The Mainz TPC: a two-phase Xenon TPC for R&D towards future Dark Matter searches

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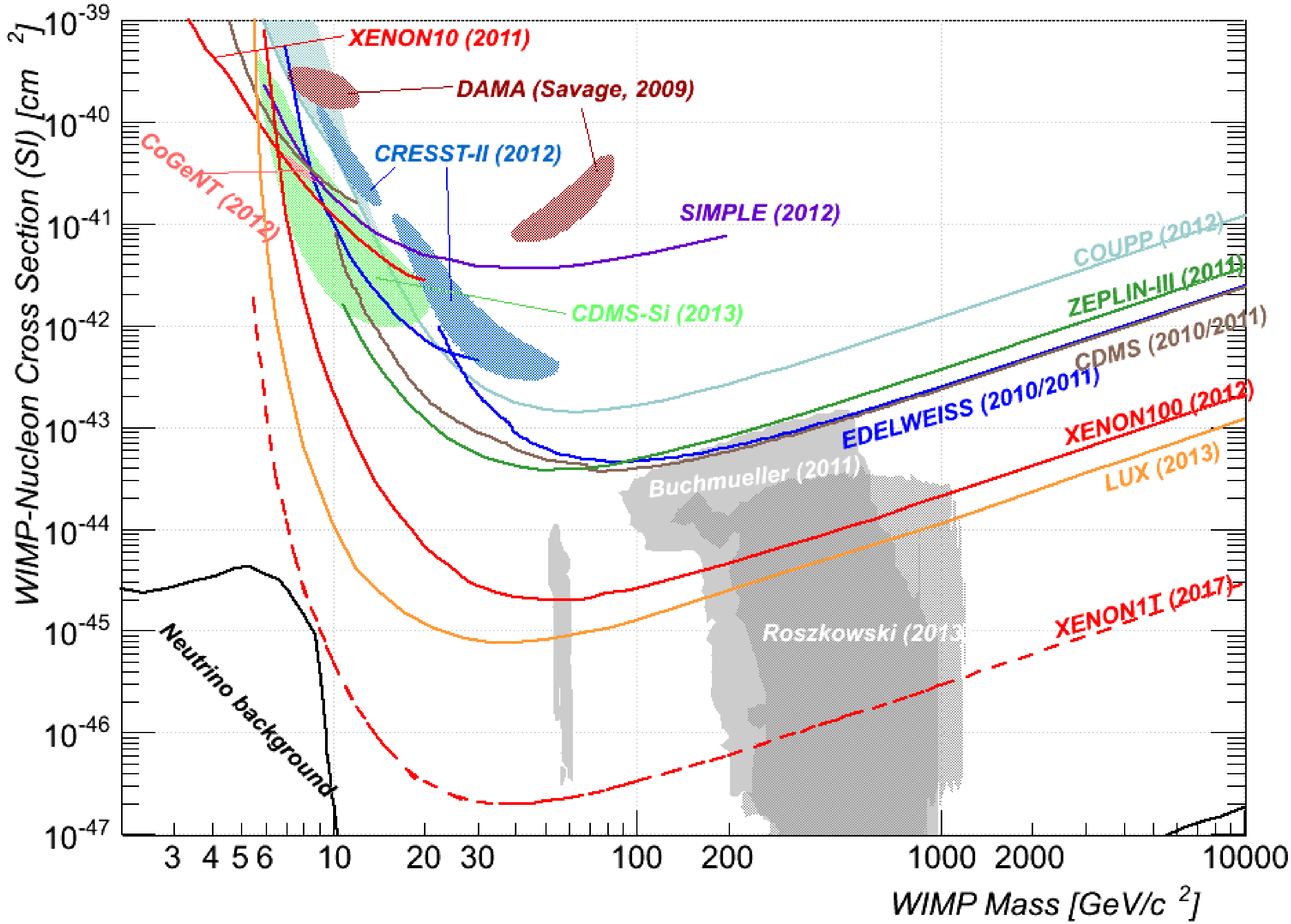
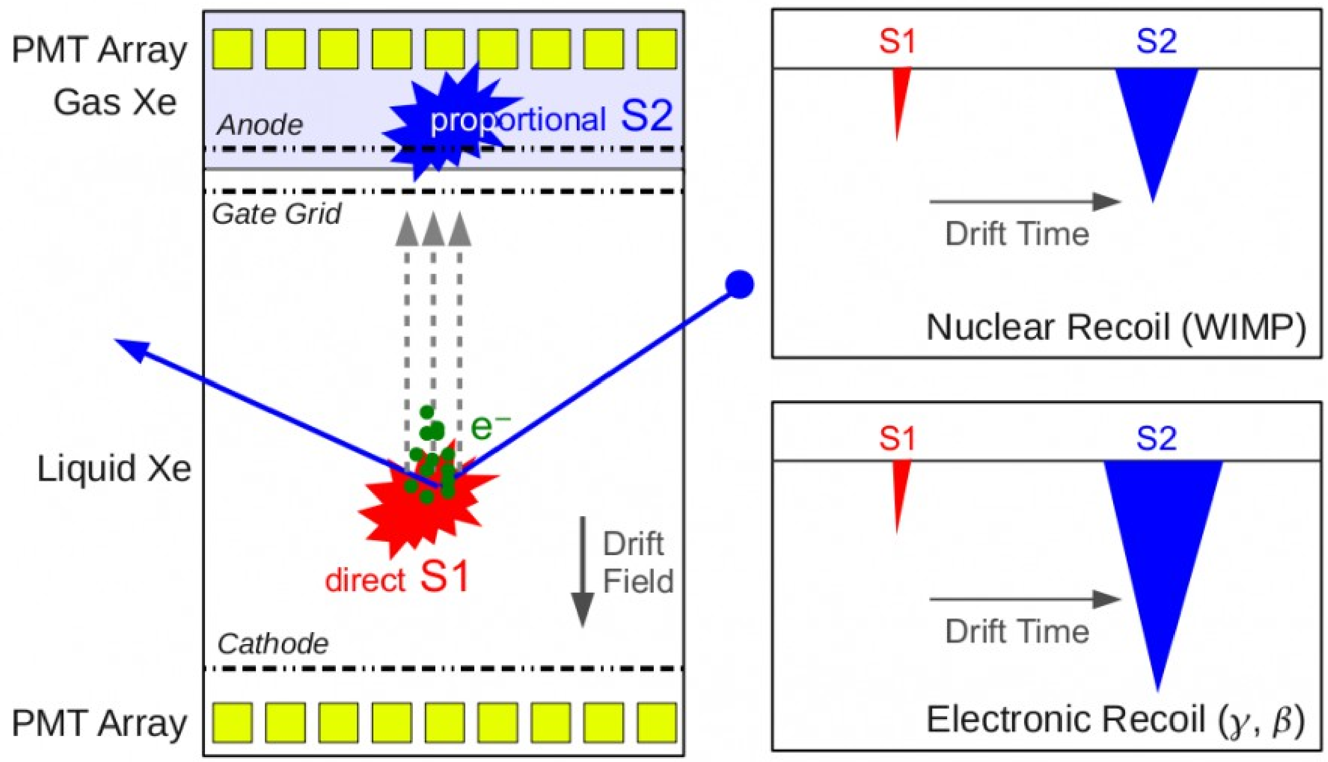
Johannes Gutenberg University Mainz

Darwin meeting, Napoli,Italy, December 11, 2013

Status DM search



Dual phase Xenon TPC



3D position reconstruction with ~1mm resolution:
- XY from PMT pattern
- Z from electron drift time

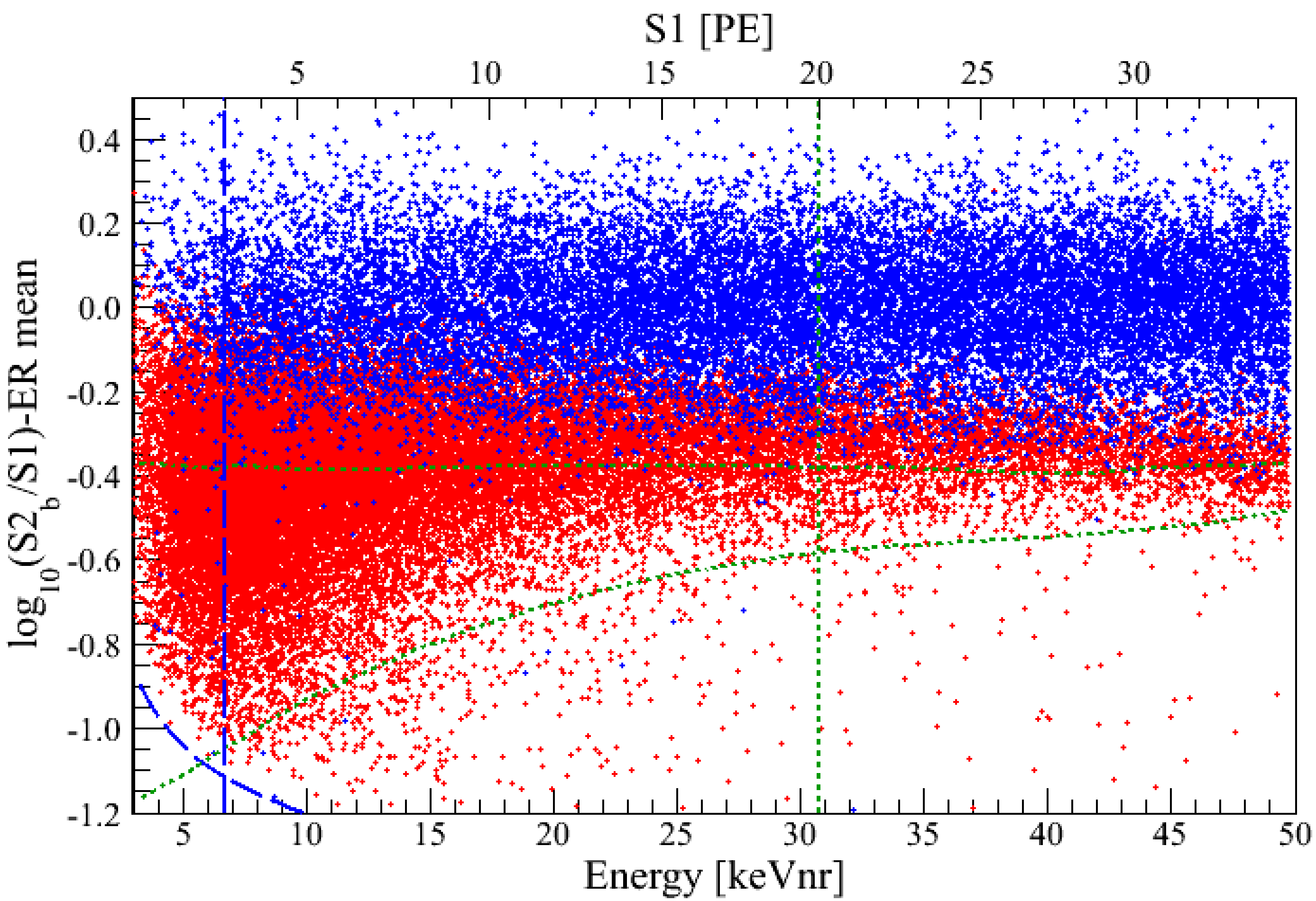
Multi-scatter rejection

Fiducial volume cut

Discrimination of e^-/γ and nuclear recoils with > 99.75% efficiency with an averaged nuclear recoil acceptance of 50%:

$(S2/S1)_{wimp} < (S2/S1)_{ER}$

ER/NR Calibration

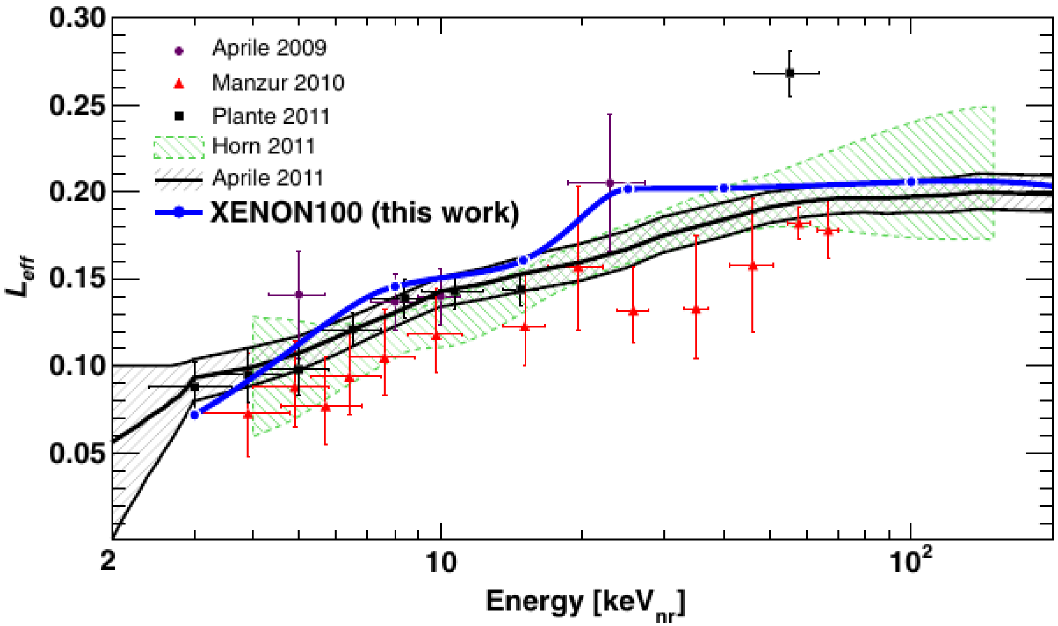


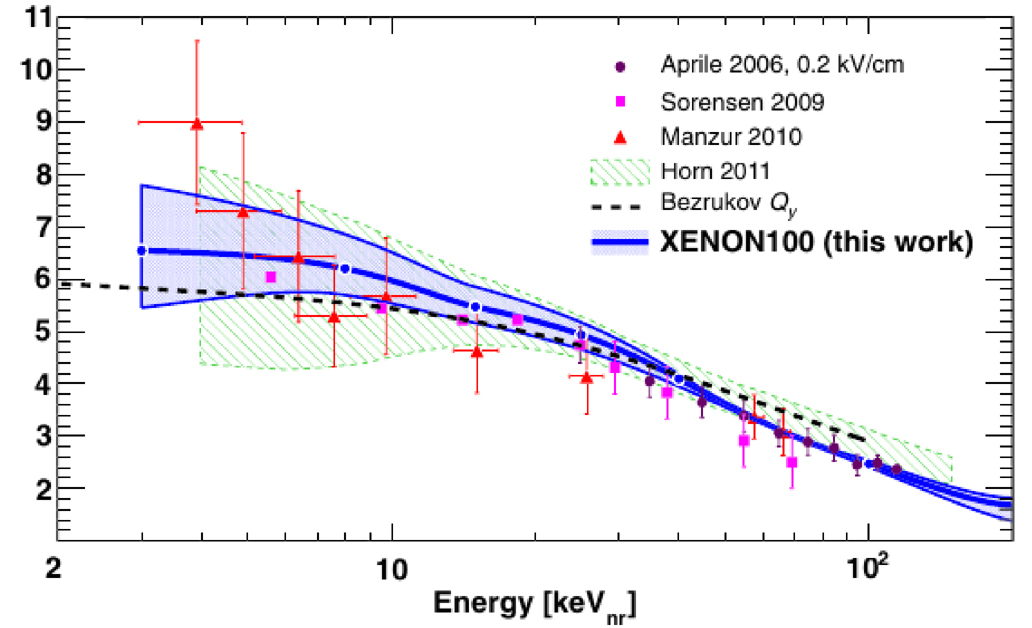
ER calibration with ^{60}Co and ^{232}Th: 35x statistics of background

NR Calibration with AmBe Calibration at beginning and end of the run

99.75% ER rejection for 50% efficiency loss on NRs

Response to nuclear recoils



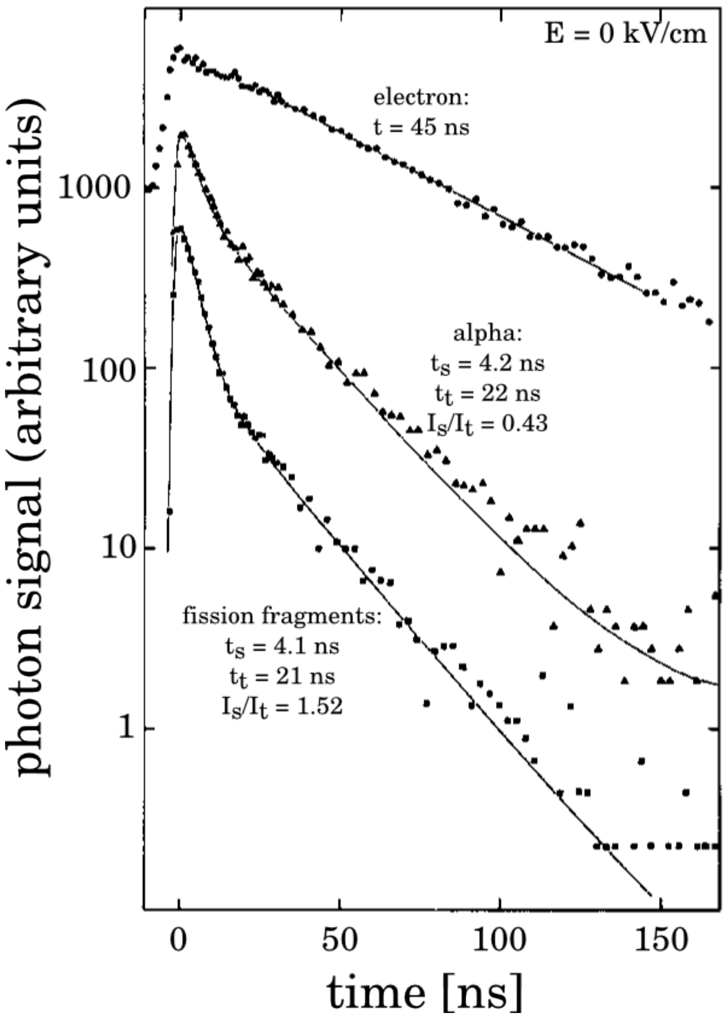


$$S1 = E_{nr}\ L_y\ L_{eff}(E_{nr})\ \frac{S_{nr}}{S_{ee}}$$

$$S2 = E_{nr}\ Q_y(E_{nr})\ Y$$

Need to improve knowledge of Leff and Qy at low recoil energies

Pulse shape discrimination in LXe



From the 80's:

A. Hitachi et al. Phys. Rev. B, Condens. Matter 27(9): 5279-85 (1983)
S. Kubota et al. J. Phys. C : Solid State Phys., Vol. 11, 1978.

More recently:
D. Akimov et al., Phys.Lett. B524 (2002) 245-251

J. Kwong et al. NIM A612, (2010) 328–333

K.Ueshima et al. NIM A659 (2011) 161-168 : XMASS collaboration

Promising technique

Need measurements with fast electronics

Study as function of electric field

Potential of PSD in a large Xenon TPC

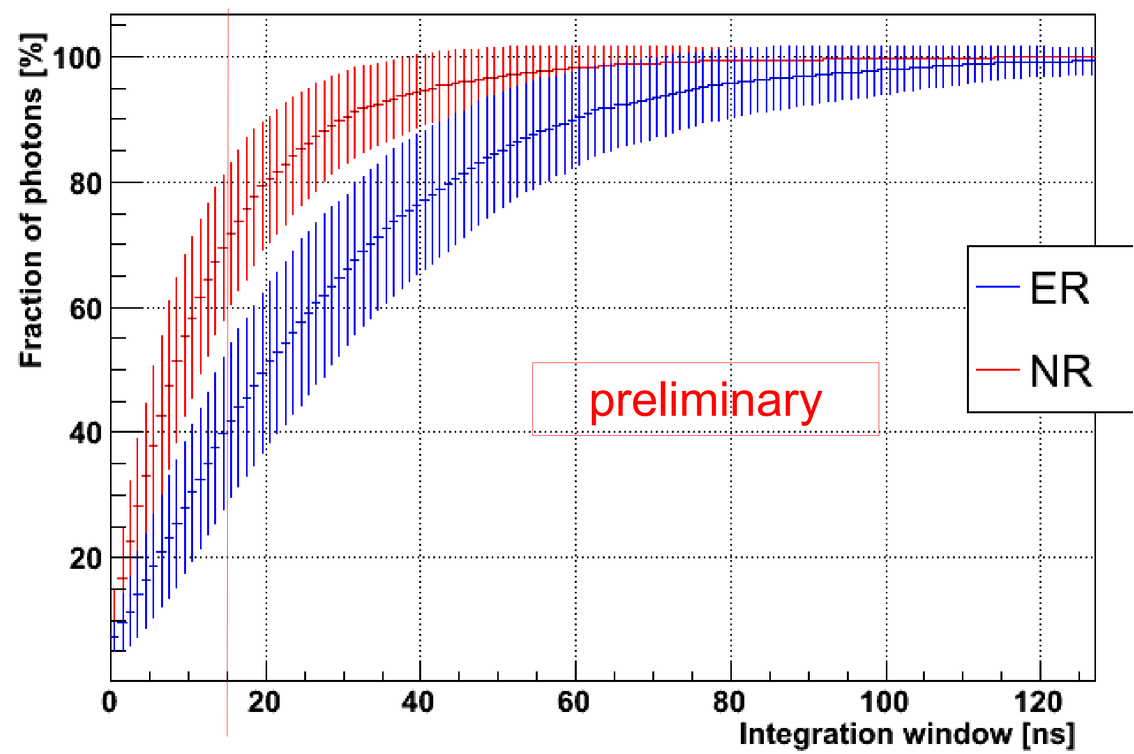
Preliminary results of MC simulation of PSD:

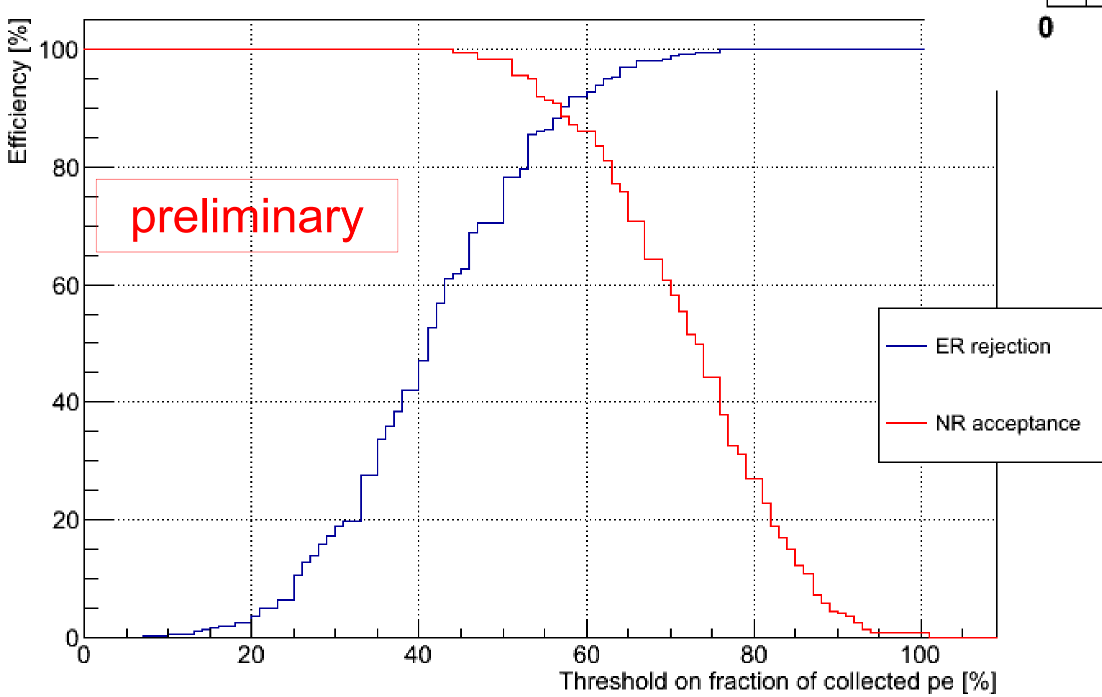
NEST: http://arxiv.org/abs/1310.1117

Decay time: 3.1±0.7 ns and 24±1.0 ns

Fast / Slow: 7.8±1.5 (NR), 0.17± 0.05 (ER)

Used XENON1T geometry:
- 50m absorption length
- 3” PMTs, with fast response
- 1GHz sampling and





S1 = 20 pe detected
15 ns integration window for prompt signal

- reject 60% of ER while keeping all NR
- addition to log(S2/S1) criteria
- need to study this effect for different sampling frequencies in a dedicated setup

Mainz TPC

Electronic Recoils: L_{eff} and Q_Y

- focus: low energies (1-10 keV)
- what is new compare to former measurements:
  - simultaneous measurement of L_{eff} and Q_Y
  - improved measurement of recoil energy (using a Ge-detector) in the Compton scatter experiment
  - cleaner data: 3D-position reconstruction allows fiducialization and detection of multiple scattering

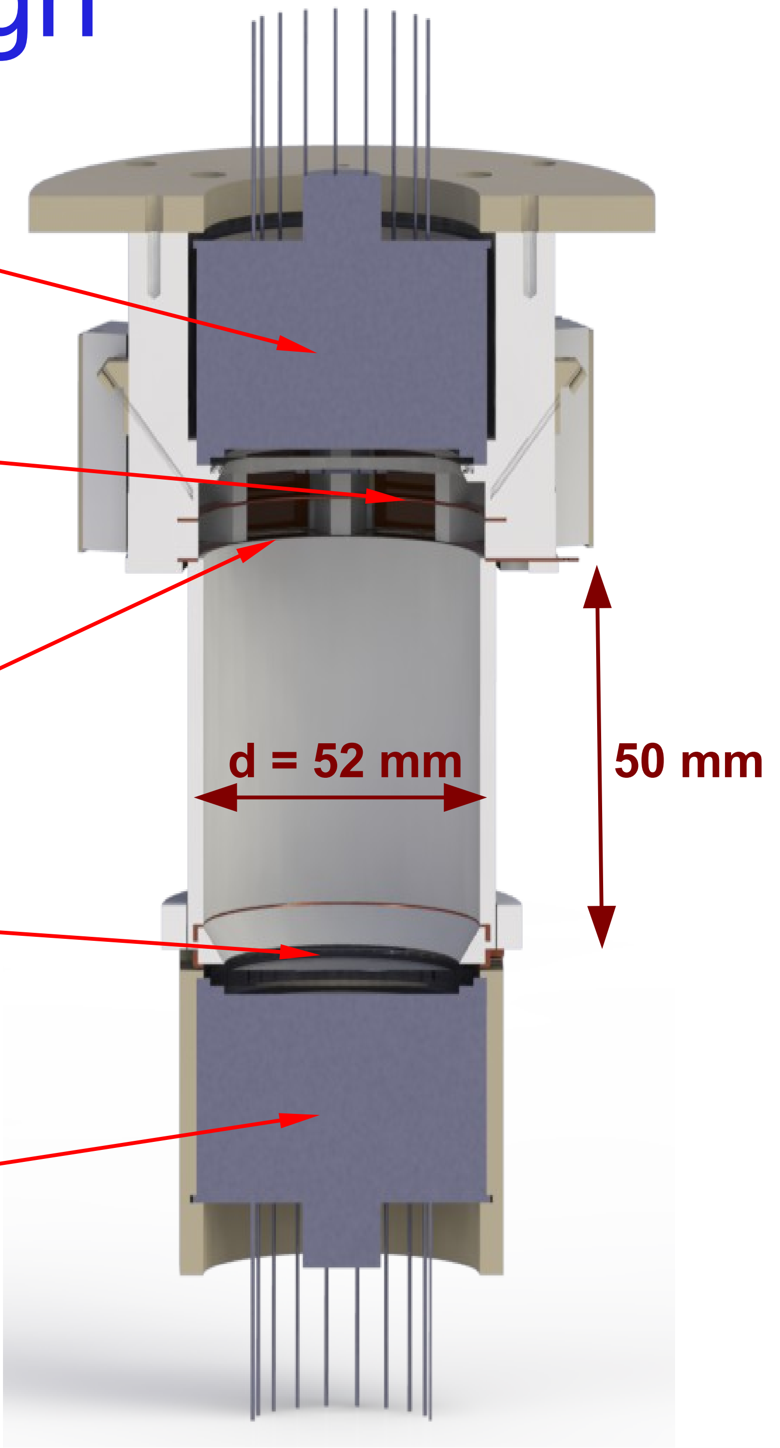
Nuclear Recoils: L_{eff} and Q_Y

- as for electronic recoils
- second step, as measurement of nuclear recoils requires a suitable neutron source (neutron scatter experiment)

Scintillation pulse shape (S1): Nuclear and electronic recoils

- measure systematically pulse shape for different drift fields and recoil energies with fast digitizers

TPC design



2” PMT

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

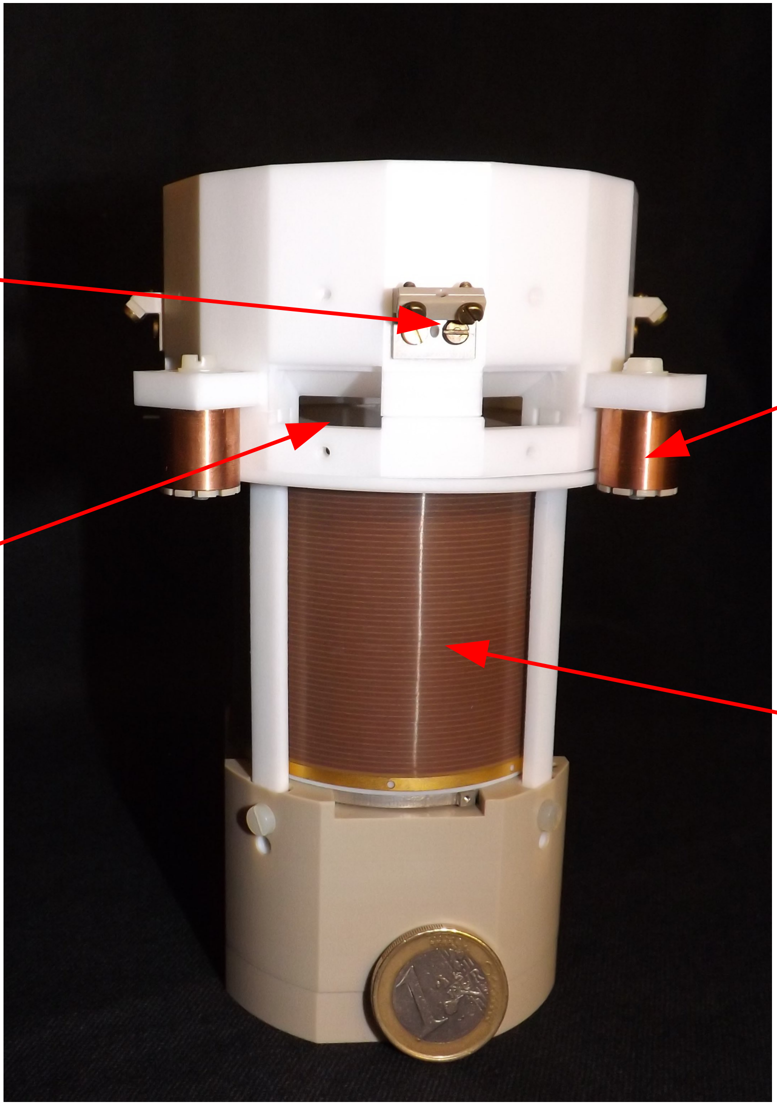
high transparency meshes
pitch: 268 µm
wire-diameter: 14 µm
transparency: 88 % @ 90°

2” PMT

TPC design

holder for
optical fiber

liquid xenon
level meter

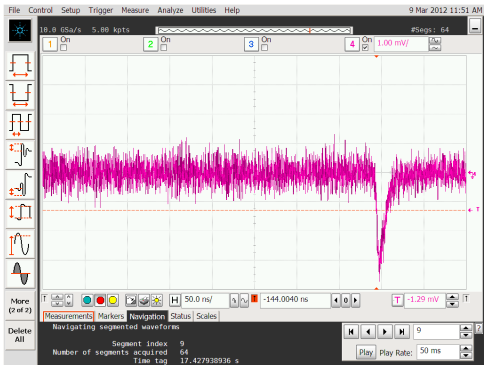


gap for APD

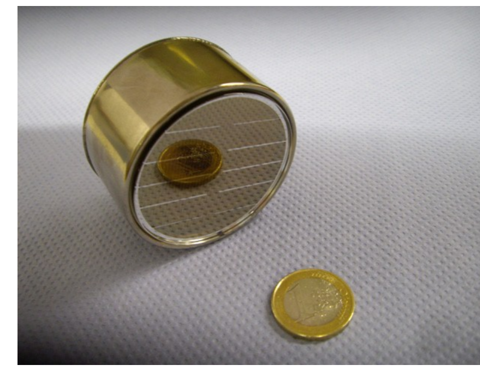
PCB for field
shaping

PMT: Hamamatsu R6041

PMT single photo electron pulseshape



Datasheet figures (800V)
gain: 1 x 10^6
anode pulse rise time: 2.3 ns
transit time spread: 0.75 ns
QE > 30% @ 178nm
2” diameter

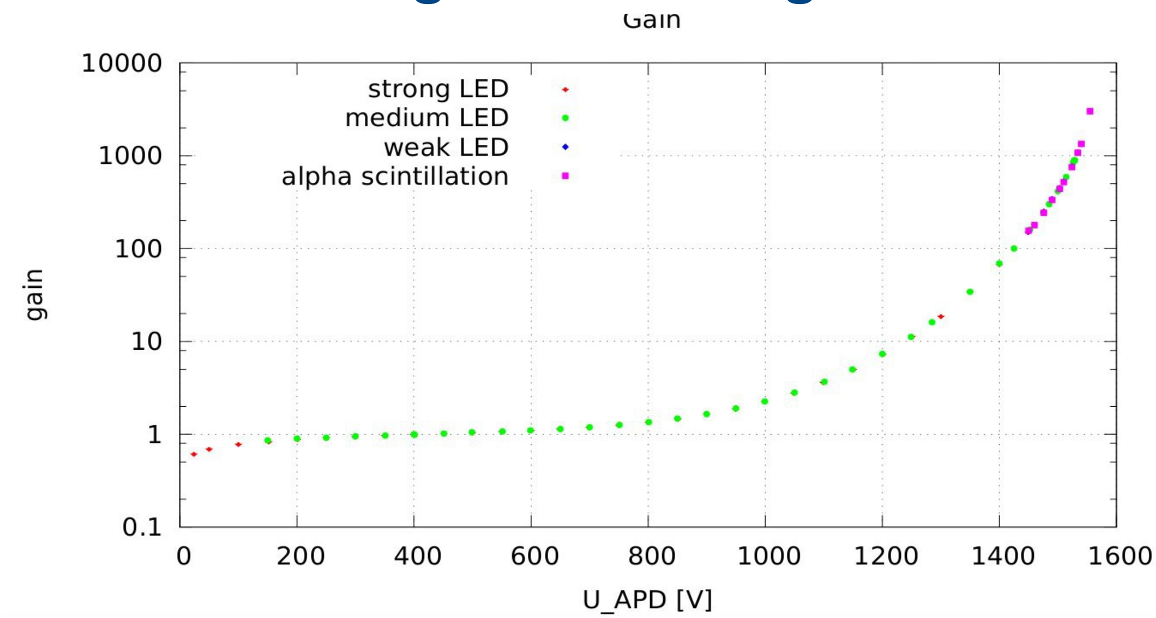


supply voltage volts	rise time ns	fall time ns	pulse width ns	gain 10^6 e^- per p.e.
750	2.249	14.16	33.96	-
800	2.229	14.29	33.73	2.3
850	2.132	16.09	33.56	4.9
900	1.997	18.34	33.39	9.4

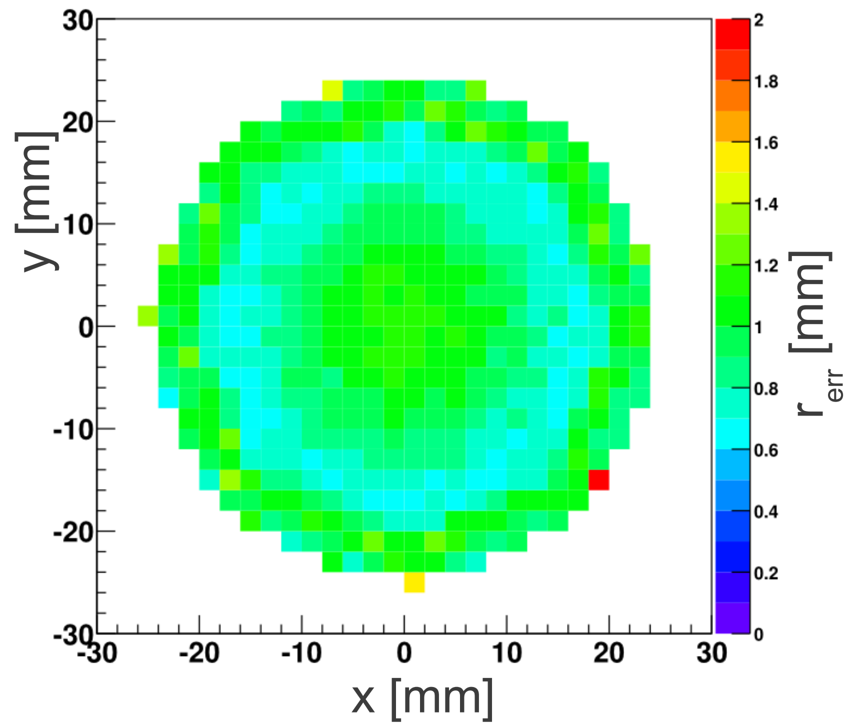
BA-thesis: Thomas Jennewein

APD: RMD S1315

gain vs. voltage

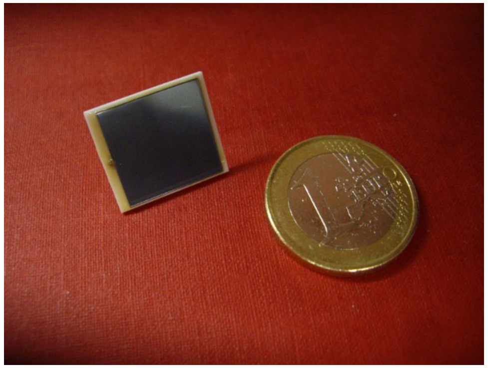


position reconstruction



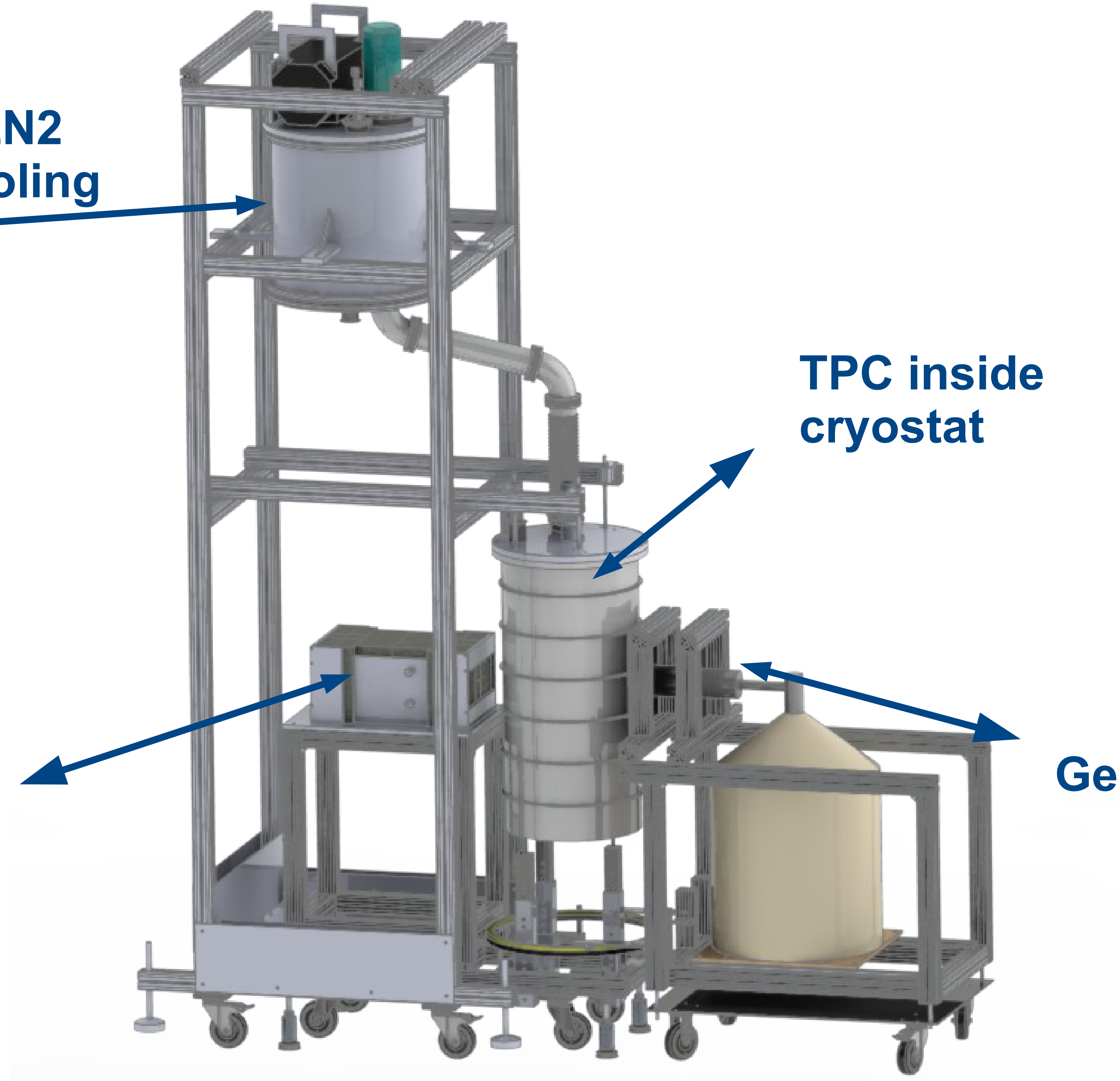
RMD S1315:

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

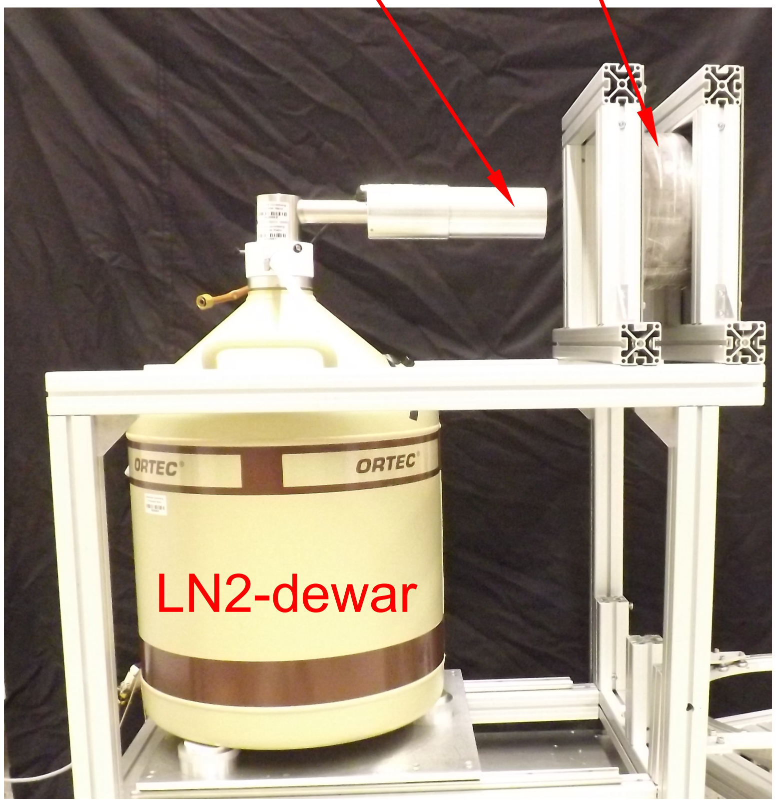


BA-thesis: Matthias Morbitzer

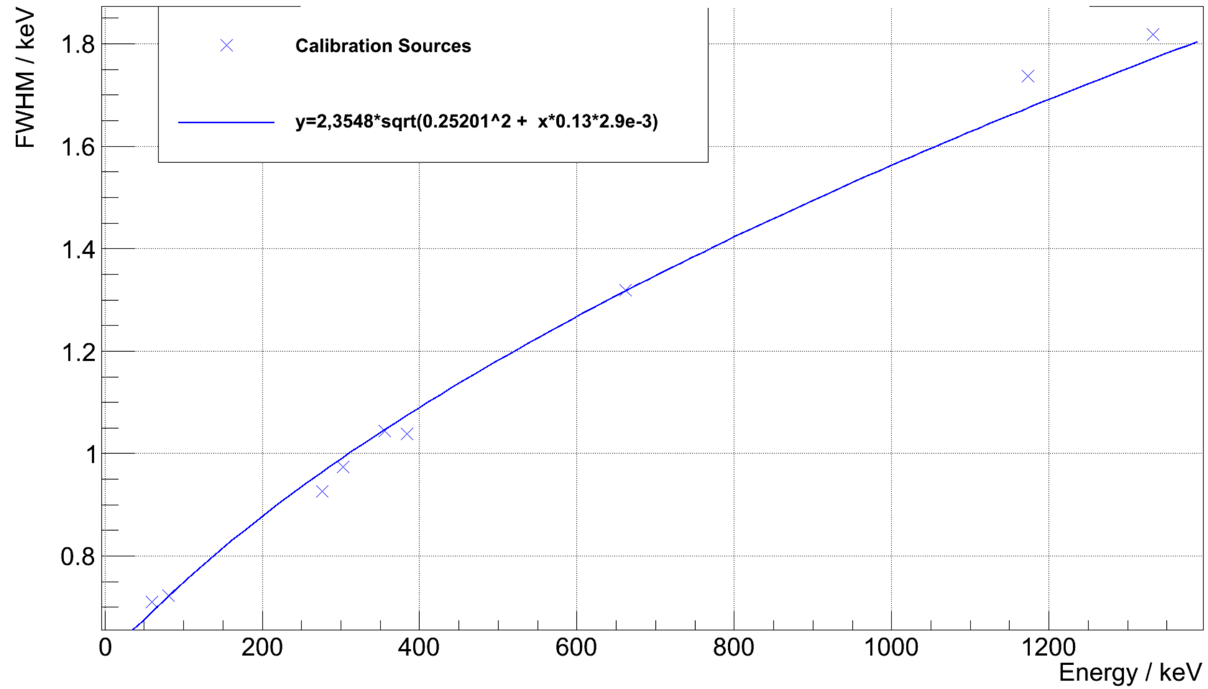
Setup for the Compton scatter experiment



Germanium detector



Measured energy resolution



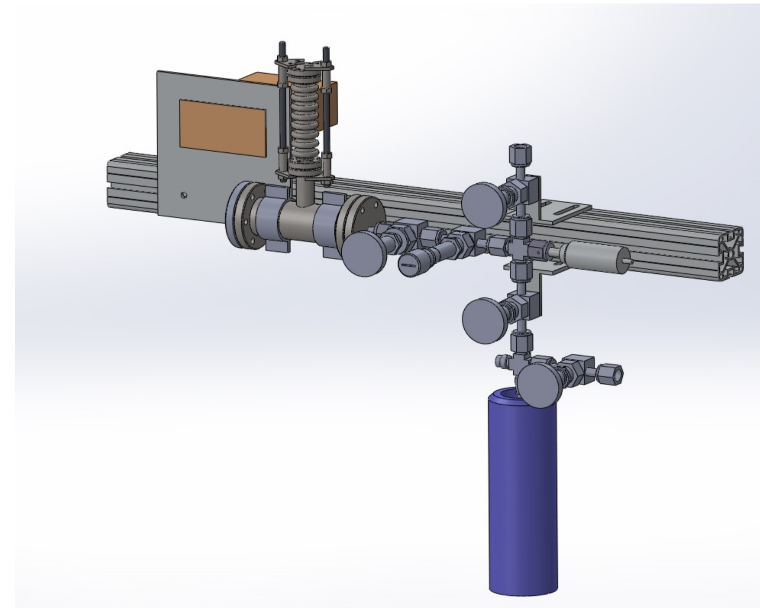
Ortec GEM HPGe:

- coaxial detector:
  - diameter: 58.8mm
  - length: 42.2 mm
- energy resolution:
  - 1.8 keV @ 1.33 MeV (^{60}Co)
  - 725 eV @ 122 keV (^{57}Co)
- efficiency: 24% @ 1.33 MeV (^{60}Co)

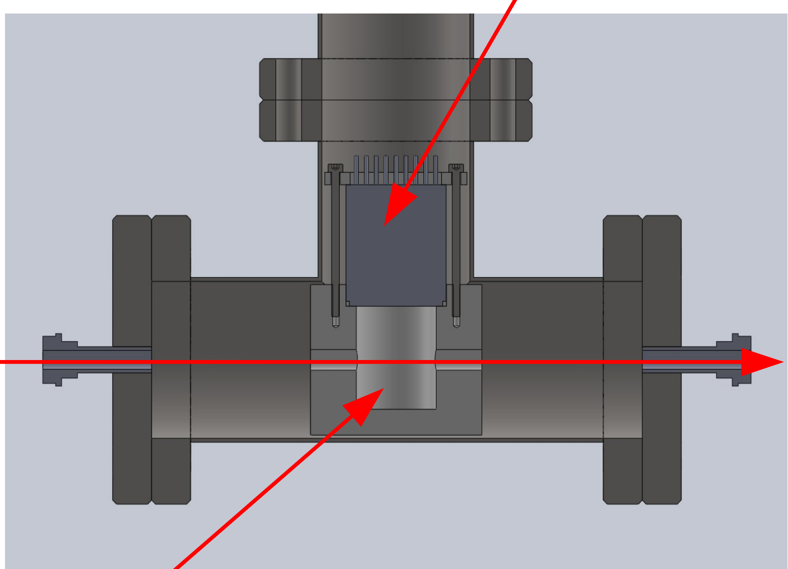
dth: Melanie Scheibelhut

Test of calibration techniques

Ampulla of ^{37}Ar produced at Mainz neutron reactor (~ $2cm^3$):
- electrons with E = 2.38 keV
- 35d half life
- nice to calibrate our TPC



Test setup with 1” PMT



Also plan to test:
- ^{83m}Kr
- tritiated methane

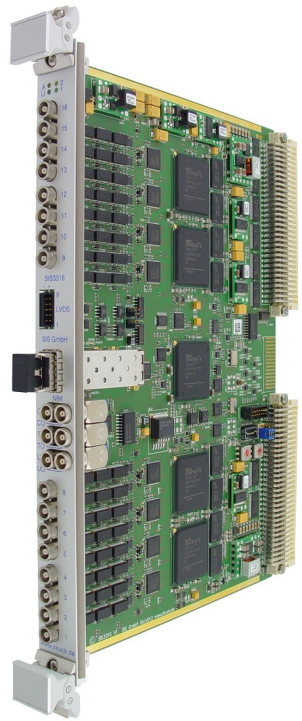
dth: Christopher Hils

Readout electronics

Struck SIS3305
- 10 bit FADC
- 2/4/8 channels
- 5/2.5/1.25 GS/s
- 1.5 GHz bandwidth

digitize PMT signal with good time-resolution

Struck SIS3316
- 16 bit FADC
- 16 channels
- 125 MS/s
- 62.5 MHz bandwidth

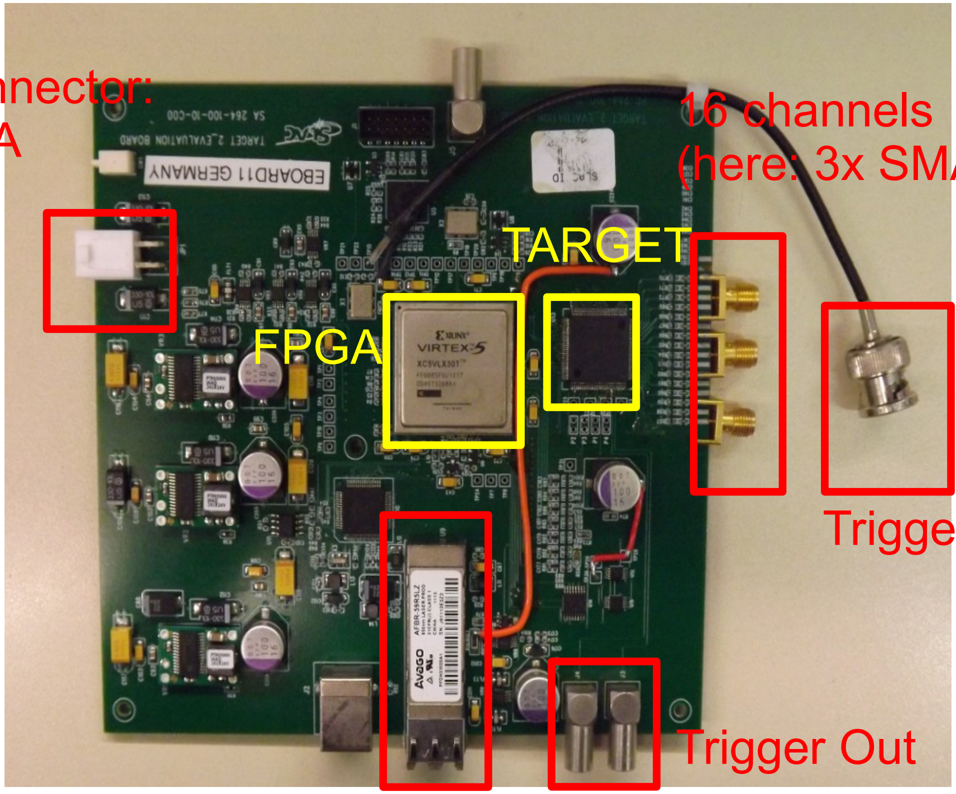


digitize Ge-detector and APDs with good energy-resolution

CAEN V1730 (new !!)
- 14 bit FADC
- 16 channels
- 500 MS/s
- 250 MHz bandwidth

Possible upgrade of XENON1T or XENONnT

Readout electronics: TARGET5 evalboard



technical specifications:

- 16 channels
- up to 12 bit resolution
- up to 1GS/s
- buffer depth: 16384 cells/channel
- trigger outputs: 4 (each sum of 4 channels)
- 0...+2.5V input signal

features:

- internal or external trigger
- DC offset can be applied
- input impedance can be changed for each channel 100/1k/10k Ohm

K. Bechto et al., Astropart.Phys. 36 (2012) 156-165

Status and future

Done:
- PMT and APD tests
- Ge detector test
- TPC construction
- Slow control

Ongoing:
- "finalize" gas system & commissioning.
- Construction of cryogenic system
- Testing level meters
- DAQ and trigger system

Next steps:
- Test calibration gas
- Commissioning TPC & cryogenics

Thanks to the Mainz XENON group

U. Oberlack, R. Othegraven, C. Grignon

PhD students: B. Beskers, P. Sissol

Master students: M. Scheibelhut, C. Hils

Bachelor theses: E. Kjartansson, T. Jennewein, M. Morbitzer

Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter
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Symmetry Breaking

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