Update on EL simulations in noble gases using Garfield and Magboltz 7.1

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Purpose of the work

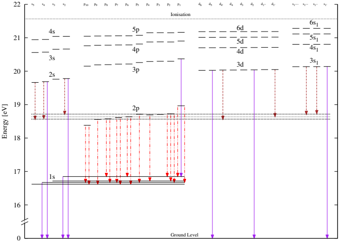
- Study of the physical processes of electroluminescence during the drift of electrons in noble gases

  (bellow and above ionisation threshold)
- Compare the behavior of different noble gases
- This information can be useful for:
  - Dark Matter search detectors
  - $\beta\beta^{0\nu}$ - NEXT
  - Dual phase detectors
  - other detectors

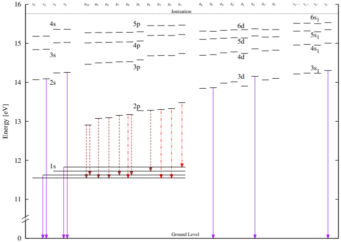
Atomic Energy Diagram

Pure noble gases

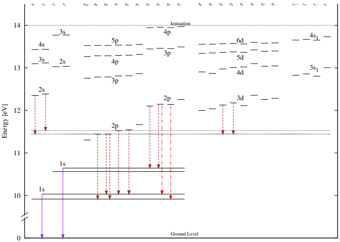
Ne



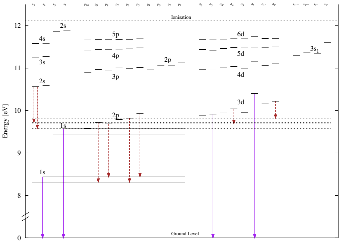
Ar



Kr



Xe



- e^- *impact* :
- 1*s* heavily populated
- 2*p* also contribute
- $1s_5$ & $1s_3$ forbidden transitions (J rule)
- $1s_4$ & $1s_2$ metastable
- $\Rightarrow$ excimers

Excimers

Formation & Decay

- Excimer formation (3 body collision)

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

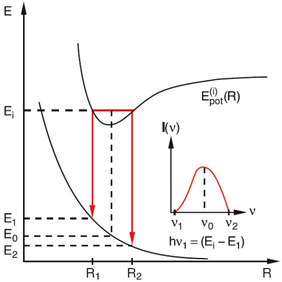
- Direct radiative decay ($p < 400 mbar$)

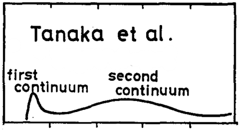
$$R_2^{**} \rightarrow 2R + h\nu$$

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

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

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



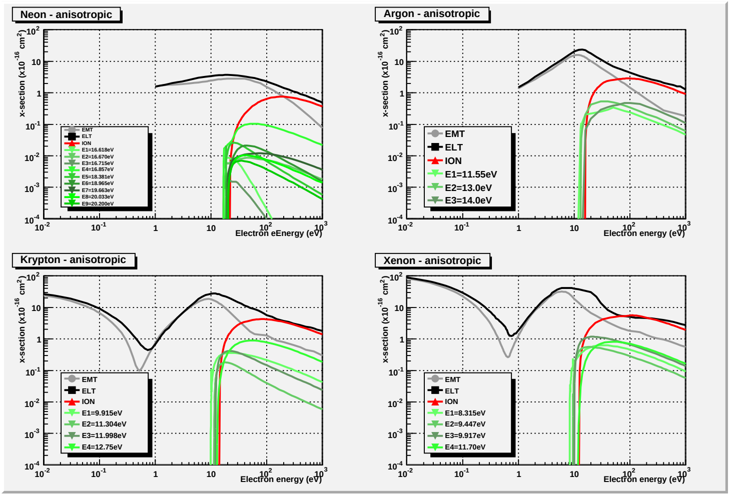


Garfield program / interface

- Geometry:
  - Geometry with planes, wires and tubes $\vec{E}$ is calculated analytically
  - Finite elements can be used
- Gas:
  - Define the gas through Magboltz
  - Noble gases x-sections: elastic, excitation, ionisation
- Drift - Microscopic technique:
  - 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 (Magboltz 7.1)
  - At each excitation collision we have information about:
    - time, (x, y, z), energy
    - Magboltz group (excited energy level)

Magboltz 7.1

x-sections



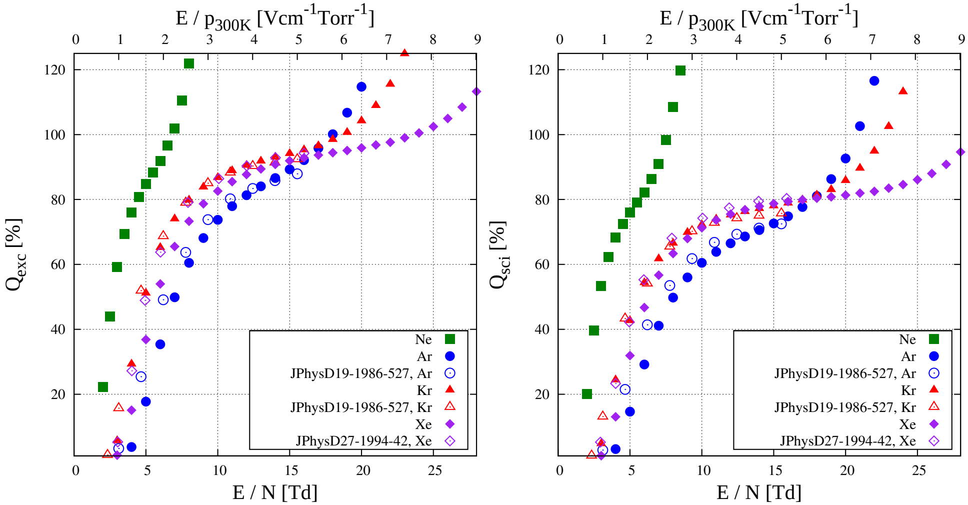
- 1 excited state -> 1 VUV

$(\varepsilon_{sci,Ne} = 15.1eV, \varepsilon_{sci,Ar} = 9.8eV, \varepsilon_{sci,Kr} = 8.3eV, \varepsilon_{sci,Xe} = 7.3eV)$

Suzuki et al, NIM, 164, 1979, 197 | Tanaka et al, Journal Opt Soc of America, 48, 1958, 304.

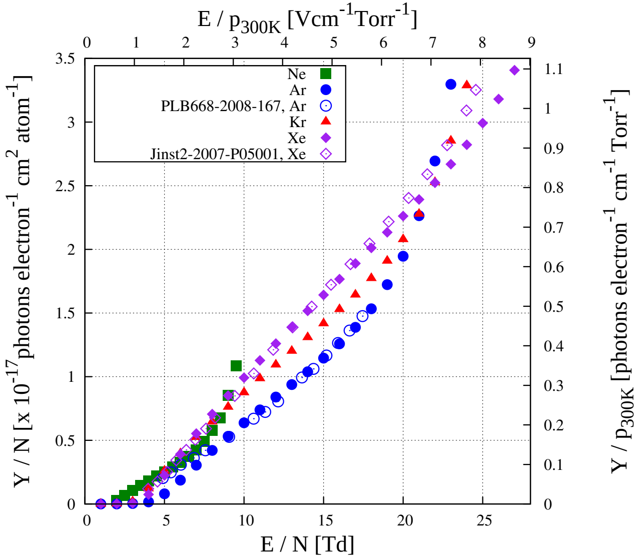
Uniform field geometry

Results - Q_{exc} & Q_{sci}



Uniform field geometry

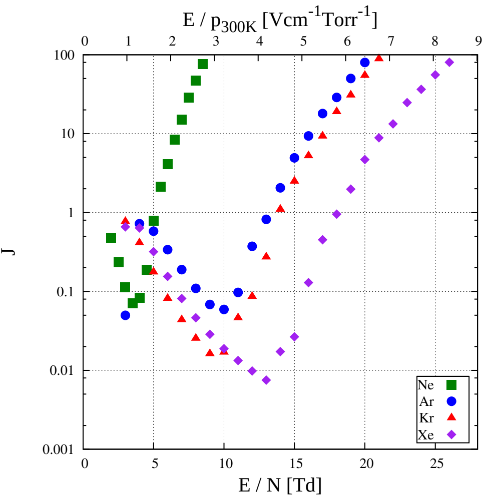
Results - Y

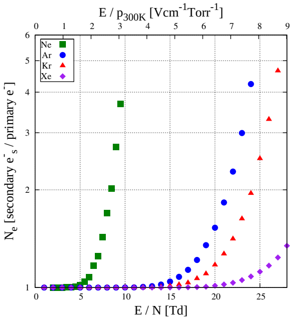


- Good agreement with experimental data (Ar & Xe)
- Experimental measurements for Ne & Kr are in progress

Uniform field geometry

Results - Light fluctuations



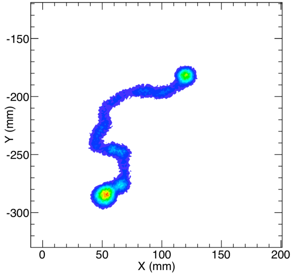


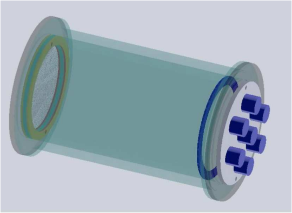
- $J = \frac{\sigma^2_{N_{UV}}}{\bar{N}_{UV}}$
- J decreases until ionisations begin
- R_E is a critical information for detector design:
- $R_E = \sqrt{\frac{F}{\bar{N}} + \frac{1}{\bar{N}}\left(\frac{J}{\bar{N}_{UV}}\right) + \frac{1}{\bar{N}_e}\left(1 + \left(\frac{\sigma_q}{G_q}\right)^2\right)}$

NEXT

Neutrino Experiment with Xe TPC

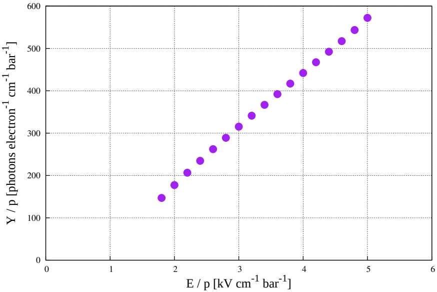
- $\beta\beta^{0\nu}$ decay search
- Are $\nu's$ Majorana particles?
- Xe TPC enriched in ^{136}Xe
- $p = 10bar$ & $T = 293K$
- EL signal ($R_E < 1\%$ @ $Q_{\beta\beta} = 2480keV$)
- Energy function: cathode
- Tracking function: anode

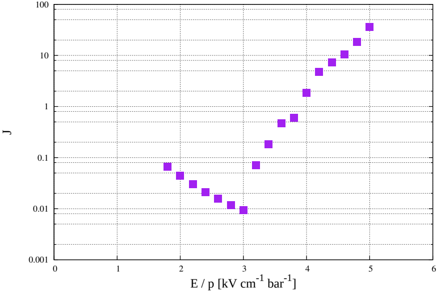


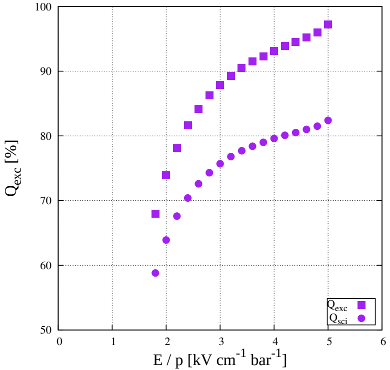


NEXT

Results







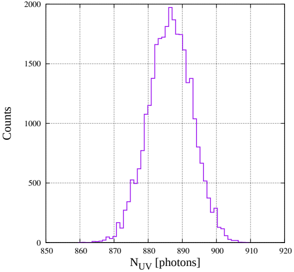
- parallel planes (5*mm* gap)
- real meshes will be considered

FEM

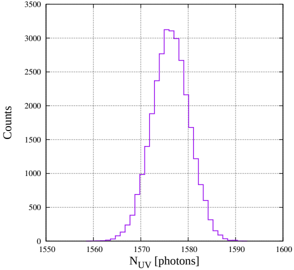
NEXT

N_{UV} distribution

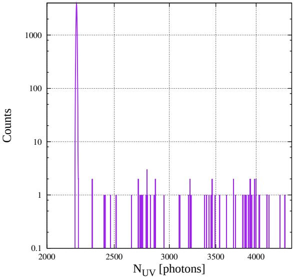
$2kVcm^{-1}bar^{-1}$



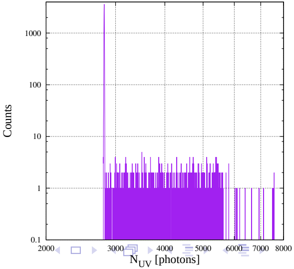
$3kVcm^{-1}bar^{-1}$



$4kVcm^{-1}bar^{-1}$

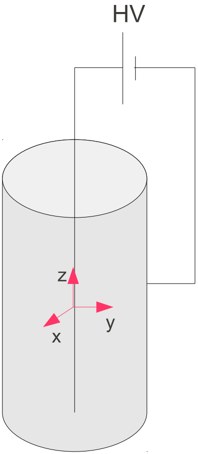


$5kVcm^{-1}bar^{-1}$



Cylindrical geometry

Xe

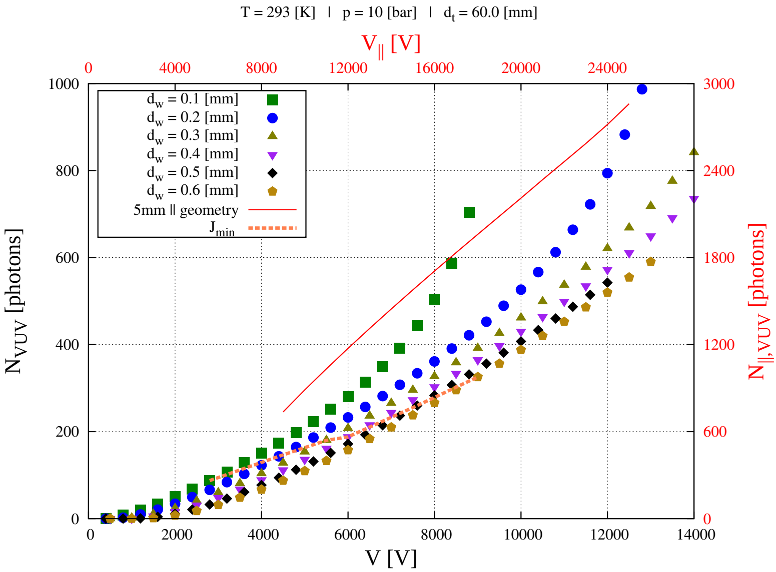


- Cylindrical geometry with wire anode
- Construct a multiwire based TPC using EL produced near the wires (without ionisation)
- Mechanically more stable than two parallel meshes
- $(0, y_{start}, 0)$ calculated to be 1mm far from EL region $\rightarrow \left(\frac{E}{p}\right)\rangle 1Vcm^{-1}torr^{-1}$ (293K)

Collaboration David Nygren

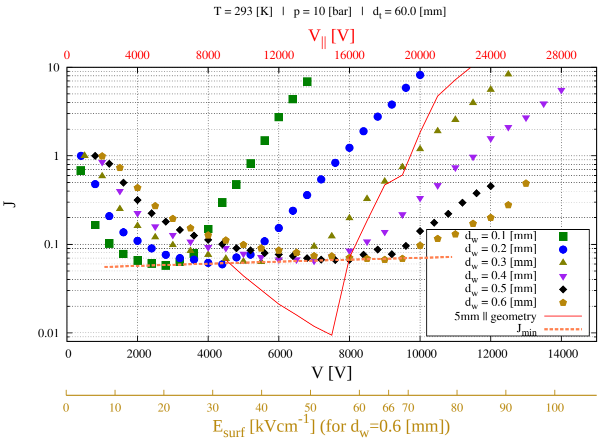
Cylindrical geometry

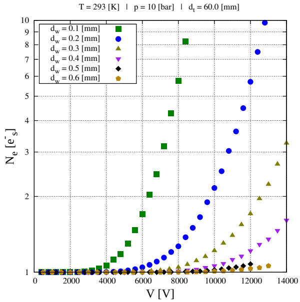
EL Yield - 10 bar Xe



Cylindrical geometry

Fluctuations - 10 bar Xe

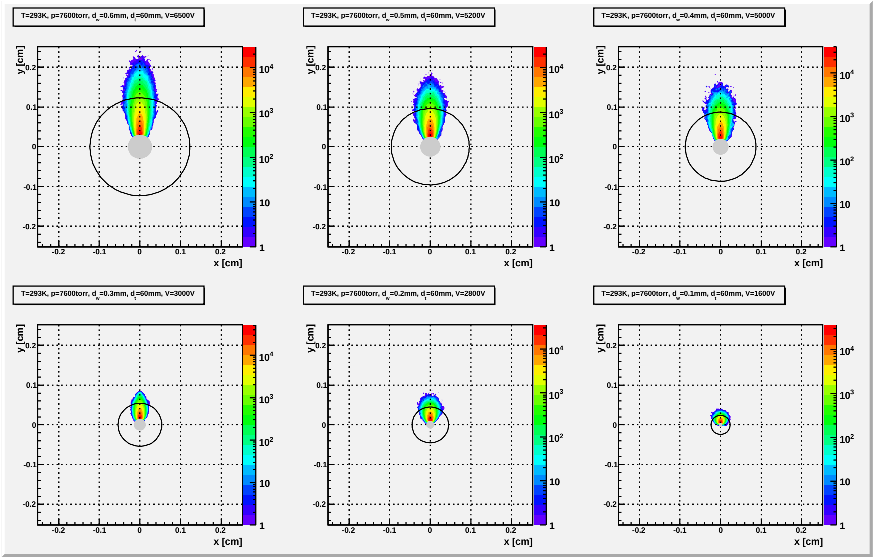




$$R_E = \sqrt{\frac{F}{\bar{N}} + \frac{1}{\bar{N}}\left(\frac{J}{\bar{N}_{UV}}\right) + \frac{1}{\bar{N}_e}\left(1 + \left(\frac{\sigma_q}{G_q}\right)^2\right)}$$

Cylindrical geometry

(x, y) distribution - 10 bar



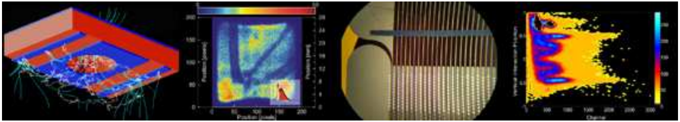
Conclusions

- 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 MC simulation results
- Reliable method for EL simulations (uE validation)
- EL Yield, efficiency & J were evaluated (uE, cylindrical)
- R_E can be predicted

Current and future work

- Repeat simulations with the new C++ version of Microscopic Technique (Heinrich & Rob)
- X-sections files updated (Stephen)
- Study the light emission spatial distribution and signal
- Consider the mesh of EL region of NEXT (FEM)
- Simulate the EL produced in a whole MWPC
- Measure experimentally Y of Kr & Ne in uE (in progress)
- Measure experimentally Y of Xe in wires (in progress)

Thank you!!



DRIM - Radiation Detection & Medical Imaging