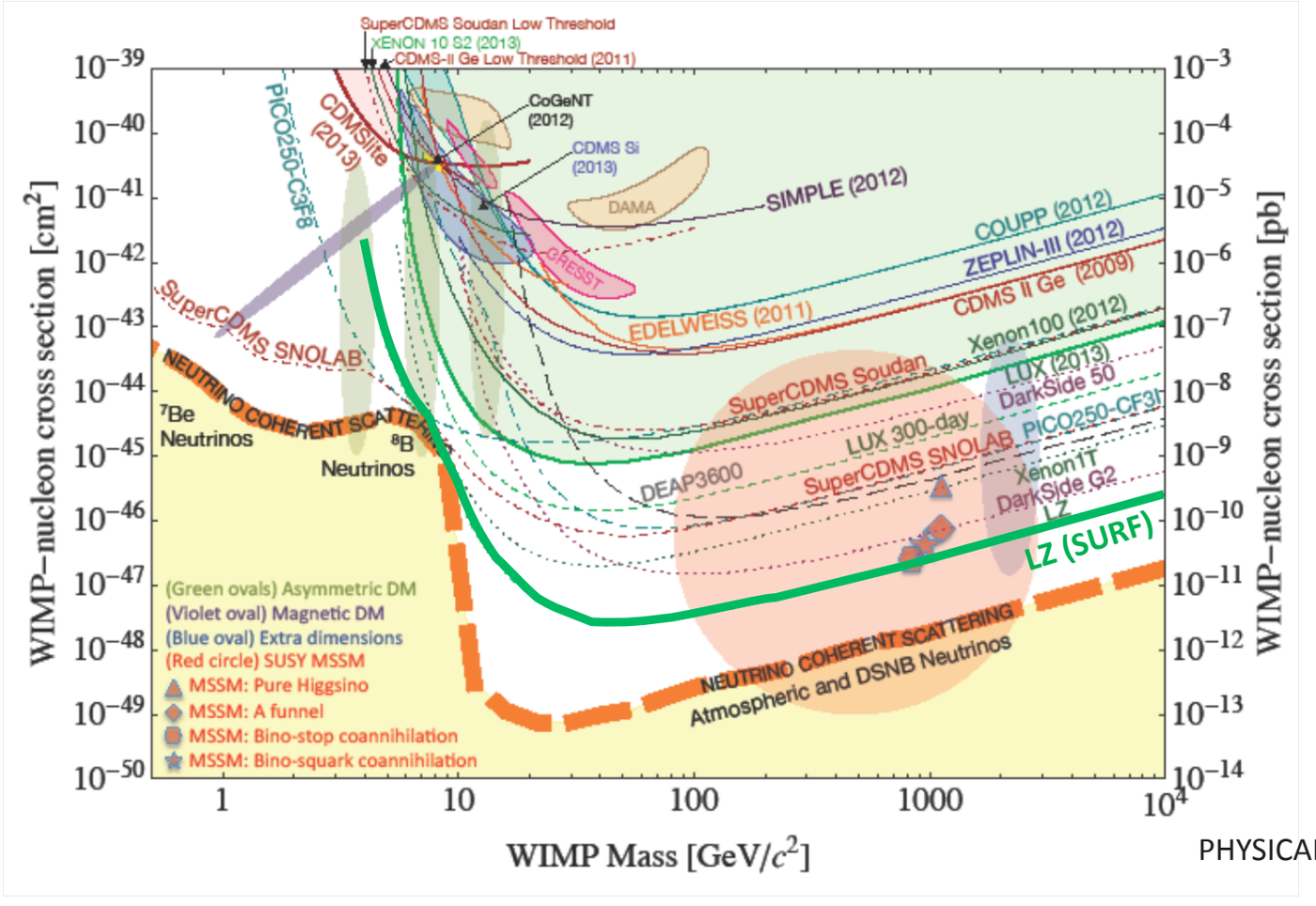
LZ background estimation and sensitivity goal

DM-UK meeting 8/12/2104

Paolo Beltrame
(V. Kudryavstev, E. Korolkova, D. Woodward)

Sensitivity goal and background

Sensitivity goal	Max allowed background from the detector	
	Electronic	Nuclear Recoils
2E-48 cm^2 @ 50 GeV/c^2 WIMP mass in total exposure of 3 years of science data 5.6 ton of fiducial LXe mass	≲ 24 cts/exposure [1.5 - 6.5] keVee total Exposure	≲ 0.1 cts/exposure [6 - 30] keVnr total Exposure



PHYSICAL REVIEW D 89, 023524 (2014)

Detector Background

Material radioactivity (bulk)

- **Electron recoils:**
  beta (walls, LXe), gamma (materials): ~10% of pp ν ER
- **Nuclear recoils**:
  (α,n) and spontaneous fission (materials): ~0.1 NR

Surface contamination (radon progeny plate-out)

- Wall events mis-reconstructed into fiducial (both **ER** and **NR**)
- (α,n) neutrons from PTFE and other surfaces

Dispersed radioactivity

- Emanation of radon (Pb-214), krypton (Kr-85), argon (Ar-39); 2νββ Xe-136
- Radon emanation

Cosmogenic activation

LUX/LZSim package

(H. Araujo's talk)

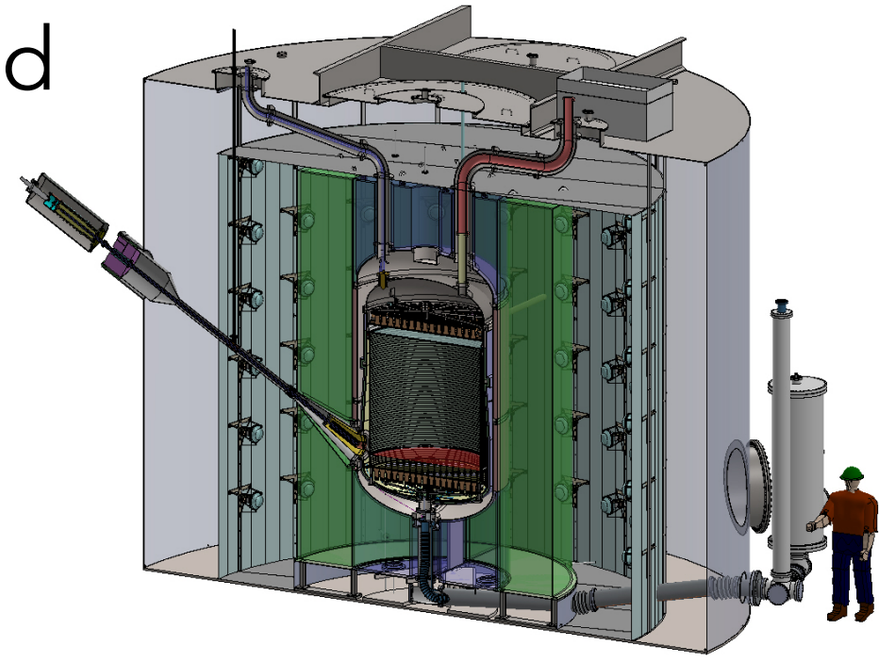
Simulation based on `GEANT4` toolkit and LUXSim softwares

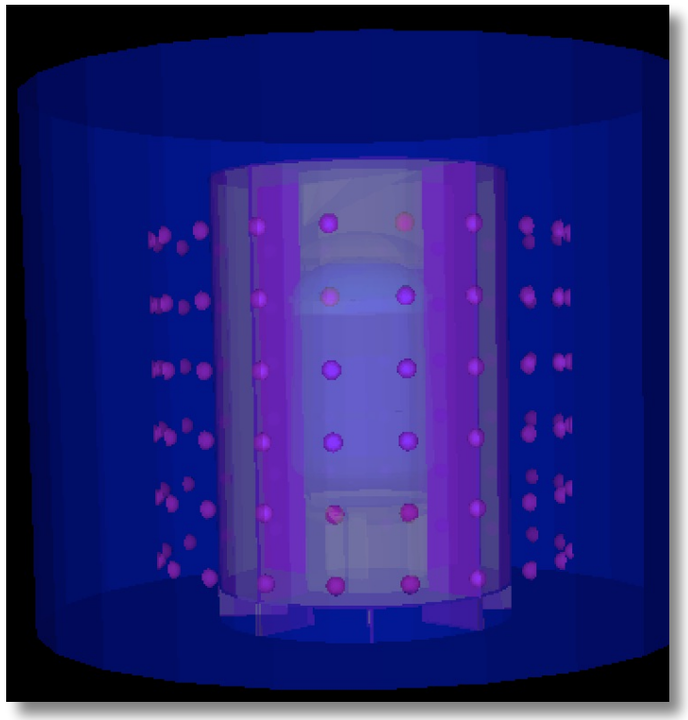
Inputs from `SOURCES` and `ACTIVIA`

Detailed correspondence between engineer design and simulation

Cryostat, PMT arrays, PTFE walls, Scintillator Veto implemented.

- work (continuously) in progress





UK involvement

Background: Edinburgh, Sheffield, Oxford, UCL

Calibration: Liverpool

Radioactivity budget and counts

Background event counts for main items

Total exposure of 5.6 ton and 1000 days

ER and NR counts

Item	^{238}U	^{232}Th	^{40}K	^{60}Co	ER counts	NR counts
Cryostat	0.6 mBq/kg	0.6 mBq/kg	2.5 mBq/kg	-	4.1 (8.2)	0.07 (0.14)
TPC PTFE	0.01 mBq/kg	0.002 mBq/kg	0.06 mBq/kg	-	0.1 (0.3)	0.003 (0.007)
TPC PMTs	3 mBq/PMT	3 mBq/PMT	30 mBq/PMT	2.5 mBq/PMT	12.5 (25.0)	0.04 (0.12)
Other	various	various	various	-	4 (20)	0.05 (0.25)
Sub-total					**20.7 (53.6)**	**0.17 (0.54)**
Kr + Rn + Ar					52 (234)	-
Neutrinos					234 (270)	0.6 (0.9)
Total	Total number of interactions				**307 (558)**	**0.74 (1.43)**
	99.5% ER rejection, 50% NR acceptance				**1.5 (2.8)**	**0.4 (0.7)**
	Combined background counts				**1.9 (3.5)**	

baseline & (conservative scenario)

Radioactivity budget and counts

Background event counts for main items

Total exposure of 5.6 ton and 1000 days

ER and NR counts

Item	^{238}U	^{232}Th	^{40}K	^{60}Co	ER counts	NR counts
Cryostat	0.6 mBq/kg	0.6 mBq/kg	2.5 mBq/kg	-	4.1 (8.2)	0.07 (0.14)
TPC PTFE	0.01 mBq/kg	0.002 mBq/kg	0.06 mBq/kg	-	0.1 (0.3)	0.003 (0.007)
TPC PMTs	3 mBq/PMT	3 mBq/PMT	30 mBq/PMT	2.5 mBq/PMT	12.5 (25.0)	0.04 (0.12)
Other	various	various	various	-	4 (20)	0.05 (0.25)
Sub-total					**20.7 (53.6)**	**0.17 (0.54)**
Kr + Rn + Ar					52 (234)	-
Neutrinos					234 (270)	0.6 (0.9)
Total	Total number of interactions				**307 (558)**	**0.74 (1.43)**
	99.5% ER rejection, 50% NR acceptance				**1.5 (2.8)**	**0.4 (0.7)**
	Combined background counts				**1.9 (3.5)**	

baseline & (conservative scenario)

Detector design and Monte Carlo simulation

Radioactivity budget and counts

Background event counts for main items

Total exposure of 5.6 ton and 1000 days

ER and NR counts

Item	^{238}U	^{232}Th	^{40}K	^{60}Co	ER counts	NR counts
Cryostat	0.6 mBq/kg	0.6 mBq/kg	2.5 mBq/kg	-	4.1 (8.2)	0.07 (0.14)
TPC PTFE	0.01 mBq/kg	0.002 mBq/kg	0.06 mBq/kg	-	0.1 (0.3)	0.003 (0.007)
TPC PMTs	3 mBq/PMT	3 mBq/PMT	30 mBq/PMT	2.5 mBq/PMT	12.5 (25.0)	0.04 (0.12)
Other	various	various	various	-	4 (20)	0.05 (0.25)
Sub-total					**20.7 (53.6)**	**0.17 (0.54)**
Kr + Rn + Ar					52 (234)	-
Neutrinos					234 (270)	0.6 (0.9)
Total	Total number of interactions				**307 (558)**	**0.74 (1.43)**
	99.5% ER rejection, 50% NR acceptance				**1.5 (2.8)**	**0.4 (0.7)**
	Combined background counts				**1.9 (3.5)**	

baseline & (conservative scenario)

Material screening (E. Meehan and P. Scovell's talk)

Radioactivity budget and counts

Background event counts for main items

Total exposure of 5.6 ton and 1000 days

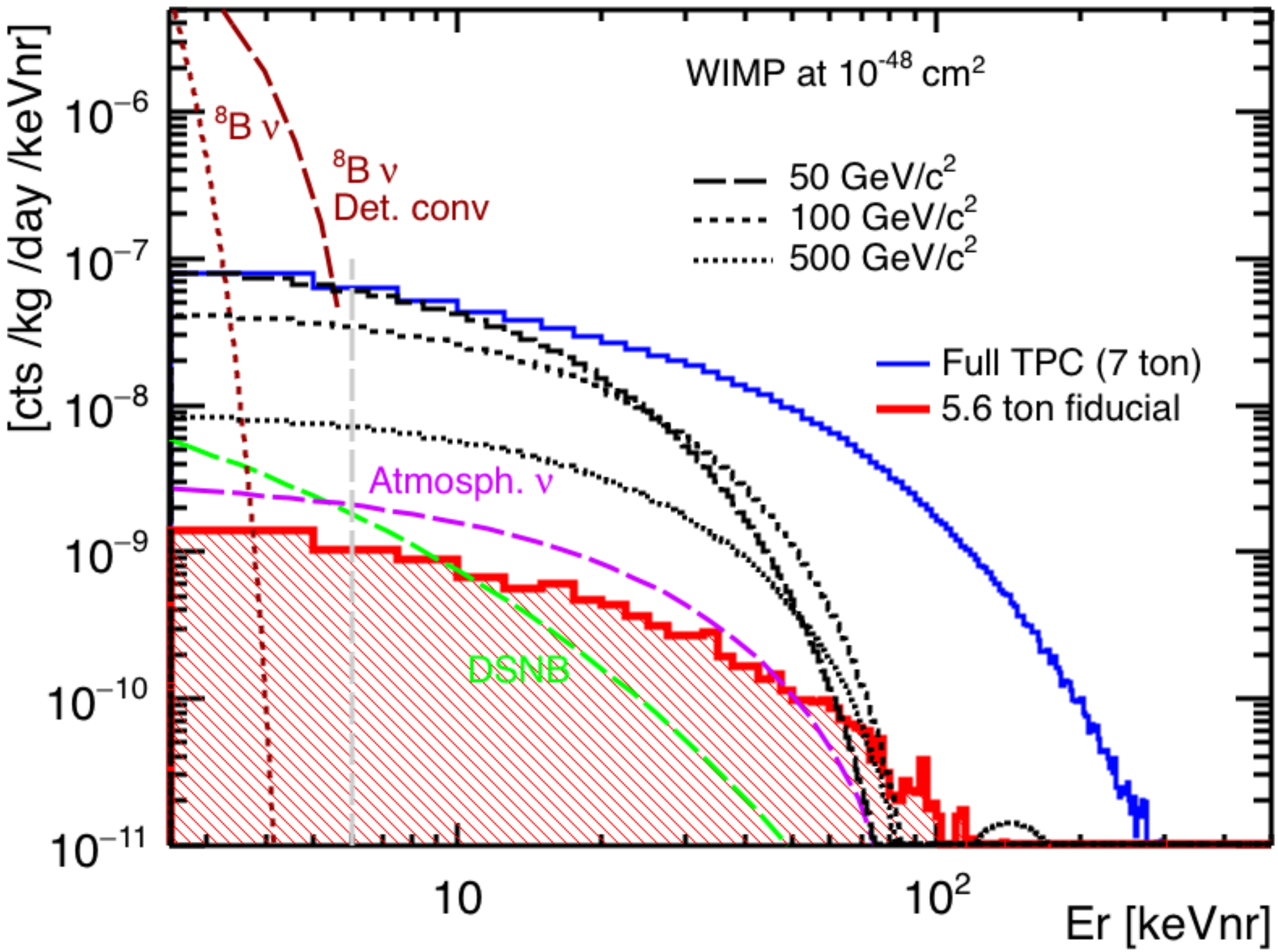
ER and NR counts

Item	^{238}U	^{232}Th	^{40}K	^{60}Co	ER counts	NR counts
Cryostat	0.6 mBq/kg	0.6 mBq/kg	2.5 mBq/kg	-	4.1 (8.2)	0.07 (0.14)
TPC PTFE	0.01 mBq/kg	0.002 mBq/kg	0.06 mBq/kg	-	0.1 (0.3)	0.003 (0.007)
TPC PMTs	3 mBq/PMT	3 mBq/PMT	30 mBq/PMT	2.5 mBq/PMT	12.5 (25.0)	0.04 (0.12)
Other	various	various	various	-	4 (20)	0.05 (0.25)
Sub-total					**20.7 (53.6)**	**0.17 (0.54)**
Kr + Rn + Ar					52 (234)	-
Neutrinos					234 (270)	0.6 (0.9)
Total	Total number of interactions				**307 (558)**	**0.74 (1.43)**
	99.5% ER rejection, 50% NR acceptance				**1.5 (2.8)**	**0.4 (0.7)**
	Combined background counts				**1.9 (3.5)**	

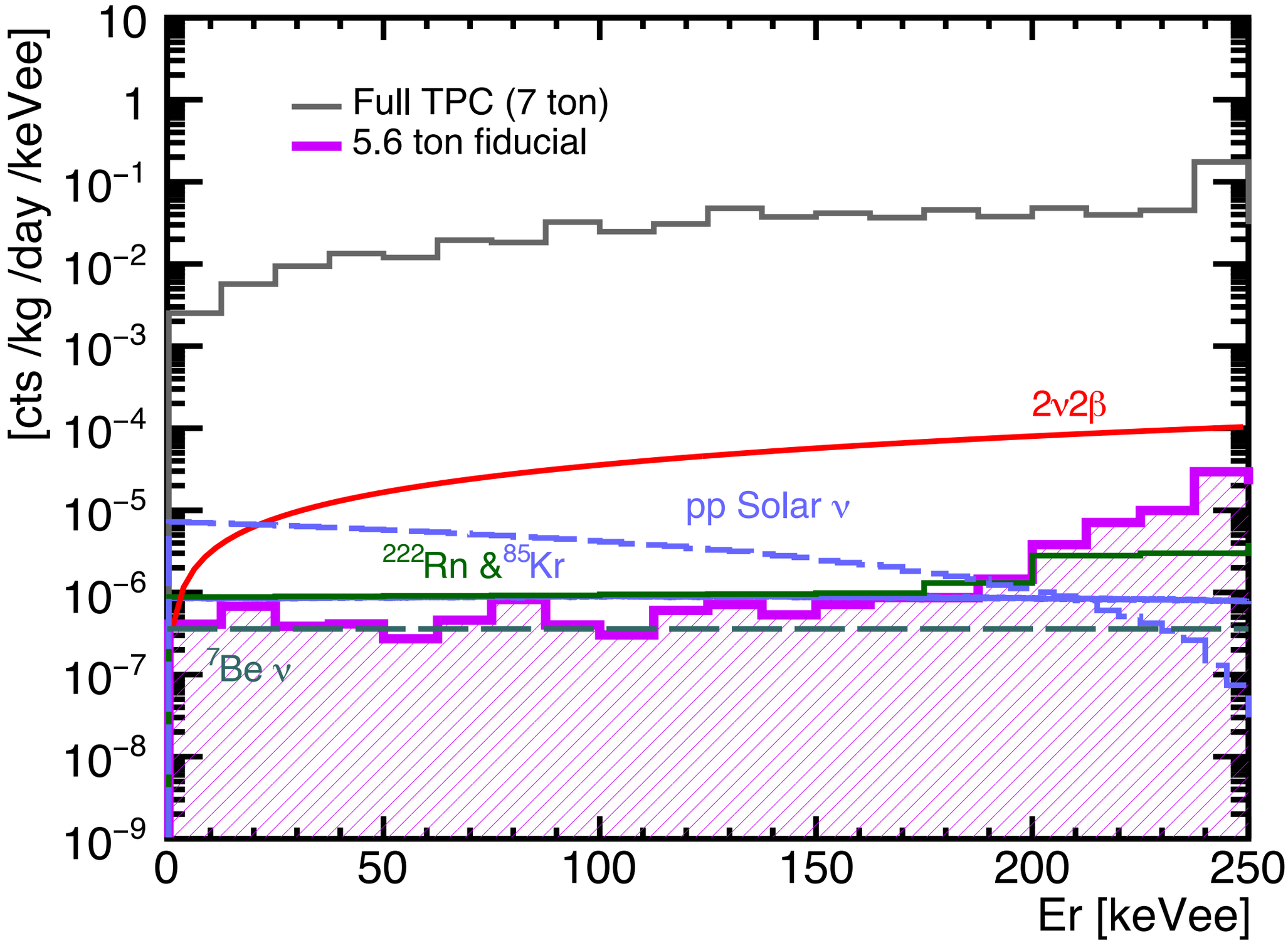
baseline & (conservative scenario)

Detector performances (H. Araujo's talk)

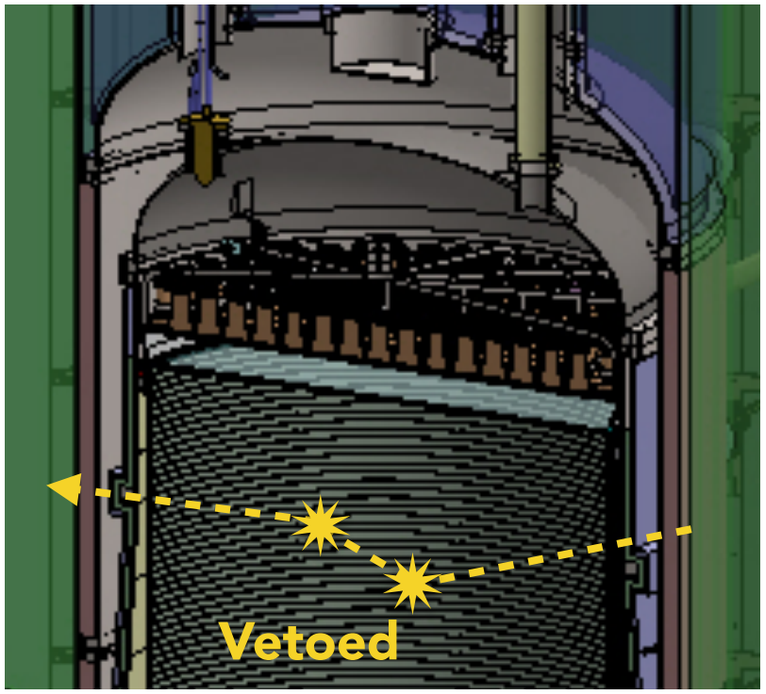
NR Background & WIMP

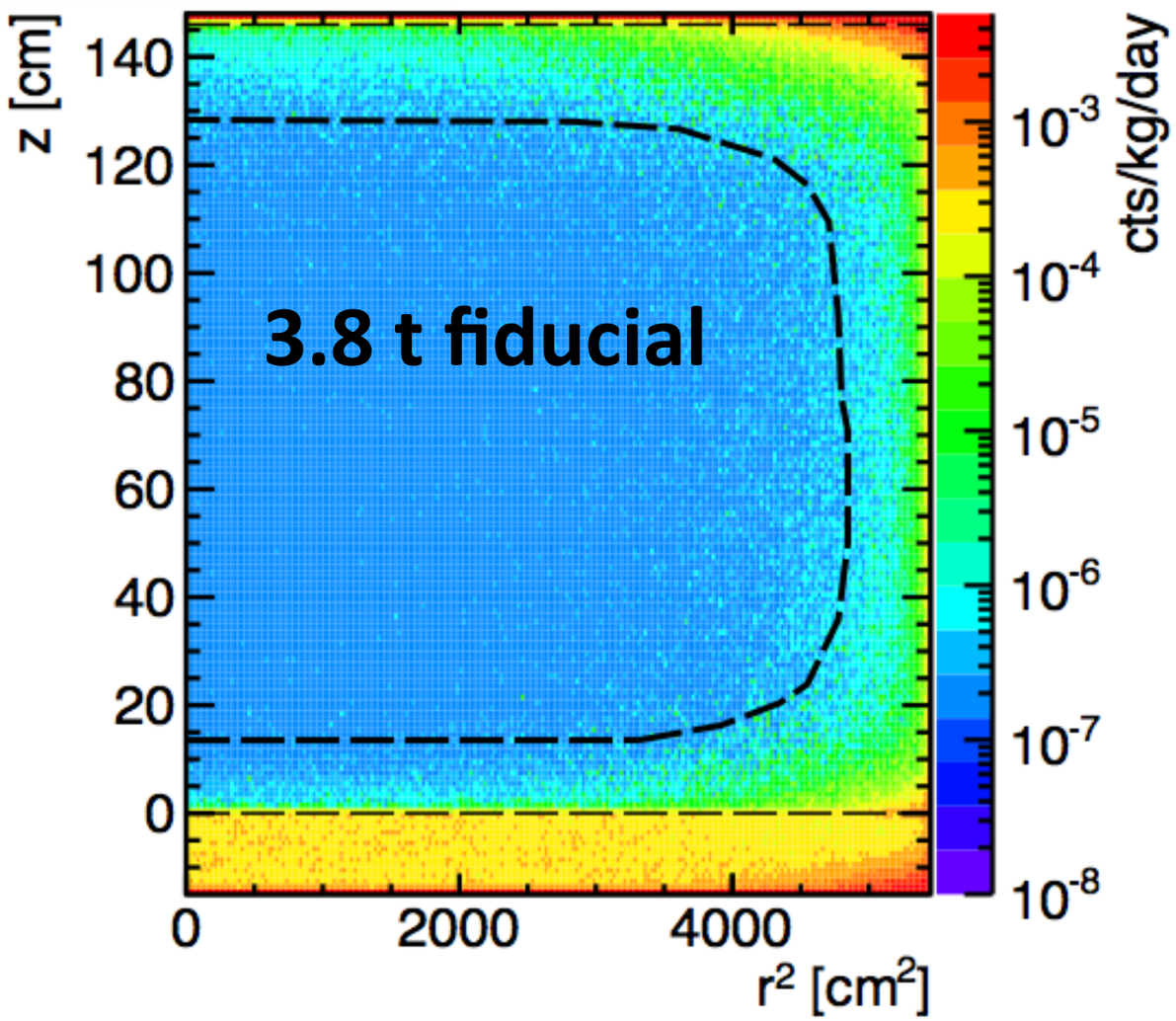


ER background

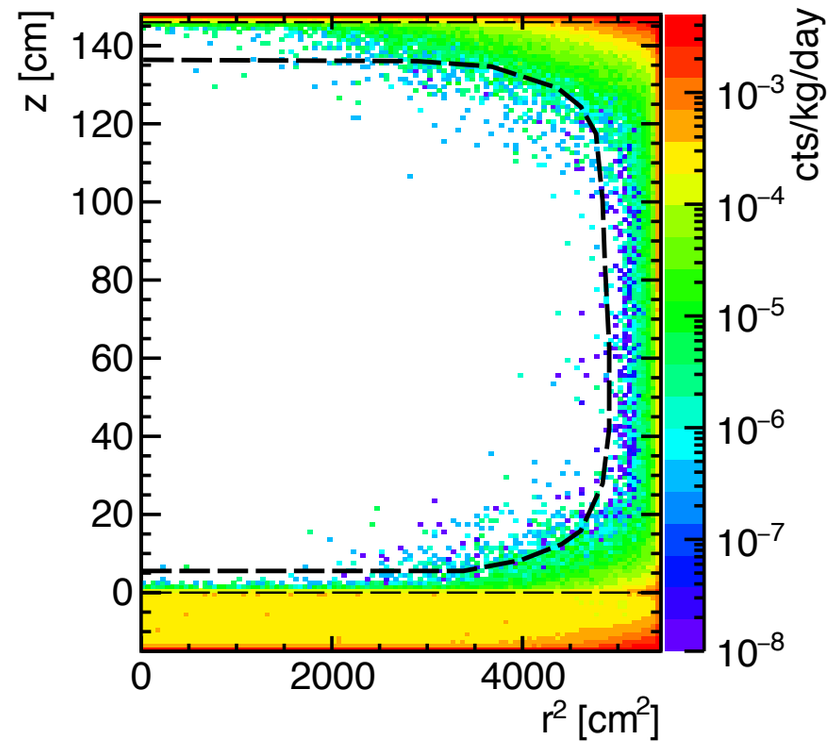


Single hit

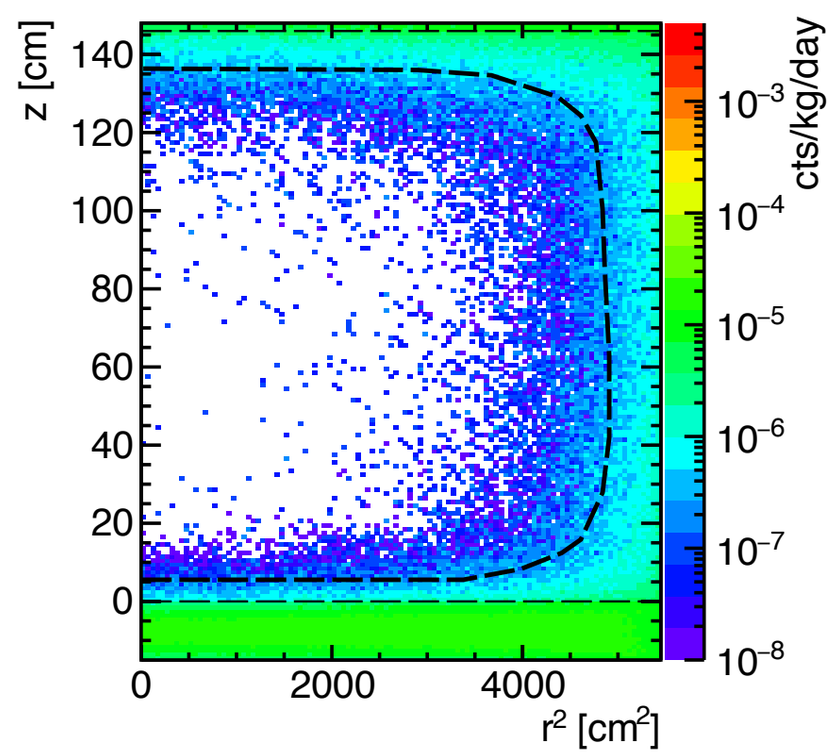




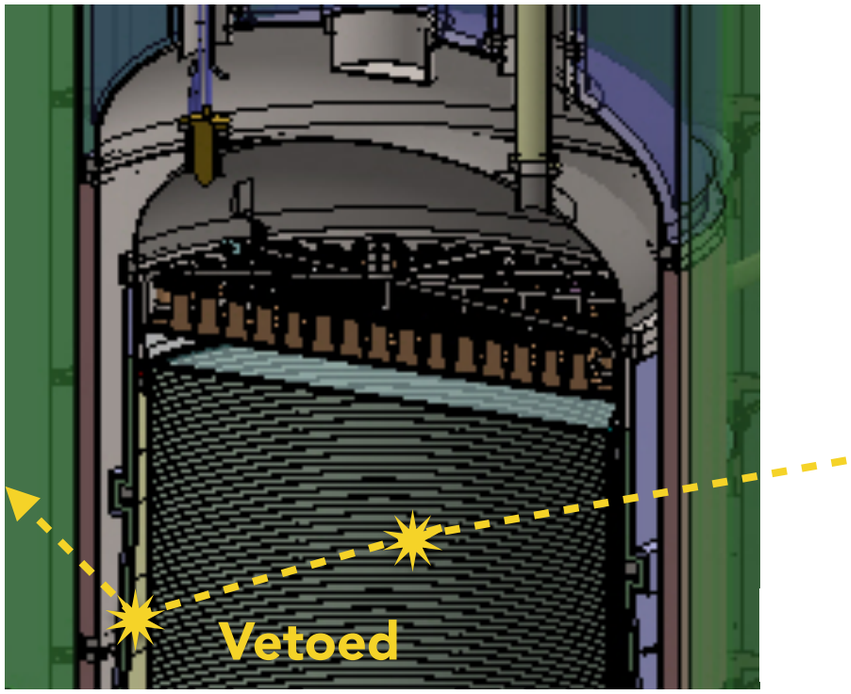
Single Hit (ER)

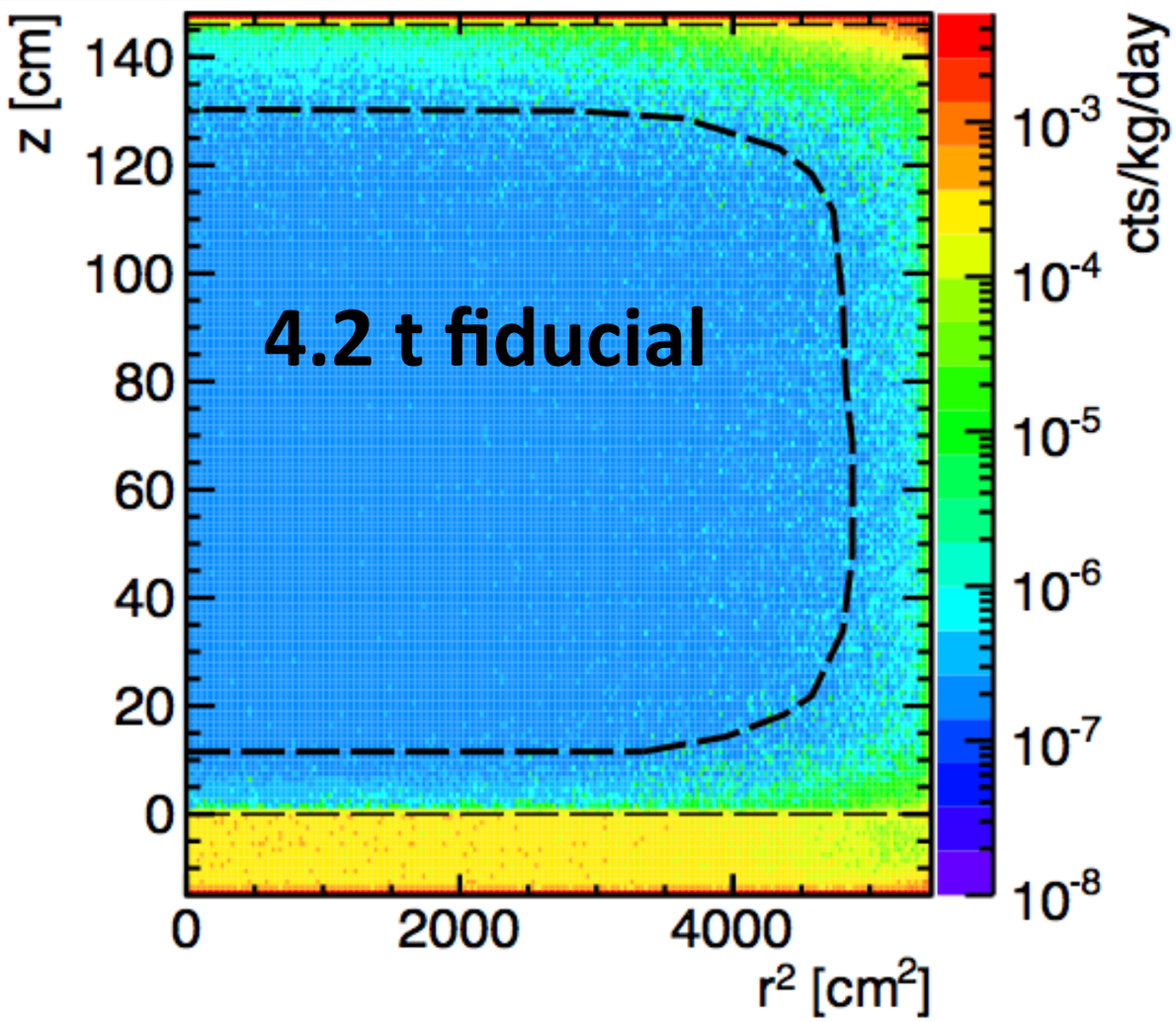


Single Hit (NR)

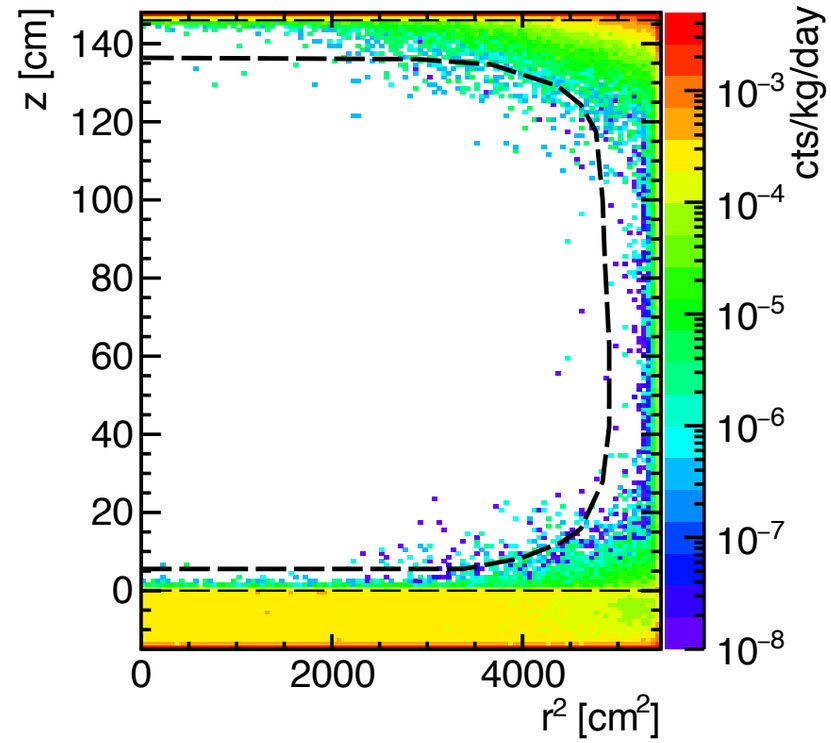


Single hit + LXe skin

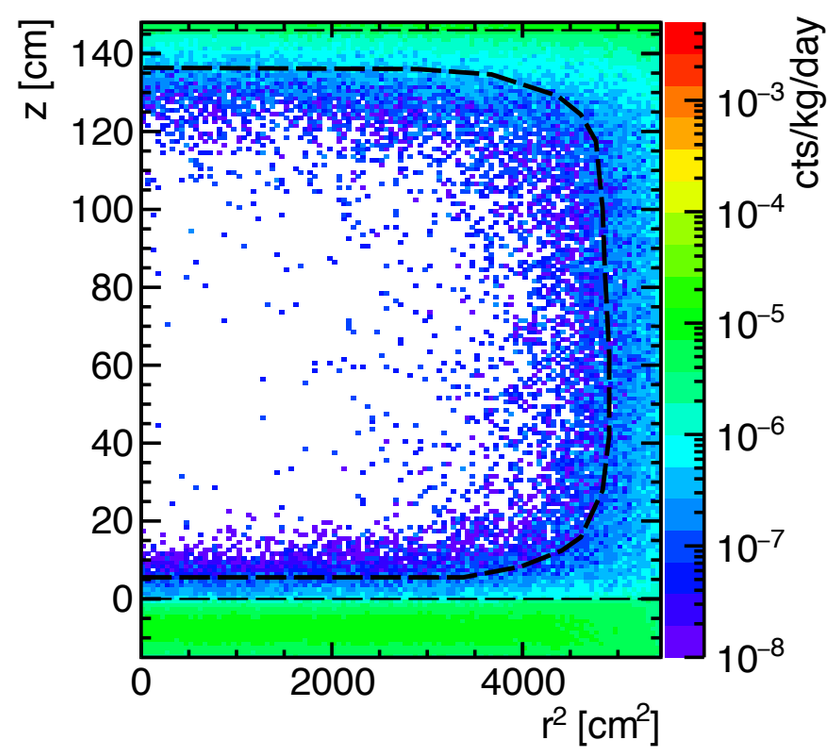




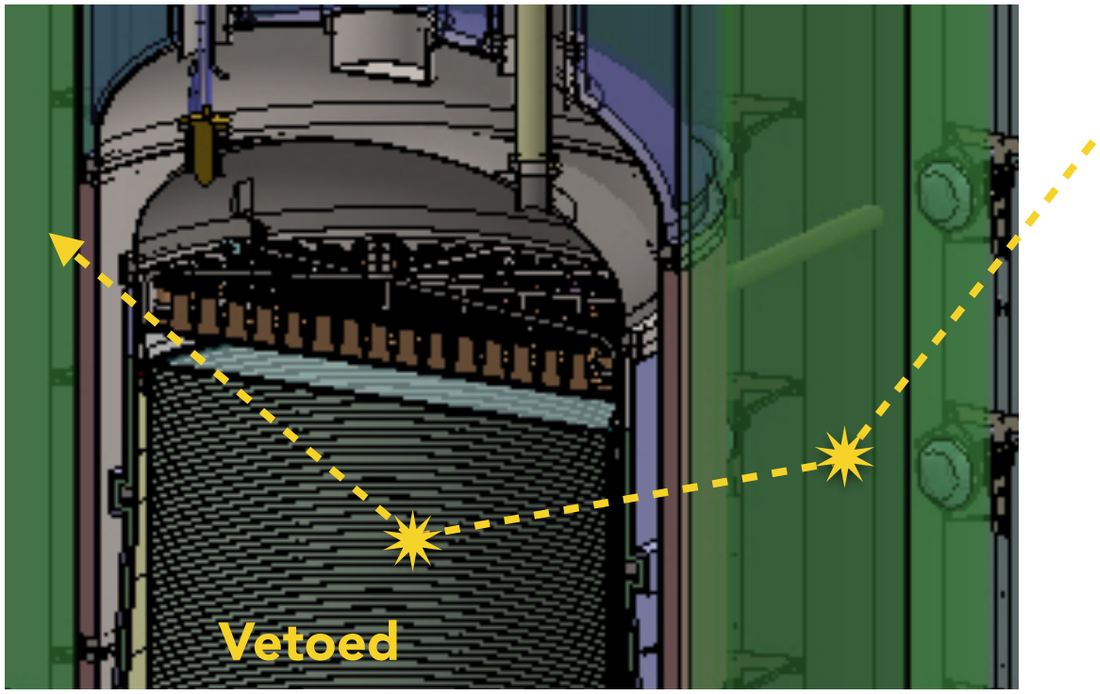
Single Hit + LXe Skin (ER)

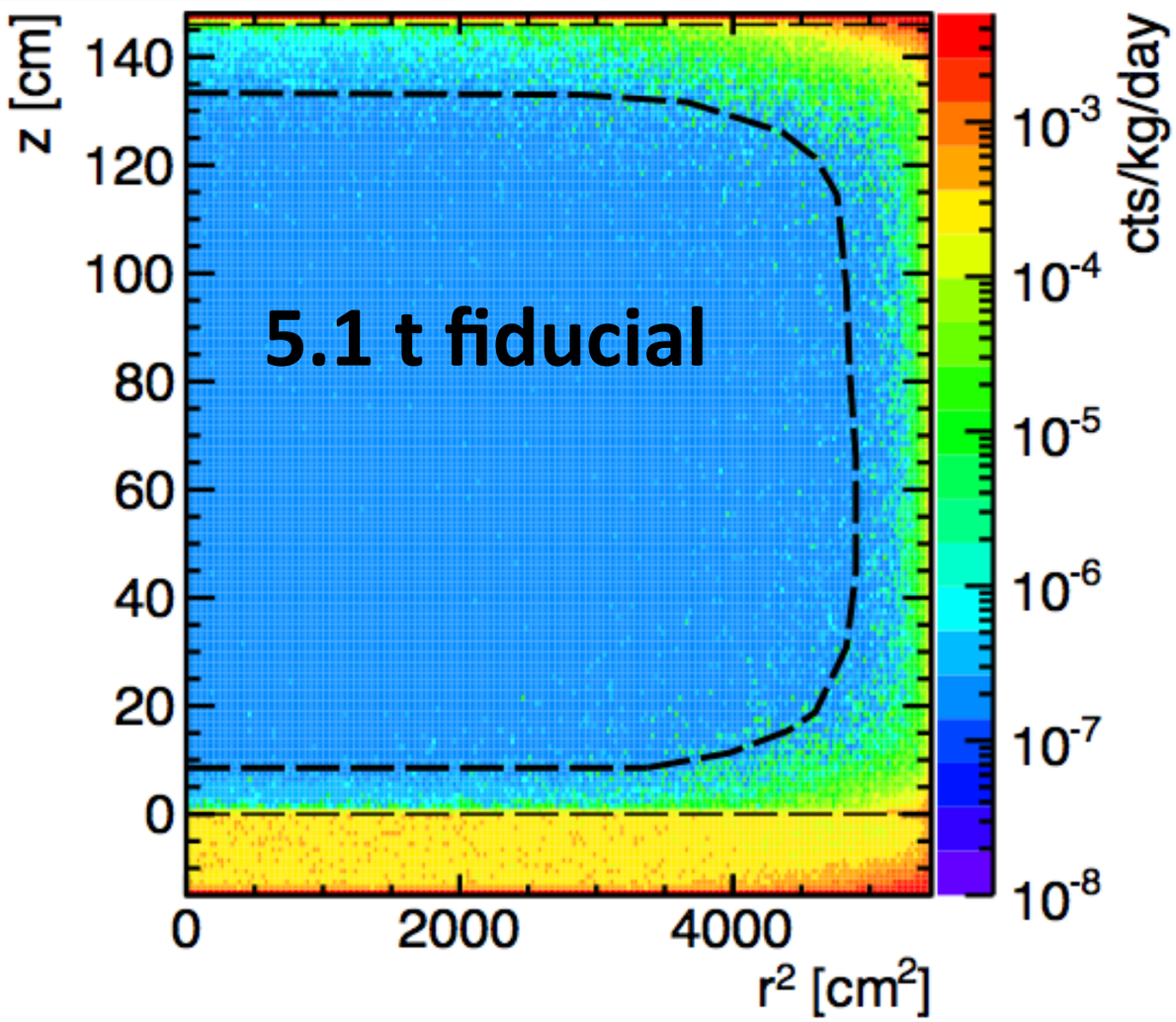


Single Hit + LXe Skin (NR)

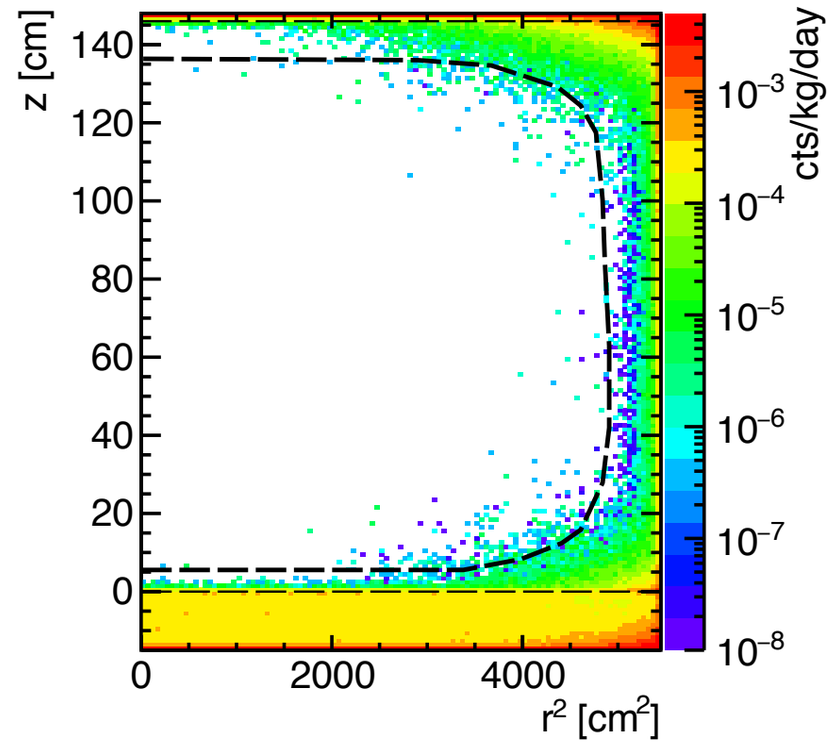


Single hit + liquid scintillator

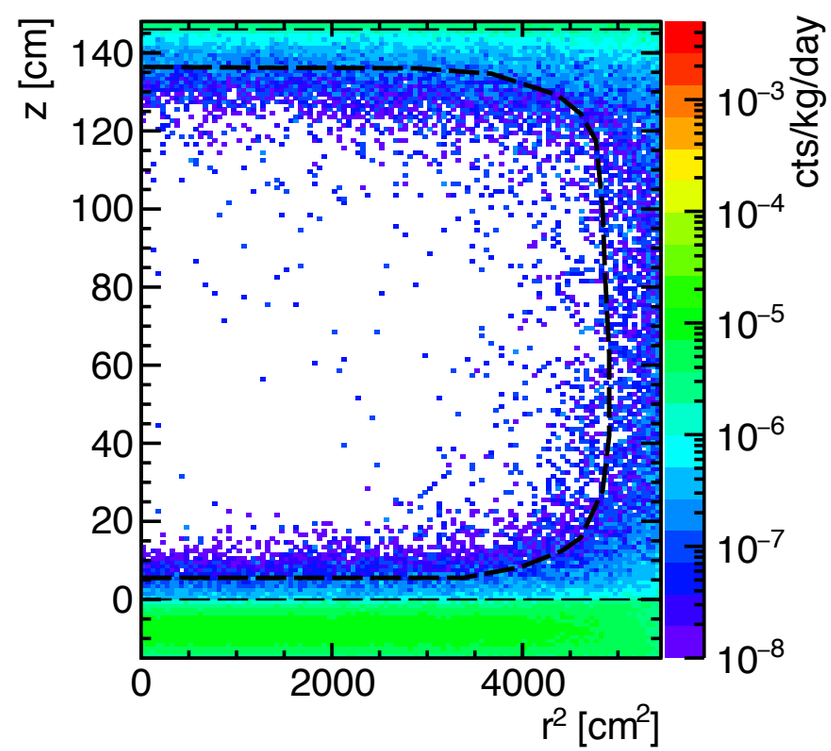




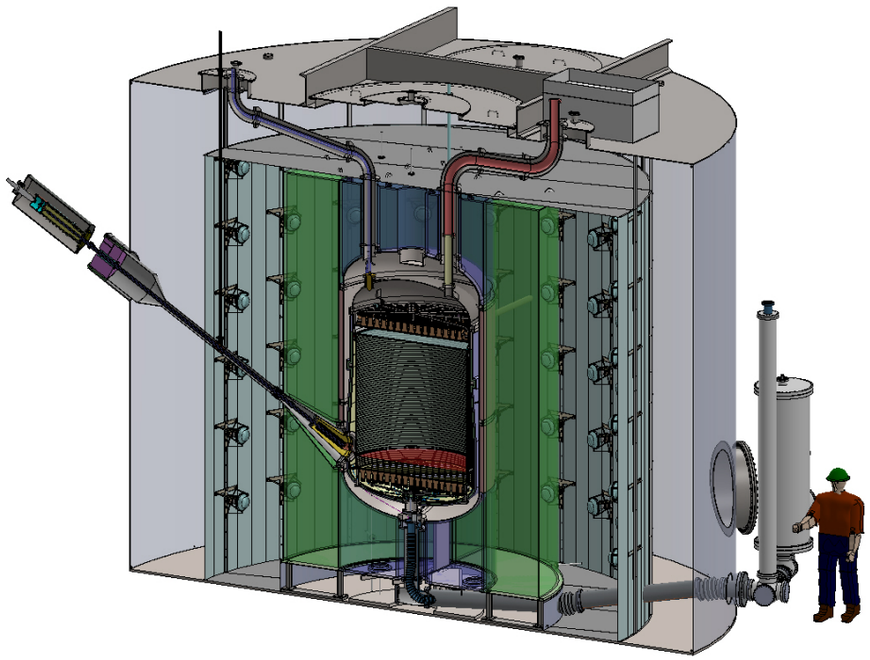
Single Hit + Gd-LS (ER)

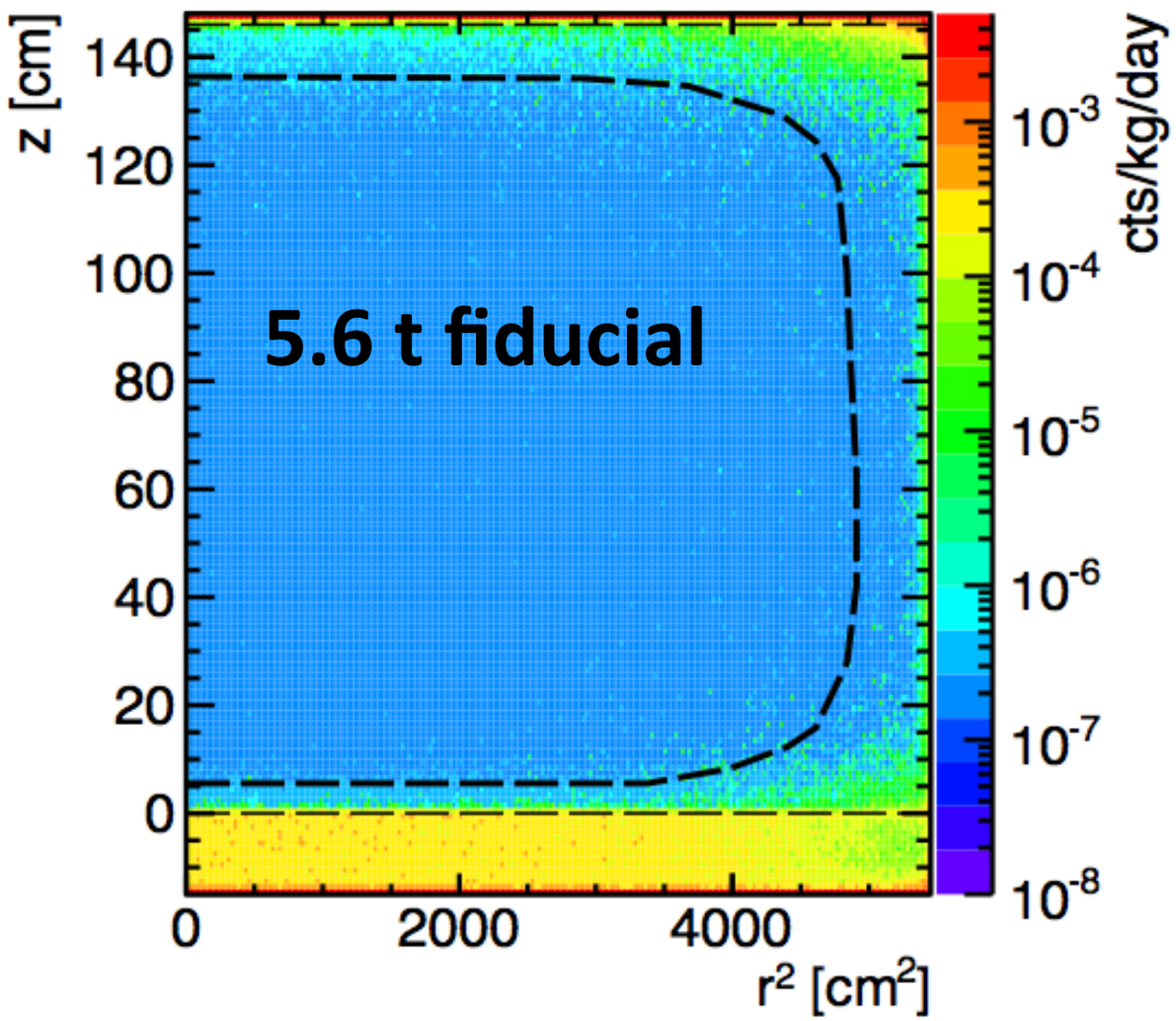


Single Hit + Gd-LS (NR)

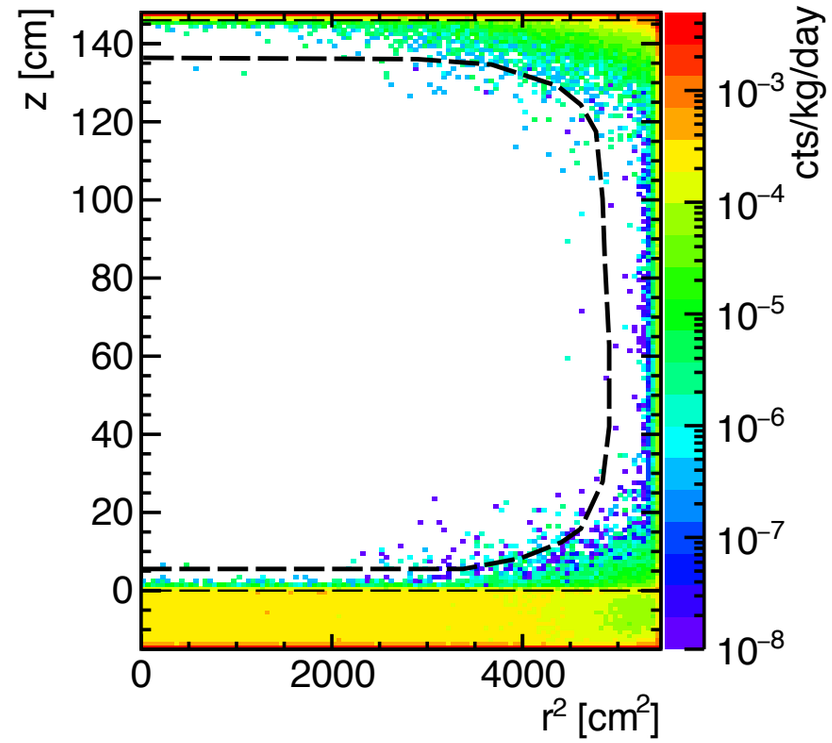


All veto systems

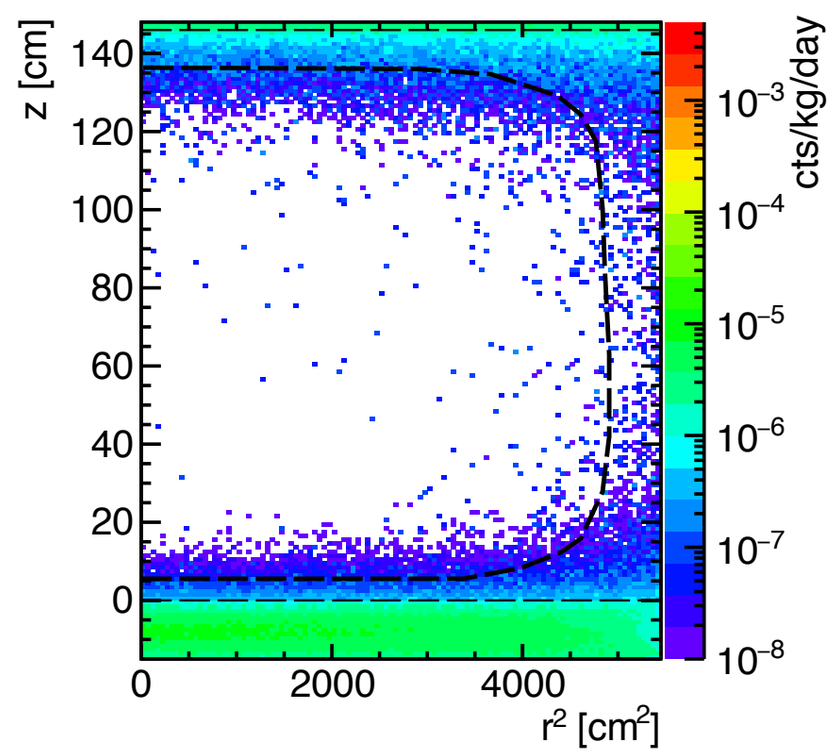




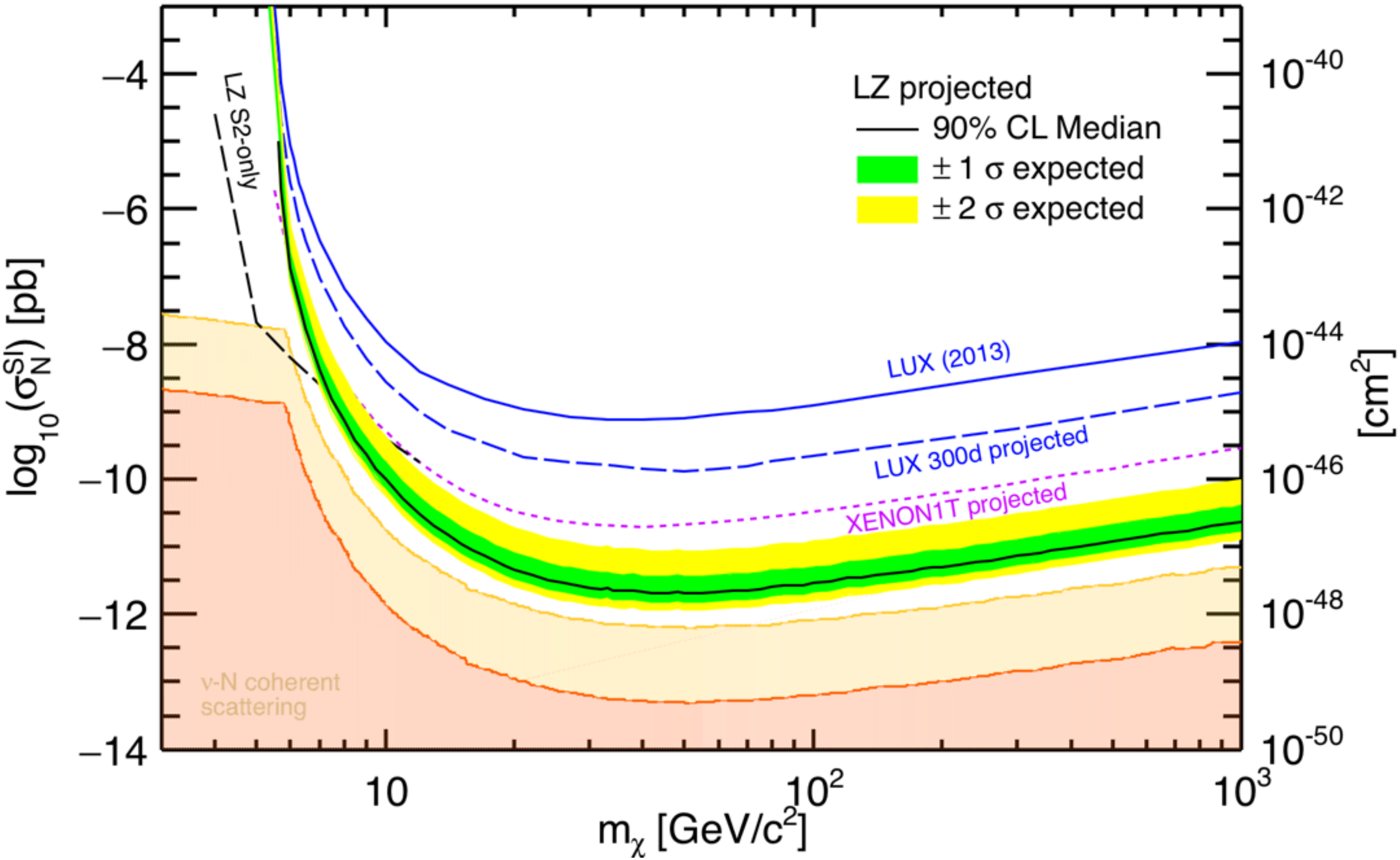
Single Hit + LXe Skin + Gd-LS (ER)



Single Hit + LXe Skin + Gd-LS (NR)



Projected sensitivity



Summary

Large effort in detailed background understanding

- Detector design and performances
  - Talk from H. Araujo
  - Liquid scintillator study (Liverpool)
  - Position reconstruction algorithm
- Monte Carlo simulation and physics background description
  - Software package and optimisation (Edinburgh, Sheffield)
  - Large computing power and storage employed. More than 5 TB just for the data analysed, production on O(10) yrs for ER and O(10^3) yrs for NR
- Material screening selection campaign
  - Talk from P. Scovell

=> 2×10^{-48} cm^2 sensitivity for SI cross section (50 GeV/c^2, 90% CL)

One order of magnitude better than direct competitors in the same WIMP mass range

This work has made use of the resources provided by the Edinburgh Compute and Data Facility (ECDF) (http://www.ecdf.ed.ac.uk/).

Backup slides