given by: $W = \kappa S(Z\overline{Z} - M_1^2)$, while in the second brane $W = \kappa S(\phi\overline{\phi} - M_2^2)$, where $\phi, \overline{\phi}$ belong to $(\bar{\mathbf{4}}, \mathbf{1}, \mathbf{2})$ and $(\mathbf{4}, \mathbf{1}, \mathbf{2})$ [696]. Similar constructions were made in Ref. [77] where on one brane $SU(5) \times U(1)_X$ and on the other $SU(5)' \times U(1)'_X$ were preserved, inflationary potential arises to the breaking of $U(1)$ at a scale close to the GUT scale.

In all the above examples, see Refs. [67, 70, 76, 77, 83, 692, 696, 701], it is possible to excite non-thermal leptogenesis either from the direct decay of the inflaton or the Higgs coupled to it or from non-perturbative excitation from the coherent oscillations of the inflaton.

6. Inflation, neutrino sector and family replication

The right handed Majorana sneutrino as an inflaton has been proposed as a particle physics candidate for inflation [505, 702]. These initial models were based on a chaotic type potential for the inflaton with a superpotential [72]

$$W = \frac{1}{2} M N_i N_i + \mu H_u H_d + h^{ij} N_i L_j H_u + k^{ij} e_i L_j H_d \,, \tag{297}$$

where the right handed Majorana neutrino superfield, N, has been treated as a gauge singlet. In order to avoid higher order contributions such as N^3 term in the superpotential, the right handed neutrino can be assigned odd under R-parity. The lightest right handed electron sneutrino acts as an inflaton with an initial VEV larger than $M_{\rm P}$. After the end of inflation the coherent oscillations of the sneutrino field generates lepton asymmetry with the interference between tree-level and one-loop diagrams. The largest lepton asymmetry is proportional to the reheat temperature, $n_L/s \sim \epsilon(3T_{\rm R}/4M_{\rm P})$. The CP asymmetry, $\epsilon \sim (\ln 2/8\pi){\rm Im}h_{33}^{*2}$. Models of inflation and non-thermal leptogenesis were also considered in Refs. [339, 703, 704].

Sneutrino hybrid inflation was constructed in Refs. [79, 80]. In [79] the following superpotential has been used to generate inflation and the masses for the right handed neutrinos:

$$W = \kappa S \left(\frac{\Phi^4}{M'^2} - M^2 \right) + \frac{(\lambda_N)_{ij}}{M_*} N_i N_j \Phi\Phi \; + \ldots \,, \tag{298}$$

where $\kappa, (\lambda_N)_{ij}$ are dimensionless Yukawa couplings, M, M', M_* are three independent mass scales. Φ, S, N are all gauge singlets. The waterfield is Φ generates masses for the right

[72] We are using the superfield and the field notation to be the same for the right handed neutrinos, i.e. N.