



# Data analysis of pnCCDs

From raw CCD data to X-ray spectra

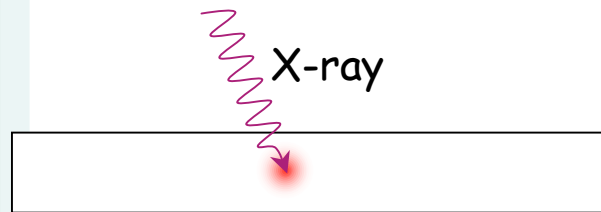
Robert Andritschke

April, 24<sup>th</sup>, 2007

# Measurement Process

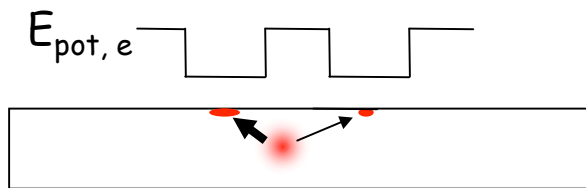


## Conversion



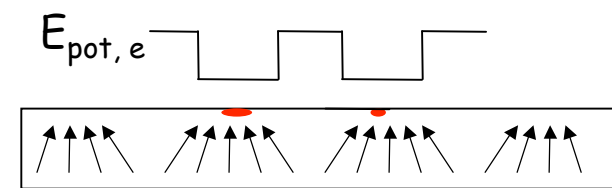
photon  $\rightarrow$   $e^-$ - $h$  pairs + phonons  
 $\Rightarrow$  Fano noise (physical limit)

## Storage



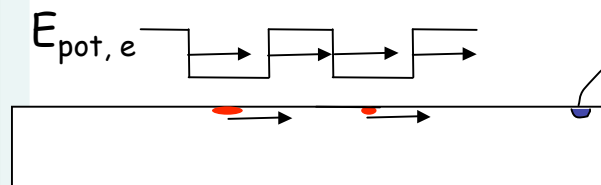
splitting of charges between neighbouring pixels

## Leakage currents



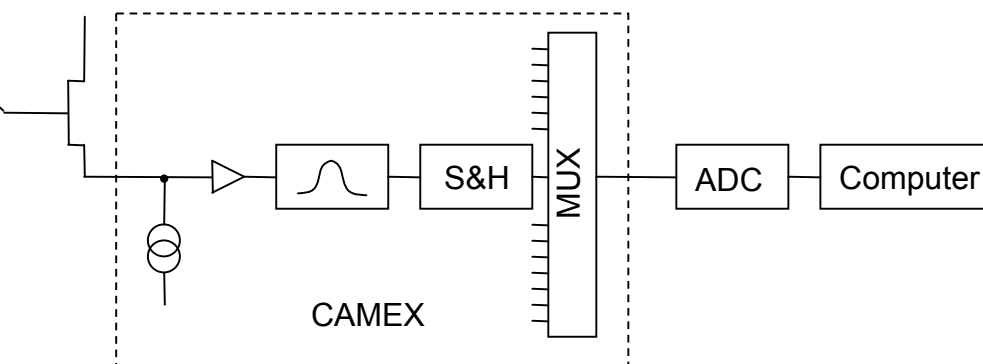
dark current noise

## Charge transfer



charges are shifted to the readout anode  
 charge trapping  $\Rightarrow$  CTE

## Amplification, shaping, serialization, digitalization



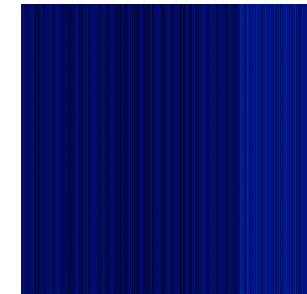
- electronics noise
- gain variations between channels
- offsets
- non-linearities, esp. of output stage

# First Step: "Initializing"

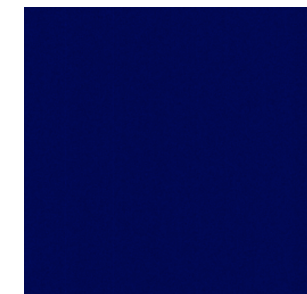


Usually 200 dark frames are taken at beginning of measurement.

- Calculate baseline level of each pixel (offset map): averages of each pixel



- Calculate the baseline fluctuations of each pixel (noise map including electronics and dark current noise): standard deviation of each pixel



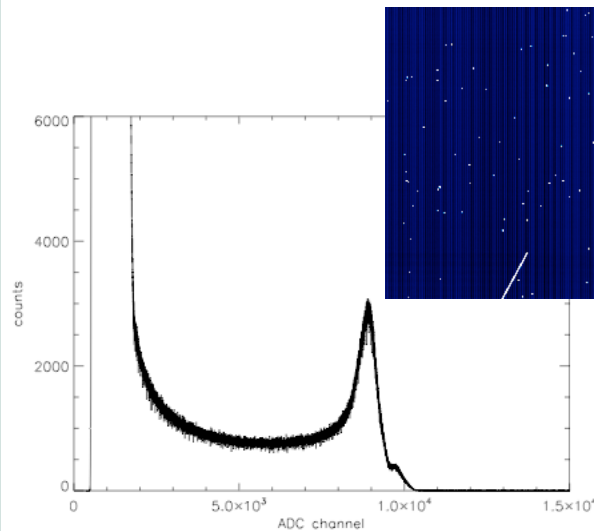
Signals from muons are filtered.

# Subtracting Offsets

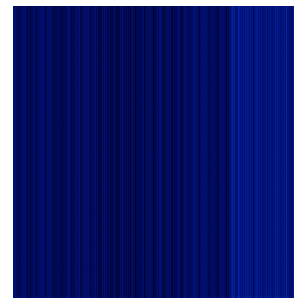


Each measurement stage contributes to the overall offset:

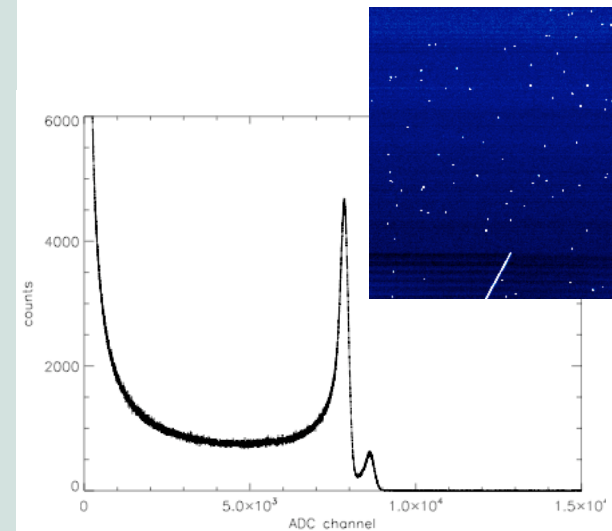
- amplification and driving stage add offsets
- the ADC has an (adjustable) offset
- integrated leakage currents in the CCD pixels



raw frame



offset map



offset corrected  
frame

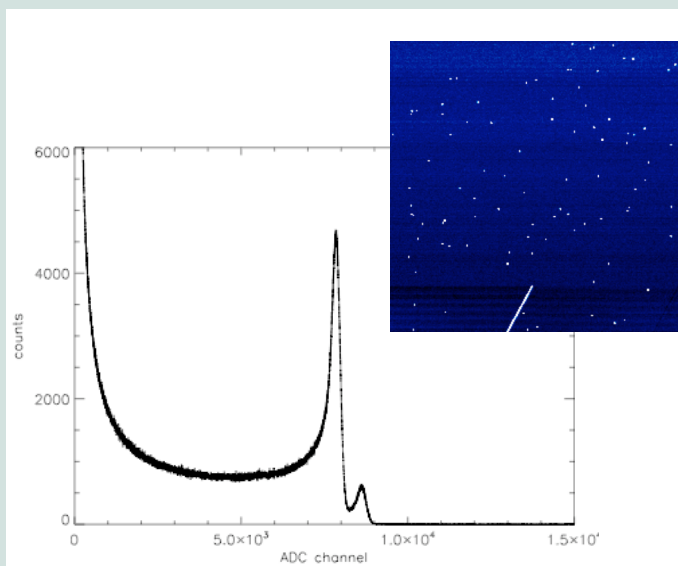
- =

# Common-mode Correction



**Common-mode noise:** Distortion of all readout channels by the same amplitude mainly due to crosstalk of the environment

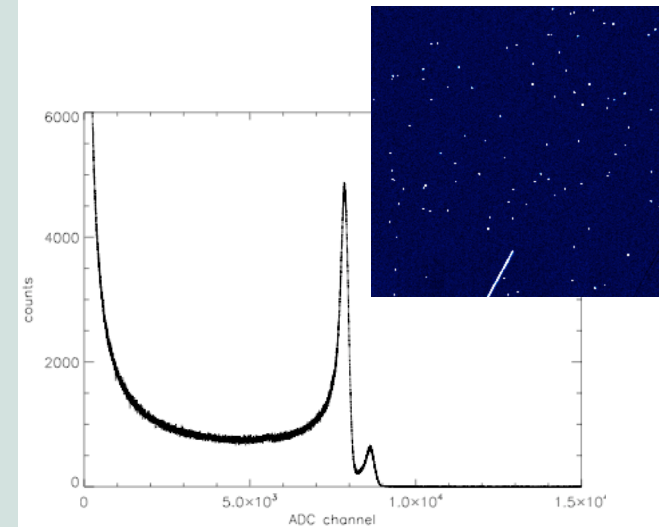
**can be determined:** Average deviation from the baseline levels of channels without signal  
**and subtracted.**



offset  
corrected  
frame



common-  
mode

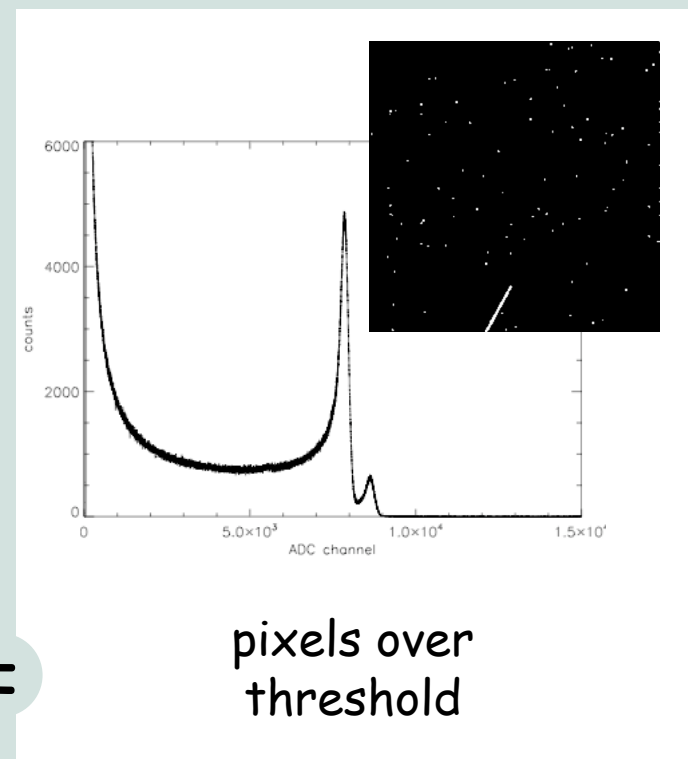
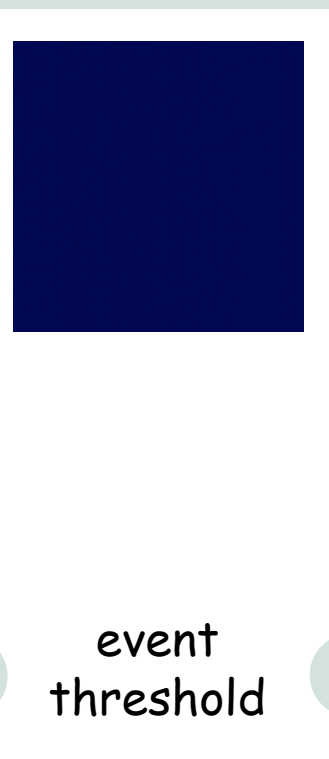
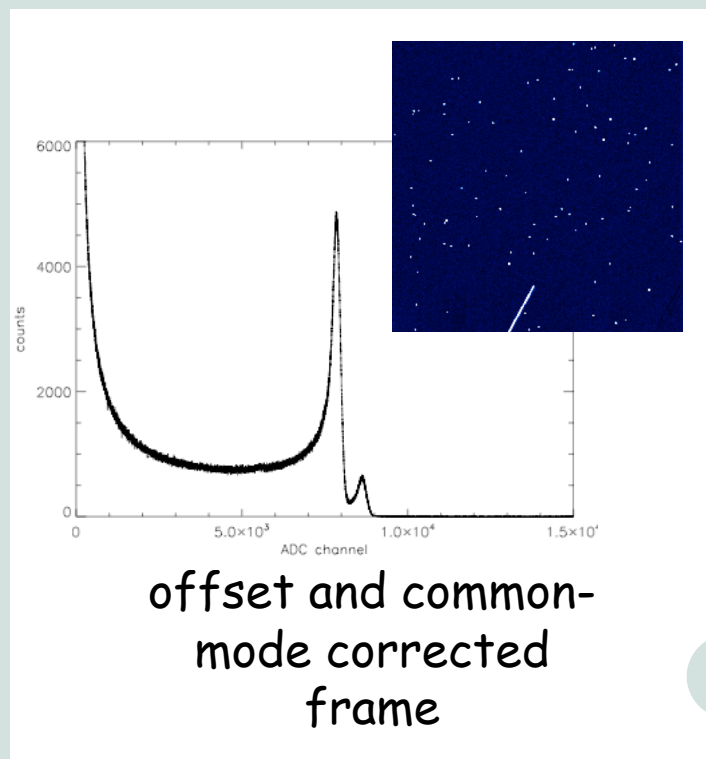


offset and  
common-mode  
corrected frame

# Signal Filtering



- pixels showing a signal are selected
- criterium: pixel exceeds  $4 \times$  its noise

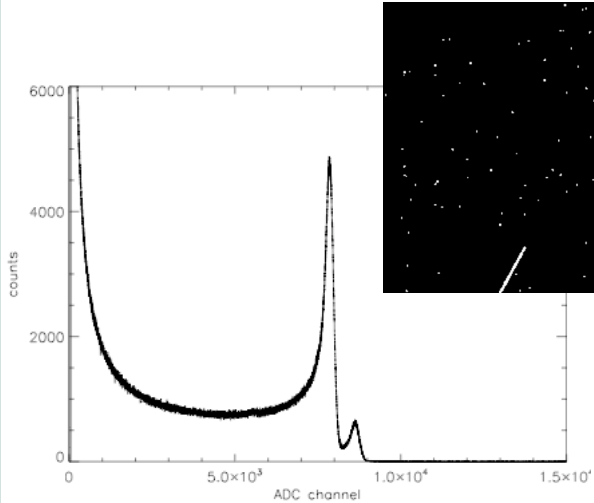


# Event Recombination

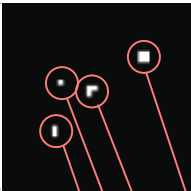


Recombination of charge clouds distributed over one or more pixels:

- neighbouring pixels showing signals are combined to an event
- events are stored in a list
- further processing exclusively from event list

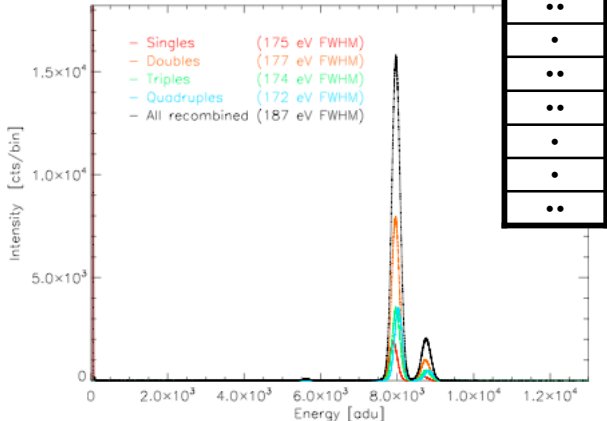


pixels over threshold



- quadruple
- triple
- single
- double

recombination



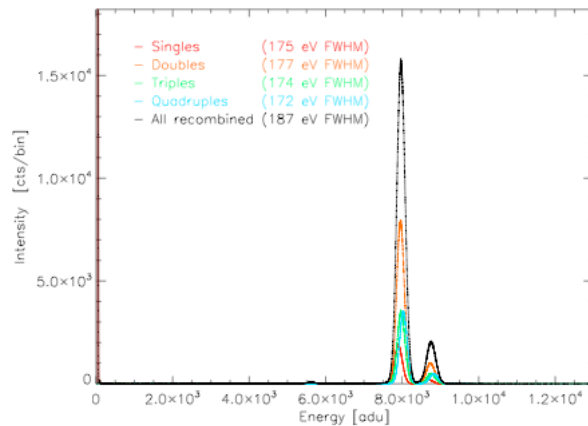
raw photon list

# Gain and CTE Correction

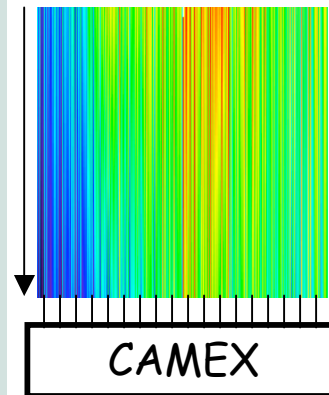


Different gains of the amplification stages and Charge Transfer Efficiency from shifting the charges are corrected **at once**.

- Gain and Charge Transfer Efficiency (CTE) factors are determined:
  - Fit of a simple model channel-by-channel
- Apply gain and CTE matrix



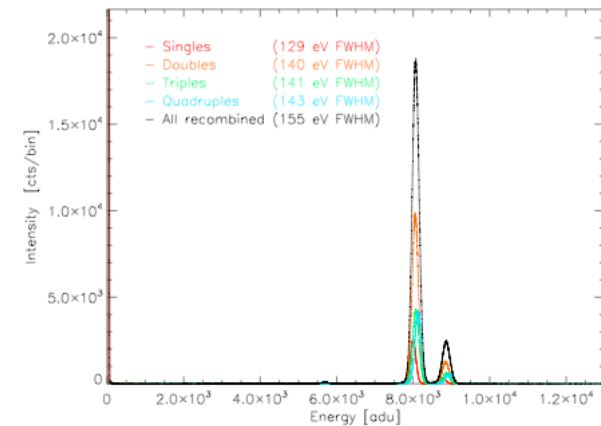
raw photon list



×

gain and CTE  
matrix

=



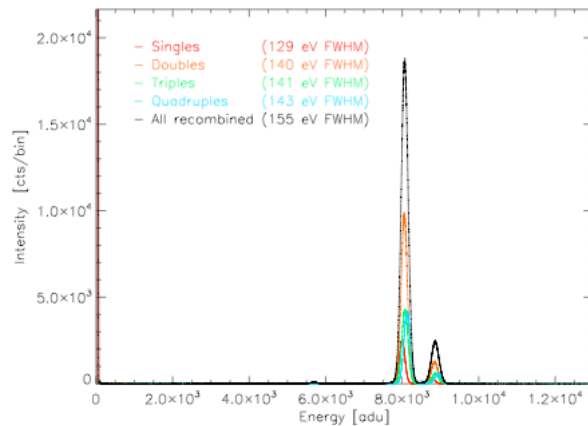
gain and CTE corrected  
photon list



# Non-linearity Corrections



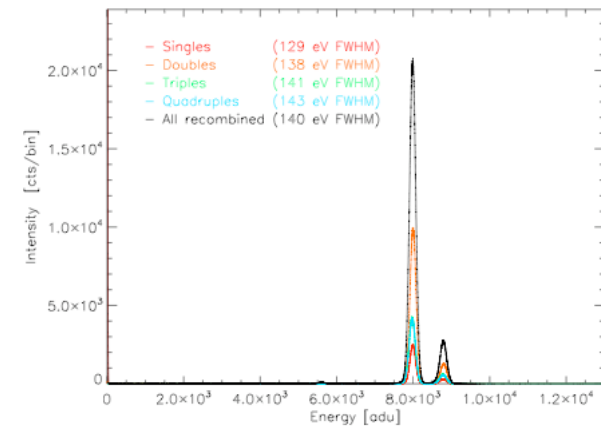
- Empirically gained corrections for
- non-linearities of the output buffer of the CAMEX
  - unidentified sources for non-linearity
- ⇒ work in progress



gain and CTE corrected  
photon list

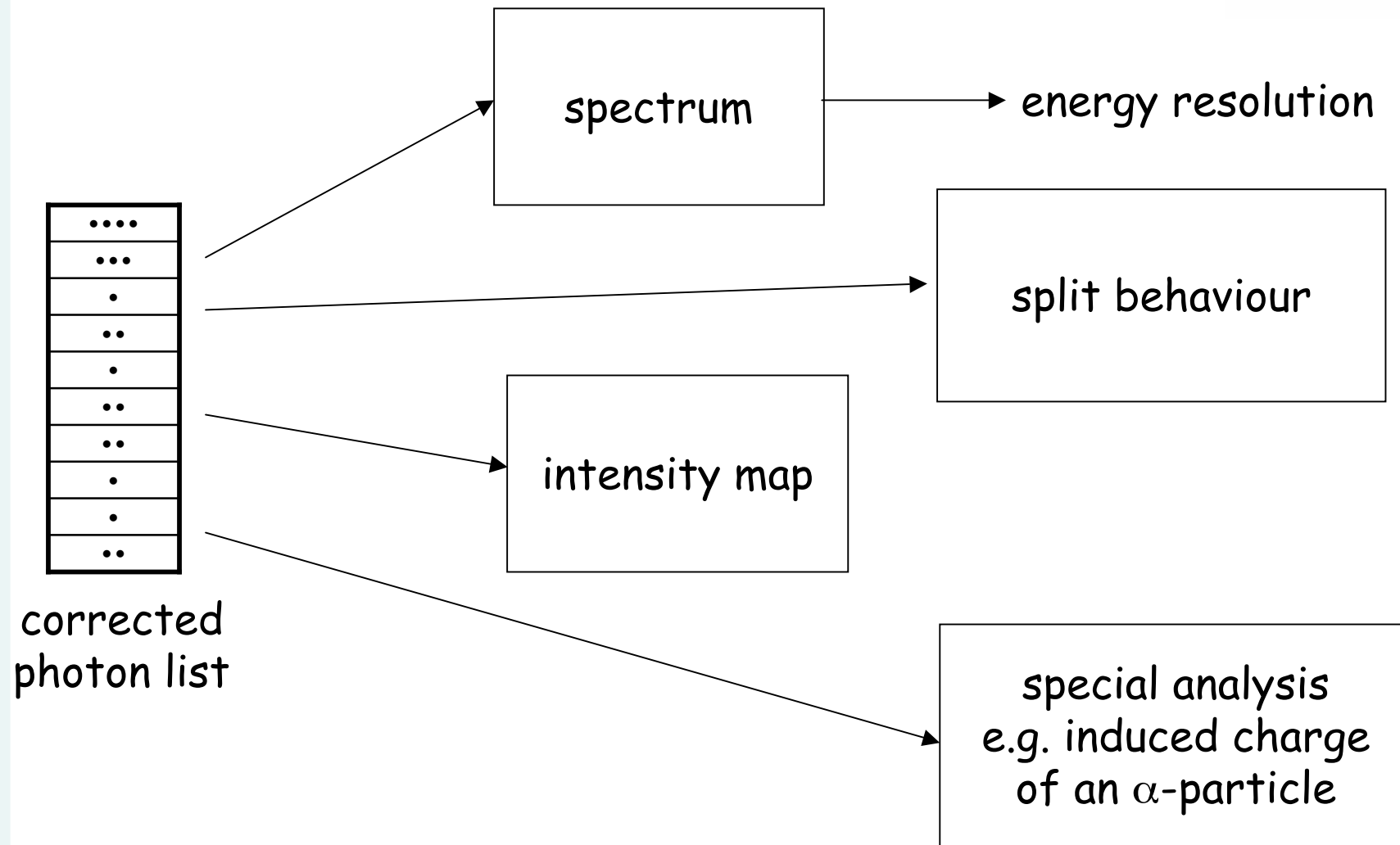
$$nloff = 42.5$$
$$q = 5 \cdot 10^{-5}$$

$$f(q, nloff, a)$$



photon list corrected  
for non-linearities

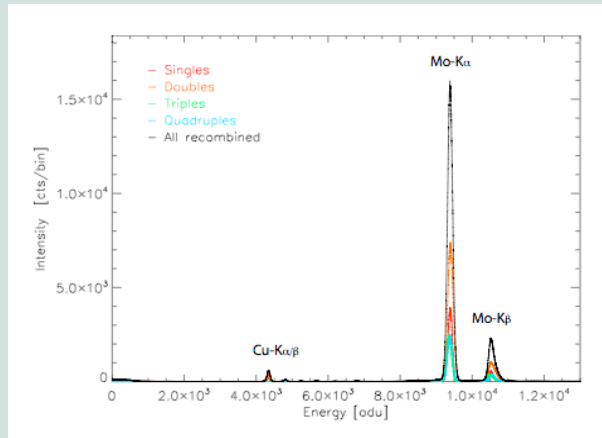
# Extracting Characteristic Parameters



# Current Applications

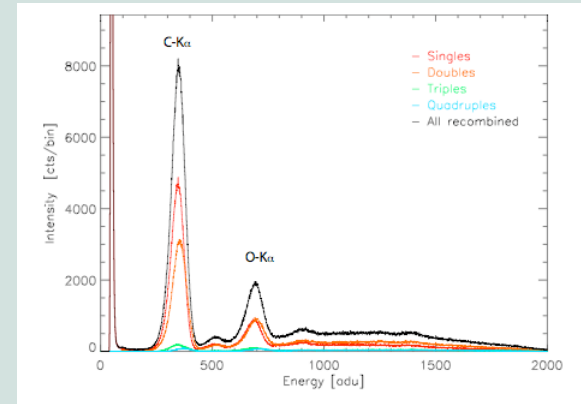


## eROSITA

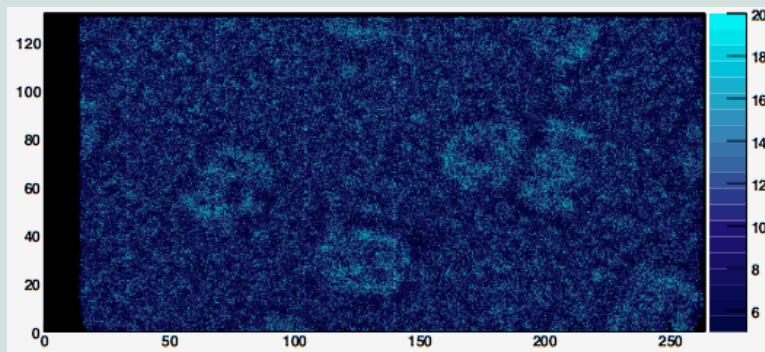


## TROPIC

Testphase (G. Hartner, Neuried)



## TEM (Transmission Electron Microscopy) first tests



## XFEL first tests at Bessy and Desy

