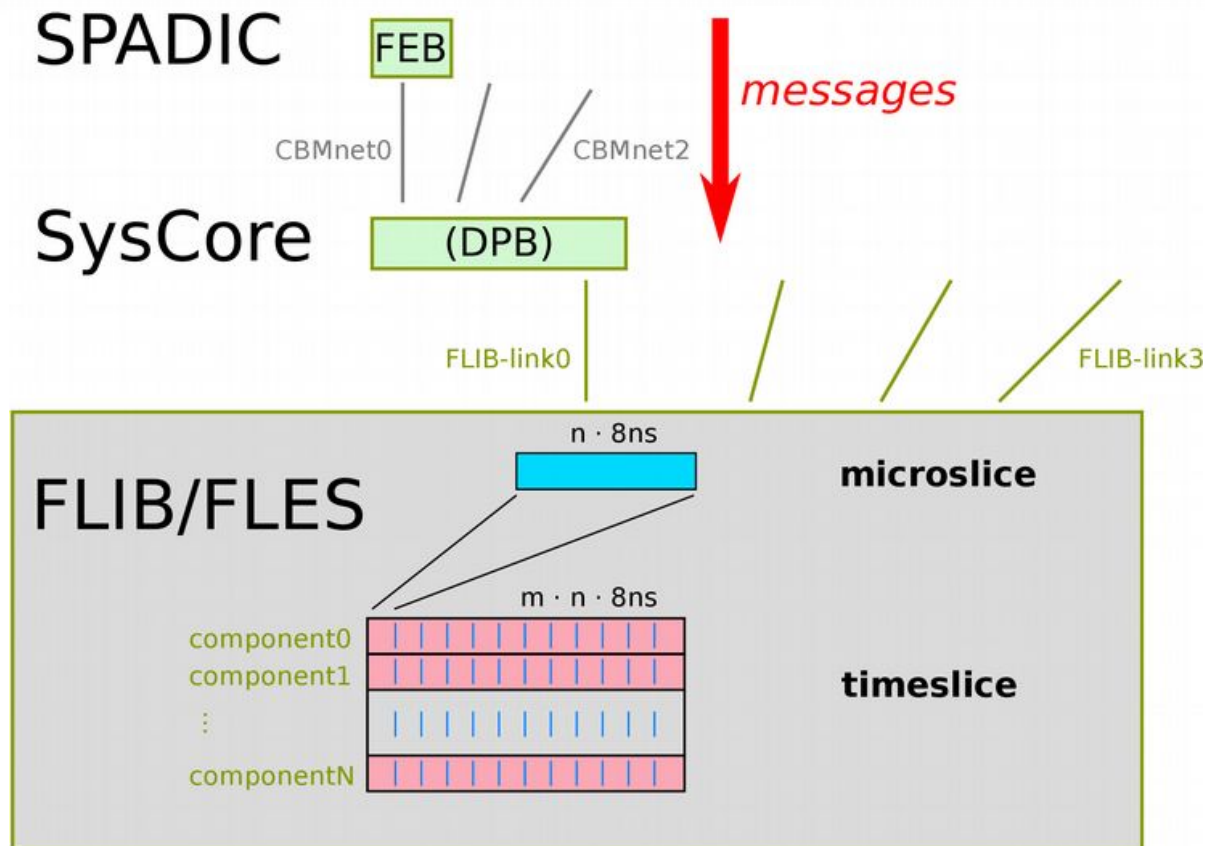


$$PRF(d/h) = \int_{d/h-W/2}^{d/h+W/2} \rho(d'/h) d(d'/h) dd'$$

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

- 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
data recording

SPADIC

DPB

CLOCK

timestamp (12 bit) $66 \text{ ns} \times 4096 = 273 \text{ } \mu\text{s}$


overflows in

epoch (12 bit) $\times 4096 = 1118 \text{ ms}$

offline/online
analysis

FLIB/FLES

Storage



Towards event-building:

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

Container Unpacking

Message Extraction

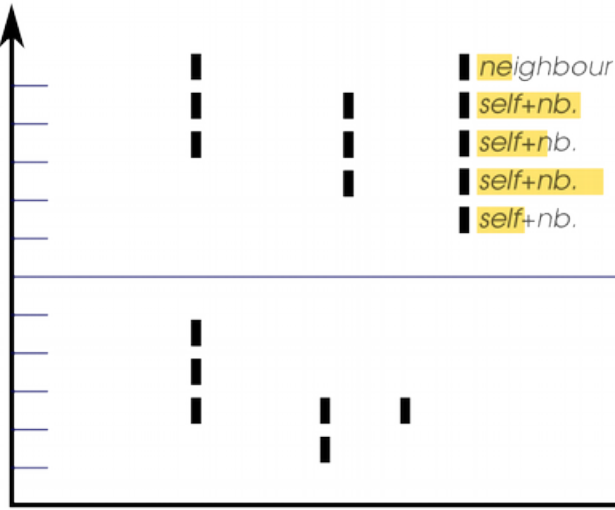
overflows in

super-epoch (12 bit) $\times 4096 = 4581 \text{ s}$

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

SPADIC A SPADIC B

Channel



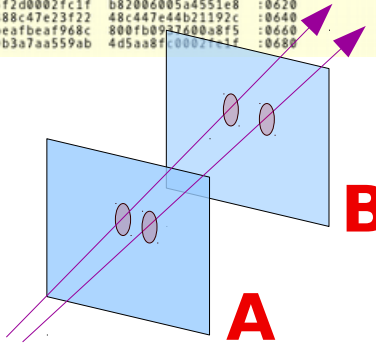
```

timeslice 92 microslice 95 component 0
hi hv eqid flag si sv idx/start      crc      size      offset
dd 01 e001 0000 40 01 000000000000244f 00000000 000064f8 0000000000080e80

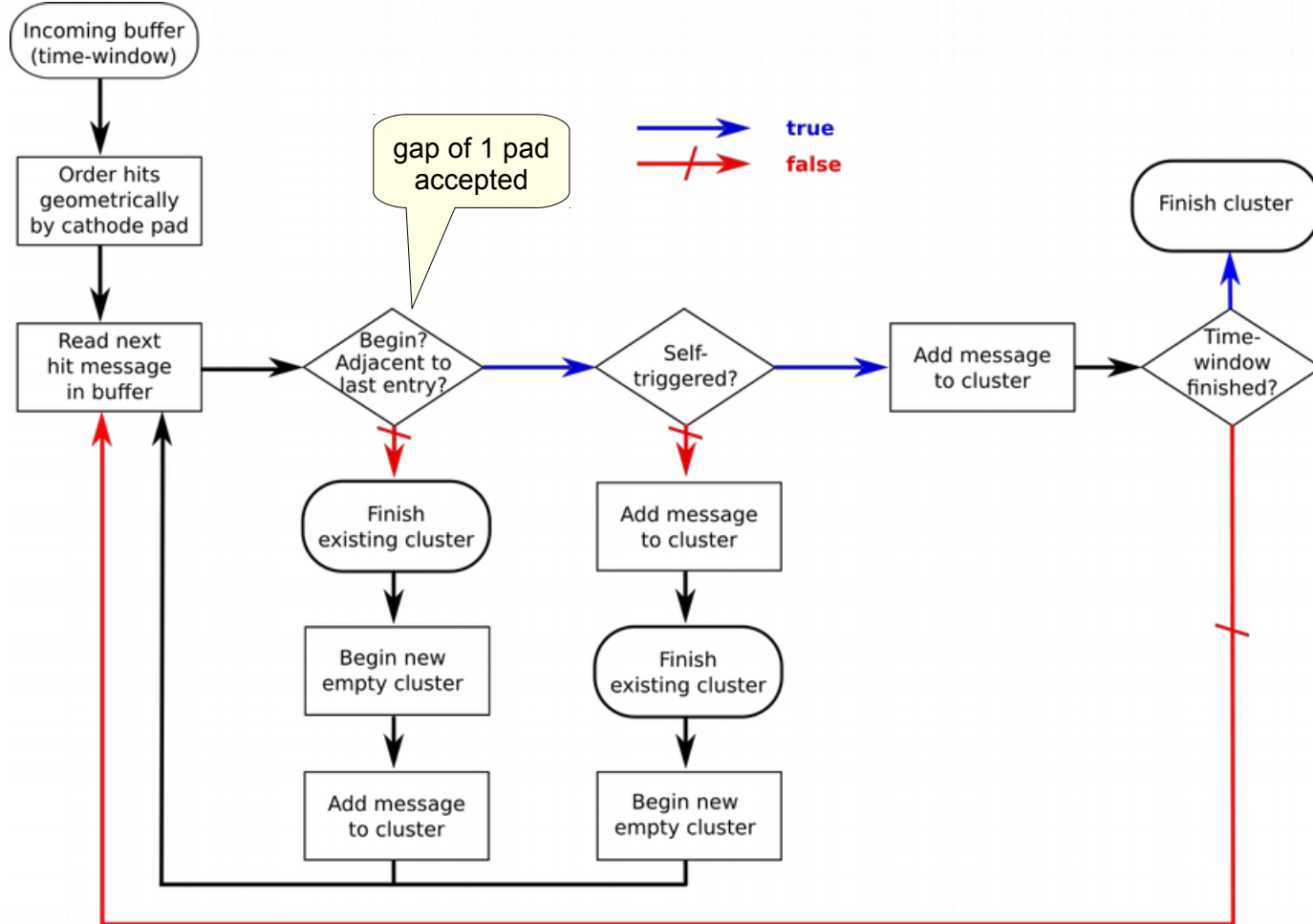
6a4553a9154b6a45 52280d480001da1f 000000000000244f 01400000000101dd :0000
5269314b4ae5572b 5d626be565b17996 aae593a48015b820 10000a4d52291747 :0020
194d4a9d0000db1f beafbeafbeaf5329 21523a5d5329154b 0a6d54ea15516a55 :0040
b8201a001a7551e9 14445a8553690b4b 6a2551e81f4b1a6d 546a19500a6d52e9 :0060
beafbeafbeaf3755 4ae582b4625b65 606308b4d6e6c16 11a4ab4e936280bd :0080
52e9134b7a555569 27576a559a29f5f5 aaf093a48017b810 1c004a750001d1ca :00a0
3a95546a0000dd1f b82014002a5d5229 15460a6551691b45 2a552a9134d4ad6e :00c0
0795ab8e9363800f b063aaf89362800f b81020007a9552a9 1f4e7a7d53a92b50 :00e0
beafbeafbeaf53a9 11505a95542a3150 4ac556aa3f592b05 5bad7b7e5c2d63f2 :0100
1a55542a1b4daa4d 9468a817001df0d0 b81014007a8d529 1d4f6a850000e0e6 :0120
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2a7d55aa0f4e4a7d 53e9234a0001e30b beafbeafbeaf2a65 51e91d48a6f55369 :01e0
7a7554292351aa3d 94ec80170001e40d beafbeafbeafb820 1a006a4d53a9114a :0200
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52a91b4e5a60d53e9 15537a8554e93554 5af55b6c255daa45 961d801608202c00 :0440
beafbeafbeaf3995 aa40961d8017b820 10001a2d52280b4a 0a1552aa0b432a4d :0460
3a8552a91b4c7a65 53a929154ab0582b 595f4b351a1f419c 3d1d6ccf60001f31f :0480
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9149801f0003f60d 432339448643f24 590c4aa40002f506 beaf4b293914494a :04e0
55291f4e0001f71f beaf552c497c4ce6 6736298450662b4c 2b56d3169fa370 :0500
515f4b355dae2d6c aa95961d8019b830 00000a5554a27af 2a8553e92146e8a5 :0520
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6133098c4fe7414e 4bb568b17995a91c 968a8005b8204200 494449e40002f81f :0560
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968c800db0a31200 a917968c800bb820 3200388c47e23f22 48c447444b21192c :0640
beafbeafb8103a00 790c49e40003f004 beafbeafbeaf9968 800fb08924600a8f5 :0660
4925090447e4311d 78cc49e359262944 4c650b3a7aa559ab 4d5aa8f10102717e :0680

```

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

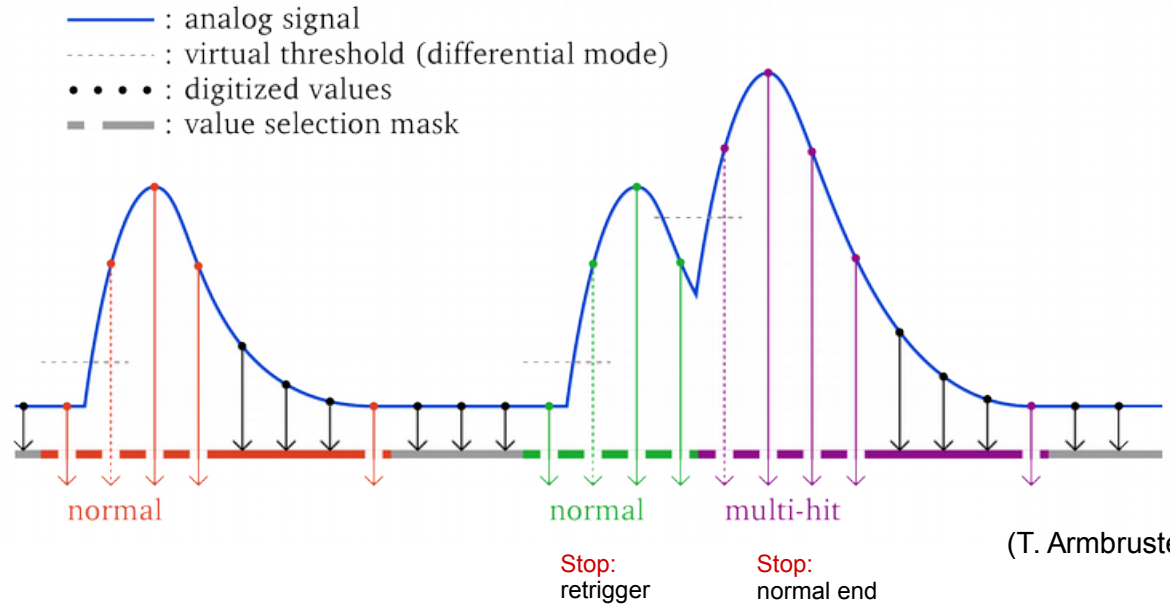


- Second: order hits geometrically, process in spatial clusteriser



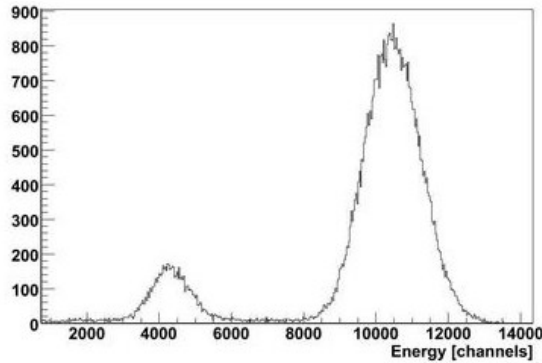
- Chip response on delta pulse known

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



- 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 source for calibration:
K lines and escape peak

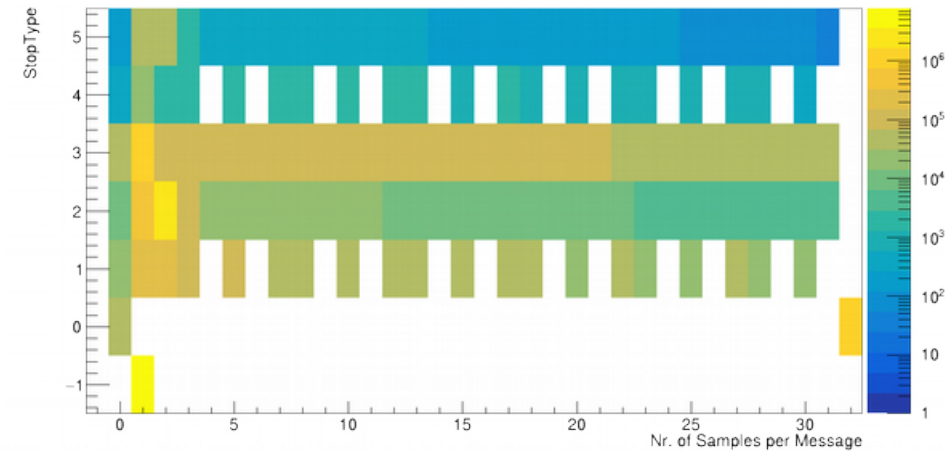
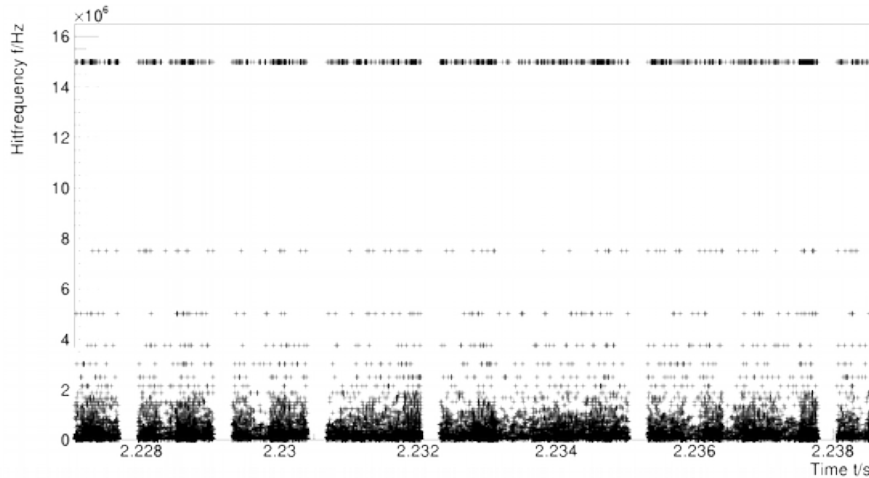
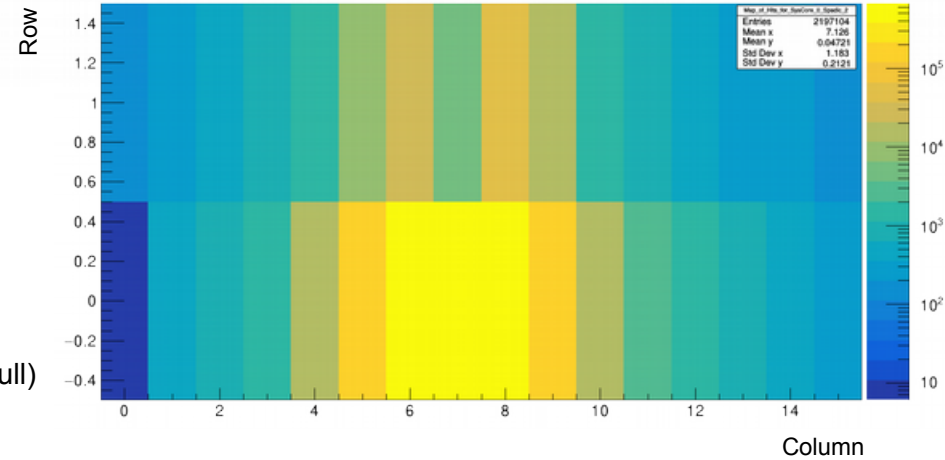


(example spectrum)

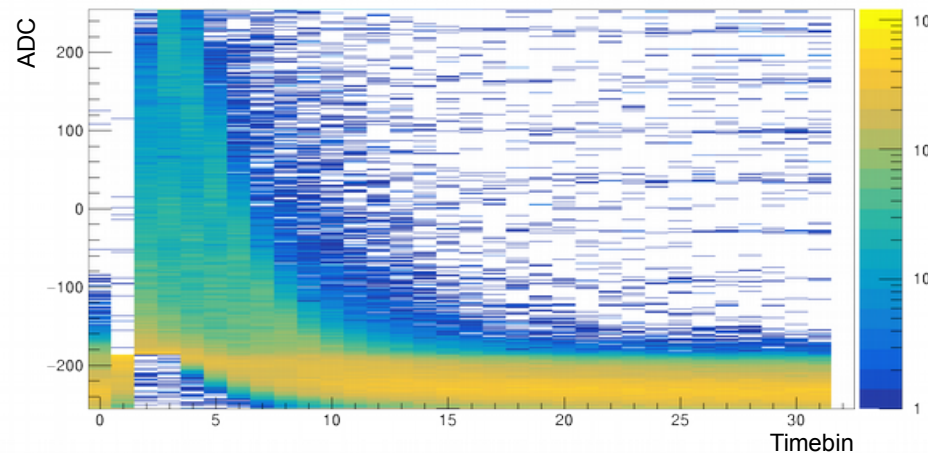
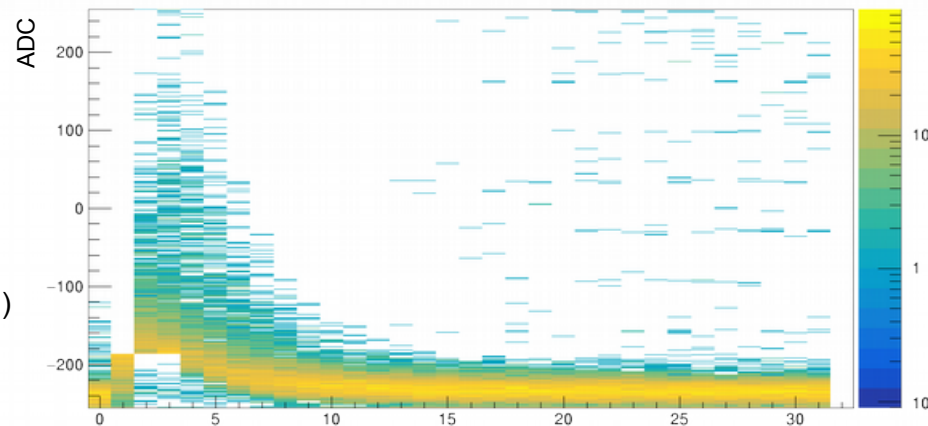
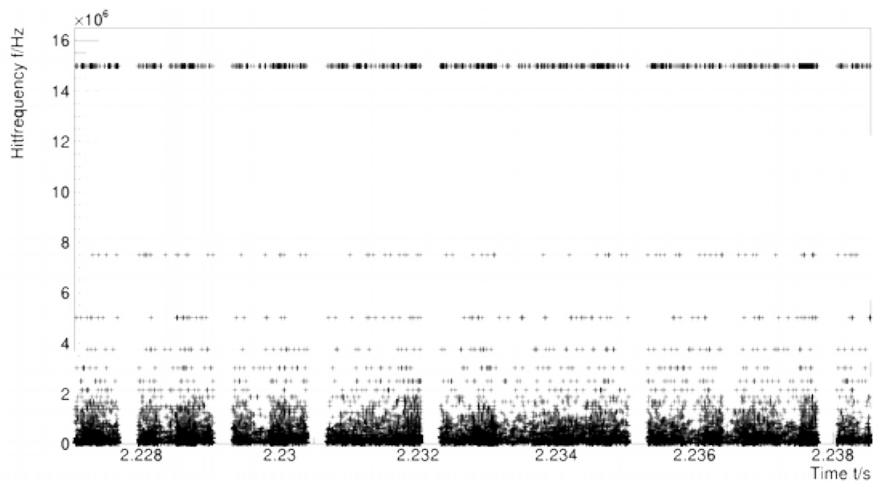
- 227 MBq
(assume 10% in chamber) \rightarrow 23 MHz,
or 1 γ every 43 ns
- Sampling with 15 MHz
 \rightarrow 1 timebin = 67 ns



- 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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- 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



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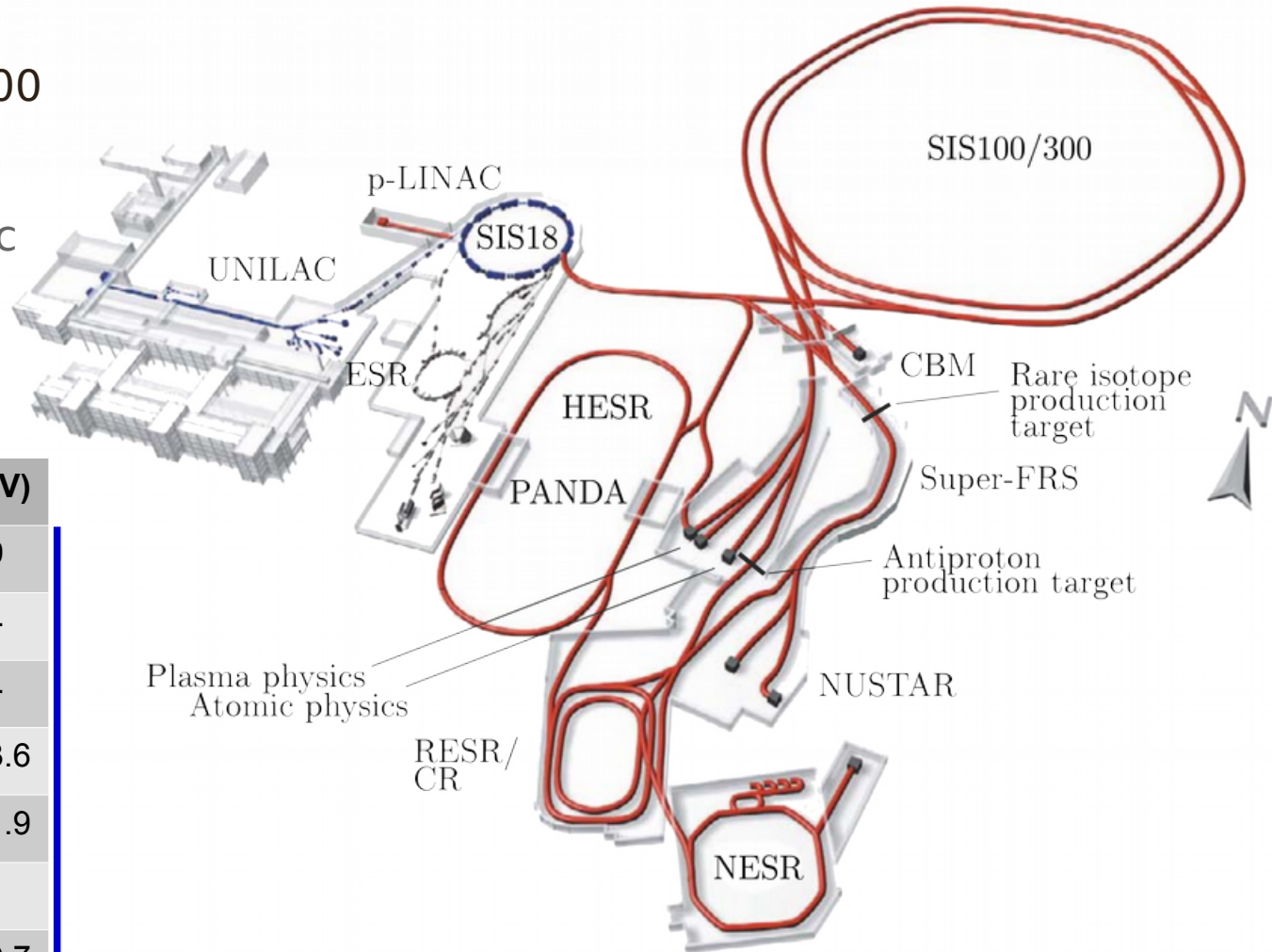
BACKUP



- In construction: SIS100 (magnetic rigidity of 100 Tm)
- **Compressed Baryonic Matter** 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

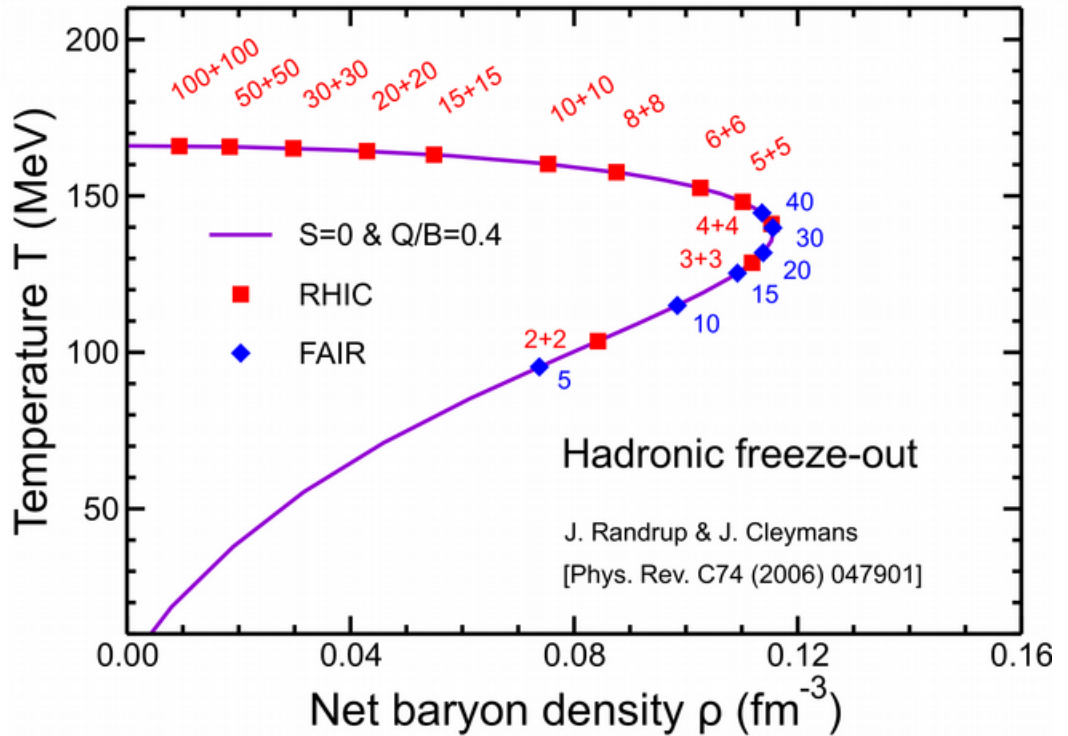




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Au	79	197	11
U	92	238	10.7

SIS100 energies



- 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

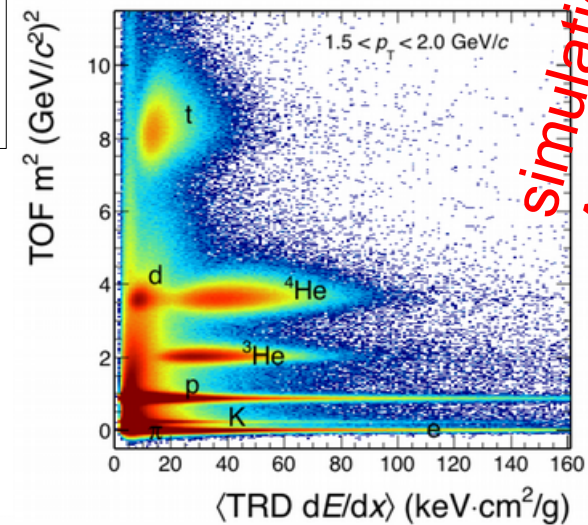
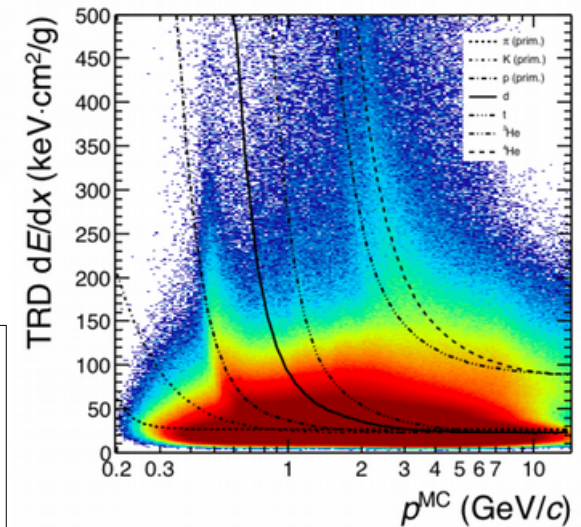
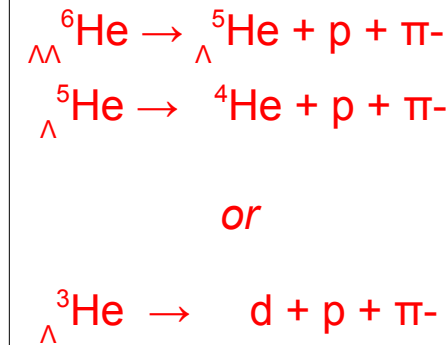
- Pion rejection capability ... pion suppression up to 50 and 10^4 with RICH
- (Charged) Particle identification ... dE/dx resolution below 30%
- Tracking capabilities ... track resolution below 300 μm (pad granularity)
- High interaction rates ... optimised: 5×10^6 Hz & realistic multiplicities
- Tracking of muons ... high track matching with the MUCH

- Physics objectives

- Intermediate mass di-leptons
- **Fragments**
- Quarkonia
- Low mass vector mesons
- Direct Photons

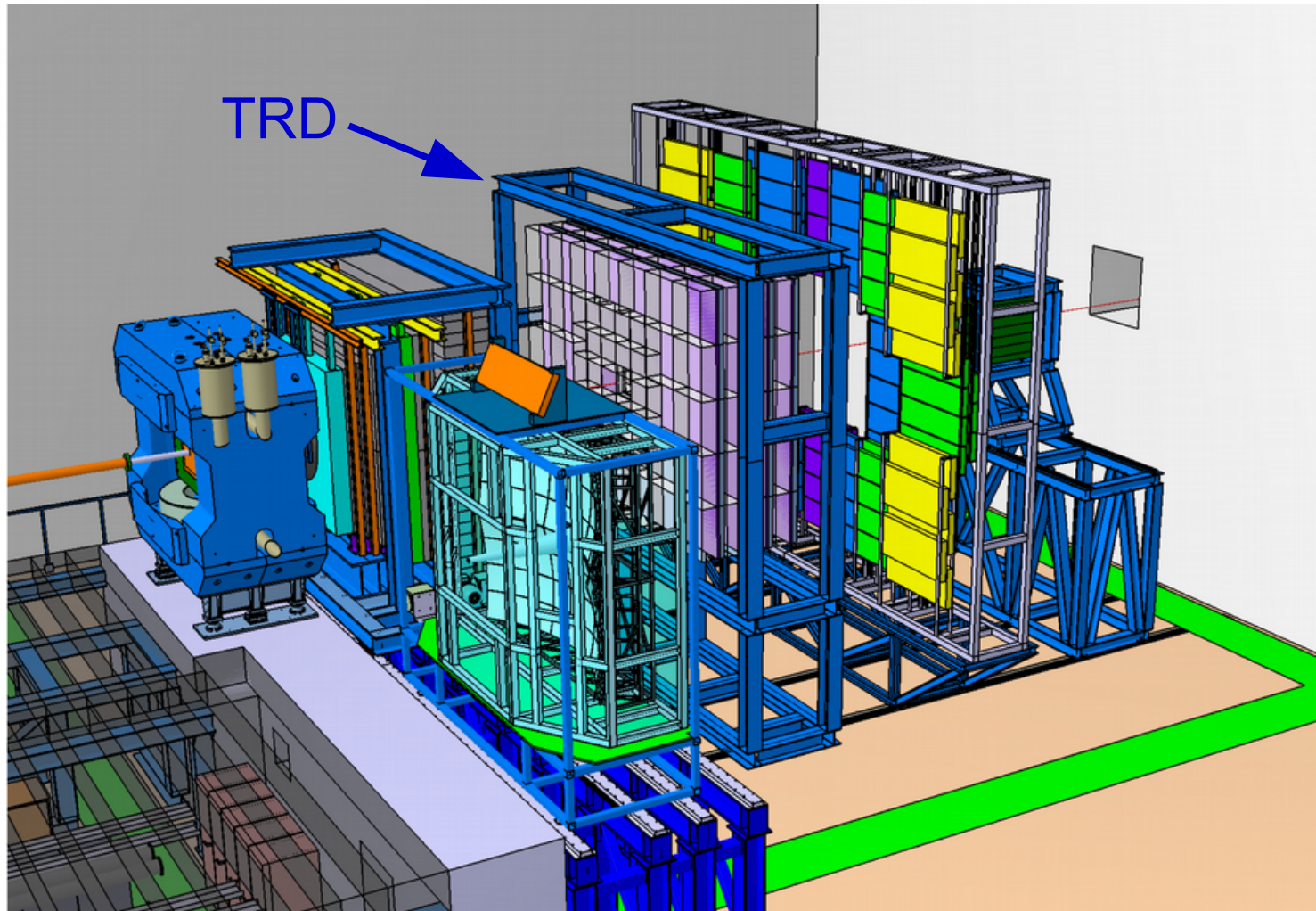
- Design considerations

- Pion rejection capability
- **(Charged) Particle identification**
- Tracking capabilities
- High interaction rates
- Tracking of muons

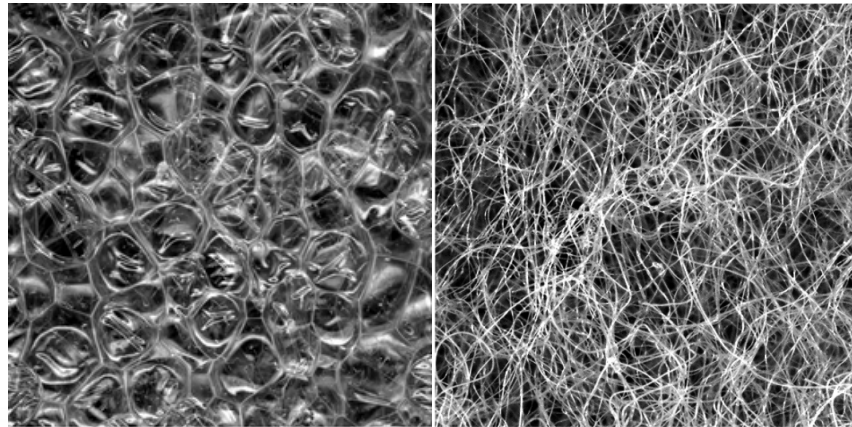
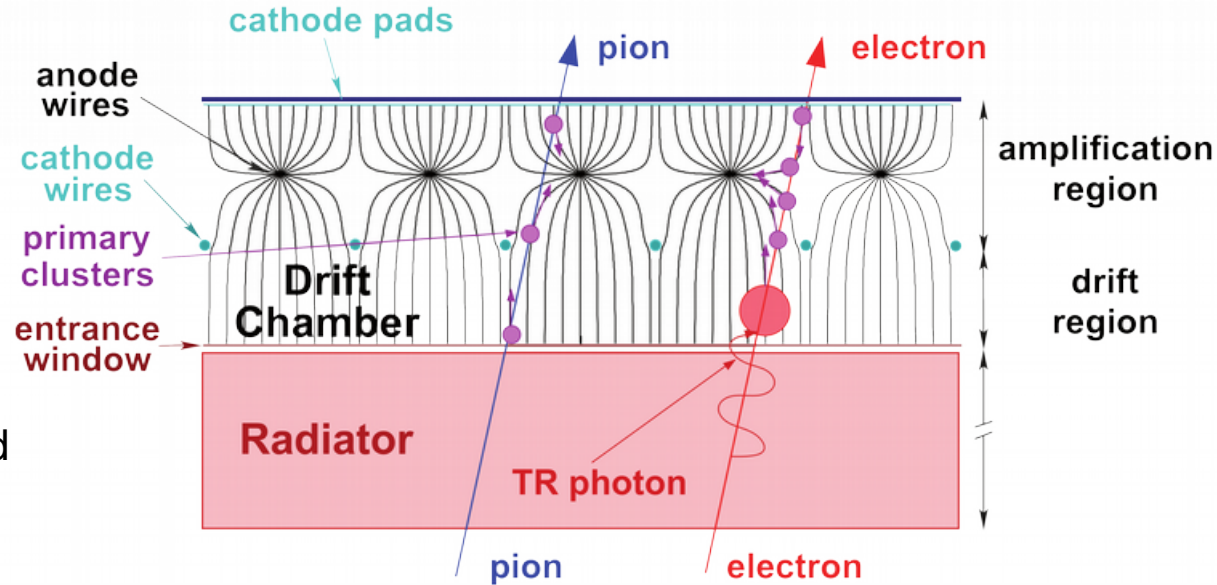


simulation,
Au + Au
8 GeV

- 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



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



Transition radiation at one ϵ -interface:

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

ω : photon frequency

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

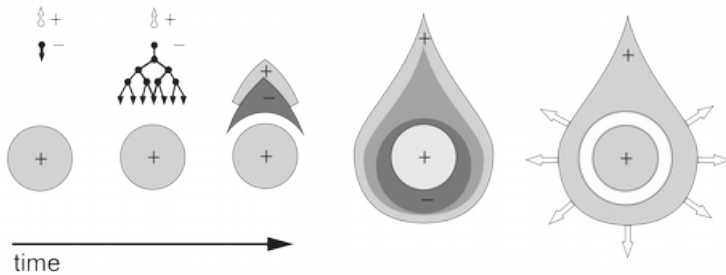
α : fine structure constant

ϑ : emission wrt. particle motion

γ : Lorentz factor

Design principles

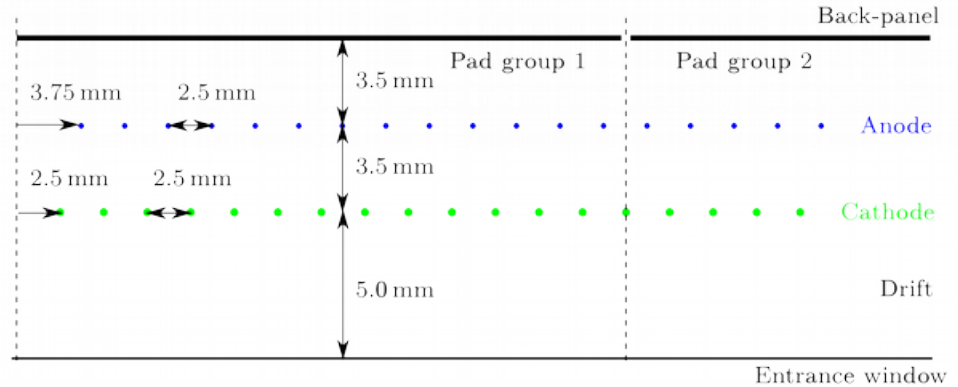
- High-voltage wire geometry: drift zone + two symmetrical amplification zones
- Proportional chamber: rate limits



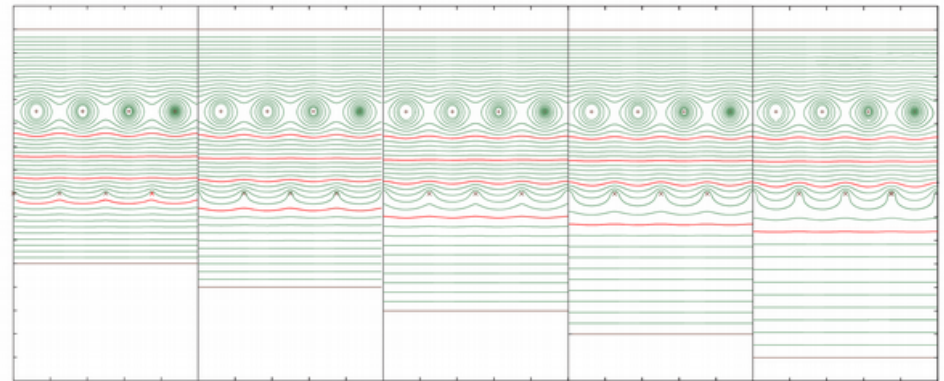
from F. Sauli, CERN lectures 1977

→ short ion drifts (3.5/3.5+5 mm)

- Special conditions: flexible cathode (entrance window)

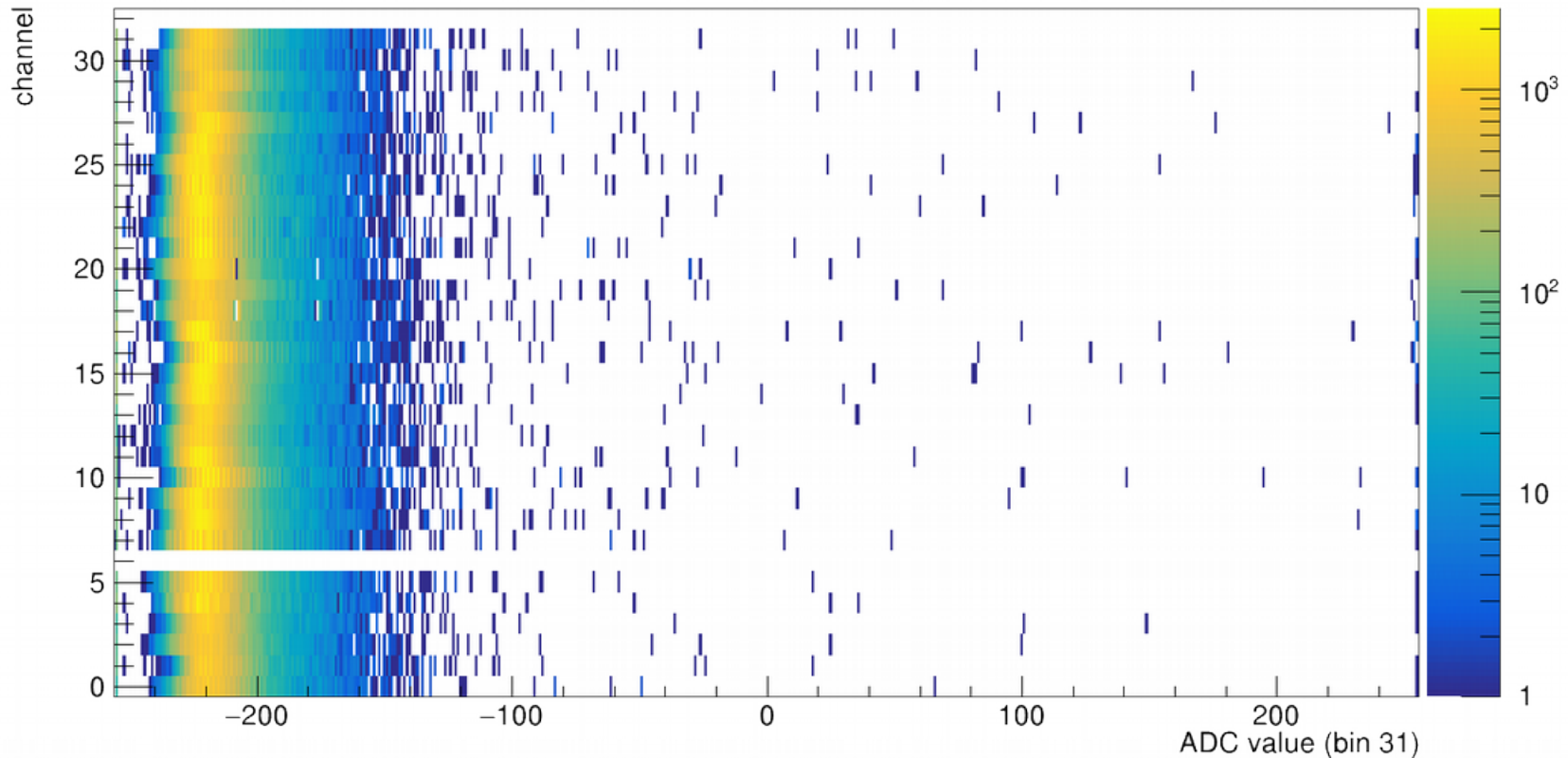


Anode+Drift HV geometry

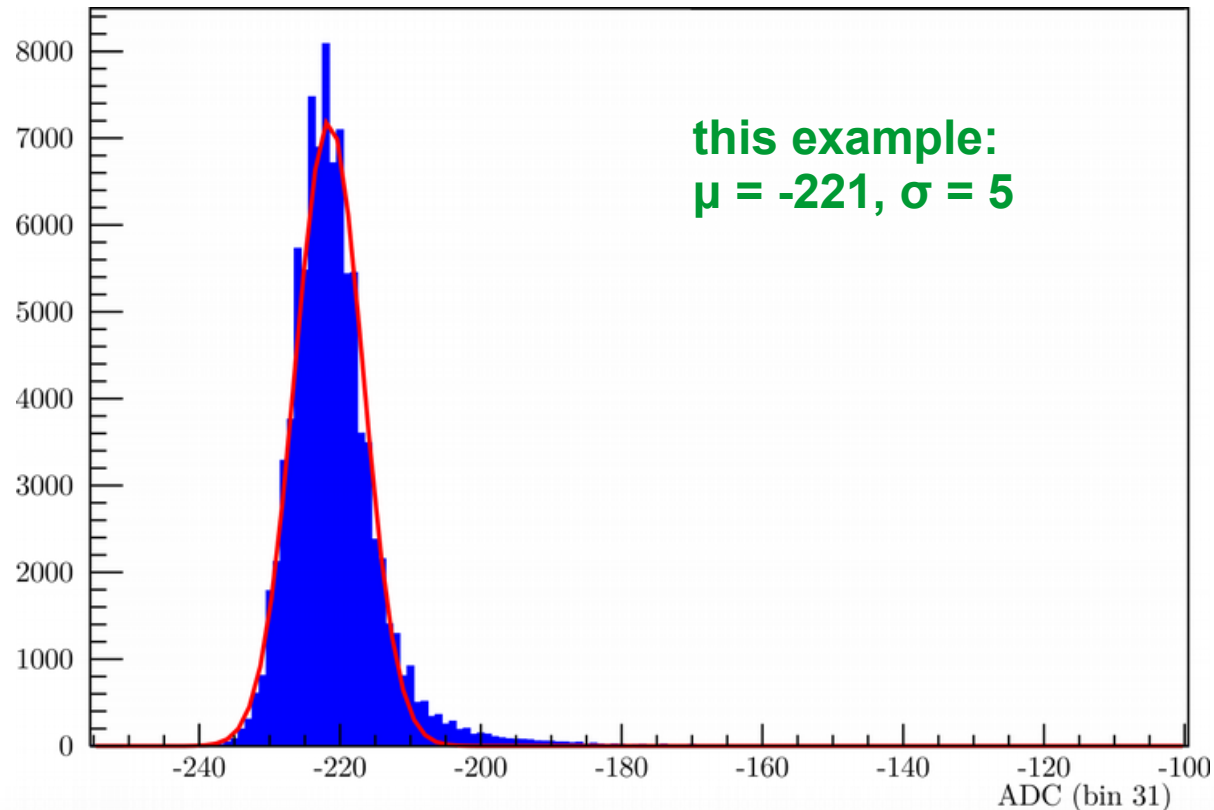


Example: Field distortion by entrance window stretching (Garfield sim.)

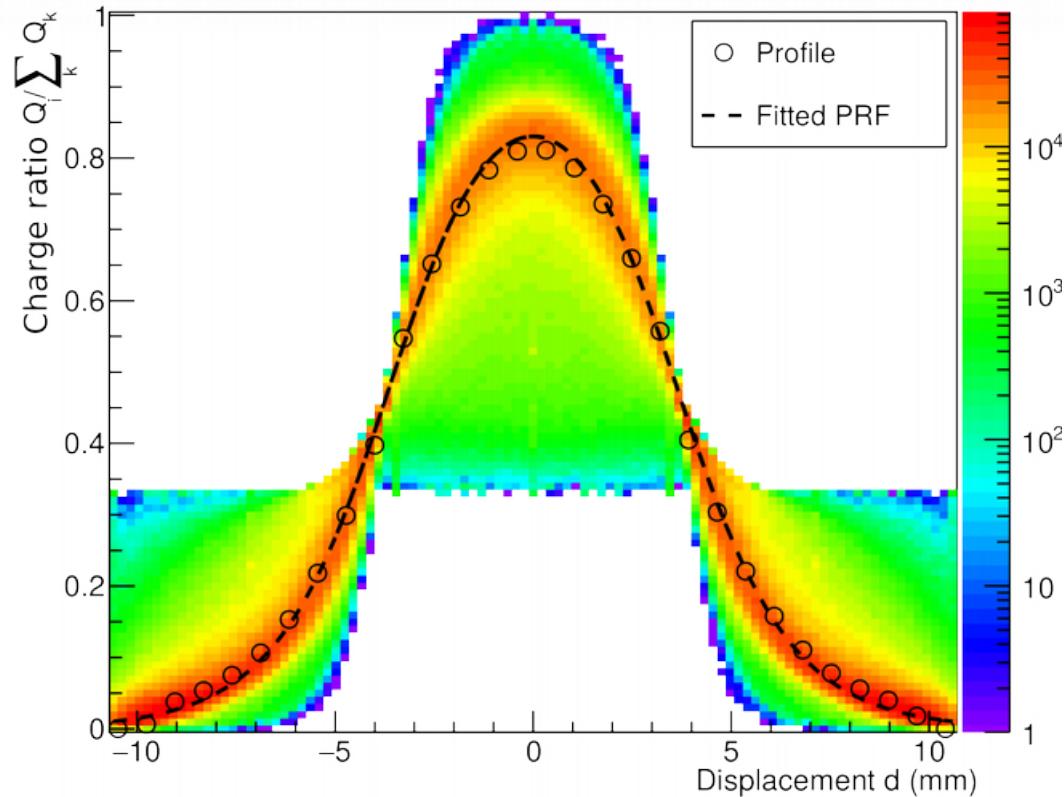
- Determination of a channel-wise baseline
 - Use ADC value of **last timebin** from all complete, self-triggered hit messages
 - Collect this baseline distribution separately for every channel



- 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



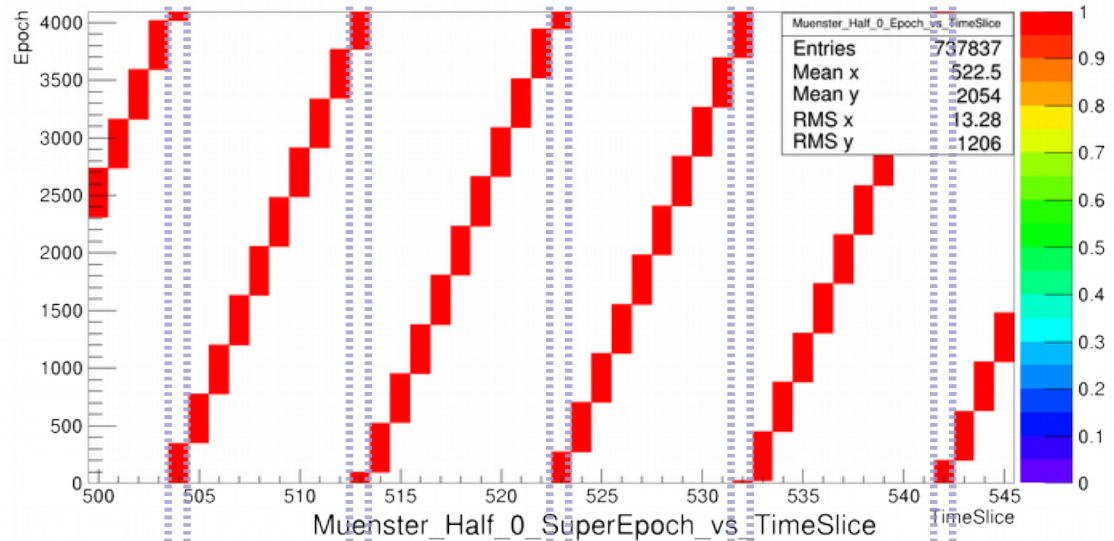
- Resulting Pad-Response Function from 3-pad clusters, type 0:



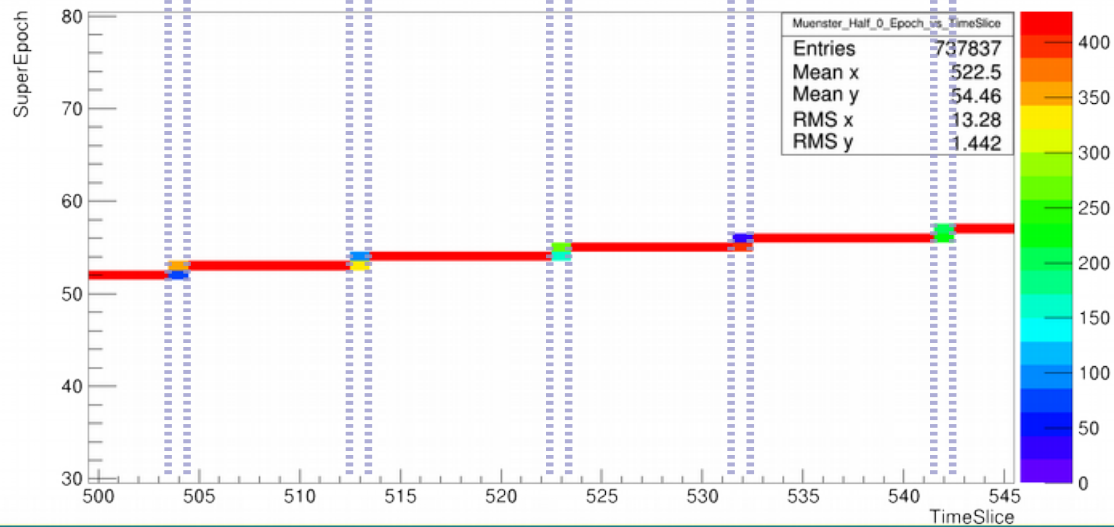
- From fitting: $K_3 = 0.388 \pm 0.008$ (expectation for this geometry: 0.38)

- 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

Muenster_Half_0_Epoch_vs_TimeSlice

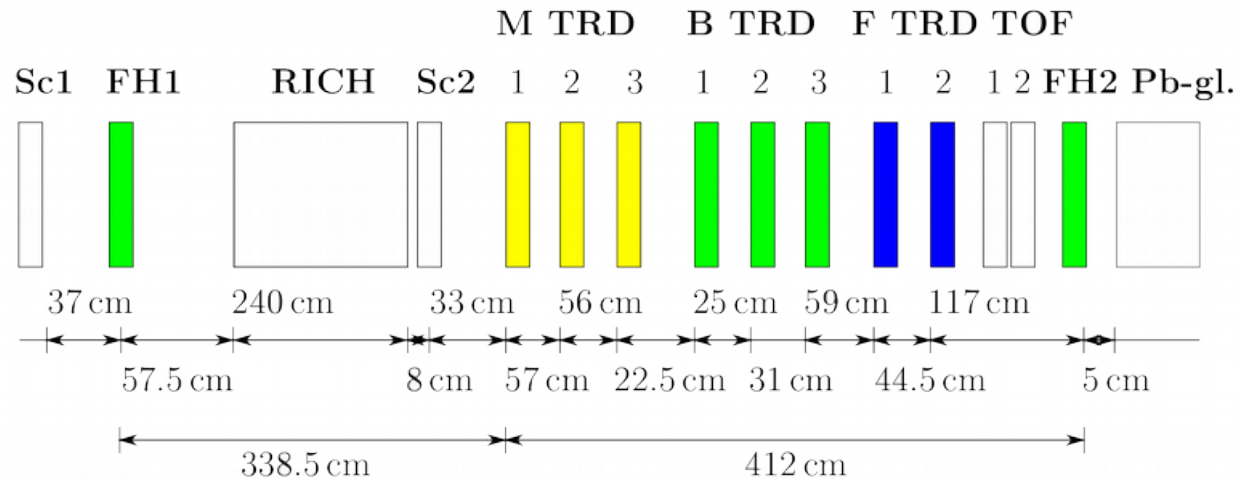


Muenster_Half_0_SuperEpoch_vs_TimeSlice





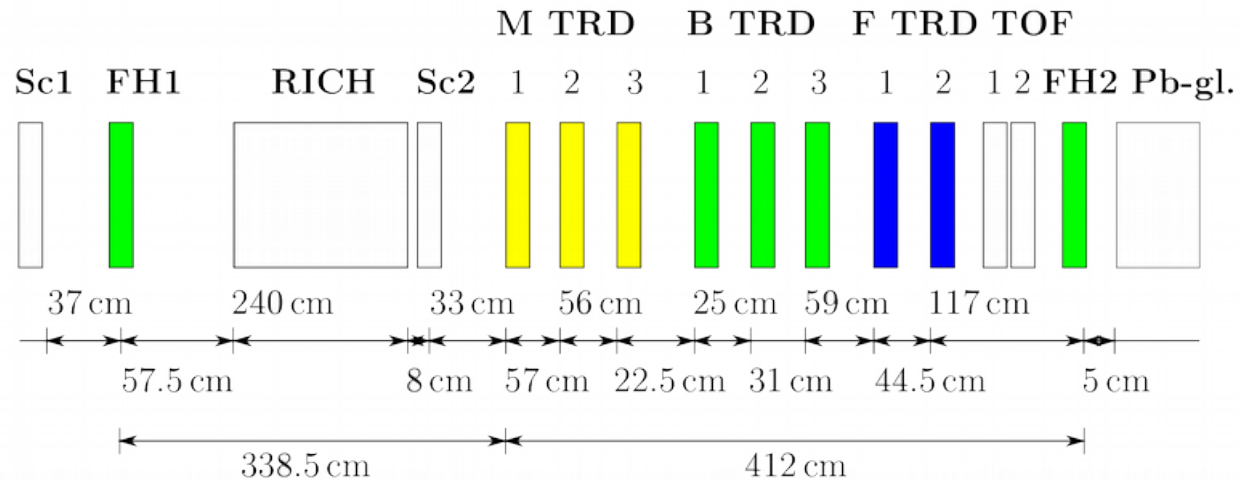
- CERN-PS/T9
- Mixed e, μ , π beam
with particle momenta between 1 and 10 GeV
- Read-out with SPADIC 0.3 Rev3 and SUSIBO
- Triggered using the fibre hodoscopes
- Test radiators mounted also on MWPC used here
- Xenon/CO₂



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

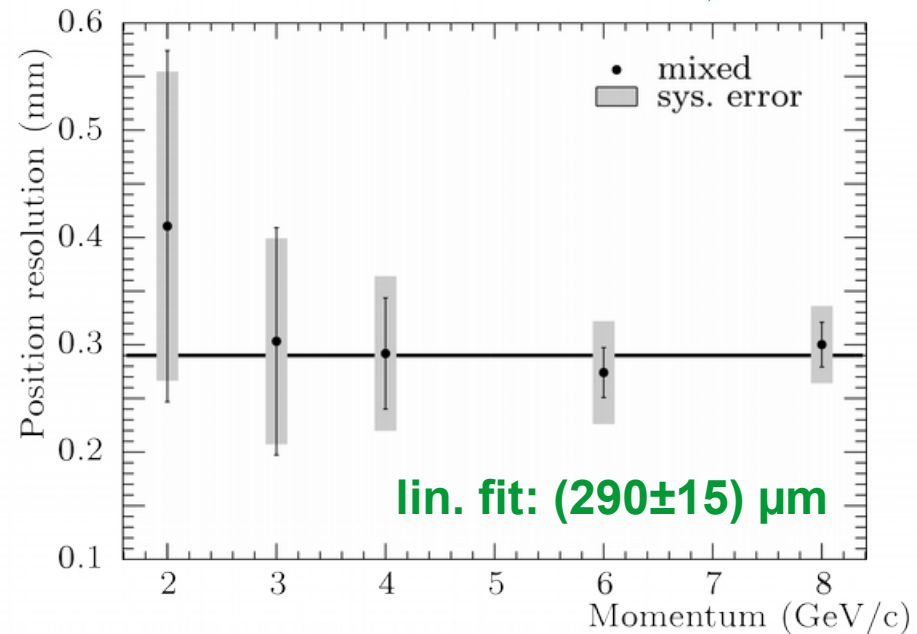
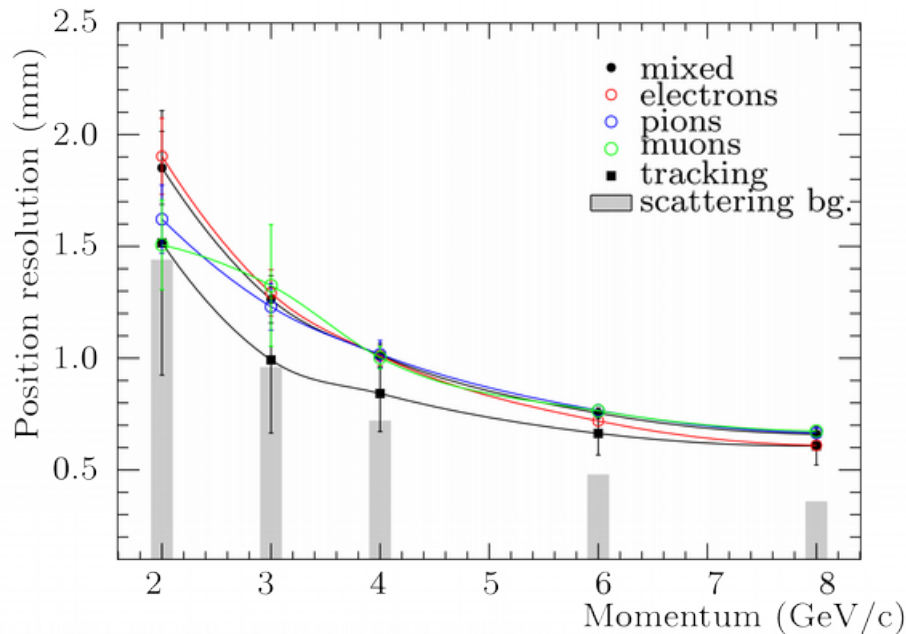
$$\theta_{proj}^{rms} = \frac{13.6 \text{ MeV}}{\beta pc} z \sqrt{\frac{X}{X_0}} \left[1 + 0.038 \ln \left(\frac{X}{X_0} \right) \right]$$

- **Material budget:** Scintillators ($X/X_0 = 2 \times 3.0\%$), Fibre hodoscope 1 ($X/X_0 = 2.0\%$), RICH 2 mm PMMA ($X/X_0 = 2 \times 0.58\%$) 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



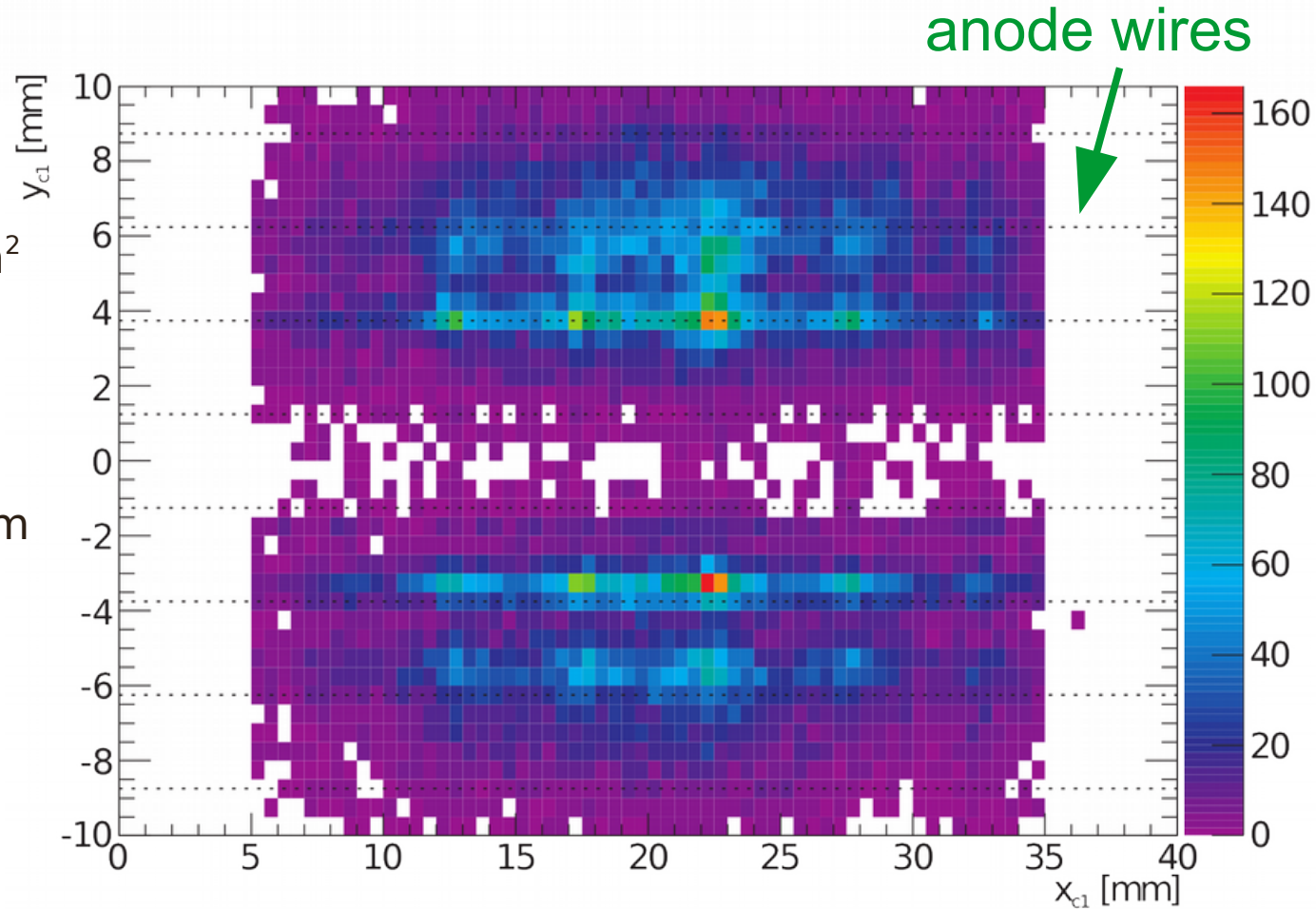
- Misalignment compensation for parallel displacement along wire direction & rotation of the chambers
- Position determined by pad-response function fit
- Resolution as Gaussian fit to **residual distributions**: positions from detectors // checked by lin. tracks between hodoscopes

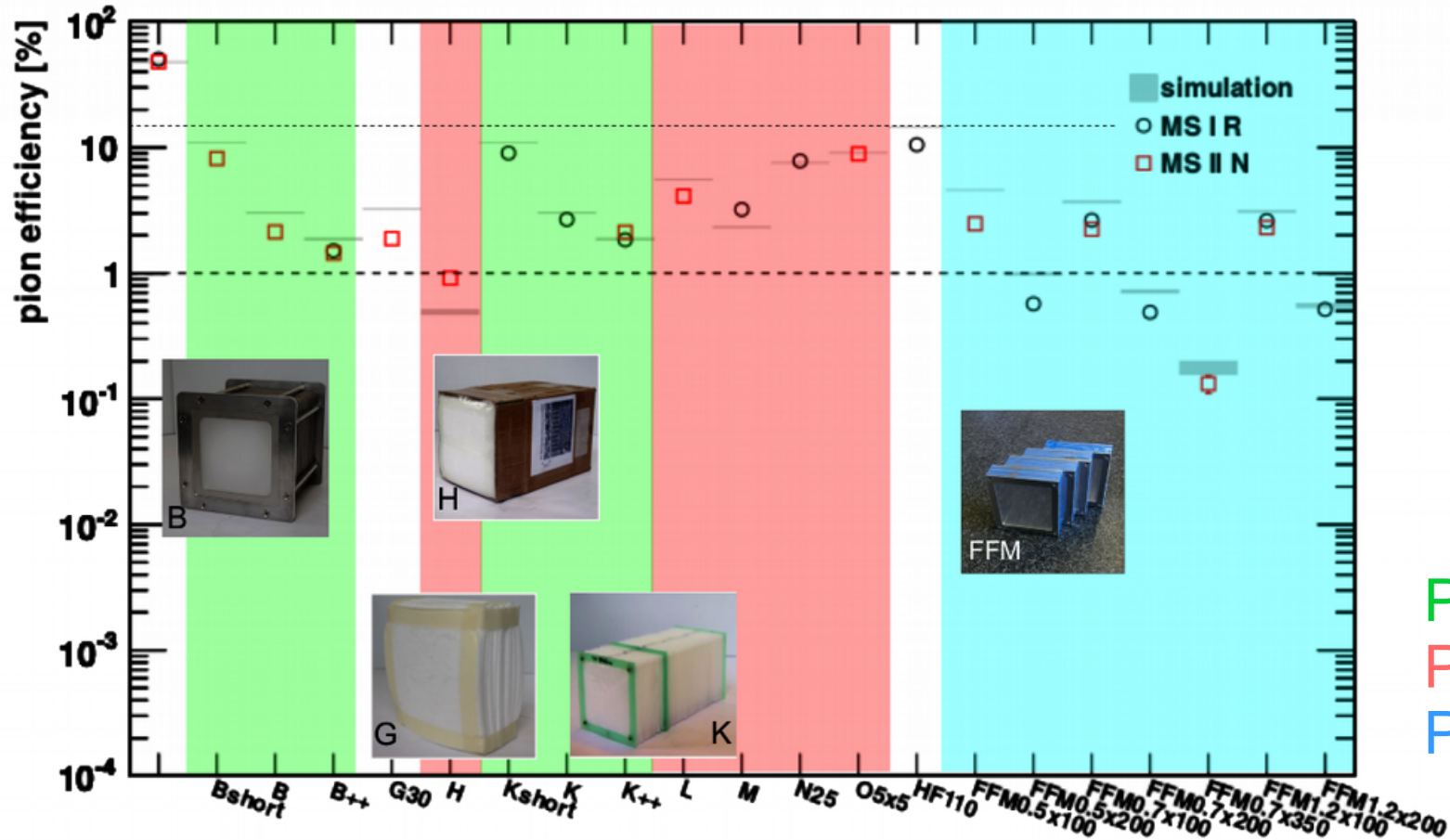
after scattering compensation





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





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