Canadian Association of Physicists
Association canadienne des physiciens et physiciennes

Contribution ID: **3991** Type: **Oral (Non-Student) / Orale (non-étudiant(e))**

# Probing Physics Beyond the Standard Model: Limits from BBN and the CMB Independently and Combined

*Thursday 22 June 2023 09:00 (15 minutes)*

We present new Big Bang Nucleosynthesis (BBN) limits on the cosmic expansion rate or relativistic energy density, quantified via the number $N_\nu$ of equivalent neutrino species. We use the latest light element observations, neutron mean lifetime, and update our evaluation for the nuclear rates d + d $\longrightarrow$ $^3$He + n and d + d $\longrightarrow$ $^3$H + p. Combining this result with the independent constraints from the cosmic microwave background (CMB) yields tight limits on new physics that perturbs $N_\nu$ and the baryon-to-photon ratio $\eta$ prior to cosmic nucleosynthesis: a joint BBN+CMB analysis gives $N_\nu$ = 2.898 ± 0.141, resulting in $N_\nu$ < 3.180 at 2$\sigma$. The strength of the independent BBN and CMB constraints now opens a new window: we can search for limits on potential *changes* in $N_\nu$ and/or $\eta$ between the two epochs. The present data place strong constraints on the allowed changes in $N_\nu$ between BBN and CMB decoupling; for example, we find -0.708 $< N_\nu^{\rm CMB} - N_\nu^{\rm BBN} <$ 0.328 in the case where $\eta$ and the primordial helium mass fraction $Y_p$ are unchanged between the two epochs; we also give limits on the allowed variations in $\eta$ or in ($\eta$, $N_\nu$) jointly. We discuss scenarios in which such changes could occur. Looking to the future, we forecast the tightened precision for $N_\nu$ arising from both CMB Stage 4 measurements as well as improvements in astronomical $^4$He measurements. We find that CMB-S4 combined with present BBN and light element observation precision can give $\sigma(N_\nu) \simeq$ 0.03. Such future precision would reveal the expected effect of neutrino heating ($N_{\rm eff}$ - 3 = 0.044) of the CMB during BBN, and would be near the level to reveal any particle species ever in thermal equilibrium with the standard model. Improved $Y_p$ measurements can push this precision even further.

## Keyword-1

Big Bang Nucleosynthesis

## Keyword-2

Cosmology

## Keyword-3

Astroparticle Physics

**Author:** Dr YEH, Tsung-Han (TRIUMF)

**Co-authors:** Prof. SHELTON, Jessie (University of Illinois); Prof. OLIVE, Keith (University of Minnesota); Prof. FIELDS, Brian (University of Illinois)

**Presenter:** Dr YEH, Tsung-Han (TRIUMF)

**Session Classification:** (PPD) R1-1 DM / Neutrino 5 | DM / Neutrino 5 (PPD)

**Track Classification:** Technical Sessions / Sessions techniques: Particle Physics / Physique des particules (PPD)