DARWIN
dark matter wimp search with noble liquids

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(on behalf of the DARWIN Consortium)

DM 2012
Marina del Rey, February 24, 2012

DARWIN
darwin.physik.uzh.ch

The Consortium

- R&D and design study for a next-generation noble liquid facility in Europe

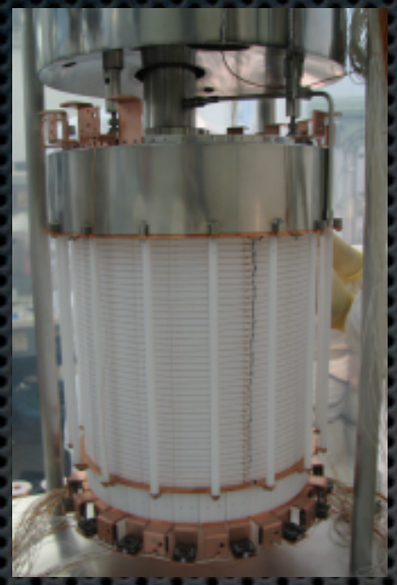
- **A total of 25 groups from ArDM, DarkSide, WARP, XENON**
- **Europe: UZH, INFN, ETHZ, Subatech, Mainz, MPIK, Münster, Nikhef, KIT, TU Dresden, Israel: WIS, USA: Columbia, Princeton, UCLA, Arizona SU**

Evolution

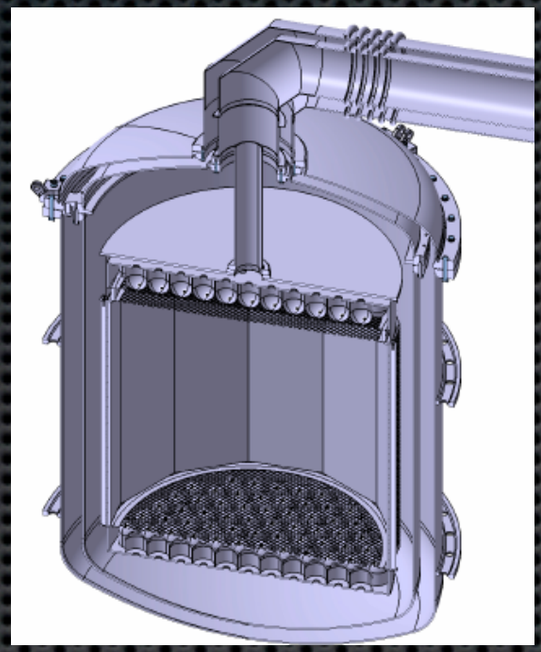
DARWIN

XENON10:
22 kg (5.4 fid)

XENON100:
161 kg (62 fid.)

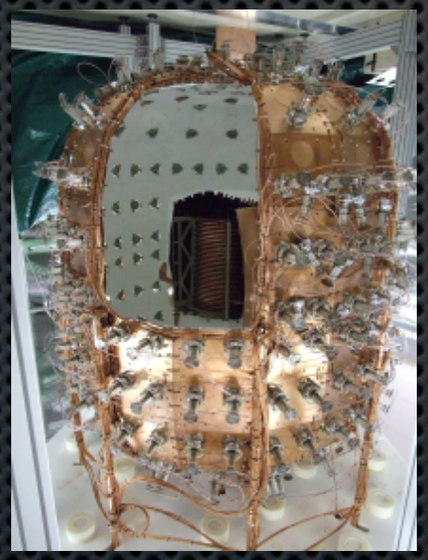


XENON1t:
2.4 t (1 t fid)

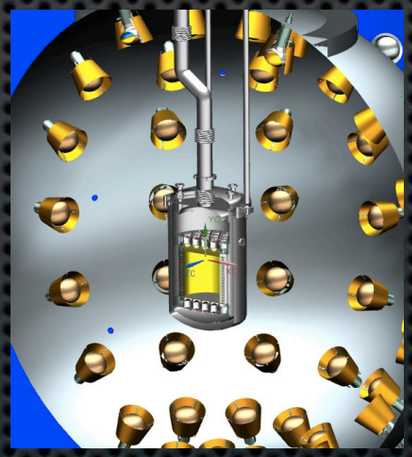


DARWIN:
20 tons LXe/LAr (10 t fid)
(indicative masses*)

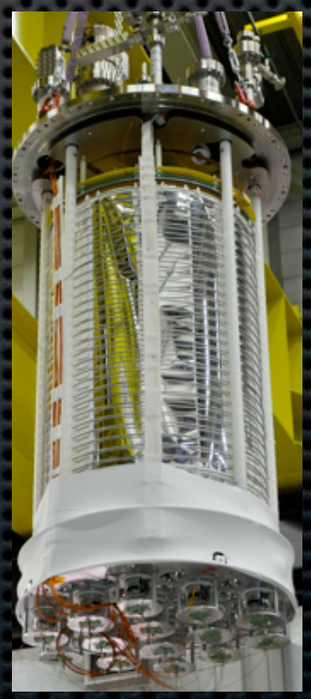
WARP: 2.3 l



WARP:
140 kg



DarkSide:
55 kg (33 fid.)



ArDM: 850 kg

(*optimal masses for LAr/LXe to be determined in the study; here MC sketch)

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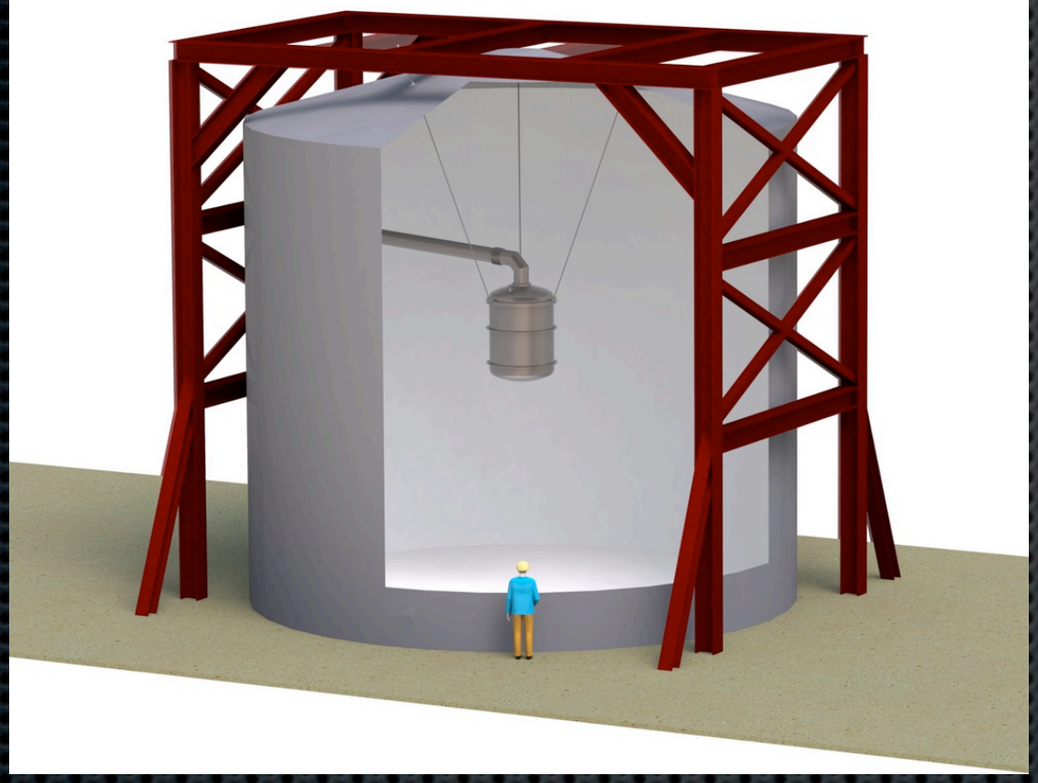
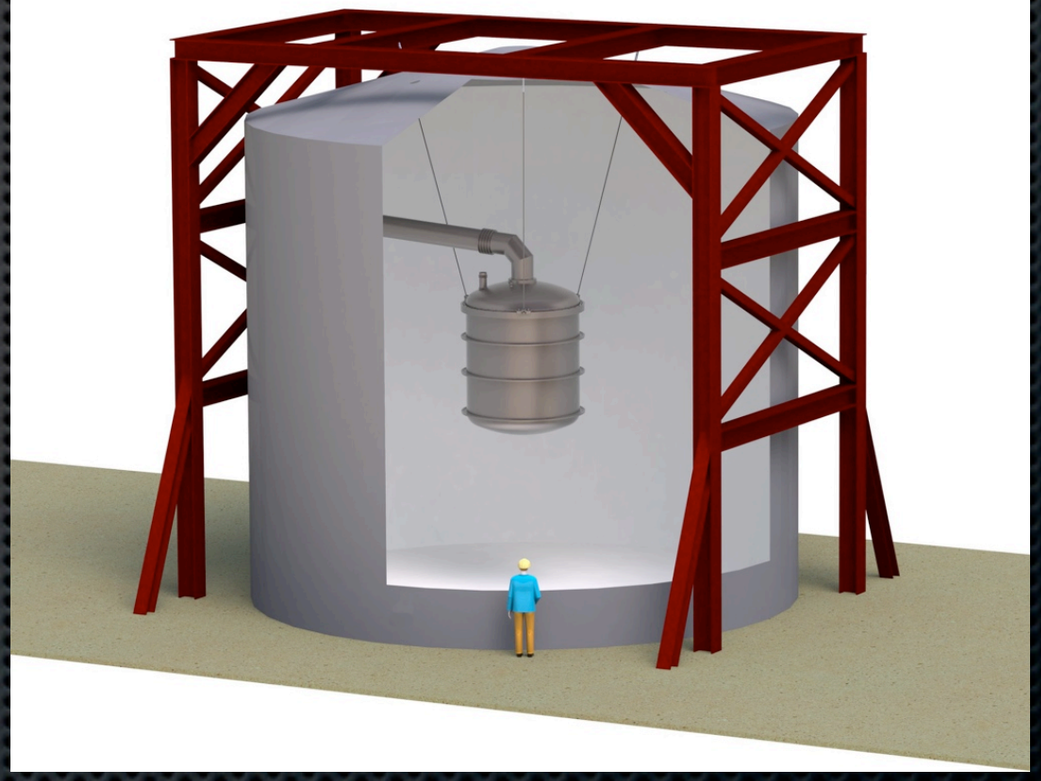
DARWIN

Comparison: XENON1T and DARWIN



XENON1T

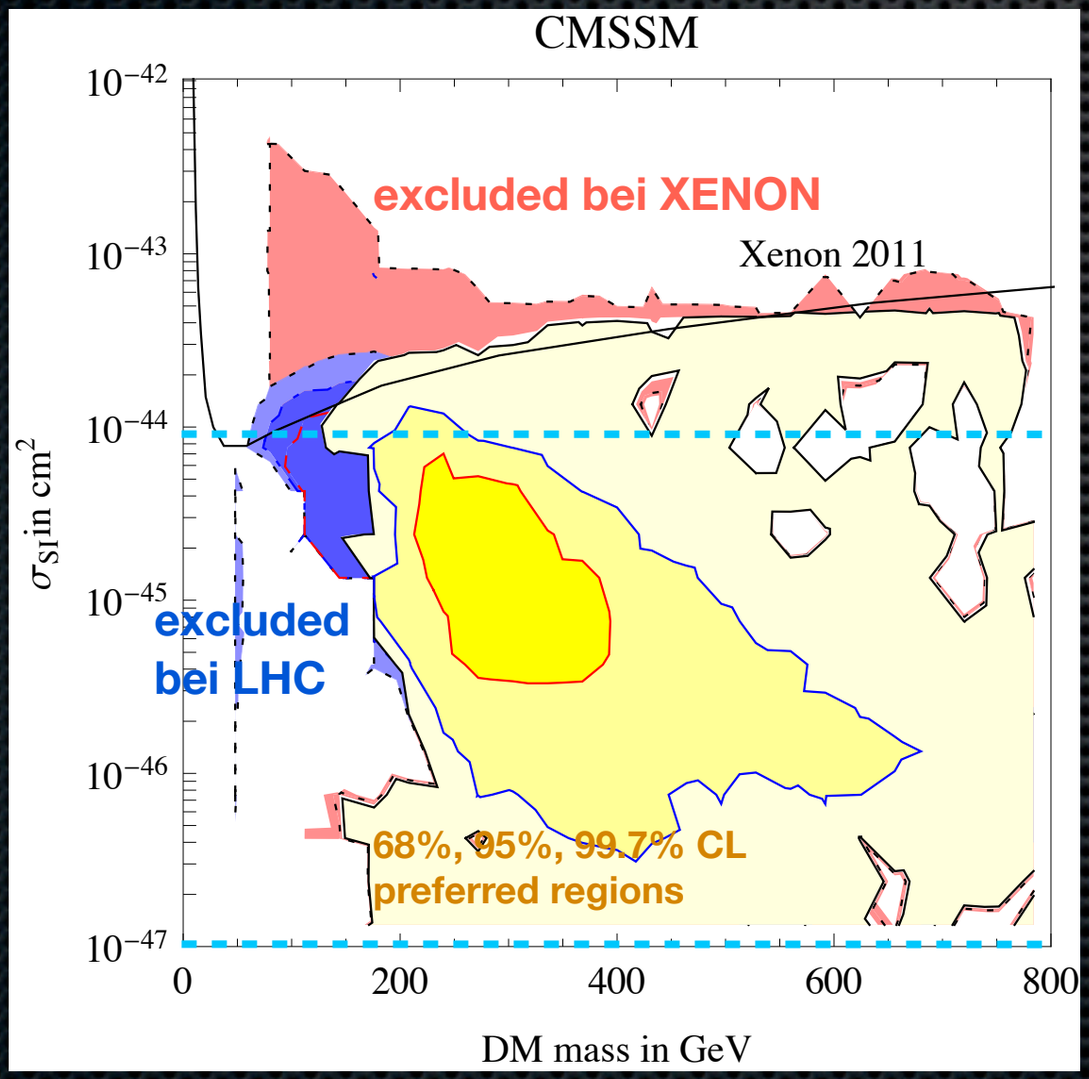


DARWIN
(LXe part, 20 tons in total)

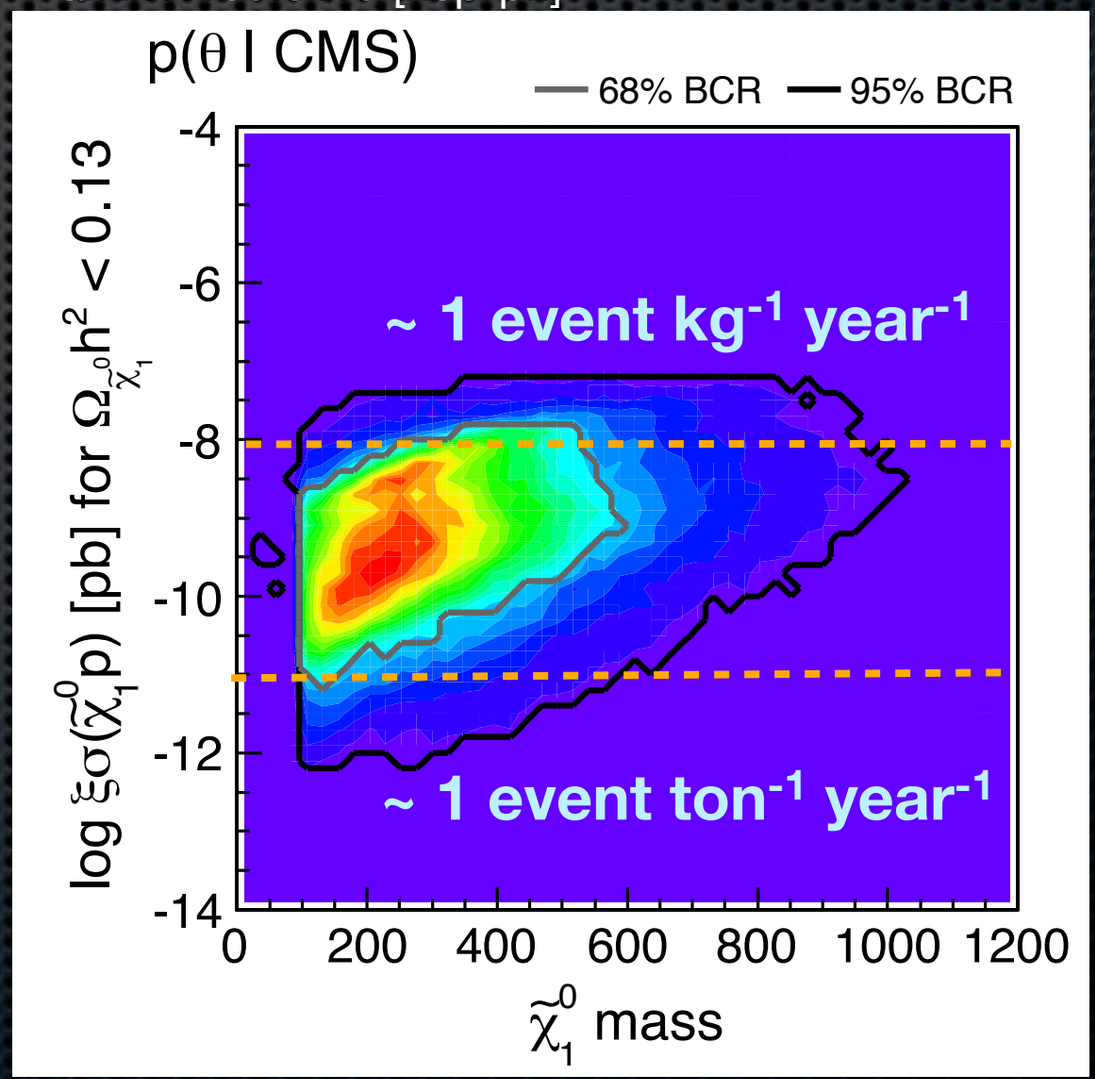
Physics Motivation, I

- Definitive test of the CDM-WIMP hypothesis, complementary to the LHC

http://arxiv.org/pdf/1104.3572v3



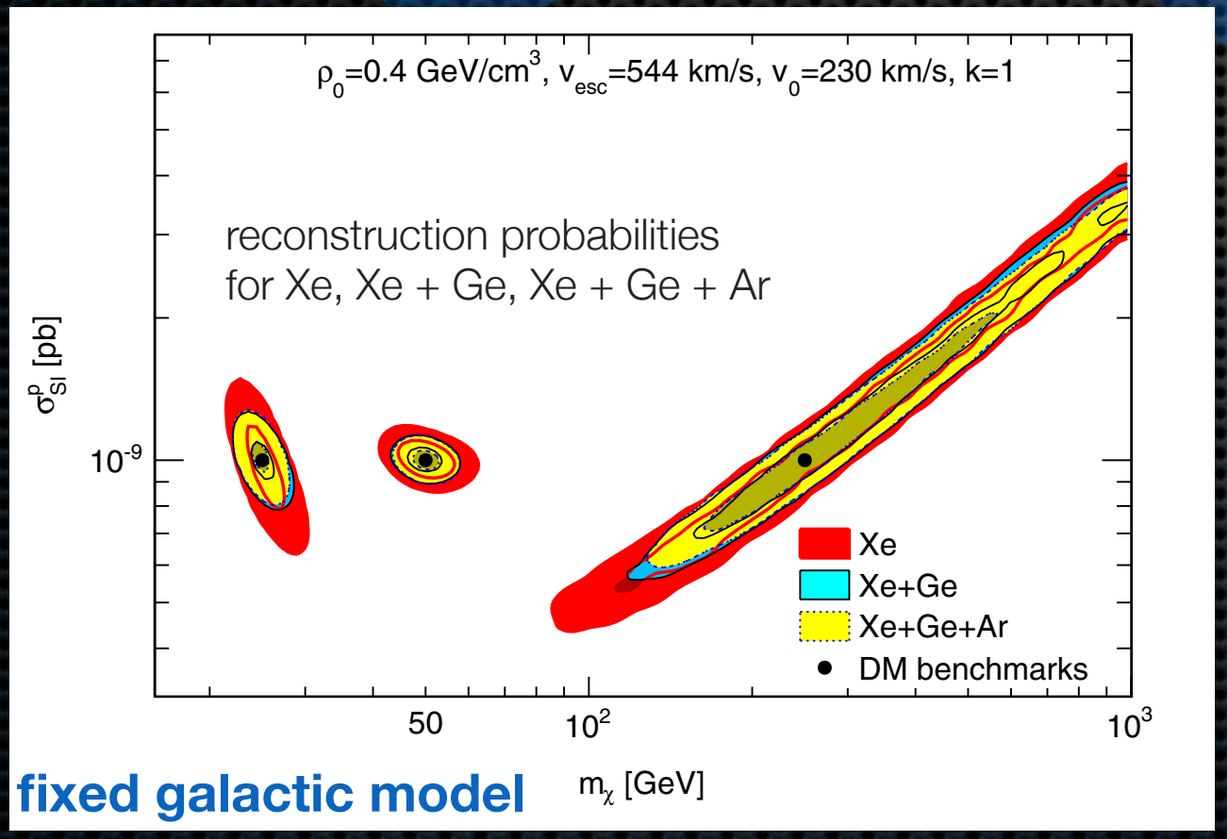
pMSSM (19 parameters at the weak scale)
arXiv:1109.5119 [hep-ph]



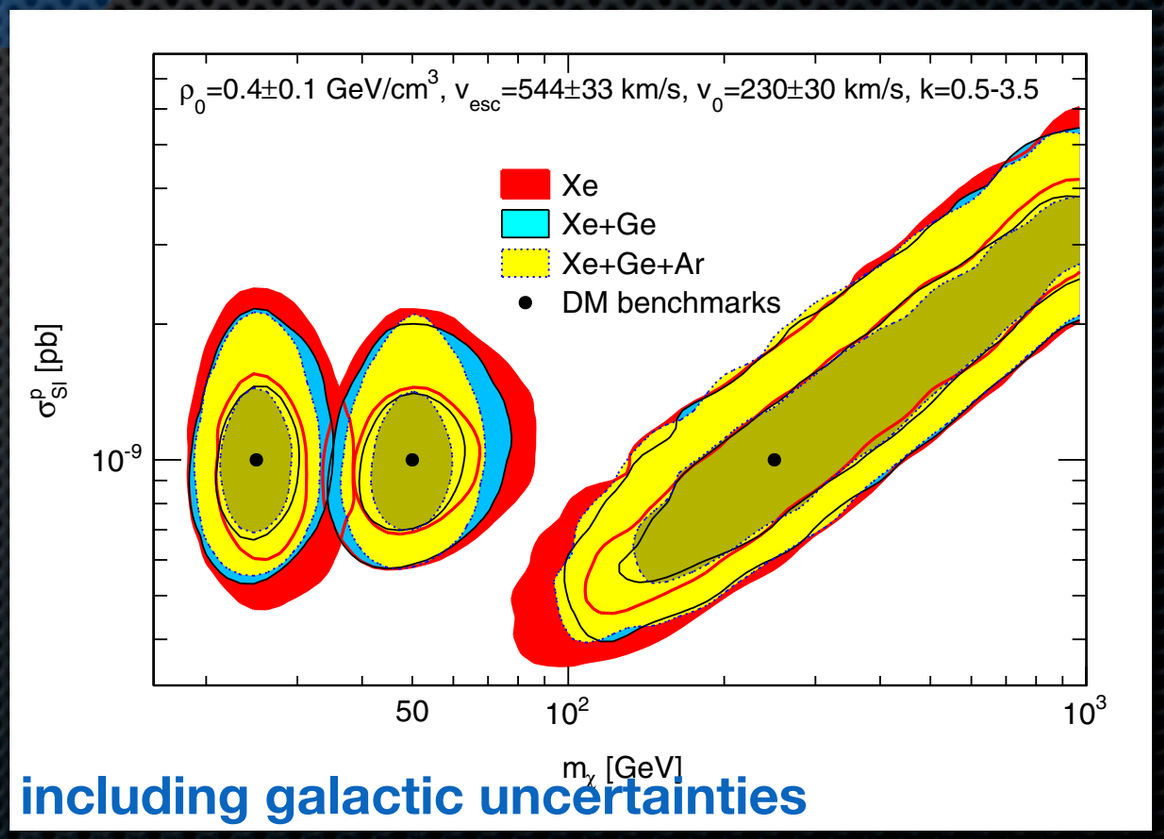
Physics Motivation, II

- Reconstructing WIMP properties:
- *different targets are sensitive to different directions in the m_χ- σ_{SI} plane*

target	ϵ [ton×yr]	η_{cut}	A_{NR}	ϵ_{eff}	[ton×yr]	E_{thr} [keV]	$\sigma(E)$ [keV]	background events/ϵ_{eff}
Xe	5.0	0.8	0.5	2.00		10	Eq. (7)	< 1
Ge	3.0	0.8	0.9	2.16		10	Eq. (6)	< 1
Ar	10.0	0.8	0.8	6.40		30	Eq. (8)	< 1



fixed galactic model



including galactic uncertainties

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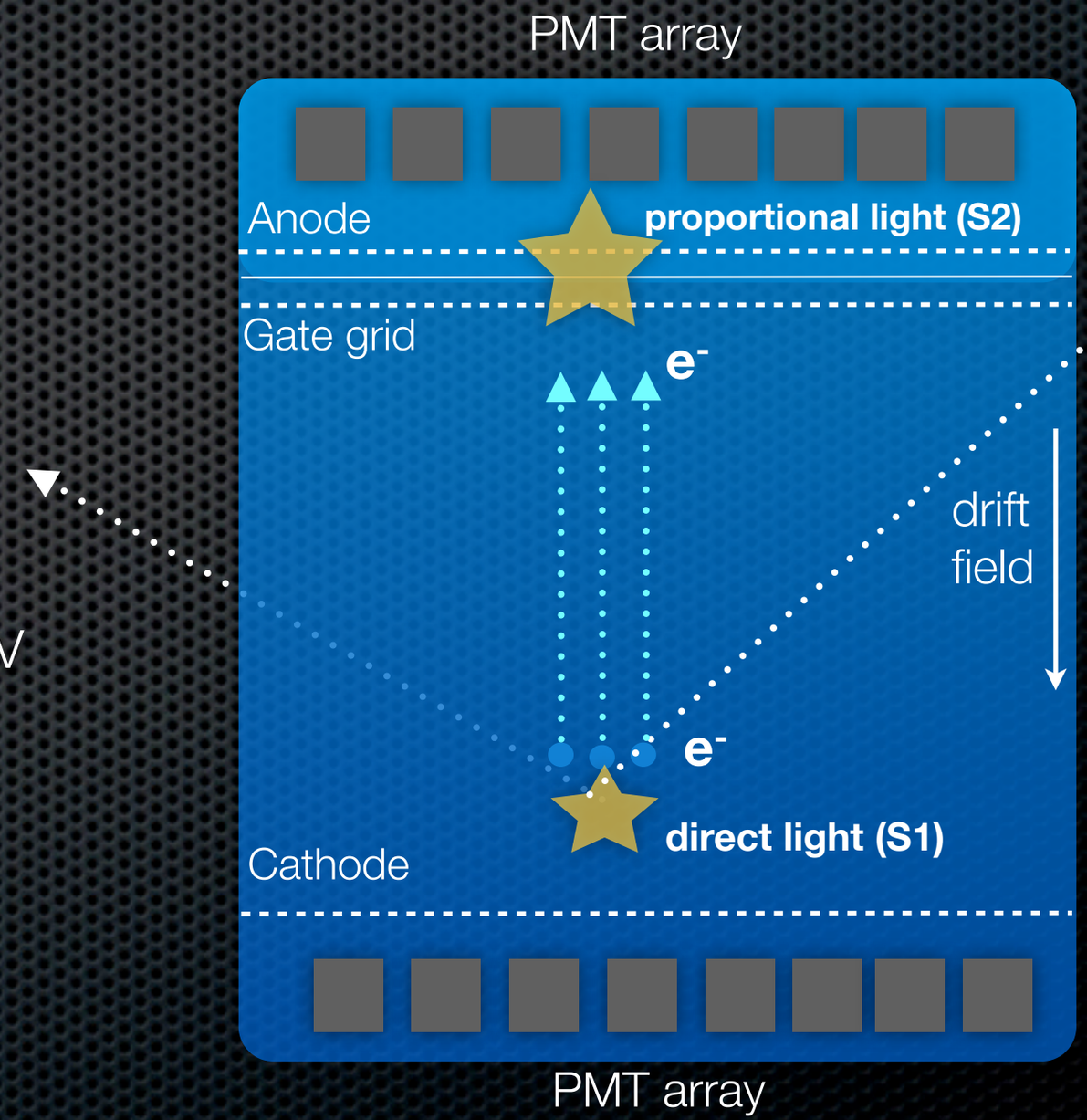
Miguel Pato, Laura Baudis, Gianfranco Bertone, Roberto Ruiz de Austri, Louis E. Strigari and Roberto Trotta Phys. Rev. D 83, 083505 (2011)

DARWIN

Principle and some detector R&D

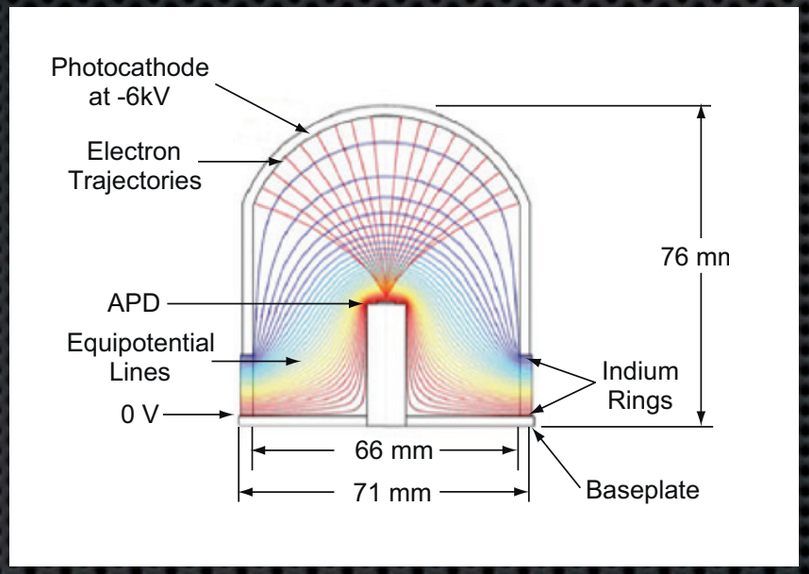
- Inner detector: dual-phase TPC
- Optimize light and charge readout, HV system and drift field
- Cryostat: titanium; optimize cooling, Xe recirculation, radon emanation
- Design calibration system (m.f.p. of 1 MeV photons is ~ 6 cm in LXe and 12 cm in LAr): internal calibration (energy scale) using ^{83m}Kr*

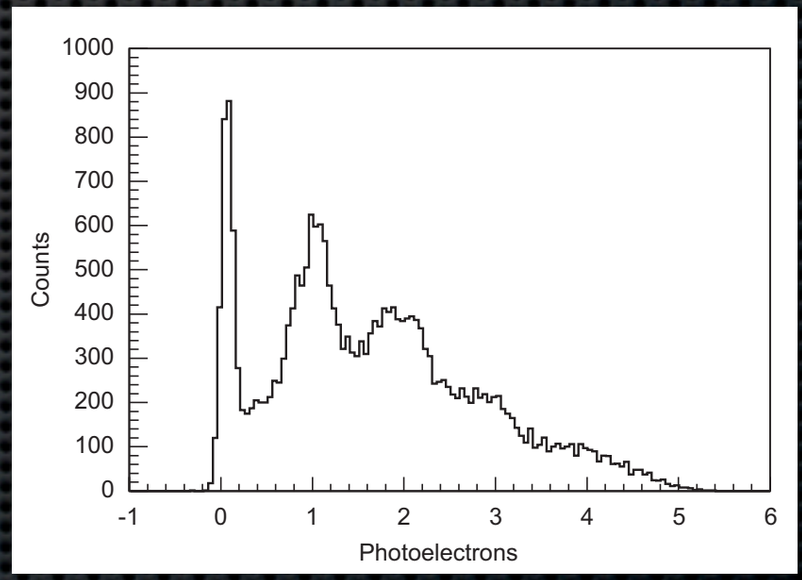


* A. Manalaysay, T. Marrodan Undagoitia, A. Askin, L. Baudis, A. Behrens, A. Ferella, A. Kish, O. Lebeda, D. Venos, A. Vollhard Review of Scientific Instruments 81, 073303 (2010)

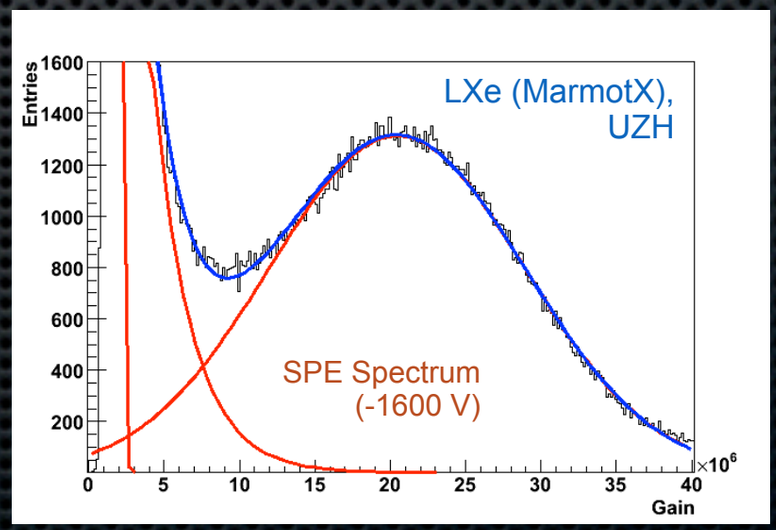
R&D on light readout

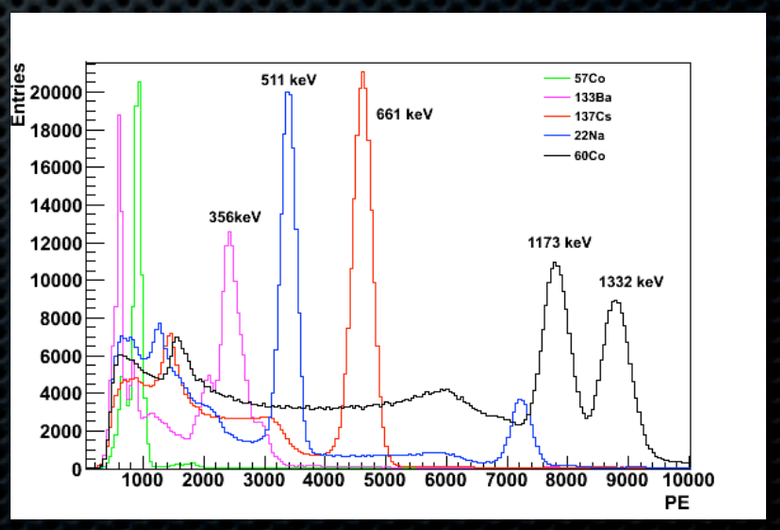
- Under study: hybrid (APD + photocathode) sensors (QUPIDs*); new bialkali 12-dynode stage photomultipliers (R11410 for LXe, R11065 for LAr)





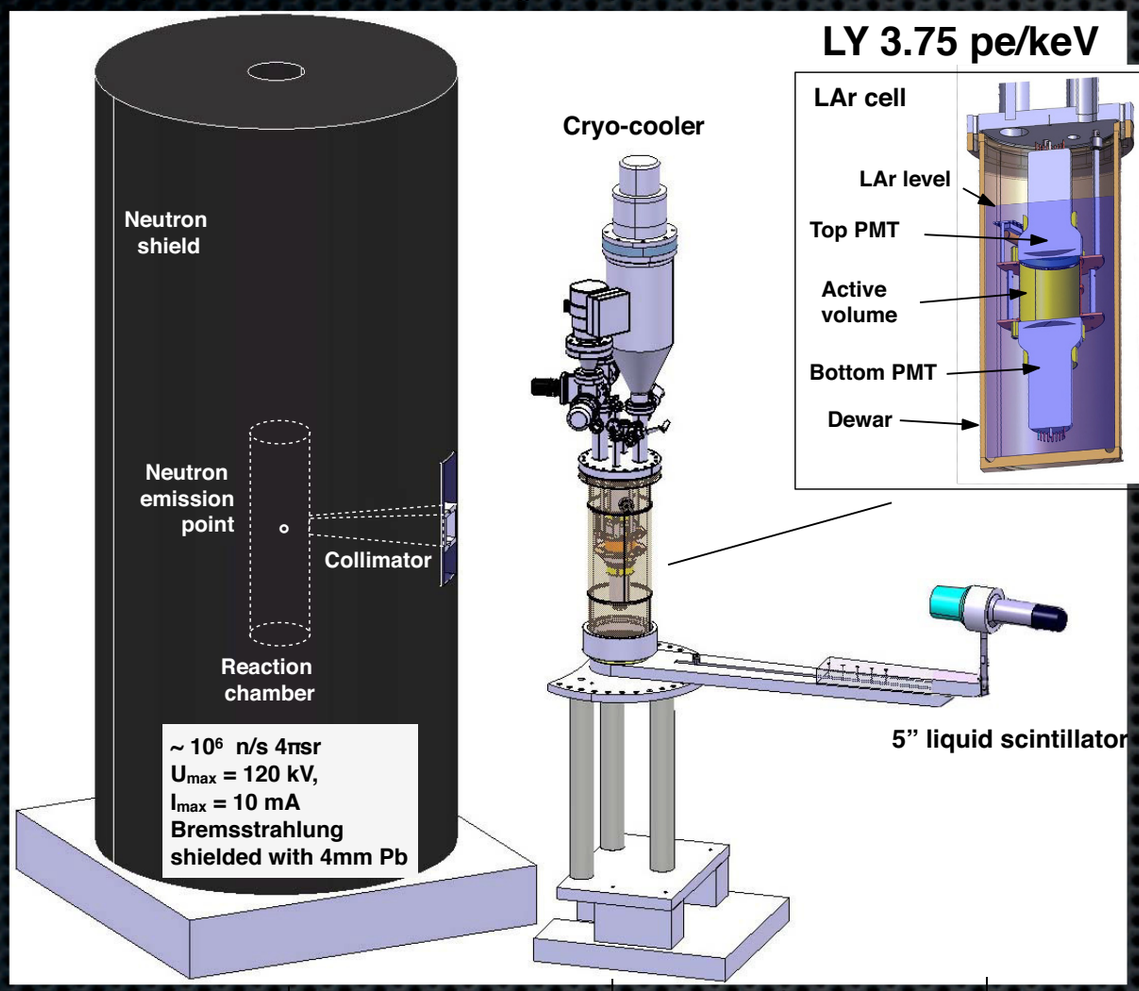
*A. Teymourian, et al, NIM A 654 (2011)

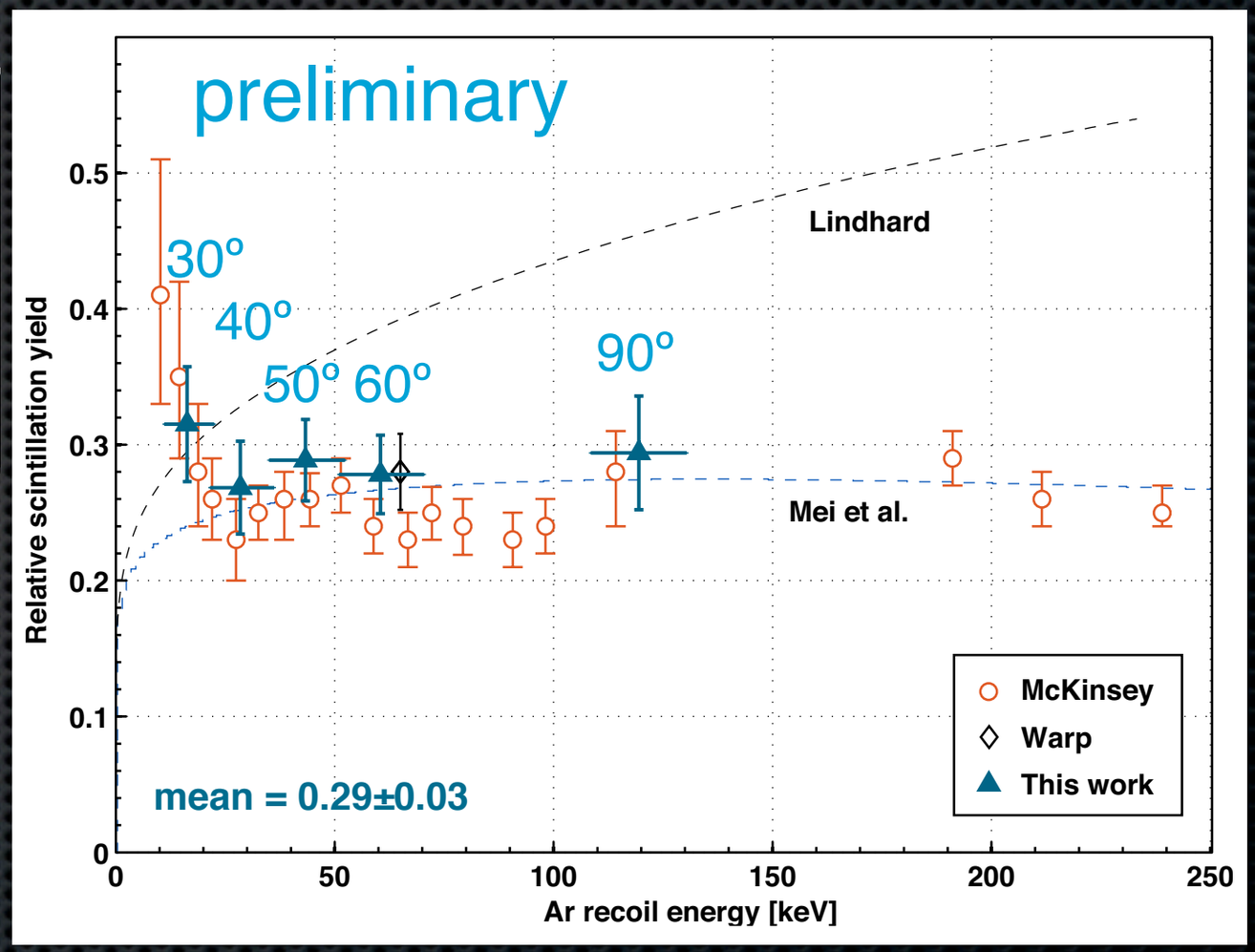




R&D on scintillation properties: argon

Setup at CERN (UZH group)

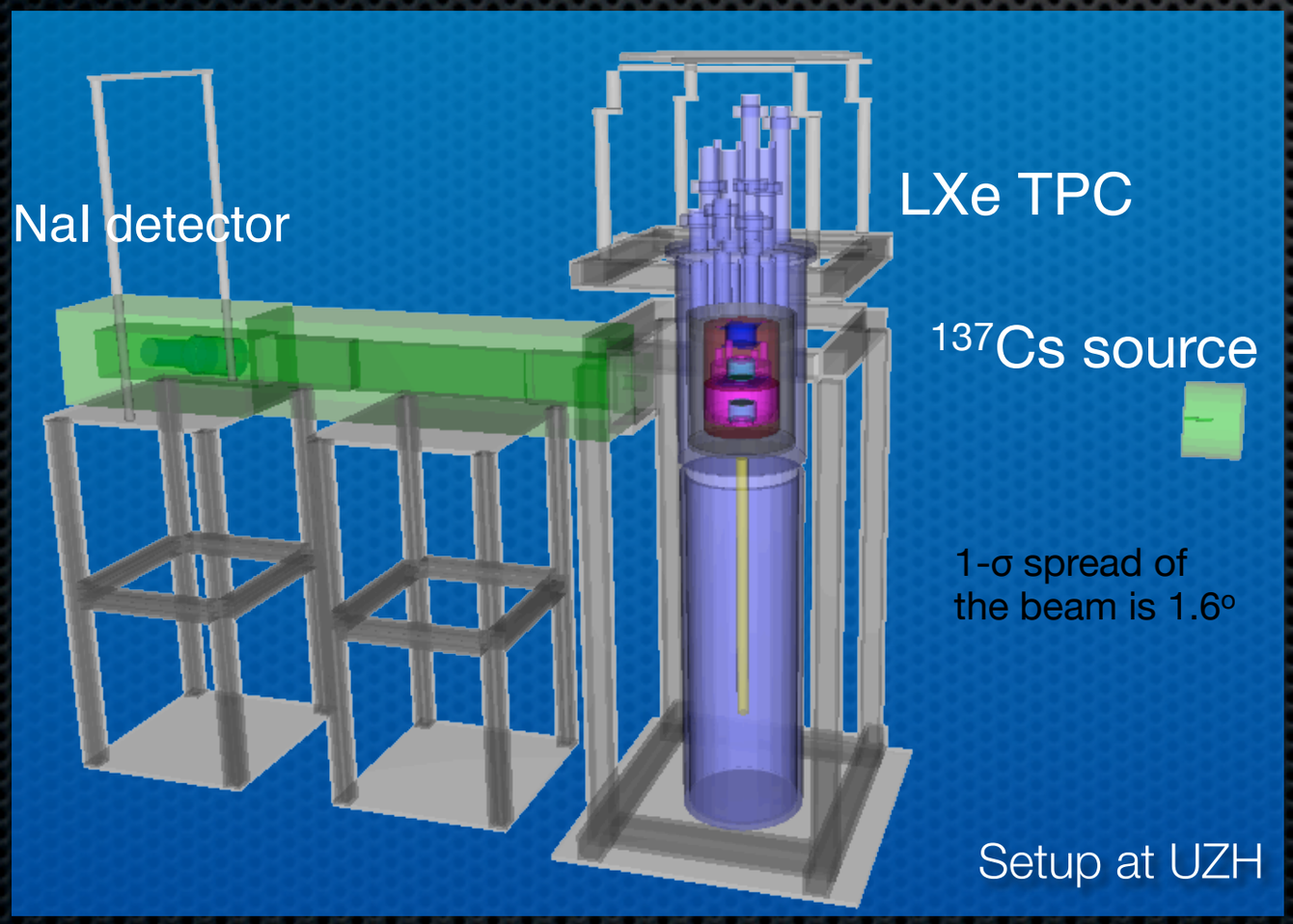


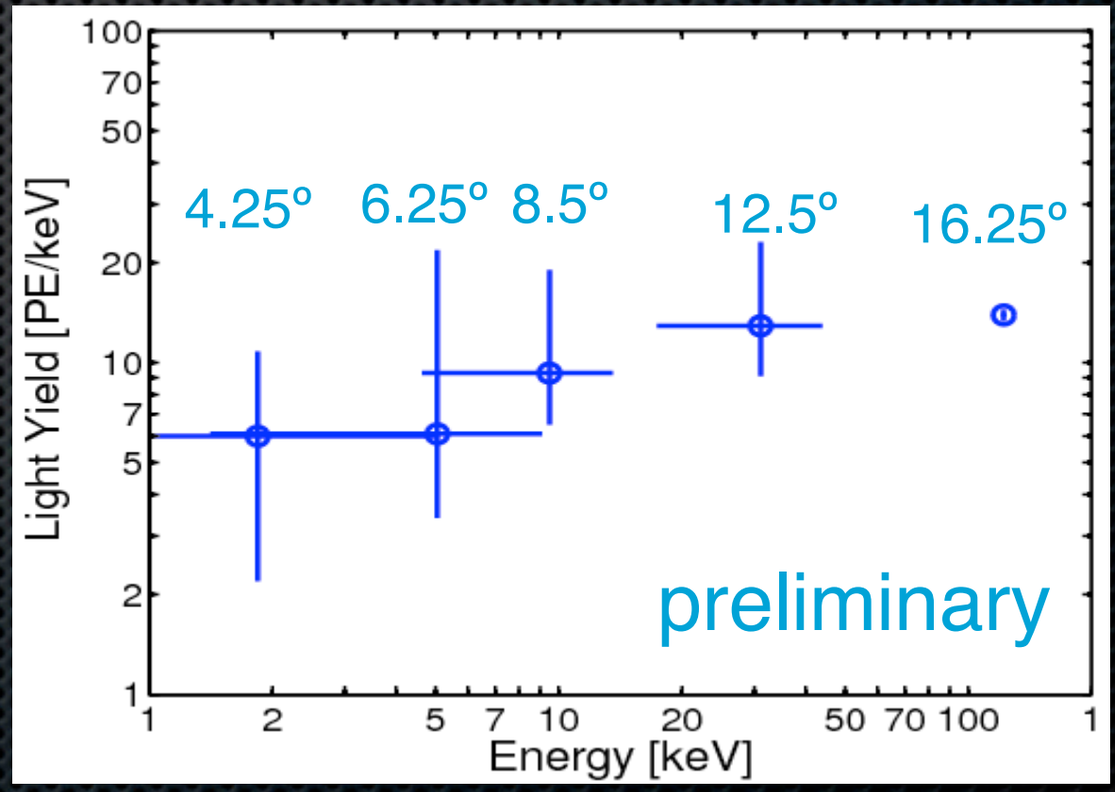


- Light yield of nuclear recoils in LAr: using neutron D-D generator, LAr and n-detectors
- C. Regenfus (UZH) talk at TAUP2011

R&D on scintillation properties: xenon

- Light yield of low-energy electronic recoils in Xe: at UZH, using strong ^{137}Cs source, LXe and NaI detector in coincidence to measure light yield of electronic recoils down to ~ 2 keV

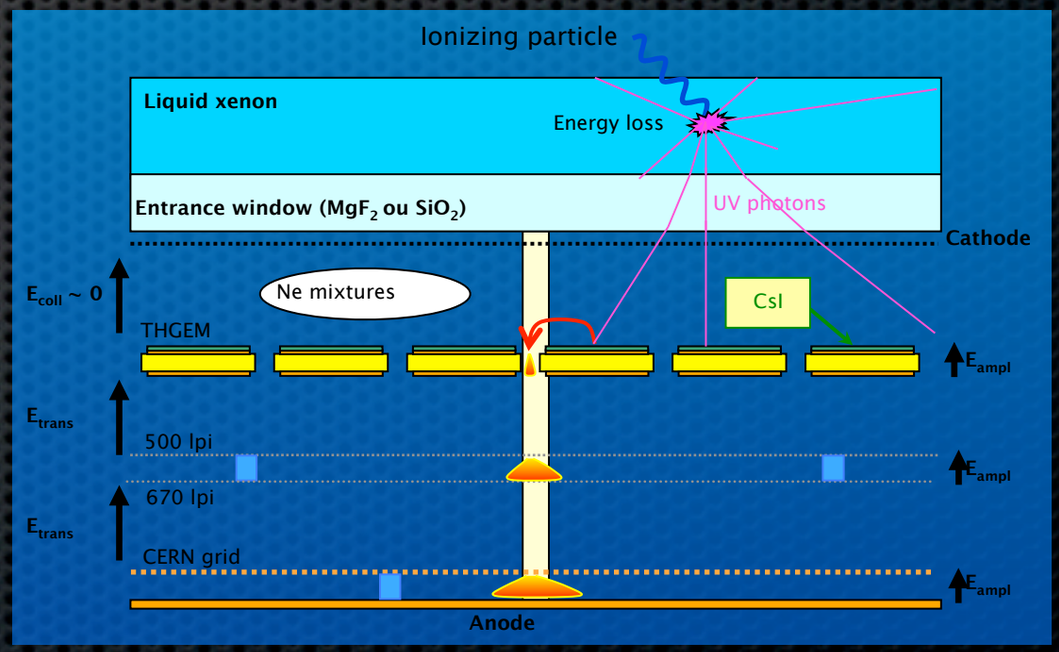




- A. Manalaysay (UZH) talk at TAUP2011
- detailed analysis in progress

R&D on charge readout

- **Idea:** good position resolution for S-to-B discrimination; charge cloud in the TPC is localized (< 1 mm); large scale charge readout structures can keep this information and provide low radioactivity and costs
- **Alternative to proportional scintillation: read out the charge directly, via:**
  - **LEM** (macroscopic GEMs)
    - charge amplification in holes
  - **GridPix:** gaseous detector
    - pixel chip readout coupled to EM
- **Or, read out proportional scintillation**
  - via **gaseous PMs**, with MF_2 window
  - CsI photocathode, on thick GEMs



Cryogenic gaseous photomultiplier: gain > 10^6 in LXe

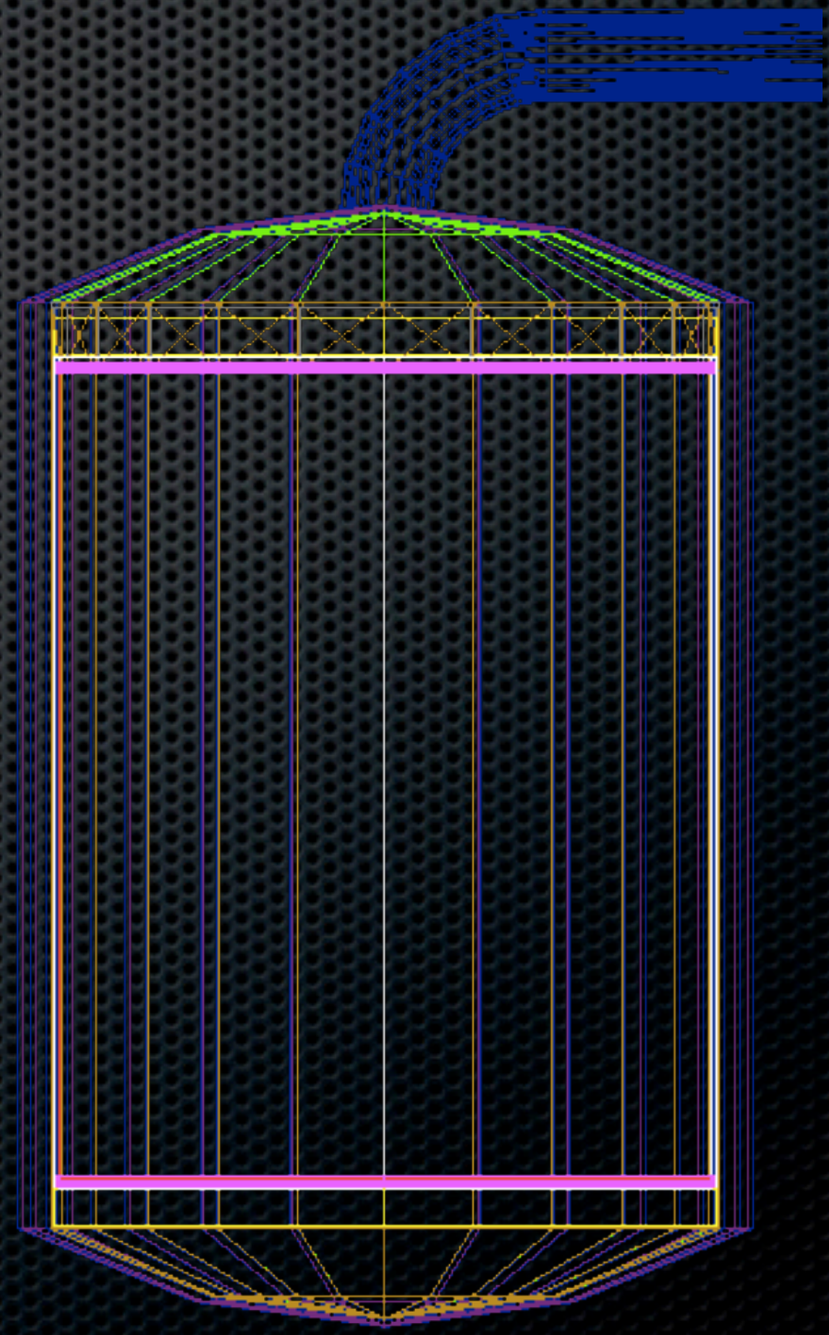
S. Duval et al, NIM A (2011), doi: 10.1016/j.nima.2011.11.018

Background modeling

*a subset of screened materials using Gator

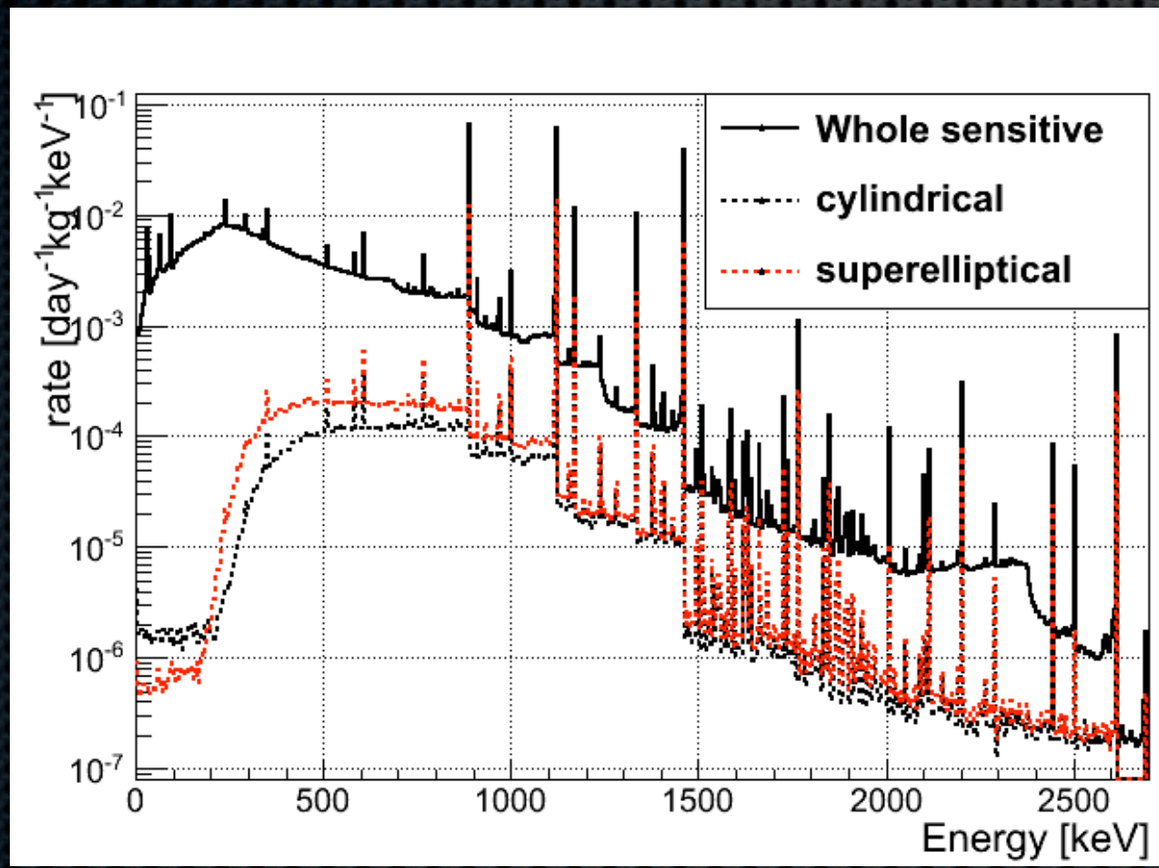
Material*	**^{226}Ra**	**^{228}Th**	**^{60}Co**	**^{40}K**
PTFE (mBq/kg)	< 0.06	< 0.10	< 0.3	< 0.75
Titanium Nironit (mBq/kg)	1.2 ± 0.4	0.6 ± 0.3	< 0.2	< 2.8
Titanium Supra Alloy (mBq/kg)	<0.6	0.9 ±0.2	< 0.2	< 2.5
QUPIDs (mBq/piece)	0.3 ± 0.1	0.4 ± 0.2	< 0.2	5.5 ± 0.6
PMT R11410-MOD (mBq/PMT)	0.5 ± 0.1	1.5 ± 0.2	4.0 ± 0.8	13 ± 2
PMT R11410 (mBq/PMT)	6.1 ± 0.7	3.0 ± 0.6	8.4 ± 0.8	50 ± 8
Copper powder (mBq/kg)	50 ± 10	12 ± 5	< 0.2	23 ± 8
Anode Feedthrough (Bq/kg)	9.0 ± 1.0	11.3 ± 0.8	< 0.3	2.0 ± 1.0
Quartz block (mBq/kg)	< 1.0	< 1.8	< 0.07	17 ± 3

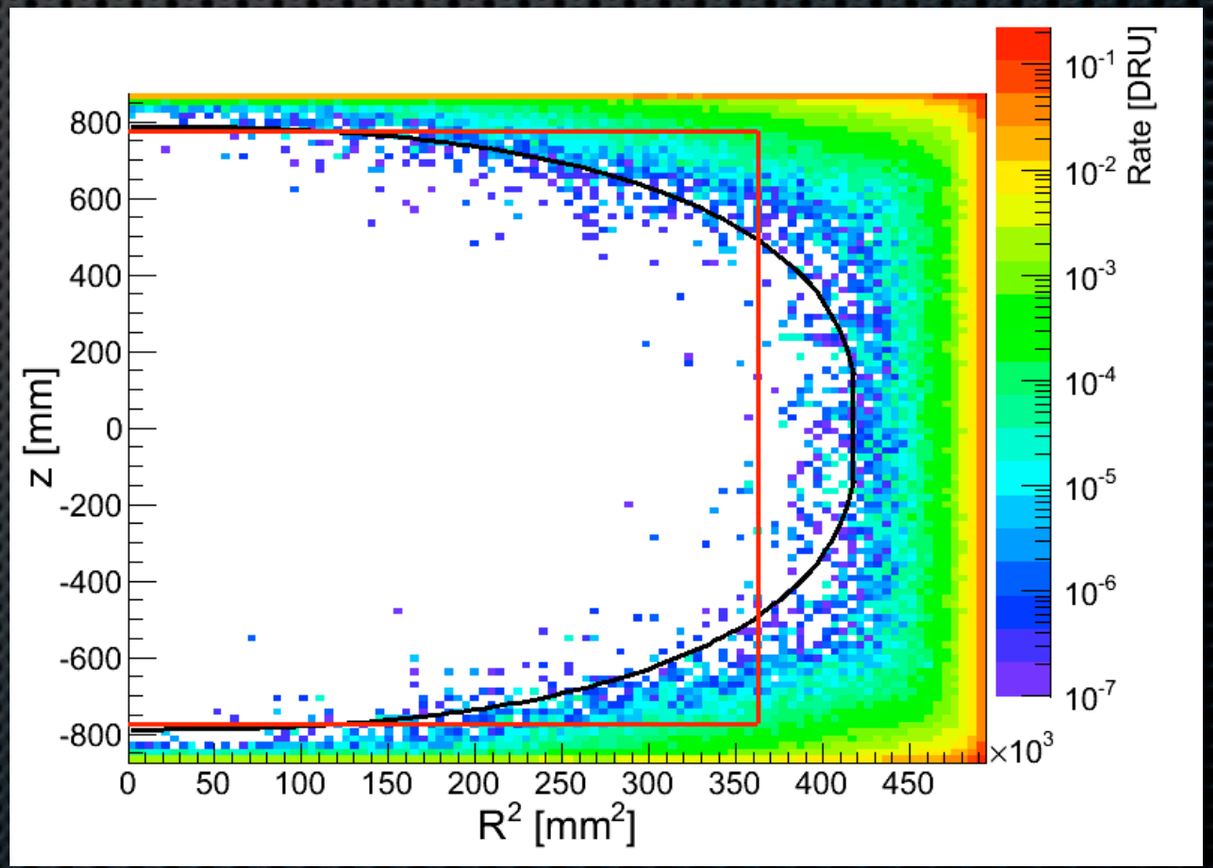
L Baudis, A. Ferella, A. Askin, J. Angle, E. Aprile, T. Bruch, A. Kish, M. Laubenstein, A. Manalaysay, T. Marrodan, M. Schumann 2011 *JINST* **6** P08010



Gamma backgrounds

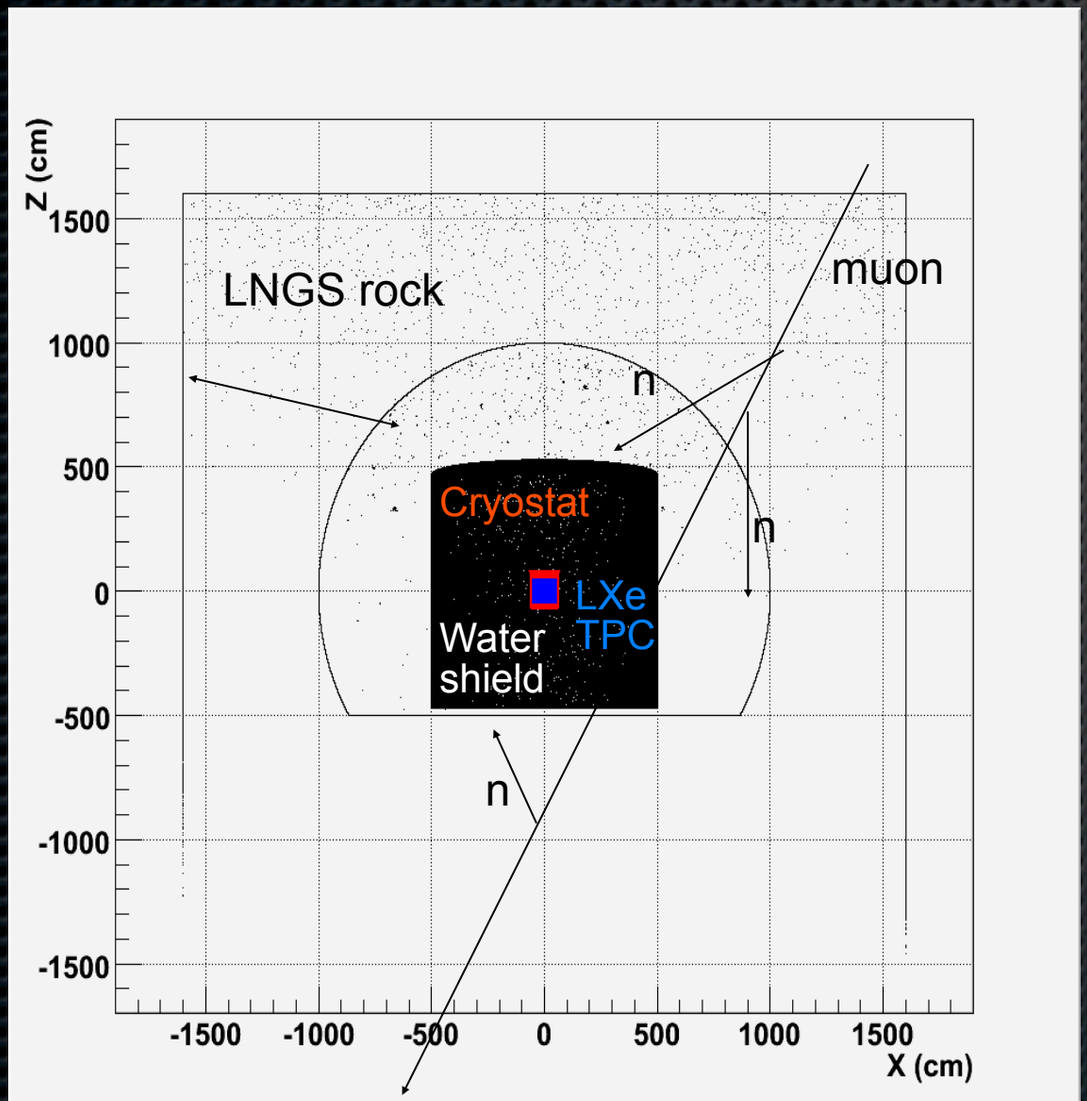
- Initial MC simulations for 10 t (5 t) total (fiducial) liquid xenon mass
- Background below 10^{-6} dru in the central detector region (in DM-ROI)



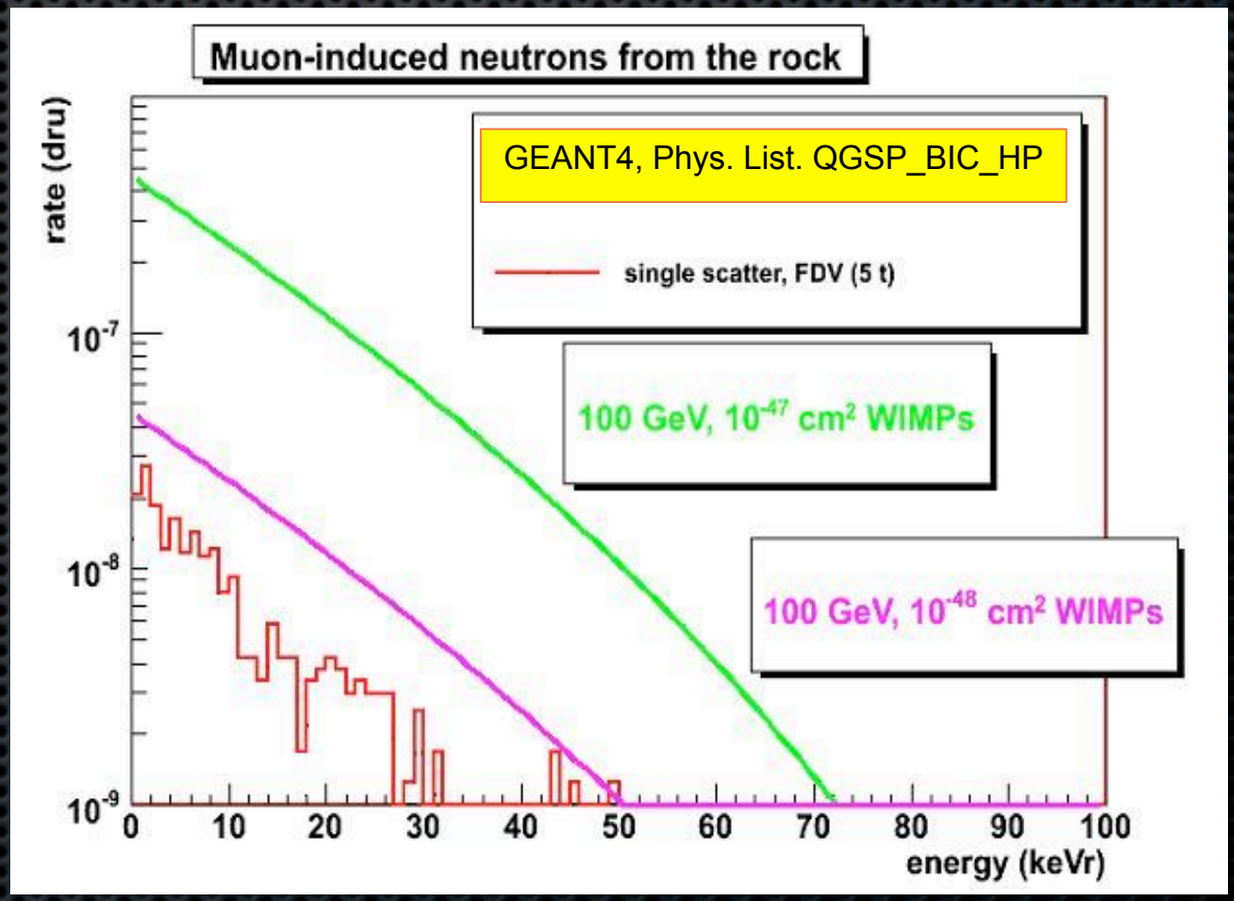


Neutron backgrounds

LNGS: water Cherenkov shield 10m x 10m



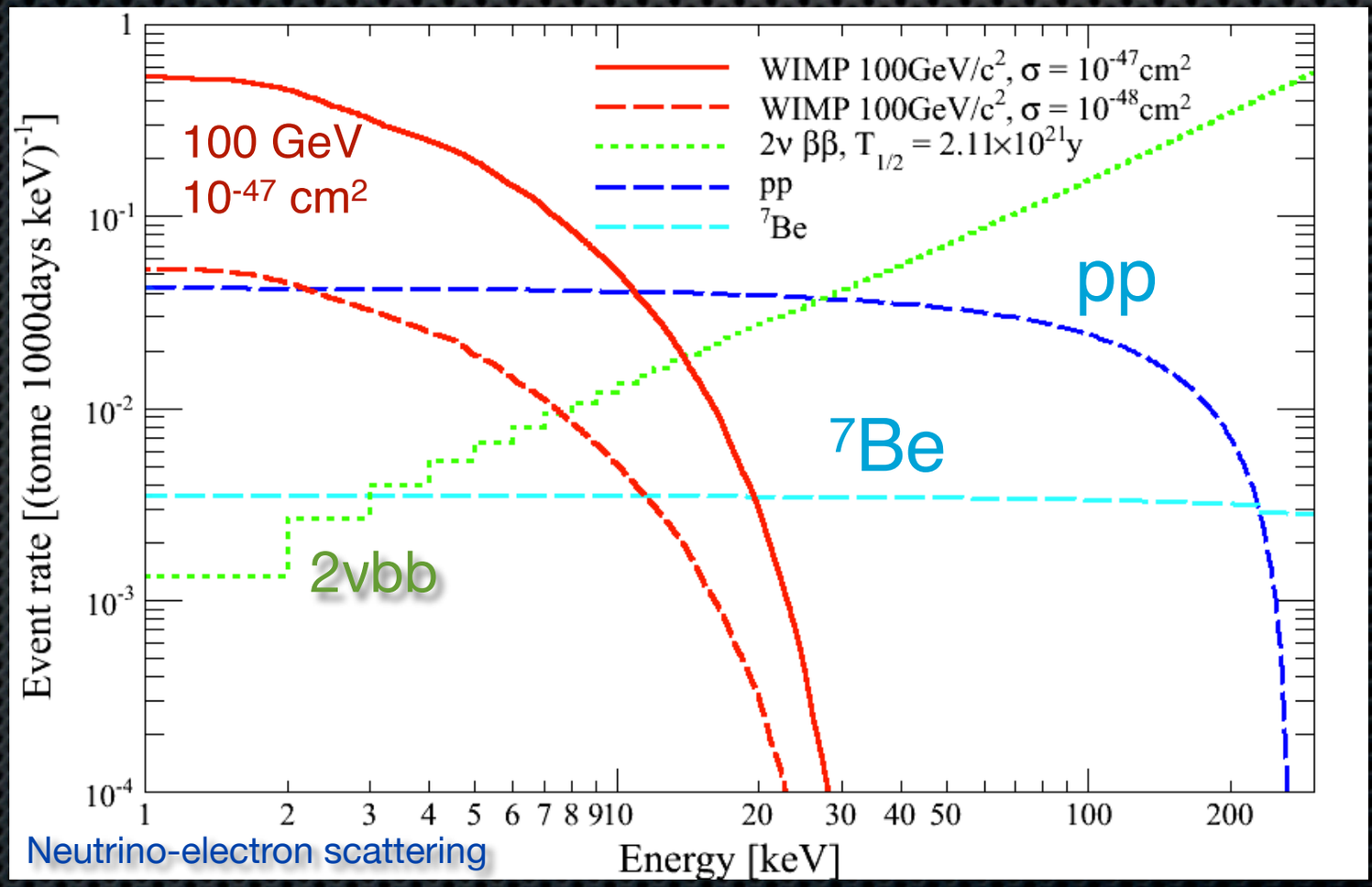
Selection criteria:
single scatter (segmentation 3 mm z-coordinate)
fiducial volume - linear 10 cm LXe cut



Rate of single scatter, nuclear recoils, in the fiducial volume in [9,45] keV_{nr}: 0.2 per year

Neutrino backgrounds

- Neutrinos may be the ‘ultimate’ background source
- (will eventually deliver a new physics channel)
- ^{85}Kr (^{nat}Kr < 0.1 ppt) and ^{222}Rn < 0.1 μBq/kg required



2vbb: EXO measurement of ^{136}Xe $T_{1/2}$
Assumptions: 50% NR acceptance, 99.5% ER discrimination, 80% flat cut acceptance
Contribution of 2vbb background can be reduced by using depleted xenon

Expected sensitivity

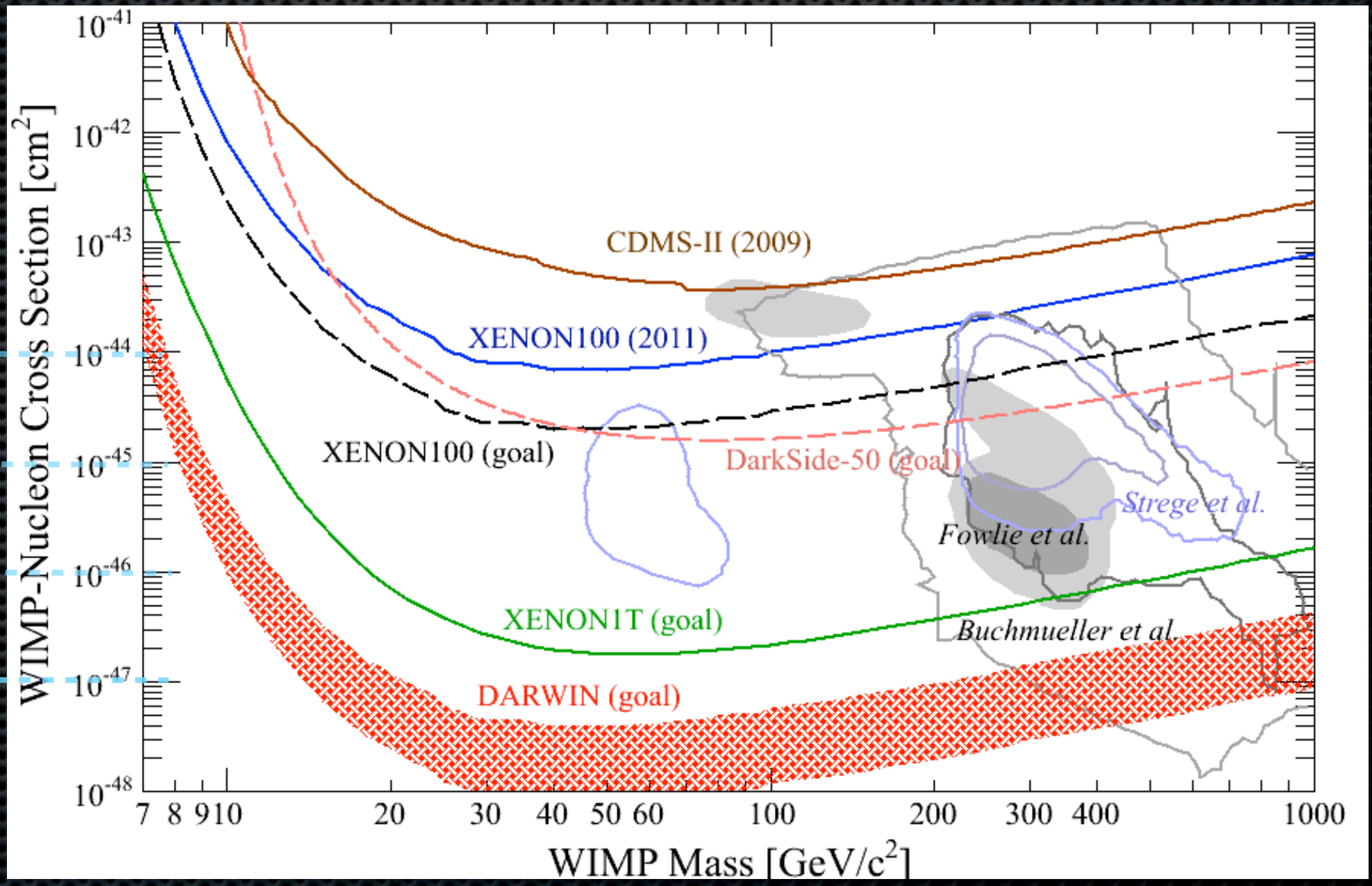
- However, goal is not exclusion limits, but WIMP detection

~ 1 event kg^{-1} year^{-1}

~ 1 event (10 kg)$^{-1}$ year^{-1}

~ 1 event (100 kg)$^{-1}$ year^{-1}

~ 1 event ton^{-1} year^{-1}



DARWIN

Aspera and CHIPP roadmaps

Recommendation: **The last 2-3 years have seen dramatic progress of the liquid-xenon based technology for the direct detection of WIMPs. The 100 kg scale has been realised with a low background level and the 1-ton scale is currently being planned. On this basis, the committee recommends that DARWIN, a program to further extend the target mass of noble liquids to several tons, is pursued and supported. The choice in favour of a double-target option should be taken after a clear experimental confirmation that a liquid argon target is competitive with liquid xenon in terms of rejection efficiency, background and operation reliability.**

Recommendation 6 – Direct and Indirect Dark Matter Detection

CHIPP recommends that the necessary resources be provided for the construction, maintenance, operation and physics exploitation of the present generation XENON100, XENON1T and ArDM experiments for the direct detection of Dark Matter. The construction and operation of the DARWIN multi-ton Dark Matter search facility should receive an appropriate Swiss contribution.

ASPERA Astroparticle Physics for Europe

PARTICLE PHYSICS IN SWITZERLAND