Present State of R&D for GEM-TPC Prototypes of PANDA

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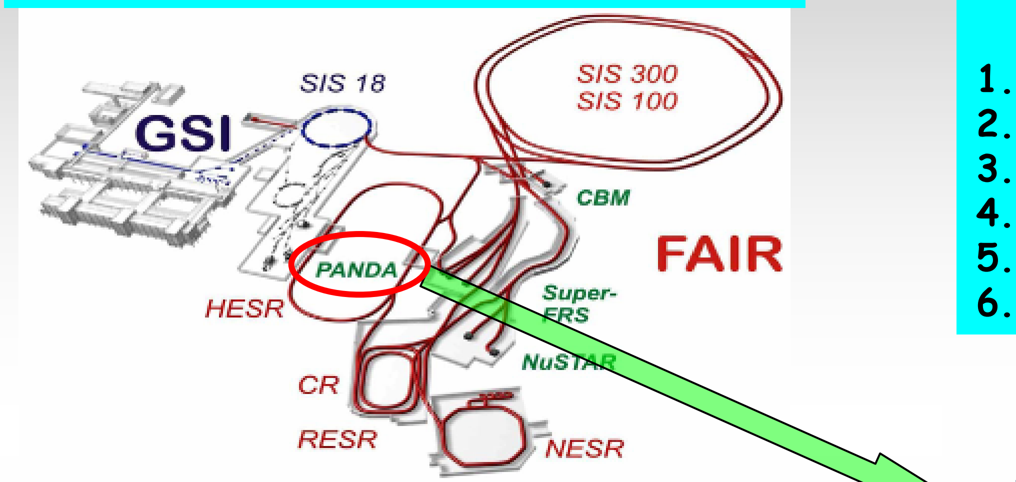
for GEM-TPC collaboration

14 June, 2009

Overview of PANDA@HESR@FAIR

FAIR: Facility for Antiproton and Ion Research

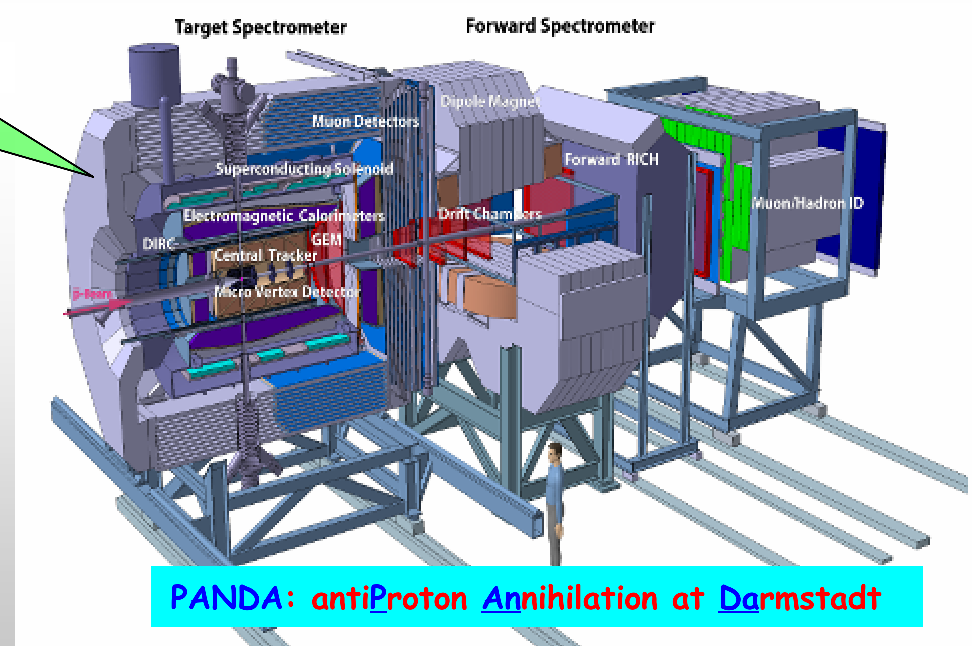


Physics of PANDA:

1. QCD Bound States
2. Non-perturbative QCD Dynamics
3. Hadrons in Nuclear Matter
4. Hypernuclear Physics
5. Electromagnetic Processes
6. Electroweak Physics

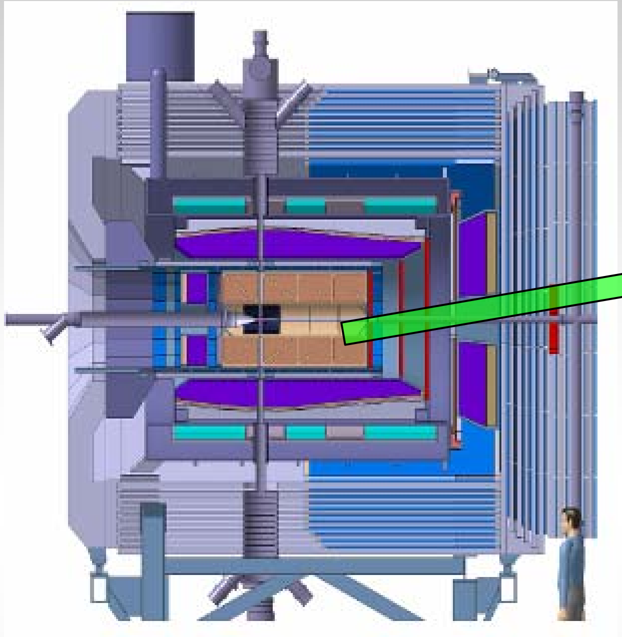
Key parameters of HESR and PANDA:

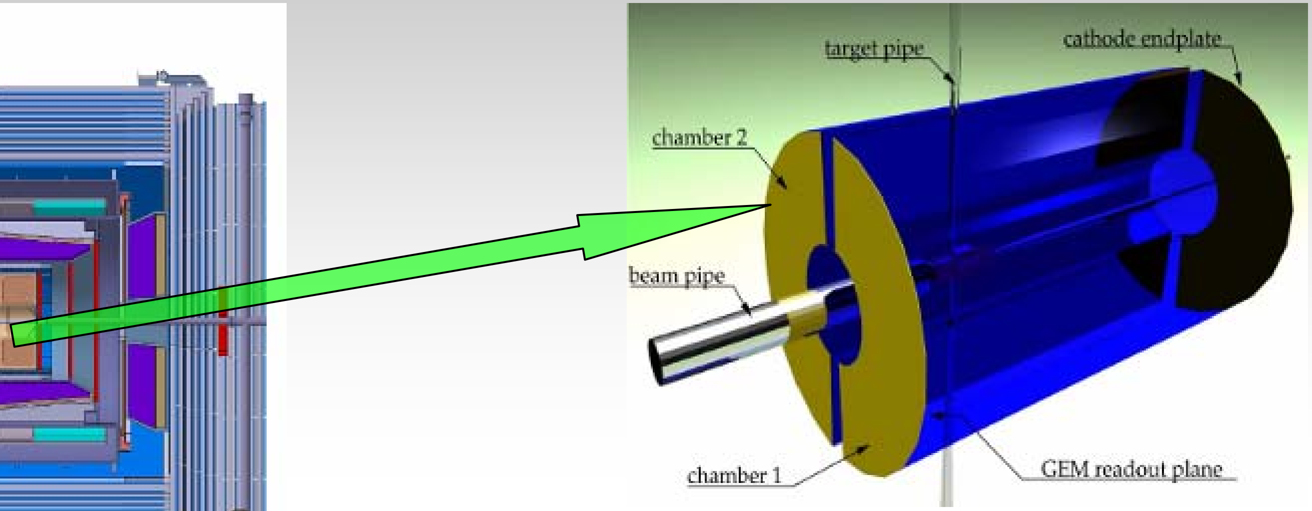
Momentum range: 1.5 to 15 GeV/c
High luminosity: 2×10^{32} $cm^{-2}s^{-1}$
High resolution: $\leqslant 2 \times 10^{-5}$
Antiproton production rate: 2×10^{7}/s
Target thickness (H2 pellets): 4×10^{15}atoms/cm^2



PANDA: antiProton Annihilation at Darmstadt

Requirements and Dimensions of Central Tracker@PANDA





Requirements:

>almost full solid angle coverage

>spatial resolutions: $\sigma_{r\phi}$~ 150 μm;

σ_z ~ 1 *mm*

>momentum resolution: ~%

>material budget: X_0/X ~%

>resistance against aging effect

Dimensions of GEM-TPC

- Length: 150 cm
- R_{inner} = 15 cm; R_{outer} = 42 cm

Advantages of GEM-TPC

- operated in magnet field
- working in un-gated mode
- very low material budget
- PID at low momenta
- fulfill all of requirements listed left

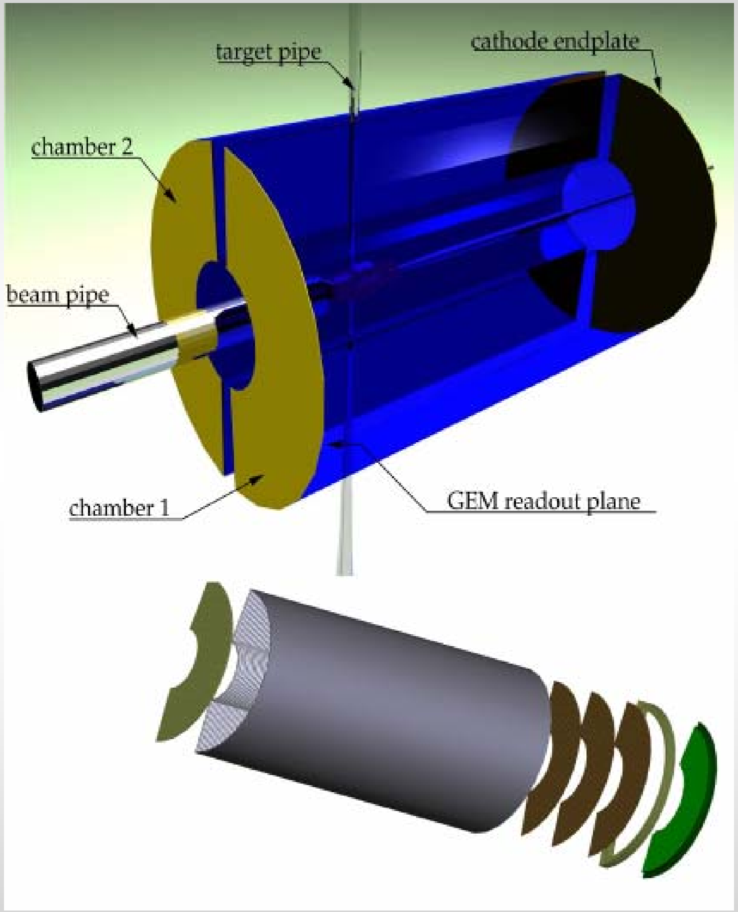
Challenges and Validations of PANDA GEM-TPC

Challenges

- High interaction rate: 2×10^7/s
- Long drift time: ~55 μs
- About 1000 events superimposed inside TPC

Validations:

- **Simulation of performance**
  - Momentum resolution
  - Ion backflow, Space-charge accumulation and distortion
  - Event deconvolution
- **Experimental validation**
  - Performance with ungated operation
  - Prototype construction



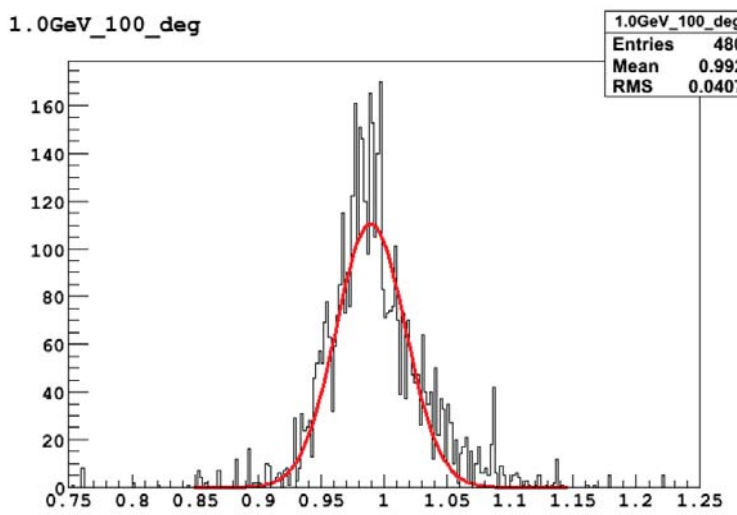
Momentum Resolution Simulation

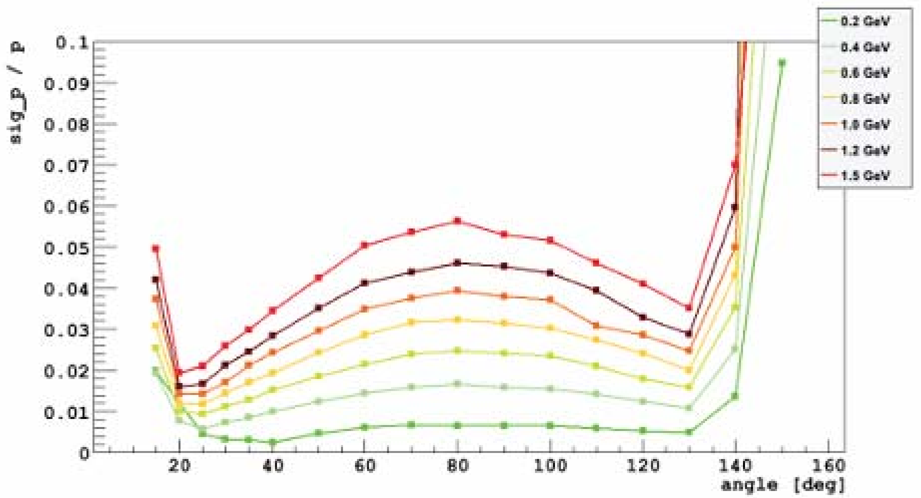
Simulation inputs:

- **Each bin (momentum and angle): 5000 pion tracks, uniform in** ϕ
- ***MC modeling: GEANT3 ALICE***

Reconstruction using GENFIT$_1$ and TPC hits only no space-charge distortions considered.

1. developed by Sebastian Neubert and Christian Hoeppner (TUM E18)





Momentum resolution of TPC for pions

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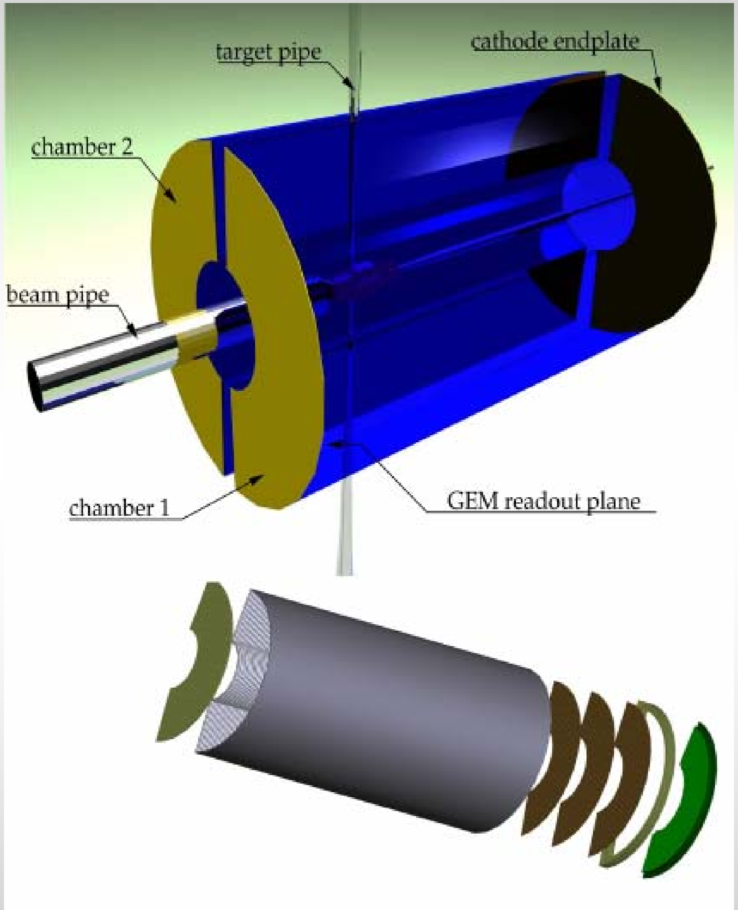
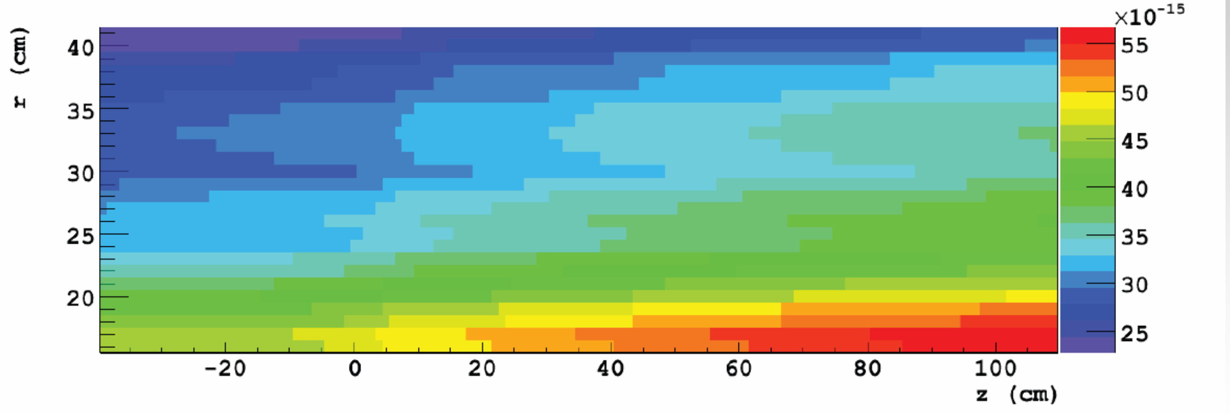


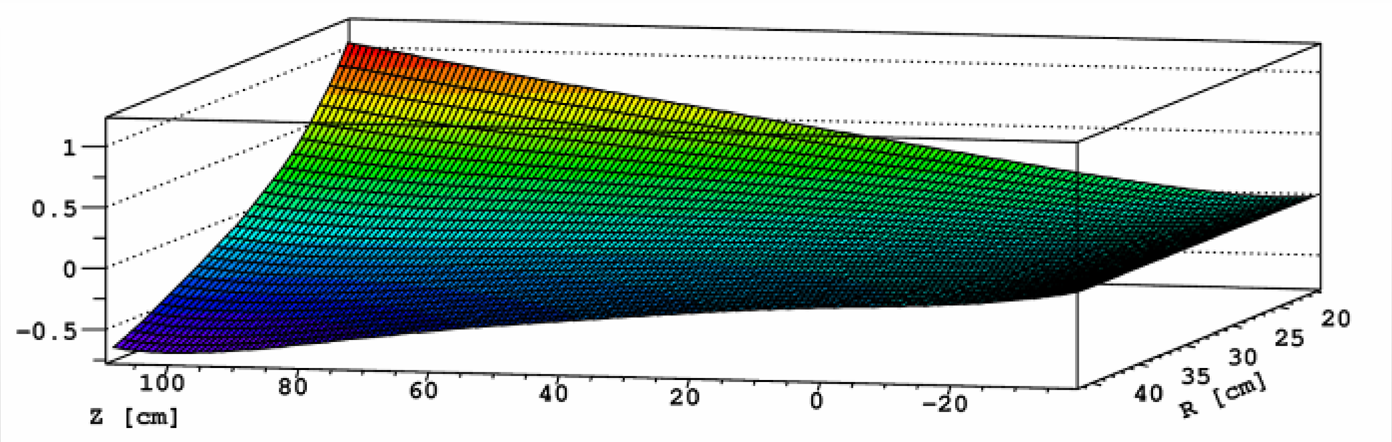
Space-charge Simulation

Boundary condition:

- **Interaction rate: 1×10⁷/s**
- **Ratio of back-flow ions to primary ions: ε =4**
- **Electron drift time: 50μs**
- **Ion drift time: 5ms**



Ion space-charge (C/cm3) map in the chamber, integrated over all azimuth

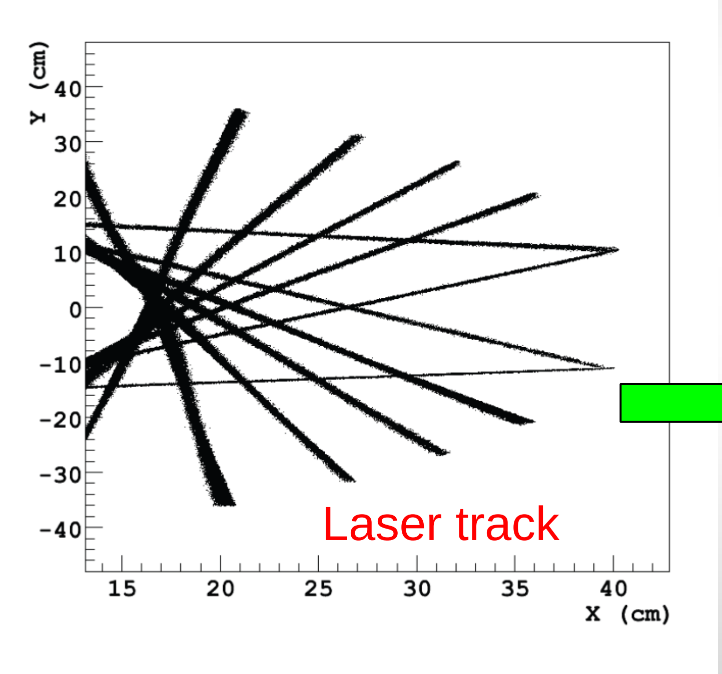


Final drift distortions (in cm) as a function of the volume coordinates

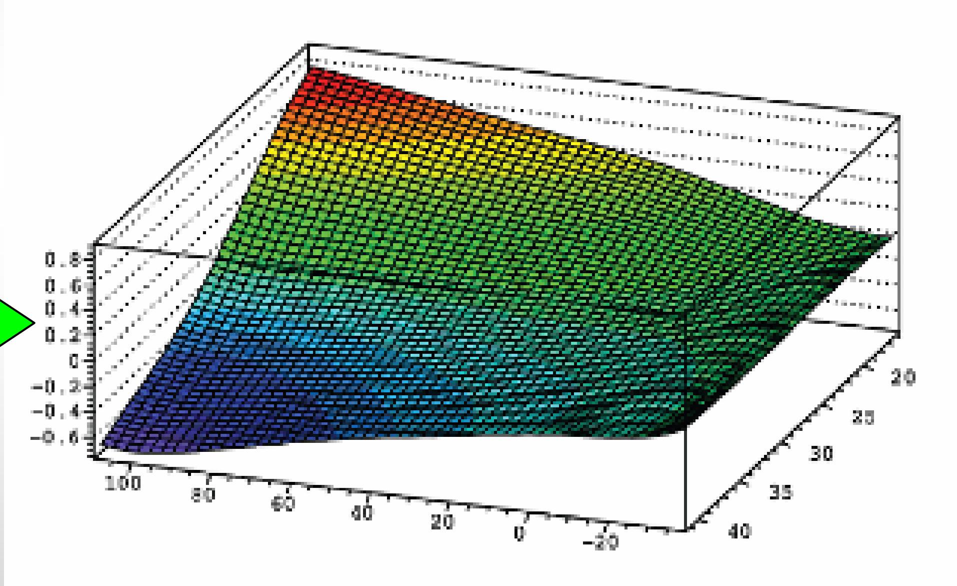
Space-charge Correction

--with laser mesh for track and momentum reconstruction

1. To be able to correct this effect, drift distortions have to be measured
2. One way to do this (e.g. STAR TPC) is constructing laser tracks in the chamber
3. We have constructed a possible mesh of laser tracks on simulation level



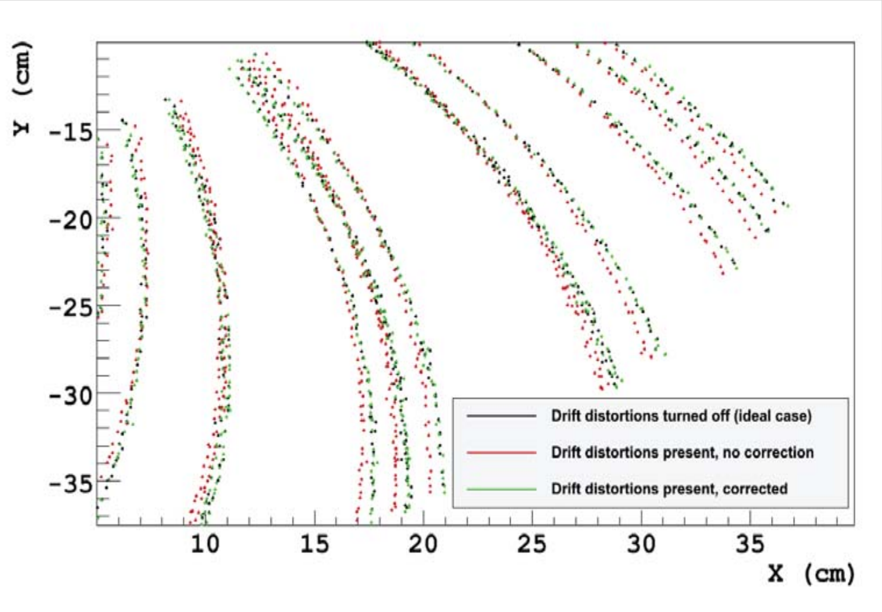
Top view of laser mesh



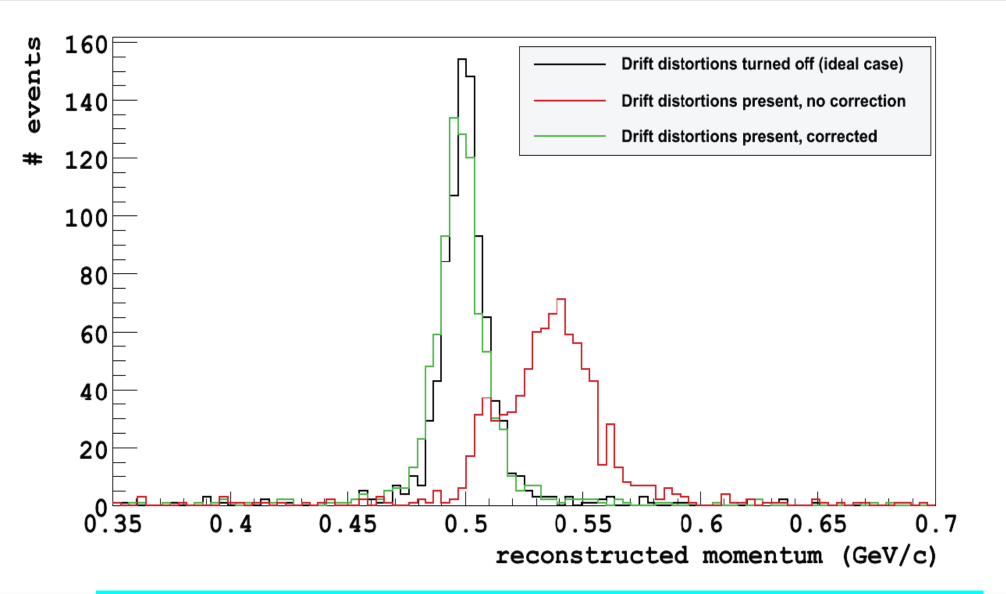
Reconstructed deviation

Effect of Space-charge Correction

--for track and momentum measurement



Effect of drift distortion and laser correction on spatial track measurements



Effect of drift distortions and laser correction on momentum measurements for 500MeV pions
Better plot

Note that:

1. By applying the reconstructed deviation map we can correct the drift distortion
2. It also works well for momentum correction and is as good as 1% for mean and sigma of momenta

Challenges and Validations of PANDA GEM-TPC

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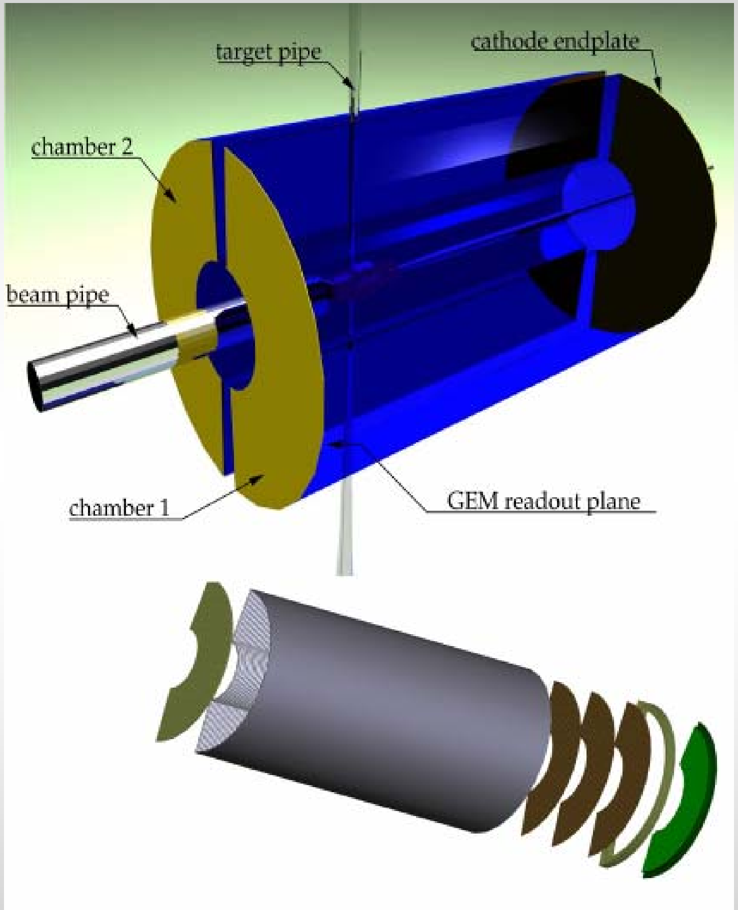

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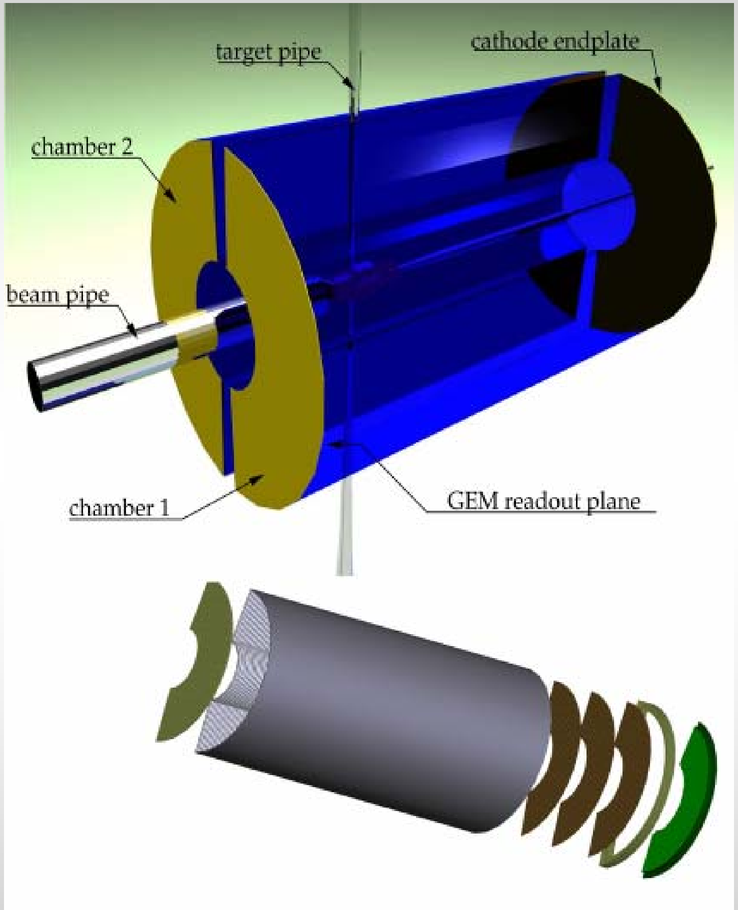
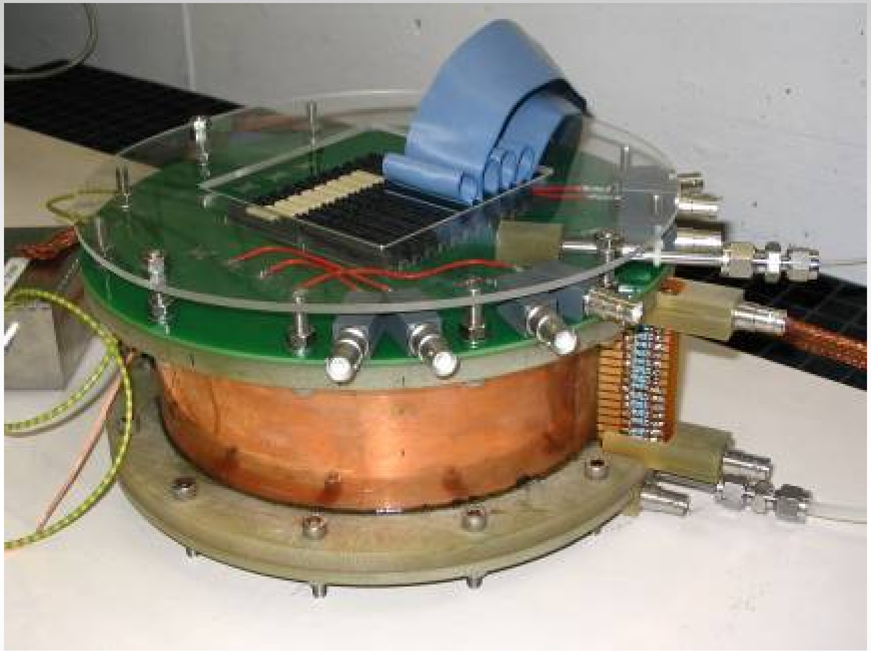
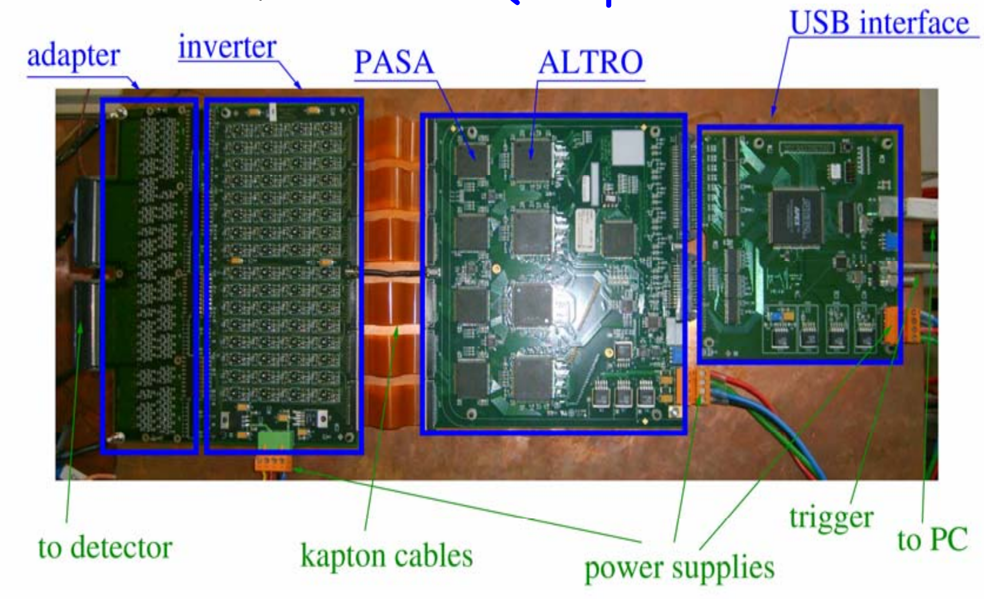


Small-size GEM-TPC and its readout electronics



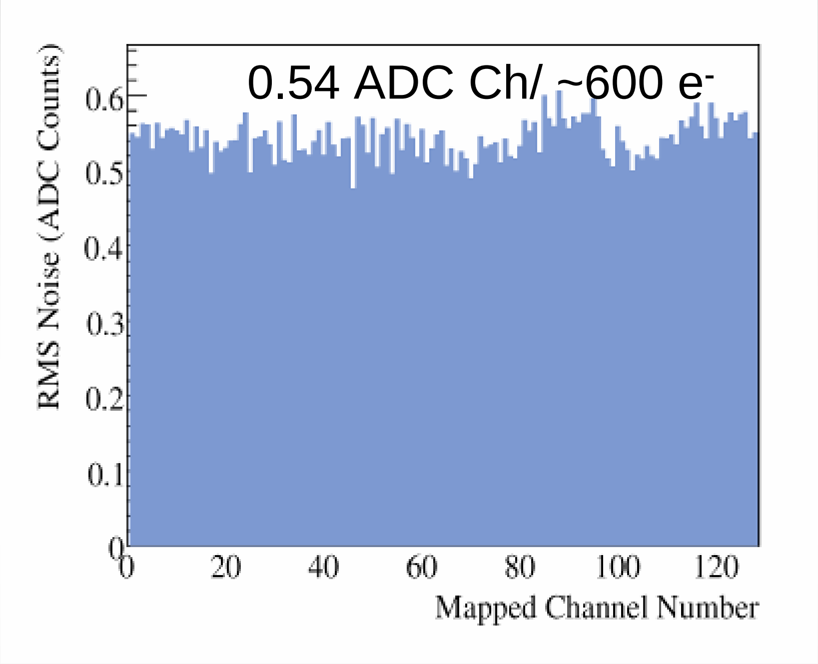
1. Adapter:
   Protect circuits from damage in case of discharge;
   Adaptor between flat cables and SPI
2. Inverter:
   Signal polarity inverter (SPI) card
3. PASA ASIC (16-ch charged pre-amplifier/shaper):
   Gain: 12mV/fC; Shaping time(FWHM): 190ns
4. ALTRO ASIC (Sampling rate (adjustable) of 10MHz)
   16ch ADC, data processor, and memory
5. USB interface: **to DAQ computer**

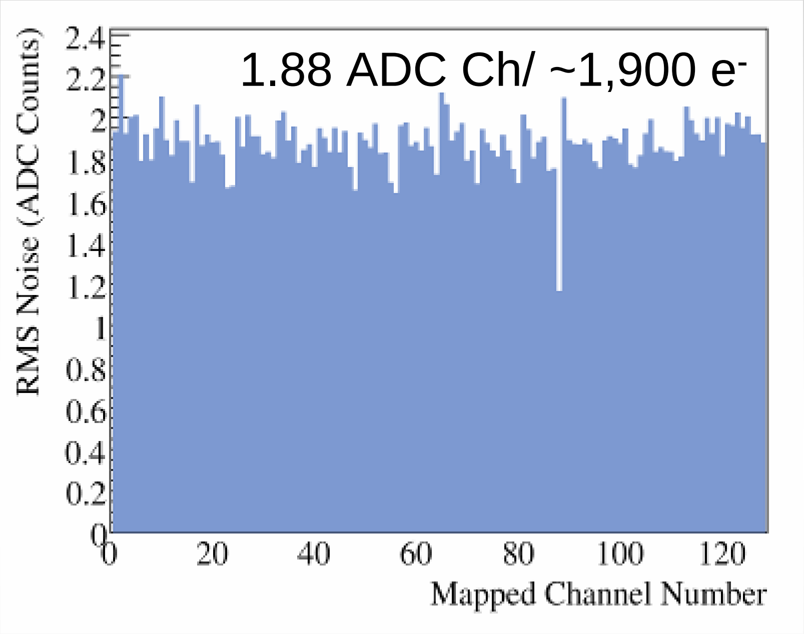


- Size: ϕ200mm×80mm
- Active area: 10×10cm2
- Pitch size: 1.0×6.2mm2
- Pad size: 0.8×6.0mm2
- Pad number: 1,536(128 read out)
- Gas mixture: Ar/CO2(70/30)

Refer to R.Esteve et al., IEEE Trans Nucl. Sci. 506(2004)2460-2469

Noise of PASA-/ALTRO electronics





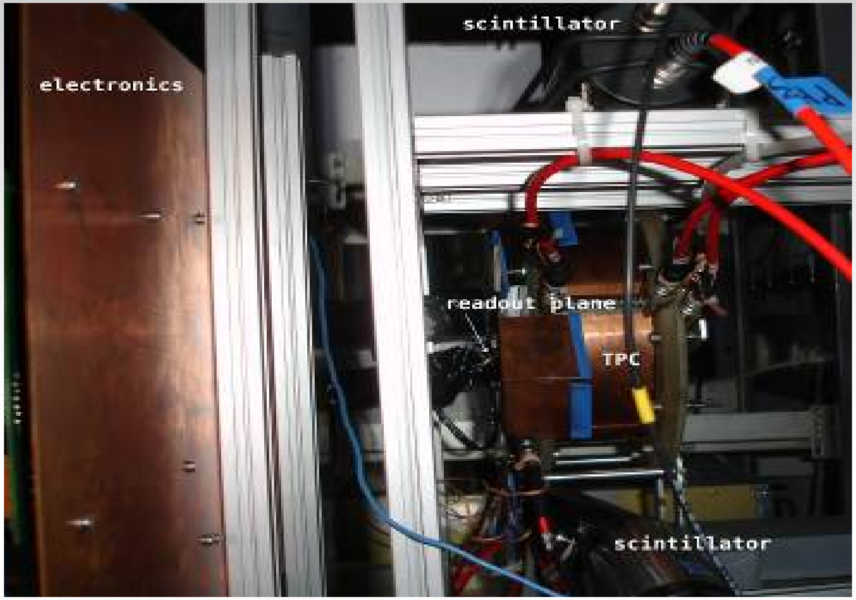
Noise of PASA-/ALTRO electronics

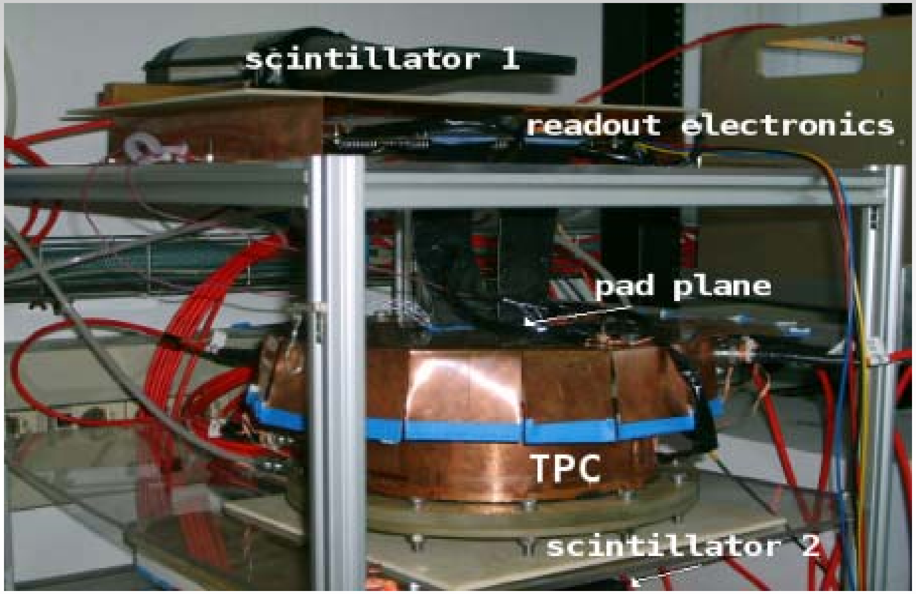
Left: only PASA-/ALTRO card connected

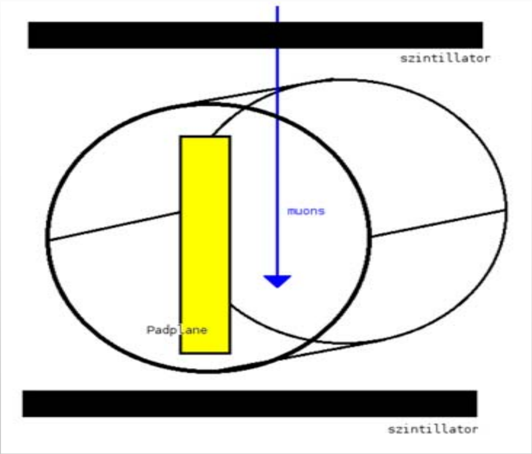
Right: all cards and GEM-TPC connected

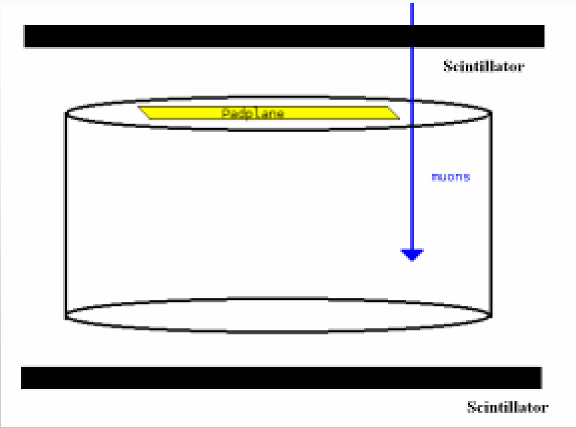
Mounting Ways of GEM-TPC Prototype

--vertical and horizontal mounting



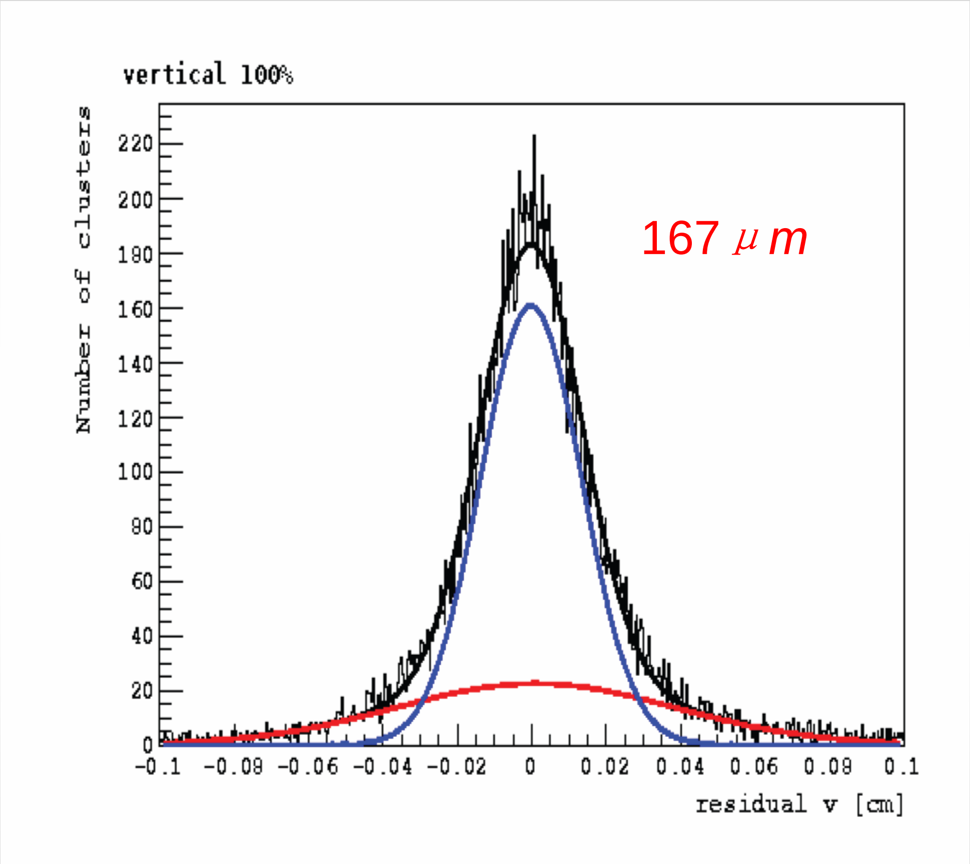


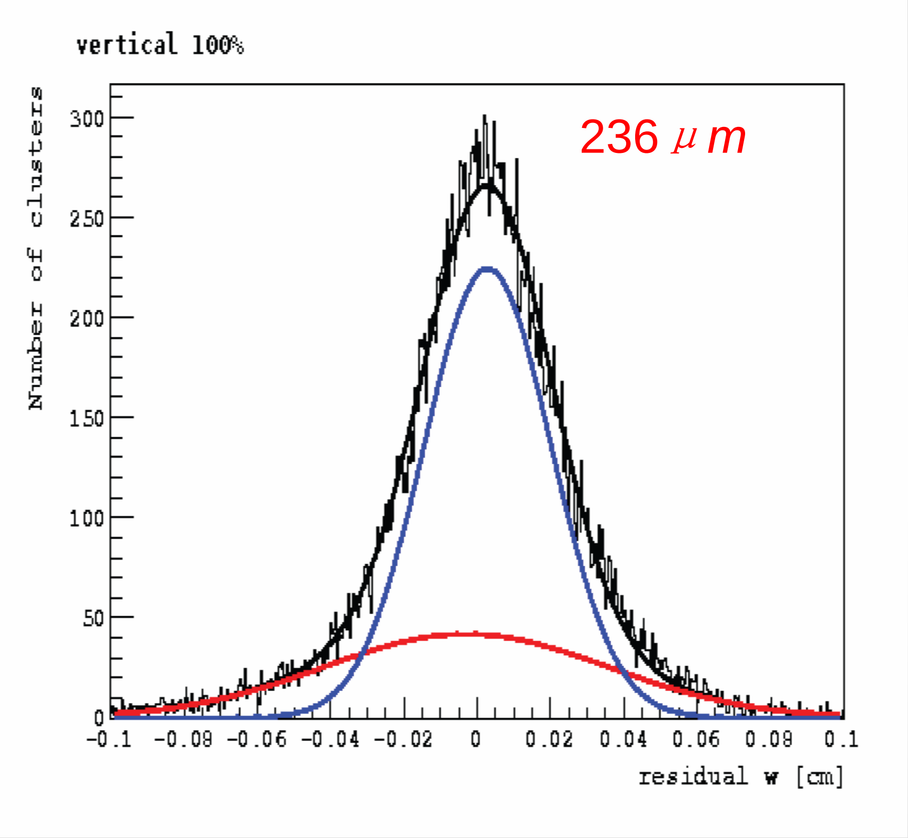




Spatial Resolution of GEM-TPC Prototype

--vertical mounting



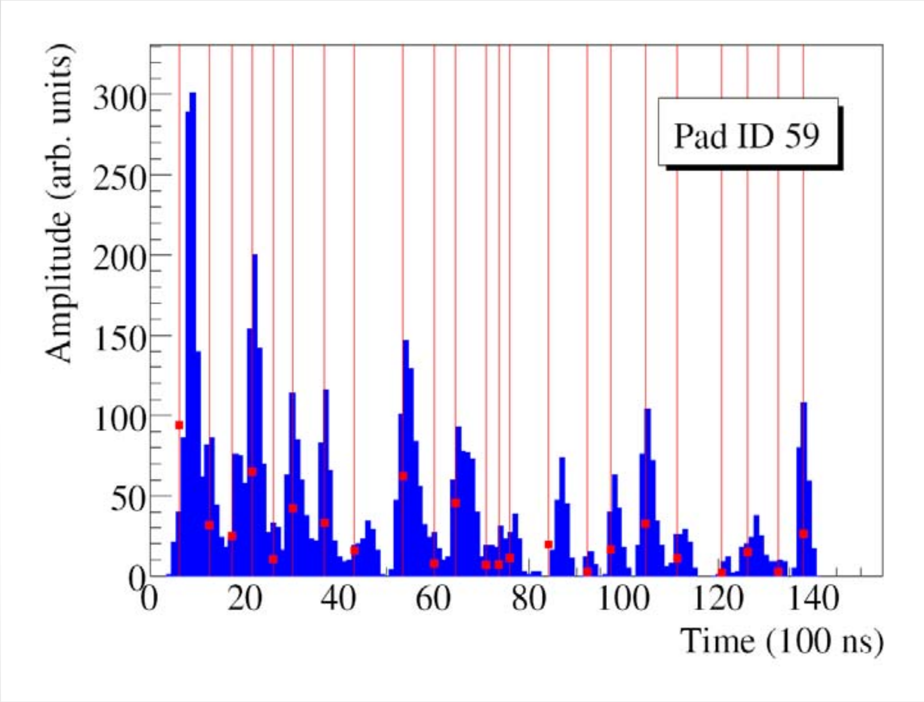


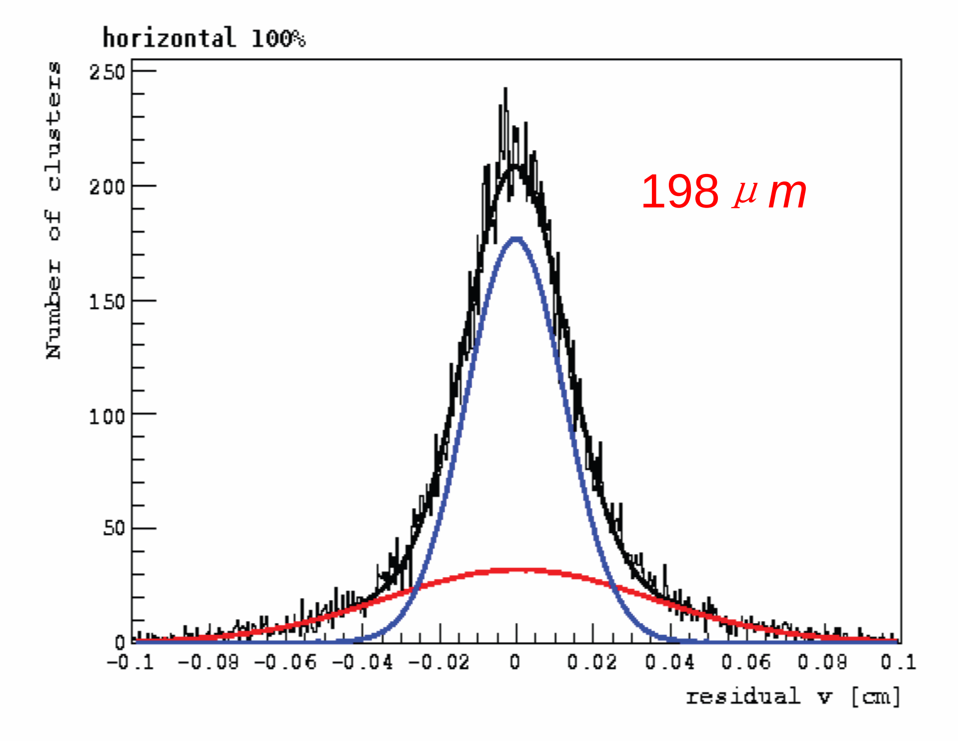
Spatial resolution along short side of pads

Spatial resolution along the drift direction

Spatial Resolution of GEM-TPC Prototype

--horizontal mounting

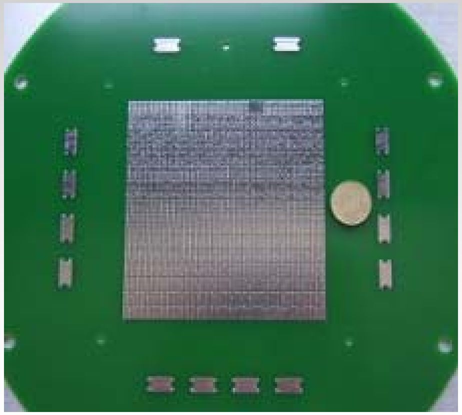


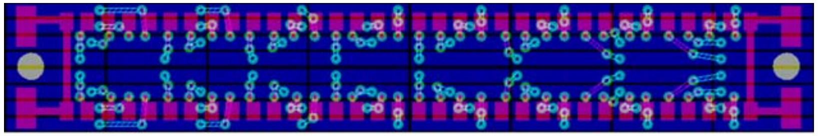


Time structure of the charge on a readout pad for one complete electron drift time

Spatial resolution along short side of pads

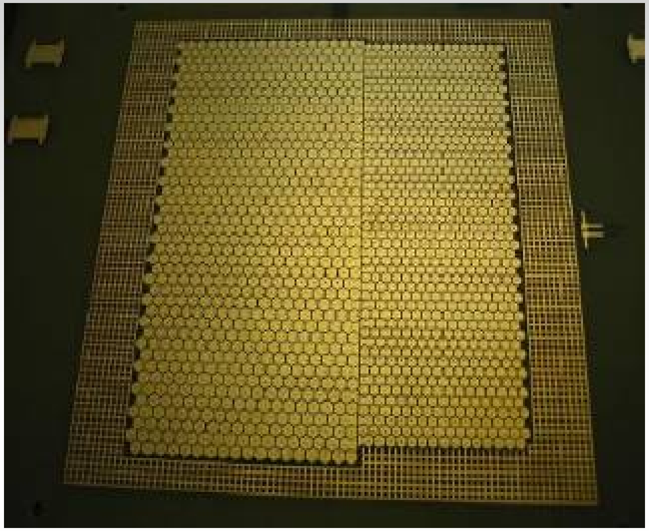
Upgrade (I) of GEM-TPC Prototype





Rectangular pads

1. Pad size: 0.8×6.0mm2
2. Active area: 100×100mm2
3. Pad number: 1,536(128 read out)



Two different size hexagonal pads

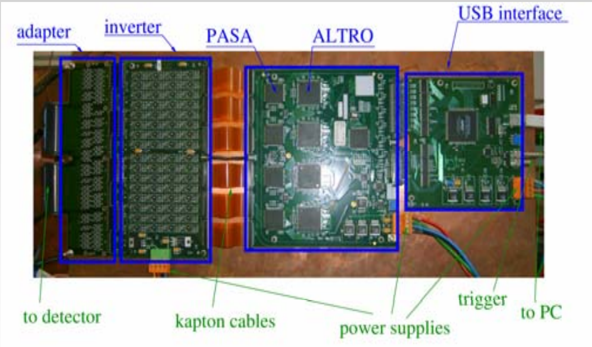
1. Outer radius of hexagonal pad: 1.25 and 1.5mm
2. Active area: 100×100 mm2
3. Pad number: 1,500

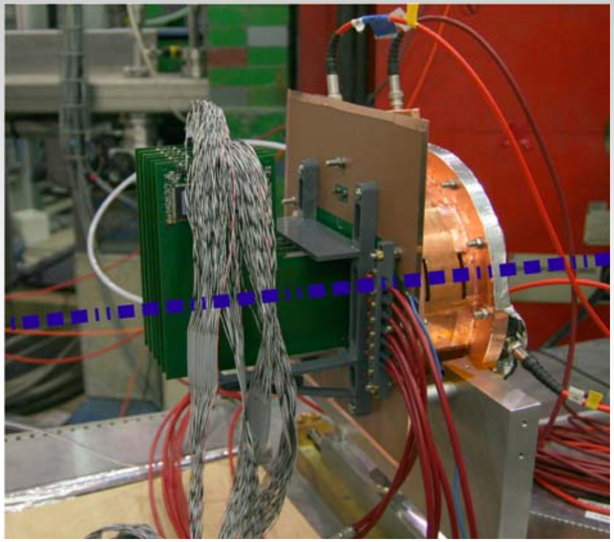
Note that:

1. hexagonal pads yield a more uniform spatial resolution along different directions than square pads;
2. Effect on the spatial resolution for different pad size will be studied.

Upgrade (II) of GEM-TPC Prototype

PASA-/ALTRO





+ 6 X

ADC

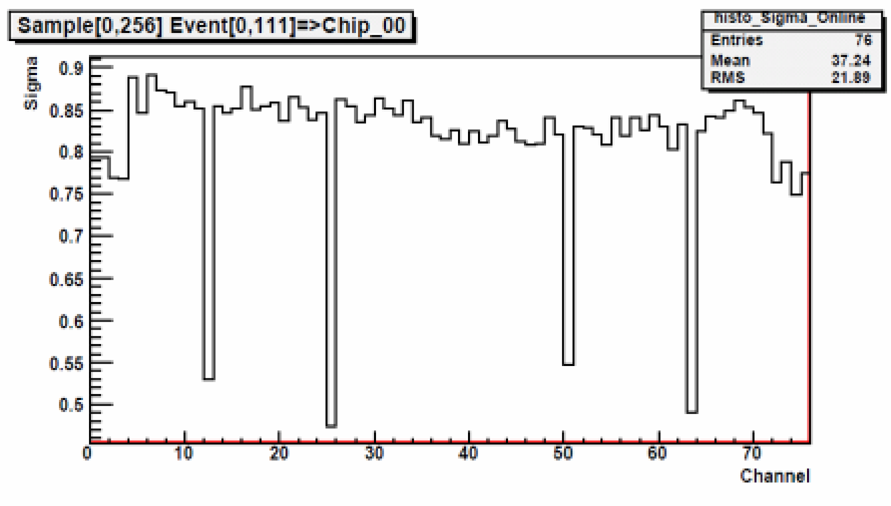
FEC with 4 AFTER ASICs

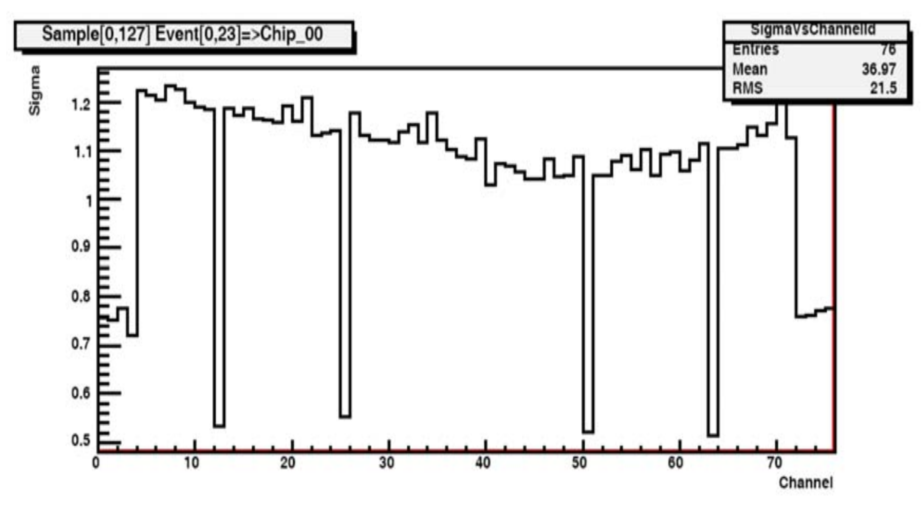
Performance of new electronics

1. **AFTER ASIC:**
   - ① Shaping time: 100ns to 2 μs
   - ② Sampling frequency: 10 to 50MHz
   - ③ Analog sample memory: 511
   - ④ Number of channel: 76 (4 for CM)
2. **Custom-made pipelined ADC**

Refer to P. Baron et al., ASIC AFTER internal user manual V2.1

Noise Performance of New Electronics





Noise without chamber

0.85 ADC Channel / ~ 600 e^-

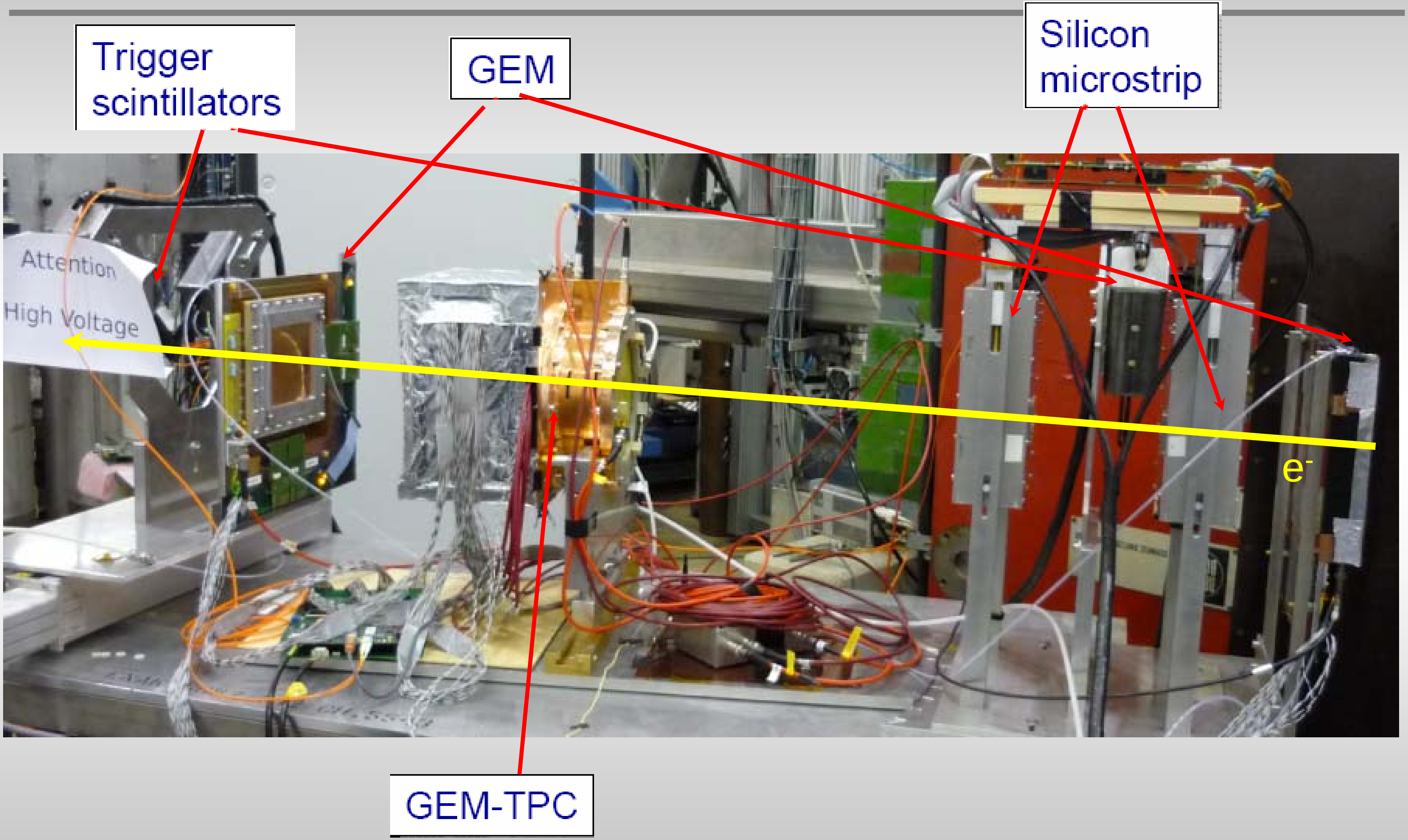
Noise with chamber

1.12 ADC Channel / ~ 850 e-

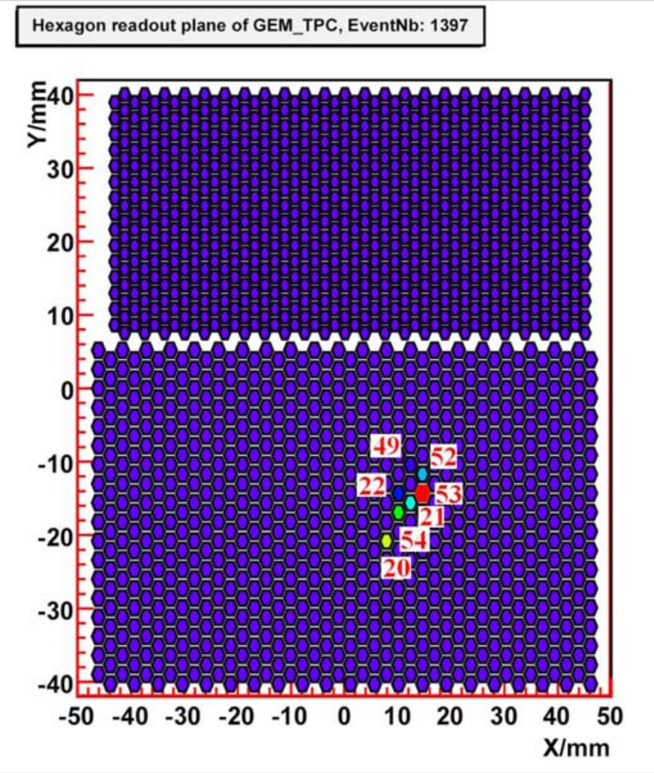
Note that:

1. **Low noise means the chamber can be operated at low gain, which will reduce the ion back-flow into the drift volume. In other words, it will reduce the space-charge distortion.**

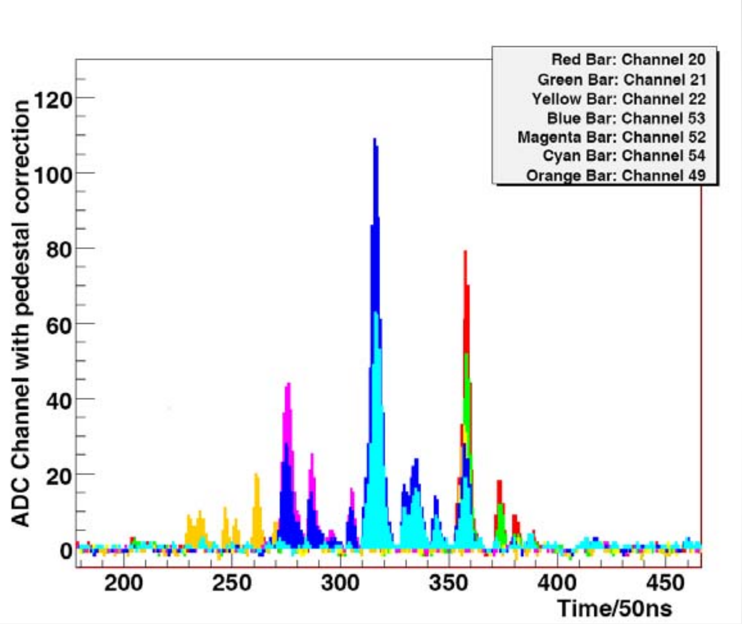
Test Setup at ELSA in Bonn



Electron Track and its Time Structure



Electron track inside the chamber. Numbers beside active pads on the plot are corresponding channel number.



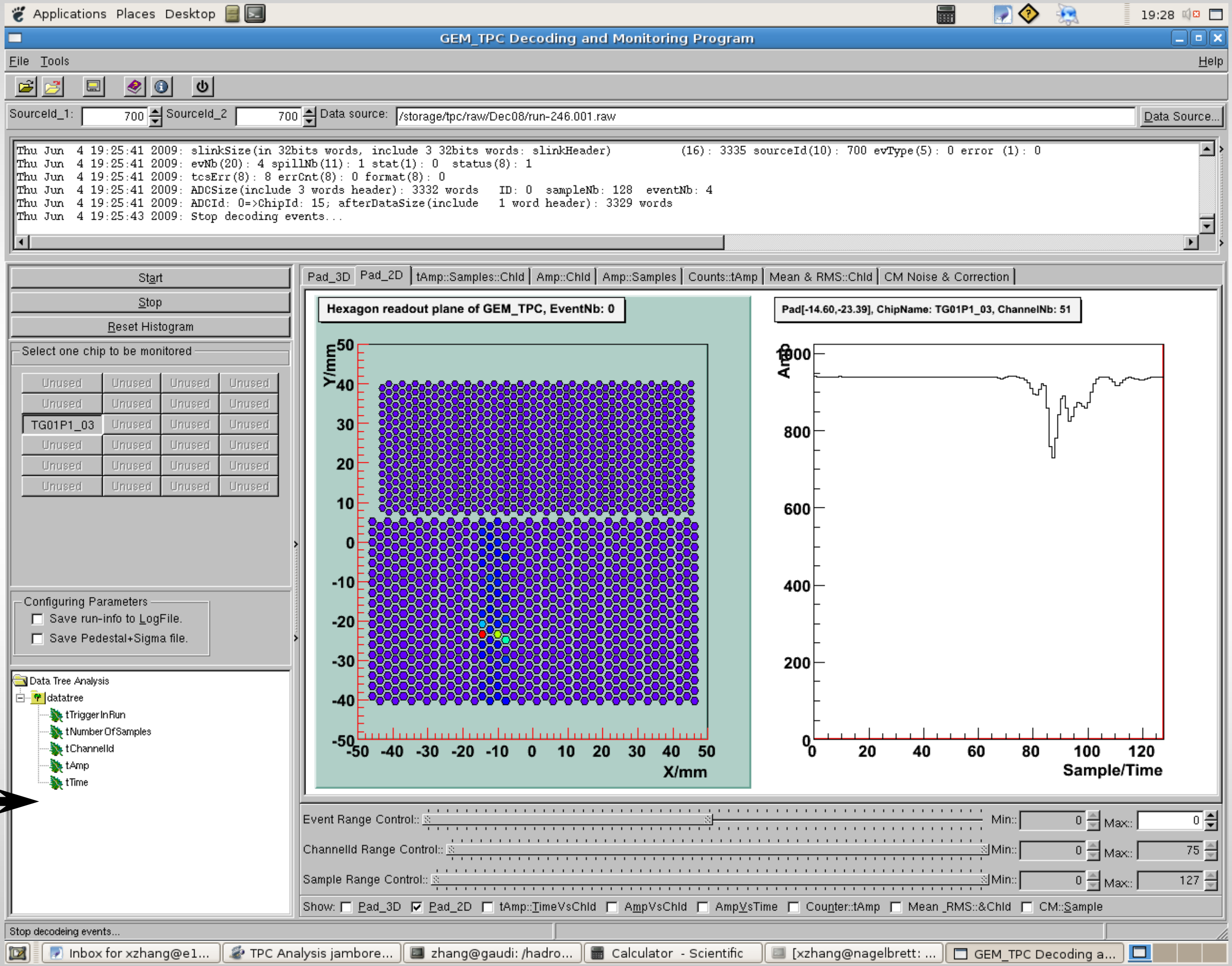
Time structure of active pads on the left track.

Graphical User Interface

--monitoring program

1. **Written in C/C++**
   Based on ROOT
2. **Decode the raw data (DATE)**
   On-Line/Off-Line

Data Tree



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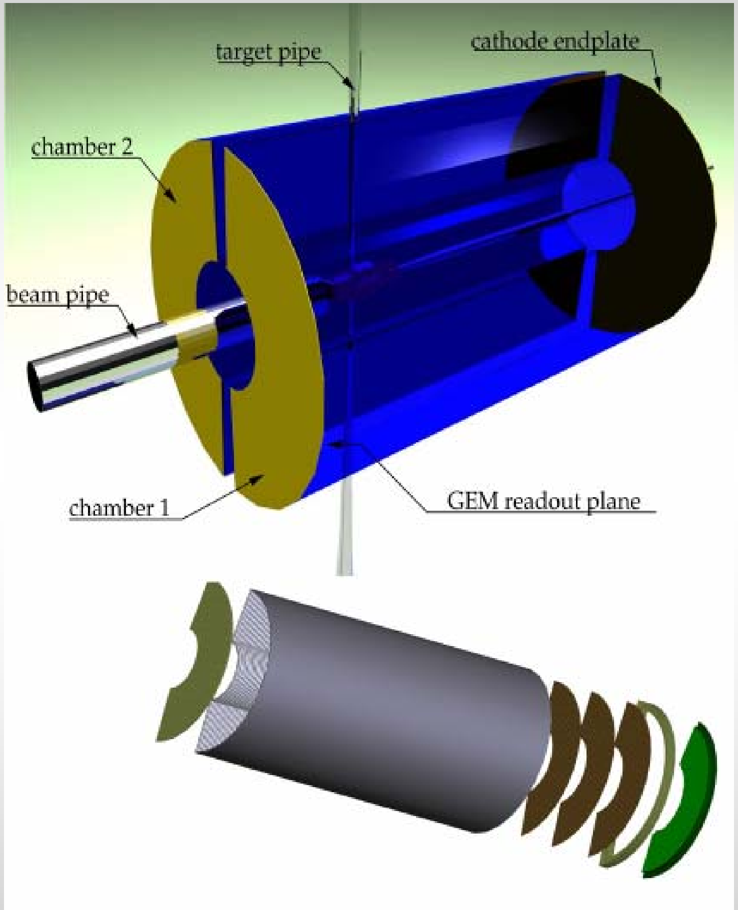
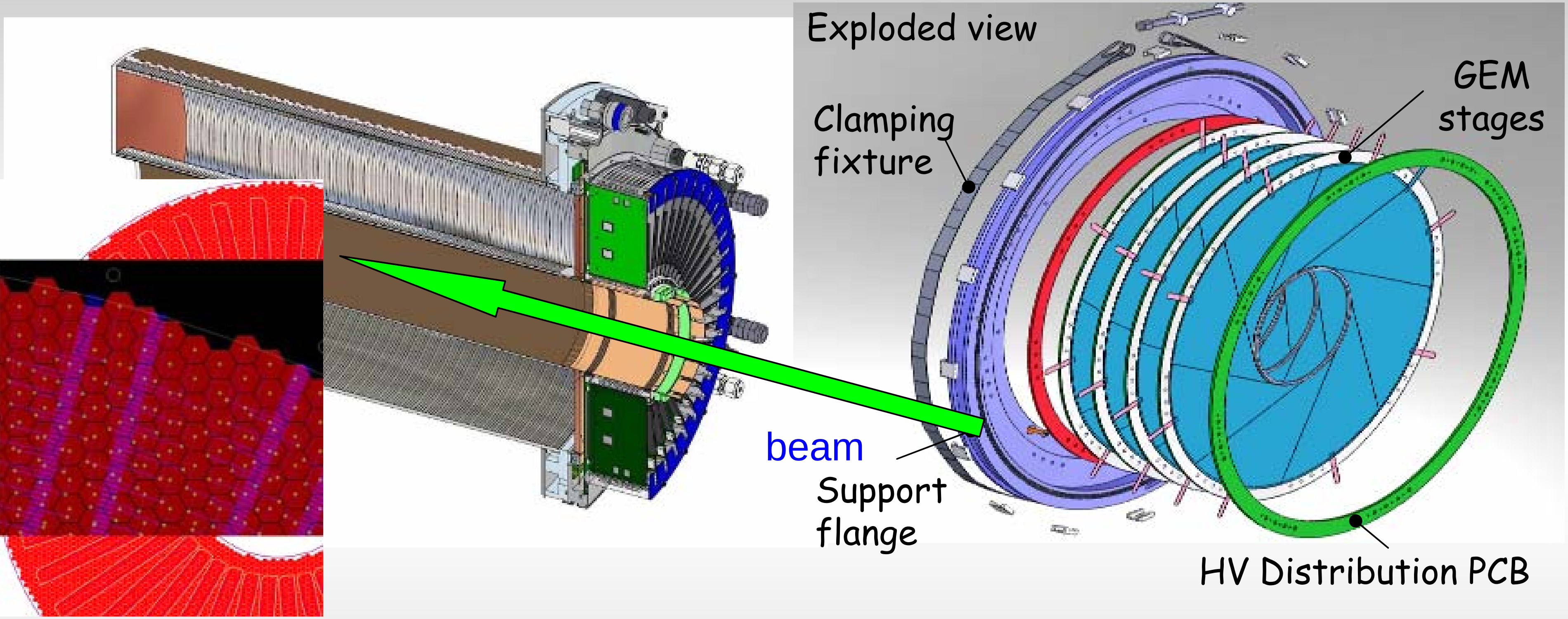


GEM-TPC Prototype



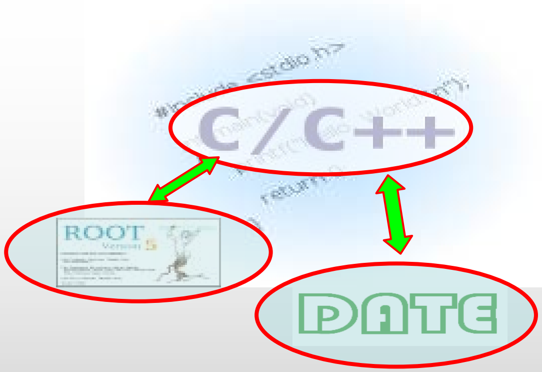
Size: ϕ300mm $\times$ 650mm
Active area: 105mm $< \phi <$ 300mm
Hexagonal pad size: 1.5mm
Number of pads: 9,636

test at FOPI@GSI and ELSA
New tracker for CB@ELSA

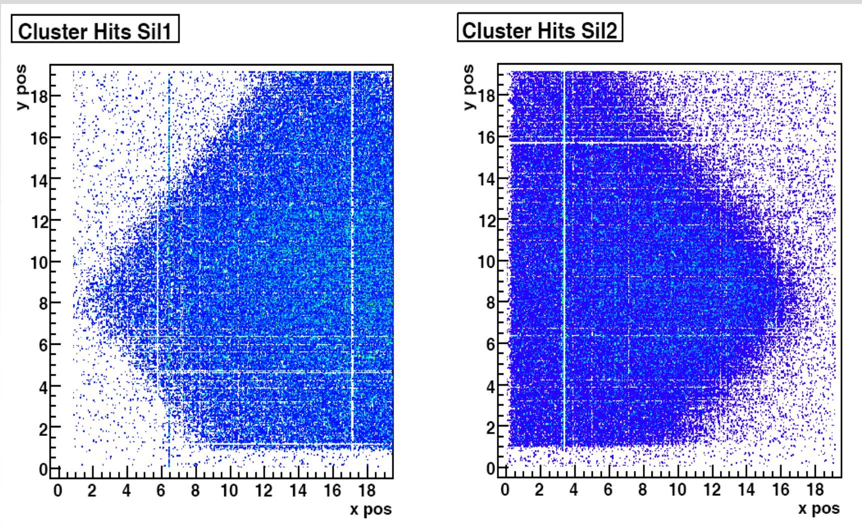
Summary and Outlook

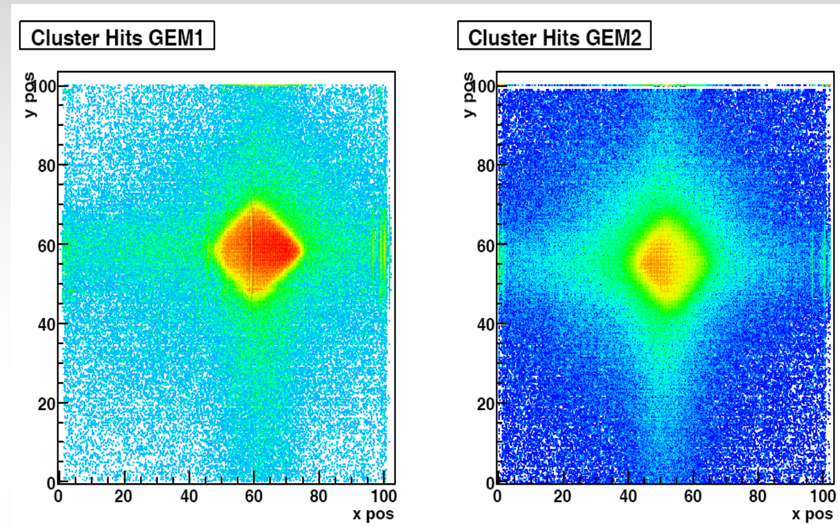
- Simulations
  - Momentum resolution ~%
  - Space-charge correction with laser mesh method works well.
- Spatial resolution of small chamber tested with cosmic muons:
  - Vertical and horizontal mounting: different track topologies
  - <200 μm along the short side of readout pads (no magnetic field)
  - <250 μm along the drift direction
- Setup of TPC test bench at ELSA
  - External definition by 4 planes of Si and 4 planes of GEM detectors
  - First electron tracks are observed
- Future schedule
  - Test of small size GEM-TPC with new electronics and telescope is on going at ELSA
  - Test of GEM-TPC prototype at FOPI@GSI and CB@ELSA

Thank you for your attention



3.9 Hit pattern of Silicon strips and GEM detectors

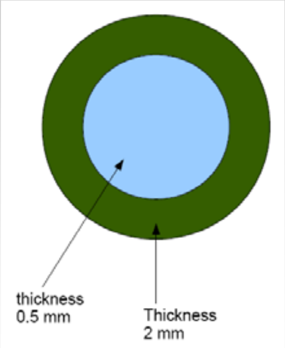




Note that:

1. a little bit shift of Silicon strip detectors or trigger scintillators needed;
2. Broadening of distribution in GEM2 caused by the multiple scattering.

3.14 Additional upgrade on the drifting-end plate

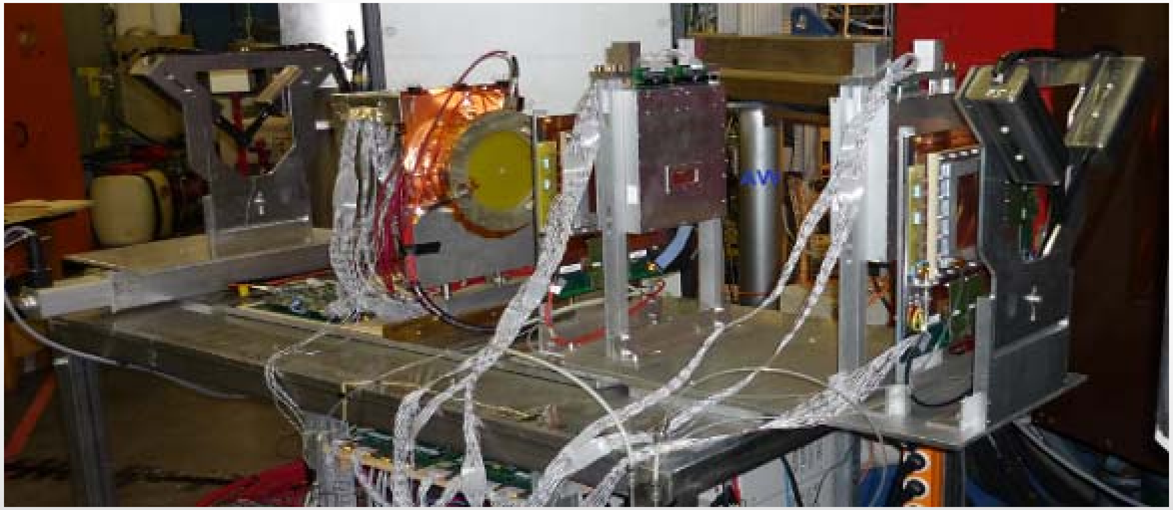


Minimize the influence of multiple scattering

- Copper layer: 35 -> 15 micrometer
- No gold/nickel coating
- Thickness of plate: 2 -> 0.5 mm

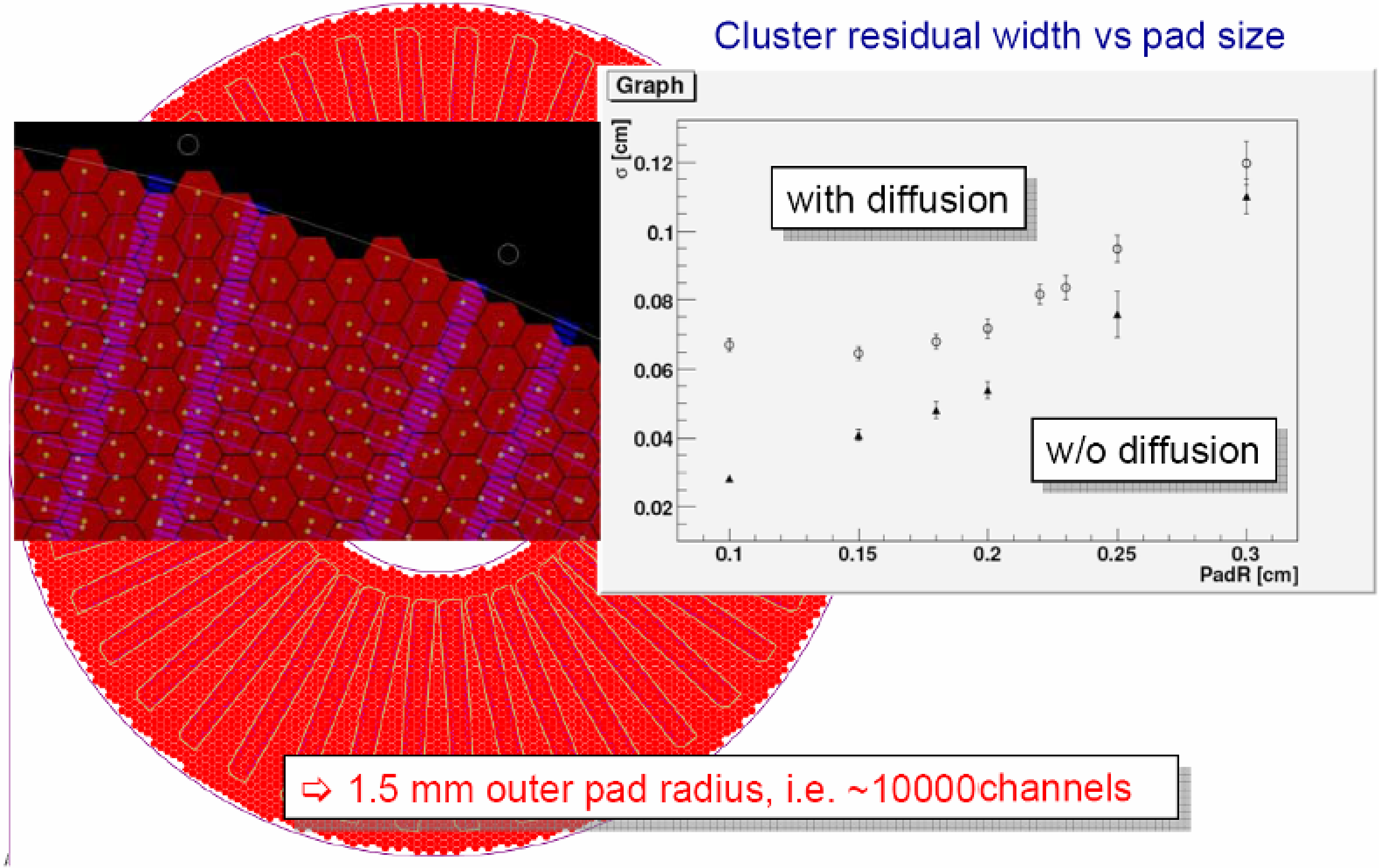
Thickness of Radiation length:

- 1.334% -> 0.34%



New layout of telescope system
will improve the definition of electron track.
Now, the test is on going at ELSA in Bonn.

Cluster residual width vs pad size



⇨ 1.5 mm outer pad radius, i.e. ~10000channels

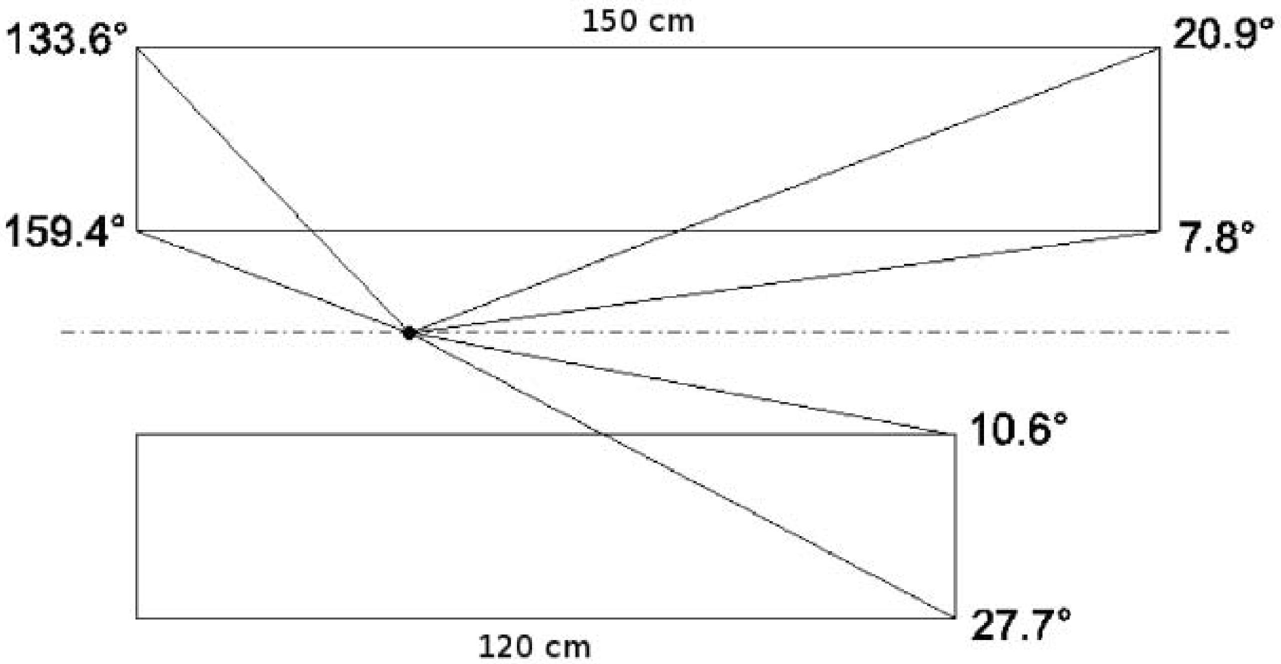


Figure: The two length options and resulting key angles