XENON and DARWIN

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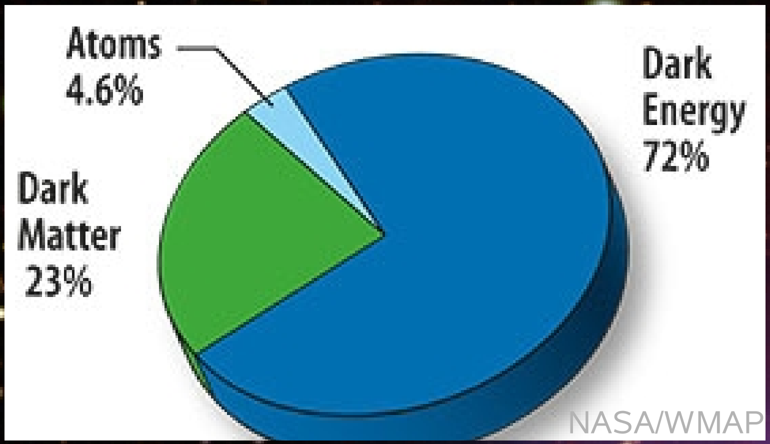
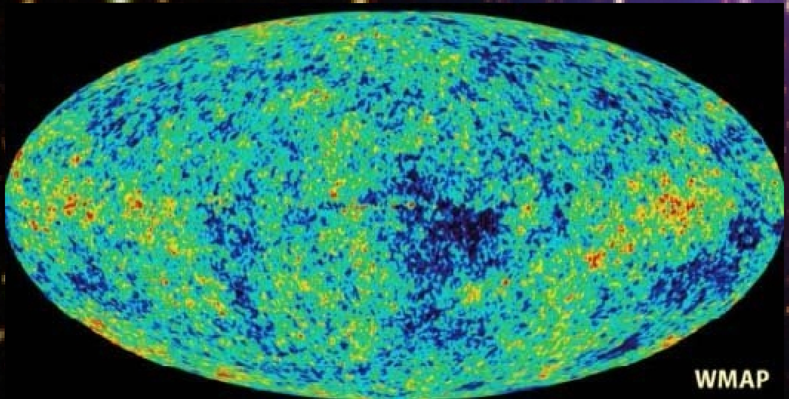
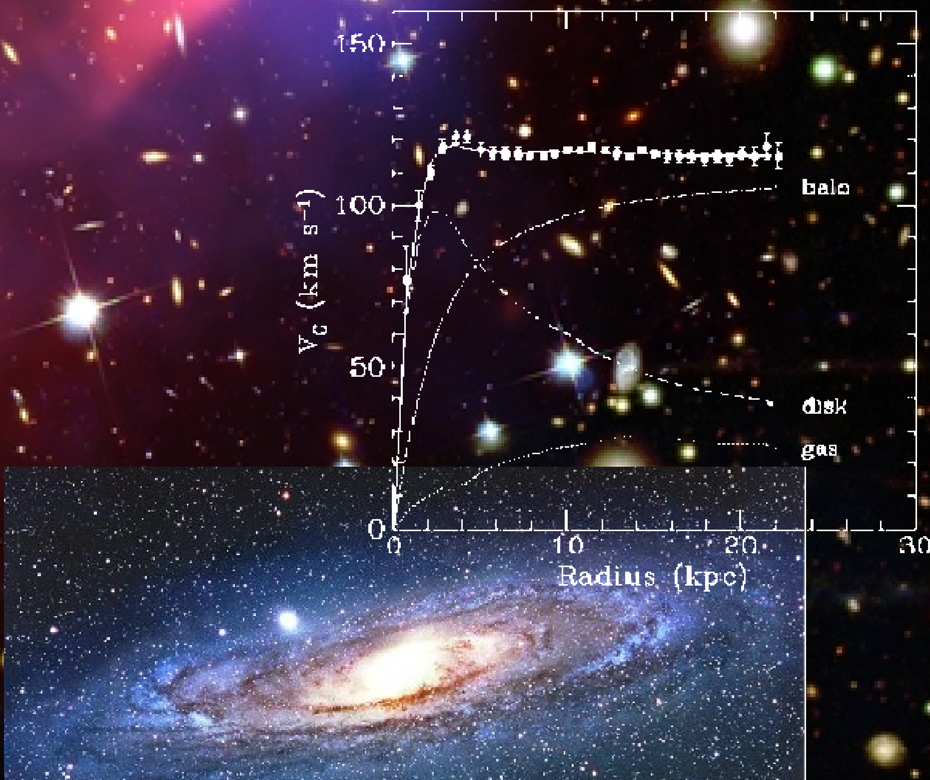
CHIPP meeting 2010, August 23-24, 2010

www.physik.uzh.ch/groups/groupbaudis/xenon/

Dark Matter: (indirect) **Evidence**







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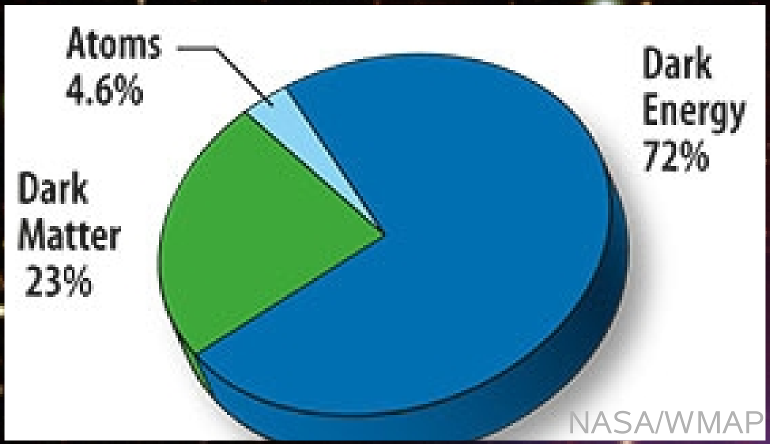
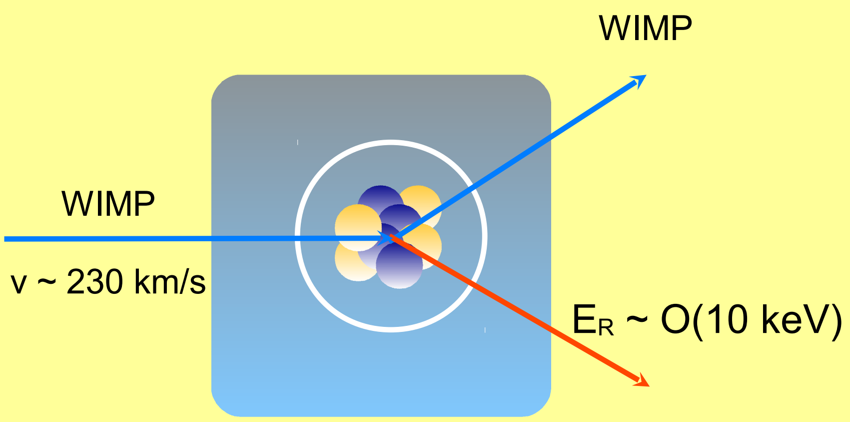
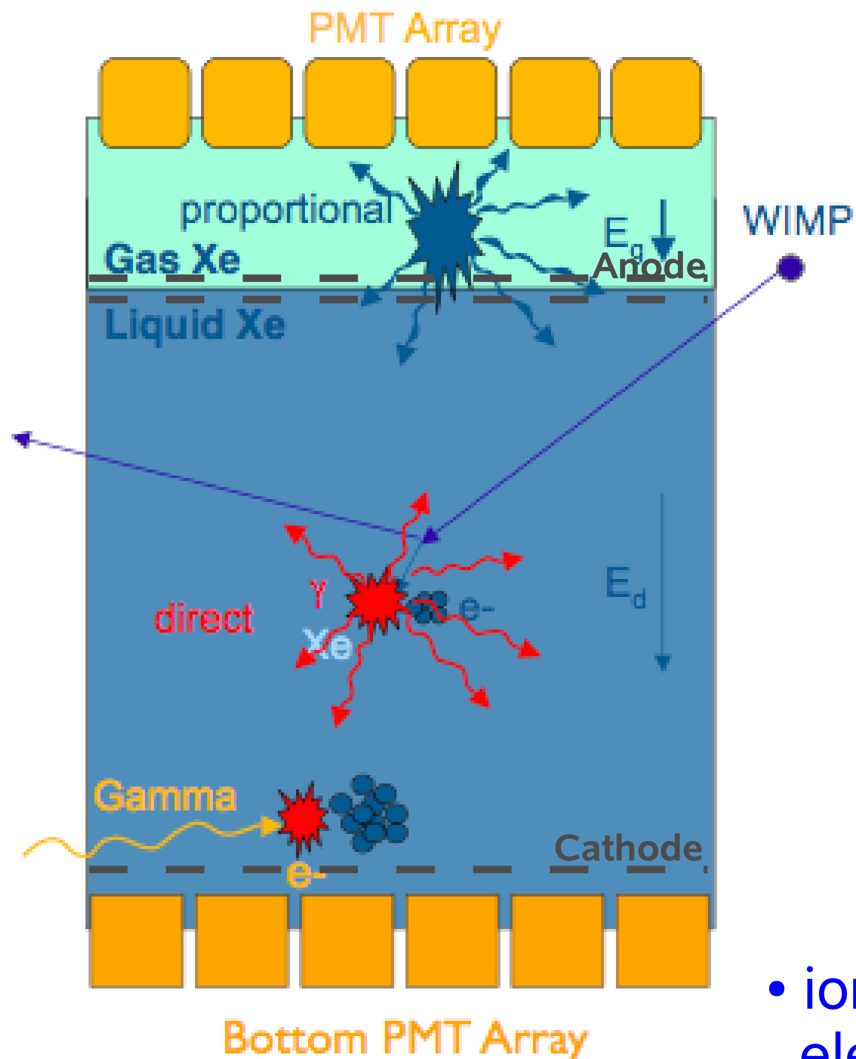


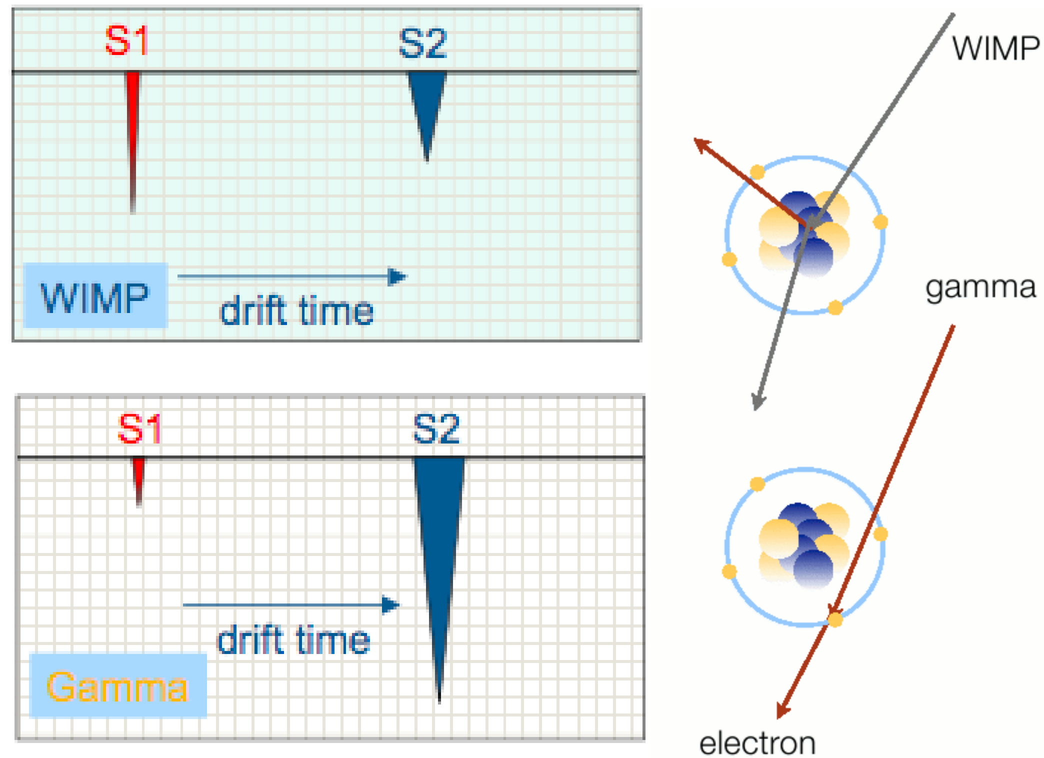
Direct Detection:

Elastic Scattering of
WIMPs off target nuclei
→ nuclear recoil



Dual Phase TPC



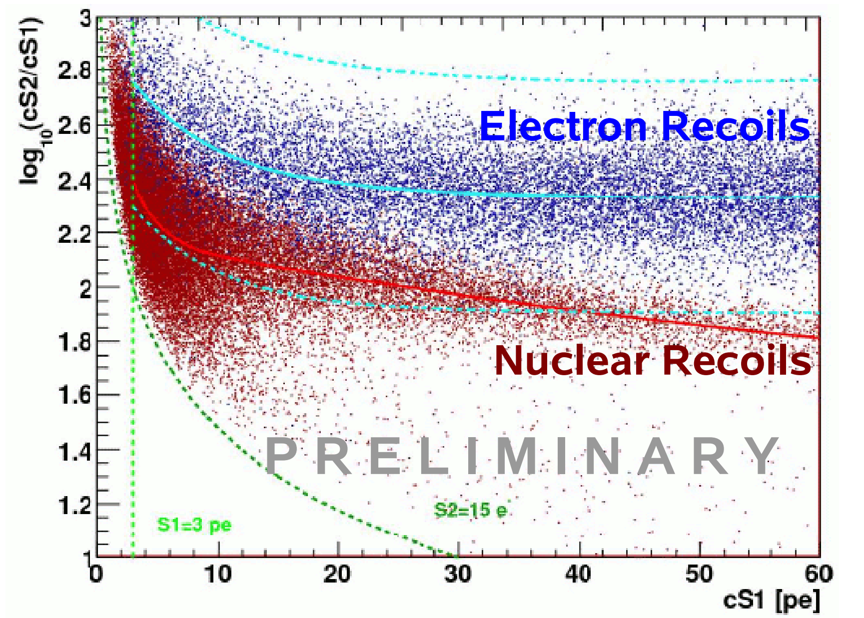


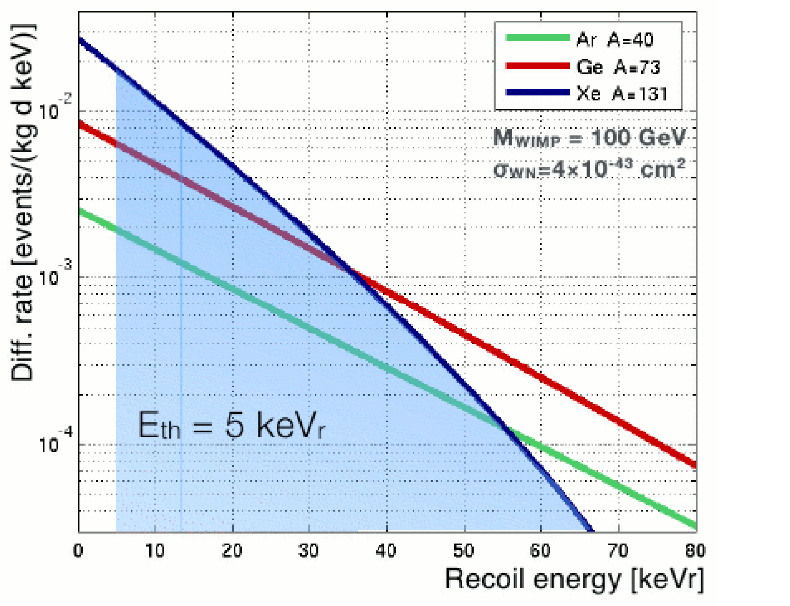
$(S2/S1)_{wimp} << (S2/S1)_{gamma}$

- ionization/scintillation ratio (S2/S1) allows electron recoil rejection to >99.5%
- 3D position reconstruction in TPC

Why WIMP search with Xenon?

- efficient, fast scintillator (178nm)
- high mass number *A*~131:
  SI: high WIMP rate @ low theshold
- high atomic number *Z*=54,
  high density (~3kg/l):
  self shielding, compact detector
- no long lived Xe isotopes,
  Kr-85 can be removed to ppt level
- "easy" cryogenics @ −100°C
- scalability to larger detectors
- in 2-phase TPC:
  background discrimination/suppression

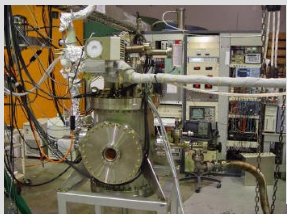




The XENON program

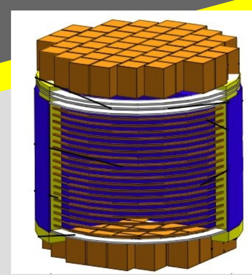
XENON Dark Matter Project

XENON: A phased WIMP search program

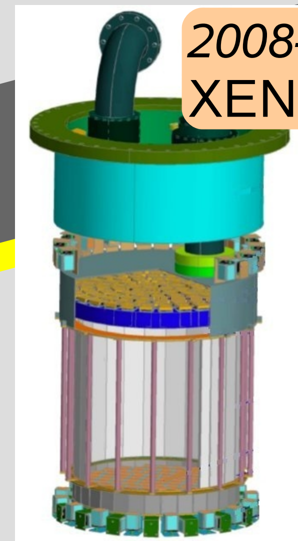


XENON R&D

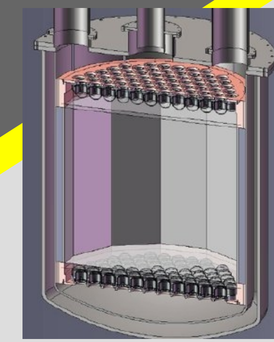
2005-2007: XENON10



2008-2011: XENON100



2010-2015: XENON1T



Columbia *Rice* *UCLA* *U Zürich* *Coimbra* *LNGS* *SJTU*

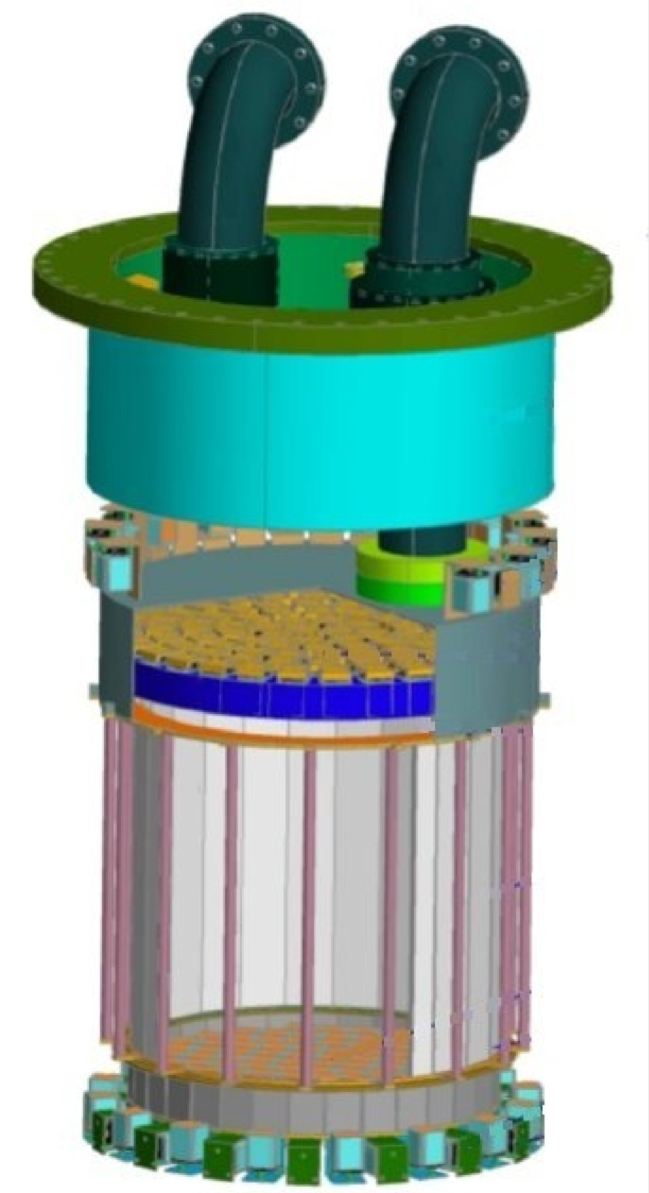
Bologna *MPIK* *NIKHEF* *Mainz* *Subatech* *Münster* *WIS*

XENON100

Goal (compared to XENON10)**:**
- increase target ×10
- reduce gamma background ×100

→ material selection & screening
→ detector design

Quick Facts:
- 161 kg LXe TPC (mass: 10 × Xe10)
- 62 kg in target volume
- active LXe veto (≥4 cm)
- 242 PMTs
- improved Xe10 shield
  (Pb, Poly, Cu, H_2O, N_2 purge)



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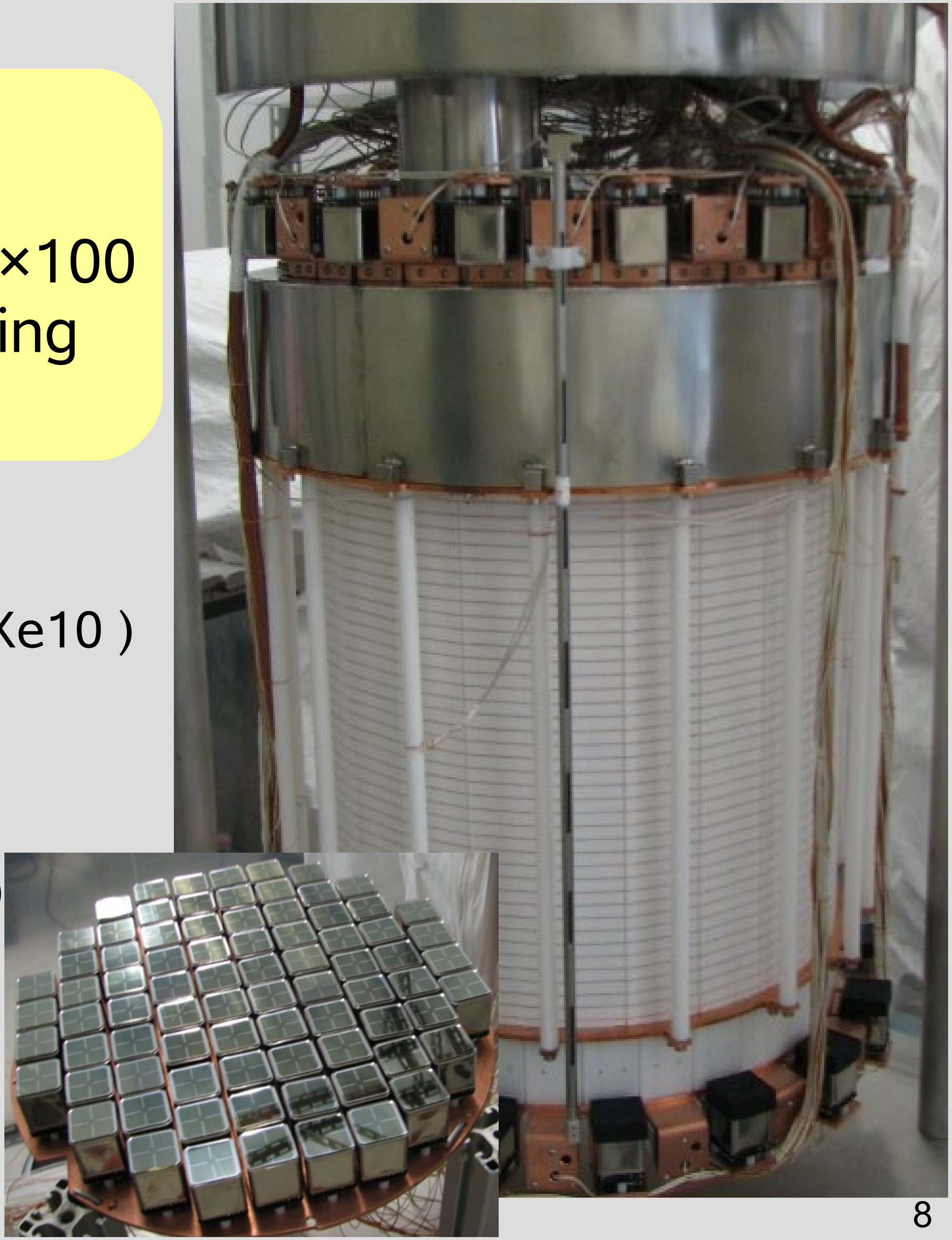

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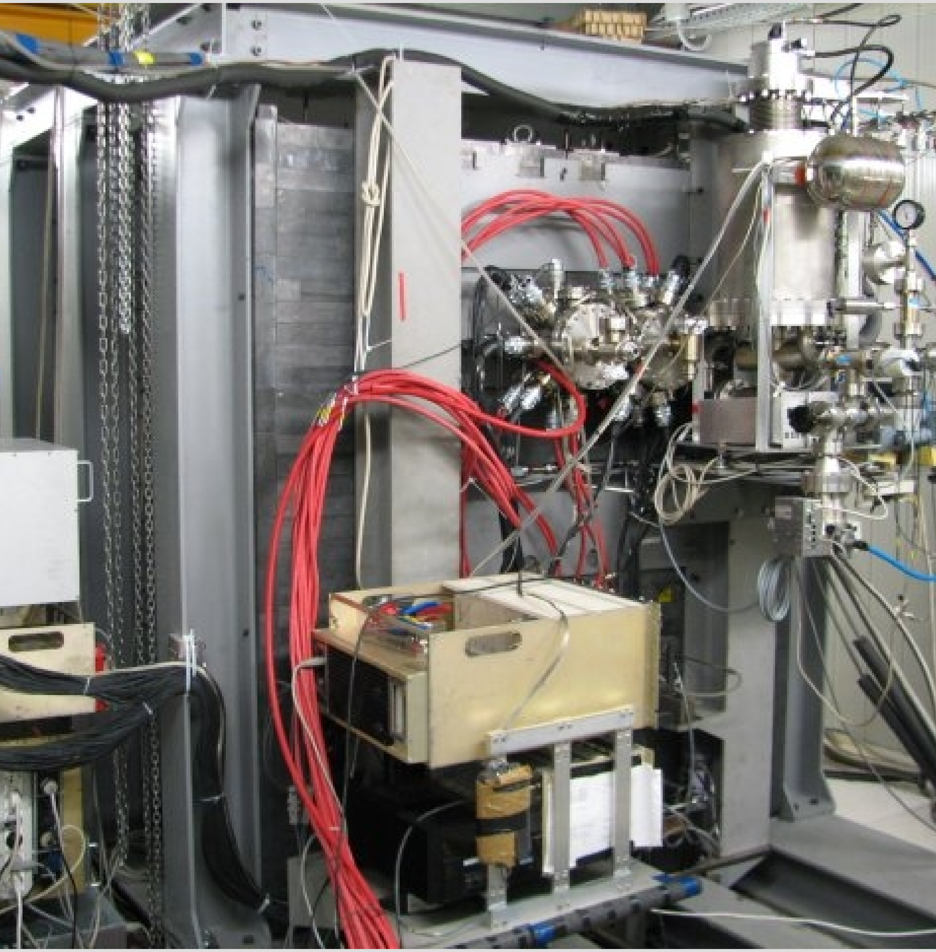
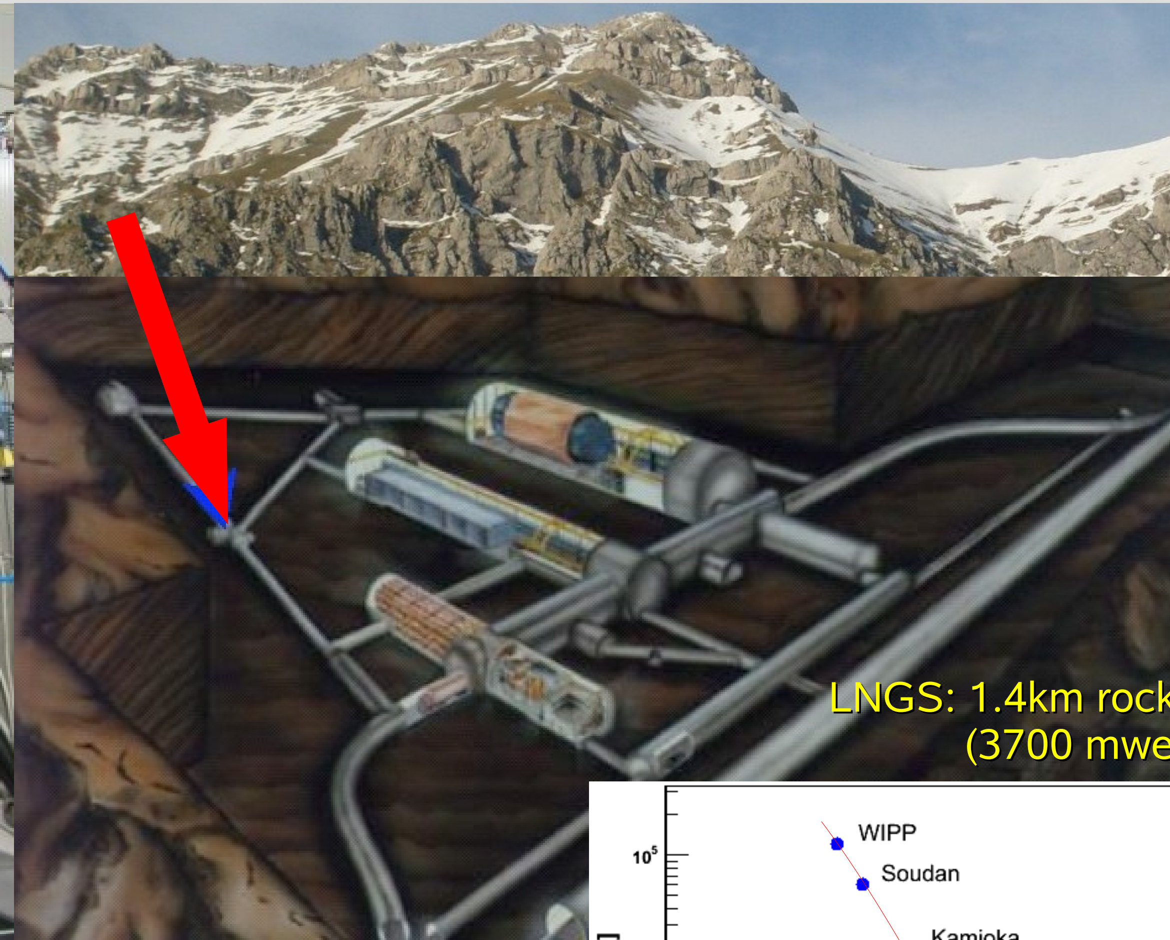
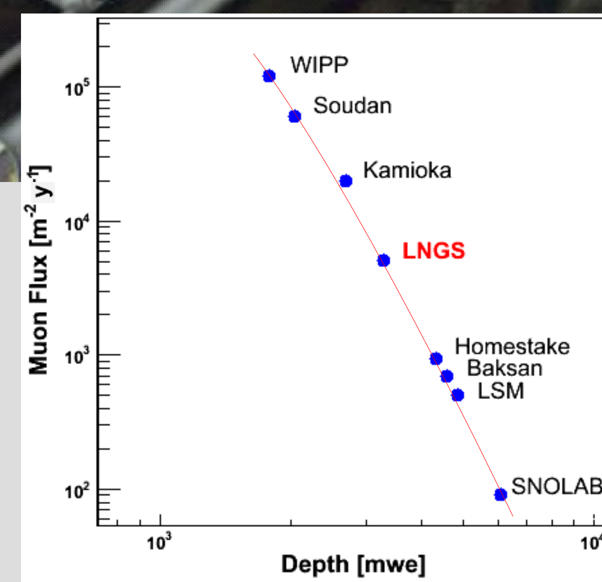
XENON100 @ LNGS

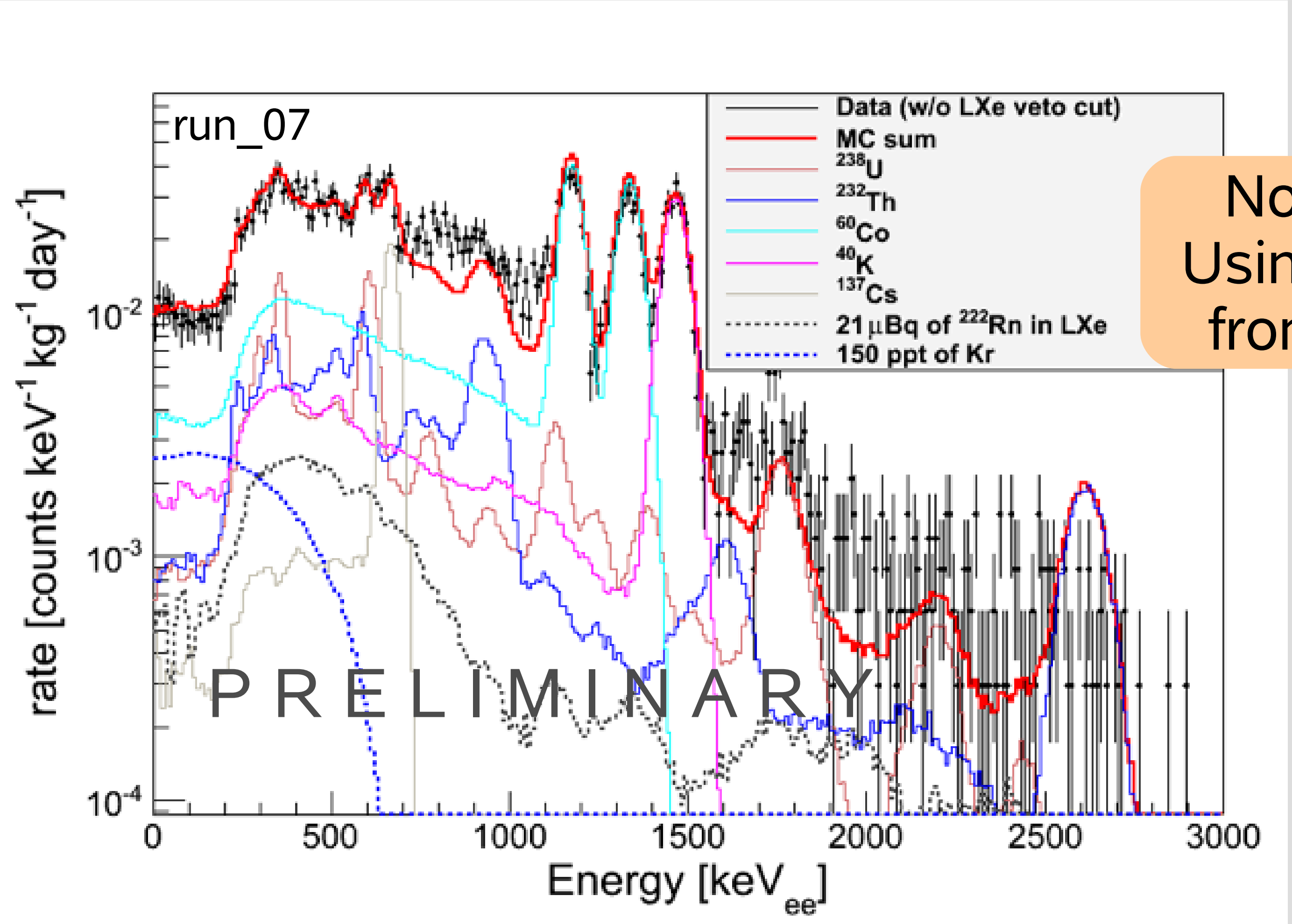






- underground since end of February 08
- first filled with Xe in mid May 08
- extensive calibrations, first science results

XENON100 Background

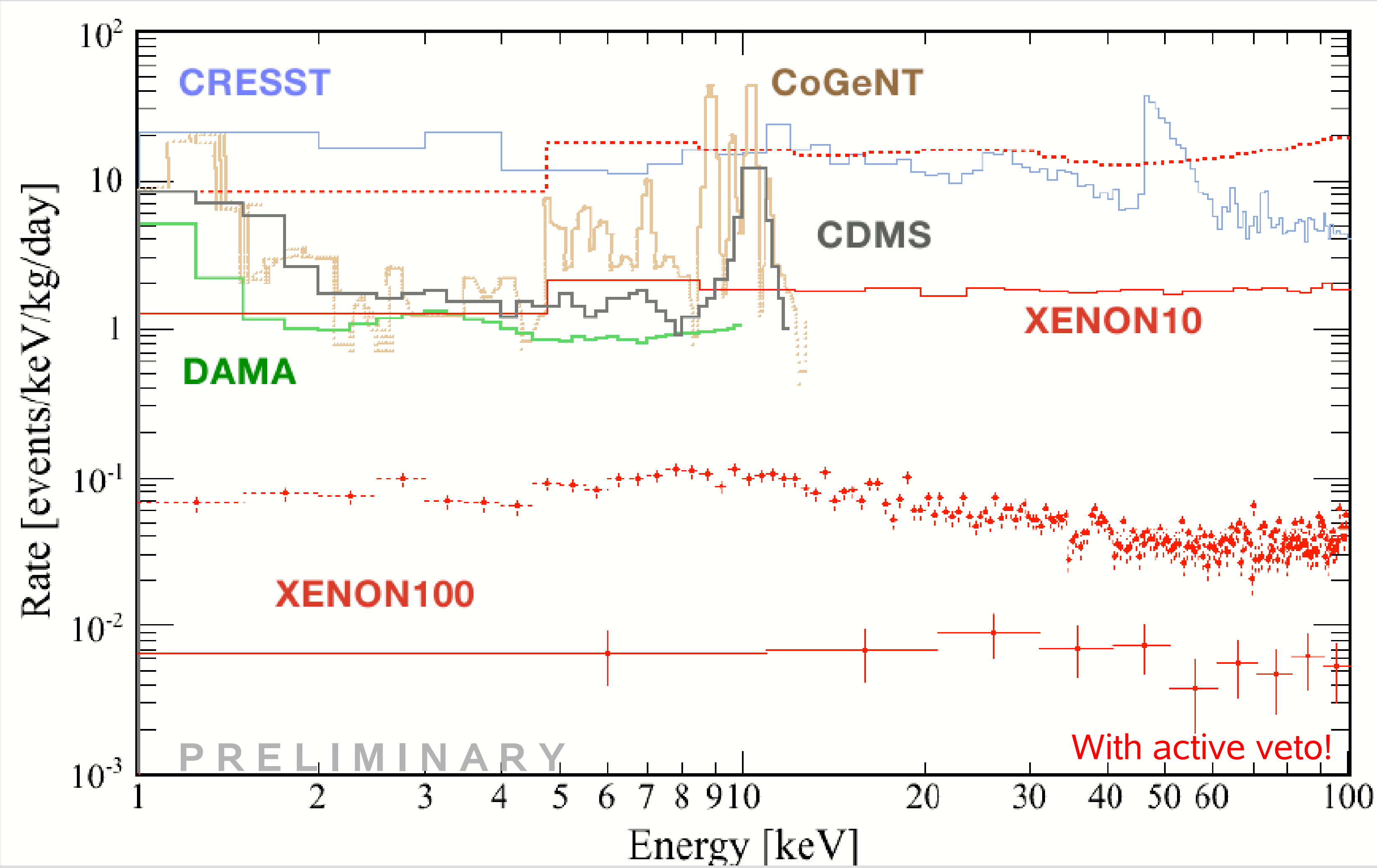


No MC tuning! Using only values from screening.

- 30 kg fiducial mass
- active LXe veto not used for this plot
- exploit anti-correlation between light and charge for better ER-energy scale

Measured Background in good agreement with Monte Carlo prediction.

Background Comparison



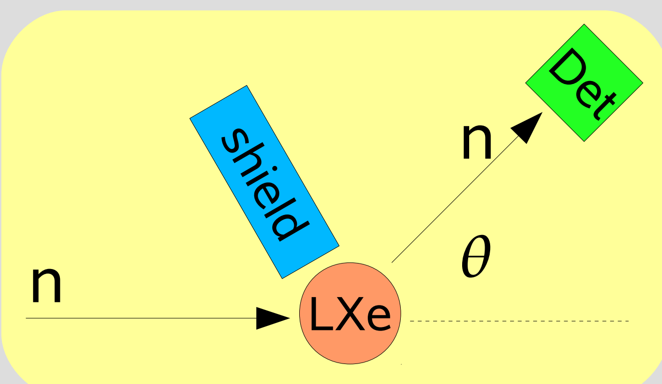
This is the lowest Background ever achieved in a Dark Matter Experiment!

Nuclear Recoil Scale

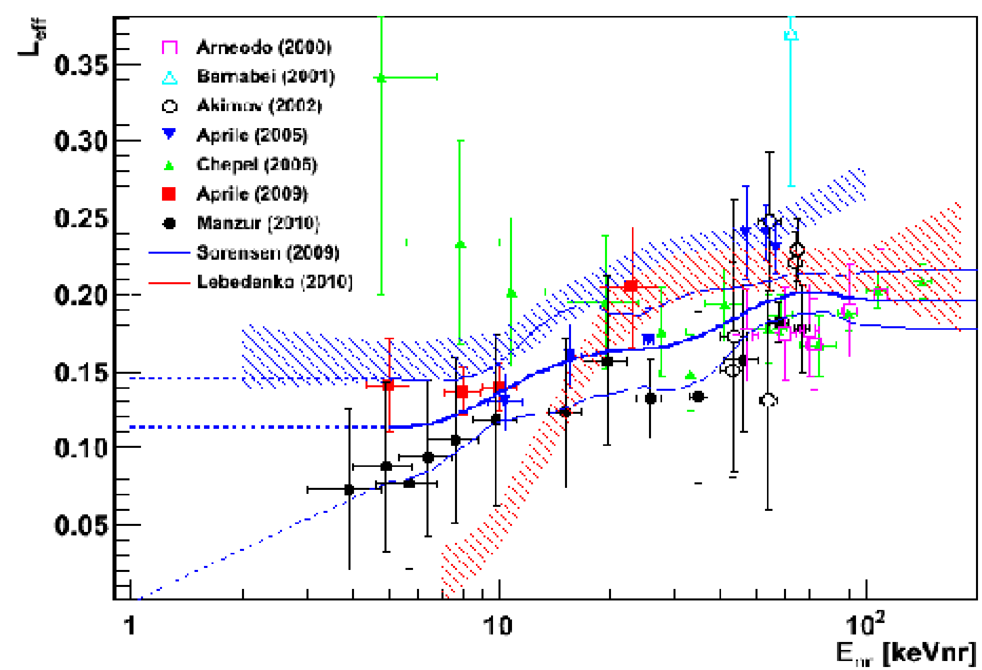
- WIMPs interact with Xe nucleus
  ➞ nuclear recoil (*nr*) scintillation (β and γ's produce electron recoils)
- absolute measurement of *nr* scintillation yield is difficult
  ➞ measure relative to Co57 (122keV)
- relative scintillation efficiency $\mathcal{L}_{\mathrm{eff}}$:

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

measurement principle:



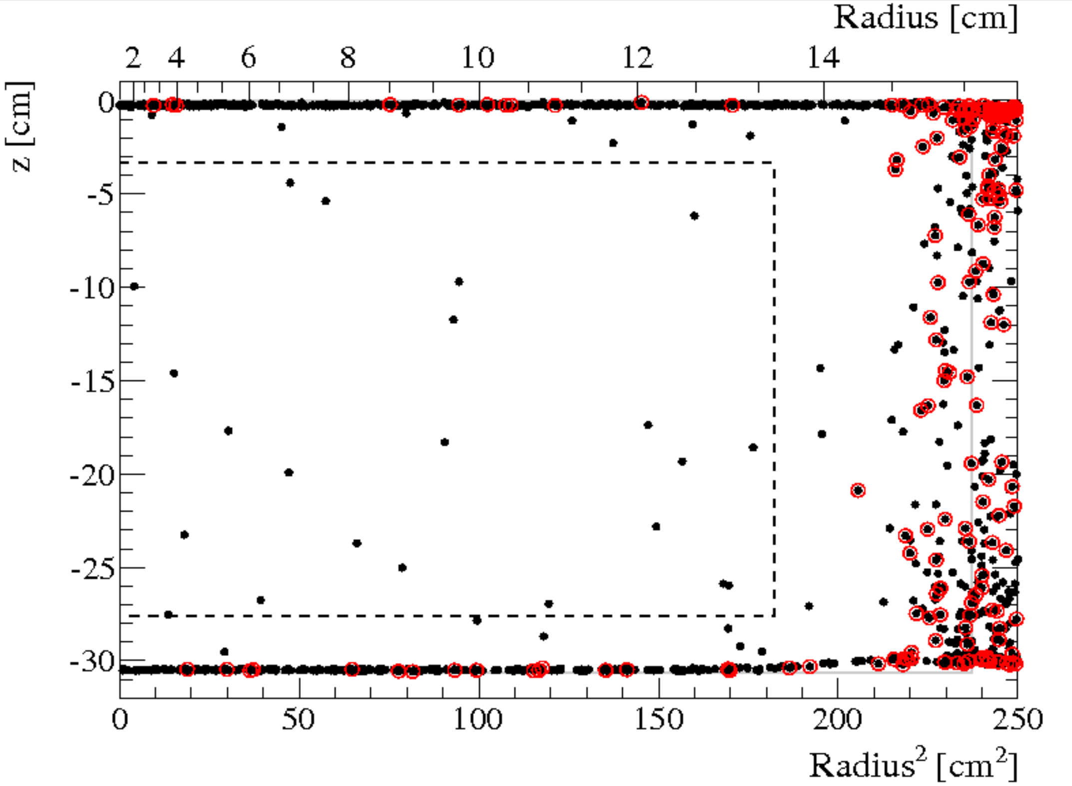
new measurement in preparation @ UZH



■ *Aprile et al., PRC 79, 045807 (2009)*
● *Manzur et al., PRC 81, 025808 (2010)*

for discussion of possible systematic errors see *A. Manalaysay, arXiv:1007.3746*

First XENON100 Data

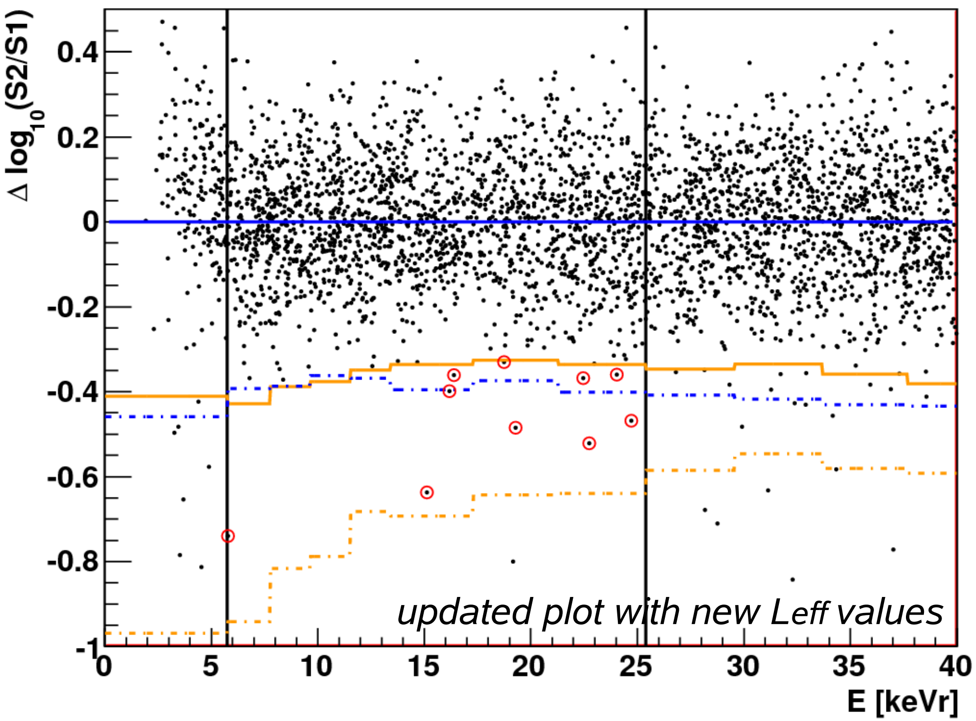


- Energy cut: <30 keVnr
- make use of excellent self-shielding capability of LXe
- 40 kg fiducial mass

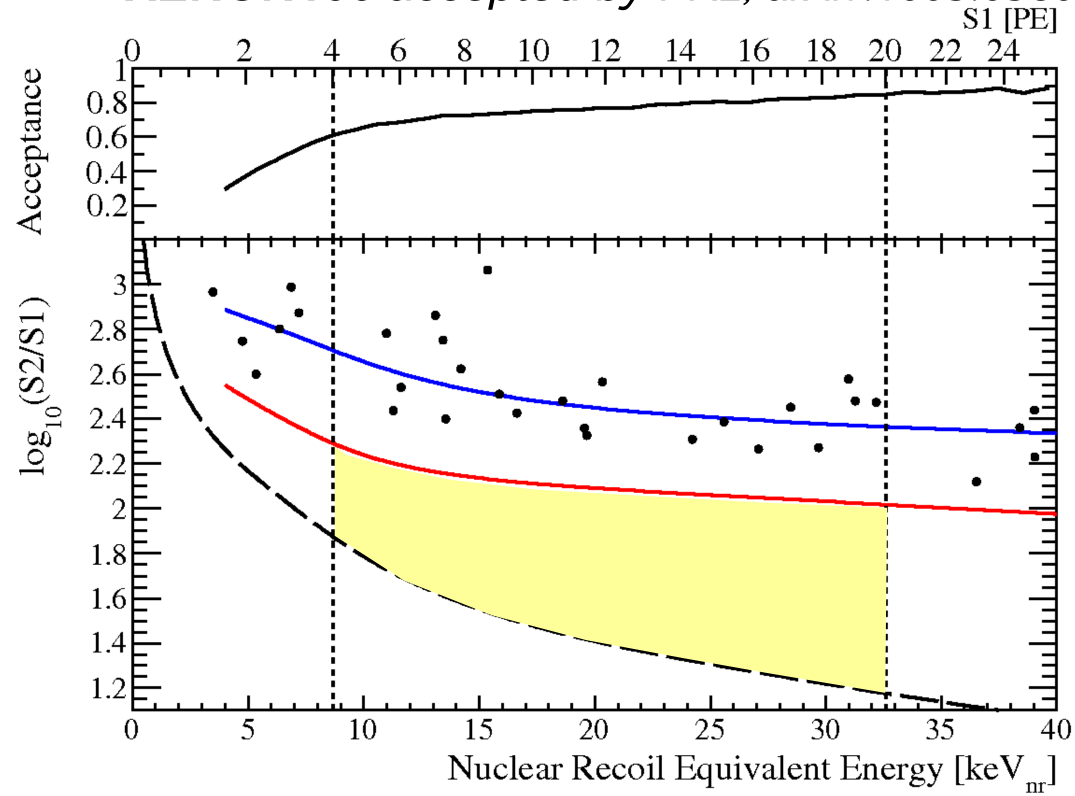
- Background data taken in stable conditions Oct-Nov 2009
- 11.2 life days
- Data was not blinded
- But: Cuts developed and optimized on calibration data only
- accepted by PRL *arXiv:1005.0380*

A Look at the Bands

XENON10 *PRL 100, 021303 (2008)*



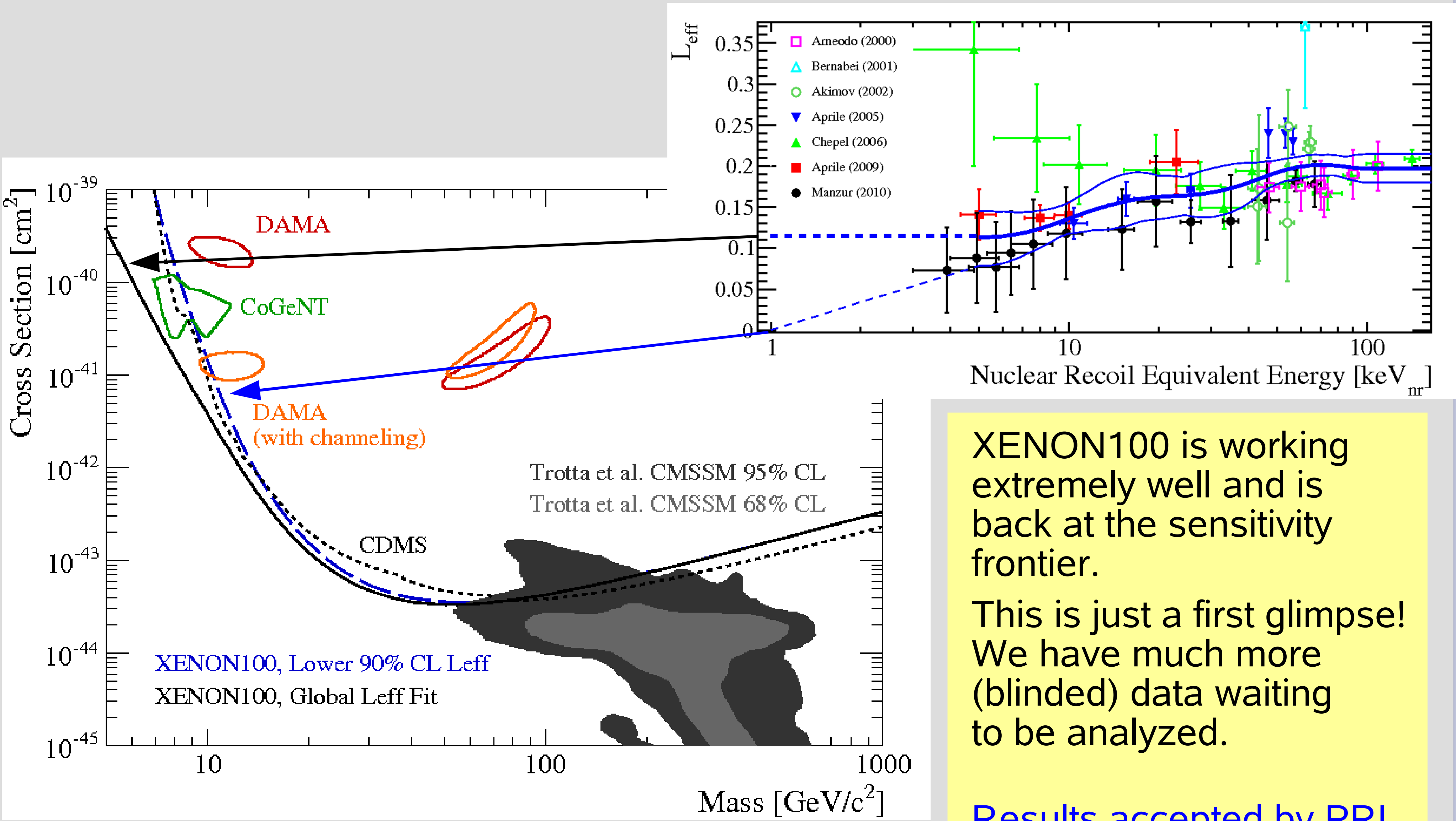
XENON100 *accepted by PRL, arXiv:1005.0380*



- Background free in 11.2 days after S2/S1 discimination
- Both plots show similar exposure

NR acceptance = 50%
cut efficiency ~ 60-85 % (conservative)
Background expectation $\ll$1

A first Limit from XENON100



spectrum averaged exposure: 170 kg days

XENON100 is working extremely well and is back at the sensitivity frontier.

This is just a first glimpse! We have much more (blinded) data waiting to be analyzed.

Results accepted by PRL.
arXiv: 1005.0380

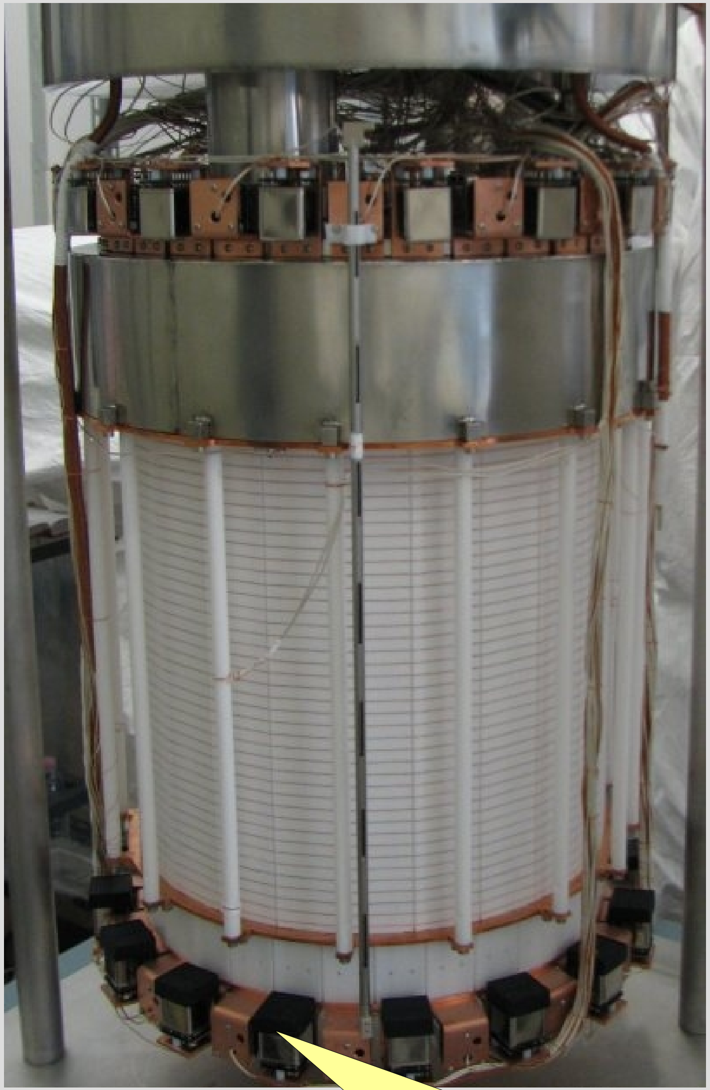
UZH Contributions

Material Screening *(Gator facility)*

Monte Carlo Background Studies

Shield Improvements

Radon Monitoring



DAQ and Trigger

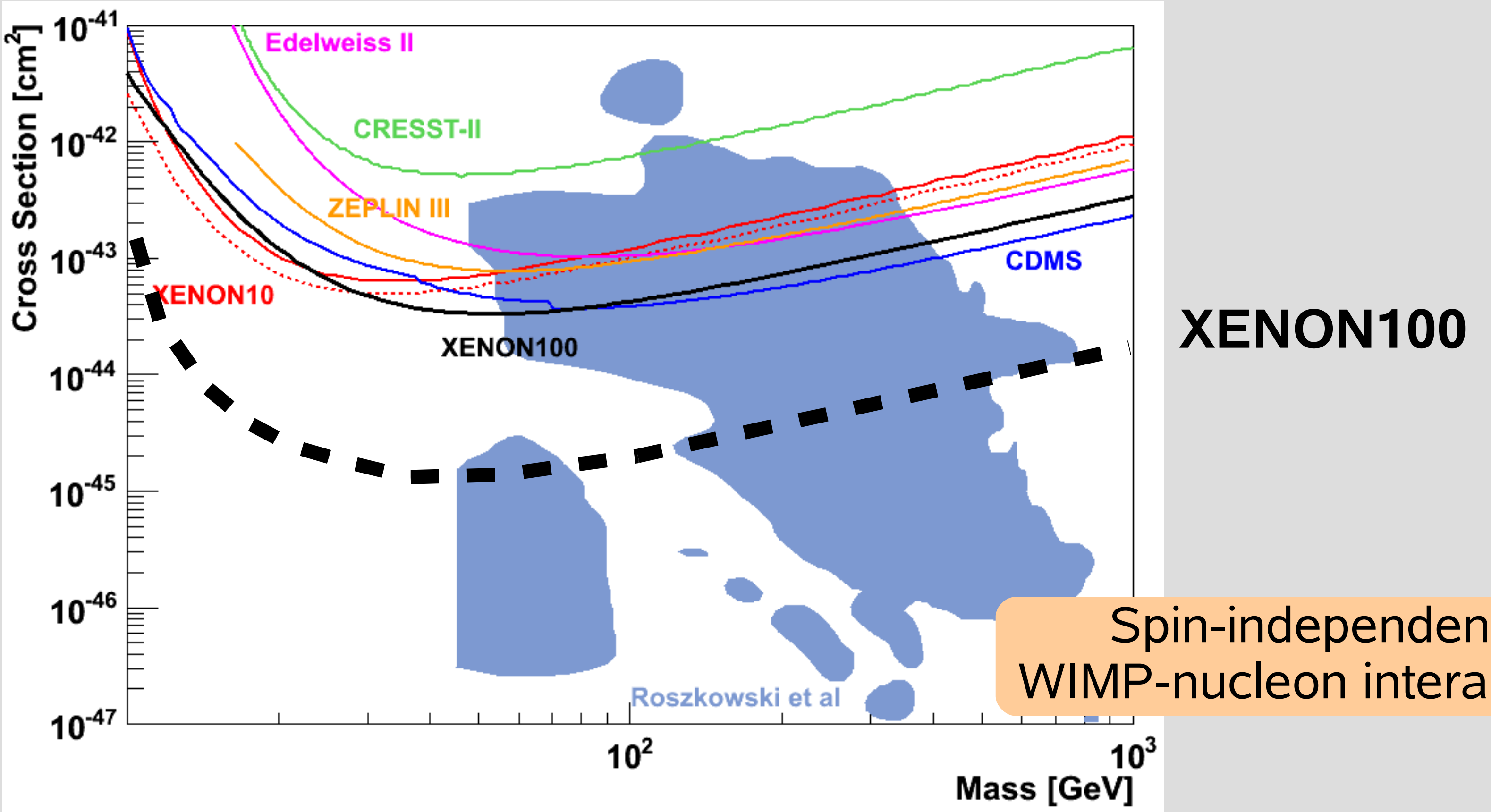
PMT Calibration *(+monitoring)*

Data Analysis *(coordination with Columbia)*

On-Site Operations *(with collaboration)*

R&D for XENON100 and future

XENON100: Sensitivity

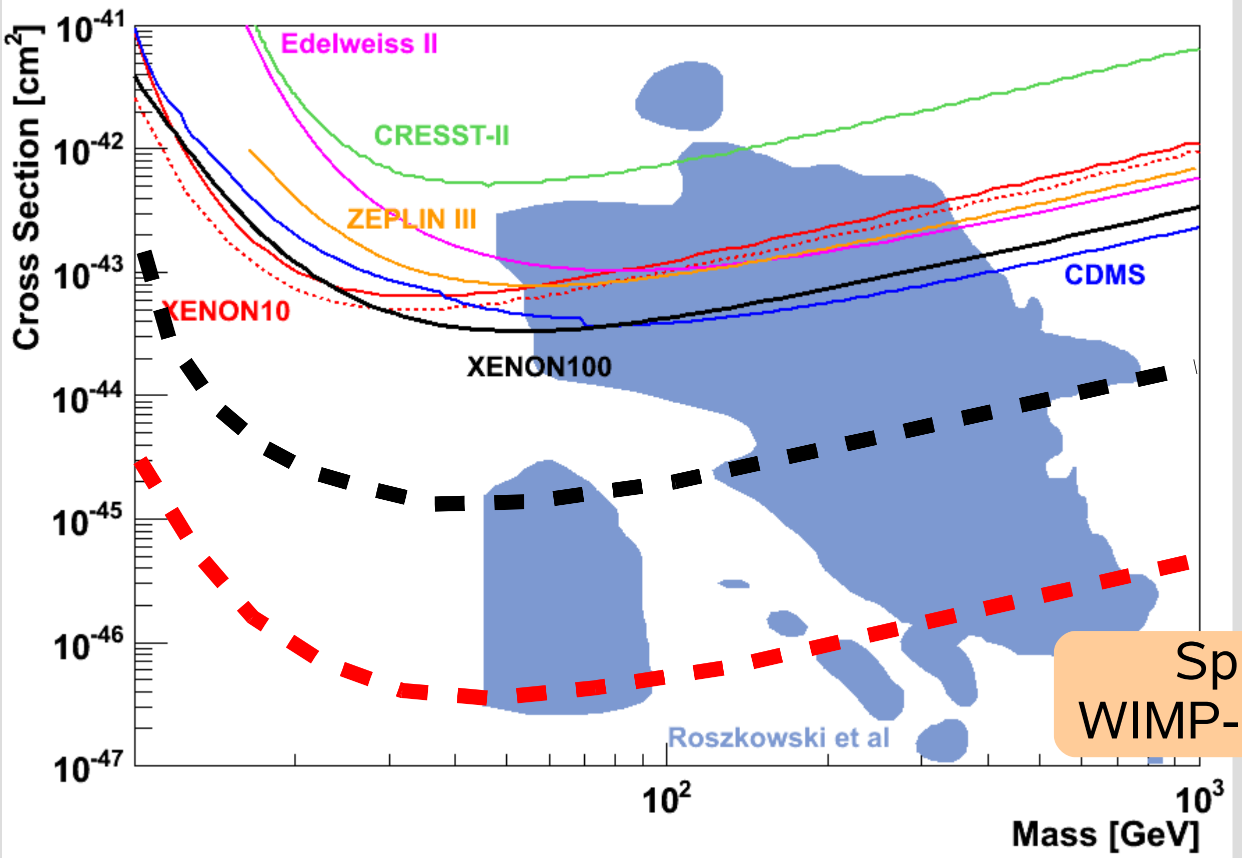


Spin-independent WIMP-nucleon interaction

50 kg Target: 40 days $\sigma = 6\times10^{-45}$ cm² (@ 100 GeV)

30 kg Target: 200 days $\sigma = 2\times10^{-45}$ cm² (@ 100 GeV)

XENON100: Sensitivity



XENON100

XENON1T

Spin-independent WIMP-nucleon interaction

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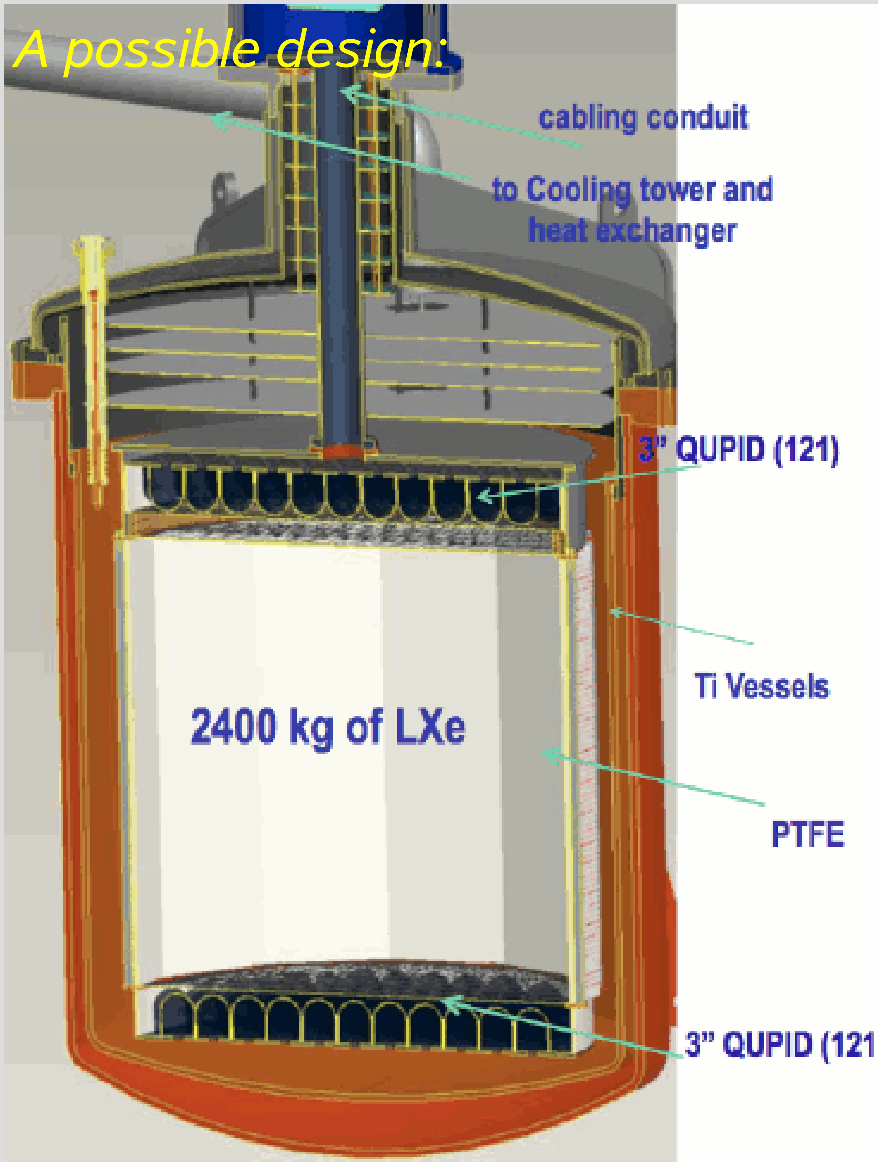
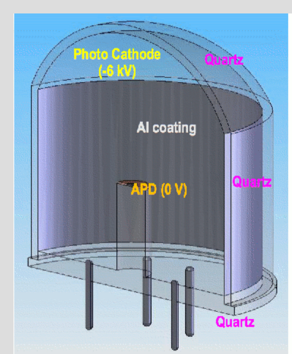
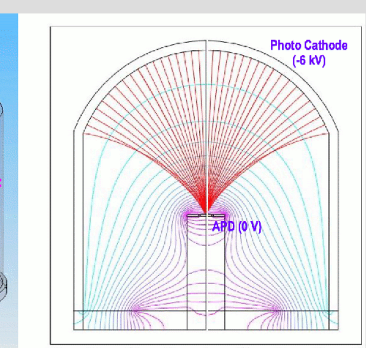
The next step: XENON1T



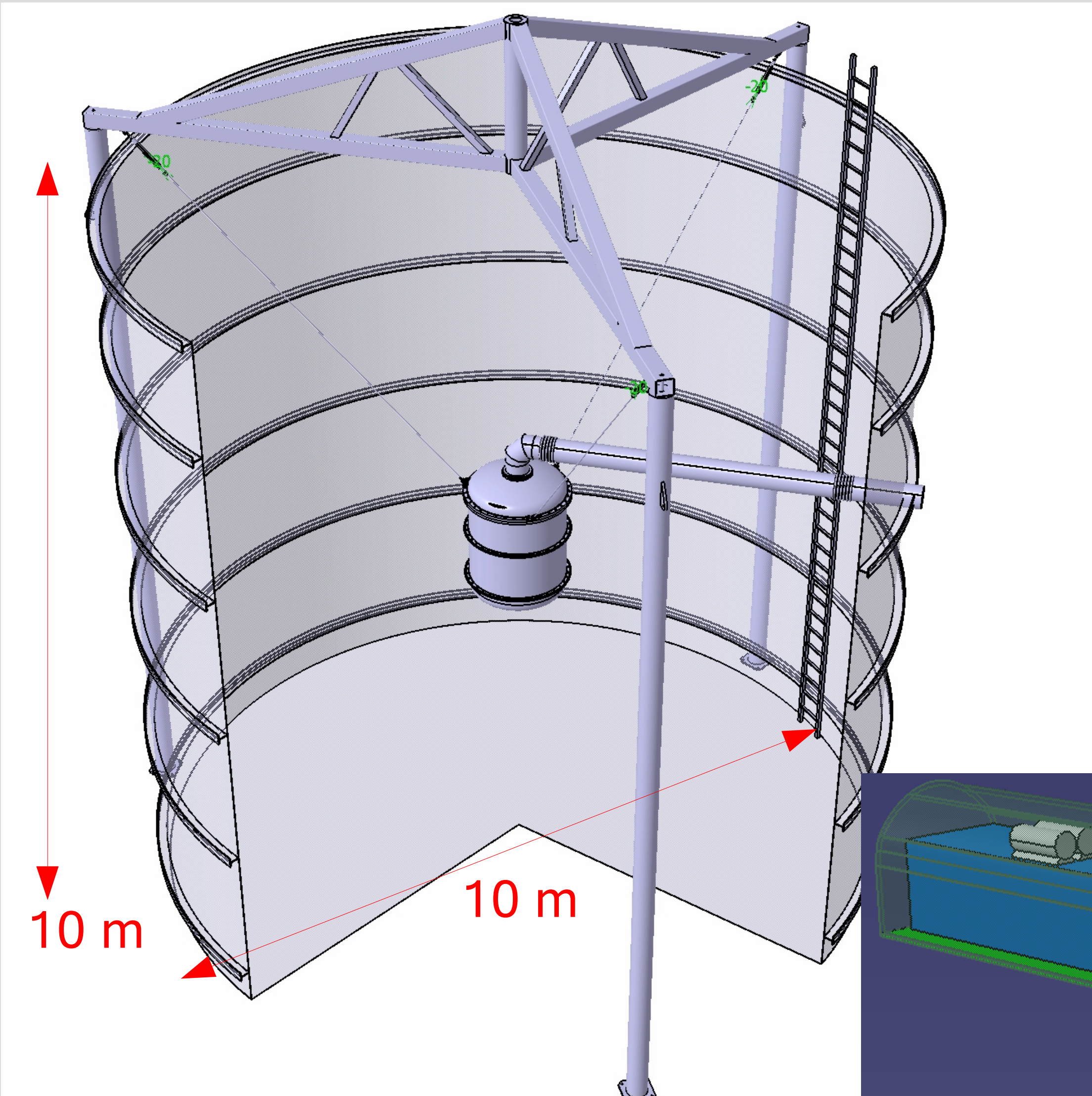
0.9m

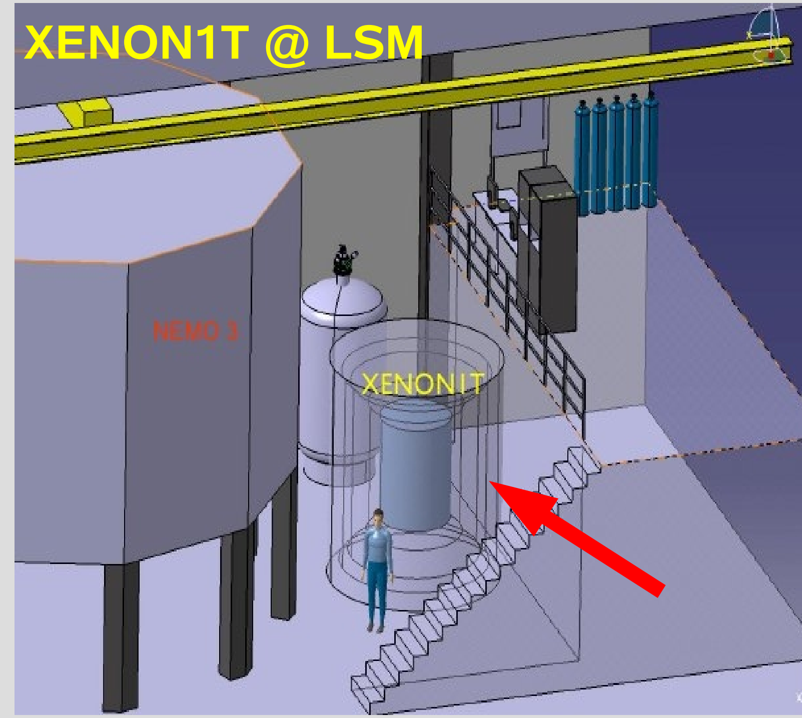
- 2.4t LXe ("1m³ detector")
  1.1t fiducial mass
- 100x lower background
  (10 cm self shielding, QUPID)
- in design phase
  proposal, TDR, R&D
- bigger collaboration
- Two possible sites:
  LNGS / Modane
- Timeline: 2010 – 2015 ???

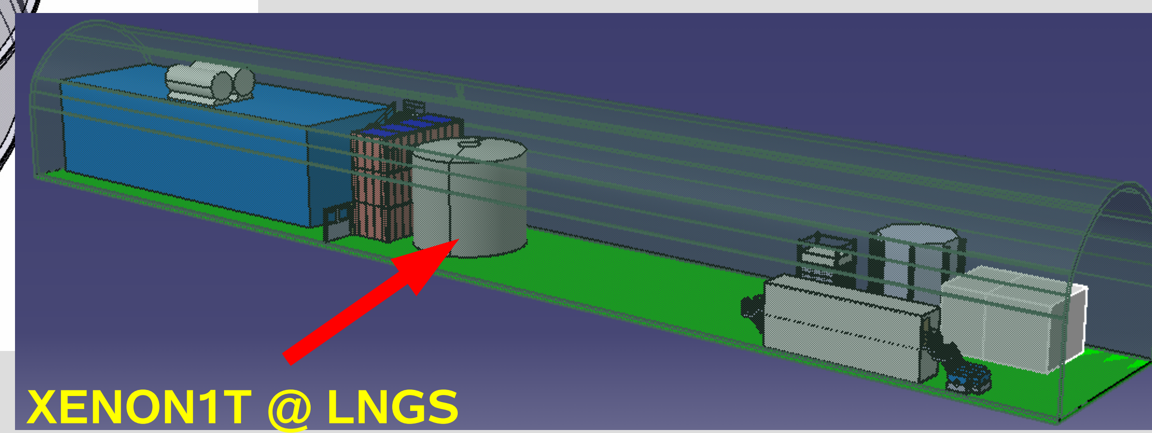




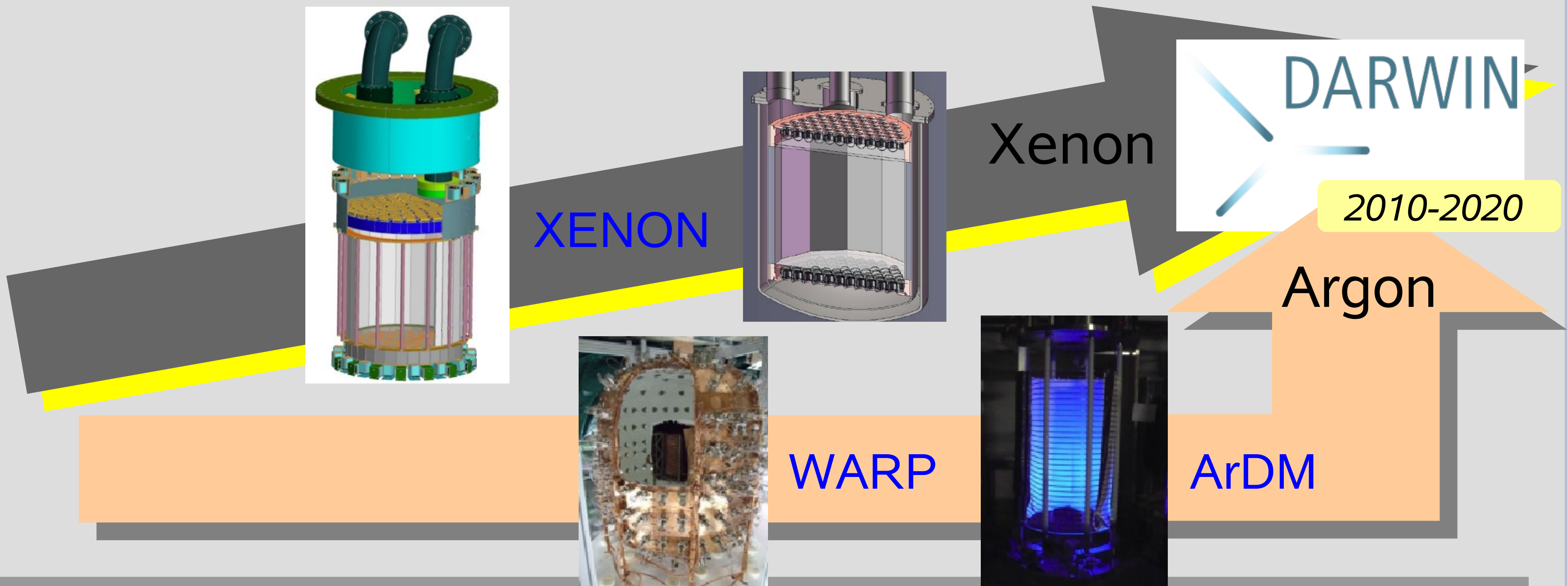
Design Studies







The Future: 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

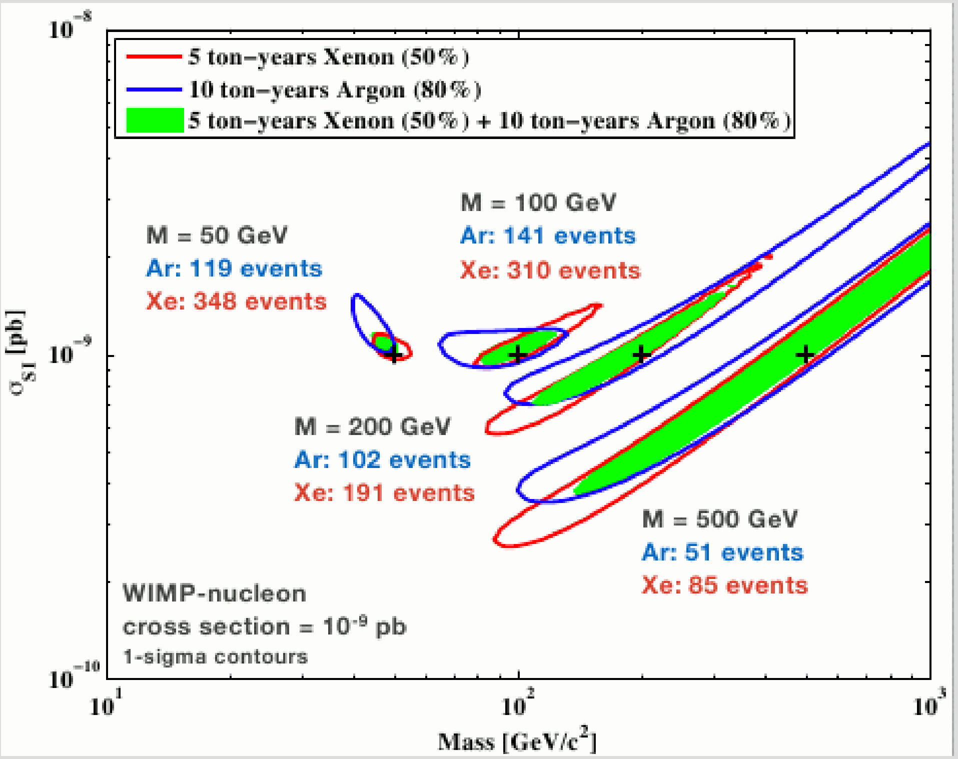
Goals and Structure

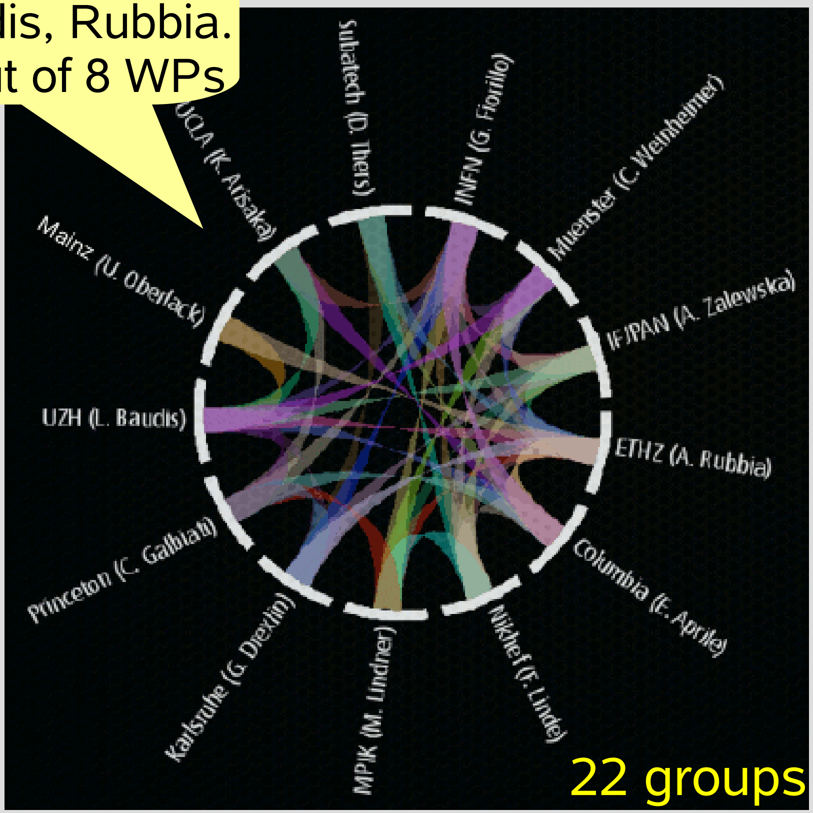
DARWIN

Swiss Groups:
Amsler, Baudis, Rubbia.
Leading 2 out of 8 WPs

R&D and Design Study for
Light/Charge Readout, Electronics/DAQ, Detector/Underground/Shield Infrastructure, Material Screening/Backgrounds, Science Impact

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

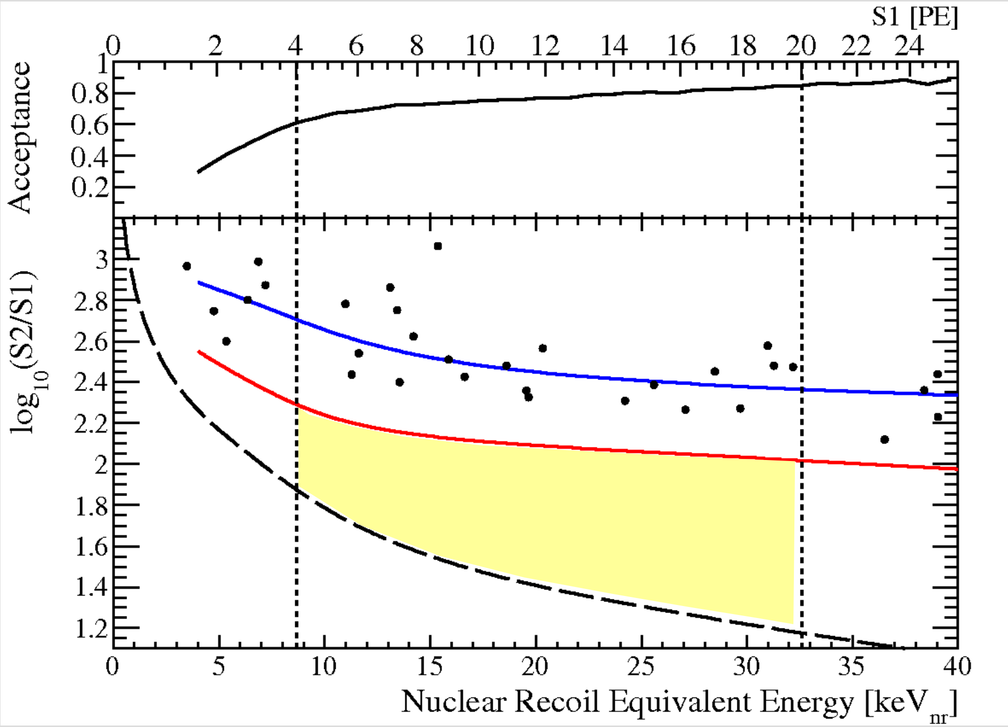




ArDM, WARP, XENON Groups:
UZH (CH), INFN (I), ETHZ (CH), Subatech (F), Mainz (D), MPIK (D), Münster (D), Nikhef (NL), KIT (D), IFJPAN (PL)
+ Columbia, Princeton, UCLA (USA)

http://darwin.physik.uzh.ch

Summary



- Dark Matter: One of the big unsolved puzzles
- **XENON100**
  62 kg dual-phase LXe TPC
- extremely low background
- first results from 11.2d data: *arXiv:1005.0380*

Two new projects upcoming:

- **XENON1T**
  1 ton LXe target mass
- **DARWIN**
  multiton LXe/LAr detector