

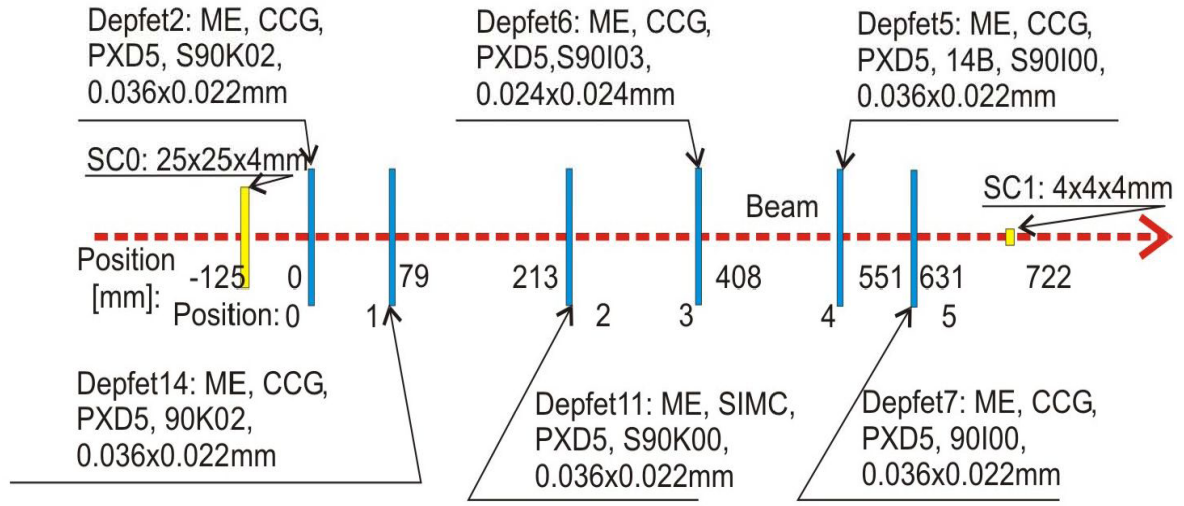
In-Pixel homogeneity and position reconstruction studies

Lars Reuen, University of Bonn

Overview

1. Reminder:
 - Test Beam 2008 setup & operation, Data analysis
2. In-pixel homogeneity studies
3. Position reconstruction studies:
 - Energy dependence of ETA
 - Charge cloud approximation fit
 - Multivariate methods
4. Summary

1 - Reminder: TB 2008 setup

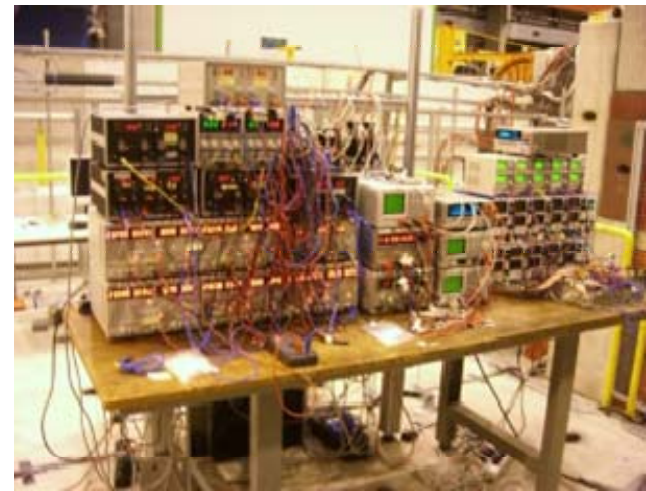


**CERN SPS,
120 GeV pions**

**ILC prototype
system:
64 x 128 PXD5**

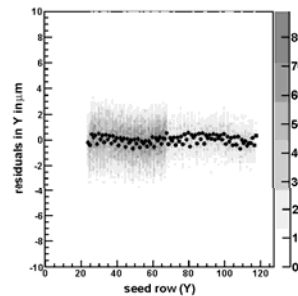
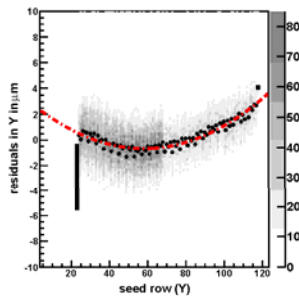
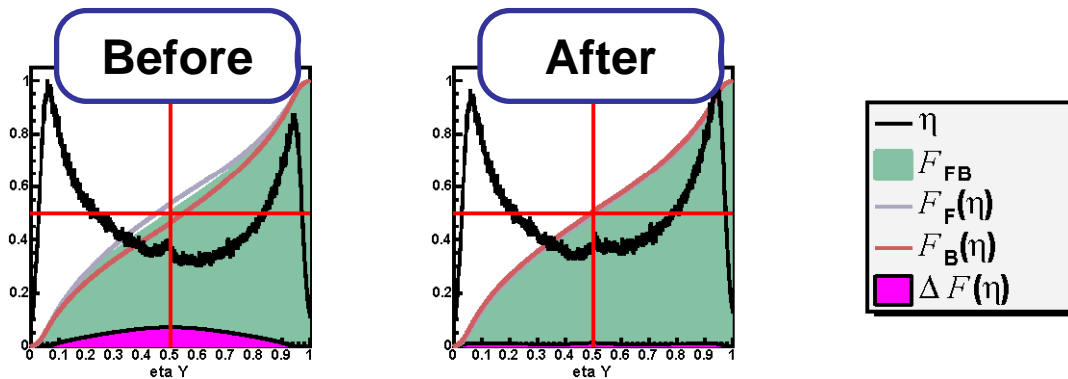
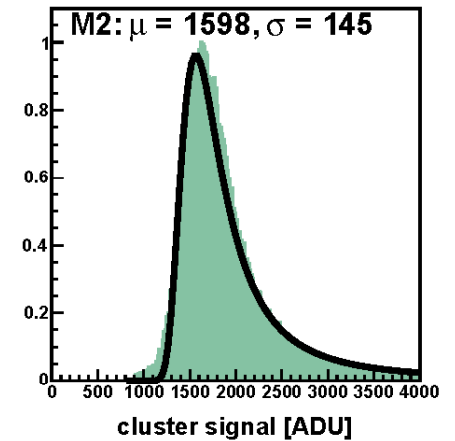
**6 sensor layers,
Old power supply
setup**

**No dedicated power supply system
→ To some modules suboptimal
bias voltages applied**

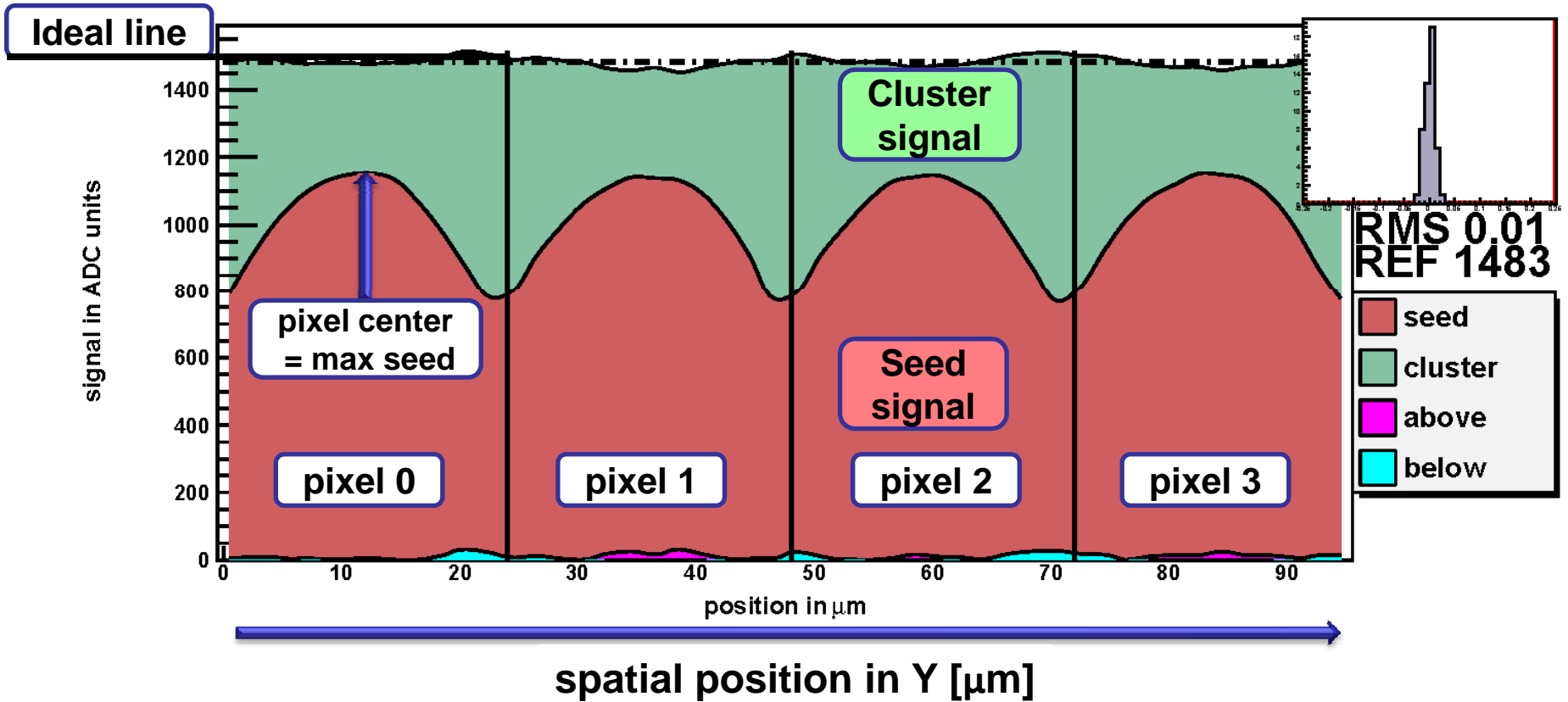


1 - Reminder: data analysis

- Pedestal & Common Mode correction
- Hit finding, Clustering & Masking
- Position reconstruction (ETA)
- Alignment & Tracking
- Advanced correction (specific to TB 2008)



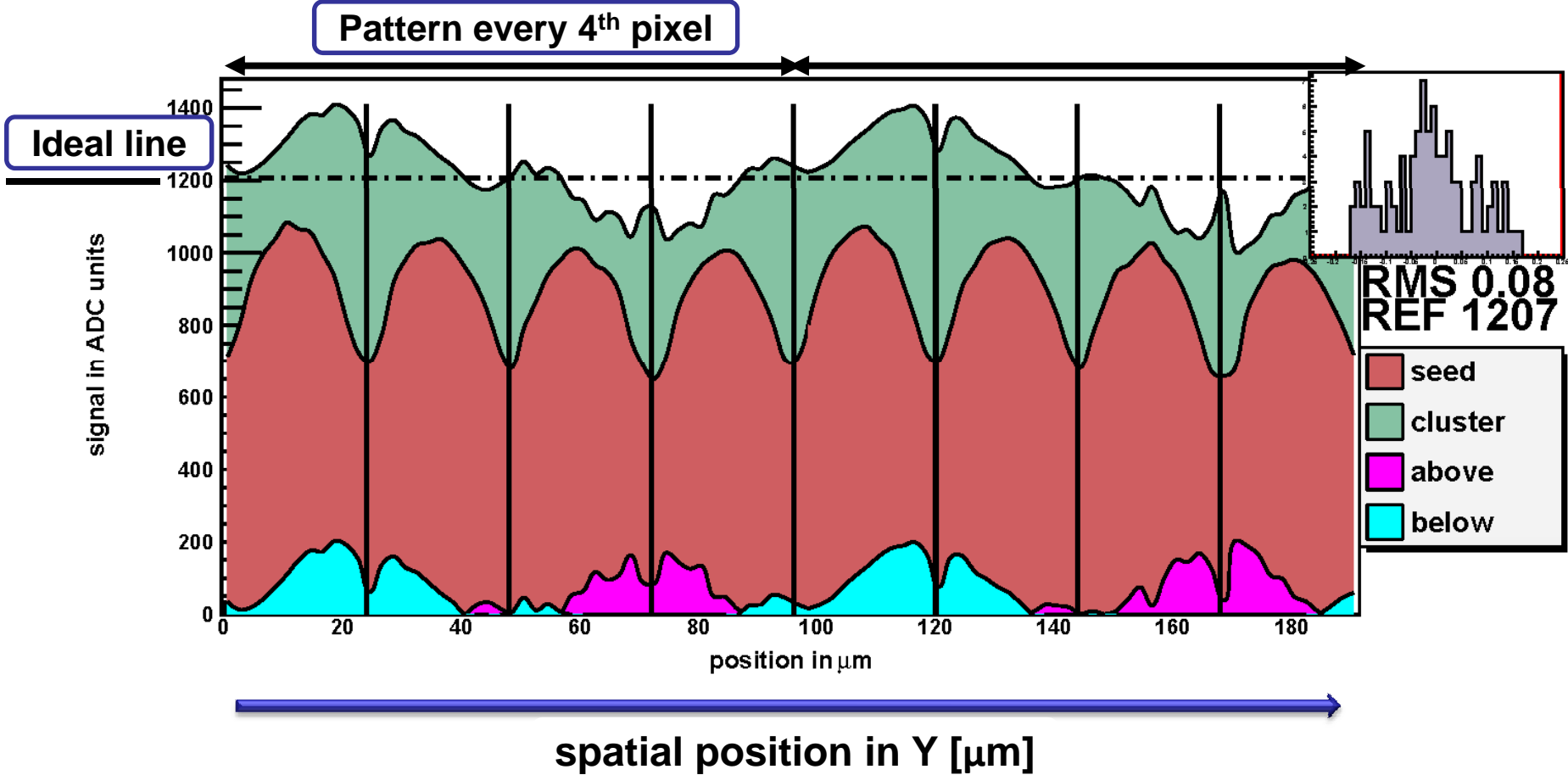
2 - In-pixel homogeneity studies



For statistical reasons:
Only projected on X and Y axis

In-pixel studies on
scale of 2 to 8 pixels

2 - In-pixel homogeneity studies

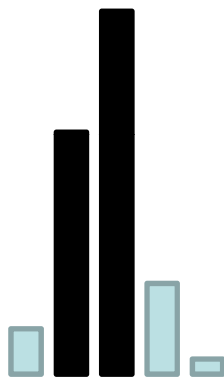


Worst case: module 5,
Biasing problems

In-pixel inhomogeneities
on a four pixel scale

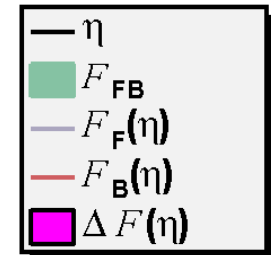
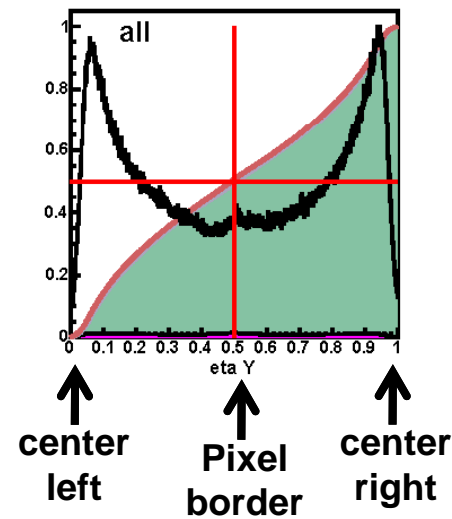
3 – Position reconstruction studies

- Energy dependence of resolution (δ -e⁻)
- Are there better alternatives to η



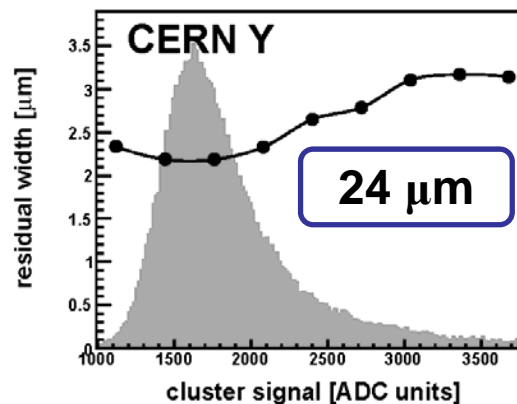
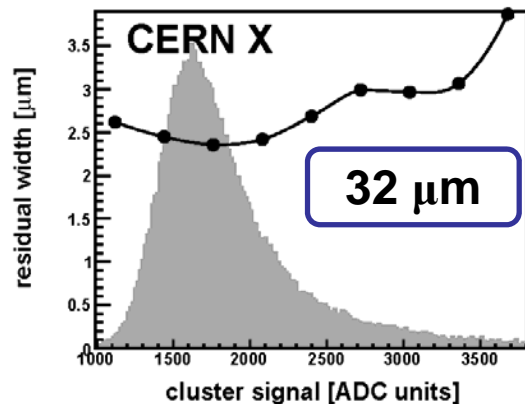
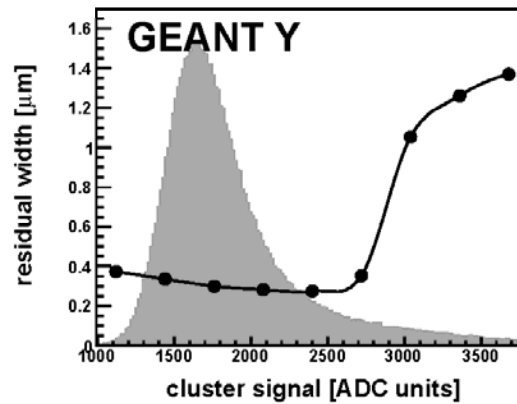
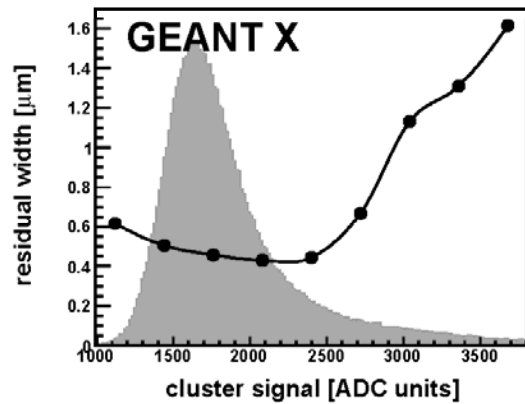
η : two highest signals

$$\eta = \frac{S_L}{S_L + S_R}$$



3 – Position reconstruction studies

- Energy dependence of resolution (δ -e⁻)
- Are there better alternatives to η



Study done with TB and MC data

Higher cluster energy means more δ -e⁻

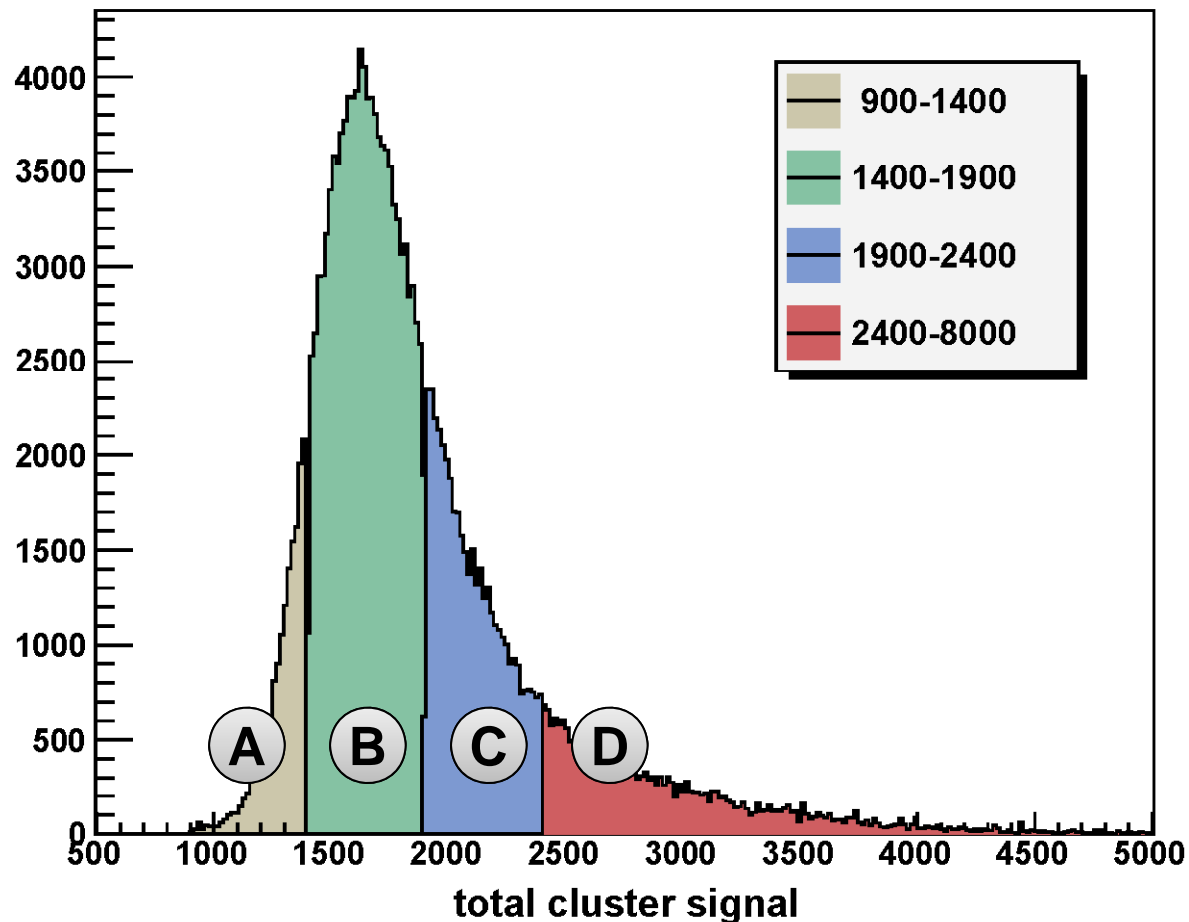
First approach: Multiple η for different energies

3 – Position reconstruction studies

- Energy dependence of resolution ($\delta-e^-$)
- Are there better alternatives to η

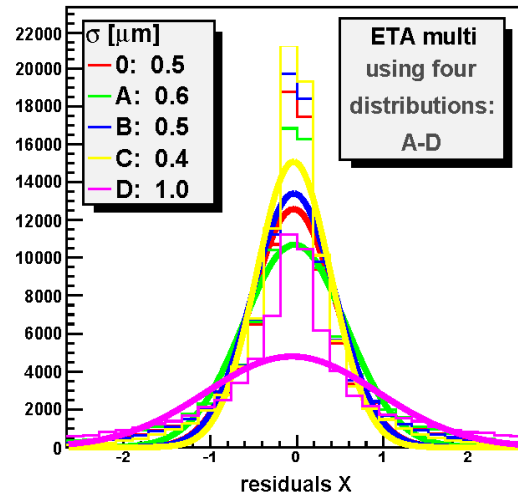
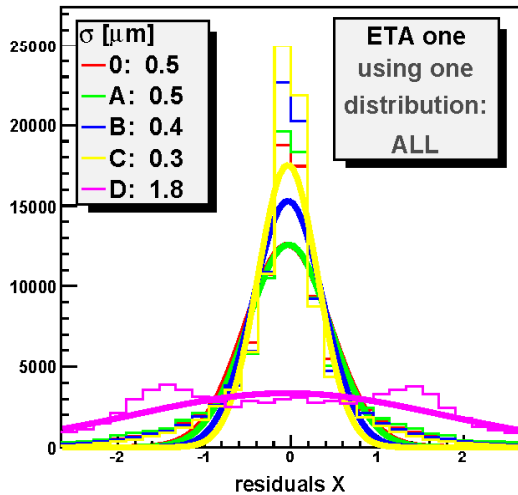
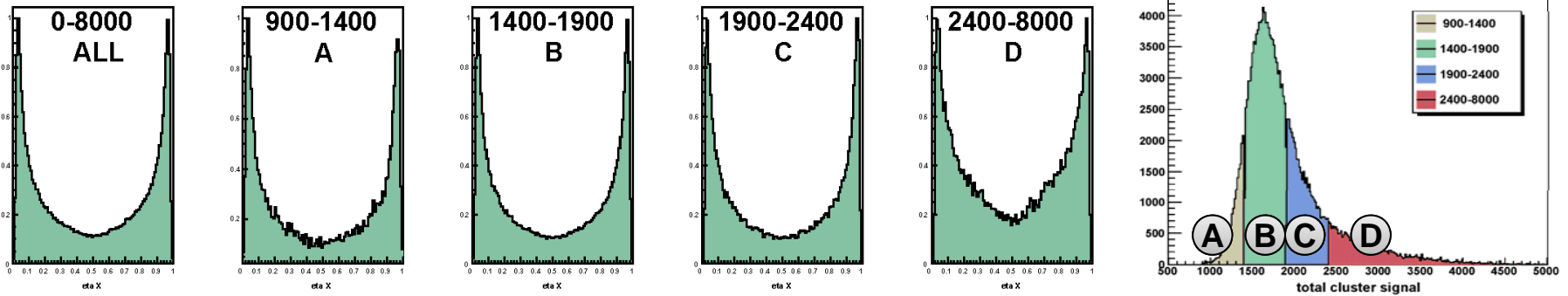
Multiple η for different energies

Split signal spectrum into different energies



3 – Position reconstruction studies

- Energy dependence of resolution (δ -e⁻)
- Are there better alternatives to η



Multiple η for different energies

improves resolution for high energies

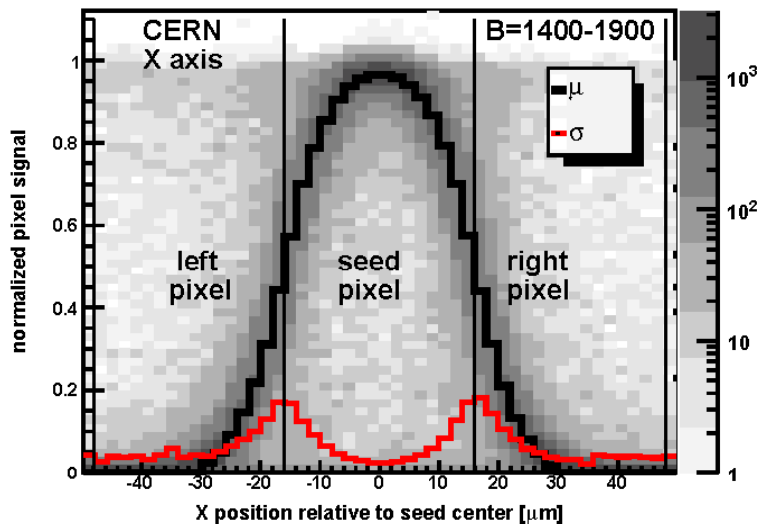
3 – Position reconstruction studies

- Energy dependence of resolution (δ -e⁻)
- Are there better alternatives to η

charge cloud shape

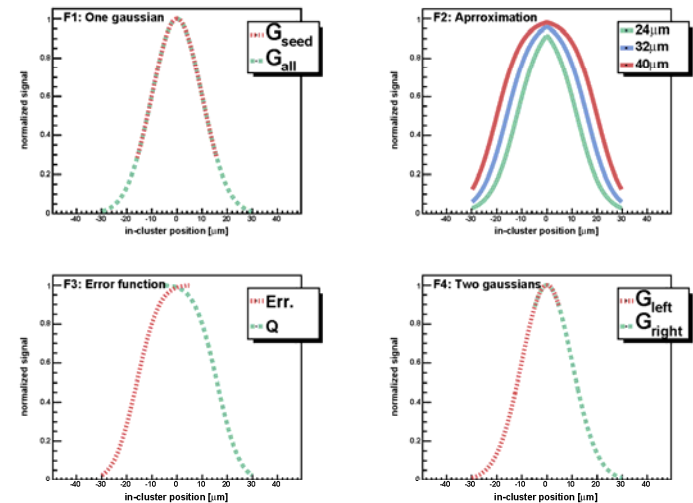
1

Sample charge cloud shape (separated by energy)



2

Four simple approximations (F1 - F4)



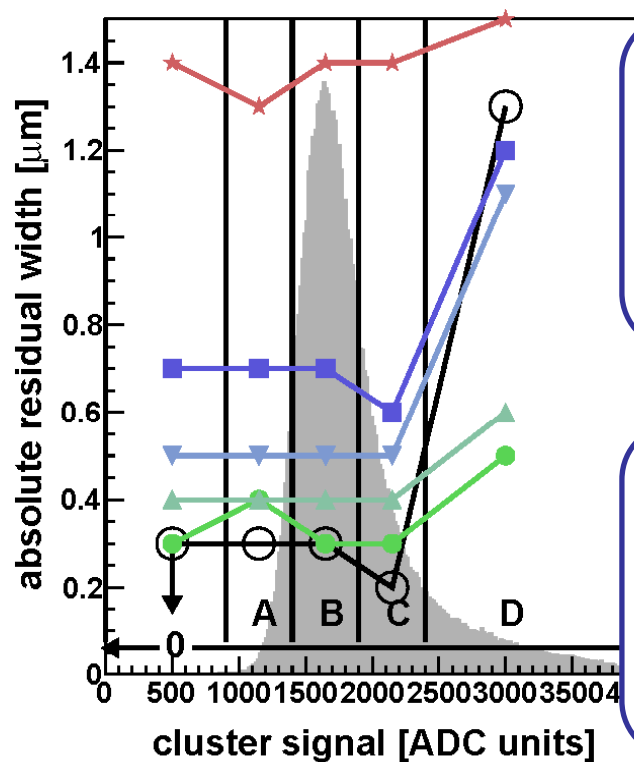
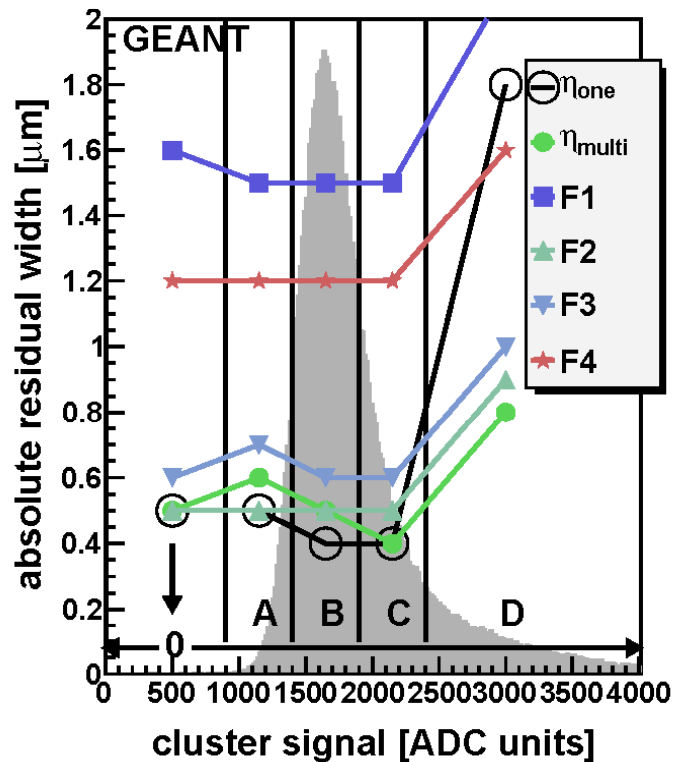
3

Use shape/fit and three pixel signals for position fit

3 – Position reconstruction studies

- Energy dependence of resolution ($\delta-e^-$)
- Are there better alternatives to η

➔ charge cloud shape



Energies ~ MPV:

1. Standard η
2. Multiple η
3. Cloud shape minor differences

High energies:

1. Multiple η
2. Cloud shape
3. Standard η major differences

3 – Position reconstruction studies

- Energy dependence of resolution ($\delta-e^-$)
- Are there better alternatives to η

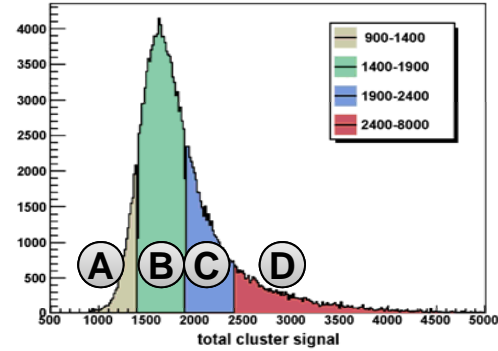
Multivariate analysis

1. Neural Network (MLP)
2. Boosted Decision Tree (BDT)
3. Probability Density Estimator (PDE)
4. Linear Discriminate (LD)

TMVA/root implementation

Study for all events and for separated energies ranges

- 1 Selection of Input Variables
- 2 Training → Testing

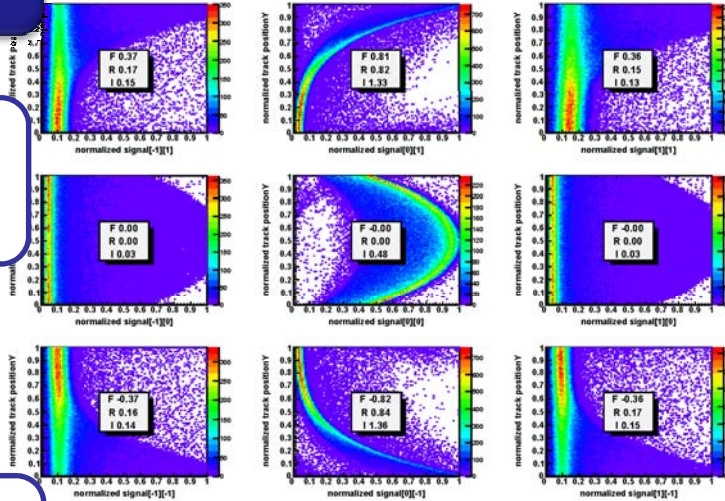


3 – Position reconstruction studies

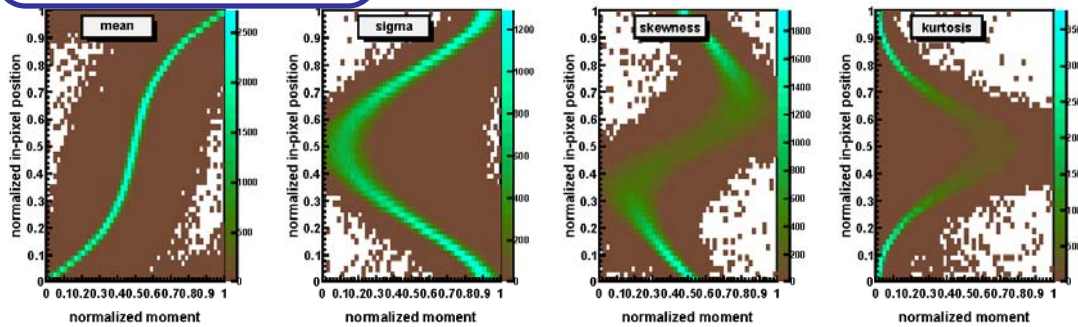
Multivariate analysis

Selection of Input Variables

1 **signal of 5x5 pixels**



2 **Moments of signal distr.**



Three statistical quantities for pre-selection:

1. Correlation Factor
2. Correlation Ratio
3. Mutual Information

→ How much information is in an input variable on the particle position



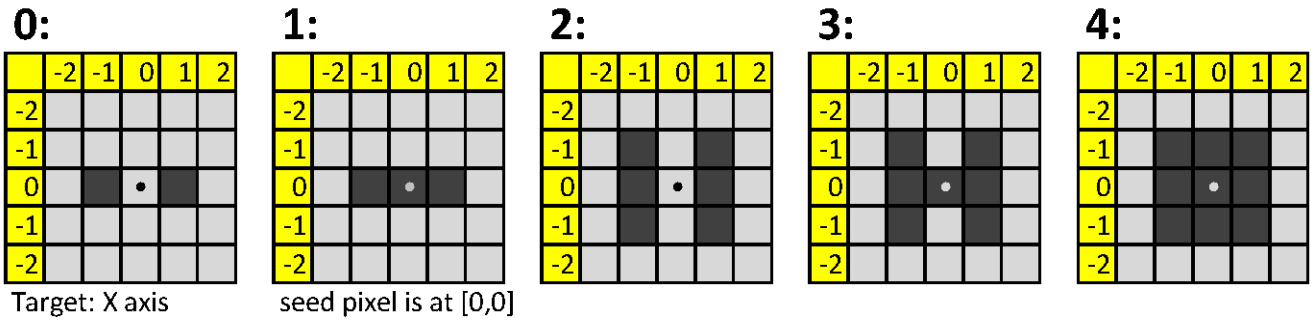
Mainly confined to the two seed neighbors, then the seed itself

3 – Position reconstruction studies

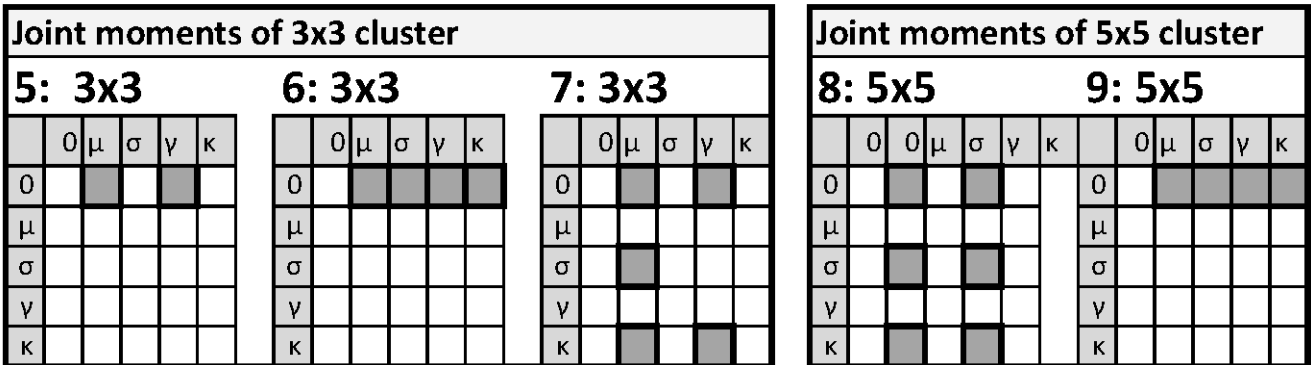
Multivariate analysis

Selection of Input Variables

Pixel Signal Inputs



Moments Inputs



Information mainly confined to the two seed neighbors, then the seed itself



11 input set:
5 pixel signal,
6 moments

3 – Position reconstruction studies

Multivariate analysis

		GEANT simulation CoCG-Large: TMVA residuals in μm								
		all events				δe^- only				
		MLP	BDTg	PDERS	LD	MLP	BDTg	PDERS	LD	
X	Signals	0	1.3	1.3	1.4	3.3	3.6	3.7	5.0	6.6
		1	0.6	0.7	0.6	3.3	2.9	3.2	4.2	6.6
		2	1.1	1.1	1.0	3.0	3.0	3.3	4.9	6.2
		3	0.8	0.8	0.9	3.0	3.2	3.1	5.1	6.2
		4	0.7	0.7	0.9	3.0	2.7	3.2	5.1	6.2
	Moments	5	1.0	1.3	1.3	2.5	6.7	5.7	10.5	7.5
		6	0.8	0.7	0.9	2.5	5.6	5.5	6.3	7.5
		7	0.9	0.8	0.9	2.5	3.4	4.3	4.4	6.3
		8	1.2	1.2	1.4	2.9	5.8	6.4	6.6	22.5
		9	1.5	1.4	1.5	3.2	6.7	6.6	7.0	17.5
10	0.9	1.0	0.9	2.6	4.6	4.0	5.1	6.2		
Y	Signals	0	1.1	1.0	1.2	1.8	2.6	2.5	2.7	4.2
		1	0.4	0.5	0.3	1.8	2.1	2.4	2.8	4.2
		2	0.9	0.9	0.9	1.6	2.3	2.3	3.4	3.9
		3	0.4	0.5	0.5	1.6	2.0	2.4	4.1	4.0
		4	0.4	0.5	0.5	1.6	2.1	2.3	4.2	3.9
	Moments	5	0.6	0.9	0.6	1.2	5.0	4.8	8.8	5.1
		6	0.5	0.5	0.5	1.2	4.0	4.4	4.4	5.0
		7	0.6	0.5	0.8	1.2	4.2	5.3	4.4	4.6
		8	0.6	0.6	0.7	1.3	3.6	3.9	4.3	4.1
		9	1.0	1.0	1.0	2.6	3.8	4.4	5.5	6.5
10	0.6	0.7	0.7	1.3	2.7	5.7	3.0	4.0		

seed + 2 neighbors
→ Best results

Moments of sig. distr. not better

1. MLP & BDT
2. PDERS
3. LD

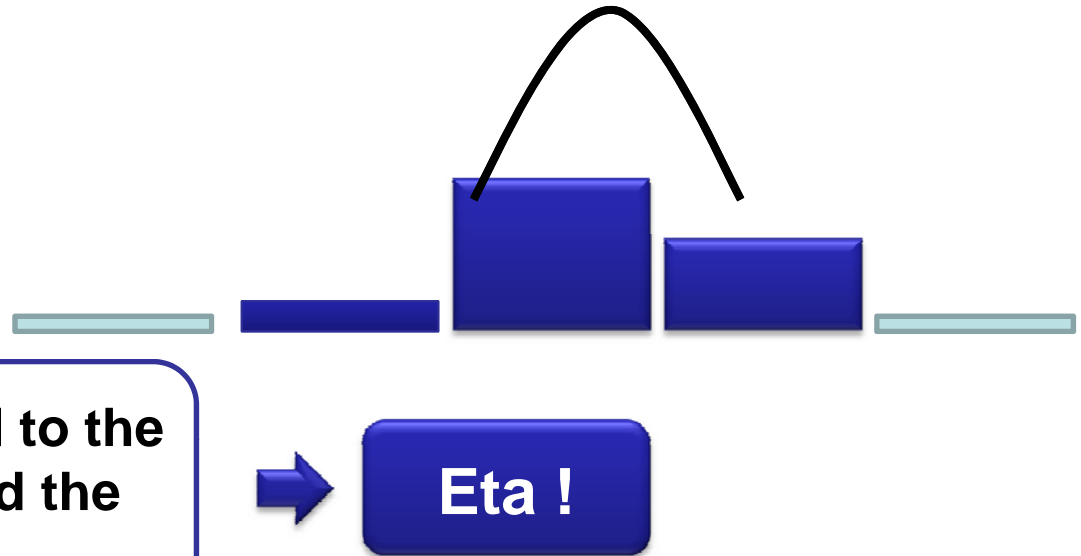
Eta method is always equal or better

3 – Position reconstruction studies

**Eta method is
always equal or
better**

**Information mainly confined to the
highest seed neighbor, and the
seed itself**

**New approaches might be useful
with smaller pixels or thicker
sensors**



Summary

- **Test Beam 2008 data used for In-pixel homogeneity study**
- **Sensors showed (near) perfect homogeneity**
- **Exception: Sensor with wrong biasing**

- **Study of position reconstruction algorithms**
- **Alternatives to eta /resolution deteriorating due to δ -e⁻**
 1. **Multiple η**
 2. **Charge cloud shape**
 3. **Multivariate analysis (PDE, MLP-ANN, BDT, LD)**
- **δ -e⁻ best tackled by multiple η**
- **Information confined to seed and highest neighbor**
- **ETA always equal or better → might different for smaller pixel sizes**

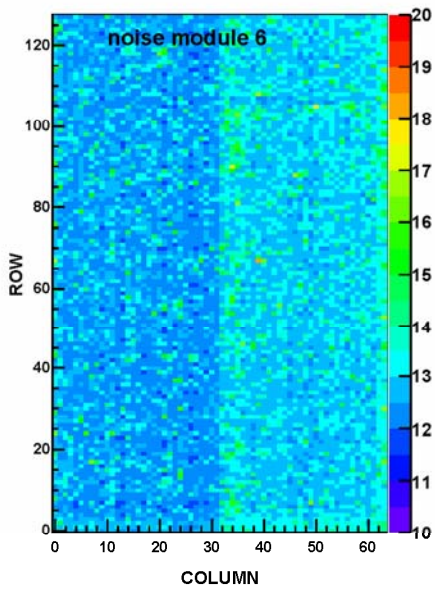
1 - Recap: Analysis of test beam data

Pedestal & Common mode

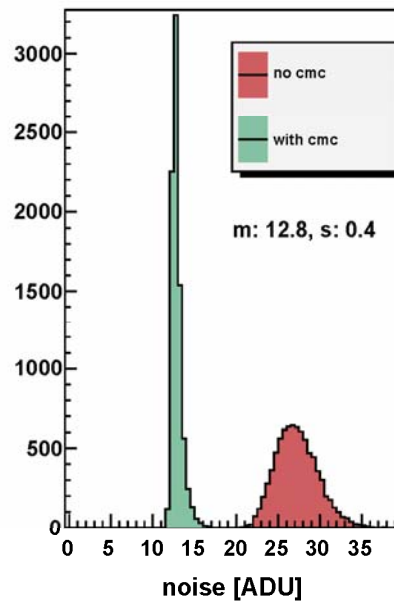
Hit finding & clustering

Position reconstruction

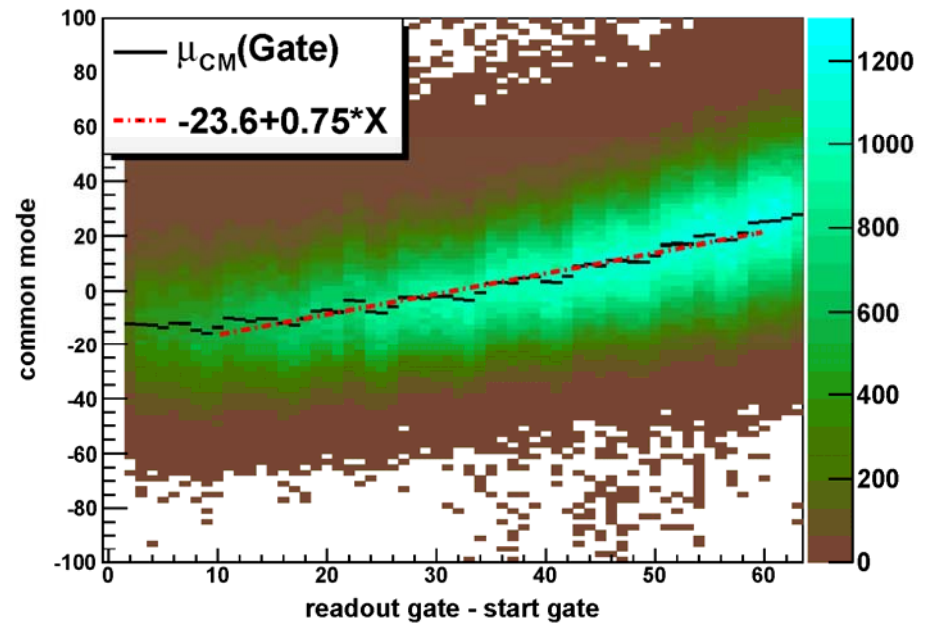
Additional corrections



Noise map



Noise before and after CMC



CM vs. readout time
→ leakage current

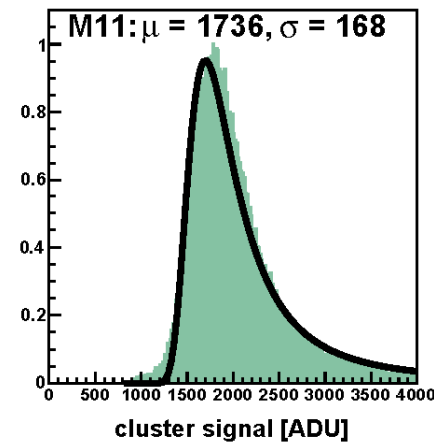
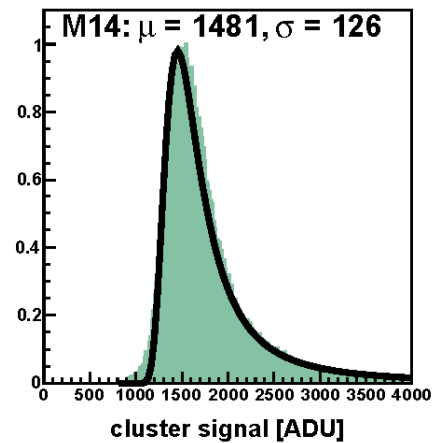
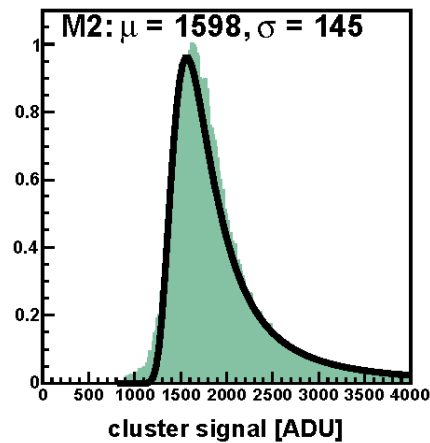
1 - Recap: Analysis of test beam data

**Pedestal &
Common mode**

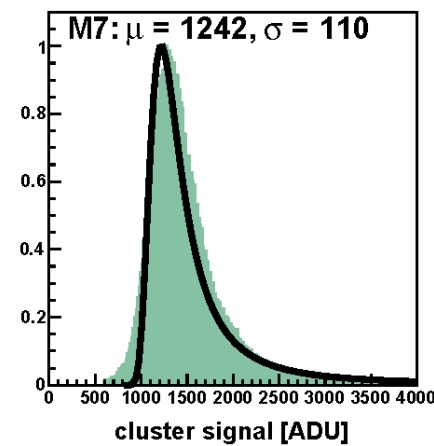
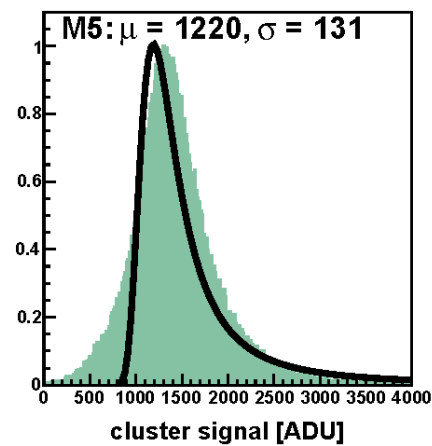
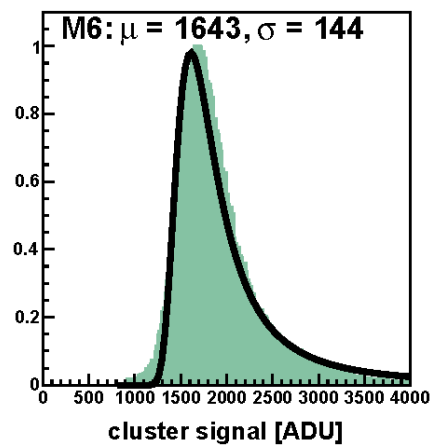
**Hit finding &
clustering**

**Position
reconstruction**

**Additional
corrections**



$S_{\text{cluster}}/N_{\text{pixel}}:$
 $\sim (90 - 130)$



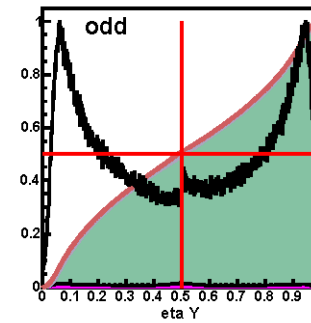
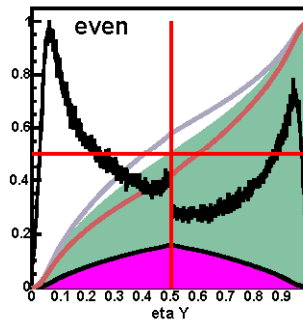
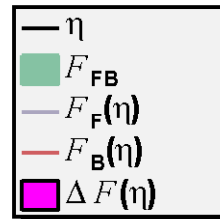
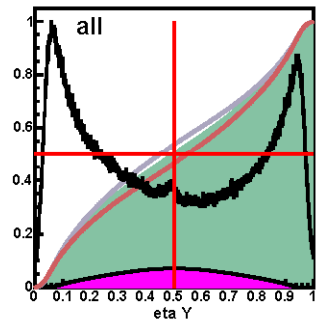
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Pedestal & Common mode

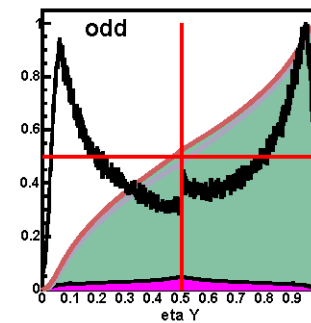
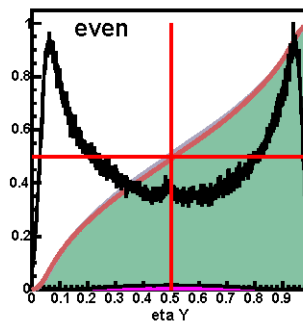
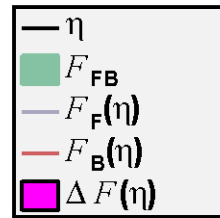
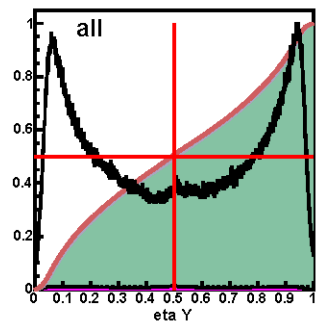
Hit finding & clustering

Position reconstruction

Additional corrections



ETA before corrections



ETA after corrections

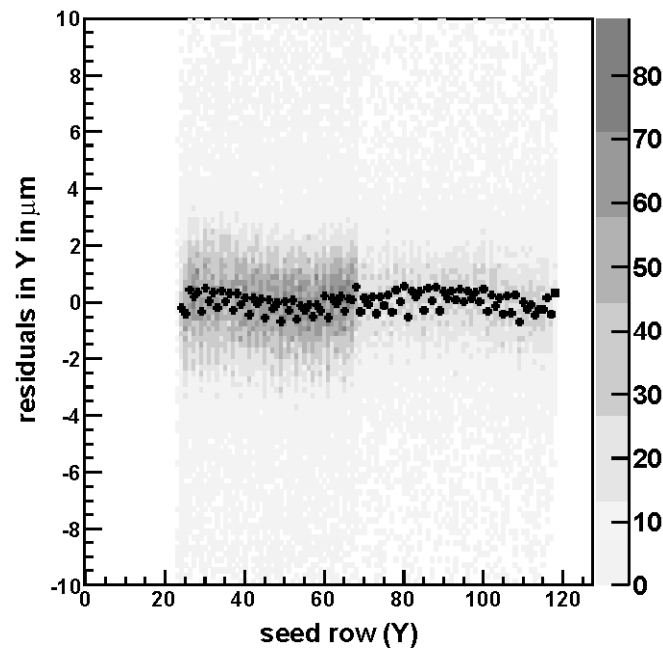
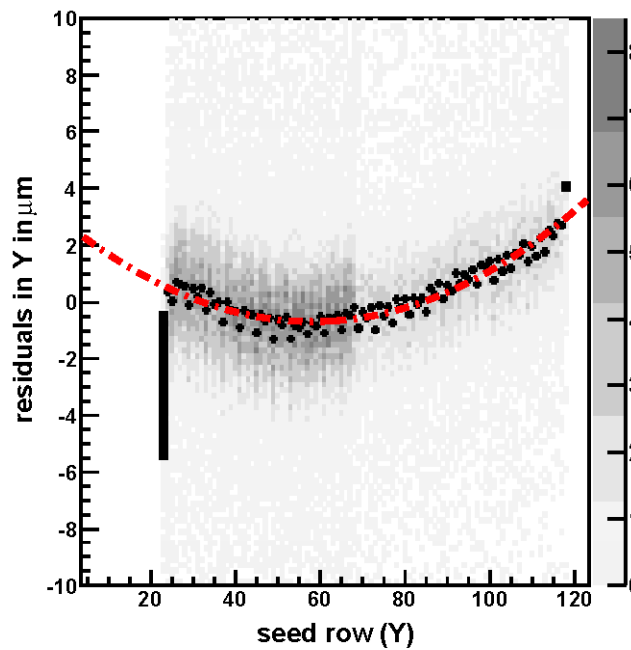
1 - Recap: Analysis of test beam data

Pedestal & Common mode

Hit finding & clustering

Position reconstruction

Additional corrections



Large scale position offset correction