Prototype Development and Simulation Studies for a GEM Based TPC

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Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

bmb+f Großgeräte der physikalischen Grundlagenforschung

Overview

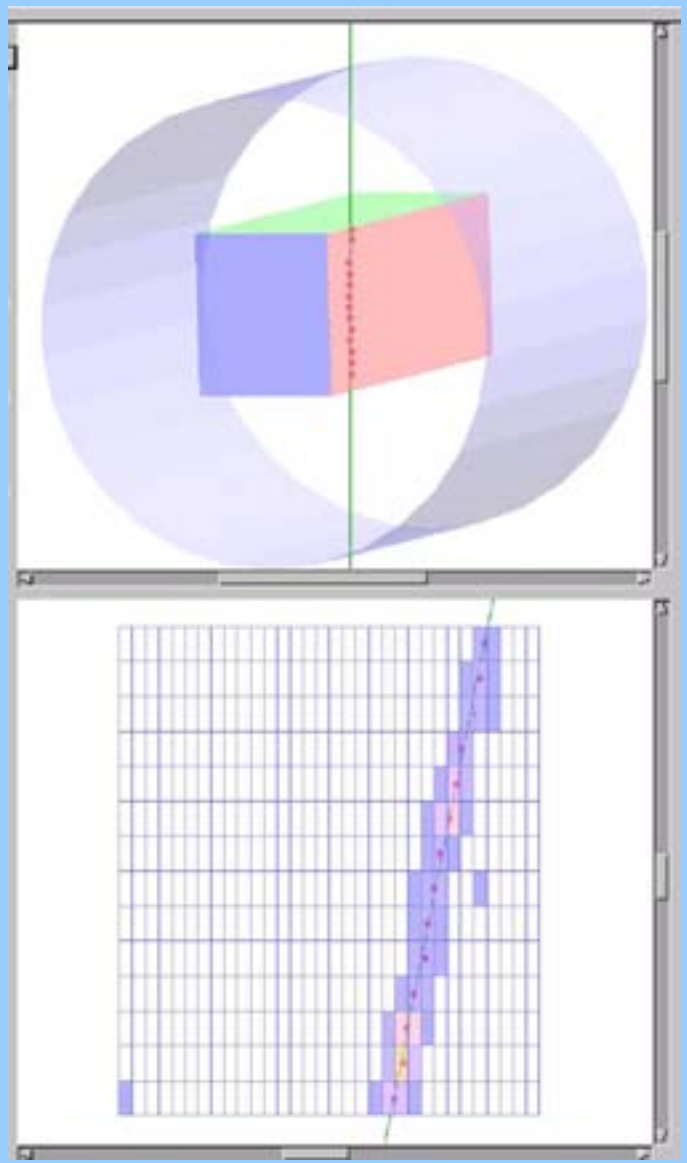
- Test Setup
  - TPC Prototype
  - Hodoscope
- “New” Readout Electronics
  - Preamplifiers
  - ADCs
- Simulation Studies
  - Modular Structure
  - Comparison with Measurements

TPC Prototype

- 5T Magnet at DESY Hamburg
  $\Rightarrow$ 260 mm diameter
- Triple GEM readout is used
- Drift distance = 260 mm
- Maximum drift field = 1000 $\frac{V}{cm}$
- Materials with low density

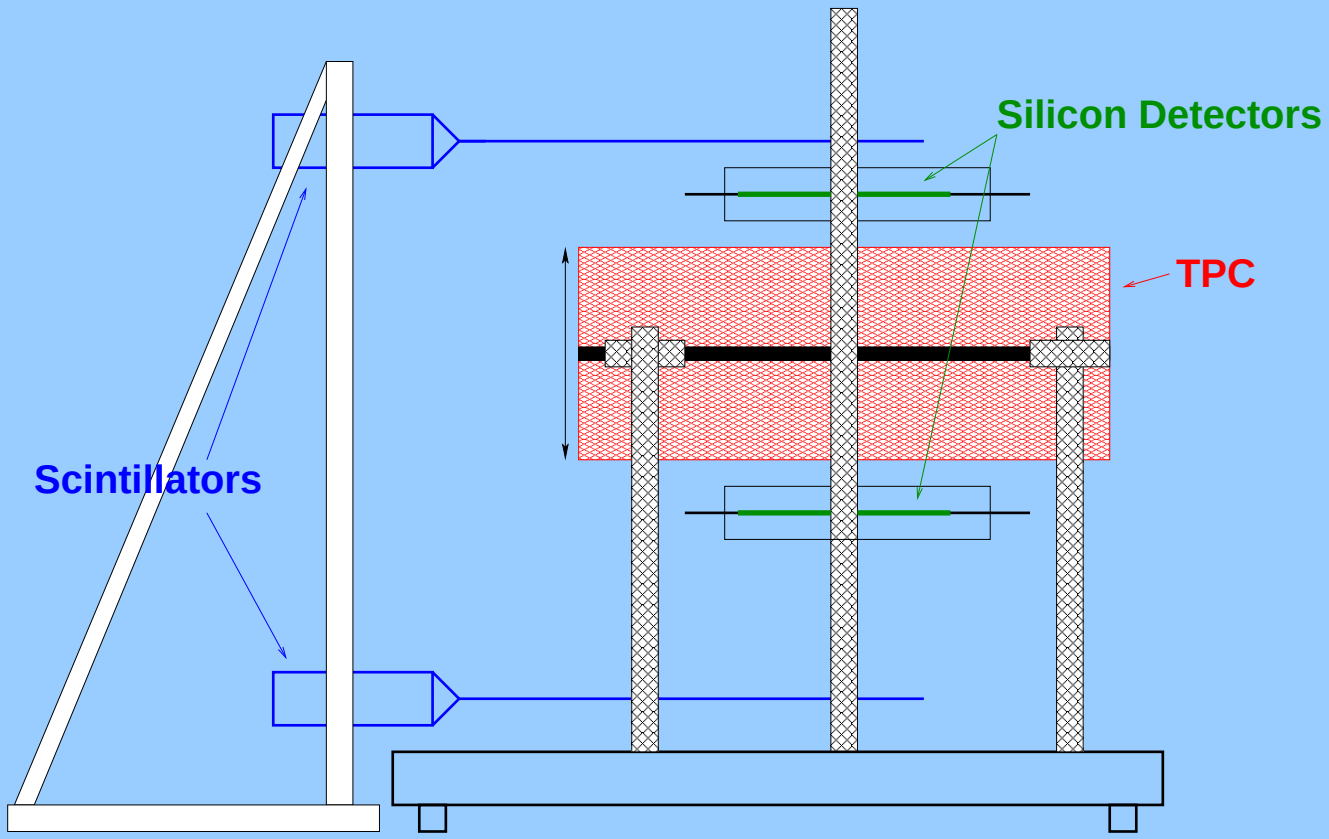
TPC Prototype: Operation

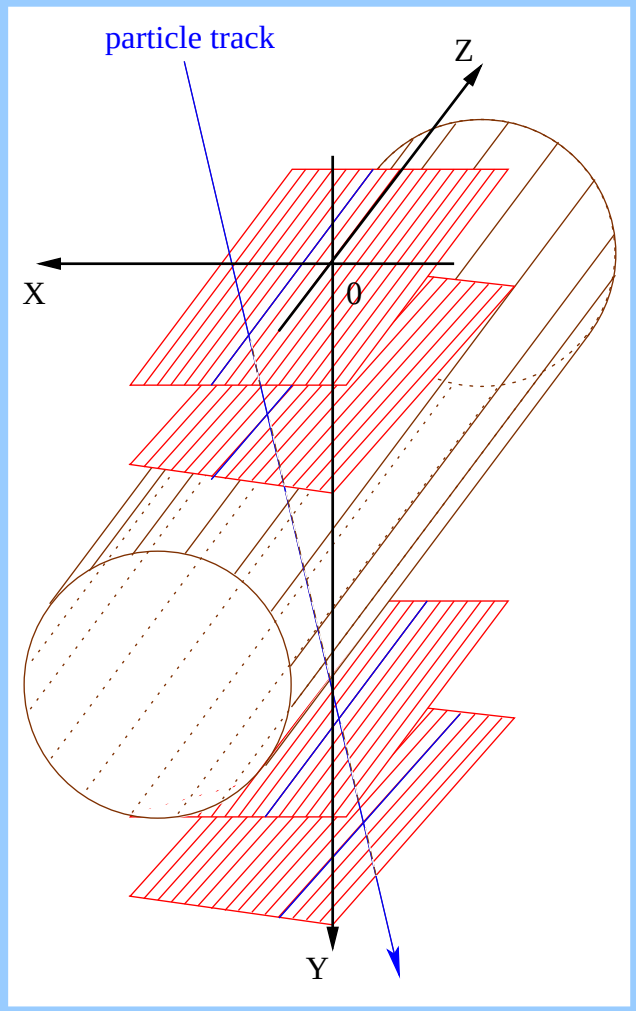
Cosmic Muon



- Stable operation: 2 weeks without problems
- Readout using old ALEPH electronics
  - “Slow” preamplifiers for wires
  - 12.5 MHz ADCs

TPC Prototype: Hodoscope Test Stand

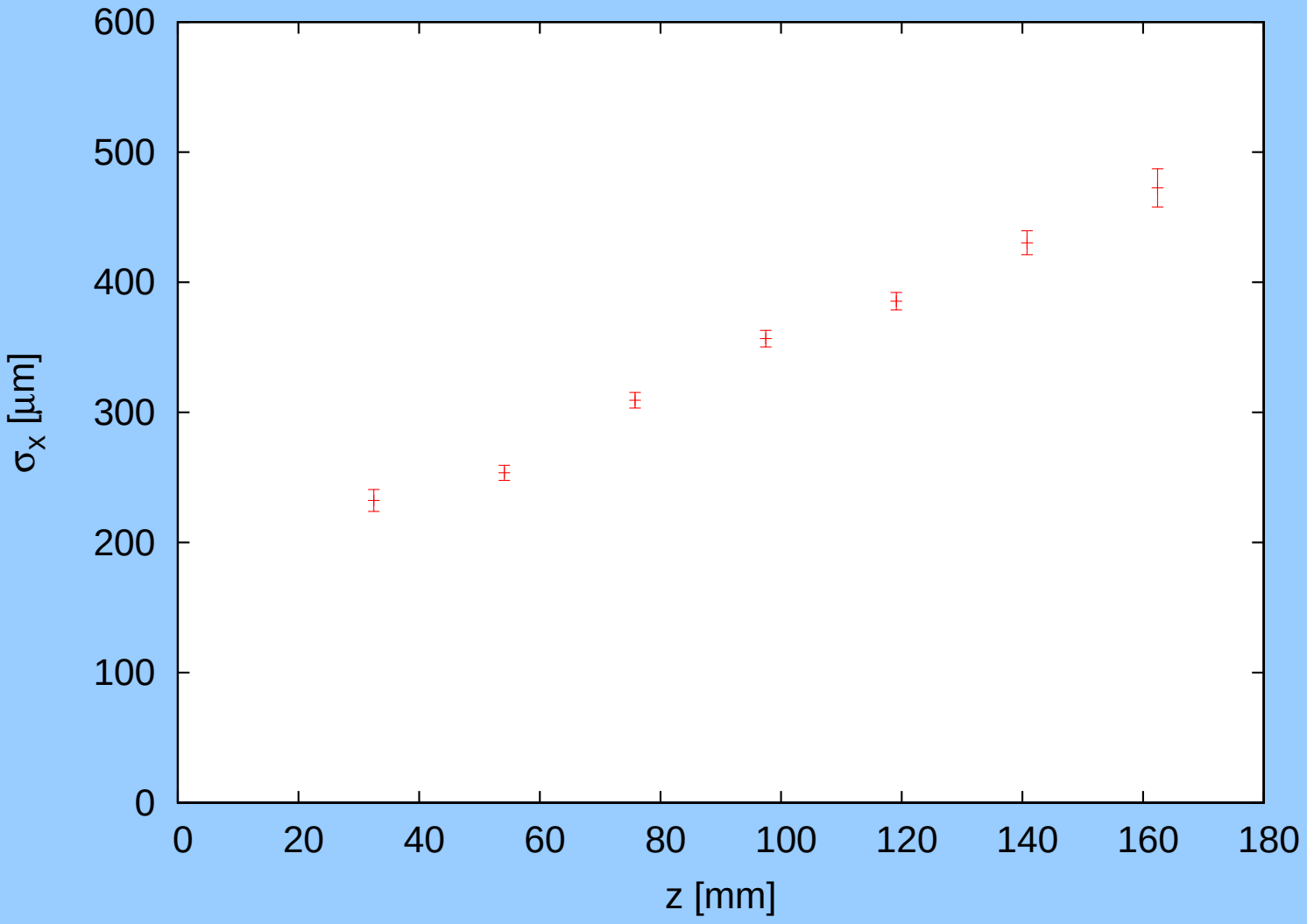




Hodoscope resolution: 60 μm

TPC Prototype: Single Point Resolution

Compare points from TPC with hodoscope tracks:



Measurement without magnetic field.

“New” Electronics: Overview

Goal:

Develop new readout electronics with 512 channels for our TPC

Requirements:

- Fast preamplifiers to take advantage of fast GEM signals
- Fast ADCs to match the preamplifier speed
- Fast data acquisition to allow reasonable operation in test beams
- Small preamplifiers to allow compact readout design with small pads

“New” Electronics: Preamplifier

Preamplifier

Preshape 32

- Predecessor of Premux & APV (CMS silicon tracker)
- 32 channel preamplifier/shaper with parallel In/Out
- Nominal peaking time: 45ns
- Needs discrete 32 channel cable driver to get signal to reasonable distance

Cable Driver

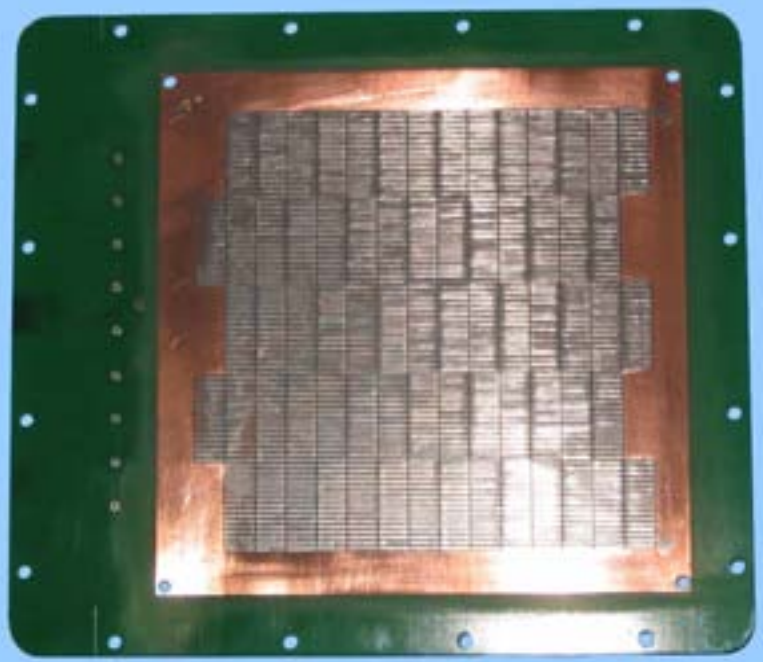
The preshape is bonded onto a small board to perform tests.

⇒Possibility to reduce size for a readout with small pads.

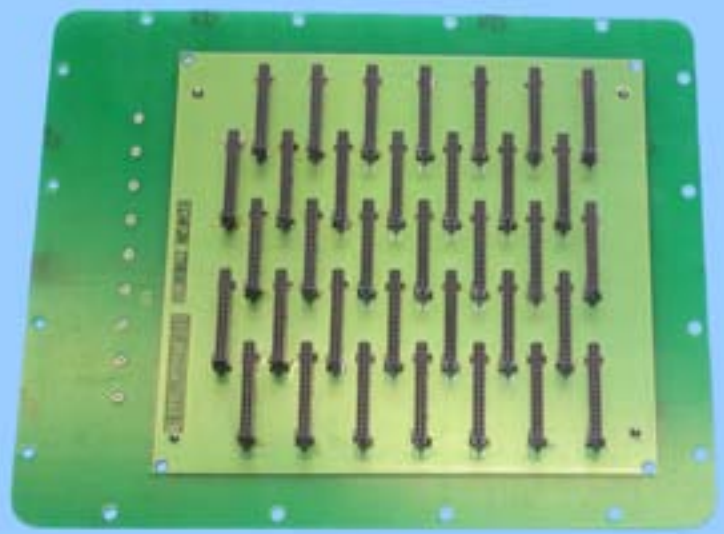
“New” Electronics: Pad Plane

- 1120 Pads $\Rightarrow$ flexible configuration of 500 active channels
- 1.27x6.985 mm^2 Pads
- Connectors for Preshapes directly on the back

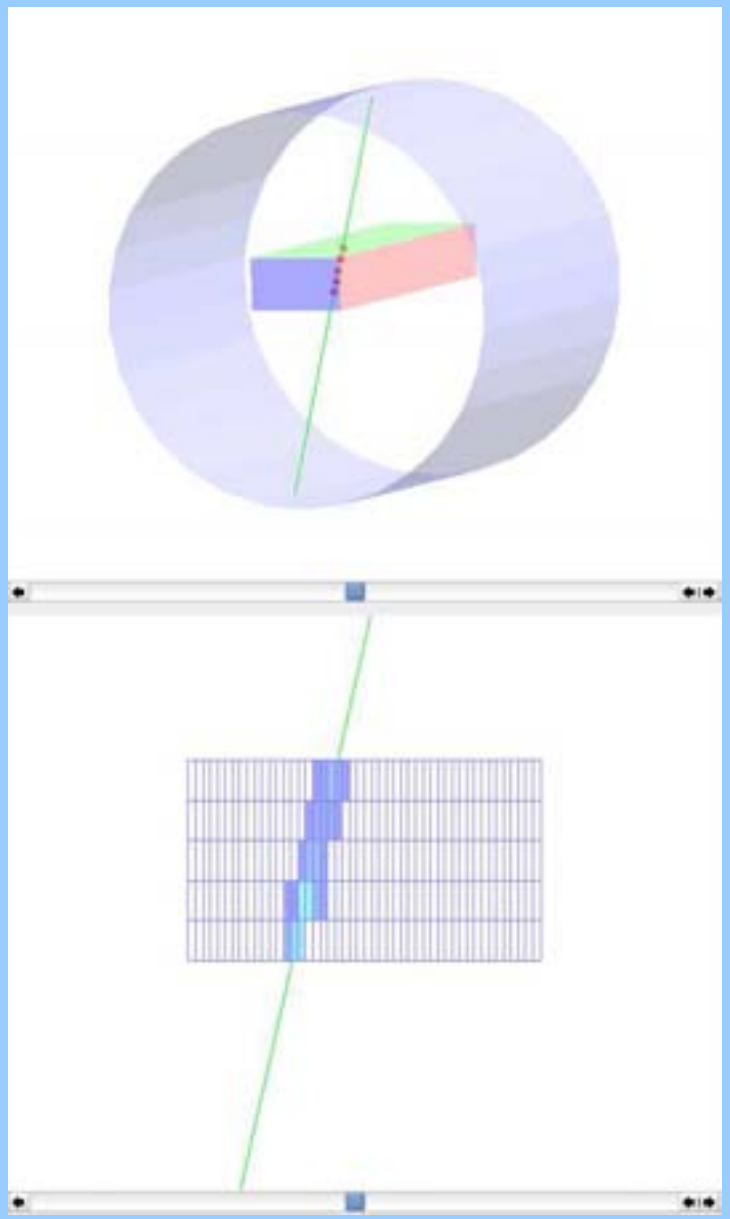
Front



Back



“New” Electronics: First Events



- 192 preamplifier channels in operation
- First events from prototype
- Currently read out with ALEPH ADCs
- 448 channels until test beam in October

Electronics: ADCs

Three ADC candidates:

Origin (Experiment)	Required	MPI Munich (Crystal Ball)	Canada (KOPIO)	DESY Hamburg (H1)
System	VME	VME	VME	VME
Resolution [bit]	>=10	10	10	8 (non linear)
Frequency [MHz]	>=40	40	40	100
Memory [sample]		1000	1000	4000
channels/module	>=16	32	48	16

Simulation Studies

Goals: Study influence of

- Electric and magnetic fields
- Ion backdrift
- Pad response, pad geometry
- GEM settings

on the spatial resolution of a TPC.

4 Modules:

1. Primary ionization
2. Drift of electrons
3. Gas amplification with GEMs
4. Electronics (shaper, ADC)

Simulation Steps 1 and 2:

Primary Ionization:

- Randomly generate distance between clusters and number of electrons per cluster according to parametrization of distributions calculated by HEED.
- Place electrons on track (helix with magnetic field, straight line without)

Drift of Electrons:

- Gaussian smearing in x, y and z according to parametrization of longitudinal and transverse diffusion calculated by MAGBOLTZ for the particular gas mixture.

Simulation Step 3: Amplifi cation with GEMs

Input from measurement:

- Detailed parameterization of charge transfer coefficients (collection, extraction, gain) as a function of GEM settings.
- Charge broadening between GEMs mainly determined by diffusion.

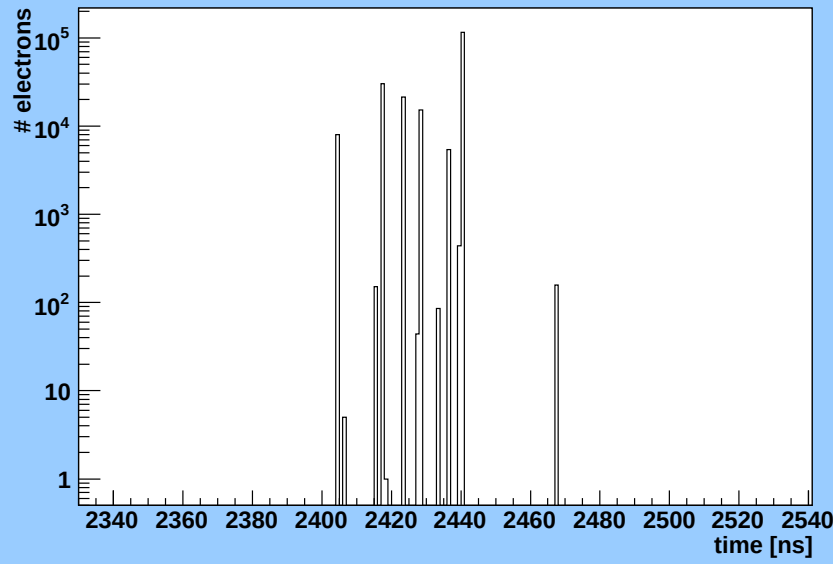
  $\Longrightarrow$ Use diffusion from parametrized MAGBOLTZ calculations.

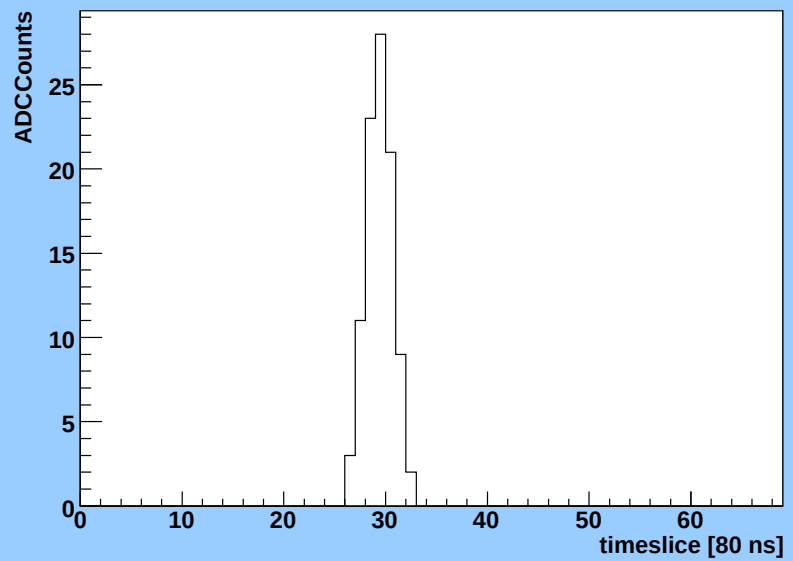
Simulation steps:

- Calculate number of electrons according to GEM settings.
- Apply smearing according to diffusion.
- Map electrons onto pads.

Simulation Step 4: Shaping and ADC

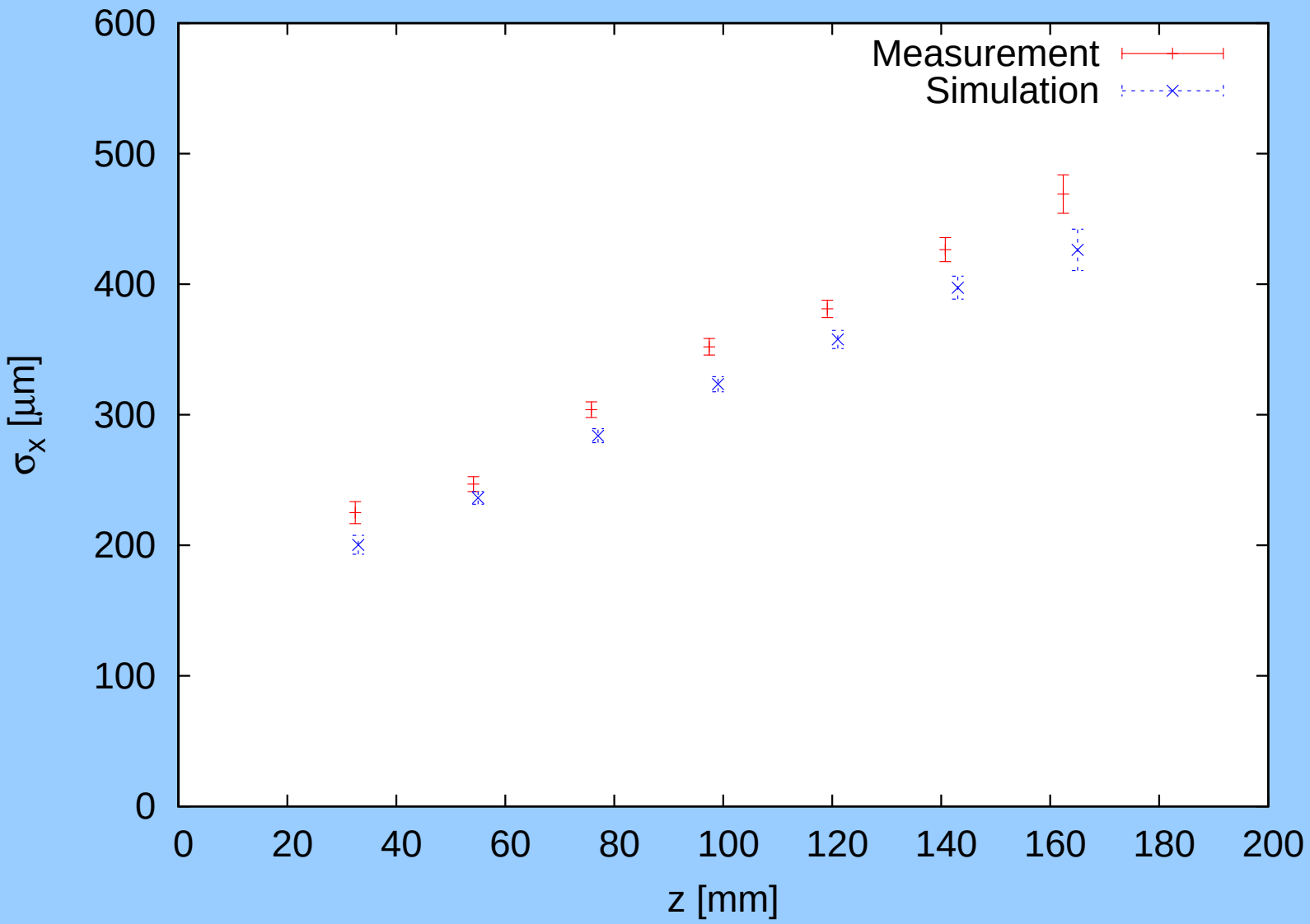
- Calculate center of gravity of electrons in pulse.
- Apply shape smearing of electronics (currently gauss).
- Fill the electrons into time bins.
- Map charge per time bin to the ADC range.



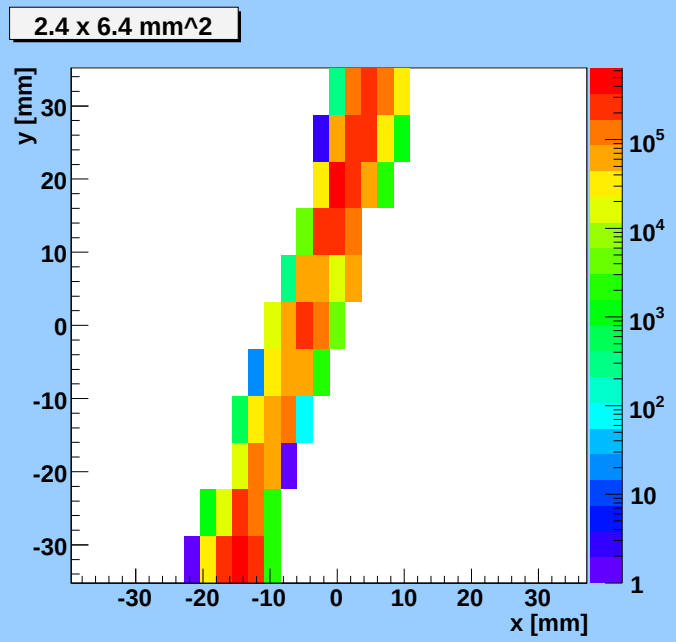


Simulation: Comparison with Measurement

Single Point Resolution :



Simulation: Different Pad Sizes



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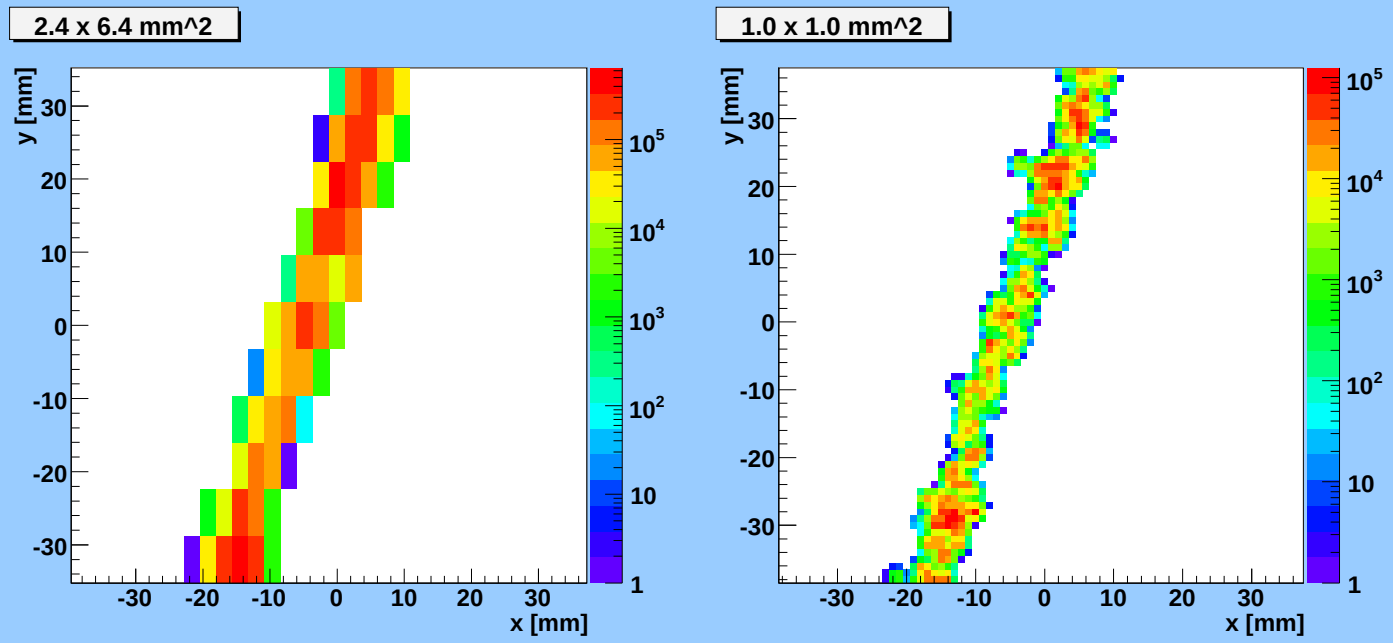

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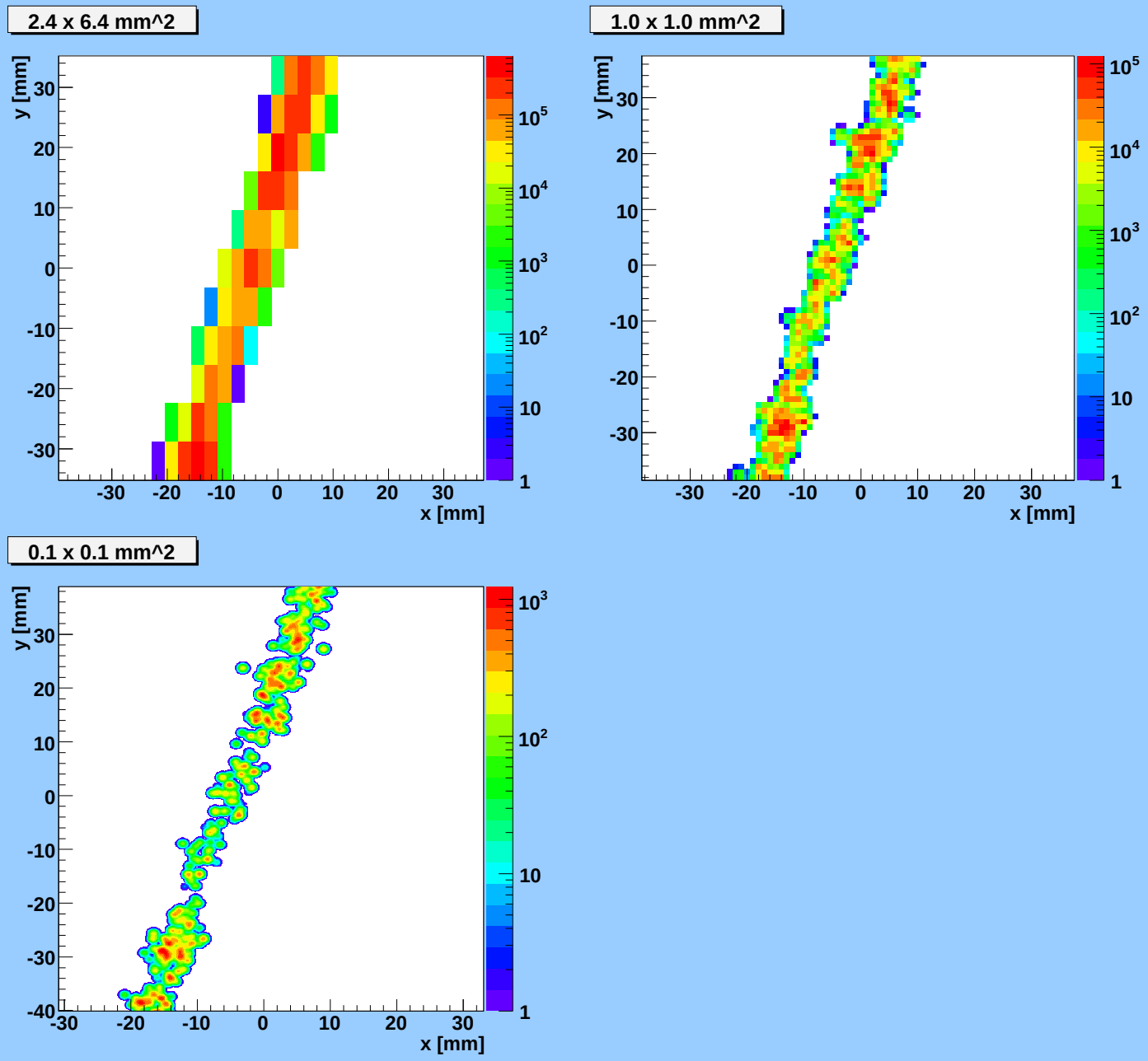

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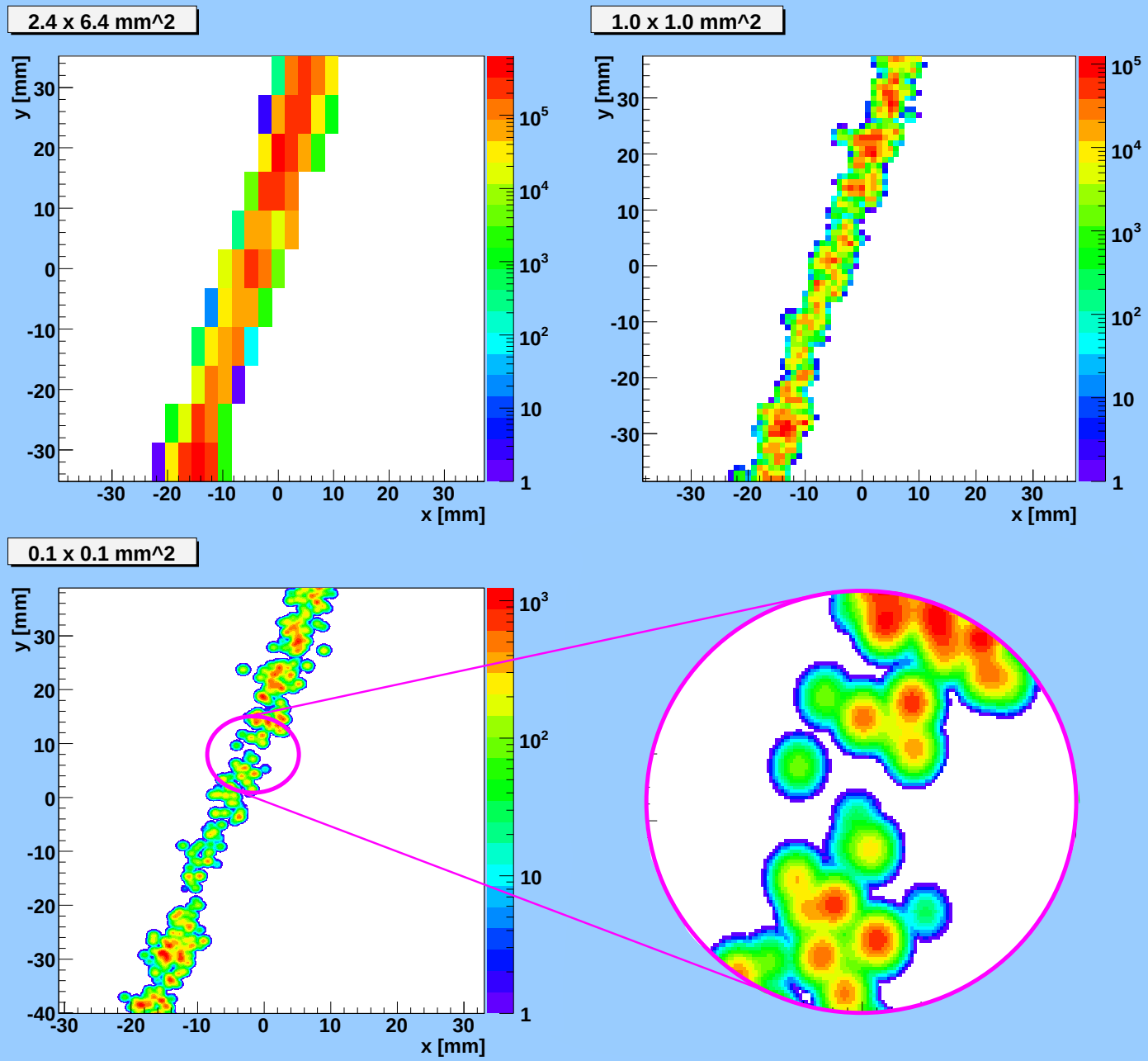
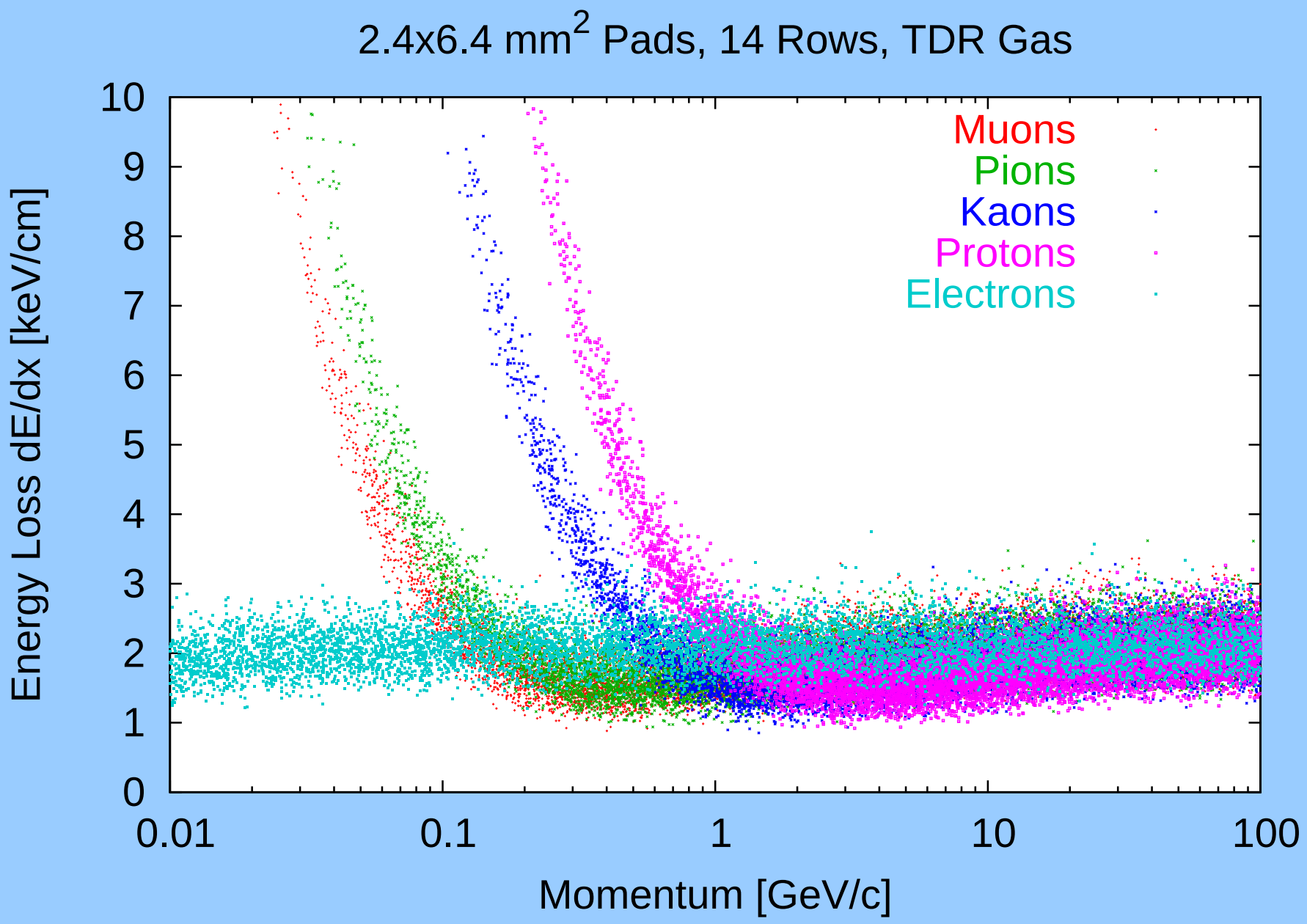


Simulation: Particle Identifi cation



Simulation

ROOT based version of the simulation package is on the workshop DVD.

New LCIO based version will soon be available at

http://www.physik.rwth-aachen.de/ group/IIIphys/TPC/en/software/

Conclusions and Outlook

Prototype ready for test beam in October:

- Detailed measurements of field homogeneity and spatial resolution
- Test new readout electronics
- Check simulation predictions

Questions for the ILC TPC:

Requirements for optimal spatial resolution?

- Readout frequency?
- Pad size and shape?
- GEM settings?