XENON and DARWIN R&D in Switzerland

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2nd CHIPP Workshop on Detector R&D
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PSI, Switzerland

Universität Zürich[UZH]

XENON & DARWIN: Dark Matter

- Both the XENON and DARWIN projects aim to directly detect Dark Matter.
- XENON: work for XENON1T already started on construction at LNGS.
- DARWIN: logical successor in the multi-ton-scale range of experiments.
- Both projects require large R&D efforts of which Swiss institutes are a big part.

XENON and DARWIN R&D in Switzerland

- Both XENON and DARWIN have a strong presence in Switzerland through UZH, UNIBE and ETH.

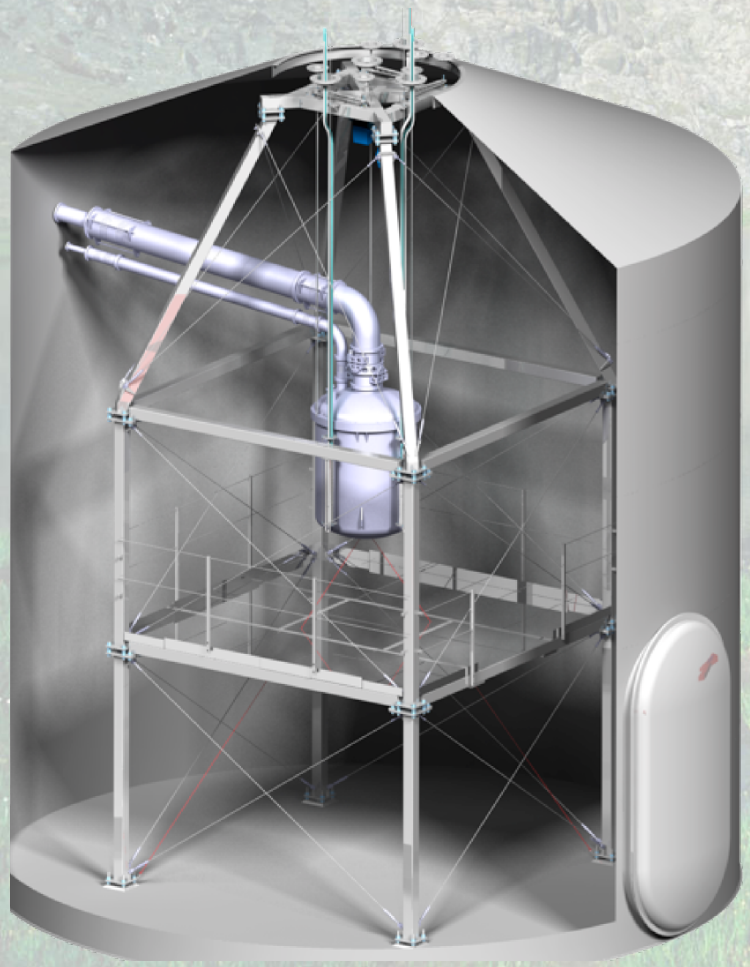
UZH:
L. Baudis (XENON, DARWIN)
B. Kilminster (DARWIN)

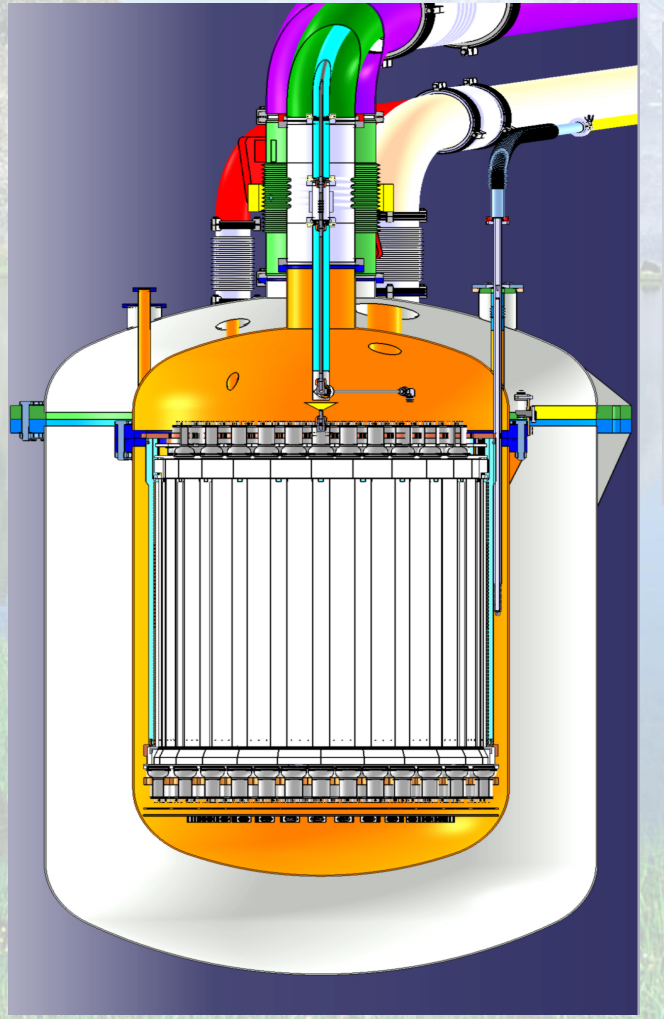
UNIBE:
C. Amsler (DARWIN)
M. Schumann (XENON, DARWIN)

ETH:
A. Rubia (DARWIN)

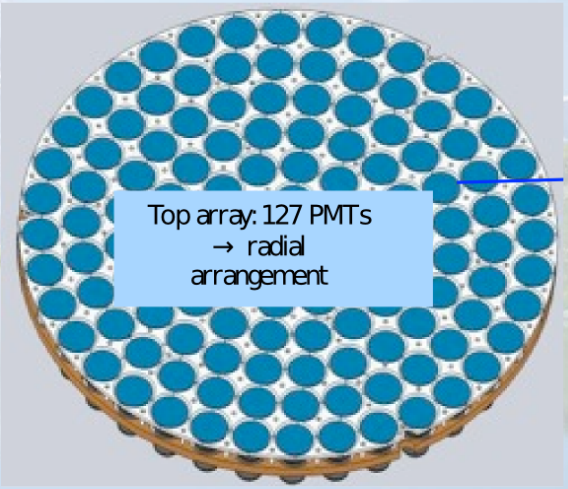
XENON1T

- 3500 kg of liquid xenon with a fiducial volume of about 2000 kg.





127 3” sensors top

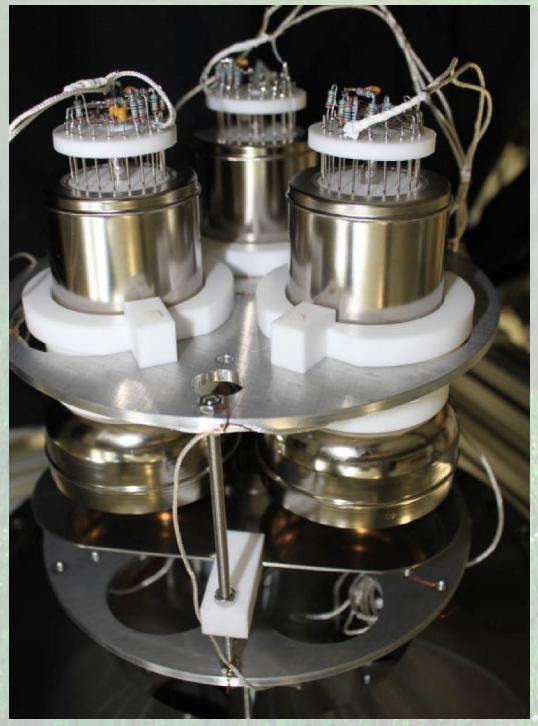


121 3” sensors bottom

XENON1T: Photomultipliers

- 248 3” R11410-21 from Hamamatsu.
- QE of 34% at 178 nm wavelength

J INST 8 P04026 (2013)

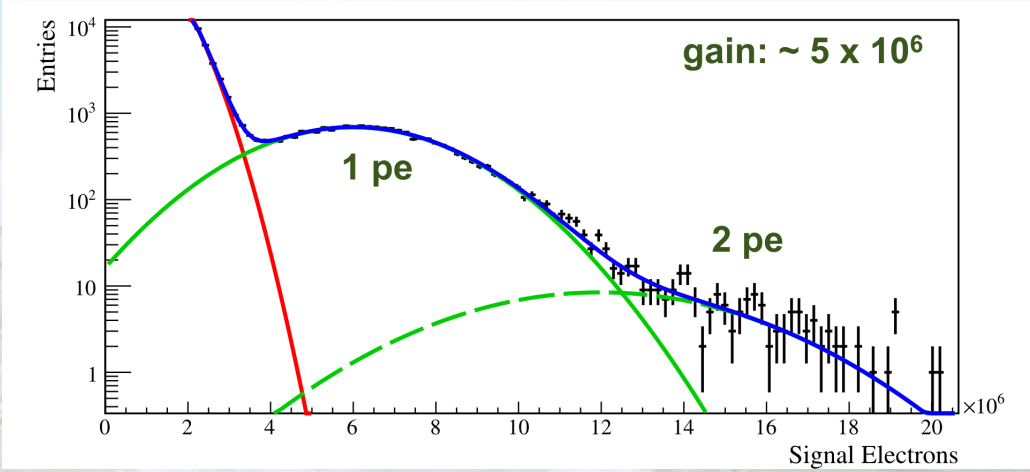


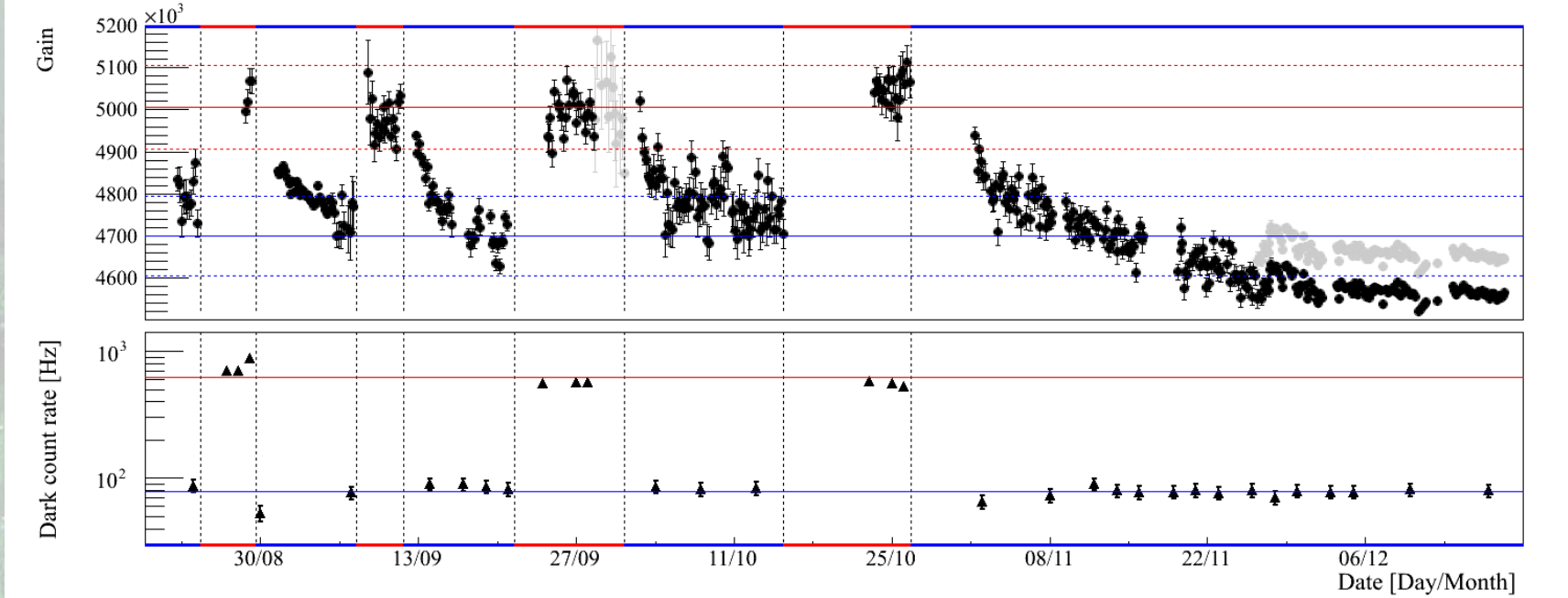
- PMTs are tested in liquid xenon in Zürich.

XENON1T: Photomultipliers

- Gain is measured both at room temperature and in LXe.
- Long-term stability and the effects of temperature cycling are also tracked.

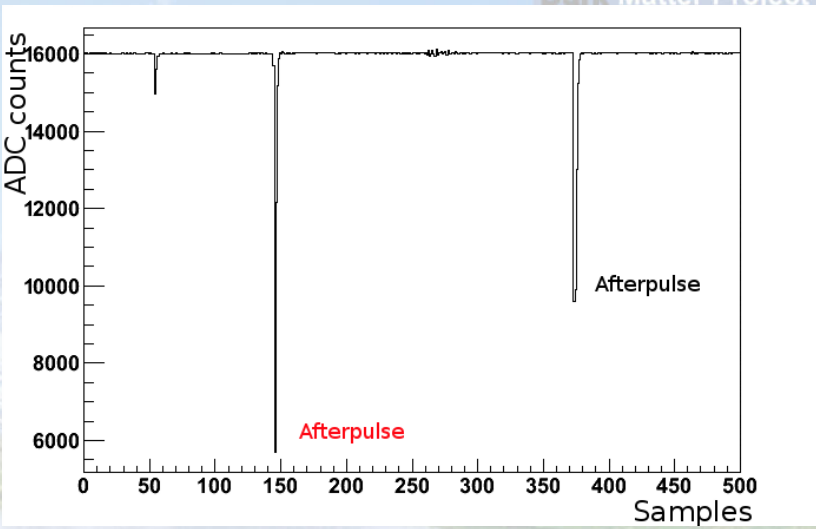
LB et al, J INST 8, P04026, 2013 (arXiv:1303.0226)

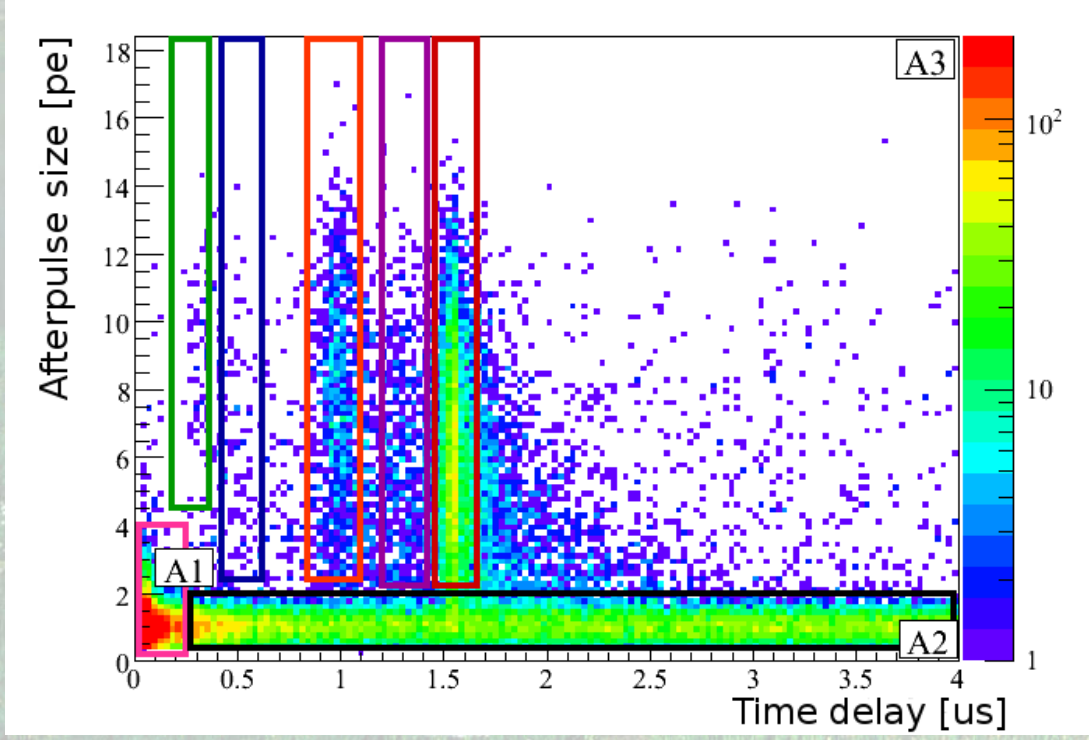




XENON1T: Photomultipliers, Afterpulses Studies

- Afterpulses are systematically studied to ensure that their rates are low enough as to not interfere with the detection of the proportional scintillation signals.





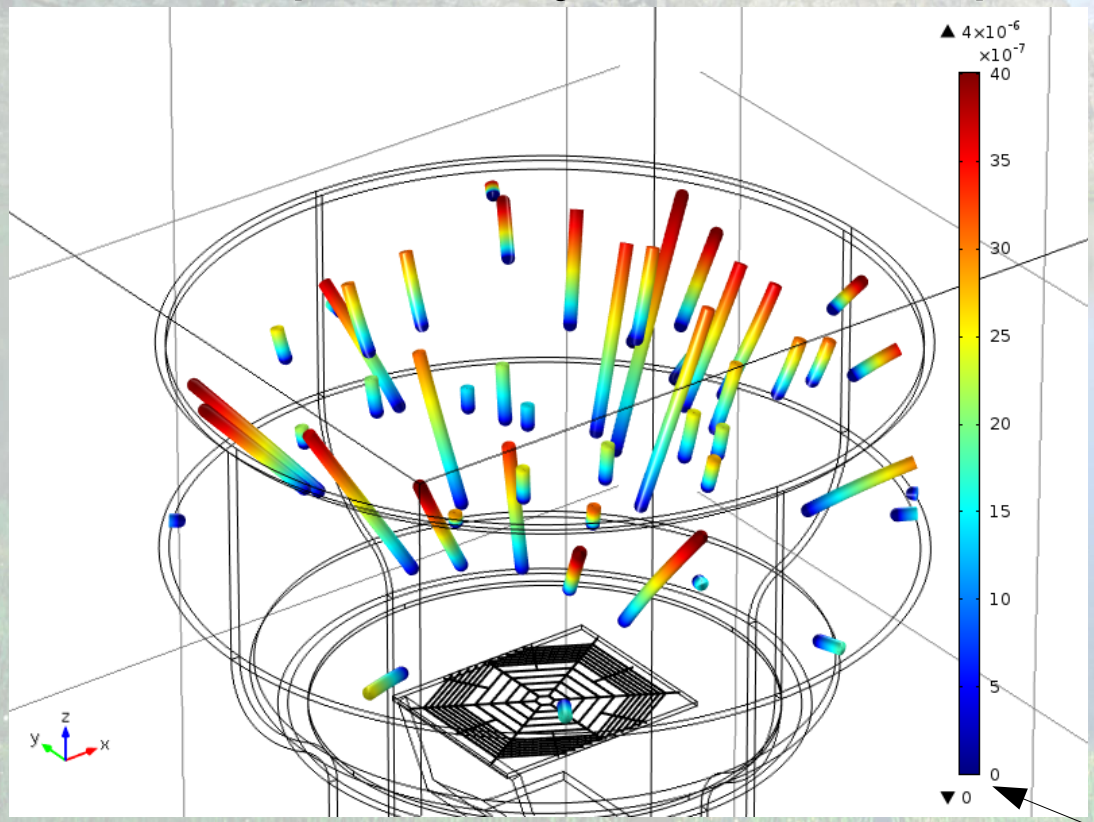
Three groups of afterpulses are observed:

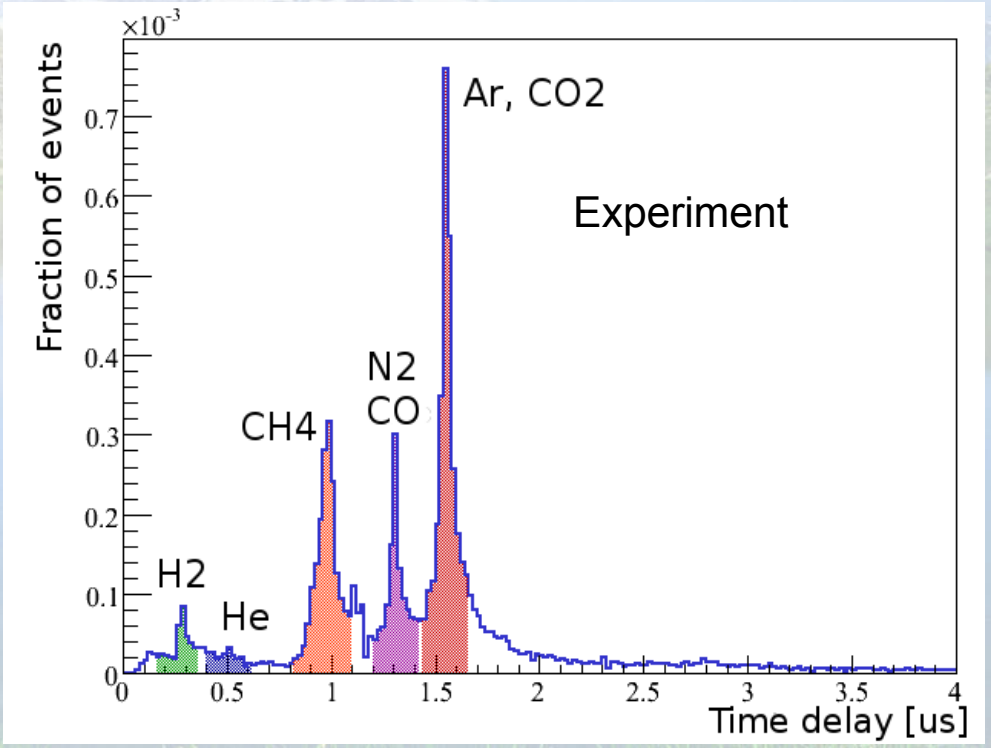
- **A1:** Pulses of short delay: elastic scattering electrons on the first dynode.
- **A2:** Mostly dark pulses.
- **A3:** Positive ions from gas within the PMT. Diagnosis of the vacuum quality and identification of contaminants.

D. Mayani, PhD student

XENON1T: Photomultipliers, Afterpulses Studies

- The afterpulse analysis allows to identify the ions present in the gas remnants within the PMT and can help identify leaks or impurities.





Simulation of ions produced in the volume of the PMT

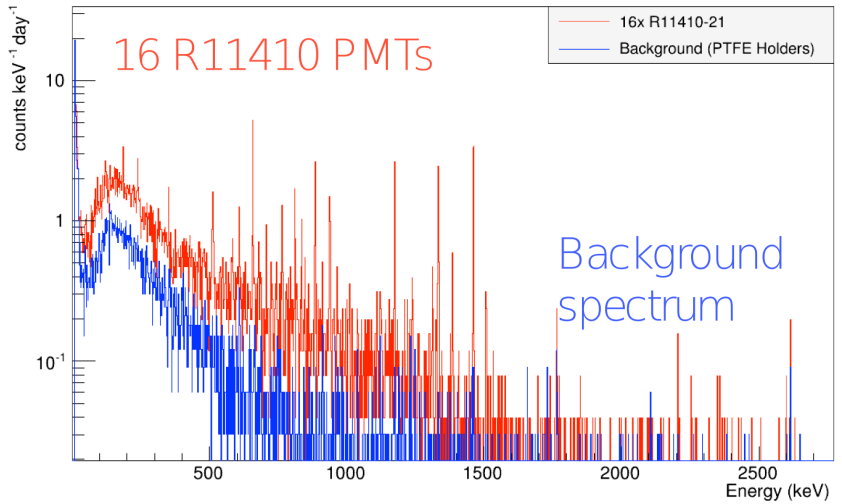
P. Barrow, PhD student

XENON1T: Screening

- All components used for the construction of XENON1T are screened with combining the following:
  - High-purity Germanium
  - Radon emanation
  - Outgassing
  - ICP-MS

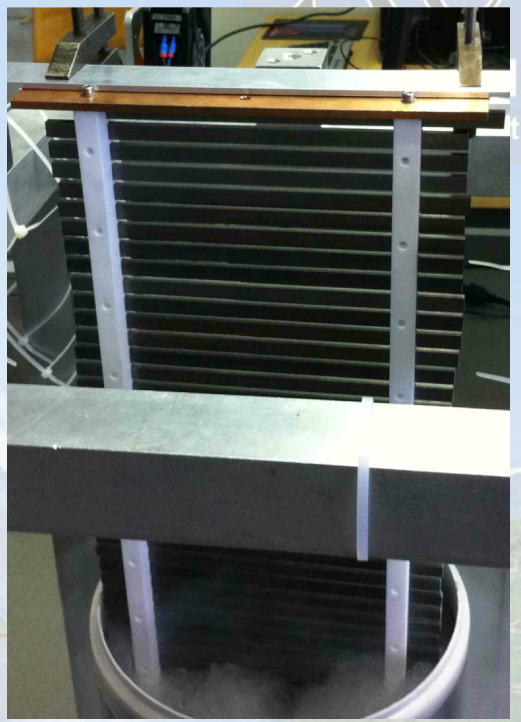
Chain/Isotope	Activity [mBq/PMT]
^{238}U - ^{230}Th	< 13.3 [7.7 +- 2.0]
^{226}Ra - ^{206}Pb	0.49 +- 0.12
^{228}Ra - ^{228}Ac	0.44 +- 0.14
^{228}Th - ^{208}Pb	0.35 +- 0.12
^{235}U - ^{207}Pb	0.353 +- 0.090
^{40}K	12.2 +- 1.6
^{60}Co	0.723 +- 0.074
^{137}Cs	< 0.187
^{54}Mn	0.233 +- 0.049

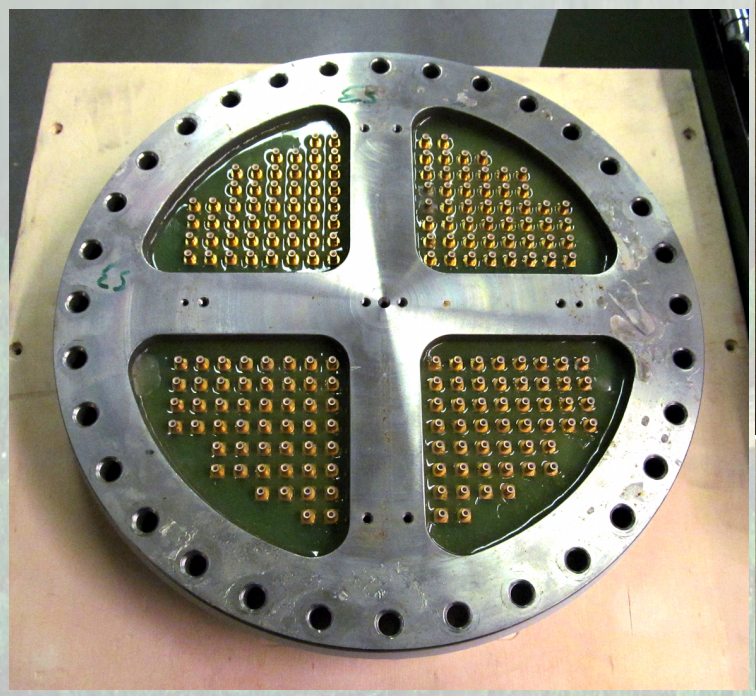
Gator: LB et al, J INST 6 P08010, 2011

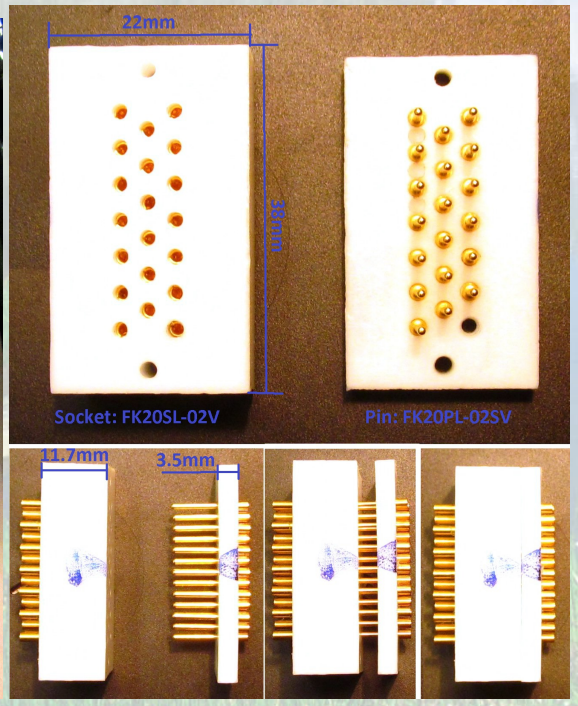


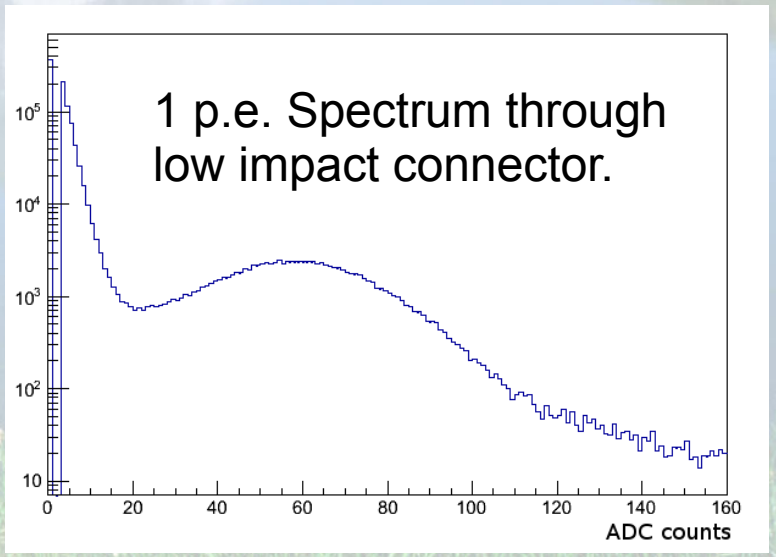
XENON1T: TPC

- We are invested in the mechanical design and testing of the structure of the TPC.
- Developing and testing low-impact connectors and feedthrough.









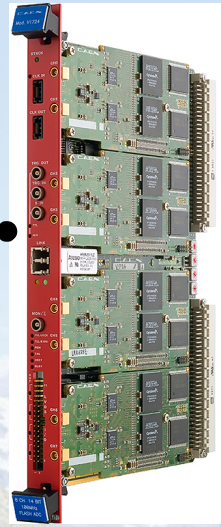
XENON1T DAQ Development

UNIVERSITÄT BERN
AEC ALBERT EINSTEIN CENTER FOR FUNDAMENTAL PHYSICS

XENON Dark Matter Project

Challenges:

- Record every signal from every PMT with **no threshold**
- Implement a flexible software trigger for calibration mode
- Achieve sustained readout rates of **300 MB/s** for calibration mode

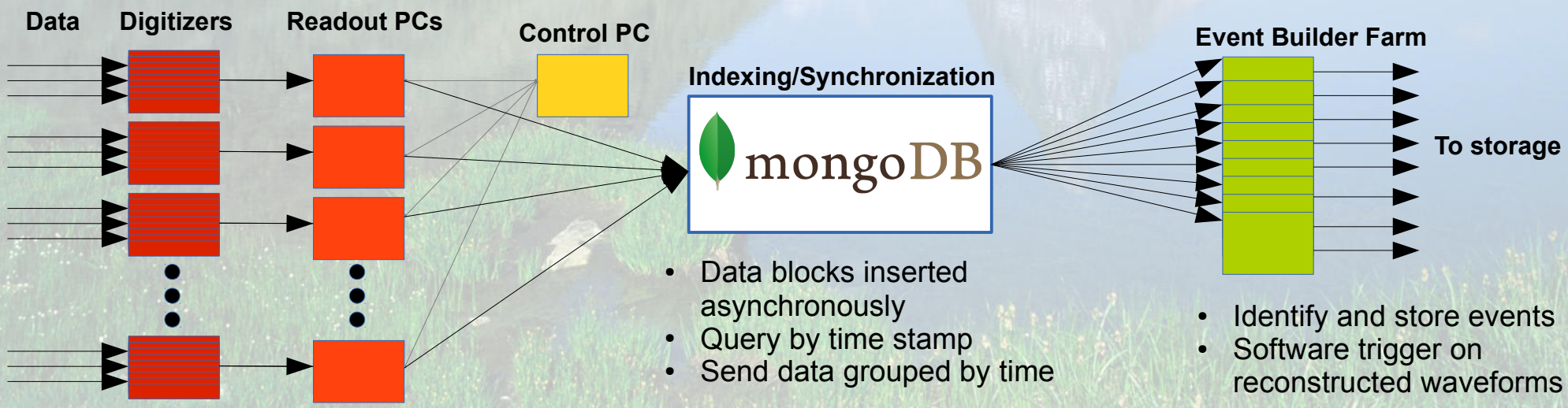


CAEN V1724 digitizers

- 100 MHz, 14-bit samples
- Custom firmware provides self-triggering readout
- Synchronous operation via common clock

Scalable, parallel readout system

On-line waveform reconstruction

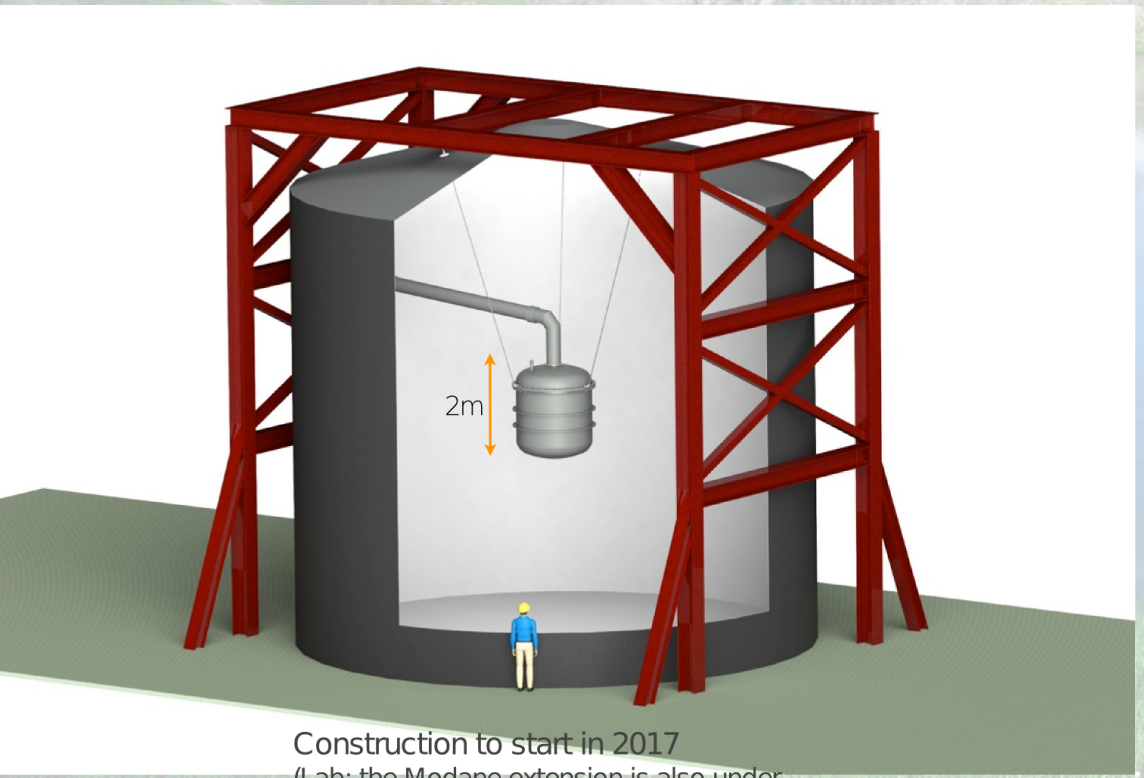


- Data blocks inserted asynchronously
- Query by time stamp
- Send data grouped by time

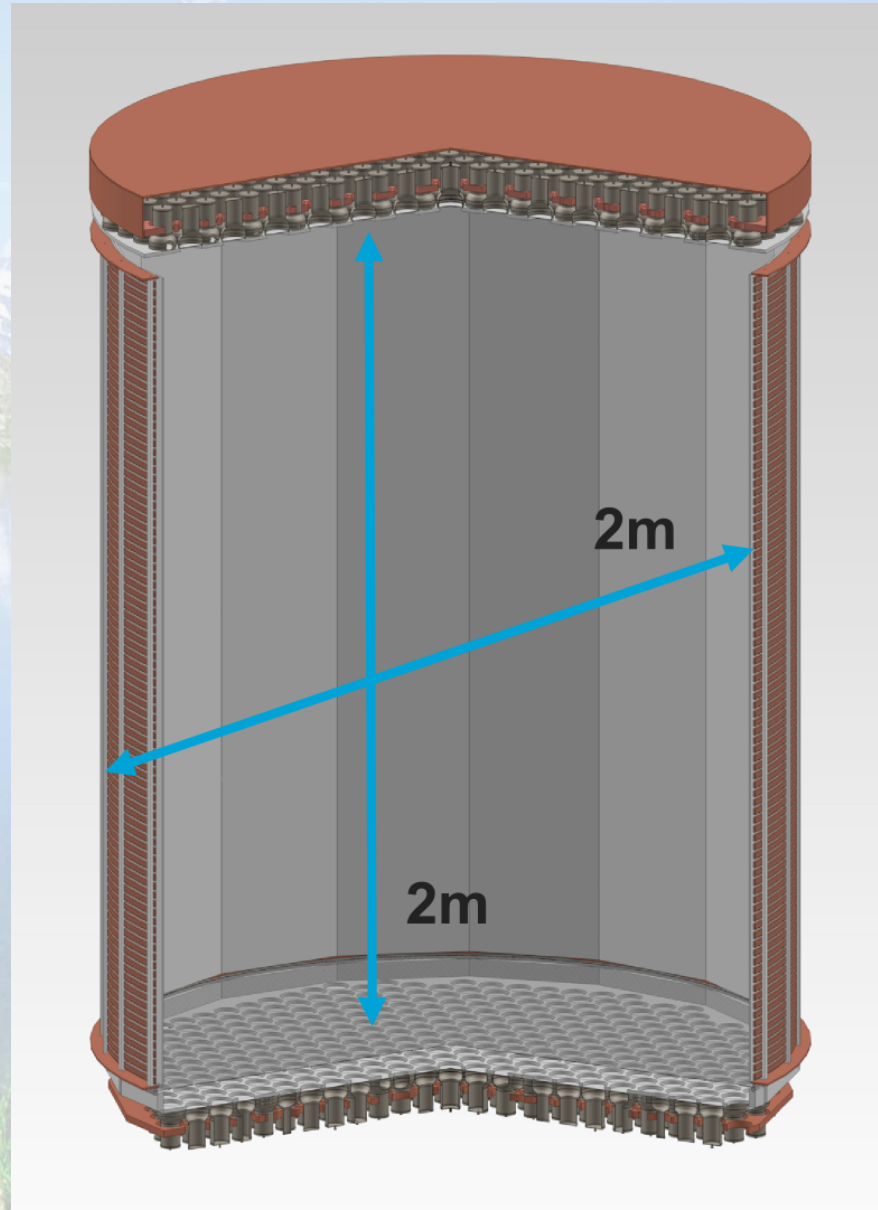
- Identify and store events
- Software trigger on reconstructed waveforms

DARWIN

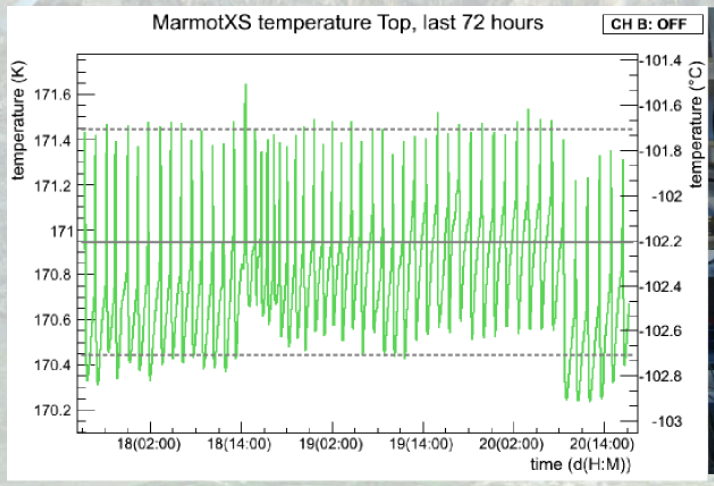
- 20 tons of liquid xenon (also considering argon) with a fiducial volume of about 12 tons.

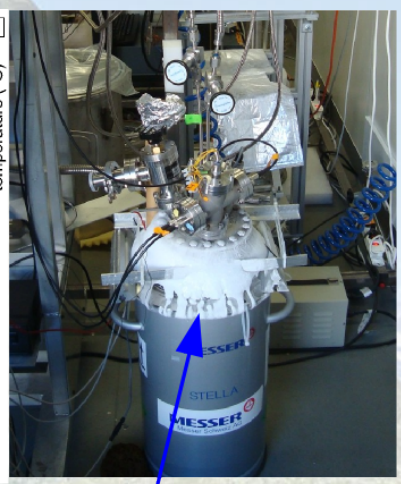


Construction to start in 2017
(Lab: the Modane extension is also under consideration)



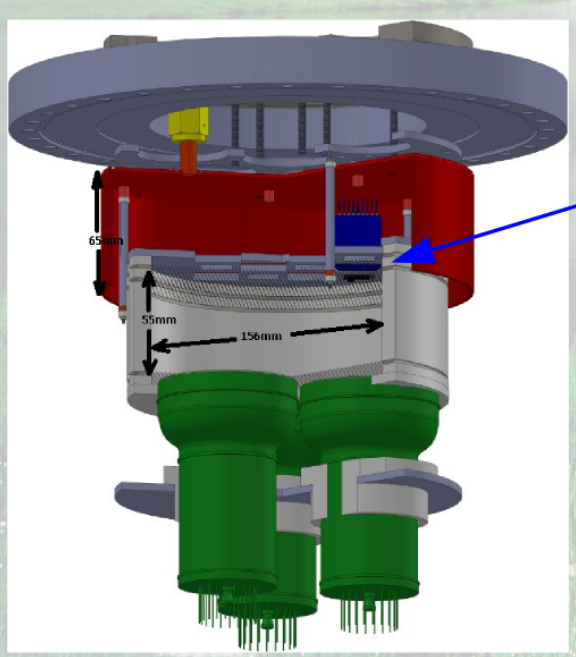
DARWIN: APD's in Liquid Xenon

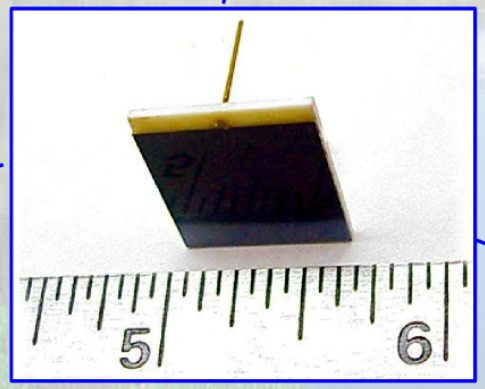


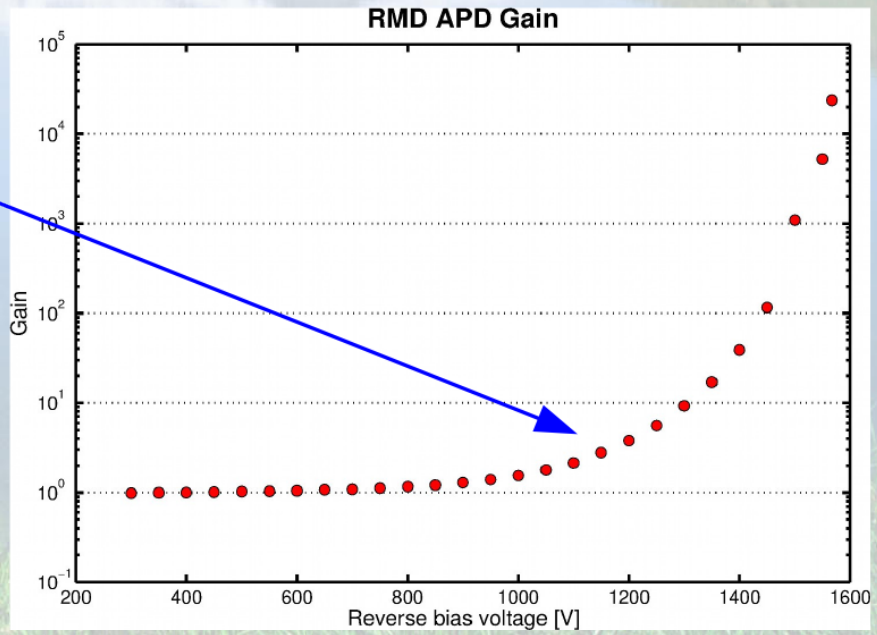


Avalanche Photodiodes (APDs) @ UZH

- 2 APDs (RMD S1315-P), 14x14 mm² area
  (10 more to come after initial characterization)
- optimized for VUV light
- gain tests in LXe, 1K T stability
  resolution and E calibration to come
- goal: increase linearity over
  large dynamic range
  → hybrid PMT+APD TPC @ UZH

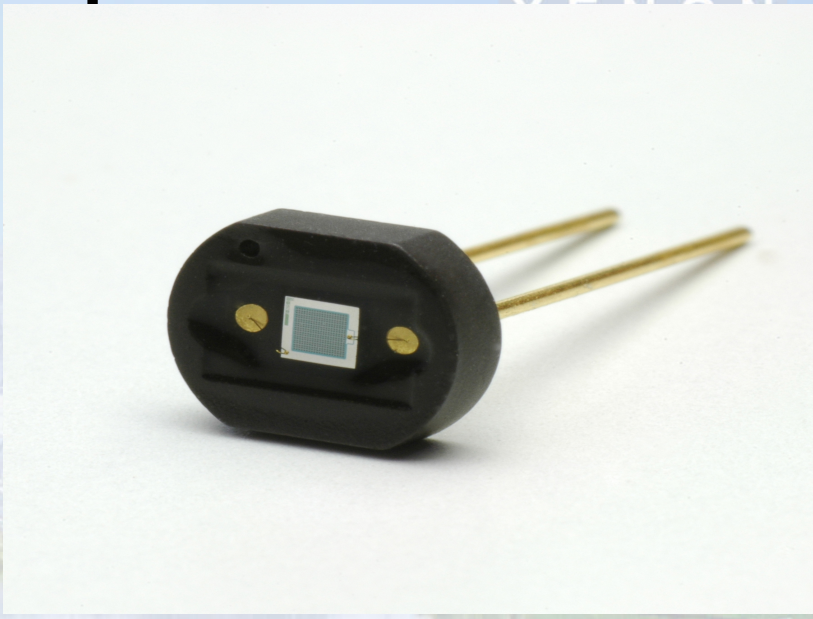


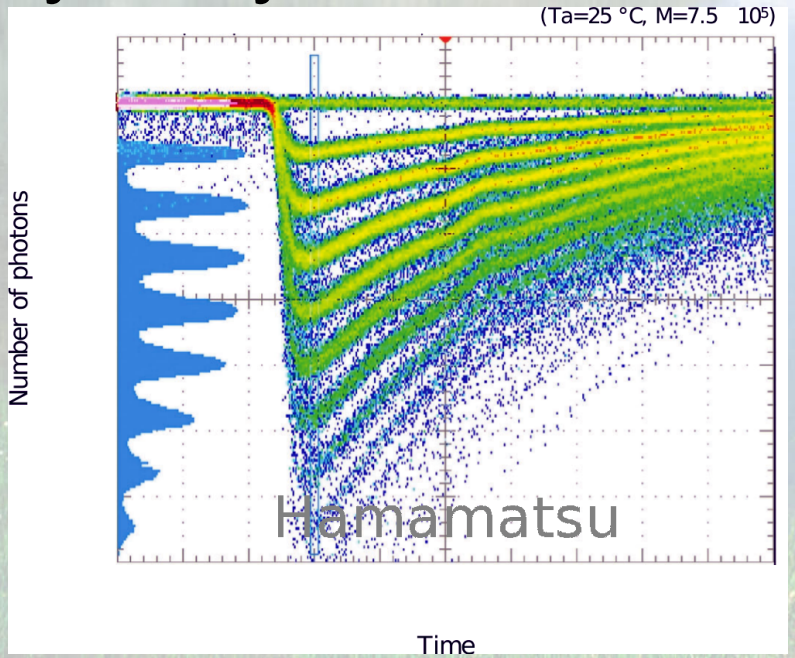


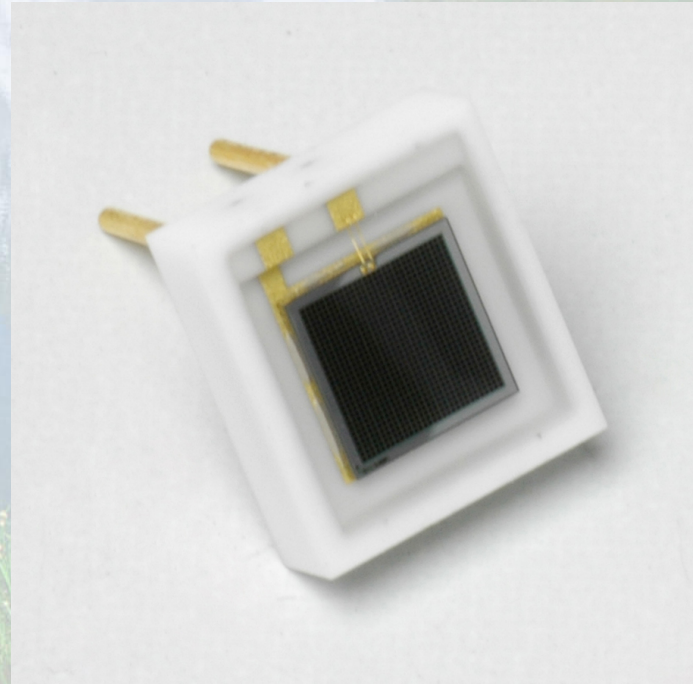


DARWIN: SiPM's in Liquid Xenon

- Designs to test:
  - Optimized VUV window
  - Windowless design
- Mix & match with APD's; possibility of hybrid, solid-state TPC.

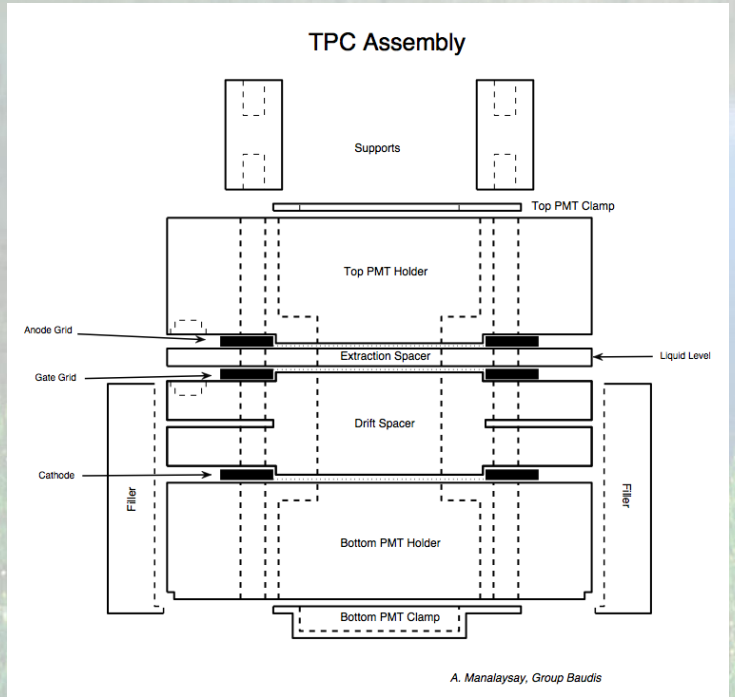


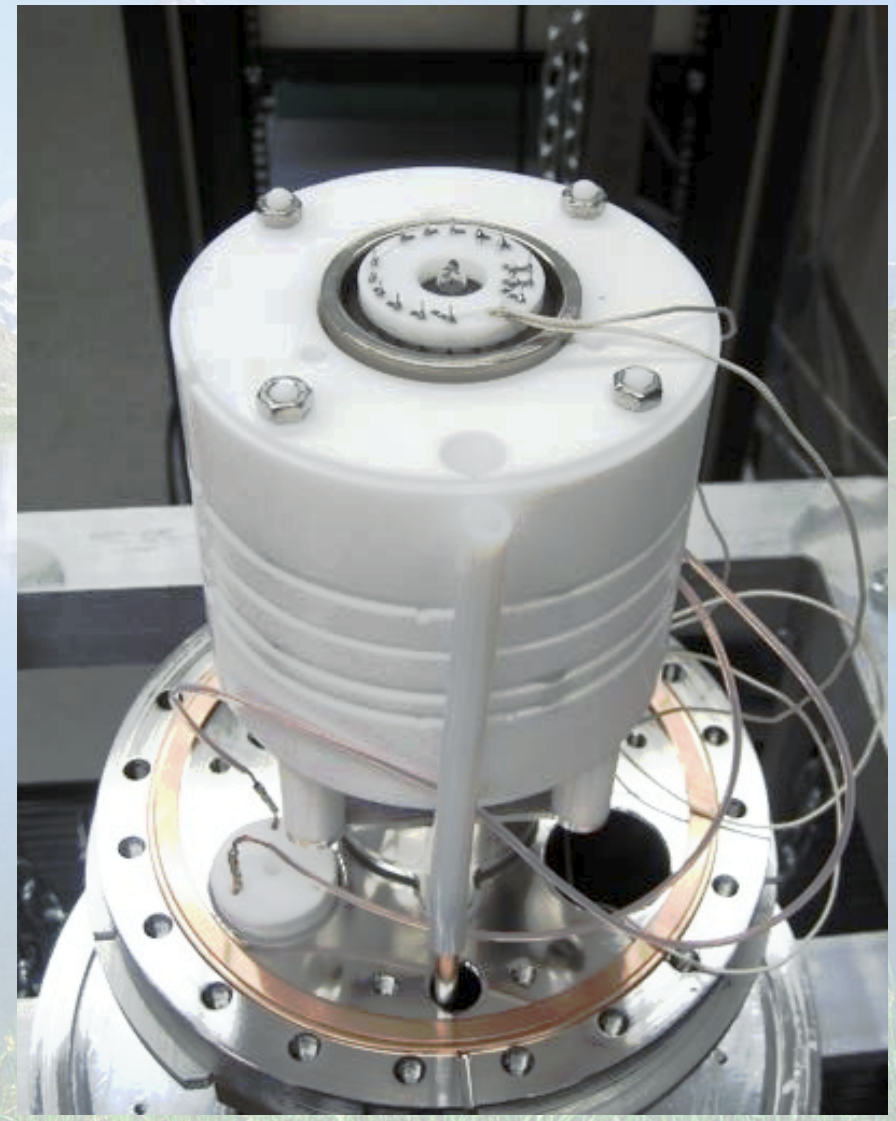




Xürich

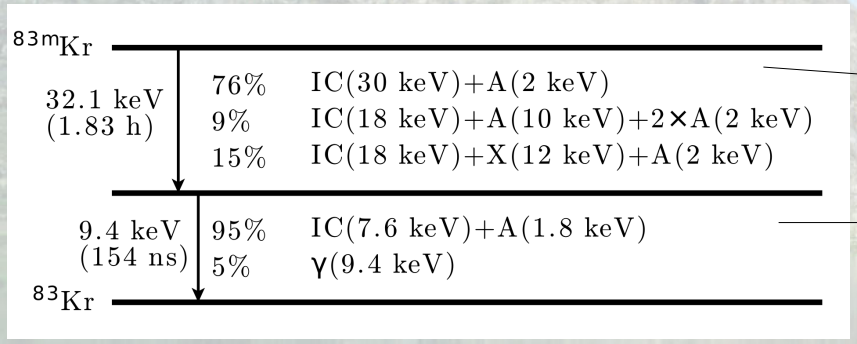
- A small (~1 kg) dual-phase xenon TPC operated in Zürich.
- Allows precise calibrations of both electronic and nuclear recoil responses, L_{eff}, Q_y and field quenching effects.

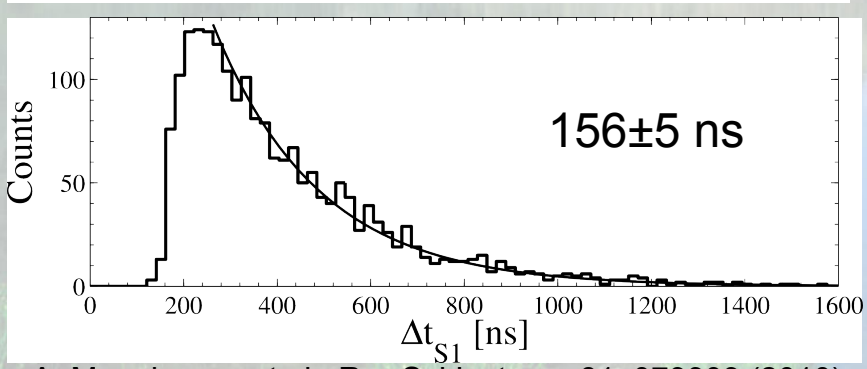




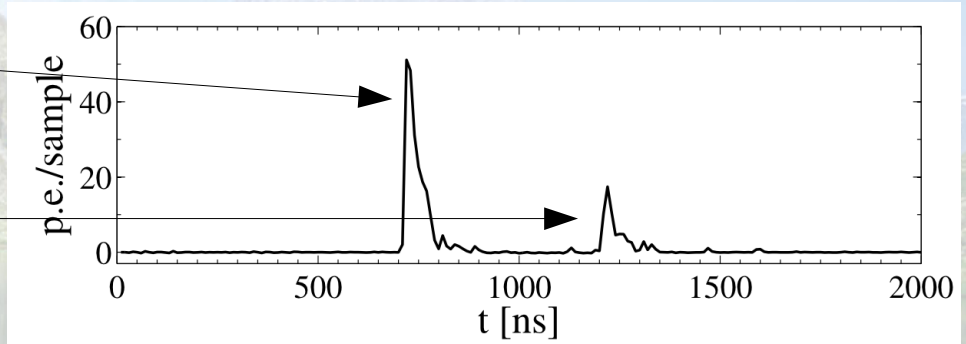
Xürich1: Calibration using Krypton

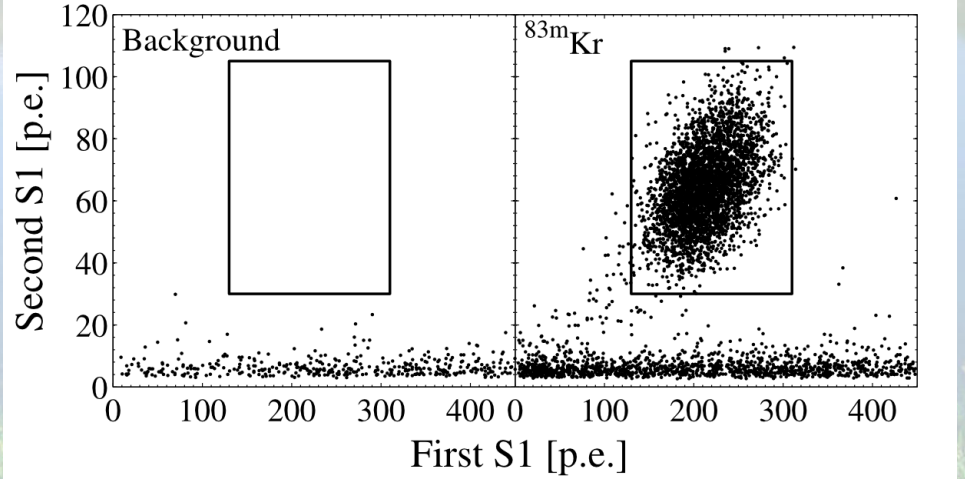
- Letting ^{83m}Kr diffuse inside the xenon volume gives valuable information on light yield at low energies





A. Manalaysay et al., Rev.Sci.Instrum. 81, 073303 (2010)



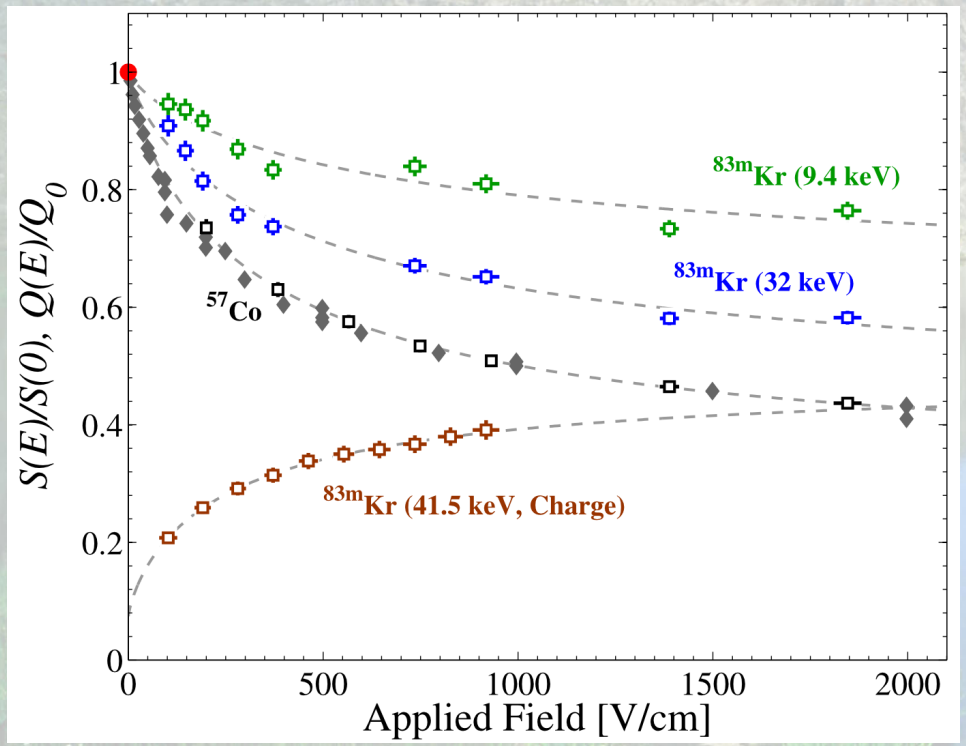


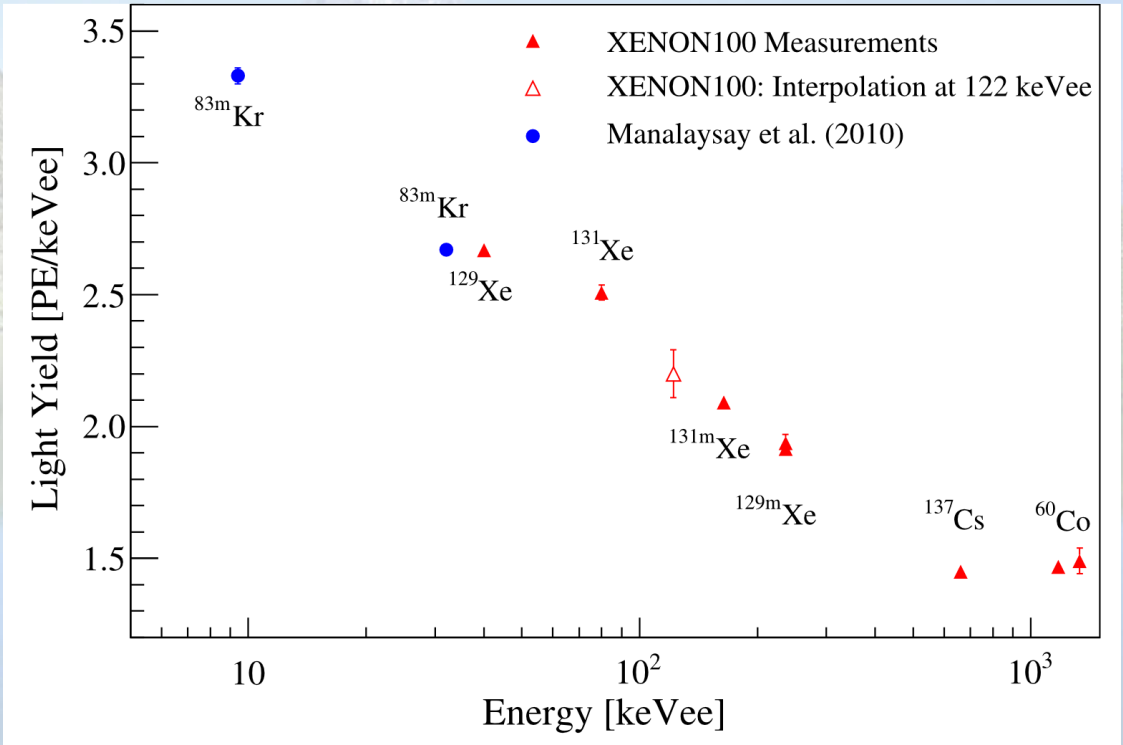
S1 = Scintillation light
S2 = Proportional light

- The Kr events are easily discernable from background events.

Xürich1: Calibration using Krypton

- Field quenching and light yield studies can also be performed



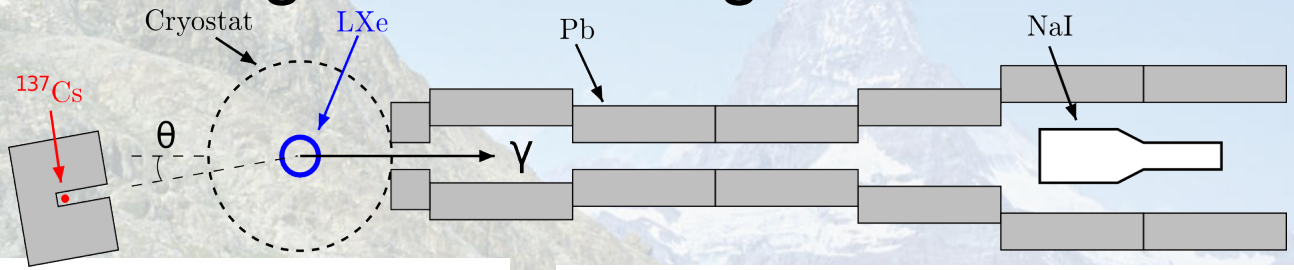


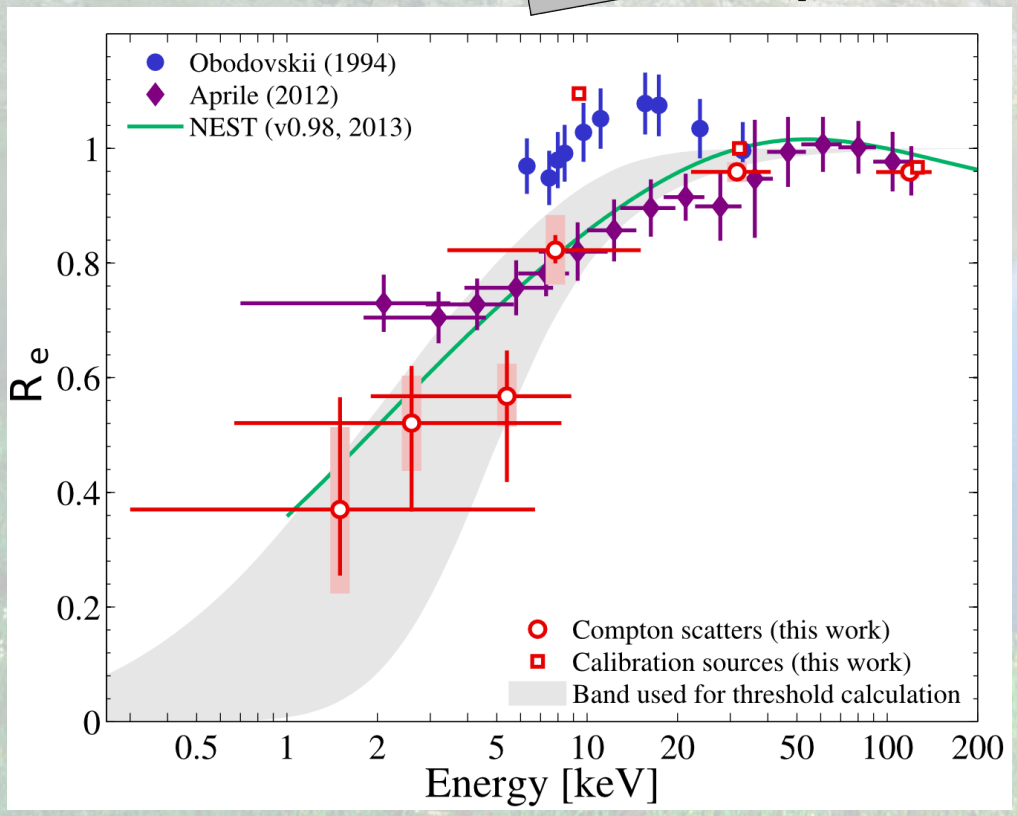
E. Aprile et al. (XENON100), Astropart. Phys. 35, 573 (2012)

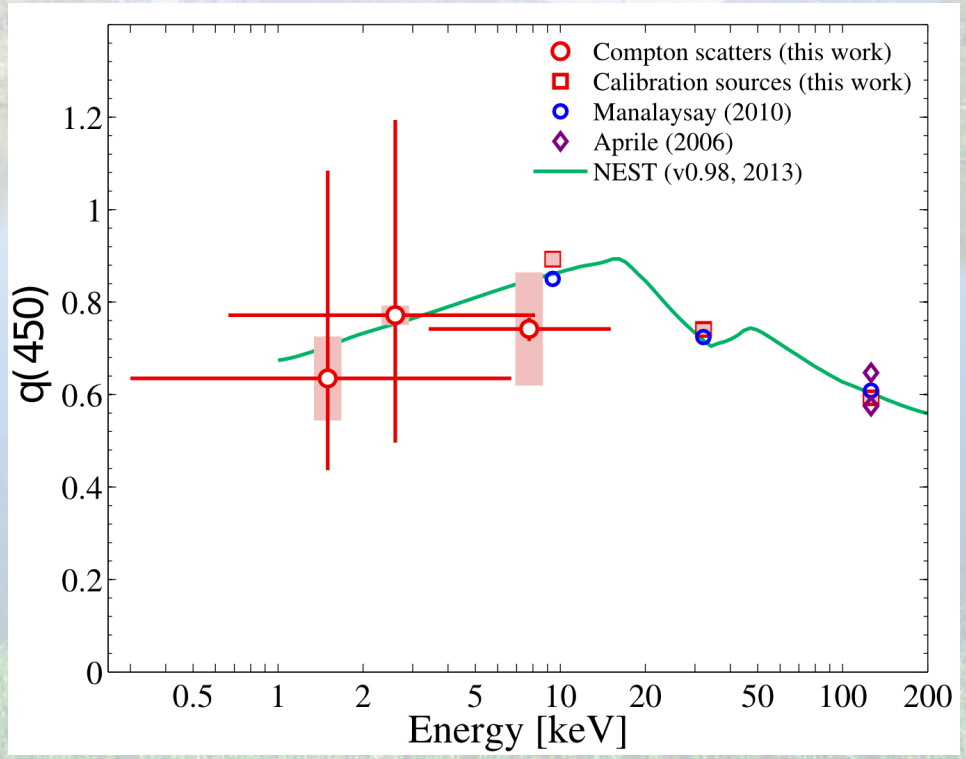
- The effects of xenon exposure to Rb are negligible.

Xürich1: Low-E ER Calibration using Compton scattering

- Compton scattering studies using ^{137}Cs as a source.



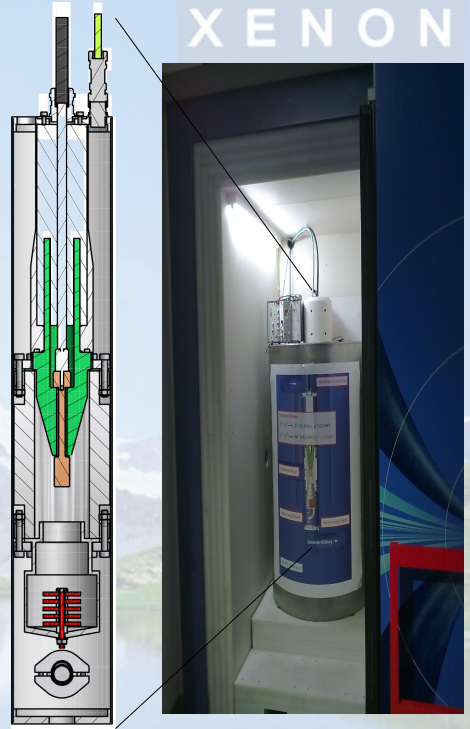


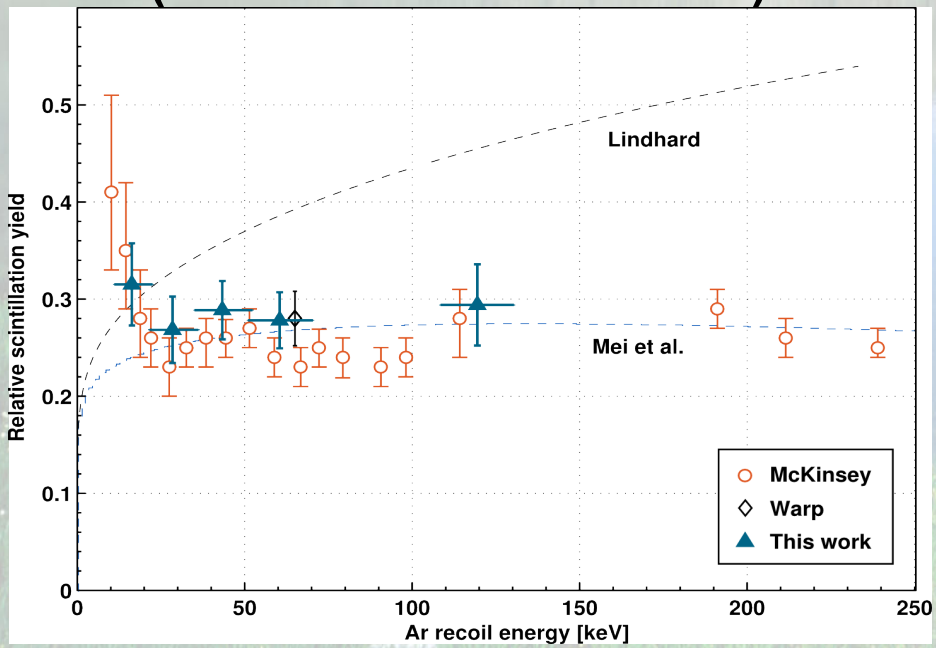


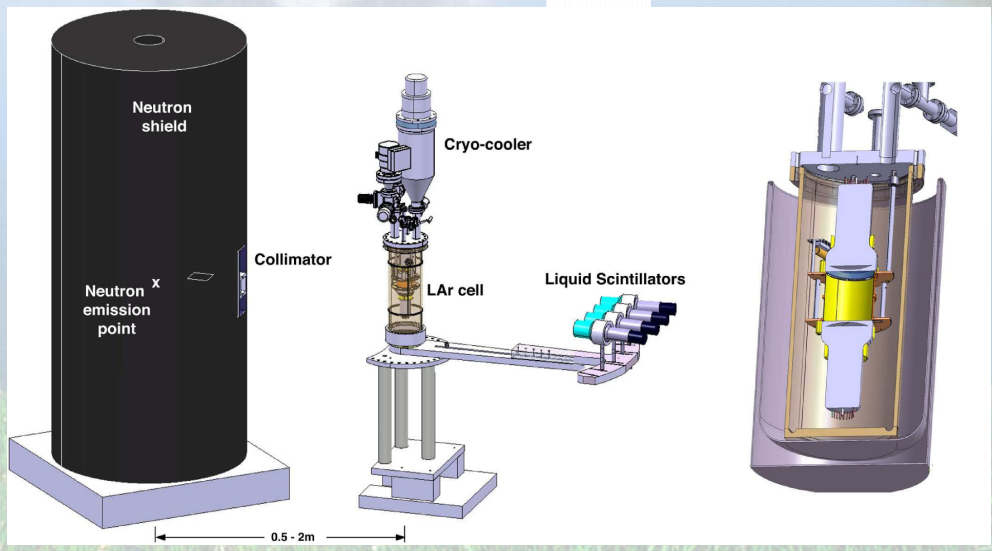
L. Baudis et al., PRD 87, 115015 (2013)

Neutron Generator in Zürich

- A DD neutron generator from NSD is installed and commissioned in Zürich.
- Provides 1.25x10^7 n/s at 2.5 MeV
- Same as installed at CERN to measure L_{eff} in LAr (Amsler: DARWIN)



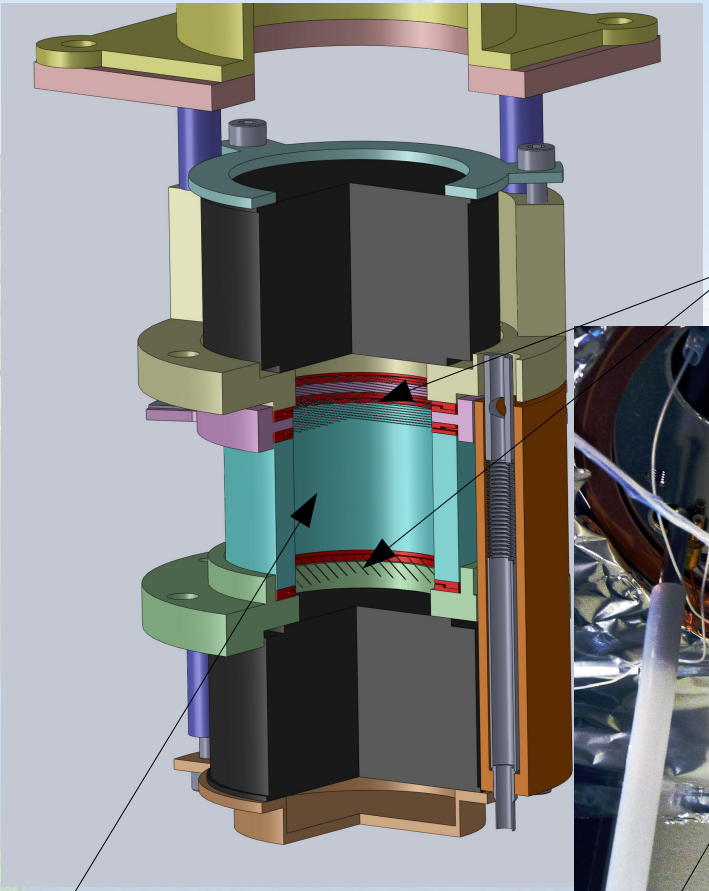




C. Regenfus et al. J. Phys. Conf. Ser. 375 (2012)

Xürich2: calibration with neutrons

- Xürich2 improves on:
  - Amount of materials
  - Uniformity of drift field
  - LXe level control
- Using the neutron source in Zürich, exploring neutron induced nuclear recoils with an improved version of the Xürich TPC will provide detailed information on the low energy nuclear recoil response at fixed energies.



R&D in Switzerland

- Swiss institutes are heavily involved in multiple aspects of R&D for the next, and next, generation experiments
- Expertise cultivated in many areas:
  - Light detection: PMTs, SiPMs
  - Screening: essaying, impact studies
  - TPC: structural, signal input/output
  - Data acquisition
- We are all looking forward to sharing and learning with other experts.

Thank you for your time