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M-B TRD Prototypes in Test Beam and Simulation

CBM Collaboration Meeting
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Dresden

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M-B (Münster-Bucharest) Prototypes for CBM TRD

Short description of M-B TRD prototypes

Experimental results of an independent analysis

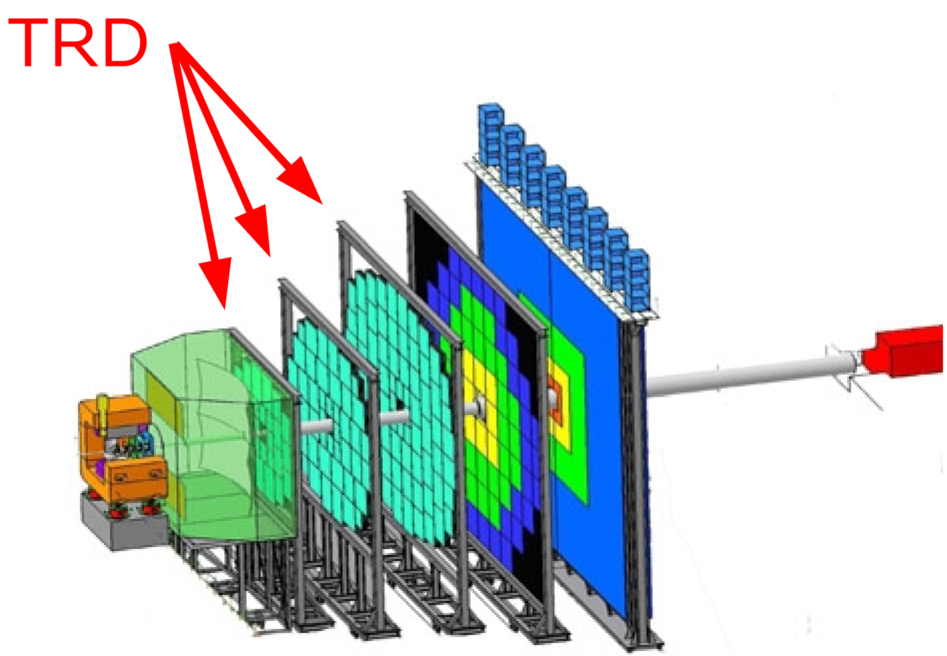
- Rate performance
- Position resolution
- PID

Simulation in CbmRoot

- d*E*/d*x* in Geant3
- PID with M-B TRD geometry
- Comparison to test data

Summary and outlook

Detector Setup



TRD

- Electron identification (with RICH, TOF)
- Tracking of all particles (with STS)

Requirements for TRD

- Pion suppression: ~100
- Position resolution: ~200-300 μm
- At high rates (up to >100 kHz/cm²) and high multiplicities

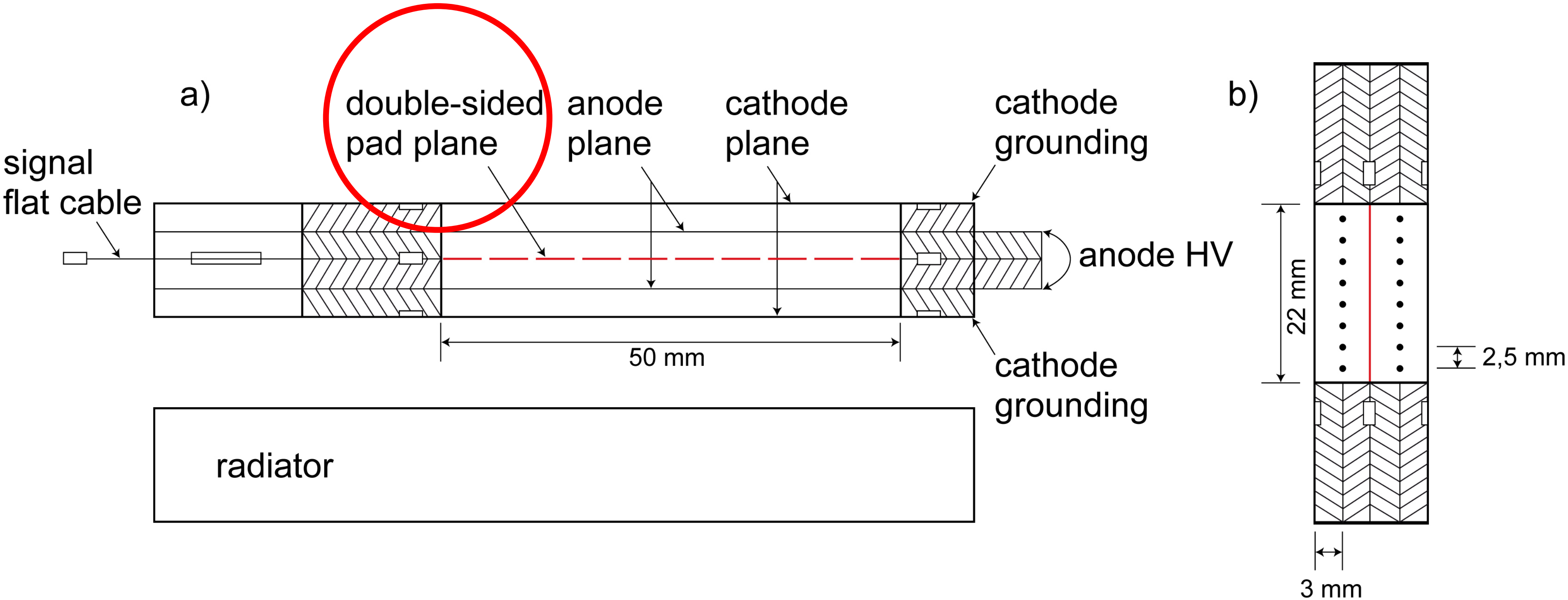
Possible Designs

- Radiator + MWPC with pad-readout
- Radiator + straw tubes
- Combination

MWPC-based Protoypes (M-B TRD)

MWPC-based prototypes (M-B TRD)

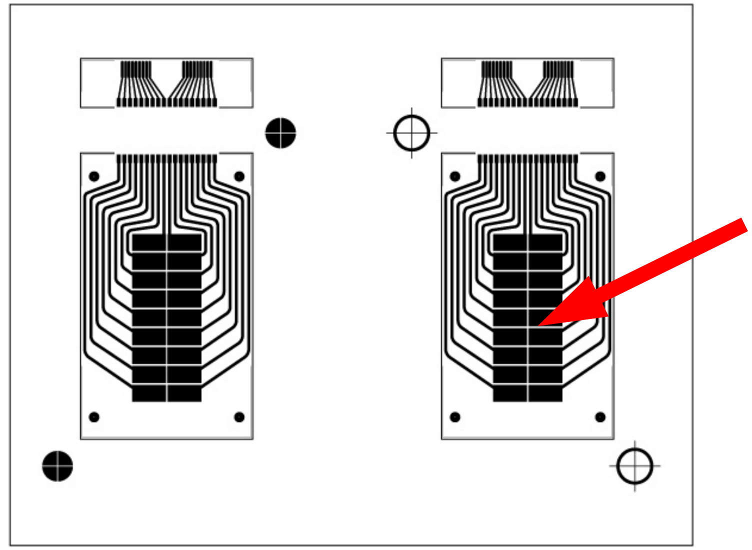
Two individual MWPCs sharing one double-sided pad plane:
~twice the detection efficiency at same rate capability



a) View parallel to anode plane

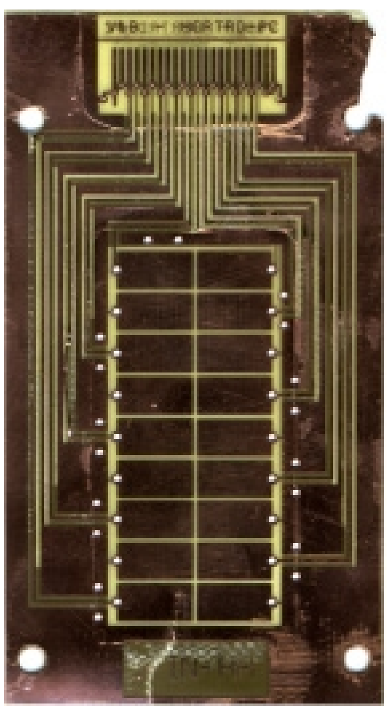
b) View perpendicular to anode plane

Pad plane

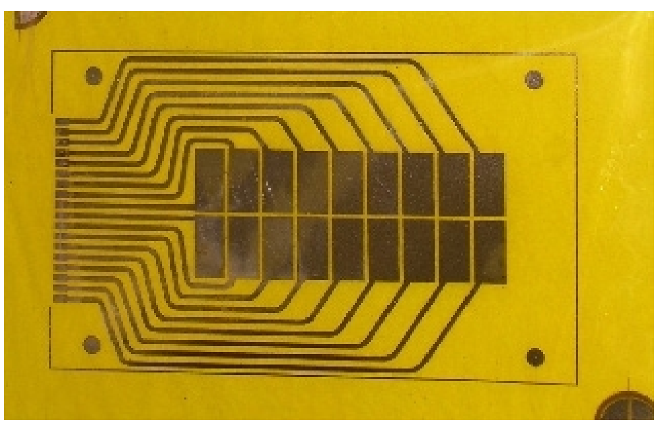


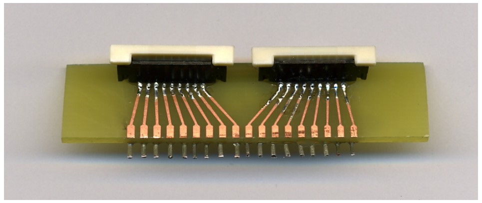
Pads
(5×10 mm²)

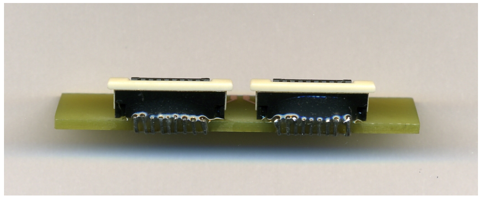
PCB



Etching the pad structure on a double-sided copper covered kapton foil of 25 μm.







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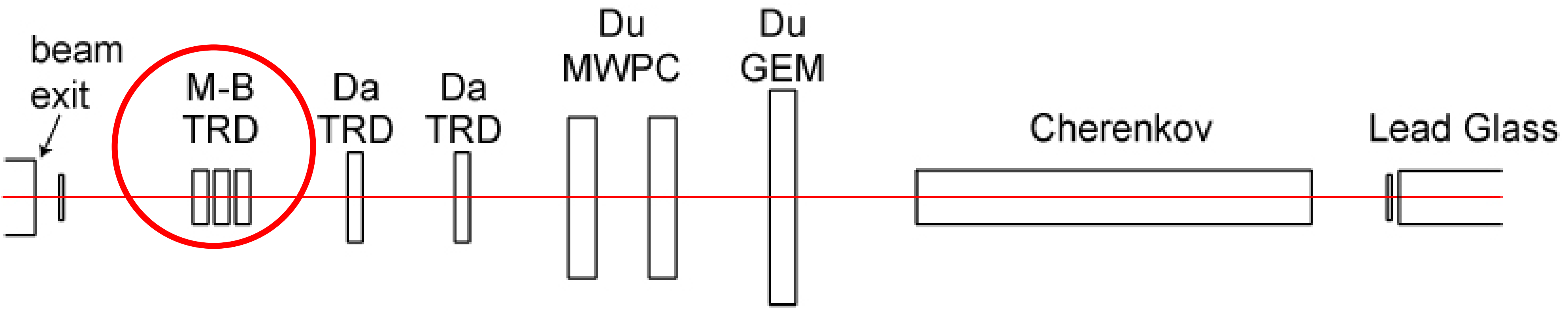
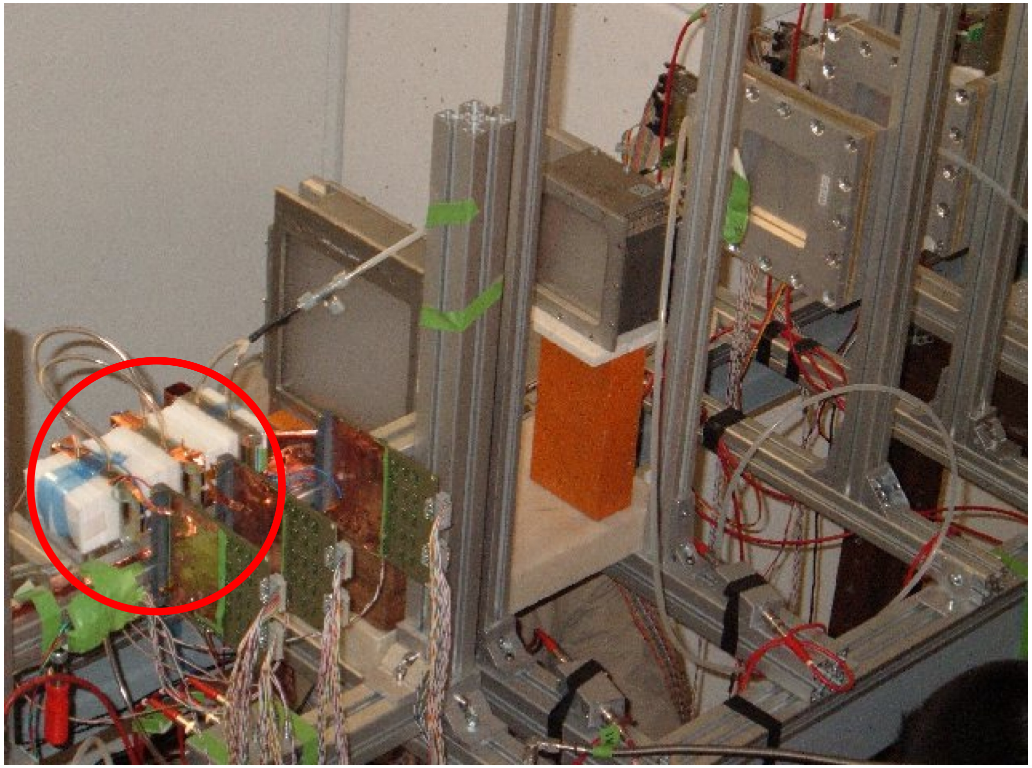
Test Beam in February 2006 (at GSI)





- Beam of pions, protons and electrons with p = 1 GeV/c, 1.5 GeV/c and 2 GeV/c
- Scintillators: rate measurement and TOF
- Pb-Glass and Cherenkov: Particle-ID
- Si-Strips: beam profile

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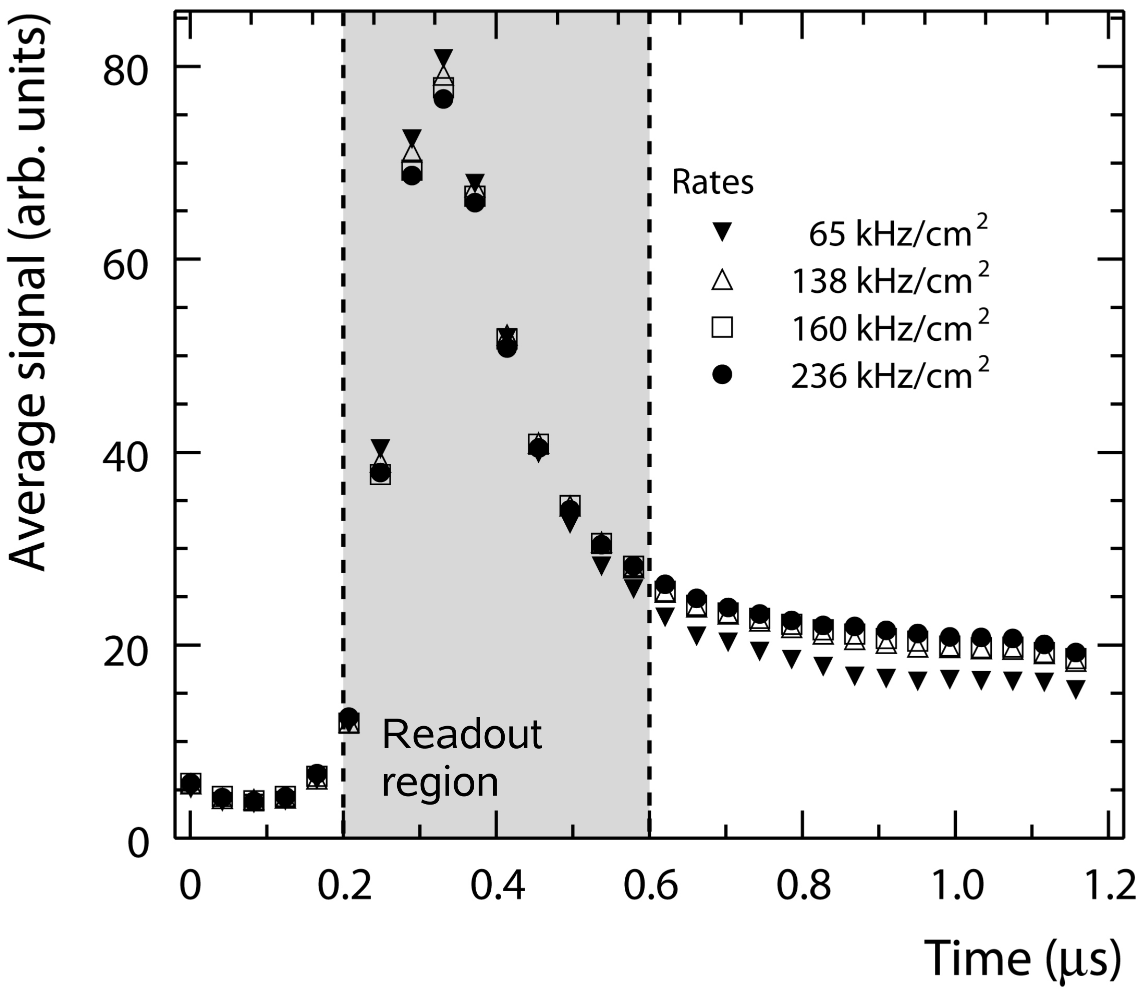
Average Signal on Three Adjacent Pads

M-B TRD

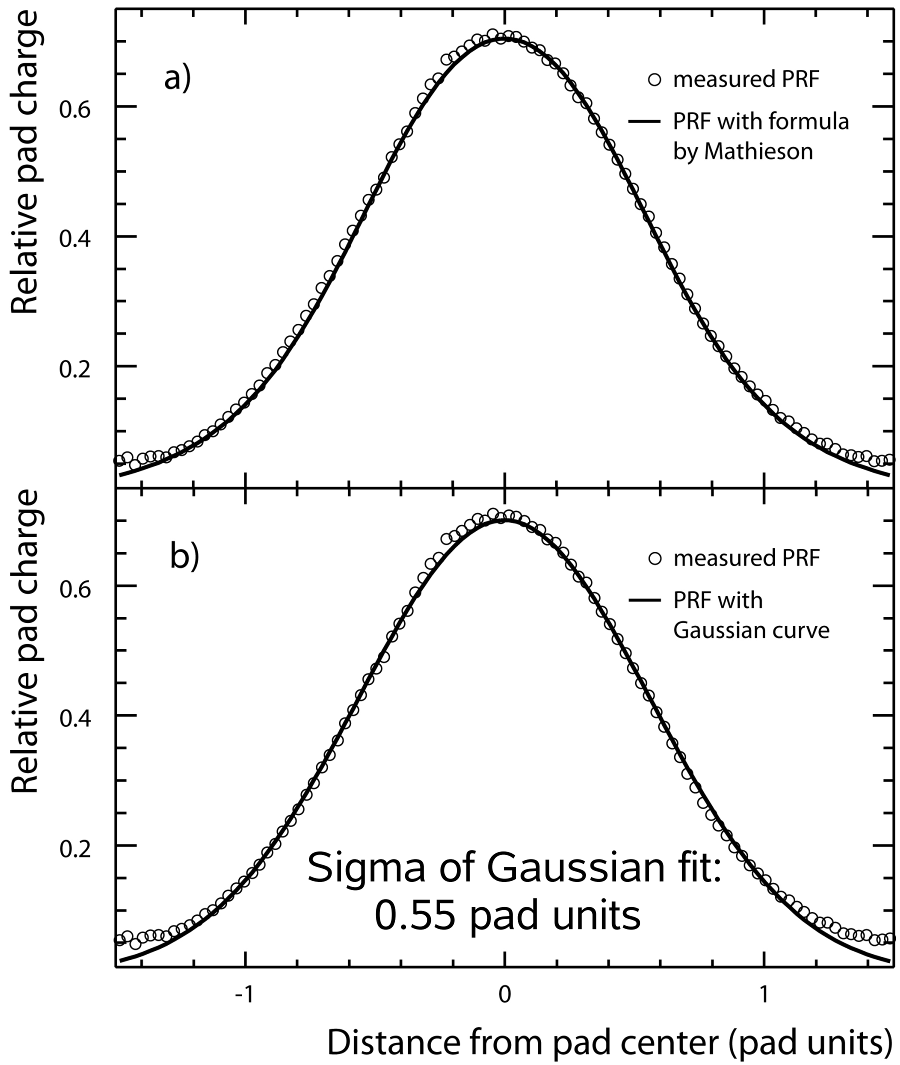


- p = 1.5 GeV/c
- HV = 1700 V
- Xe(85%)CO_2(15%)

→ Only weak rate dependence (< 2%)

Determination of Position Resolution

Reconstruction of hit positions in the chambers



Mathieson

Gauss

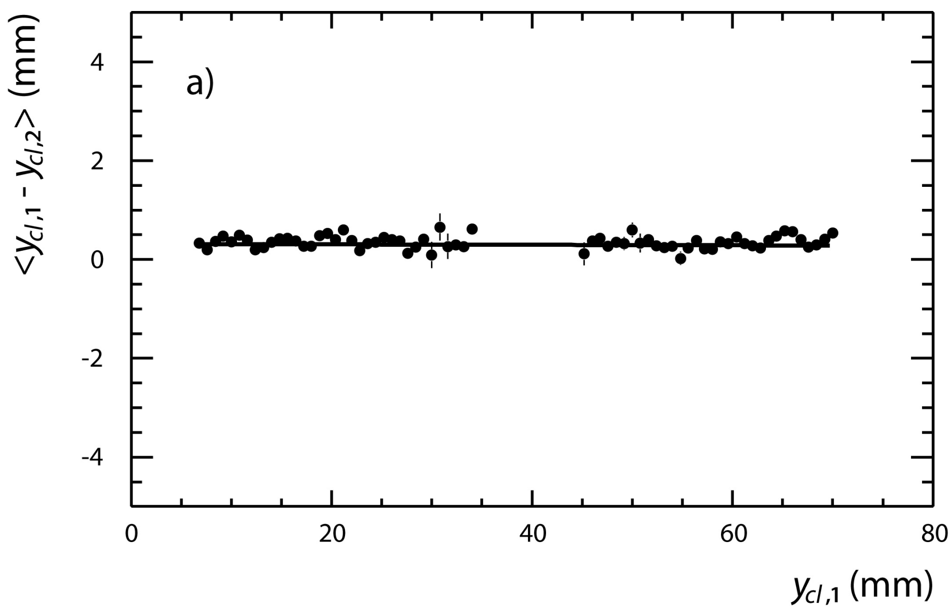
Cluster reconstructable via charge distribution on adjacent pads in *y*-direction → PRF (*Pad Response Function*)

Ref.: Mathieson et al. NIM A270 1988 602-603

Determination of Position Resolution

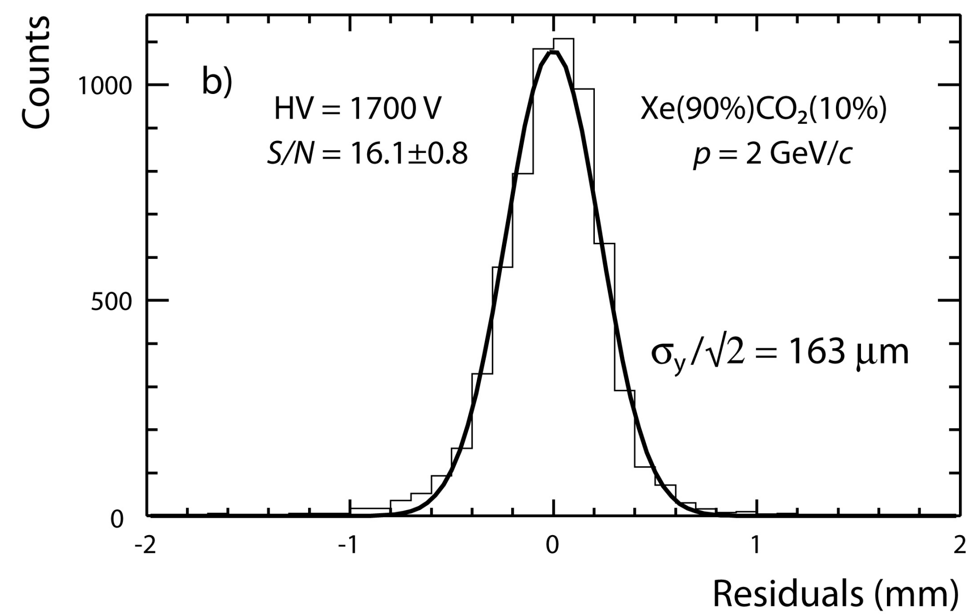
Alignment

y_1, y_2 = reconstructed hit positions in chambers 1 and 2 (M-B TRD)



Residuals = difference between reconstructed and fitted value for y_1-y_2

Residuals

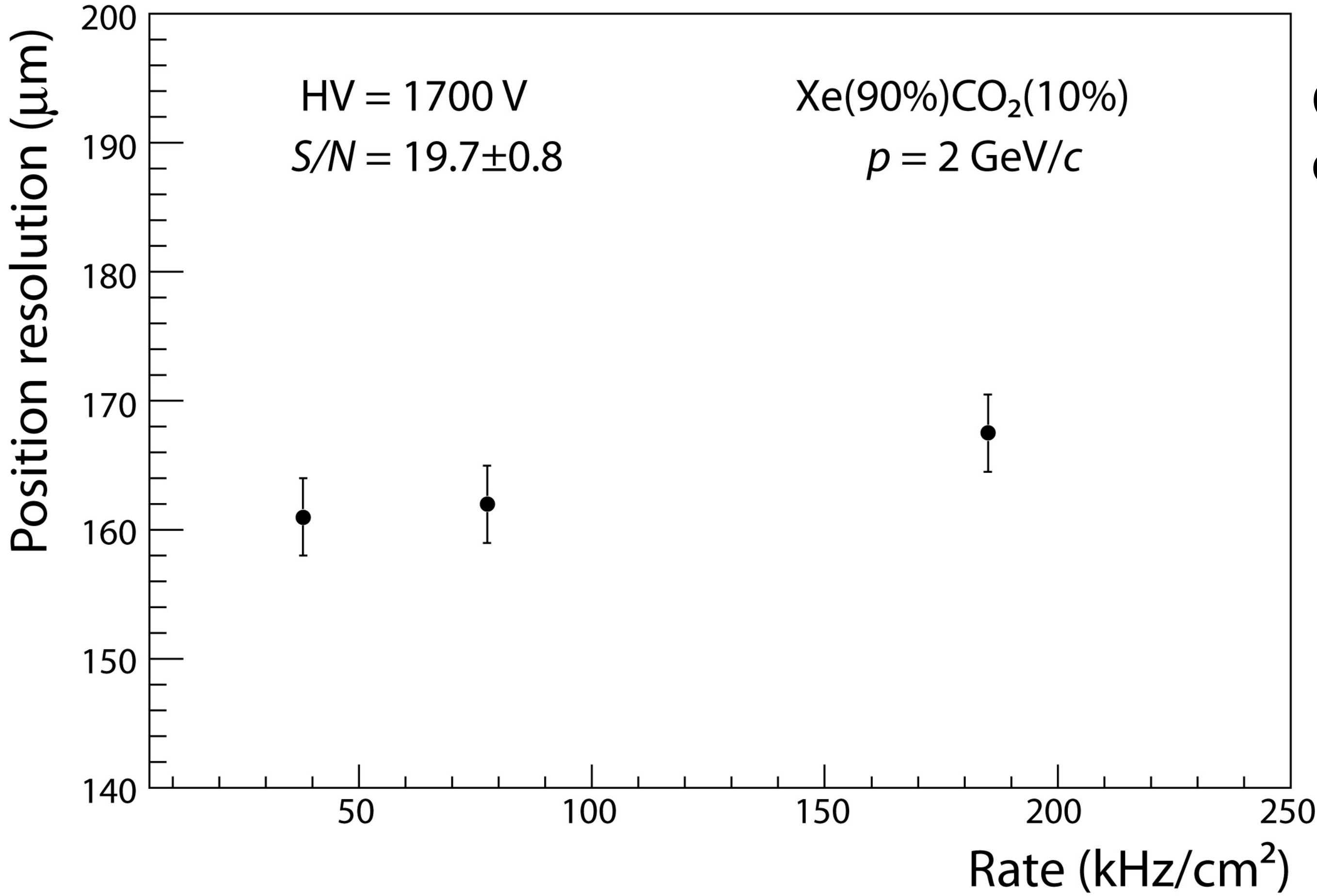


Position resolution =
Width of residual distribution for a large number of tracks

Here: Example run at moderate rates (38 kHz/cm²)

Position Resolution

Submitted to Nucl. Instr. Meth. A

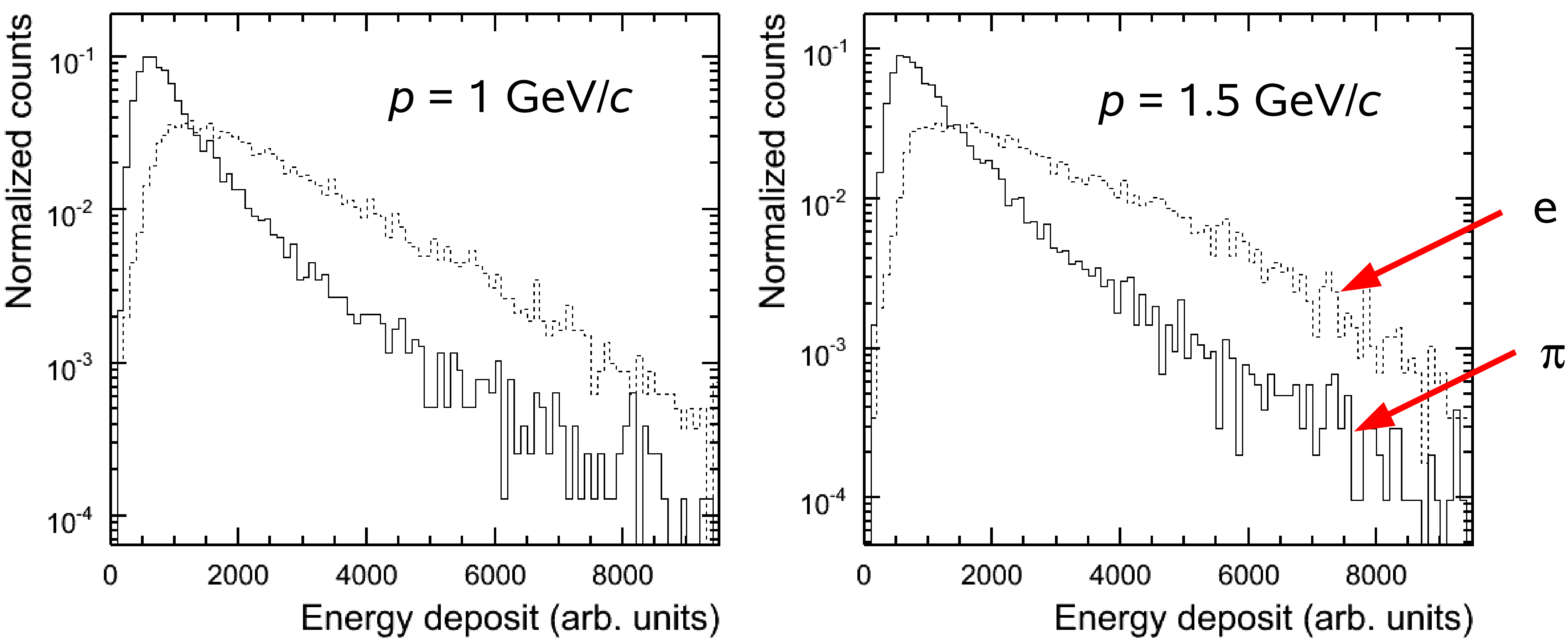


Cuts chosen for constant efficiency

→ good position resolution of <200 µm for rates up to 200 kHz/cm^2

Energy Deposit in Test Beam

d*E*/d*x* for pions and electrons



Energy Deposit in Test Beam

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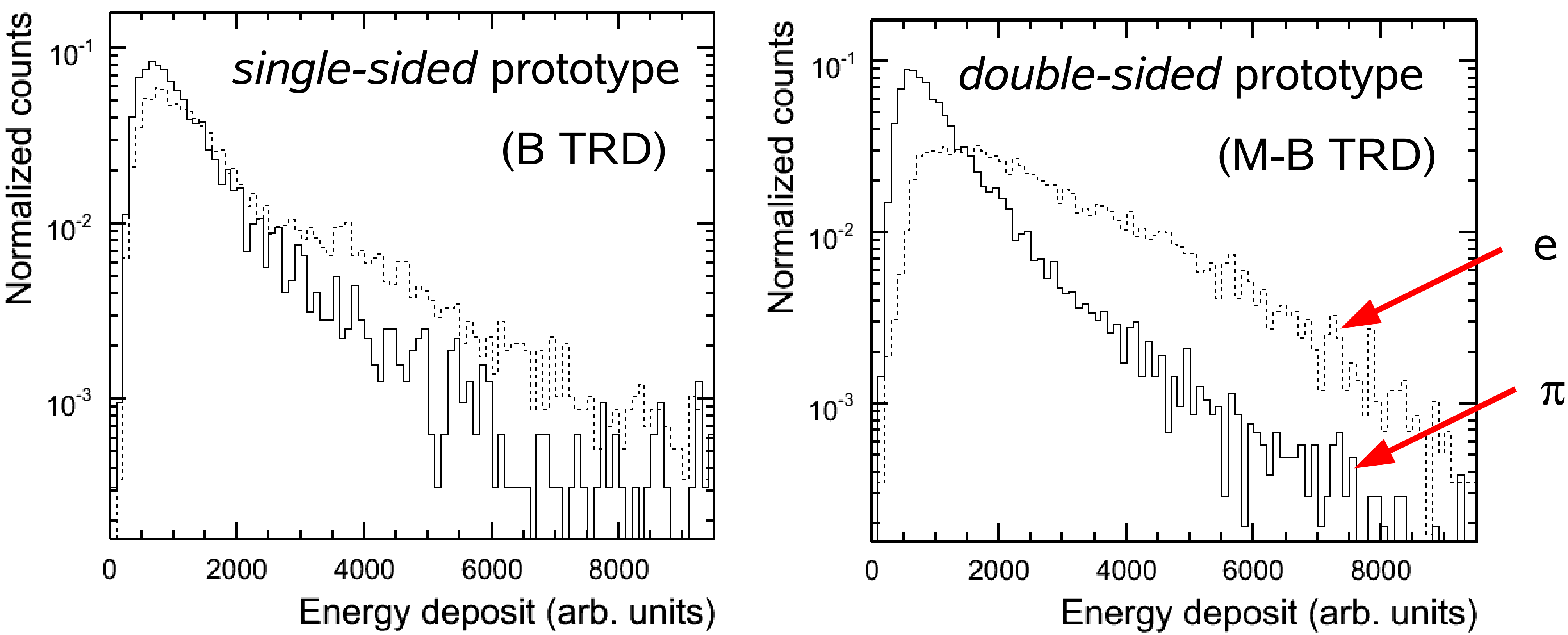
d*E*/d*x* for pions and electrons



→ Better electron identification due to higher TR conversion probability

Simulation in CbmRoot

Idea: Comparison of the shape of energy loss spectra in the test-beam data and simulation

Simulation: CbmRoot (Geant3)

CbmHitProducerIdeal.cxx Creating TRD hits using MC information

CbmHitProducerQa.cxx Performance of TRD Hit Producer

CbmHitProducerLike.cxx PID with likelihood method

Here: independent calculation of PID for a better comparison to test beam data

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M-B TRD in Simulation

Geometry

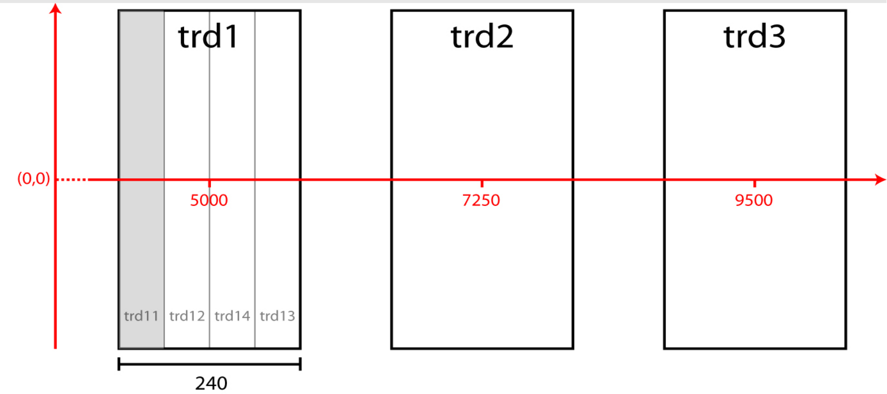
New file [trd_standard_MB.geo]

a) 3 stations with b) each 4 layers

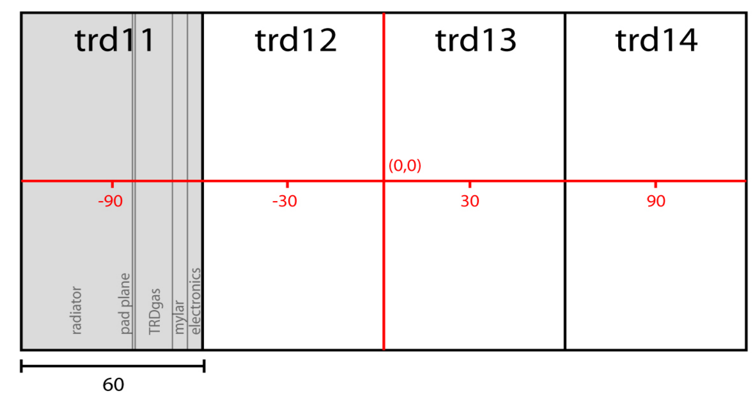
c) Layer:

- radiator
- gas volume (Xe, CO_2(15%))
- pad plane (kapton),
- window (mylar),
- electronics (gold and copper)
- **Pad plane in front of gas volume**
- **TR calculation: pad plane in the center of gas volume**

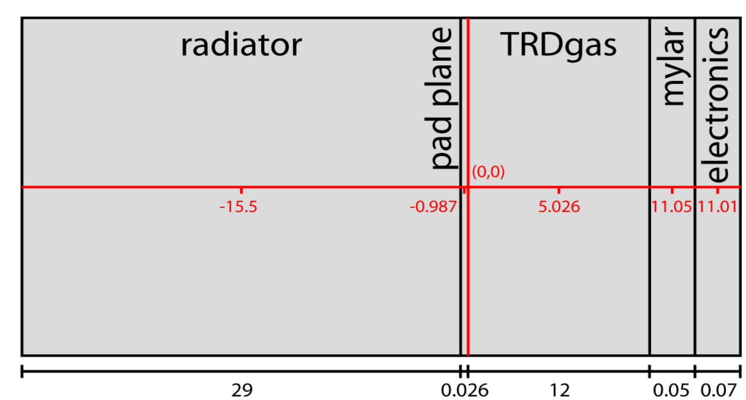
a) trd



b) trd1



c) trd11



Simulation in CbmRoot

Particle simulation

- Box generator: electrons and pions with fixed momenta

distributed uniformly in cos(θ) and ϕ window,

1cm in front of Layer1.

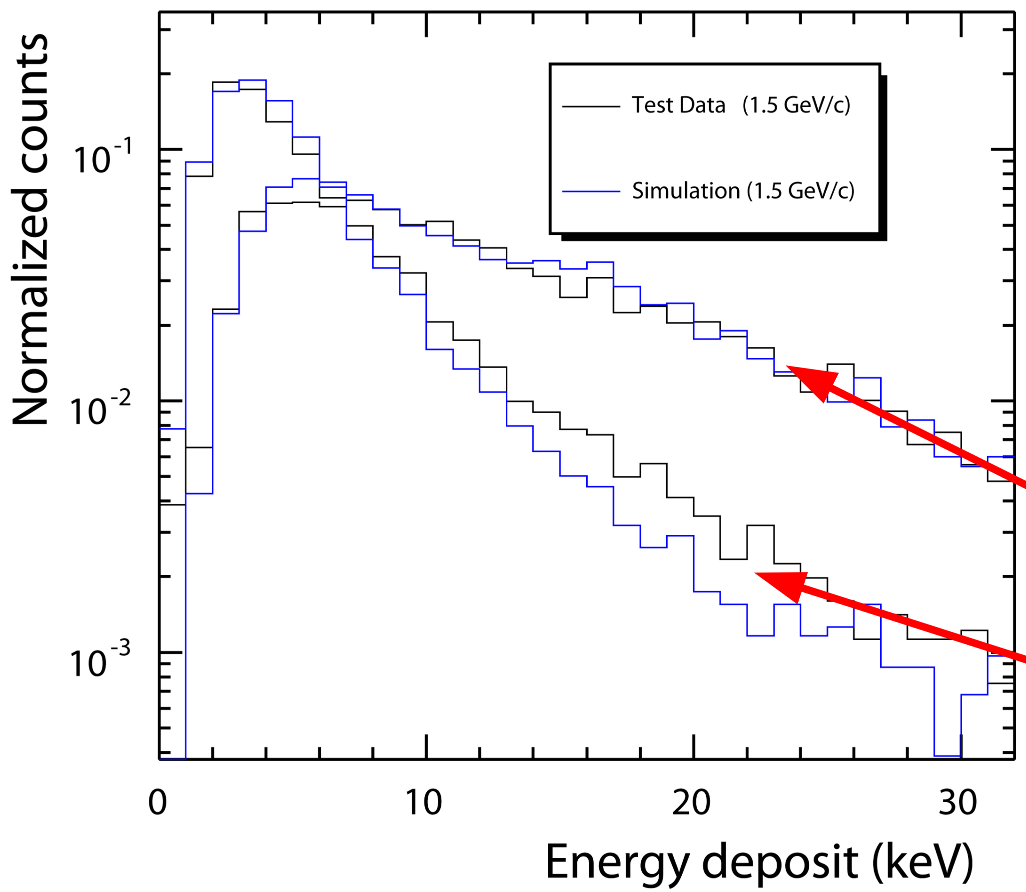
- Simulation of prototypes: readout of d*E*/d*x*+TR for e and π behind first layer TRD
- Radiator: routine with foil stack parameter **[CbmTrdRadiator.cxx] by F.Uhlig**

  → TR production and absorption

- Radiator parameters: nFoils, FoilThick, GapThick

Simulation in CbmRoot

Energy deposit



Simulation parameter set to match the test data:

- p = 1.5 GeV/c
- same event numbers
- TRDgas = 12 mm
- Radiator: 50 foils

e: good agreement

π: distributions don't fit

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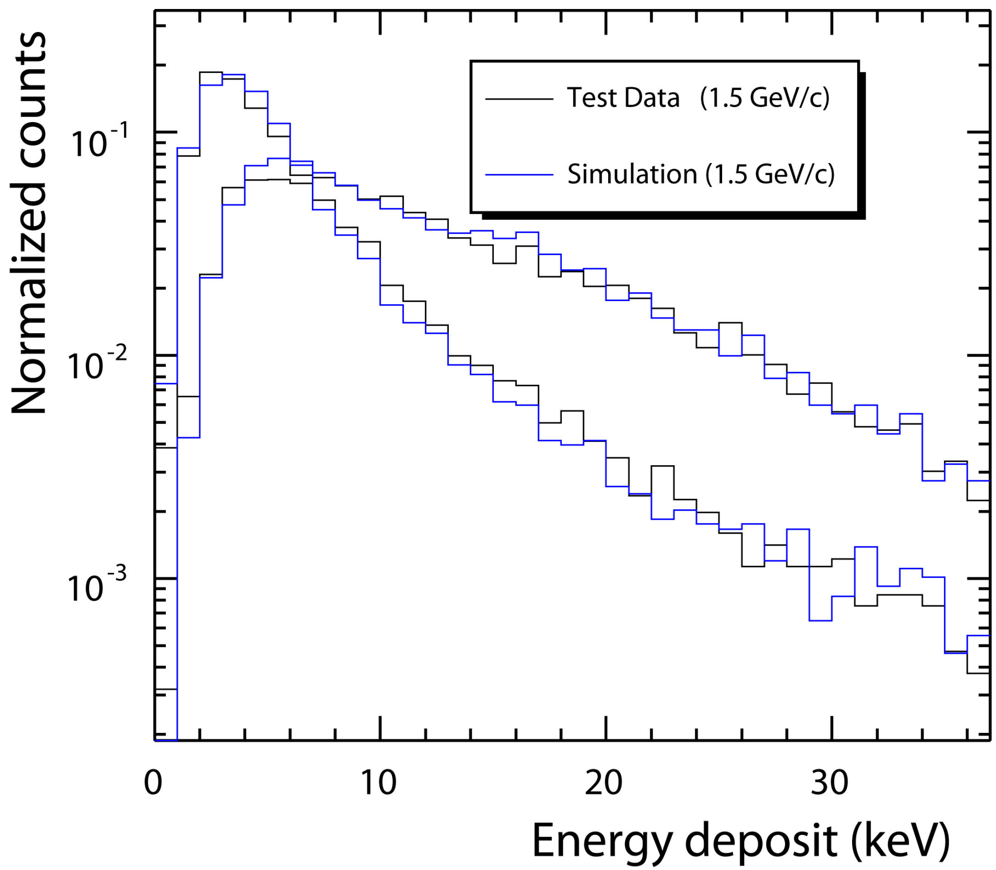
Simulation in CbmRoot

Energy deposit

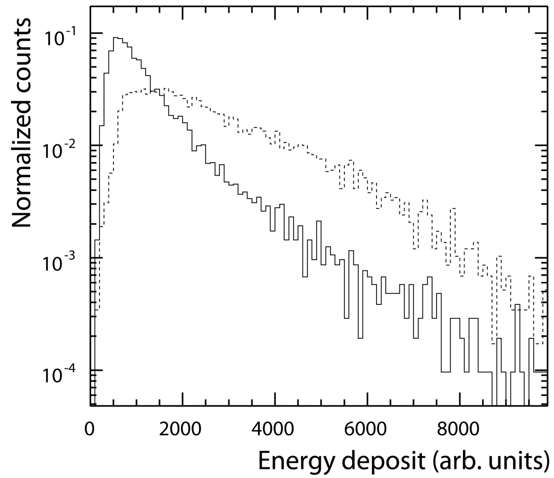


Simulation parameter set to match the test data:

- p = 1.5 GeV/c
- same number of events
- TRDgas = 12 mm
- Radiator: 50 foils
- pions with 5% electron contamination

Determination of Pion Efficiency

Likelihood (LQ) method



- *dE*/d*x*-distribution as likelihood distribution:
e and π having probability P(E) to deposit a certain energy in a chamber.

- Creating random values E^e und E^π corresponding to energy distributions → information on identification probability.

- Relative likelihood to be an electron:

$$L_e = \frac{P_e(E^e)}{P_e(E^e) + P_\pi(E^e)}, \quad \text{with} \quad 0 \leqslant L_e \leqslant 1$$

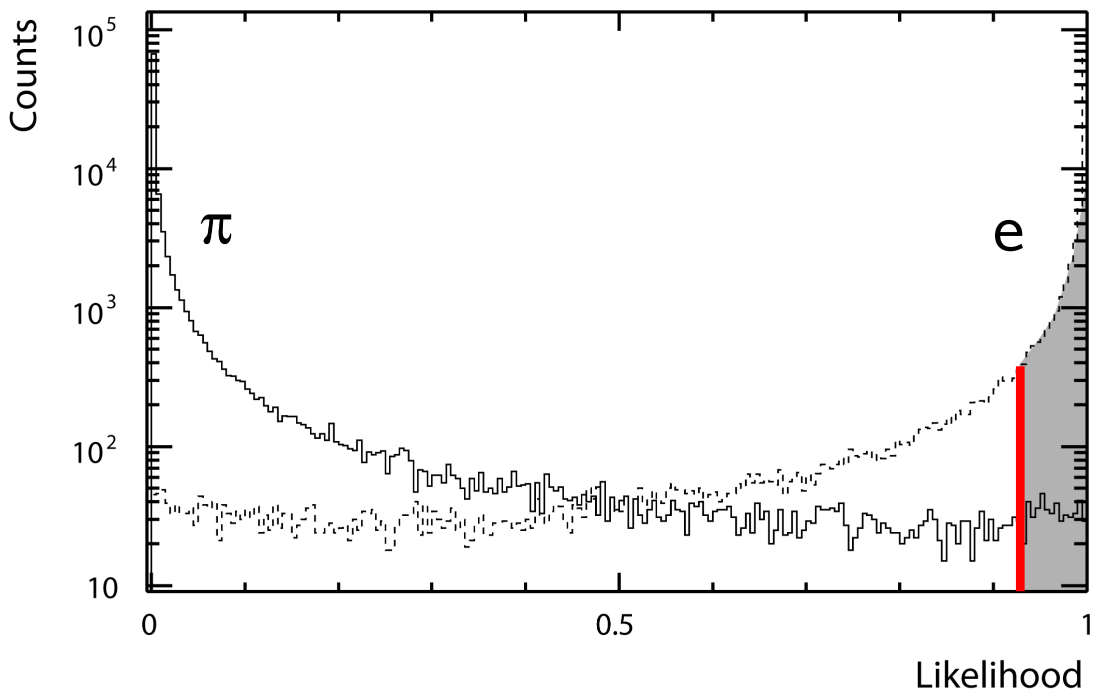
- Relative likelihood, that a pion is identified as electron:

$$L_e = 1 - L_\pi = \frac{P_e(E^\pi)}{P_e(E^\pi) + P_\pi(E^\pi)}, \quad \text{with} \quad 0 \leqslant L_e \leqslant 1$$

Determination of Pion Efficiency

Likelihood distribution

(Likelihood to be identified as electron)

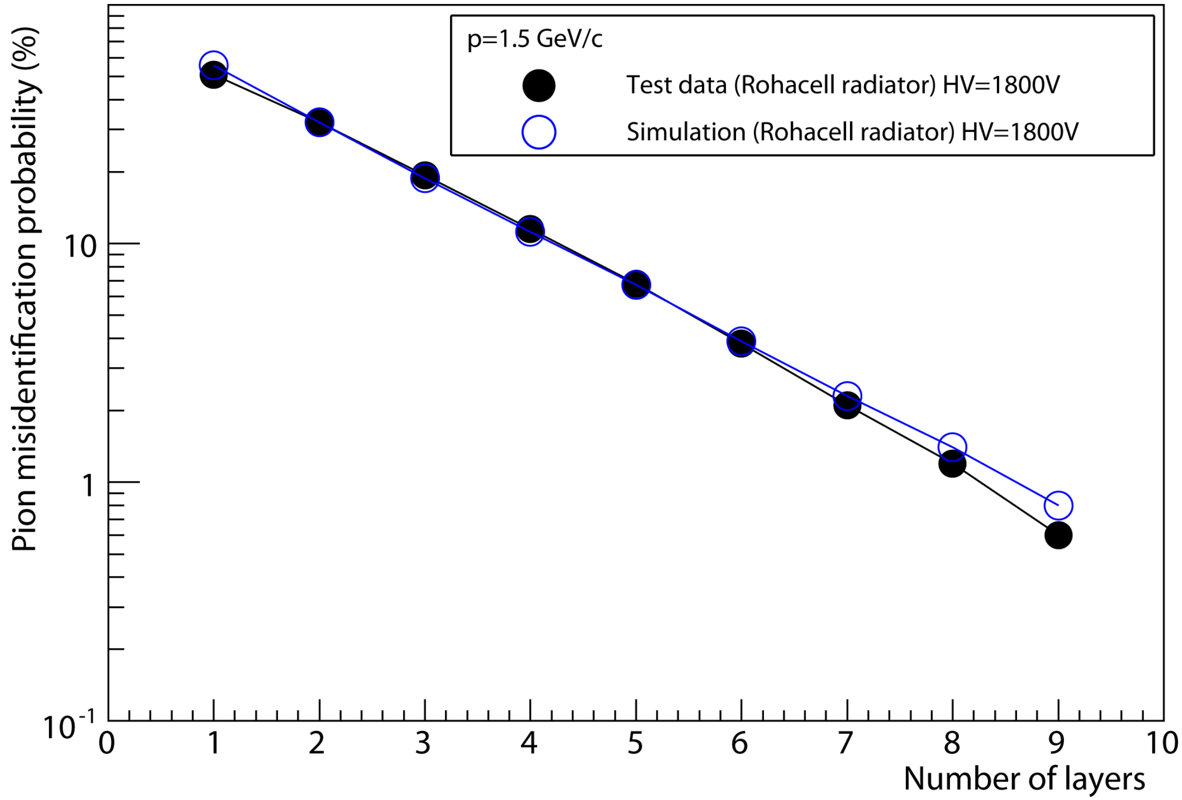


Limit for 90% electron efficiency

→ Determination of pion efficiency and extrapolation for more detector layers

Pion Efficiency

Pion misidentification probability at 90% electron efficiency



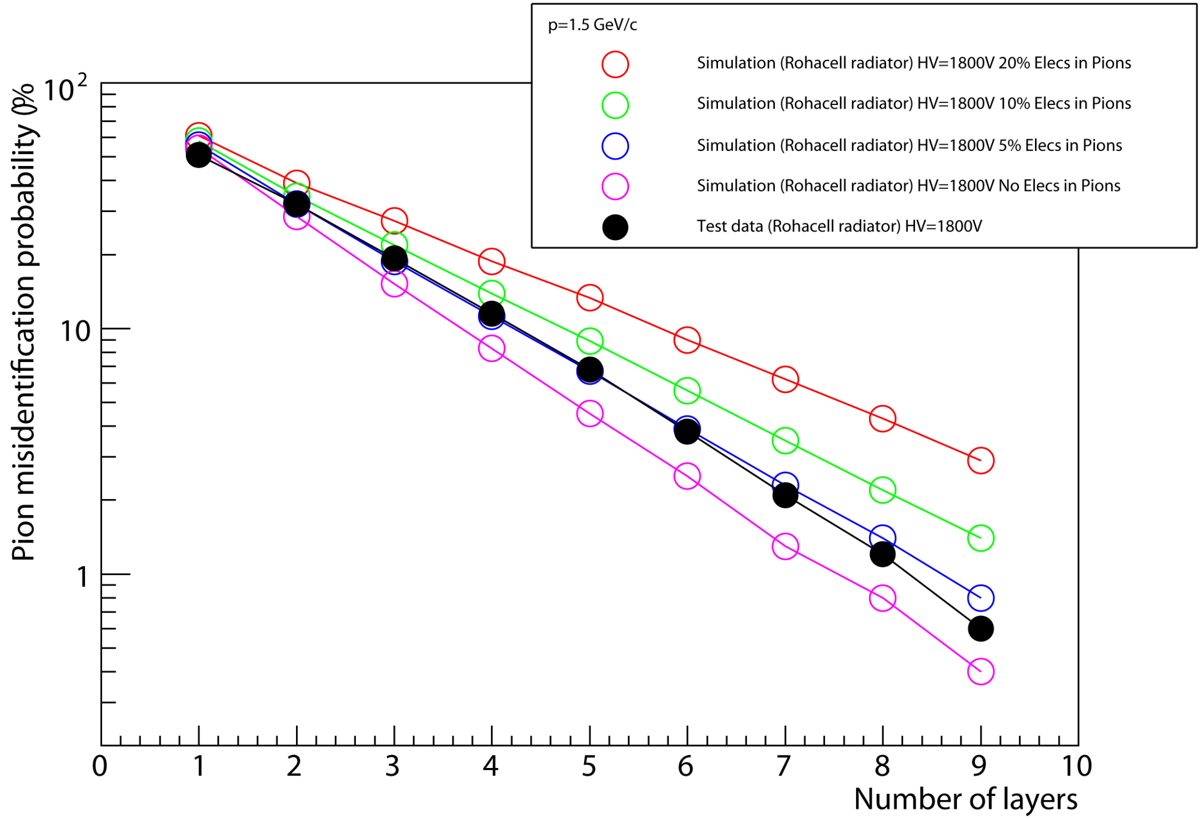
→ Pion efficiency (= 1/pion suppression) in the desired region of 1/100 for 9 detector layers

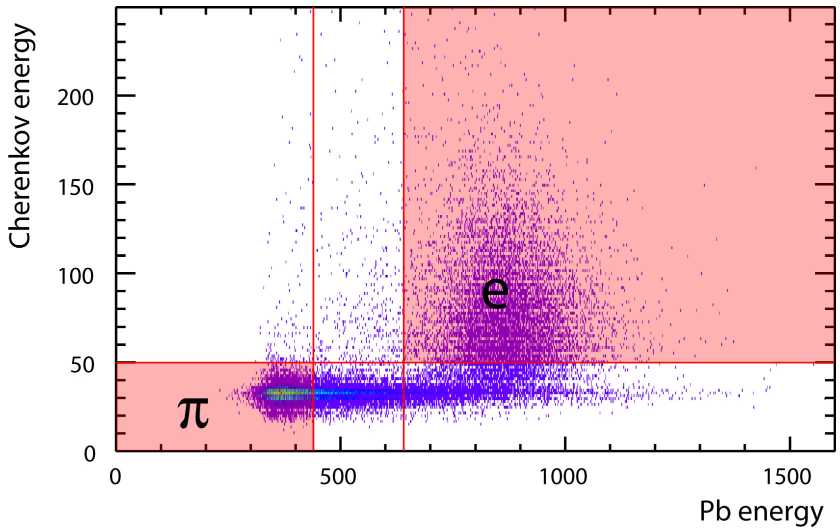
→ Very good agreement of simulated and test beam data

See also Mariana's talk

Pion Efficiency

Electron contamination in pion data sample needed to describe test data

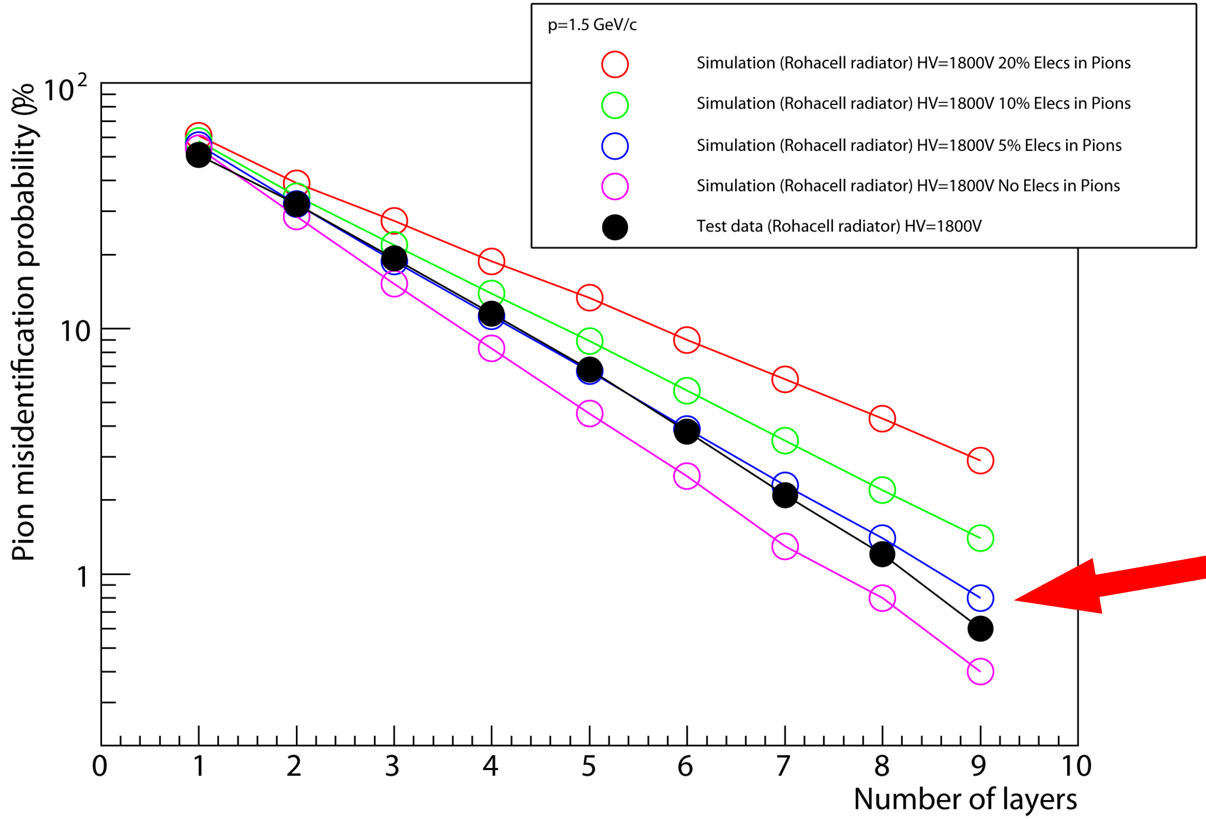


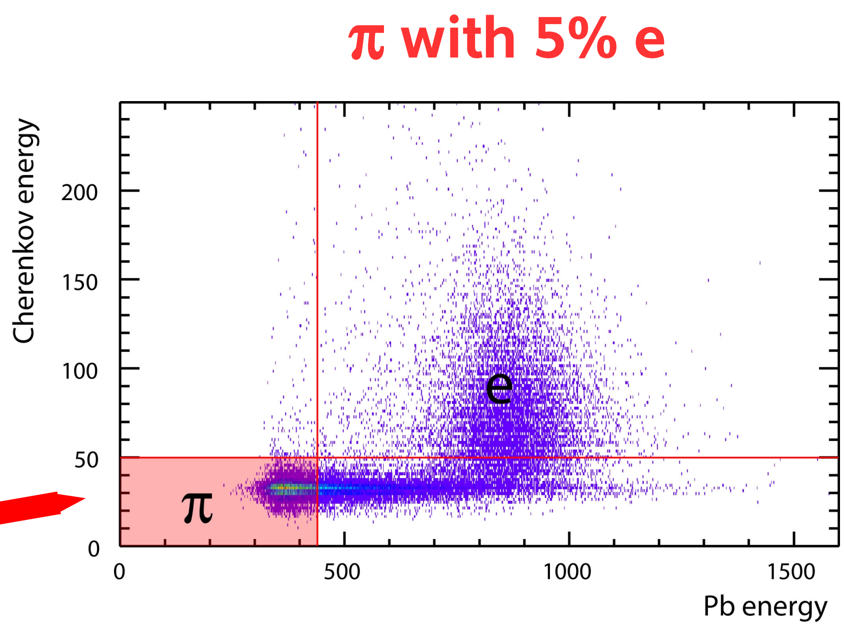


→ Cuts in Pb-glass and Cherenkov detectors (test beam data)

Pion Efficiency

Electron contamination in pion data sample needed to describe test data





→ Cuts in Pb-glass and Cherenkov detectors (test beam data)

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Pion Efficiency

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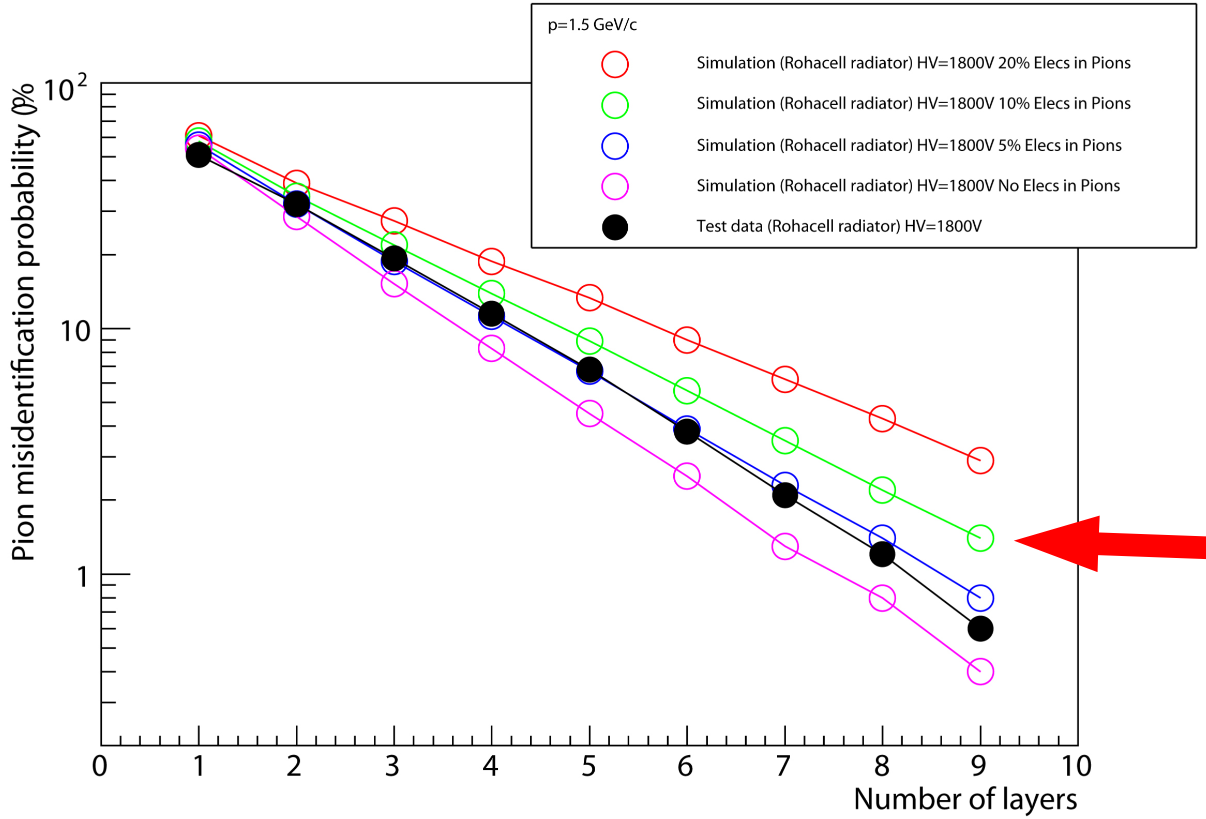
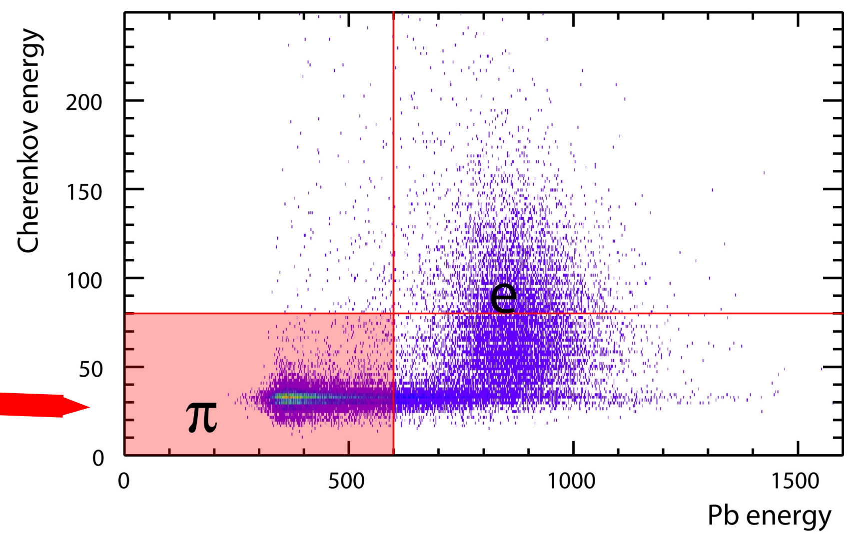


π with 10% e



→ Cuts in Pb-glass and Cherenkov detectors (test beam data)

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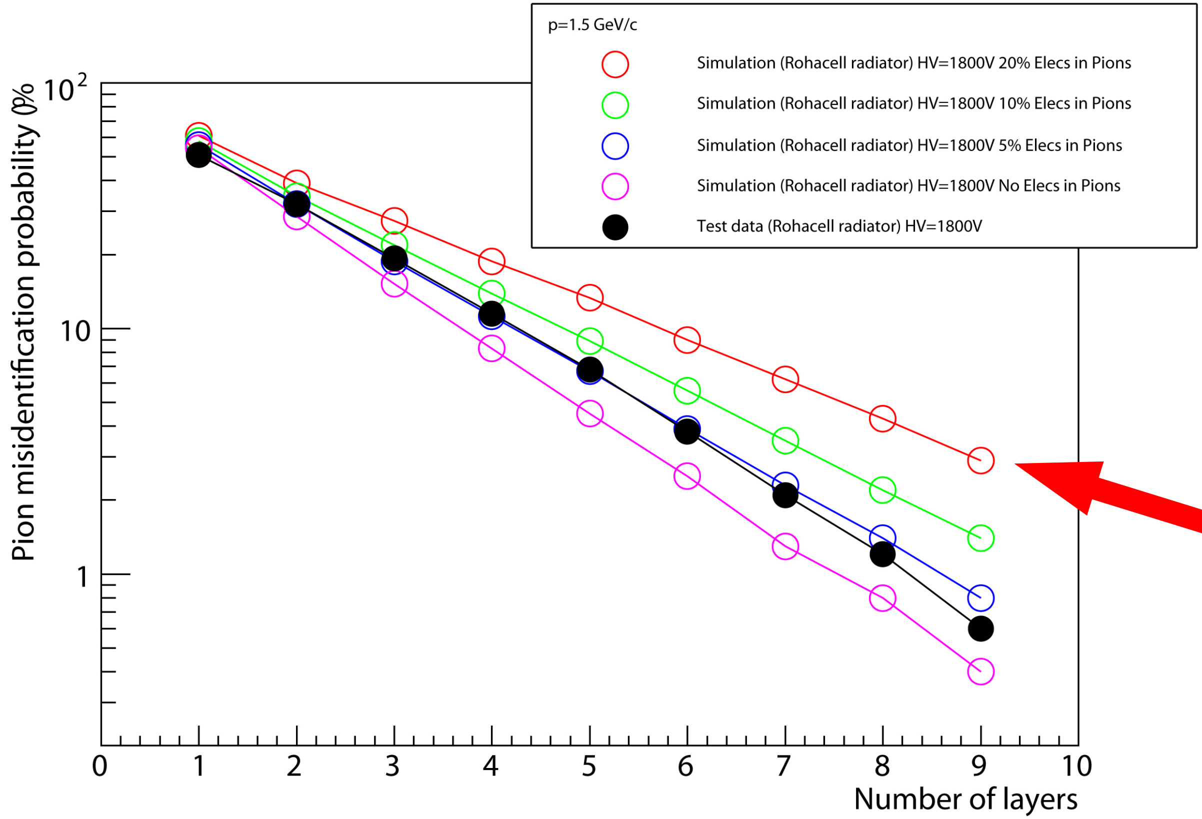
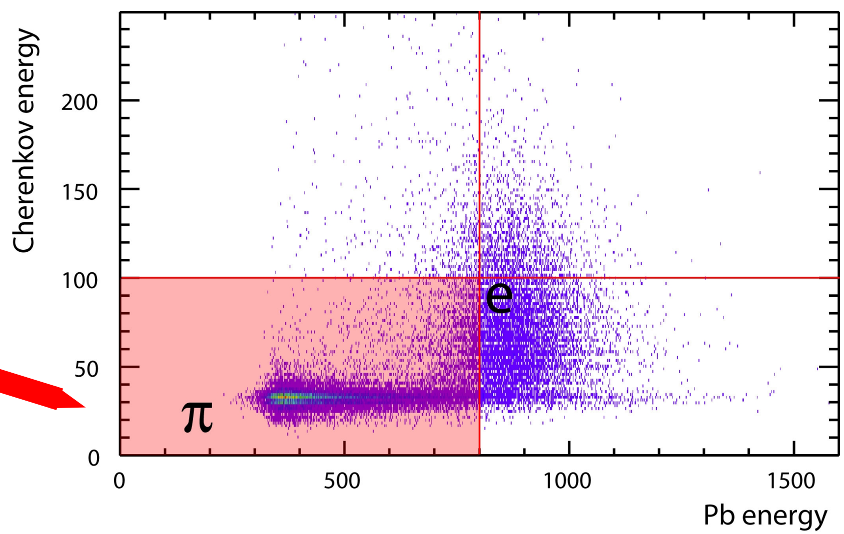
Pion Efficiency

Electron contamination in pion data sample needed to describe test data



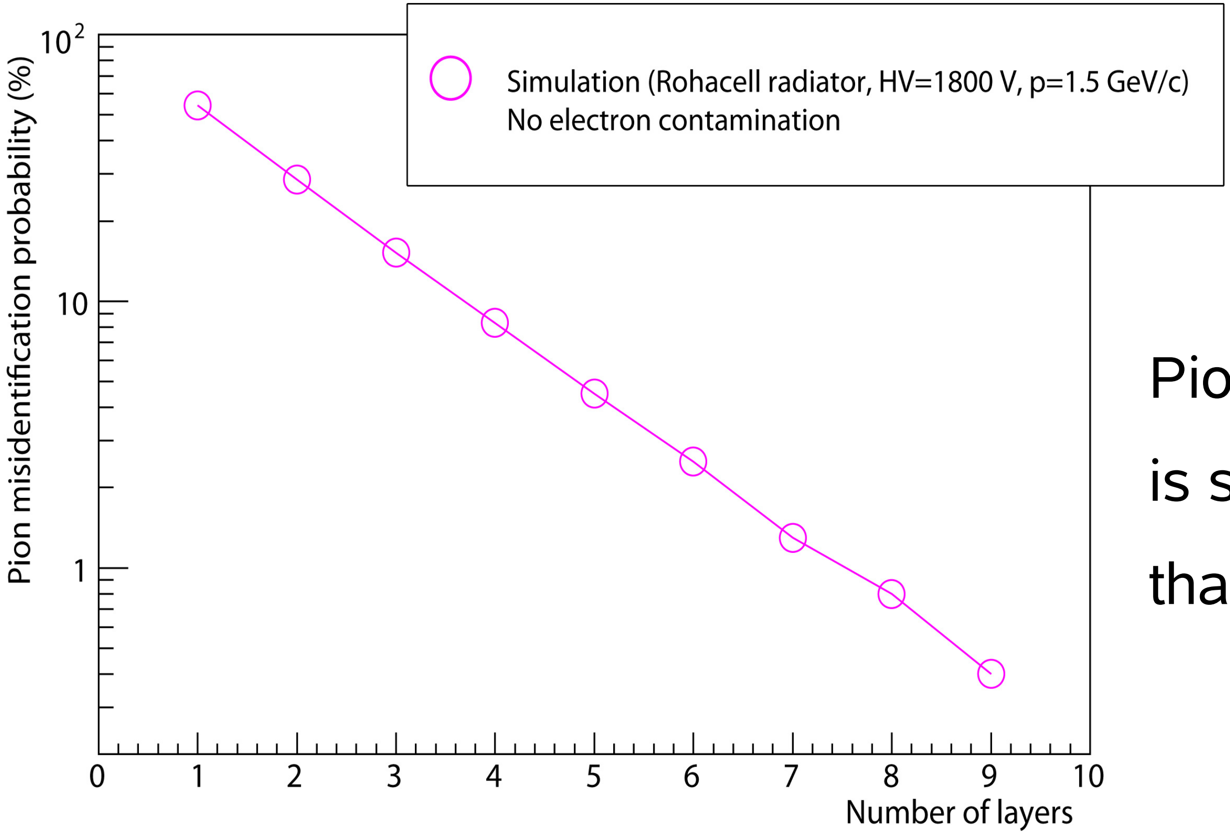
π with 20% e



→ Cuts in Pb-glass and Cherenkov detectors (test beam data)

Pion Efficiency

Simulation without electron contamination



Pion suppression factor is significantly better than 100 for 9 TRD layers

Summary

M-B TRD prototypes constructed and tested

- Pion suppression factor is significantly better than 100 for 9 TRD layers (dependence on radiator)
  MARIANA'S TALK, PUBLISHED IN NIM A 579/3 961-966 (2007)
- Position resolution at high rates better than 200 μm
  SUBMITTED TO NUCL. INSTR. METH. A
- Simulated energy deposit spectra describing well measured energy deposit
- Pion supression factors described well in simulation

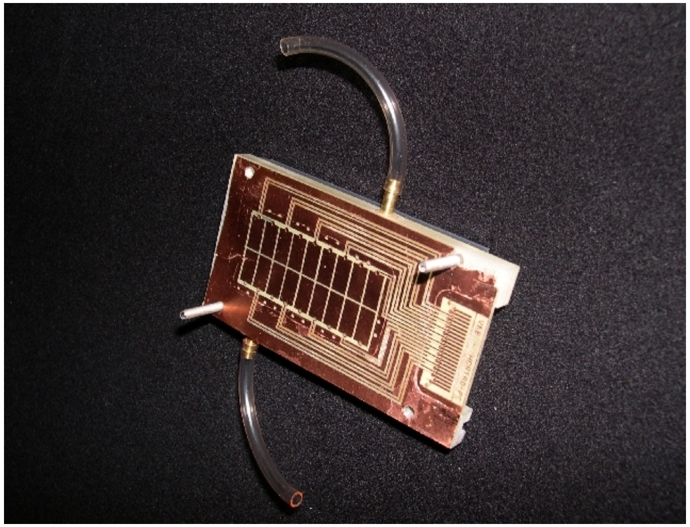
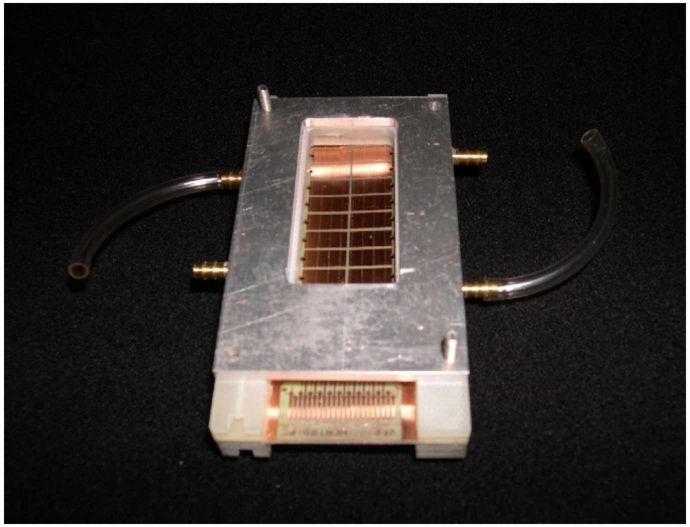
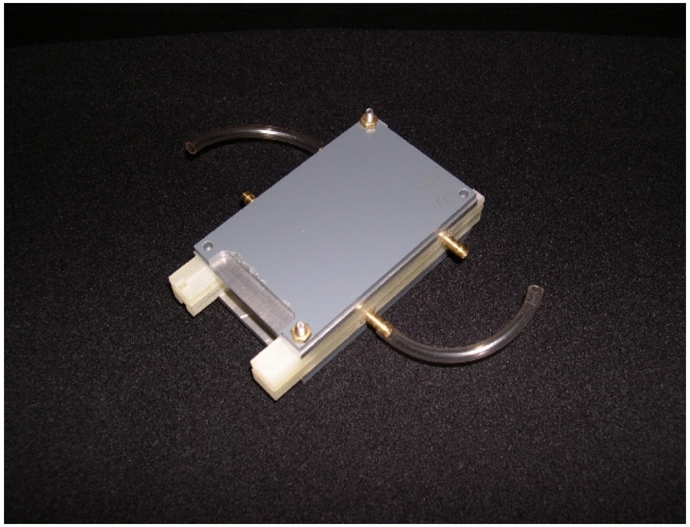
Outlook

- Development of real size prototypes for large detector areas
- Dilepton reconstruction analysis with M-B TRD geometry

Backup

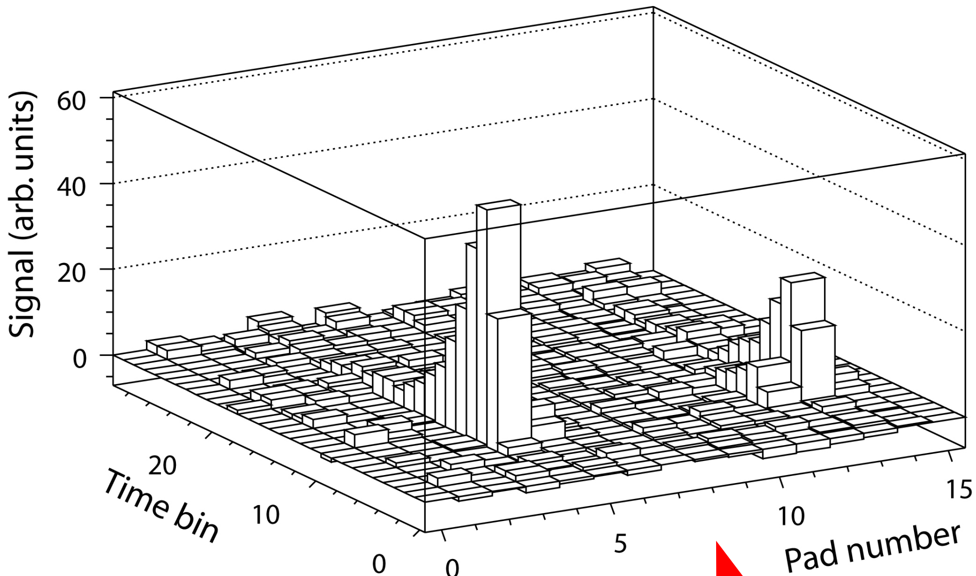
MWPC-based Protoypes (M-B TRD)

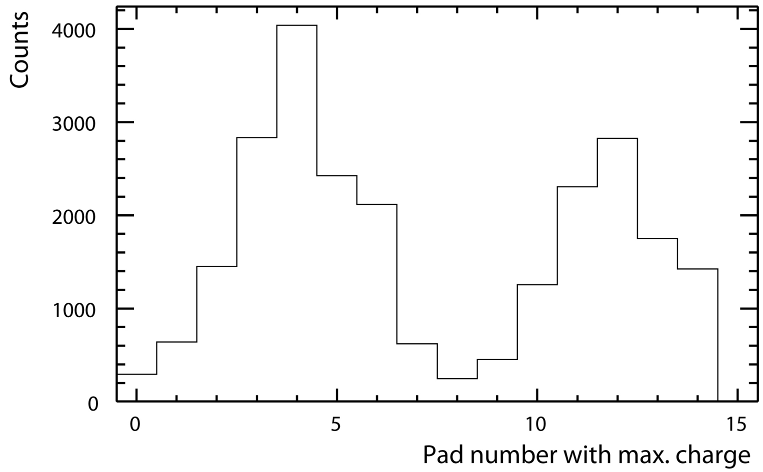
Setup of prototypes

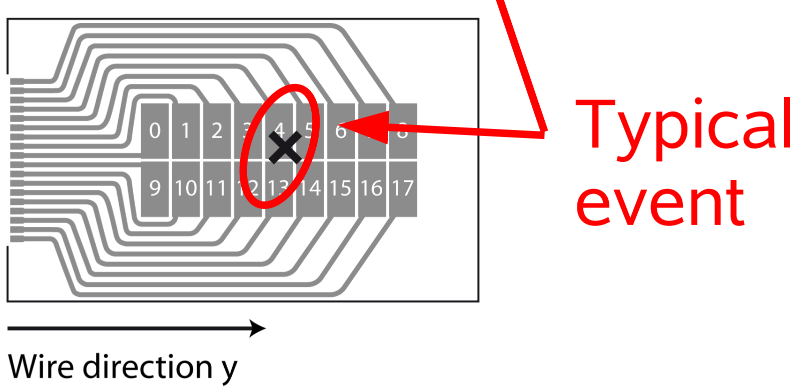




Charge Distribution on the Pads

M-B TRD







- Upper pad row (no. 0-7)
- Lower pad row (no. 9-16)
- Readout of 8 pads/row

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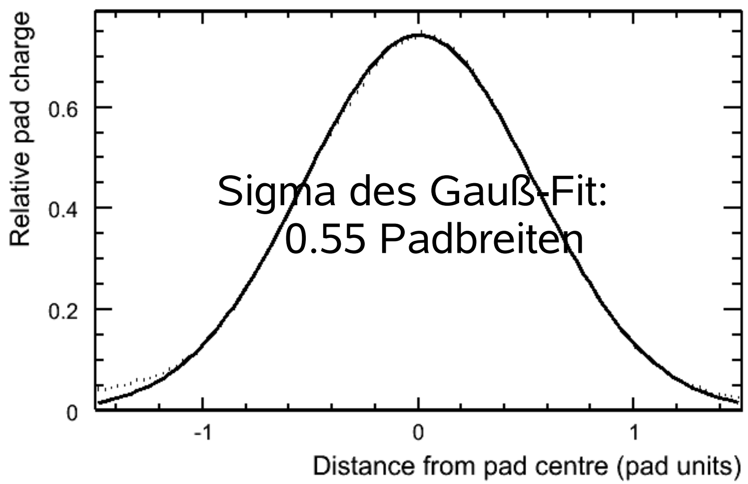
Bestimmung der Ortsauflösung

PRF mit Gauß-Fit



Cluster rekonstruierbar durch Ladungsverteilung entlang benachbarter Pads in y-Richtung
→ *Pad Response Function*

Bestimmung des *Displacement x*

(Abstand zwischen Hit-Position und Zentrum des Pads mit maximaler Ladung)

$$x = \frac{1}{w_1 + w_2}\left[w_1 \left(-\frac{W}{2} + \frac{\sigma^2}{W} \ln \frac{Q_i}{Q_{i-1}} \right) + w_2 \left(\frac{W}{2} + \frac{\sigma^2}{W} \ln \frac{Q_{i+1}}{Q_i} \right) \right]$$

Rekonstruktion der Hit-Positionen in den Kammern

$$P1 = 5\,mm \cdot (iPadMax_1 + 0.5) + x_1 \qquad P2 = 5\,mm \cdot (iPadMax_2 + 0.5) + x_2$$

Simulation in CbmRoot

Energy deposit

Parameters for best matching of test data:

- Particle momenta
- Gas volume
- Radiator
- Position and material of pad plane

Same binning and scaling for simulation and test beam data

- Most probable value of Landau fit to pions dEdx