Xe electroluminescence assessment in uniform field geometry and GEM using Garfield and Magboltz

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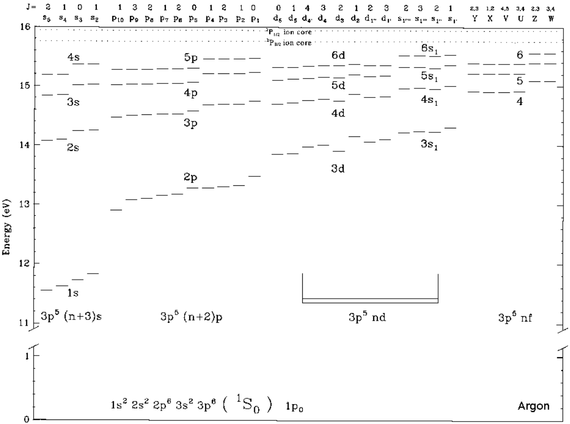
Purpose of the work

- Study of the physical processes of light emission during e^{-} avalanches
- This information can be useful for:
  - Dark Matter research
  - $\beta\beta - 0\nu$
  - other TPCs

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

- Eximer formation (3 body collision)

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

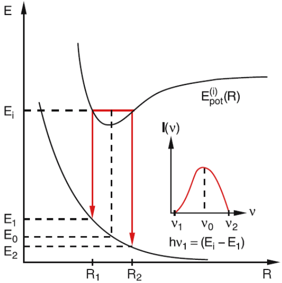
- Direct radiative decay $(p < 400mbar)$

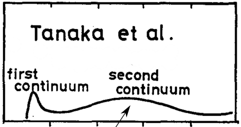
$$R_2^{**} \rightarrow 2R + h\nu$$

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

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

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

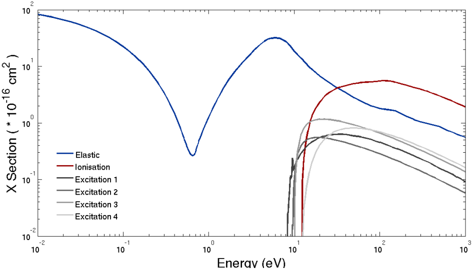




Xe: $\varepsilon_{VUV} = 7.2eV$

Simulation model

- 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]
- X sections from Magboltz 7.1



- 4 groups of excitations:

  $\epsilon_{exc_1} = 8.315eV$

  $\epsilon_{exc_2} = 9.447eV$

  $\epsilon_{exc_3} = 9.917eV$

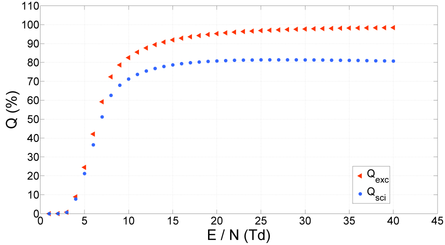
  $\epsilon_{exc_4} = 11.7eV$

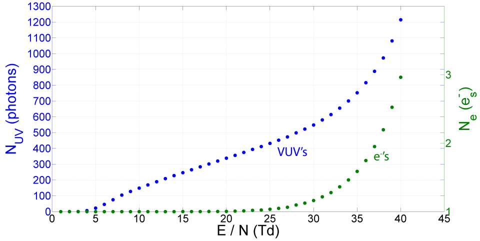
- 1 excited state ->

  -> 1 VUV ($\varepsilon_{sci} = 7.2eV$)

Uniform field geometry

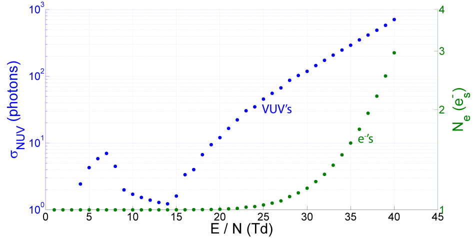
Results

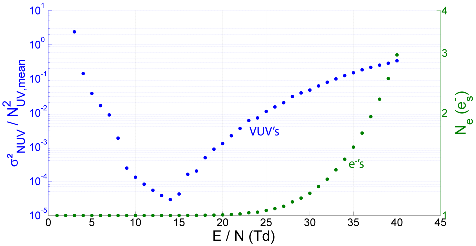




Uniform field geometry

Results

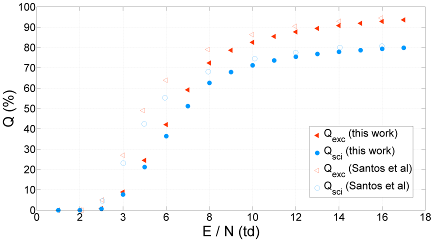


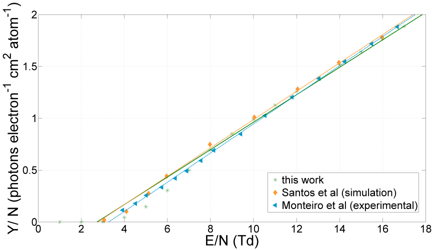


- $\sigma_{N_{UV}}$ peak
  -> new x-sections
- $\frac{\sigma^2_{N_{UV}}}{\bar{N}^2_{UV}}$ decreases until ionisations begin
- for $\left(\frac{E}{N}\right) > 15\,Td$ ionisation fluctuations dominate

Uniform field geometry

Validation

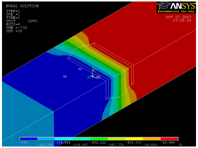


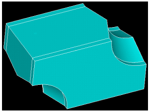


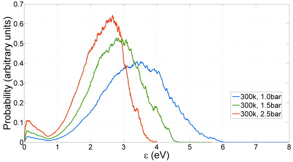
- Good agreement with former simulation work and experimental data

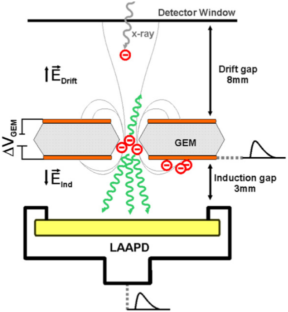
Santos et al ≡ J.Appl.Phys. 27 (1994) 42, Monteiro et al ≡ JInst 2 (2007) P05001

Model applied to MPGD's
GEM case

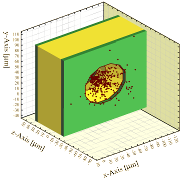








Monteiro et al, PLB677 (2009) 133

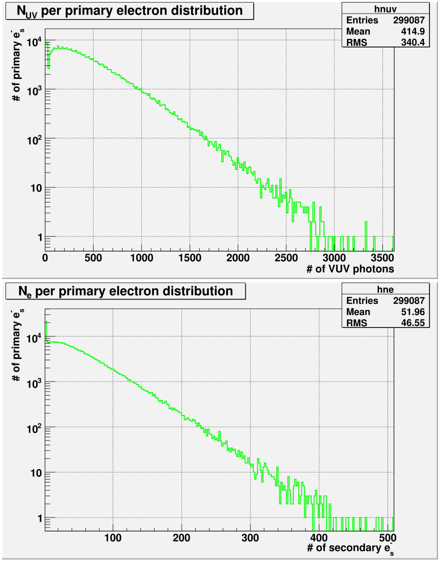


- Ansys 11 field maps
- $z_{start} = 250\mu m$
- random (x, y)
- random ε_{start} (Magboltz)

Results

GEM - light and charge distributions

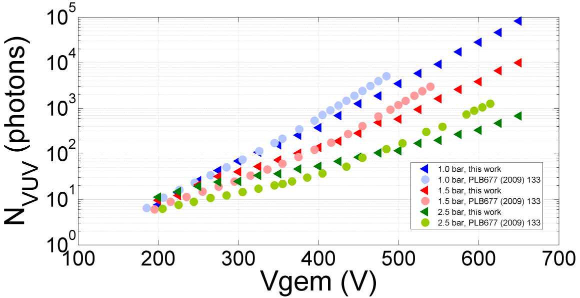
- $E_{drift} = 0.5kVcm^{-1}$
- $E_{ind} = -0.1kVcm^{-1}$
- $p = 1.0bar$
- $T = 300K$
- $V_{GEM} = 400V$



Results

GEM - Scintillation Yield

$$E_{drift} = 0.5kVcm^{-1}$$
$$E_{ind} = -0.1kVcm^{-1}$$
$$T = 300K$$

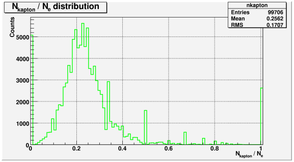


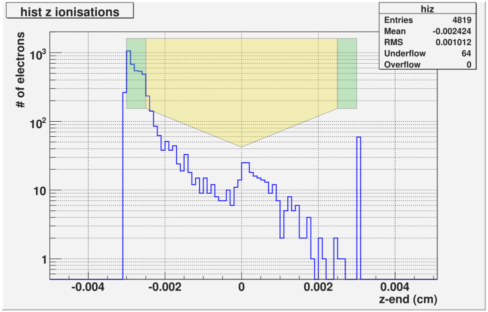
- Similar behavior as experimental data
- Little differences are being studied
  - low V_{GEM}: $N_{exc,1/2^+} \sim N_{exc,1/2^-}$ (photon block)
  - high V_{GEM}: charging up ??
  - $\vec{E}$ modulation via finite elements method ??

Results

GEM - Electrons ending at kapton

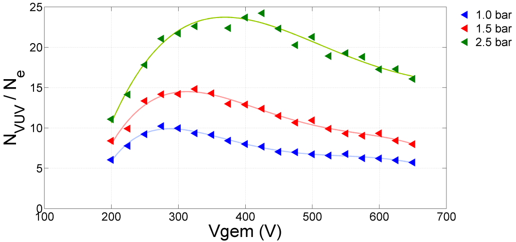
$E_{drift} = 0.5kVcm^{-1}$, $E_{ind} = -0.1kVcm^{-1}$, $T = 300K$, $p = 1.0bar$, $V_{GEM} = 400V$

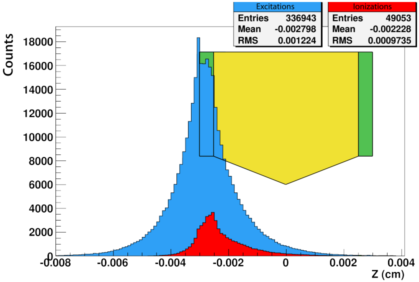




- $\vec{E}$ is modified
- Charging-up is being studied (iterative modulation of $\vec{E}$)

$E_{drift} = 0.5kVcm^{-1}$, $E_{ind} = -0.1kVcm^{-1}$, $T = 300K$





- $N_{exc} >> N_e$
- $\frac{N_{exc}}{N_e}$ increases with p

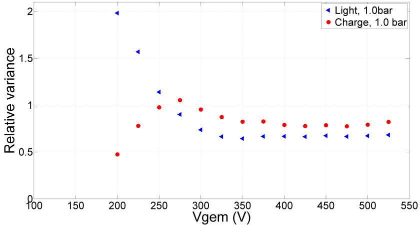
(λ decreases -> less $\varepsilon_{electron}$

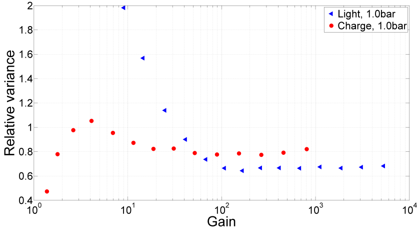
-> P_{ion} decreases)

Results

GEM - Light and charge fluctuations

$E_{drift} = 0.5kVcm^{-1}$, $E_{ind} = -0.1kVcm^{-1}$, $T = 300K$



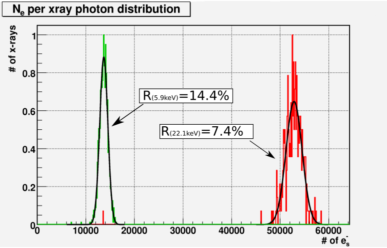


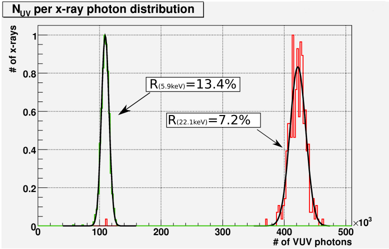
- $J_{VUV} = \frac{\sigma^2_{N_{VUV}}}{\bar{N}^2_{VUV}}$
- $f_e = \frac{\sigma^2_{N_e}}{\bar{N}^2_e}$

Results

Monochromatic x-ray full energy absorption peaks

$E_{drift} = 0.5kVcm^{-1}$, $E_{ind} = -0.1kVcm^{-1}$, $T = 300K$





- Dias et al, J.Appl.Phys. 82 (1997) 2742
  - $w_{5.9keV} = 22.4eV$
  - $w_{22.1keV} = 22.1eV$
  - $F_{5.9keV} = 0.20$
  - $F_{22.1keV} = 0.17$
- Monteiro et al, JInst 2 (2007) P09010
  - $R_{sci,22.1keV,400V} \sim 9\%$
  - $R_{e^-,22.1keV,490V} \sim 10\%$

Conclusions

- A simulation tool based in Magboltz / Garfield was developed to follow produced excited states in Xe avalanches
- Q_{exc}, Q_{sci}, Y was accessed in uniform $\vec{E}$ geometry
- Y was accessed in GEM (same behavior as experimental data)
- $\frac{N_{exc}}{N_e}$ increases with p
- $N_{exc} >> N_e$ (> 1 order of magnitude)

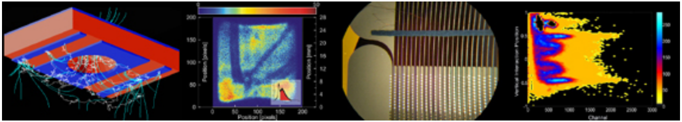
-> Light is an additional information which can be useful

- VUV fluctuations are not higher than charge fluctuations

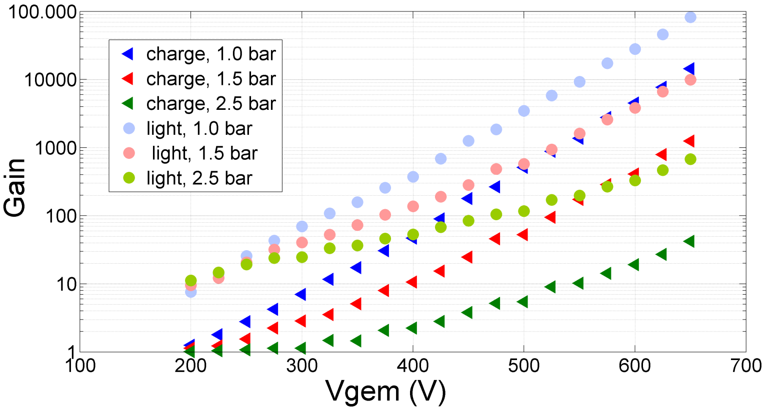
Current and future work

- Charging-up is being implemented
- Xe x-sections file was updated recently
  (writing interface for 23 excitation groups)
- Apply the model to Ar
  (new file with 44 excitation groups is being interfaced)
- Study the effect of impurities
- Apply to other microstructures (THGEM, THMHSP, Micromegas)
- Other properties will be accessed (light position distribution, light signal)
- Gas mixtures (Penning transfers, ...)
- Include $\vec{B}$
- Use neBEM

Thank you!!



Backup 1


charge, 1.0 bar
charge, 1.5 bar
charge, 2.5 bar
light, 1.0 bar
light, 1.5 bar
light, 2.5 bar
Gain
100.000
10000
1000
100
10
1
Vgem (V)
100
200
300
400
500
600
700