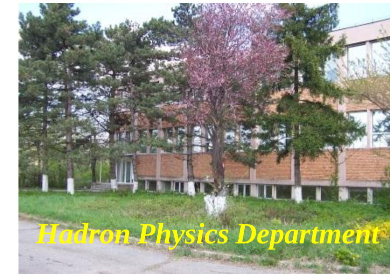

TRD detector development for CBM experiment

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I. Berceanu, A. Bercuci, G. Caragheorgheopol, F. Constantin, L. Radulescu

IFIN-HH Bucharest

S. Linev, J. Adamczewski-Musch

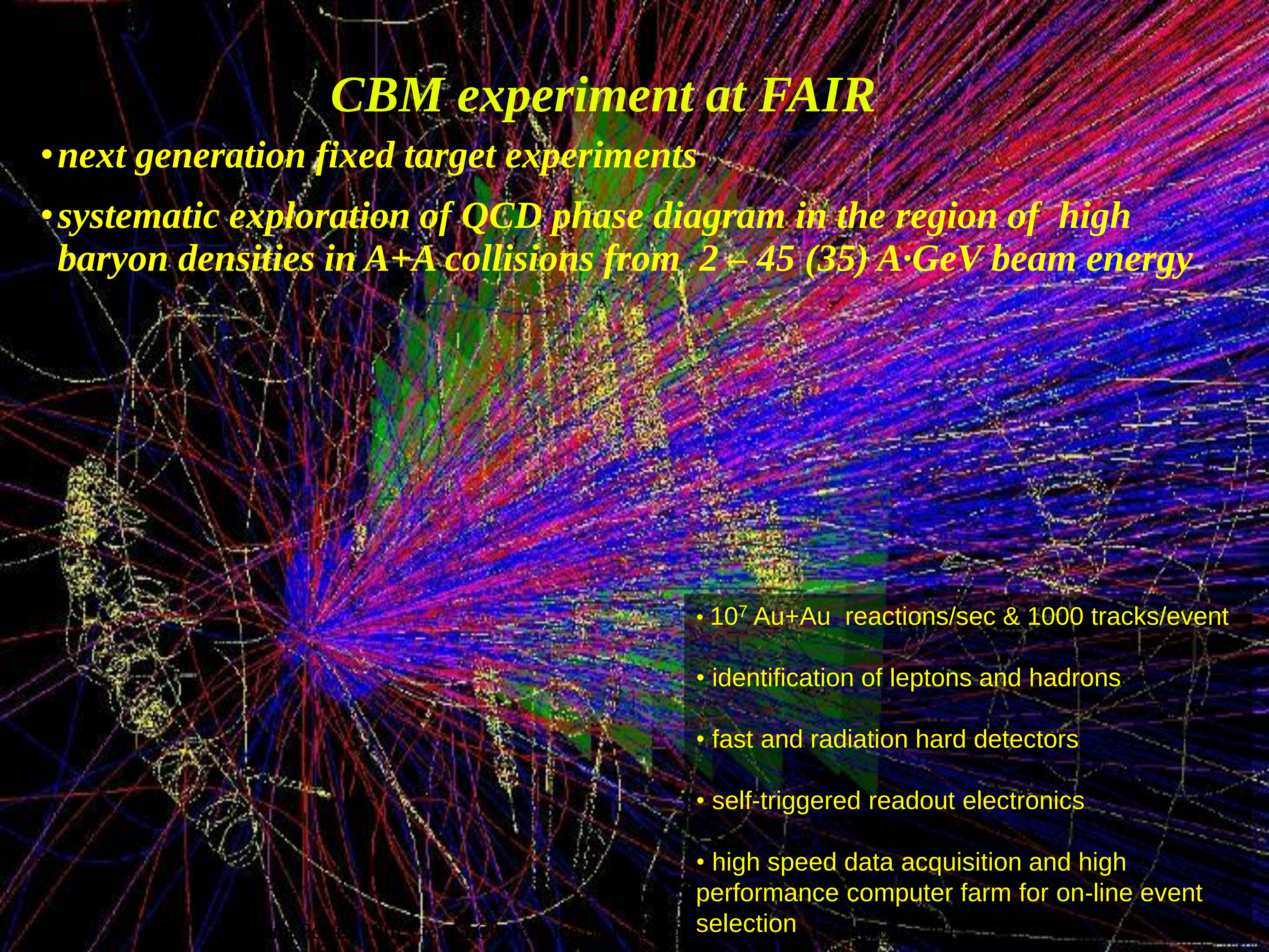
GSI Darmstadt

C. Bergmann, D. Emschermann, J.P. Wessels

Münster University

Outline

- ***Motivation – inner zone of the TRD detector of CBM experiment @ FAIR***
- ***High Counting Rate TRD detector development – short history***
- ***Two dimensional position sensitive TRD prototype***
- ***Fast Analog Signal Processor (FASP) developed as dedicated FEE***
- ***^{55}Fe source tests***
- ***In-beam measurements at CERN-PS***
- ***Toward a TRD basic cell for the inner zone of CBM-TRD detector***
- ***Design of the inner zone of the CBM-TRD detector***
- ***Conclusions & Outlook***



CBM experiment at FAIR

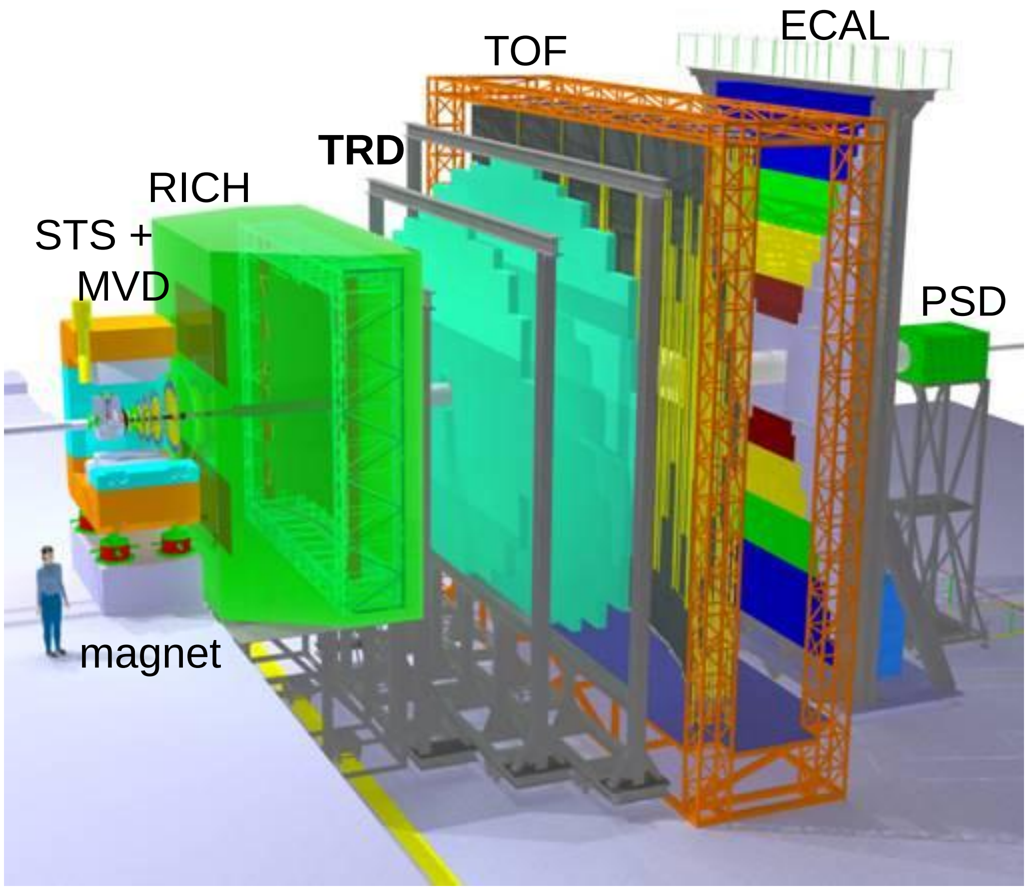
- ***next generation fixed target experiments***
- ***systematic exploration of QCD phase diagram in the region of high baryon densities in A+A collisions from 2 – 45 (35) A·GeV beam energy***

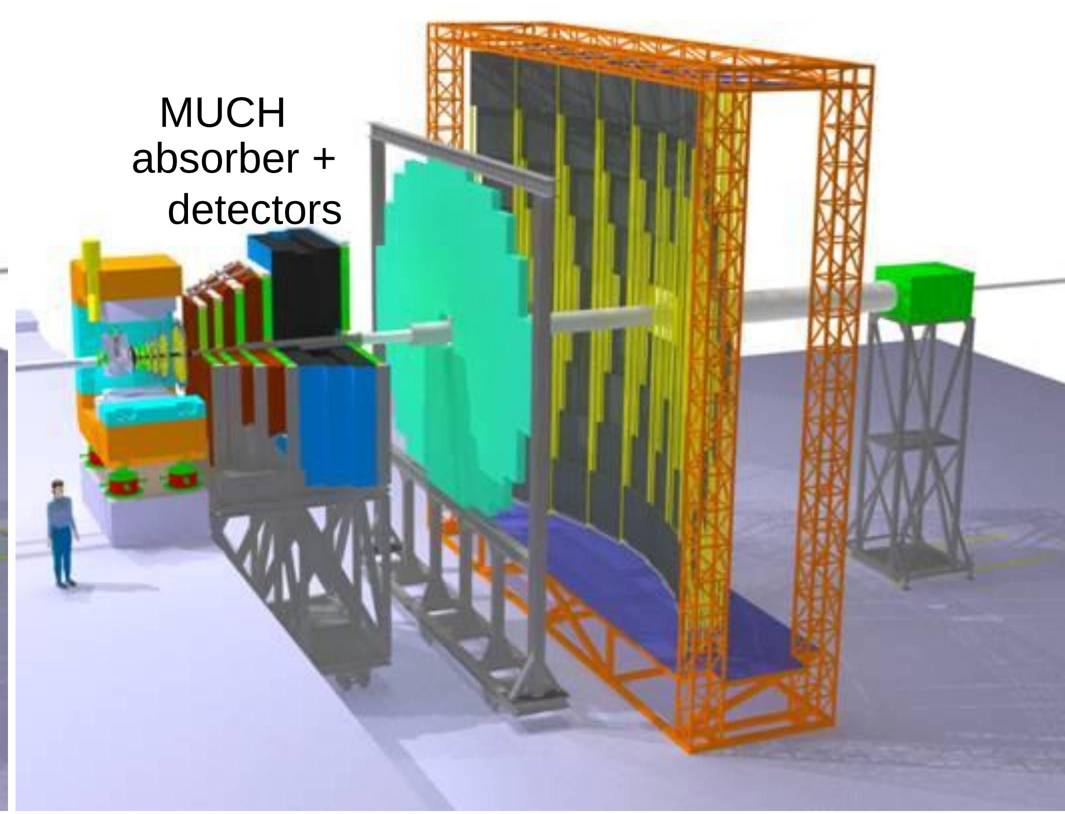
- 10^7 Au+Au reactions/sec & 1000 tracks/event
- identification of leptons and hadrons
- fast and radiation hard detectors
- self-triggered readout electronics
- high speed data acquisition and high performance computer farm for on-line event selection

The CBM experimental setup

• **electron ID**: RICH & TRD
→ π suppression ≥ 10^4

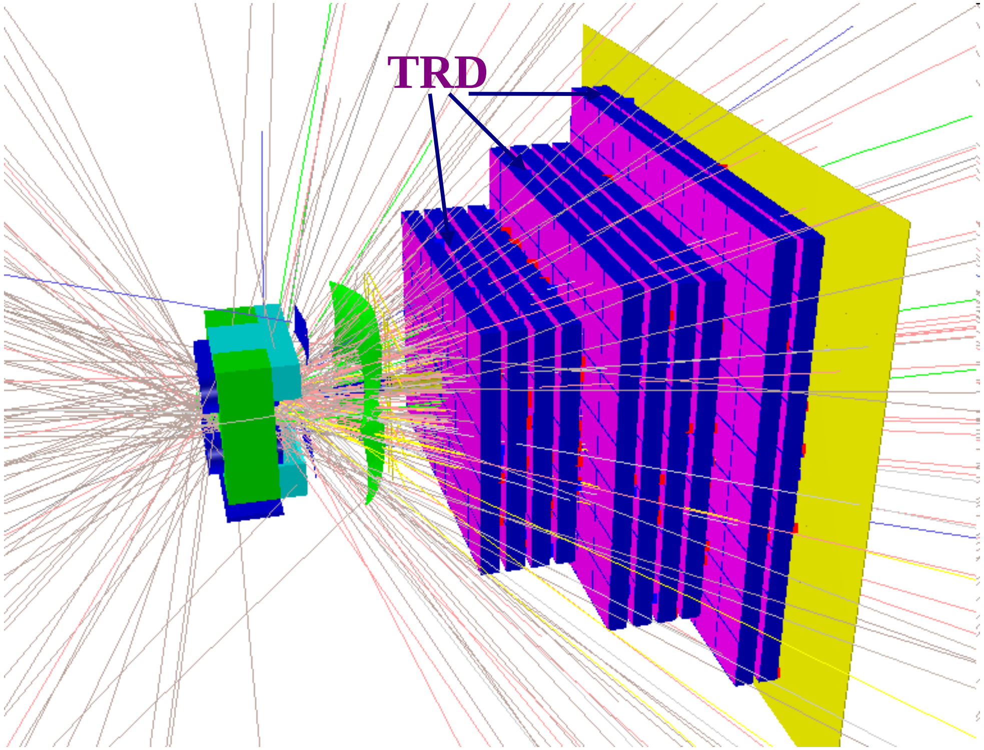
• **muon ID**: absorber + detector layer sandwich
→ move out absorbers for hadron runs





Intensive detector R&D activity

The CBM-TRD requirements



- *585 m² surface*
  708 modules
  785.408 channels

  matching RICH & TOF acceptance

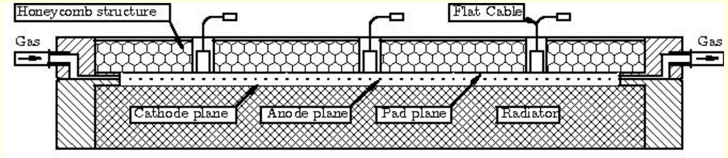
TRD subdetector – possible scenario:

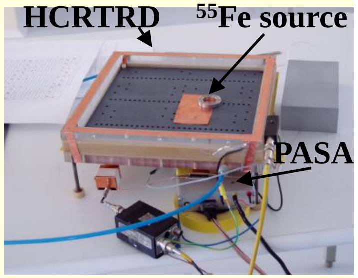
- ***3 stations @ 4.5, 6.75, 9 m from target***
- ***Highly granular and fast detectors which can stand the high rate environment up to 10^5 part/cm^2 ·sec***
- ***Tracking of all charged particles with a position resolution of:***
  - 200 – 300 μm across the pads
  - 3 – 30 mm along the pads
- ***Identification of high energy electrons (γ > 1000) with a pion rejection factor > 100 @ 90% electron efficiency***

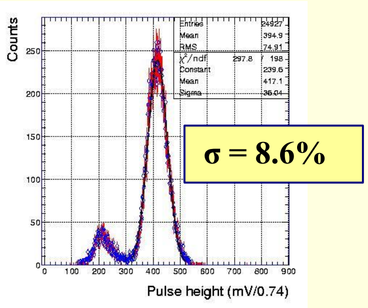
Short History

2004 - first HCRTRD prototype

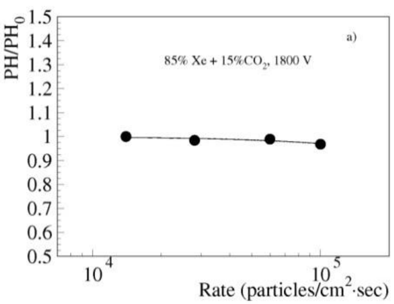
Single – MWPC 2 x 3 mm gas gap, 2.5 mm anode pitch
1 x 6 cm^2 rectangular pad area

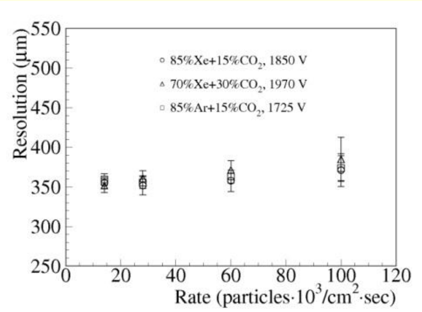




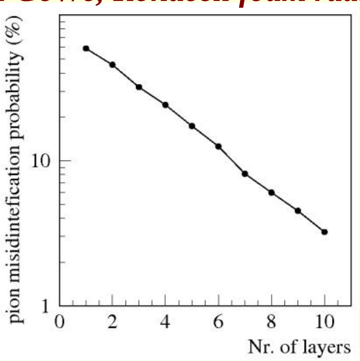


High counting rate in-beam test
SIS, GSI – Darmstadt, proton = 2 GeV/c





1 GeV/c, Rohacell foam radiator



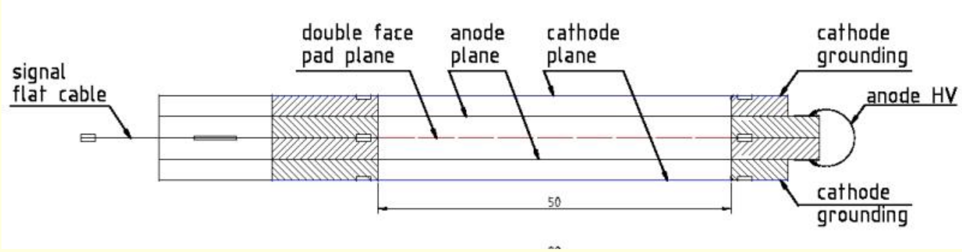
e/π discrimination @ 1 GeV/c:

- *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., NIMA 581(2007), 406

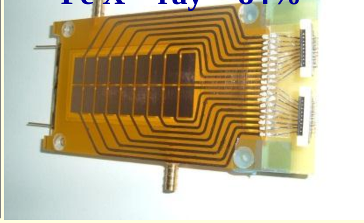
2006 - second HCRTRD prototype

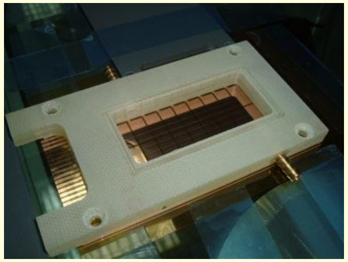
Double – MWPC 2 x 3 mm gas gap, 2.5 mm anode pitch
0.5 x 1 cm^2 rectangular pad area

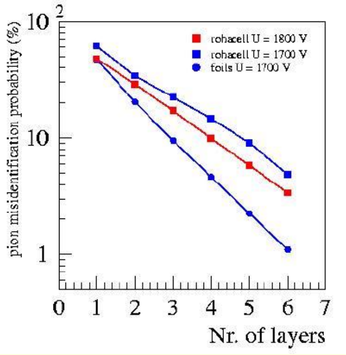


Readout electrode made from kapton foil of 25 µm; rectangular pads and signal traces are etched on both sides in the 0.3 mm evaporated Cu layer.

Transmission of ^{55}Fe X – ray = 84%







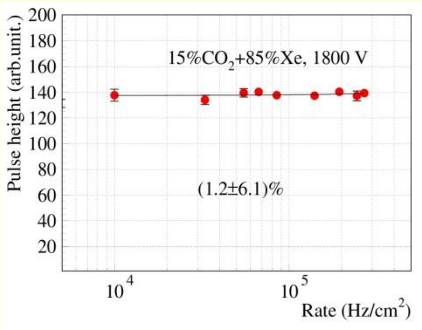
In-beam test SIS, GSI – Darmstadt

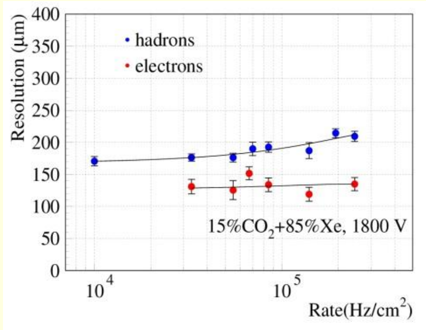
e/π discrimination @1.5 GeV/c:

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

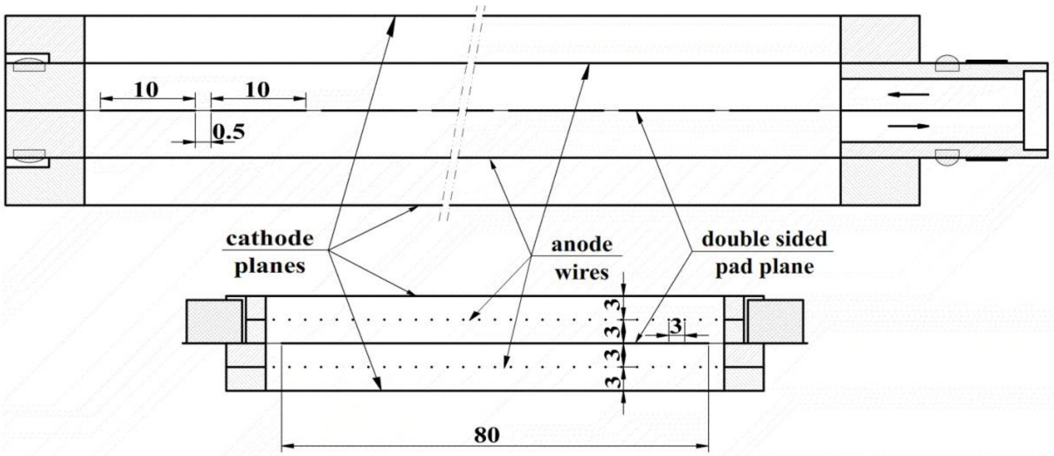
M. Petrovici et al., NIMA 579(2007), 961

High counting rate in-beam test 2 GeV/c proton

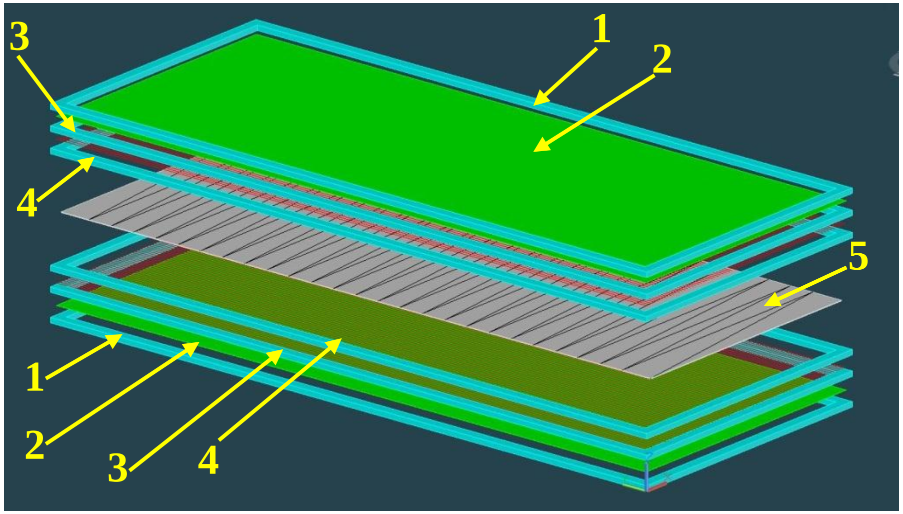




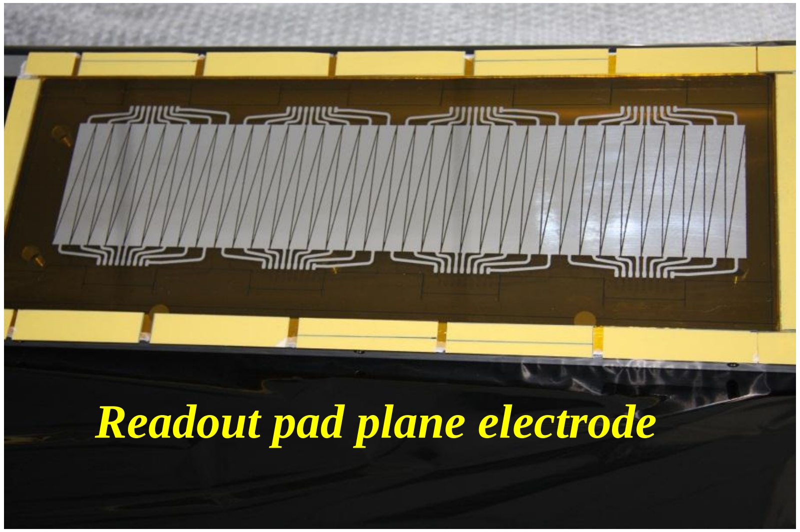
Two dimension position sensitive double -sided TRD prototype version



- 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

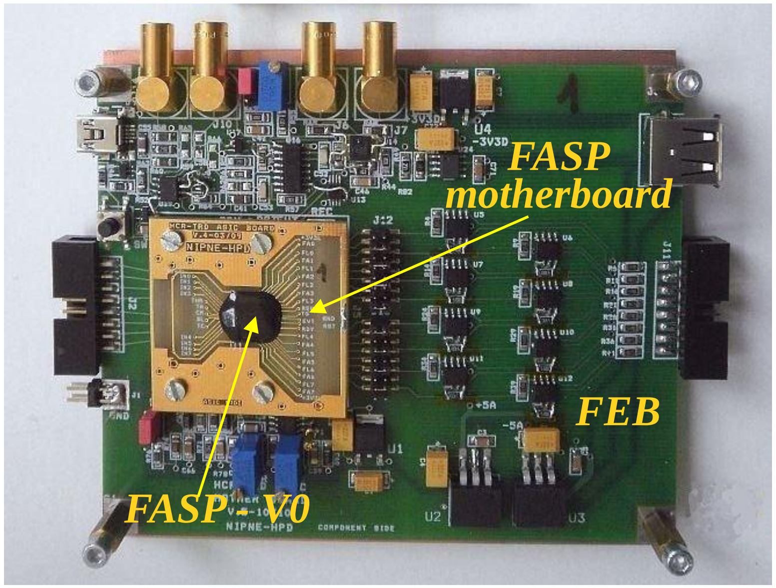


Two versions:

DSTRD-V1 of 3 mm anode – cathode gap

DSTRD-V2 of 4 mm anode – cathode gap

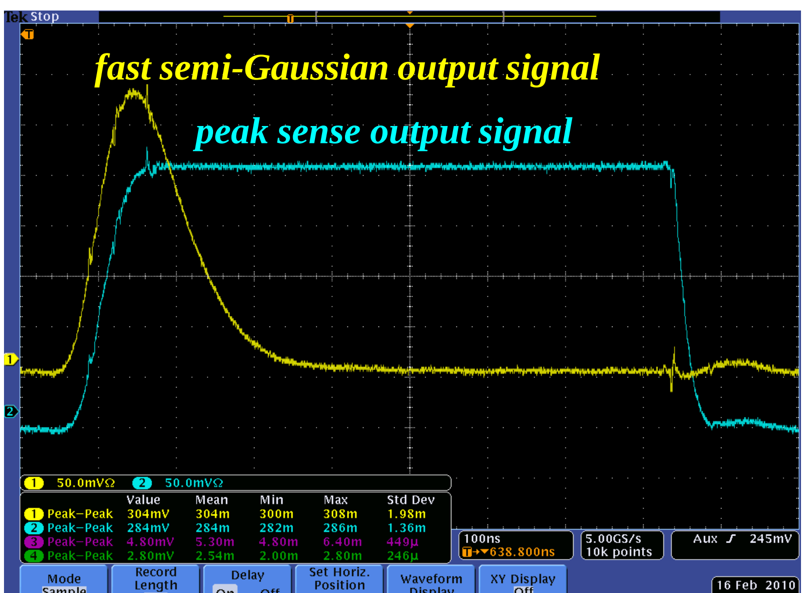
Fast Analog Signal Processor - FASP

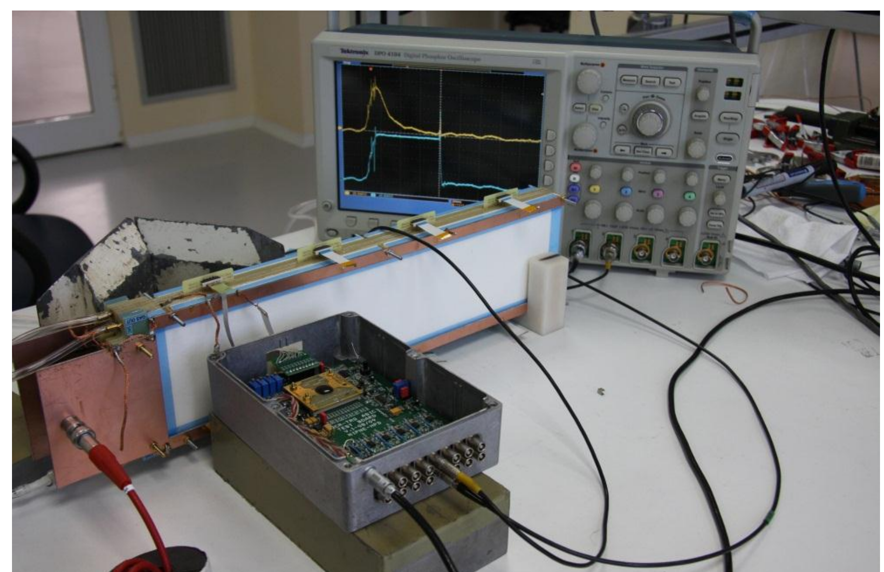


First version – FASP-VO

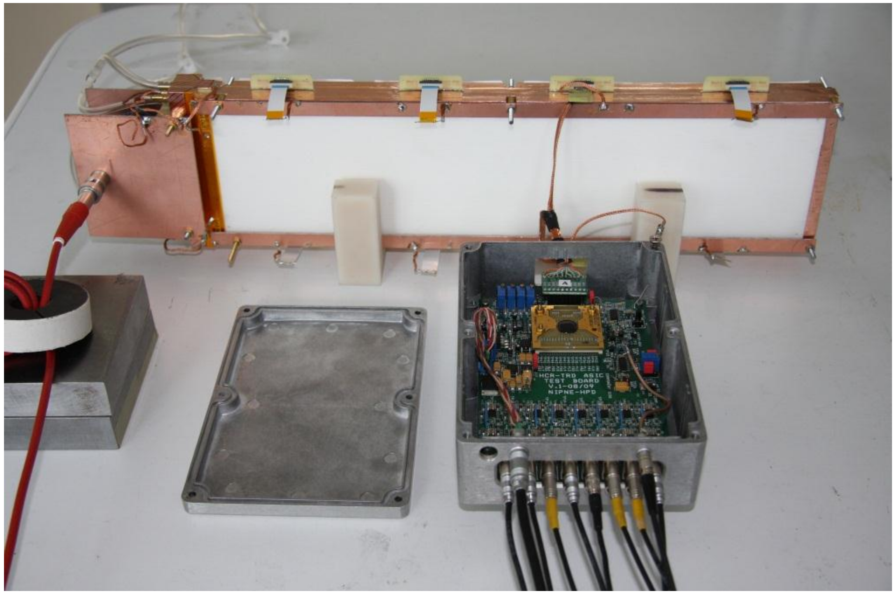
- *Designed in AMS CMOS 0.35 μm technology*
- *Gain: 6.2 mV/fC*
- *Selectable shaping time (ST): 20 ns and 40 ns*
- *Noise (C_{in} = 25 pF): 980 e^-@40 ns ST and 1170 e^-@20 ns ST*
- *Power consumption = 11 mW/channel*
- *Variable threshold*
- *Self trigger capability*
- *8 input/output channels*

Analog channel outputs

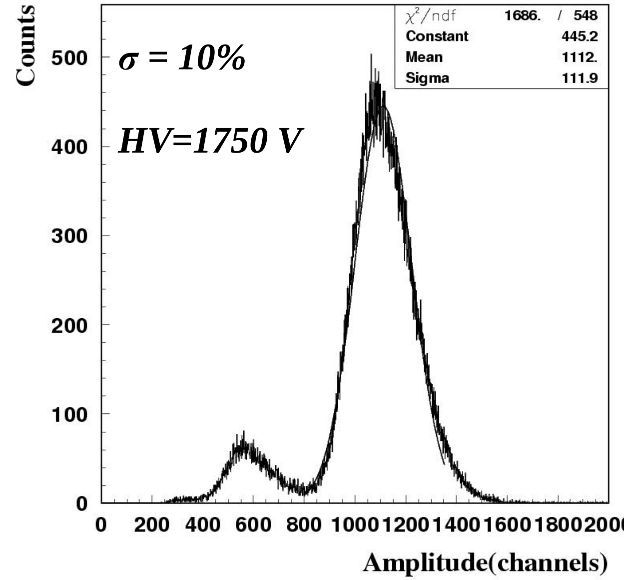




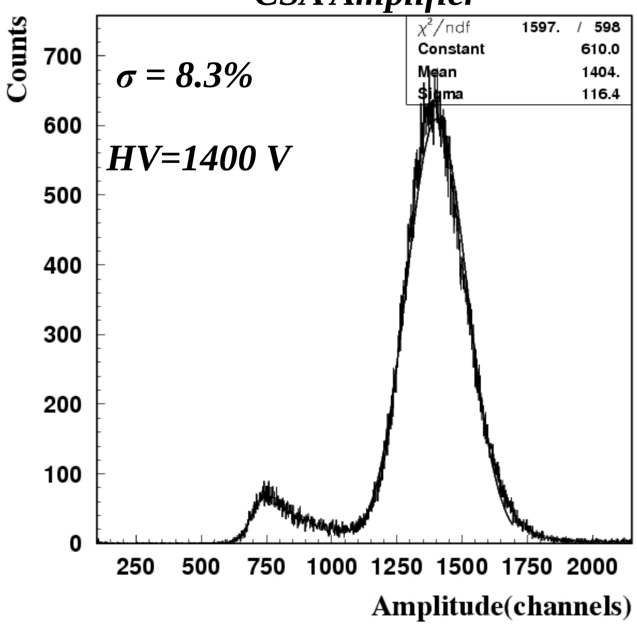
^{55}Fe source tests



DSTRD-V2 Pad signal
FASP-V0: fast Gaussian output

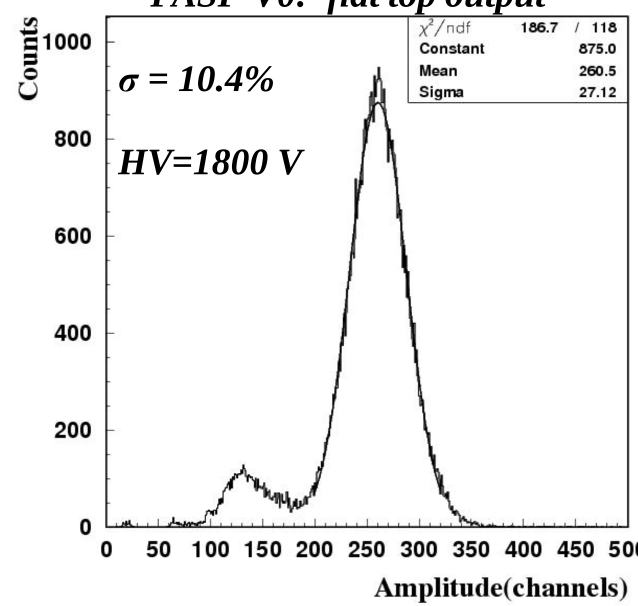


DSTRD-V1 Anode signal
CSA Amplifier

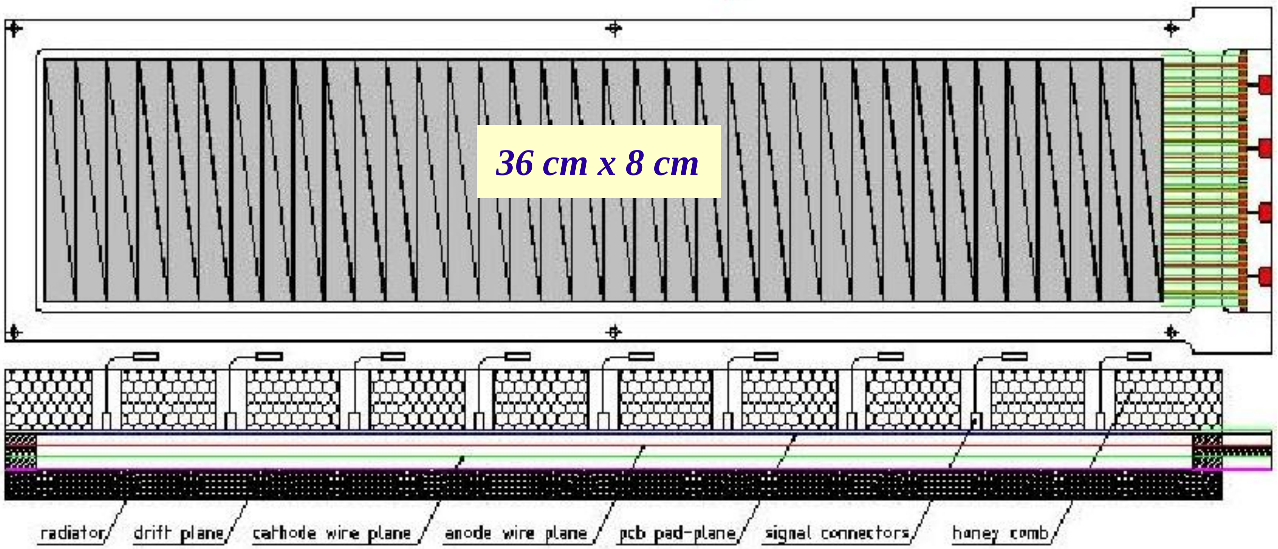


80%Ar+20%CO_2

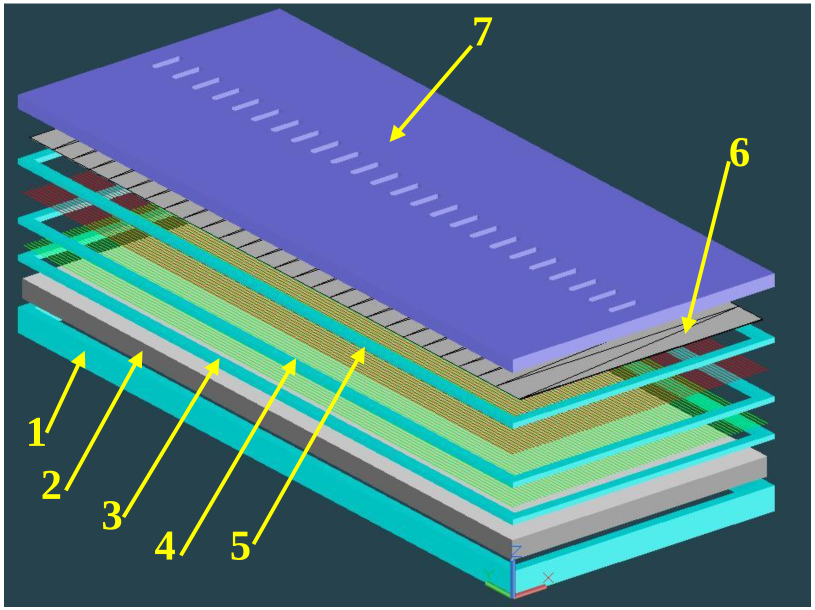
DSTRD-V2 Pad signal
FASP-V0: flat top output



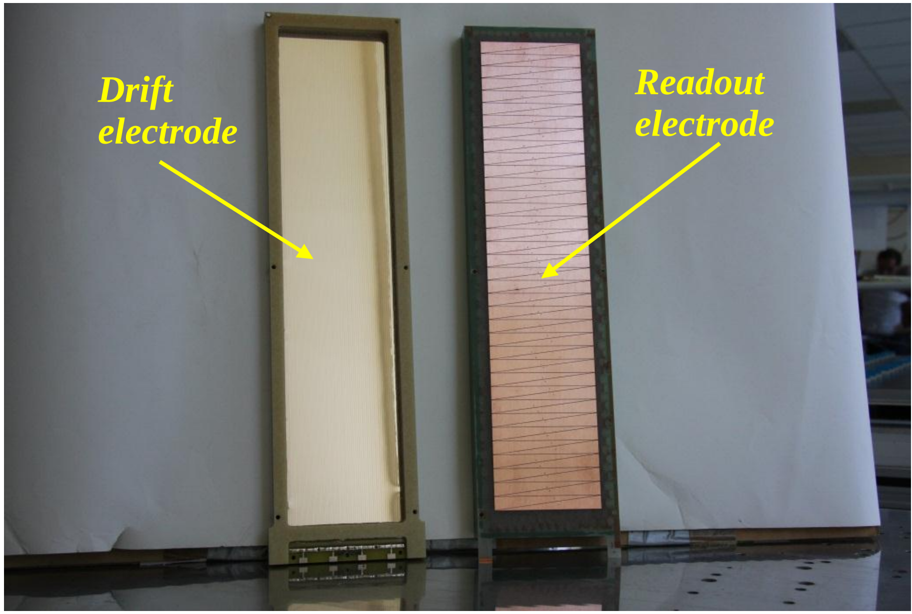
Two dimension position sensitive single – sided TRD Prototype - SSTRD



- *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*

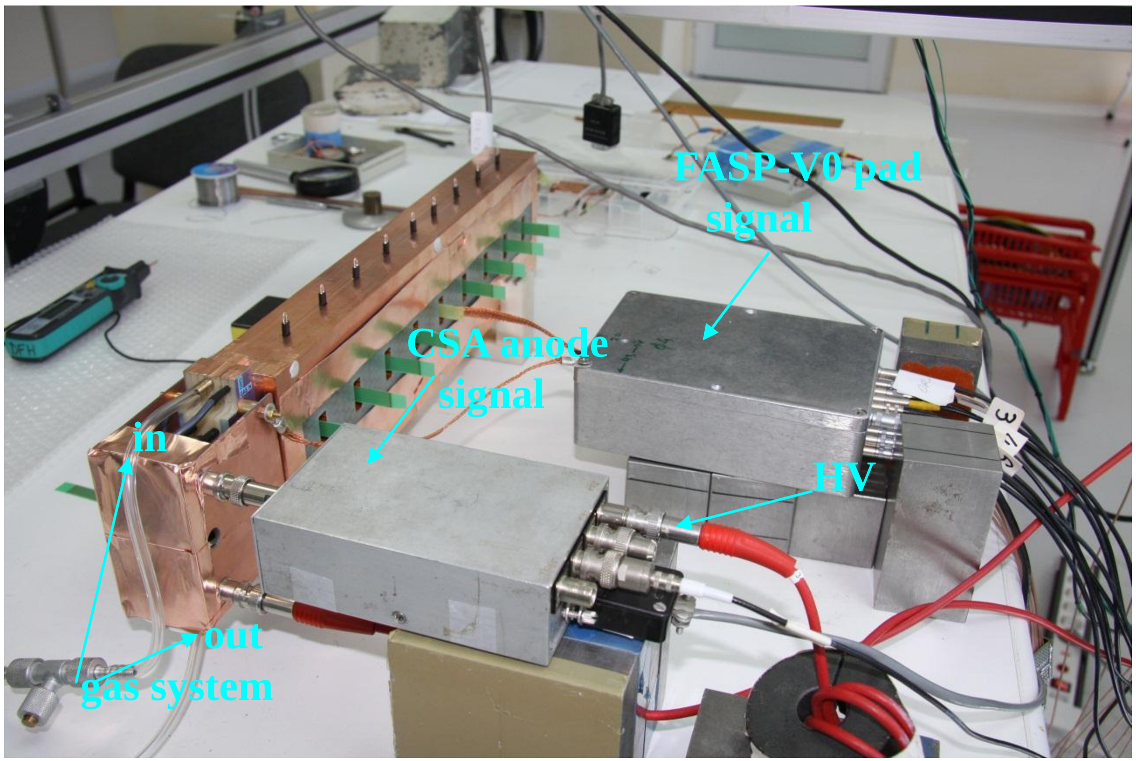


1. *drift electrode frame*
2. *drift electrode*
3. *cathode wires + frame*
4. *anode wires + frame*
5. *distance frame*
6. *readout electrode*
7. *honeycomb panel*

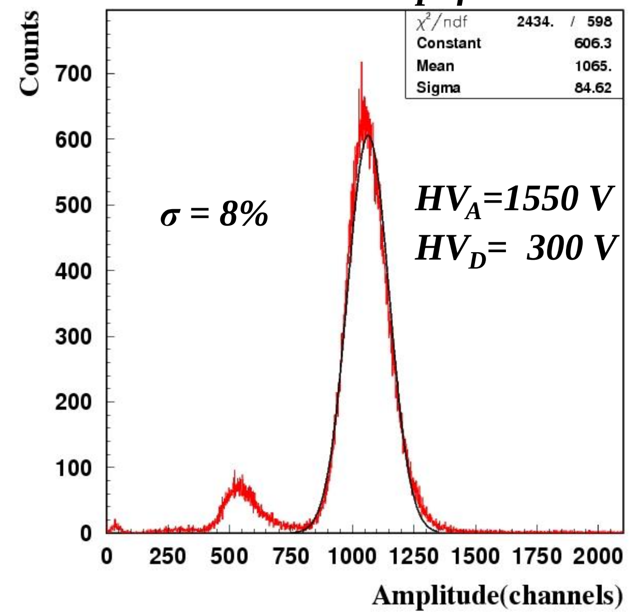


^{55}Fe source tests

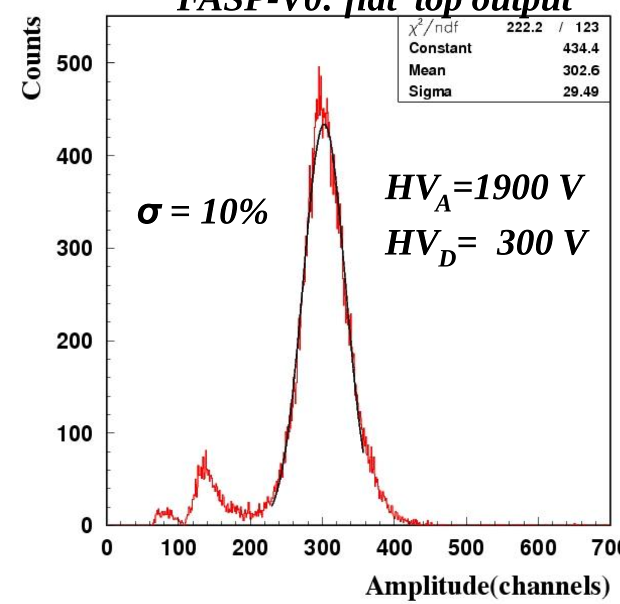
80%Ar+20%CO_2



SSTRD Anode signal
CSA Amplifier



SSTRD Pad signal
FASP-V0: flat top output

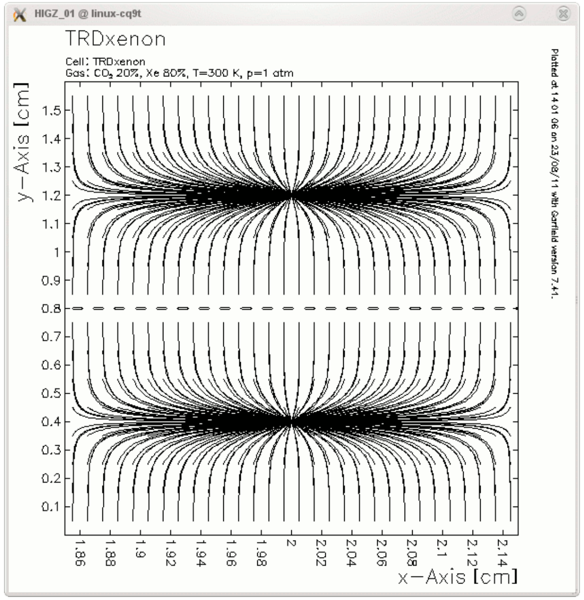


Detector Garfield simulation – drift time study (I)

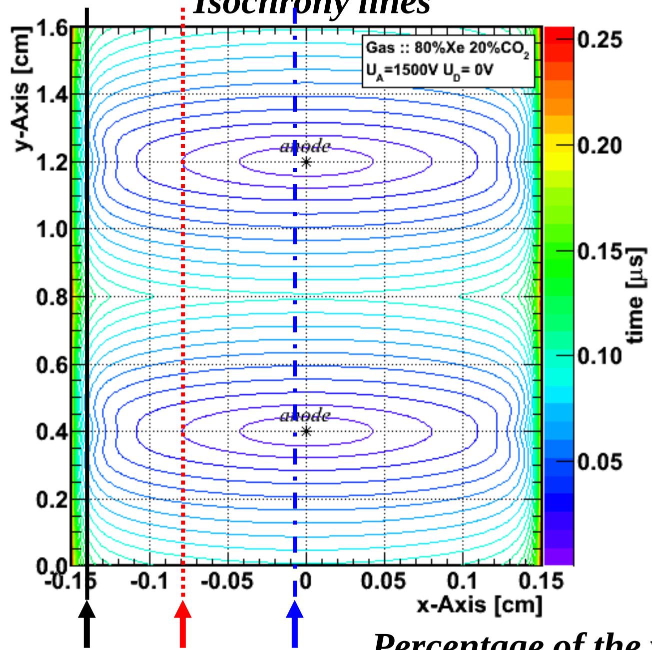
Double MWPC TRD prototype (4 x 4 mm)

80%Xe+20%CO_2

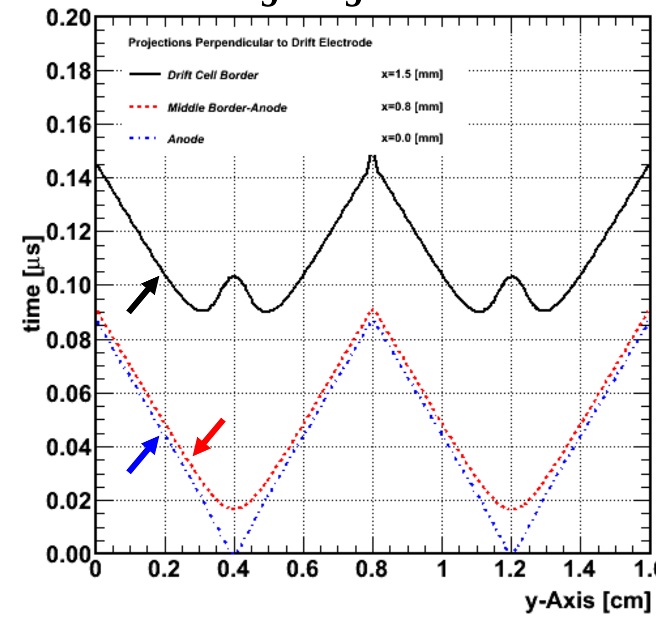
Drift lines



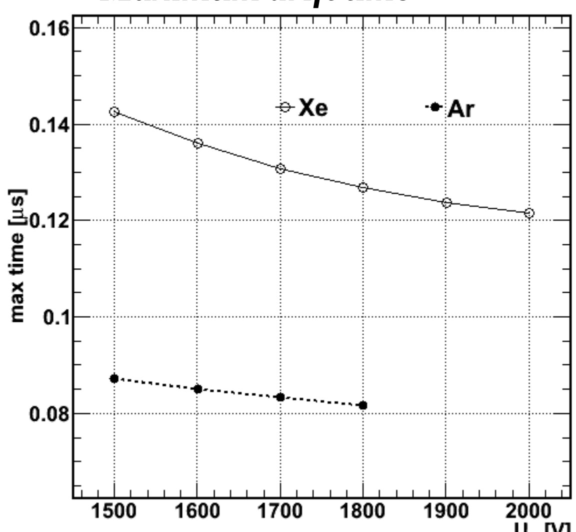
Isochrony lines



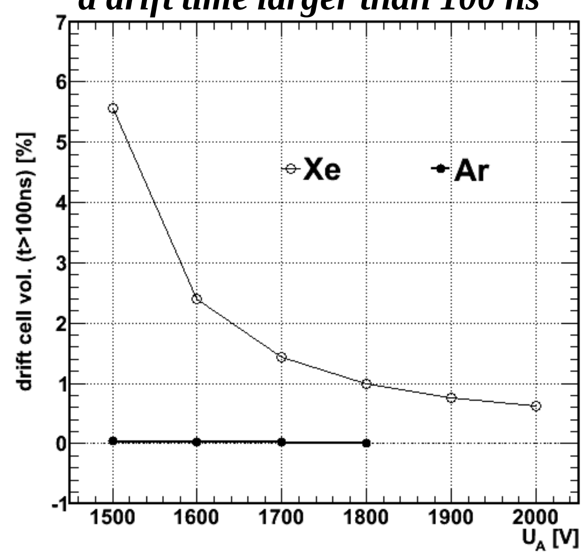
Drift time projection along the gas thickness



Maximum drift time



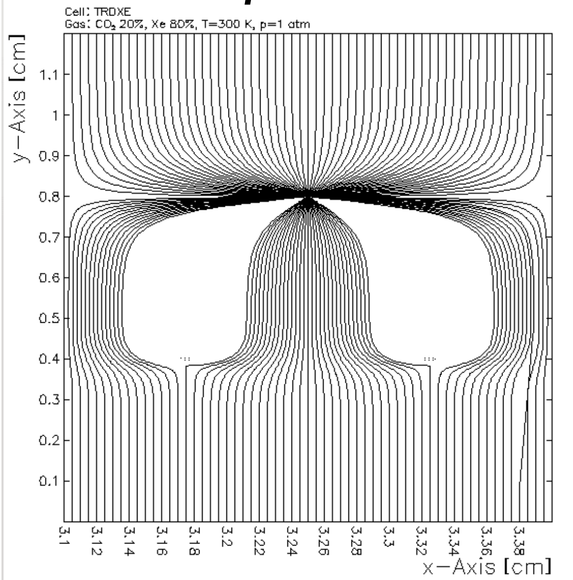
Percentage of the volume with a drift time larger than 100 ns



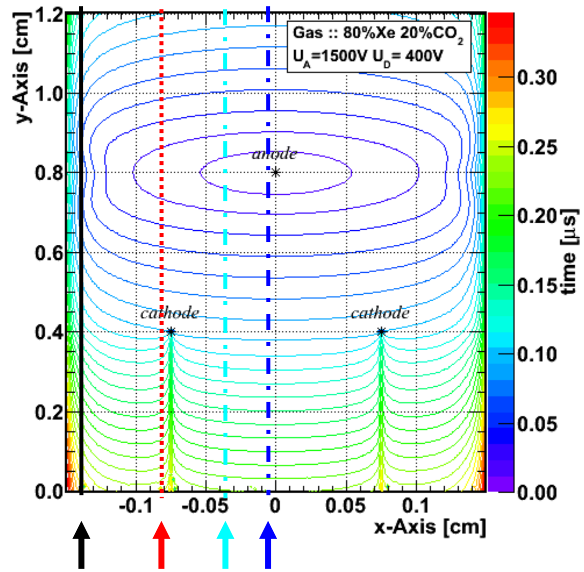
Detector Garfield simulation – drift time study (II)

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

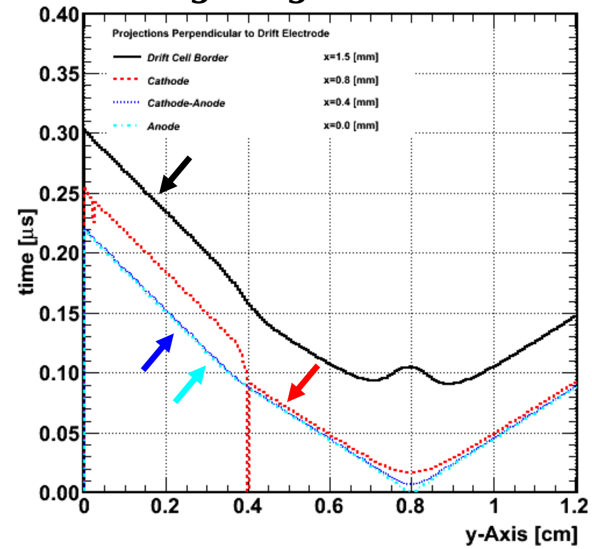
Drift lines



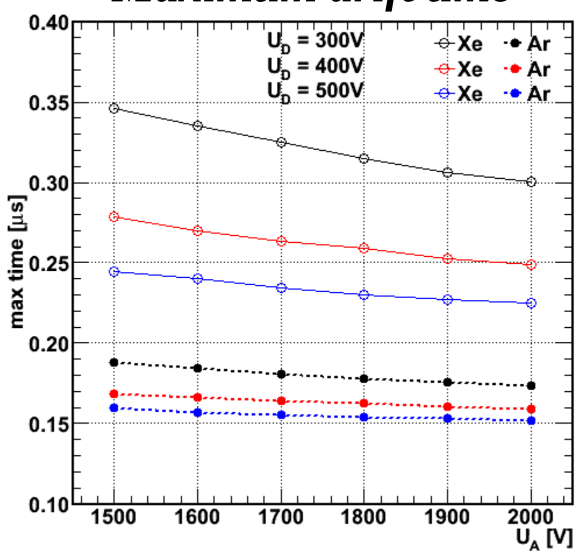
Isochrony lines



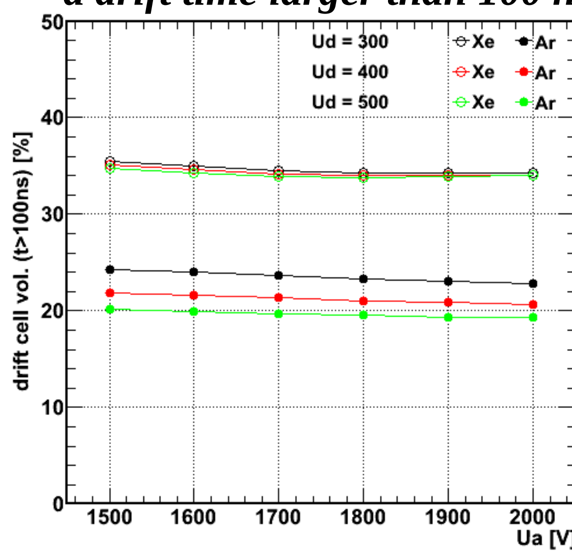
Drift time projection along the gas thickness



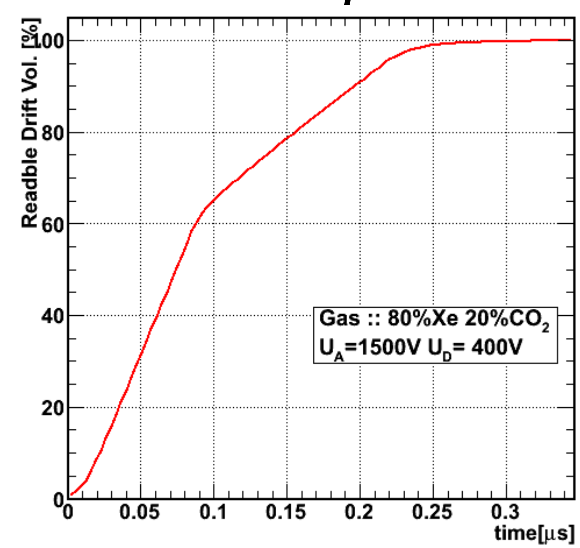
Maximum drift time



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

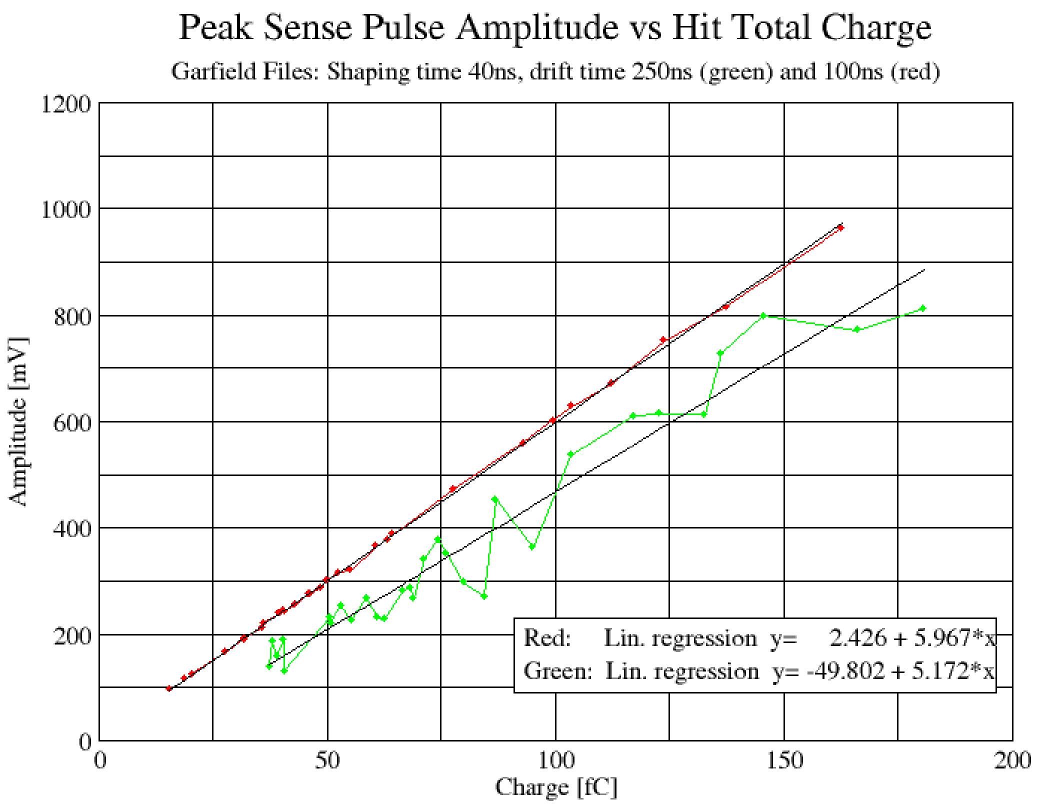


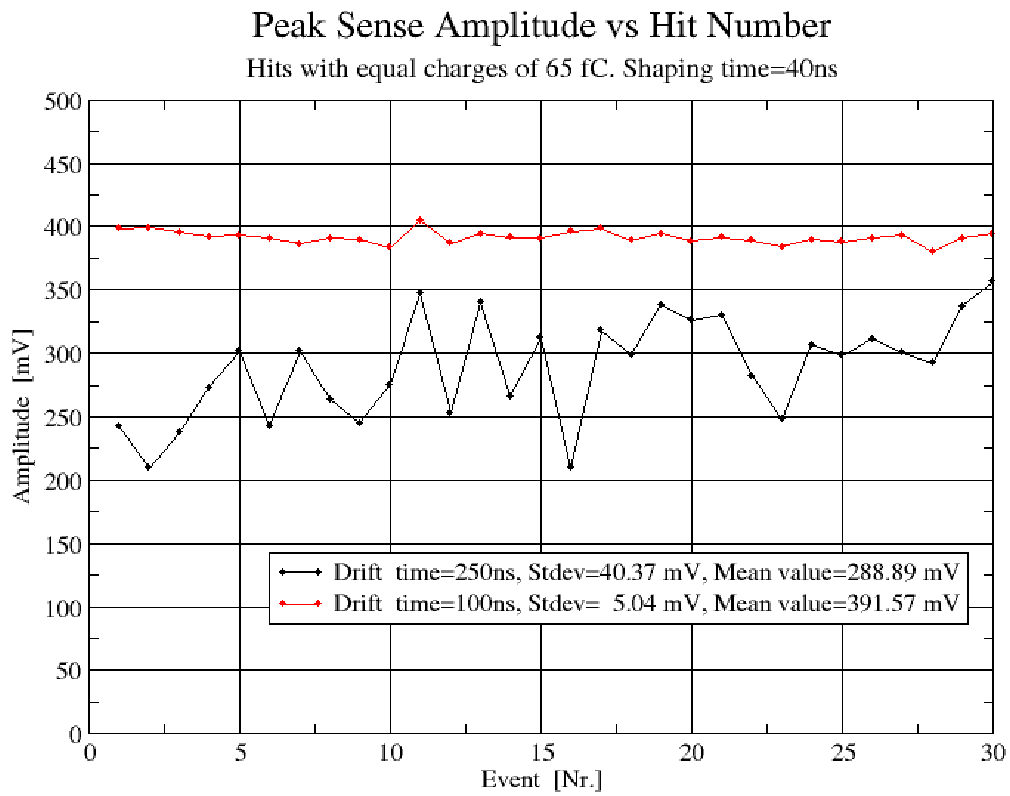
Readable drift volume



CADENCE simulation

- use as input detector signal simulated with Garfield
- 40 ns FASP shaping time

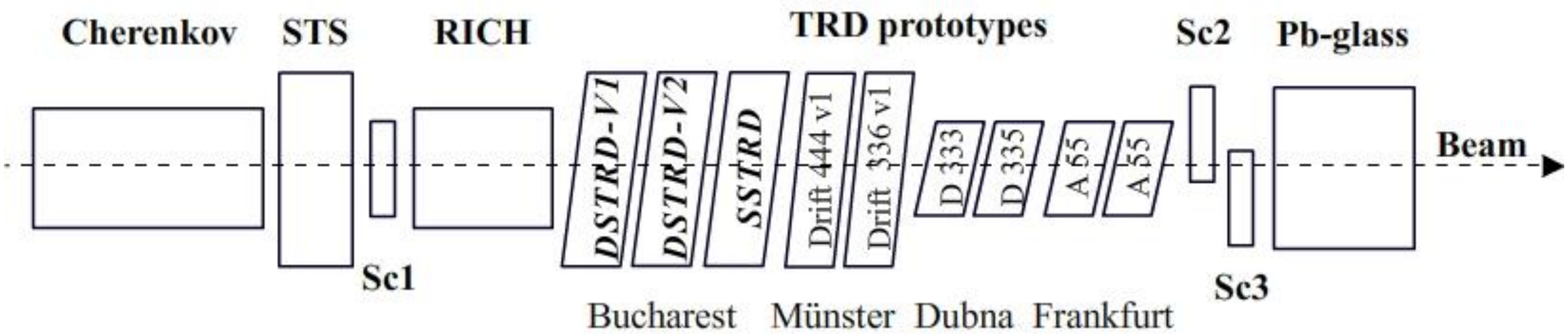


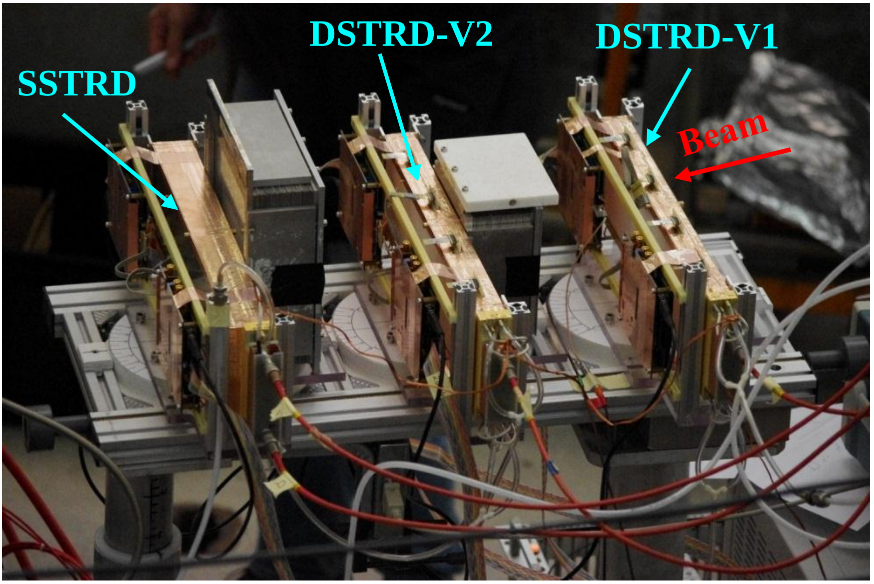


- linearity of the FASP response for hits with an input charge in the range 15 fC-170 fC having the ionization clusters randomly distributed in a time window of 100 ns for DSTRD and of 250 ns for SSTRD

- uniformity of the FASP response for hits with the same input charge of 65 fC and having the ionization clusters randomly distributed in a time window of 100 ns for DSTRD and of 250 ns for SSTRD

CBM common experimental set-up of in-beam test performed @ CERN T10/PS beam line





- *Cherenkov detector (e/π identification)*
- *STS prototype*
- *Plastic Scintillator (beam trigger)*
- *RICH prototype*
- *3 TRD prototypes - Bucharest*
- *2 TRD prototypes - Muenster*
- *2 TRD prototypes - Dubna*
- *2 TRD prototypes - Frankfurt*
- *2 Plastic Scintillators (beam trigger)*
- *Pb-glass calorimeter (e/π identification)*

- *16 triangular pads were readout for each TRD*
- *FASP-V0 – flat top output, 40 ns ST*
- *Mesytec ADC readout*
- *DAQ - MBS*

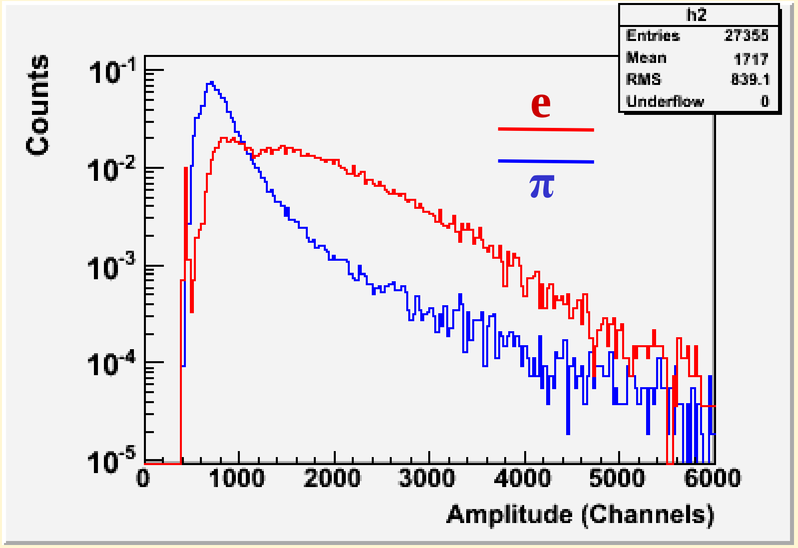
2 regular foil radiators:

- *Reg1 (20/500/120)*
- *Reg2 (20/250/220)*

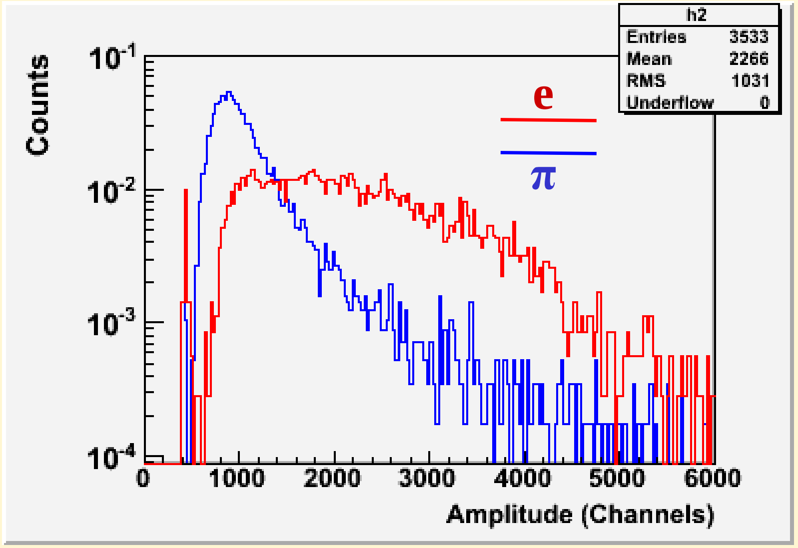
e/π discrimination

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

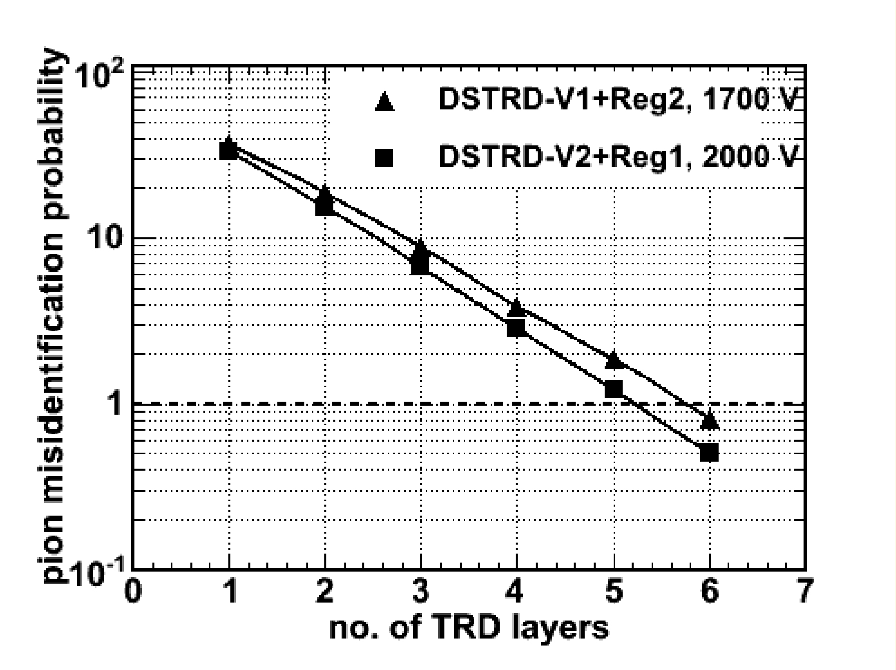
DSTRD-V1 4 gaps x 3 mm, radiator: Reg2 (20/250/220)



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



Pion misidentification probability as a function of number of layers

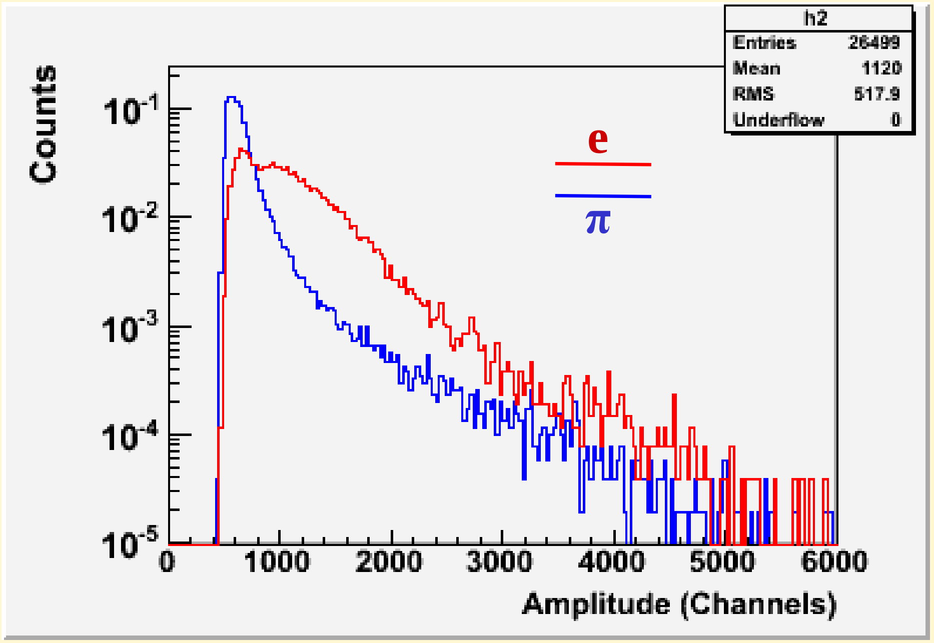


- *0.8% @ 6 TRD layers for DSTRD-V1*
- *0.5% @ 6 TRD layers for DSTRD-V2*

e/π discrimination

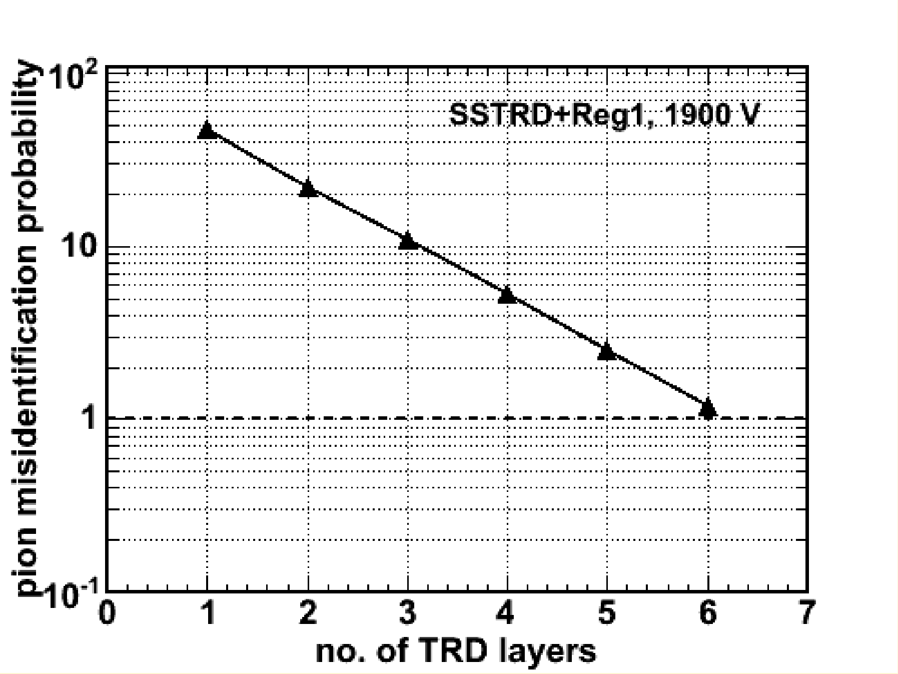
Pulse height distribution for electrons and pions @ 2 GeV/c momentum

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



Pion misidentification probability as a function of number of layers

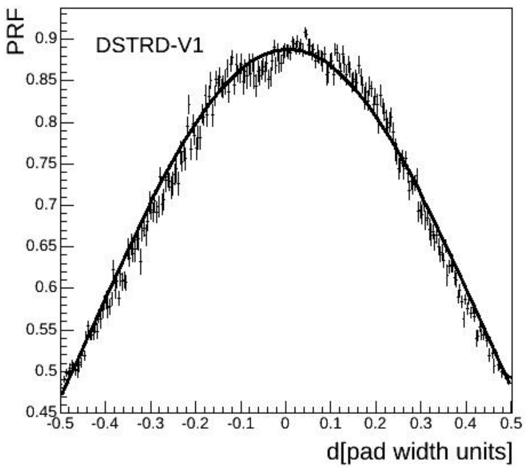
HV_A = 1900 V
HV_D = 400 V

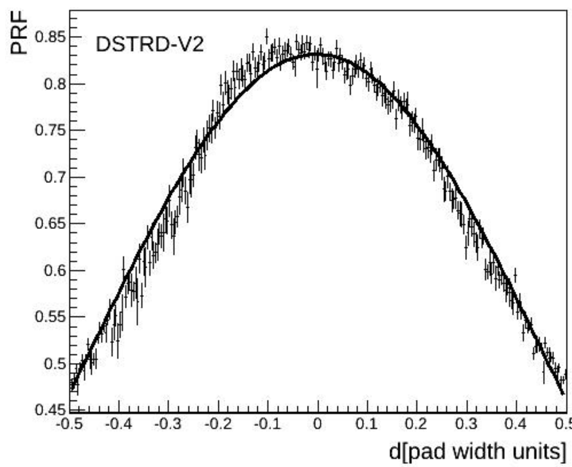


- ***1.18% @ 6 TRD layers for SSTRD***

Position Reconstruction

Pad response function for rectangular pads





Reconstructed position across the pads

Track position relative to the center of the pad with maximum charge (Q_i)

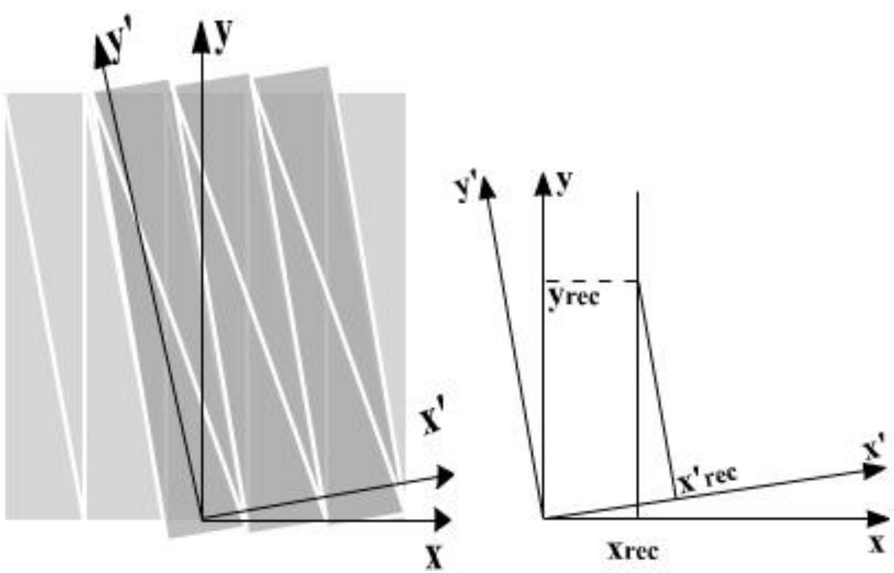
$$d = \frac{1}{Q_{i-1}^2 + Q_{i+1}^2} \times \left(W_1 + W_2\right)$$

$$W_1 = Q_{i-1}^2 \left(\frac{\sigma^2}{w} \ln\left(\frac{Q_i}{Q_{i-1}} - \frac{w}{2}\right)\right)$$

$$W_2 = Q_{i+1}^2 \left(\frac{\sigma^2}{w} \ln\left(\frac{Q_{i+1}}{Q_i} + \frac{w}{2}\right)\right)$$

$$x_{rec} = d + \left(i + \frac{1}{2}\right) w$$

Reconstructed position along the pads



Pad width w = 1 cm

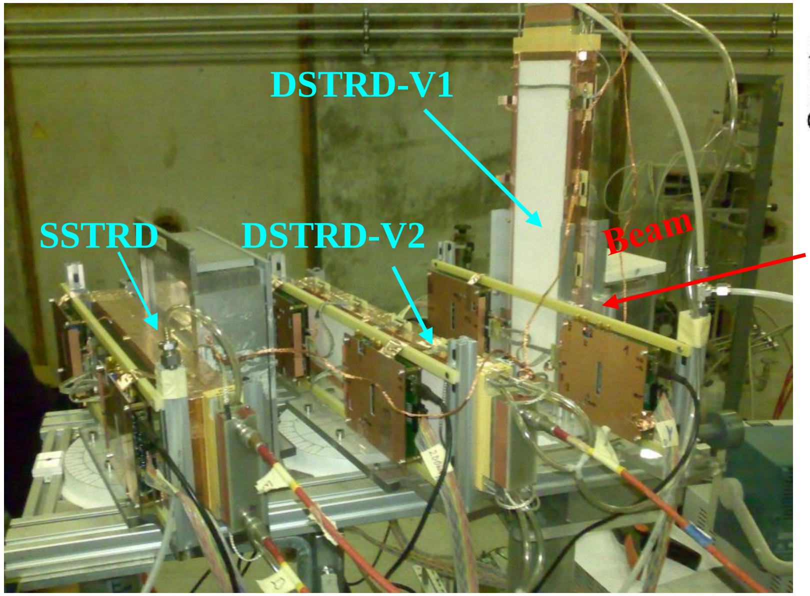
Algorithm:

1. Pairing of triangular pads resulting:

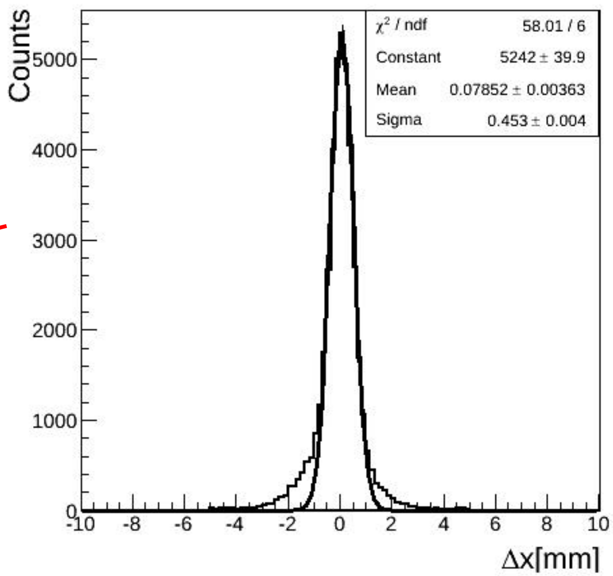
- ***a rectangular pad configuration***
- ***a tilted pad configuration***

2. Position along the pads is the intersection of two lines each one parallel with the y coordinate in the system associated with the pad configurations from above

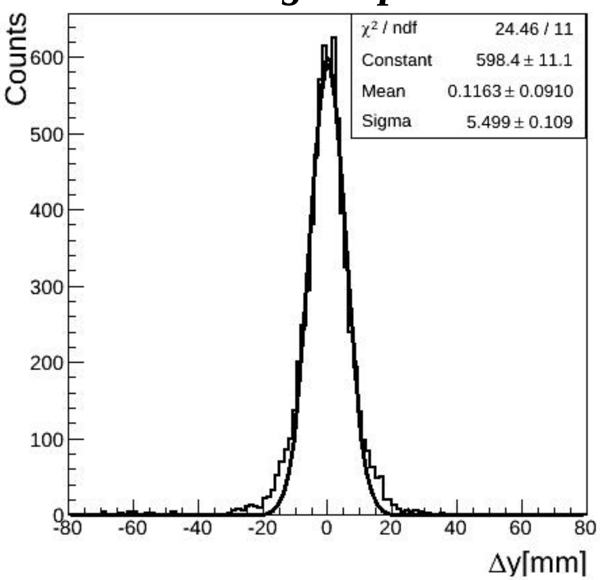
Position Resolution



position resolution across the pads



position resolution along the pads

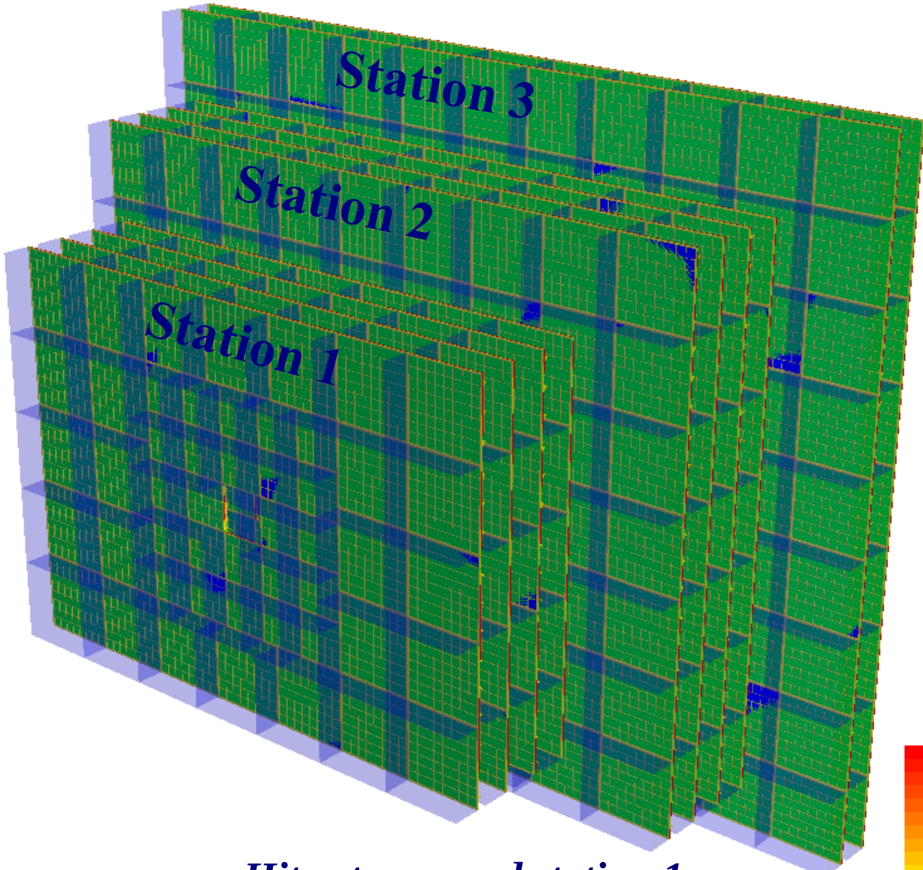


$\sigma_x = 320\ \mu m$

$\sigma_y = 5.5$ mm

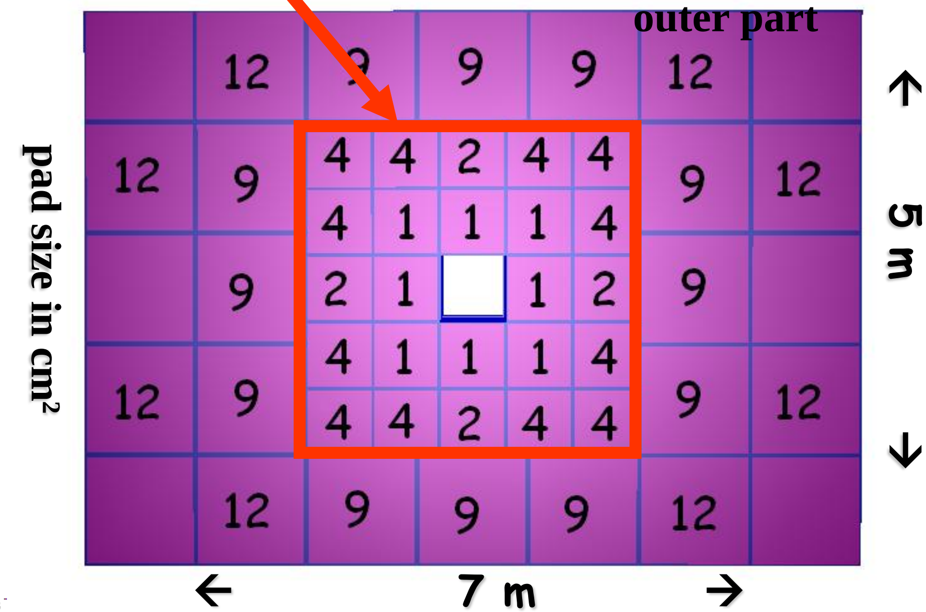
Pad size = 1 cm x 8 cm

Current CBM TRD geometry



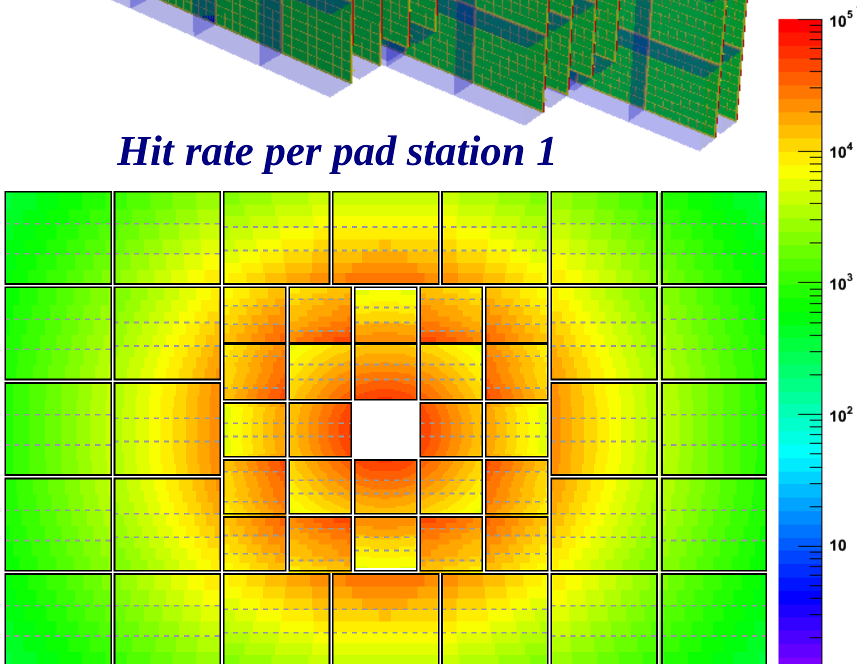
TRD Station 1

inner part (3m x 3m)

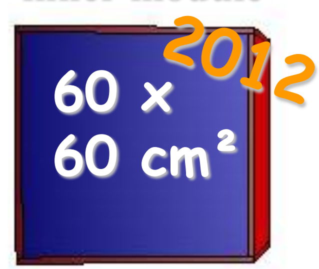


scale pad size with radial distance to the beam

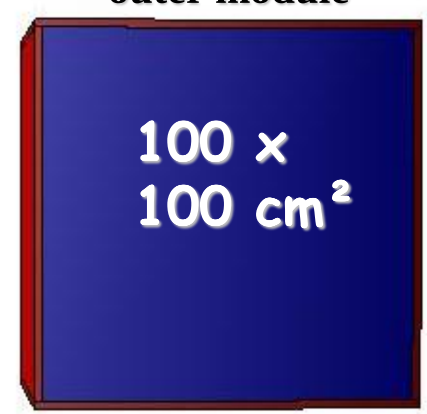
Hit rate per pad station 1



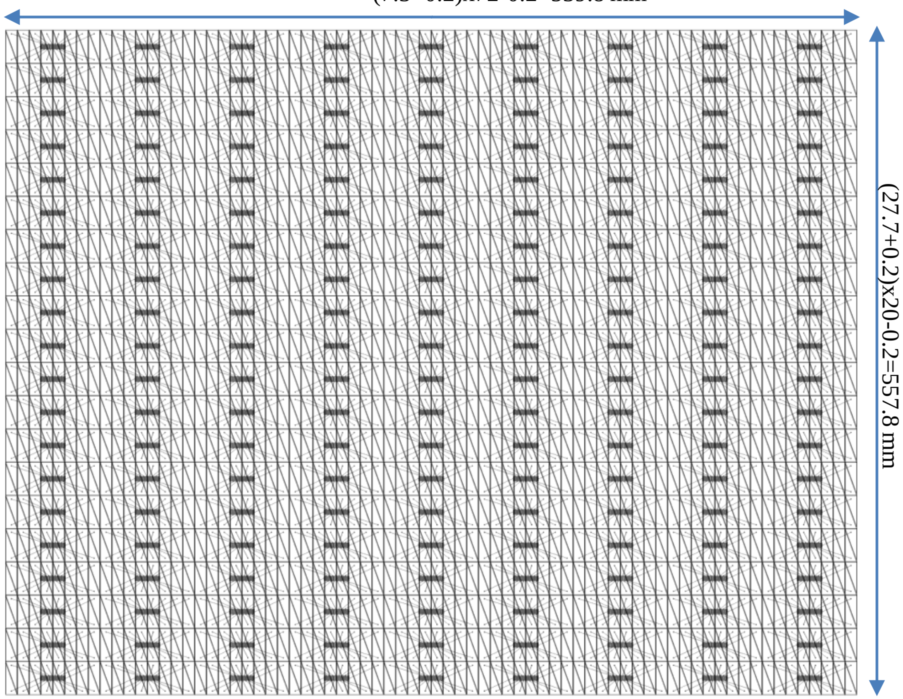
inner module



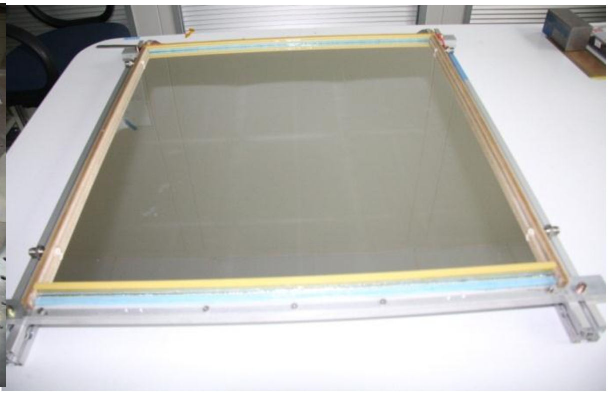
outer module



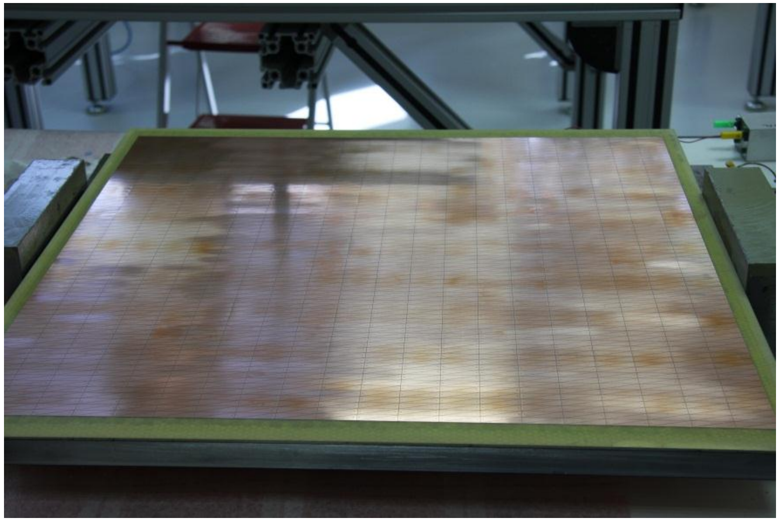
Toward a TRD basic cell for the inner zone of CBM-TRD detector



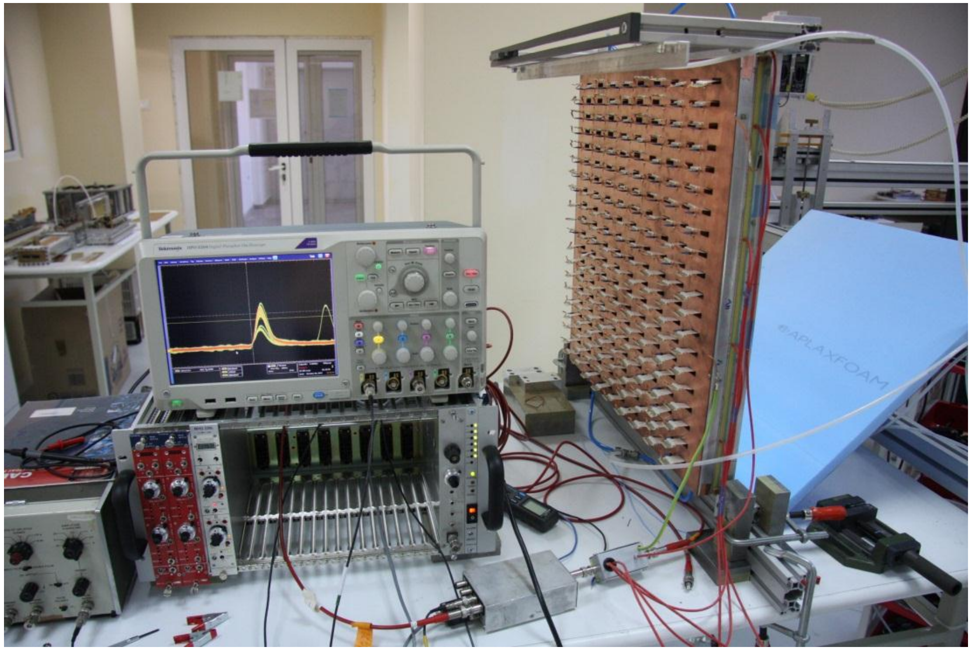
Drift electrode
Al-kapton/3mm Rohacell/9 mm honeycomb/3 mm Rohacell/Al-kapton



20 rows x 144 triangular pads/row = 2880 readout channels
readout cell area (0.7 x 2.7)/2 cm^2 ≈ 1 cm^2

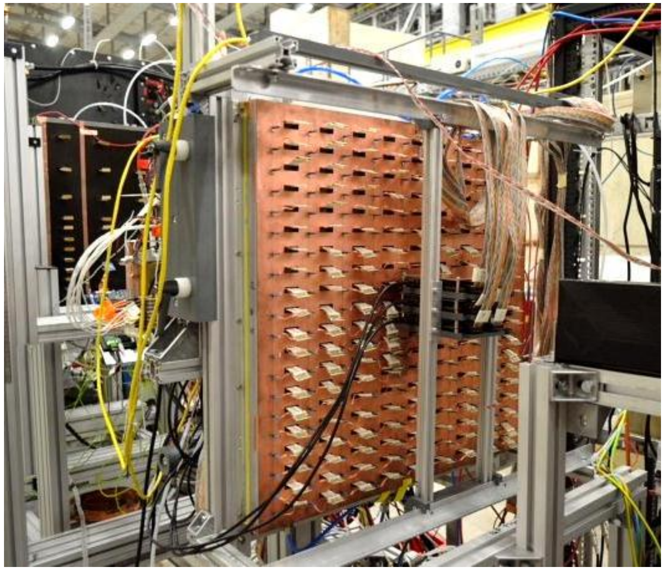


^{55}Fe source test in DetLab

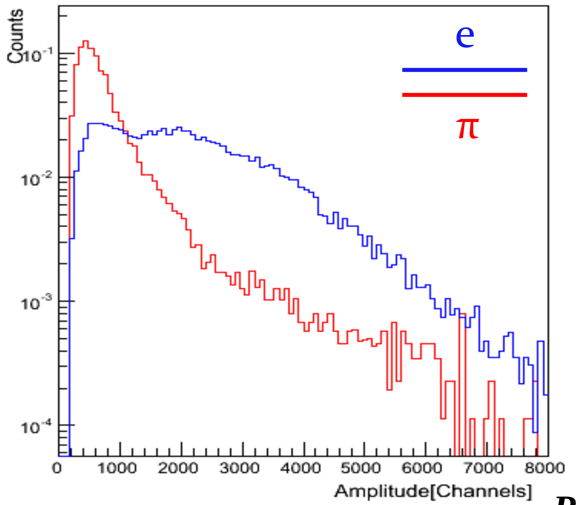


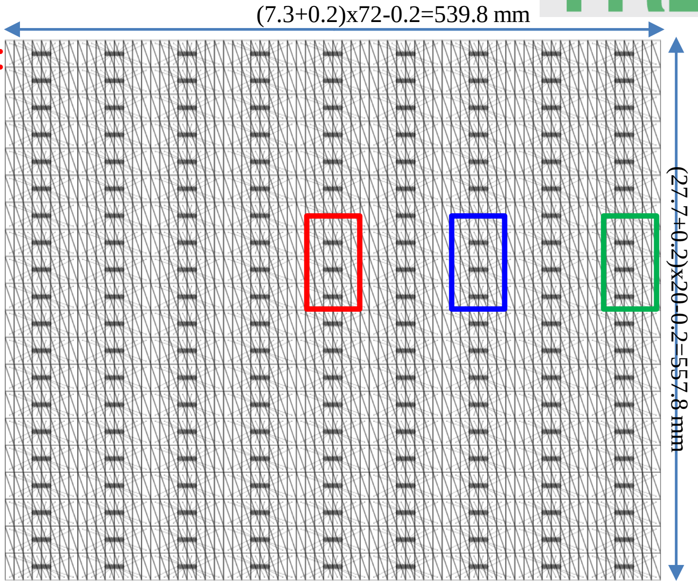
In-beam test of TRD basic cell prototype

In-beam test @ T9 beam line of CERN PS

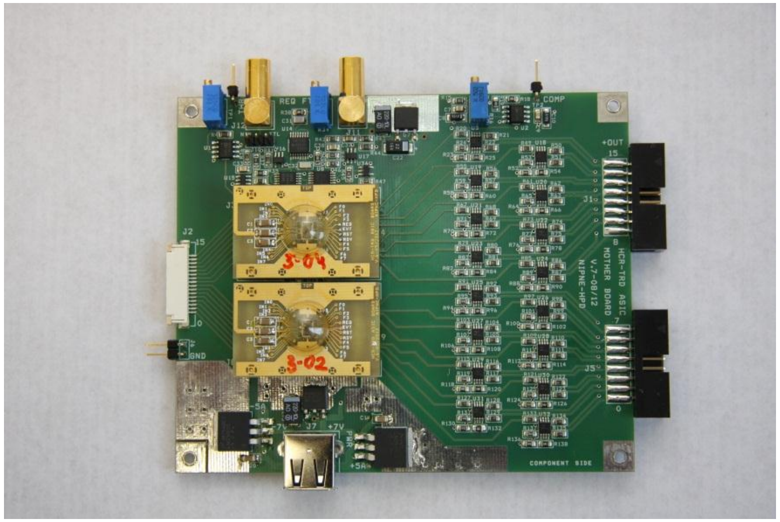


Pulse height distribution for e and π:



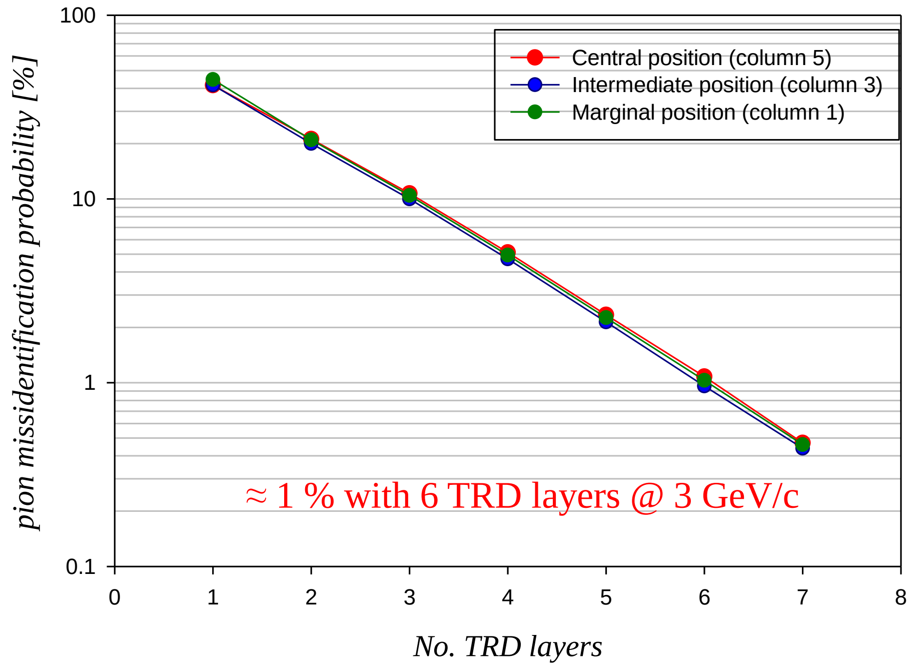


FEE – FASP – flat top output, 40 ns shaping time



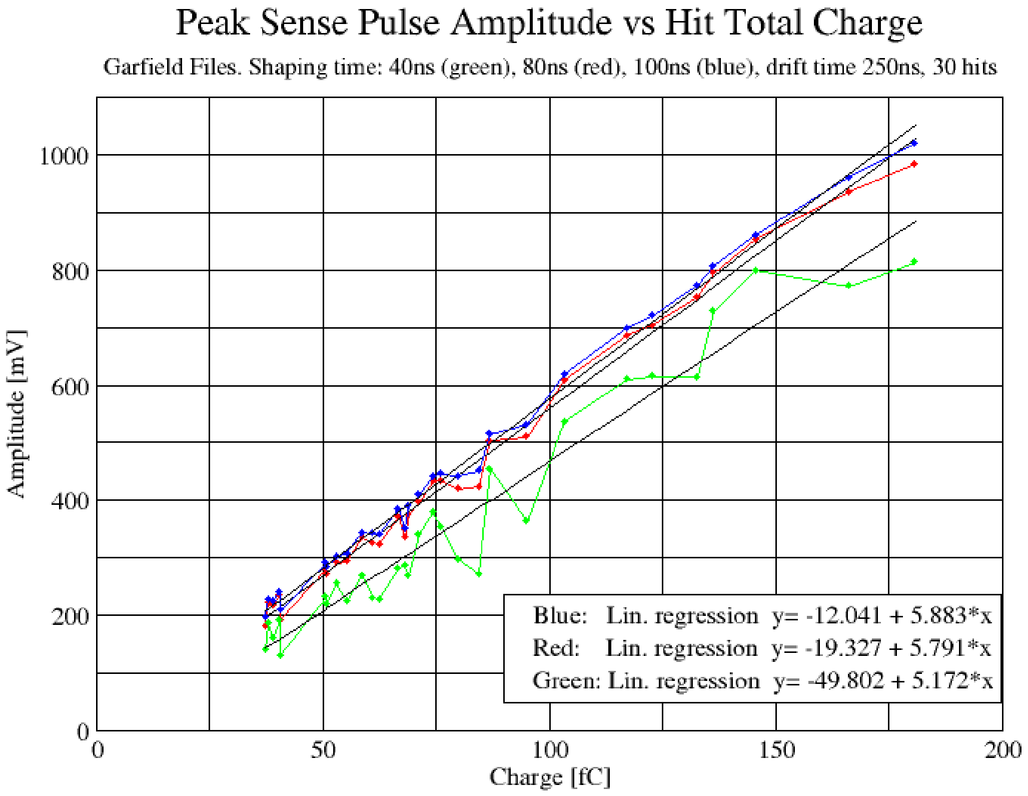
Two ASIC Chips per FEB -> 16 input/output channels

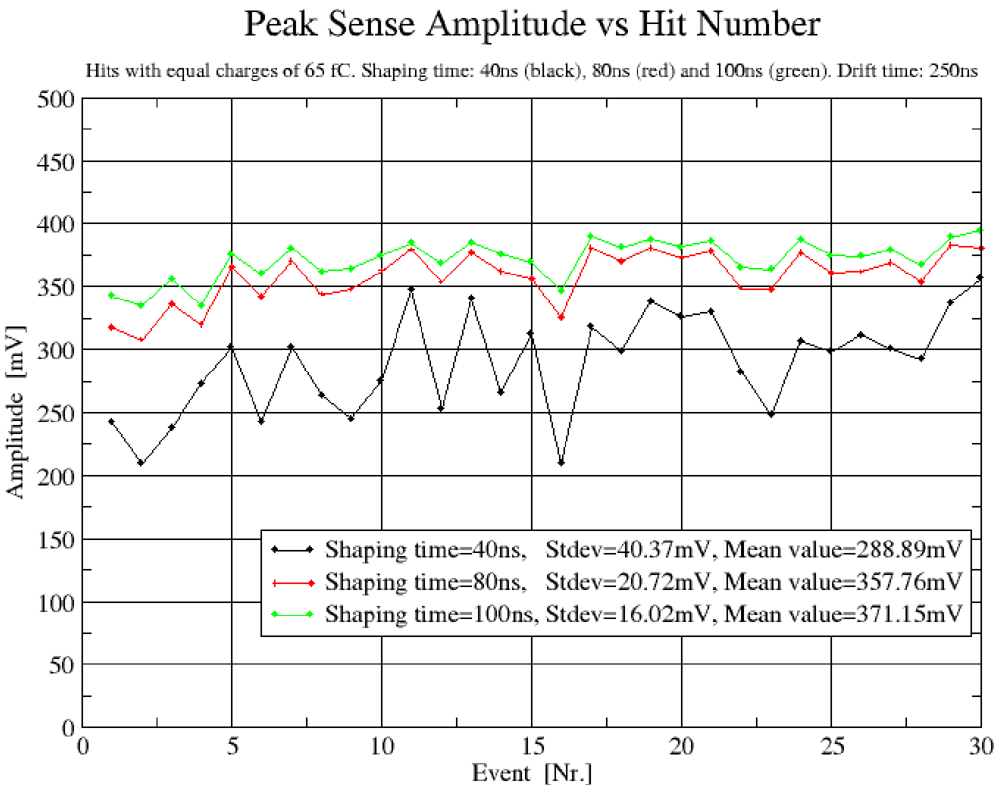
Reg2, HV_A = 2000 V, HV_D = 800 V



Optimization of FASP characteristics for better performance with SSTRD architecture

- *increased shaping time of 100 ns*
- *pairing of the triangular pad signals inside the ASIC chip*
- *16 input/output channels*
- *input signal polarity switch*
- *chip submission in the second part of the year*





- linearity 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

- uniformity of the FASP response for hits with the same input charge of 65 fC and having the ionization clusters randomly distributed in a time window of 250 ns for 40 ns, 80 ns and 100 ns ST

Optimization of FASP characteristics for better performance with SSTRD architecture

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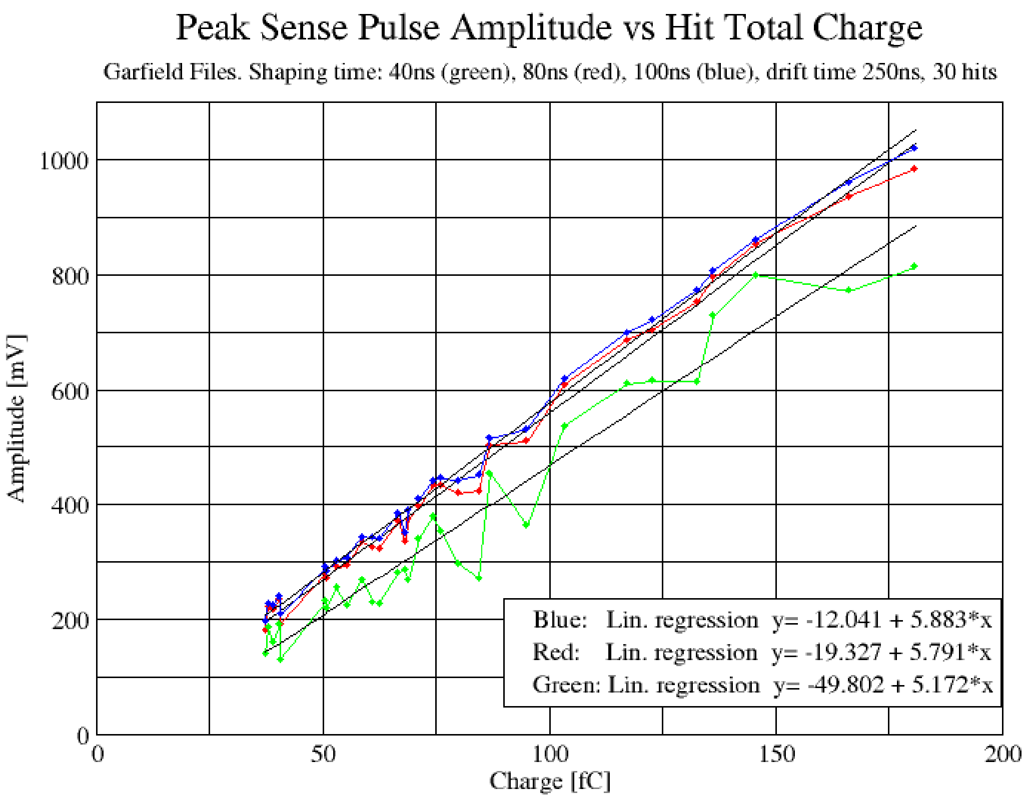

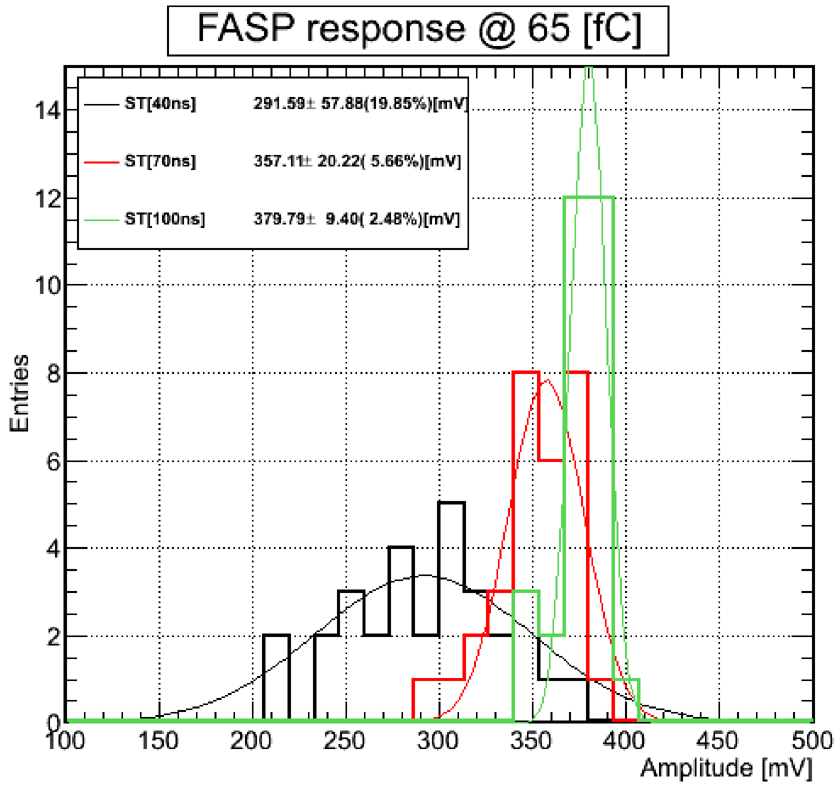

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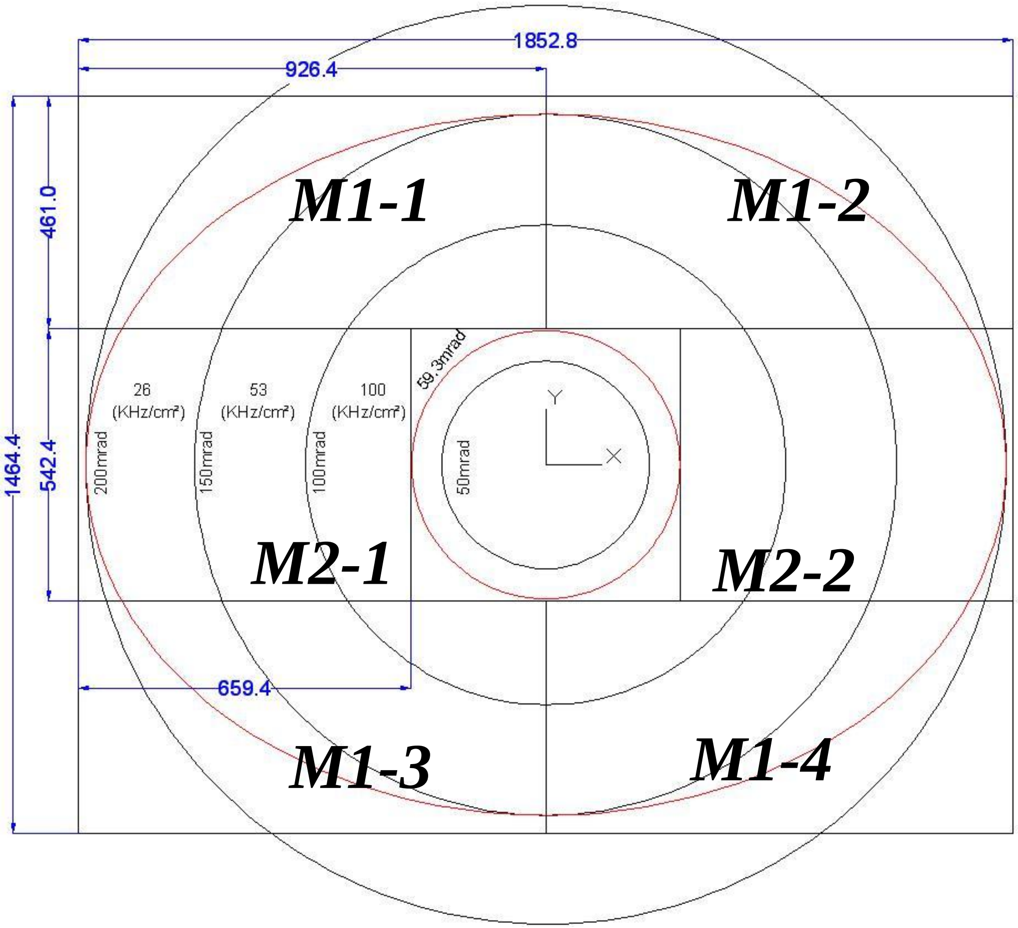
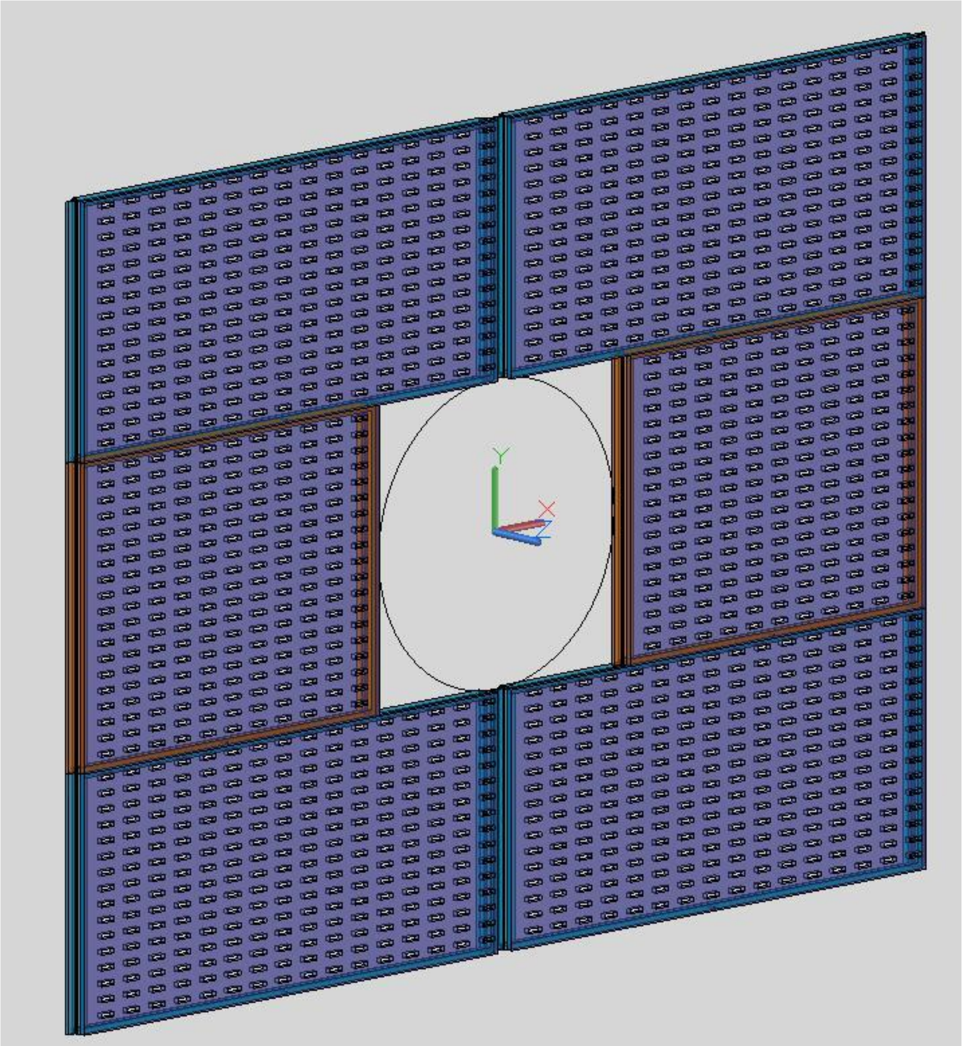
- uniformity of the FASP response for hits with the same input charge of 65 fC and having the ionization clusters randomly distributed in a time window of 250 ns for 40 ns, 80 ns and 100 ns ST

Proposed design of the inner zone of the first station of CBM-TRD detector



~ 93% geometric efficiency



Conclusions & Outlook

- *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*
- *Split pad geometry of the readout electrode gives access to two dimensional position reconstruction with good position resolution*
- *A real size TRD prototype with the same inner geometry as single sided TRD was designed, constructed and tested for systematic performance evaluation*
- *FASP is optimum FEE in terms of performance and selection of data information to be stored*
- *A new FASP version with 100 ns shaping time is under development for optimum operation of two dimensional position sensitive single sided TRD architecture*
- *Based on the real size TRD prototype, a design of the inner zone of the first TRD station with a maximum geometric efficiency was proposed*

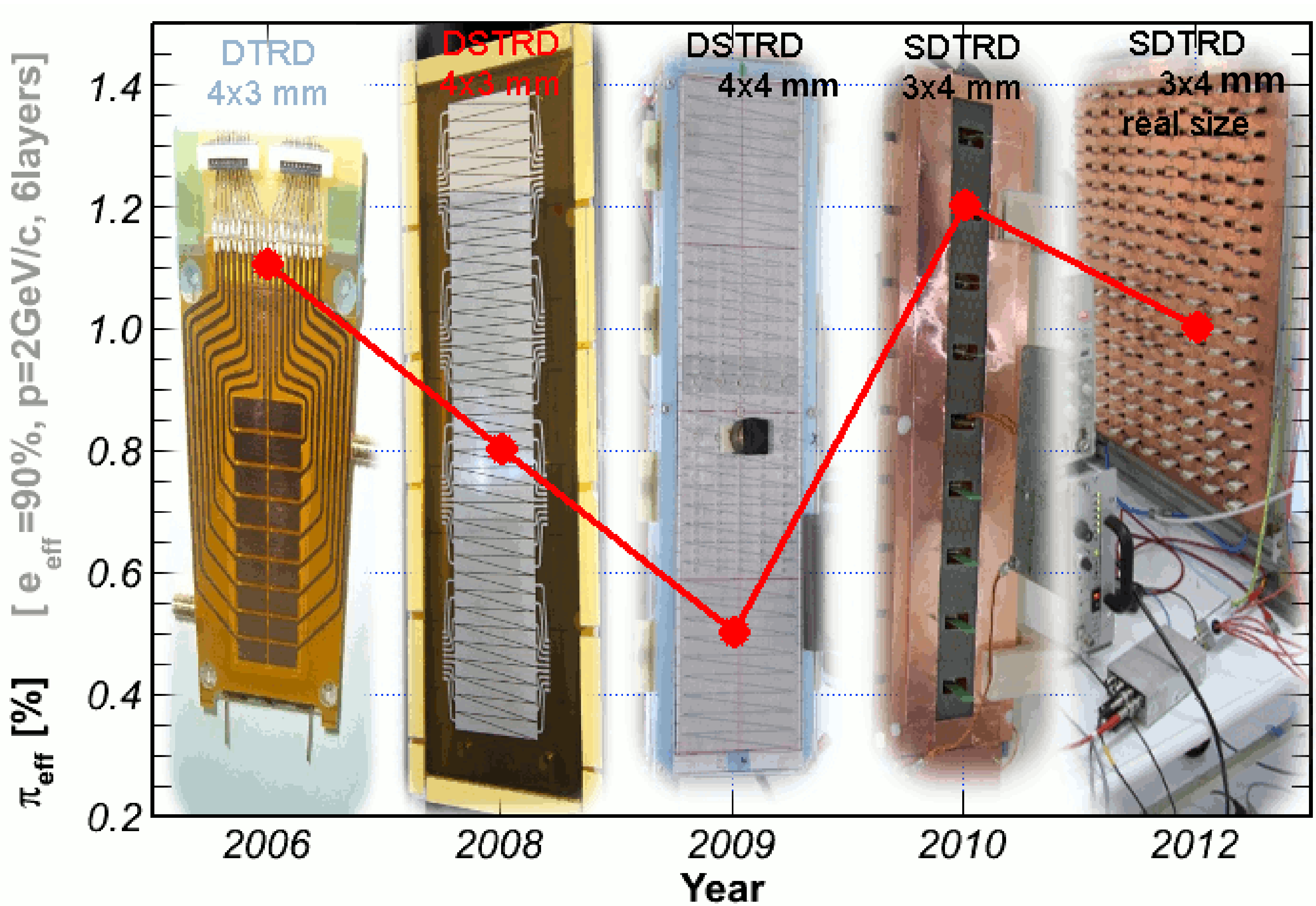
Mandatory near future detailed investigations of:

- position resolution using high position resolution reference counter

- high counting rate and multi-hit environment on the whole active area

- GEANT simulations of the full configuration including realistic distribution of the material budget

Thank you for your attention!



Backup slides

CADENCE Simulation of 10 hits that succeed at 1 μs one to the other