# The COSMOS air shower simulation program

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for the COSMOS development team

<u>Official web : http://cosmos.icrr.u-tokyo.ac.jp/cosmosHome/</u> <u>New web under develop : http://cosmos.icrr.u-tokyo.ac.jp/COSMOSweb/</u>

# Congratulations 30 years anniversary of CORSIKA!!

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## How old is COSMOS?

## Slides by Prof. Kasahara in the atmospheric neutrino workshop at Nagoya in March 2019



#### What are these ?











### **COSMOS** General Features

- Monte Carlo air shower simulator
- Fortran (+ C)
- User Interface: Fortran (or C++)
- Compiler: Formal Fortran
  - Intel Fortran
  - GFortran (available since COSMOS v8 in 2017)
  - cmake available soon
- Thinning
- Parallel computing
  - MPI
  - Skelton-smach- flesh method
- Hybrid AS size computing (MC + analytical)

New team :

K.Kasahara, T.Sako, A.Taketa, N.Sakurai, H.Menjo, Y.Tameda, N.Sakaki, Y.Tsunesada, T.Fujii +

### Physics Processes

#### • Elemag

- Photoelectric eff., Rayleigh scat., Compton scat.
- (Mag.) Pair cre.
- Brems., e+ annihilation, Bhabha, Moller scat.
- Synchrotron
- Photo-hadron prod.
- LPM effect on brems. and pair.
- Multiple scat.
- Muon
  - Brems, pair, nucl. In.
  - Polarization, stopping mu- capture
- Hadron
  - Interaction models

#### **Control parameter list**





'primary' file

'p'	'GeV' 0.1 0.2 .3 .4 .5	'KE/n' 1.2 1.5 1.7 1.9 1.93	' d'	0 /
	. 6 . 8 1. 5 2. 3. 4. 10. 20.	$1.9 \\ 1.8 \\ 1.5 \\ 1.25 \\ .8 \\ .55 \\ .1 \\ .02$		
'He'	100. 0 'GeV' . 1 . 2 . 4 . 6 . 8 1. 2. 5	2.8e-4 0, KE/n, 7 1. 1.2 1.25 1.2 1.15 .7	'd'	0 /
'CNO'	5. 10. 30. 100. 0 'GeV' .1 .2 .3 .5 .8 1. 1. 3	0.35 0.065 .008 2.e-4 0 'KE/n' .013 .28 .4 .65 .8 .85 .88	'd'	0 /
	2. 0 4. 6. 10. 20.	. 75 . 35 . 2 . 07 . 012		11

### COSMOS User Interface



#### Early days application "Atmospheric neutrino fluxes"

M.Honda, K.Kasahara, K.Hidaka, S.Midorikawa, PLB 248 (1990)





- Muon polarization, which biases e and  $v_{\mu}$  energies in  $\mu$  decay, was implemented
- 20% effect in flux, but 5% in ratio
- Kamiokmande  $(v_e + \bar{v}_e)/(v_\mu + \bar{v}_\mu)$  anomaly was not explained

=> Neutrino oscillation scenario

#### Interaction modification in a user function T. Sako et al., ICRC 2013



Softening in the COSMOS user hook function.

## Muography

(R.Nishiyama, A.Taketa, S.Miyamoto, K.Kasahara, Geophys. J. Int. (2016) 206)



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momentum (GeV/c)



## Muography

(R.Nishiyama, A.Taketa, S.Miyamoto, K.Kasahara, Geophys. J. Int. (2016) 206)



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#### Recent Application by K.Ohashi (LHCf, Nagoya)

1<sup>st</sup> interaction category and <X<sub>max</sub>>



#### CORSIKA – COSMOS comparison

S. Roh et al., Astroparticle Physics 44 (2013) 1-8



• >80GeV QGSJET II-03

10<sup>19.5</sup> eV Fe vertical

<80GeV FLUKA for CORSIKA, PHITS and JAM in COSMOS</li>

#### CORSIKA – COSMOS comparison



- >80GeV QGSJET II-03
- <80GeV FLUKA for CORSIKA, PHITS and JAM in COSMOS</li>

## Tracking in the geo (arbitrary) magnetic field



## Tracking in non-air material fusion with EPICS – on going update --





- EPICS is a detector simulation code allowing arbitrary material, shape, ...
- Seamless simulation into rock, ice, water, ... using high energy interaction models
- Muongraphy

## Extra-Terrestrial Air showers !? -- proposed application --



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- Fermi/LAT observation
- GCR + solar atmosphere

A.Abdo et al., ApJ, 734:116 (10pp), 2011







- Time dependent energy spectrum, emission region
- GCR + solar magnetic field + interaction with H, He, ...

4.2

• Quantitative explanation by COSMOS?

### More applications?

Tracking in strong magnetic field





#### Air showers in other planets

### Summary

- COSMOS is...
  - old in origin, but updating continuously
  - maintained by a new development team formed recently
  - easily used under Gfortran environment
- COSMOS can...
  - simulate air showers under various conditions CROSS CHECK WITH CORSIKA
  - extend to non-terrestrial atmosphere simulations
    ORIGINALITY W.R.T. CORSIKA