Hadronic Gamma Rays

Previously…

- Apply Lorentz boost depending on pi0 eta sign in COM
- Could Tevatron data be interesting ([CDF forward detectors](#))?
- Do we have forward 900 GeV data? →only AFP
- Need pi0 energy fraction and pT for gamma-like classification

29.2.2024

Link between frames: Lorentz Boost depending on side (QGSJET II-04)

$\eta(\pi 0) < 0$ in COM frame→Lorentz boost to -z
$\eta(\pi 0) > 0$ in COM frame→Lorentz boost to +z
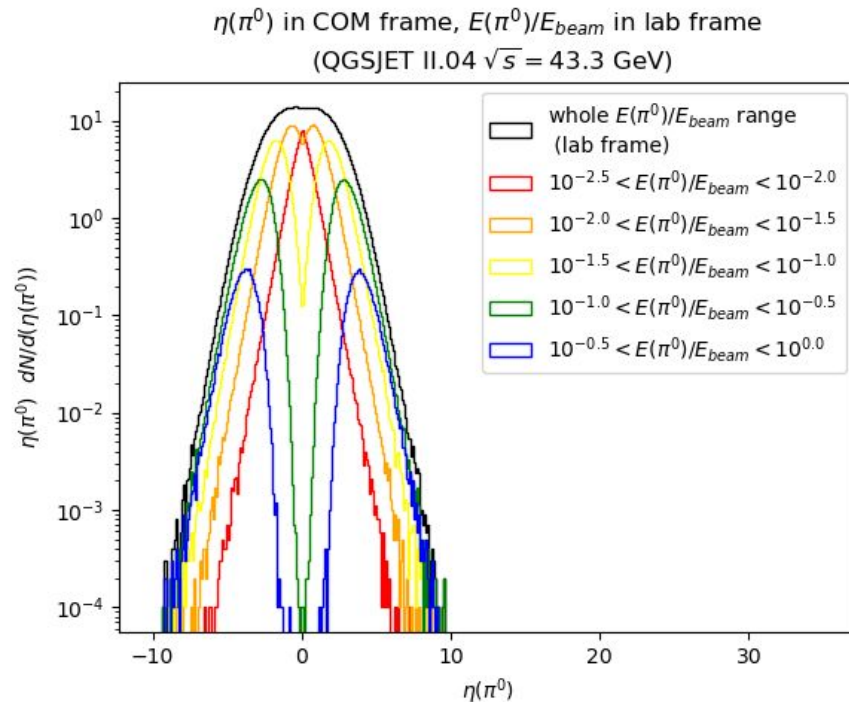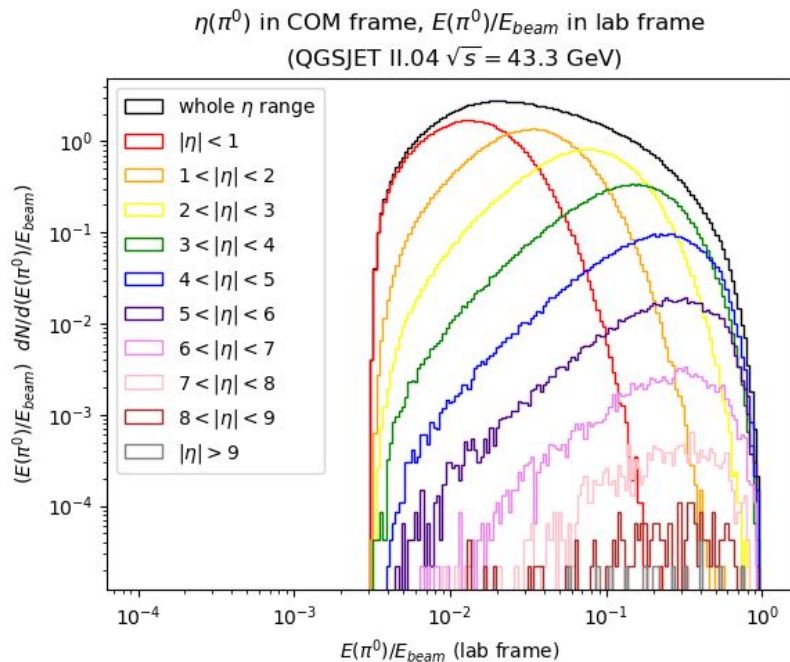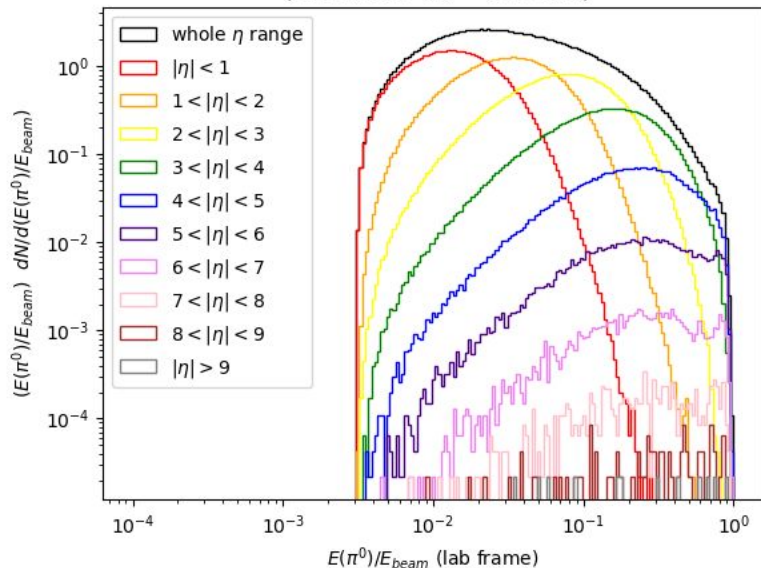
Link between frames: Lorentz Boost depending on side (PYTHIA 8.3)
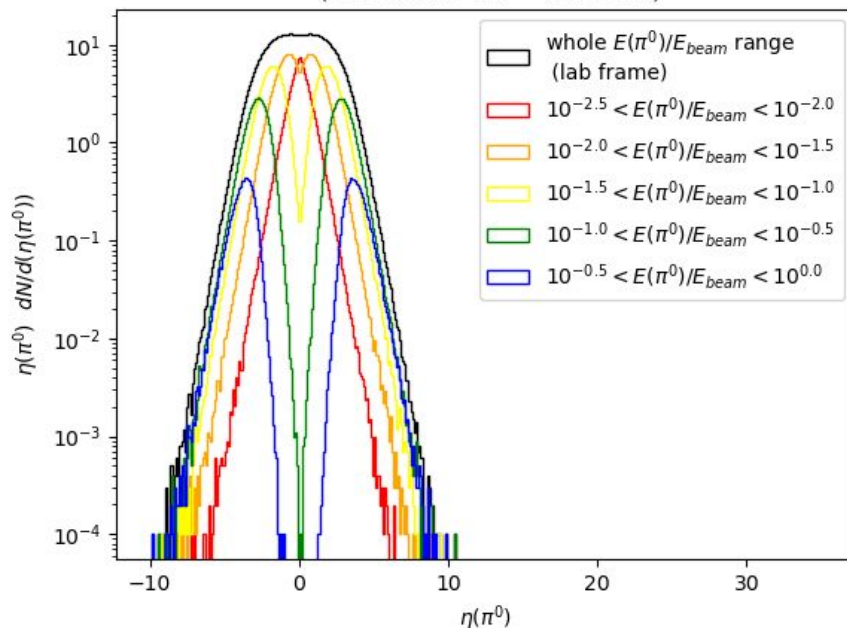
$\eta(\pi 0) < 0$ in COM frame→Lorentz boost to -z
$\eta(\pi 0) > 0$ in COM frame→Lorentz boost to +z

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(PYTHIA 8.3 $\sqrt{s}$ = 43.3 GeV)

whole η range
$|\eta| < 1$
$1 < |\eta| < 2$
$2 < |\eta| < 3$
$3 < |\eta| < 4$
$4 < |\eta| < 5$
$5 < |\eta| < 6$
$6 < |\eta| < 7$
$7 < |\eta| < 8$
$8 < |\eta| < 9$
$|\eta| > 9$

$(E(\pi^0)/E_{beam})$ $dN/d(E(\pi^0)/E_{beam})$

$E(\pi^0)/E_{beam}$ (lab frame)

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(PYTHIA 8.3 $\sqrt{s}$ = 43.3 GeV)

whole $E(\pi^0)/E_{beam}$ range
(lab frame)
$10^{-2.5} < E(\pi^0)/E_{beam} < 10^{-2.0}$
$10^{-2.0} < E(\pi^0)/E_{beam} < 10^{-1.5}$
$10^{-1.5} < E(\pi^0)/E_{beam} < 10^{-1.0}$
$10^{-1.0} < E(\pi^0)/E_{beam} < 10^{-0.5}$
$10^{-0.5} < E(\pi^0)/E_{beam} < 10^{0.0}$

$\eta(\pi^0)$ $dN/d(\eta(\pi^0))$

$\eta(\pi^0)$

Link between frames: Lorentz Boost depending on side (EPOSLHC)

$\eta(\pi 0) < 0$ in COM frame→Lorentz boost to -z
$\eta(\pi 0) > 0$ in COM frame→Lorentz boost to +z

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
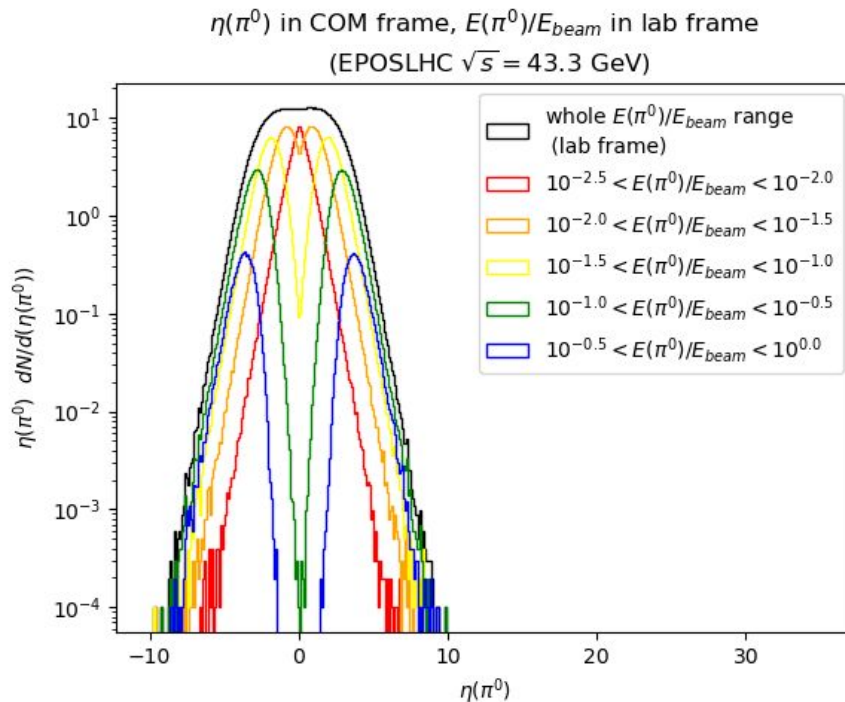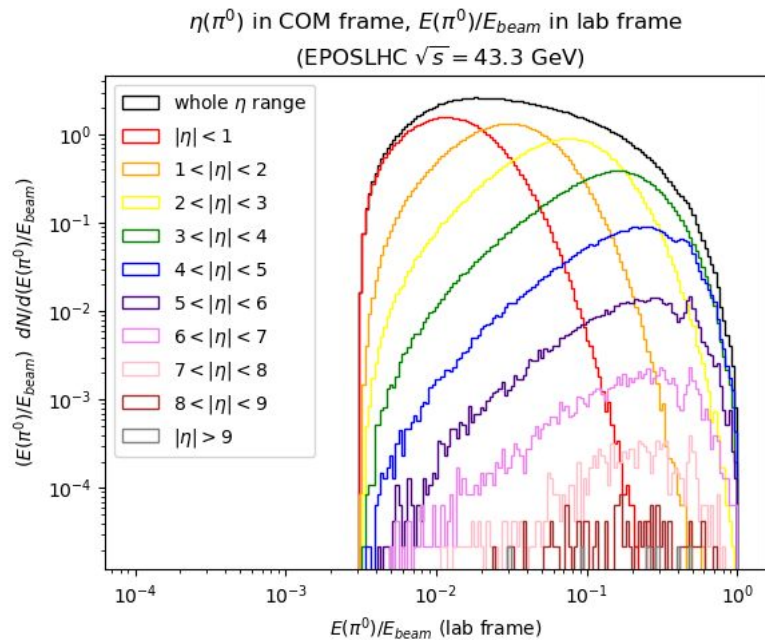(EPOSLHC $\sqrt{s}$ = 43.3 GeV)

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(EPOSLHC $\sqrt{s}$ = 43.3 GeV)
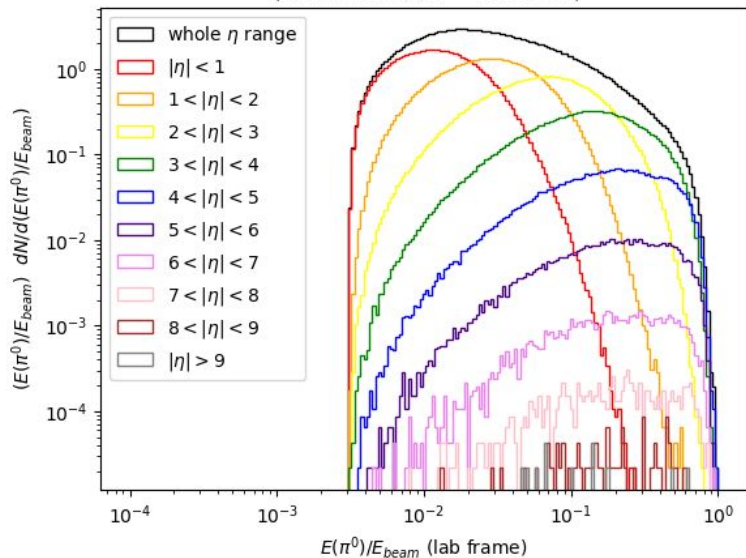
Link between frames: Lorentz Boost depending on side (SIBYLL 2.3d)
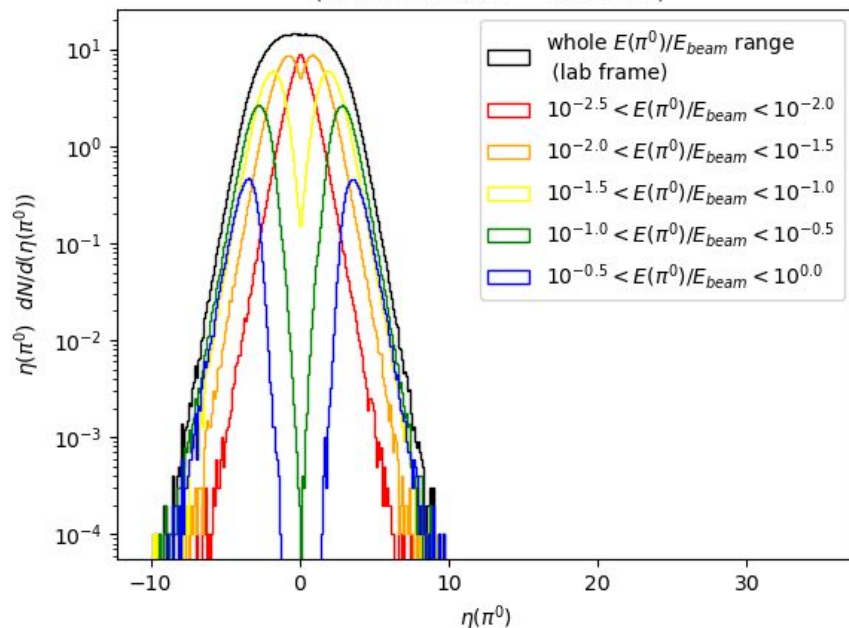
$\eta(\pi 0) < 0$ in COM frame→Lorentz boost to -z
$\eta(\pi 0) > 0$ in COM frame→Lorentz boost to +z

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(SIBYLL 2.3d $\sqrt{s}$ = 43.3 GeV)

- whole η range
- $|\eta| < 1$
- $1 < |\eta| < 2$
- $2 < |\eta| < 3$
- $3 < |\eta| < 4$
- $4 < |\eta| < 5$
- $5 < |\eta| < 6$
- $6 < |\eta| < 7$
- $7 < |\eta| < 8$
- $8 < |\eta| < 9$
- $|\eta| > 9$

$E(\pi^0)/E_{beam}$ (lab frame)

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(SIBYLL 2.3d $\sqrt{s}$ = 43.3 GeV)

- whole $E(\pi^0)/E_{beam}$ range (lab frame)
- $10^{-2.5} < E(\pi^0)/E_{beam} < 10^{-2.0}$
- $10^{-2.0} < E(\pi^0)/E_{beam} < 10^{-1.5}$
- $10^{-1.5} < E(\pi^0)/E_{beam} < 10^{-1.0}$
- $10^{-1.0} < E(\pi^0)/E_{beam} < 10^{-0.5}$
- $10^{-0.5} < E(\pi^0)/E_{beam} < 10^{0.0}$

$\eta(\pi^0)$

Link Between 2 Energy Scales?

→ $\eta\_max = 0.5 * \ln(s / m(\pi0)^2)$ ($p\_T \to 0$)
→ $\eta\_min = 0.5 * \ln(s / (m(\pi0)^2 + p\_T^2))$

E.g. $\sqrt{s}$ = 43.3 GeV → $p\_T(\pi0) \lesssim 1.5$ GeV (Pythia) for $E\_lab/E\_beam > 0.9$
→ $3.36 < |\eta| < 5.77$ (CDF MiniPlug but wrong energy?)

$\sqrt{s}$ = 13.6TeV → $p\_T(\pi0) \lesssim 1.5$ GeV (Pythia) for $E\_lab/E\_beam > 0.9$
→ $9.11 < |\eta| < 11.52$ (LHCf coverage!)

$\sqrt{s}$ = 900GeV → $p\_T(\pi0) \lesssim 1.5$ GeV (Pythia) for $E\_lab/E\_beam > 0.9$
→ $6.40 < |\eta| < 8.80$ (maybe CMS CASTOR? - only very small rapidity overlap, $-6.6 < \eta < -5.2$)

$\sqrt{s}$ = 1.96 TeV → $p\_T(\pi0) \lesssim 1.5$ GeV (Pythia) for $E\_lab/E\_beam > 0.9$
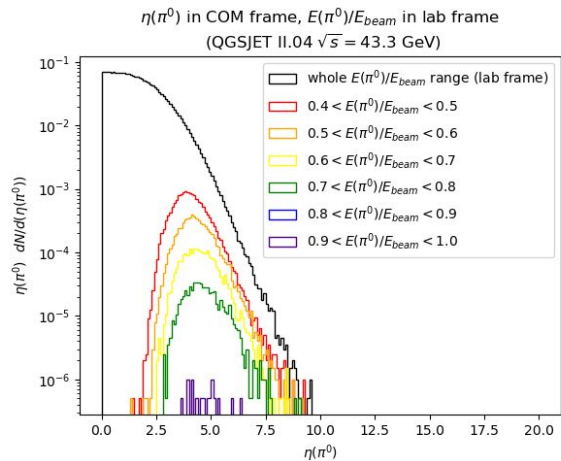→ $7.17 < |\eta| < 9.58$ (no overlap with any CDF forward detector coverage - see here)
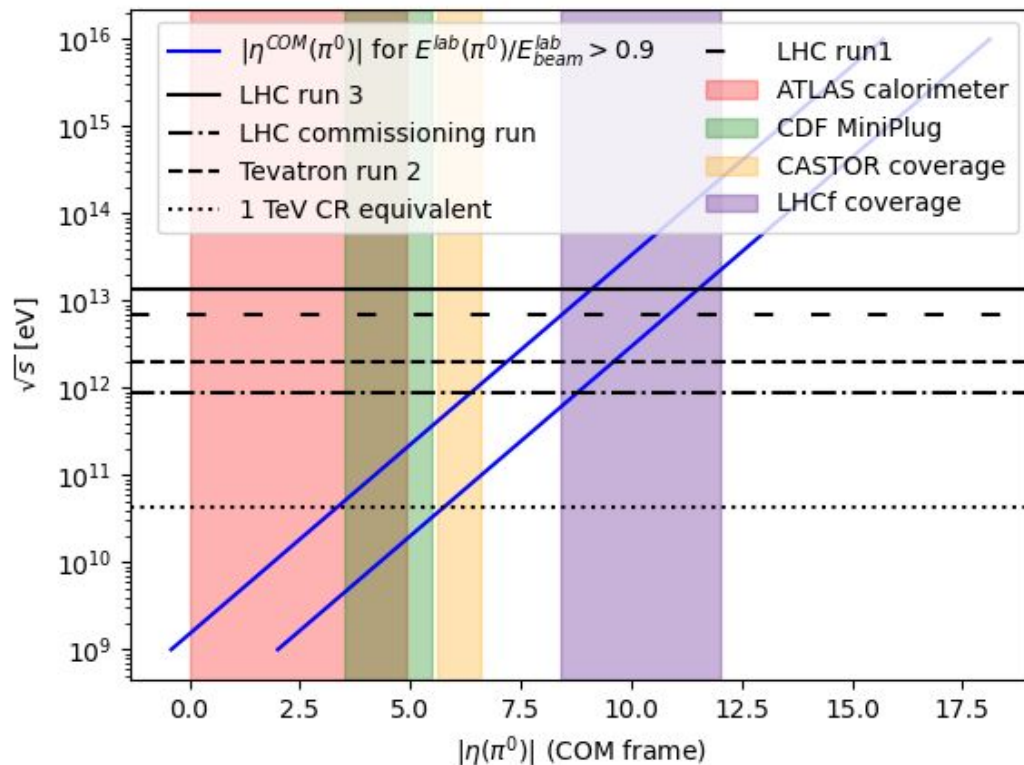
So far only LHCf data seems to be in right rapidity region.
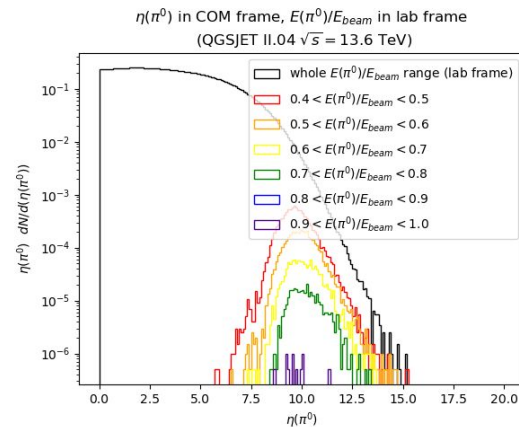
Link between energy scales: QGSJET II-04

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(QGSJET II.04 $\sqrt{s}$ = 43.3 GeV)

- whole $E(\pi^0)/E_{beam}$ range (lab frame)
- $0.4 < E(\pi^0)/E_{beam} < 0.5$
- $0.5 < E(\pi^0)/E_{beam} < 0.6$
- $0.6 < E(\pi^0)/E_{beam} < 0.7$
- $0.7 < E(\pi^0)/E_{beam} < 0.8$
- $0.8 < E(\pi^0)/E_{beam} < 0.9$
- $0.9 < E(\pi^0)/E_{beam} < 1.0$

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(QGSJET II.04 $\sqrt{s}$ = 900 GeV)

$\eta(\pi^0)$ in COM frame, $E(\pi^0)/E_{beam}$ in lab frame
(QGSJET II.04 $\sqrt{s}$ = 13.6 TeV)
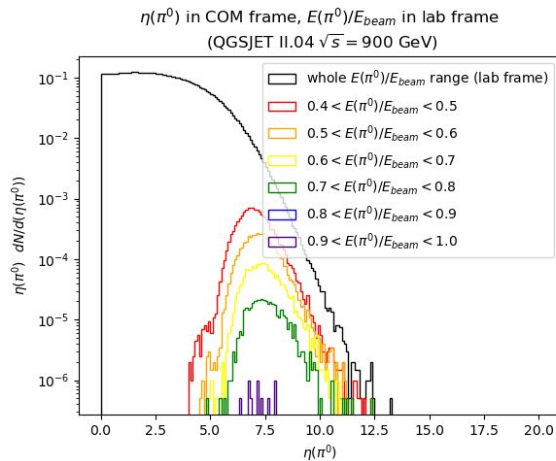
Scaling rel: $3.36 < |\eta| < 5.77$ $6.40 < |\eta| < 8.80$ $9.11 < |\eta| < 11.52$

Link between energy scales: PYTHIA 8.3

√s = 43.3 GeV
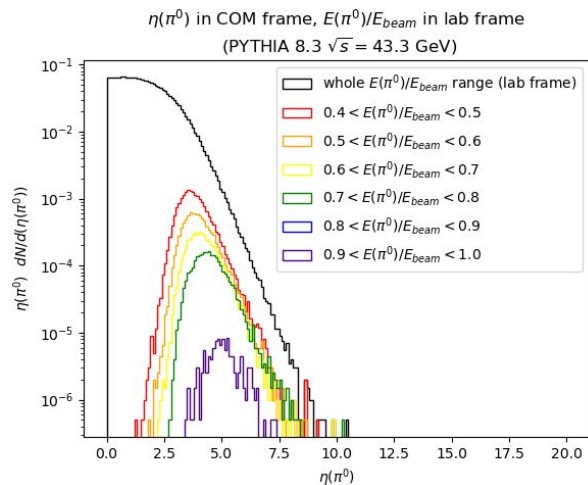
√s = 900 GeV
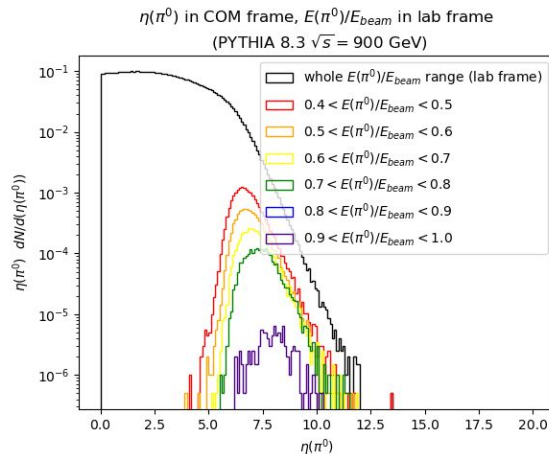
√s = 13.6 TeV

Scaling rel: $3.36 < |\eta| < 5.77$ $6.40 < |\eta| < 8.80$ $9.11 < |\eta| < 11.52$
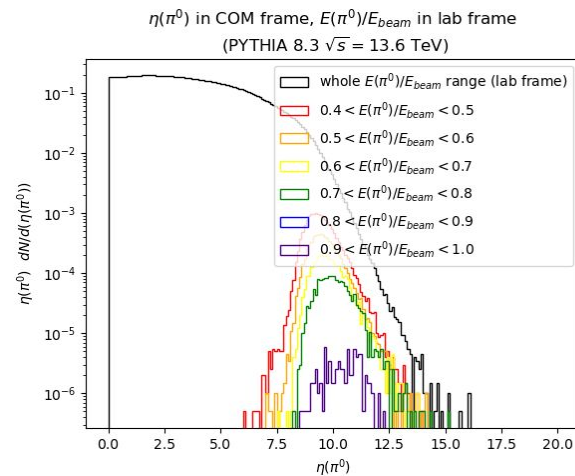
Link between energy scales: EPOSLHC

√s = 43.3 GeV
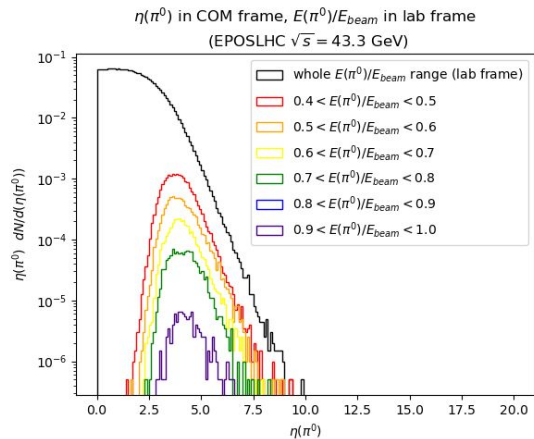
√s = 900 GeV
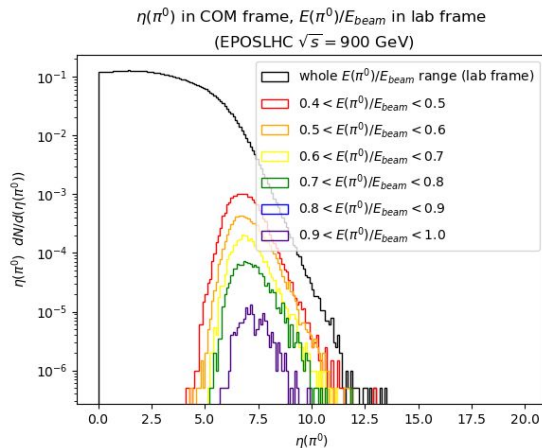
√s = 13.6 TeV
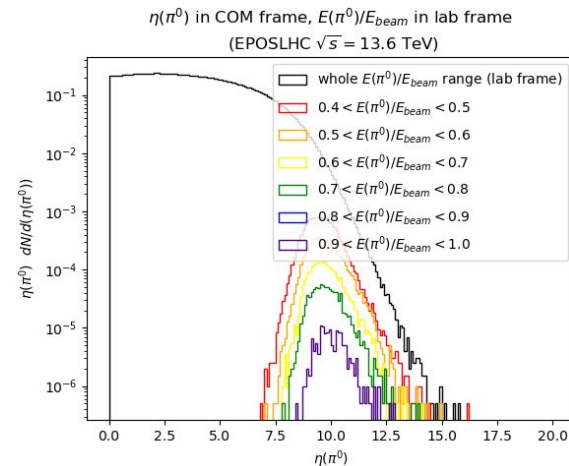
Scaling rel: $3.36 < |\eta| < 5.77$ $6.40 < |\eta| < 8.80$ $9.11 < |\eta| < 11.52$

Link between energy scales: SIBYLL 2.3d

√s = 43.3 GeV

√s = 900 GeV

√s = 13.6 TeV

Scaling rel: 3.36 < |η| < 5.77

6.40 < |η| < 8.80
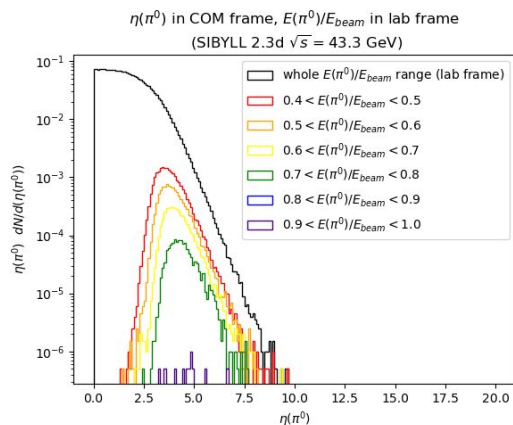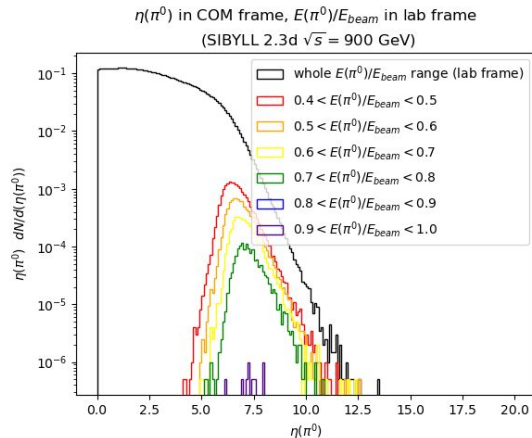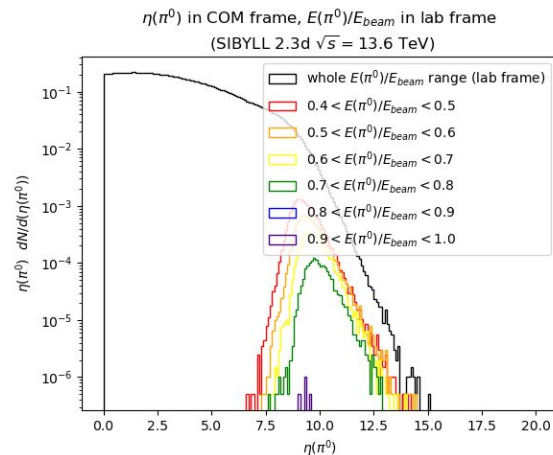
9.11 < |η| < 11.52

Current Status

✅ All samples for all energies and generators produced
✅ Plots for eta in energy bins + energy in eta bins with eta in COM and energy
   in lab frame for sqrt(s)=43.3GeV and 13.6TeV for all generators
✅ Scaling relation for interesting eta region with sqrt(s)
✅ Lower bound of eta region redefined

✅ Plots with sqrt(s)=900GeV
❌ Need pion energy range for gamma-like shower classification (Jan?) →for
   plotting and for eta range calculation
❌ Need pion pT range for gamma-like shower classification (Jan?) → lower
   bound of eta range
✅ Implemented eta sign dependent Lorentz boost
✅ Comparison of interesting eta regions with available experiments/data: LHCf (ZDC) so
   far only known option
❌ Paper draft on overleaf?

Any other interesting ideas to check for the paper?