

Matter-neutrino resonance (MNR)
transitions above a neutron star
merger remnant

Yonglin Zhu

(North Carolina State University)

Joint CNA and JINA-CEE Winter School on Nuclear Astrophysics 2016



NC STATE

Neutrino Oscillation In Astrophysical environment

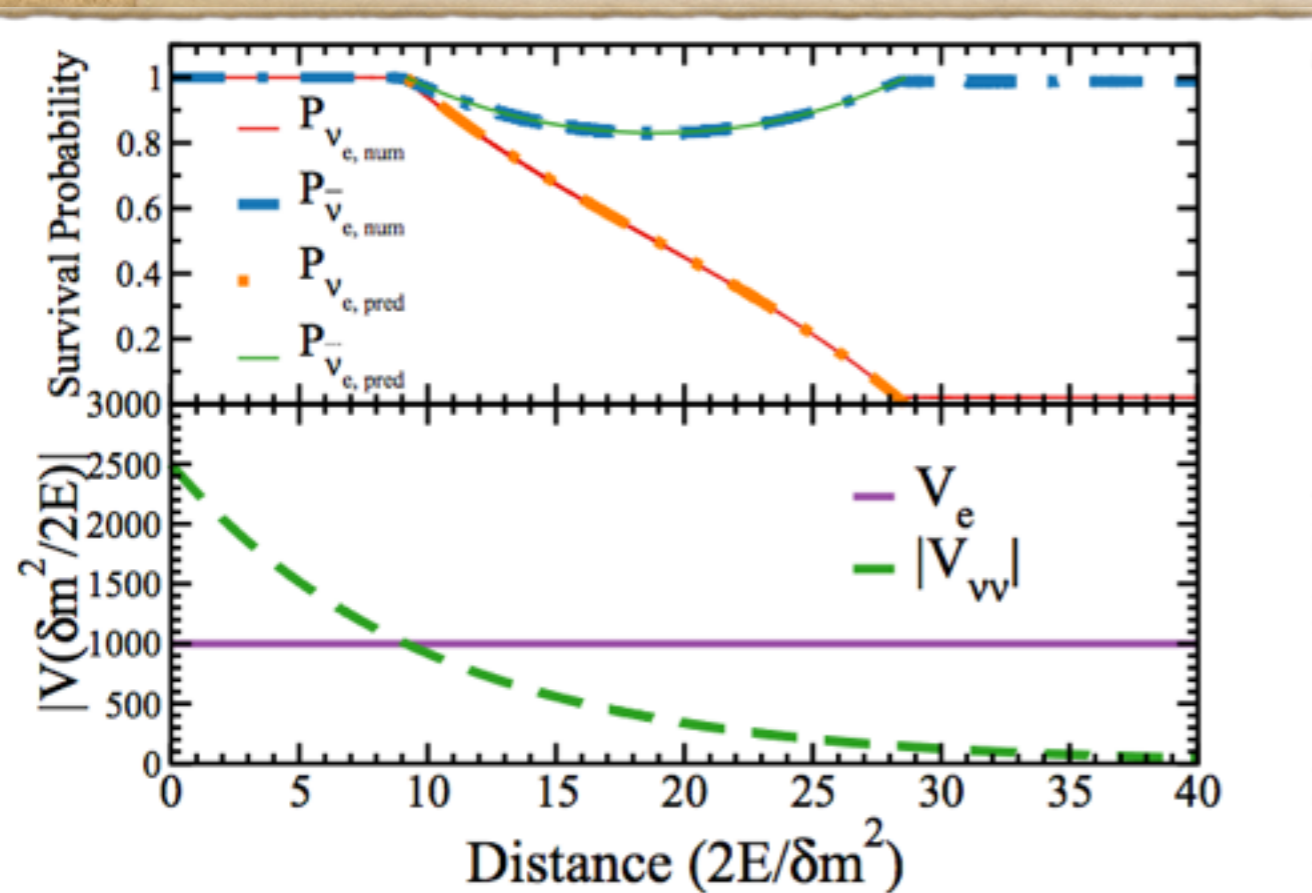
- ◆ Collective Neutrino Oscillation in dense neutrino environment, especially in Supernova (Duan, Fuller, Qian, 2005)
- ◆ Collective Neutrino Oscillations also in Mergers, e.g. Matter-neutrino resonance (MNR) (Malkus, et al, 2012)
- ◆ IN Mergers, Anti-neutrinos can be dominant

Matter-neutrino resonance

The evolution of neutrinos/antineutrinos follows

$$i \frac{d}{dt} S(E, \mathbf{x}, t) = (H_V(E) + H_e(\mathbf{x}, t) + H_{\nu\nu}(\mathbf{x}, t)) S(E, \mathbf{x}, t)$$

$$i \frac{d}{dt} \bar{S}(E, \mathbf{x}, t) = (-H_V(E) + H_e(\mathbf{x}, t) + H_{\nu\nu}(\mathbf{x}, t)) \bar{S}(E, \mathbf{x}, t)$$



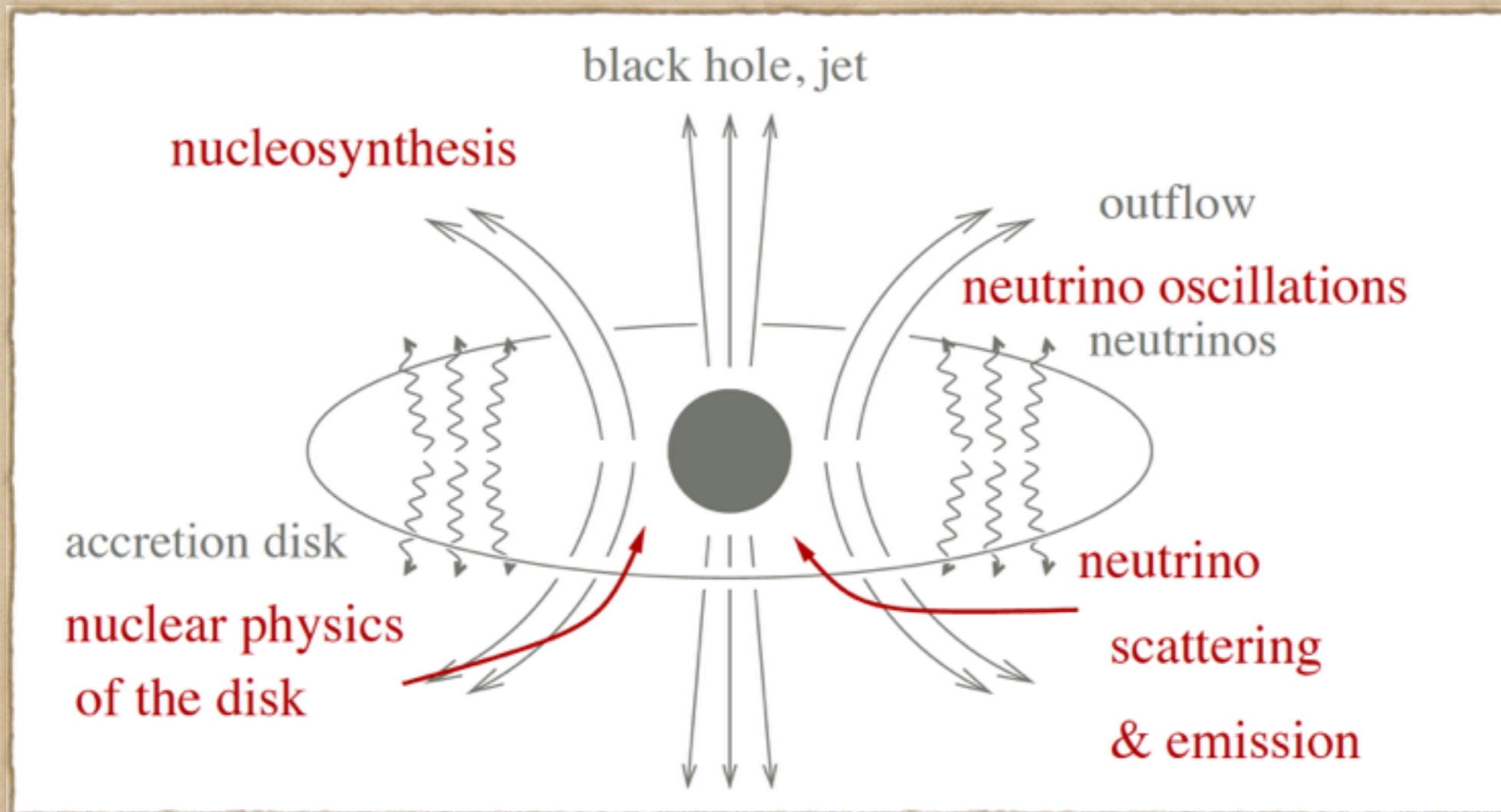
- ◆ In MNR, Negative Self interaction potential,

$$H_{e,11} \approx -H_{\nu\nu,11} \gg H_V$$

(Malkus+2012/2014/2016, Wu+2016, Väänänen+2016, Zhu+2016, Frensel+2016)

- ◆ Electron Neutrino can be fully converted

Why we care about MNR?

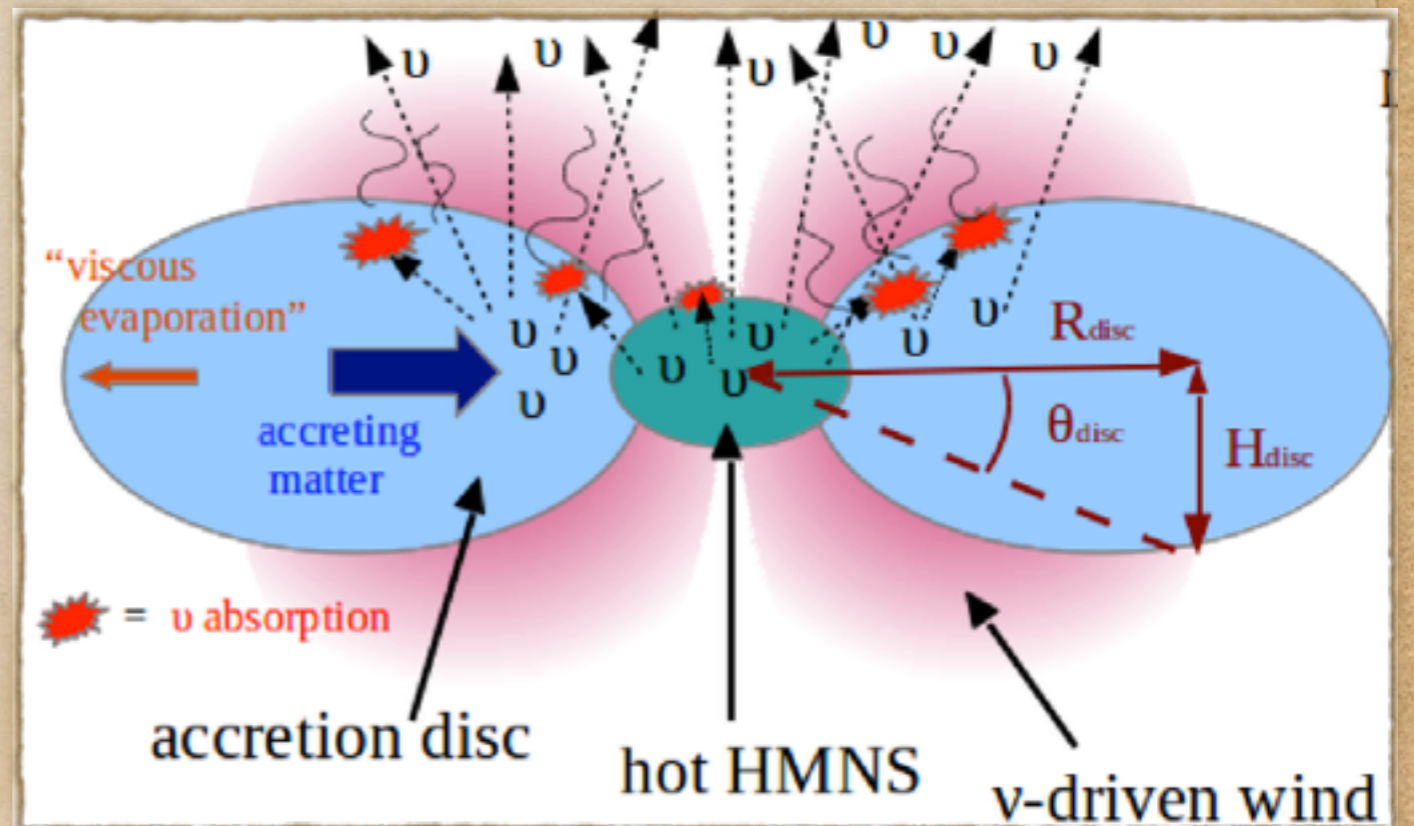
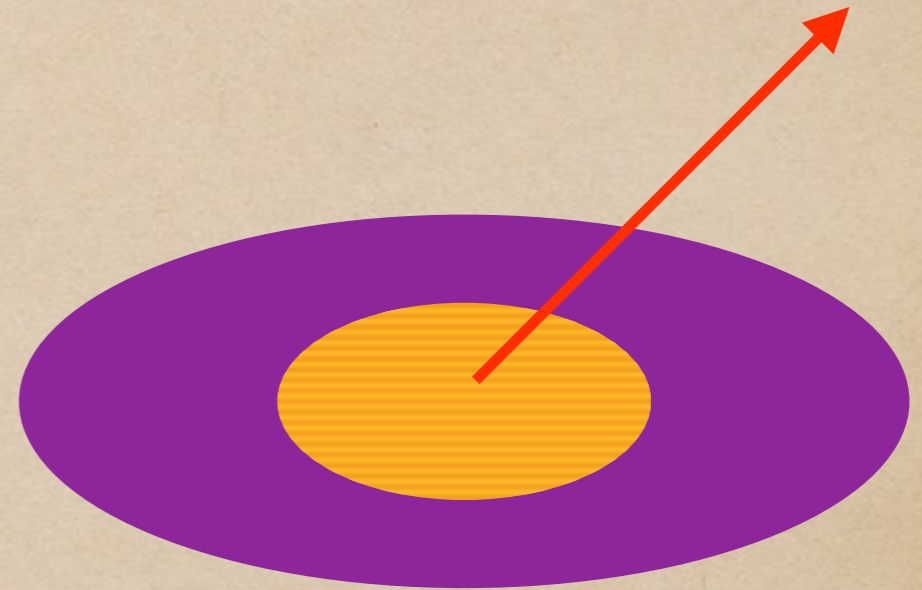


- ◆ Nucleosynthesis in mergers!

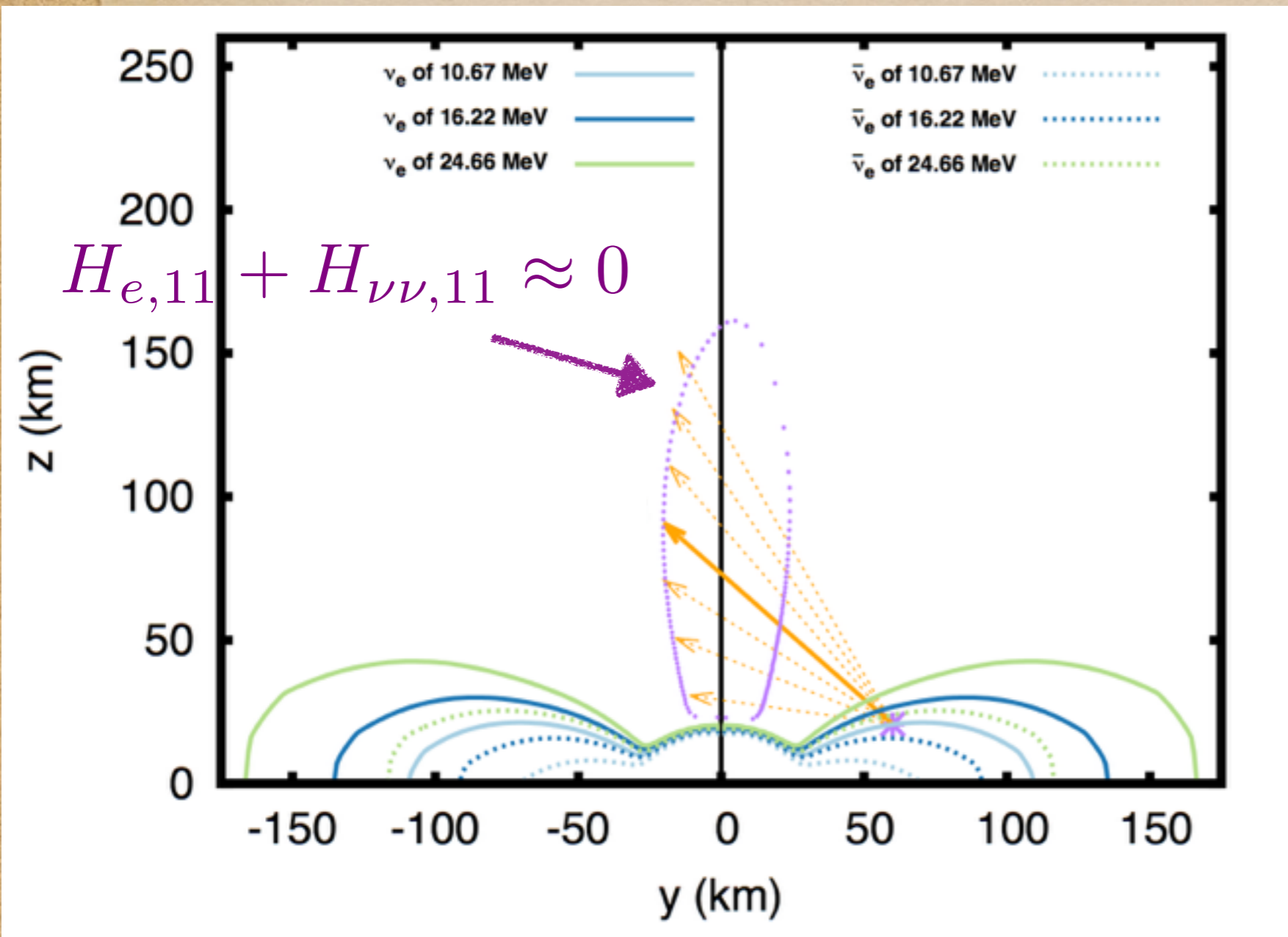
(e.g. see work by Aprahamian, Horowitz, Qian)

Does MNR happen in NS Merger?

- MNR in Simple Flat disk model (Malkus+2012/2016)
- 3D hydrodynamic study of the neutrino-driven winds that emerge from the remnant of a neutron star merger.
- A binary neutron star merger forms initially a central, hypermassive neutron star (HMNS) surrounded by a thick accretion disc.



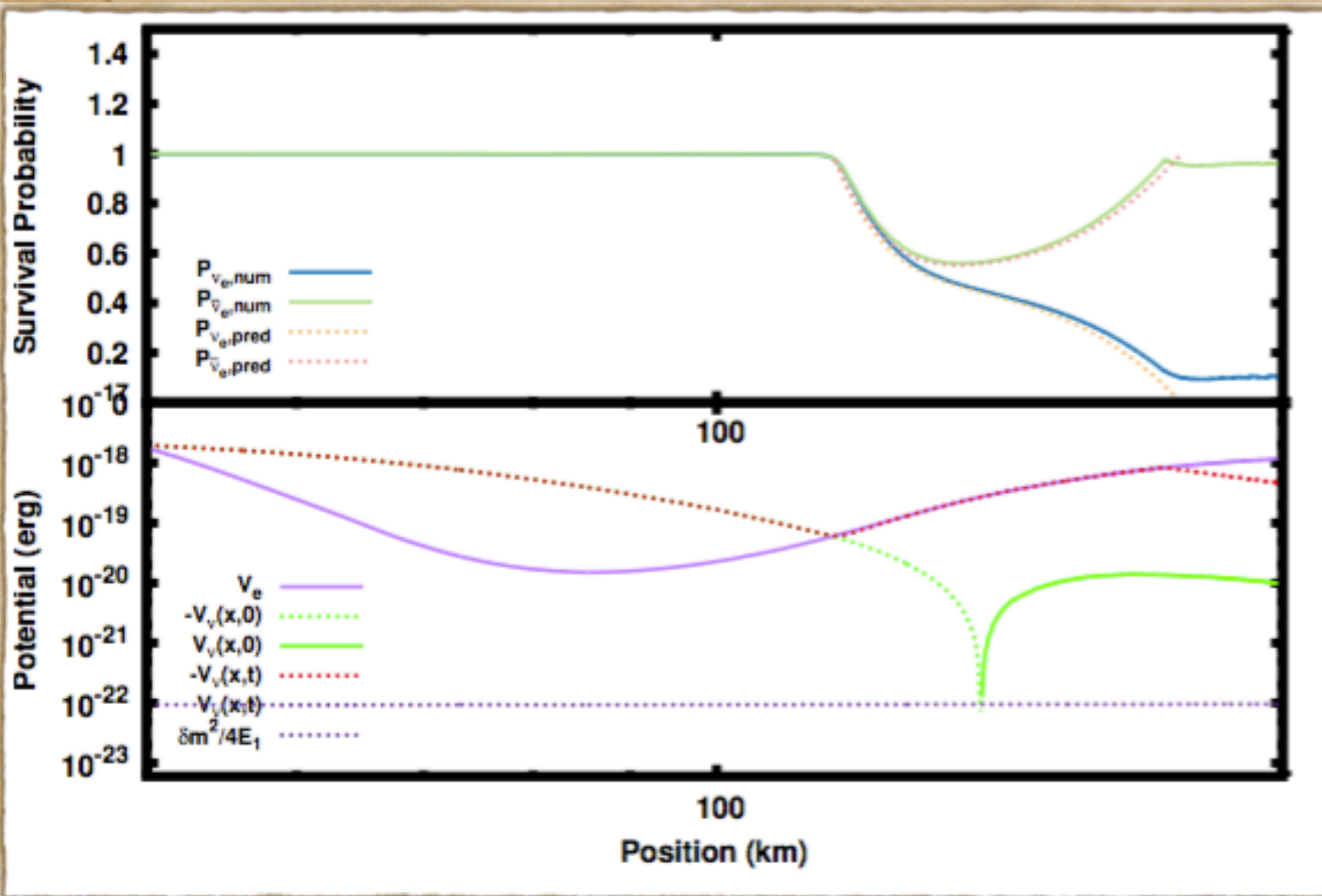
Calculations



- Self-consistent density profile
- Multi-energy neutrinos/anti-neutrinos
- Single-angle approximation

Zhu+2016

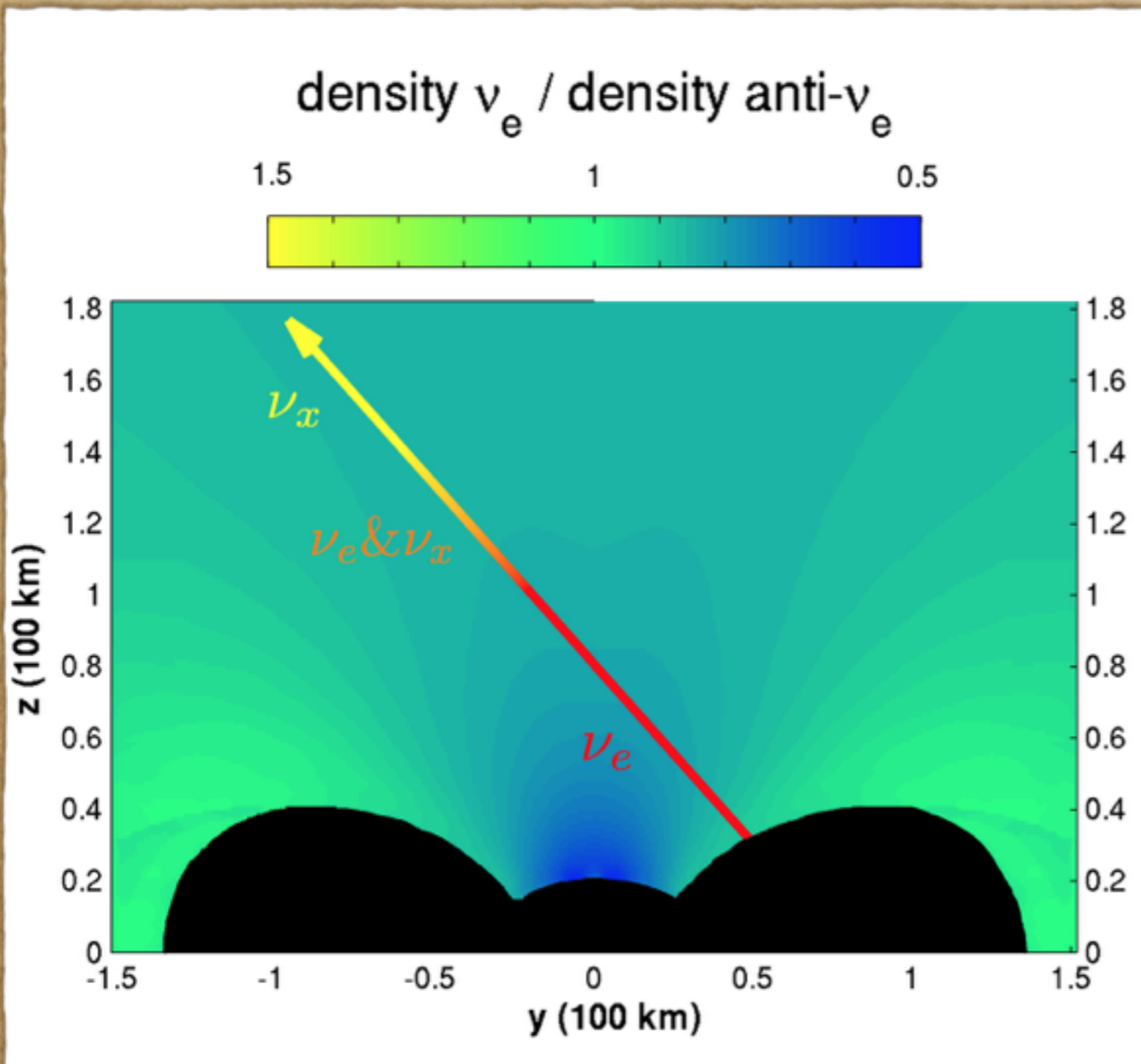
Calculations



- Second cancelling pointing
- Potential scales
- Active cancellation of potentials

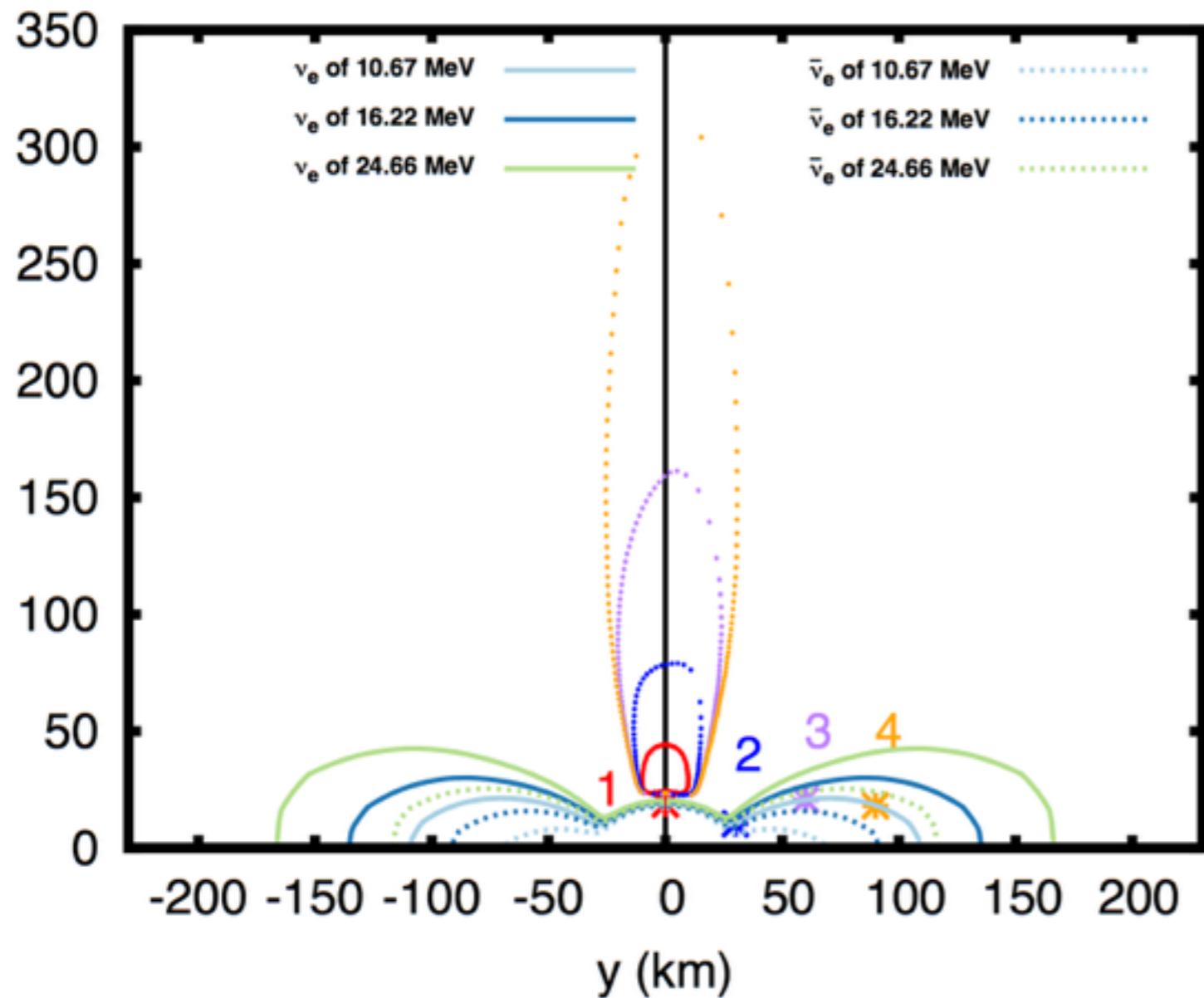
Zhu+2016

Calculations



Zhu, Perego,
McLaughlin, 2016,
highlighted as PRD
editor's suggestion

Geometric effect on MNR

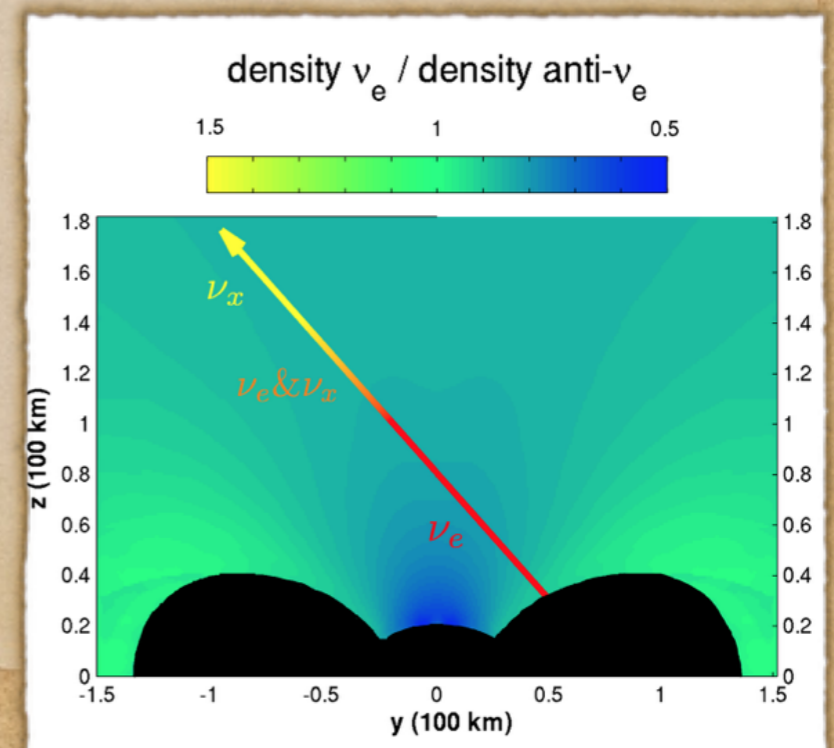


- Different emitting points
- MNR shell
- Coupled with energy effect

Zhu+2016

Conclusions & Plans

- ◆ Significant fraction of neutrinos undergo MNR in a self-consistent dynamical merger calculation!
- ◆ MNR transition happen close to the core of merger
- ◆ More calculation to confirm (GR, Multiangle, etc)
- ◆ Impact on the physics around (Nucleosynthesis, GRB, etc)



Thanks to ...

You

JINA, CNA, NCSU

A. Perego, G. C. McLaughlin

NC STATE

