

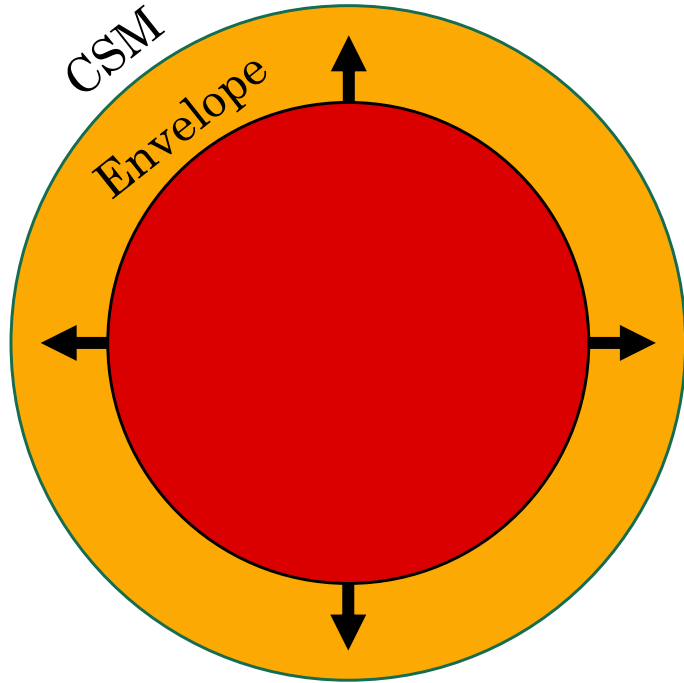


Multimessenger Picture of SNe and Nuclear Processes

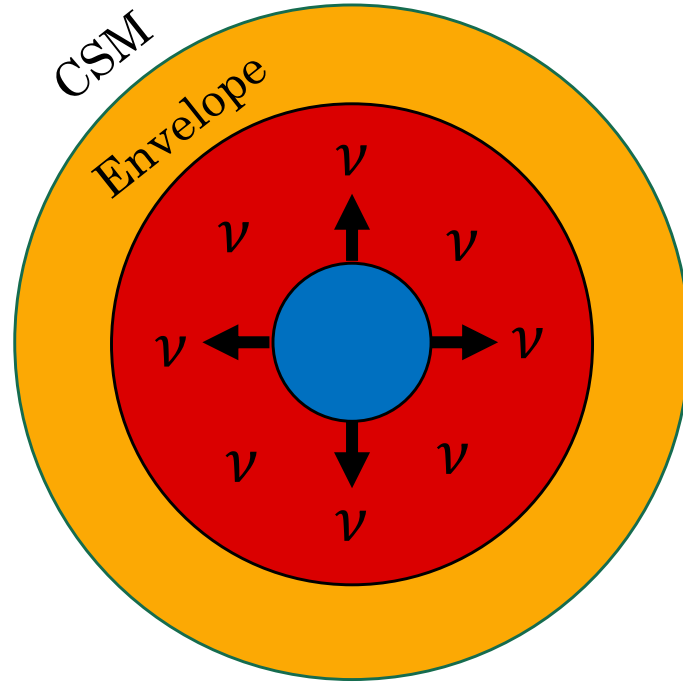
Nick Ekanger (Tohoku University)

Collaborators: Carpio, Bhattacharya, Murase, Horiuchi, Kimura, Kashiya

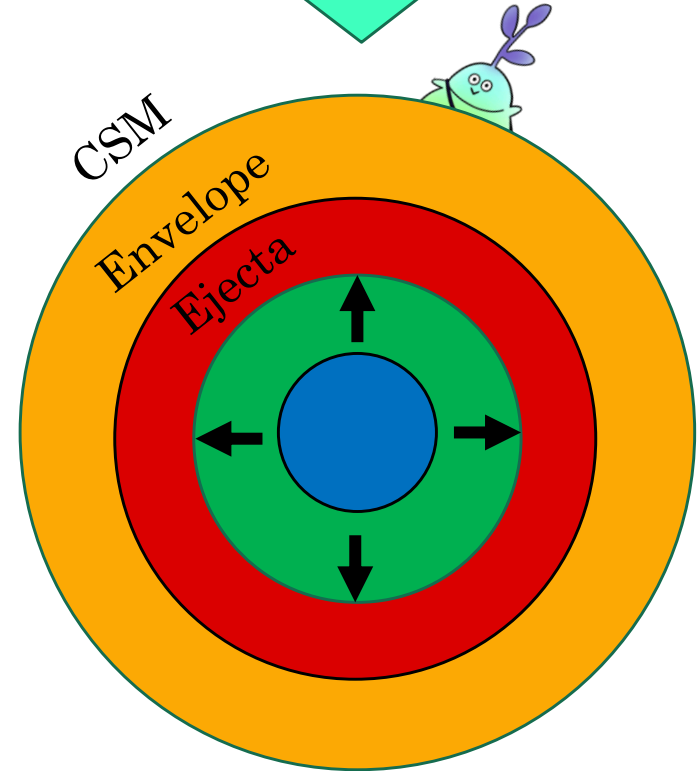
1. Pre-SN



2. ν -wind

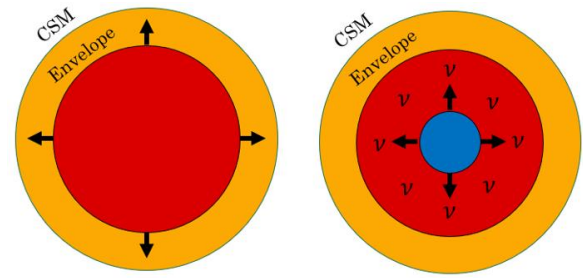


3. Interacting layers



1. Pre-SN mass loss

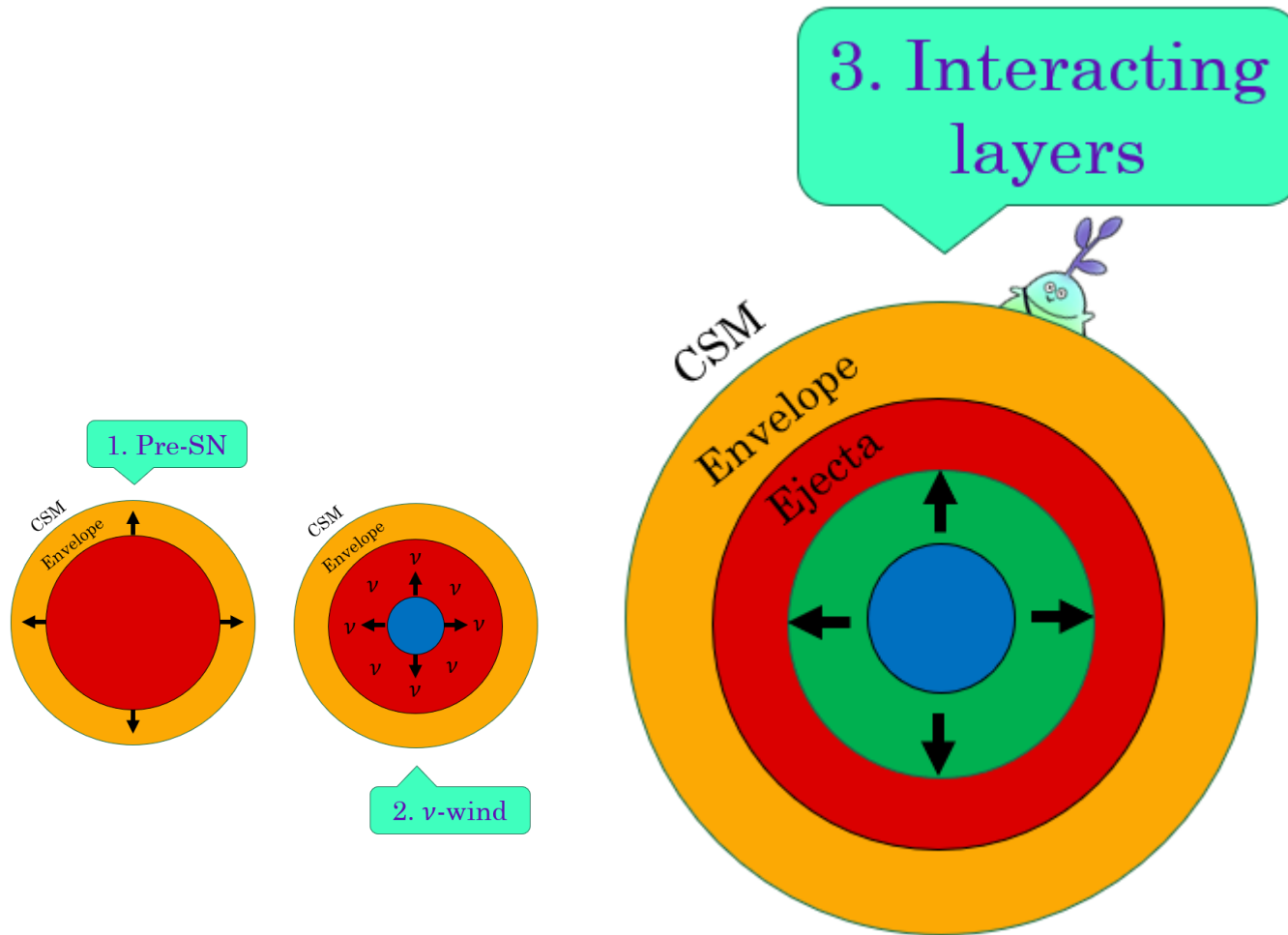
- $\sim 0.3\text{-}30$ years before SN
- $10 - 10^3 \text{ km s}^{-1}$, $10^{-5} - 10^{-1} M_{\odot} \text{ yr}^{-1}$, from H-rich to C/O-rich
- Extreme cases, progenitor dependent, and binary effects



2. Post-SN wind composition

- Competition of *Nucleosynthesis & Disintegration*
- Composition affects MMA signals
- *Previous/ongoing work on this, please feel free to ask me!*





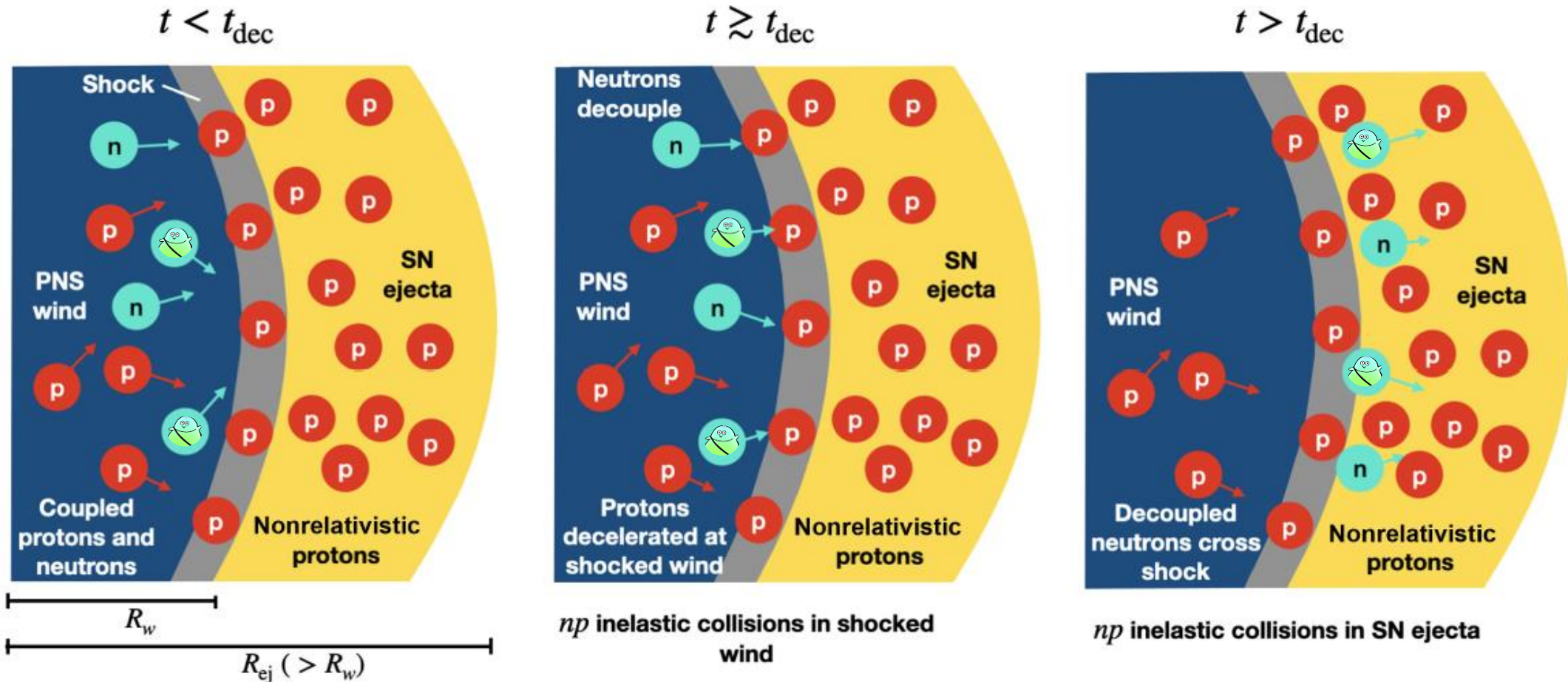
A. Quasithermal neutrinos:
Wind/ejecta interactions

B. Cosmic rays:
Ejecta/CSM interactions

3. Interacting layers

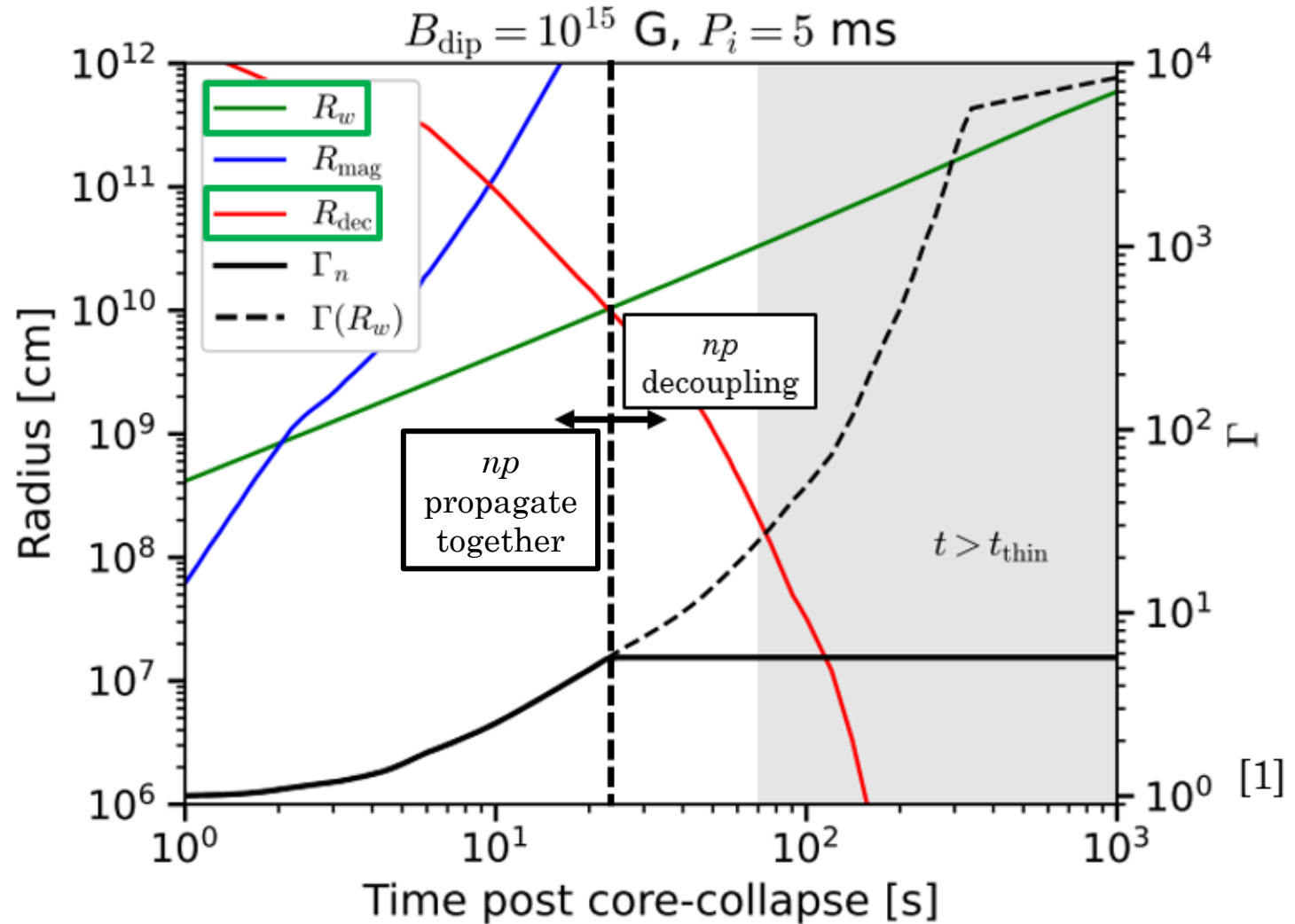
Quasithermal neutrinos

[1]



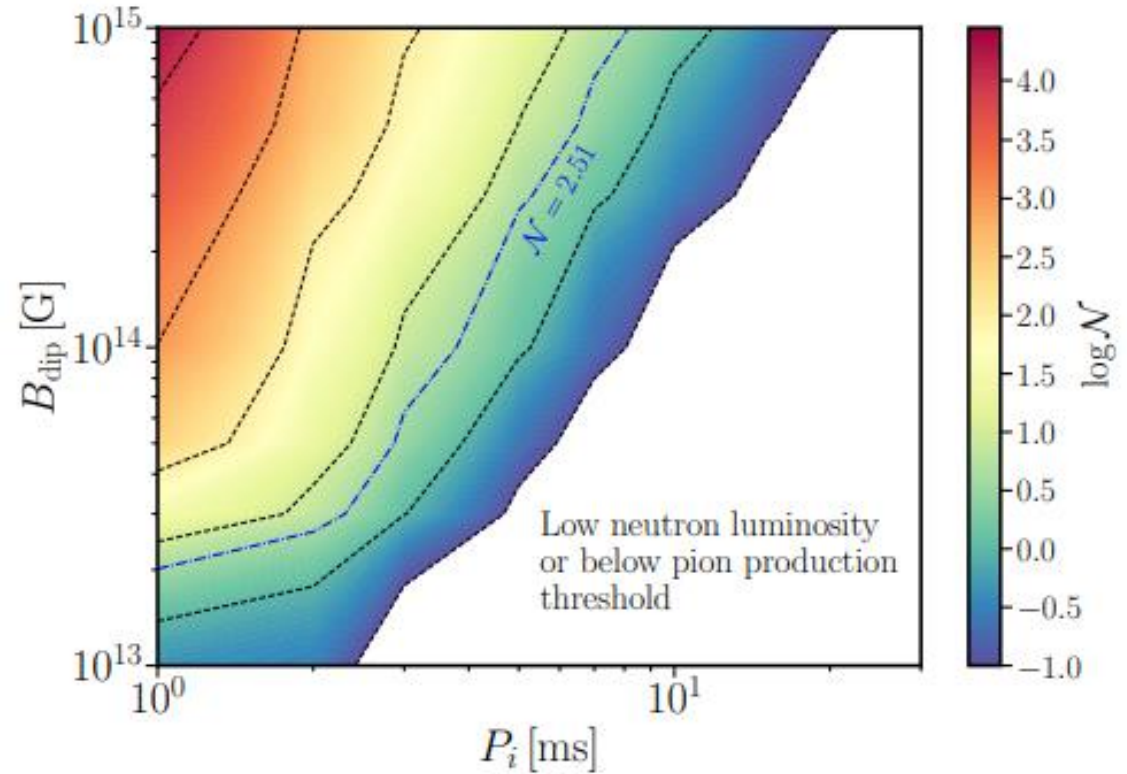
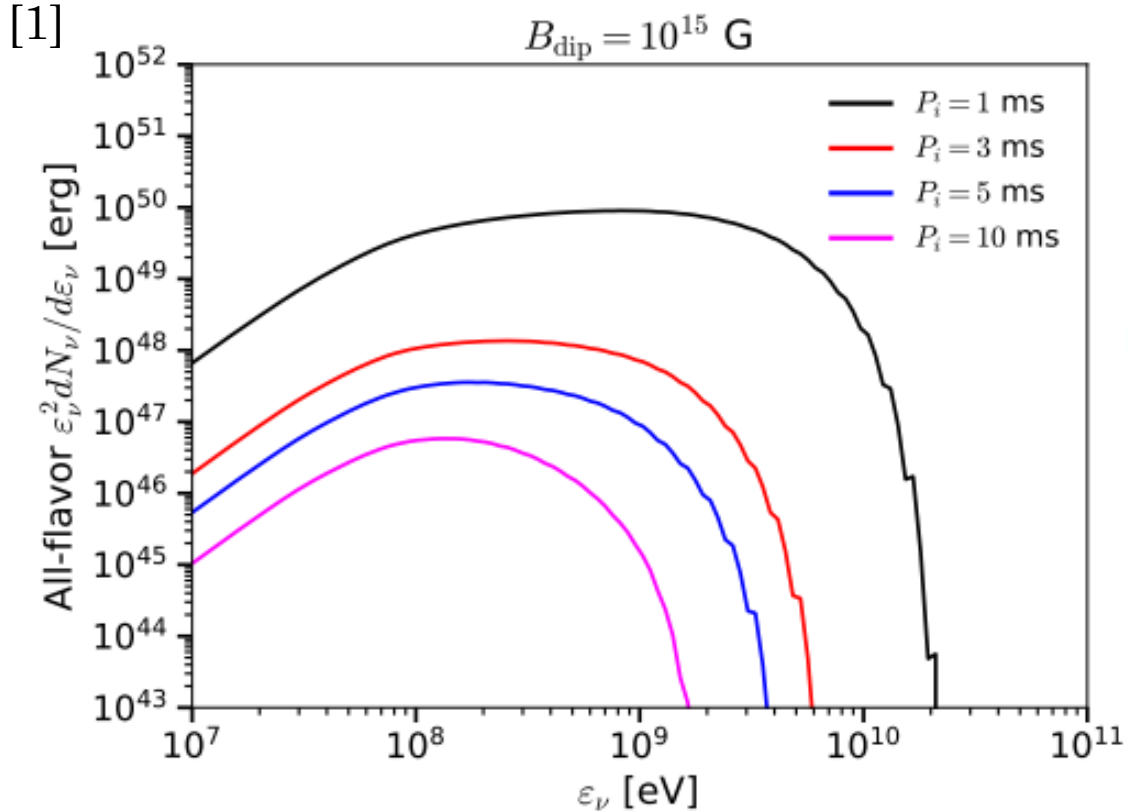
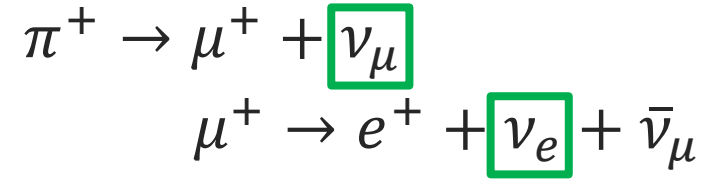
Quasithermal neutrinos

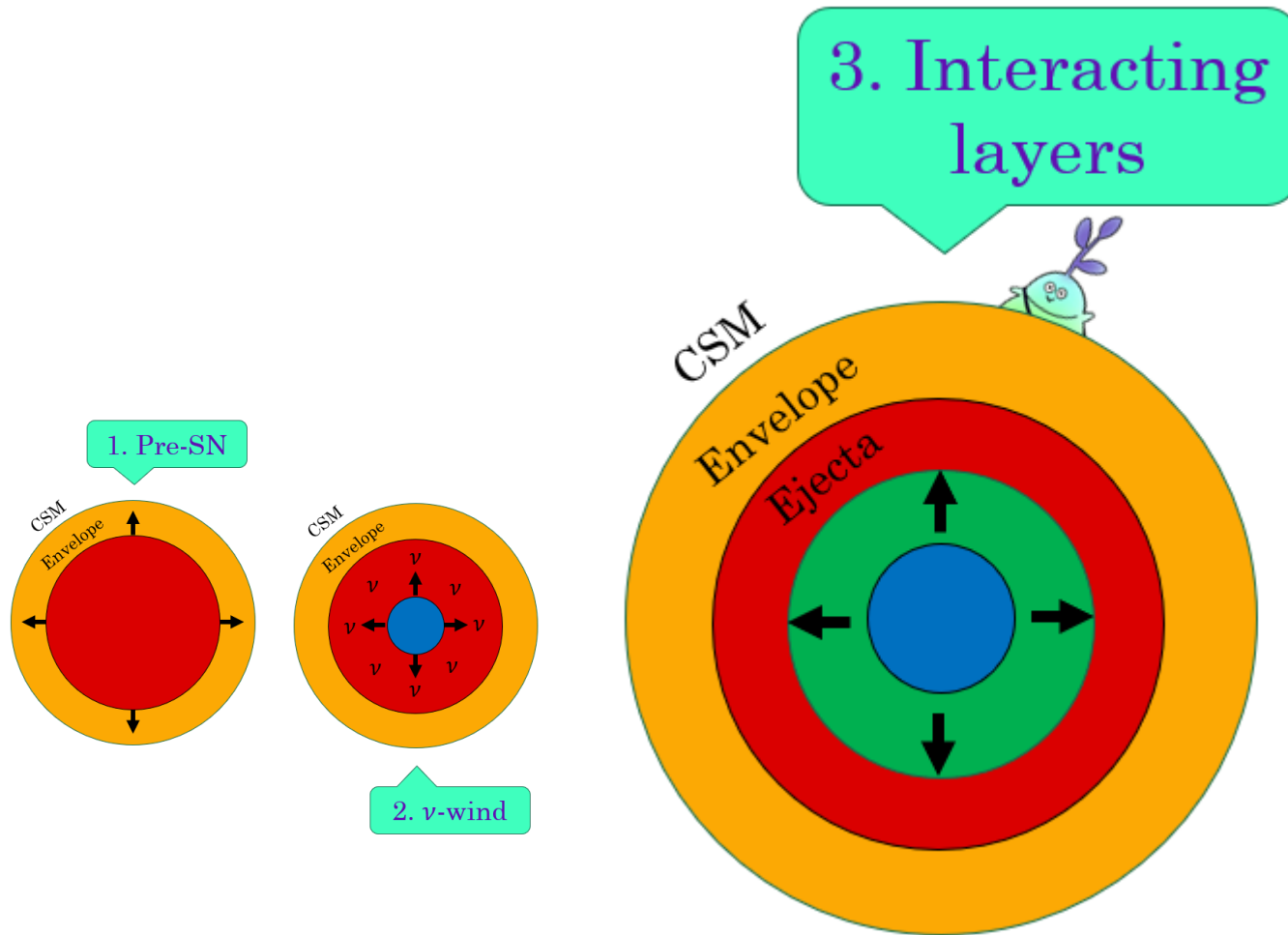
- Photo-disintegration assumed:
 - $n + p$ composition
- Inelastic np collisions produce π



Quasithermal neutrinos

$*R_{dec} \sim A^{-1}, \sigma_{Ap} \sim A^{2/3}$

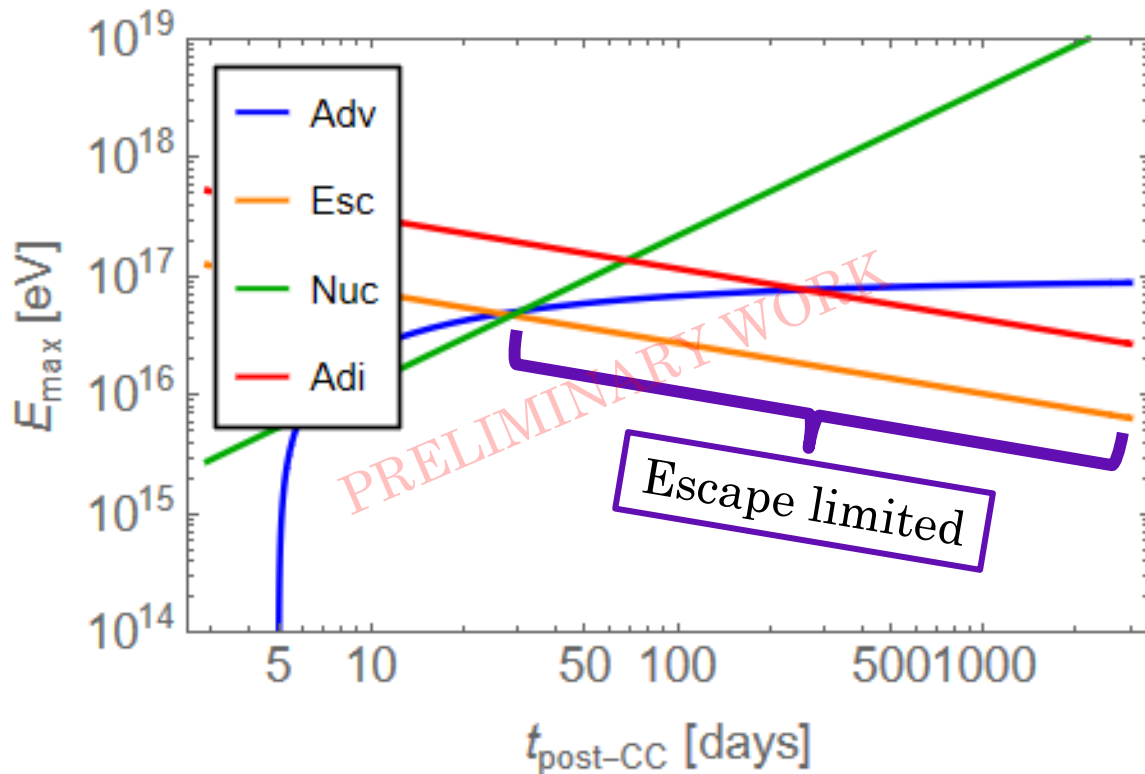




A. Quasithermal neutrinos:
Wind/ejecta interactions

B. Cosmic rays:
Ejecta/CSM interactions

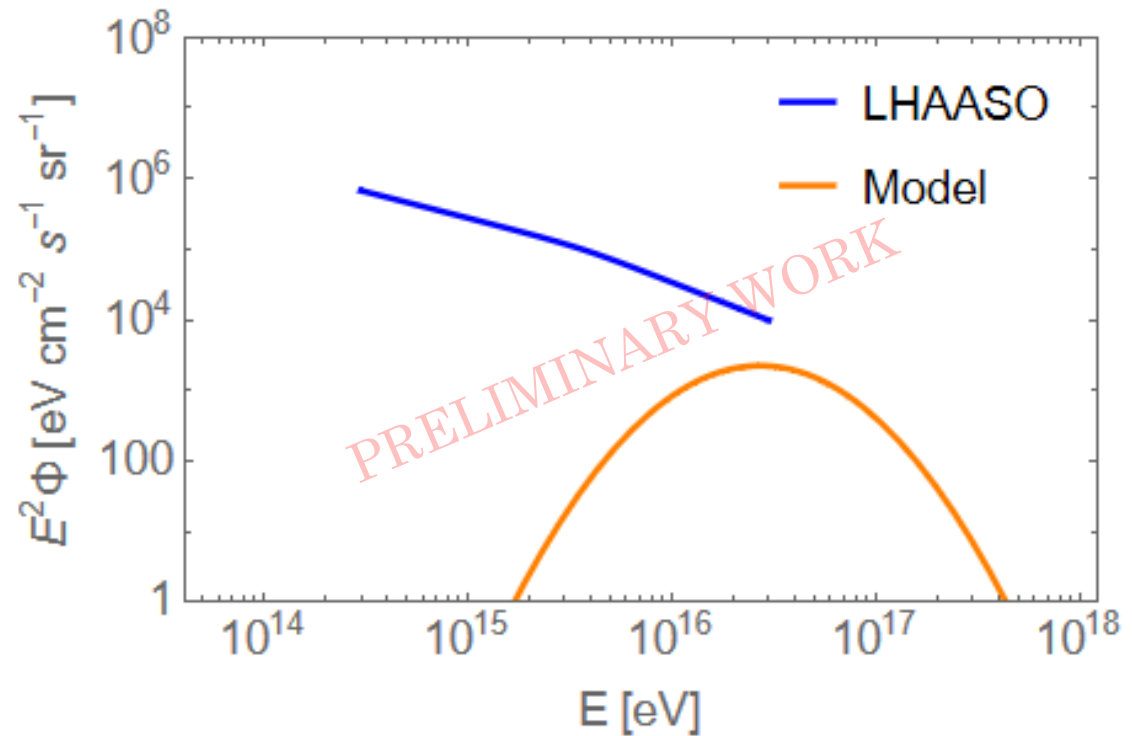
SN cosmic rays



- SN ejecta + CSM interaction
- DSA \rightarrow \geq PeV cosmic rays
- Max energy limited:
 - Advection
 - Geometric escape
 - Nuclear interactions:
 - Nuclei-proton interactions
 - He-p
 - Adiabatic losses

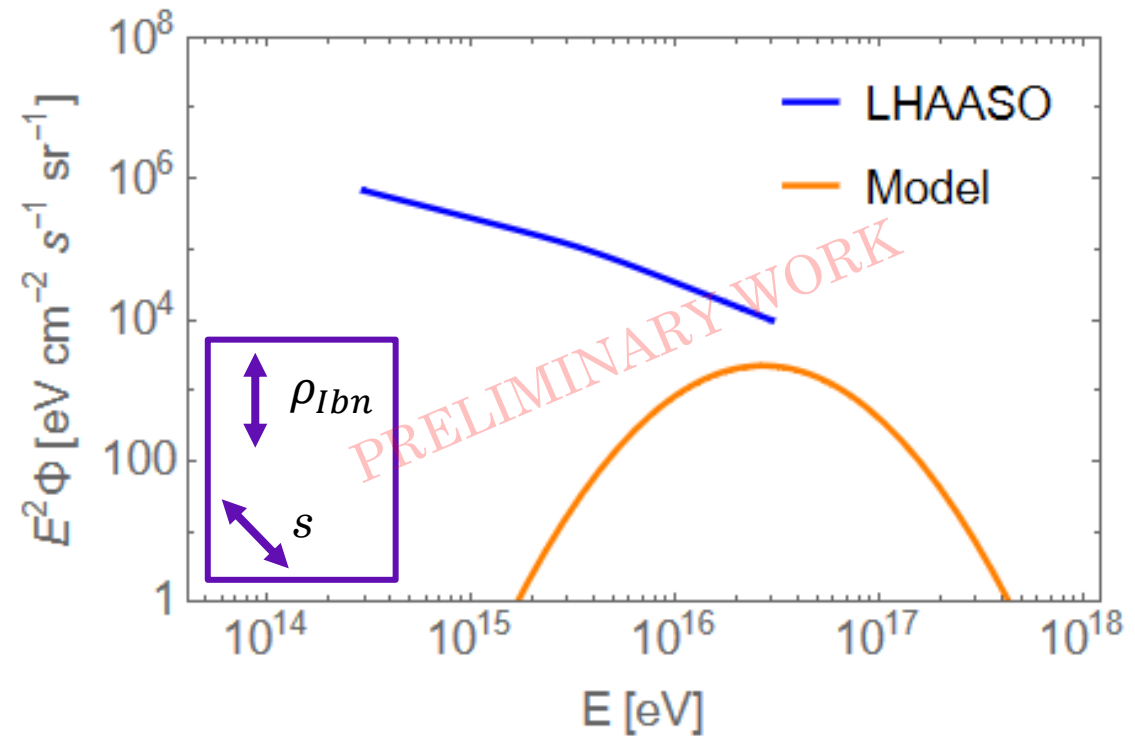
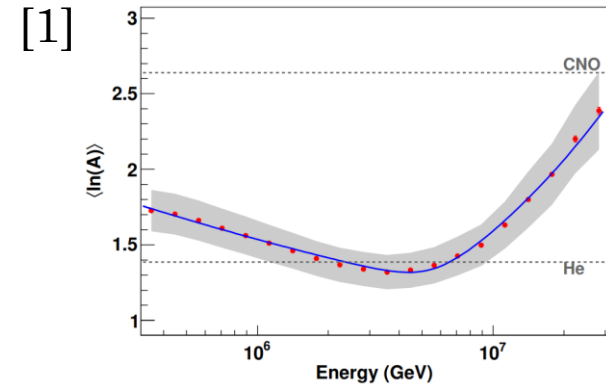
SN cosmic rays

- Ibn reference, update:
 - Nuclear interaction
 - Spectrum (escape limited model from DSA)
- He-rich CSM
- May be important near CR knee



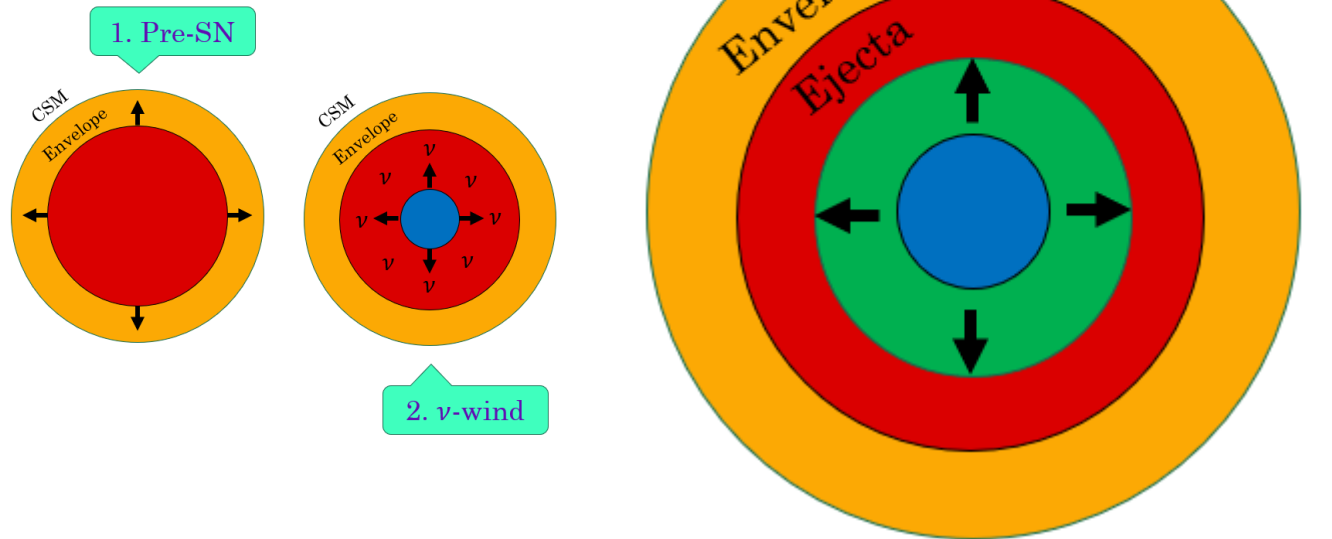
SN cosmic rays

- Observational connection:
 - Nuclear composition of CRs from *LHAASO*
 - Sensitive to parameters, notably:
 - Rate of subclasses (e.g. ρ_{Ibn})
 - Density gradient (s)





Recap



High energy signals:

- $\sim GeV \nu$ from wind / ejecta
- $\sim PeV CRs$ from ejecta / CSM

Takeaways:

- Composition affects signal
 - QTN ν timing
 - CR spectrum
- Observations can constrain parameters

Thank you!