Simulations for Freiburg 3GEM+MediPix test beam set-up

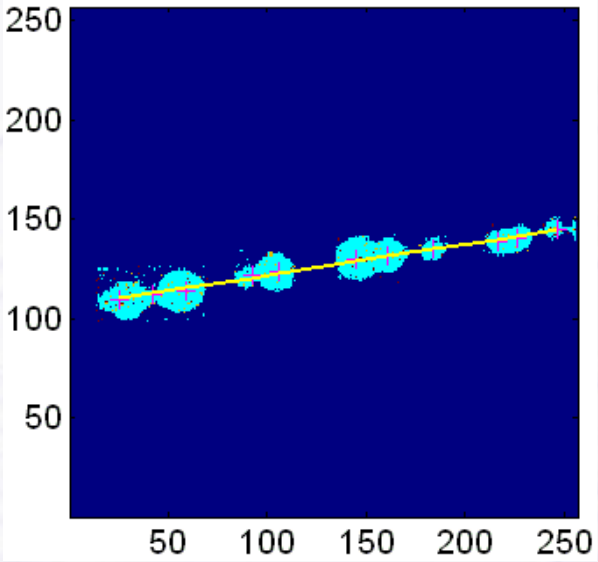
- Simulation Tool
- Gas Properties
- Cluster Finding
- Resolutions...

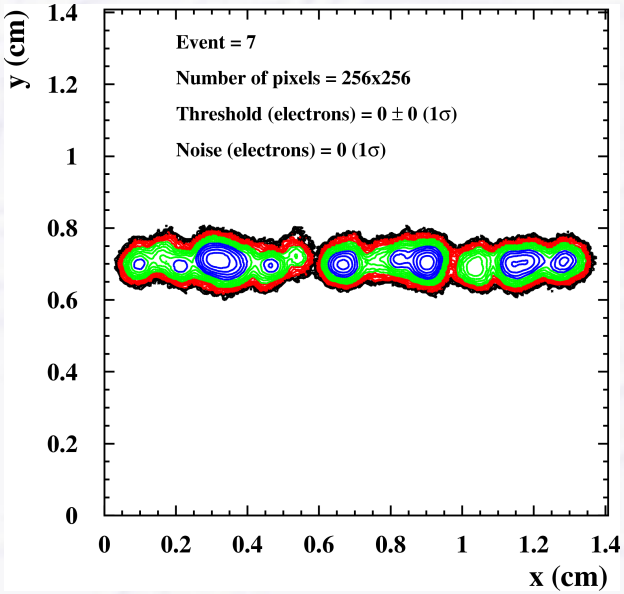
Reminder: Simulation Tool CLUSCO

- Generates ionization clusters/electrons along tracks and drifts electrons towards GEMs/MicroMegas structures
  - HEED (I. Smirnov) for cluster generation (incl. δ-electrons, mult. scat.)
  - MAGBOLTZ (S. Biagi) for gas properties (diffusion, drift velocity)
- "Squeeze" electrons through GEM/MicroMegas holes and perform gas amplification
  - use simple geometric transformations, no detailed E-field simulation
  - exponential gas gain distribution
    - measurements from Aachen group indicate exponential distribution
    - gas gain on wires more follows Polya distribution
- Drift ALL electrons created in gas amplification to next GEM or MediPix (can be several Millions in total)
- Count electrons collected on MediPix, generate noise + apply detection thresholds (digitization step)

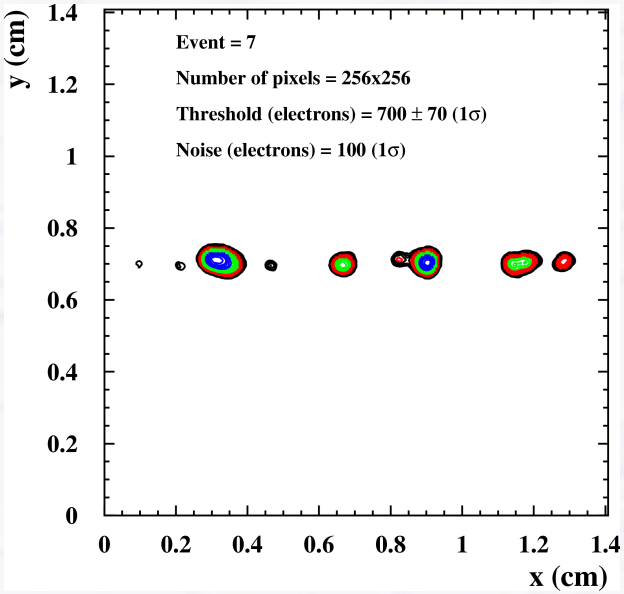
Freiburg triple-GEM set-up

- Nice "blobs" seen along tracks from ^{106}Ru source (β^- with 3.5 MeV max.)
- Cluster density for Ar/CO_2 (70:30) and a few MeV electrons (~m.i.p.)
  - expect: ~30 clusters/cm
  - reconstructed: ~6 clusters/cm (~20% eff.)



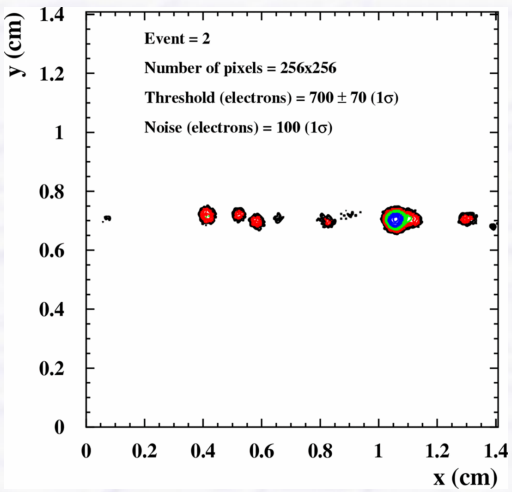


threshold = 700 ± 70 e⁻
noise = 100 e⁻

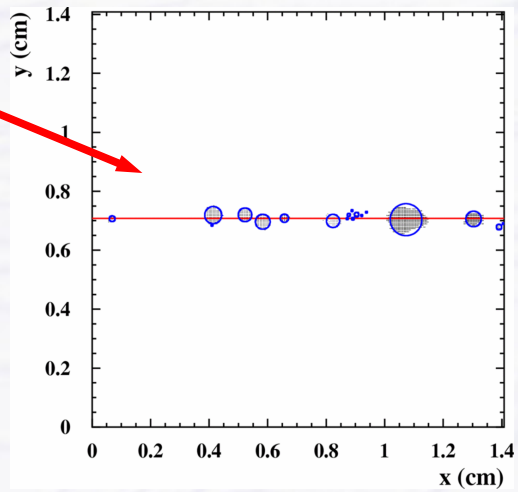


Cluster Finding

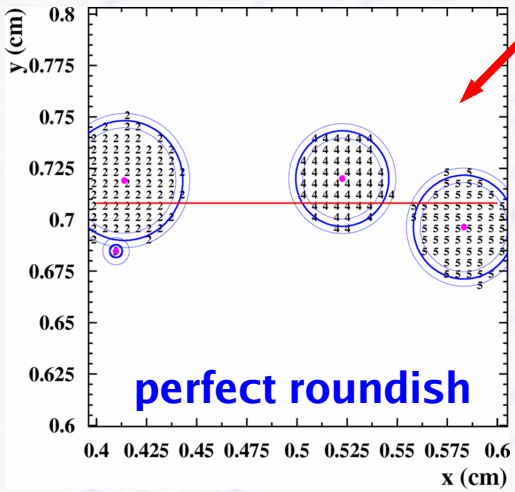
- **Apply simple cluster finding algorithm + check performance**
  - **search for simply connected areas, use center-of-gravity**
    - **algorithm to resolve two (or more) overlapping clusters still missing**

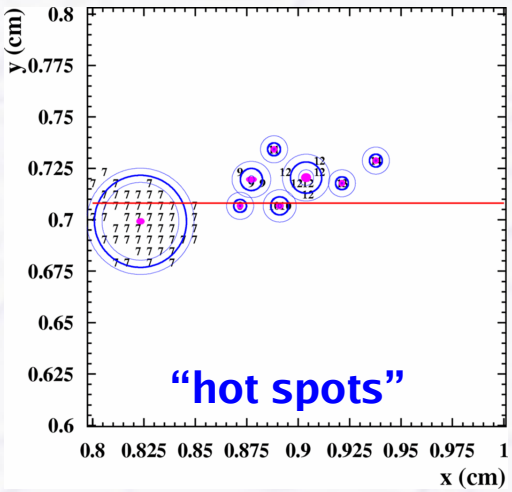


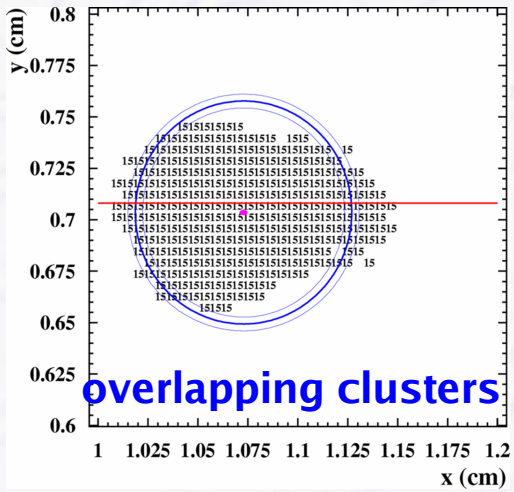
reconstructed clusters with straight line fit (NO charge information used)



circles with same area as pixel area





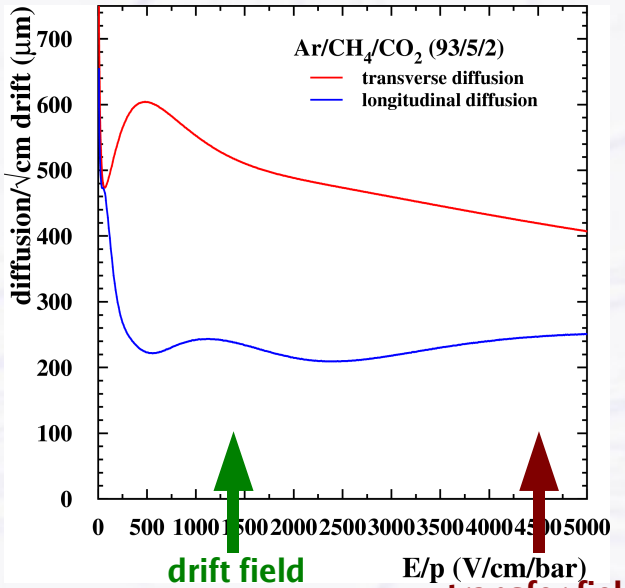


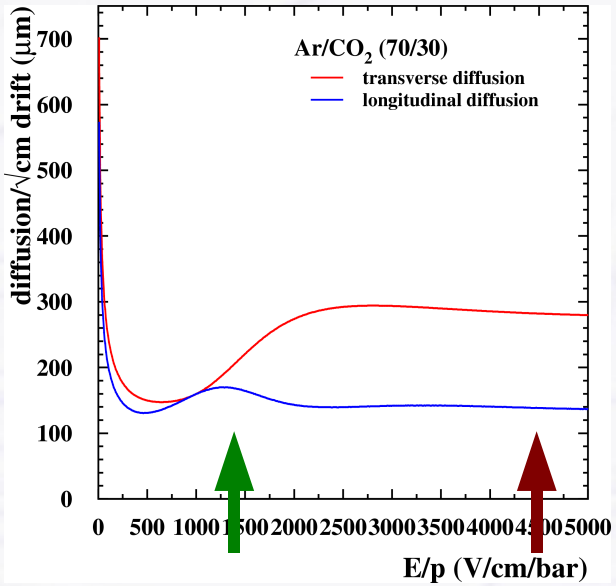
Test Beam Gases + Set-up

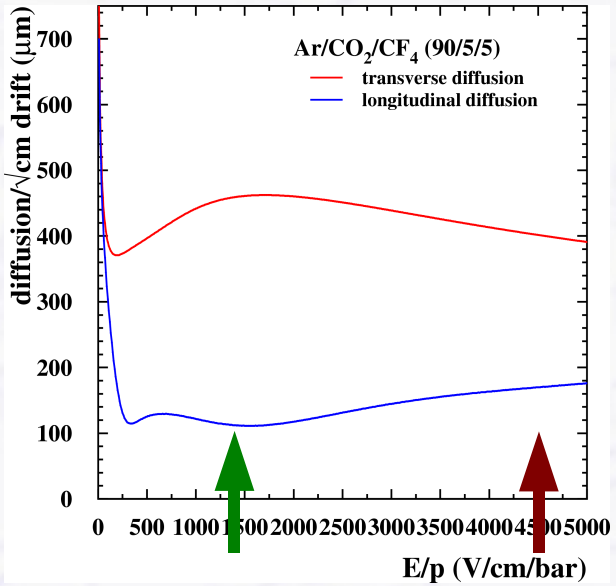
- 6 different combinations of gas and GEM set-up simulation
  - Ar/CH_4/CO_2 93/5/2 (TESLA-TDR gas)
    - GEM stack: 1 mm – 1 mm – 1 mm
  - Ar/CO_2/CF_4 90/5/5 (fast, aggressive?)
    - GEM stack: 1 mm – 1 mm – 1 mm
  - Ar/CO_2 70/30 (same as used with ^{106}Ru source in FR)
    - GEM stack: 1 mm – 1 mm – 1 mm
    - GEM stack: 2 mm – 2 mm – 1 mm
  - He/CO_2 70/30 (also used with ^{106}Ru source in FR)
    - GEM stack: 1 mm – 1 mm – 1 mm
    - GEM stack: 2 mm – 2 mm – 1 mm
- 6 GeV electrons (with multiple scattering), 1000 tracks
  - full drift range 0 – 6 mm (uniformly distributed)
  - tracks uniformly distributed between 0.5500 – 0.9350 cm (pixels 100 – 170)

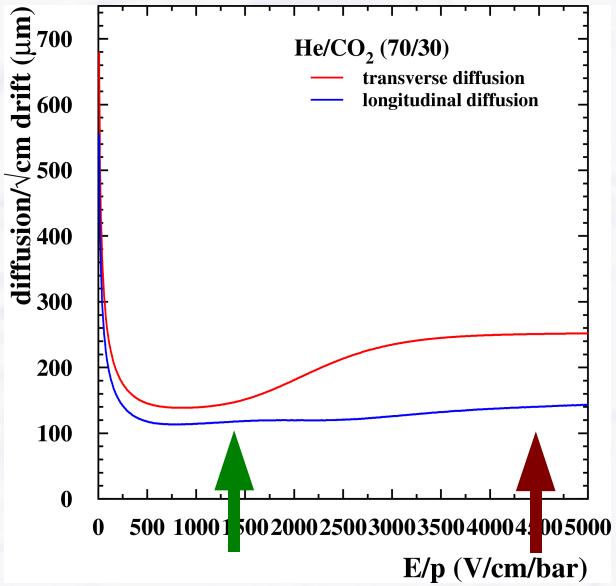
Diffusion

- Ar/CO_2 and He/CO_2 have low (transverse) diffusion at both drift field and transfer field region
- Expect...
  - size of "blobs" smaller than for Ar/CH_4/CO_2 and Ar/CO_2/CF_4
    - blob size determined by diffusion in transfer region
  - better resolution
    - resolution determined by diffusion in drift region







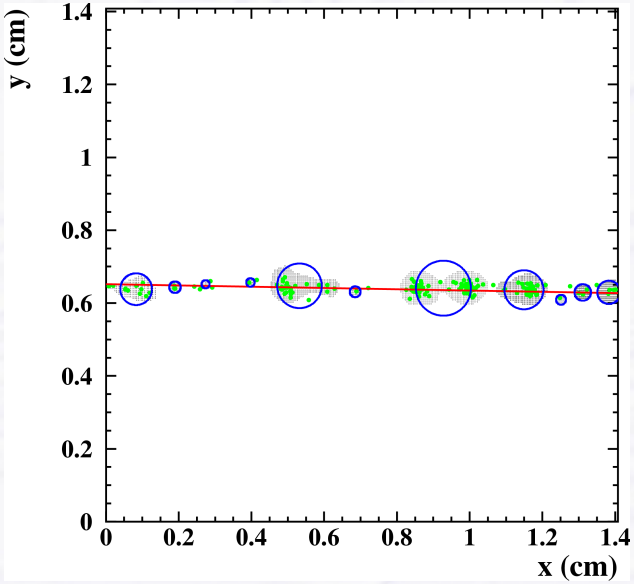


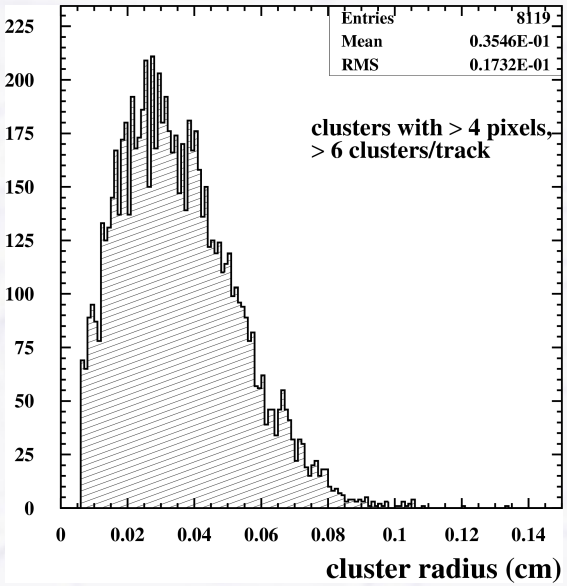
Cluster Radius

- sometimes large blobs at $Ar/CH_4/CO_2$
- average cluster radius similar
  - 350 – 400 µm
- but broader distribution at $Ar/CH_4/CO_2$
  - no real peak

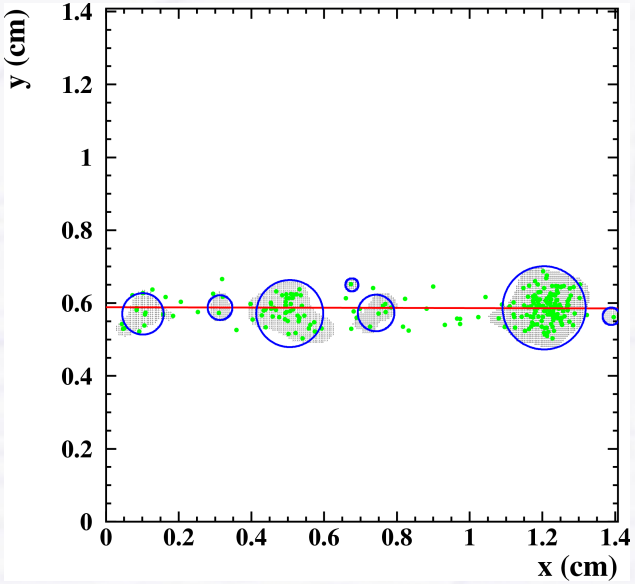
cluster radius →

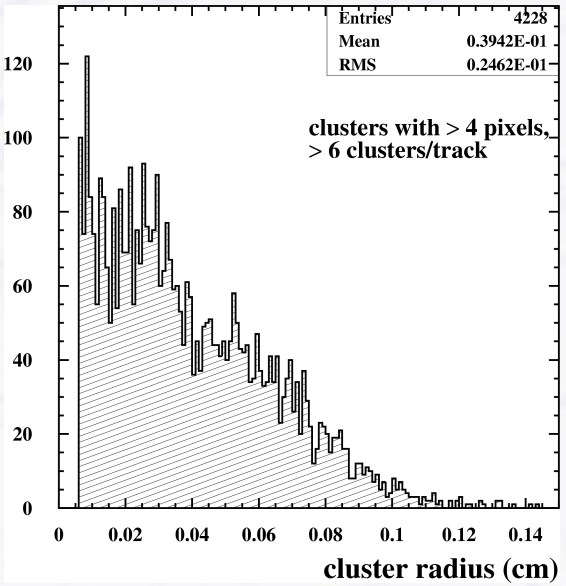
Ar/CO_2 70/30





$Ar/CH_4/CO_2$ 93/5/2





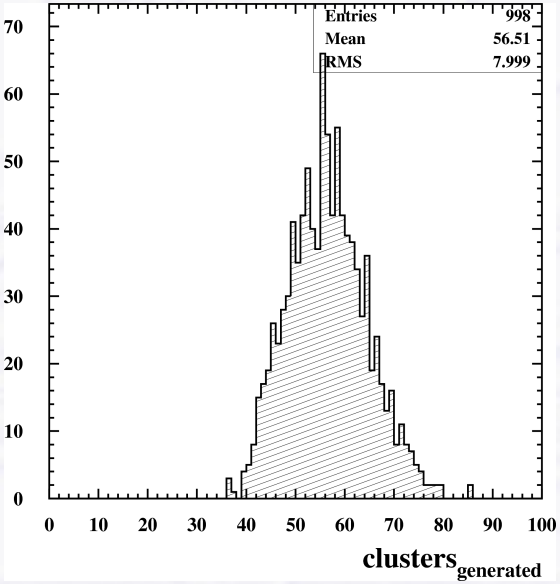
Cluster Finding Efficiencies

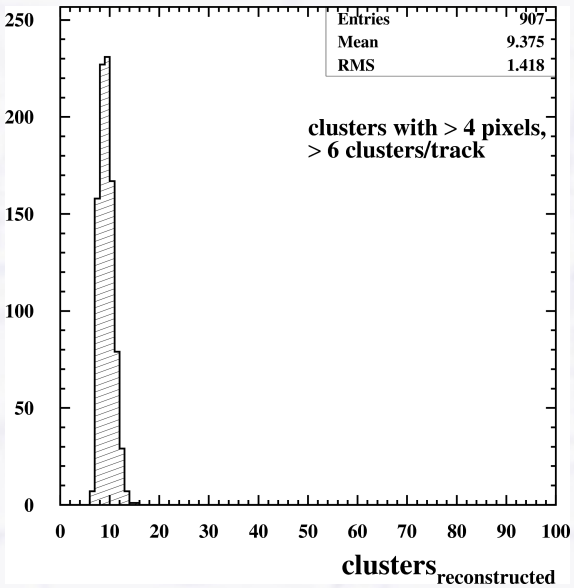
- **Very different primary cluster density**
  - Ar/CO_2 (70/30): 40.0 cl./cm
  - He/CO_2 (70/30): 18.4 cl./cm

track length = 1.408 cm

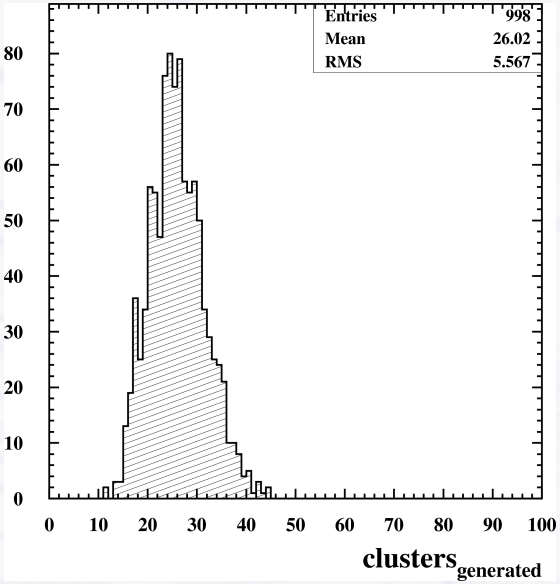
- **Reconstructed cluster density very similar**
  - Ar/CO_2 (70/30): 6.3 cl./cm
  - He/CO_2 (70/30): 6.2 cl./cm

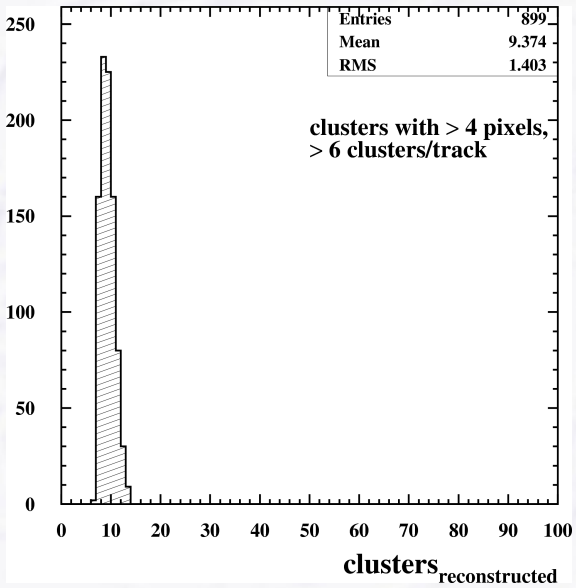
Ar/CO_2 70/30





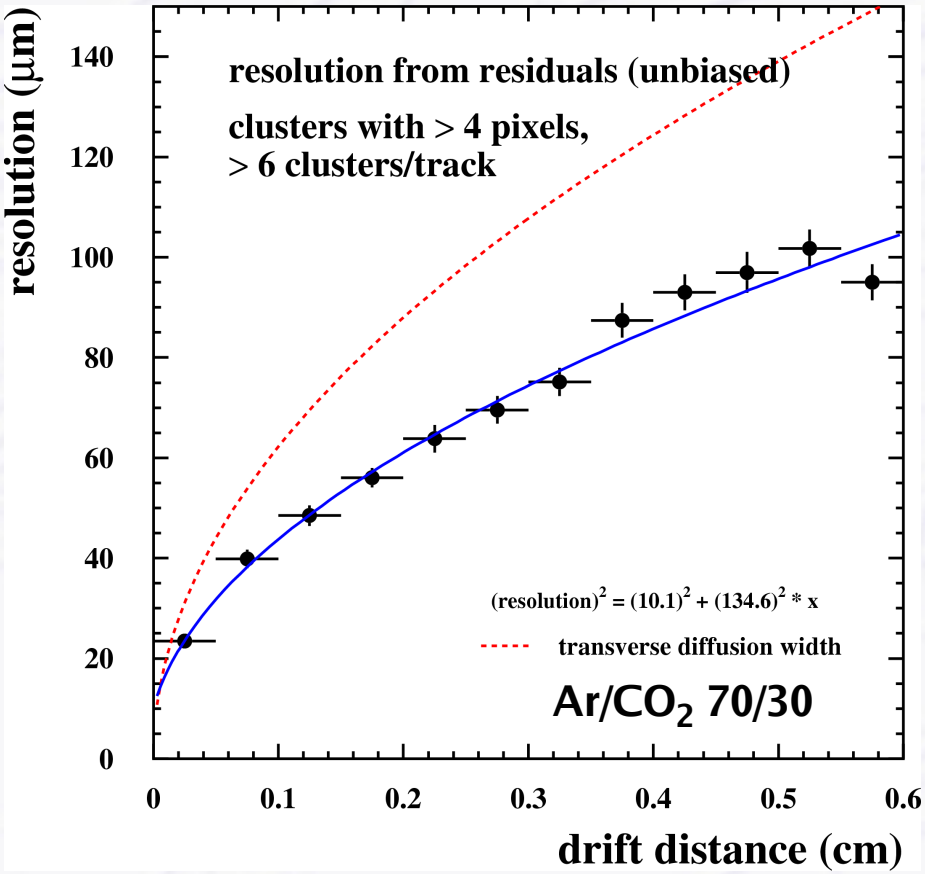
He/CO_2 70/30

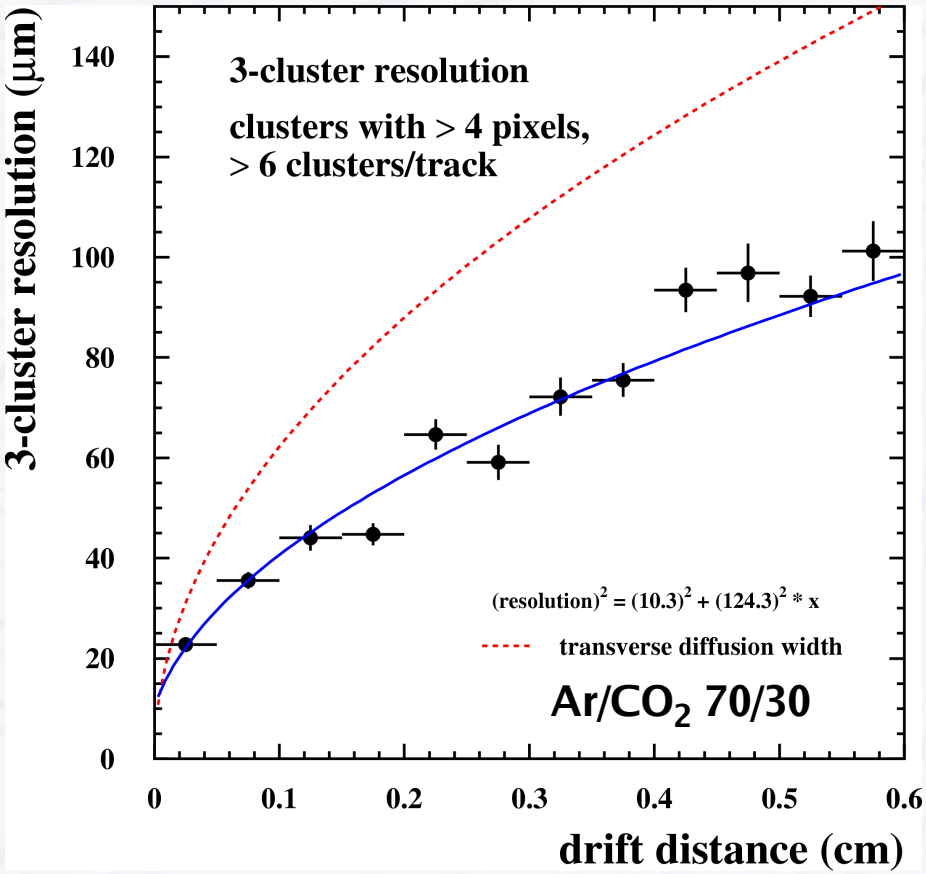




Resolutions I

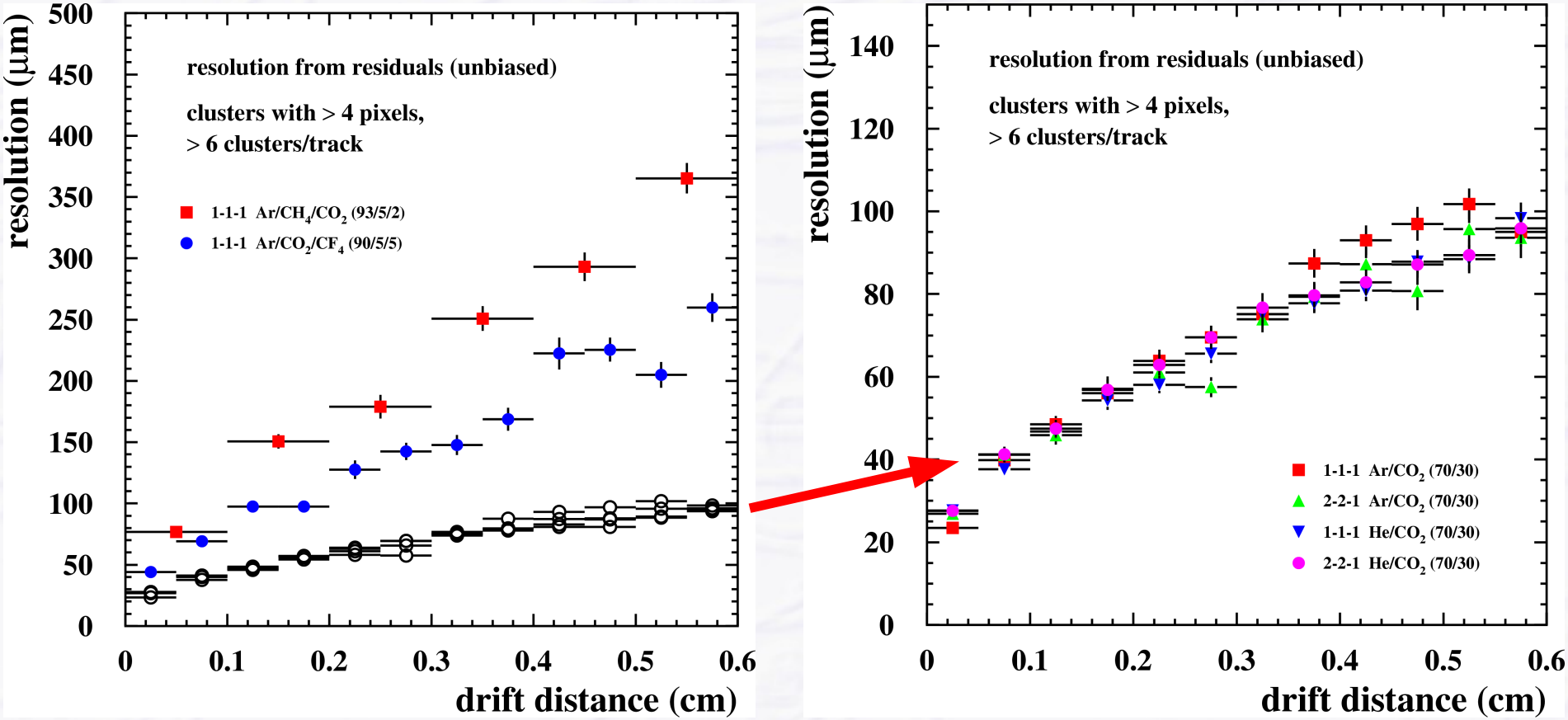
- **Get single cluster resolutions from**
  - **unbiased residuals of straight line fit** (point in question not included in fit)
  - **3-cluster distributions**
    - take 3 cluster positions, form difference $\Delta y = (y_1 - y_3)/2 - y_2$, resolution = $\sigma_{\Delta y} * \sqrt{(2/3)}$





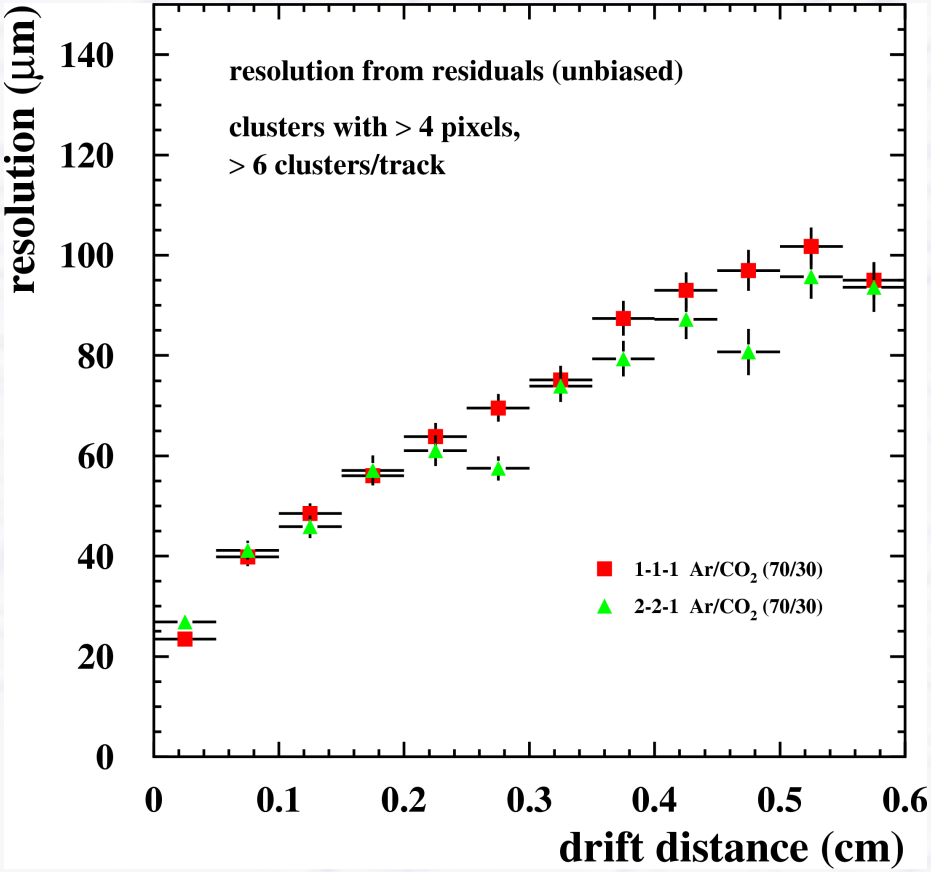
Resolutions II

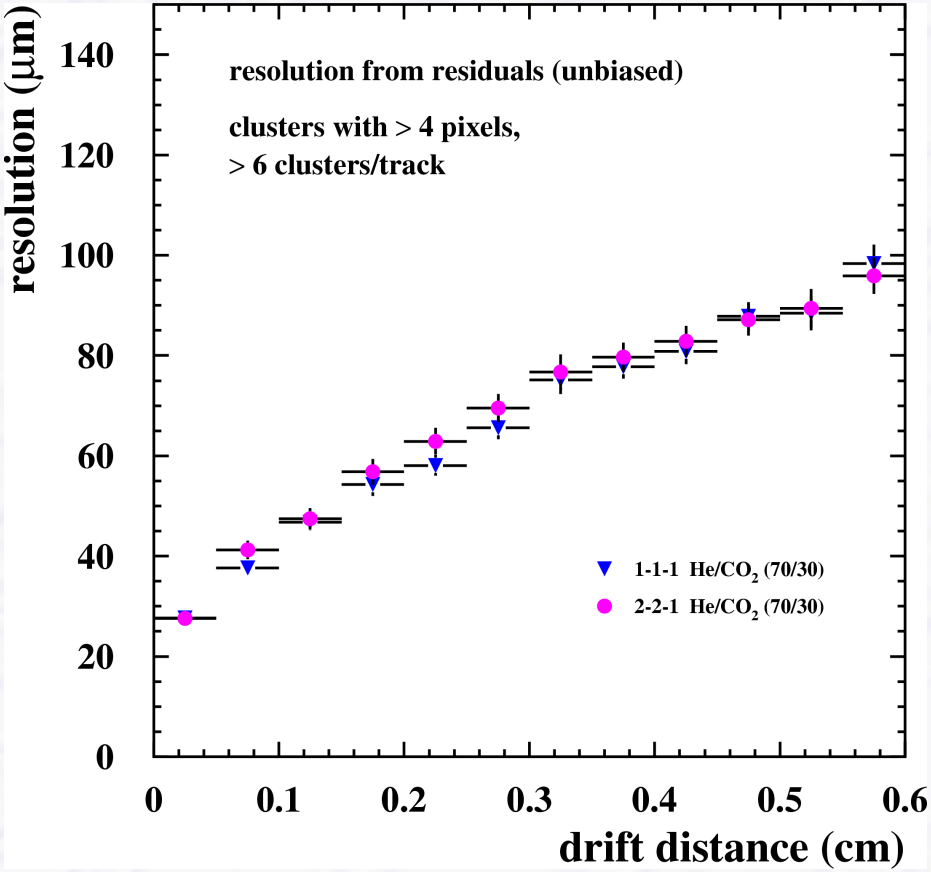
- $Ar/CH_4/CO_2$ (93/5/2) and $Ar/CO_2/CF_4$ (90/5/5) worse than mixtures with more CO2 content (as expected from diffusion)
- Ar/CO2 and He/CO2 similar, ~60-70 µm for 0.3 cm drift



Resolutions III

- No significant differences between 2-2-1 and 1-1-1 set-up





Summary of Results

	$Ar/CH_4/CO_2$ 93/5/2 1-1-1	$Ar/CO_2/CF_4$ 90/5/5 1-1-1	Ar/CO_2 70/30 1-1-1	Ar/CO_2 70/30 2-2-1	He/CO_2 70/30 1-1-1	He/CO_2 70/30 2-2-1
trans. diff. at 1.33 kV/cm [µm/√cm]	521.8	457.5	196.7	196.7	145.3	145.3
trans. diff. at 4.5 kV/cm [µm/√cm]	419.3	401.6	282.0	282.0	251.0	251.0
cluster/cm (6 GeV electrons)	36.9	39.1	40.0	40.0	18.4	18.4
electrons/cm (6 GeV electrons)	91.5	96.6	91.8	91.8	29.8	29.8
cluster/cm (rec.), > 4 pixels, > 6 clust./track	5.9	5.4	6.3	5.5	6.2	5.5
cluster reconstruction efficiency [%]	15.4	14.6	16.3	14.7	35.8	32.2
average cluster radius [µm]	394	409	355	391	327	380
resolution from residuals at 3 mm drift [µm]	225	153	74	69	69	71
3-cluster resolution at 3 mm drift [µm]	163	119	69	58	61	63

Conclusions

- Cluster finding efficiencies
  - ~15% for Ar-based mixtures
  - ~35% for He-based mixtures
- But overall numbers of reconstructed clusters/cm (~5-6 cl./cm) very similar for both Ar- and He-based mixtures
  - primary cluster density of He only ~half than for Ar
- $Ar/CH_4/CO_2$ (93/5/2) and $Ar/CO_2/CF_4$ (90/5/5) mixtures have ~2x worse resolutions than Ar/CO_2 or He/CO_2
  - large diffusion in drift region and transfer region
  - large blobs
- No significant differences between 2-2-1 and 1-1-1 set-up