SIBYLL 2.3c

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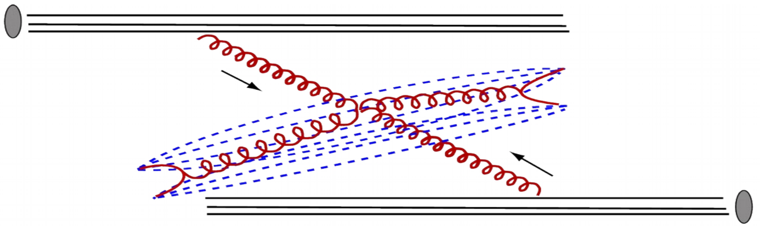
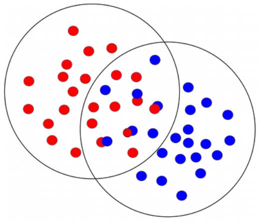
ICRR workshop, 25.03.2019

Interactions in SIBYLL

Hard & soft scattering

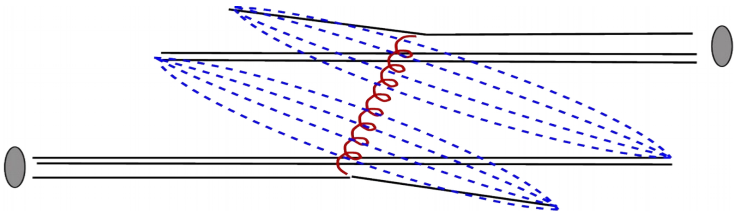


* parton picture
* LO QCD jets → minijets
* Multiparticle interactions



* diffraction dissociation
* leading particles, assoc. production

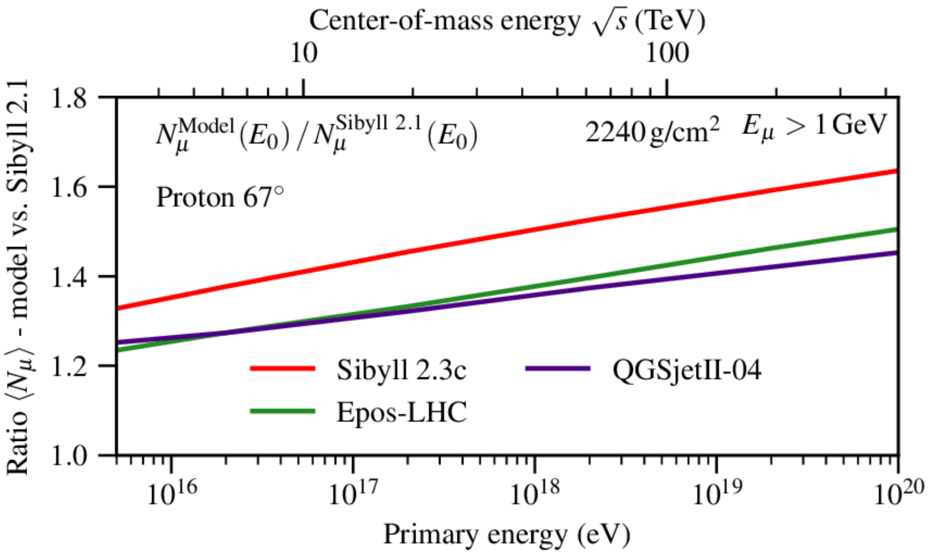
soft



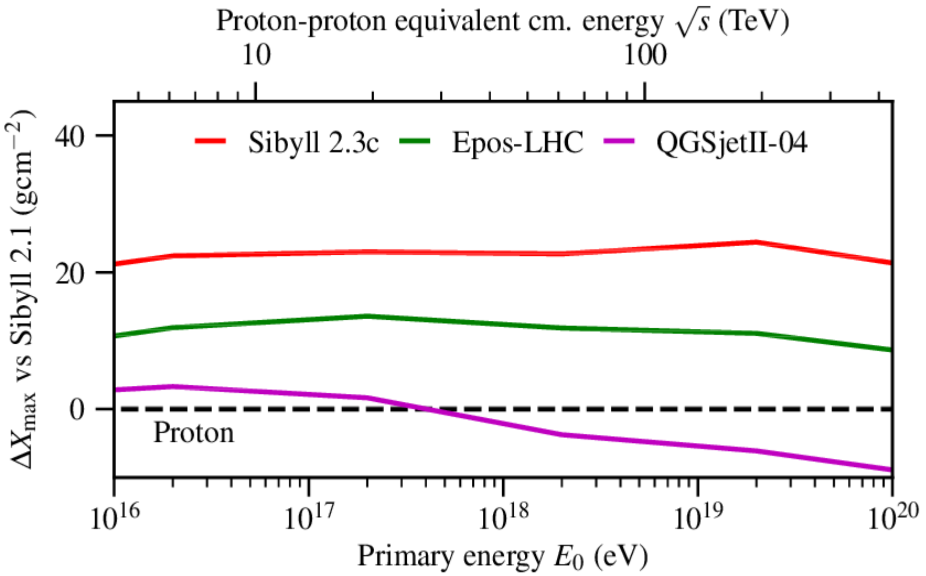
For more: Sibyll 2.1 (PRD 80 094003 (2009))

Sibyll 2.3c predictions

N_μ

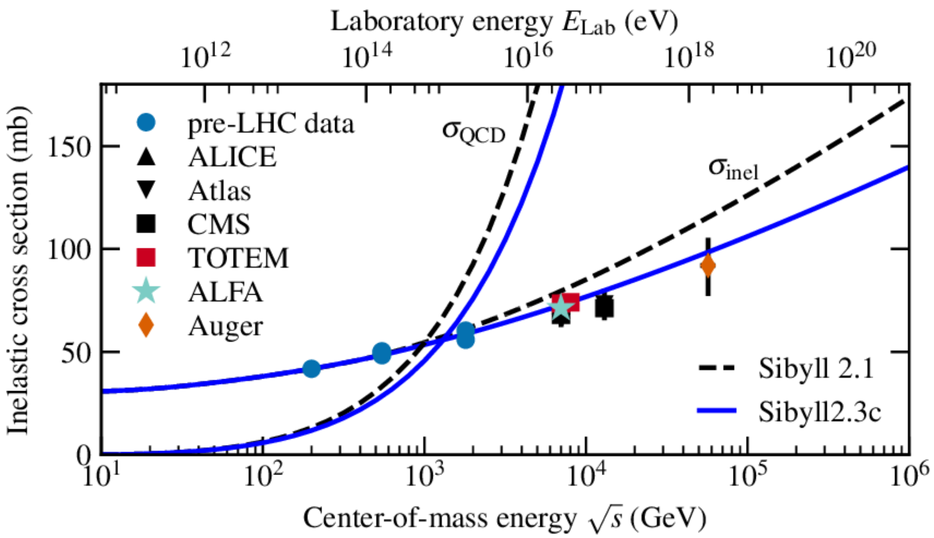


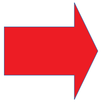
$X_{\max}$

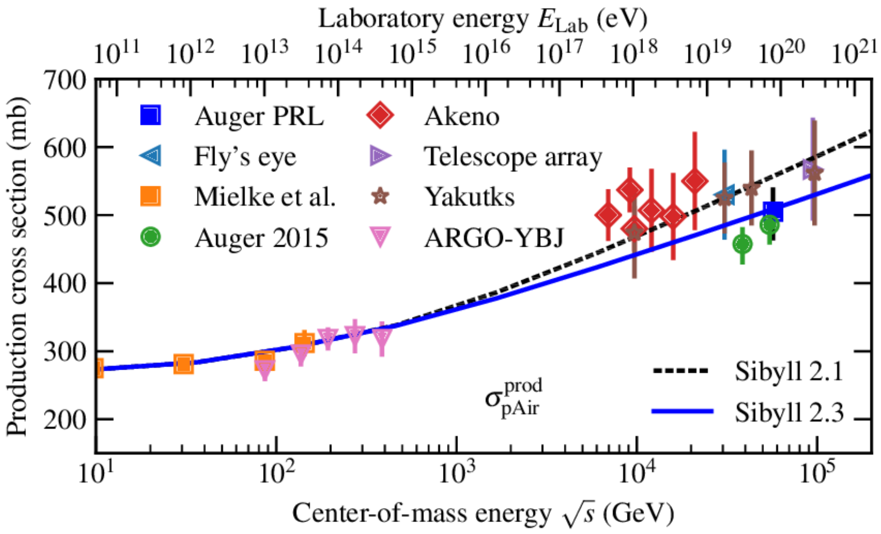


How ? / Whats new

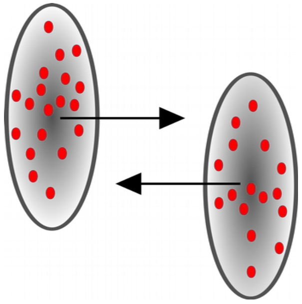
Cross section: p-p





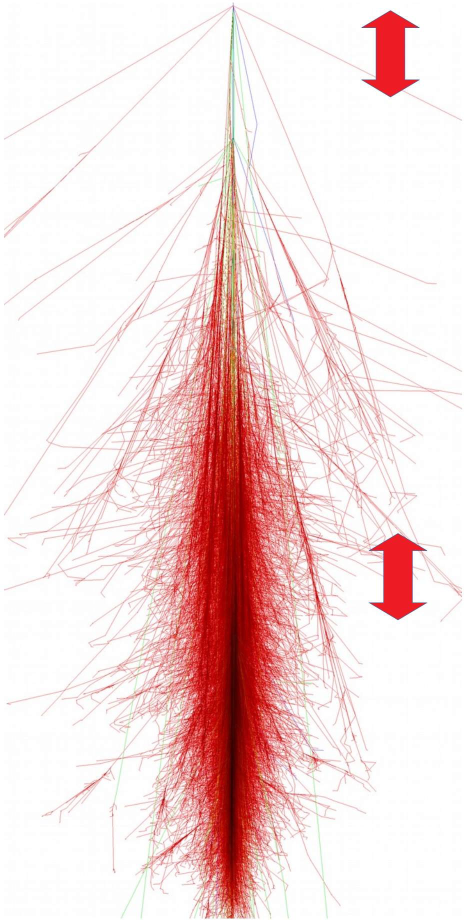


Sibyll 2.1 from 2001
(TeVatron)



- narrow hadron profile
- increase soft-hard threshold

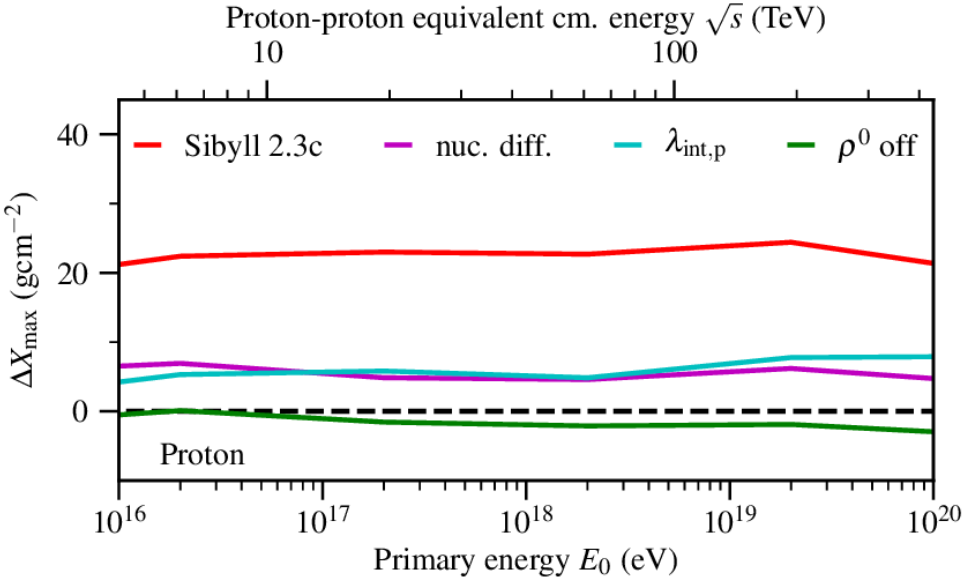
Xmax



* p-p cross section reduced

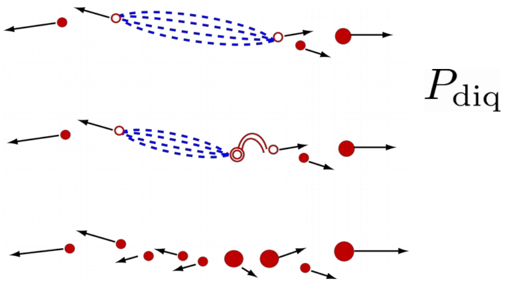
* p-air cross section reduced

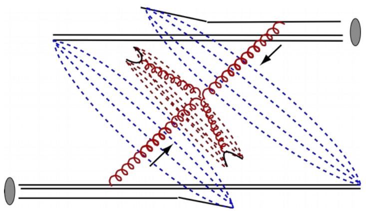
* p-air diffraction increased
  (coherent diffraction)

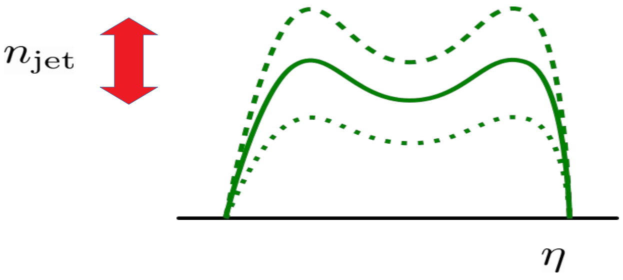


→ 20 g/cm**2 deeper proton shower

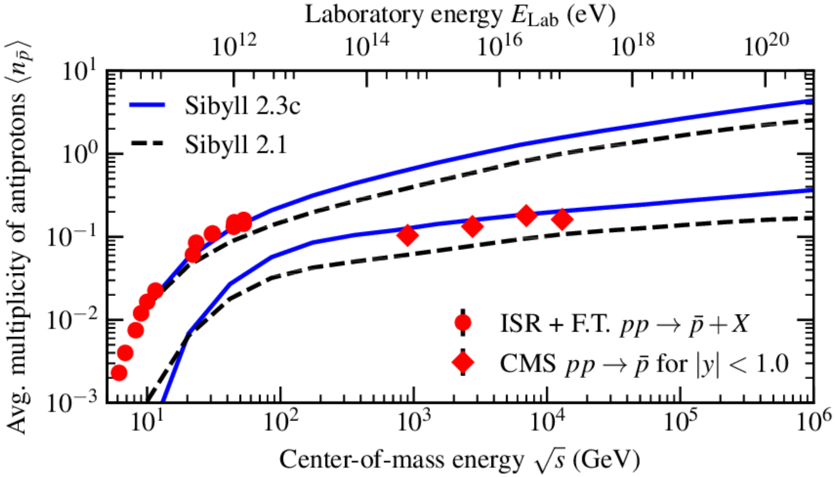
Baryon production

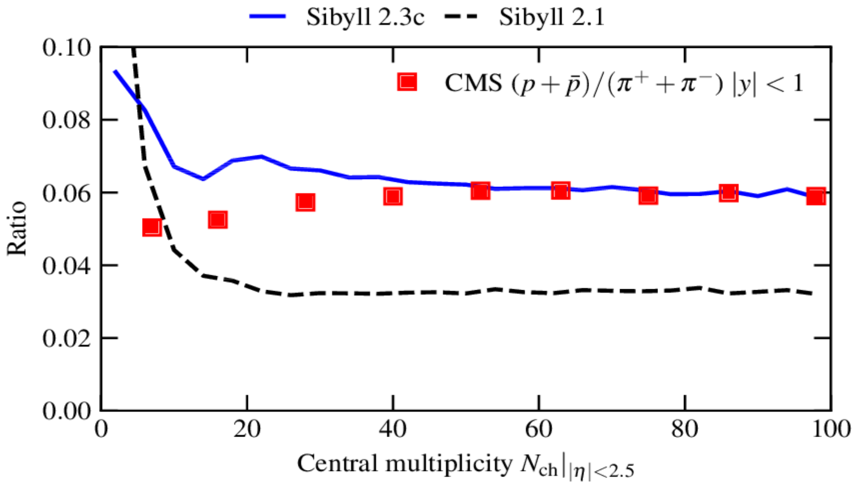






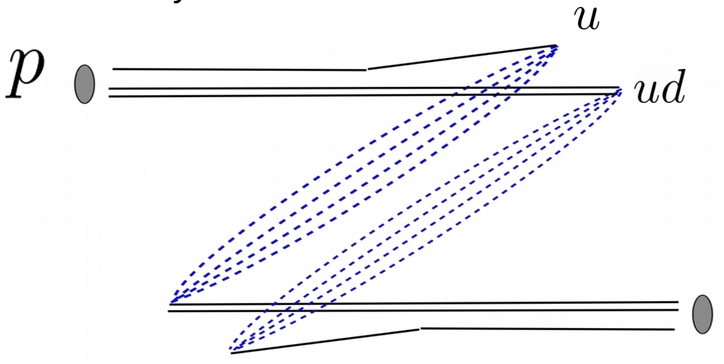
Different hadronisation





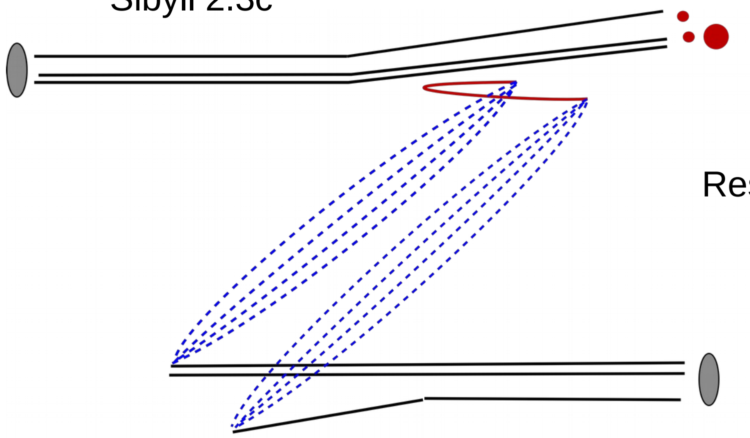
Remnants

Sibyll 2.1



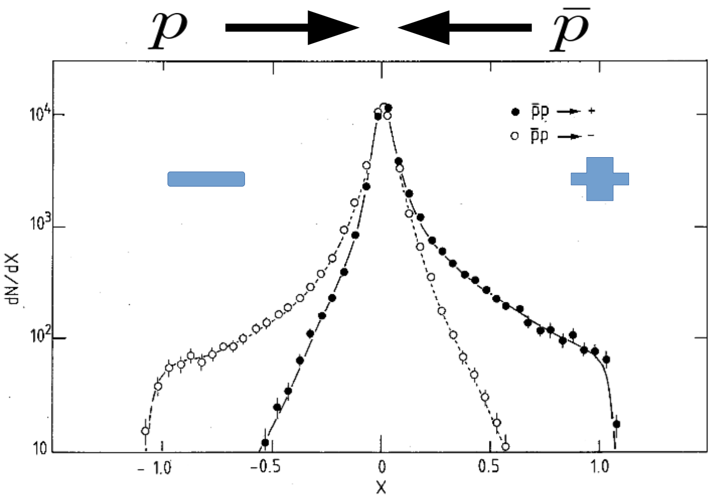
continuum

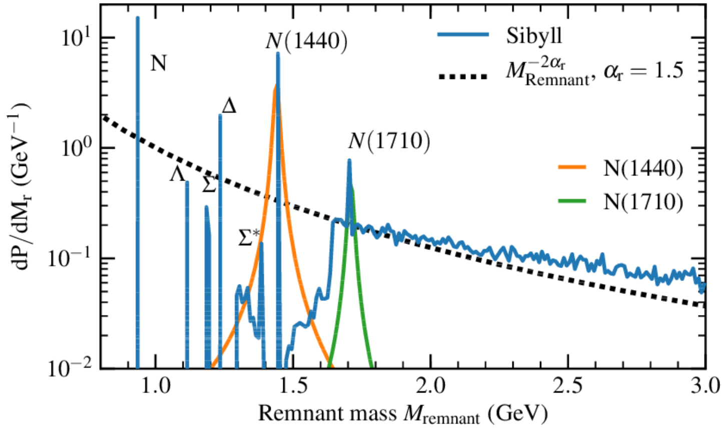
Sibyll 2.3c



Resonances
+ continuum

Breakstone et al. (Phys.Lett. B132 (1983) 458)

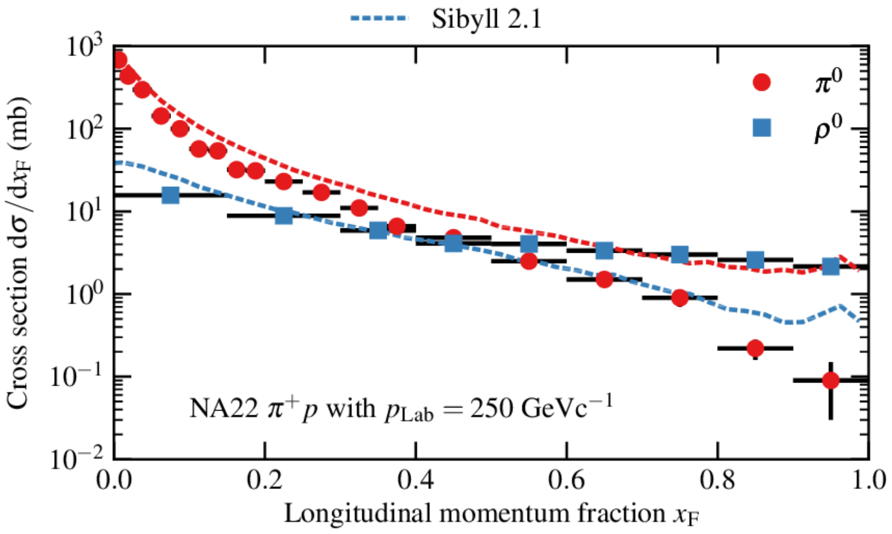


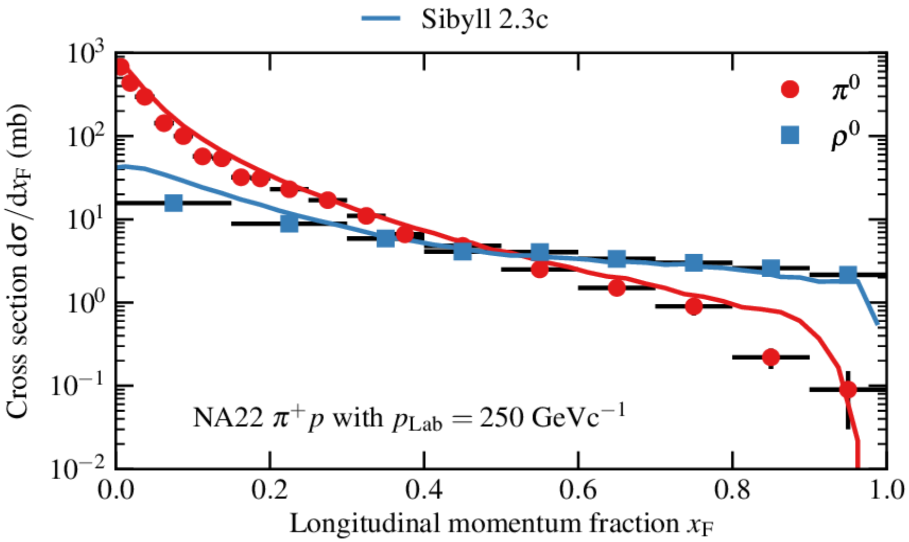


Leading particles

$\pi^+ + p \;\rightarrow\; \text{leading} + X$

$\text{leading} : \pi, \;\; \rho$



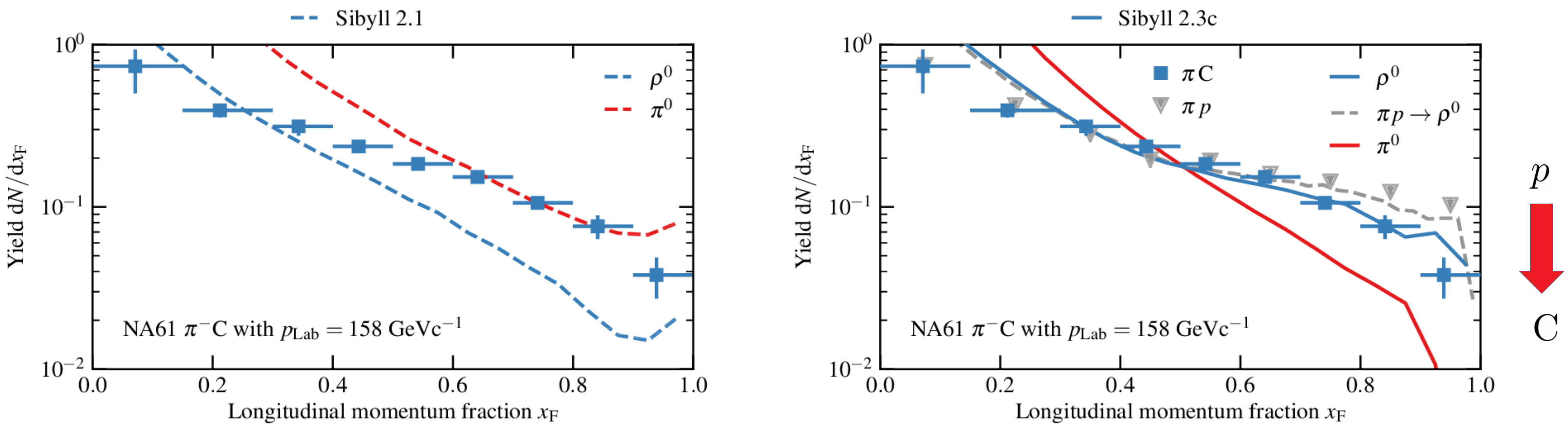


$P_{\pi:\rho} = 1/3$

$\pi\text{Air?}$

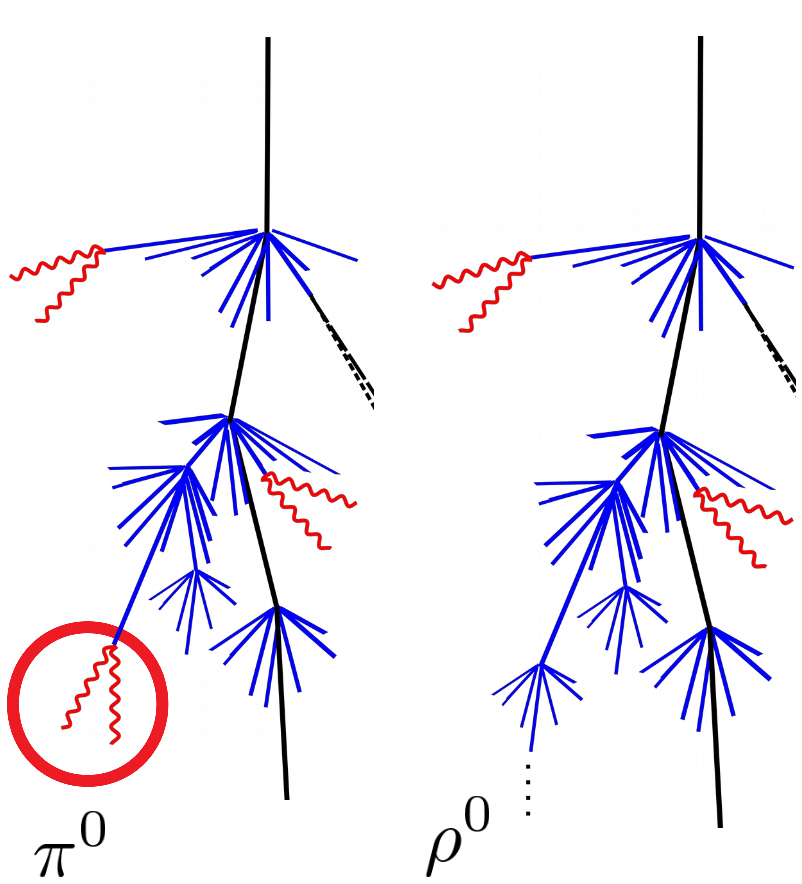
Leading particles

$\pi^+ + \mathrm{C} \rightarrow \text{leading} + X$

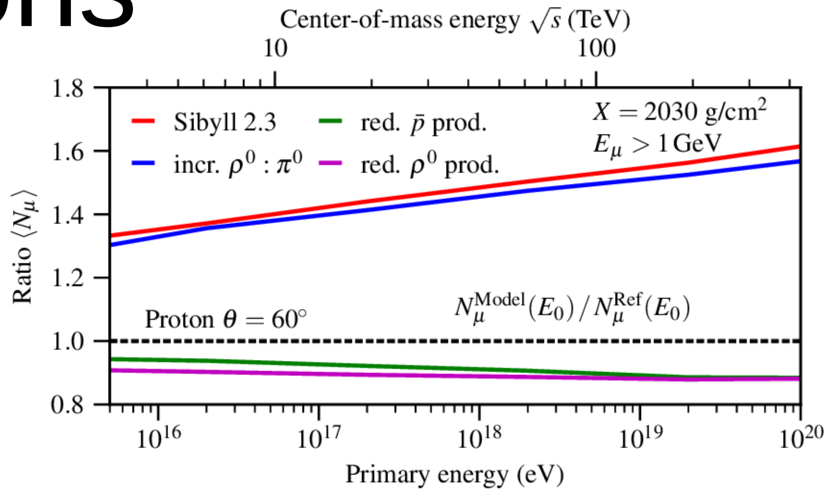


P → C transition reproduced

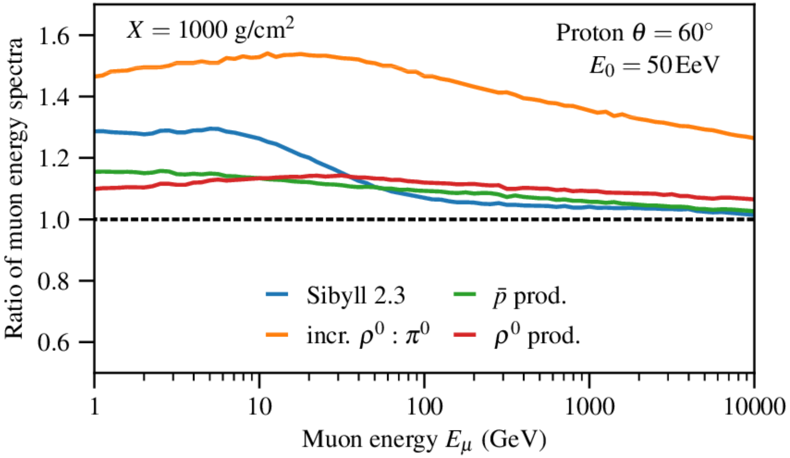
Muons



π^0
ρ^0



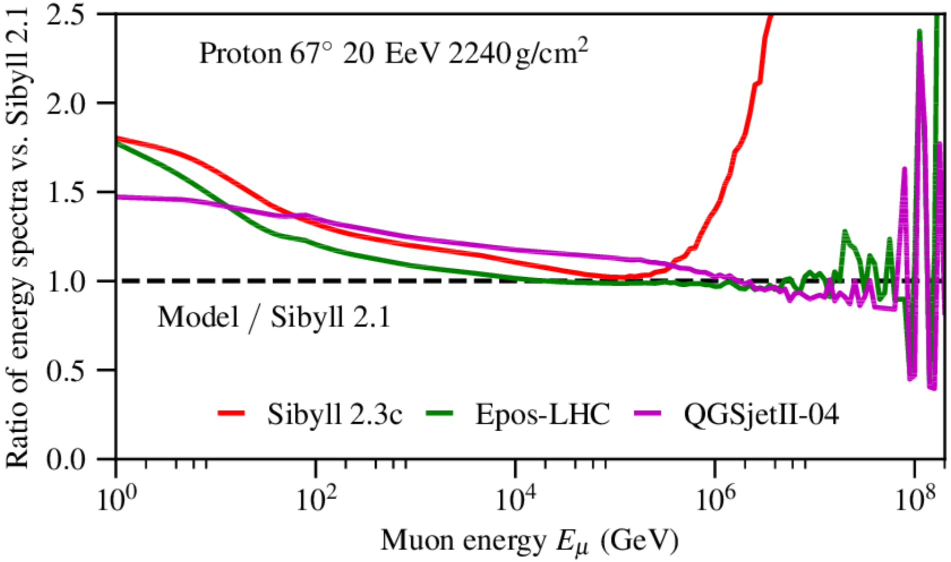
Center-of-mass energy $\sqrt{s}$ (TeV)
10
100
Sibyll 2.3
incr. $\rho^0 : \pi^0$
red. $\bar{p}$ prod.
red. ρ^0 prod.
$X = 2030$ g/cm^2
$E_\mu > 1$ GeV
Ratio $\langle N_\mu \rangle$
Proton $\theta = 60°$
$N_\mu^{\mathrm{Model}}(E_0) / N_\mu^{\mathrm{Ref}}(E_0)$
1.8
1.6
1.4
1.2
1.0
0.8
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
Primary energy (eV)



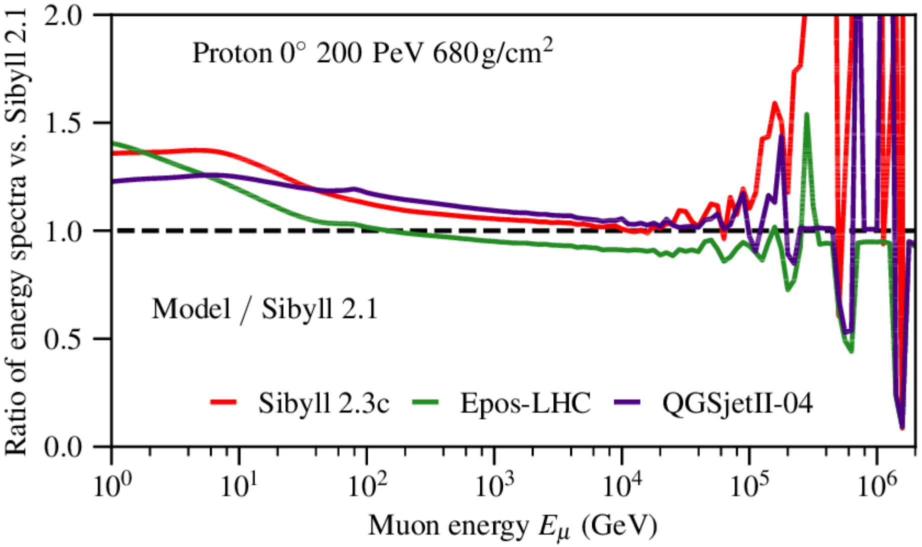
$X = 1000$ g/cm^2
Proton $\theta = 60°$
$E_0 = 50$ EeV
Ratio of muon energy spectra
1.6
1.4
1.2
1.0
0.8
0.6
Sibyll 2.3
incr. $\rho^0 : \pi^0$
$\bar{p}$ prod.
ρ^0 prod.
1
10
100
1000
10000
Muon energy E_μ (GeV)

Muon energy spectrum

Auger



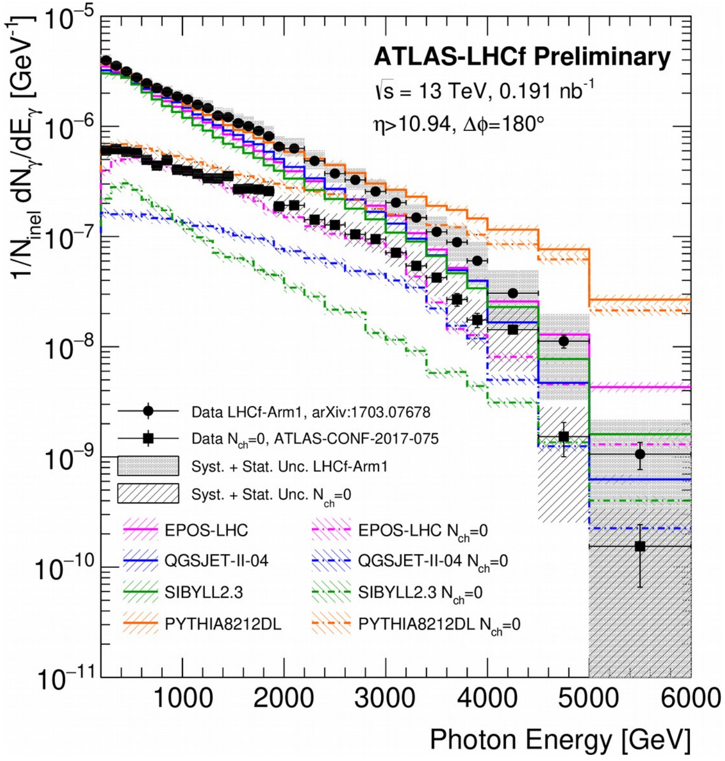
IceTop



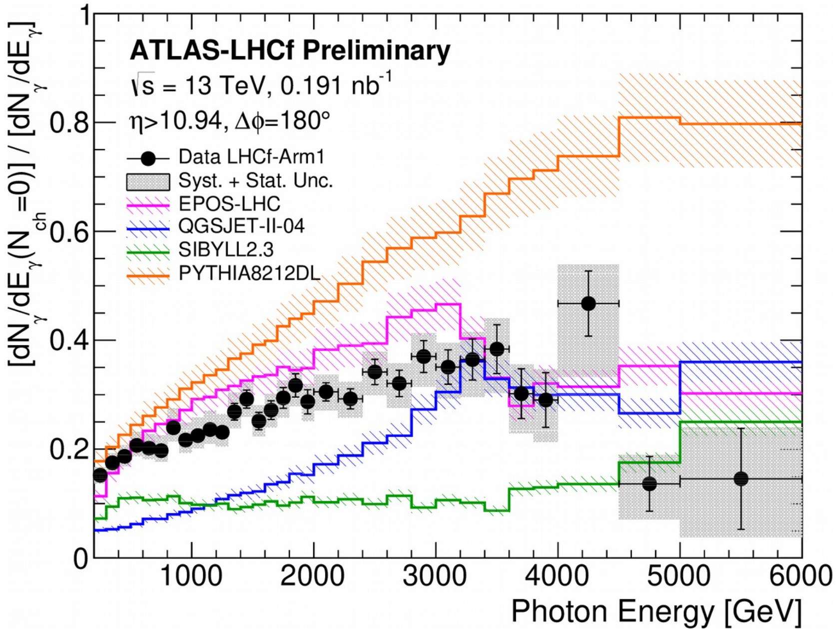
Beyond Sibyll 2.3c ..

future challenges a.k.a problems

LHCf: Forward photons

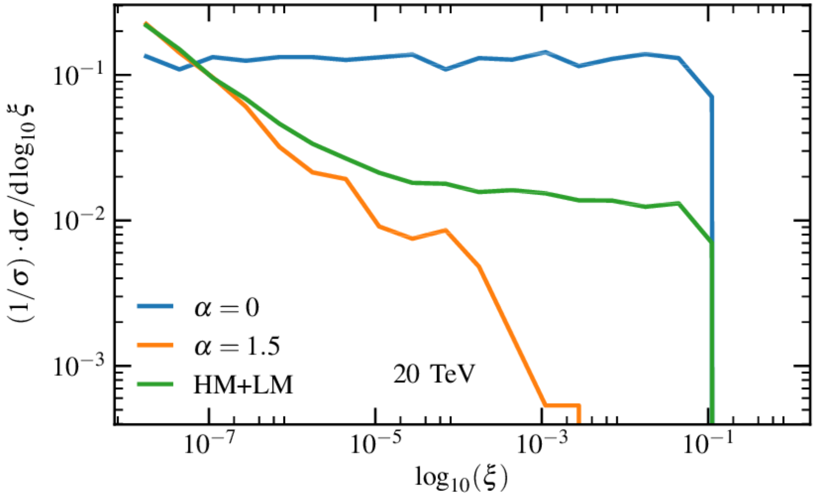


LHCf + ATLAS veto



(Quidong Zhou et al.)

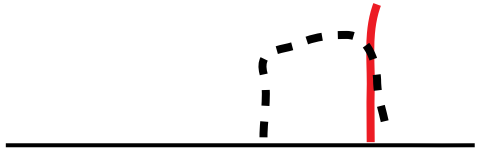
Diffractive mass



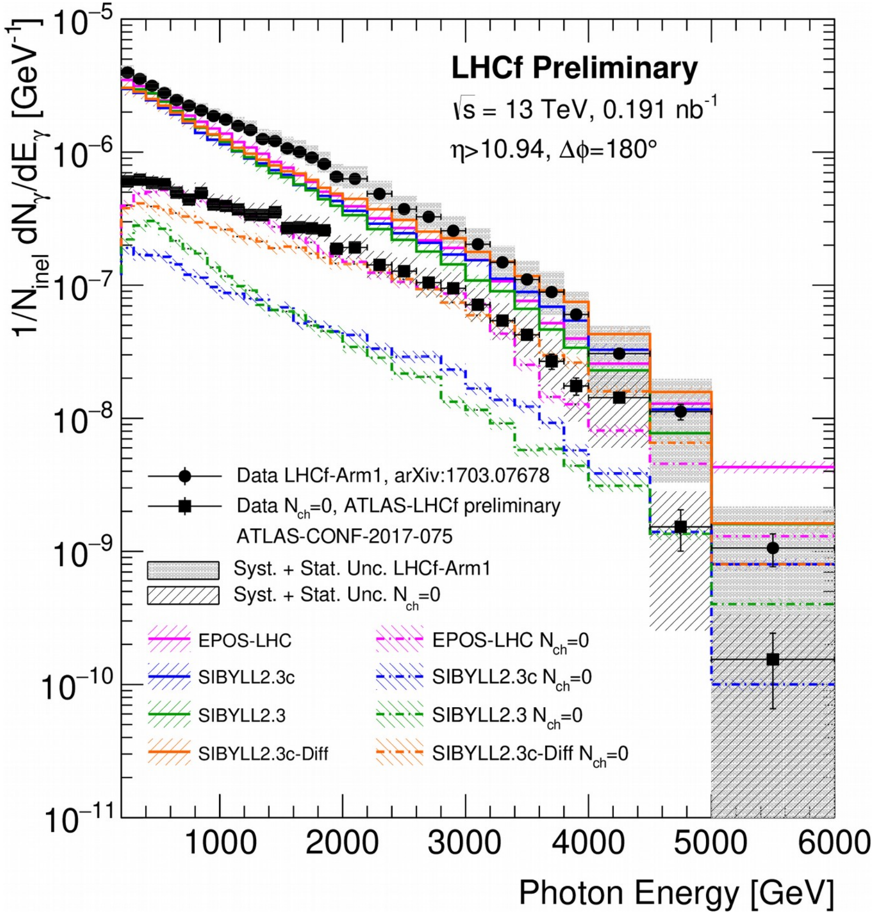
$\xi = M^2/s$ $\quad \frac{d\sigma}{d\xi} \sim \frac{1}{\xi^\alpha}$

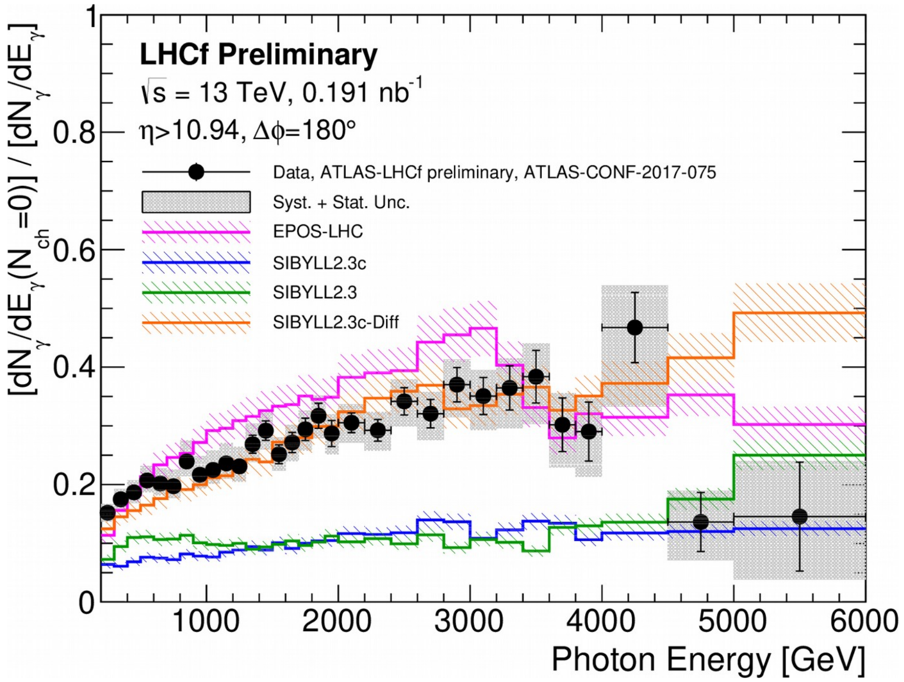
Lower mass → more forward

$$\Delta\eta \sim M_X^2$$

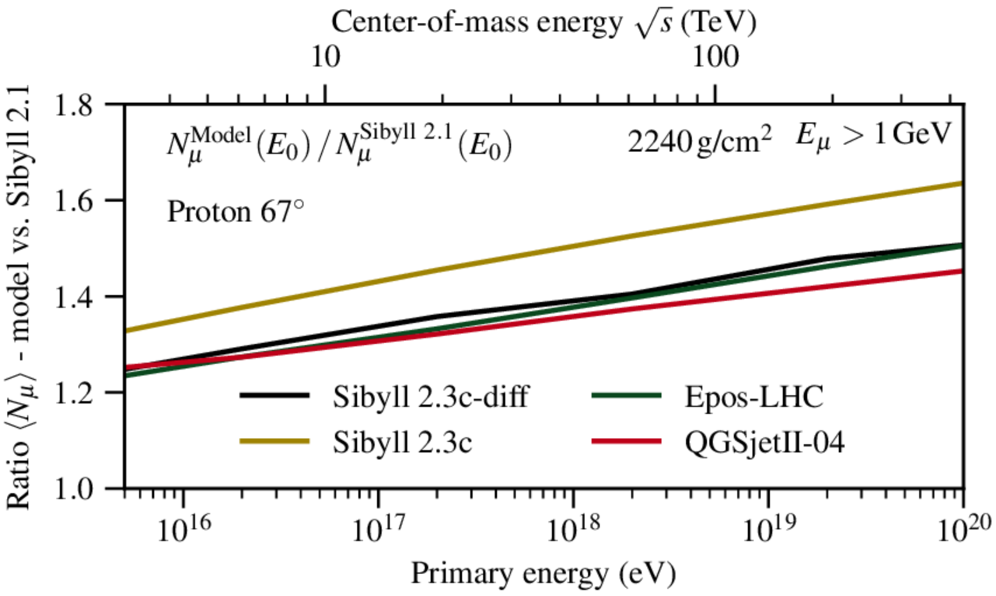


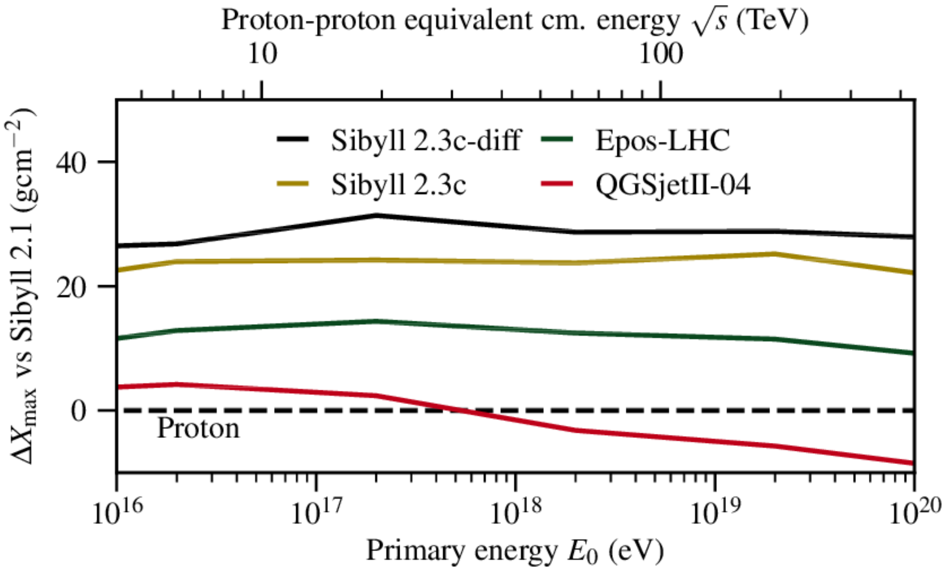
LHCf: forward photons





Effect on EAS

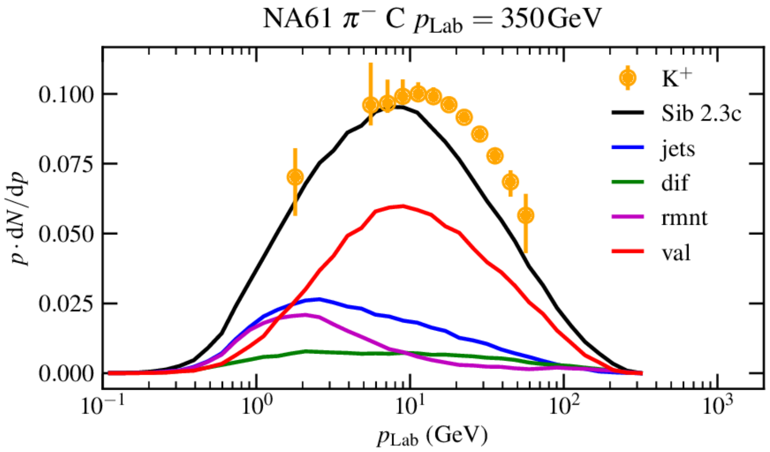


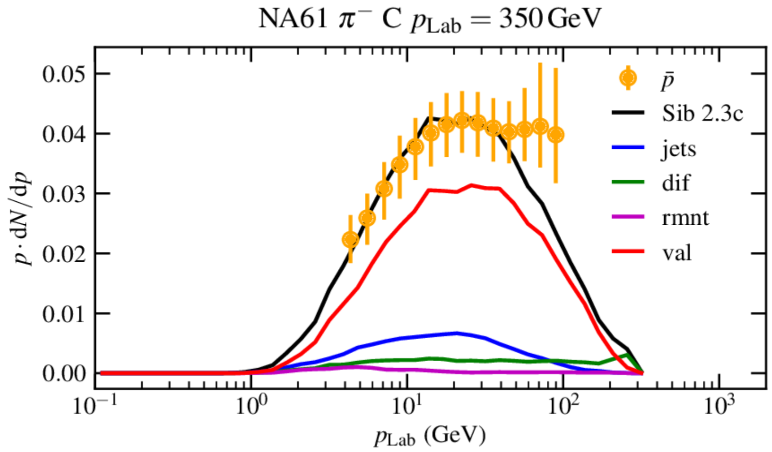


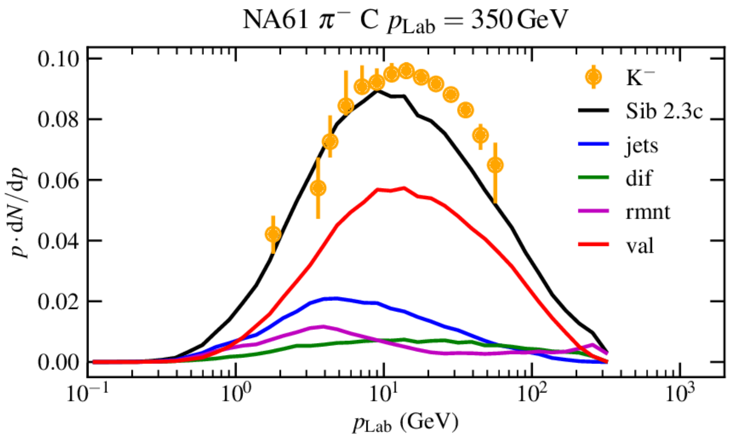
Reduction of number of muons,
increase in Xmax

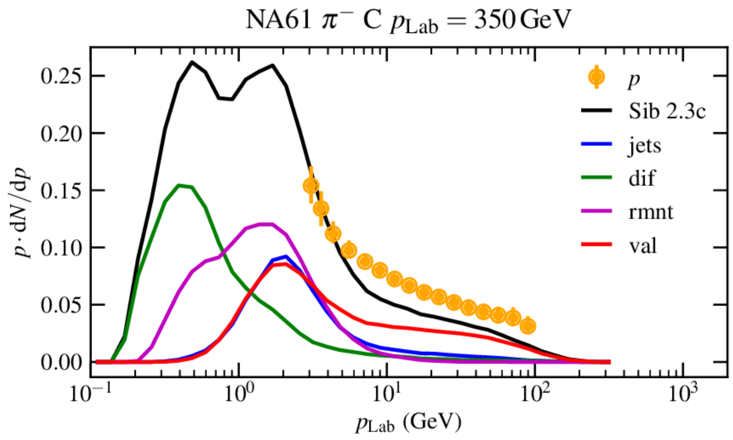
But retuning required!

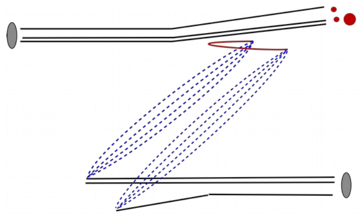
Pion interactions in NA61











Summary

* new Sibyll 2.3c including:

  - remnant model
  - charm production
  - pp cross section
  - revised baryon production
  - coherent nuclear diffraction

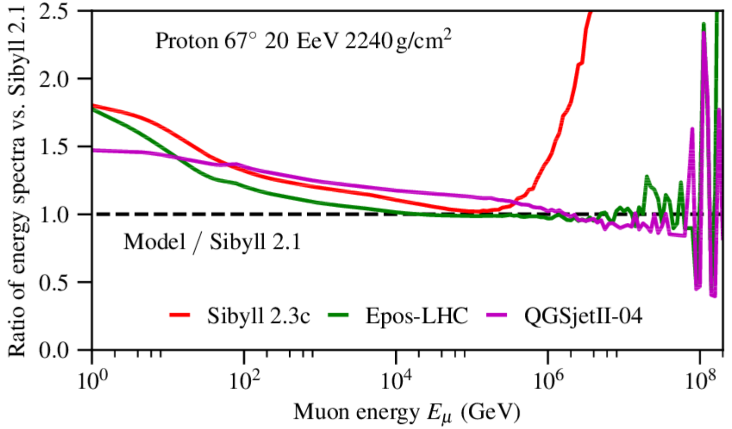
* improved description of accelerator measurements

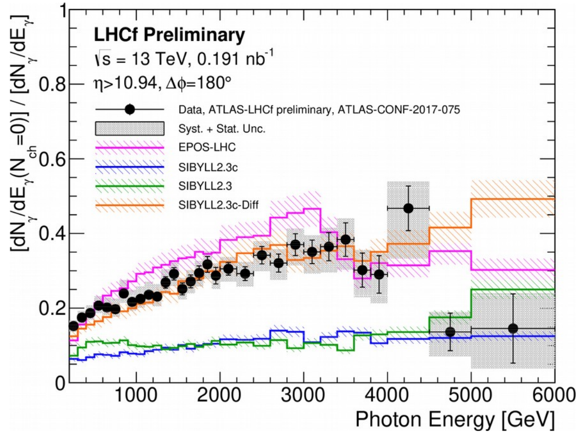
* predictions for EAS:

  - ~20g/cm2 deeper Xmax
  - ~1.6 more muons (all ground, E>1GeV)

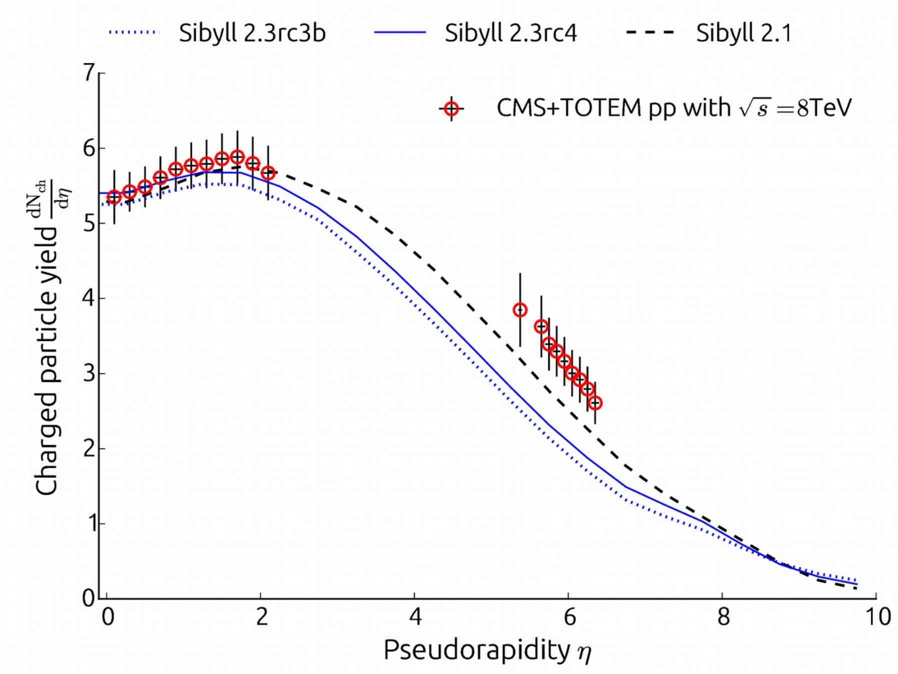
* future:

  - adjust diffractive interactions to describe LHCf data
  - NA61 tuning

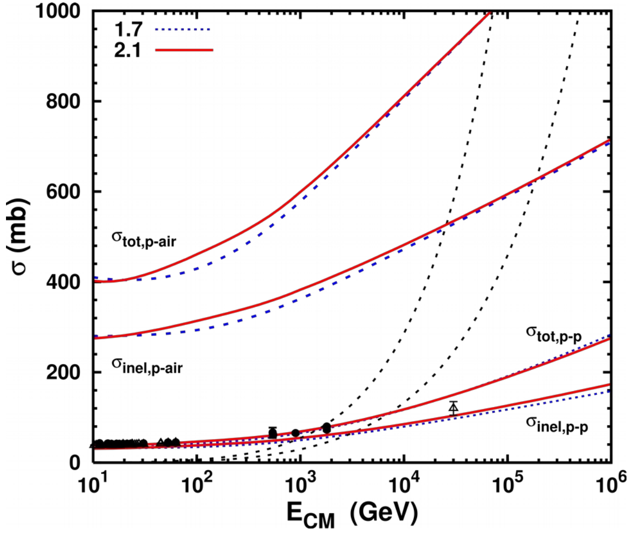




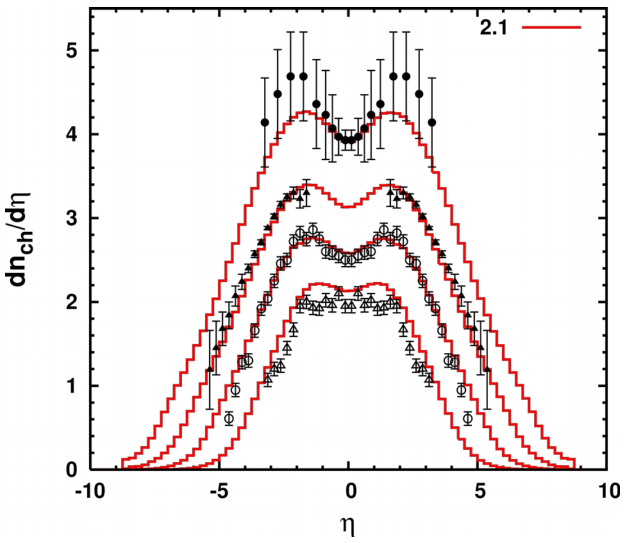
Limits of the simplified minijet model



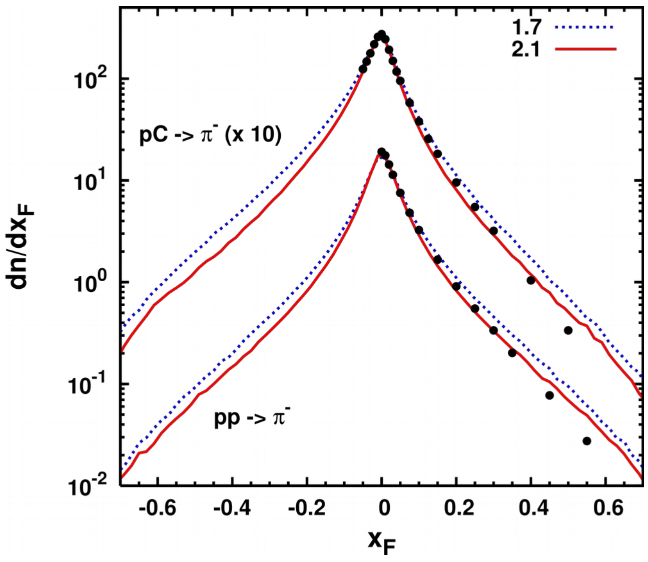
Sibyll 2.1 performance



(CDF, UA5, NA22)



(NA49)



Sibyll 2.1 tuned to TeVatron

$$\eta \sim \tan(\theta/2)$$