Calculation of Gain Fluctuations

Heinrich Schindler

CERN

February 23, 2010

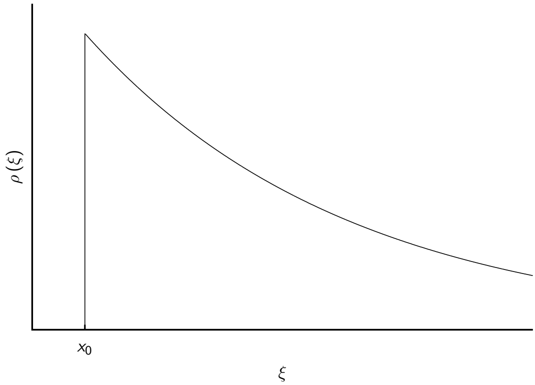
Toy Models

- For uniform fields, simplified models emphasizing aspects like ionisation threshold and interplay of ionising vs. non-ionising inelastic collisions have been devised
- Theoretical framework by G. D. Alkhazov (1970)
- Probability of ionisation depends on path ξ travelled since the last ionising collision
- Gain spectrum is determined by the distribution $\rho(\xi)$ of this "ionisation distance"
- $\rho(\xi)$ can be compared to realistic MC calculations

Toy Models

- Legler's model

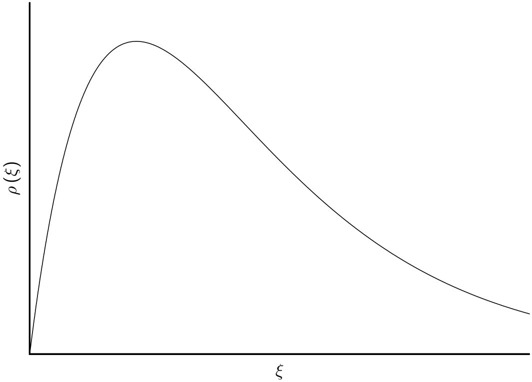
$$\rho(\xi) = e^{-\alpha(\xi - x_0)} \Theta(\xi - x_0)$$



Toy Models

- Pólya "model"

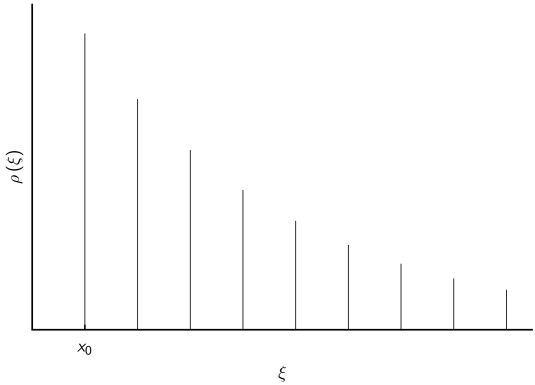
$$\rho(\xi) = \frac{\Gamma(2(\theta+1))}{\Gamma(\theta+1)^2} \alpha e^{-\alpha(\theta+1)\xi} \left(1 - e^{-\alpha\xi}\right)^{\theta}$$



Toy Models

- Stepwise Evolution

$$\rho_k = p\,(1-p)^{k-1}$$



Magboltz Model

- In a realistic simulation of gain fluctuations one needs to take
  - ionising and non-ionising inelastic collisions,
  - energy dependence of scattering rates

  into account $\rightarrow$ Magboltz cross-sections and algorithm
- Input parameters: field configuration, initial energy and direction
- Energy of secondary electrons is sampled according to

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\varepsilon'} \propto \frac{1}{1 + \left(\frac{\varepsilon'}{w}\right)^2}$$

with gas dependent constant w.

Experimental Data

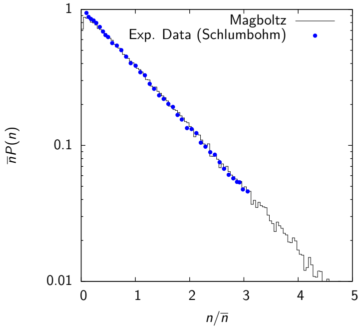
Direct measurements of ("rounded") single electron gain spectra in constant fields:

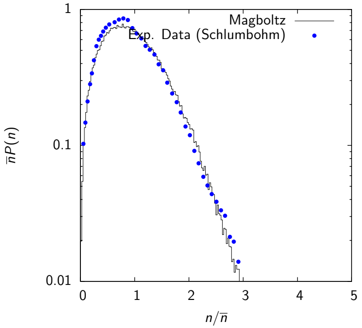
- Parallel plate chamber, extraction of single electrons from cathode with UV lamp
  - Schlumbohm (1958): Methylal
  - Cookson and Lewis (1966), Vidal (1974): Methane
- Recent measurements with Micromegas
  - T. Zerguerras et al.: Ne/iC_4H_{10}
  - P. Colas et al.: Ar/iC_4H_{10}

Methylal

good agreement between simulation and exp. data, but cross-sections are not reliable (bad rating in Magboltz database) and actually partially extracted from Schlumbohm's data

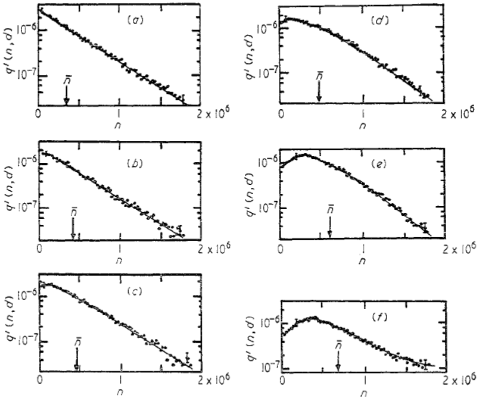
- $E/p = 70\ \text{V cm}^{-1}\ \text{Torr}{-1}$
- $E/p = 426\ \text{V cm}^{-1}\ \text{Torr}{-1}$



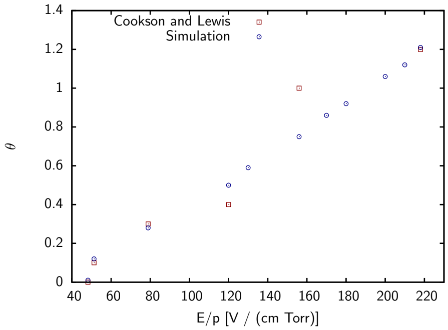


Methane

Measurements by Cookson, Lewis and Ward (1966)



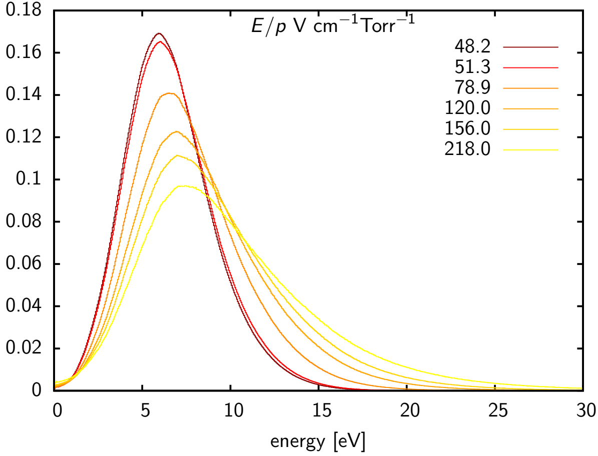
Methane



E/p	θ (meas.)	θ (calc.)
48.2	0.0	0.01
51.3	0.1	0.12
78.9	0.3	0.28
120.0	0.4	0.50
156.0	1.0	0.75
218.0	1.2	1.20

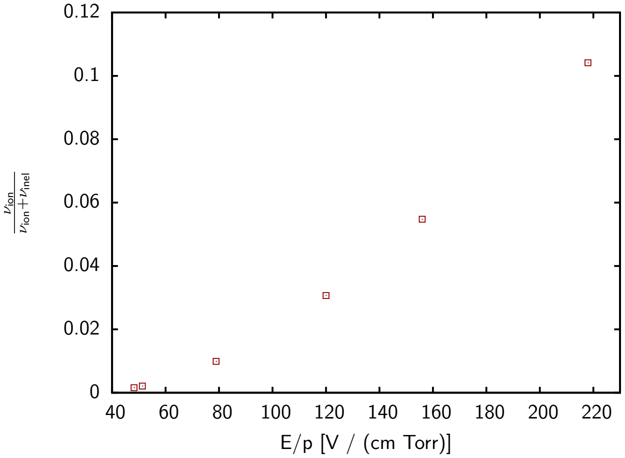
Methane

- Energy distribution



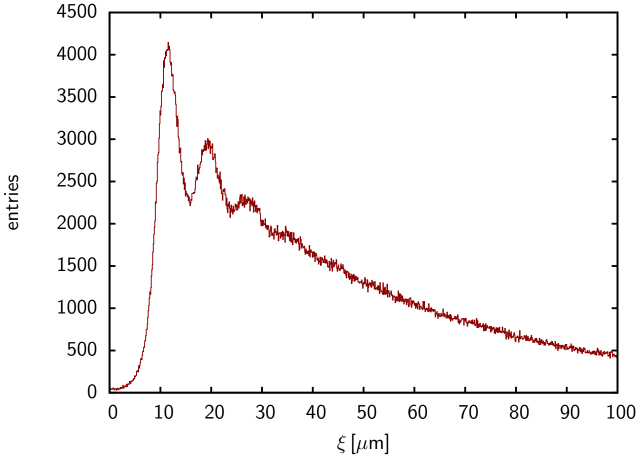
Methane

- Ionising vs. non-ionising collisions



Methane

- Distance between ionising collisions



Measurements with Micromegas

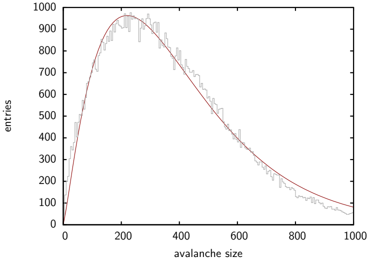
- Both Ne/iC_4H_{10} and Ar/iC_4H_{10} are Penning mixtures
- Penning transfer probability r for Ar/iC_4H_{10} extracted from gain curve fits:

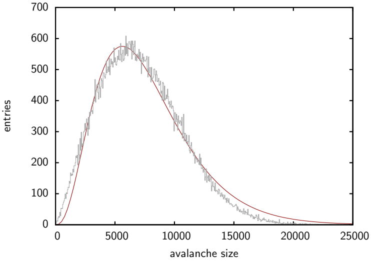
$$r \approx 0.4$$

- Simple model:
  - All Ar excitations lead with probability r to a secondary electron
  - no time delay
  - electrons produced "on the spot"

Ar/iC_4H_{10}

50 μm gap:



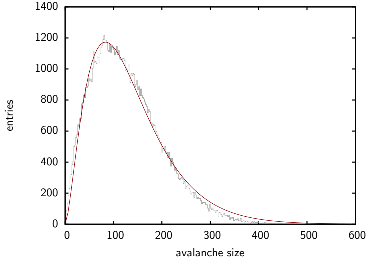


V_{mesh}	θ (without Penning)	θ (with Penning)
320	1.13	2.50
330	1.40	2.59
340	1.22	2.70

Ne/iC_4H_{10}

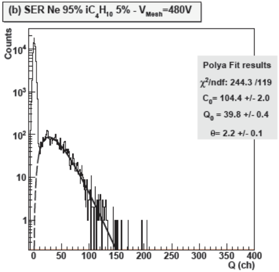
Example: $E = 30$kV/cm

- Calculation (without Penning transfer)



- $\theta \approx 1.6$

- Measurement (Zerguerras et al. 2009)



- $\theta \approx 2.2$

Summary

- Magboltz model provides fair agreement with "classic" measurements (Methylal, CH_4)
- Toy models may help for qualitative understanding (importance of ionising vs. non-ionising energy losses)
- Detailed modelling of Penning transfer (e. g. photon emission/reabsorption) to be included
- Impact of space charge