PDG2010: Gaseous Detectors Reviews

PDG particle data group

Chapter 28.6 – Gaseous Detectors (8 pages in PDG2010)

- **28.6.1 – Energy Loss and Charge Transport in Gases**
  (F. Sauli and M. Titov, revised March 2010)
- **28.6.2 – Multi-Wire Proportional and Drift Chambers**
  (F. Sauli and M. Titov, revised March 2010)
- **28.6.3 – High-Rate Effects**
  (F. Sauli and M. Titov, revised March 2010)
- **28.6.4 – Micro-Pattern Gas Detectors**
  (F. Sauli and M. Titov, revised March 2010)
- **28.6.5 – Time Projection Chamber**
  (D. Karlen, written September 2007)
- **28.6.6 – Transition Radiation Detectors**
  (P. Nevski and A. Romaniouk, written August 2007)
- **28.6.7 – Resistive Plate Chambers**
  (H. Band, revised September 2007)

Gaseous Detectors Basics: a complete re-write

Older version PDG2006 contained 5 gas-detector related chapters:

- **28.6 Transition Radiation Detectors (D. Frodevaux)**
- **28.7 Wire Chambers (A. Cattai, G. Rolandi)**
- **28.8 Micro-Pattern Gas Detectors (M. Ronan)**
- **28.9 Resistive Plate Detectors (H. Band)**
- **28.10 Time Projection Chamber (M. Ronan)**

→ Limited introduction to the basic physics of gaseous detectors

F. Sauli accepted to re-write from scratch in 2007

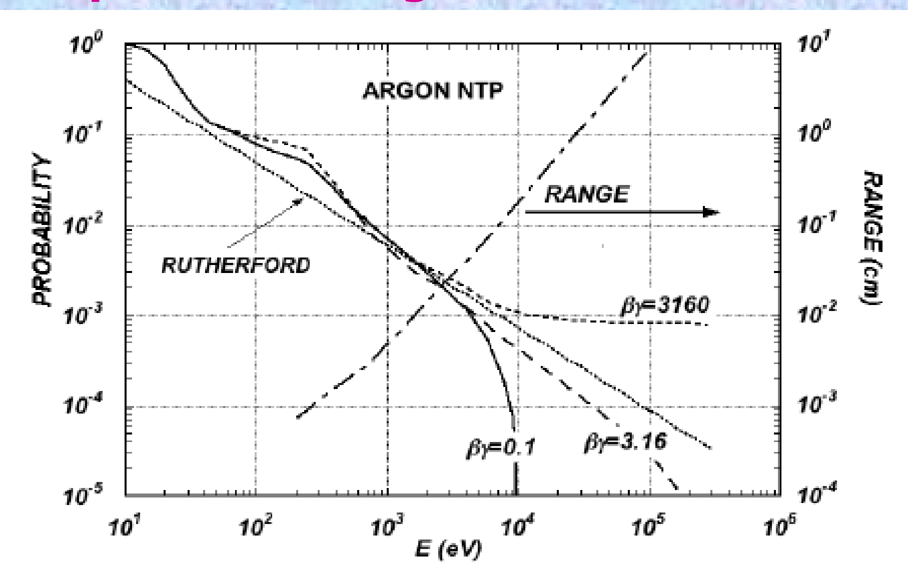
→ First version appeared in PDG2008
→ Improved version (after interaction with reviewers) in PDG2010

PDG2008/2010: Energy Loss and Charge Transport in Gases

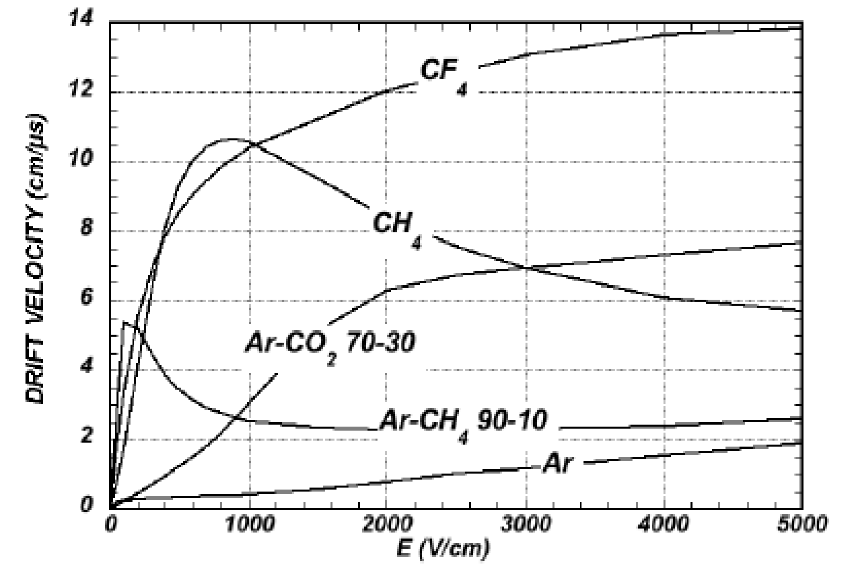
28.6.1 Basic energy loss processes in gases:

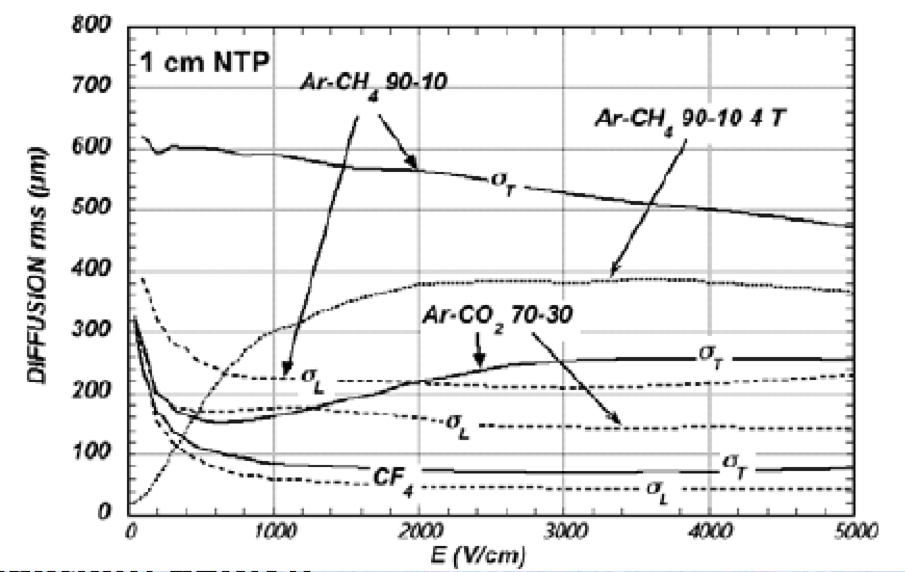
Table 28.5: Properties of noble and molecular gases at normal temperature and pressure (NTP: 20° C, one atm). E_X, E_I: first excitation, ionization energy; W_I: average energy per ion pair; $dE/dx|_{\min}$, N_P, N_T: differential energy loss, primary and total number of electron-ion pairs per cm, for unit charge minimum ionizing particles.

Gas	Density, mg cm^{-3}	E_x eV	E_I eV	W_I eV	$dE/dx\|_{\min}$ keV cm^{-1}	N_P cm^{-1}	N_T cm^{-1}
He	0.179	19.8	24.6	41.3	0.32	3.5	8
Ne	0.839	16.7	21.6	37	1.45	13	40
Ar	1.66	11.6	15.7	26	2.53	25	97
Xe	5.495	8.4	12.1	22	6.87	41	312
CH_4	0.667	8.8	12.6	30	1.61	28	54
C_2H_6	1.26	8.2	11.5	26	2.91	48	112
iC_4H_{10}	2.49	6.5	10.6	26	5.67	90	220
CO_2	1.84	7.0	13.8	34	3.35	35	100
CF_4	3.78	10.0	16.0	54	6.38	63	120



28.6.1 Drift, diffusion and multiplication in the gases:





PDG2008/2010: Multi-Wire and Drift Chambers, High Rate Effects

28.6.2 Multi-Wire Proportional and Drift Chambers; 28.6.3. High Rate Effects

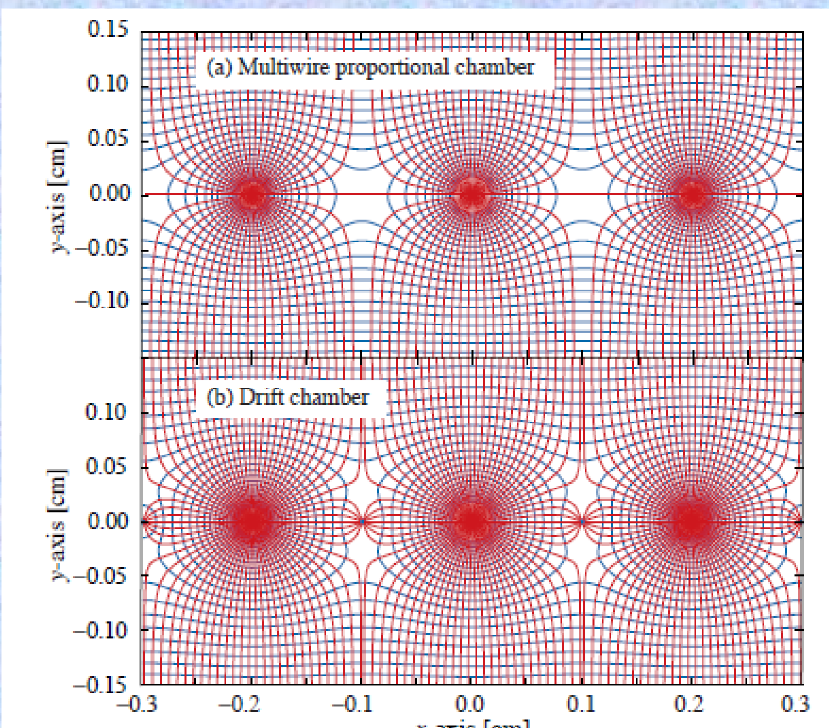
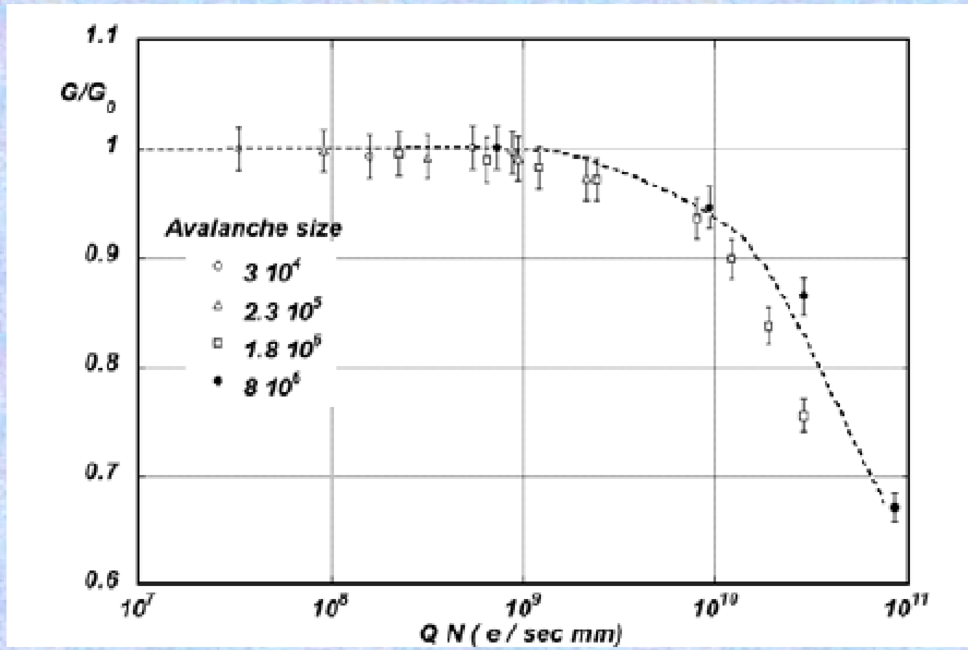


Figure 28.7: Electric field lines and equipotentials in (a) a multiwire proportional chamber and (b) a drift chamber.



- **Gas Detector basics review is completed; no comments except for Table 28.5**
- **No immediate plan to update this part for the next revision(s)**

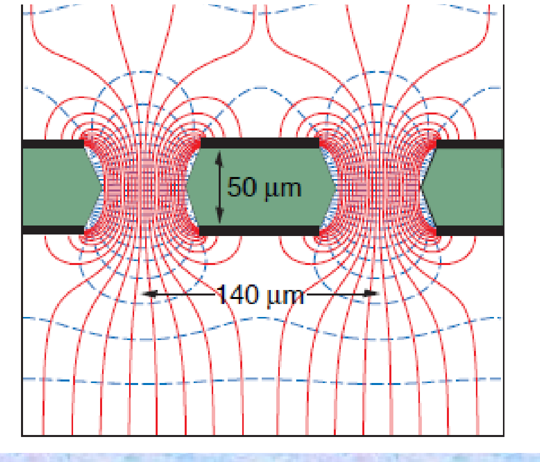
PDG2008/PDG2010: Micro-Pattern Gaseous Detectors

Older Version (M. Ronan in PDG 2006) contained 26 lines and 2 figures

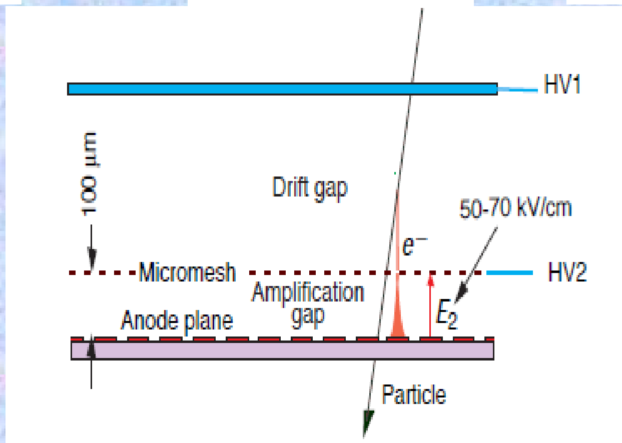
→ MPGD is very rapidly growing field with RD51 Collaboration @ CERN (~ 75 institutes, 450 people) supporting MPGD technological developements

Try to address the most modern developments (to keep up-to-date picture):

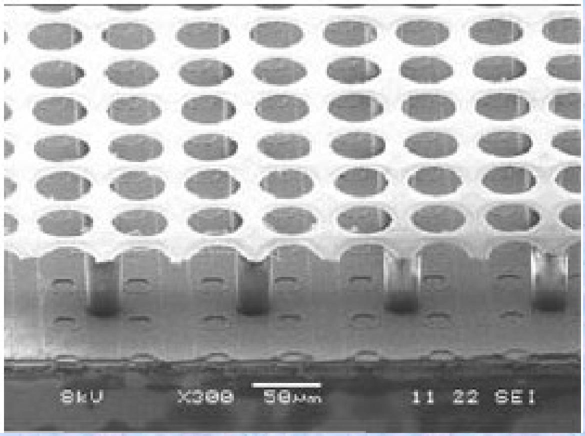
Gas Electron Multiplier (GEM)



MicroMegas



Pixel Readout of MPGD "InGrid"



- **New write-up appeared in PDG2008, revised version in PDG2010 (<~1.5 pages, limited by the space constraints)**

- **Active field of research – requires bi-annual updates**

F. Sauli (TERA Foundation/CERN), M. Titov (CEA Saclay)

Summary and Outlook

• **Significant help and support from Don Groom – thank you very much !**

• **Gaseous Detector Reviews is up-to-date**
(some gas detectors appears in other reviews – e.g. should we keep gaseous (MPGD) photon detectors in "Photon Detectors" review)

Some ideas for general RPP updates (Particle Detectors at Accelerators):

• **Revision of the Table 28.1 – Typical resolution of common detectors**

• **Balance between basic detector physics and concise up-to-date review of modern trends in technology**

(e.g. Gas-det. Basics vs MPGD, Si-det. basics vs 3D interconnect/"wafer-through vias", …) – e.g. a lot of new developments for LHC/ILC (and not only)

→ criteria for relative length/space requirements

Table 28.1: Typical resolutions and deadtimes of common detectors. Revised September 2009.

Detector Type	Accuracy (rms)	Resolution Time	Dead Time
Bubble chamber	10–150 μm	1 ms	50 ms[a]
Streamer chamber	300 μm	2 μs	100 ms
Proportional chamber	50–100 μm[b,c]	2 ns	200 ns
Drift chamber	50–100 μm	2 ns[d]	100 ns
Scintillator	—	100 ps/n[e]	10 ns
Emulsion	1 μm	—	—
Liquid argon drift [7]	~175–450 μm	~ 200 ns	~ 2 μs
Micro-pattern gas detectors [8]	30–40 μm	< 10 ns	20 ns
Resistive plate chamber [9]	$\lesssim 10$ μm	1–2 ns	—
Silicon strip	pitch/(3 to 7)[f]	[g]	[g]
Silicon pixel	2 μm[h]	[g]	[g]

[a] Multiple pulsing time.
[b] 300 μm is for 1 mm pitch (wirespacing/$\sqrt{12}$).
[c] Delay line cathode readout can give ±150 μm parallel to anode wire.
[d] For two chambers.
[e] n = index of refraction.
[f] The highest resolution ("7") is obtained for small-pitch detectors ($\lesssim 25$ μm) with pulse-height-weighted center finding.
[g] Limited by the readout electronics [10]. (Time resolution of $\lesssim 25$ ns is planned for the ATLAS SCT.)
[h] Analog readout of 34 μm pitch, monolithic pixel detectors.