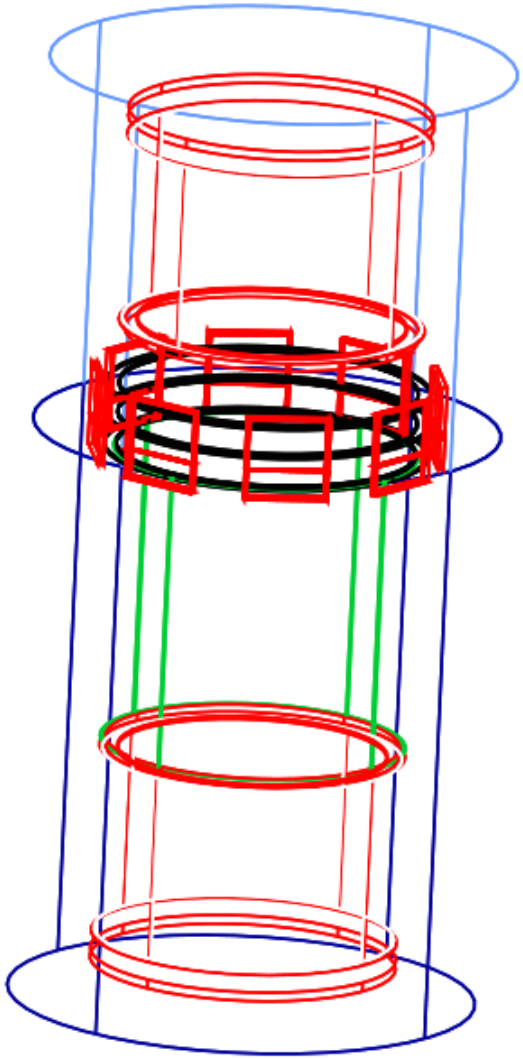
Mainz LXe TPC

Design of a two-phase Xenon TPC for study of fast scintillation in LXe dark matter detectors



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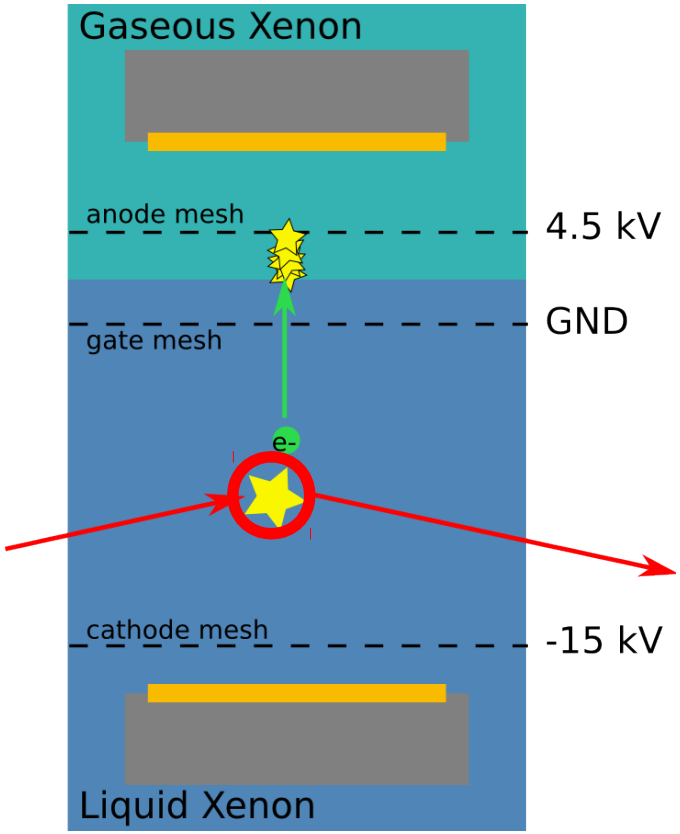
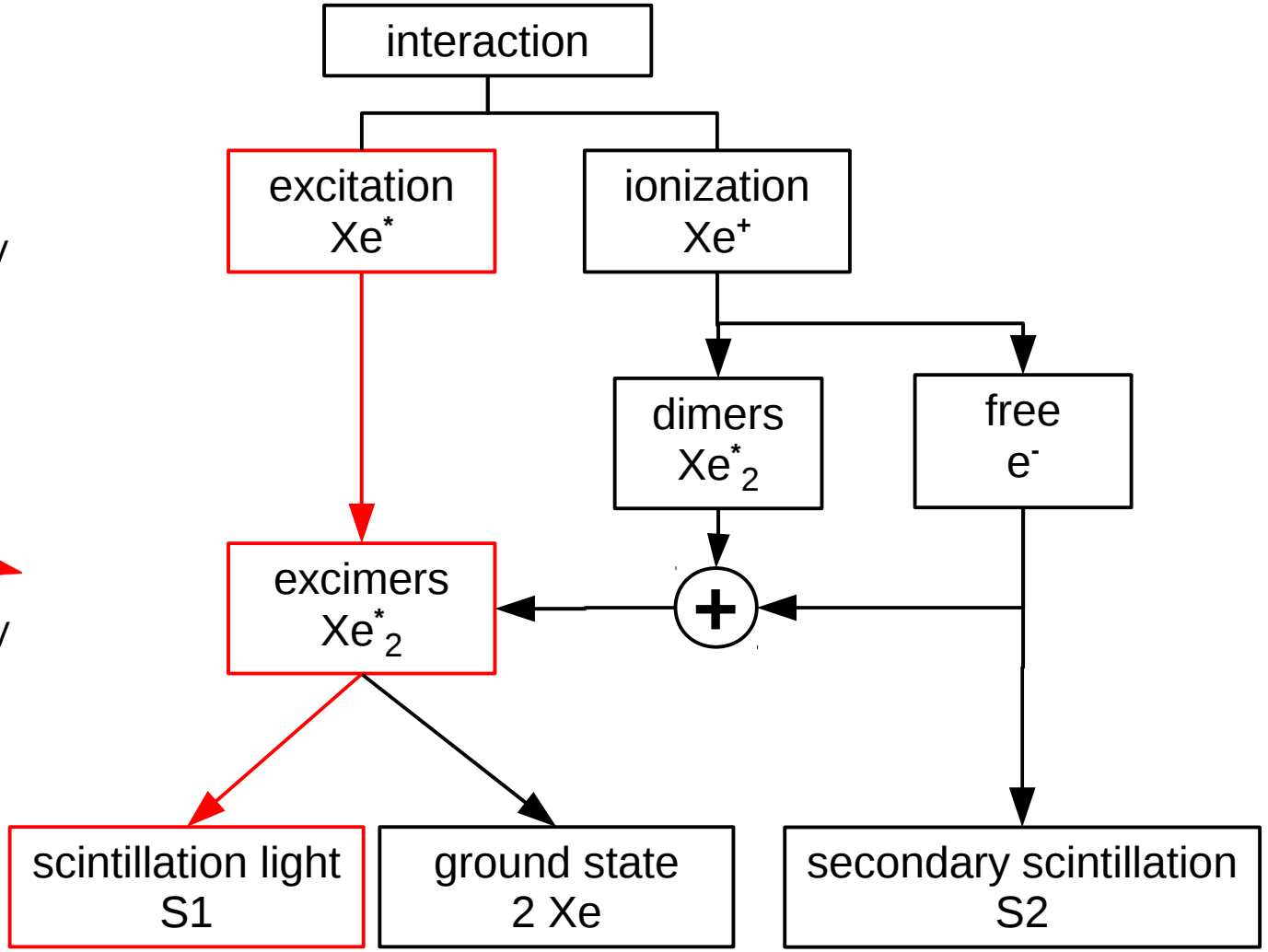
DPG Frühjahrsagung Göttingen 2012

Outline

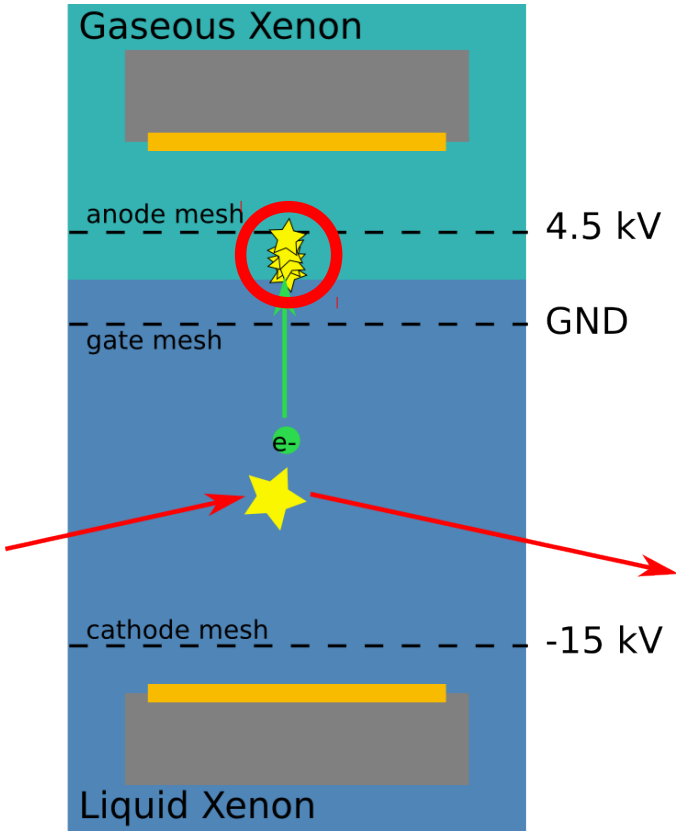
- background discrimintion in XENON-DM-Experiments
- Mainz LXe TPC
- experiment measurement program
- simulations

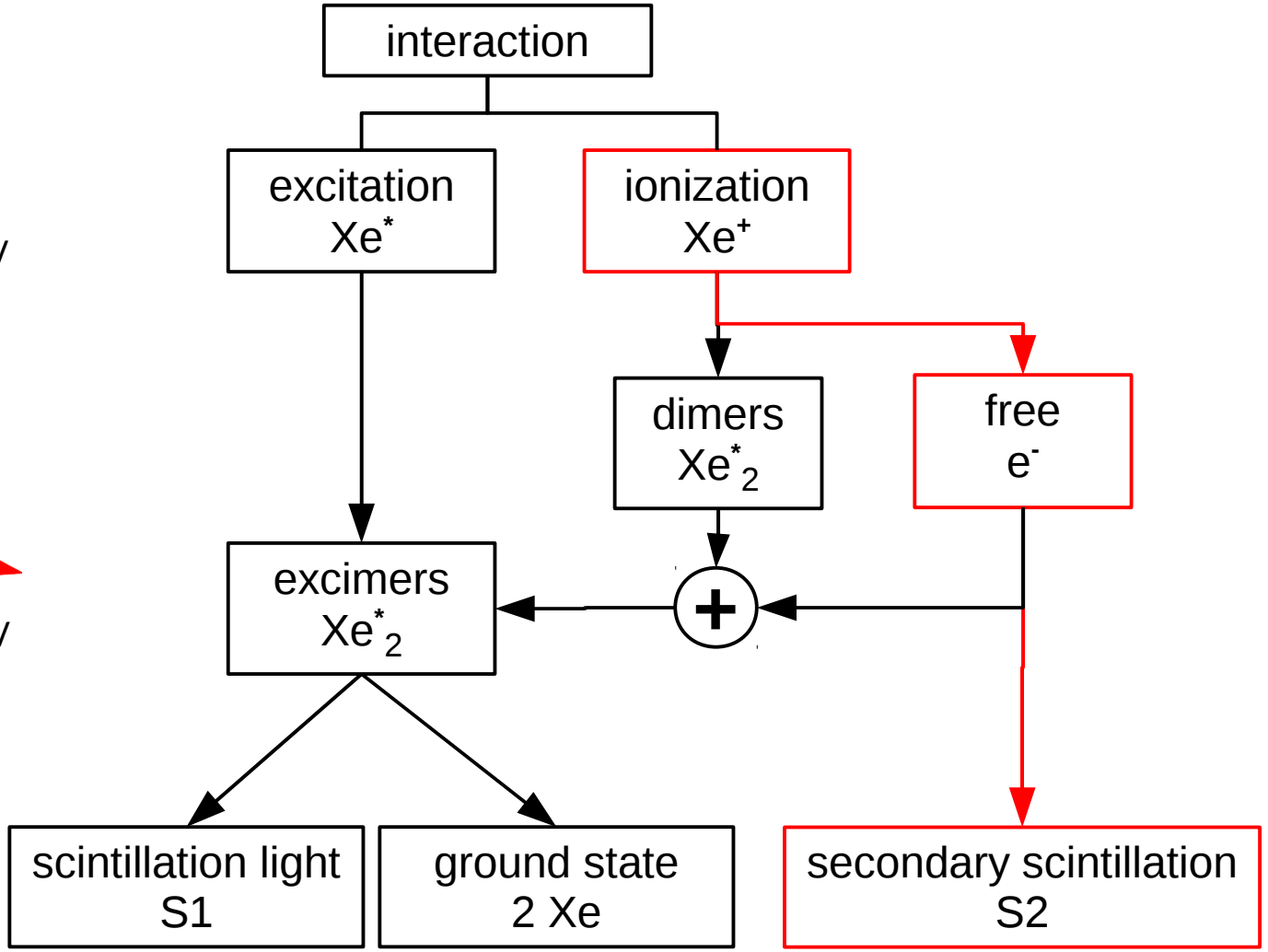
LXe interaction





LXe interaction

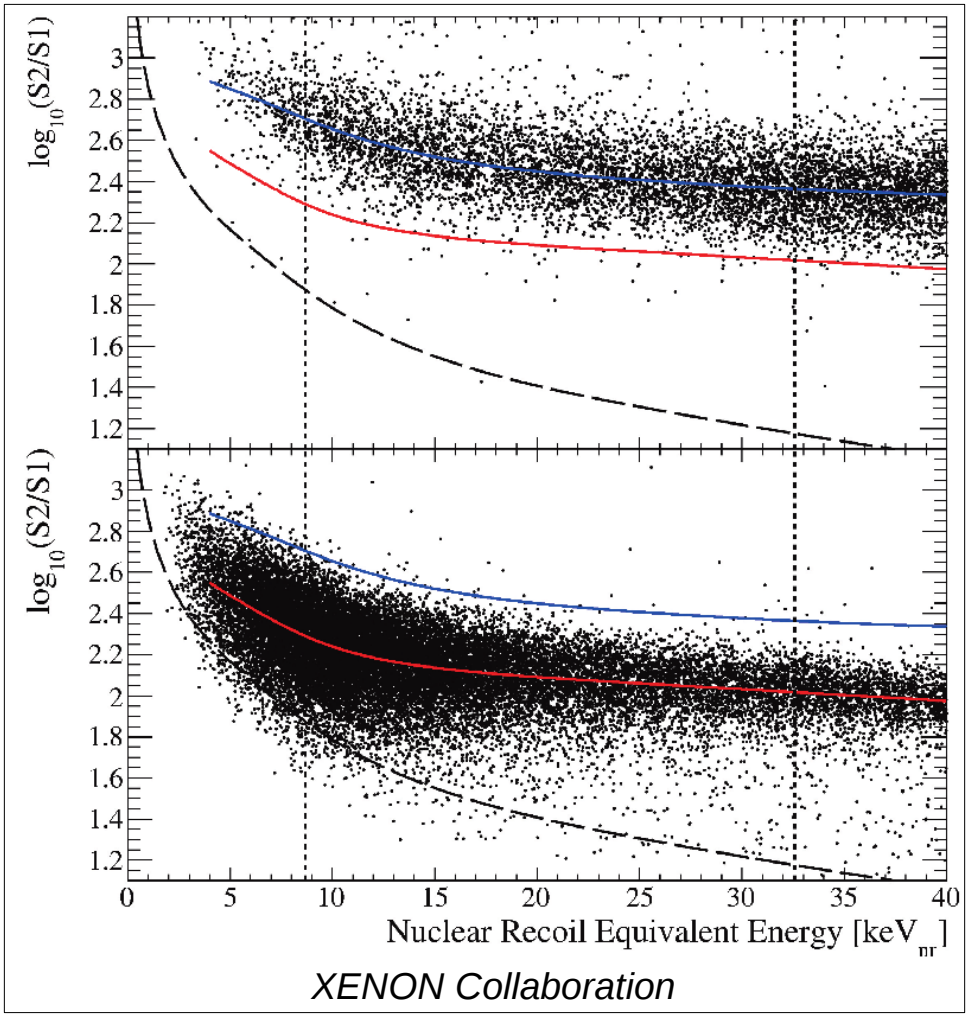




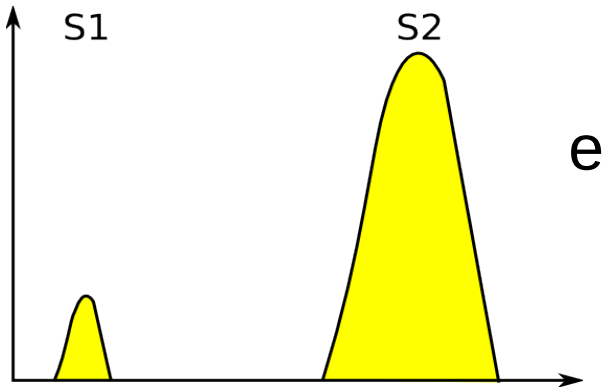
XENON Dark Matter

background discrimination

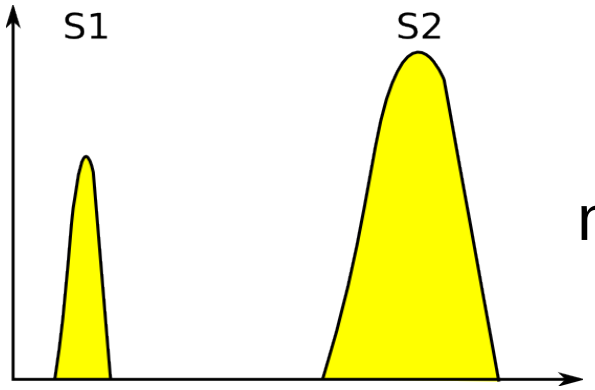
S2/S1 can be used to identify interaction type:
electron recoil vs. nuclear recoil



XENON Collaboration



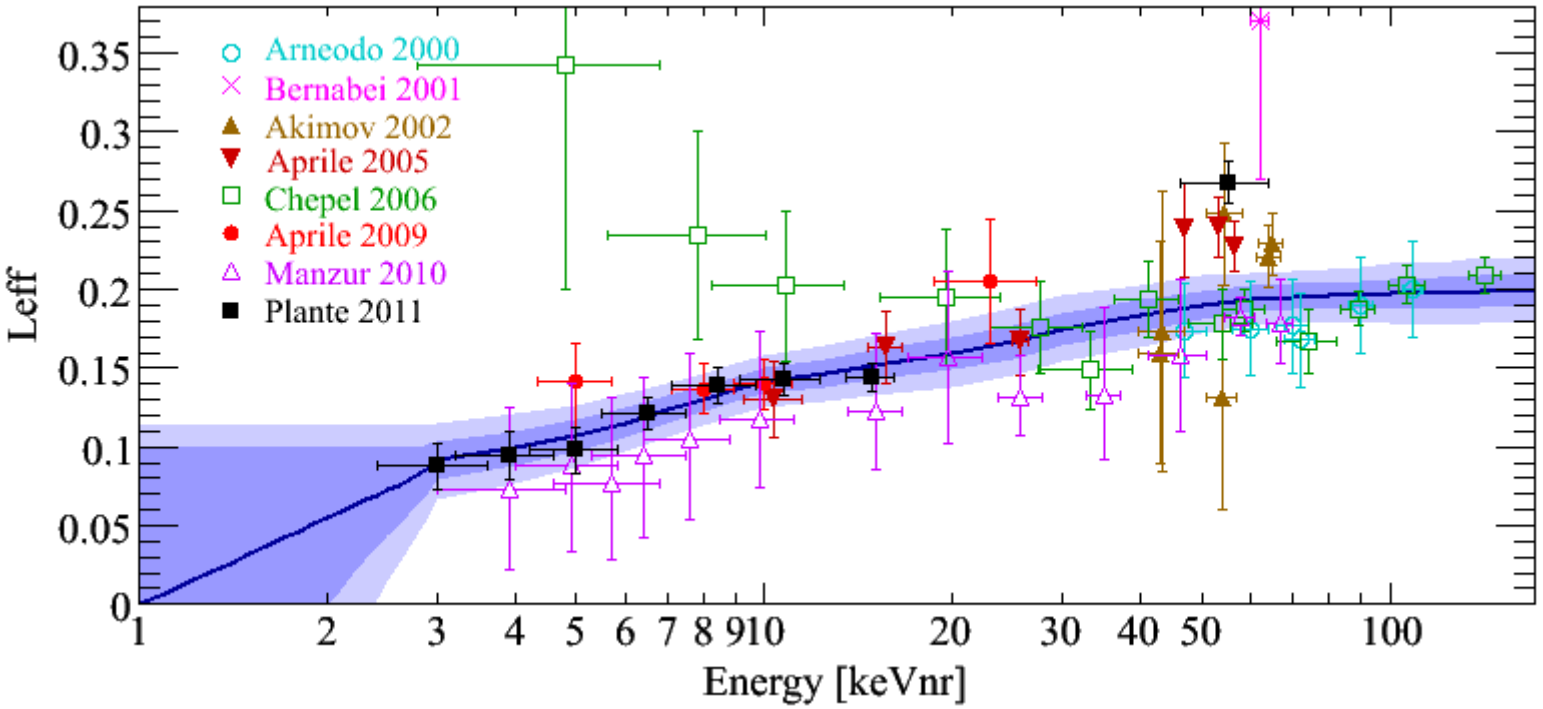
electronic recoil
e^-,γ



nuclear recoil
neutron, **WIMP**

scintillation efficiency

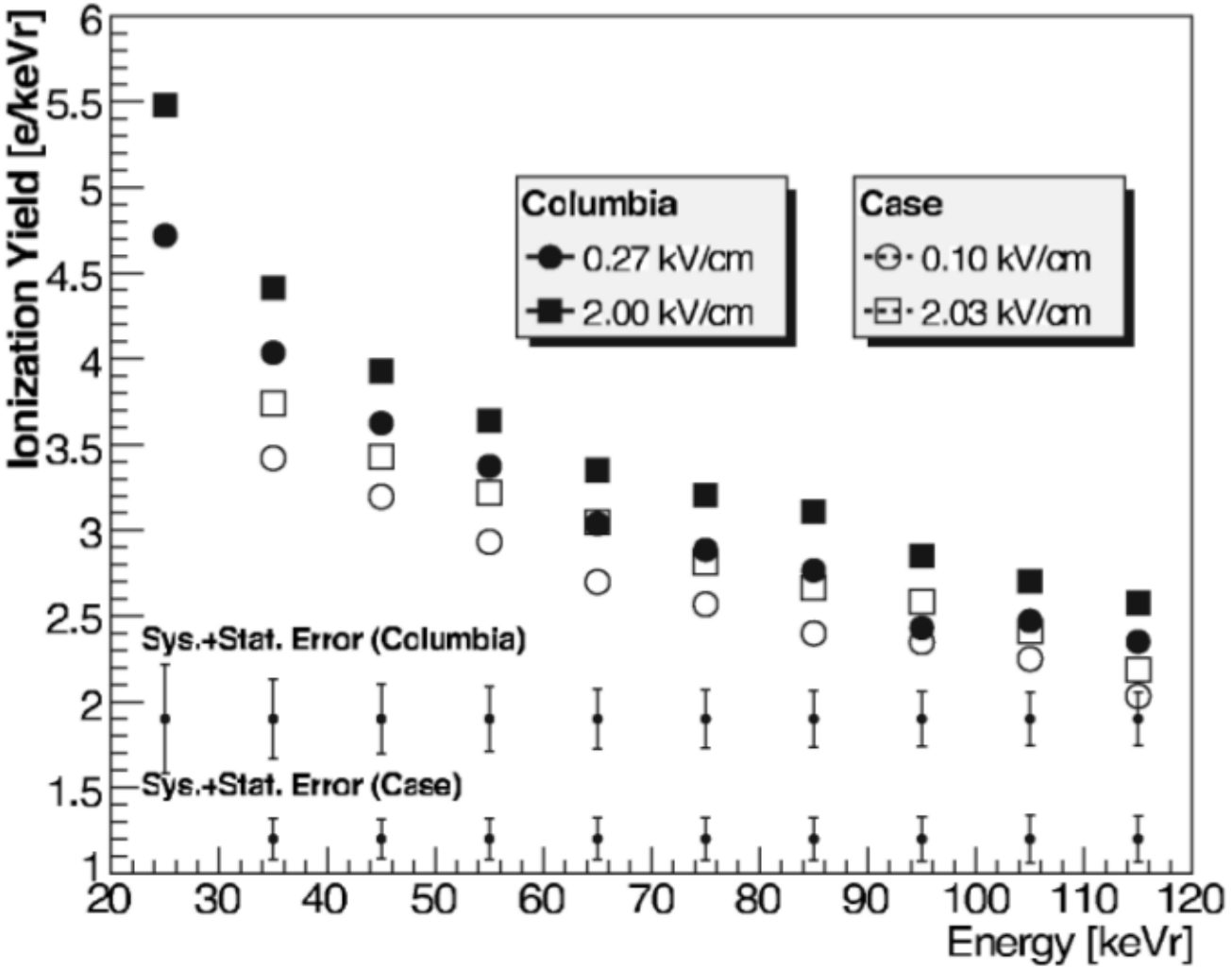
it is necessary to know scintillation efficiency and ionization yield for nuclear recoils of LXe
=> have to be measured in independent experiments



L_{eff} is proportional to the energy going into scintillation light

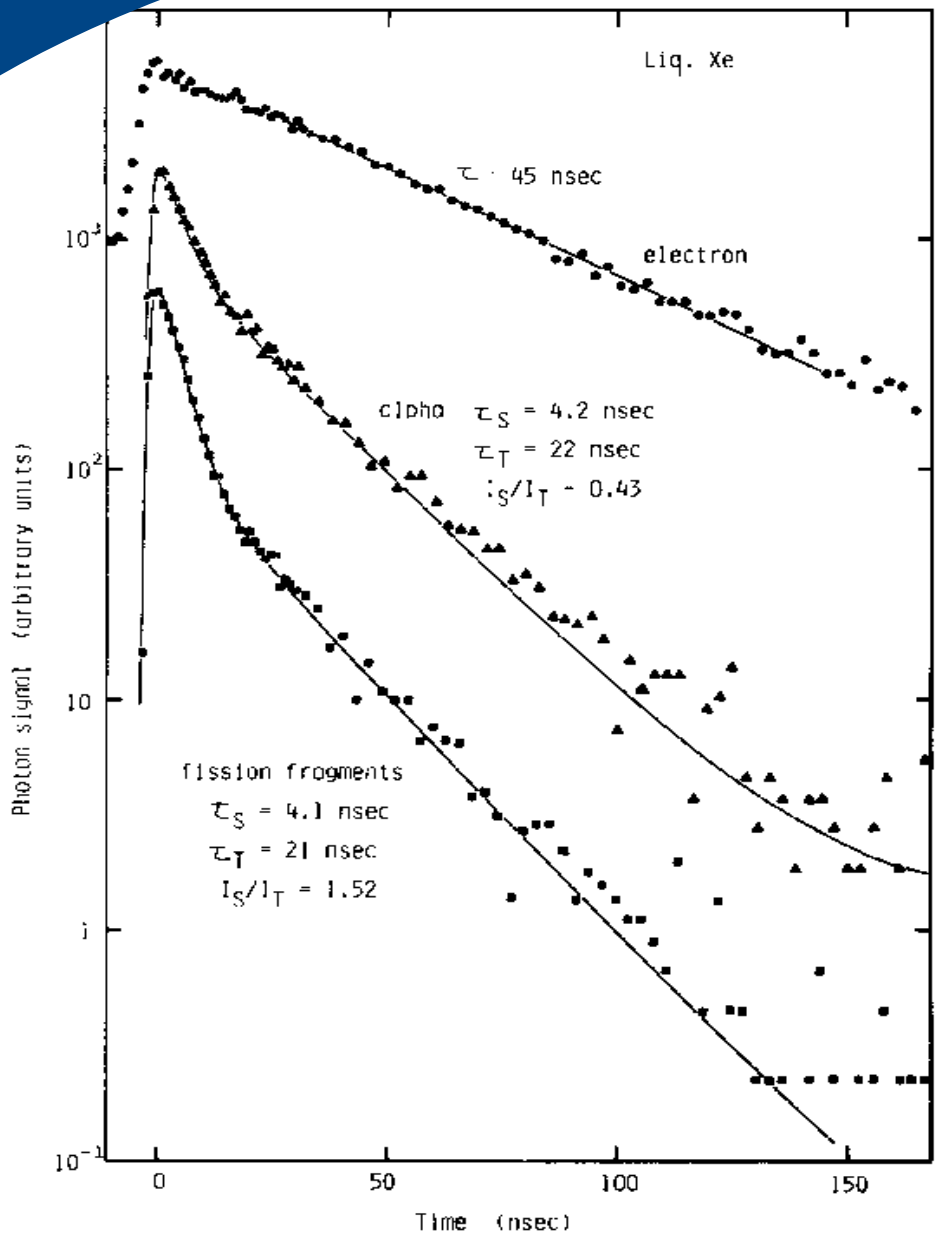
Phys. Rev. Lett. 107, 131302 (2011): E. Aprile et al. (The XENON100 Collaboration)

ionization efficiency



PRL 97, 081302 (2006); Aprile et al.

LXe scintillation pulse shape



Can PS be used to improve background discrimination in future LXe DM searches?

two excimer states

triplet $^3\Sigma^+$: $\tau_T \sim 20 - 27$ ns

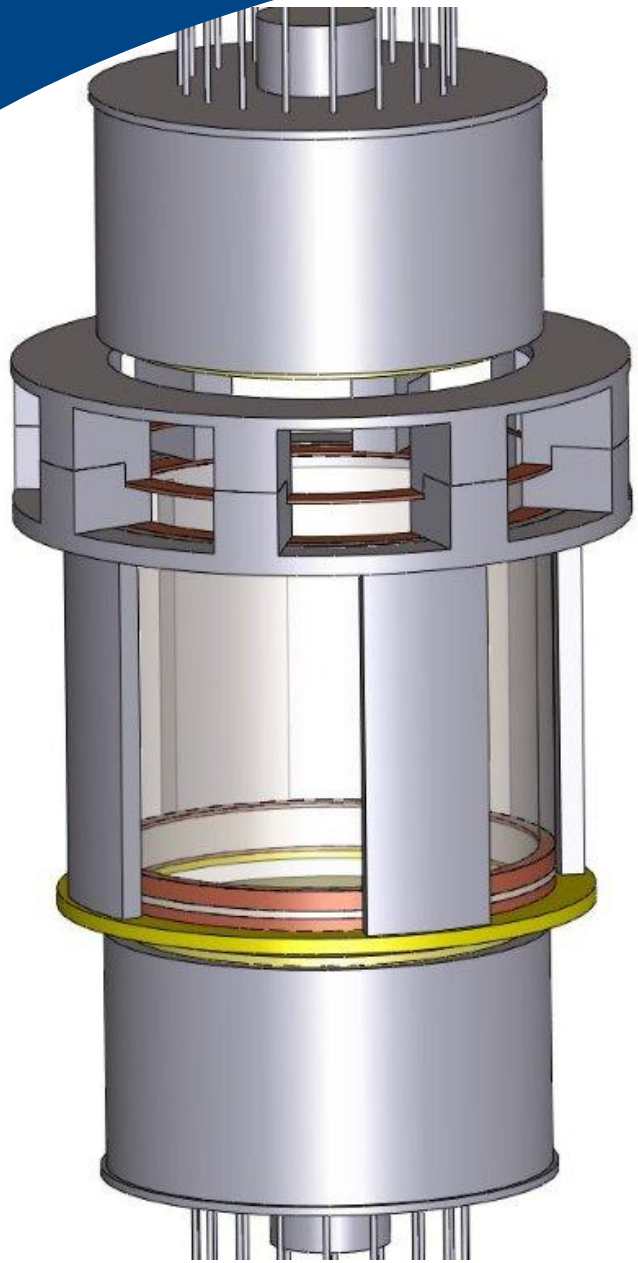
singlet $^1\Sigma^+$: $\tau_S \sim 2 - 4$ ns

singlet-to-triplet ratio A_s/A_t is dependent on:

- nuclear/electronic recoil
- electrical drift field

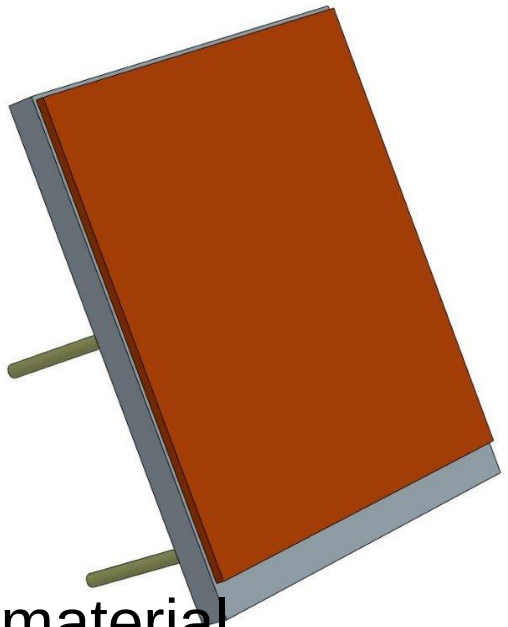
Physical Review B - Vol.27 - No. 9, May 1983
A. Hitachi, T. Takahashi

experimental setup



Active volume:

- diameter d=53mm
- heigth h=50mm
- 1 top-, 1 bottom-PMT
- 8 APDs for x/y resolution



APDs:

- active area: 14x14 mm²
- QE ~ 30% @ 178nm
- no housing - little passive material

experimental setup

compact PMTs (Hamamtsu R6041):

- 2 inch diameter
- QE > 30% @ 178 nm
- fast response: electron transit time spread t(FWHM) = 0.75 ns

5 GS/s FADC (Struck SIS3305)

- 10bit
- 2/4/8 channels
- 5/2.5/1.25 GS/s
- 1.5 GHz bandwidth

experimental program

Phase 1:

- commissioning
- fast studies of S1 (2.5GS/s) at higher energies (100-1000 keV)
- study and optimization of position reconstruction etc.

Phase 2:

- setup of a Compton-scatter experiment at low energies (2-100 keV)
- requirements & systematic errors studied in ongoing diploma thesis

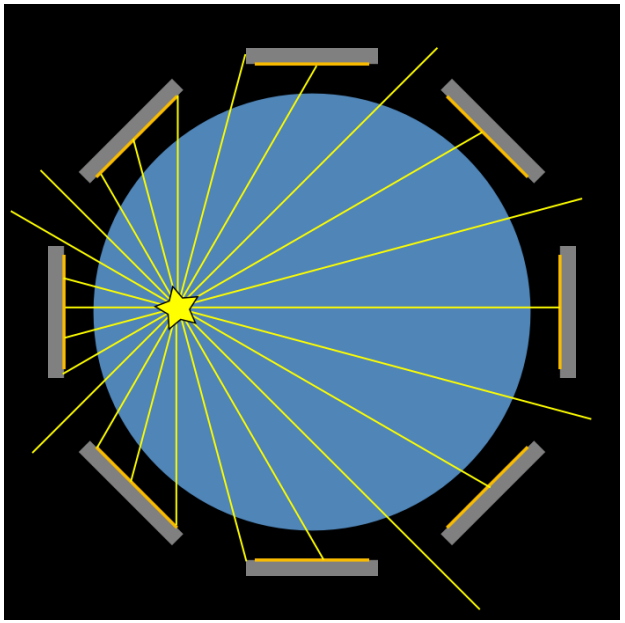
Phase 3:

- neutron-scatter experiment to probe DM energy range for nuclear recoils (2-100 keV)

Mainz LXe TPC: simulation

Geant4: position reconstruction:

- events generated randomly in x/y
- between liquid-gas-interface and anode 10k photons were generated (equivalent to ~2.5 keV electronic recoil energy)
- for each APD the number of detected photons has been saved
- different configurations of APDs have been tested:
  - Size 8x8mm², 14x14mm²
  - quantity n_{APD} = 6, 8, 12

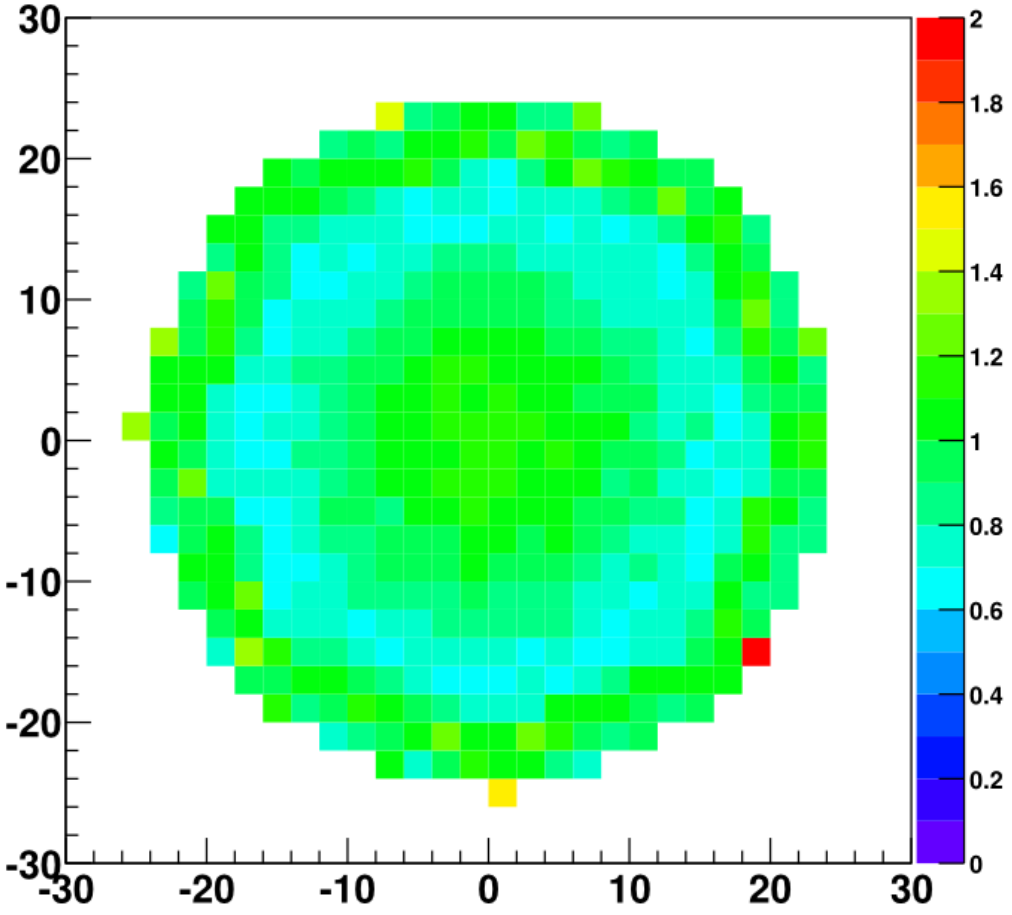


Mainz LXe TPC: simulation

Geant4: position reconstruction:

reconstruction error using 8 APDs - 14x14 mm²

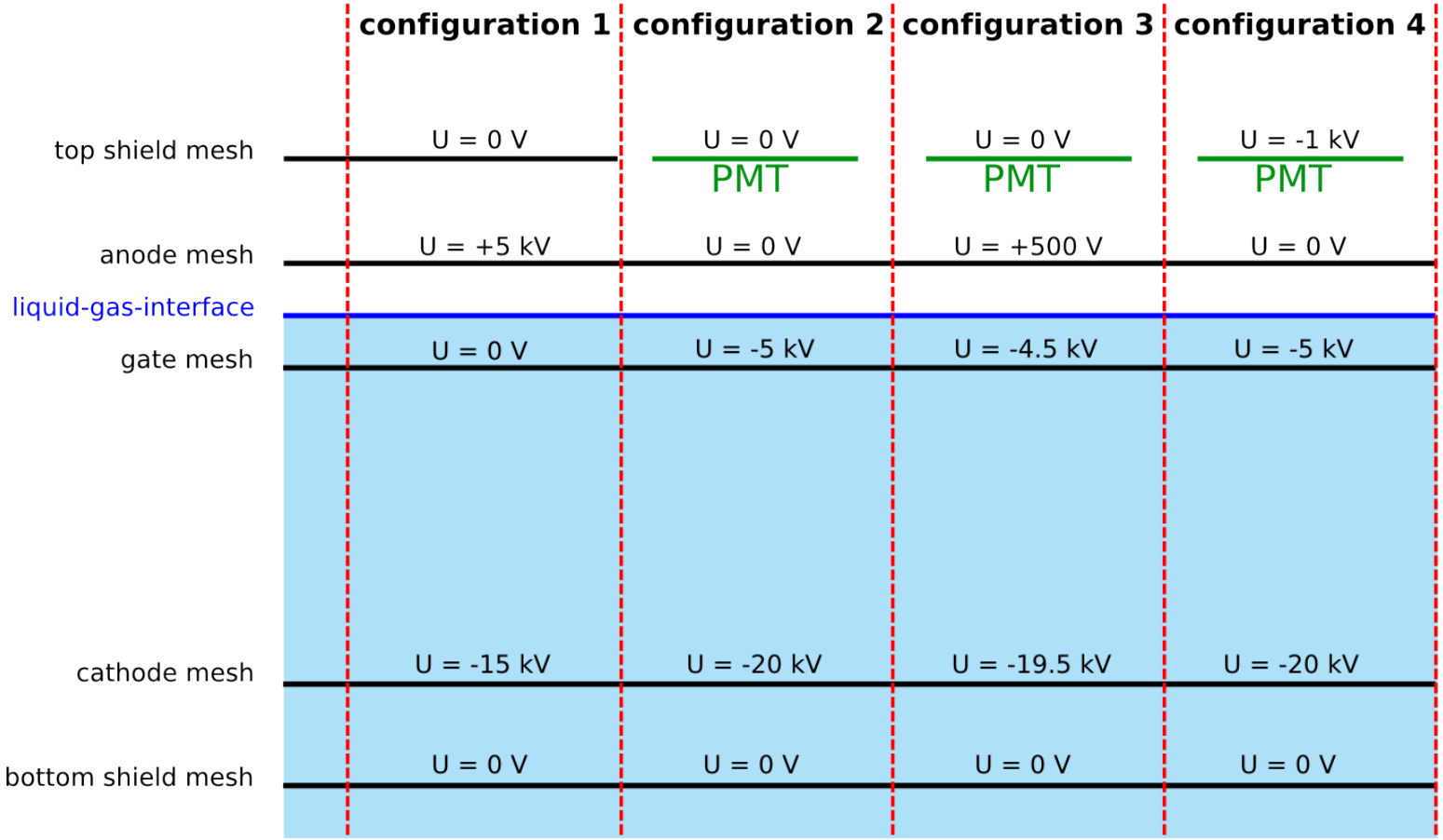
- reconstruction error < 0.5 - 1.3 mm
- only 8 readout channels required
- no strong φ dependency



Mainz LXe TPC: simulation

COMSOL: electrostatic field

simulated different potential distributions with same resulting potential between cathode and anode



meshes:

- pitch ~200µm
- wires ~13µm
- T > 88%

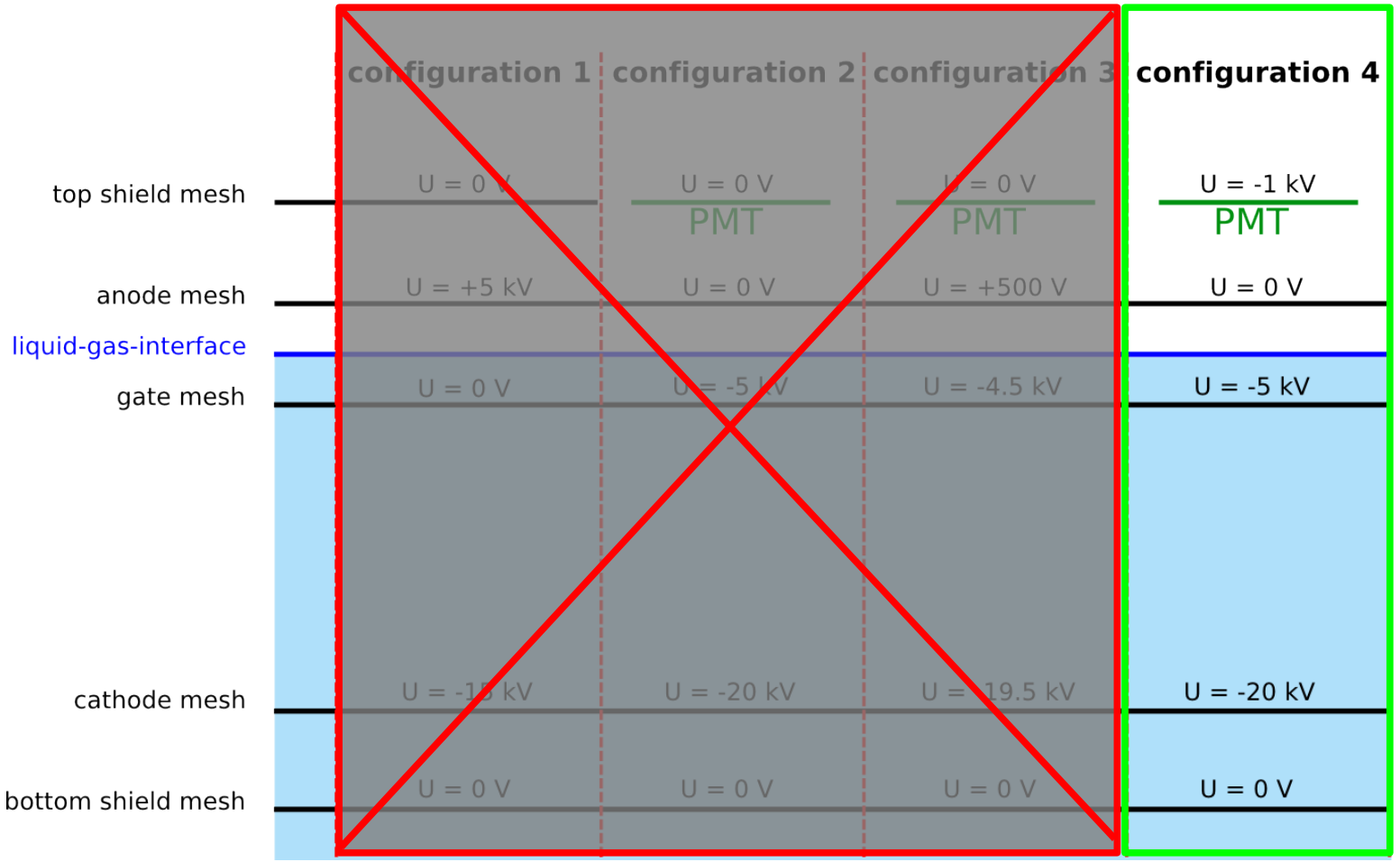
fieldcage:

- 1 wire/mm

Mainz LXe TPC: simulation

COMSOL: electrostatic field

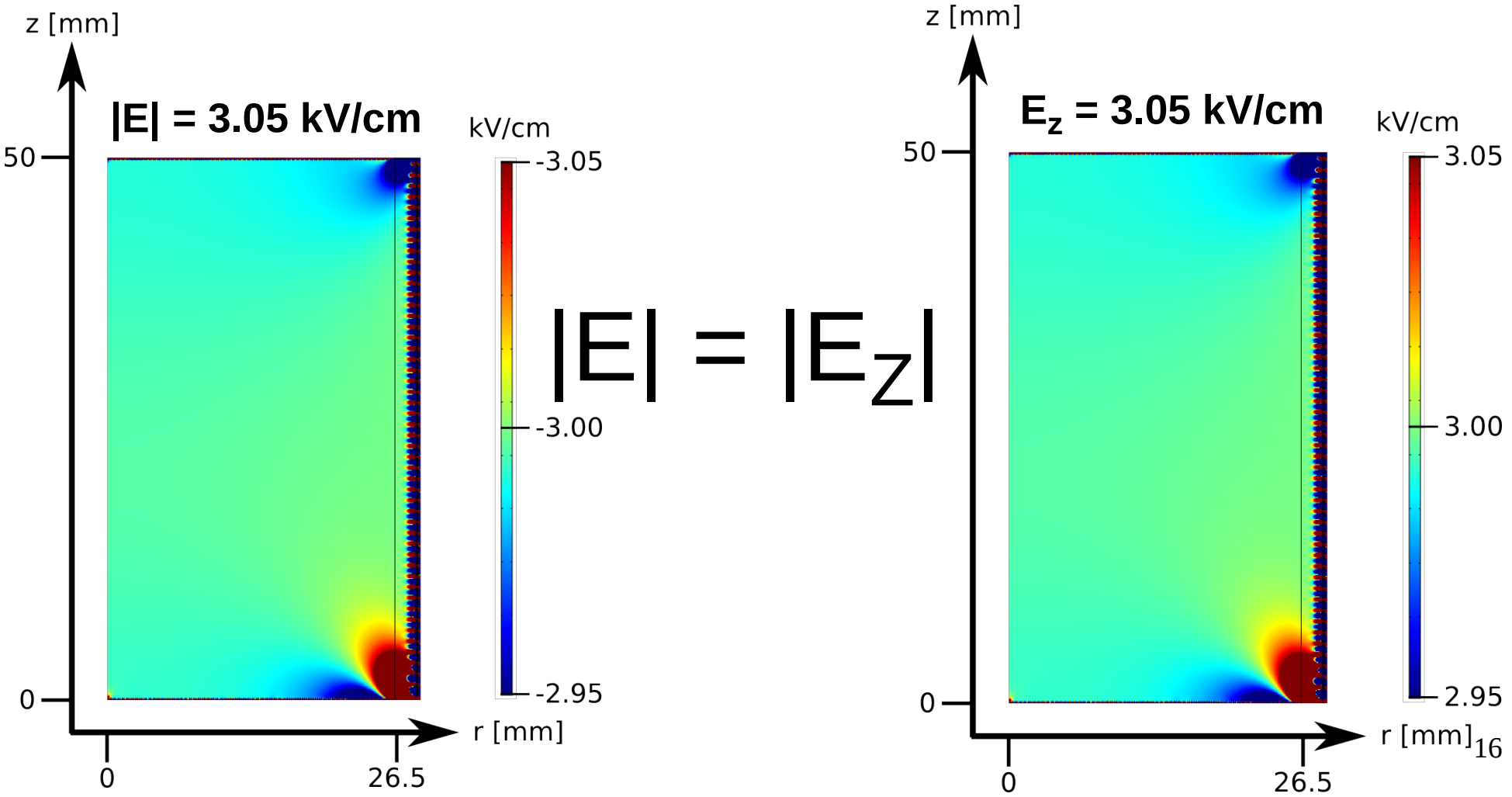
simulated different potential distributions with same resulting potential between cathode and anode



no top-shield-mesh = higher transparency

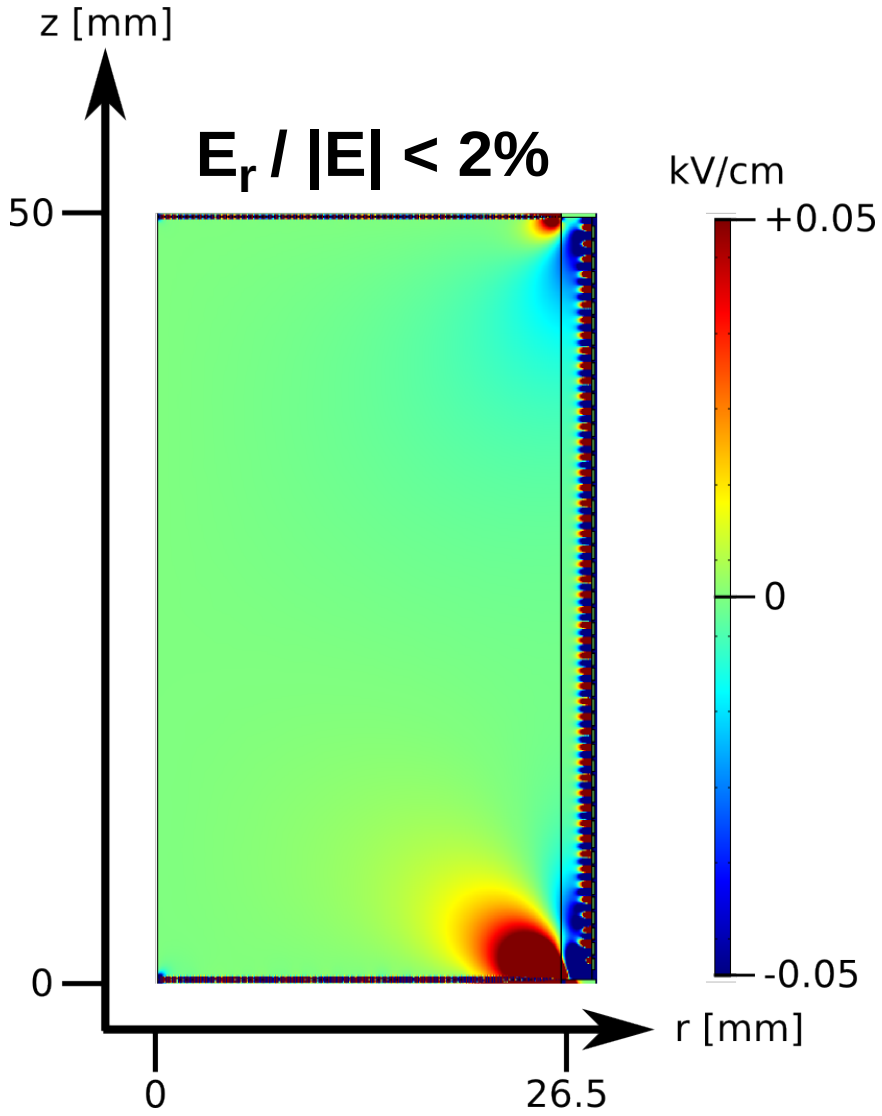
Mainz LXe TPC: simulation

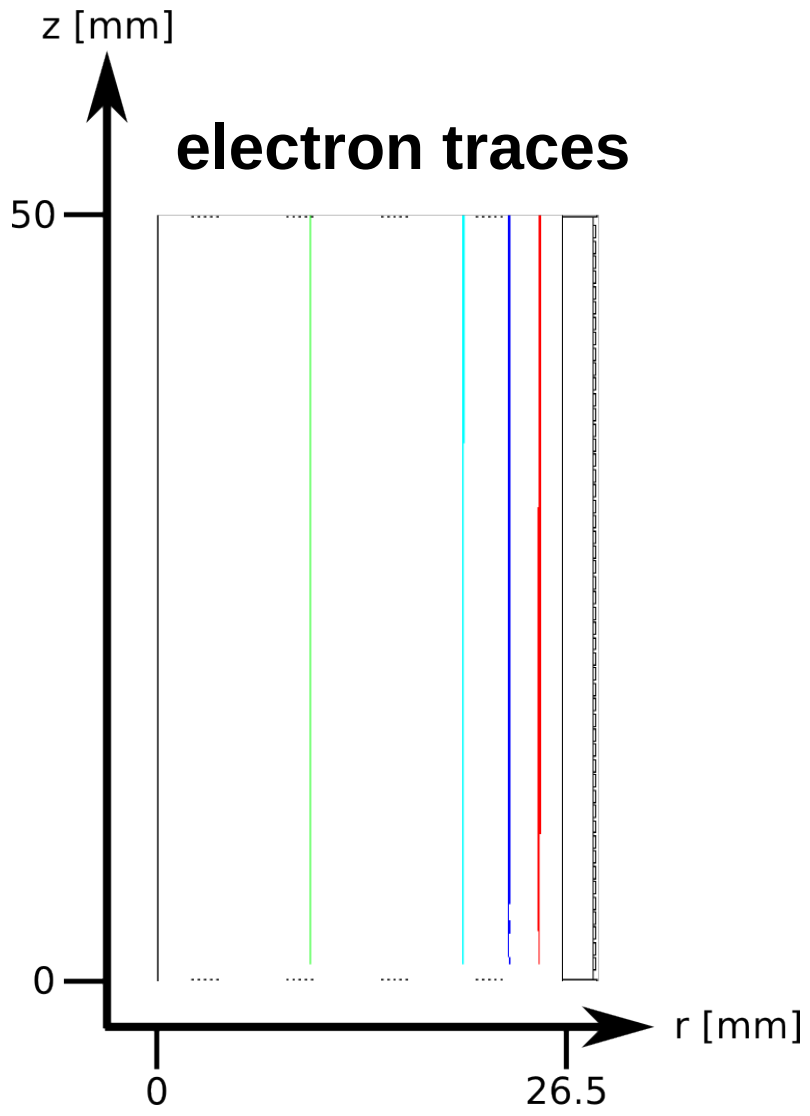
COMSOL: electrostatic field



Mainz LXe TPC: simulation

COMSOL: electrostatic field





summary of simulations

APD-ring

→

- position resolution (x/y) < ± 1.3mm
- fiducializing active volume
- correcting path/position errors due to inhomogenities of E-field

fine gate- and cathode-mesh

+

fine field-cage

→

<u>very uniform E-field</u>

E_{min} = 0.2 kV/cm ± 10%

E_{opt} = 3 kV/cm ± 2%

Outlook

- measuring light- and charge Yield of LXe in low-energy range (< 10 keV) for improved calibration of LXe DM experiments
- studies of fast LXe-scintillation can help improving background discrimination in future LXe DM searches

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