Status of the XENONnT Dark Matter experiment

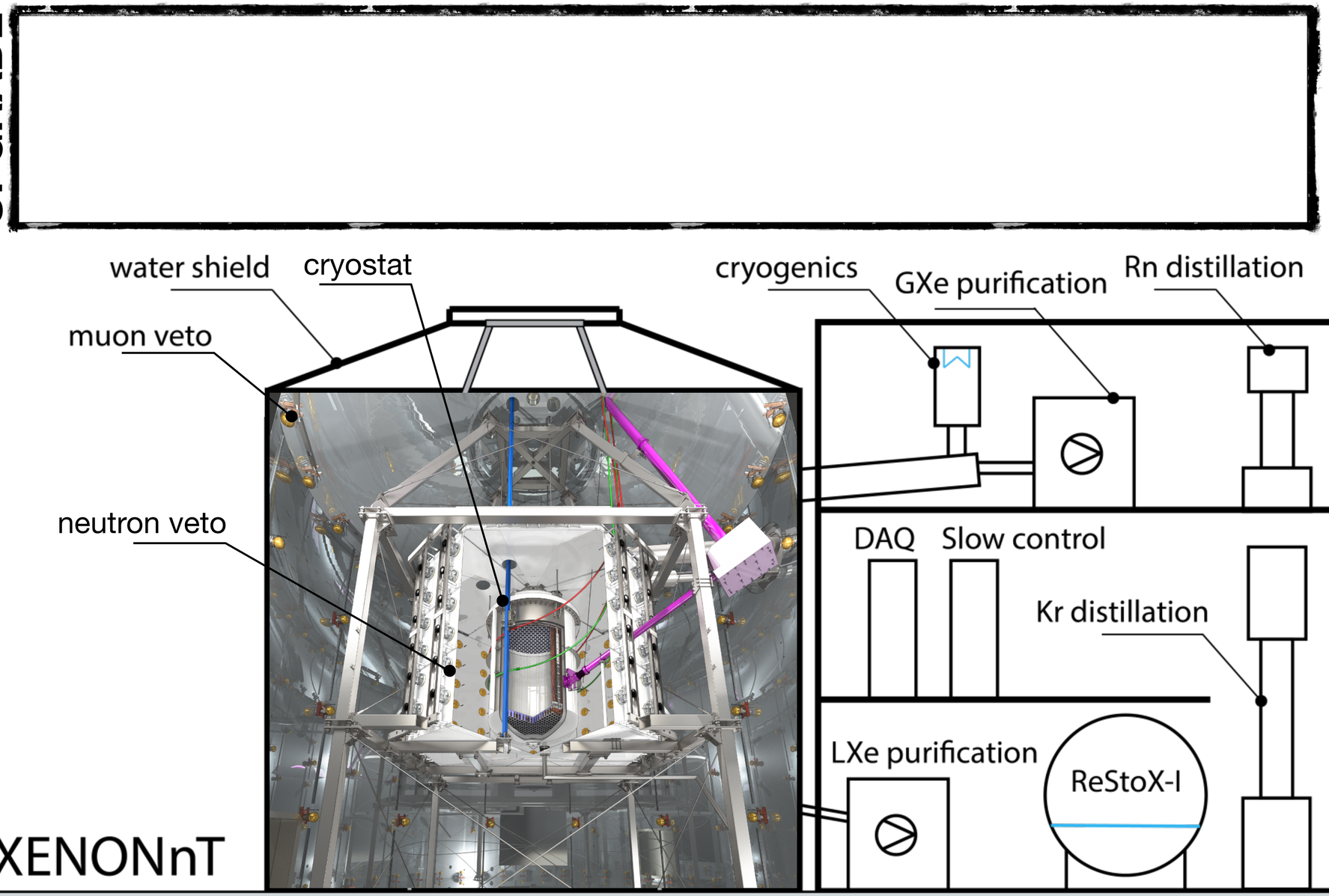
Dr. Maxime Pierre
maxime.pierre@nikhef.nl
Universiteit van Amsterdam
Nikhef

Nikhef Jamboree
Amsterdam
14th of May, 2024

From XENON1T to XENONnT

Maxime Pierre
maxime.pierre@nikhef.nl

UPGRADE

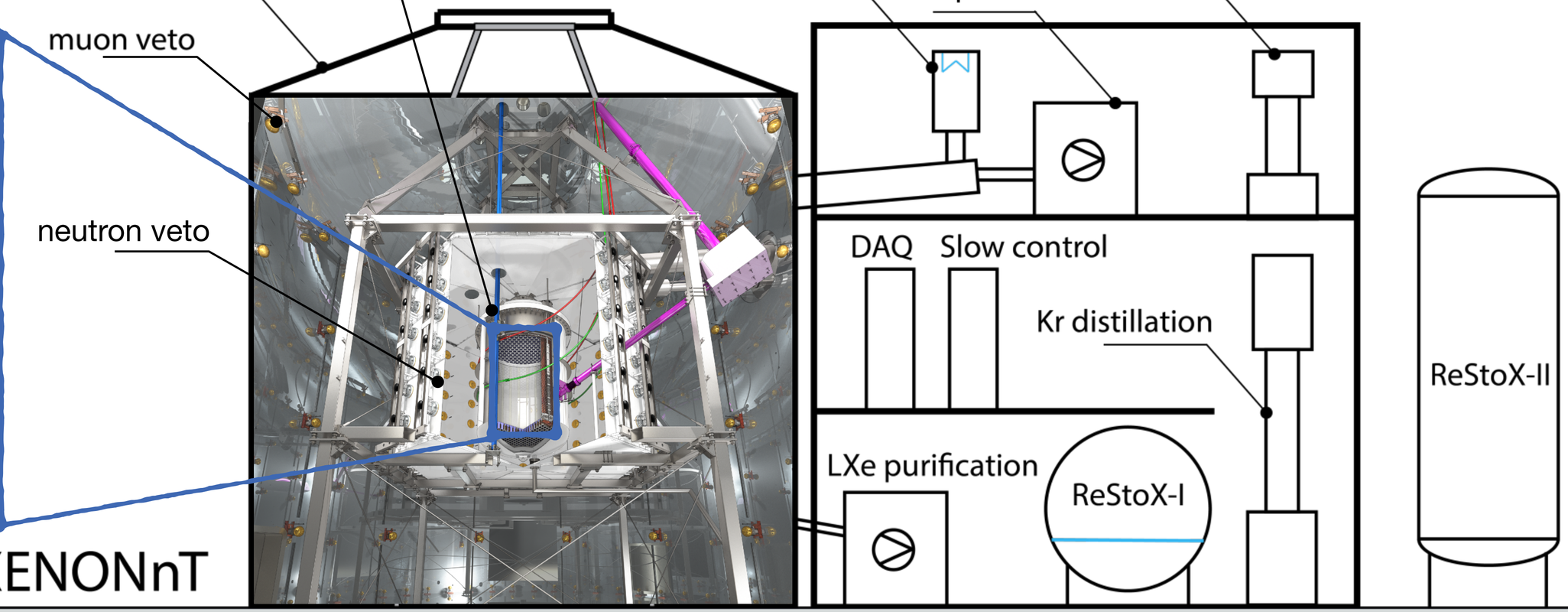


From XENON1T to XENONnT

Maxime Pierre
maxime.pierre@nikhef.nl

UPGRADE

x3 larger TPC
8.5 t LXe
494 PMTs



XENONnT

From XENON1T to XENONnT

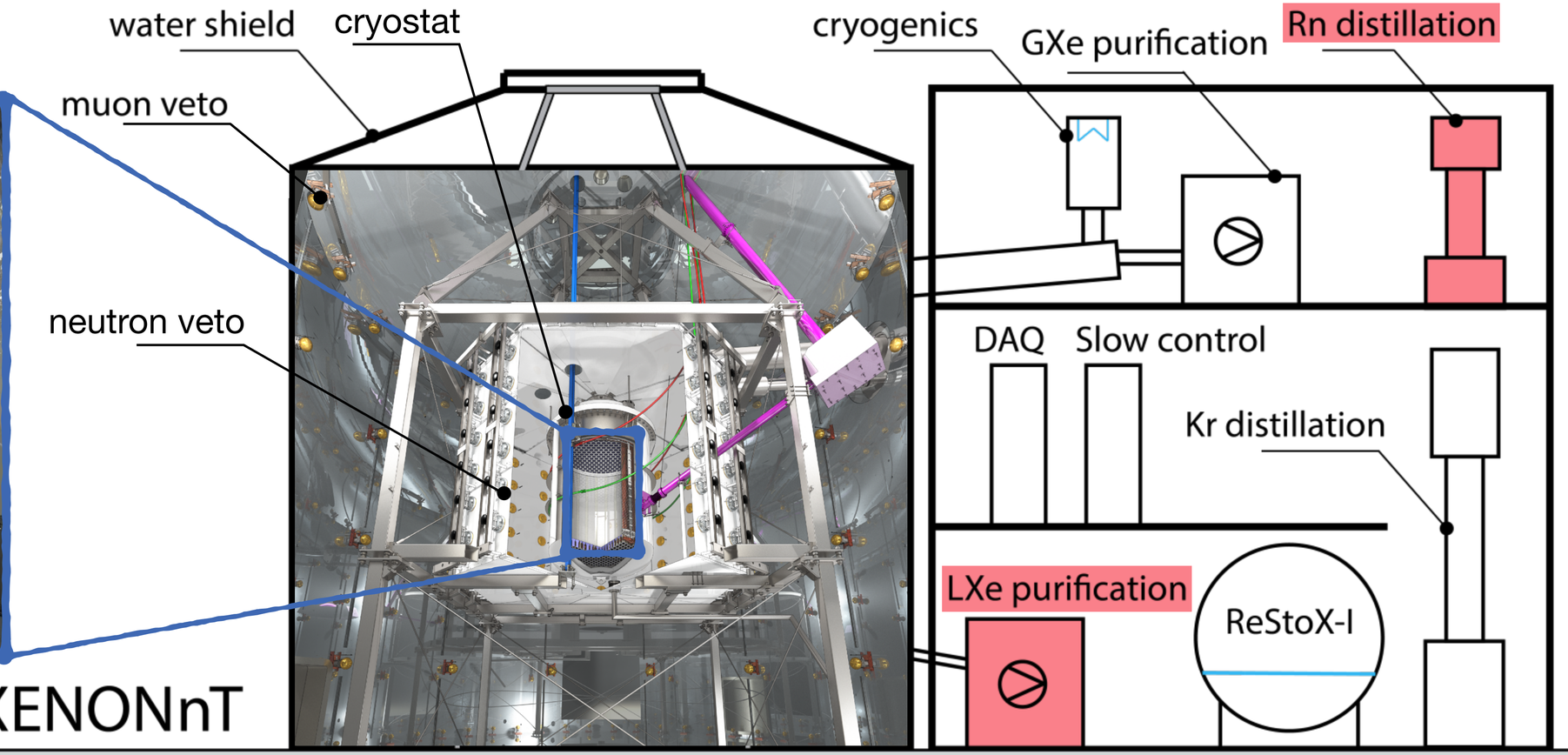
Maxime Pierre
maxime.pierre@nikhef.nl

XENON

UPGRADE

x3 larger TPC
8.5 t LXe
494 PMTs

Xenon handling
New purification
& ER bkg. reduction
New recovery/storage



XENONnT

From XENON1T to XENONnT

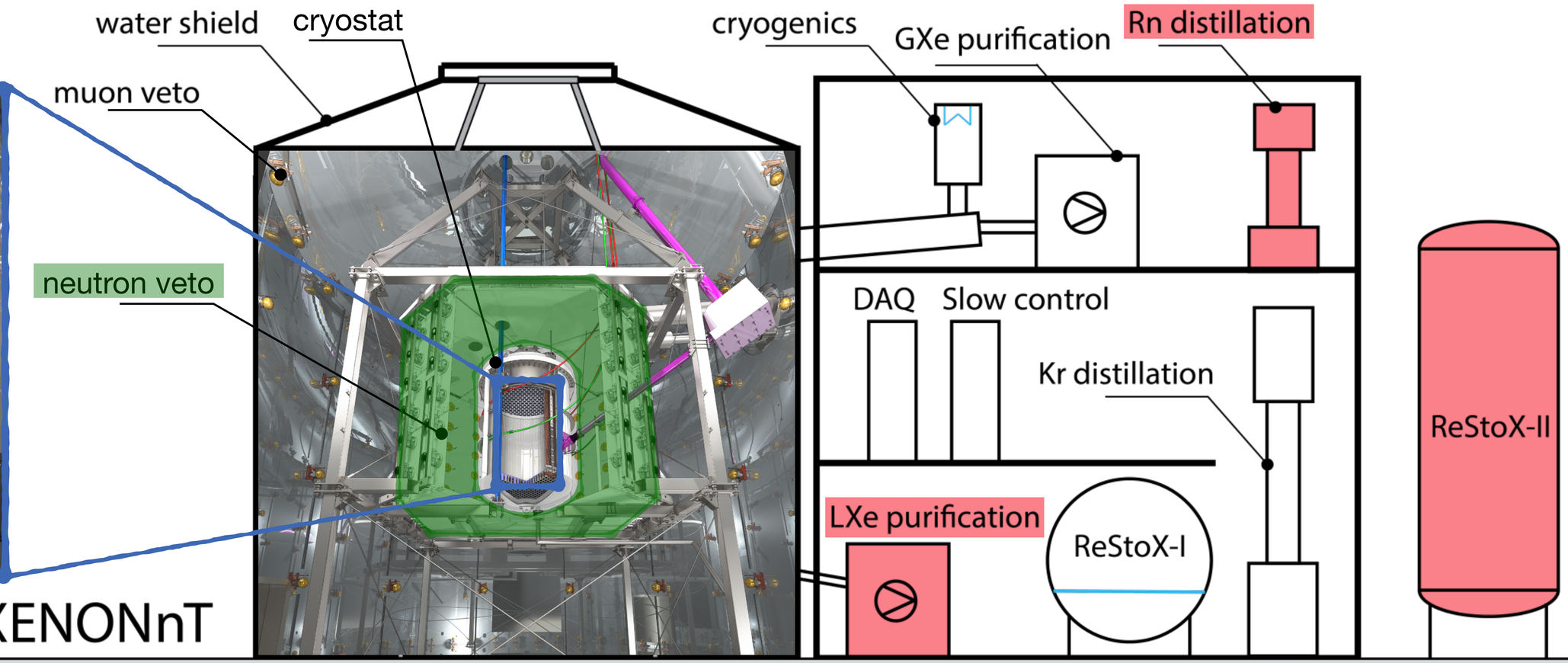
Maxime Pierre
maxime.pierre@nikhef.nl

UPGRADE

x3 larger TPC
8.5 t LXe
494 PMTs

Xenon handling
New purification
& ER bkg. reduction
New recovery/storage

Water Cherenkov Neutron Veto
Gd-doping in preparation



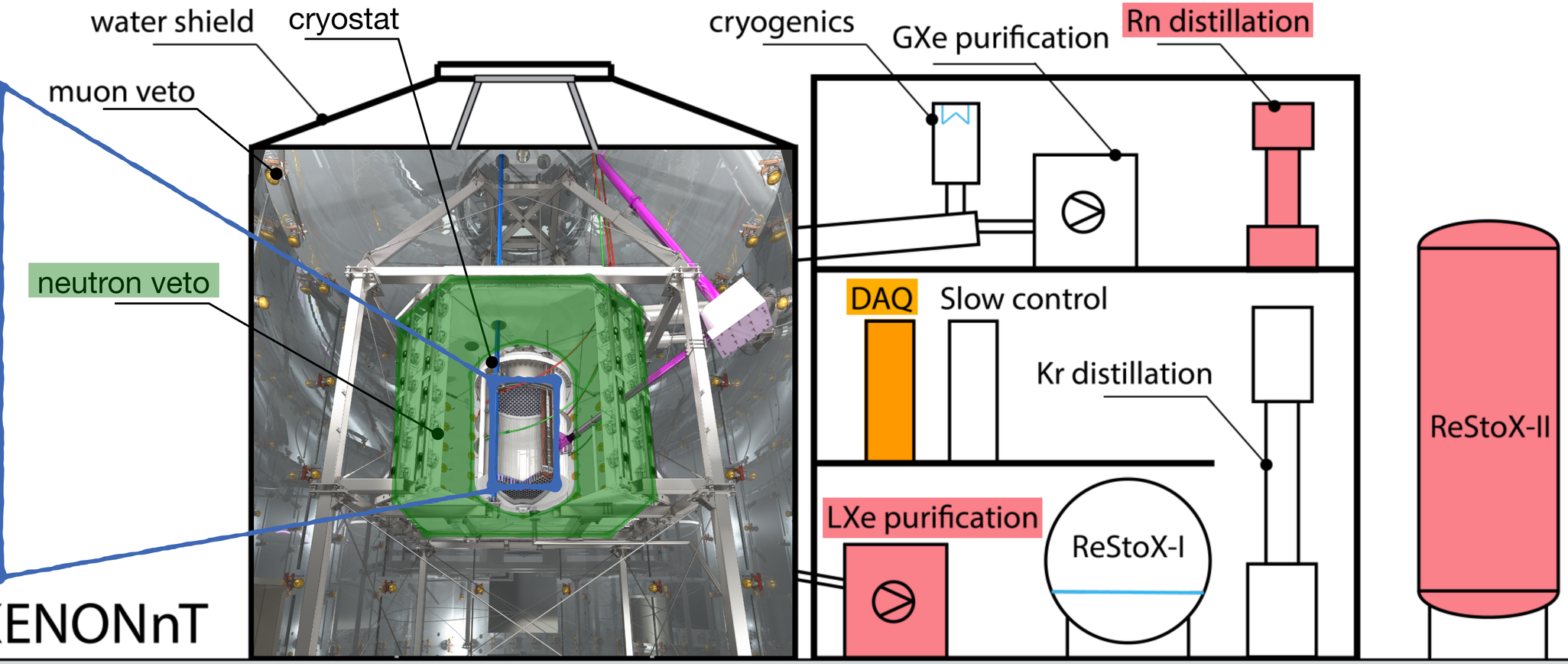
From XENON1T to XENONnT

Maxime Pierre
maxime.pierre@nikhef.nl

Nikhef

UPGRADE

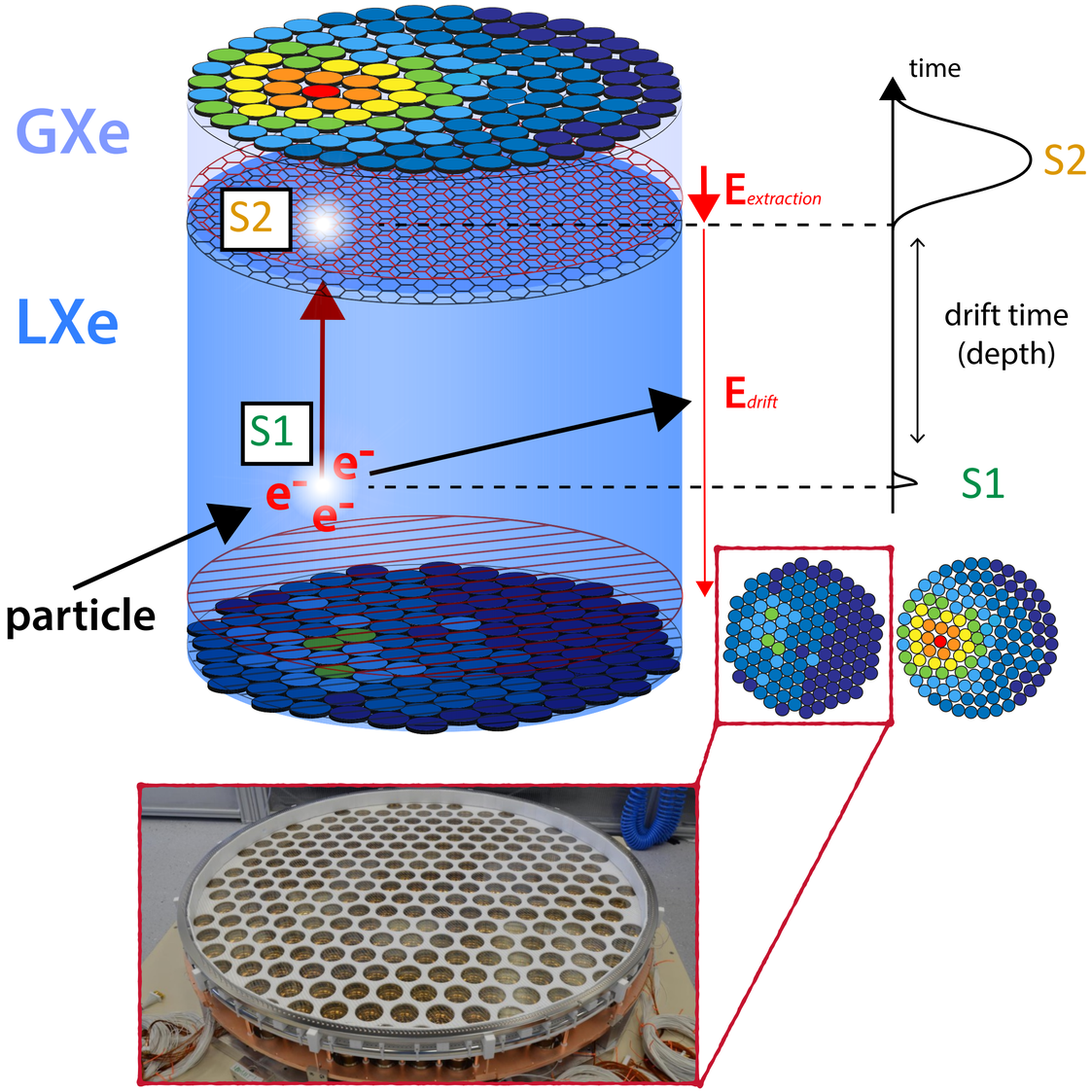
x3 larger TPC	Xenon handling	Water Cherenkov Neutron Veto	Triggerless DAQ
8.5 t LXe 494 PMTs	New purification & ER bkg. reduction New recovery/storage	Gd-doping in preparation	To improve low-energy sensitivity (JINST 18 P07054)



XENONnT

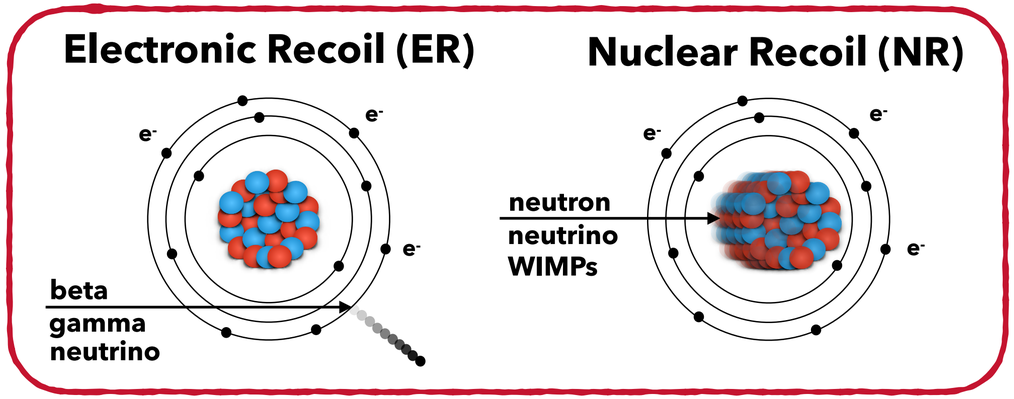
TPC Detection Principle

Maxime Pierre
maxime.pierre@nikhef.nl



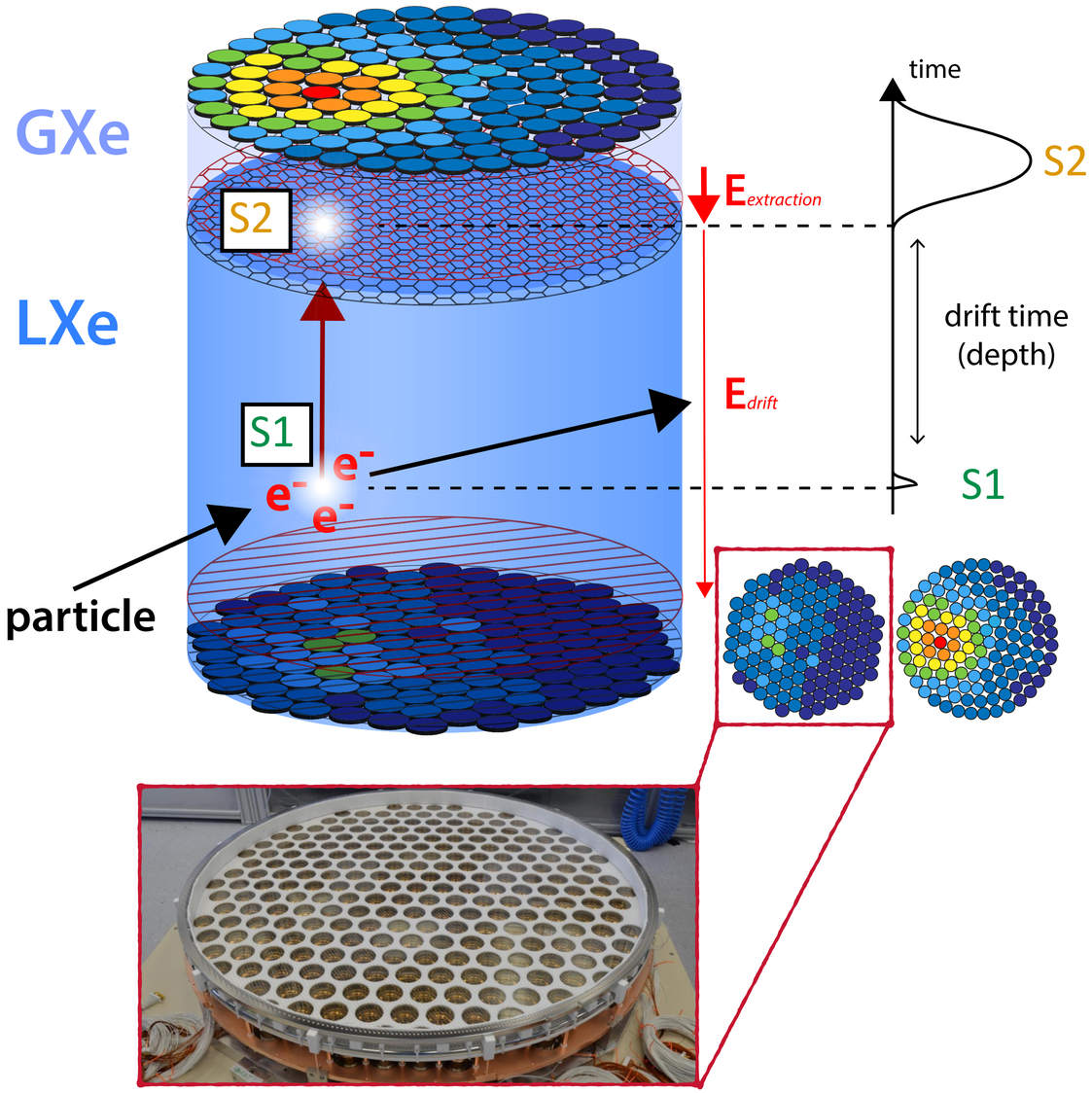
Readout of scintillation and ionisation signals:

- Prompt light signal (**S1**)
- Secondary light in GXe from drifted electrons (**S2**)
- Reconstruction of position (**x, y, z**), energy (**E**) and interaction type (**ER**/**NR**) through **S1**/**S2** ratio



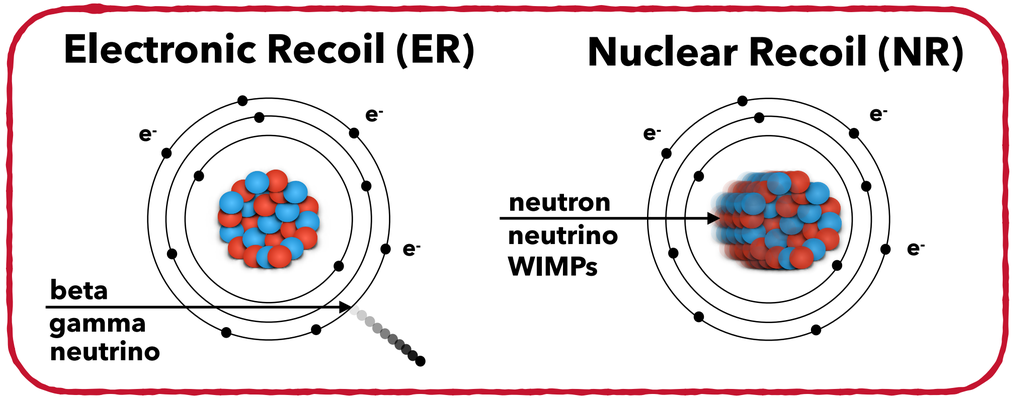
TPC Detection Principle

Maxime Pierre
maxime.pierre@nikhef.nl



Readout of scintillation and ionisation signals:

- Prompt light signal (**S1**)
- Secondary light in GXe from drifted electrons (**S2**)
- Reconstruction of position (**x, y, z**), energy (**E**) and interaction type (**ER**/**NR**) through **S1**/**S2** ratio



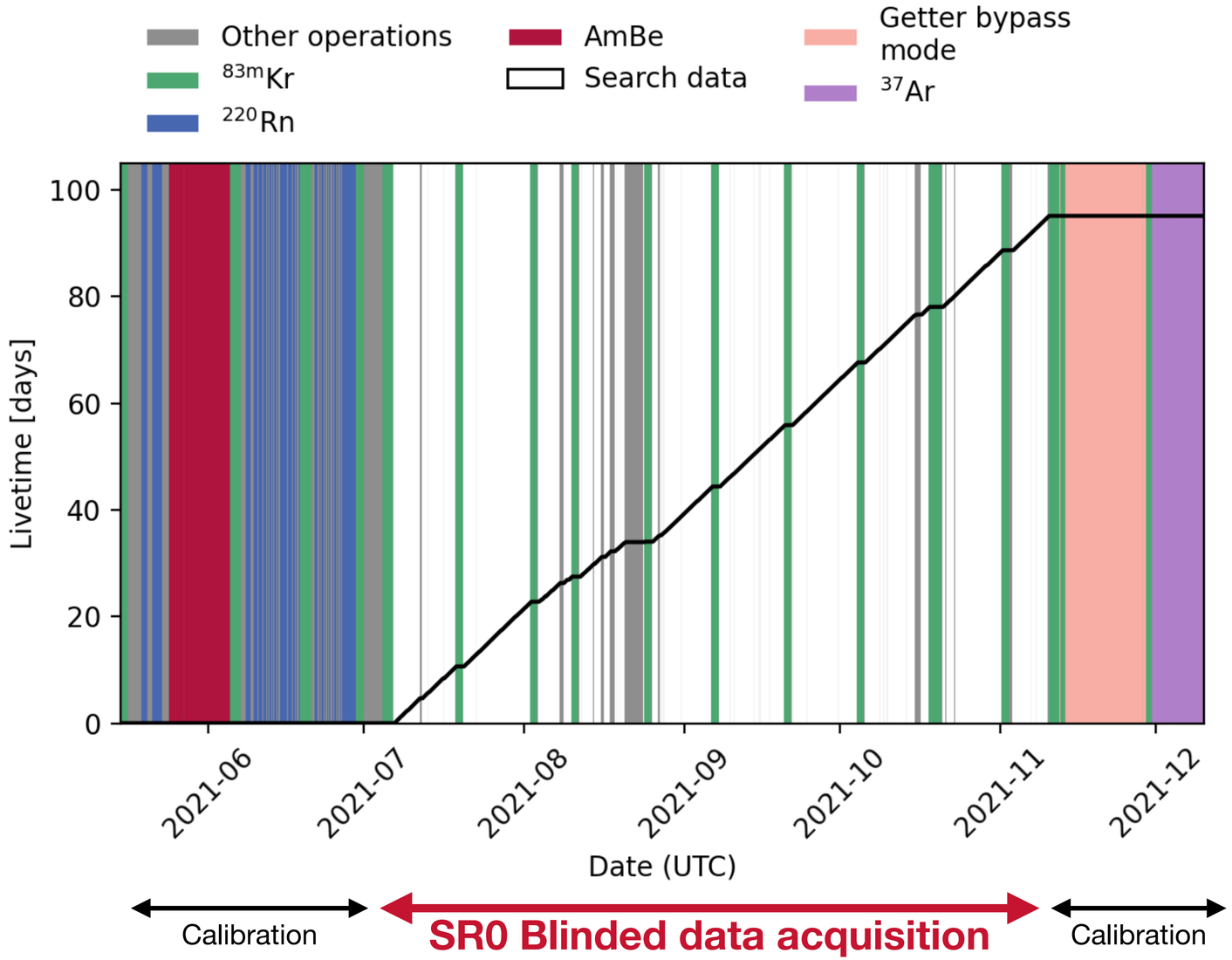
Analysis pipeline: Strax(en)

Nikhef

- Handle the data stream from the new triggerless DAQ
- Reconstruct high-level data structure (S1/S2 peaks, events) from PMTs signals

XENONnT - Science Run 0

Maxime Pierre
maxime.pierre@nikhef.nl



Science run summary

- July 6 to Nov 10, 2021 (97.1 days)
- 95.1 days lifetime corrected
- 4.18 ± 0.13 tonnes Fiducial Volume
- Exposure: 1.1 tonne-year

Detector configuration

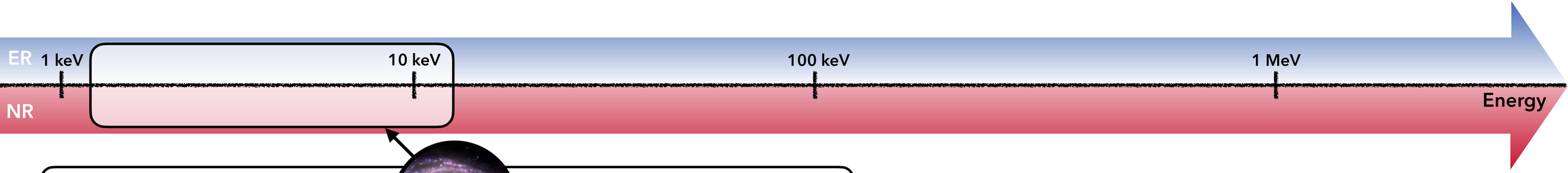
- Drift field: 23 V/cm
- Extraction field: 2.9 kV/cm (~50% e^- extr. eff.)
- 477 out of 494 PMTs working (~3.4% loss)
- LY & CY stable at 1% and 1.9% respectively during blinded data taking

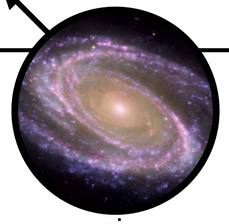
Physics output

- First WIMP & Low-energy ER results published
- **...But much more to come!**

XENON Physics Program

Maxime Pierre
maxime.pierre@nikhef.nl





WIMPs DM candidate

- Spin-independent
  - ➡ **PRL 131, 041003**
  - ➡ PRL 119, 181301
  - ➡ PRL 121, 111302
- Spin-dependent
  - ➡ **PRL 131, 041003**
  - ➡ PRL 122, 141301
- Sub-GeV
  - ➡ PRL 122, 071301
  - ➡ PRD 103, 063028

Other DM candidate

- Light DM
  - ➡ PRL 123, 241803
  - ➡ PRL 123, 251801
- Heavy DM
  - ➡ PRL 130, 261002
- Bosonic DM
  - ➡ **PRL 129, 161805**
  - ➡ PRD 102, 072004

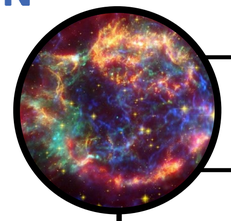
XENONnT latest results

Primary goal → DM direct detection at low-energy recoil in our xenon target

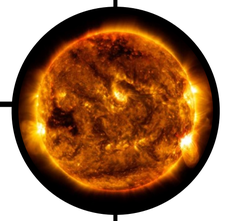
XENON Physics Program

Maxime Pierre
maxime.pierre@nikhef.nl

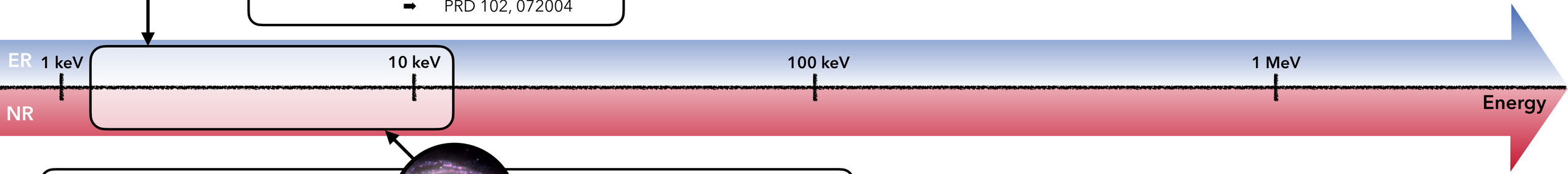
XENON

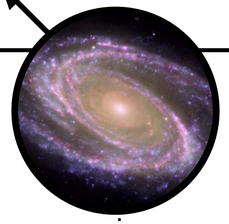


- Supernova neutrinos
  - ➡ PRD 94,103009



- Solar ^{8}B CEvNS
  - ➡ PRL 126, 091301
- Solar pp neutrinos
  - ➡ EPJC 80:1133
- Solar axions
  - ➡ PRD 102, 072004





WIMPs DM candidate

- Spin-independent
  - ➡ **PRL 131, 041003**
  - ➡ PRL 119, 181301
  - ➡ PRL 121, 111302
- Spin-dependent
  - ➡ **PRL 131, 041003**
  - ➡ PRL 122, 141301
- Sub-GeV
  - ➡ PRL 122, 071301
  - ➡ PRD 103, 063028

Other DM candidate

- Light DM
  - ➡ PRL 123, 241803
  - ➡ PRL 123, 251801
- Heavy DM
  - ➡ PRL 130, 261002
- Bosonic DM
  - ➡ **PRL 129, 161805**
  - ➡ PRD 102, 072004

XENONnT latest results

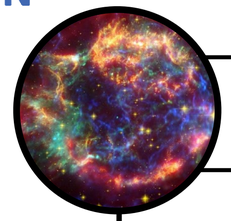
Primary goal → DM direct detection at low-energy recoil in our xenon target

Lower background level → open new physics channel…

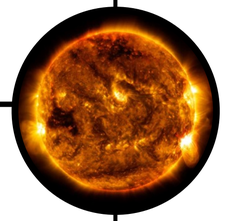
XENON Physics Program

Maxime Pierre
maxime.pierre@nikhef.nl

XENON



- Supernova neutrinos
  - ➡ PRD 94,103009

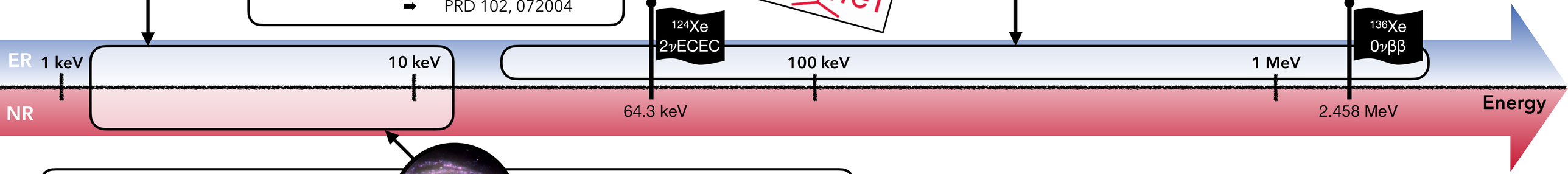


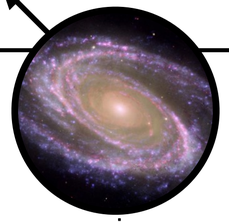
- Solar ^{8}B CEvNS
  - ➡ PRL 126, 091301
- Solar pp neutrinos
  - ➡ EPJC 80:1133
- Solar axions
  - ➡ PRD 102, 072004

Rare physics searches at high-energy ER

- ^{124}Xe 2νECEC capture
  - ➡ **PRL129, 161805**
  - ➡ PRC 106, 024328
  - ➡ Nature 568, 532
- $^{136/4}$Xe 2/0$\nu\beta\beta$ decay
  - ➡ PRC 106, 024328
  - ➡ EPJC 80:785
- ^{124}Xe 2/0ν(EC,β^{+}) decay
- Fermionic DM search
- Solar neutrino
- Precise nuclear transition measurement

Nikhef





WIMPs DM candidate

- Spin-independent
  - ➡ **PRL 131, 041003**
  - ➡ PRL 119, 181301
  - ➡ PRL 121, 111302
- Spin-dependent
  - ➡ **PRL 131, 041003**
  - ➡ PRL 122, 141301
- Sub-GeV
  - ➡ PRL 122, 071301
  - ➡ PRD 103, 063028

Other DM candidate

- Light DM
  - ➡ PRL 123, 241803
  - ➡ PRL 123, 251801
- Heavy DM
  - ➡ PRL 130, 261002
- Bosonic DM
  - ➡ **PRL 129, 161805**
  - ➡ PRD 102, 072004

XENONnT latest results

Primary goal → DM direct detection at low-energy recoil in our xenon target

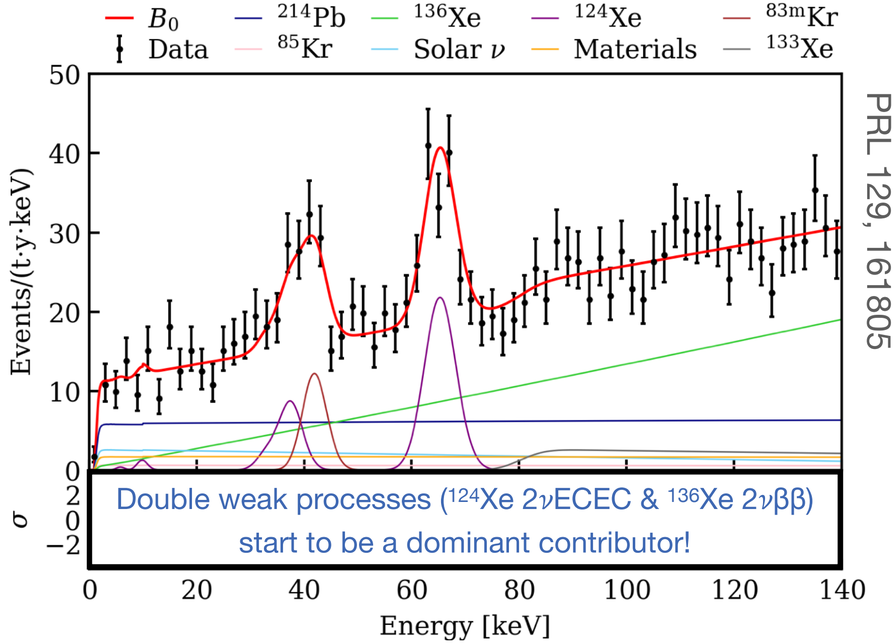
Lower background level → open new physics channel… up to the MeV scale

^{136}Xe 2$\nu\beta\beta$ decay energy spectrum

Maxime Pierre
maxime.pierre@nikhef.nl

Motivation

- First measurement of 2$\nu\beta\beta$ spectra from few keV to $Q_{\beta\beta}$ @ 2.6 MeV
- Path to precision measurement with xenon dual-phase TPC
  - Study of quenching of Nuclear Matrix Elements
  - Search for BSM physics in spectral shape



PRL 129, 161805

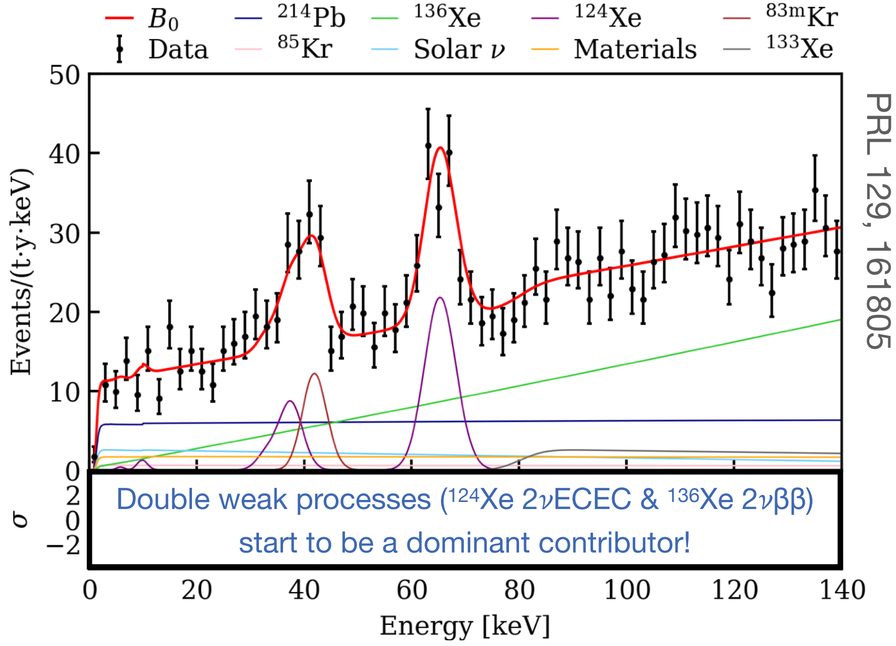
^{136}Xe 2$\nu\beta\beta$ decay energy spectrum

Maxime Pierre
maxime.pierre@nikhef.nl

XENON

Motivation

- First measurement of 2$\nu\beta\beta$ spectra from few keV to $Q_{\beta\beta}$ @ 2.6 MeV
- Path to precision measurement with xenon dual-phase TPC
  - Study of quenching of Nuclear Matrix Elements
  - Search for BSM physics in spectral shape



PRL 129, 161805

Signal

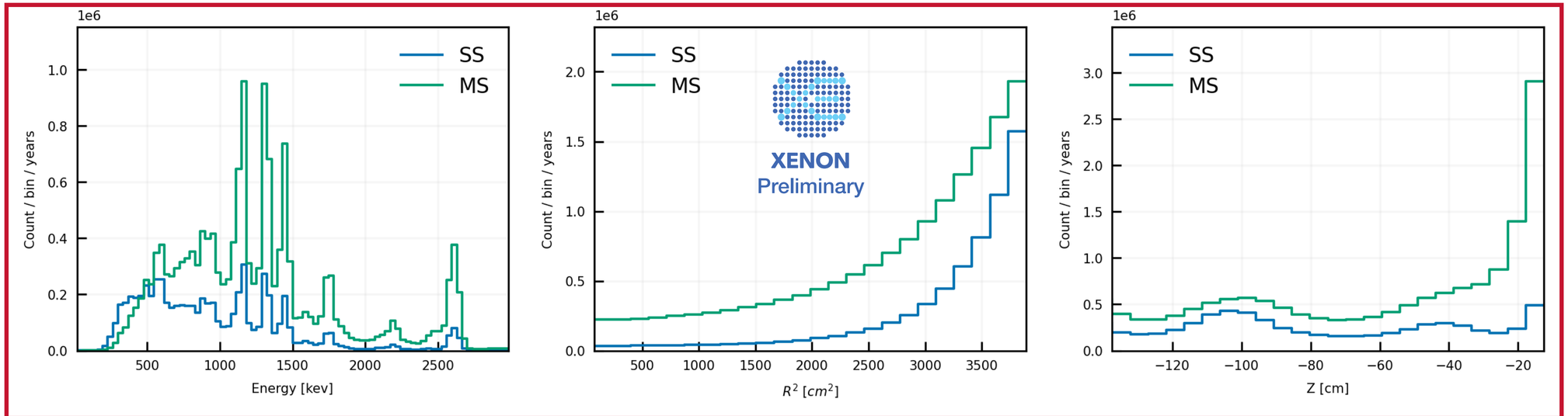
Homogeneously distributed in the detector

Background →

Strong spatial dependency

3D binned likelihood

Detector material's radiogenic background model



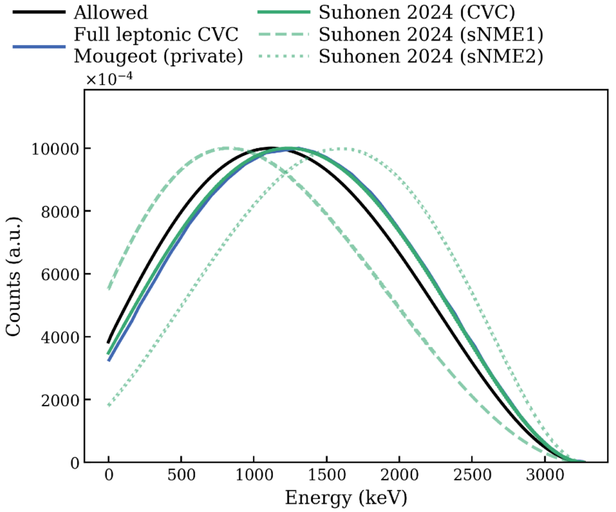
^{214}Bi β-decay to g.s. measurement

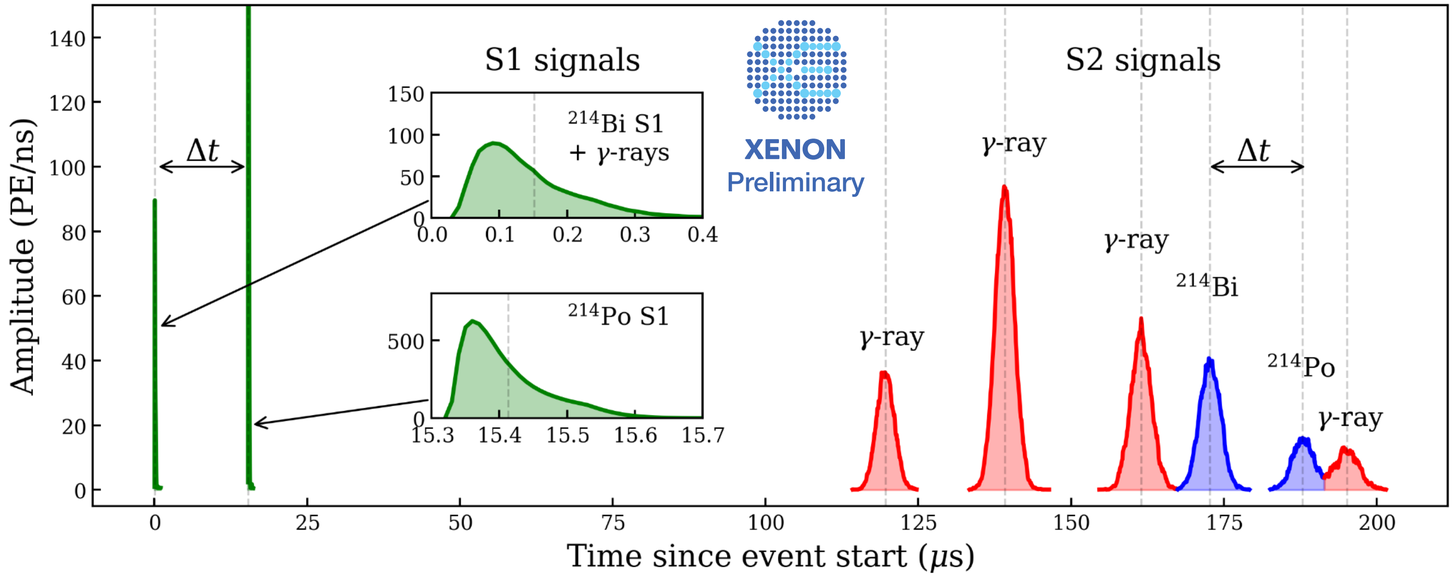
Maxime Pierre
maxime.pierre@nikhef.nl

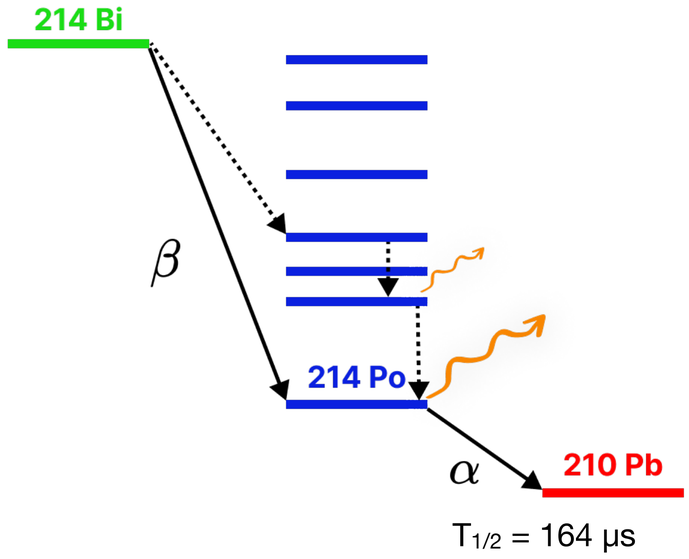
XENON

Motivation

- **First-forbidden non-unique β-decay spectrum**
  - ➡ Theoretical predictions must take into account nuclear structure models → complex
  - ➡ Lack of data in the full energy range to test prediction
- **Promising source of calibration up to 3.2 MeV**
  - ➡ Light & Charge Yields, Position reconstruction resolution, etc…





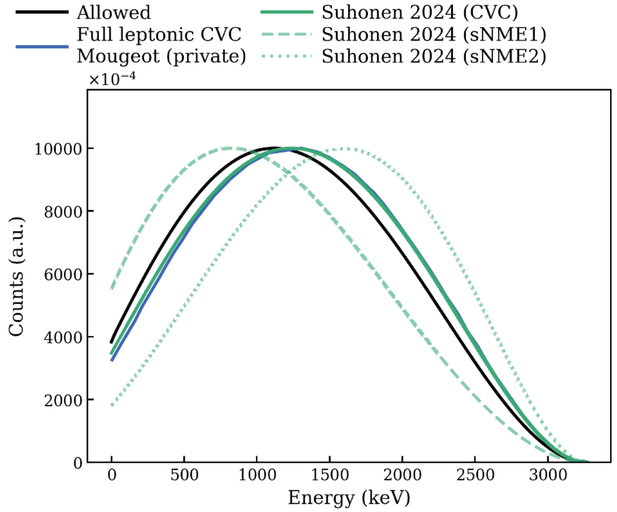


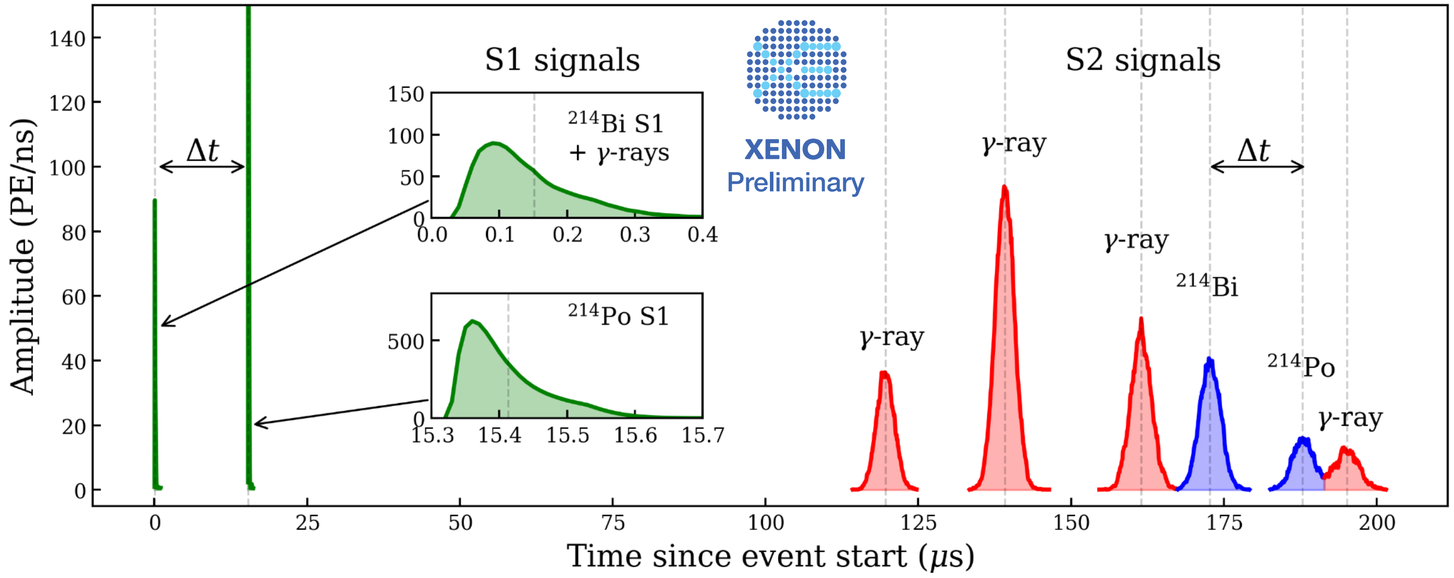
^{214}Bi β-decay to g.s. measurement

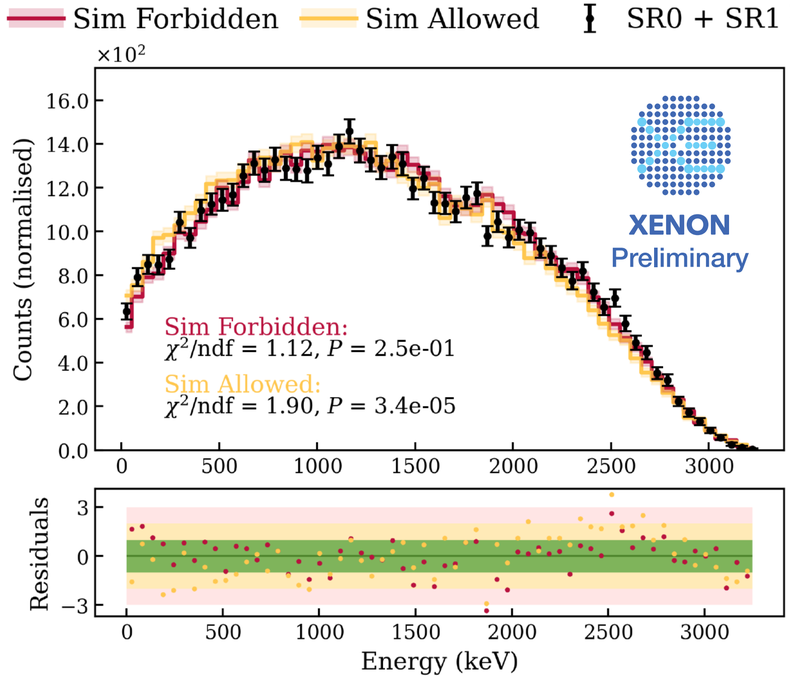
Maxime Pierre
maxime.pierre@nikhef.nl

Motivation

- **First-forbidden non-unique β-decay spectrum**
  - ➡ Theoretical predictions must take into account nuclear structure models → complex
  - ➡ Lack of data in the full energy range to test prediction
- **Promising source of calibration up to 3.2 MeV**
  - ➡ Light & Charge Yields, Position reconstruction resolution, etc…







Conclusion & Outlook

Maxime Pierre
maxime.pierre@nikhef.nl

XENON

1 First XENONnT science run results were only a first step

WIMPs results
PRL 131, 041003

Low-ER results
PRL129, 161805

...

Broad Physics Program
New Results to come… stay tuned!

Conclusion & Outlook

Maxime Pierre
maxime.pierre@nikhef.nl

XENON

1 First XENONnT science run results were only a first step

WIMPs results
PRL 131, 041003

Low-ER results
PRL129, 161805

...

Broad Physics Program
New Results to come… stay tuned!

Strong contribution from our Ph.D. students


Maricke Flierman


Carlo Fuselli


Saad El Morabit


Pranati Kharbanda

Conclusion & Outlook

Maxime Pierre
maxime.pierre@nikhef.nl

XENON

1 First XENONnT science run results were only a first step

WIMPs results
PRL 131, 041003

Low-ER results
PRL129, 161805

• • •

Broad Physics Program
New Results to come… stay tuned!

Strong contribution from our Ph.D. students


Maricke Fliermann

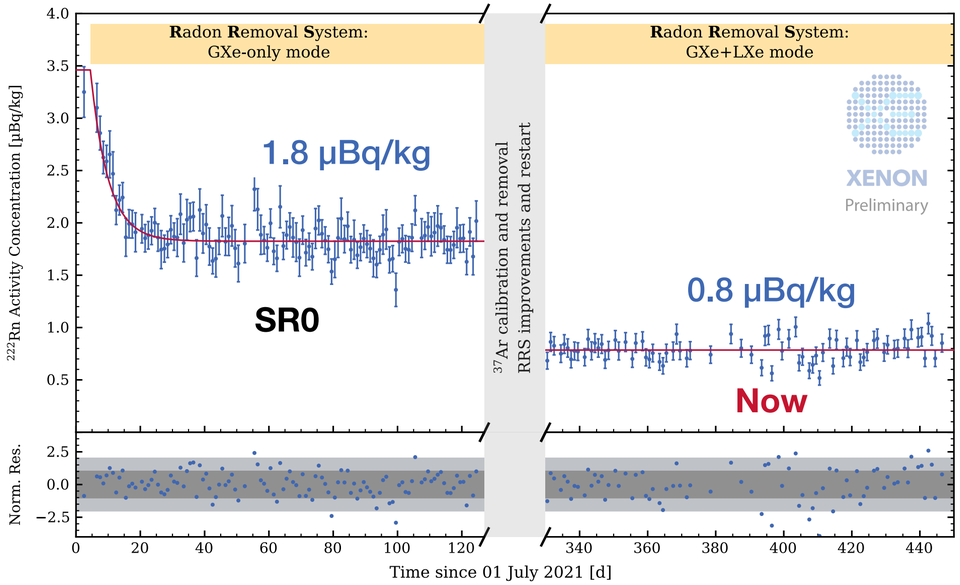

Carlo Fuselli

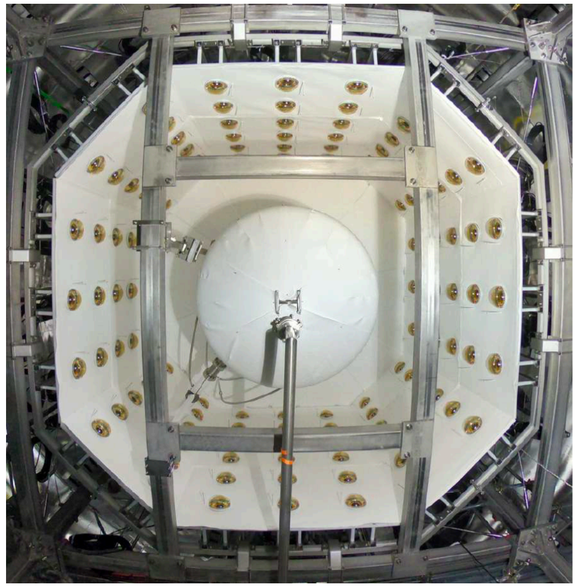

Saad El Morabit


Pranati Kharbanda

2 So what is coming next?

- Further reduction of ER background by improved radon distillation flow path
- Gd-loaded water in the nVeto will improve our neutron tagging efficiency





Conclusion & Outlook

Maxime Pierre
maxime.pierre@nikhef.nl

XENON

1 First XENONnT science run results were only a first step

WIMPs results
PRL 131, 041003

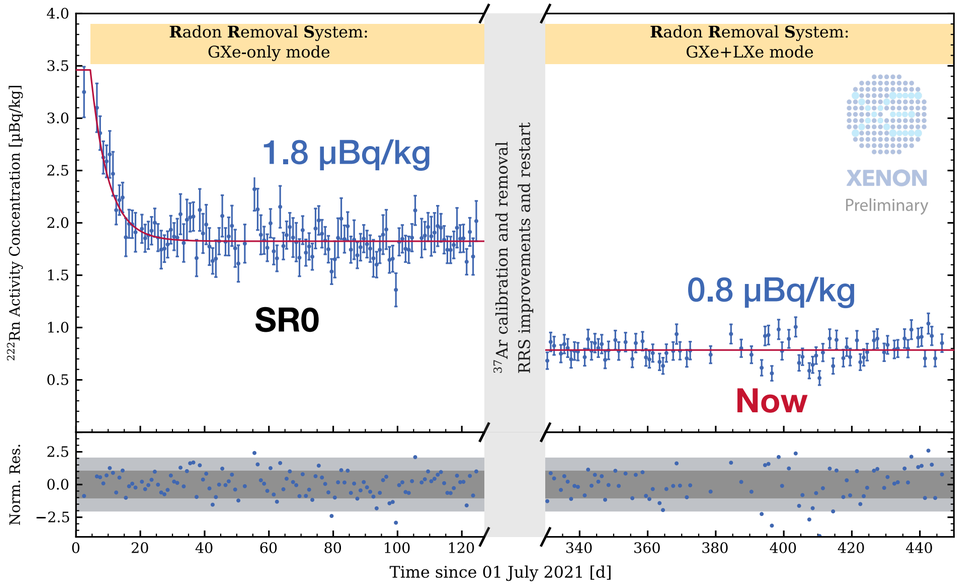
Low-ER results
PRL129, 161805

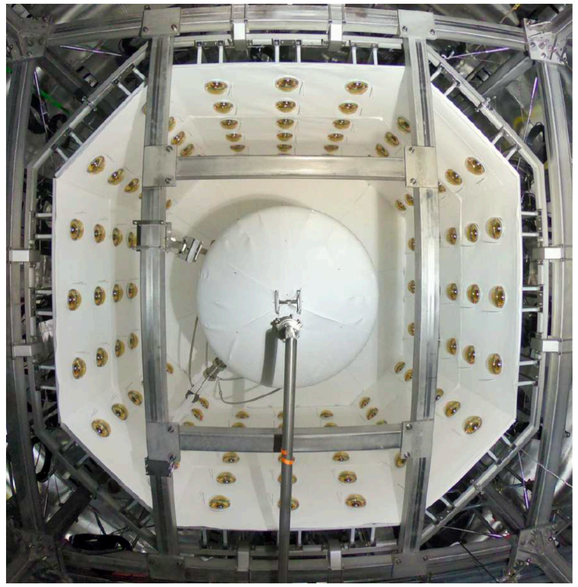
• • •

Broad Physics Program
New Results to come… stay tuned!

2 So what is coming next?

- Further reduction of ER background by improved radon distillation flow path
- Gd-loaded water in the nVeto will improve our neutron tagging efficiency





Strong contribution from our Ph.D. students


Maricke Fliermann


Carlo Fuselli


Saad El Morabit


Pranati Kharbanda

Thank You!