Electroluminescence in noble gases using Garfield and Magboltz 7.1

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RD51
Micro Pattern Gaseous Detectors R&D

Purpose of the work

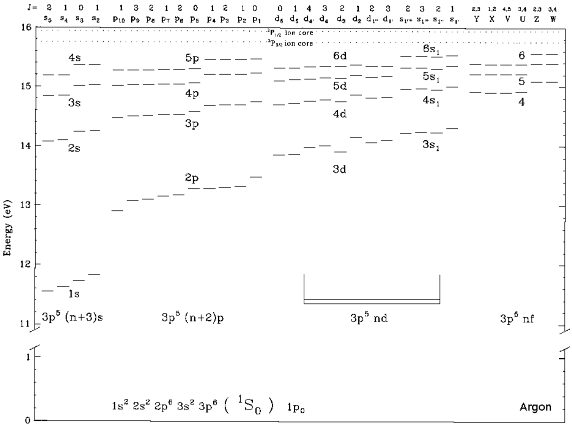
- Study of the physical processes of electroluminescence during the drift of electrons in a noble gas

  (bellow and above ionisation threshold)

- Compare the behavior of different noble gases
- This information can be useful for:
  - Dark Matter research
  - $\beta\beta - 0\nu$
  - Dual phase detectors
  - other detectors

Atomic Energy Diagram

Pure noble gases



- $1s$:

  $^1P_1$, $^3P_0$, $^3P_1$, $^3P_2$

- 2 forbidden transitions (J rule)
- 2 metastable states
- $\Rightarrow$ excimers

Excimers

Formation & Decay

- Excimer formation (3 body collision)

  $$R^* + 2R \rightarrow R_2^{**} + R$$

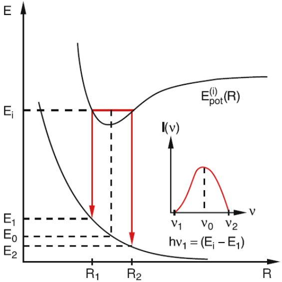
- Direct radiative decay $(p < 400 mbar)$

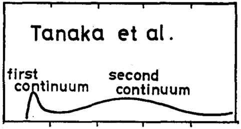
  $$R_2^{**} \rightarrow 2R + h\nu$$

- Vibrational & radiative decays $(p > 400 mbar)$

  $$R_2^{**} + R \rightarrow R_2^* + R$$

  $$R_2^* \rightarrow 2R + h\nu$$

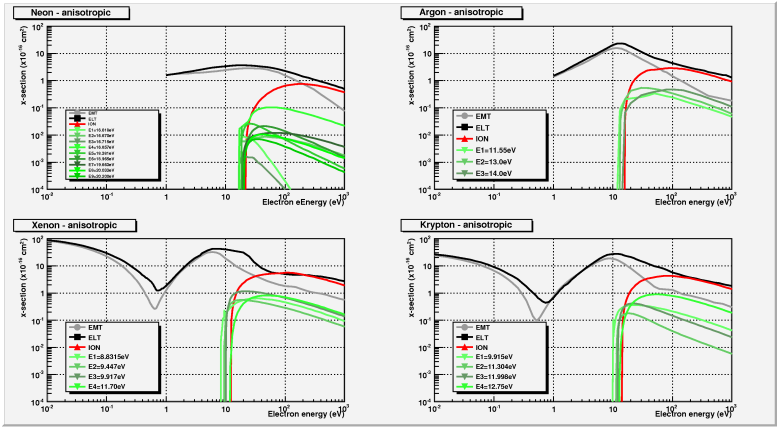




Simulation model / interface

- Microscopic technique of Garfield 9
- Vacuum trajectory between collisions for e_s^-
- $\lambda(\varepsilon) = \frac{e^{-x/l(\varepsilon)}}{l(\varepsilon)}$ - Null-collision technique [H.R. Skullerud 1968]
- C++ Wrapper around Fortran version of Garfield (with Magboltz 7.1)

Magboltz 7.1 x-sections

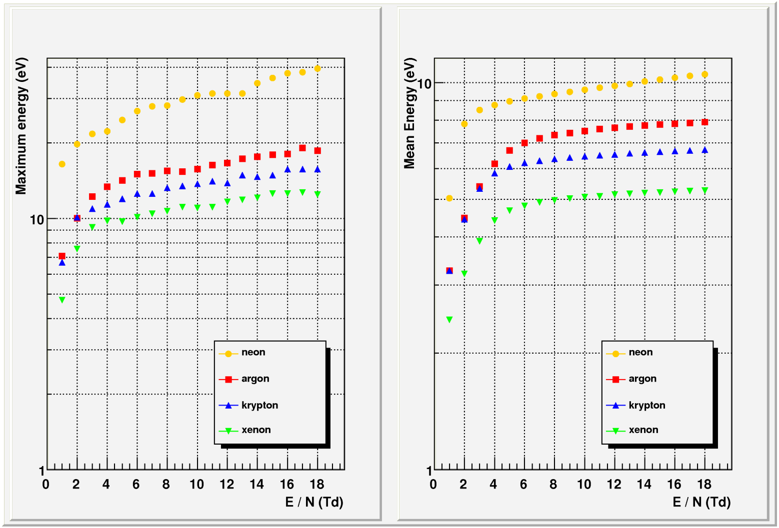


- 1 excited state -> 1 VUV

  $(\varepsilon_{sci,Ar} = 9.6eV, \varepsilon_{sci,Kr} = 8.3eV, \varepsilon_{sci,Xe} = 7.2eV)$

  K. Saito, TNS, 49, 2002, pp. 1674

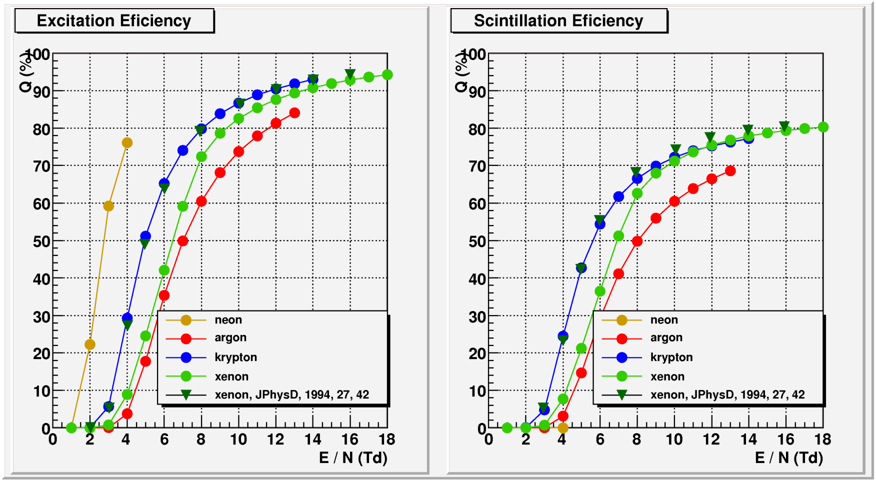
Magboltz 7.1



Maximum energy (eV)
10
1
0 2 4 6 8 10 12 14 16 18
E / N (Td)
neon
argon
krypton
xenon
Mean Energy (eV)
10
1
0 2 4 6 8 10 12 14 16 18
E / N (Td)
neon
argon
krypton
xenon

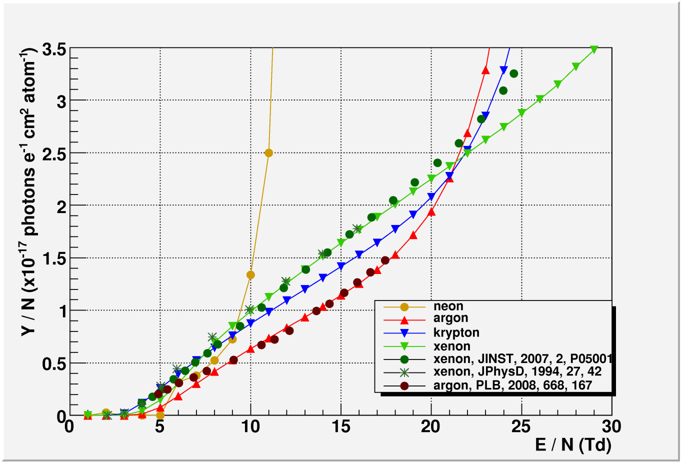
Uniform field geometry

Results - Q_{exc} & Q_{sci}



Uniform field geometry

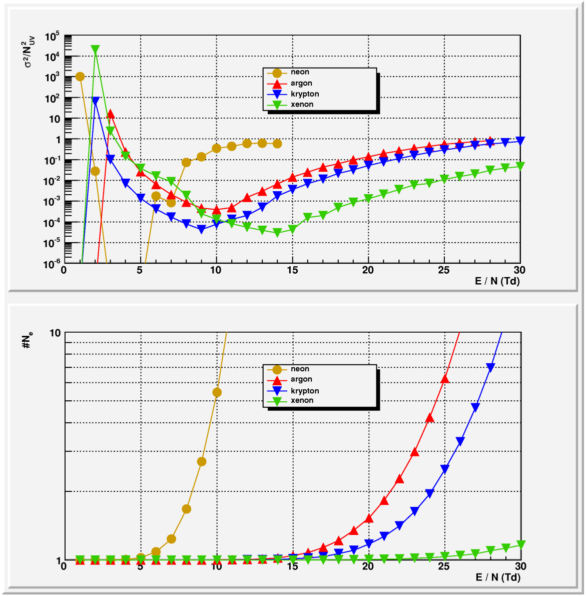
Results - Y



- Good agreement with former simulation work and experimental data (Ar & Xe)
- Experimental measurements for Ne & Kr are in progress

Uniform field geometry

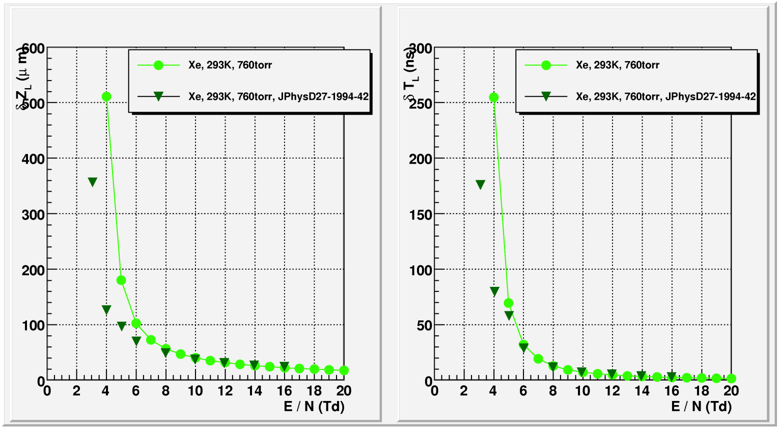
Results - Light fluctuations



- $\frac{\sigma^2_{N_{UV}}}{\bar{N}^2_{UV}}$ decreases until ionisations begin
- E_{res} is a critical information for detector design

Uniform field geometry

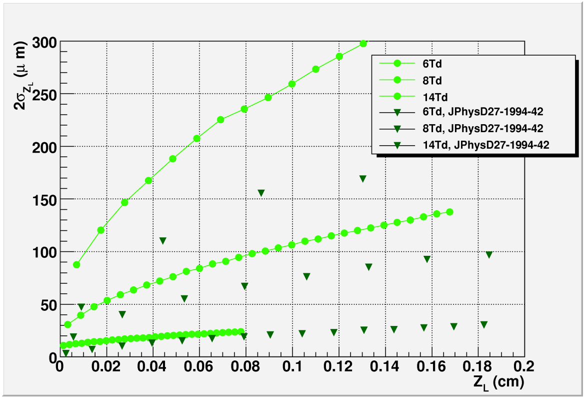
Results - Luminous layers (Xe)



- For used $\left(\frac{E}{N}\right)$ range, after excitation, e^- is left with low energy
- Before other excitation e^- needs to drift a certain distance to reach the ϵ_{thr}
- Agreement with former simulation work -> δZ_L & δT_L

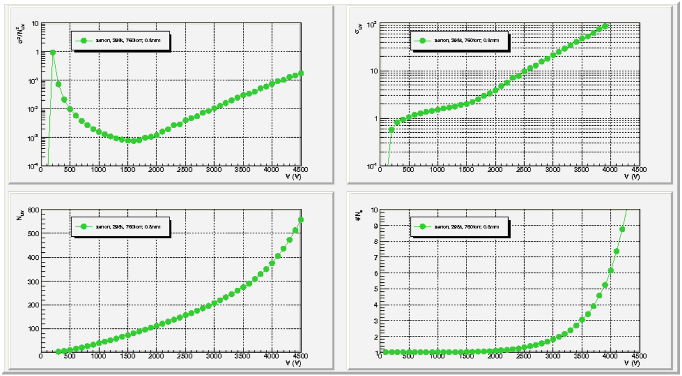
Uniform field geometry

Results - Luminous layers (Xe)



- Differences when compared with former simulation work
- In practice maybe it is not relevant but it is important for understanding the process

Cylindrical geometry
Results



- Cylindrical geometry with wire anode
- Construct a multiwire based TPC which uses the electroluminescence produced near the wires (without ionisation)
- Collaboration David NyGren, Lawrence Berkeley National Laboratory

Conclusions

- A simulation tool based (C++ wrapper) in Magboltz / Garfield was developed to follow produced excited states in noble gases
- Strong agreement with experimental data and with other independent Monte Carlo simulation results
- Reliable method for electroluminescence simulations
- Other applications were shown namely electroluminescence produced in a cylindrical geometry with thick wire

Current and future work

- New C++ version of Microscopic Technique available interfacing Magboltz 8.3

  (studies are being repeated)
- X-sections files were updated recently by Stephen Biagi
- Systematic studies for cylindrical geometry as a function of wire and tube diameter, gas type and pressure
- Compare fluctuations with uniform field geometry
- Complete multiwire detector simulation

  $\left(\frac{E}{N}\right)$ bellow ionisation threshold
- Study of light emission spatial distribution and light signal

Thank you!!