Cosmic Ray shower simulations for KM3NeT

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KM3NeT

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Outline

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Cosmic Rays

https://www.quantamagazine.org/ultrahigh-energy-cosmic-rays-traced-to-hotspot-20150514/

Cosmic Ray (CR) – a highly-energetic particle arriving at Earth from space

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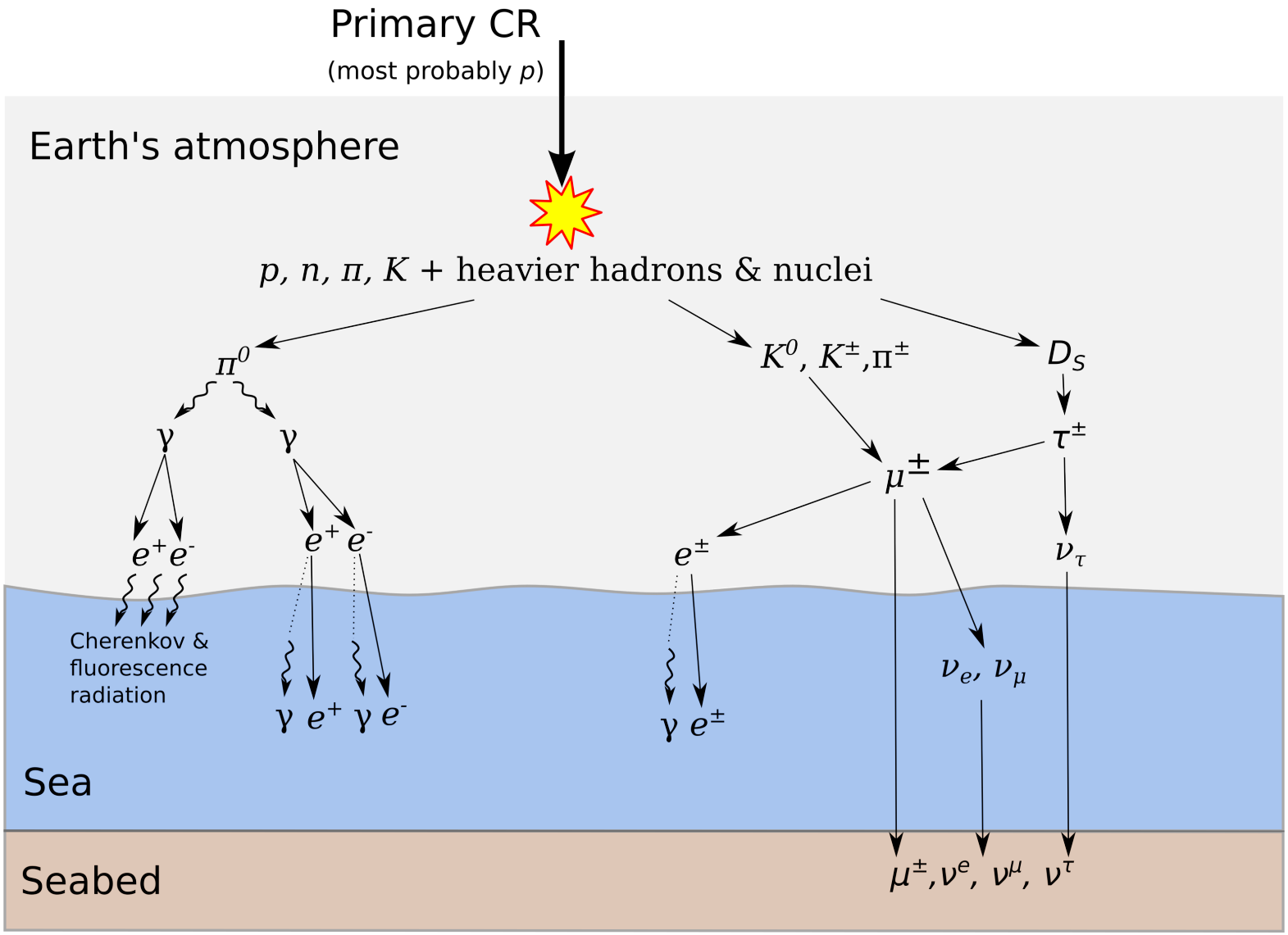
Extensive Air Showers (EAS)



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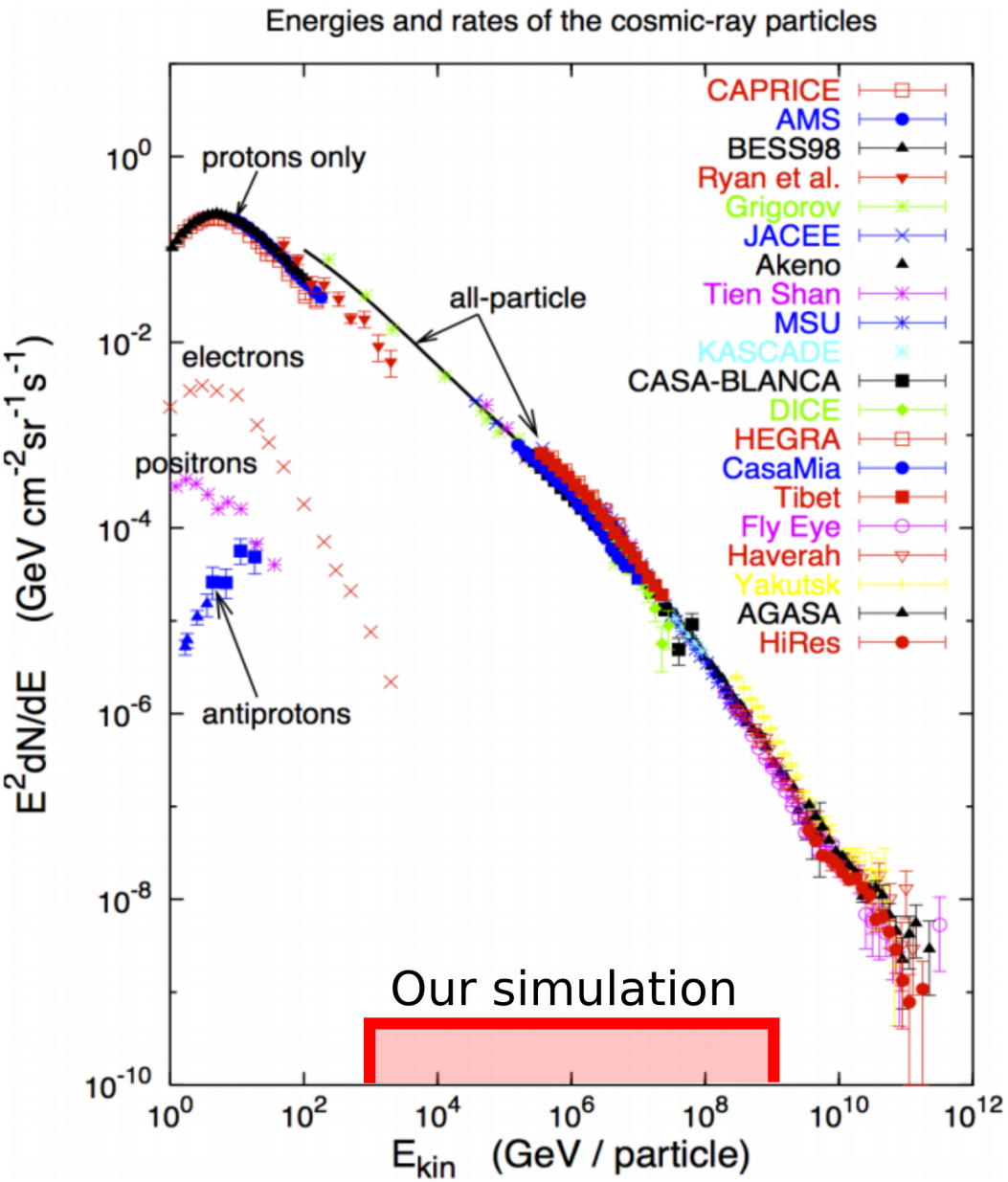
CR primary energy spectrum



$E_{\text{primary}} \longrightarrow$ our simulation input

astro-ph/0607109

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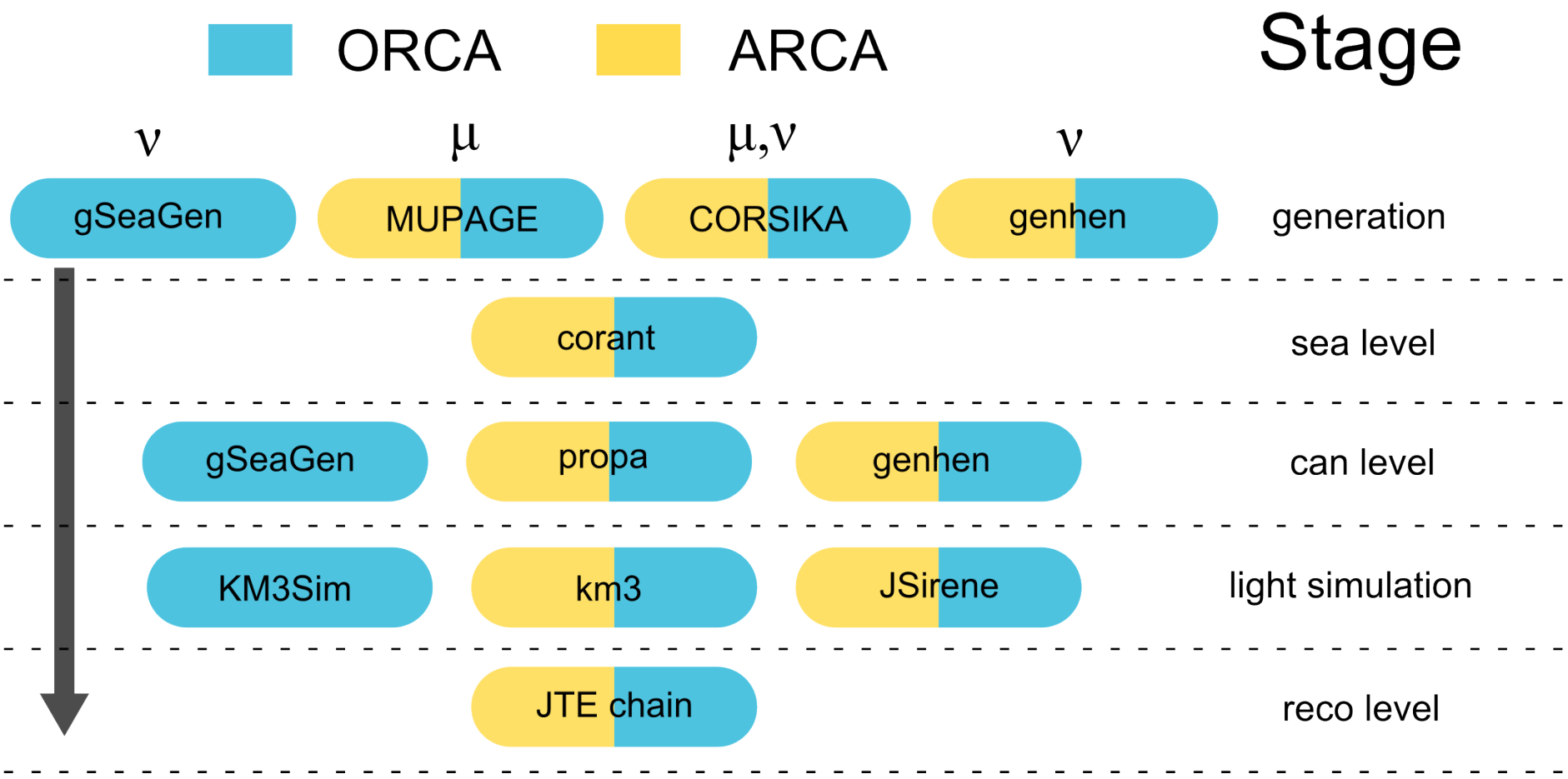
KM3NeT processing chain



can $\Longleftrightarrow$ detector

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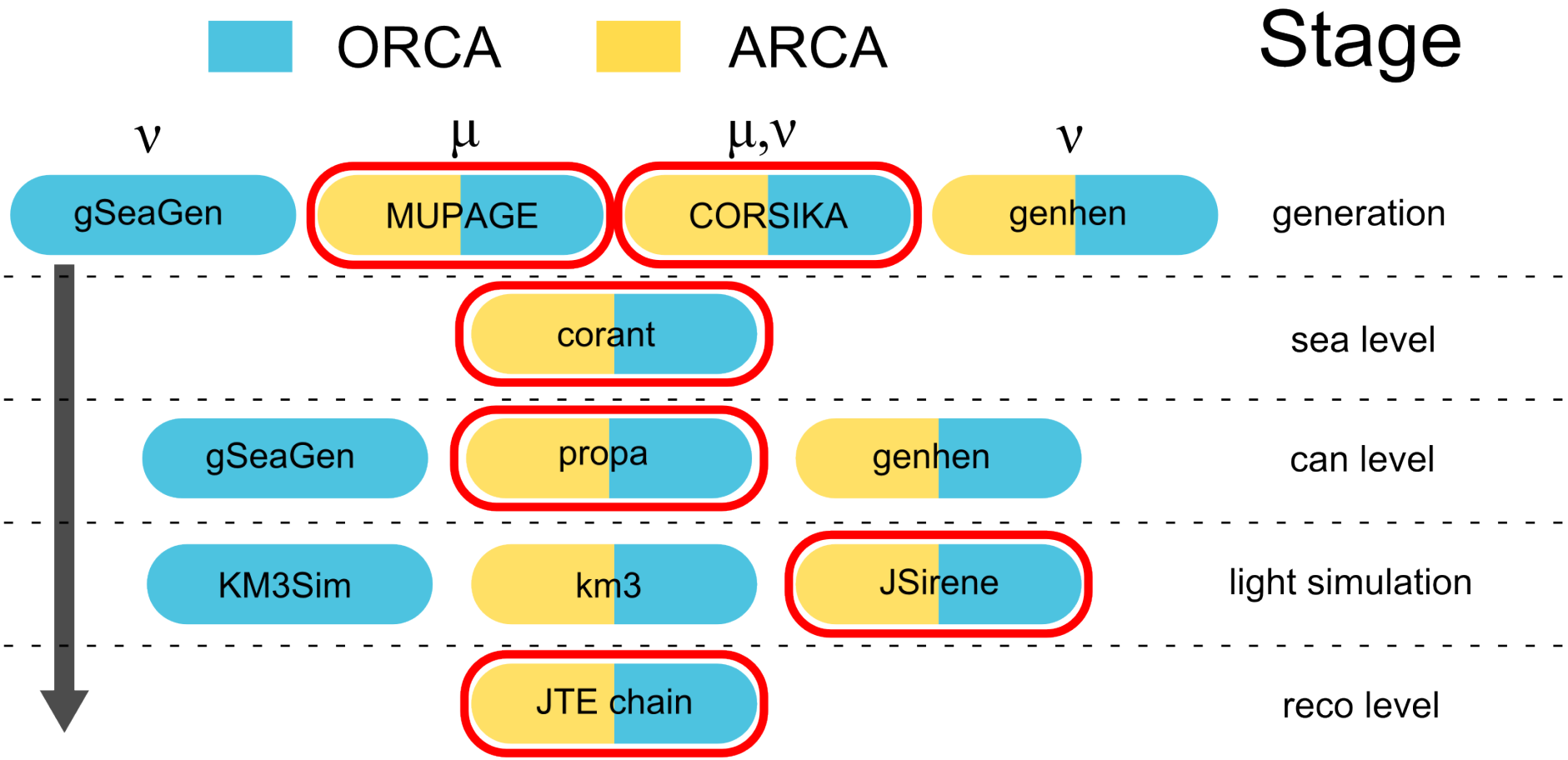
KM3NeT processing chain (our branch)



can $\Longleftrightarrow$ detector data & MC $\rightarrow$ same reconstruction!

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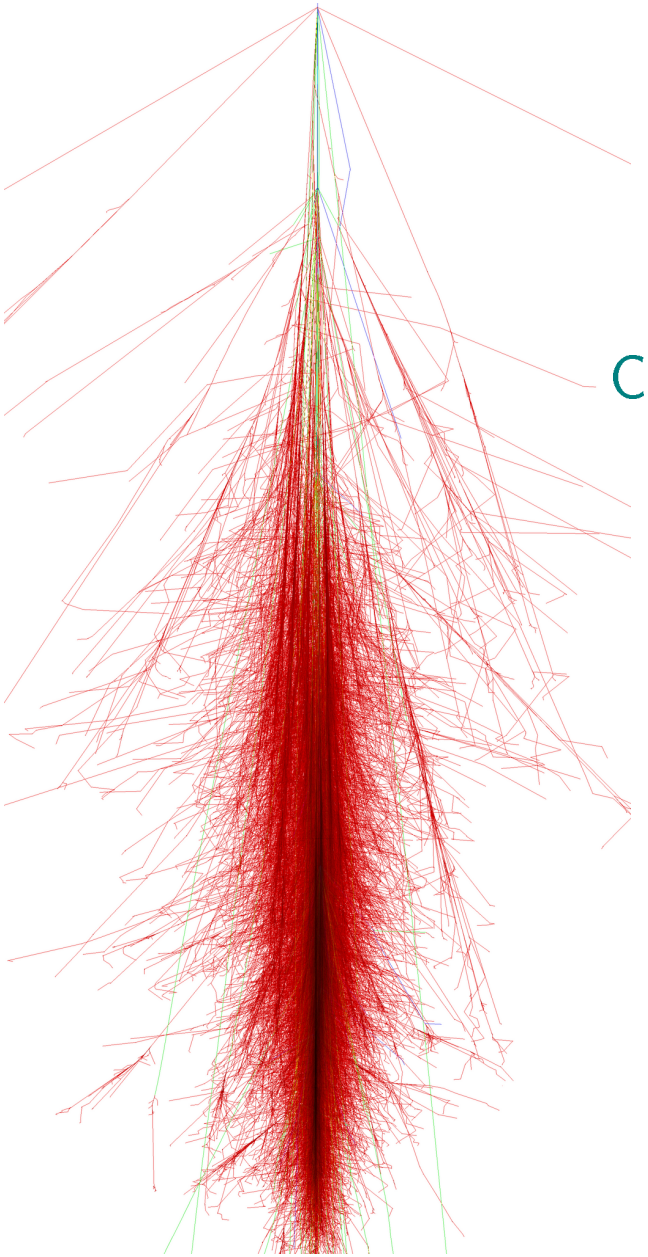
What is CORSIKA?



CORSIKA – COsmic Ray SImulations for KAscade

- developed for KASCADE experiment (Karlsruhe)
- full simulation of air showers
- customizable (models, primaries, etc.)
- we are interested in ν and μ at sea level

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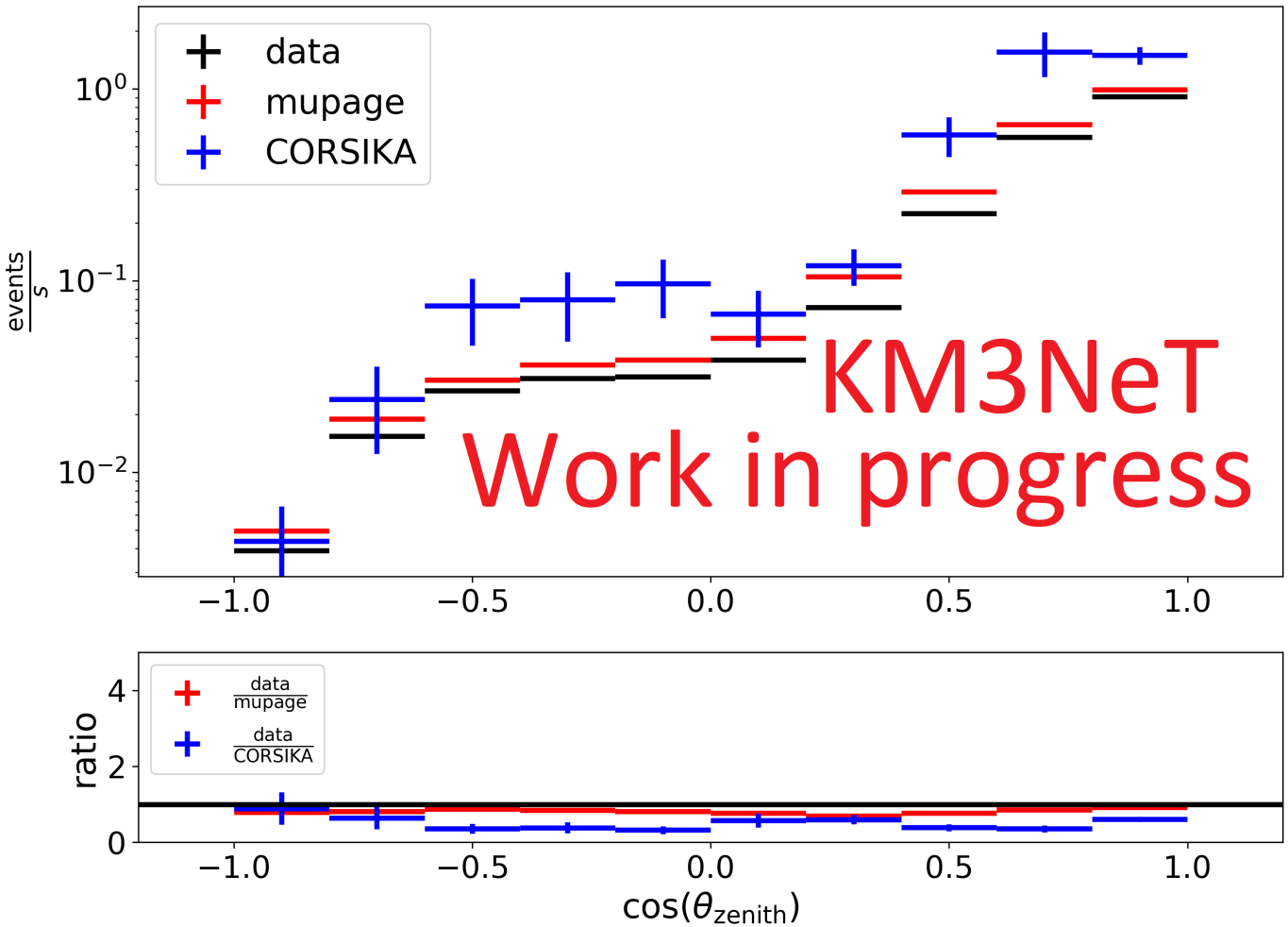
Atmospheric μ spectrum for ORCA1 (Zenith)



detector
ORCA1

generator
CORSIKA
mupage

CORSIKA statistics
173 k

stage
reco level

livetimes: 4.24 d (mupage), 19.62 d (data)

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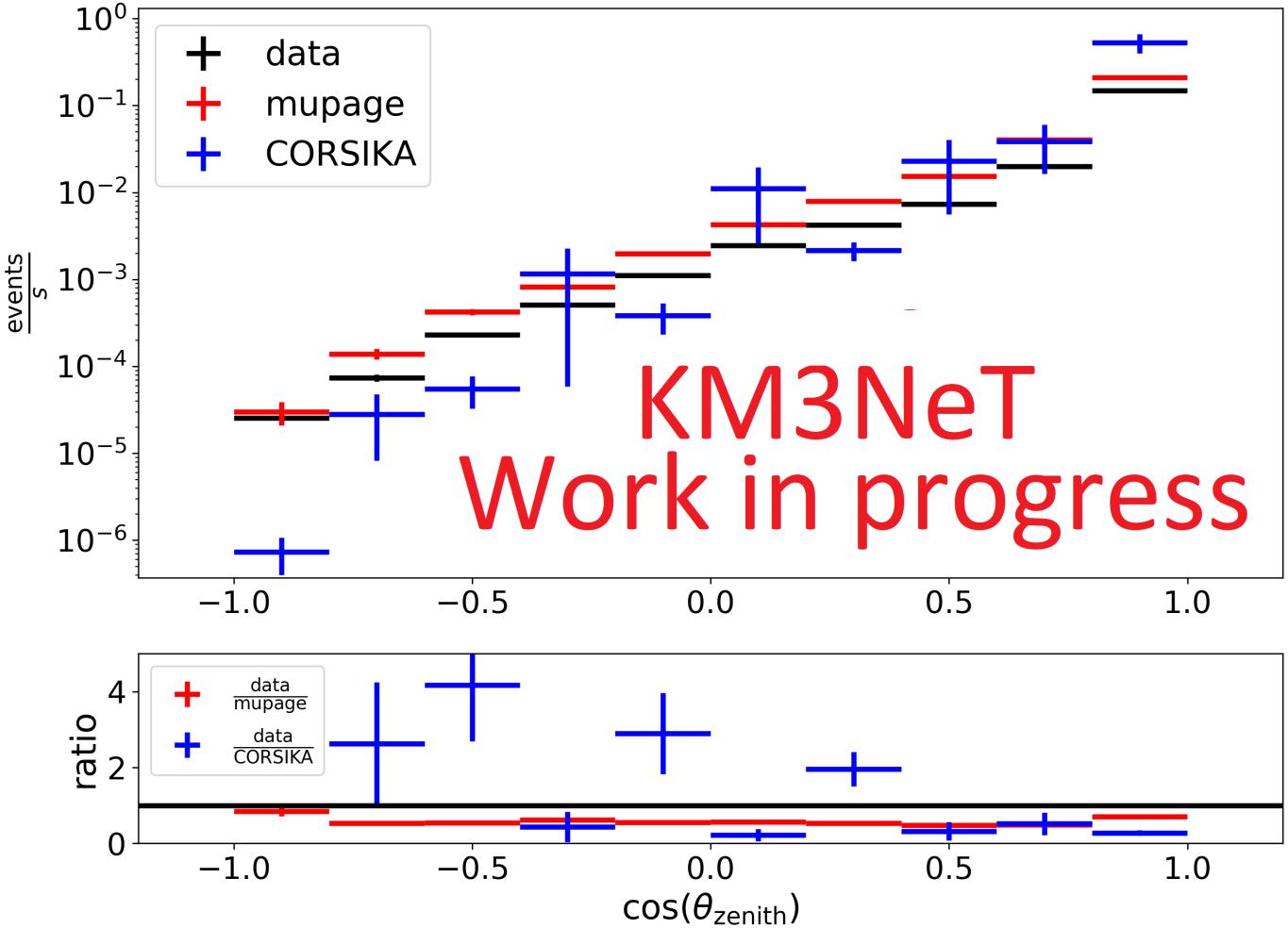
Atmospheric μ spectrum for ARCA2 (Zenith)



detector
ARCA2

generator
CORSIKA
mupage

CORSIKA statistics
95 k

stage
reco level

livetimes: 1 d (mupage), 1.37 d (data)

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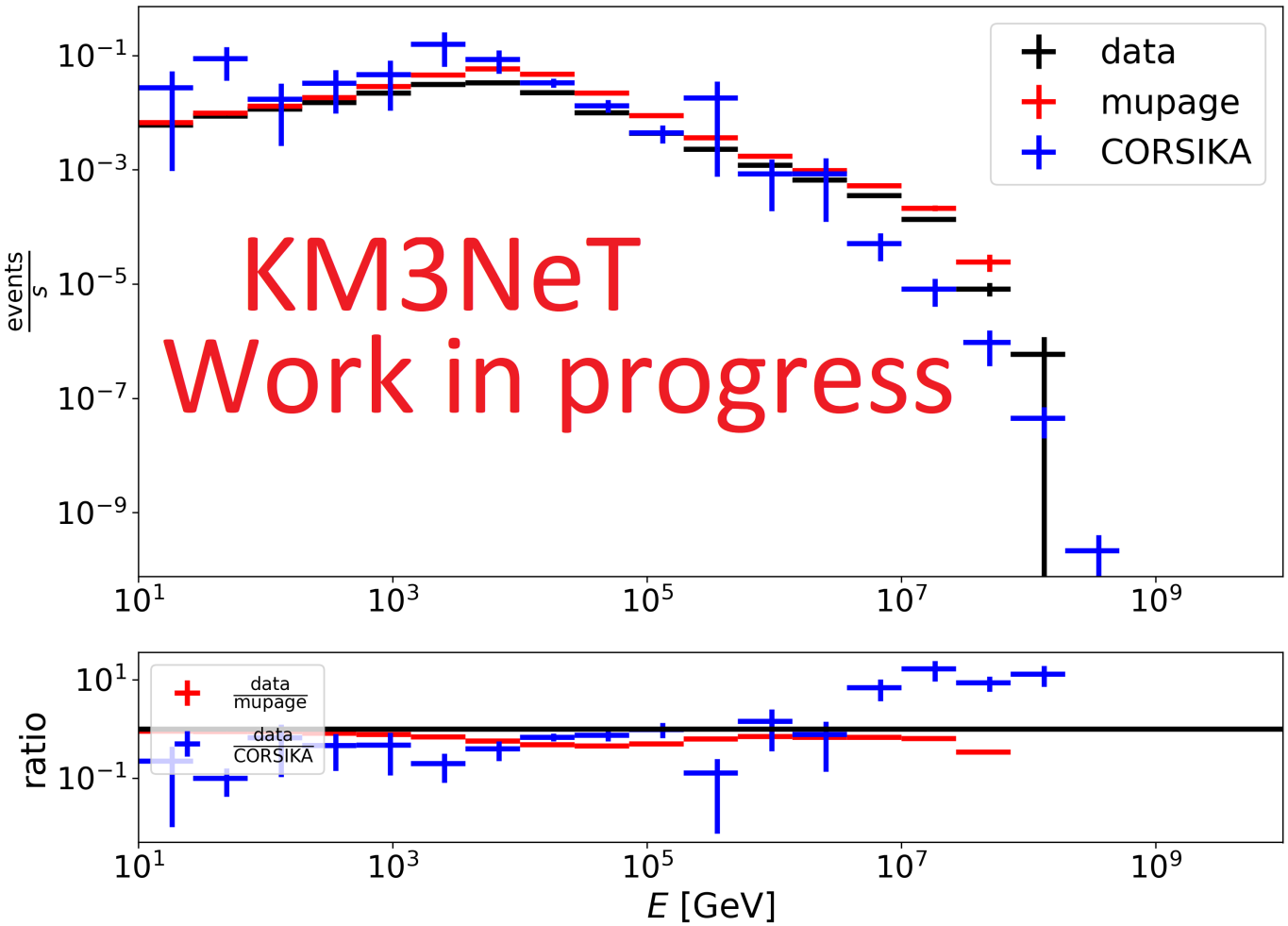
Atmospheric μ spectrum for ARCA2 (Energy)



detector
ARCA2

generator
CORSIKA
mupage

CORSIKA statistics
95 k

stage
reco level

livetimes: 1 d (mupage), 1.37 d (data)

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Summary

The main message:

- Detailed event-by-event MC simulation of air showers possible
- We developed a complete simulation chain for ARCA and ORCA detectors
- Good agreement with first data (and still improving)
- More statistics needed (work in progress)
- unique possibility to measure CR μ at 3.5 km underwater
  $\hookrightarrow$ upcoming paper : "Measurement of the atmospheric muon rate dependence on the sea depth with the KM3NeT neutrino telescopes"

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Thank you for your attention. Any questions?

thank you!

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CORSIKA simulation settings

Settings used for simulations:

- HE hadronic interaction model: SIBYLL 2.3c
- LE hadronic interaction model: GHEISHA 2002d (not so important in our case)
- Charmed particles handled explicitly
- CR flux model: GST3, using 5 primaries: p, He, C, O, Fe
- $10^3 < \frac{E_{\text{primary}}}{\text{GeV}} < 10^9$

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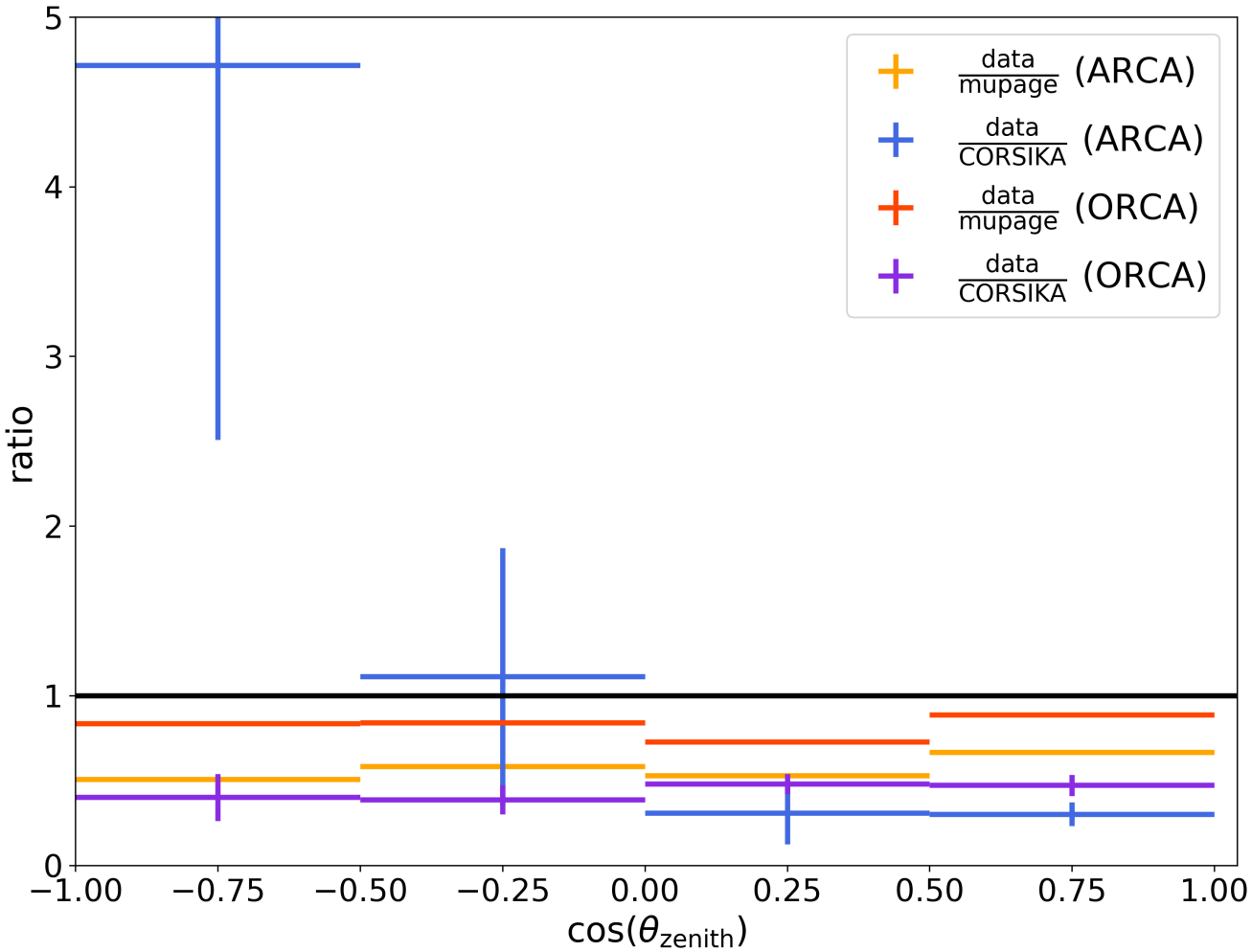
Data vs MC ratios



detector
ARCA2, ORCA1

generator
CORSIKA
mupage

stage
reco level

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Implemented Hadrons (Mesons + Baryons)

Meson	C	S	B
π			
K		×	
ρ			
ω			
ϕ		×	
η		×	
η_c	×		
η_b			×
D	×		
D_s	×	×	
J/ψ	×		
B			×
B_c	×		×
B_s		×	×
Υ			×

Baryon	C	S	B
p			
n			
Λ		×	
Λ_b			×
Λ_c	×		
Σ		×	
Σ_c	×		
Σ_b			×

Baryon	C	S	B
Δ			
Ξ		×	
Ξ_c	×	×	
Ξ_{cc}	×		
Ξ_b		×	×
Ω		×	
Ω_c	×	×	
Ω_b		×	×

■ – not implemented
■ – not sure

$\gamma \longrightarrow \mu^+\mu^-$
(suppressed by 10^{-4} w.r.t. $\sigma_{e^+e^-}$)

$\gamma \longrightarrow \tau^+\tau^-$
(suppressed by 10^{-10} w.r.t. $\sigma_{e^+e^-}$)

nuclear μ interactions

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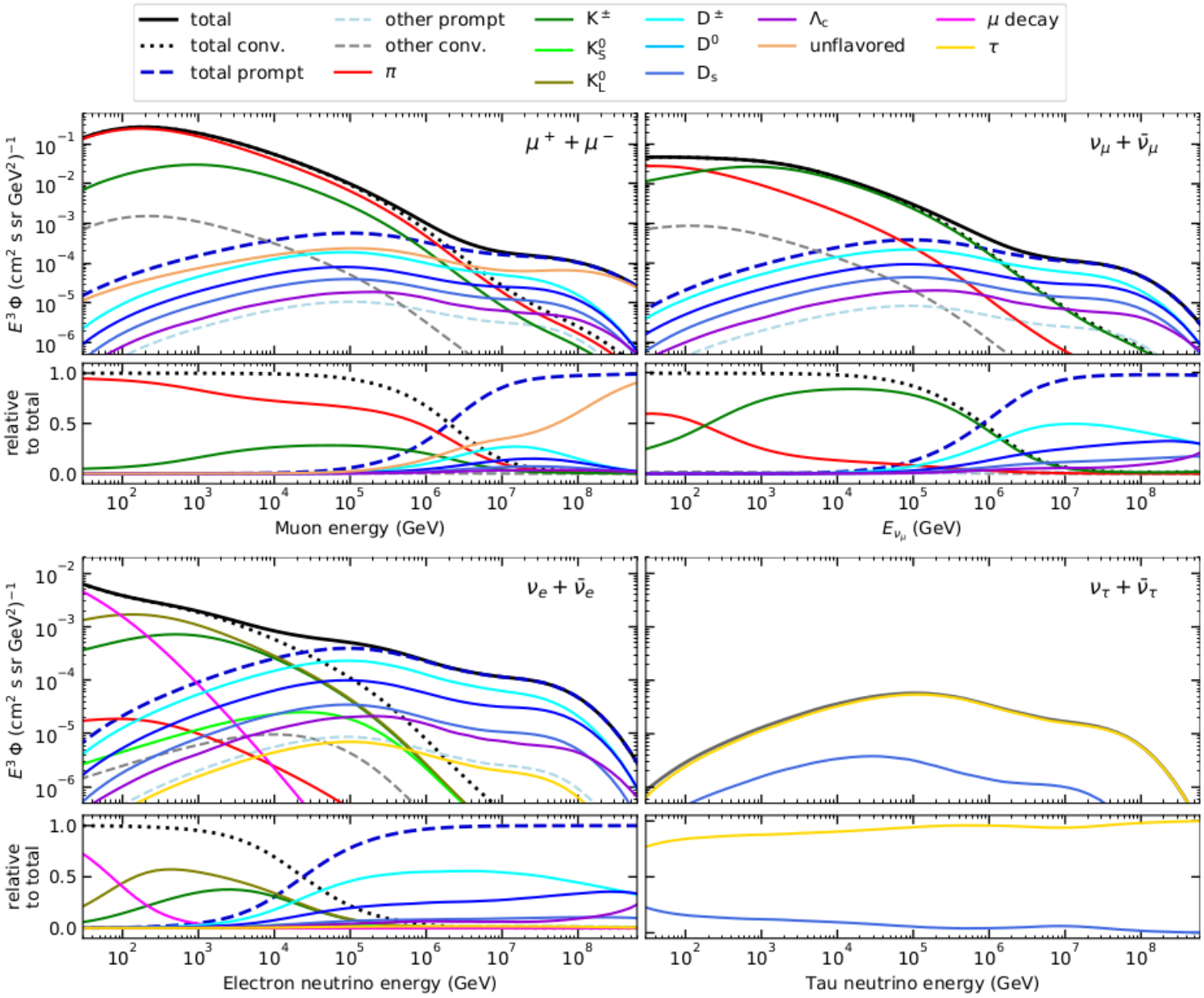
Atmospheric flux contributions



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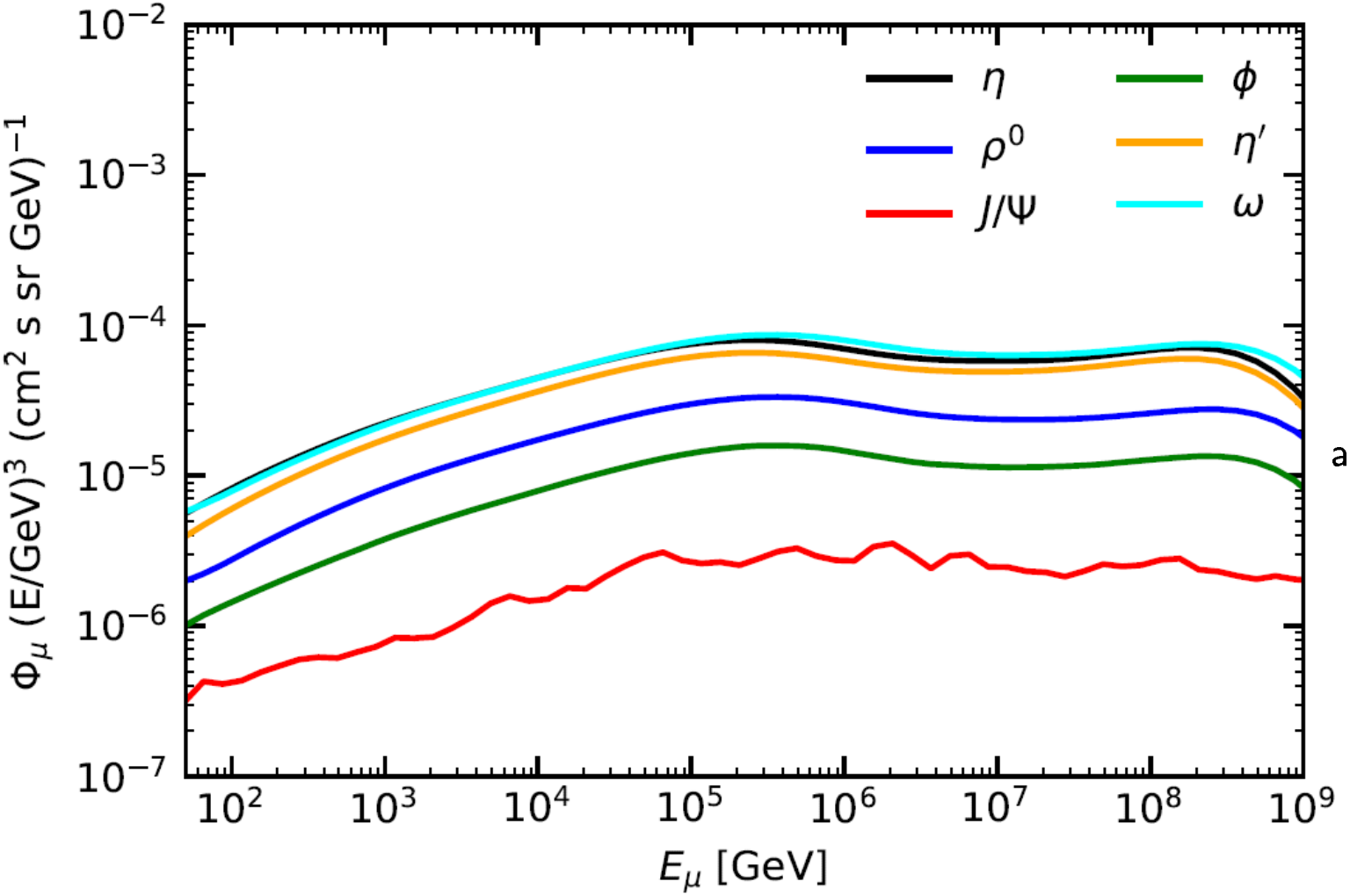
Unflavoured atmospheric flux contributions



arXiv:1806.04140v1

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