# Simulation of gaseous Ar and Xe electroluminescence in the Near Infra-Red range

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Apr 24th 2013

*RD51 Mini-Week, CERN, Geneva, Switzerland*

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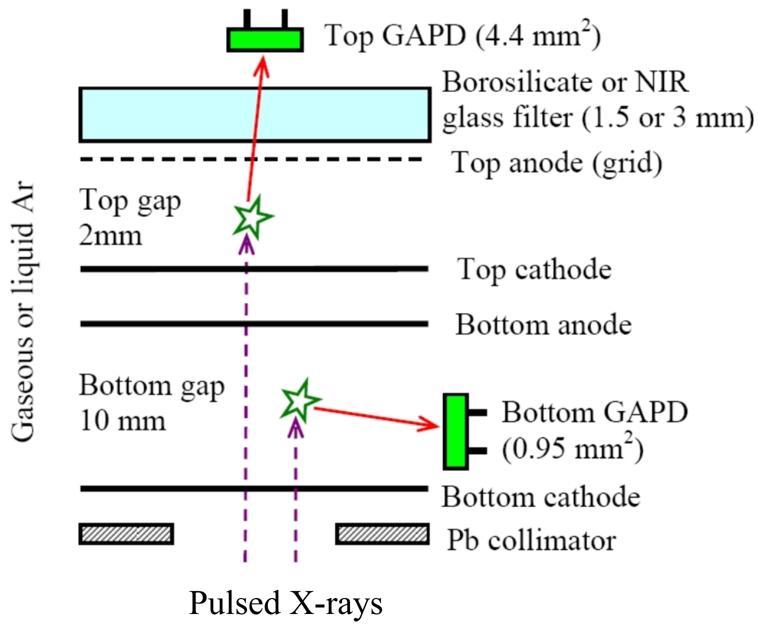
# Purpose

- VUV EL yield in pure noble gases is high but light detection not easy
    - Specific detectors
    - WLS coatings (to improve ε)
- NIR light is also produced during EL amplification
    - However, the yield is lower than VUV
- Geiger-mode Avalanche Photodiodes (GAPDs) @ cryogenic temperatures:
    - Very low noise (important for low energy threshold rare events, e.g., DM searches)
    - High ε in the NIR range (~ 17 % average for Wls of interest)
- Simulation is important for future design
    - Garfield++ has the main ingredients
- A. Bondar et al, JINST 7 (2012) P06014
    - Experimental results of Argon $Y_{NIR}$ at cryogenic temperatures (gas and liquid)
- This work: first insight into the problem (gas phase)

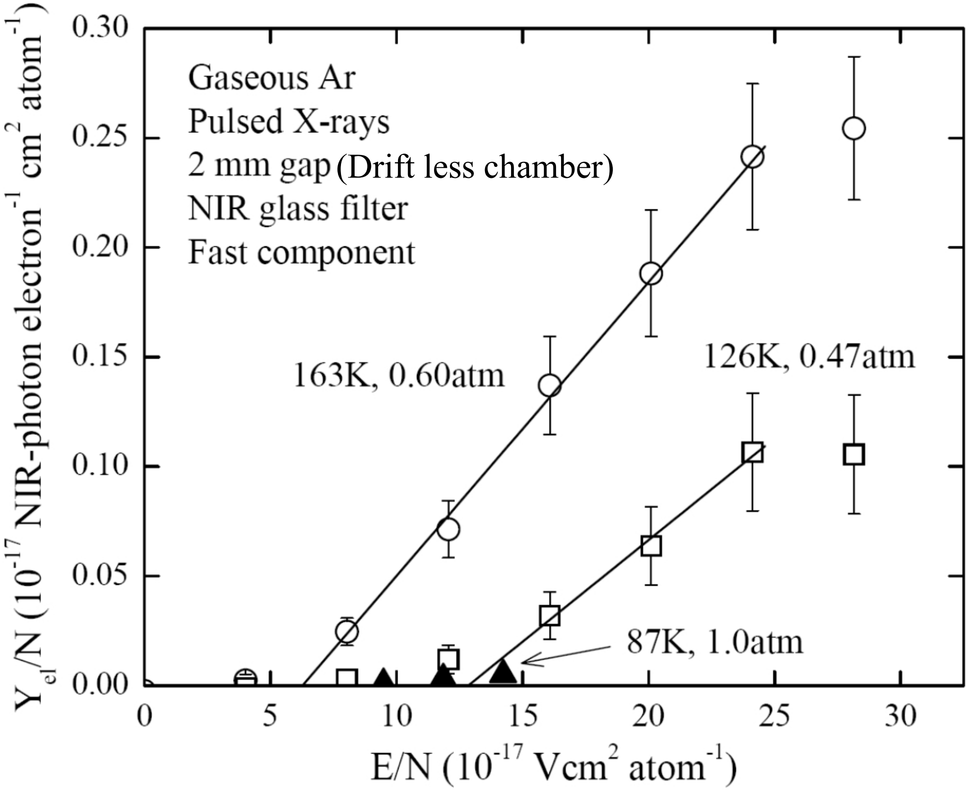
Accepted for publication in *Nuclear Instruments and Methods A*

# Available experimental NIR EL data

## Pure Argon, cryogenic temperatures



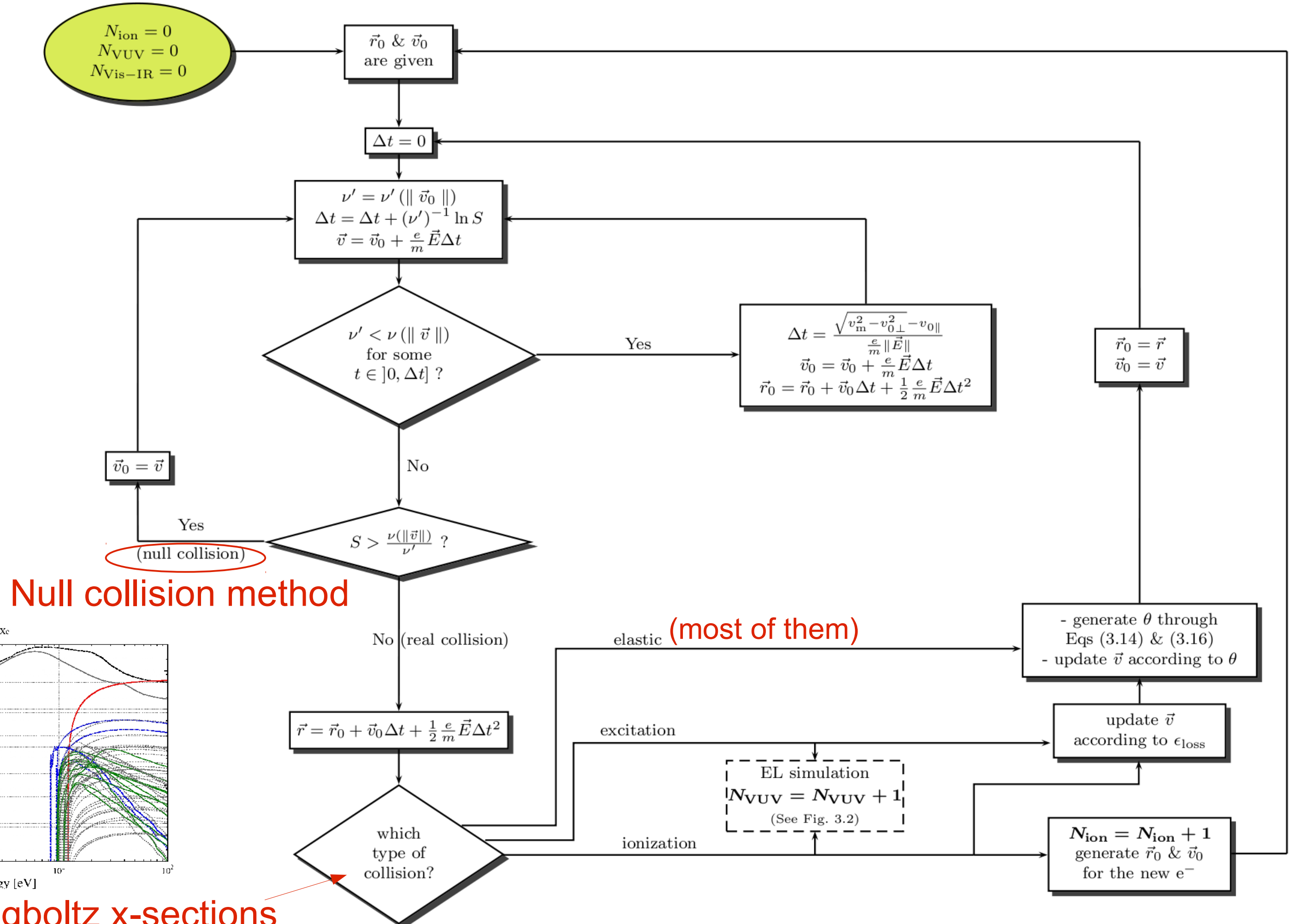

Reduced NIR EL yield normalized to $N_e$:

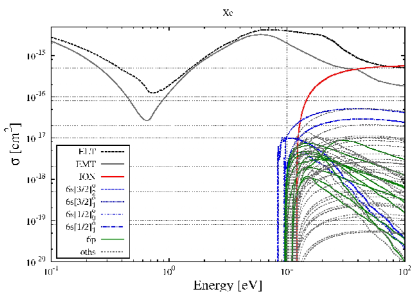



*A. Bondar et al, JINST 7 (2012) P06014*

# Garfield++ / Magboltz

## Pure noble gases



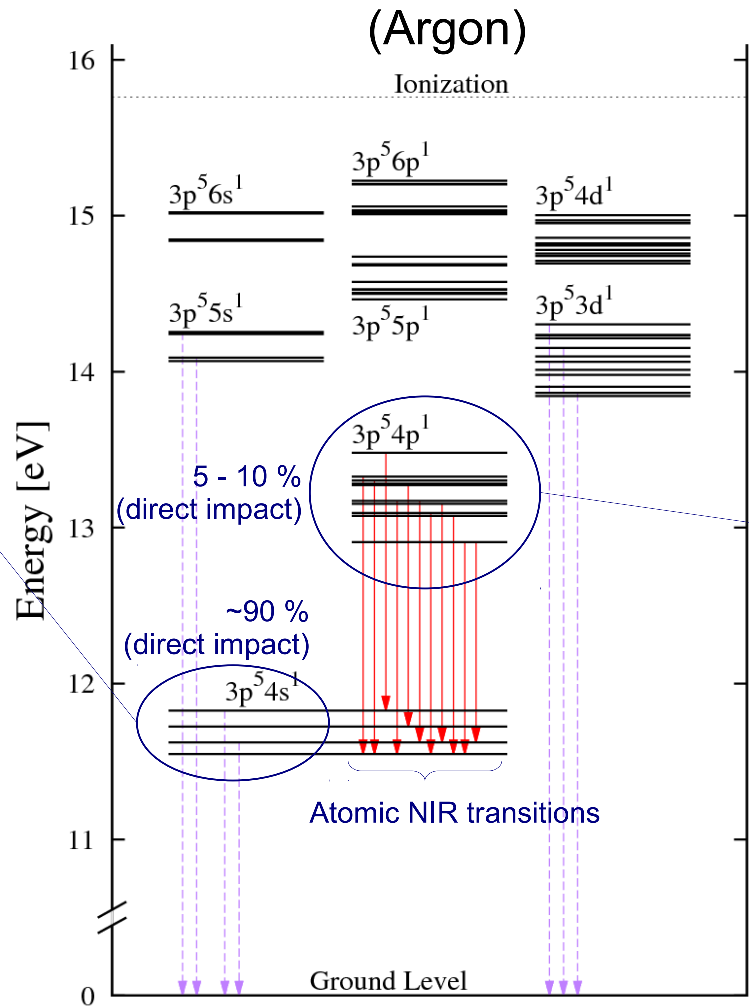

Based on Magboltz x-sections

# Atomic excited states

## Argon

@ high pressures (1 bar or higher):

- $\tau_{rad,eff} > \tau_{coll}$
- Decay through excimers
- 128 nm VUV light




Additionally populated by cascades from upper levels:

- radiative
- λ < 1 μm

  not detectable by GAPDs

  not considered in this work
- collisional

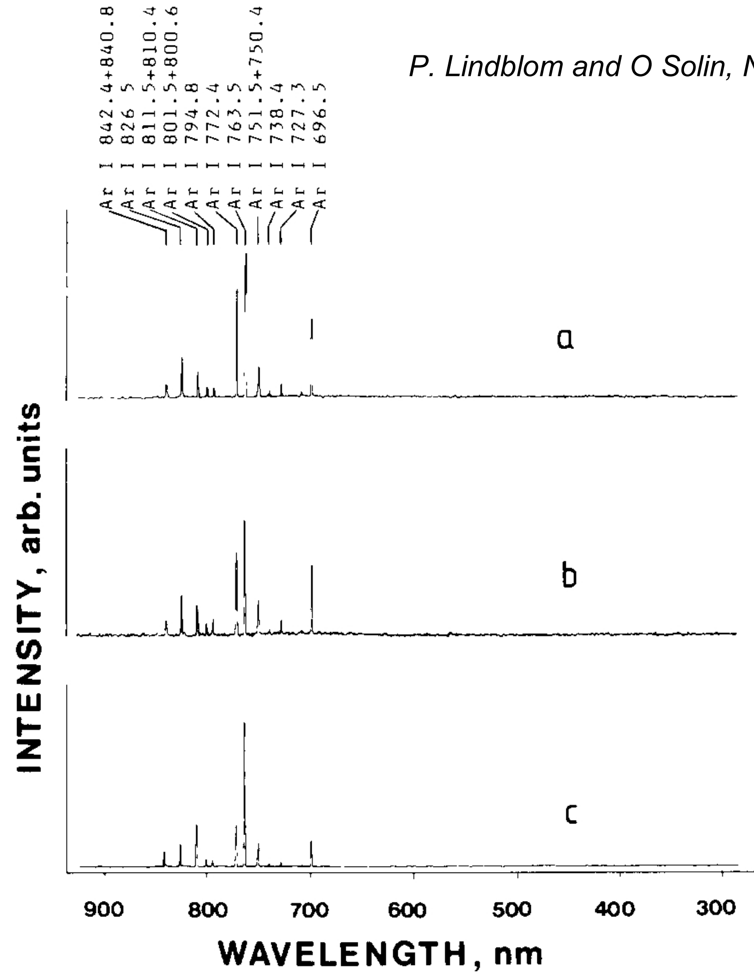
# NIR spectrum

## Argon

- Cylindrical geometry
  - a) primary scintillation (direct, beam excited)
  - b) EL (+1600 V on the wire)
  - c) EL (-1600 V on the wire)
- 2.0 bar
- Room temperature
- Atomic lines: 690 – 850 nm

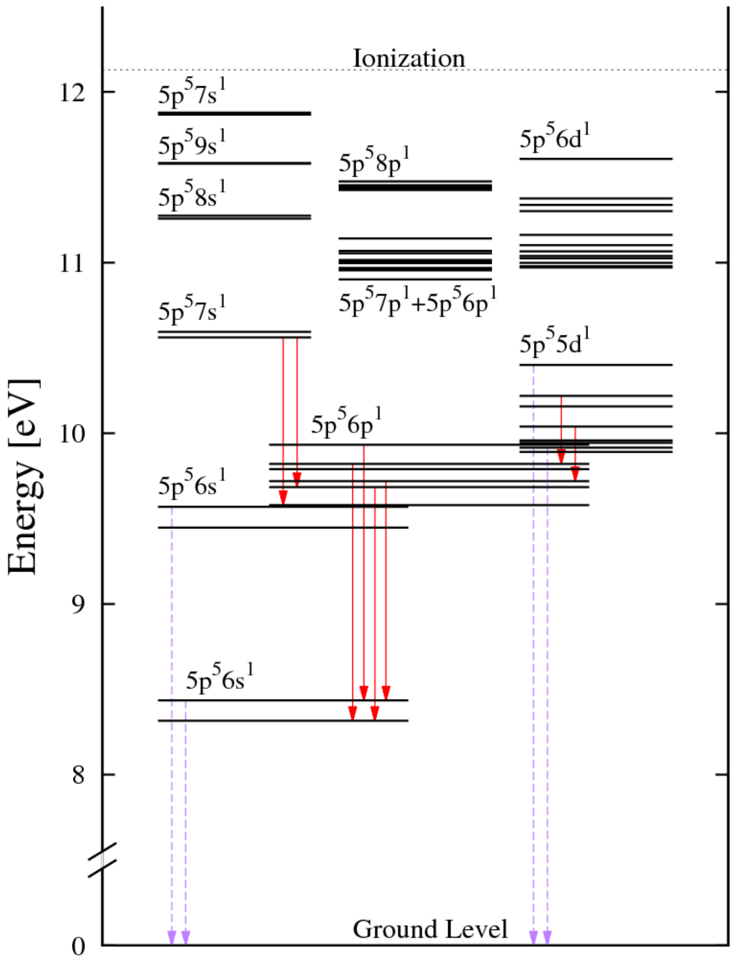
*G. Bressi et al, PLA 278 (2001) 280:*
for atomic lines with λ > 1 μm
(**<u>not considered in this work</u>**)

*P. Lindblom and O Solin, NIM A 268 (1988) 204*



# Atomic excited states

Xenon




- Excimer decay:
  - 172 nm
- Atomic NIR radiative transitions:
  - 820 – 885 nm

# NIR spectrum

## Xenon

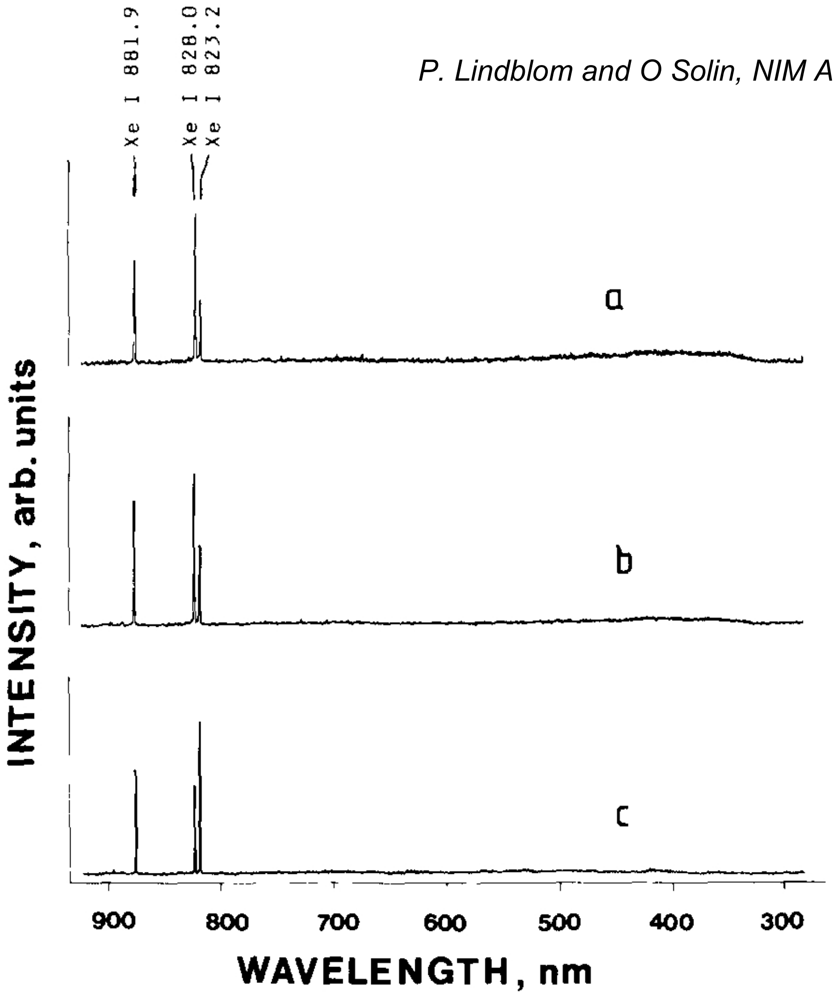
- Cylindrical geometry
  - a) primary scintillation (direct, beam excited)
  - b) EL (+1600 V on the wire)
  - c) EL (-1600 V on the wire)
- 1.6 bar
- Room temperature
- Atomic lines: 820 – 885 nm

*G. Bressi et al, NIM A 461 (2001) 378:*

Broad band around 1300 nm not consistent with atomic lines

(**not considered in this work**)

*P. Lindblom and O Solin, NIM A 268 (1988) 204*



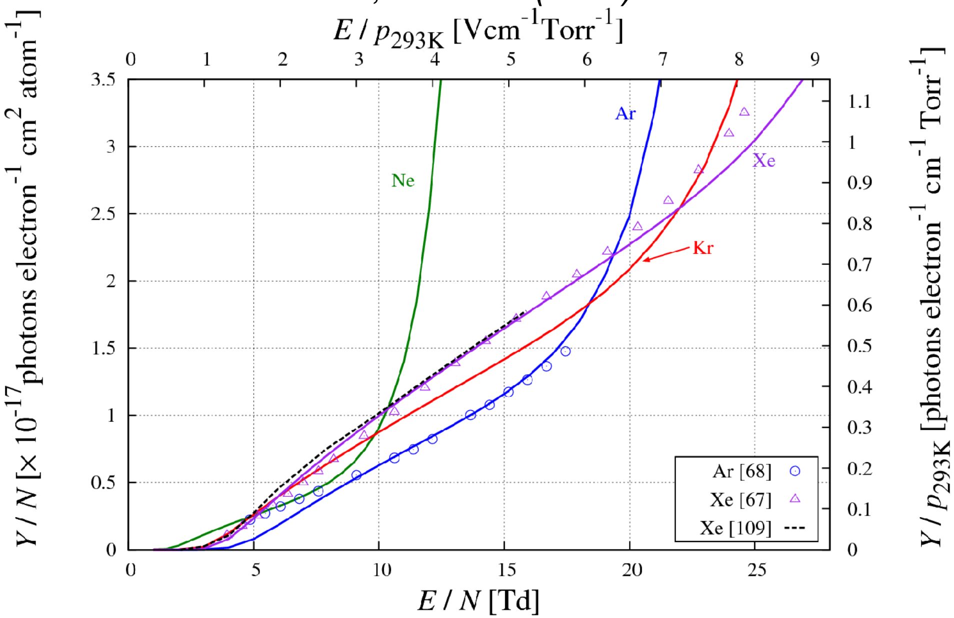
# EL model

- VUV EL:
  - Any single excited state leads to the emission of a VUV photon
- Two first approaches for NIR EL:
  - Only $np^5(n+1)p^1$ states excited by direct e- impact
  - Also higher states produce ultimately a NIR photon
    - After radiative ($\lambda$ < 1 μm) or collisional decay to $np^5(n+1)p^1$

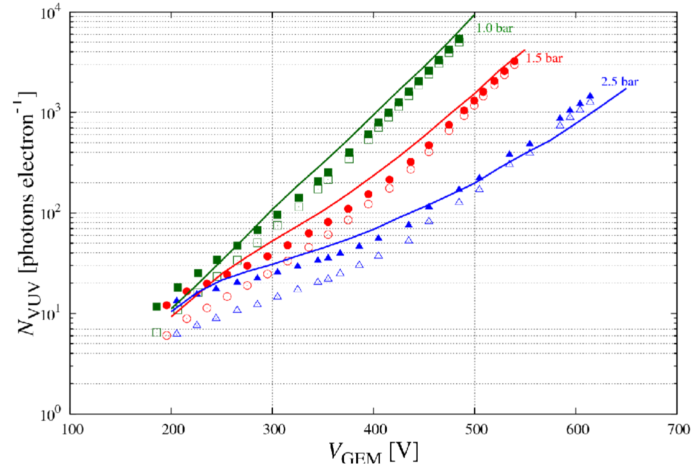
# VUV EL

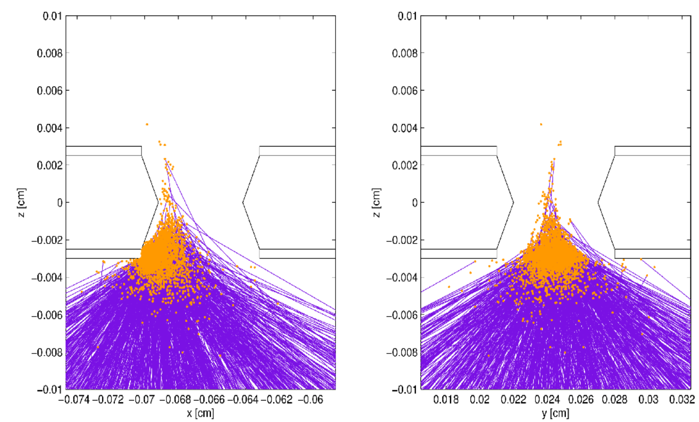
## Results

*C. A. B. Oliveira et al, PLB 703 (2011) 217*




*C. A. B. Oliveira et al, JINST 7 (2012) P09006*



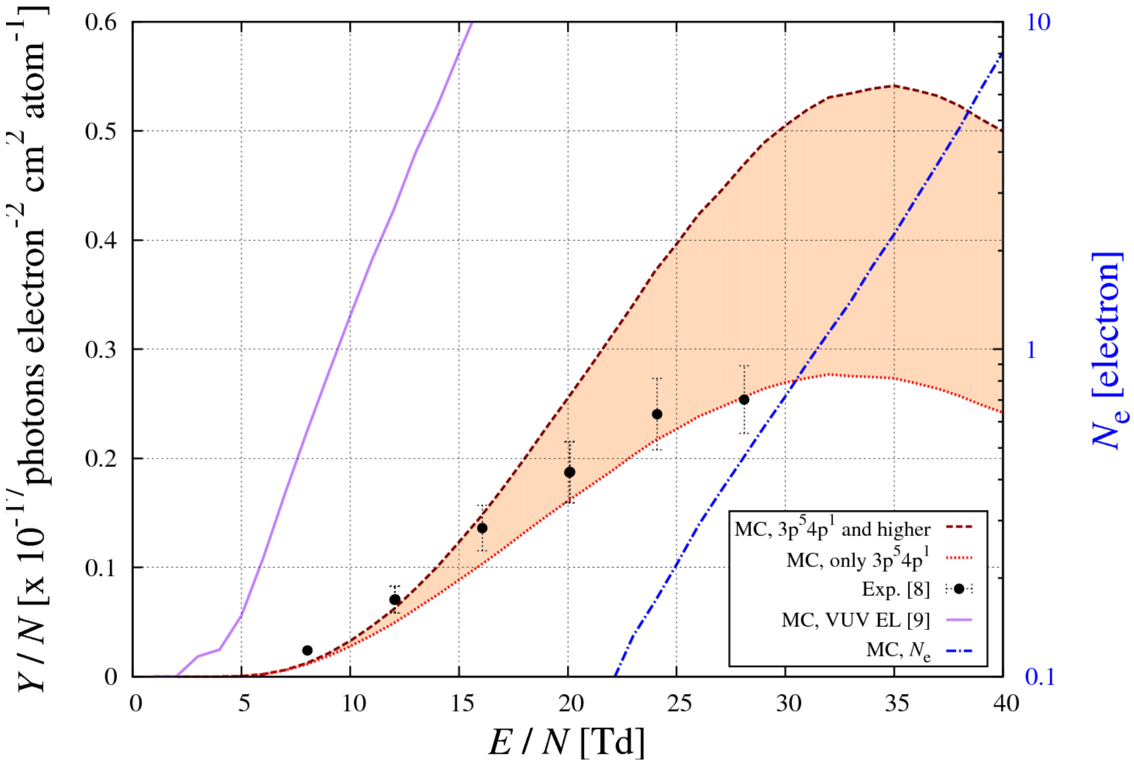

- Toolkit validated by comparing experimental and MC results
  - Uniform electric field (both Ar and Xe)
  - GEM (Xe), after correction for Ω(V)

# NIR EL results

## Argon

- *Y/N*:
  - # of NIR γs / primary e- / d / N / Ne
  - d: unit of drift length

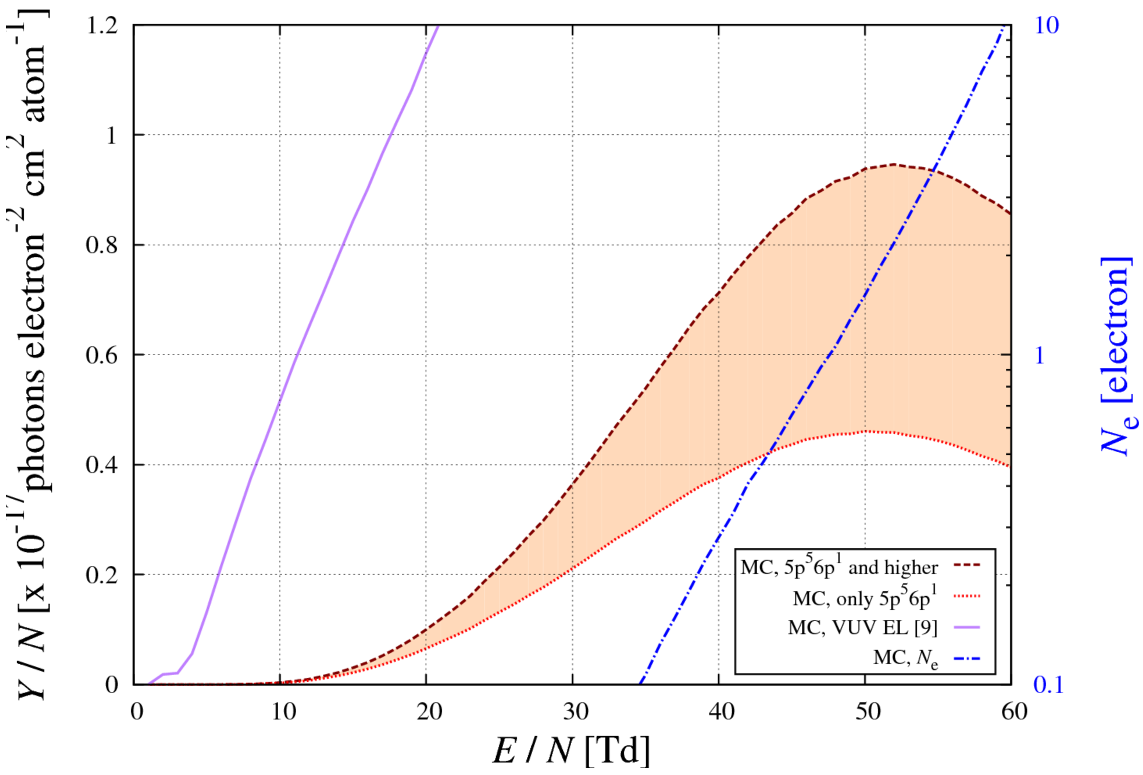
    (1 mm average – drift-less chamber)
  - N: atom density of the gas
  - Ne: # of secondary e-s
- Experimental *Y/N* is between the two approaches, within errors
  - Good starting points for simulation of NIR EL
- NIR *Y/N* ~10x lower than VUV *Y/N*
- Decrease for *E/N* > 30 Td:
  - Secondary e-s don't produce EL for the whole avalanche length
- NIR threshold is higher than VUV
  - Energy of associated energy levels



# NIR EL results

## Xenon

- Seems to have an higher absolute yield
- Measurements not available for comparison
- Still an interesting gas from the point of view of possible applications (DM, 0νββ, ...)



# Conclusions / Future work

- First attempt in order to simulate NIR EL in gaseous Ar and Xe
- Two different approaches considered
  - Based on which excited states contribute for NIR EL
- Measurements are between the two approaches
  - Good starting points for accurate simulation of NIR EL in gaseous detectors
- Further work needed
  - Detailed model of decays between individual atomic states
    - Life times?
    - Radiative transition strengths?
    - Branch ratios?
    - Collisional transfer rates?

# Thank you!!!