Invisible neutrino decays at the MOMENT

Jian Tang
(Sun Yat-Sen University, China)
email: tangjian5@mail.sysu.edu.cn

In collaboration with Tse-Chun Wang and Yibing Zhang

arXiv: 1811.05623, JHEP 1904 (2019) 004

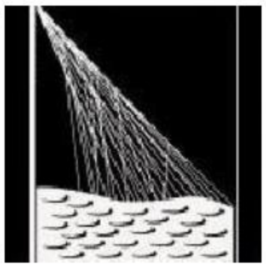
NuFact2019, Daegu, Korea
August 30, 2019

Table of contents

Table of contents

Motivations

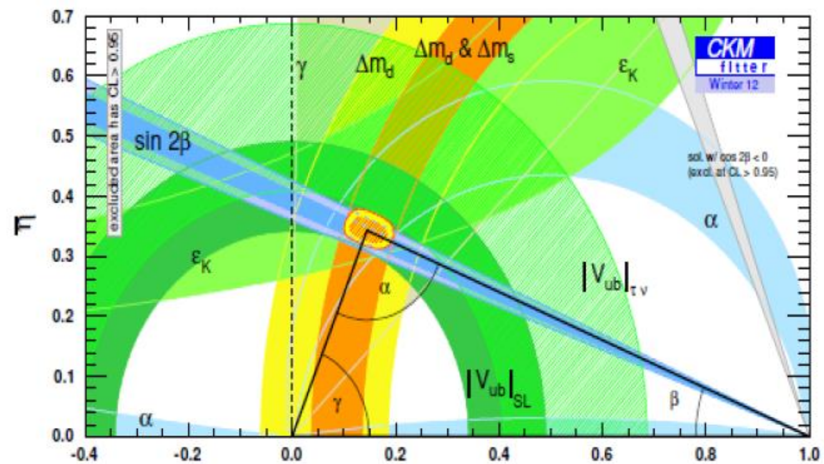
$$U_{\rm PMNS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}\, e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}\, e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}.$$

= () x (

) x ()

Parameter	Value	Precision (%)
Δm^2_{21}	$7.37\ 10^{-5}\ eV^2$	2.3
θ_{12}	34°	5.8
Δm^2_{32}	$2.52\ 10^{-3}\ eV^2$	1.6
θ_{23}	42°	~9
θ_{13}	8.4°	4

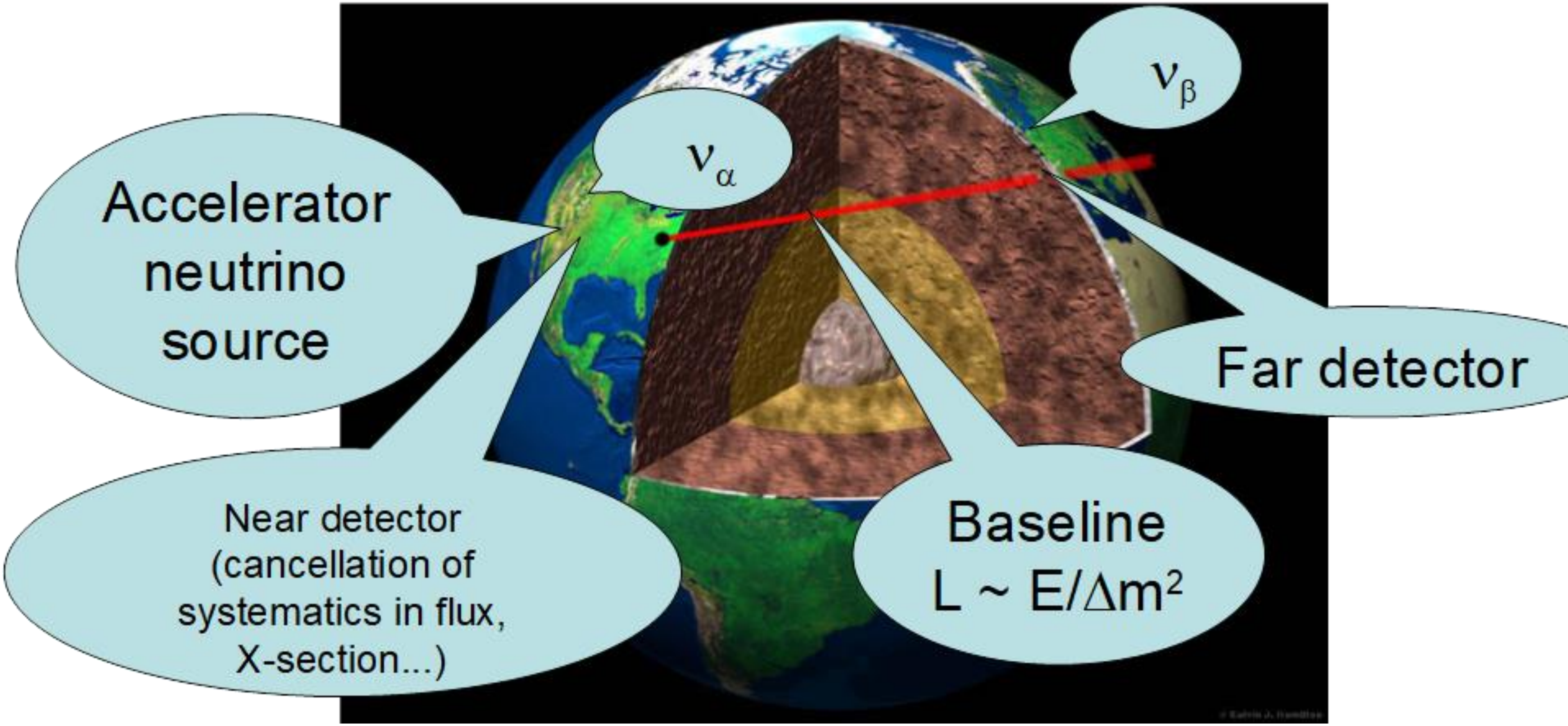
Capozzi et al.
PRD 95, 096014 (2017)



- PMNS precision ~ O(1) %
- New physics might be hidden there

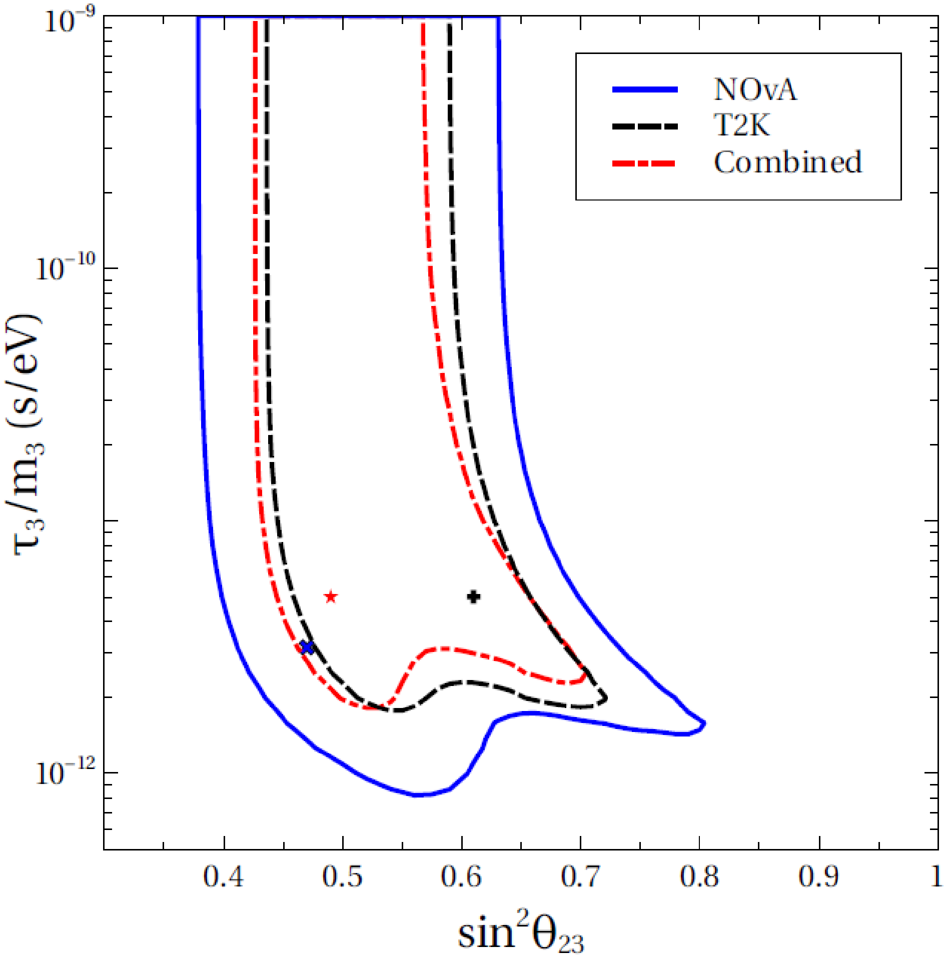
- CKM precision ~O(1) ‰
- Previous discovery used as a tool to probe new physics

Precision measurement and new physics searches by accelerator neutrino oscillations



- Get the neutrino source as clean as possible. Muon decay v.s pion decay beams.
- Deploy the best detector to reconstruct the oscillated neutrino spectra: Gd-WC, LAr TPC, scintillator detector with charge identifications…
- Data mining: precision measurement & discovery of new physics…

Recent hints of neutrino decays by T2K&NOvA?



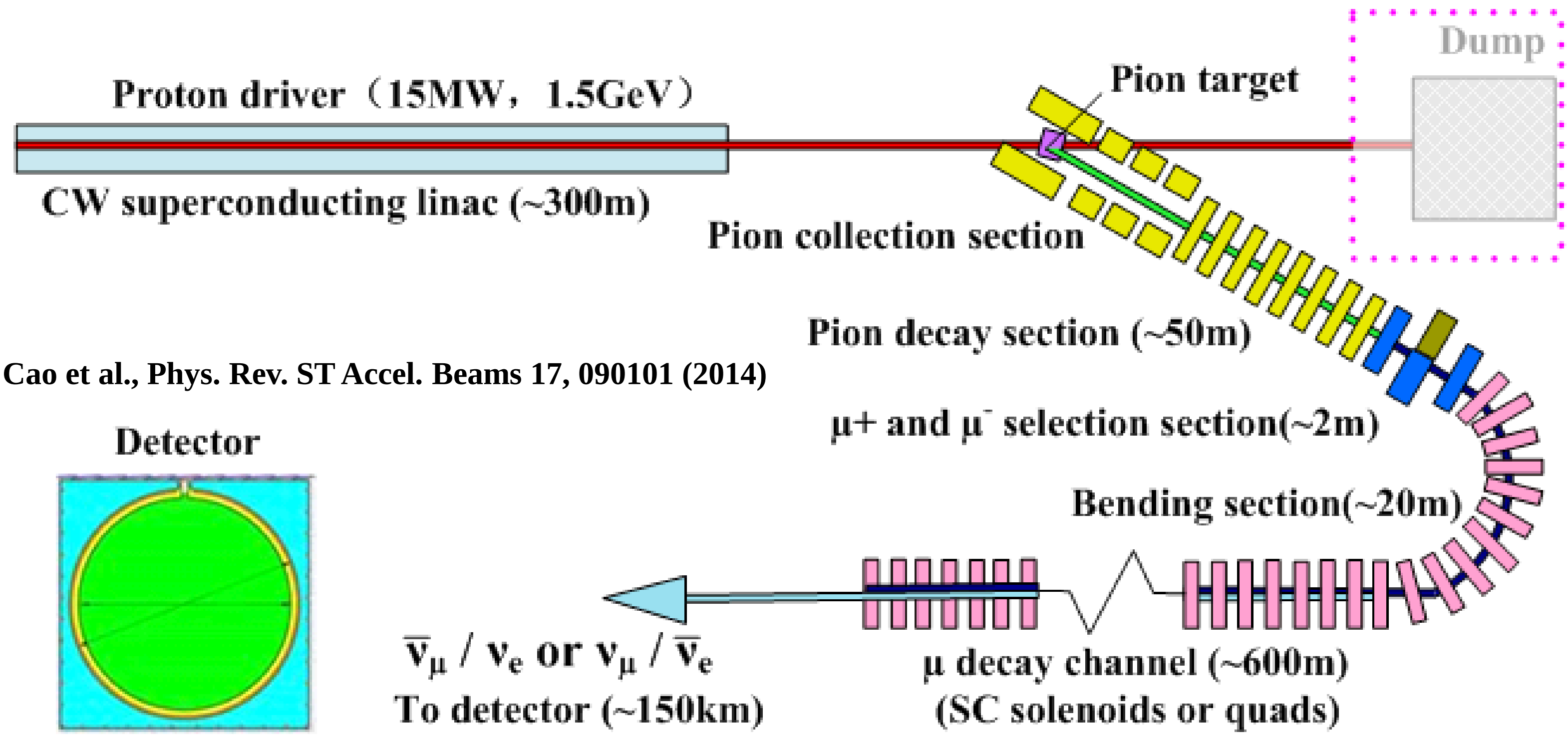
- NOvA and T2K data sets are better fitted with invisible neutrino decays.
- The best-fit lifetime corresponding to the T2K data is $\tau_3/m_3 = 1.0 \times 10^{-11}$ s/eV.
- The best-fit lifetime from NOvA data corresponds to $\tau_3/m_3 = 3.16\times10^{-12}$ s/eV.
- Hints for serious new physics or not?

Ref: Sandhya Choubey, Debajyoti Dutta, Dipyaman Pramanik
JHEP 1808 (2018) 141, arXiv:1805.0184

Table of contents

History of the MOMENT project

- As DYB-III, the original goal is to measure the leptonic CP phase.
- Features: ADS or ADS-like linac, High-field SC solenoids + fluidized target, DC muon beam for neutrinos, medium energy neutrinos.
- Three working areas: accelerator muon source, target station, detector and physics.

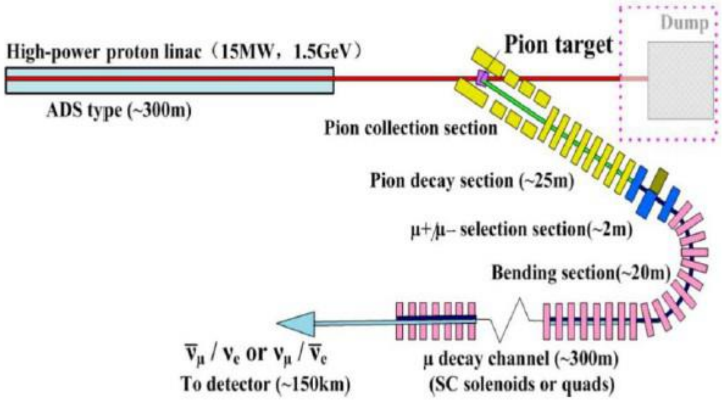


Ref: J. Cao et al., Phys. Rev. ST Accel. Beams 17, 090101 (2014)

Overview of MOMENT

(Muon-decay MEdium baseline NeuTrino beam facility)

•MOMENT: the proposal is still in an early stage ; the details have not been completely fixed.



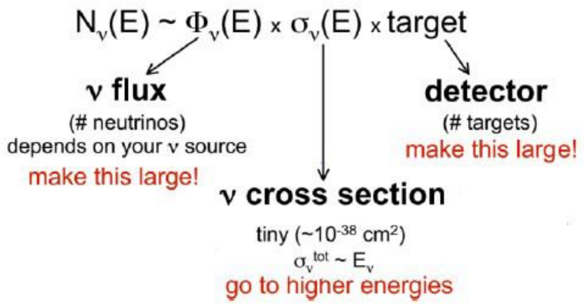
•Peak energy: 200 MeV

Neutrino energy range: 100MeV—800MeV

•The lower beam energy at ~ 300 MeV: free from pi0 background

•Baseline: L=150 km

In the MOMENT: the neutrino flux peak at low energies ➡ require a very massive detector to compensate the low interaction cross section



Recent activities of MOMENT

- Organize domestic workshop annually to coordinate the accelerator neutrino physics in China: develop local accelerator neutrino beam techniques, detector and physics performance studies, new physics ideas …
- This year SYSU will hold the workshop on Sep. 7 and 8, 2019.
- Accelerator: CiADS project at Huizhou under civil constructions, 500 MeV, 2.5 MW DC proton beam. CSNS on service in a year: 1.6 GeV, 100 kW pulsed proton beam → 500 kW upgrade on the way.
- Muon beamline: Experimental Muon Source (EMuS) to be built in China Spallation Neutron Source (CSNS), pass the international review of CDR last November.
- EMuS is the first R&D effort towards MOMENT. Ref: talk by Nikolaos Vassilopoulos.
- Target station: further development on the waterfall target concept. Ref: poster by Nitin Yatav.
- Neutrino detector: not decided yet and welcome advanced technologies. Take a Gd-WC detector as the benchmark.
- Physics study: search for NSIs, test flavor symmetry models, precision measurement of the CP phase, neutrino scatterings, neutrino invisible decays …

Table of contents

If a neutrino decays?

- Visible decay:

If the decay products are active, interact at the detector and give a visible signal. → Increase/depletion of event rates.

- Invisible decays:

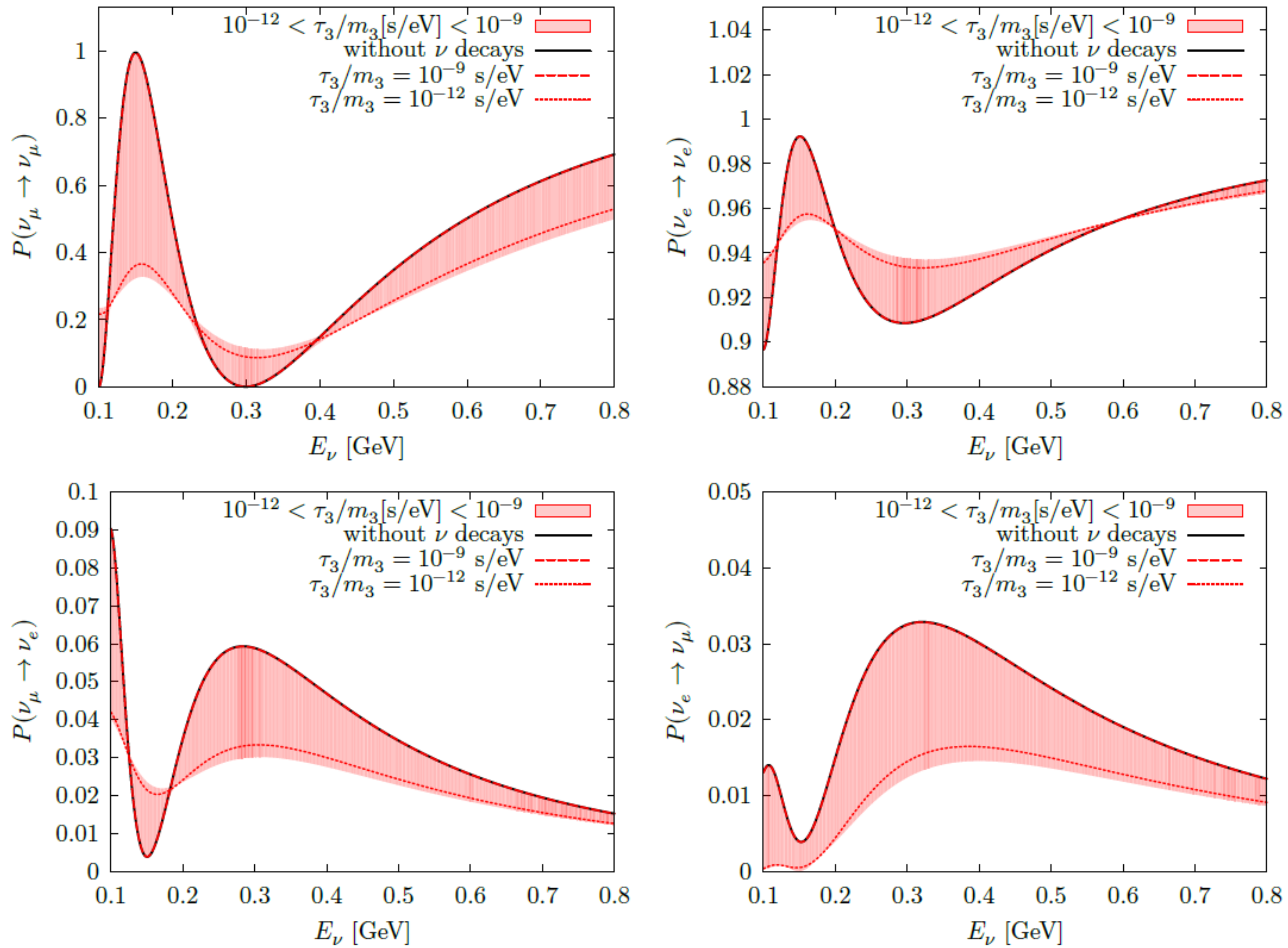
Sterile states, below the detector threshold, depletion of event rates...

- Consider the decay mode: $\nu_3 \to \nu_4 + J$

$$\begin{pmatrix} \nu_\alpha \\ \nu_s \end{pmatrix} = \begin{pmatrix} U & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_i \\ \nu_4 \end{pmatrix}$$

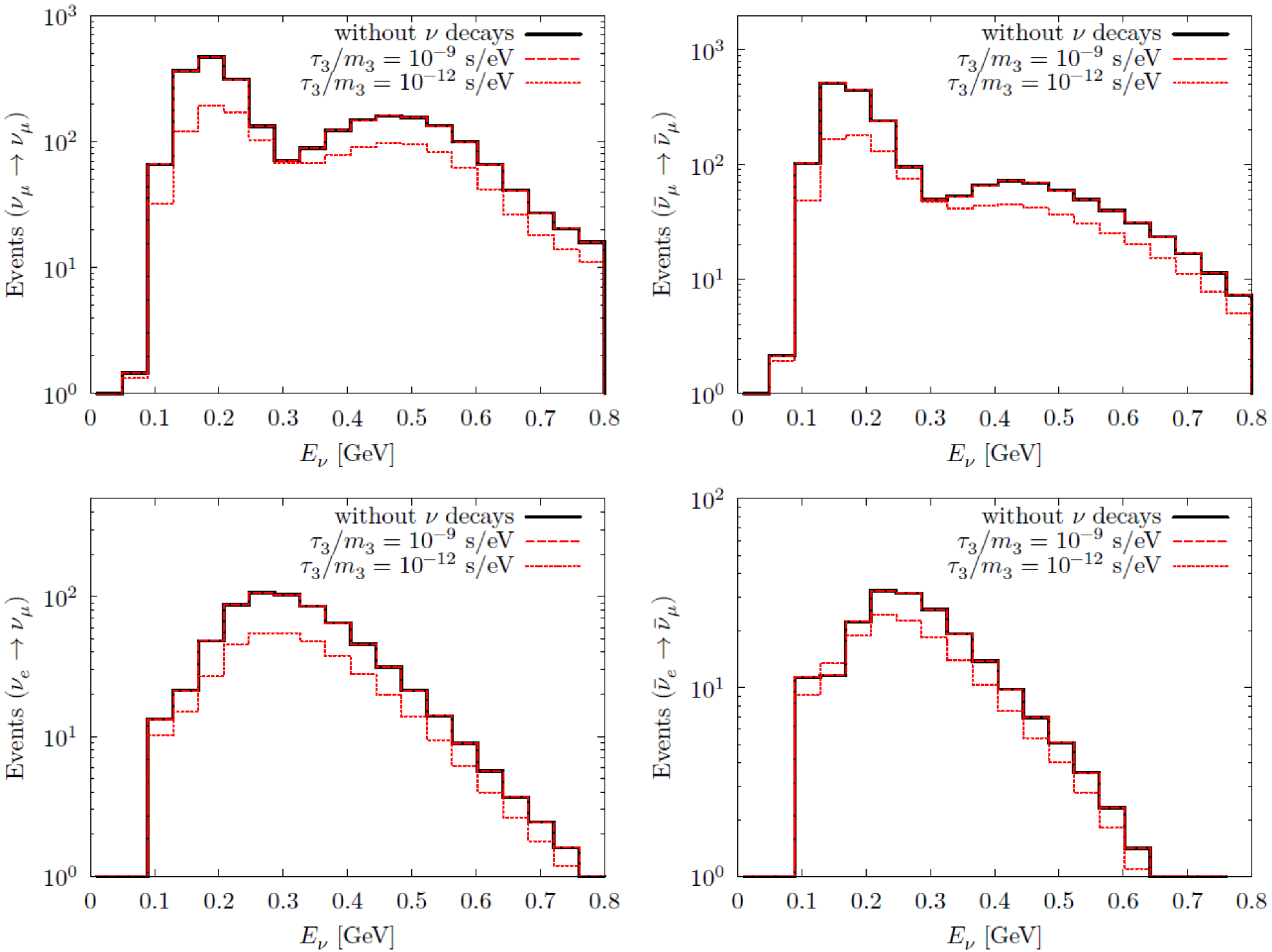
$$H = U\left[\frac{1}{2E}\begin{pmatrix} 0 & 0 & 0 \\ 0 & \Delta m_{21}^2 & 0 \\ 0 & 0 & \Delta m_{31}^2 \end{pmatrix} - i\frac{m_3}{2E\tau_3}\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}\right]U^+ + \begin{pmatrix} 2\sqrt{2}G_F N_e E & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Oscillation probabilities w/o decays

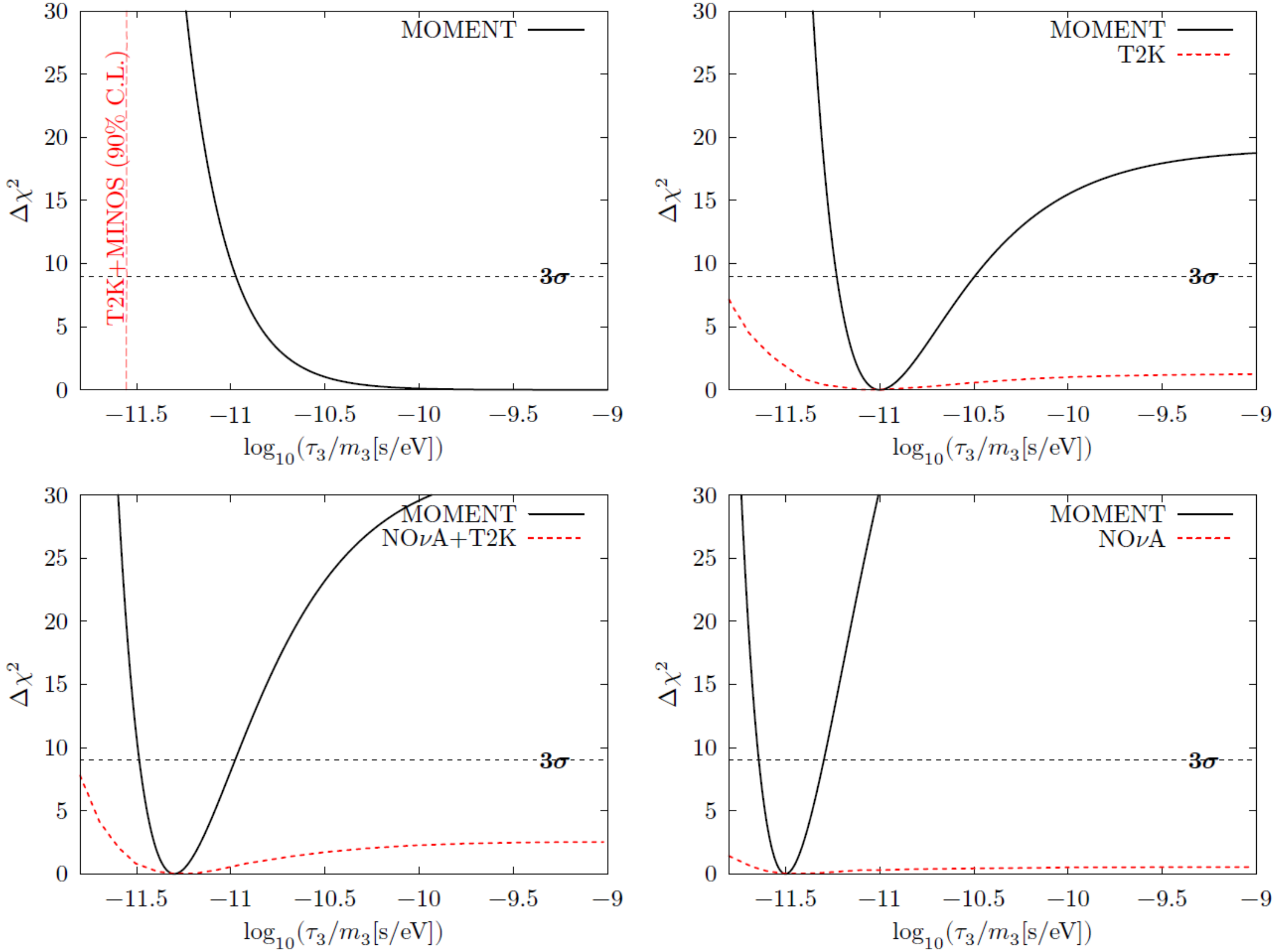


- Many thanks to T. Hahn's package "Diag" and GLoBES

Simulated neutrino oscillation spectra w/o decays

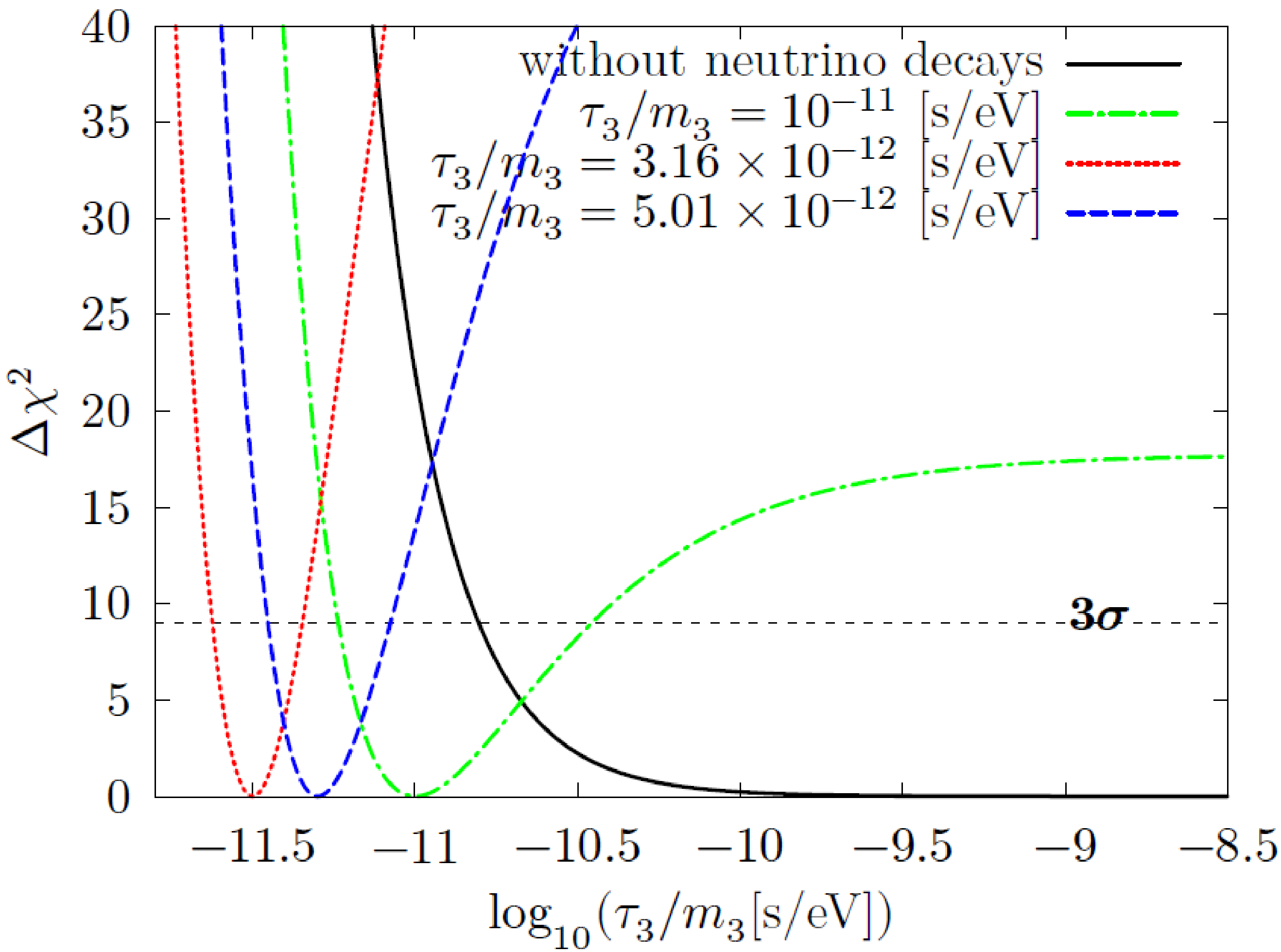


Confirm or exclude the hint from T2K&NOvA?



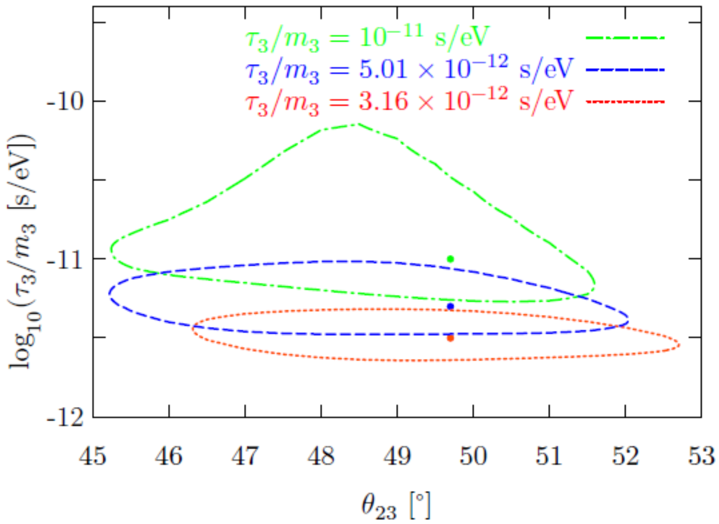
- Better than combined results at T2K and MINOS.

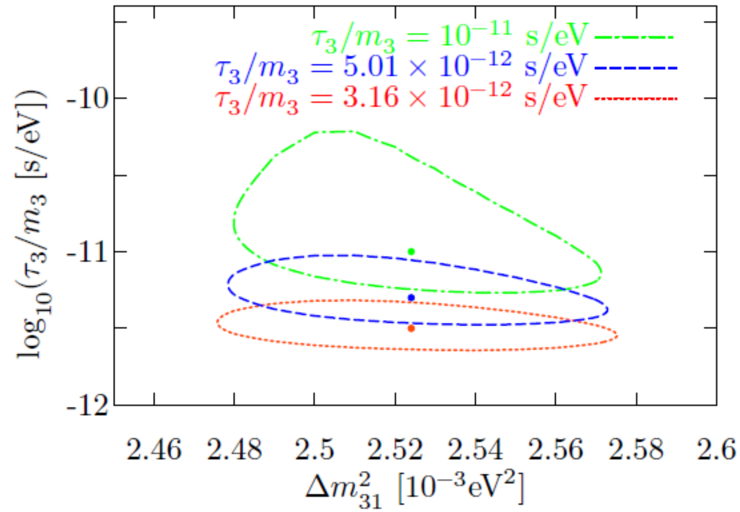
Bounds on the lifetime of ν_3

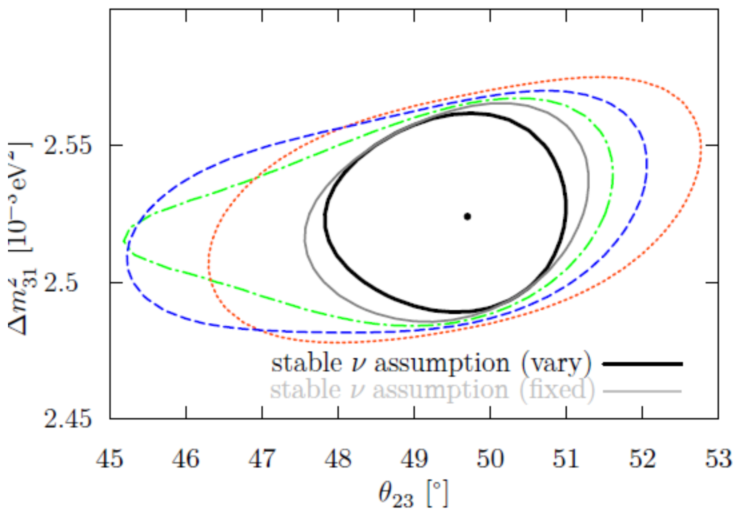


- The true value gets smaller, the constraint becomes tighter, especially the upper bound.
- When τ_3/m_3 is larger enough, the spectra behave the same as those for the stable neutrino.

Precision measurements w/o neutrino decays







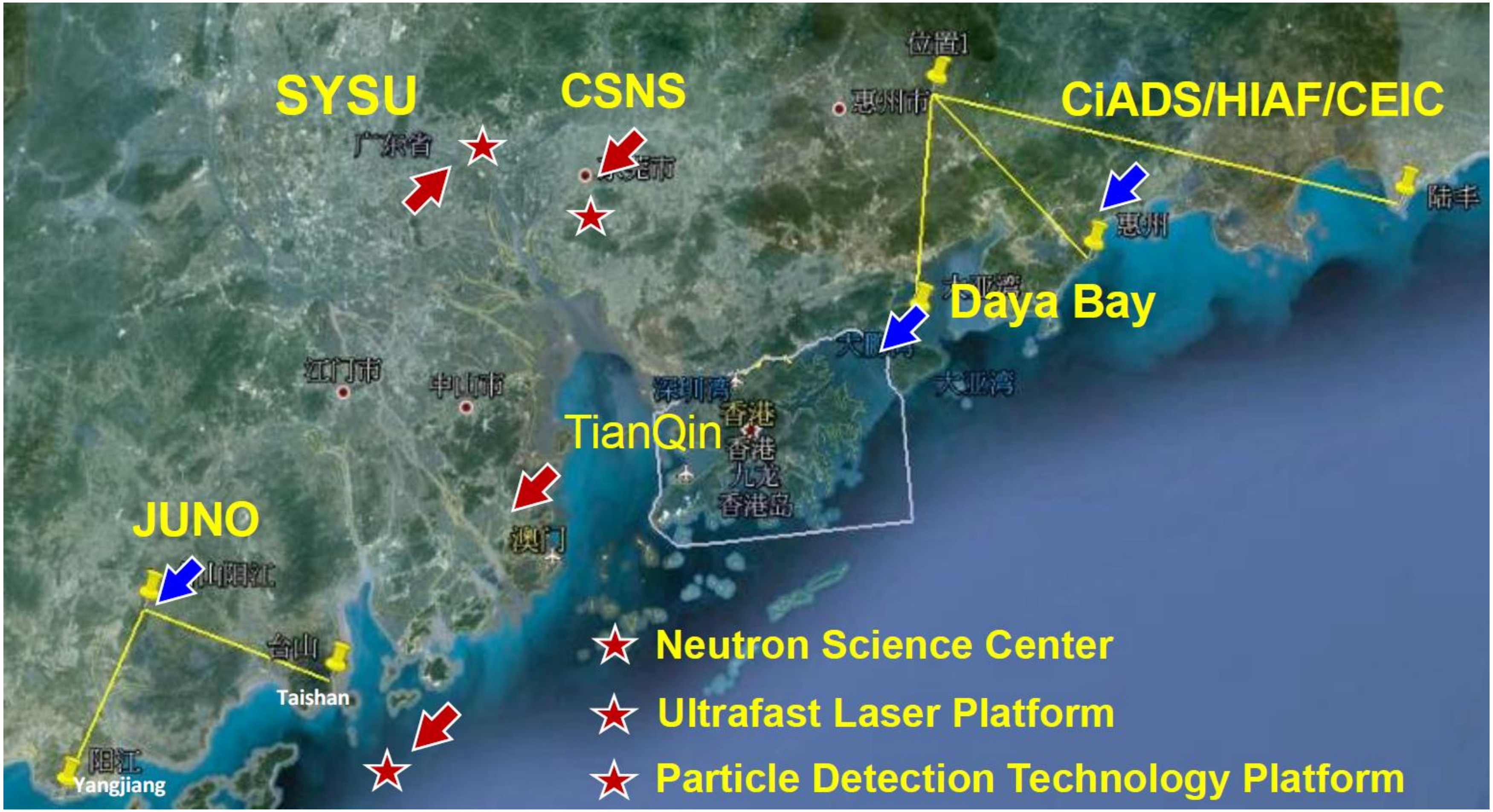
- Sizable changes on precision measurement of θ_{23}
- Little impact on Δm^2_{31}

Table of contents

Summary

- Push forward muon and neutrino physics based on accelerator muon beams in China.
- EMuS to be built at CSNS as the first demonstration towards MOMENT.
- CDR of the EMuS passed the international review.
- Detector of MOMENT not fixed yet. Benchmark: Gd-WC.
- Lots of physics to be done with accelerator neutrinos: neutrino invisible decays as an example…
- Welcome new ideas in muon and neutrino physics…
- Still dream of neutrino factory…

PostDoc advertisement in SYSU



Postdoc openings in our group: **~2K euros/month + bonus + on-campus housing + Postdoc funding** supported by local province**.**

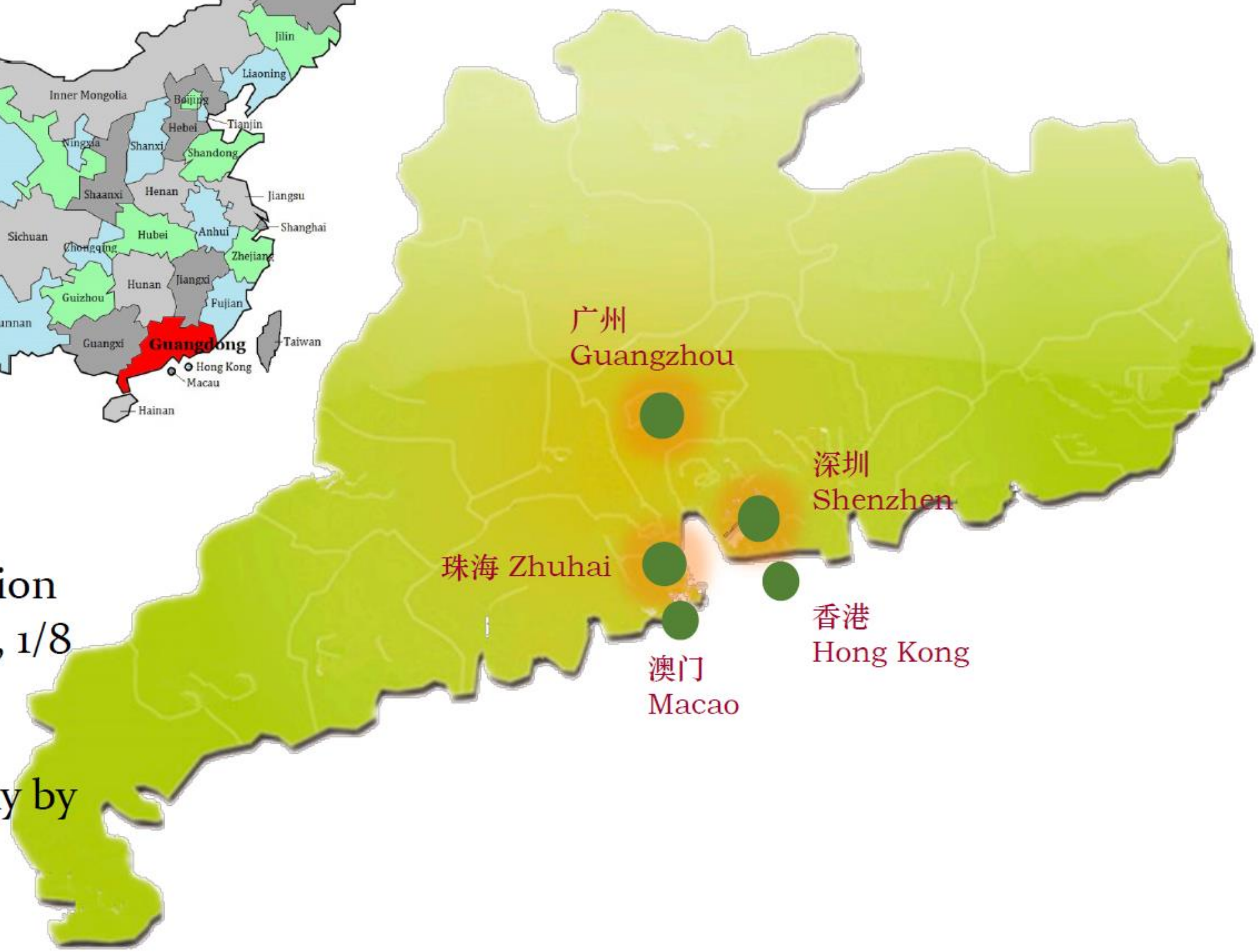
Email: tangjian5@mail.sysu.edu.cn

Sun Yat-sen University

中山大學
SUN YAT-SEN UNIVERSITY

- A leading comprehensive research university in China
- Founded in 1924 by Dr. Sun Yat-sen
- 19 disciplines ranked in the top 1% in the world, second most in China (ESI, 2018)
- 11 "Double First" disciplines
- Top 10 university in China

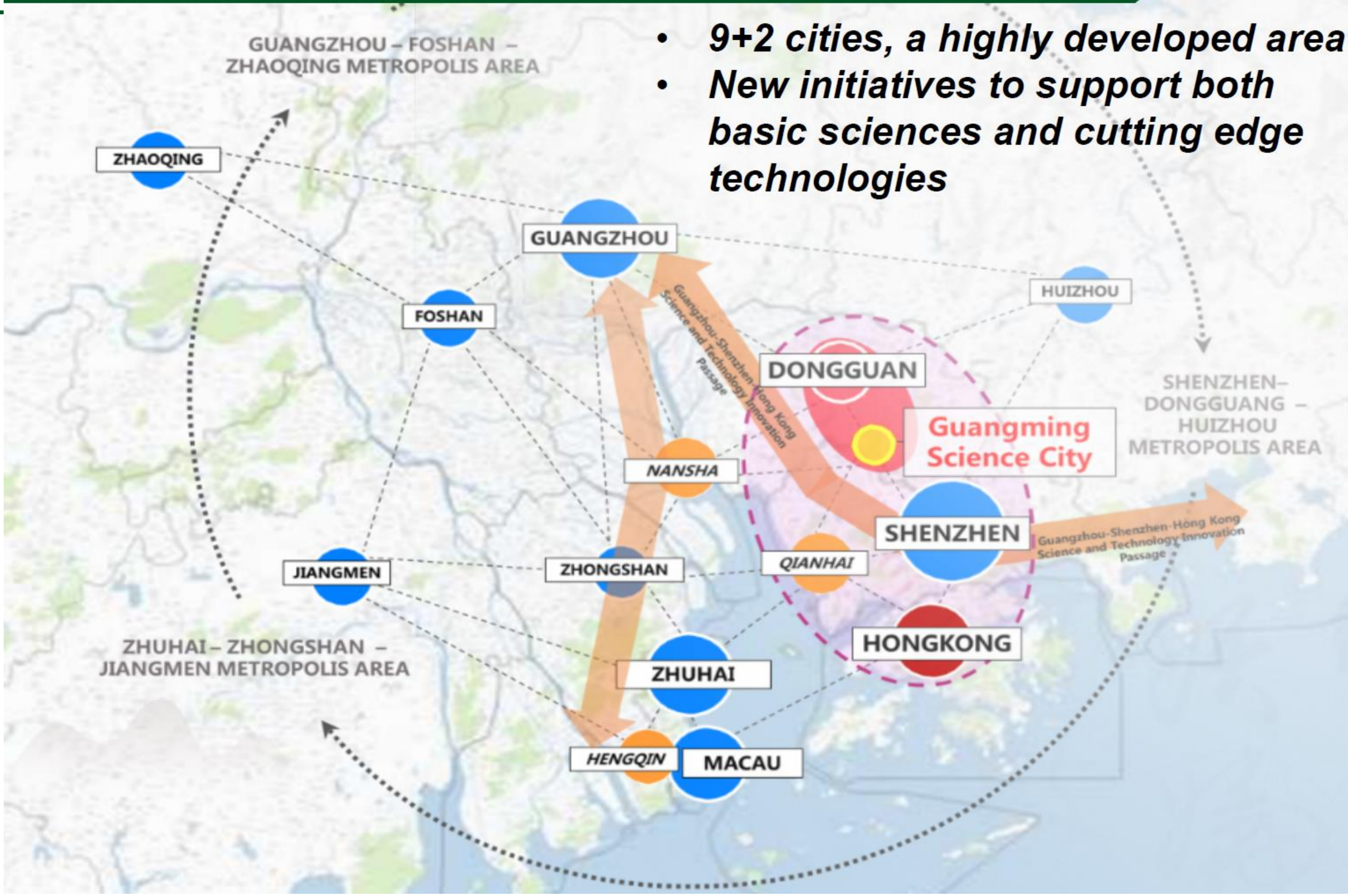
Guangdong-Hong Kong-Macao Greater Bay Area



- Population: ~100M
- GDP: RMB 11.7 trillion ($1.83 trillion) in 2017, 1/8 of national total
- Largest bay economy by 2020

The Greater Bay Area and the Guangming Science City

- ***9+2 cities, a highly developed area***
- ***New initiatives to support both basic sciences and cutting edge technologies***



THANK YOU