

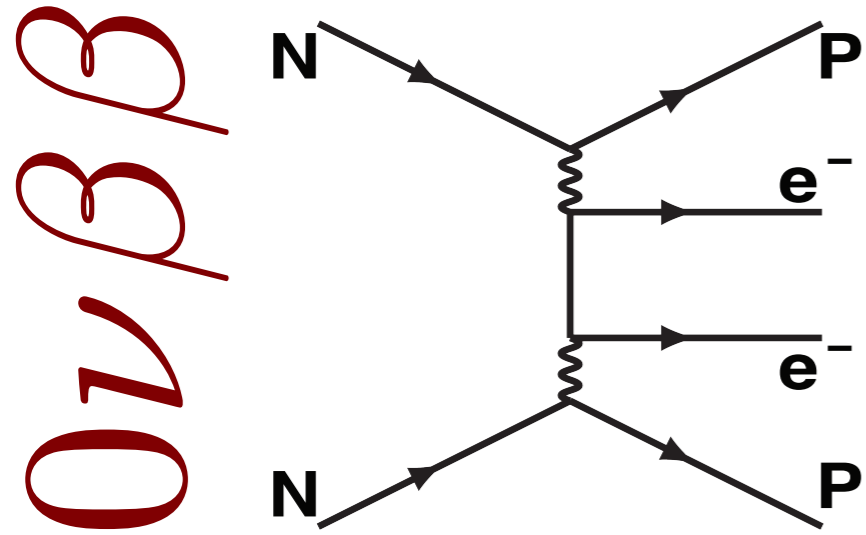
# Prospects for a 100-ton scale $0\nu\beta\beta$ decay search at DUNE

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*\*\* Paper in preparation*



# Neutrino-less double beta decay

$0\nu\beta\beta$  is only allowed for Majorana neutrinos.

Observation of  $0\nu\beta\beta$  would:

Show that the mechanism for  $\nu$  mass is beyond the SM Higgs coupling

Imply lepton number violation.

Test predictions of leptogenesis to explain matter-antimatter asymmetry.

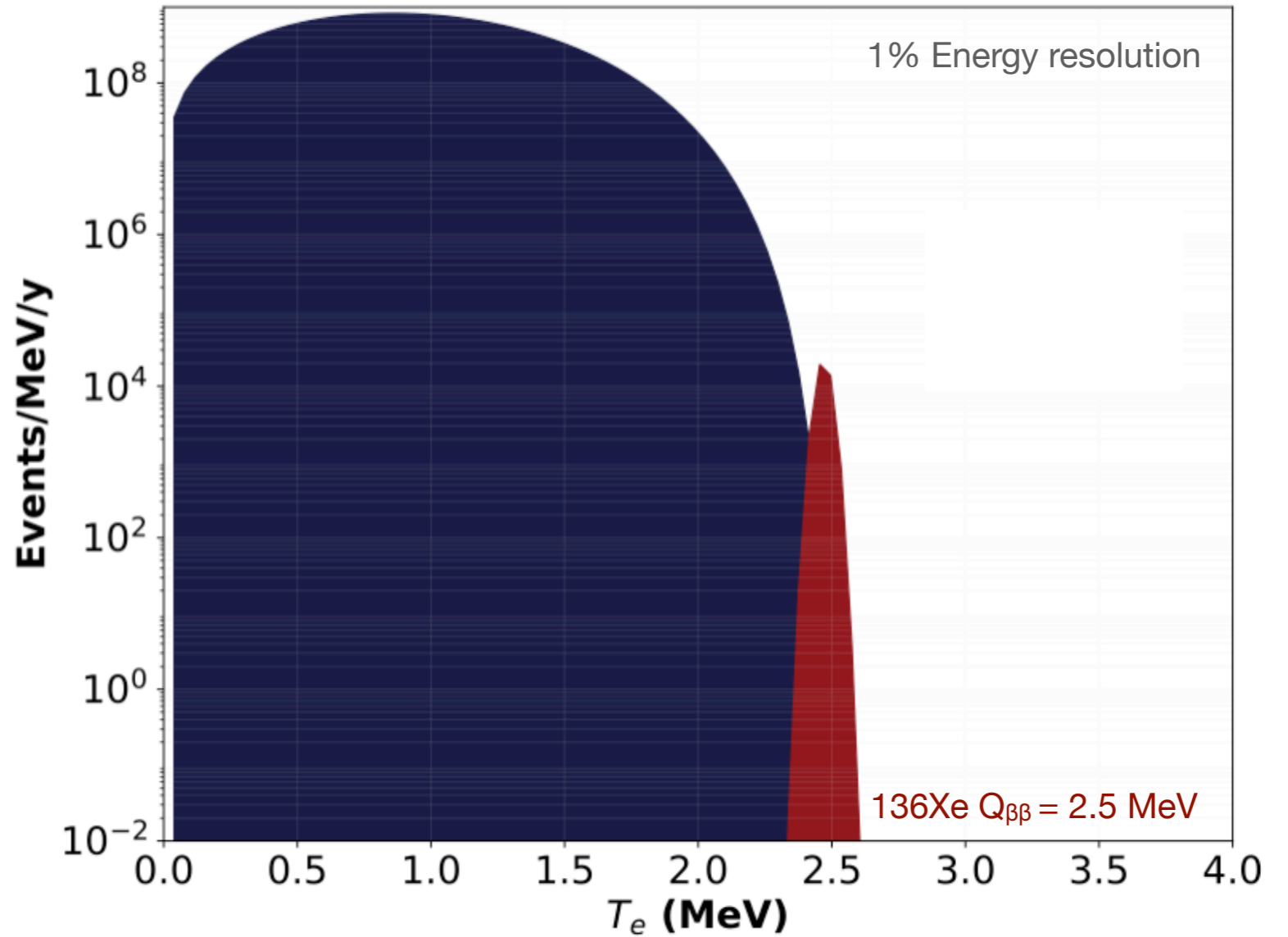
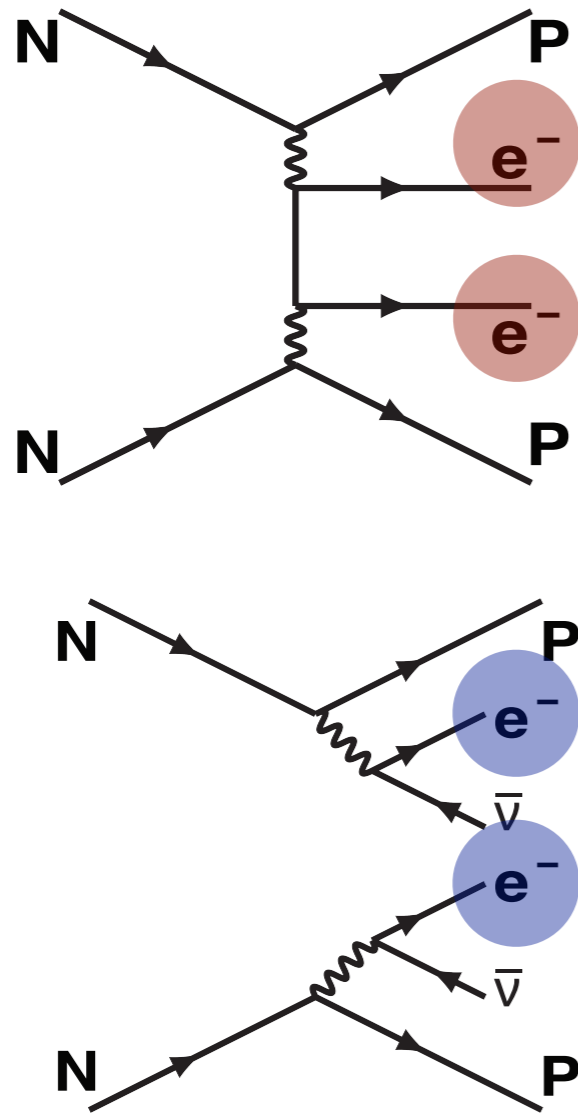
$$m_{\beta\beta} \propto (T_{1/2}^{0\nu})^{-1}$$

Effective  $\nu$  mass

Half-life

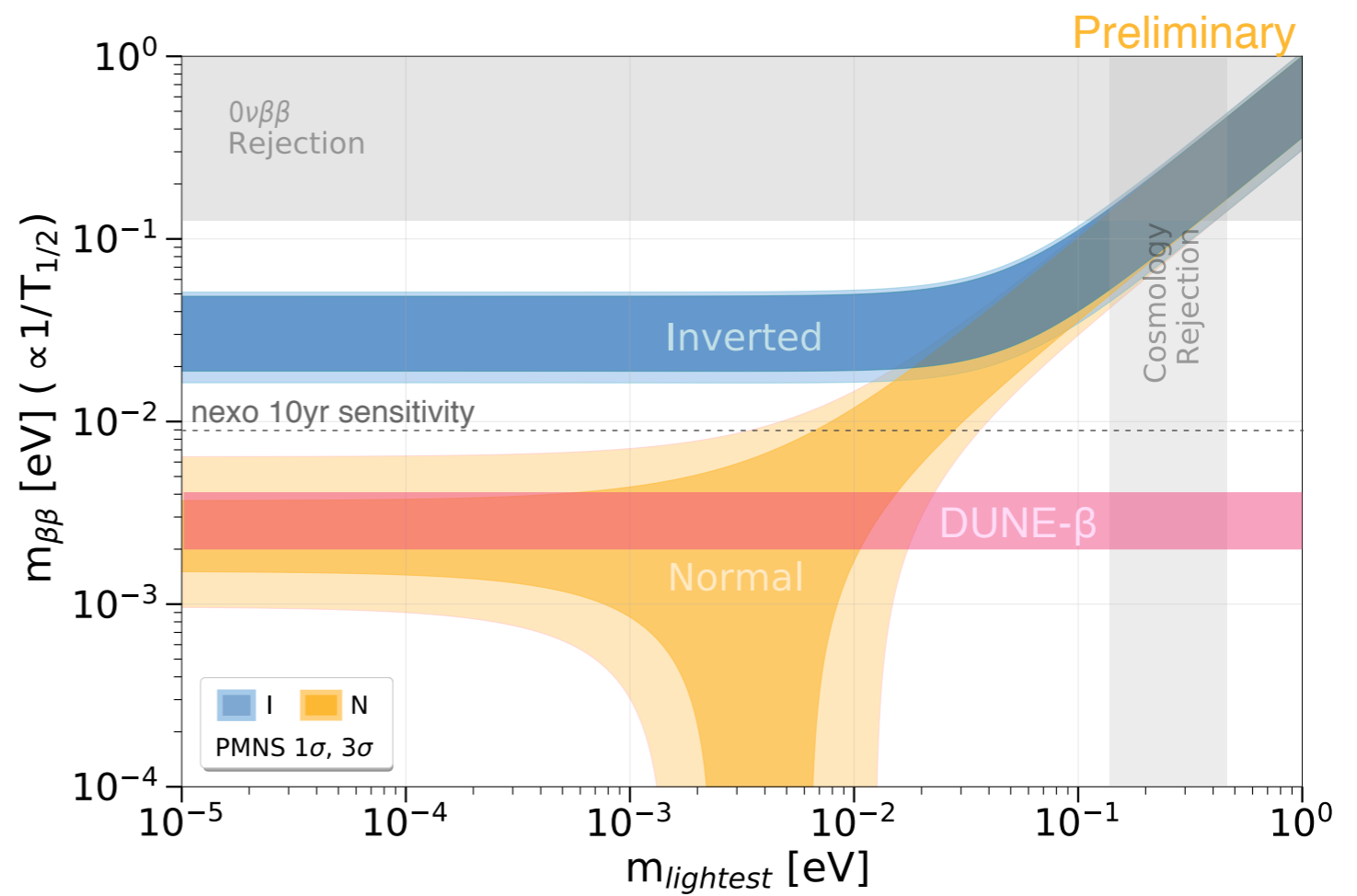
# Measurement

$2\nu\beta\beta$   
 $0\nu\beta\beta$

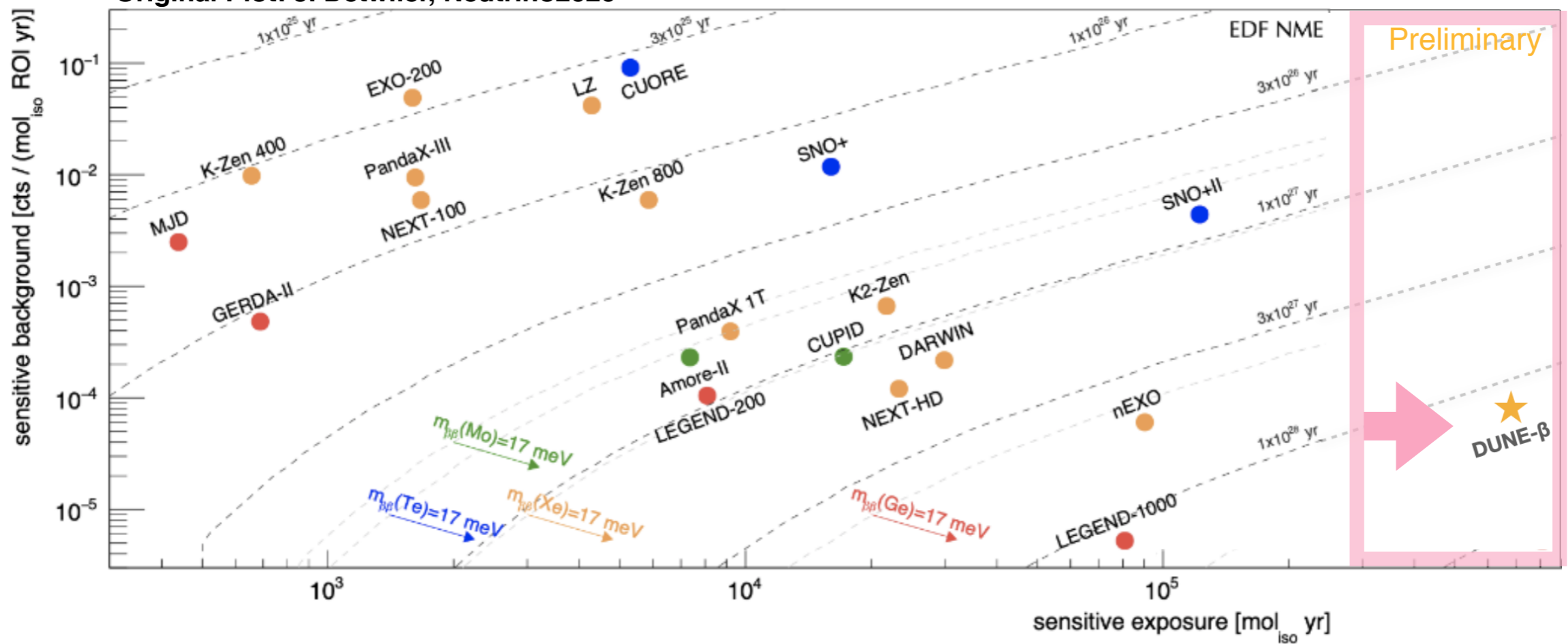


Signal is 2 electrons with energy =  $Q_{\beta\beta}$

# DUNE- $\beta$ Potential

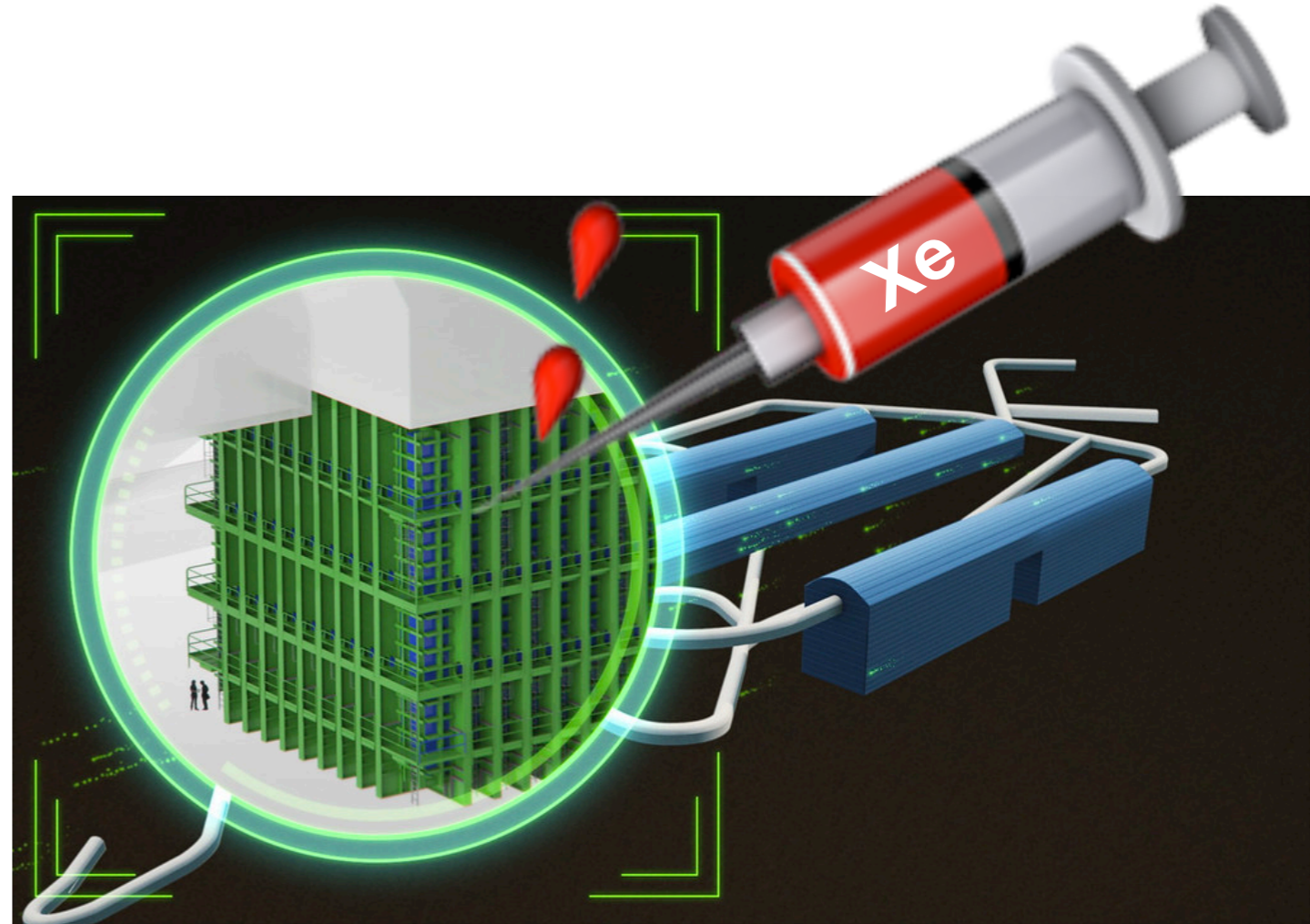


Original Plot: J. Detwiler, Neutrino2020



# DUNE- $\beta$ CONCEPT

Doping one DUNE's module's liquid argon with  $^{136}\text{Xe}$  at 2% by mass would allow us to extend DUNE's physics program to search for  $0\nu\beta\beta$  decay



Dope with 100s  
of tons of  $^{136}\text{Xe}$

Mitigate low E  
Backgrounds

Resolve a  
2.5MeV Signal

**WHAT WOULD NEED  
TO BE MODIFIED?**

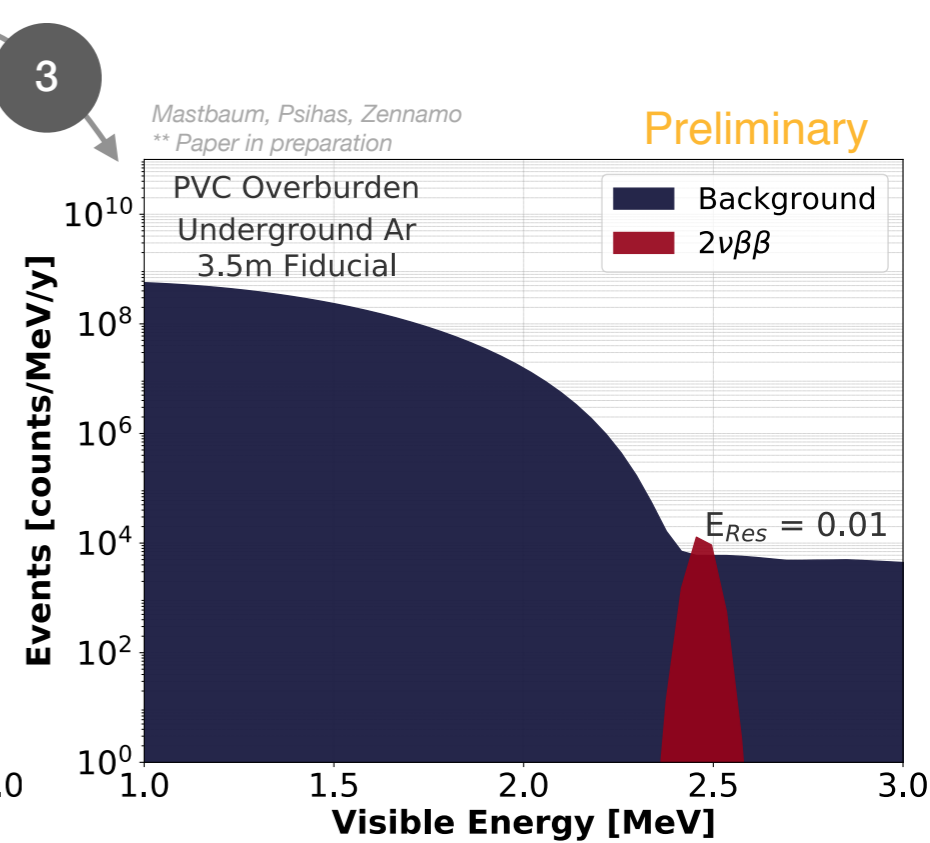
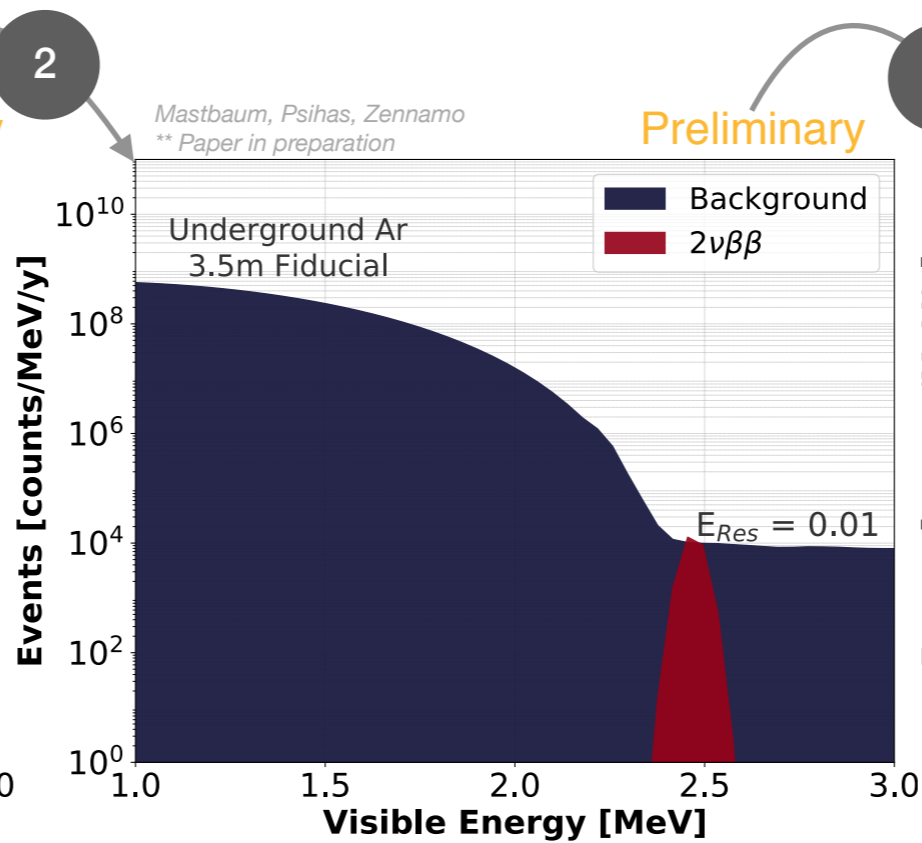
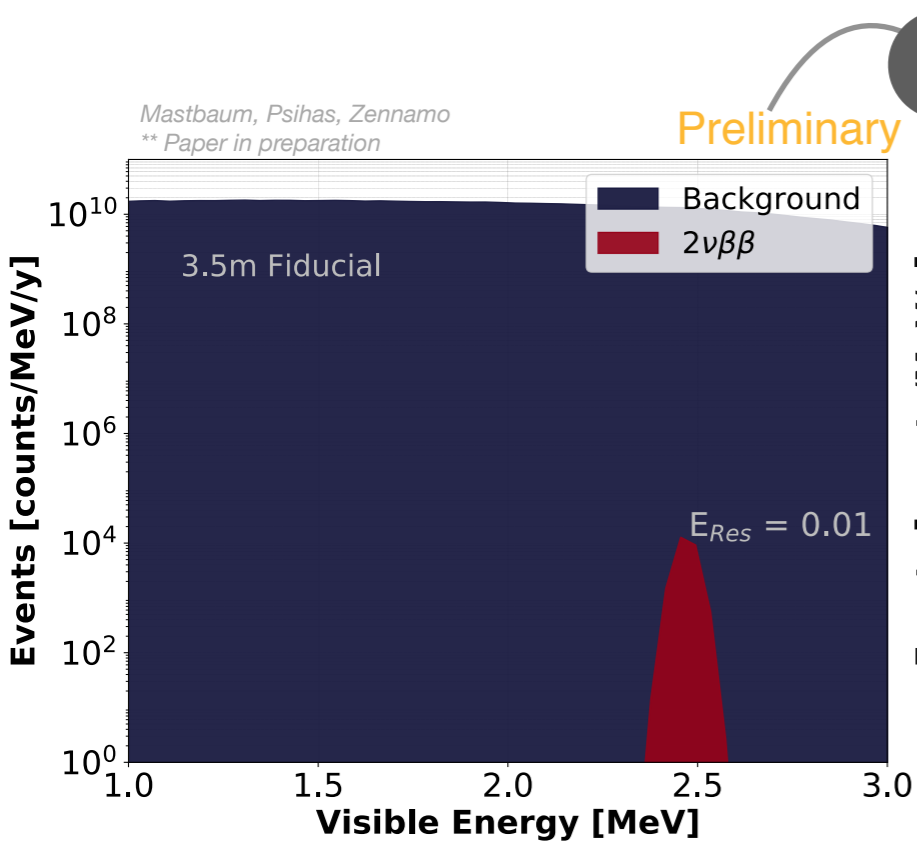
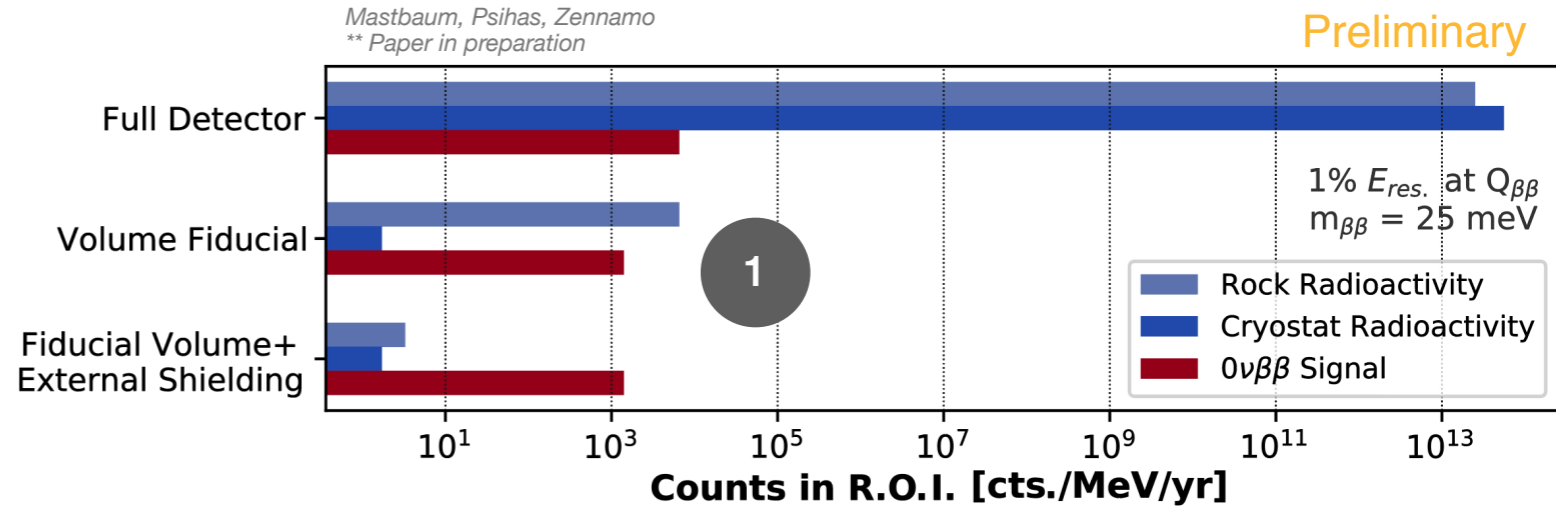
**WHAT HAPPENS TO THE  
DUNE PHYSICS PROGRAM?**

**WHAT R&D QUESTIONS  
DOES THIS OPEN?**

# BACKGROUNDS THE KILLERS:

\*Backgrounds simulated using RAT-PAC

- 1 Radioactivity
- 2 42K From the 42Ar decay
- 3 Environmental Neutrons



WHAT WOULD NEED  
TO BE MODIFIED?

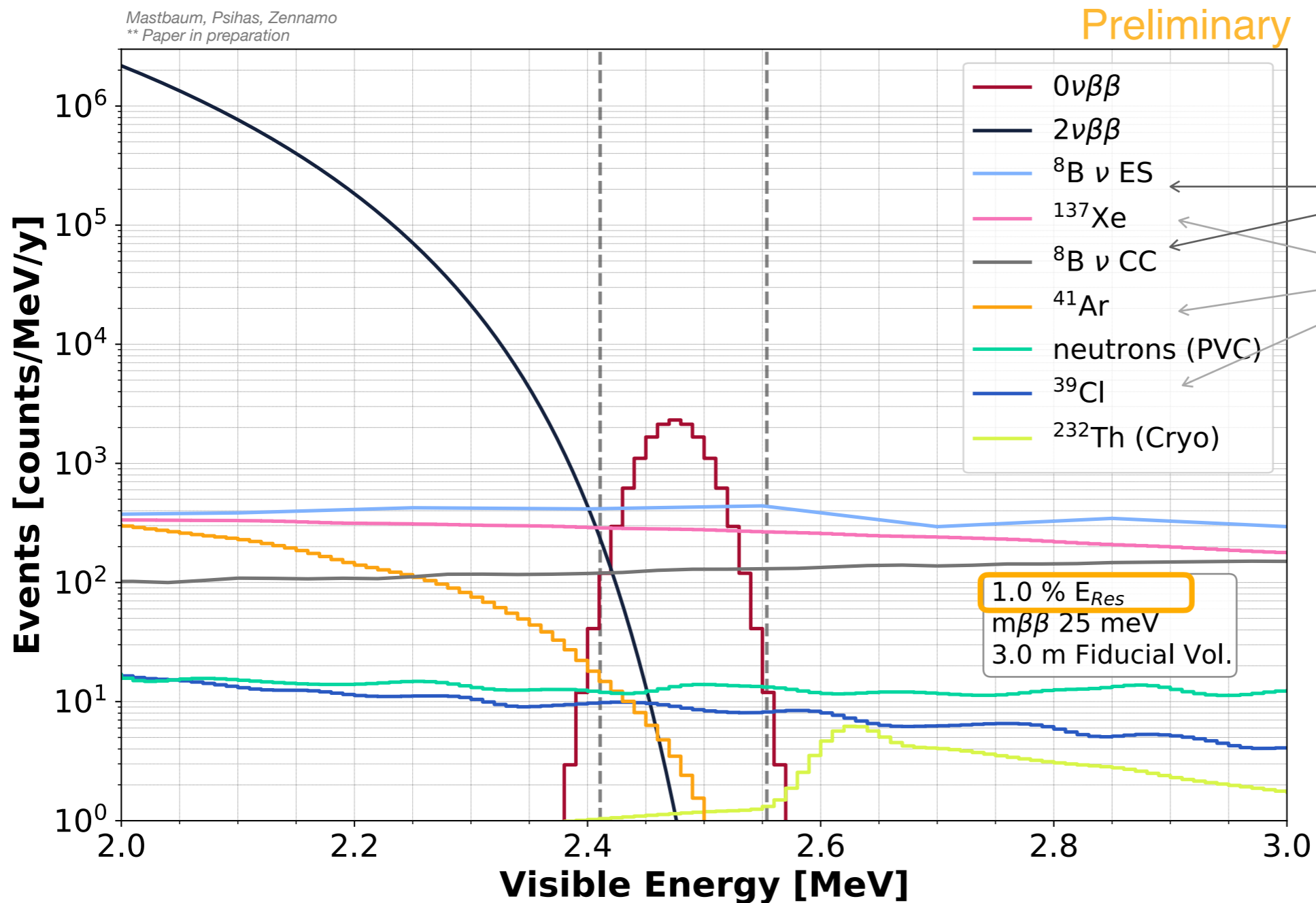
Low-radioactivity argon\*

\*similar to what could enable dark matter searches  
E. Church et. al., *JINST* 15 (2020) 09, P09026

Shielding 1m water equiv.+

+similar for what has been proposed for solar neutrinos  
Capozzi, et. al., *Phys.Rev.Lett.* 123 (2019)

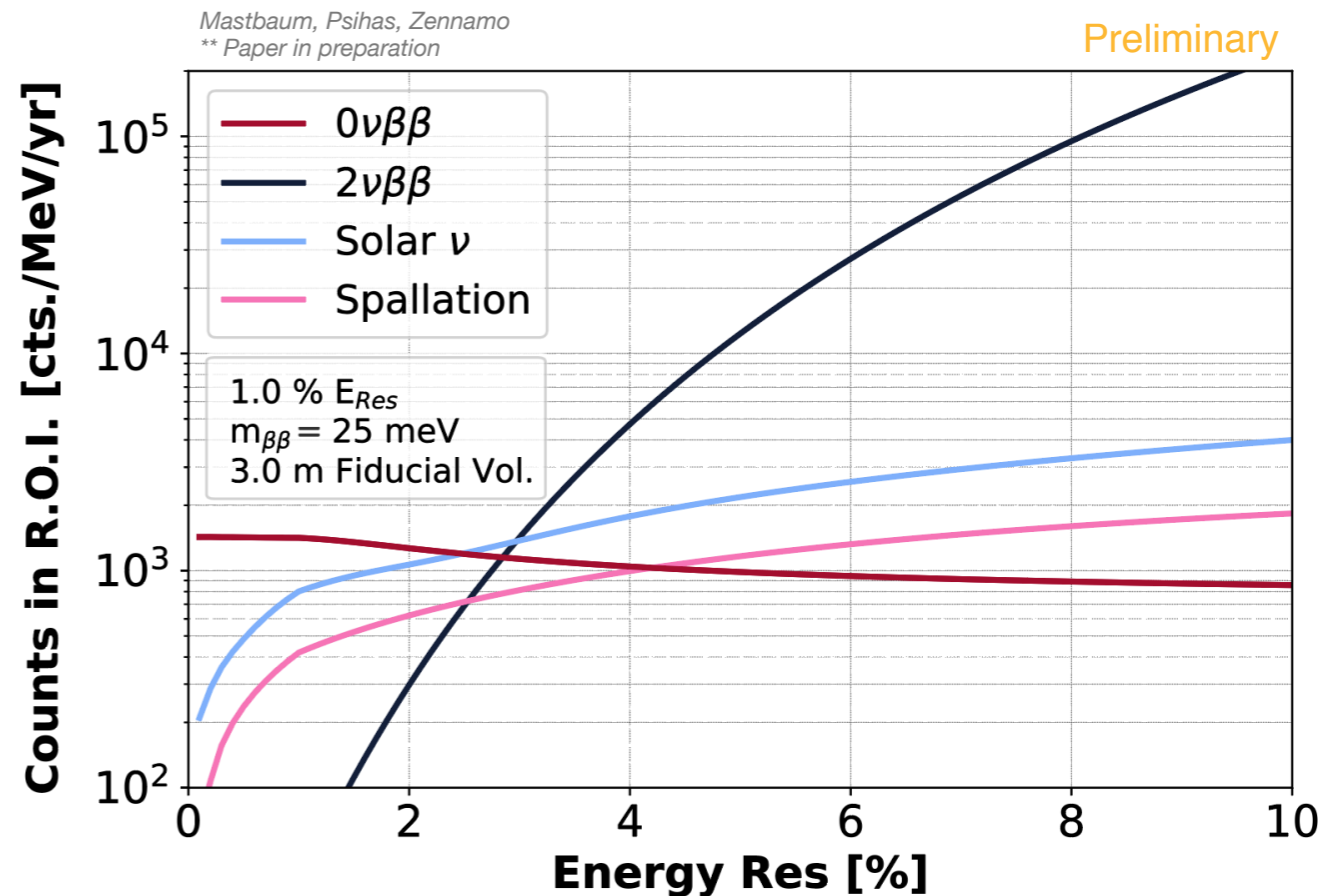
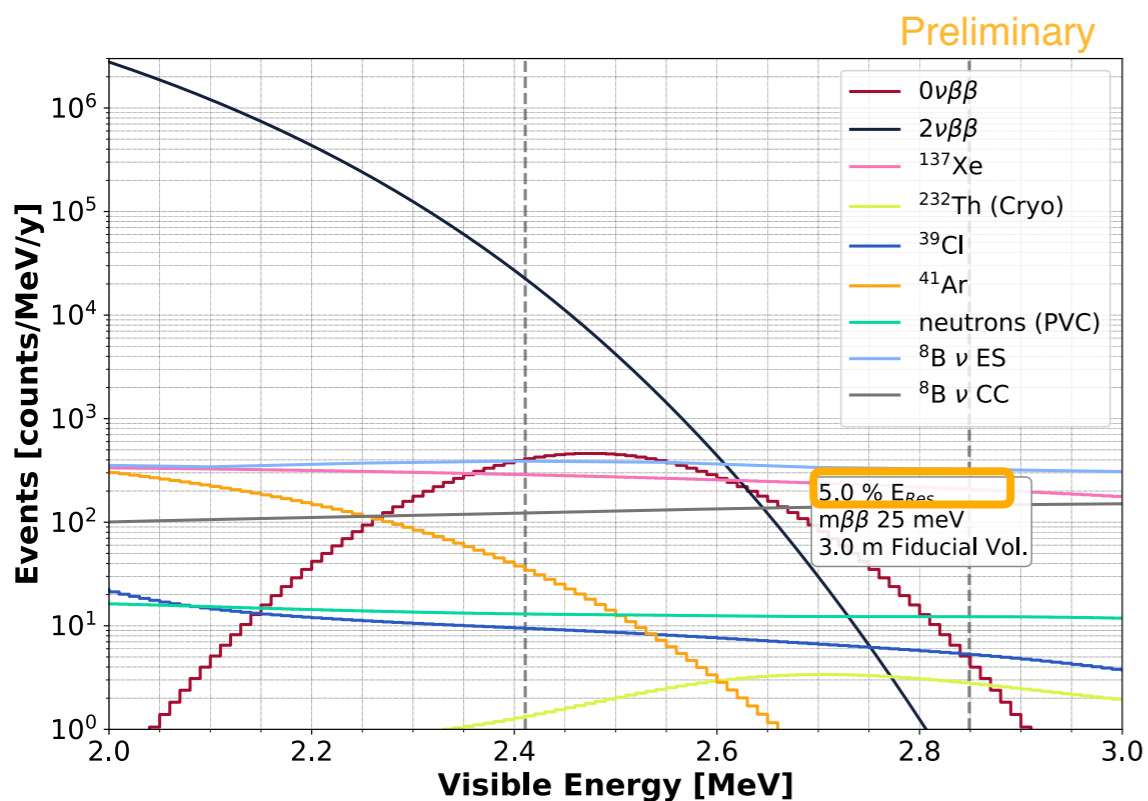
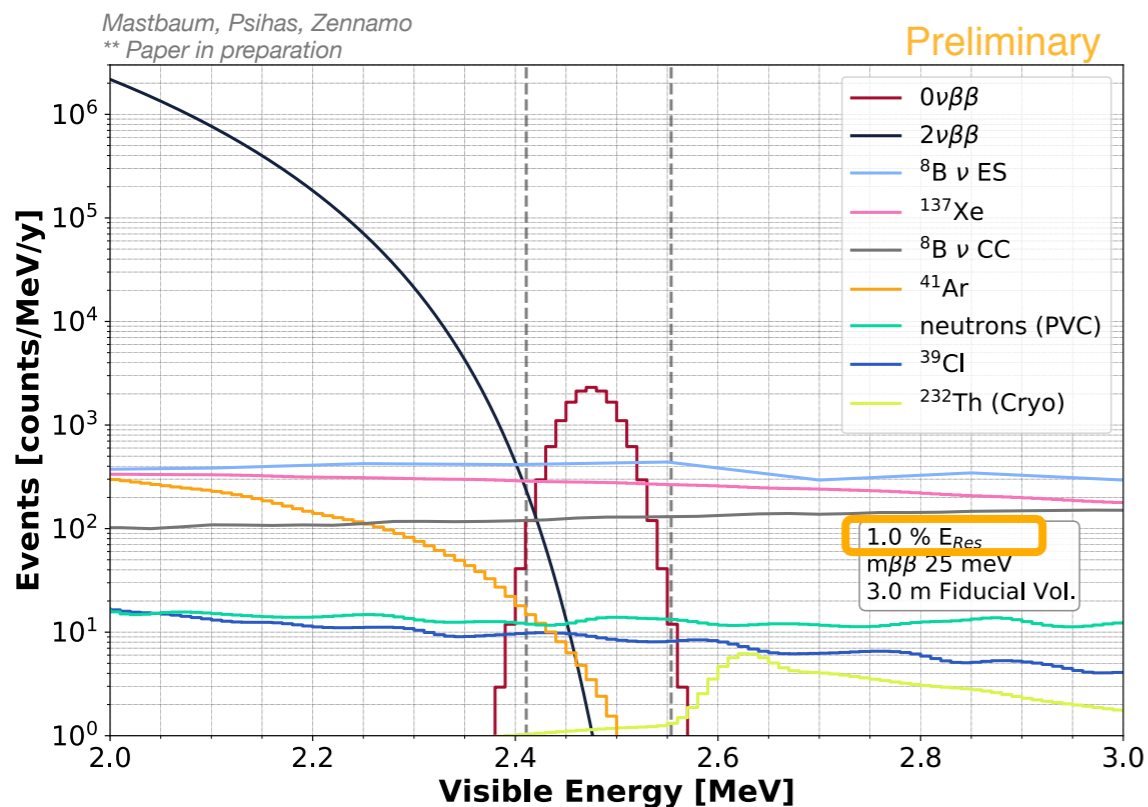
# BACKGROUNDS HONORABLE MENTIONS



Solar  
Spallation

Background reduction  
for the remaining  
backgrounds relies on  
Photon coincidence  
and Muon coincidence

# BACKGROUNDS AND ENERGY RESOLUTION



Energy resolution is a crucial component of this concept.  $E_{Res} < 5\%$  is essential to reduce the  $2\nu\beta\beta$  background.



# ENERGY RESOLUTION

DUNE's light collection efficiency is low by design. MeV energy measurement would come exclusively from the ionization signal.

We propose adding **photosensitive dopants** to convert some of the scintillation light into ionization.

These dopants would enable an energy resolution as good as  $\sim 1\%$  in the energy range of interest.

## NECESSARY MODIFICATIONS

Photosensitive dopants added to the LAr

## NEW R&D QUESTIONS

Optimal photosensitive dopants.

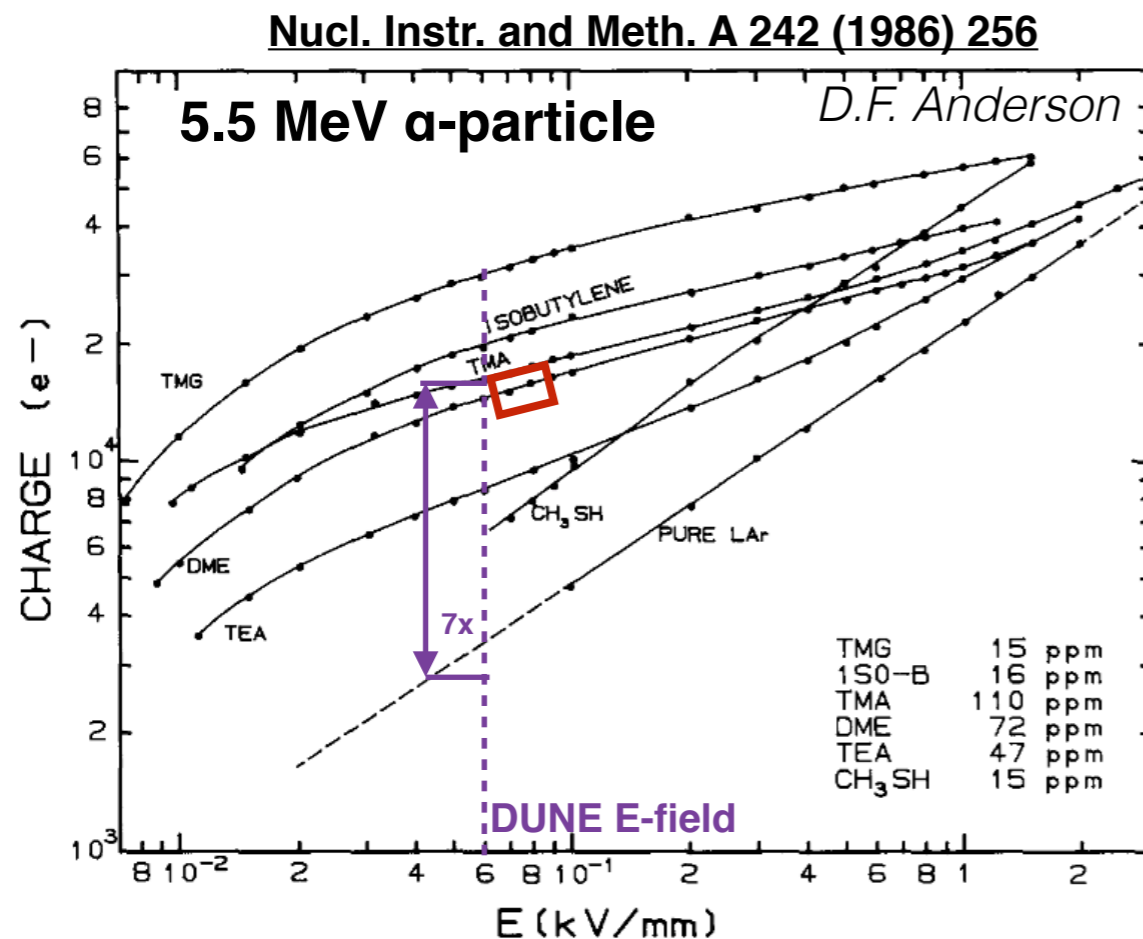
Test pixelated readouts for thresholds and energy resolution improvements.

Study the effects on remaining scintillation light.

## EFFECT ON DUNE'S PHYSICS

Can we keep enough light for timing?

Can we introduce and recover dopants?



# XENON DOPING

Xenon doping has been demonstrated at 2%.

The effect of filtering and high pressure on the Xe-doped Ar solution is unknown.

Current production of natural Xe is ~60tons per year worldwide. Reliant on developing R&D in industry for Xe extraction and enrichment.

WHAT WOULD NEED TO BE MODIFIED?

Xe doping at 2%

NEW R&D QUESTIONS

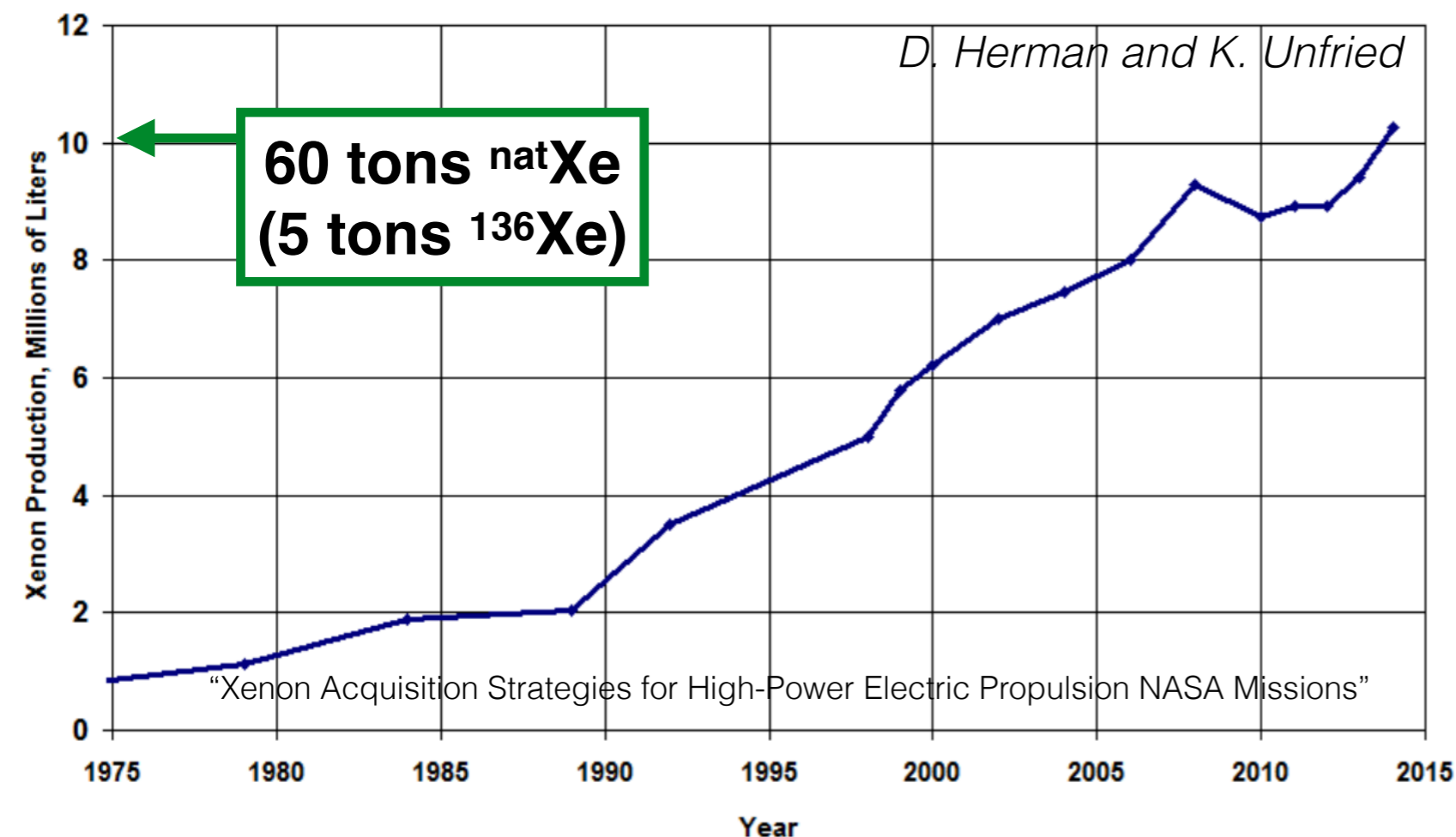
Design of systems for injection, filtration (and recovery?)

Doping tests in a cryogenic environment

EFFECT ON DUNE'S PHYSICS

Microphysics of adding Xe

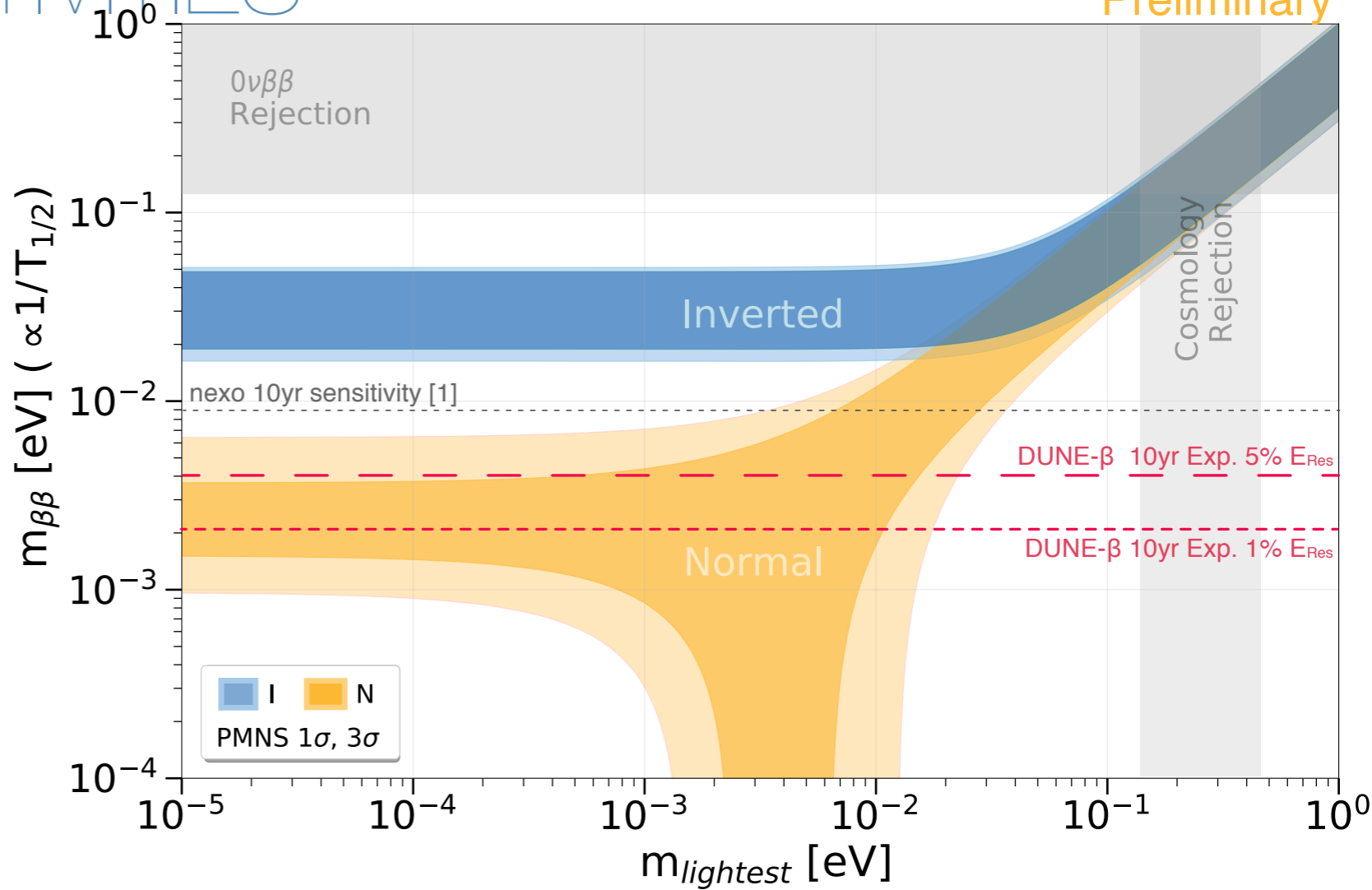
Xe effects on scintillation yields



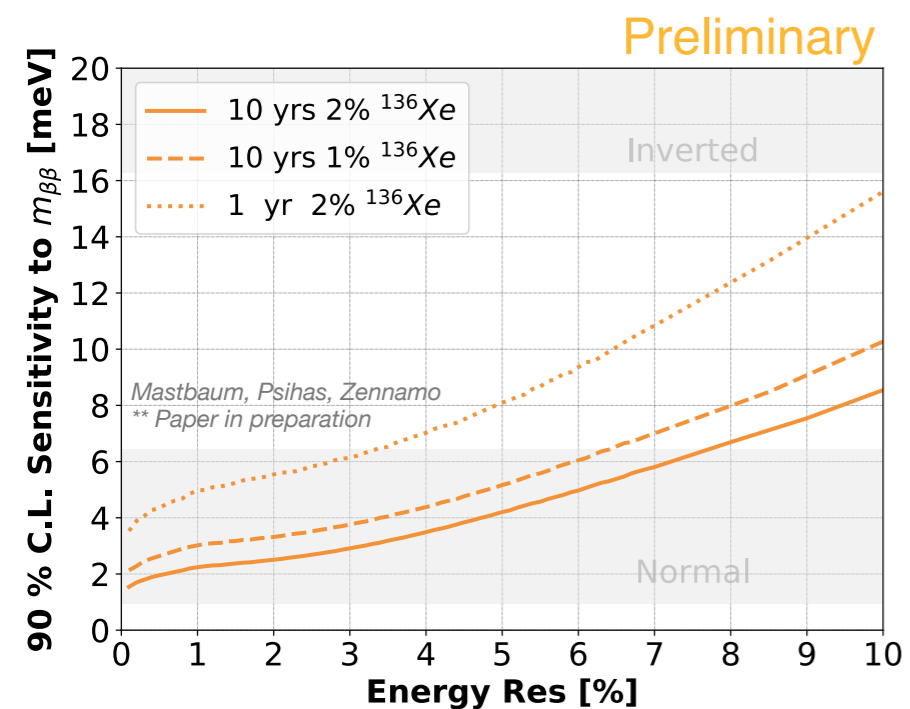
# ESTIMATED SENSITIVITIES

We perform a counting analysis with 2%  $^{136}\text{Xe}$ , 10 year exposure, and 1% energy resolution, DUNE- $\beta$ .

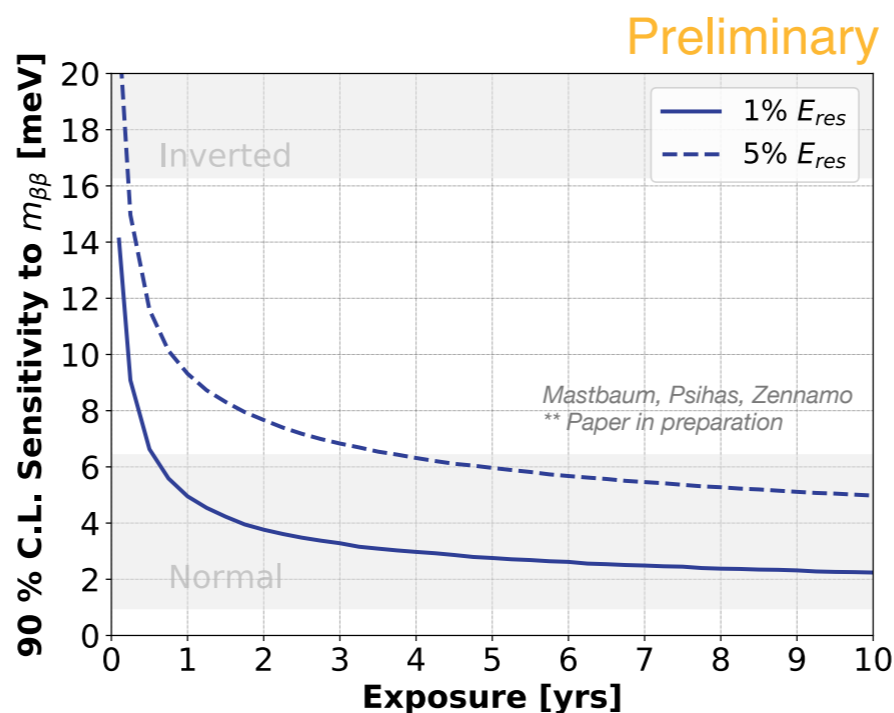
There is room for modifying this base-concept while still attaining sensitivities in the 2-4 meV range.



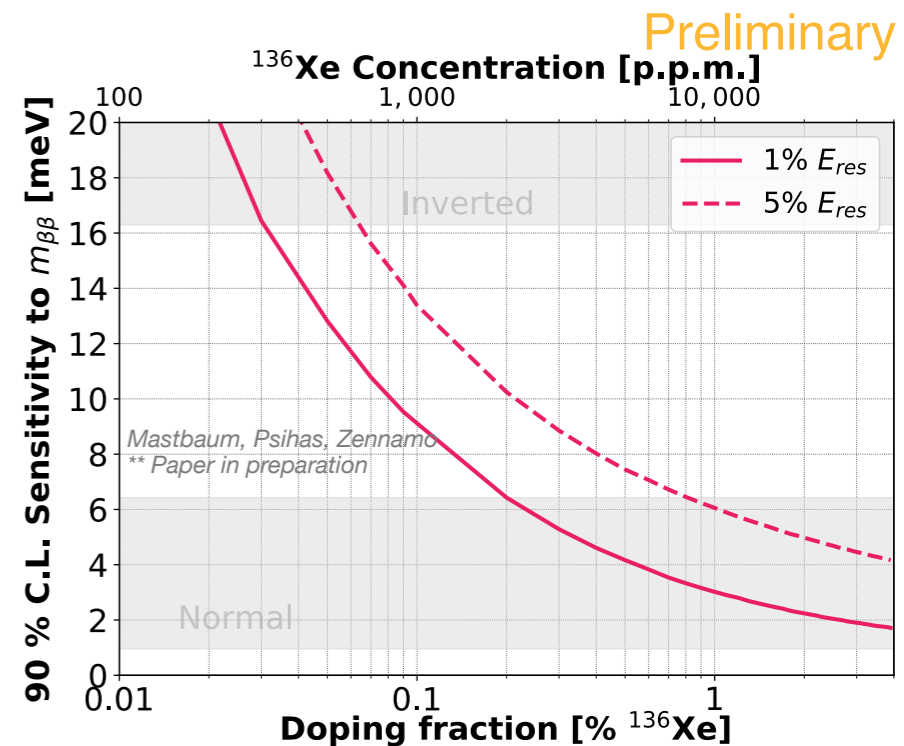
Preliminary



Preliminary



Preliminary



Preliminary

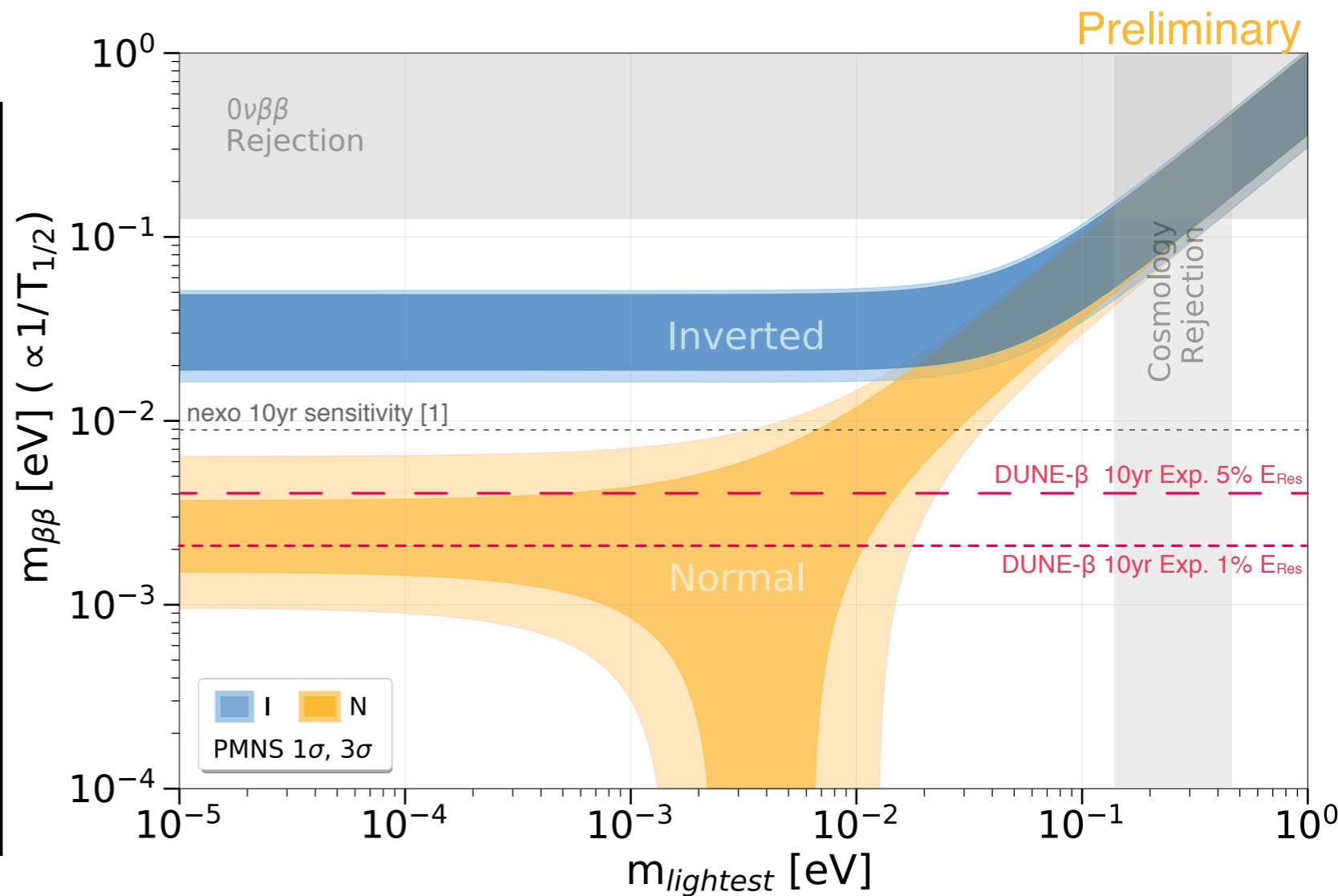
# SUMMARY

The DUNE- $\beta$  concept could extend DUNE's physics program with sensitivities to  $0\nu\beta\beta$  decay as low as  $m_{\beta\beta} \sim 2\text{meV}$ .

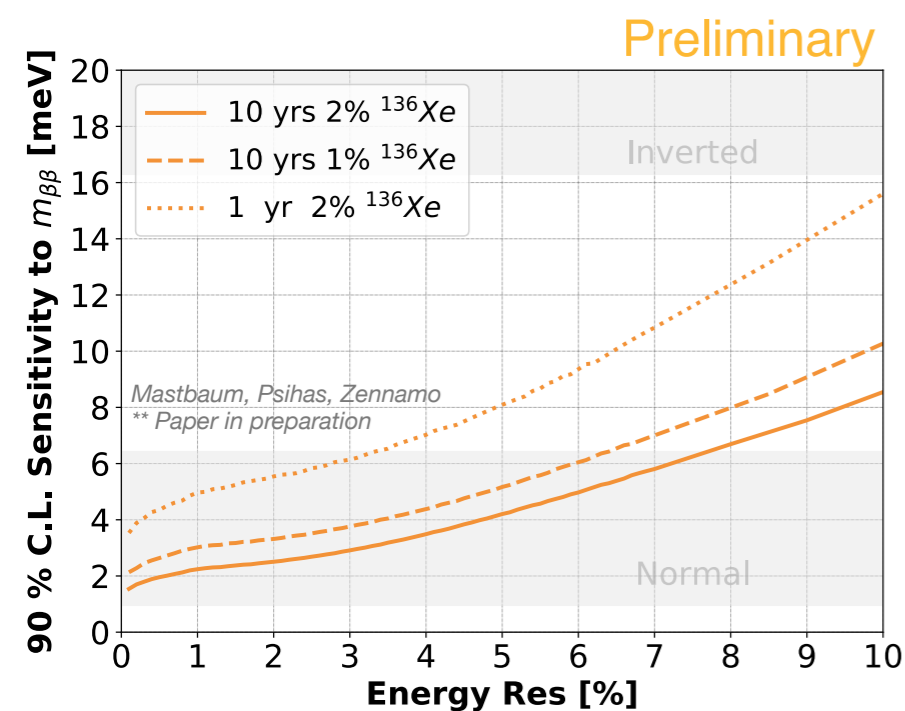
This concept employs **Xe-doping**, **photo-sensitive dopants**, **depleted argon**, and an **external overburden** compatible with other low energy physics concepts for DUNE.

The required modifications open a **rich R&D program** in detector technology, analysis techniques, microphysics, etc.

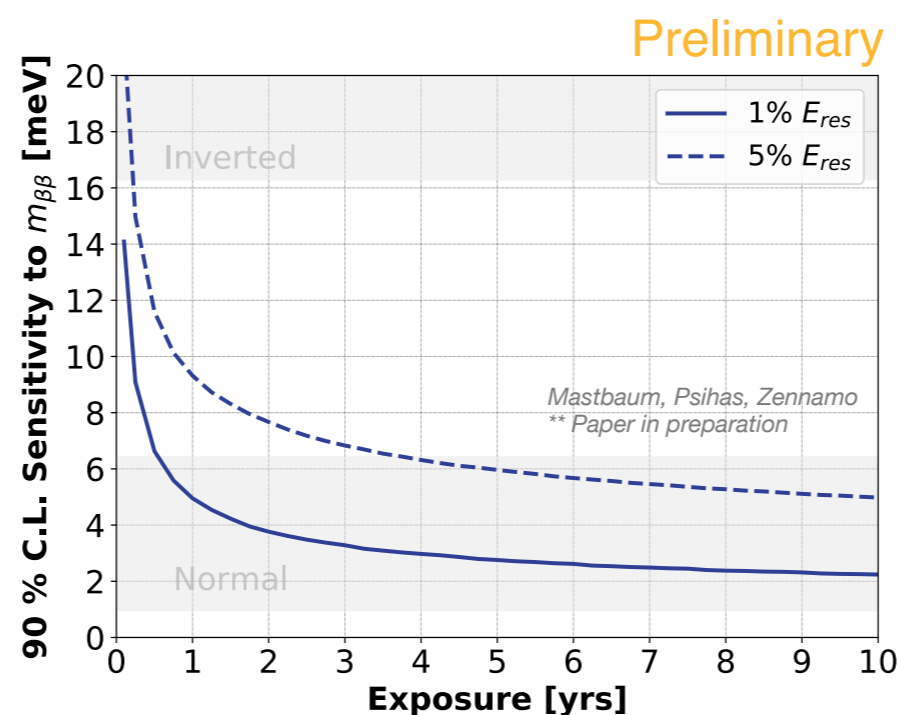
\*Coming to the arxiv very soon\*



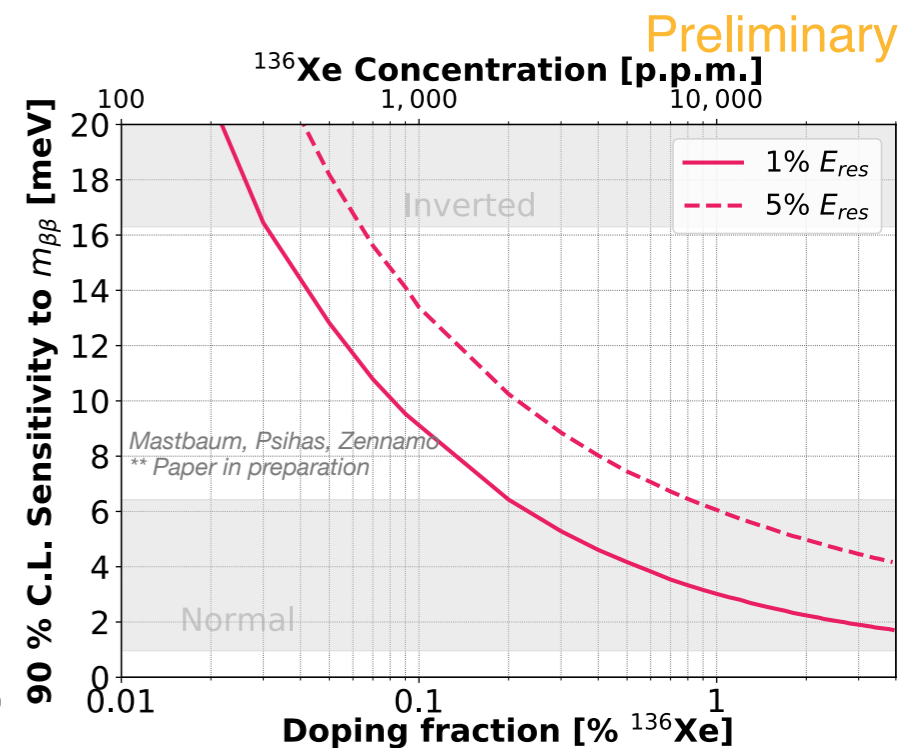
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