Hadronic interaction models for CR EAS

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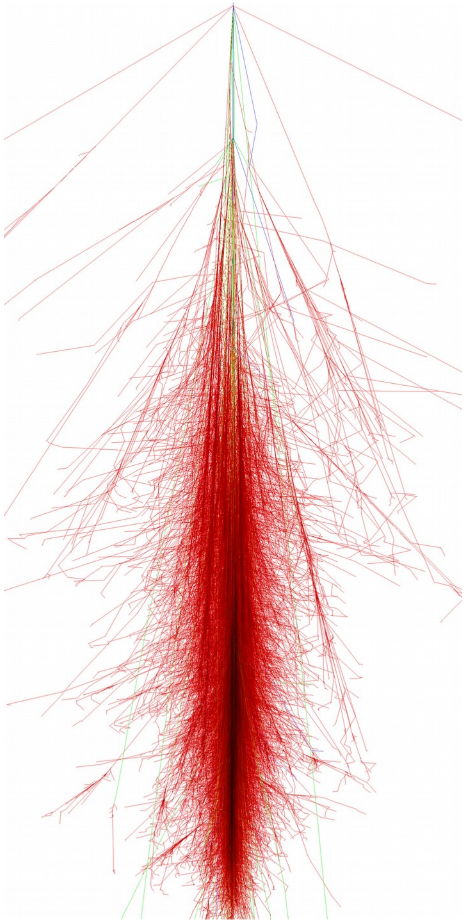
10 / 18 / 2018

CFNS workshop on Forward Physics And Instrumentation
From Colliders To Cosmic Rays

Stony Brook University

The goal: describing extensive air showers



* Many interactions → fast code

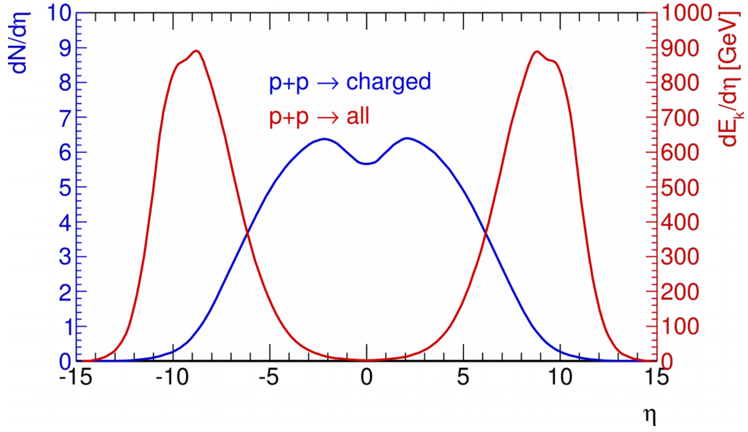
* Nuclear target

* pion & kaon interactions

* broad energy range

* very sensitive to energy flow

* average interaction



CR models

SIBYLL 2.3c (R. Engel, A. Fedynitch, T.K Gaisser, FR, T. Stanev)
- DPM based
- charm production
- phenomenologic

DPMJET III
(R. Engel, A. Fedynitch, S. Roesler, J. Ranft)
- DPM based
- photon interactions
- collective effects

QGSJET II (S. Ostapchenko)
- Gribov-Regge
- non-linear effects

EPOS LHC (H.J. Drescher, F. Liu, T. Pierog, K. Werner)
- Gribov-Regge
- collective effects

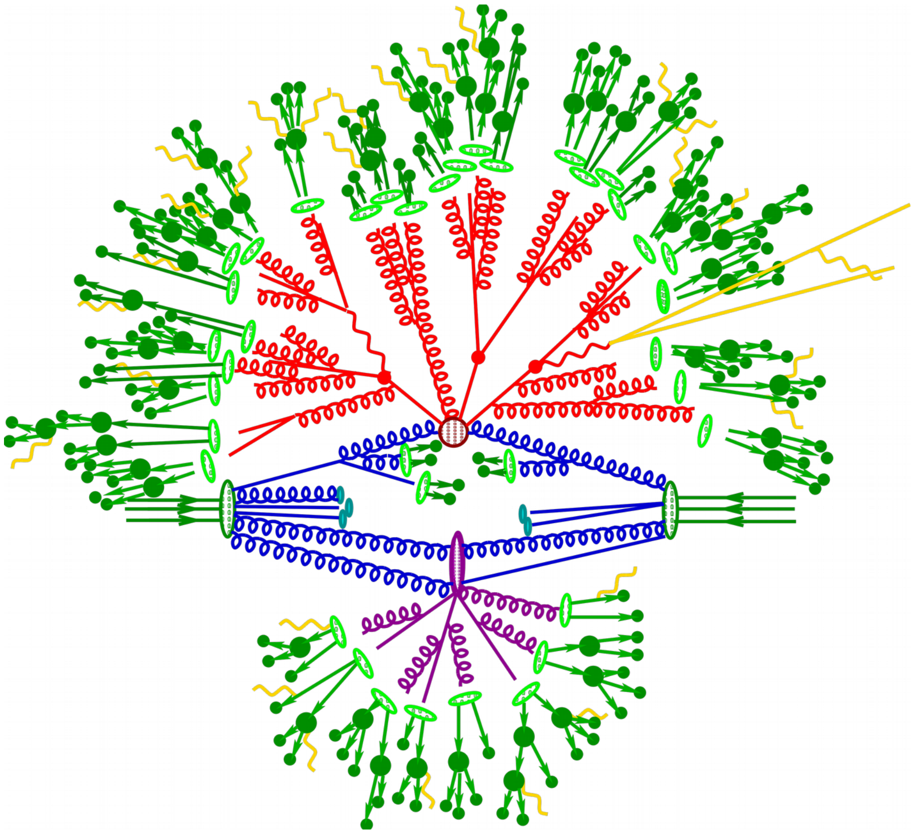
CR models: similarities

Parton picture

pQCD

String fragmentation

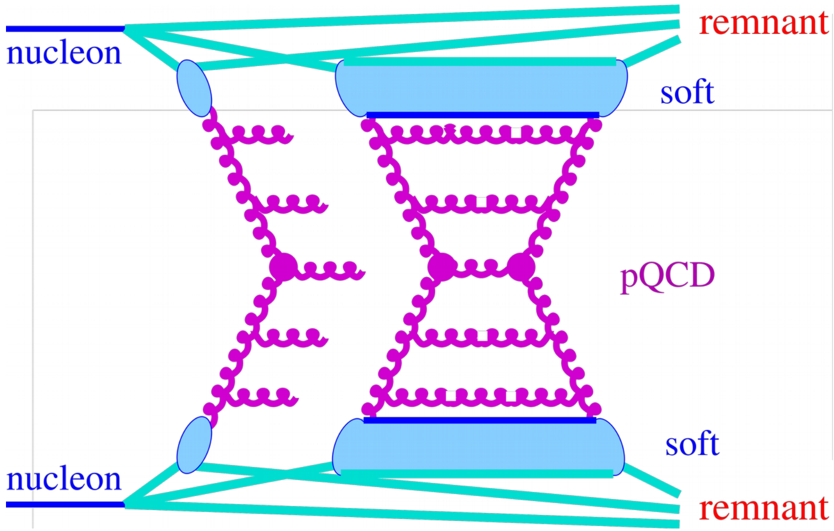
Beam remnants



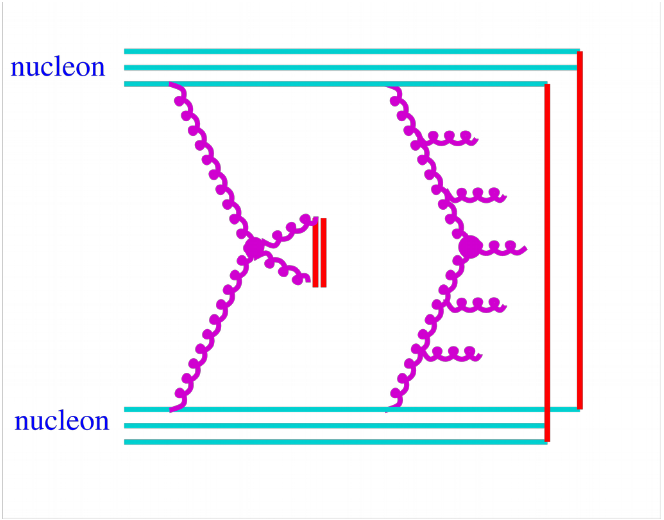
Other approaches possible:
- dipole picture (DIPSY)
- cluster fragmentation

Scattering picture

EPOS, QGSJET II

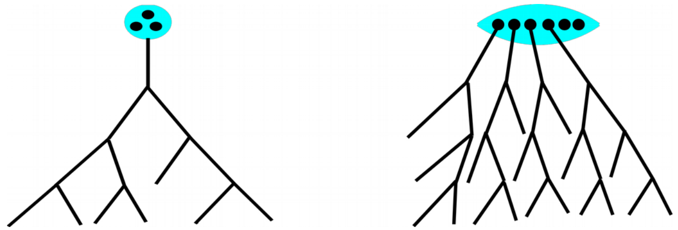


SIBYLL

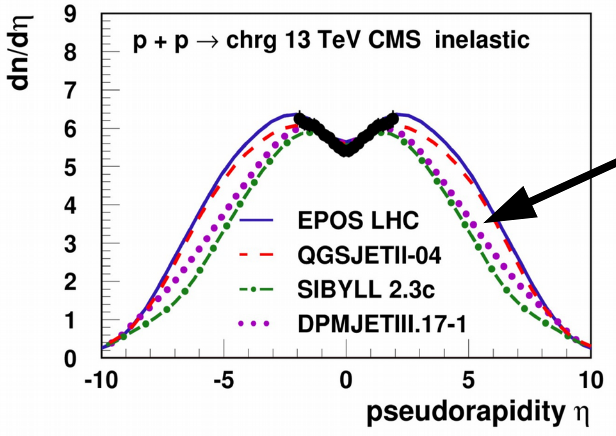


CR models: differences I

* amplitude definition:
    factorization or full Gribov-Regge

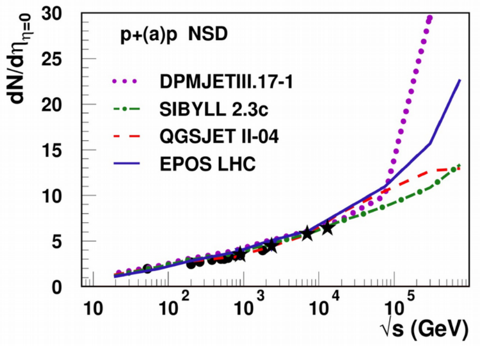


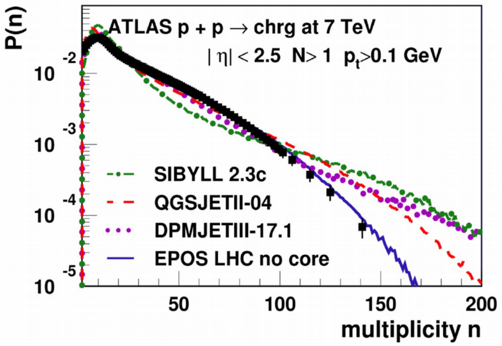
(Ostapchenko et al. 1608.07791)



?

* energy evolution, saturation behavior:
    pT/Q0 cut or non-linear effects,
    impact parameter dependence





CR models: differences II

SIBYLL
h+A(<18)

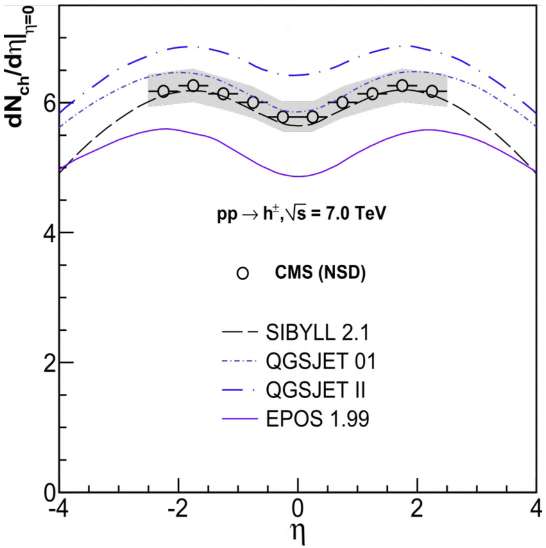
DPMJET (h+A,γ+A, A+A)
QGSJET II (h+A,A+A)

EPOS (h+A,γ+A, A+A)

Complexity, runtime, #parameters, #data

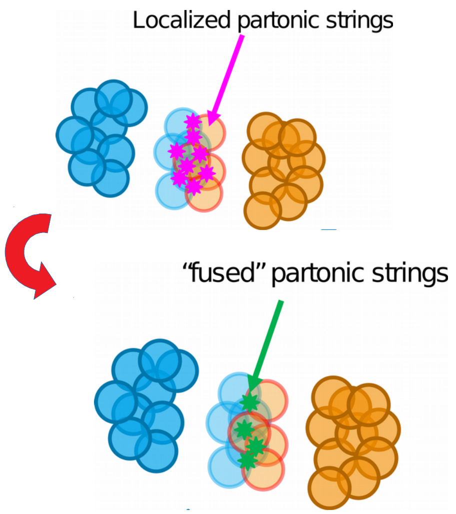
Performance:

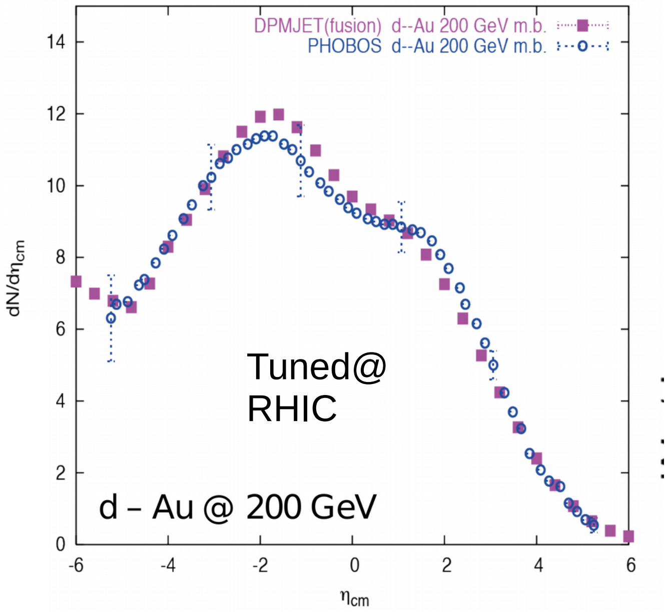
TeVatron tunes!

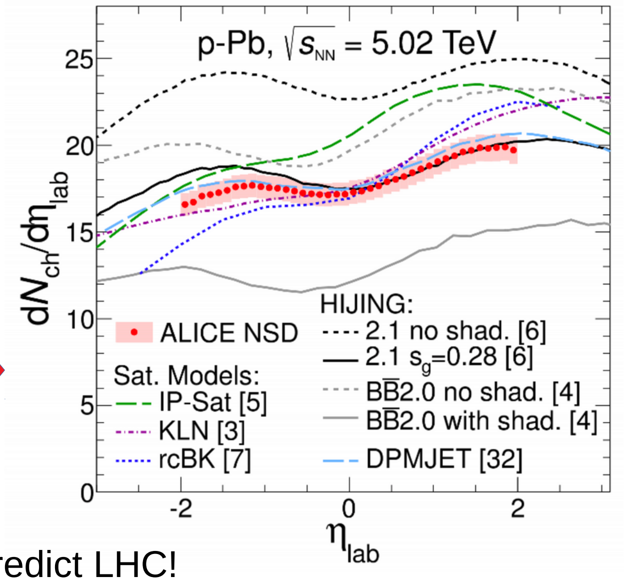


RHIC impact I

Example: fusion in DPMJET







Predict LHC!

F.W.Bopp, J. Ranft, R.Engel, S.Roesler
arXiv:hep-ph/0403084v1

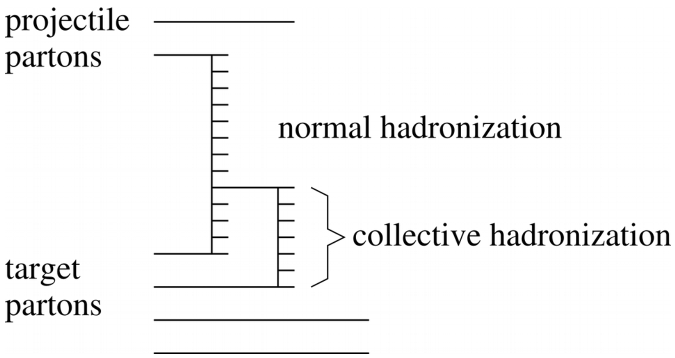
ALICE Coll.,PRL 110, 032301 (2013)

RHIC impact II

Example: parton ladder splitting in EPOS

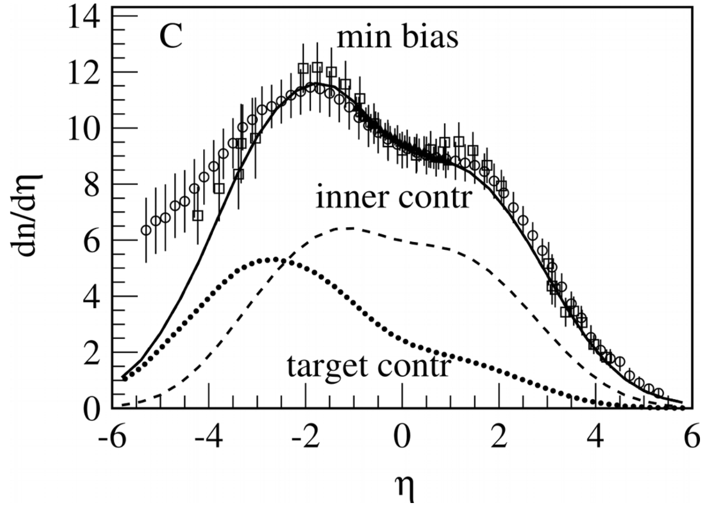
(Werner et al.,
Phys.Rev. C 74, 044902 (2006)

tuned@RHIC



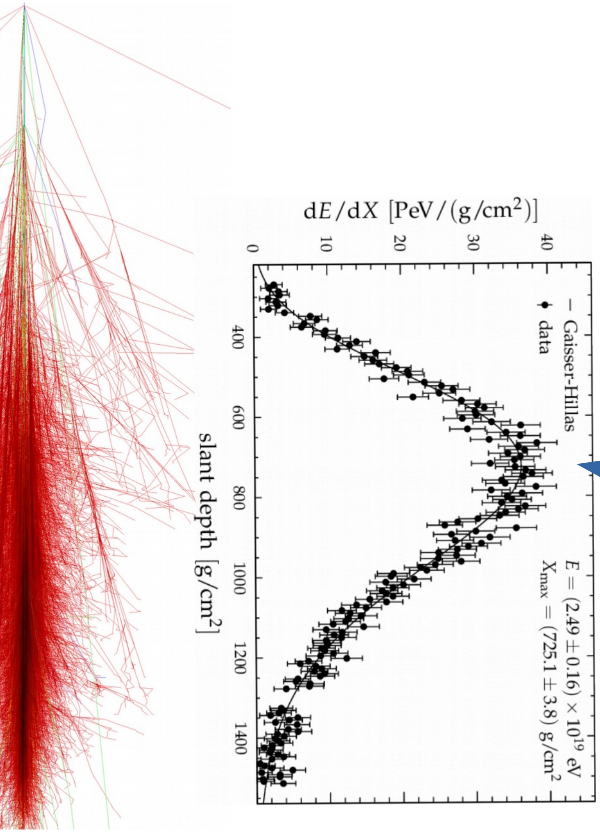
Coeff cient	Corresponding variable	Value
s_M	Minimum squared screening energy	$(25\ \mathrm{GeV})^2$
w_M	Def nes minimum for Z_0	6.000
w_Z	Global Z coeff cient	0.080
w_B	Impact parameter width coeff cient	1.160
a_S	Soft screening exponent	2.000
a_H	Hard screening exponent	1.000
a_T	Transverse momentum transport	0.025
a_B	Break parameter	0.070
a_D	Diquark break probability	0.110
a_S	Strange break probability	0.140
a_P	Average break transverse momentum	0.150

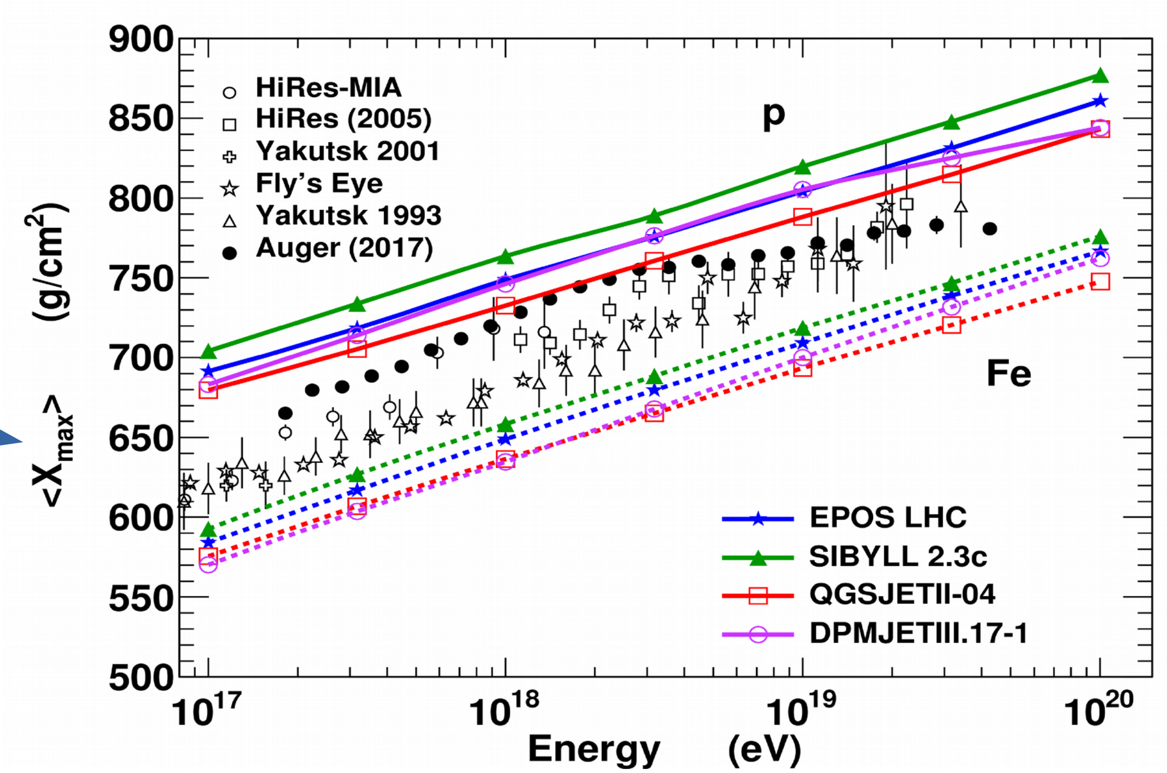
New parameters



Air shower performance

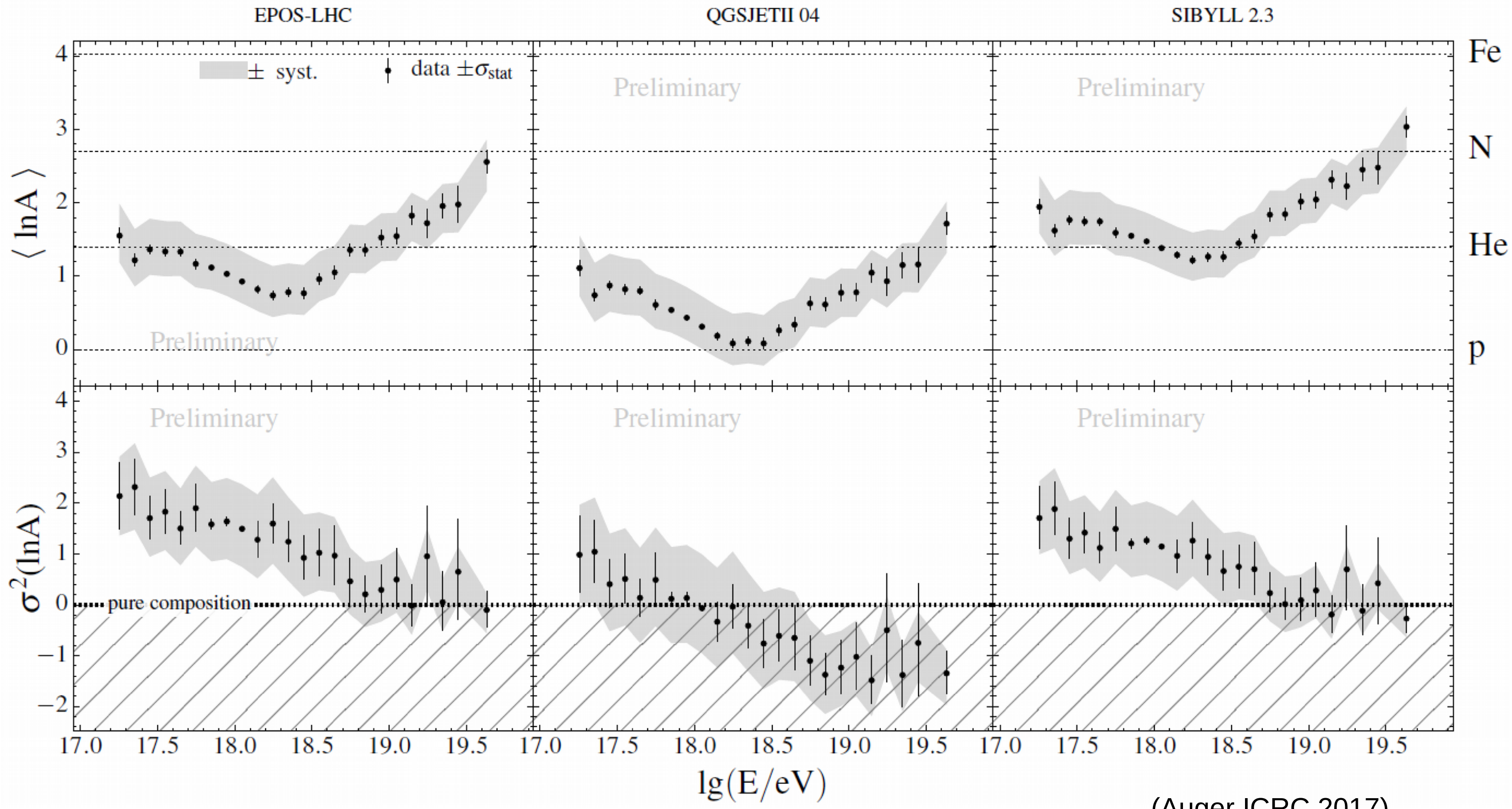
Does it matter? EAS performance





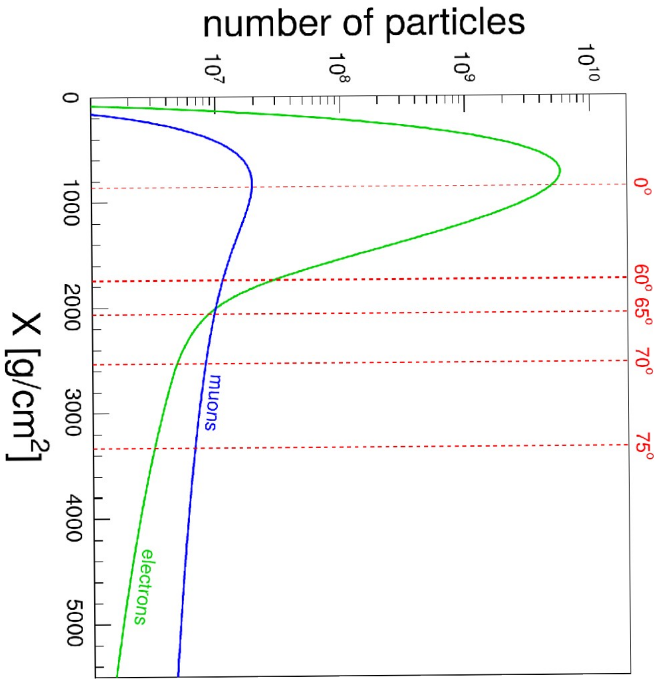
Maybe!

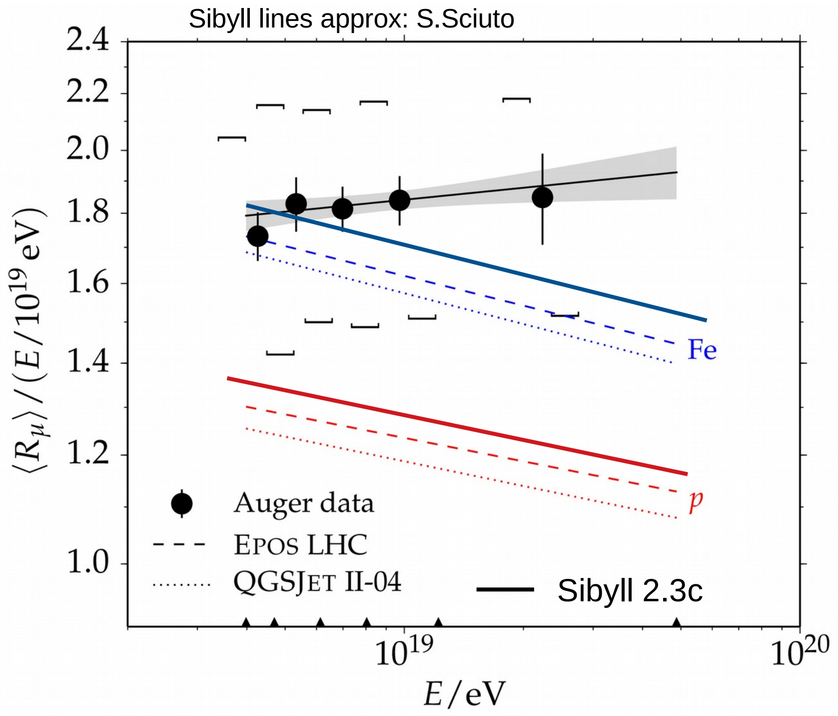
EAS performance: consistency



(Auger ICRC 2017)

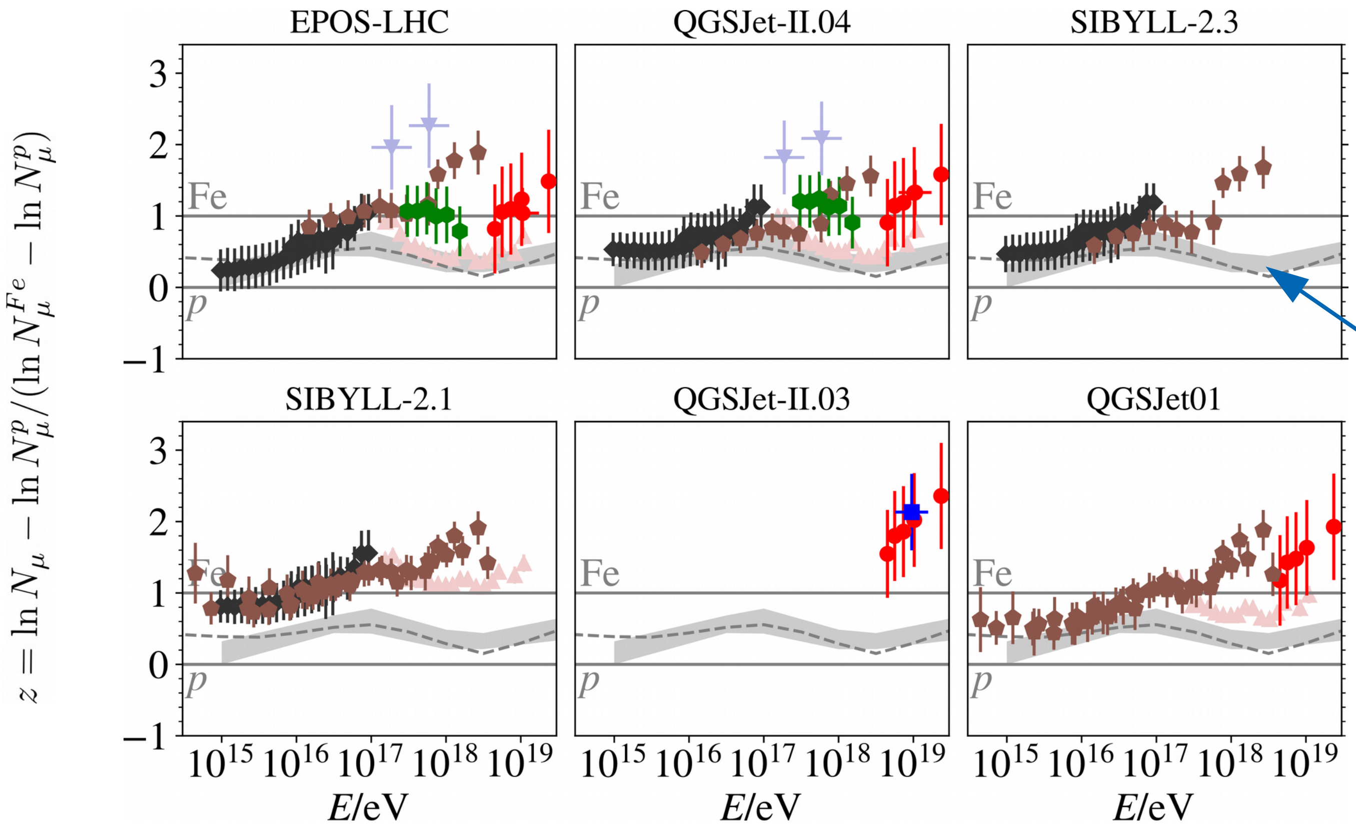
EAS performance: muons





(Auger, Phys. Rev. D, 91, 032003 (2015))

Problem universal?

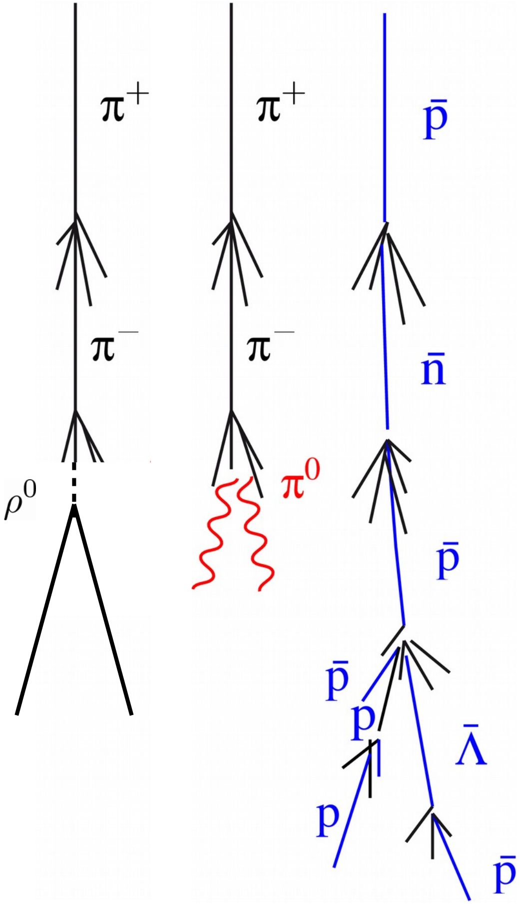


energy scale included

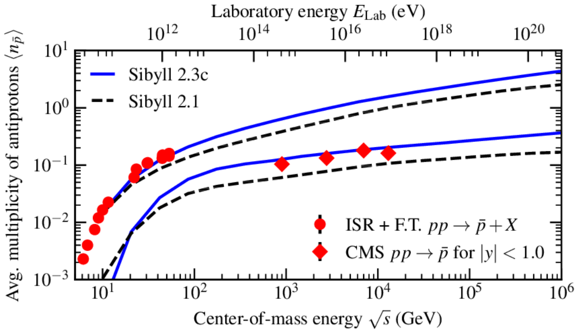
Expectation from CR beam composition

(Hadronic Interactions WG at UHECR meeting)

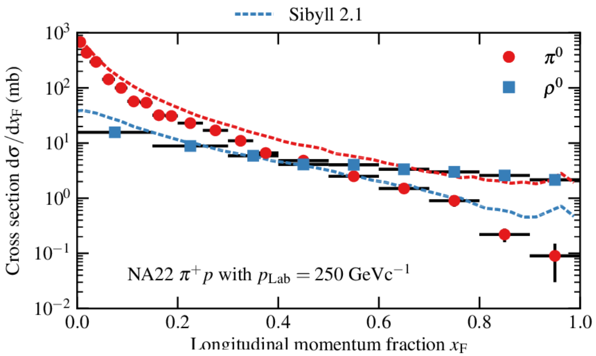
Solution? rho0/pbar in pion interactions

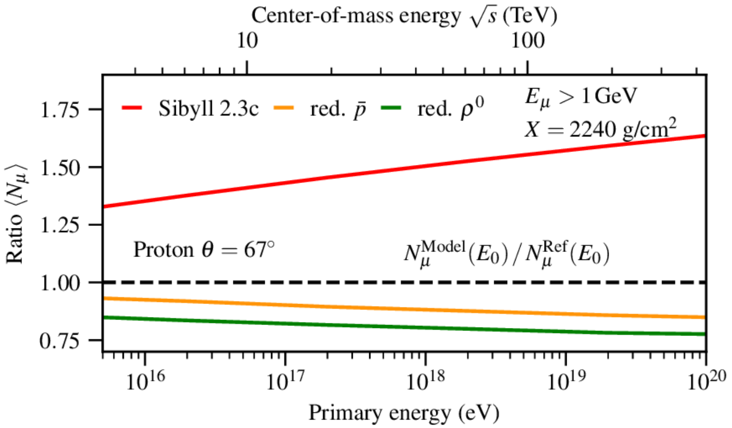


* Baryon production

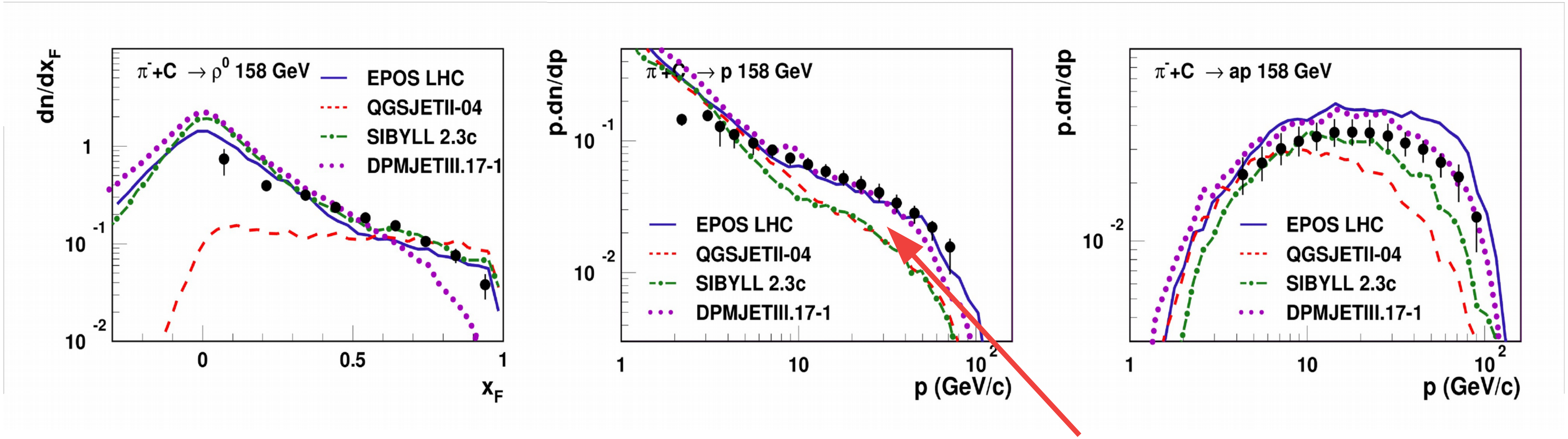


* leading rho0





NA61

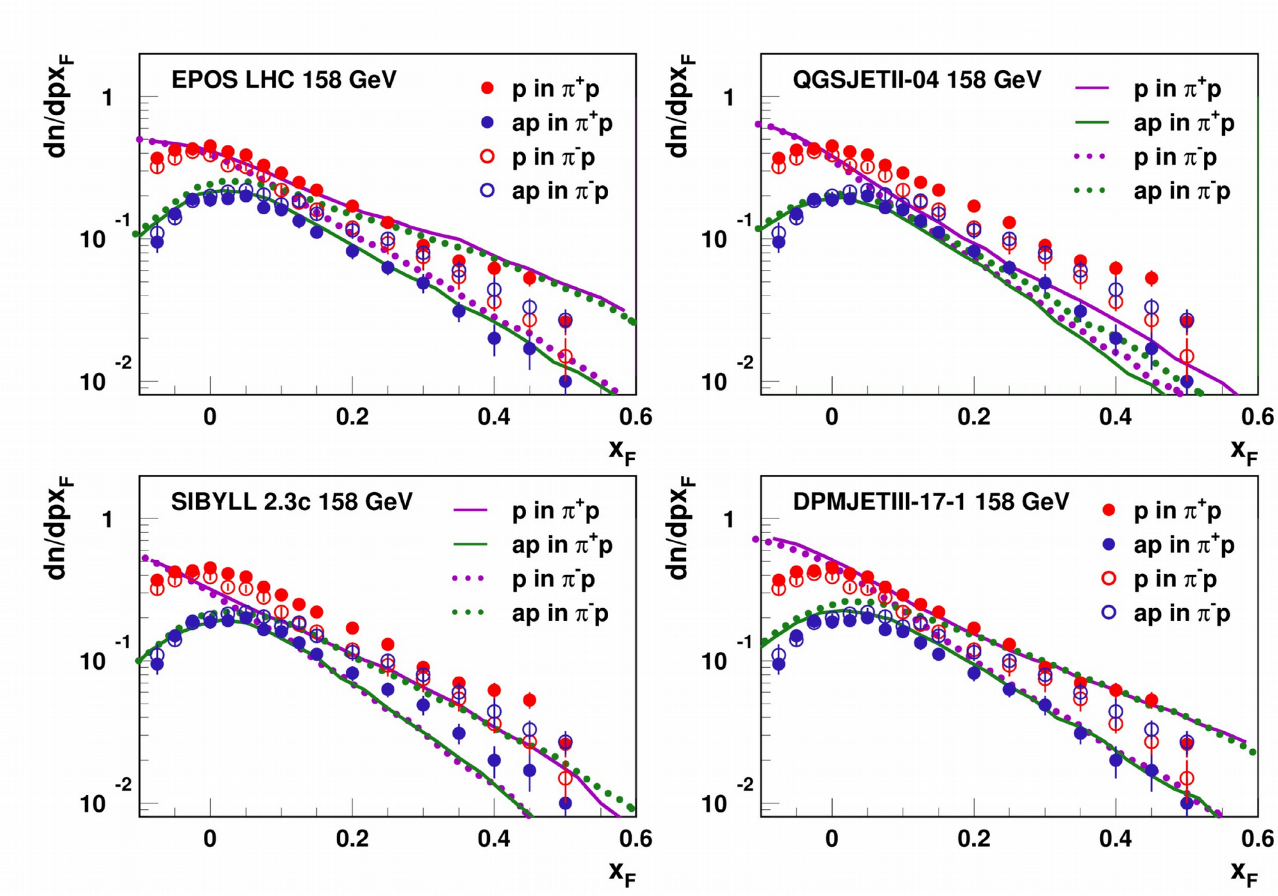


π^-+C $\rightarrow \rho^0$ 158 GeV
dn/dx$_F$
x$_F$
EPOS LHC
QGSJETII-04
SIBYLL 2.3c
DPMJETIII.17-1
π^-+C $\rightarrow$ p 158 GeV
p.dn/dp
p (GeV/c)
EPOS LHC
QGSJETII-04
SIBYLL 2.3c
DPMJETIII.17-1
π^-+C $\rightarrow$ ap 158 GeV
p.dn/dp
p (GeV/c)
EPOS LHC
QGSJETII-04
SIBYLL 2.3c
DPMJETIII.17-1

Enough ?

NA49

‘Baryon stopping’



Unpublished,
G. Veres thesis

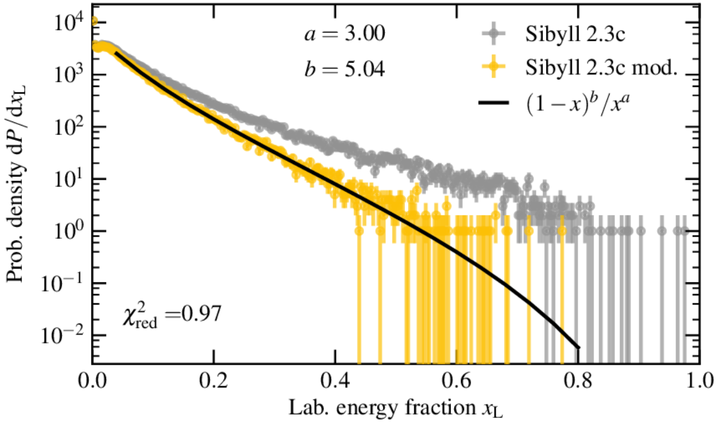
Confirmation?

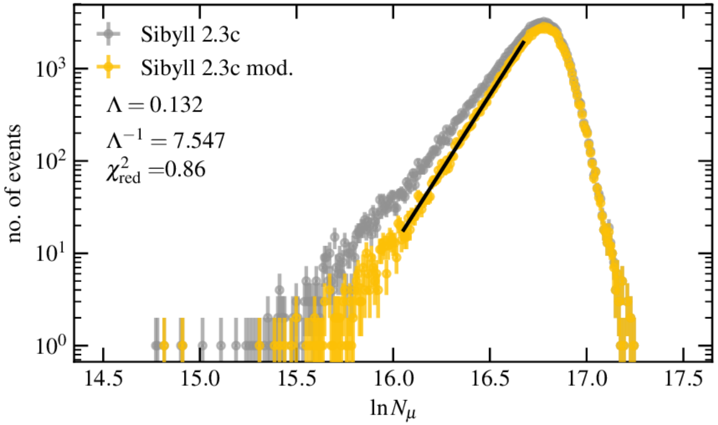
$$\gamma^* + A$$

Future: measure pion spectrum in EAS

Inclusive production cross section

$$p + Air \rightarrow \pi^0 + X$$





(L. Cazon, R. Conceicao, FR, work ongoing)

Slope of muon distribution == Shape of inclusive production cross section at high-xF !

Summary: its difficult

* EAS particular requirements
* models of different complexity → include different exp. Data

* RHIC measurements essential for A-A models

* generally models perform well on accelerator data, Min Bias

BUT:
* no model entirely consistent with CR measurements !
 → in particular: muon production → low energy interactions

* too few measurements of pion interactions
* no light nuclei!

way forward ==> more data, EAS and accelerator

Decide: Models incomplete? Or not tuned well enough