SPAM with CORSIKA

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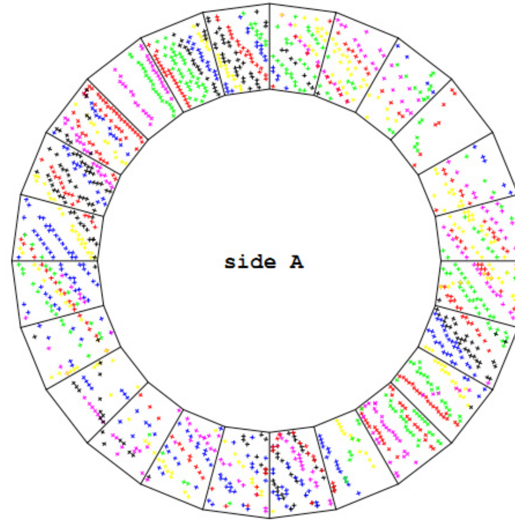
Ebr, Ridky, Necesal, Astropart.Phys.90:37-49,2017

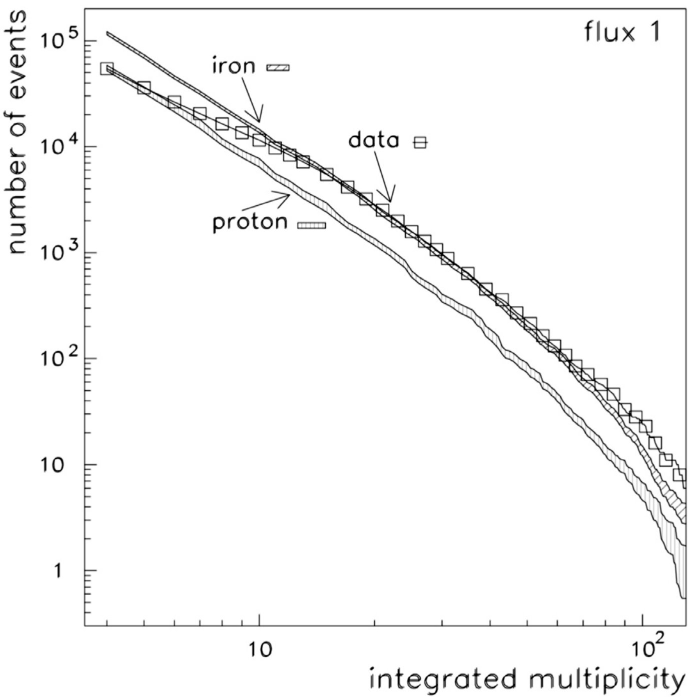
Overview

- DELPHI muon bundles from cosmic rays: excess of high-energy muons from moderate-energy CR showers
    - connection to UHECR excesses can (but won't) be argued
- Re-investigation wtih modern CORSIKA and interaction models
- Single-Particle Addition Model as a proposed "solution"
- Results: a lot of highly confusing plots
- Experience with using CORSIKA and personnal opinions

DELPHI as a cosmic ray detector

- rock overburden: vertical cutoff ~ 52 GeV
- cosmic measurement in concurence with normal run: effective uptime ~ 18 days





Bundles of parallel tracks in HCAL

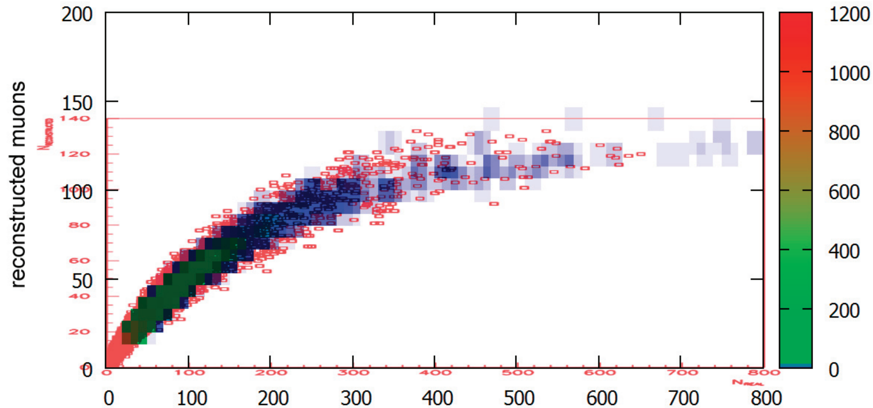
- not every muon reconstructed (shadowing, saturation, non-active areas)
- high-multiplicity events mainly from EAS between 10^{15}–$10^{17.5}$ eV

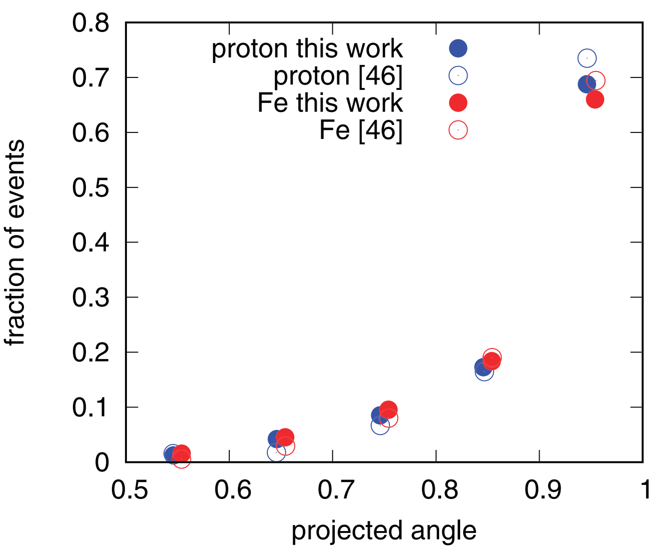
$DPH_{20} = 2.24 \pm 0.17$
$DPH_{80} = 1.45 \pm 0.23$

DELPHI Collaboration, Astropart.Phys.28:273-286,2007

DELPHI simulations

- whole relevant energy range (10^{14}–10^{18} eV), spectrum and chemical composition from KASCADE + Grande
- simple "toy DELPHI" to roughly reproduce the response of the system to EAS
- fit of efficiency and saturation



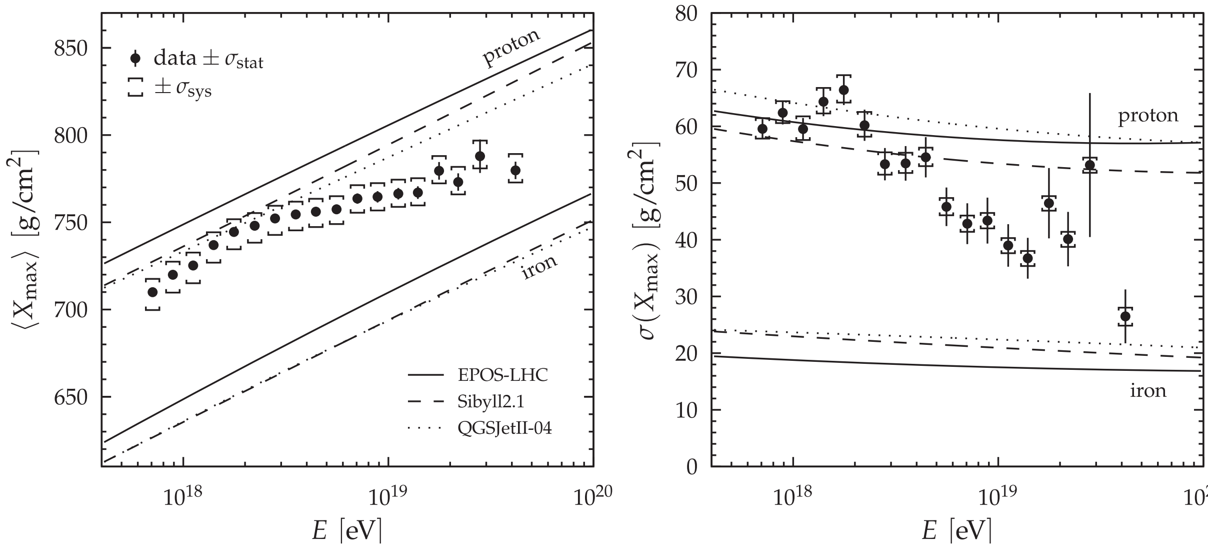


model composition	DPH_{20} p only	DPH_{80} Fe only	DPH_{20} mixed	DPH_{80} mixed
QGSJET01	1.00	1.00	1.43	0.70
QGSJET-II-03	1.11	0.75	1.54	0.57
QGSJET-II-04	1.11	1.37	1.72	0.83
EPOS-LHC	0.85	0.86	1.27	0.59

$$DPH_{20} = 2.24 \pm 0.17$$
$$DPH_{80} = 1.45 \pm 0.23$$

Auger simulations

- Auger depth of maximum constrains models (no lighter than protons)
  - simulations at 3.2×10^{18} eV
- Some amount of muon excess on Auger
  - increasing muon production would be nice
  - reading out N_μ at 1000 meters using NKG fit between 250–1500 meters



Soft-particle addition model

particles: π, K, p, n

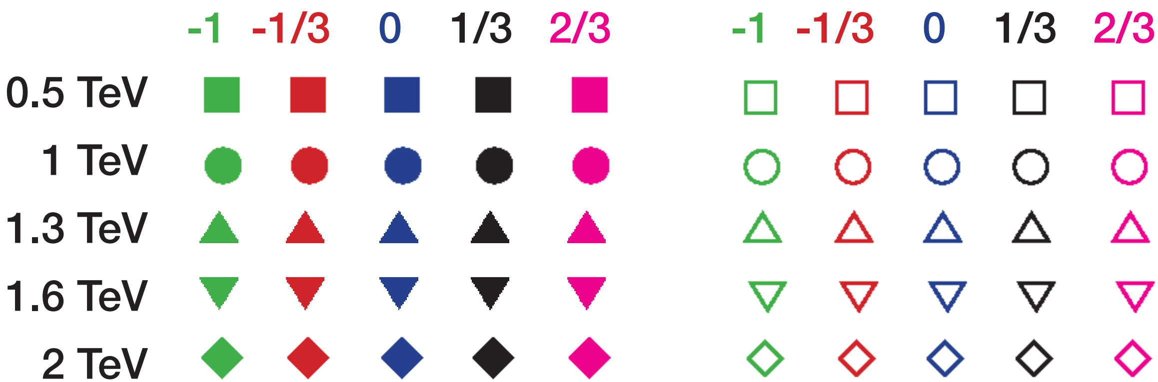
colour: $(\mathrm{NWT}+\mathrm{NWP})^{\eta}$

distribution $p\,\exp(-p/p_0)$

angle: within ~~1°~~ 0.1° from axis in c.m.s.

shape: energy treshold (or special p_0)

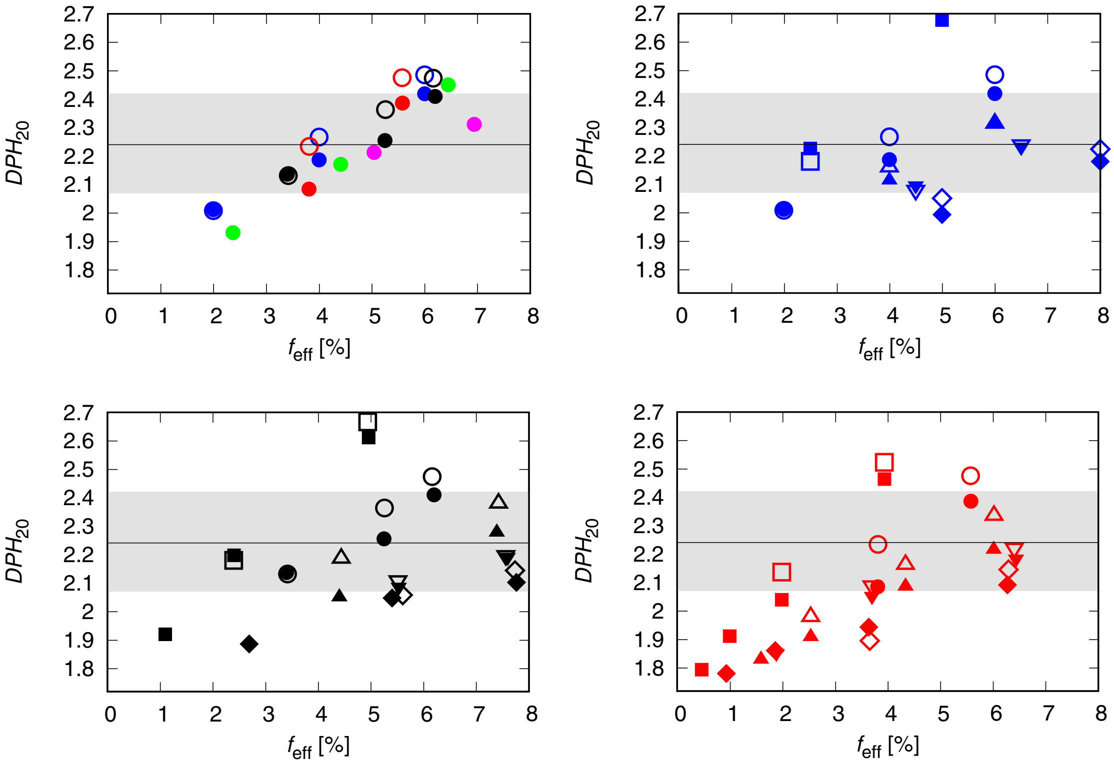
filled vs. empty: p_0



p_0 = 200 MeV @ threshold
500 MeV @ 100 TeV

p_0 = 200 MeV

SPAM: DELPHI data at multiplicities >20



color: η

blue = 0
black = 1/3
pink = 2/3
red = –1/3
green = –1

shape: threshold

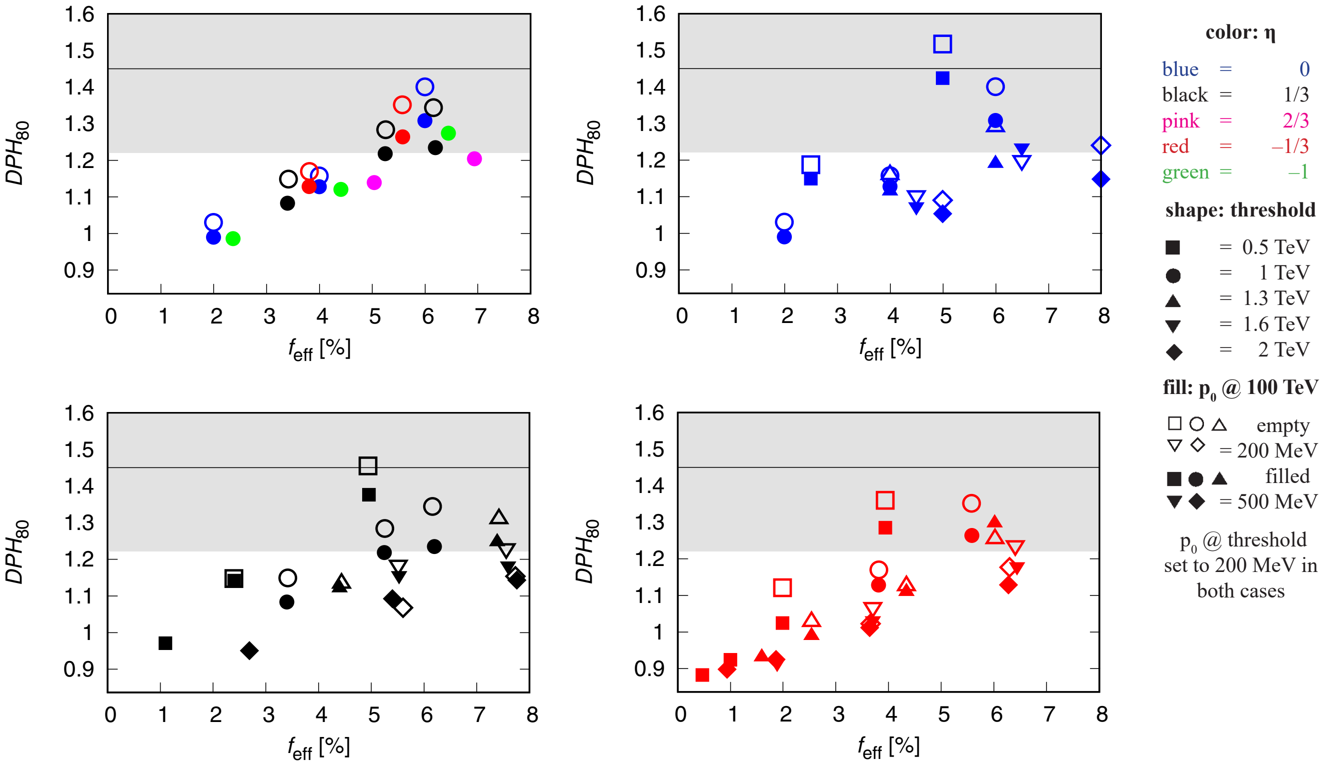
■ = 0.5 TeV
● = 1 TeV
▲ = 1.3 TeV
▼ = 1.6 TeV
◆ = 2 TeV

fill: p_0 @ 100 TeV

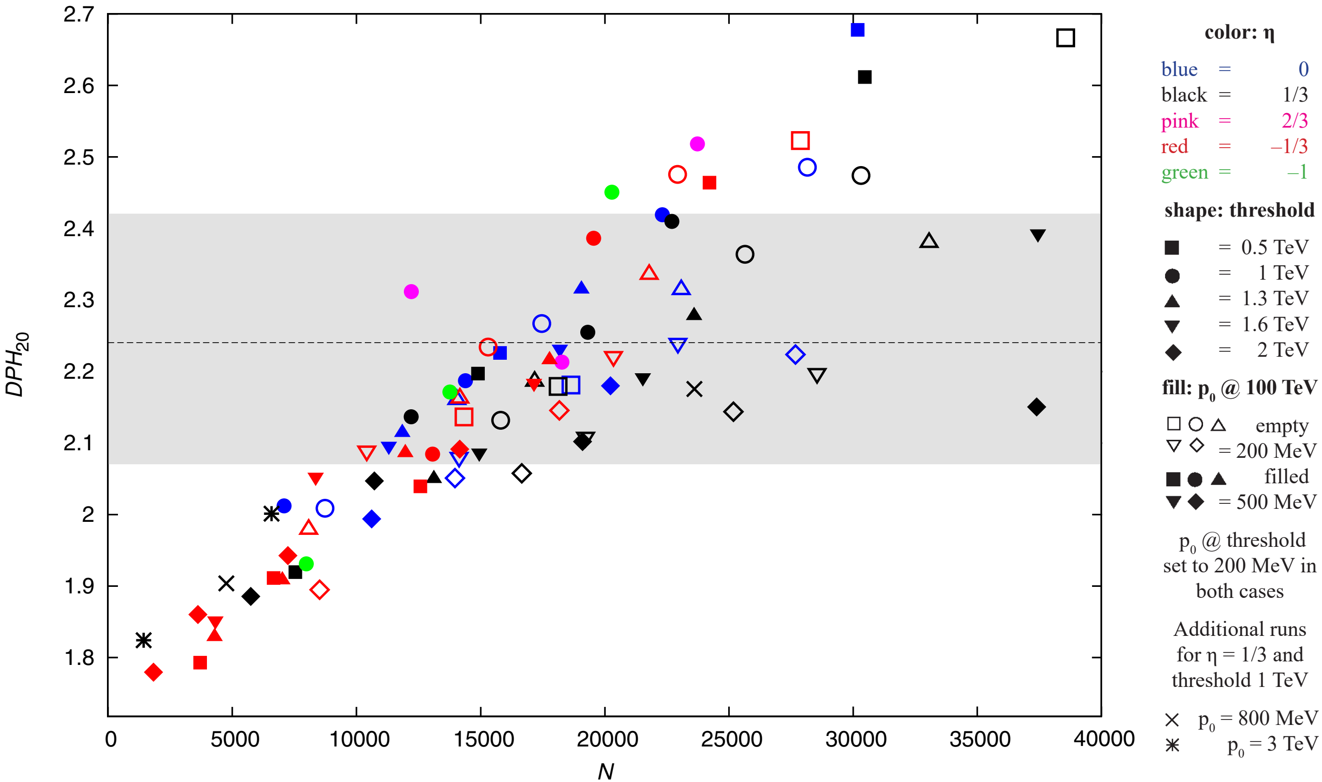
□ ○ △ ▽ ◇ empty = 200 MeV
■ ● ▲ ▼ ◆ filled = 500 MeV

p_0 @ threshold set to 200 MeV in both cases

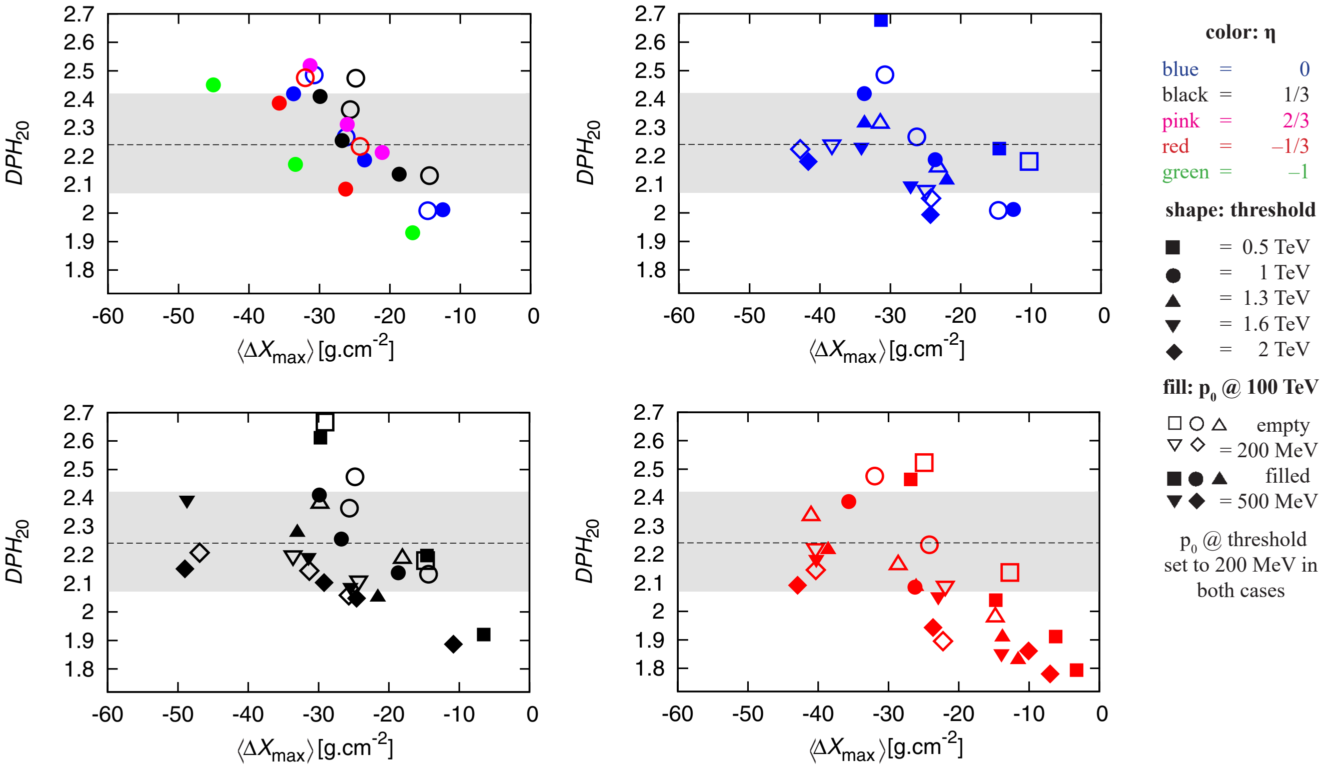
SPAM: DELPHI data at multiplicities >80



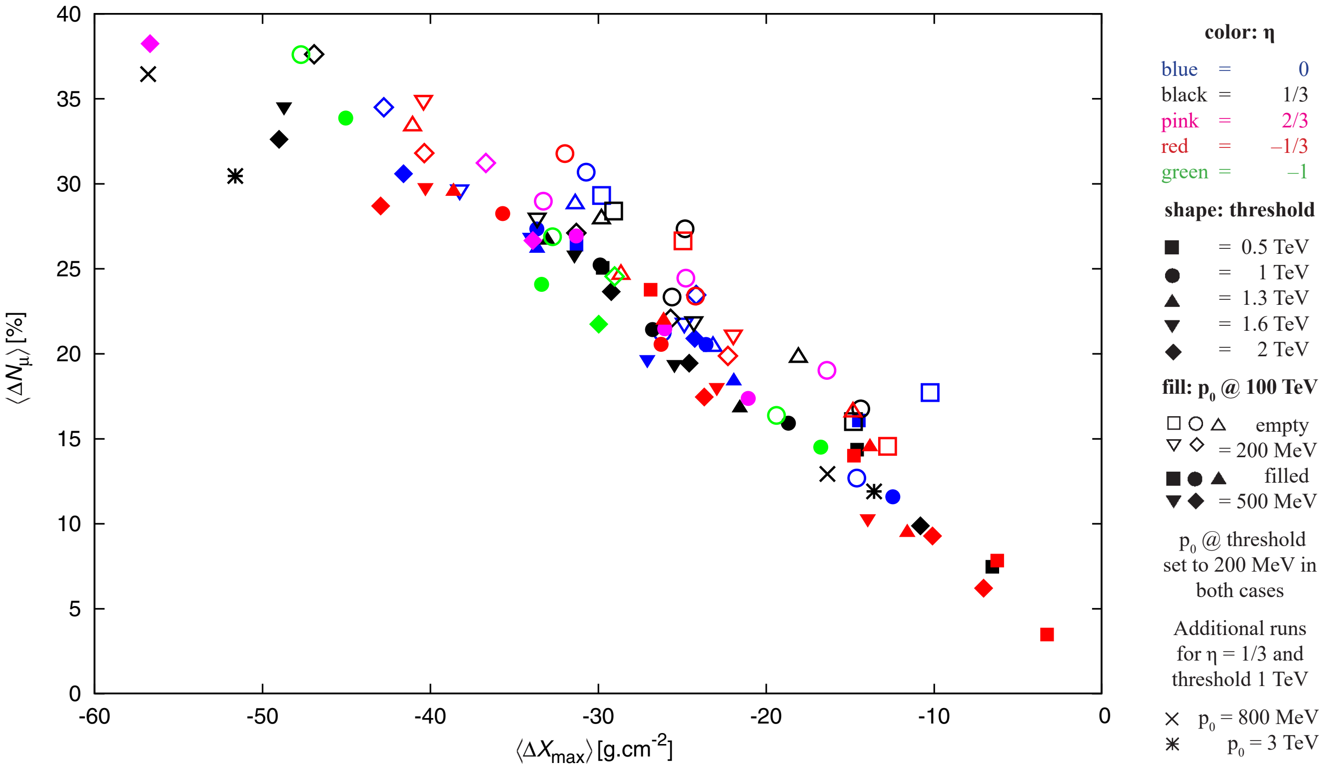
SPAM: total number of added particles



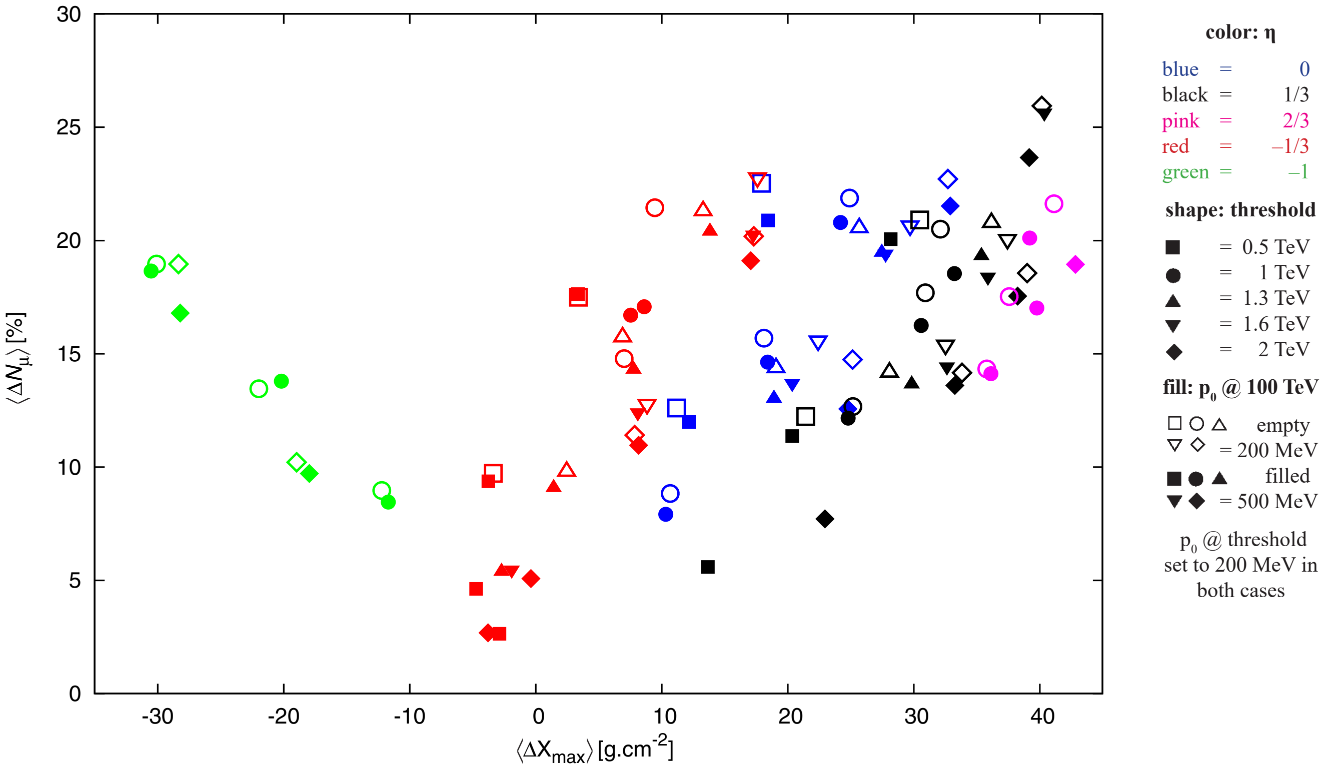
SPAM: DELPHI vs. Auger X_{max}



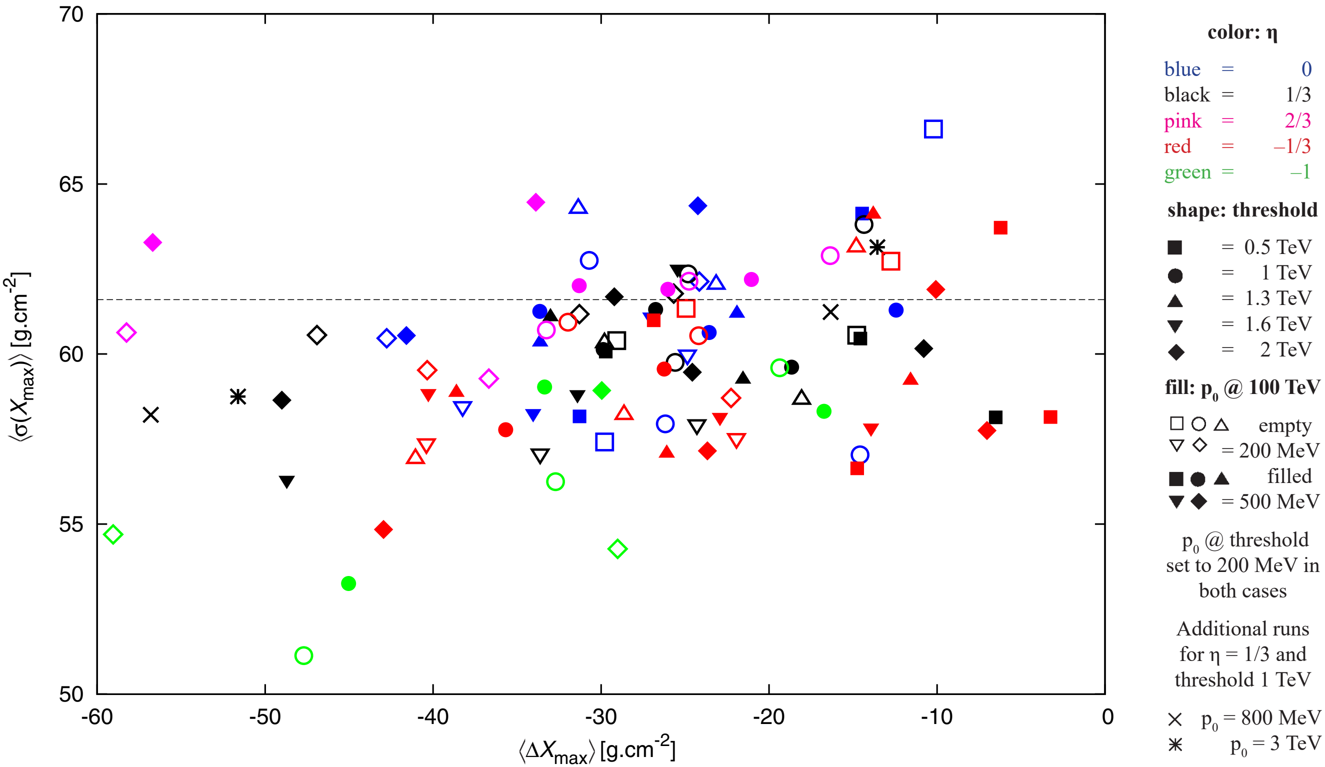
SPAM: Auger X_{max} vs. number of muons (protons)



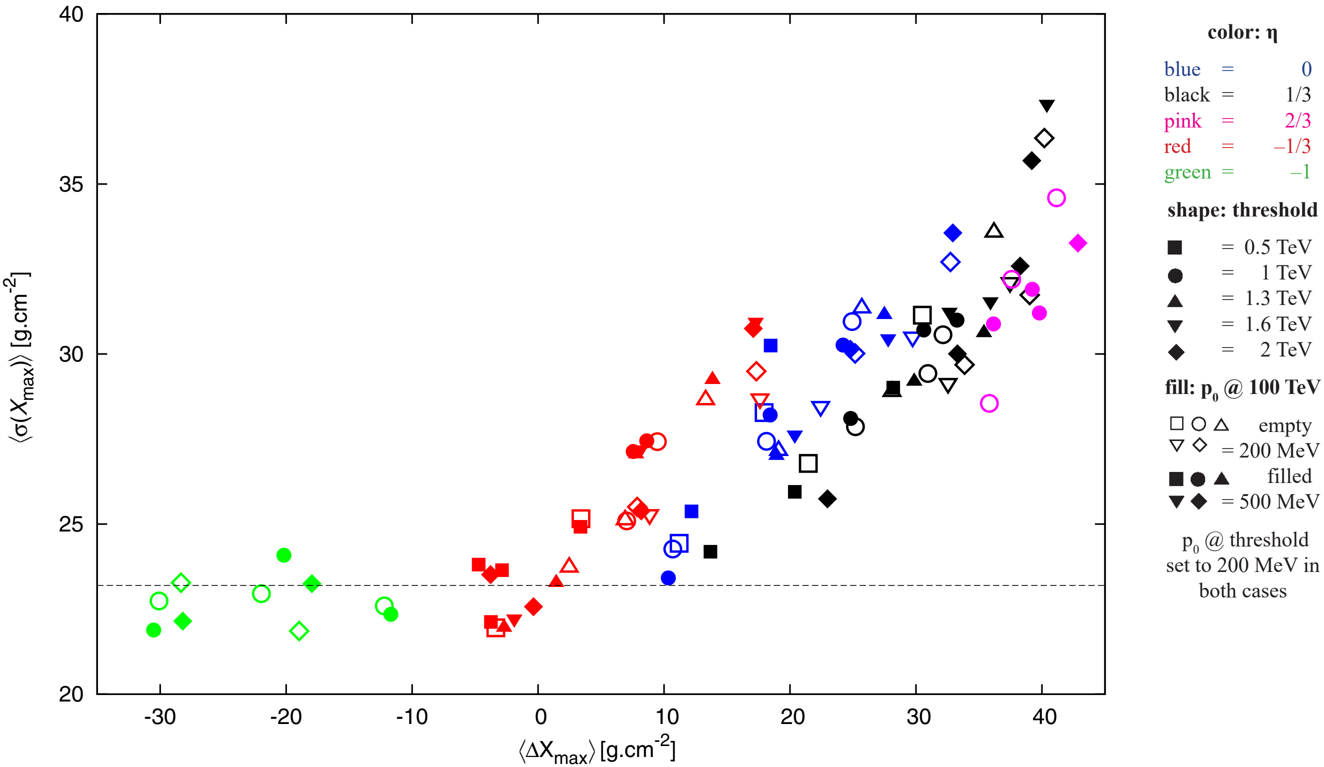
SPAM: Auger X_{max} vs. number of muons (irons)



SPAM: Auger X_{max} vs. RMS (protons)



SPAM: Auger X_{max} vs. RMS (irons)



CORSIKA simulations

- (part of) Prague ~8000 CPU cluster
  - long development of SPAM -> many centuries of CPU time
- own utility to manage simulations:
  - ~300 lines of Pascal
  - produce steering files from table, babysit the jobs
  - CORSIKA steering format easy to generate from any software
  - switch to HTCondor -> a lot of funcitons obsolete
- DELPHI: no thinning (for muon tracking)
  - no EM cascade simulated
  - ECUTS 53.0 53.0 100.0 100.0
  - all relative to QGSJET-01 (still availabe in new CORSIKA)
- Data processed in Pascal/bash/GNUplot
  - ASCII output from CORSIKA easy to work with in any language
  - .long files a bit confusing, extraction of fluorescence profile unclear

Modifying interactions CORSIKA

- Own Fortran code within CORSIKA subroutine that calls HE model
    - let the model run, then modify produced particles
    - lower energy of all particles, add new ones (all in CMS)
    - after boost back, usually some minor imbalance
        - conserving 4-momentum in full 3D not easy
    - additional simple changes to steering code to allow own keywords
- The experiences of a very bad programmer:
    - the preprocessor system makes original source unreadable
        - work on the "-compilefile.f"
        - fast and easy to recompile, but cannot change HE model etc.
    - simplicity of Fortran code allows fast learning curve
        - particles just in an array, most variables explained in source, so implementing the actual model was rather easy
        - anything else a bit difficult - reading files, passing configuration etc...
        - lack of scoping prone to weird side effects (crashes with FLUKA)
- Data processed in Pascal/bash/GNUplot
    - ASCII output from CORSIKA easy to work with in any language
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My wishes for CORSIKA 8

- Keep providing plaintext input/output interface
  - allow the user to use the tools they like: can't foresee tastes of every user
  - simple, human-readable files have unbeatable portability
    - saving outputs only in ROOT is a terrible idea
- Allow modification of interactions by outsiders
  - easy access to secondaries and easily adding/changing/removing them
- "Easy" means being able to do it without:
  - complex C++ magic
  - using a lot of things from CORSIKA-specific framework and libraries
  - understanding details of a complex build system

- Always remember that the user may be somewhat acceptable with physics, but unimaginably bad with computers!