Cryo Noble Liquids in Switzerland

Marc Schumann AEC, *Universität Bern*

CHIPP Plenary Meeting, 25.06.2013

marc.schumann@lhep.unibe.ch
www.lhep.unibe.ch/darkmatter

Swiss Institute of Particle Physics

UNIVERSITÄT BERN

AEC
ALBERT EINSTEIN CENTER
FOR FUNDAMENTAL PHYSICS

Noble Liquids in Switzerland

LAGUNA
LBNO with LAr
ETHZ, UNIGE, UNIBE

MEG
LXe-Calorimeter
PSI

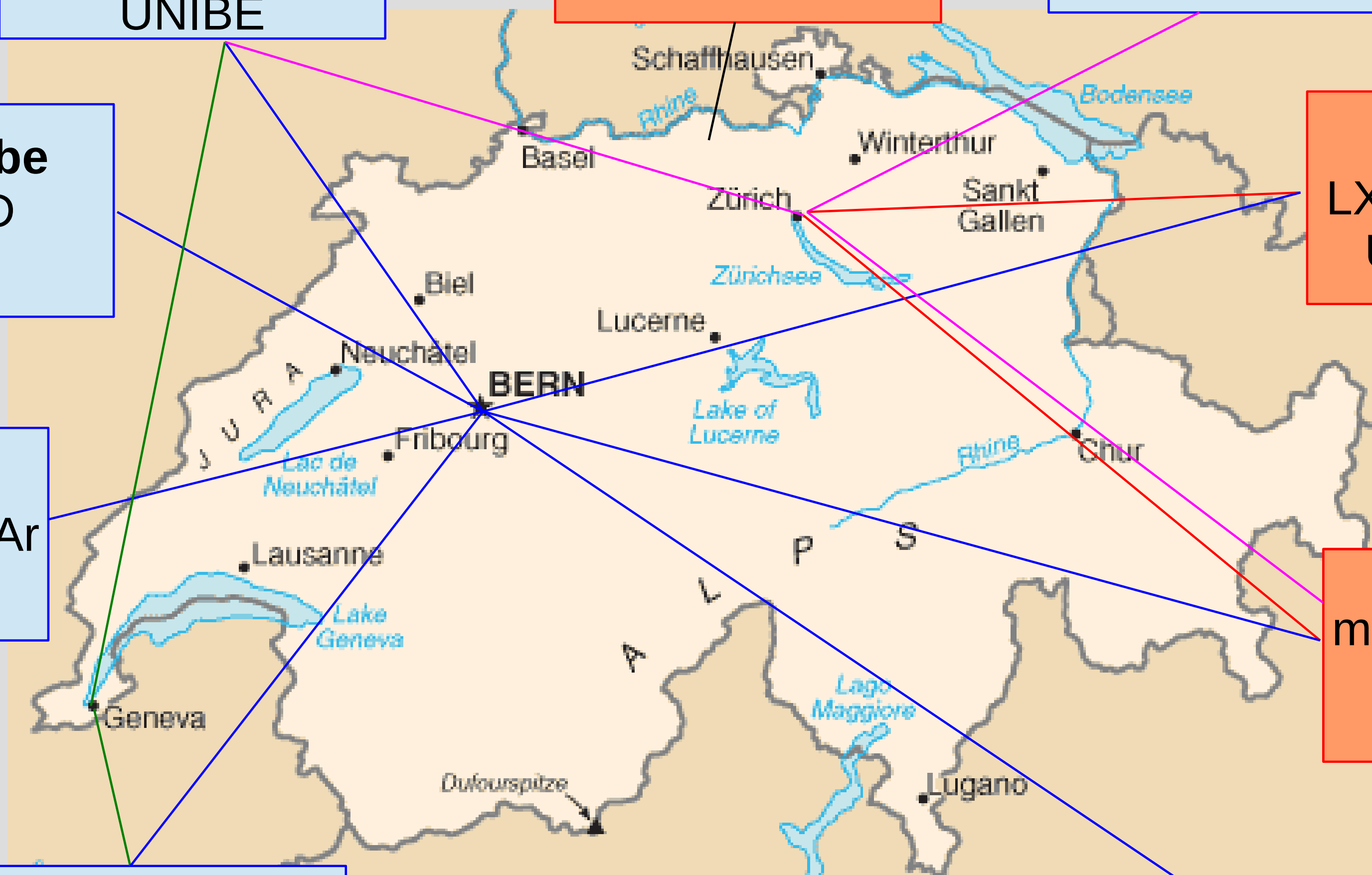
ArDM
LAr DM
ETHZ

ArgonTube
LAr R&D
UNIBE

XENON
LXe Dark Matter
UZH, UNIBE

MicroBoone
low-E νs with LAr
UNIBE

DARWIN
multi-ton LXe/LAr
UZH, ETH, UNIBE



ATLAS
LAr-Calorimeter
UNIGE, UNIBE

EXO
LXe $0\nu\beta\beta$
UNIBE

Noble Liquids in Switzerland

LAGUNA
LBNO with LAr
ETHZ, UNIGE, UNIBE

talk A. Rubbia

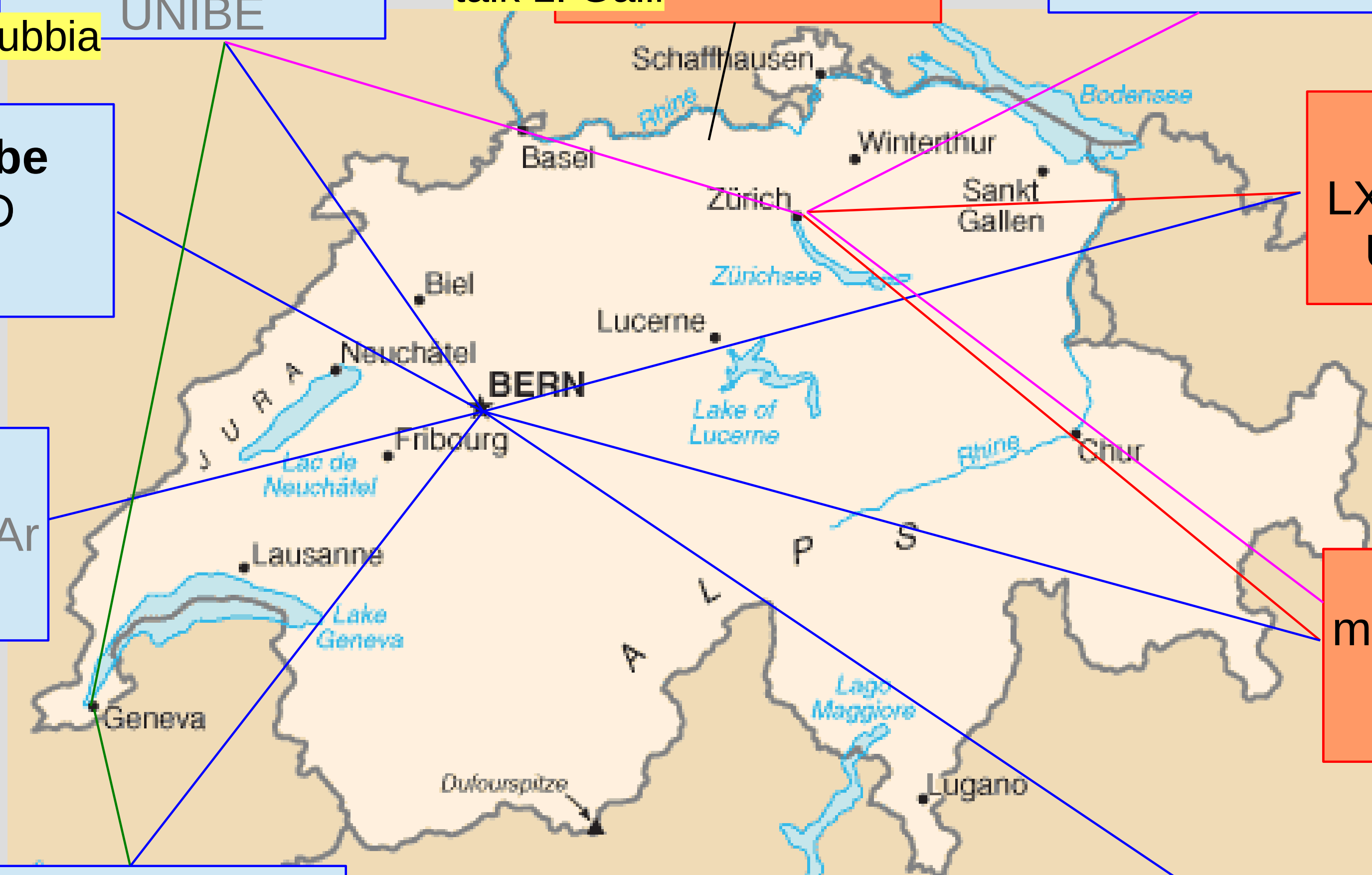
MEG
LXe-Calorimeter
PSI

talk L. Galli

ArDM
LAr DM
ETHZ

ArgonTube
LAr R&D
UNIBE

XENON
LXe Dark Matter
UZH, UNIBE



MicroBoone
low-E νs with LAr
UNIBE

talk I. Kreslo

DARWIN
multi-ton LXe/LAr
UZH, ETH, UNIBE

talk L. Baudis

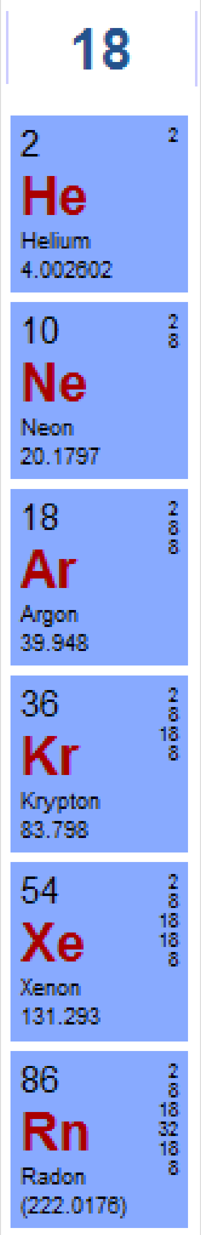
ATLAS
LAr-Calorimeter
UNIGE, UNIBE

talks Doglioni/Weber

EXO
LXe $0\nu\beta\beta$
UNIBE

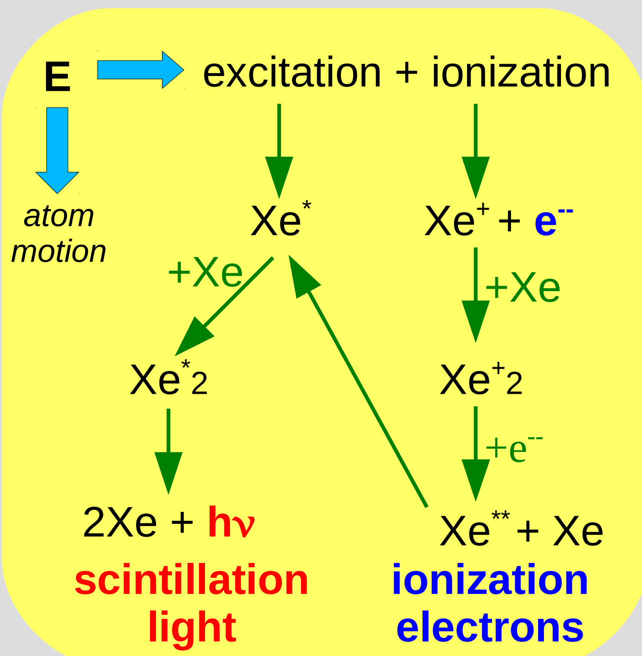
Cryogenic Noble Liquids

Target	LXe	LAr	LNe
Atomic Number	54	18	10
Atomic mass	131.3	40.0	20.2
Boiling Point T_b [K]	165.0	87.3	27.1
Liq. Density @ T_b [g/cm³]	2.94	1.40	1.21
Fraction in Atmosphere	0.09	9340	18.2
Price	$$$$	$	$$
Scintillator	✔	✔	✔
Ionizer	✔	✔	✘
W (E to generate e-ion pair) [eV]	15.6	23.6	
W_{ph} (α,β) [eV]	17.9 / 21.6	27.1 / 24.4	
Experiments in CH [stopped, running, in preparation]	~7	~4	0

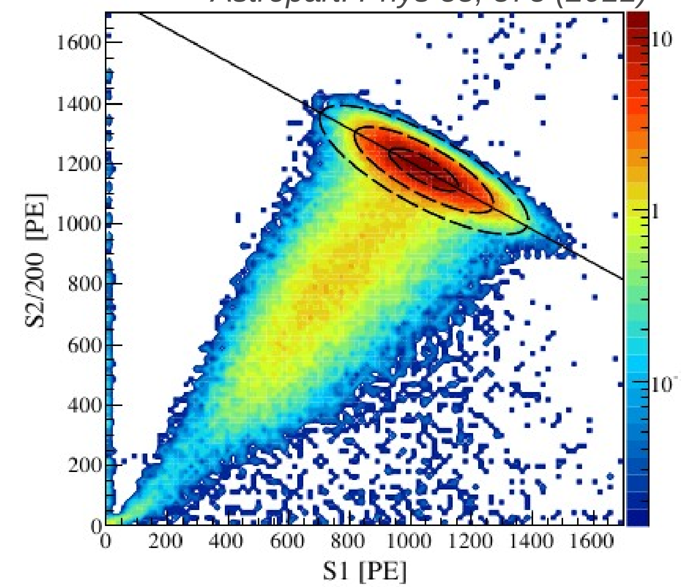


Scintillation and Ionization

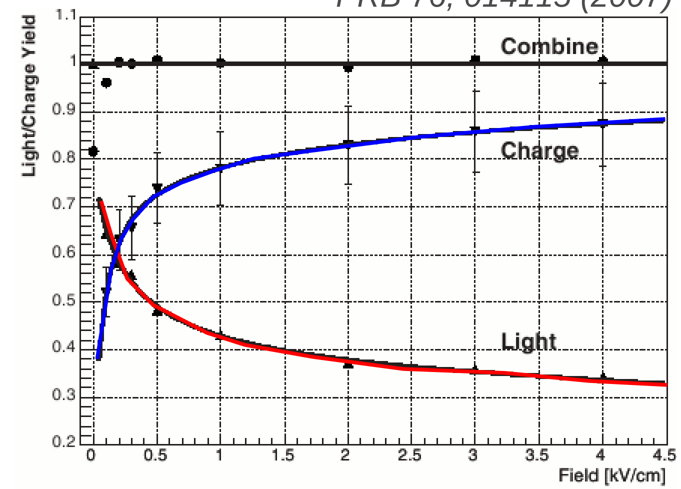
- energy deposition produces *electron-ion pairs* and *excited atom states*; both processes can lead to scintillation
- anti-correlation between charge and light
  ➡ improvement of energy resolution possible
- E-field dependence (field quenching)
- response depends on particle type and energy



Astropart. Phys 35, 573 (2011)

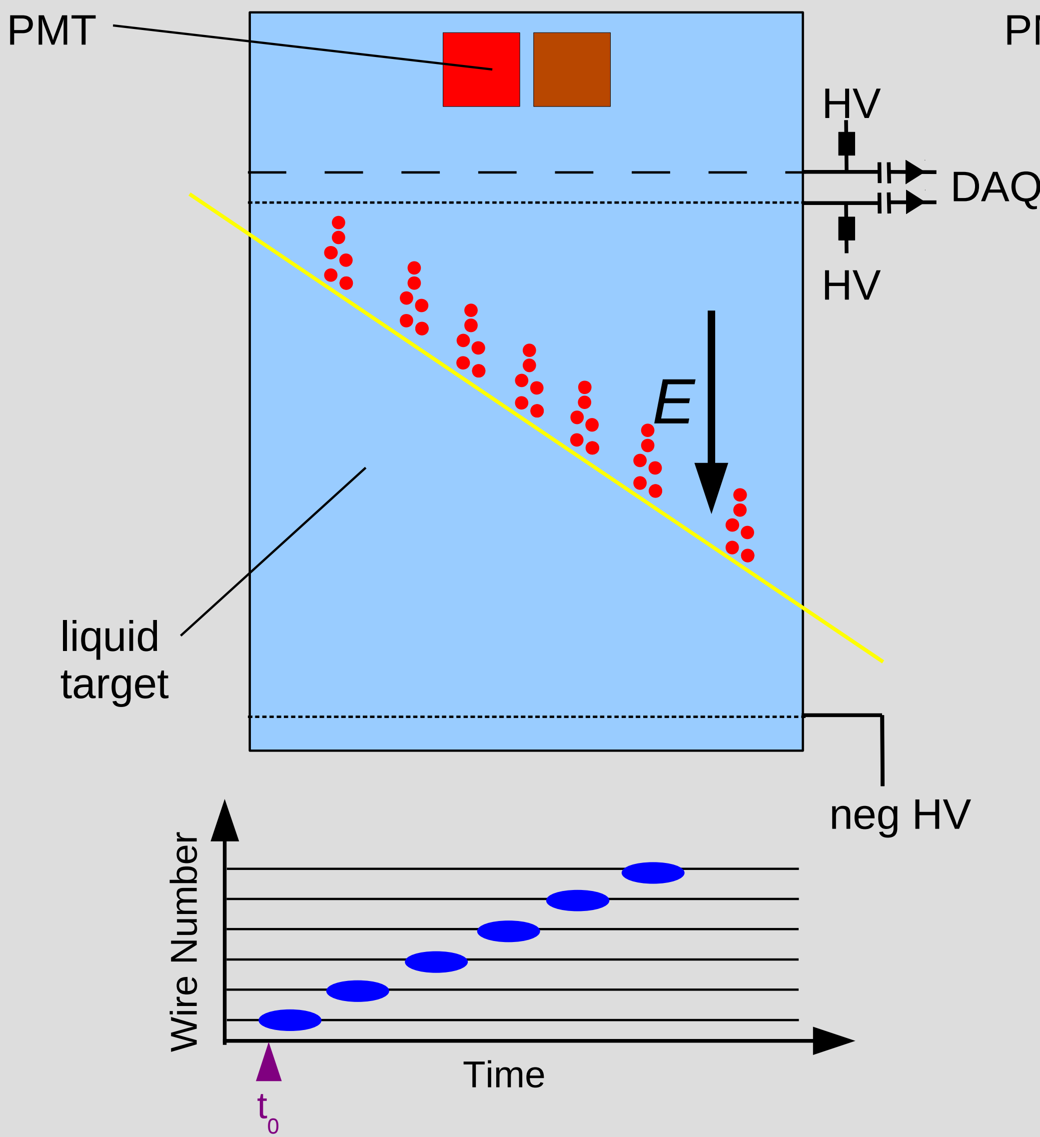


PRB 76, 014115 (2007)

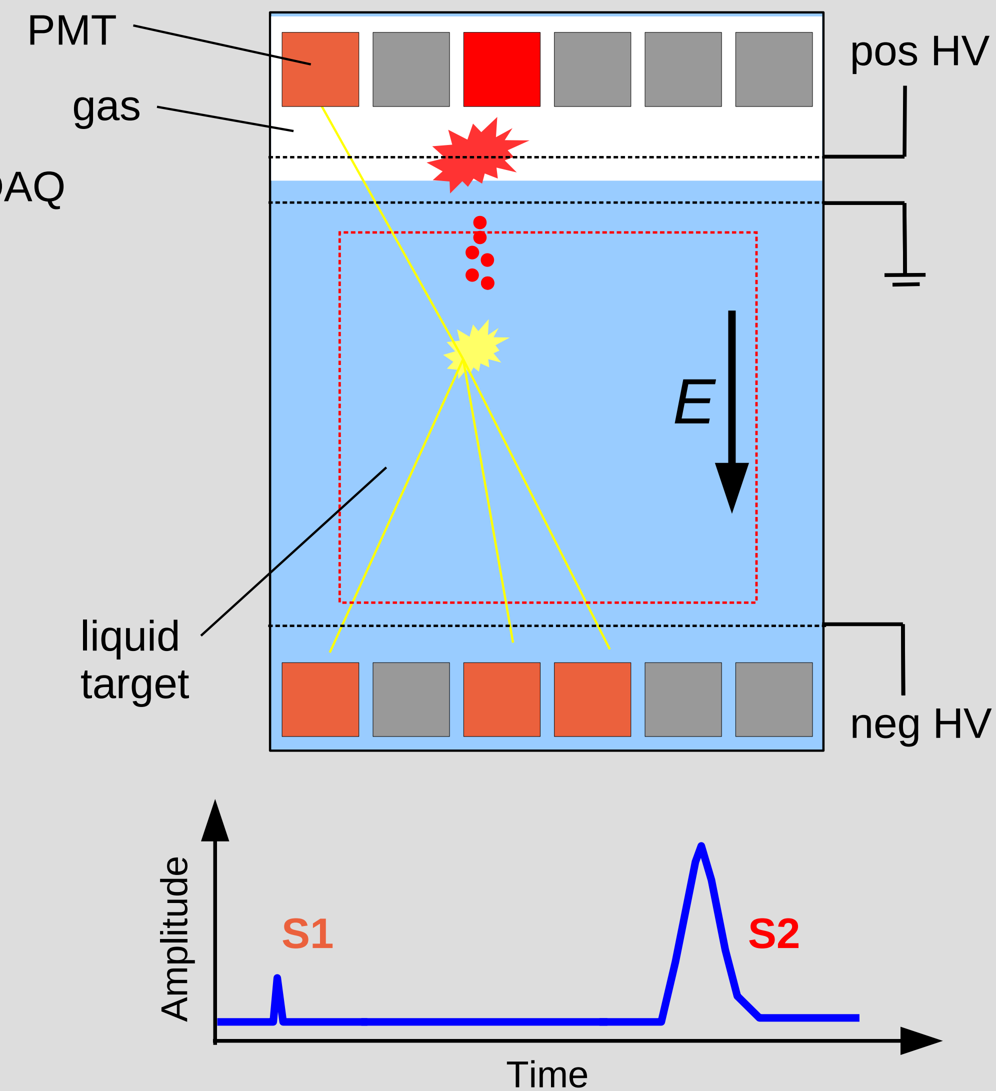


Time Projection Chambers

Time Projection Chamber



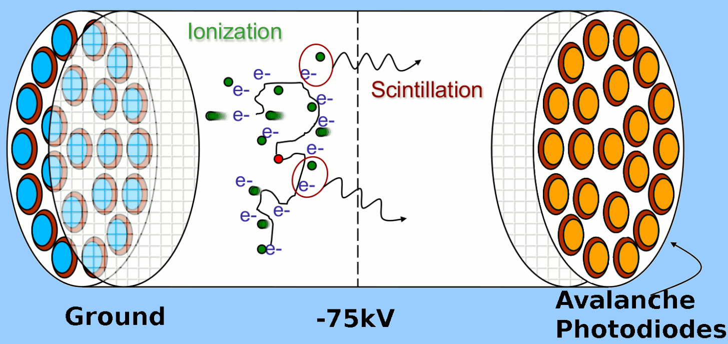
2-phase Time Projection Chamber

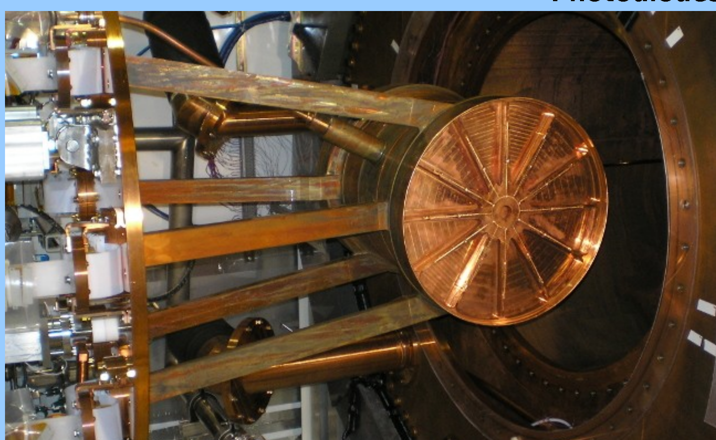


EXO: Neutrinoless Double β-Decay

Bern

EXO-200 running @ WIPP





TPC with light (APDs) and charge (wire channels) readout.

Future:
improve systematics via Ba tagging

$$^{136}\mathrm{Xe} \rightarrow {}^{136}\mathrm{Ba}^{++} + 2\,e^{-} + 0\,\nu$$

R&D for Barium Tagging @ AEC Bern

Ba identification is done with a laser-based system (developed at Standford+Colorado).

Bern focuses on extraction of the ion from the LXe TPC. **EXO-100** is a cryogenic setup to test ion collection in LXe and CF_4

To control systematics, start to try tagging the daugther of Rn-222 (Po-218) and detect its subequent decay with an α-detector outside of the TPC

$$\tau_{1/2}:\quad \sim 3.8\ \text{day} \qquad\qquad \sim 3.1\ \text{min.}$$

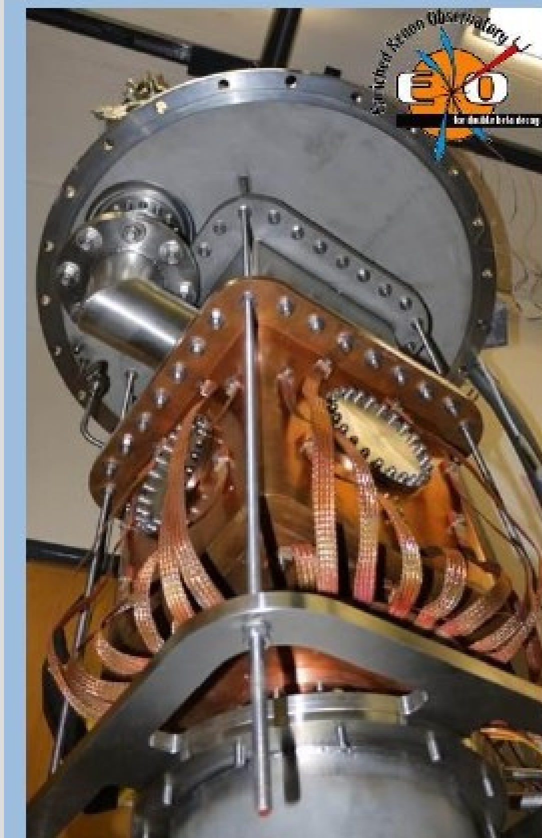
$$^{222}\mathrm{Rn} \xrightarrow{100.\%} \underset{(5.5\ \mathrm{MeV})}{\alpha_1} + {}^{218}\mathrm{Po} \xrightarrow{99.98\%} \underset{(6.0\ \mathrm{MeV})}{\alpha_2} + {}^{214}\mathrm{Pb}$$

→ need good α-detection efficiency with the TPC

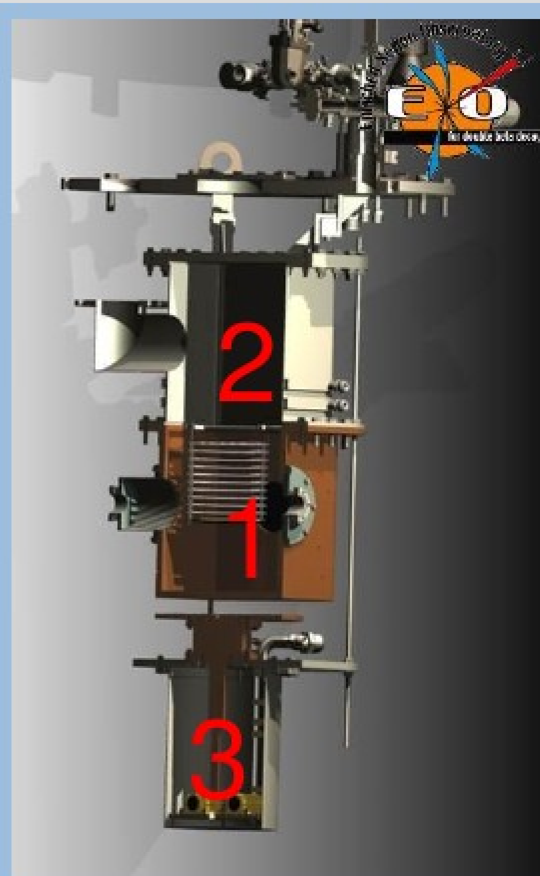
EXO: Neutrinoless Double β-Decay

Bern

Status of EXO-100:



Photograph of the inner chamber of the cryostat along with the LN_2 tank showed below

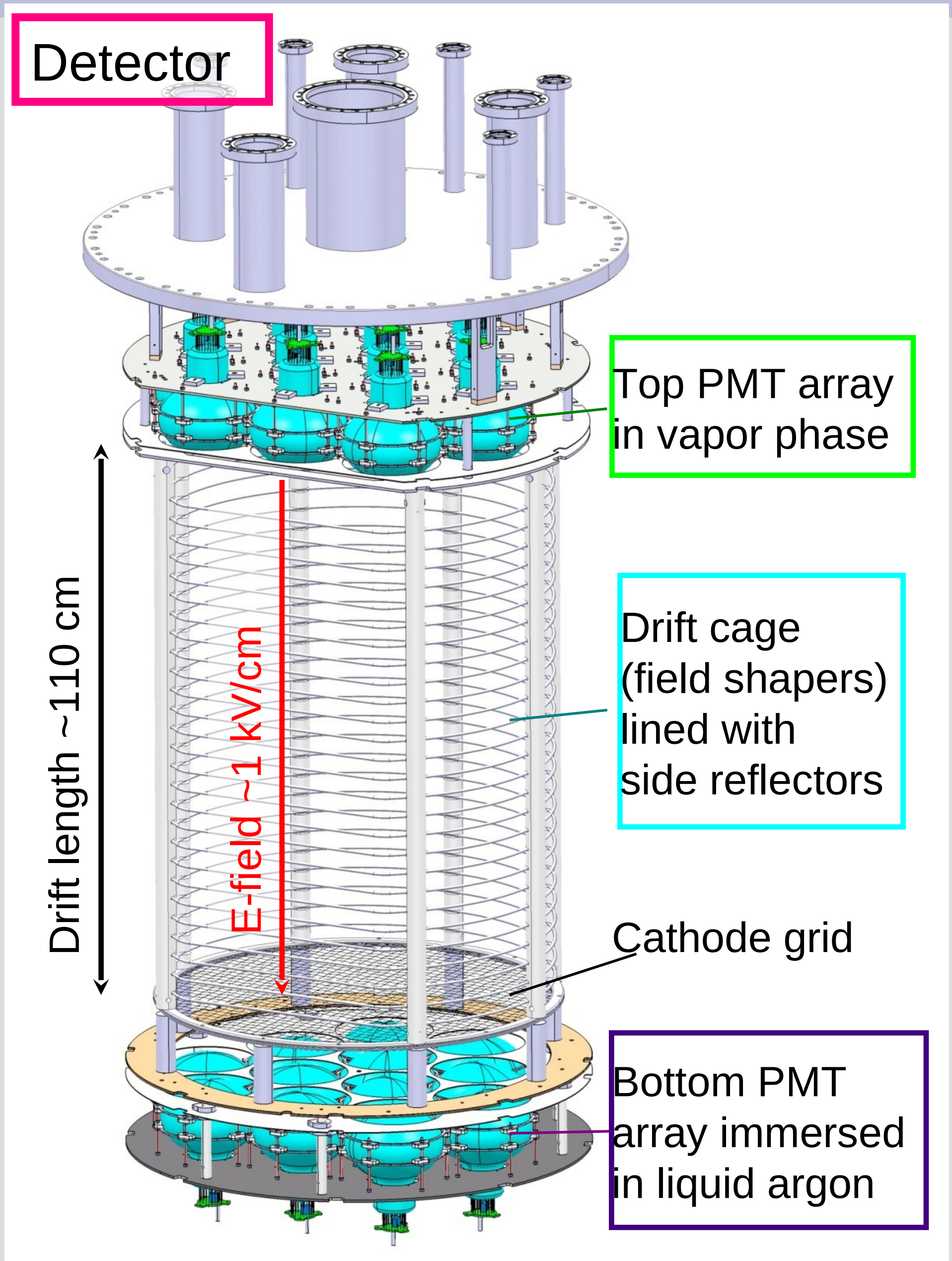


CAD render of the inner chamber of the cryostat and of the LN_2 tank

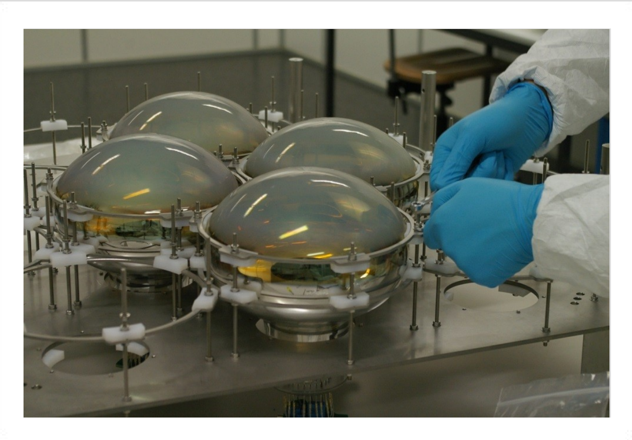
1. space to host the TPC
2. space for the displacement device, dipper and alpha detector
3. LN_2 tank with cold finger

ArDM: Dark Matter with 1t-LAr TPC

ETHZ



- Fully PMT-based readout:
  - 2 new arrays of 12 x 8" Hamamatsu PMTs (R5912-02MOD-LRI), TPB coating
  - primary scintillation light (in liquid)
  - charge via proportional scintillation (in vapor)
    - → discrimination with PSD, charge/light ratio
- Active LAr target: ~0.8 ton
- Tetratex® side reflectors coated with TPB
- Drift field : ~1 kV/cm
  - ~100 kV at cathode, supplied using VHV feedthrough



ArDM: Dark Matter with 1t-LAr TPC

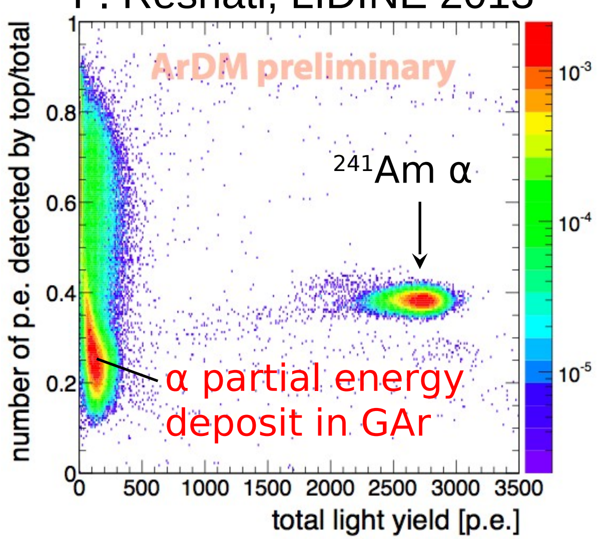
ETHZ

Installed at Laboratorio Subterráneo de Canfranc (LSC)

The new ArDM detector, fully assembled in the LSC clean room, being installed into the detector vessel

GAr data@LSC

F. Resnati, LIDINE 2013



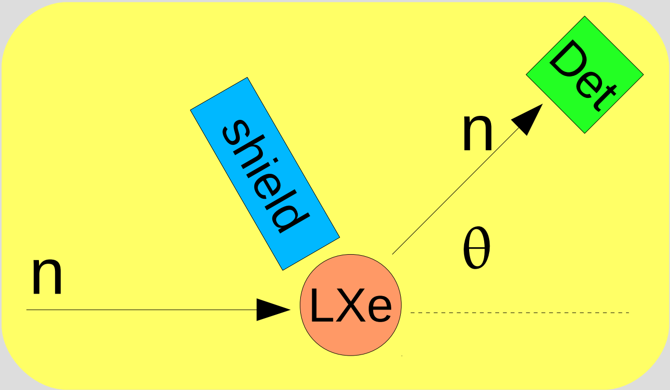
- Installation of ArDM finished March 2013
- **currently: commissioning with GAr**
  - improved uniformity. Detector is taking data.
  - LY=2 pe/keVee @ E=0 keV, measured with α
  - material screening with HPGE @ LSM
  - in-situ n-measurement with liquid scintillator
- **Next: LAr comissioning**
  - LAr tests: HV, purification, cryogenics...
  - expect physics run by 2014

Nuclear Recoil Energy Scale

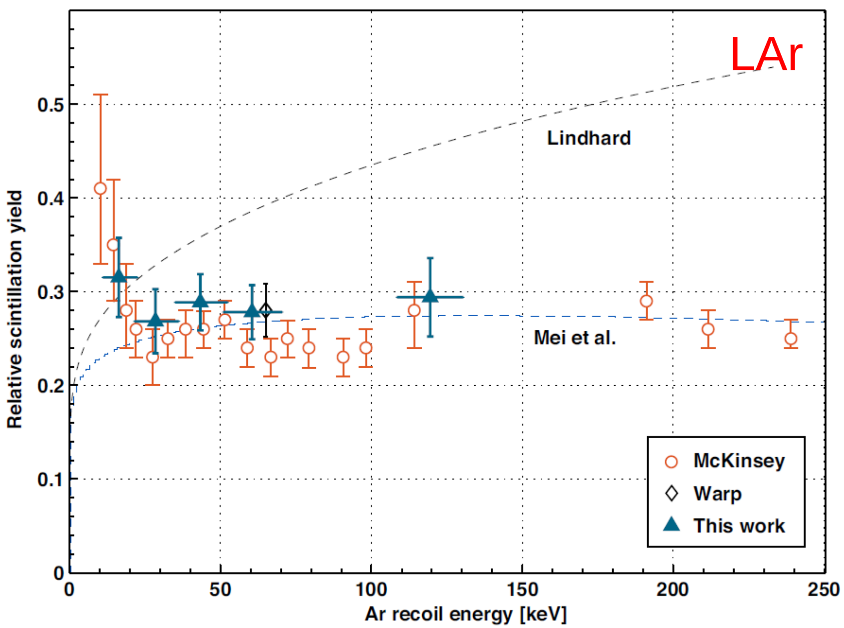
- WIMPs interact with target nucleus
  - ➞ nuclear recoil (*nr*) scintillation
    (β and γ's produce electronic recoils)
- absolute measurement is difficult
  - ➞ measure relative to ^{57}Co (122keV)
- relative scintillation efficiency L_{eff}:

$$\mathcal{L}_{\rm eff}(E_{\rm nr}) = \frac{\rm LY(\mathit{E}_{nr})}{\rm LY(\mathit{E}_{ee} = 122\ keV)}$$

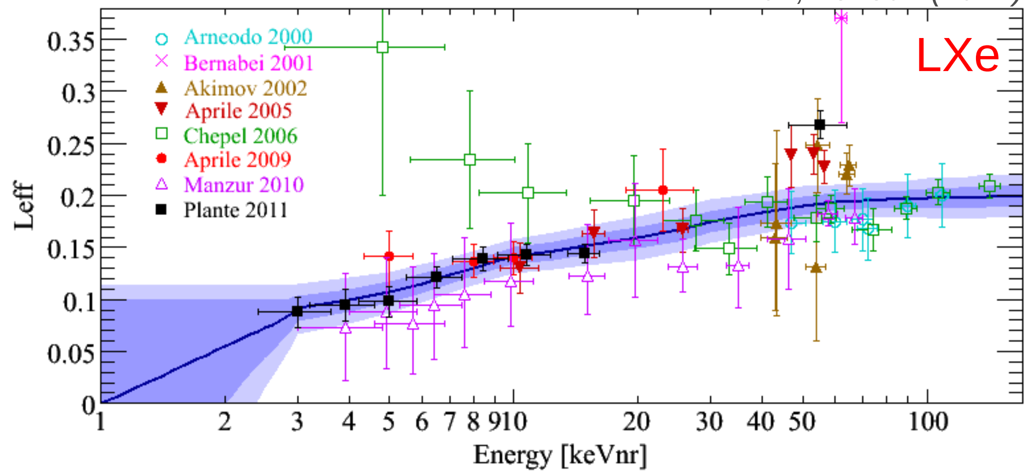
measurement principle:



arXiv:1203.0849



PRL 107, 131302 (2011)



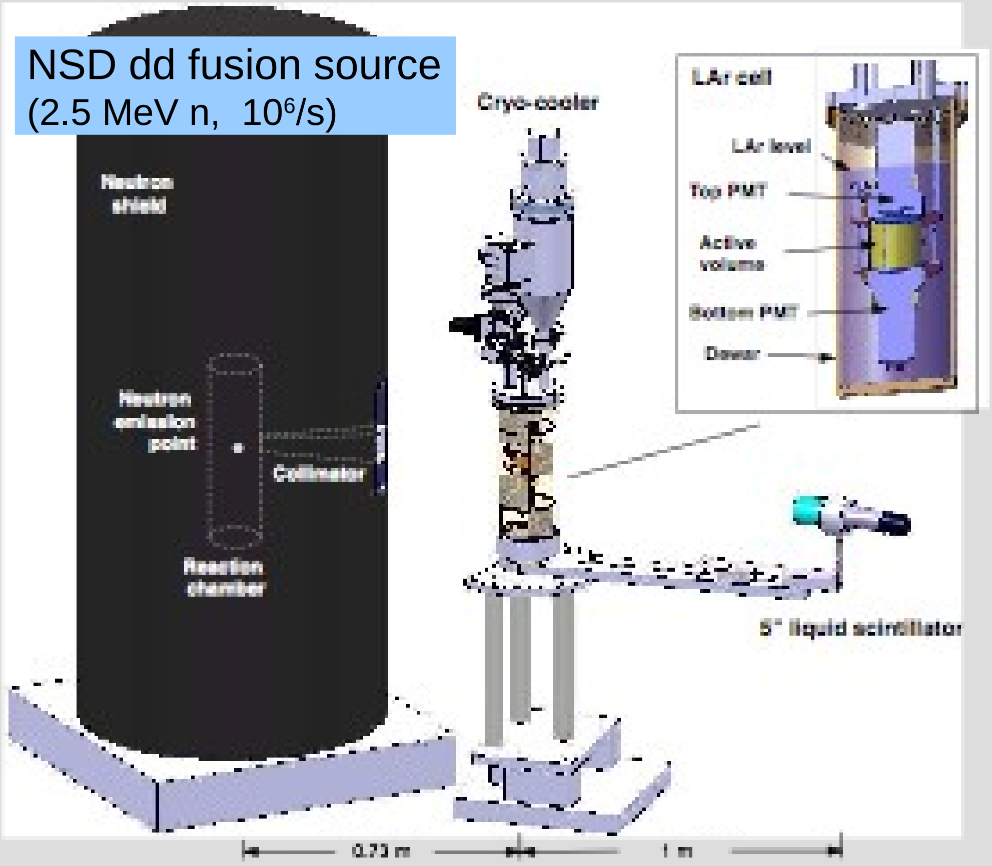
DARWIN: LAr NR Quenching

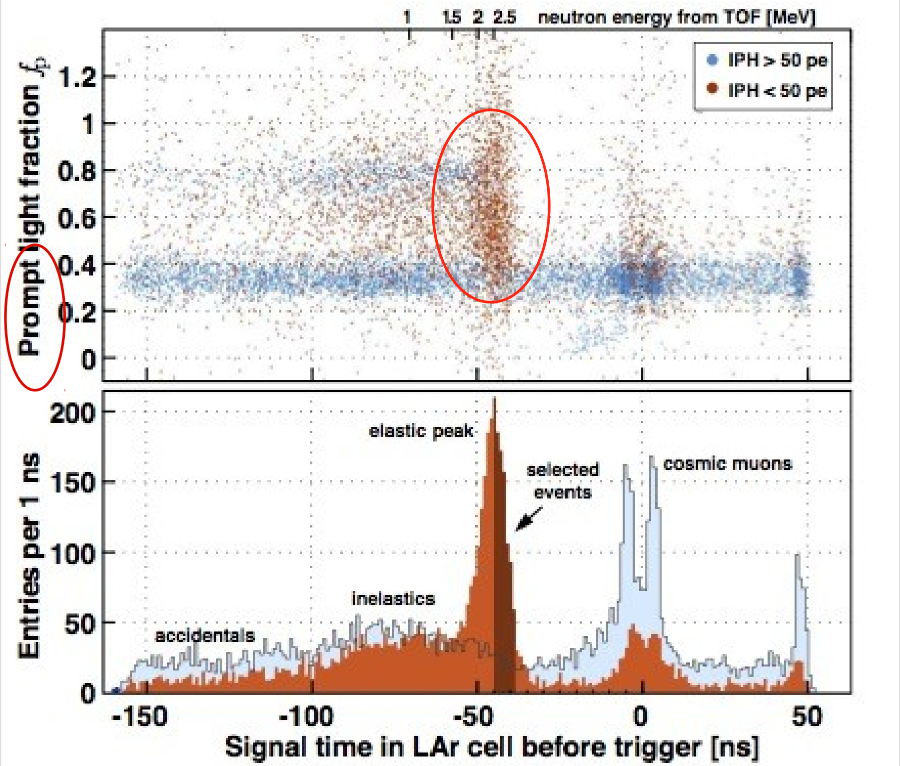
DARWIN

UHZ

- Active volume surrounded by 30 mm LAr
- Active volume 0.2 l
- 2 x R6091 3” Hamamatsu (Pt underlay, QE ~15%)
- PMT coating: evaporated TPB, 0.08 mg/cm²
  Side reflector: Tetratex/TPB, 1 mg/cm²

NSD dd fusion source
(2.5 MeV n, 10^6/s)





LY in LAr for a given n scattering angle, coupled to TOF measurements

C. Regenfus, Y. Allkofer, C. Amsler, W. Creus, A. Ferella, J. Rochet, M. Walter, arXiV:1203.0849 (TAUP 2011)

C. Amsler, arXiv:1105.4524 (WIN’11)

W. Creus, PhD thesis, in preparation

DARWIN: LAr NR Quenching

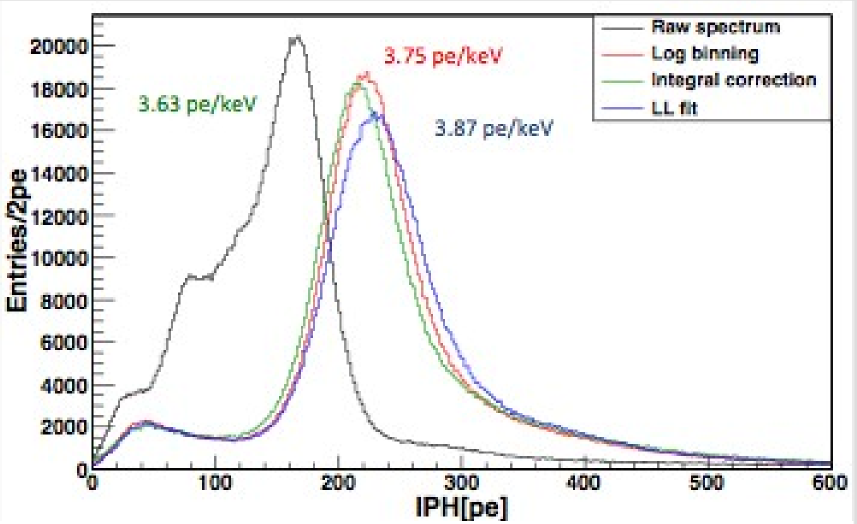
DARWIN

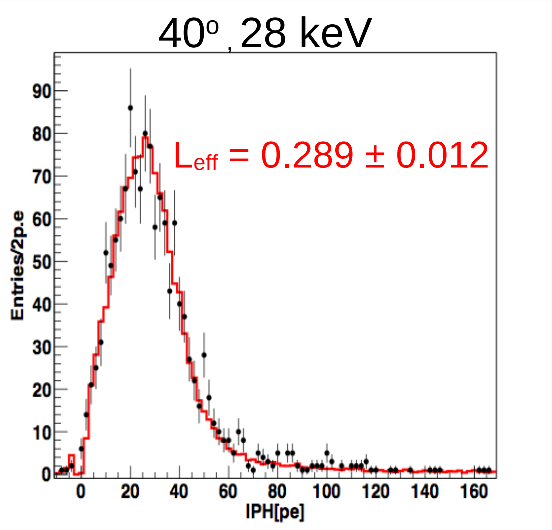
UHZ

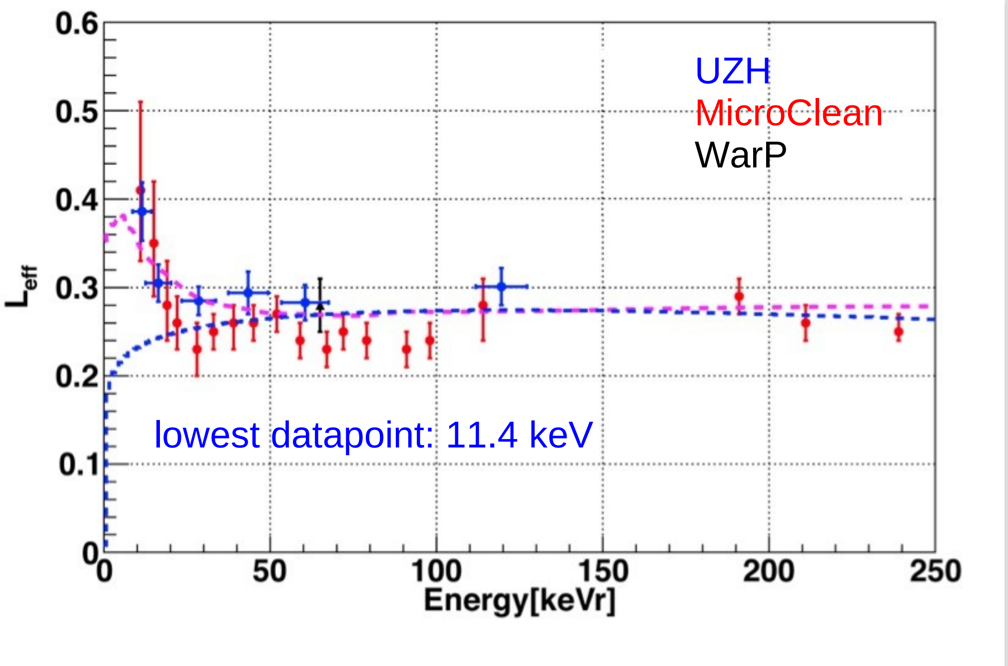
Analysis:
- Geant4 MC simulation
- correction for LAr impurities
  slow component is very sensitive to impurities
  JINST 3, P02001 (2008)
  fast component dominates for NRs

→ strong reduction of systematics reached
→ indication for rising LY

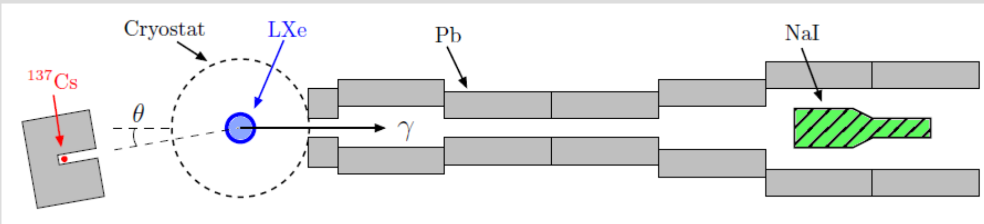
Ongoing upgrades, plans:
- repeat measurements with E-field
- go to smaller angles (energies)
- problem: personnel?

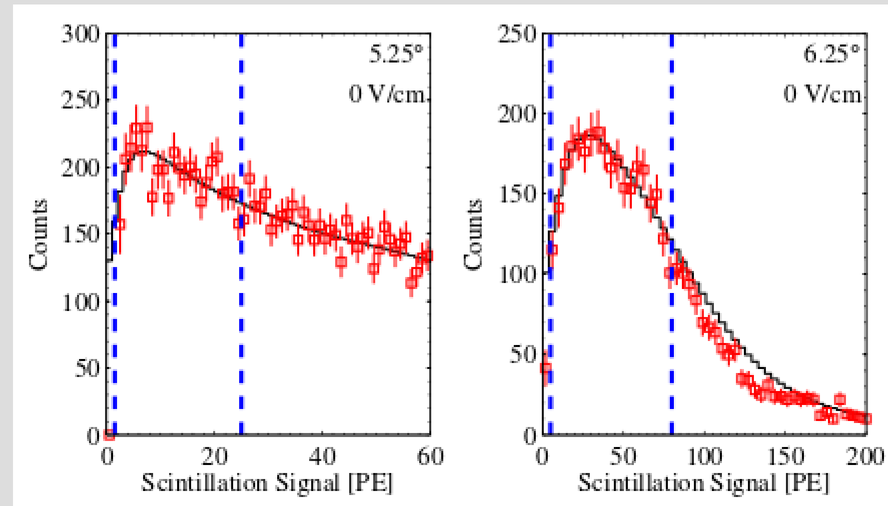






DARWIN: LXe ER energy Scale

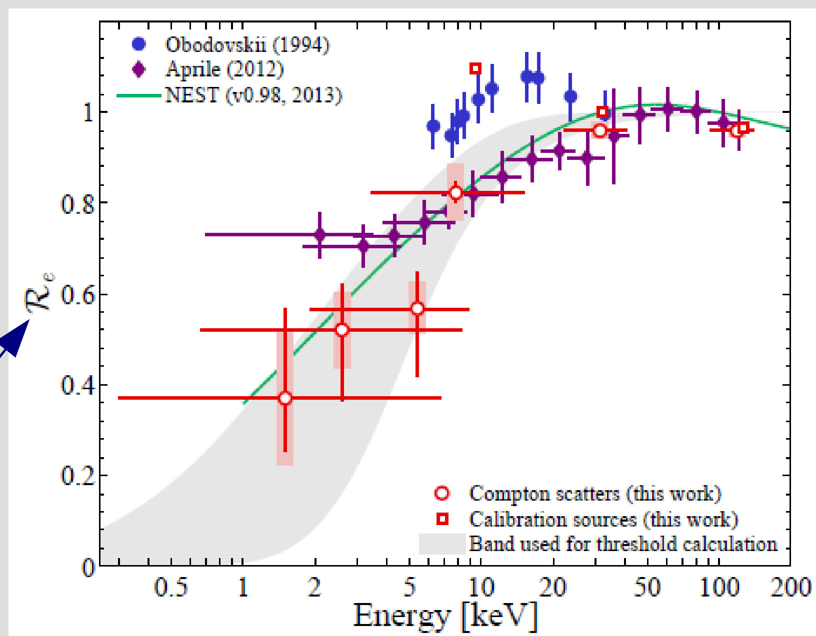


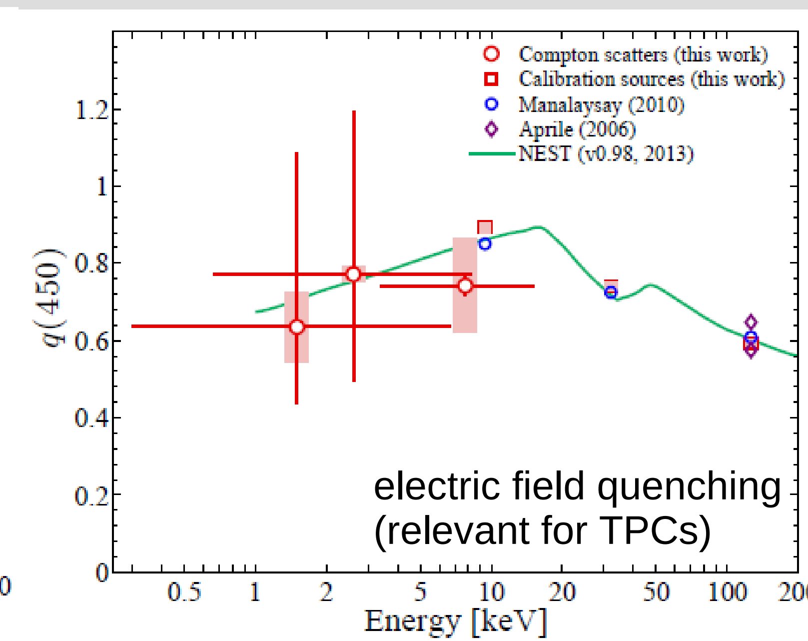


Measurement of LXe response
to electronic recoils shows
that LXe detecors can probe
the DAMA energy range (2-4 keVee)

PRD 87, 115015 (2013)

Light output relative to $^{83}Kr^{m}$ (32.1 keV)

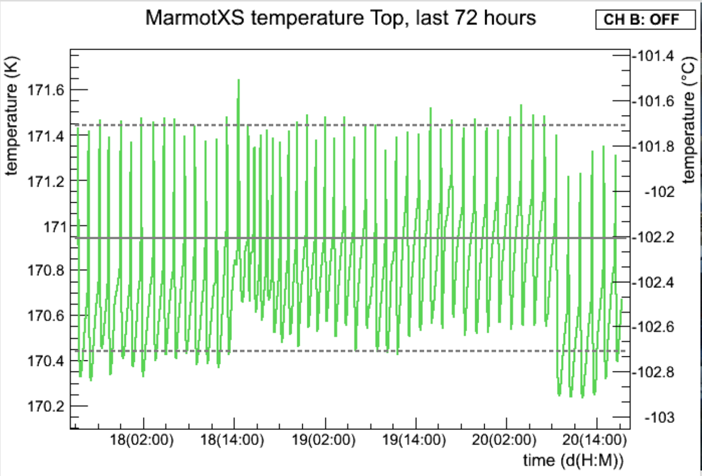


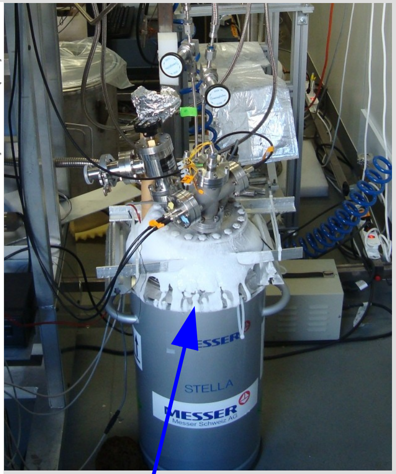


electric field quenching
(relevant for TPCs)

DARWIN: Photosensor R&D

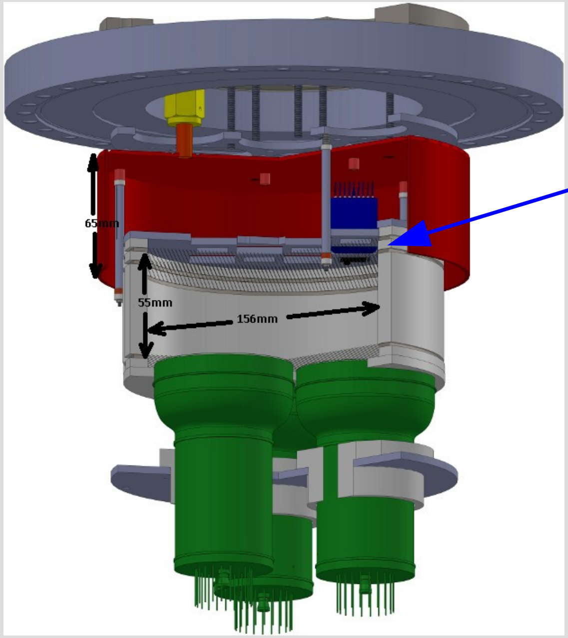
UHZ

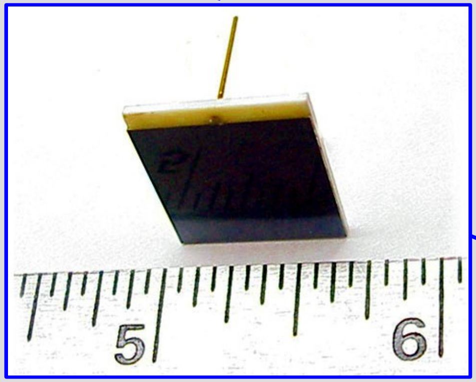




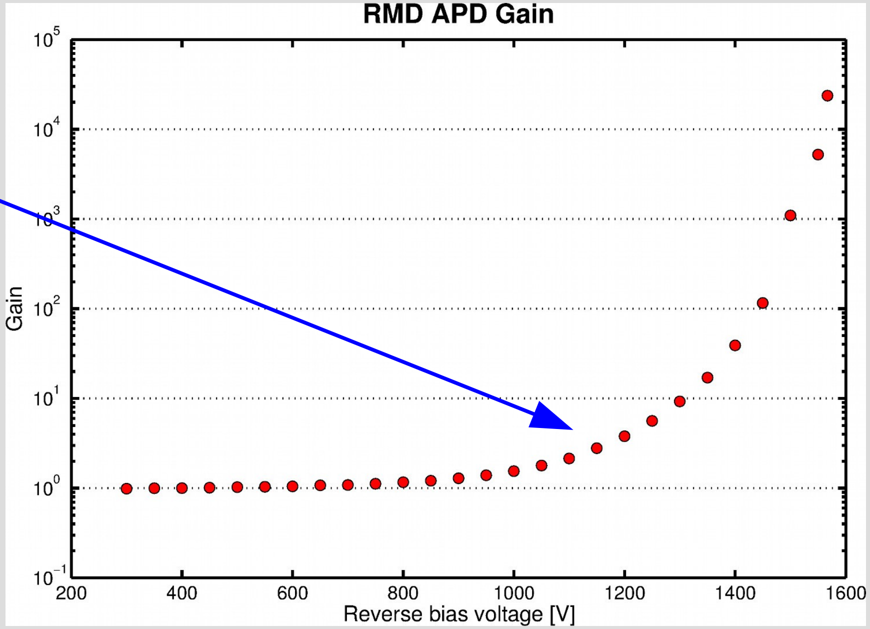
Avalanche Photodiodes (APDs) @ UZH

- 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





will also study SiPMs (Hamamatsu)

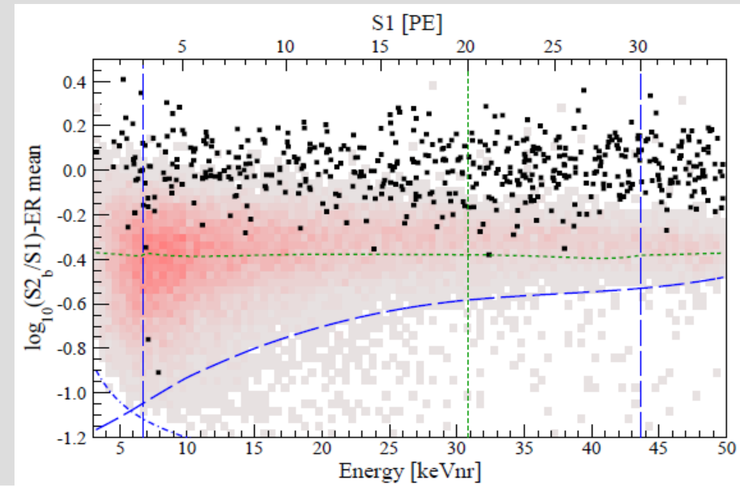


XENON100: Spin-dependent Limit

UHZ, Bern

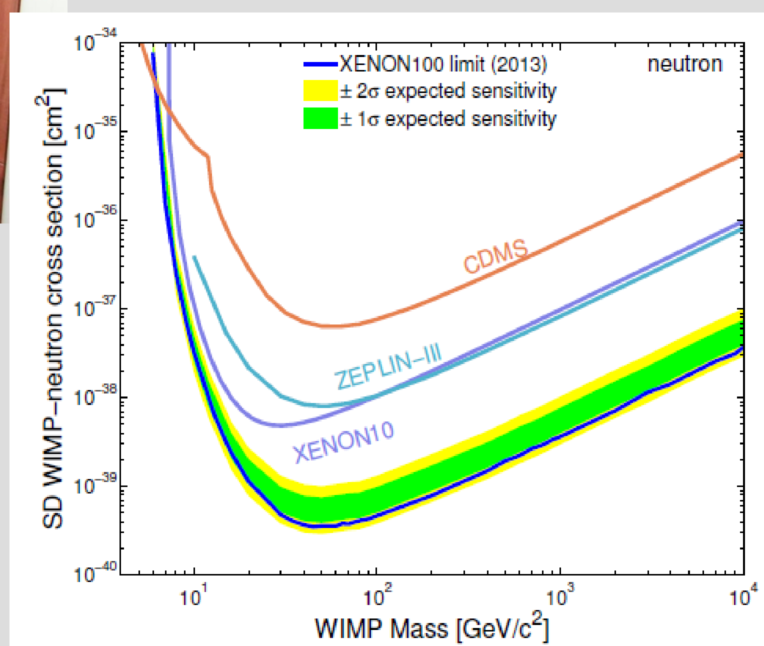
Latest science data (2012) of 225 x 34 kg days exposure has been analyzed in terms of spin-dependent WIMP-nucleon interactions

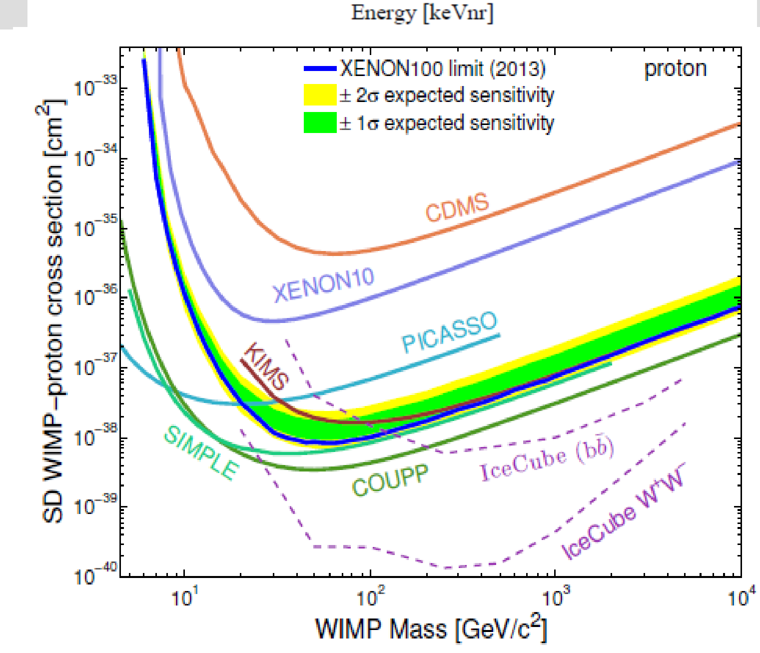
accepted by PRL, arXiv:1301.6620



Quick Facts

- 62 kg **LXe** target
- 2-phase TPC
- 242 PMTs
- Lowest background of all DM detectors
- running @ LNGS (IT)

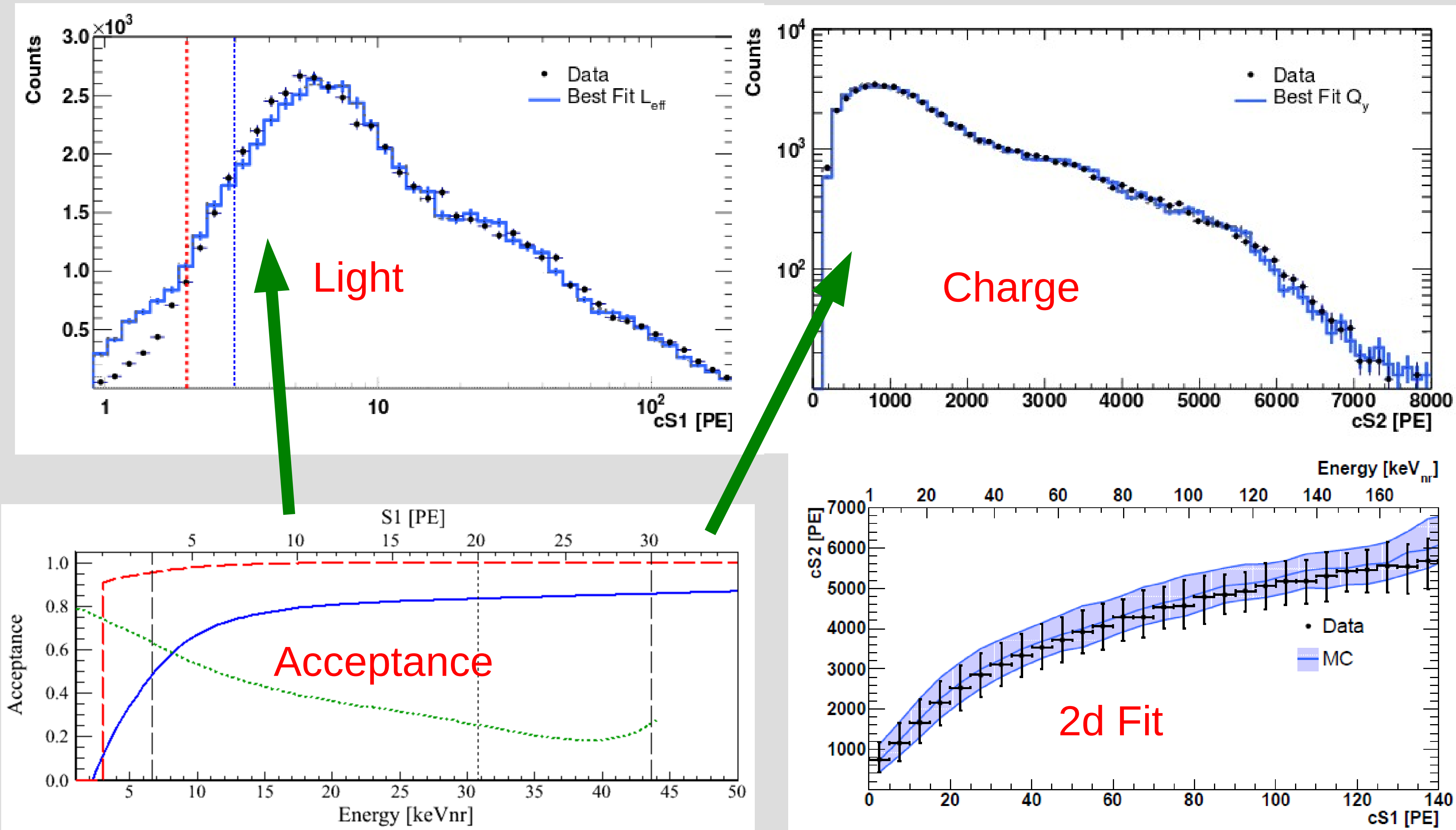




XENON100: Low E NR Response

UHZ, Bern

→ successful absolute neutron data/MC matching down to ~3 keVr



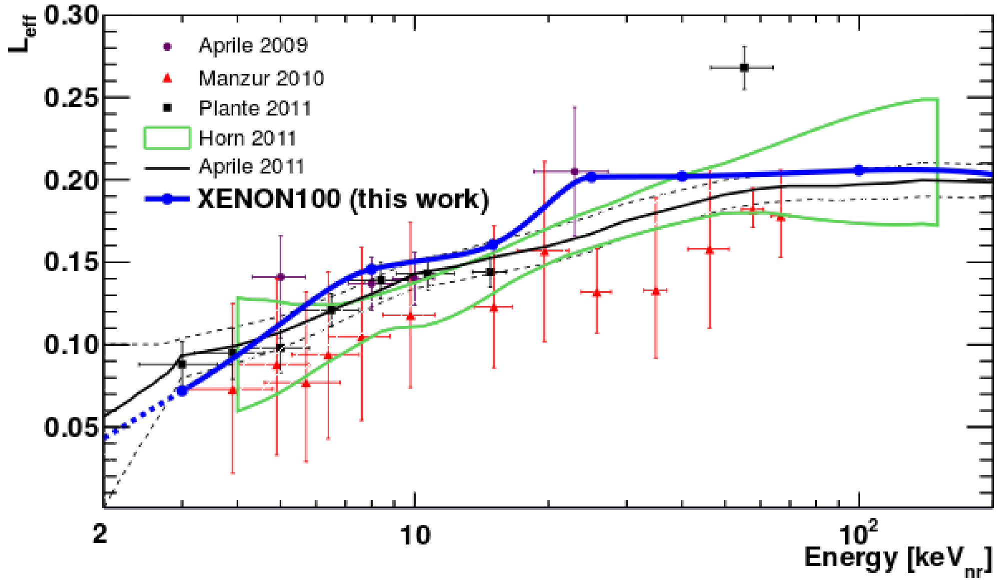
arXiv:1304.1427

XENON100: Low E NR Response

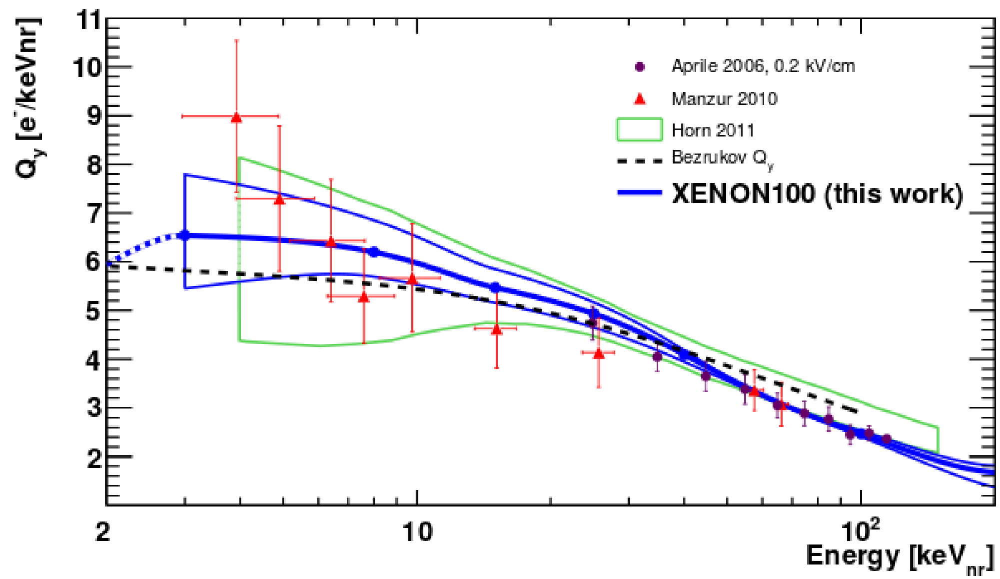
UHZ, Bern

→ successful absolute neutron data/MC matching down to ~3 keVr

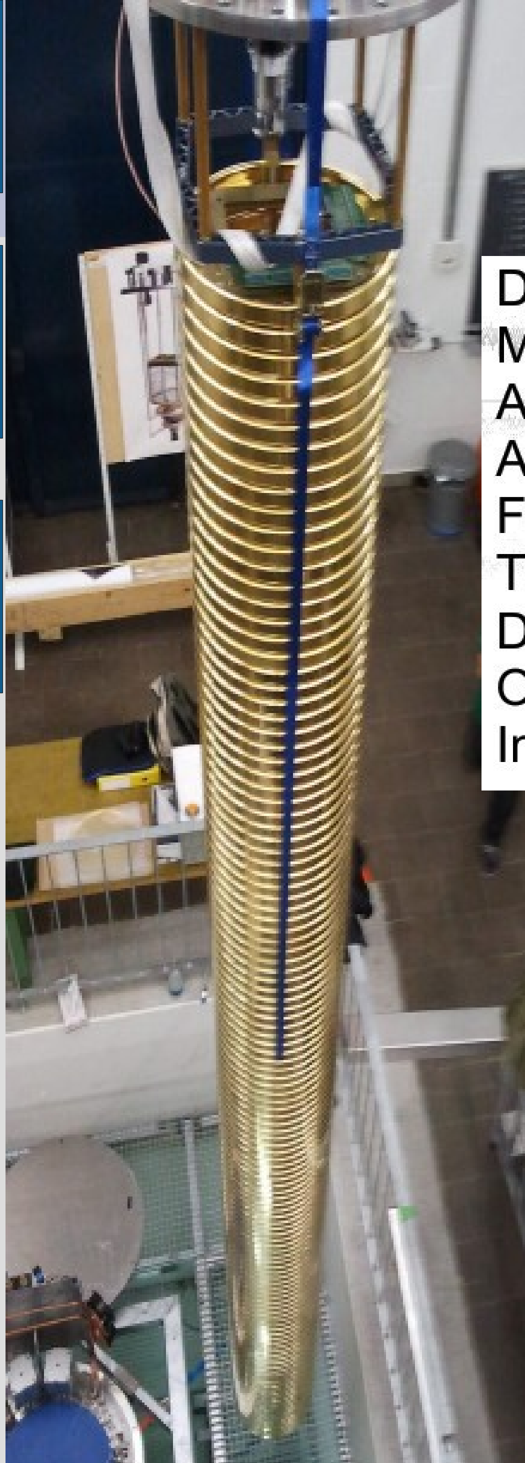
Light: Relative Scintillation Efficiency



Charge: Charge Yield



arXiv:1304.1427



ARGONTUBE

Drift length: 5 m
Max Cathode Voltage: -500 kV
Active volume: 0.2 m^3
Active mass: 280 kg
Full drift time @1 kV/cm: 2.5 ms
Temperature: 87 K
Dewar with outer LAr bath
Outer volume: 1.2 m^3
Inner volume: 1.1 m^3

arXiv:1304.6961

Bern

XY-wire readout (64x64 ch, 3mm pitch)
warm preamps: ETH design
cold preamps: BNL LARASIC-4
→ under study

T_0 via 2 PMTs coated with TPB

Science Goals of ARGONTUBE:

- Achieve lifetimes of O(ms)
- Apply 500kV generated in situ by Greinacher chain
- Measure charge diffusion at dt~O(ms)
- Test threshold achievable at 5m drift with direct charge readout and warm/cold electronics; also test charge amplification

ARGONTUBE

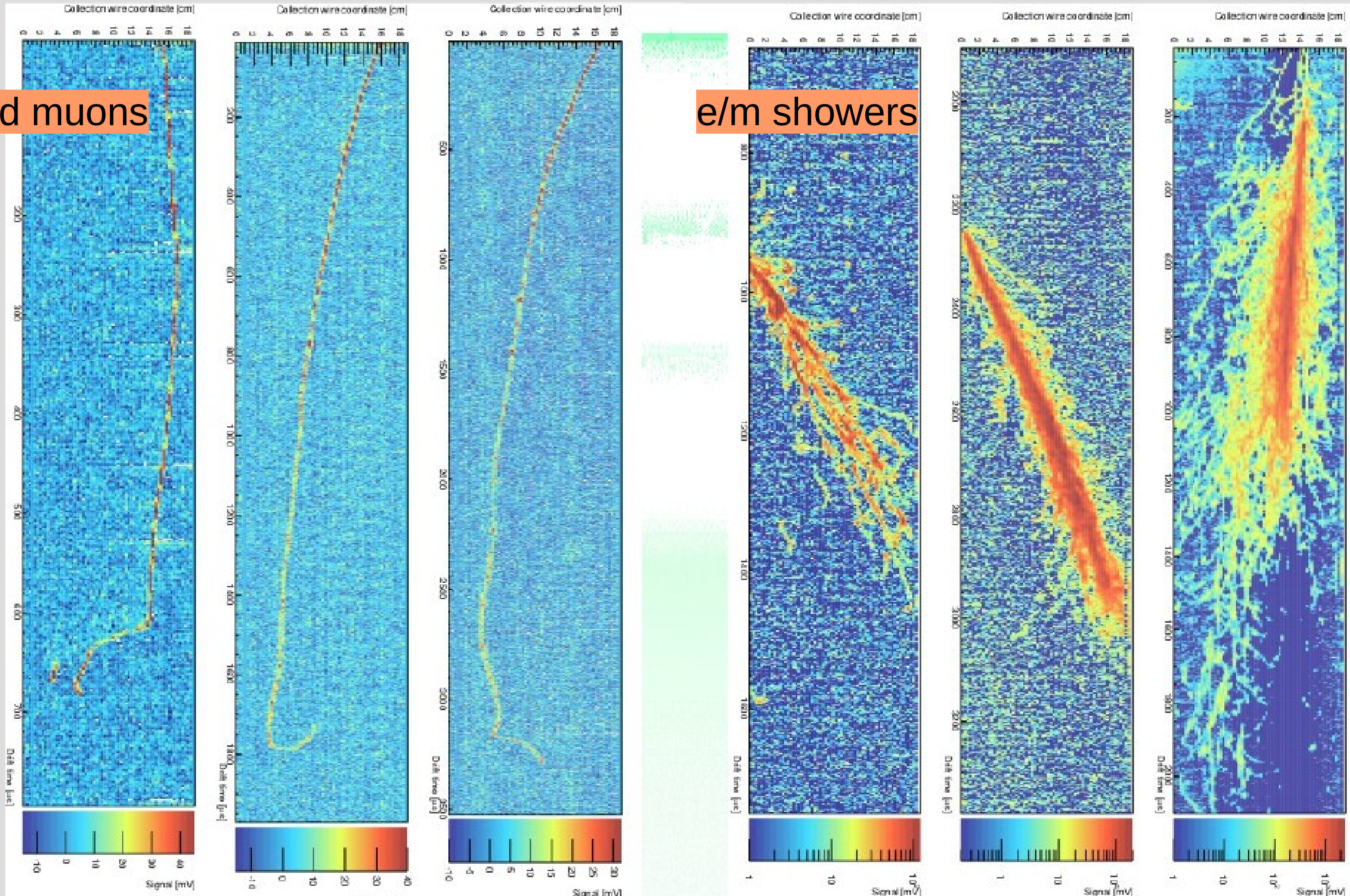
LHEP Universität Bern

Bern

Tracks from ARGONTUBE:

stopped muons

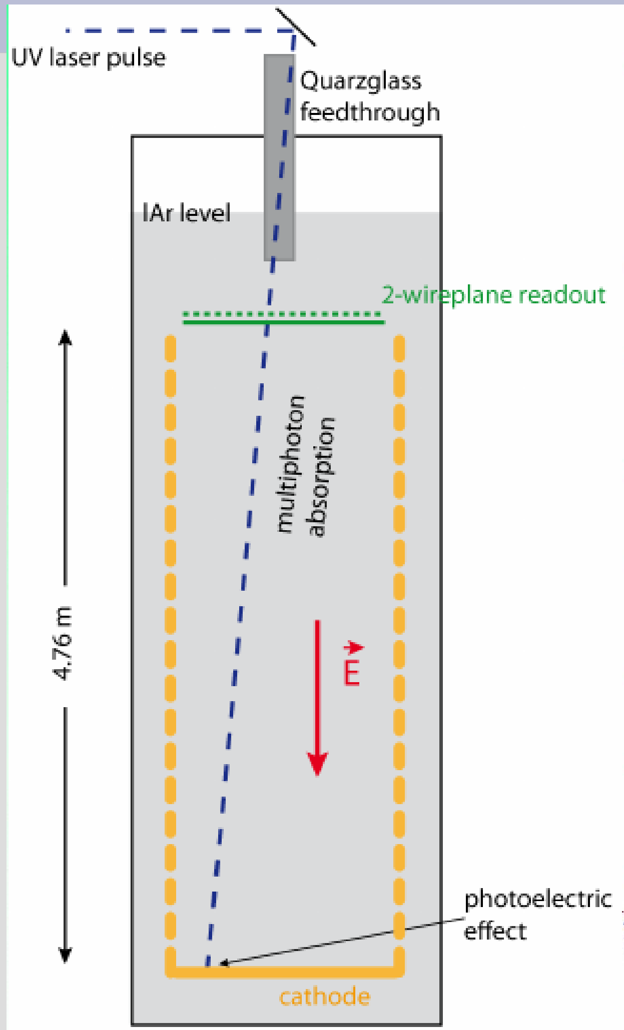
e/m showers

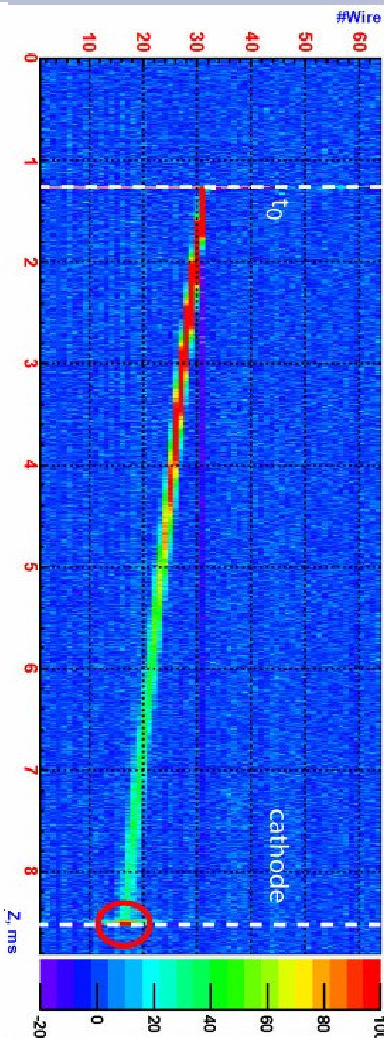


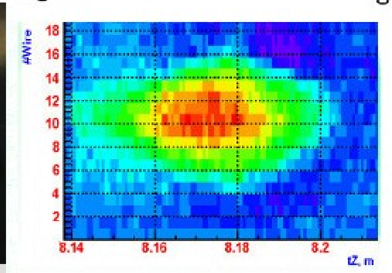
ARGONTUBE

LABORATORIUM FÜR HOCHENERGIEPHYSIK LHEP UNIVERSITÄT BERN

Bern





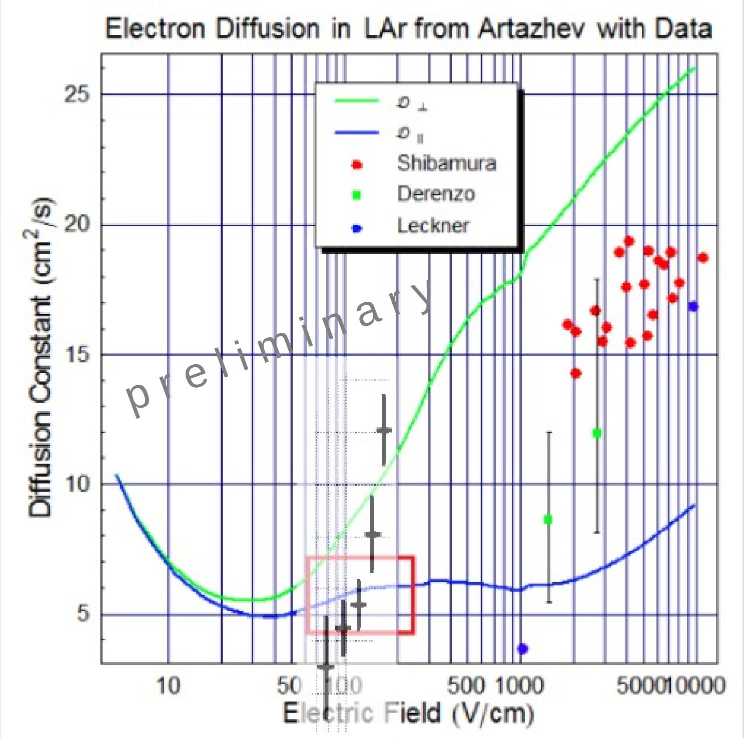


Calibration Laser

Use laser for calibration.
Measure space charge effect?

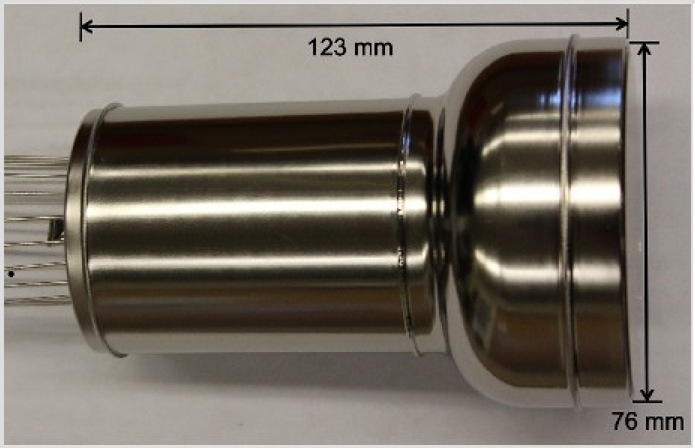
Laser: λ=266 nm
efficiency Q~10^{-5} e/photon
pulse duration 5-6 ns

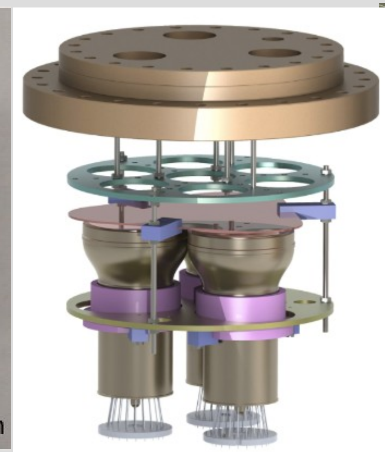
New measurement of longitudinal diffusion:



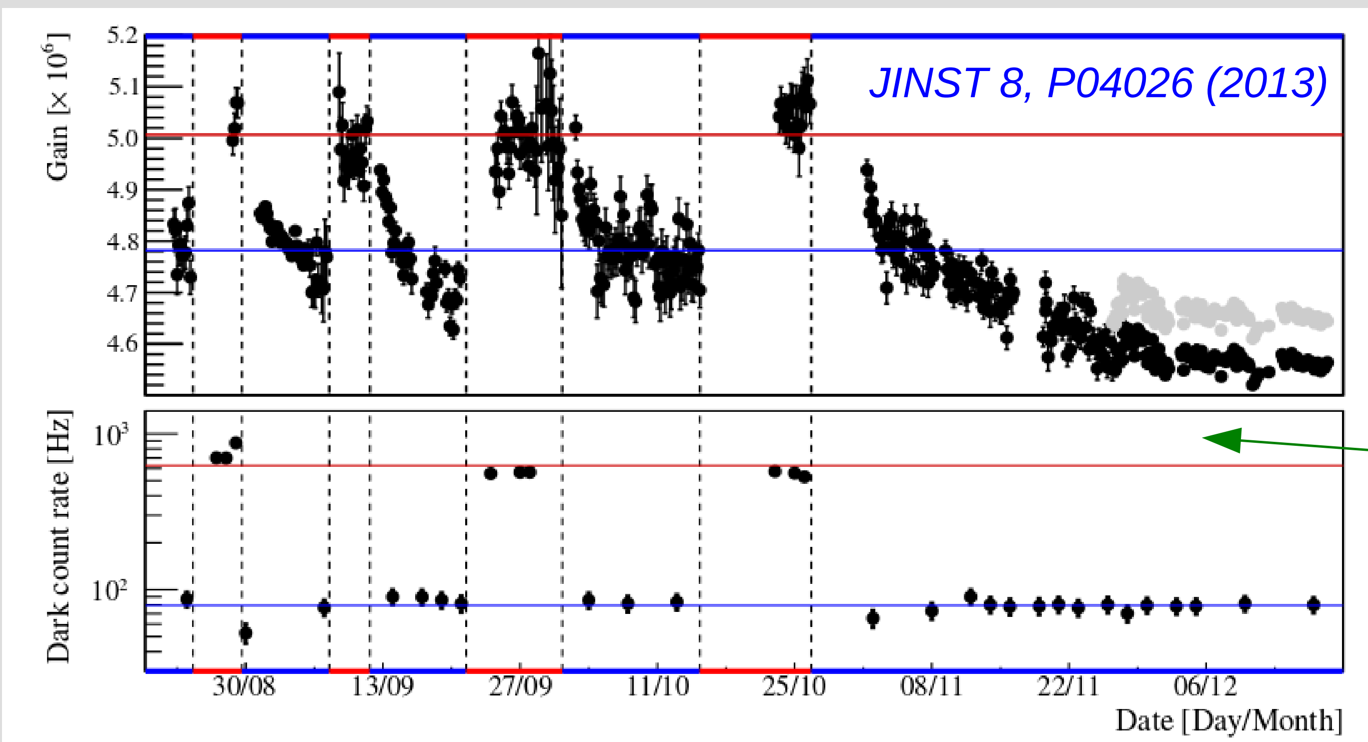
XENON1T: PMT Studies

UHZ, Bern





Hamamatsu R11410
- high QY (~35%)
- high CE (~95%)
- LXe operation
- low radioactivity



Tube was tested at UZH in realistic LXe/GXe environments:
- gain, P/V in warm/cold
- afterpulses
- radioactivity
- performance in E field
- long-term LXe stability
- thermal cycling

→ 248 of these PMTs will be used in XENON1T
(purchased by **UZH**, Columbia, MPIK)

XENON1T starts NOW

UHZ, Bern

Swiss Responsibilities:
TPC Design (UZH, Bern)
TPC construction/testing,
  LXe cabling, material screening,
  MC background studies,
  PMTs+PMT caibration (UZH)
DAQ, air side cabling (Bern)

Building construction
starts next week,
by mid-August, a big
part of the water
shield will be finished

Summary

LAGUNA
LBNO with LAr
ETHZ, UNIGE, UNIBE

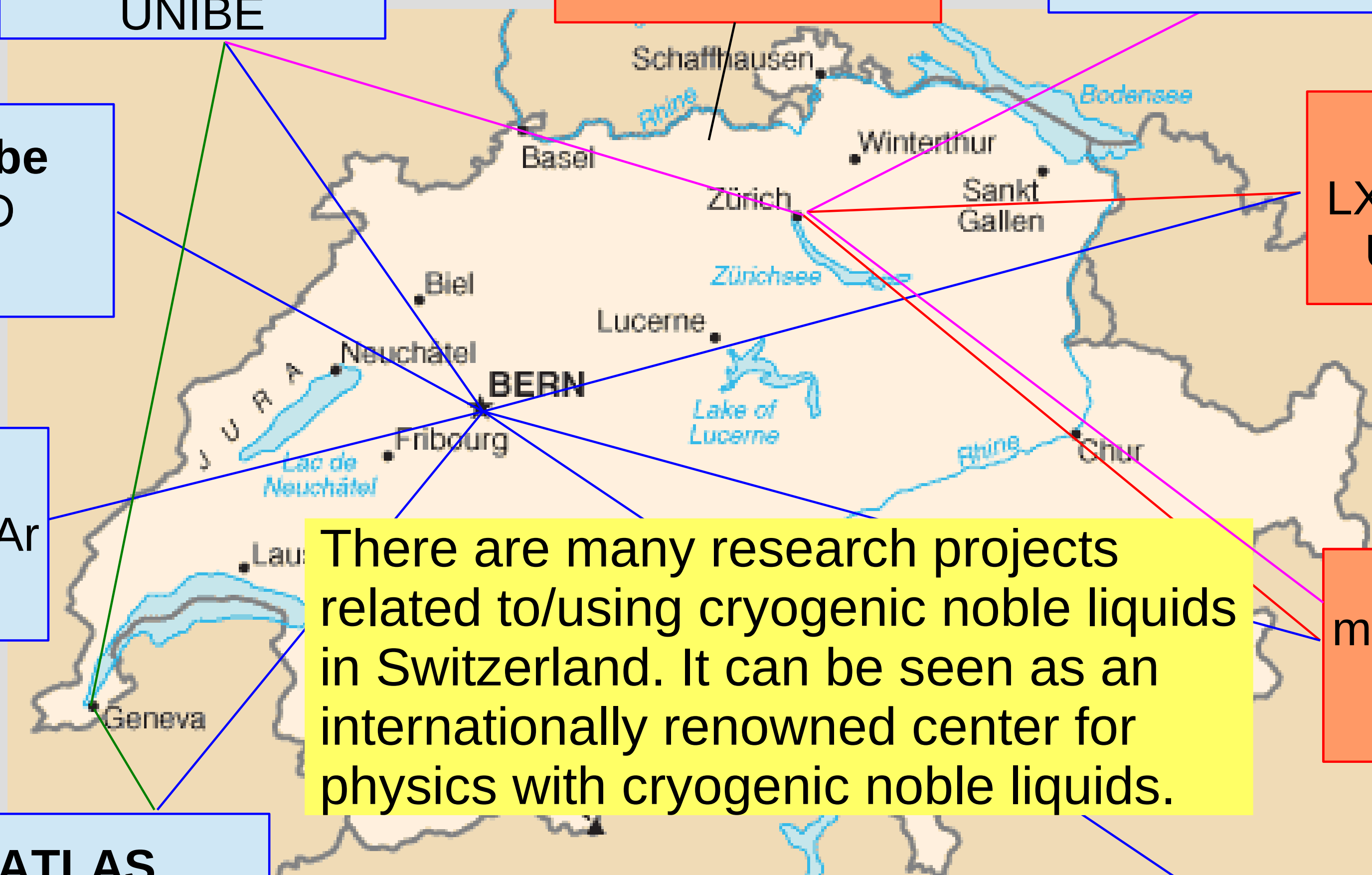
MEG
LXe-Calorimeter
PSI

ArDM
LAr DM
ETHZ

ArgonTube
LAr R&D
UNIBE

XENON
LXe Dark Matter
UZH, UNIBE

MicroBoone
low-E νs with LAr
UNIBE



DARWIN
multi-ton LXe/LAr
UZH, ETH, UNIBE

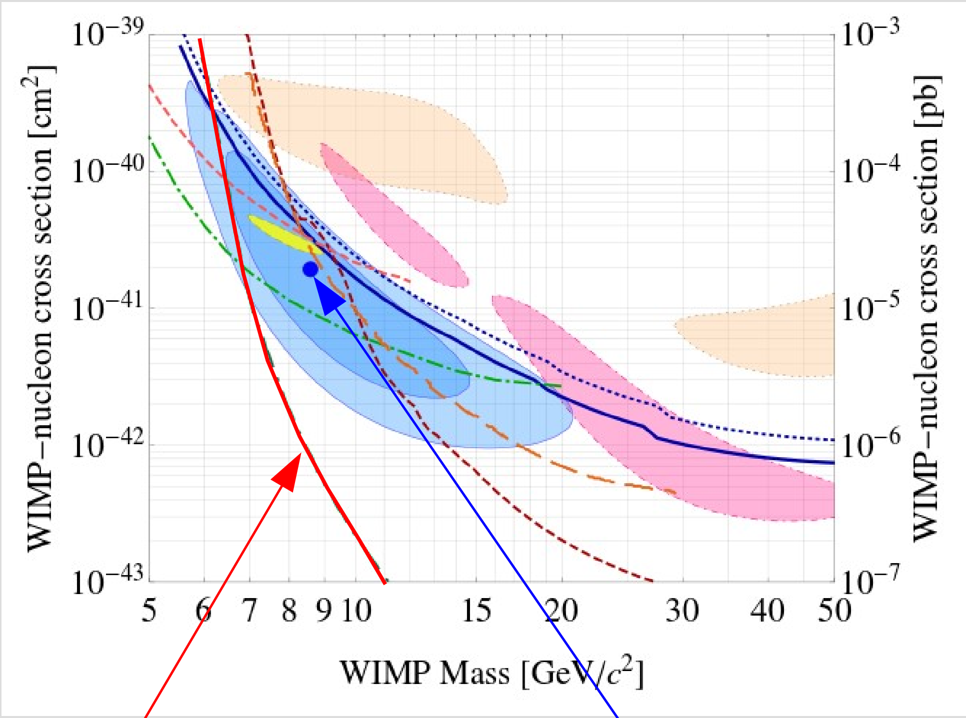
There are many research projects related to/using cryogenic noble liquids in Switzerland. It can be seen as an internationally renowned center for physics with cryogenic noble liquids.

ATLAS
LAr-Calorimeter
UNIGE, UNIBE

EXO
LXe $0\nu\beta\beta$
UNIBE

Backup

CDMS-II (Si) and XENON100



XENON100
PRL 109, 181301 (2012)

CDMS-II (Si)
arXiv:1304.4279

- CDMS claim challenged by XENON100 non-observation
- XENON100 result backed-up by recent low-E NR study (*arXiv:1304.1427*)

How would the (most likely) CDMS-II (Si) signal look like in XENON100: