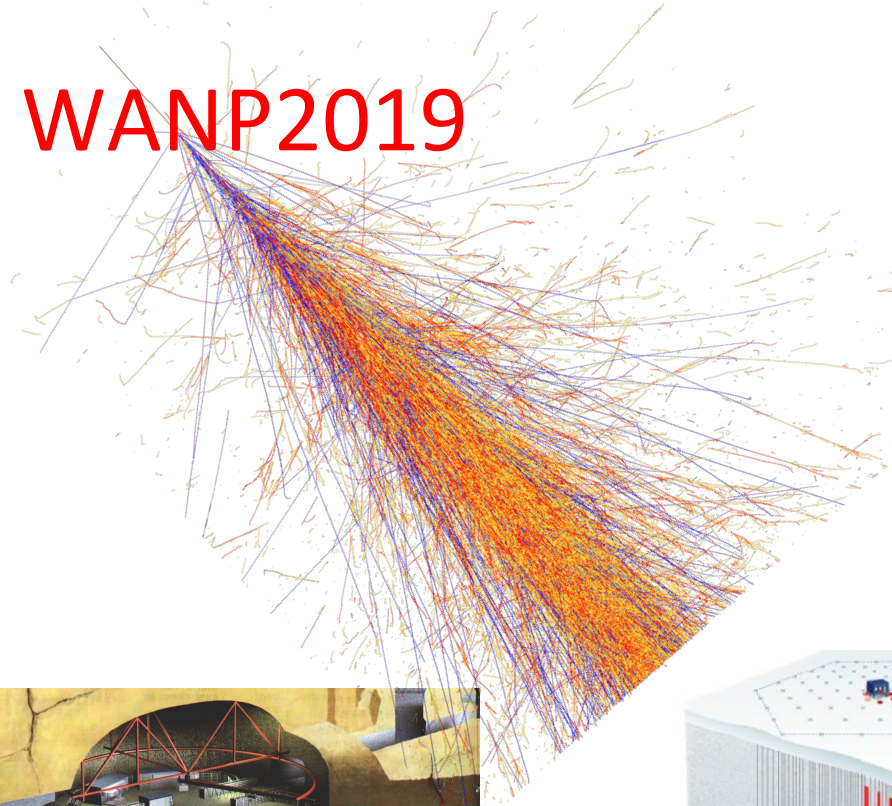
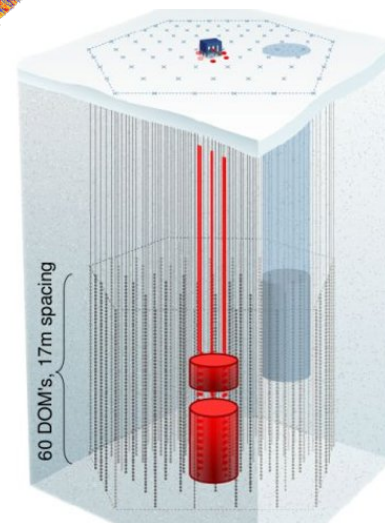
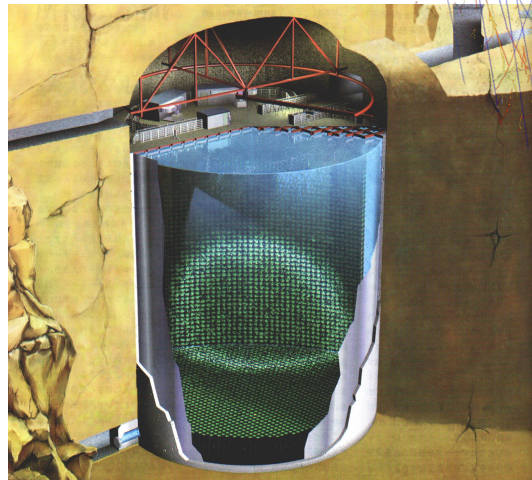


Workshop for Atmospheric  
Neutrino Production 2019  
"Opening and Goal of the meeting"

Yoshitaka Itow  
ISEE/KMI Nagoya University

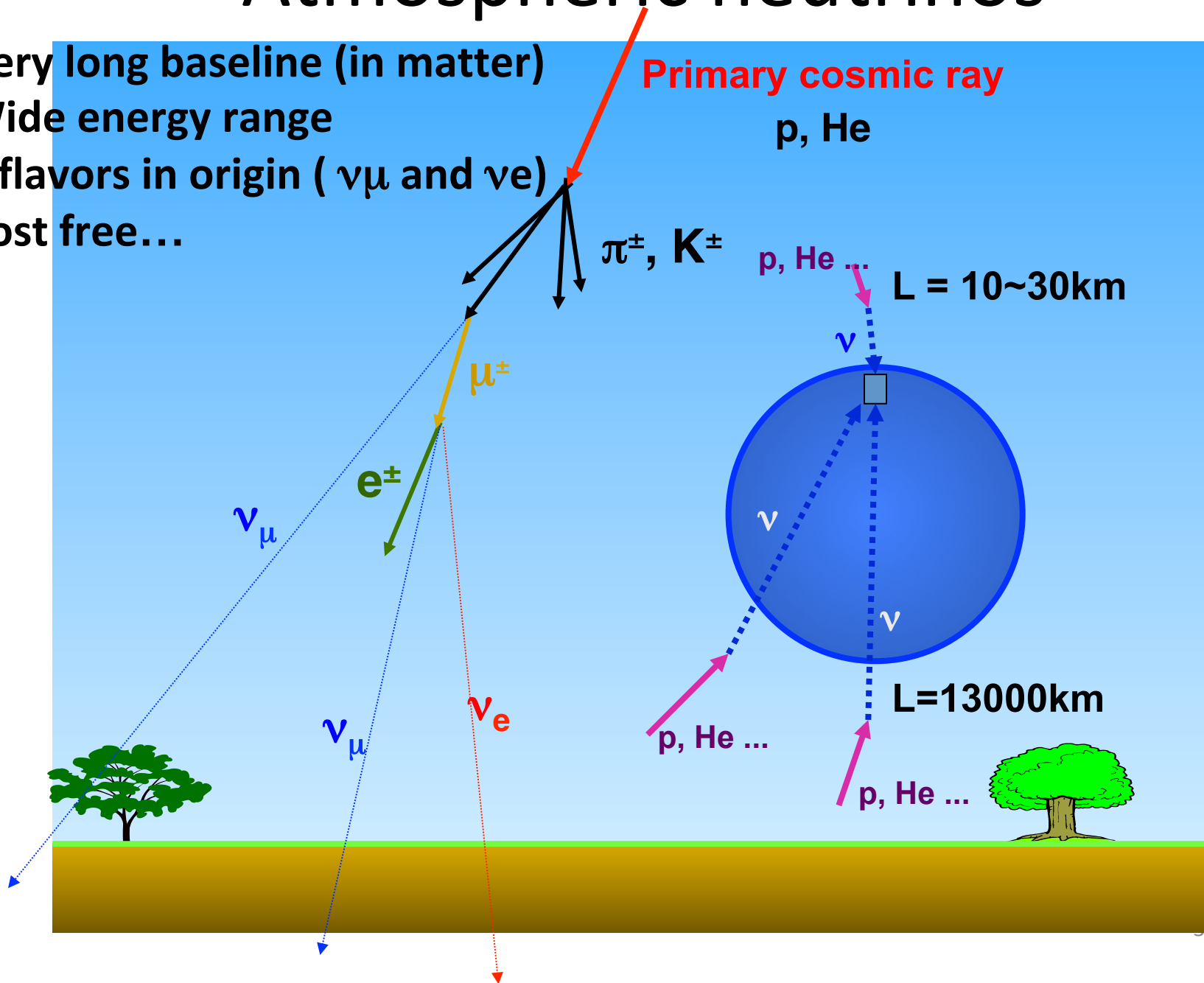
# Encounter of Neutrinos and Air-showers

WANP2019



# Atmospheric neutrinos

- Very long baseline (in matter)
- Wide energy range
- 2 flavors in origin ( $\nu_\mu$  and  $\nu_e$ )
- Cost free...



# $\nu_e$ appearance in 3-flavor atmospheric $\nu$ oscillations

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{-i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$$\begin{aligned} \frac{\Phi(\nu_e)}{\Phi_0(\nu_e)} - 1 &\approx P_2 \cdot (r \cdot \cos^2 \theta_{23} - 1) \\ &\quad - r \cdot \sin \tilde{\theta}_{13} \cdot \cos^2 \tilde{\theta}_{13} \cdot \sin 2\theta_{23} \cdot (\cos \delta \cdot R_2 - \sin \delta \cdot I_2) \\ &\quad + 2 \sin^2 \tilde{\theta}_{13} \cdot (r \cdot \sin^2 \theta_{23} - 1) \end{aligned}$$

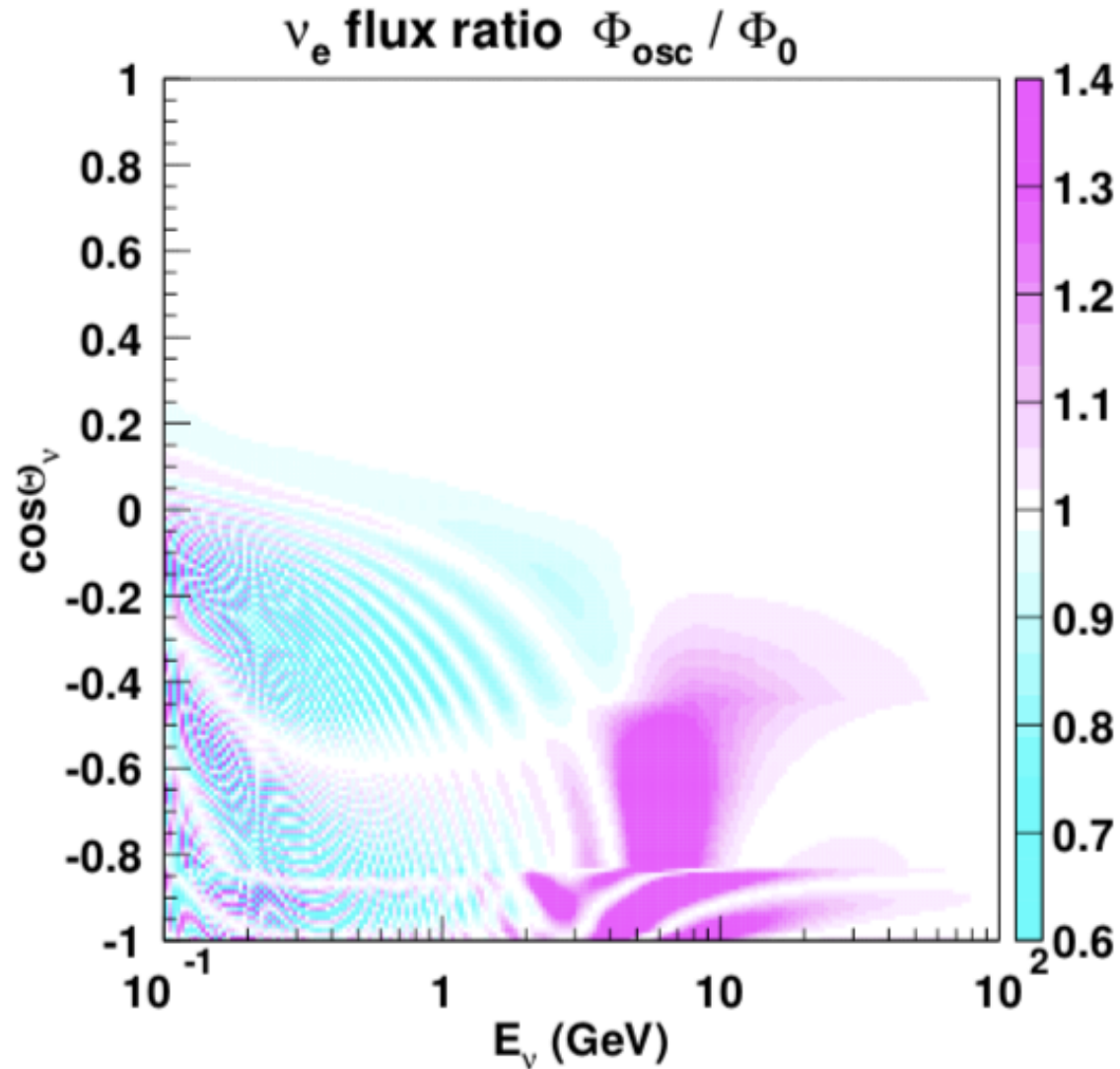
$P_2$ : 2-flavor  $\nu$ -oscillation probability (w/  $\theta_{23}$ )

$\theta_{13}$ : 1-3 mixing angle in matter

$R_2$  ( $I_2$ ); CP-even (CP-odd) amplitude

$r$ :  $\nu_\mu/\nu_e$  ratio  $\sim 2$  @  $\sim 1$  GeV,  $\sim 3$  @  $\sim 10$  GeV

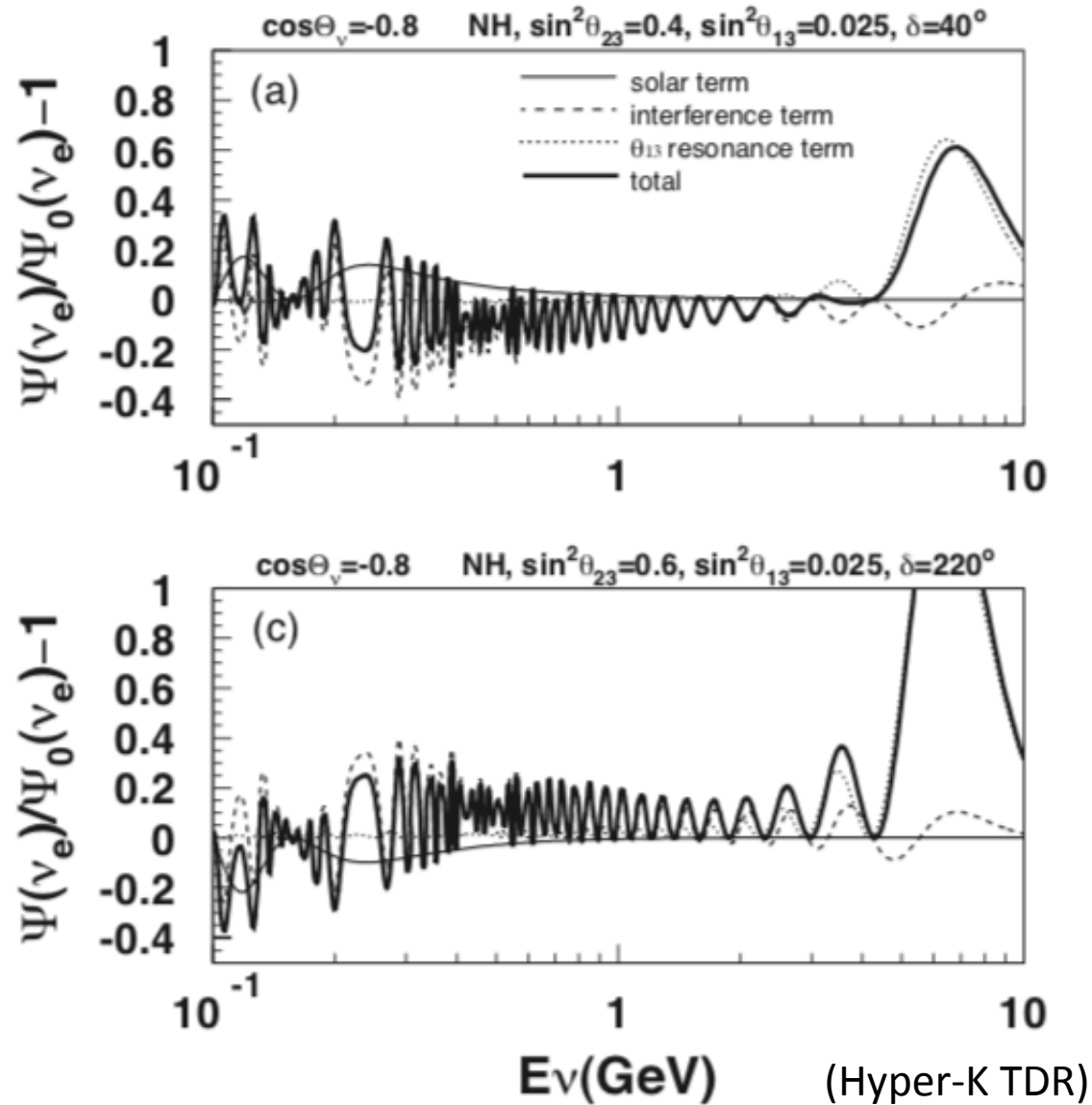
# 3-flavor neutrino oscillogram (Normal Hierarchy vs Inverted Hierachy)



ROI: 0.1 – 20 GeV

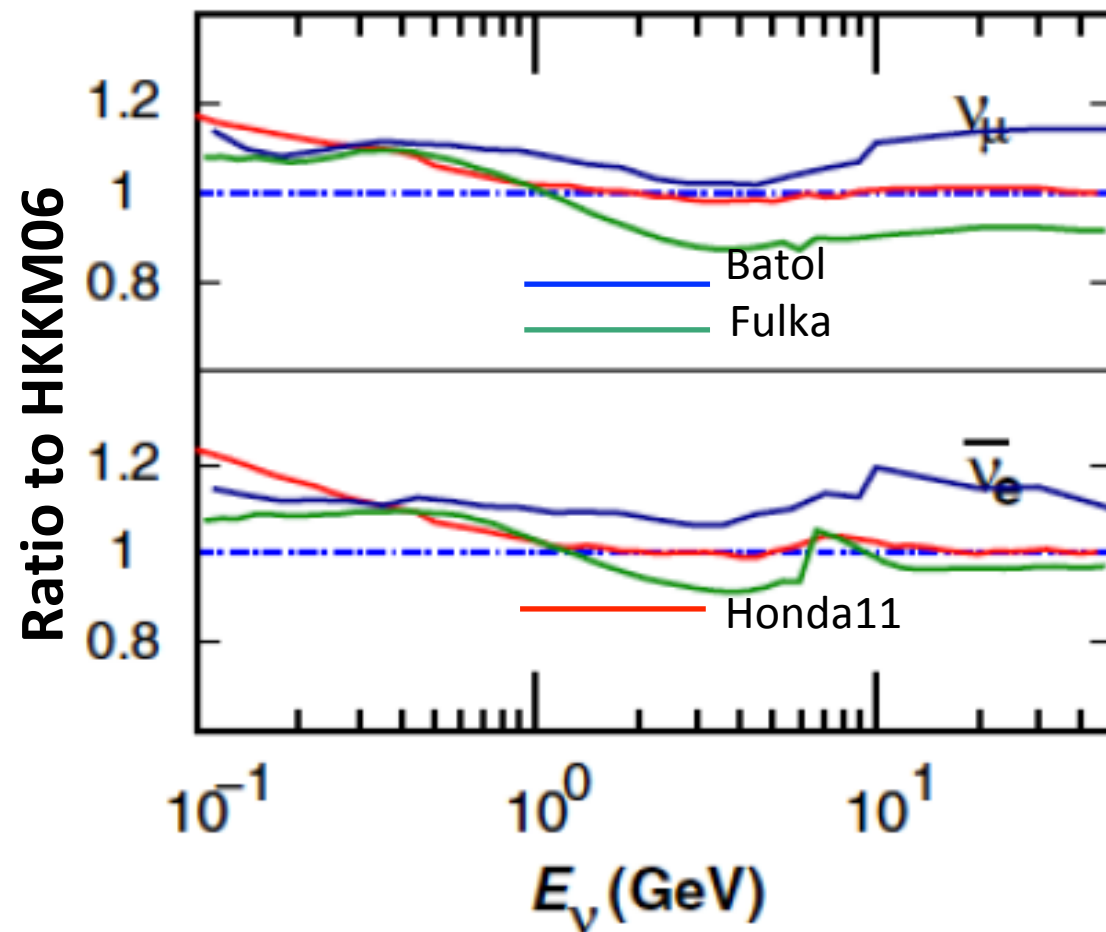
(Lee Kai Pik , PhD thesis 2012)

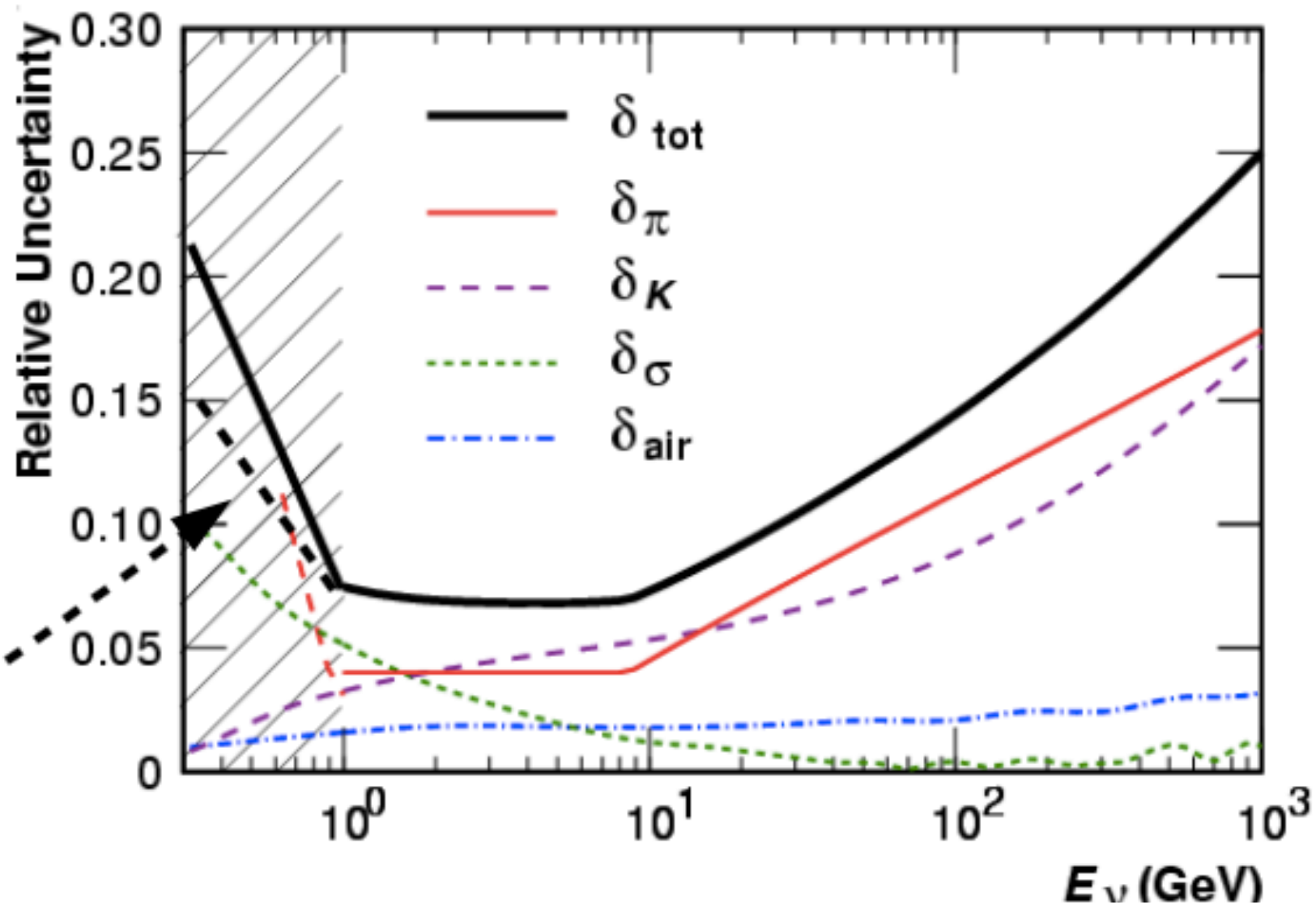
# Precise $\nu$ oscillation in future large $\nu$ detectors



# Atmospheric $\nu$ flux modeling

M. Honda et al.,  
PHYSICAL REVIEW D 83, 123001 (2011)









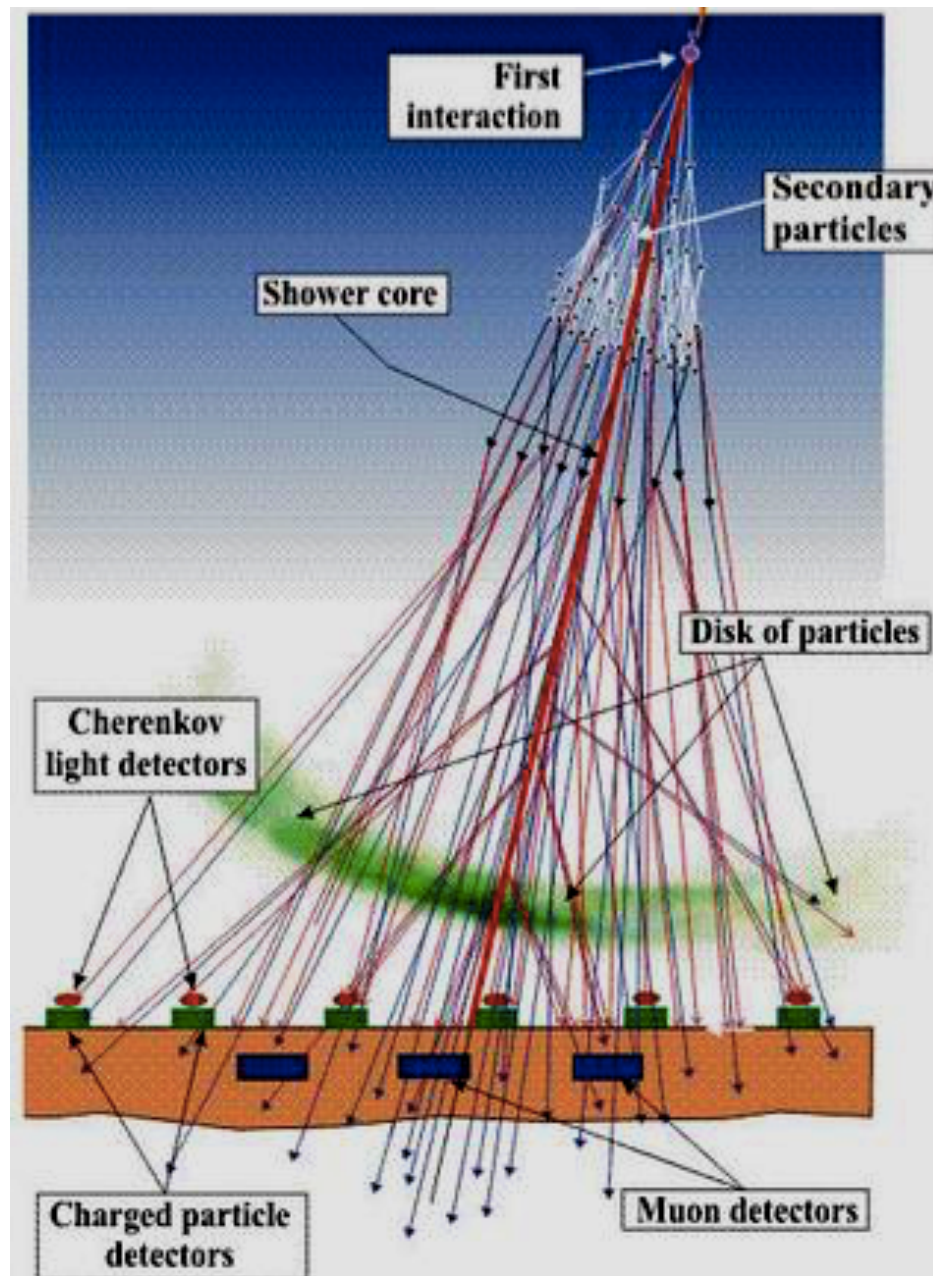
## **RCCN International Workshop**

sub-dominant oscillation effects  
in atmospheric neutrino experiments

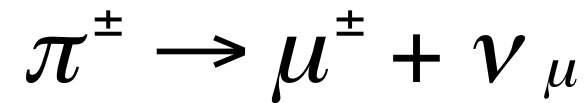
9-11 December 2004, Kashiwa Japan

December 9				
9:00	9:30	Registration		
9:30	9:40	Welcome and the goal of this meeting	T. Kajita (ICRR)	<a href="#">ppt</a>
9:40	10:30	Sub-dominant oscillation effects in atmospheric neutrinos	M. C. Gonzalez-Garcia (CERN/SUNY/Valencia)	<a href="#">pdf</a>
10:30	11:05	Three-flavor subleading effects and systematic uncertainties in Super-Kamiokande	E. Lisi (Bari)	<a href="#">pdf</a>
coffee				
11:30	11:55	Constraint on theta13 from the atmospheric neutrino data from Super-Kamiokande	K. Okumura (ICRR)	<a href="#">ppt</a>
11:55	12:35	Effect of the solar terms to the theta23 determination in Super-Kamiokande and important systematic error for future improvements	S. Nakayama (ICRR)	<a href="#">ppt</a>
lunch				
14:00	14:30	Future possibilities	M. Shiozawa (ICRR)	<a href="#">ppt</a>
Input data to the neutrino flux calculation				
14:30	15:00	Primary cosmic ray fluxes at various solar activities	Y. Shikaze (JAERI)	<a href="#">ppt</a>
15:00	15:30	Atmospheric muon fluxes at various locations	T. Sanuki (Tokyo)	<a href="#">pdf</a>
15:30	16:00	Hadron production experiments	G. Barr (Oxford)	<a href="#">ppt</a>
coffee				
Methods and technique used in the flux calculations around 1GeV (Hadron models, details of the 3D calculation methods, mountain effects, effect of atmosphere .... )				
16:30	17:00	Flux calculation in HKKM	M. Honda (ICRR)	<a href="#">pdf</a>
17:00	17:30	Flux calculation in Bartol	G. Barr (Oxford)	<a href="#">ppt</a>
19:00	21:00	Banquet		
December 10				
Flux calculation results, and the estimated systematic errors in the mu/e, nu/nu-bar, up/down, vertical/horizontal ratios.				
9:30	10:05	Flux calculation results and the systematic errors in HKKM	M. Honda (ICRR)	<a href="#">pdf</a>
10:05	10:40	Flux calculation results and the systematic errors in Bartol	G. Barr (Oxford)	<a href="#">ppt</a>
coffee				
11:10	11:40	Discussion on flux calculation improvements	P. Lipari (Rome)	<a href="#">pdf</a>
lunch				
12:30	14:00	NUFIT neutrino interaction code used in Super-Kamiokande and K2K	T. Kajita (ICRR)	<a href="#">ppt</a>

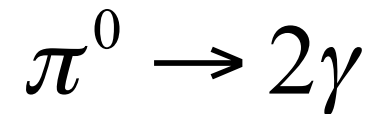
# Air showers vs Atmospheric $\nu$



Leptonic component<sup>(-)</sup>



EM component (>90%)

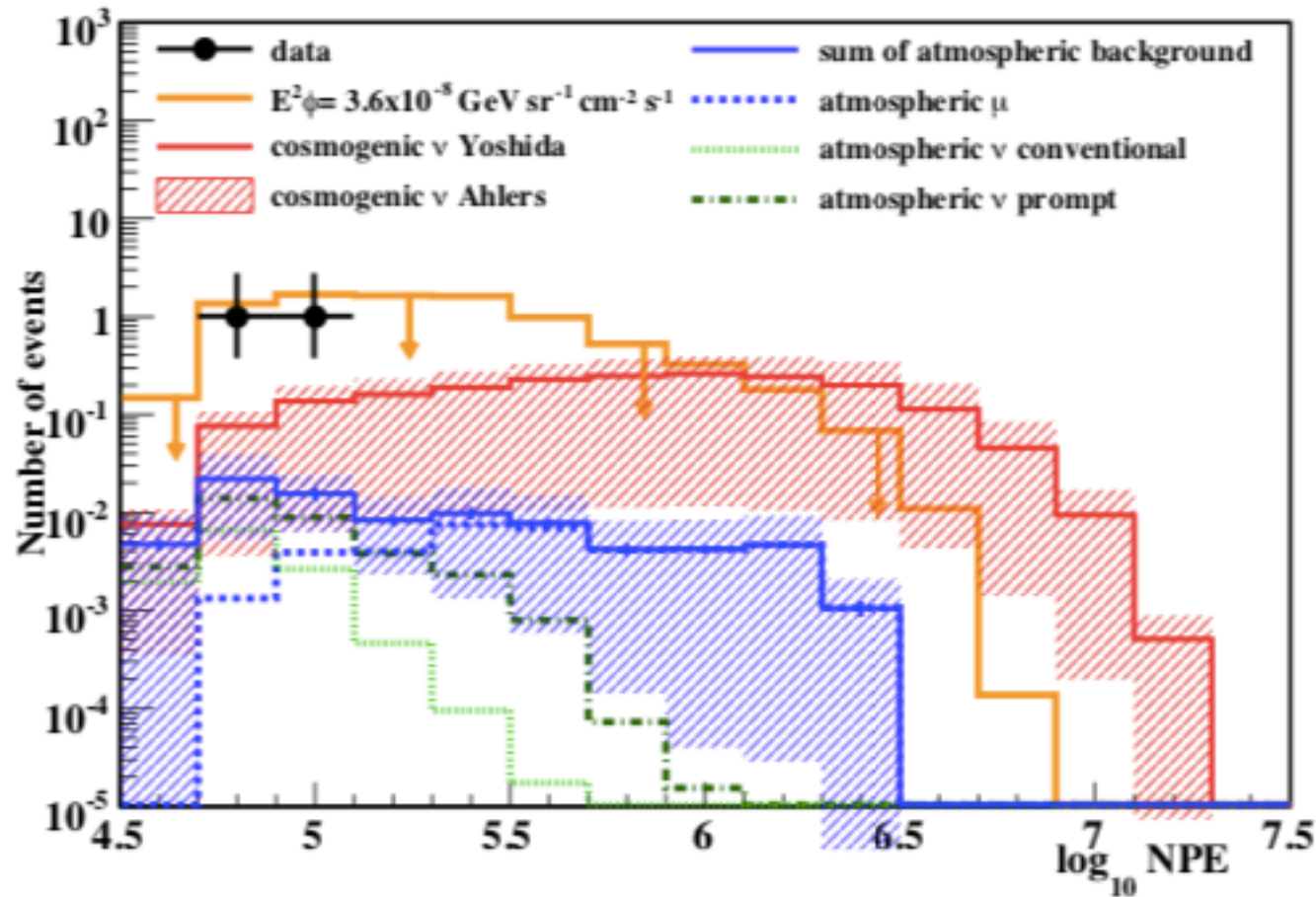


Atmospheric charm production

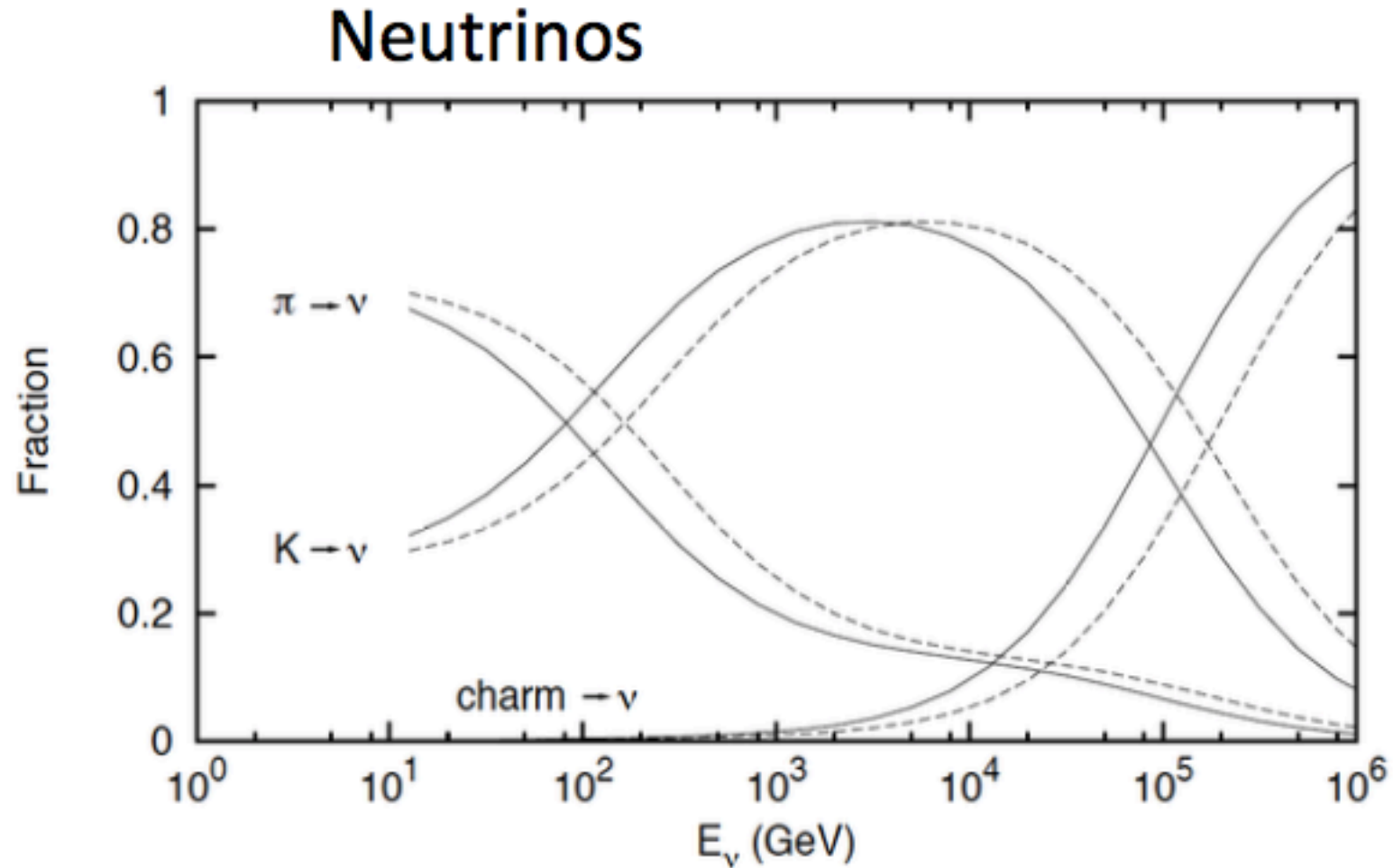
prompt  $\nu, \mu$

# Cosmic- $\nu$ , atm prompt- $\nu$ , non-standard interactions

IceCube

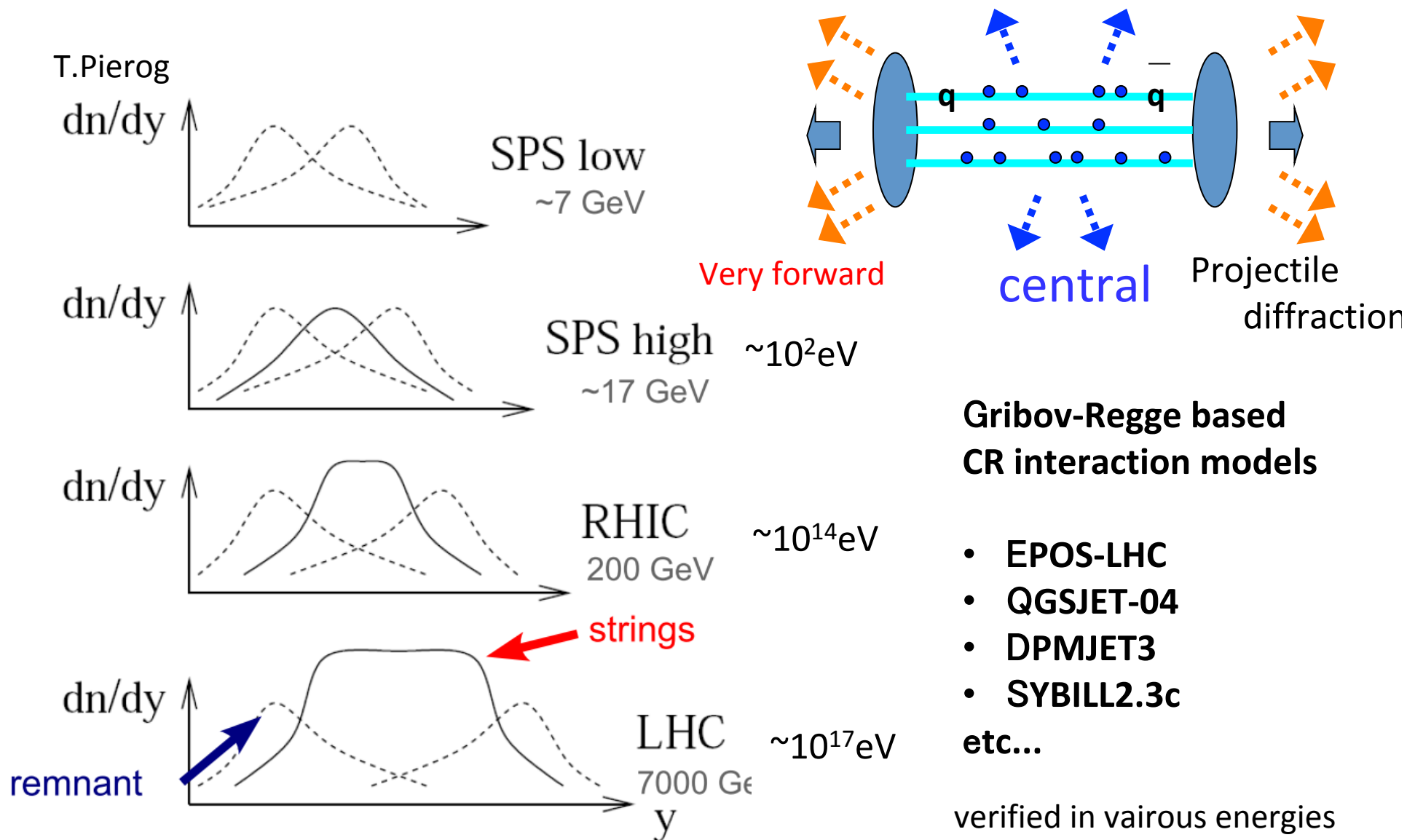


# High energy atmospheric component

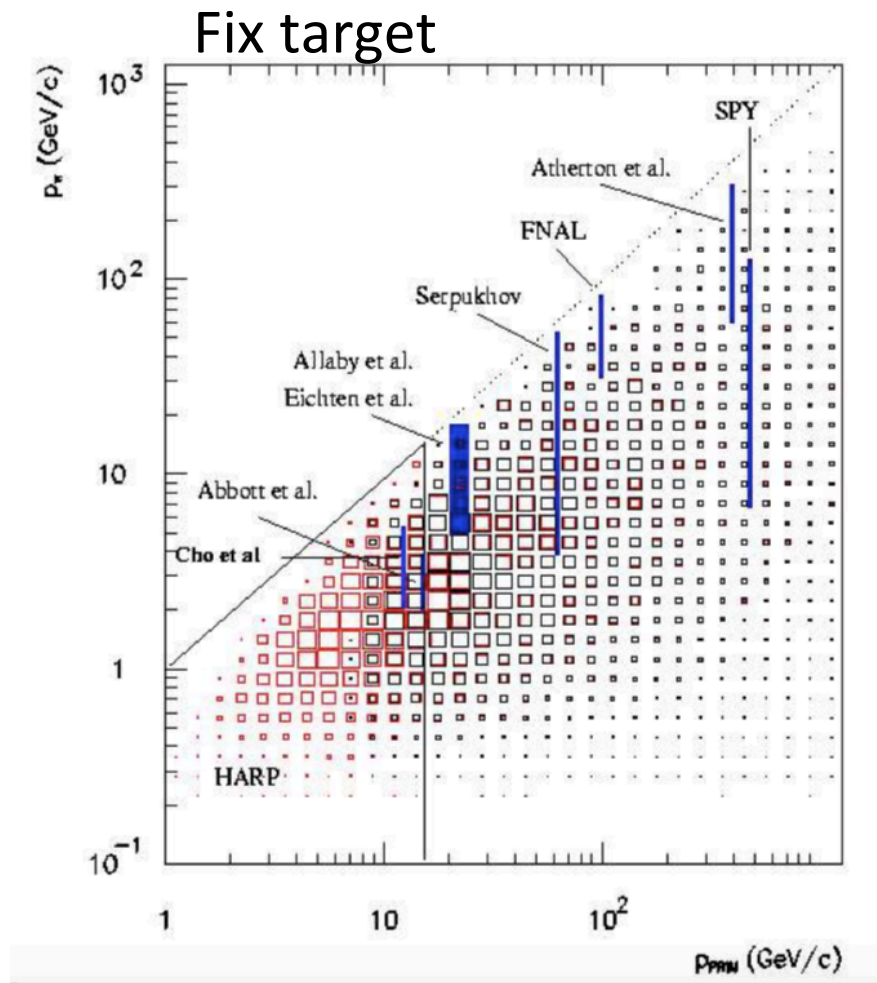


T.Gaisser,  
ISVHECRI2014

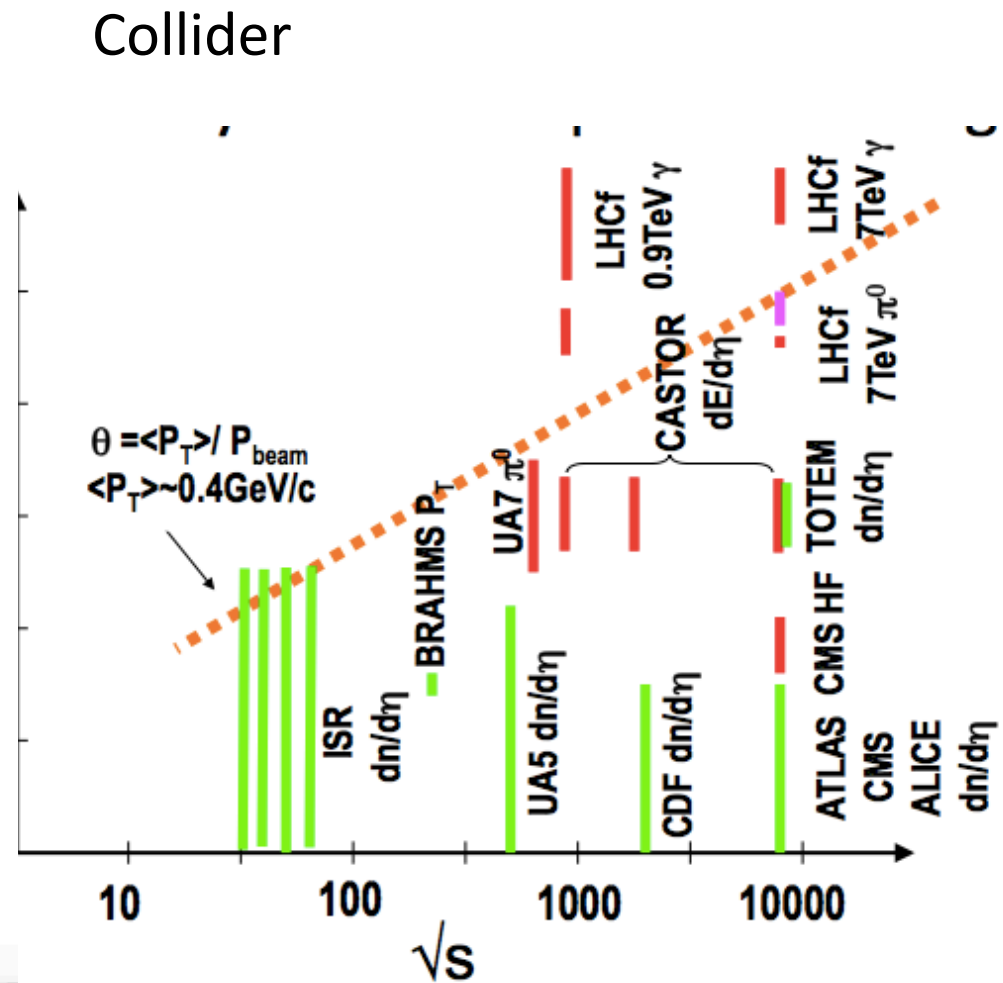
# CR interactions & particle productions



# New inputs (accelerator experiments)



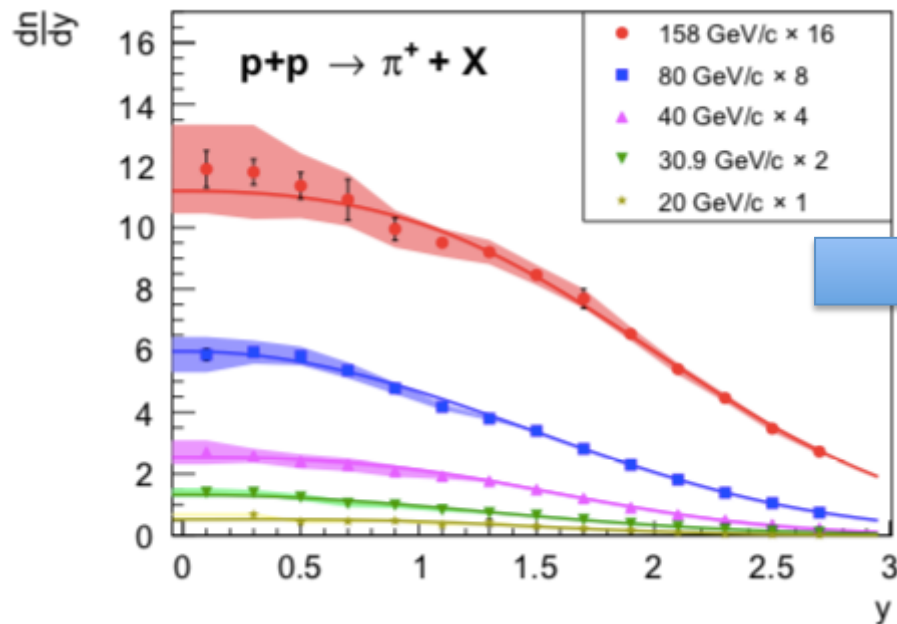
(Honda, RCCN workshop 2004)



(Itow, ISVHECRI2014)

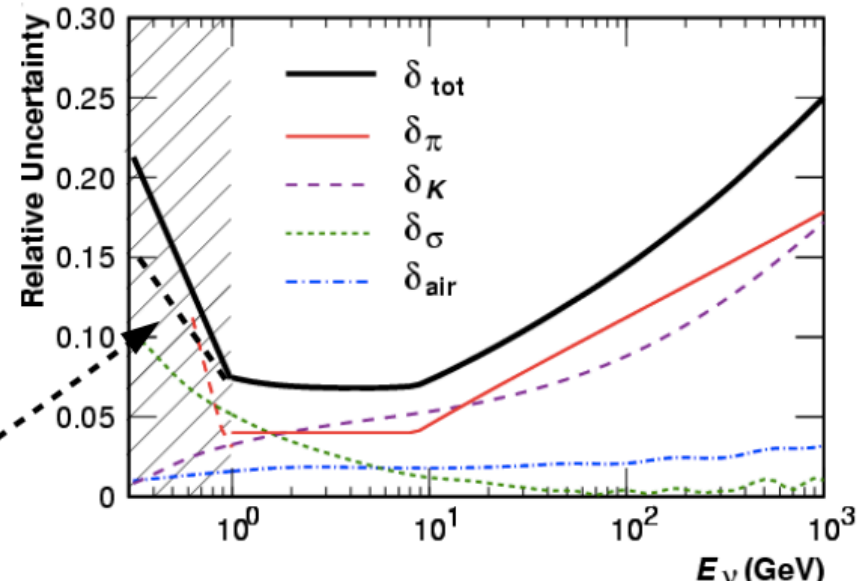
# Common treatment of hadron systematic errors in the analysis

Accelerator data systematics (NA61)



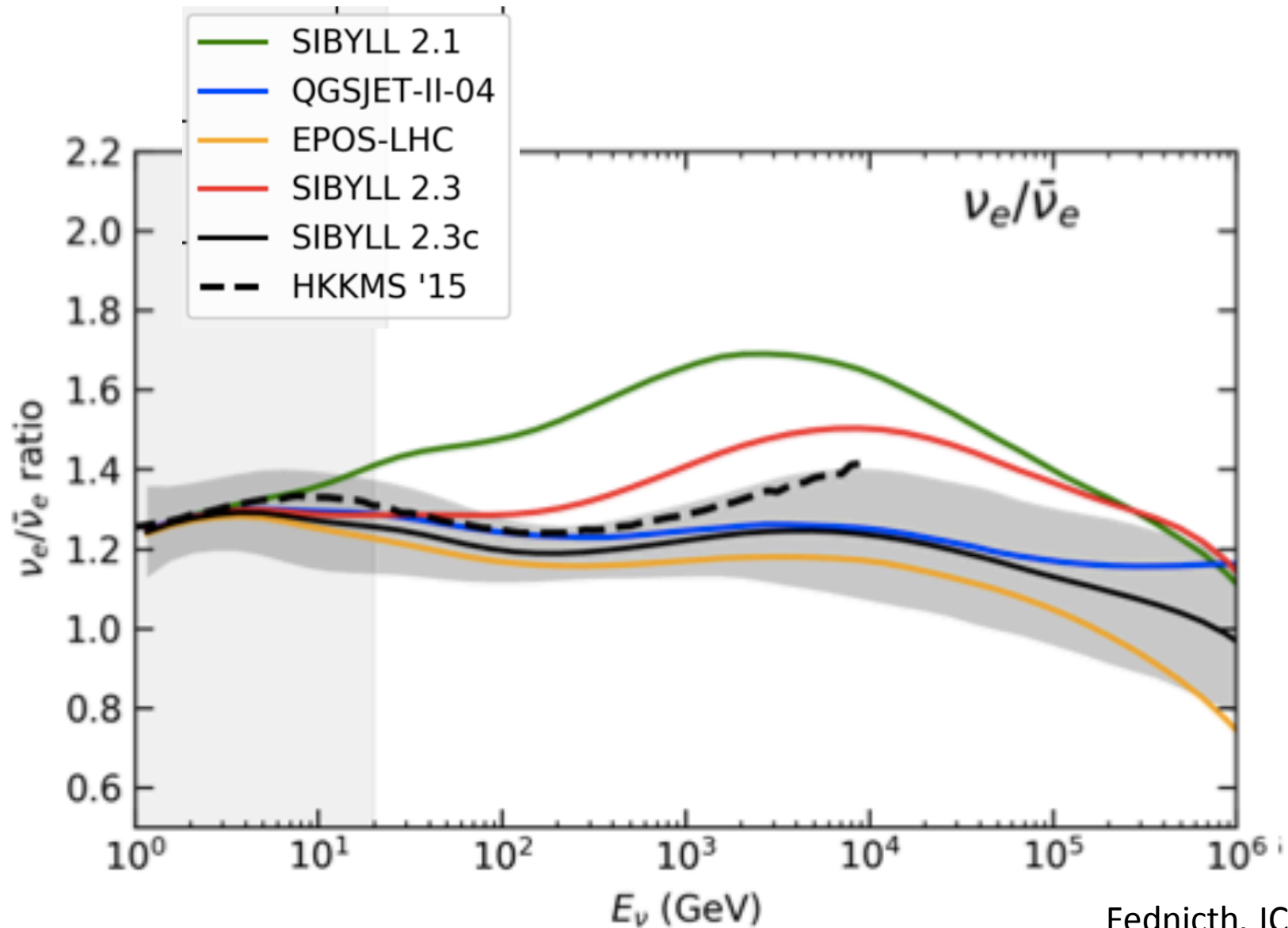
[Eur. Phys. J. C 77 \(2017\) 671](#)

$\nu$ -flux modeling errors





# Common picture in all the energy range



# Goal of meeting

- Put 2 communities ( $\nu$  & AS) together to share the knowledge, demand, and future
  - How much precision needed/possible ?
- Update state-of-art neutrino flux codes with the newest and common knowledge and framework
  - Honda flux, Bartol flux, and newest air shower MC.
- Provide common treatment of  $\nu$ -production systematics in LBLE/atm combined-analysis
  - i.e. T2K-SK combined oscillation analysis
- Brain-storming for what's new measurements
  - Accelerator / ground CR / airbourne CR
- Discuss to form a real-working group

# This meeting organization

	Mar 20 (Wed)	Mar 21 (Thu)	Mar 22 (Fri)
AM		Atm- $\nu$ flux modeling	CR measurements
		Atm- $\nu$ flux modeling	Accelerator measurements
PM	Intorduction & motivation	Air shower modeling	Future/brainstorming
	KMI colloquium	hadon interaction models	
Evening	Dinner		

# Enjoy Nagoya, have a fruitful discission !



Some logistics from LOC

# Welcome to Nagoya University !

~ From LOC ~

- You can use your laptop or MBA there for presentation
- For speakers, please upload your slide in FUSS server of Nagoya-U (will email to you)
  - <https://nuss.nagoya-u.ac.jp/s/H6eAo2kL5NDW67g>
  - Or please email the location of file to [menjo@isee.nagoya-u.ac.jp](mailto:menjo@isee.nagoya-u.ac.jp)
- No foods and drink in this conference room
  - Coffee break will at the lounge
- Campus is strictly smoking-free.
  - Only allowed at limited smoking area (see map next)

# Smoking area

指定喫煙場所以外は **禁煙**  です。

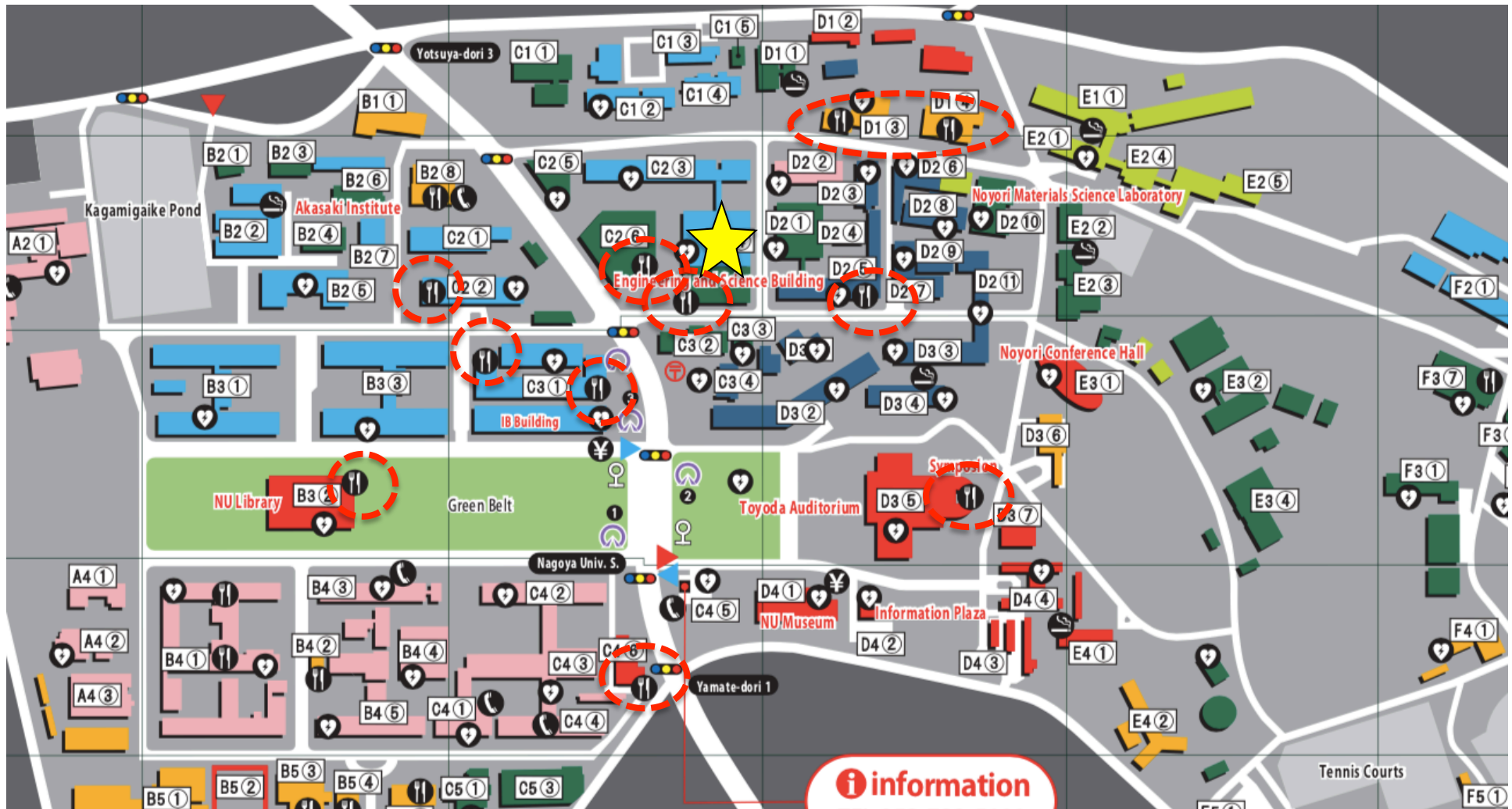
平成 30 年 4 月 1 日現在



- ◎ 指定喫煙場所は、図中 ● に示すとおりです。
- ◎ ● は、**豊田講堂でのイベント開催時のみ**使用可能。  
普段は灰皿等は設置していません。
- ◎ 指定喫煙場所には右図のような看板が設置してあります。
- ◎ 建物内および歩行喫煙は禁止です。
- ◎ 学内外問わず、マナーを守って喫煙してください。



# Lunch place



Tomorrow (March 23<sup>rd</sup>) is holiday. You need to go outside restaurant



# Dinner together

- After KMI colloquium today, dinner together from 19:00
- At "WAN" Motoyama (15min. walking or 1 stop by subway)
- Please inform Menjo or Itow at registration



end