The NEXT-100 time projection chamber and electroluminescent region

Helena Almazán, on behalf of the next collaboration

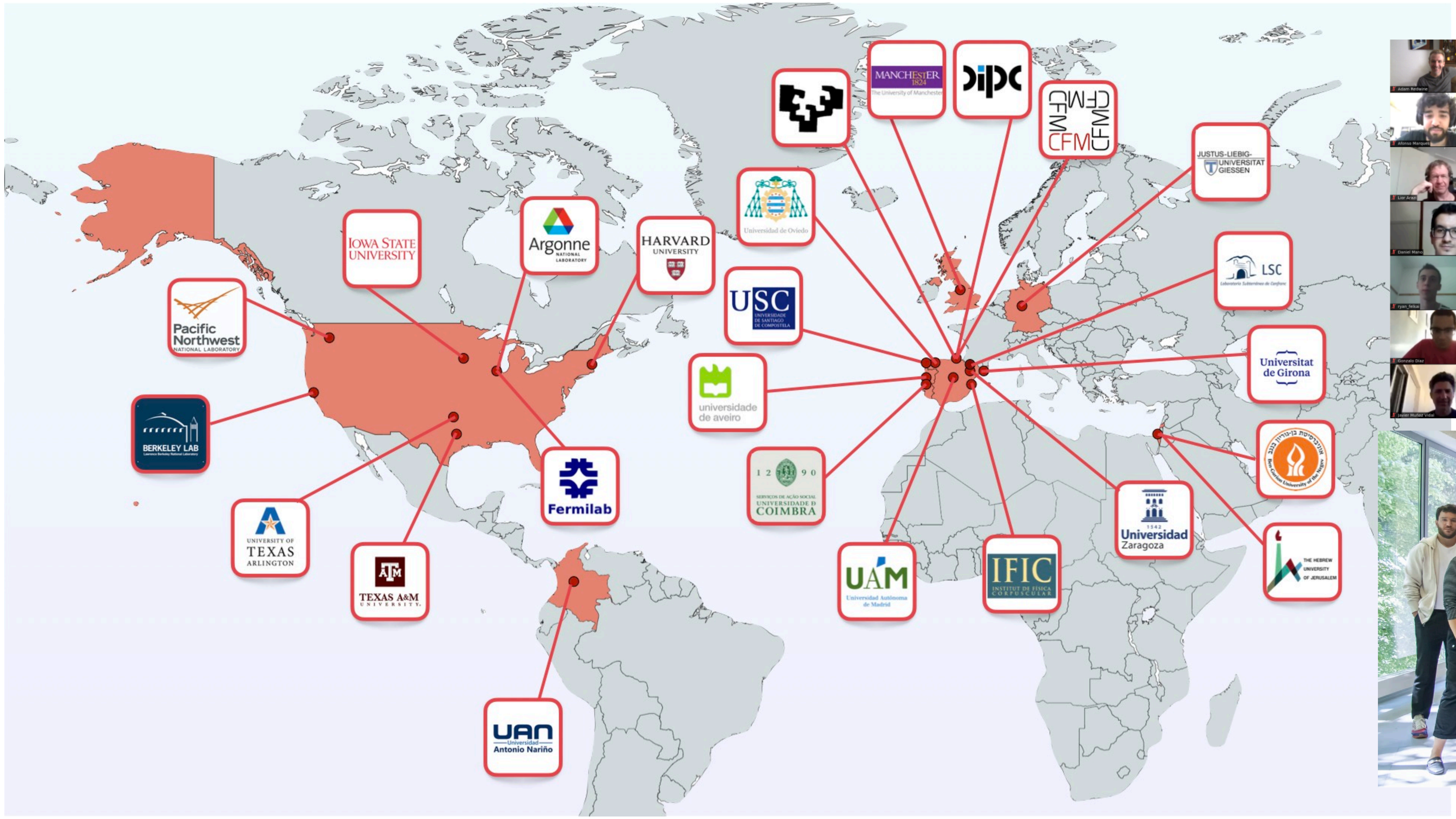
HARVARD UNIVERSITY

erc

ICHEP Bologna, Italy - July 9 2022

The @next* collaboration

*Neutrino Experiment with Xenon TPC



June 2020

Spokespersons: J. J. Gomez-Cadena (Spain), D. Nygren (USA)

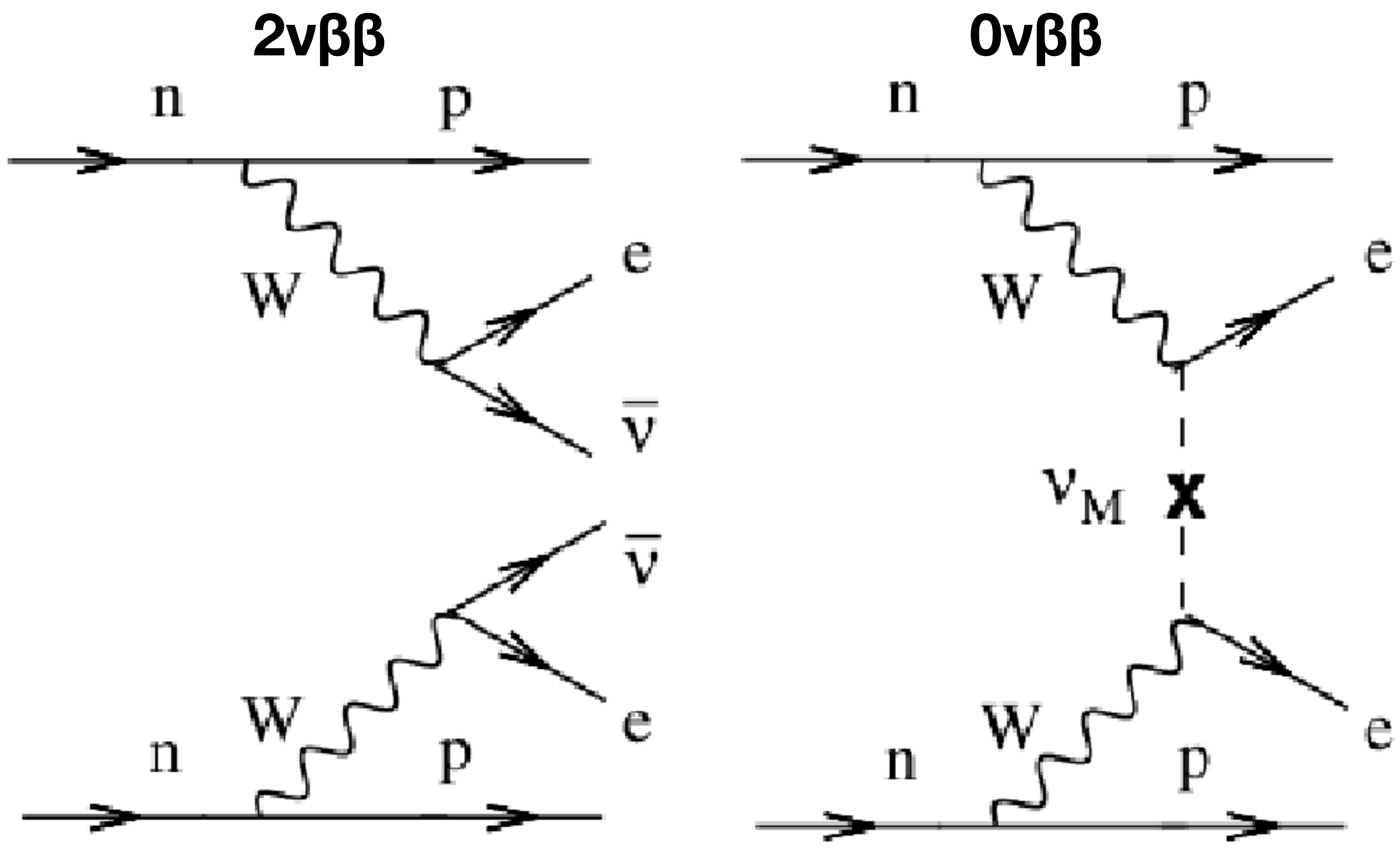
The next motivation

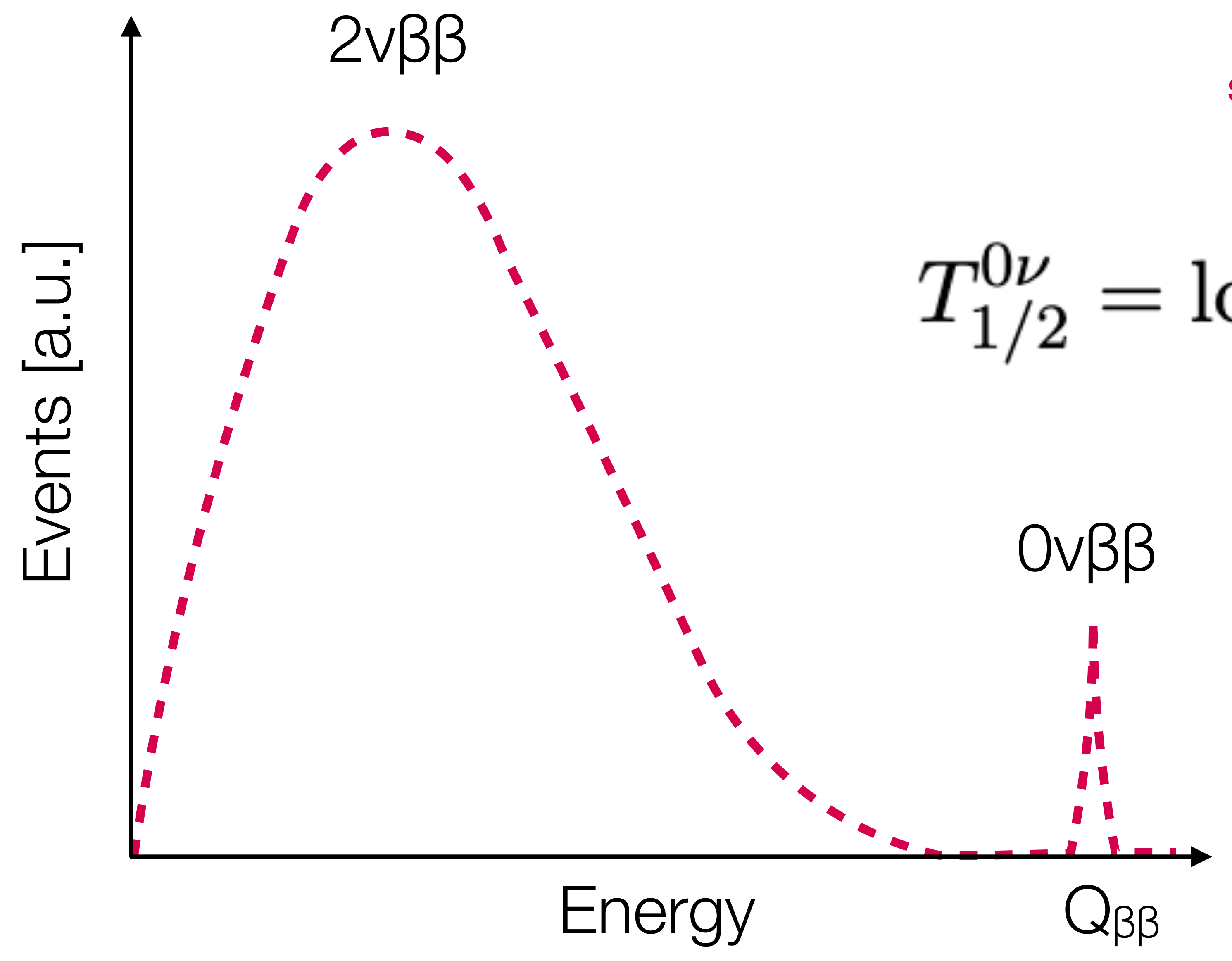
Demonstrate neutrino is a **Majorana particle**
(= neutrinos are their own antiparticle)
by detecting the **neutrinoless double beta decay process**

Search for 0νββ requires:
- Great **energy resolution**
- Extremely **low background**
- Scalability

next

High Pressure Gaseous Xenon Time Projection Chamber with Electroluminescent Amplification

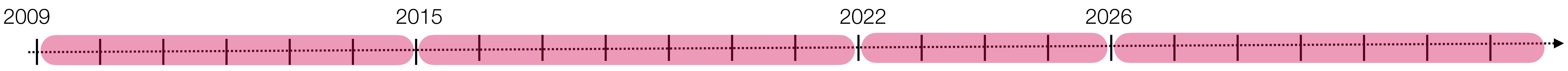




$$T^{0\nu}_{1/2} = \log 2 \, \frac{N_A}{W} \, \frac{\varepsilon \, M \, t}{N}$$

signal detection efficiency
[source mass x measuring time]
number of events

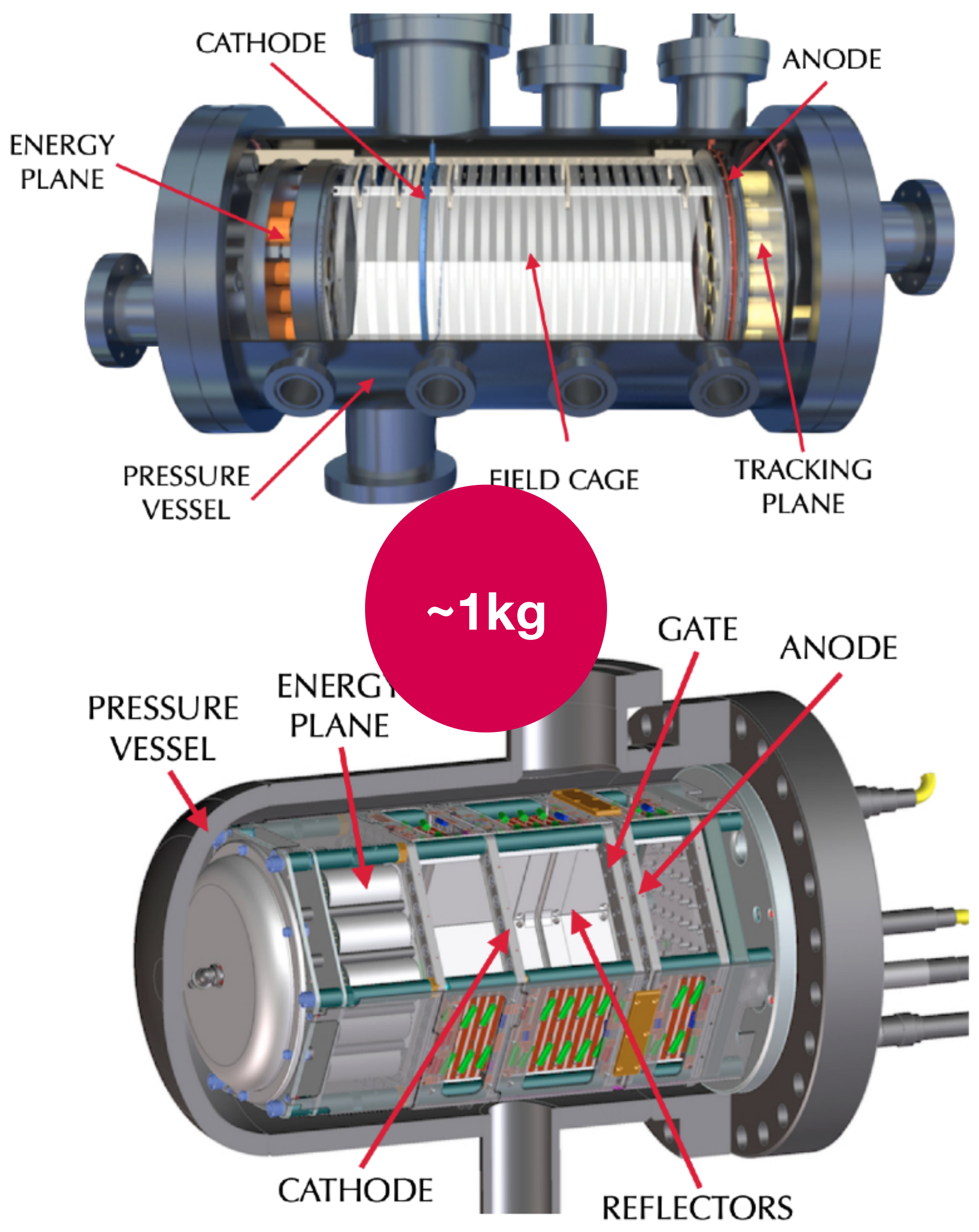
The next programme



PROTOTYPES

2009/2014

Demonstration of the detector concept

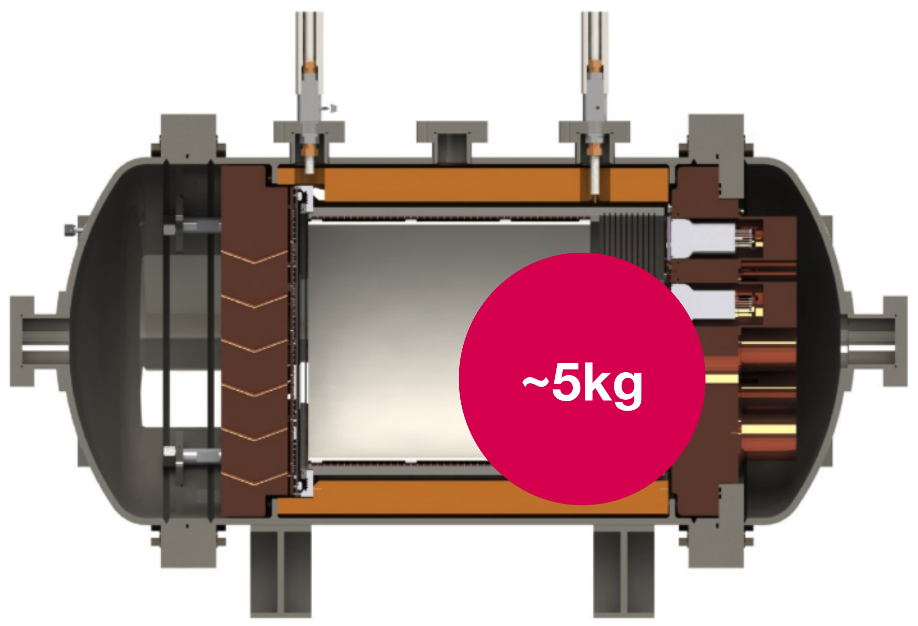


NEXT-WHITE (NEW)

2015/2021

Background model assessment

$2\nu\beta\beta$ measurement for ^{136}Xe



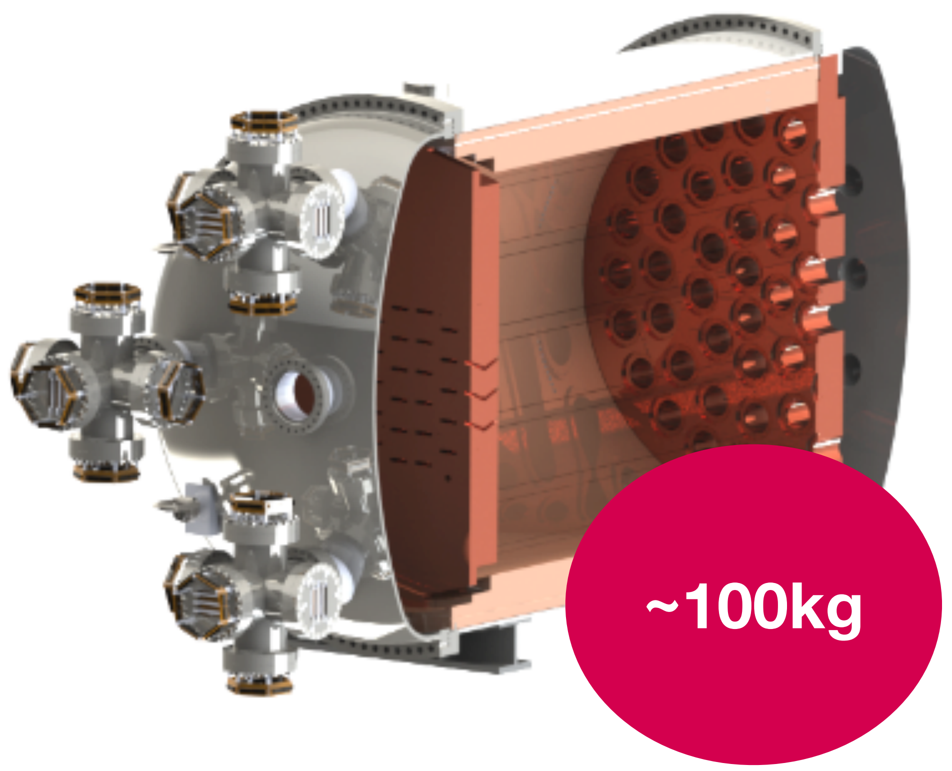
@ LSC Laboratorio Subterráneo de Canfranc

NEXT-100

2022/2025

Background model assessment

Neutrinoless double beta decay search in ^{136}Xe



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NEXT-HD

2026?

Neutrinoless double beta decay search through inverted neutrino mass ordering

NEXT-BOLD

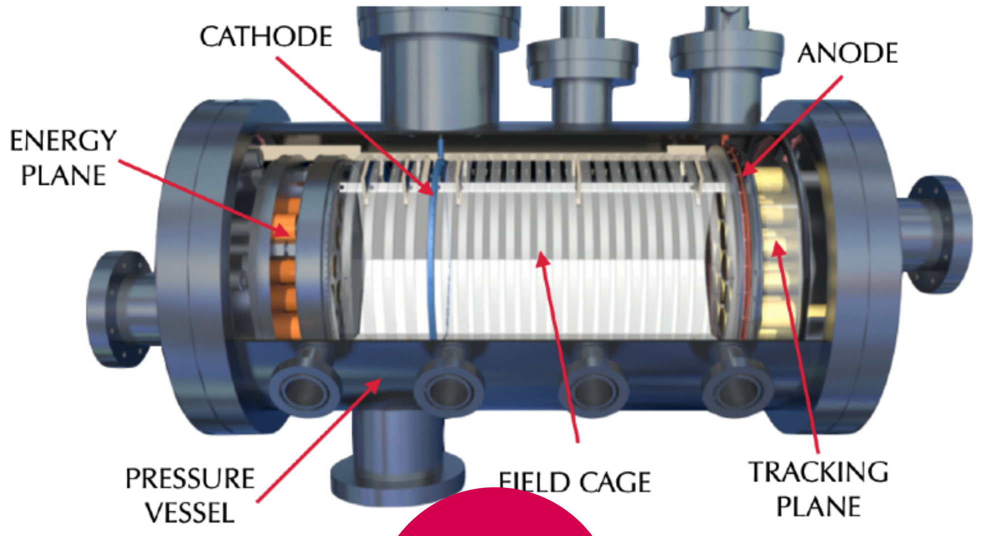
Barium tagging for background-free experiment inverted neutrino mass ordering

The next programme

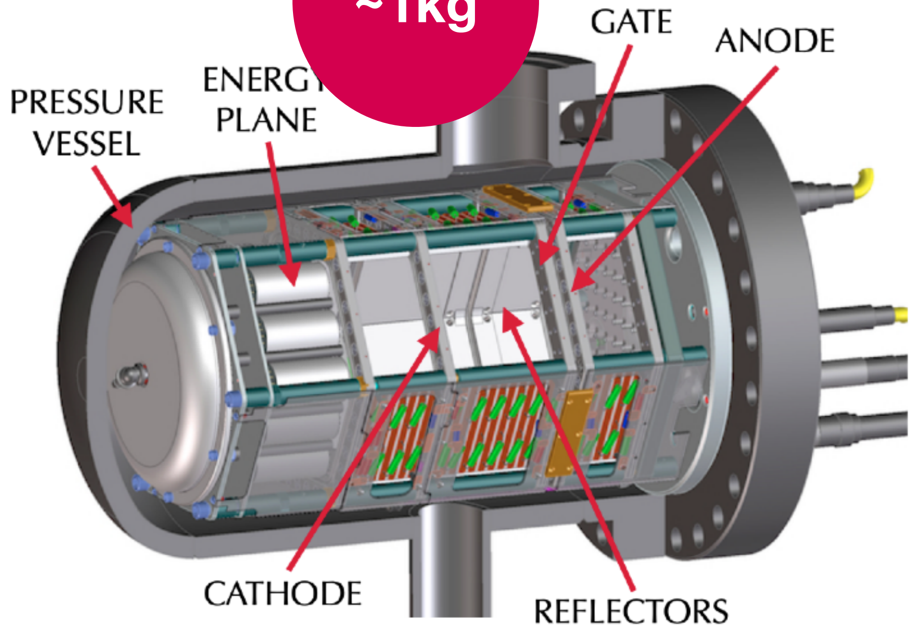
2009 2015 2022 2026

PROTOTYPES
2009/2014

Demonstration of the detector concept



~1kg



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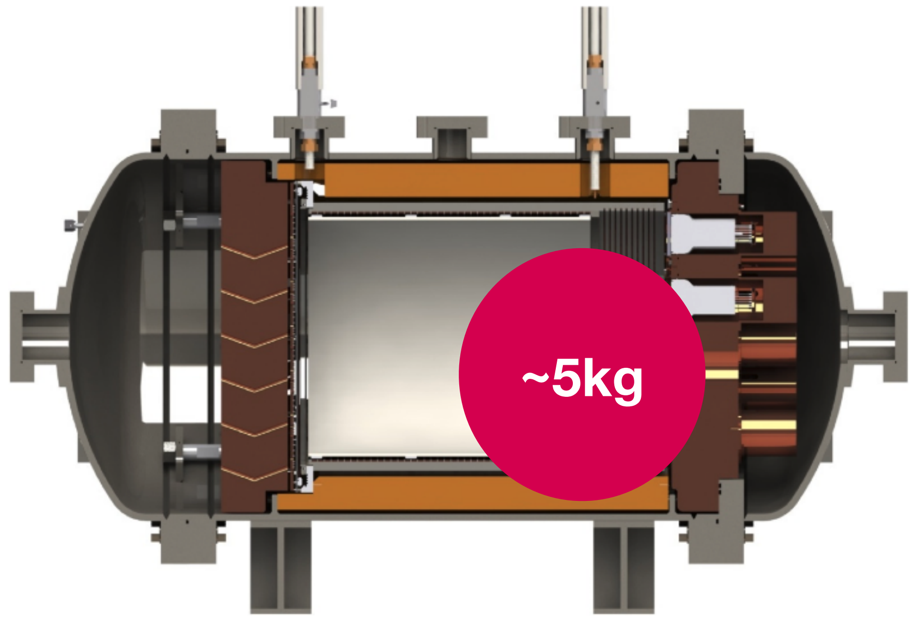

~5kg

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Talk by A. Redwine

NEXT-100
2022/2025

Background model assessment

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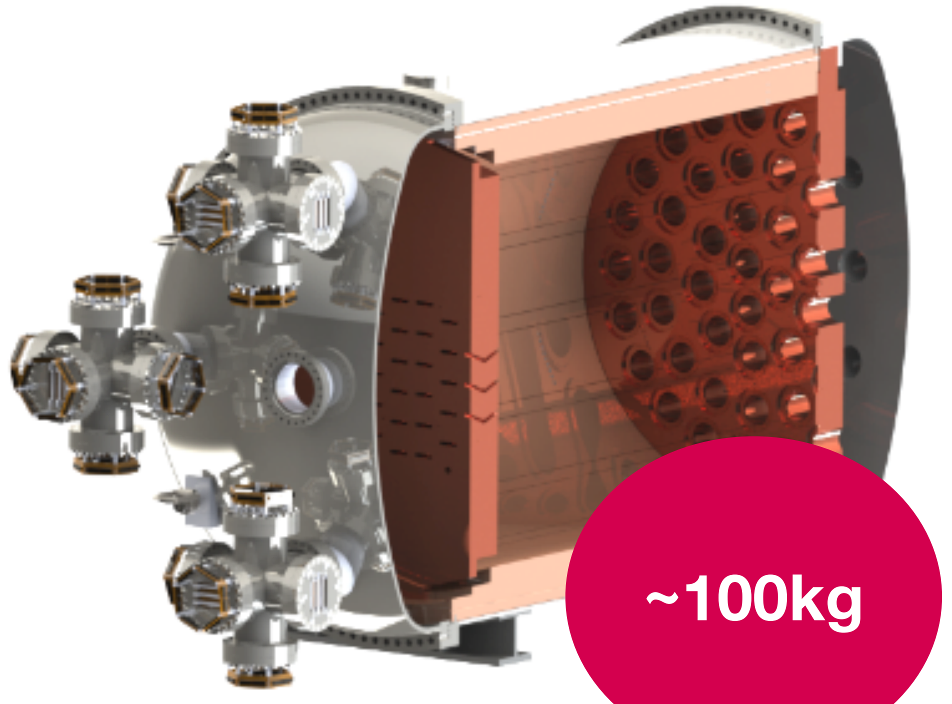


~100kg

@ LSC Laboratorio Subterráneo de Canfranc

This talk

NEXT-HD
2026?

Neutrinoless double beta decay search through inverted neutrino mass ordering

NEXT-BOLD

Barium tagging for background-free experiment inverted neutrino mass ordering

1T

Talk by P. Herrero

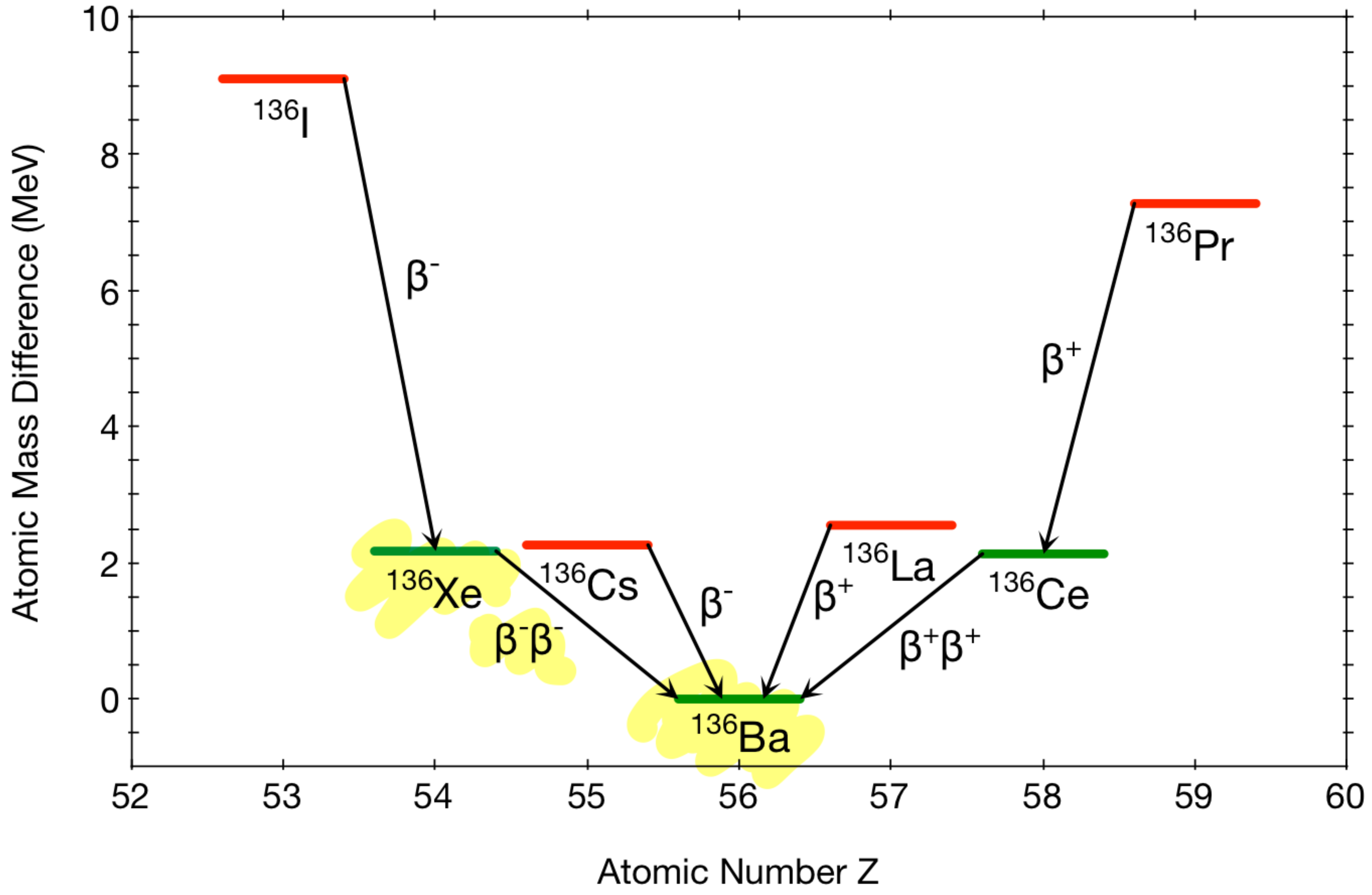
The next detector concept

High Pressure Gaseous Xenon Time Projection Chamber with Electroluminescent Amplification

The next detector concept

High Pressure Gaseous Xenon Time Projection Chamber with Electroluminescent Amplification

^{136}Xe Isotope: High enough abundance
$Q_{\beta\beta}$ = 2.5 MeV
Noble gas → ideally suited to detection technology (TPC)



The next detector concept

High Pressure Gaseous Xenon Time Projection Chamber with Electroluminescent Amplification

Fully active and homogenous detector
→ source = detector
Great intrinsic energy resolution in gas

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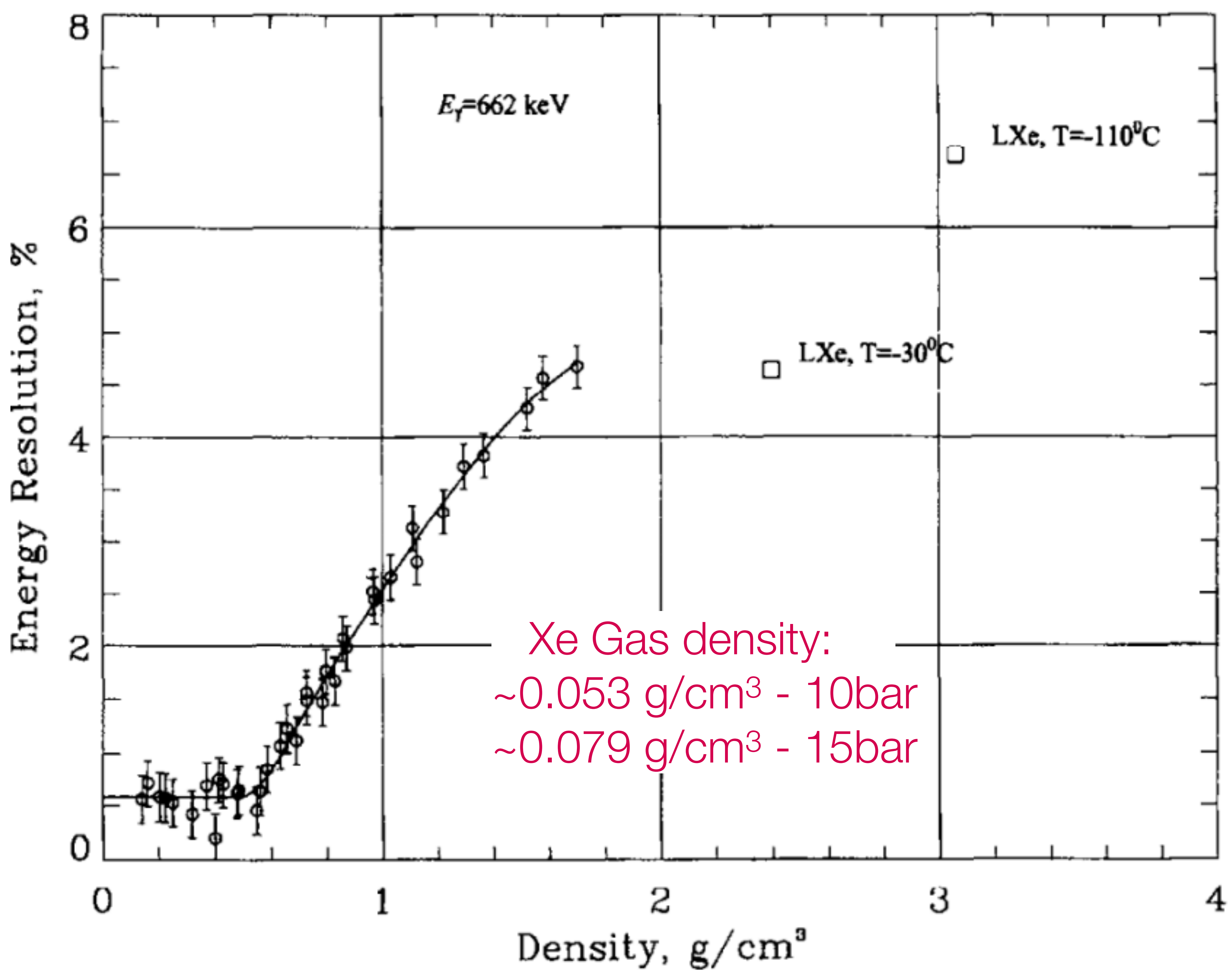
Noble gas → ideally suited to detection technology (TPC)

Bolotnikov and Ramsey, NIM A 396 (1997) 360



Xe Gas density:
~0.053 g/cm^3 - 10bar
~0.079 g/cm^3 - 15bar

The next detector concept

High Pressure Gaseous Xenon Time Projection Chamber with Electroluminescent Amplification

More isotope in the same volume

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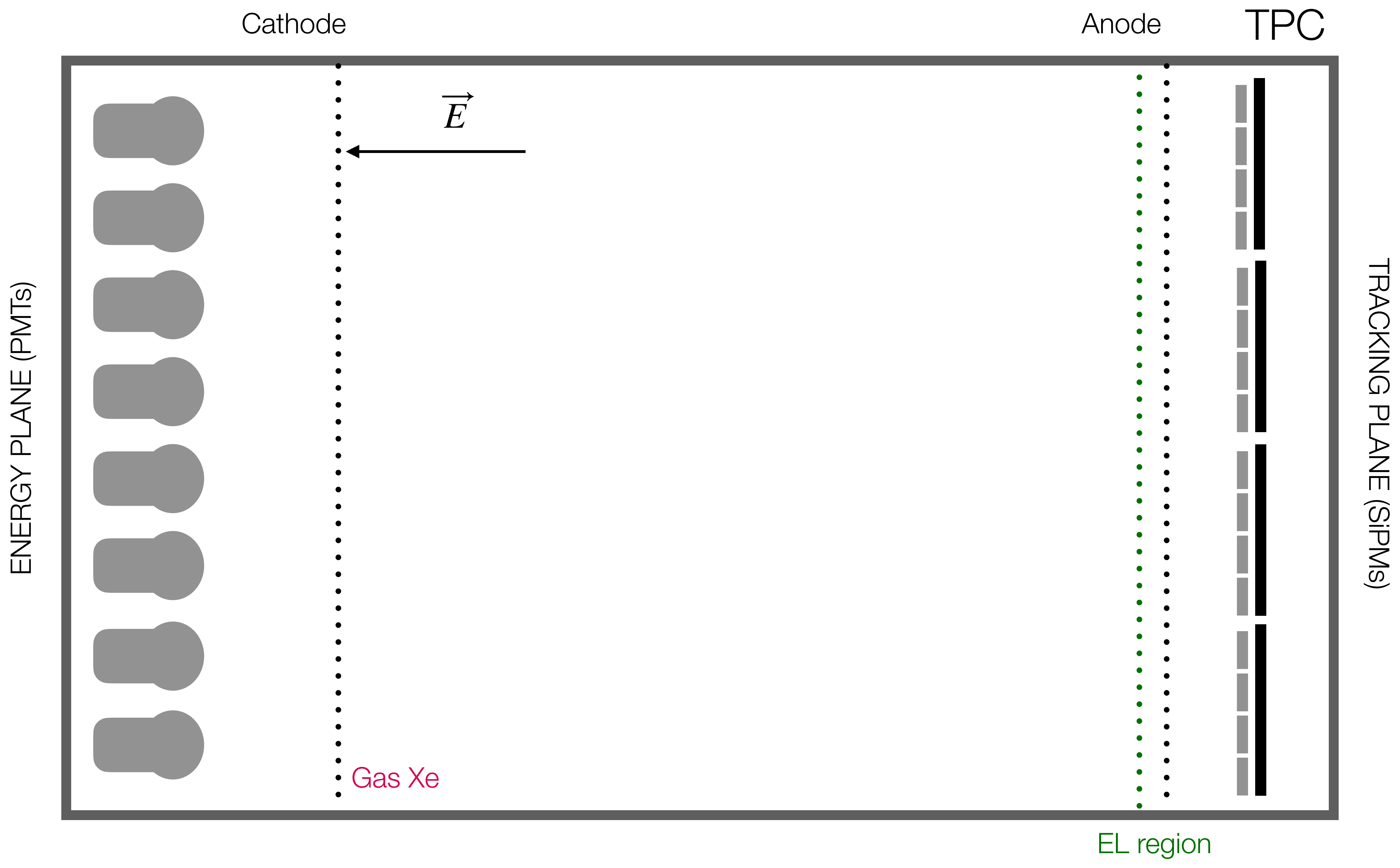

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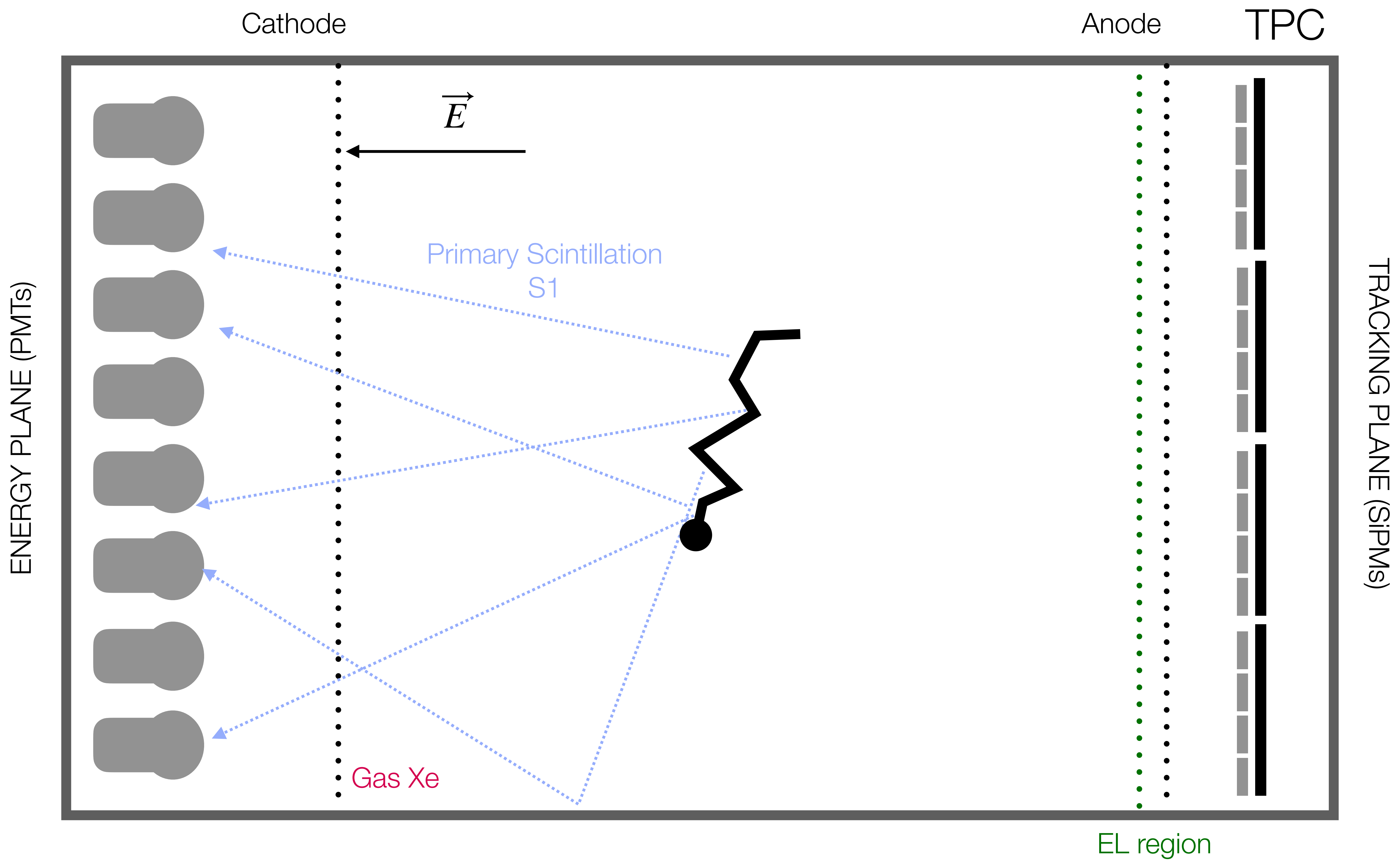

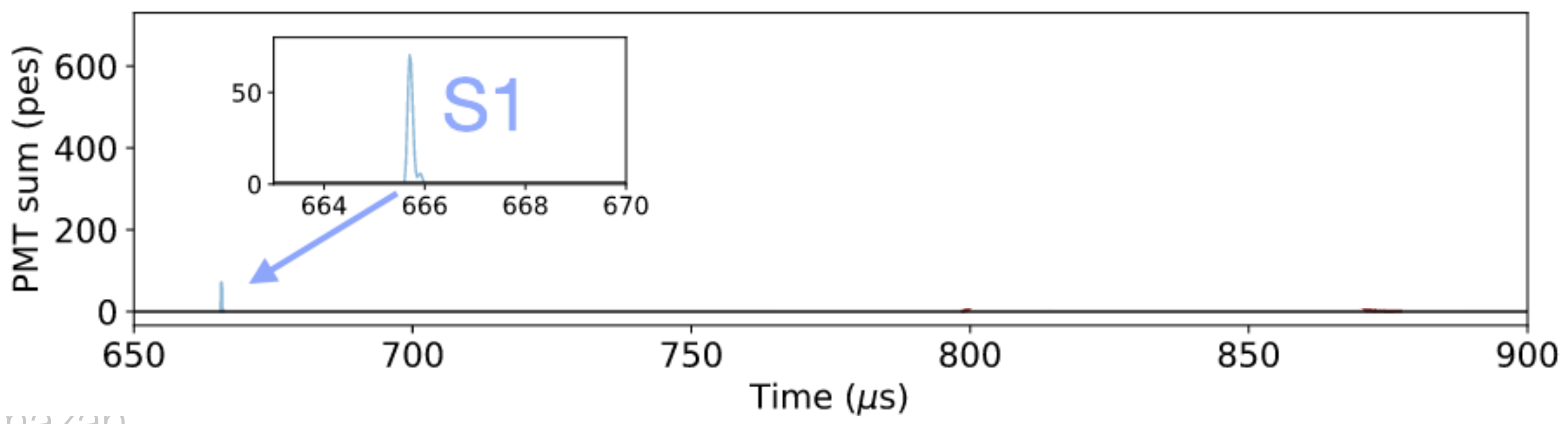

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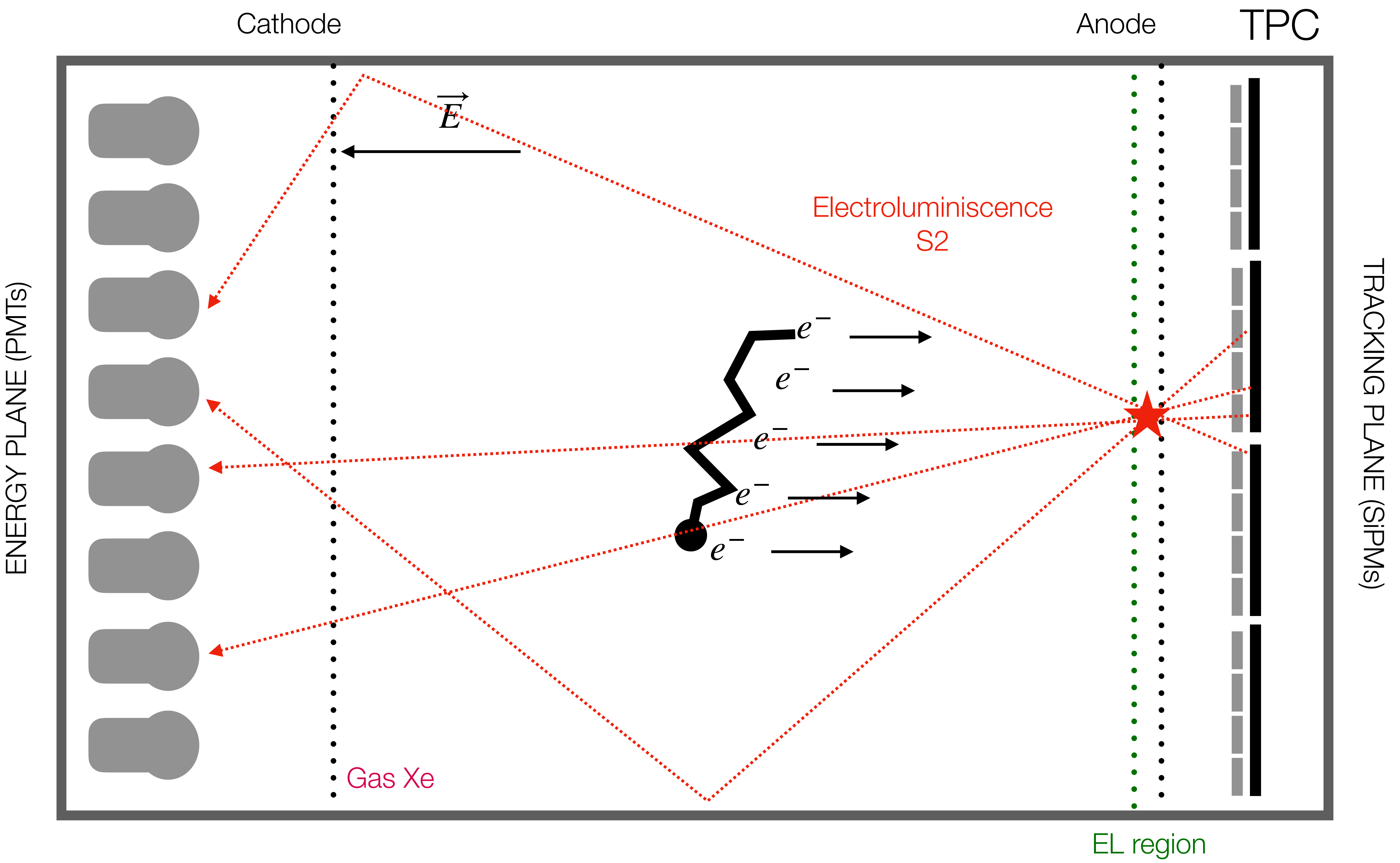
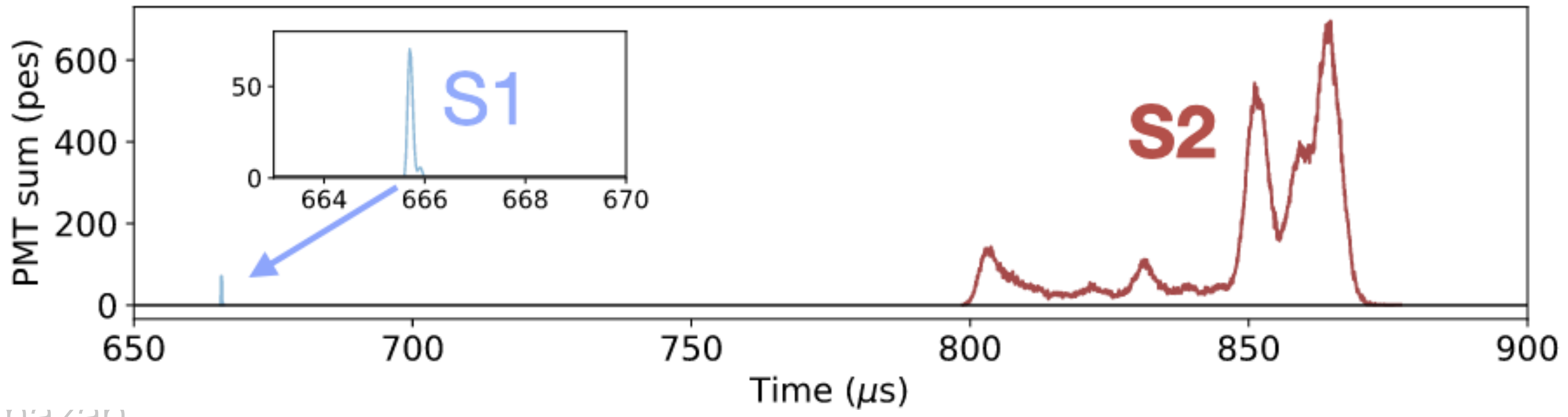
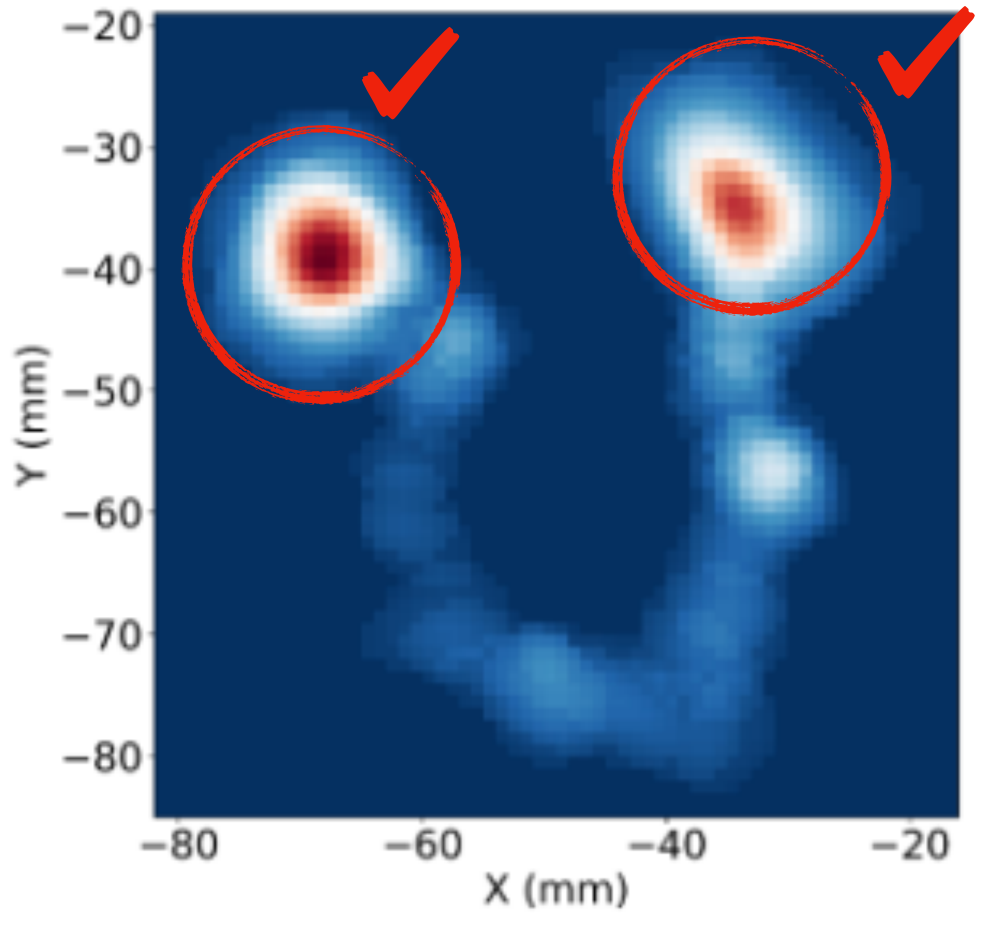




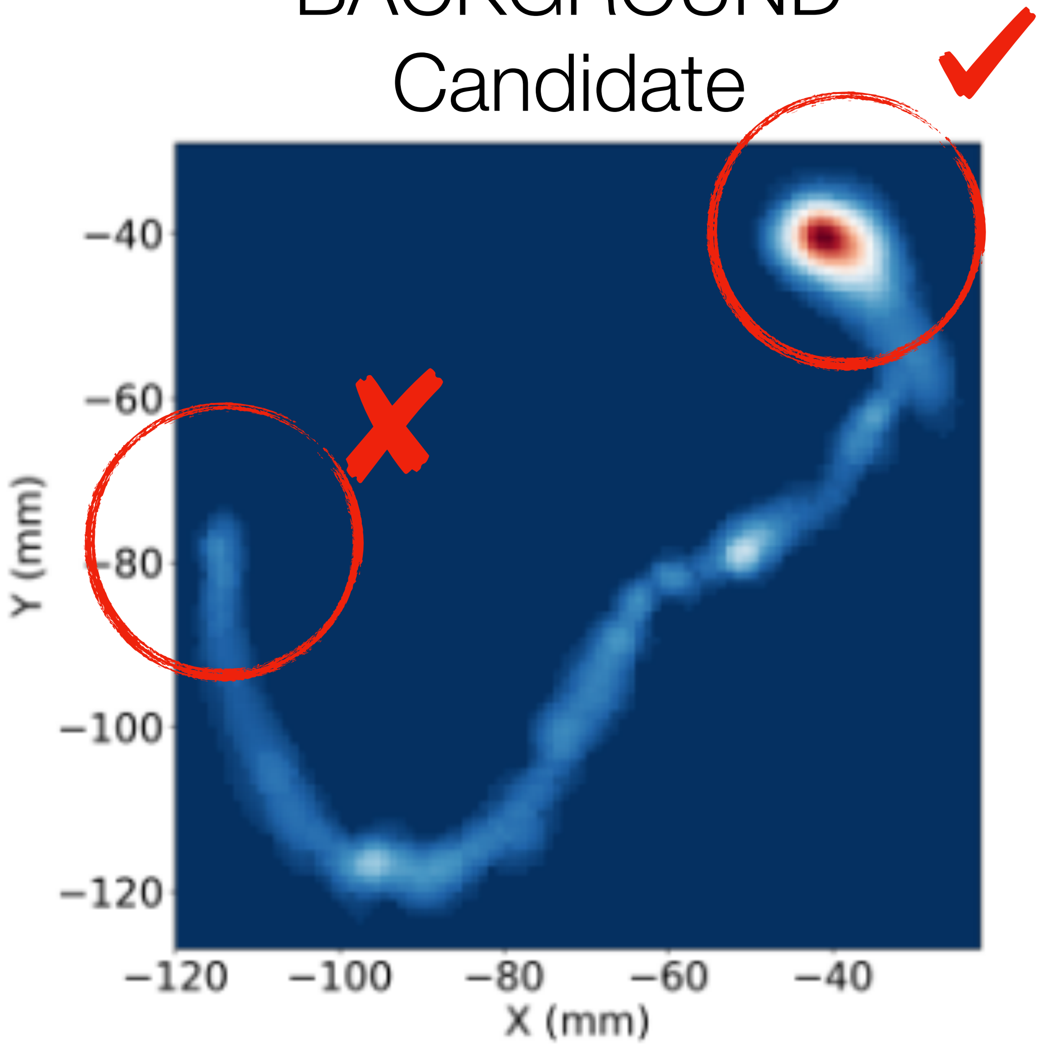
The next detector concept

High Pressure Gaseous Xenon Time Projection Chamber with Electroluminescent Amplification

SIGNAL
2νββ candidate



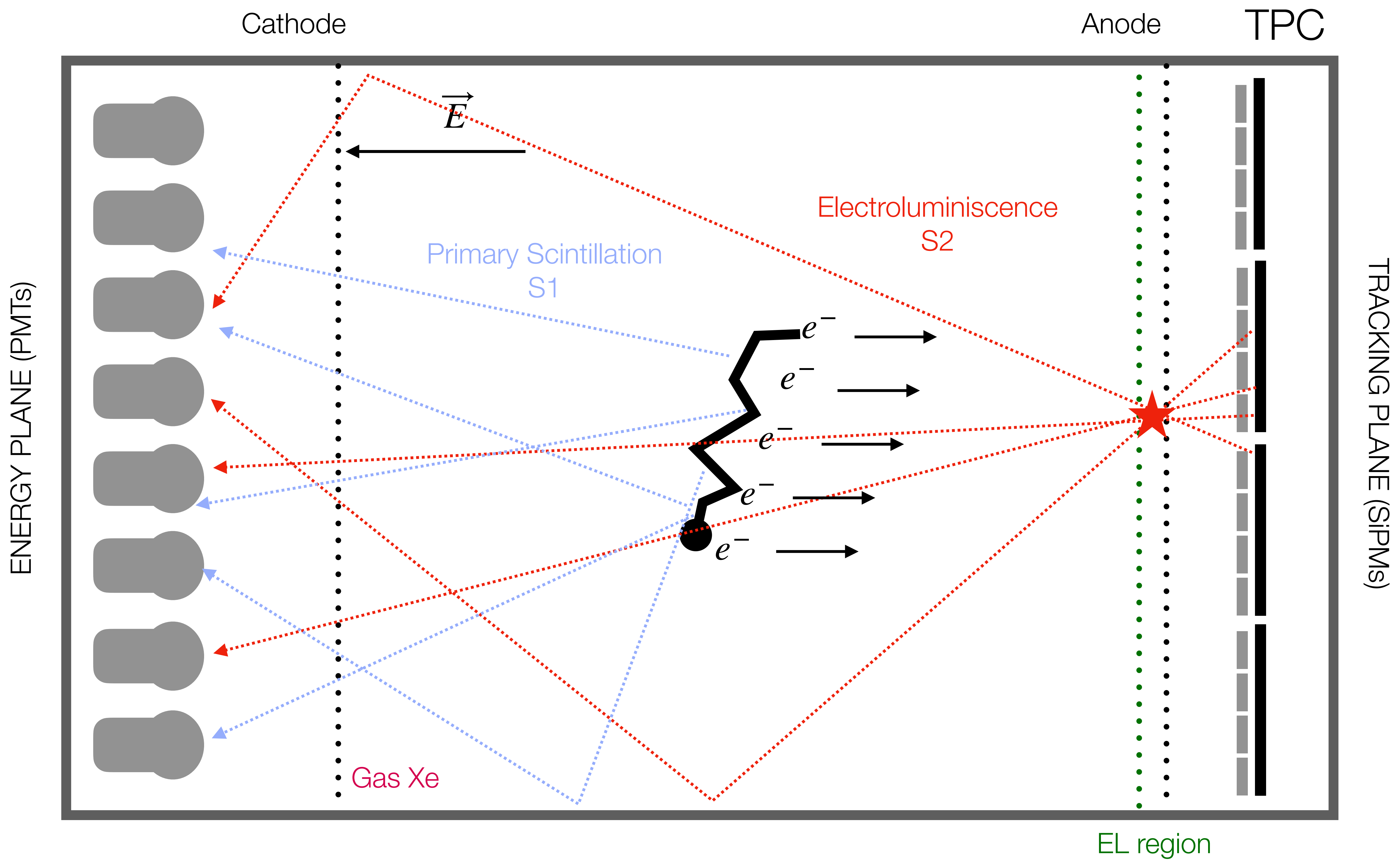
BACKGROUND
Candidate

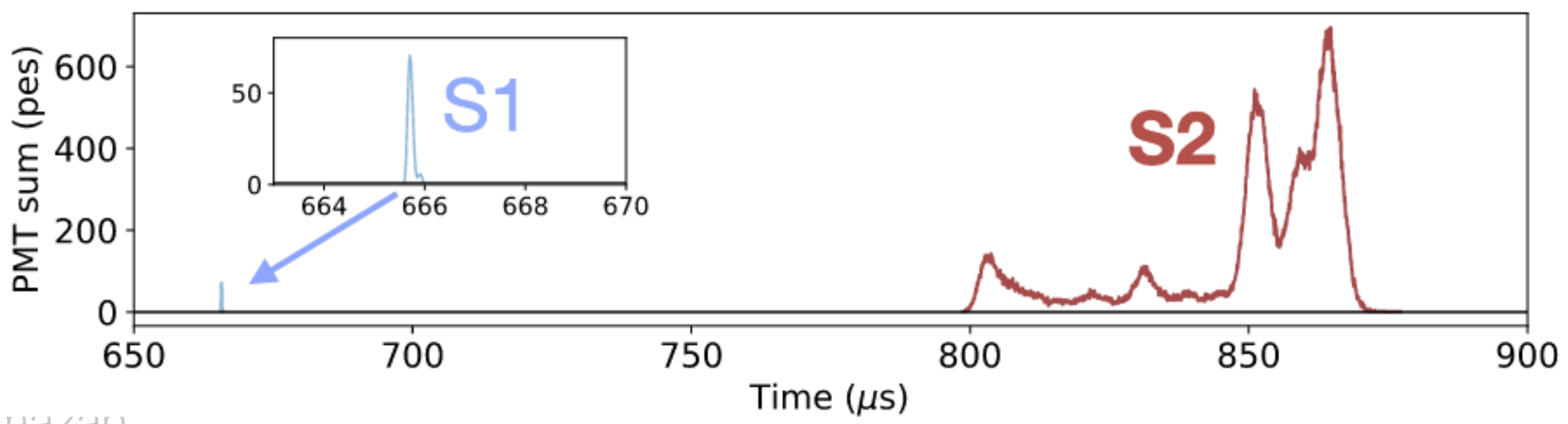


TPC allows 3D event reconstruction → improvement signal over background

Search for 0νββ requires:

- Great **energy resolution**
- Extremely **low background**
- Scalability



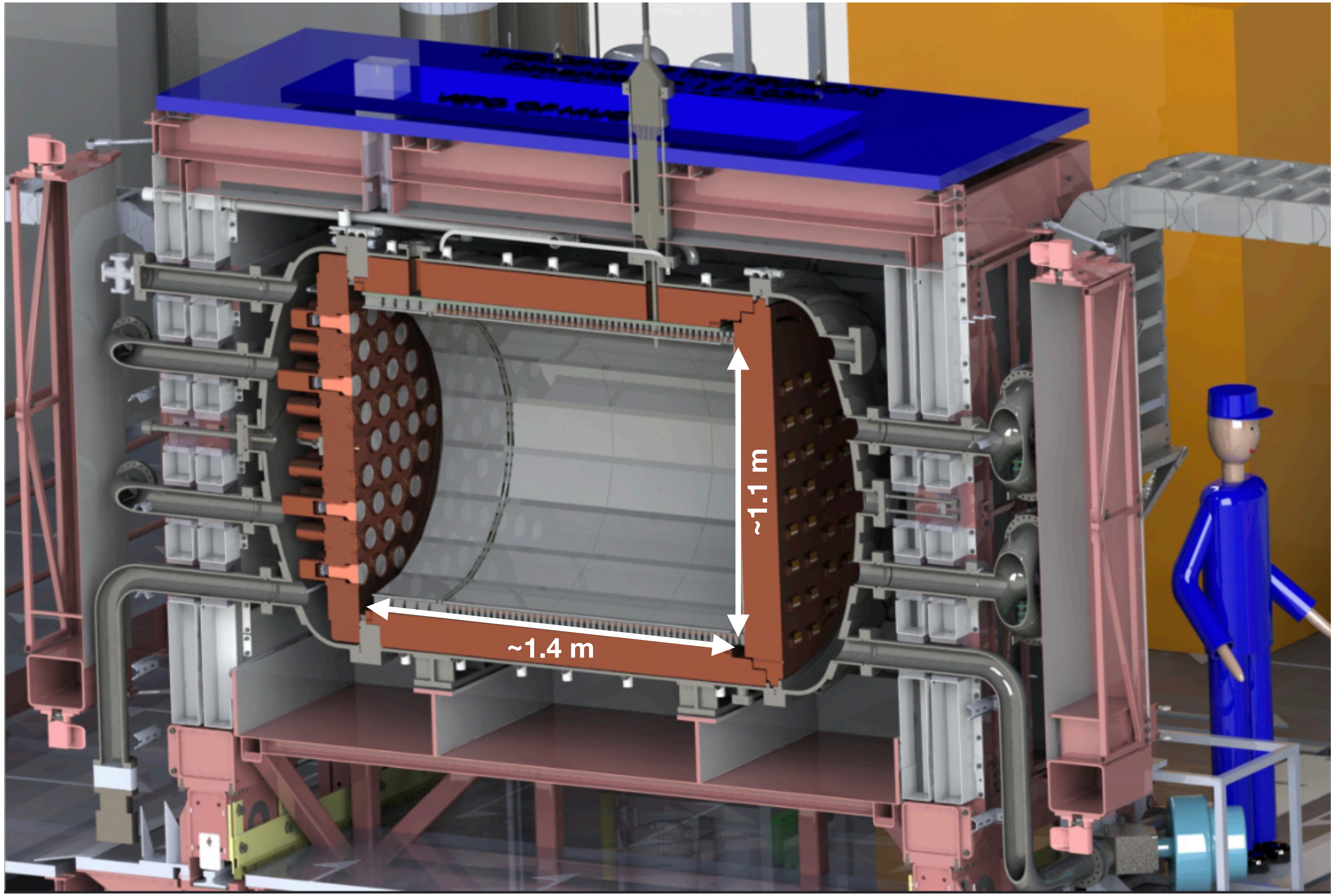


The NEXT-100 detector

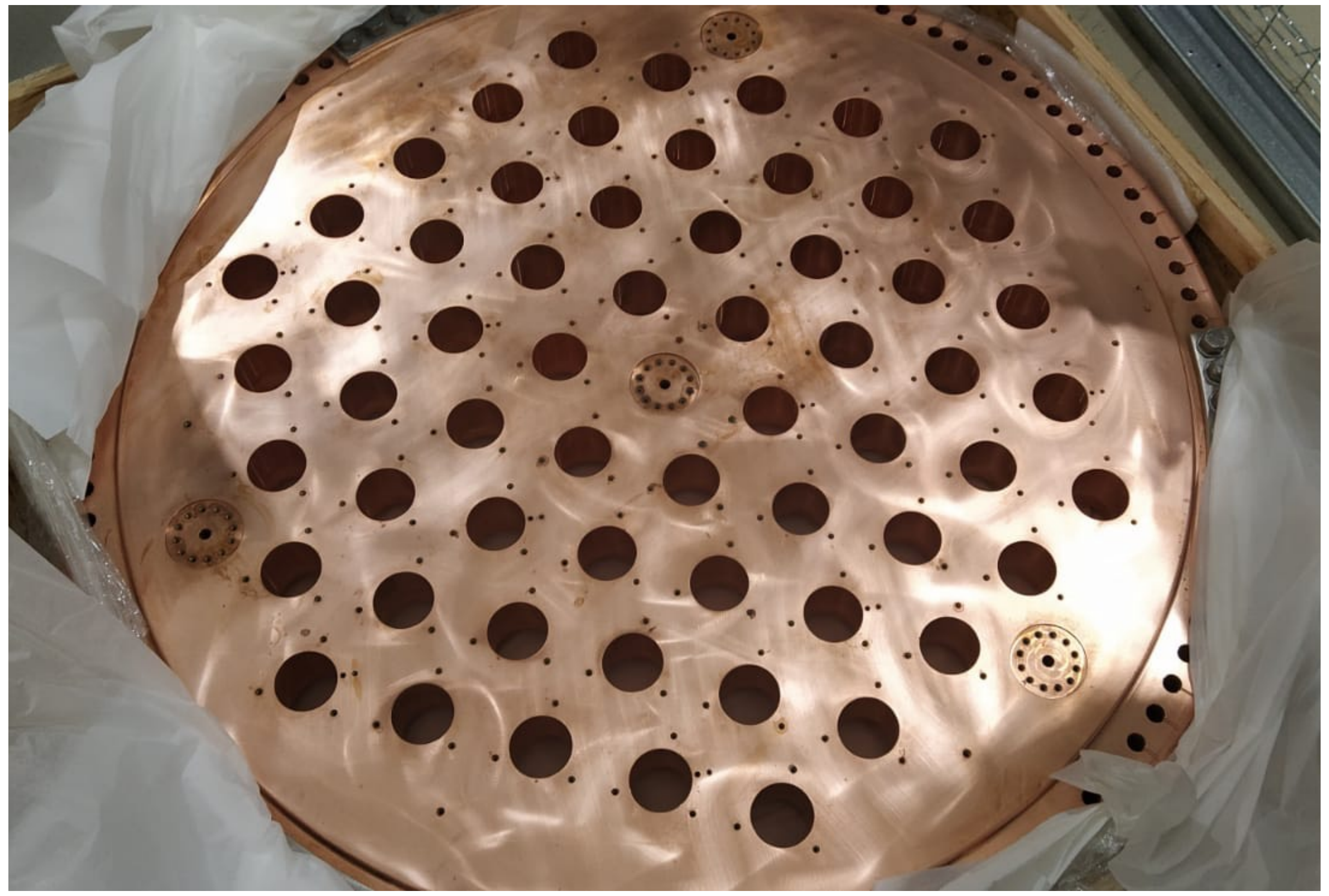
- **Currently**:
  construction and assembly
- **End of 2022**: commissioning

NEXT-100 detector:

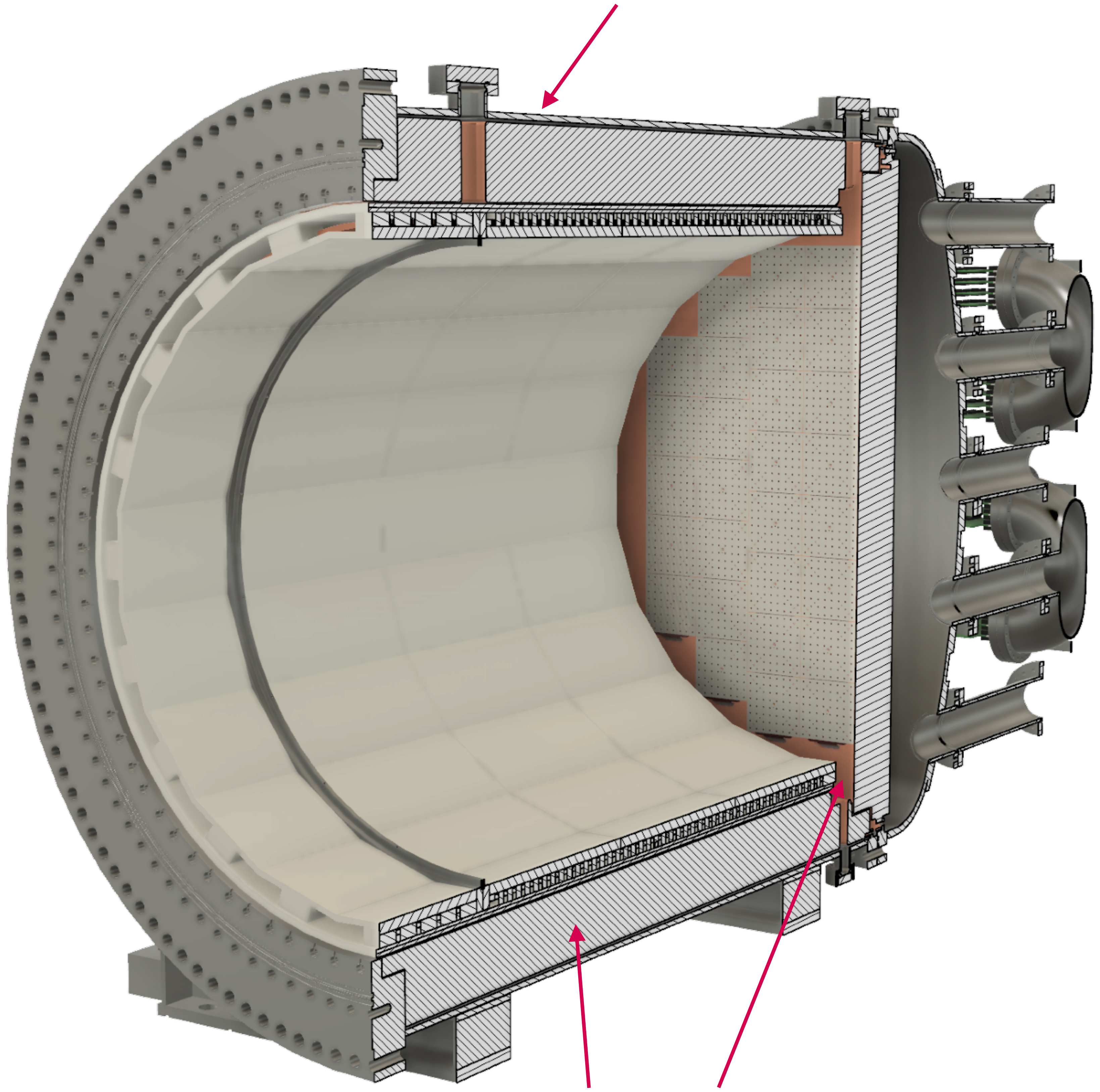
- **Energy resolution <1% FWHM**
- Improve **radioactive** budget
- Competitive search of **0νββ**
- Prepare for the ton-scale



The NEXT-100 detector

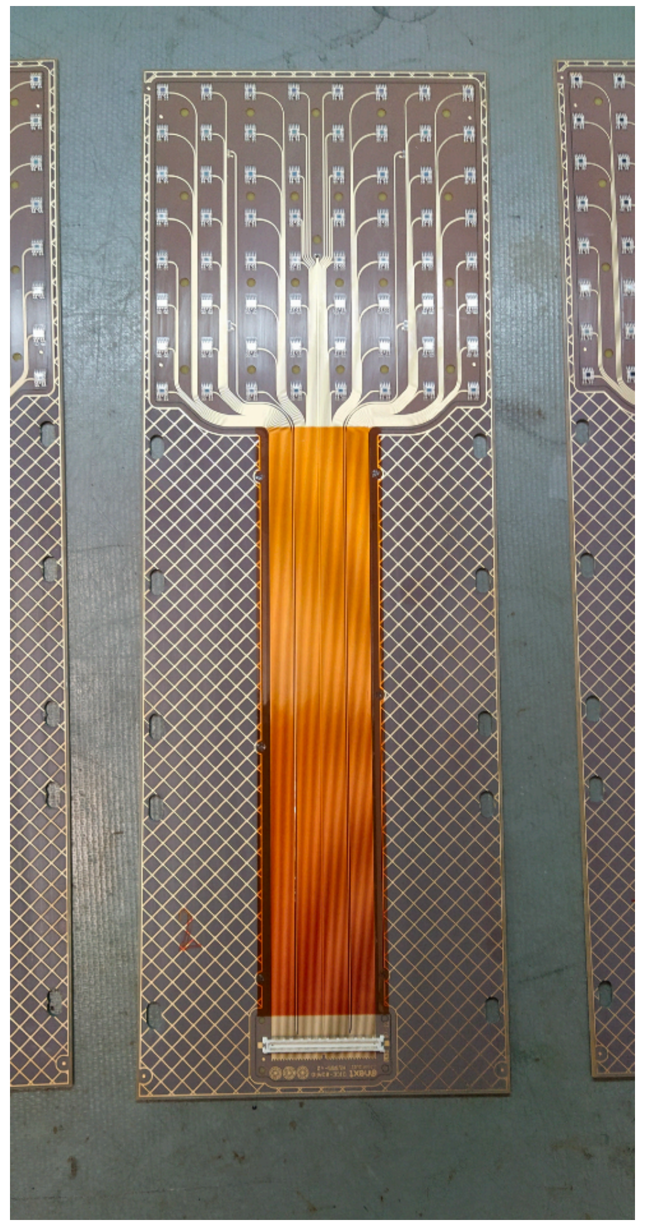


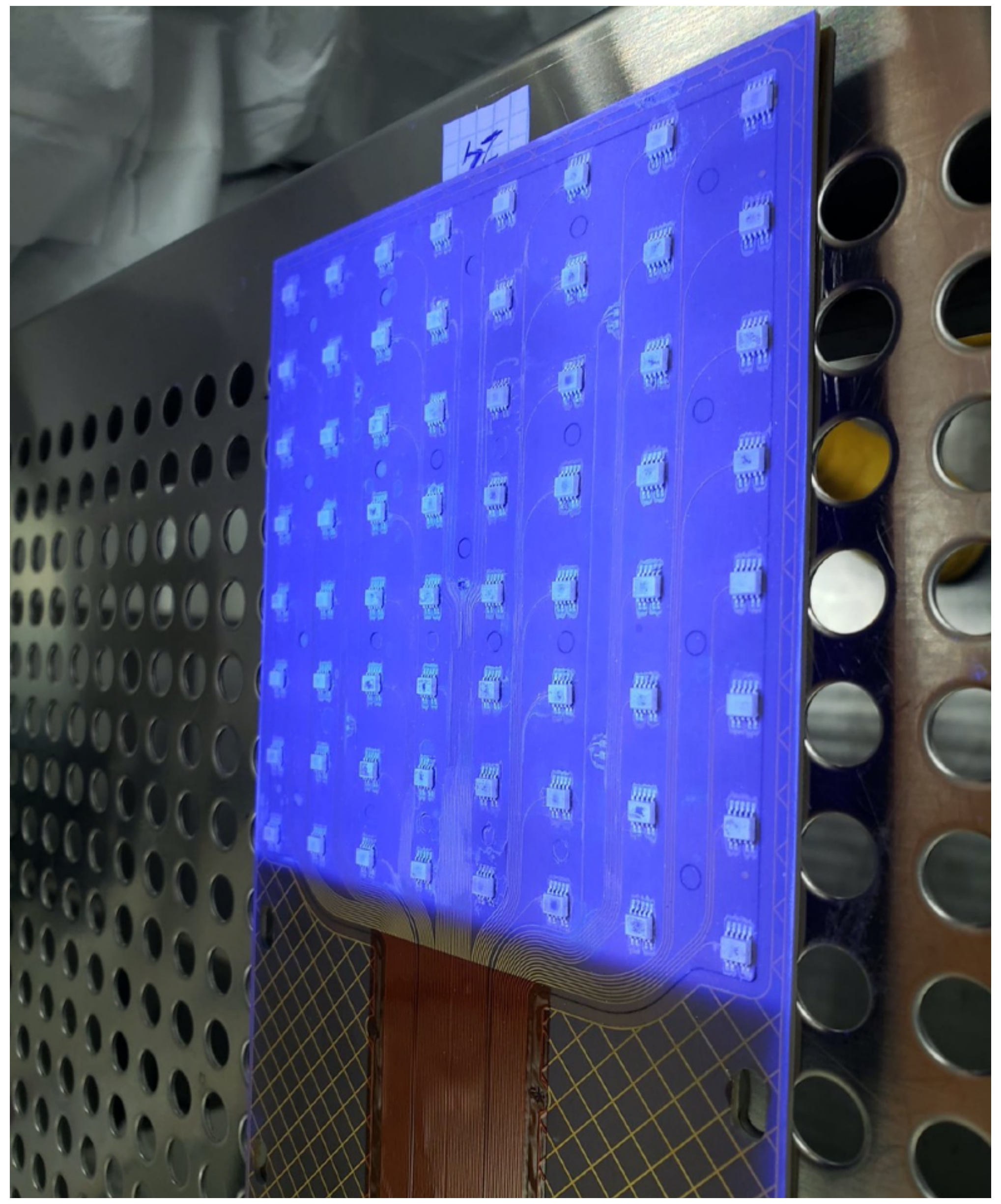
Pressure Vessel
100kg fiducial mass @ ~15bar

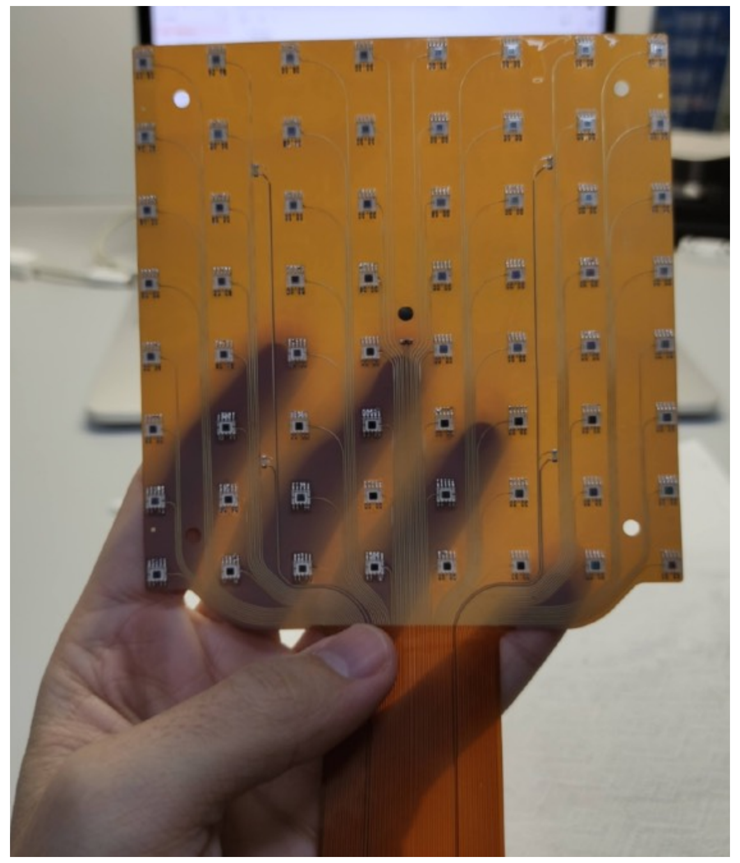


Copper Shielding
Thicker (12cm) ultra-pure copper shielding
Big machinery for production

The NEXT-100 detector



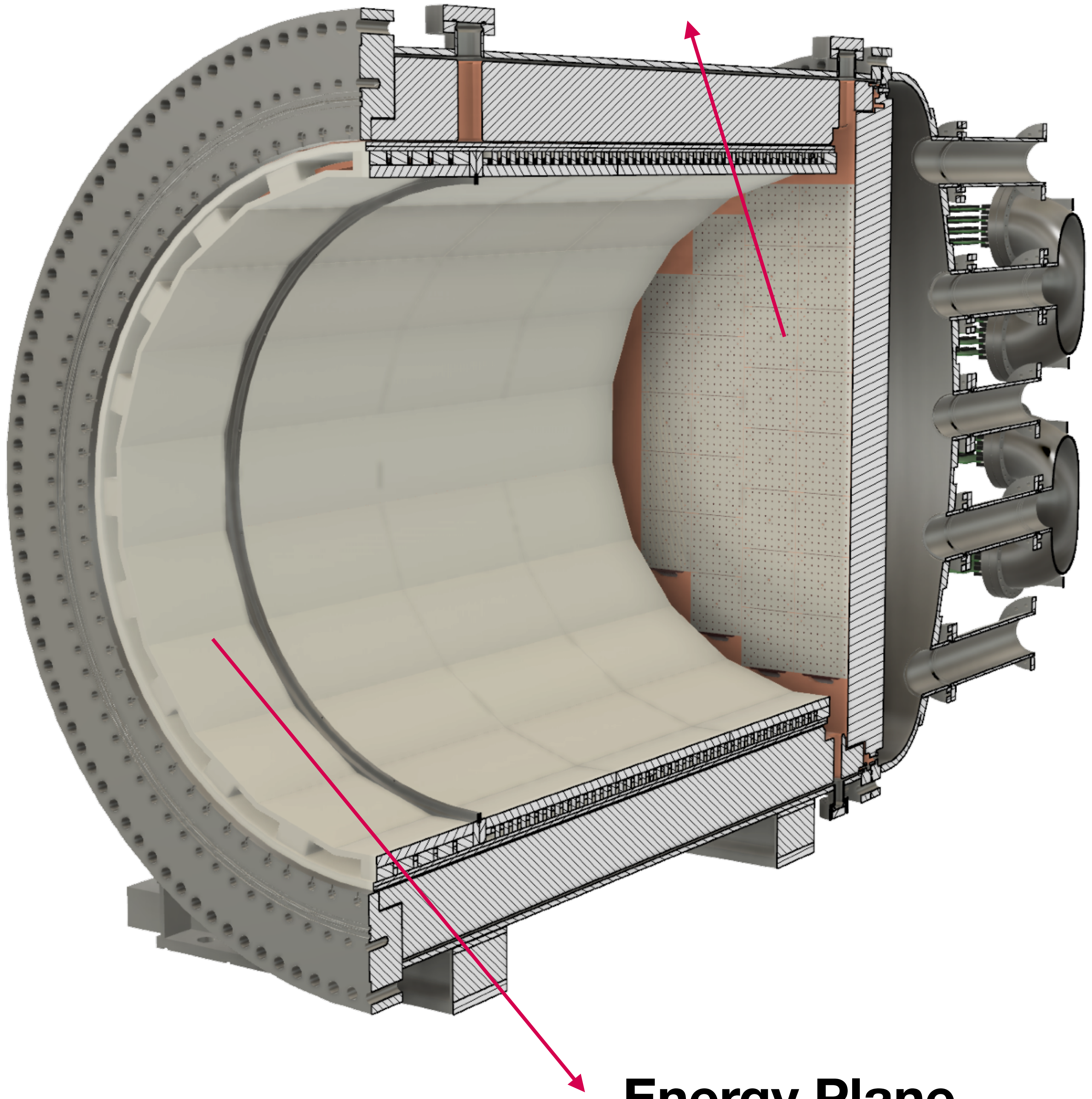




Hamamatsu SiPMs:
easier to mount,
more robust,
larger area.
Better for
dynamic range

Coated with TPB
for better light
detection

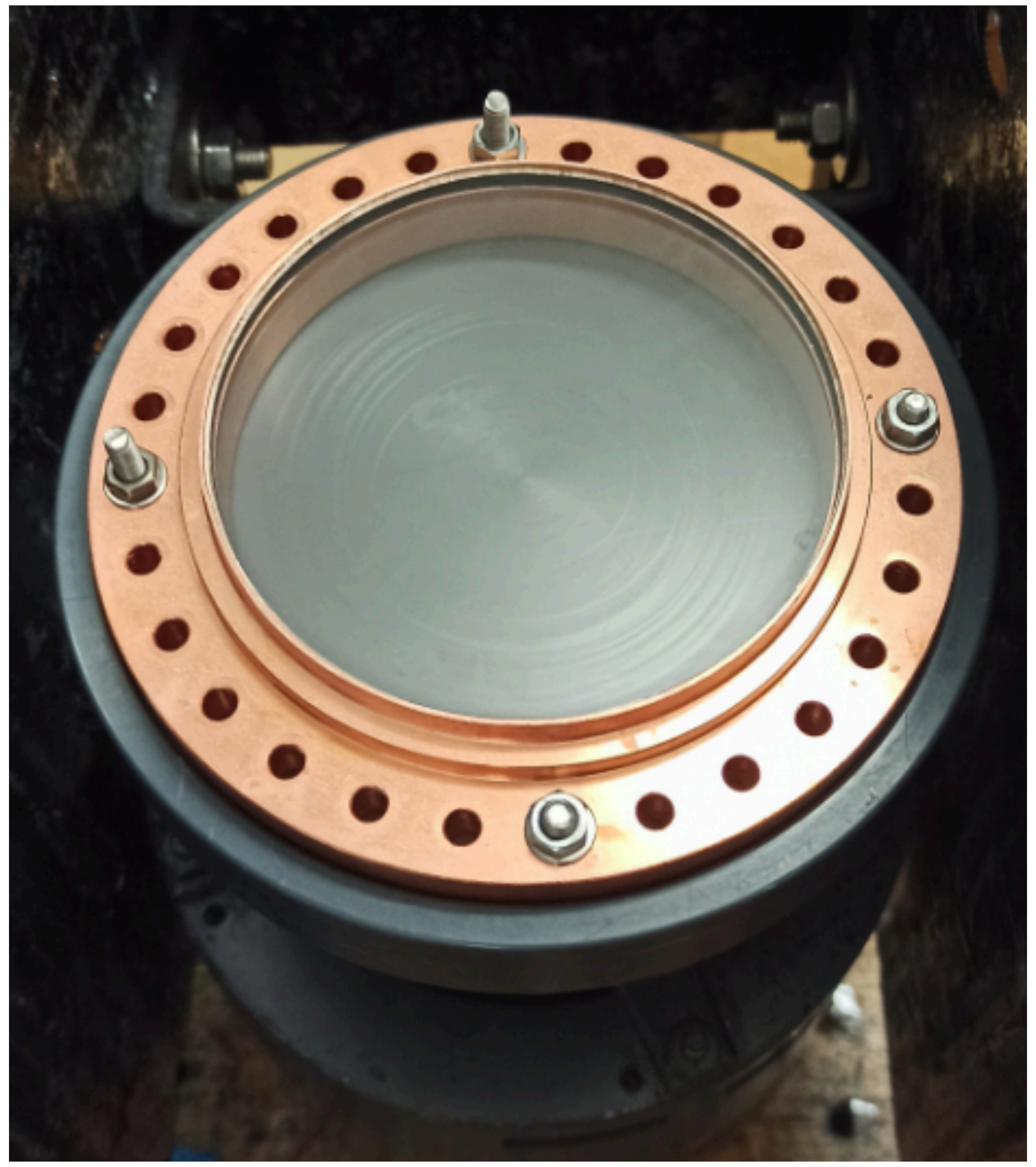
Tracking Plane
3584 Hamamatsu SiPMs
1.3x1.3 mm2 - 15.55 mm pitch
(60% more photons)



Energy Plane
60 Hamamatsu PMTs
R11410-10 - Same NEW
(30% coverage)

PMTs coupled
to xenon gas
through
sapphire
windows
welded to a
radio pure
copper frame

Windows are
coated with PEDOT



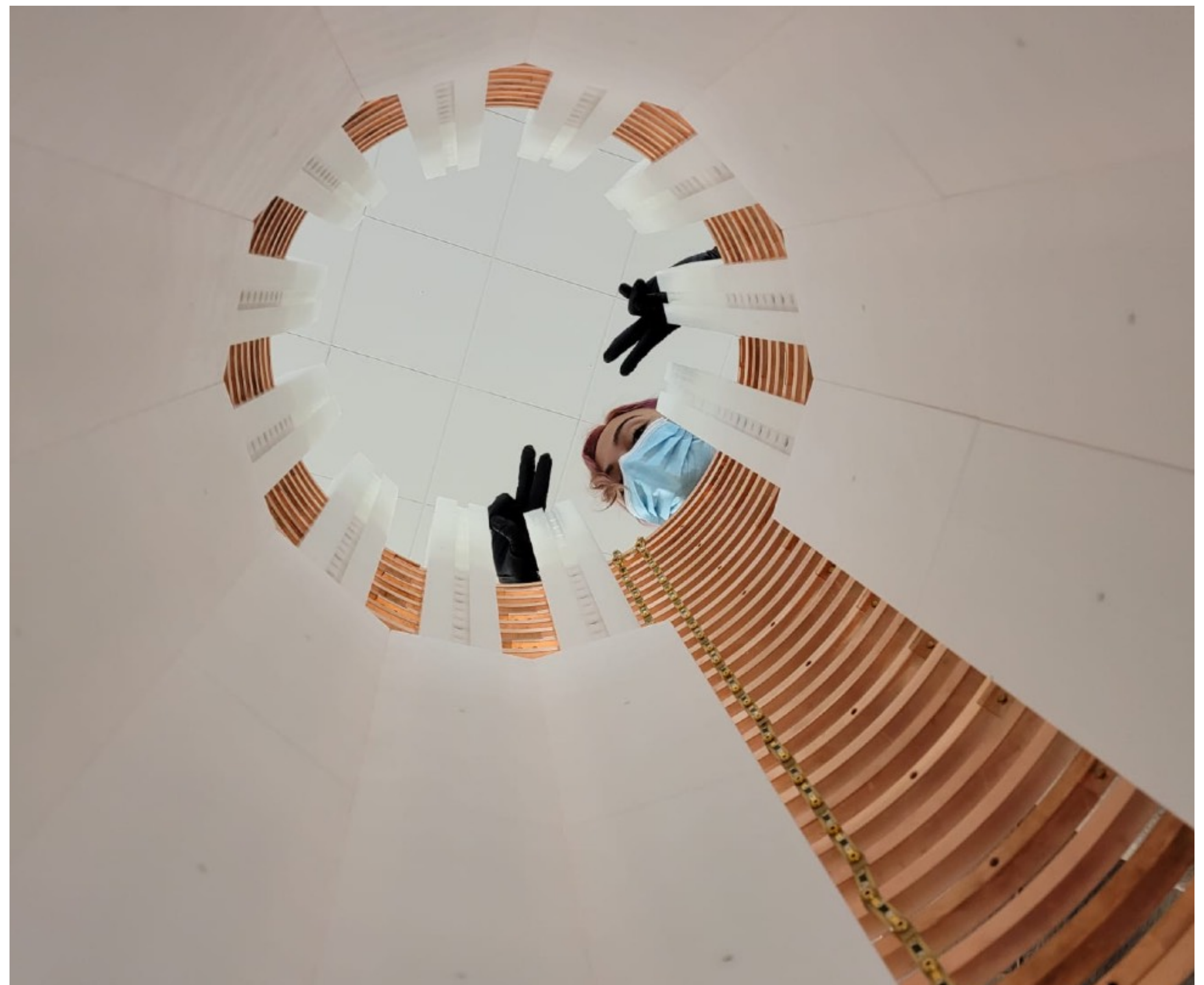
The NEXT-100 detector

N100 - Prototype

Designed and tested in prototype

- held voltage to at least ~70kV,
- vacuum to 10-7 torr
- pressures ranging from 15-20 bar

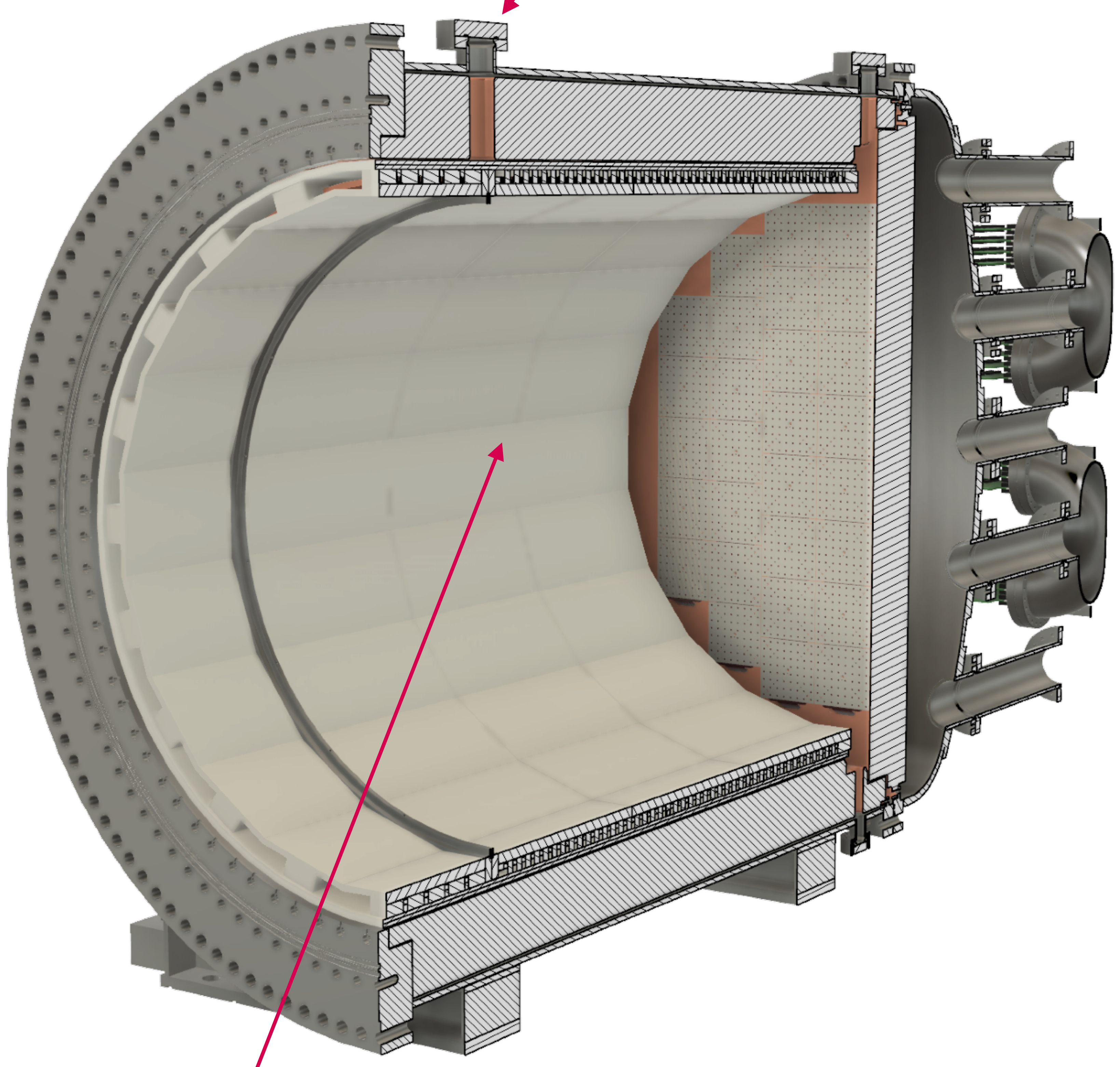
Larger separation among rings for an easier assembly and more robust resistor chain



N100 - Prototype

Covered with reflector panels coated with TPB for optimal light collection

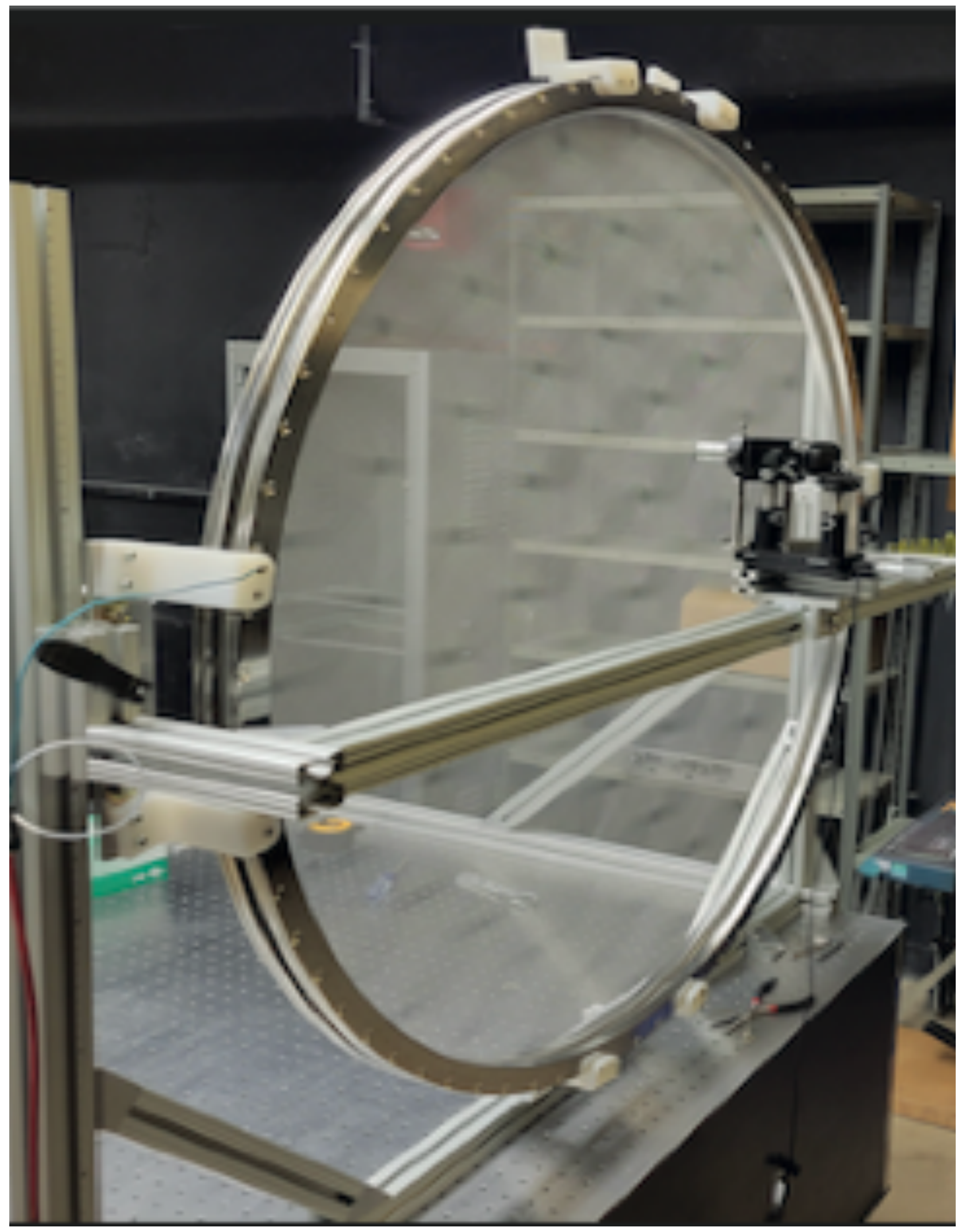
High Voltage Feedthrough (HVFT)

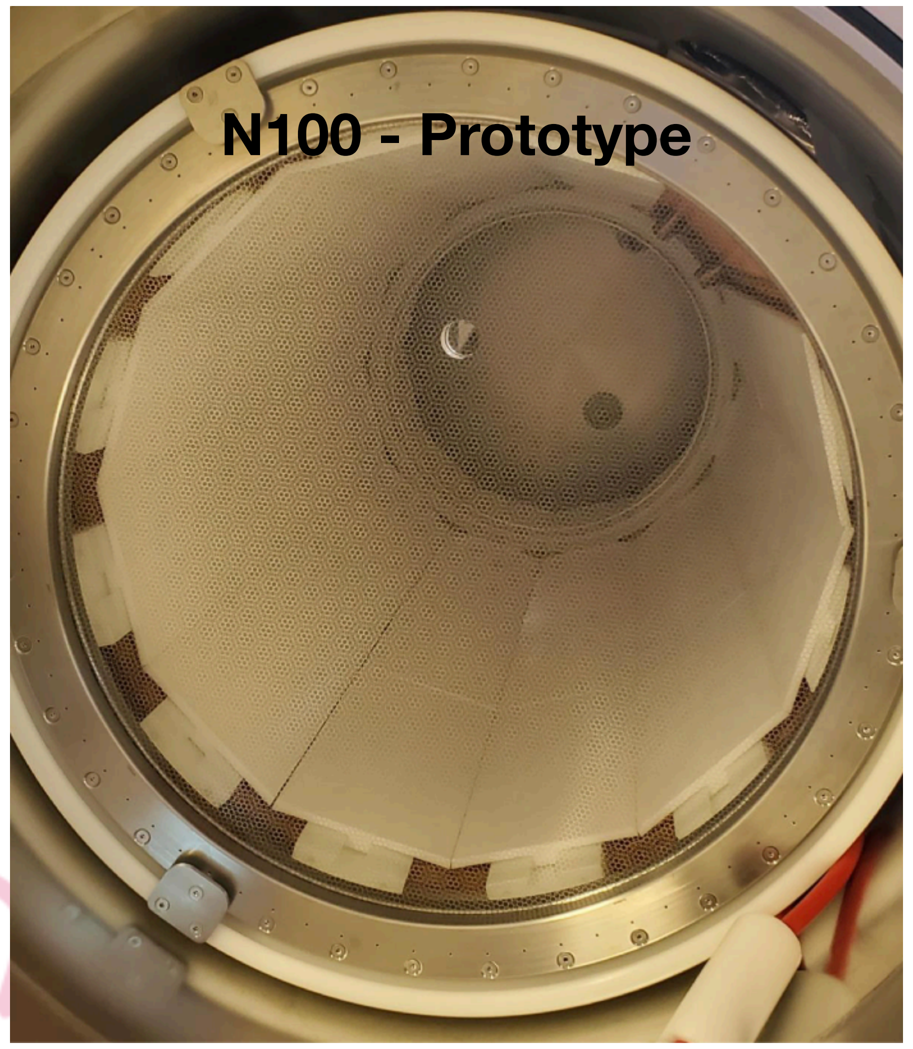


Field Cage

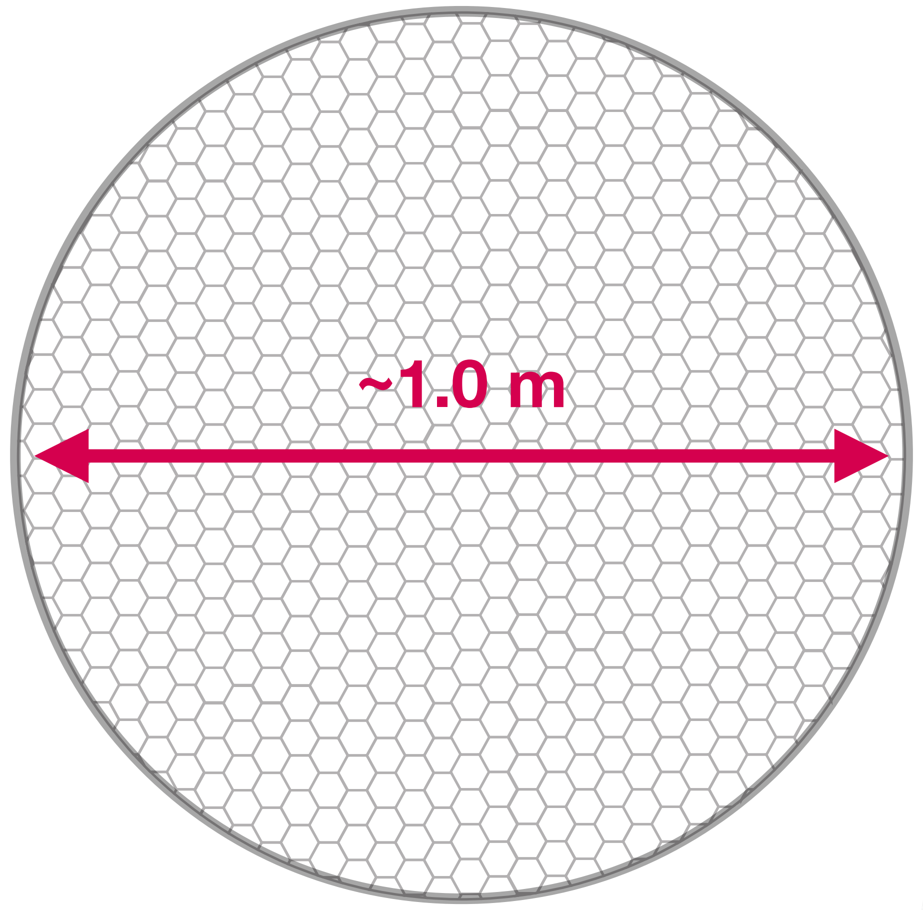
Abandon solid HDPE structure: reduction of outgassing

The NEXT-100 detector

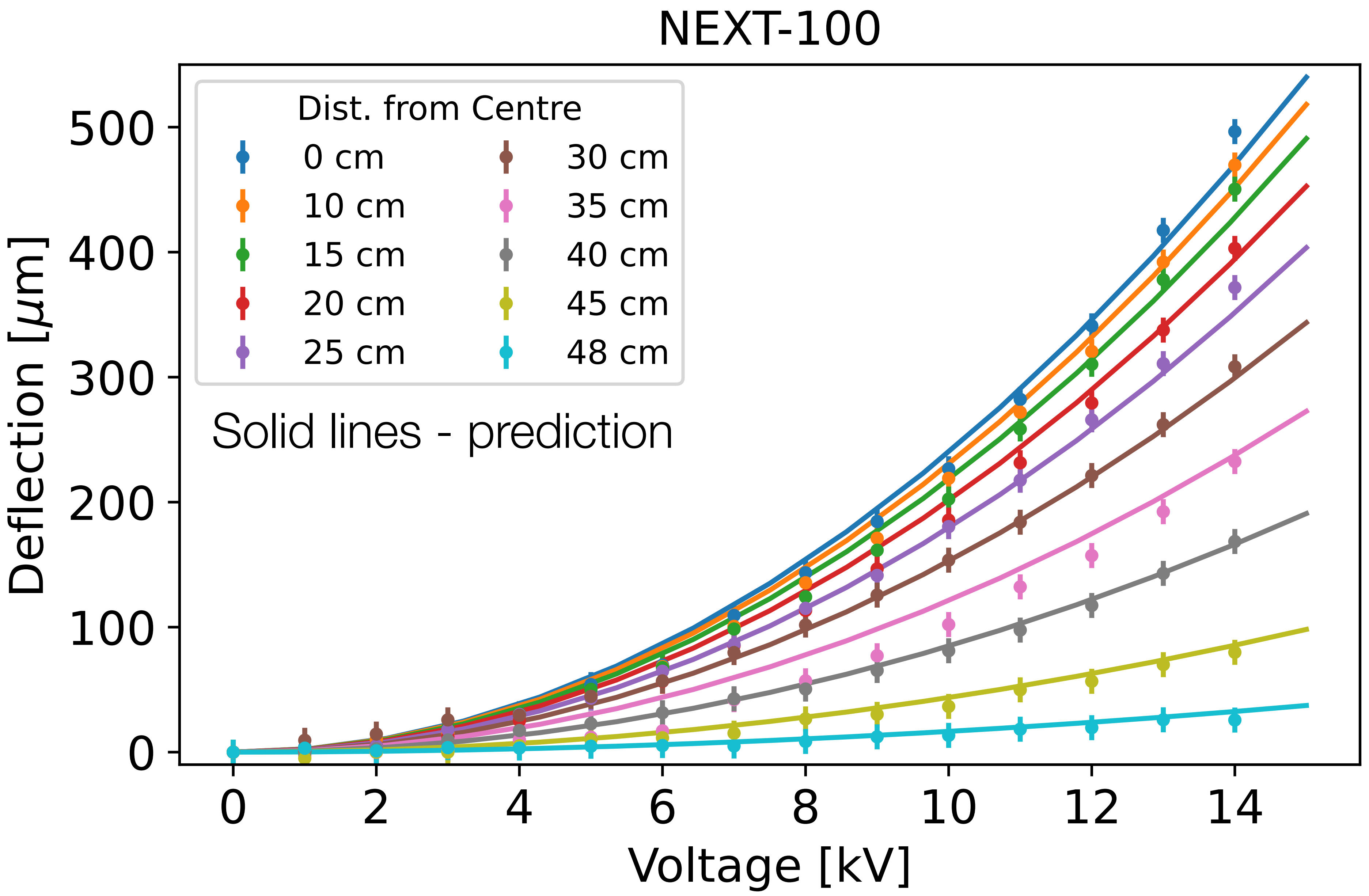


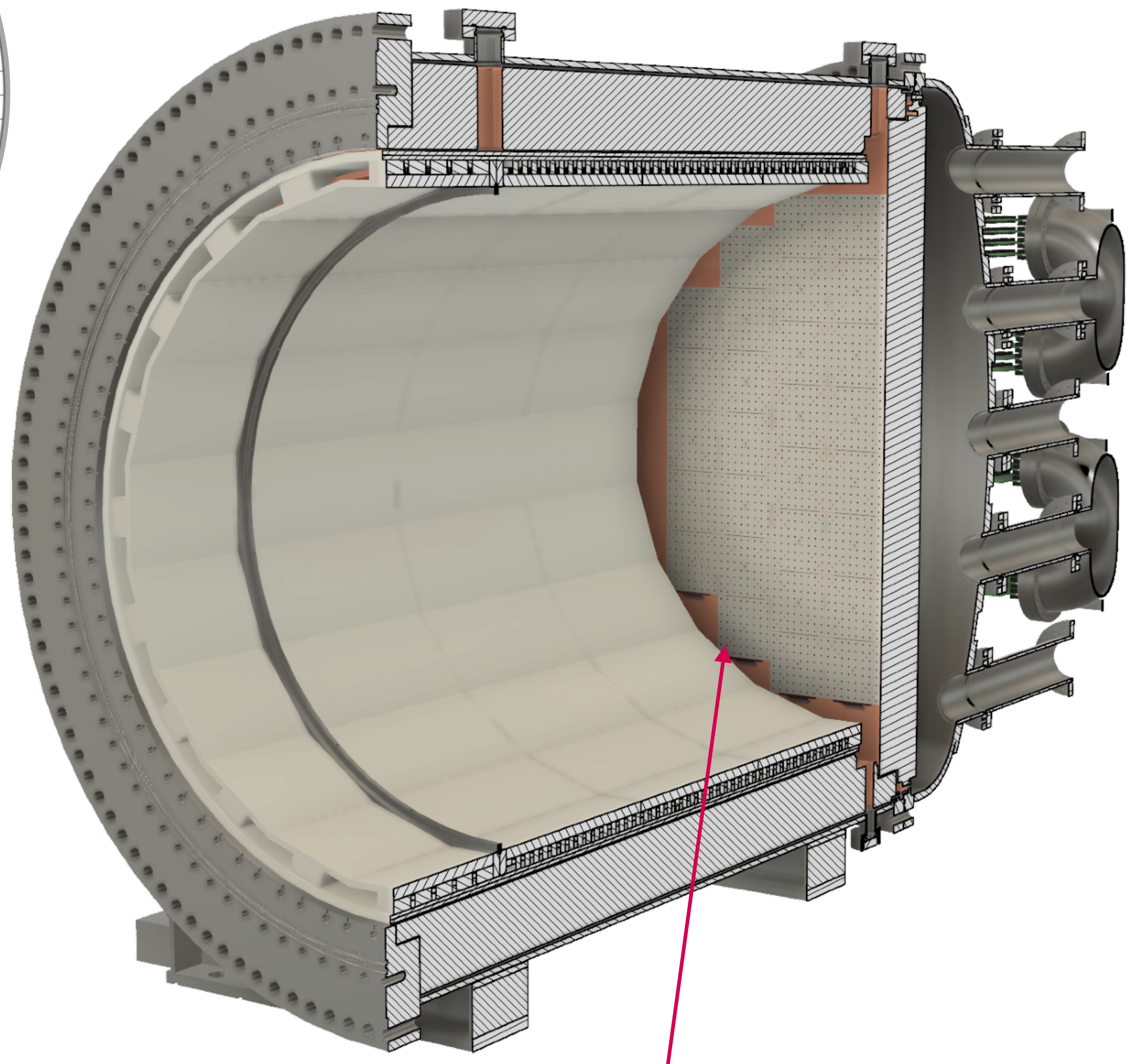


EL and cathode constructed from tensioned hexagonal meshes (~100 µm thickness)



Electrostatic deflection of the EL measured (important for energy resolution)





Anode-EL region using meshes

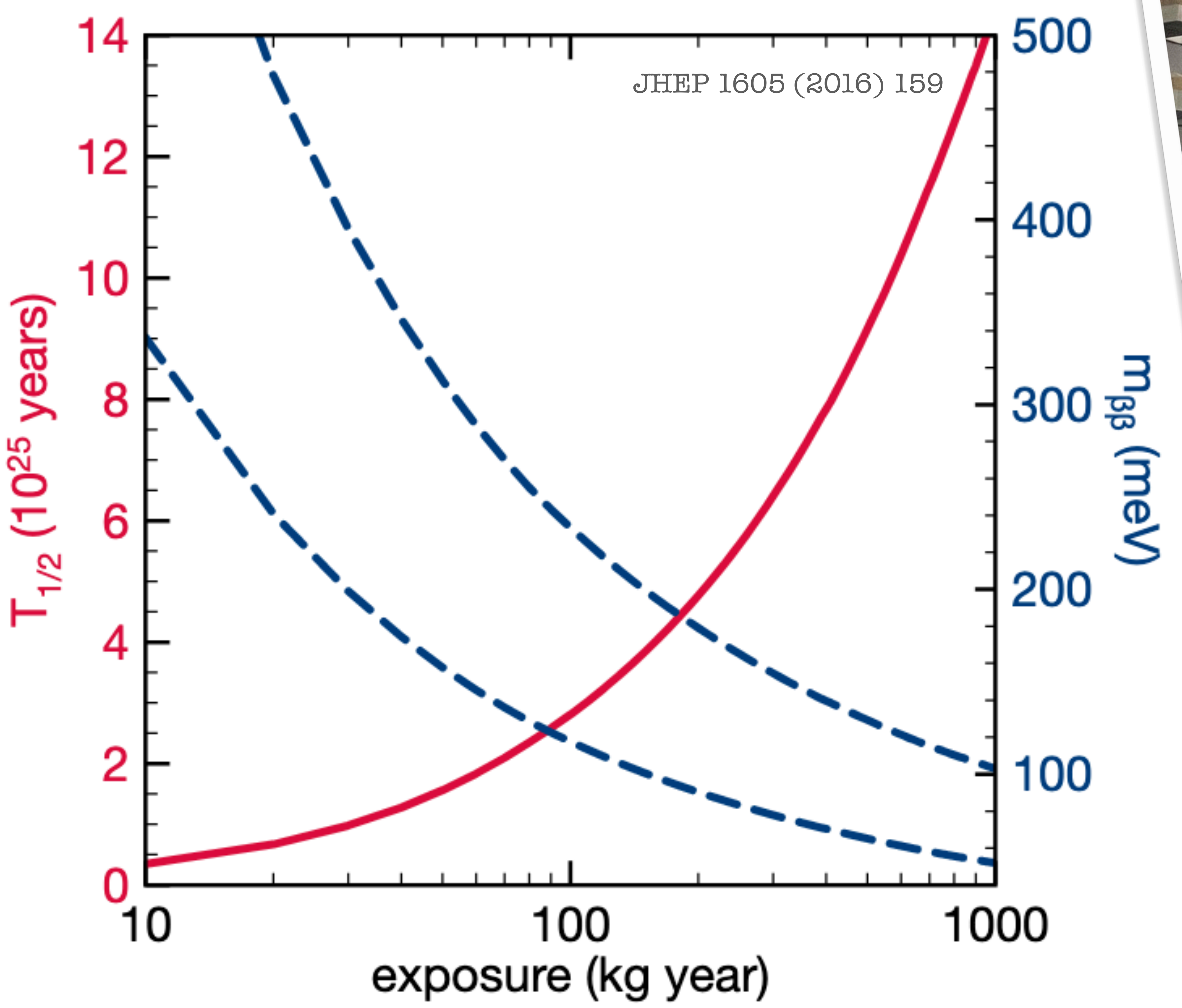
Summary

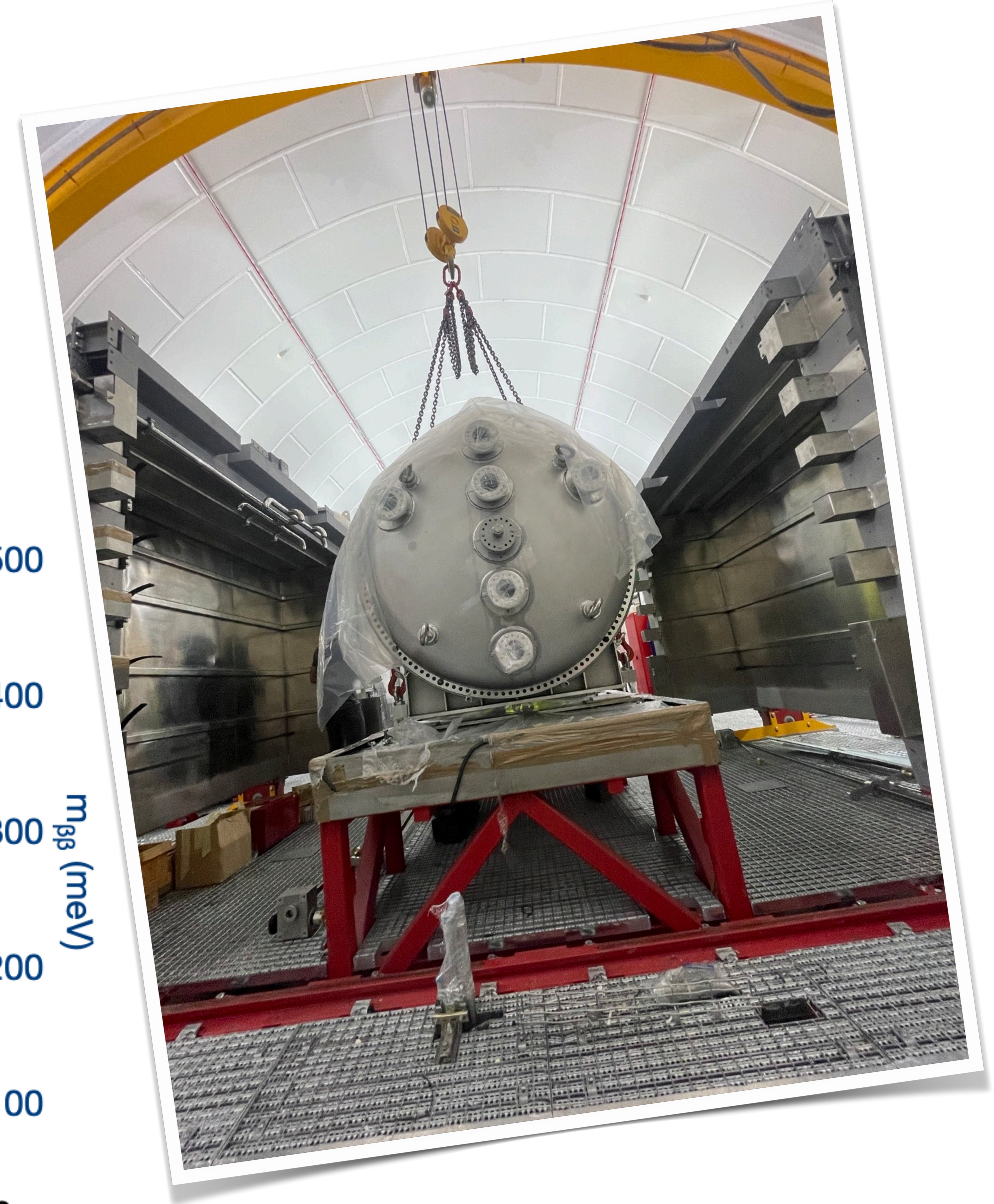
- **Currently**: construction and assembly
- **End of 2022/beginning 2023**: commissioning
- Target background rate $4 \cdot 10^{-4}$ counts/(keV · kg · yr), or ~1 count/(ROI · yr) *(majority coming from PMTs)*

NEXT-100 detector:

- **Energy resolution <1% FWHM**
- Improve **radioactive** budget
- Competitive search of **0νββ**
- Prepare for the ton-scale

next

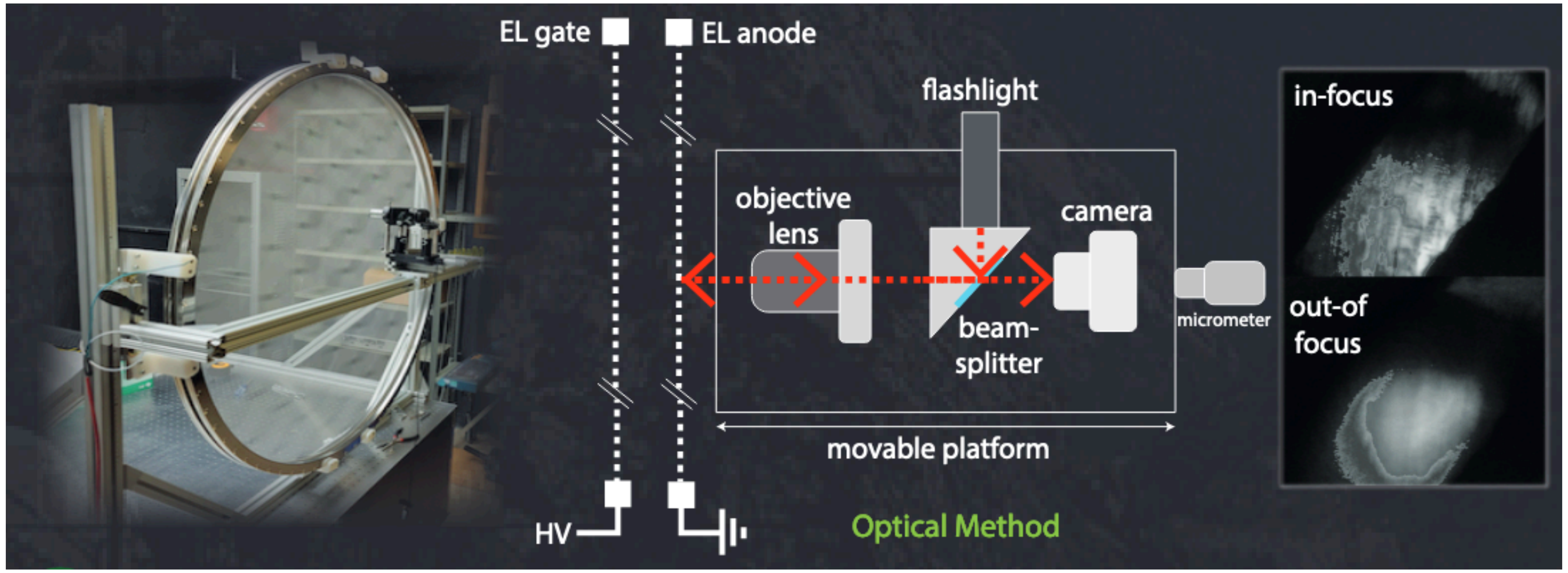




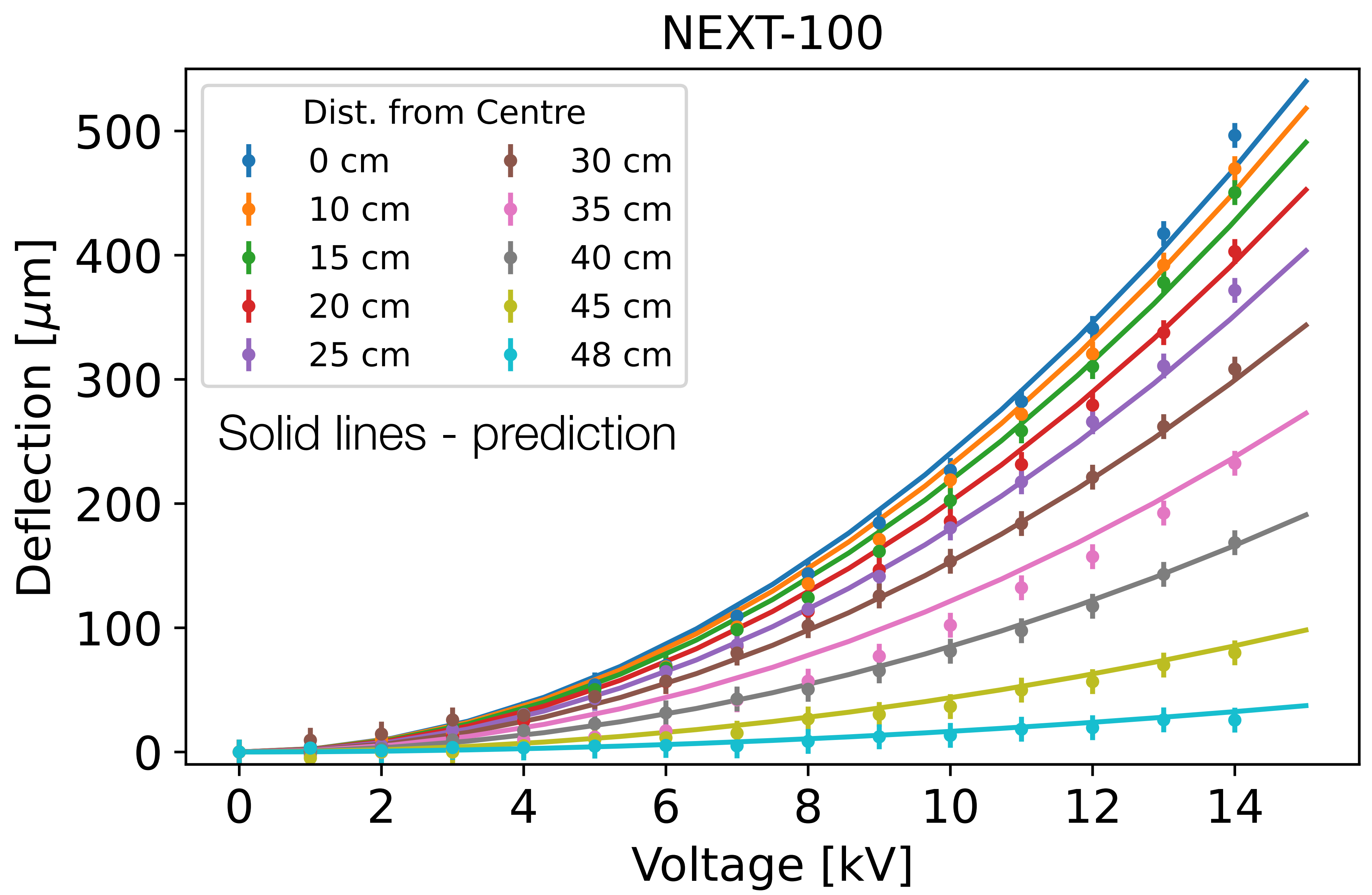
Back-up

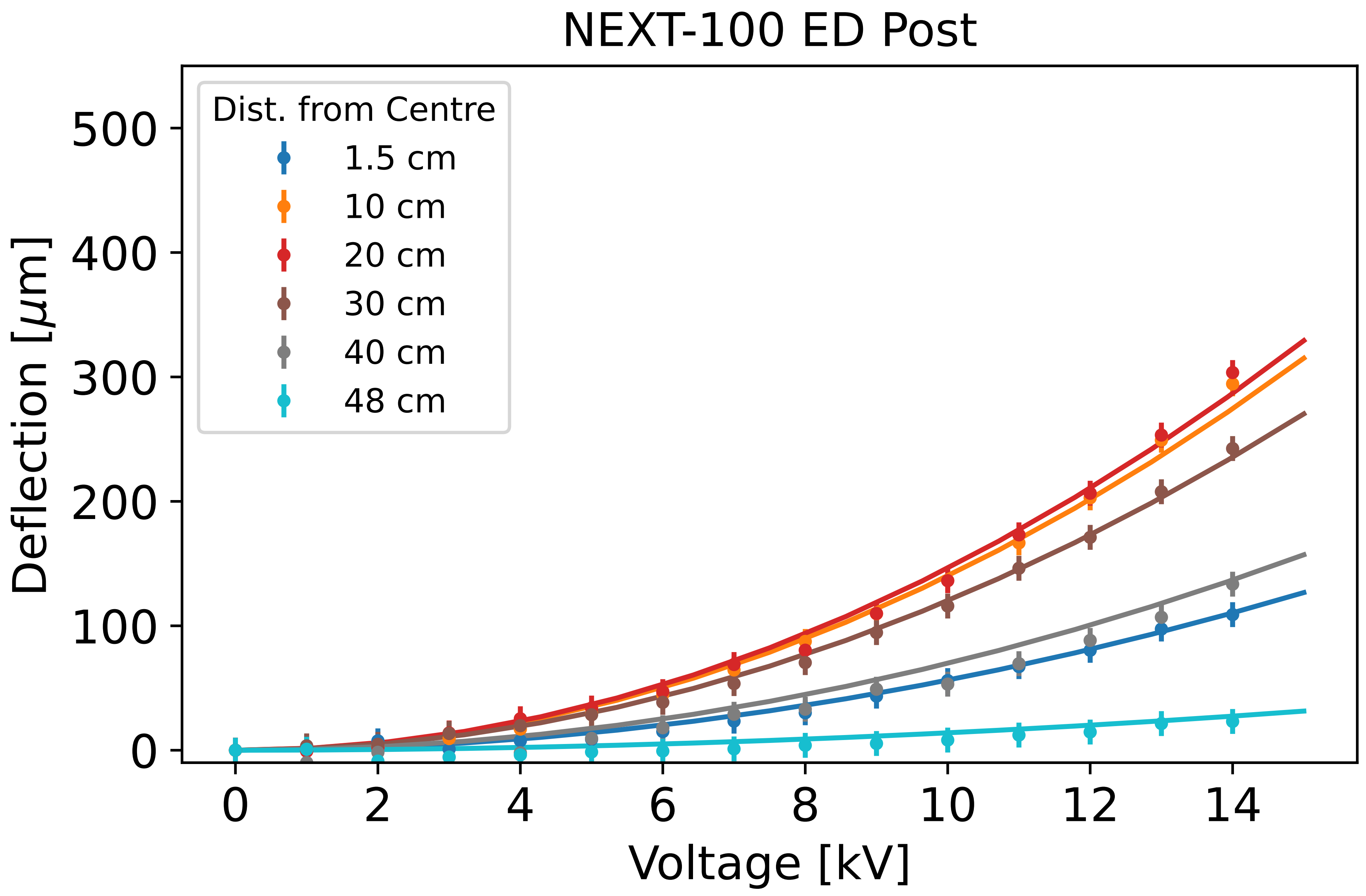
NEXT-100 EL deflection

Determine electrostatic deflection at different radii with optical method by bringing EL mesh in/out of focus for a given voltage, 5 μm sensitivity

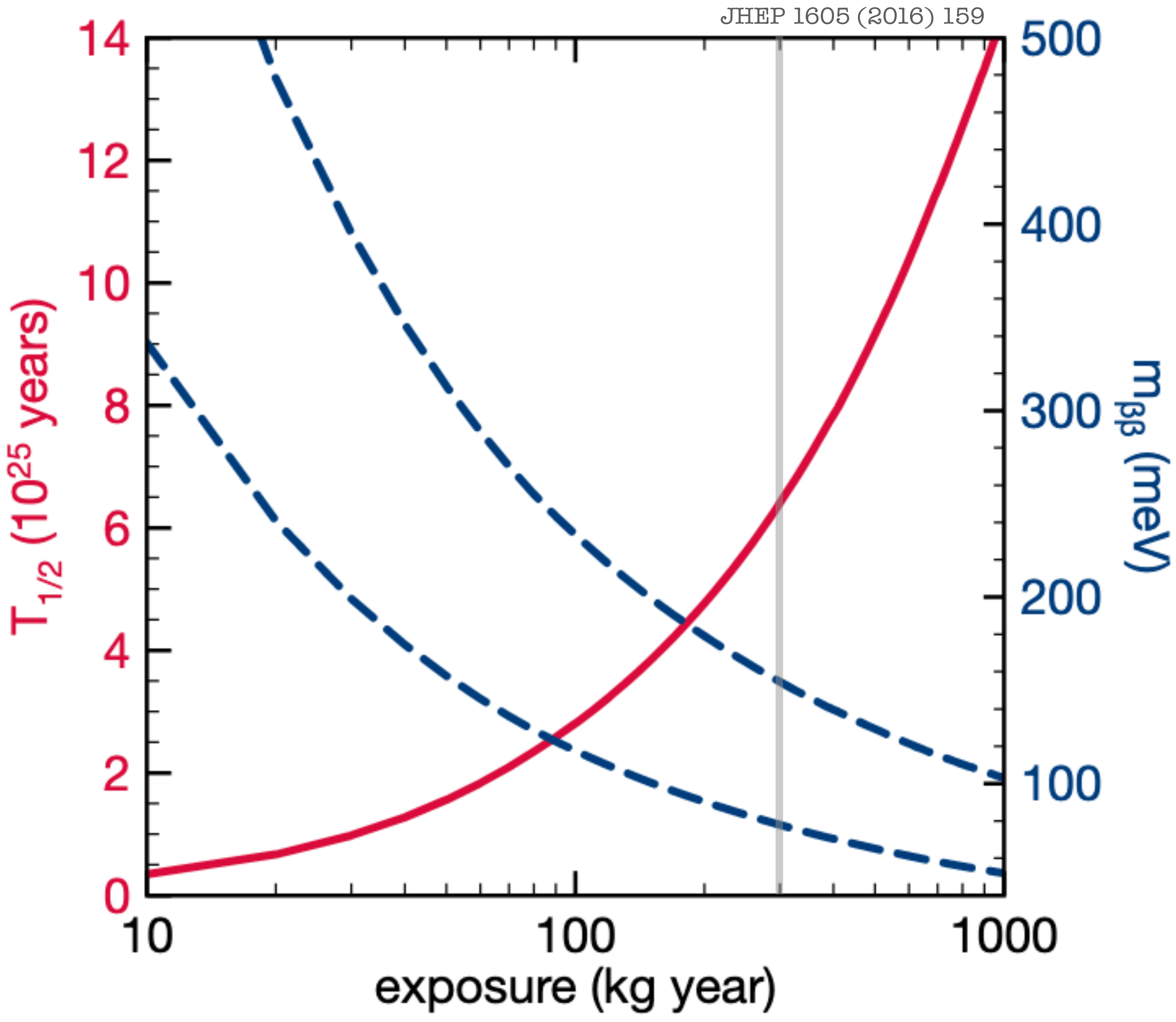


Insert insulating HDPE post (ED post) between EL meshes to reduce electrostatic deflection





NEXT-100



$$\left(T^{0\nu}_{1/2}\right)^{-1} = G^{0\nu}\,|M^{0\nu}|^2\, m^2_{\beta\beta}$$

$m_{\beta\beta} = |\sum_i U^2_{ei} \cdot m_i|$ *effective Majorana mass*

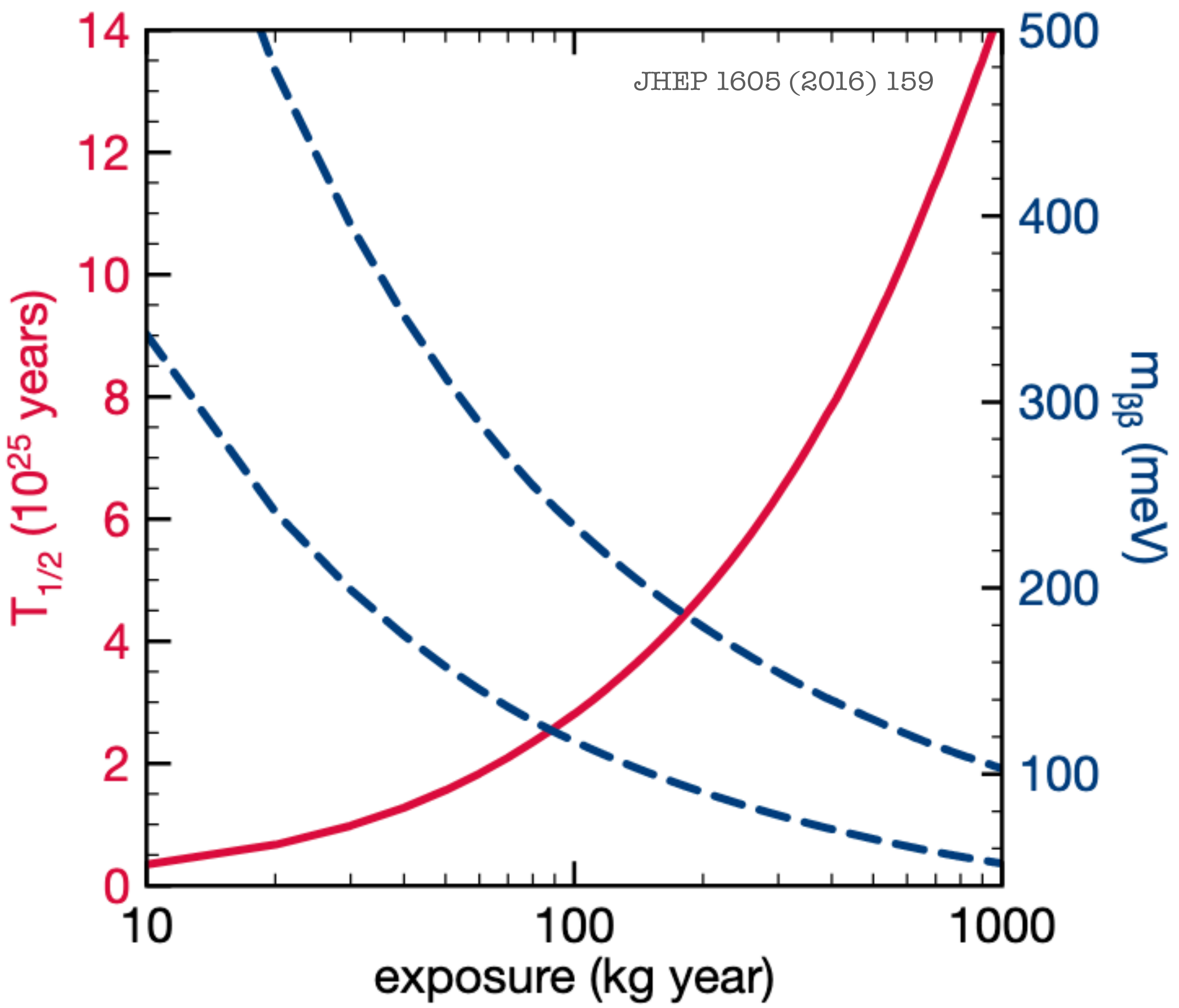
ββ0ν lifetime

$$T^{0\nu}_{1/2} = \log 2 \, \frac{N_A}{W} \, \frac{\varepsilon \, M \, t}{N}$$

Relative atomic mass	135.907219(8) [24]
Q value ^{136}Xe $\to$ ^{136}Ba	2457.83(37) keV [25]
	2458.7(6) keV [26]
	2458.1(3) keV (average)
$G^{0\nu}$ (10^{-15} year^{-1})	14.58 [27]
	14.54 [28]
$0\nu\beta\beta$ decay NME	2.19 (ISM) [29]
	3.05 (IBM-2) [30]
	2.46 (QRPA) [31]
	2.91 (QRPA) [32]
	4.12 (EDF) [33]
	4.32 (EDF) [34]

$T^{0\nu}_{1/2} = 6.0 \times 10^{25} years$ **@ 90% CL**
(3 years of data)

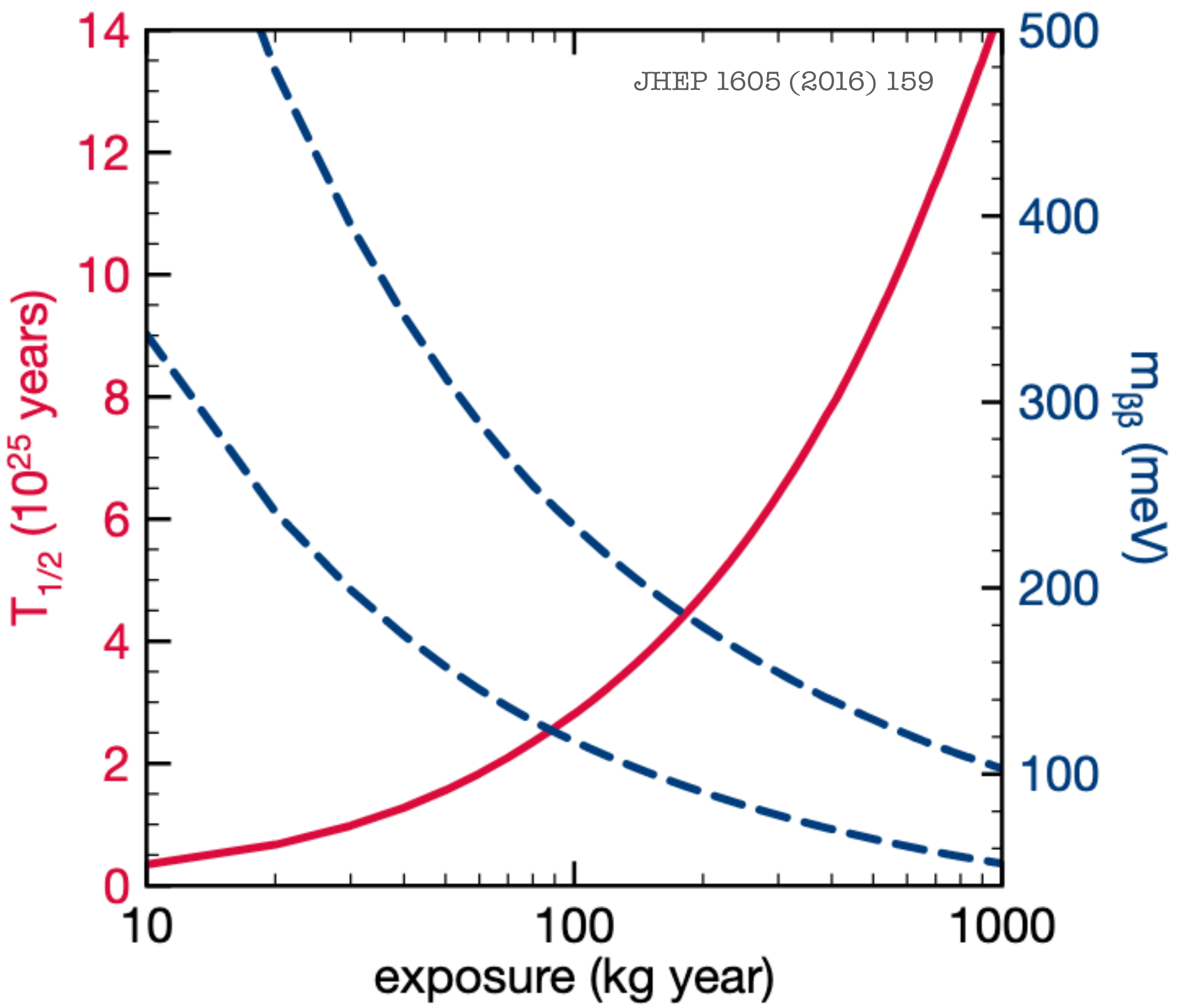
NEXT-100



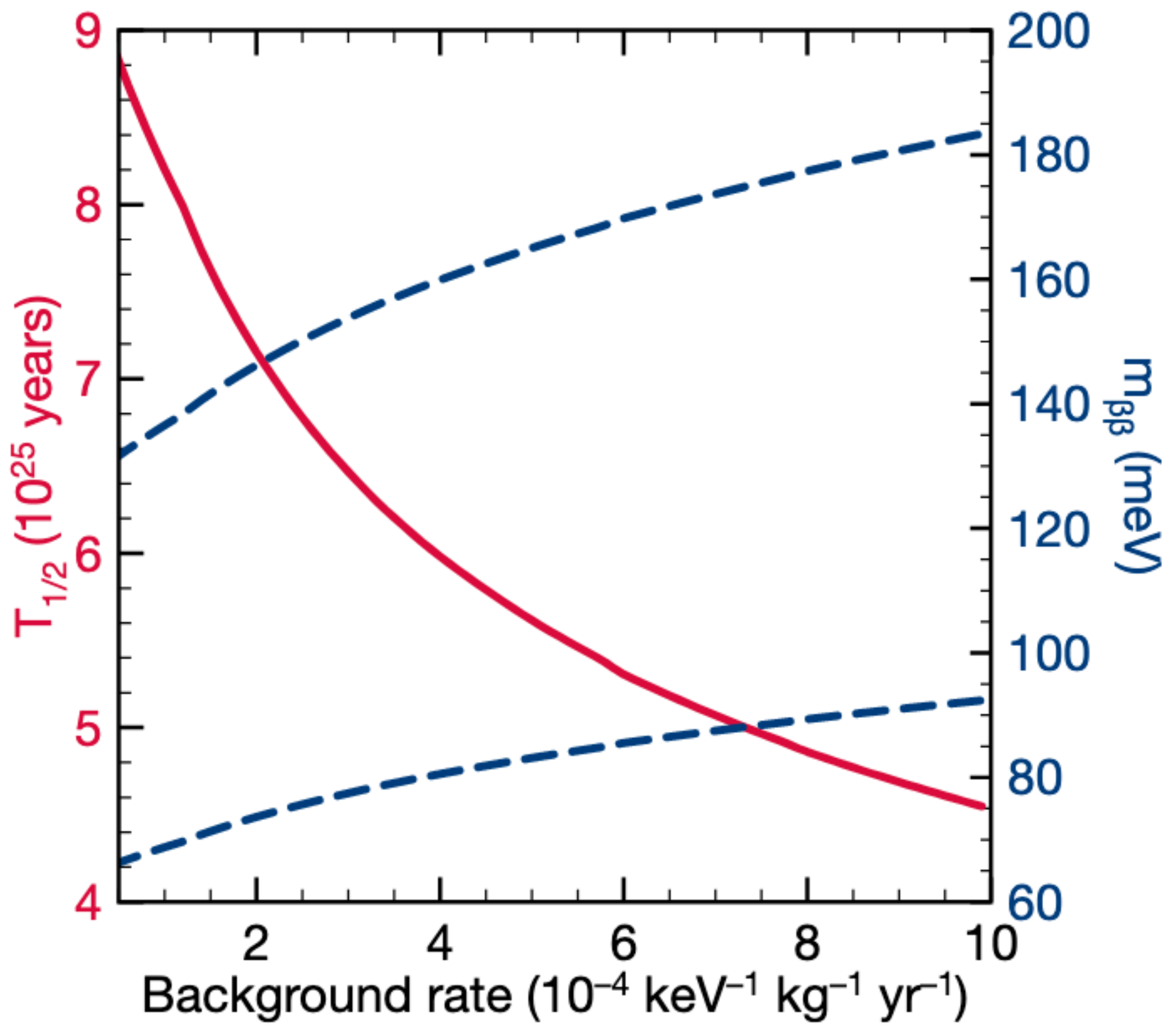
$$\mathcal{S}(m_{\beta\beta}) = \mathcal{K} \sqrt{\frac{\overline{N}}{\varepsilon\, M\, t}}$$

$$\mathcal{K} \equiv \left(\frac{W \;\, m_e^2}{\log 2 \;\, N_{\mathrm{A}} \;\, G^{0\nu} \;\, |M^{0\nu}|^2} \right)^{1/2}$$

NEXT-100

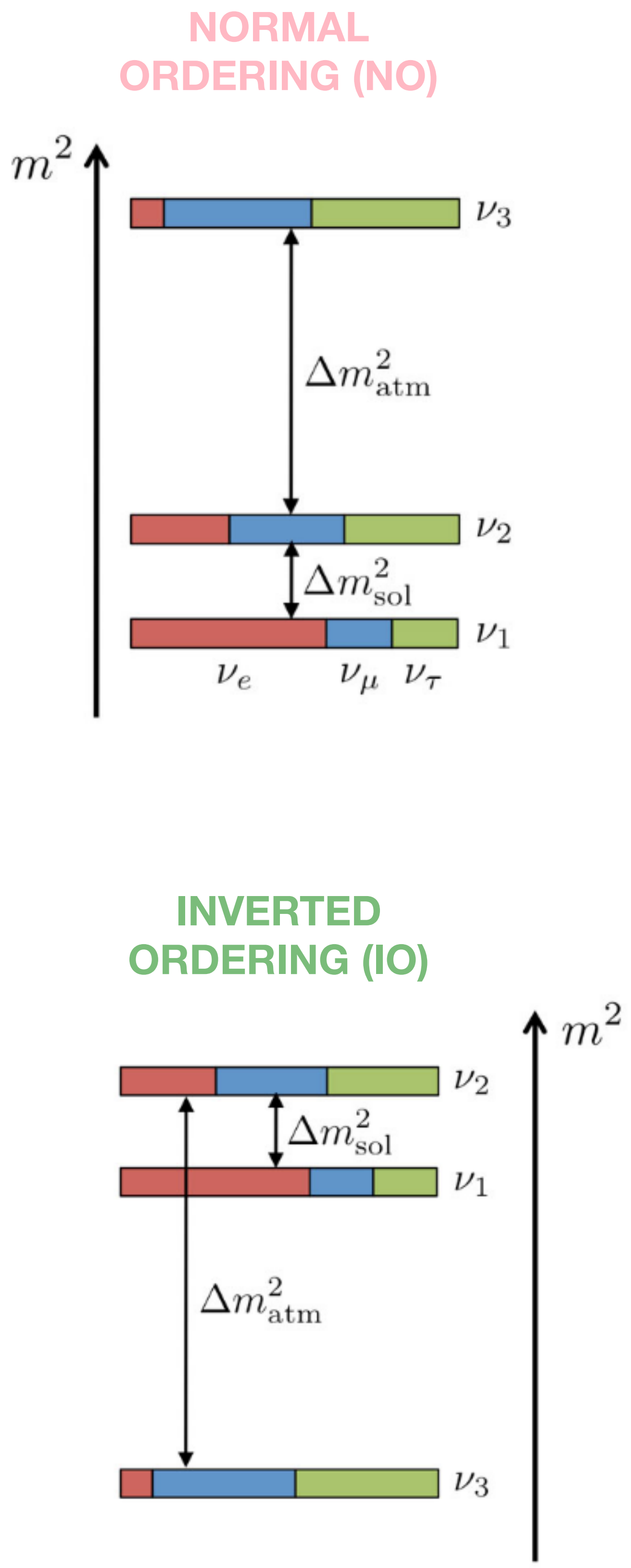


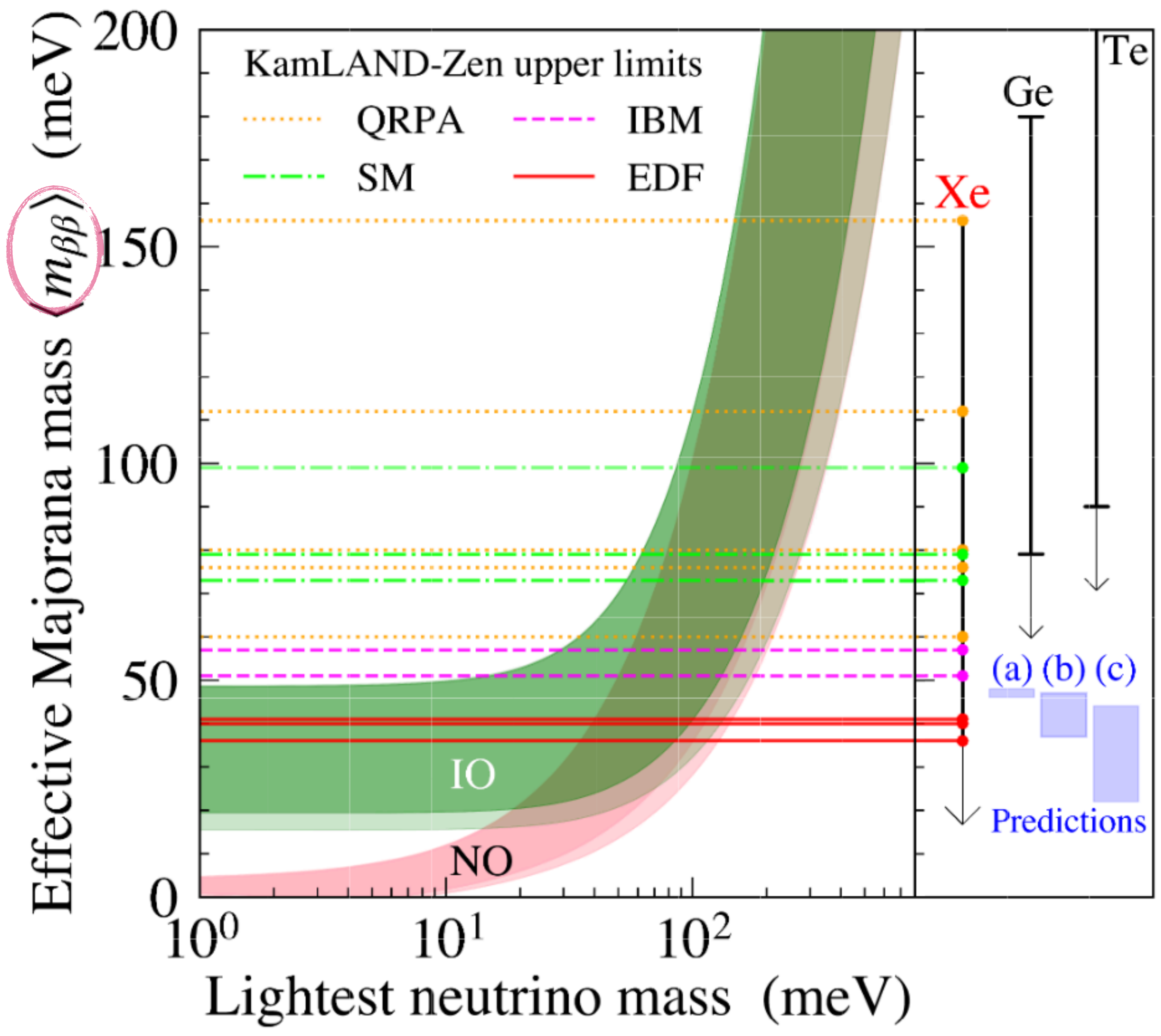
JHEP 1605 (2016) 159
$T_{1/2}$ (10^{25} years)
$m_{\beta\beta}$ (meV)
exposure (kg year)
14
12
10
8
6
4
2
0
500
400
300
200
100
10
100
1000



$T_{1/2}$ (10^{25} years)
$m_{\beta\beta}$ (meV)
Background rate (10^{-4} keV^{-1} kg^{-1} yr^{-1})
9
8
7
6
5
4
200
180
160
140
120
100
80
60
2
4
6
8
10

Tonne-scale detectors





Aim to explore the **Inverted Ordering (IO)** region

$$m_{\beta\beta} = |\sum_i U_{ei}^2 \cdot m_i|$$ *effective Majorana mass*

$$\left(T_{1/2}^{0\nu}\right)^{-1} = G^{0\nu}\,|M^{0\nu}|^2 m_{\beta\beta}^2$$

ββ0ν lifetime

Sensitivity of IO region requires tonne-scale detectors