Developments of CORSIKA
Historical Review

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CORSIKA
Cosmic Ray Simulation Workshop
Hotel ACHAT PLAZA, Karlsruhe
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CORSIKA

The name CORSIKA stands for:

COsmic Ray SImulation for KASCADE

KASCADE = KArlsruhe Shower Core and Array DEtector

Header of First CORSIKA Version

```
C=====================================================================
C
C       OOO        OOO       OOOO          OOOO     OO    O         O        O
C      O   O      O   O     O    O        O    O    OO    O     O          O O
C     O           O       O    O       O    O          OO    O   O           O    O
C     O           O       O    O       O    O          OO    OO              O       O
C     O           O       O    OOOO                    O    OO    O   O     OOOOOOO
C      O   O      O   O     O    O       O    O    OO    O     O         O        O
C       OOO        OOO       O      O     OOOO     OO    O          O    O       O
C
C     COSMIC RAY SIMULATION AT KARLSRUHE
C
C
C   A PROGRAM TO SIMULATE EXTENSIVE AIR SHOWERS IN ATMOSPHERE
C
C   BASED ON A PROGRAM OF P.K.F. GRIEDER, UNIVERSITY BERN
C   DUAL PARTON MODEL ACCORDING TO J.N. CAPDEVIELLE, UNIVERSITY BORDEAUX
C   EGS4 AND NKG FORMULAS FOR SIMULATION OF ELECTROMAGNETIC PARTICLES
C
C   INSTITUT FUER KERNPHYSIK
C   KERNFORSCHUNGSZENTRUM AND UNIVERSITY OF KARLSRUHE
C
C   VERSION :  1.0
C   DATE    :  26.  OCTOBER 1989
C
C=====================================================================
```

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Origin of CORSIKA

October 26, 1989 CORSIKA Vers. 1.0 merged from:

SH2C-60-K-OSL-E-SPEC (Grieder, 1980):
main structure, isobar model

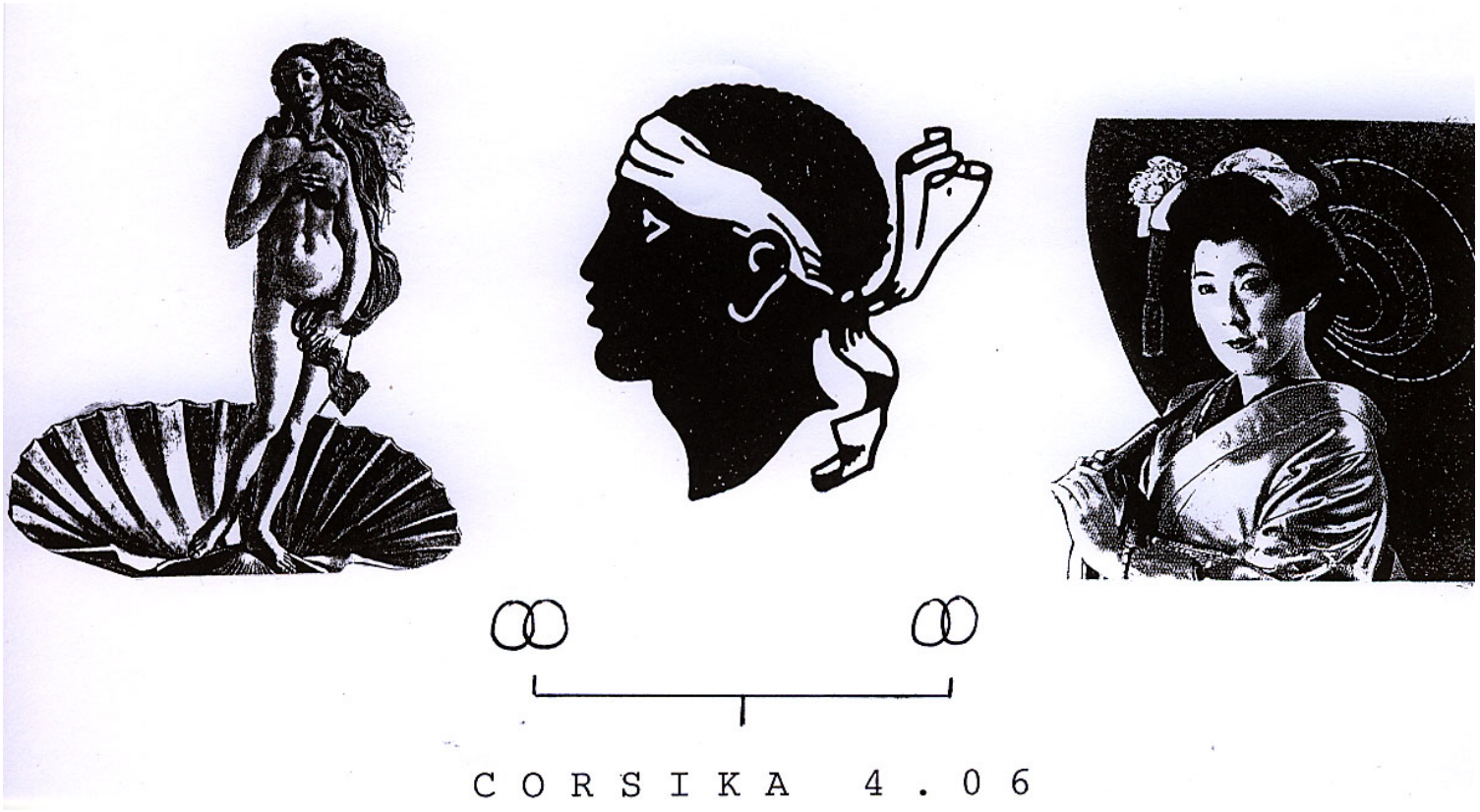
ESKAR (HDPM) (Capdevielle, 1987):
high-energy hadronic interactions

EGS4 (Nelson et al., 1985):
electron gamma shower

NKG (Capdevielle, 1989):
analytic treatment of EM-subshowers

source code size: $\approx$ 13 000 lines ($<$ 1/6 of present version 7.6900)

CORSIKA: Development



Wedding of the year 1994.

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CORSIKA: Development

1994 CORSIKA Vers. 4.06

GHEISHA (Fesefeldt, 1985):
low-energy hadronic interactions

VENUS (Werner, 1993):
high-energy hadronic interactions

CERENKOV option (HEGRA Collaboration, 1993):
production of Cherenkov radiation

INTERACTIONTEST option (Knapp, 1994):
compare models (identical conditions)

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CORSIKA: Development

1997 CORSIKA Vers. 5.20

SIBYLL (Fletcher, Gaisser et al., 1994):

high-energy hadronic interactions

QGSJET (Kalmykov et al., 1993):

high-energy hadronic interactions

DPMJET (Ranft, 1995):

high-energy hadronic interactions

THIN option:

simulate highest energies in reasonable time

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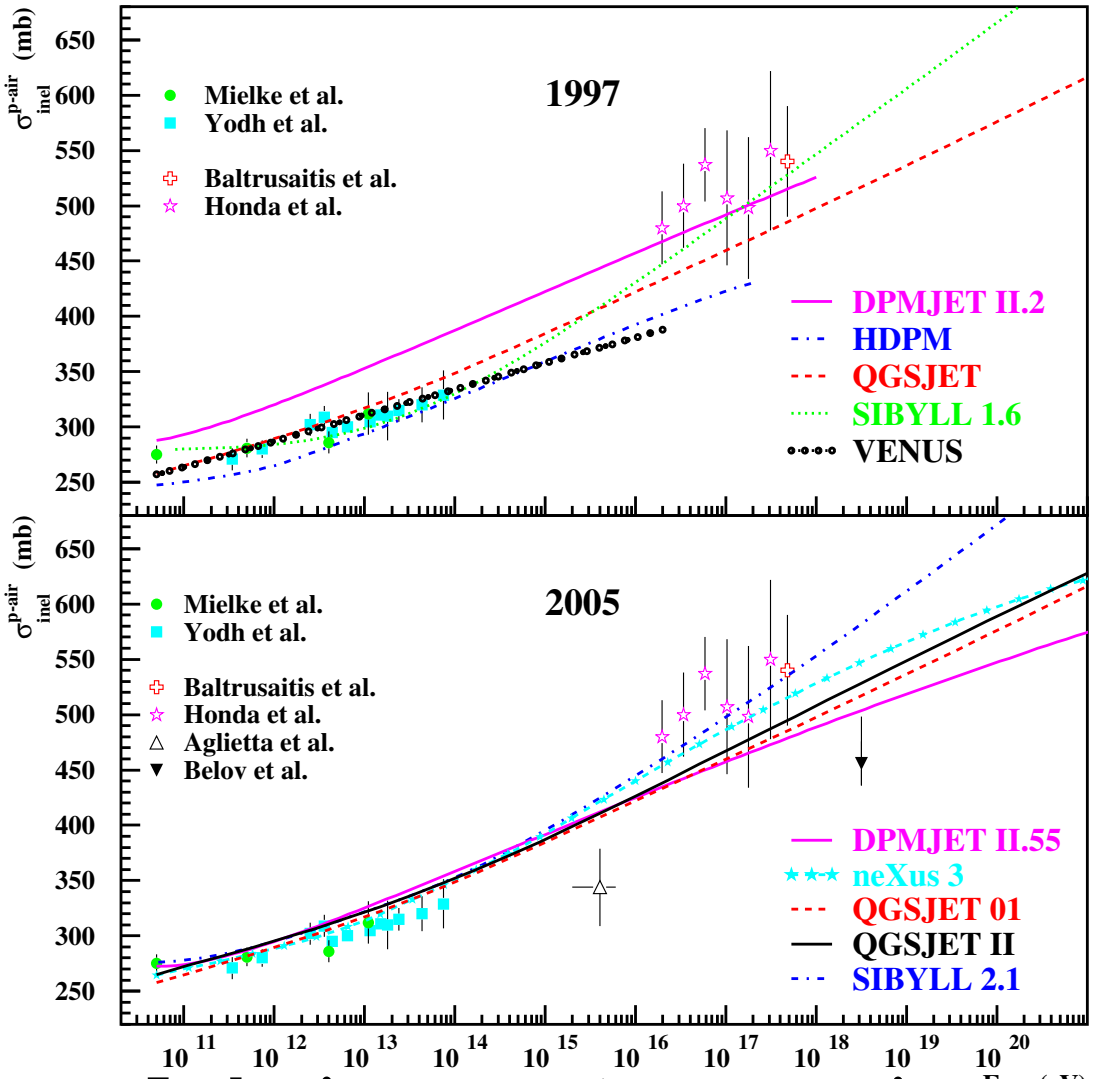
Interaction Models

Why so many hadronic interaction models ?

Different interaction models produce different mean values. Scattering of mean values gives estimation on systematic uncertainty introduced by different extrapolations of accelerator data to high energy and very forward direction.

Cross-Sections



Inelastic *proton-air* cross-sections.

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CORSIKA: Development

2000 CORSIKA Vers. 6.00

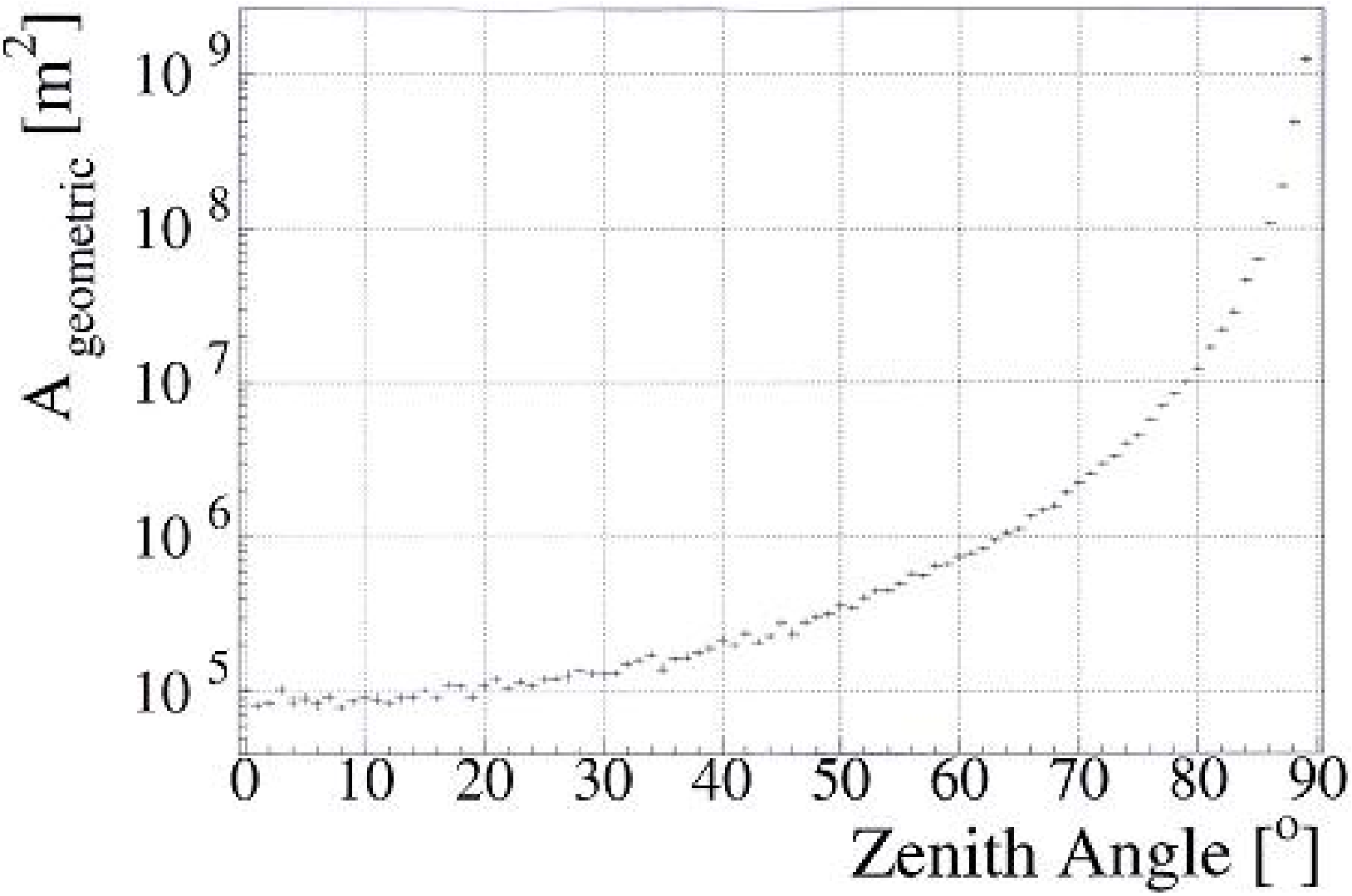
NEXUS (Drescher et al., 2001):
high-energy hadronic interactions

URQMD (Bleicher et al., 1999):
low-energy hadronic interactions

IACT option (Bernlöhr, 2000):
Cherenkov routines incl. telescopes

CURVED option (Schröder, 2001):
option for very inclined showers

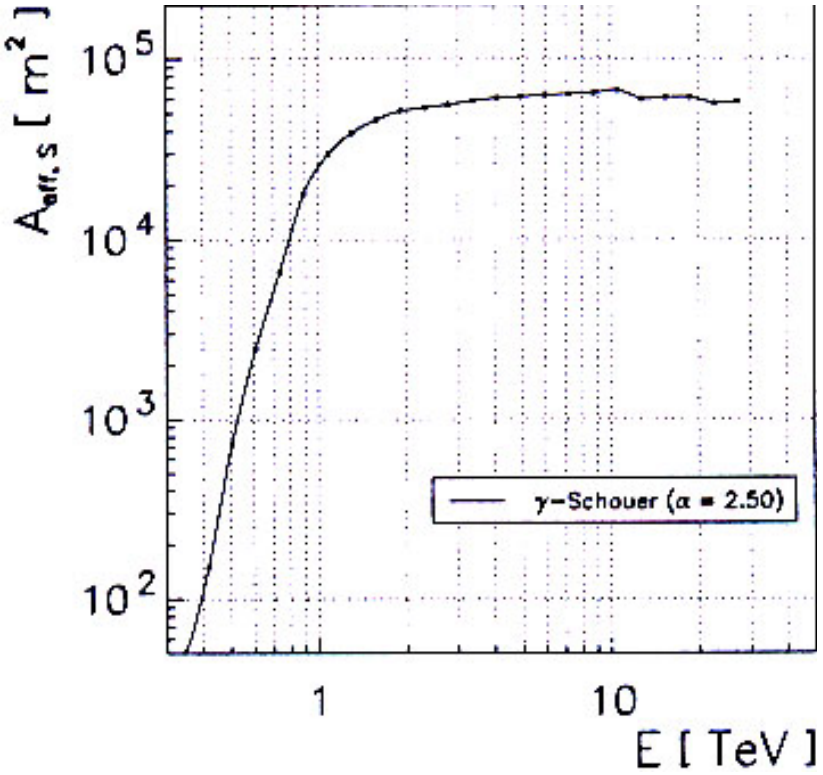
Motivation: Curved Option



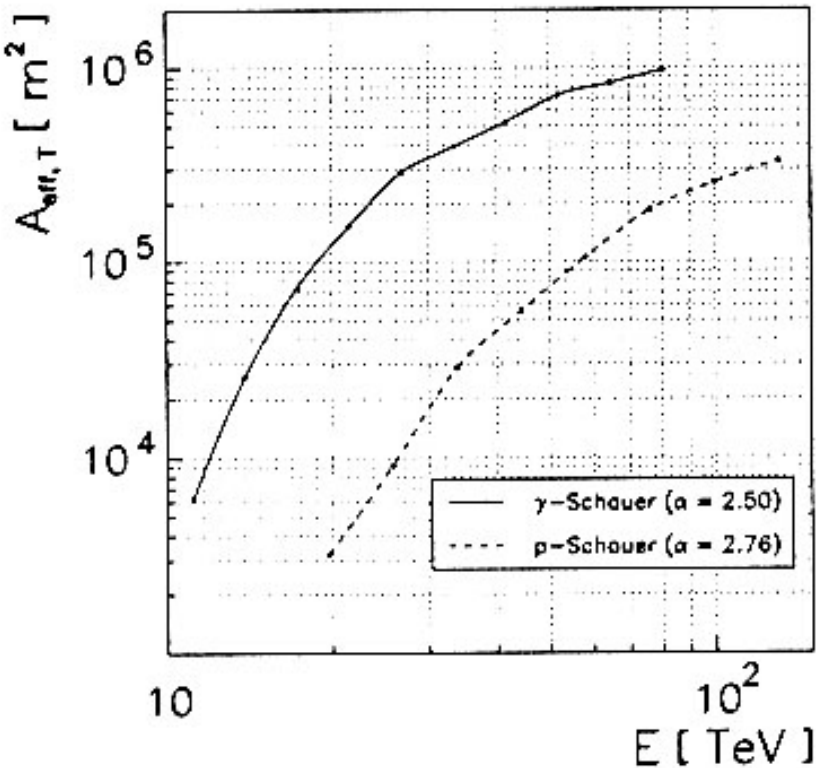
Geometric collection area vs. zenith angle for HEGRA CT1 (Schröder). (HEGRA CT1 was precursor of MAGIC Cherenkov telescope).

Motivation: Curved Option

$\Theta = 10°$



$\Theta = 70°$



Effective collection area vs. γ-energy for HEGRA CT1 (Schröder).

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CORSIKA: Development

2004 CORSIKA Vers. 6.20

PRESHOWER option (Homola et al., 2003):

UHE primary gammas

FLUKA (Ferrari et al., 2001):

low-energy hadronic interactions

NUPRIM option (Ambrosio, Pisanti et al., 2003):

primary neutrinos (HERWIG)

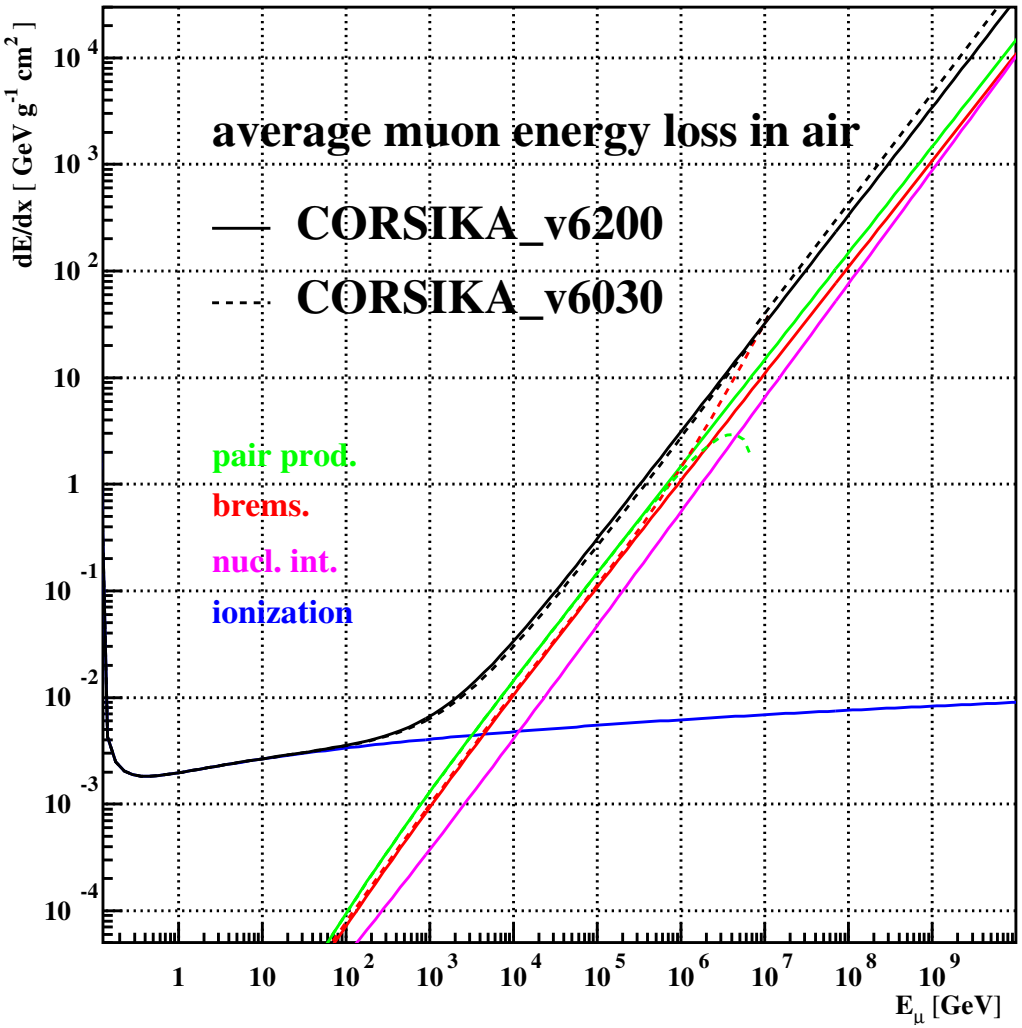
SLANT option:

slant depth (instead of vertical depth)

muon treatment (Bottai & Perrone, 2001):

improved muon interactions

Energy Loss of Muons



Average Muon Energy Loss in Air at Sea Level.

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CORSIKA: Development

2007 CORSIKA Vers. 6.60

COAST option (Ulrich, 2005):

write ROOT output

EPOS (Werner et al., 2005):

high-energy hadronic interactions

QGSJET-II-3 (Ostapchenko, 2006):

improved model for high energies

2009 CORSIKA Vers. 6.900

CHARM option:

PYTHIA treats charmed hadrons

./coconut:

automated installation of CORSIKA

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CORSIKA: Development

2012 CORSIKA Vers. 7.350

CONEX option (Bergmann et al., 2007):

hybrid simulation by cascade equations

QGSJET-II-04 (Ostapchenko, 2011):

improved model for highest energies

EPOS-LHC (Pierog et al., 2013):

improved model for highest energies

PARALLEL option (Poghosyan et al., 2012):

parallel treatment on multi-CPU cluster

with Message Passing Interface

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CORSIKA: Development

2013 CORSIKA Vers. 7.400

CoREAS (Huege et al., 2013):

coupling with radio emission program

2016 CORSIKA Vers. 7.500

SIBYLL 2.3 (Riehn et al., 2016):

improved model for highest energies

with production of charmed secondaries

CORSIKA 7.6900: Technical Features

program language (portability):
Fortran 77 / 90 + some few C-routines

source code: ≈ 81 800 lines (without external programs)
≈ 340 routines

optional code: ≈ 65 preprocessor options selectable
during installation with ./coconut

steering input: free format with key words + parameters
≈ 120 key words

availability: download from anonymous ftp://ikp-ftp.ikp.kit.edu/
needs password for access

application: ≈ 1450 registered users worldwide

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CORSIKA 7.6900: Documentation

Physics: Report FZKA 6019 (1998)

cited by 930 refereed publications

User's Guide: https://web.ikp.kit.edu/corsika/70.php

In-Line: variables used in COMMONS:

patch VARINDEX (corsika.h) contains list

Web Page: https://web.ikp.kit.edu/corsika/

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CORSIKA – COsmic Ray SImulations for KAscade

- Home
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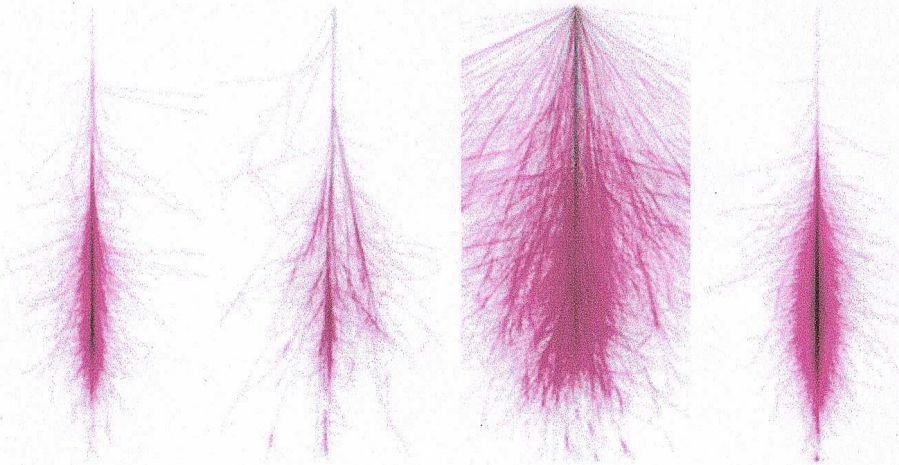
- Downloads
- Documentation
- CORSIKA Schools
- CoREAS (radio)
- COAST
- KCETA
- KSETA

CORSIKA – an Air Shower Simulation Program



Photon shower | Proton shower | Iron shower | Muon shower

(Compiled by Fabian Schmidt, University of Leeds, UK)

CORSIKA (**CO**smic **R**ay **SI**mulations for KAscade) is a program for detailed simulation of extensive air showers initiated by high energy cosmic ray particles. Protons, light nuclei up to iron, photons, and many other particles may be treated as primaries.

The particles are tracked through the atmosphere until they undergo reactions with the air nuclei or - in the case of instable secondaries - decay. The hadronic interactions at high energies may be described by several reaction models alternatively:The VENUS, QGSJET, and DPMJET models are based on the Gribov-Regge theory, while SIBYLL is a minijet model. The neXus model extends far above a simple combination of QGSJET and VENUS routines. The most recent EPOS model is based on the neXus framework but with important improvements concerning hard interactions and nuclear and high-density effect. HDPM is inspired by findings of the Dual Parton Model and tries to reproduce relevant kinematical distributions being measured at colliders.

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CORSIKA: Development

2018 CORSIKA Vers. 8

start of development for the complete new program

CORSIKA 8 written in C++ with modular design

references:

R. Engel et al., *Comput. Softw. Big Sci.* **3 (2019) 2**

M. Reininghaus & R. Ulrich, arXiv:1902.02822[astro-ph]

https://gitlab.ikp.kit.edu

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Alternative Programs

AIRES	**transscript of MOCCA to Fortran (Sciutto)**
CONEX	**hybrid with cascade equations (Bergman et al.)**
COSMOS	**hybrid with subshower library (Kasahara et al.)**
FLUKA	**multi-purpose detector MC (Ferrari et al.)**
GEANT 4	**multi-purpose detector MC (CERN)**
HEMAS	**used for MACRO (Battistoni, Forti et al.)**
MOCCA	**split algorithm, thinning, Pascal language (Hillas)**
SENECA	**hybrid with cascade equations (Drescher et al.)**

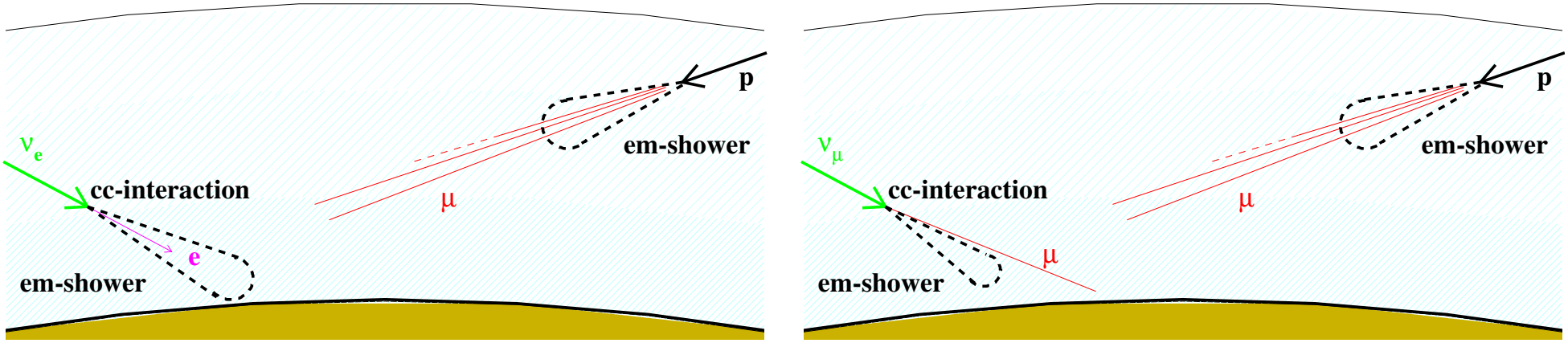
CORSIKA Users Worldwide

am	=	Armenia	ge	=	Georgia	pk	=	Pakistan
ar	=	Argentina	gr	=	Greece	pl	=	Poland
at	=	Austria	gt	=	Guatemala	pt	=	Portugal
au	=	Australia	hk	=	Hong Kong	ro	=	Romania
be	=	Belgium	hr	=	Croatia	rs	=	Rep. Serbia
bd	=	Bangladesh	hu	=	Hungary	ru	=	Russia
bg	=	Bulgaria	ie	=	Ireland	sa	=	Saudi Arabia
bo	=	Bolivia	il	=	Israel	se	=	Sweden
br	=	Brazil	in	=	India	si	=	Slovenia
ca	=	Canada	iq	=	Iraq	sk	=	Slovakia
ch	=	Switzerland	ir	=	Iran	tj	=	Tajikistan
cn	=	China	it	=	Italy	tr	=	Turkey
co	=	Colombia	jp	=	Japan	tw	=	Taiwan
cz	=	Czech Republic	ke	=	Kenya	ua	=	Ukraine
de	=	Germany	kr	=	South Korea	uk	=	United Kingdom
dk	=	Denmark	kz	=	Kazakhstan	edu/gov	=	USA
dz	=	Algeria	mx	=	Mexico	ve	=	Venezuela
es	=	Spain	nl	=	Netherlands	vn	=	Vietnam
fi	=	Finland	no	=	Norway	za	=	Rep. South Africa
fr	=	France	pe	=	Peru			

In 59 countries $\approx$ 1450 registered CORSIKA users (outside KIT).


WITH THE NEW SIMULATION PROGRAM
WE CAN SIMULATE THE SIMULATION
OF SIMULATION PROCESSES!
OH

Motivation: Neutrino-Induced EAS



Very inclined ν_e-induced (left) and ν_μ-induced (right) air showers with CC-interaction.

Experiments Using CORSIKA

AGASA	Japan	EAS-TOP	Italy	MAGIC	Spain
AMANDA	Antarctica	EAS-1000	Russia	MAKET-ANI	Armenia
ANTARES	France	EUSO	space	MILAGRO	USA
ARGO-YBJ	China (Tibet)	Fly's Eye	USA	NEMO	France
Auger	Argentina	Frejus	France	NESTOR	Greece
Baikal	Russia	GRAAL	Spain	NuTel	USA (Hawaii)
CACTUS	USA	Guwahati	India	PAMIR	Tajikistan
CAKE	USA	Havera Park	UK	Sky-View	Germany (NRW)
CANGOROO	Australia	HEGRA-AIROBICC	Spain	STACEE	USA
CASA-BLANCA	USA	HEGRA-CT	Spain	TA	USA
CASA-MIA	USA	HESS	Namibia	TACTIC	India
CAT	France	HiRes	USA	THEMISTOCLE	France
CELESTE	France	IceCube	Antarctica	TUNKA	Russia
Chacaltaya	Bolivia	KASCADE-Grande	Germany	VERITAS	USA
CORAL	Switzerland	LOPES	Germany	WACT	USA
DECOR	Russia	L3-cosmic	Switzerland	WILLI	Romania
DICE	USA	MACRO	Italy	WHIPPLE	USA

CORSIKA is used for $>$ 50 cosmic ray experiments.