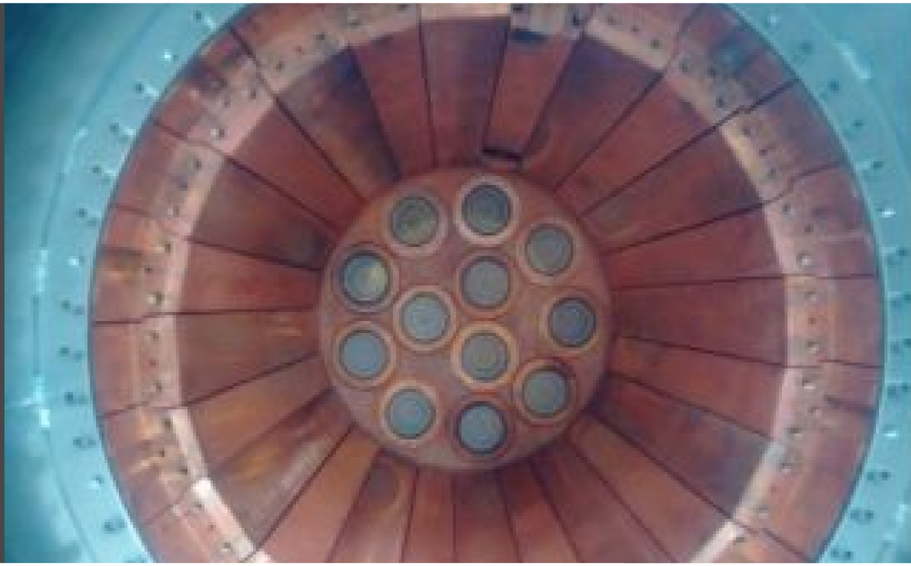
Status and future for the NEXT collaboration in neutrinoless double beta decay



NEXT-NEW Xenon pressure chamber

Sereres Johnston
For the NEXT collaboration

May 29, 2018

Outline

- Majorana Neutrino
- Intro to NEXT
- Recent Operation
- Ongoing R&D
- Summary

Majorana Neutrino

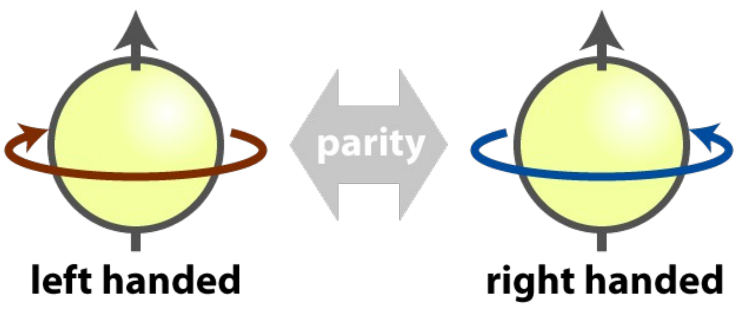
- What if Neutrino and Anti-Neutrino were fundamentally the same?
- Antiparticle / Particle behavior would be determined by helicity

Dirac

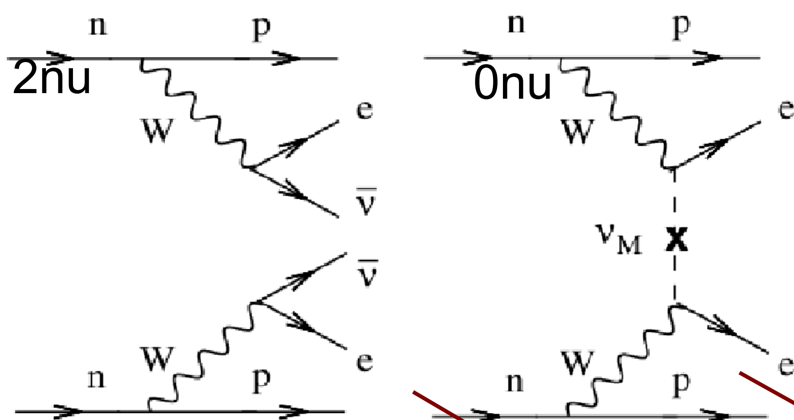
- Opposite particle / antiparticle parity
- All charged fermions

Majorana

- Parity does not separate particle / antiparticles
- Neutrinos only candidates



Experimental Signal

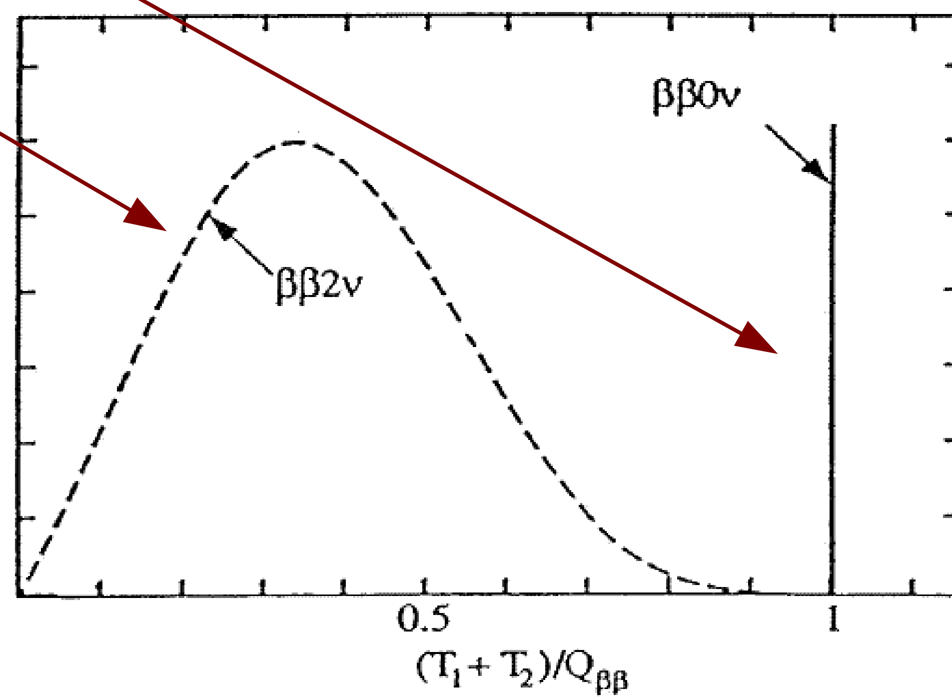


- Electron energy detected
- Neutrinos carry off some of the decay energy
- Observe peak at Q value as 0ν signature
- Second order process, rare

Example Mechanism:
0ν by weak exchange of light neutrino

$$[T^{0\nu}_{1/2}]^{-1} = G^{0\nu}(E_0, Z)|M^{0\nu}_{GT} - \frac{g_V^2}{g_A^2} M^{0\nu}_F|^2 \langle m_\nu \rangle^2$$

Majorana neutrino mass inversely related to decay rate.



Why Use Xenon Gas

High pressure capsule of liquid Xe

^{136}Xe decays via ββ

- ^{136}Ba daughter

High Q value

- Above many backgrounds

Source = Detector

- Xe is Scintillator

Fluid Material

- Constant purification

Energy Resolution

- Intrinsic: 0.3%FWHM

Topology Discrimination

- Single vs. Double β

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0νββ Decay Resolution, Topology

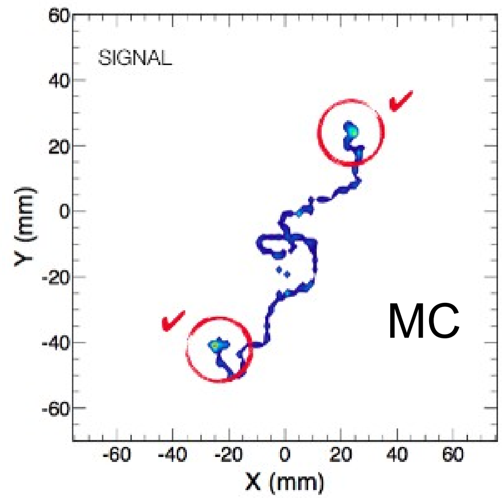
DBDM demonstrator:

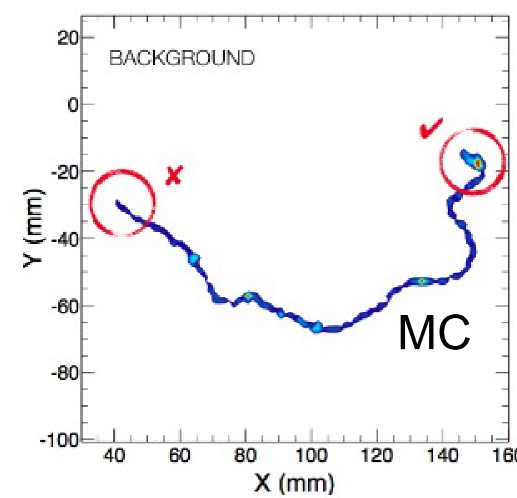
- Near intrinsic resolution
- 662keV ^{137}Cs source
- ~1% FWHM

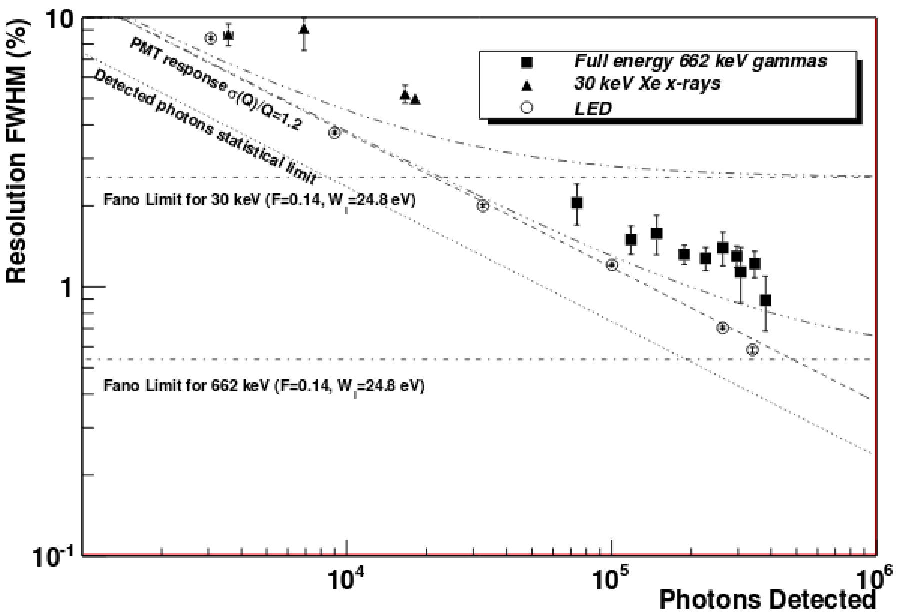
$Q_{\beta\beta}$ extrapolation @ 2459keV:

- ~0.5% FWHM expected

JHEP, 01:104, 2016







NIM A708:101-114:2012

NEXT-DEMO Prototype:

- ^{22}Na 1275keV γ interaction
  - Single electrons
- ^{228}Th decay chain γ conversion
  - Electron/Positron pairs

Discrimination algorithm:

- Background rejection 24.3%
- Signal efficiency 66.7%

Neural Networks:

- Improvement factor 1.2-1.6
- 2017 JINST 12 T01004

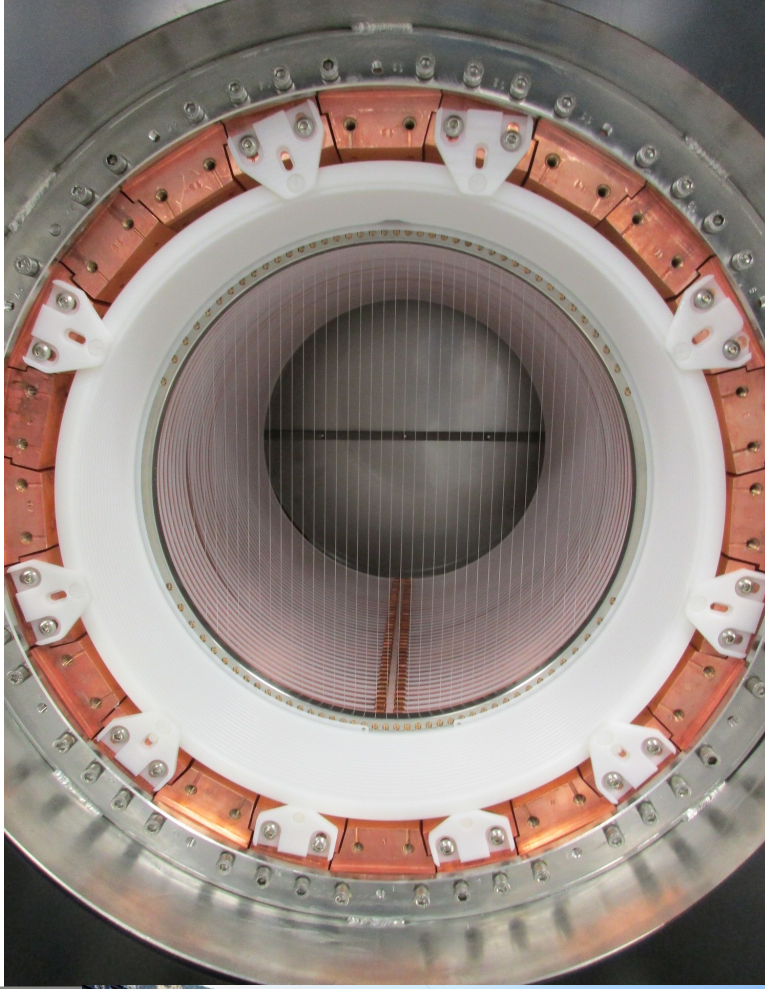
NEXT

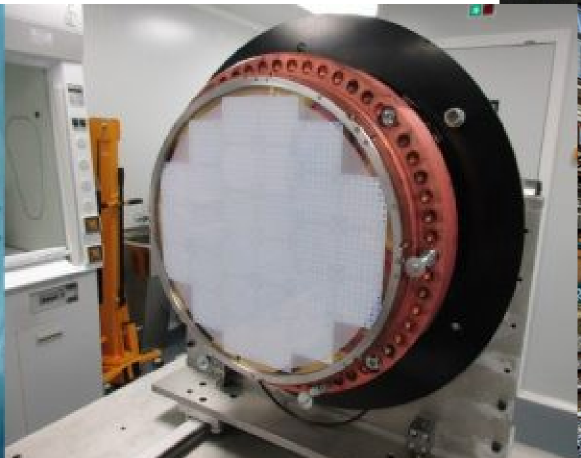
Neutrino Experiment Xenon TPC
(Time Projection Chamber)

Canfranc Underground Laboratory
(LSC)

Currently Running Class 10 kg

Class 100 kg: 2019



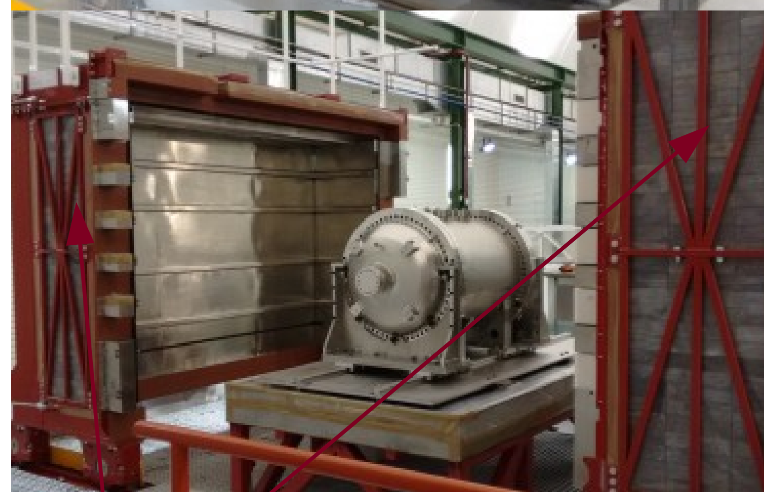


NEXT Pressure Vessels

10-15 bar operation

Room Temperature

10 and 100 kg Vessels



Next-NEW Vessel

Next-100 Vessel

Lead Castle

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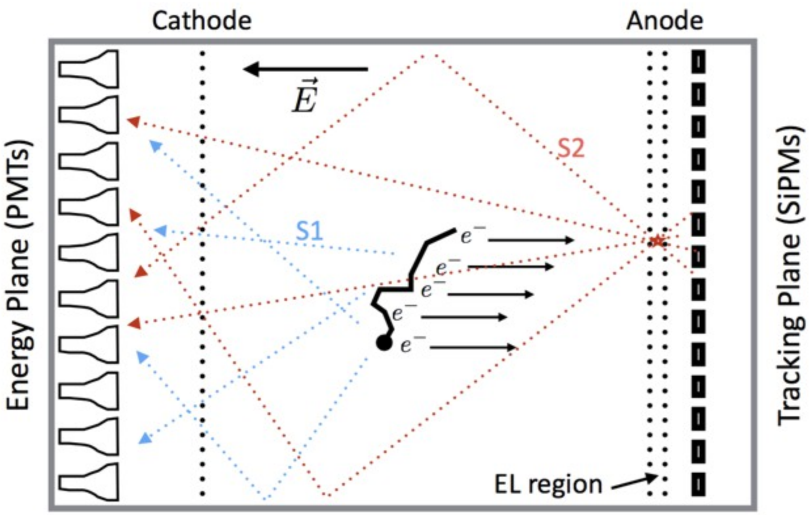
Xenon Time Projection Chamber

Energy Deposited
- Ionization
- Scintillation

Light Detected

Electric Field
- Drifts electron cloud to endcap
- Detected via sensors
- 2 dimensional location

Time Delay
- Electrons drift at known rate
- 3rd dimension determined



Separation of Function TPC (SOFT):

Energy plane
Tracking plane

NEXT
Electroluminescent region:
Electron cloud detection
2D location

PMTs at cathode:
Light detection
Precision energy resolution

The Next White (NEW) Detector

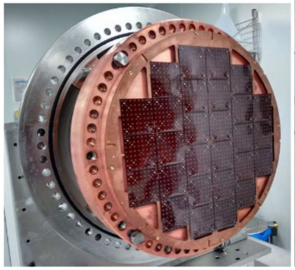
NEXT-White has been operating since October 2017

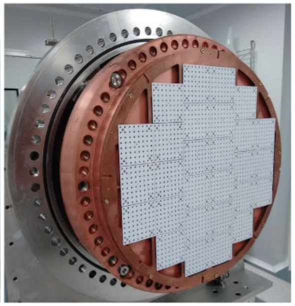
Arxiv 1804.02409
Submitted to JINST

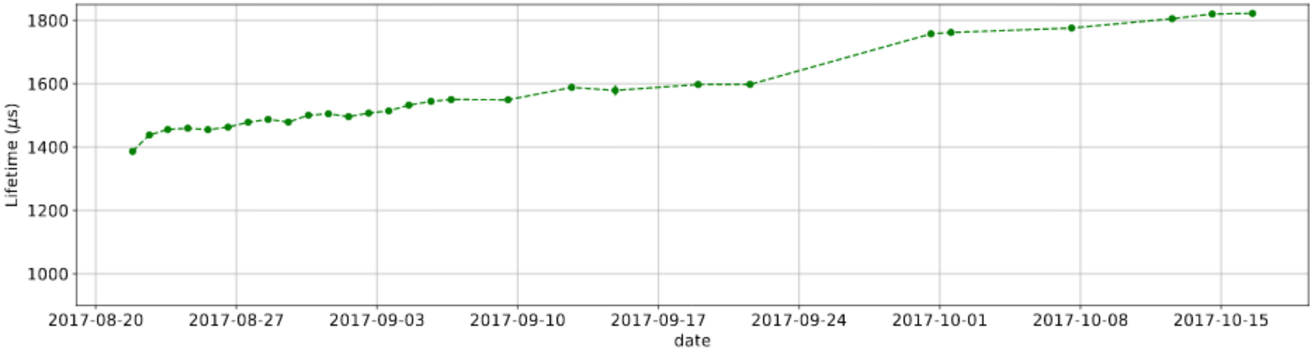
Scale model for NEXT-100

Paper includes operational detail
- Detector
- Support system

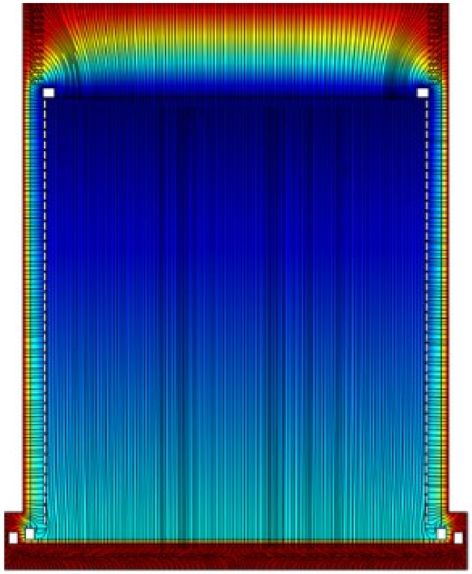
TPC parameter	Nominal	Run II (4734)	Run II (4841)
Pressure	15 bar	7.2 bar	9.1 bar
EL field (E/P)	$2.2\,kV\,cm^{-1}\,bar^{-1}$	$1.7\,kV\,cm^{-1}\,bar^{-1}$	$1.7\,kV\,cm^{-1}\,bar^{-1}$
EL gap	6 mm	6 mm	6 mm
V_{gate}	16.2 kV	7.0 kV	8.5 kV
Length	664.5 mm	664.5 mm	664.5 mm
Diameter	454 mm	454 mm	454 mm
Fiducial mass	5 kg	2.3 kg	3 kg
Drift length	(530.3 ± 2.0) mm	(530.3 ± 2.0) mm	(530.3 ± 2.0) mm
Drift field	$400\,V\,cm^{-1}$	$400\,V\,cm^{-1}$	$400\,V\,cm^{-1}$
$V_{cathode}$	41 kV	28 kV	30 kV







Evolution of the lifetime during a fraction of Run II



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Calibration of the NEXT-White detector using ^{83m}Kr decays

Arxiv 1804.01780
Submitted to JINST

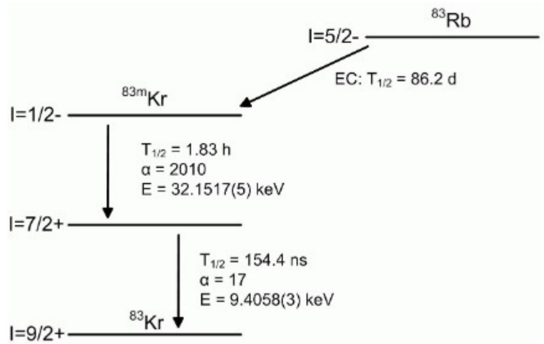
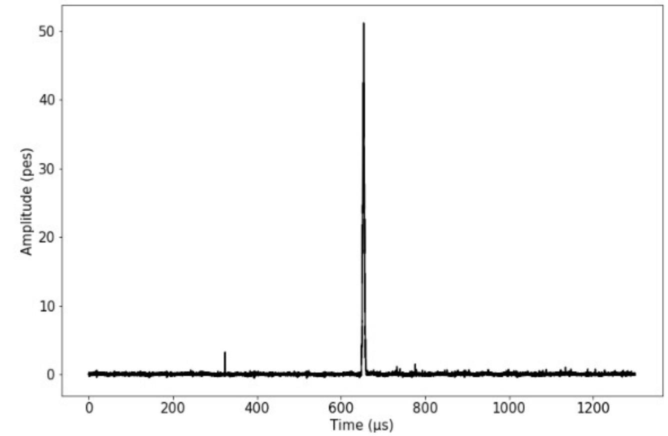


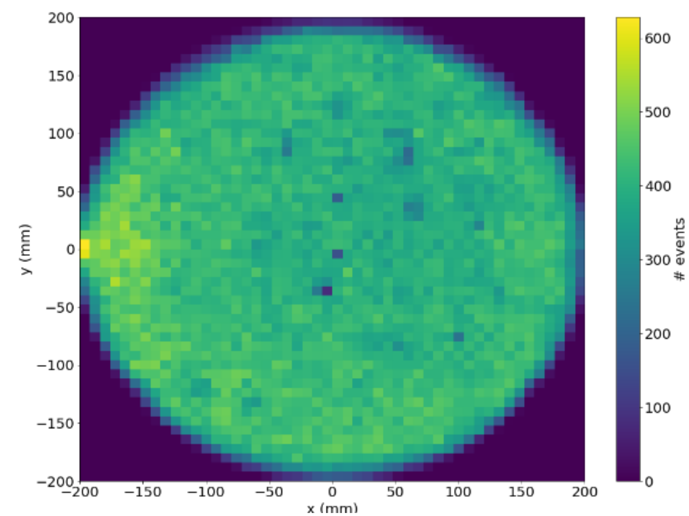
Figure 2: ^{83}Rb decay scheme.



Krypton Decays:
- Energy calibration
- Light Map

Correct finite drift-electron lifetime
Correct energy/position

Energy Resolution:
- 3.88±.05%FWHM
- At 41.5 keV point-like Kr decay
- Restricted fiducial volume

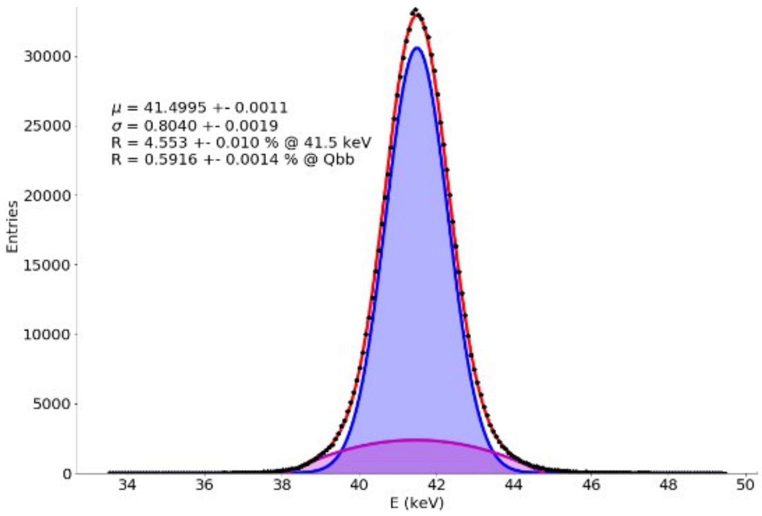


Scale to ROI:
- 0.504±.005%FWHM
- At 2458 keV Qbb
- Restricted fiducial volume

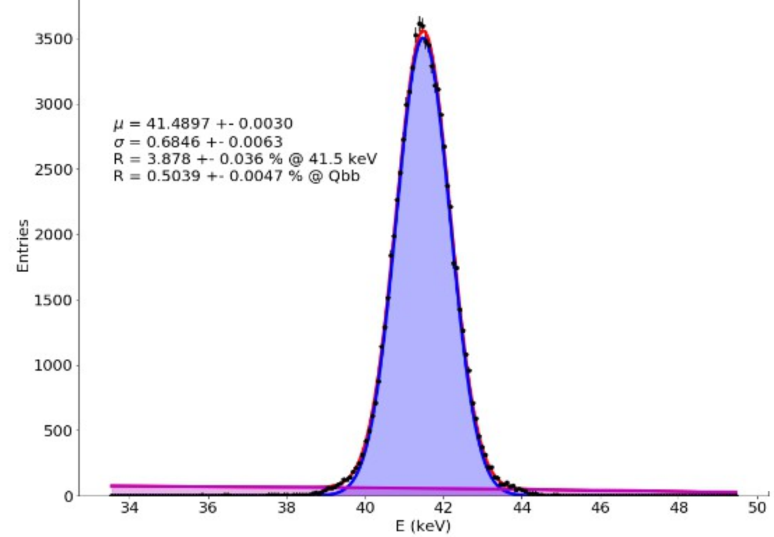
$$R_{int} = 2.35\sqrt{\frac{F}{\bar{N}_e}} \sim 0.3\,\%$$

Calibration of the NEXT-White detector using ^{83m}Kr decays

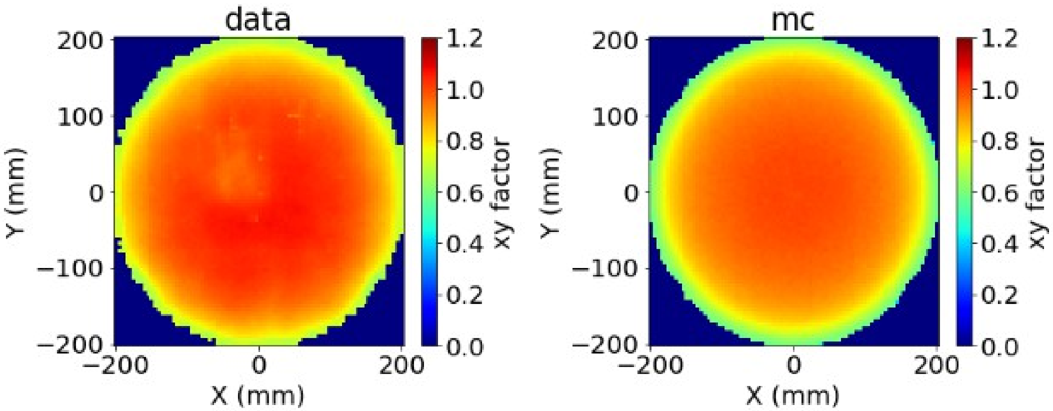
Run 4840 Full Fiducial



Run 4840 Restricted Fiducial



Energy map for Run 4734



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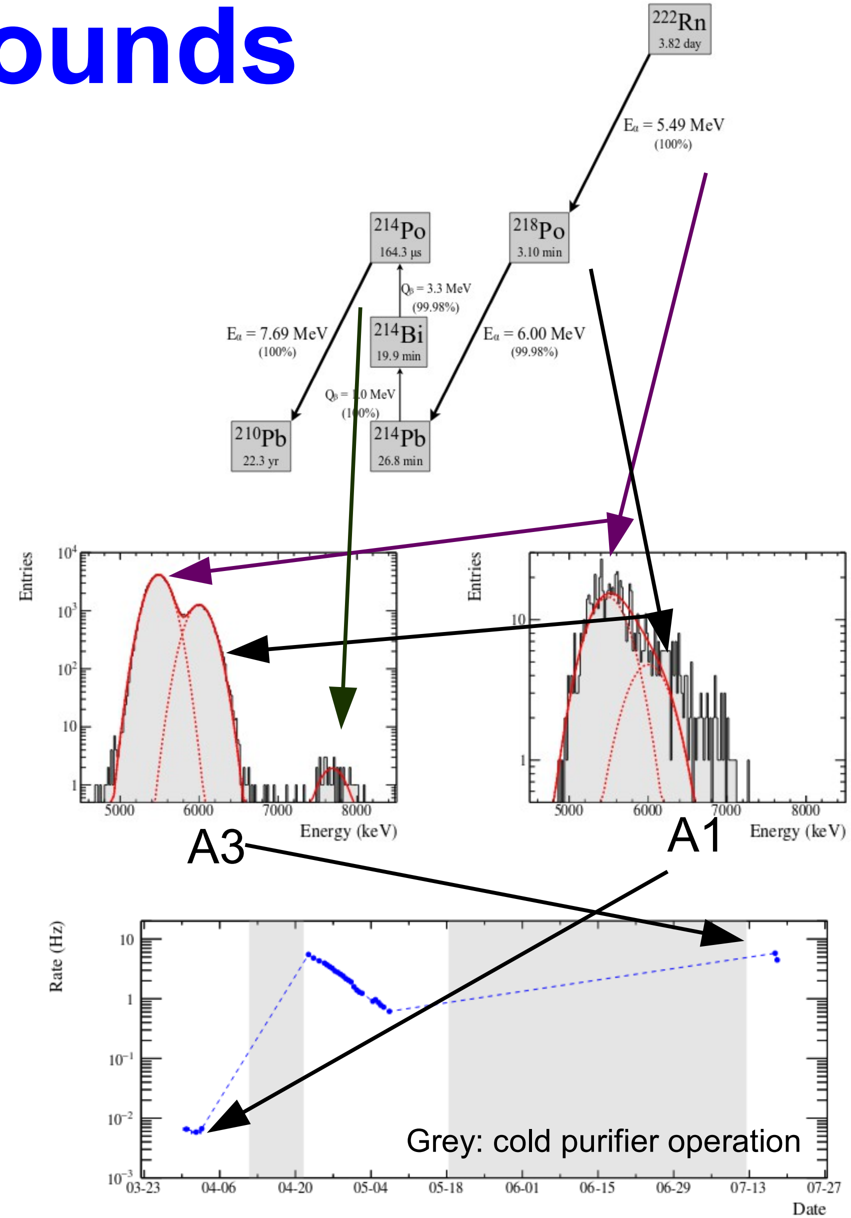
Measurement of Radon-induced backgrounds



Radon Chain Backgrounds

Alpha: ^{222}Rn, ^{218}Po, ^{214}Po

Beta: ^{214}Bi

Three Run Periods

Cold purifier Rn contamination

Alpha Specific Activity:

37.5±2.3±5.9 mBq/m^3

Beta Fiducial Rate ROI:

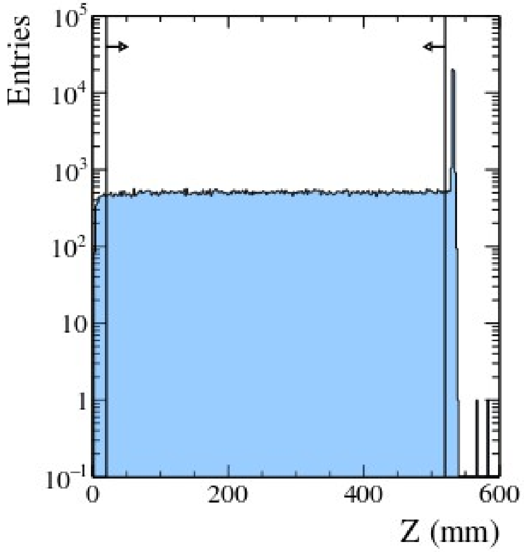
<0.2 cts/year

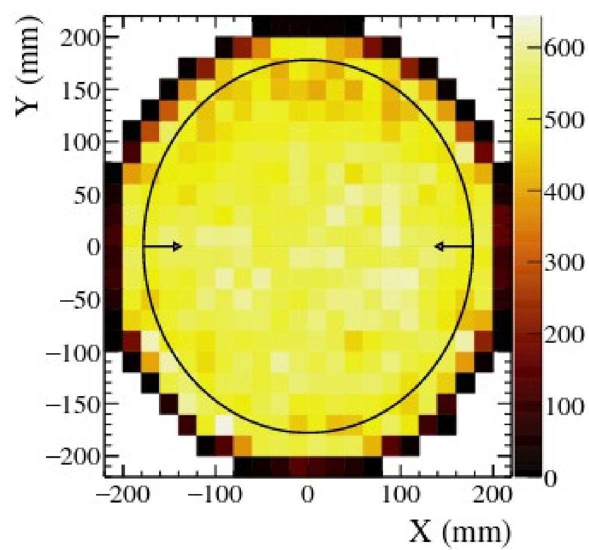
Scenario	Total ^{214}Bi activity from cathode (counts/yr)	Background acceptance	$\beta\beta0\nu$ background rate (counts/yr)
Optimistic	$(9.7 \pm \pm 1.6) \times 10^4$	7×10^{-8}	$(6.8 \pm 1.1) \times 10^{-3}$
Pessimistic	$(6.0 \pm \pm 1.0) \times 10^5$	2.7×10^{-7}	0.16 ± 0.03

Arxiv 1804.00471

Submitted to JHEP

Measurement of Radon-induced backgrounds

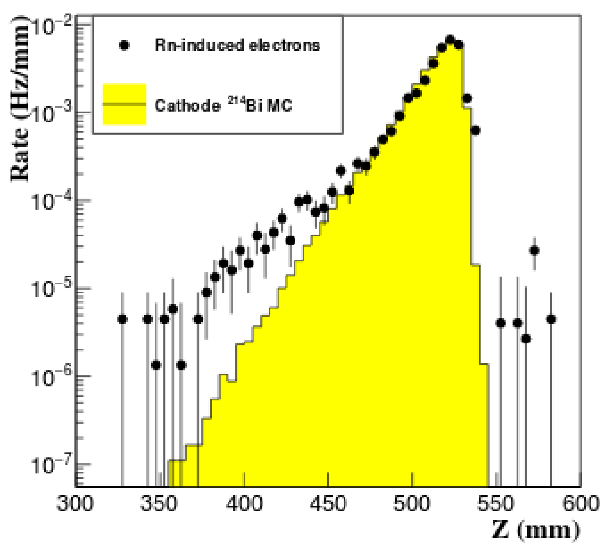


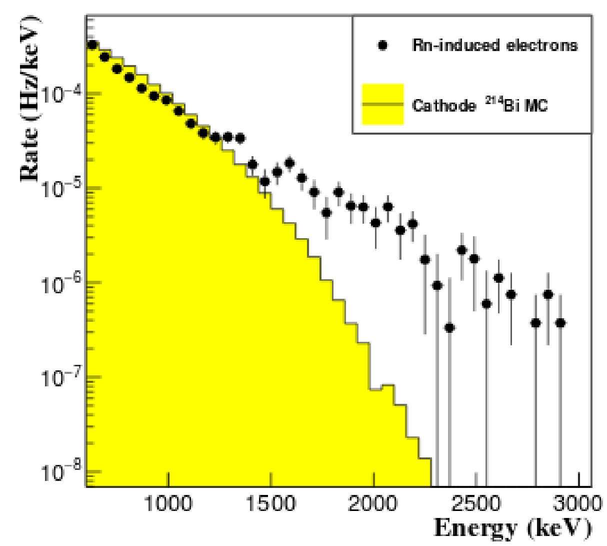


Spatial distribution of alpha candidate events.

solid black lines for fiducial region

Radon-induced electrons originating from the cathode (black dots) superimposed on the MC expectation (yellow histogram)





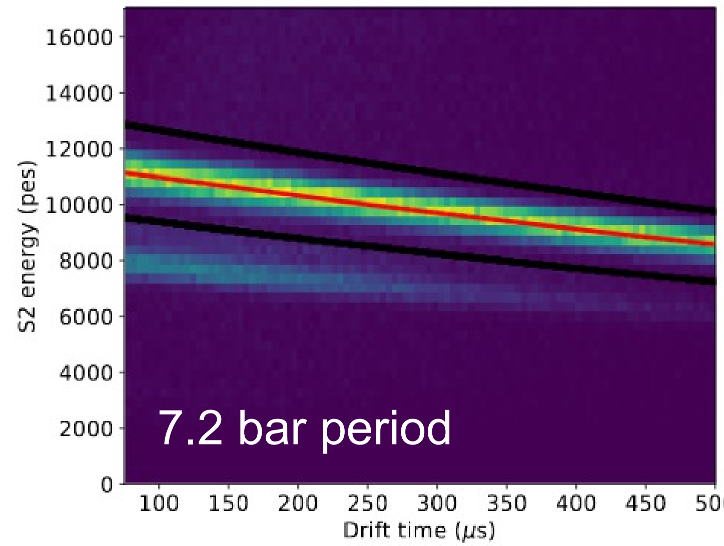
Electron drift properties in high pressure gaseous xenon

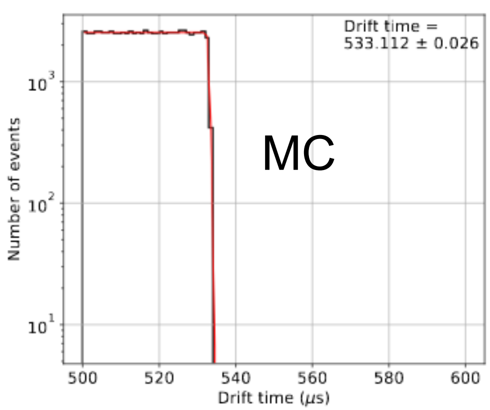
Electron Lifetime:

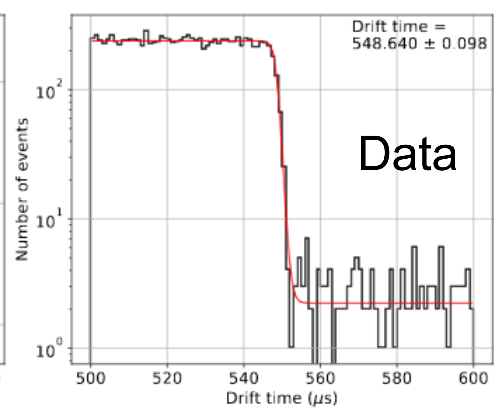
Exponential fit of S2 vs Drift Time
7.2 bar: (1617±40) µs lifetime

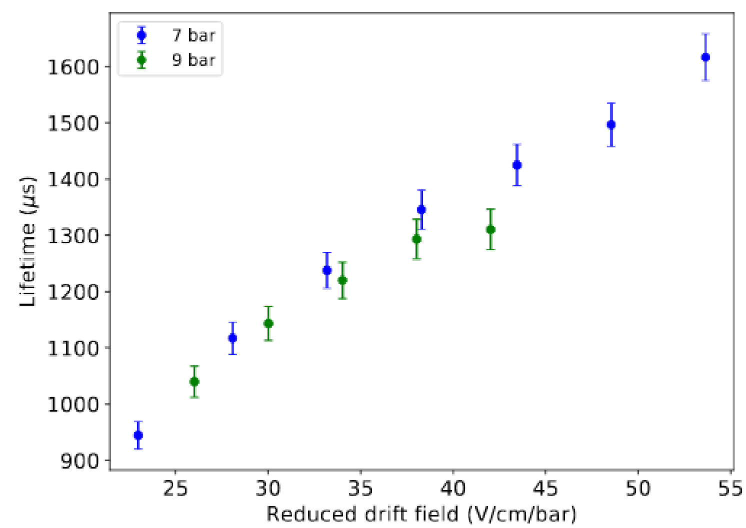
Drift Velocity

Maximum Drift Time
Cathode/gate distance
967.99±0.17(stat.)±4.06(sys.) $\mu m \mu s^{-1}$









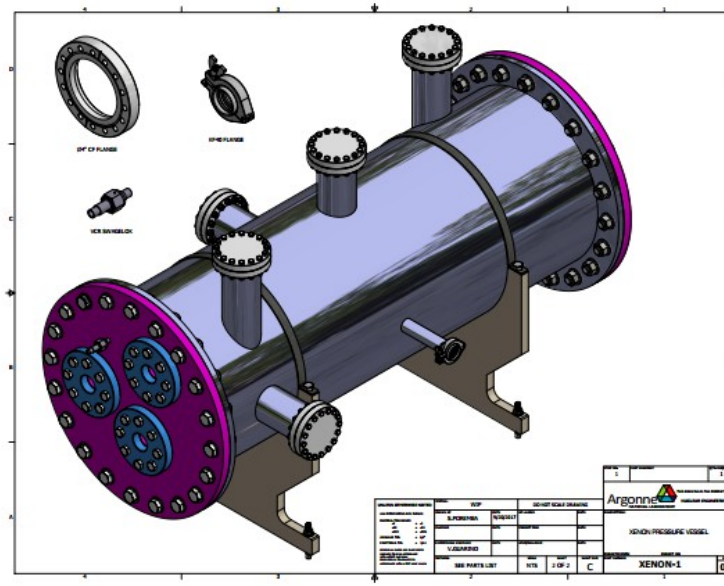
Arxiv 1804.1680
Submitted to JINST

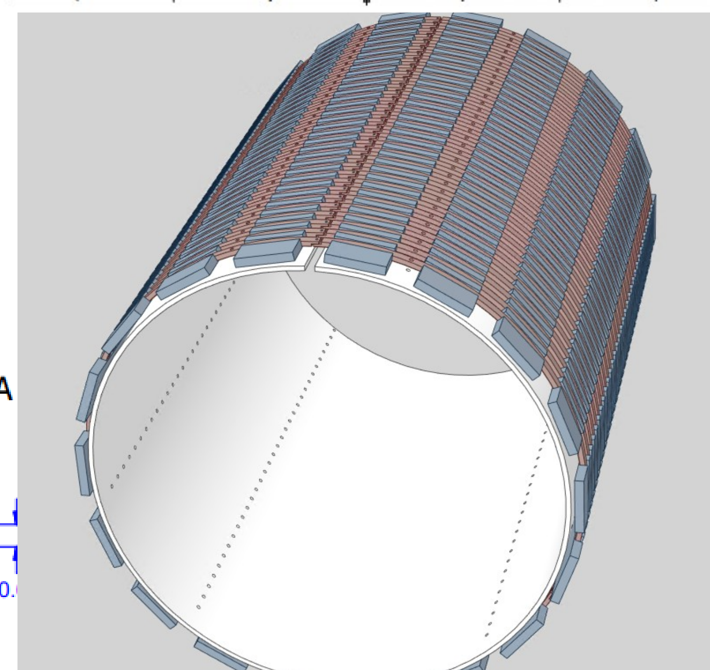
NEXT-100

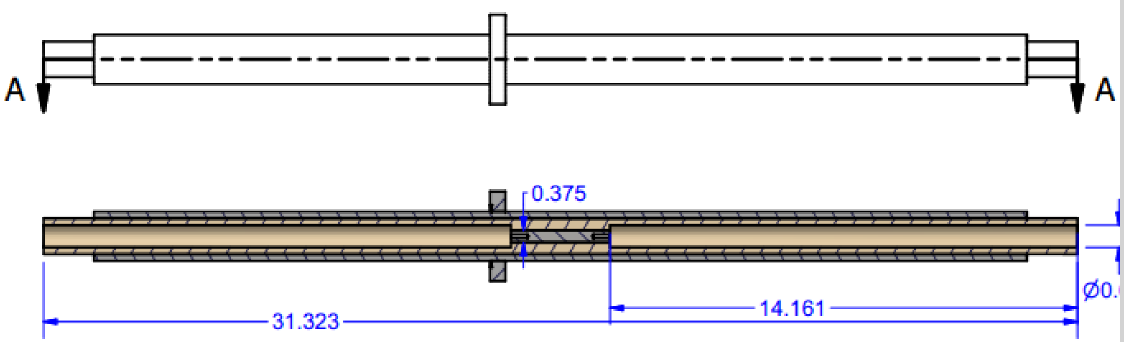
- Vessel, gas system, shielding
  - IFIC, UPV, IGFAE, DIPC, LSC
- Electroluminescent gate, Cathode
  - UTA
- Field cage, feed through
  - ANL
- TPC integration
  - Harvard
- Installation expected 2019
  - Commissioning, physics run 2020-2021

Argonne's Xenon TPC R&D

- Field Cage
  - Shape electric field
  - Provide structure to barrel
  - Reflect light
  - Ultra low background materials
- High Voltage Feed Through
  - Introduce voltage to pressure vessel
  - Maintain voltage at catholde
  - No sparking, no breakdown
  - Ultra low background materials
- Test Facility
  - High Pressure Vessel
  - Purifying gas system

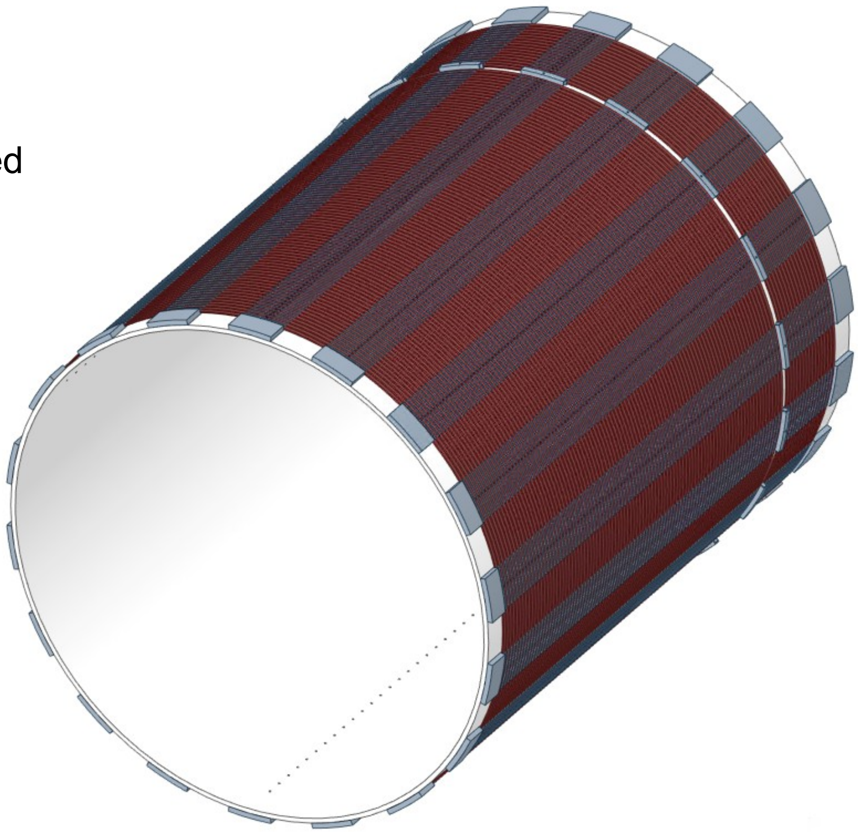


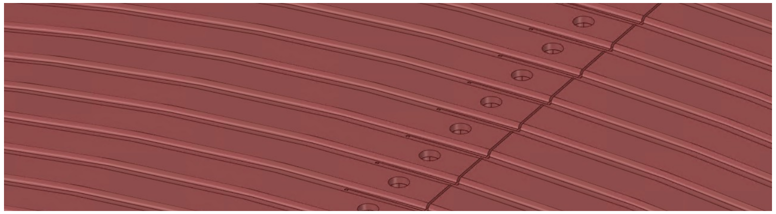




Field Cage

- Conceptual Design Process
  - Wide range of design considered
  - Assessed on 8 key points
  - Maximize performance
  - Minimize risk
- Fiducial mass
  - 69 kg at 15 bar
- Structural mass
  - ~140 kg plastic



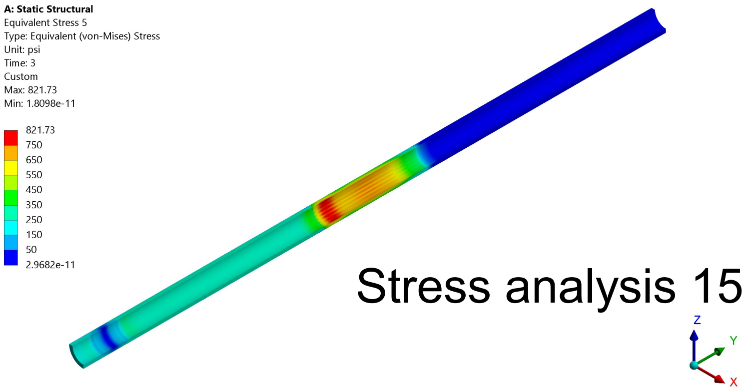


Ring detail matches NEXT-NEW geometry

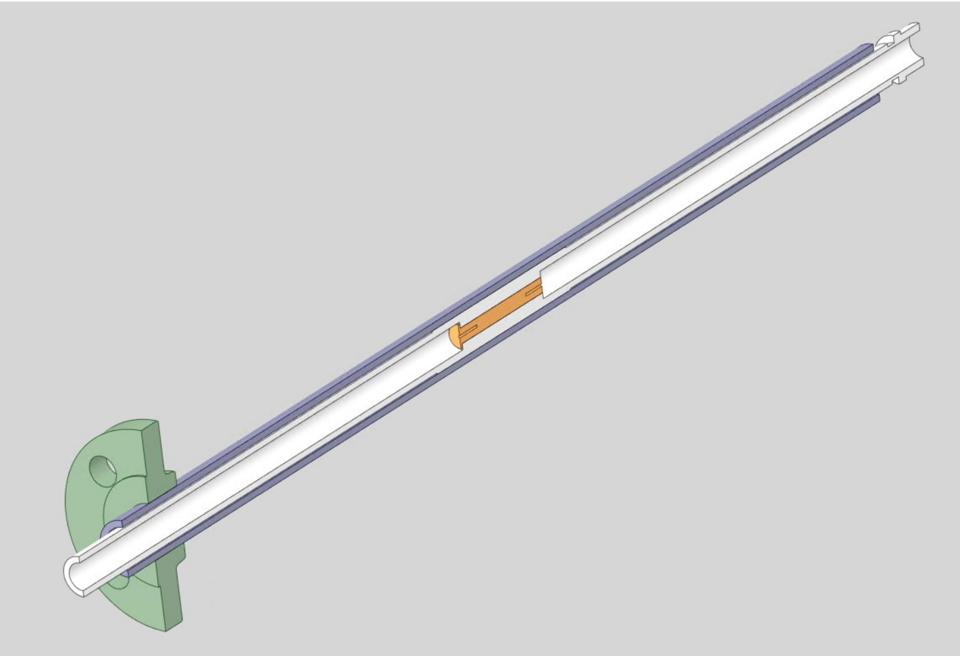
Largest fiducial volume using known materials
Simplified design reduces background material.
Minimizes risk, maximizing performance.

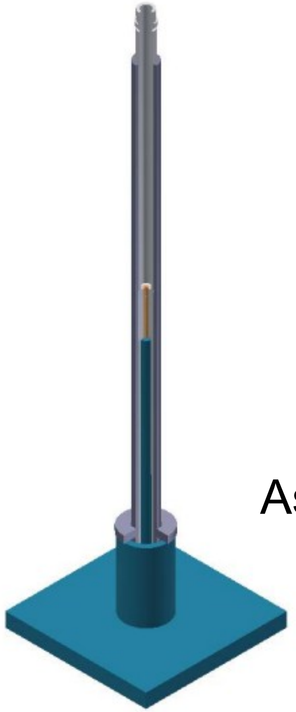
High Voltage Feed Through

- Mimic commercial FT design
  - Reduces risks
  - Cable runs inside vessel to cathode
- Plug, Cable
  - Commercial solutions acceptable
- Cryo-Assembled Components
  - Provides pressure penetration



Stress analysis 15 bar





Assembly Jig

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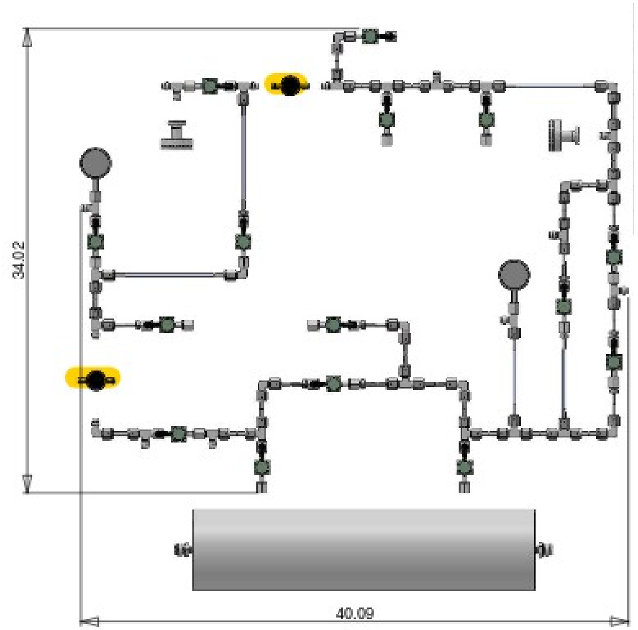
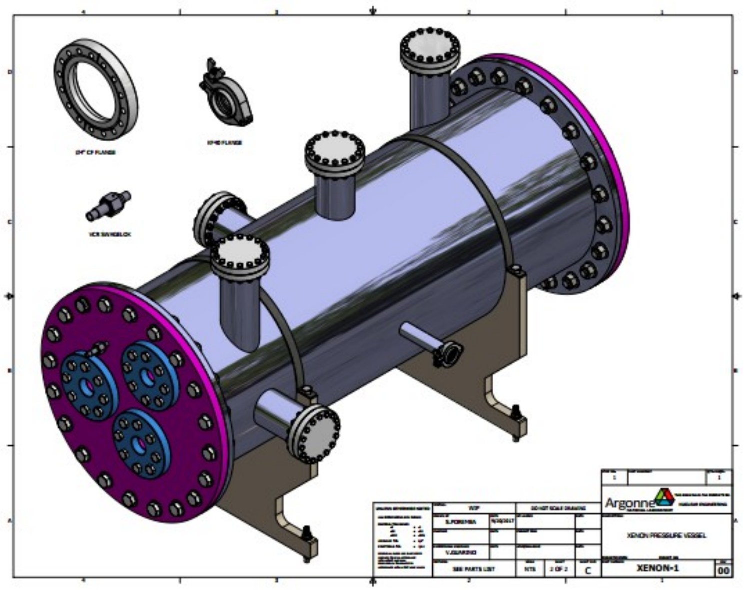
Argonne Test Facility

- Pressure Vessel
  - 15 bar capable
  - 10^{-5} torr vacuum
  - 60 inch length
  - 20 inch diameter
  - Sapphire window

- Planned tests
  - Full length field cage component
  - Reduced diameter required
  - Gas mixtures possible
  - Pressure, high voltage





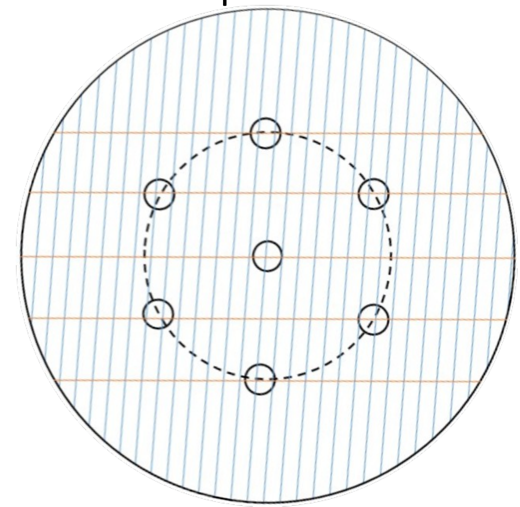
- Gas System
  - Recirculating
  - Purifier
  - Xenon, Argon Mix
  - RGA

EL Region for NEXT-100

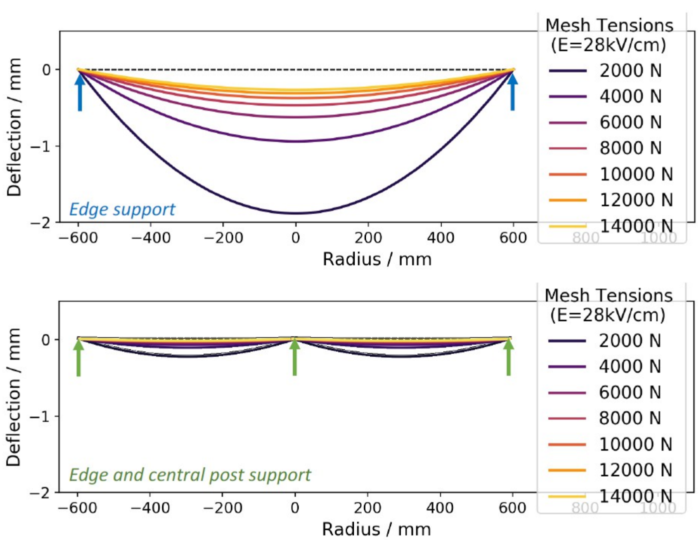
University of Texas at Arlington

- Gate is a supported mesh with HDPE support posts
- Electrical and mechanical tests of candidate support materials have been made in high pressure xenon gas in UTA test facility [1]
- Anode is laser cut from resistive plastic

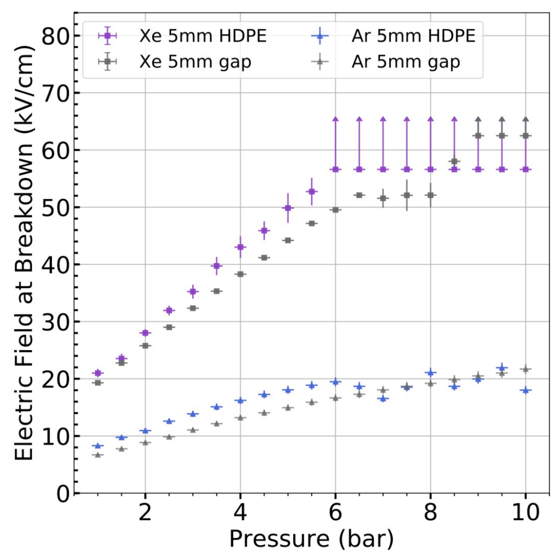
Top view

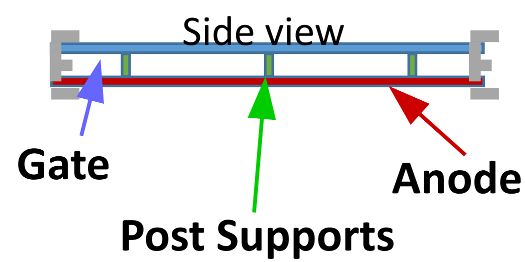


Effect of supports on mechanical deflection



HV strength of HDPE in HPGXe





[1]: High Voltage Insulation and Gas Absorption of Polymers in High Pressure Argon and Xenon Gases, arXiv:1804.04116

Cathode and Test Facility at UT Arlington

Large scale testing facility designed for high pressure gas and can be used for testing components up to tonne scale proportions

NEXT-100 Cathode has been manufactured and is to be tested in July; EL is in production for testing in later summer / fall.

Summary

- NEXT-NEW Operational
    - Stay tuned for new results
- NEXT-100 at ANL
    - Field Cage
    - Feed Through
    - Test Facility
- NEXT-100 at UTA
    - EL Region
    - Cathode