# Calibration of the EPIC-pn Camera in Timing Mode

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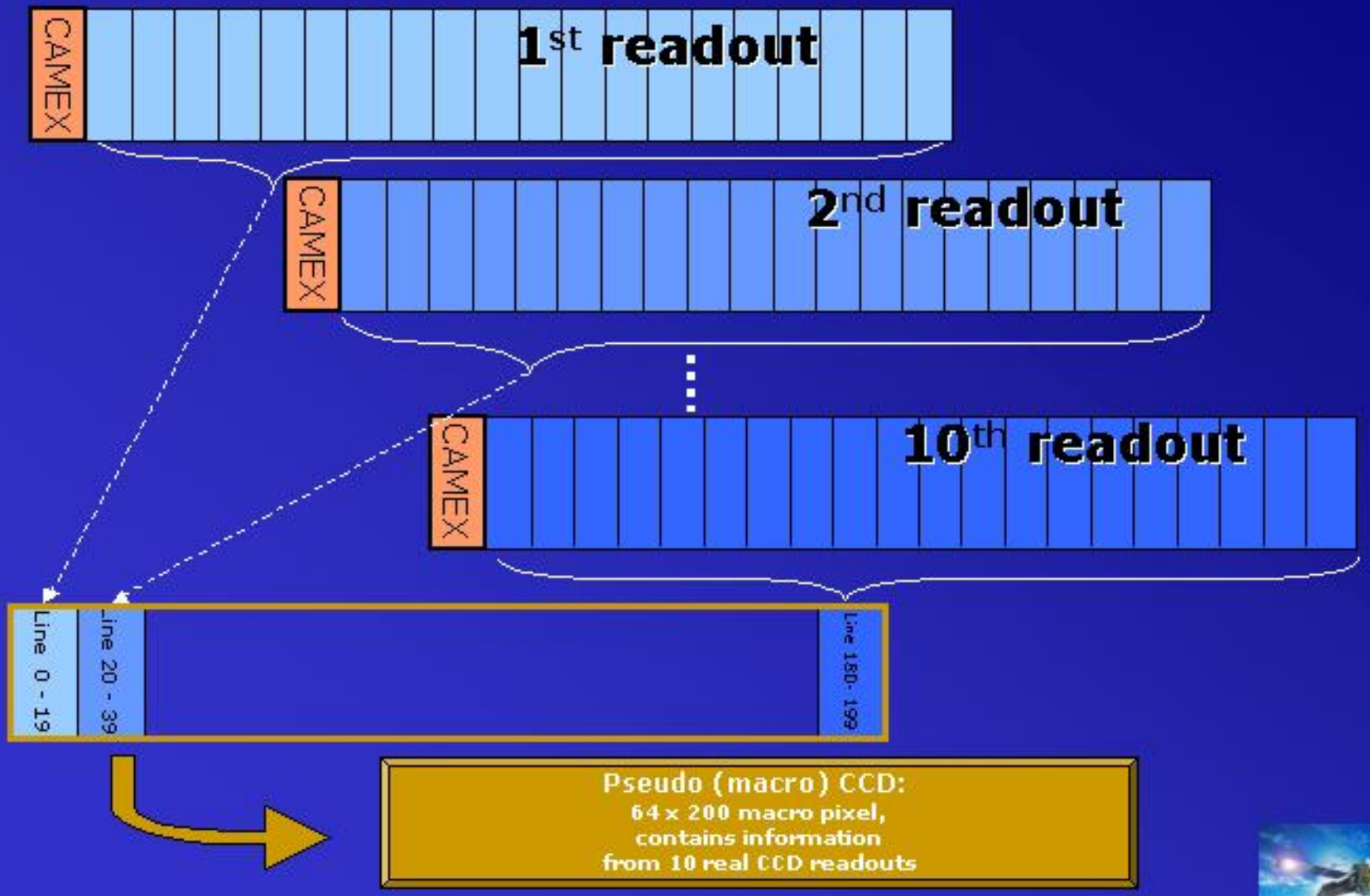
- main points for calibration
- modelling the CTE in Timing Mode
- ground calibration
- in orbit calibration
- results

# CCD readout in Timing Mode



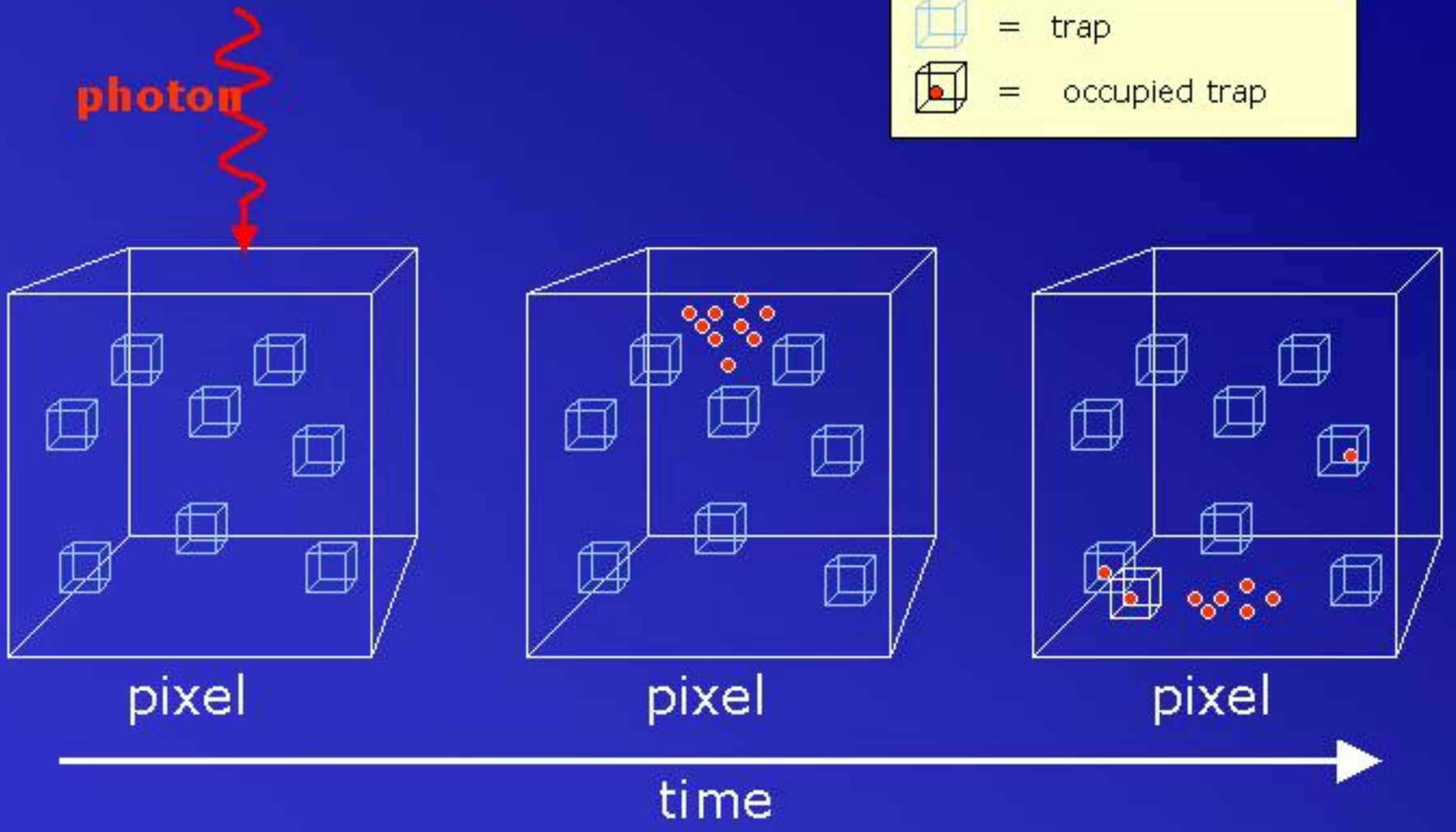
# Main Points for Calibration

- Charge Transfer Efficiency
- Amplification
- Partial Event Effect
- Energy Redistribution
- Energy Resolution

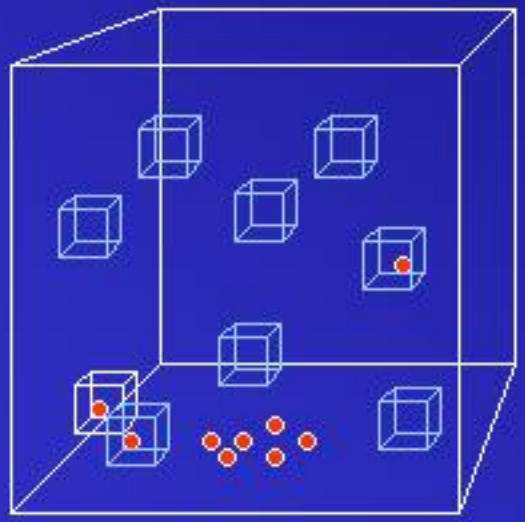


# the model:

## i) capture of electrons in traps



# ii) capture & reemission of electrons



pixel

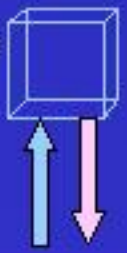
$n_e$= density of free electrons

$n_{t0}$= total density of traps

$n_0$= total density of occupied traps at $t=0$

$n_{ec}$= density of captured electrons

trap



$c_n$= capture probability

$e_n$=emission probability

change in captured electrons

$$\frac{d}{dt} n_{ec}(\vec{r},t) = \underbrace{c_n(\vec{r}) n_{t_0}}_{\uparrow} - \underbrace{c_n(\vec{r}) n_{ec}(\vec{r},t)}_{\uparrow} - \underbrace{e_n n_{ec}(\vec{r},t)}_{\downarrow}$$

# iii) solution

$$n_{ec}(\vec{r},t) = \frac{n_{t_0}}{1-\frac{e_n}{c_n}}\left(1-e^{-t(e_n+c_n)}\right)+n_0 e^{-t(e_n+c_n)}$$

$$N_{ec} = \int_{pixelvolume} n_{ec}\,dV$$

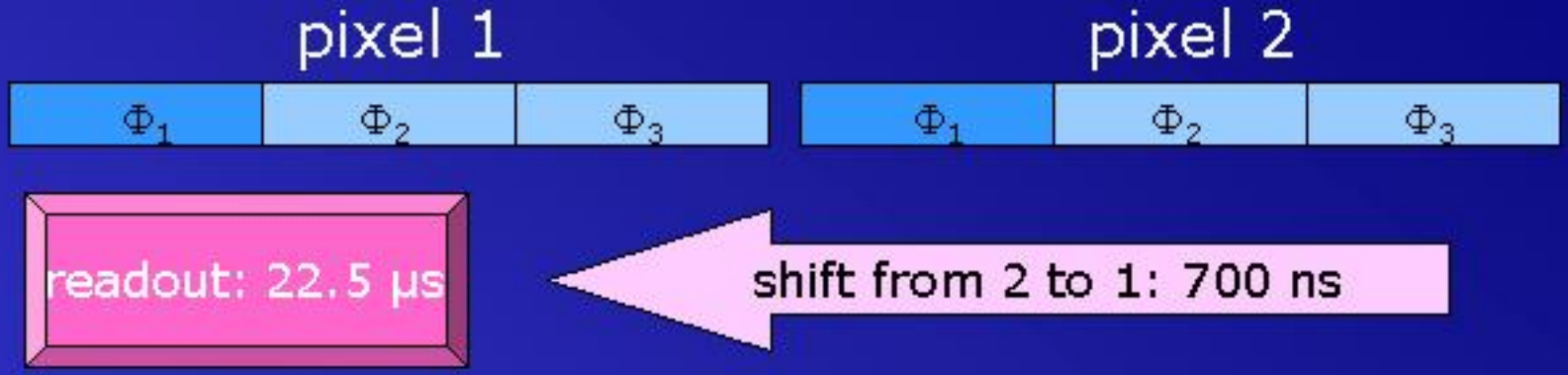
$$e_n = AT^2 e^{\left(-\frac{E_{act}}{kT}\right)}$$ $e_n$=emission probability

$$c_n = \sigma v_{th} n_e$$ $c_n$= capture probability

T = temperature in K
k = Boltzmann constant
A = temperature independent constant
$E_{act}$= thermal activation energy for the emission of electrons
σ = capture cross section
$v_{th}$= thermal velocity of electrons
$n_e$ = free electron density

$$CTE = \frac{E_\gamma - 3{,}65\text{eV}\cdot N_{ec}}{E_\gamma}$$

# iv) charge loss per pixel in Full Frame mode




modelling

- collection of charge only under $\Phi_1$
- shift = store m times with t = (700 ns)/m $m \in \mathbb{N}$

  → charge loss: $m \cdot n_{ec2}$
- main storage under $\Phi_1$ with t = 22.5 µs

  → charge loss: $n_{ec1}$

$$n_{ec} = n_{ec1}\left(22.5\mu s\right) + m \cdot n_{ec2}\left(700ns/m\right)$$

# v) charge loss per pixel in Timing mode


compared to Full Frame:

- collection of charge only under $\Phi_1$
- shift = store m times with t = (700 ns)/m  $m \in \mathbb{N}$
  - → charge loss: m • $n_{ec2}$
- main storage under $\Phi_1$ with t = 22.5 µs but only every **10** pixel
  - → charge loss: : $n_{ec1}/10$

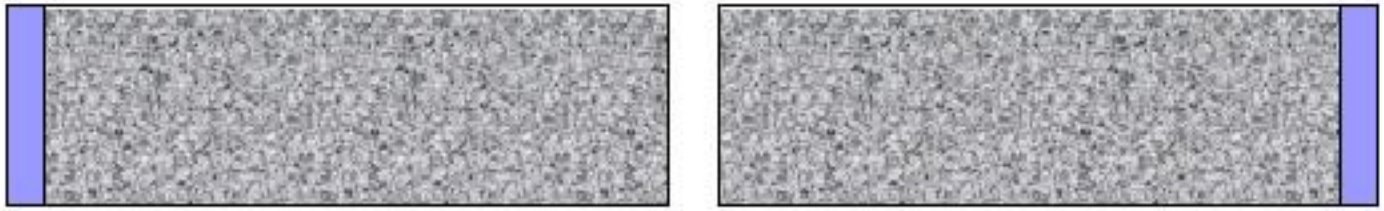
$$n_{ec} = \frac{n_{ec1}(22.5\mu s)}{10} + m \cdot n_{ec2}\left(700 ns/m\right)$$

# calibration on ground:
## the slit-slit-method

**Full Frame Mode**

Slit-Measurement near CAMEX

Slit-Measurement opposite to CAMEX

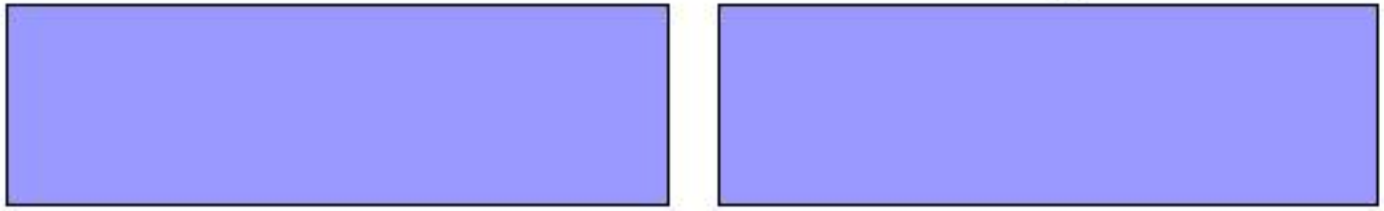


$S_0$ & Position

**Timing Mode**

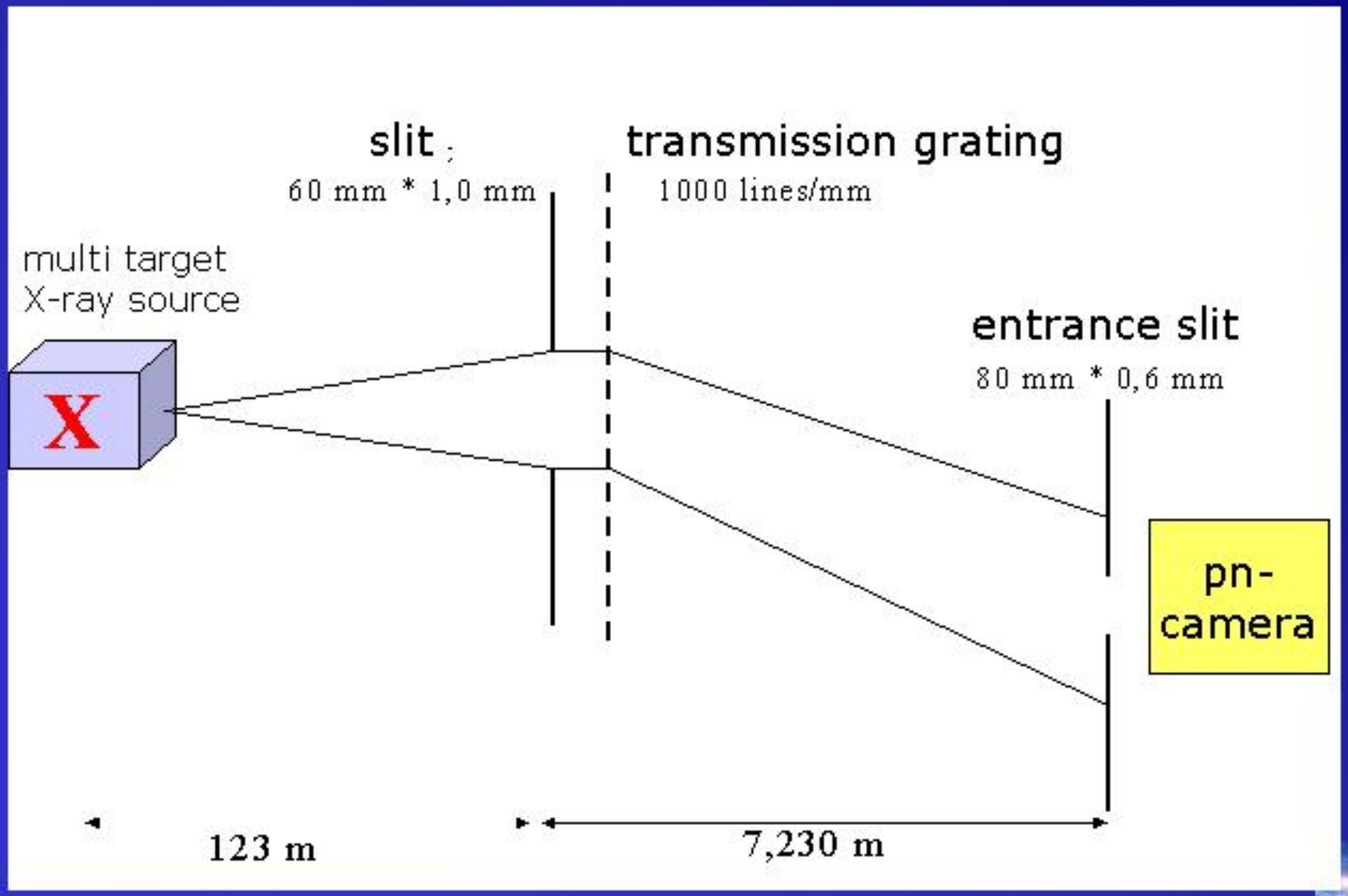
Slit-Measurement near CAMEX

Slit-Measurement opposite to CAMEX



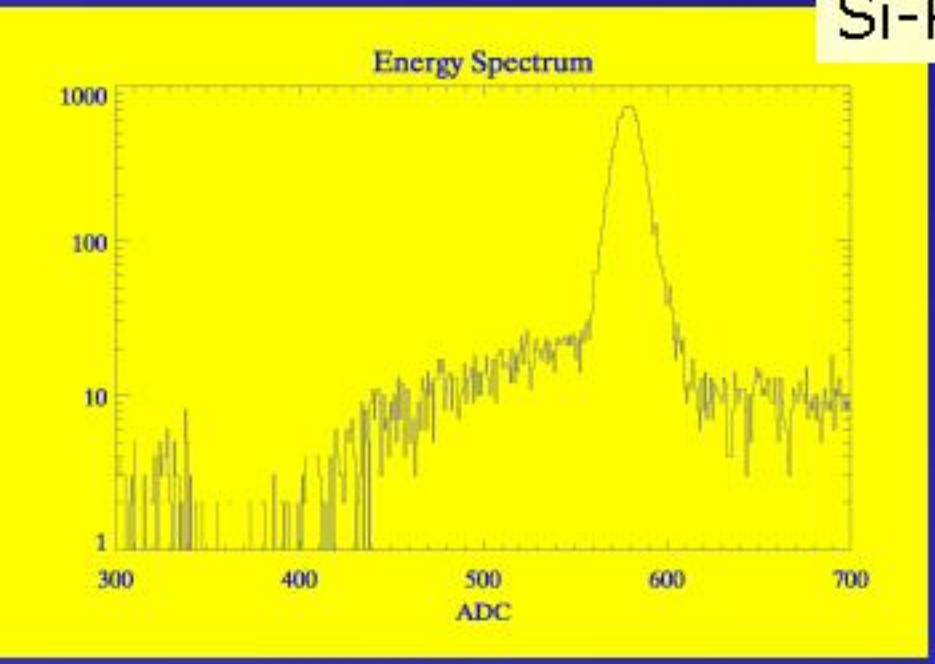
$S_0$ & $S_n$

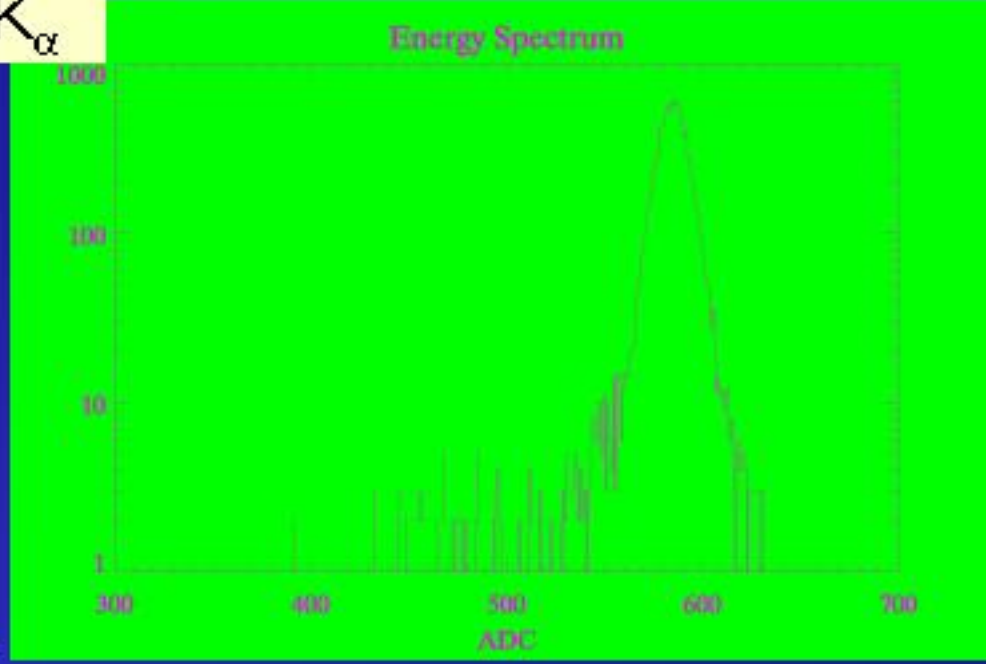
# calibration on ground:
## monochromator at MPE-PANTER



# calibration on ground:
## spectra without and with monchromator

Si-$K_\alpha$

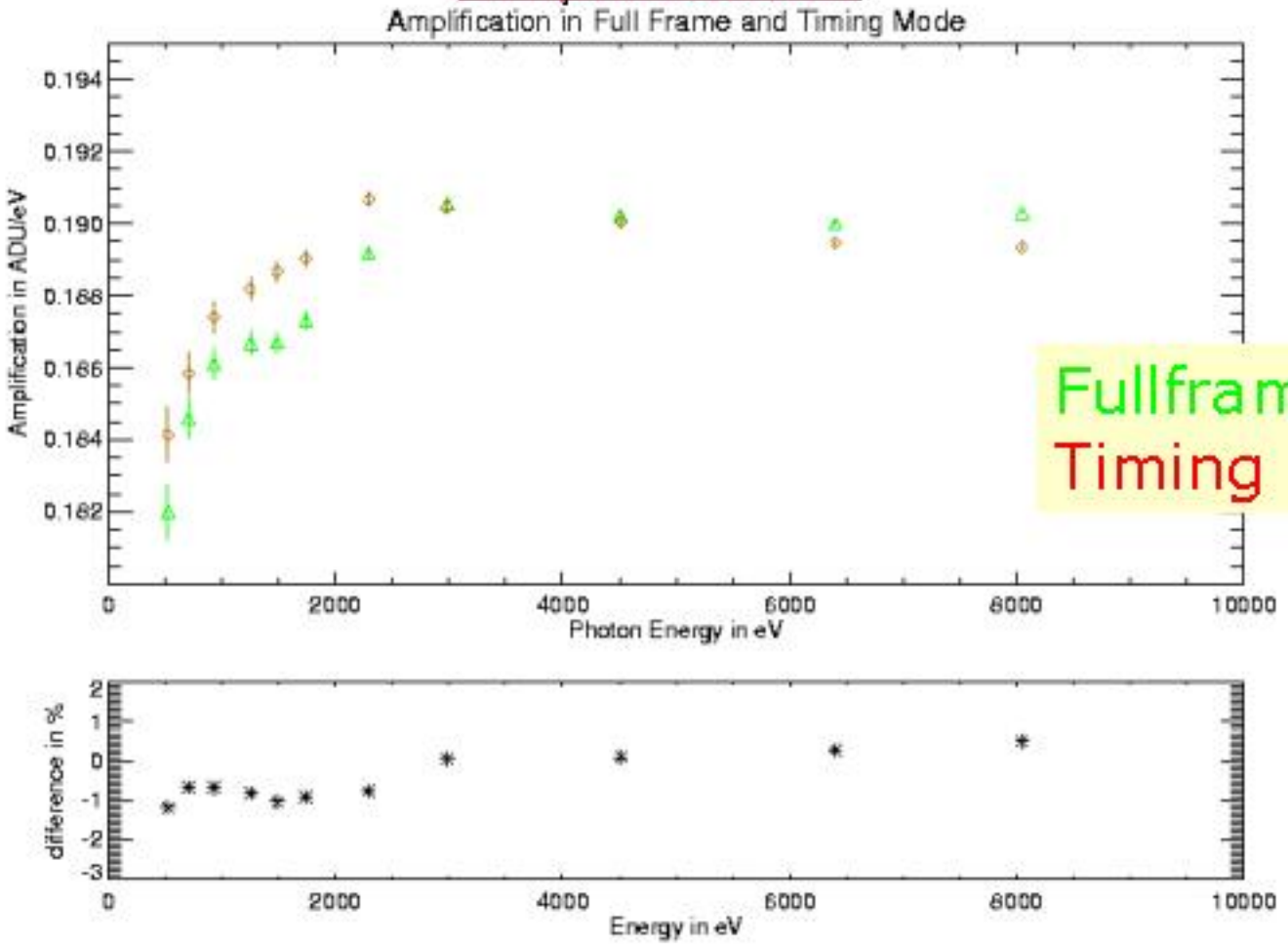


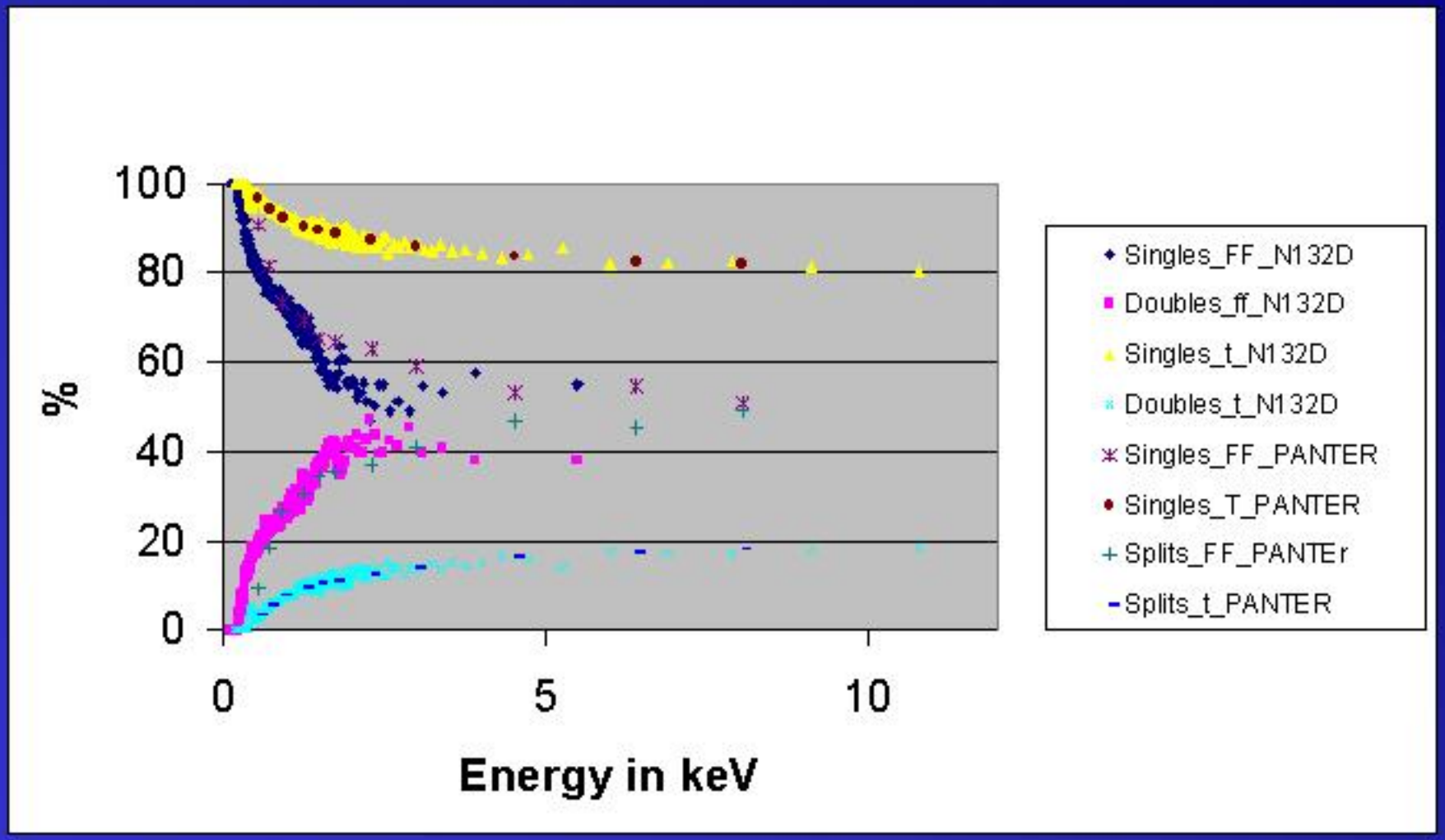

- reduction of Bremsstrahlung
- cleaner lines

# calibration on ground:

## Amplification

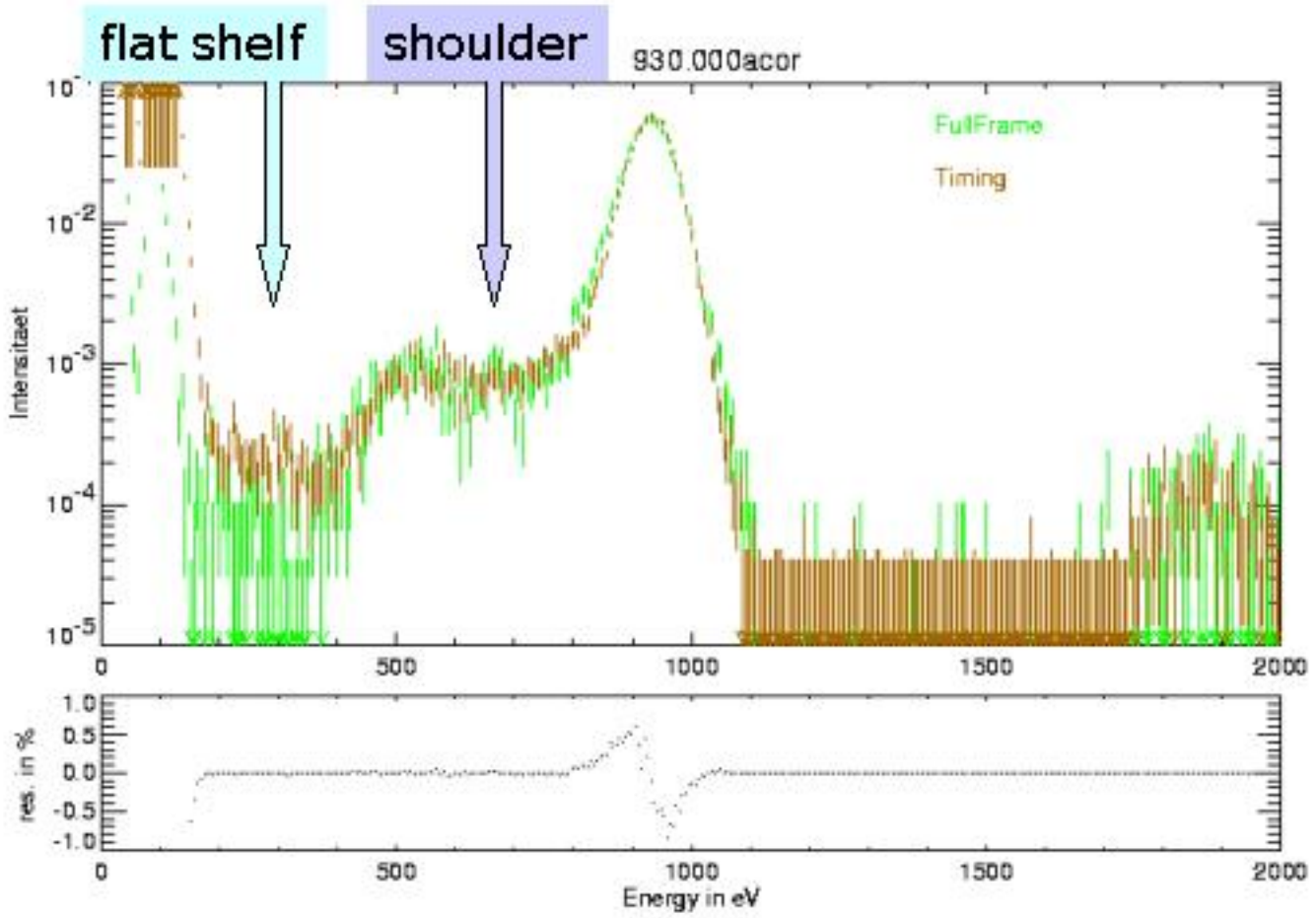


# Pattern FF & Timing

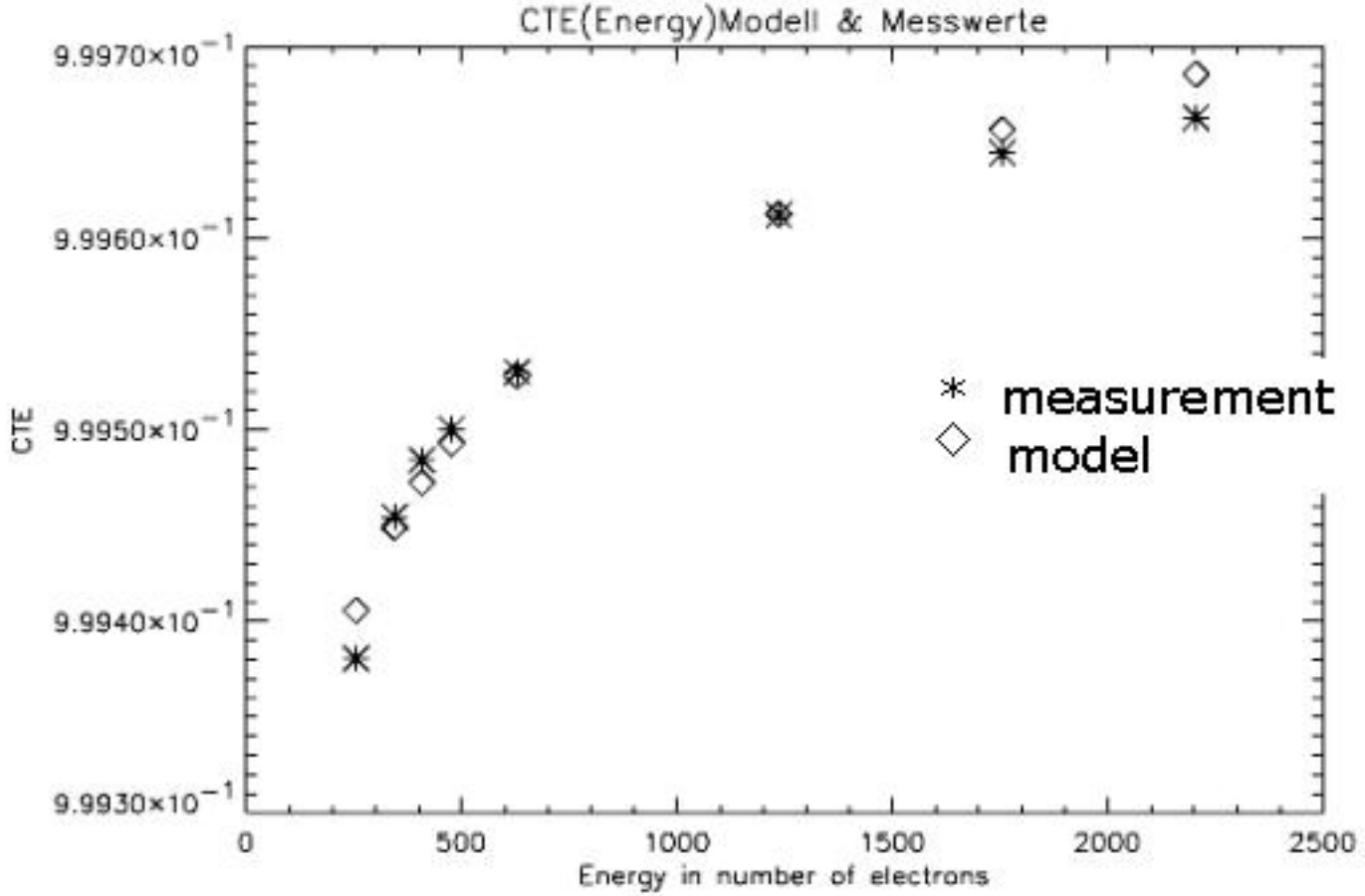


# calibration on ground:

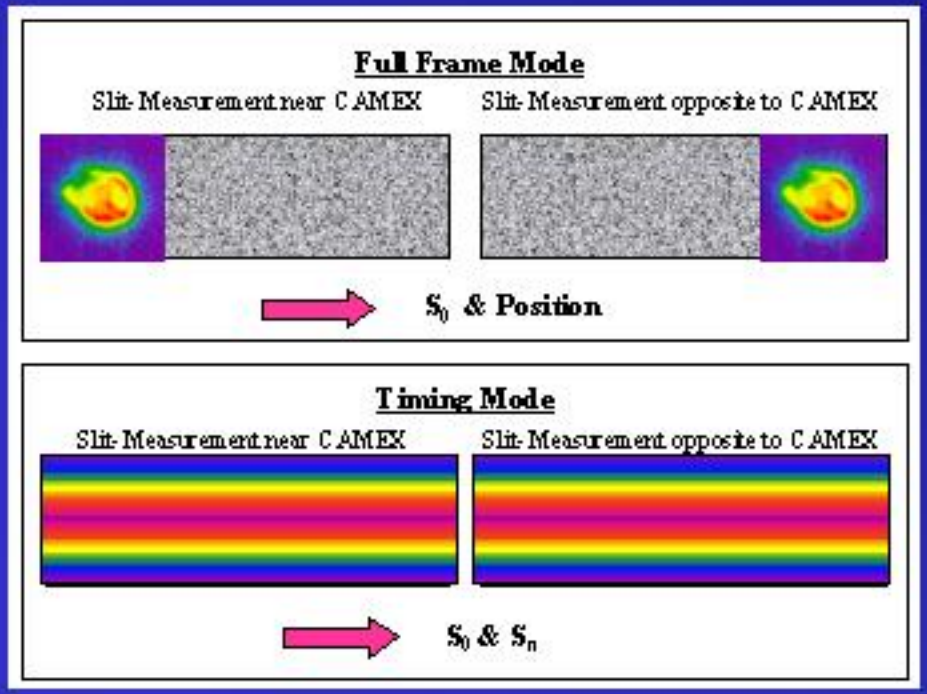
## Partial Events



# calibration on ground:
## CTE



# in orbit calibration




- idea:
  - do "slit-slit-method" with a source with many spectral lines
  - compare peak positions after new CTE correction

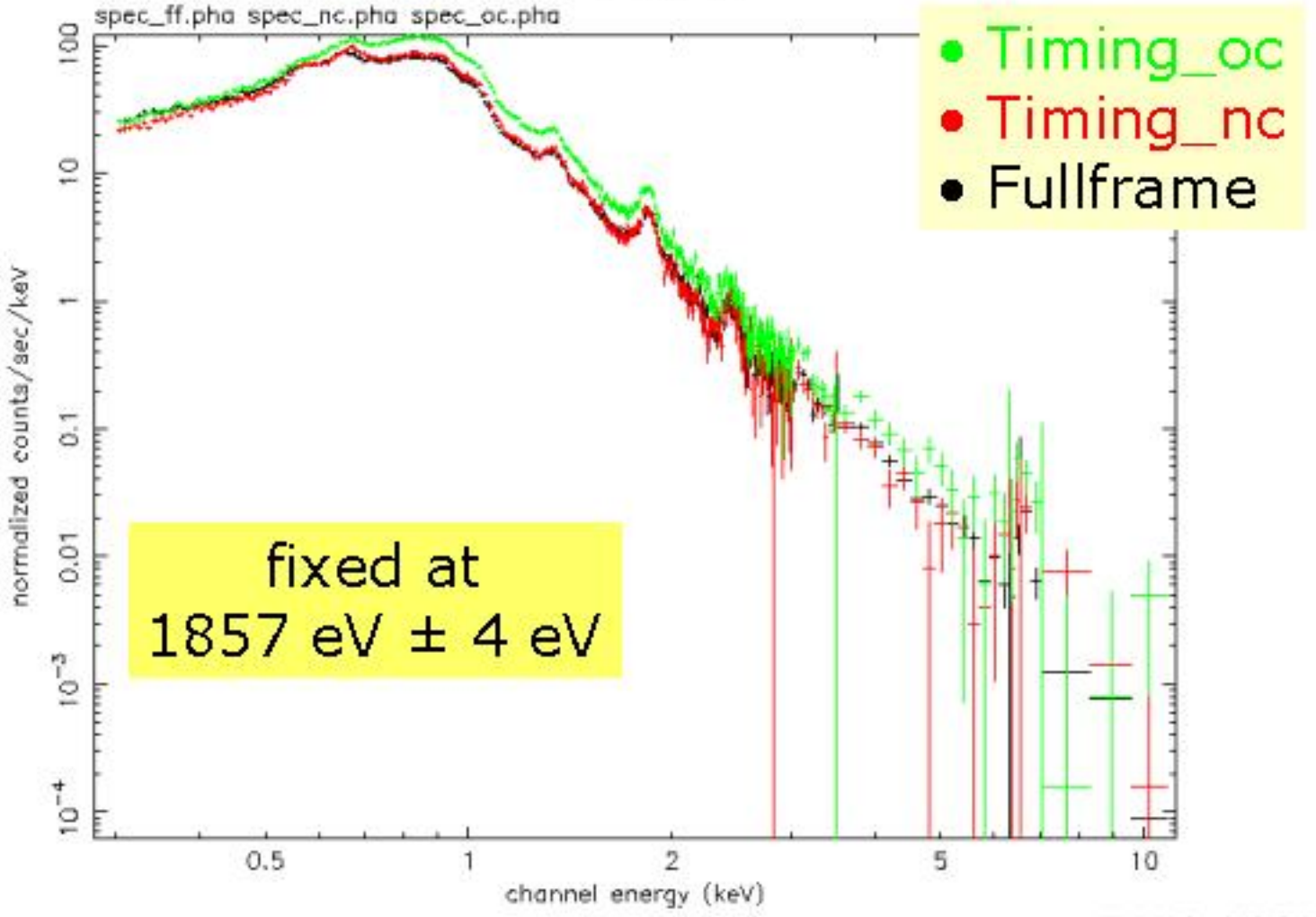
- observations:

  2 observations of N132D in revolution 83

  143.10.23.43: 35,2 ks

  144.12.39.52: 24,6 ks

# in orbit calibration



# to be done

- fit data with partial-event model
- separate partial event effect from amplification
- verify CTE-correction after timing-amplification correction
- energy resolution
- 2nd observation of N132D (only half source in FOV → less "over"-correction)