Simulation tool for electroluminescence assessment in gaseous avalanche detectors

C. A. B. Oliveira[1] A. L. Ferreira[1] J. F. C. A. Veloso[1]
S. Biagi[2] R. Veenhof[3]

[1]I3N, Physics Department, University of Aveiro, Aveiro, Portugal

[2]Physics Department, University of Liverpool, Liverpool, UK

[3]CERN, Geneva, Switzerland

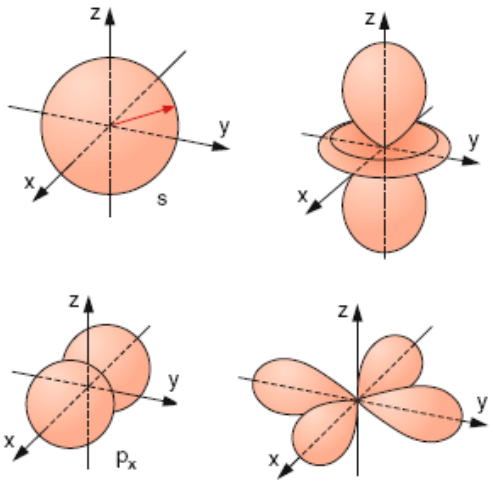
14/06/09

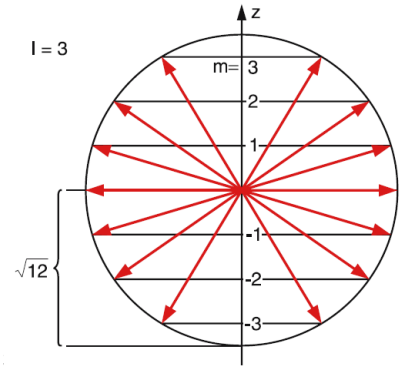
Propose of the work

- Study of the physical processes of light emittion in avalanche detectors
- This information can be usefull for:
  - Dark Matter research
  - $\beta\beta - 0\nu$
  - other TPCs

Electron
quantum numbers

- n
  - orbital quantum number
  - distance from the nucleous
- l
  - orbital quantum momentum
  - shape of probability distribution
  - $0 < l < n - 1$
  - $l = 0, 1, 2, 3, \ldots$ -> $s, p, d, f, \ldots$
- m_l
  - magnetic quantum momentum
  - $-l < m_l < l$
  - l projection along zz'
  - effect of a $\vec{B_z}$
- m_s
  - spin magnetic quantum momentum
  - projection of electron spin along zz'

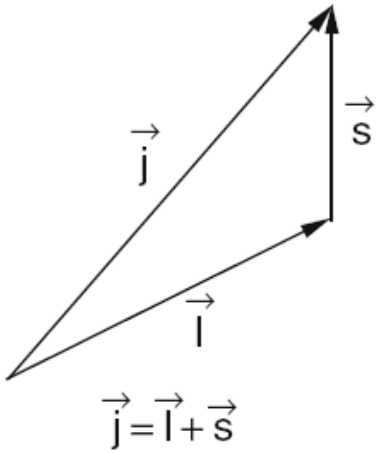


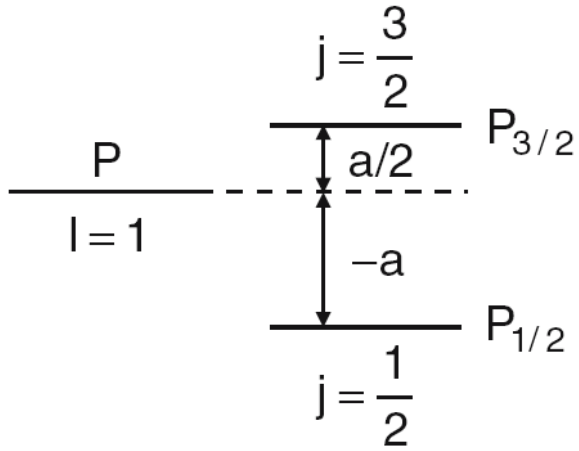


- Total angular momentum

$$\vec{j} = \vec{l} + \vec{s},\ j = |l + s|, |l + s - 1|, ..., |l - s|$$

- Split levels only for $l > 0$





Term Symbol
defining atomic energy states

$$^{2S+1}L_J$$

- $\vec{S} = \sum_i \vec{s_i}$, total spin
- $\vec{L} = \sum_i \vec{l_i}$ total orbital momentum

  $L = 0, 1, 2, 3, 4, 5 \rightarrow S, P, D, F, G, H$

  $L = |l_1 + l_2, |l_1 + l_2 - 1, |.., |l_1 - l_2|$
- $\vec{J} = \vec{L} + \vec{S}$, total angular momentum
- $2S + 1$, multiplicity

$$[Kr]3s^2 3p^6$$

- $S = 0$
- $L = 0$
- $J = 0$
- $^1S_0$

$$[Kr]3s^2 3p^5 4s^1 \sim p^1 s^1$$

- $S = 0$
  - $L = 1$
  - $^1P_1$
- $S = 1$
  - $L = 1$
  - $J = 0, 1, 2$
  - $^3P_0, ^3P_1, ^3P_2$

- $N = \frac{6!}{5!1!}\frac{2!}{1!1!} = 12$
- $^1P \rightarrow (2S+1)(2L+1) = 3$
- $^3P \rightarrow (2S+1)(2L+1) = 9$

$$[Kr]3s^2 3p^5 4p^1 \sim p^1 p^1$$

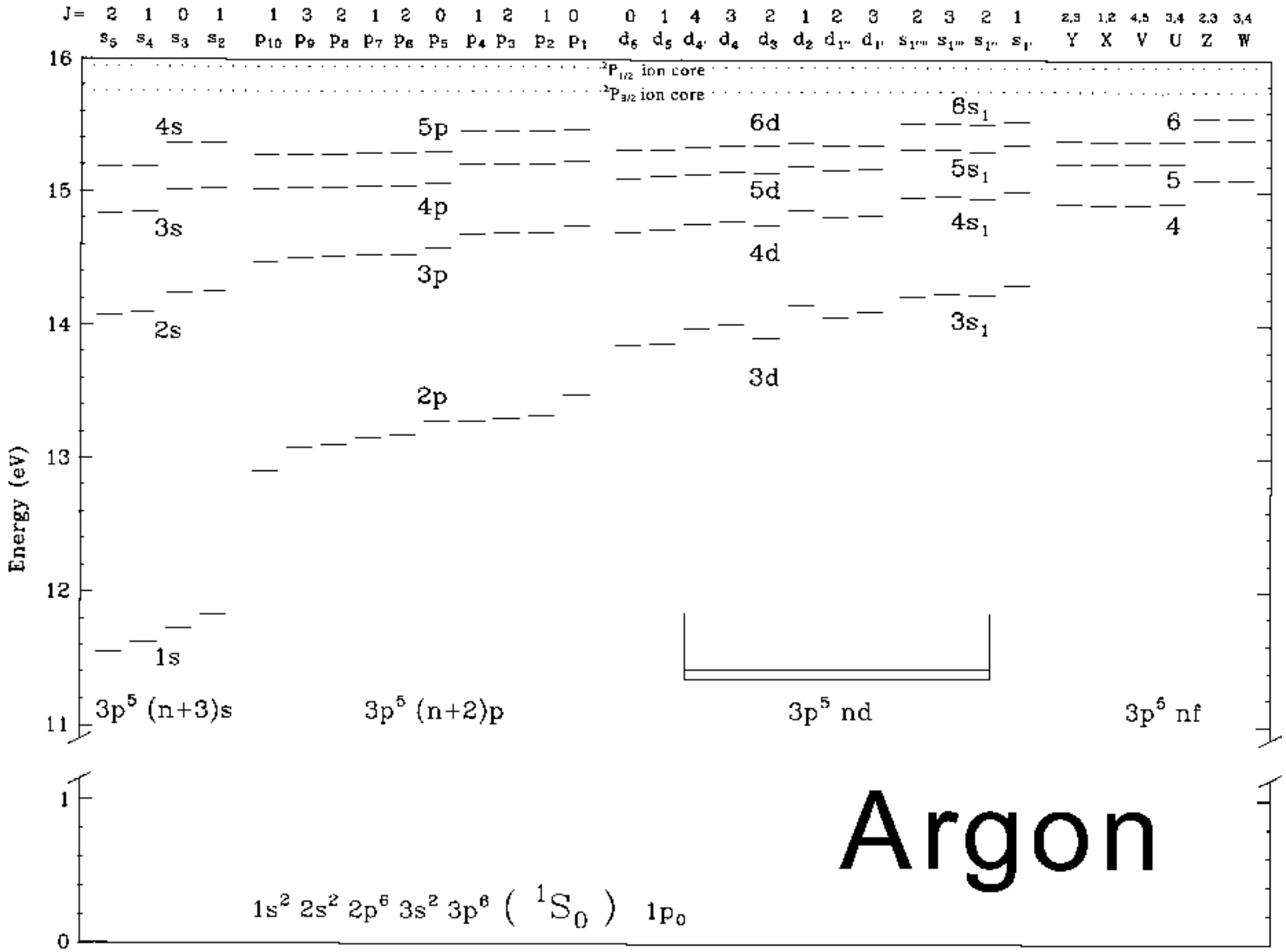
- $S = 0$
  - $L = 0, 1, 2$
  - ${}^1S_0, {}^1P_1, {}^1D_2$
- $S = 1$
  - $L = 0$
    - $J = 1$
    - ${}^3S_1$
  - $L = 1$
    - $J = 0, 1, 2$
    - ${}^3P_0, {}^3P_1, {}^3P_2,$
  - $L = 2$
    - $J = 1, 2, 3$
    - ${}^3D_1, {}^3D_2, {}^3D_3,$

- $N = \frac{6!}{5!1!}\frac{6!}{5!1!} = 36$
- ${}^1S \rightarrow (2S+1)(2L+1) = 1$
- ${}^1P \rightarrow (2S+1)(2L+1) = 3$
- ${}^1D \rightarrow (2S+1)(2L+1) = 5$
- ${}^3S \rightarrow (2S+1)(2L+1) = 3$
- ${}^3P \rightarrow (2S+1)(2L+1) = 9$
- ${}^3D \rightarrow (2S+1)(2L+1) = 15$

Radiative Decay
Selection Rules

- $\Delta L = \pm 1$
- $\Delta M = 0, \pm 1$
  - $\Delta M = 0 \rightarrow$ linear polarized light
  - $\Delta M = \pm 1 \rightarrow$ cicurlarly polarized light
- $\Delta S = 0$
- $\Delta J = 0, \pm 1$, $J = 0 \rightarrow J = 0$ is forbidden

Energy diagram
Argon



- Eximer formation (3 body collision)

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

- Direct radiative decay

  $(p > 400mbar)$

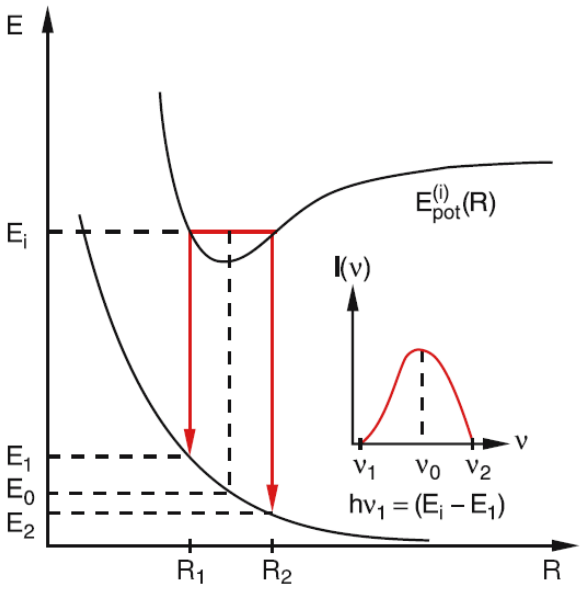
  $R_2^{**} \rightarrow 2R + h\nu$

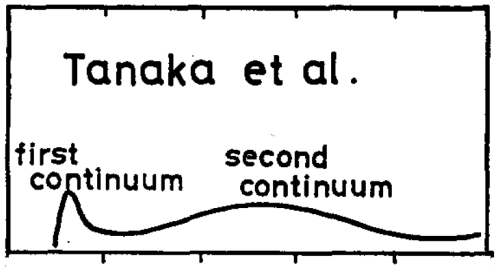
- 3 body collision + radiative decay

  $(p < 400mbar)$

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

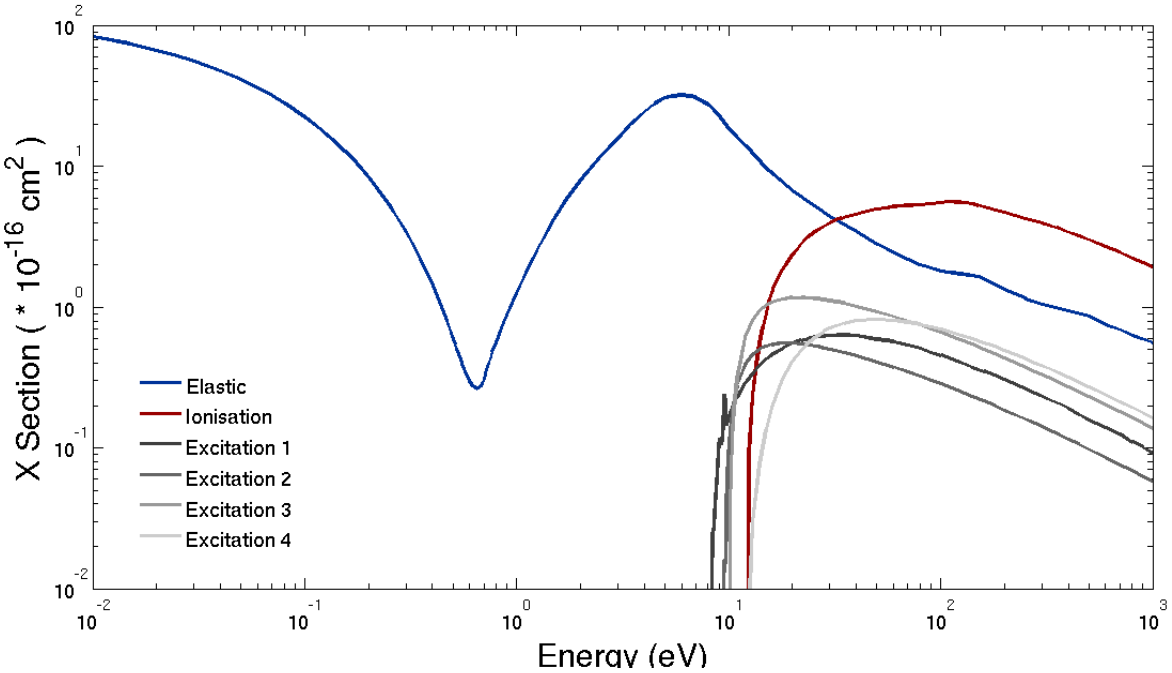
  $R_2^* \rightarrow 2R + h\nu$



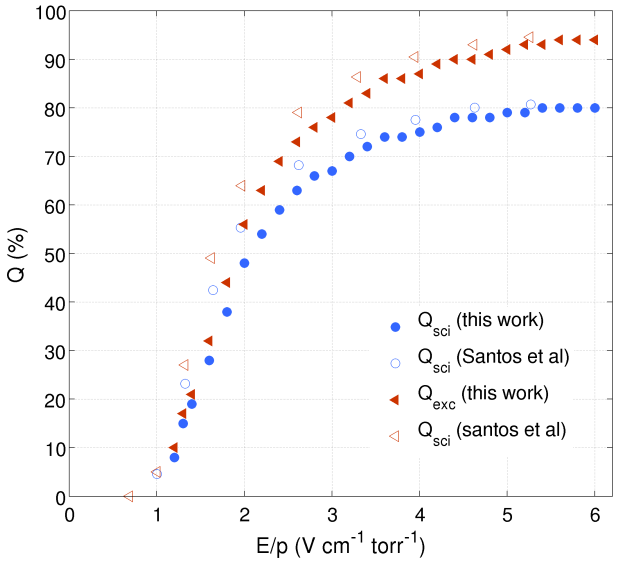


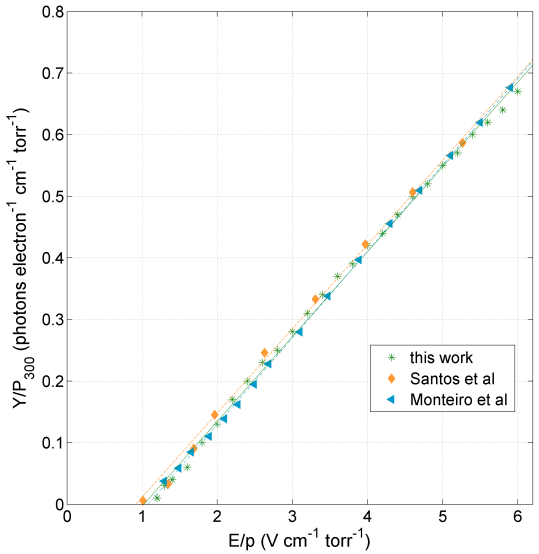
Simulation model

- 1 excited state -> 1 VUV photon of $\varepsilon_{sci} = 7.2eV$
- X sections from Magboltz
- Microscopic technique of Garfield

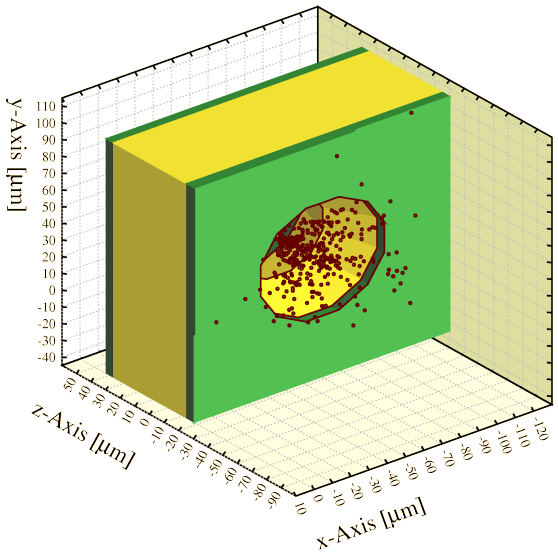


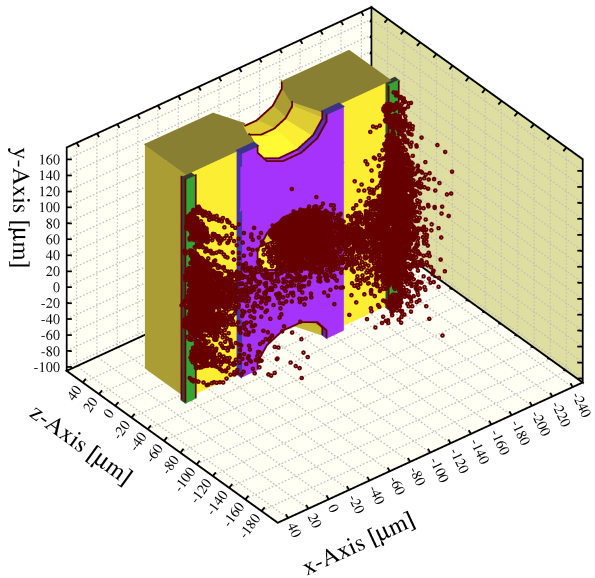
- $1 < \left(\frac{E}{p}\right) < 6\,Vcm^{-1}\,torr^{-1}$ (only elastic and excitation collisions)
- Q_{exc}, Q_{sci}, $\frac{Y}{p}$
- good agreement with former simulation work and experimental data
  (F. P. Santos et al, JPhysD-27(1994)42 & Monteiro et al, JInst-2(2007)5001)

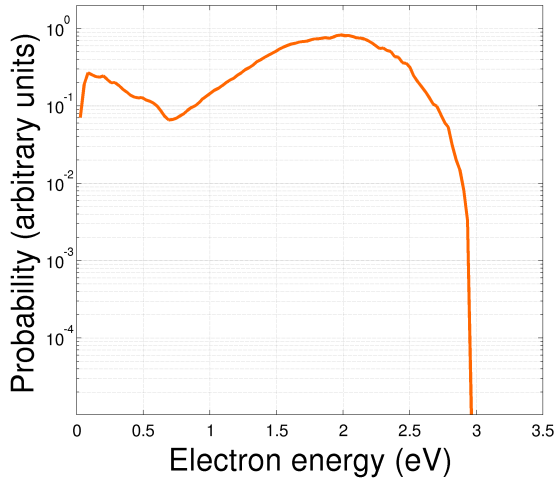




Model apllied to MPGD's
GEM & MHSP



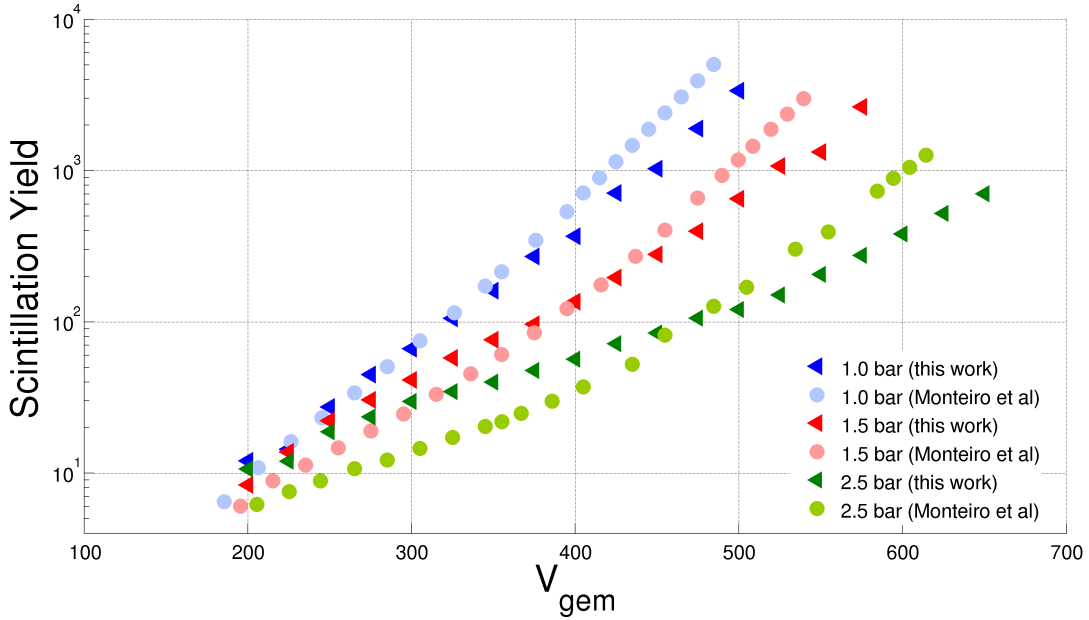




- Ansys field maps
- $z_{start} = 250\mu m$
- random ε_{start} (Magboltz)
- random (x, y)
- $N_e = f(V, p)$
- $N_{exc} = f(V, p)$

$E_{drift} = 0.5 kVcm^{-1}$

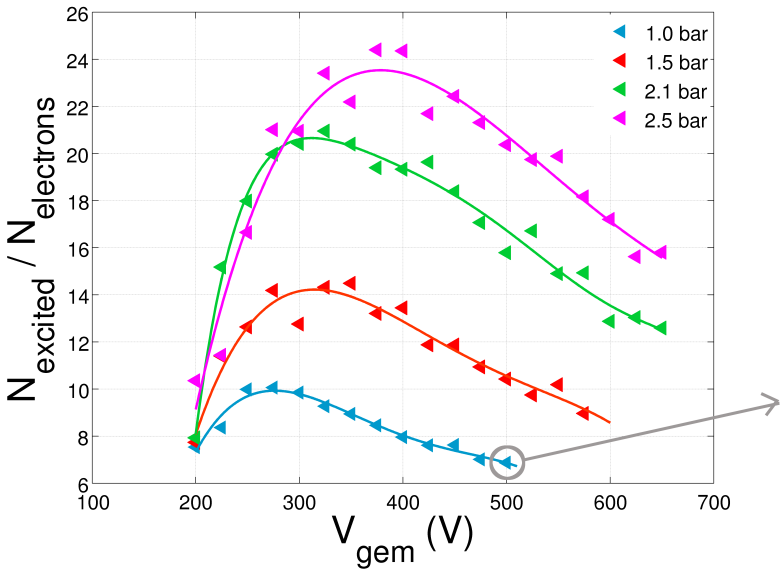
$E_{ind} = -0.1 kVcm^{-1}$

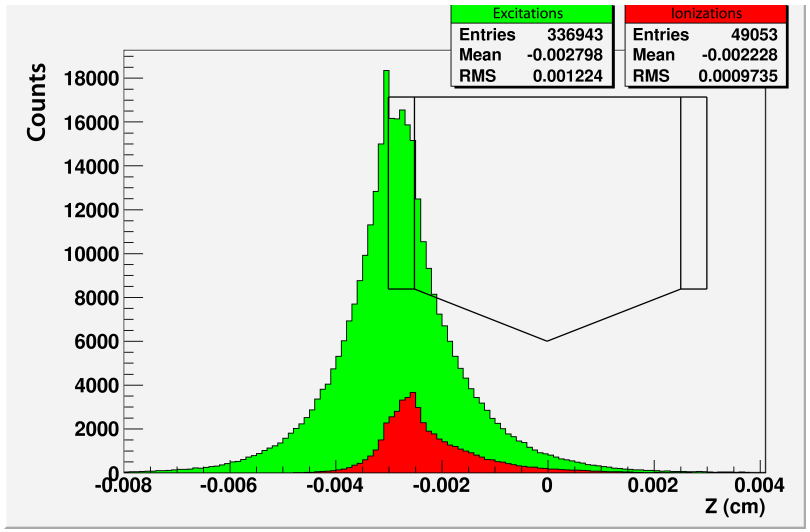


- Similar behaviour as experimental data (Monteiro et al, PLB)
- Little differences are being studied
  - low V_{GEM}: $N_{exc,1/2^+} \sim N_{exc,1/2^-}$ (photon block)
  - high V_{GEM}: charging up ??
  - ...

Results

GEM - Racio between light and charge



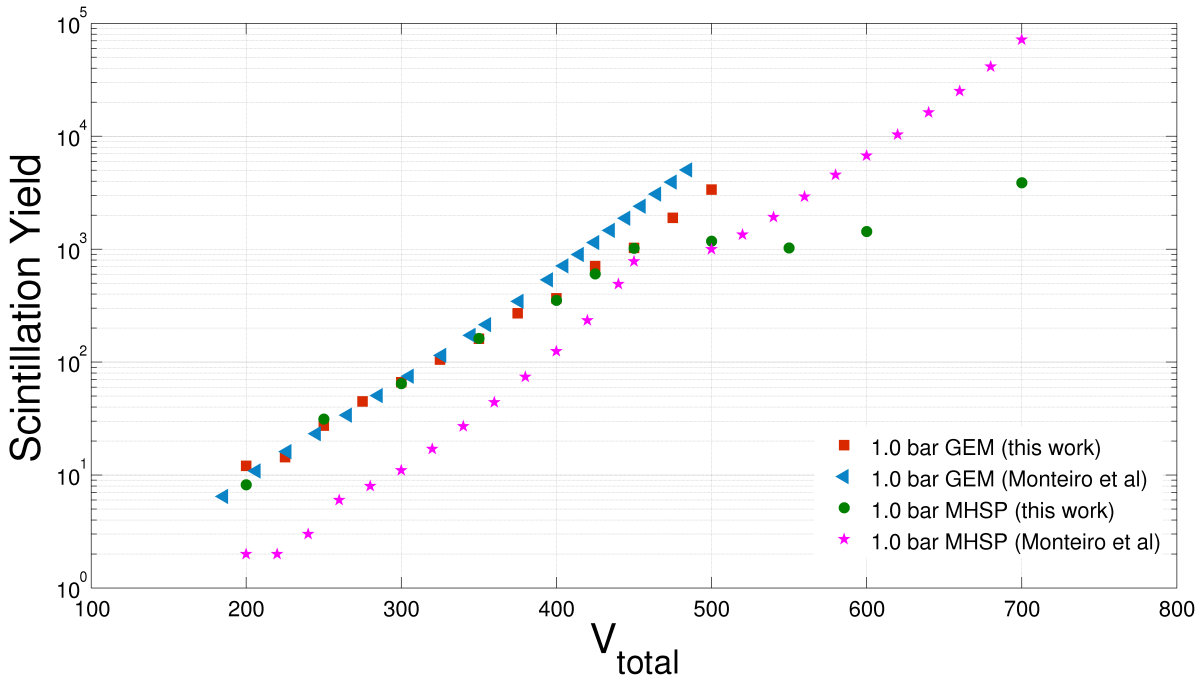


- $N_{exc} >> N_e$
- $\frac{N_{exc}}{N_e}$ increases with p

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

$p = 1.0 bar$

$E_{drift} = 0.1 kVcm^{-1}$



- Bigger differences
- More complex structure
- E_{max} estimation ??

Conclusions

- A simulation tool based in Magboltz / Garfield was developded to follow produced excited states in gas avalanches
- Y was accessed in GEM

  same behaviour as experimental data
- $\frac{N_{exc}}{N_e}$ increases with p
- $N_{exc} >> N_e$

  Light is an addicional information which can be usefull

Future Work

- Optimize simulation parameters (ε_{max}, ...)
- Understanding of differences between simulation and experimental results
- Consider charging-up effect in dielectric surface
- Apply the model to other microstructures (THGEM, THMHSP, Micromegas)
- Other properties will be accessed
  - Light position distribution (isotropic emittion, atoms diffusion)
  - Light signal (cascade radiative decay processes between states)
- Gas mixtures (Penning tranfers, ...)
- Use neBEM
- Interfacing with GEANT4

Thank you!!