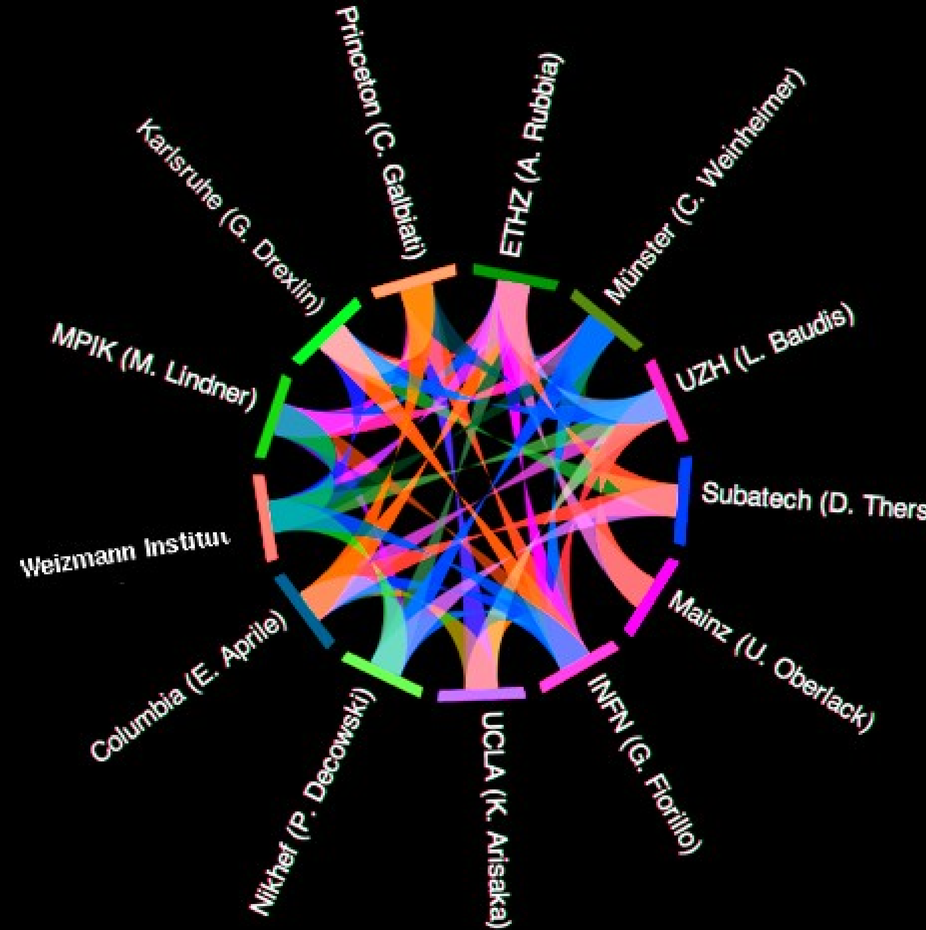


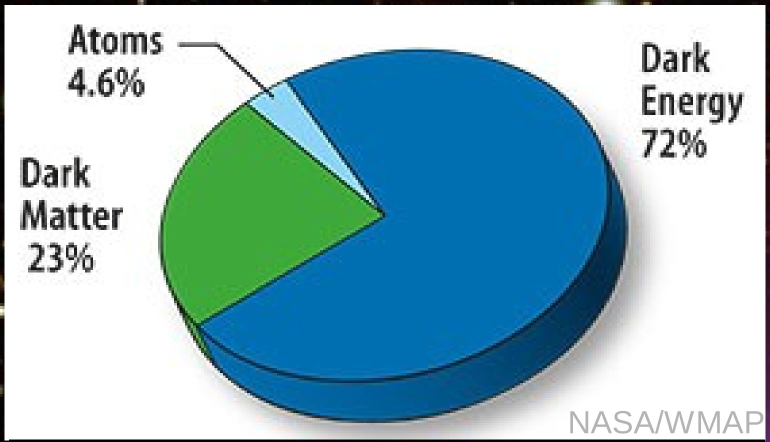
DARWIN

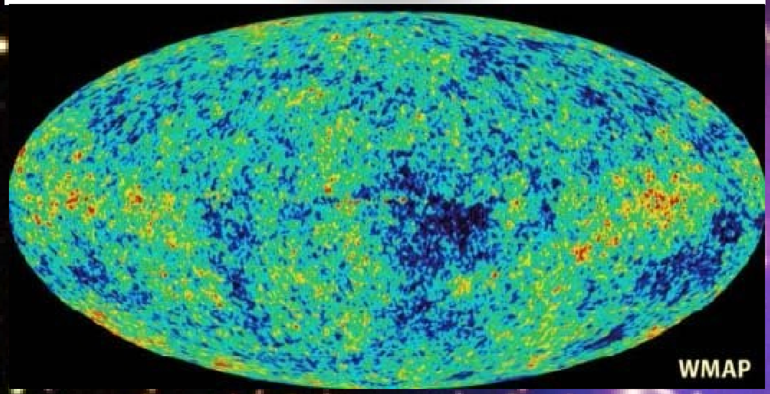
Marc Schumann *Physik Institut, Universität Zürich*

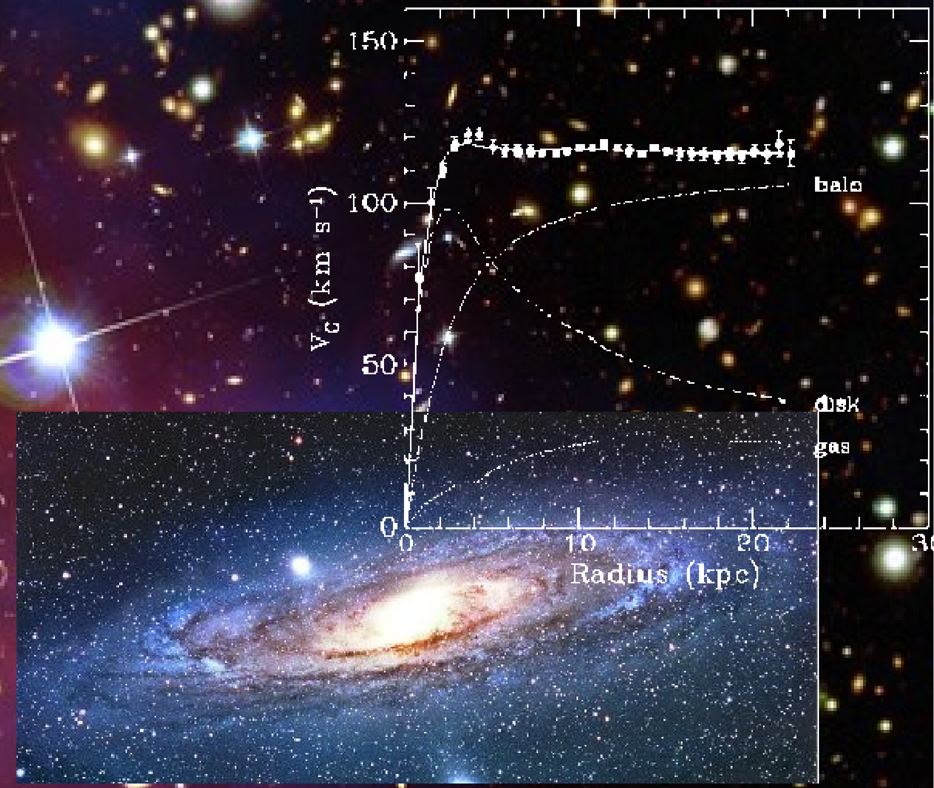
PATRAS 2011, June 27 – July 1, 2011

www.darwin.physik.uzh.ch

Dark Matter: Evidence & Detection

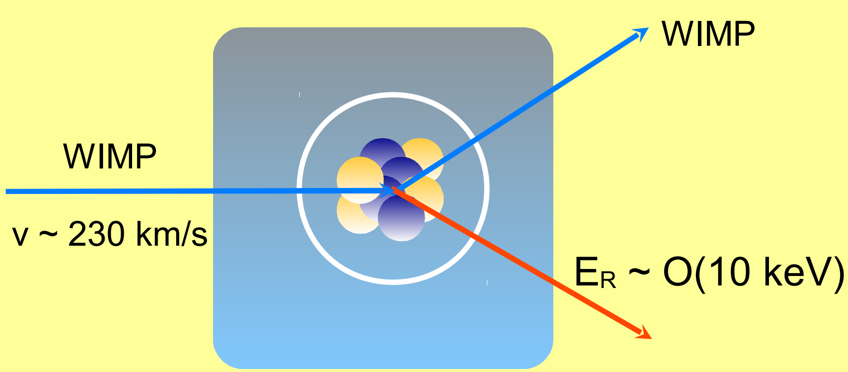




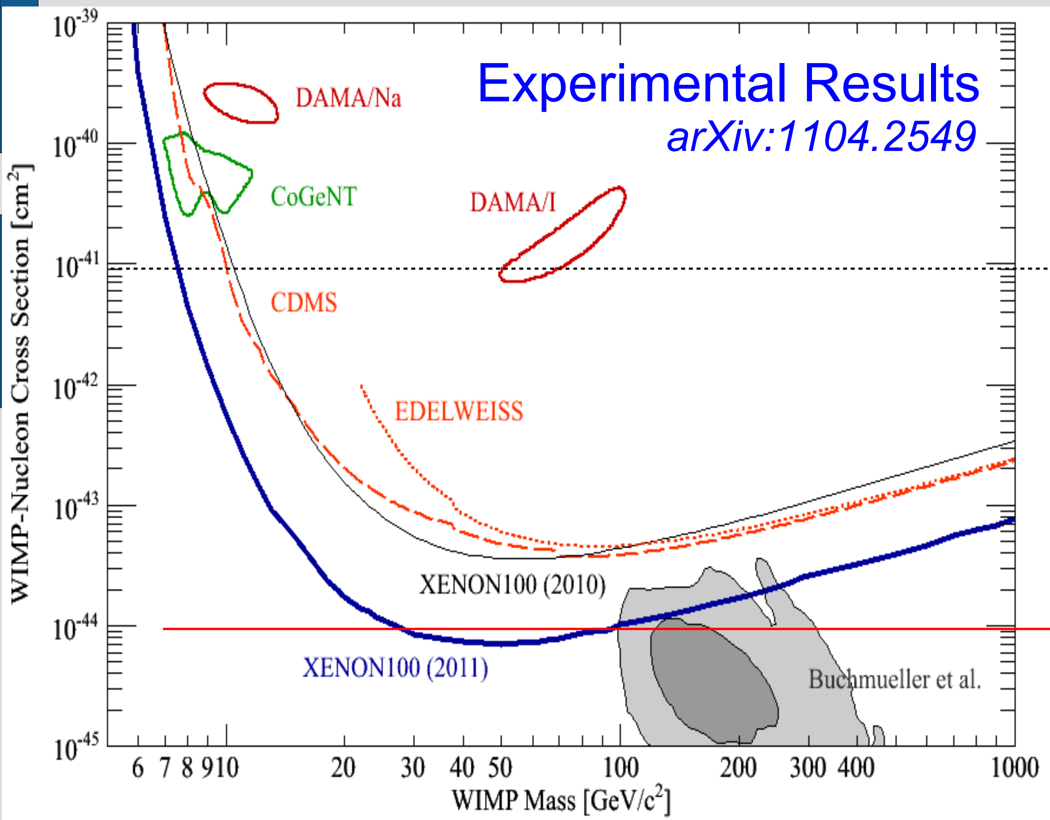


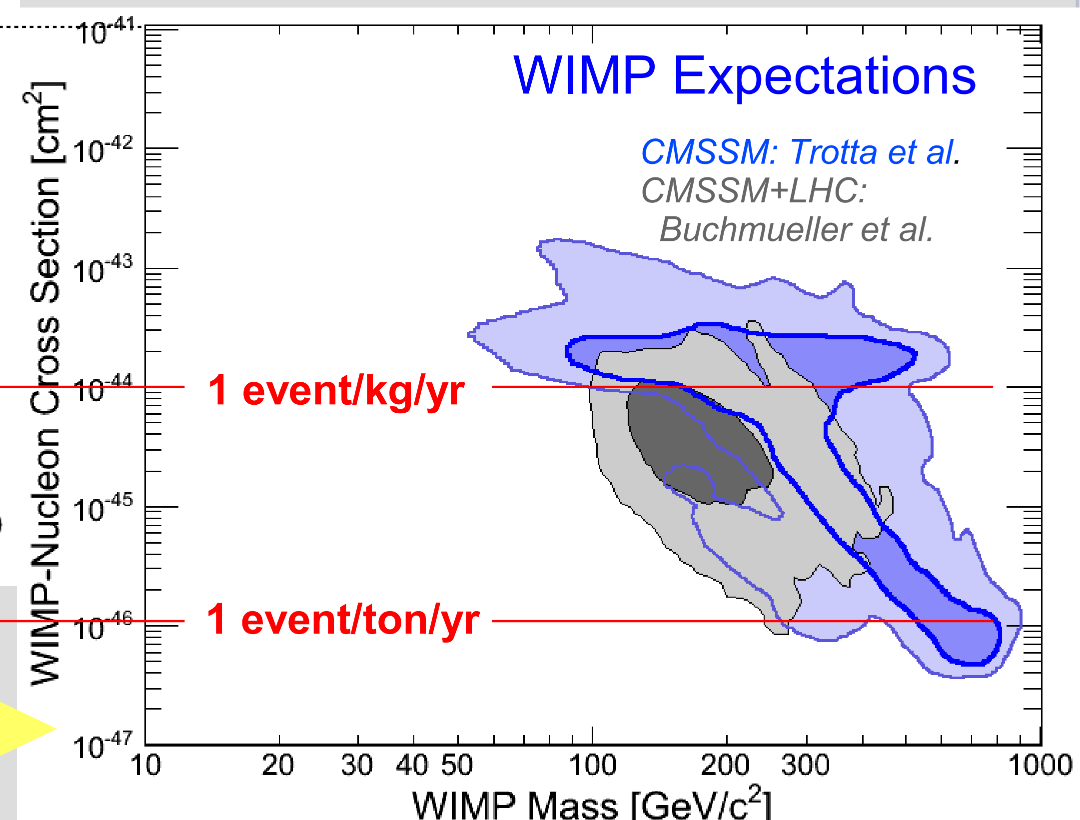
Direct Detection:

Elastic Scattering of WIMPs off target nuclei
➞ nuclear recoil



Where are we? Where do we go?





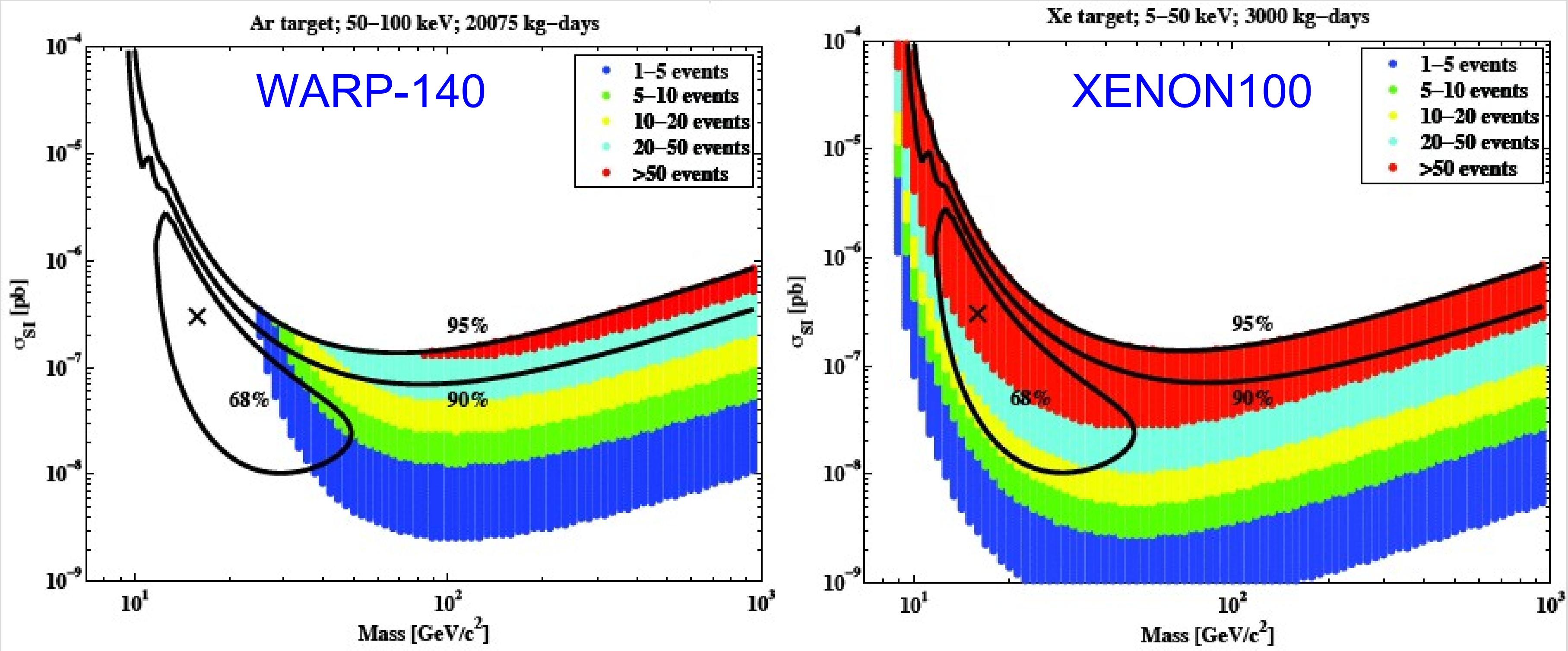
How do we get there?

WIMP Spectroscopy?

Assume the 2 events „seen“ by CDMS in 2009 would be WIMPs

Science 327, 1619 (2010)

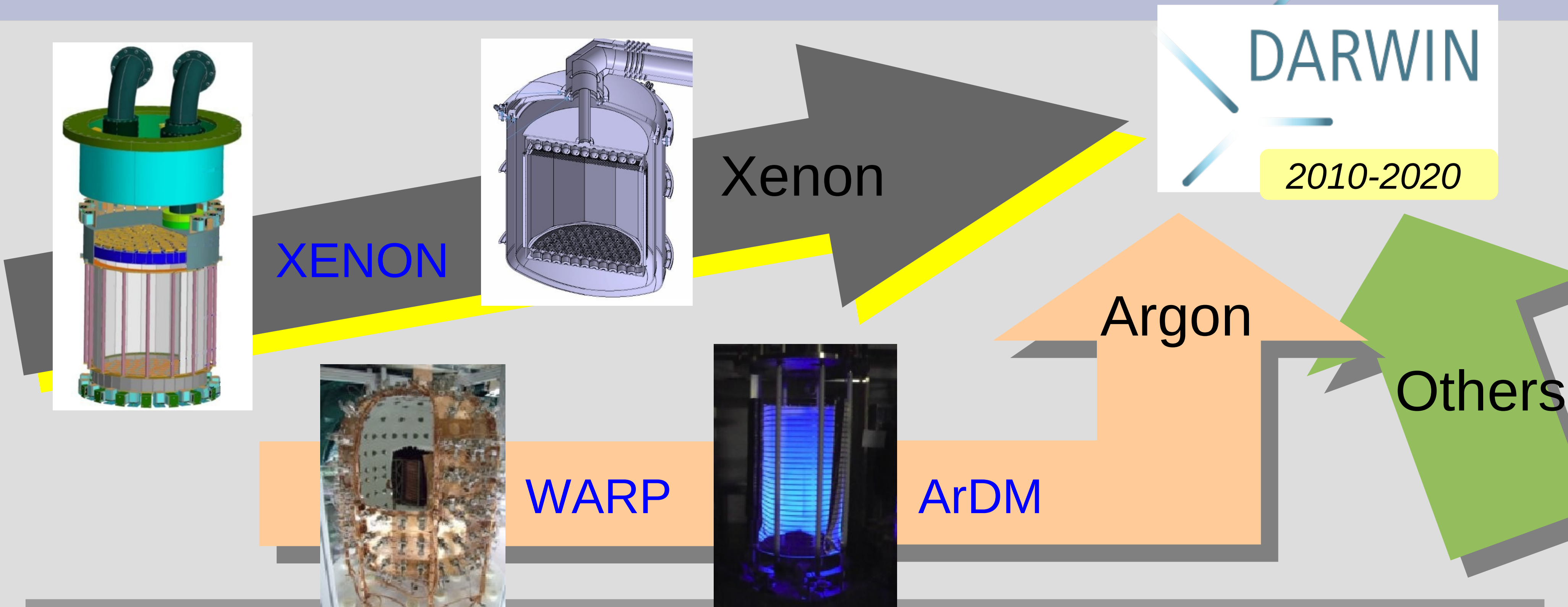
What would existing LAr/LXe detectors see?



110 kg x 365 d x 50% acceptance

30 kg x 200 d x 50% acceptance

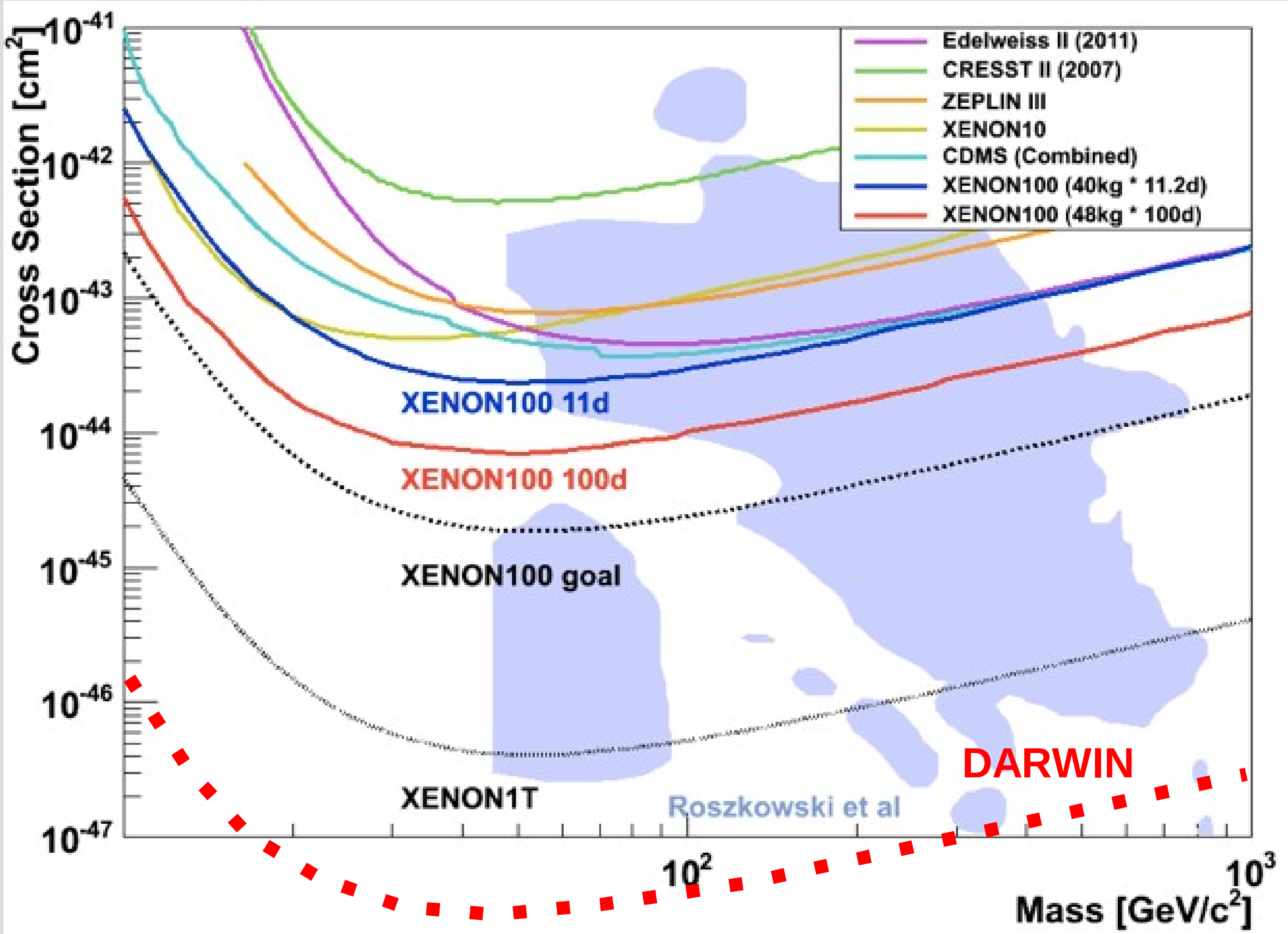
DARWIN



DARWIN – Dark Matter WIMP Search with Noble Liquids

- *R&D and Design Study* for a next generation noble liquid facility in Europe. Approved by ASPERA in late 2009
- Coordinate existing European activities in LXe and LAr towards a multi-ton Dark Matter facility
- Physics goal: probe WIMP cross sections well below 10^{-47} cm²

Science Goal

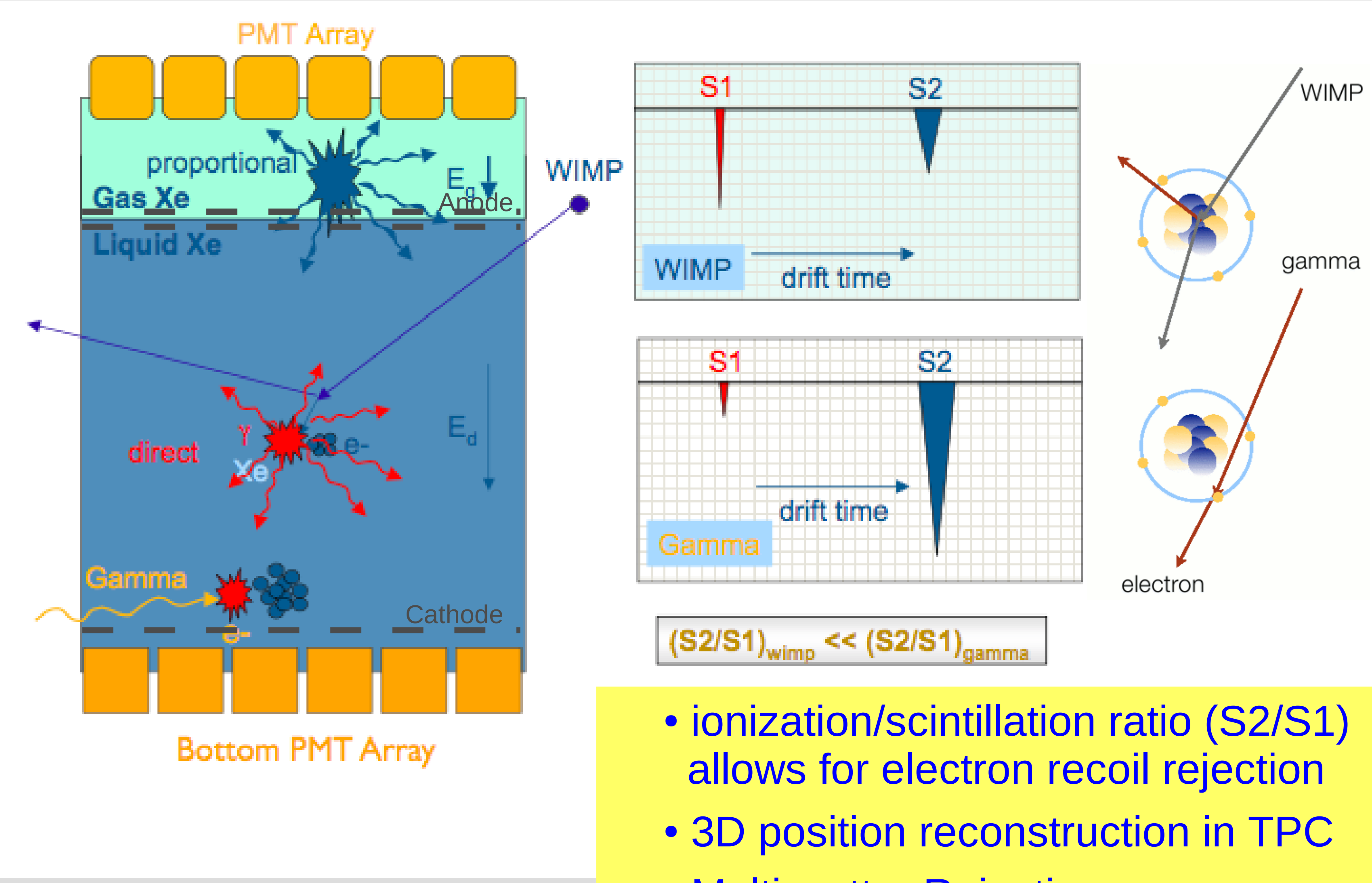


DARWIN

DARWIN is a Design Study
for a next-to-next generation
Dark Matter detection experiment
based on LXe/LAr

Most technical requirements
have not beed defined yet.
They are the outcome of
the DARWIN study.

TPC Approach



- ionization/scintillation ratio (S2/S1) allows for electron recoil rejection
- 3D position reconstruction in TPC
- Multiscatter Rejection
- LAr: Pulse Shape Discrimination

DARWIN Consortium

2nd DARWIN meeting Sept 2010, UZH

ArDM, WARP, XENON + new Groups:
UZH (CH), INFN (I), ETHZ (CH), Subatech (F), Mainz (D), MPIK (D), Münster (D), Nikhef (NL), KIT (D), WIS (IS)
+ Columbia, Princeton, UCLA (USA)

This talk presents contributions from many members

`http://darwin.physik.uzh.ch`

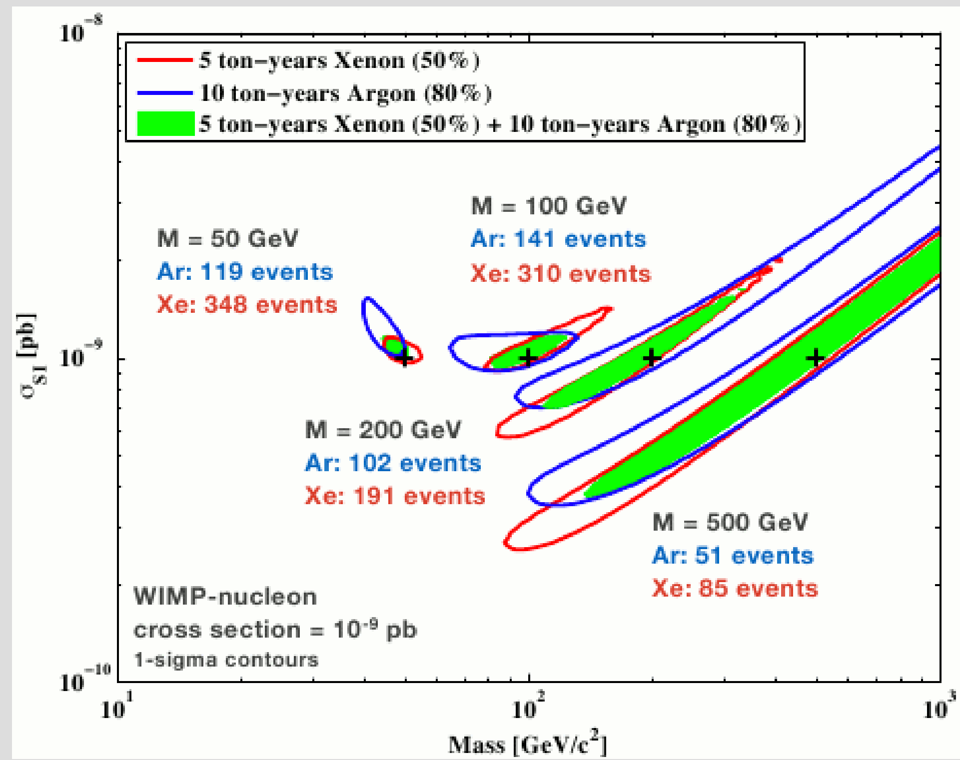
Structure

R&D and Design Study for

- Detector Infrastructure
- Light/Charge Readout
- Electronics/DAQ
- Underground / Shield Infrastructure
- Material Screening and Backgrounds
- Science Impact

The DARWIN proposal

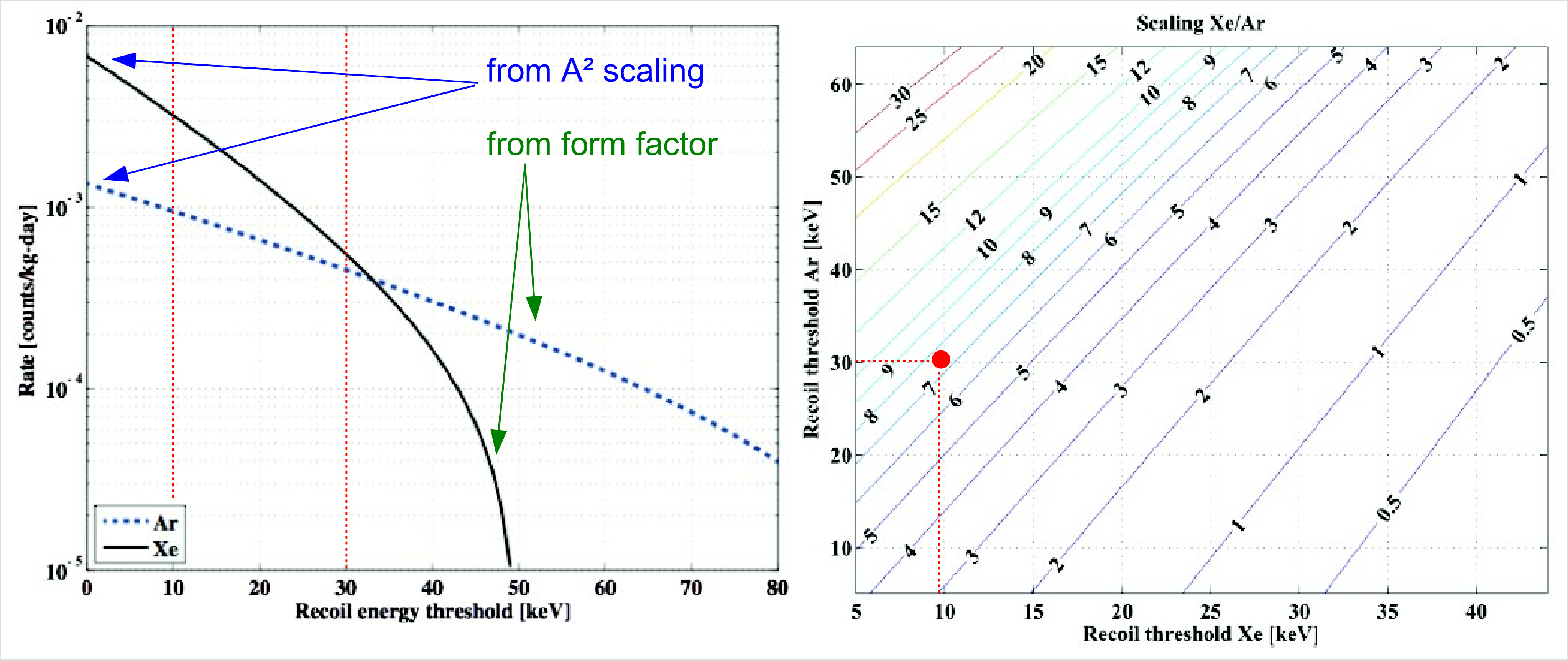
Multiton LXe
and/or LAr WIMP detector
find best choice/design,
exploit complementarity?



Optimal Ar / Xe Scaling

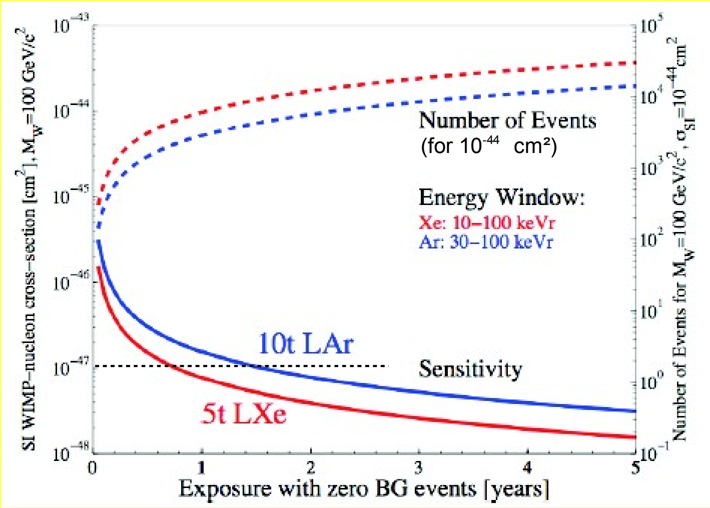
Optimization for 100 GeV/c² WIMP:

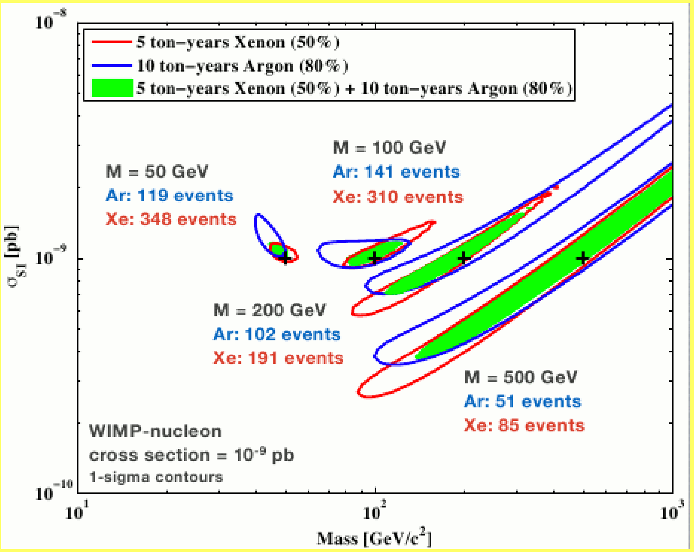
Which scaling factor is required to give same number of events above threshold?

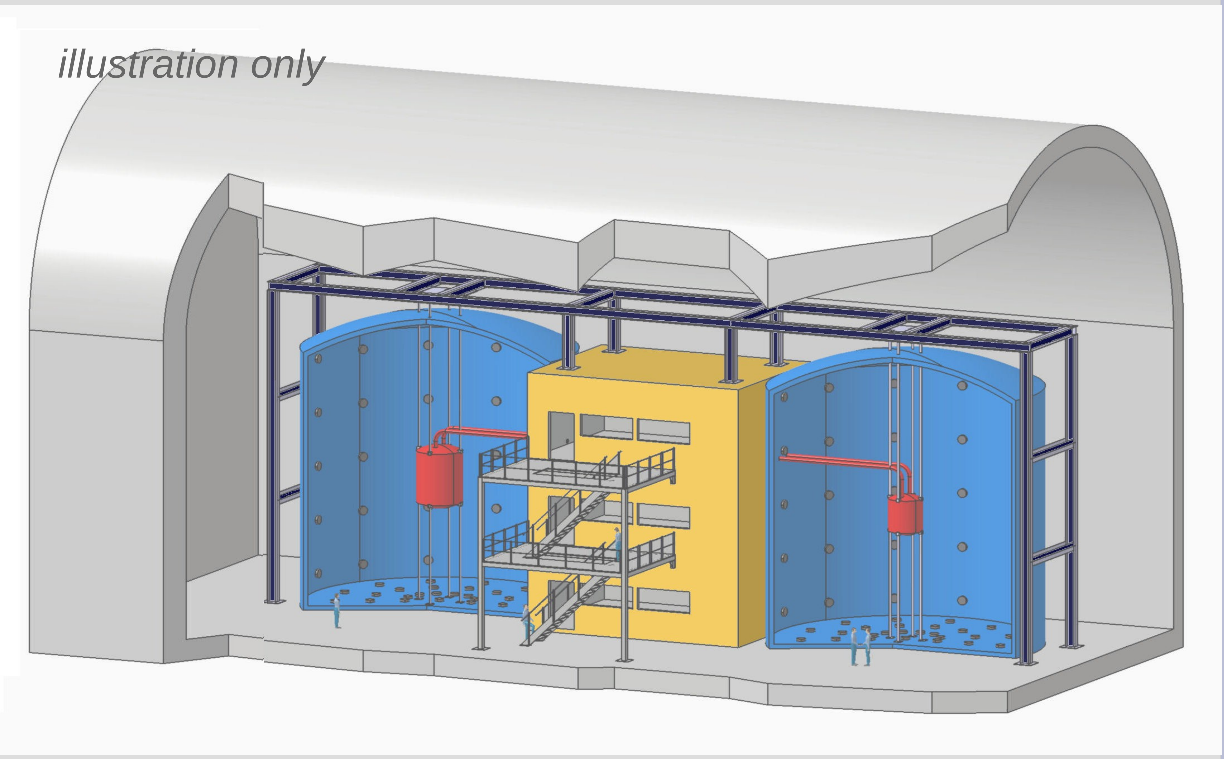


Realistic: Scaling Factor 2

Scaling factor 2:







Assumptions here:

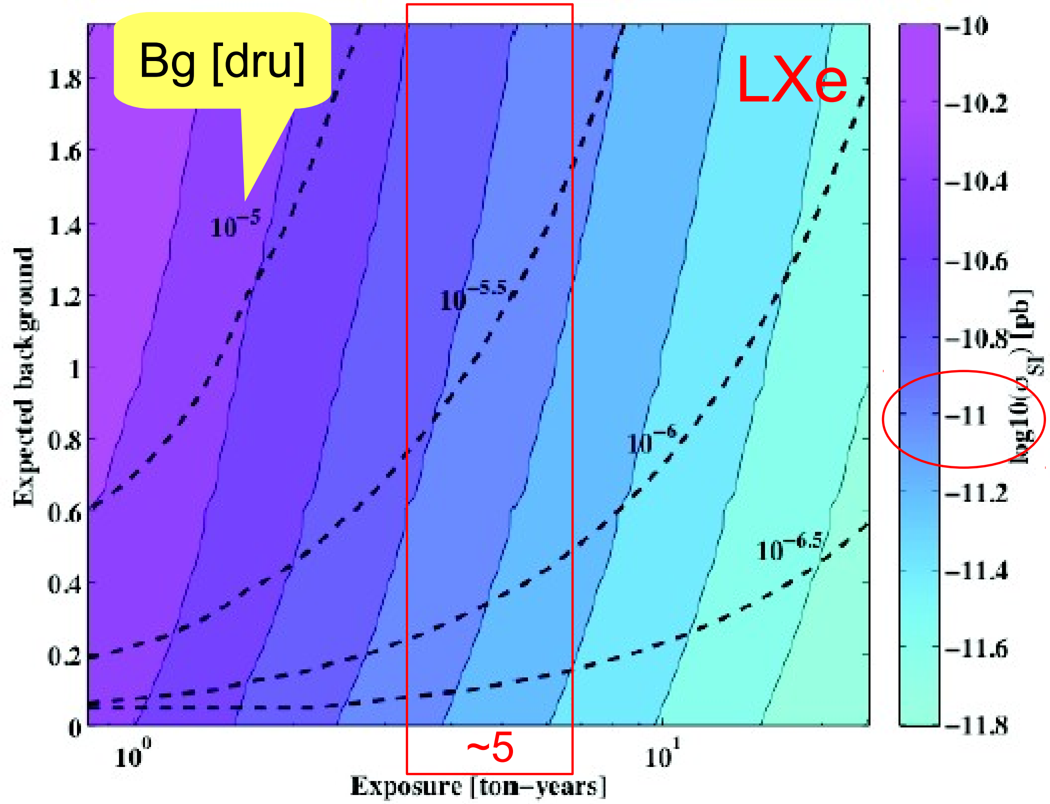
20 t LAr ➞ 10 t fiducial mass

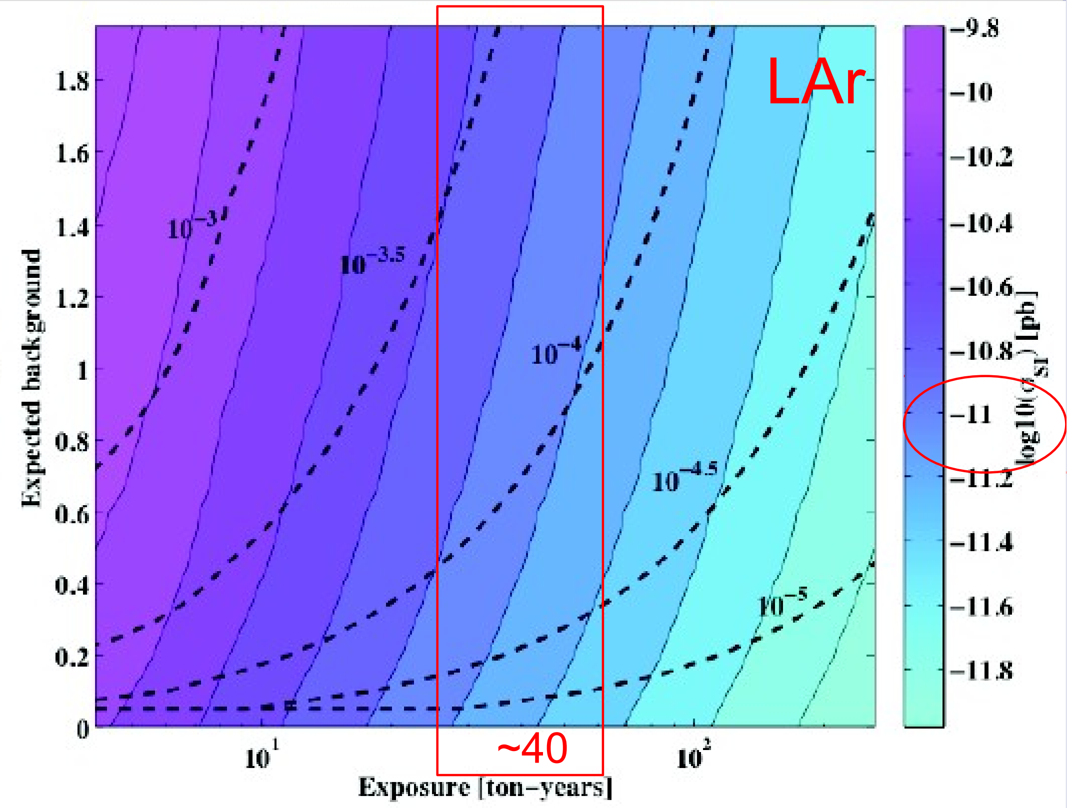
8 t LXe ➞ 5 t fiducial mass

in a Cerenkov water shield

Sensitivity vs. Background

calculations use already achieved values for background, acceptance
energy threshold (10 keVr / 30 keVr), and background rejection (99.5% / 3×10^{-7})





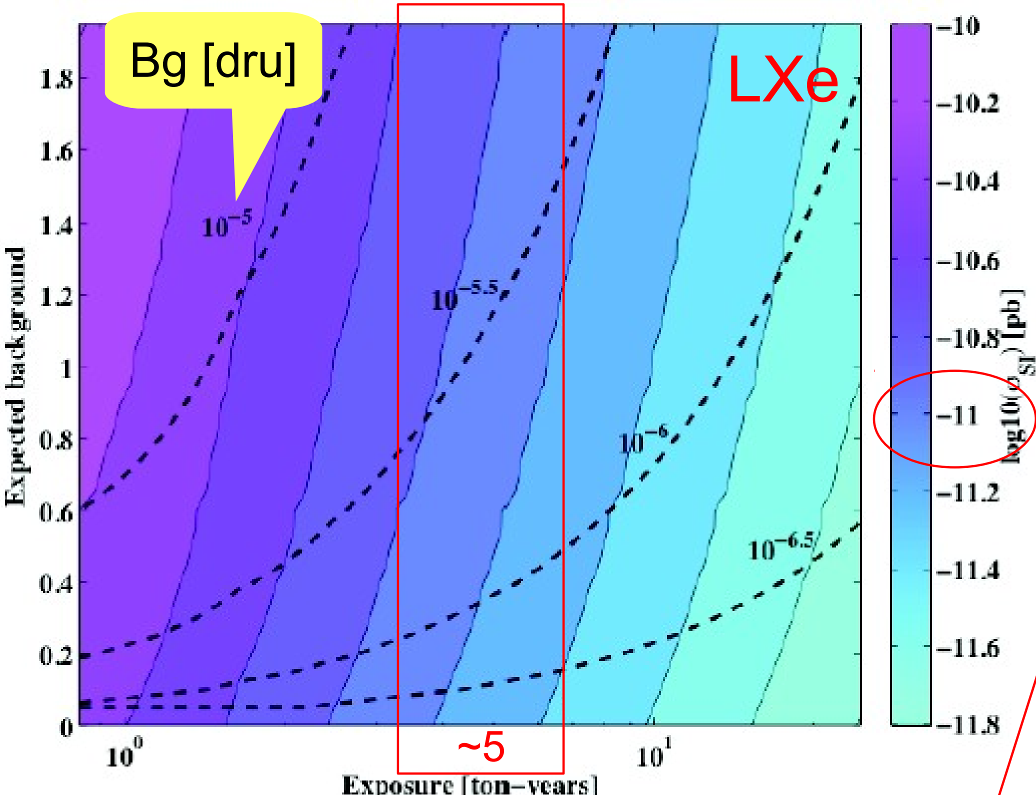
Challenges:
- Background must be 10^3 lower than now
- Kr85 must be reduced down to 1 ppt level
- pp-neutrino background (ER)?

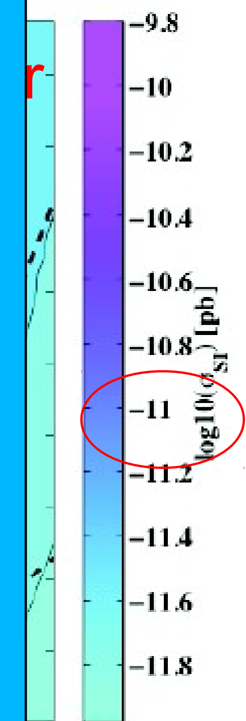
Challenges:
- background is dominated by Ar39
- depleted Ar gives factor ~25 reduction
- need >10x better PSA rejection (even with depleted Ar)

Sensitivity vs. Background

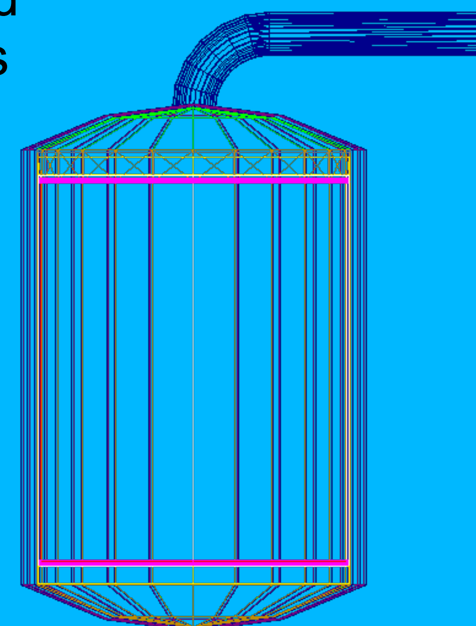
DARWIN

calculations make already achieved assumptions for background, acceptance
energy threshold (10 keVr/ 30 keVr), and

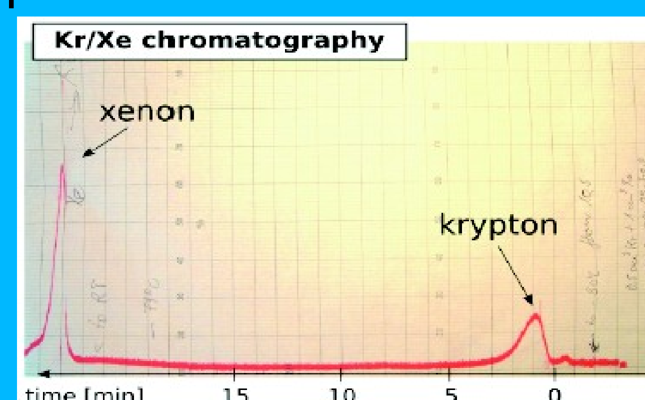




Background
MC Studies



Kr purification

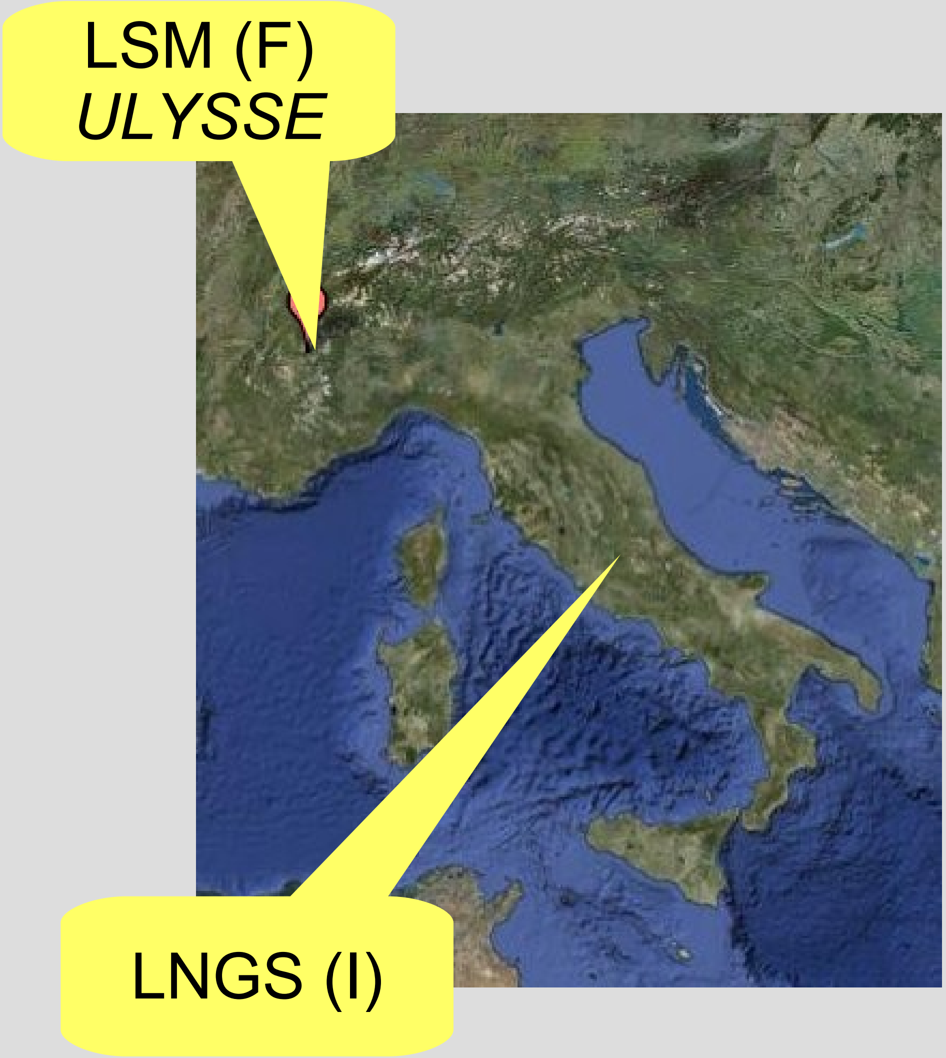


Challenges:
- Background must be 10³ lower than now
- Kr85 must be reduced down to 1 ppt level
- pp-neutrino background (ER)?

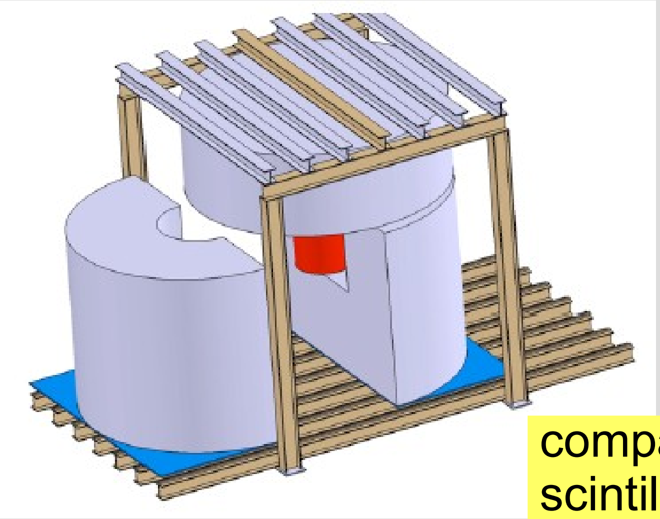
tion

Laboratory and Shield

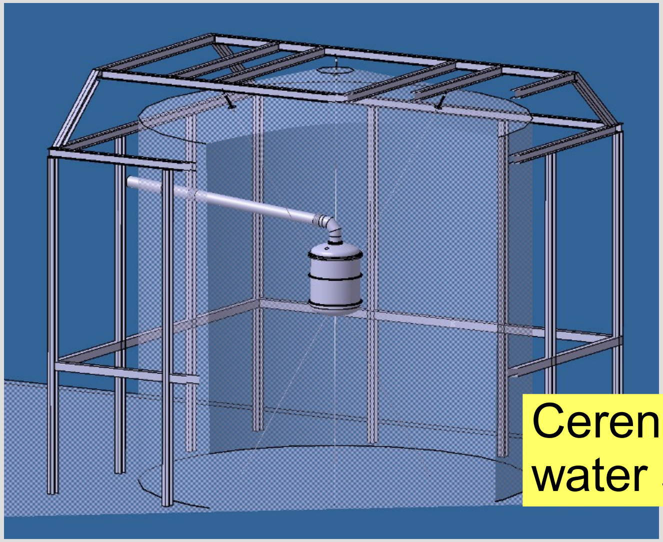
Backgrounds are currently studied for 2 sites :



Several shielding options:



compact liquid scintillator



Cerenkov water shield

R&D: Light Readout

„Classic“ Approach:
The same photosensors detect
S1 (light) and S2 (charge) signal.

- Photodetectors

  (a) large area PMTs
  - low radioactivity
  - high QE, high collection efficiency
  - operation at cryogenic temperatures

  (b) hybrid detectors with large cathode and solid state e-multiplier (QUPID)
  - extremely low radioactivity
  - for LXe and LAr

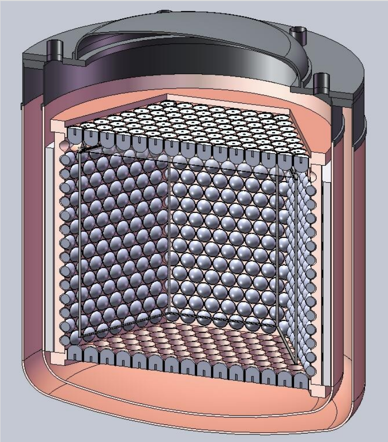
- UV light collection

  (a) co-doping of Ar with Xe (→ shift light emission)

  (b) LAr: wavelength shifters, coating of light sensors

  (c) surface properties of materials (reflection, diffusion)

  (d) 4 geometry: challenges? Light guides?

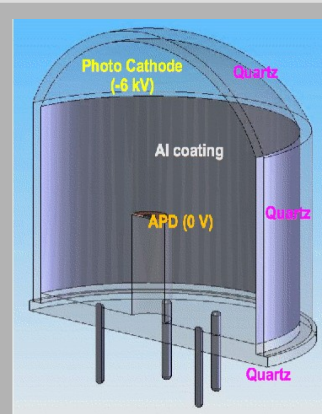


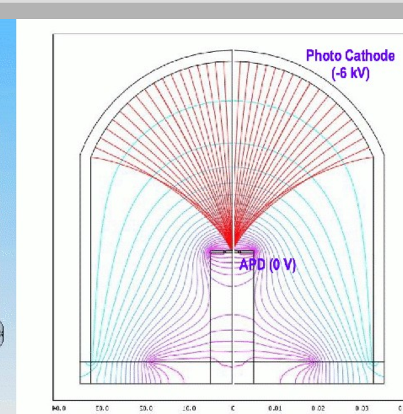
R&D: Photosensors

QUPID for LXe and LAr

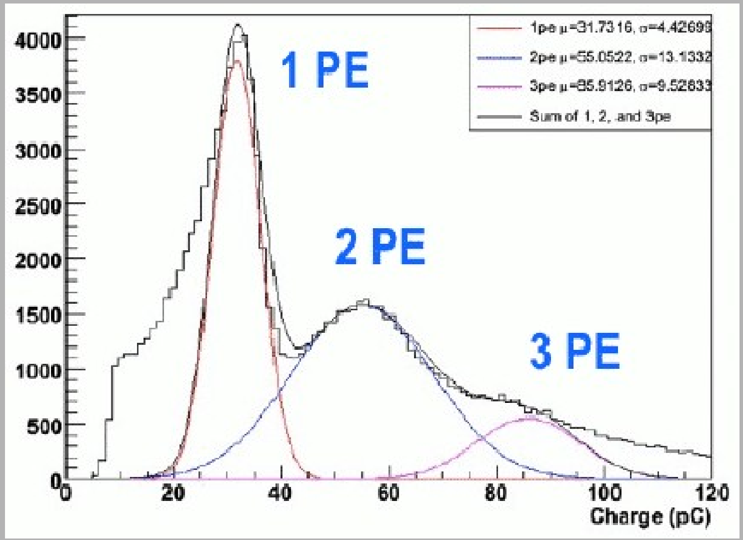
Quartz Photon Intensifying Detector

- developed by UCLA group (Arisaka/Wang)
- very low radioactivity
  APD, quartz, no voltage divider
- ongoing tests and R&D at UCLA



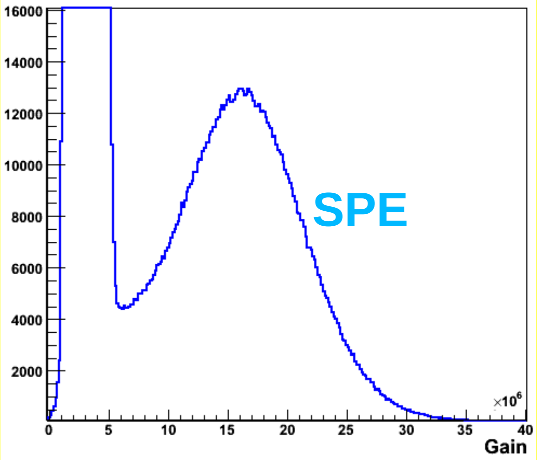


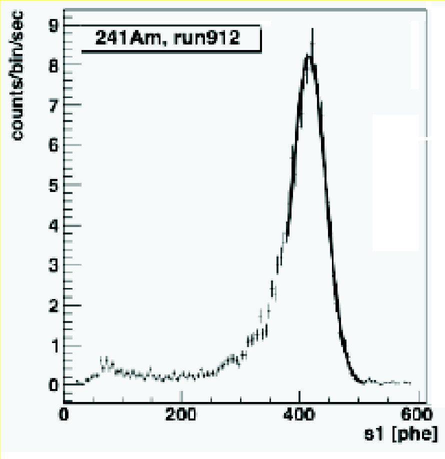
arXiv:1103.3689



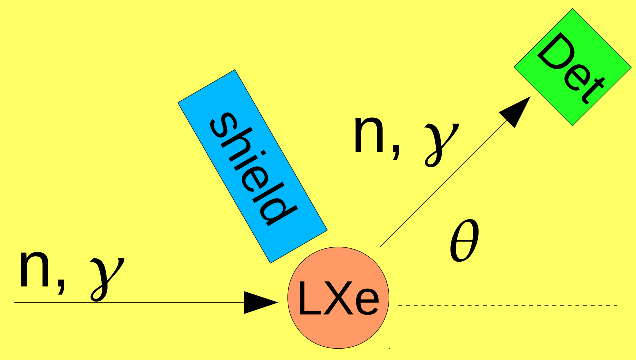
Hamamatsu R11410 / R11065

3" PMT, high gain
LXe/LAr operation
low radioactivity

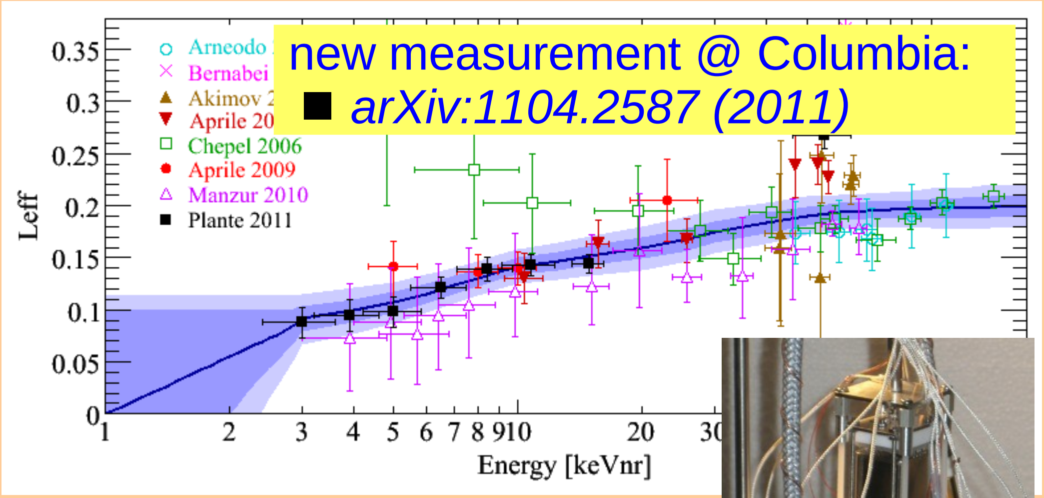


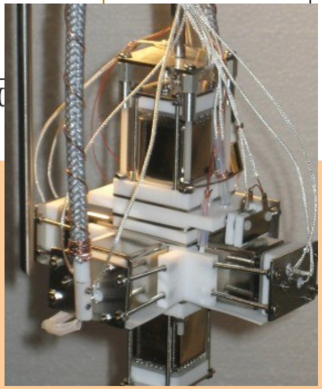


R&D: Scintillation Properties

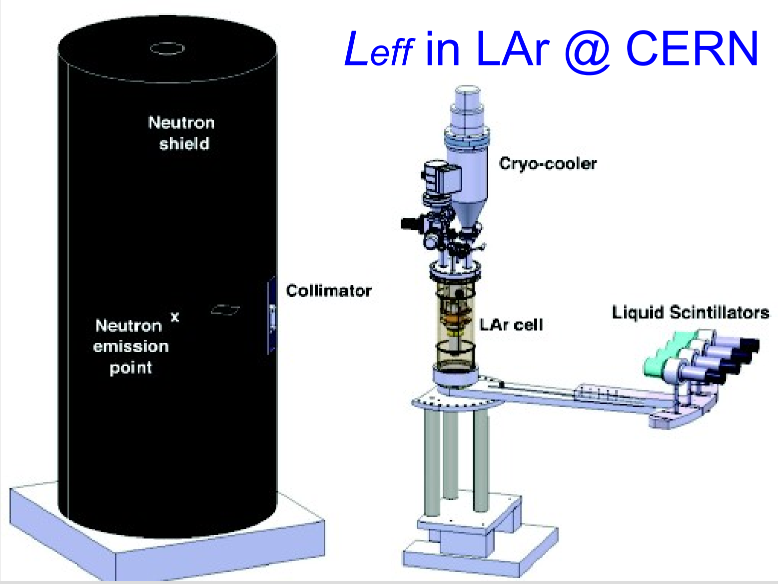


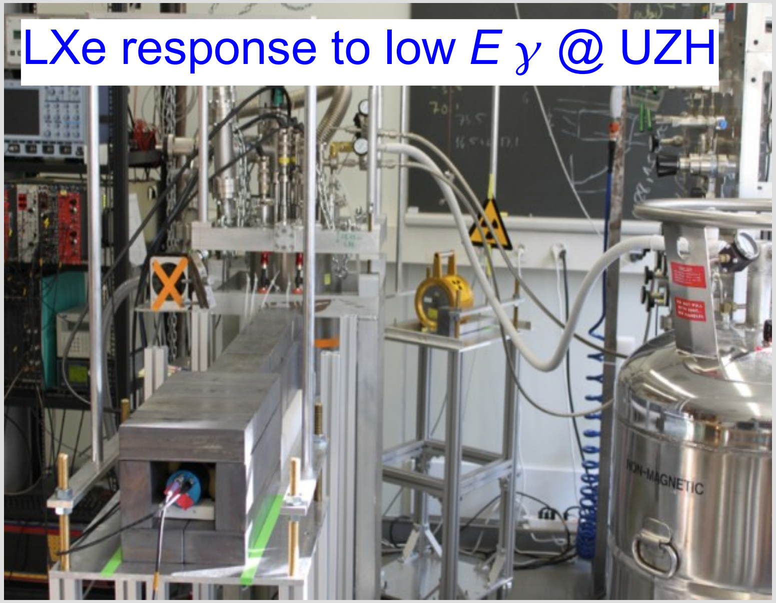
$$\mathcal{L}_{\mathrm{eff}}(E_{\mathrm{nr}}) = \frac{\mathrm{LY}(E_{\mathrm{nr}})}{\mathrm{LY}(E_{\mathrm{ee}} = 122\ \mathrm{keV})}$$





LY=20 PE/keV @ 122 keV





R&D: Charge Readout

DARWIN

- Idea:
  - good position resolution for signal / background discrimination
  - charge cloud in TPC is very localized (<1 mm)
  - large scale charge readout structures can keep this information
  - cost

Goal: Investigate and develop new concepts for readout of ionization produced by keV energy events, independent of scintillation readout.

- Approach:

  (a) Large cryogenic LEM / THGEM / Micromegas for noble liquids

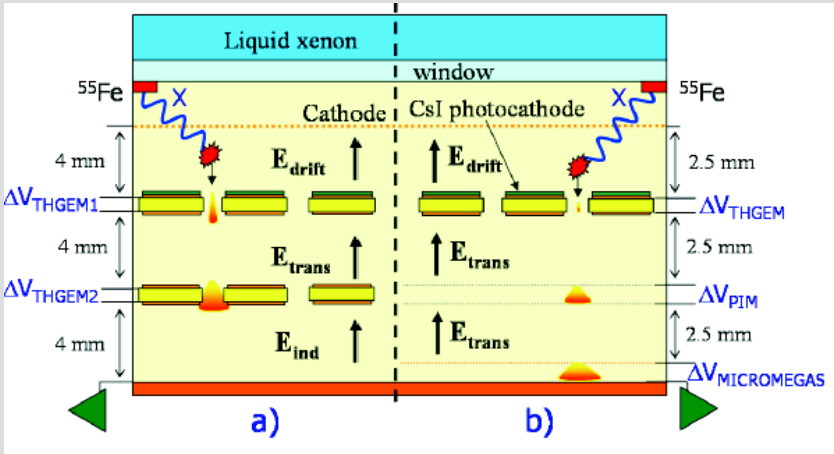
  → charge amplification in holes

  (b) Gaseous PMTs without dead zone

  → MgF_4 window because of quencher

  (c) CMOS pixel detector coupled to electron multipliers (GridPix)

  → low radioactivity is possible

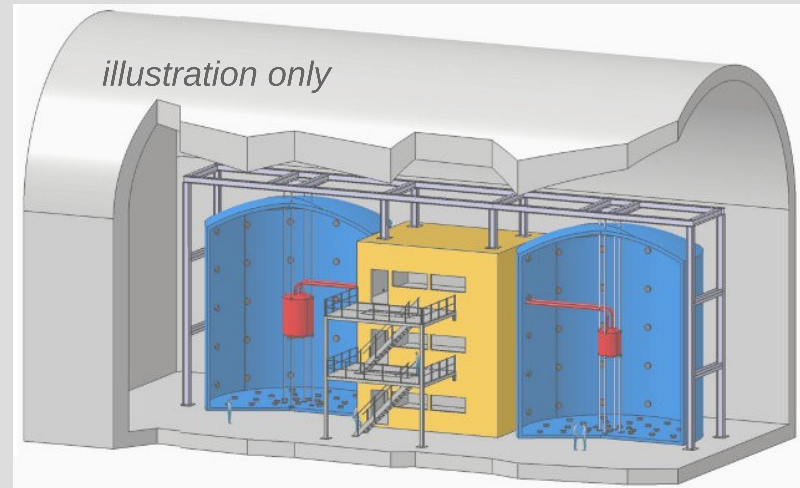


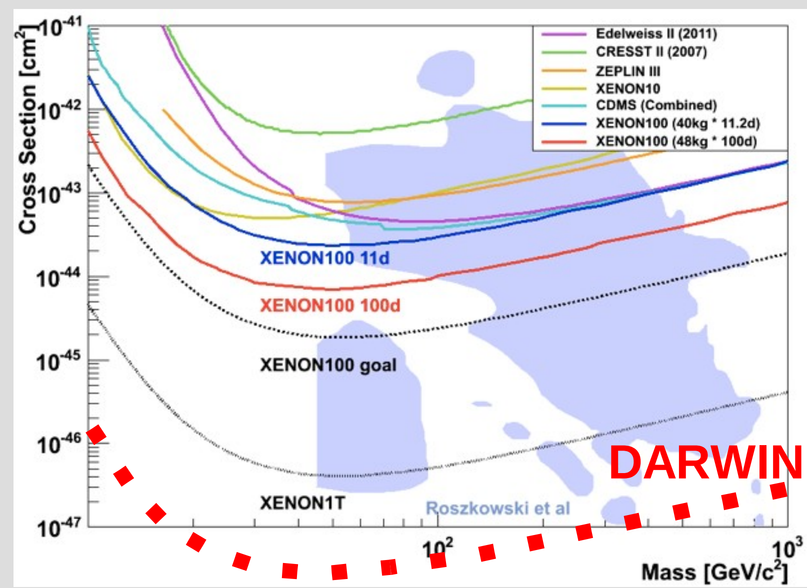
Summary

- **DARWIN:**
  a multiton LXe/LAr detector
  to explore cross sections
  below 10^{-47} cm²
- design study approved by ASPERA,
  timeline 2010 — end 2012
- outcome will be a proposal for
  the DARWIN facility

Technical Challenges:

- lowest background
- lowest threshold
- high discrimination
- large number of channels
- high sensitivity (QE)
- large area sensors





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