DARWIN

DARk matter WImp search with Noble liquids

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(on behalf of the DARWIN Consortium)

DARWIN
darwin.physik.uzh.ch

TAUP2011
Munich, September 8, 2011

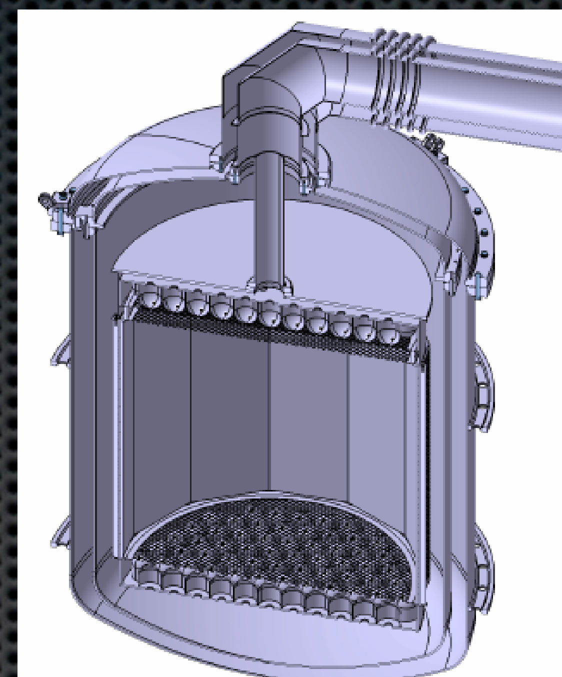
DARWIN

Evolution

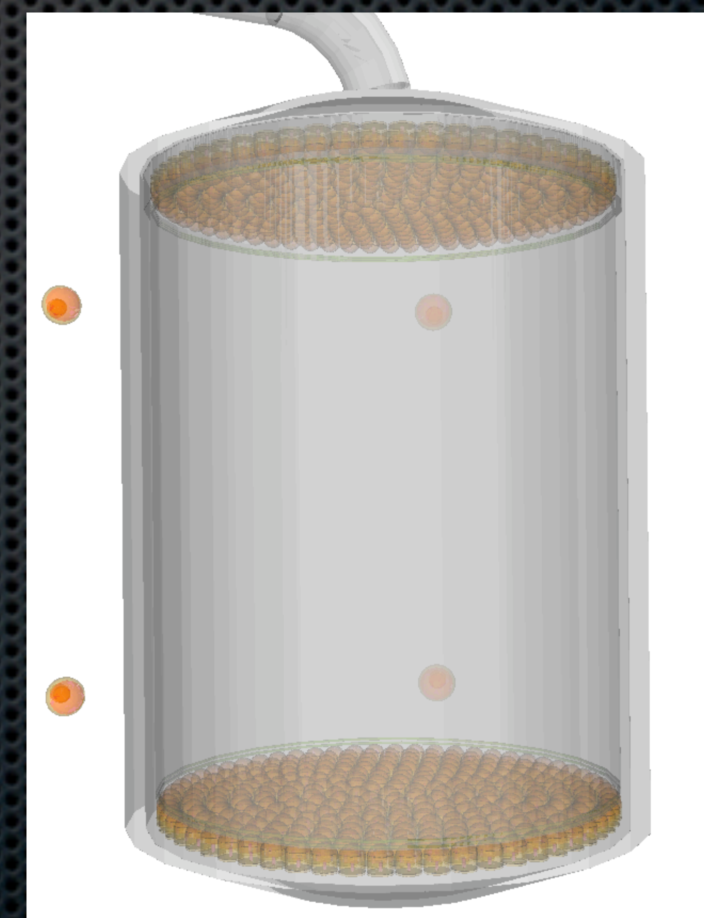
XENON10:
22 kg (5.4 fid)

XENON100:
161 kg (62 fid.)

XENON1t:
2.4 t (1 t fid)

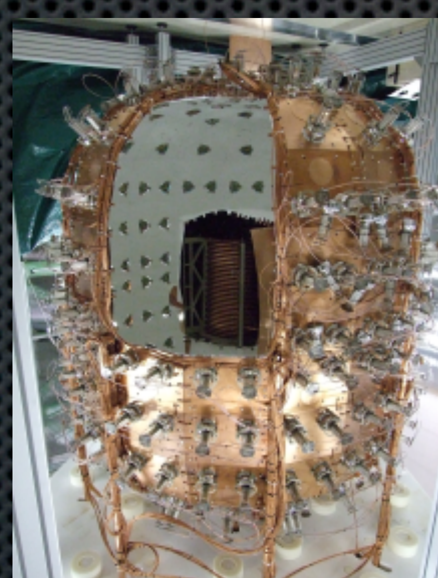


DARWIN:
8 t LXe (5t fid)
20 t LAr (10 t fid)
(indicative masses*)

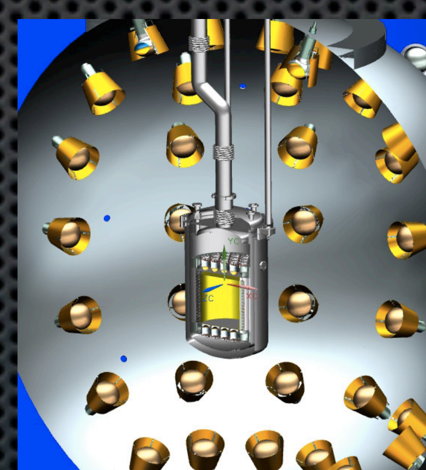


(*optimal masses for LAr/LXe to be determined in the study; here MC sketch)

WARP: 2.3 l



WARP:
140 kg



DarkSide:
55 kg (33 fid.)

ArDM: 850 kg

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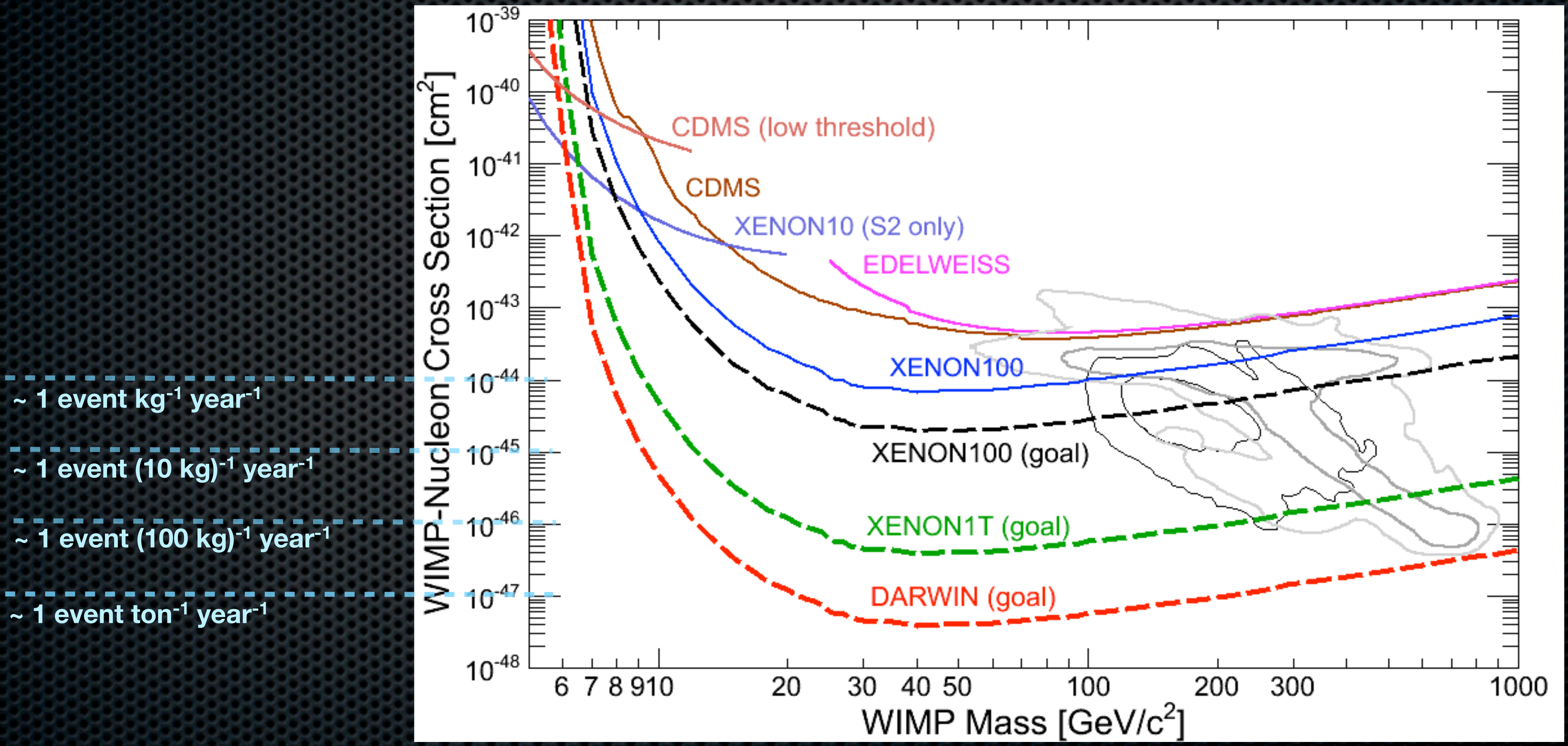
Expected Sensitivity

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



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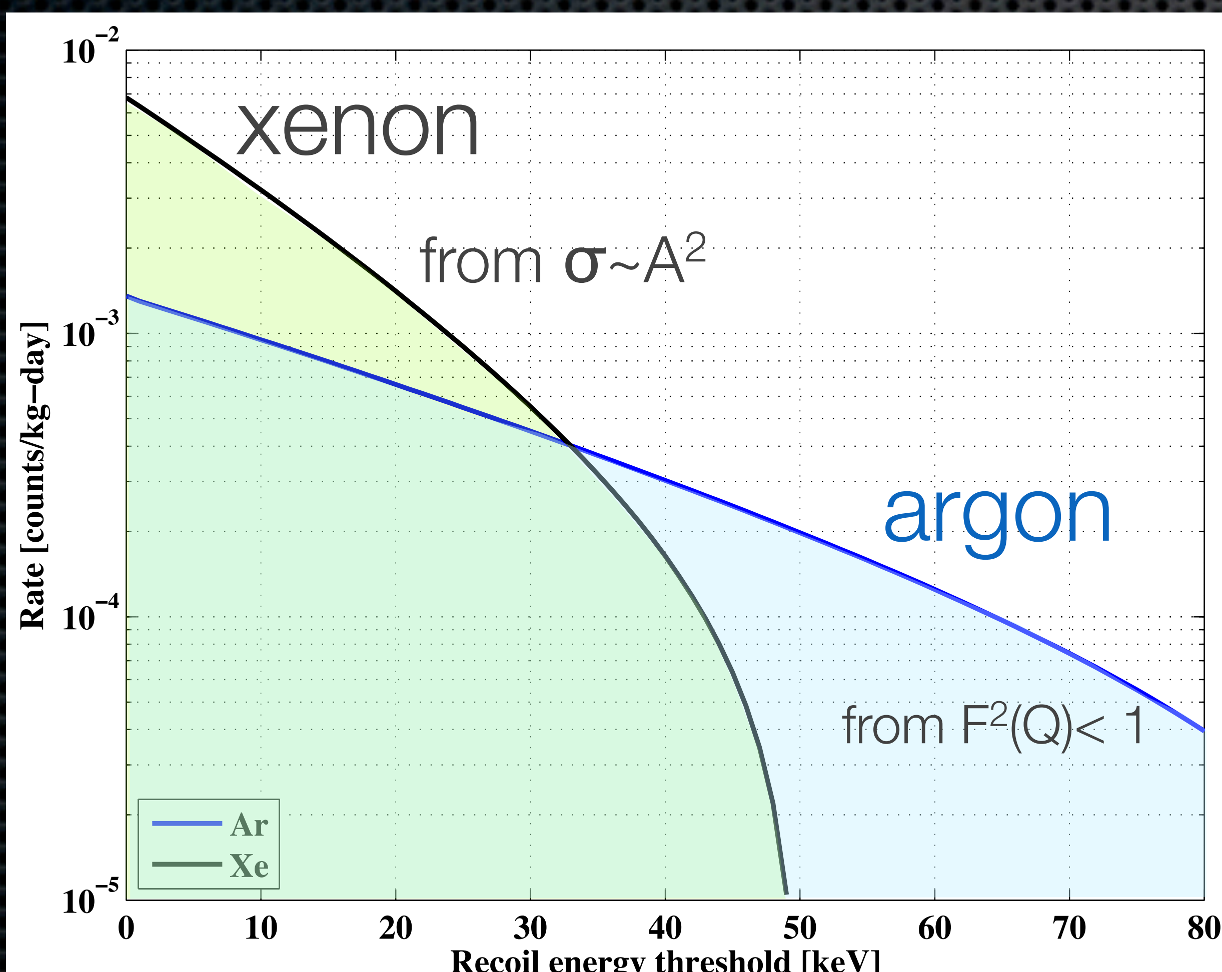
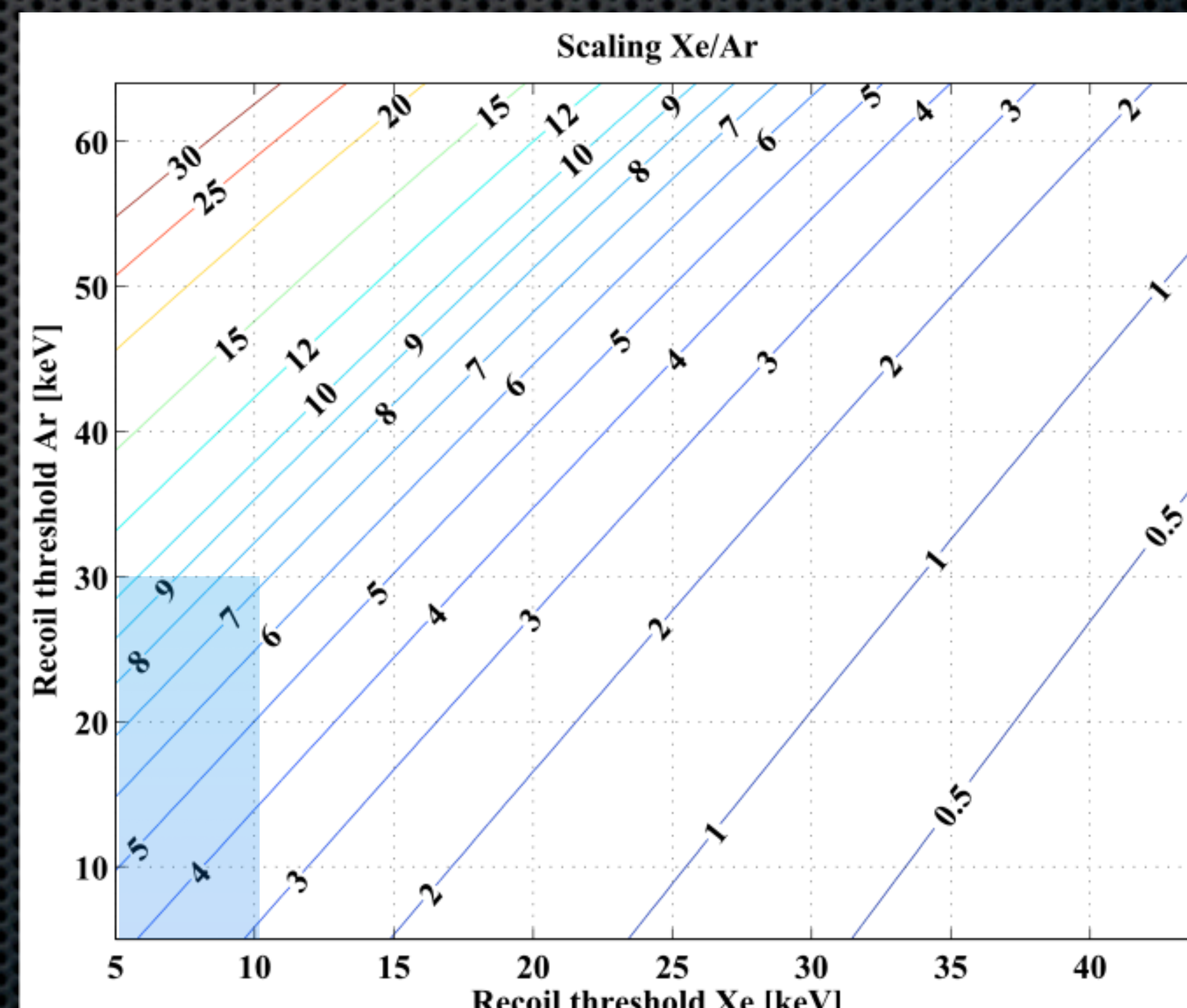
Sensitivity comparison between LAr and LXe

- the relative sensitivity depends highly on the energy threshold



Integrated rate in Xe and Ar



Scaling factor between Xe and Ar

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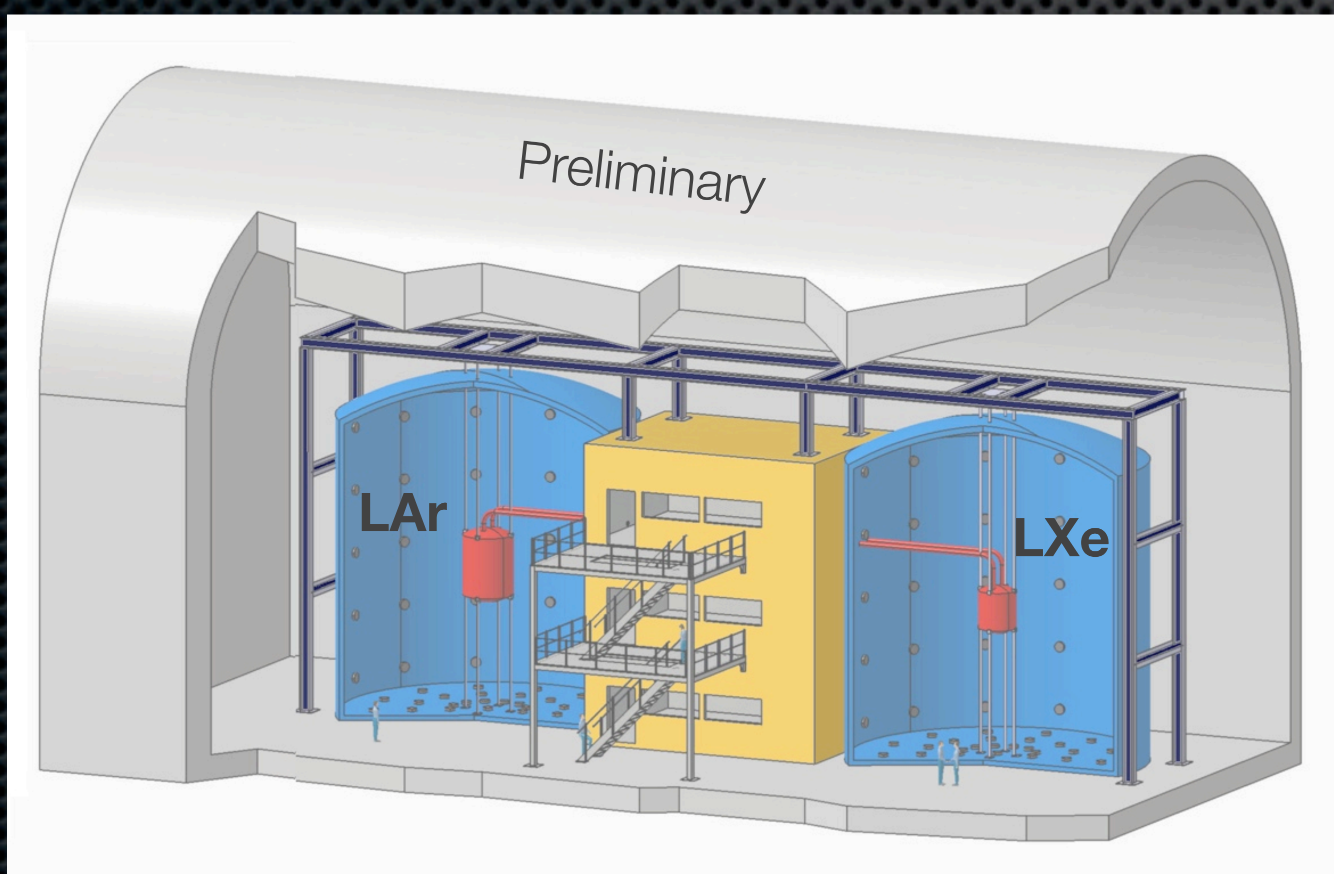
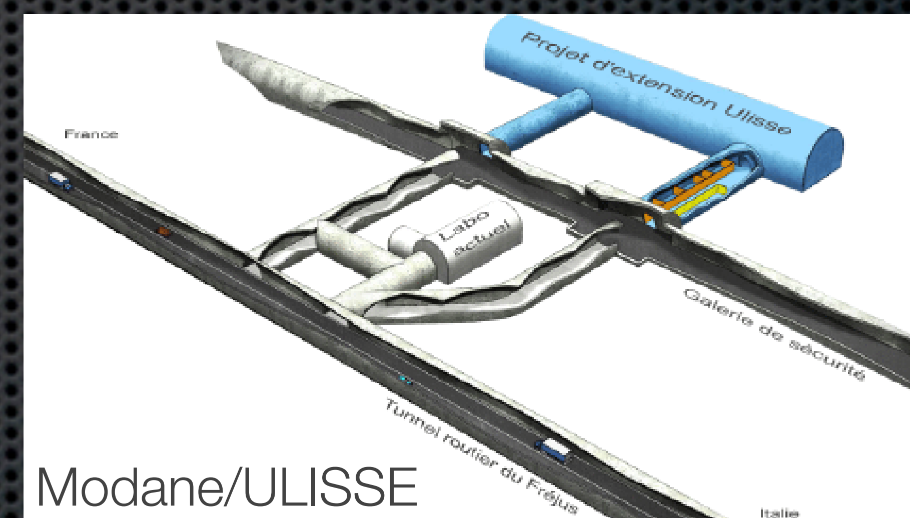
Layout and Location

- Baseline design (to be optimized during the study):
- 8 t (5 t) of LXe in total (fiducial); 20 t (10t) of LAr in total (fiducial)



Sketch of possible layout for LAr and LXe cryostats in large water Cerenkov shields



Reconstructing WIMP properties

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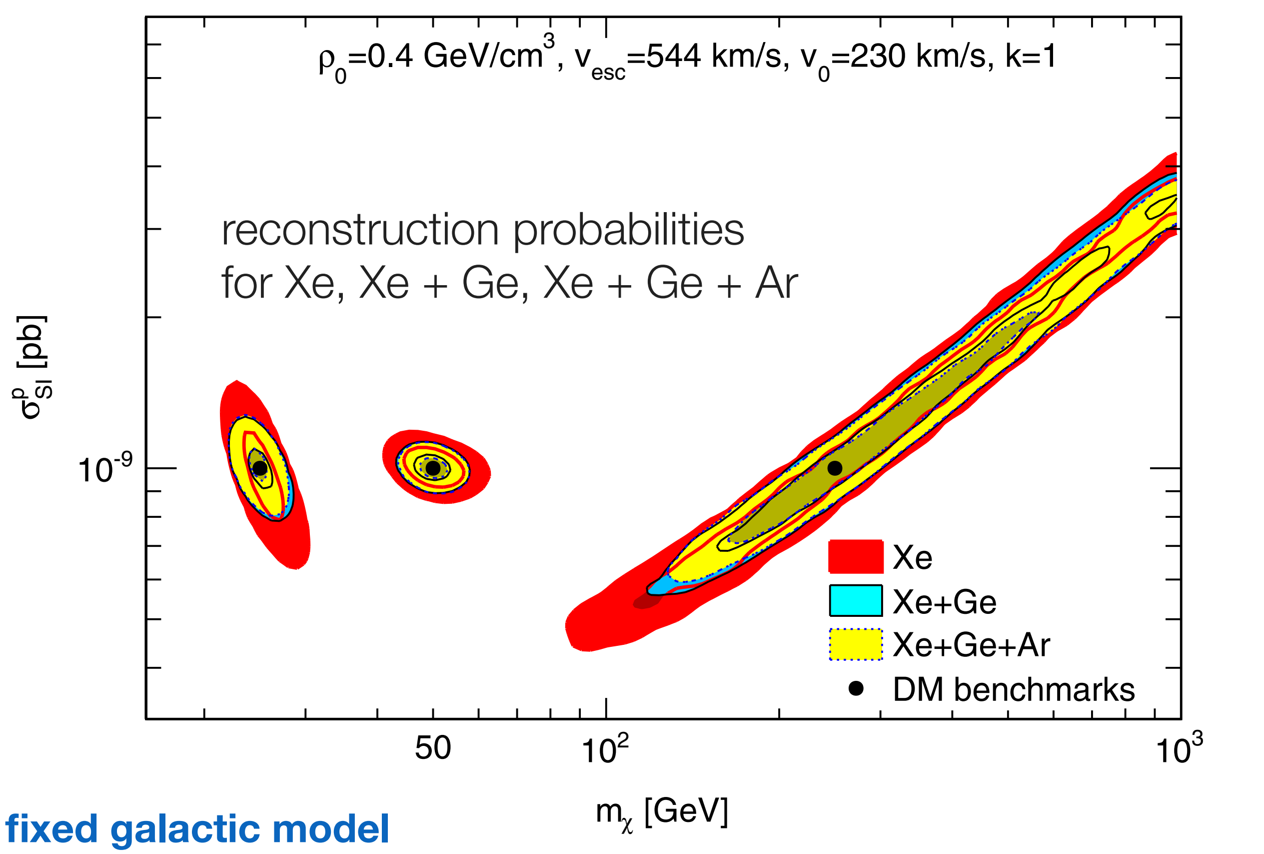
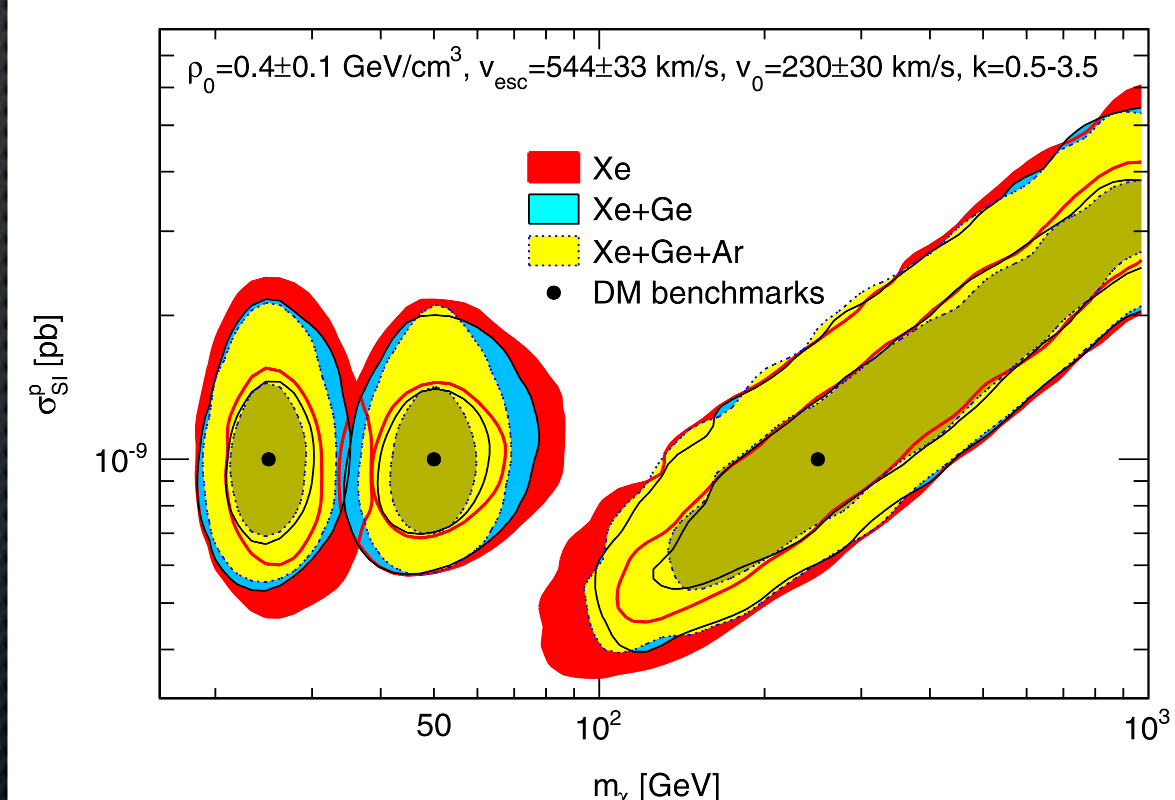
- Different targets are sensitive to different directions in the m_χ- σ_{SI} plane

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

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

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 for LAr, XENON for LXe
- **Europe**: UZH, INFN, ETHZ, Subatech, Mainz, MPIK, Münster, Nikhef, KIT, IFJPAN, **Israel:** WIS, **USA:** Columbia, Princeton, UCLA

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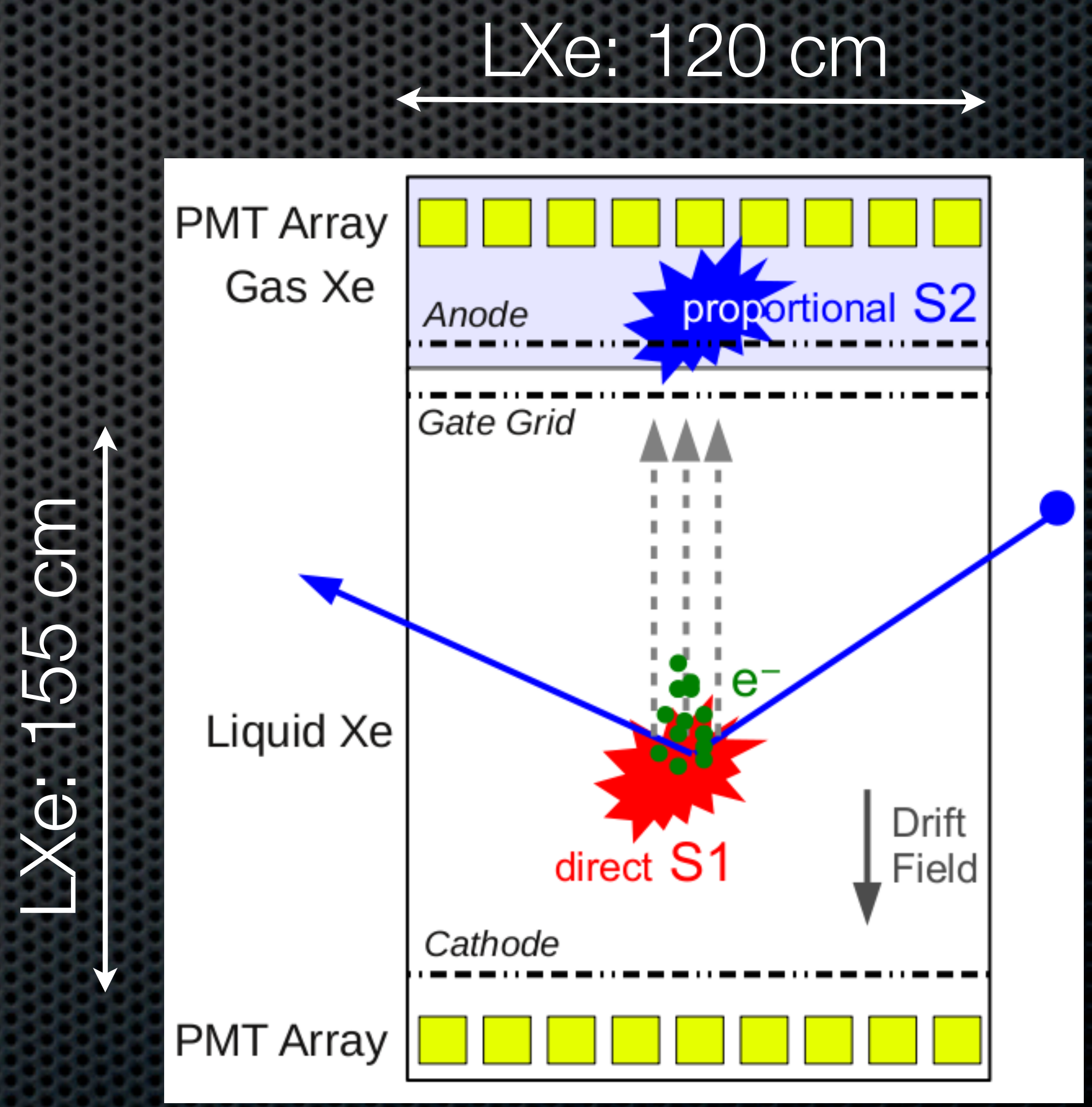
R&D on detector infrastructure

- 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*



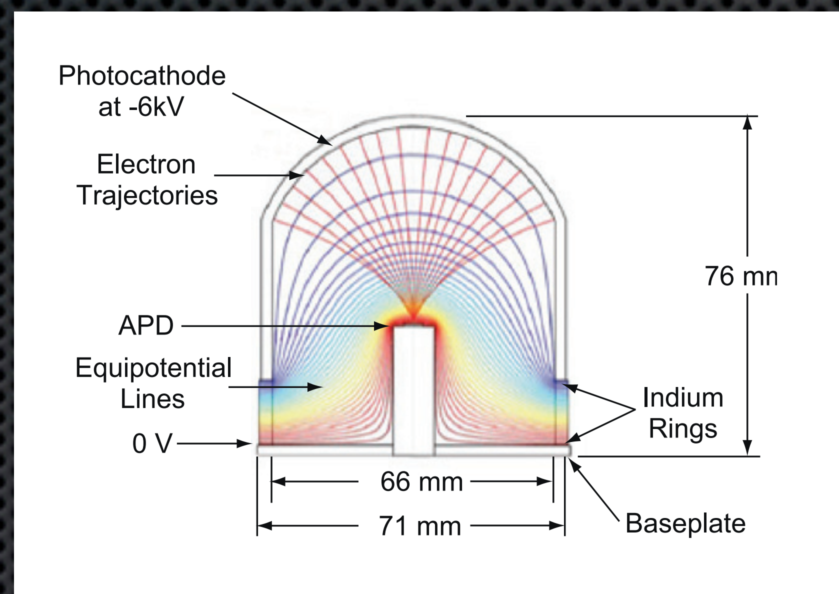
Principle of a noble liquid TPC

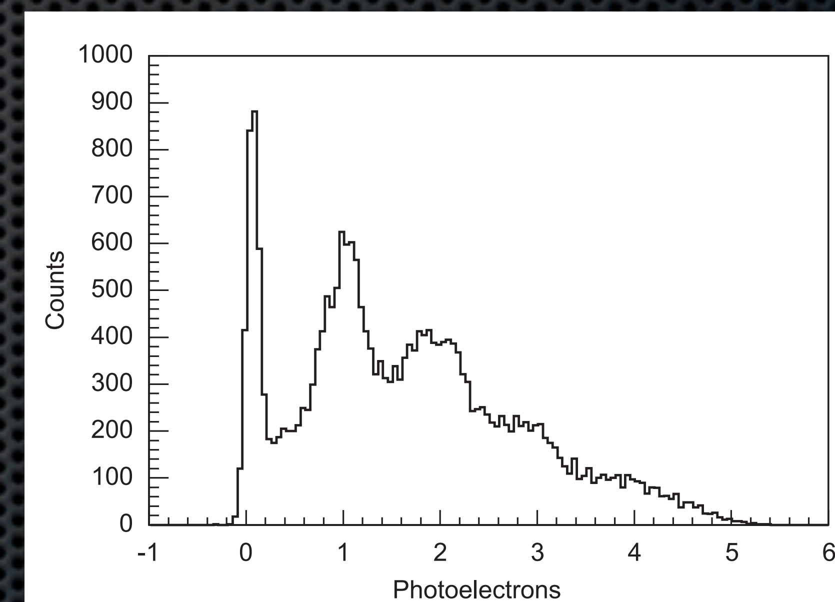
Ar (A = 40); λ = 128 nm
Xe (A=131); λ = 178 nm

* 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)

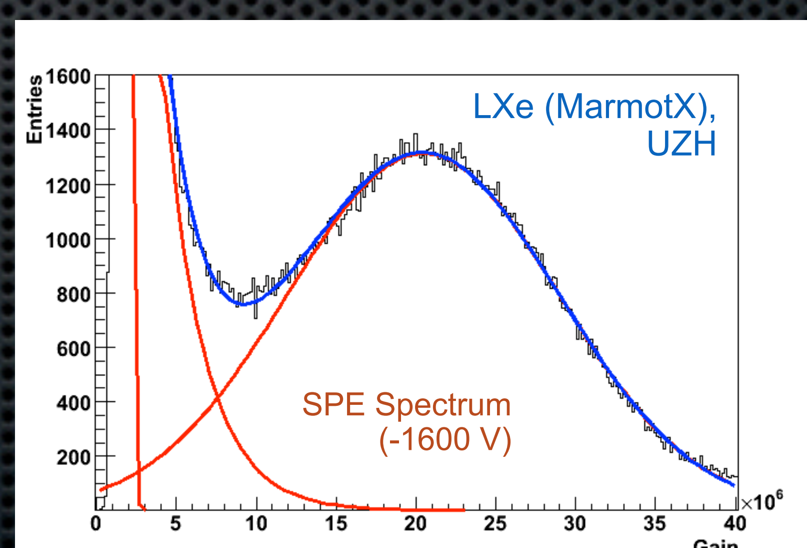
R&D on light readout

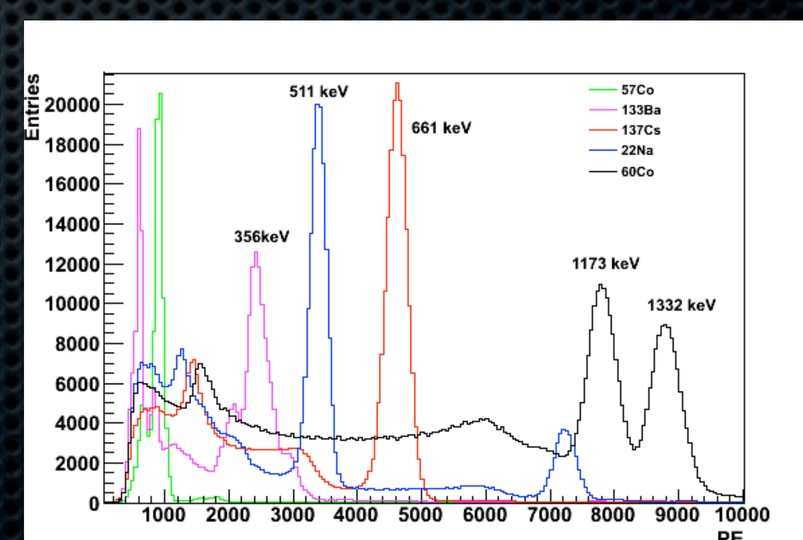
- Under study: hybrid (APD + photocathode) sensors (QUPIDs*); new bialkali 12-dynode stage photomultipliers (R11410 for LXe, R11065 for LAr)





*A. Teymourian, D. Aharoni, L. Baudis, P. Beltrame et al, in press at NIM A, arXiv:1103.3689v1



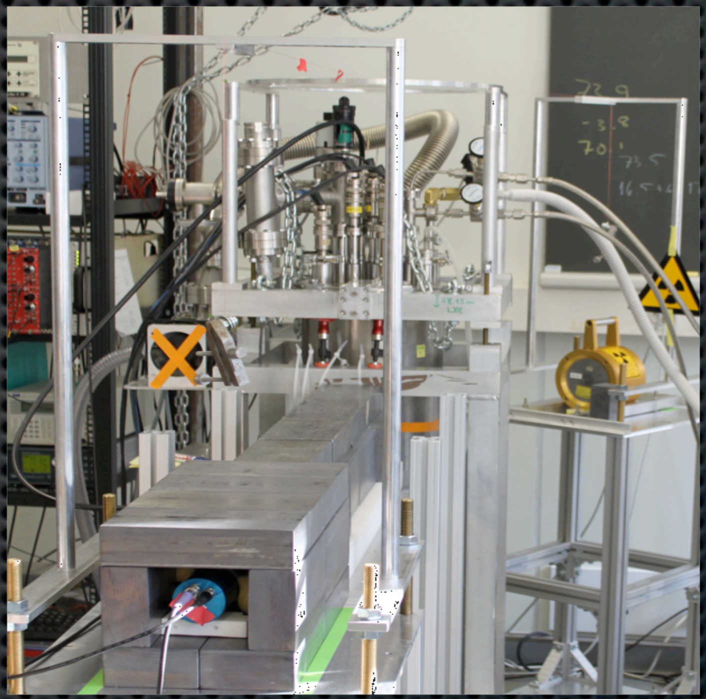


R&D on scintillation properties

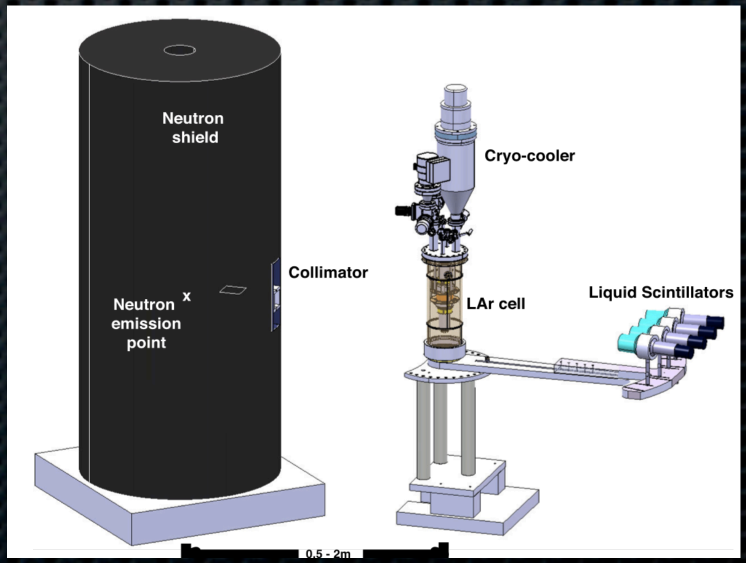
- Light yield of low-energy electronic recoils in Xe: at UZH, using strong ^{137}Cs source, LXe and NaI detector in coincidence to measure light yield of electronic recoils down to ~ 2 keV
(see talk by A. Manalaysay)

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

Setup at UZH

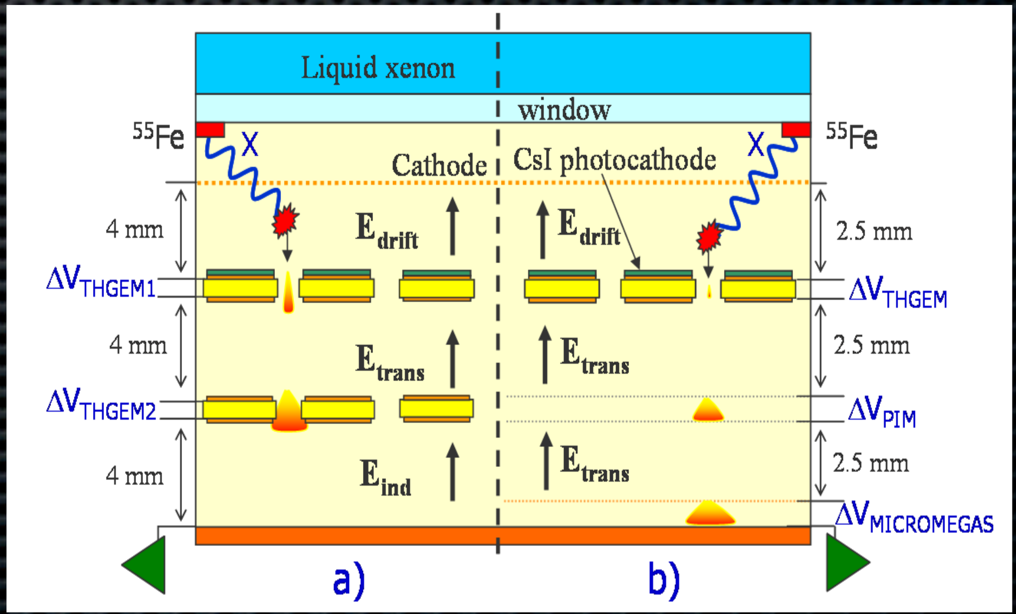


Setup at CERN (UZH group)



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



Double-THGEM detector (a) and in the triple-structure (b) in a pulse-mode gain measurement configuration, with a 5.9 keV ^{55}Fe X-ray source.

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Material screening and background modeling

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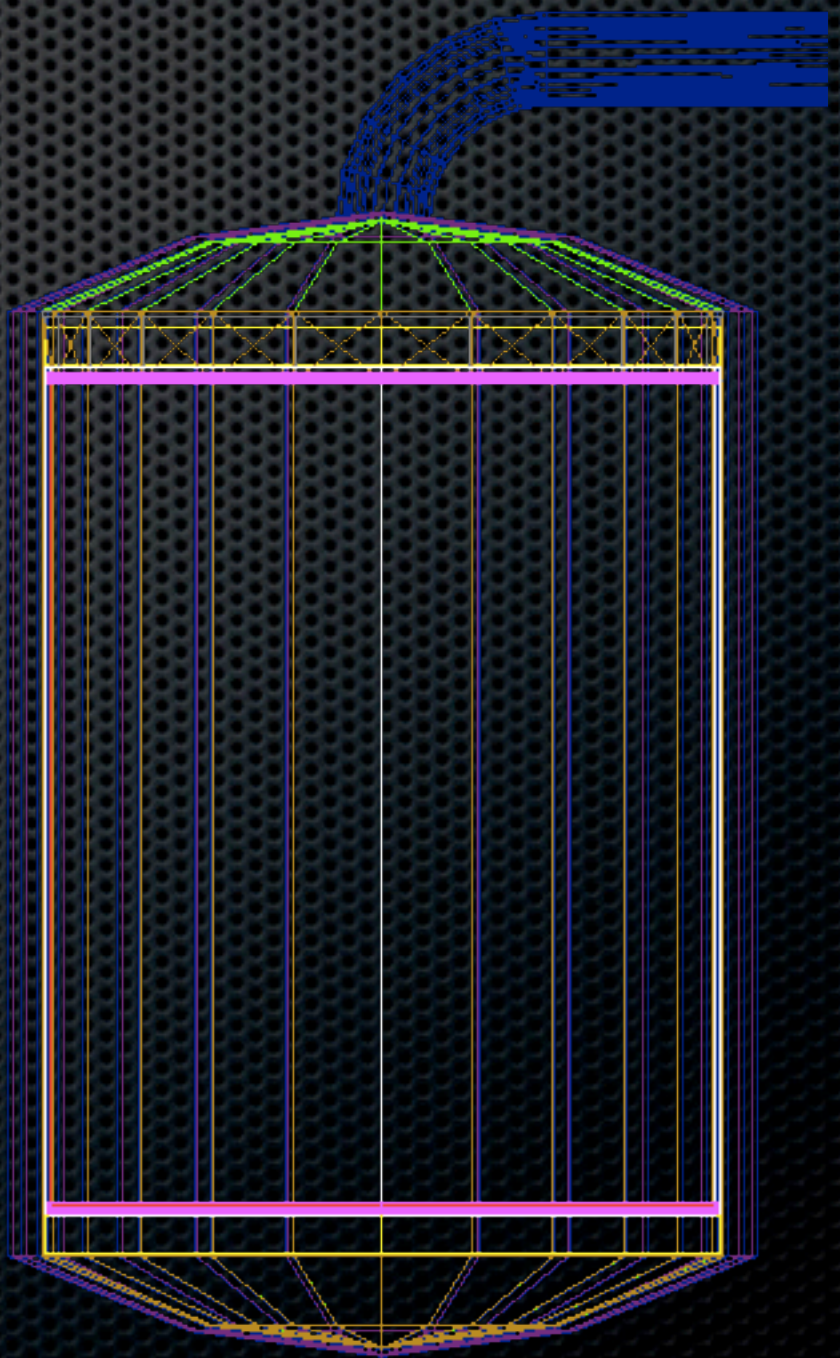
*a subset of screened materials using Gator

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

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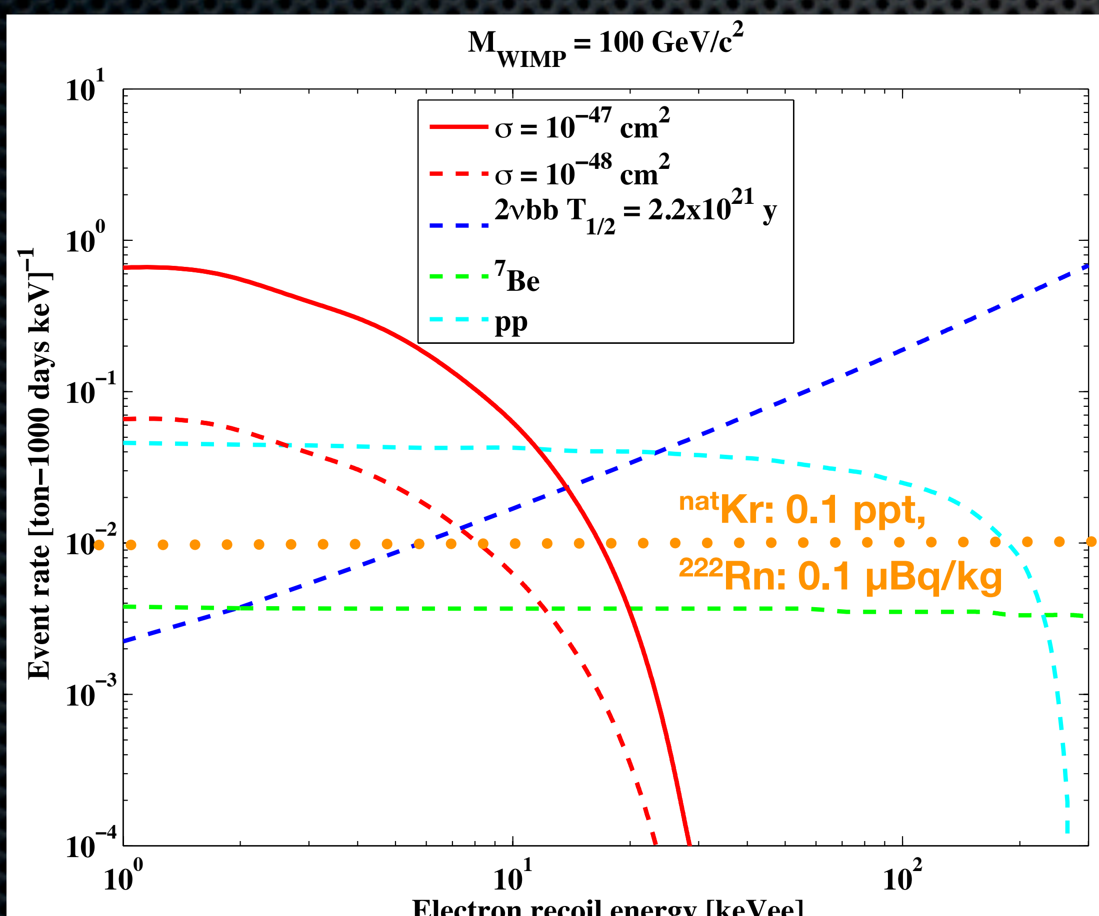
‘Ultimate’ backgrounds?

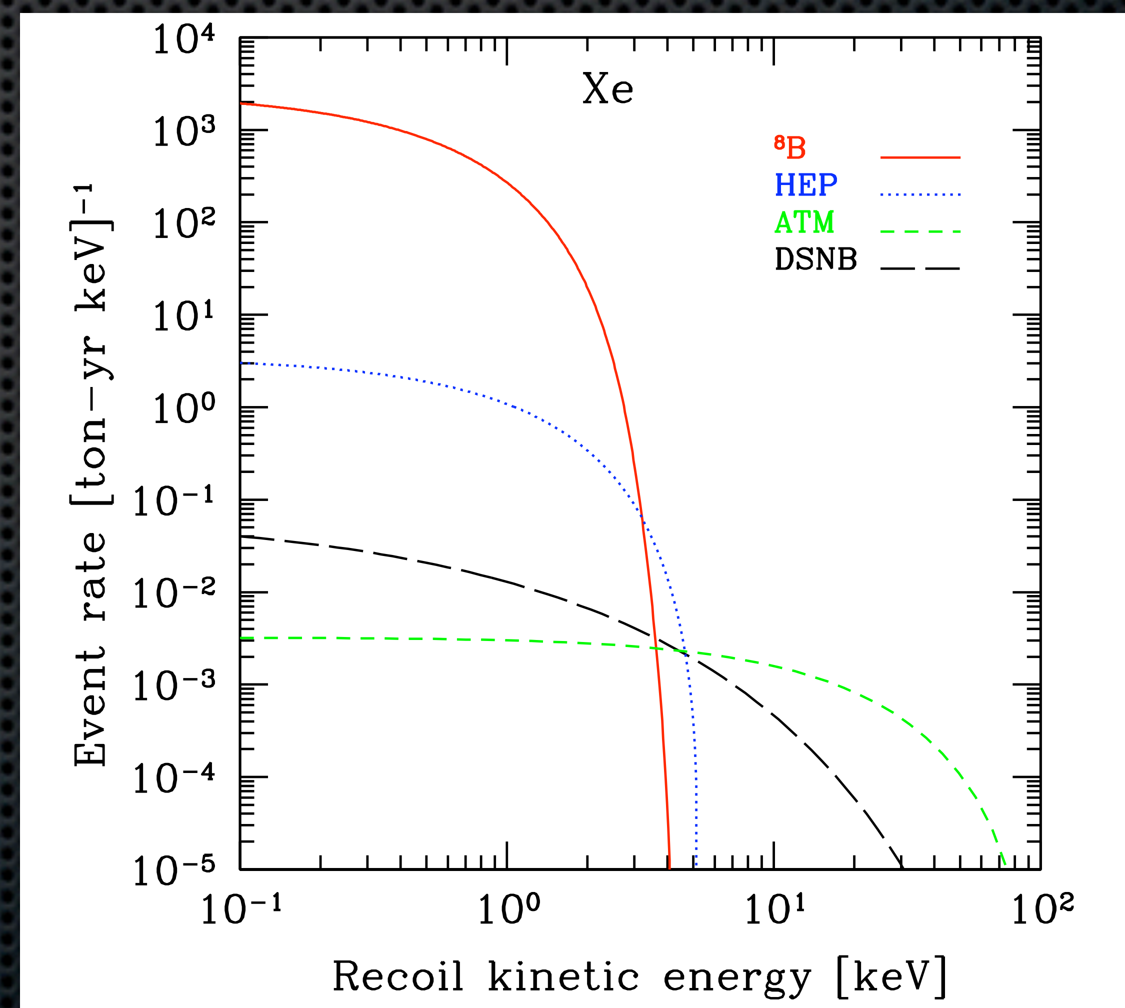
- Neutrinos (will eventually deliver a new physics channel)
- ^{85}Kr (^{nat}Kr < 0.1 ppt) and ^{222}Rn < 0.1 µBq/kg is required

Neutrino-electron scattering



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

Neutrino-nucleus scattering



Neutrino spectra: L. Strigari, New J. Phys. 11 (2009) 105011
Coherent neutrino-nucleus scattering: dominated by 8B and HEP, however below the detector’s threshold

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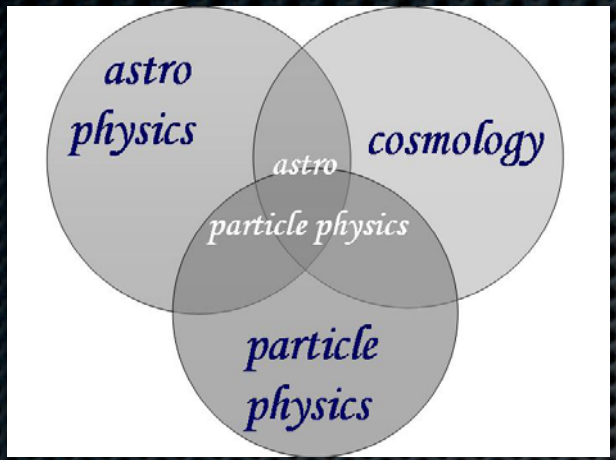
Aspera and CHIPP (Swiss) Roadmaps



Aspera, draft edition, 2011

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.**

http://www.aspera-eu.org/images/stories/roadmap/SAC-Roadmap-14-7-2011.pdf

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Aspera and CHIPP (Swiss) Roadmaps

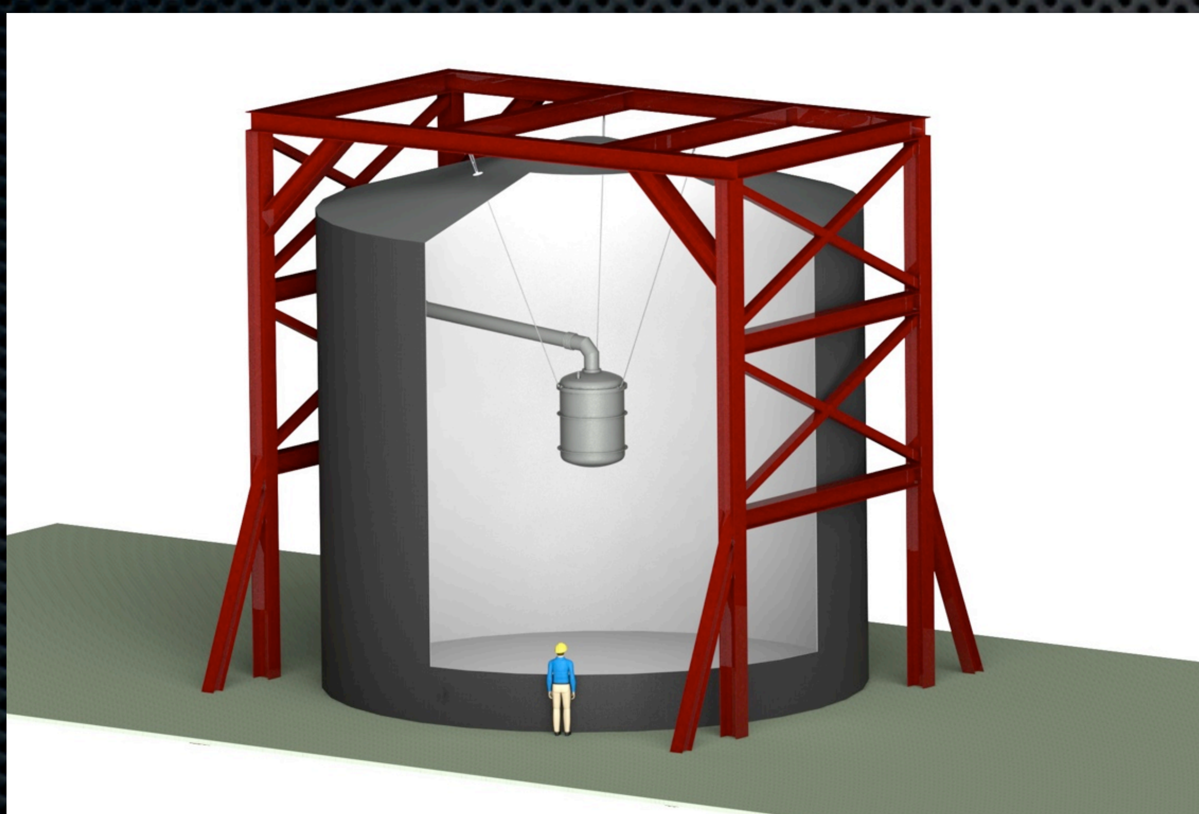
PARTICLE PHYSICS IN SWITZERLAND

Recommendation 6 – Direct and Indirect Dark Matter Detection

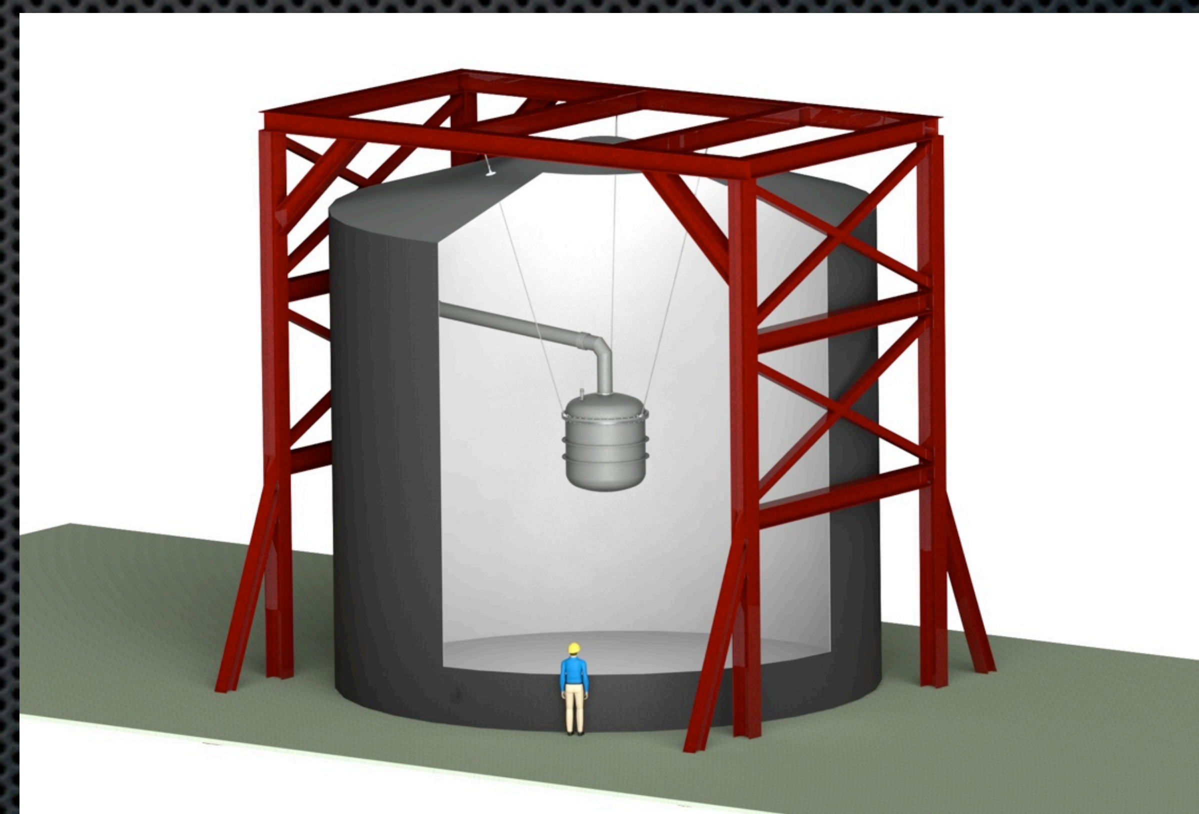
CHIPP recommends that the necessary resources be provided for the construction, maintenance, operation and physics exploitation of the present generation XENON100, XENON1T and ArDM experiments for the direct detection of Dark Matter. The construction and operation of the DARWIN multi-ton Dark Matter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

Backup slides

Comparison: XENON1T and DARWIN



XENON1T



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(LXe part, possible layout)

Overall Physics Goals

- **5 t and 10 t of fiducial mass for LXe and LAr** (to be optimized by this study!)

- raw BG: 0.1 mdru in LXe, with 99.9% rejection of ERs, based on the S2/S1-ratio (factor 100 better than current XENON100 background of ~10 mdru)

- raw BG: 0.45 dru in LAr, with 10^8 rejection of ERs, based on PSA and on the S2/S1-ratio (reduction of the ^{39}Ar rate by a factor 25 relative to ^{atm}Ar, corresp. to an activity of 40 mBq/kg for ^{39}Ar)

- a NR acceptance of 50% for LXe and of 80% for LAr

- thus, zero BG events (< 1 event) for the given exposure

Assumptions