# ZDC Studies for u-Channel Physics

Zachary Sweger
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# ePIC Current ZDC Design Parameters

ePIC current ZDC design

- 60×60 cm transverse area
- 2×2 cm transverse tower size
- $PbWO_4$ Moliere radius is 1.75 cm, so typical shower diameter is ~3.5 cm
- With shower spreading to multiple crystals, hit location can be determined to ~10% of transverse tower dimensions
- Rough estimated resolution in x and y: $\sigma_{xy} \approx 2$ mm
- Rough estimated high-energy resolution: $\Delta E/E \approx (2\%\text{-}5\%)/\sqrt{E} \oplus 1\%$

# UC Riverside ZDC Design Parameters

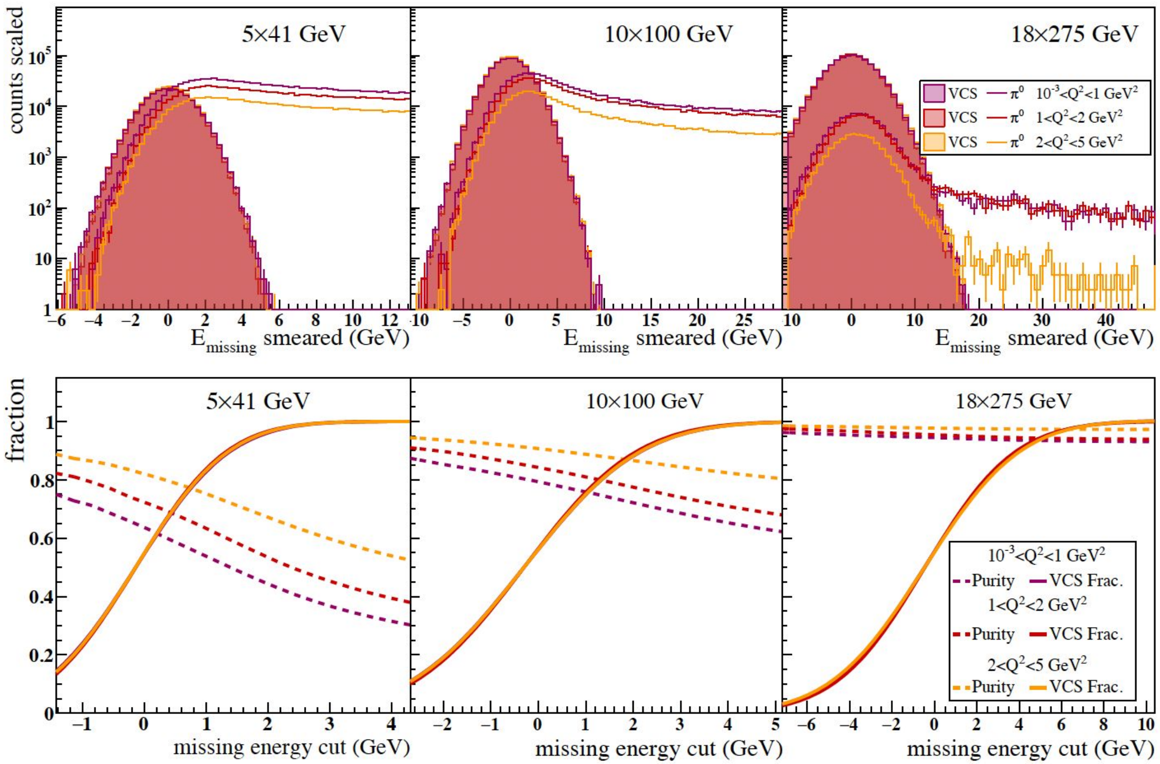
UCR ZDC design

- 60×60 cm transverse area
- 25 $cm^2$ hexagonal tiles
- Rough estimated resolution in x and y: $\sigma_{xy} \approx (19\%)/\sqrt{E} \oplus 1.4\% \approx 1mm$
- Rough estimated high-energy resolution: $\Delta E/E \approx (15\%\text{-}20\%)/\sqrt{E} \oplus 1\%$

# Effect of Energy Resolution on DVCS Purity

- Larger stochastic ZDC energy resolution does not noticeably affect DVCS purity at 18x275 GeV

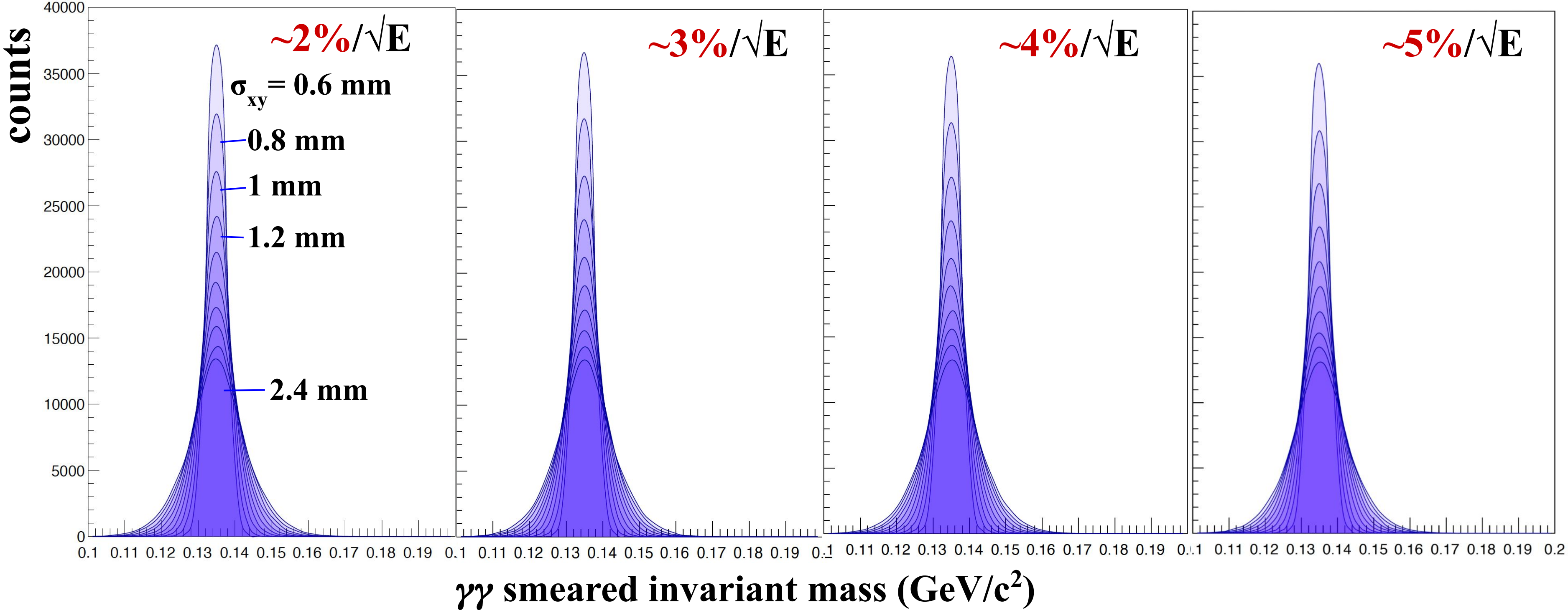
$$\Delta E/E = 20\%/\sqrt{E} \oplus 1\%$$



# $\pi^0$ Reconstruction

- Stochastic energy resolution term does not affect π0 reconstruction resolution over expected range for ePIC ZDC design. Position resolution does.

$$\Delta E/E = (2\%\text{-}5\%)/\sqrt{E} \oplus 1\%$$



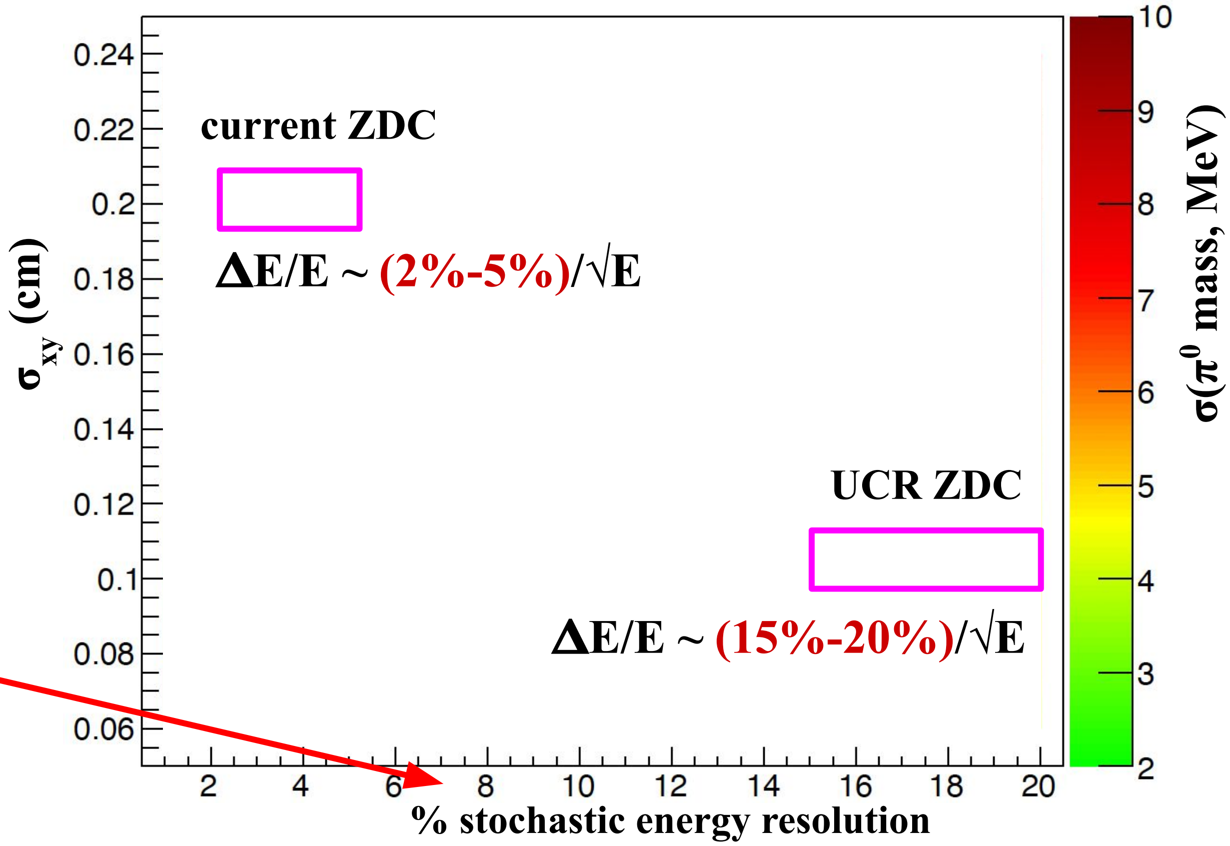
# $\pi^0$ mass resolution

$\pi^0$ was reconstructed with various position resolutions $\sigma_{xy}$

For each position resolution, the stochastic energy resolution term was varied

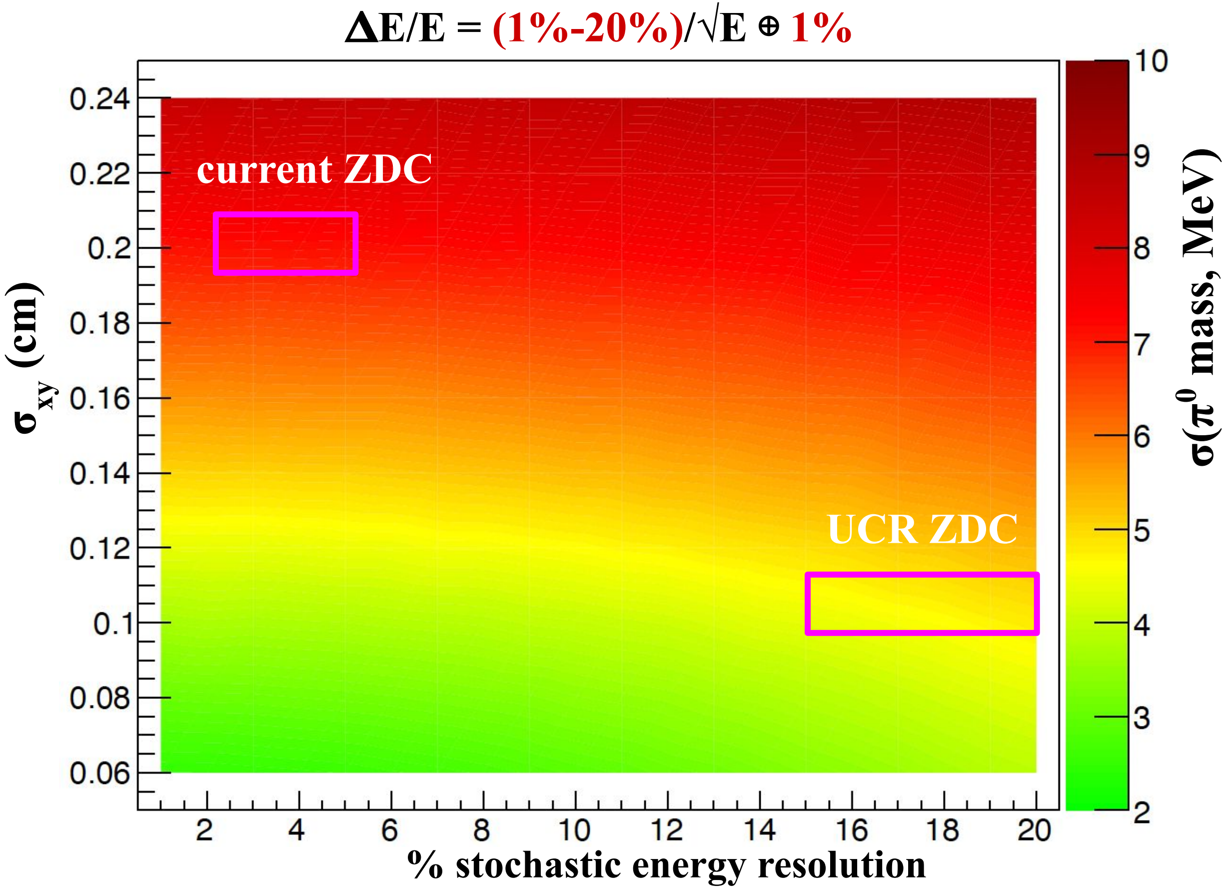
$$\Delta E/E = (1\%\text{-}20\%)/\sqrt{E} \oplus 1\%$$

The standard deviation of the mass peak is represented on the color axis in MeV



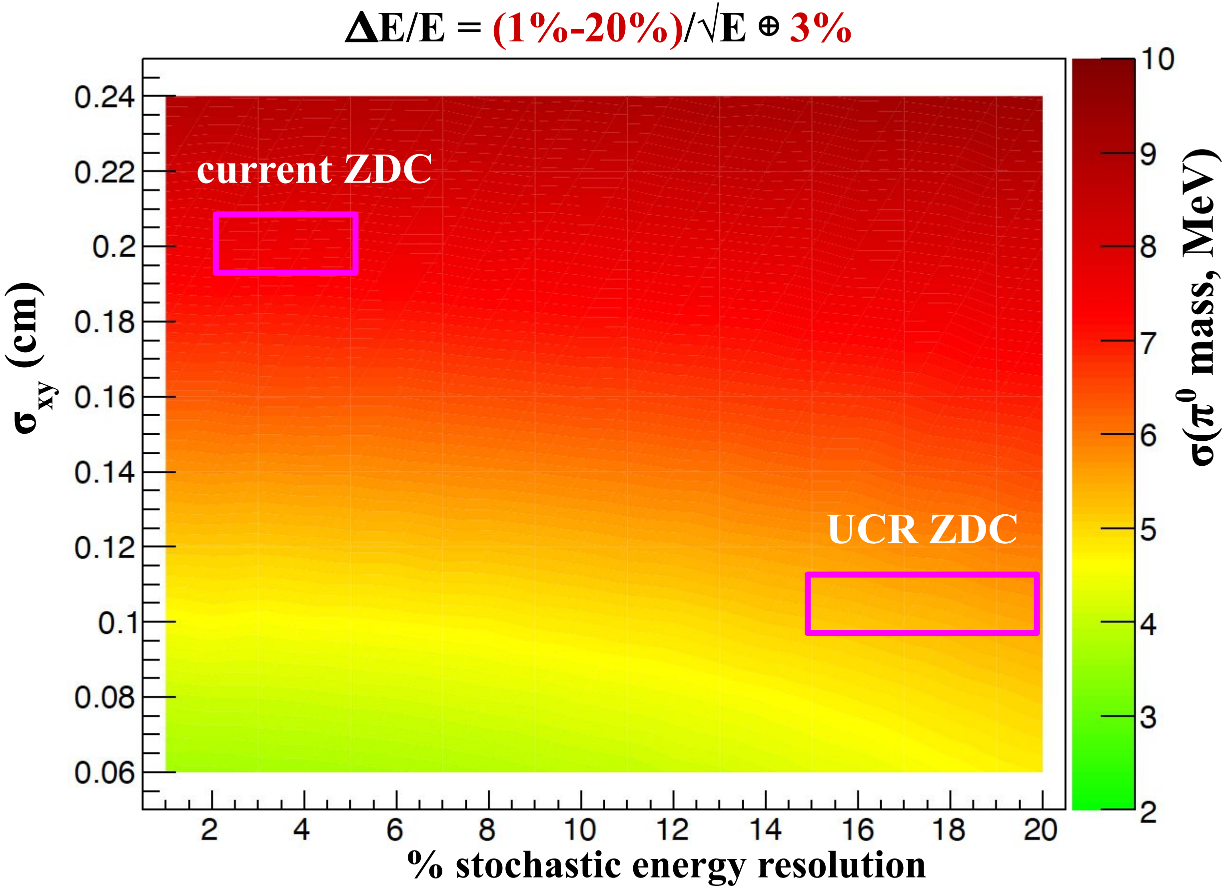
# $\pi^0$ mass measurement with $\oplus$1% term

- UCR ZDC design results in higher $\pi^0$ reconstruction resolution
- Position resolution drives reconstruction resolution



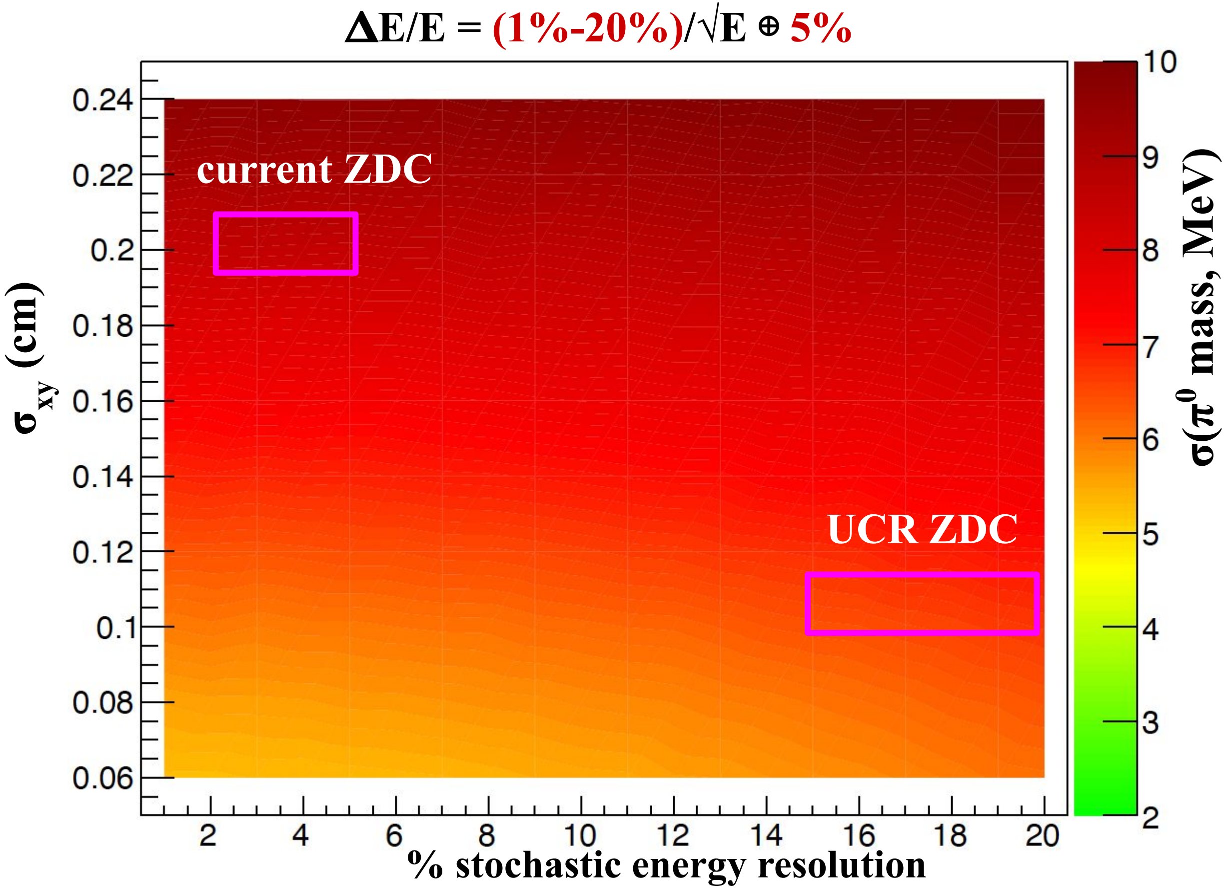
# $\pi^0$ mass measurement with $\oplus$3% term

- UCR ZDC design results in higher $\pi^0$ reconstruction resolution
- Position resolution drives reconstruction resolution



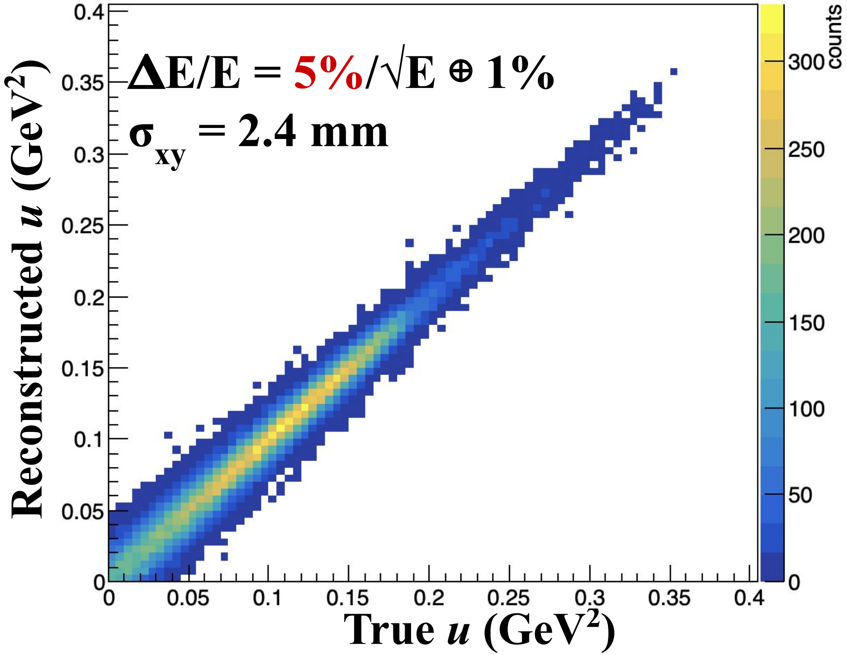
# $\pi^0$ mass measurement with $\oplus$5% term

- UCR ZDC design results in higher $\pi^0$ reconstruction resolution
- Position resolution drives reconstruction resolution



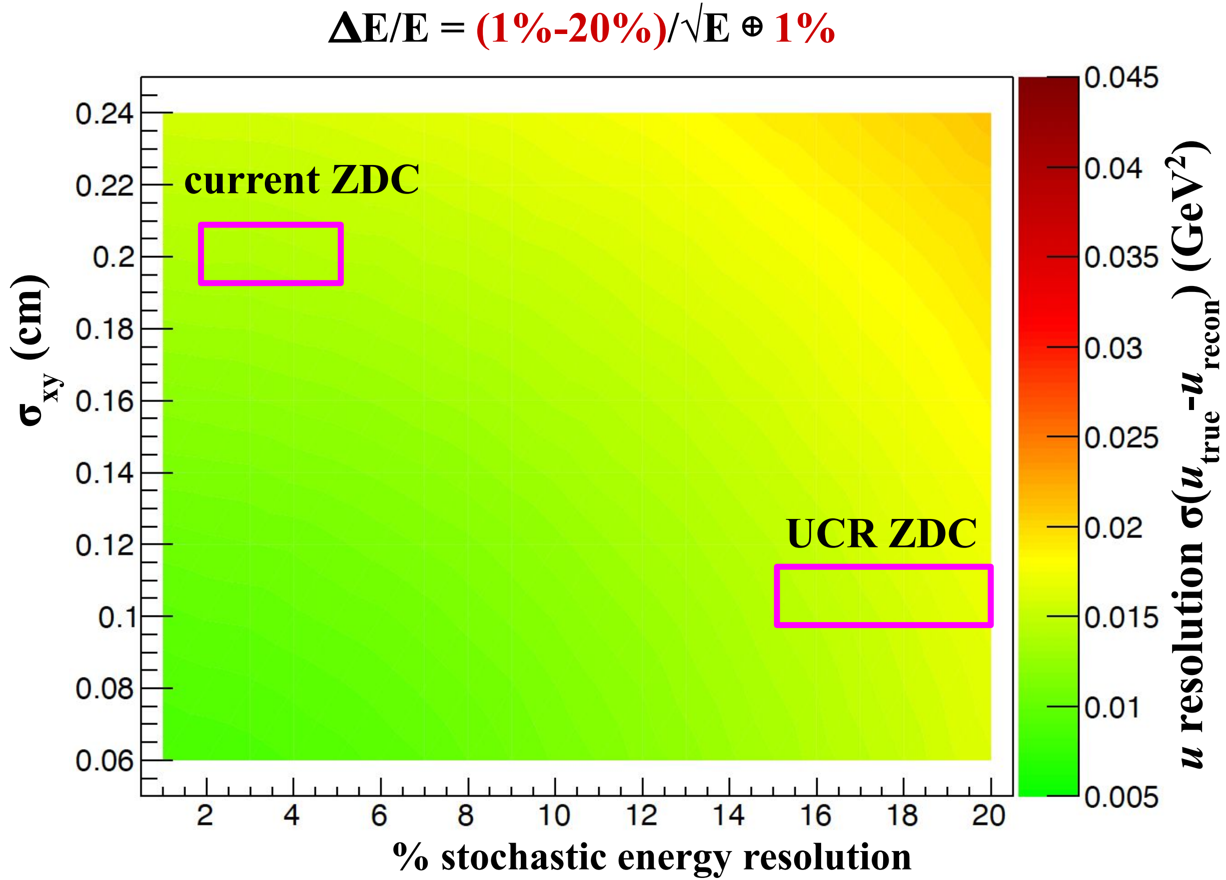
# u-channel cross section measurement

- We aim to measure backward cross sections as a function of the Mandelstam $u = (p_{proton\ beam} - p_{meson})^2$
- So the ability to reliably measure the true u value will determine how useful these measurements are



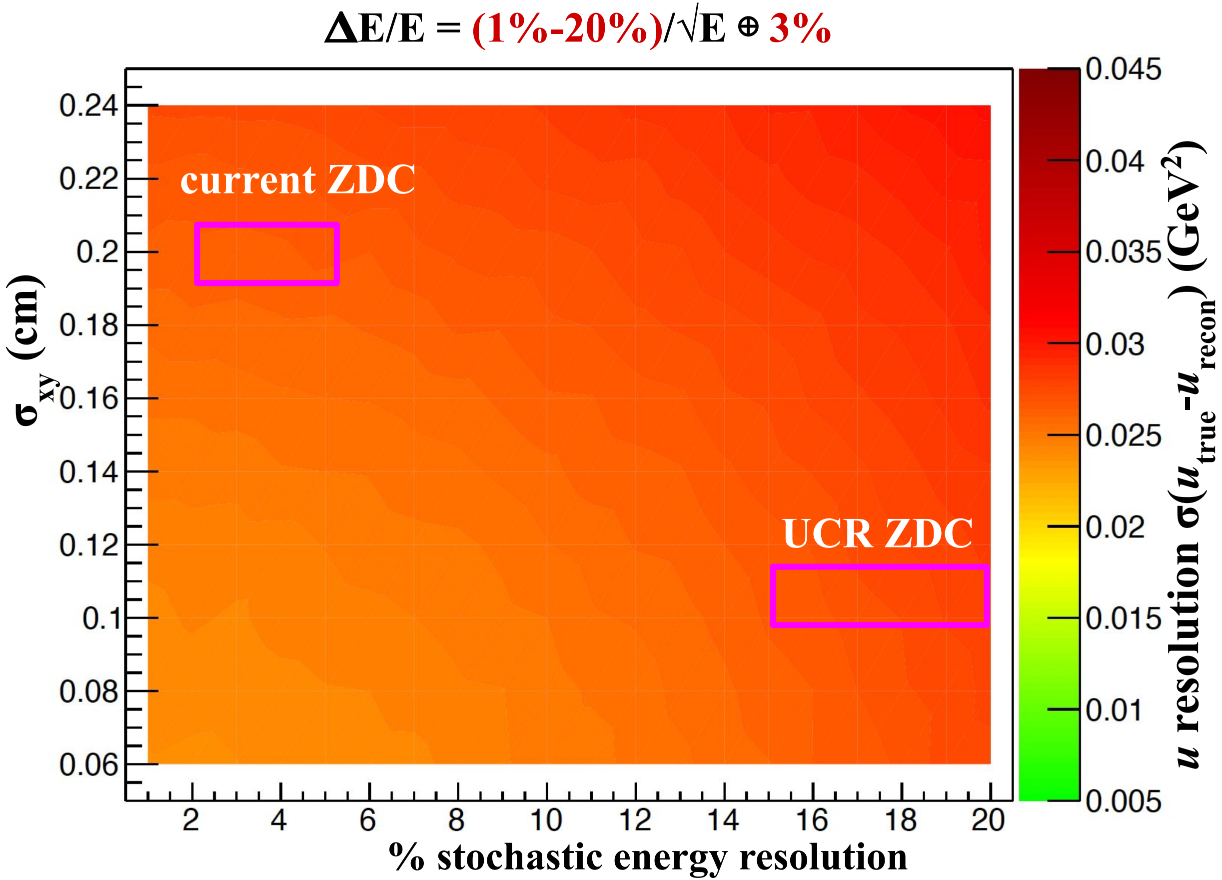
# Mandelstam-u resolution with ⊕1% term

- With a 1% constant efficiency term, both current and UCR ZDC designs are well within tolerance for measuring $u$



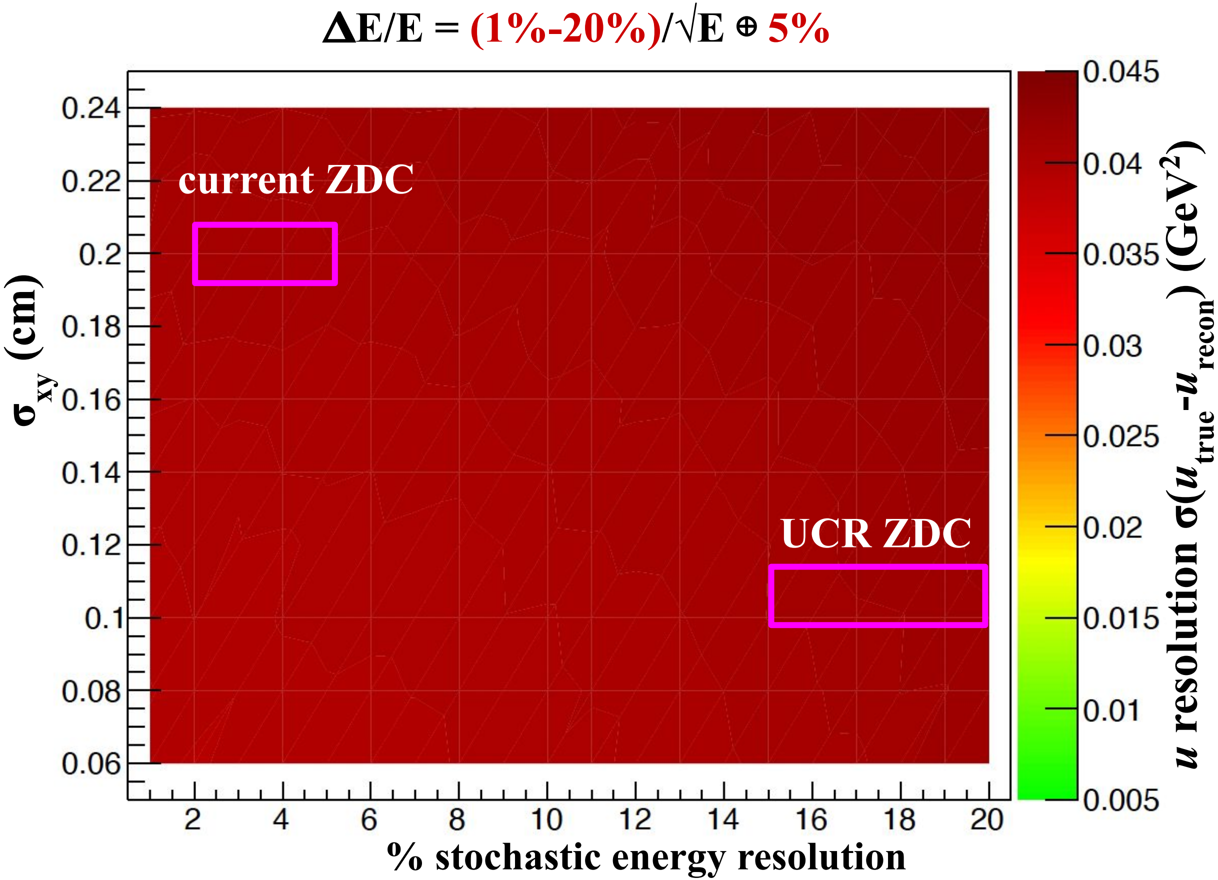
# Mandelstam-u resolution with ⊕3% term

- With a 3% constant efficiency term, both current and UCR ZDC designs are within tolerance for measuring $u$
- Resolution is ~0.025 $GeV^2$
- Worse but not horrible



# Mandelstam-u resolution with ⊕5% term

- With a 5% constant efficiency term, both current and UCR ZDC designs are approaching tolerance limit for measuring $u$
- Resolution is ~0.04-0.045 $GeV^2$
- Getting concerning

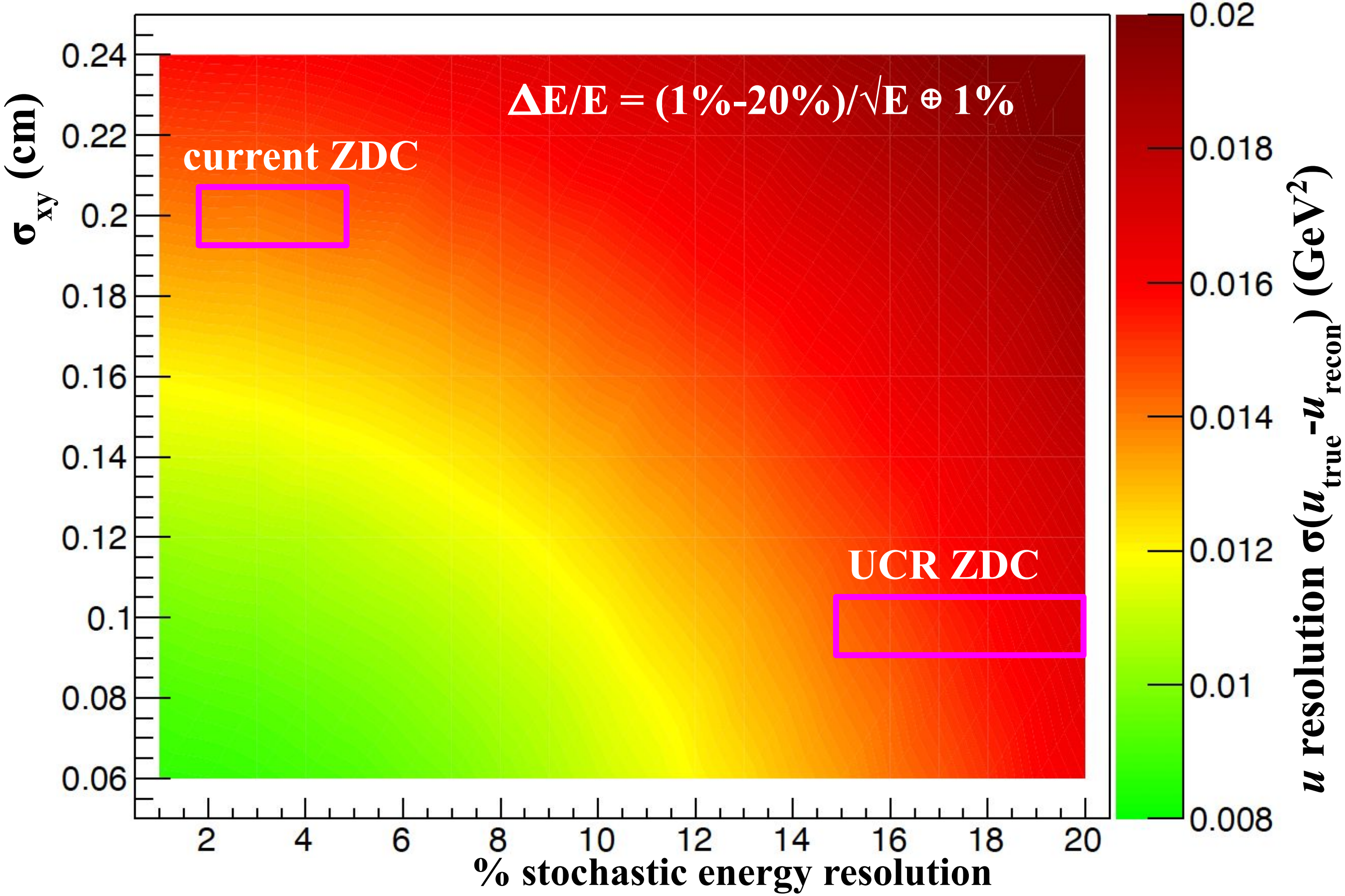


# u Resolution Zoomed

I've zoomed in on the z-axis to make a point.

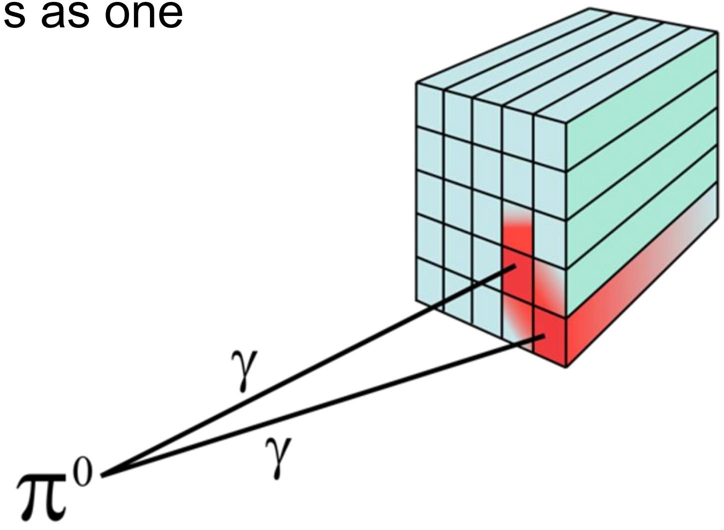
Both ZDC designs give a good u resolution when a 1% constant term is used

I just think it's funny that despite their differences the two designs lie along roughly the same contour



# A final (very important) consideration

- The elephant in the room here is that position resolution may be complicated by two adjacent clusters from π0 decay
- The two photons will never be closer than 3.4 cm, but it's possible that those clusters overlap in a difficult way
- Validating which detector design is able to do this separation is very important, because these can easily be mistaken for DVCS if the clustering algorithm categorizes the two photons as one

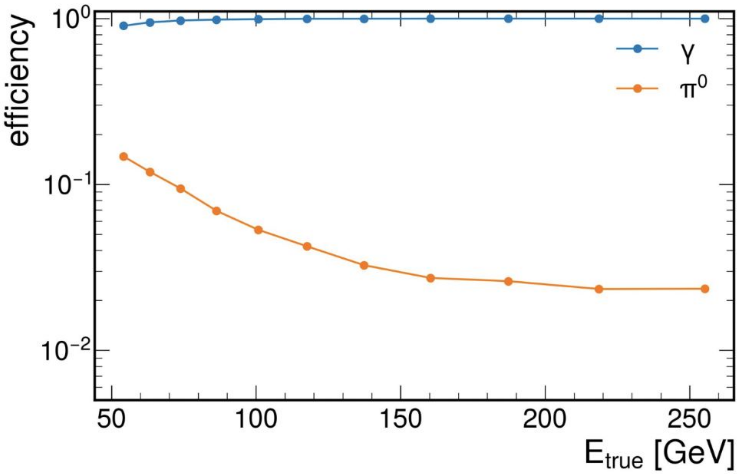


# A final (very important) consideration

- Sebouh Paul at UCR has been working on simulating their ZDC design performance. (I’ve just sent them u-channel events to help)
- Comparable studies with other ZDC designs would be very helpful

## Preliminary performance plots for γ/π0 identification

- Baseline identification algorithm:
  - Only a few percent of the π0s are misidentified as photons
    - Some of these could be events where one of the two photons from the π0 decay misses the ZDC
- Improvements in the algorithm could reduce this number even further.

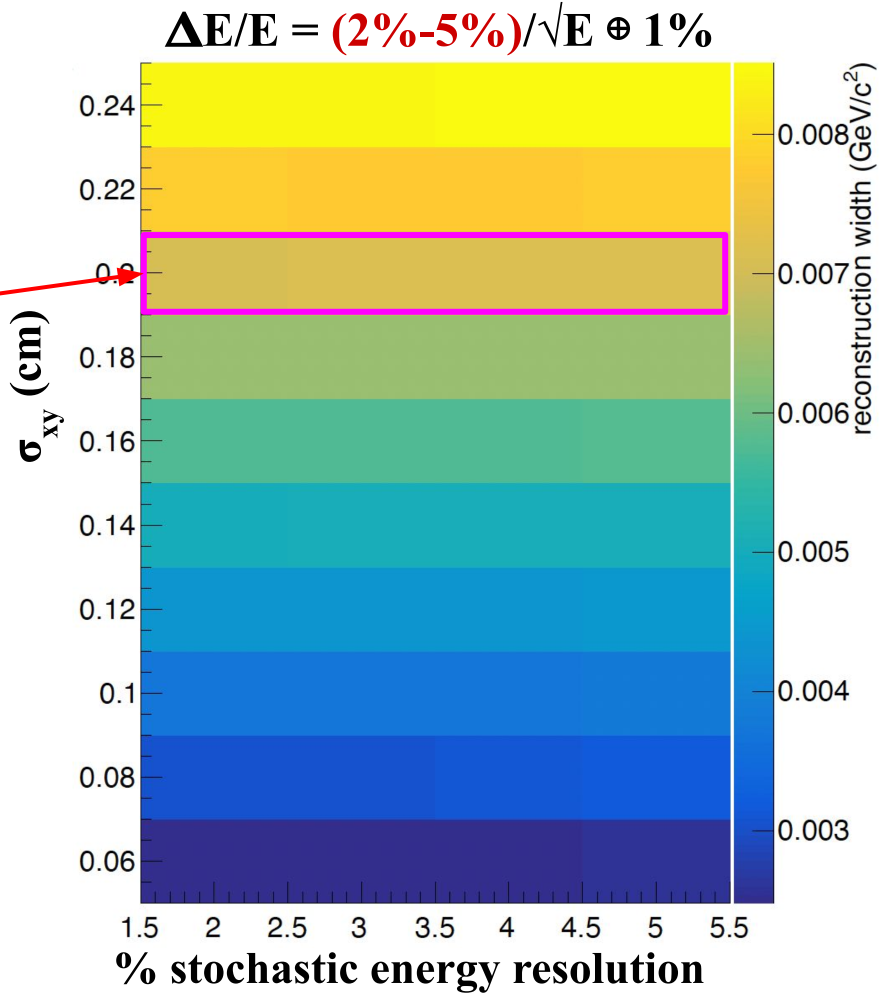


# Conclusions

- **DVCS sample purity**
  - Worst-case scenario energy resolutions do not affect DVCS purity at 18x275 GeV
- **$\pi^0$ mass reconstruction**
  - greatly improved by better positioning resolution
  - energy resolution has little effect on width
  - UCR ZDC design will result in a greater resolution
- **Mandelstam-u reconstruction**
  - two proposed ZDC designs give roughly consistent results, and are within tolerance
  - Upper limits of $\Delta E/E = (2\%\text{-}5\%)/\sqrt{E} \oplus 5\%$ and $\Delta E/E = (15\%\text{-}20\%)/\sqrt{E} \oplus 5\%$ approach the measurement tolerance. The 1% and 3% constant terms are much better
- **Two-photon separation**
  - We don't know which design will better separate two-photon showers

# $\pi^0$ Reconstruction

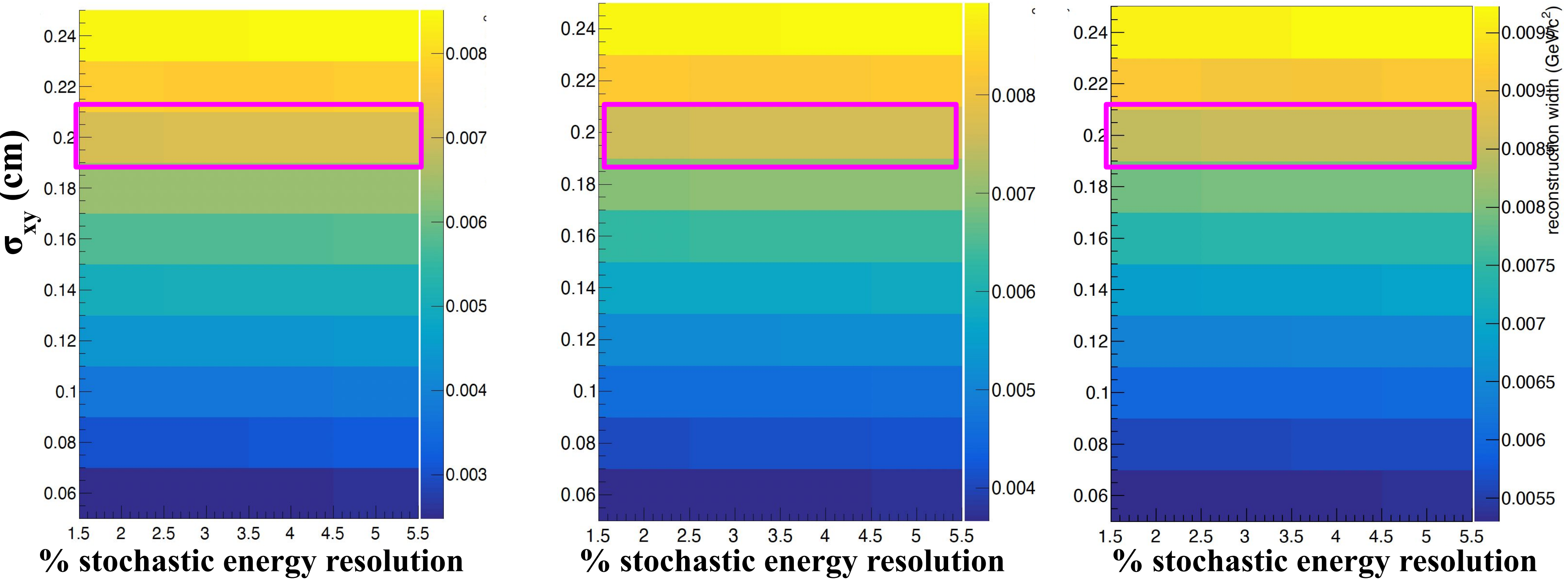
- Improved positioning resolution greatly improves reconstruction
- Estimate of ePIC ZDC position resolution results in π0 reconstruction standard deviation of ~7 MeV



# $\pi^0$ Reconstruction in ePIC Standard ZDC

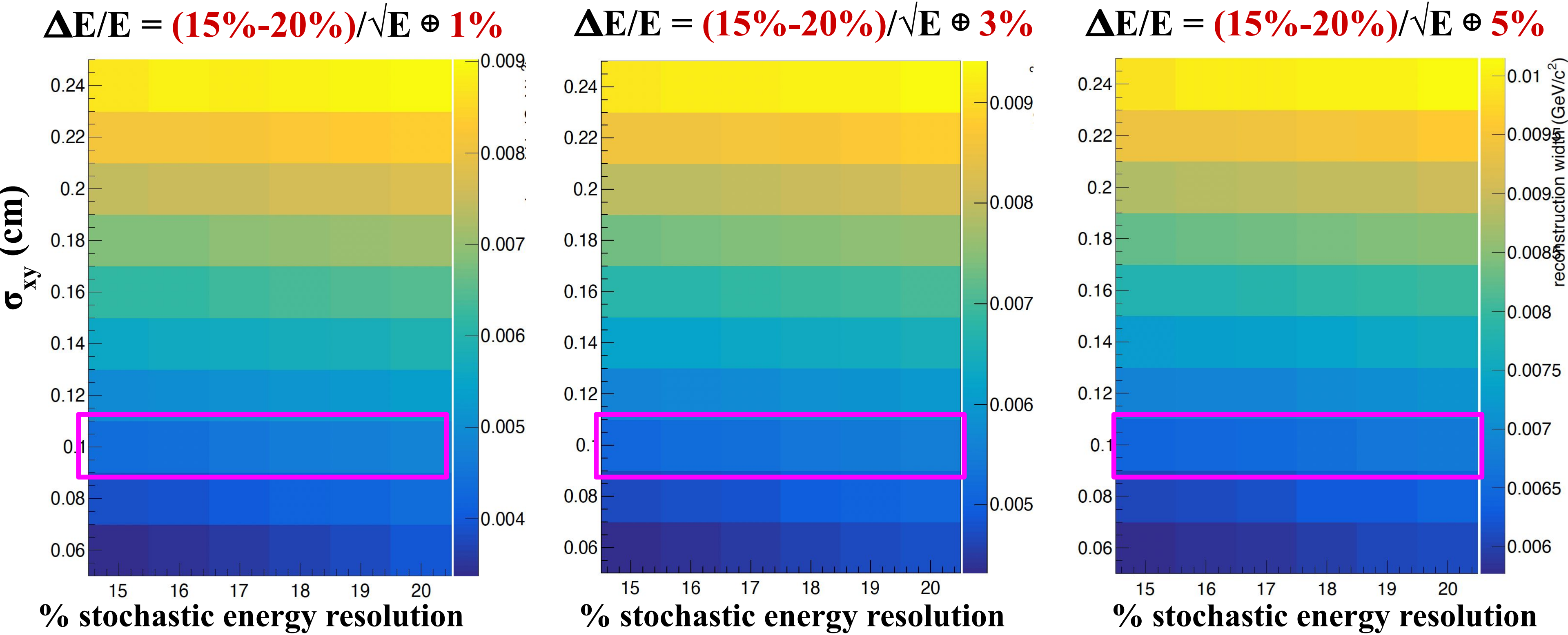
- 1%, 3%, 5% constant terms at 2mm spatial resolution result in ~7 MeV, 7.5 MeV, 8.5 MeV as the standard deviations of $\pi^0$ mass reconstruction

**$\Delta E/E = (2\%\text{-}5\%)/\sqrt{E} \oplus 1\%$** **$\Delta E/E = (2\%\text{-}5\%)/\sqrt{E} \oplus 3\%$** **$\Delta E/E = (2\%\text{-}5\%)/\sqrt{E} \oplus 5\%$**



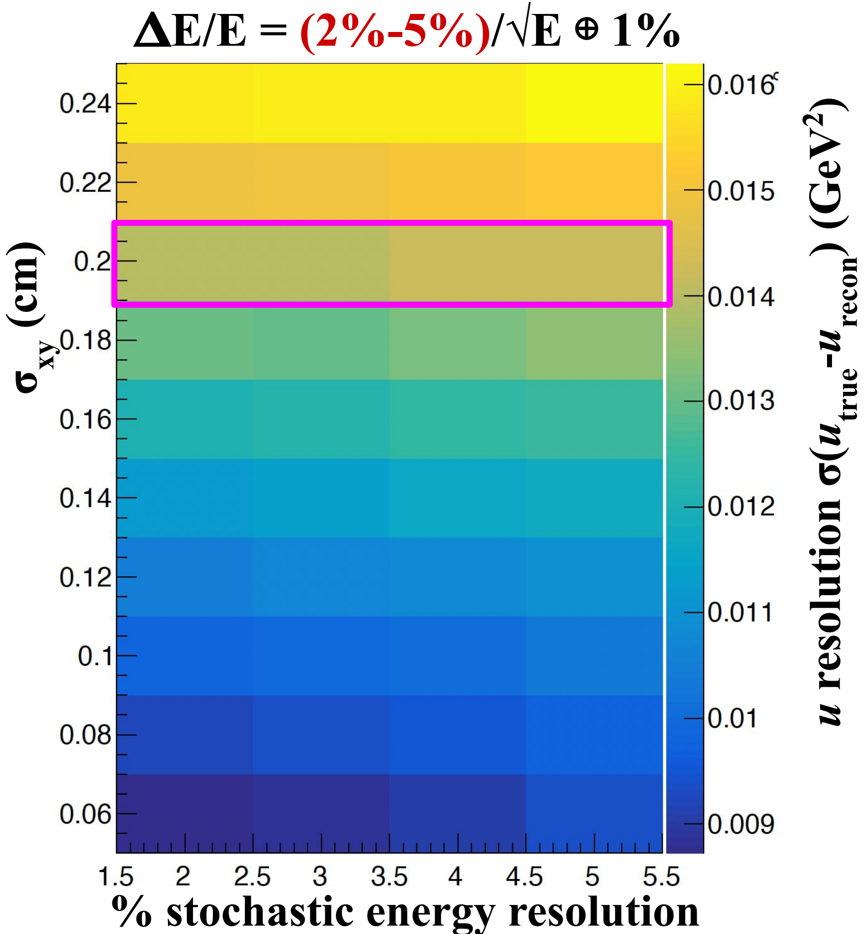
# $\pi^0$ Reconstruction in UCR ZDC

- 1%, 3%, 5% constant terms at 1mm spatial resolution result in ~5 MeV, 5.5 MeV, 7 MeV as the standard deviations of $\pi^0$ mass reconstruction



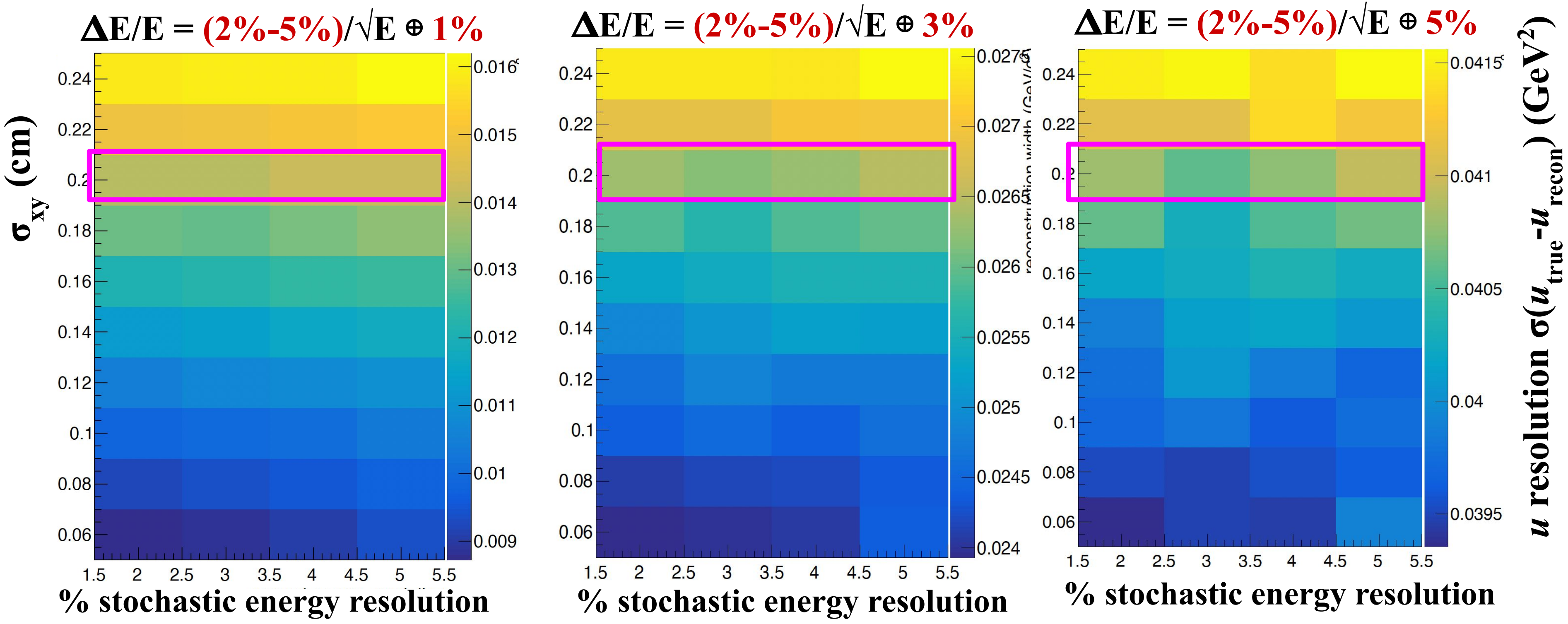
# u-channel cross section measurement

- We require u-resolution of ~0.05 GeV$^2$ at worst
- Current ePIC ZDC with a 1% constant resolution term achieves ~0.014 GeV$^2$



# Mandelstam-u measurement: Standard ZDC

- $\sigma_u$ < 0.05 GeV$^2$ across the span of the ePIC design resolutions
- $\sigma_u$ ~ 0.041 GeV$^2$ for 5% constant resolution, which starts to get troubling



# Mandelstam-u measurement: UCR ZDC

- $\sigma_u < 0.05$ GeV$^2$ across the span of the UCR design resolutions
- $\sigma_u \sim 0.042$ GeV$^2$ for 5% constant resolution, which starts to get troubling