At which pseudorapidities should we look if we want to see π^0 at maximal energy?

Following up on Marcel's work...

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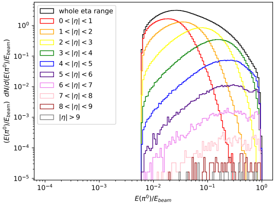
Humboldt University Berlin, 18.1.2023

Which Frame?

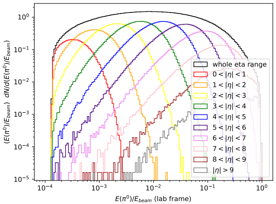
PYTHIA 8.3 Simulations

pp central collision: $\sqrt{s} = 43.3$ GeV
Lab = COM frame: $E_{\text{beam 1}} = E_{\text{beam 2}} = 21.66$ GeV

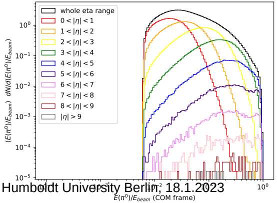


pp fixed target collision: $\sqrt{s} = 43.3$ GeV

Lab frame: $E_{\text{beam}} = 1$ TeV, $E_{\text{target}} = 0$ TeV
$E(\pi^0)$, E_{beam}, $\eta(\pi^0)$ in lab frame:



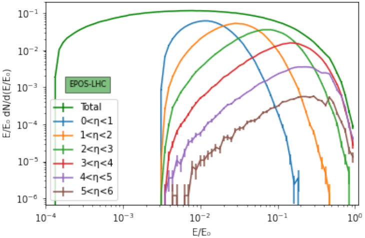
$E(\pi^0)$, E_{beam}, $\eta(\pi^0)$ in COM frame:



- ✓ Fixed target simulation in COM frame $\equiv$ central collision simulation
- > Lower end of spectrum $\sim \dfrac{m(\pi^0)}{E_{\text{beam}}}$
  - ✓ Fixed target lab frame: $\sim 1.35 \cdot 10^{-4}$
  - ✓ COM frame: $\sim 6.23 \cdot 10^{-3}$

Which Frame?

Marcel's Plots



→ η-binned distributions are in COM frame

→ Total distribution is in lab frame

Higher η bins in my plots visible than in Marcel's plots?

η-Bins

Marcel's derivation:

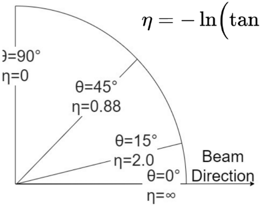


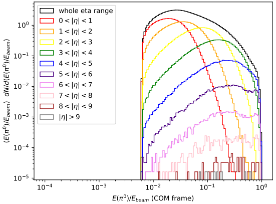
Fig. 11: Schematic of Pseudorapidity

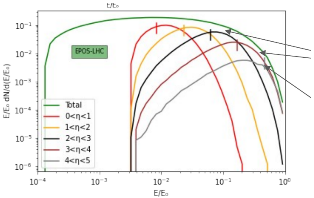
$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right) = \frac{1}{2}\ln\left(\frac{|p|+p_z}{|p|-p_z}\right) \approx \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$$

$$= \frac{1}{2}\ln\left(\frac{(E+p_z)^2}{E^2-p_z^2}\right) \approx \frac{1}{2}\ln\left(\frac{s}{m^2}\right) = \ln\left(\frac{\sqrt{s}}{m}\right)$$

Region to probe the cut-off:

$$\ln\left(\frac{0.1\sqrt{s}}{m_\pi}\right) < \eta < \ln\left(\frac{\sqrt{s}}{m_\pi}\right)$$





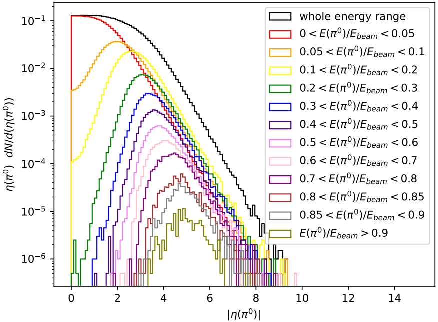
Observation:
$(E(\pi^0) + p_z(\pi^0))^2 = s$: assumes π^0 inherits $\sim$ all energy from beam particle (only valid for π^0 in COM frame)

In fixed target $E_{\text{beam}} = 1$ TeV case: ln $\left(\frac{\sqrt{s}}{m(\pi^0)}\right) \approx 5.8$

Maybe should check η-"cutoff" in a different way?

We are interested in expected $\eta(\pi^0)$ for highest energy pions!

$\rightarrow$ Plot η in energy bins! (COM frame)

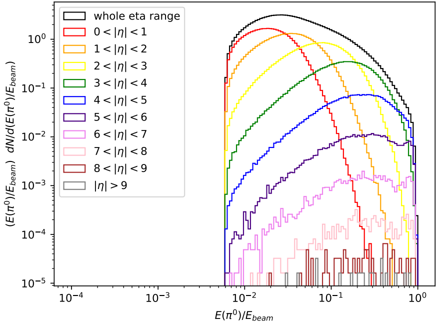


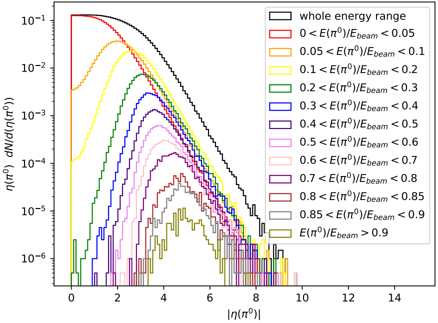
Observations:

- $\eta(\pi^0)$ is not just growing with $E(\pi^0)/E_{\text{beam}}$
- $\eta(\pi^0)$ seems to approach a certain value for high energies

Some Thoughts...

How do these two plots fit together?





- High η-bins in left plot correspond to “summed up” tails of energy bins in right plot

$\rightarrow$ contributions for higher η come from many different energy bins in right plot

$\rightarrow$ Hence energy distributions in left plot get flatter for higher η

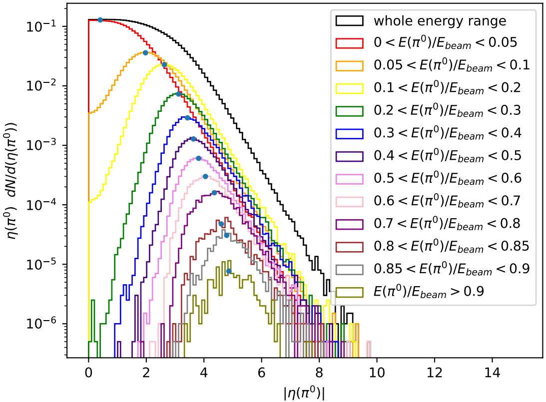
- What we are really interested in is expected η-range for π^0 close to beam energy

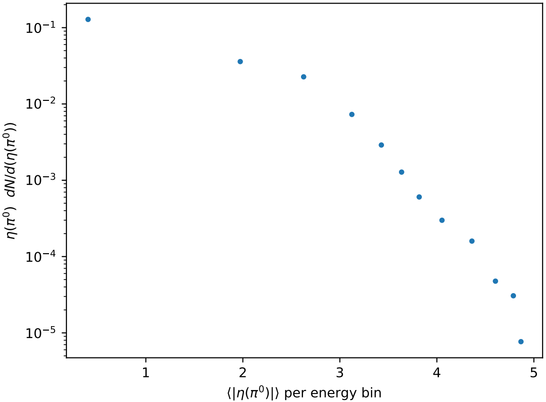
$\rightarrow$ does not necessarily coincide with highest possible η

$\rightarrow$ Interested in η-composition at energy cut-off rather than η-cutoff

Quick Check

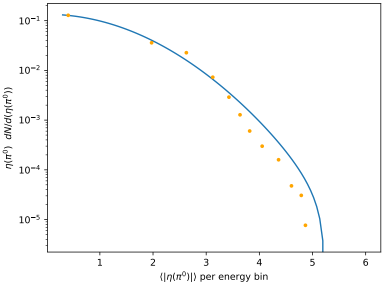
Fit η-distributions for energy bins with Gaussian and extract means:





Quick Check

Fit $\langle\eta\rangle$ with $\sim$ exp $\left(-\alpha x^2\right)$



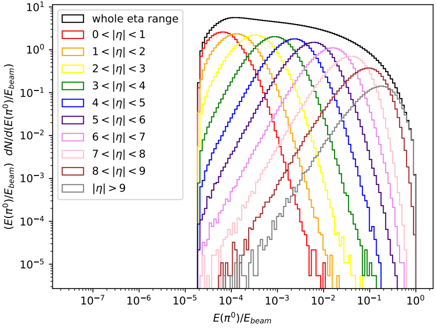
- Fitted function gets 0 at $\langle\eta\rangle = 5.23$

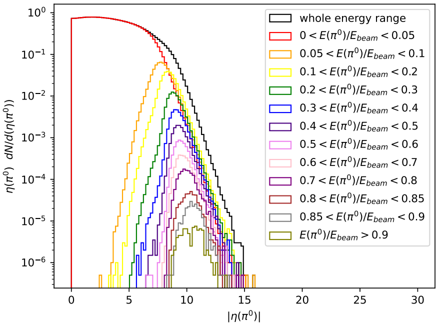
$\rightarrow$ Expected $\eta(\pi^0)$ for high energy limit?

- Mean width of Gaussians ~ 0.7

$\rightarrow$ (crude) estimate for expected COM η-interval for highest $E(\pi^0)$ at $\sqrt{(s)} = 43.3$ GeV: $4.43 < |\eta(\pi^0)| < 5.93$

Try LHC energies

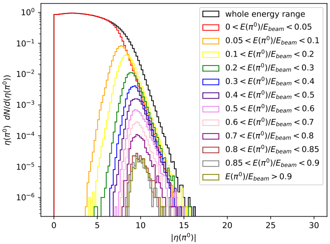




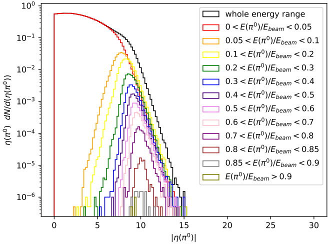
- Higher $\sqrt{s} \rightarrow$ higher expected $|\eta(\pi^0)|$
- Quick check: Mean and width from Gauss fit of last energy bin (with enough statistics): $9.7 < |\eta(\pi^0)| < 11.1$

Try different Generators (Still LHC Scenario)

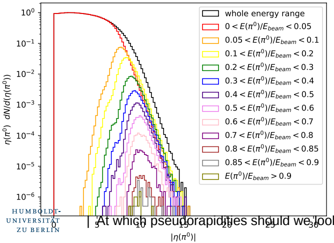
EPOSLHC:



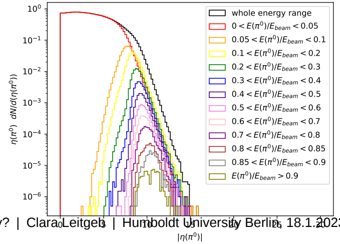
SIBYLL:



QGSJET:



PYTHIA:



Try different Generators (Still LHC Scenario)

Observations:

- Different generators show differences in high energy bin population (seen already before in energy distributions)
- However, not so much differences in expected $|\eta(\pi^0)|$ (judging by eye)
- Seems to coincide nicely with LHCf η acceptance
- Also compatibel with Marcel's estimation for $\sqrt{s} = 13.6$ TeV ($|\eta(\pi^0)| < 11.5$)

Conclusion

- Marcel's η estimation corresponds to highest π^0-energy bin in COM frame
- Highest energy bins are dominated by certain η-range (instead of just going to higher and higher η-values)
- Could develop strategy for extracting expected η-range for highest π^0 energies from fitting η-distributions for different energy bins and extrapolating to highest energies

$\rightarrow$ This was only a very crude attempt (try different fit functions, look at fit quality etc.)

- η-range for highest energies is then defined by extrapolated Gaussian mean and width
- Especially for the lower bound of the range this could deliver a better motivation than ln $\left(0.1 \cdot \sqrt{s}/m(\pi^0)\right)$

Something different...

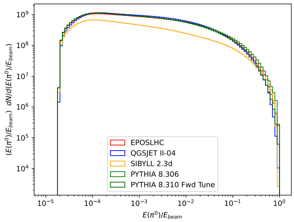
New forward Pythia tune available!

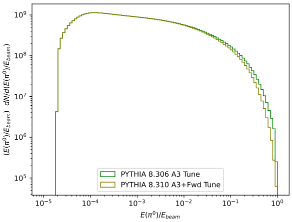
New Pythia Forward Tune

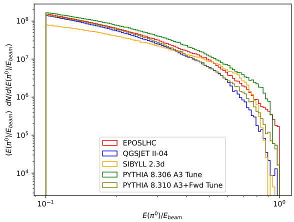
- Developed by people from FASER and FPF (forward physics facility), presented in MPI@LHC
- Based on LHCf results from run 1 and run 2!
- Publication here

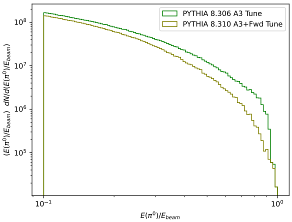
Full name	Shorthand	Baseline (Monash)	Forward Tune	Uncertainty
`BeamRemnants:dampPopcorn`	d_{pop}	1	0	
`BeamRemnants:hardRemnantBaryon`	f_{remn}	off	on	
`BeamRemnants:aRemnantBaryon`	a_{remn}	-	0.68	
`BeamRemnants:bRemnantBaryon`	b_{remn}	-	1.22	
`BeamRemnants:primordialKTsoft`	σ_{soft}	0.9	0.56	$0.2 \ldots 1.42$
`BeamRemnants:primordialKThard`	σ_{hard}	1.8	1.8	
`BeamRemnants:halfScaleForKT`	Q_{half}	1.5	10	
`BeamRemnants:halfMassForKT`	m_{half}	1	1	
`BeamRemnants:primordialKTremnant`	σ_{remn}	0.4	0.56	$0.22 \ldots 1.42$

Quick Check









$\rightarrow$ Strong impact on highly energetic π^0 distribution!