Status and First Results of the CBM TRD Development

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for the CBM TRD Group

Outline

1) **Introduction**

2) **Small prototypes and their results**
   Detector concept, prototype design, beamtime at CERN 2011, results for electron/pion separation and position resolution

3) **New developments**
   Next generation data read out, large scale prototypes, simulation of gas gain and mechanical detector parameters

4) **Upcoming beamtimes, summary and outlook**

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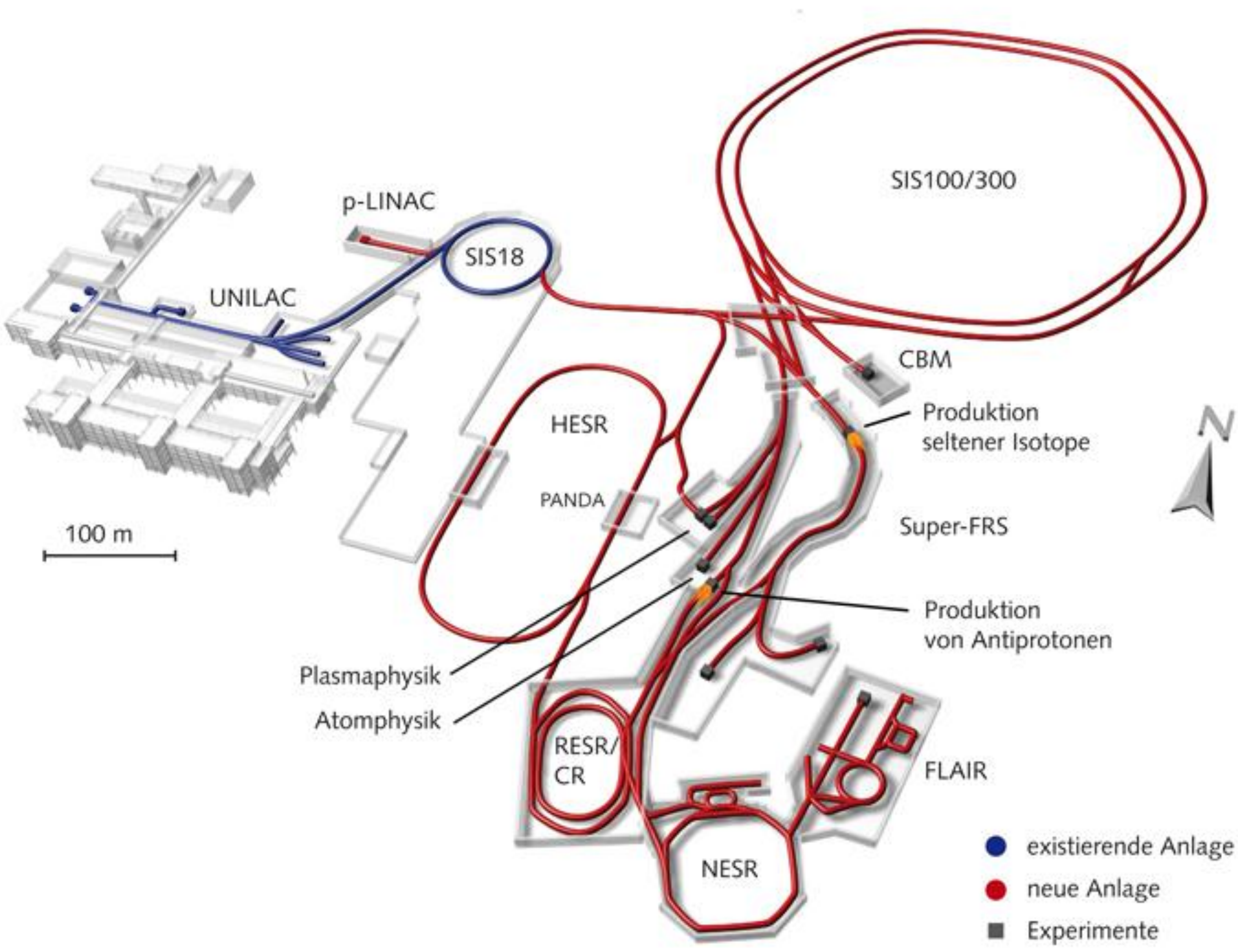
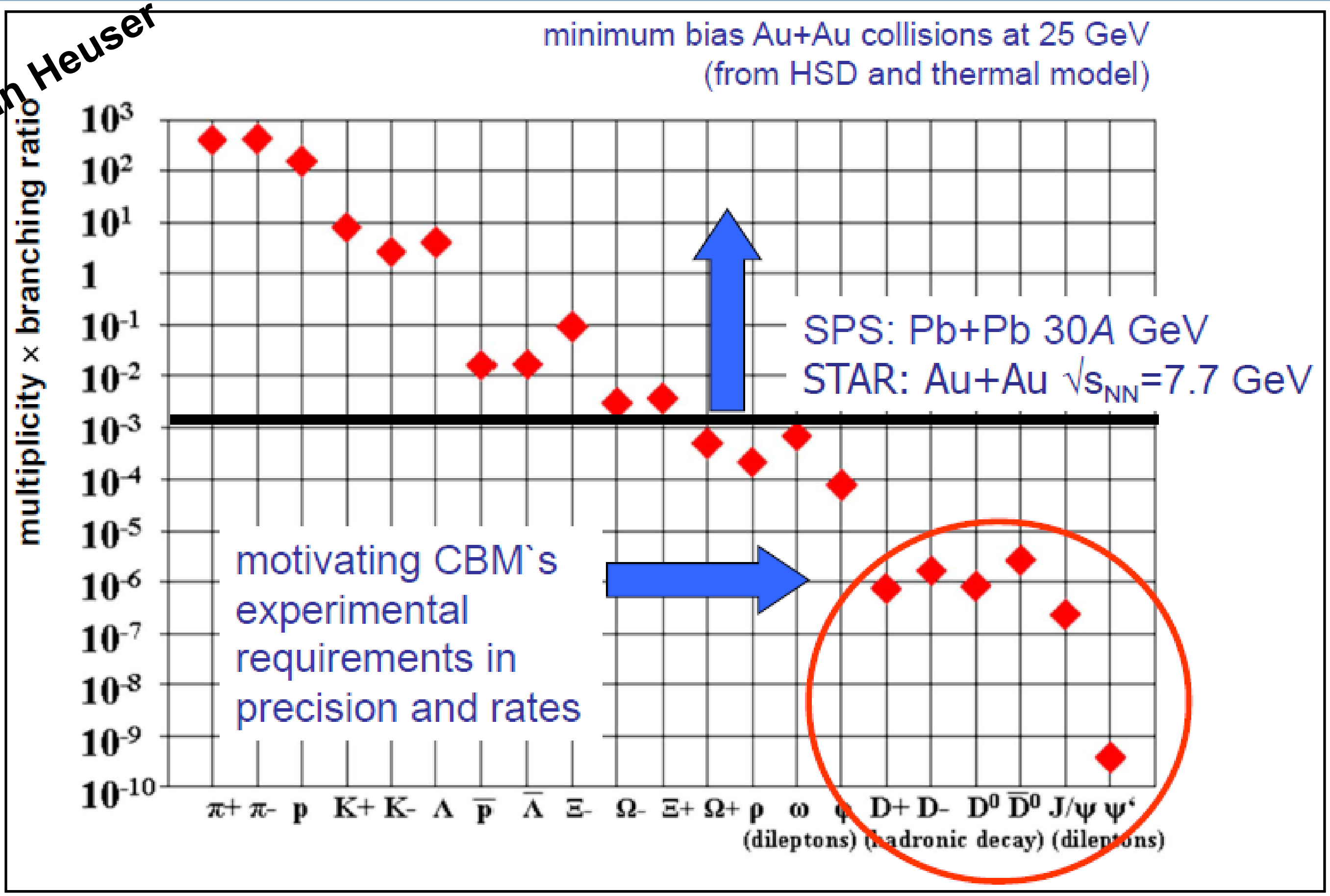
FAIR and CBM overview



Motivation

Slide by Johann Heuser at QM2012

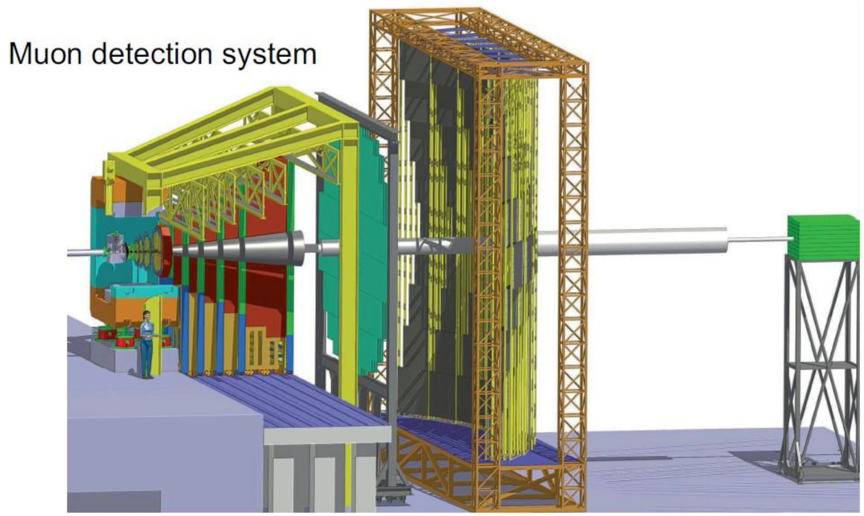


- **Almost all of them decay into $\pi^{\pm}$ and/or $e^{\pm}$**
- **Fair delivers a very high event rate (up to 10 *MHz*)**

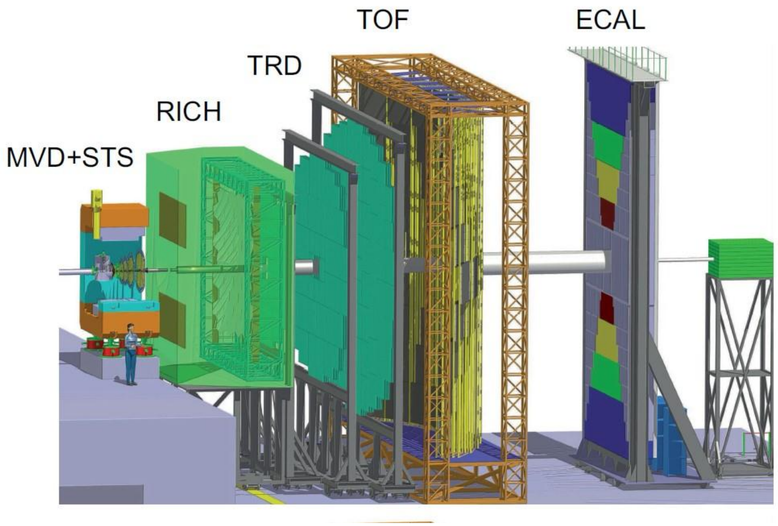
- **Very fast and efficient *e/π* separation required**
- **Capable for high particle densities**

FAIR and CBM Overview

- **Electron ID setup**
  - Efficient electron/pion separation and tracking
- **Muon detection setup**
  - TRD contributes to tracking between MUCH and TOF
- ***StartUp*-Version of CBM at SIS100 includes a TRD station for track matching to TOF**



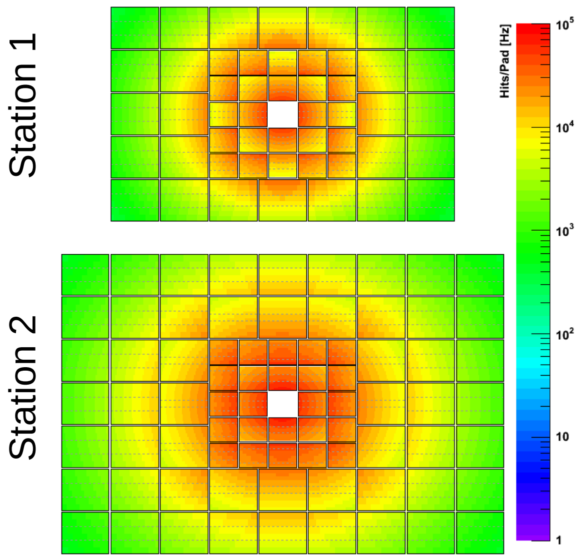
SIS300 Muon Setup



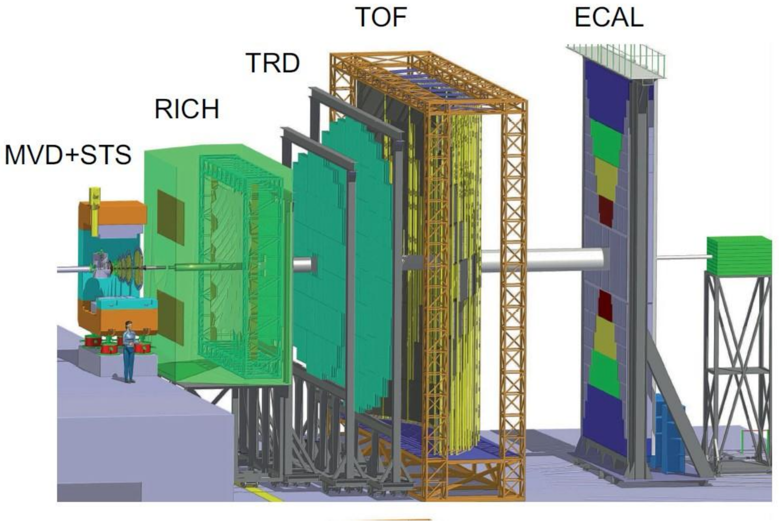
SIS300 Electron Setup

CBM TRD Overview

- **Current design for SIS300:**
  - Covered detector area: 585 m^2
  - Nb. Read out channels: 750.000
  - 10 Layers in 3 Stations
  - First 2 Stations subdivided in inner / outer part



- **Performance:**
  - Track density ~600 charged particles in ±25° at 10 MHz (required)
  - *pi-as-e* – misidentification < 1% for $e^{\pm}$ with p > 1.5 GeV/c (required)
  - Typical position resolution in the TRD of ~250 µm sufficient for track matching and reconstruction



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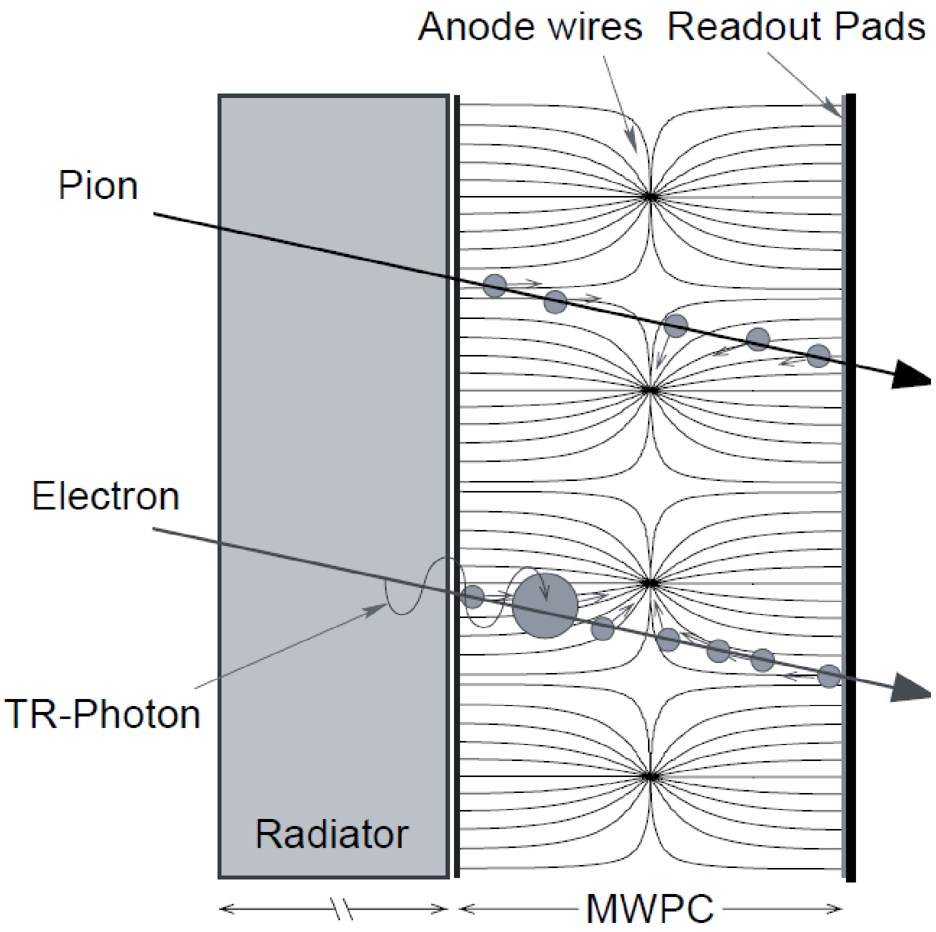
TRD with or without drift region

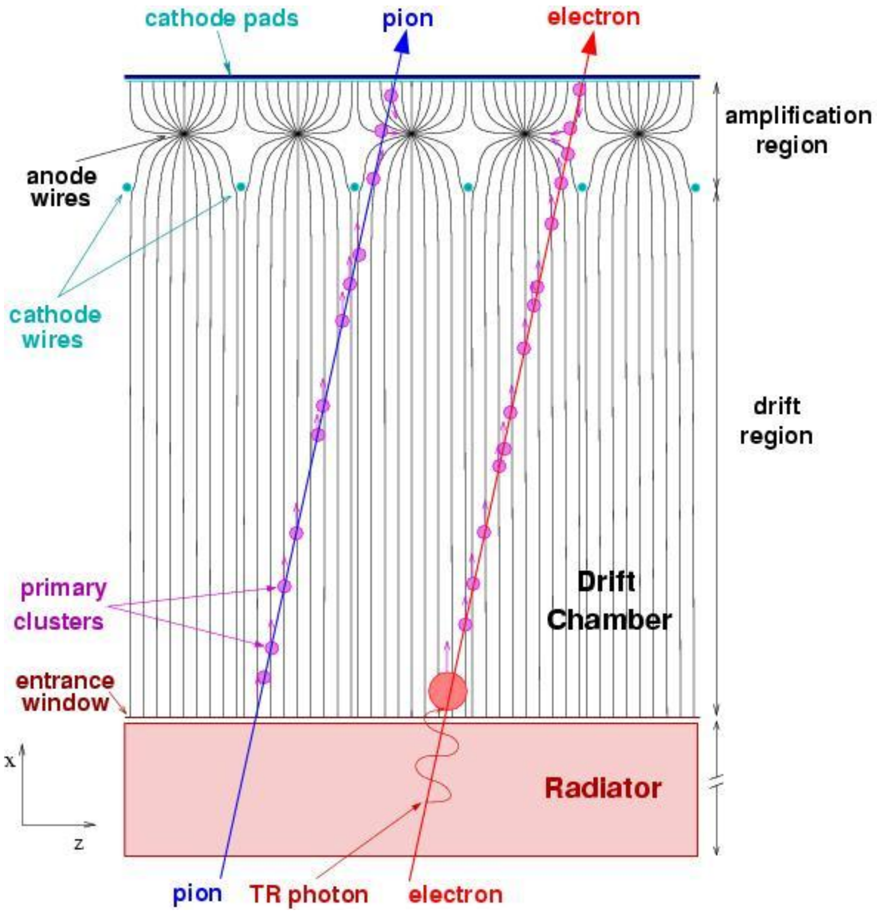
Symmetric Detector design <u>without</u> a dedicated drift region:

- **MWPC only with amplification region → only one wire plane**
- **Fast signal generation**
- **Entrance window of detector made out of Kapton foil**

→ This design is followed by the group in Frankfurt



TRD with or without drift region



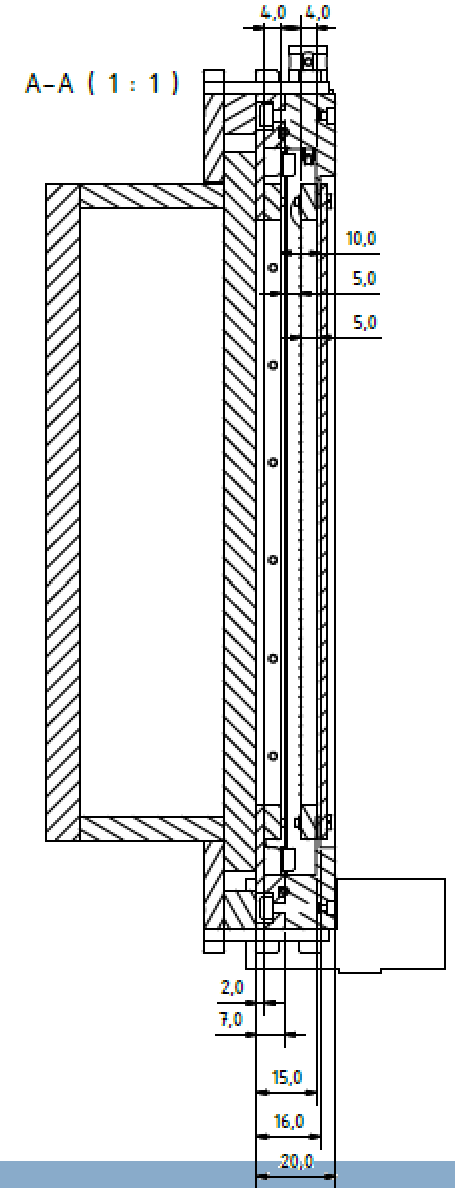
Detector design with drift region:

- **MWPC with dedicated drift and amplification region → Requires two wire planes**
- **Intrinsic signal generation is factor 2 slower due to dedicated drift region**
- **Decouples detector granularity from the remaining parts → gain flexibility in detector construction**
- **Detectors of this type have been built for the ALICE TRD**

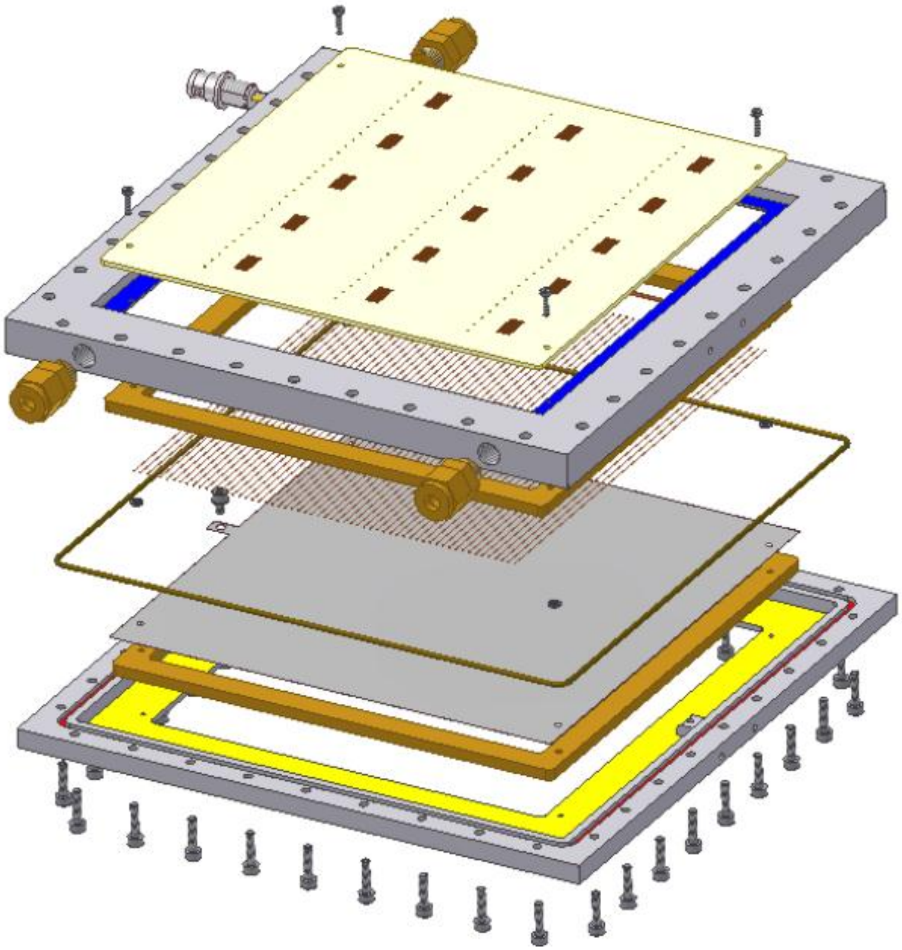
→ This design is followed by the team in Münster

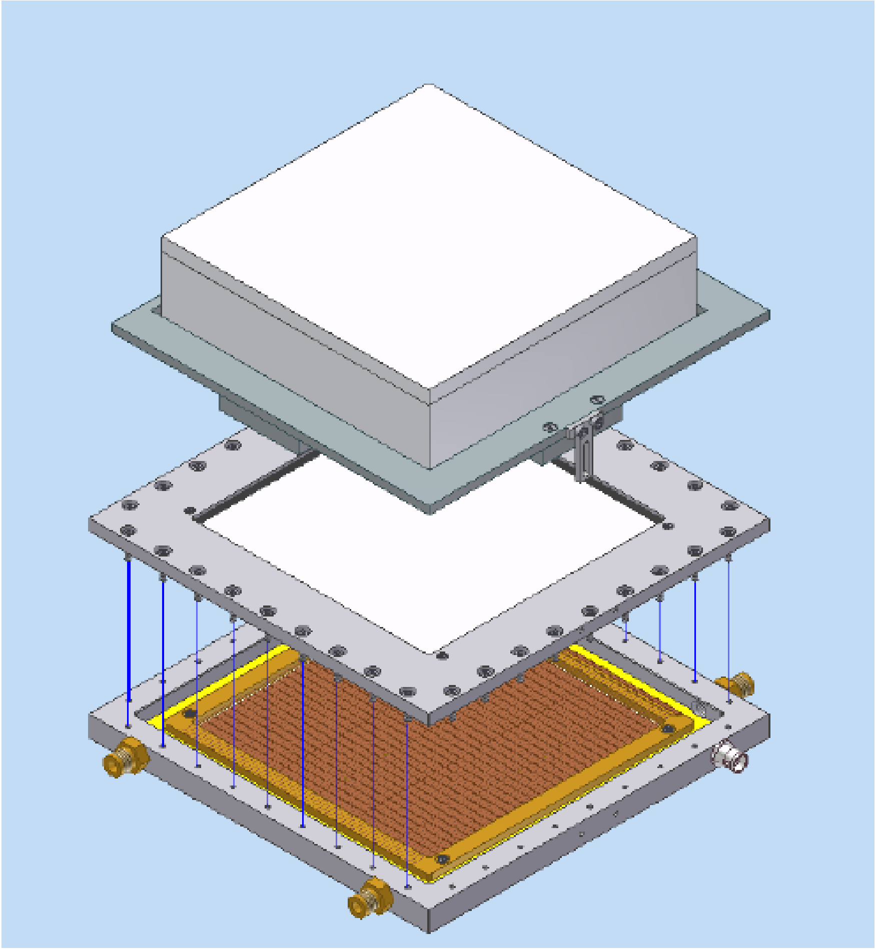
ROC Geometries

- **Based on results of previous test beam times and simulations three prototypes have been built:**
  - Dimensions of active gas volume:
    150 mm x 150 mm x [8; 10; 12] mm
    - FFM 4+4 mm
    - FFM 5+5 mm
    - FFM 6+6 mm
  - Frame material: Aluminum
  - Entrance window: 20 µm Mylar foil (aluminized)
  - Anode wires: 20 µm tungsten wire gold plated
    2.5 mm spacing
  - Pad size: 5 mm * 50 mm
    (not optimized to applied geometry)



Development of small Prototypes





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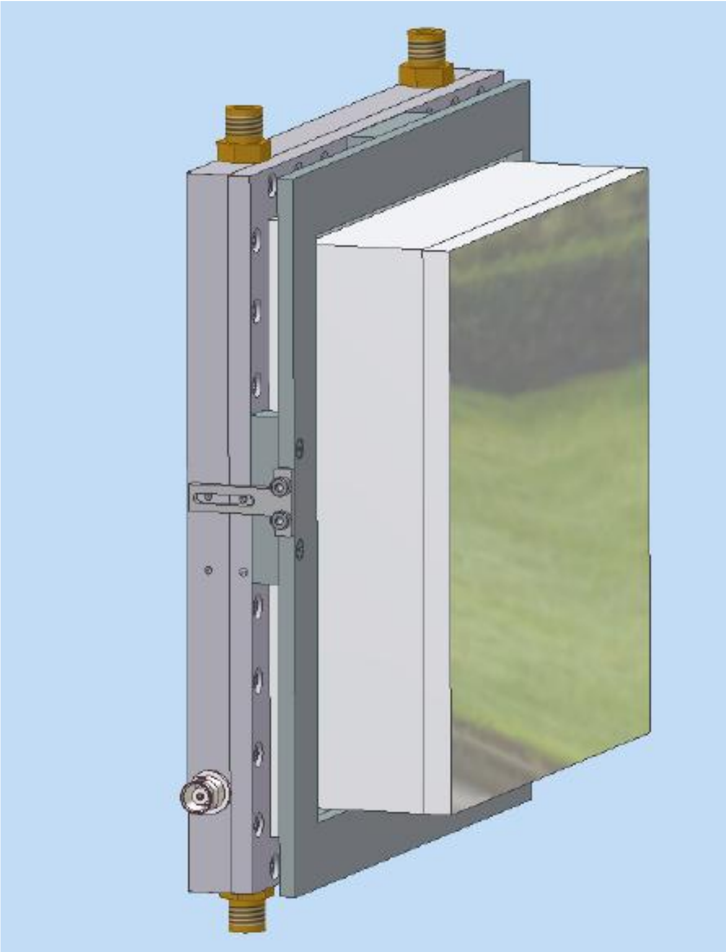
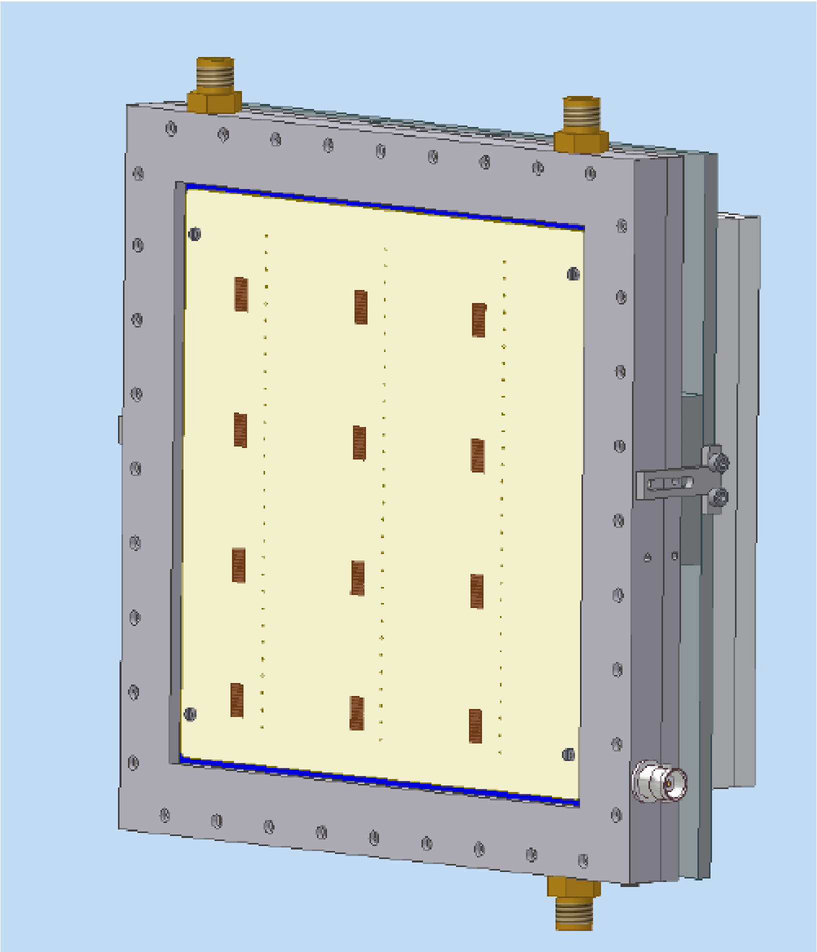
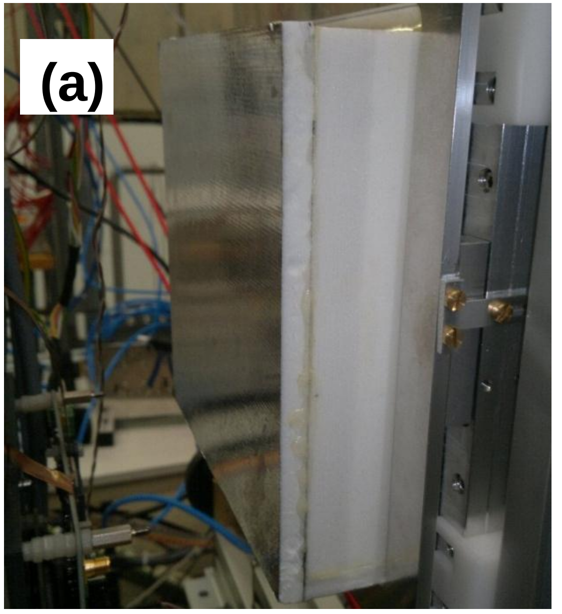




Radiator Development

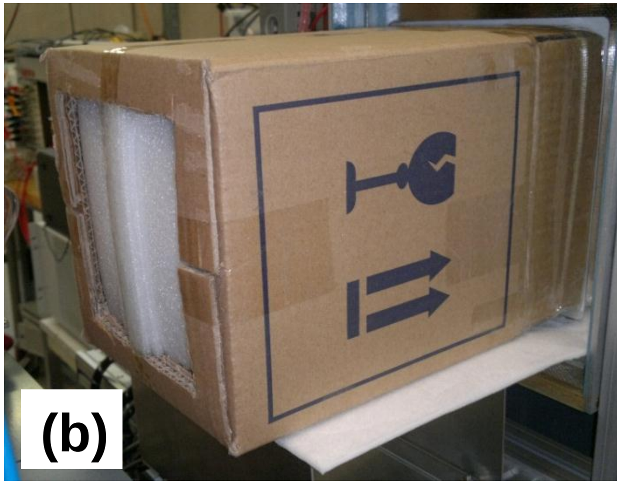
a) Fiber Radiator

- **Sandwich Radiator out of Rohacell and fiber mats:**
  - **25 µm aluminized Mylar foil**
  - **8 mm Rohacell**
  - **40 mm Polypropylene fibers**
- **Built following ALICE TRD Radiator layout**
- **Well understood and measured**
- **Provides mechanical stability**



b) Foam Radiator

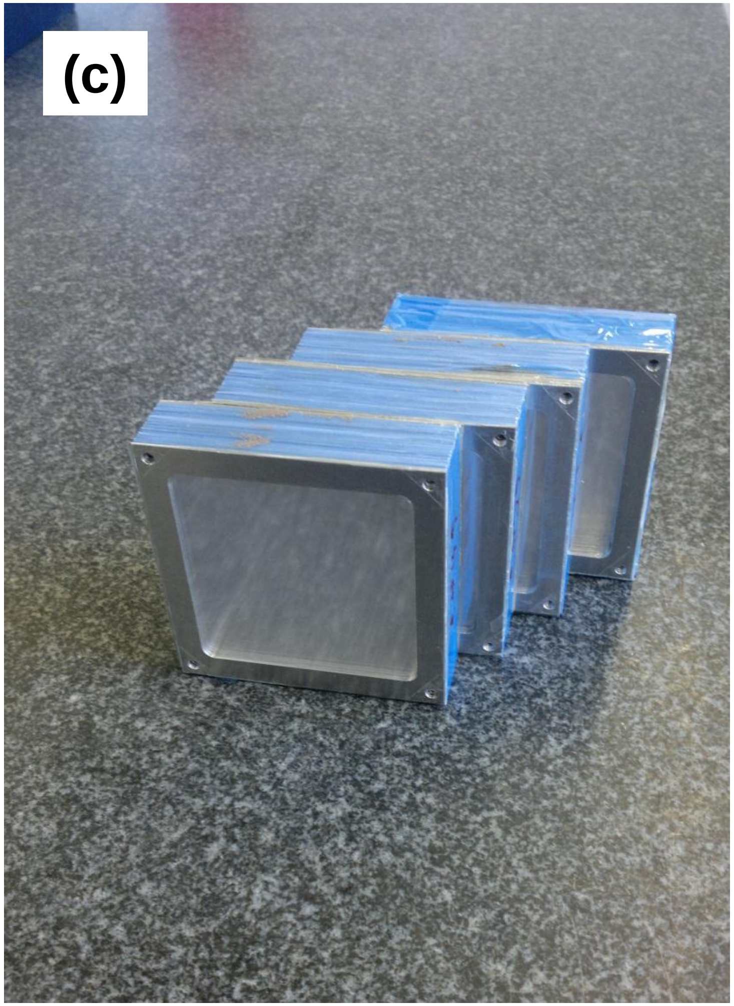
- **Polyethylene Foam (commercial packing material)**
  - **Bubble size of ~0,7mm**
  - **Thickness chosen to achieve ~350 transitions (→ 25cm)**
- **Cheap and easy to handle**



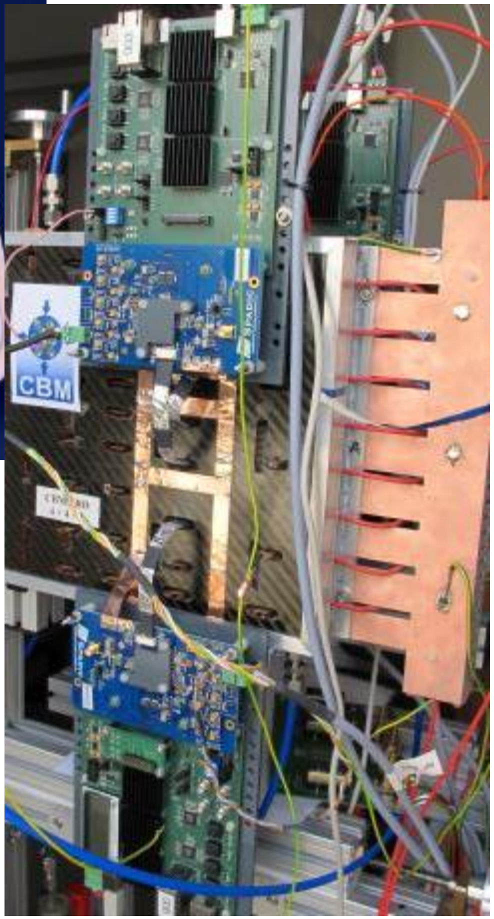
Radiator Development

c) Foil Radiator

- Regular radiator:
  - 20 µm Polypropylene foil
  - 0.5 mm aluminum frame as spacing between foils
  - Radiators with 0.3 / 0.4 / 0.6 / 0.7 mm spacing ready for testing
  - Constructed in stacks of 50 foils each
  - Up to 7 stacks (350 foils) used
- Best performance of all tested radiators (>200 foils)
- Construction of large scale radiators challenging (bending of foil, very sensitive to variations)



Read Out Electronic during Beamtime 2011



- **Readout during beamtime:**

  Spadic 0.3 (<u>S</u>elf-triggered **<u>P</u>**ulse **<u>A</u>**mplification and **<u>D</u>**igitization as**<u>IC</u>) with SUSIBO connector board**

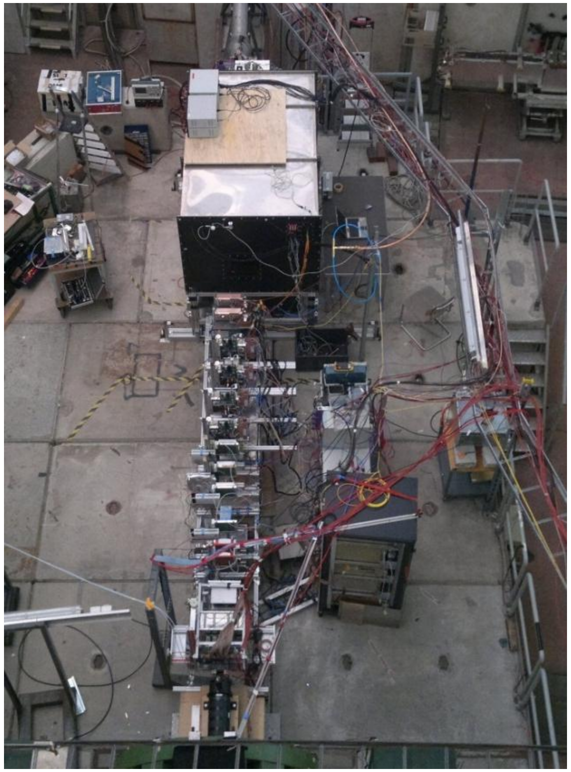
- **Developed in Heidelberg / Mannheim**

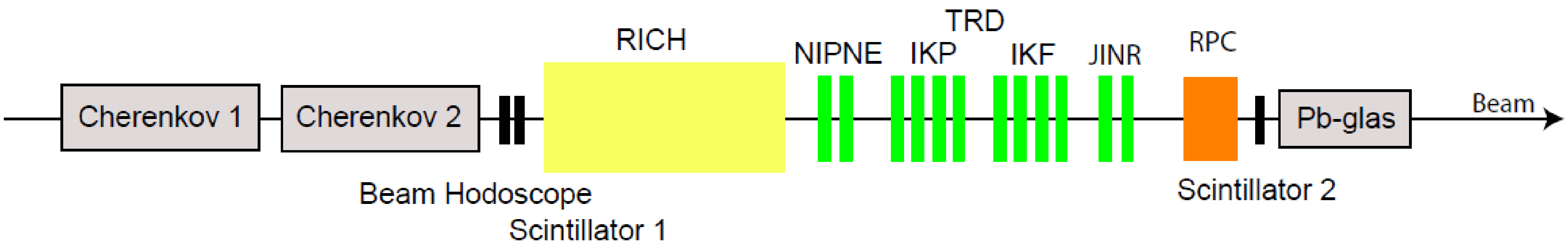
- **8 Channels with 45 Timebins, 1 Timebin = 40ns**

- **8 Bit (255) current ADC with 25 MSamples/s**

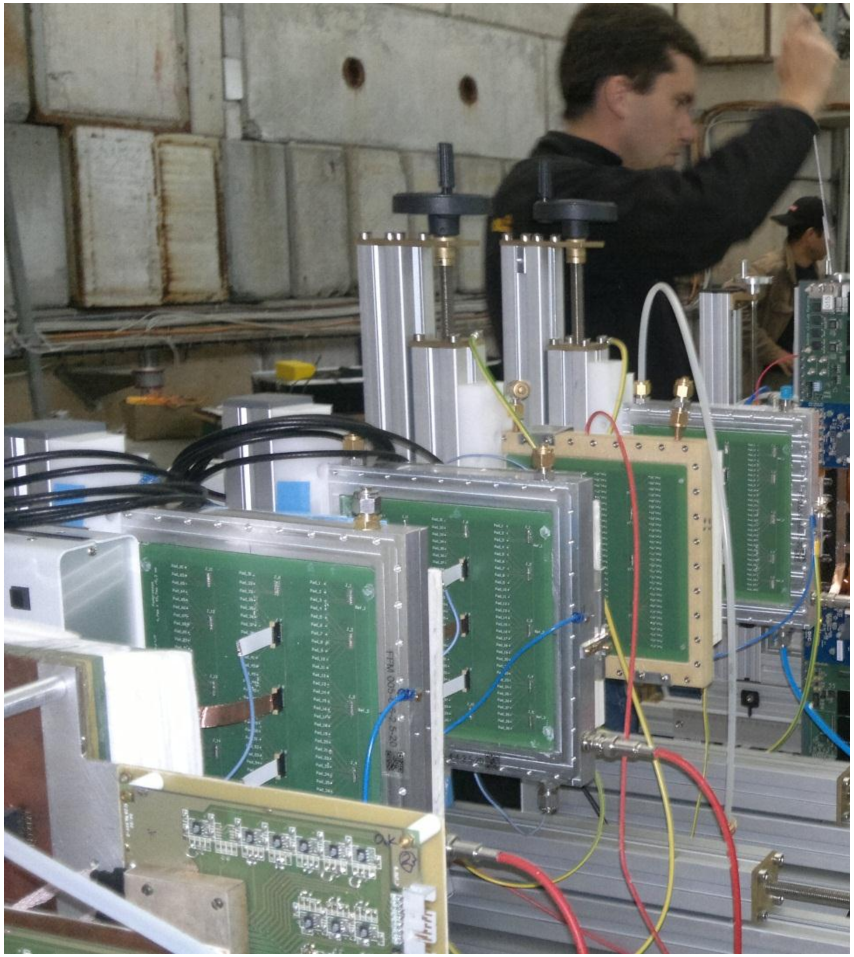
Test Beam at CERN T9

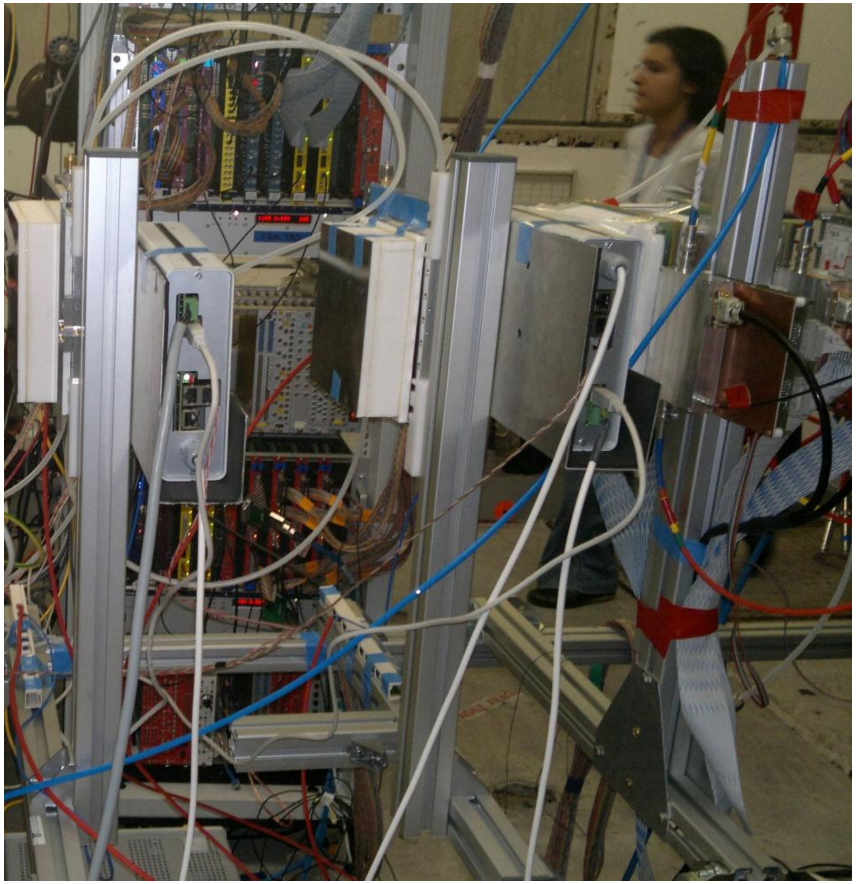
- October 2011 at CERN PS
- Mixed electron / pion beam of 2 – 10 GeV/c
- Together with RICH, RPC, and TRD groups from Münster, Dubna and Bucharest





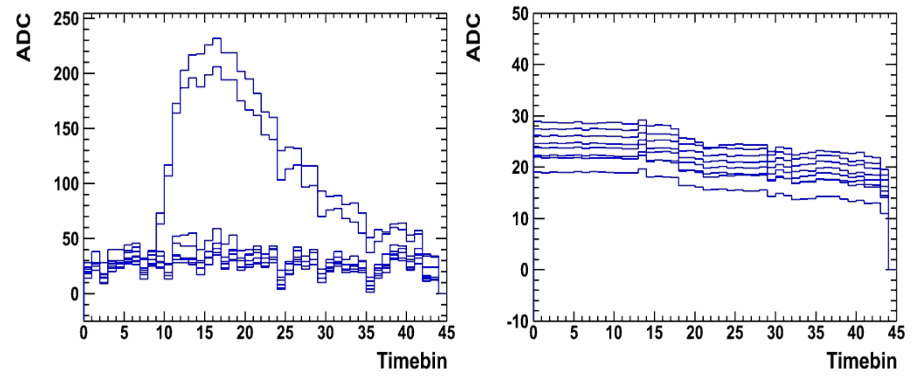
Prototype Testing at CERN

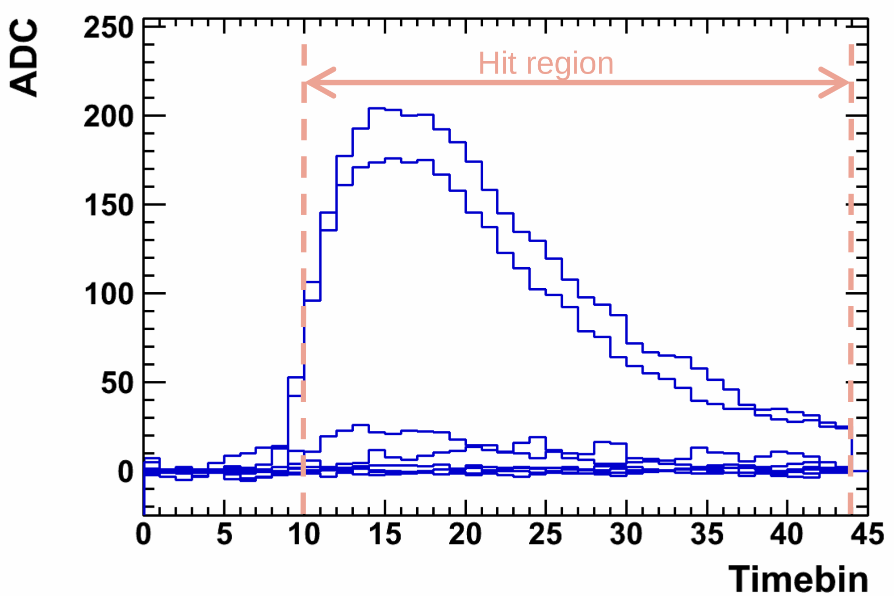




Signal Extraction and Noise Cancellation

- **Readout via SPADIC rev 0.3**
  - 8 Channels → 8 pads read out
- **Noise cancellation**
  - Use offspill events to subtract trigger correlated down shift of baseline
  - Use correlation matrix to get rid of correlated noise
- **Integral of hit region (time bins 10 – 44) for all signal channels defined as q_{tot}**
  - Minimum intensity per channel = 100
  - No events with hits in border pad

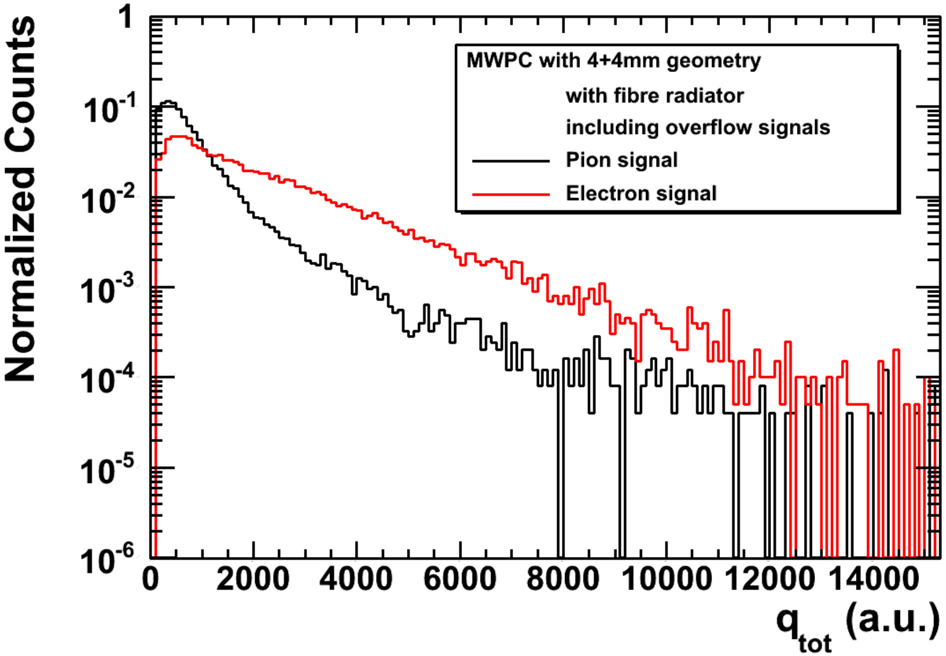




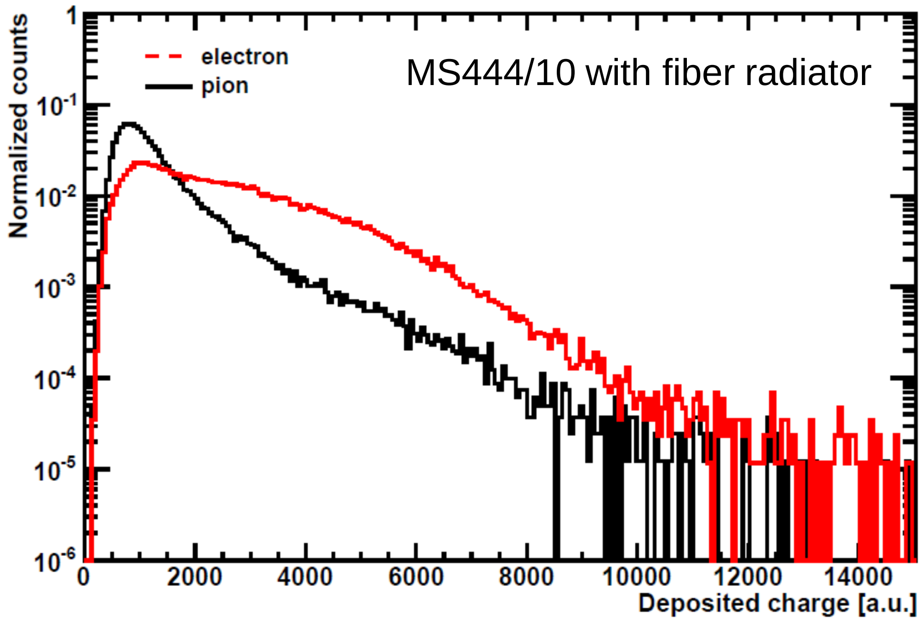
Spectra: Total Deposited Charge

- Same Radiator used for different detector types
- Comparison of results only less significant due to different analysis frameworks
- Different cut values on cluster determination

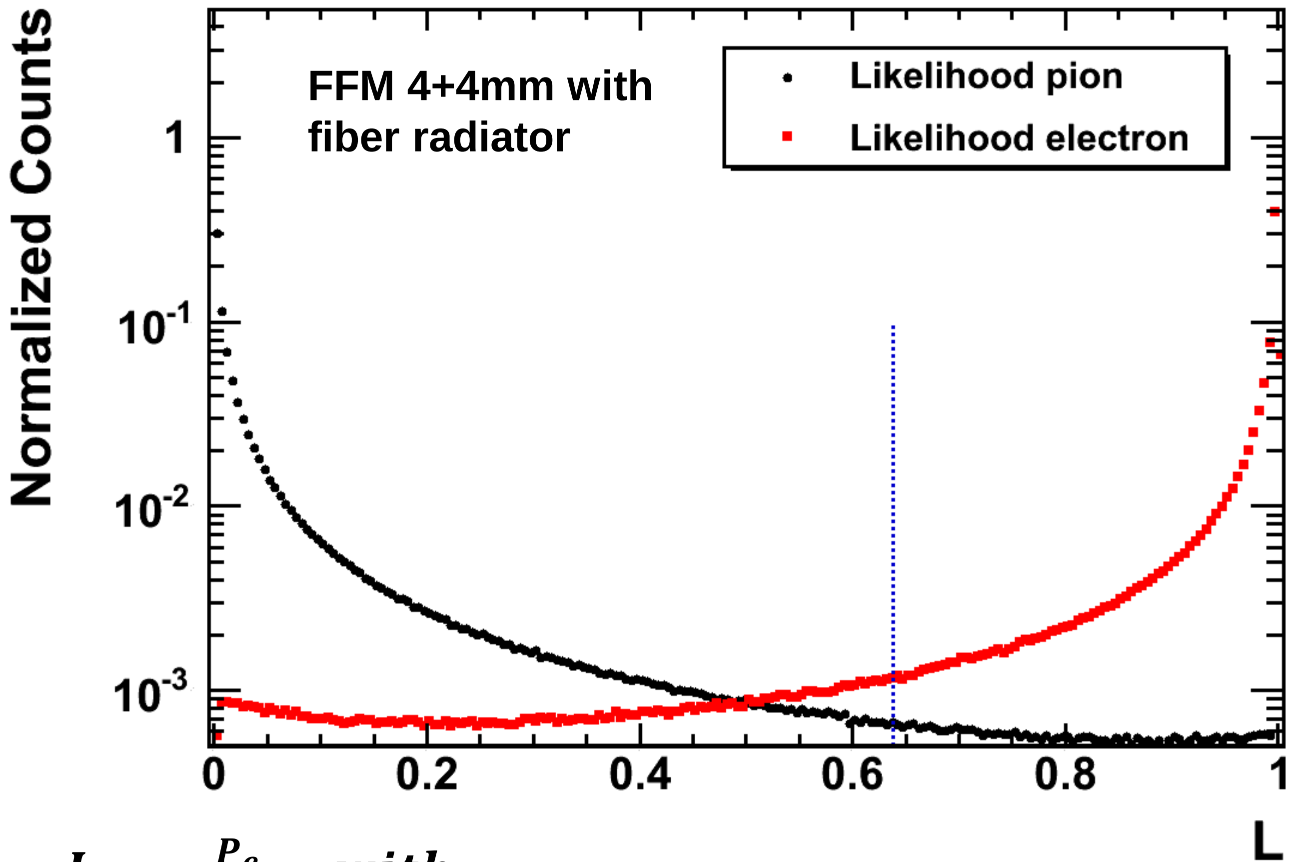
Results Frankfurt
(Prototype without drift)



Results Münster
(Prototype with drift)



π - as - e^- - Misidentification: extrapolation

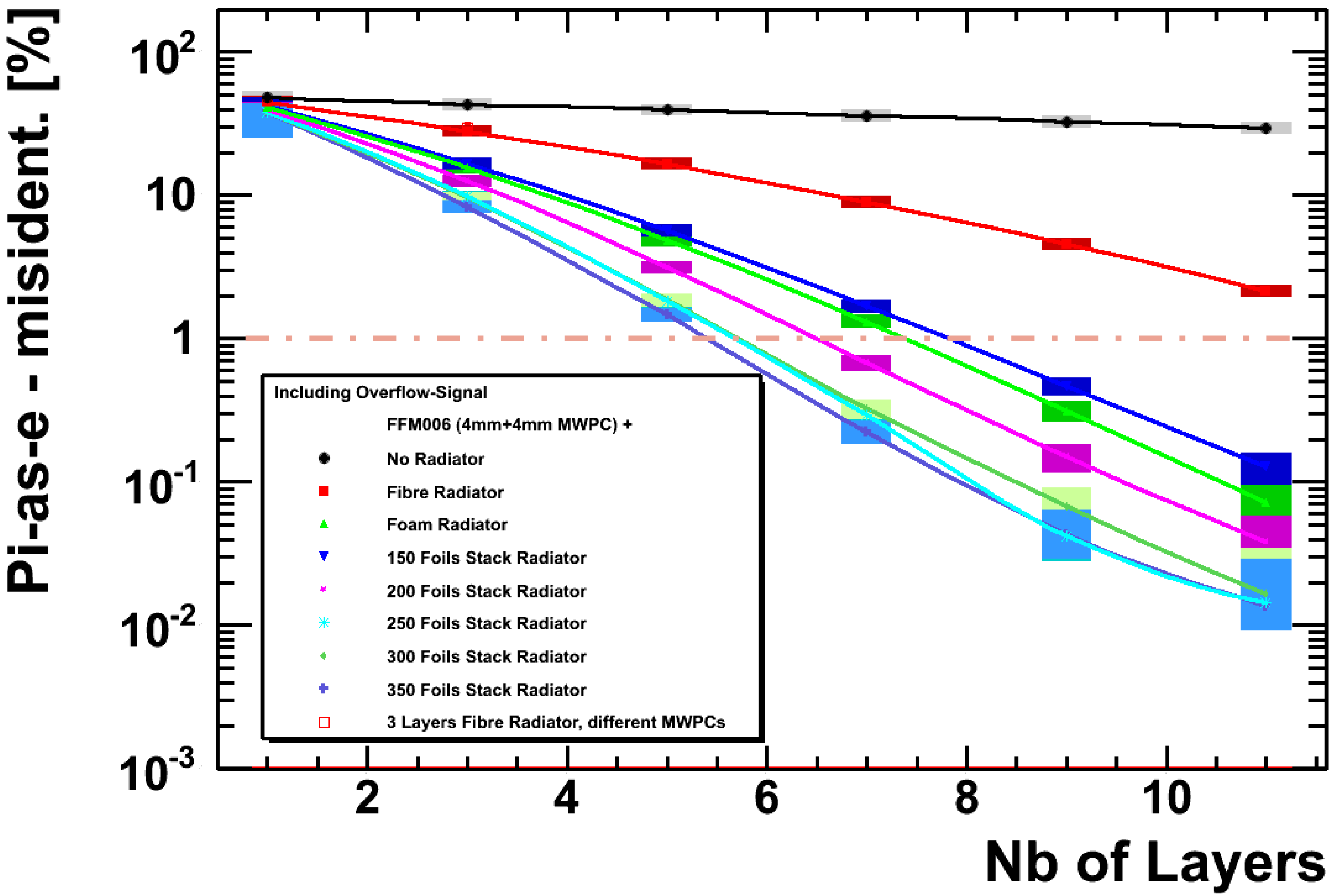


$$L = \frac{P_e}{P_e + P_\pi} \quad with$$

$$P_e = \prod_{i=1}^{N} P(q_{tot}|e)\ , \quad P_\pi = \prod_{i=1}^{N} P(q_{tot}|\pi)$$

9 Layer of 4mm+4mm MWPC with fiber radiator → *pi-as-e* – misidentification of ~4.3% at 90% electron identification

π - as - e^- - Misidentification: extrapolation



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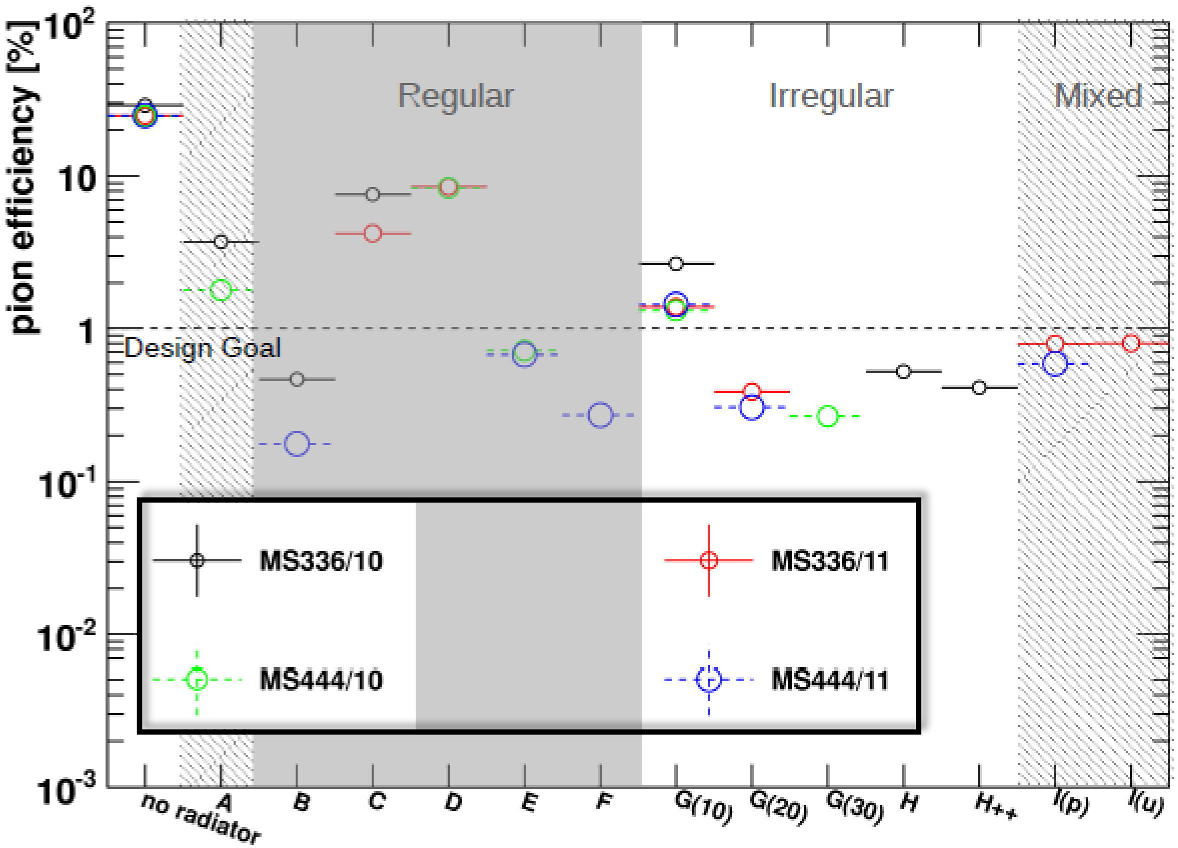


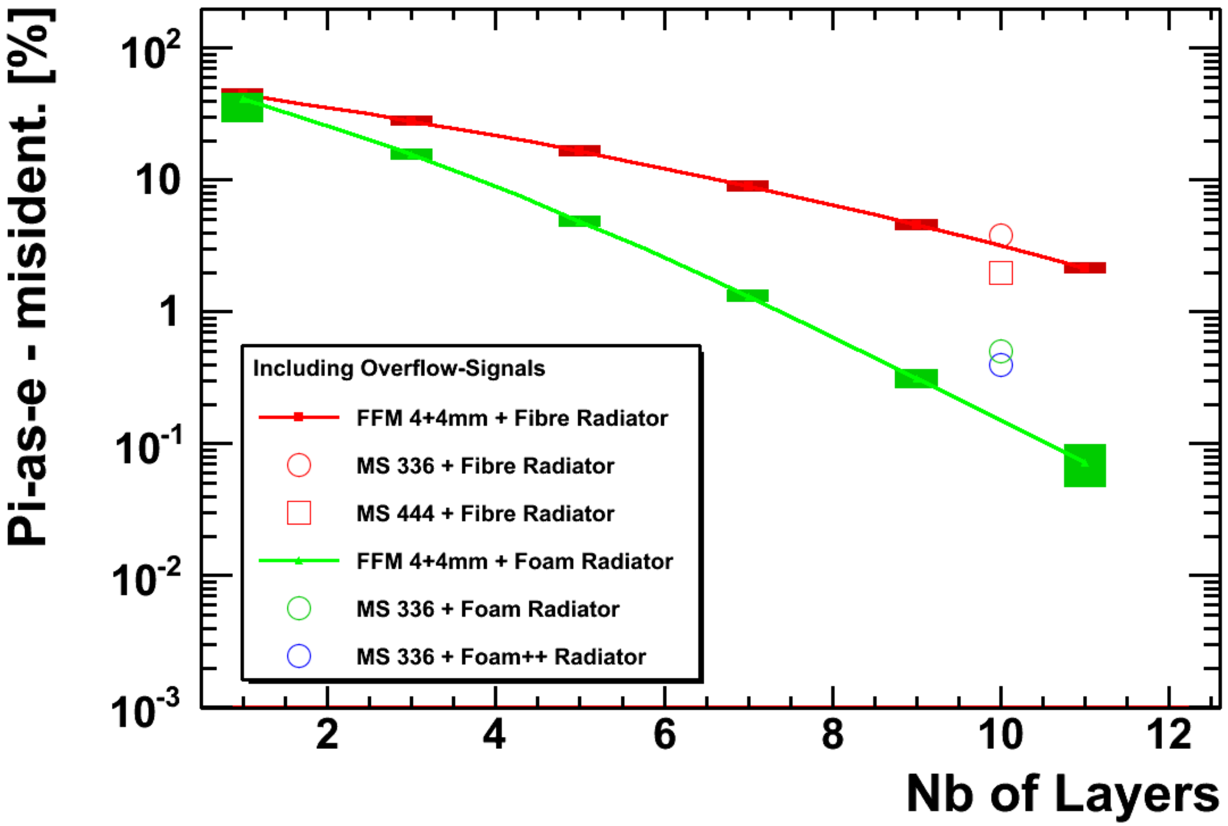
(A) ALICE Fiber & Foam
(B) Pokalon (250/700/24)
(C) PP (200/700/15)
(D) PP (100/500/15)
(E) PP (120/500/20)
(F) PP (220/250/20)
(G) Fiber Mat
(I) Mixed Foam & Foil
(H) Foam

Extrapolating to 10 detector Layers

Naming scheme “MS336/10”:

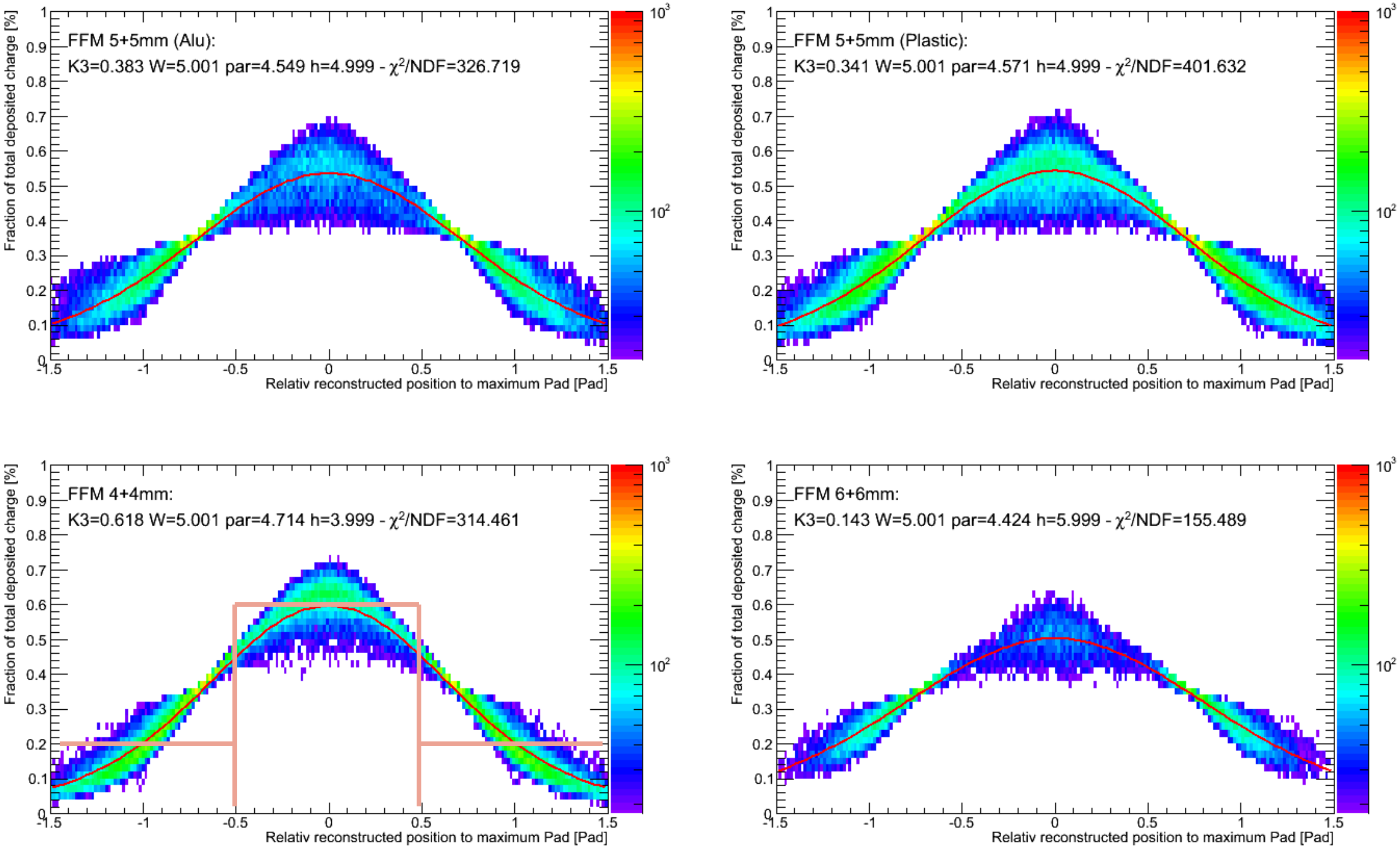
- **Pad plane <3mm> anode wires <3mm> cathode wires <6mm> entrance window**
- **10 → Prototype manufactured 2010**

π - as - e⁻ - Misidentification: comparison



- Reminder: present analysis uses different cuts for input spectra
  →small differentness are enhanced due to the extrapolation
- MS444 + Foam radiator is expected to be better than FFM 4+4mm
- No obvious preferences → still work in progress!

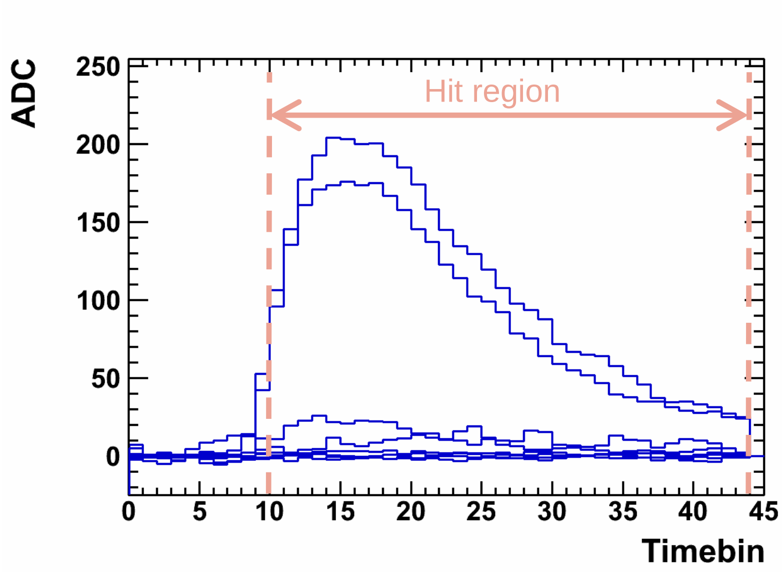
Pad Response Function



- **Fit of PRF: small variations of geometrical parameters allowed**
- **Fixed to three pad clusters**
- **Pad size (5mmx50mm) need to be optimized for next prototypes**

Position Resolution

- Integral of hit region per channel → pulse height
- Position derived by Gauss fit of maximum channel ± one channel in pulse height distribution
- Interpolate between first and third detector → distance to measured Position in second detector



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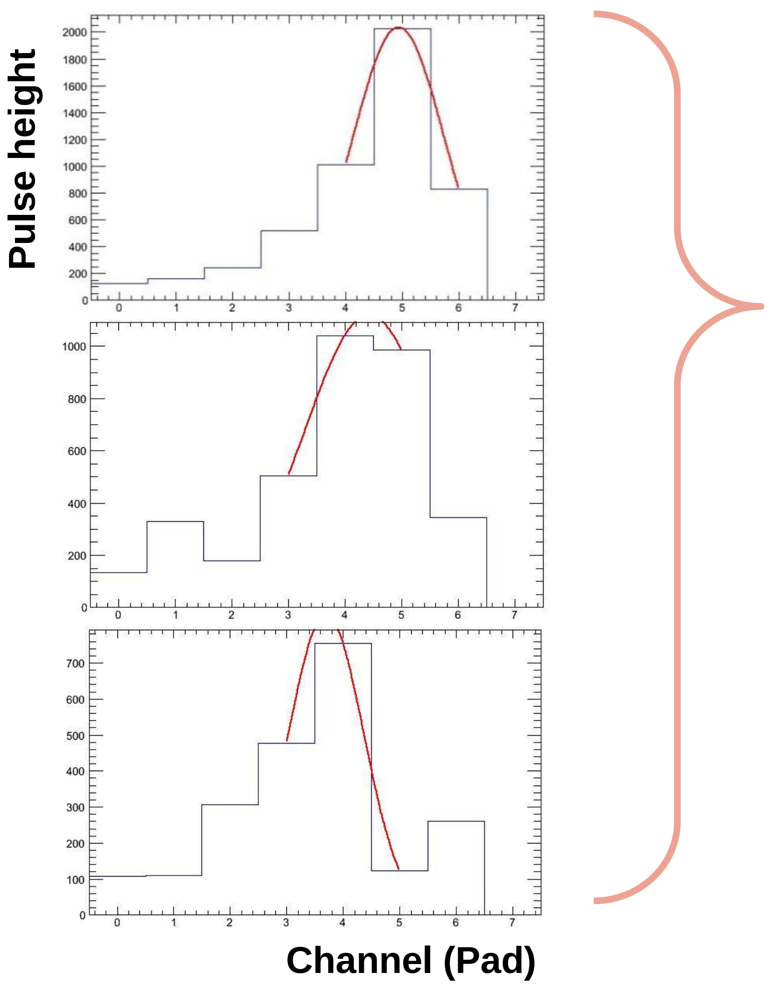
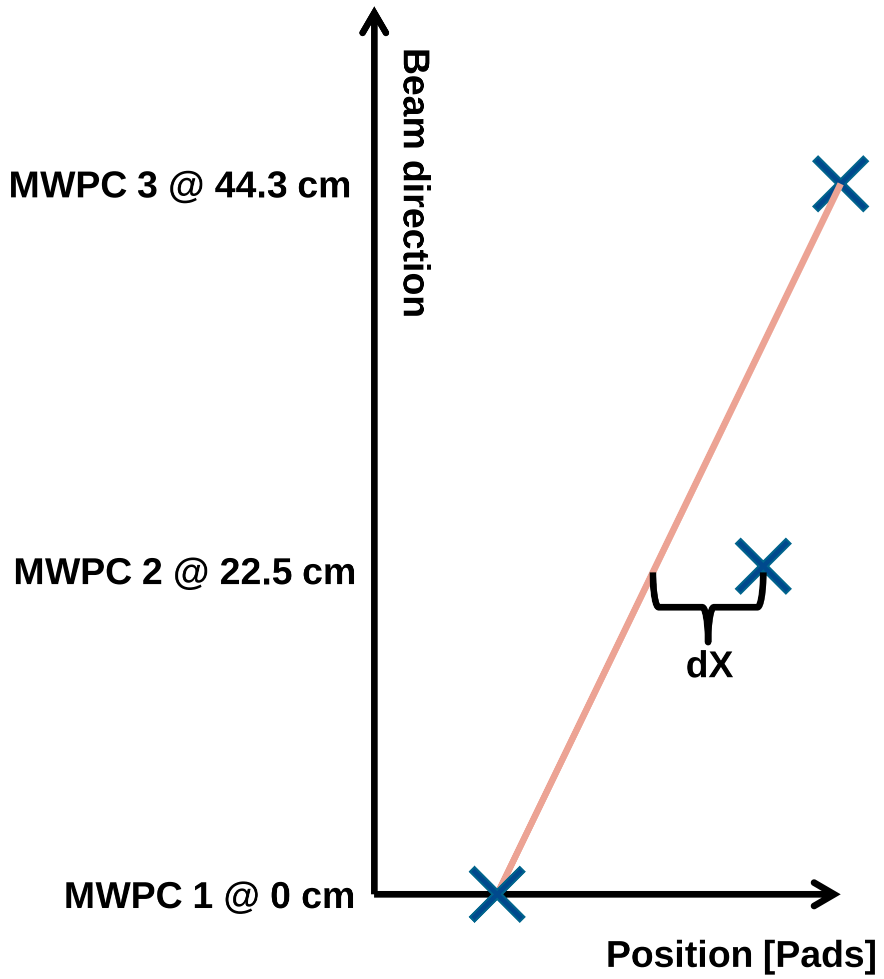


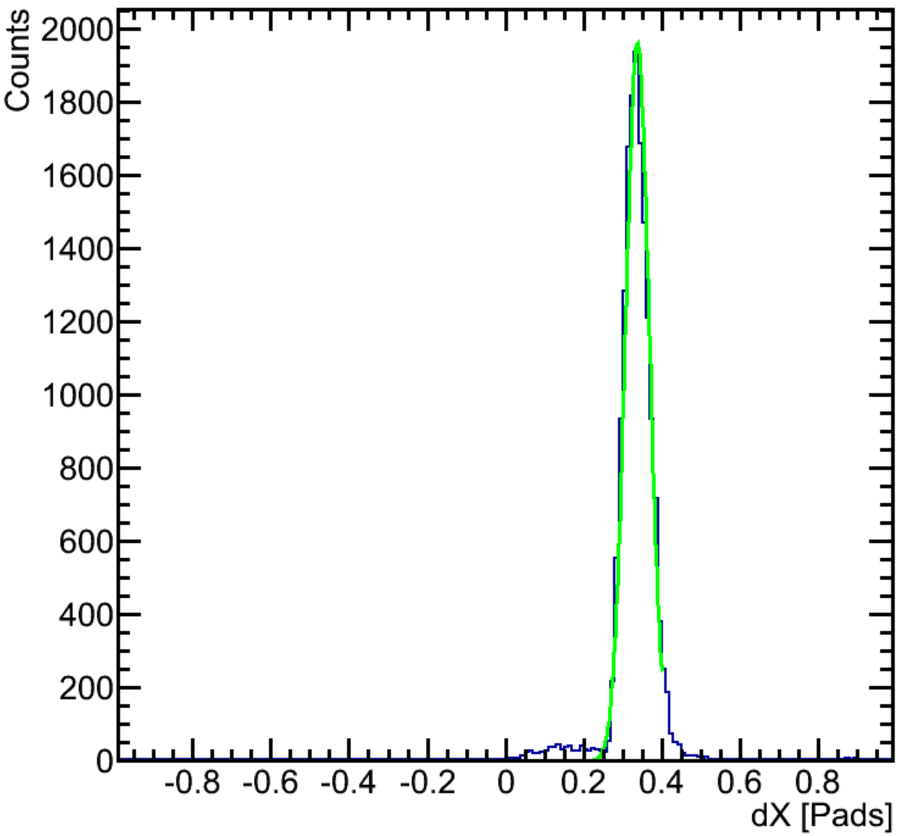


- **Only maximum + neighboring channels to clean up signal**
- **dX = distance of interpolated to reconstructed position**

Position Resolution

- **Only basic "tracking", no alignment, no external reference**
- **Offset due to misalignment between used detectors, outliers may be double hits (to be understood)**
- **Width of distribution is folded with position resolution of all 3 MWPCs (2x 5mm 1x 4mm)**
- **Correction assumes same position resolution for all used detectors**

➢ **Position resolution for 5+5mm MWPC with fiber radiator is <u>291,8µm</u>**



Position Resolution

Results Münster (Prototype with drift)

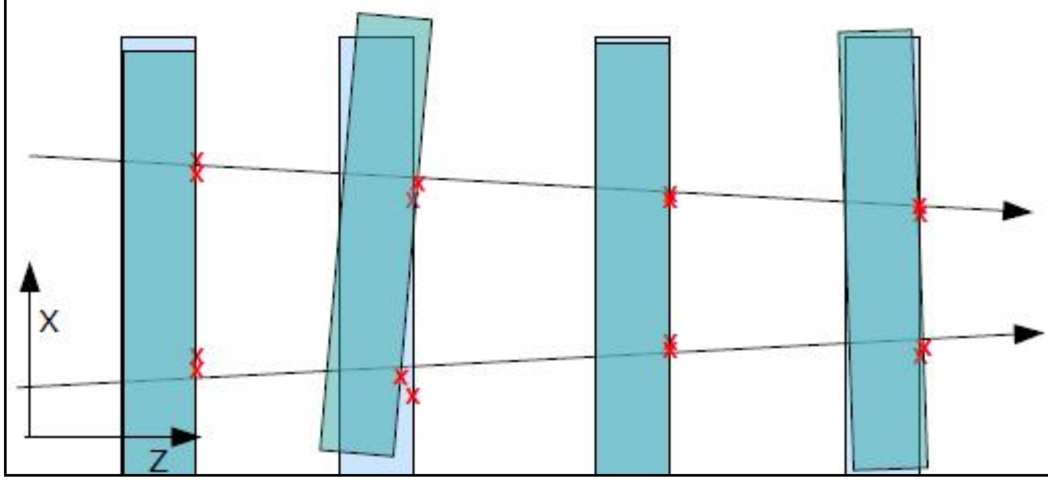
At least 3 space points in 4 TRDs are required to perform tracking:

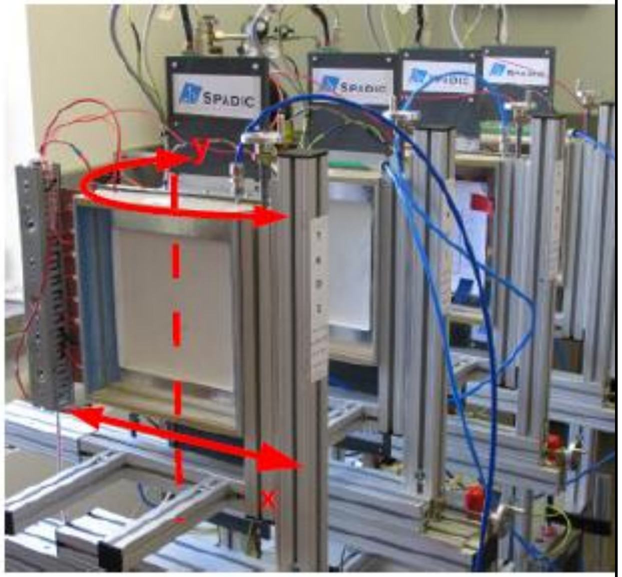
1) Compensation of average chamber misalignment (recursive)

 -minimize average distance of hit to fitted track for each chamber
 by rotation around y-axis and displacement along x-axis

 -refit tracks with iterated chamber position (x,y)

2) Width of residual distribution is then interpreted as position resolution



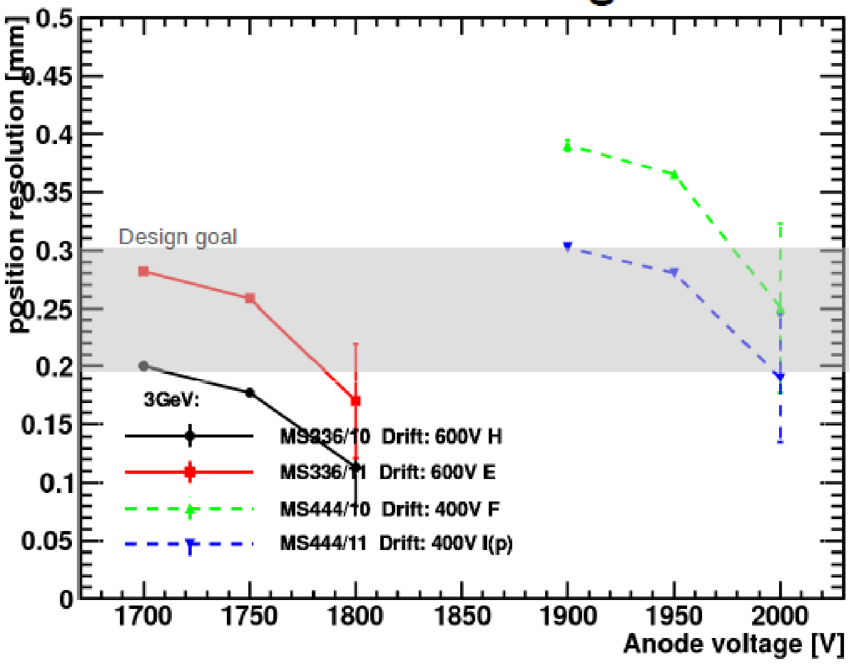


Position Resolution

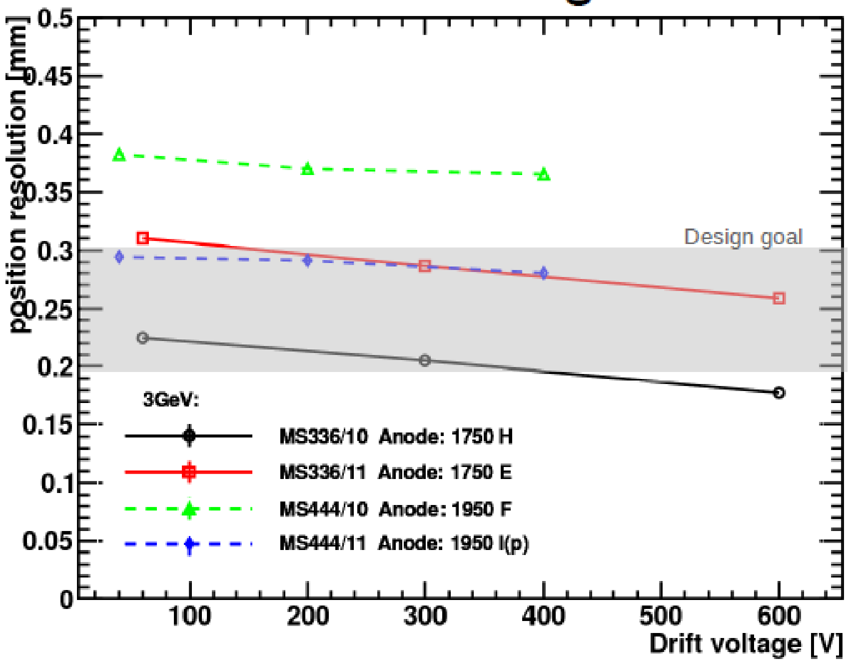
Results Münster (Prototype with drift)

- **Results for position resolution in order of 0.25mm using all 8 (MS + FRA) detectors in beam**

Anode Voltage



Drift Voltage



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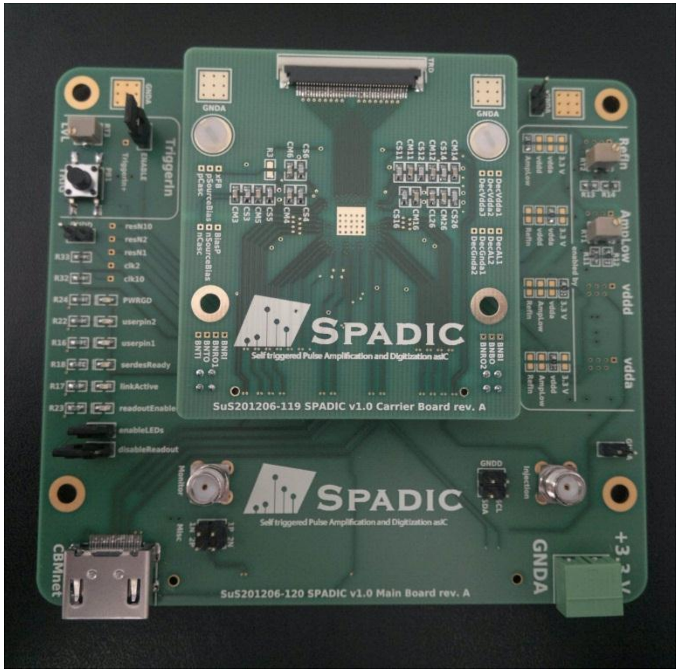
Next Steps: New Generation of Readout Electronic

New Front End Electronic SPADIC 1.0:

- **2 logical groups of 16 Channels → 32 Channels read out in parallel**
- **First free streaming data readout device for the CBM TRD**
- **Read out chain (integration into CBMnet) and software under development**



Next Steps:
Larger scale Prototypes

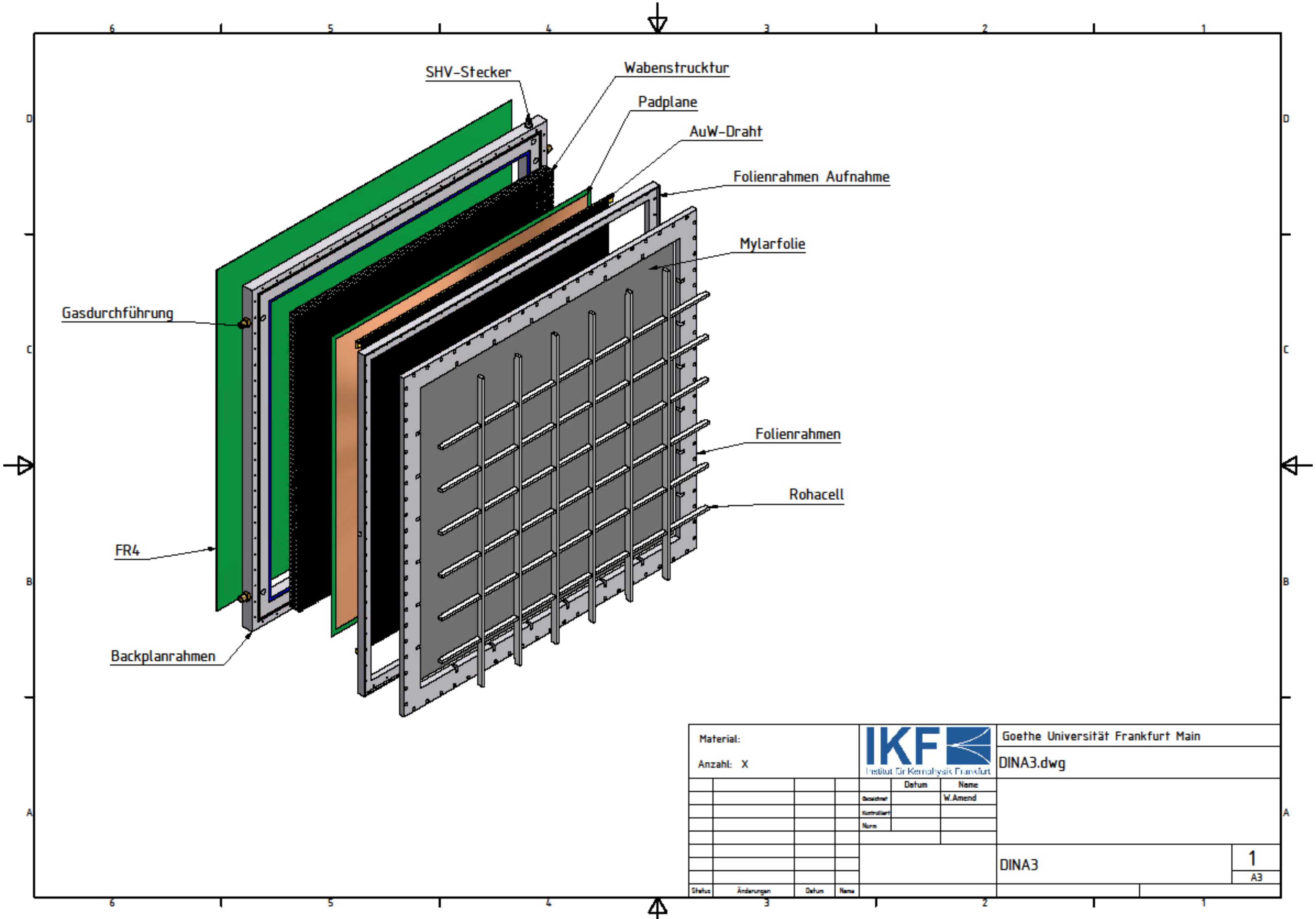
- Large scale prototypes have a dimension of 600mm x 600mm (Size of detector in the inner part) built with and without dedicated drift region

- Modular construction of prototypes
  - Body: Frame + Honeycomb, pad plane, distance ledges for wires
  - Cab: Entrance window (aluminized Mylar foil) + optional support structure

- Pad plane is designed to provide different sizes of readout pads

- Stretching of foil for entrance window done by thermal method:
  - Method developed for GEM – Foils delivers very good results

Next Steps:
Larger scale Prototypes



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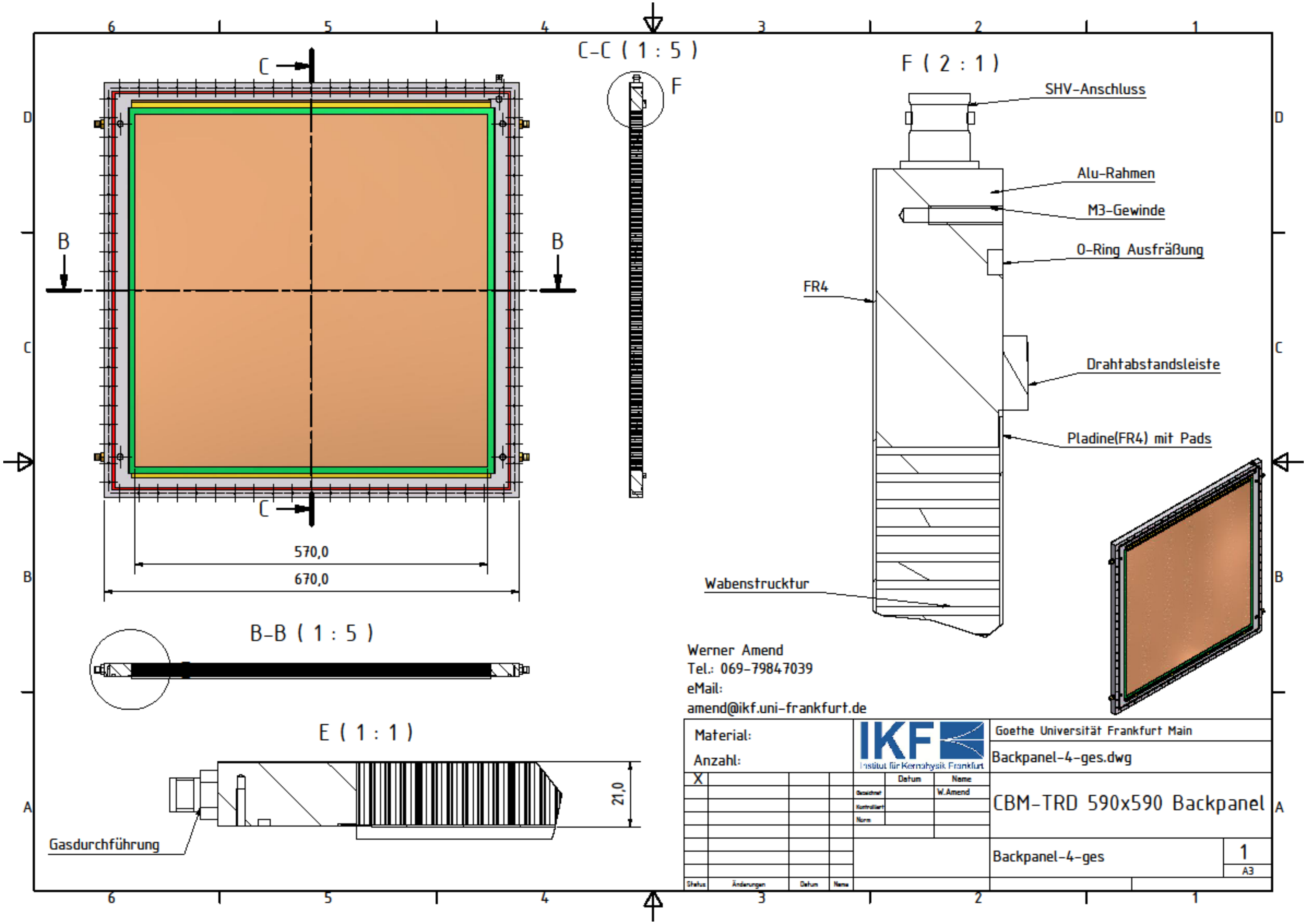
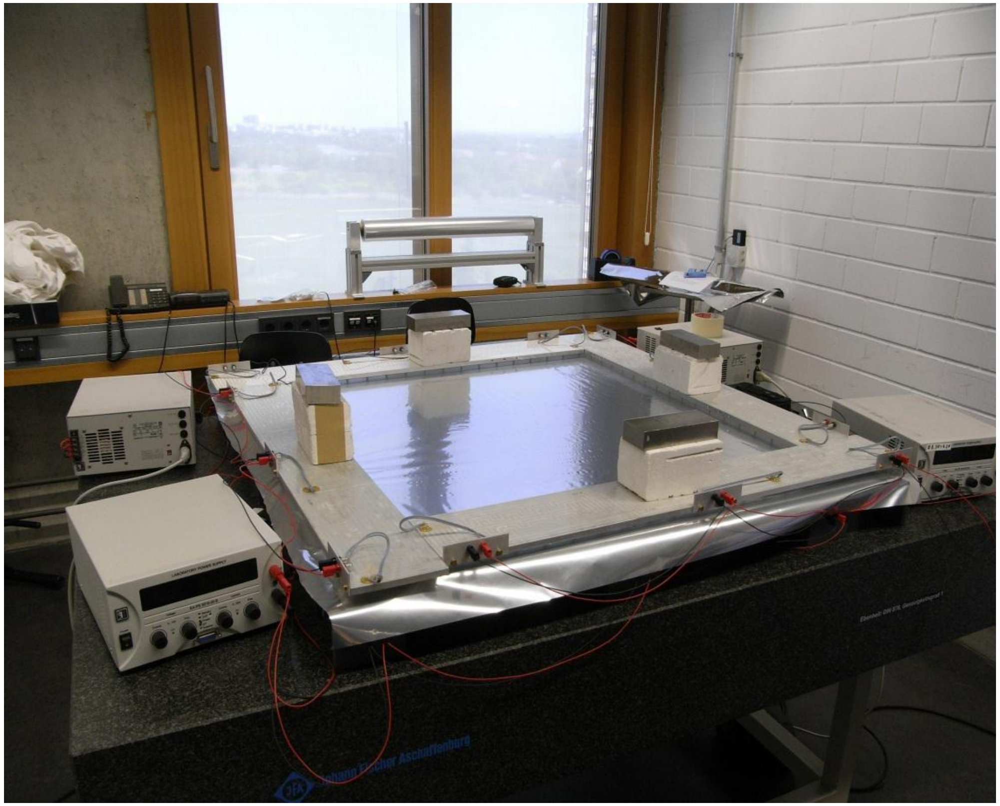


Next Steps: Foil based Entrance Window

- **Idea based on thermal stretching procedure for GEM foils (Michael Staib, et al (RD51-Note- 2011-004))**
- **Foil is fixed in aluminum frame**
- **Frame is warmed up with heating spirals**
- **→ aluminum frame expands**
- **→ foil gets stretched**



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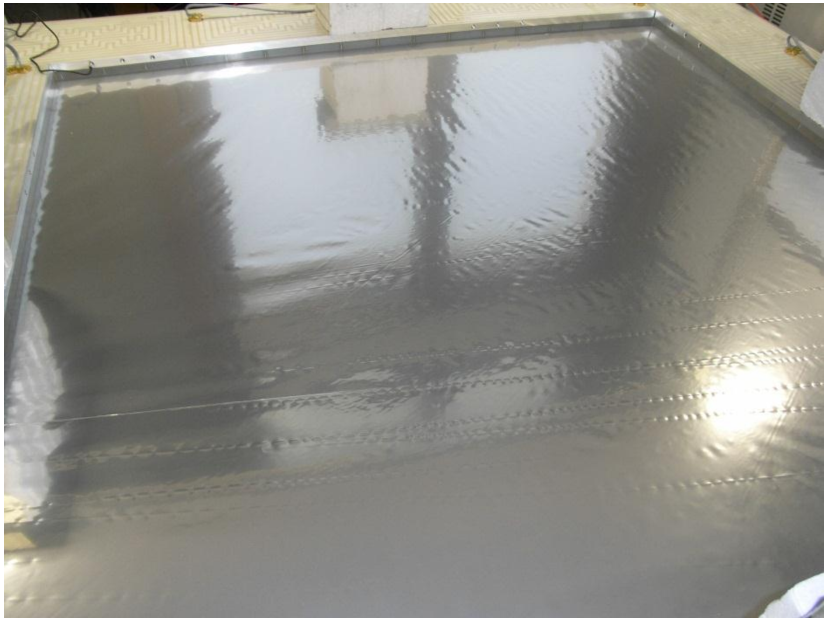
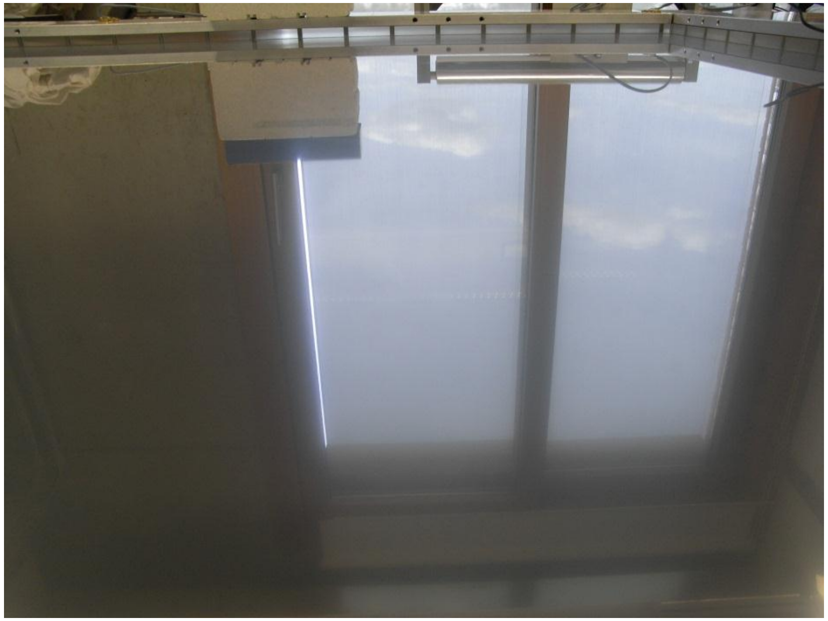
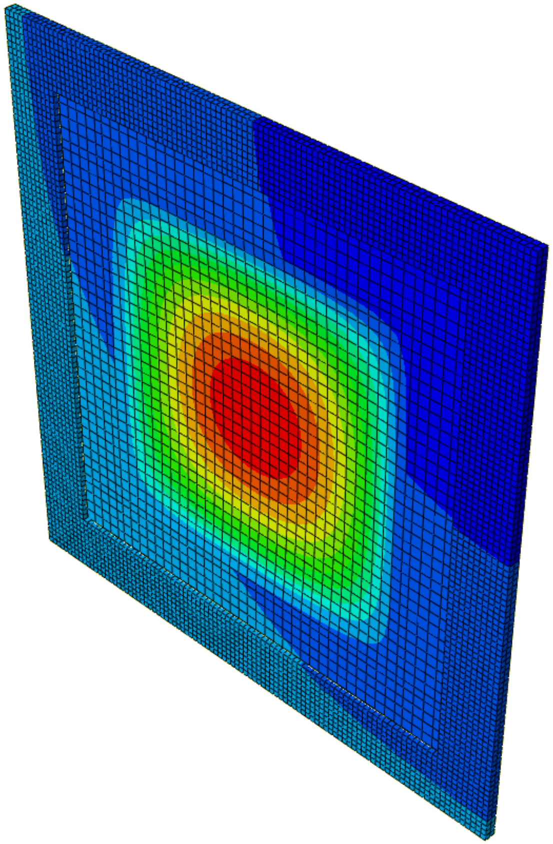




- **Unstretched 60 x 60cm foil at room temperature.**

- **Stretched foil at ~55°C after 1h of heating.**

Next Steps:
Foil based Entrance Window



- **Simulation of entrance window deformation and mechanical stress of MWPC body using ABAQUS software framework**
- **Foil stretched at 60°C**
- **Overpressure → deformation (very preliminary):**

1mbar	**→**	**10.57mm**
0.5mbar	**→**	**6.05mm**
0.1mbar	**→**	**0.77mm**
0.01mbar	**→**	**0.0076mm**

→ Requires a sophisticated gas system in complete experimental setup
… or an enforced entrance window to minimize bulging of the foil

CBM TRD

Next Steps: Foil based Entrance Window

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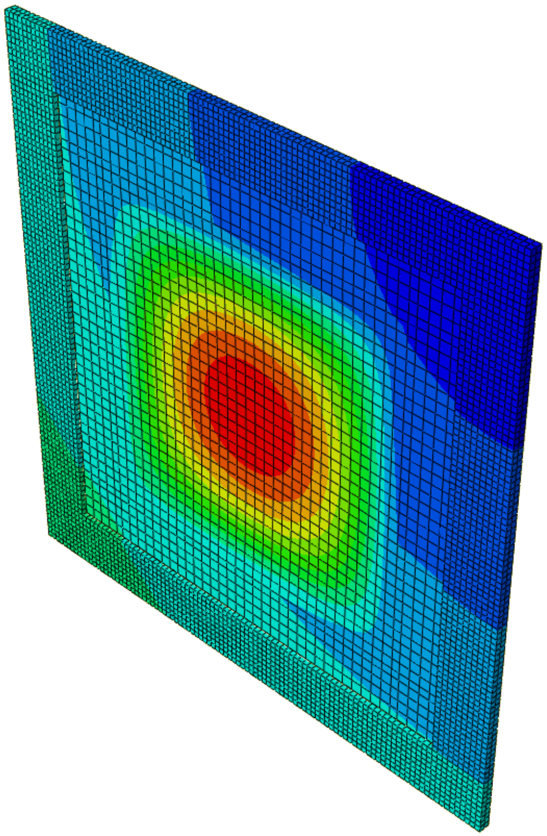

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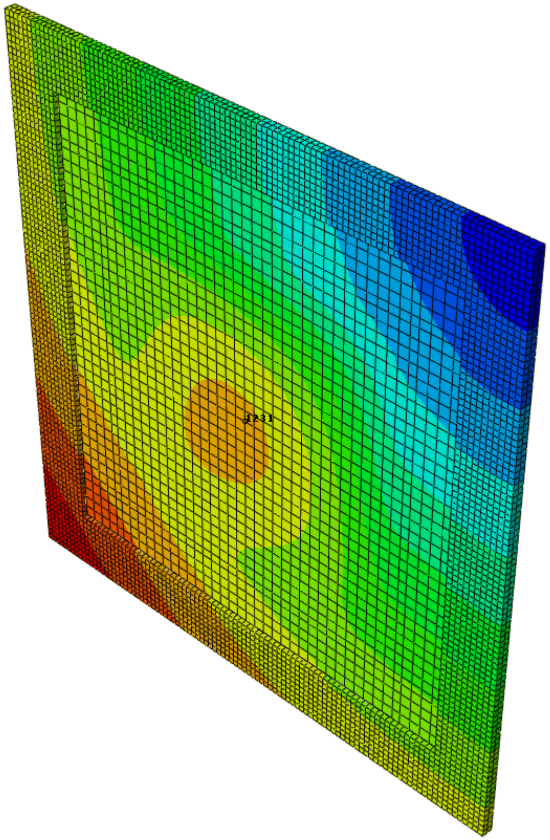
Next Steps:
Foil based Entrance Window



- **Simulation of entrance window deformation and mechanical stress of MWPC body using ABAQUS software framework**
- **Foil stretched at 60°C**
- **Overpressure → deformation (very preliminary):**

1mbar	**→**	**10.57mm**
0.5mbar	**→**	**6.05mm**
0.1mbar	**→**	**0.77mm**
0.01mbar	**→**	**0.0076mm**

→ Requires a sophisticated gas system in complete experimental setup
… or an enforced entrance window to minimize bulging of the foil

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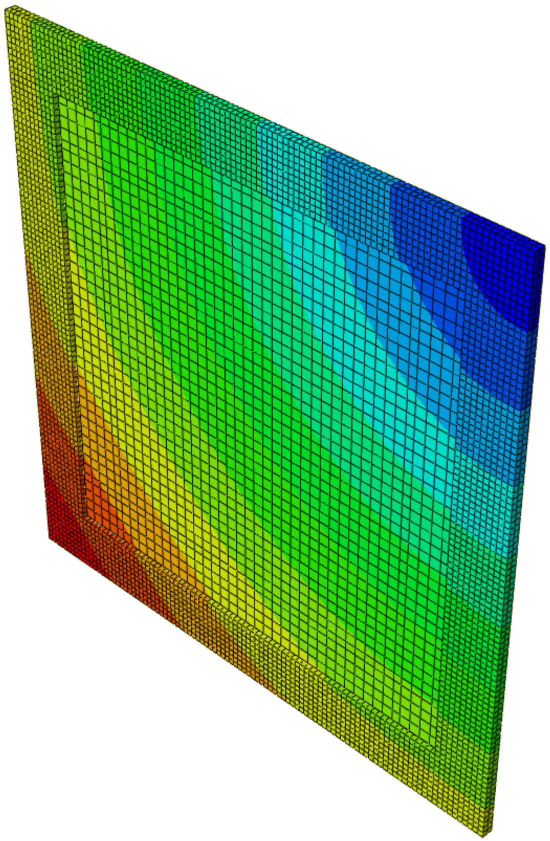

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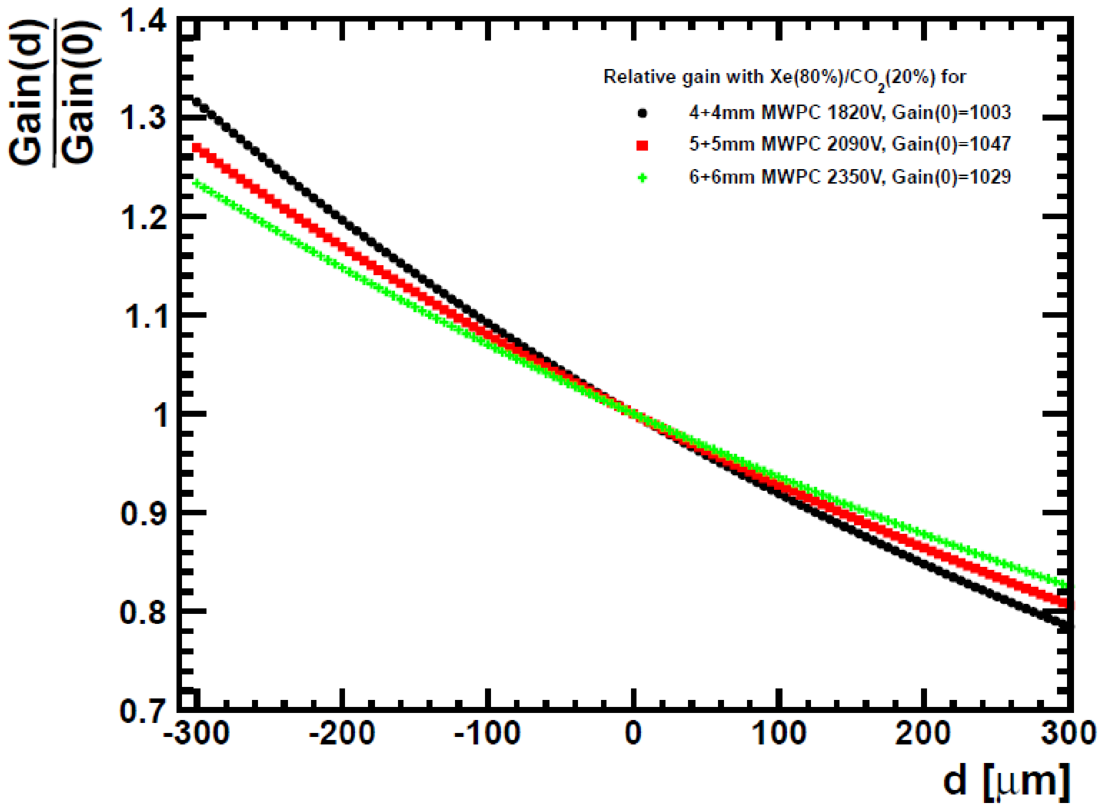
Gain Simulations: Variations

- Variation of detector geometry according to the deformation of entrance window simulated with GARFIELD
- Design goal is less than ±10% gain variation → 200µm deformation of entrance window
- According to simulation 200µm → ~100µbar overpressure
- Comparable modern gas systems achieve up to 10µbar stability in overpressure for small volumes (e.g. HERMES TRD) and up to 100µbar for large volumes (e.g. ALICE TPC)



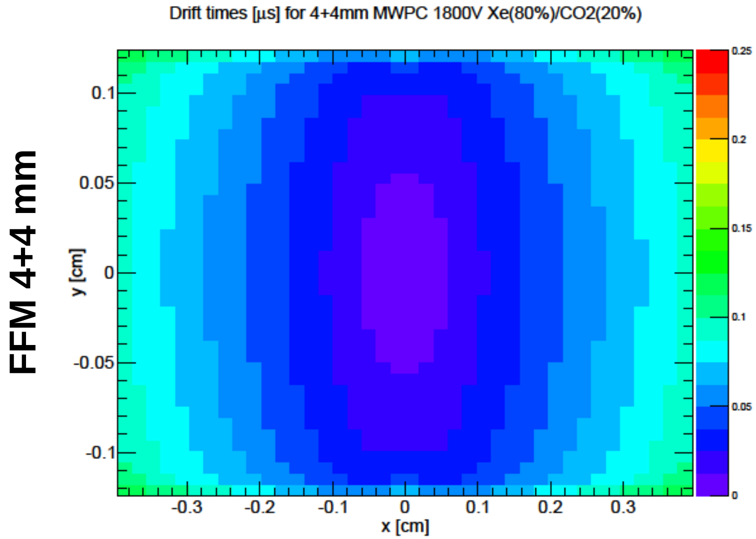
Drift Time Simulations

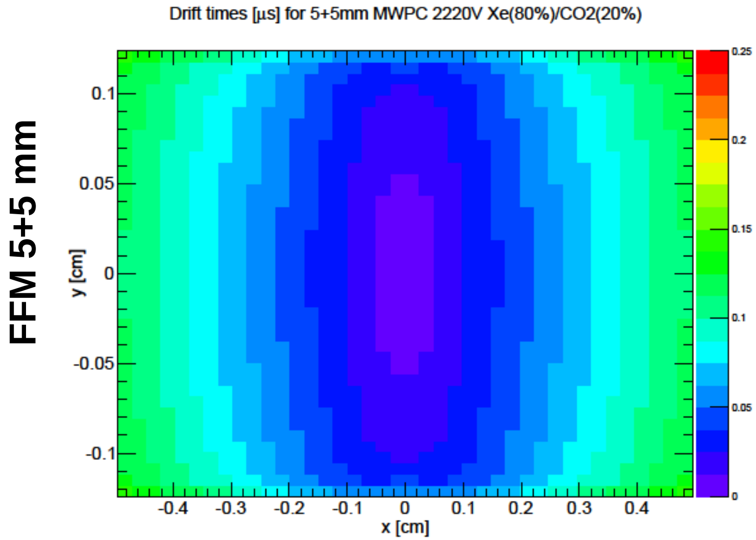
- Simulation of drift time for electrons generated in the amplification region

- Large scale prototypes with 4+4mm and 5+5mm geometry with $XeCO_2$ 80:20

  → maximal ~ 0.15µs drift (6.6MHz)

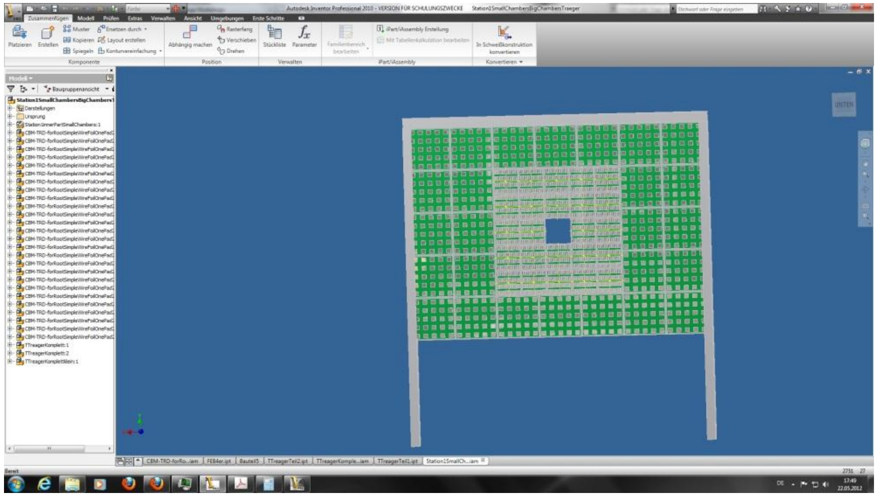
- Defines maximal spread in time for signals from same event (jitter) → important information for development for front end electronic and reconstruction software

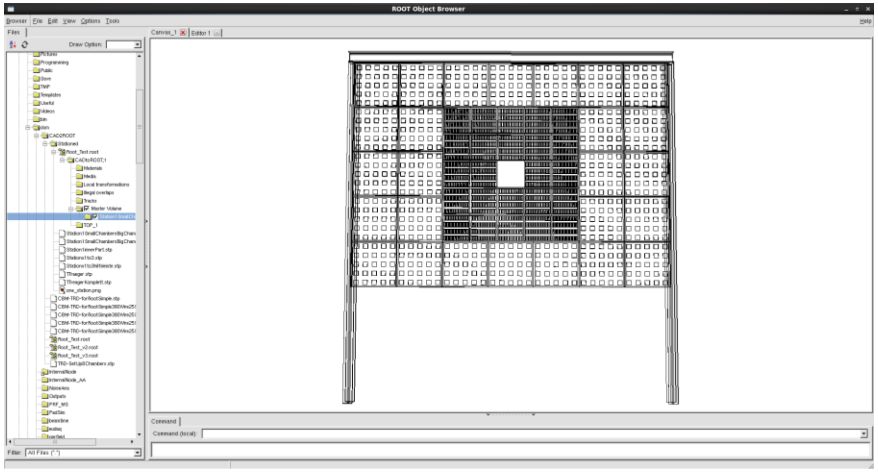




Geometry-Integration into Simulations

- **Current status of complete detector geometry have to be implemented into simulation and analysis framework (CBMroot)**
- **Only basic construct of detector modules for the inner and outer part with simple support frame created using CAD2root converter tool, no infrastructure, no supply, no cooling…**
- **Realistic detector and electronic response to be implemented (“Digitizer”)**
- **First simulations to be done…**





Outline

1) Introduction

2) Small prototypes and their results
   Detector concept, prototype design, beamtime at CERN 2011, results for electron/pion separation and position resolution

3) New developments
   Next generation data read out, large scale prototypes, simulation of gas gain and mechanical detector parameters

4) Upcoming beamtimes, summary and outlook

Next Steps: Upcoming Beamtimes

Two in beam tests currently scheduled:

1) At GSI:

- **At GSI in the FOPI cave**
- **Beam of secondary particles with very high intensity**
- **High rate capability tests for 60x60 cm prototypes**
- **Scheduled for 15. – 19. Oct 2012**

2) At CERN T9:

- **At CERN PS in the T9 experimental area**
- **Mixed beam of Electrons and Pions up to 10GeV/c**
- **Verification of results from small prototypes with real size prtotypes**
- **Scheduled for 25. Oct 2012 – 12. Nov 2012**

Summary & Outlook

- **Small prototypes with and without additional drift region have proven to fulfill requirements in Electron/Pion separation and position resolution → no obvious preferences**
- **Large scale prototypes will verify these results in upcoming beamtimes.**
- **New generation of read out electronics is about to be implemented and tested.**
- **Complete detector setup (Number of stations, Radiator, …) and requirements for infrastructure and supply have to be evaluated.**
- **Technical design report mid 2014!**