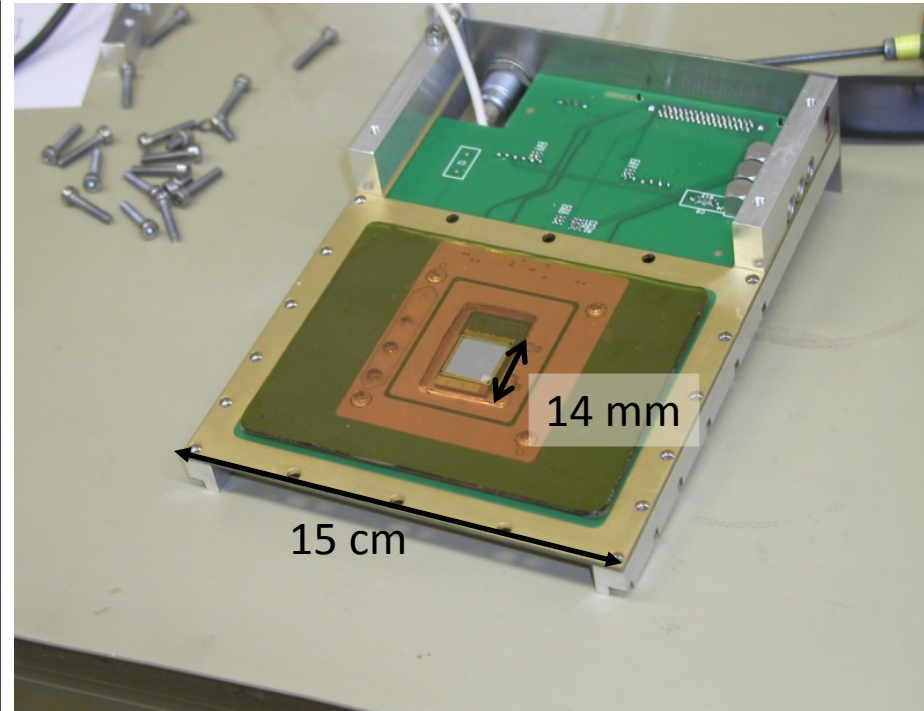
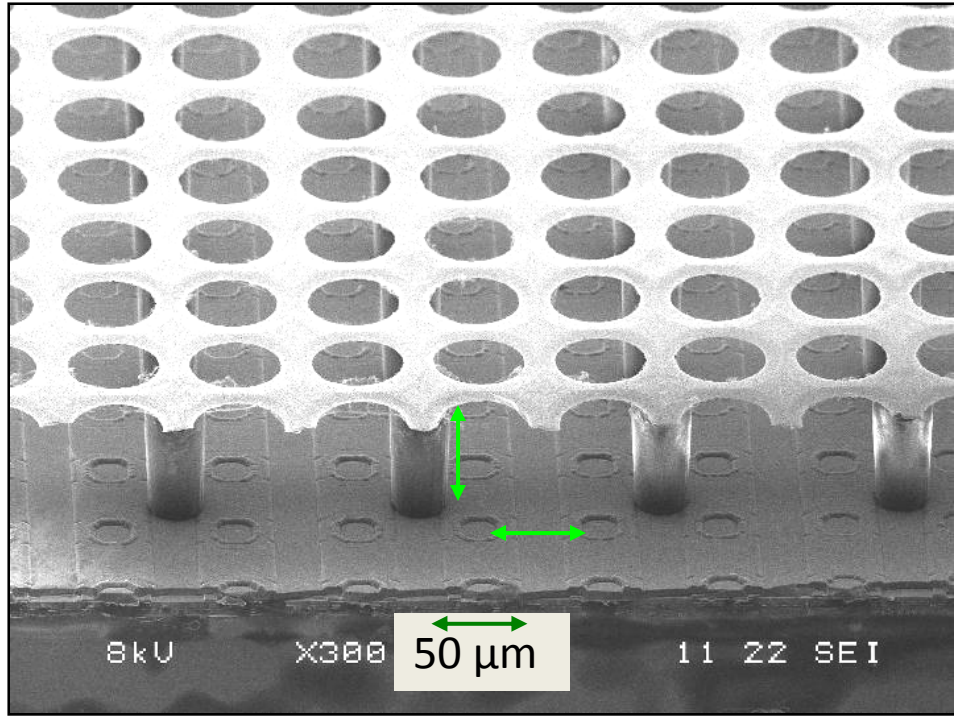


An aerial photograph of a large, multi-story building complex, likely a university or research facility, surrounded by dense green forest. The building has a prominent central tower and several long wings. The text is overlaid on a semi-transparent white box in the center of the image.

Data Analysis of Measurements on a GridPix detector

Lucie de Nooij
Supervisor: Jan Timmermans

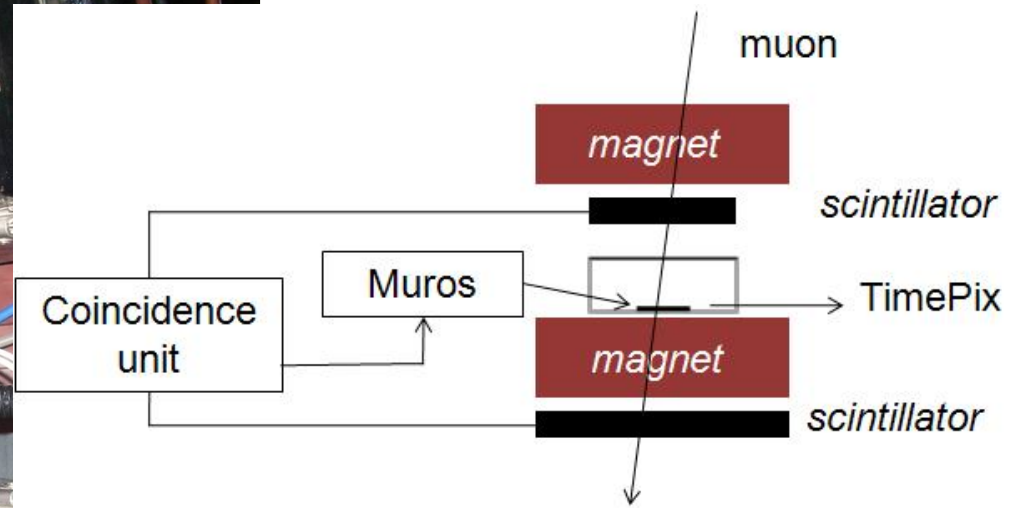
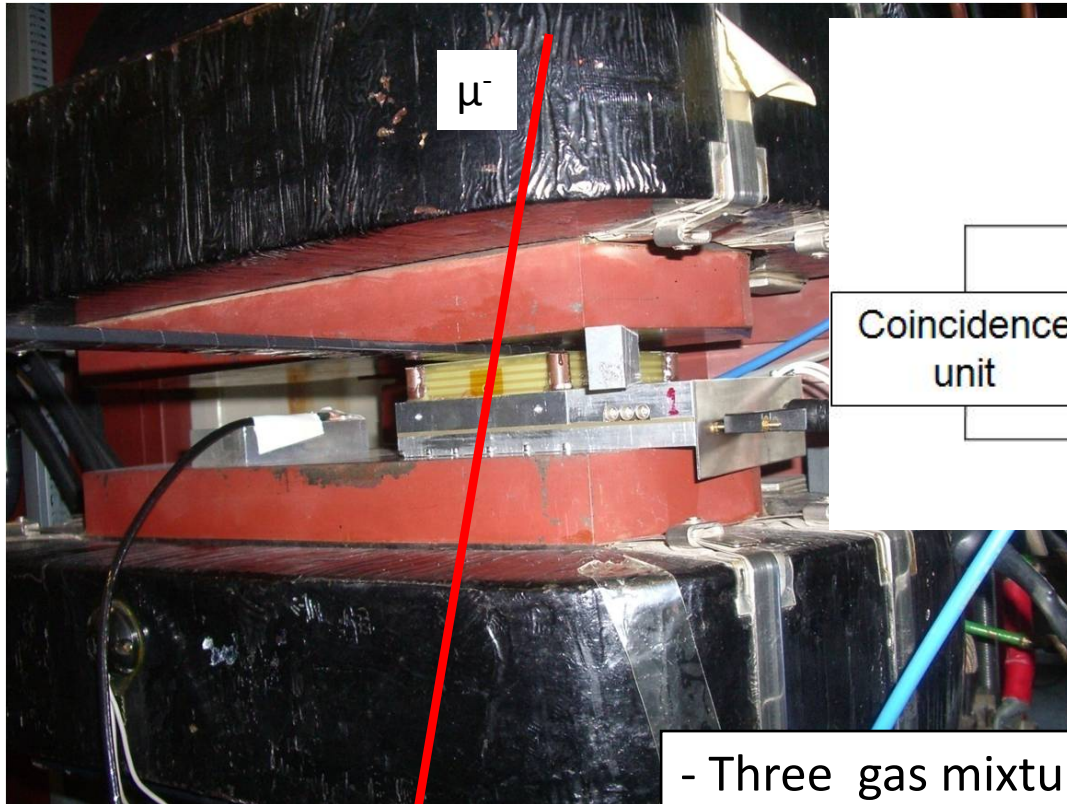
GridPix with Integrated Grid (InGrid)



Research project goals

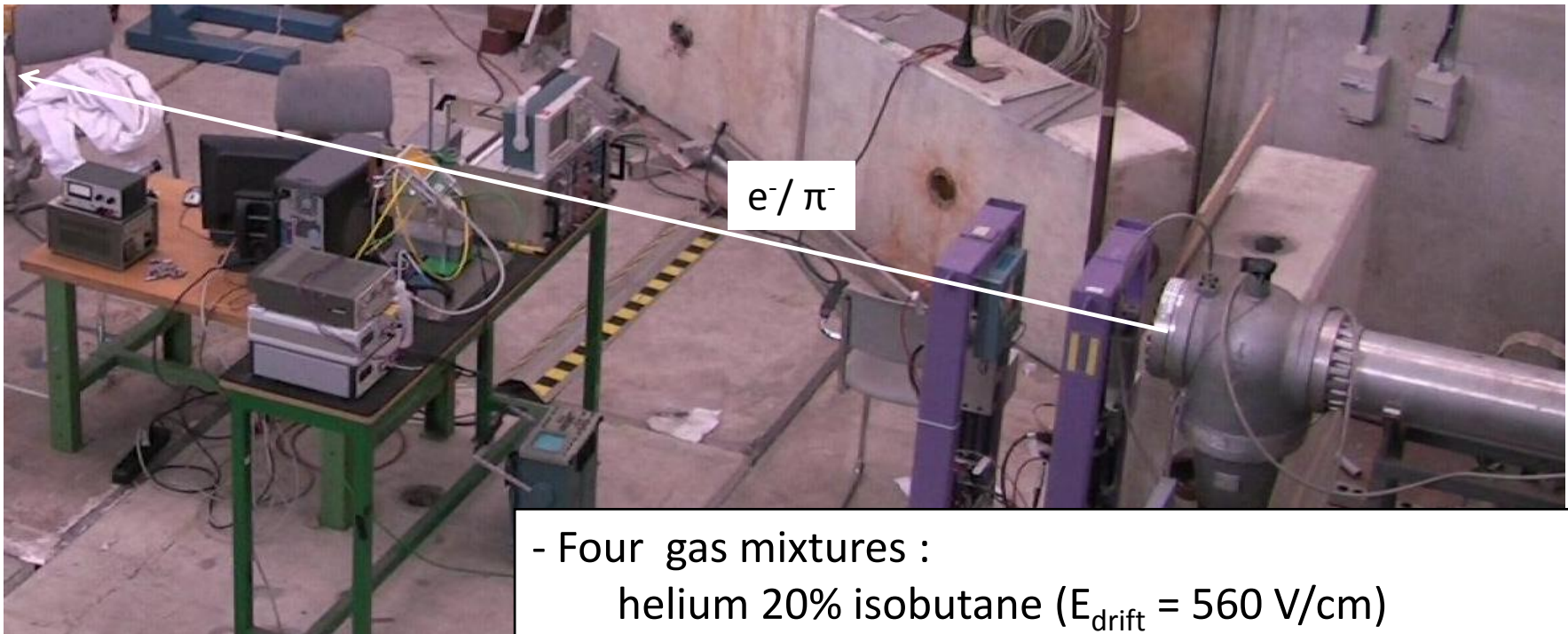
- Test if GridPix can successfully be operated in a magnetic field
- Participate in beam test at PS/T9 at CERN
- Measure transverse diffusion and zero point resolution
- Measure energy loss beam test particles

Measurements Nikhef



- Three gas mixtures :
 - helium 23% isobutane ($E_{\text{drift}} = 600 \text{ V/cm}$)
 - argon 20% isobutane ($E_{\text{drift}} = 600 \text{ V/cm}$)
 - argon 3% CF_4 2% isobutane ($E_{\text{drift}} = 200 \text{ V/cm}$)
- Three different B field strengths (0, 0.5, 1 T)
- 100 triggers in a night

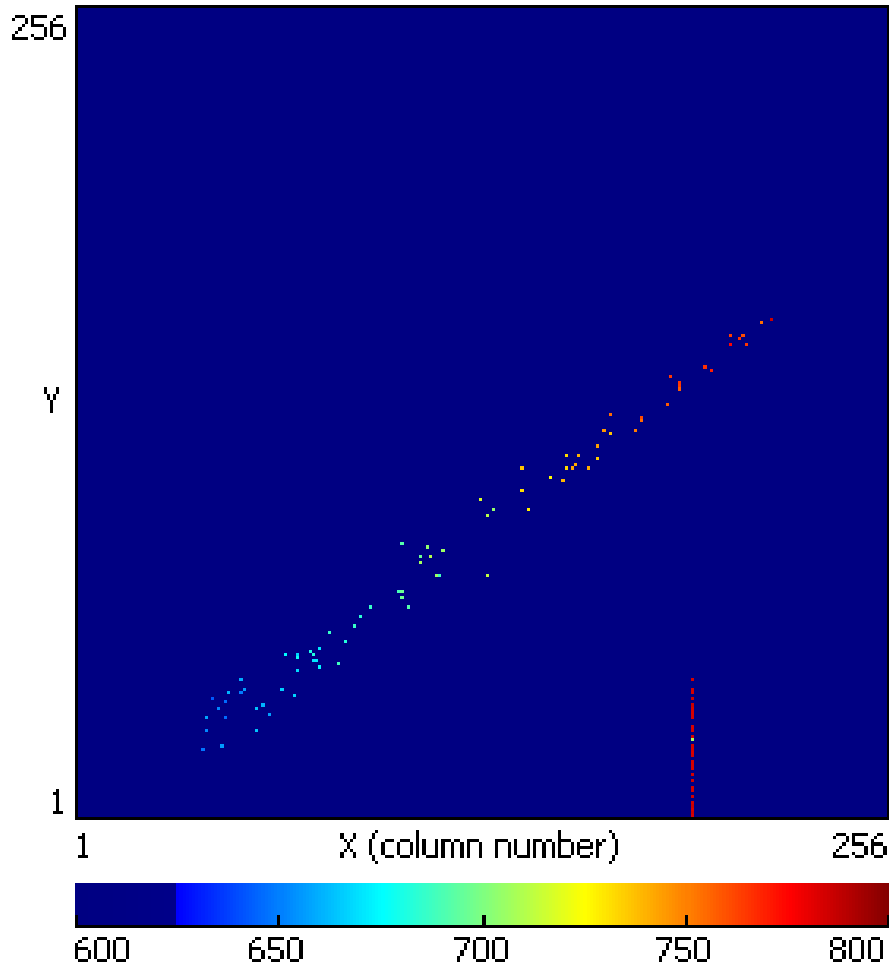
Measurements PS/T9 CERN



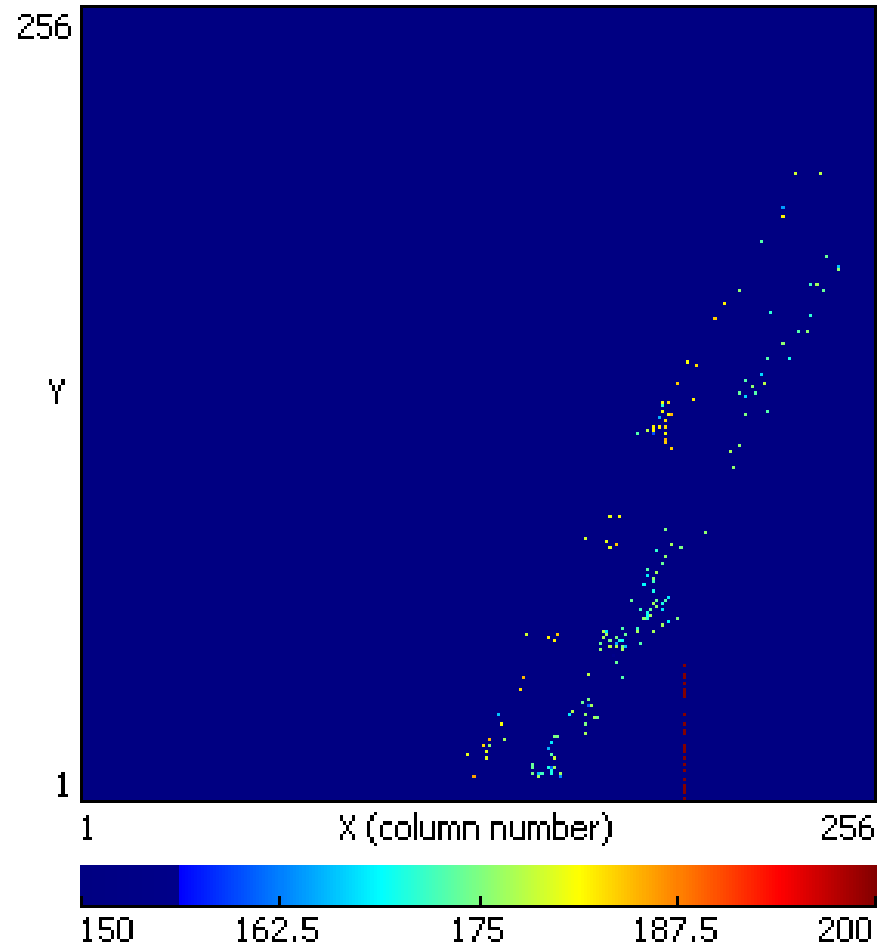
e^-/π^-

- Four gas mixtures :
 - helium 20% isobutane ($E_{\text{drift}} = 560 \text{ V/cm}$)
 - argon 30% CO_2 ($E_{\text{drift}} = 470 \text{ V/cm}$)
 - argon 3% CF_4 2% isobutane ($E_{\text{drift}} = 200 \text{ V/cm}$)
 - xenon 30% CO_2 ($E_{\text{drift}} = 1000, 1400, 1900 \text{ V/cm}$)
- Beam parallel or under 25° angle w.r.t anode
- 25 triggers per minute

Raw output



Nikhef, helium 23% isobutane,
 $B = 0$ T, $V_{\text{grid}} = -420$ V

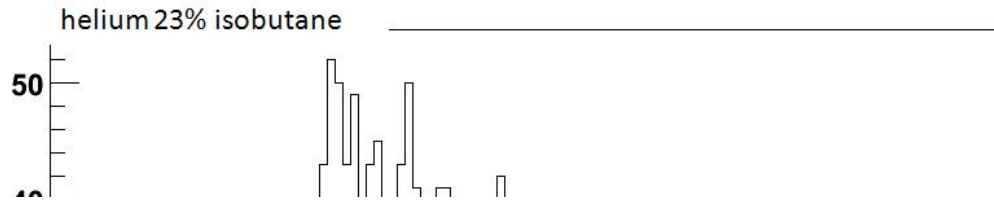


CERN, helium 20% isobutane,
flat wrt anode, $V_{\text{grid}} = -440$ V

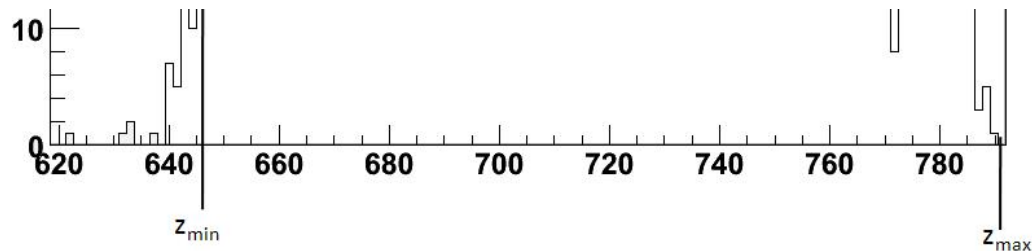
Raw data examining

- Drift velocity
- Number of hits per track
- Removing multipixel hits

Drift velocity



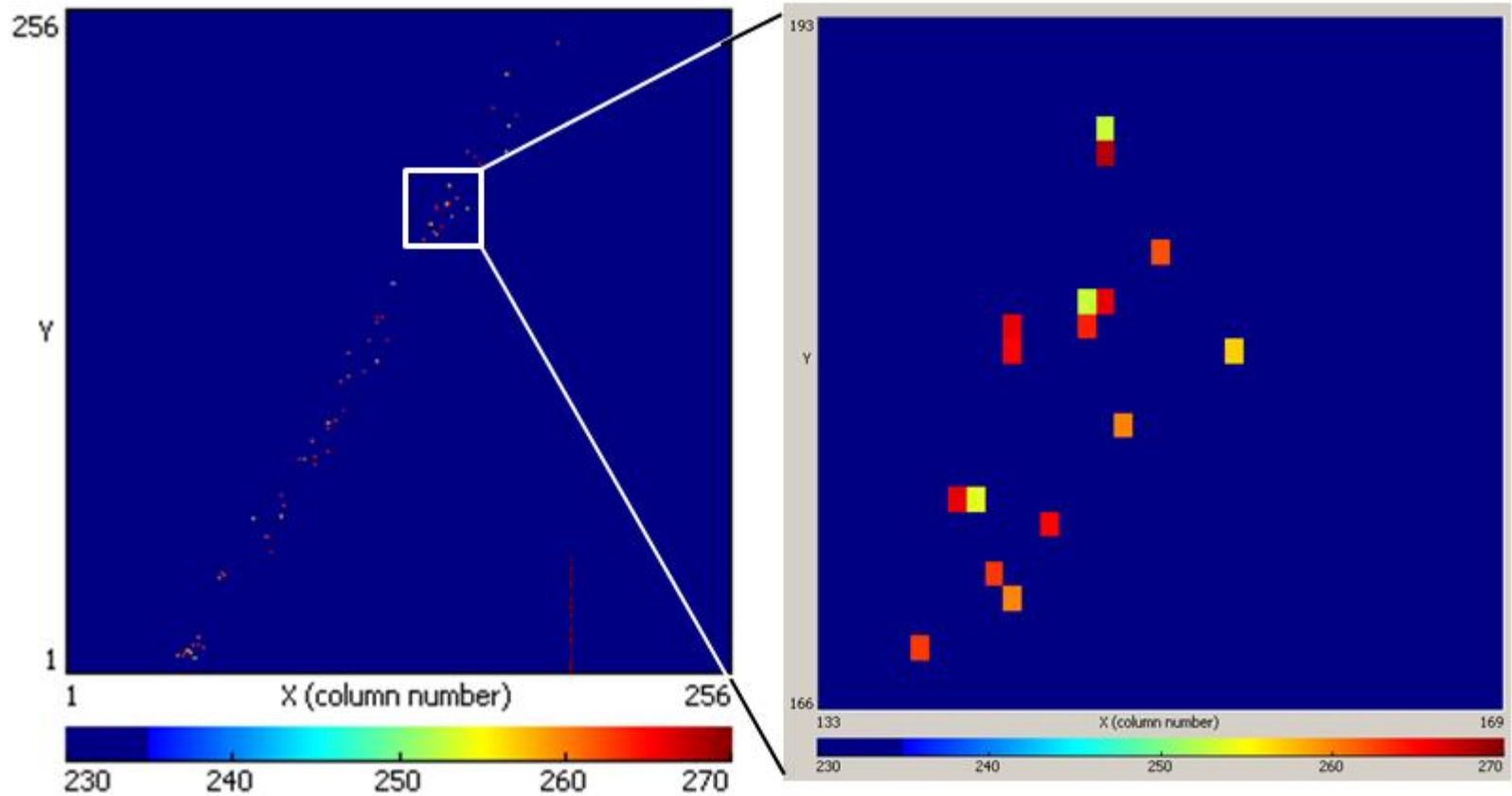
gas	E_{drift} (V/cm)	v_{drift} exp (cm/ μ sec)	v_{drift} measured (cm/ μ sec)
Ar 3% CF ₄ 2% IsoBut	200	7.5	4.3 ± 0.4
Ar 30% CO ₂	470	1.2	1.2 ± 0.1
Xe 30% CO ₂	1000 / 1400 / 1900	1.9 / 3.5 / 5	1.9 ± 0.2 / 3.4 ± 0.3 / 4.9 ± 0.5
He 20% IsoBut	560	2.1	2.2 ± 0.2
Ar 20% IsoBut	600	4.3	4.4 ± 0.4



Hits per track

gas	E_{drift} (V/cm)	$-V_{\text{grid}}$ (V)	N_{hits}
Ar 3% CF ₄ 2% IsoBut	200	320	24
Ar 3% CF ₄ 2% IsoBut	200	340	50
Ar 3% CF ₄ 2% IsoBut	200	360	76
Ar 30% CO ₂	470	430	21
Ar 30% CO ₂	470	440	23
Ar 30% CO ₂	470	460	50
Xe 30% CO ₂	1000	490	102
Xe 30% CO ₂	1400	440	63
Xe 30% CO ₂	1900	460	101
Xe 30% CO ₂	1900	465	121
Xe 30% CO ₂	1900	470	132
He 20% IsoBut	560	400	52
He 20% IsoBut	560	420	57
He 20% IsoBut	560	440	62

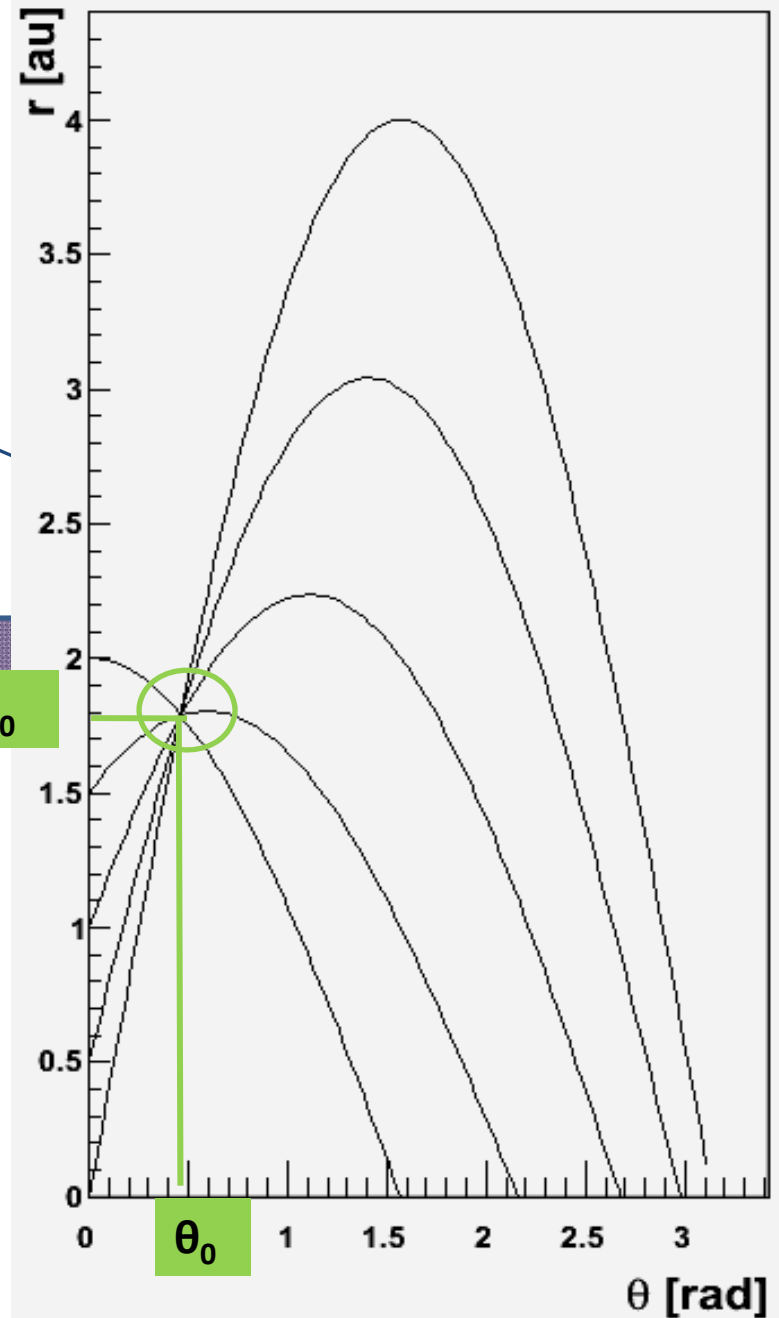
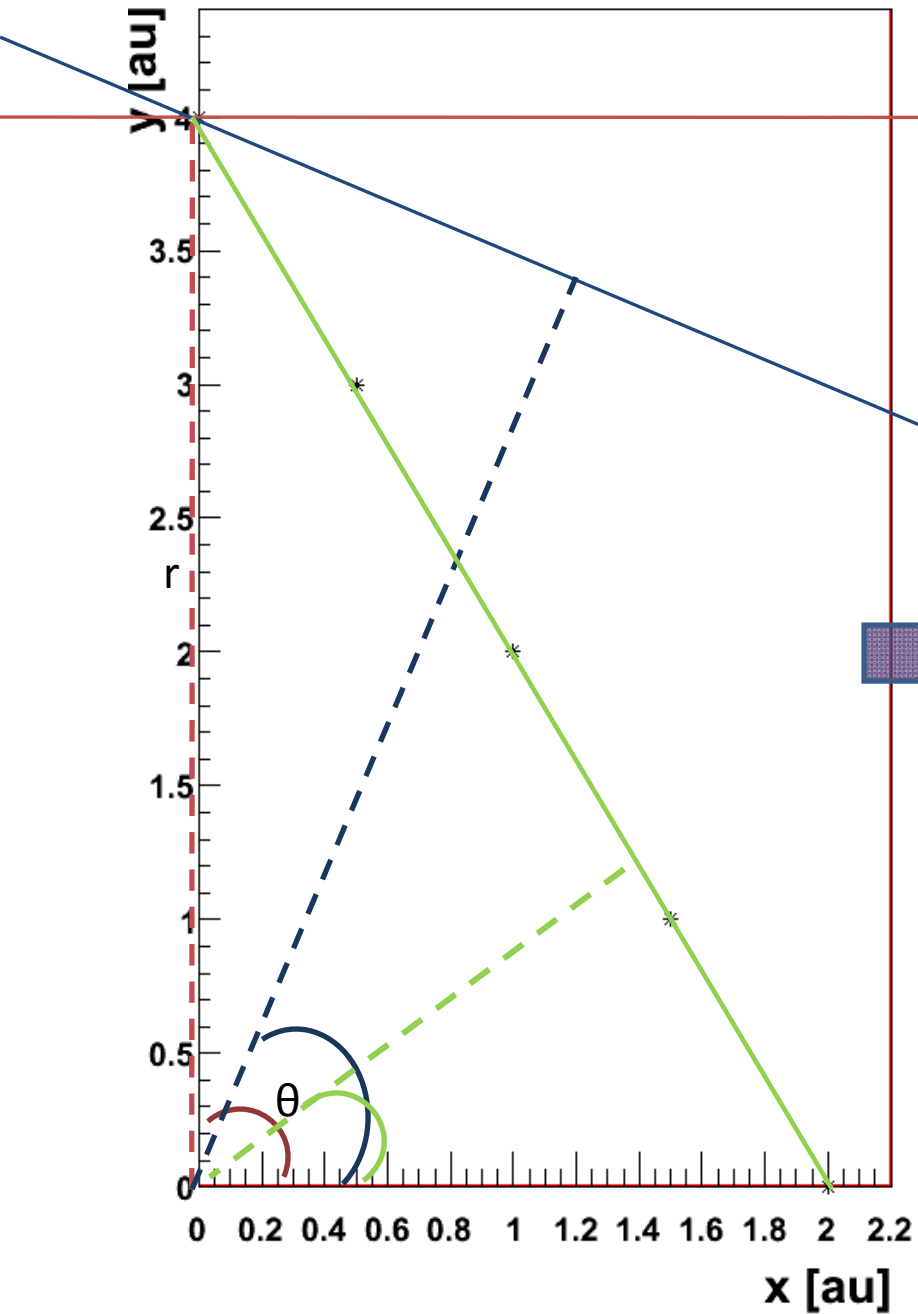
Multi pixels: cluster finding



Analysis steps

- Track finding
- Track fitting
- Goodness of fit test
- Measuring diffusion
- Measuring zero point resolution
- Measuring energy loss

Track Finding: Hough Transform

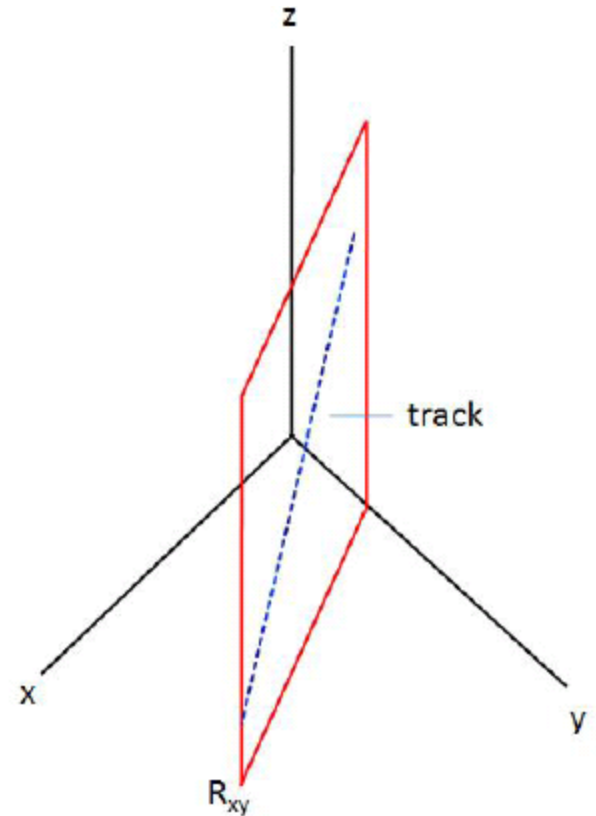


Track fitting

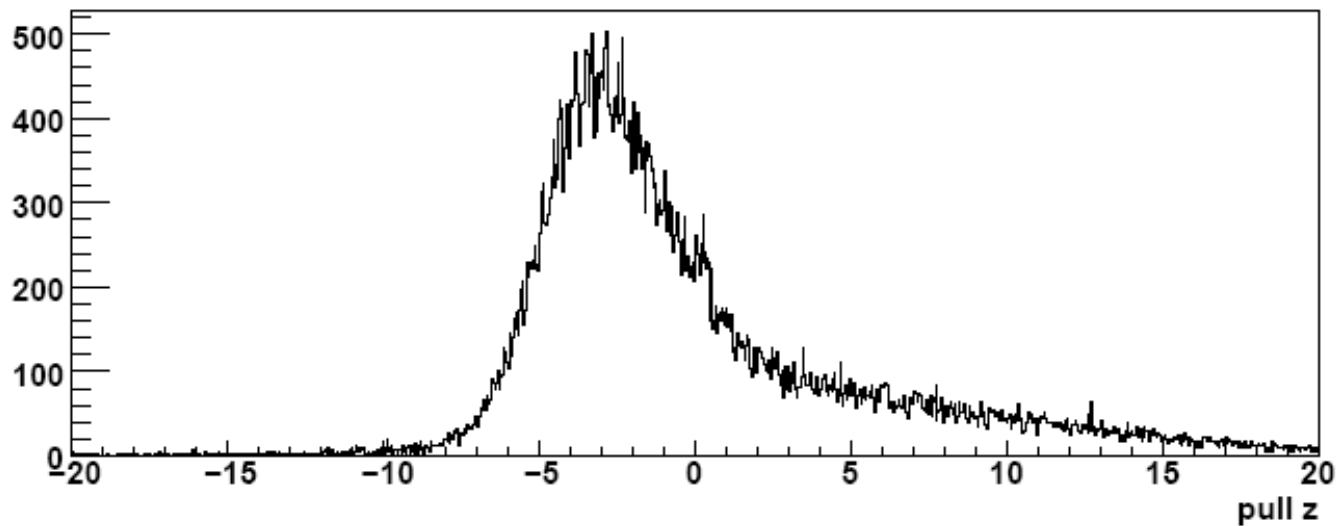
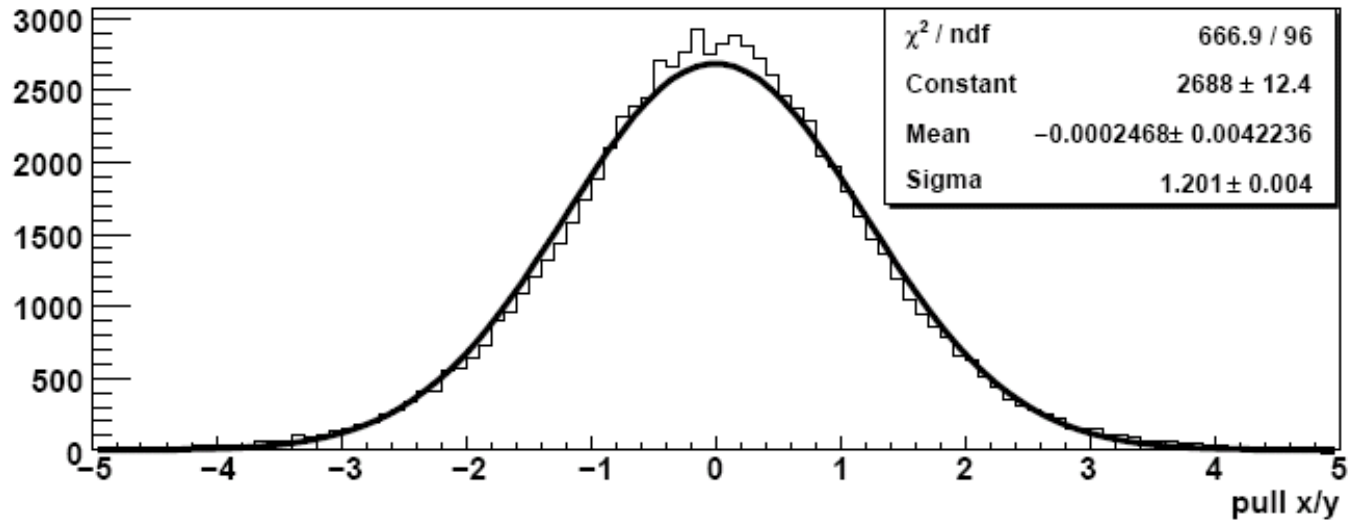
- Only to selected hits
- χ^2 in x/y, with errors in both dimensions:

$$\chi^2(a, b) = \sum_{i=0}^{N-1} \frac{(y_i - a - bx_i)^2}{\sigma_{yi}^2 + b^2\sigma_{xi}^2}$$

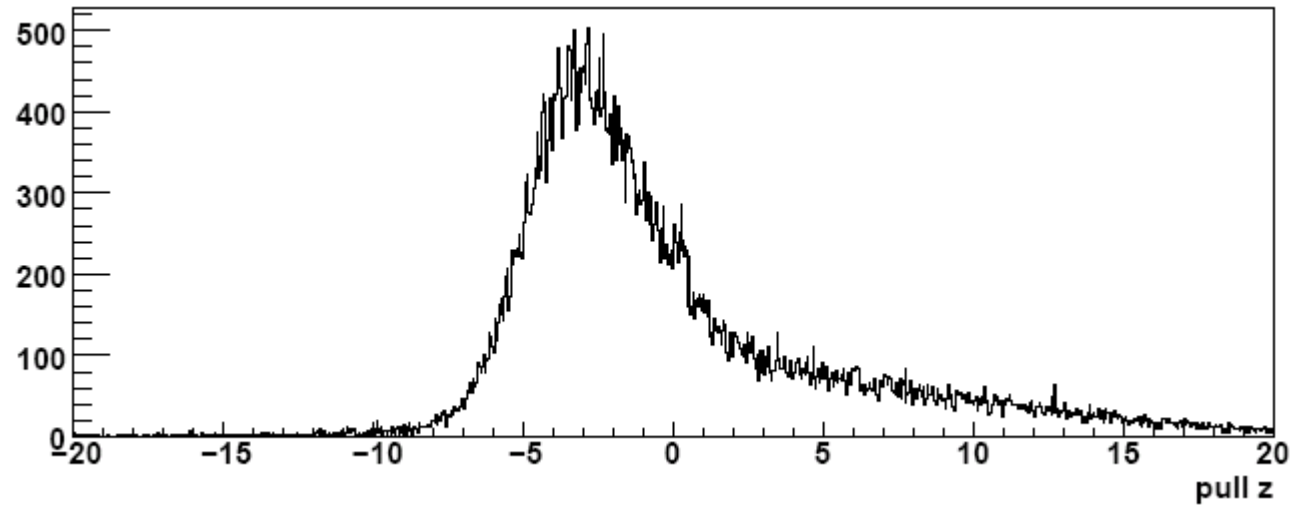
- χ^2 in R_{xy}/z



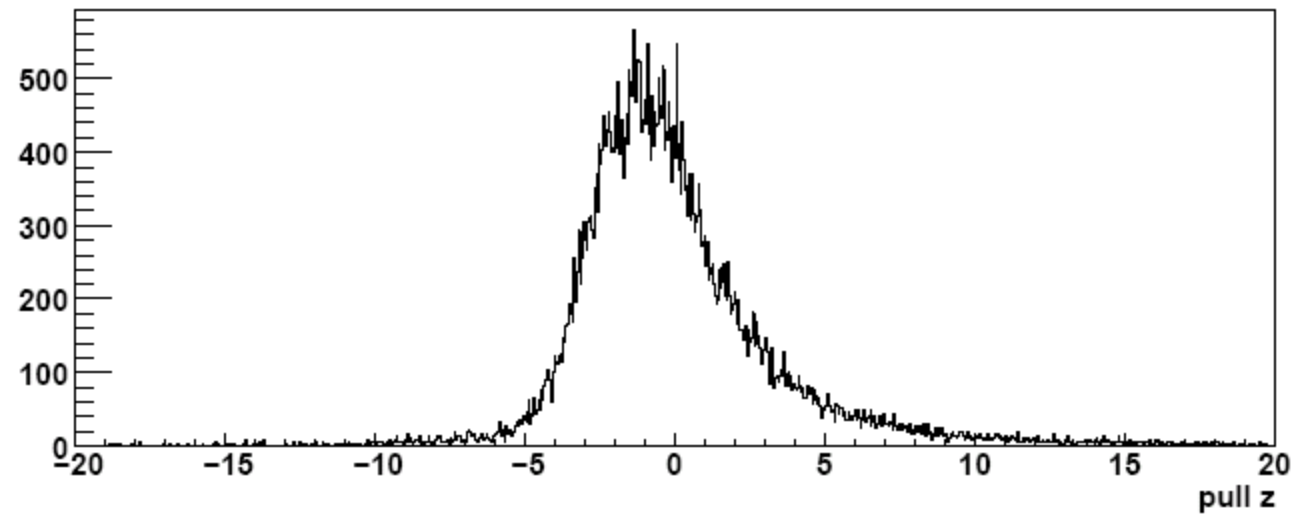
Goodness of fit



Goodness of fit in z



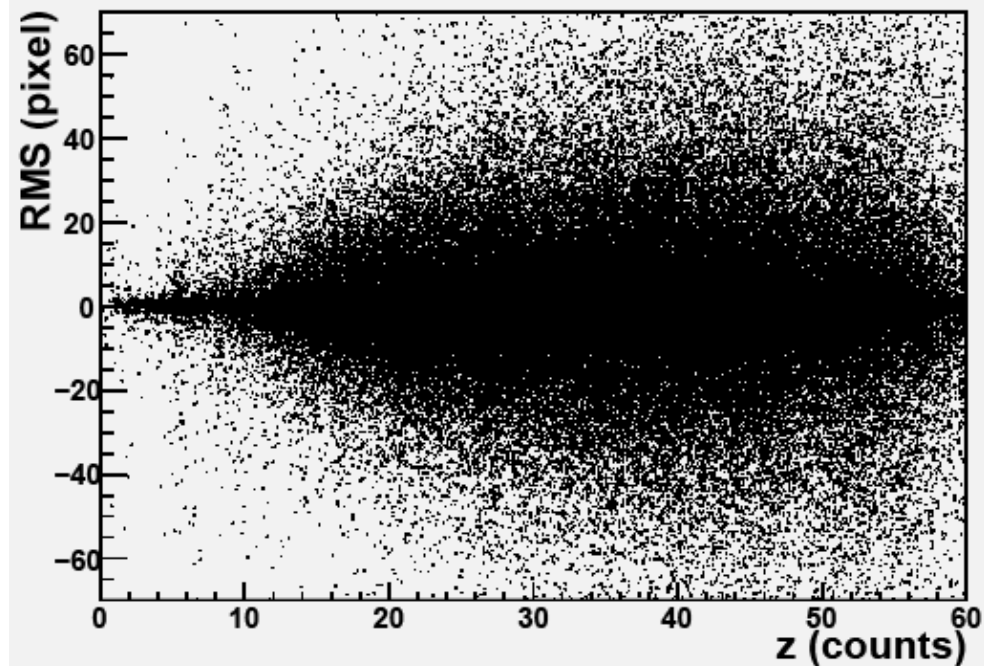
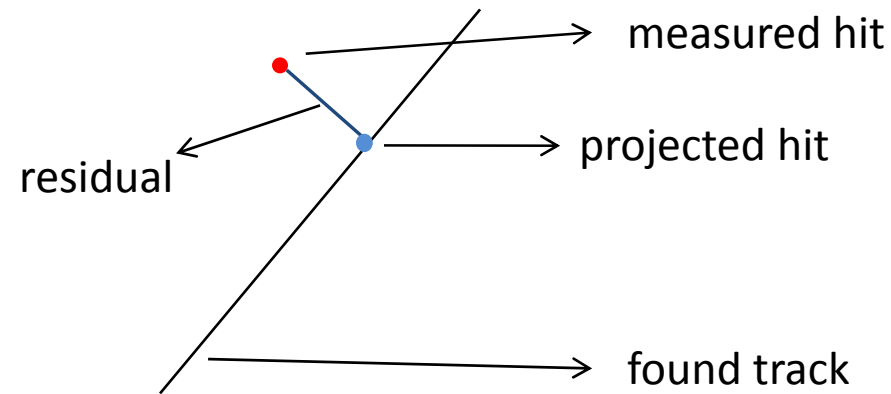
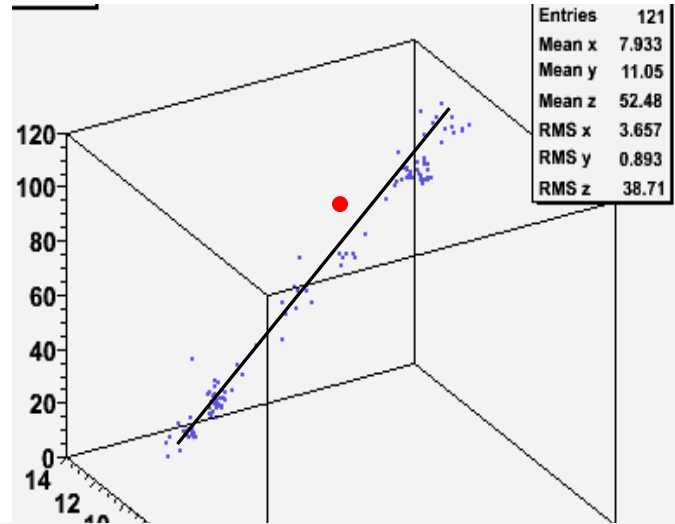
Not removed



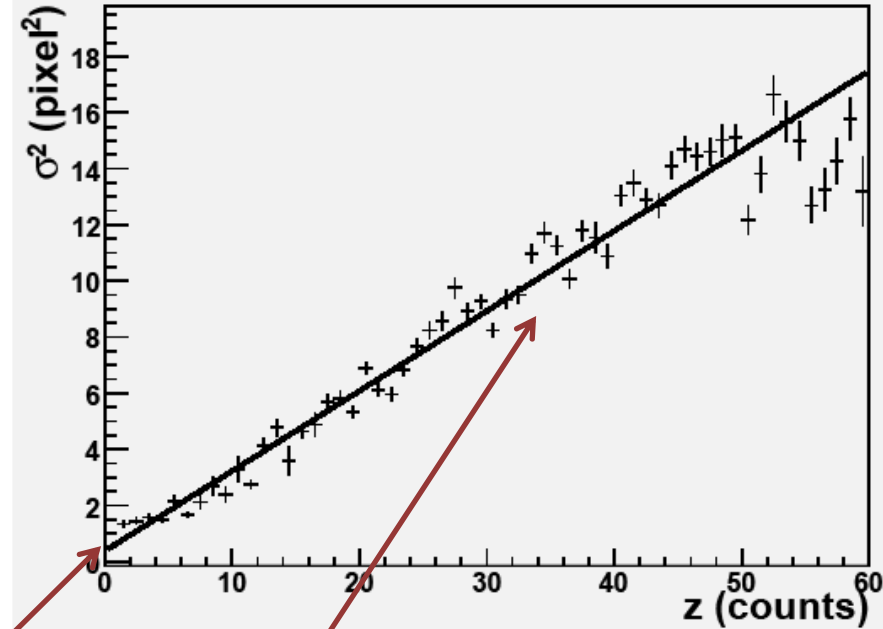
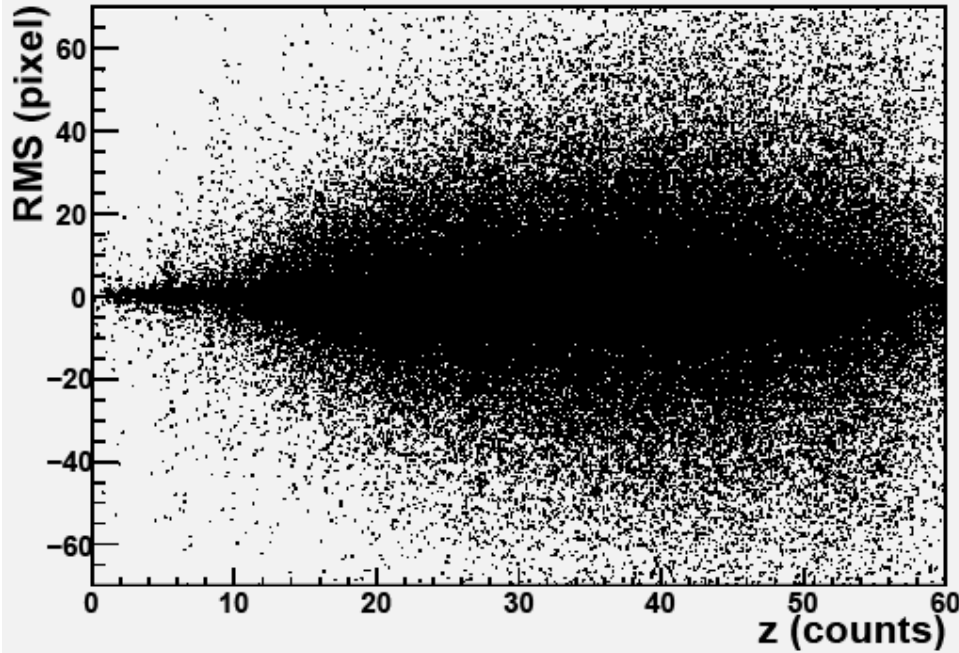
Removed

Measuring diffusion

$$res^2 = \frac{pixel^2}{12} + D_t^2 z$$



Fit Slices



intersection

slope

$$res^2 = \frac{pixel^2}{12} + D_t^2 z$$

Results diffusion and zero point

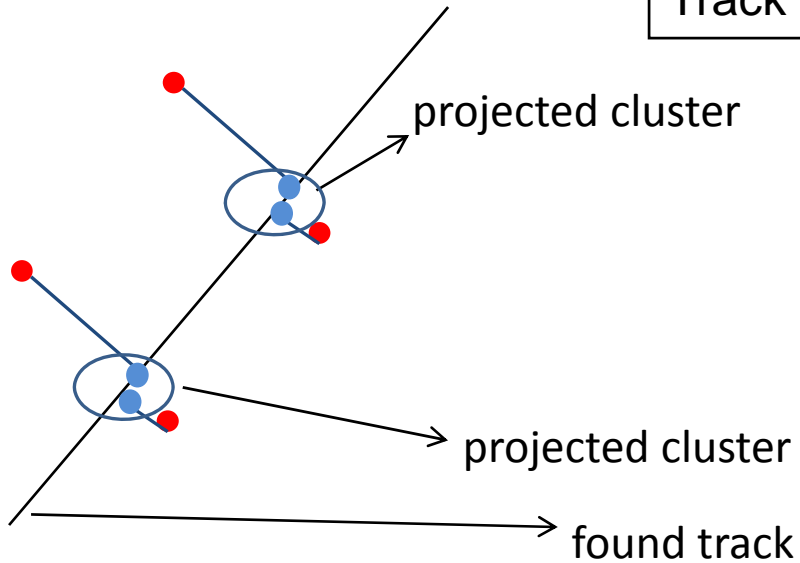
gas	E_{drift} (V/cm)	D_t exp ($\mu\text{m}/\sqrt{\text{cm}}$)	D_t measured ($\mu\text{m}/\sqrt{\text{cm}}$)	$\sigma_{xy,0}$ (μm)
Ar 3% CF ₄ 2% IsoBut	200	290	138 ± 2.5	35 ± 11
Ar 30% CO ₂	470	148	80 ± 2	24 ± 7
Xe 30% CO ₂	1000	185	40 ± 8	30 ± 15
Xe 30% CO ₂	1400	103	134 ± 3	23 ± 11
Xe 30% CO ₂	1900	110	171 ± 4	17 ± 14
He 20% IsoBut	560	175	176 ± 2	27 ± 14

Diffusion & zero point

- Diffusion measurable
- Results obtained in gas mixtures with helium consistent with calculations
- Not all measurements consistent with calculations
- Zero point resolution measured with large error
- Due to large error on z (count) measurement

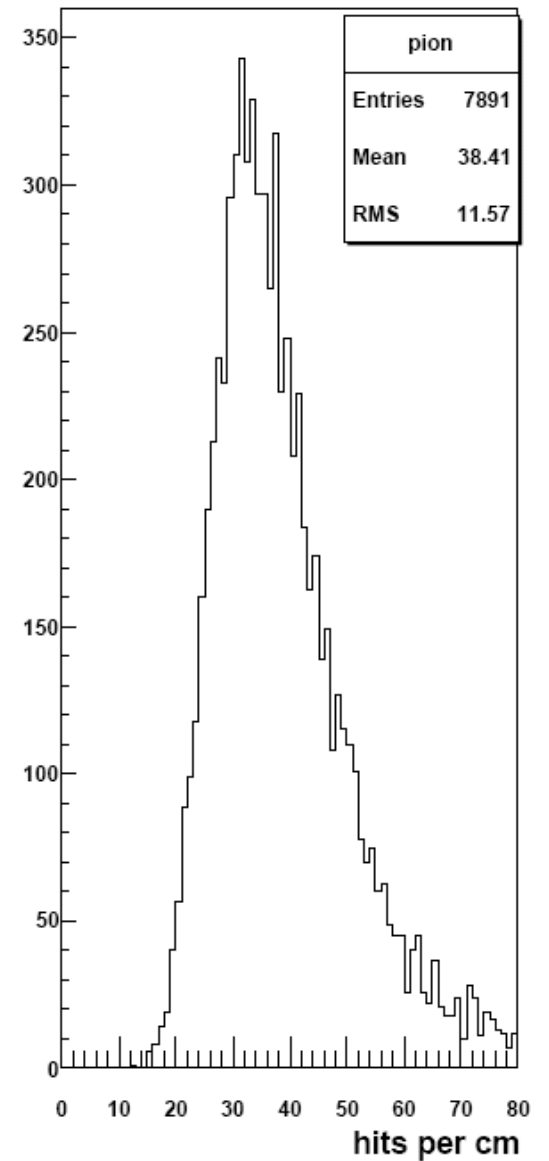
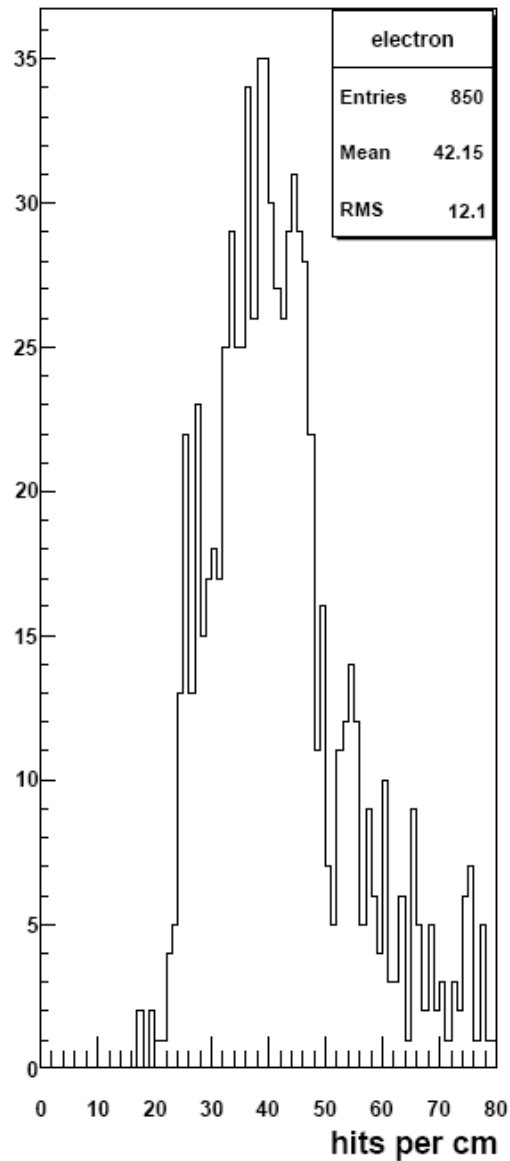
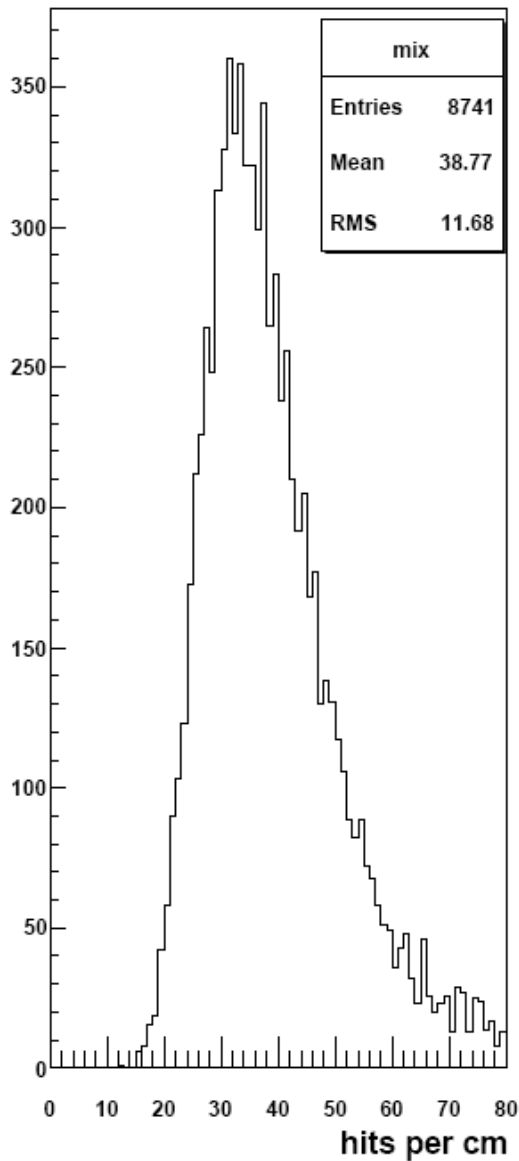
Energy loss

Track length known (horizontal tracks)

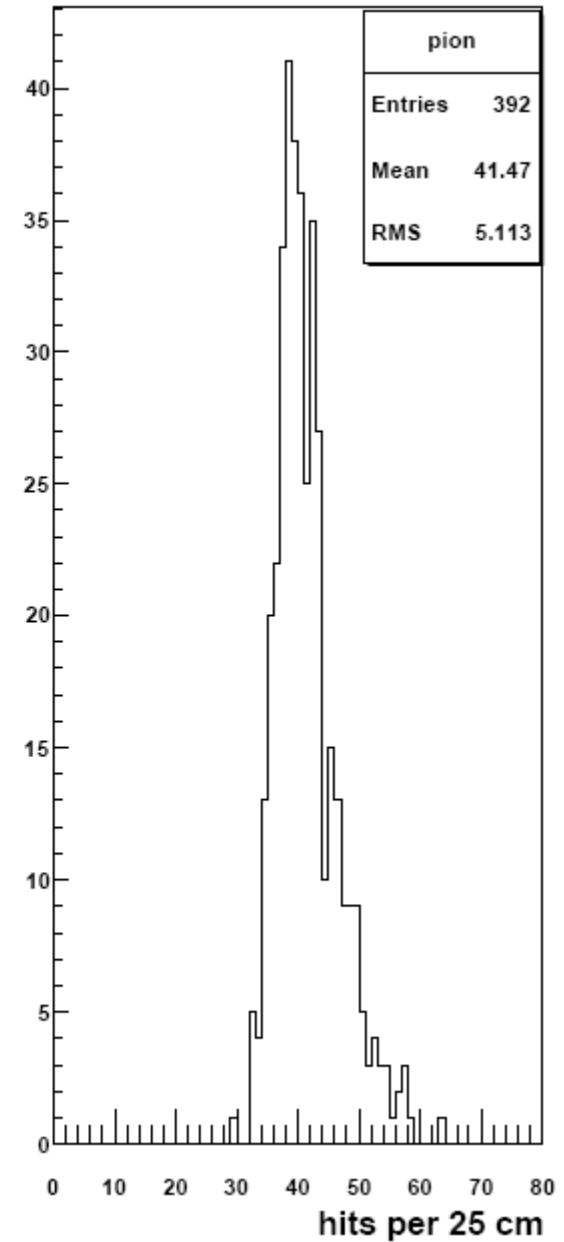
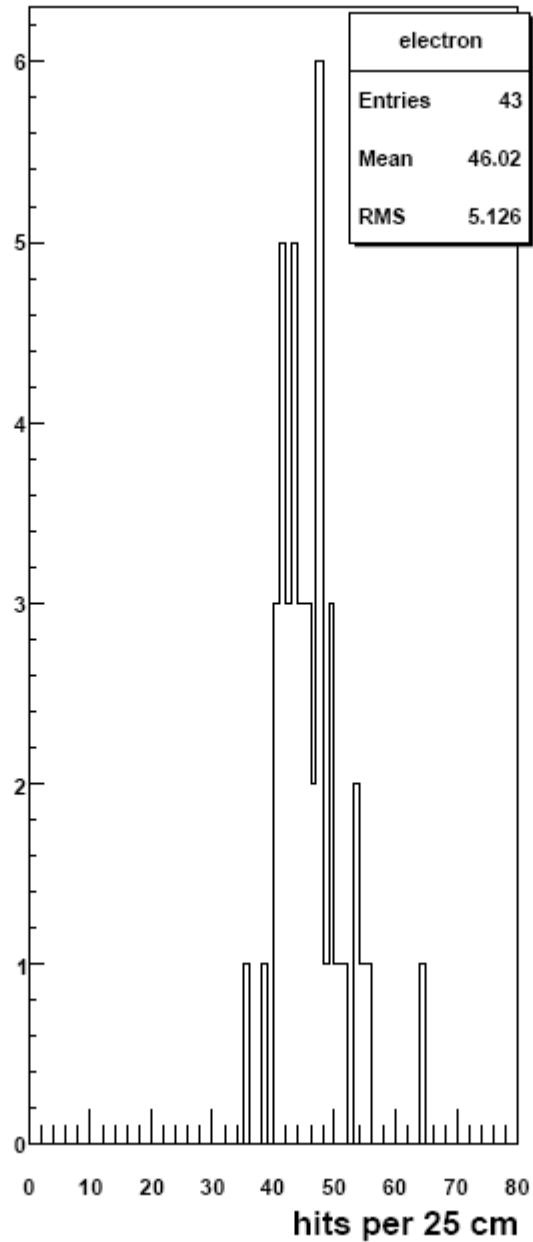
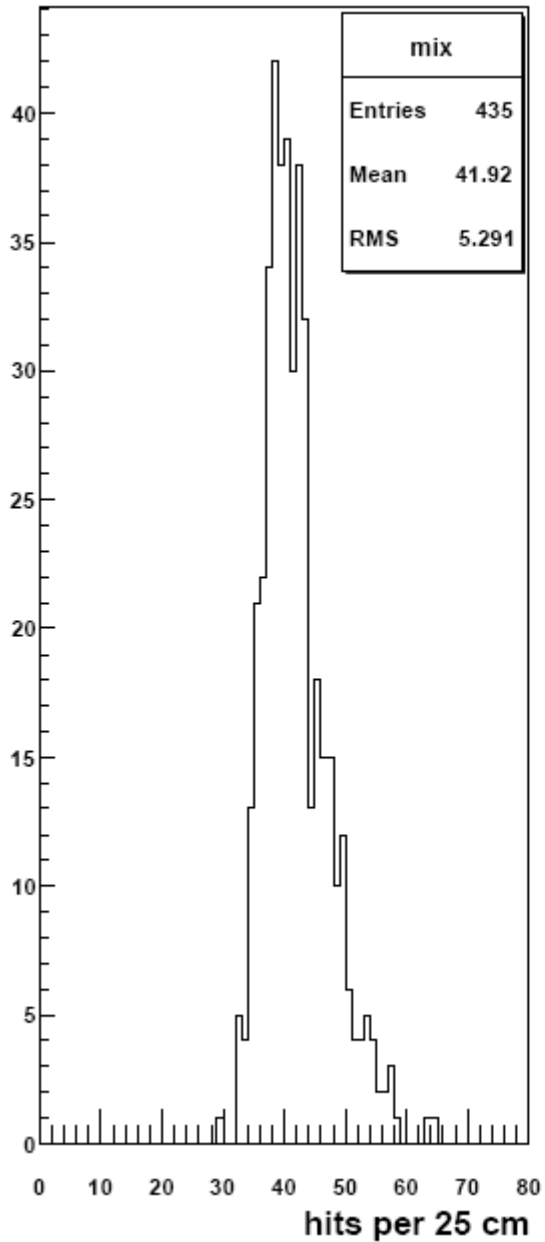


Is there a difference between counting projected clusters and counting projected hits?

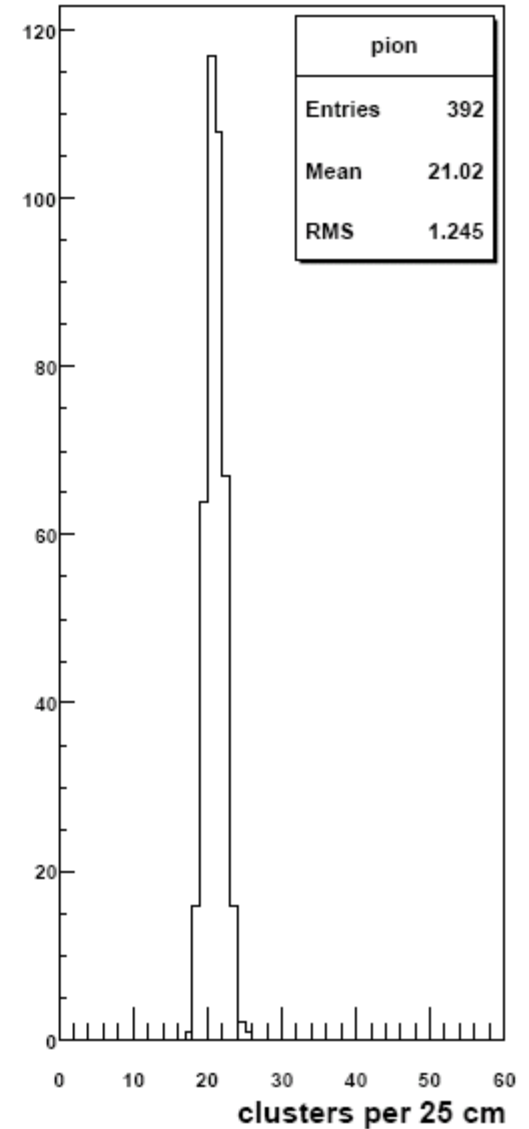
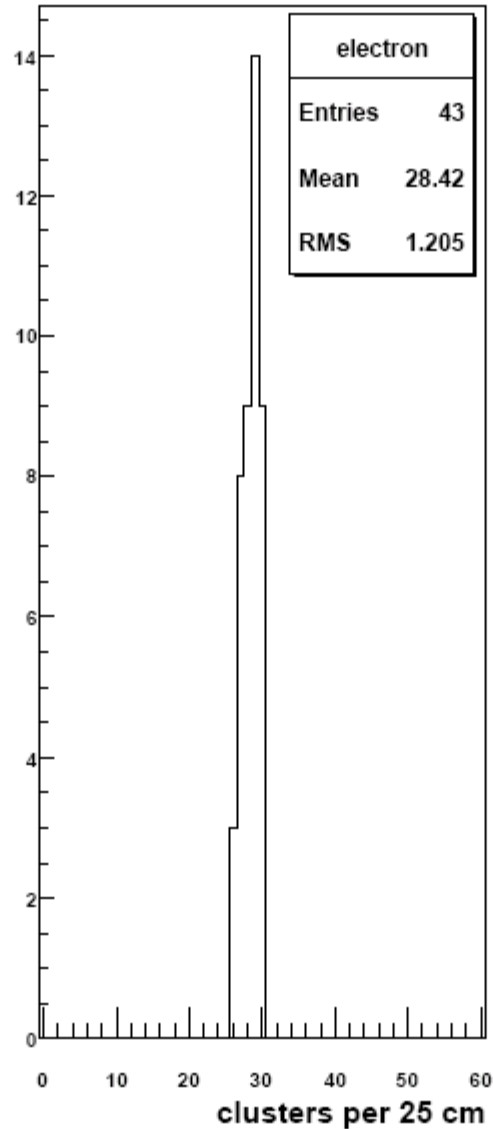
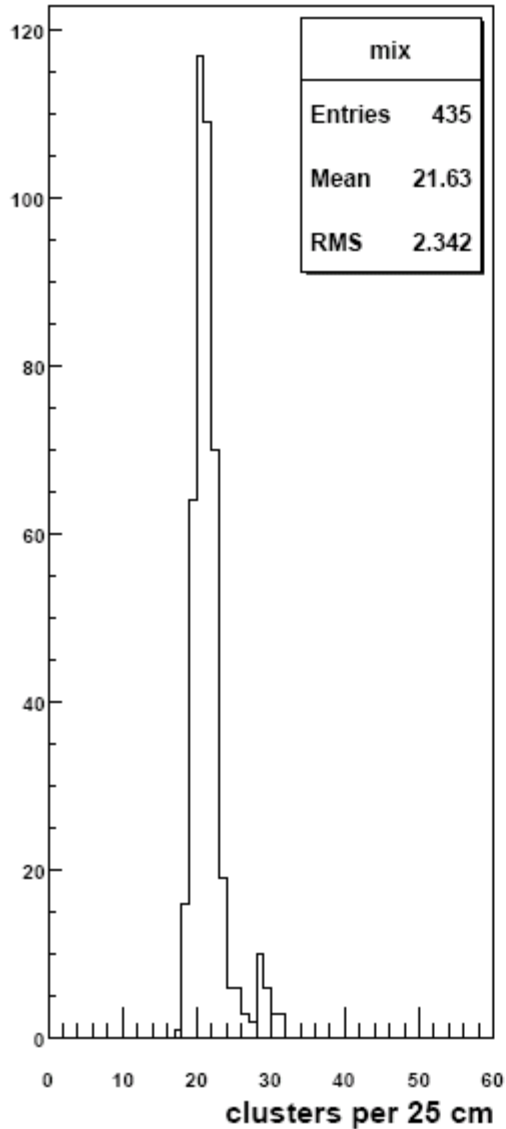
Projecting hits



Longer track



Projecting clusters




Conclusions

- Removing multi pixel hits improves fitting results, but reduces information on charge deposited
- Hough transform is very powerful, but can be overkill in this case;
- Only χ^2 -fit very fast in terms of computing time;
- May need another way to measure zero point resolution;

Conclusions

- It is useful to identify clusters for energy loss measurement;
- With tracks of 25 cm length, particle identification up to 4.4σ is possible ; (In the ILC tracks of 1.2m are expected.)

A large, blue, smiling shark with sharp teeth is shown from a close-up perspective. The shark's mouth is wide open, revealing rows of sharp, white teeth. In the center of the shark's mouth, two small fish, Nemo and Dory, are swimming. Nemo is orange with white stripes, and Dory is blue with white stripes. They both have wide-eyed, surprised expressions. The background is a deep blue, suggesting an underwater environment. A semi-transparent white rectangular box is overlaid across the middle of the shark's mouth, containing the word "Thanks" in a black, sans-serif font.

Thanks