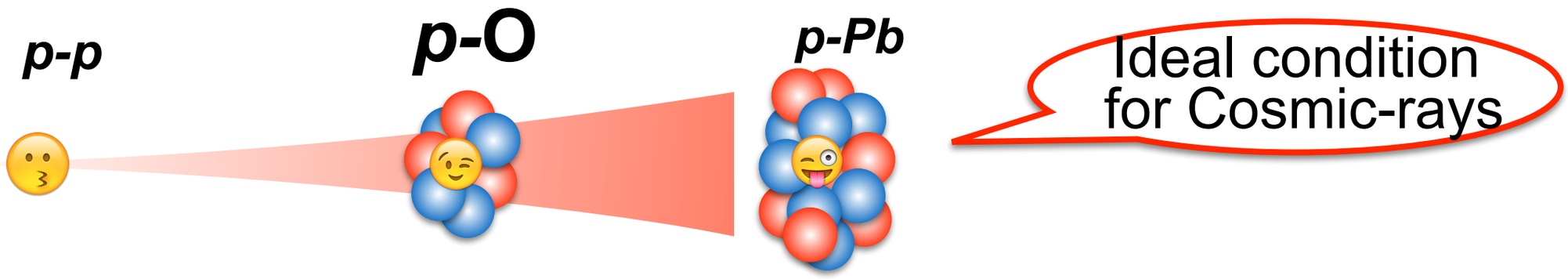
Studies for p-O collisions

H. Menjo

Motivation for p-O collisions

- Ideal to reproduce HECR-Air interactions

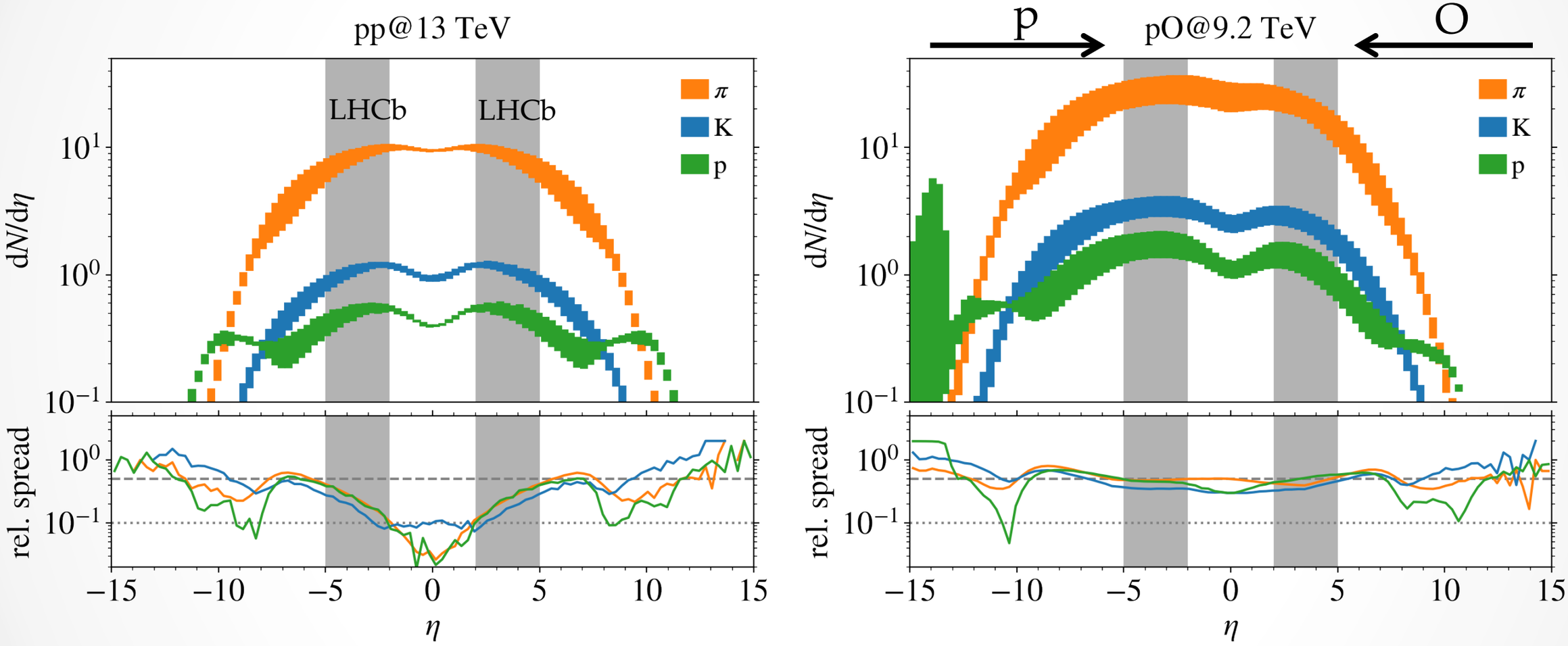


  - p-Pb collisions are too heavy for CR surely.
    However, we must qualify the necessary of p-O instead of interpolation between pp + pPb.

    A study was been done by H. Dembinski
    for the p-O section of Yellow report for LHC-RUN3.
    It gave an answer to it.

Hadron spectra

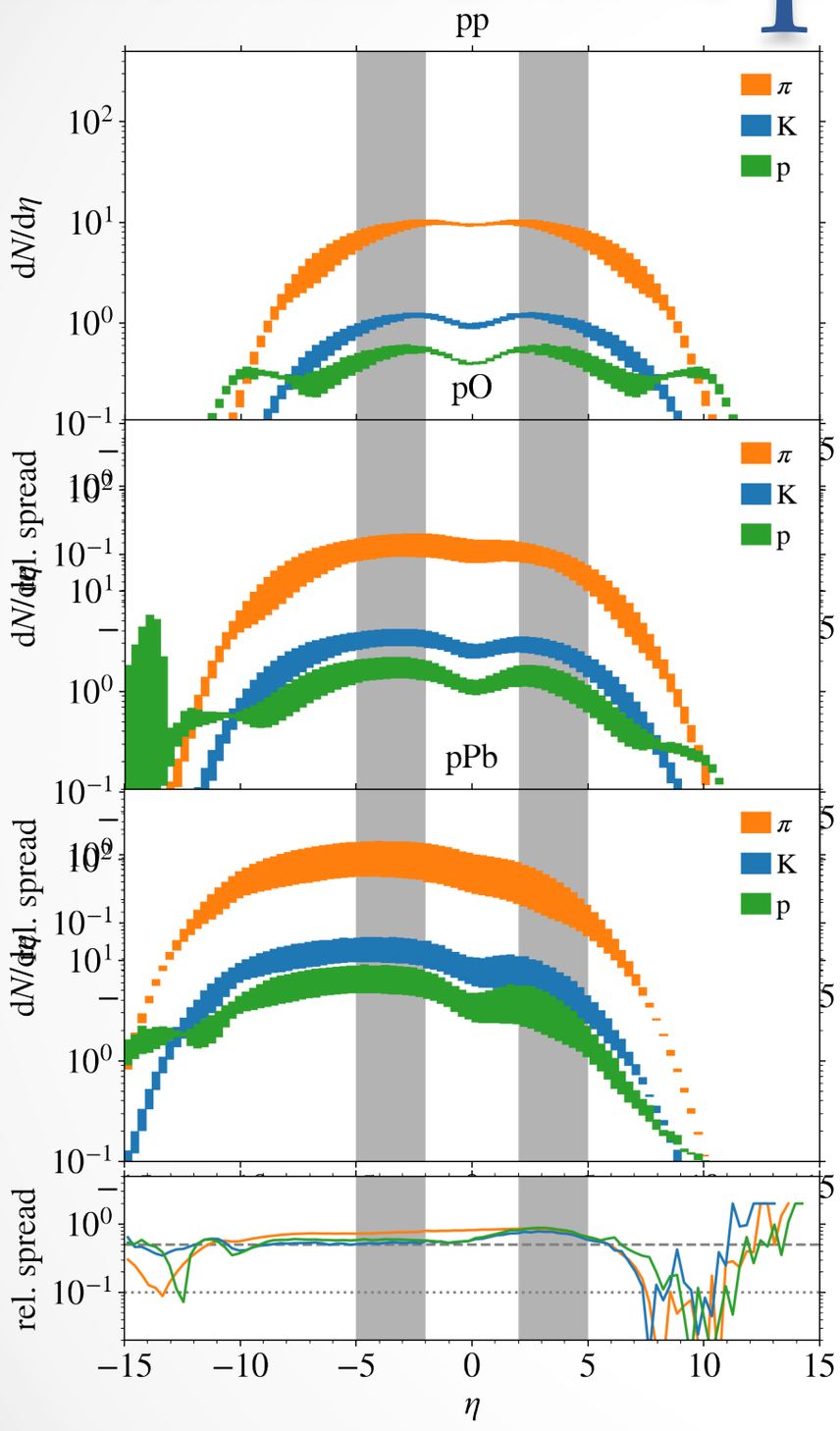
- Simulations done with CRMC: R. Ulrich et al. https://web.ikp.kit.edu/rulrich/crmc.html
- Model spread: EPOS-LHC, QGSJet-II.04, SIBYLL-2.3

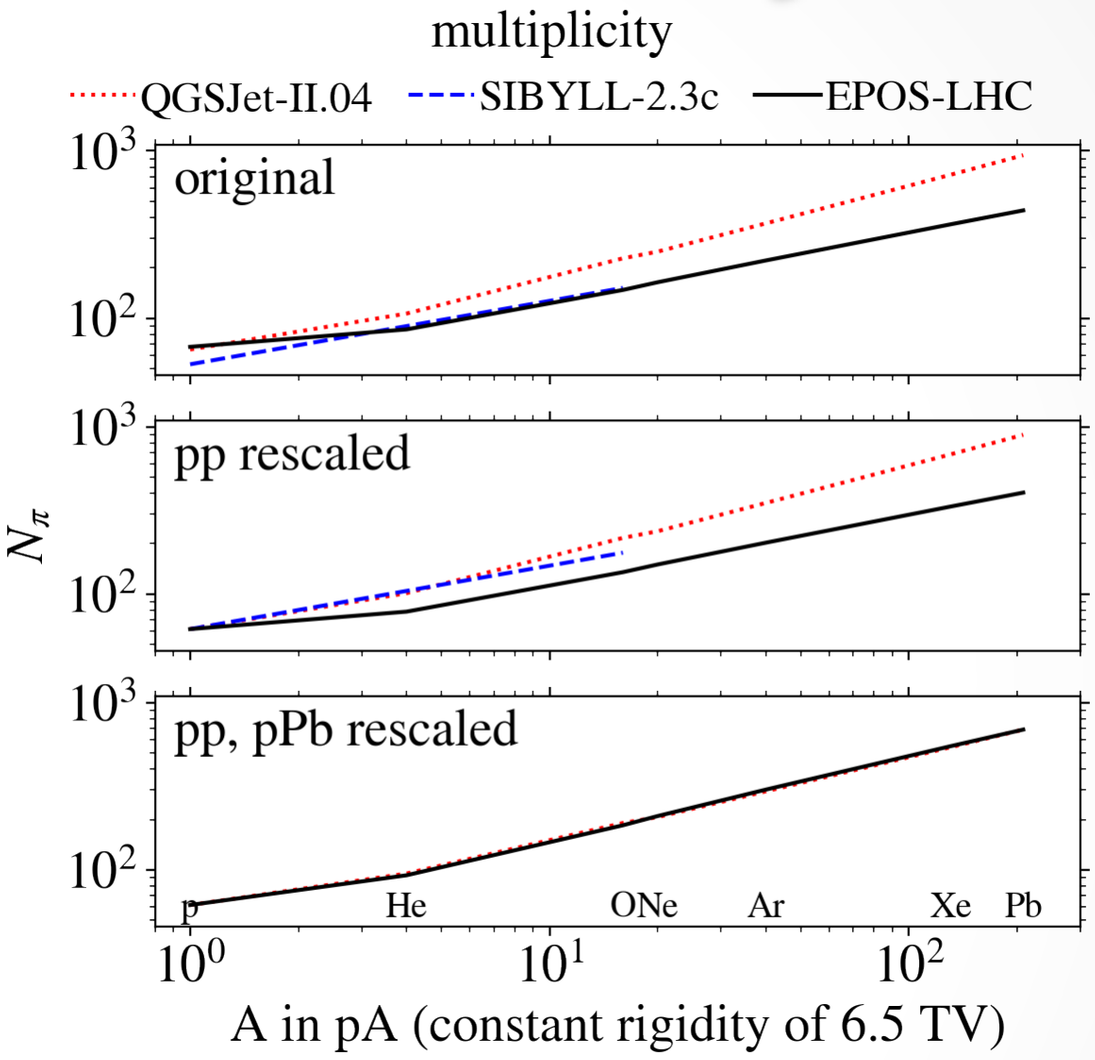


Models mostly tuned to pp data at |eta| < 2

- |eta| < 2: p+p 10 % model spread, **p+O 50 %** model spread

Hadron spectra vs. system

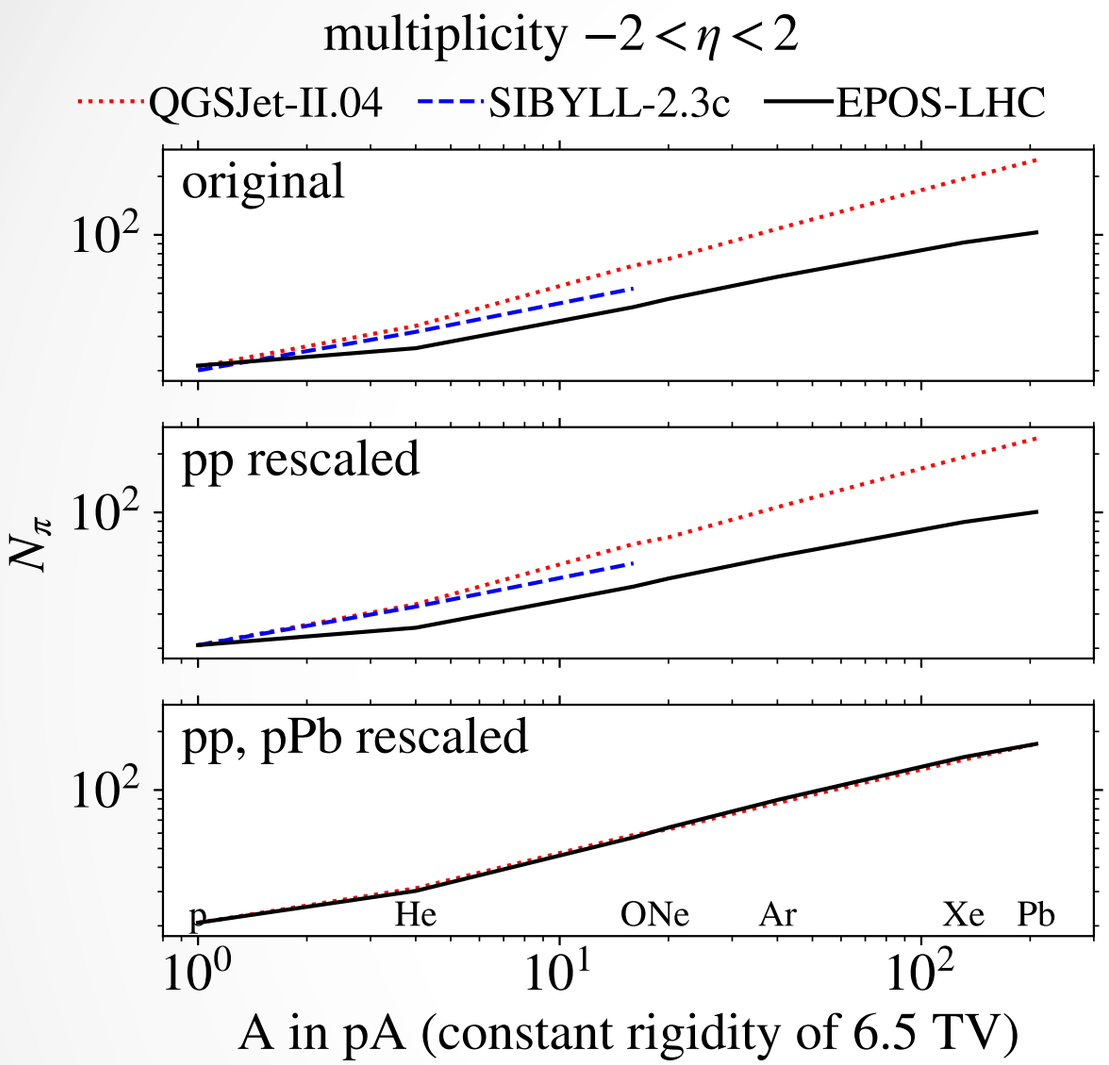


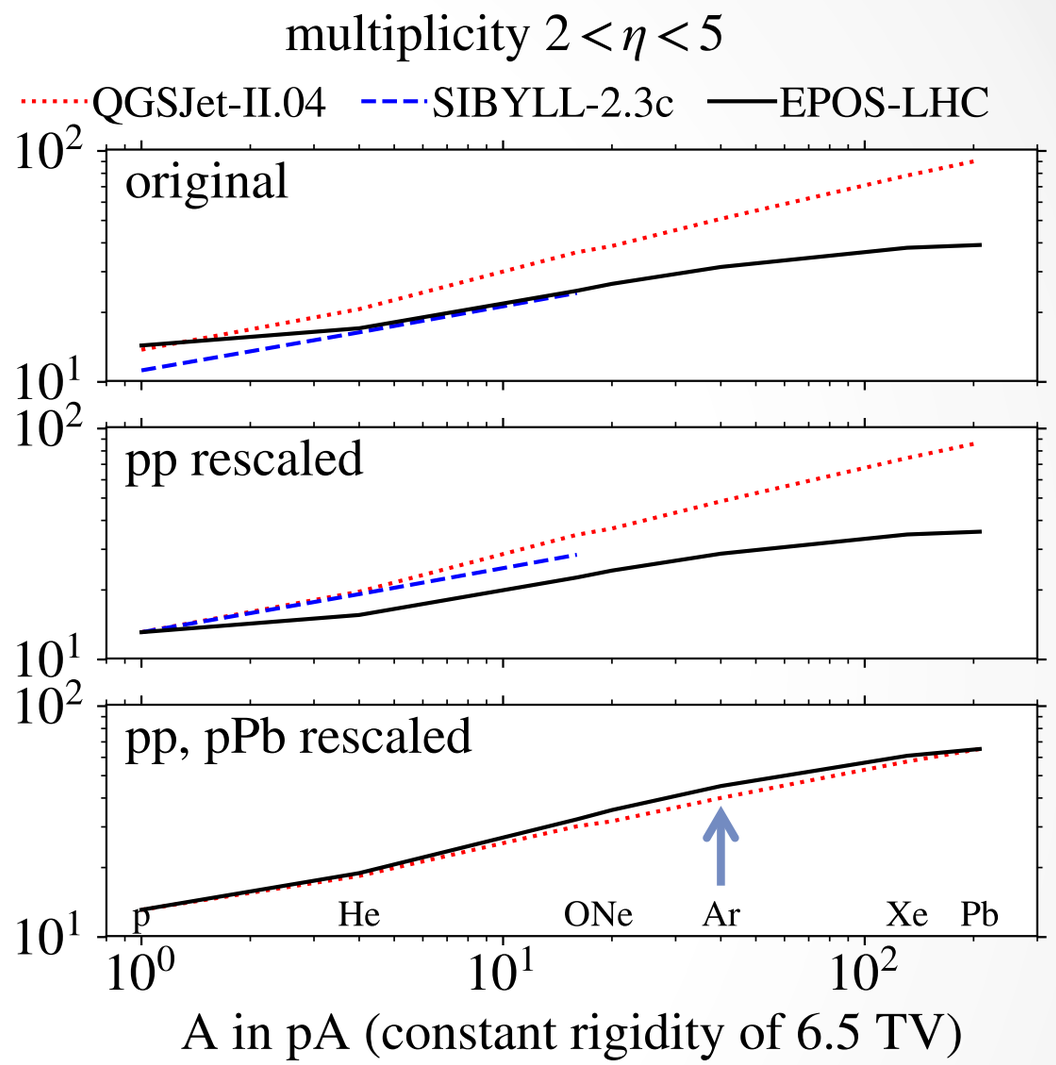


Simultaneous rescaling to pp and pPb:
apply correction $a + b\ log(A)$, with a and b such that models converge at pp and pPb

pp and pPb together may constrain pO, but **need measurement to confirm**

Multiplicity in forward rapidity

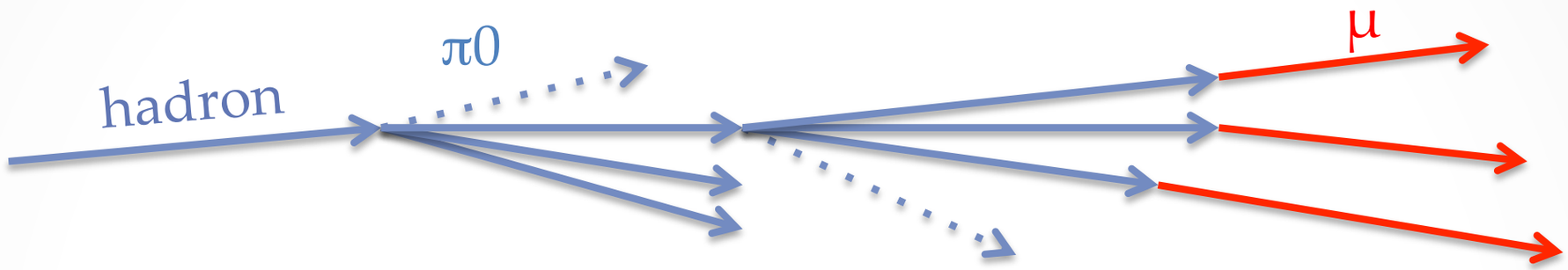


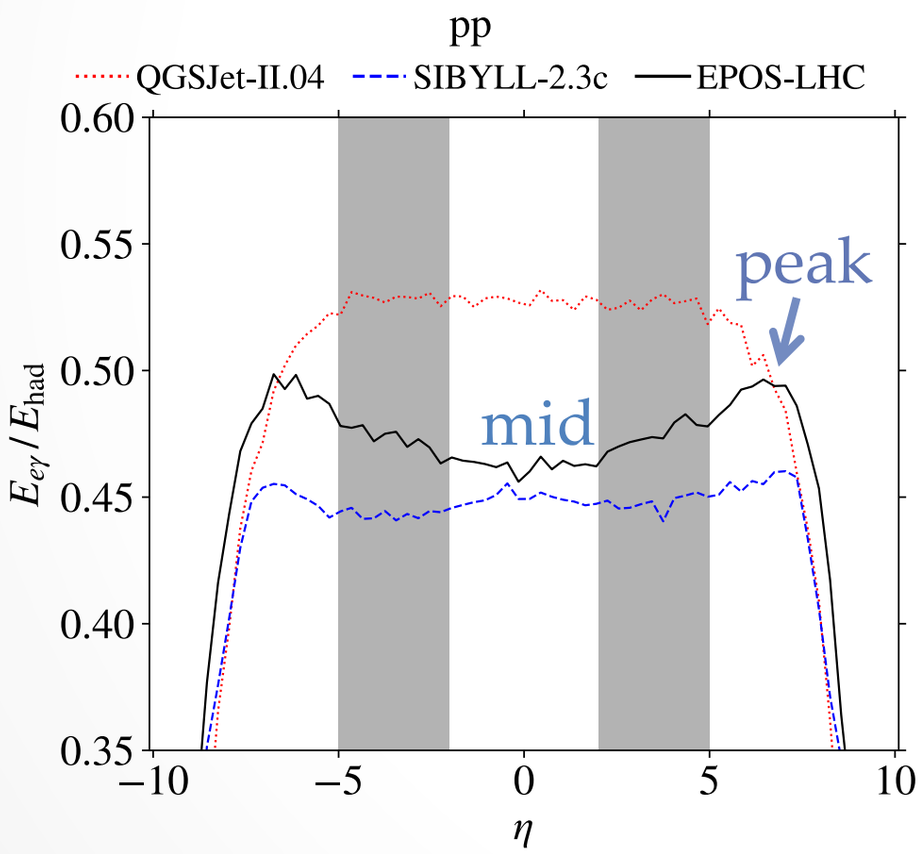


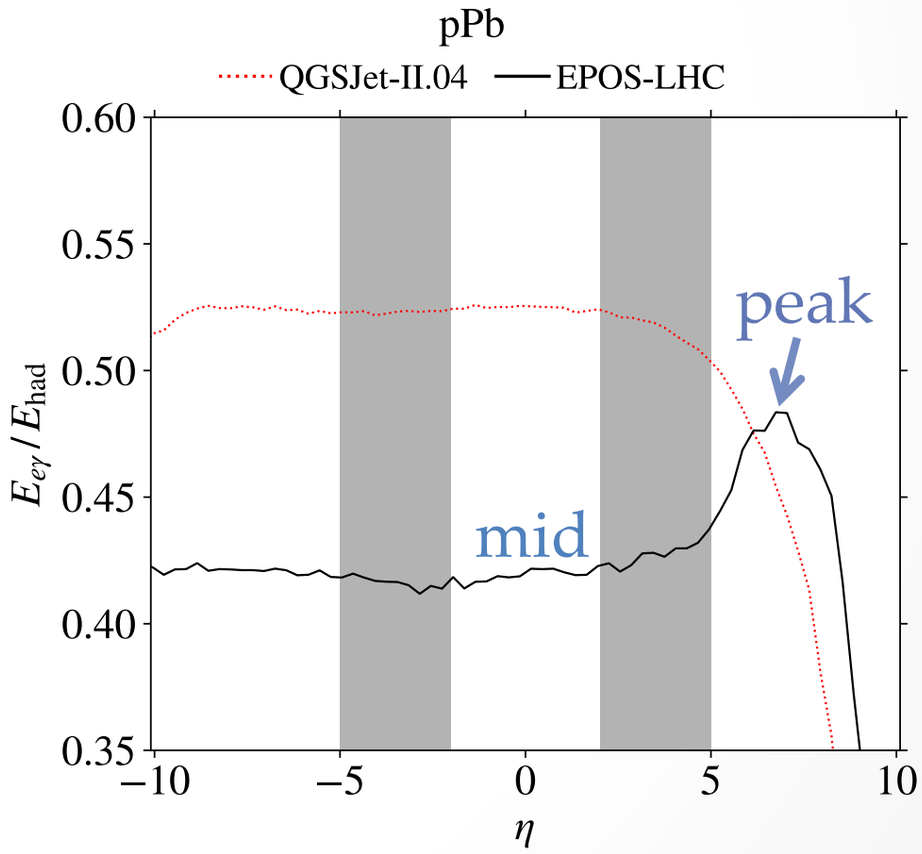
- Saturation visible in EPOS, not in QGSJet-II.04
- **7 % deviation in pO** even if models are fixed to same values in pp and pPb
  - 4 % shift in N_μ, 7 g cm-2 shift in Xmax (comparable to exp. uncertainties)
- p+p and p+Pb may be able to constrain p+O, need measurement to confirm

em-hadron energy ratio

- Hadronic energy "lost" to π^0s cannot produce muons in late shower
- "Energy loss" described by observable $E_{e\gamma}/E_{hadrons}$

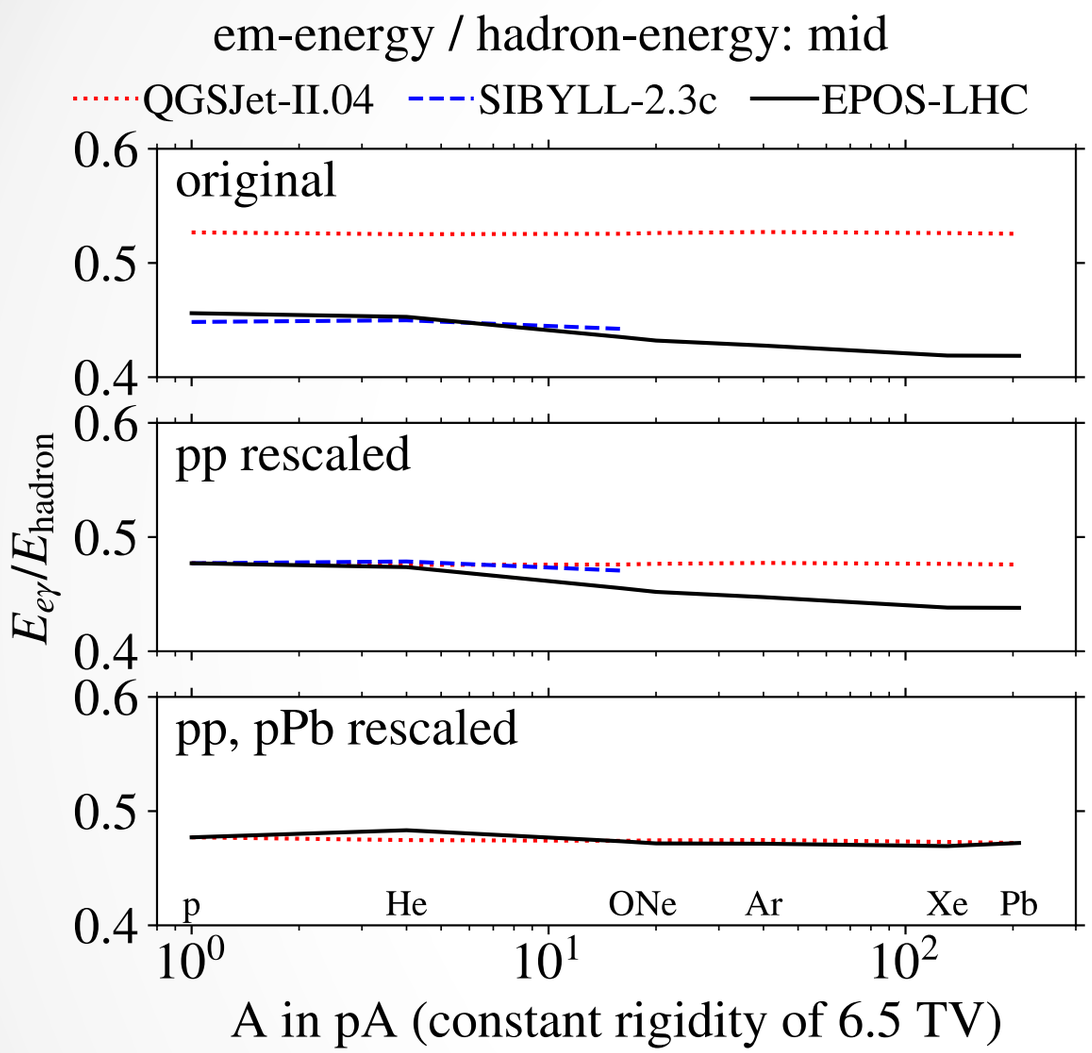


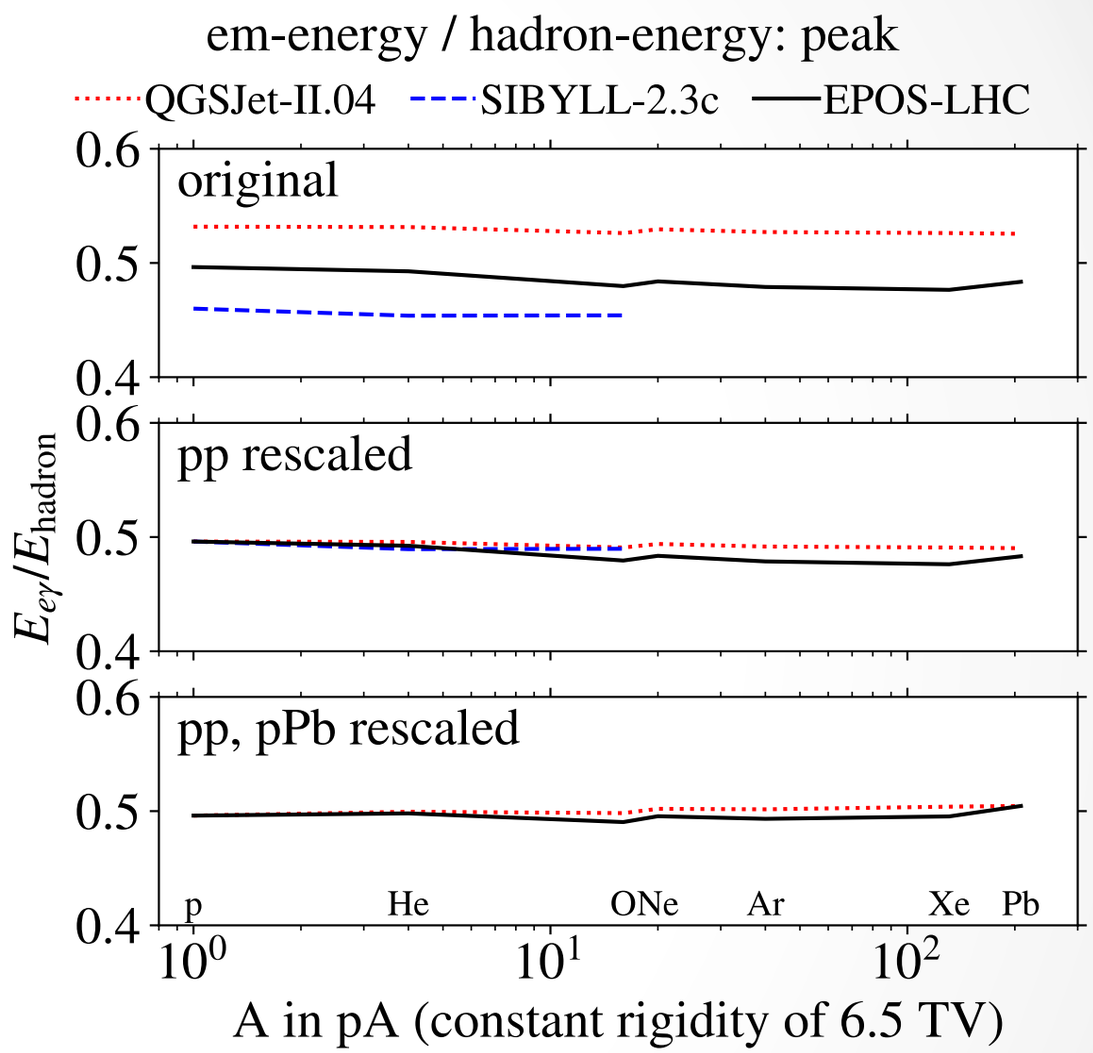




- Model predictions differ by **13 %** and in **shape**: only EPOS has forward peaks
- Translates to > **15 % shift in N_μ**, **best bet to solve muon puzzle**

em-had. energy ratio vs. system





- p+p and p+Pb together may be able to constrain p+O
- **need p+O measurement to confirm**

From Hans's studies

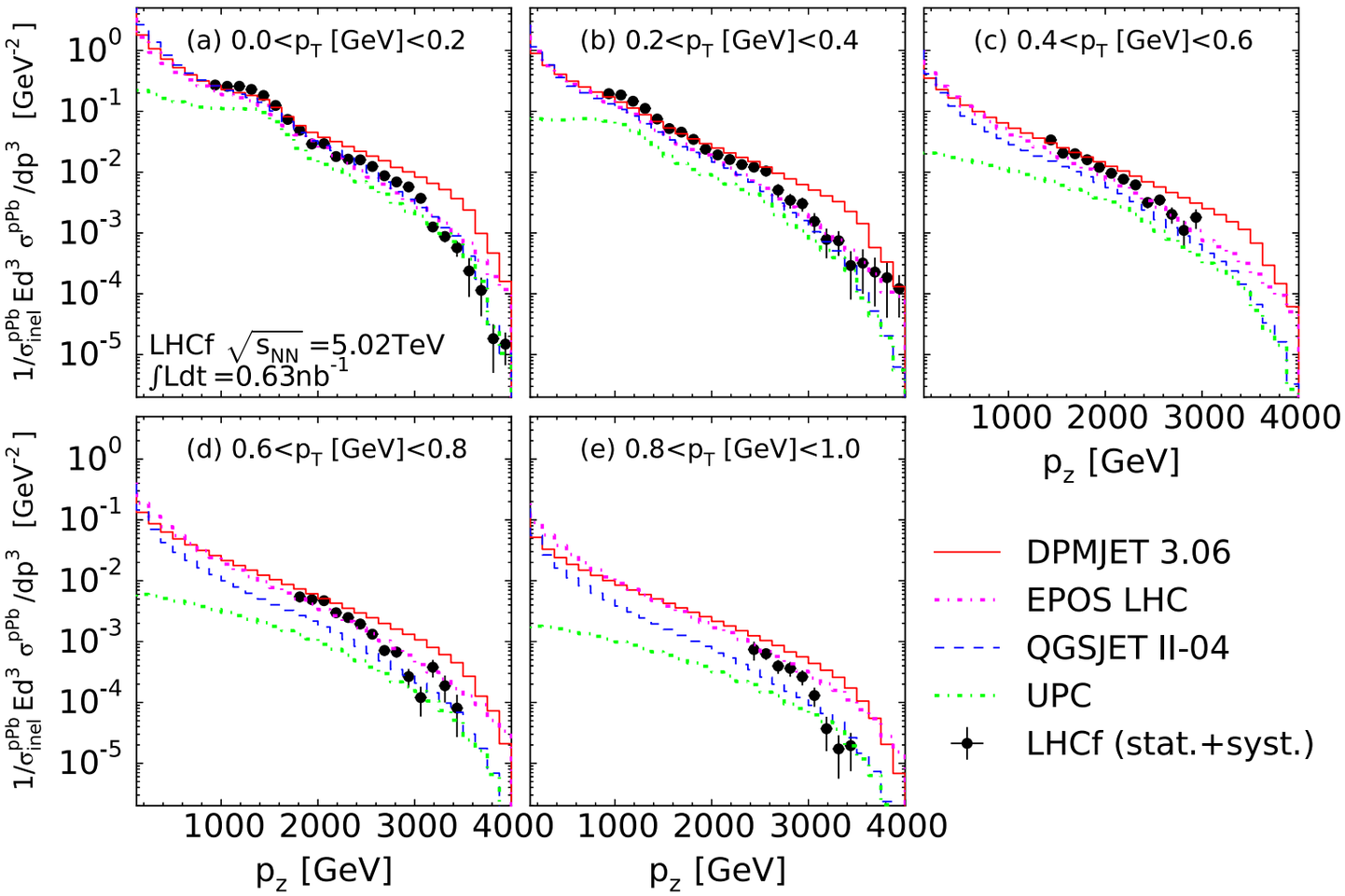
- In his studies, interpolation between pp and pPb works to reproduce the pO results in "MC".
  He concluded the necessary of confirmation with data.

- His work inspire me.

  How about the parameters measured by LHCf ?

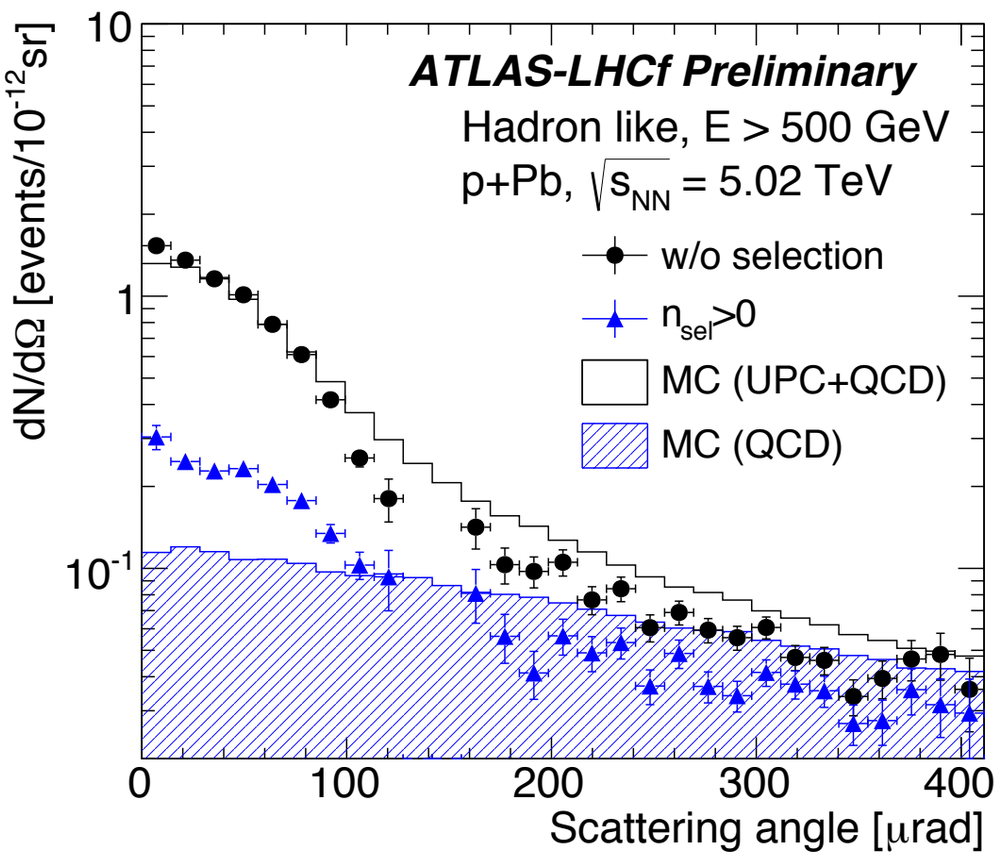
  - EM(photon or π^0) energy flow and spectrum shape in very forward region $\eta > 8$?
  - Neutron energy spectrum (related to inelasticity) ?
  - The precision of our pp and pPb measurements is enough for the interpolation to p-O ?

Measurement at 5TeV pPb



π0 results
UPC <~ QCD

neutron results
UPC > QCD



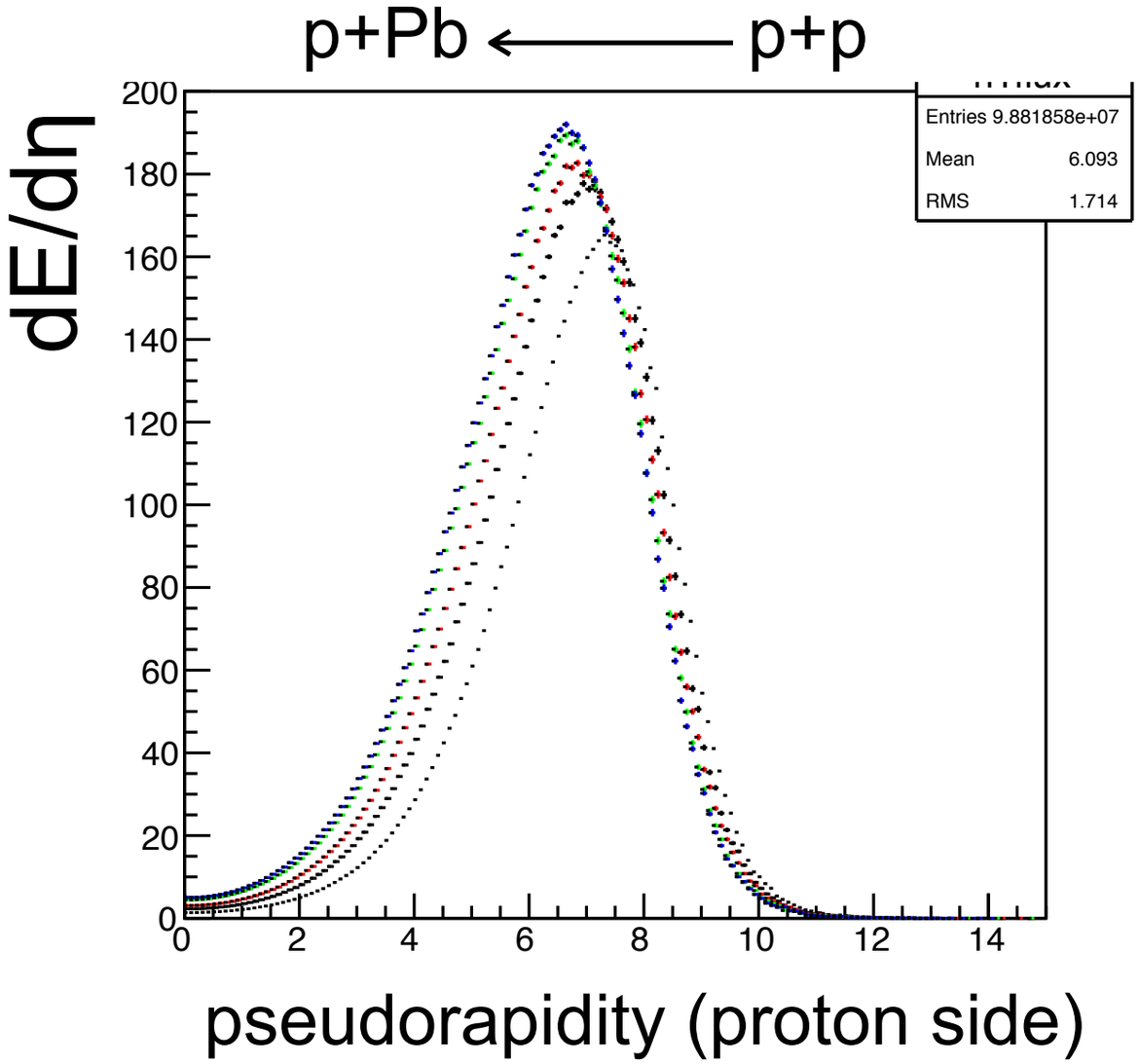
MC study setup

- Analysis of generator output
  - Use CRMC
  - Fixing $\sqrt{s_{NN}}$ = 6.5TeV and proton beam = 3.5TeV
  - $5x10^5$ collisions for each pp, pO, pAr, pXe, pPb with QGSJET2 and EPOS-LHC

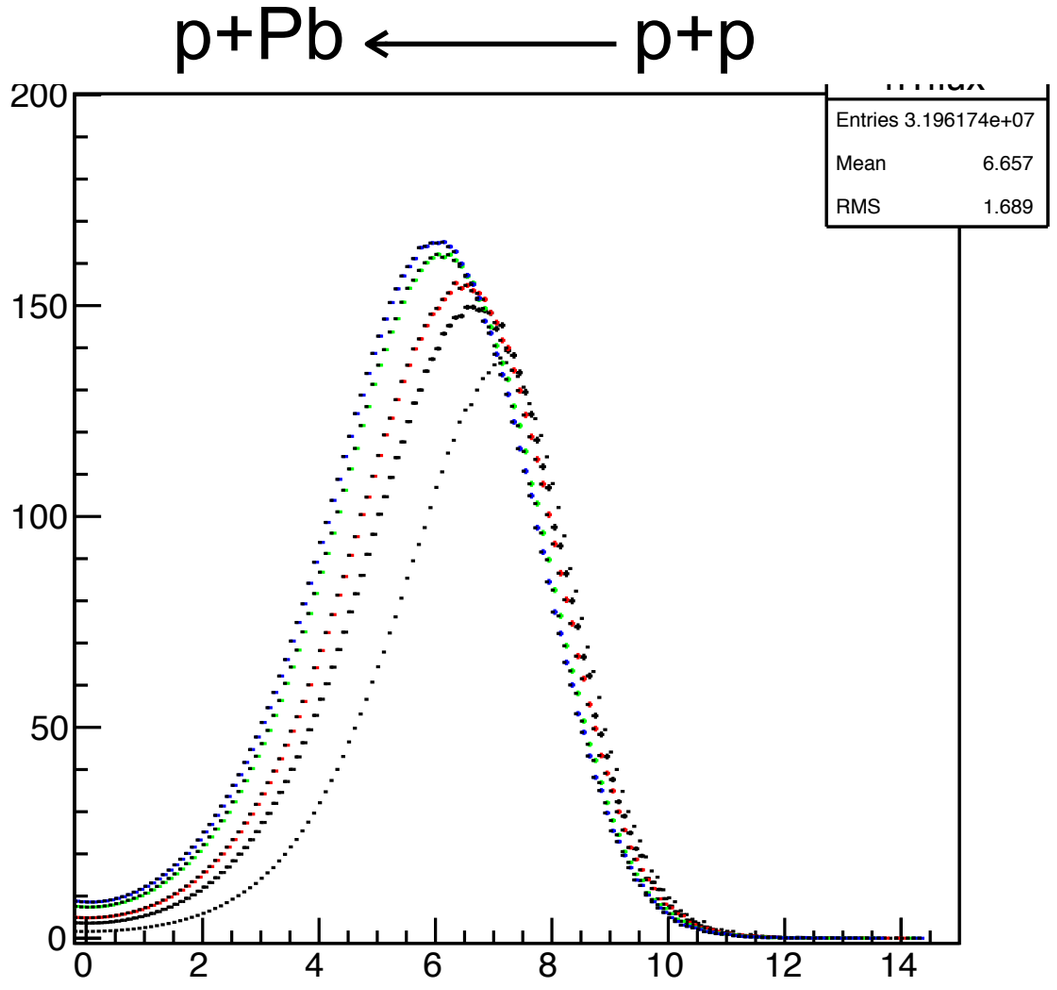
↔Hans's Study
Fixing to 6.5 TV
$\sqrt{s_{NN}}$ depends on the Z/A

Energy flow of photons

EPOS-LHC

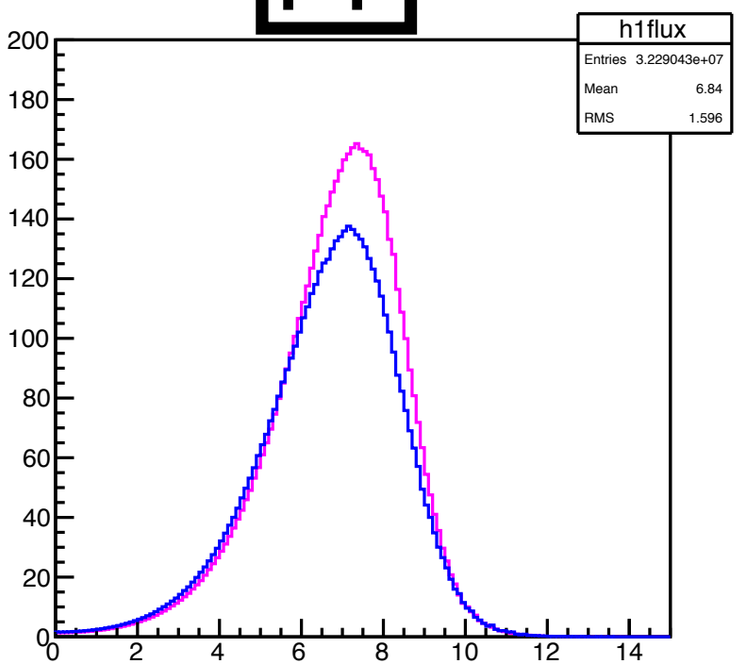


QGSJET2-4

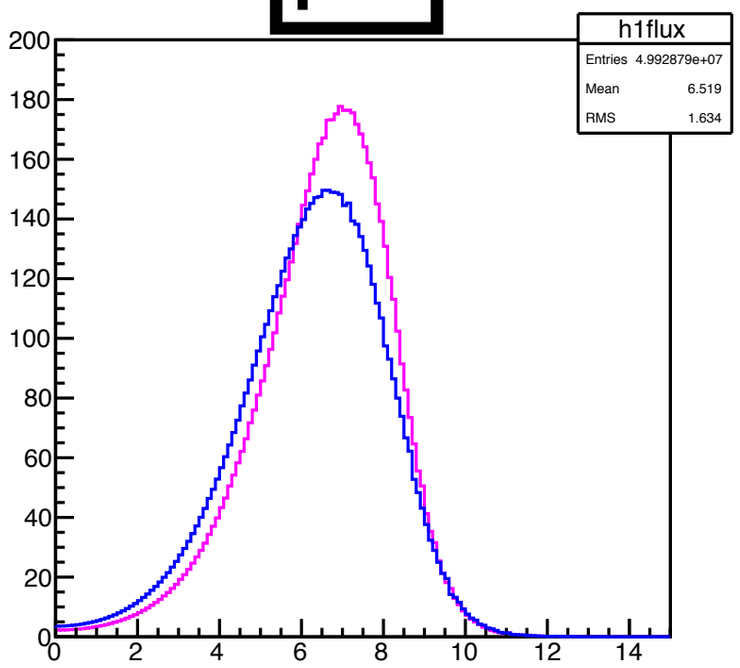


Energy flow of photons

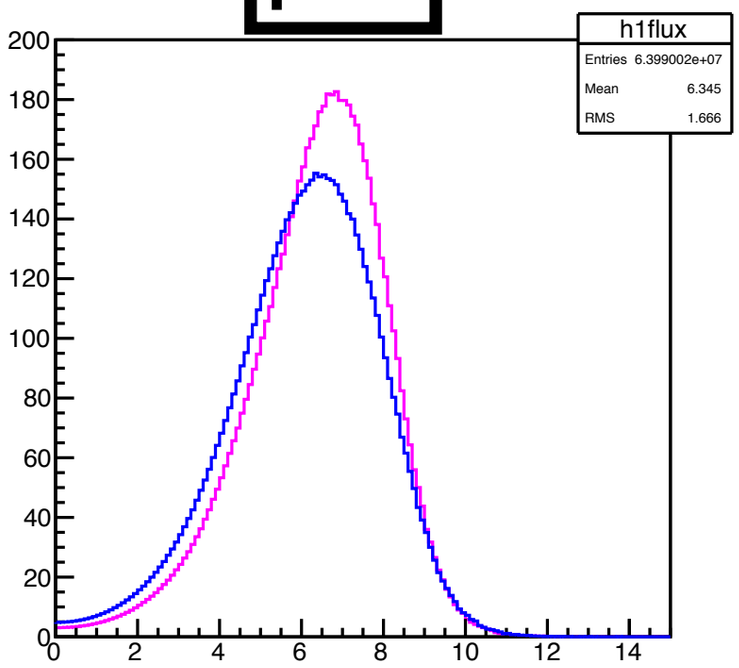
p-p



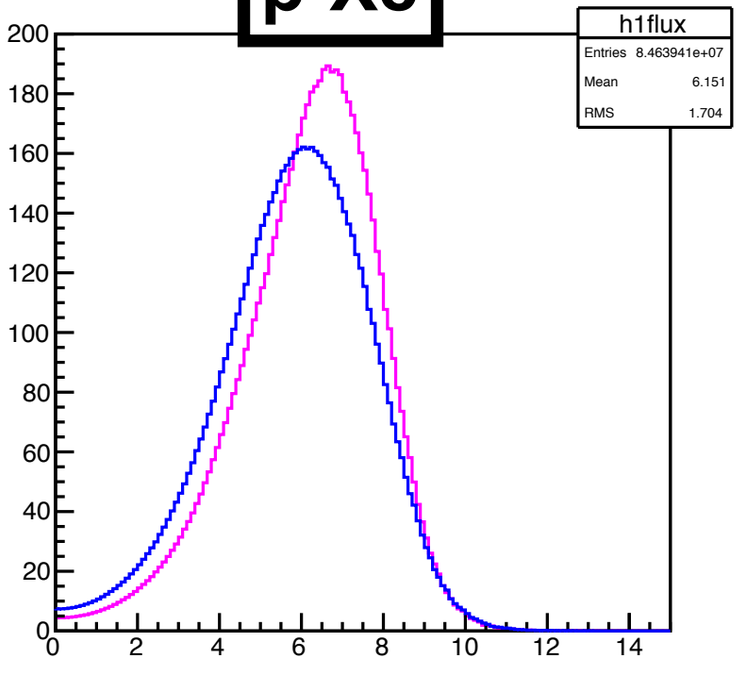
p-O



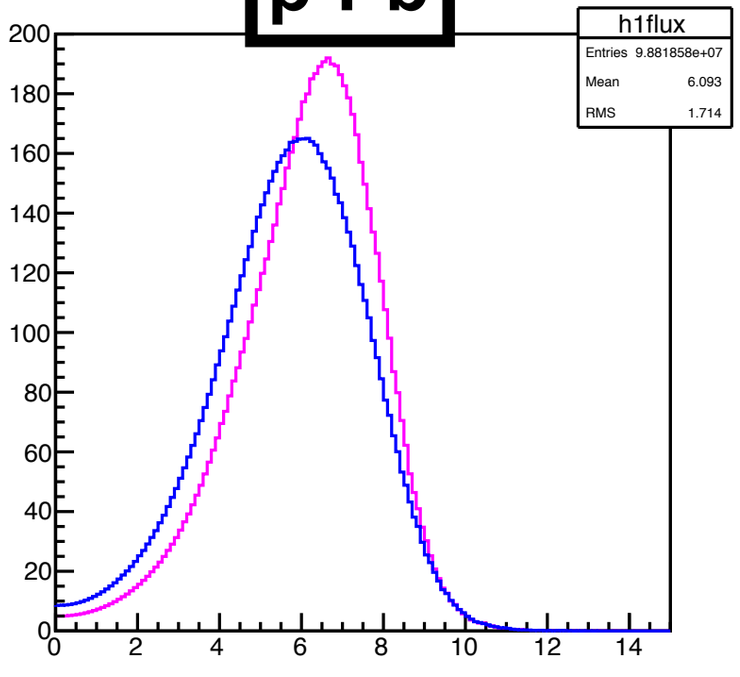
p-Ar



p-Xe



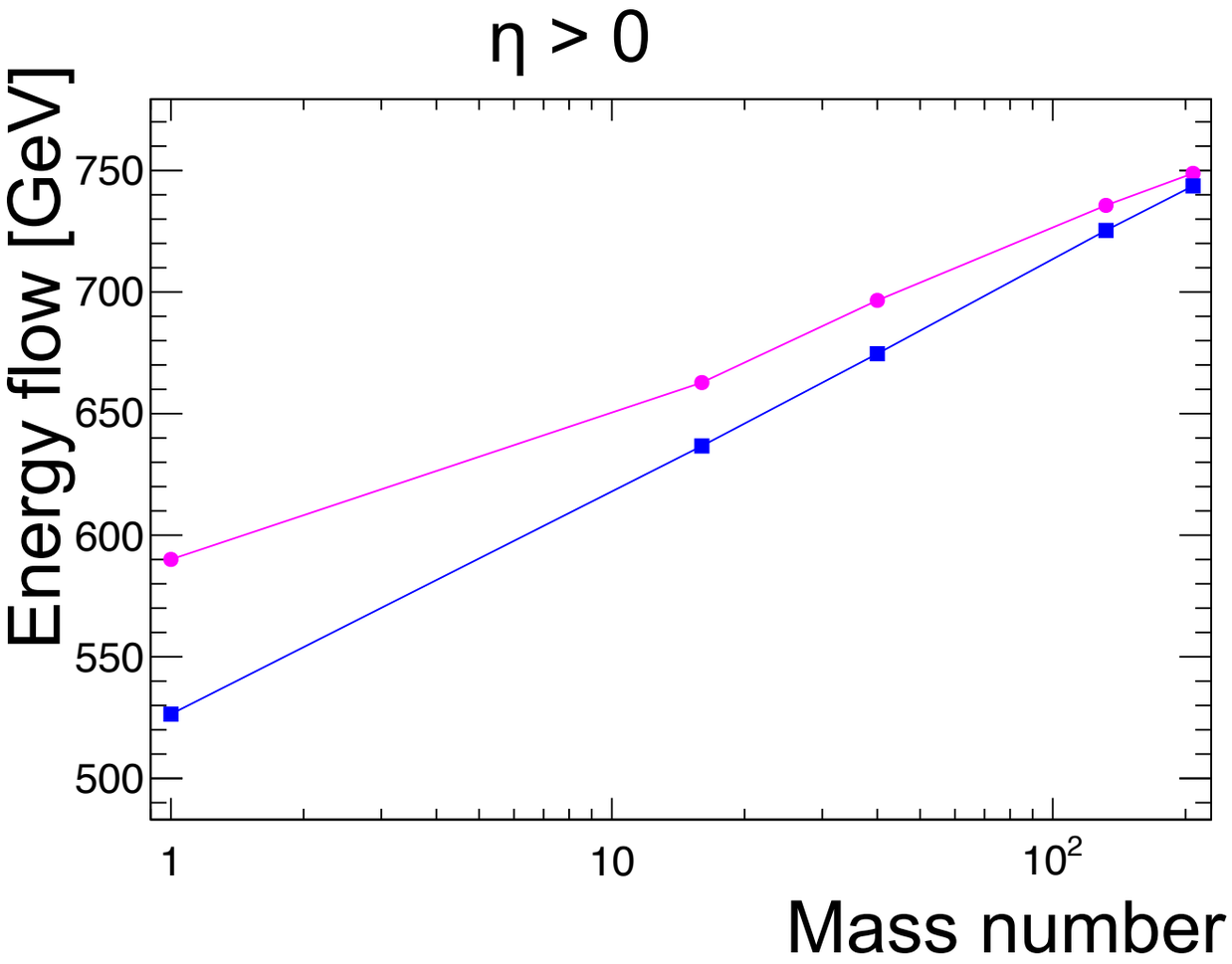
p-Pb

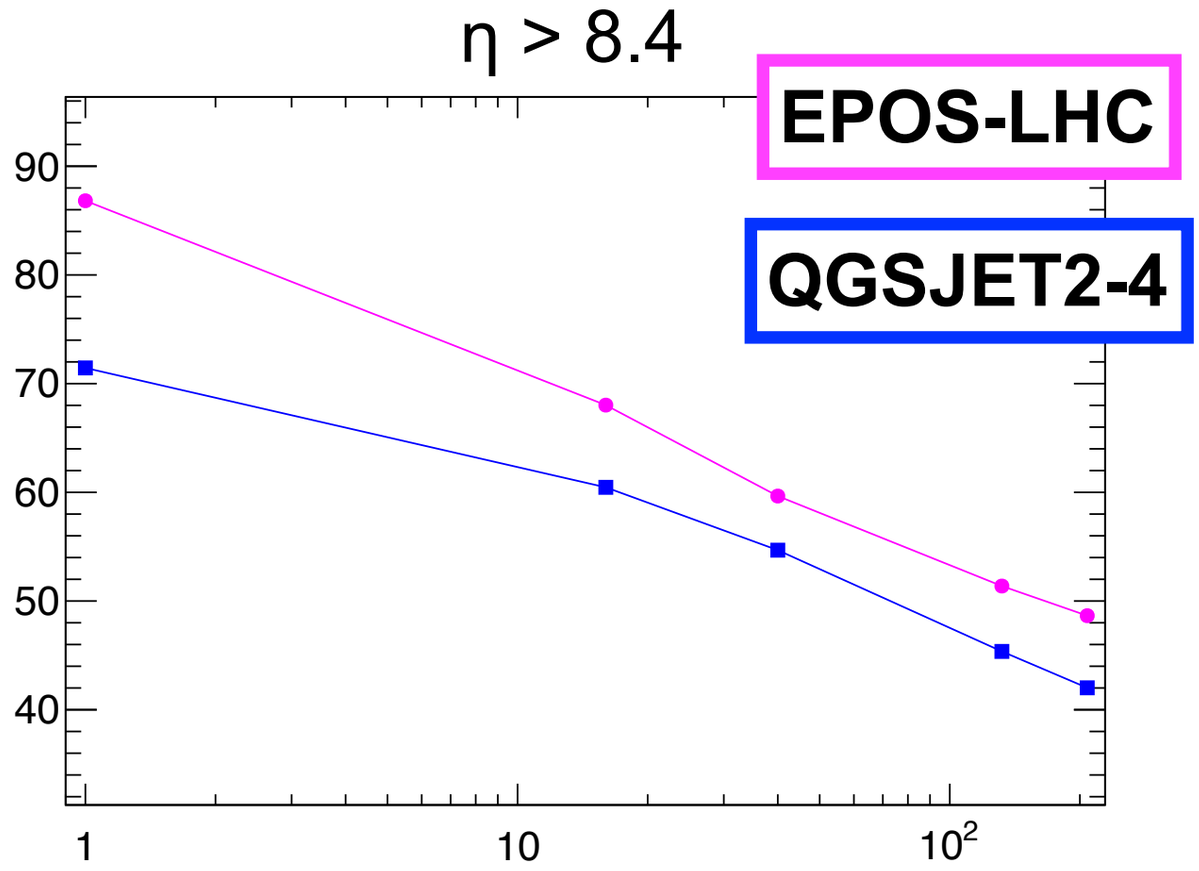


EPOS-LHC

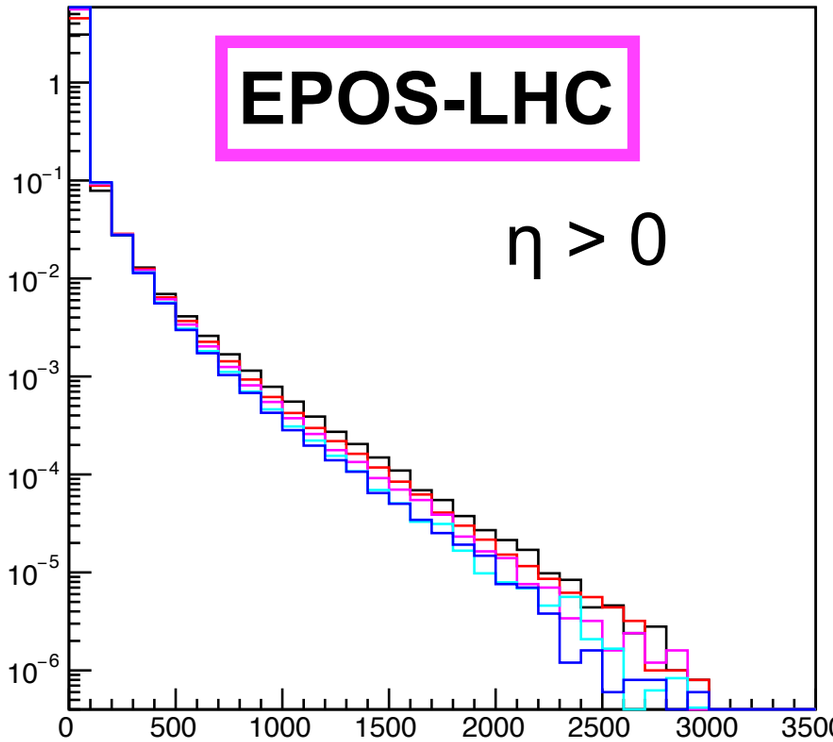
QGSJET2-4

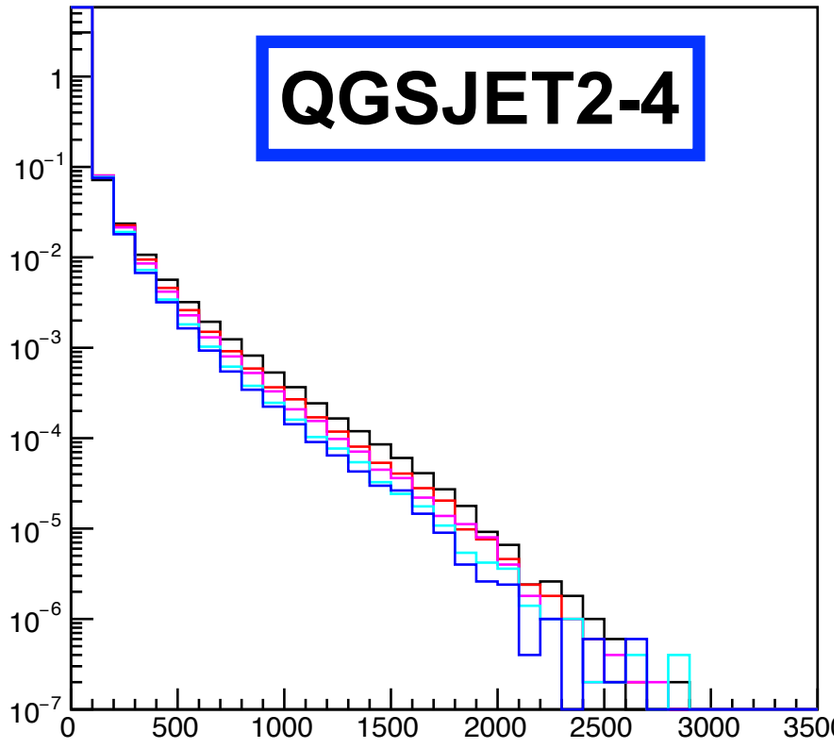
Energy flow of photons

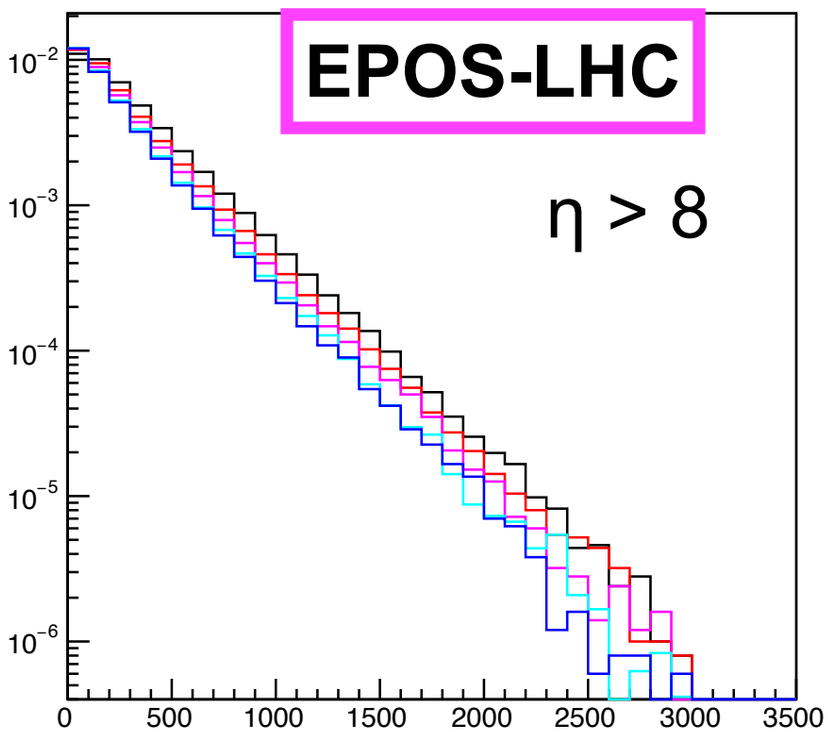


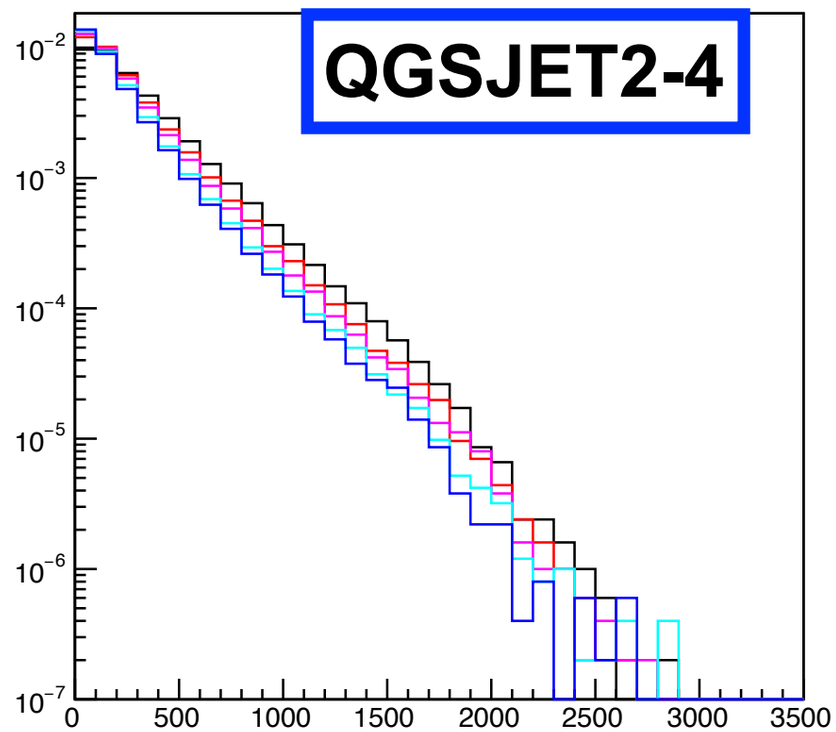


Energy spectrum of photons

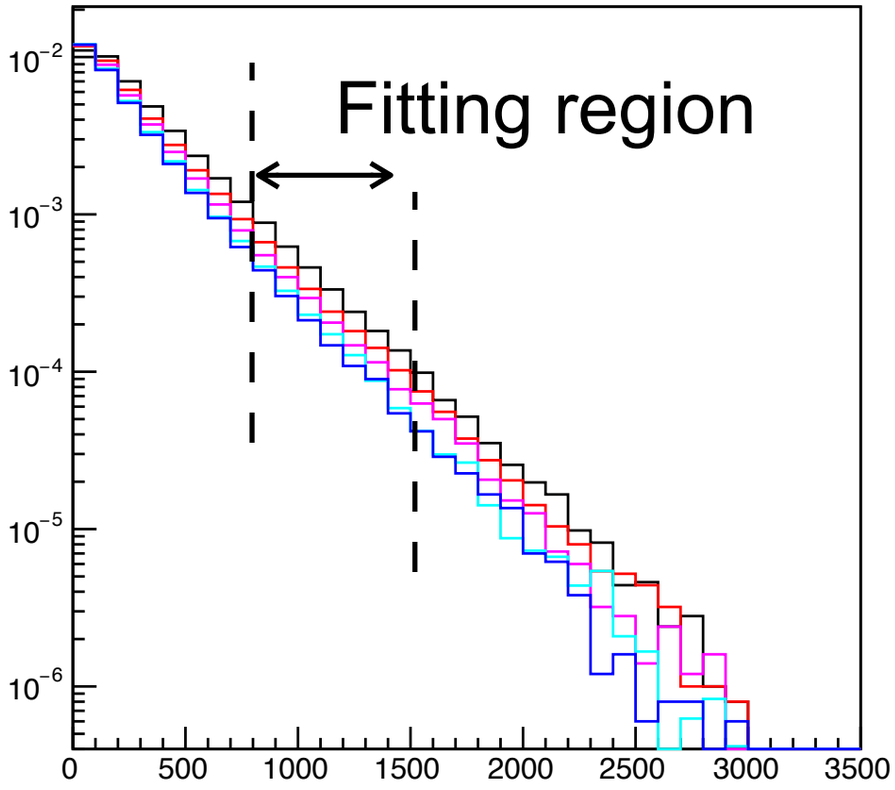


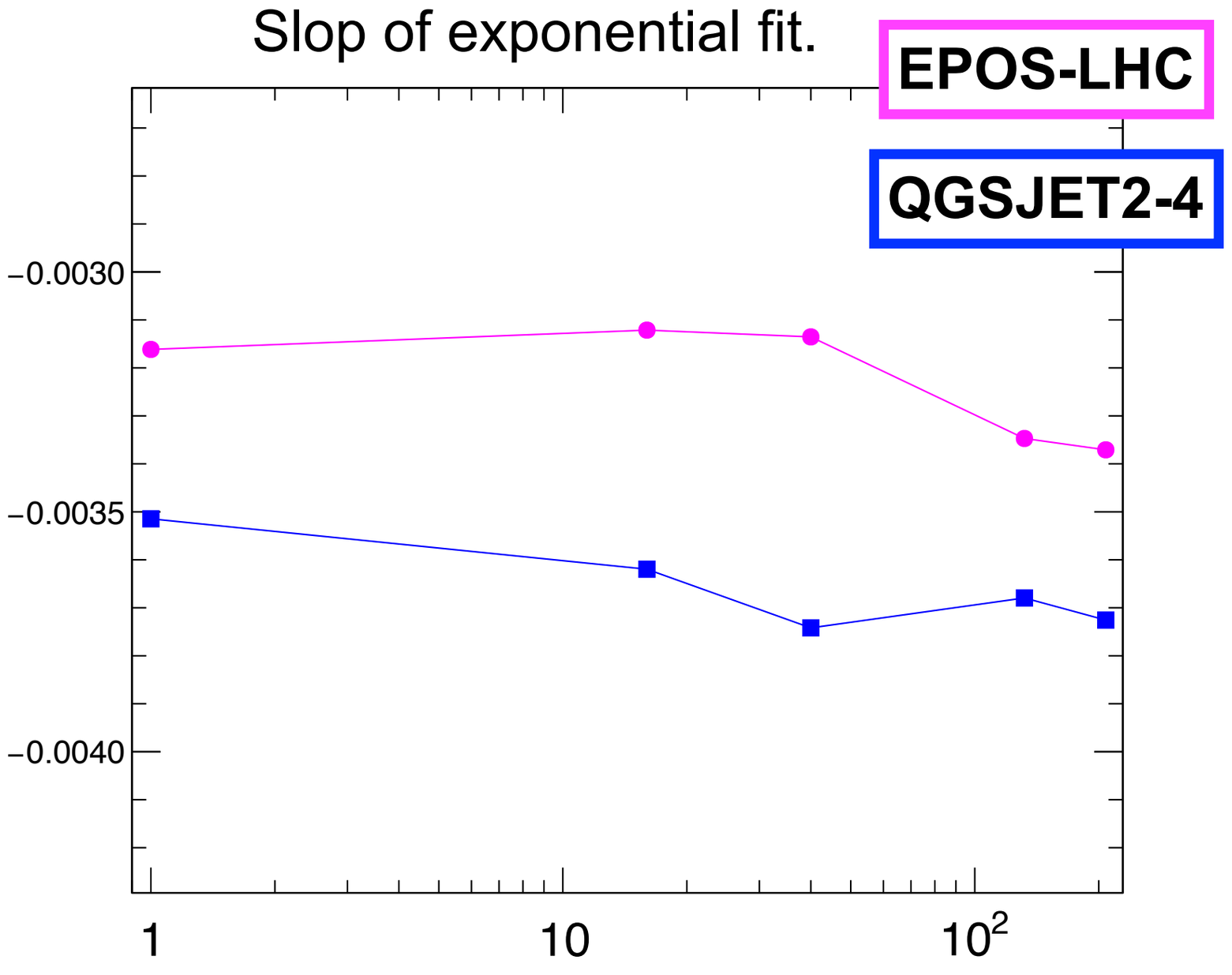






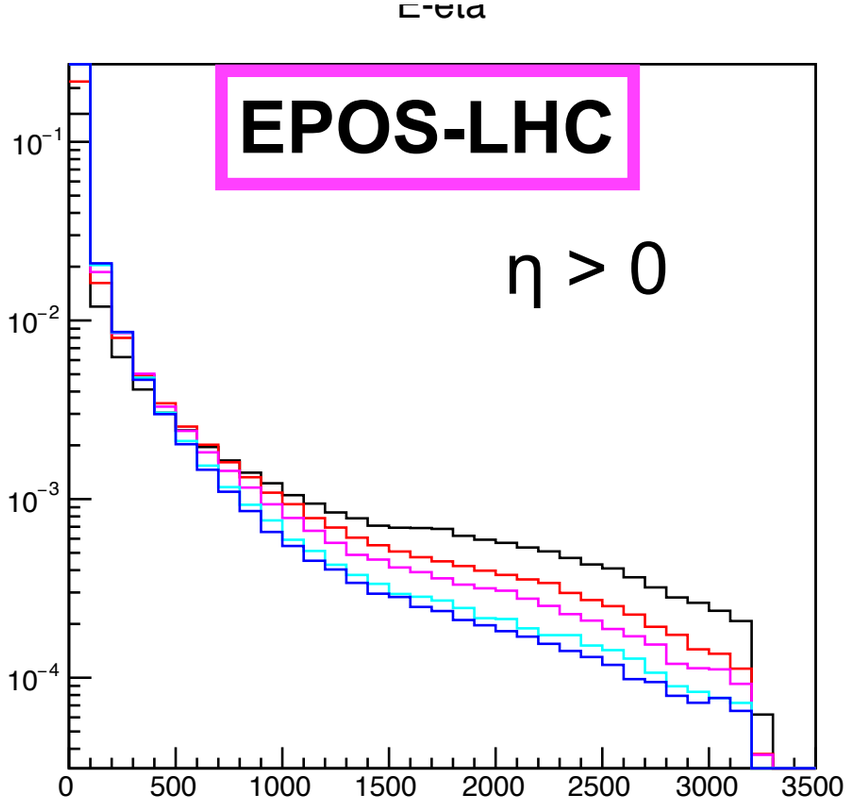
Energy spectrum of photons

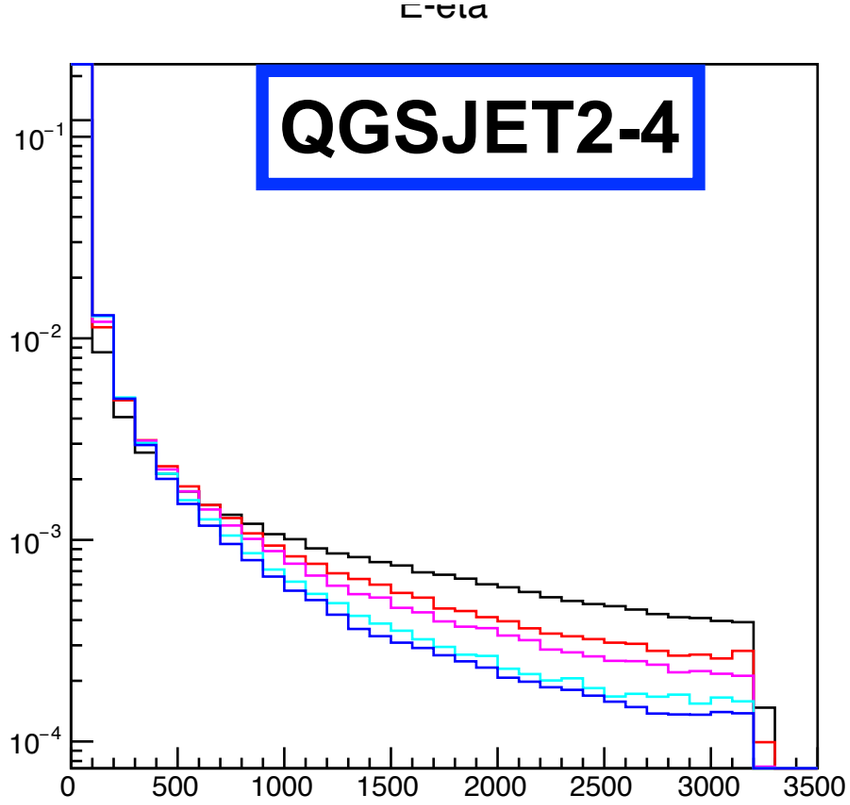


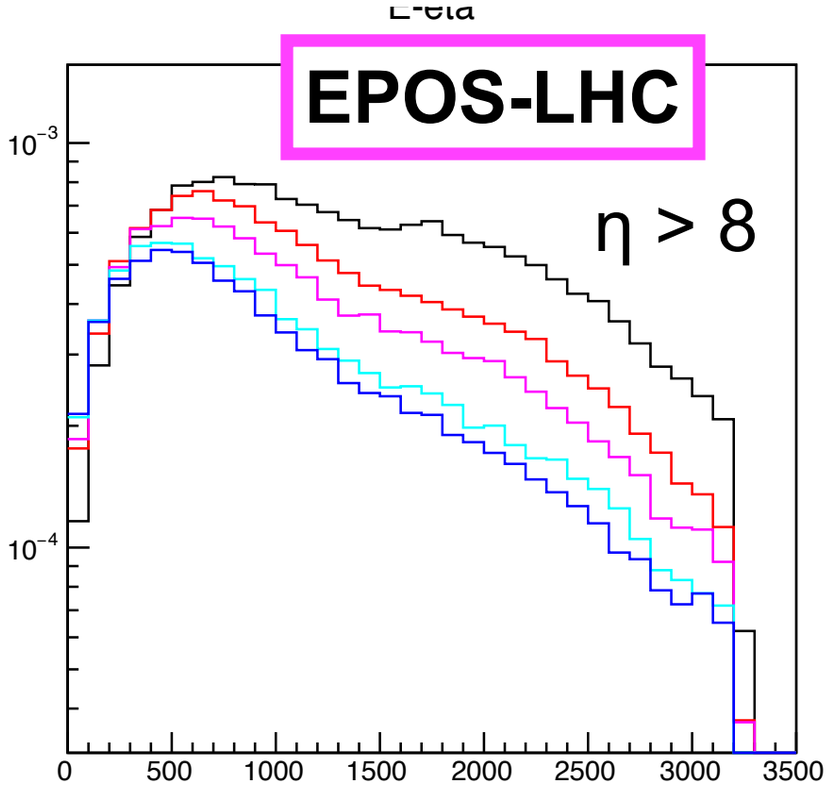


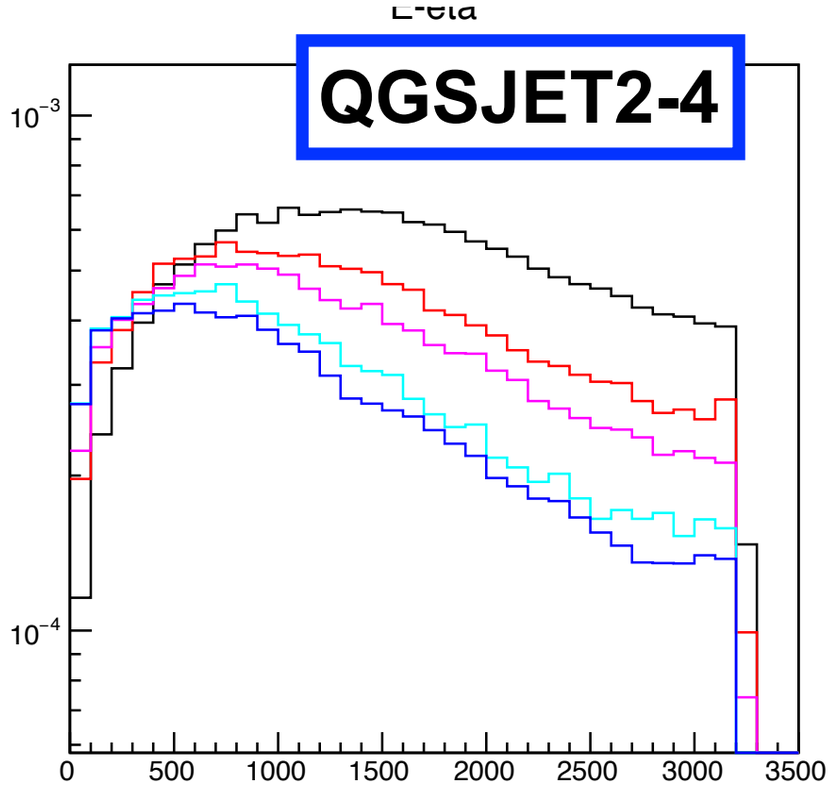
Consistent
with LHCf-RUN1 π^0 result
Little y, pT dependency
of nuclear modification factor

Energy spectrum of Neutron

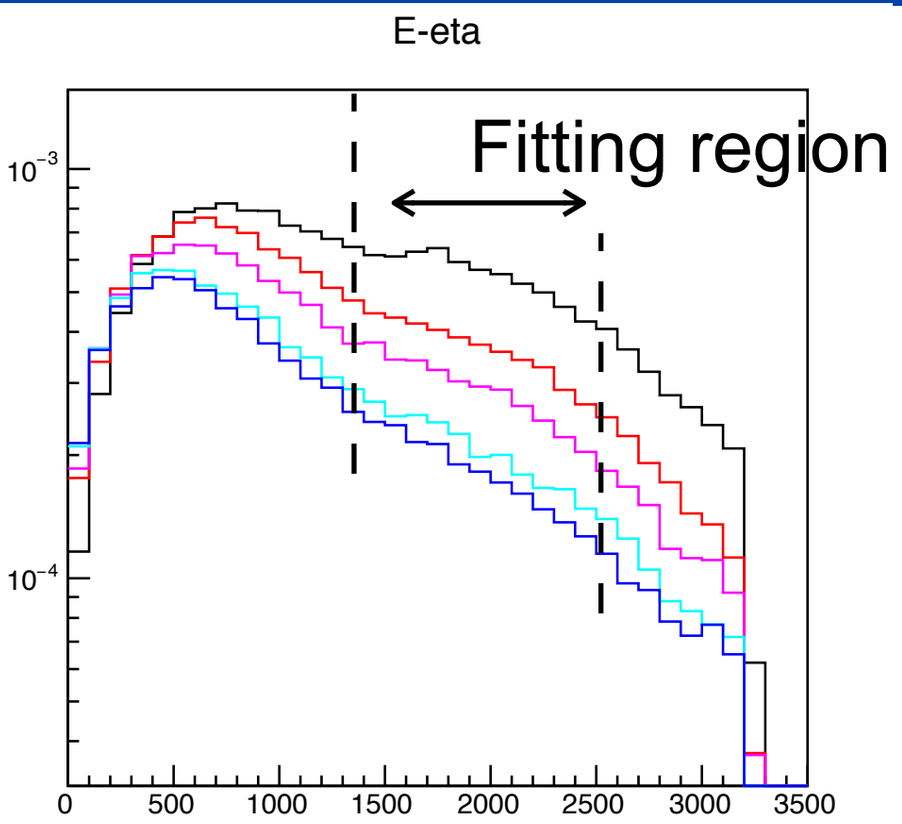




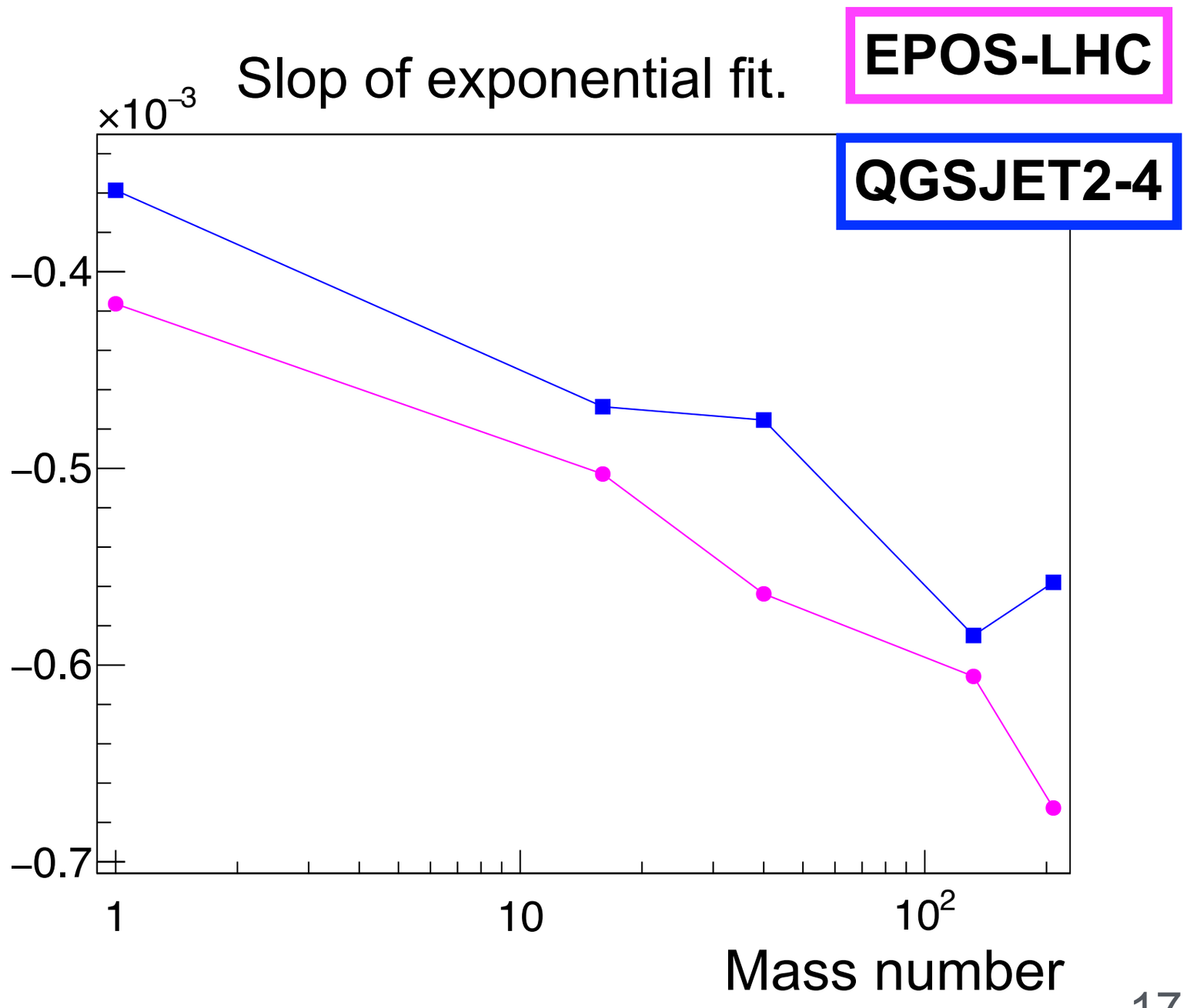




Energy spectrum of neutrons



Large dependency
on mass number
however, very difficult
to have spectrum of
neutron spectrum
with p-Pb data
due to large background
from UPC collisions

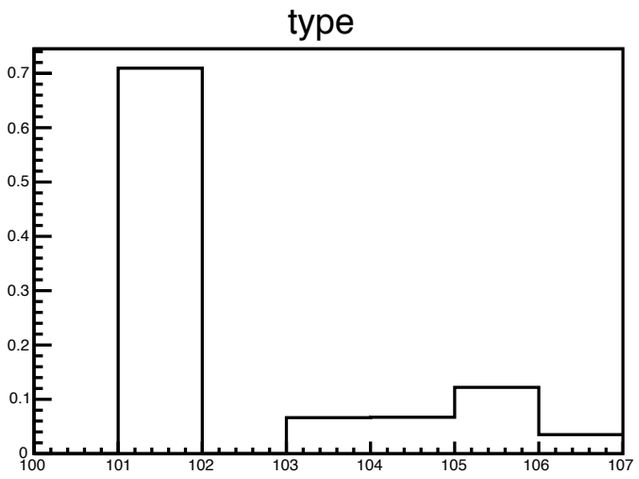


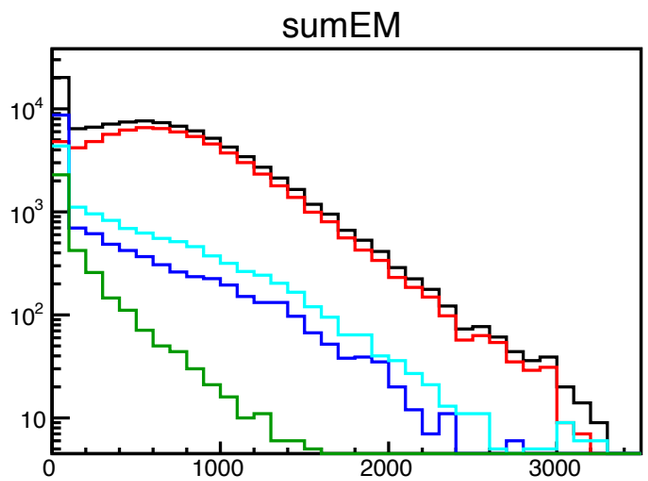
Summary about mass dependency

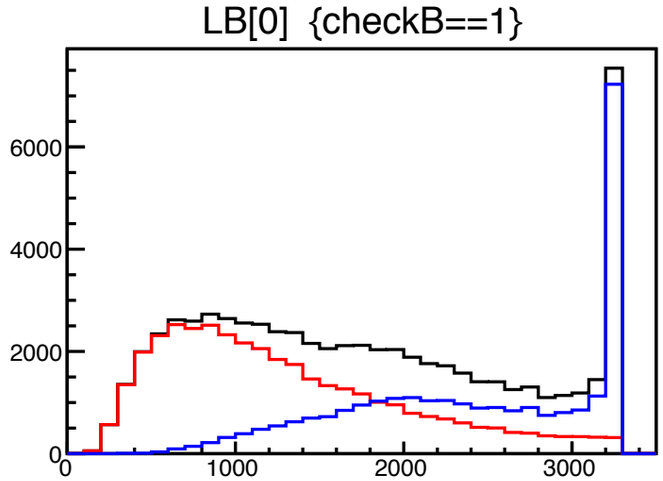
- Forward photons
  - Energy flow: Yes
  - Spectrum shape: No
    <= p-O might be addressed
    by the interpolation between pp and pPb.
- Forward neutrons
  - Spectrum flow: Yes
    <= No precise measurement at p-Pb is possible
    due to very large contribution from UPC

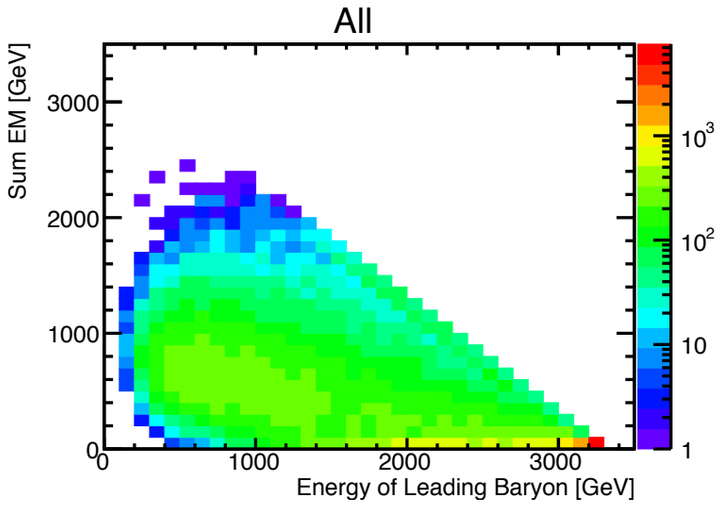
Clear motivation for p-O collisions can be from neutron (inelasticity) measurement.

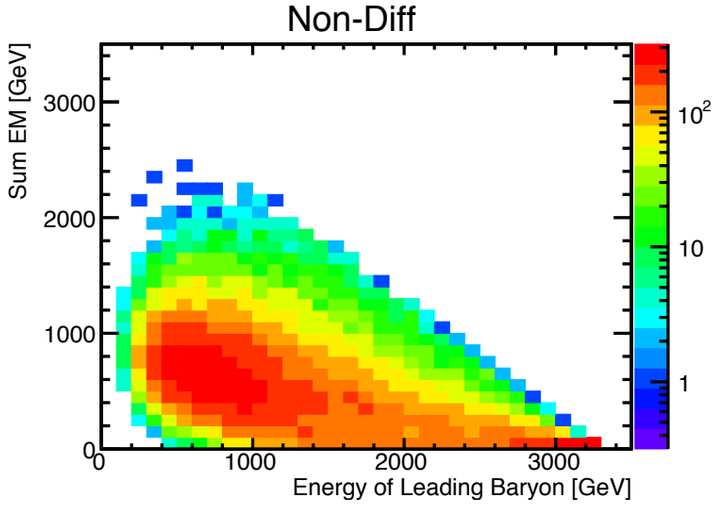
Some result with pp 6.5TeV.

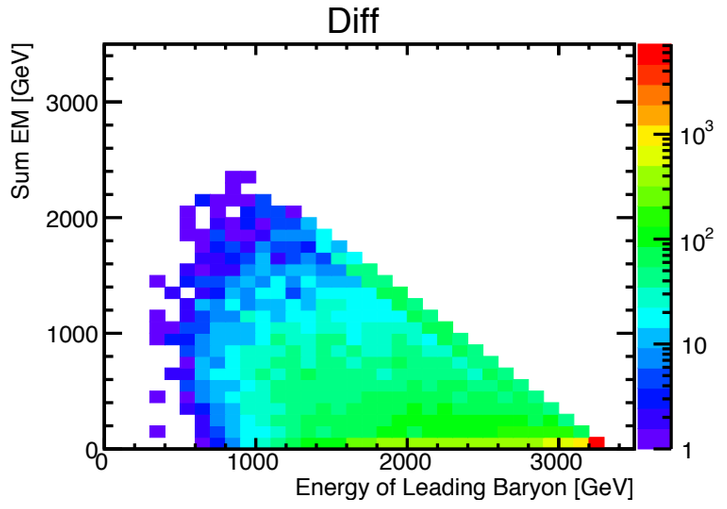


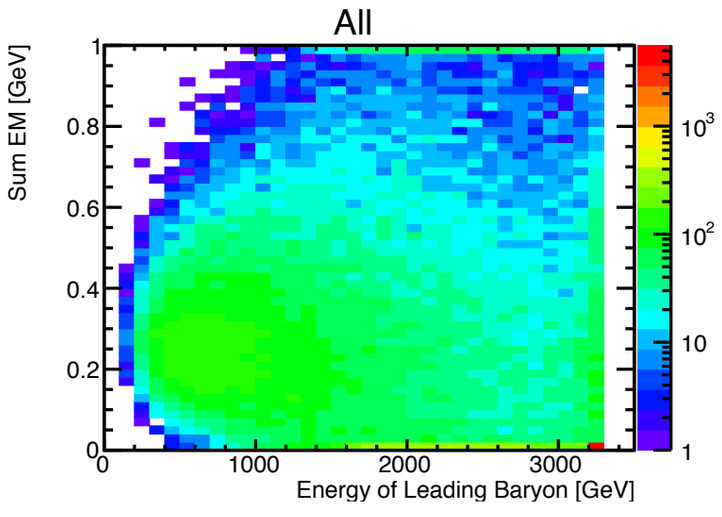


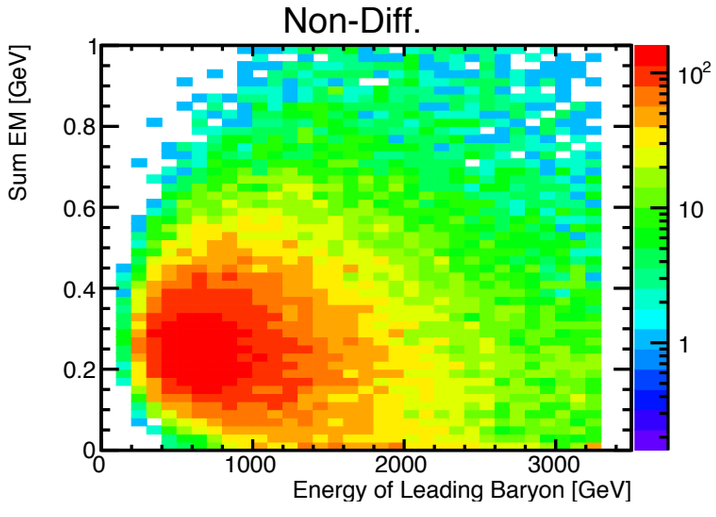


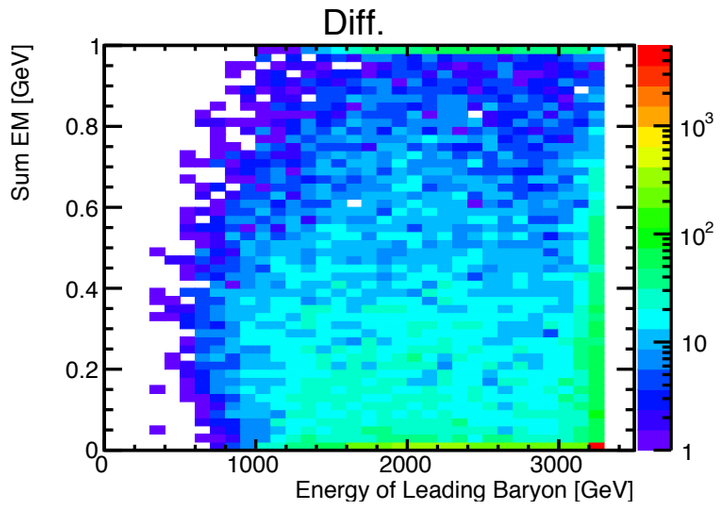












Fraction of diffractive events