Studying Extensive Air Showers with **CONEX**

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CONEX is

- Easy to install
- Has just a few command line options
  $\Rightarrow$ very straightforward to configure
- Very fast
- Produces small ROOT output files

Outline

Introduction

- CONEX is a small self-contained program with ROOT output. It can can be obtained after request from `tanguy.pierog@kit.edu`
  (version v2r2.3i is on the USB-sticks)
- The only required prerequisite is: ROOT
- Mix of fortran and C++

Installation

- Unpack: `tar xzvf conex2r2.3i.tgz`
- `cd conex2r2.3i`
- Compile: `make [opt]`

opt	Description
	QGSJet01, SIBYLL2.1
epos	QGSJet01, SIBYLL2.1, EPOS1.99
nexus	QGSJet01, SIBYLL2.1, EPOS1.99, QGSJetII.3, neXus3.97
qII	QGSJet01, SIBYLL2.1, EPOS1.99, QGSJetII.3
tutti	QGSJet01, SIBYLL2.1, EPOS1.99, QGSJetII.3, neXus3.97

Parameters and Options

- See `README` for all details
- `bin/conex2r -h`

```
conex2r -s [random seed] -S [autosave range] -a [alpha] -e [log10(emin/eV)] -E [log10(emax/eV)]
        -z [min zenith angle/deg] -Z [max zenith angle/deg] -i [azimuth angle/deg]
        -n [nShower] -p [0=gamma,100=p,5600=Fe,...]  -x [prefix] -m [2=QGSJET, 5=Sibyll]
        -K [maxDetailLevel]
```

- The `*.param` files (e.g. `conex_sibyll.param`)

```
set xmaxp 2000 !  max slant depth
set hacut1 1.  !  cut for hadrons in GeV (not less than 1)
set emcut1 0.001 !  cut for leptons in GeV (not less than 0.001)
set hground 0.  !  height of the observer in meter
set altitude 0.  !  height of the shower core (compared to hground) above obs.  point
set fehcut 0.05 !  relative threshold MC->CE for hadronic particle
set feecut 0.005 !  relative threshold MC->CE for e/m particles
set femcut 0.0005 !  relative threshold MC->CE for muons
```

CONEX searches for the param files at run-time at
$CONEX_ROOT and $PWD

Simulation Of Showers

- `bin/conex2r -e 20 -E 20 -n 5 -p 100 -m 5`
- `ls -sh *.root`

```
85K conex_sibyll_179324753_100.root
```

- `root conex_sibyll_179324753_100.root`
- `.ls`

<2 min

CONEX writes output files to $ROOT_OUT or $PWD

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CONEX writes output files to $ROOT_OUT or $PWD

You just simulated 5 air showers at 10^{20} eV in ~ 1 min.
File size: $\sim$100 kBytes.

Description of Header

```
Seed1     : random seed1
Particle  : particle ID
Alpha     : spectral index
lgEmin    : log10 of the minimum energy in eV
lgEmax    : log10 of the maximum energy in eV
zMin      : minimum zenith angle in degree
zMax      : maximum zenith angle in degree
Version   : conex version
HEModel   : High Energy interaction model flag
            (1=NeXuS, 2= QGSJet, 4=Sibyll)
LEModel   : Low Energy (E < 80 GeV) model flag (only 3=Gheisha)
hadCut    : hadron and muon cutoff (minimum energy)
emCut     : e/m particles cutoff
            (minimum energy for electrons, positrons and gammas)
hadThr    : Emax(CE)/Emax(MC) for hadrons (threshold)
muThr     : Emax(CE)/Emax(MC) for muon (threshold)
emThr     : Emax(CE)/Emax(MC) for e/m particles (threshold)
SVNRevision    : svn revision
OutputVersion : cxroot output version
```

Description of Shower

```
lgE       : log10 of the primary energy in eV
zenith    : zenith angle in degree
azimuth   : azimuth angle in degree (0 = East)
Seed2     : random seed2 (number of random number generator calls
            below 1 billion)
Seed3     : random seed3 (number of billions of random number
            generator calls)
XfirstIn  : inelasticity of first interaction ([0,1])
Xfirst    : real first interaction point in slant depth (g/cm^2)
Hfirst    : altitude of real first interaction point (m)
X0        : pseudo first interaction point for GH fit
Xmax      : GH fit result for slant depth of the shower maximum (g/cm^2)
Nmax      : Number of charged particles above cut-off at the shower maximum
p1        : first parameter for the polynomial function of the GH fit
p2        : second parameter for the polynomial function of the GH fit
p3        : third parameter for the polynomial function of the GH fit
chi2      : Chi squared / number of degree of freedom / sqrt (Nmax)
            for the fit
            (small number not realistic because it's divided by sqrt (Nmax) )
Xmx       : Quadratic fit on real profile for slant depth of the
            shower maximum (g/cm^2)
Nmx       : Quadratic fit on real profile of the number of charged
            particles above cut-off at the shower maximu
```

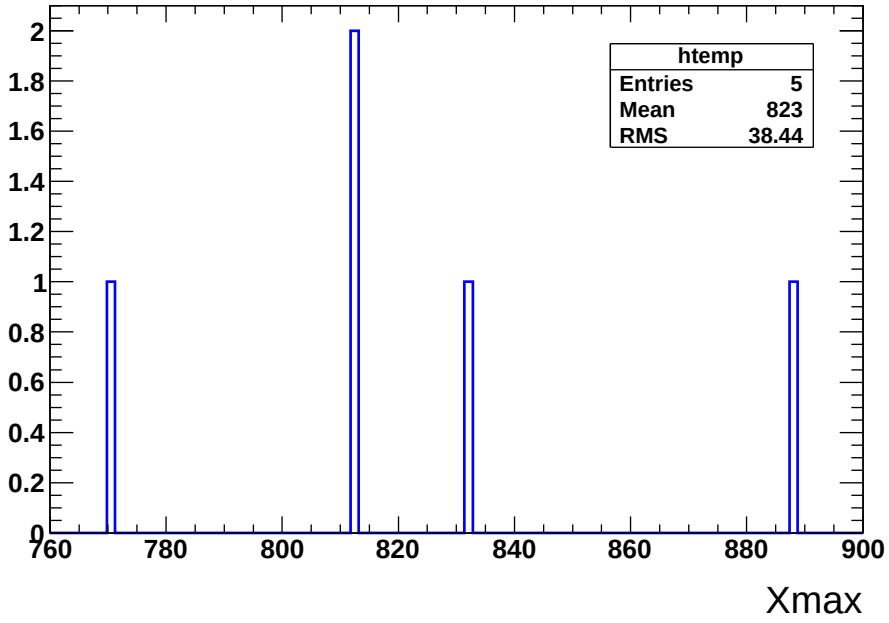
Description of Shower, Longitudinal Profiles

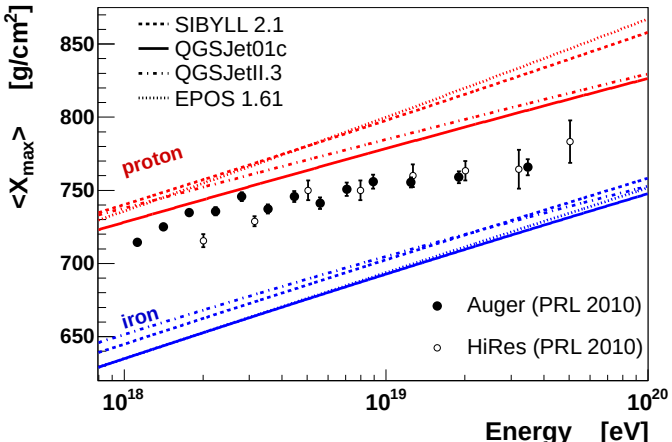
```
nX         : number of points of X, N, H, D, dEdX, Mu, dMu,
             Gamma, and Electrons array
X          : slant depth array (g/cm^2)
H          : height array      (m)
D          : distance array    (m)
N          : array of number of charged particles above cut-off
             crossing each X plane
dEdX       : array of energy deposit (GeV/(g/cm^2)) in the MIDDLE of
             each X bin
Mu         : array of number of muons above cut-off crossing each X plane
dMu        : array of number of muons produce above cut-off in each bin
Electrons: array of number of e^+ + e^- above cut-off crossing each X plane
Gamma      : array of number of gammas above cut-off crossing each X plane
EGround    : Energy of particles at maximum X (EGround[0]=e+gamma;
             EGround[1]=hadrons; EGround[2]=muons)
```

Analysing the Data

$\Rightarrow$ Depth of the Shower Maximum

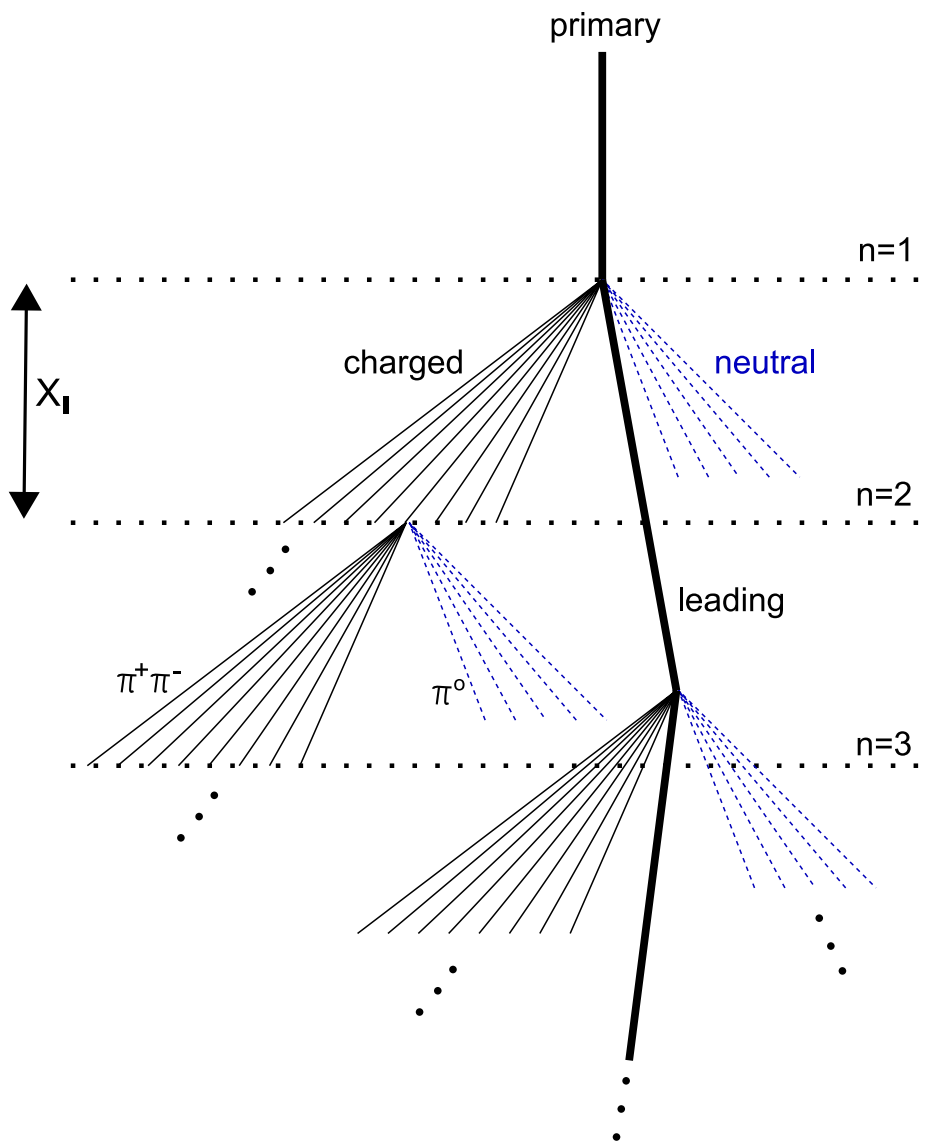
```
Shower->Draw("Xmax")
```





Save Leading Interactions

- `bin/conex2r -e 20 -E 20 -n 5 -p 100 -m 5 -K 2`



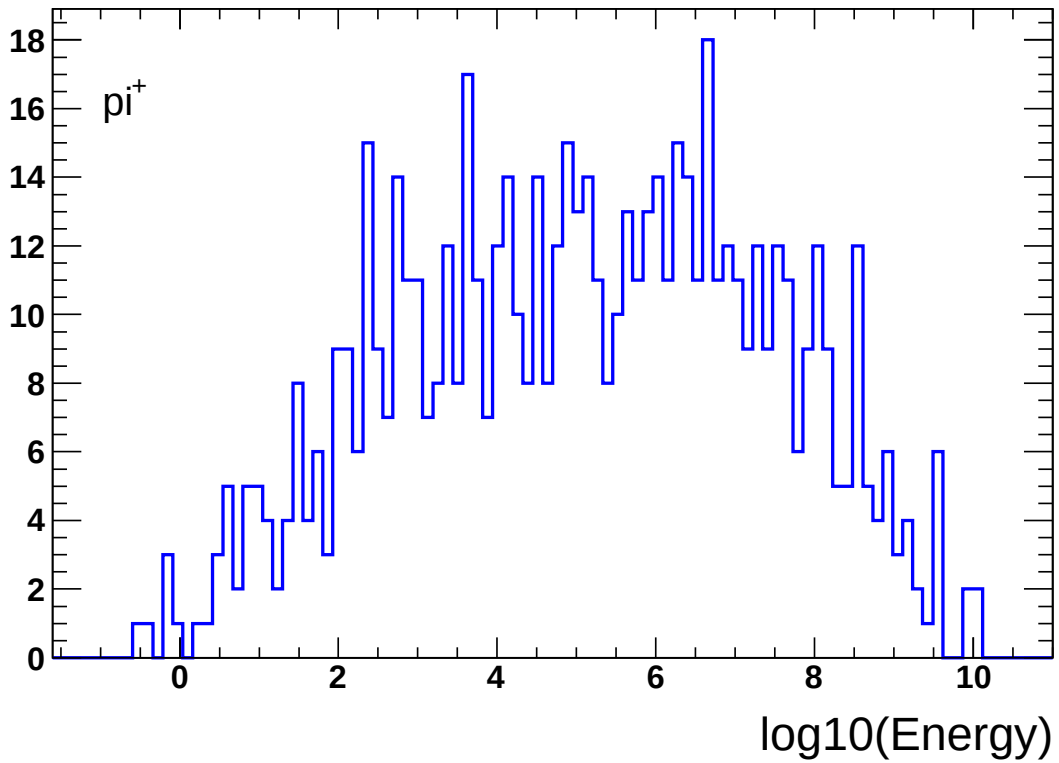
Description of FirstInteraction Tree

```
nInt     : Number of saved Interactions (size of array kinel, pId, pEnergy,
           mult, matg, depth) per shower
kinel    : Inelasticity for each saved interactions
pId      : Id of parent particle (CONEX Id)
           (CORSIKA Id if LEADING_INTERACTIONS_CORSIKA is defined
            in conexConfig.h )
pEnergy  : Energy of parent particle for each saved interactions
mult     : Multiplicity for each saved interactions
matg     : Mass of target nucleus  for each saved interactions
depth    : Slant depth (g/cm2) of each saved interactions
height   : altitude above see level (m) of each saved interactions
nPart    : total number of recorded secondary  particles per shower
           (nPart=sum[nInt](mult))
           (size of array Energy, px, py, pz, Type, and idInt)
idInt    : Interaction number
Type     : Id of secondary particles (CONEX Id)
           (CORSIKA Id if -DLEADING_INTERACTIONS_CORSIKA is selected
            in Makefile)
Energy   : total energy (GeV) of secondary particles
px,py,pz : momentum (GeV/c) of secondary particles
           (if -DLEADING_INTERACTIONS_TREE_EXT is used in Makefile)
```

Working with the FirstInteraction Data

$\Rightarrow$ Energy Distribution of π^+ in first interaction:

```
FirstInteraction->Draw("log10(Energy)","Type==8&&idInt==0")
```



The End