

Initial Panel

Simulation tool for electroluminescence assessment in gaseous avalanche detectors

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Propose of the work

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Propose

- 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

Initial Panel

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- Propo

Atoms & Molecul

Electron

Quantum numbers LS coupling

Term Symbo

Decay Selection Rules Energy diagram

Model Technique

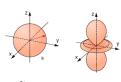
MPGD

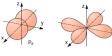
Model apllication Results GEM MHSP

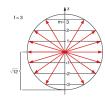
Conclusions

n

- orbital quantum number
- distance from the nucleous
- •
- orbital quantum momentum
- shape of probability distribution
- 0 < l < n-1
- $l = 0, 1, 2, 3, ... \rightarrow s, p, d, f, ...$
- m_l
 - magnetic quantum momentum
 - $-1 < m_1 < 1$
 - I projection along zz'
 - effect of a $\vec{B_z}$
- m_s
 - spin magnetic quantum momentum
 - projection of electron spin along zz' > (3) (3) (3)







Electron Spin-Orbit coupling

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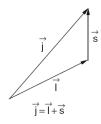
Conclusion

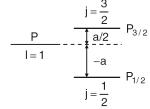
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Total angular momentum

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

Split levels only for I > 0





Term Symbol defining atomic energy states

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Term Symbol

2S+1L./

- $\vec{S} = \sum_{i} \vec{s_i}$, total spin
- $\vec{L} = \sum_{i} \vec{l_i}$ total orbital momentum $L = 0, 1, 2, 3, 4, 5 \rightarrow S, P, D, F, G, H$

$$L = |\textit{I}_1 + \textit{I}_2, |\textit{I}_1 + \textit{I}_2 - 1, |..., |\textit{I}_1 - \textit{I}_2|$$

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

Xenon Term Symbols

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Xenon

 $[Kr]3s^23p^6$

$$[Kr]3s^23p^6$$

• S = 0

$$[Kr]3s^23p^54s^1 \sim p^1s^1$$

•
$$S = 0$$

•
$$J = 0, 1, 2$$

$$\bullet$$
 ${}^3P_0, {}^3P_1, {}^3P_2$

•
$$N = \frac{6!}{5!1!} \frac{2!}{1!1!} = 12$$

$$P \rightarrow (2S+1)(2L+1) = 3$$

•
$${}^{3}P \rightarrow (2S+1)(2L+1) = 9$$

Xenon Term Symbols

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$[Kr]3s^23p^54p^1 \sim p^1p^1$

•
$$S = 0$$

•
$$L = 0, 1, 2$$

$$\bullet$$
 ${}^{1}S_{0}, {}^{1}P_{1}, {}^{1}D_{2}$

$$\bullet$$
 $L=0$

•
$$J = 0, 1, 2$$

• ${}^{3}P_{0}, {}^{3}P_{1}, {}^{3}P_{2}$

$$\bullet$$
 $^3D_1, ^3D_2, ^3D_3,$

$$N = \frac{6!}{5!1!} \frac{6!}{5!1!} = 36$$

$$^{1}S \rightarrow (2S+1)(2L+1)=1$$

•
$${}^{1}P \rightarrow (2S+1)(2L+1) = 3$$

• ${}^{1}D \rightarrow (2S+1)(2L+1) = 5$

•
$${}^{3}S \rightarrow (2S+1)(2L+1) = 3$$

2
3 \rightarrow (23 + 1)(2L + 1) = 3

•
$${}^{3}P \rightarrow (2S+1)(2L+1) = 9$$

•
$$^3D \rightarrow (2S+1)(2L+1) = 15$$

Radiative Decay Selection Rules

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Atom Term Symbol Xenon

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$$\Delta L = \pm 1$$

•
$$\Delta M = 0, \pm 1$$

•
$$\Delta M = 0 \rightarrow \text{linear polarized light}$$

•
$$\Delta M = \pm 1 \rightarrow$$
 cicurlarly polarized light

$$\bullet$$
 $\Delta S = 0$

•
$$\Delta J = 0, \pm 1, J = 0 \rightarrow J = 0$$
 is forbidden



Energy diagram

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Propos

Molecules Electron

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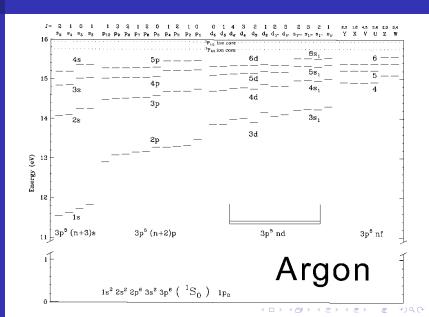
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Excimers Formation & Decay

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Future Work

Eximer formation (3 body collision)

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

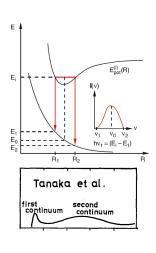
Direct radiative decay

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

 3 body collision + radiative decay

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

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





Simulation model

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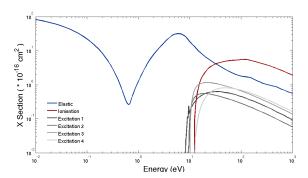
Validation

Model apllicatio

GEM MHSP

Conclusions

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





Validation Uniform field

Initial Panel

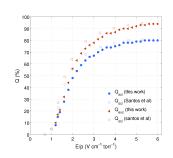
Validation

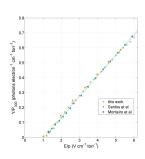
$$ullet$$
 $1<\left(rac{E}{
ho}
ight)<6$ Vcm^{-1} $torr^{-1}$ (only elastic and excitation collisions)

•
$$Q_{exc}$$
, 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

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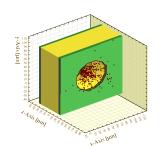
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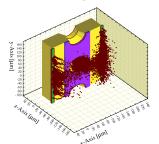
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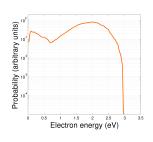
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- Ansys field maps
- $z_{start} = 250 \mu m$
- random ε_{start} (Magboltz)
- random (x, y)
- $N_e = f(V, p)$
- $N_{exc} = f(V, p)$

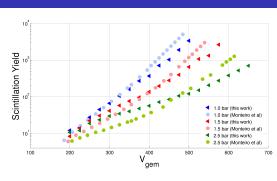


Results **GEM - Scintillation Yield**

 $E_{drift} = 0.5 kV cm^{-1}$ $E_{ind} = -0.1 kV cm^{-1}$

Initial Panel

GEM



- 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

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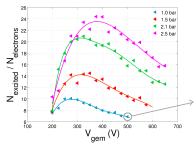
Model Technique

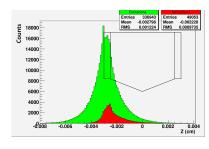
MPGDs Model apllication Results

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Future Work





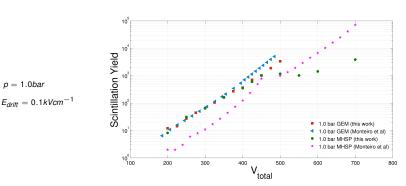
- $N_{exc} >> N_e$
- $\frac{N_{exc}}{N_e}$ increases with p

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

Results MHSP - Scintillation Yield

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MHSP



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



Conclusions

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Conclusions

 A simulation tool based in Magboltz / Garfield was developed 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

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Conclusions

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



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Future Work

Thank you!!

