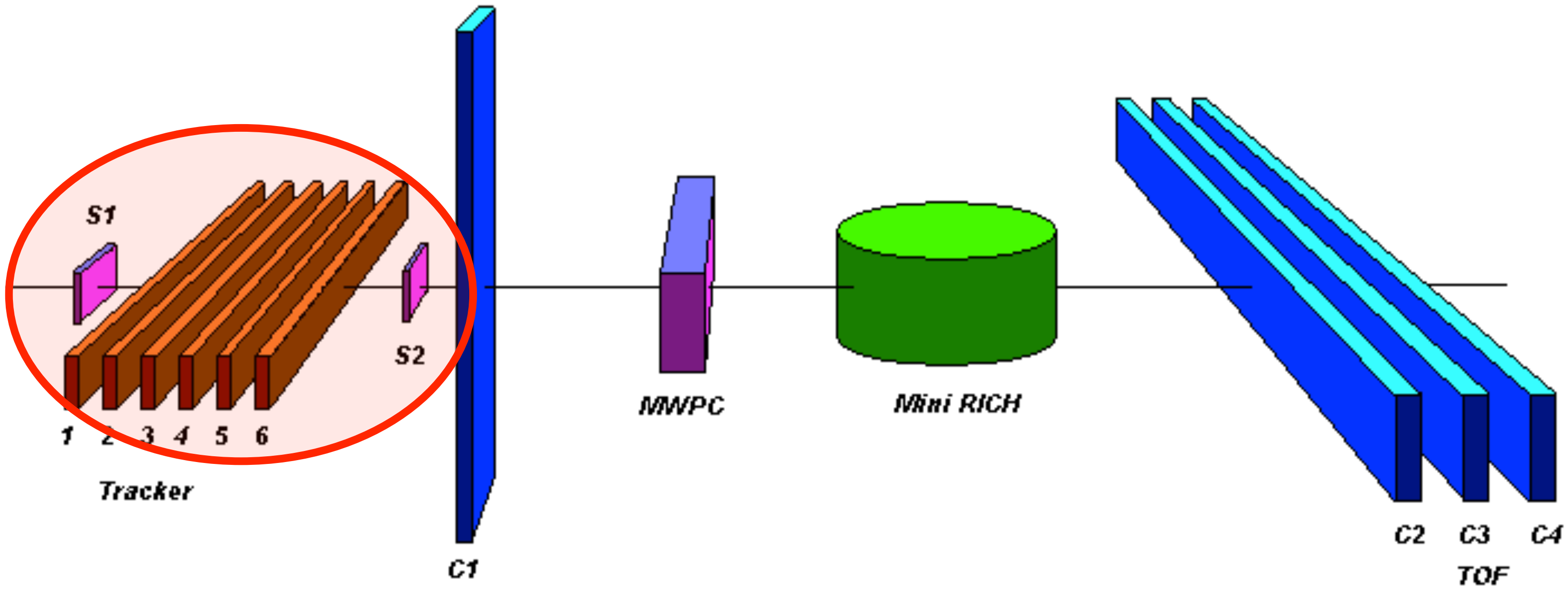
Beam Test Oct 2003: Ion Charge Analysis

- Beam test 2003
- Goal: charge discrimination algorithm with high efficiency and low contamination
- Signal characterization for charges from Beryllium to Neon
- Probability P_Z that a cluster is generated by a particle of charge Z
- Implementation of a probability test for the estimation of the charge associated to a track
- Status of the work

Beam test 2003



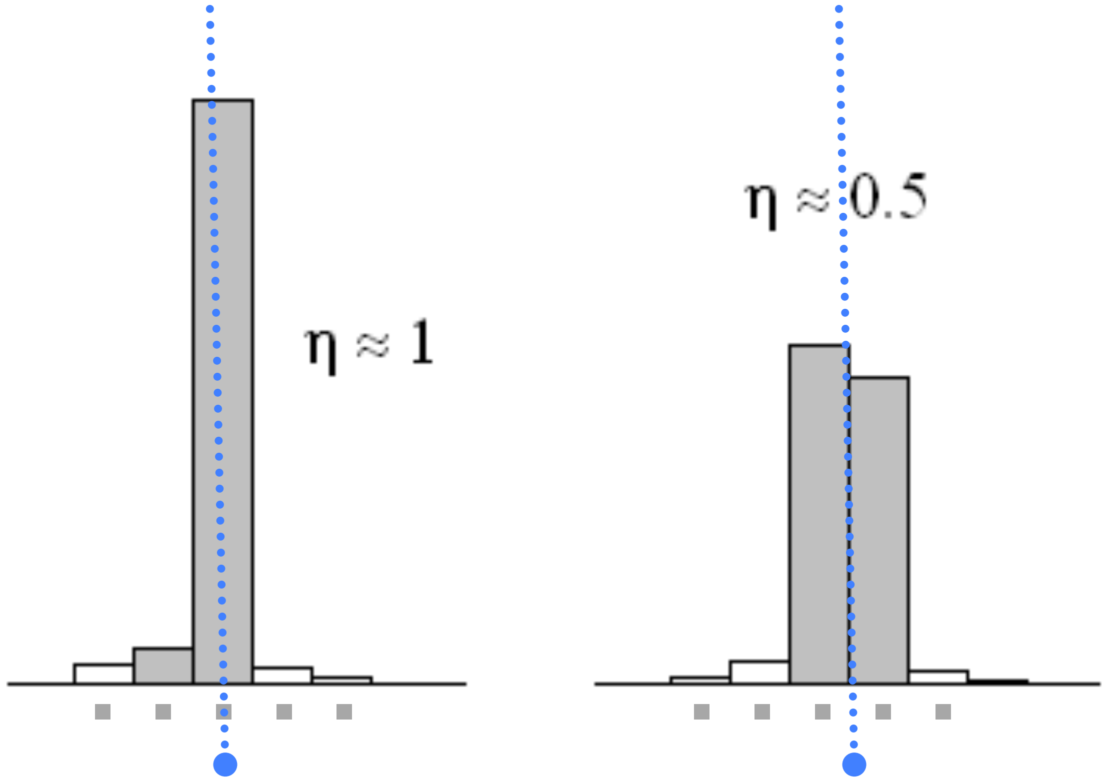
Ions of average energy » 10 GeV/n extracted from an Indium beam of 158 GeV/n on a Beryllium target, selected by A/Z ratio:

- A/Z = 1.00, 6% of tot. ev., mainly protons
- A/Z = 2.00, 77 % of tot. ev., He component is dominant (Be is suppressed)
- A/Z = 2.25, 16 % of tot. ev., ^{9}Be component is dominant
- A/Z = 2.35, 1 % of tot. ev., ^{7}Li component is dominant (He is suppressed)

Sample selection

Calibration

- σ_{ped} » 2.5(3) for p(n)-side



Clusterizzation

- Seed with Signal/Noise (SN) > 5.
- Neightboring strips with SN > 2.

Identification of an event of Z>2

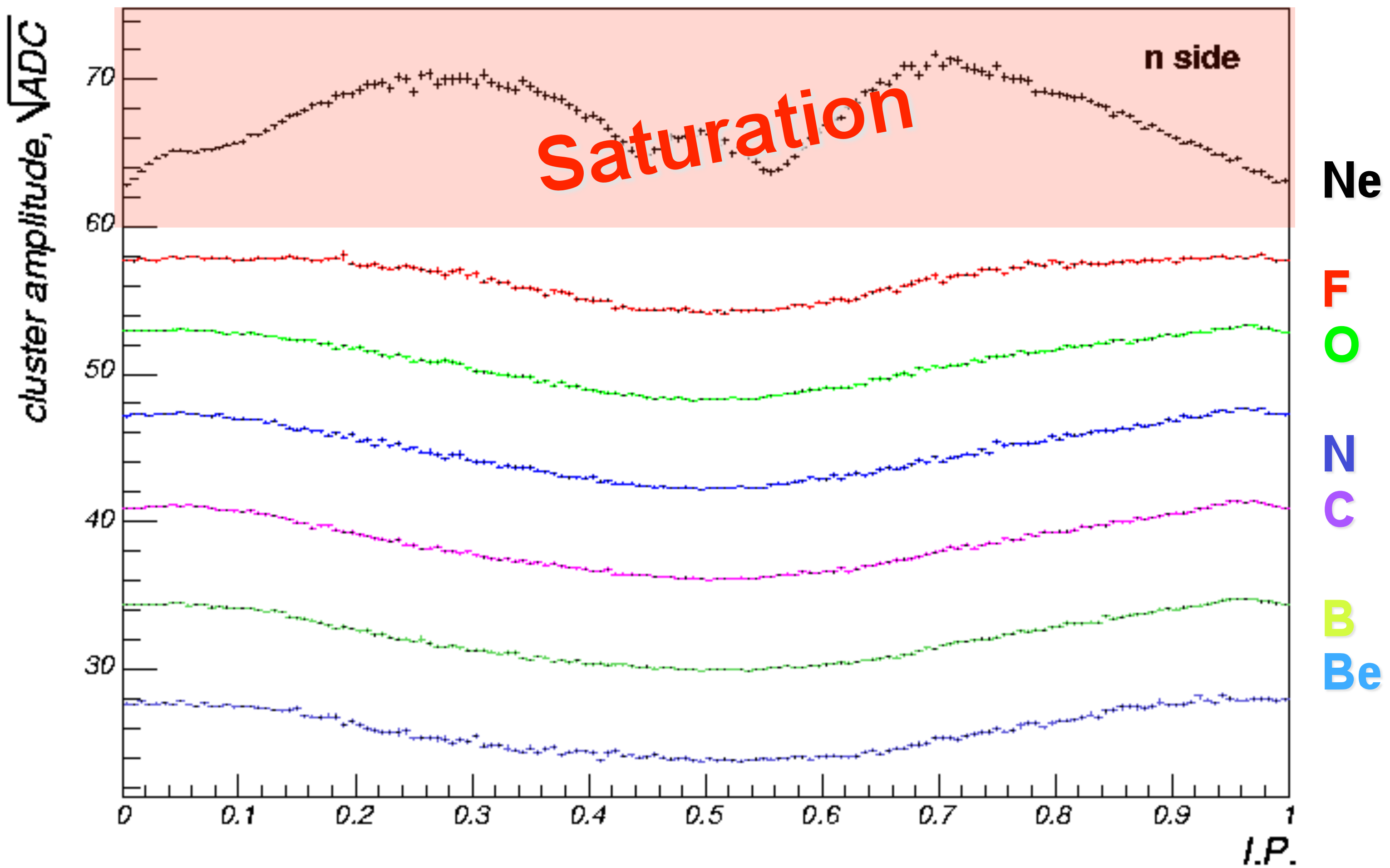
- One and only one cluster for each ladder/side (only 12 clusters)
- Cluster charge amplitude > helium total charge
- A good probability for χ^2 of the linear fit between the 6 points of p(n) side

Alberto Oliva
INFN/University of Perugia

impact point VS cluster amplitude: n-side

Cluster amplitude: total charge of a cluster, all strips ($\sum s_i$)

Impact Point (IP): obtained with a 5 point fit



Alberto Oliva
INFN/University of Perugia

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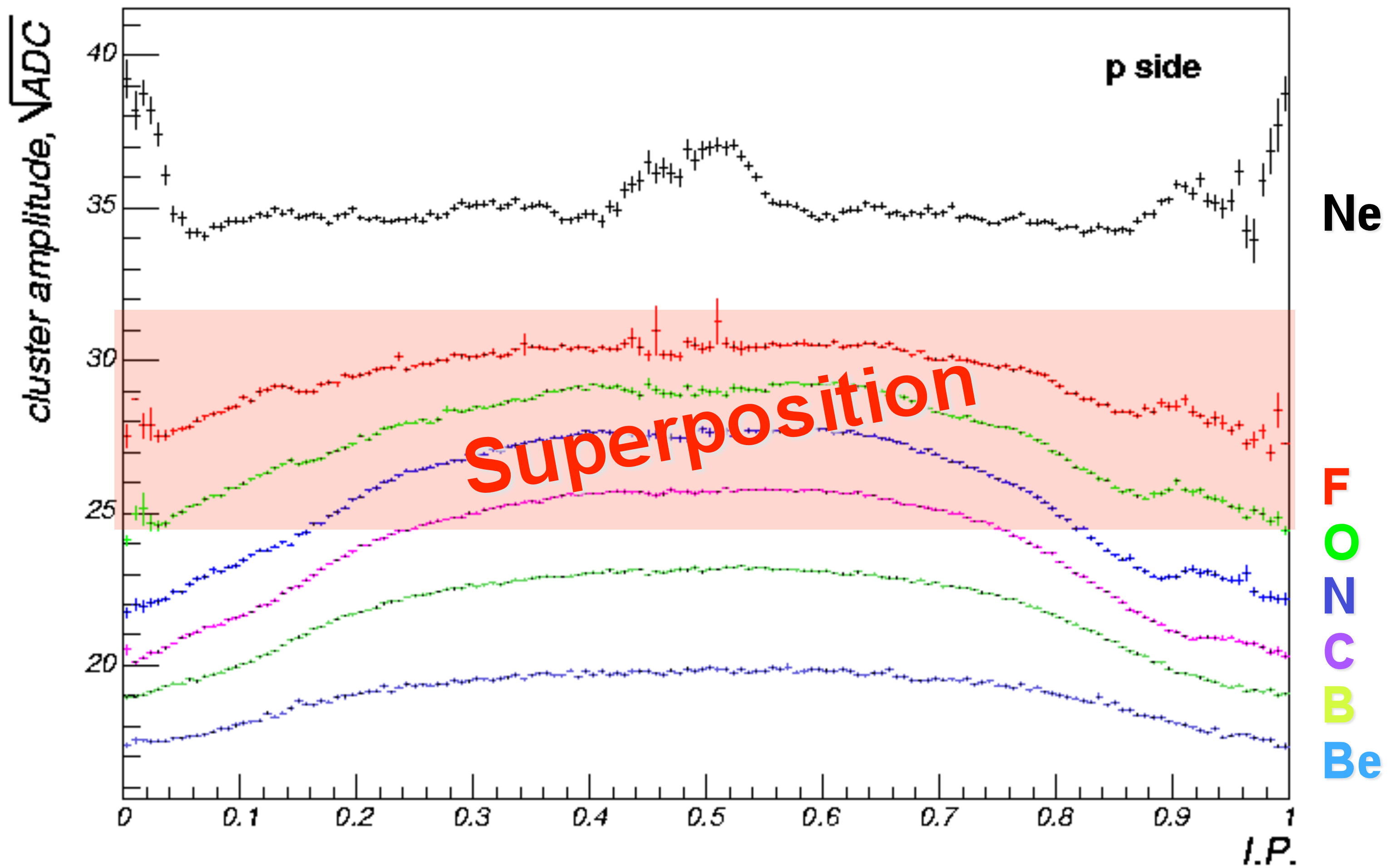

The charge separation will be done with the n-side knowledge...

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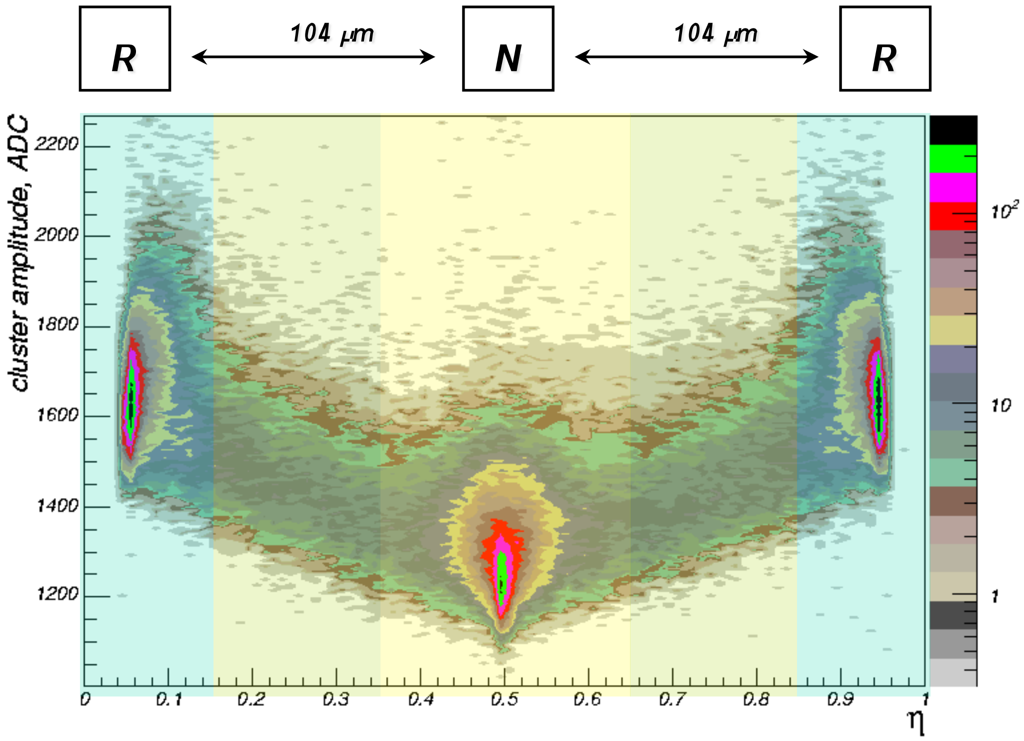
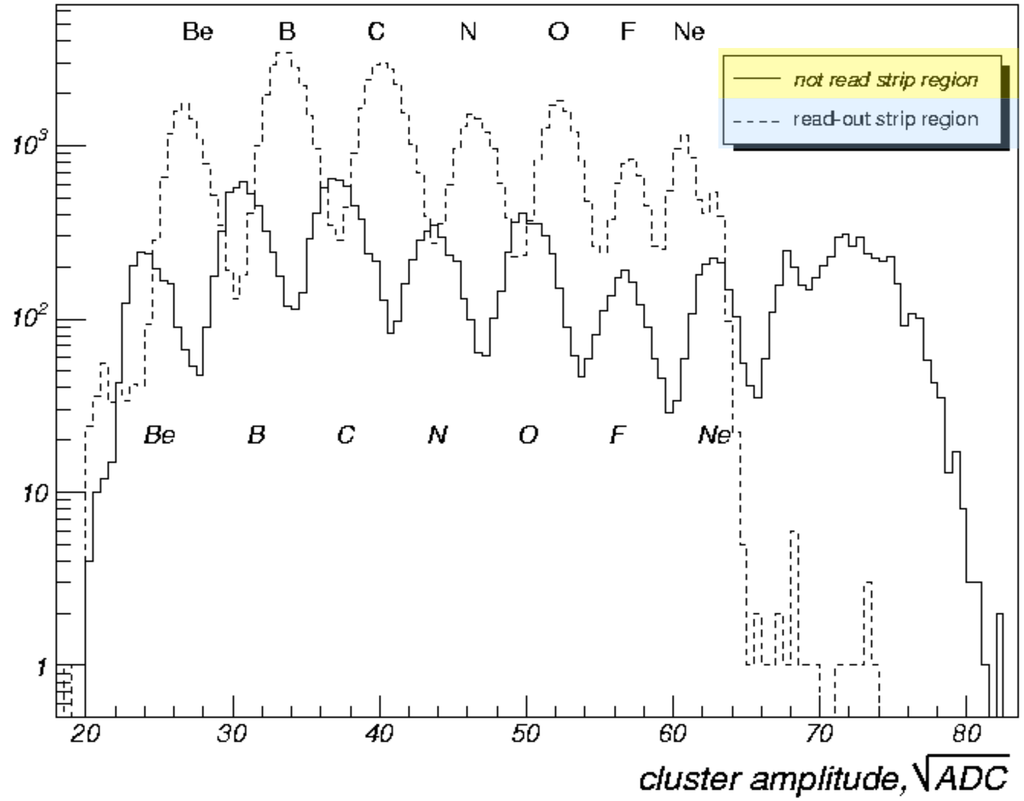
n-side: η distribution

η: charge center of gravity between the two higher strips

$$\eta = \frac{Q_R}{Q_R + Q_L}$$





Three "η regions"

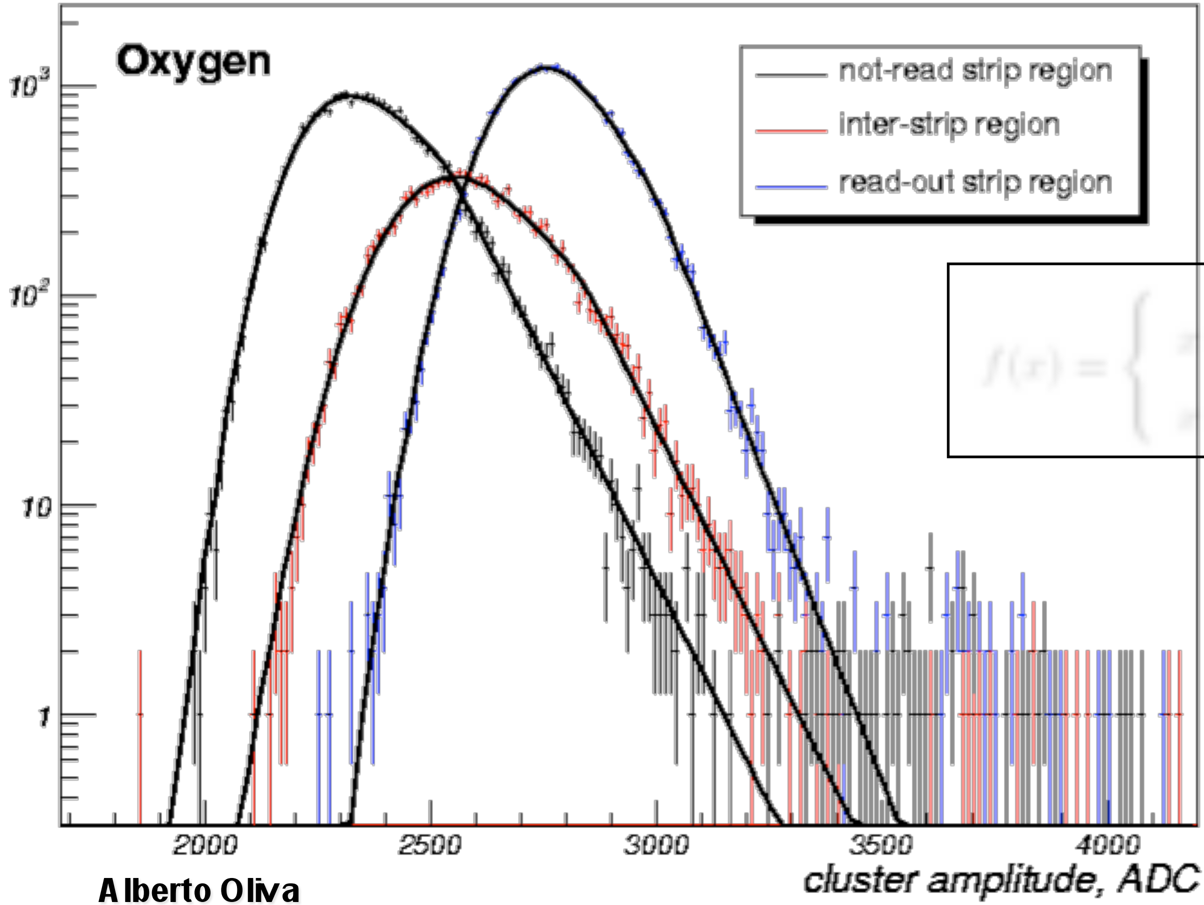
- **Readout region**: η · 0.15 or η > 0.85
- **Interstrip region**: 0.15 < η · 0.35 or 0.65 < η · 0.85
- **Not read strip region**: 0.35 < η · 0.65

Charge samples

- 3 different charge specta
- Charge peak selection on the sixth ladder

n-side: signal characterization

- Sixth ladder amplitude selection in a restricted window around the energy loss peaks (first ladder peak selection to study the sixth ladder)
- Study the charge distributions on the other ladders
- Signal characterization with a **Landau - Gauss + exponential tail**
- Low efficiency and great purity samples



$$f(x) = \begin{cases} x < x_{sep} & N \int_{-\infty}^{x} L(\tau; MPV, c) G\left(\frac{x-\tau}{\sigma}\right) d\tau \\ x \geq x_{sep} & N_{LG} \cdot N_{rel} e^{-\lambda x} \end{cases}$$

7 parameters

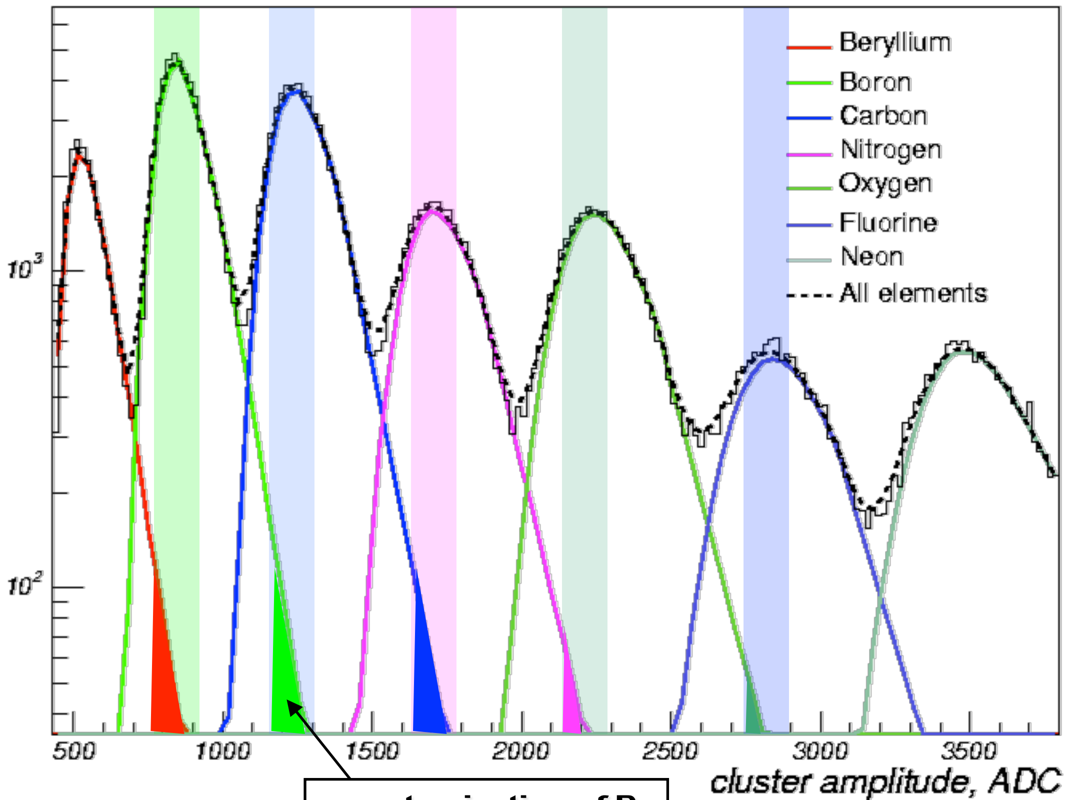
- 1 for the position (**MPV**)
- 4 shape parameters (slope, σ,...)
- 2 normalizations

n-side: purity of the samples

- fit the all charges spectrum of the sixth ladder: the only free parameters are the normalizations of the charge distributions
- integration of the charge contributions around the peaks

sample purity : » 98% with a Z – 1 contamination of » 1%

low efficiency ⇒ improve the efficiency using a likelihood based test



contamination of B
In the C sample

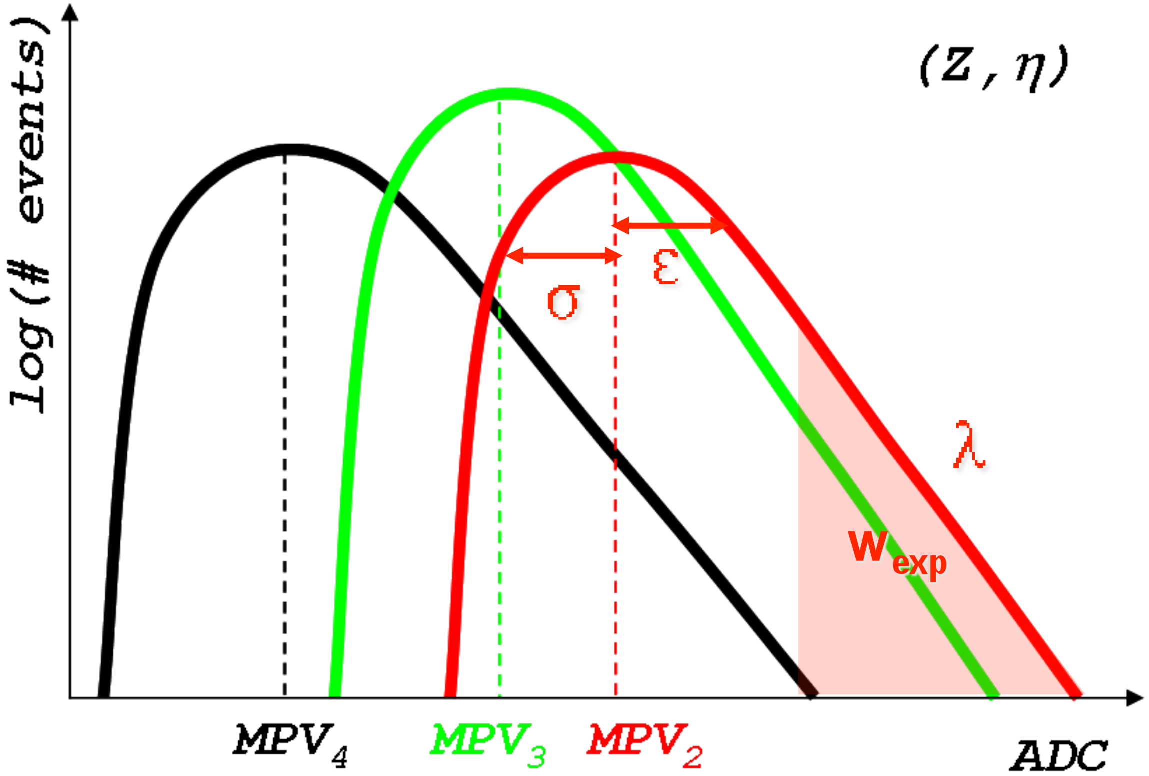
B C N

%	$A_Z(Z-2)$	$A_Z(Z-1)$	$A_Z(Z)$	$A_Z(Z+1)$
Be*	—	—	100. ± 1.5	0.
B*	—	0.85 ± 0.04	99.1 ± 1.0	0.
C*	0.	1.22 ± 0.04	98.8 ± 1.0	0.020 ± 0.005
N*	0.	2.3 ± 0.1	97.7 ± 1.4	0.022 ± 0.007
O*	0.	1.46 ± 0.07	98.5 ± 1.3	0.023 ± 0.006
F*	0.	2.9 ± 0.2	97. ± 2.	0.02 ± 0.01
Ne*	0.02 ± 0.01	2.1 ± 0.1	98. ± 2.	—

Z – 1

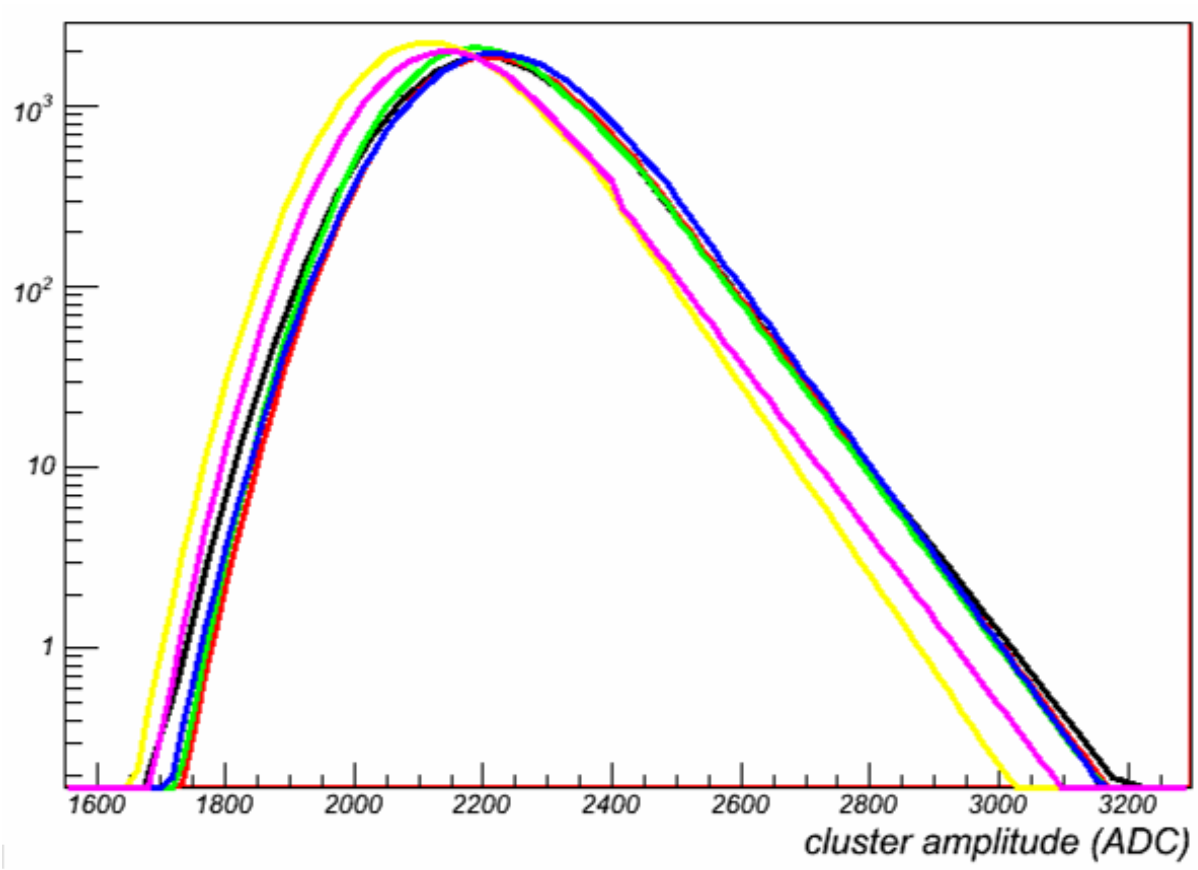
n-side: shape parameters

- Shape parameters
  - σ: width of the Gaussian distribution
  - ε: width of the Landau distribution
  - λ: slope of the exponential function
  - w_{exp}: weight of the exponential function ($Area_{exp}/Area_{tot}$)
- Given Z and η these parameters are **similar** for the different ladders (the maximum variation is of the order of »10%)
- MPV values differ from ladder to ladder



n-side: shape parameters

parameters	ladder 1	ladder 2	ladder 3	ladder 4	ladder 5	ladder 6	spread (%)
ϵ (ADC)	21,12	27,6	30,01	22,37	29,3	25,51	14,0611
σ (ADC)	111,48	101,04	96,01	110,11	95,08	97,55	7,0787
λ (1/ADC)	94,73	91,71	91,24	88,07	82,6	92,04	4,6943
W_{exp}	0,1012	0,0747	0,0587	0,0566	0,0647	0,0492	27,5204



Nitrogen (readout region)

The shape is not so different

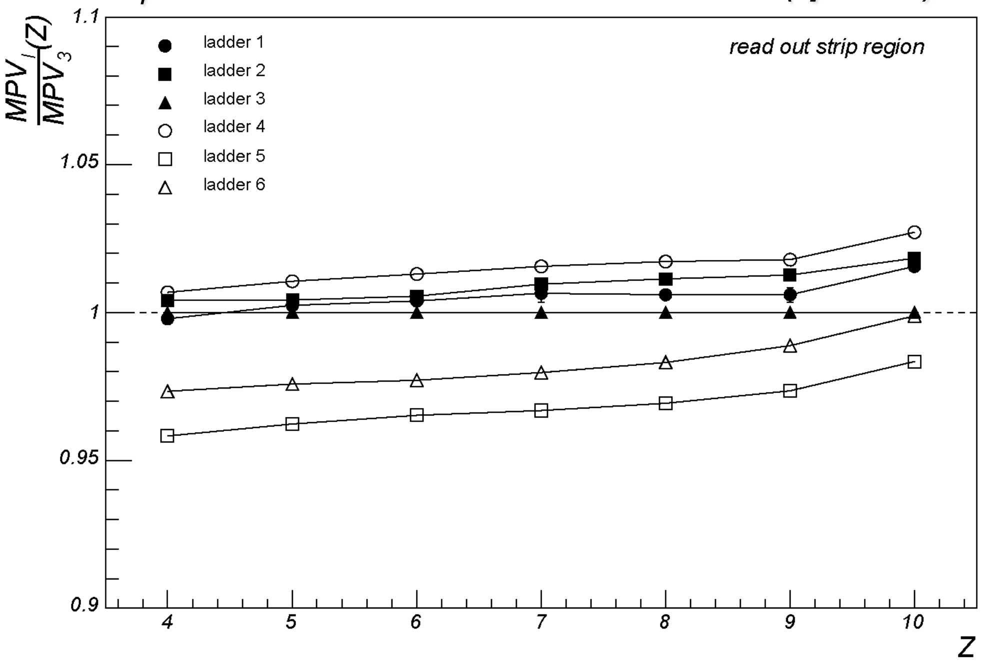
n-side: relative gain

- Ladder to ladder differences are parametrized by a traslation coefficient:

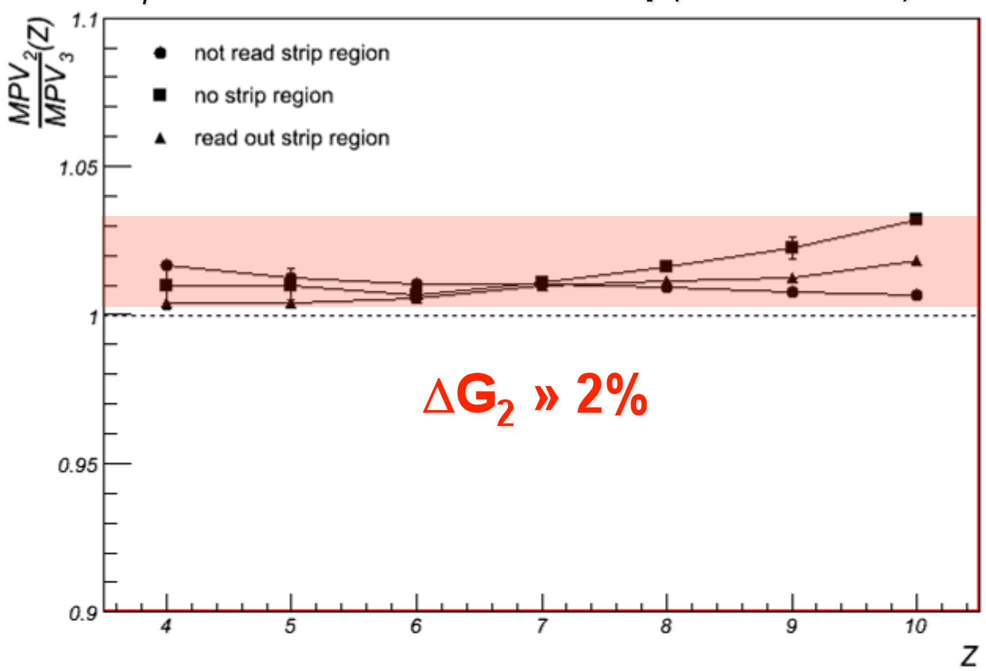
$$G_l(Z,\eta) = \frac{MPV_l}{MPV_3}(Z,\eta) = G_l$$

- The parameter G_l is independent from Z and η → **relative gain**
- **A unique charge parametrization can be used for all the ladders**

G_l function of Z for different ladders (η fixed)



G_l function of Z for different η (ladder fixed)



n-side: probability and likelihood

Probability distribution on the single ladder

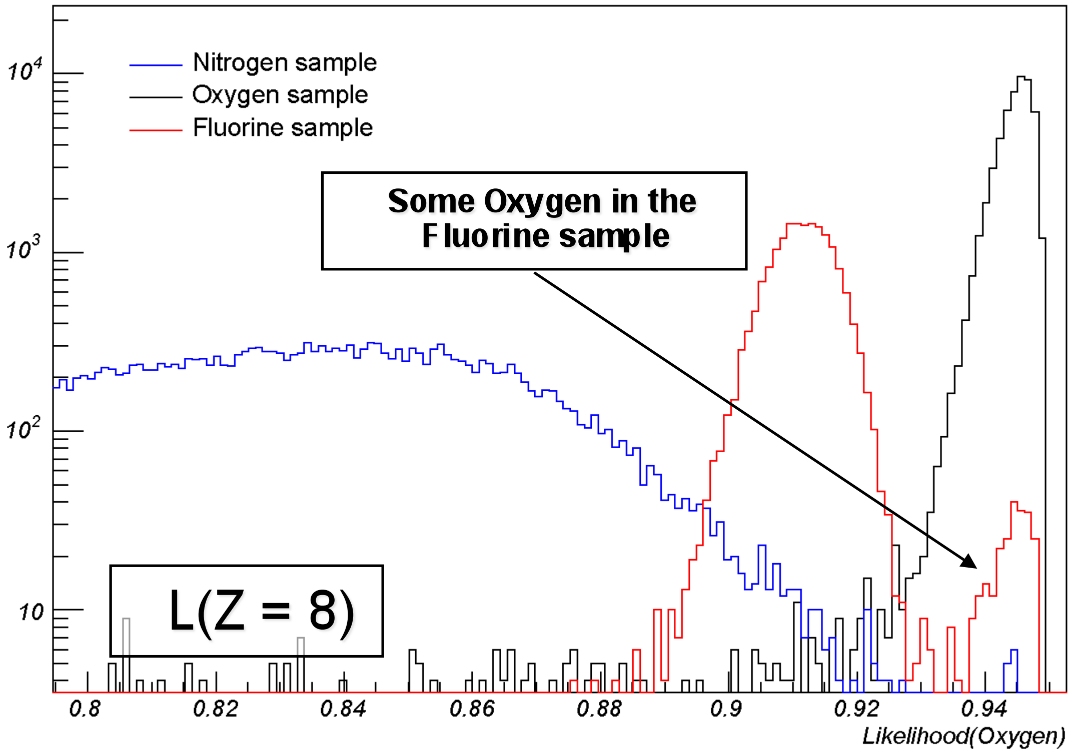
- The probability P_Z that a cluster corresponds to a Z ion is defined as:

$$P_Z(x;l,\eta) = \frac{f(G_l \cdot x; Z, \eta)}{\int_{-\infty}^{+\infty} f(G_l \cdot x; Z, \eta)}$$

Likelihood on n ladders

$$L(Z) = -\sum_{i}^{n} \log P_Z(x;l,\eta)$$

- we want 0 · L · 1, then:
  - if $L(Z) < 10^{-50} \rightarrow L(Z) = 10^{-50}$
  - $L(Z) = 1 + L(Z)/(50¢n)$



Alberto Oliva
INFN/University of Perugia

n-side: likelihood ratio test (6 ladders)

- *which test for the charge estimation?*
  - **Maximum likelihood**: has the maximum efficiency
  - **Recursive likelihood ratio**: a parametrized contamination

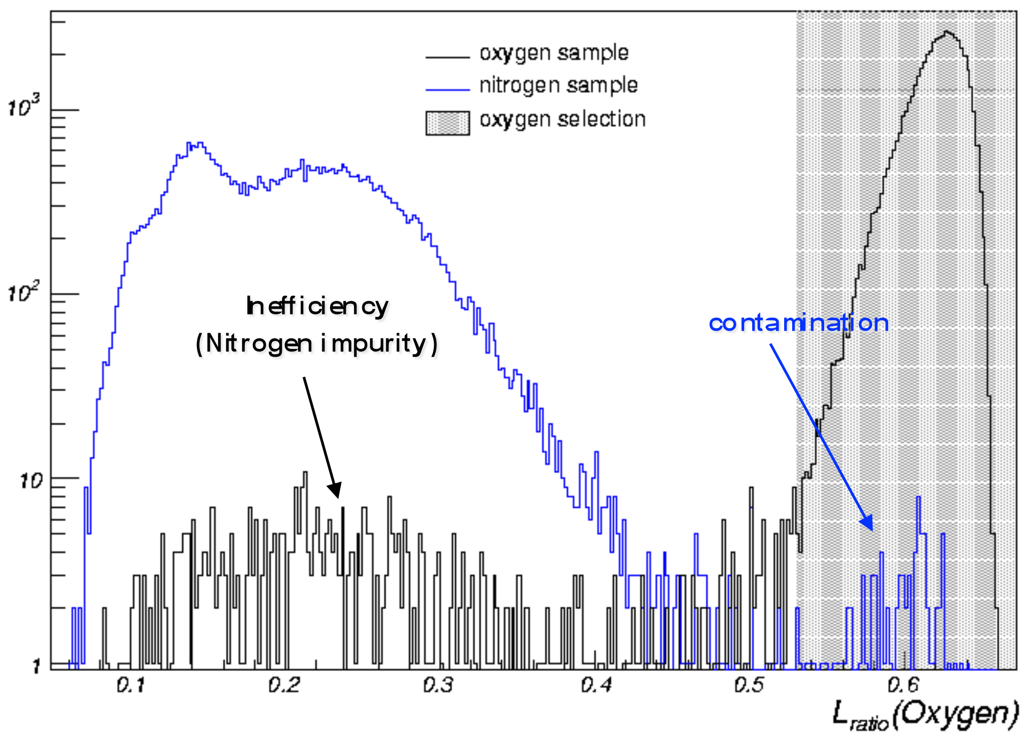
$$LR(Z) = \frac{L(Z)}{L(Z) + L(Z-1)} > c$$

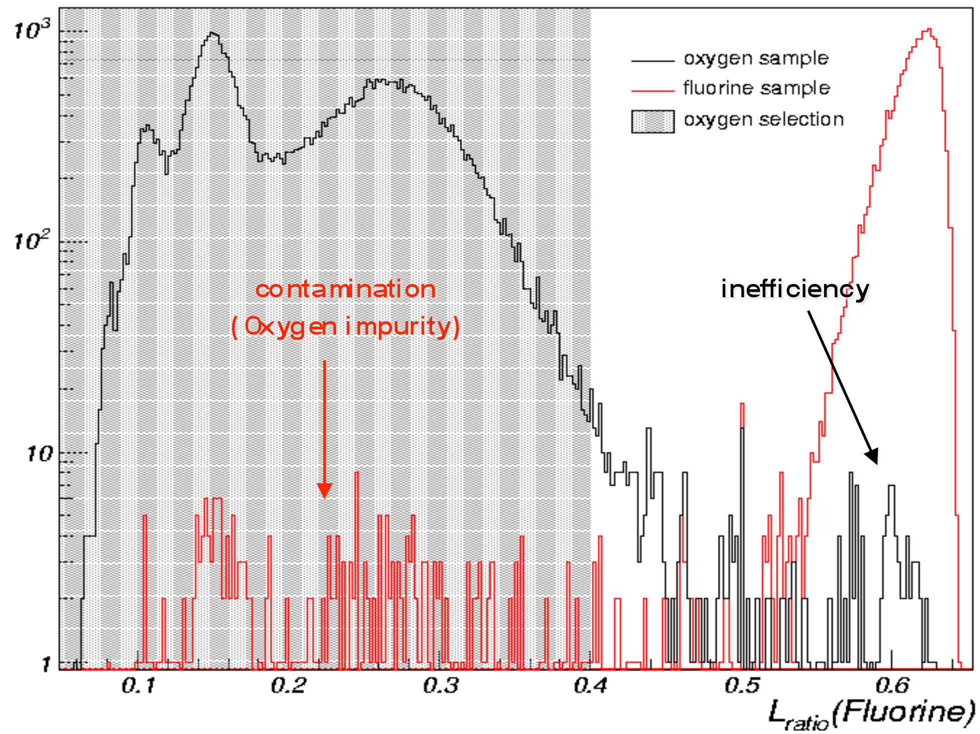
Separation between Z and Z – 1

Separation between Z and Z + 1

$LR(Z) > c_1$ $\quad c_1 = 0.53$

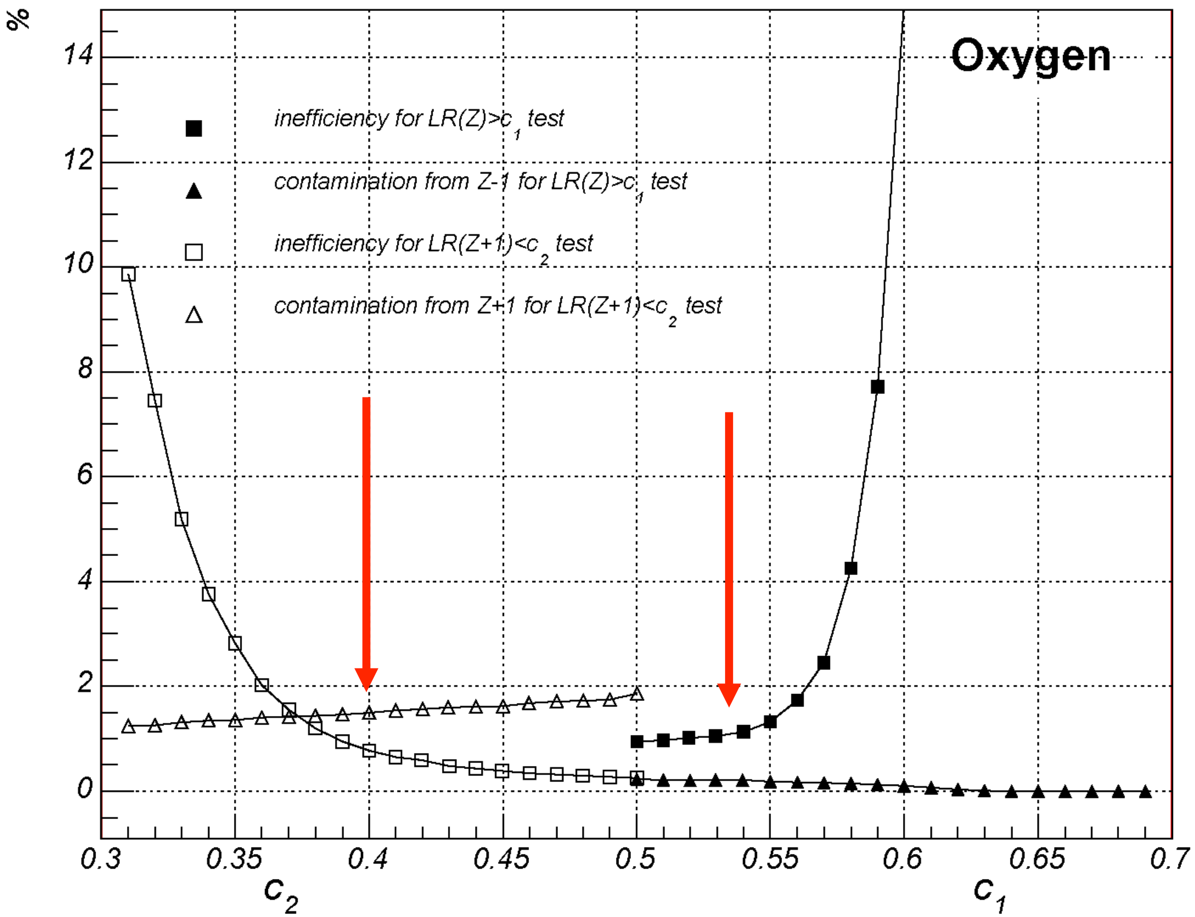
$LR(Z+1) < c_2$ $\quad c_2 = 0.40$





n-side: inefficiency and contamination (6 ladders)

- tests have been applied to clean samples (» 98%) tuning c_1 and c_2
- **inefficiency**: percentage of not recognized Z events
- **contamination**: percentage of not–Z events recognized as Z



- c_1 and c_2 are nearly charge independent
- for **c_1 = 0.53 e c_2 = 0.40** → efficiency »98% and contamination »1%

n-side: inefficiency and contamination (6 ladders)

%	Inefficiency	Contamination by $Z-1$	Contamination by $Z+1$
Be*	2.2 ± 0.1	—	0.76 ± 0.03
B*	1.39 ± 0.05	1.24 ± 0.05	1.02 ± 0.03
C*	1.70 ± 0.06	0.23 ± 0.02	1.52 ± 0.06
N*	2.3 ± 0.1	0.13 ± 0.01	0.88 ± 0.04
O*	1.81 ± 0.08	0.10 ± 0.02	1.7 ± 0.1
F*	3.2 ± 0.2	0.07 ± 0.01	1.27 ± 0.08
Ne*	1.67 ± 0.09	0.14 ± 0.03	—

Table 3: Inefficiency and contamination in % for the LR test with a choise of $c_1 = 0.53$ and $c_2 = 0.40$ for the different samples selected with the sixth ladder amplitude neighbors peak criterion.

- Inefficiency and contamination can be an **overestimated** because the sample are not clean (there is »1% of Z – 1 events in each Z sample)

n-side: charge with only one ladder

Charge reconstructed with the **sixth** ladder

10						*0.006*	*0.993*
9					*0.013*	*0.945*	*0.041*
8				*0.014*	*0.953*	*0.029*	*0.001*
7			*0.011*	*0.958*	*0.027*	*0.001*	
6		*0.01*	*0.961*	*0.026*			
5	*0.009*	*0.962*	*0.026*	*0.001*			
4	*0.945*	*0.042*	*0.003*				
Z	*4*	*5*	*6*	*7*	*8*	*9*	*10*

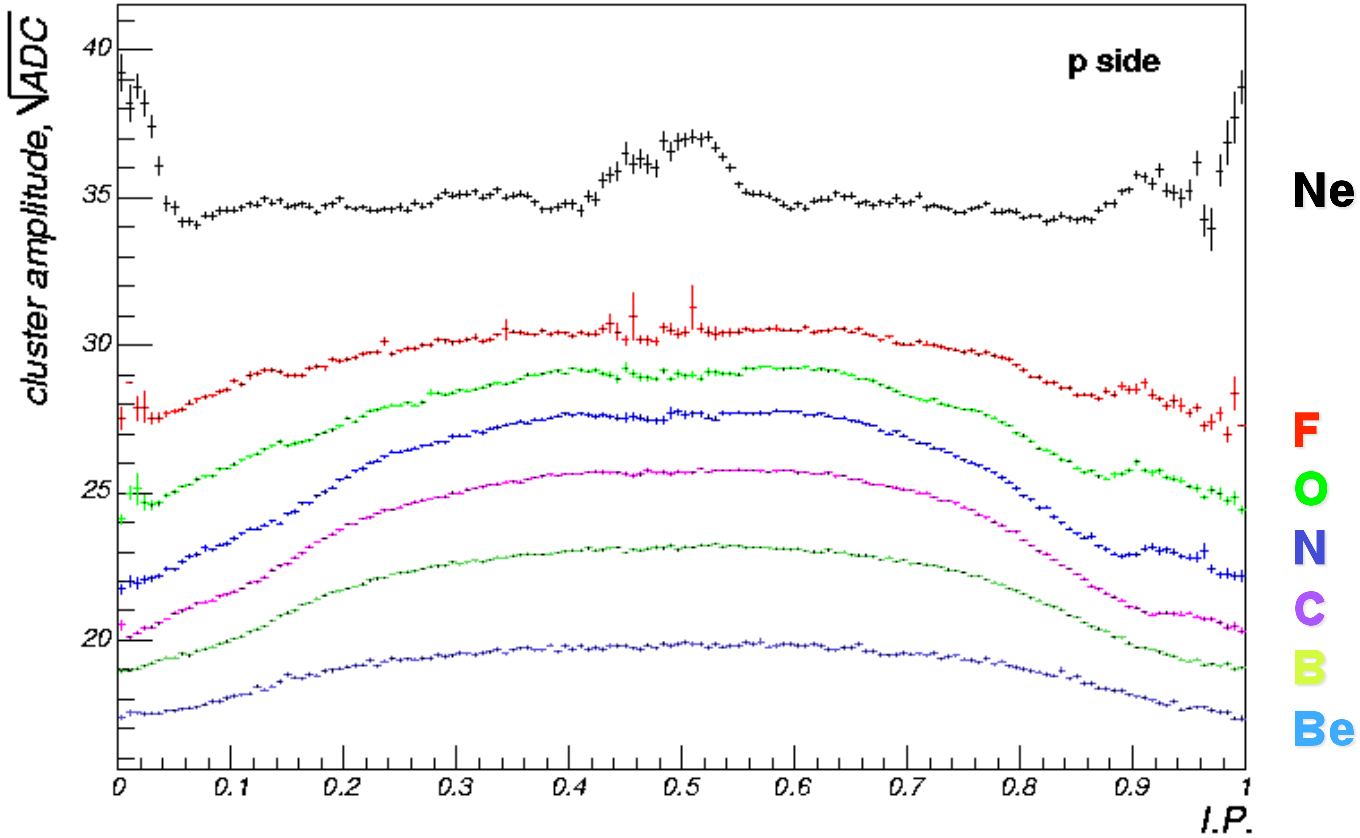
Charge reconstructed with the likelihood ratio of **5 ladder**

- "real charge" estimated with 5 ladders
- the charge on the last ladder is reconstructed with the maximum likelihood method
- the right charge is reconstructed at **» 95%** while at »3% is reconstructed as Z – 1

iteration of the charge selection procedure ...

p-side: problems

- superposition of the total charge profile function of I.P. for the different ions
- not linear relation between amplitude and energy deposited [*B. Alpat et al., NIMA 540 (2005) 121–130*]
- a deformed η distribution (the spatial resolution has a strong systematic component)



Alberto Oliva
INFN/University of Perugia

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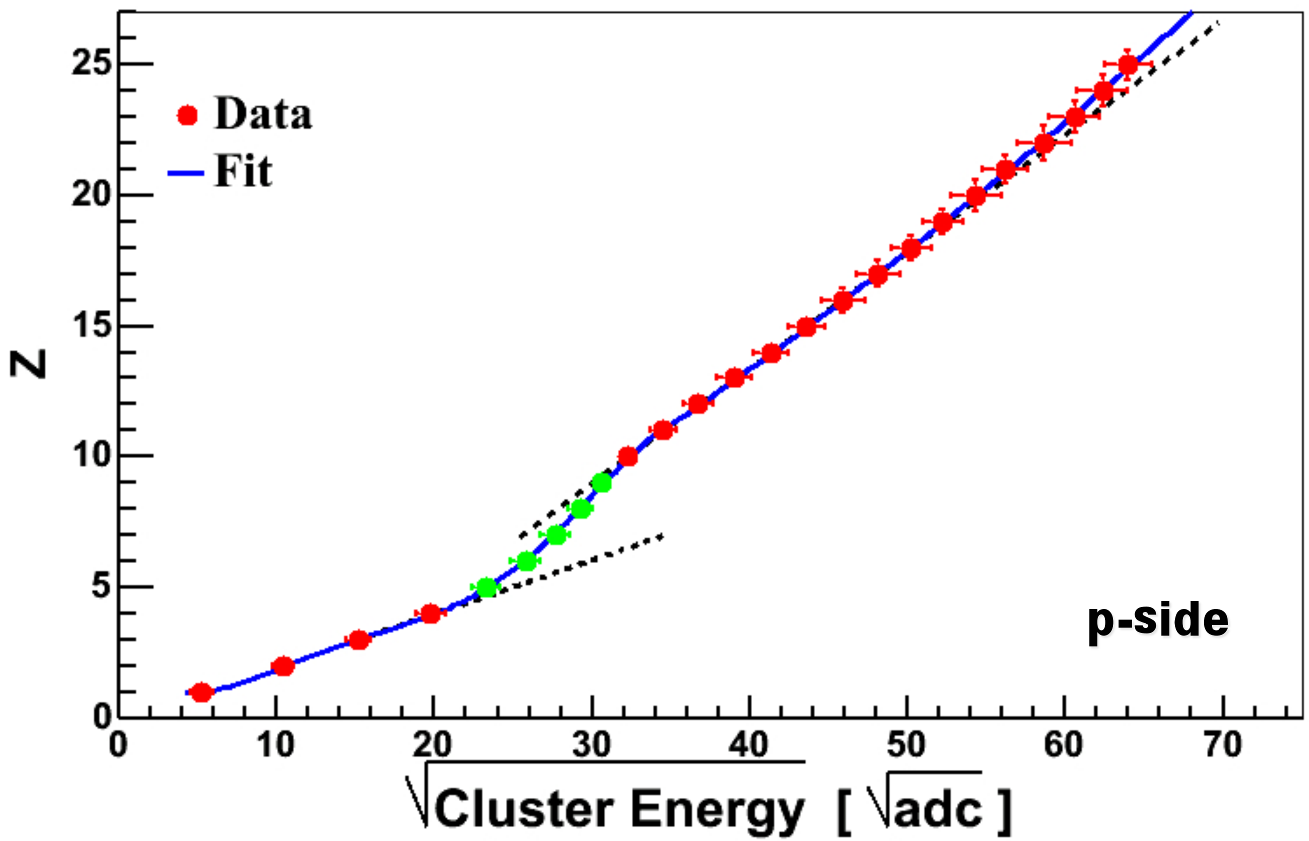

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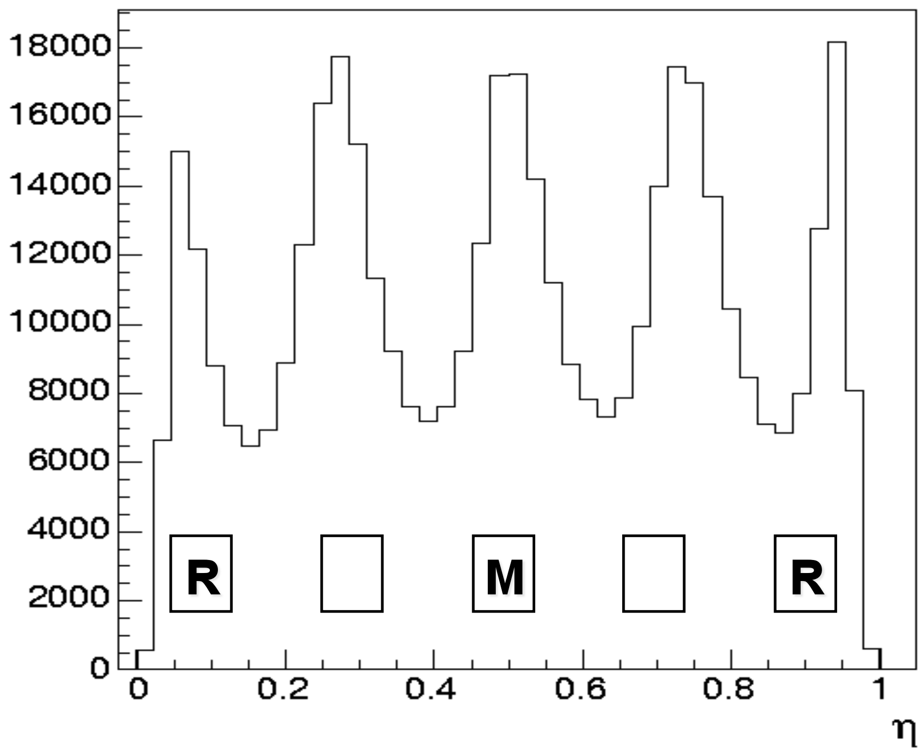
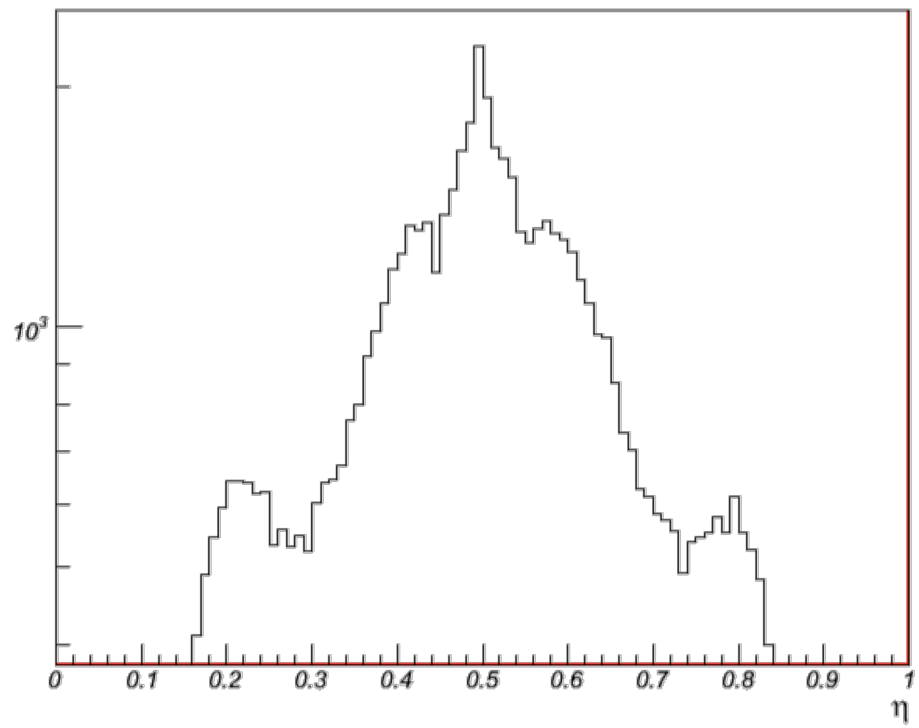
Helium



Carbon



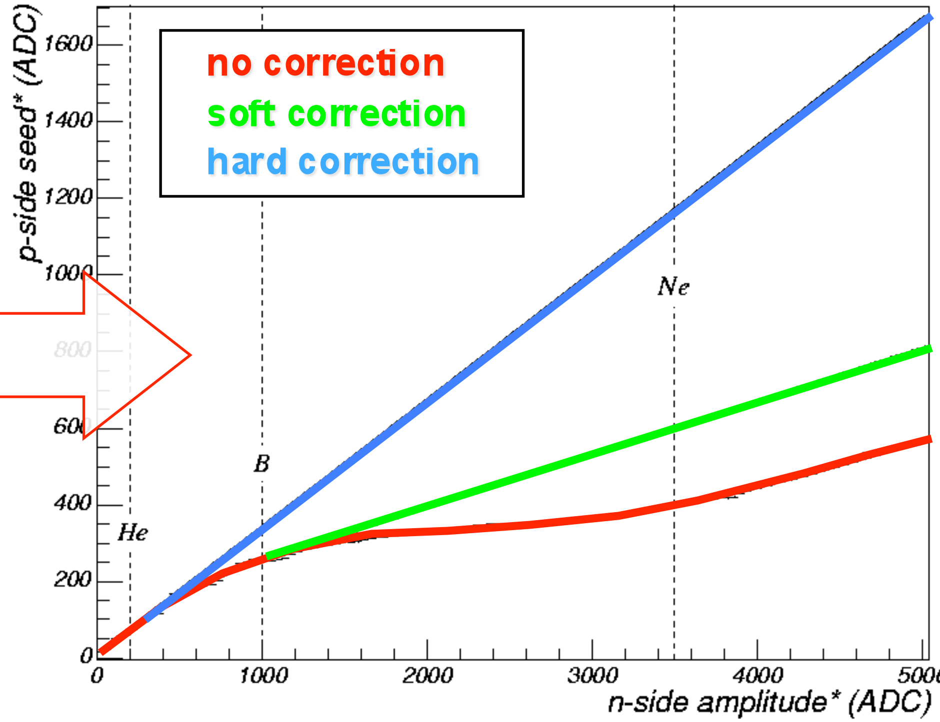
p-side: strip correction

Hypothesis

- The η deformation could arise from a not linear behaviour in the single strip signal

Proof

- A n-cluster is associated to each p-cluster
- On p-side only the seed strip is considered
- Interstrip region: $0.45<\eta_p<0.55$
- On n-side the cluster amplitude is considered
- Combine the information of all the ladder using the relative gain



Proposed correction

- a polynomial fit of the seed VS n-side amplitude
- **Linearization (hard, soft)**
- **Correction applied to all the p-cluster strips** (the same for all the ladders)

$$ADC_{corr,l} = G_l \cdot ADC^*_{corr} = f_{SC}(ADC^*) = f_{SC}\left(\frac{ADC_l}{G_l}\right)$$

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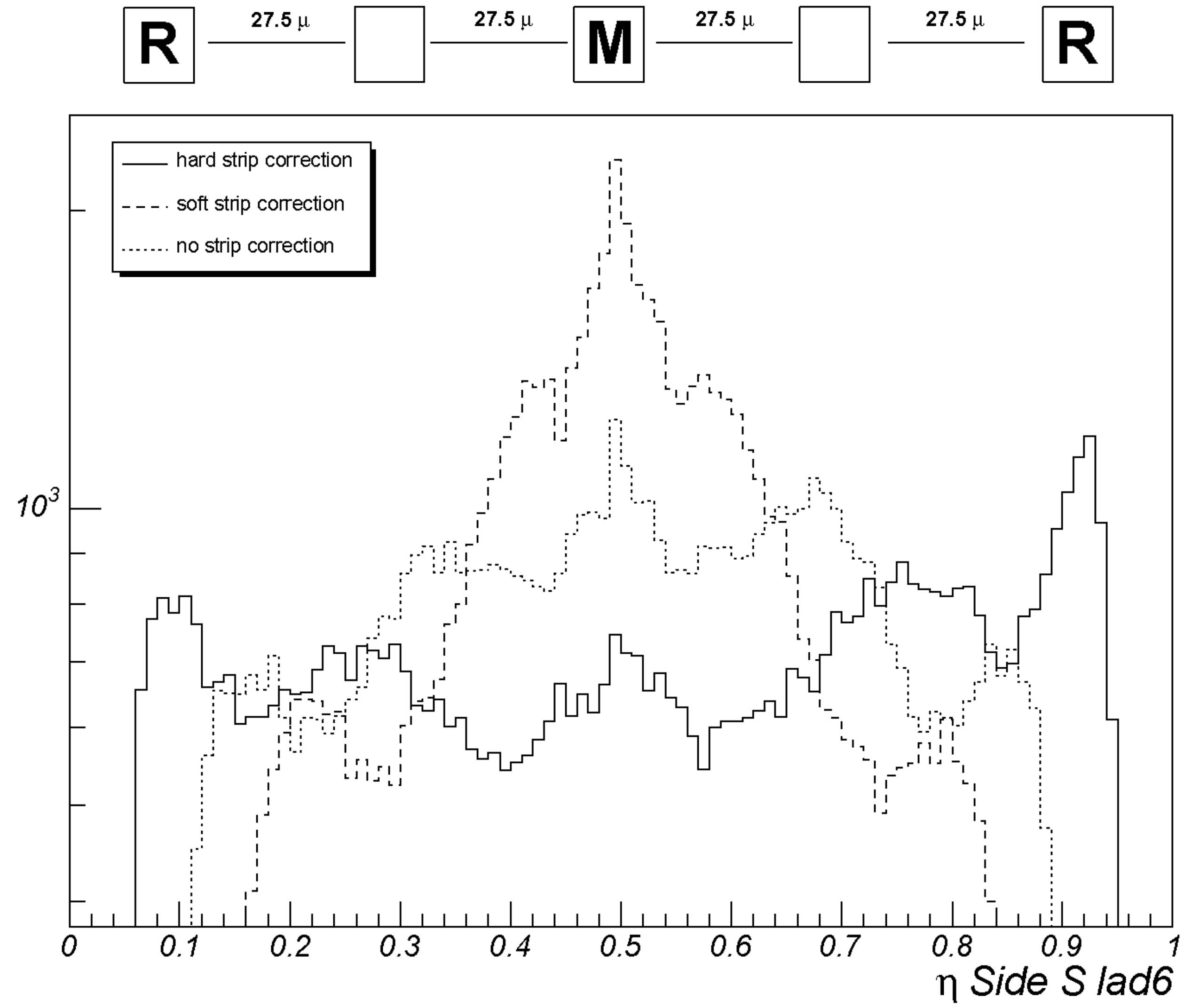
INFN/University of Perugia

p-side: η distribution



- more **uniform**
- **Implantation structure**

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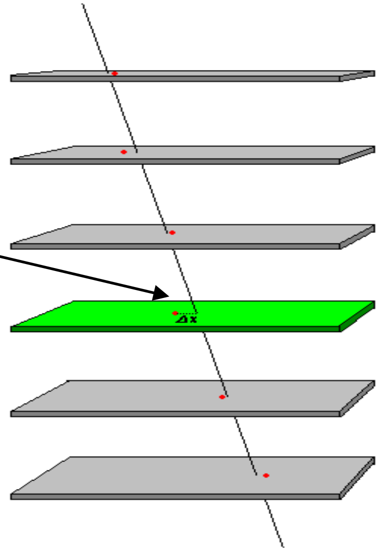
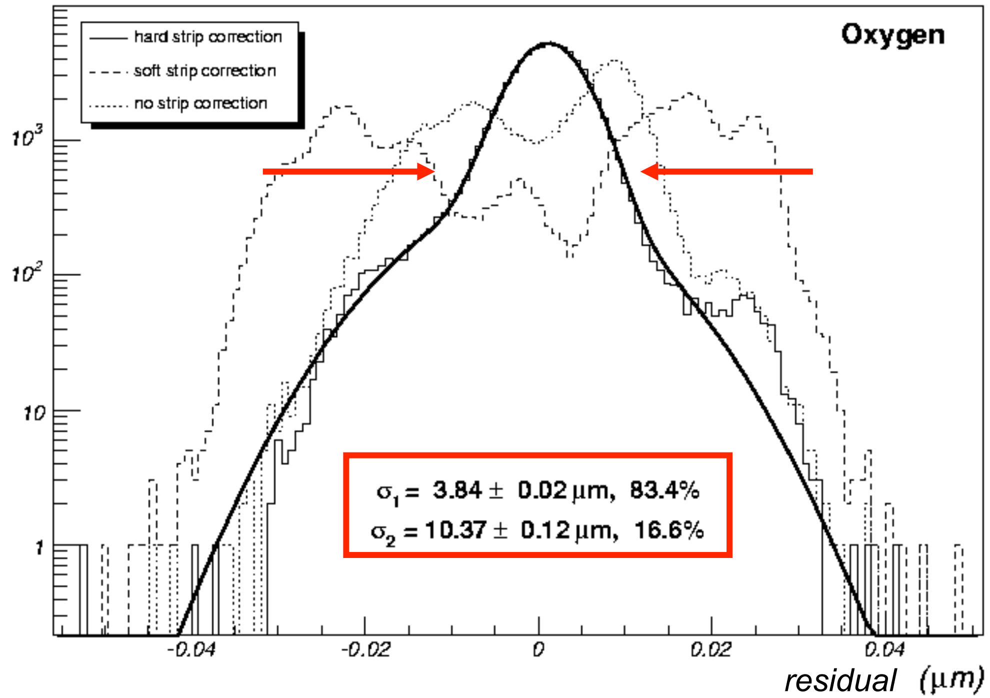
INFN/University of Perugia

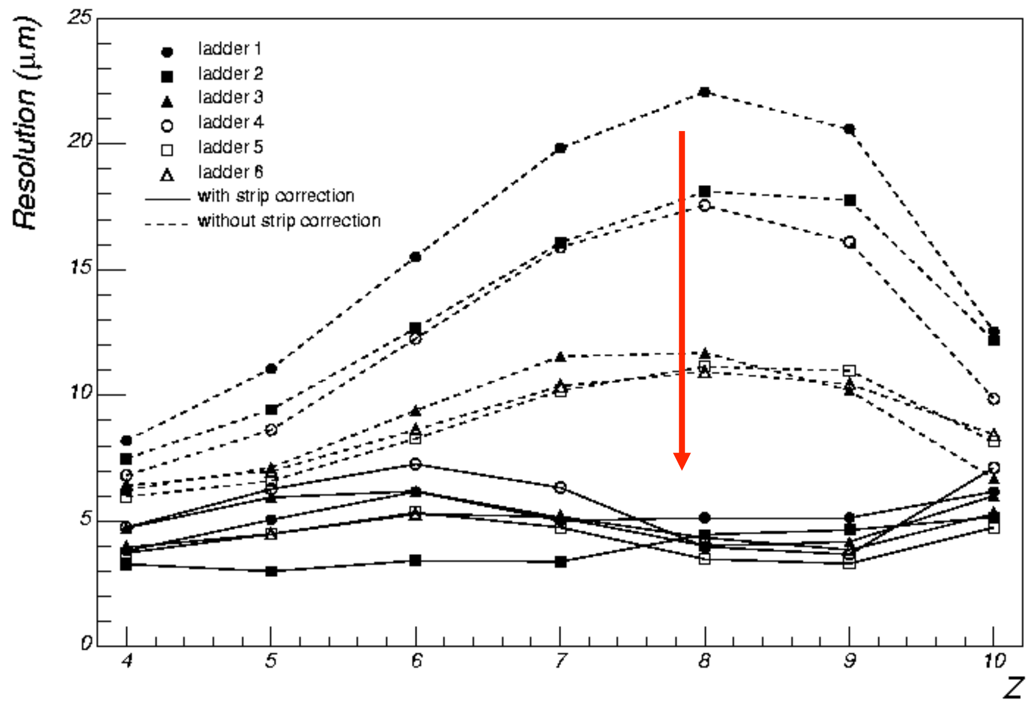
p-side: spatial resolution

- ladders allignement
- fit of a 5 point track
- analisys of the residual Δx distribution
- evaluation of the spatial resolution ($\approx \sigma_{\Delta x} - \sigma_{fit}$)

$$\Delta x = x_{mis} - x_{fit}$$

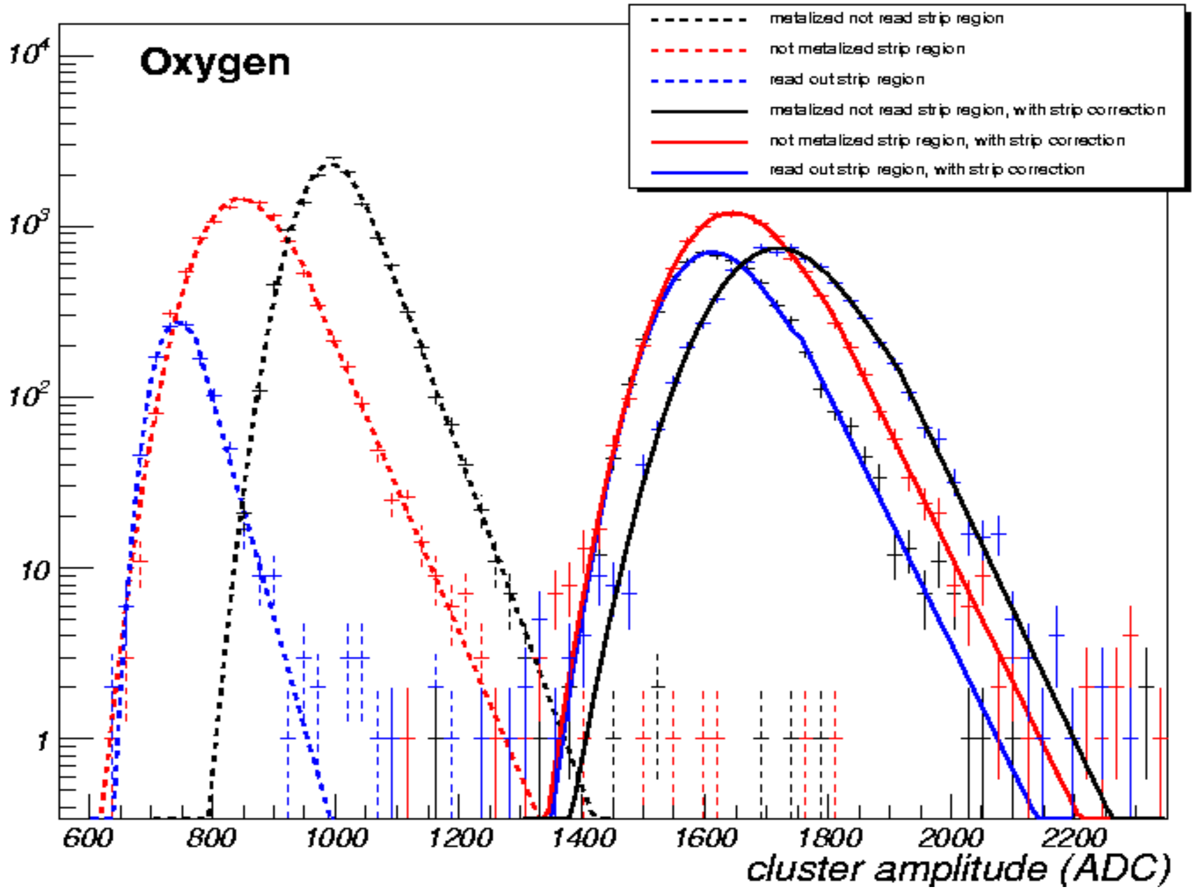






p-side: charge characterization

- Charge samples are obtained with the n-side likelihood test
- Clean separation in η region is now possible also on p-side
- The ladders differences can be parametrized with a single parameter (relative gain)
- A set of p.d.f. have been calculated for the different ions
- Costruction of a p-side likelihood test



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INFN/University of Perugia

p-side: test efficiency

Charge reconstructed with 6 **p-side** ladders

9				0.005	0.05	0.943
8				0.095	0.903	0.002
7			0.109	0.885	0.002	0.001
6	0.002	0.025	0.984	0.005	0.001	
5	0.012	0.961	0.026			
4	0.949	0.05				
Z	4	5	6	7	8	9

Charge reconstructed with 6 n-side ladders

- **the p-side charge is reconstructed with the maximum likelihood method**
- **the right charge is recognized in » 90% of the events**

Status of the work

→ Implementation of a charge discrimination algorithm with high efficiency and low contamination. An AMS-note is in preparation:

Heavy Ions ($Z > 2$) Charge Analysis for the October 2003 Beam Test of the AMS-02 Tracker Ladders

→ Use the algorithm to find fragmentation events and to study their topology

→ Compare these result with a FLUKA Monte Carlo simulation