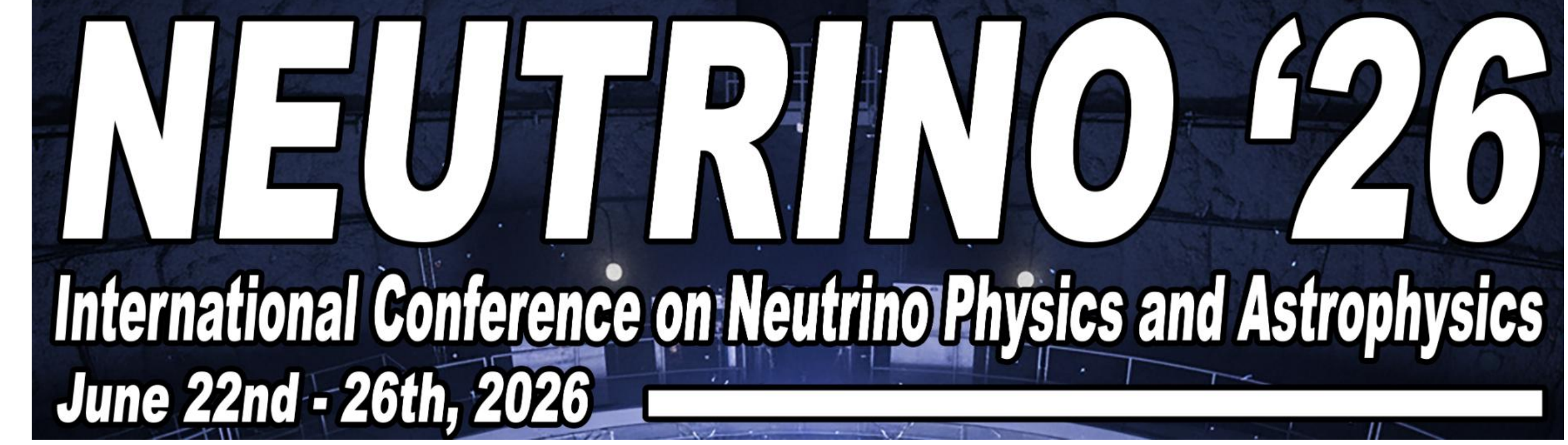




Constraints on Generalized Neutrino Interactions in the keV Region of the Tritium β -Decay Spectrum from the LiFE-SNS project

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Generalized Neutrino Interactions (GNIs)

Extension of effective potential

: Addition of Lorentz invariant term with $\epsilon_{j,ud}$

$$\mathcal{L}_{\text{GNI}}^{\text{CC}} = -\frac{G_{\text{F}}V_{\gamma\delta}}{\sqrt{2}} \sum_{j=1}^{10} \left(\tilde{\epsilon}_{j,ud} \right)^{\alpha\beta\gamma\delta} (\bar{e}_{\alpha} \mathcal{O}_j \nu_{\beta}) (\bar{u}_{\gamma} \mathcal{O}'_j d_{\delta}) + \text{H.c.},$$

For charge current, $V_{\gamma\delta}$: CKM matrix, $\alpha, \beta, \gamma, \delta$: Flavor index for PMNS

| j | ϵ_j | \mathcal{O}_j | \mathcal{O}'_j |
|-----|-----------------------|-------------------------------|-------------------------------|
| 1 | ϵ_L | $\gamma_{\mu}(1-\gamma^5)$ | $\gamma^{\mu}(1-\gamma^5)$ |
| 2 | $\tilde{\epsilon}_L$ | $\gamma_{\mu}(1+\gamma^5)$ | $\gamma^{\mu}(1-\gamma^5)$ |
| 3 | ϵ_R | $\gamma_{\mu}(1-\gamma^5)$ | $\gamma^{\mu}(1+\gamma^5)$ |
| 4 | $\tilde{\epsilon}_R$ | $\gamma_{\mu}(1+\gamma^5)$ | $\gamma^{\mu}(1+\gamma^5)$ |
| 5 | ϵ_S | $(1-\gamma^5)$ | 1 |
| 6 | $\tilde{\epsilon}_S$ | $(1+\gamma^5)$ | 1 |
| 7 | $-\epsilon_P$ | $(1-\gamma^5)$ | γ^5 |
| 8 | $-\tilde{\epsilon}_P$ | $(1+\gamma^5)$ | γ^5 |
| 9 | ϵ_T | $\sigma_{\mu\nu}(1-\gamma^5)$ | $\sigma^{\mu\nu}(1-\gamma^5)$ |
| 10 | $\tilde{\epsilon}_T$ | $\sigma_{\mu\nu}(1+\gamma^5)$ | $\sigma^{\mu\nu}(1+\gamma^5)$ |

Physics beyond the SM

- Chirality ν ($\tilde{\epsilon}$ vs ϵ)

- ϵ^V/ϵ^A : Heavy Z^0

- ϵ^S/ϵ^P : Triplet Higgs

- ϵ^T : Leptoquark

Tritium beta spectrum with GNIs

$$\frac{d\Gamma}{dE} = \frac{G_{\text{F}}^2 V_{\text{ud}}^2}{2\pi^3} F(E, 2) \sqrt{(E+m_e)^2 - m_e^2} (E+m_e) \quad \text{PRL } 134.251801$$

$$\cdot \sum_j \sum_{k=\beta, N} \zeta_j \epsilon_j \sqrt{\epsilon_j^2 - m_k^2} \xi_k \left[1 - b'_k \frac{m_k}{\epsilon_j} \right] \Theta(\epsilon_j - m_k).$$

- Parameters ($\xi_{\beta, N}, b'_{\beta, N}$) are function of $\epsilon_{j,ud}$
→ Shape distortion more with neutrino mass, m_N .

e.g) If only for $(\epsilon_L, \tilde{\epsilon}_R)$

$$\xi_{\beta} = \underbrace{(g_V^2 + 3g_A^2)}_{\text{SM}} |U|^2 + \underbrace{(g_V^2 + 3g_A^2)}_{\text{term for BSM}} (|U|^2 (2\epsilon_L + \epsilon_L^2) + |T|^2 \tilde{\epsilon}_R^2)$$

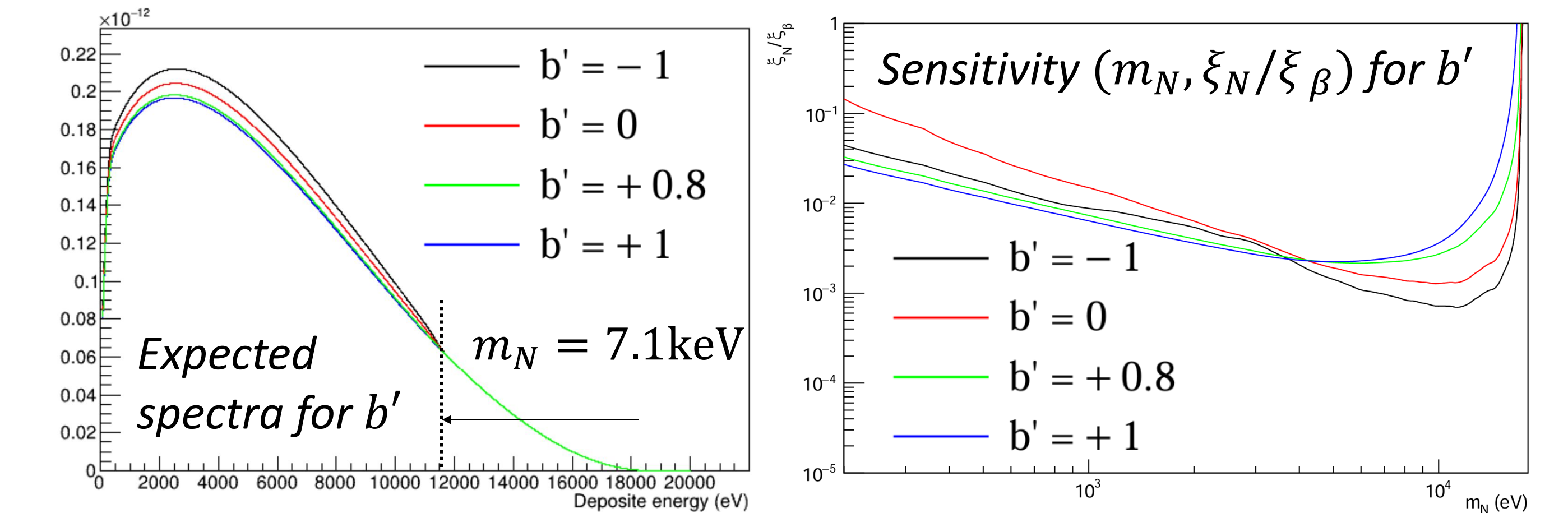
- Spectrum shape is distorted ($m_{\beta} = 0$) by

- a single ϵ case: $\tilde{\epsilon}_{L,R,S,T}$

- Two ϵ case: $(\epsilon_{L,R,S,T}, \tilde{\epsilon}_{L,R,S,T}), (\tilde{\epsilon}_{L,R,S,T}, \tilde{\epsilon}_{L,R,S,T})$

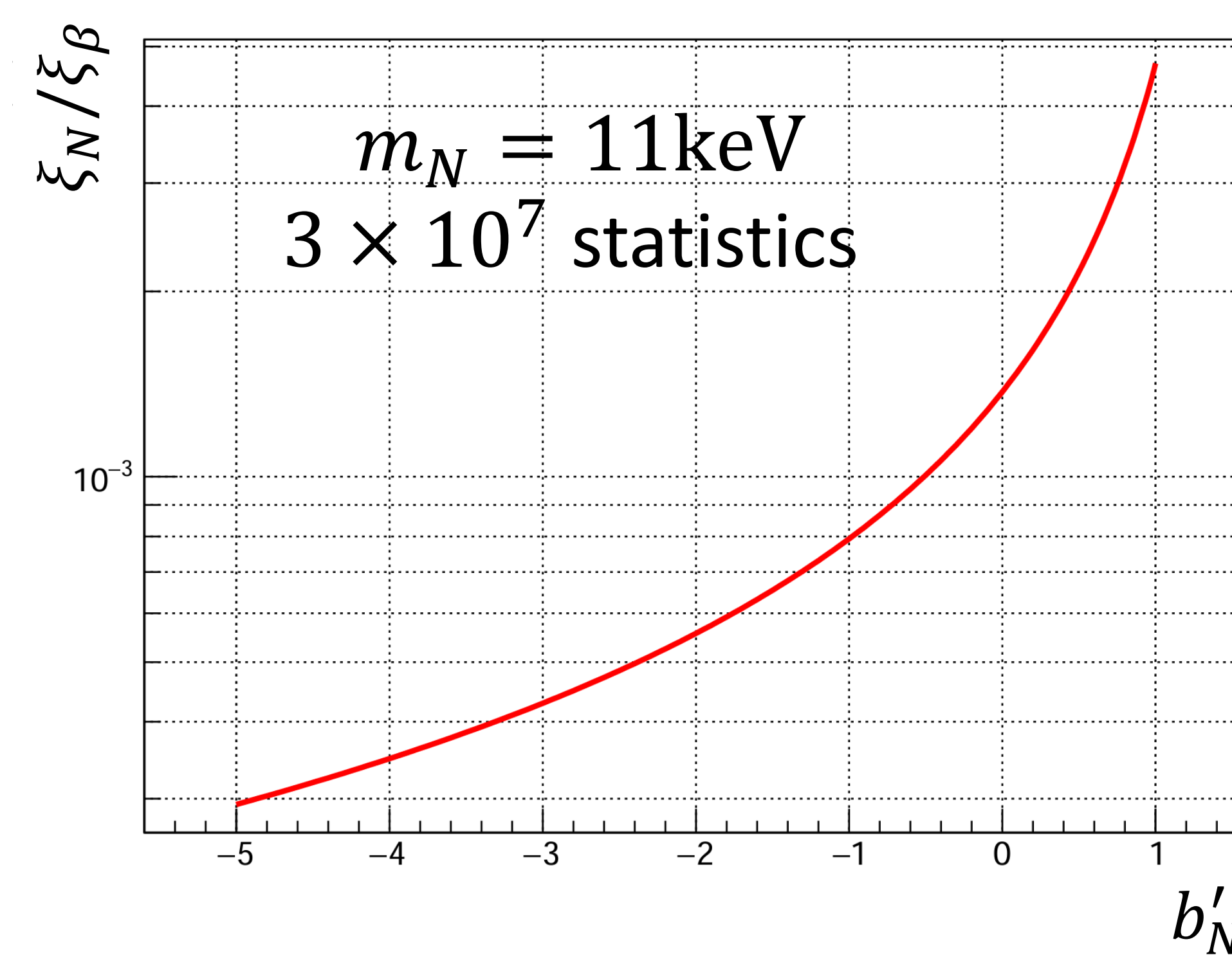
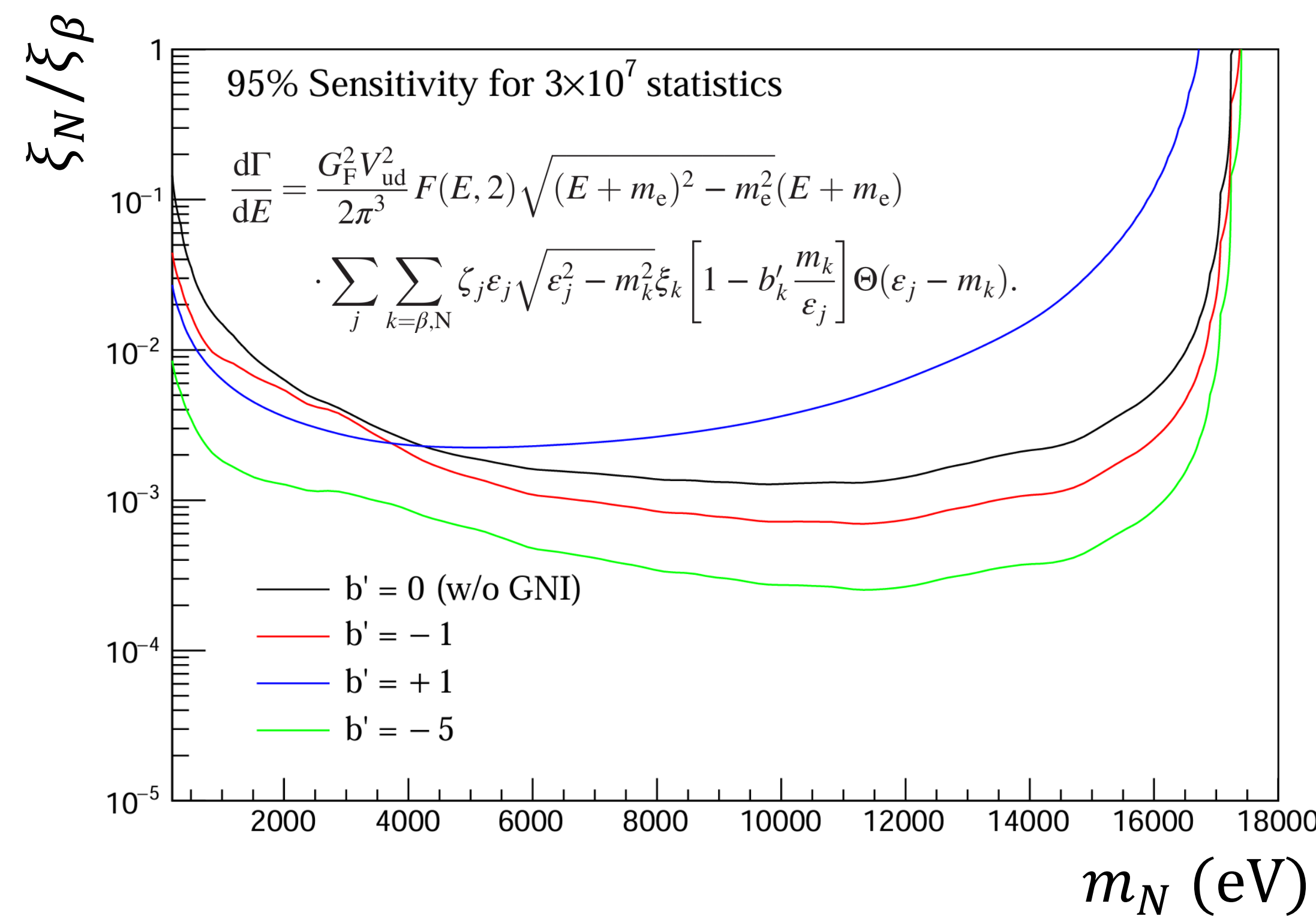
Sensitivity with GNI parameters

For sensitivity, pseudo events (3×10^7) are generated **not considering background, pileup and calibration peaks.**



@E = m_{ν}
 $b' = -5$ $b' = 0$ $b' = 0.2$ $b' = 1$
 ++concave kink +Kink small kink very small kink

Sensitivities for ξ_N/ξ_{β} , m_N and b'_N

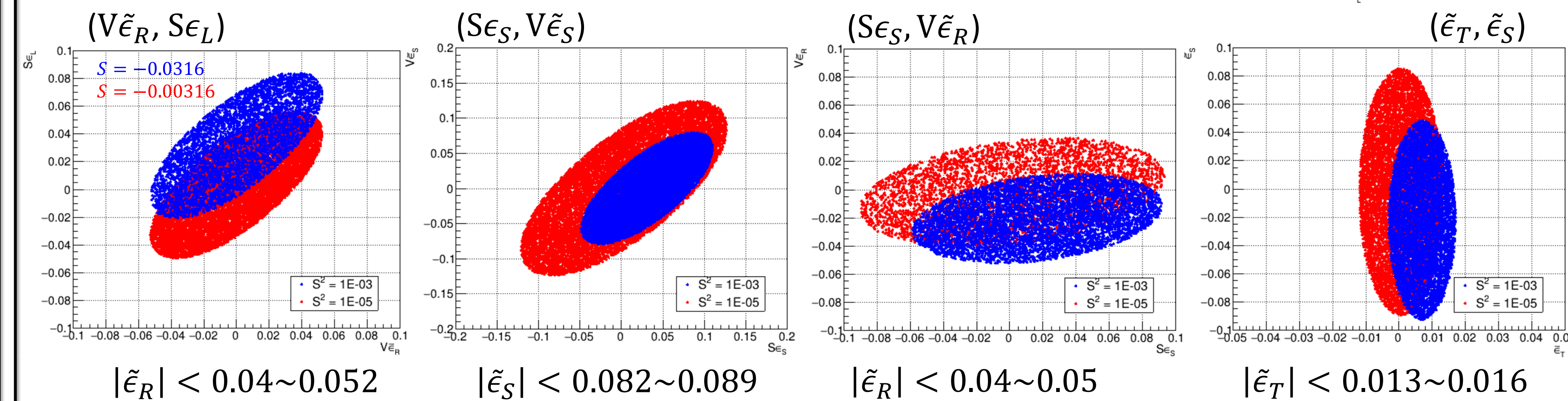
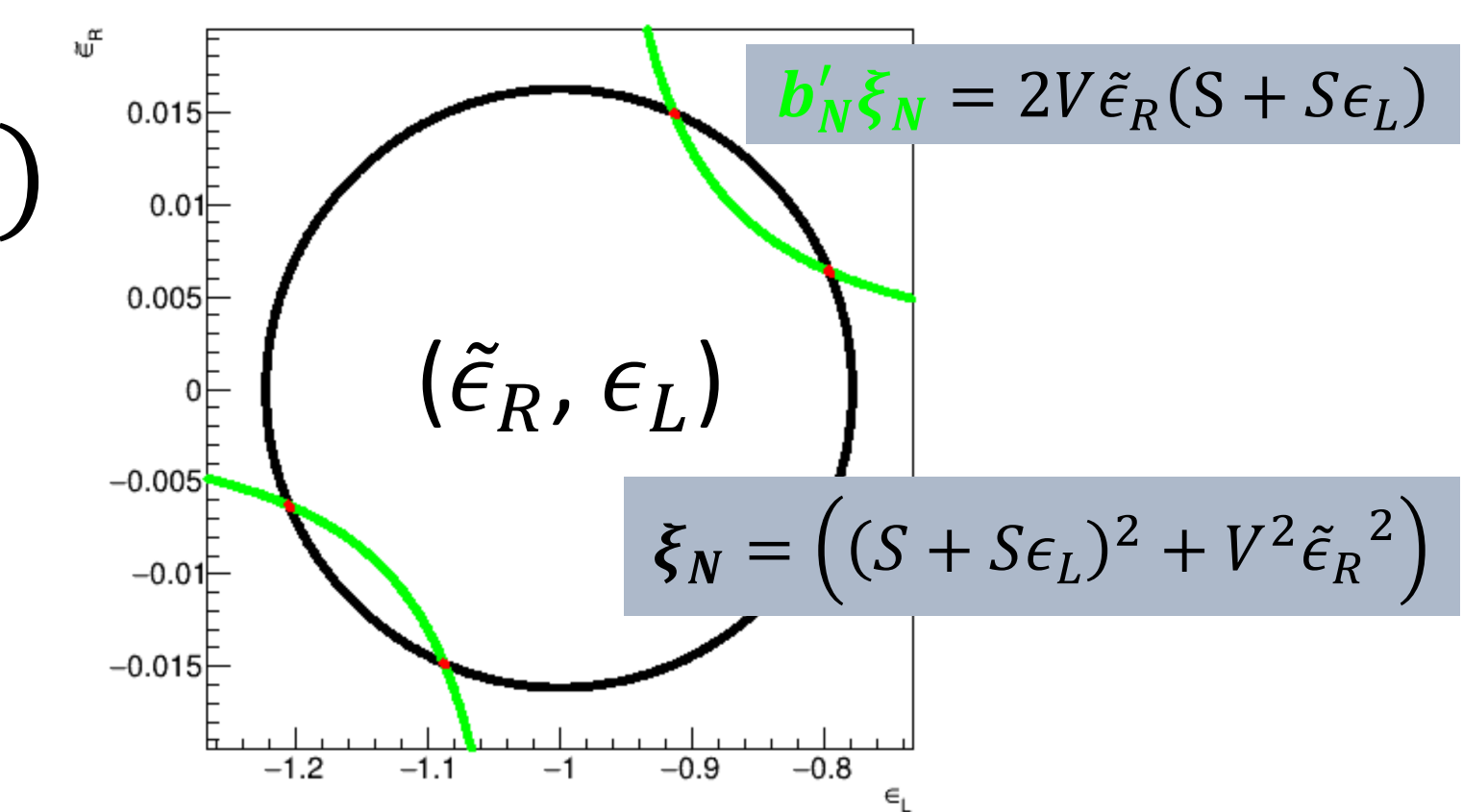


- The search for sterile ν is the case $b' = 0$
- $m_{\nu} < 4\text{keV}$, more sensitive for non-zero b' : Leading term 1st order of ϵ
 $m_{\nu} > 4\text{keV}$, more sensitive negative b'
- The more negative b' , the more sensitive

- For $(\tilde{\epsilon}_S, \tilde{\epsilon}_T)$, mixing $S = \sqrt{10^{-3}}$
 $b' \sim \frac{2V}{S} (\tilde{\epsilon}_S - 12\tilde{\epsilon}_T) \sim 60(\tilde{\epsilon}_S - 12\tilde{\epsilon}_T)$

Exclusion contours for ϵ_i and $\tilde{\epsilon}_j$

- Assume ϵ as real number, ($S < 0, V = \sqrt{1 - S^2}$)
- Use $\xi_{\beta} \equiv g_V^2 + 3g_A^2$ and $g_V = 1.0, g_A/g_V = 1.2646, g_S = 1.02, g_P = 349, g_T = 1.02$
- Find solution ϵ of two equations, b'_N and $b'_N \xi_N$



Ref.) KATRIN $|\tilde{\epsilon}_R| < 0.057 \sim 0.118, |\tilde{\epsilon}_S| < 0.134 \sim 0.278, |\tilde{\epsilon}_T| < 0.020 \sim 0.042$ (PRL 134.251801)

Conclusion

- We conduct sensitivity of the GNI effect in tritium beta spectrum with total 3×10^7 events equivalent to 10-day statistics of LiFE-SNS.
- Expected constrains for GNI parameters ($\sim 10^{-2}$) for 10-days LiFE-SNS statistics would be lowest among the result of low energy experiment.