Observation of two-neutrino double electron capture in Xe-124 with XENON1T

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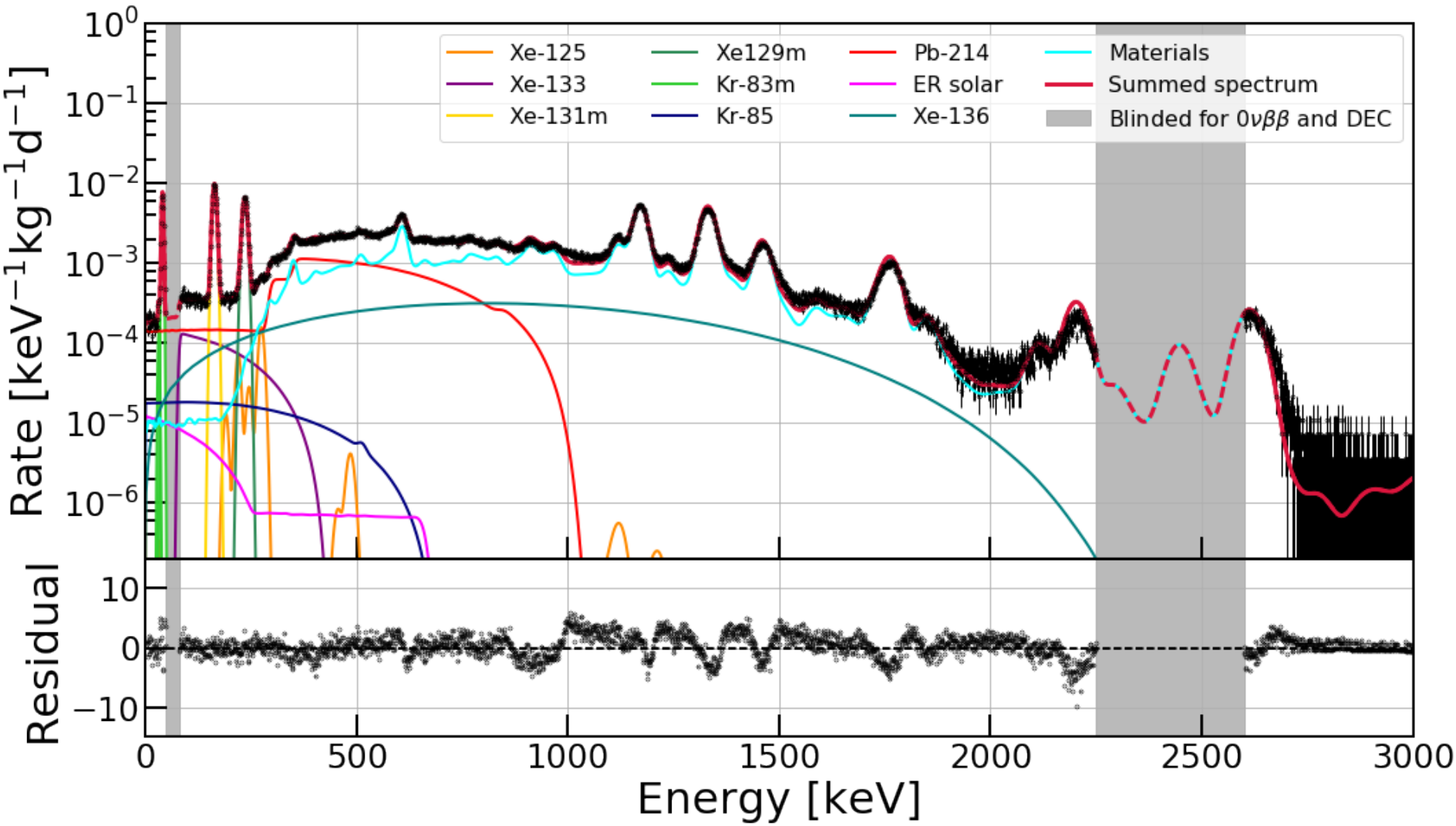
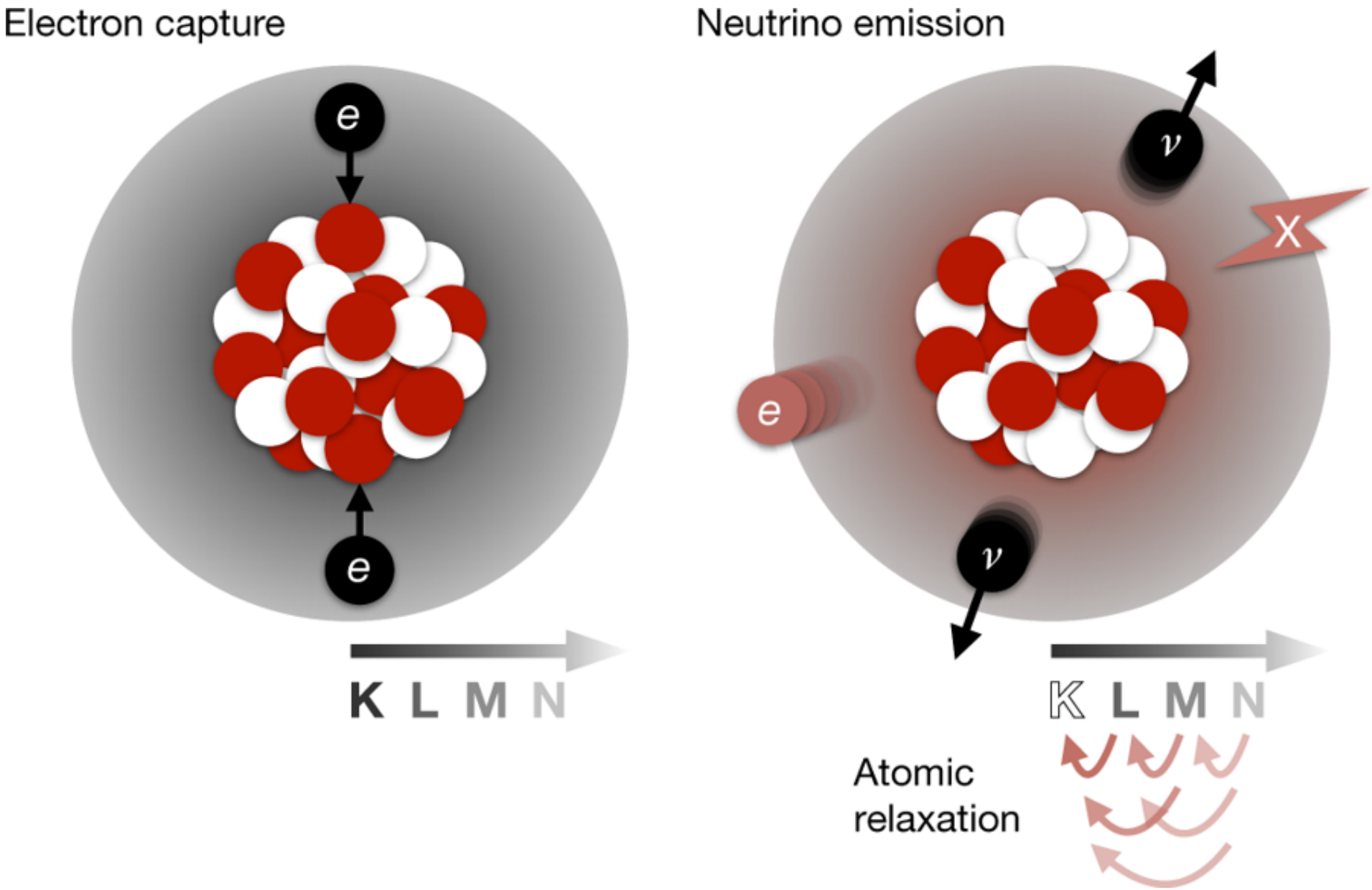
Outline

1. Double Electron Capture
2. Xenon1T Experiment
3. Results
4. Conclusion

Xenon energy spectrum



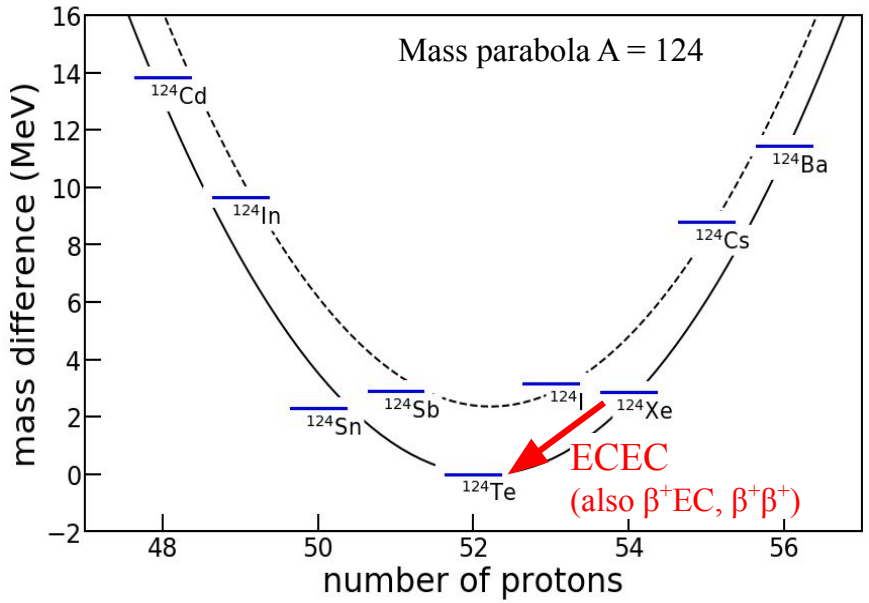
Double Electron Capture



Double electron capture in Xenon

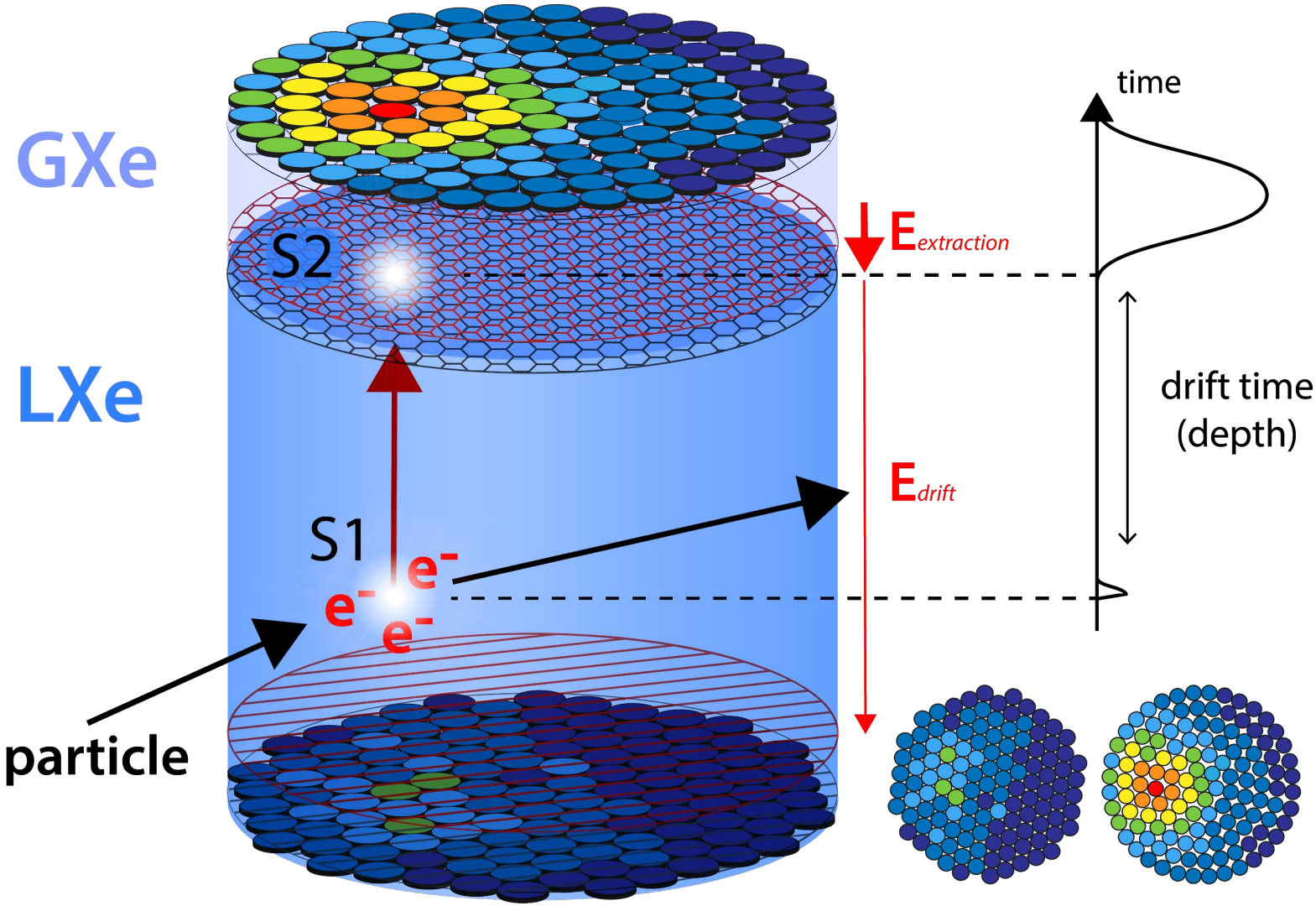
$$(T_{1/2}^{2\nu DEC})^{-1} \propto G^{2\nu DEC} \left| M^{2\nu DEC} \right|^2$$

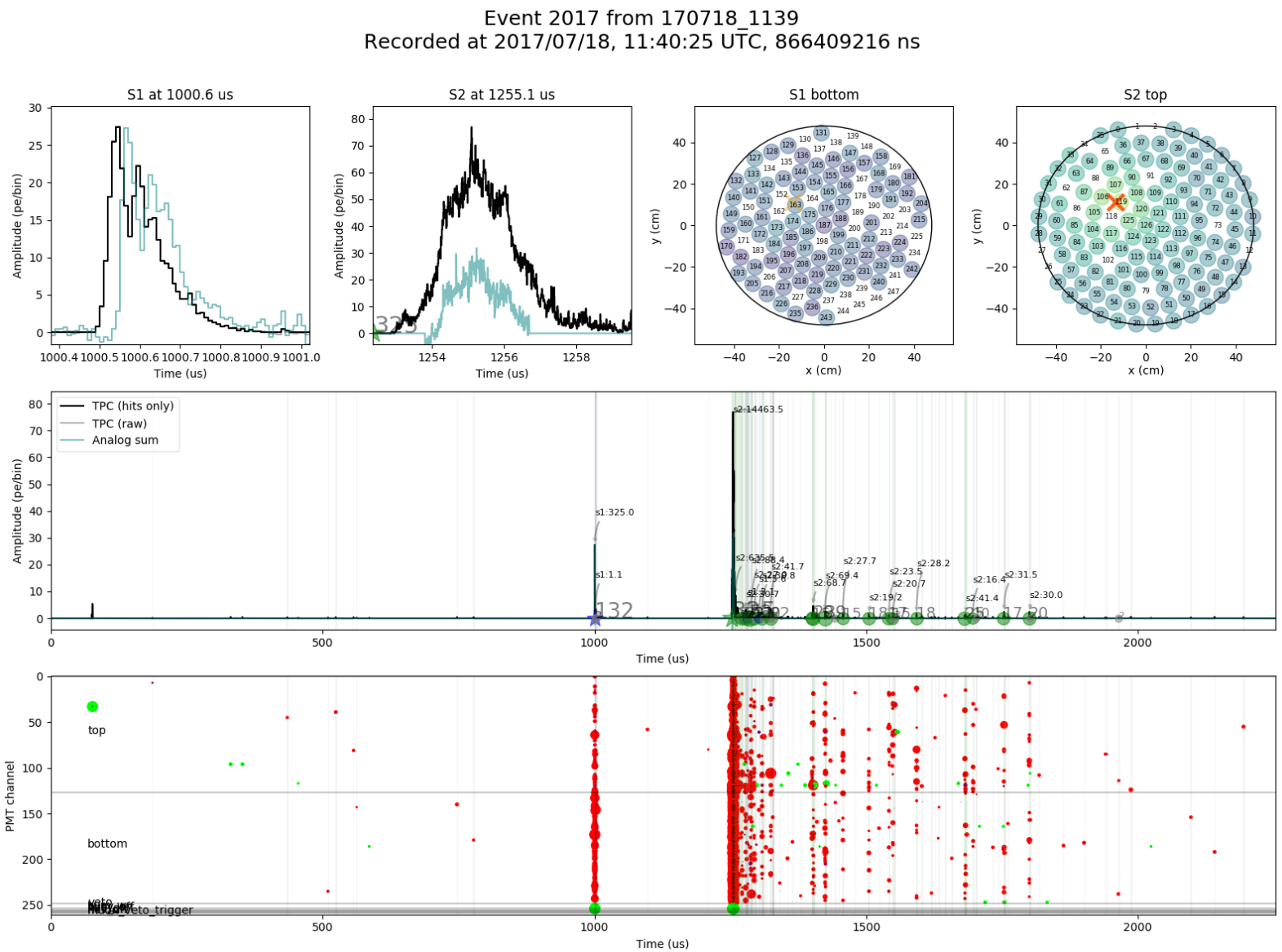
- DEC is second-order weak interaction
- $M^{2\nu DEC}$ related to $M^{0\nu DEC}$
- Natural abundances
  - ^{124}Xe ~ 0.095 %
- $^{124}\mathrm{Xe} + 2e^- \rightarrow {}^{124}\mathrm{Te} + 2\nu_e$ (Q = 2864 keV)
- 64.33 keV detected through X-rays and Auger electrons



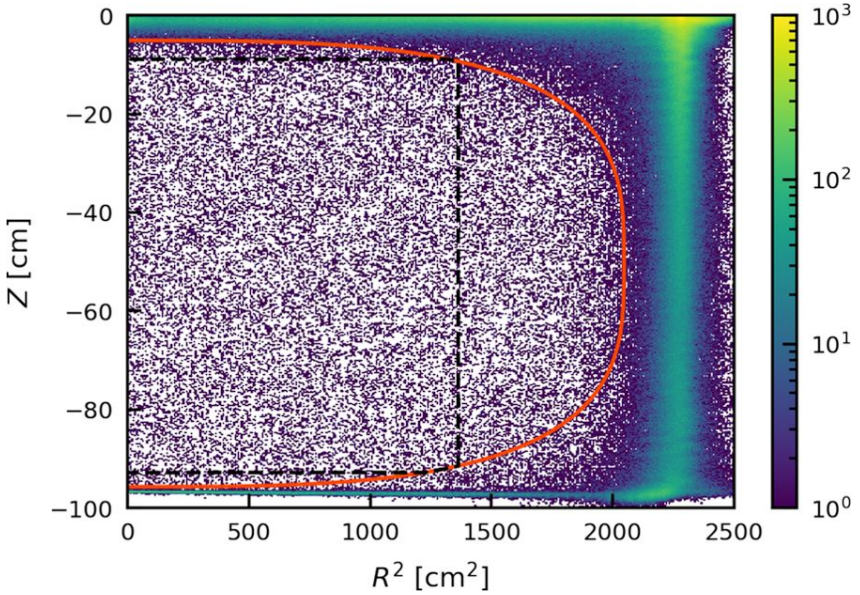
XENON1T

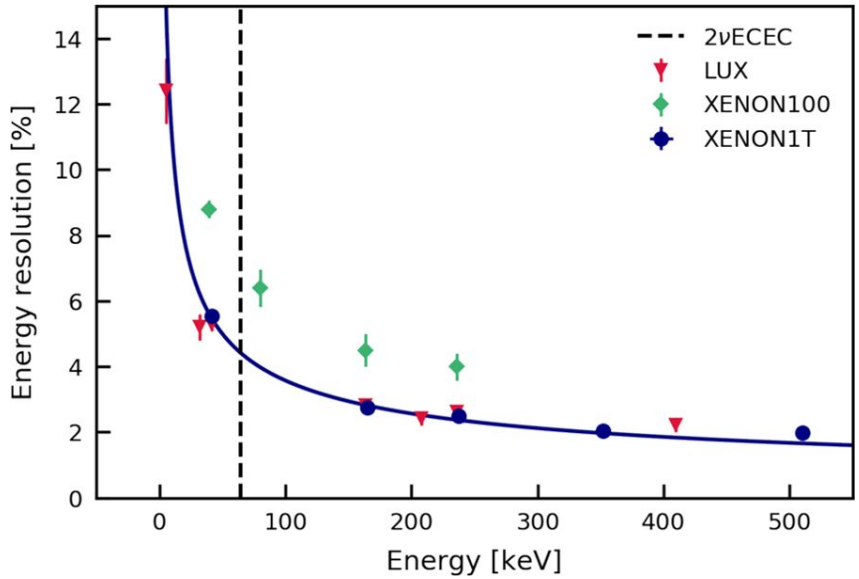
It has been pointed out that large volume dark matter detectors with natural xenon as targets have the potential to measure the 2νECEC on ^{124}Xe. *XMASS Collaboration*


GXe
LXe
S2
S1
e-
e-
e-
particle
E extraction
E drift
time
drift time
(depth)


Event 2017 from 170718_1139
Recorded at 2017/07/18, 11:40:25 UTC, 866409216 ns
S1 at 1000.6 us
S2 at 1255.1 us
S1 bottom
S2 top
Amplitude (pe/bin)
Time (us)
x (cm)
y (cm)
TPC (hits only)
TPC (raw)
Analog sum
s1:325.0
s1:1.1
s2:14463.5
PMT channel
top
bottom
veto_trigger

Fiducial Volume & Energy Resolution

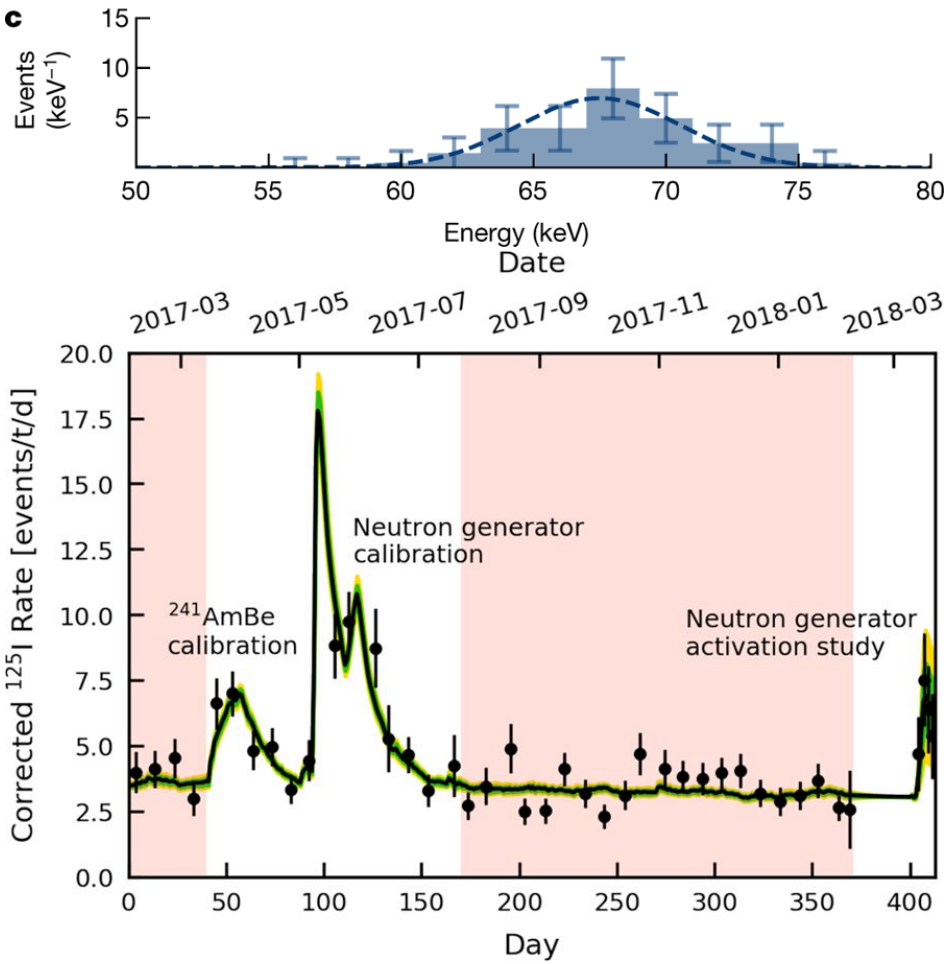




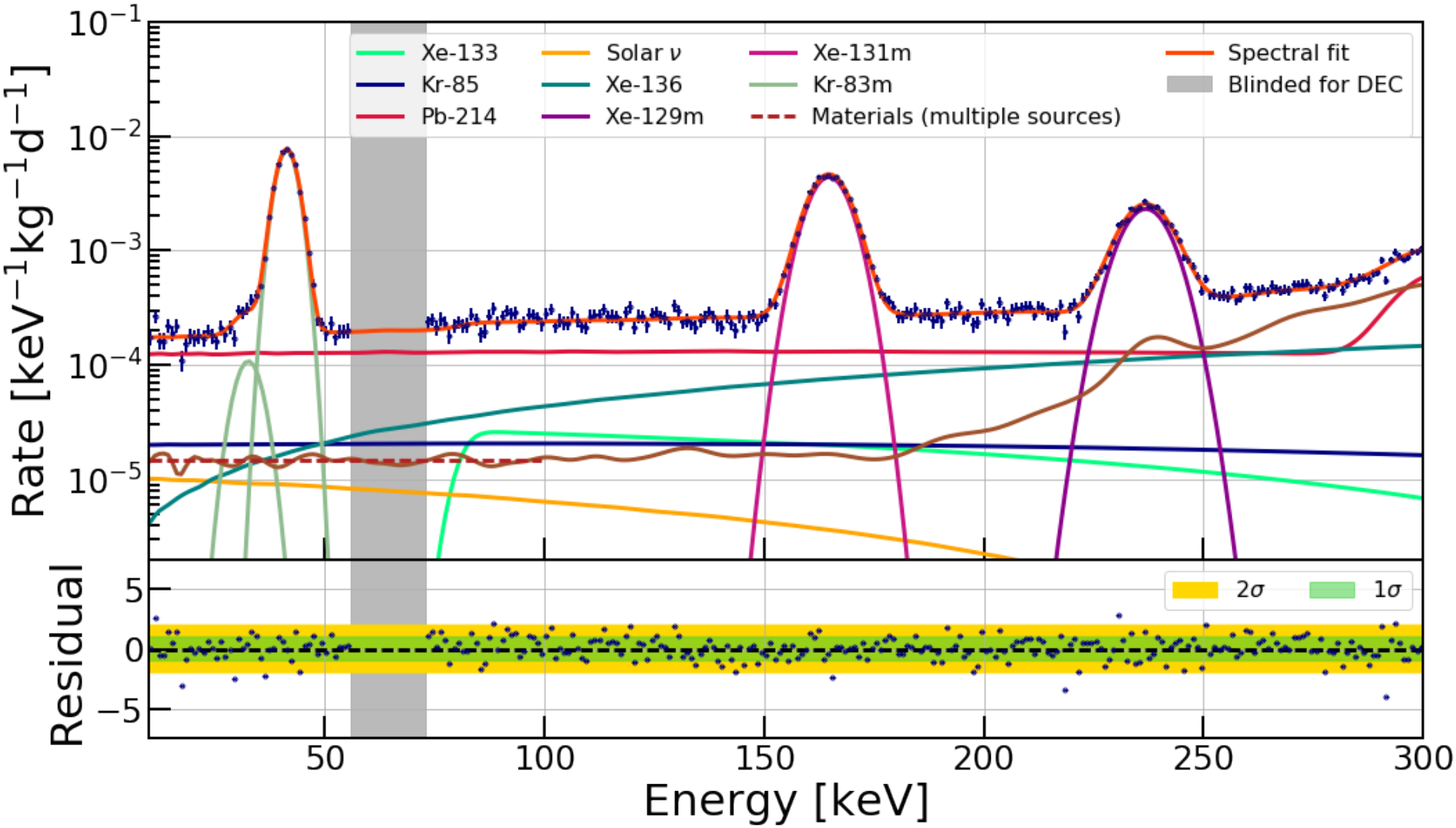
- Volume chosen such that $\mathrm{S} = \frac{m_{\mathrm{Xe}}}{\sqrt{\mathrm{N}_{\mathrm{bkg}}}}$ is maximum

Background: Iodine-125

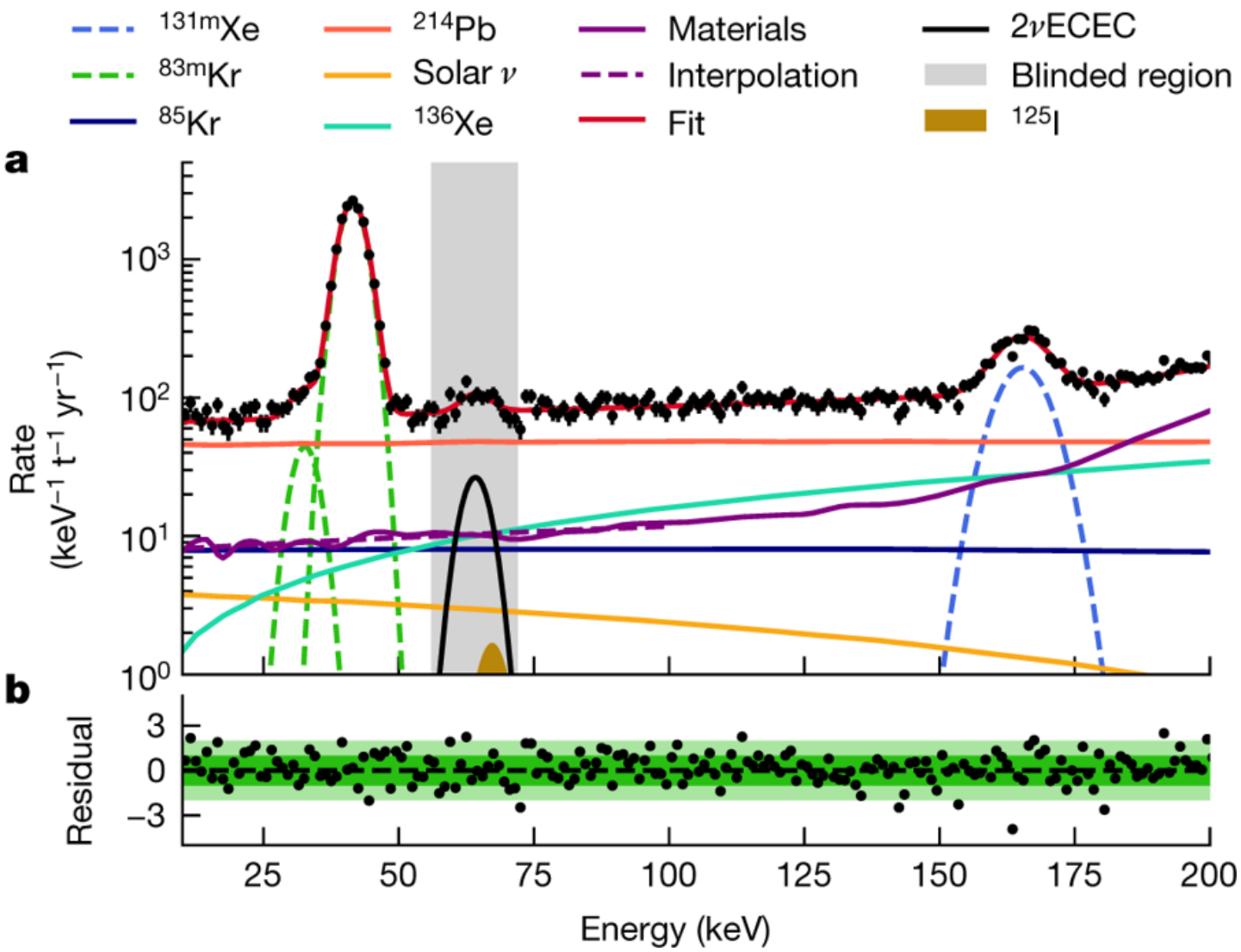
- $^{124}\mathrm{Xe} + \mathrm{n} \rightarrow ^{125}\mathrm{Xe} + \gamma$
  - $^{125}\mathrm{Xe} \rightarrow ^{125}\mathrm{I}^{*} + \nu_{\mathrm{e}}$
  - $^{125}\mathrm{I}^{*} \rightarrow ^{125}\mathrm{I} + \gamma + \mathrm{X}$
- $^{125}\mathrm{I} \rightarrow ^{125}\mathrm{Te}^{*} + \nu_{\mathrm{e}}$
  - $^{125}\mathrm{Te}^{*} \rightarrow ^{125}\mathrm{Te} + \gamma + \mathrm{X}$
- $^{125}\mathrm{I}$ decay of 67.3 keV



Results: Blinded

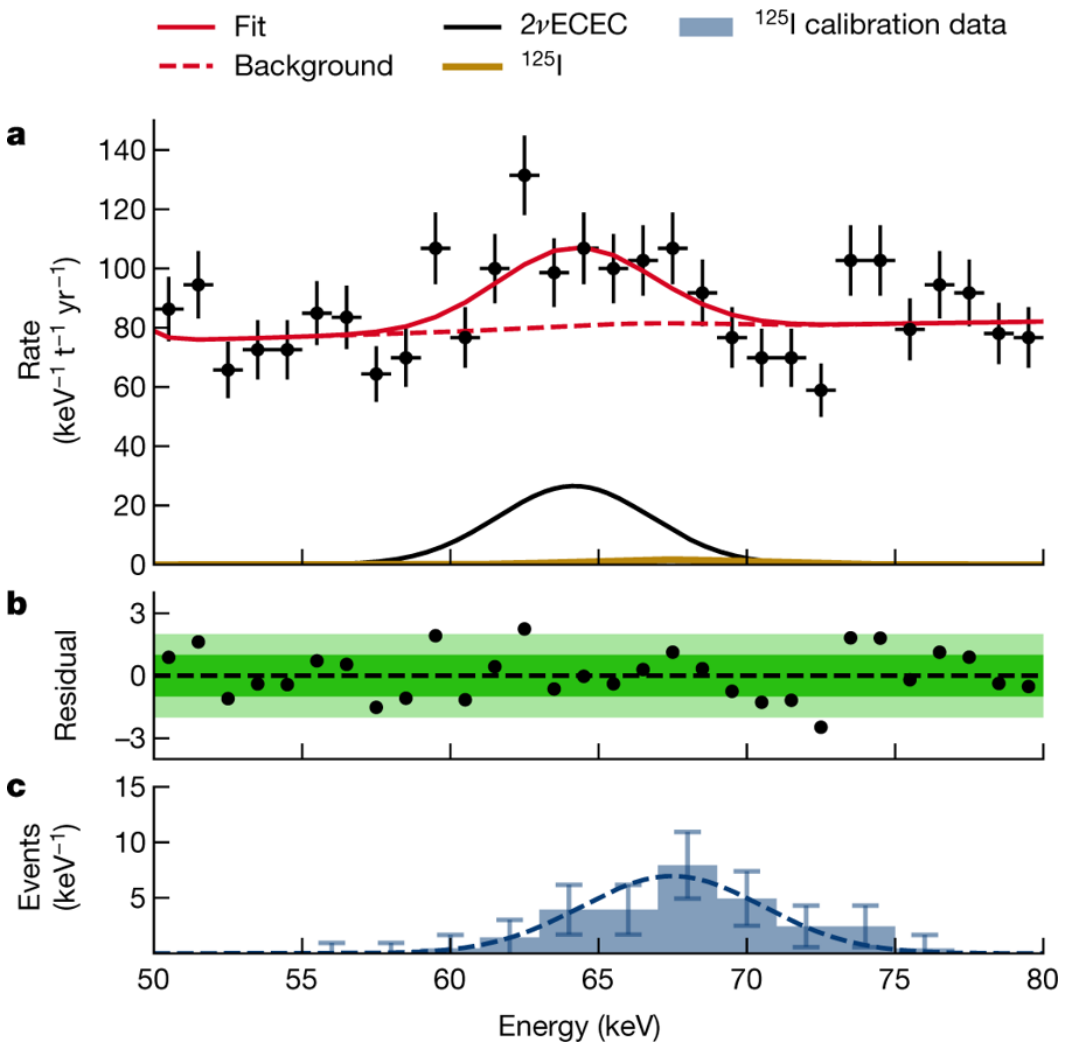


Results: Unblinded



- $N_{2\nu DEC} = 126$
- $N_I = 9$

Results: Unblinded



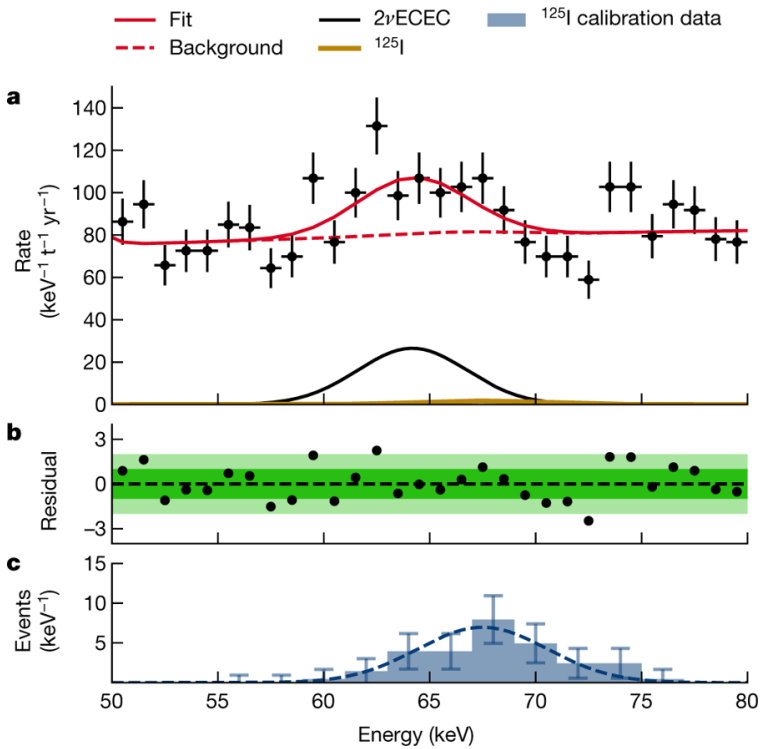
- $N_{2\nu DEC} = 126$
- 4.4 σ significance
- $N_{^{125}I} = 9$

Results: Unblinded

$$T_{1/2}^{2\nu DEC} = \ln(2)\frac{\eta\epsilon \mathrm{N_A mt}}{\mathrm{M_{Xe} N_{2\nu DEC}}}$$

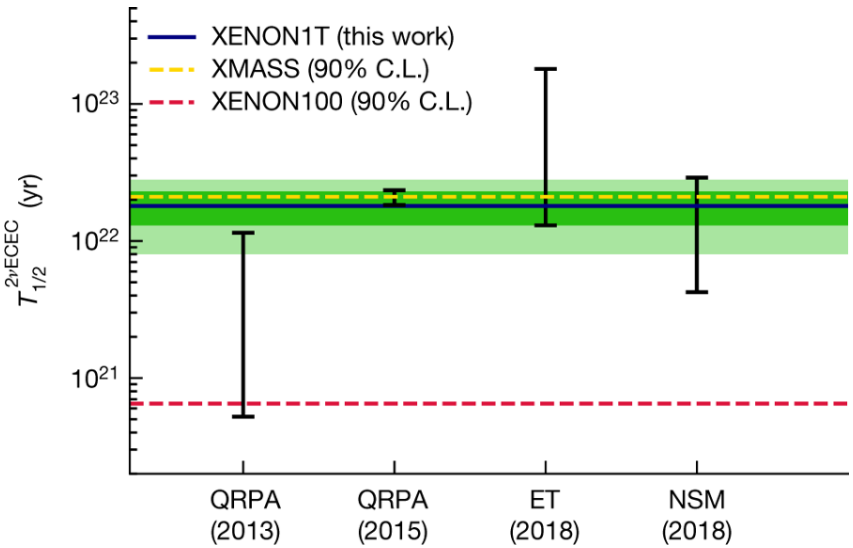
- $\mathrm{N_{2\nu DEC}} = 126$
- $\epsilon = 0.967 \pm 0.07_{\mathrm{stat}} \pm 0.033_{\mathrm{sys}}$

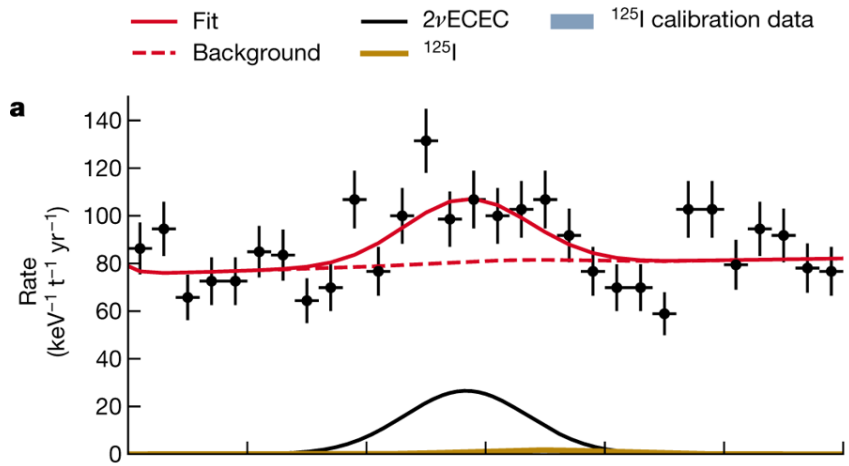
$$\mathrm{T_{1/2}^{2\nu DEC}} = (1.8 \pm 0.5_{\mathrm{stat}} \pm 0.1_{\mathrm{sys}}) \times 10^{22}\ \mathrm{yr}$$

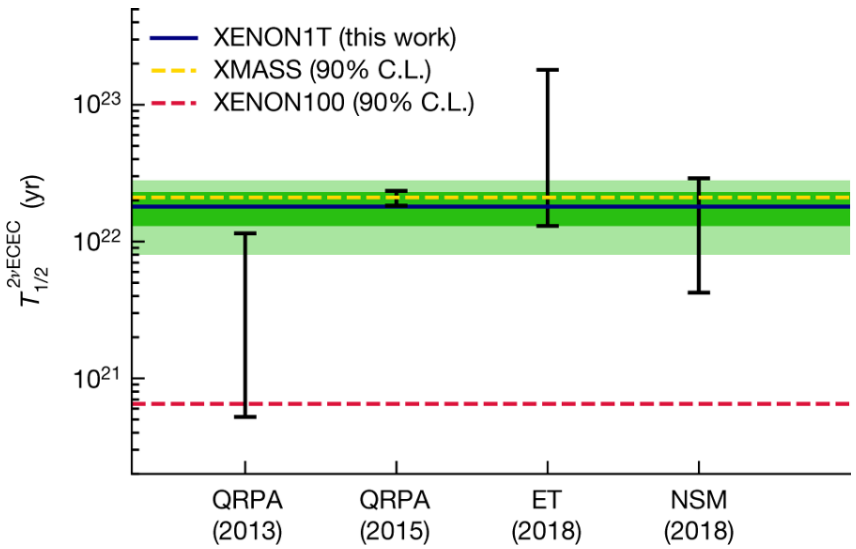
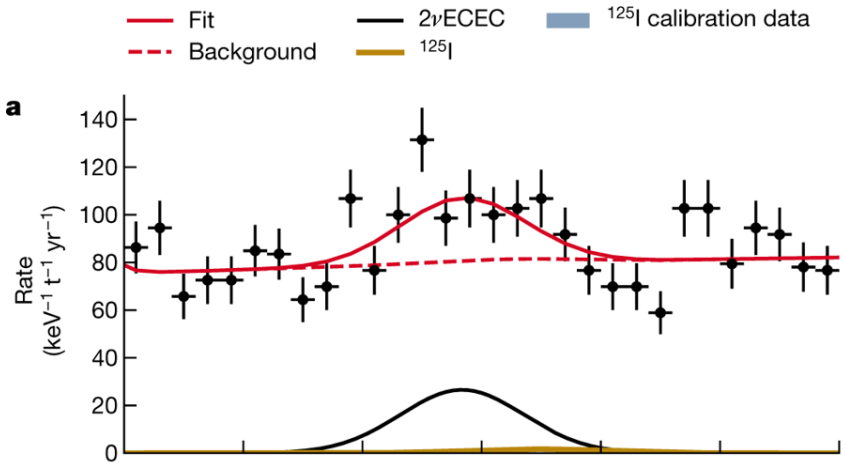


Conclusion

- First Liquid Xenon TPC signal detection
- ^{124}Xe DEC measured:
  $T^{2\nu DEC}_{1/2} = (1.8 \pm 0.5_{stat} \pm 0.1_{sys}) \times 10^{22}$ yr
- 4.4 σ significance





Thank you

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- ^{124}Xe DEC measured:
  $T_{1/2} = (1.8 \pm 0.5_{\text{stat}} \pm 0.1_{\text{sys}}) \times 10^{22}$ yr
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