Status of the CBM-TRD

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4th HIC for FAIR Detector Systems Networking Workshop
20-Feb-2014

Outline

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The CBM experiment

- **CBM @ FAIR**
  - General overview
- **Transition-Radiation Detector**
  - General working principle
- **CBM-TRD - General overview**
  - Purpose and challenges
  - ➡Current design
    - *@ SIS 300*
    - *@ SIS 100*

Development of the CBM-TRD

- **Prototypes @ IKF**
  - Fast readout chambers
  - Radiators
- **Problems and Solutions**
  - Gas gain stability
- **Summary and Outlook**

CBM @ FAIR

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The dedicated heavy ion experiment

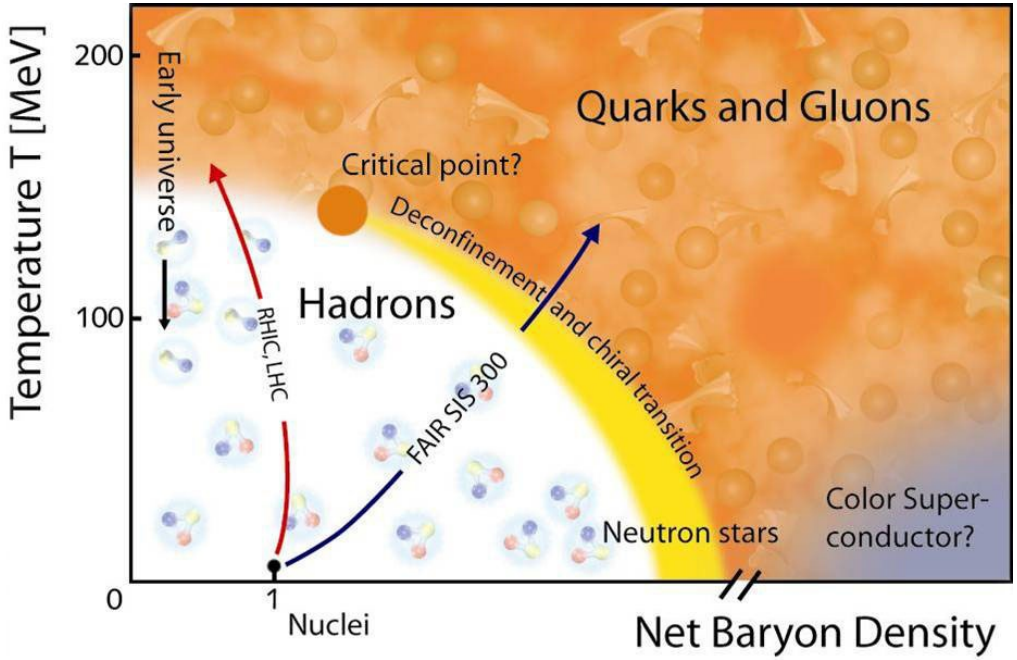
- Study phase diagram at low temperatures but high densities

Accelerators

- SIS 100:
  - *10.7 GeV/u for U^{92+}*
  - *5 x 10^{11} Ions per bunch*
- SIS 300:
  - *34 GeV/u for U^{92+}*

Observables

- Charmonium
- Direct photons
- Low mass dileptons
- ρ- and ϕ-mesons…



CBM @ FAIR

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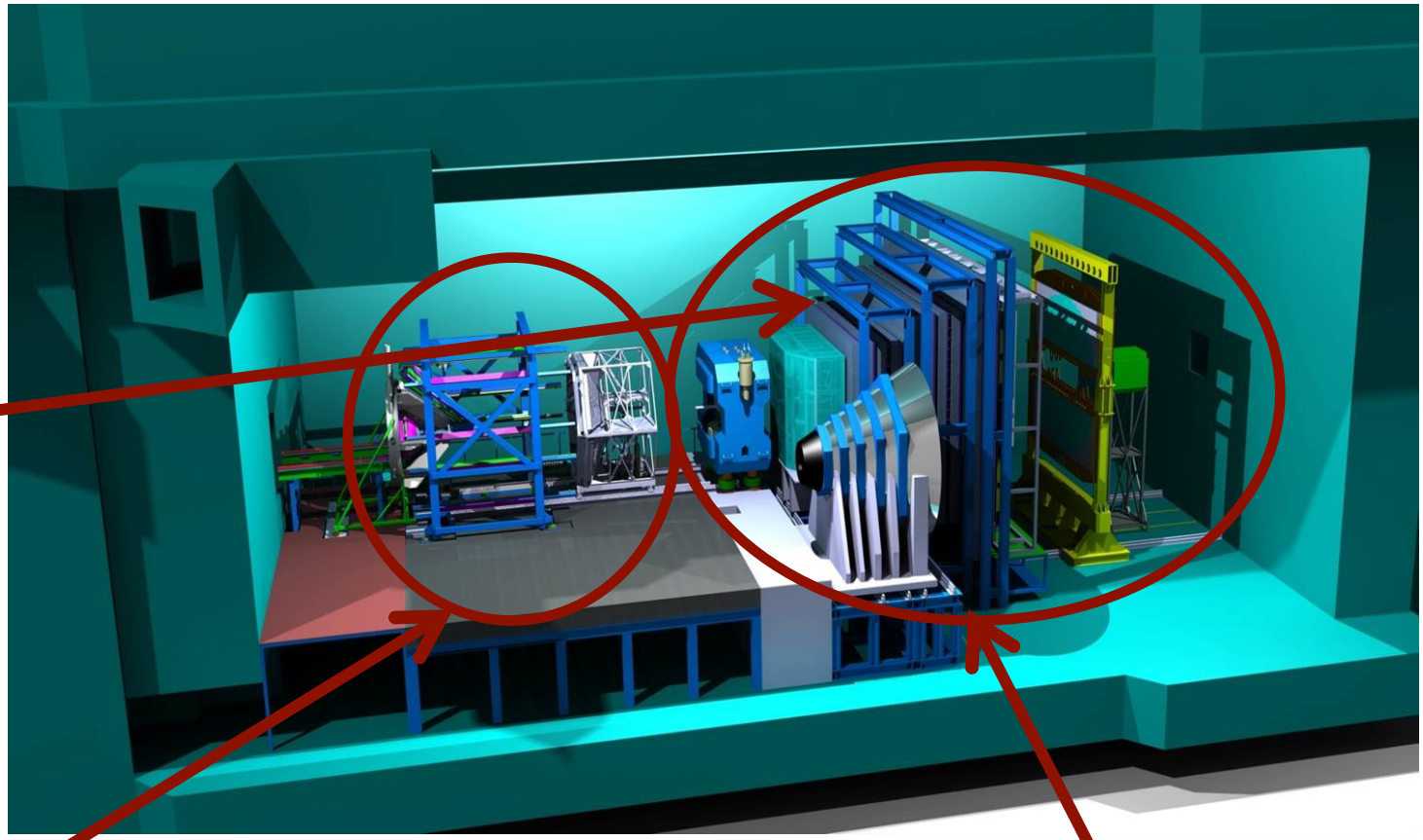
Detector systems:

- MVD
- STS
- RICH
- TRD
- ToF
- EMCal
- MuCh



HADES

CBM

Short reminder

Transition-Radiation Detector

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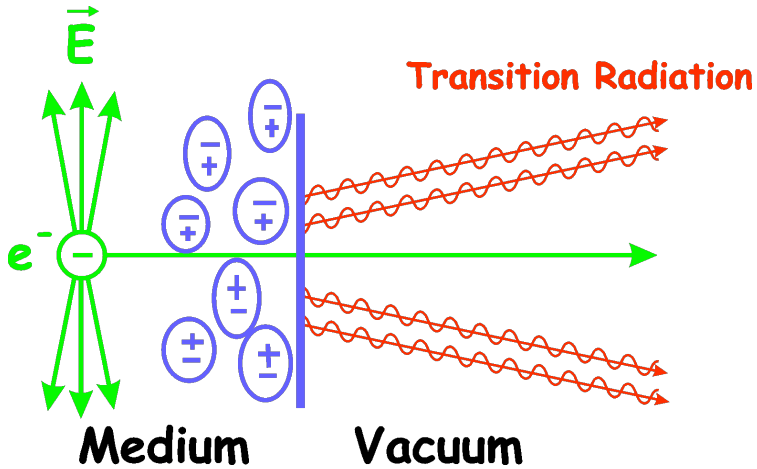
Working principle of a TRD

Radiator produces TR-photons ⇝ Readout chamber

TR-probability ~ γ-Factor

—› Electrons produce TR-photons, pions not

- **Radiator**
  - Transitions between two materials
    - *i.e. gas + foils*
    - *~ 20 µm foil*
    - *~ 1 mm gas gap*
  - 100 ~ 400 transitions
- **Readout chamber**
  - Photon detector
    - *Usually gas detector -› adds dE/dx information*



X1 Kollaboration. TR-Sceme. url: http://wwwkph.kph.uni-mainz. de/X1/images/trsceme.gif.

CBM-TRD

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Purose:

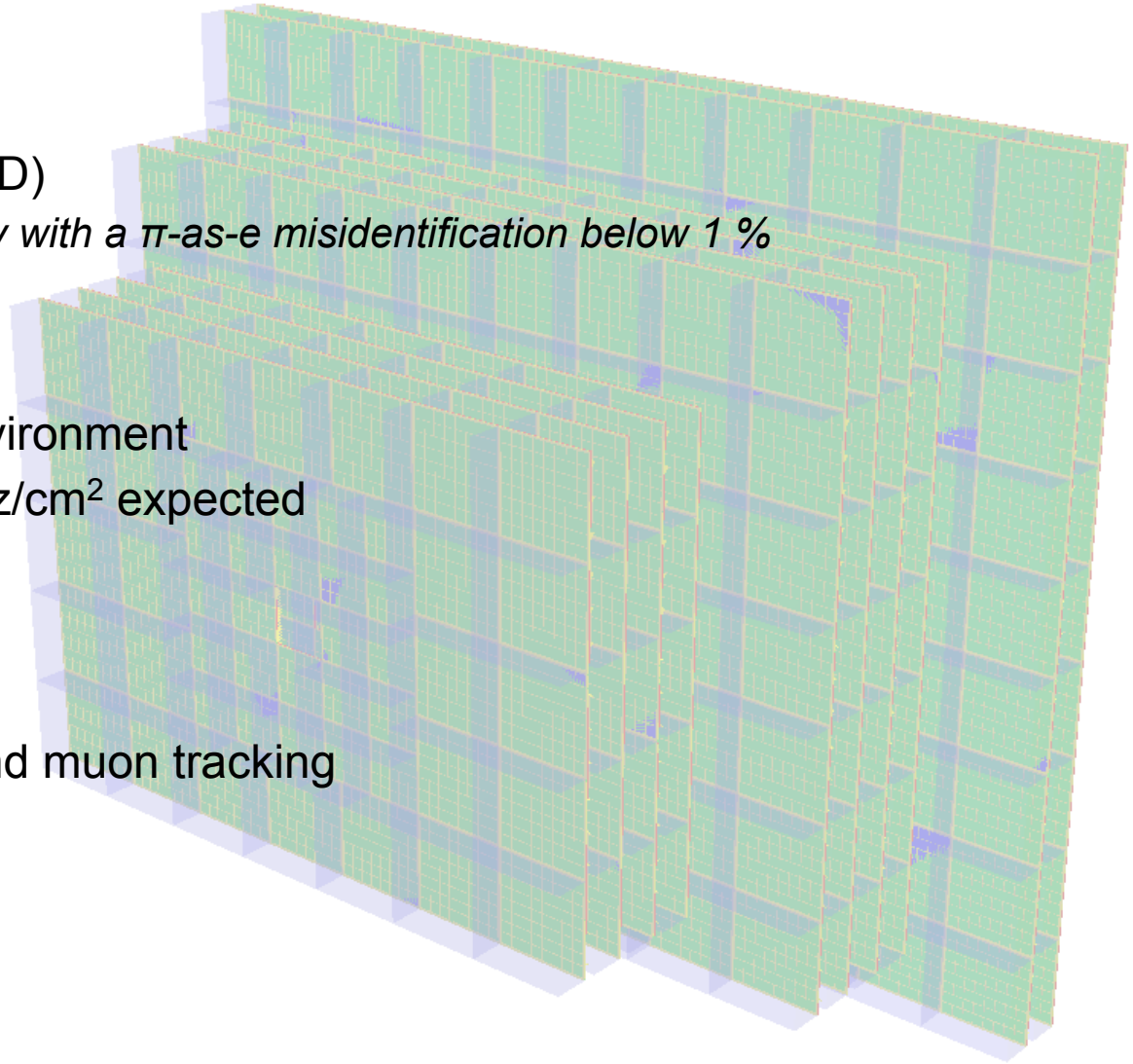
- Tracking
- Particle identification (PID)
  - *90 % electron efficiency with a π-as-e misidentification below 1 %*

Challenge:

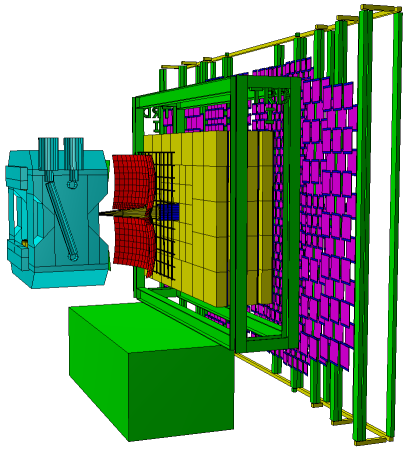
- High particle-density environment
- Hit rates around 100 kHz/cm^2 expected

Different setups for:

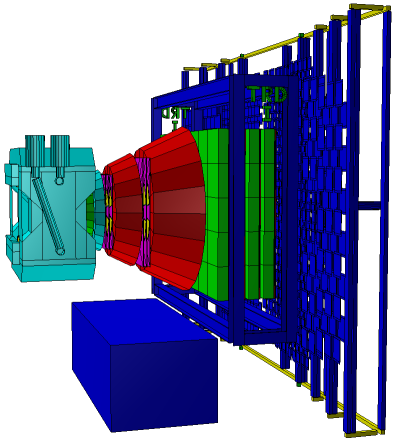
- SIS 100 and SIS 300
- Electron identification and muon tracking



Current Design

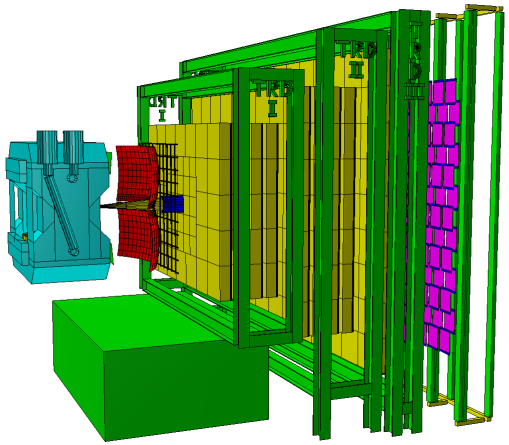


SIS 100

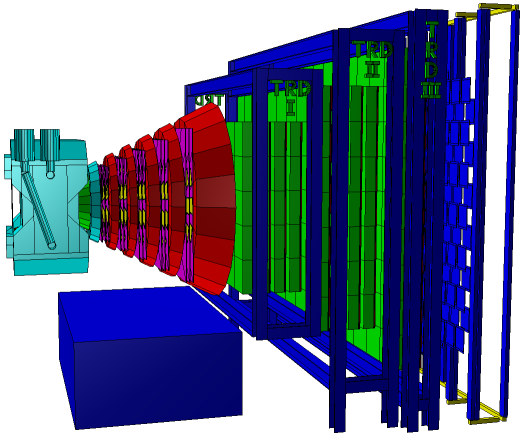


electron setup

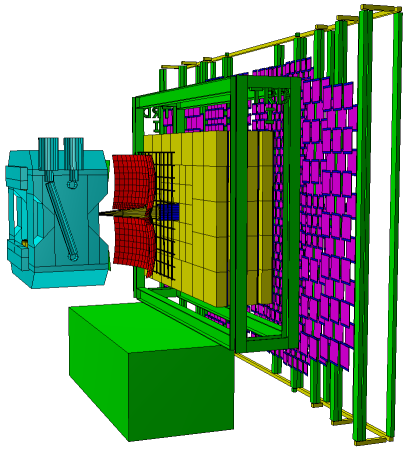
muon setup



SIS 300



Current Design



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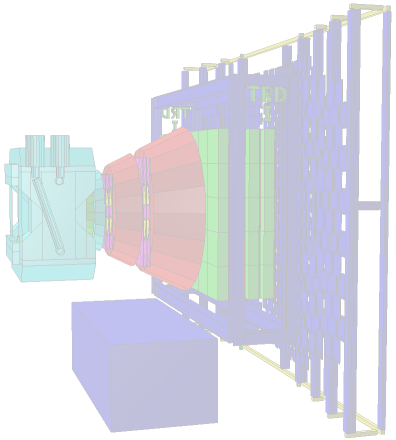
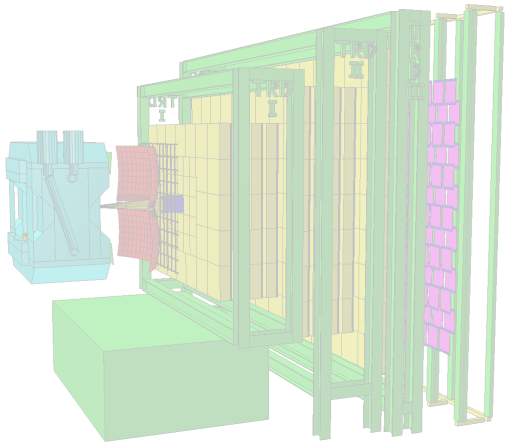
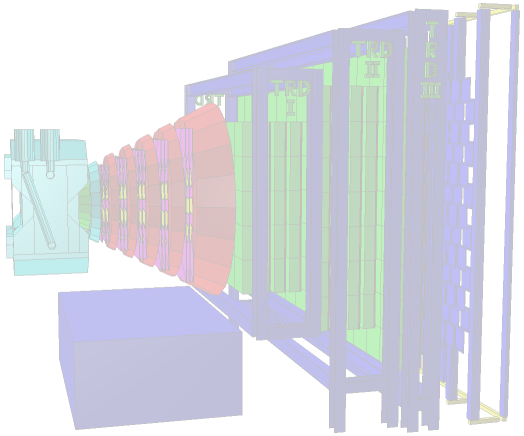
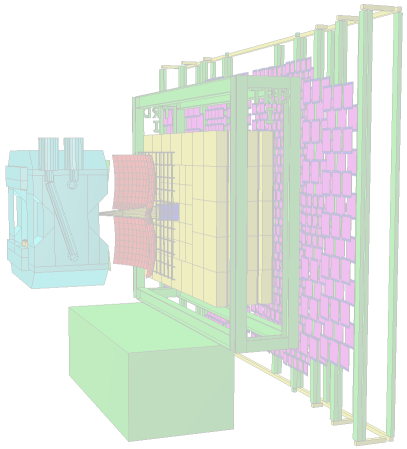


electron setup ‹–› 1 station with 4 layers

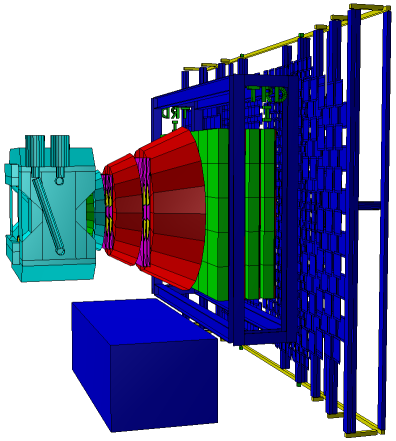




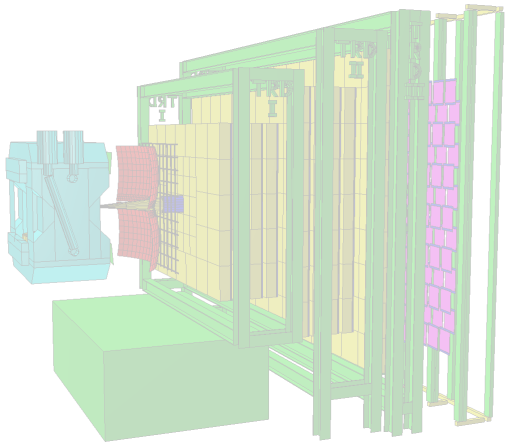
Current Design

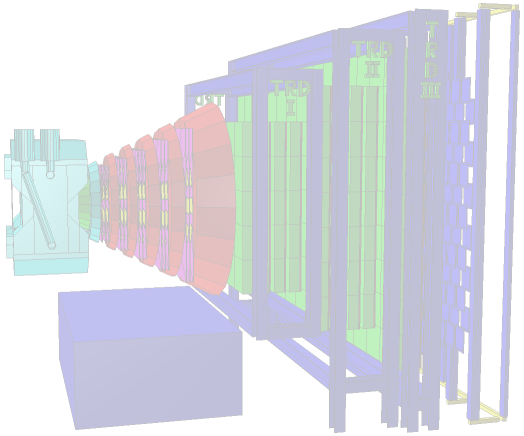


SIS 100

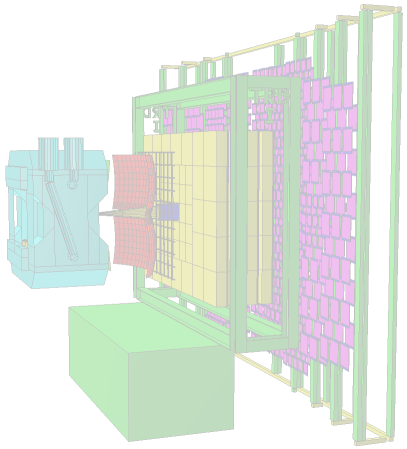


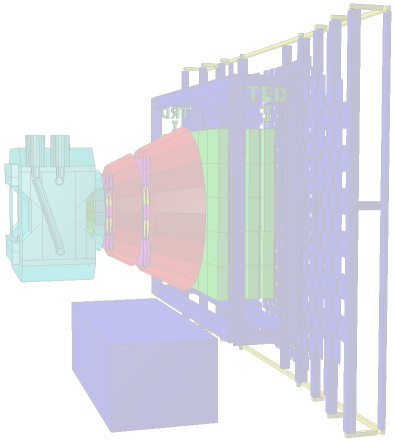
1 station with 4 layers ‹–› muon setup



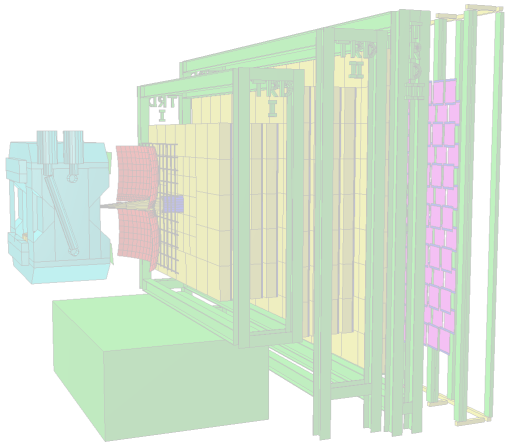


Current Design

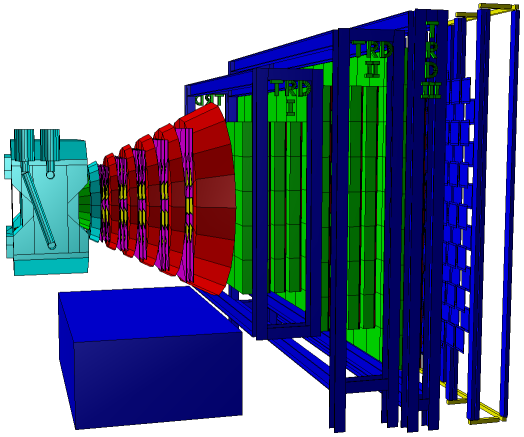




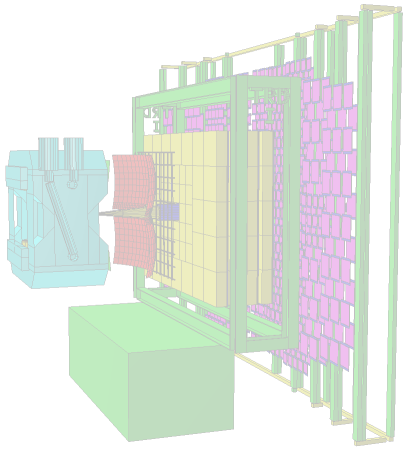
3 stations with 4-4-2 layers ‹–› muon setup

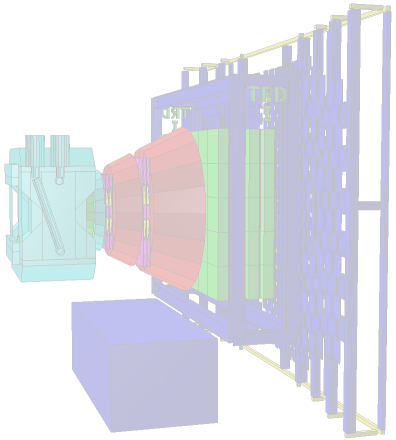


SIS 300

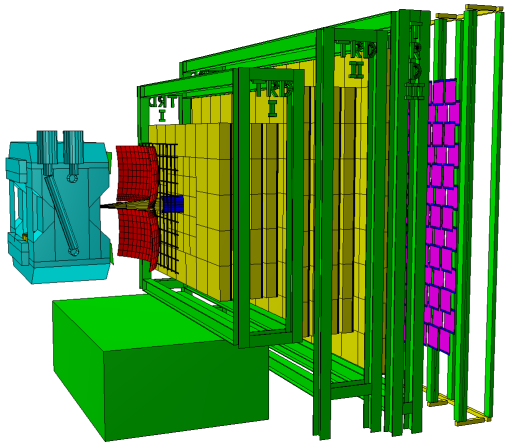


Current Design





electron setup ‹–› 3 stations with 4-4-2 layers



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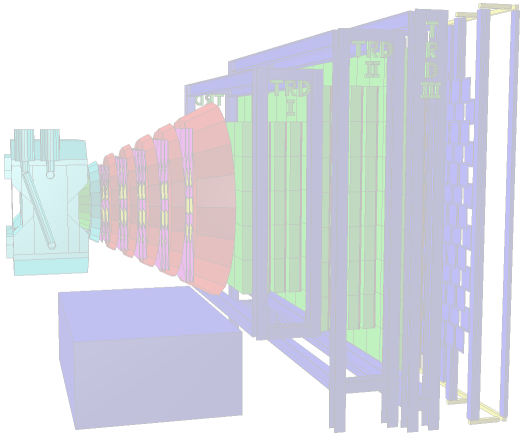
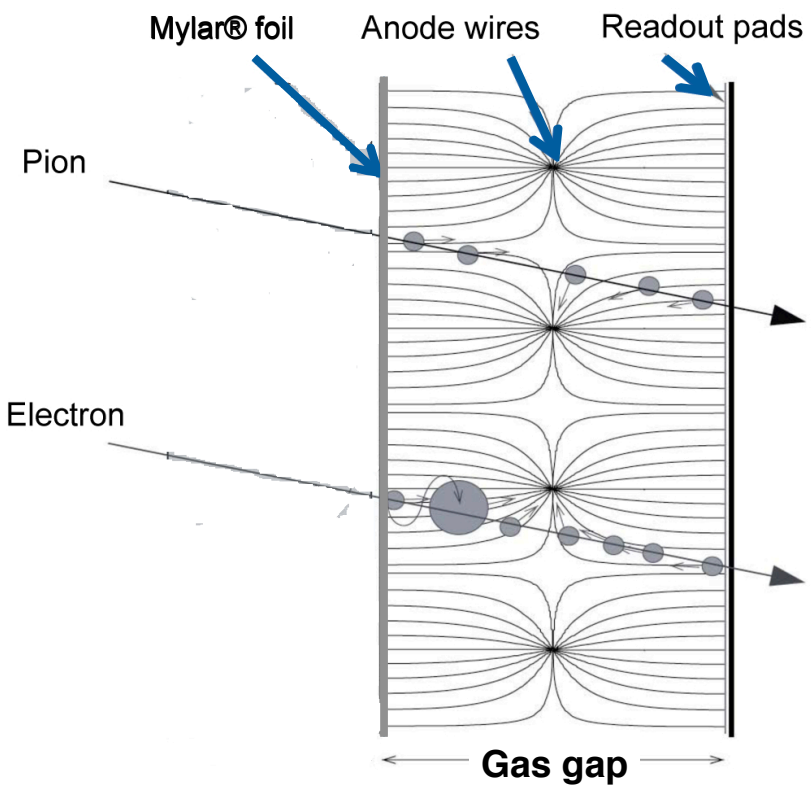


Development of the CBM-TRD

Approach



Different approaches by:

- **Münster**
- **Bucharest**
- **Frankfurt**

Münster and Bucharest:

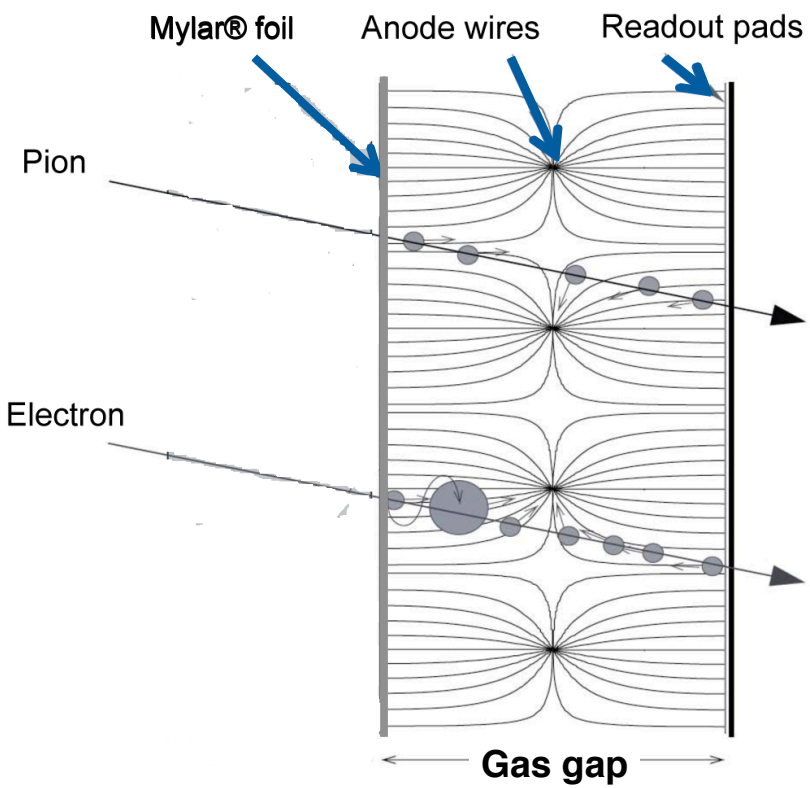
- **~ 12 mm MWPC with drift region**

Frankfurt

- **8 and 10 mm MWPC**

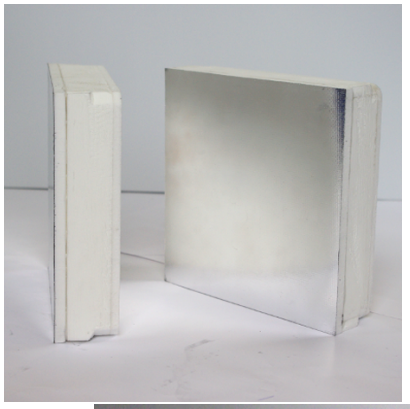
➡Fastest readout chambers

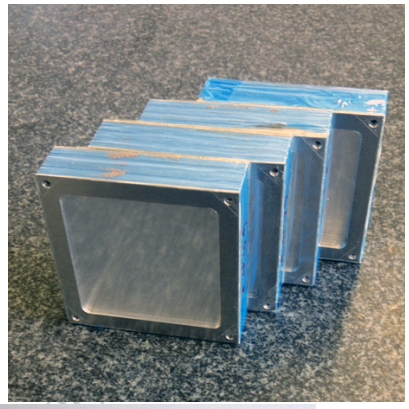
Prototypes @ IKF

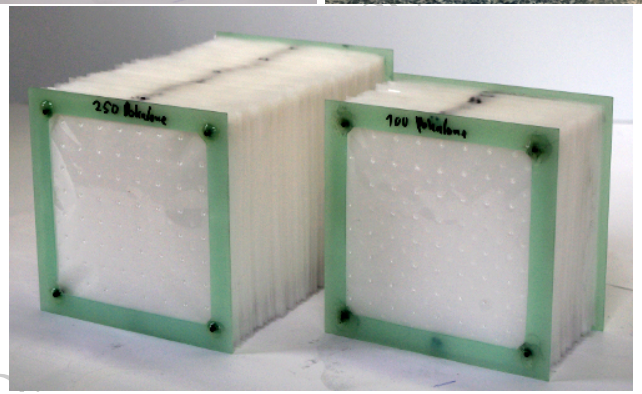


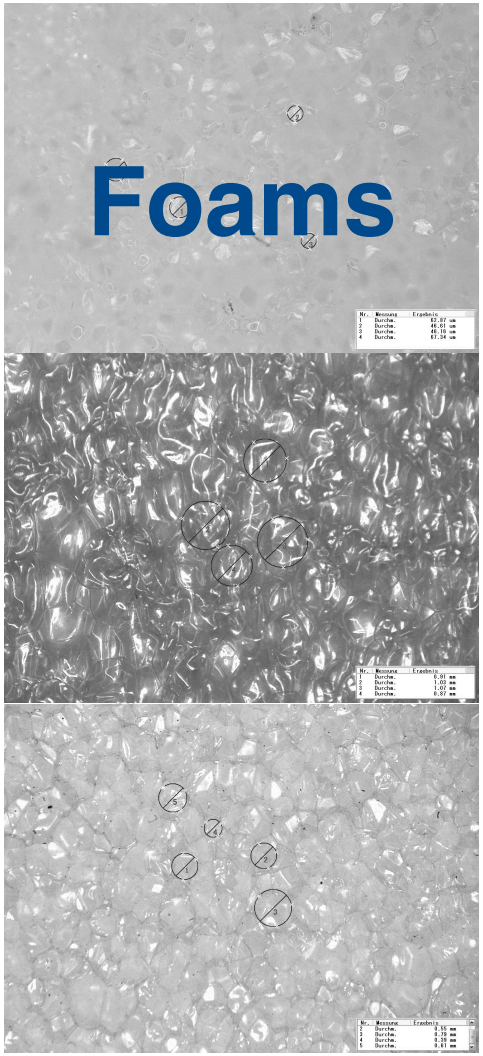
Serial #	Active Area [cm	Pad Size [mm	Gas Gap [mm]
FFM-p1	8×6	7.5×16	4+4
FFM-p2	8×6	7.5×16	5+5
FFM-001	15×15	4.7×49.7	4+4
FFM-002	15×15	4.7×49.7	5+5
FFM-003	15×15	4.7×49.7	6+6
FFM-004	15×15	4.7×49.7	5+5
FFM-005	15×15	4.7×49.7	6+6
FFM-006	15×15	4.7×49.7	4+4
FFM-007	15×15	4.7×49.7	5+5
FFM-010	59×59	15/45/75 × 7.125	4+4
FFM-011	59×59	15/45/75 × 7.125	5+5

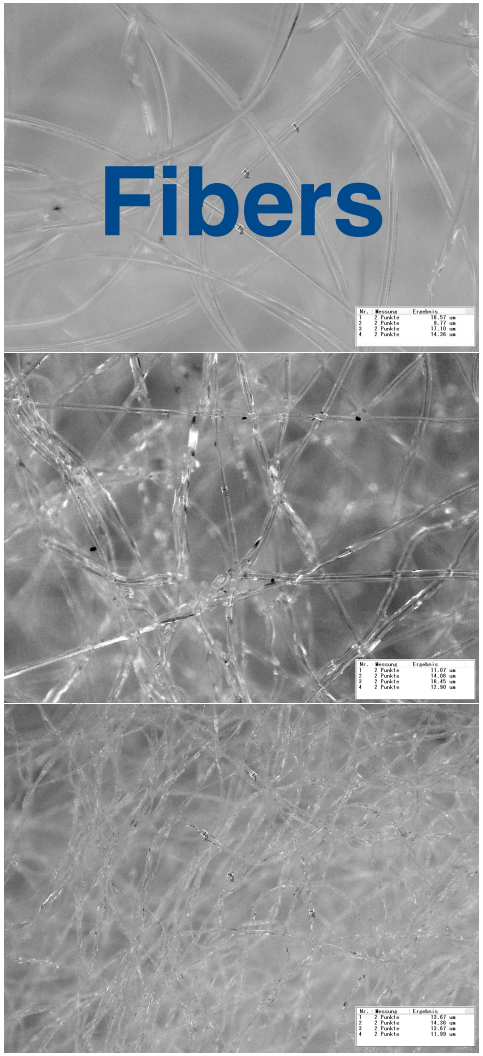
Radiators











Radiators

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Regular foils

Irregular foils

Foams

Fibers

Radiator	Configuration	Material	⟨ [µm]	⟨ [µm]	Thickness [mm]	Transitions
Alice Type	Sandwich	reinforced HF71	8	75	2×8	2×96
		Polypropylene fibers	17	50	30	448
R005	Sandwich	HF71	8	75	2×8	2×96
		Polyethylene Fibers	15	120	103	760
R003	Sandwich	HF71	8	75	2×8	2×96
		Organic Fibers	13	40	226	4200
Foil Radiators	Regular	Polyethylene Foils	20	500	78-182	150-350
Foil Radiators	Regular	Polyethylene Foils	20	700	108-252	150-350
Foil Radiators	Regular	Polyethylene Foils	20	1200	183-247	150-350
Micro-structured Foil	Irregular	POKALON N470	24	700	250	350
Type N	Foam	Polyethylene (Cell-Aire)	12	600	260	425
R002	Foam	Polyethylene (hard)	12	600	260	424
R007	Foam	Polyethylene (soft)	12	1000	118	116
HF 110	Foam	Rohacell HF 110	15	75	30	333
Type H	Foam	Polyethylene (Cell-Aire)	12	900	177	388

Performance tests

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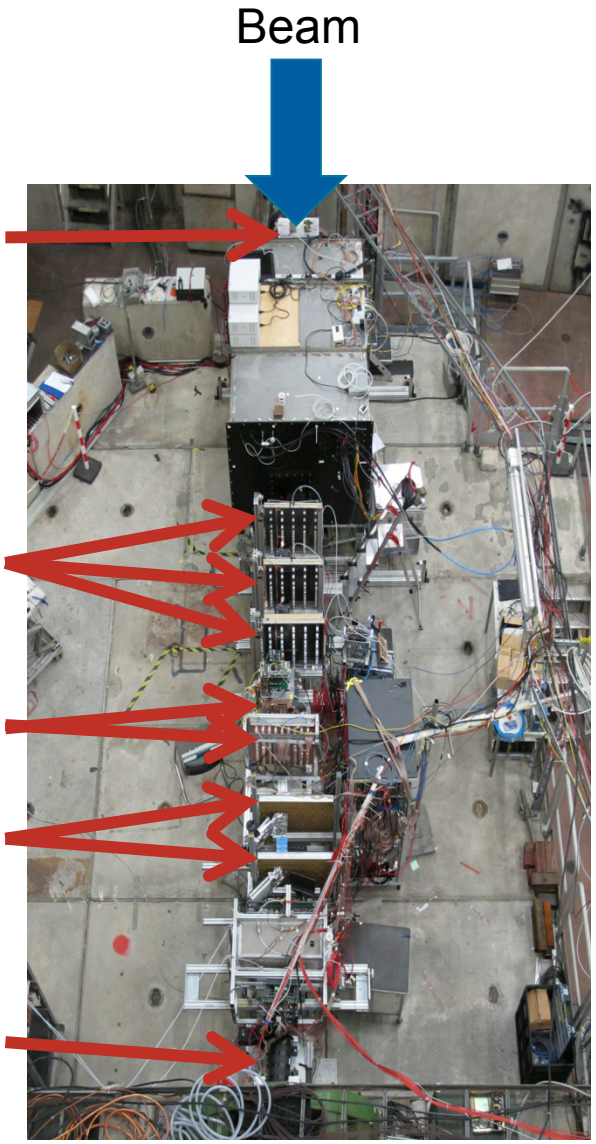
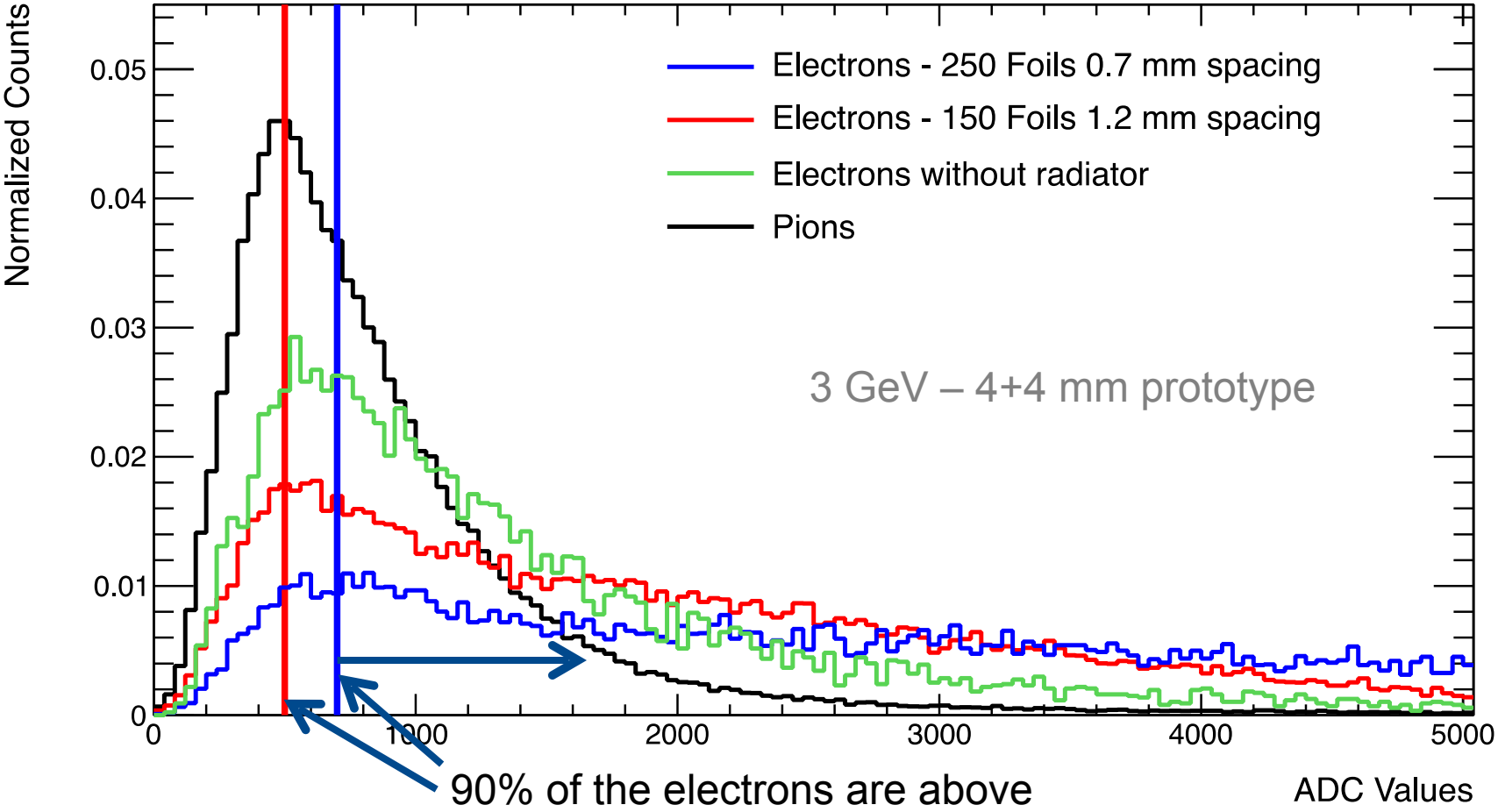
Laboratory tests with ^{55}Fe-Source

In-beam tests @ CERN-PS
‹—› mixed electron-pion beam

Used readout electronic:
SPADIC v0.3 - http://spadic.uni-hd.de/

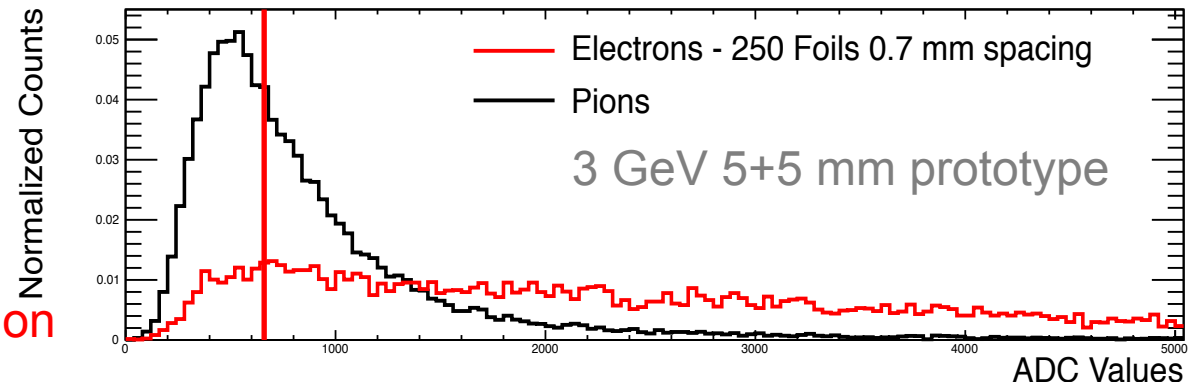


Performance tests

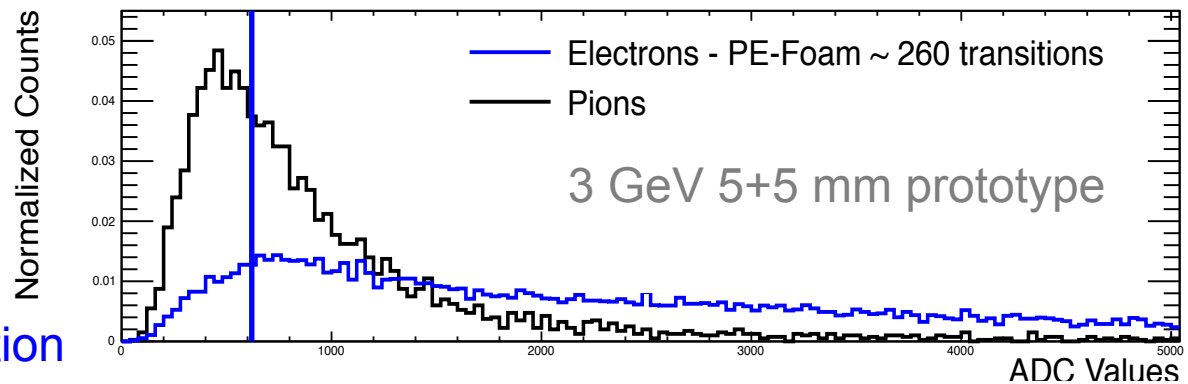


Performance tests

- **Regular foils**
  - 250 foils
  - 20 µm thick foils
  - 90% electrons
  - ➡ 38.1 ± 0.4% π-contamination

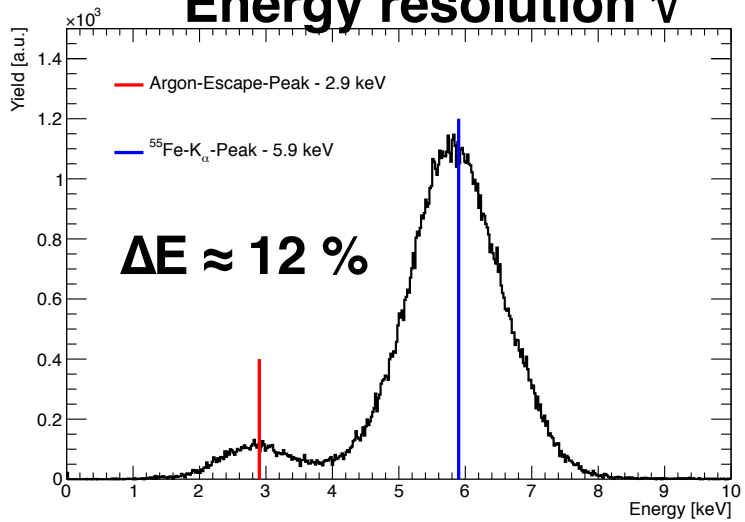


- **PE-foam**
  - ~ 260 transitions
  - ~ 25 µm thick PE
  - ~ 1 mm bubble size
  - 90% electrons
  - ➡ 40.2 ± 0.2 % π-contamination

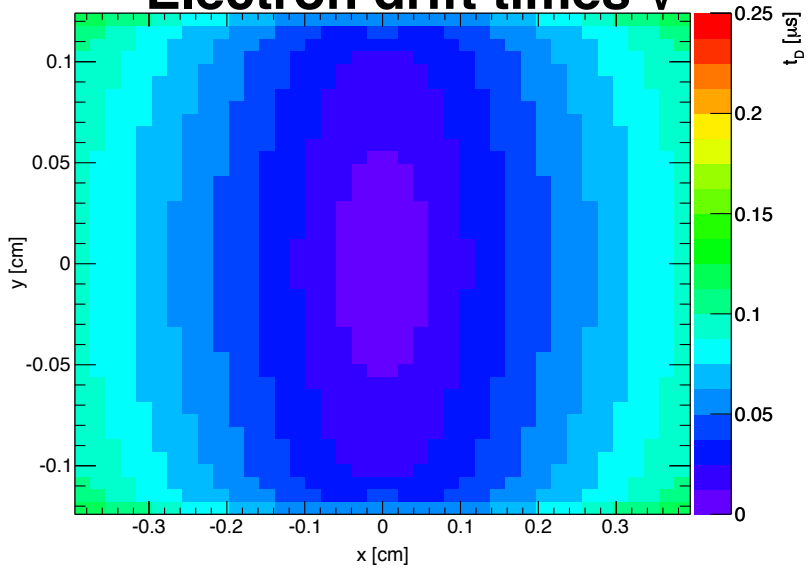


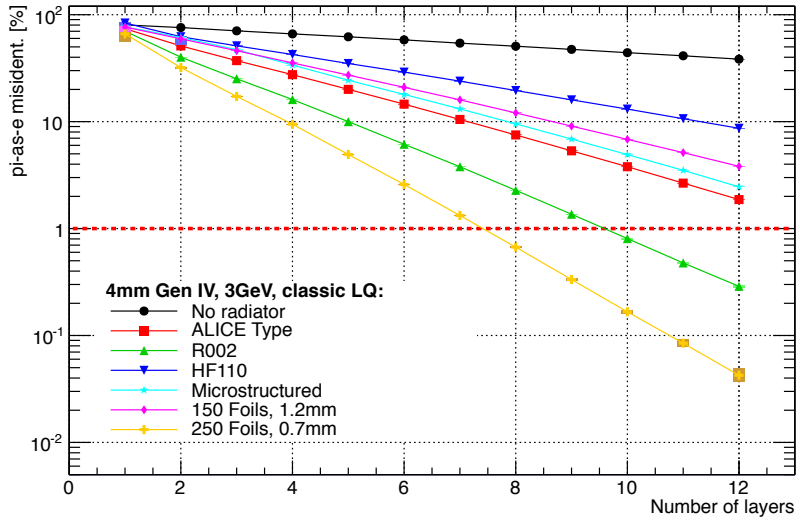
General results

Energy resolution √



Electron drift times √





‹— PID performance √

Challenge

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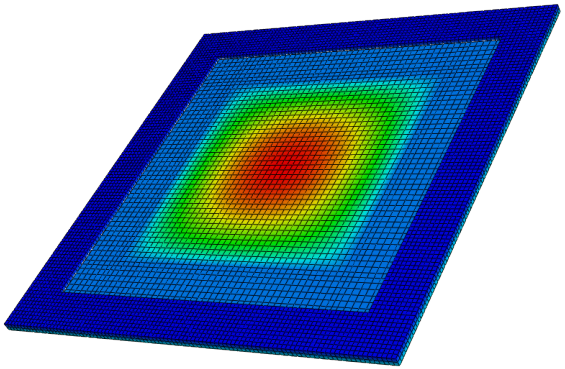
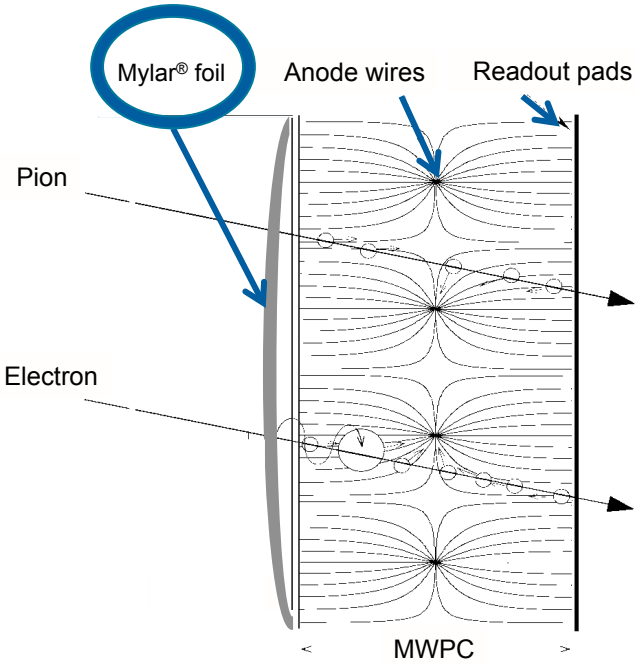
Electric field between entrance window and anode wires

—› Electrical field looses homogeneity because of deformations of the foil

—› Position and pressure dependent gas gain



K. Reuß. „Studien zur Ausdehnung des Eingangsfensters des CBM-TRDs“. Bachelor Arbeit. Institut für Kernphysik Frankfurt, März 2013.



First step

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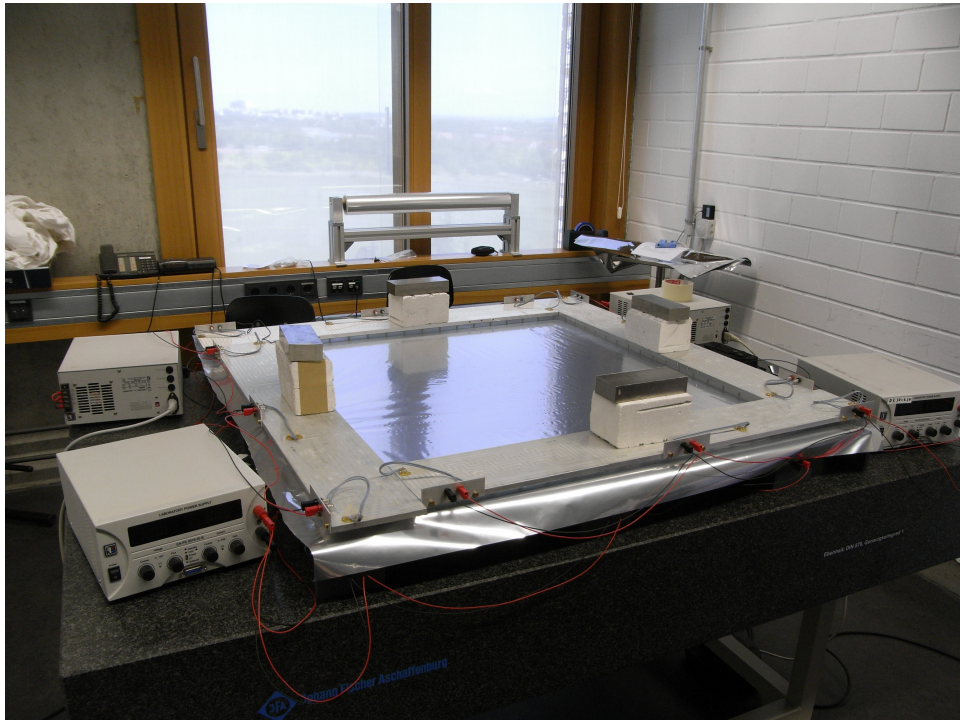
Procedure to stretch the Mylar® foil

- **Based on thermal expansion**
  - Michael Staib, et al.
    - CERN Internal RD51-Note-2011-004
- **Foil fixed in a Plexiglas® frame**
- **Frame is heated up to ≈ 55˚C**

➡Homogeneously stretched foil



Before - After

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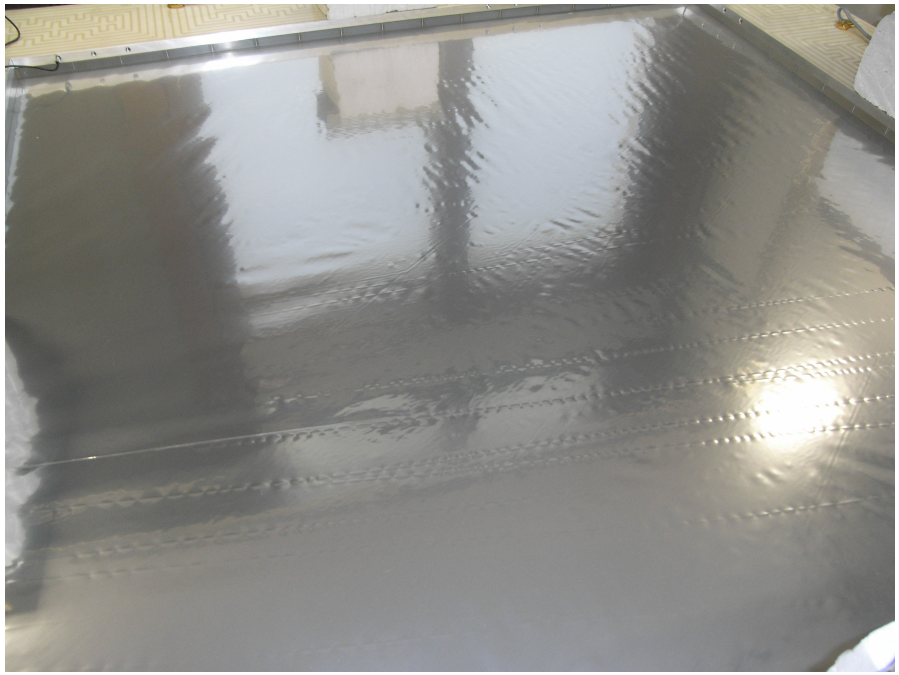
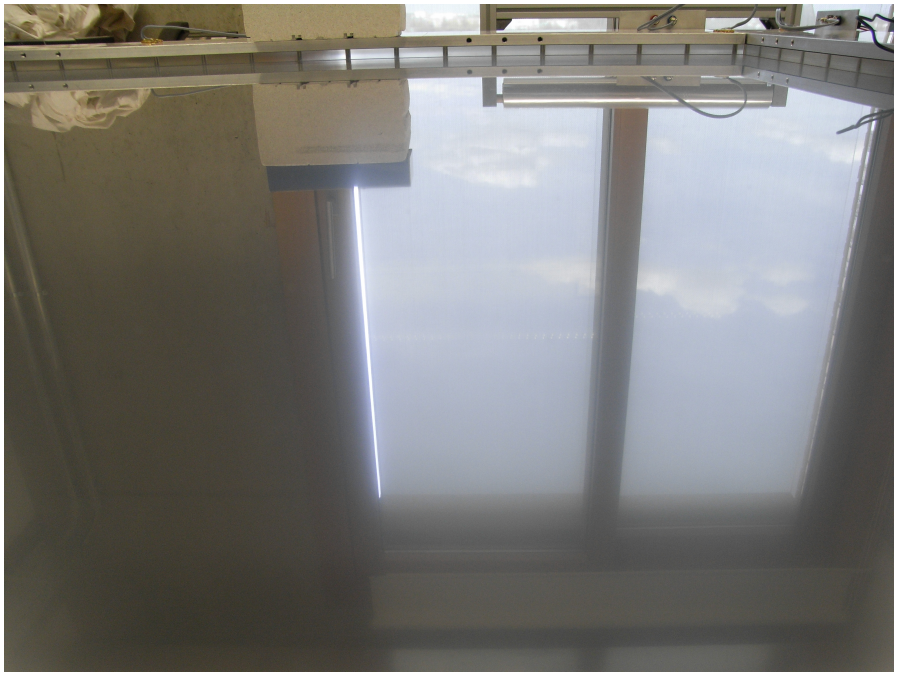
~ 1 m^2 of foil stretched in the frame at 55˚C

Before



After



Inhomogeneous gas gain

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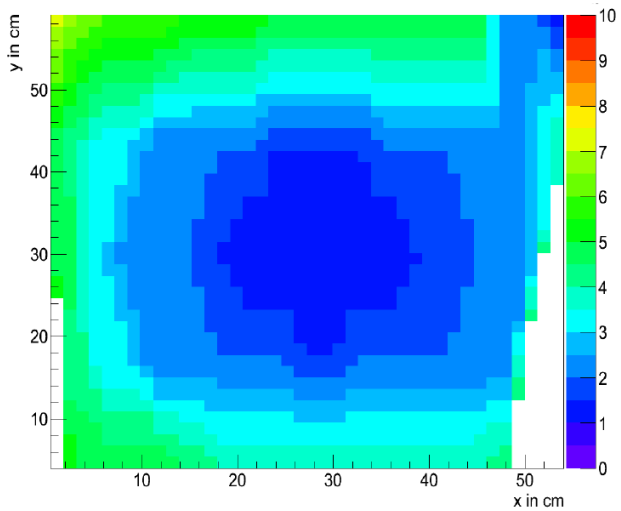
Laboratory measurement

Setup:

- **59x59 cm² Prototype**
- **Stretched foil**
- **Overpressure in the chamber**
  - 400 µbar
- **^{55}Fe-Source**



—› Still deformation of the entrance window

—› Position and pressure dependent gas gain ⚡

Balle´, Tanita: Studien zum Einfluss der Ausdehnung des Eingangsfensters auf die Gasverst¨arkung des CBM-TRD. Bacherlor Thesis, December 2013

Possible solutions 1/3

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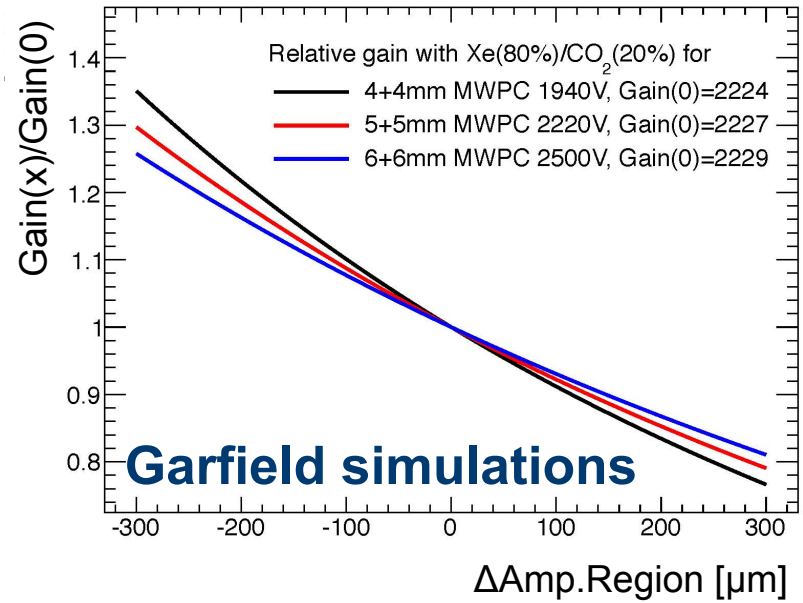
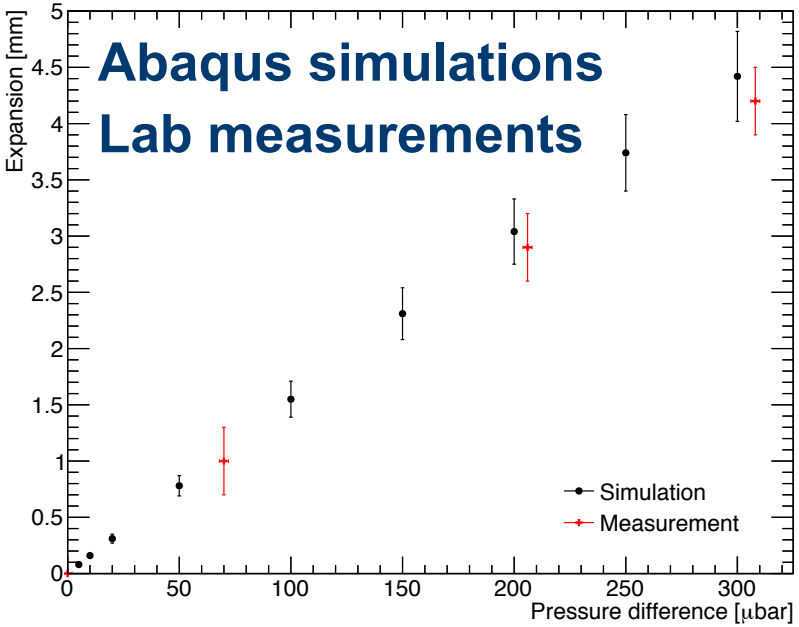
Data correction algorithms:

- **Understand quantitive correlation between the gain variations and the overpressure in the chamber**





E. Hellbär. „Elektrostatische Simulationsstudien zum Übergangsstrahlungsdetektor des CBM-Experiments“. Bachelor Arbeit. Institut für Kern- physik Frankfurt, Jan. 2013.

K. Reuß. „Studien zur Ausdehnung des Eingangsfensters des CBM-TRDs“. Bachelor Arbeit. Institut für Kernphysik Frankfurt, März 2013.

Possible solutions 1/3

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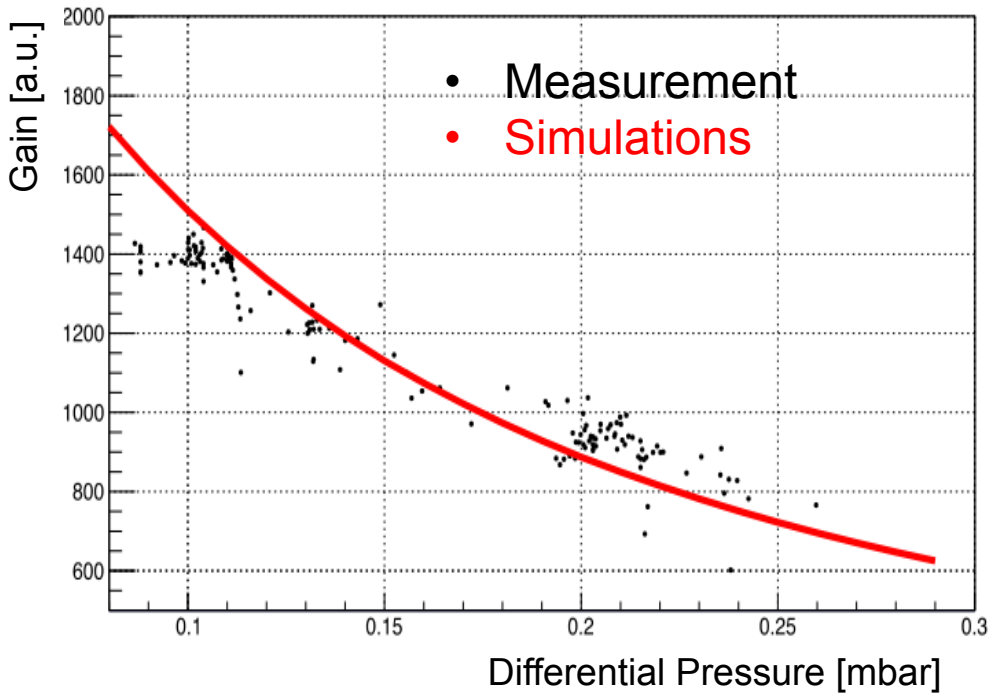
Data correction algorithms:

- **Understand quantitive correlation between the gain variations and the overpressure in the chamber**

- **Measured pion peak**

➡ **Gas gain**

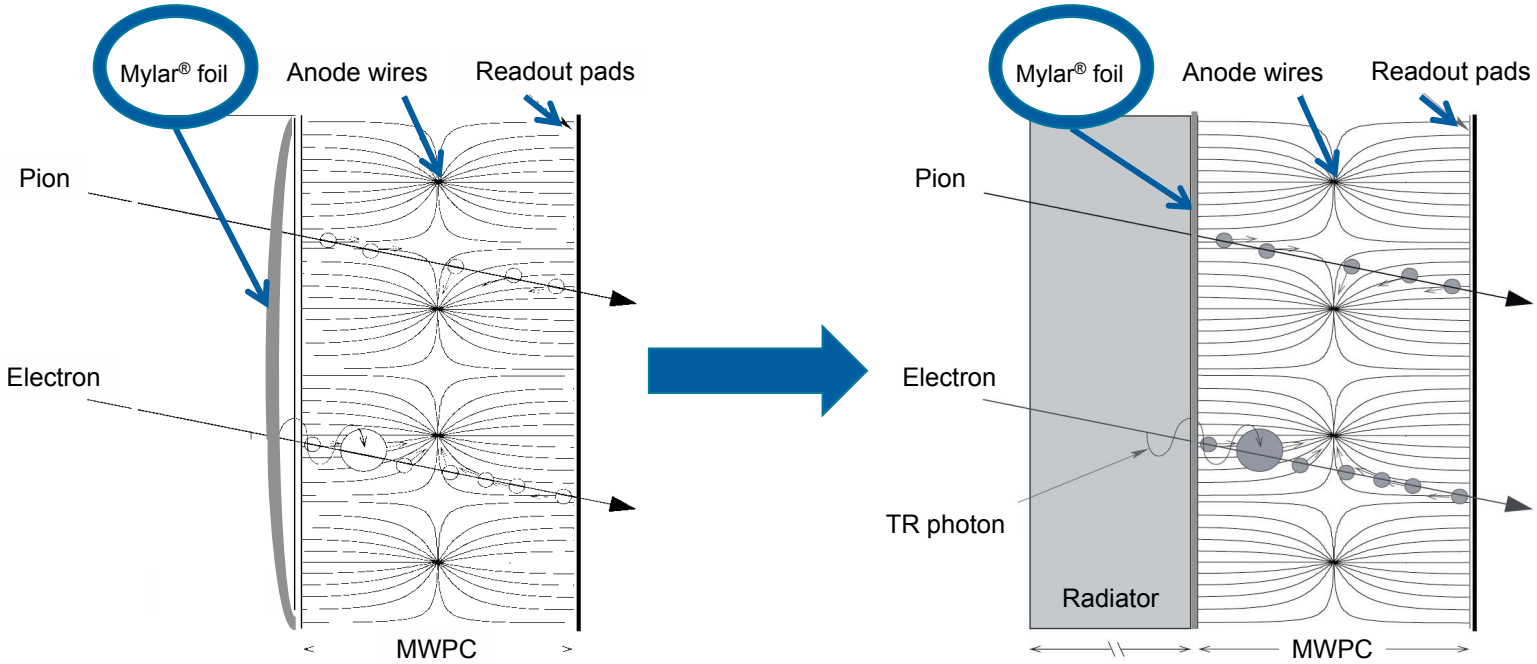


Possible solutions 2/3

Mechanical stabilisation by the radiator:

- **Several foam radiators showed a good PID performance**

➡ **Use solid foam as radiator and connect it to the foil**



Possible solutions 2/3

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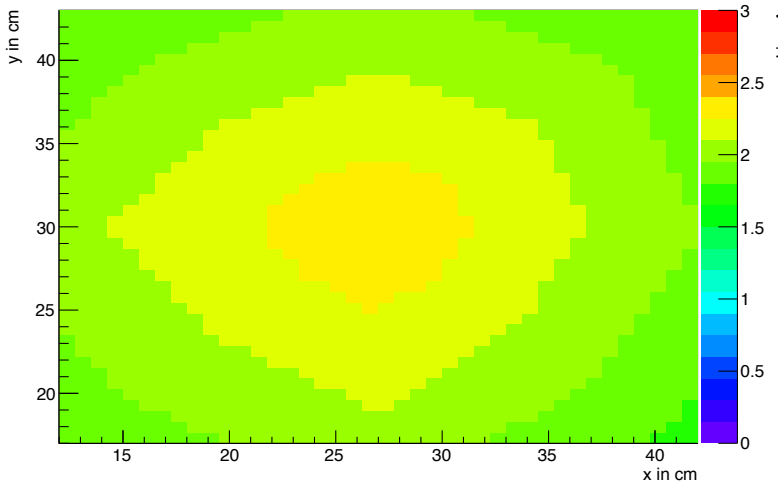
Mechanical stabilisation by the radiator:

- **Several foam radiators showed a good PID performance**

➡ Use stiff foam as radiator and connect it to the foil

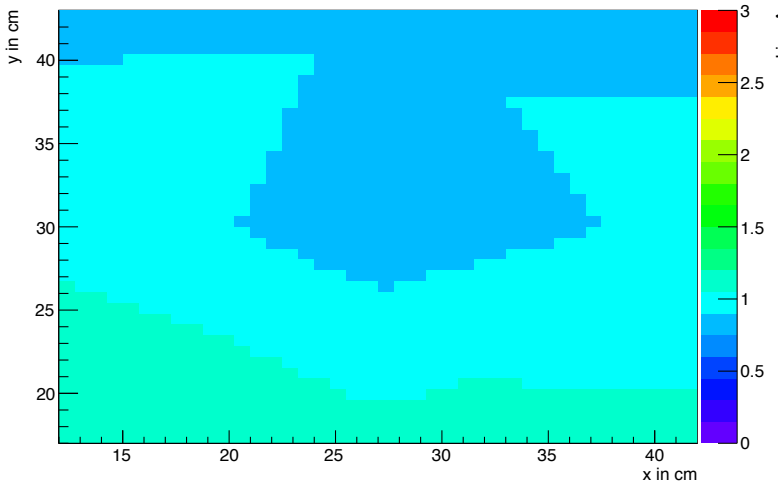
No radiator

Gain(200µbar)/Gain(400µbar)



With radiator

Gain(200µbar)/Gain(400µbar)



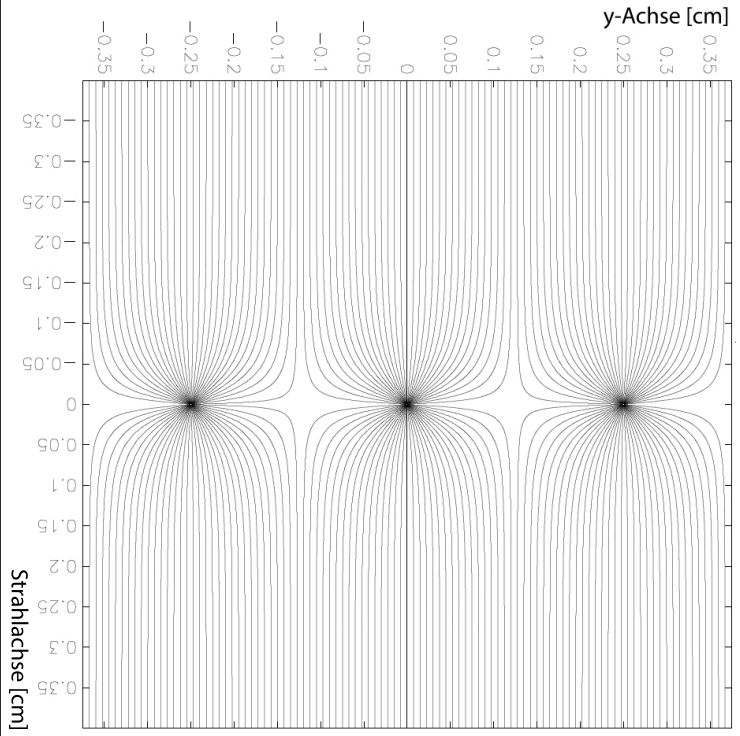
Balle´, Tanita: Studien zum Einfluss der Ausdehnung des Eingangsfensters auf die Gasverstärkung des CBM-TRD. Bachelor Thesis, December 2013

➡But not a solution for under pressure

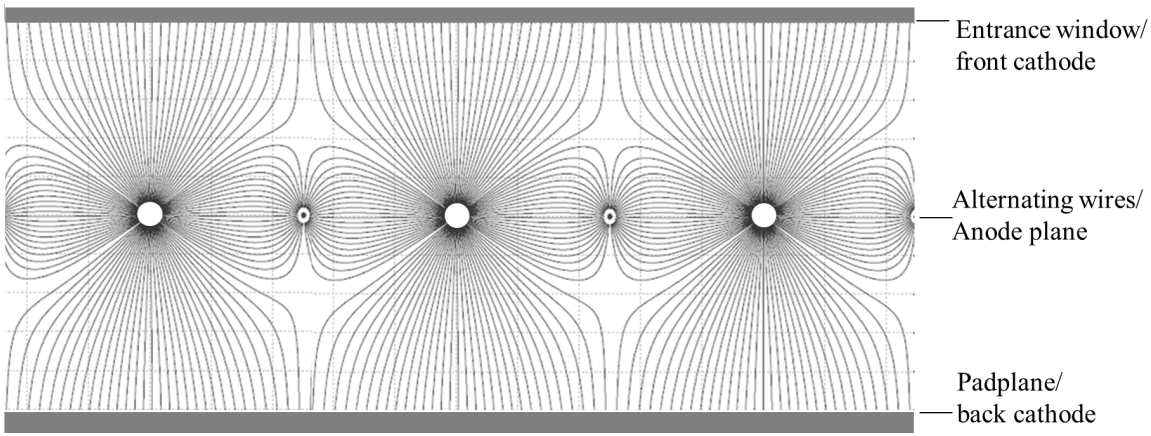
Possible solutions 3/3

Alternating wire geometry:
Field wires between the anode wires

inspired by: D.Varga et al. Nuclear Instruments and Methods in Physics Research A 648 (2011) 163–167



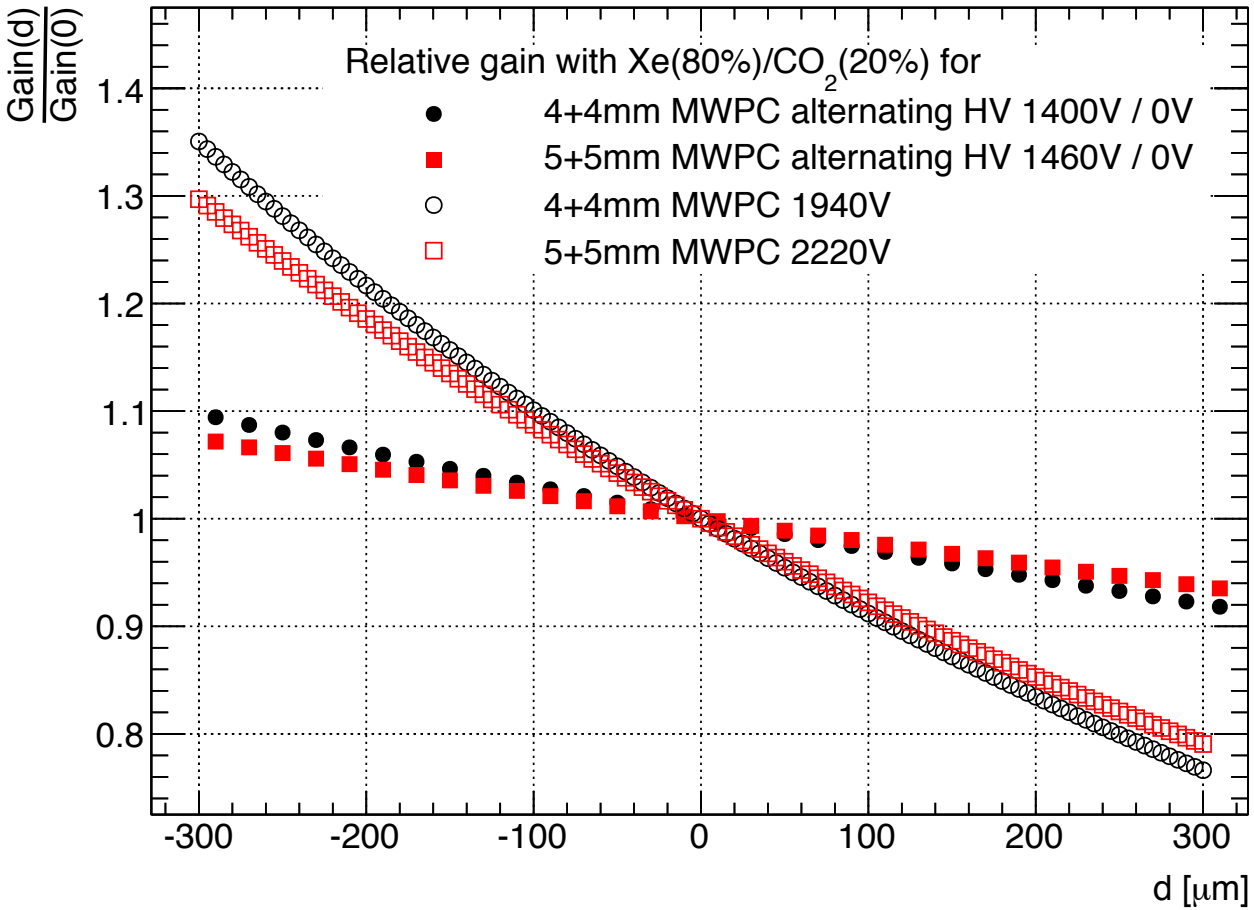
„Classical“ geometry



Alternating wire geometry

Possible solutions 3/3

Garfield simulations:



Possible solutions 3/3

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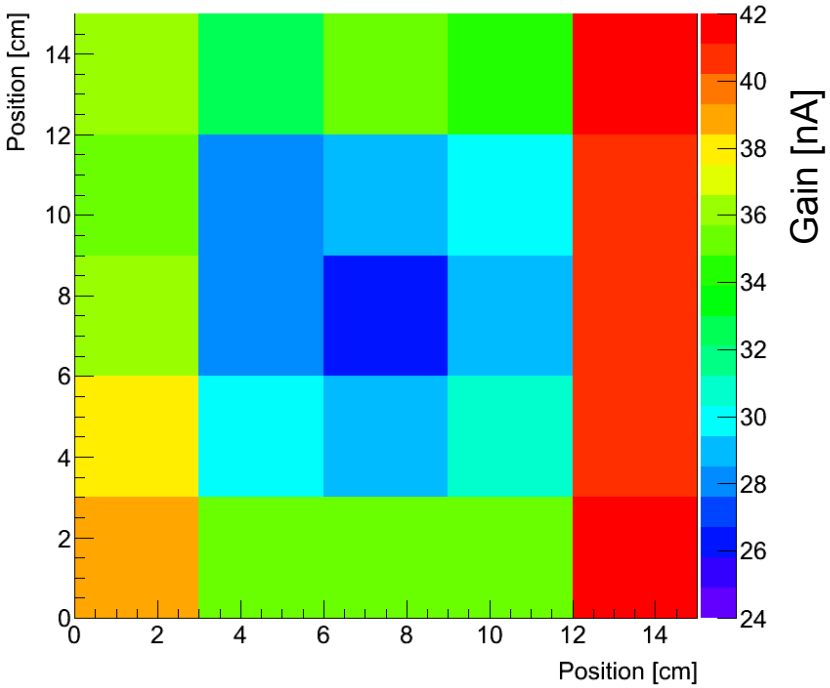
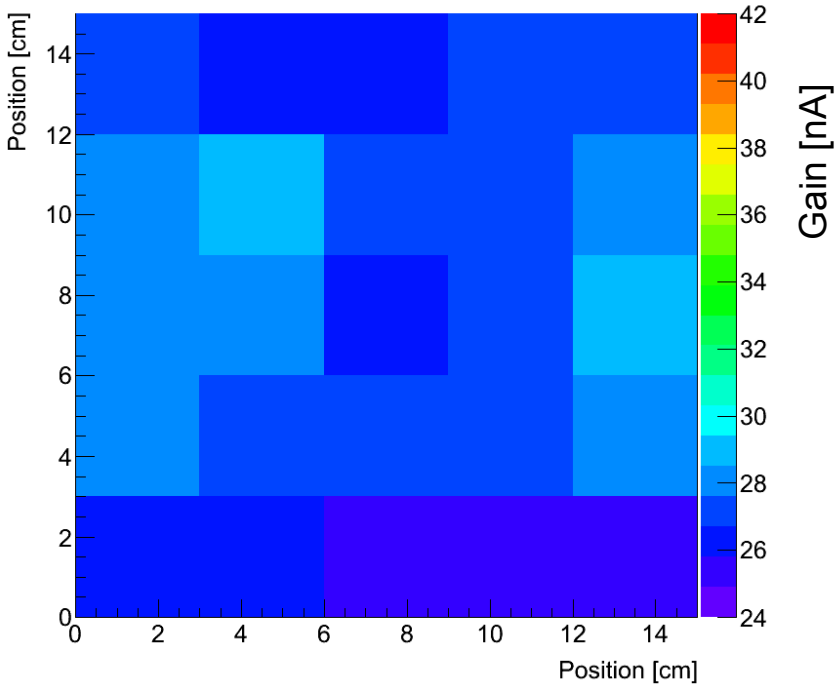
First measurements:
Gain map @ ~280 µbar overpressure



„Classical“ geometry



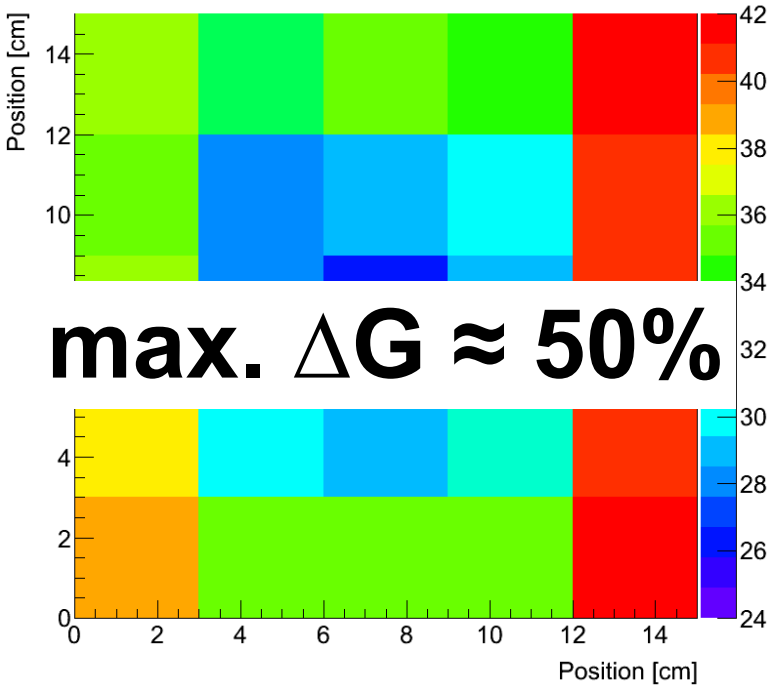
Alternating wire geometry

S. Gläßel: Bachelor Thesis, to be published.

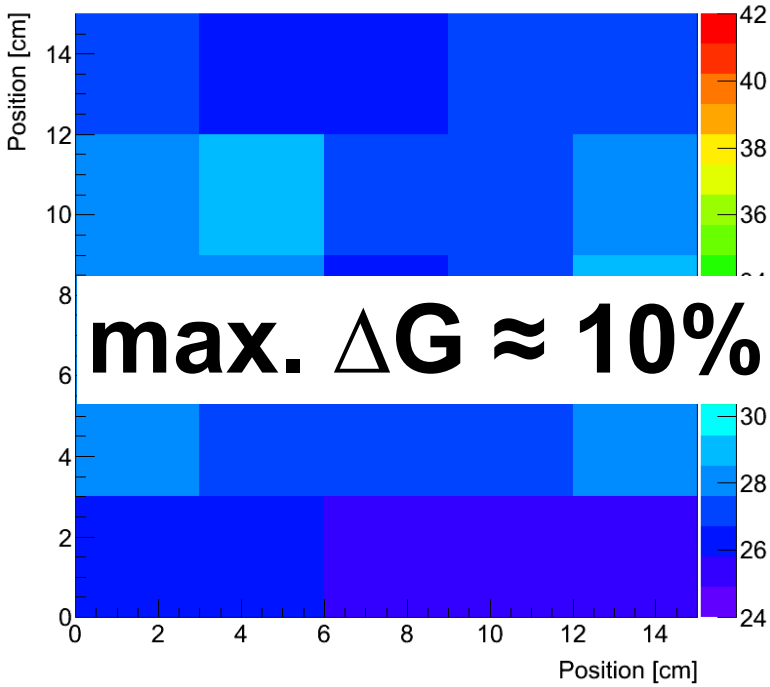
Possible solutions 3/3

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

First measurements:
Gain map @ ~280 µbar overpressure



„Classical“ geometry



Alternating wire geometry

S. Gläßel: Bachelor Thesis, to be published.

Summary and Outlook

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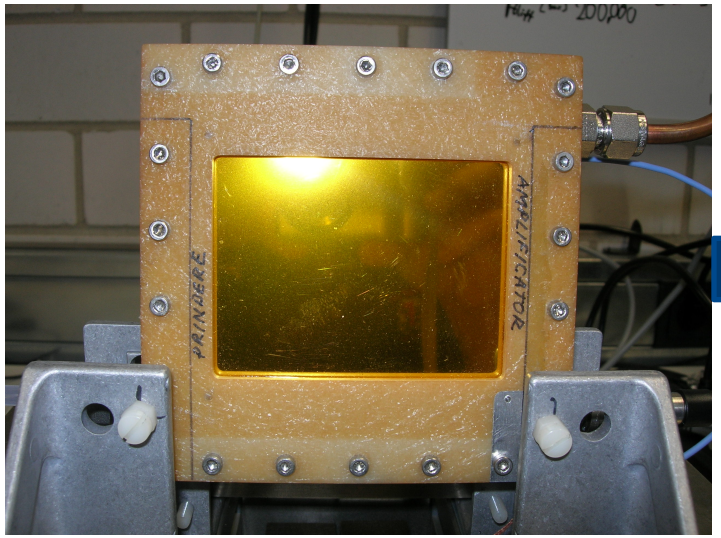
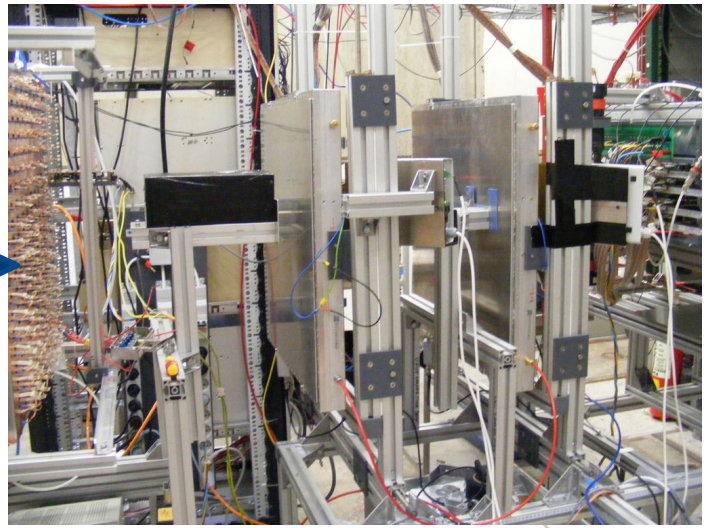
Step from small prototypes toward full-size chambers





The built prototypes show good performance in terms of:

- **Energy resolution**
- **PID performance**
- **Pad response function**

…

Next steps

- **Full-size prototypes with alternating wire geometry**
- **CERN-PS Beamtime fall 2014**
- **Finalising TDR**