Alternative Chamber design
Two dimensional position sensitive TRD chamber for the inner zone of the CBM-TRD subdetector

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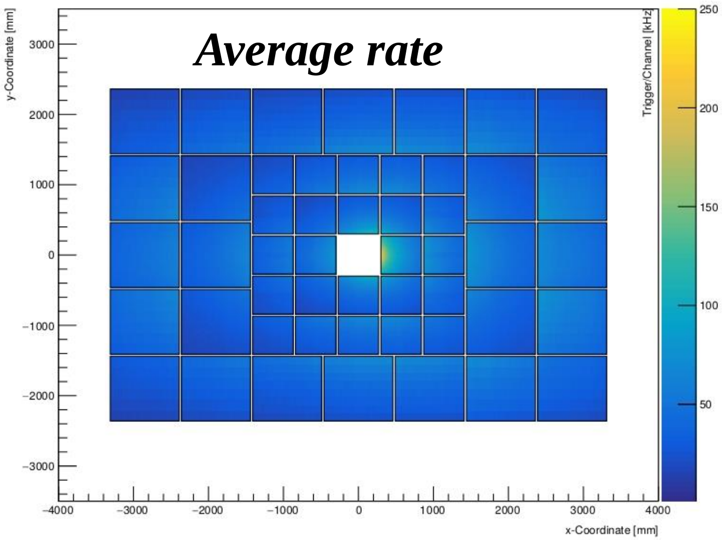
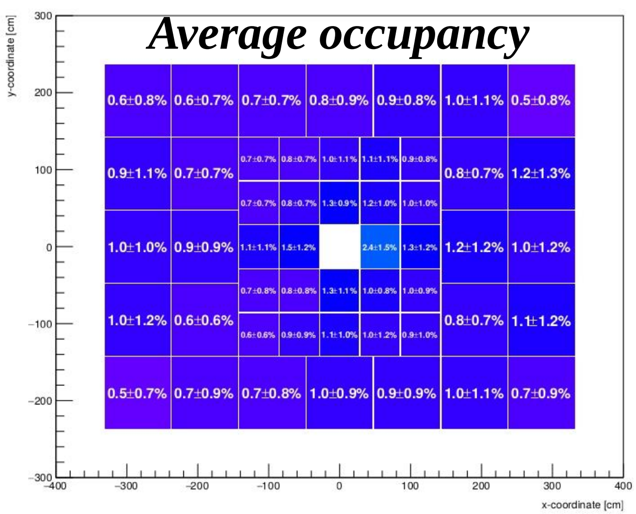
Outline

- *Motivation – inner zone of the TRD subsystem of the CBM experiment @ FAIR*
- *Short history of R&D for a High Counting Rate TRD*
- *Two dimensional position sensitive TRD prototype*
- *Fast Analog Signal Processor (FASP) developed as dedicated FEE*
- *Towards a basic TRD chamber for the inner zone of CBM-TRD subsystem*
- *Chamber construction infrastructure*
- *Summary*

The CBM-TRD requirements

Au + Au minBias @ 10A GeV





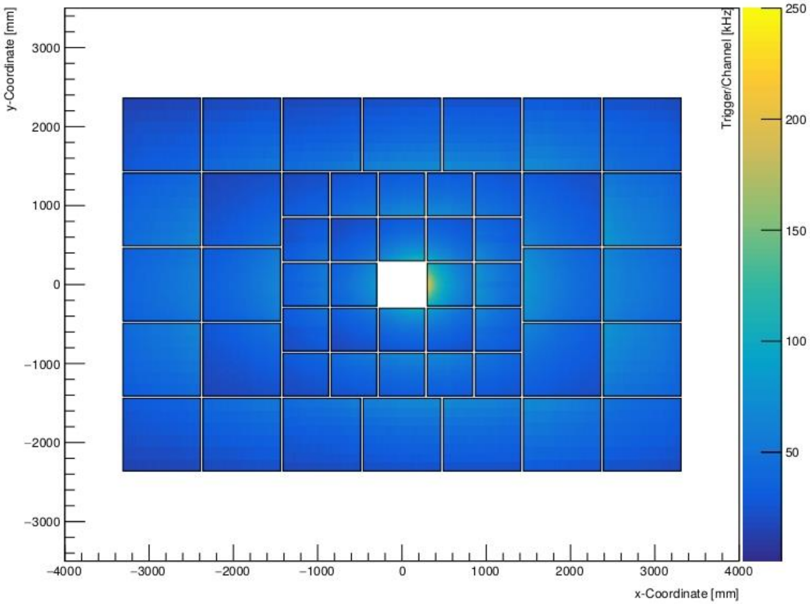
TRDv16a, Station 1 Layer 1

Inner zone of the TRD subdetector

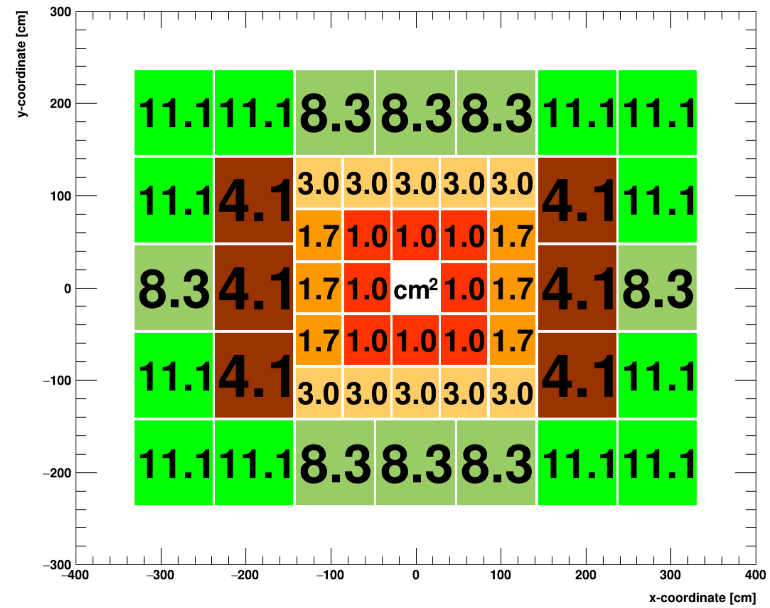
- ***Highly granular and fast detectors which can stand counting rates up to 10^5 part/cm^2 ·sec @ 10 MHz interaction rate***
- ***Tracking of all charged particles with a position resolution of:***
  - 300 μm across the pads
  - 3 – 30 mm along the pads
- ***Provide identification of high energy electrons (γ > 1000) in conjunction with RICH and mandatory beyond the momentum range accessible with RICH***
- ***Hadrons identification on the basis of a measurement of their specific energy loss***

Current CBM-TRD geometry

Detector modules in two different sizes



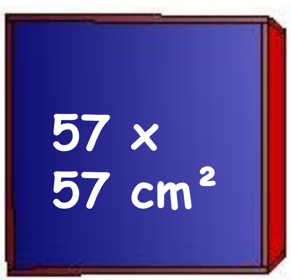
Pad areas between 1 cm^2 and 11 cm^2

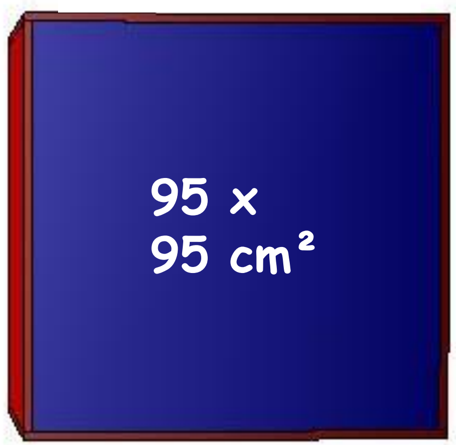


outer chamber

TRDv16a, Station 1 Layer 1

inner chamber

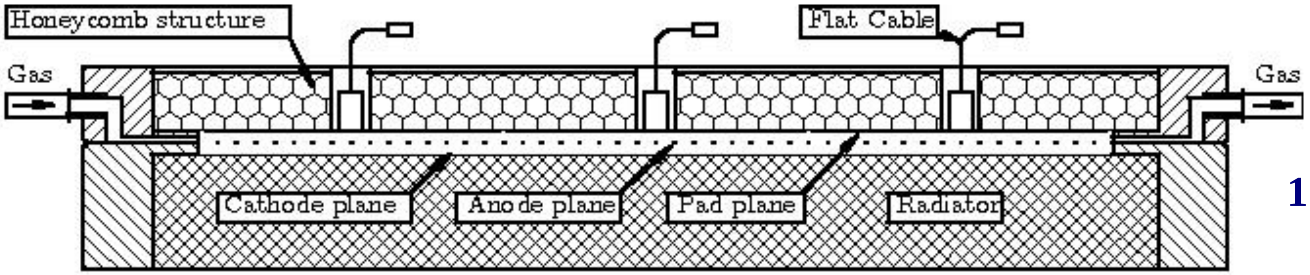




scale pad size with radial distance to the beam

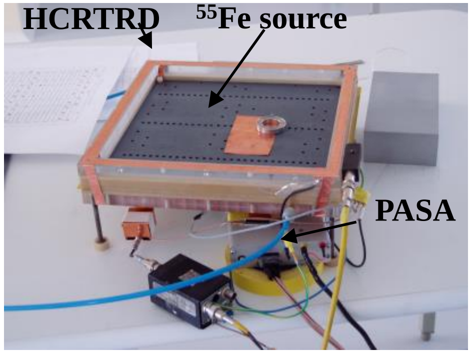
First HCRTRD attempt (2004)

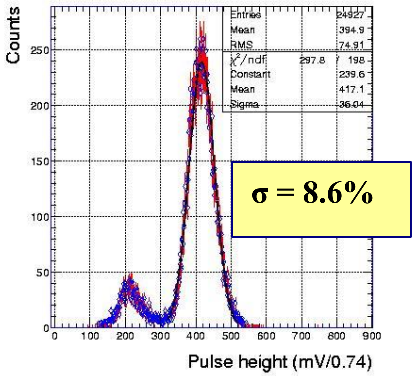
Single – MWPC



2 x 3 mm gas gap,
2.5 mm anode pitch,
1 x 6 cm^2 rectangular pad area

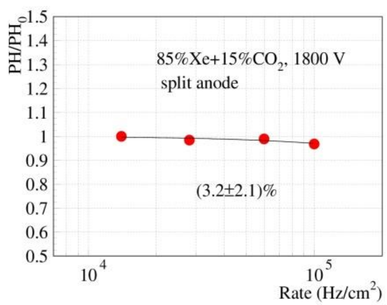
^{55}Fe Source Tests

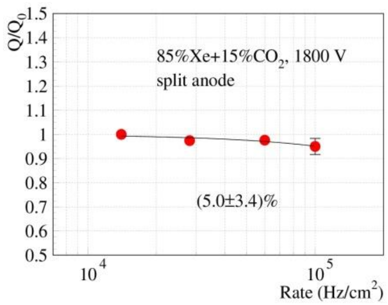


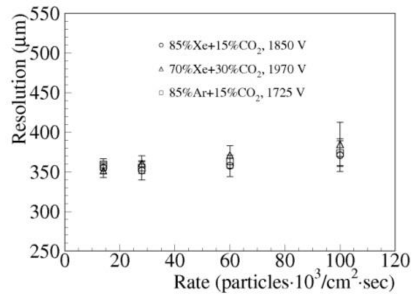


In-beam test @ SIS, GSI – Darmstadt

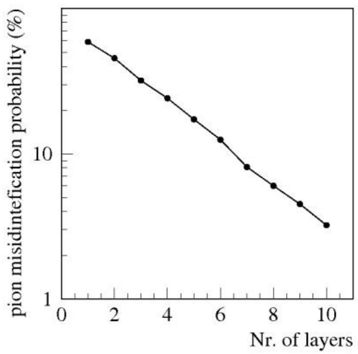
High counting rate proton = 2 GeV/c







e/π discrimination @ 1 GeV/c

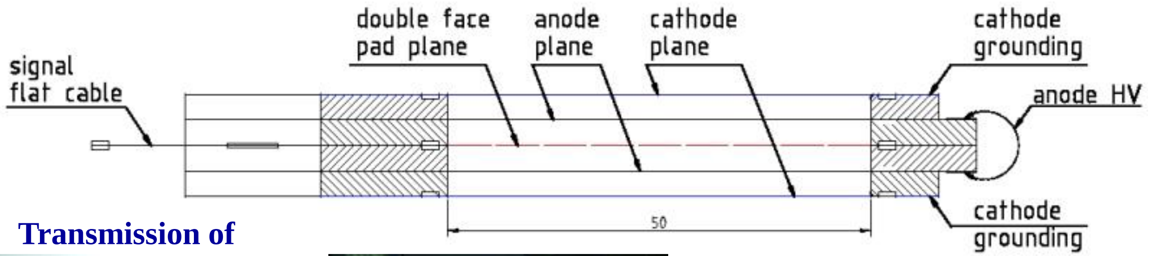


10 layers configuration = 2.9 %
Can be improved using a better radiator from the point of view of the transition radiation yield

M. Petris et al., Nucl. Instr. and Meth 581(2007), 406

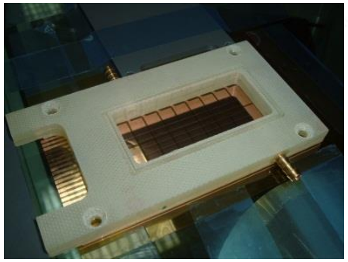
Double - sided pad readout HCRTRD prototype (2006)

Double – MWPC 2 x 3 mm gas gap, 2.5 mm anode pitch
0.5 x 1 cm^2 rectangular pad area

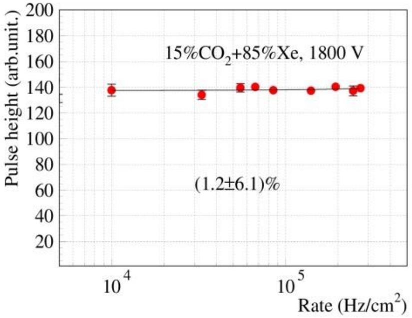


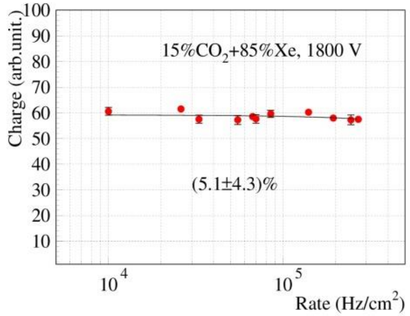
Readout electrode made from kapton foil of 25 μm; rectangular pads and signal traces are etched on both sides in the 0.3 mm evaporated Cu layer.

Transmission of ^{55}Fe X – ray = 84%



High counting rate in-beam test, p = 1.5 GeV/c

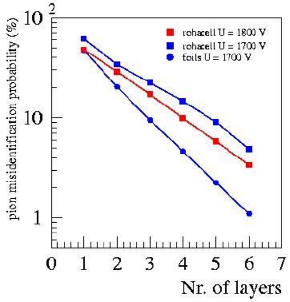


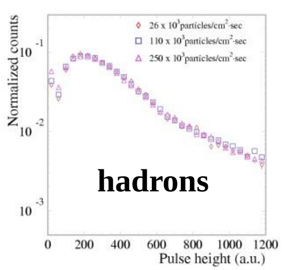


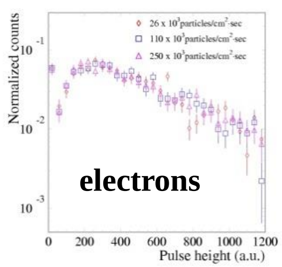
In-beam test SIS, GSI – Darmstadt

e/π discrimination @1.5 GeV/c

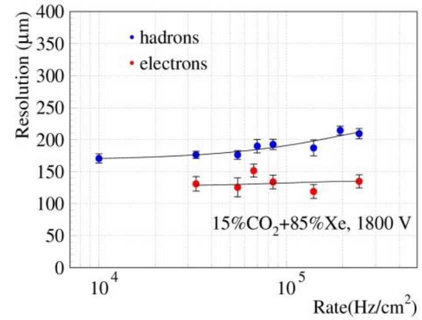
1800 V + Foil (20/500/120) @ 6 TRD layers = 0.7%





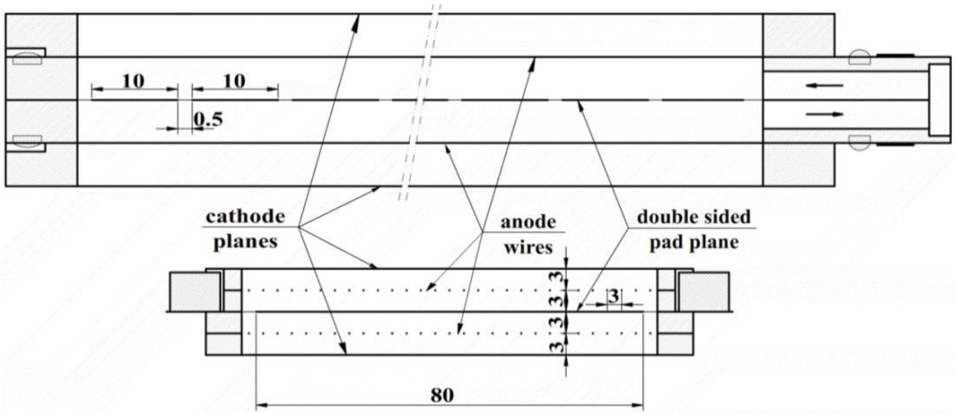


M. Petrovici et al., Nucl. Instr. and Meth .579(2007), 961

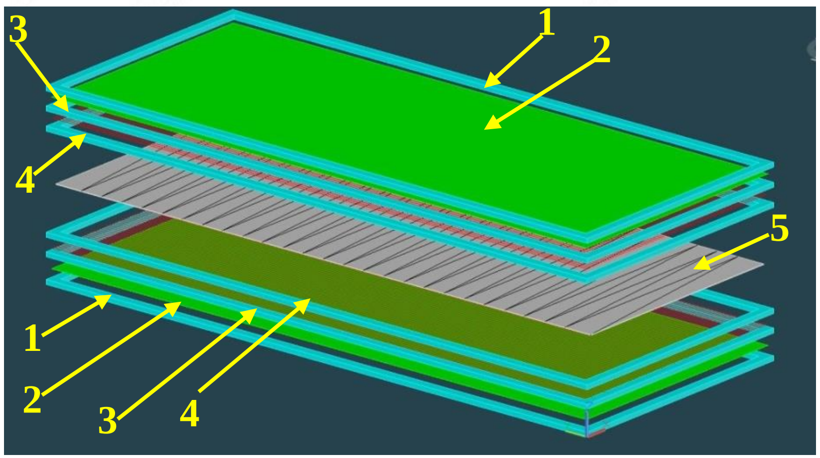


PASA – 16 channels ASIC preamplifier - shaper
H.K. Soltveit et.al, GSI Sci. Rep. 2005-1

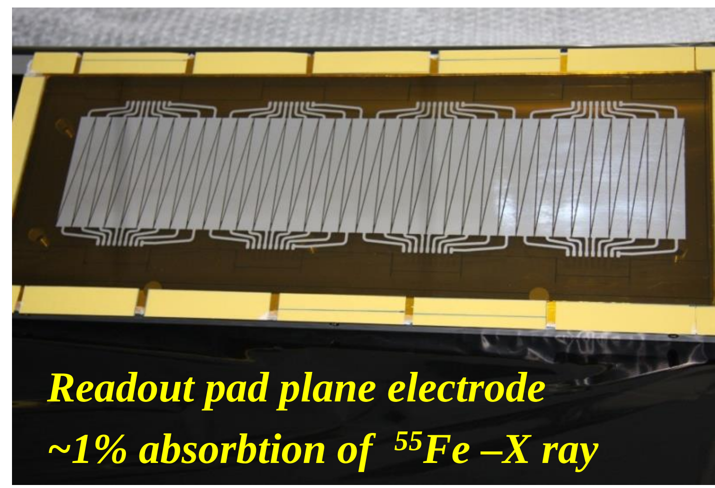
Two dimensional position sensitive double -sided TRD prototype version



- 2 MWPC readout by the a common double sided pad plane
- readout electrode: Cr(20 nm)/Al(200nm) on 25μm kapton foil
- triangular shape of readout pads
- readout cell area (1 x 8)/2 cm^2 = 4 cm^2



1. cathode frame
2. cathode plane – 25 μm Al kapton foil stretched on a 8 mm rohacell plate
3. anode wires (20 μm W/Au) + frame
4. distance frame
5. 36 cm x 8 cm readout electrode: 72 triangular pads



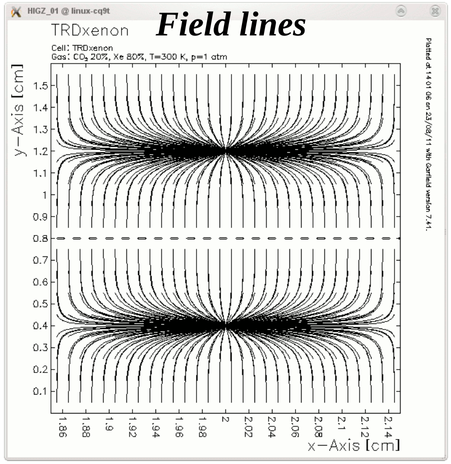
Two versions:

DSTRD-V1 of 3 mm anode – cathode gap

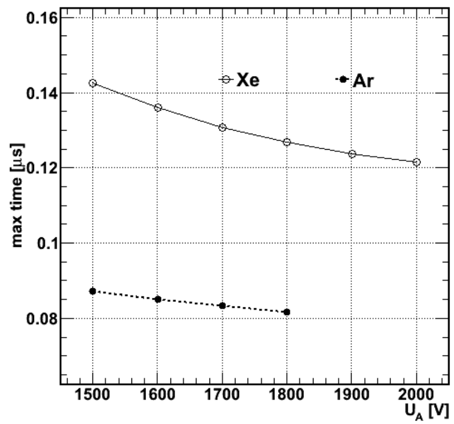
DSTRD-V2 of 4 mm anode – cathode gap

Detector Garfield simulation – drift time study (I)

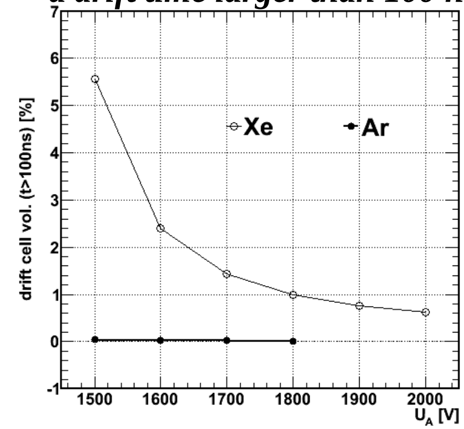
Double MWPC TRD prototype (4 x 4 mm)



Maximum drift time



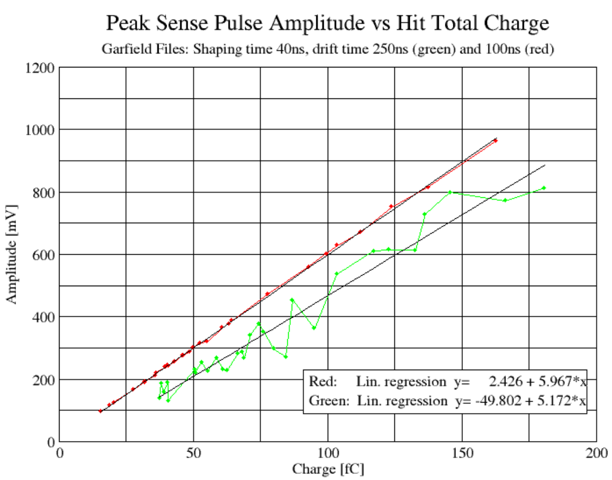
Percentage of the volume with a drift time larger than 100 ns

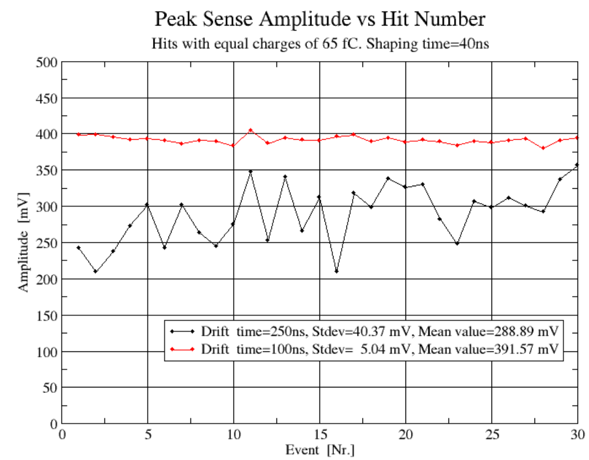


80%Xe/Ar+20%CO_2

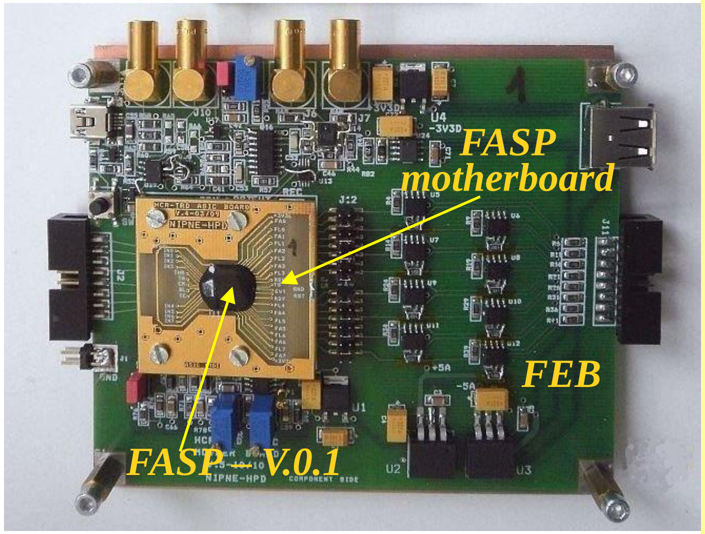
CADENCE simulation

- *linearity & uniformity of the FASP response for hits with an input charge in the range 15 fC-170 fC having the ionization clusters randomly distributed in a time window of 100ns and 250 ns for 40 ns shaping time*





Fast Analog Signal Processor - FASP

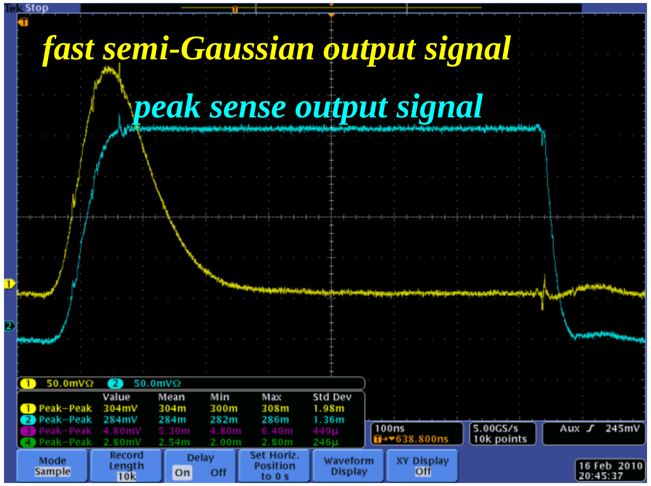


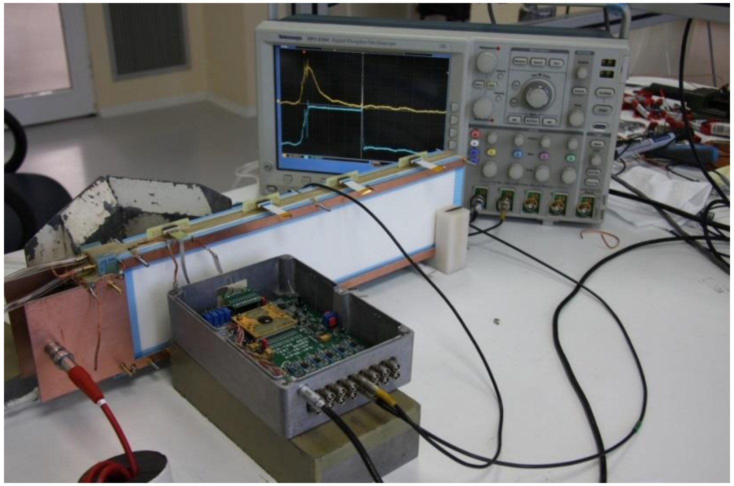
First version – FASP-V.O.1

- *Designed in AMS CMOS 0.35 μm technology*
- *Gain: 6.2 mV/fC*
- *Selectable shaping time (ST): 20 ns and 40 ns*
- *Noise (C_{in} = 25 pF): 980 e-@40 ns ST and 1170 e-@20 ns ST*
- *Power consumption = 11 mW/channel*
- *Variable threshold*
- *Self trigger capability*
- *8 input/output channels*

Analog channel outputs

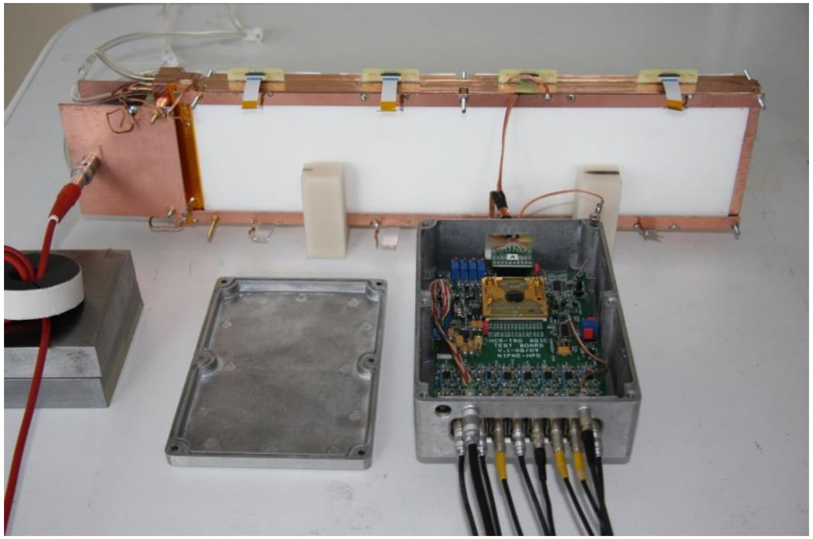
V. Catanescu et al., CBM Progress Report 2009 (2010), 47



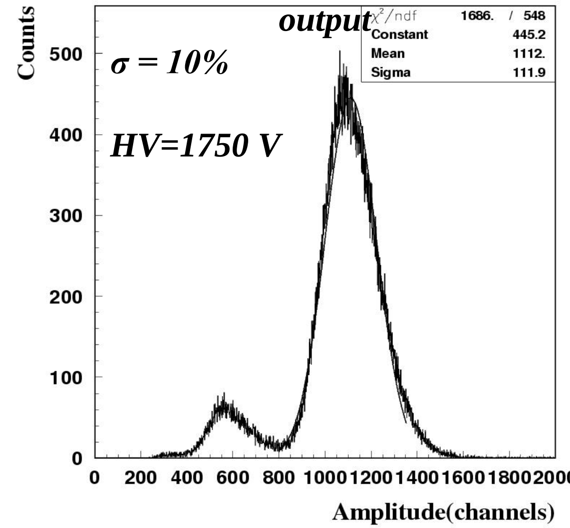


FASP-V.0.1 details in Alexandru's talk

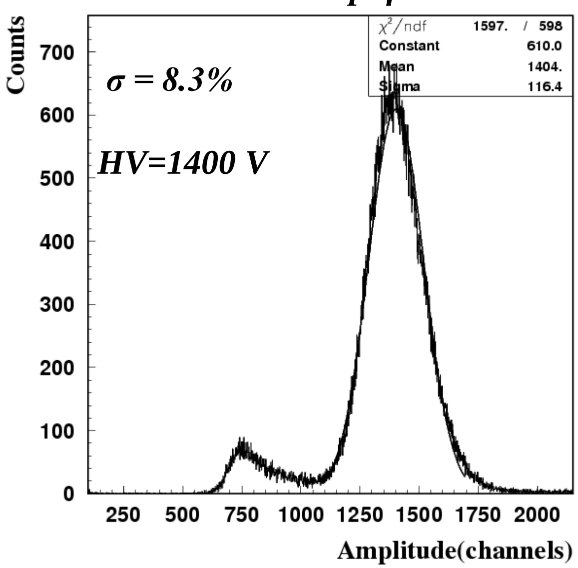
In-house ^{55}Fe source tests with FASP-V.0.1



DSTRD-V2 Pad signal
FASP-V.0.1: fast Gaussian output

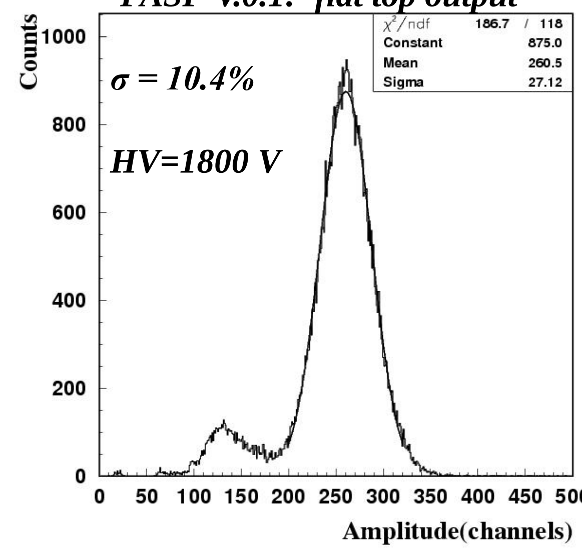


DSTRD-V1 Anode signal
CSA Amplifier



80%Ar+20%CO_2

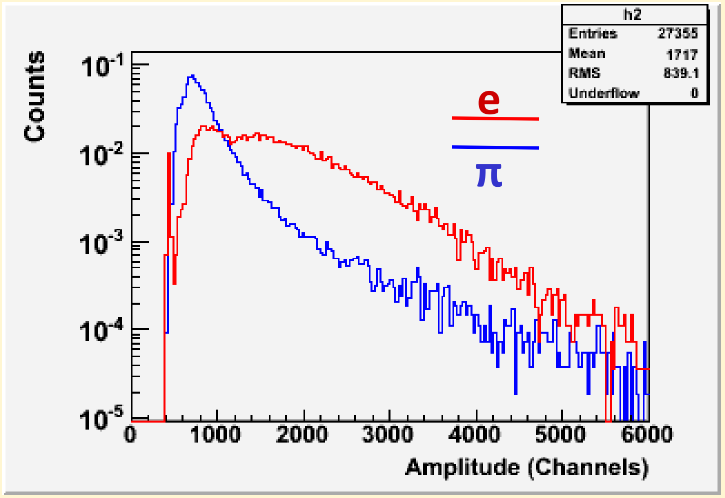
DSTRD-V2 Pad signal
FASP-V.0.1: flat top output



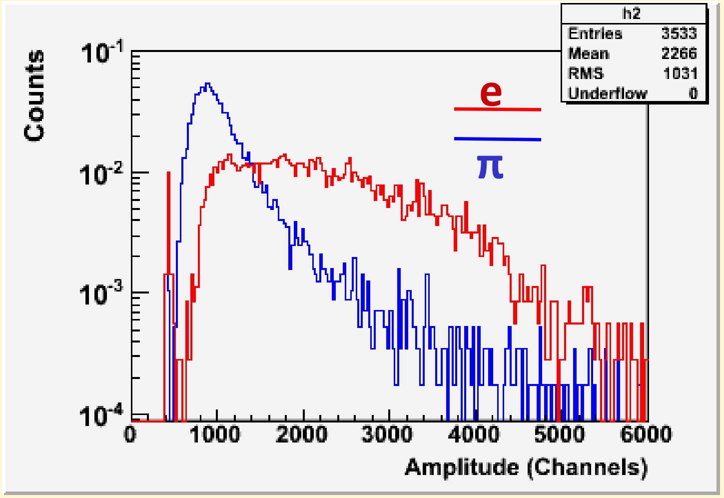
CERN-PS in beam test - e/π discrimination

Pulse height distribution for electrons and pions @ 2 GeV/c momentum

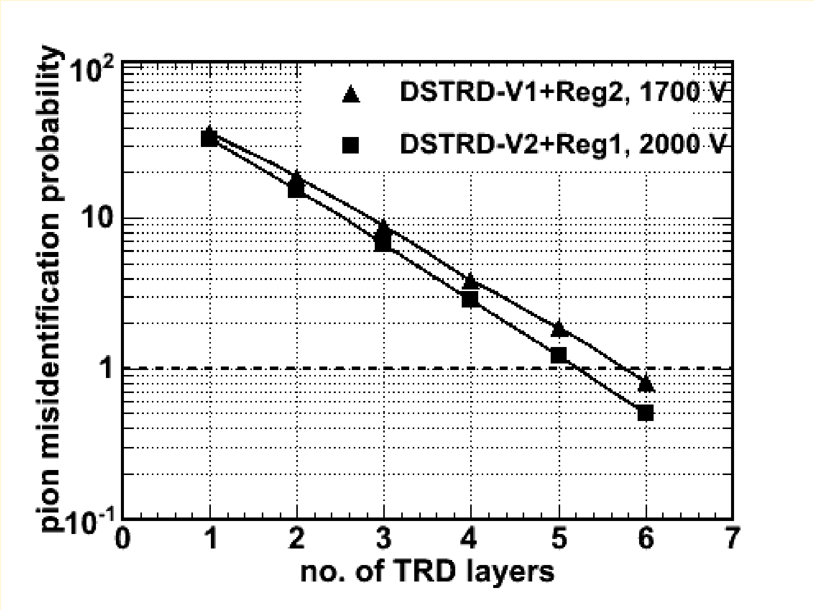
DSTRD-V1 4 gaps x 3 mm, radiator: Reg2 (20/250/220)



DSTRD-V2 4 gaps x 4 mm, radiator: Reg1 (20/500/120)



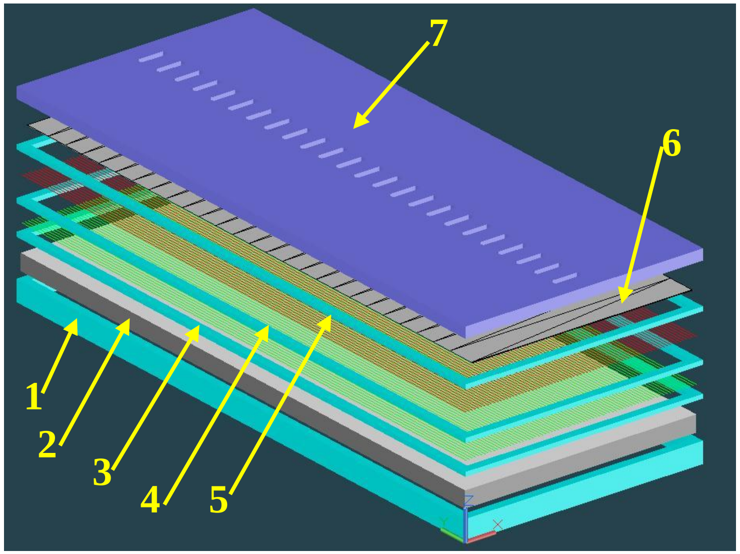
Pion misidentification probability as a function of number of layers



- *0.8% @ 6 TRD layers for DSTRD-V1*
- *0.5% @ 6 TRD layers for DSTRD-V2*

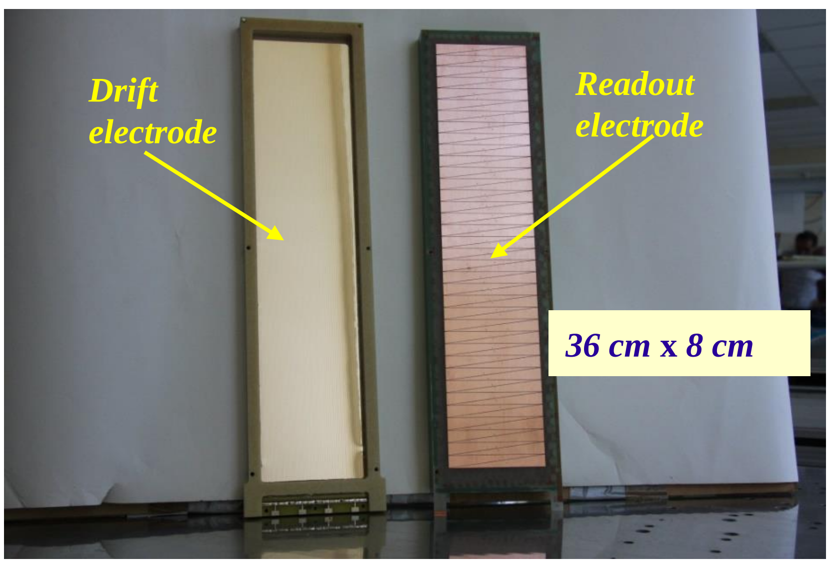
M. Petris et al., Nucl. Instr. and Meth. A 714 (2013), 17.

Two dimensional position sensitive single – sided TRD Prototype - SSTRD

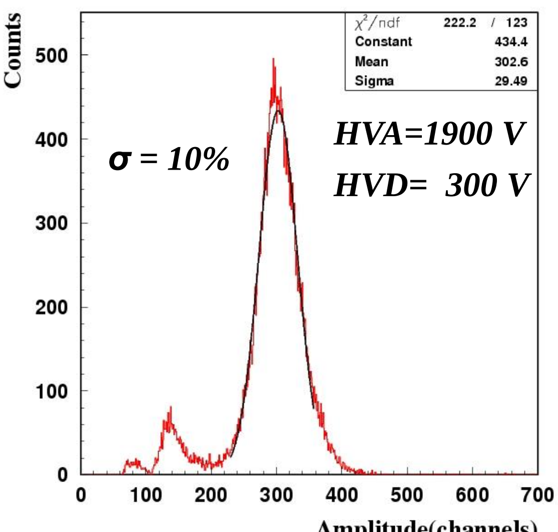


1. drift electrode frame
2. drift electrode
3. cathode wires + frame
4. anode wires + frame
5. distance frame
6. readout electrode
7. honeycomb panel

- single MWPC + 4 mm drift region
- 4 mm anode – cathode gap
- 3 mm anode wire pitch
- 1.5 mm cathode wire pitch
- drift electrode = Al kapton foil stretched on 8 mm Rohacell plate
- readout electrode 300 μm PCB
- triangular shape of readout pads
- readout cell area (1 x 8)/2 cm^2 = 4 cm^2



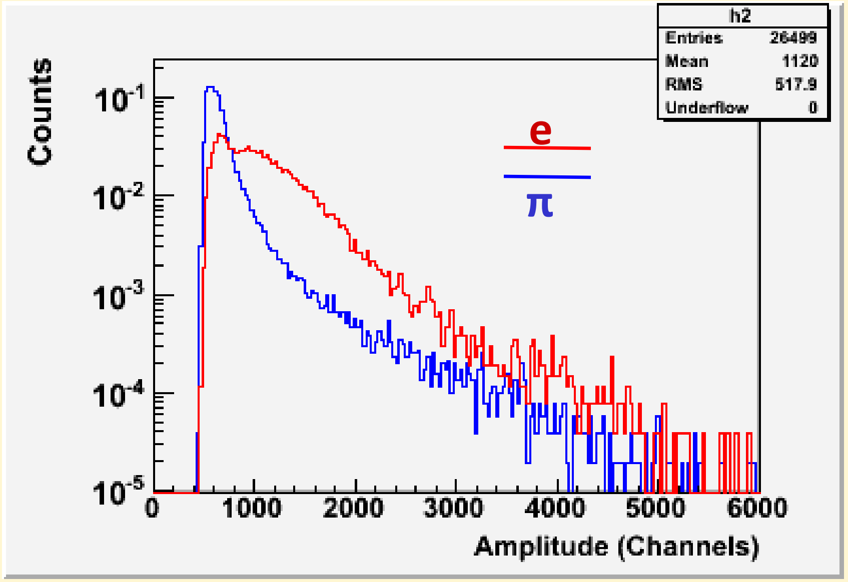
SSTRD Pad signal
FASP-V0: flat top output



CERN-PS in beam test - e/π discrimination

Pulse height distribution for electrons and pions @ 2 GeV/c momentum

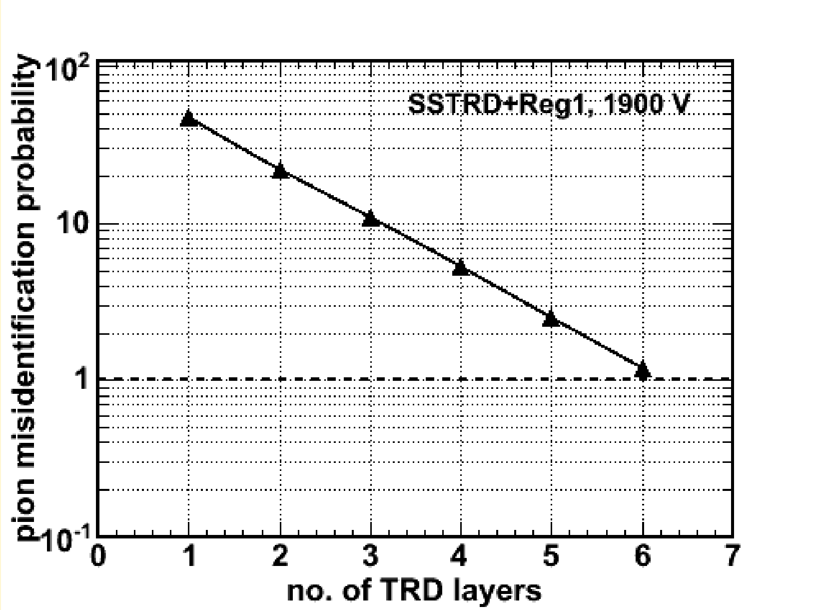
SSTRD 2 gaps x 4 mm + 4 mm drift
radiator: Reg1 (20/500/120)



80%Xe+20%CO_2

Pion misidentification probability as a function of number of layers

HV_A= 1900 V
HV_D= 400 V



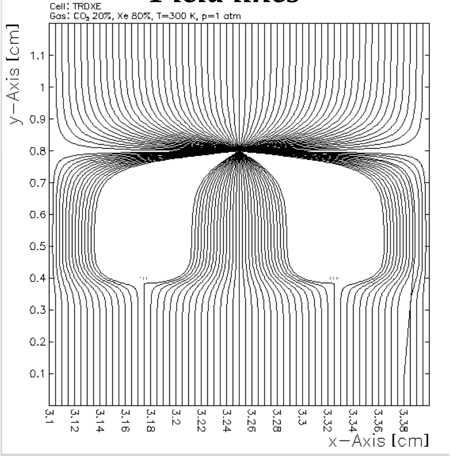
- *1.18% @ 6 TRD layers for SSTRD*

M. Petris et al., Nucl. Instr. and Meth. A 732 (2013), 375.

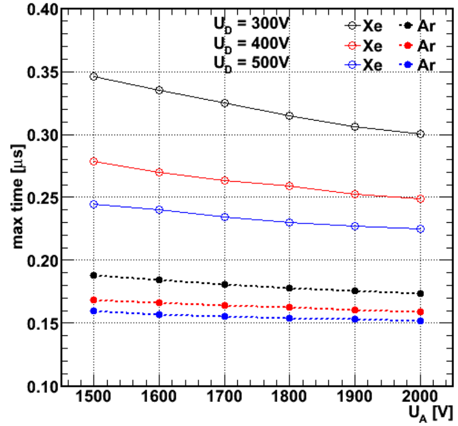
Detector Garfield simulation – drift time study (II)

Single MWPC TRD prototype (2 x 4 mm+4 mm)

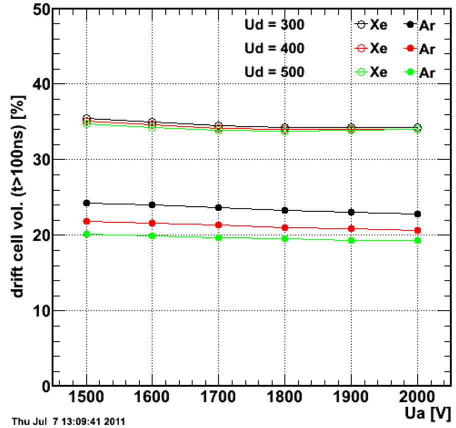
Field lines



Maximum drift time



Percentage of the volume with a drift time larger than 100 ns

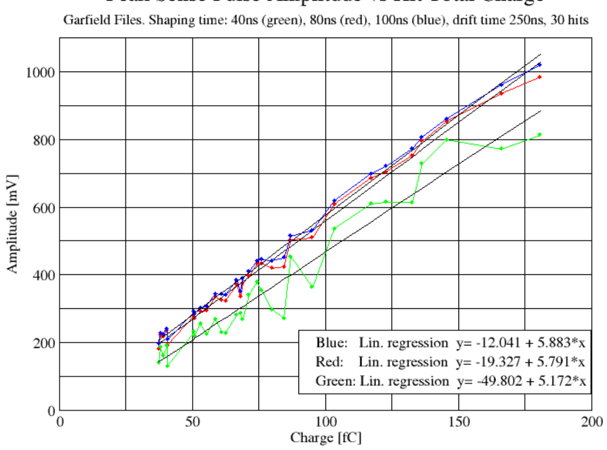


CADENCE simulation

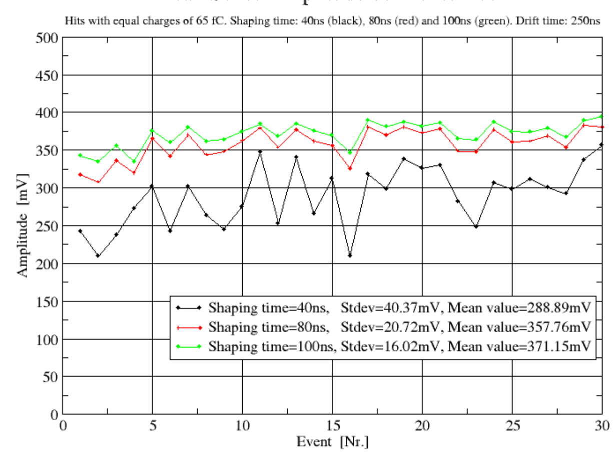
80%Xe/Ar+20%CO_2

- ***linearity & uniformity of the FASP response for hits with an input charge in the range 15 fC-170 fC having the ionization clusters randomly distributed in a time window of 250 ns for 40 ns, 80 ns and 100 ns ST***

Peak Sense Pulse Amplitude vs Hit Total Charge

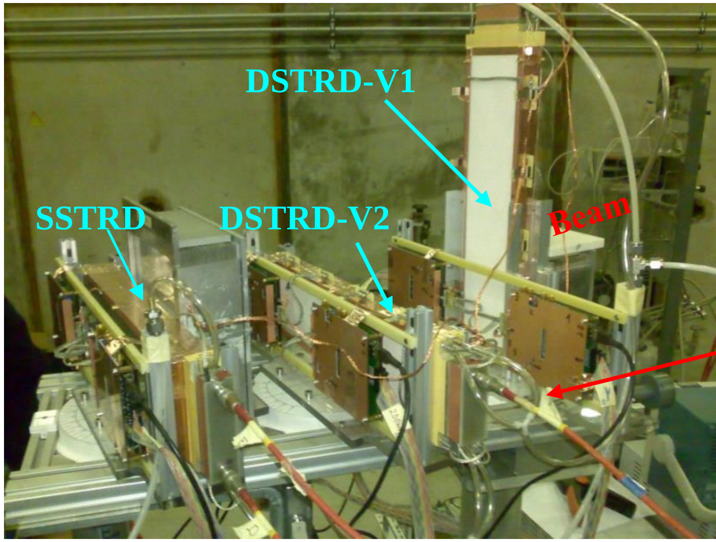


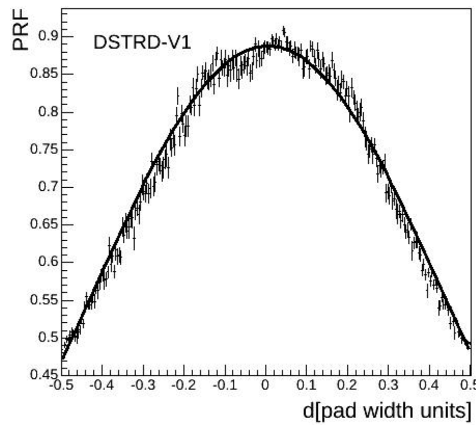
Peak Sense Amplitude vs Hit Number

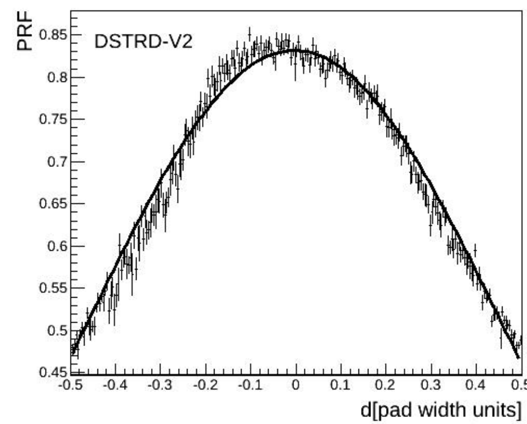


Position Resolution

Pad response function for rectangular pads





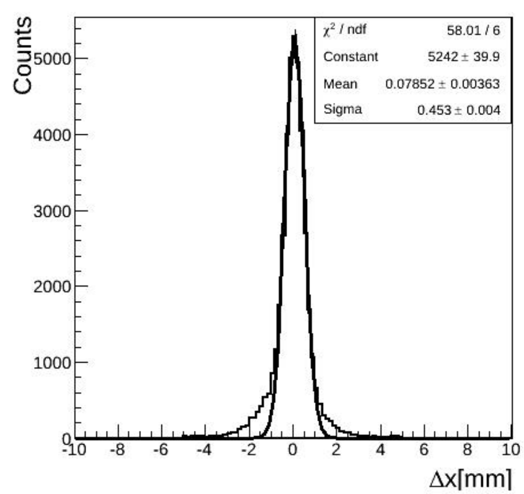


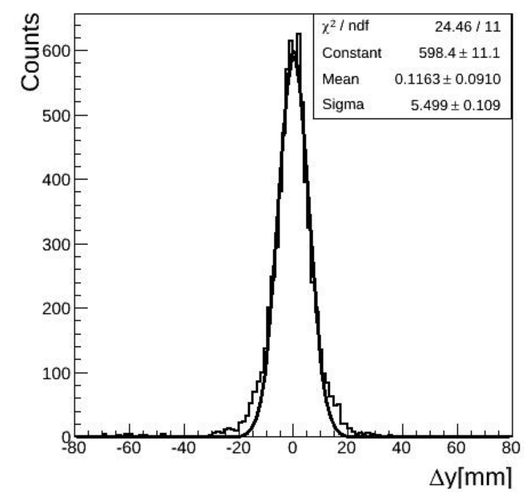
position resolution across the pads

position resolution along the pads

Pad size = 1 cm x 8 cm

Triangular pad shape – possibility to access two dimensional position information with a single TRD layer

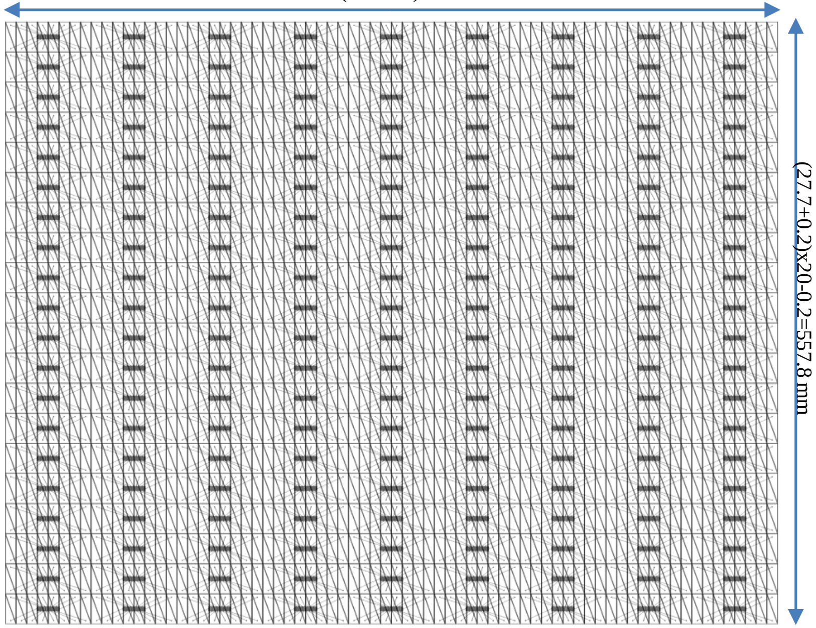




$\sigma_x = 320\ \mu m$

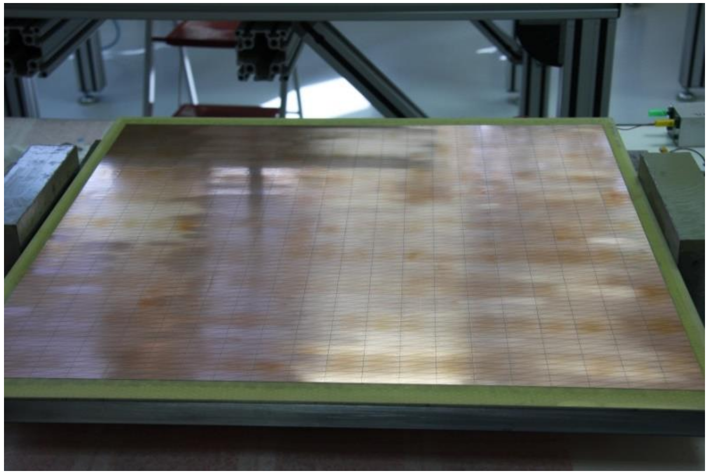
$\sigma_y = 5.5\ mm$

Toward a TRD basic cell for the inner zone of CBM-TRD detector

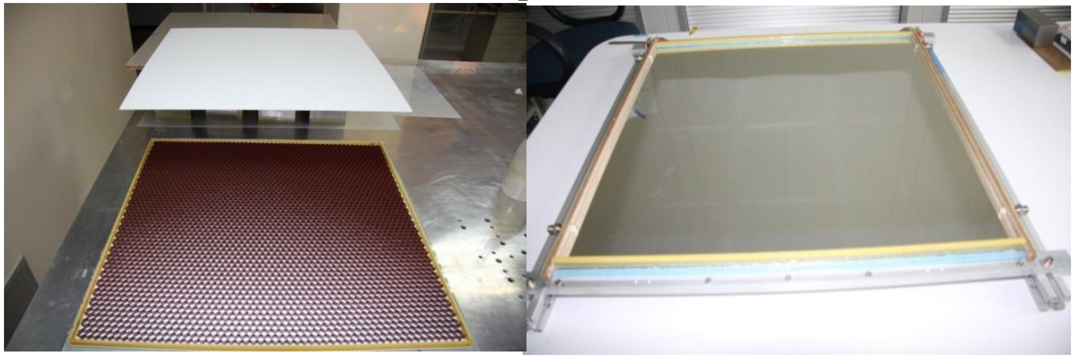


20 rows x 144 triangular pads/row = 2880 readout channels

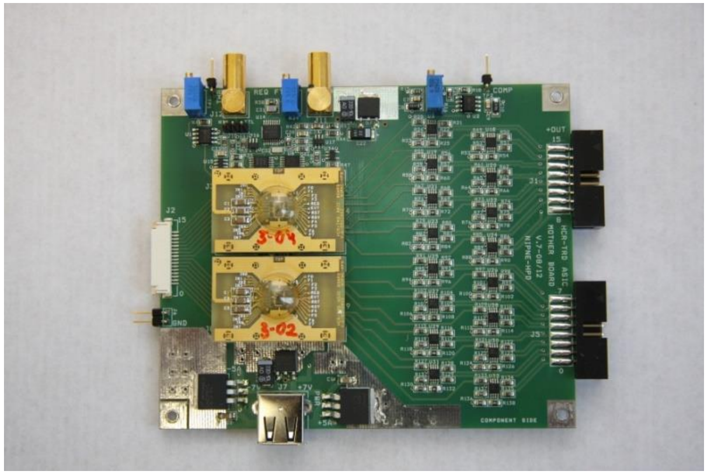
readout cell area (0.7 x 2.7)/2 cm^2 ≈ 1 cm^2



Drift electrode
Al-kapton/3mm Rohacell/9 mm honeycomb/3 mm Rohacell/Al-kapton



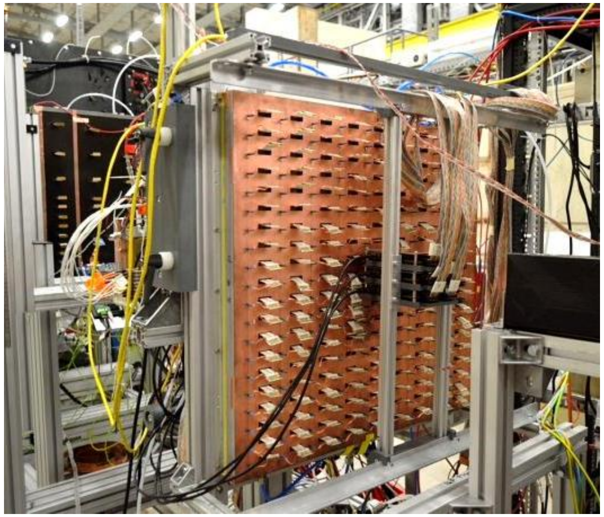
FEE – FASP – flat top output, 40 ns shaping time



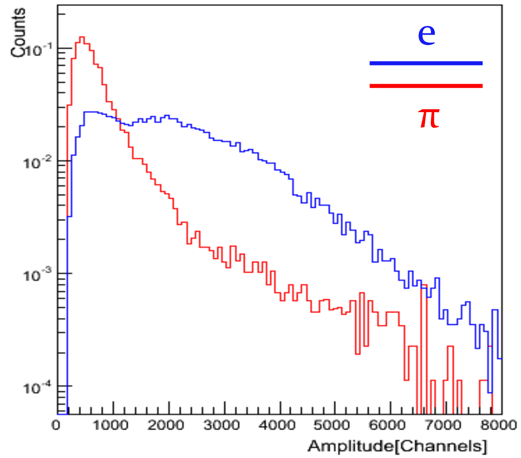
Two ASIC Chips per FEB -> 16 input/output channels

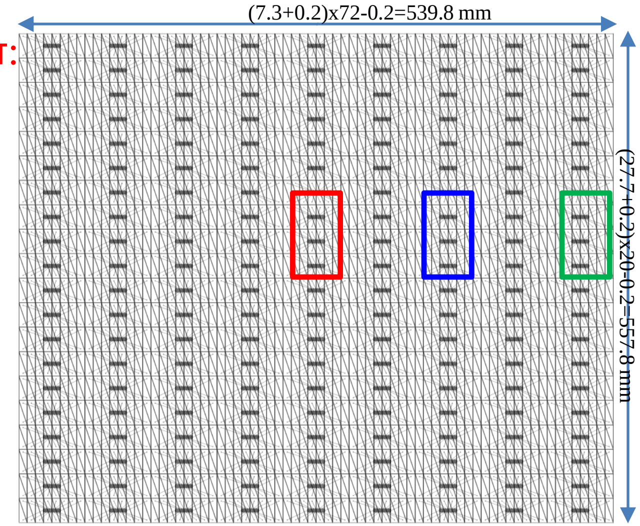
In-beam test of TRD basic cell prototype

In-beam test @ T9 beam line of CERN PS



Pulse height distribution for e and π:



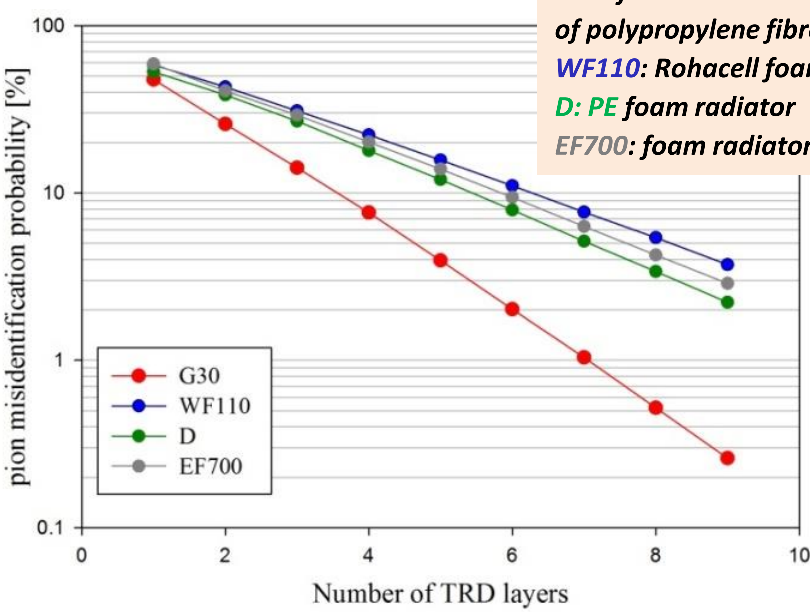


***G30**: fiber radiator = 16 mats of polypropylene fibres*

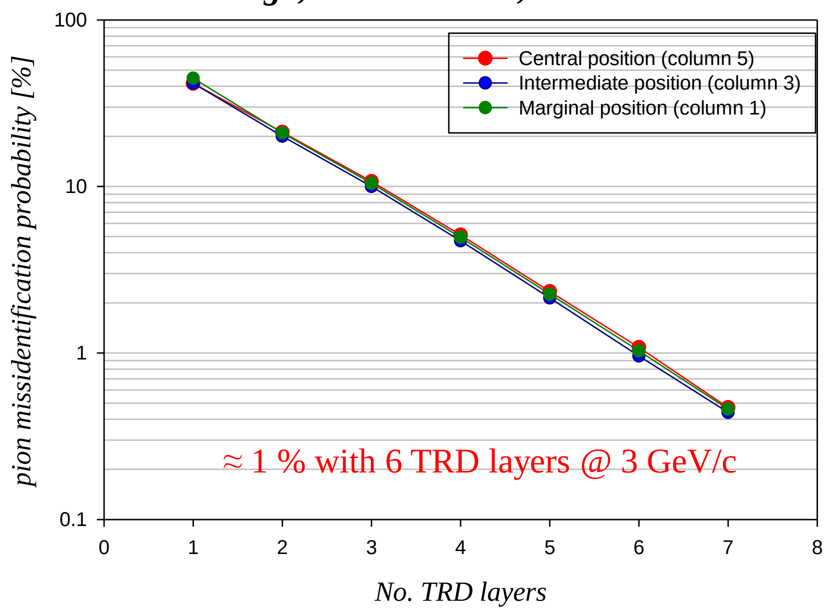
***WF110**: Rohacell foam*

***D: PE** foam radiator*

***EF700**: foam radiator*



Reg2, HVA = 2000 V, HVD = 800 V



Position Reconstruction

Details about position reconstruction and tracking with this pad geometry in close to real conditions operations (CERN SPS beam times) in Alexandru's talk

Optimization of FASP characteristics for better performance with SSTRD architecture → FASP-V.0.2

- *increased shaping time of 100 ns*
- *pairing of the triangular pad signals inside the ASIC chip*
- *16 input/output channels*
- *input signal polarity switch*
- *channel wise chip select logical signal*

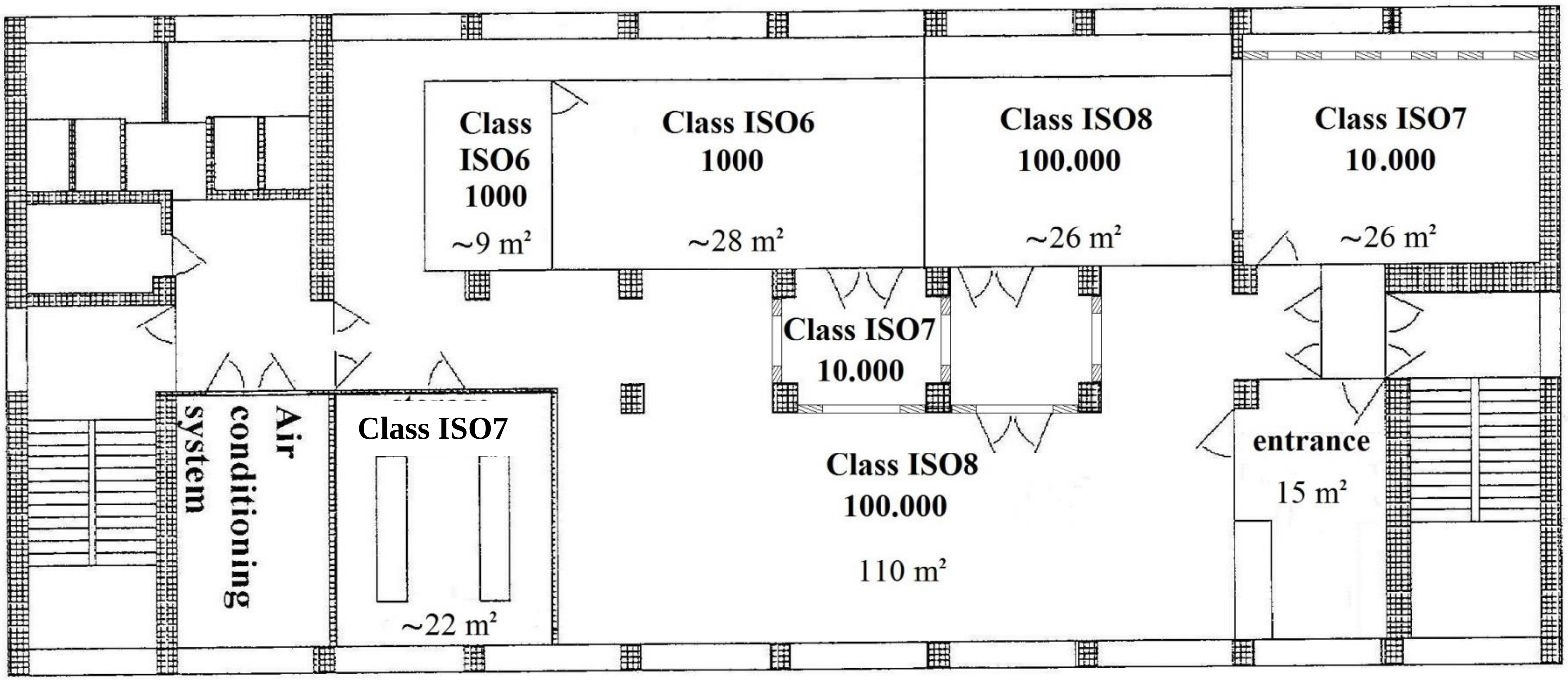
FASP-V.0.2 -> Much more details in Alexandru's talk

Experience & Infrastructure

for Chamber Construction

Detector Laboratory Infrastructure

IFIN-HH, HPD Detector Laboratory Infrastructure



Six main clean rooms with 100000, 10000 and 1000 particles/ft^3 air purity,

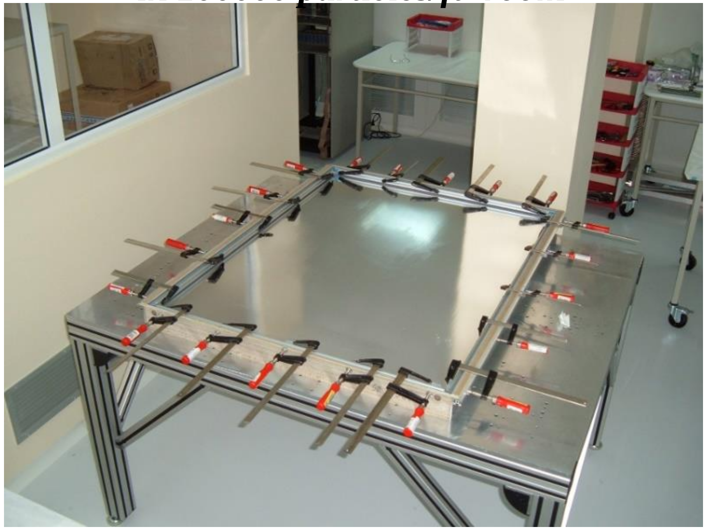
Controlled temperature and humidity

They were equipped during 2004 year for ALICE-TRD chamber construction & testing

Recently the existing infrastructure was extended

DFH Detector laboratory infrastructure used for the ALICE-TRD chamber construction

Frame assembly on the gluing table in 100000 particles/ft³ room



Pad plane assembling on the vacuum table in 100000 particles/ft³ room

Multiwire electrodes winding using winding machine

Soldering of the electrical connections of the multiwire electrodes in 10000 particles/ft³ room

DFH Detector laboratory infrastructure used for the ALICE-TRD chamber testing

Wire tension measuring

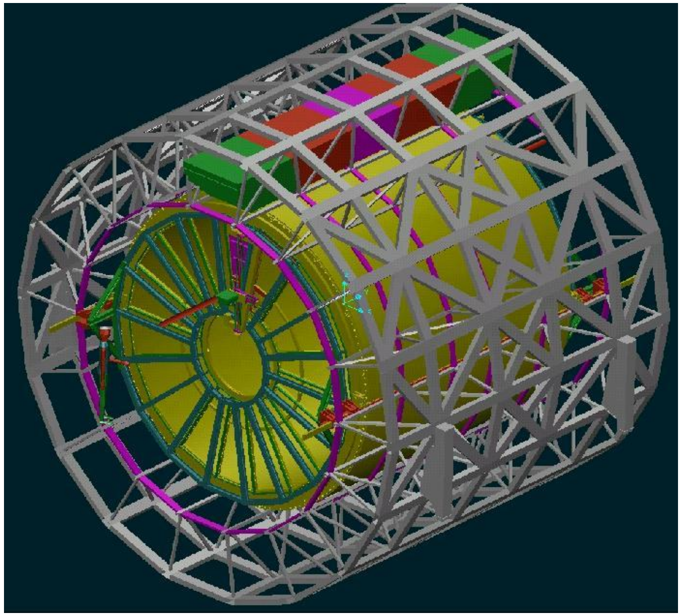
10000 particles/ft^3 room

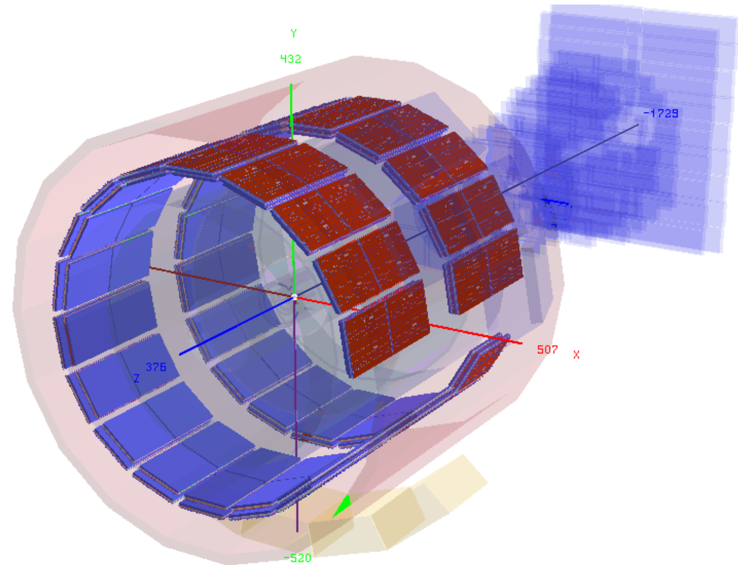
Checks of electrical connections of multiwire electrodes

Gas leak rate test

Final tests: gain uniformity & energy resolution @^{55}Fe source

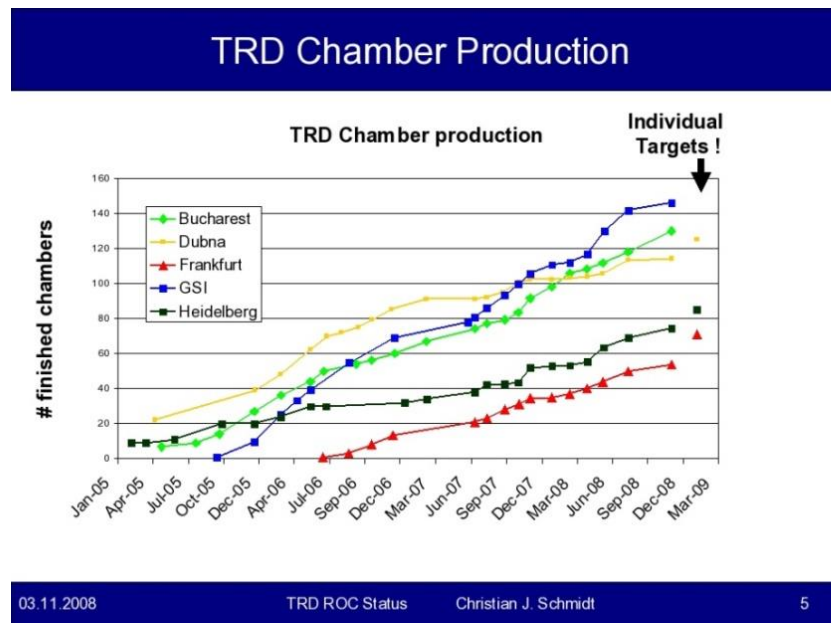
Construction of 130 (24%) out of 540 ALICE-TRD chambers





Constructed TRD chambers - 130:

- ***- 2 L1C0***
- ***- 1 L2C0***
- ***- 54 L2C1***
- ***- 73 L3C1***

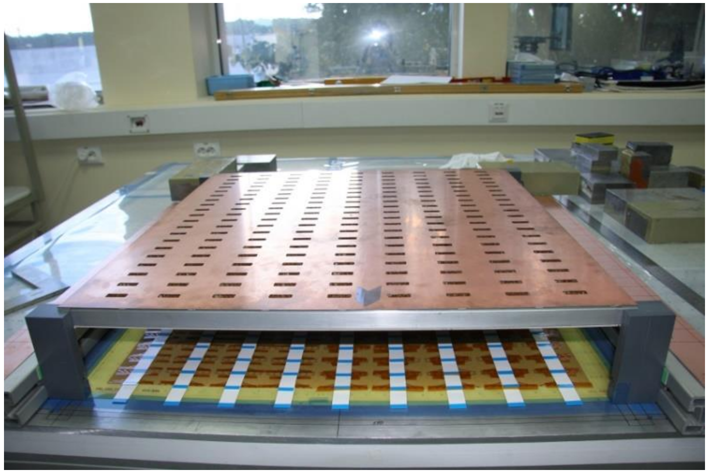


DFH Detector laboratory infrastructure used for CBM-TRD R&D

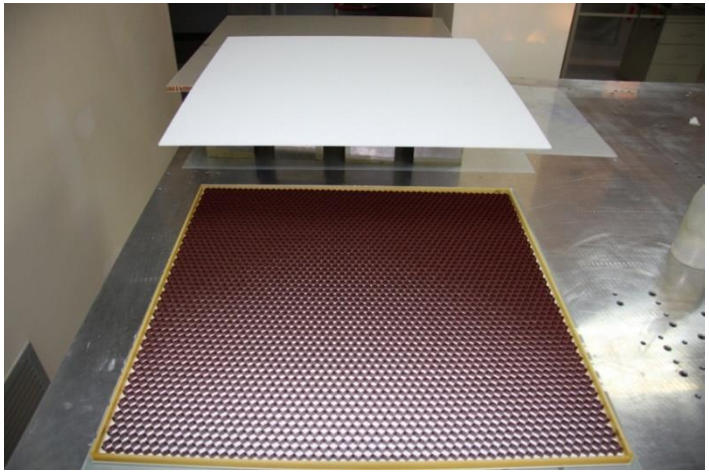
Some construction details of the real size prototype

Soldering the flat cables on the back side of the readout electrode using pick and place machine

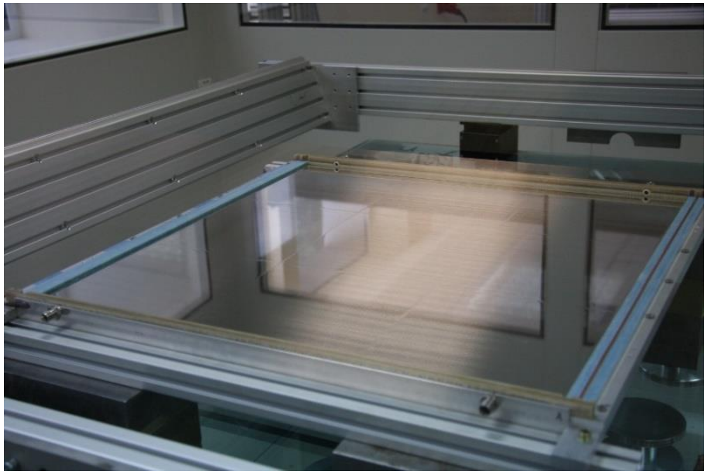
Assembling of the readout electrode using the vacuum table



Assembling of the drift electrode using the gluing table

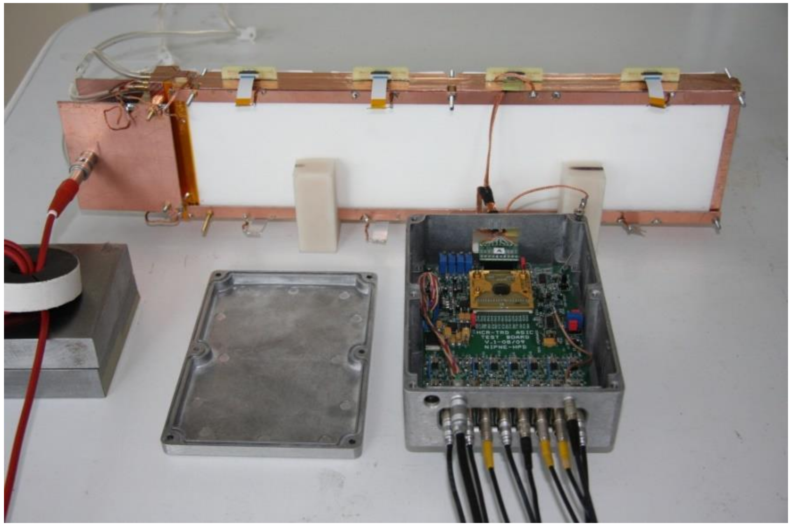


Gluing & soldering of the multiwire electrodes in 10000 particles/ft³ clean room

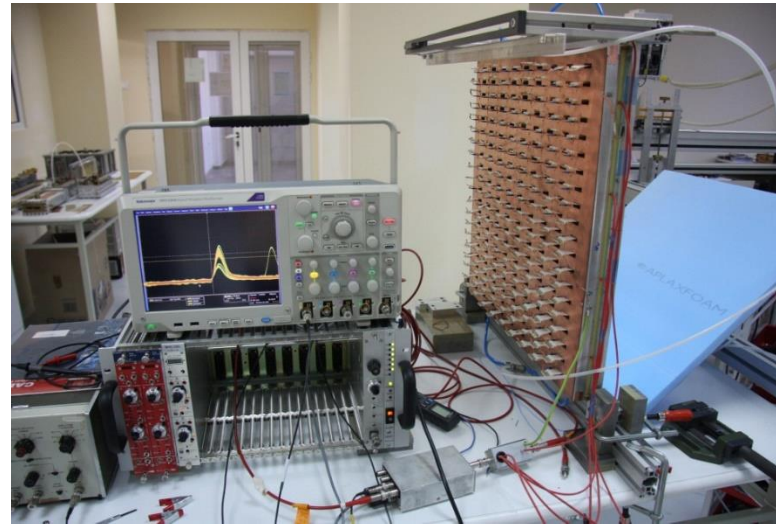


Laboratory ^{55}Fe source tests of the CBM-TRD prototypes

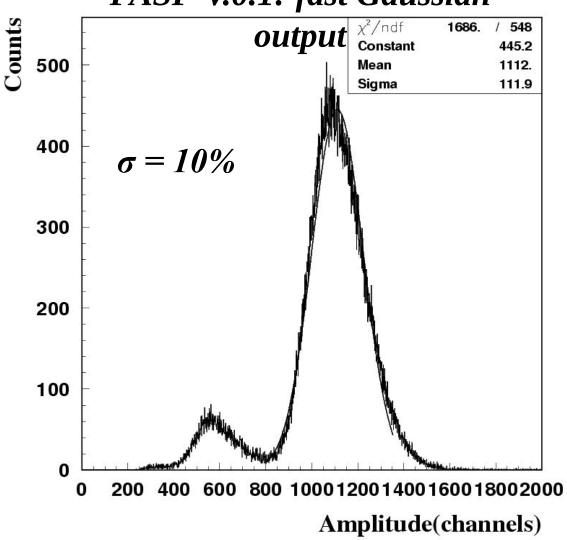
Preliminary measurements in the Detlab



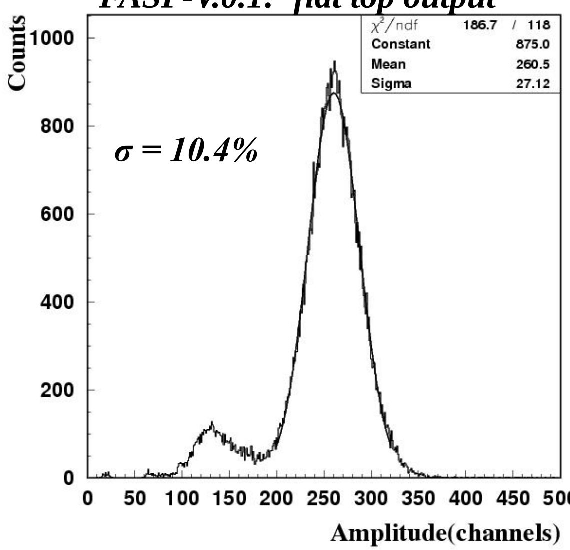
First signals from ^{55}Fe



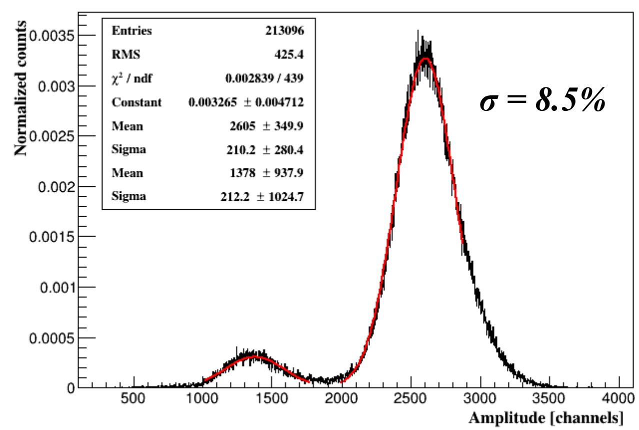
DSTRD-V2 Pad signal
FASP-V.0.1: fast Gaussian output



DSTRD-V2 Pad signal
FASP-V.0.1: flat top output



TRD2012 Pad signal
FASP-V.0.1: flat top output



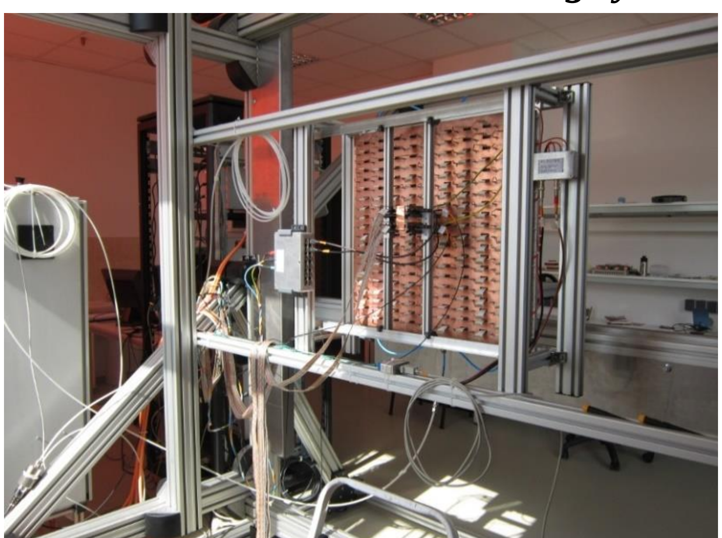
New detector laboratory for testing the TRD prototypes

Laboratory infrastructure

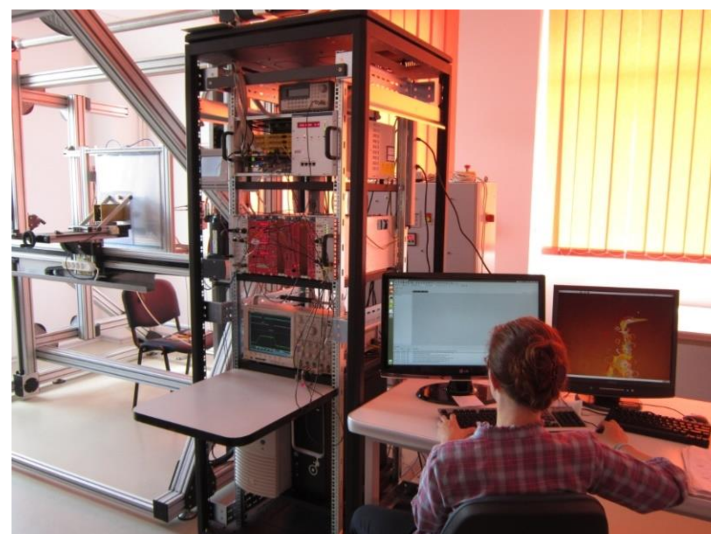
Laboratory infrastructure

- *gas system*
- *oxygen meter*
- *two-dimensional scanning system*
- *mini X-ray tube*
- *electronic modules*
- *DAQ systems*

Real size TRD prototype installed on the two-dimensional scanning system

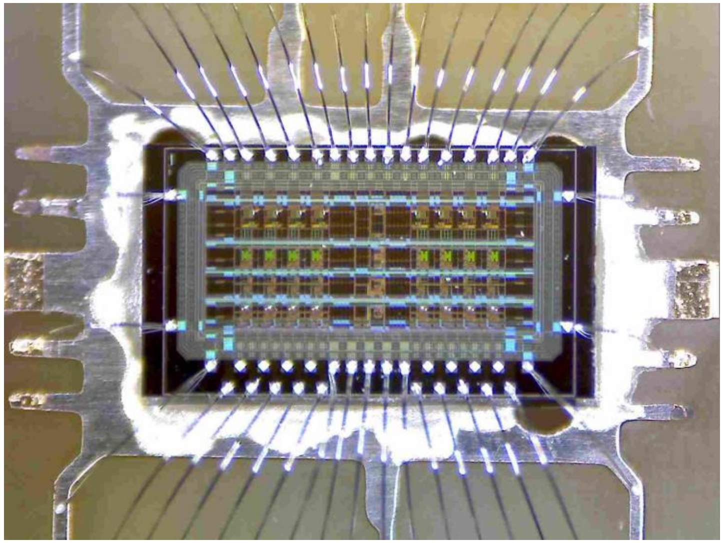


Taking data

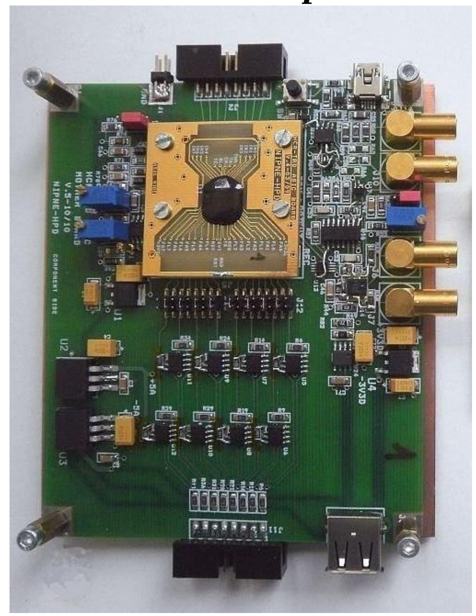


FEE R&D activities for the CBM-TRD

FASP chip bonded on an in house designed motherboard

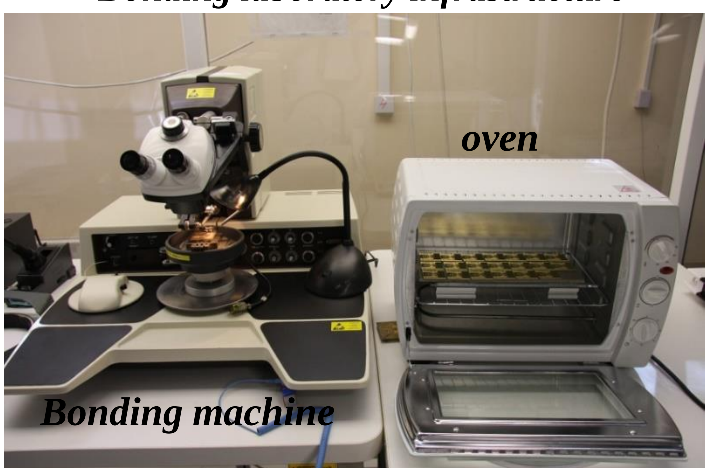


In house designed front end board (FEB) with a single FASP chip



In house designed front end board (FEB) with two FASP chips

Bonding laboratory infrastructure

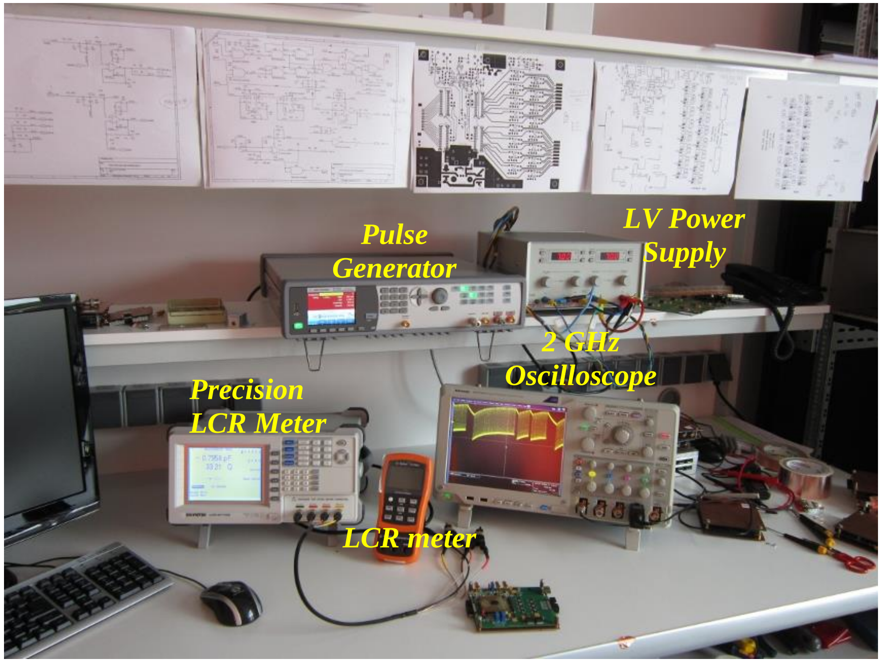


Bonding a chip

Electronics laboratories

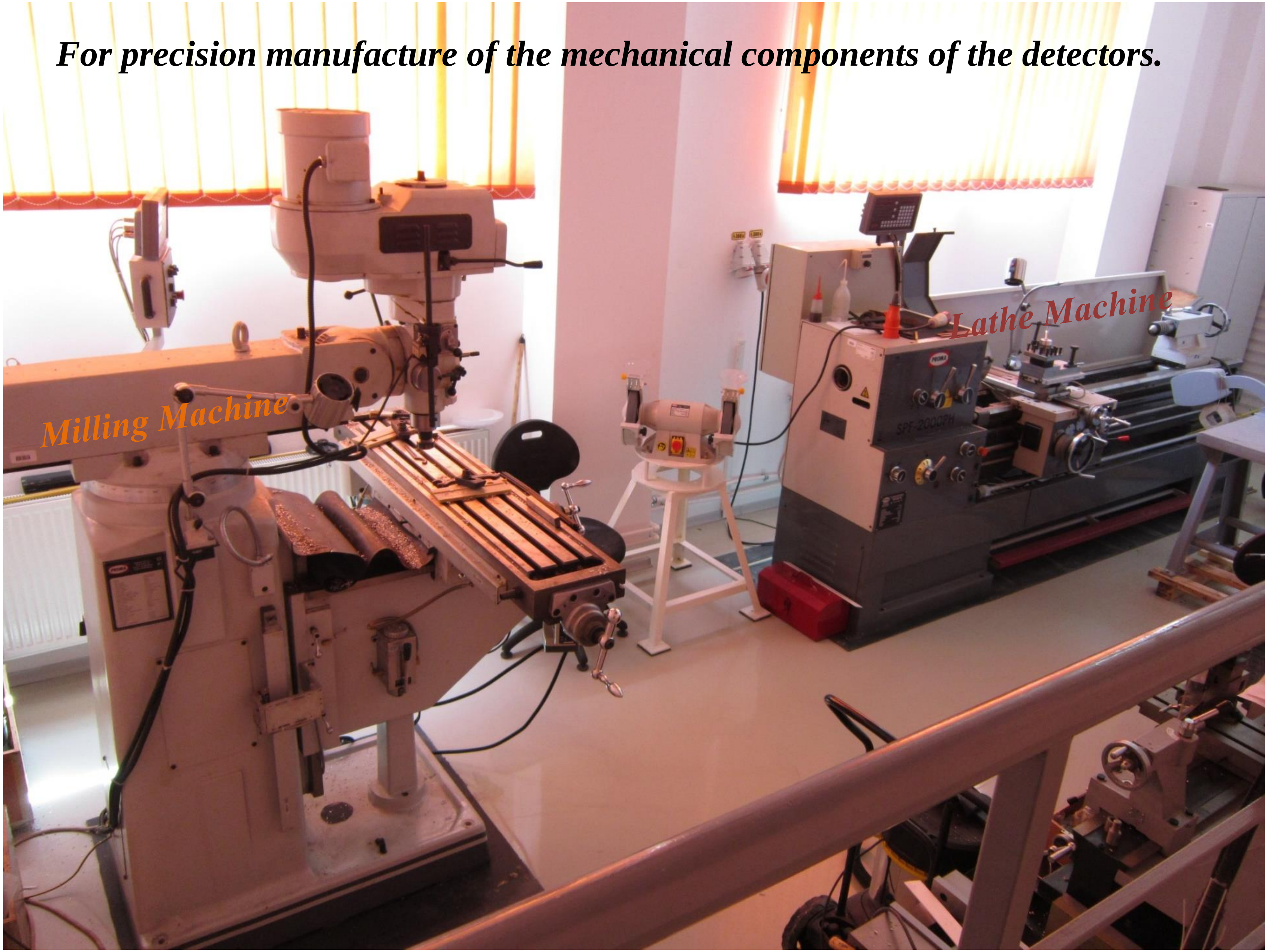
Laboratory infrastructure

Test and characterization of the FEE boards



Mechanical Workshop

For precision manufacture of the mechanical components of the detectors.



Summary

- *Double sided architecture of 4 x 4 mm gas thickness has the highest electron/pion discrimination performance operated with FASP with 40 ns shaping time; geometric efficiency of a large TRD detector based on such an architecture is <80% for a single layer*

- *Single sided architecture with 2 x4 mm + 4 mm gas thickness operated with FASP with 40 ns shaping time has still a good discrimination performance of 1% pion misidentification probability; geometric efficiency of a large TRD detector based on such an architecture is >90% for a single layer*

- *Triangular pad geometry of the readout electrode gives access to two dimensional position reconstruction with good position resolution with a single TRD layer*

- *A real size TRD prototype with the same inner geometry as single sided TRD was designed, constructed and tested for systematic performance evaluation*

- *FASP delivers optimum information for required performance and selection of data to be stored*
- *FASP version with 100 ns shaping time was designed for optimum operation of two - dimensional position sensitive single sided TRD architecture*

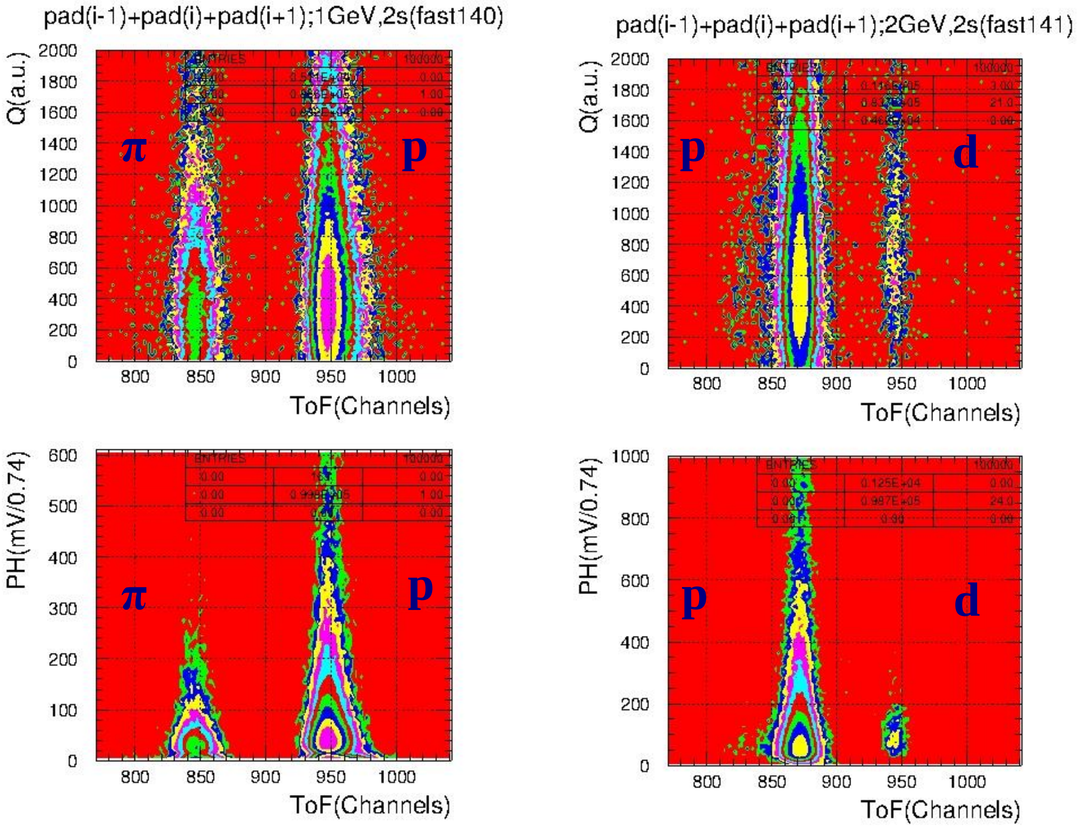
- *We will continue the activity within CBM-TRD through both R&D and chamber construction activities*


Thank you for your attention!
HADRON PHYSICS DEPARTMENT

Backup slides

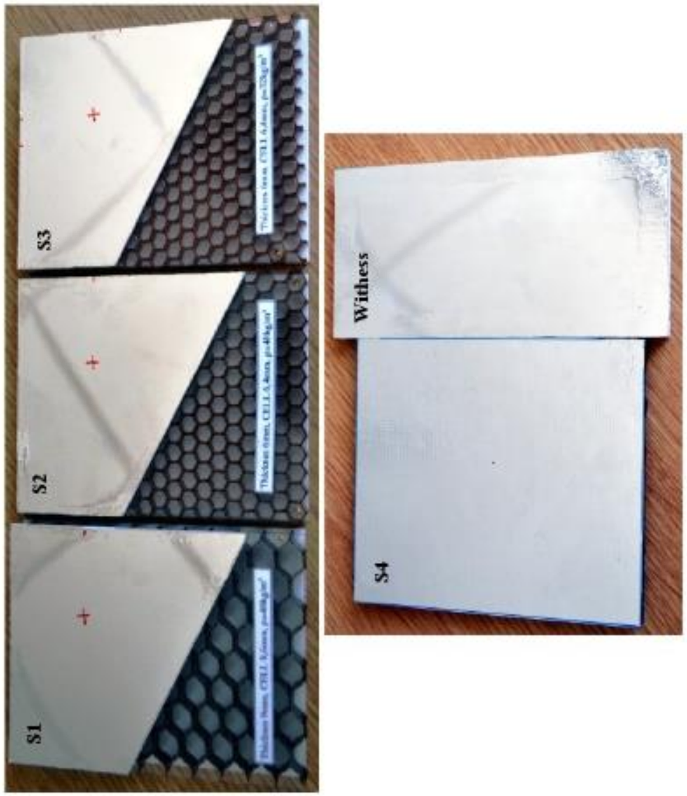
Particle identification on the bases of a measurement of their ToF & dE/dx with first TRD prototype

2004 in-beam test @ SIS, GSI – Darmstadt

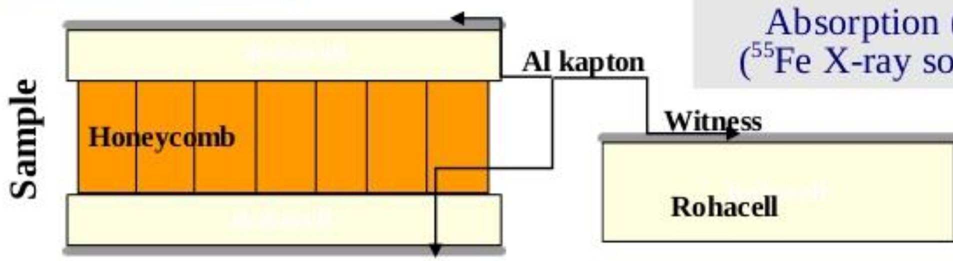


dE/dx -> Single – MWPC with 2 x 3 mm gas thickness
ToF -> 2 plastic scintillators separated by ~3m flight path

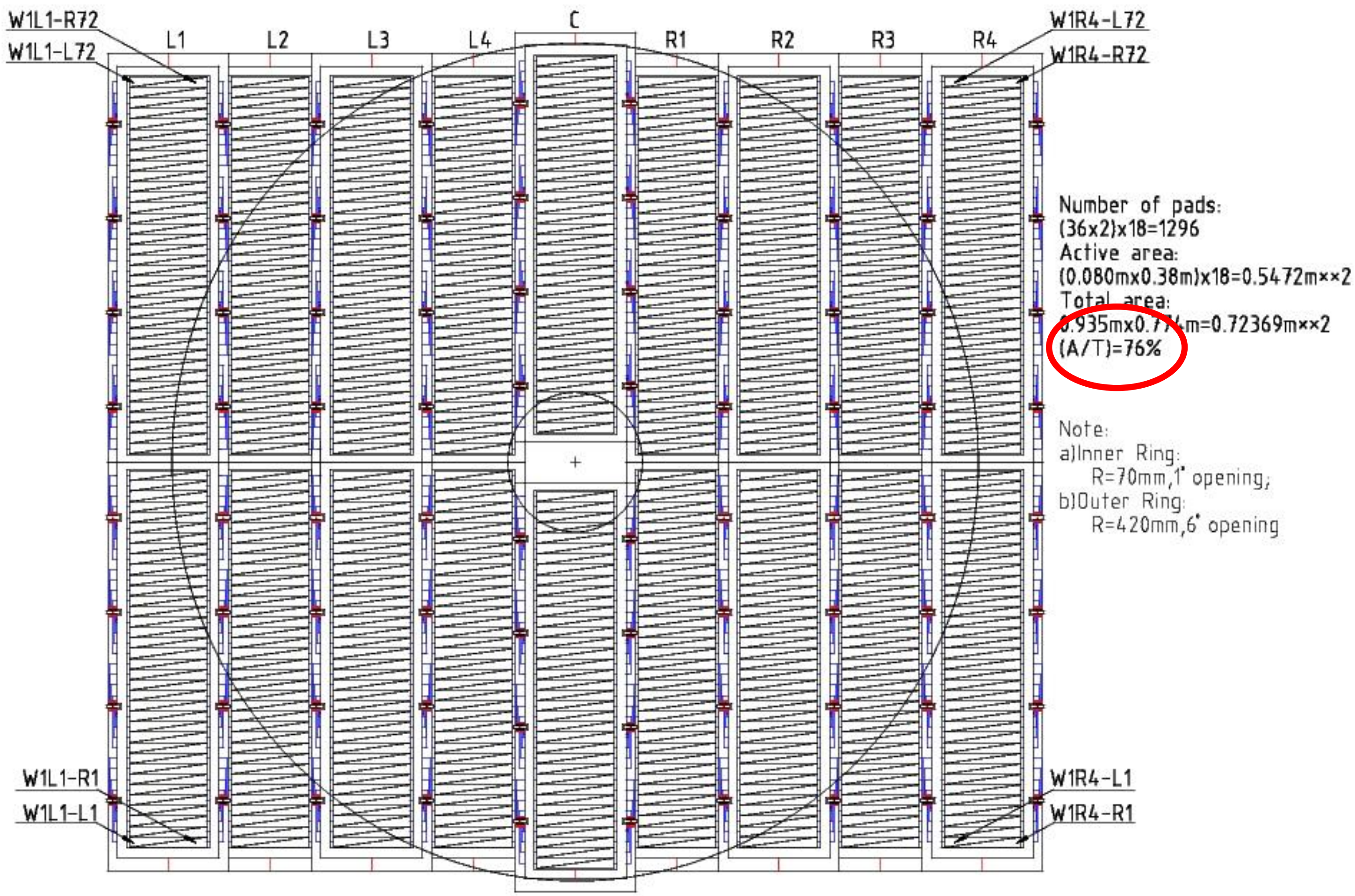
Drift electrode structures



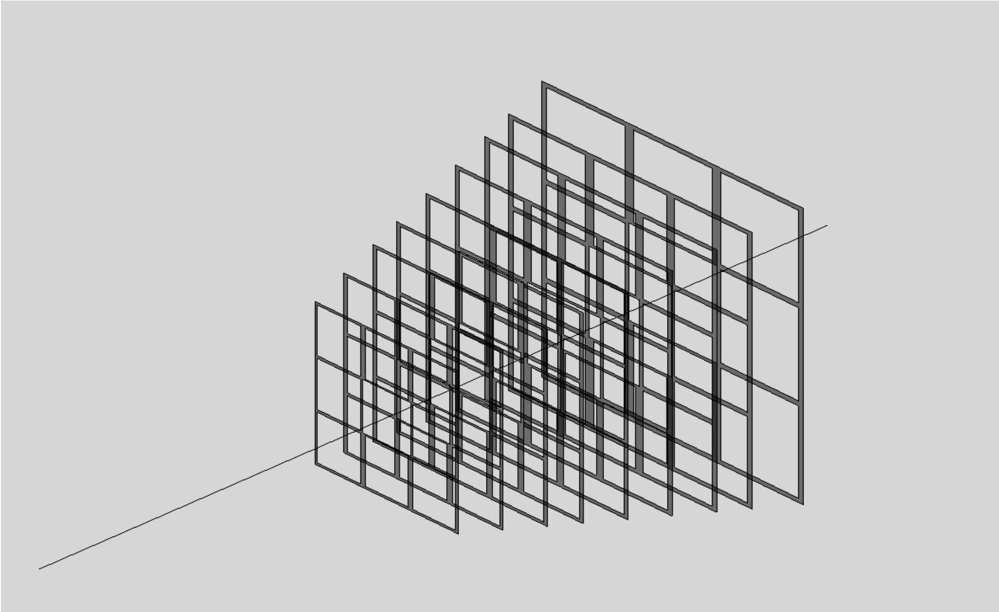
Sample/ Configuration	S1	S2	S3	S4	Wit-ness
Rohacell thickness (mm)	2 x 3	2 x 3	2 x 3		8
Honeycomb thickness (mm)	9	6	6	9	-
Honeycomb cell (mm)	9.6	6.4	6.4	9.6	-
Honeycomb density [kg/m3)	48	48	32	48	-
Al kapton thickness(μm)	2 x 20	2 x 20	2 x 20		1 x 20
Carbon layer (μm)				2 x 100	
Absorption (%) (^{55}Fe X-ray source)	57.5	57.5	57.2	52.4	62



Geometrical efficiency estimation with DSTRD modules



Optimization of the design of the CBM-TRD inner zone



Layer and stack wise optimization

Propagation of the frame shadows