Commissioning of a Dual-phase Xenon TPC and first Compton Scatter Results

Pierre Sissol

Institut für Physik
Johannes Gutenberg-Universität Mainz

DPG Frühjahrstagung
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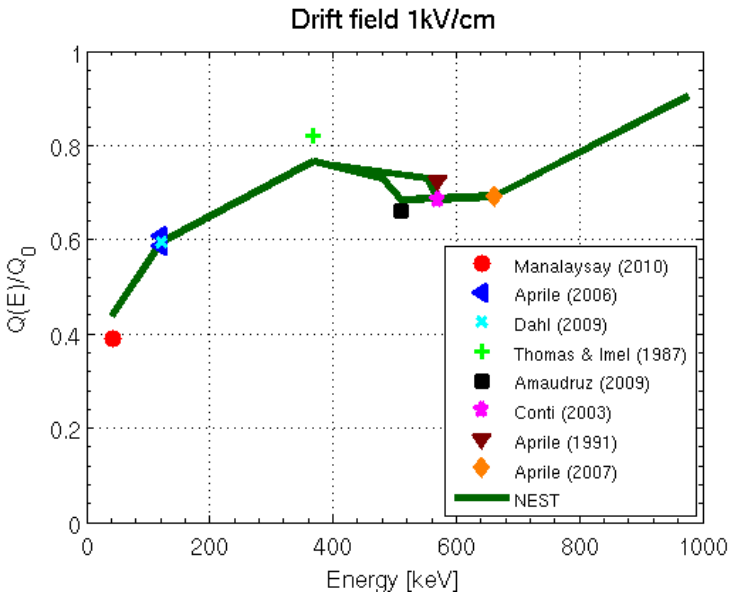
Motivation

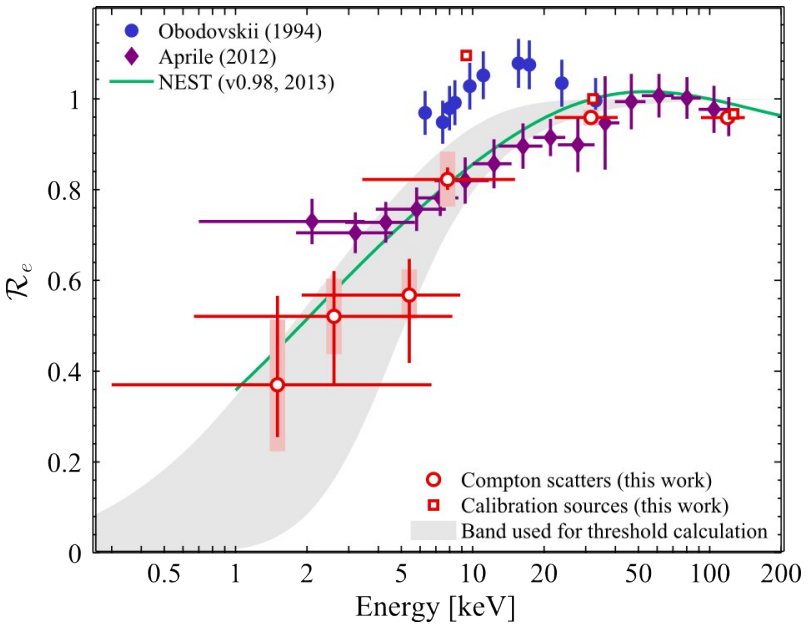
charge yield

scintillation yield

electronic recoils

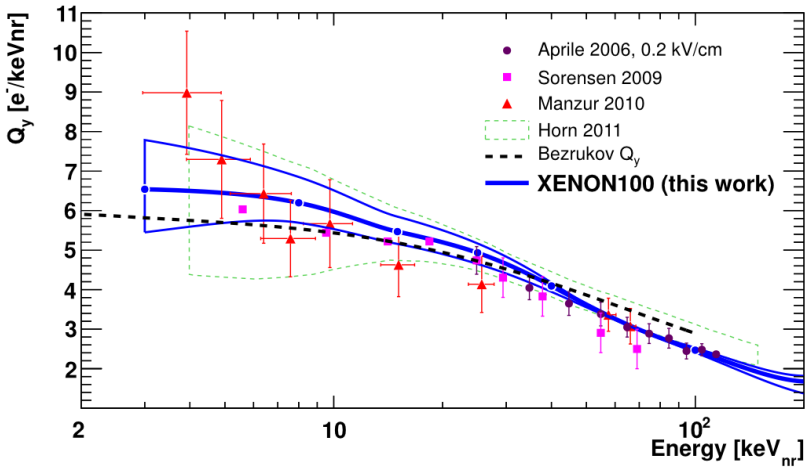


JINST 6 p10002 (2011)

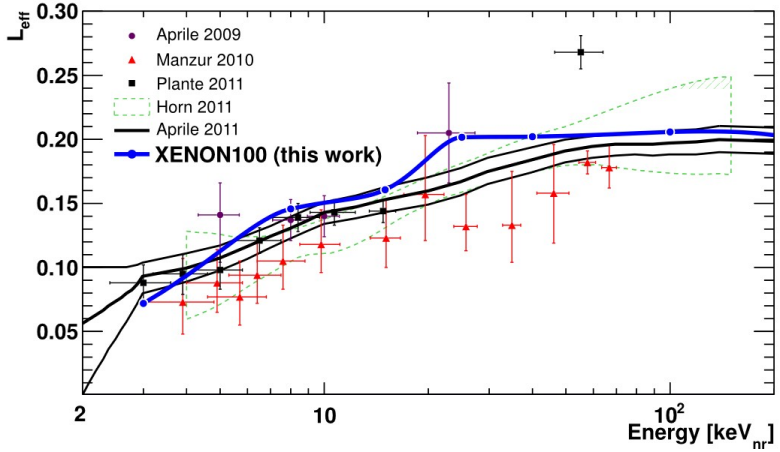


Phys.Rev.D 87, 115015: L. Baudis et al.

nuclear recoils

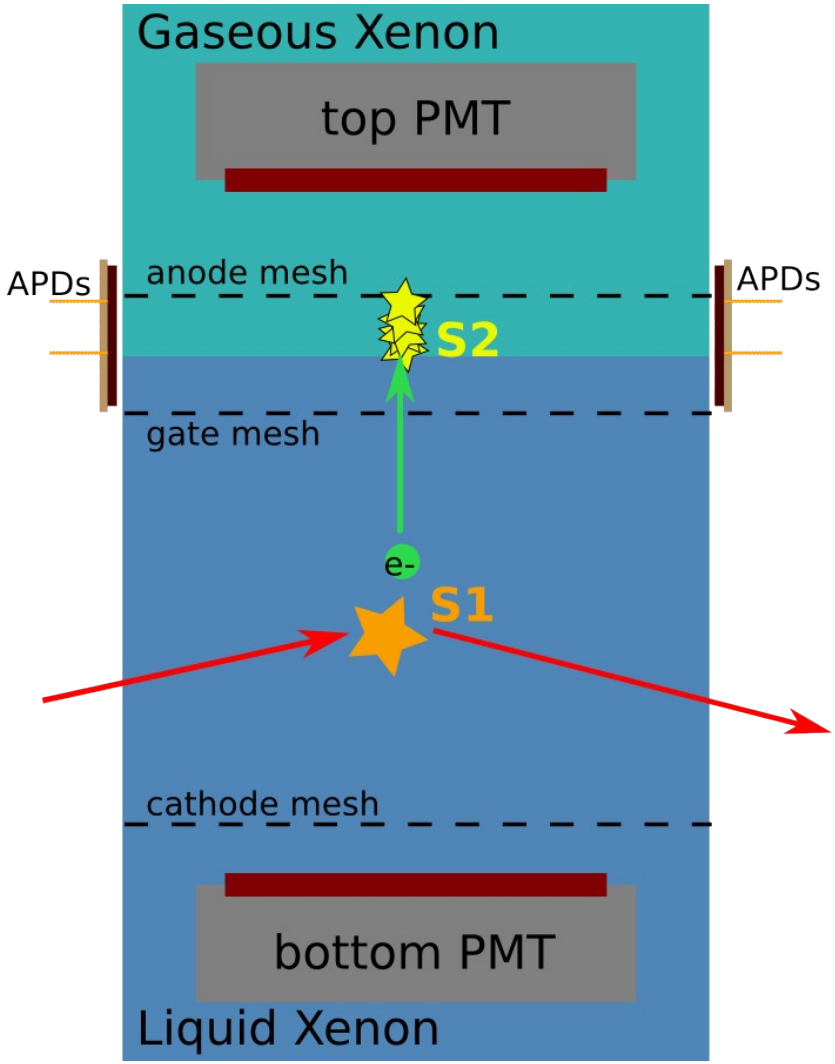


Phys.Rev.D 88, 012006: E. Aprile et al. (XENON100 Collab.)

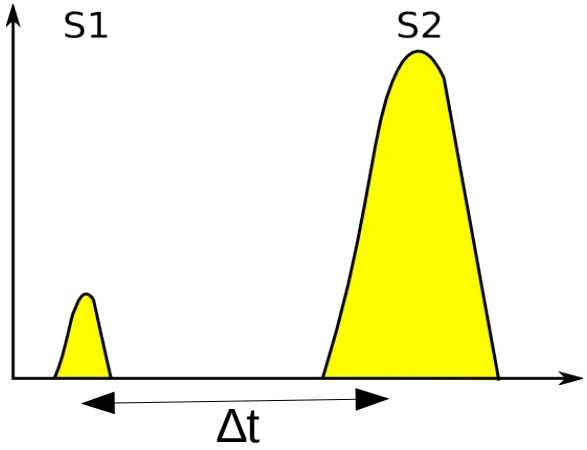


Phys.Rev.D 88, 012006: E. Aprile et al. (XENON100 Collab.)

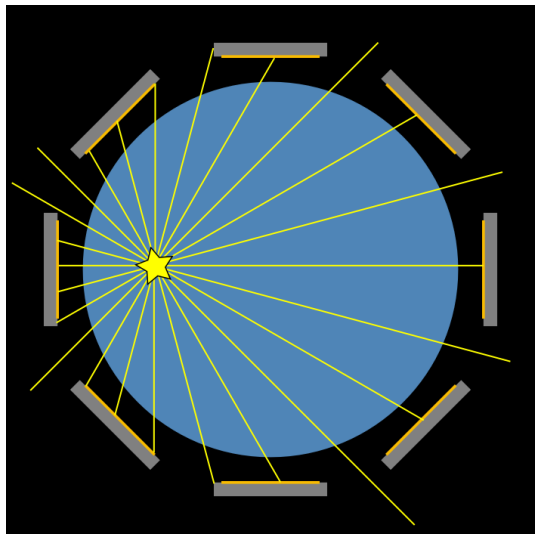
Principle of the MainzTPC



z-position
reconstructed by electron drift time:
$z = \Delta t \cdot v_{drift}$

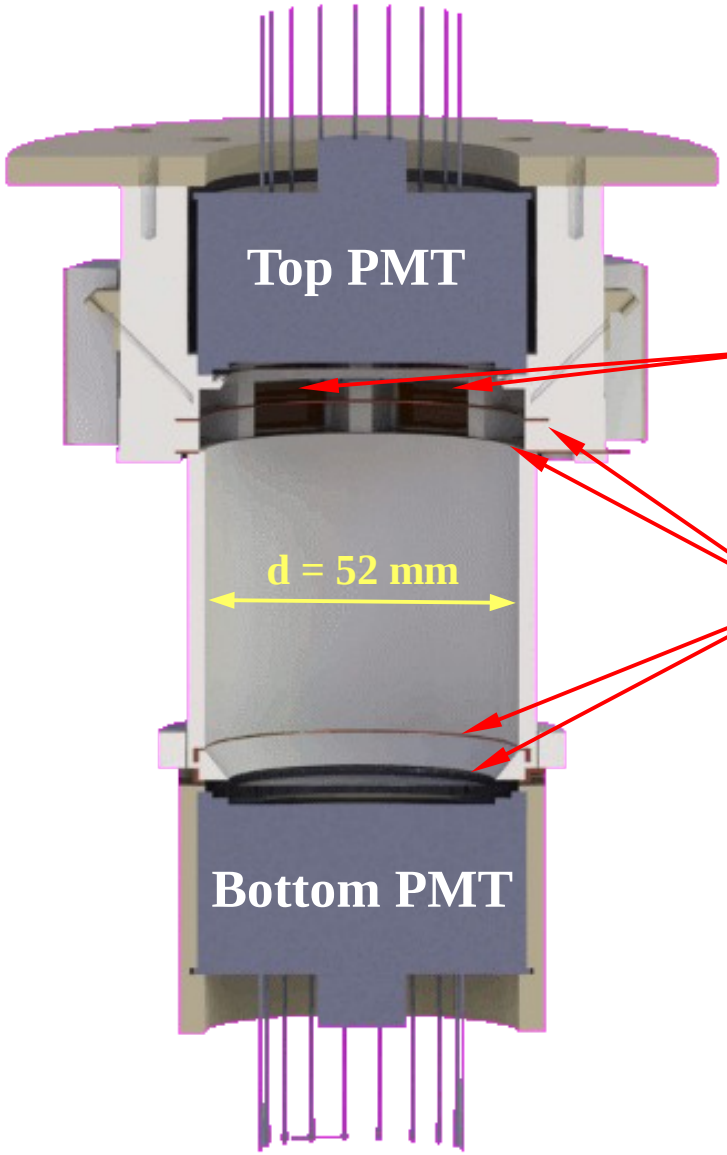


x/y-position
position of S2 detected by a photosensor array



The MainzTPC

Optimized Setup for single interaction Compton Scattering:



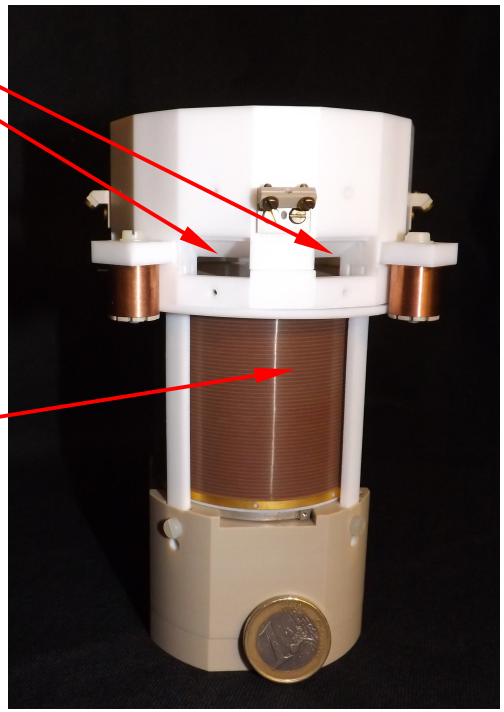
2 PMTs
QE @ 178 nm ~ 30 %

8 APDs
x/y position resolution

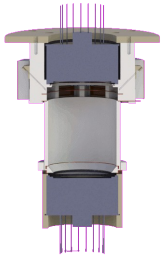
Meshes
high transparency
fine pitch

Field Cage
PCB => low passive mass

- high light yield
  (high reflectivity materials)
- small size (active mass ~300g)
- 3D position resolution
  ($\Delta d_{xy} \leq 1.3$mm; $\Delta d_z \approx 1$mm)
- small amount of passive material

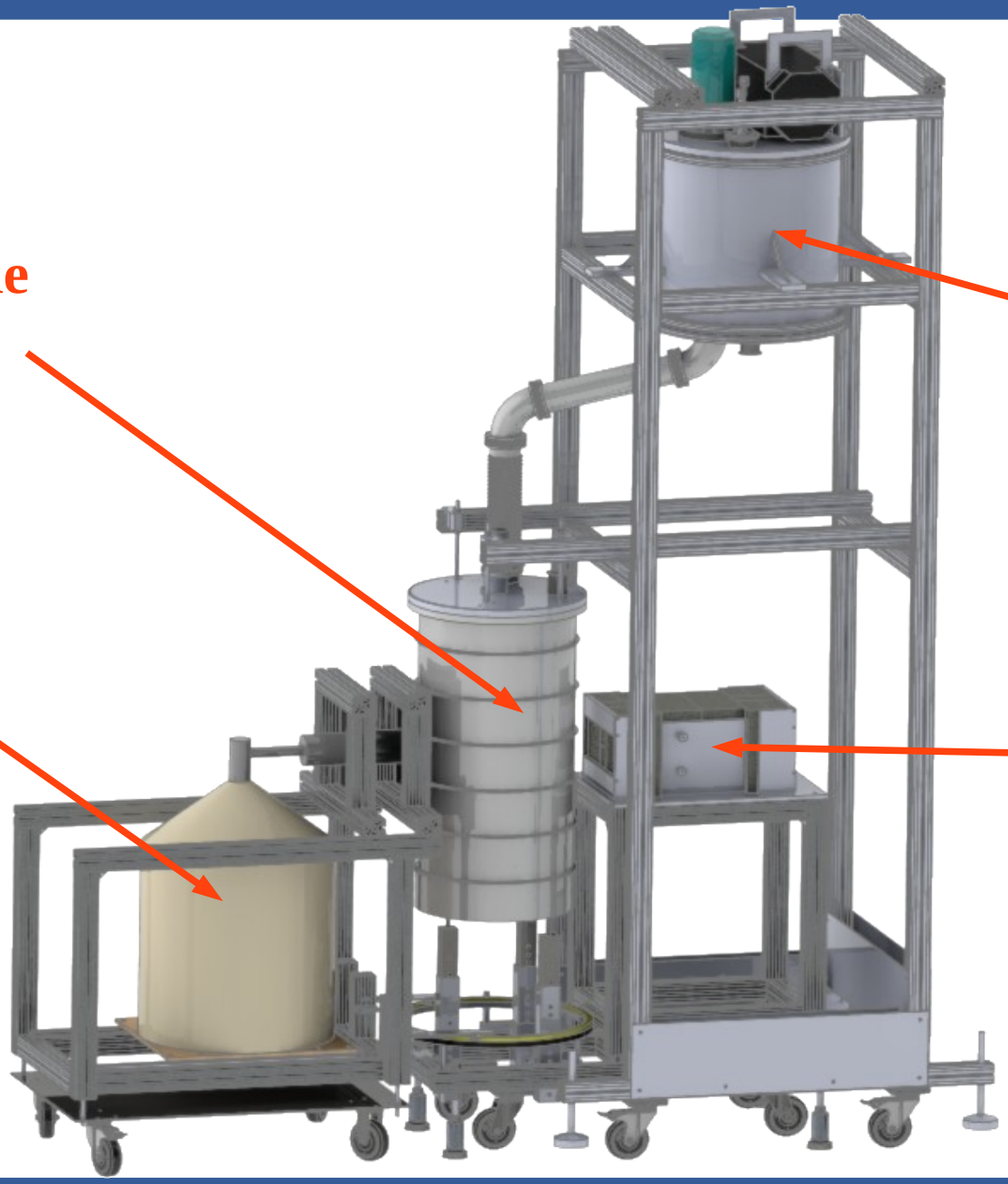


The MainzTPC Compton Setup



TPC inside cryostat

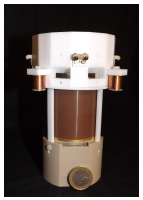
Ge-detector



pulse tube refrigerator + LN2 emergency cooling

collimator for γ-source

The MainzTPC Compton Setup



TPC inside cryostat

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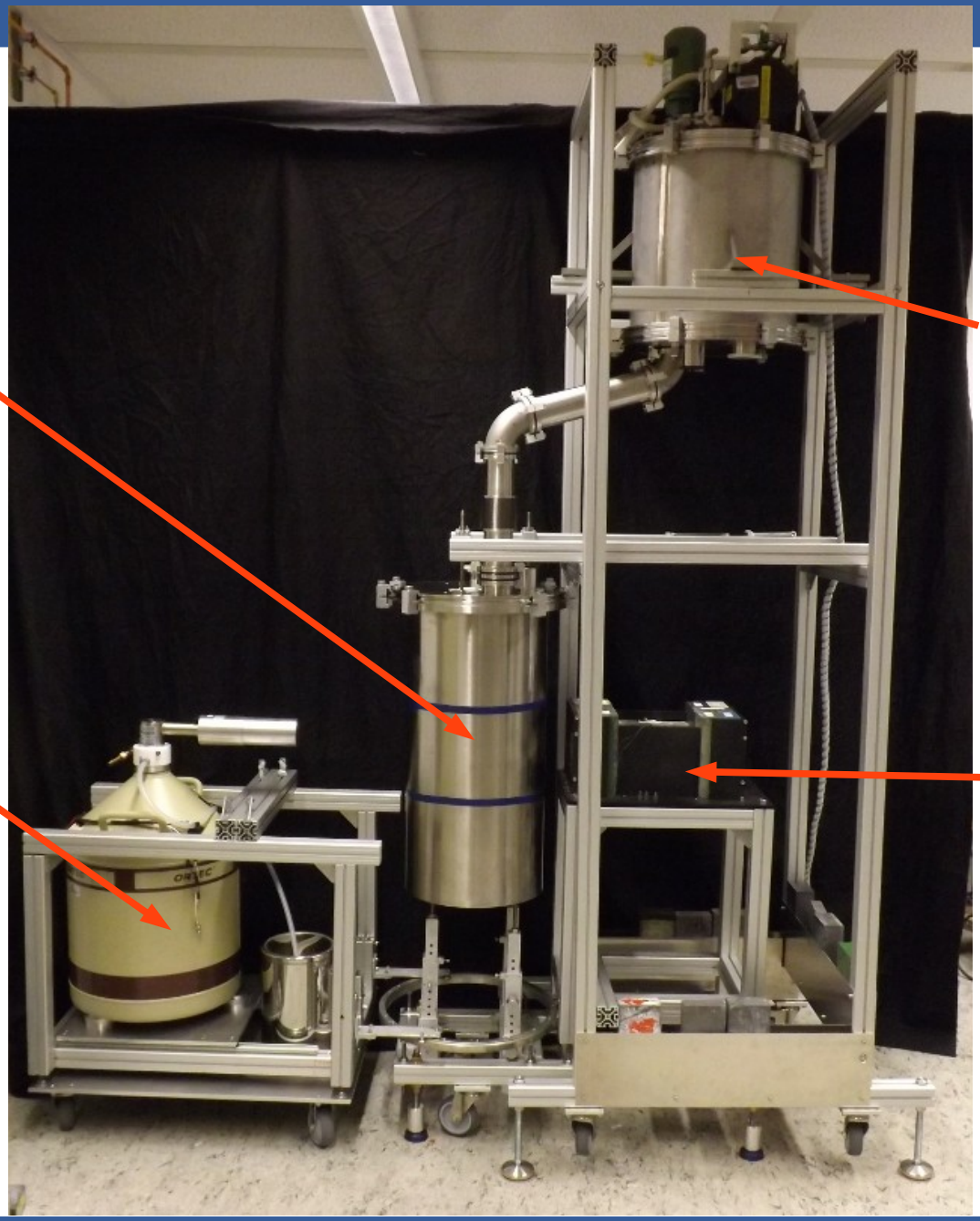


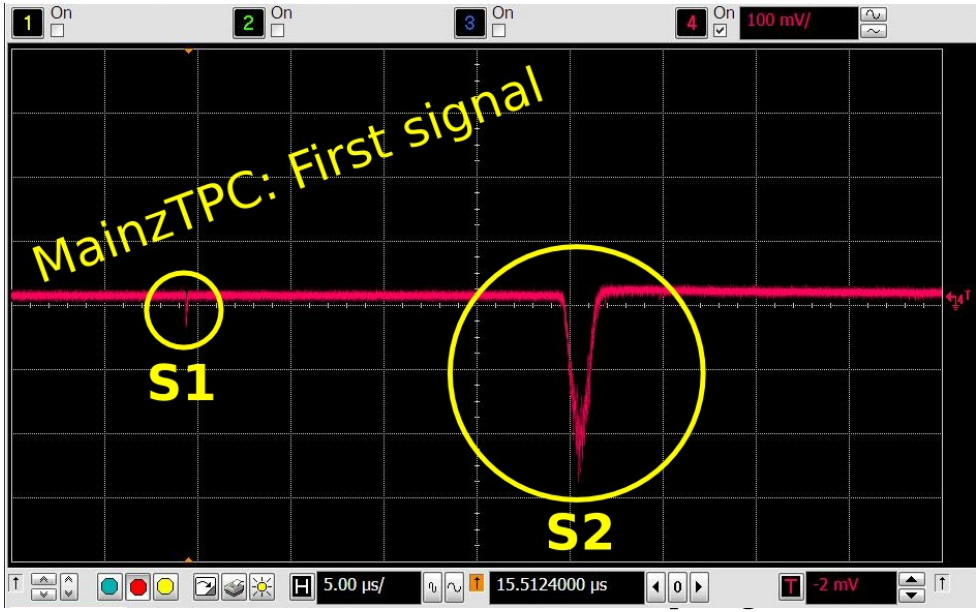
pulse tube refrigerator + LN2 emergency cooling

collimator for γ-source

Measurements

First runs successfully done:

- Oct 2014
  First application of drift and extraction fields →



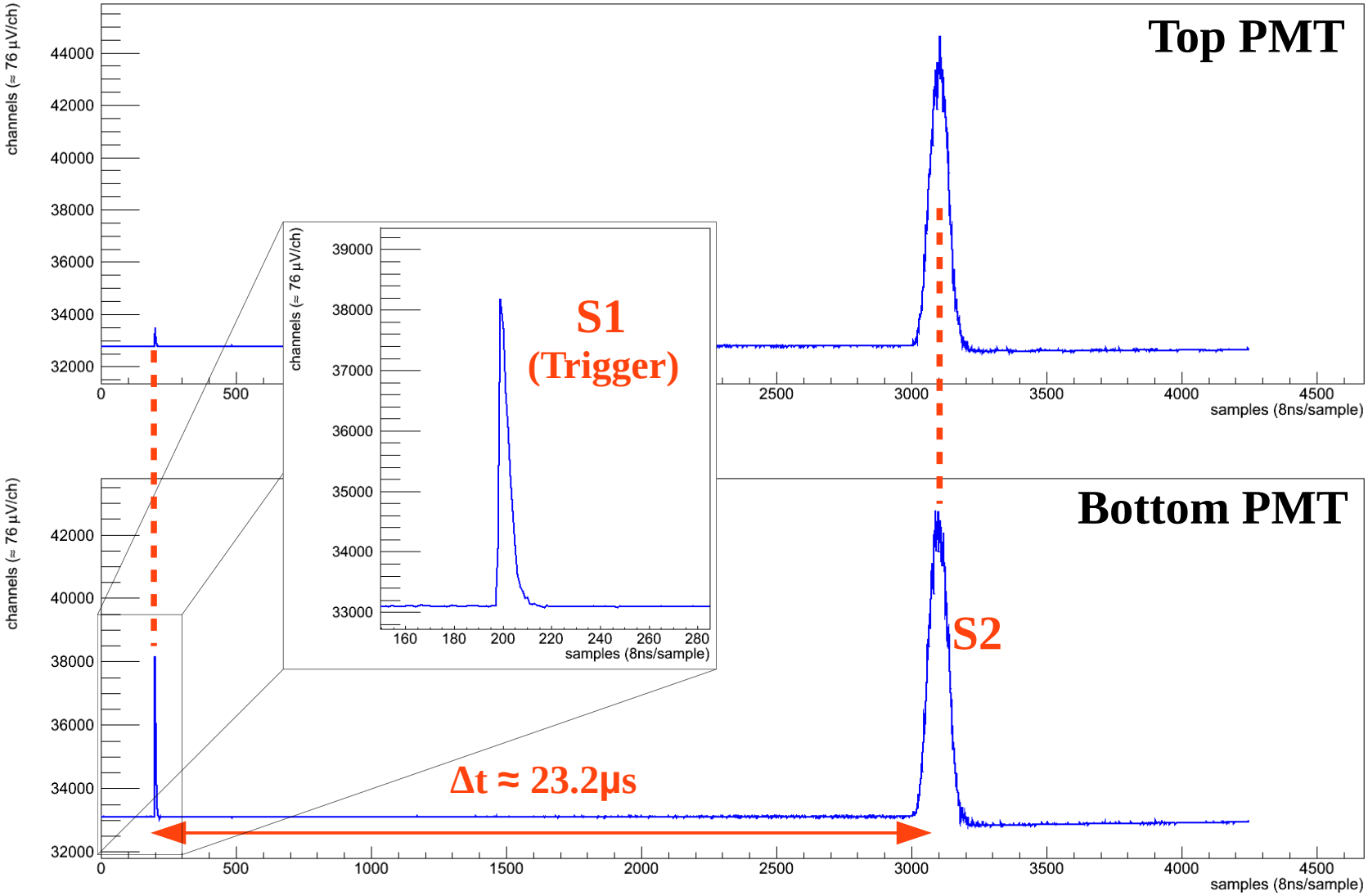
- Nov 2014
  Test of all sensors (PMTs, APDs, Ge detector)
  → no S2, no coincidence mode

- Dec 2014
  S1 + S2 measurements
  First Compton scatter measurements
  (analogue coincidence trigger)

Outcome:

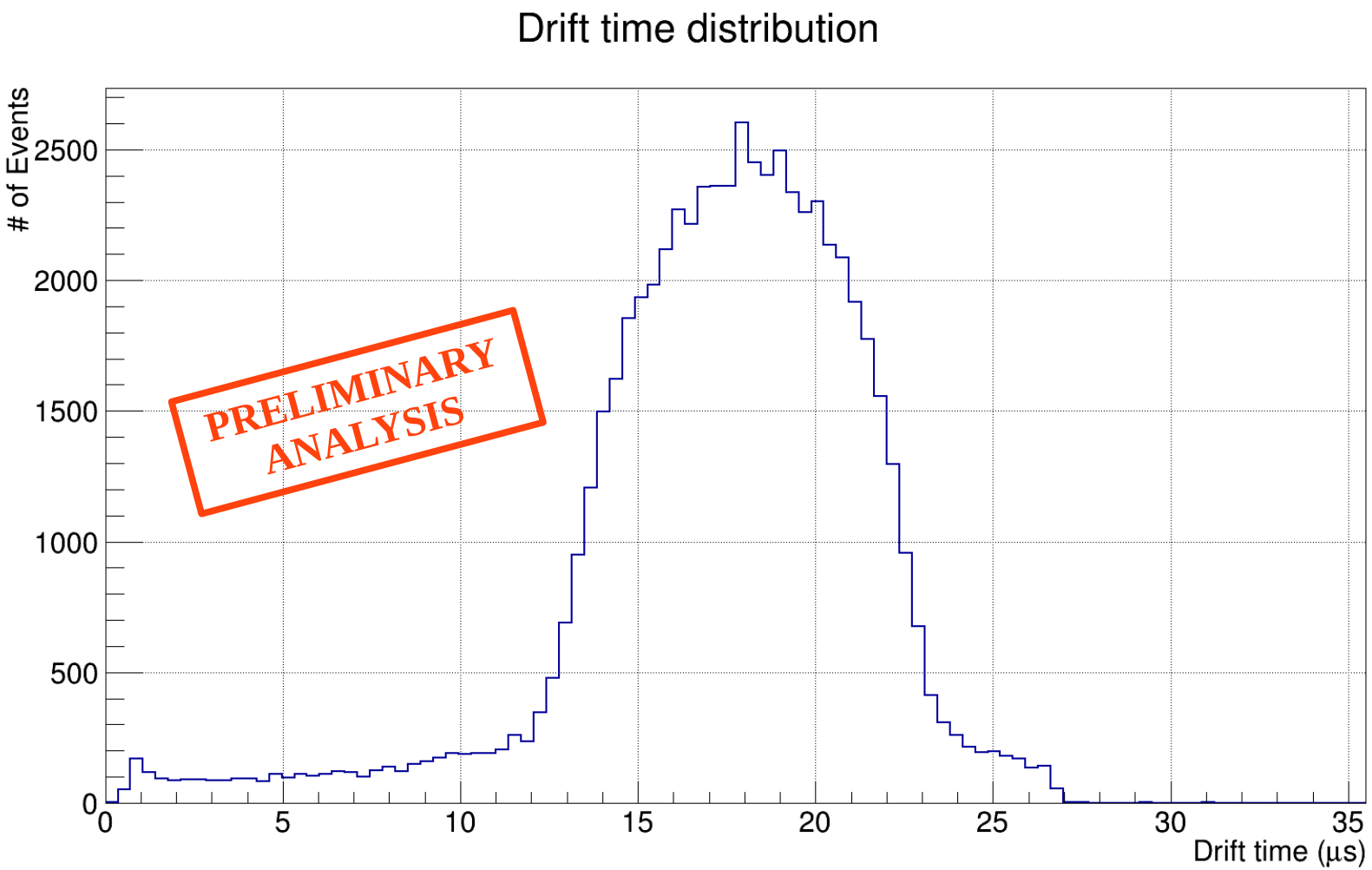
- Datasets to develop analysis routines
- Experimental prototype: identification and resolution of issues

S1 and S2 signals for for ^{137}Cs



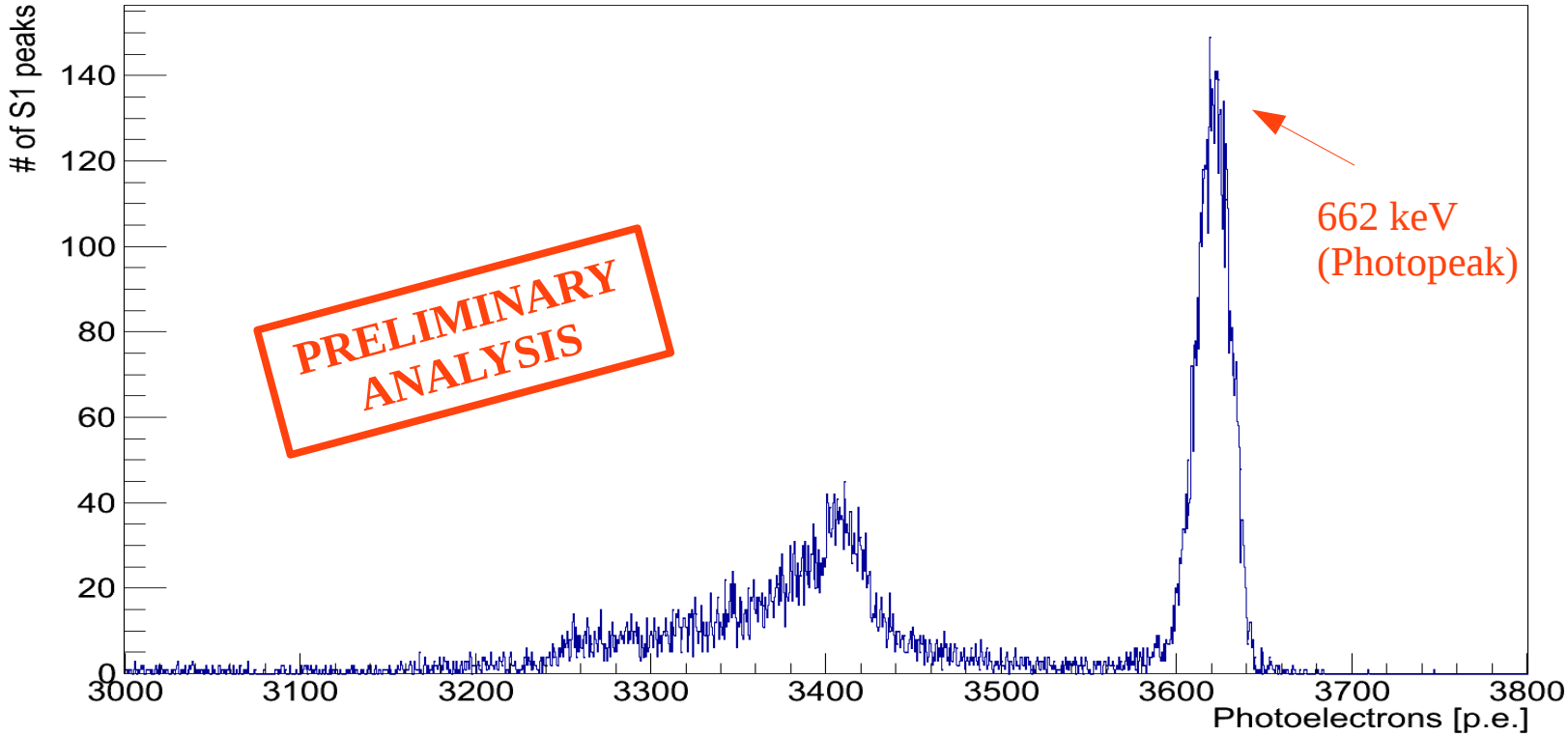
- ^{137}Cs source
- no coincidence
- Trigger on S1
- Drift field: 0.4 kV/cm
- Drift time close to maximum of Δt ≈ 30 µs with our TPC

Electron Drift Time



- ^{137}Cs source
- strong collimation
- Trigger on S1
- Drift field: 0.8 kV/cm

S1 spectrum for ^{137}Cs (662 keV)

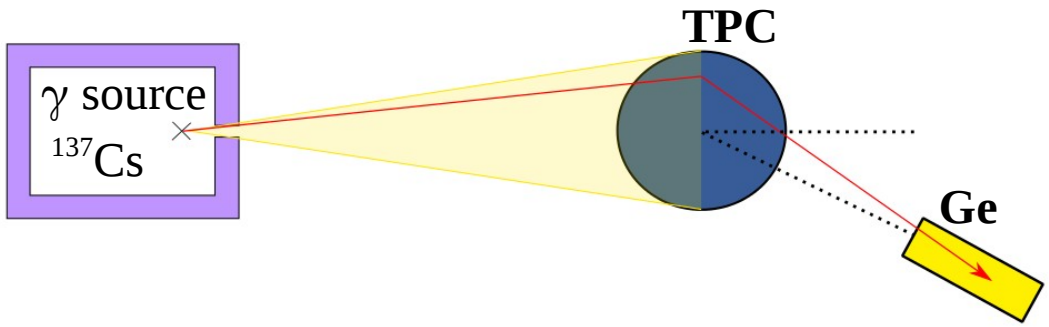


- collimated source
- Trigger on S1 signals
- all scatter angles occur
- No drift field
- No coincidence with Ge detector

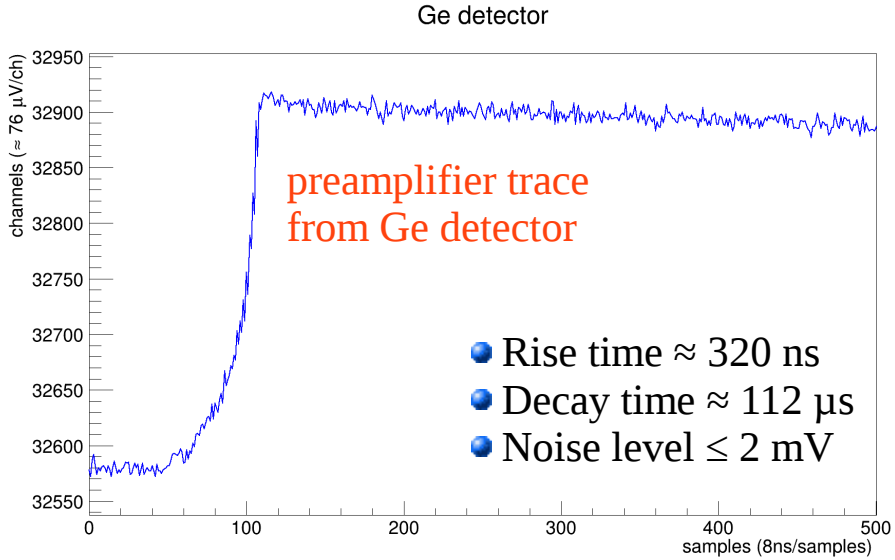
Problem with calibration
→ Nominal gain of PMTs at supply voltage was used

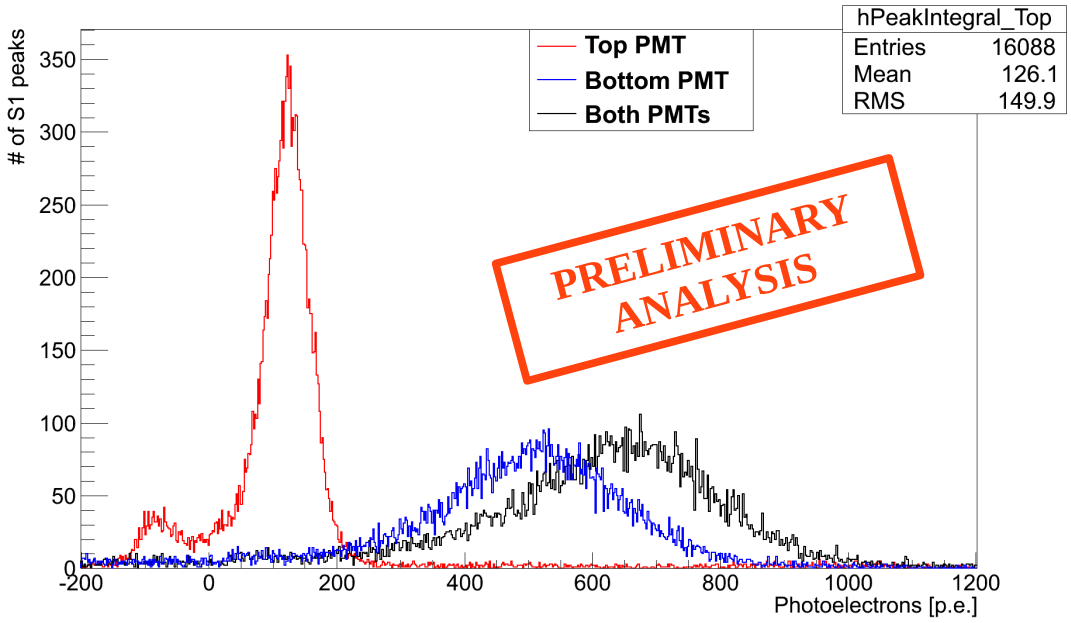
Estimated LY ≤ 5 pe/keV (only bottom PMT)

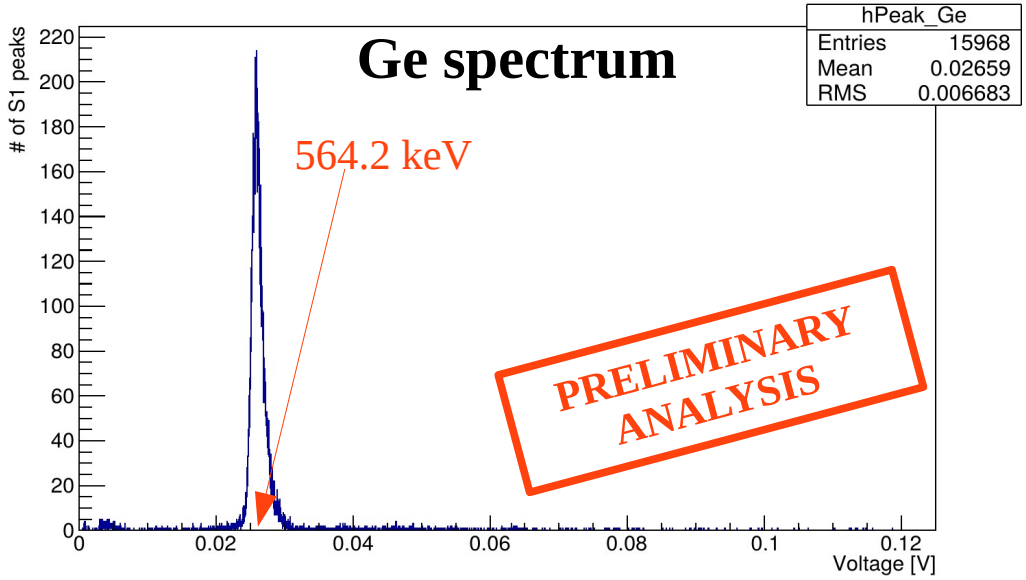
Compton scatter measurement



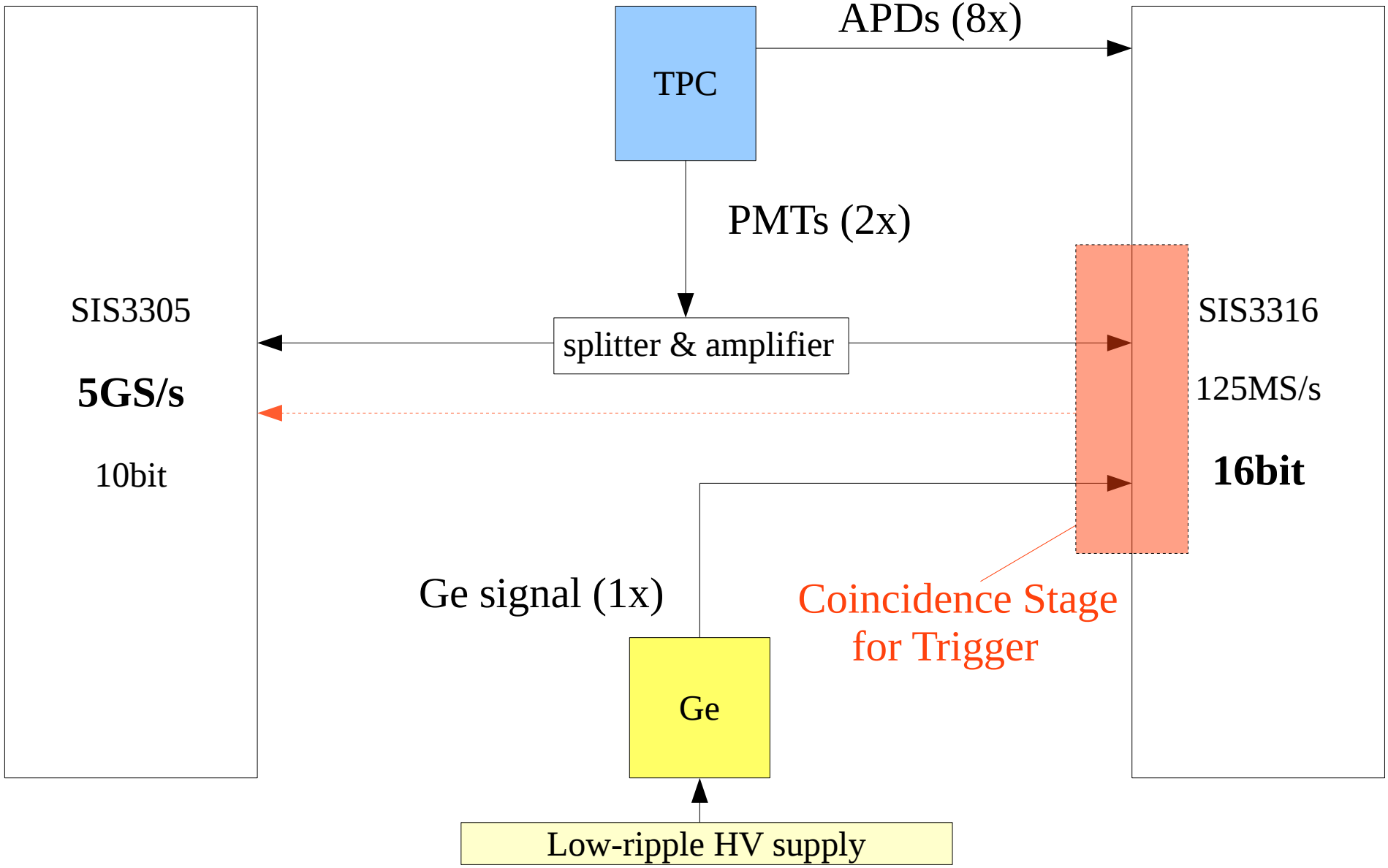
- Ge detector at 30° → ~97.8 keV energy deposit in TPC
- no position reconstruction applied





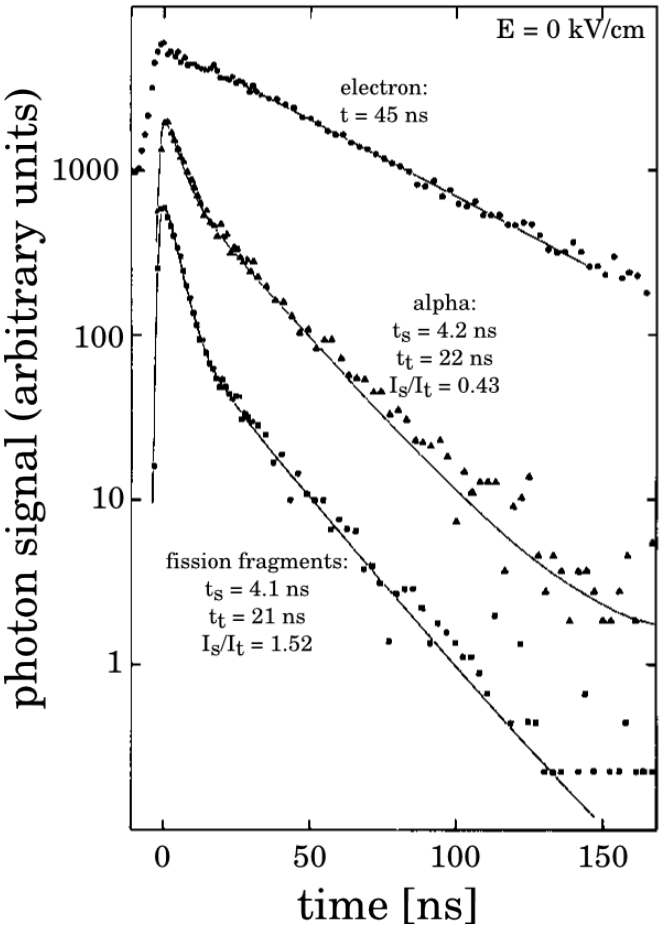


DAQ system for Compton scattering

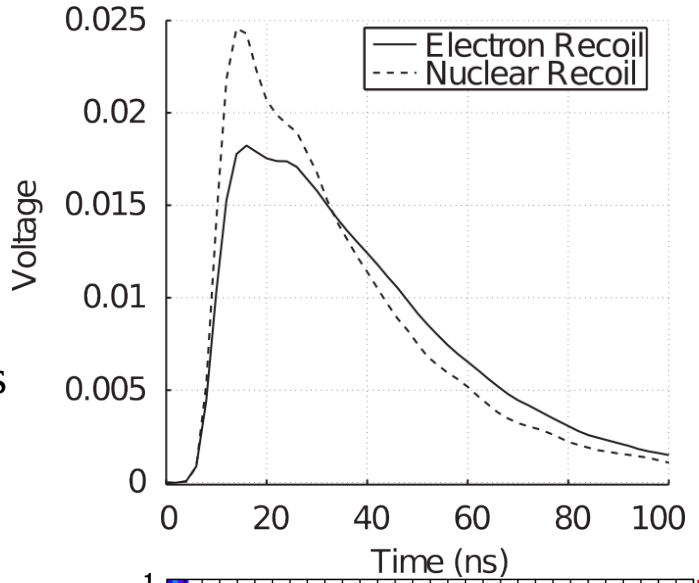


Scintillation Pulse Shape

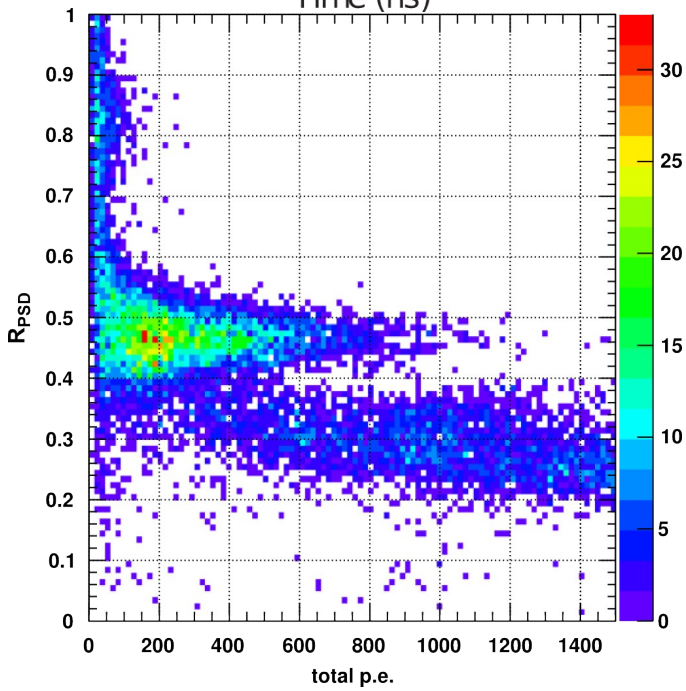
Complementary background discrimination method:



- LXe has 2 decay components (singlet, triplet state of Xe_2^*)
- Fast component ≈ 2 ns
- Slow component ≈ 27 ns
- Pulse shape is dependent of the applied electric field
- works already well in LAr
- challenging in LXe



NIM A612(2010): J. Kwong et al.



NIM A659(2011): K. Ueshima et al.

Phys. Rev. B 27, 5279 1983

Scintillation Pulse Shape

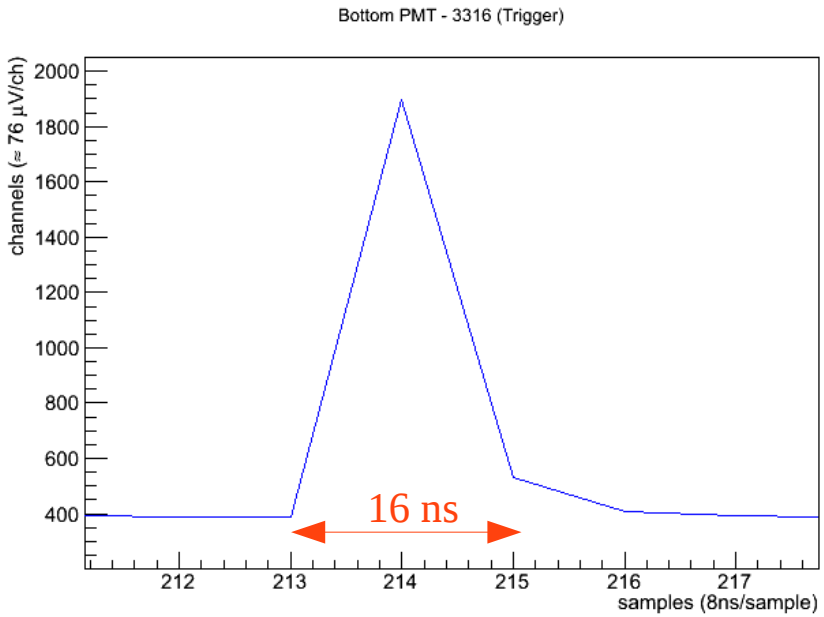
- PMT signal is splitted
- fast electronics for examination of the pulse shape

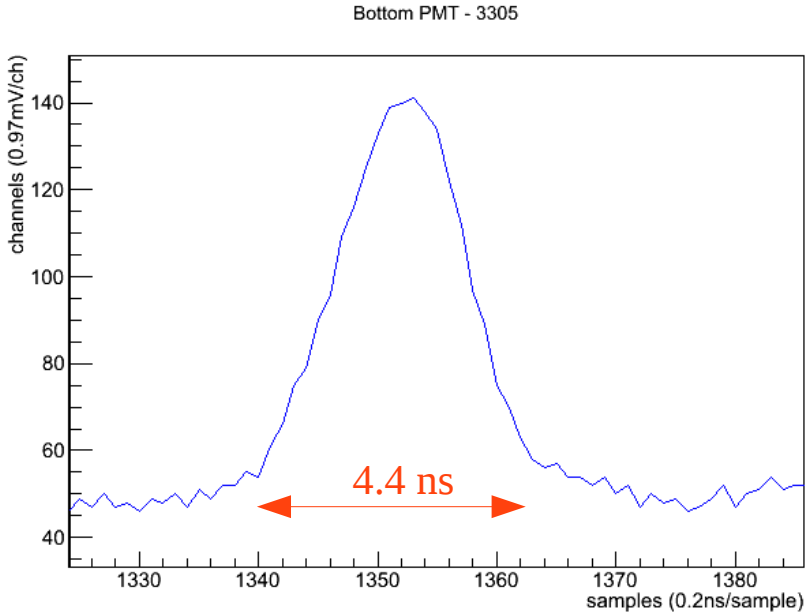
Slow FADC:
125MS/s
16 bit

x 40

Fast FADC:
5GS/s
10 bit

test-pulse width: ~ 4 ns





Preparing the next run

Hardware issues:

- ✔ Crosstalk between PMTs and APDs
  → new shielding developed
- ✔ Liquid level oscillations → occasional disappearance of S2 signal
  → introduced additional connections between volumes to grant pressure exchange
- ● Noise sources identified: PTR controller, levelmeters

Software issues:

- ● Identified bugs and inconsistencies in DAQ system
  → debugging and improving, working on new data format
- ✔ FADC firmware improvements for dedicated FADC onboard coincidence modes

Summary

- MainzTPC works: S1 and S2 signals measured
- First analysis results
- Changes and improvements on setup are carried out

- Next MainzTPC run coming soon with improved setup and DAQ system
- Include yet unused functionalities, such as position reconstruction
- More sophisticated data analysis (scintillation yield, pulse shape)
- Nuclear recoil measurements planned

Any questions?

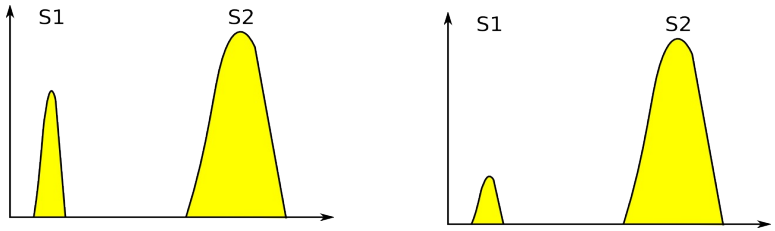
Thanks to my collaborators:

Bastian Beskers
Christopher Hils
Melanie Scheibelhut
Rainer Othegraven
Cyril Grignon
Uwe Oberlack

Pierre Sissol
sissol@uni-mainz.de

Backup

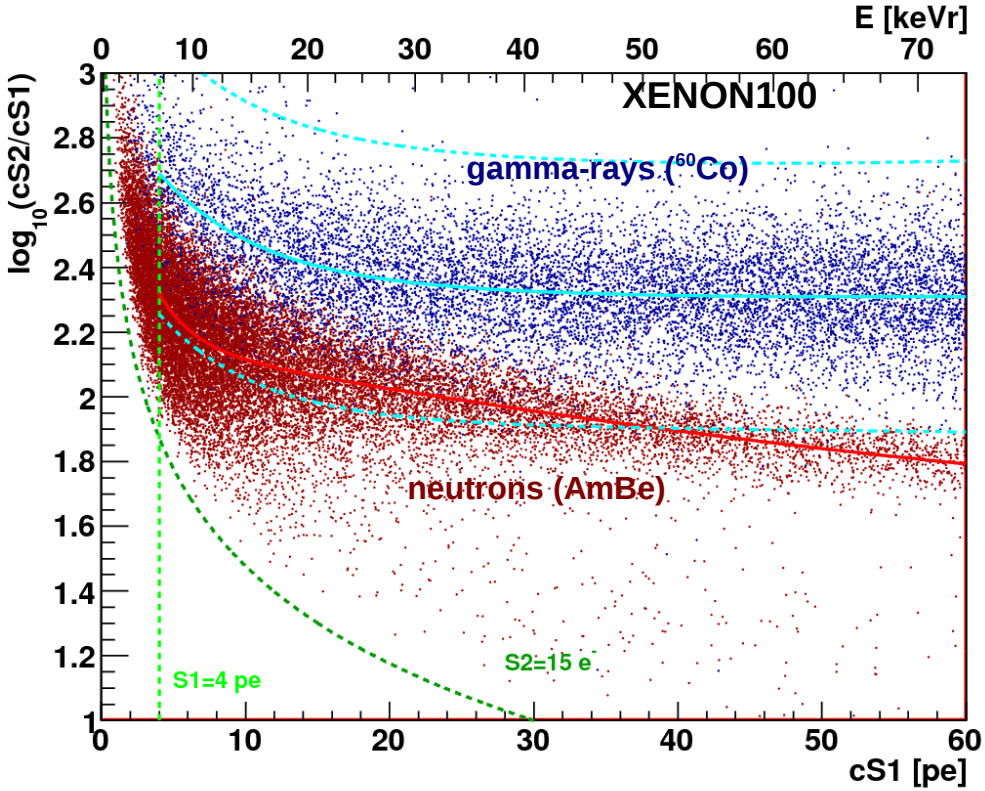
nuclear recoil (NR)
neutron, WIMP



electronic recoil (ER)
electron, gamma

S2/S1 (NR) < **S2/S1 (ER)**

Background discrimination in Dark Matter experiments

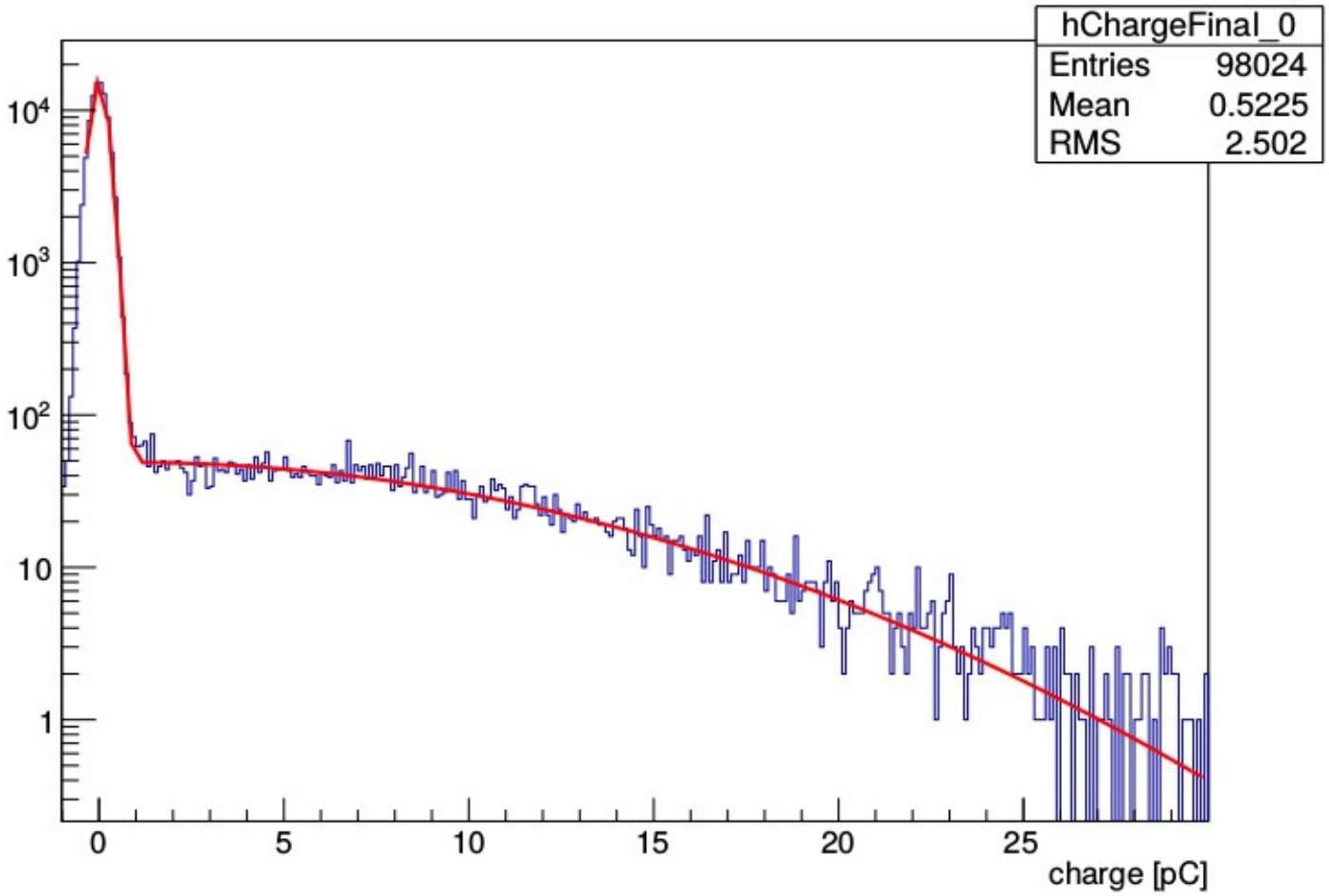


Similar in:
2013: E. Aprile et al. (XENON100 Collab.): "*Dark Matter Results from 225 Live Days from XENON100 Data*"

Backup

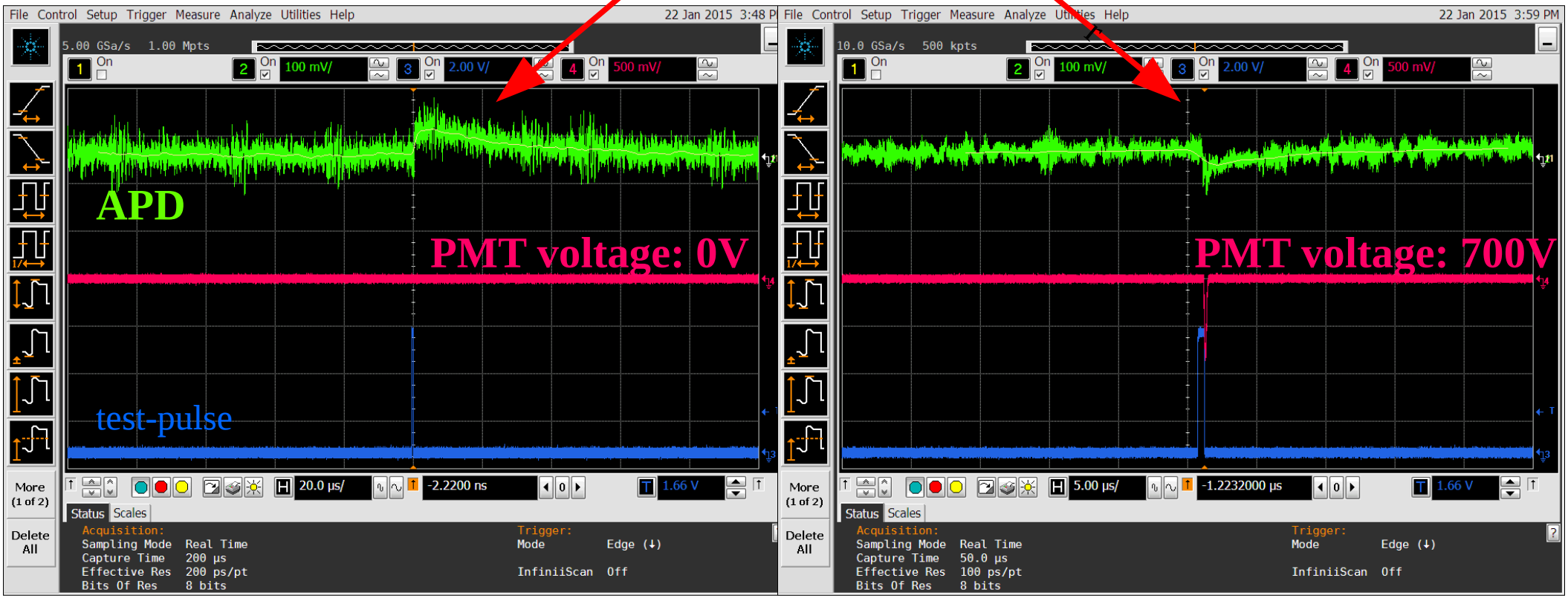
PMT Calibration:

- SPE peak lies within noise peak
- Noise peak is too broad
- Cause yet unclear



Backup

APD PMT Crosstalk

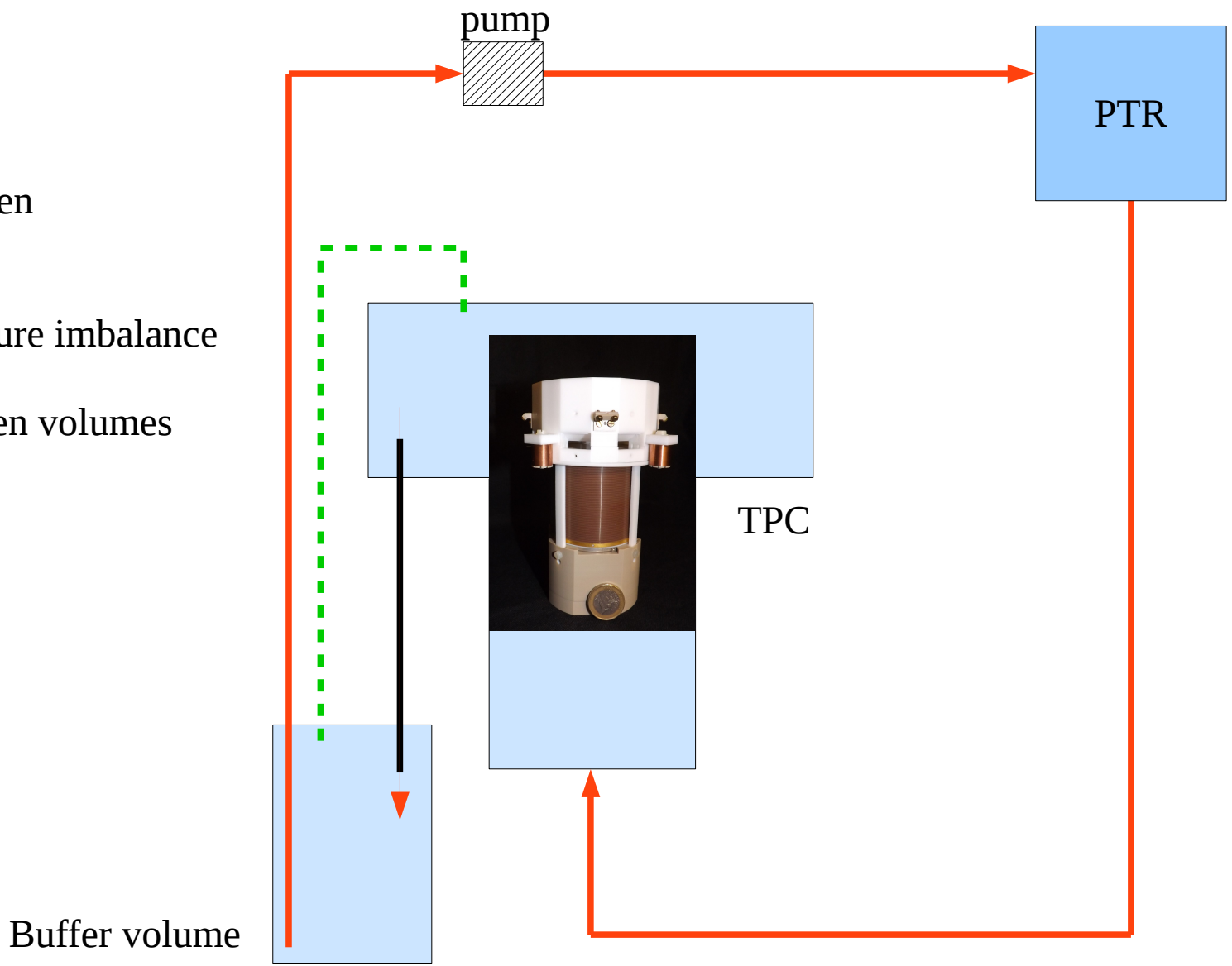


APD (green) supply voltage: 1510V

Backup

Liquid level oscillations:

- very thin connection between TPC and buffer volume
- LXe outflow → GXe pressure imbalance
- New gas connection between volumes → pressure compensation



Backup

Levelmeter noise

- Capacitive levelmeters
- Readout of time constant by charging / discharging

Coincidence Trigger setup

- Nov 2014:
  no coincidence

- Dec 2014:
  analogue coincidence stage (NIM)

  → **CH10 & CH11**
  (bottom PMT & Ge detector)

- Feb 2014:
  new firmware allows wide range of
  different setups onboard

- next Trigger configuration:

  → **(CH9 OR CH10) & CH11**
  (at least one PMT & Ge detector)