Diffraction at an EIC - Experiments

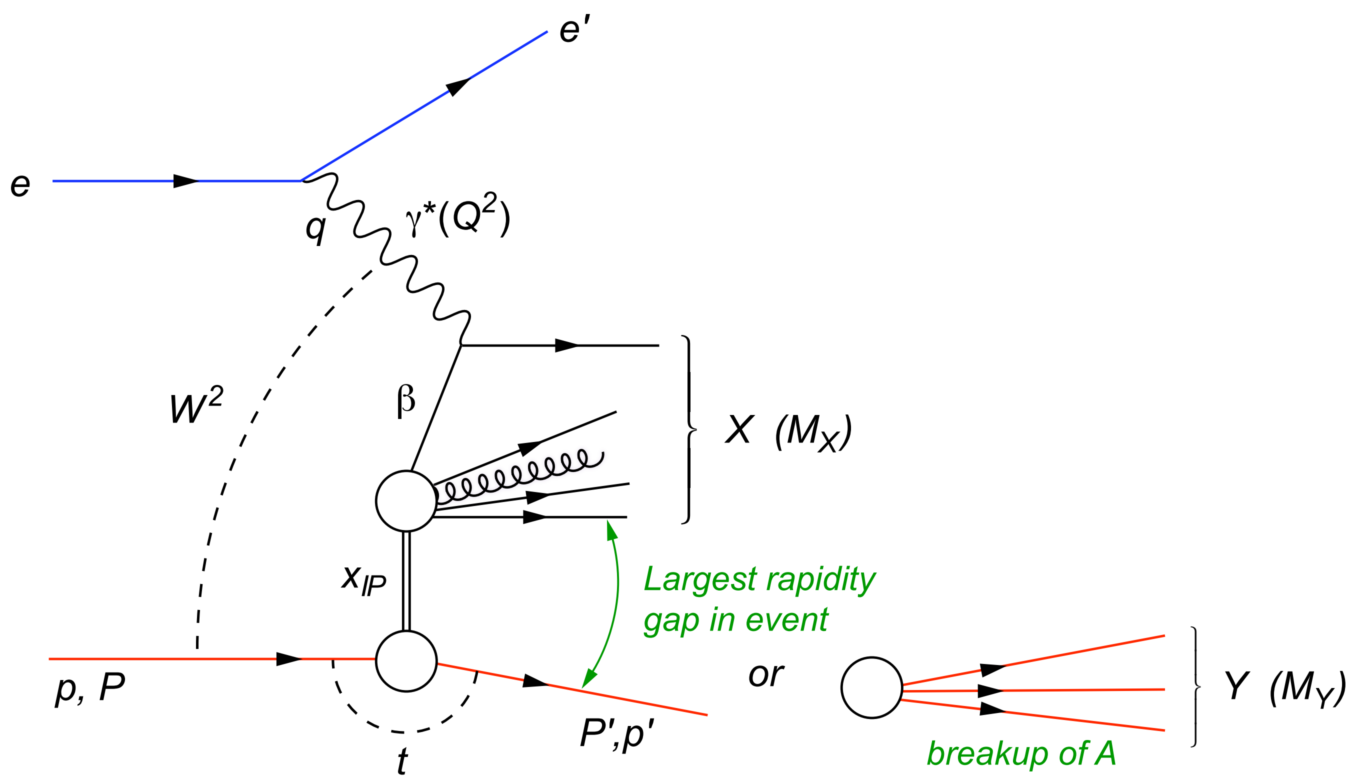
Matthew A. C. Lamont
BNL

BROOKHAVEN NATIONAL LABORATORY

Talk Outline

- Measuring diffractive events experimentally
  - ➡ Lessons learned from HERA
    - ▸ Forward Spectrometers, Rapidity Gaps
- MC studies for an EIC
  - ➡ Datasets studied
  - ➡ Forward Spectrometers
  - ➡ Large Rapidity Gaps
    - ▸ Purity/Efficiency
    - ▸ Acceptance issues
- Summary

Detection of Diffractive Events



The schematic illustration of a diffractive DIS event. The signatures are a large rapidity gap in the event and that the final state fragments still carry the quantum numbers of the nucleus.

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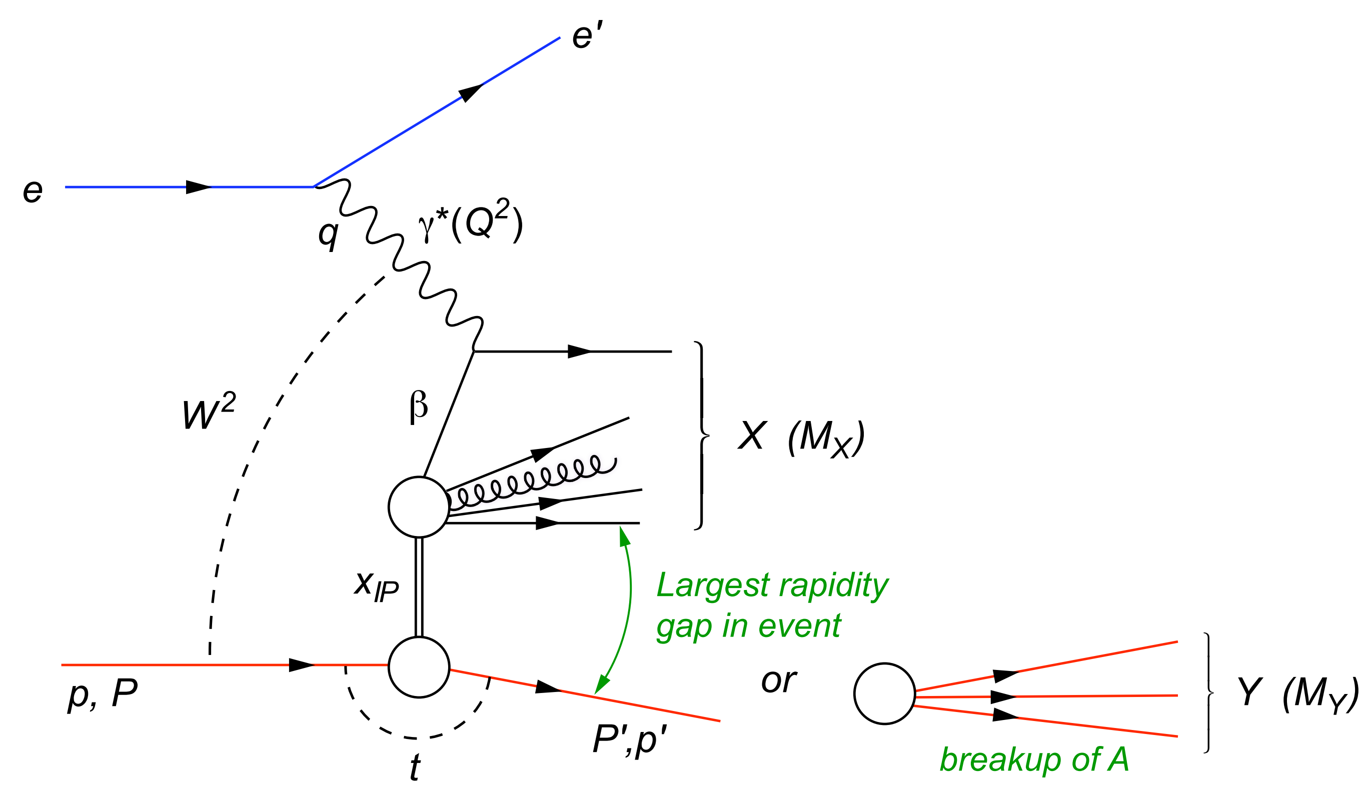

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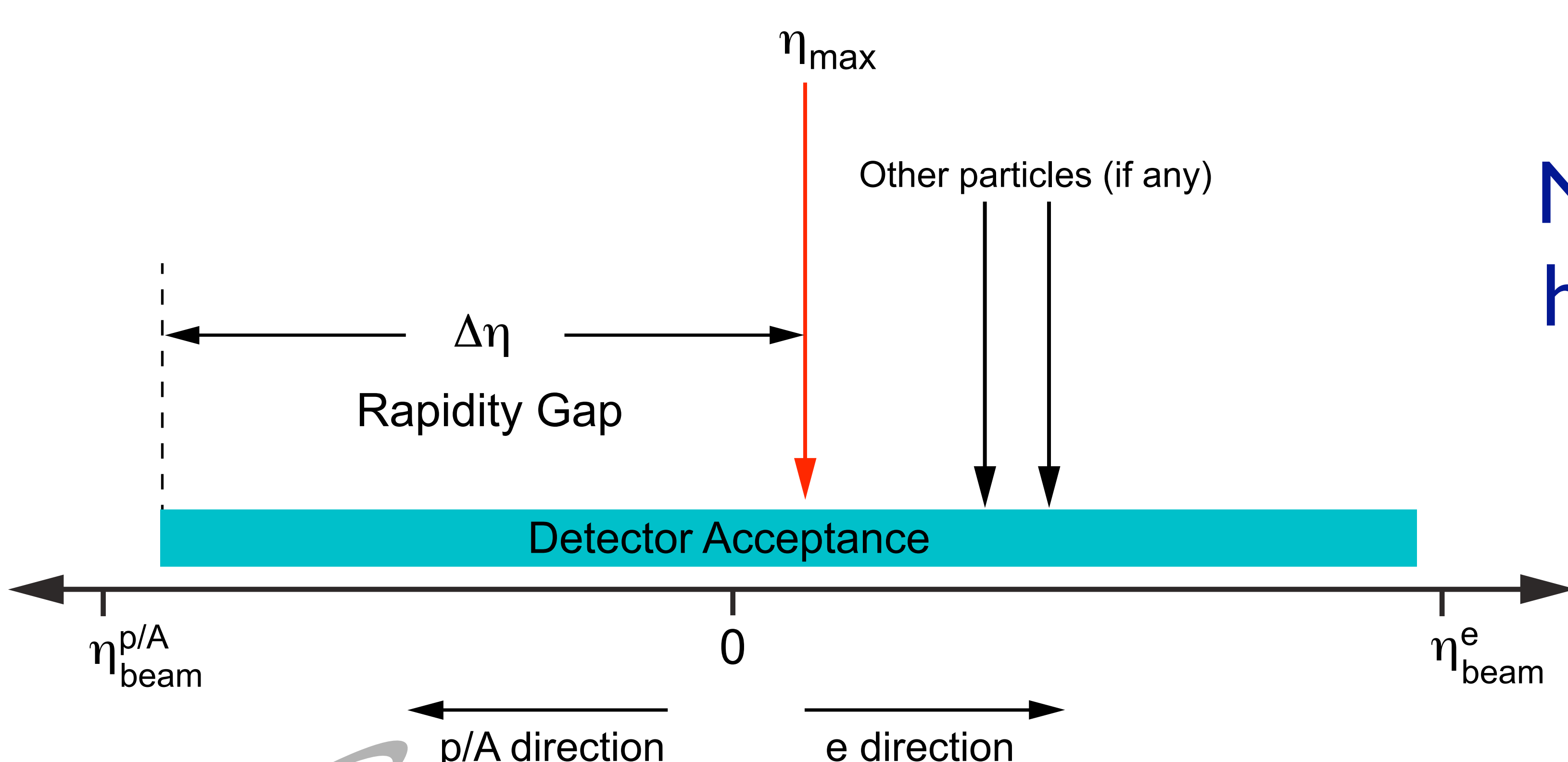
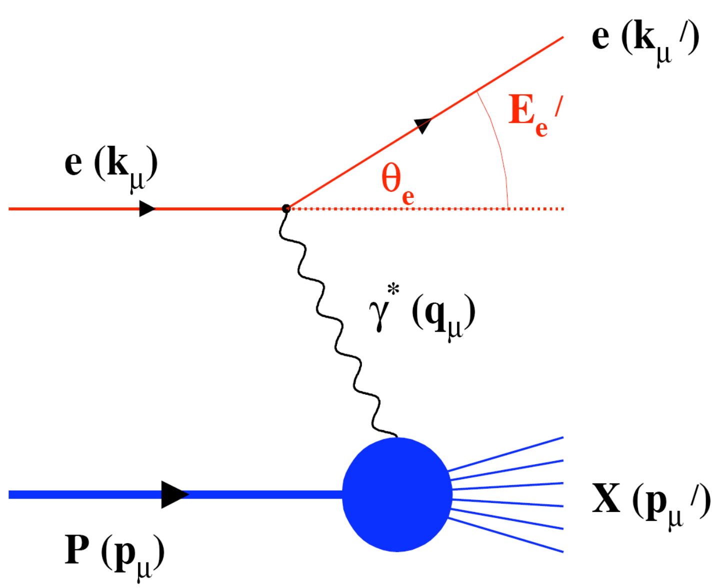
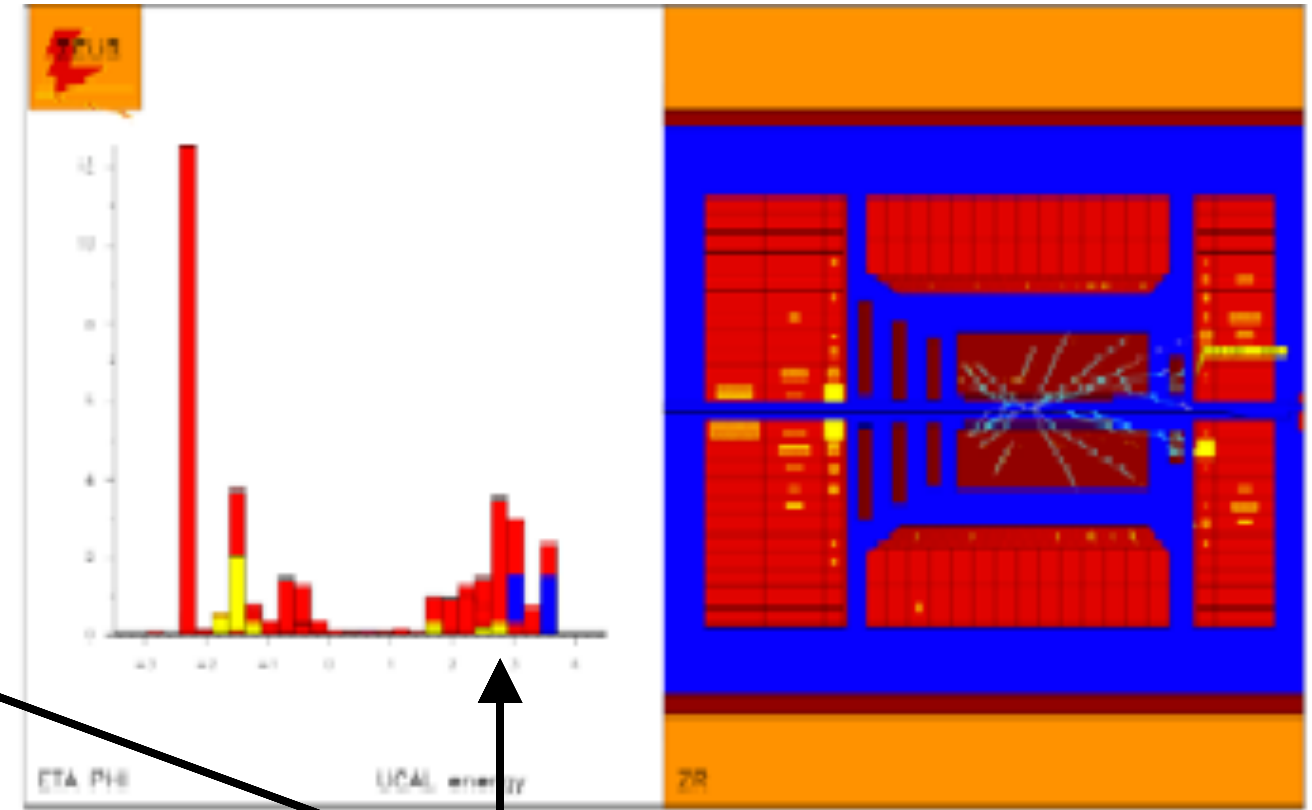


Need to transform this into how this is measured in the lab so we can calculate feasibility studies and detector requirements.

How Diffractive Events Look to an Experiment

‘Standard DIS event’





Activity in proton direction

How Diffractive Events Look to an Experiment

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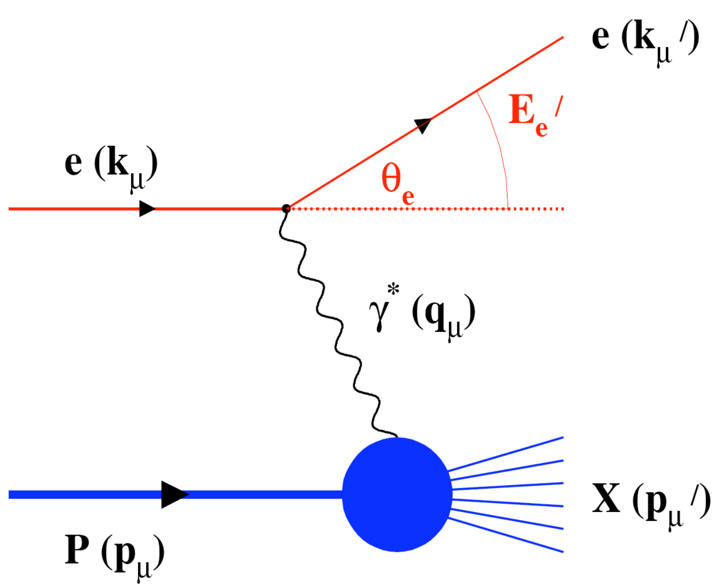
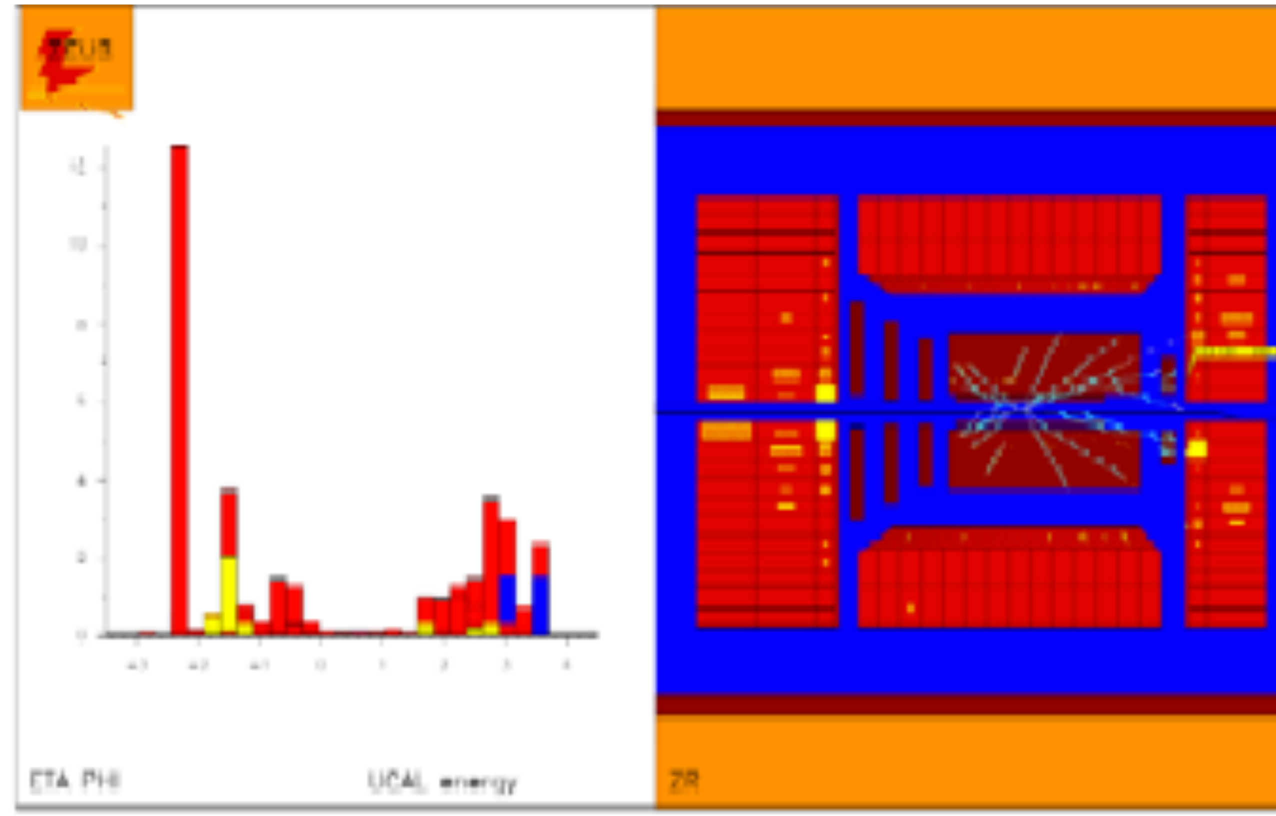
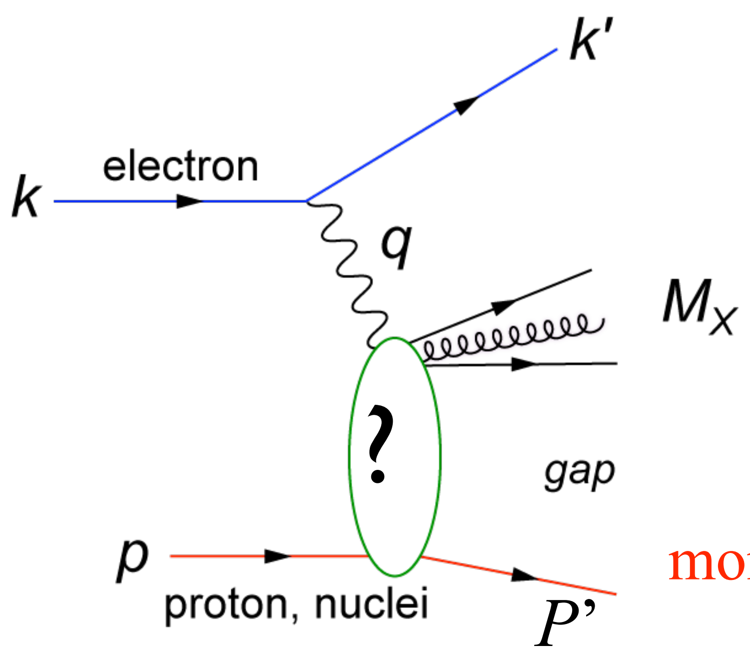
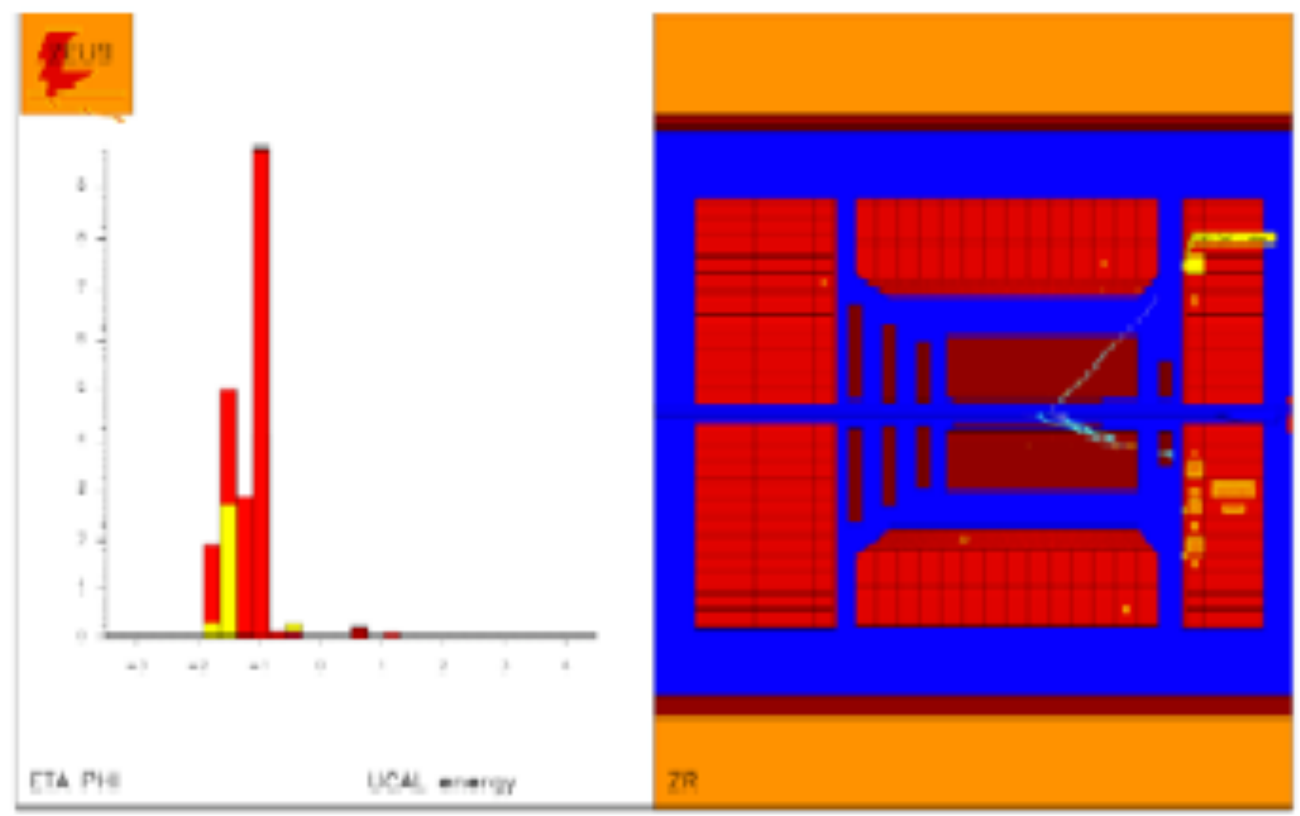




Diffractive event



momentum transfer:
$t = (P\text{-}P')^2$



Experimental techniques for diffractive events

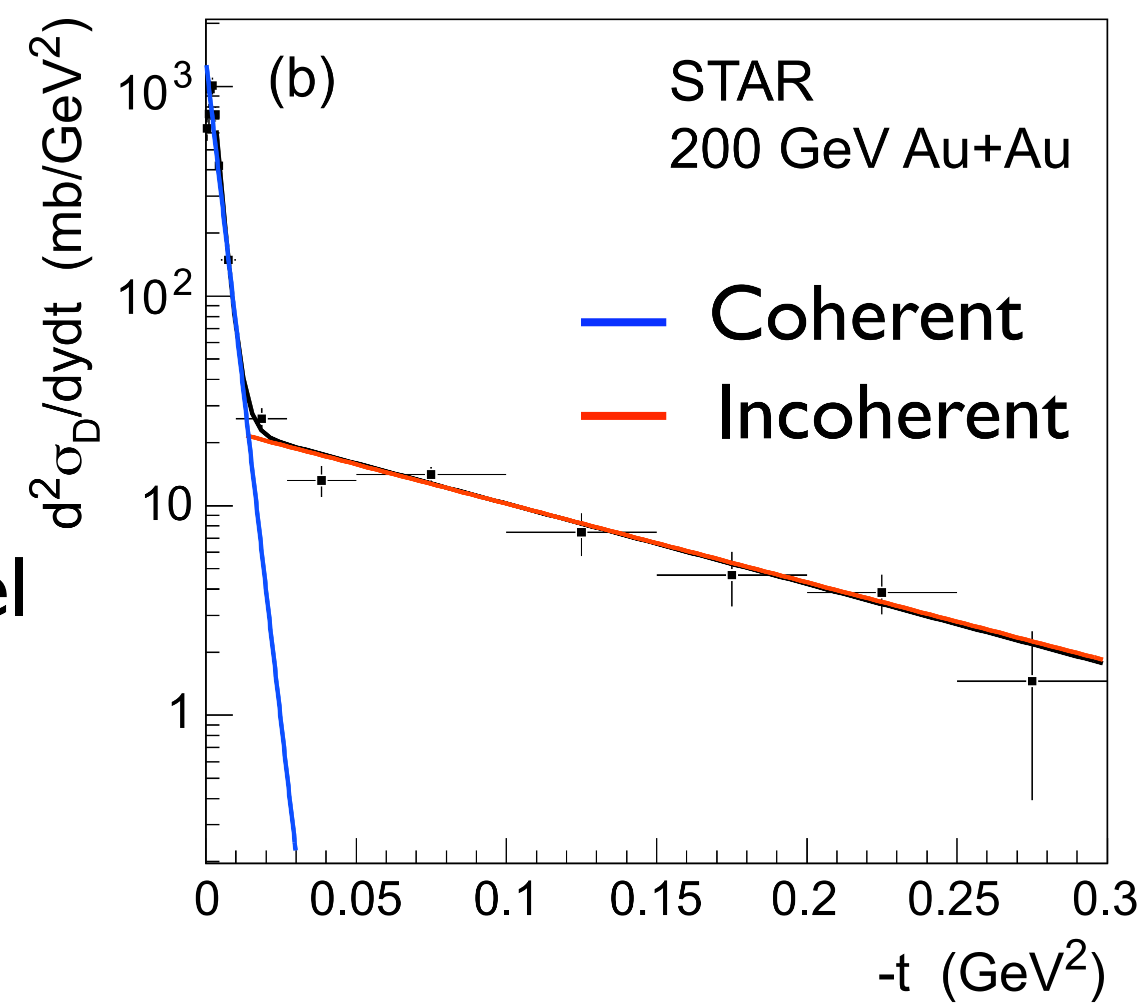
- Forward Spectrometer Method
  - ➡ Measure the final state proton/nucleus in the experiment
    - Direct measure of transferred momentum, t
    - Few events measured
- Large Rapidity Gap (LRG)/Mx Methods
  - ➡ Measure a rapidity gap between the final state proton/nucleus and most forward particle in the event
    - No direct measure of t (except for exclusive vector mesons)
    - High statistics

Forward Spectrometer Method

Due to the small t involved in coherent diffractive events, one needs to place a spectrometer far from the interaction point and close to the beam axis.

$$\theta \sim \frac{\sqrt(t)}{p}$$

Conventionally, Roman Pot (Si) detectors are placed close to the beam to measure the scattered protons.



However, beam particles do not run parallel and their angular spread is given by:

$$\theta_{beam} = \sqrt{\frac{\epsilon}{\beta*}}$$

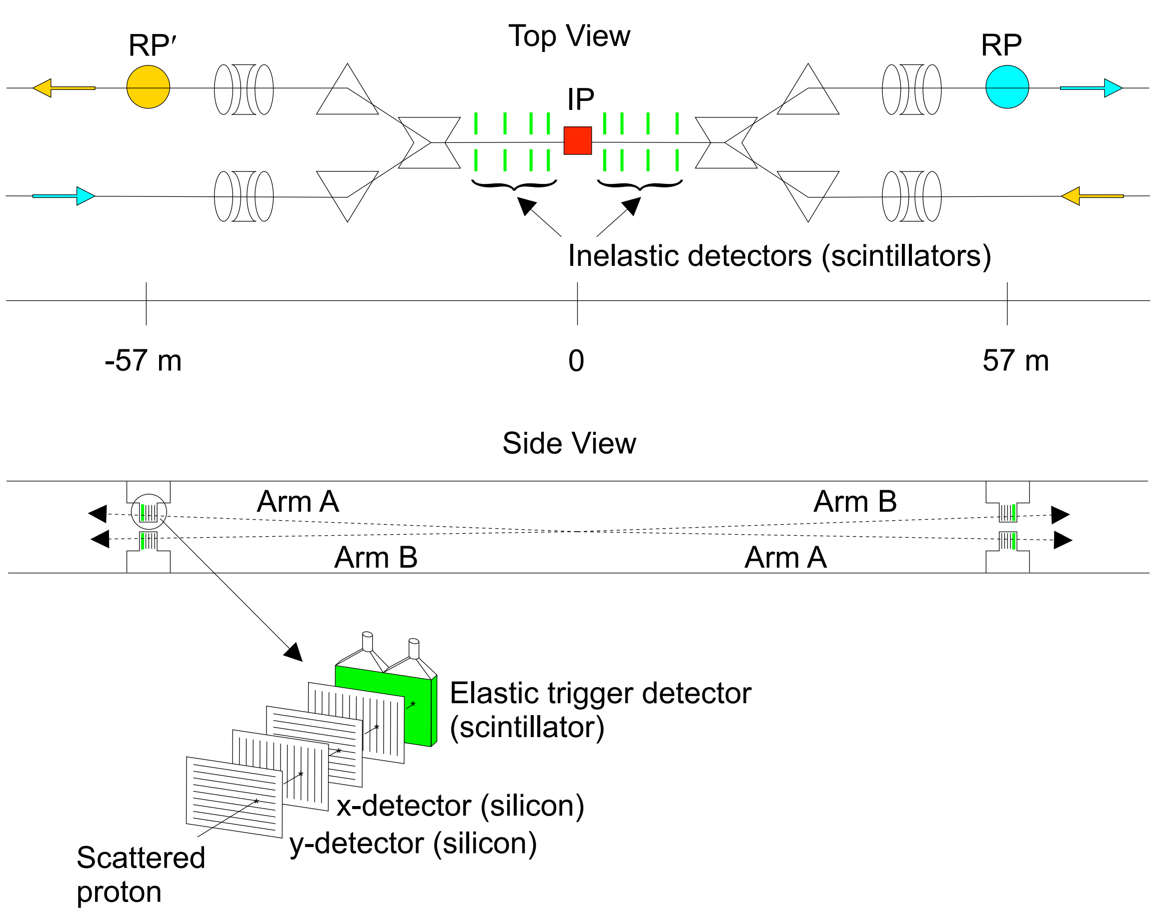
However, to realistically place Roman Pot detectors, we need to remember that:

$$\theta_{min} = 10\text{x}\theta_{beam} \;!!!$$

Forward Spectrometer Method

Typical β^* values for an EIC:

β^*_{min} (m)	θ_{min} (rad)
1	0.62
60	0.08
200	0.04



pp2pp experiment @ RHIC:

Designed to measure the elastic scattering of protons in the range:

$4\times10^{-4} < |t| < 1.3\ (\mathrm{GeV}/c)^2$

Forward Spectrometer Method: Nuclei

To achieve scattering angles larger than the minimum angular divergence, need:

$$p^T_{min} \sim pA\theta_{min}$$

Species (A)	p^T_{min} (GeV/c)
d (2)	0.02
Si (28)	0.22
Cu (64)	0.51
In (115)	0.92
Au (197)	1.58
U (238)	1.90

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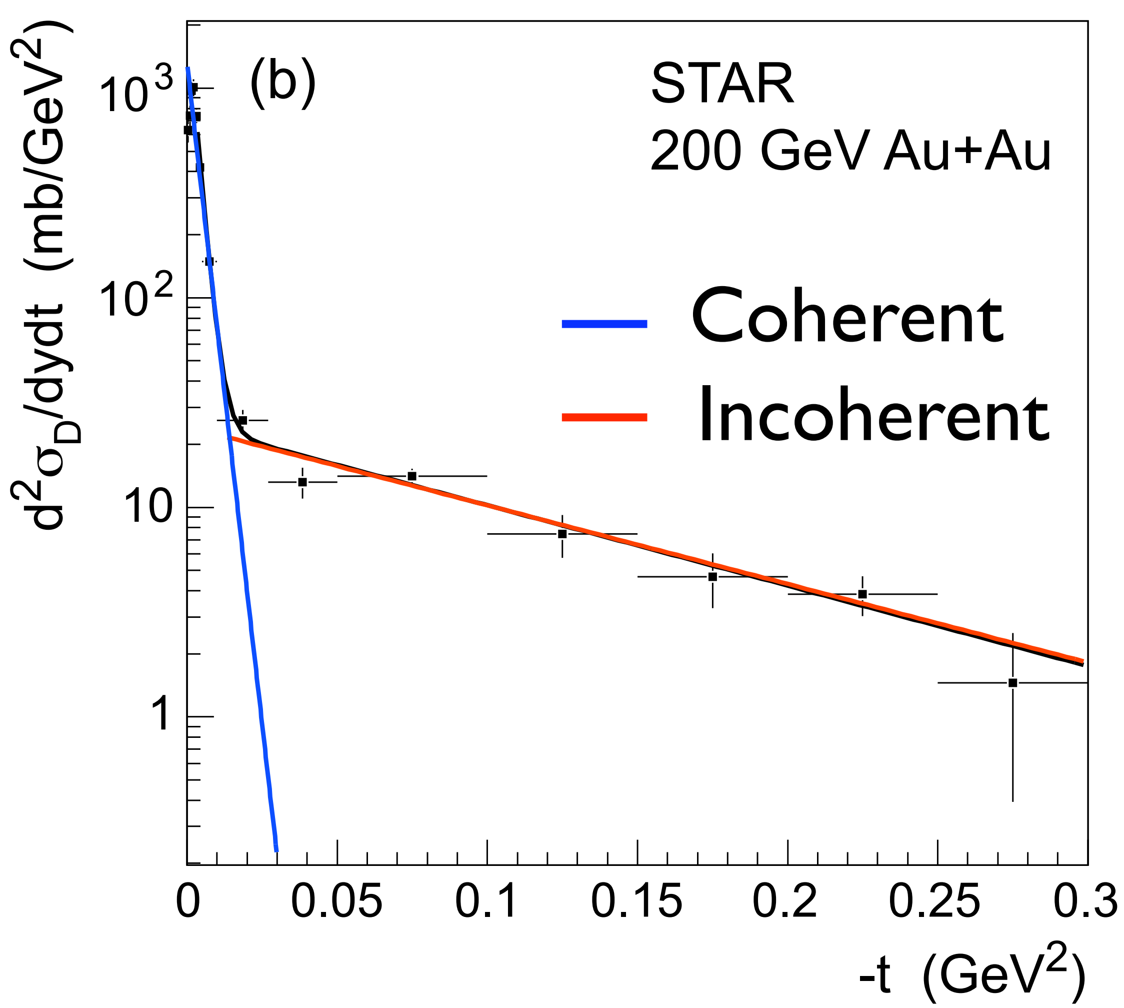

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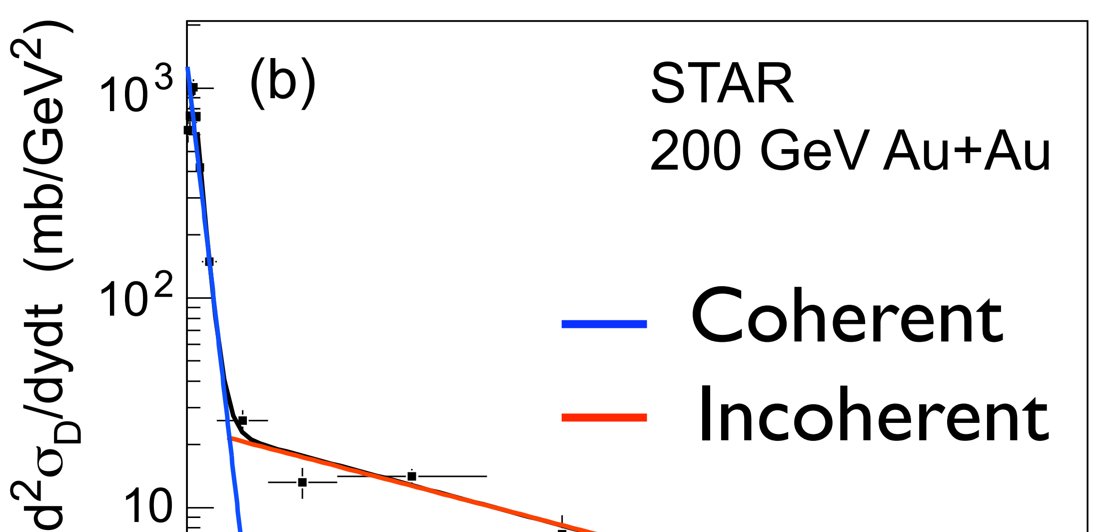

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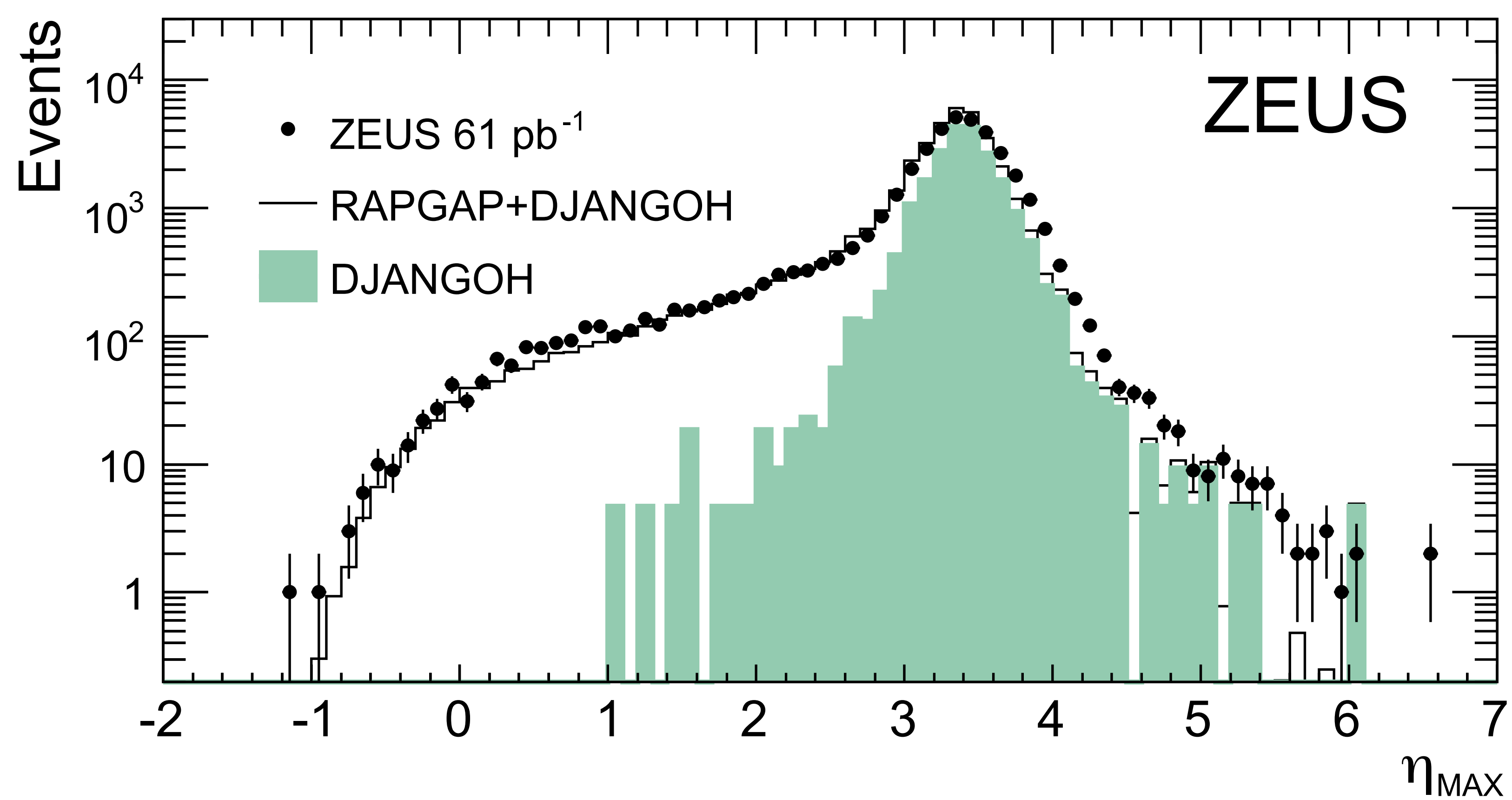
For small t (coherent diffraction), cannot separate large nuclei from beam. Therefore, we need another method to measure diffractive events in e+A collisions

Large Rapidity Gap (LRG) Method

The LRG method relies on the fact that for diffractive events, there is an angular region in the direction of the proton without any particle flow.

Experimentally, this is determined by measuring the rapidity of the most forward particle in the detector (η_{max})



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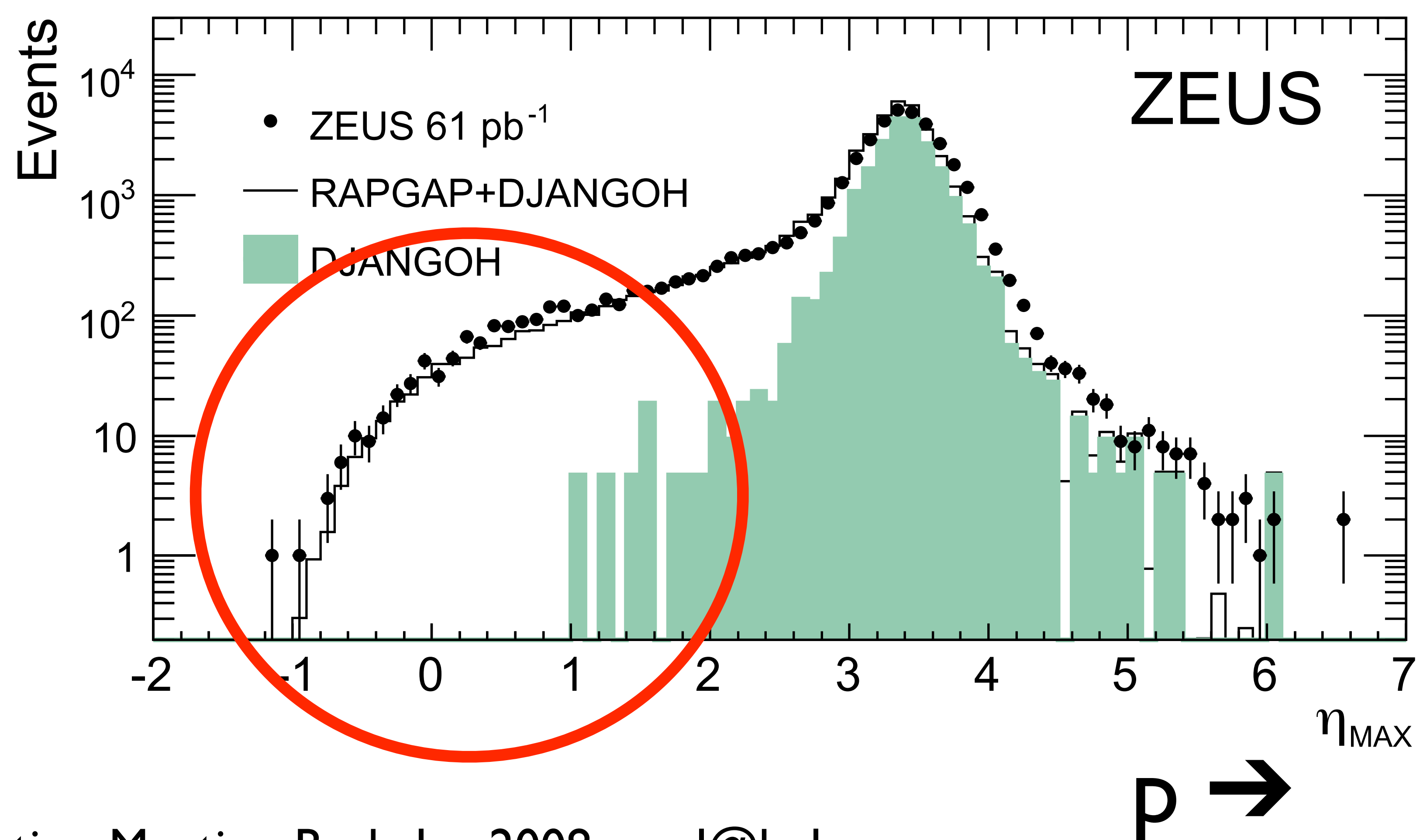

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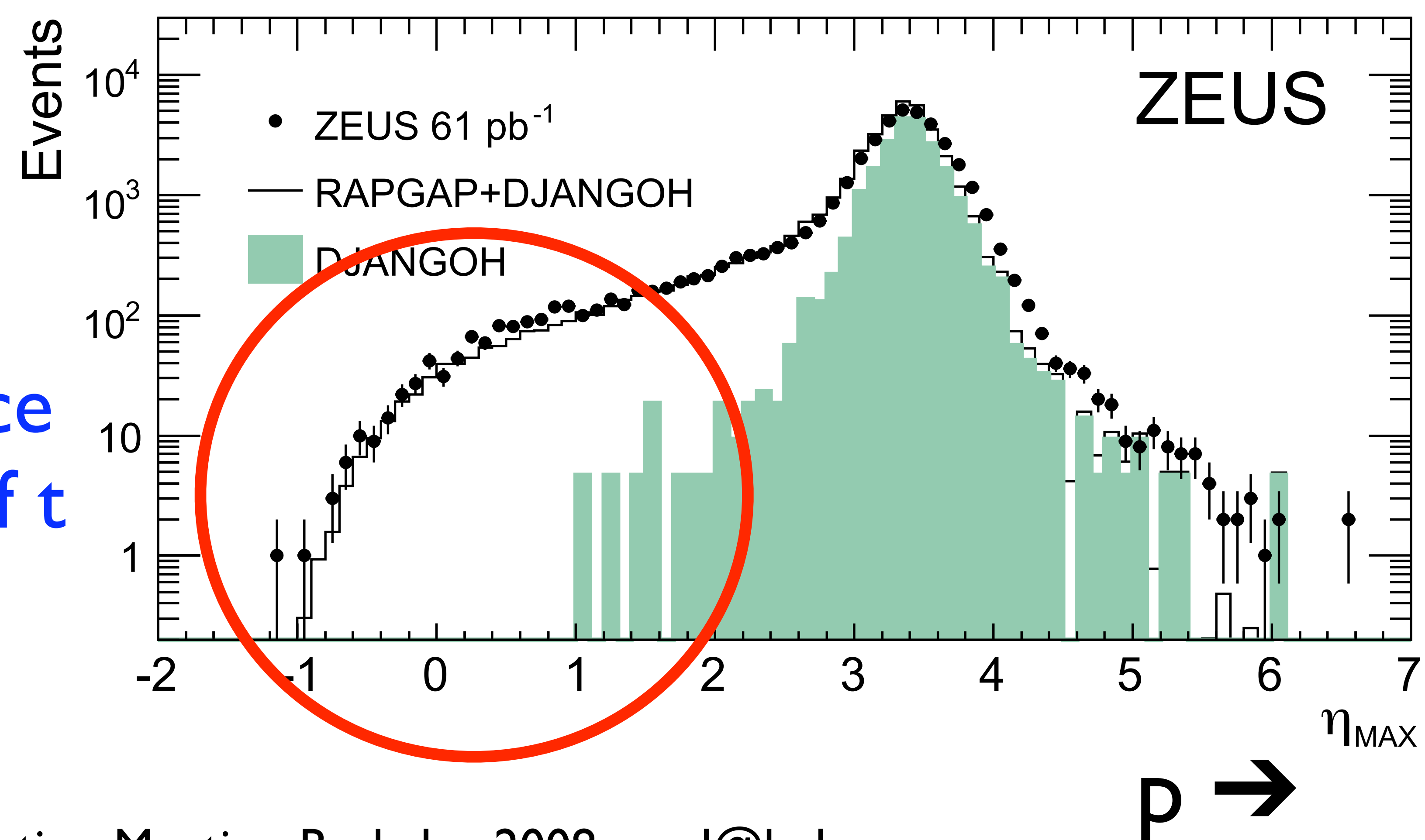
Important points:

1) High Statistics
2) Need large acceptance
3) No direct measure of t
4) Efficiency vs Purity

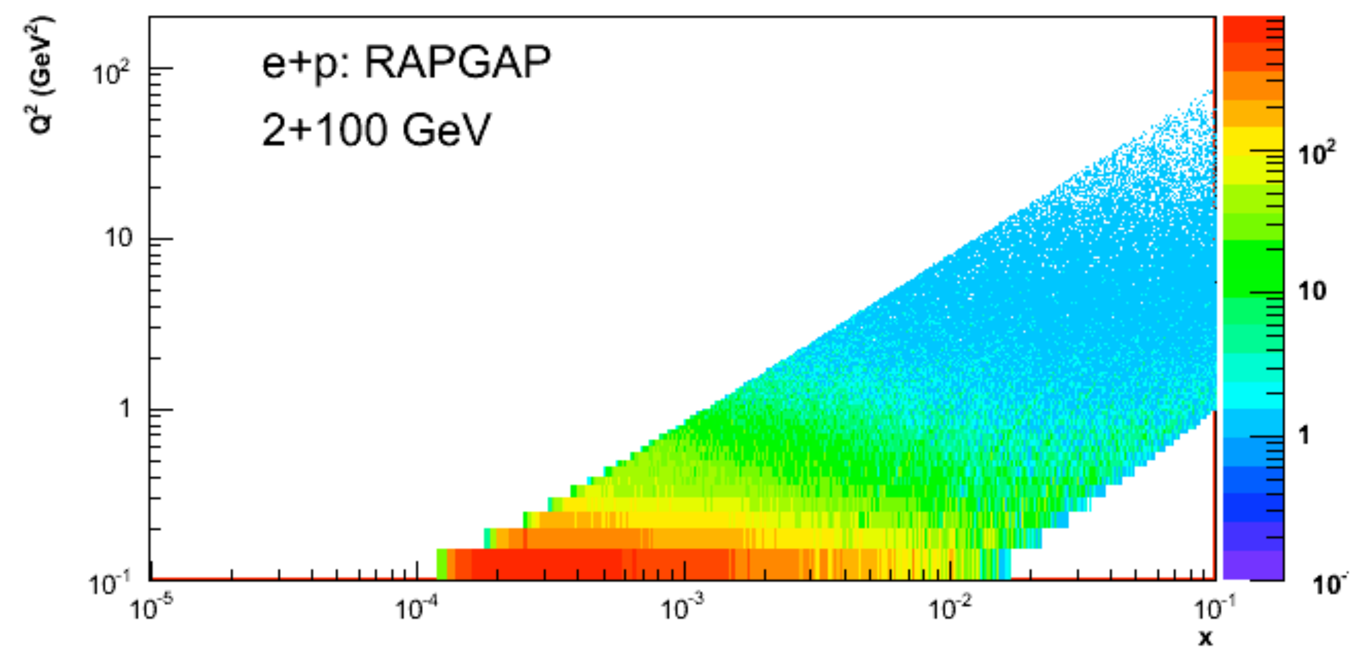


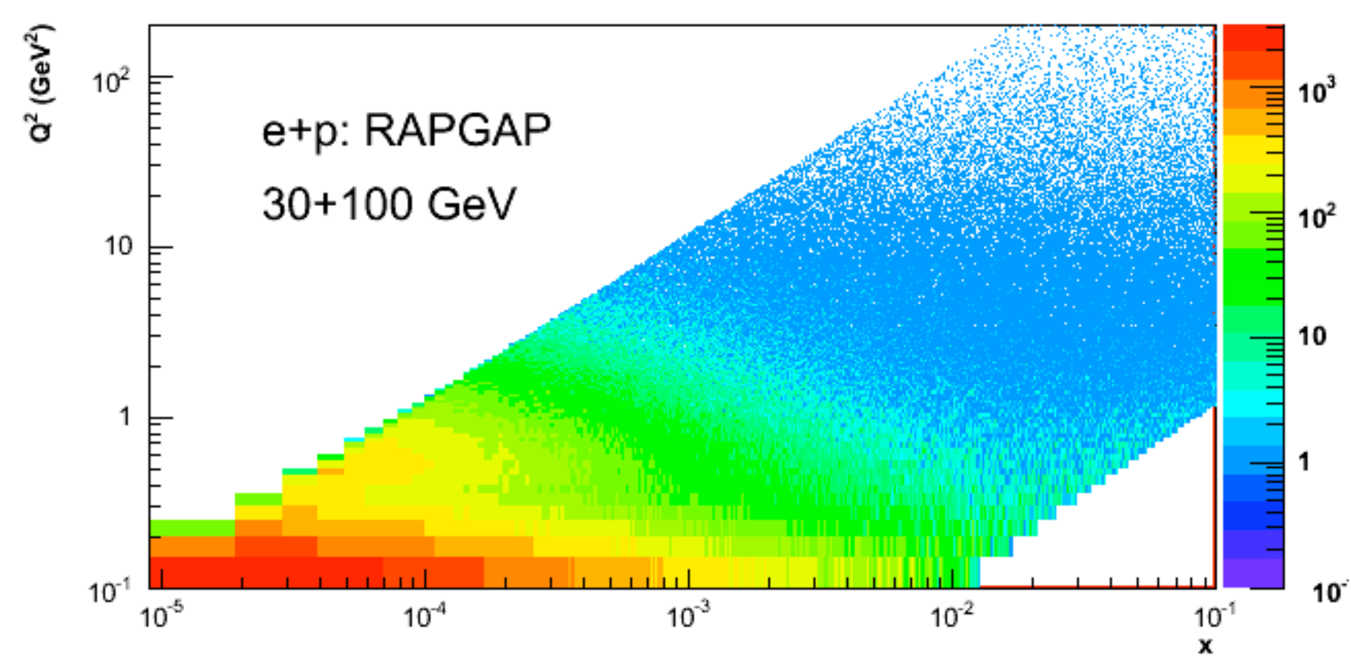
MC studies for an EIC

- Available Tools
  - ➡ RAPGAP MC Generator
    - Generated 10^6 events in both inclusive DIS and Diffractive mode for a number of prospective energies
      - 2, 5, 10, 20, 30 + 100 GeV/c
    - Advantageous that both diffractive and DIS events come from the same MC programme
- All events exist (HEP_evt format and root TTrees) exist on the eic afs space at BNL - if you want access, contact me.

Datasets Generated (e+p)

- Generated 10^6 inclusive DIS and 10^6 diffractive events for the EIC energies:
  - ➡ 2 + 100 GeV
  - ➡ 5 + 100 GeV
  - ➡ 10 + 100 GeV
  - ➡ 20 + 100 GeV
  - ➡ 30 + 100 GeV
- For cross-reference with HERA:
  - ➡ 30 + 820 GeV





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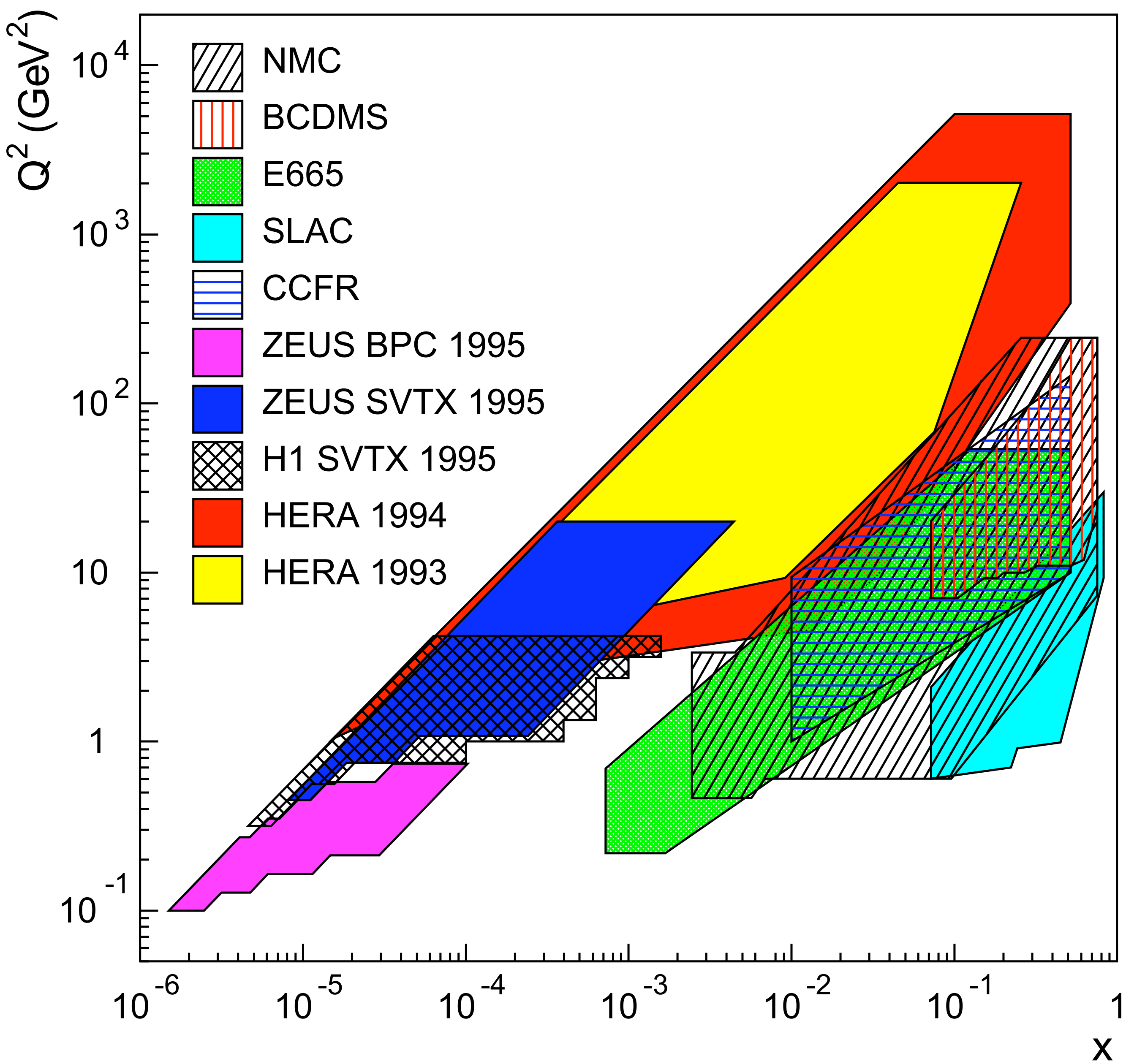

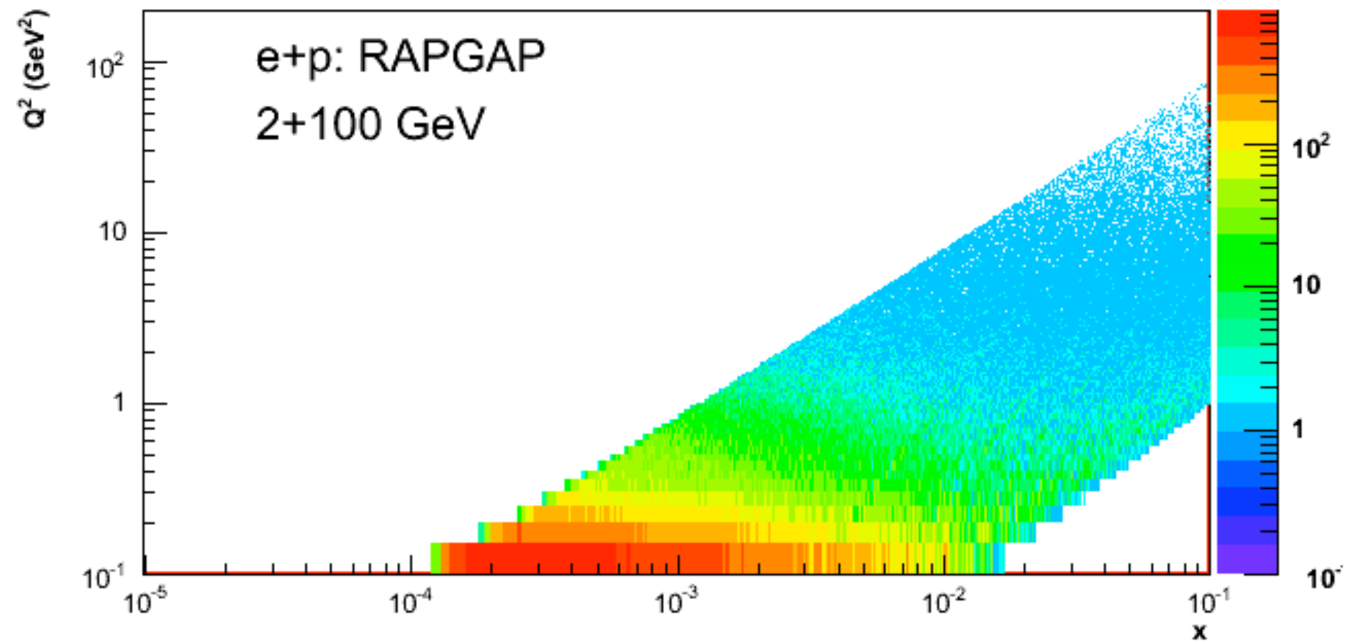

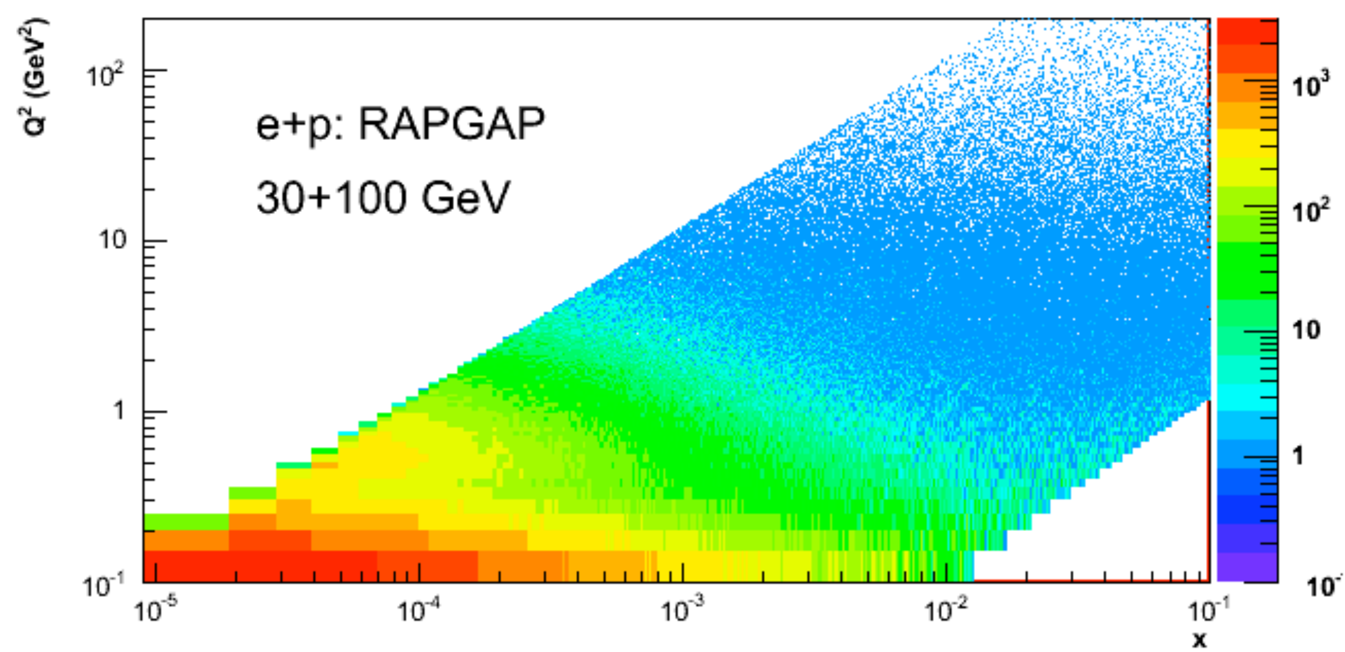

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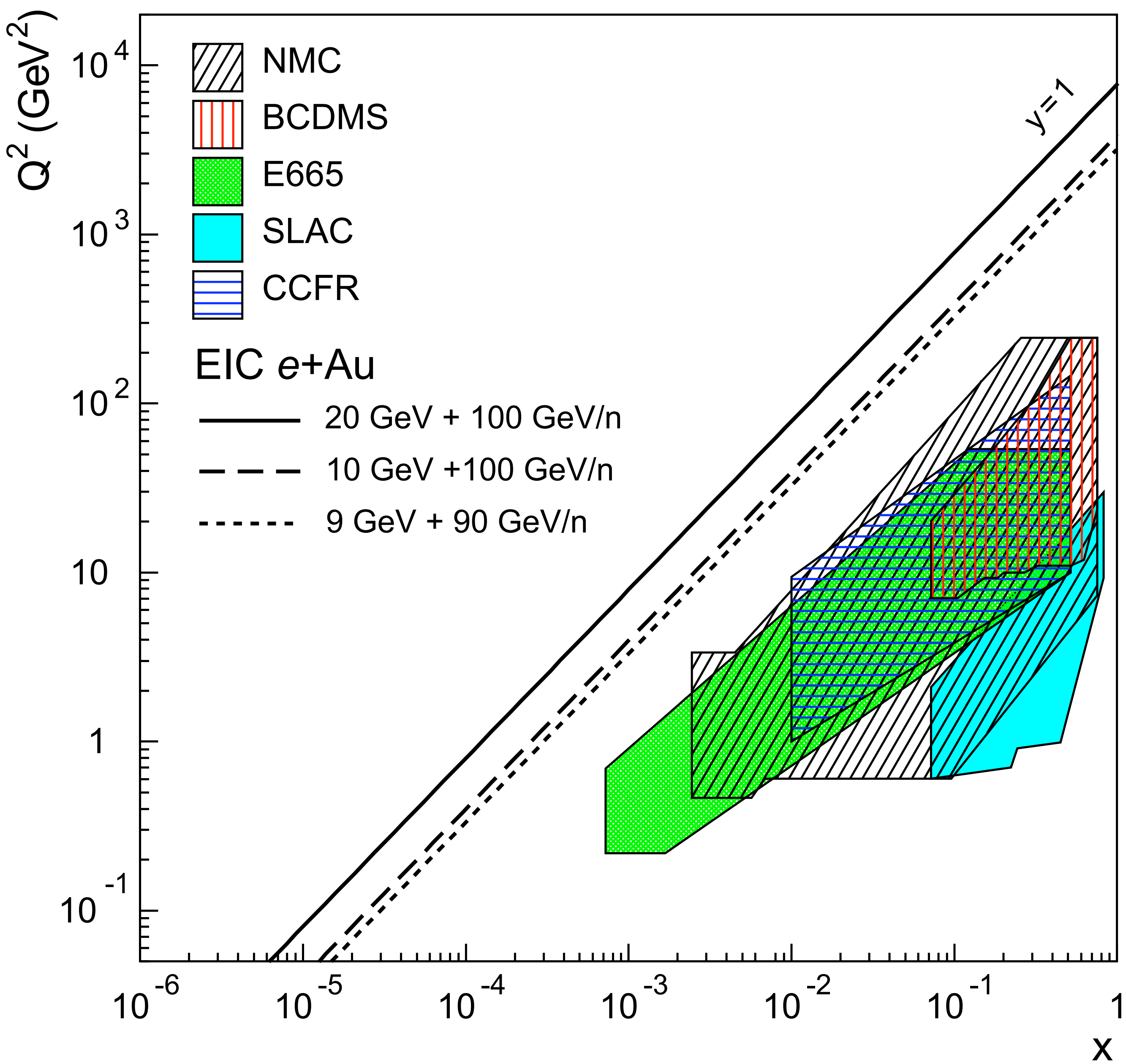

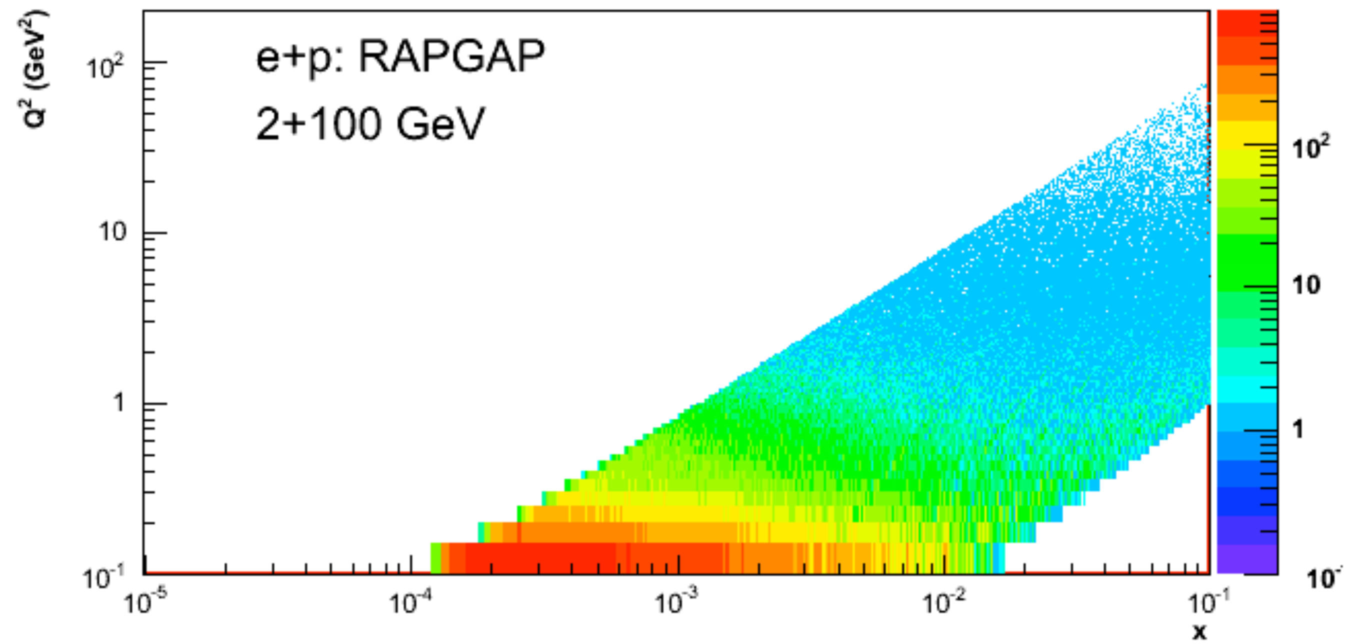

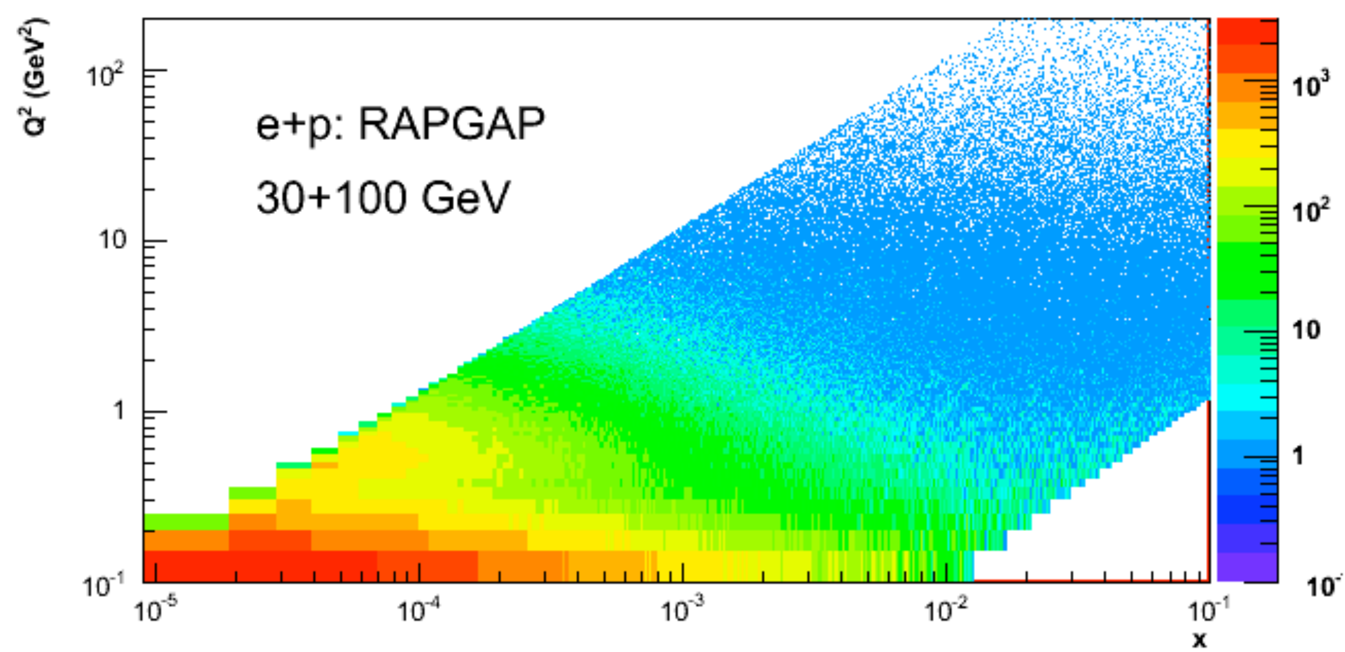

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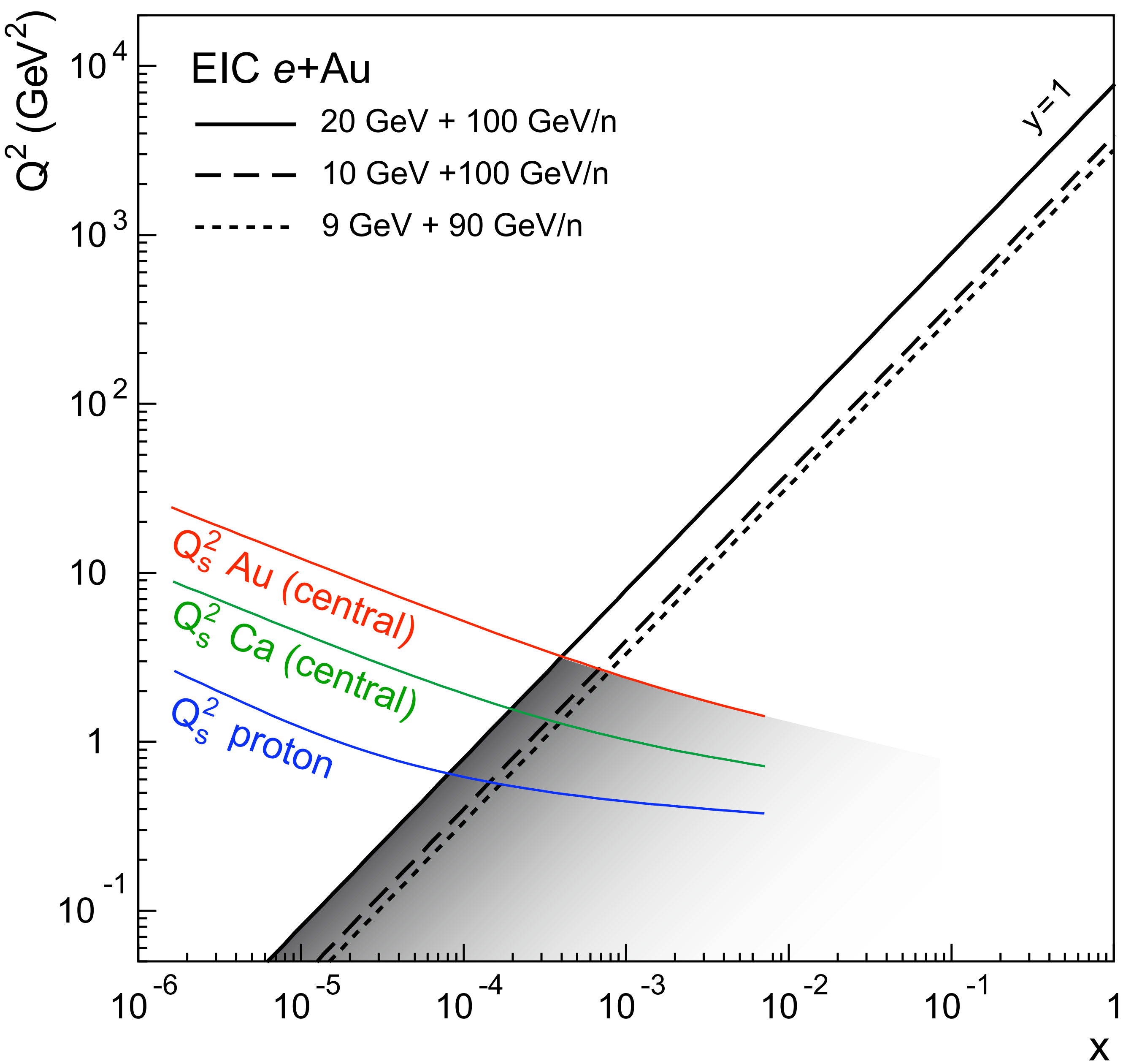

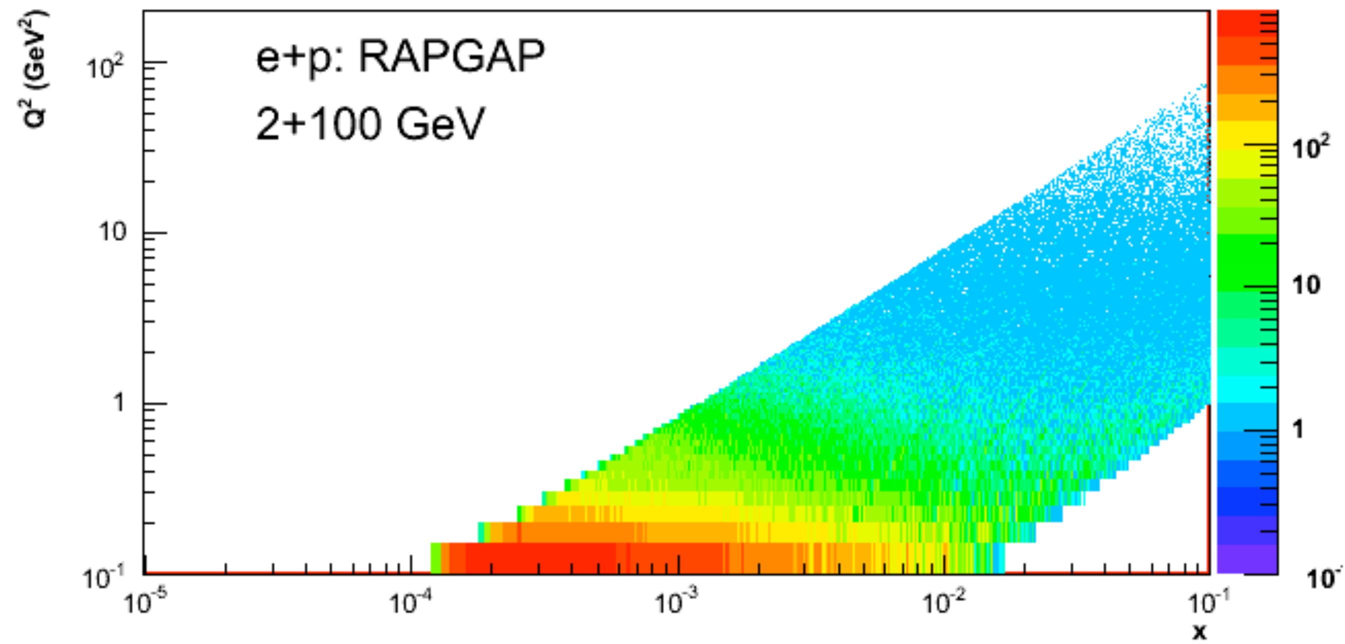

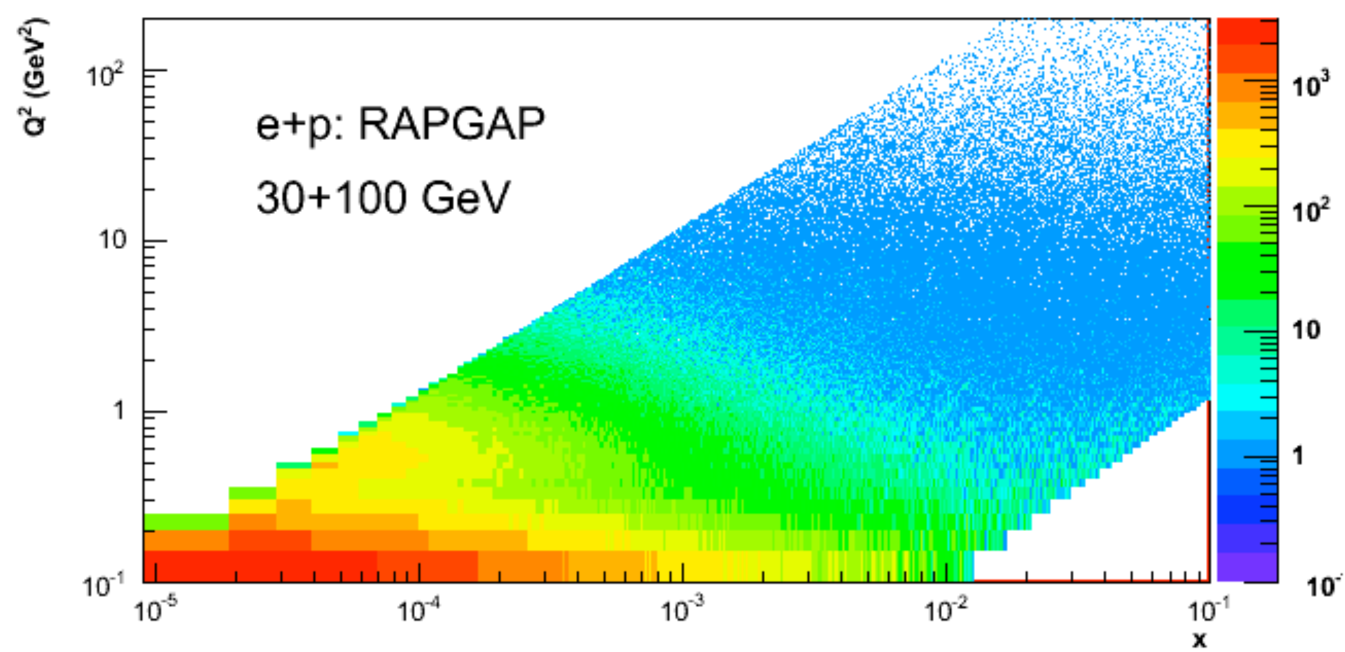

Most Forward Particle (MFP) in Event

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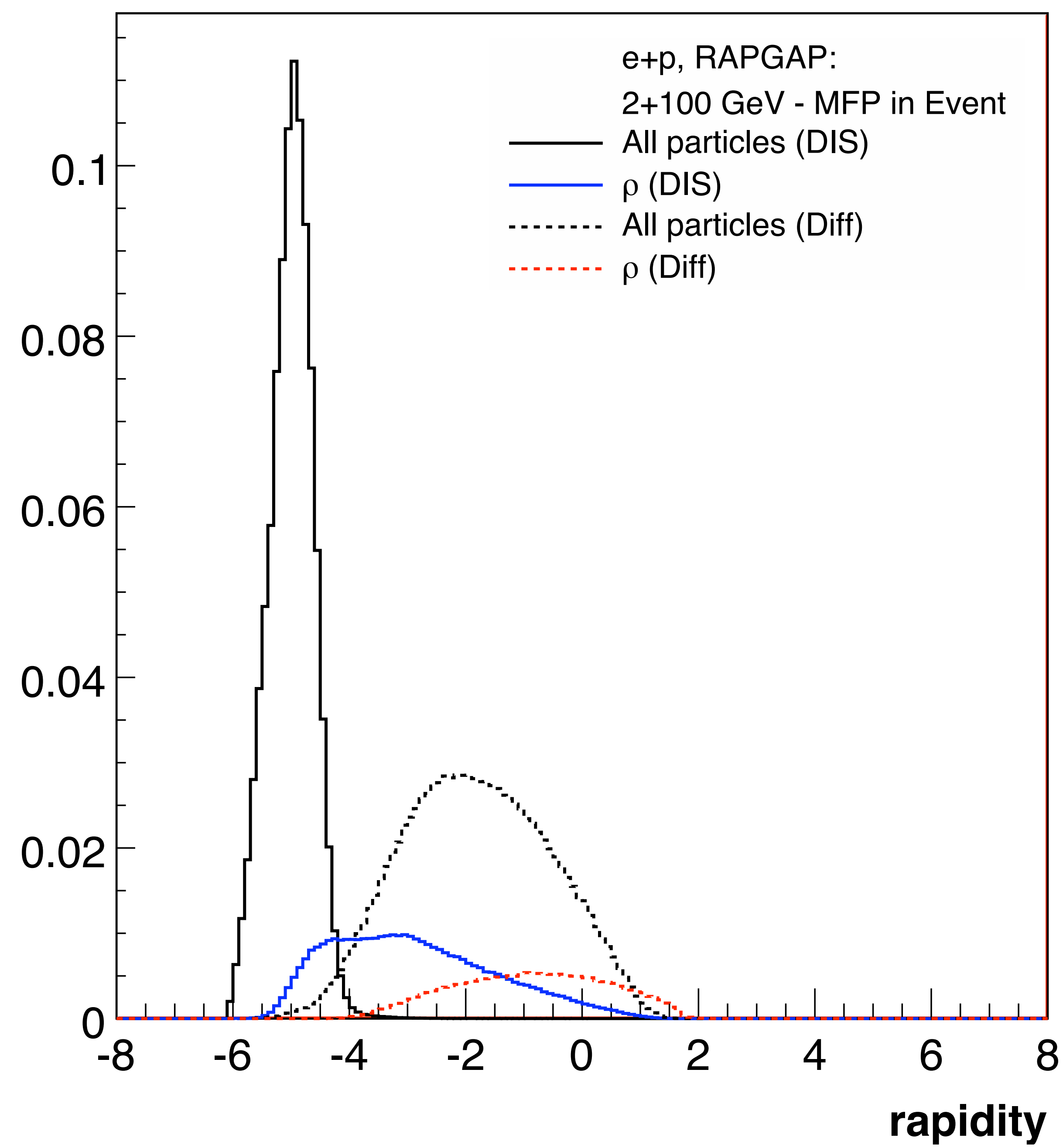
DIS: MFP distribution doesn't change with energy, ρ gets slightly wider

Diff: MFP and ρ distributions widen with energy



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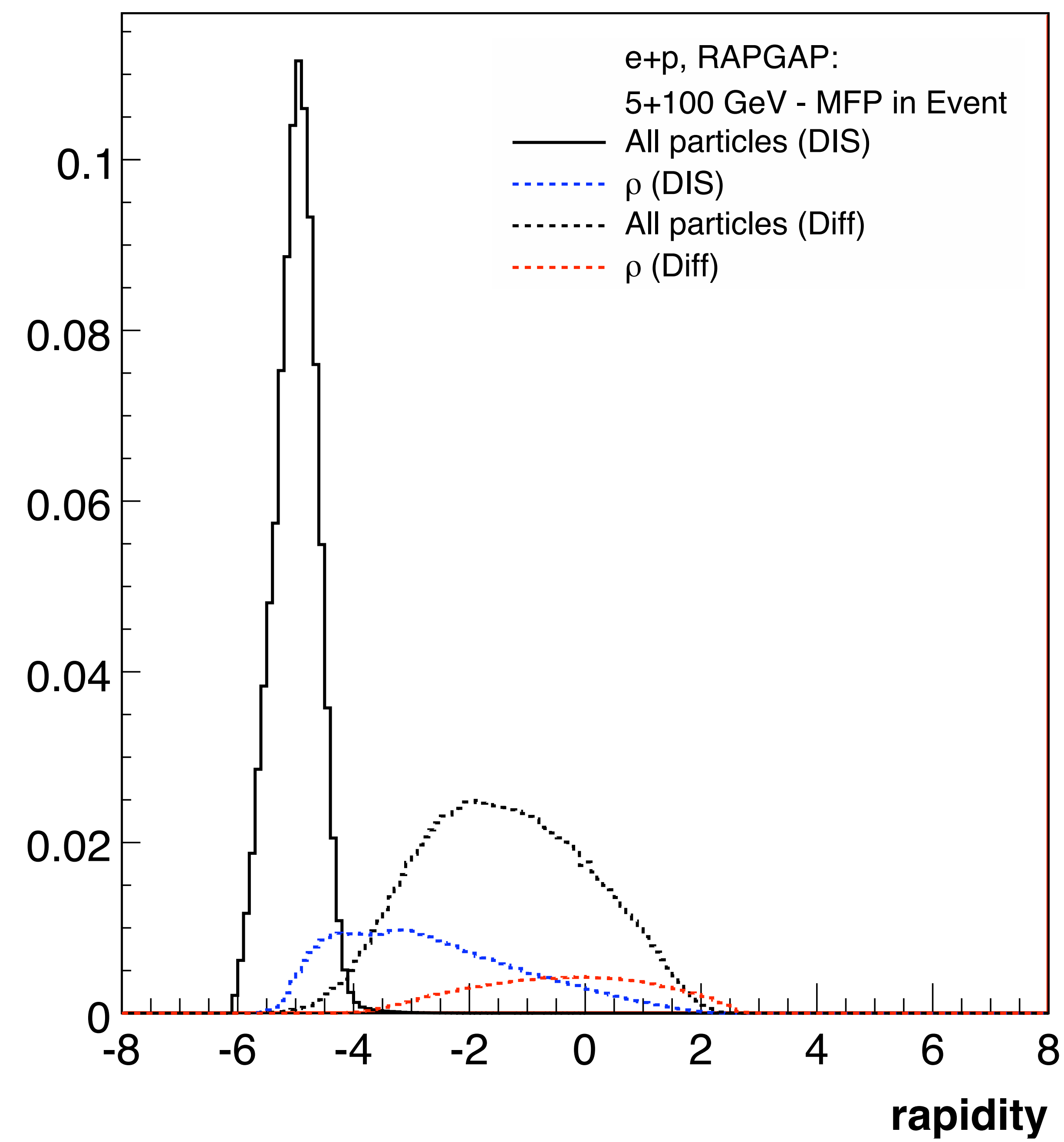

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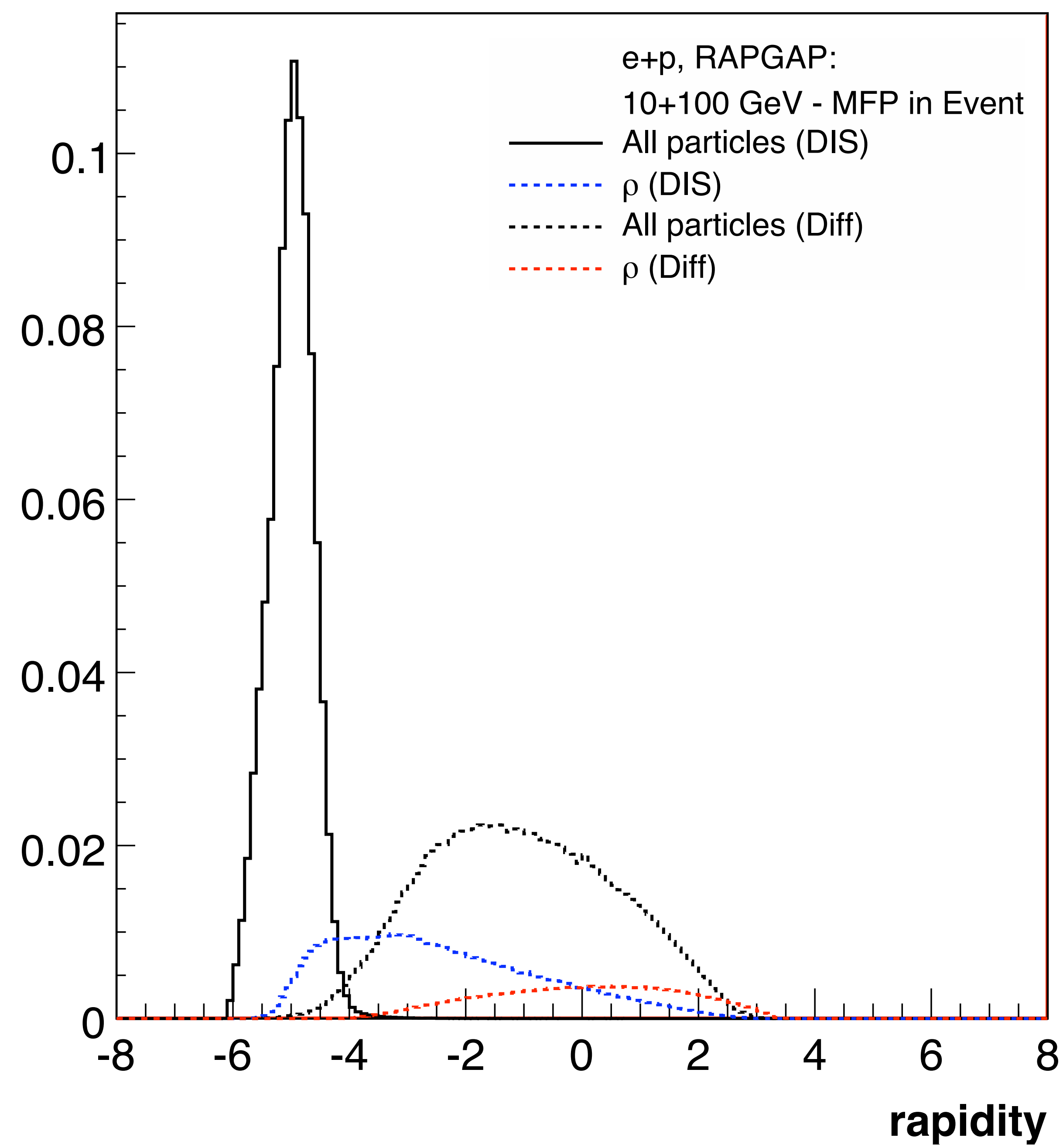

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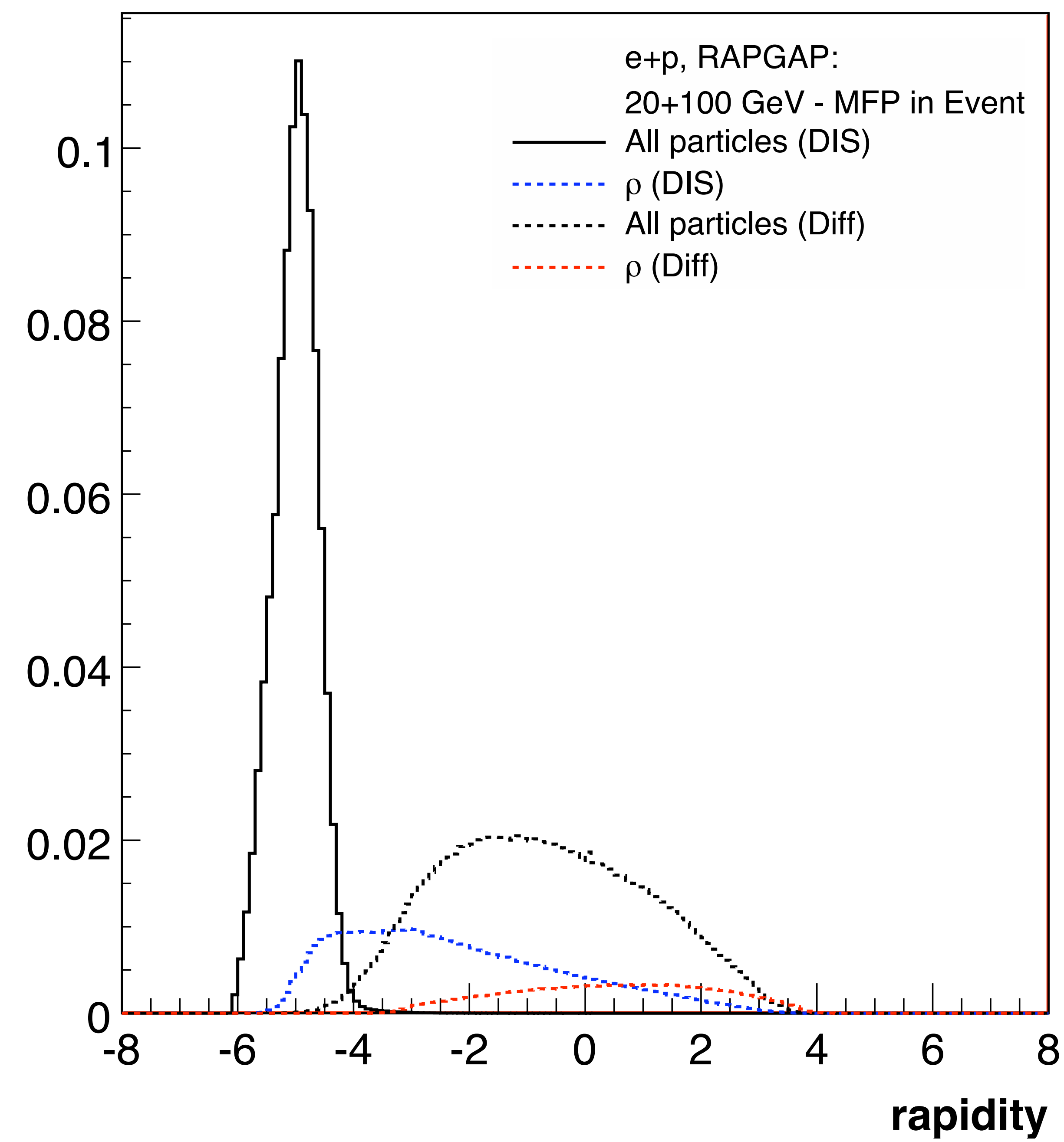

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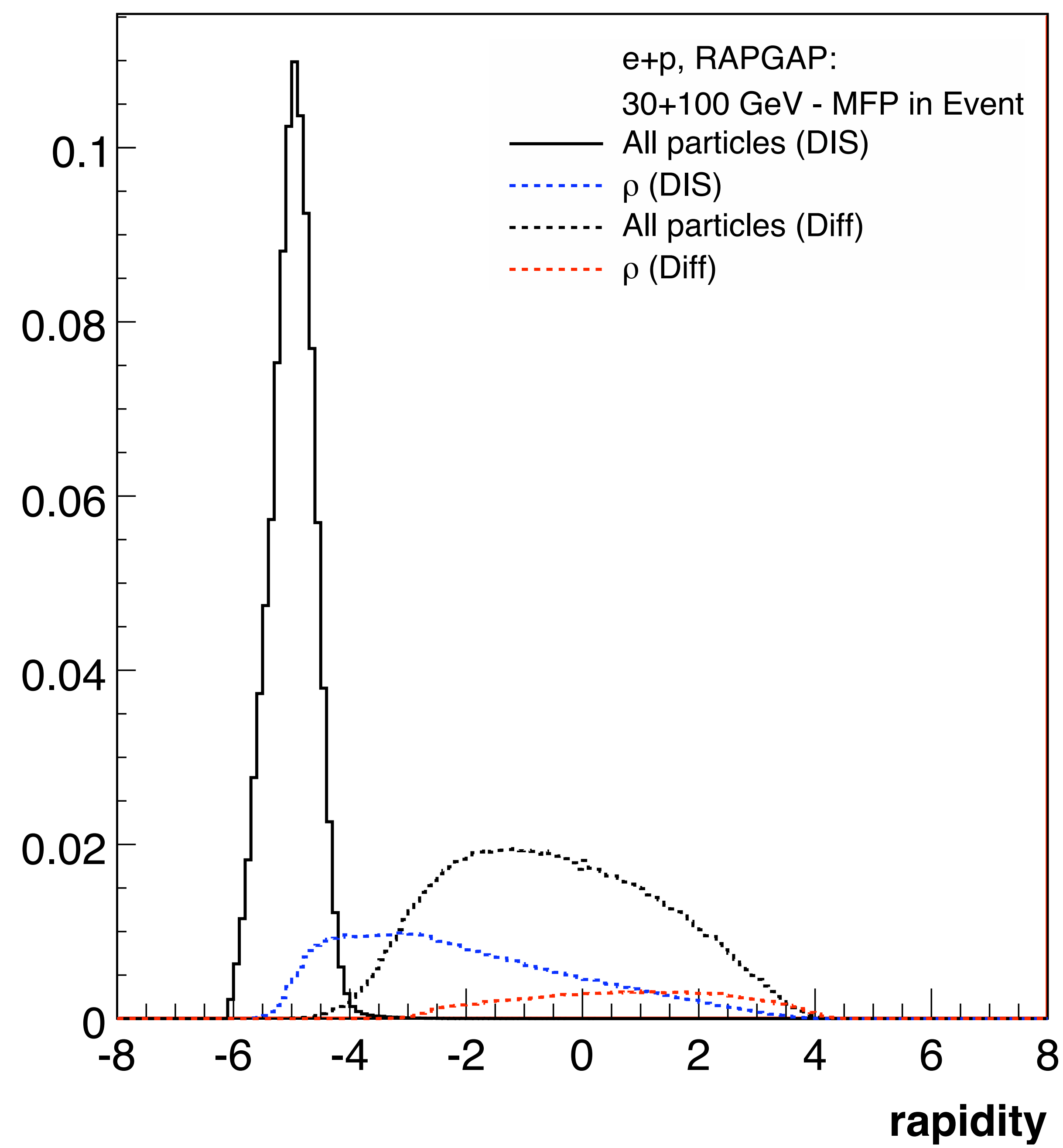

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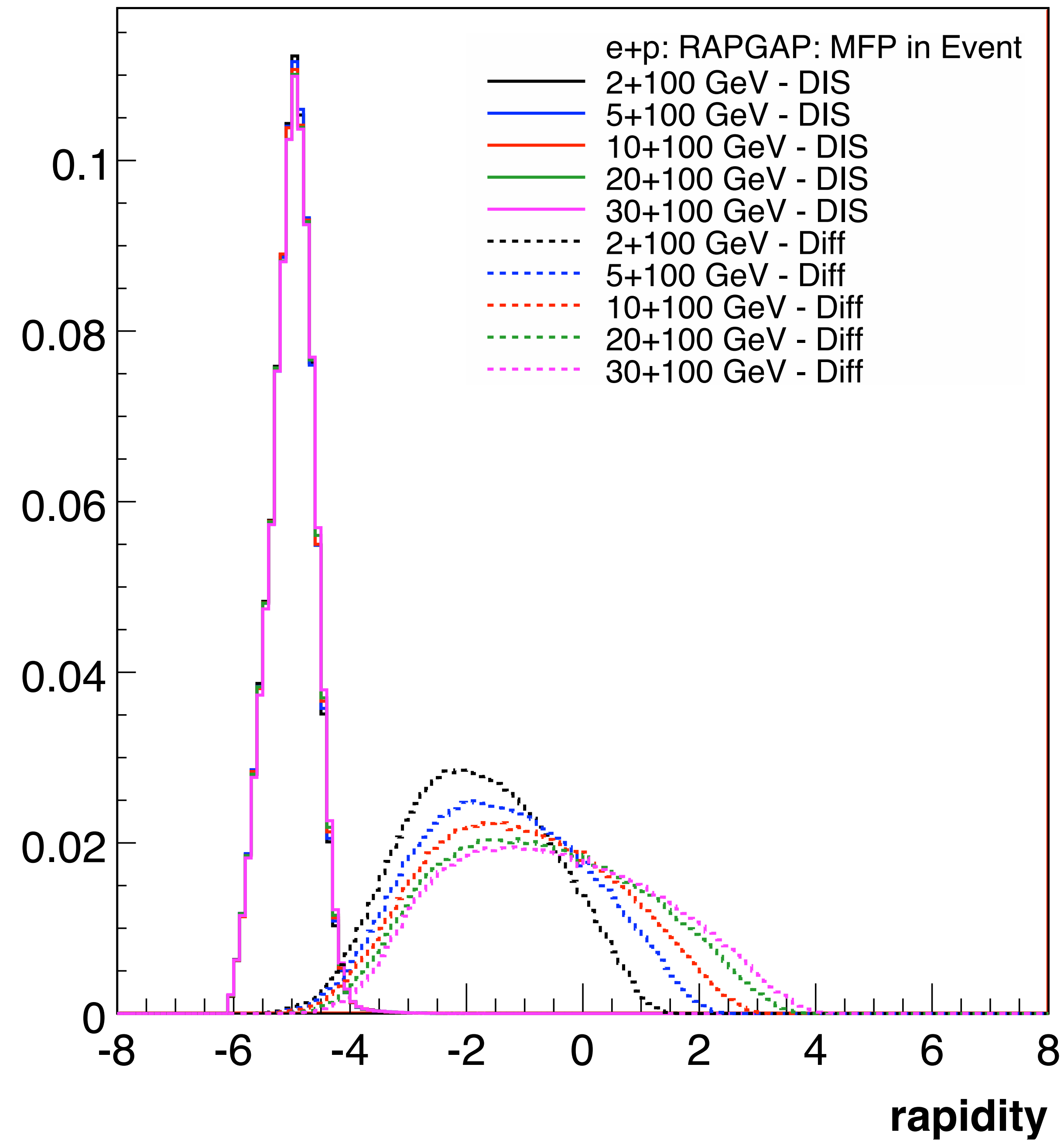

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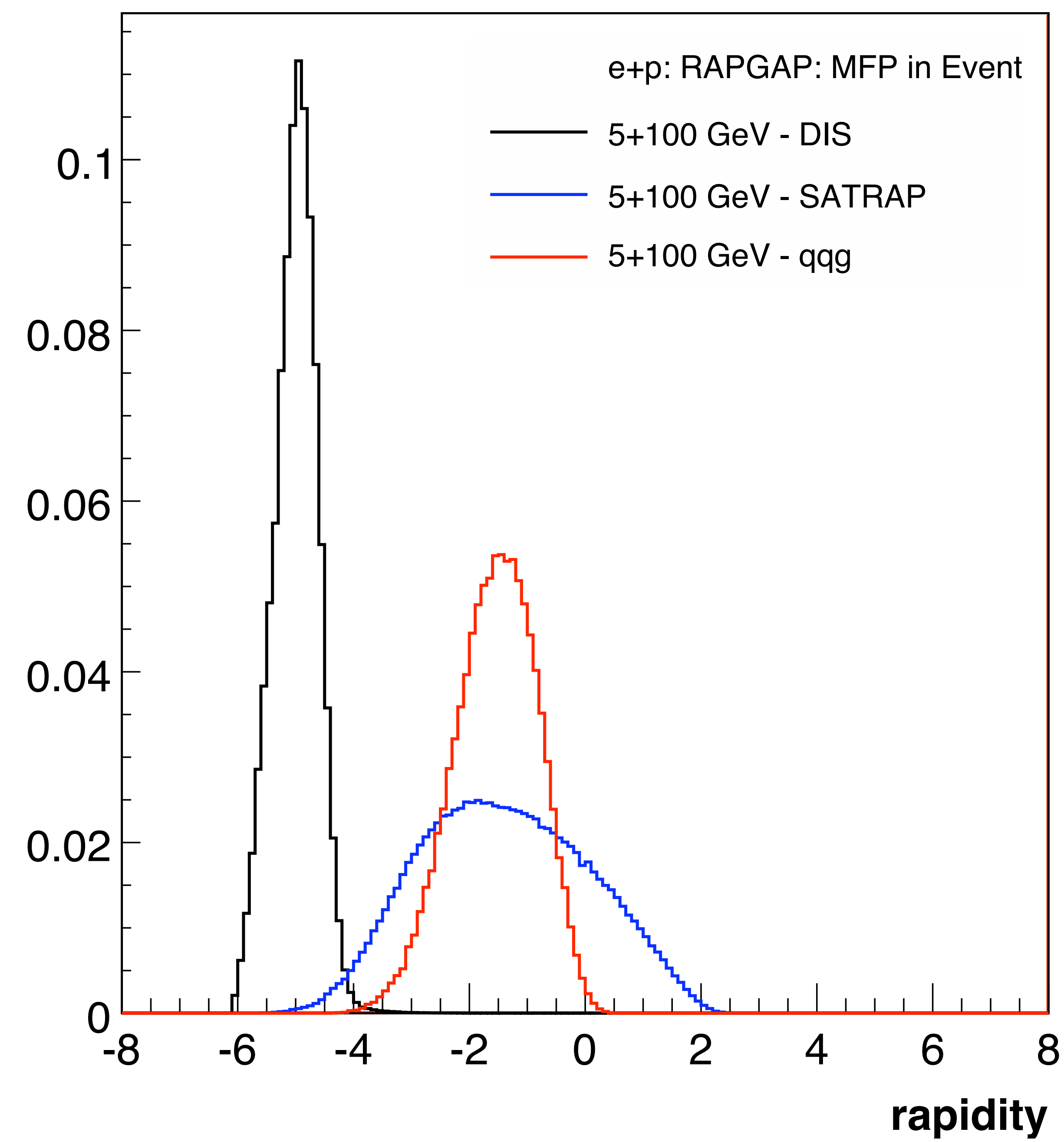
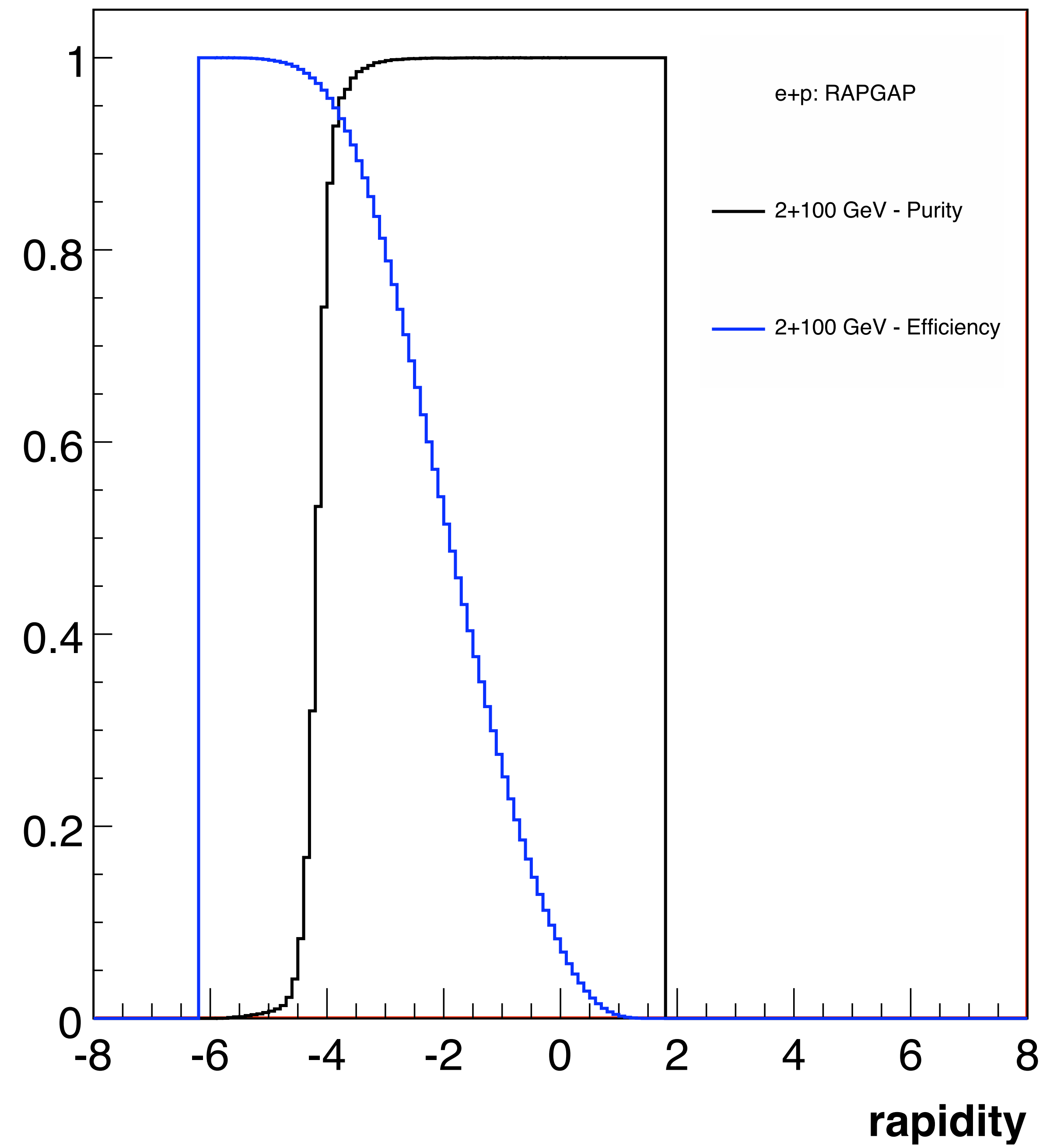


Efficiency vs Purity

- Although the separation of the rapidities looks good, this is best quantified by plotting the efficiency vs purity - a high efficiency and purity is most desirable

Efficiency: fraction of all Diff events measured

Purity: fraction of Diff events measured out of all measured events (Diff +DIS)



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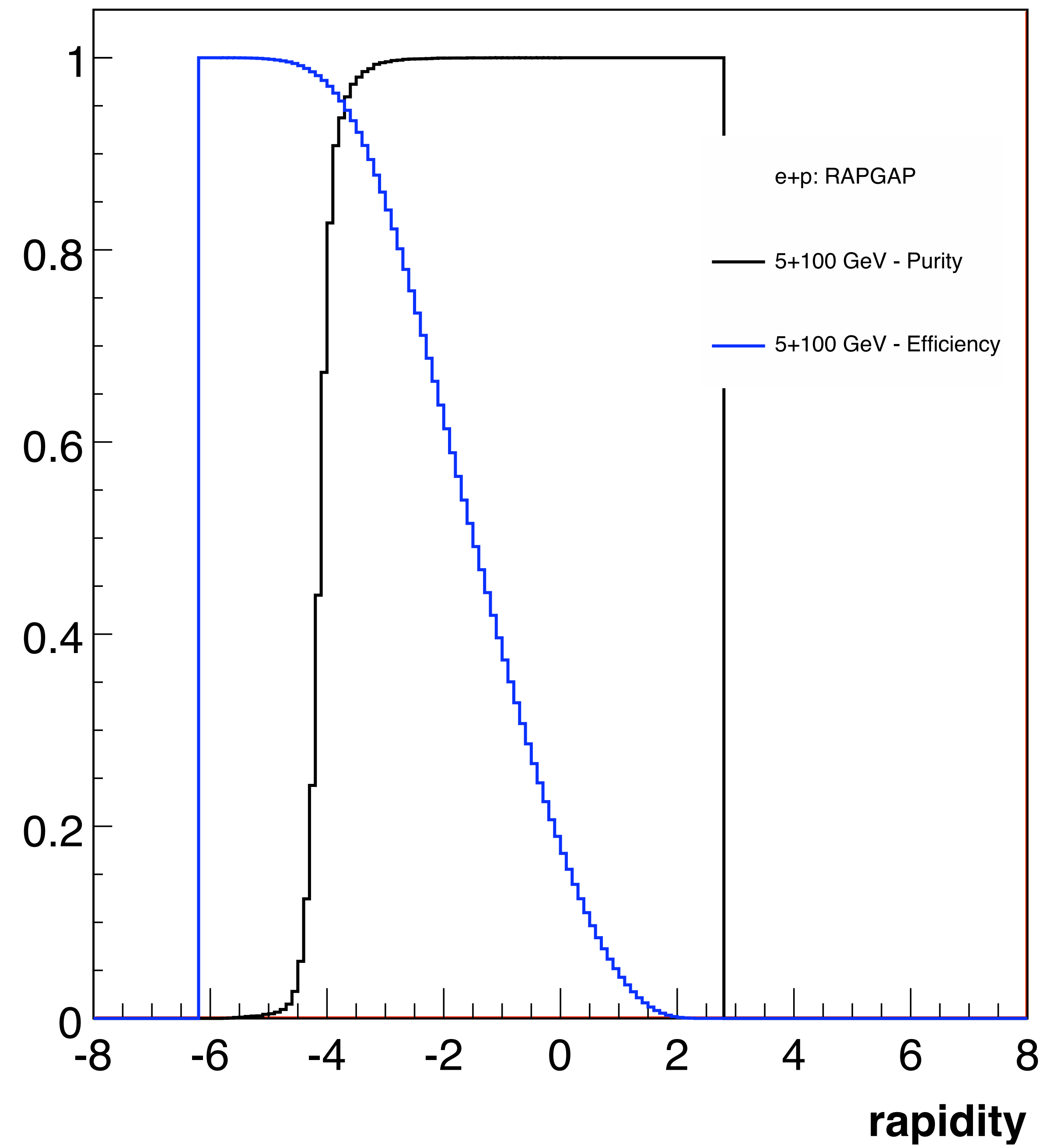

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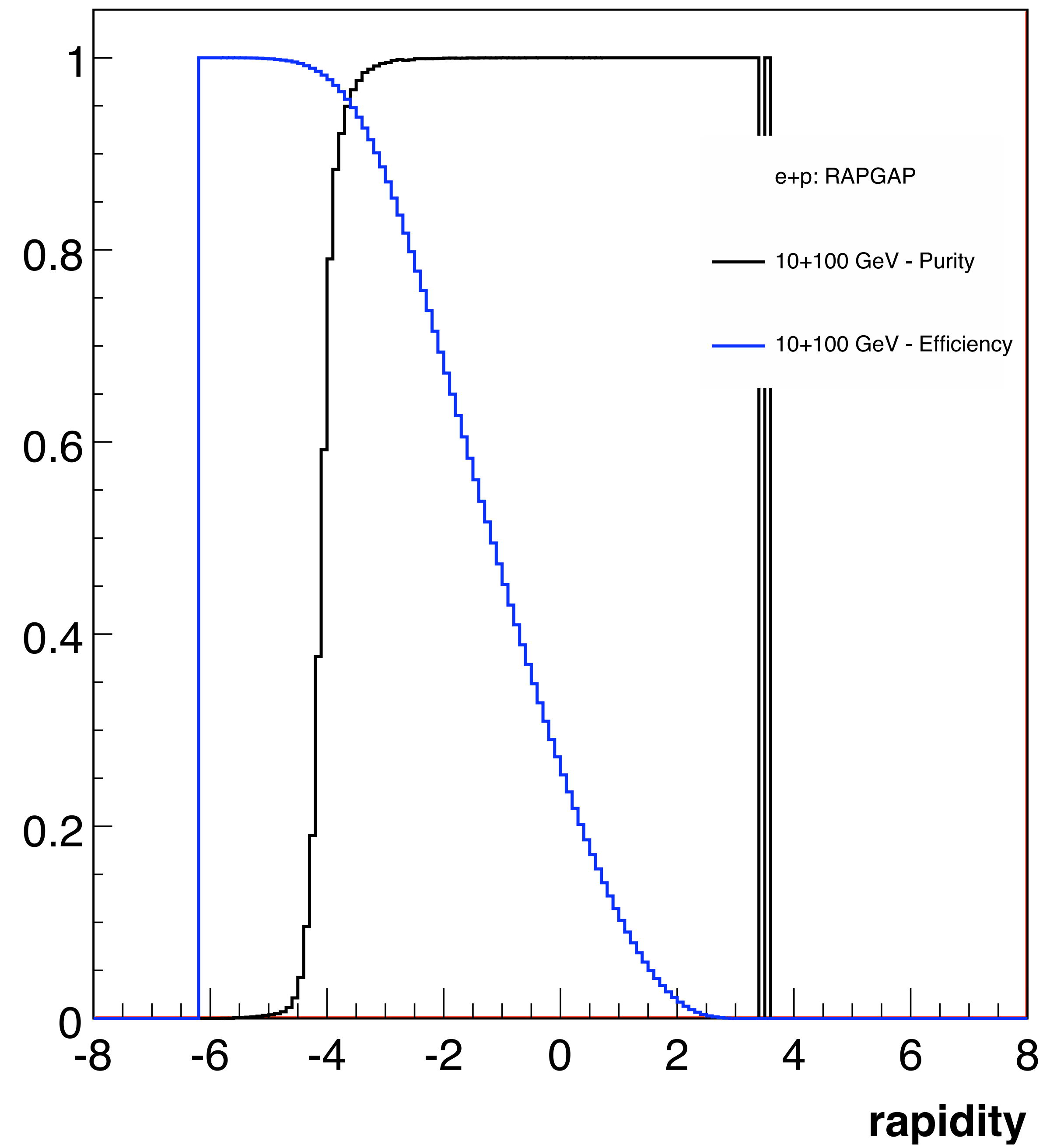

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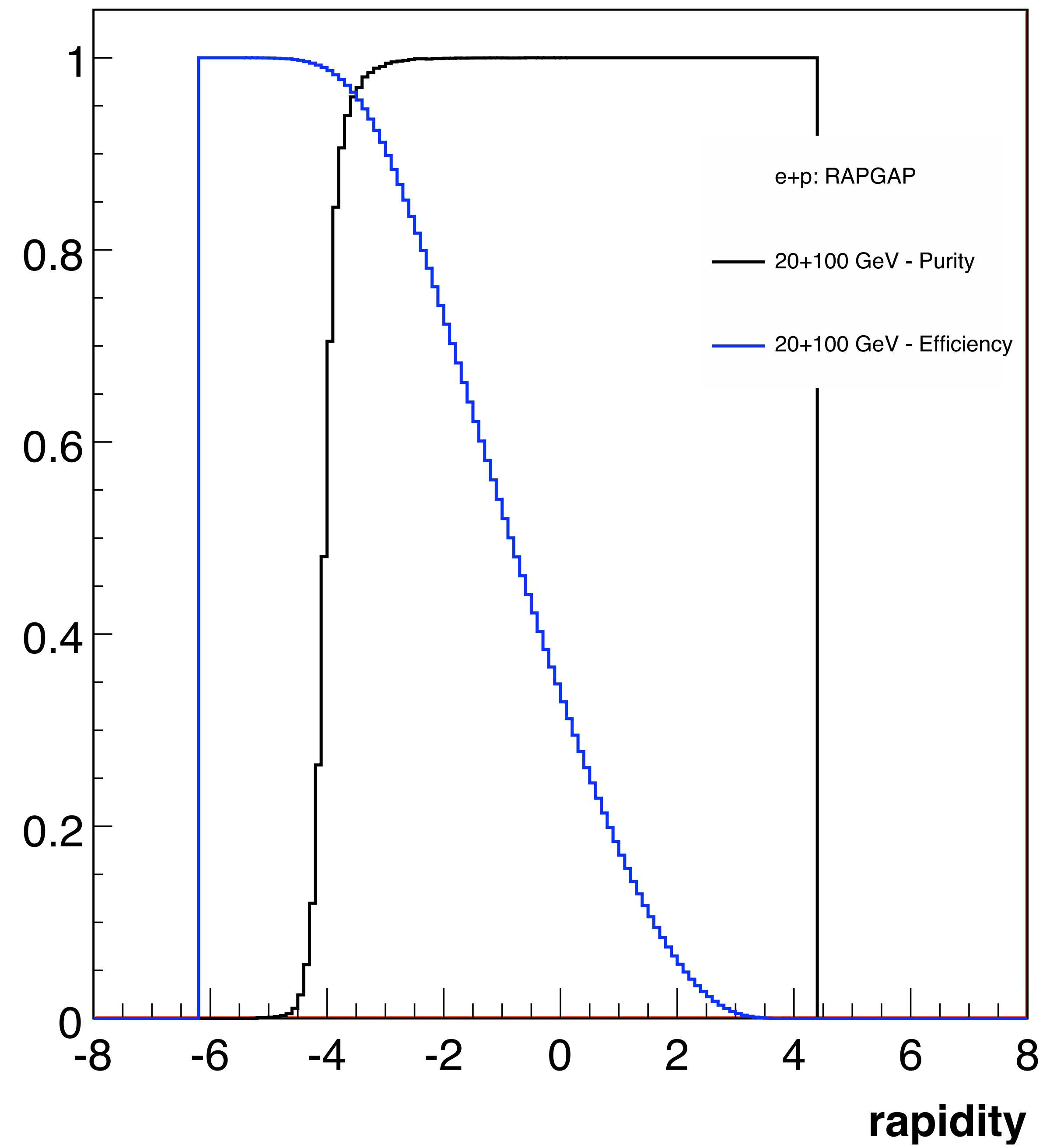

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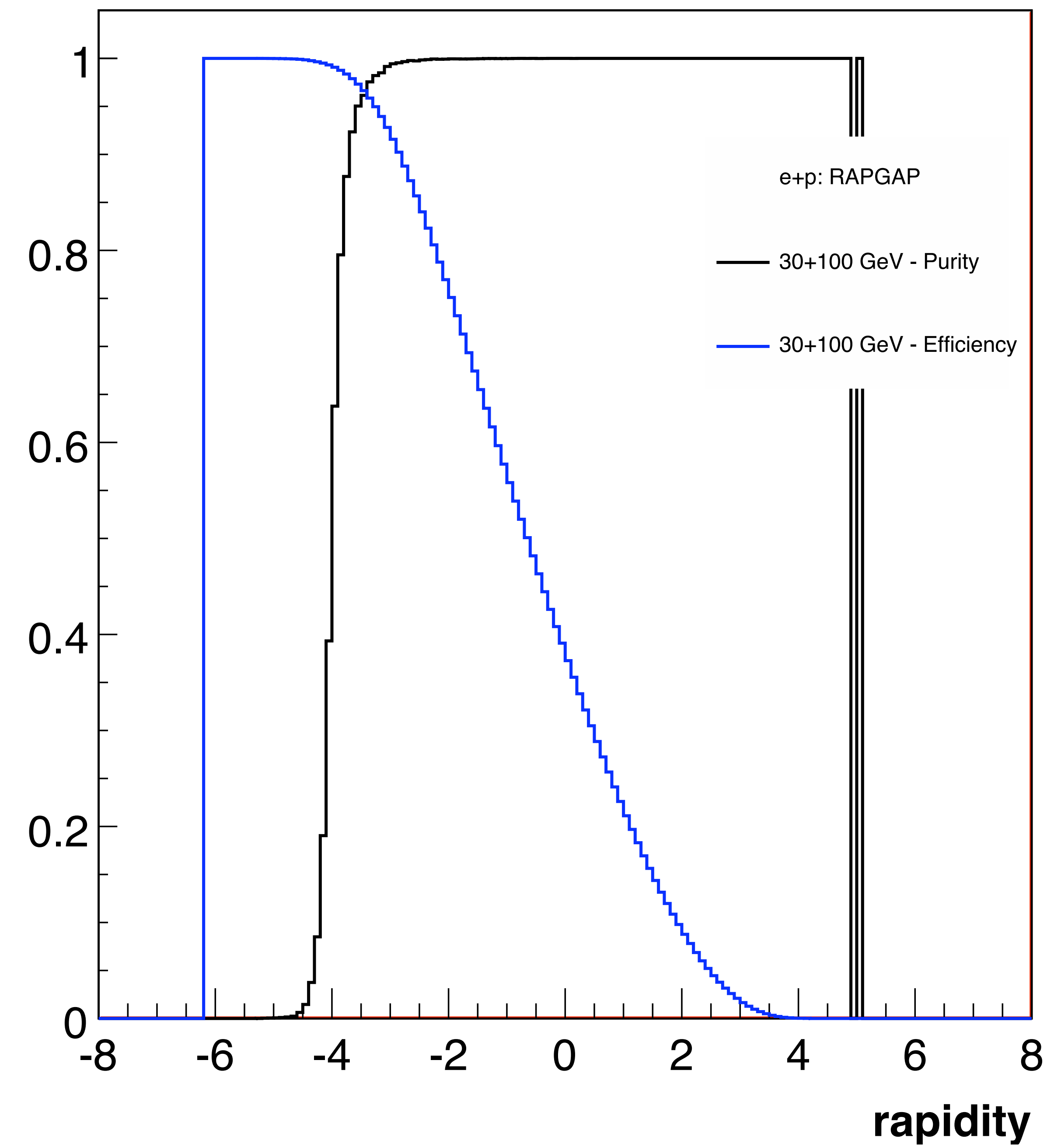

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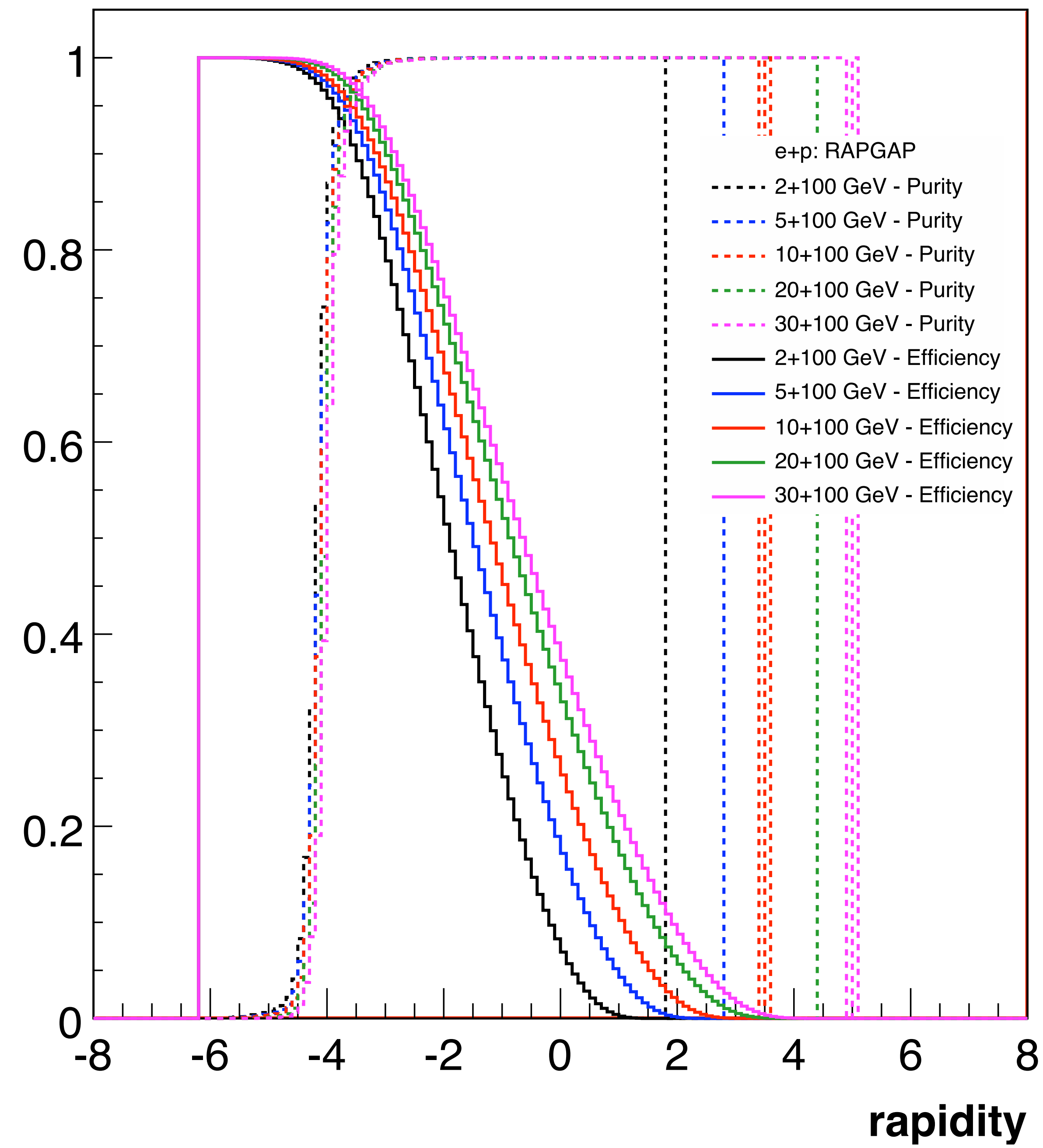

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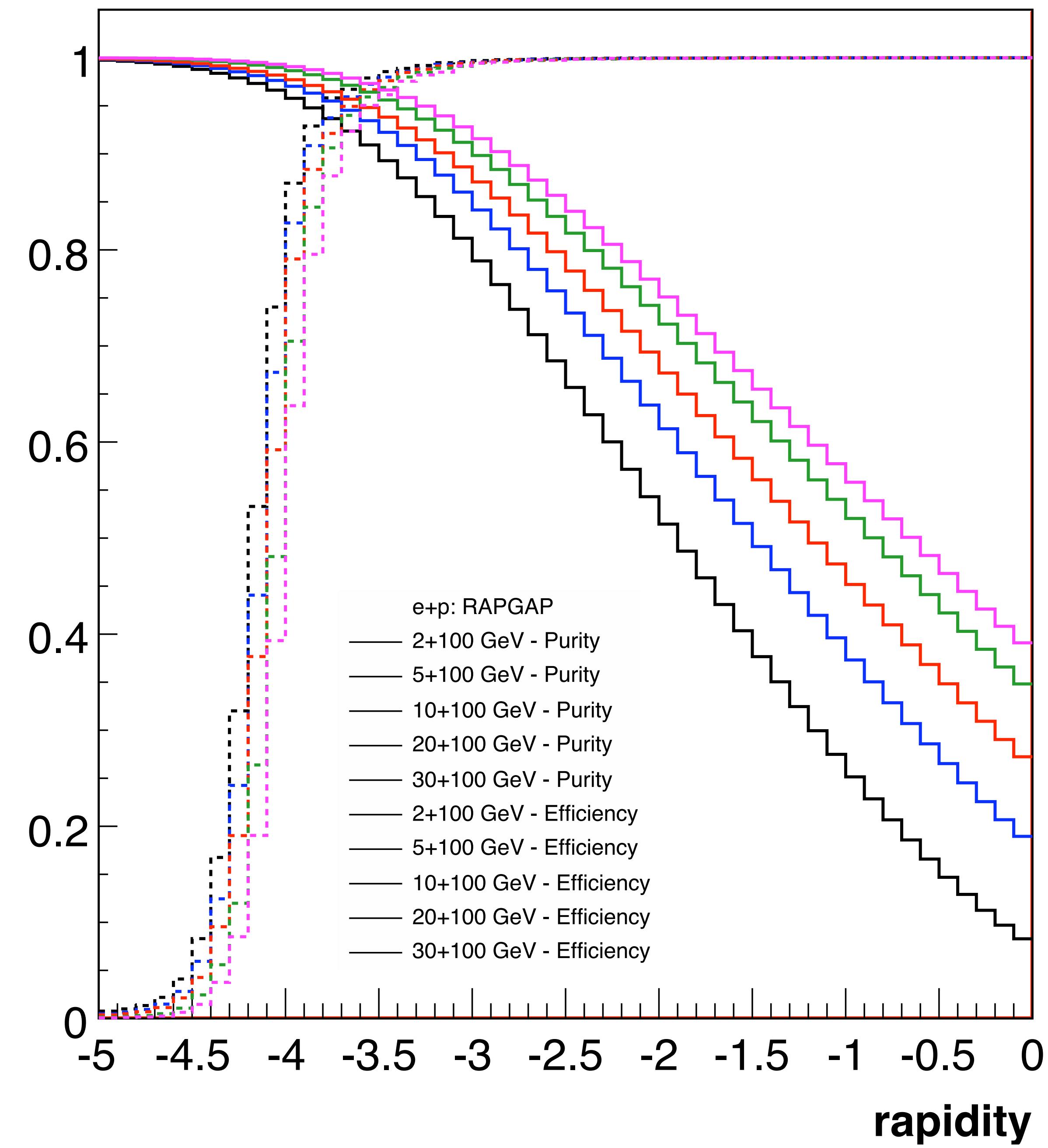

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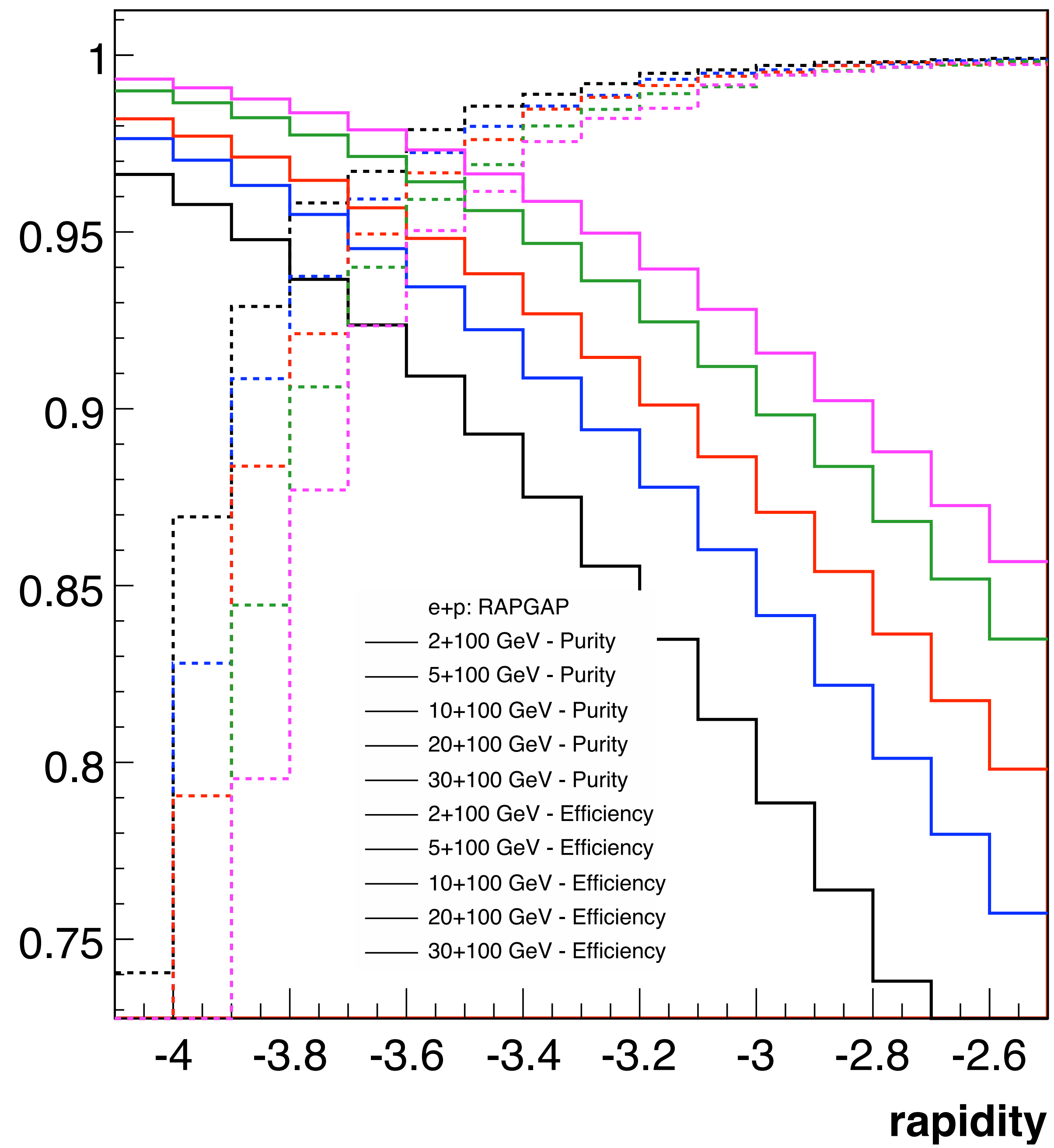

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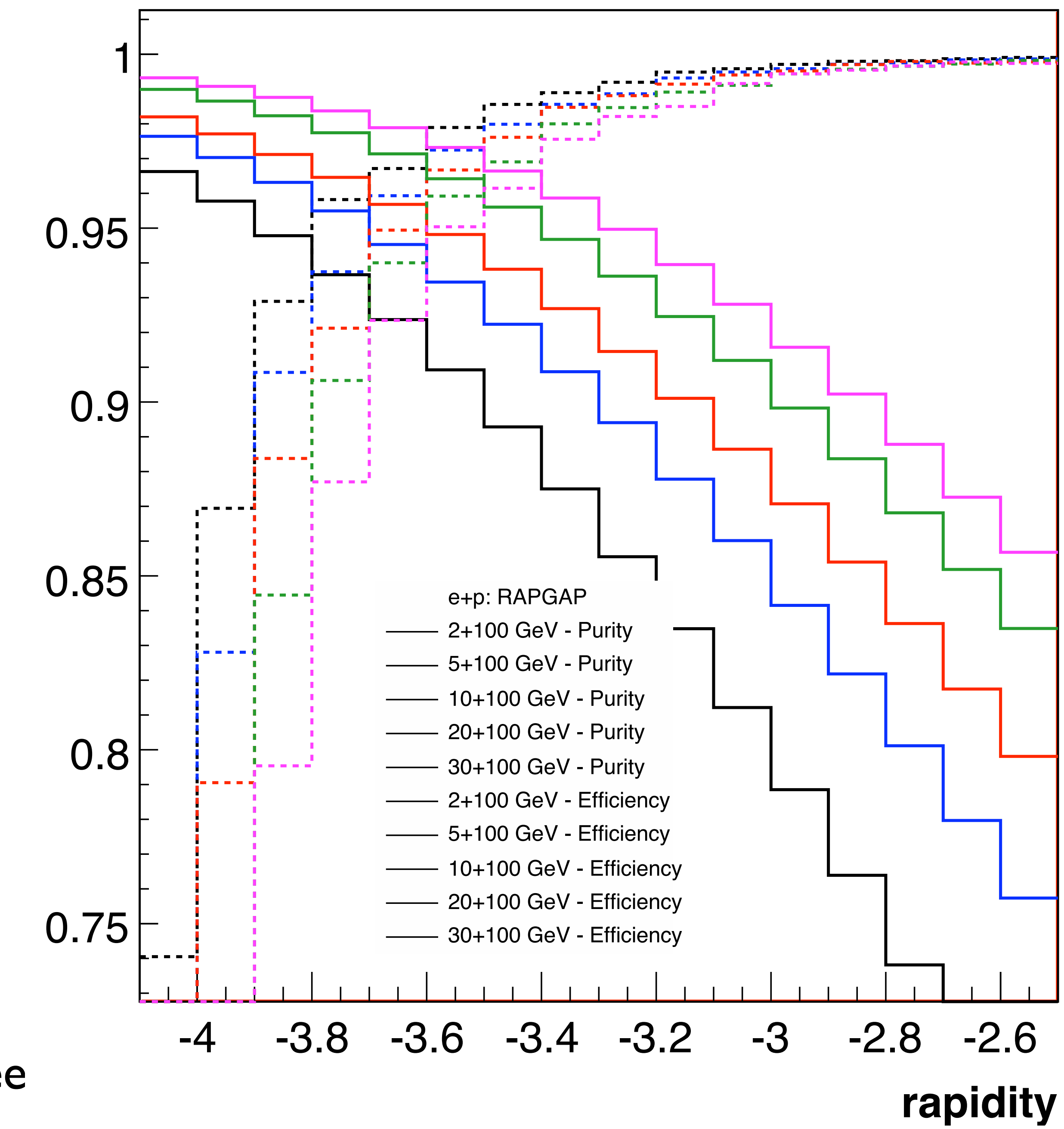
As expected from earlier plots, the efficiency and purity get better with increasing energy



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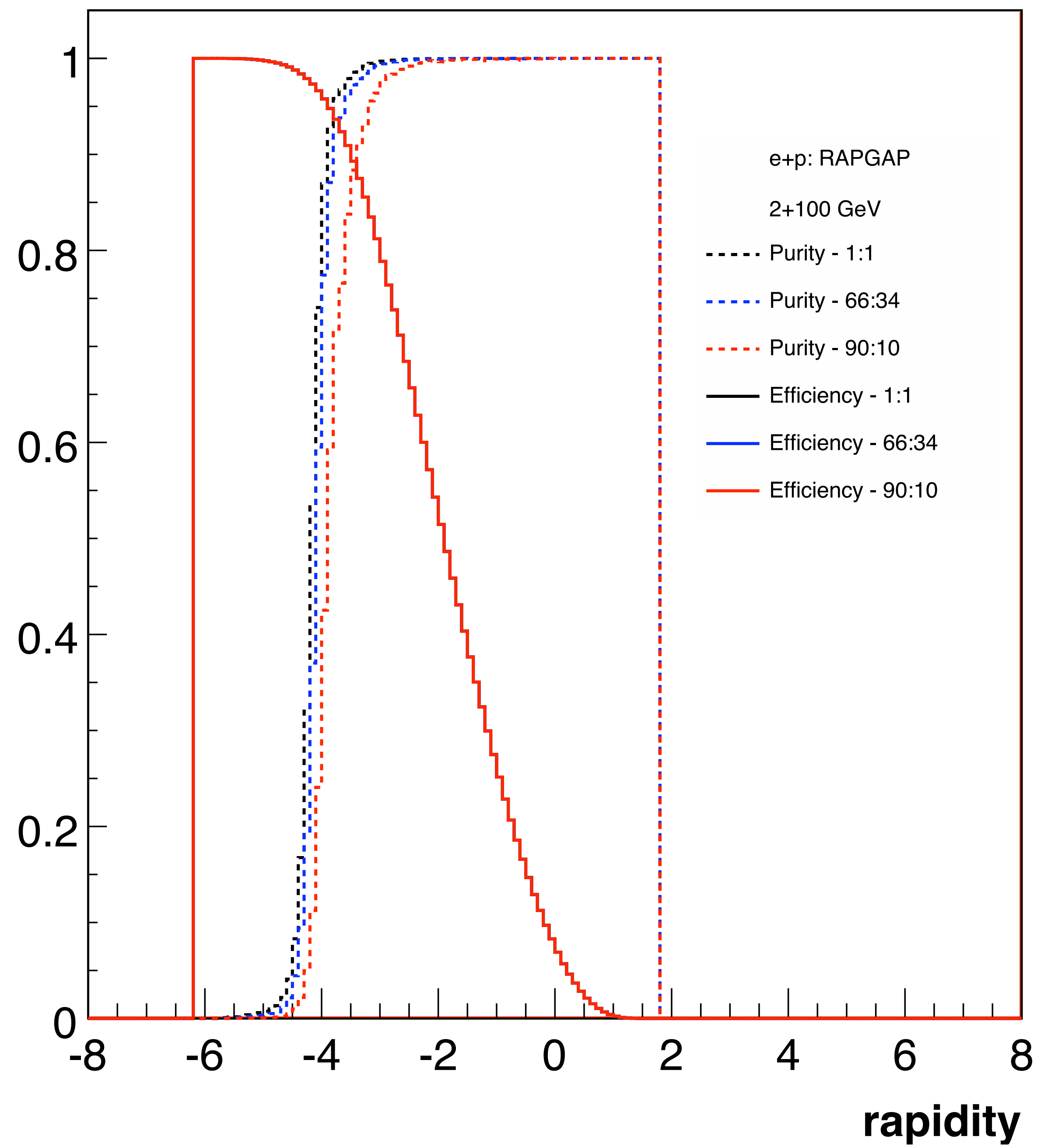

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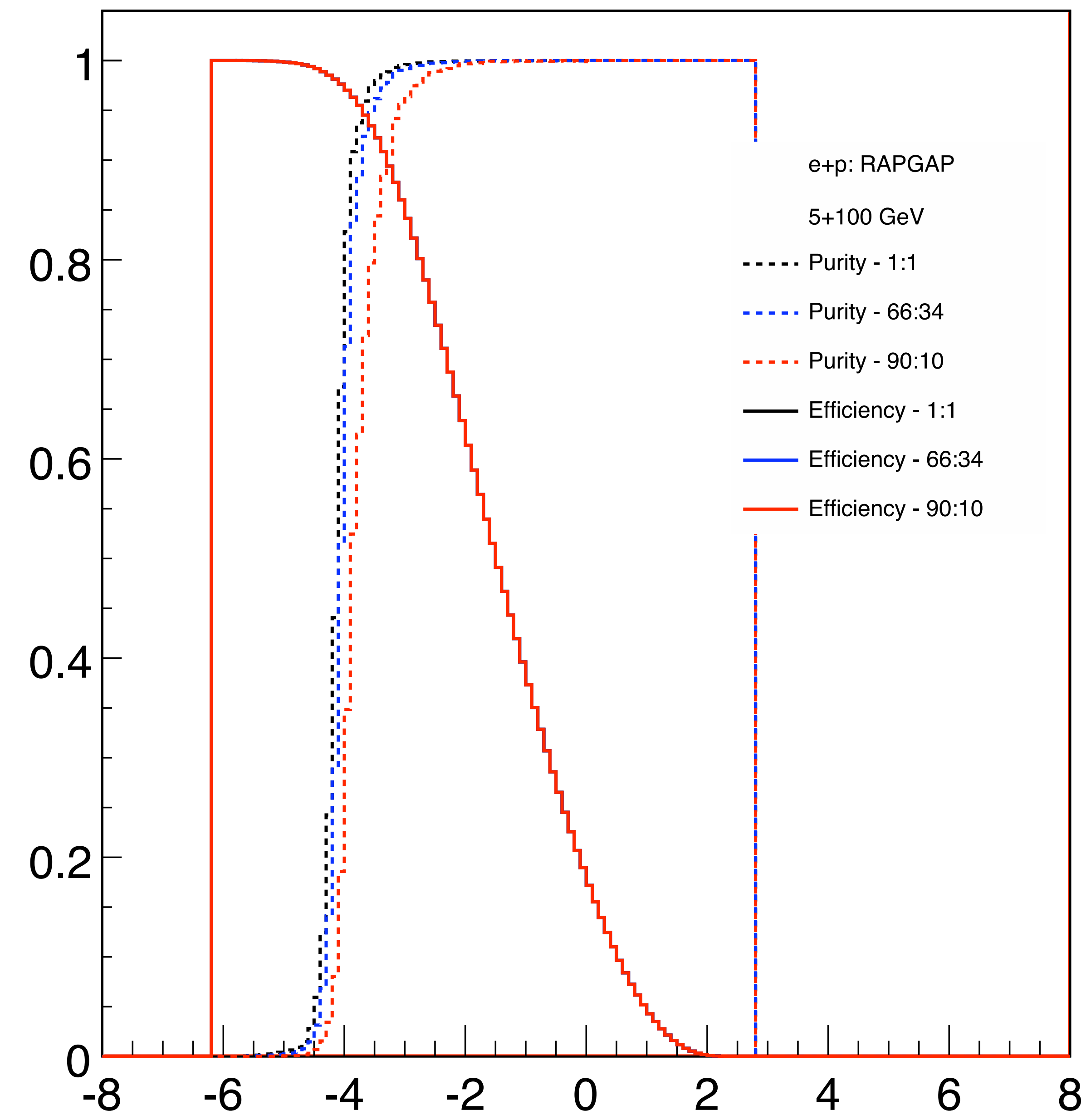

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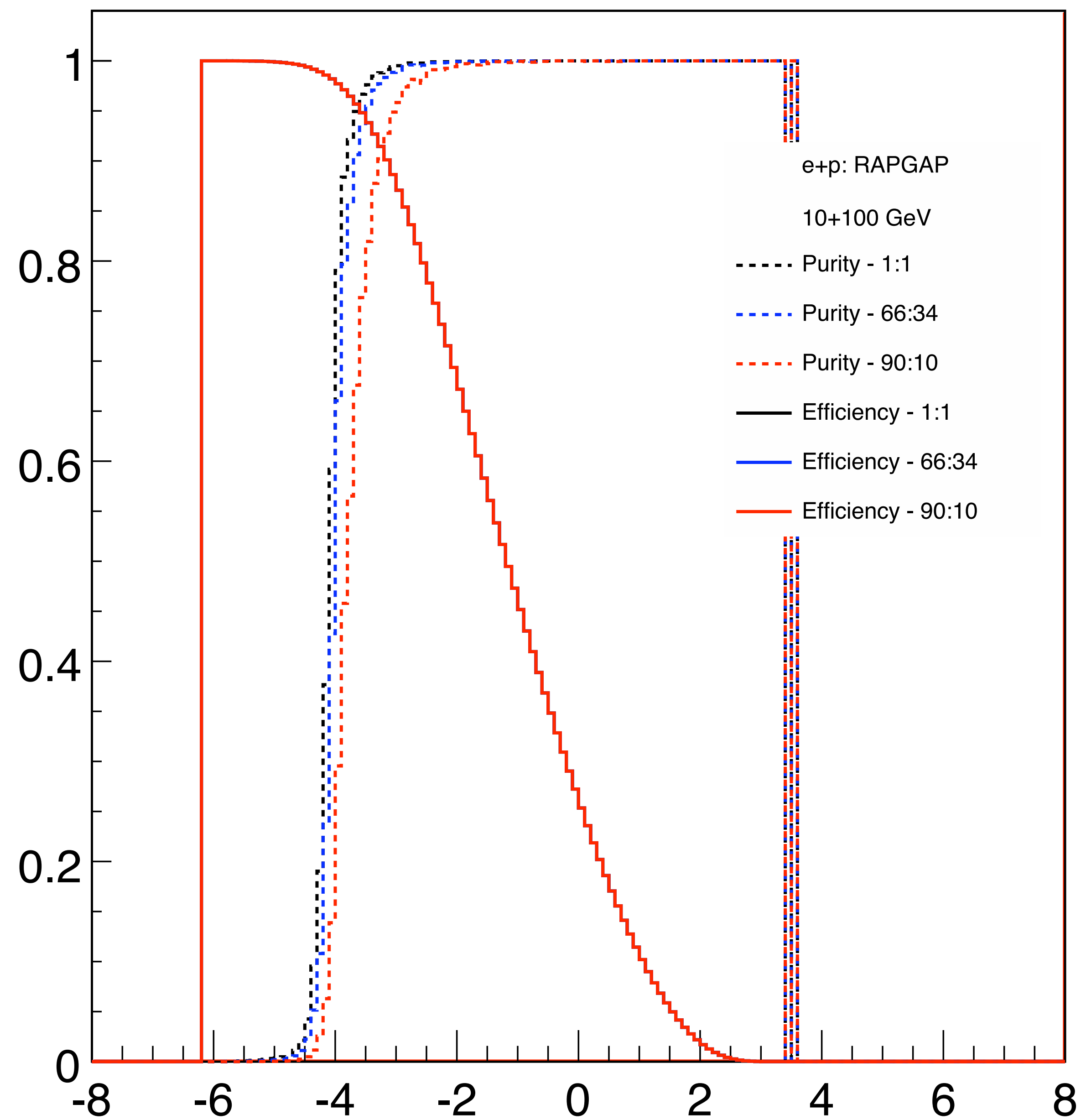

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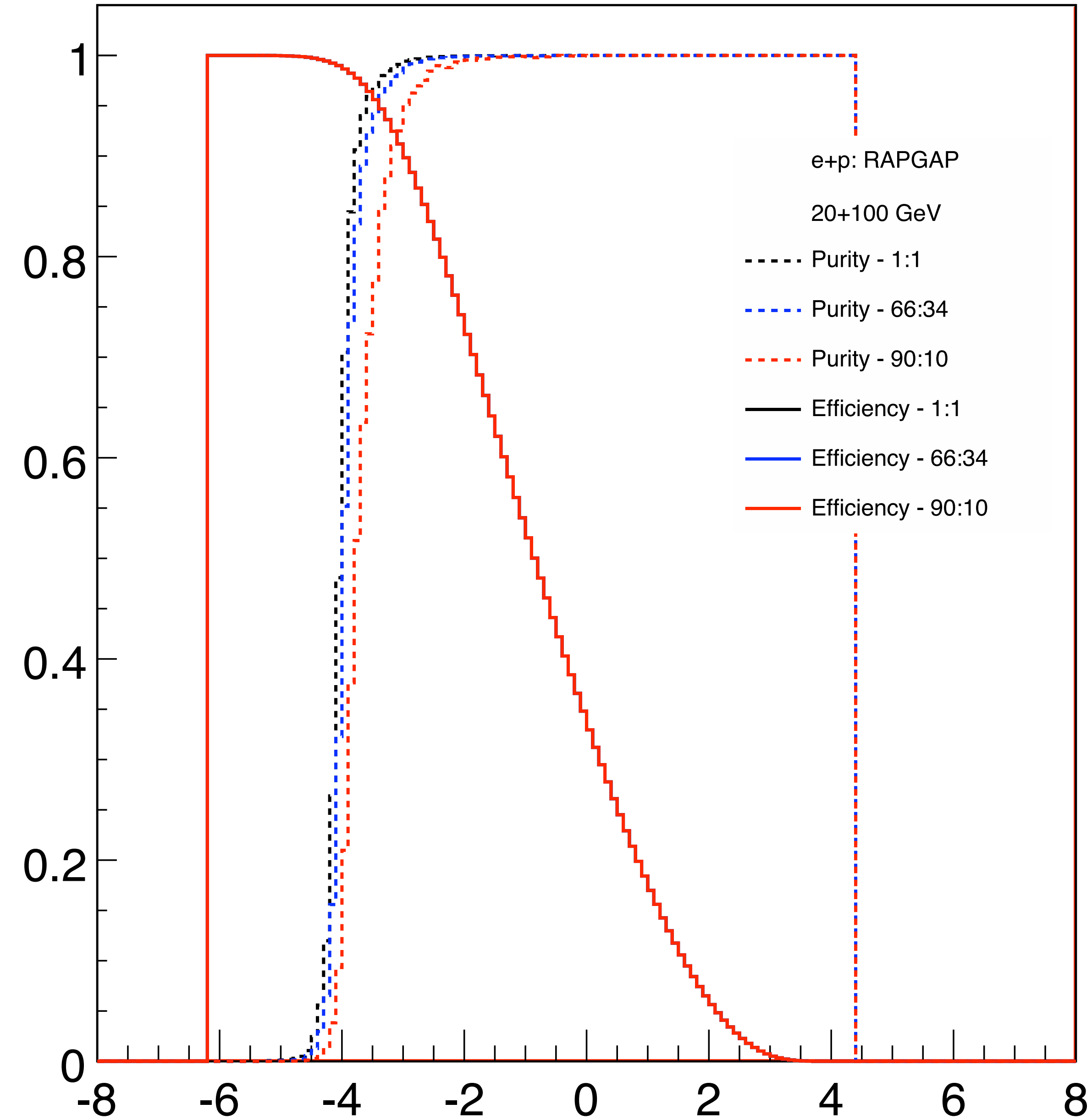

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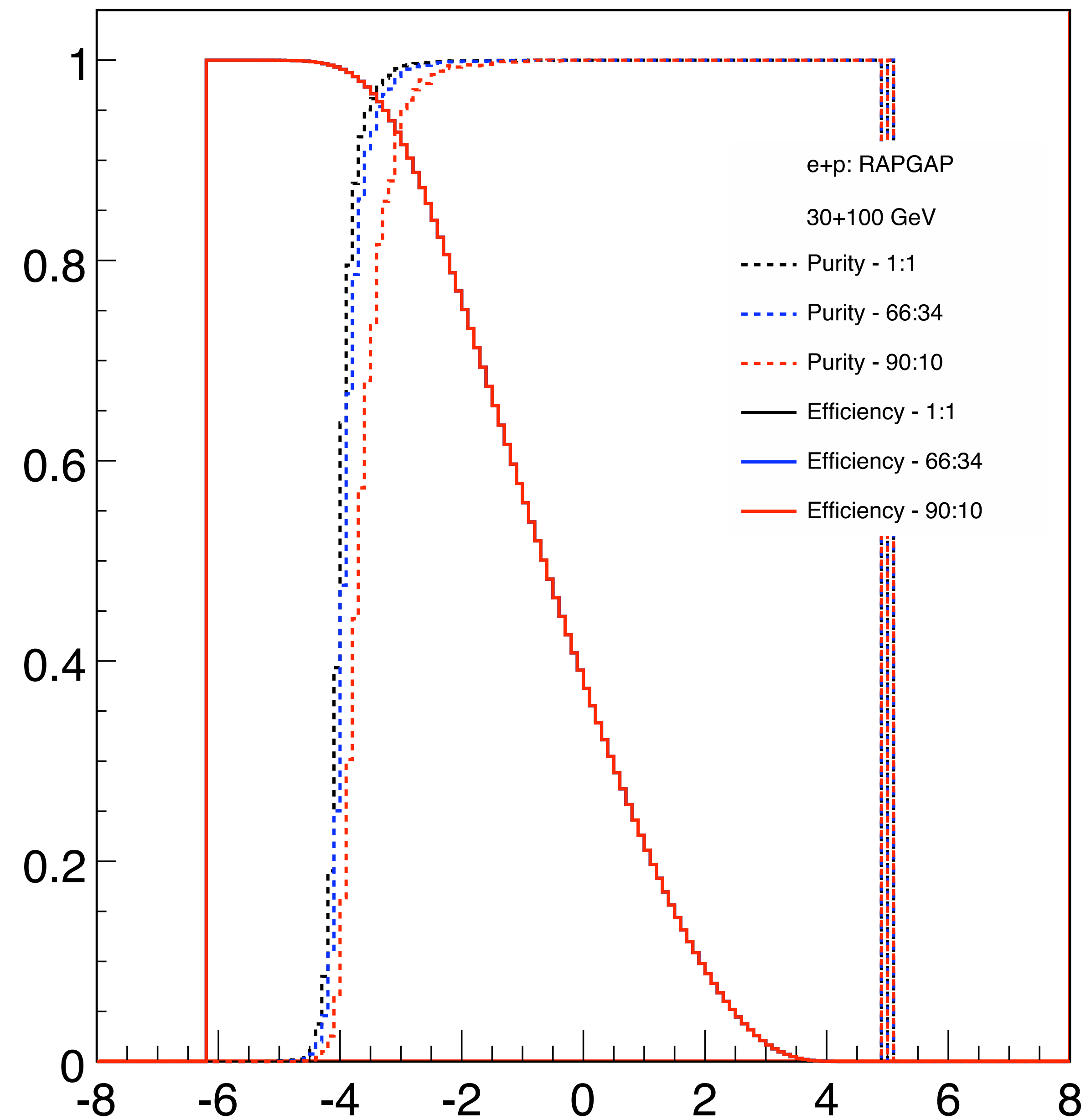

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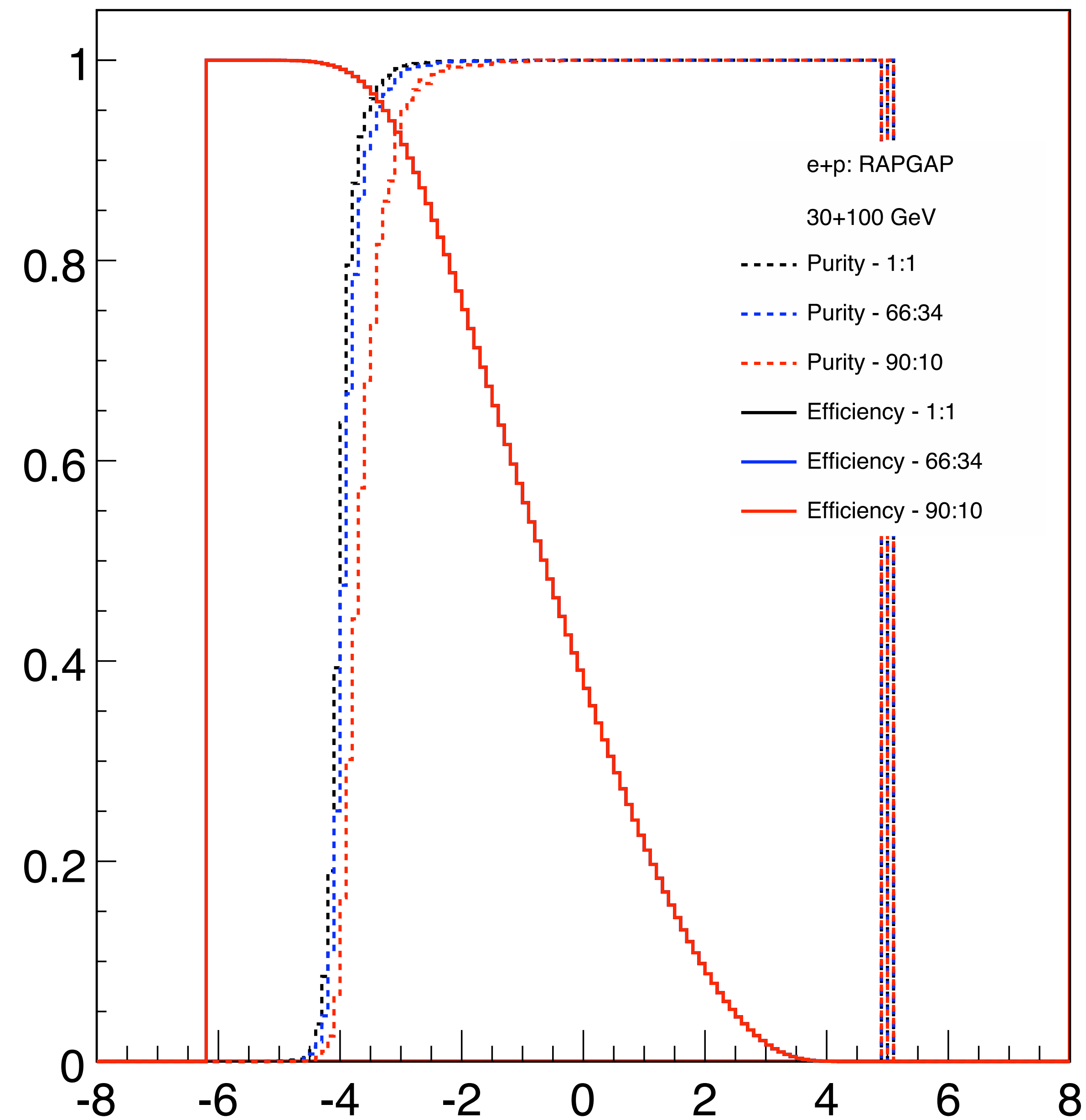
As expected, the efficiency and purity depend strongly on the ratio, but it is still acceptable



The need for a large acceptance

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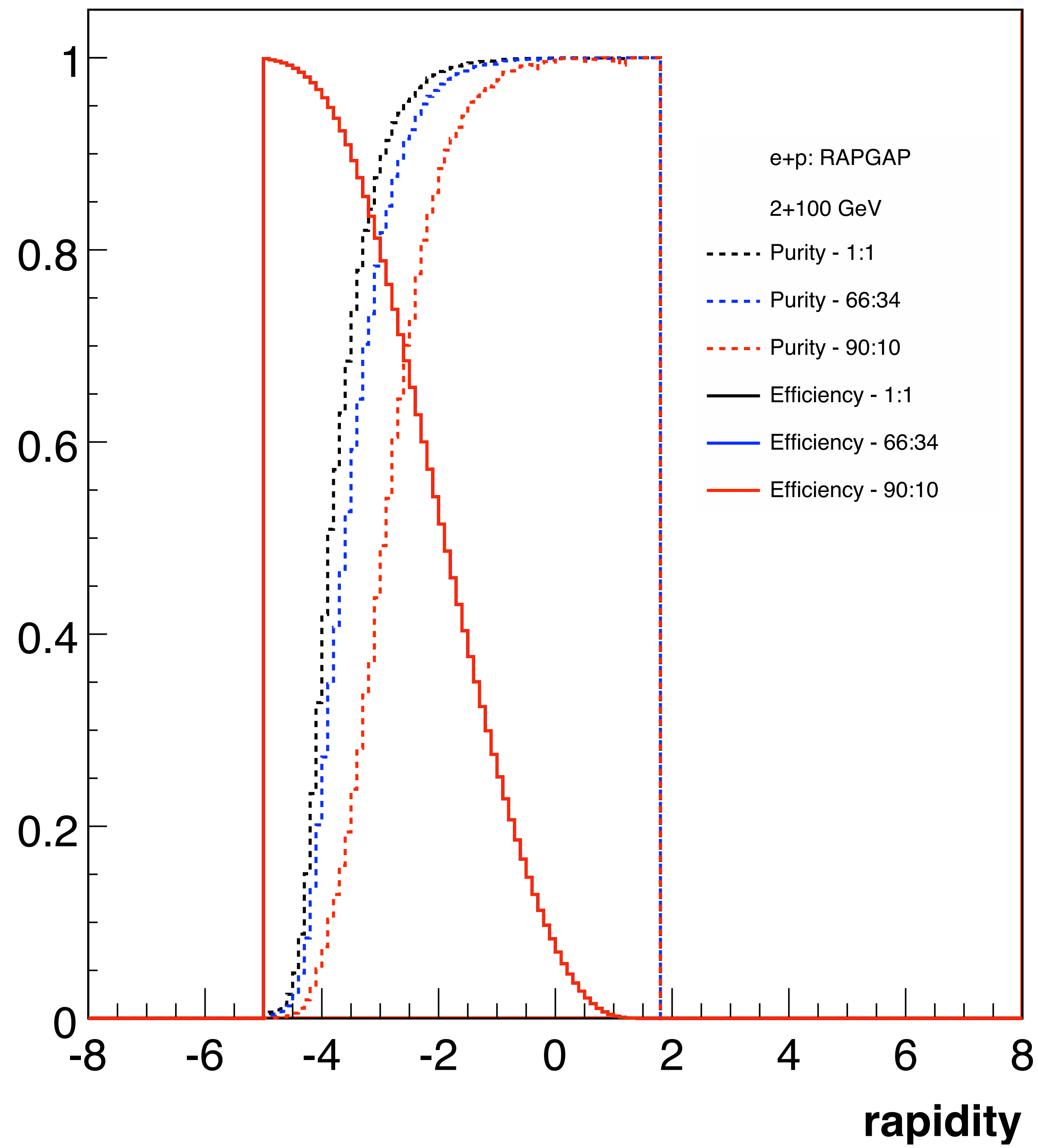
Efficiency: fraction of all Diff events measured

~1.2 units of rapidity acceptance missing



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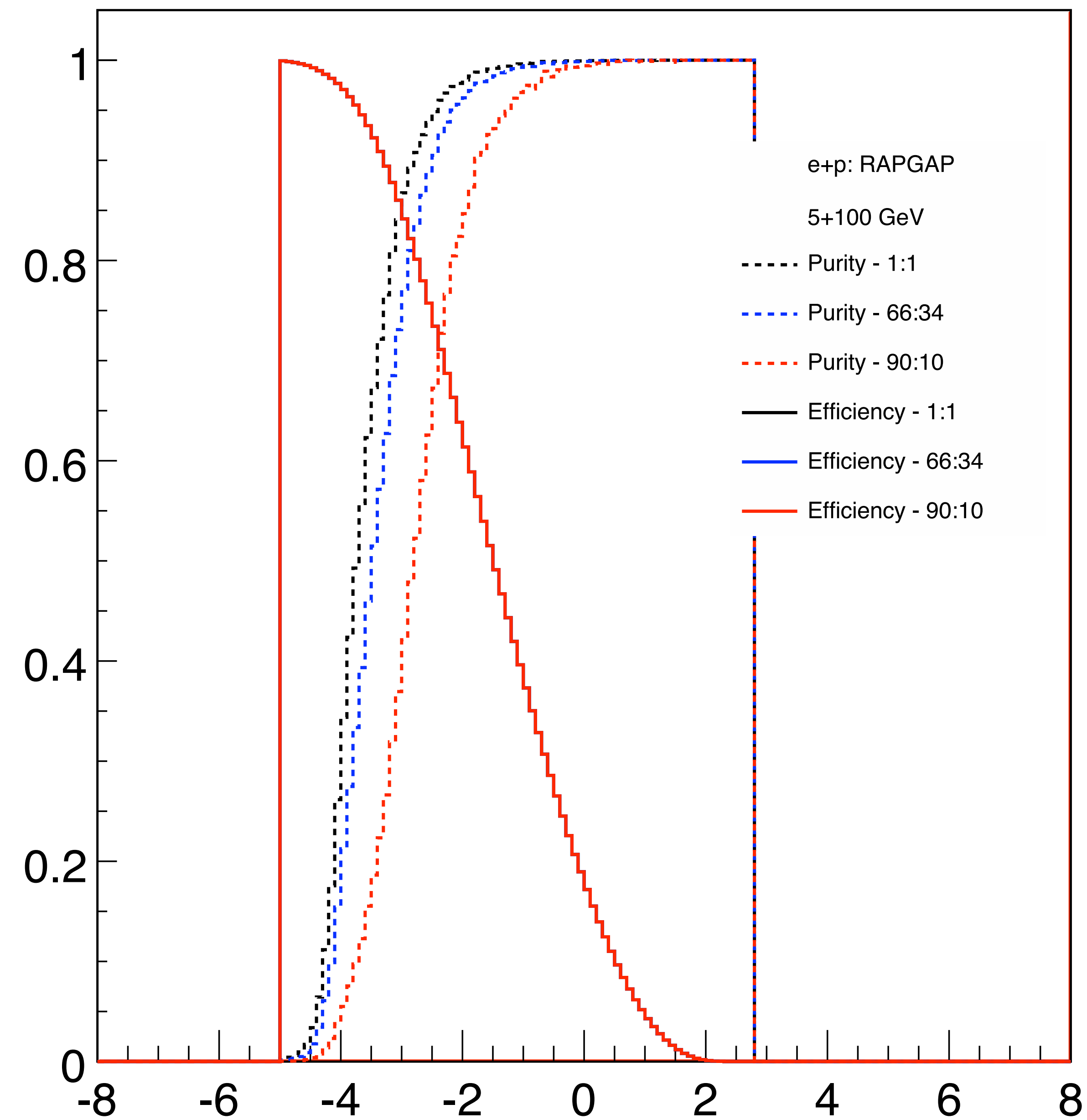

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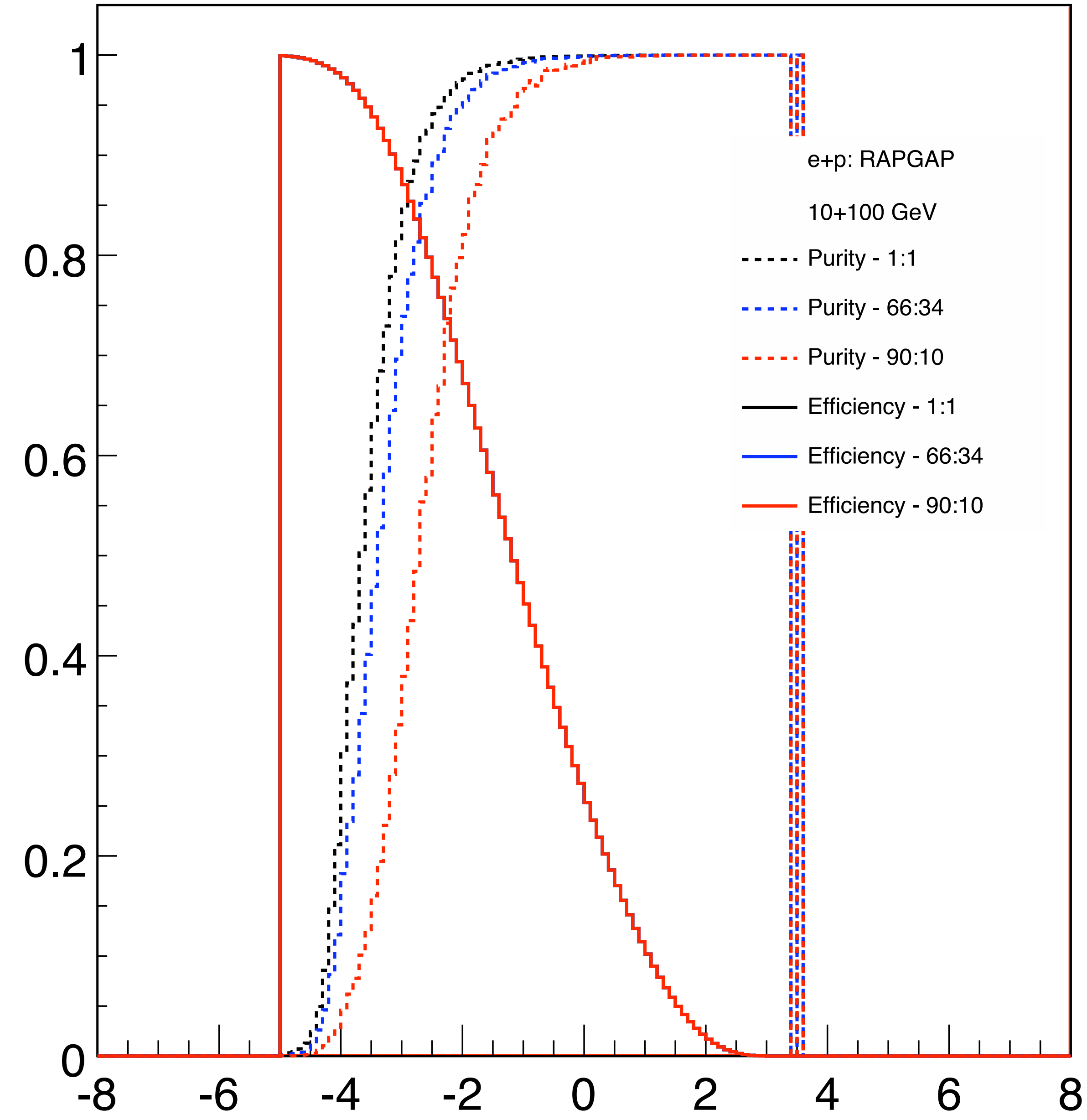

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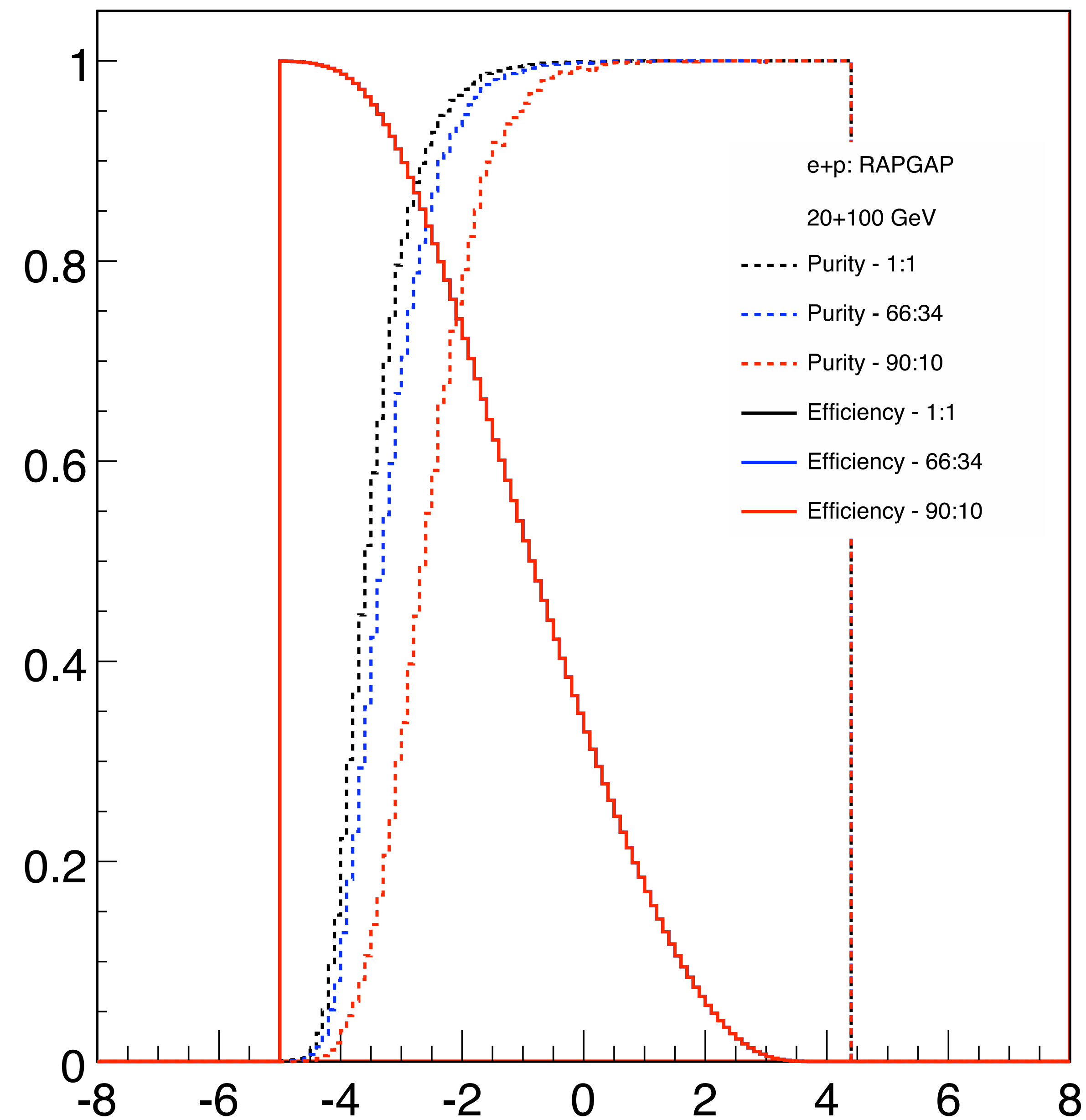

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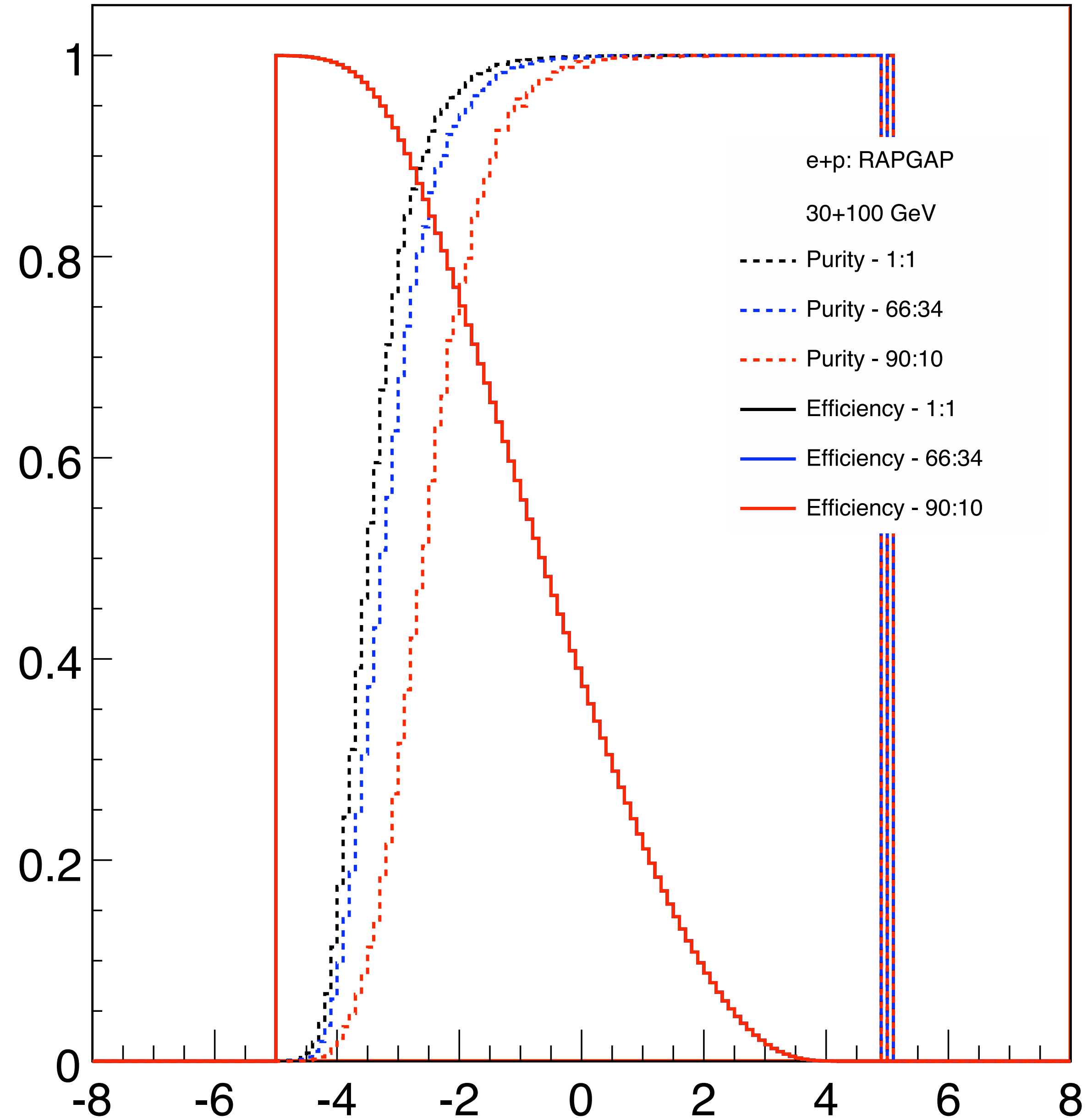

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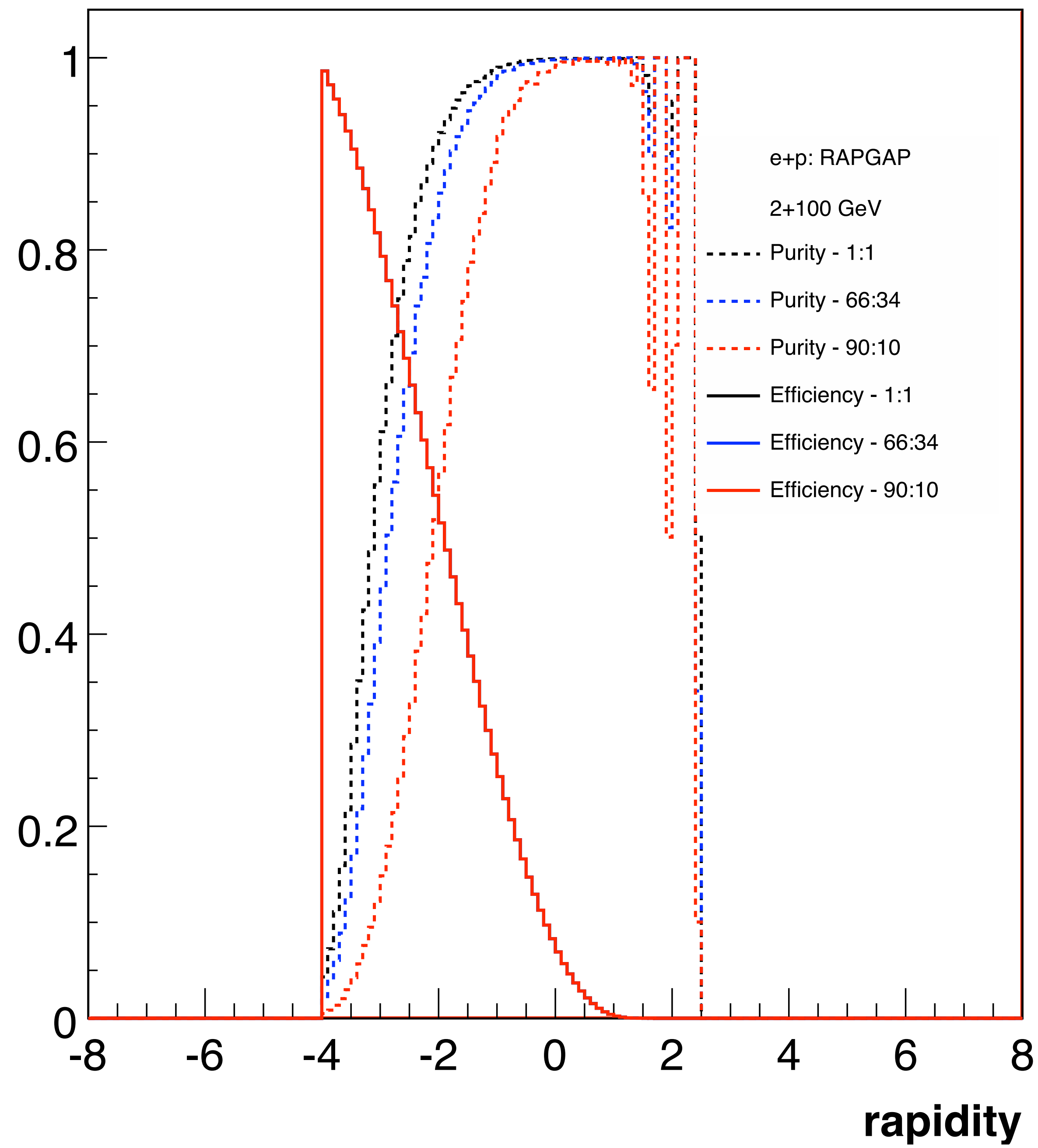

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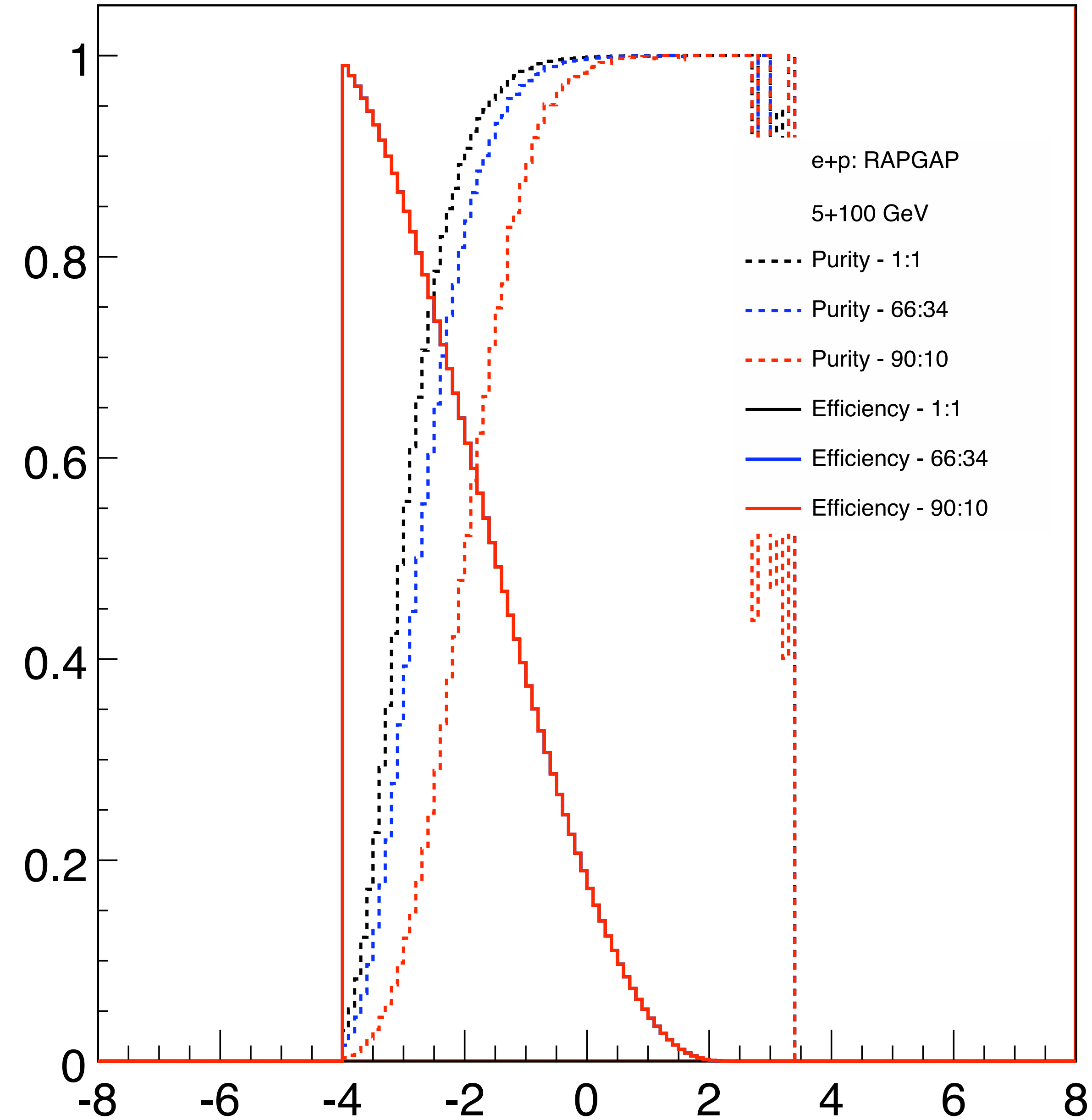

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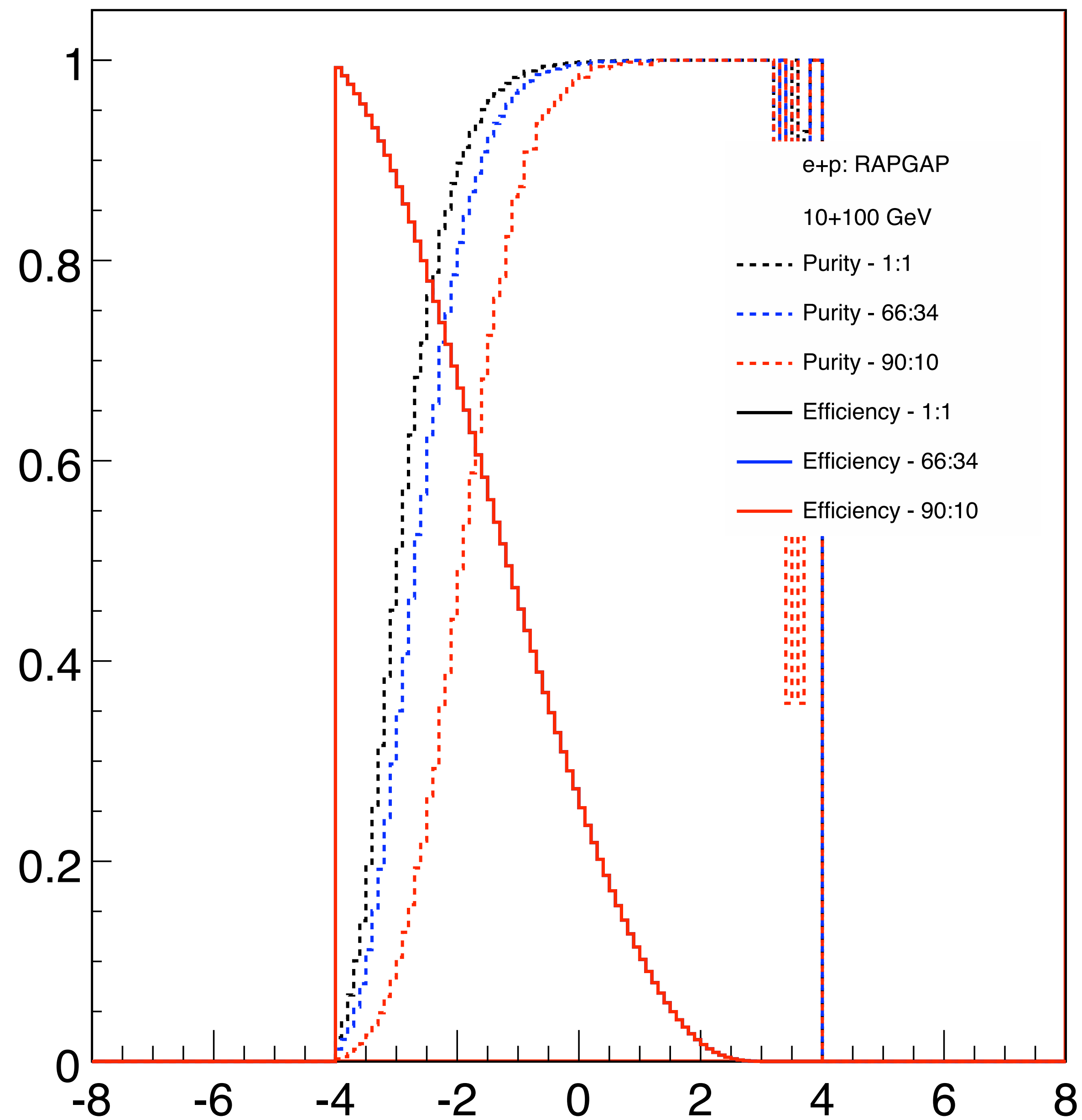

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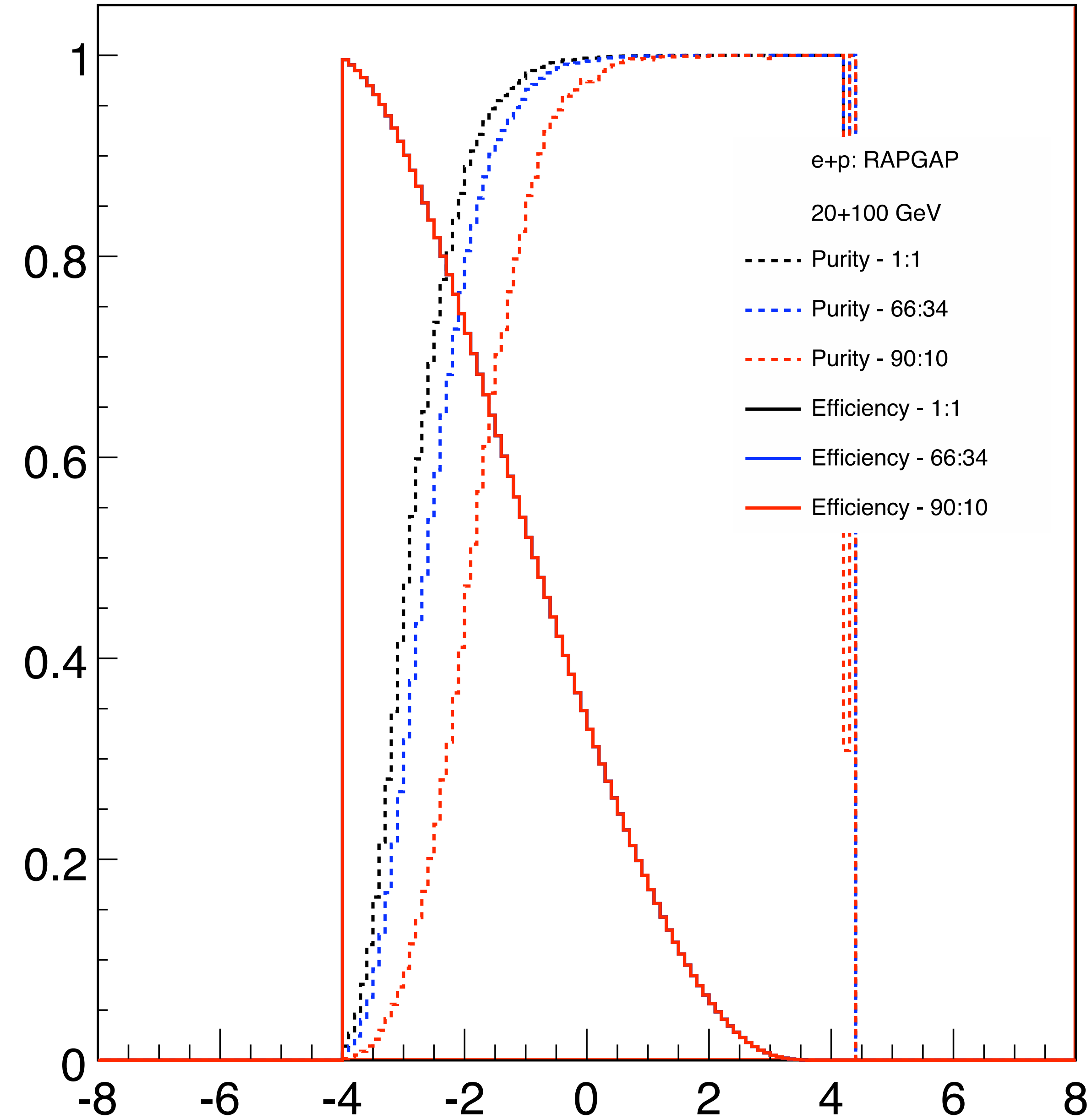

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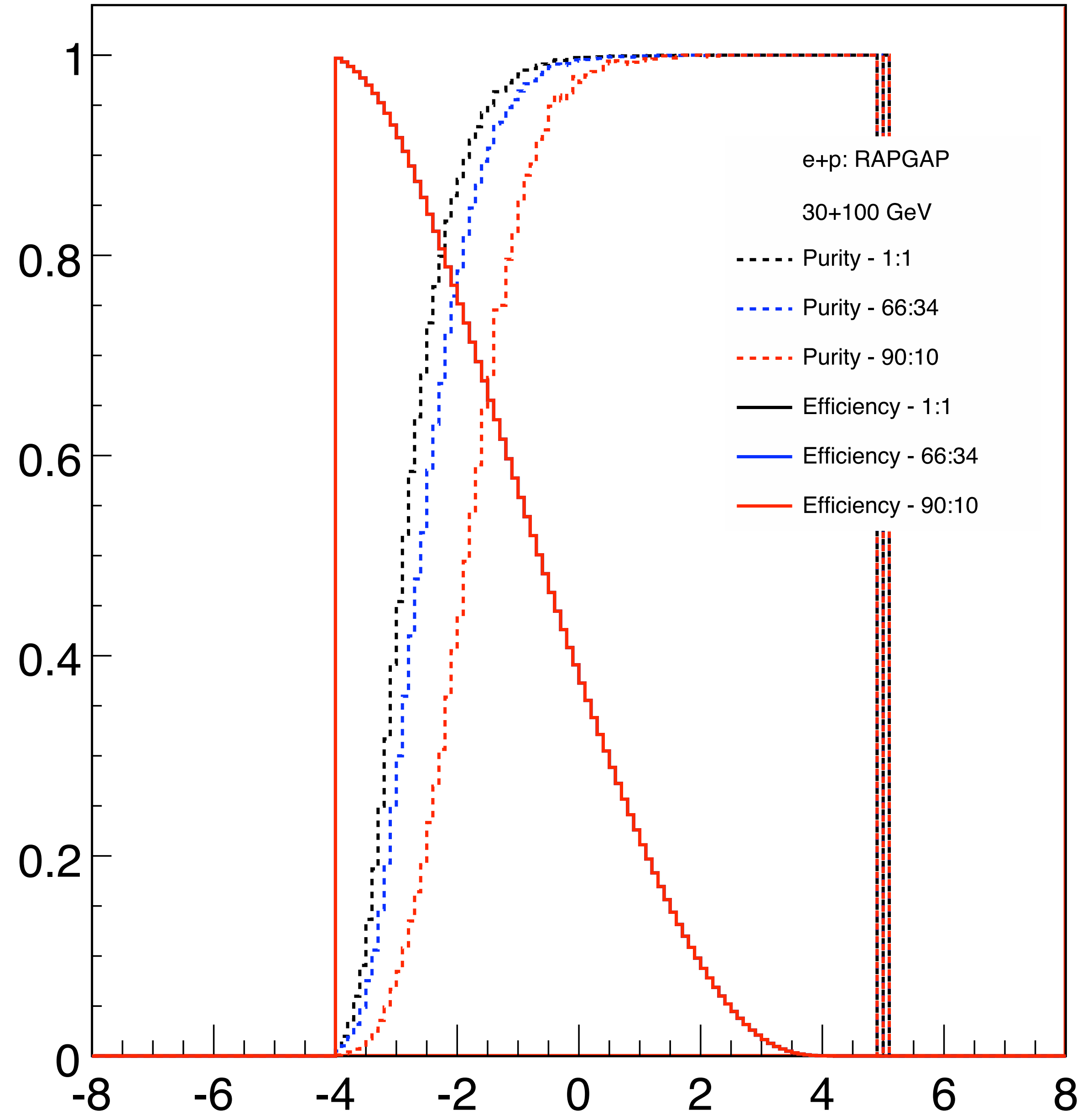
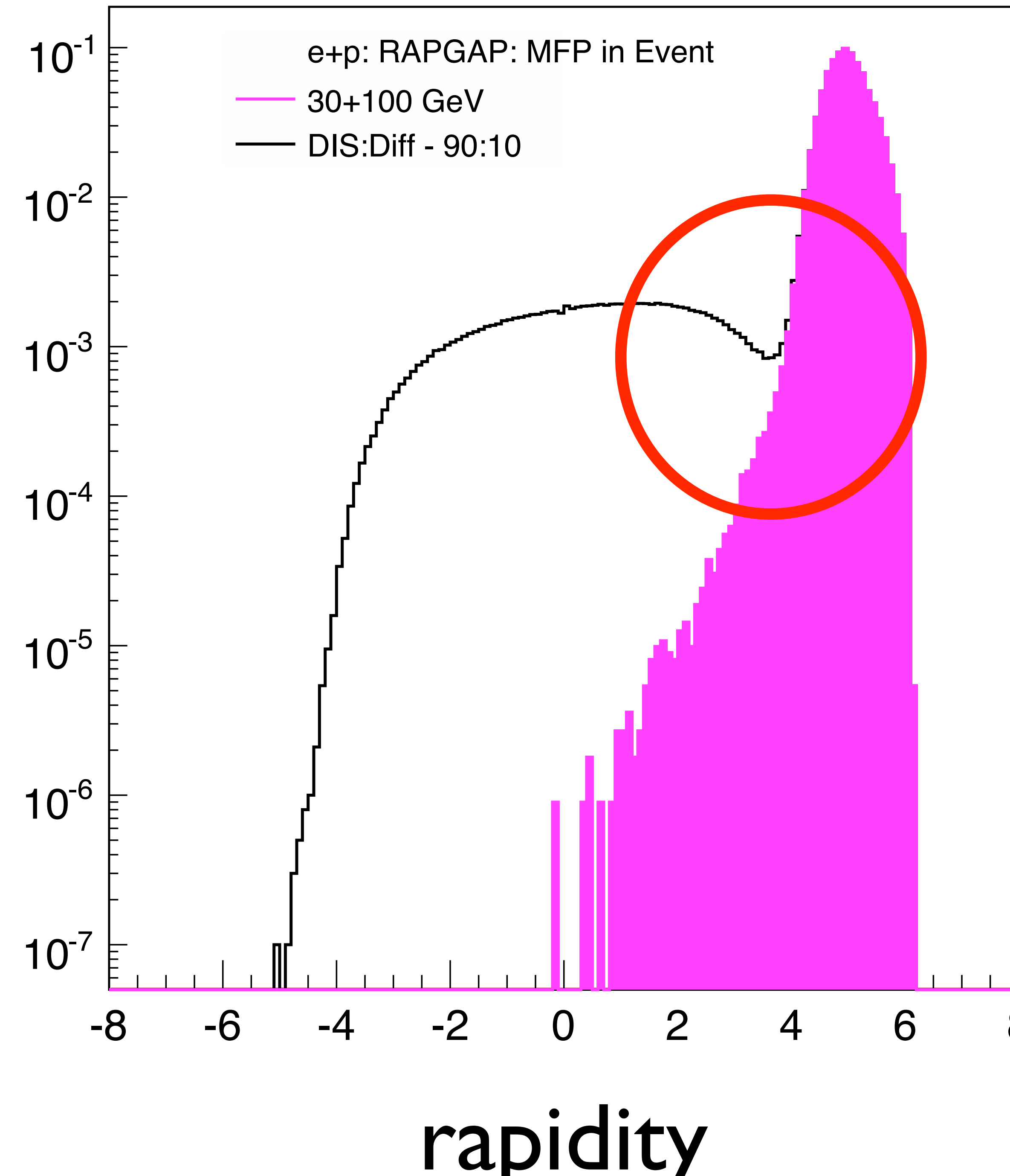
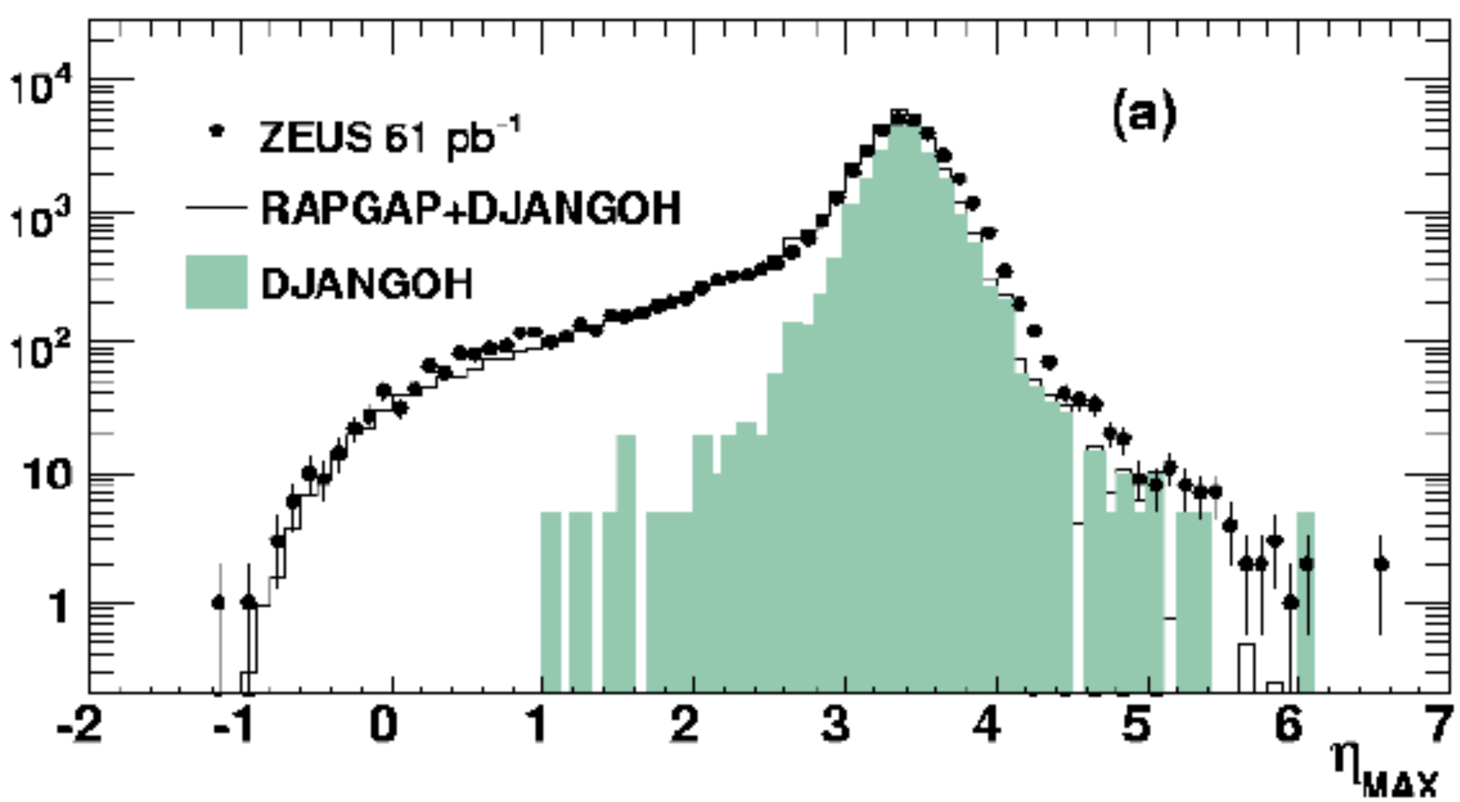


Can we reproduce the HERA plot?

- If we now apply the acceptance cuts to the HERA data, we get the following:
- Ratios:
  - ➡ DIS - 90%, Diff - 10%





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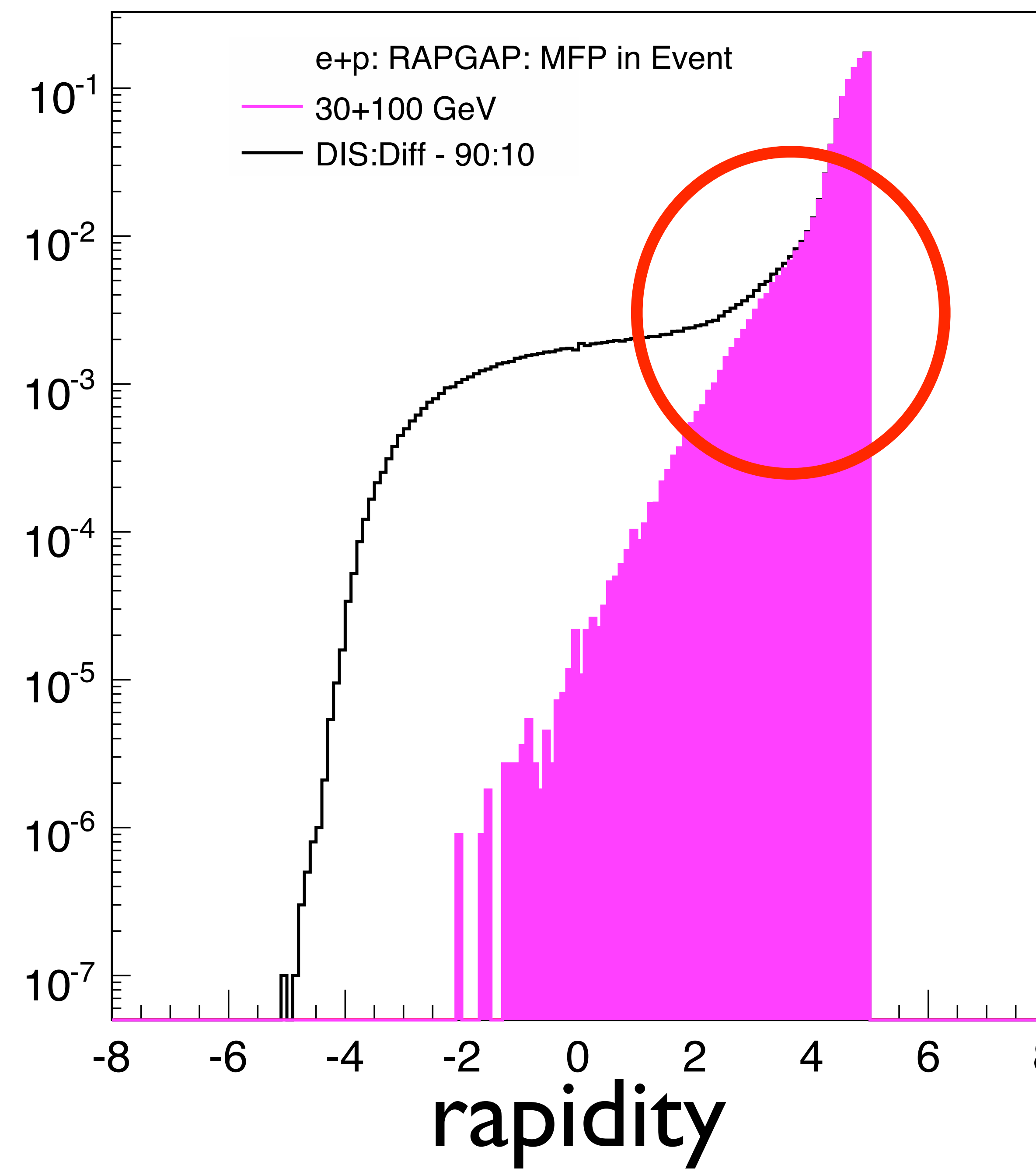

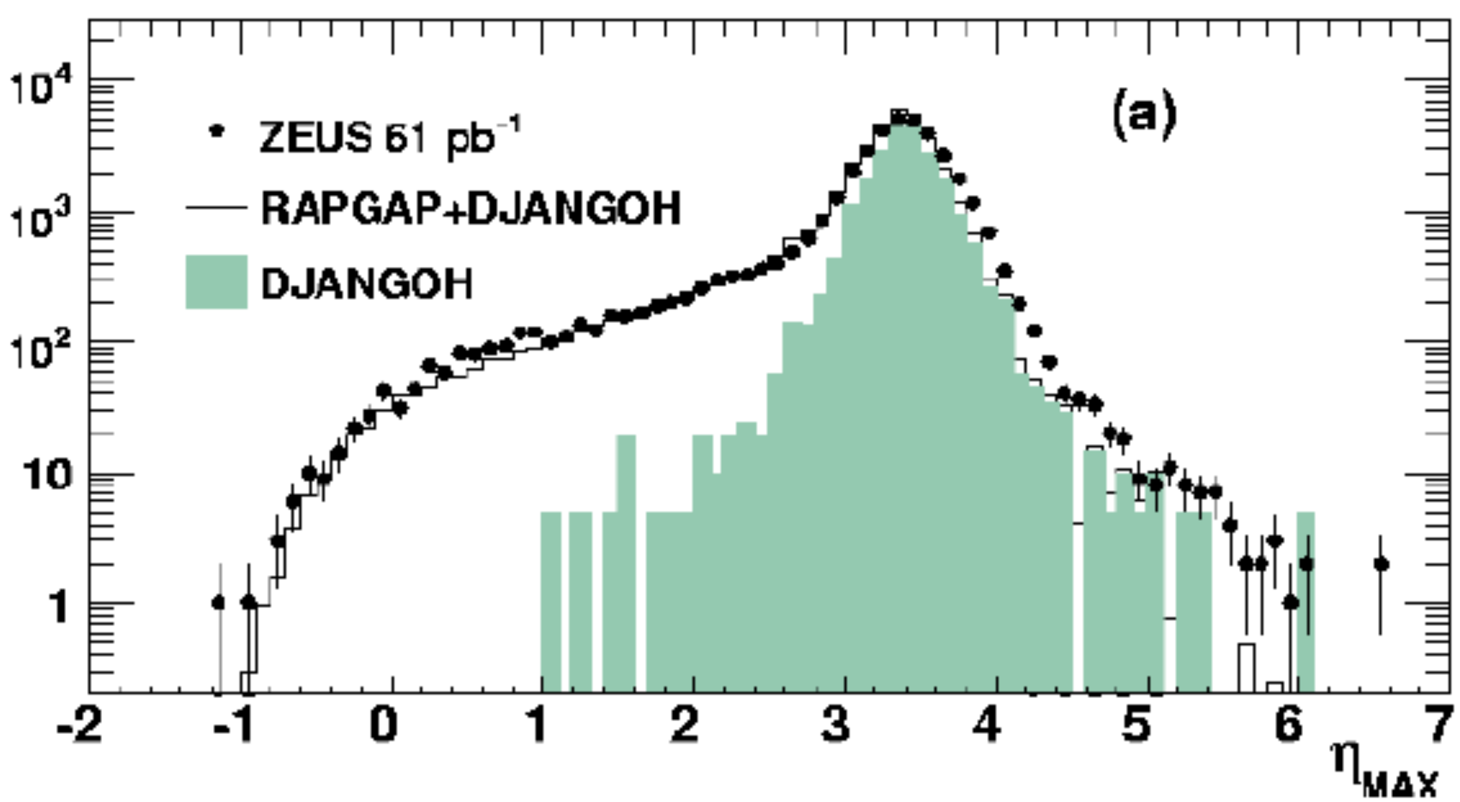

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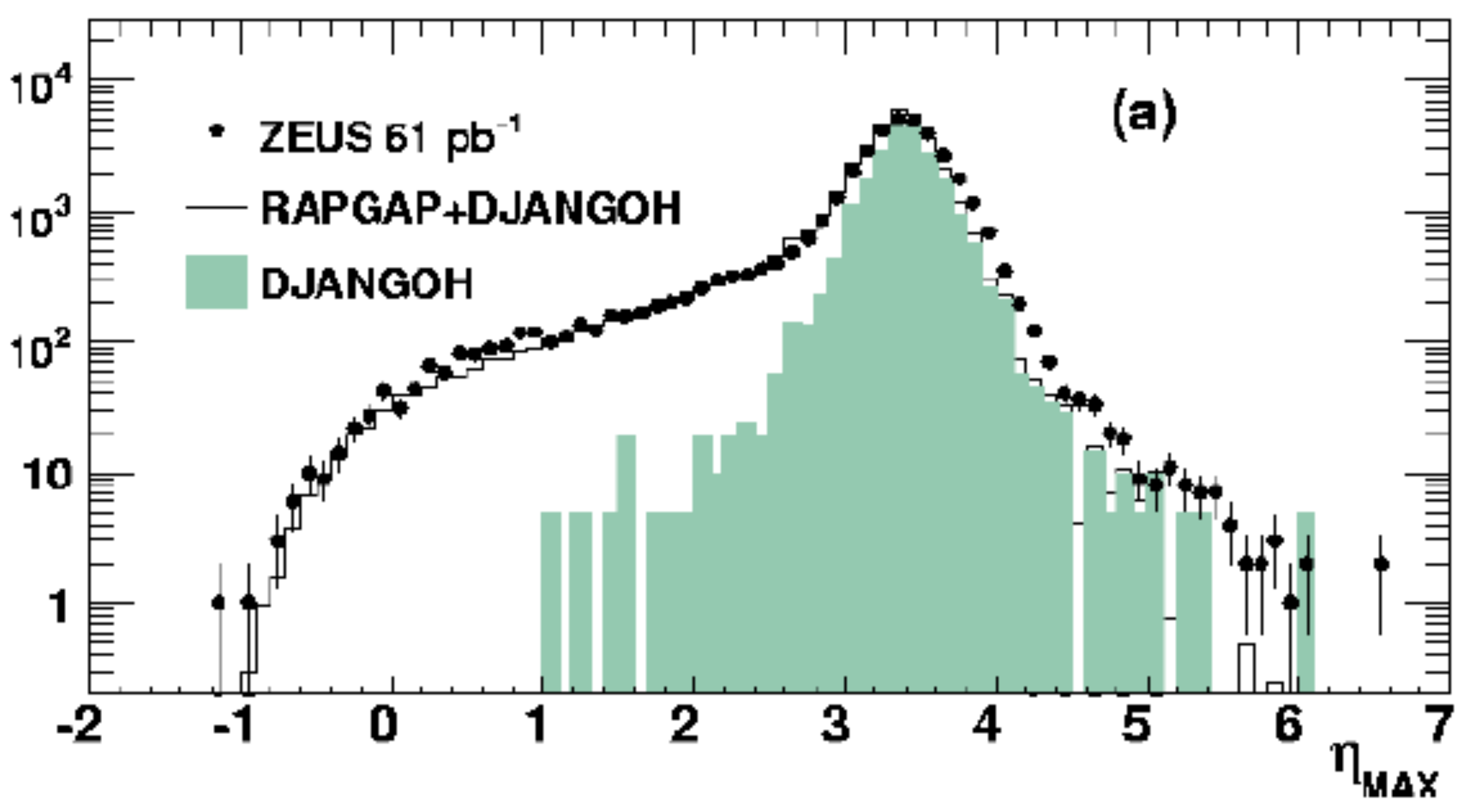

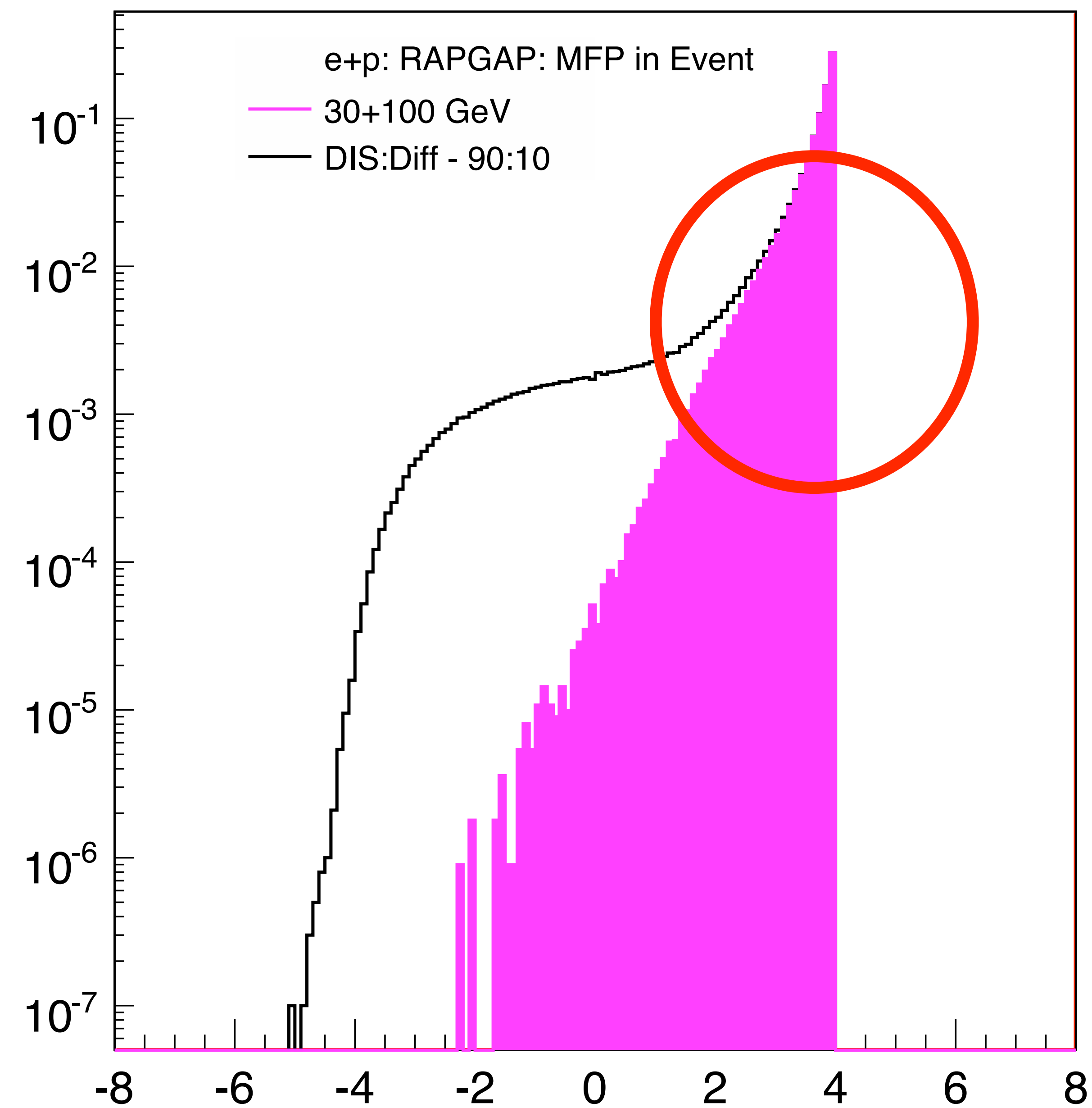

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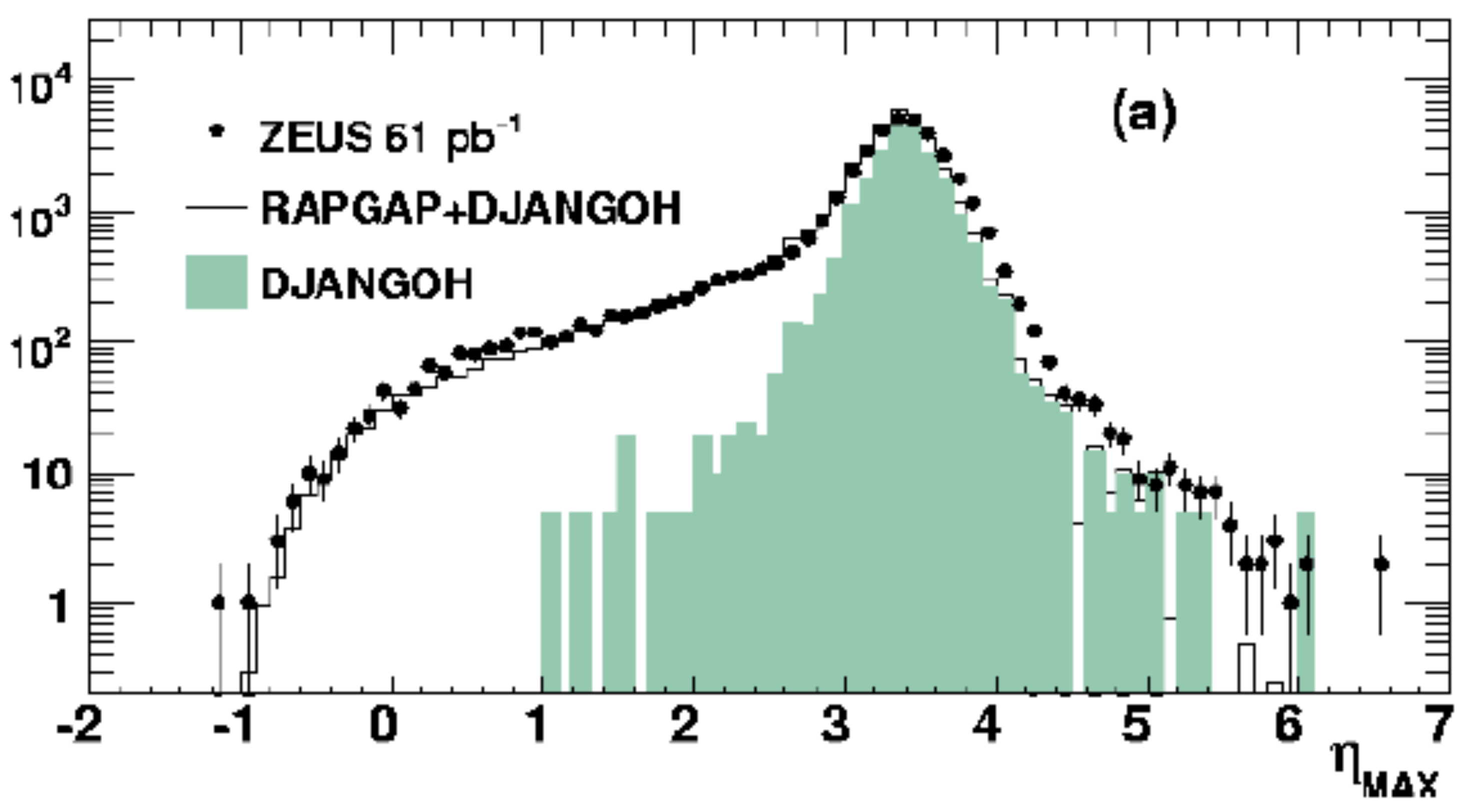
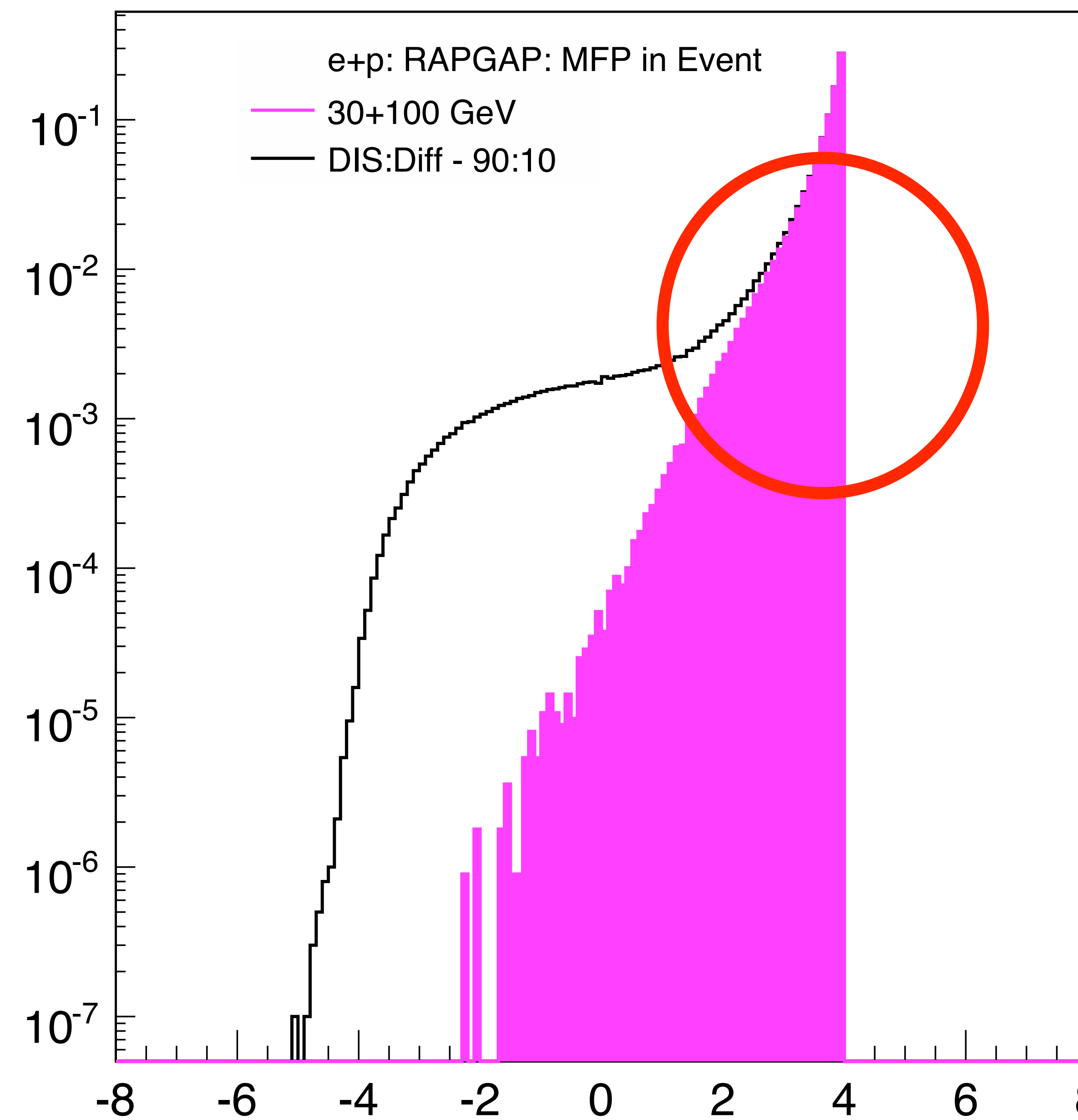
Shape is just an artefact of the acceptance coverage of the different systems





Summary and Conclusions

- Diffraction in e+p collisions at an EIC:
  - ➡ Can use forward spectrometer and LRG methods
    - Measure t dependence
    - Both coherent and incoherent measurments
- Diffraction in e+A collisions at an EIC:
  - ➡ Limited to LRG methods for large A (> ^{28}Si)
    - High statistics but no t dependence in general
      - Can measure t for exclusive v. meson production
  - ➡ Need large acceptance coverage to have both high purity and efficiency
  - ➡ Can utilise a Zero Degree Calorimeter (ZDC), in conjunction with Large Rapidity Gaps for information on coherence
    - Nothing in ZDC == coherent diffraction
    - Neutrons in ZDC == incoherent diffraction