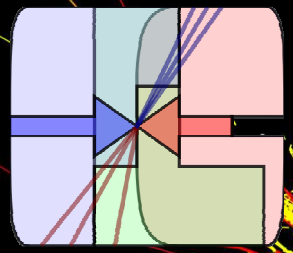
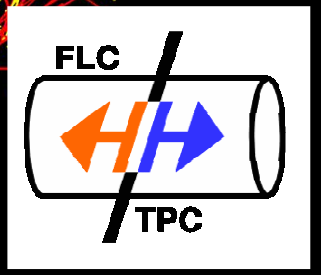




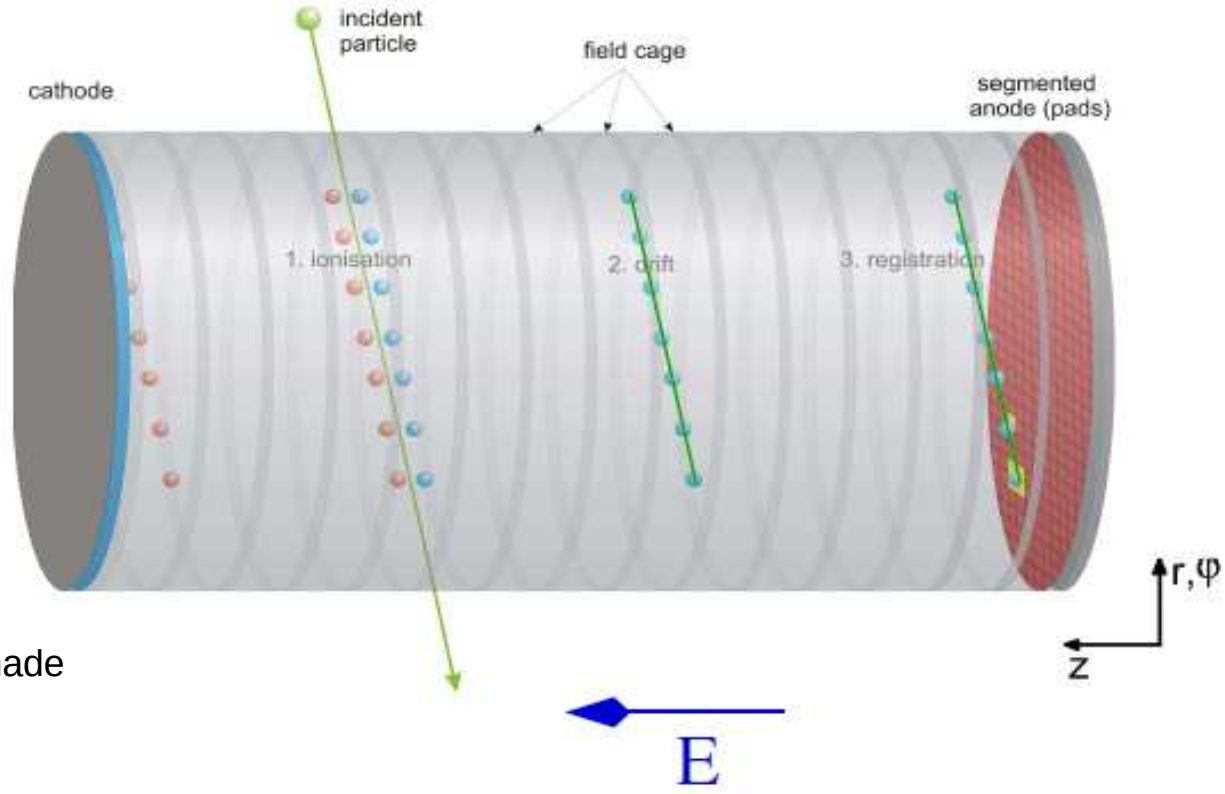
Electroluminescence as an alternative Readout Scheme for a Time Projection Chamber

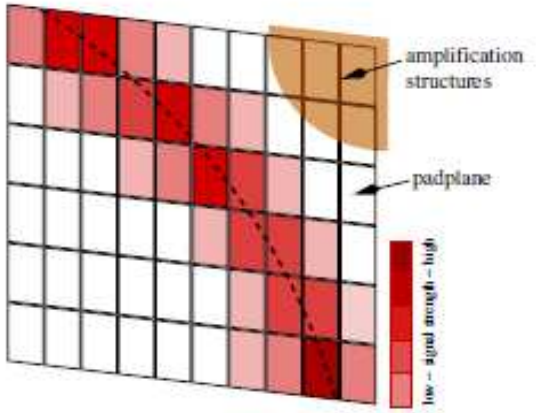
Torsten Hartmann

06/09/2010

Leibniz Universität Hannover

Time Projection Chamber (TPC)



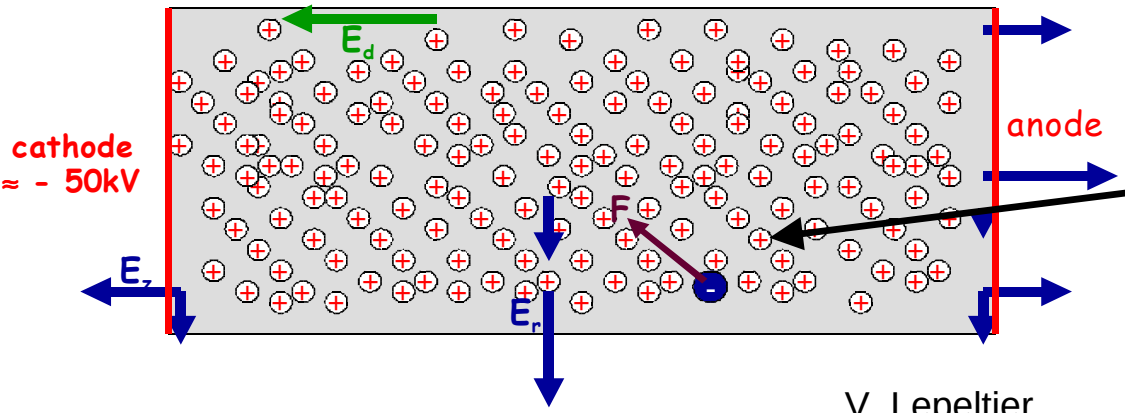


P. Schade

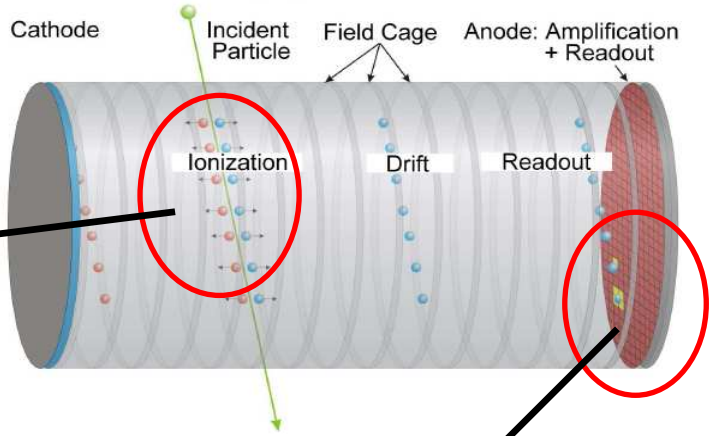
Reconstruction of the trajectory

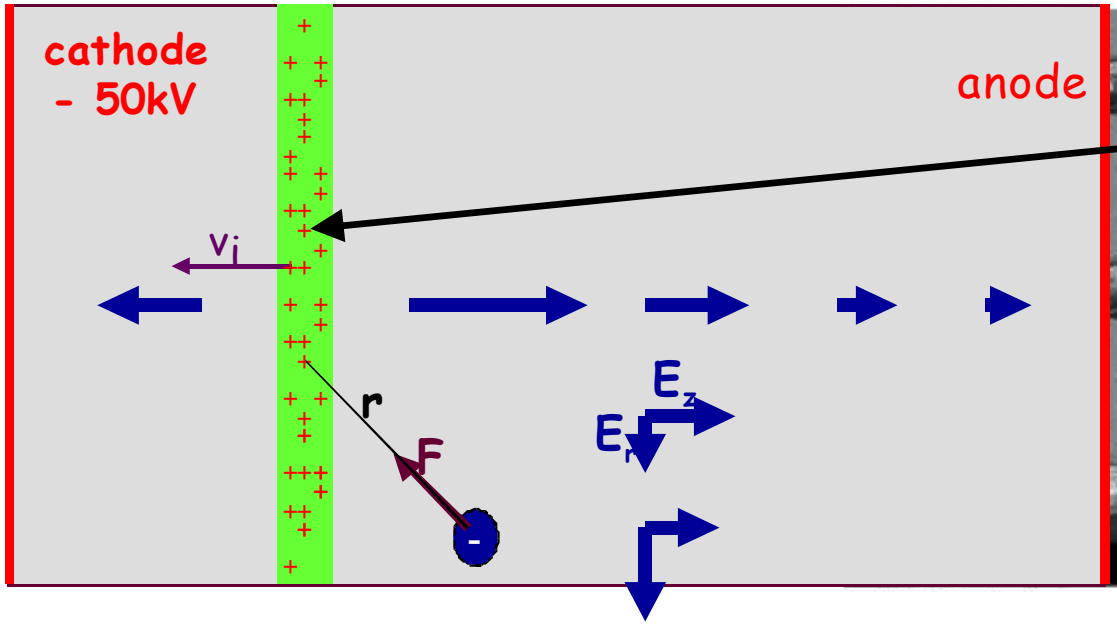
- gas ionisation → drift → amplification → sampling on pads
- reconstruction of z-coordinates from drift times
- electric field homogeneity important for undisturbed projection

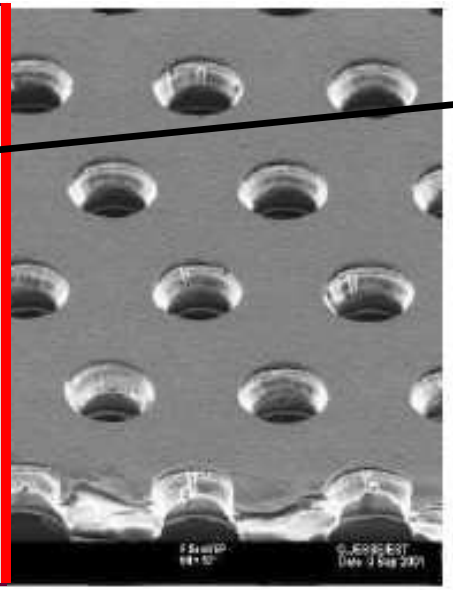
Primary and Secondary Ions inside the TPC

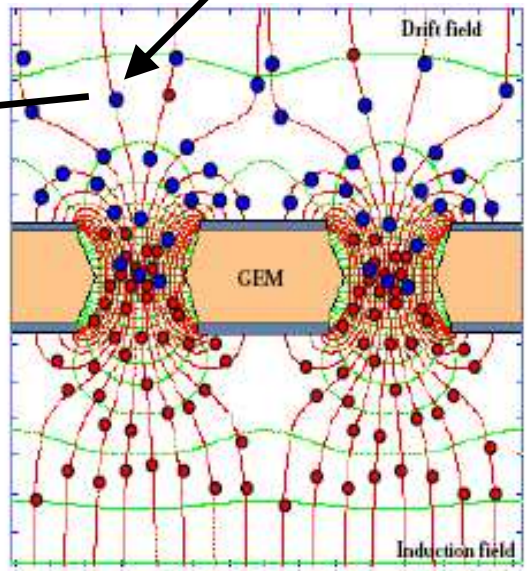


V. Lepeltier

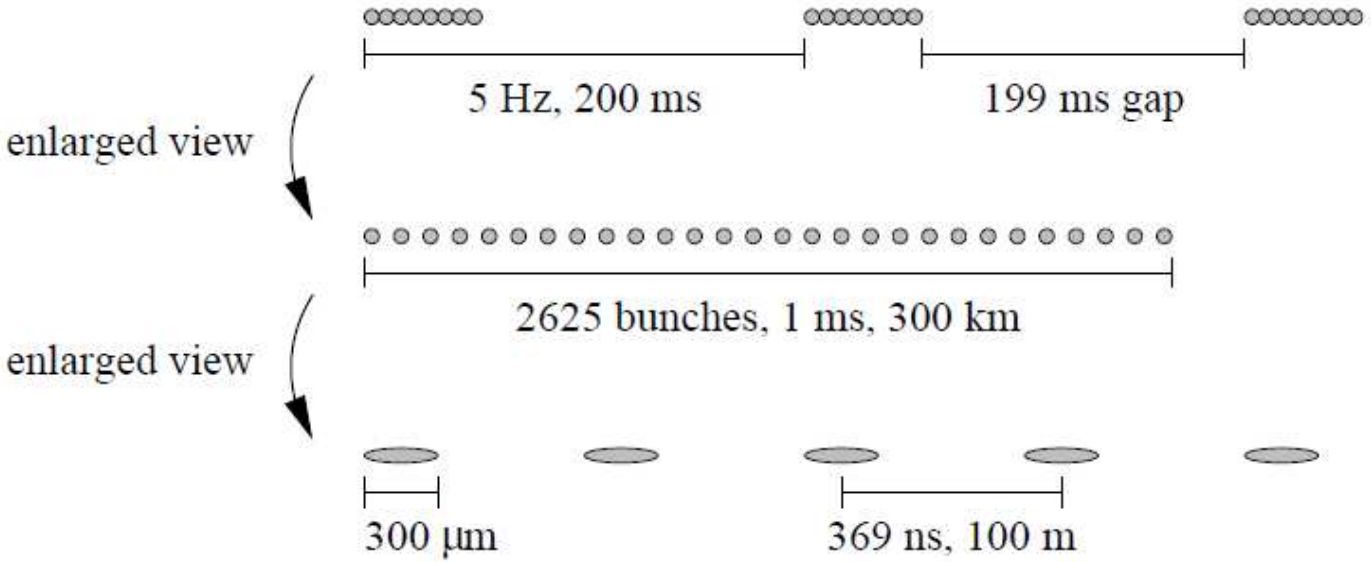


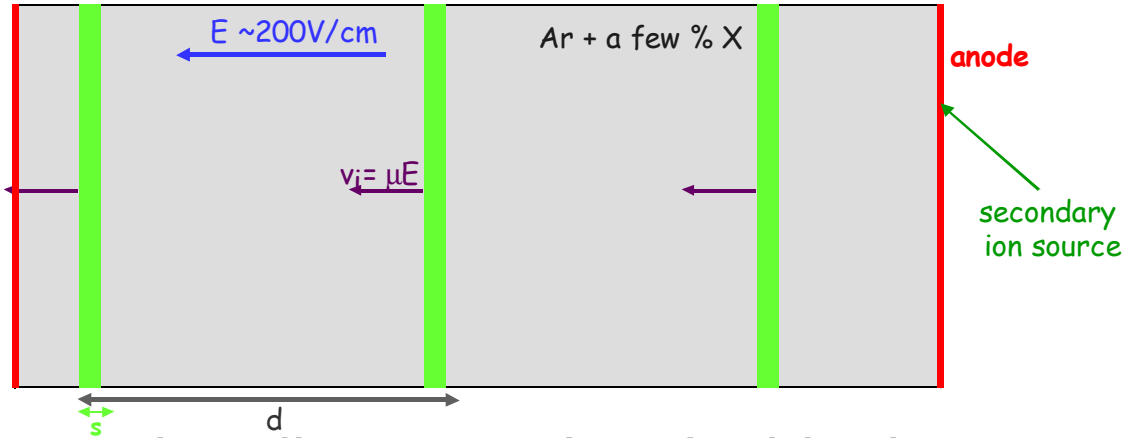






ILC bunch structure and ion discs in TPC





For argon: ~3 ion discs at a time inside the TPC for TPC-Length = 240 cm

Electroluminescence (proportional Scintillation)

Ion discs will probably disturbe the homogeneous electromagnetic field inside the TPC

Avoid secondary ions

⟹ One idea: use Electroluminescence

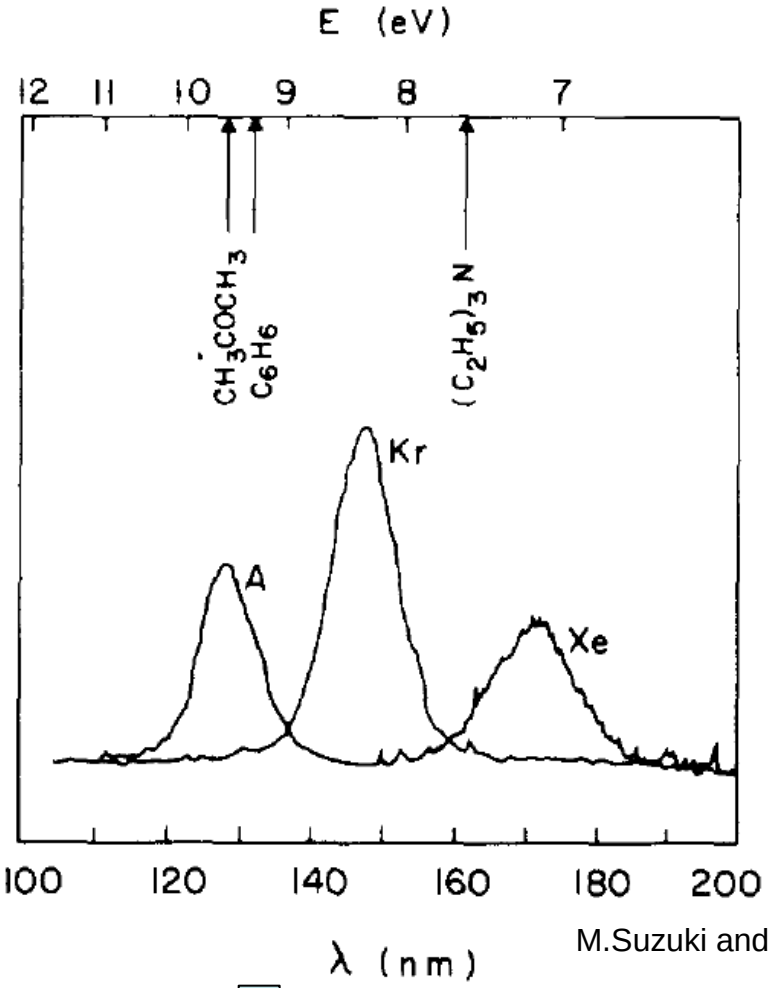
radiative de-excitation of excited molecules

$$\mathrm{Ar}_2^* \rightarrow 2\mathrm{Ar} + h\upsilon$$

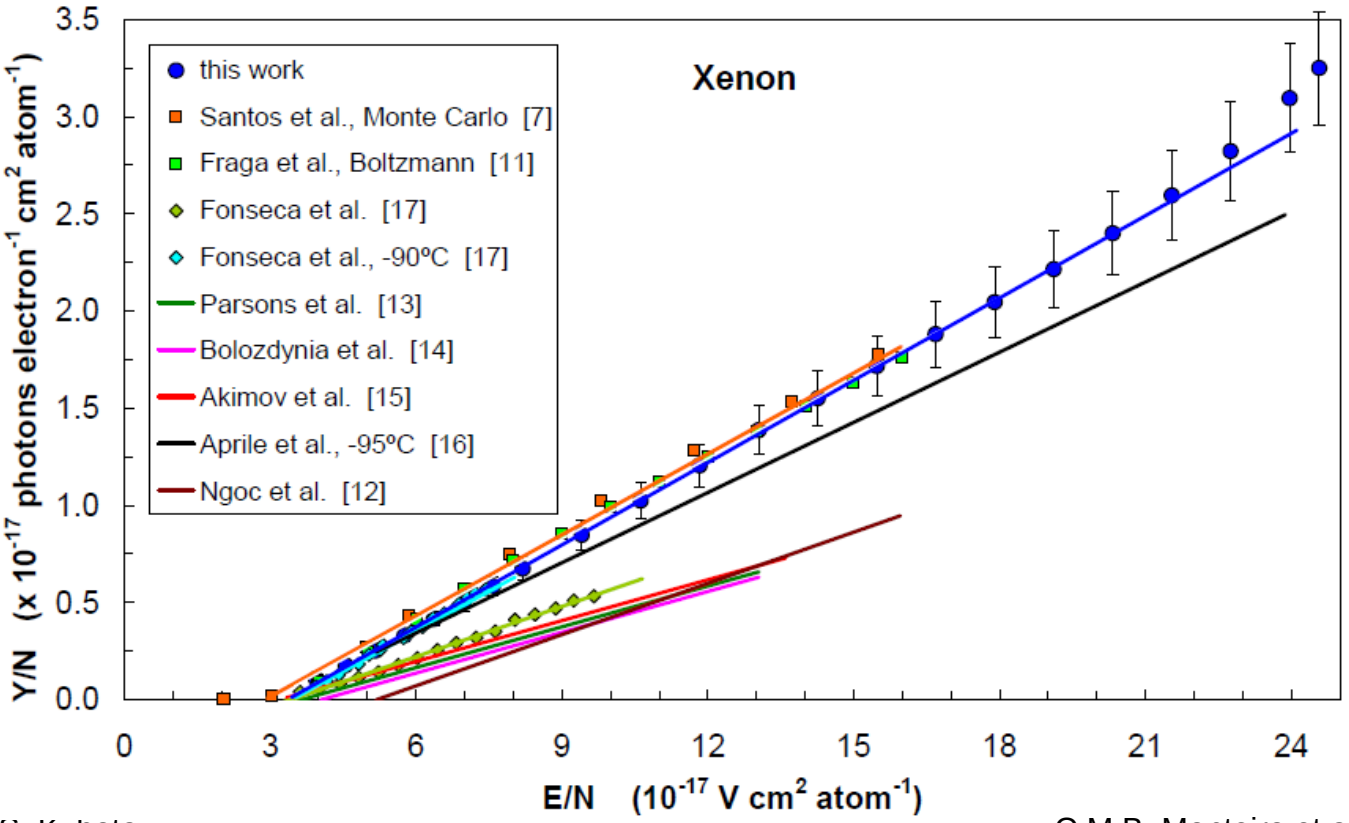
where Ar^*_2 is mainly formed through a three body collision

$$\mathrm{Ar}^* + 2\mathrm{Ar} \rightarrow \mathrm{Ar}_2^* + \mathrm{Ar}$$

Electroluminescence (proportional Scintillation)



M.Suzuki and S. Kubota



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VUV radiation

Project specification

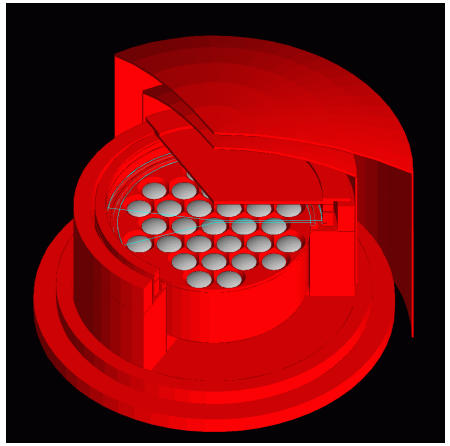
Goals:

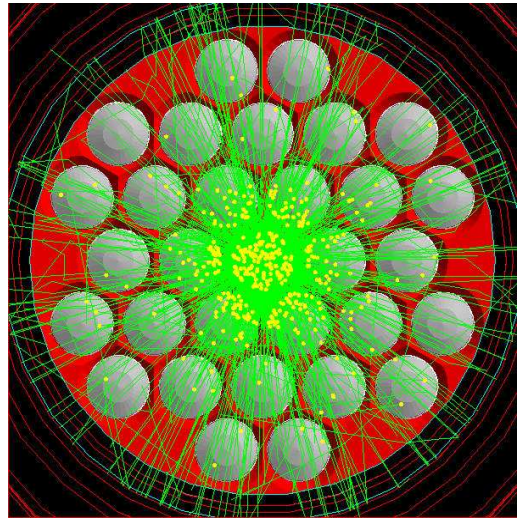
- Simulation of Electroluminescence in a TPC
- Investigation of suitability of Electroluminescence as alternative Readout Scheme

How to do the Simulation – Geant4

Geant4:

- Is a C++ based detector simulation tool
- Brings many physical processes already with its libraries
- Allows full simulation of particle interactions with matter





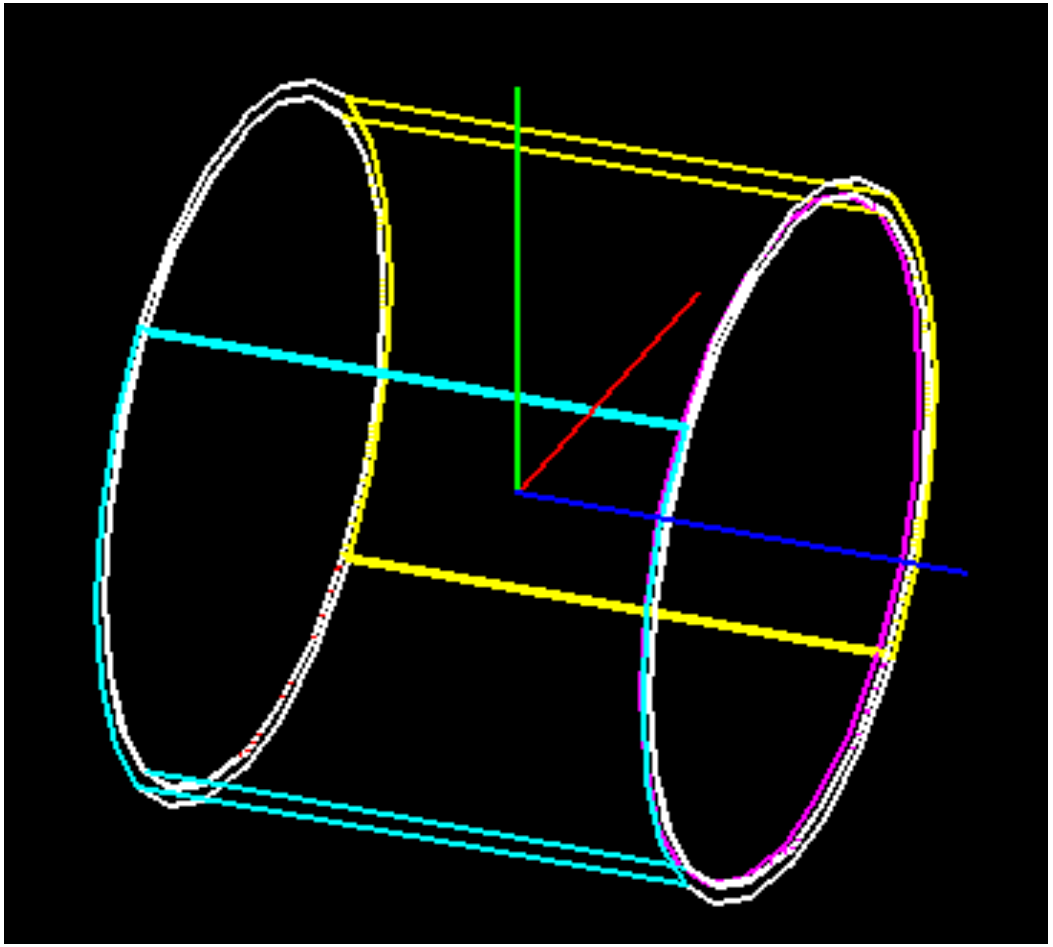
H.Araujo

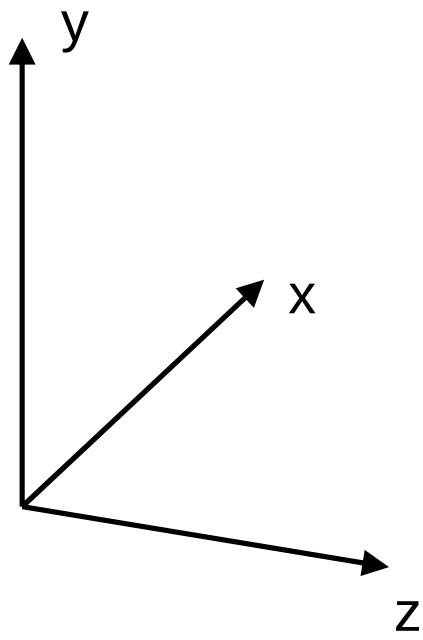
How to set up the TPC Simulation

First: Definition of the detector geometry

How to set up the TPC Simulation

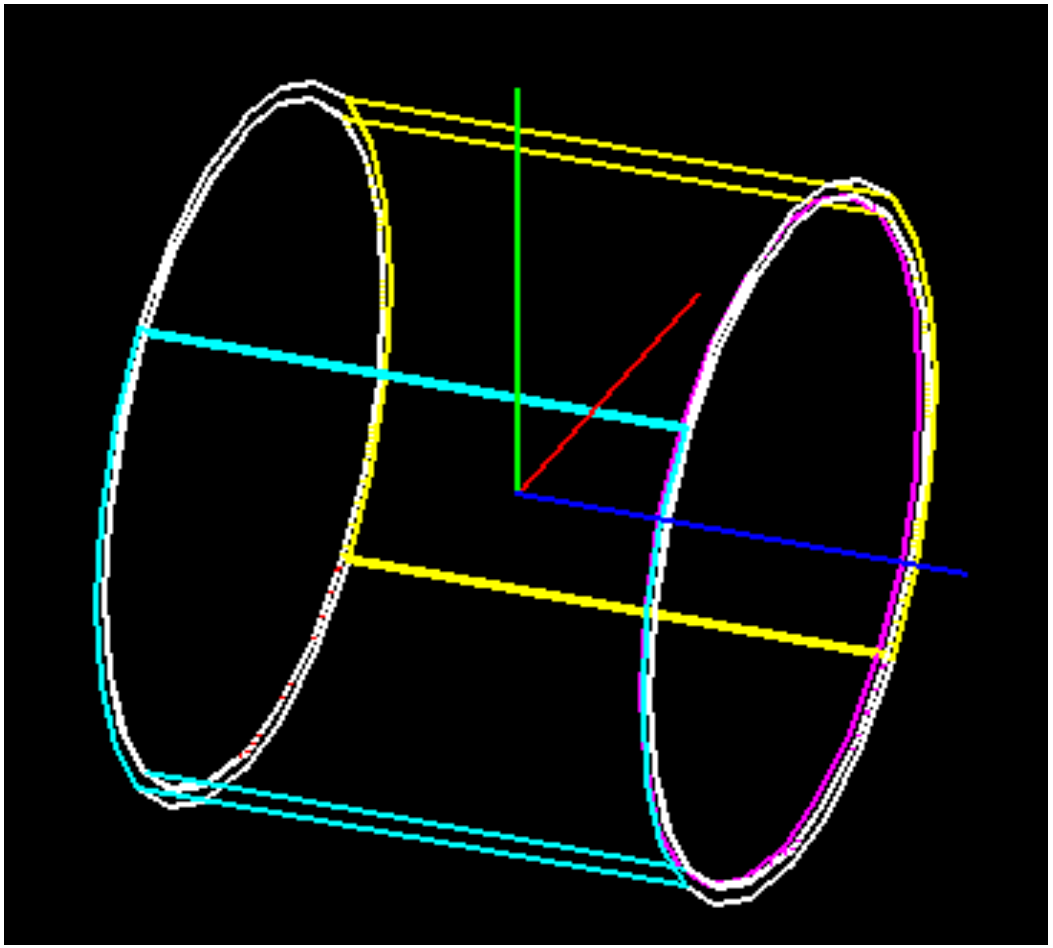
First: Definition of the detector geometry

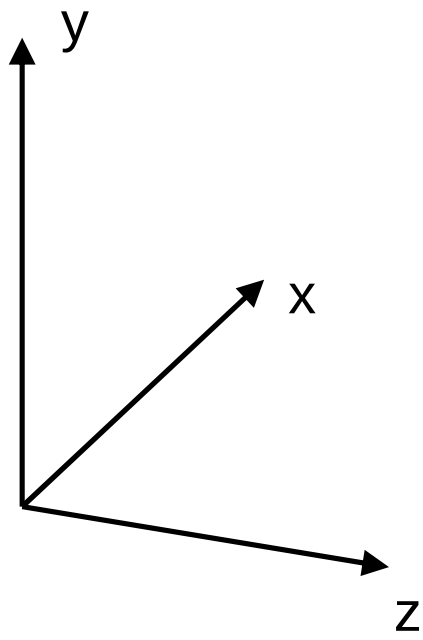




How to set up the TPC Simulation

First: Definition of the detector geometry





Used gas in this simulation: Xenon

How to set up the TPC Simulation

Second: Generate primary event (here: particle gun, 6 GeV electrons)

How to set up the TPC Simulation

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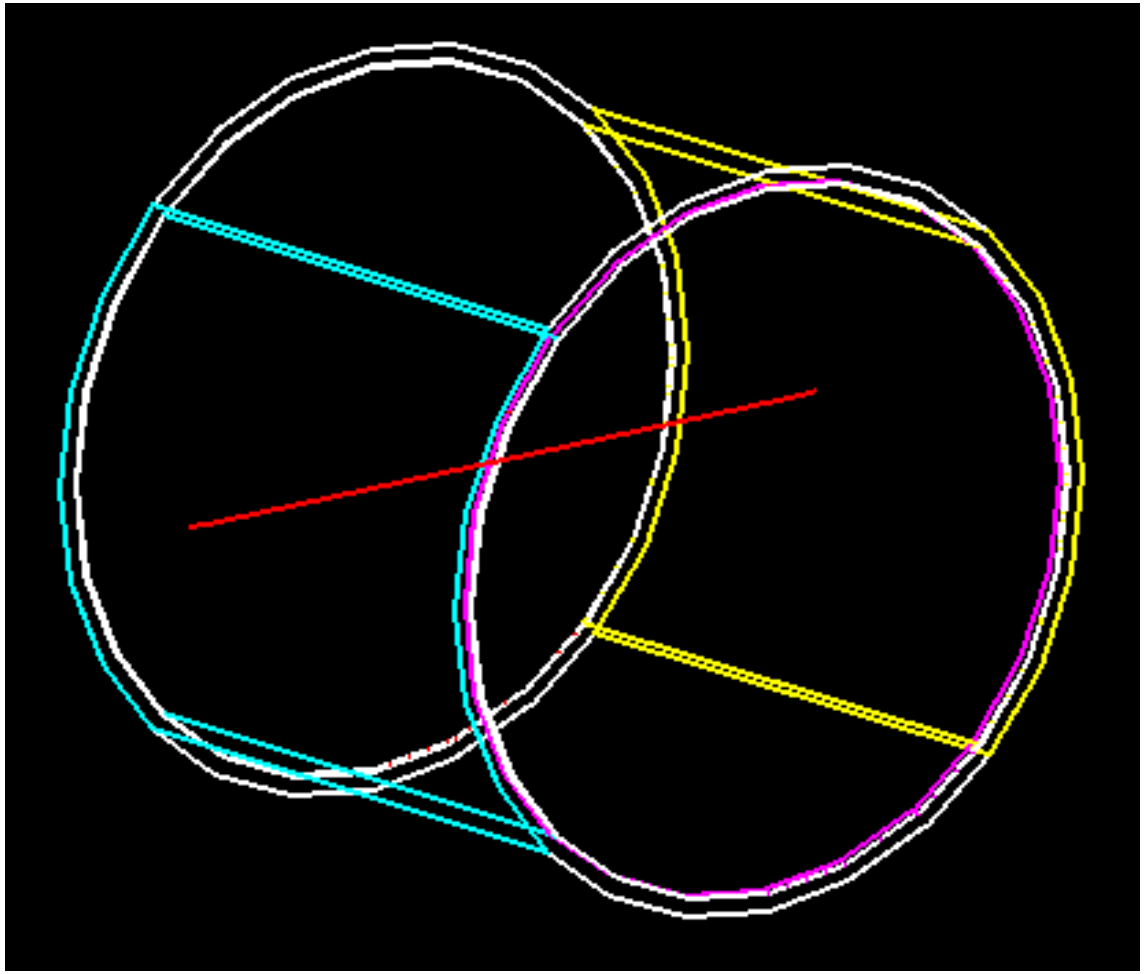

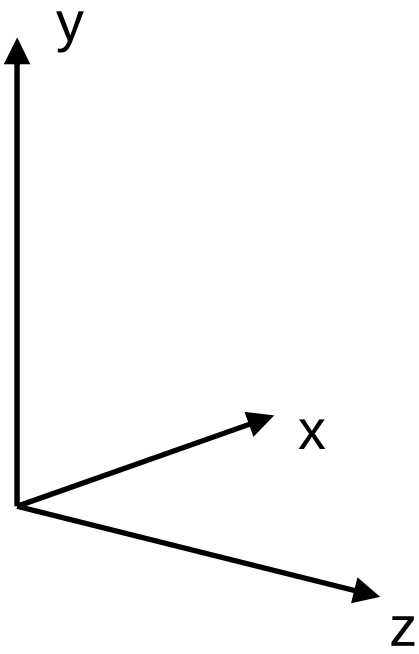

How to set up the TPC Simulation

Third: Implement the wanted physical processes

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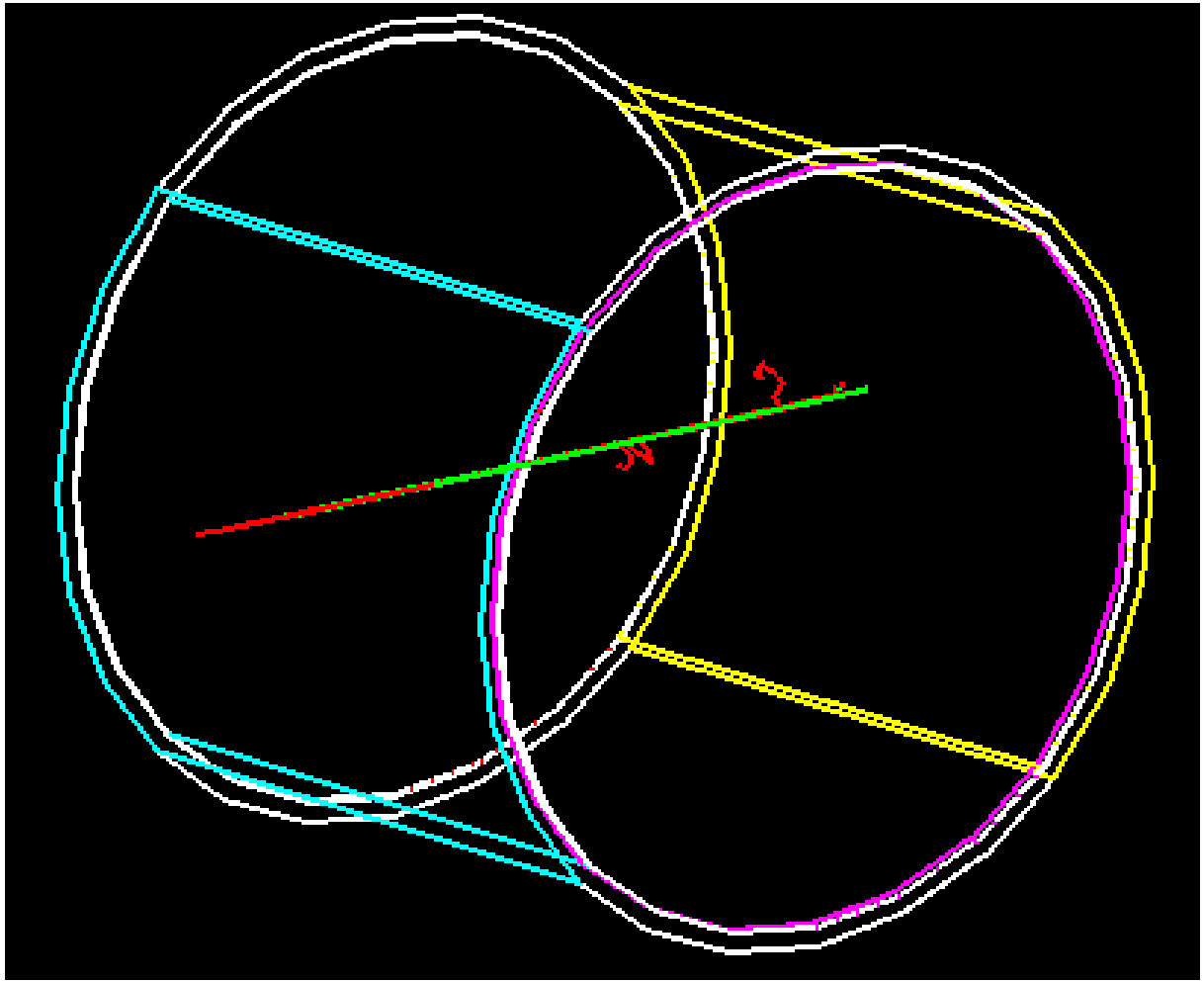

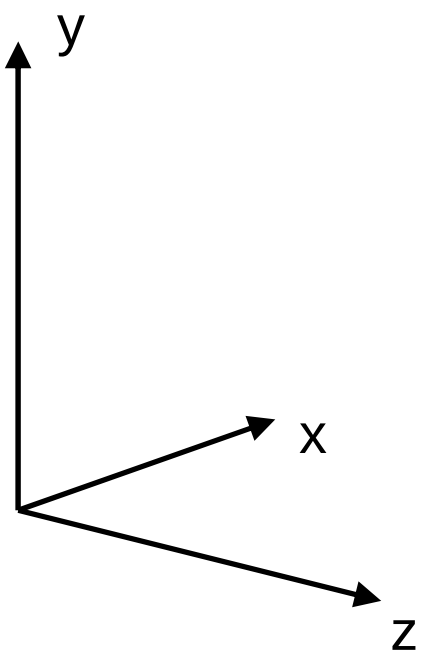

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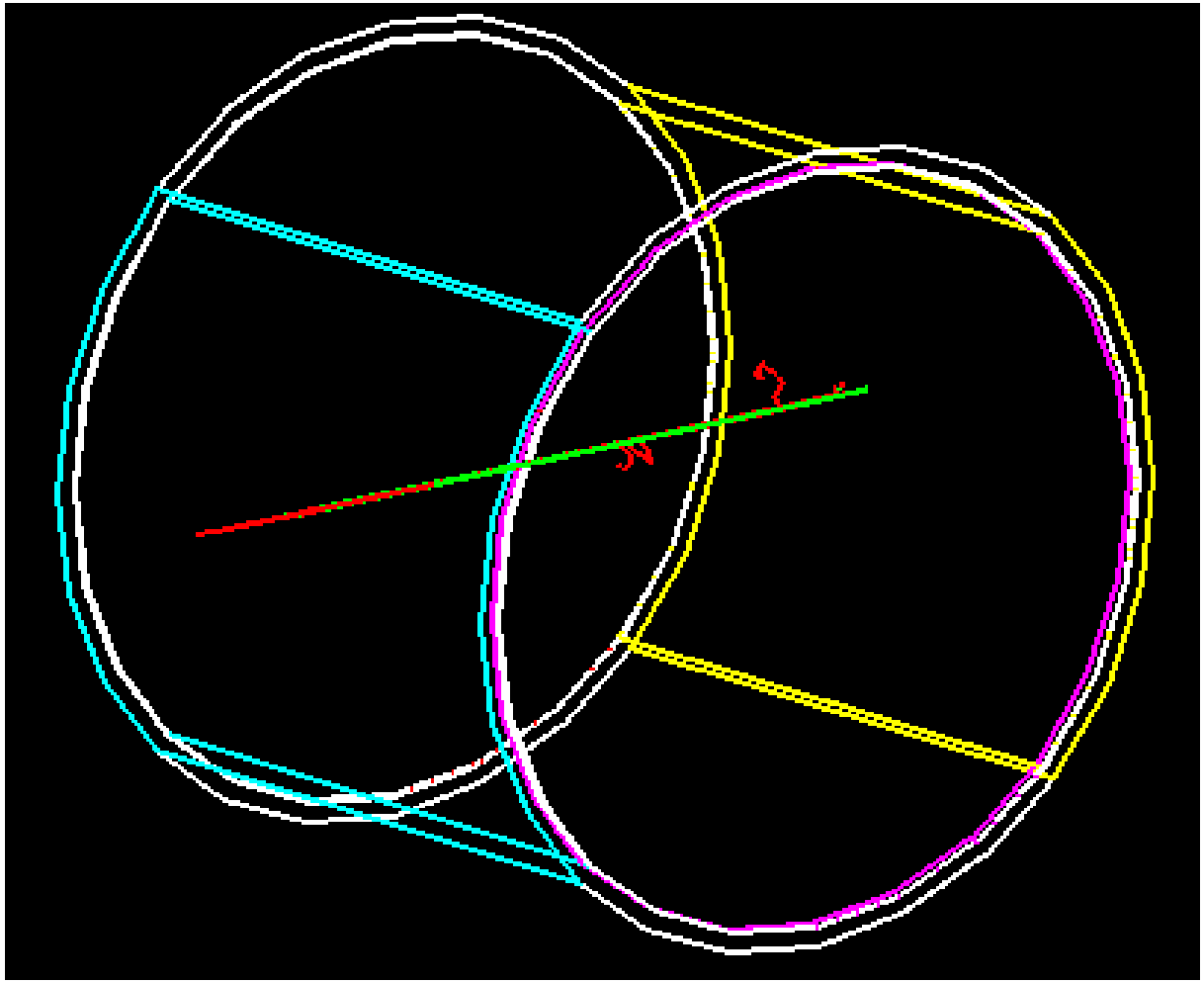
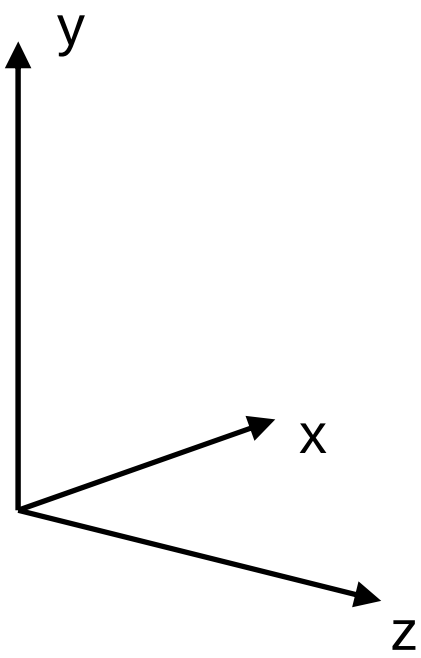
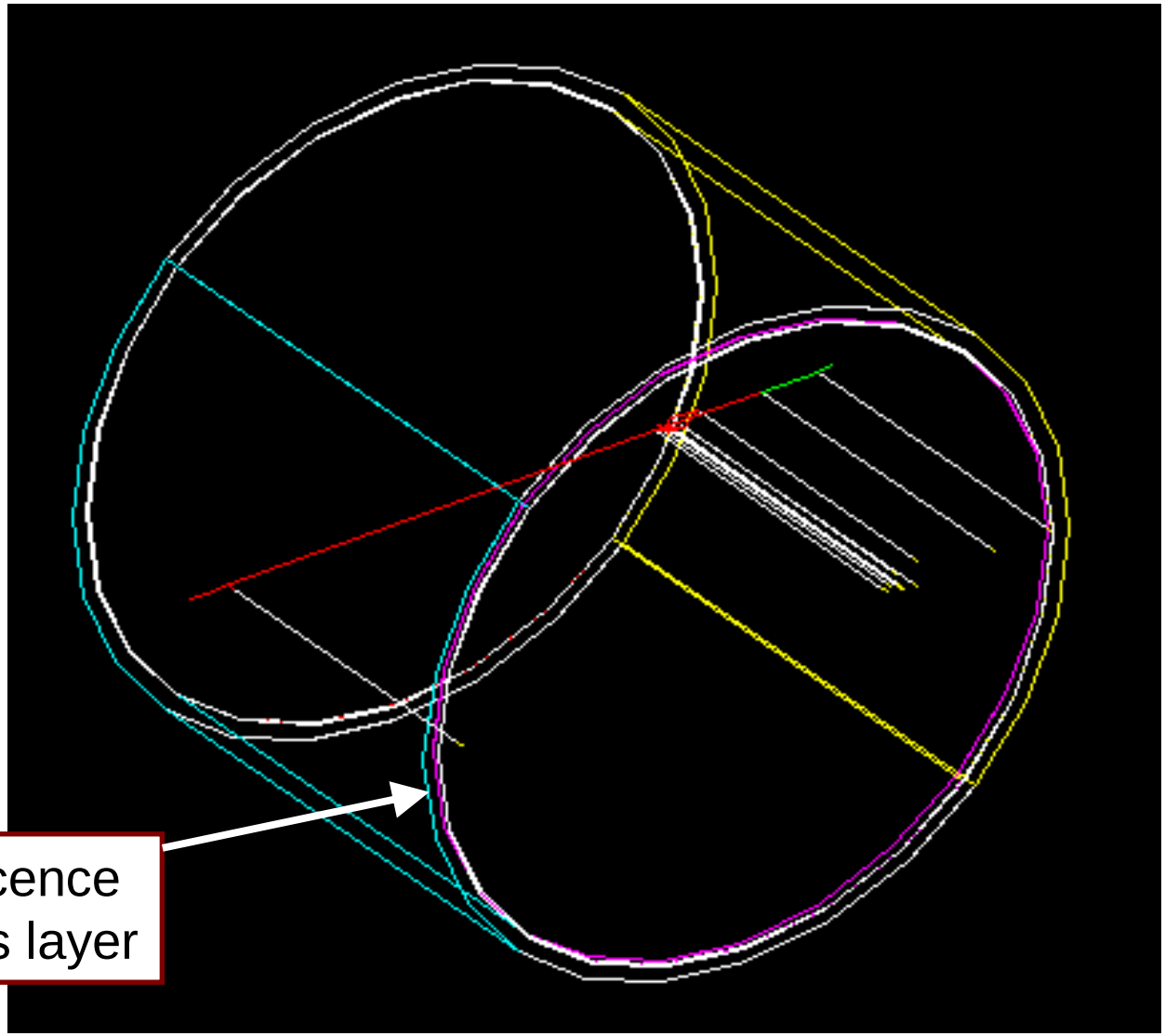


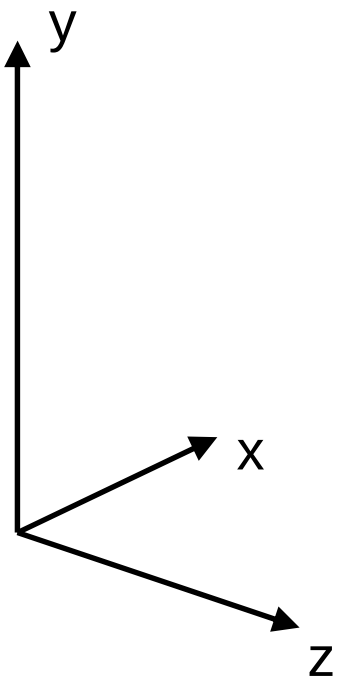


Electroluminescence is missing!

How to set up the TPC Simulation

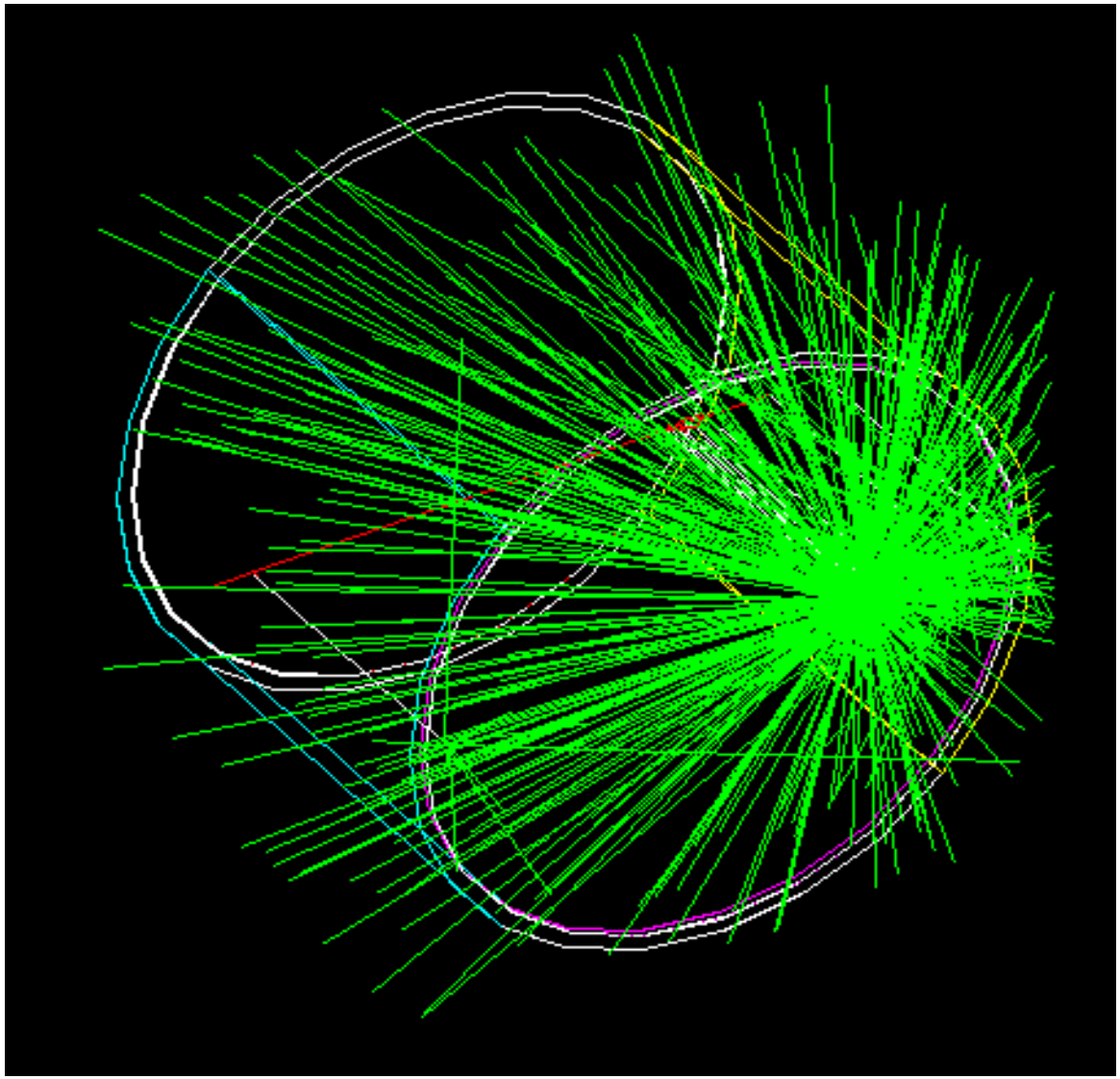


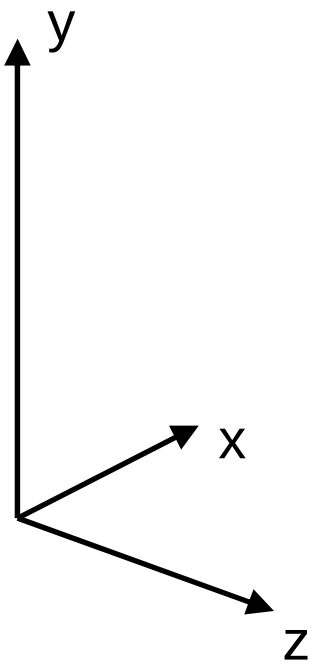
Electroluminescence amplification gas layer



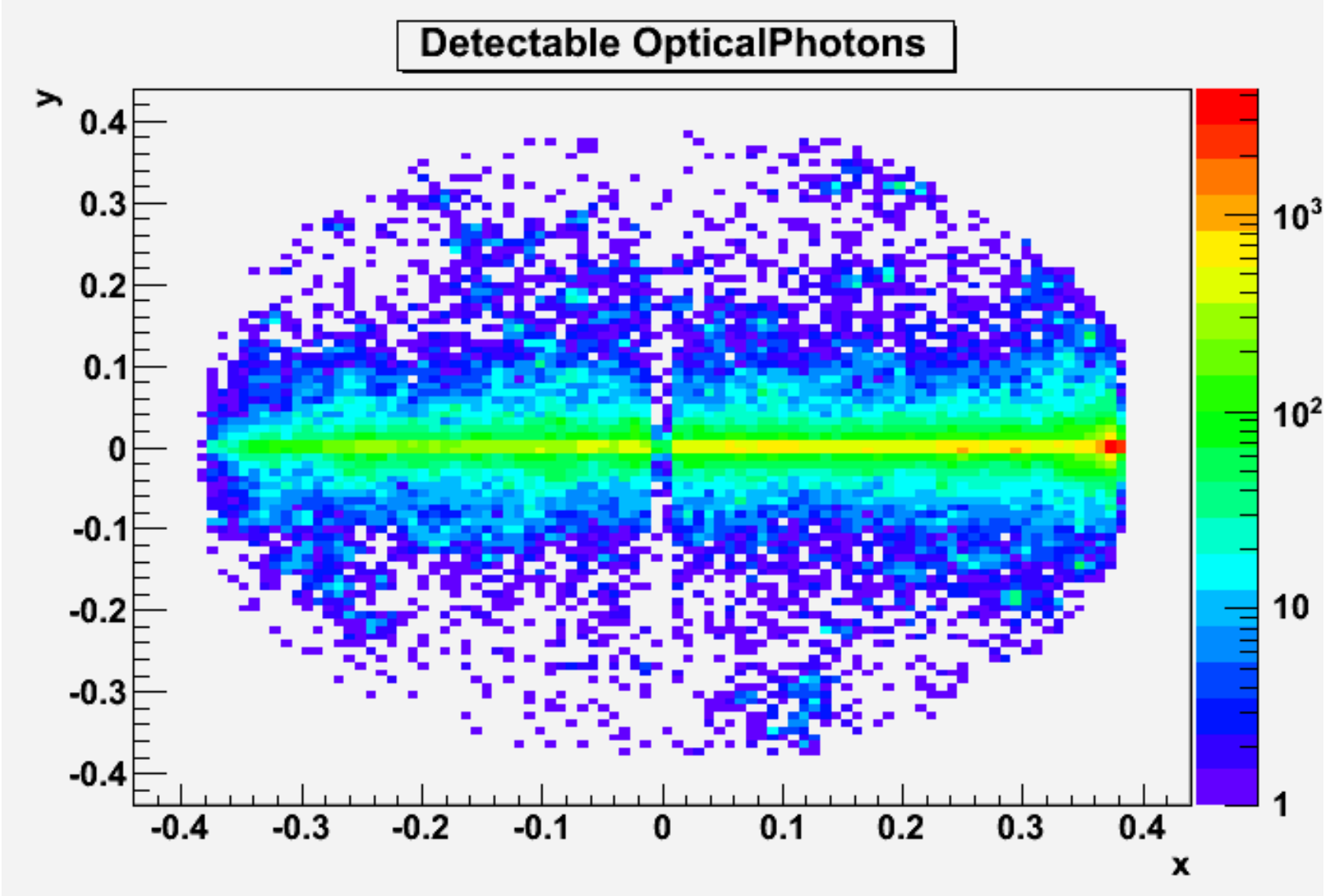
How to set up the TPC Simulation

Here it is!

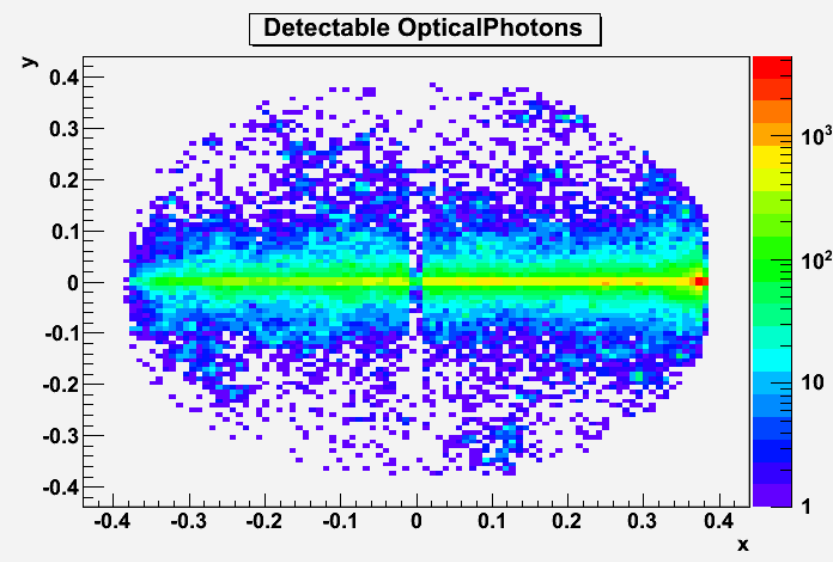




Results


Detectable OpticalPhotons
y
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
x
10^3
10^2
10
1

Results



Some numbers:

- 1000 primary 6 GeV electrons
- 299043 optical photons with ~ 7 eV (≈ 170 nm)
- 126123 of them detectable
- That means: ~ 300 photons per electron and ~ 42% of all produced photons were detected

Summary and Outlook

Summary:

- Secondary Ions can disturbe TPC resolution
- Electroluminescence as possible method to reduce secondary ions
- Investigation of Electroluminescence in a Geant4 TPC simulation
- Please note: Investigation so far not yet according to true physical processes

Outlook:

- Change gas to argon
- Find the correct yields etc. for argon
- Implement a fieldmap
- Find better description for primary ionisation
- Implement reflection of photons inside the TPC
- Add detector unit and readout system to the TPC detector geometry

The End

Thank you for your attention!

Ion discs in TPC

Some estimates:

$\mu \approx 2\text{cm}^2/(\text{V}\cdot\text{s})$ in Ar (Kr: 1, Ne: 4, He: 5-10)

slice $s = \mu \cdot E \cdot \delta t = 4\text{mm}$ for $\delta t = 1\text{ms}$
distance between 2 slices separated by ? $t = 200\text{ms}$:
$d = \mu \cdot E \cdot \Delta t = 80\text{cm}$

so with Ar and a few % X:
n~3 slices of ions together in the TPC with $L_{TPC} \approx 240\text{cm}$

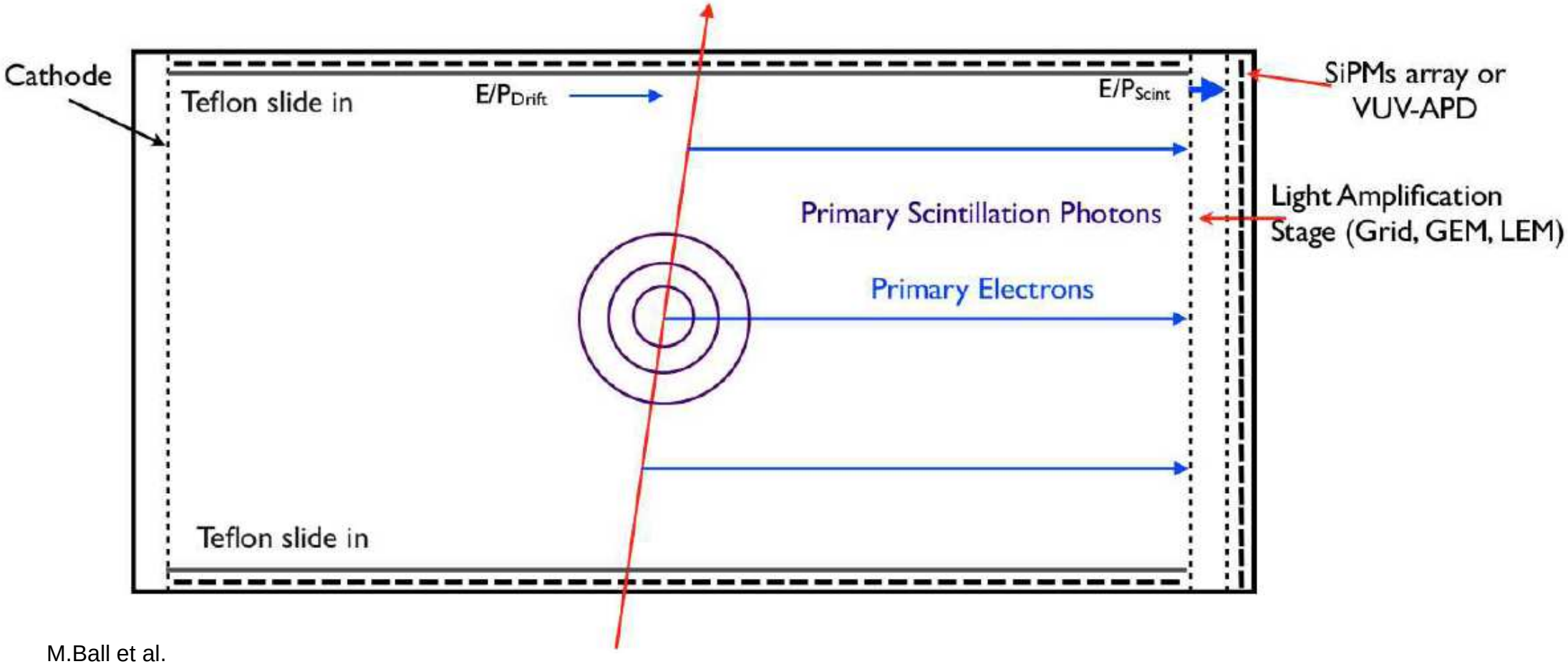
if we have $L_{TPC} \approx d \rightarrow$ n=0 slice

Secondary Ions in TPC: Solutions

- Decrease L_{TPC} to 80 cm
- Increase μ by a factor 3
  - Other gas species: less ionization
  - wt smaller, i.e. larger diffusion
  - increased HV
- Increase E or μ E by a factor of 3
  - As above
- Gating device
  - GEM: small primary electron transparency
  - wires: E x B effect, support structure needed

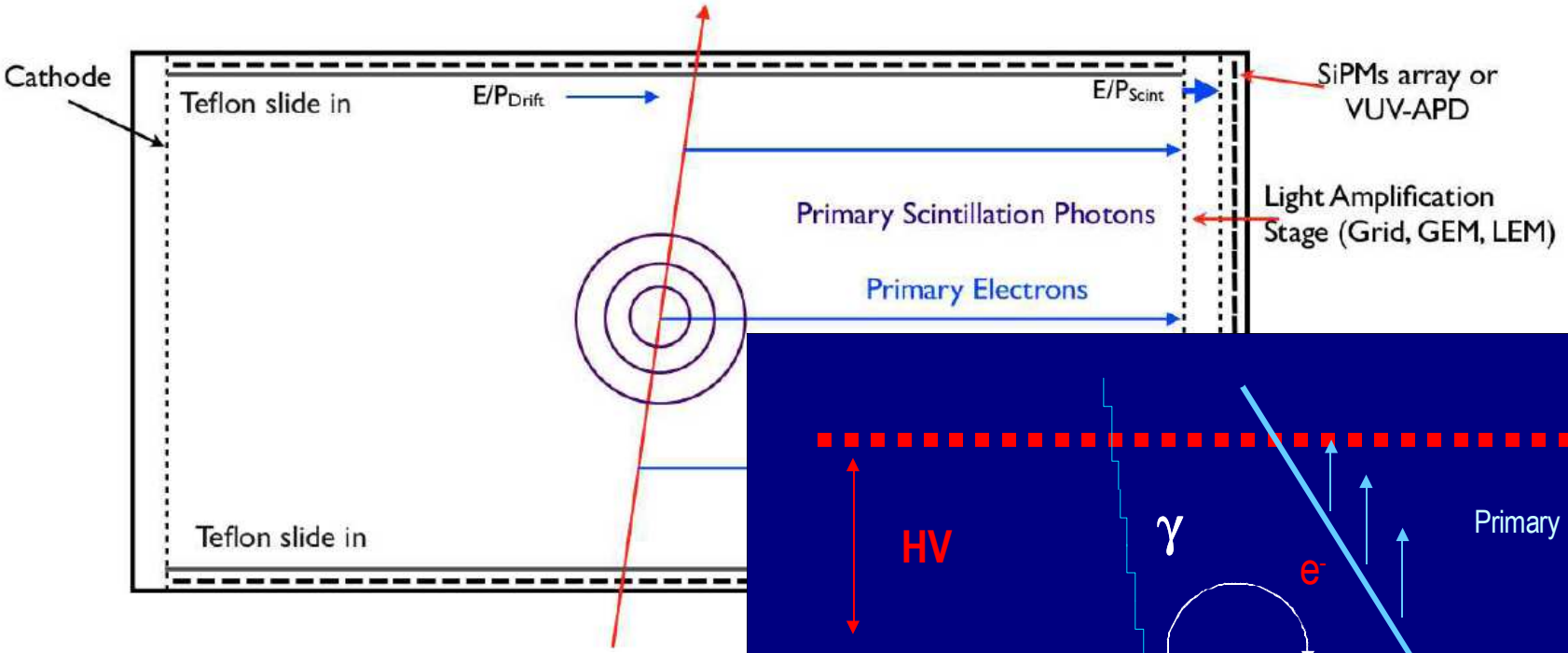
⇒ Alternative: Electroluminescence

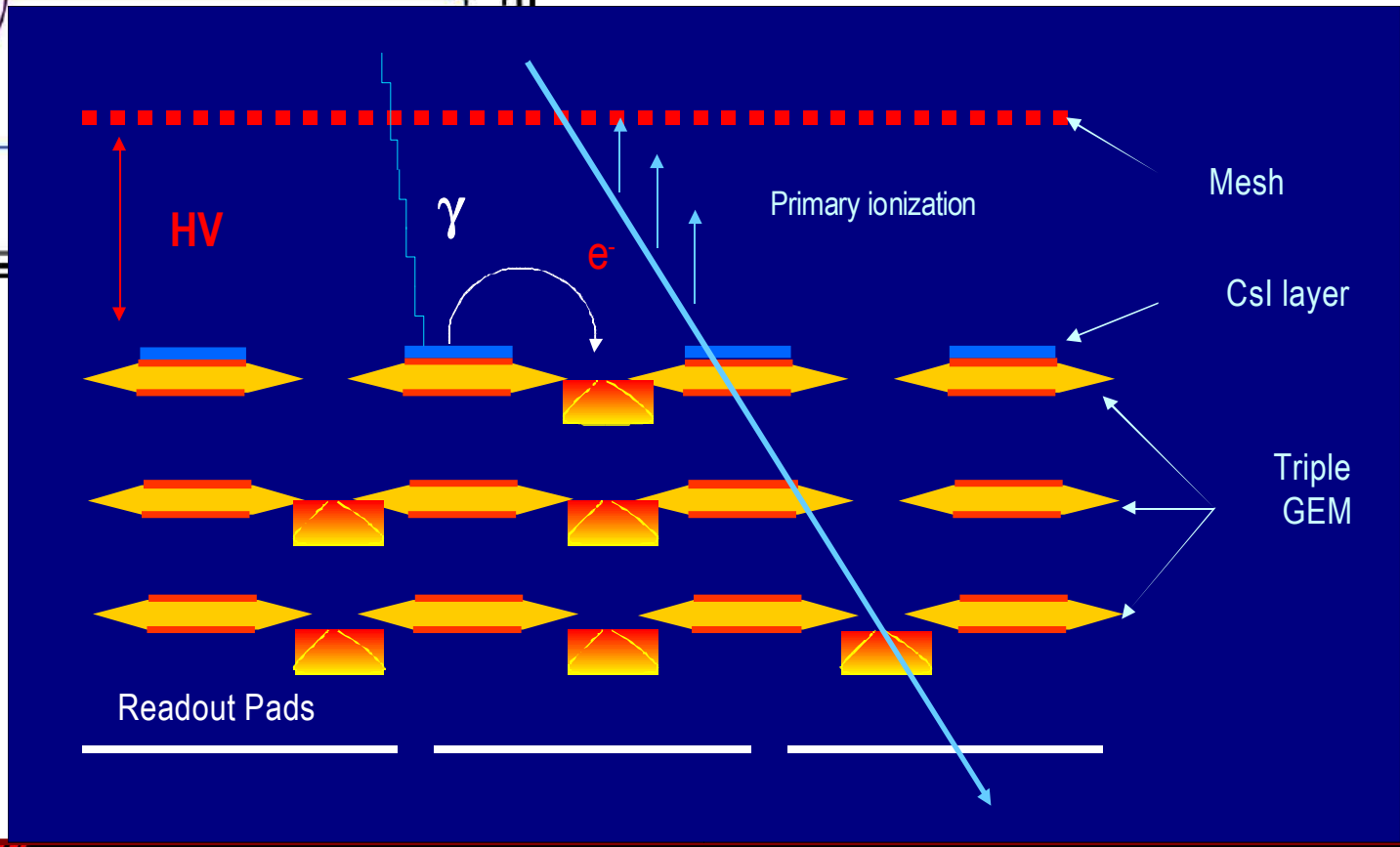
Detectionscheme for Electroluminescence



M.Ball et al.

Detectionscheme for Electroluminescence





C.Woody