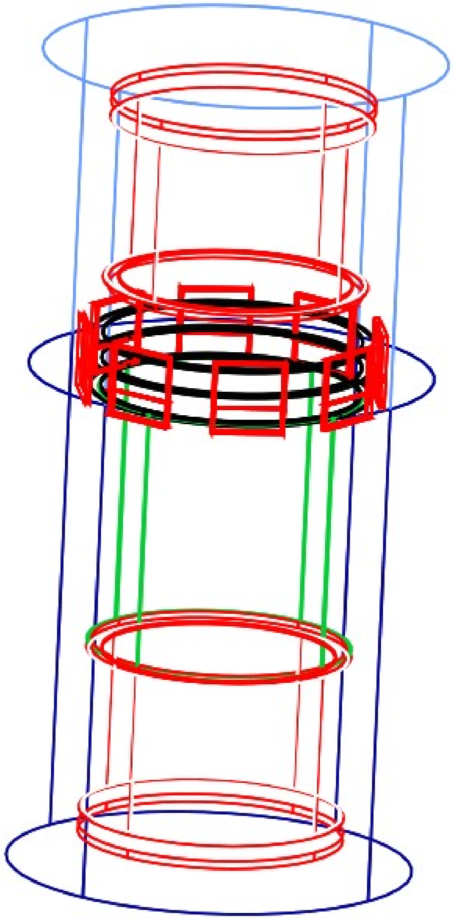
Fast sampling of liquid xenon scintillation pulse shape

application in direct Dark Matter detection



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HAP Topic 4: Advanced Technologies
24. january 2013

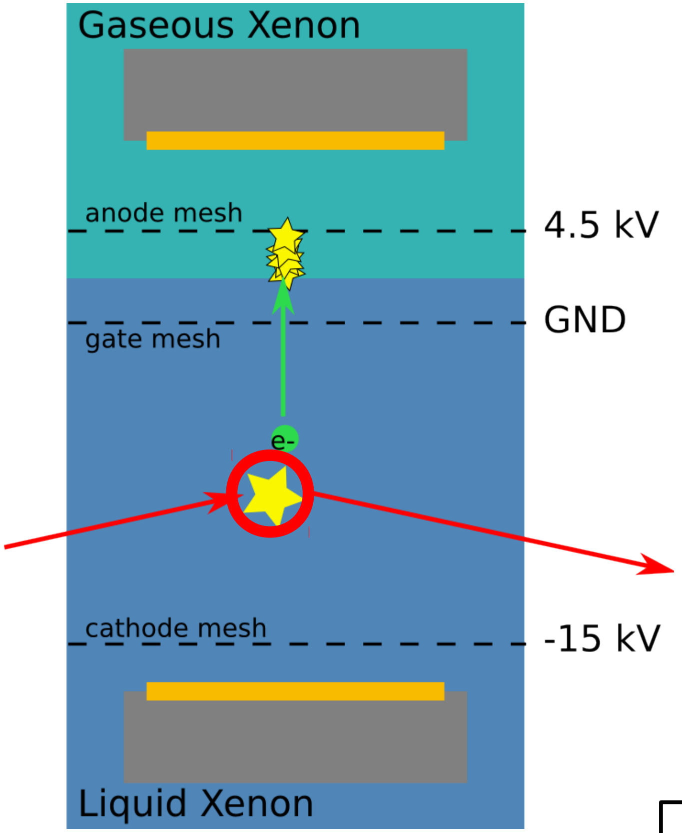
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

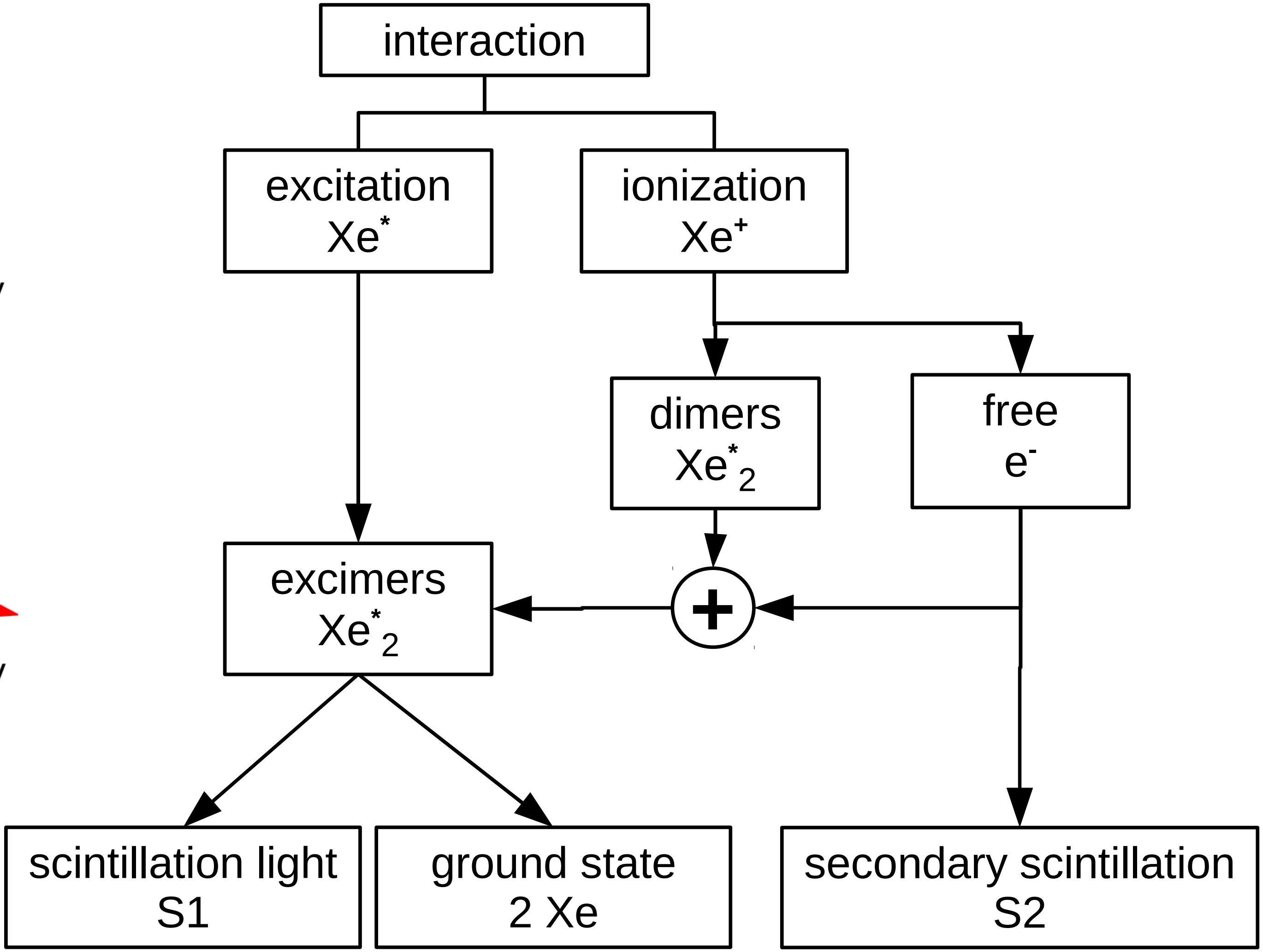
Outline

Fast sampling of liquid xenon scintillation pulseshape

- principle of a dual-phase TPC
- motivation for S1 pulseshape measurement
- technical design and status
- outlook

principle dual-phase TPC

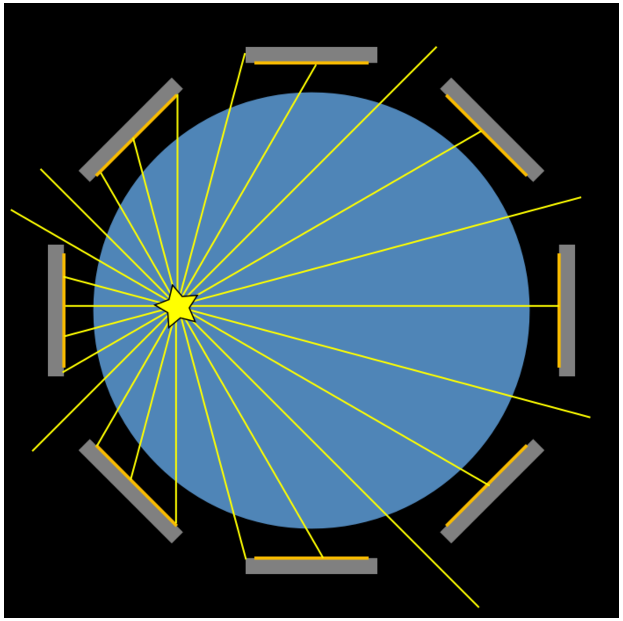


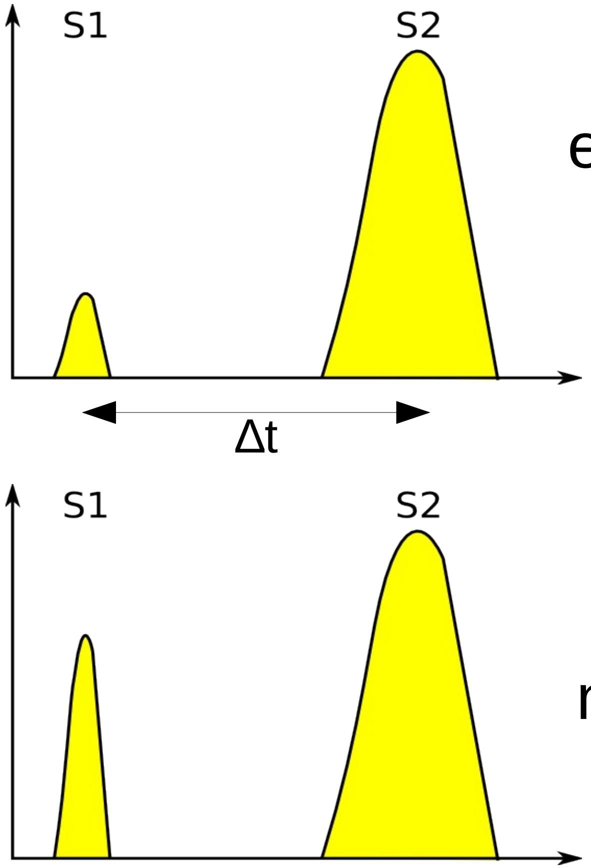


3D-position reconstruction

z-position
time difference between S1 and S2

x/y-position
position of S2 detected by a photosensor array

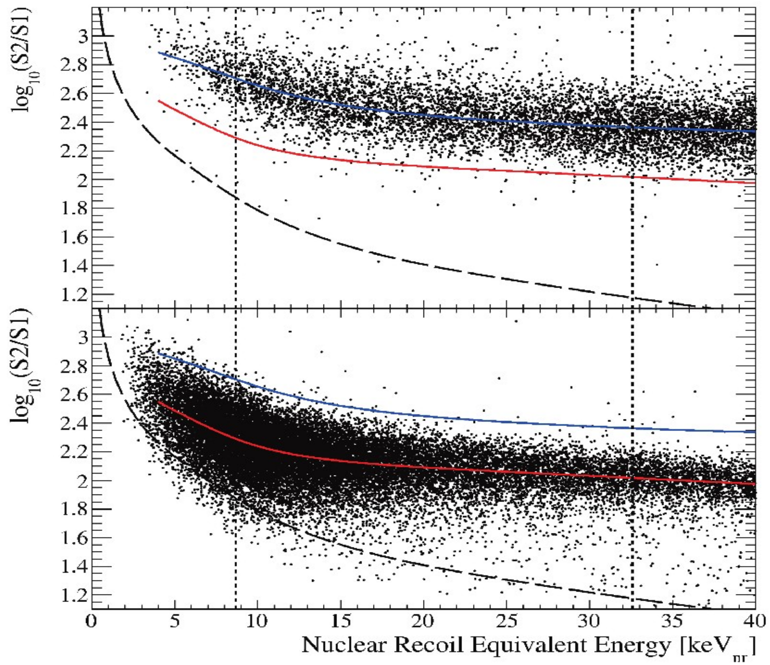




electronic recoil
e^-,γ

nuclear recoil
neutron, **WIMP**

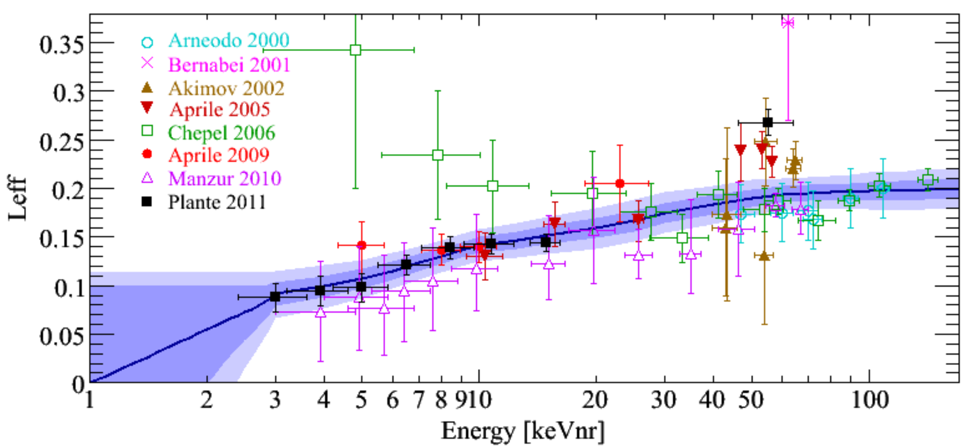
background discrimination



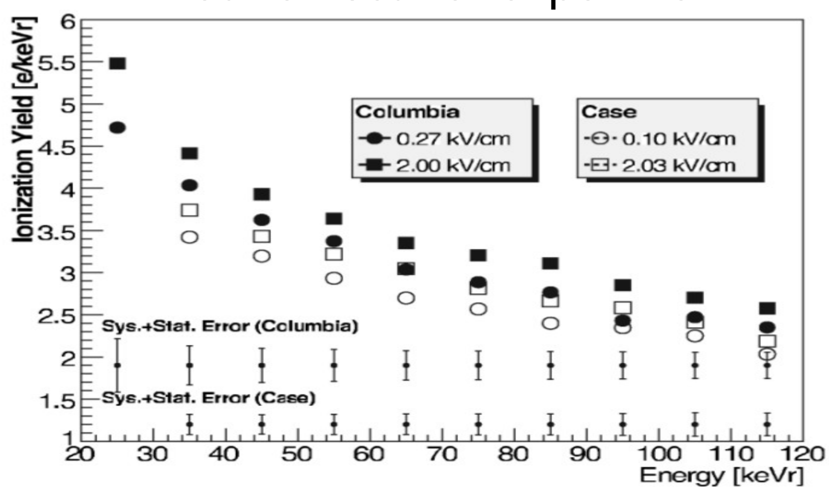
background discrimination: S2/S1

measurement of charge and light yield

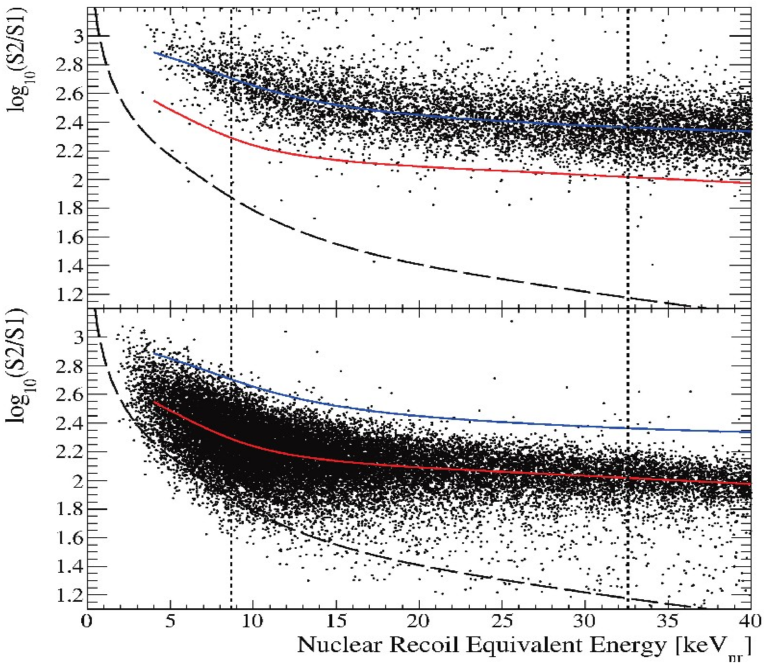
Compton scatter experiment



neutron scatter experiment



background discrimination



background discrimination: S2/S1

Can S1 pulseshape be used for further background discrimination?

S1 pulse shape

different scattering particles

comparing electron, alpha and fission fragment induced scintillation:

electron:

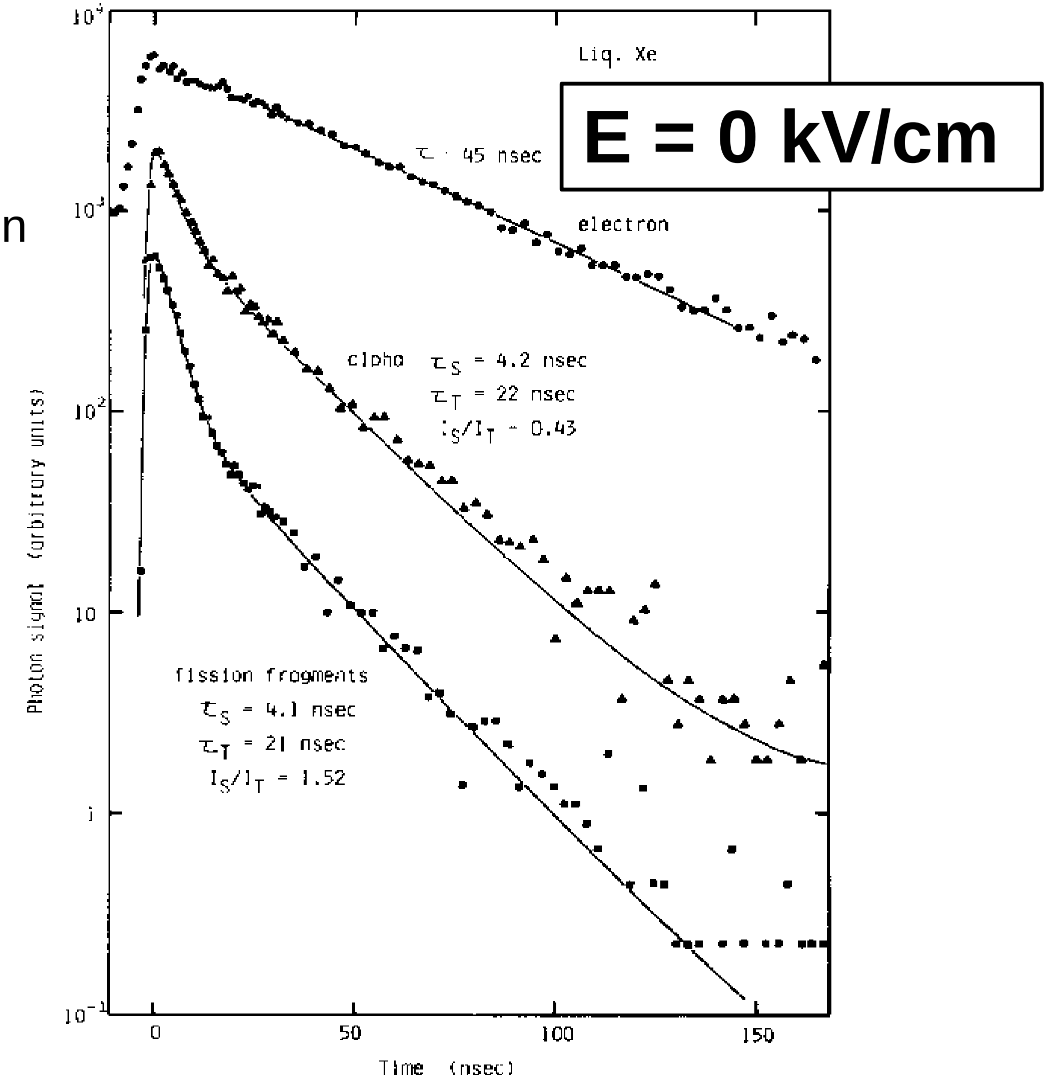
- $\tau = 45$ ns

alpha:

- $\tau_S = 4.2$ ns
- $\tau_T = 22$ ns

fission fragments:

- $\tau_S = 4.1$ ns
- $\tau_T = 21$ ns



Physical Review B - Vol.27 - No. 9, May 1983
A. Hitachi, T. Takahashi: “ *Effect of ionization density on the time dependence of luminescence from liquid argon and xenon”*

S1 pulse shape

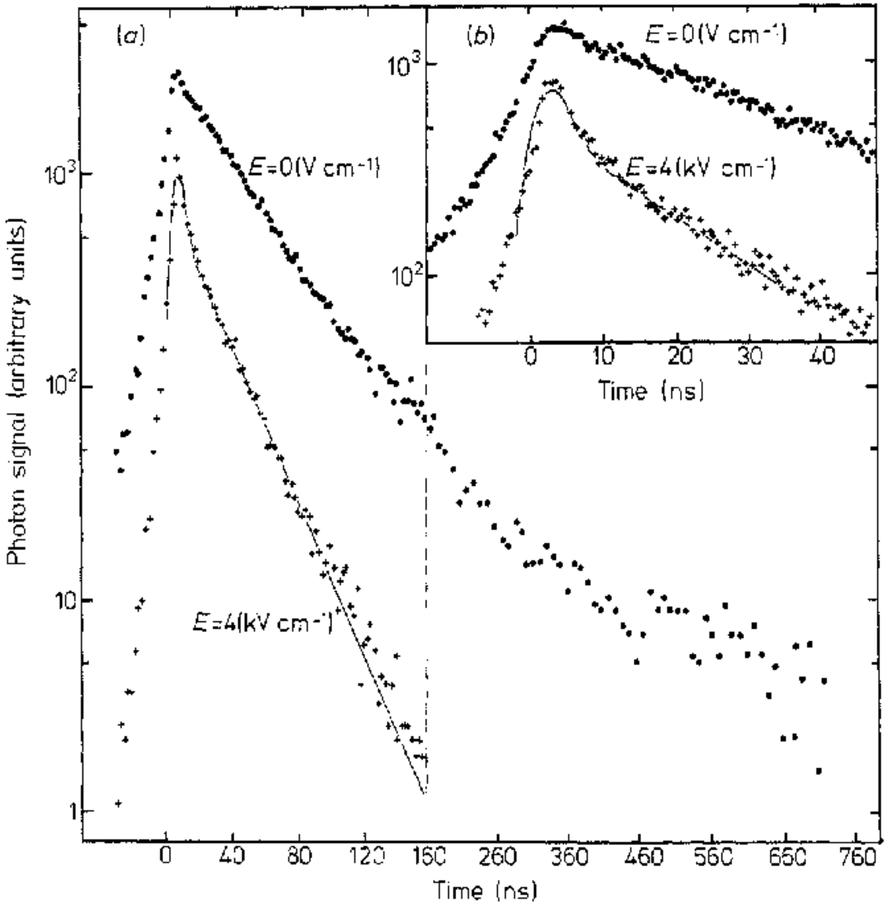
comparing different electrical drift-fields (electron recoils):

E = 0 kV/cm

- τ = 34±2 ns

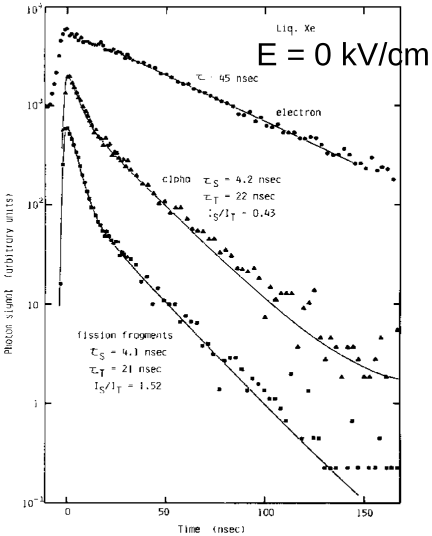
E = 4 kV/cm

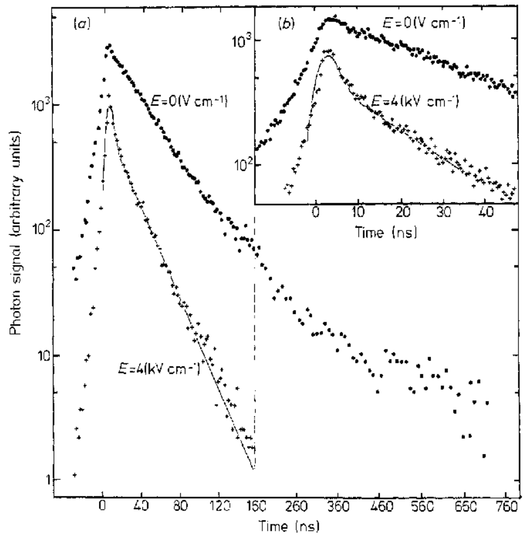
- τ_S = 2.2±0.3 ns
- τ_T = 27±1 ns



J . Phys. C : Solid State Phys., Vol. 11, 1978
Shinzou Kubota, Masahiko Hishida and Jian-zhi Raun:
"Evidence for a triplet state of the self-trapped exciton states in liquid argon, krypton and xenon"

S1 pulseshape
background discrimination?





Can S1 pulseshape be used for further background discrimination?

S1 pulse shape depends on:
- type of scattering particle
- applied drift field

=> ionization density

- systematic tests with modern instrumentation required!

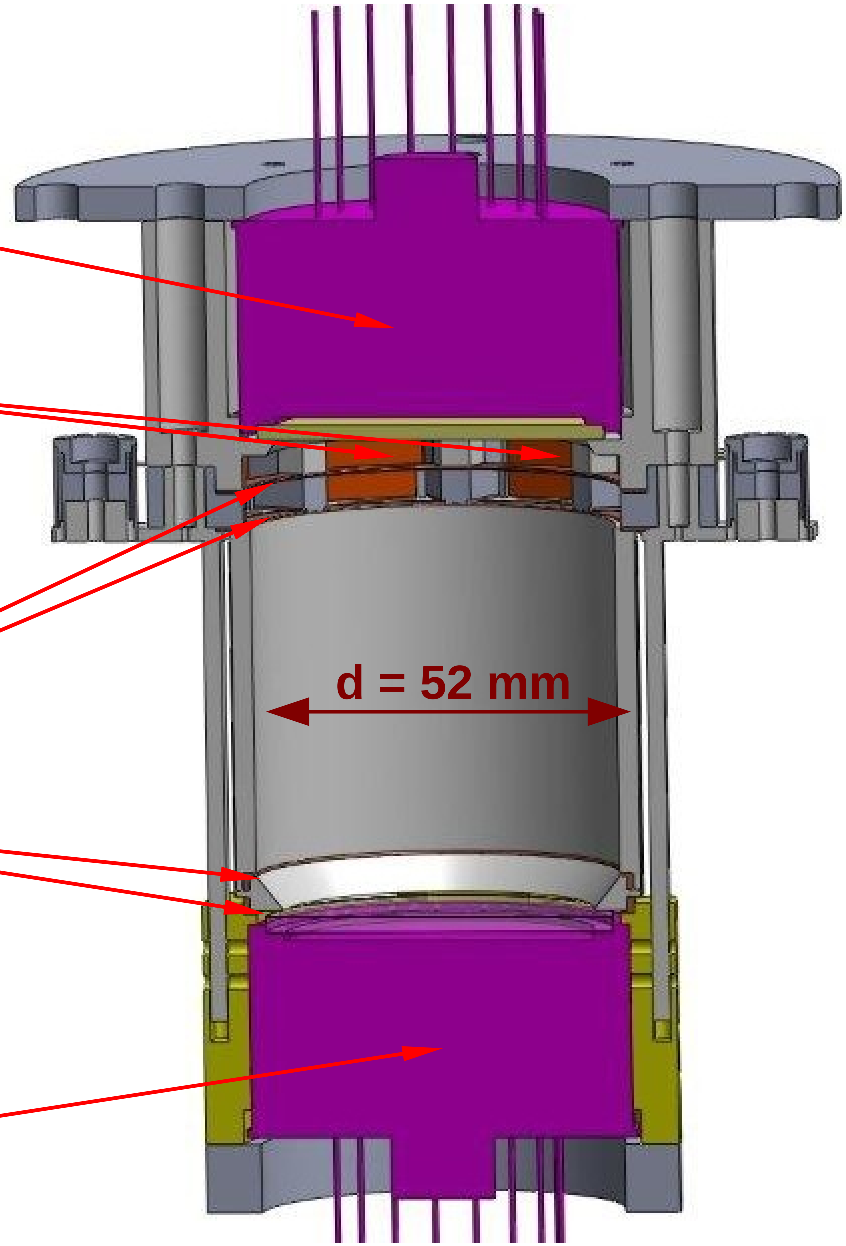
TPC design

top PMT

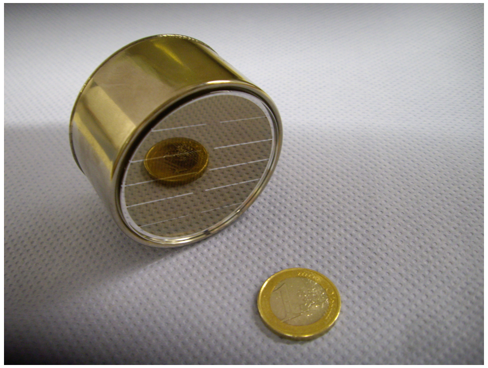
x/y-position-resolution
using 8 large area APDs
x/y-resolution <=1.3 mm

high transparency meshes
pitch: 268 µm
wire-diameter: 14 µm
transparency: 88 % @ 90 °

bottom-PMT

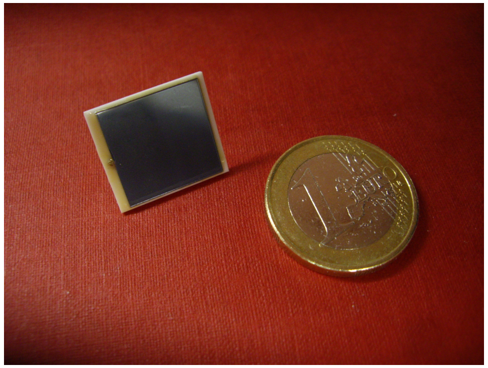


Instrumentation



2 PMTs (Hamamatsu R6041):

- QE > 30% @ 178 nm
- compact design
  - 2 inch diameter
  - 32 mm heigth
  - cathode active diameter: 45 mm
- measure S1 and S2 (energy)



8 APDs:

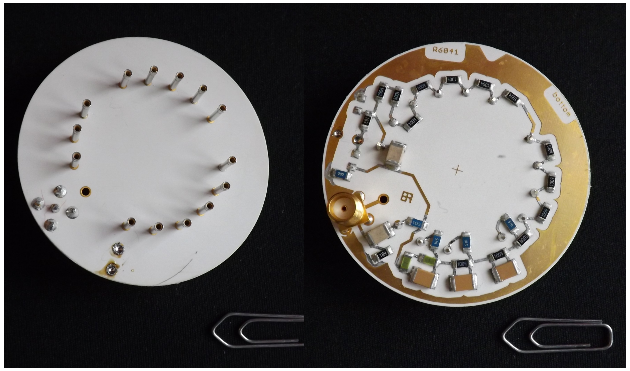
- active area: 14x14 mm²
- QE ~ 30% @ 178nm
- no housing - little passive material
- measure S2 (x-y-position)

5 GS/s FADC (Struck SIS3305)

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

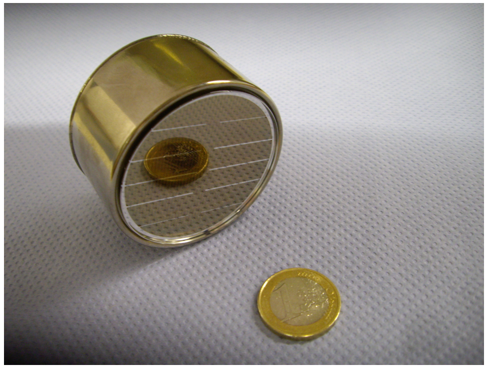
PMT: R6041

PMT single photo electron pulseshape



<u>Datasheet figures (800V)</u>

gain: 1 x 10^6
anode pulse rise time: 2.3 ns
electron transit time: 16 ns
transit time spread: 0.75 ns

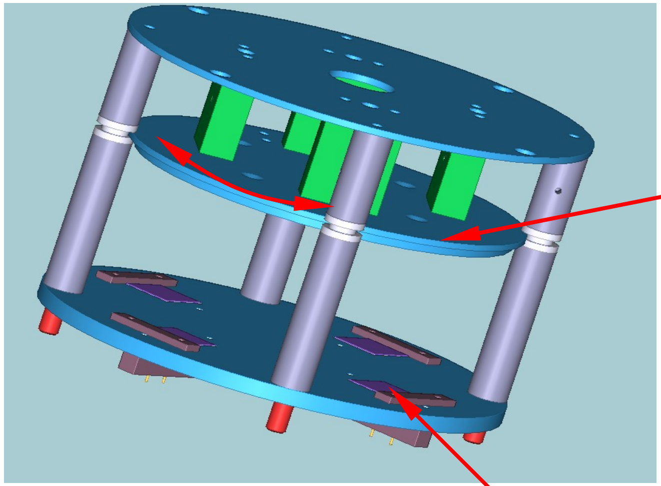


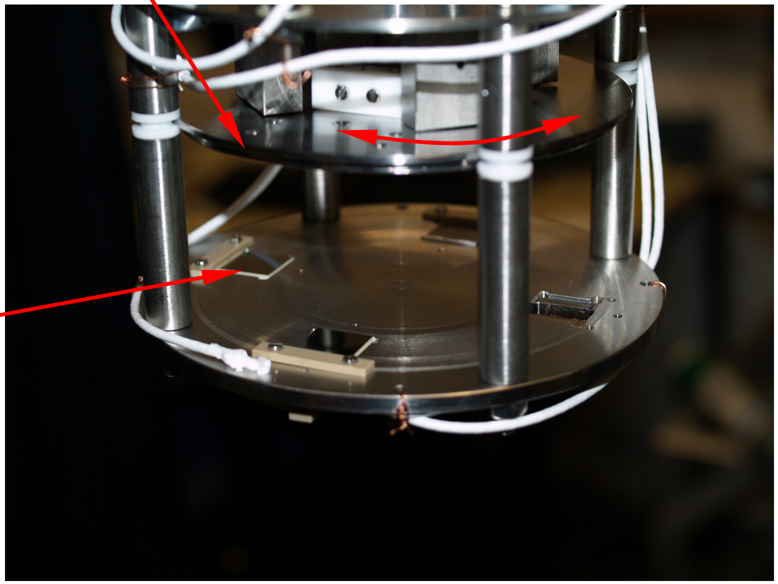
supply voltage volts	rise time ns	fall time ns	pulse width ns	gain 10^6 e^- per p.e.
750	2.249	14.16	33.96	-
800	2.229	14.29	33.73	2.3
850	2.132	16.09	33.56	4.9
900	1.997	18.34	33.39	9.4

APD: RMD S1315

measuring gain and QE

rotatable disc (45° precise positioning) with Am241-source and optical fibre mounted on bottom side (not visible here)



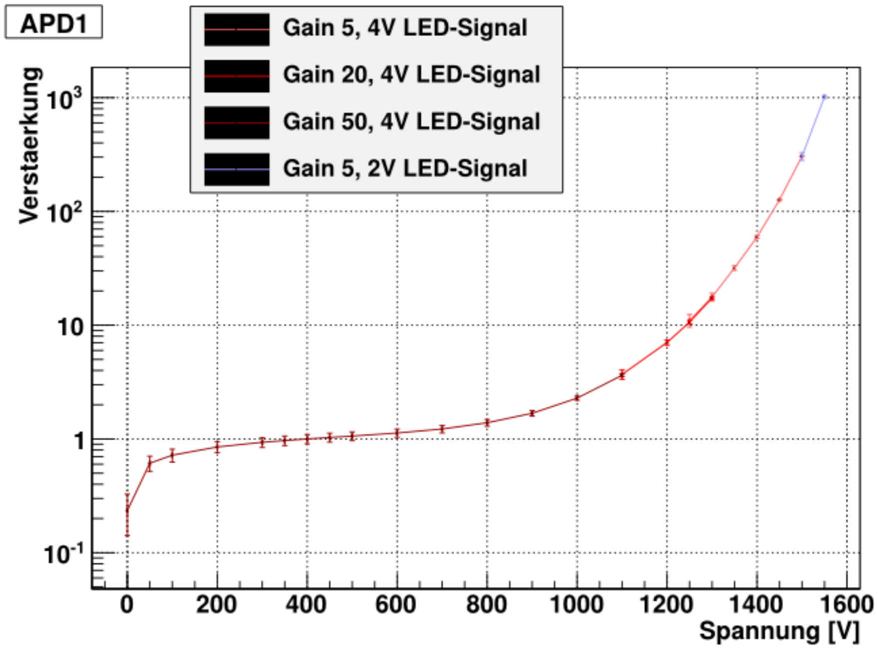


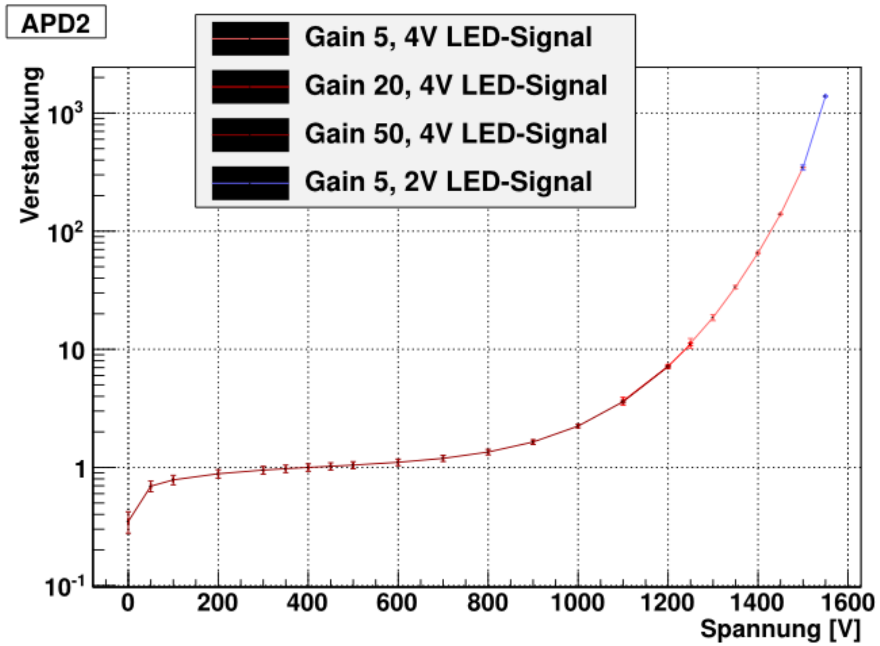
avalanche photo diodes

setting up the cooling and temperature control system and preparing to fill with Xenon these days

APD gain

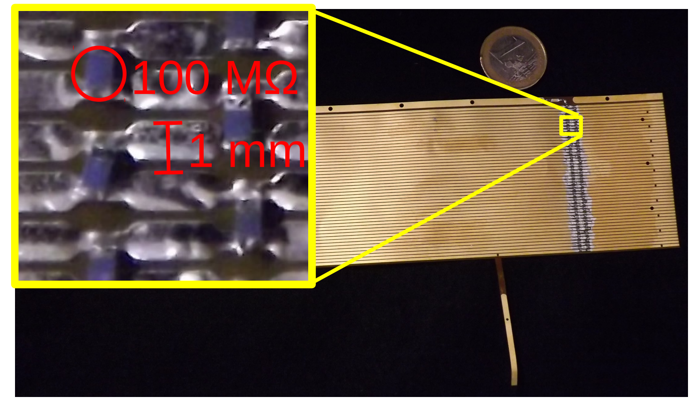
measured gain of APDs @ 165 K



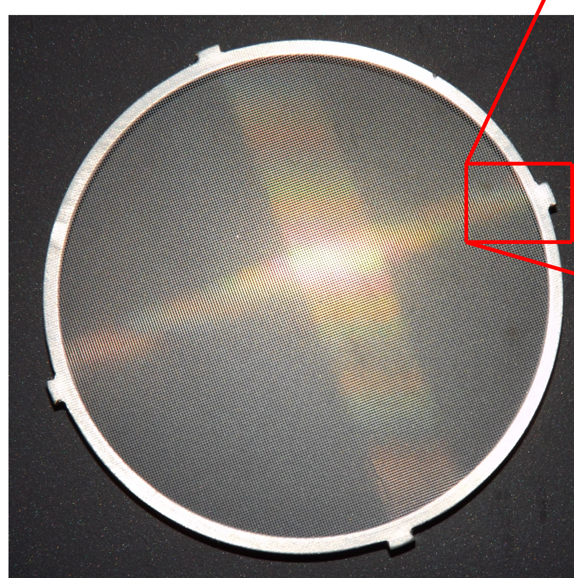


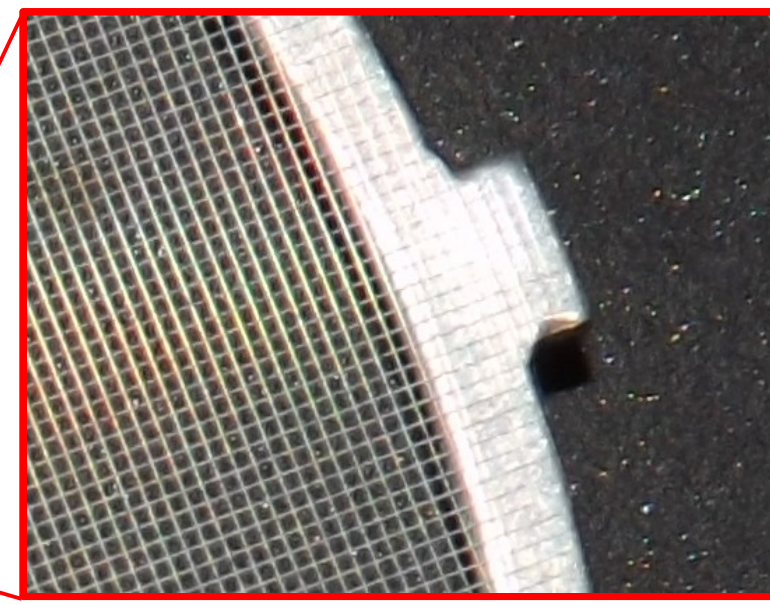
measurement using a LED
measured gain ≤ 1500
less than expected - saturation?! => will be tested

TPC: field cage



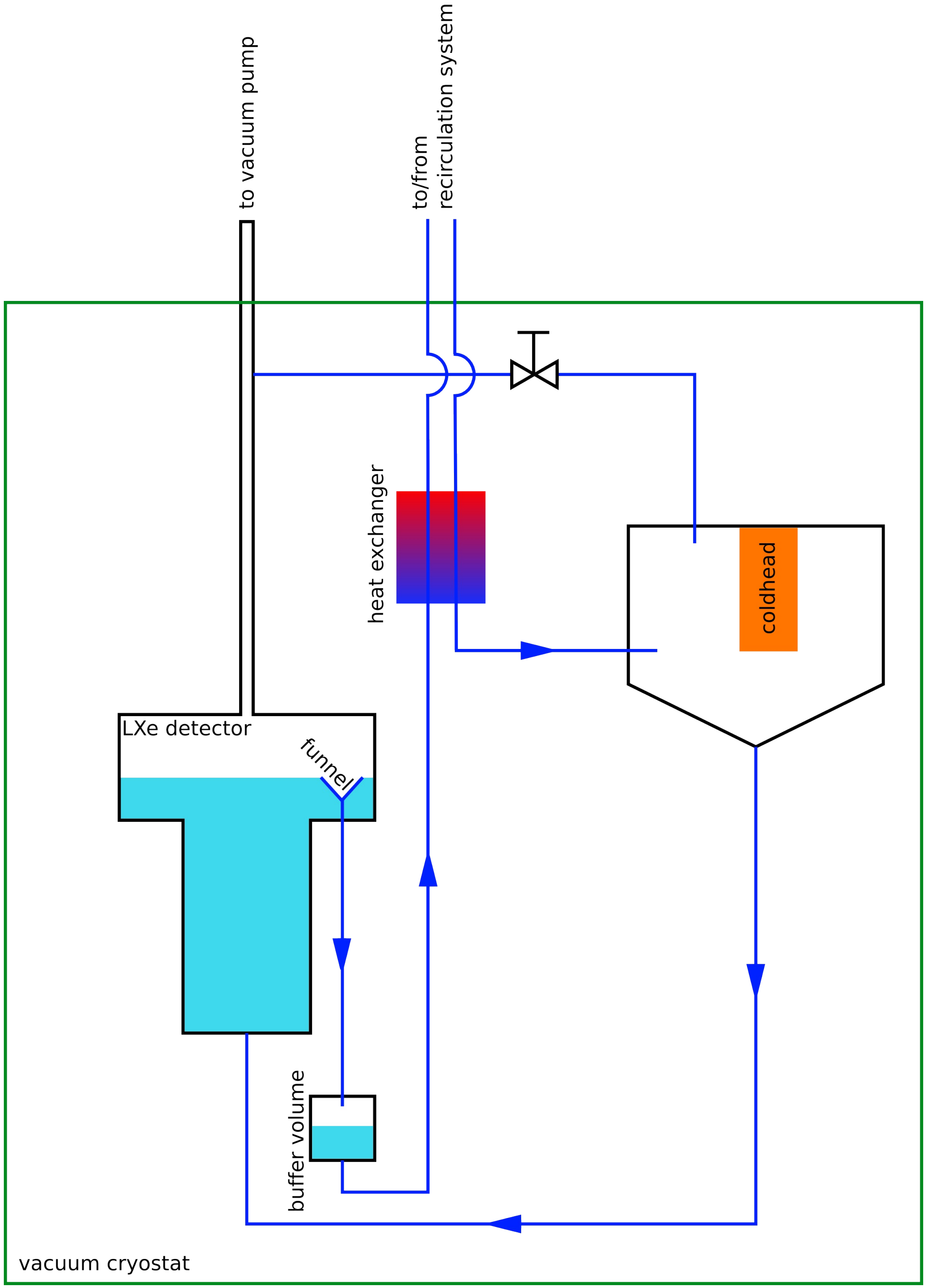
<u>PCB for field shaping</u>
pitch: 1 mm





<u>meshes</u>
pitch: 268 µm
wire-width: 14 µm

schematic: cryo-system



status and outlook

status:

- TPC is being manufactured (about 2 weeks to go)
- ongoing tests with the photosensors
- design of cryo-system and Compton scatter experiment

outlook:

- measurement of scintillation and ionization yield of LXe at low energies
- systematic measurement of scintillation pulseshape at
  - different drift fields
  - different recoil energies
  - different particles (gamma, neutron)
- fast readout using a commercial FADC
  - DM experiments: need a cheaper option (e.g. switched capacitor arrays)

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Questions?

Thanks to all collaborators:

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