Digital primary electron counting: W, Fano Factor, Polya vs Exponential

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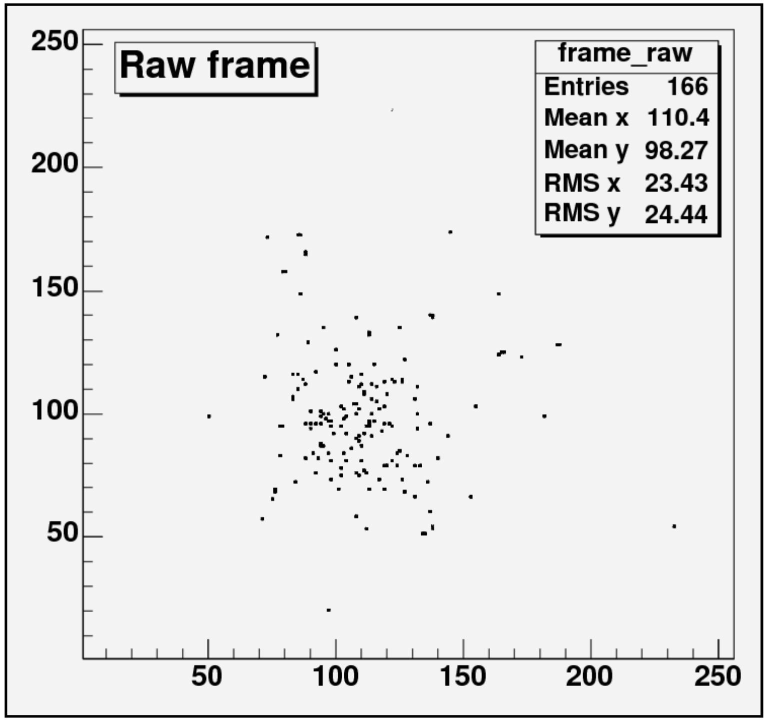
RD51, Paris, 13-15 October 2008

Introduction

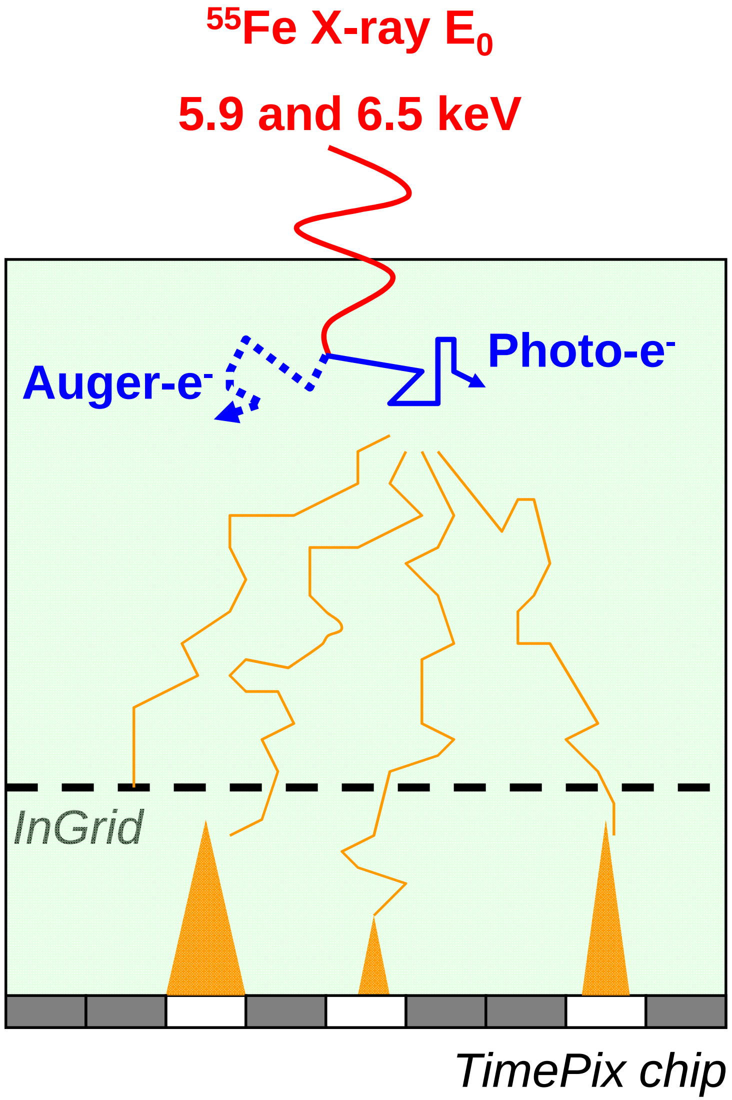
- Motivations
  - Study single electron detection efficiency of GridPix detectors
  - What are the gain fluctuations?
    Polya/Exponential-like
- Two approaches
  - Measure the single electron response (difficult)
  - Measure energy resolution, primary statistics (W & F)
    then deduce gain fluctuations
- New technique to measure F:
  count primary electrons from ^{55}Fe quanta conversions

^{55}Fe quanta conversions seen by GridPix

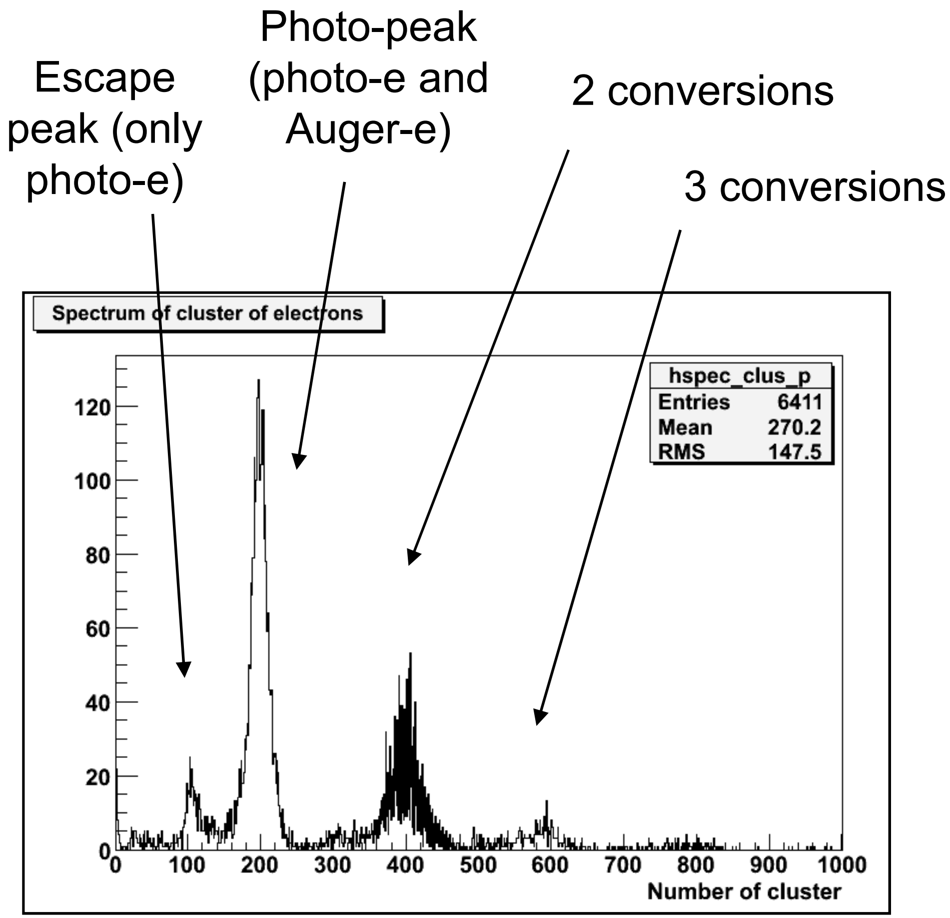
After large drift distance, primary e$^-$ separate and can be counted



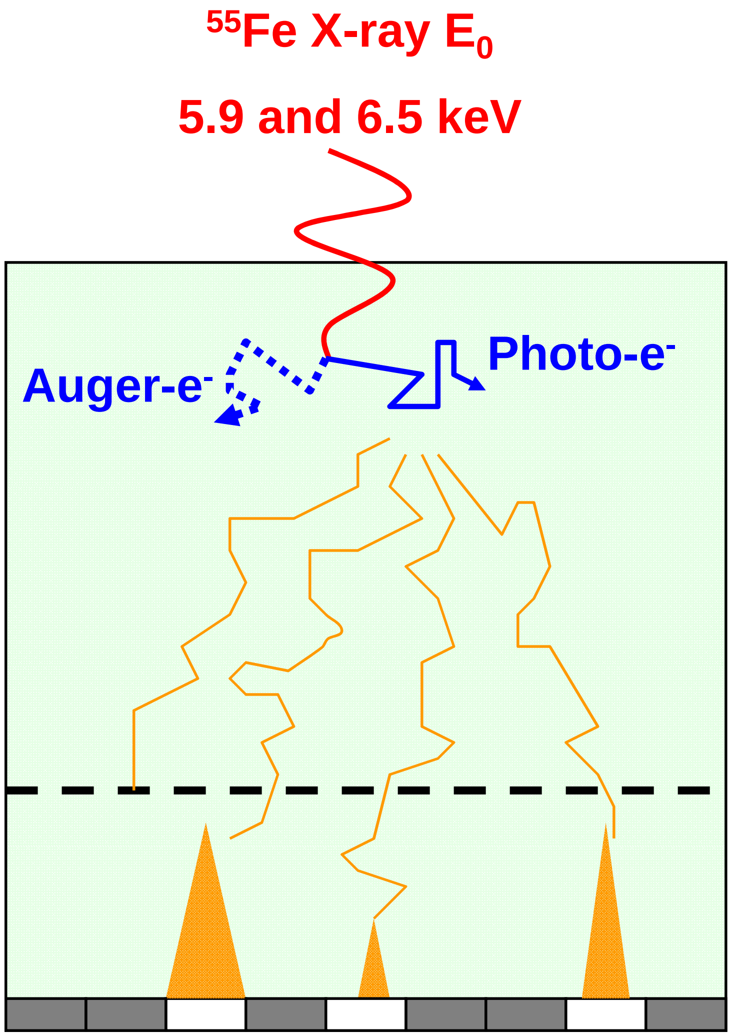
Gas mixture: Ar/iso 95/5



^{55}Fe quanta conversions seen by GridPix



Raw spectrum



TimePix chip

Look at the escape peak only (smallest number of primary electrons)

Measurements of W and F

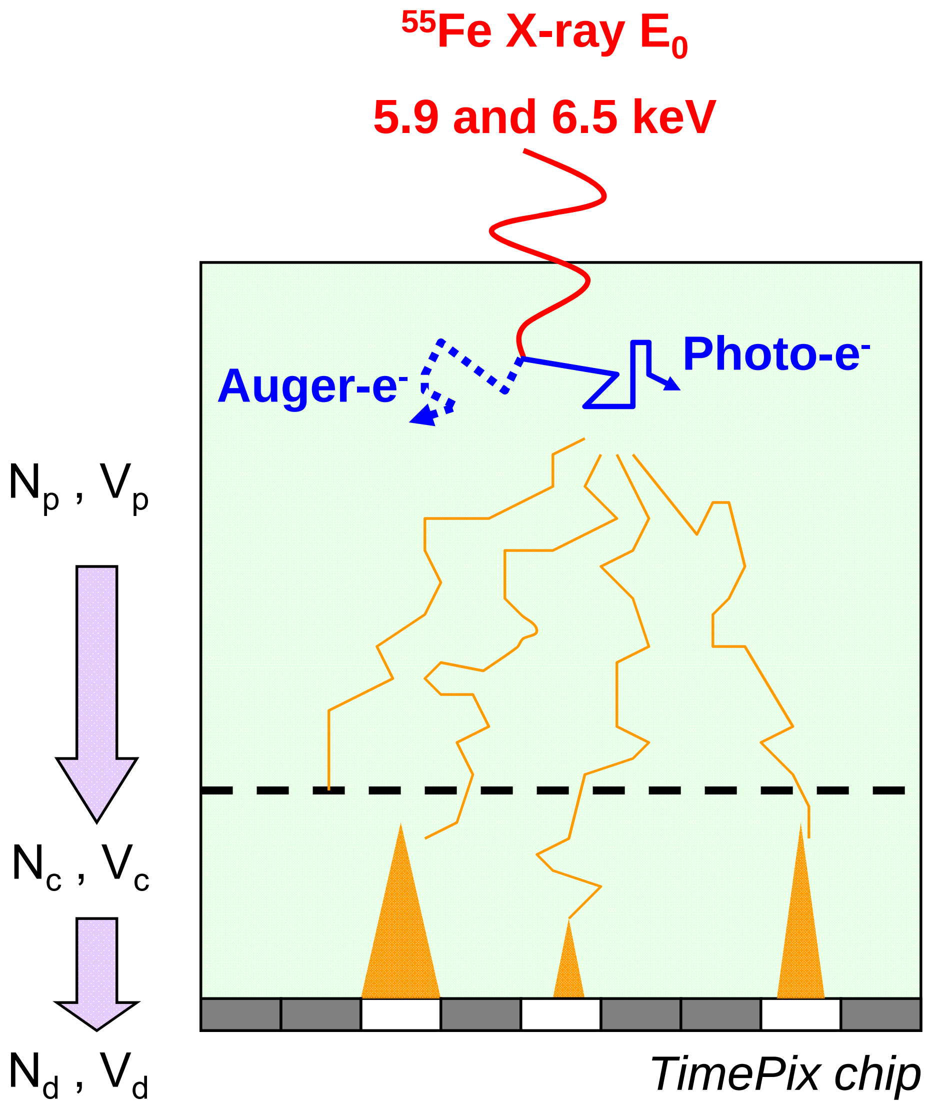
What is measured is the mean and variance of the number of detected electrons (N_d, V_d)

Correction for limited collection and detection efficiencies yield N_p and V_p

$W = E_0 / N_p$

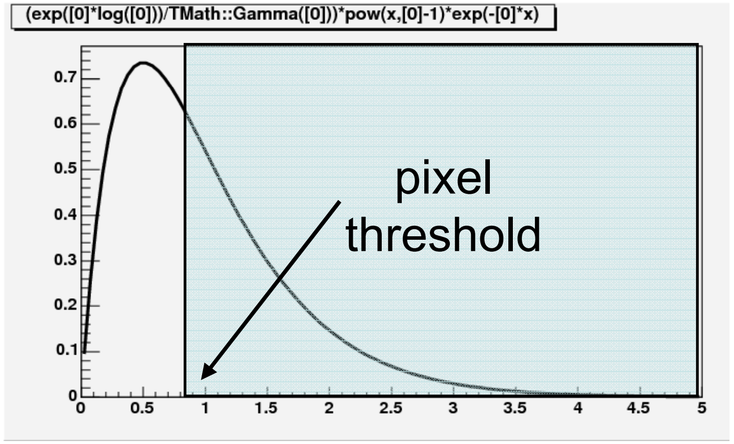
$F = V_p / N_p$

Collection and detection eff. should be known



Detection efficiency

$\kappa = \int_t^\infty p(g).dg$



Exponential fluctuations:

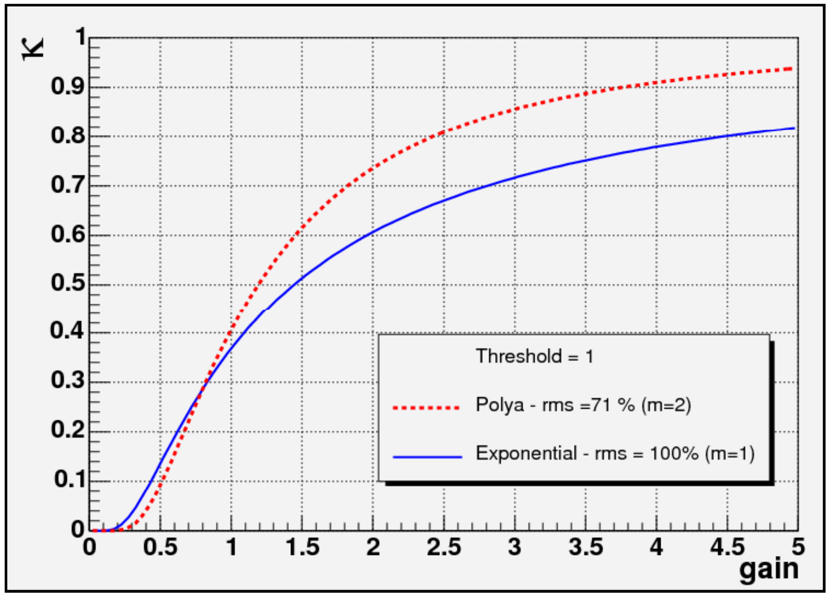
$\kappa(g) = \exp(-t/\langle g \rangle)$

Polya-like fluctuations:

parameter $m=1/b \sim 2$

with $\sqrt{b}$ the relative rms

$\kappa(2,g) = (1+2.t/\langle g \rangle) . \exp(-2.t/\langle g \rangle)$



Detection efficiency will be determined by fitting $\kappa(g)$ to (N_d, V_{grid}) data points

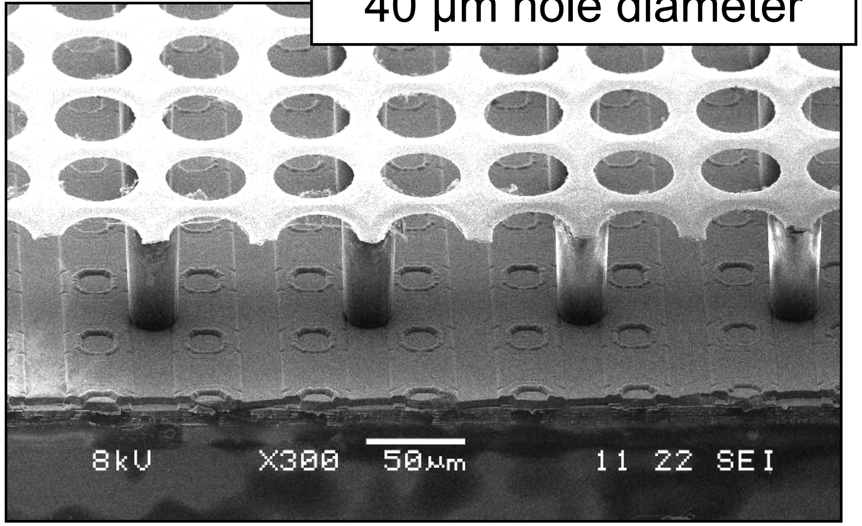
Detectors

Two measurement periods

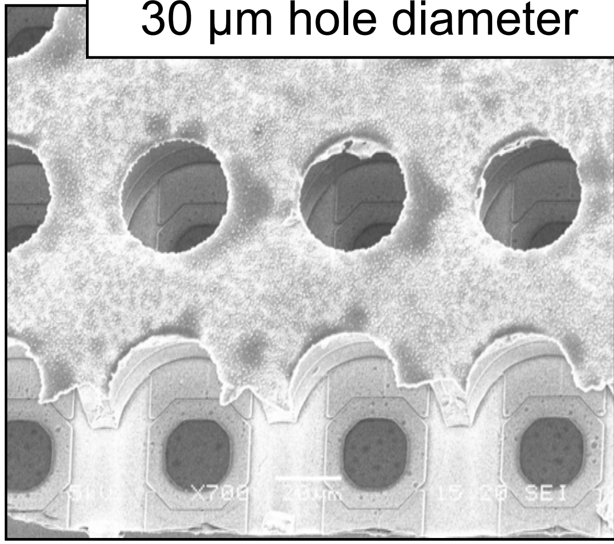
Timepix chip # 1:
- Standard InGrid
- Low event statistics

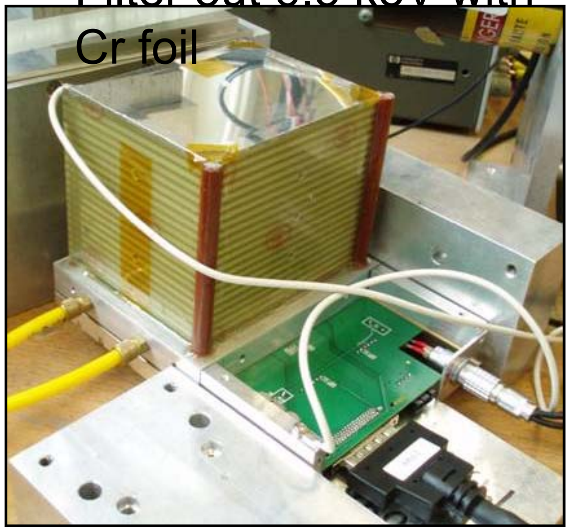
Timepix chip #2 :
- Increased event statistics
- New GEMGrid structure
- Filter out 6.5 keV with Cr foil

40 µm hole diameter



30 µm hole diameter

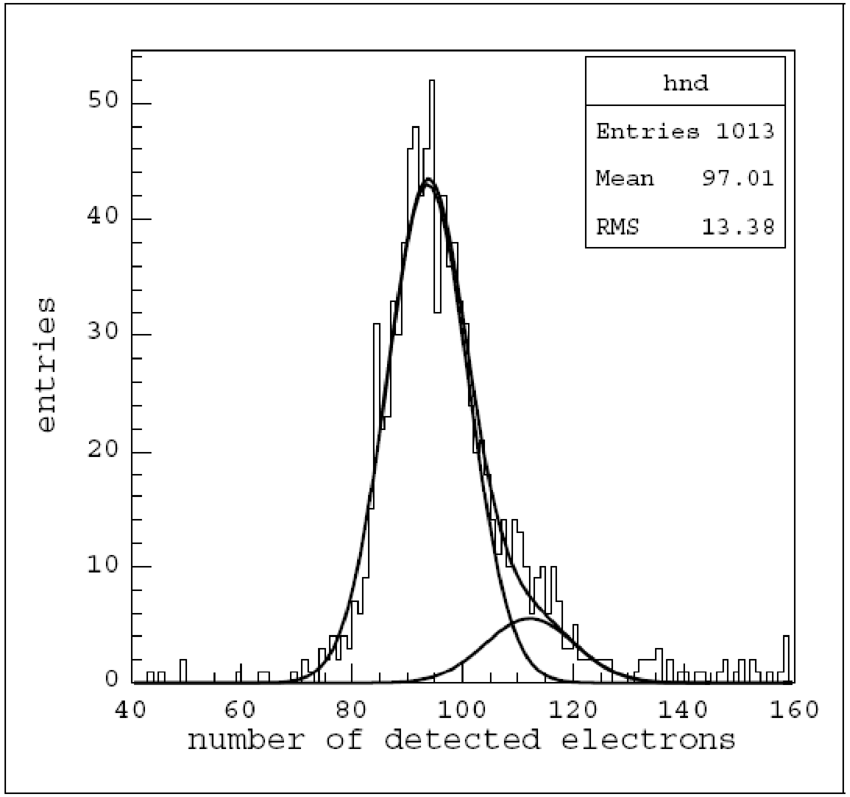




Chamber geometry:
- 10 cm field cage
- Guard electrode surrounding the chip (inside chamber)

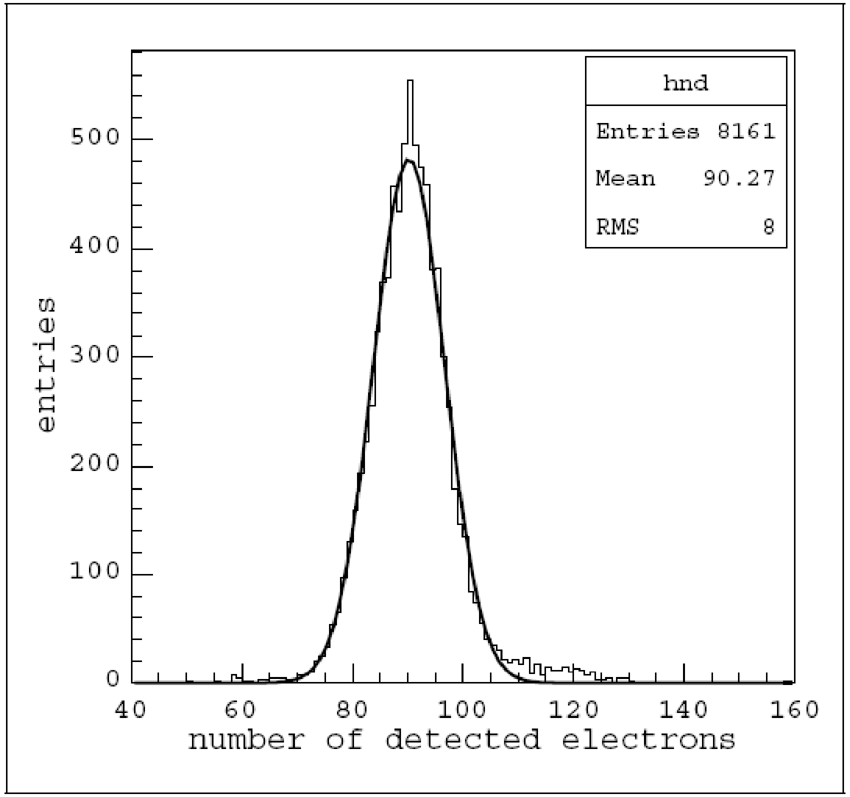
Measured spectra at -330 V

- Timepix #1



5.9 and 6.5 keV escape events
(event ratio ~ 7:1)

- Timepix #2

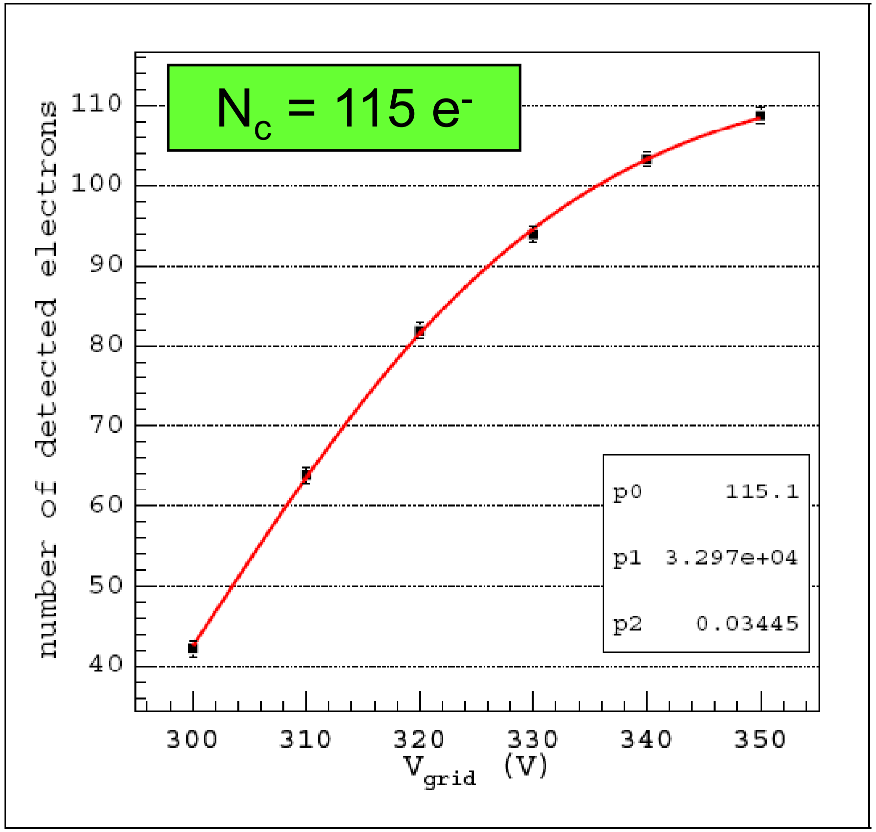


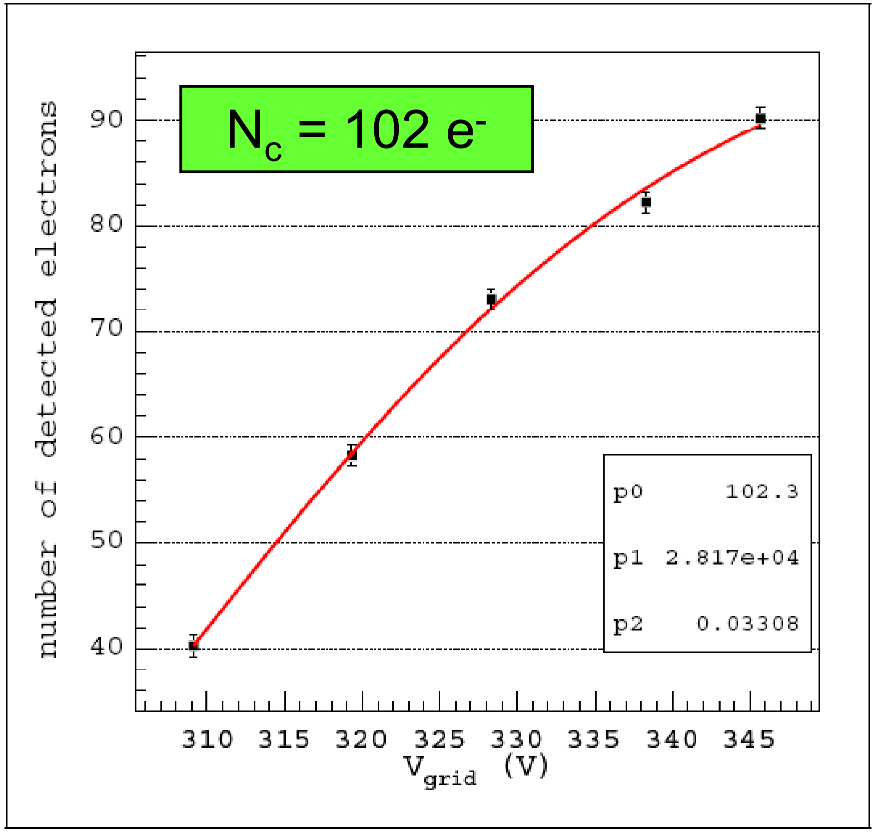
5.9 and 6.5 keV escape events
(event ratio ~ 50:1)

Peak position and grid voltage

Asymptotic value of N_d gives the number of collected electrons N_c

Polya fit works very well where exponential one (not shown) fails!





- Compatible with the smaller hole diameter of InGrid #2
- Contribution from collection efficiency to peak width now known

W and F in Ar/iso 95/5 at 2.9 keV

Assume full collection efficiency of detector #1

$N_p = N_c = 115 \pm 2$ e-

→ **W = 25.2 ± 0.5 eV**

Extrapolation to 5.9 keV photo-peak straightforward

$N_p = 230 \pm 4$ e-

Peak width measured with detector #2 corrected for detection and collection eff. (87 %)

$RMS(N_p) \sim 4.3$ %

→ **F = 0.21 ± 0.06**

Compatible with literature

W = 25.0 ± 0.6 eV

F = 0.250 ± 0.010

Ar/iso 20/80 – 1253 eV X-rays

from Pansky. *et al.*

J. Appl. Phys. **79** (1996) 8892

Conclusion

- Method works well in our experimental conditions of large gap/transverse diffusion and small number of primary electrons.

- Fit of Polya parameters to data points works very well, exponential gain distribution yield inaccurate results.

- Next steps: study of W, F and gain fluctuations in other gas mixtures.

Thanks for your attention

Acknowledgements:

all fellows from
NIKHEF-Amsterdam
SC-Twente
CEA/Irfu-Saclay