INFN Laboratori Nazionali del Gran Sasso

# Background Sources in DarkSide-20k

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***Astroparticle Physics in Poland***

***Kraków, 20 – 22 September 2017***

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darkside

two-phase argon TPC for Dark Matter Direct Detection

# OUTLINE

Motivation – background vs. sensitivity

Background sources in DarkSide-20k detector

Background mitigation techniques

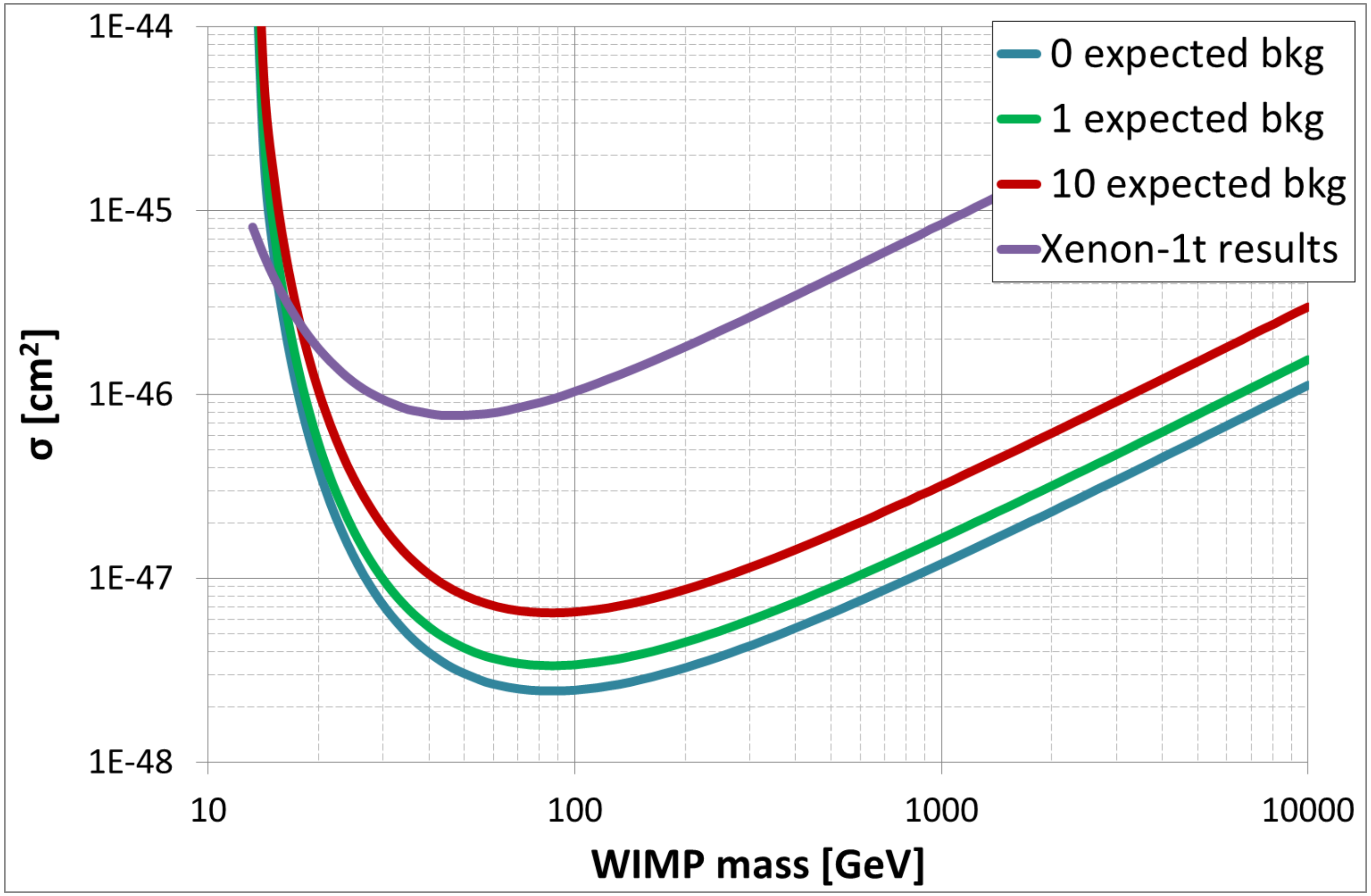
- Application of passive and active shields
- Identification and rejection of background events – PSD
- Application of radiopure materials – screening

Summary

# Motivation – background vs. sensitivity

Example: Argon target, 100 t × yr exposure
Desired background level < 0.1 event/(100 t × yr)

Expected background within the exposure




Xenon-1t result: $1.93 \pm 0.25 \times 10^{-4}$ events/(kg × day × $keV_{ee}$)
→ O(?00) events/(100 t × yr)

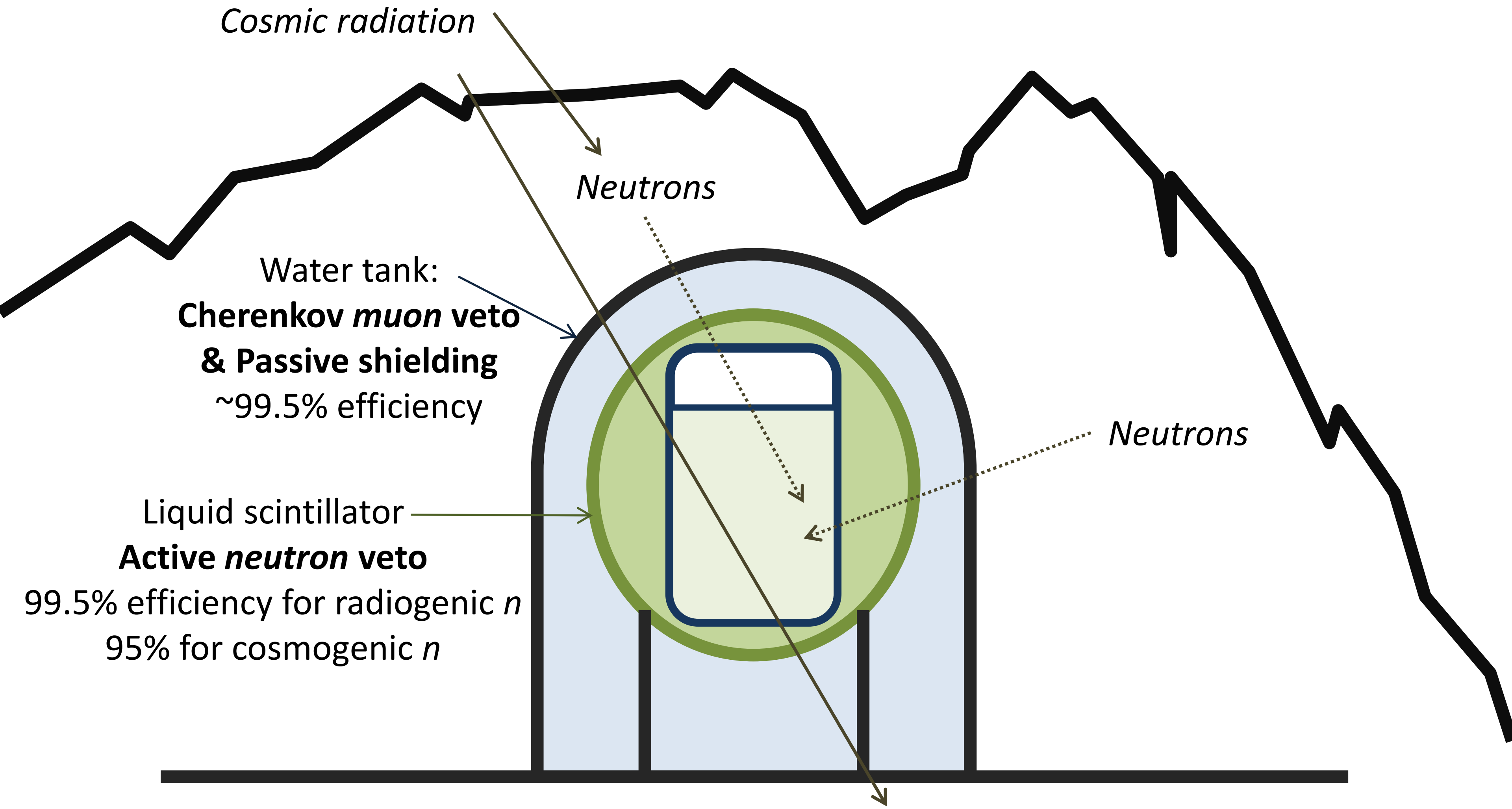
Xenon-1t: arXiv:1705.06655v2

# Background sources in DarkSide-20k detector

- Alphas – Uranium and Thorium chains, $^{210}Po$ surface contamination – $(\alpha,n)$ reactions
- Neutrons – fission products, external (cosmic radiation)
- Betas – $^{39}Ar$ and $^{85}Kr$ decays
- Gammas (gamma/electron scattering)
- Cosmic rays

# Application of passive and active shields

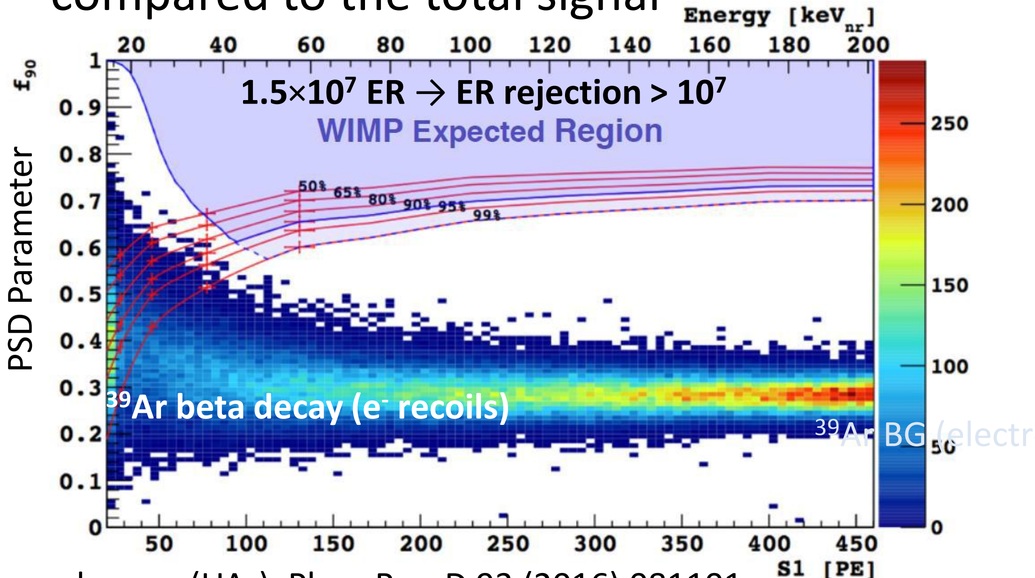
## Liquid Scintillator Veto (B-loaded, pioneered by DS) – a unique feature of DarkSide detectors



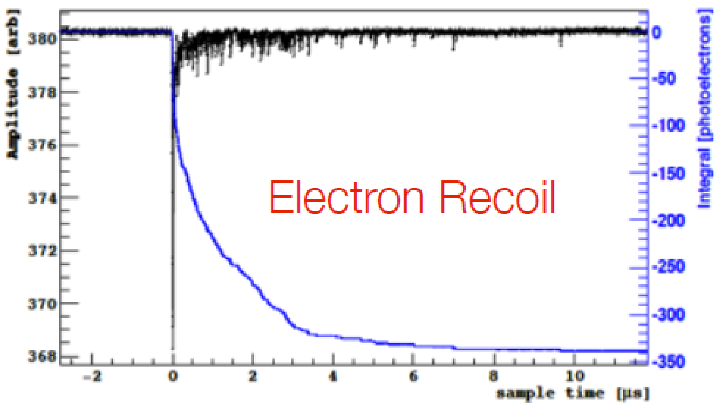
# Identification and rejection of background events – PSD

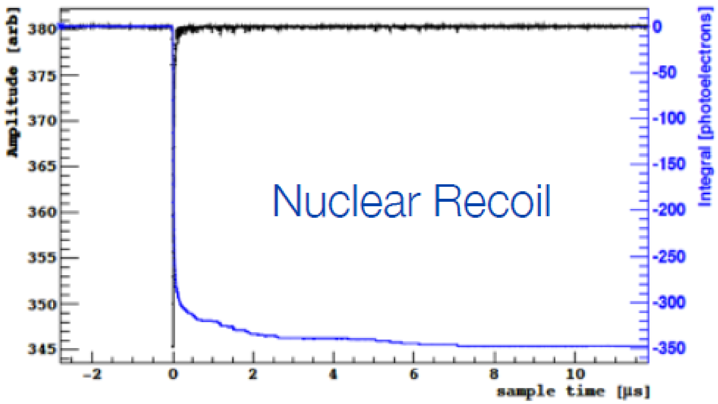
## Pulse Shape Discrimination (PSD) – unique feature of DarkSide detectors

- $^{39}Ar$ natural abundance in argon is a potential source of background (gamma/beta electron recoils)
- Liquid argon scintillation allows for efficient PSD
- $f_{90}$ – ratio of light registered in the first 90 ns, compared to the total signal




Underground argon (UAr), Phys. Rev. D 93 (2016) 081101

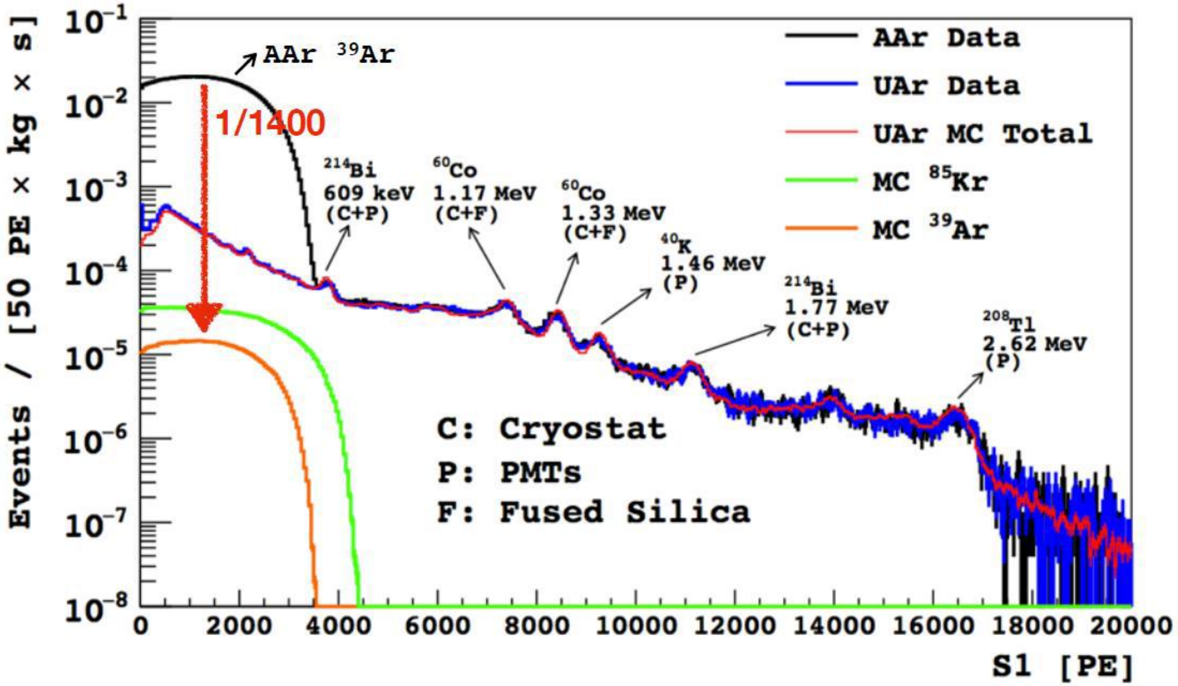


# Background mitigation techniques

**Low-radioactivity argon – a unique feature of DarkSide detectors**

- Combination of PSD and low-radioactivity Ar → ton-scale experiment
- Extraction of UAr at Colorado ($CO_2$ well) – *Urania project*
- 1:1400 reduction factor demonstrated (DS-50)
- Additional purification and depletion of UAr – *Aria project*



# Background mitigation techniques

## TPC assembly in Rn-suppressed clean rooms – a unique feature of DarkSide detectors

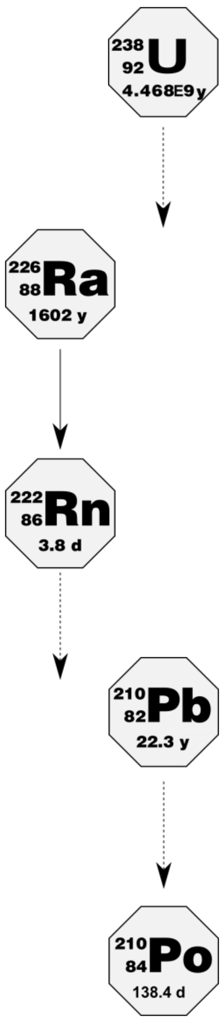
TPC is assembled in the first practically Rn-free clean rooms (5 – 50 mBq/m$^3$)

(World-first Rn suppressed clean room in Princeton for Borexino inner vessel assembly: Rn < 1 Bq/m$^3$)

- Dedicated abatemenet system reduces $^{222}$Rn concentration in the air down to 1 mBq/m$^3$
- $^{222}$Rn content in the clean rooms is monitored online by a high sensitivity detector

# Background mitigation techniques
# Material Screening Working Group

**The cryostat and the TPC must be built from radiopure materials**




**Mass Spectroscopy (ICP-MS and related)**
Institutions: PNNL, BHSU, LNGS, MSU, CIEMAT

**Gamma ray screening, Radon emanation**
Institutions: Black Hills State Univ., CIEMAT, LNGS, Jagiellonian Univ., Petersburg NPI, PNNL, Temple Univ.

*Unique:* 50 L & 250 L cryogenic $^{220}$Rn and $^{222}$Rn detector (detection limit of 20 μBq, Jagiellonian Univ.)

30 L emanation chamber + counting with proportional counters (PNNL)

**$^{210}$Po detectors**

XiA UltraLo 1800 (α–activity) 43 cm × 43 cm (Jagiellonian Univ.)

BiPo-3 (α/β–activity) 3.6 m$^2$ (CIEMAT)

**Monte Carlo** simulations used to evaluate acceptable radiopurity limits for each material in use, e.g. due to (α,n) reactions

# Background mitigation techniques

**Radio–pure liquid argon**

Xenon/LUX experiment: estimated $^{222}Rn$ contamination at ~20 µBq/kg (Eur. Phys. J. C (2017) 77:358 )

**DarkSide–50: estimated $^{222}Rn$ contamination < 2 µBq/kg**

DarkSide–20k (for solar neutrino detection): $^{222}Rn$ < 0.5 µBq/t (arXiv:1510.04196v4)

$^{222}Rn$ removal from LAr is mandatory (and possible), as it depends on $^{222}Rn$ emanation from detector's components.

Borexino High Purity Nitrogen ($HPN_2$): $^{222}Rn$ < 0.4 µBq/kg

Gerda argon purification studies: (JU involved)

- $^{222}Rn$ reduction factor in gas phase 1:2700: < 0.3 µBq/kg
- $^{222}Rn$ reduction factor in liquid phase 1:305: 3.6 µBq/kg

# Summary

DarkSide-20k:

- Background free detector
  - Feasibility proven by DS-50 with UAr
- Unique techniques for background mitigation
  - Use of radiopure argon
  - Efficient pulse shape discrimination ($f_{90}$ parameter)
  - Boron-loaded Liquid scintillator veto against neutrons (the use pioneered by DS)
  - Detector assembly in radon-free clean rooms
  - Application of radiopure Si-PMs (for light detection - not discussed here)

Bacgkround assesment

- Material Screening Working Group (world-wide effort), close cooperation with MonteCarlo Working Group (evaluation of background rate)
- All parts of the U/Th covered (ICP–MS, γ-ray spectrometry, Rn-emanation studies, alpha spectroscopy, Rn-free clean rooms)
- Expertise in gas purification
- **INFN-LNGS: hosts the experiment, substantial financial support, expertise in low background techniques (γ-ray screening, ICP-MS, …)**

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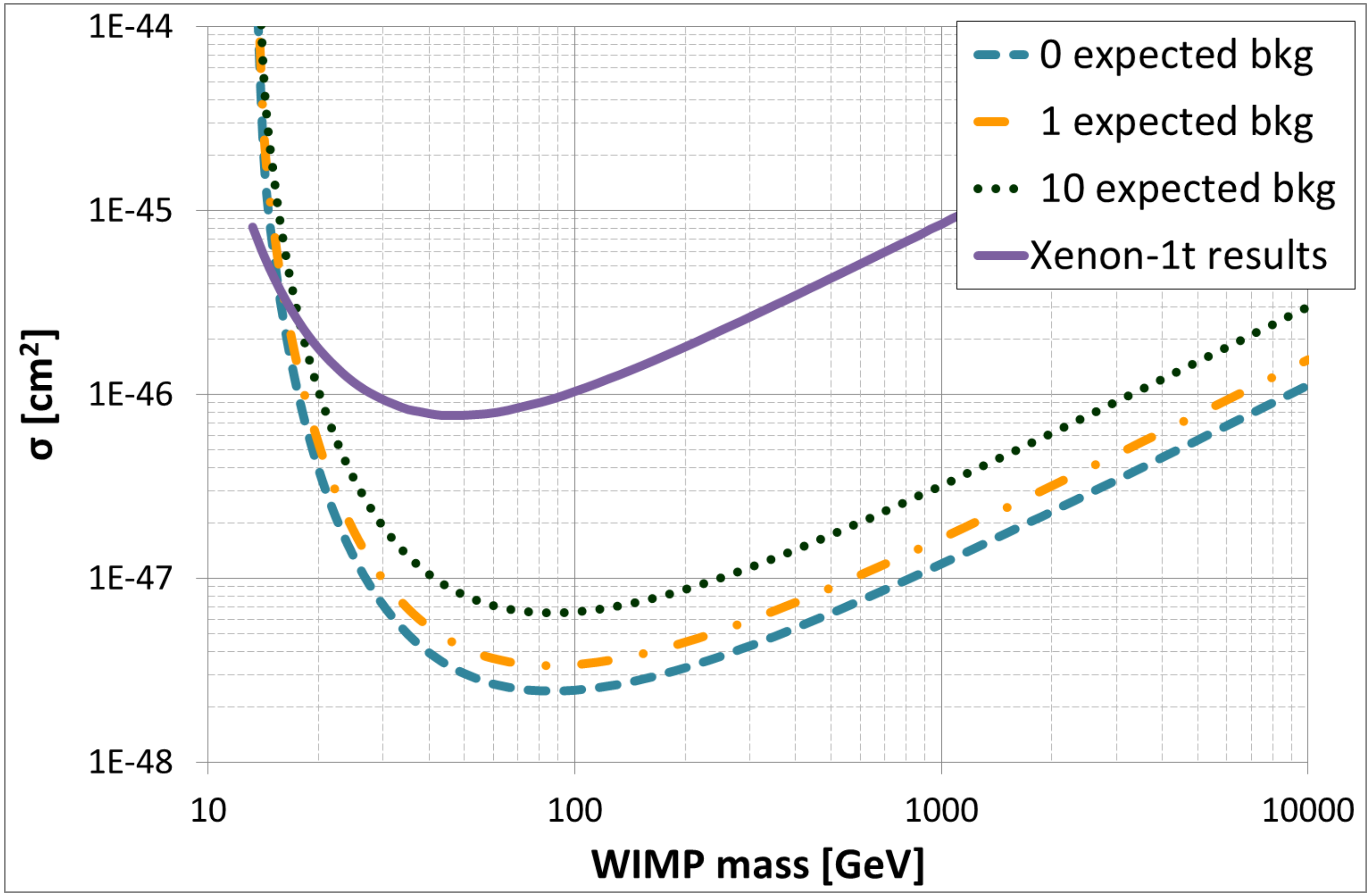


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