# Coherent Diffraction with A-1 Tagging

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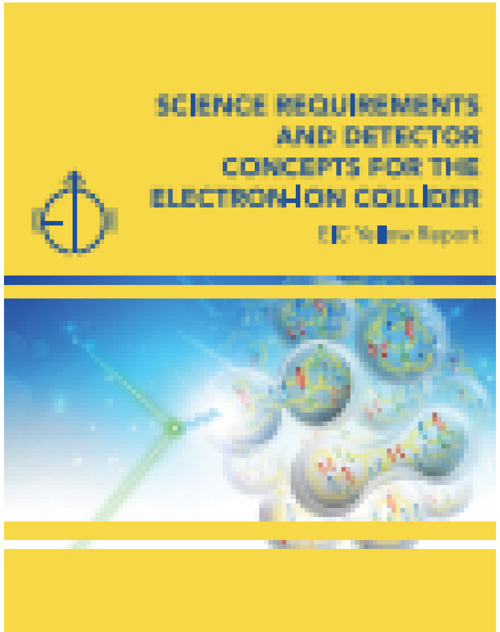
# The Message

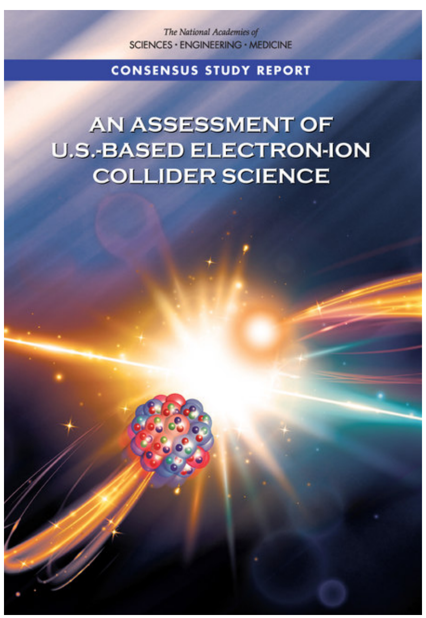
- Coherent diffraction is essential to get at G(b).
- Vetoing the incoherent events is challenging.
  - Challenging for the detector.
  - Challenging to simulate!
- A second detector at IP8 is necessary!
  - Improved measurement due to secondary focus and nuclear remnant tagging for any 2nd detector choice.
  - Insurance/crosscheck because the measurement at IP6 is so difficult.
- More work is needed!

# The importance of coherent diffraction




- Coherent diffraction is sensitive to the spatial distribution of gluons in the nucleus and to gluon saturation.
- The exact map G(b) $\leftrightarrow$ $d^3N/dtdW^2dQ^2$ is not fully understood, but it's clear that we need to measure coherent diffraction!

&

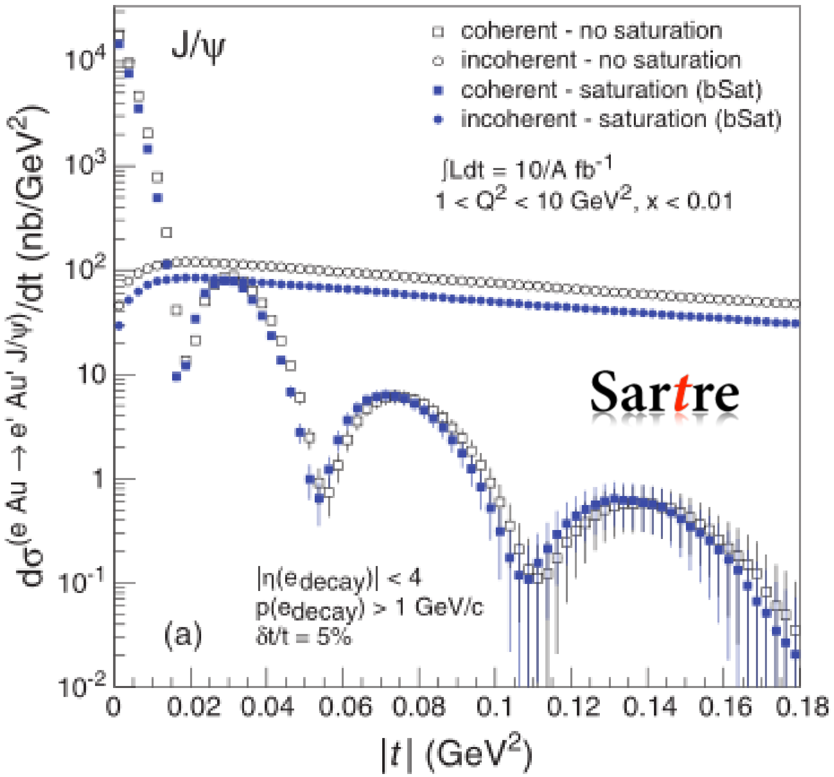





+ ...

# Focus on S/B at the PEAKS (not dips)

**T. Toll, T. Ullrich, PRC 87, 024913 (2013) & ...**




- Don’t trust the dips to be very deep.
- The dips are by definition the location where the “leading” terms in your approximation are no longer dominant...

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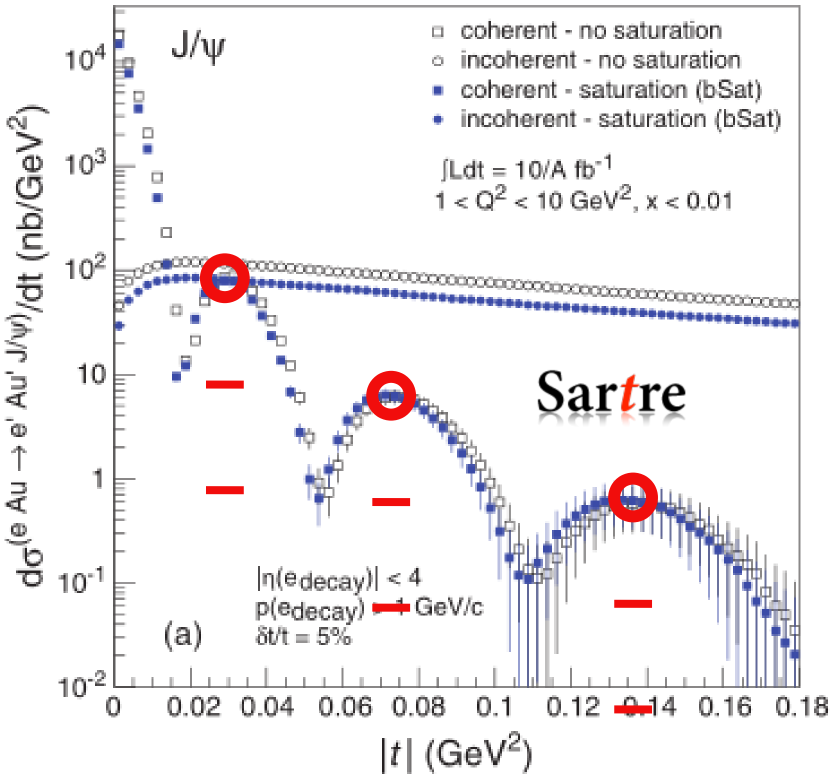
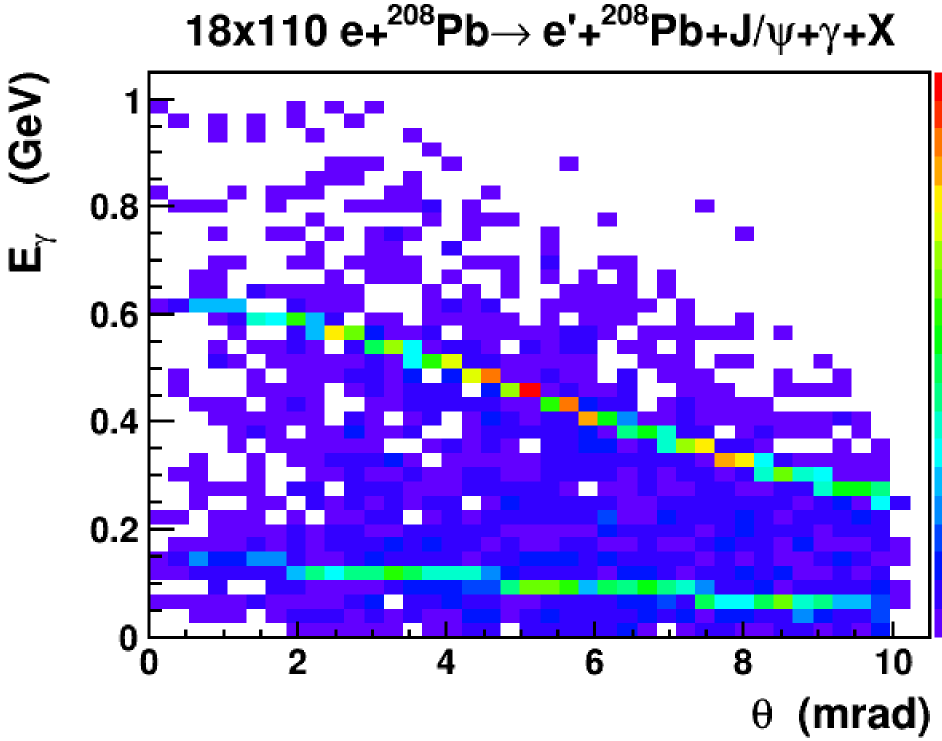


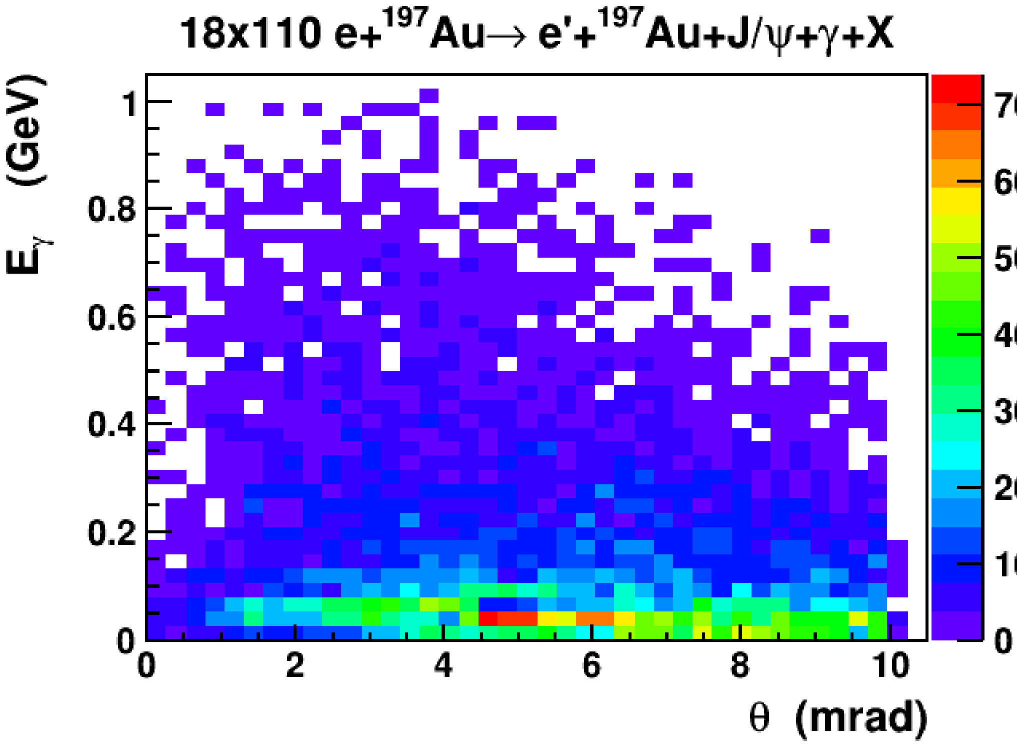

- Don't trust the dips to be very deep.
- The dips are by definition the location where the "leading" terms in your approximation are no longer dominant...

A less model-dependent experimental figure of merit is S/B at the peaks after veto. Let's get that to 1:10 or 1:100.

# Use a $^{208}$Pb beam, not $^{197}$Au



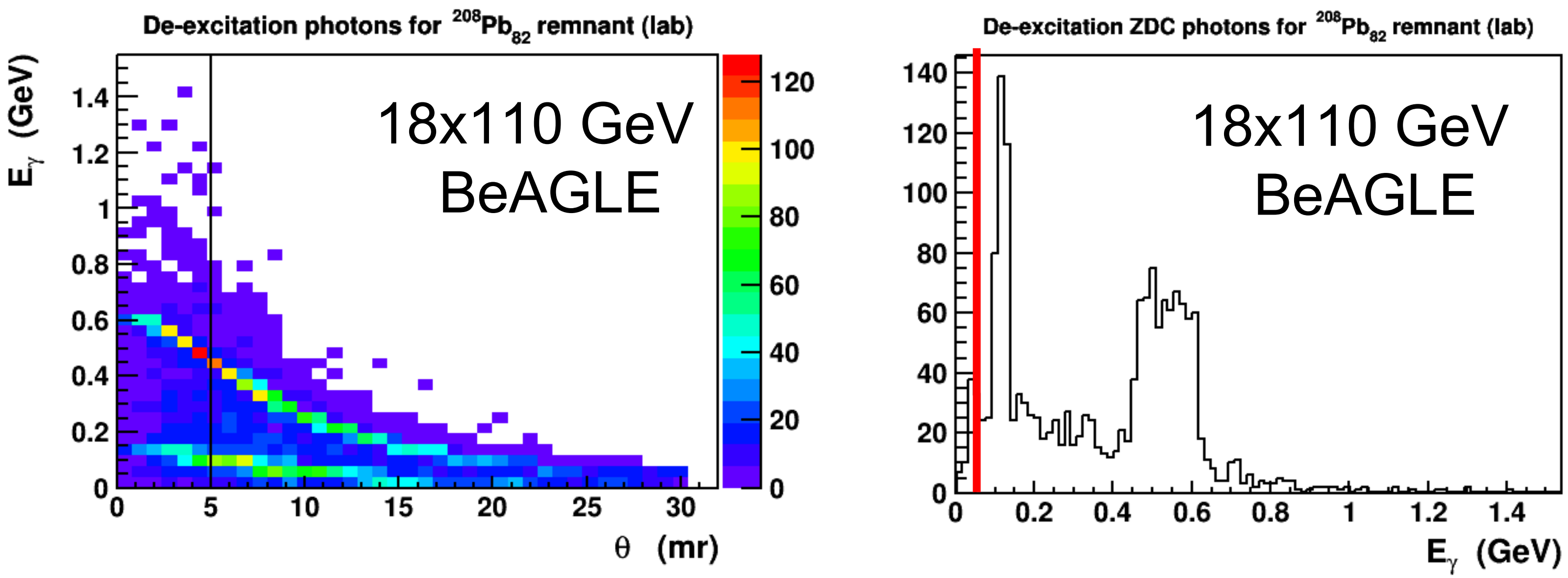





Pb much better than Au because forward photons are more energetic!

# Photon Detection is Challenging

Veto on de-excitation photons from $^{208}Pb_{82}$ following
$e+Pb \rightarrow e'+Pb^{*}+J/\psi \rightarrow e'+Pb+\gamma+\gamma+\gamma+J/\psi$ in (collider) lab frame

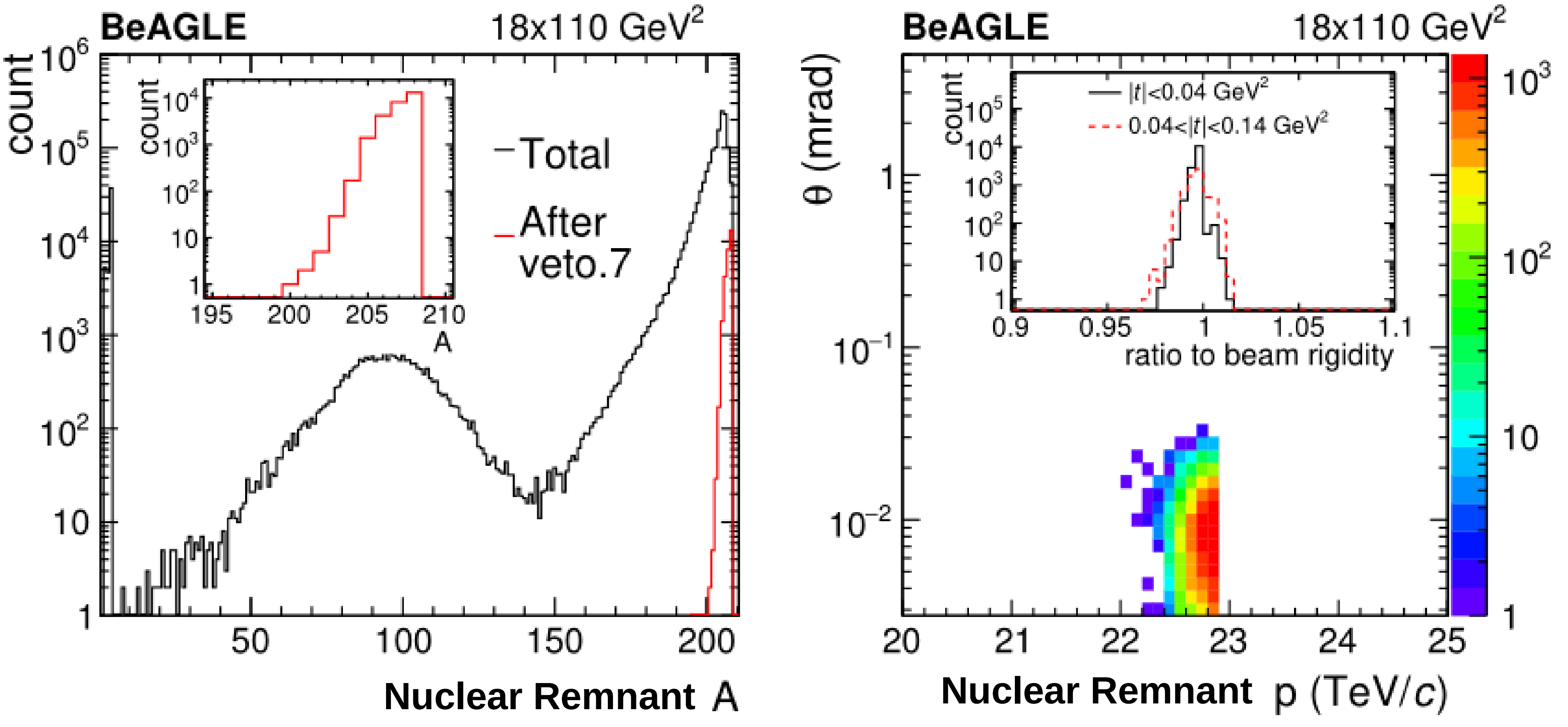



There are discussions ongoing in ePIC about how to measure soft photons in the presence of backgrounds.
Good opportunity for complementarity in detector technology or just material distribution.

# A look at e+Pb events that are HARD to cut

W. Chang et al. Phys.Rev.D 104 (2021) 11, 114030,

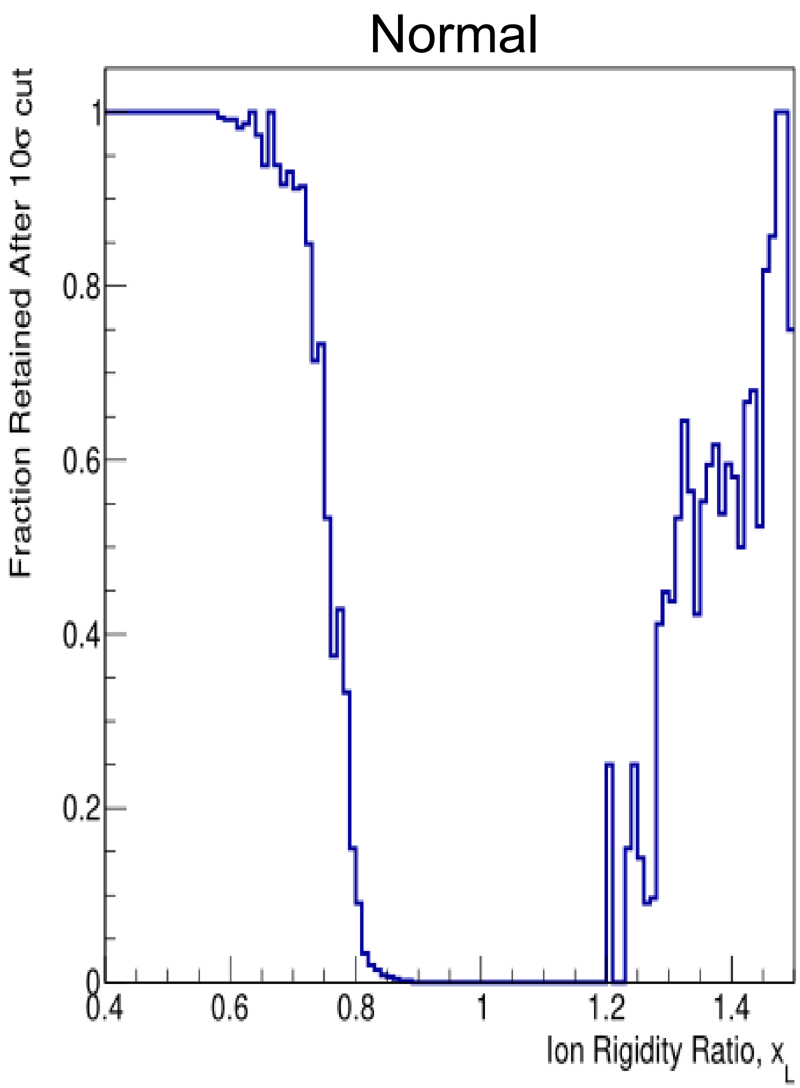
**Events remaining in IR6 after cuts on forward protons, neutrons, and photons.**

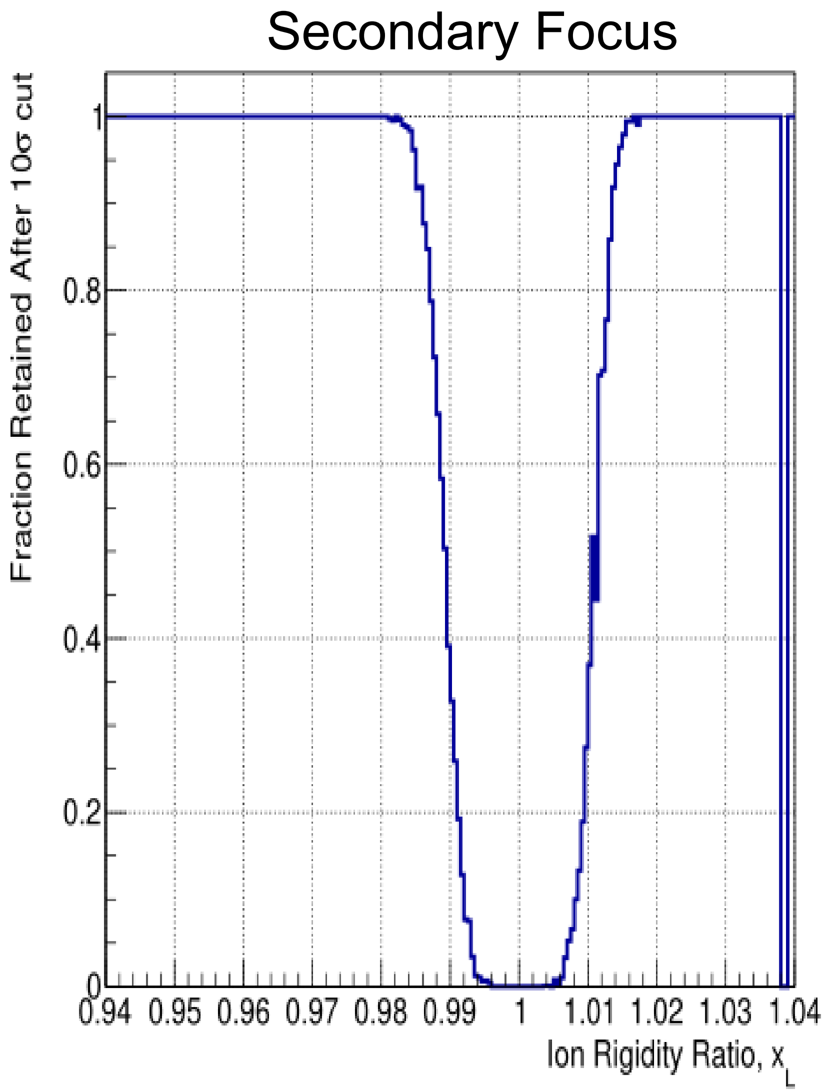



(a) (b)

# Roman Pot Acceptances for IR8

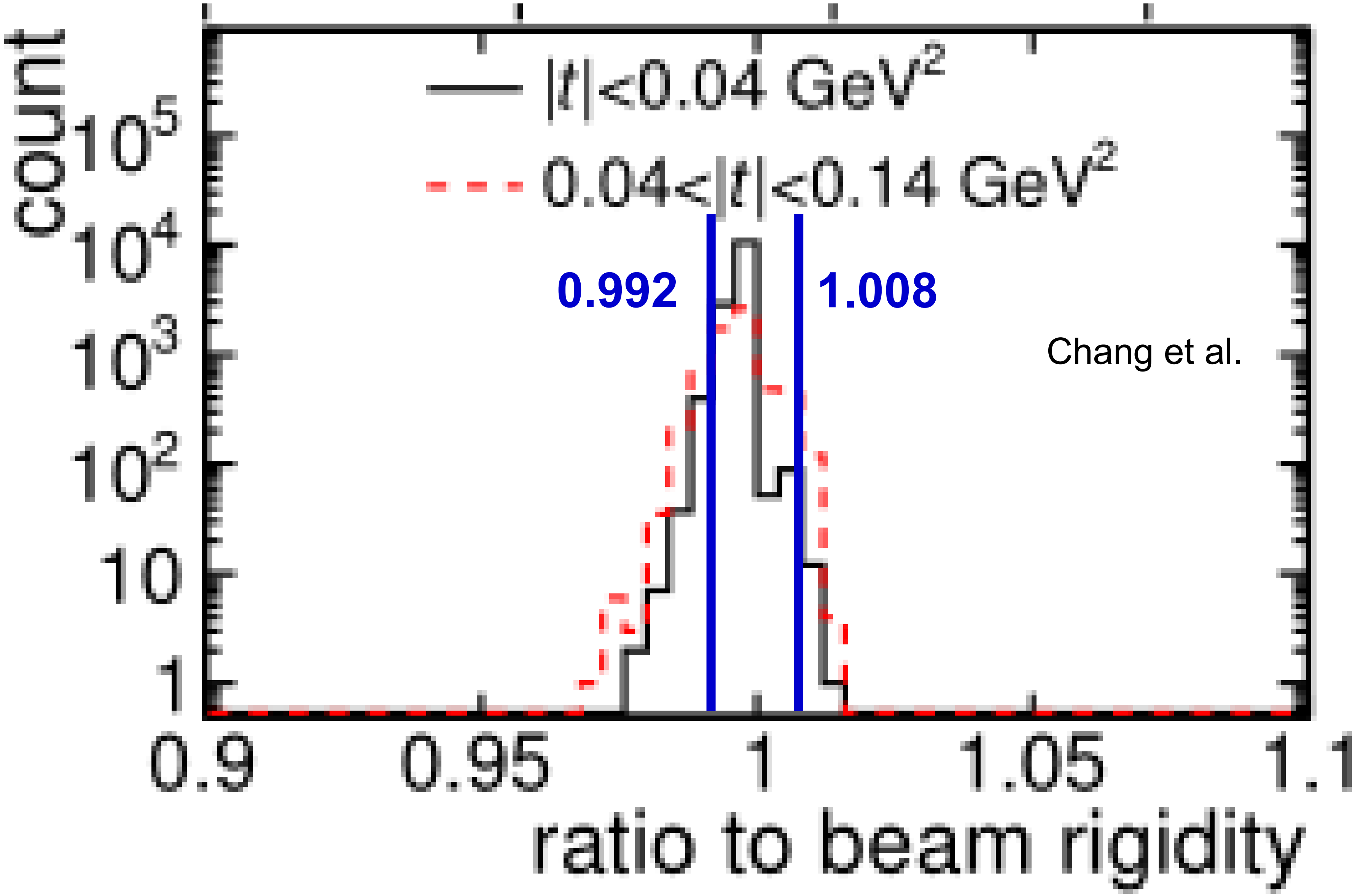
## Detected/Produced (incoh. diff. In e+Zr) for θ<1 mrad



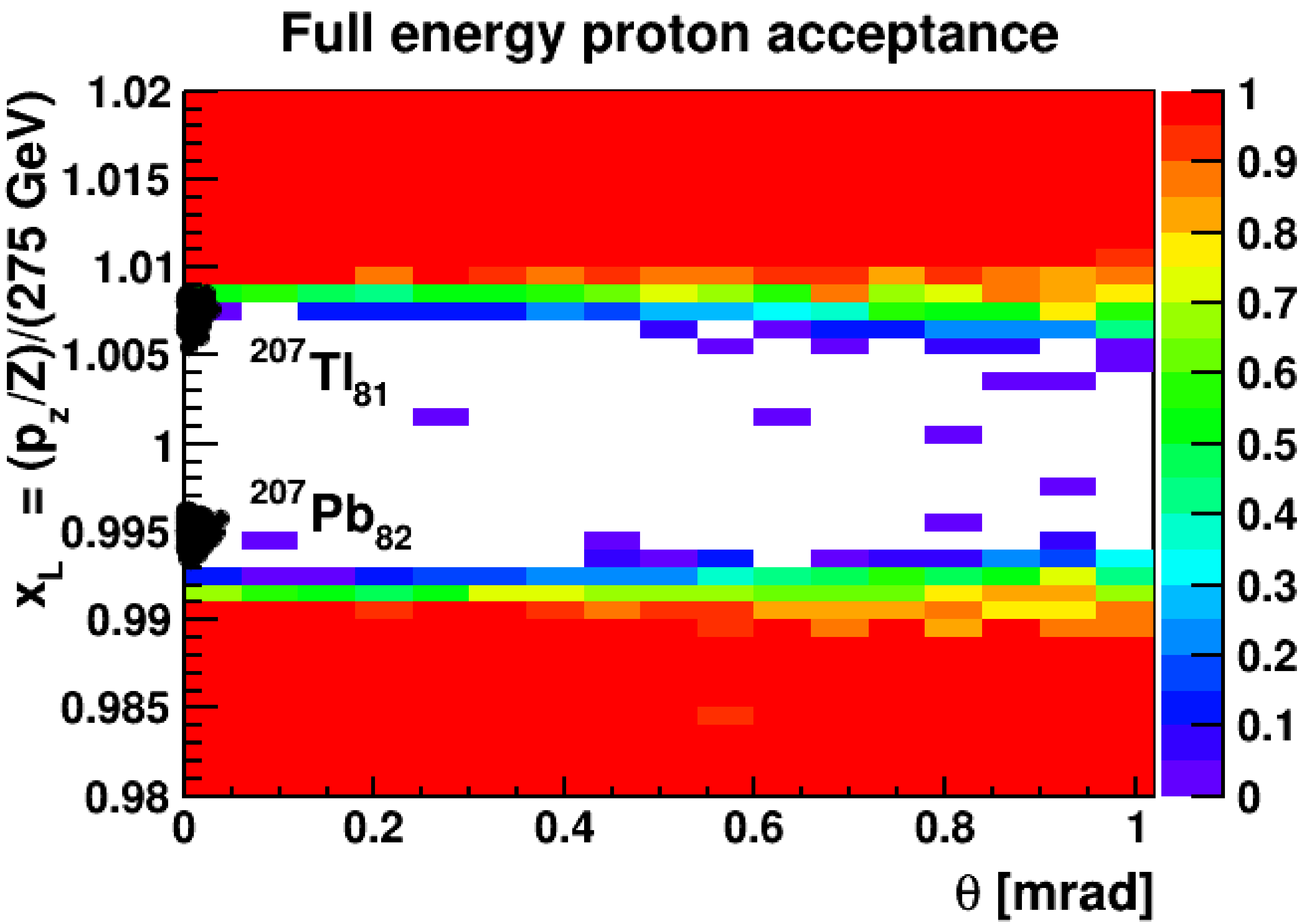




Bylinkin et al. (ECCE Collaboration) e-Print: 2208.14575 [physics.ins-det]

# Secondary focus can help for e+Pb



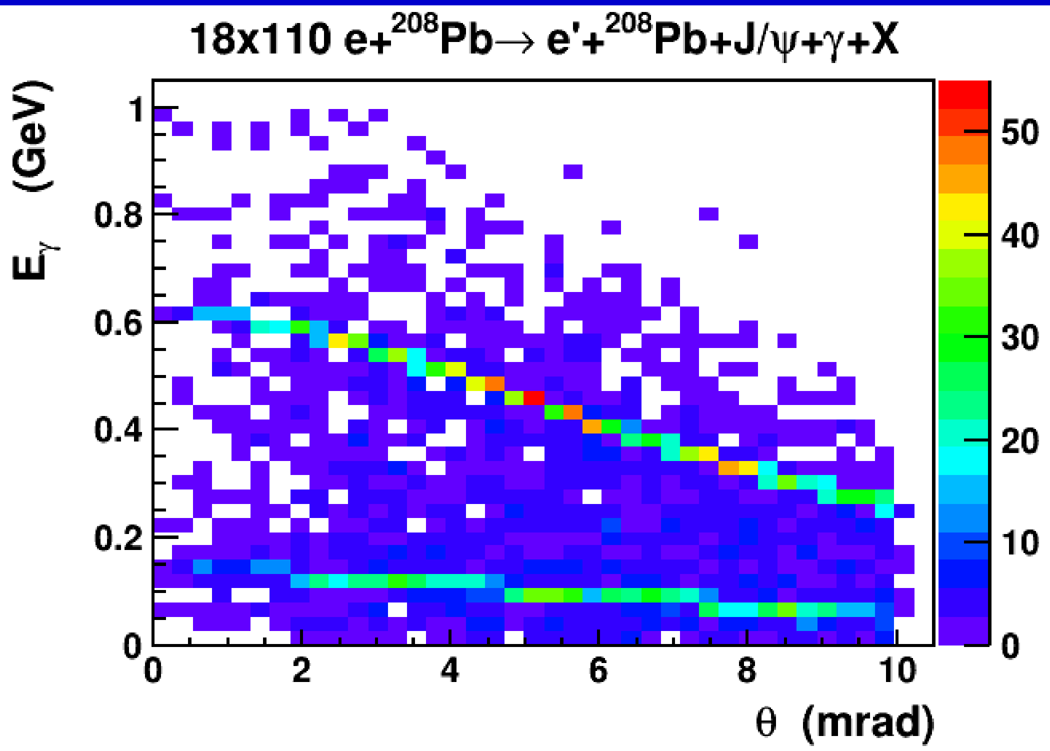
# A-1 from e+$^{208}$Pb J/ψ incoh. Diff. in BeAGLE



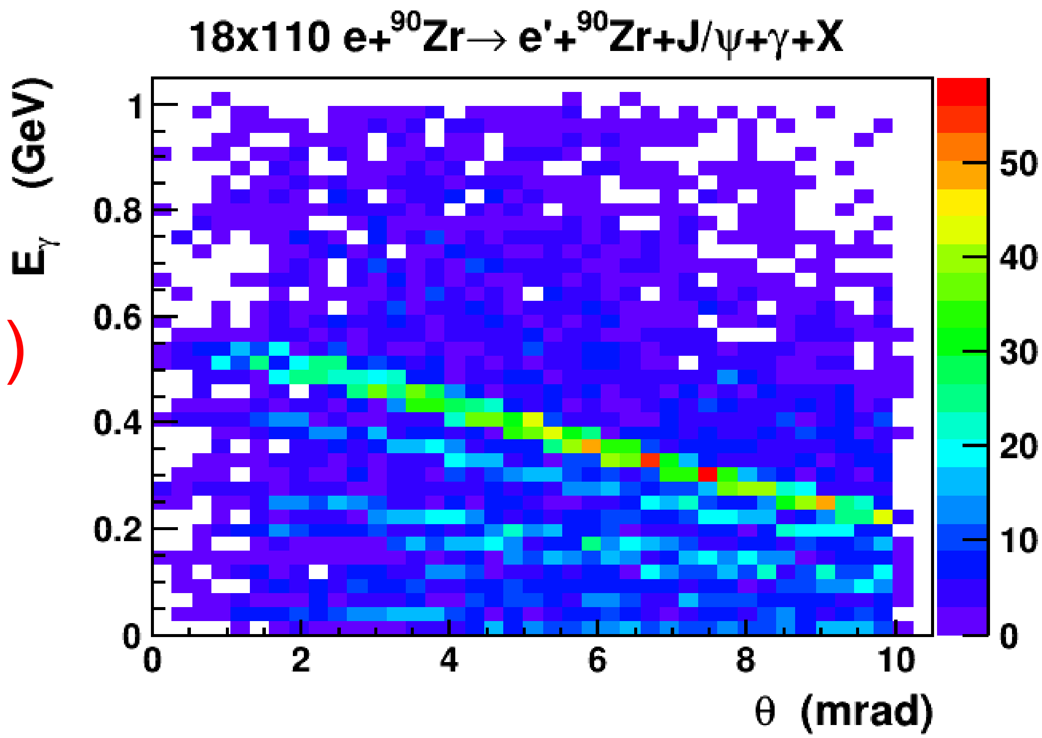
# What about Zirconium?

- Closed shells like Pb, so energetic $\gamma$'s
- Still interesting in terms of G(b)
- Saturation scale ALMOST as high
  - 24% Lower $A^{1/3}$
  - Slightly higher energy: 122.22/108.41 = +13%

# Photons from $^{208}Pb_{82}$ vs. $^{90}Zr_{40}$

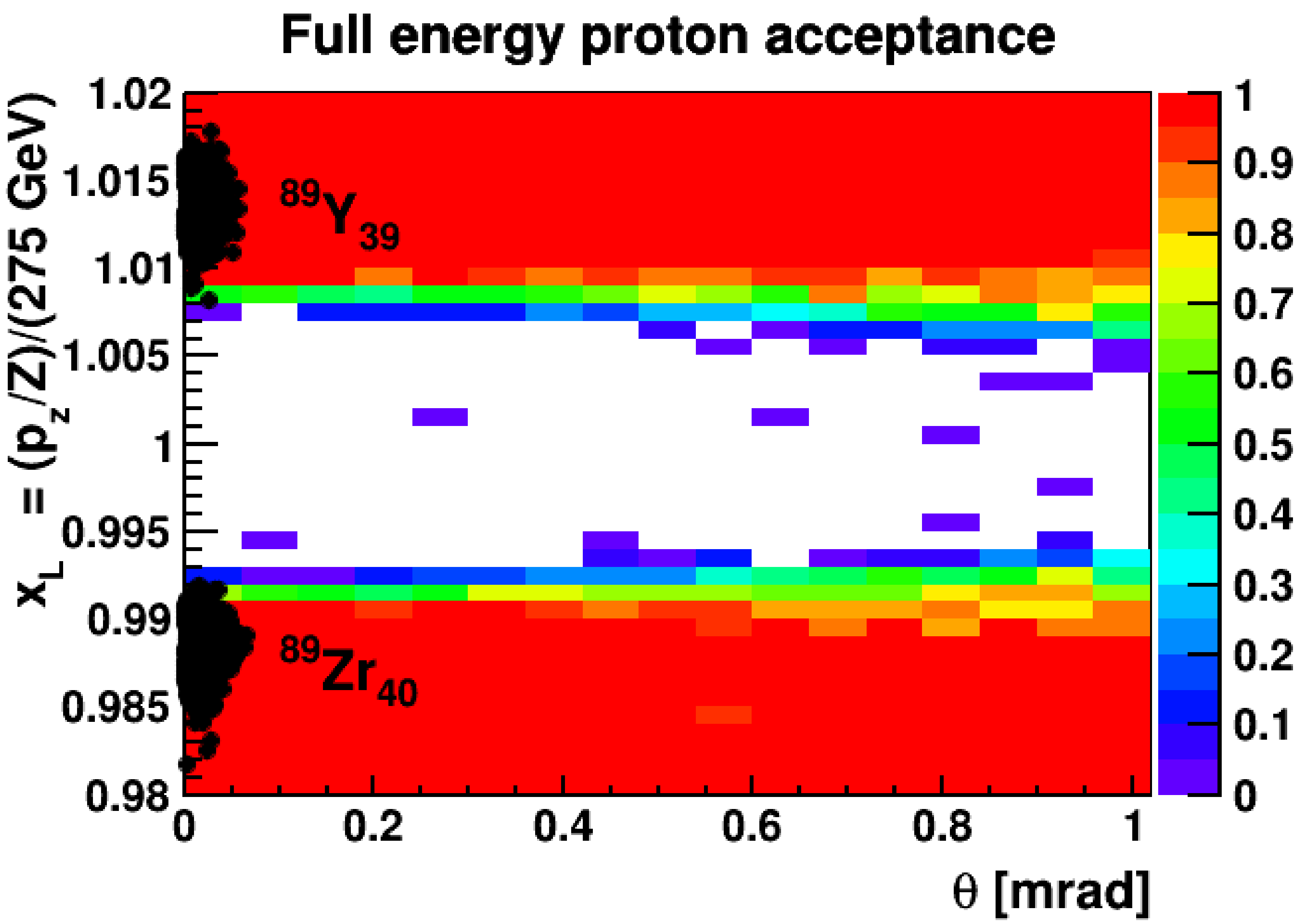




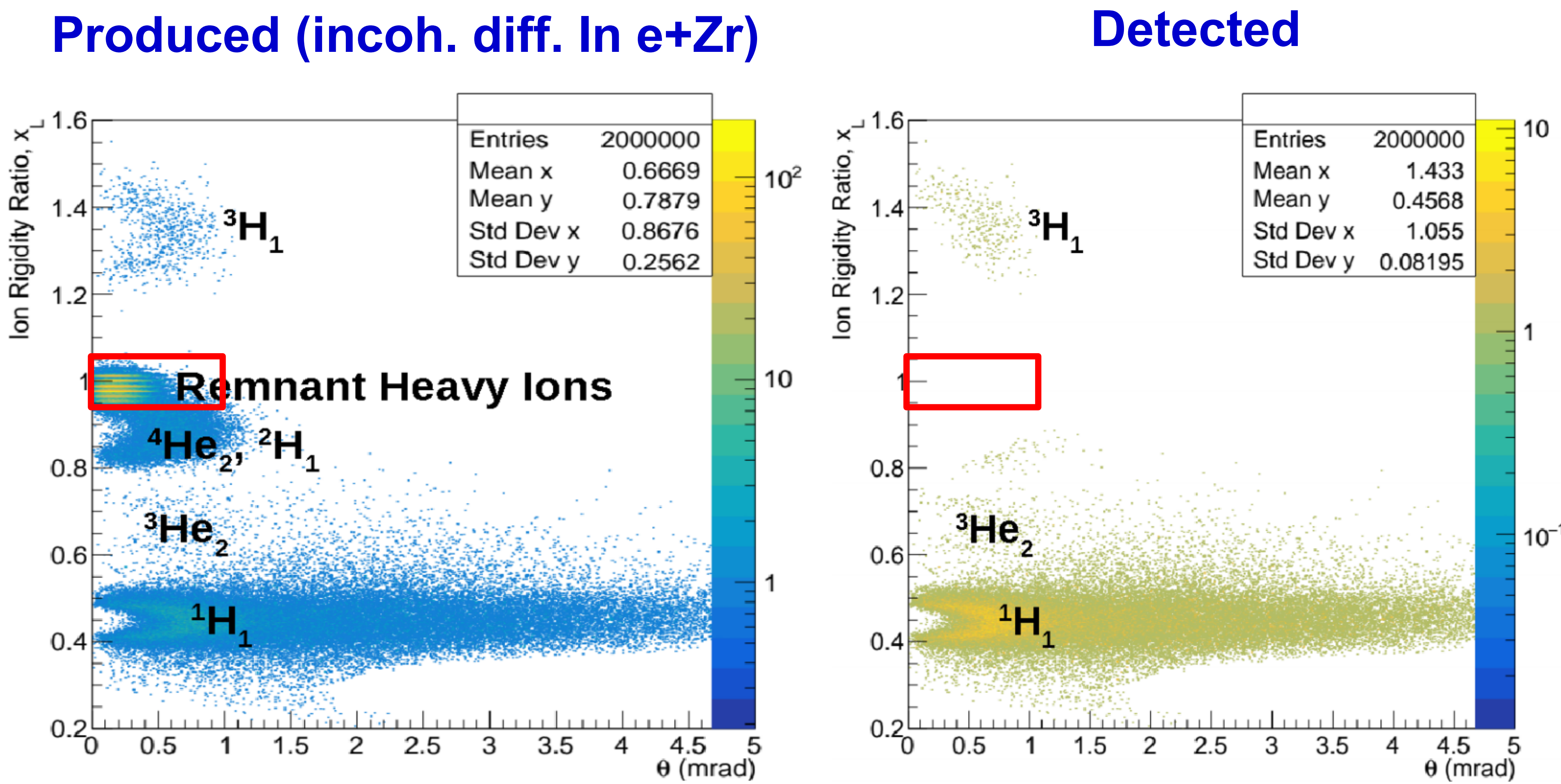



Nuclear physics (closed shells) says that $^{90}Zr$ should be similar to $^{208}Pb$…
Yes.

# A-1 particles from e+$^{90}$Zr J/ψ diffraction



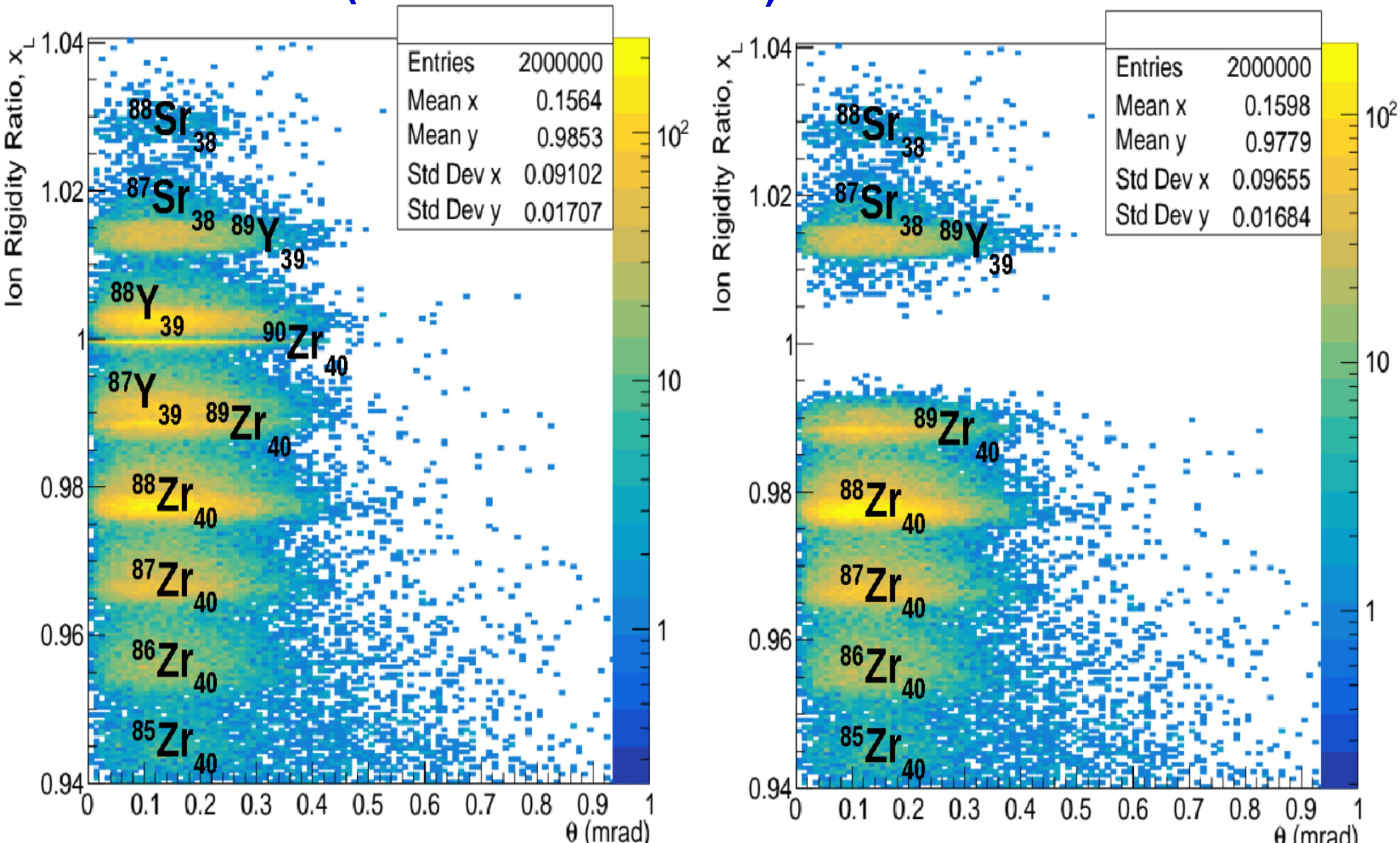
# Normal Roman Pots IP6 or IP8




Bylinkin et al. (ECCE Collaboration) e-Print: 2208.14575 [physics.ins-det]

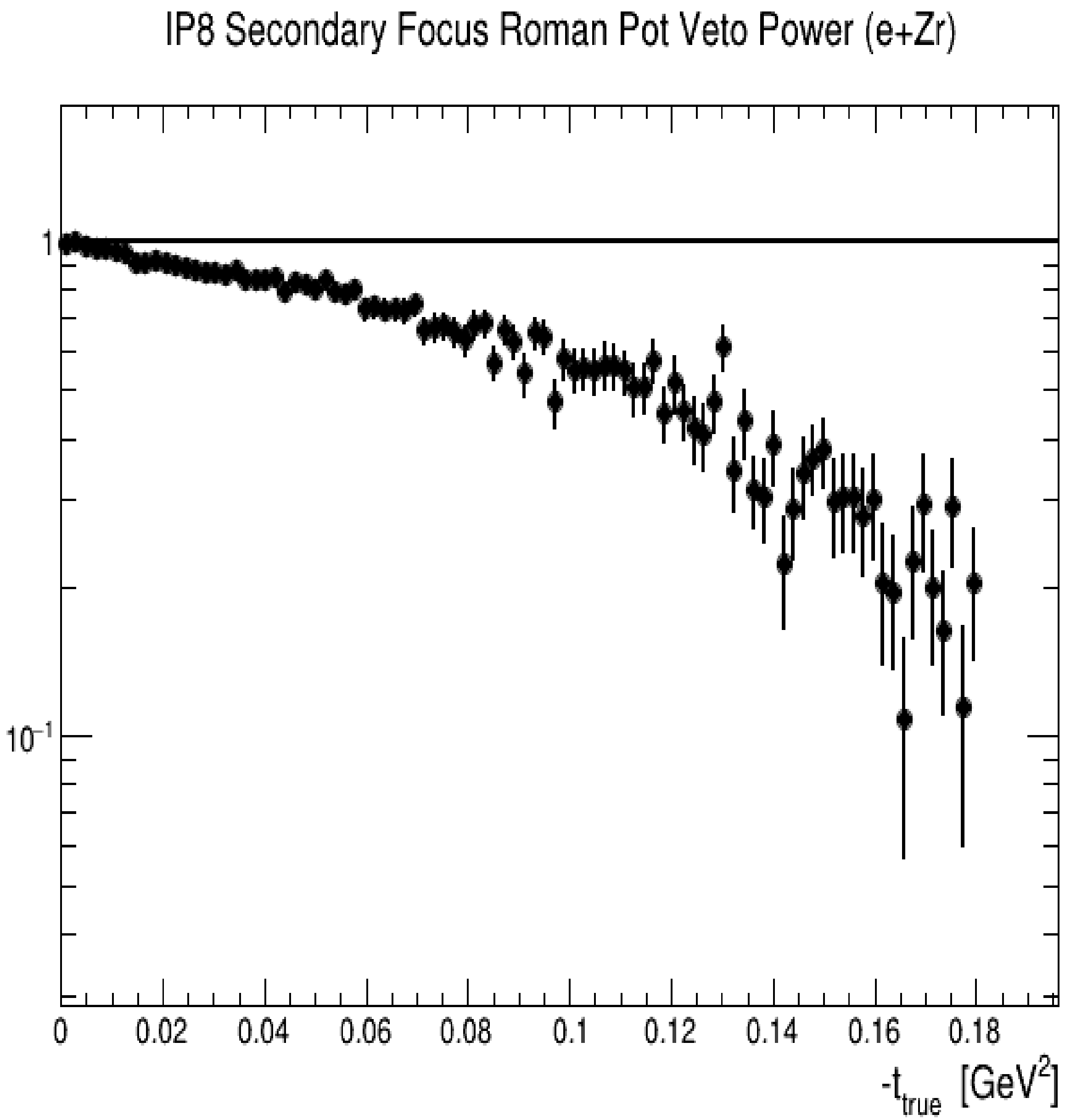
# ECCE looked at A-1 for Zr in IP8

**Produced (incoh. diff. In e+Zr)** **Detected**




Bylinkin et al. (ECCE Collaboration) e-Print: 2208.14575 [physics.ins-det]

# Extra background rejection with $2^{nd}$ary focus




**This is the** **extra** **veto power due to RPs at the $2^{nd}$ary focus.**

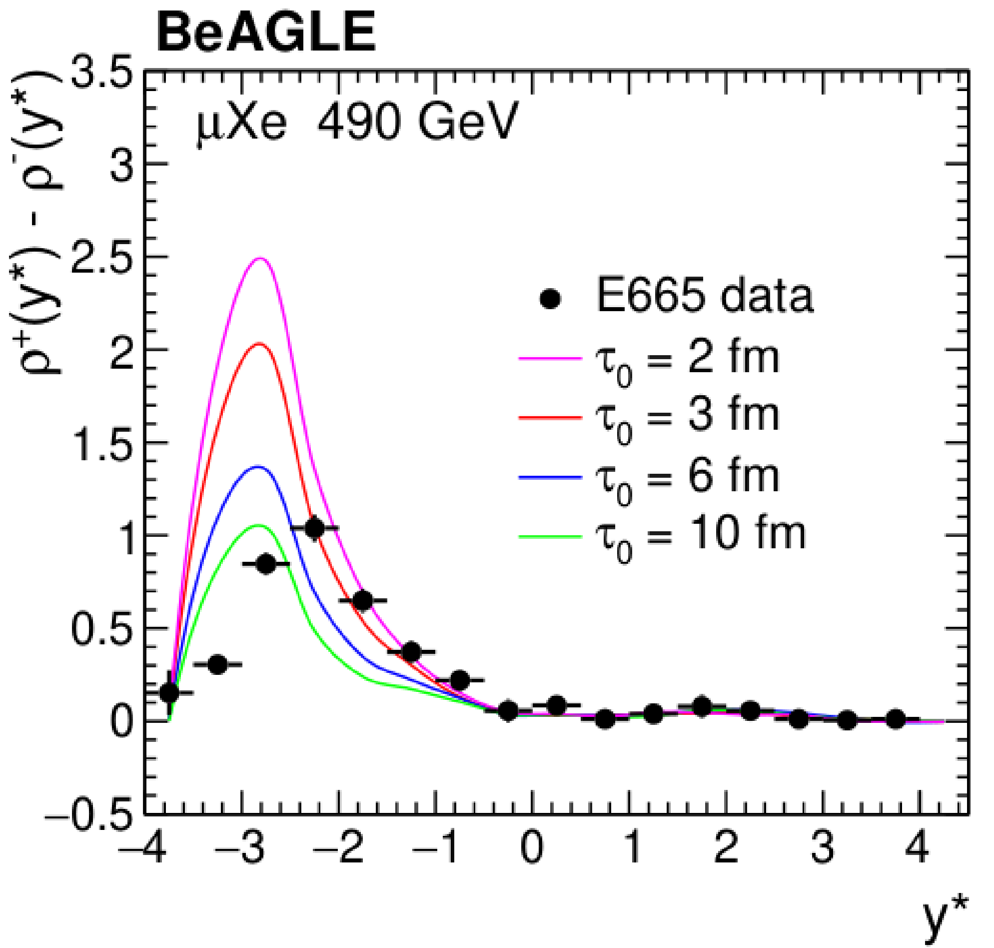
We are mostly vetoing on the non-identical nuclear remnant.

Bylinkin et al. (ECCE Collaboration) e-Print: 2208.14575 [physics.ins-det]

# Diffraction in IP8

- IP8 may offer some improvement for e+Pb
    - Remove extra events (50%?) w/ ion detection
    - Better neutron acceptance etc.
    - e+Pb is difficult enough that this improvement will likely be significant.
    - Needs study!
- e+Zr at IP8 looks very promising
    - Needs study!

# BeAGLE nuclear breakup needs tuning!




E665 target jet data from 1987-88 is difficult to describe with BeAGLE.

It is unclear whether this is a problem with the model, the data, or our understanding of the trigger and data sample.

We need to tune with more recent data that we understand better.

Chang et *al*., Phys.Rev.D 106 (2022) 1, 012007 • e-Print: 2204.11998 [physics.comp-ph]
Data from: E665 Collaboration, Z. Phys. C 61(1994), 179-198

# The E665 data are just hard to understand

**E665 could not describe the data either in 1994**

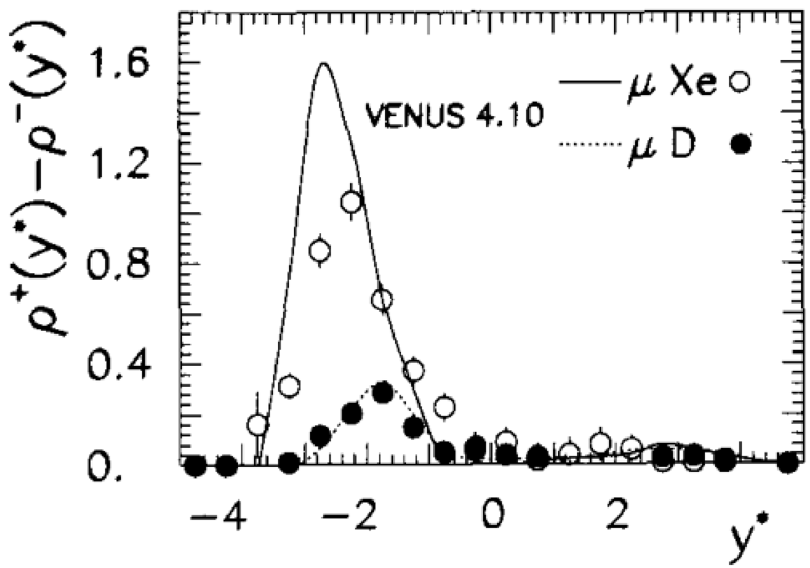
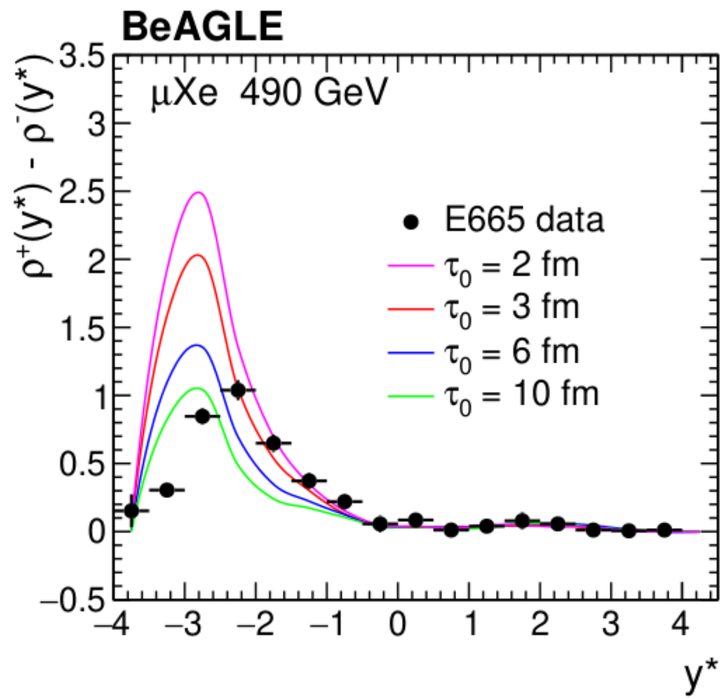



**Fig. 25.** Normalized cms-rapidity distribution of the hadronic net charge for μD (full circles) and μXe scattering (open circles). The lines represent the predictions of the VENUS model



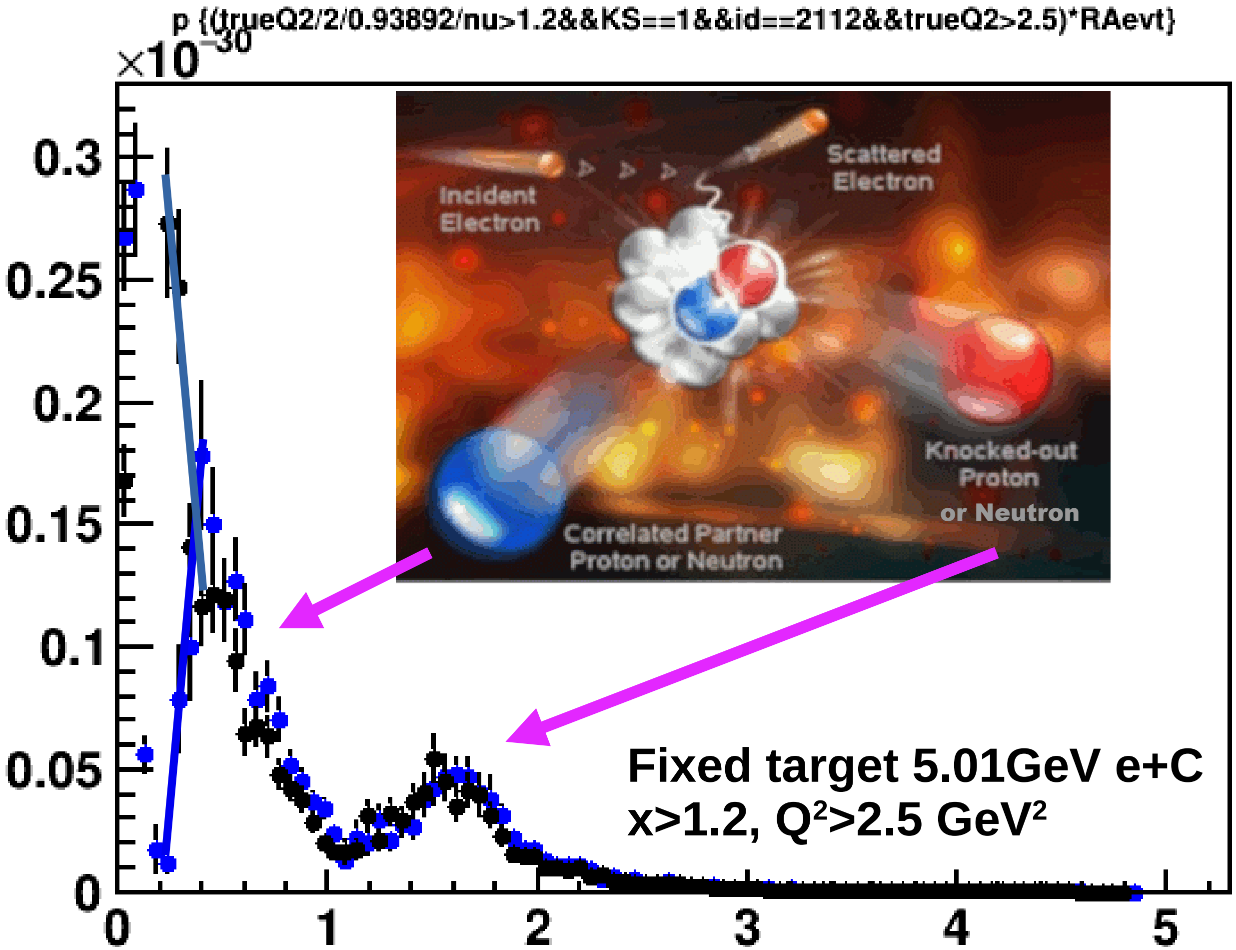

Note:
Filled circles in BeAGLE plot
Are the open circles from E665

Chang et *al*., Phys.Rev.D 106 (2022) 1, 012007 • e-Print: 2204.11998 [physics.comp-ph]
& E665 Collaboration, Z. Phys. C 61(1994), 179-198

# FSI in SRCs at JLAB may be ideal for this

Blue is w/o IntraNuclear Cascade
Black is full BeAGLE

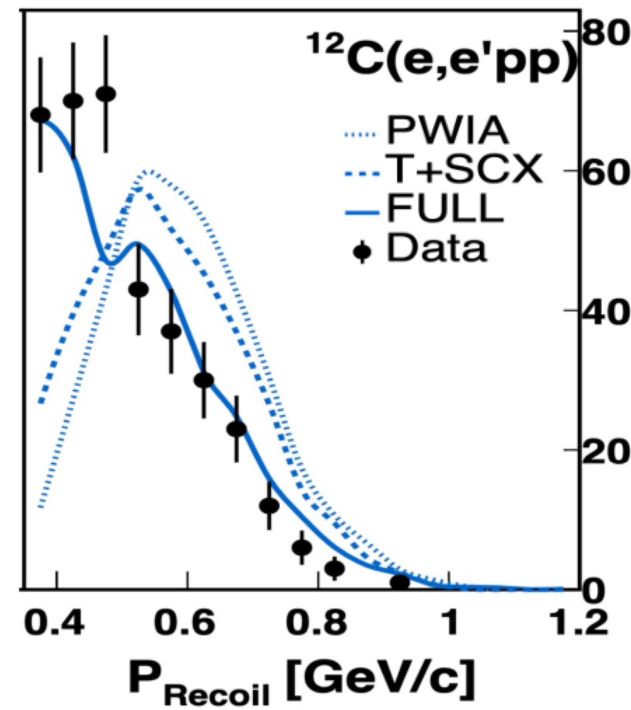
FSI=Final State Interactions
SRC = Short Range Correlations




Neutrons

p (GeV)

Natalie Wright et al.
eGENIE vs. data



# Next Steps

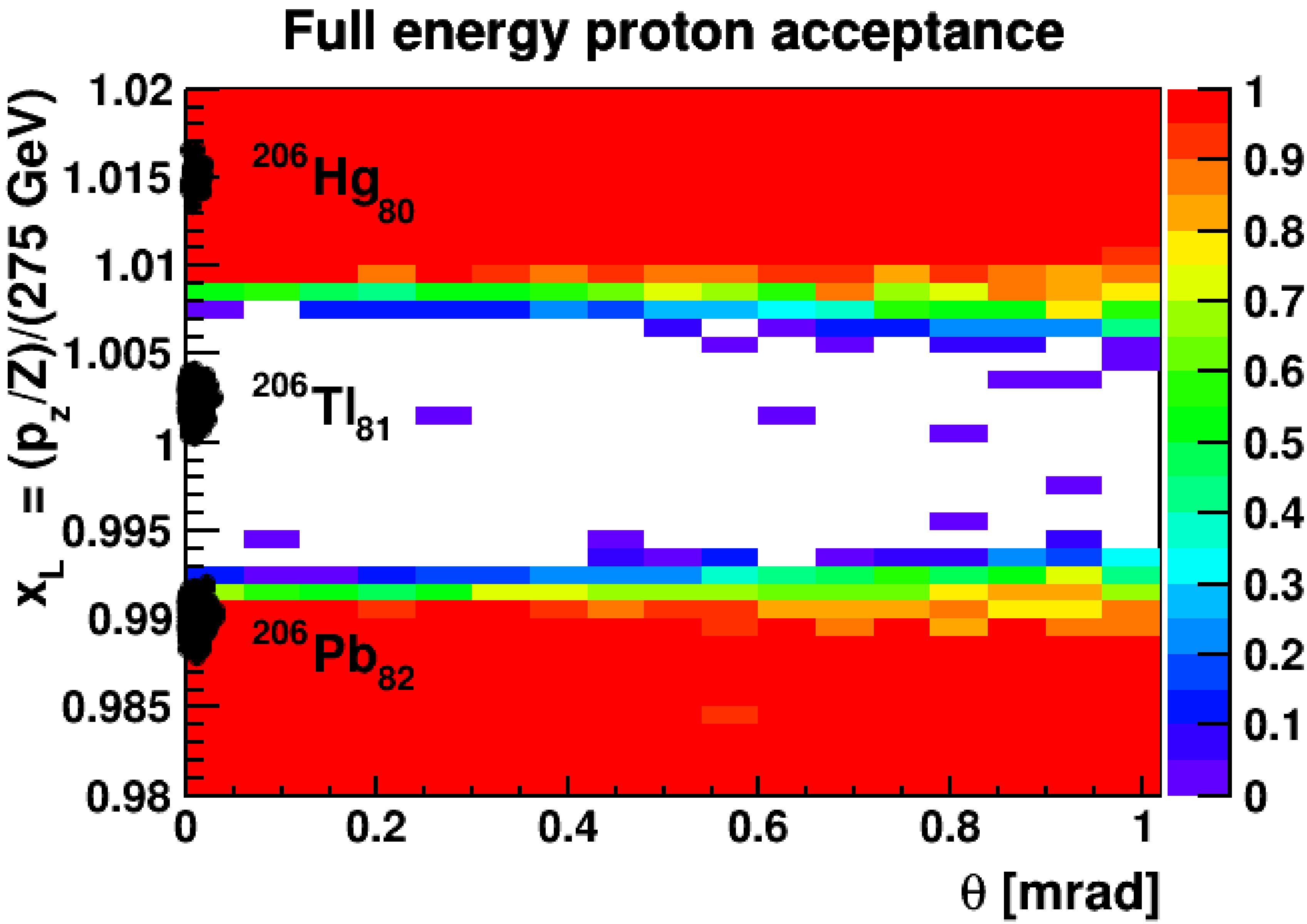
- Study coherent diffraction (and incoherent vetoing) at IP8.
- For coherent diffraction, there are theoretical issues to clear up.
- For forward tagging and vetoing in general, BeAGLE’s nuclear response should be validated and tuned.

# Conclusion

- Coherent diffraction (in Pb & Zr) should be a high priority for the 2nd Detector Working Group
  - Coherent diffraction is essential to get at G(b).
  - The 2nd detector will have a unique veto-tagging capability: Nuclear remnant detection (down to A-1 for Zr).
  - Mostly agnostic to details of central detector.
    - Something we can easily pull together on.
  - Pushes both buttons: Improves & cross-checks a crucial ePIC measurement using a new capability.
- More work is needed!

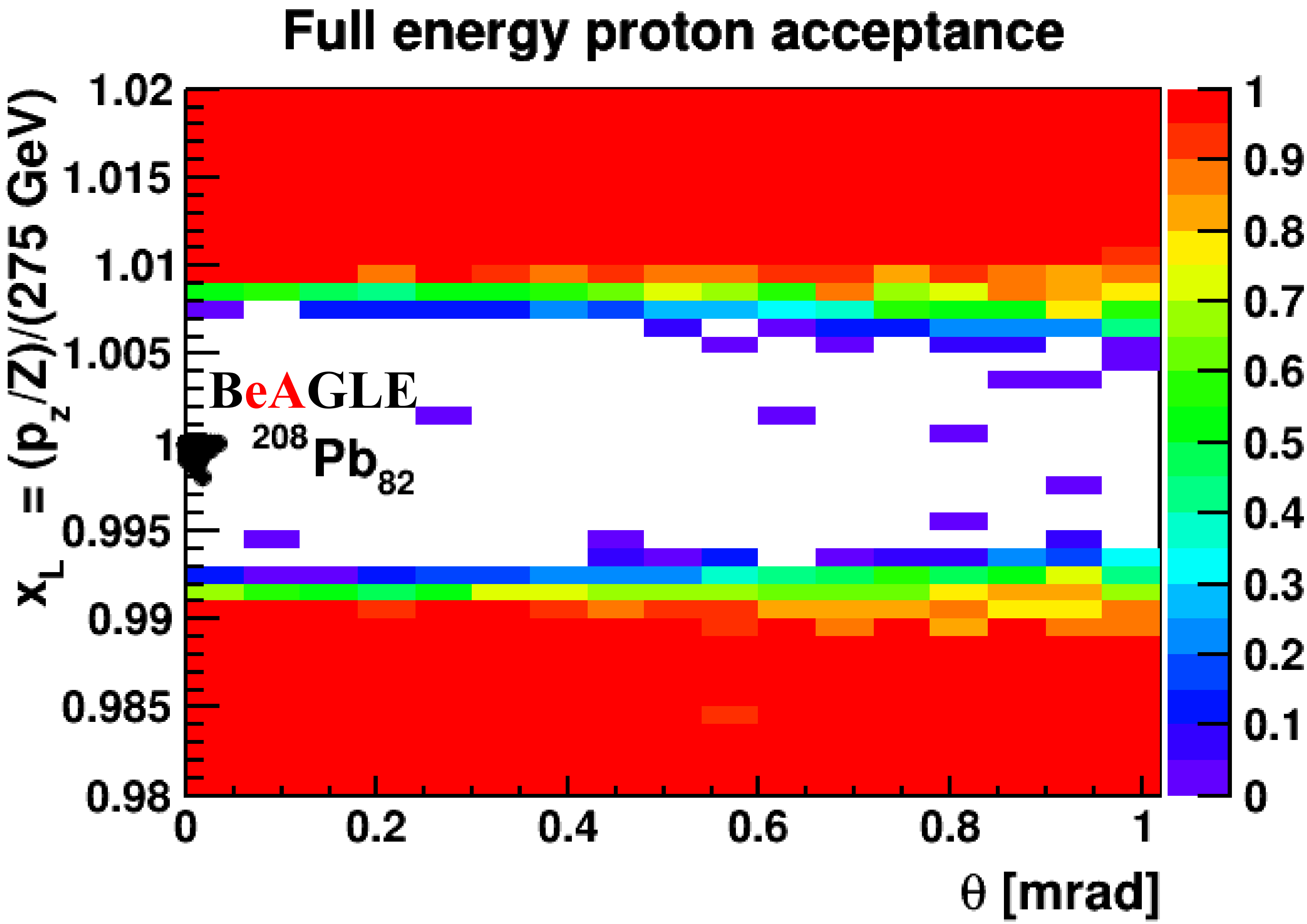
Extras

# A-2 from e+$^{208}$Pb J/ψ incoh. Diff. in BeAGLE




CAVEAT : ep acceptance assumed to carry over to ePb

# $^{208}$Pb from e+$^{208}$Pb J/ψ incoh. Diff. in BeAGLE



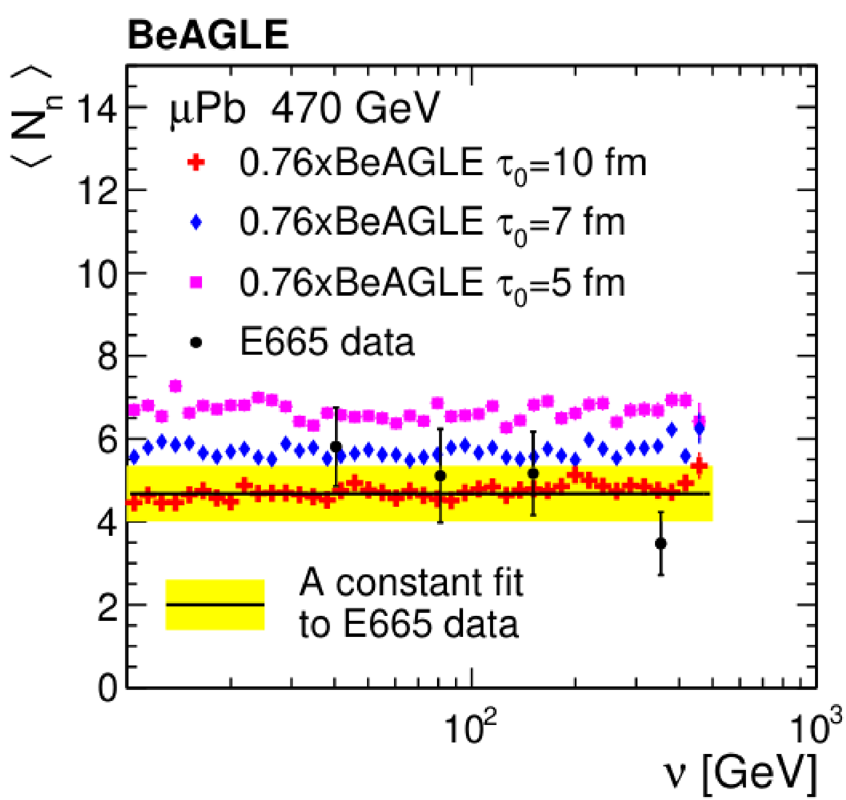

CAVEAT : ep acceptance assumed to carry over to ePb

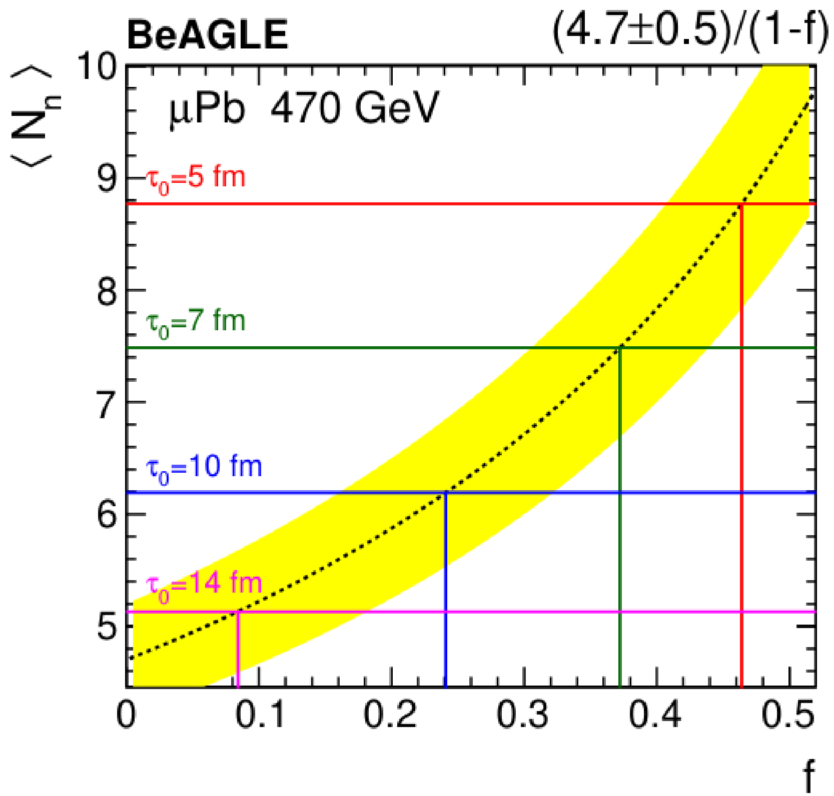
# Tuning BeAGLE parameter $\tau_0$ with neutrons

$\tau_0$ controls the hadron formation time during an IntraNuclear Cascade.

E665 neutrons prefer $\tau_0$=10 fm/c
IF we assume $f=N_{coherent}/N_{total}$ = 0.24.

Varying the unknown fraction
leads to values between 7-14 fm/c



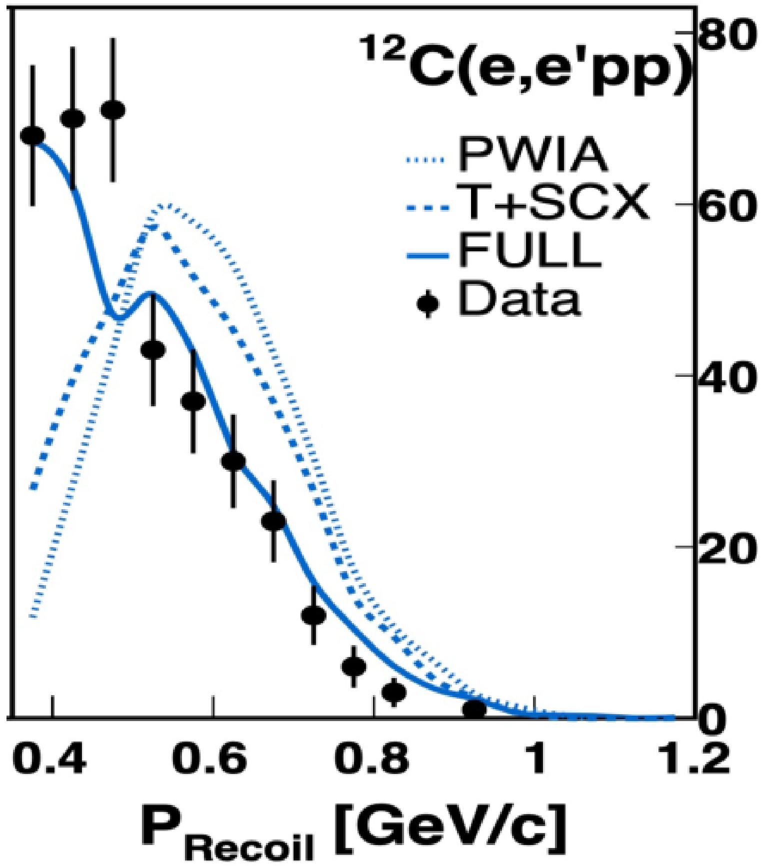




Chang et *al.*, Phys.Rev.D 106 (2022) 1, 012007 • e-Print: 2204.11998 [physics.comp-ph]
Data from: M. R. Adams et al. (E665), Phys. Rev. Lett. 74, 5198 (1995), [Erratum: Phys.Rev.Lett. 80, 2020–2021 (1998)].

# We could use JLAB data on SRC with FSI

https://indico.jlab.org/event/428/timetable/#20210325.detailed

Plot from Natalie Wright talk:
"Transport Estimations of Final State Interaction Effects on Short–range Correlation Studies"
@ 3rd Workshop on Quantitative Challenges in EMC and SRC Research



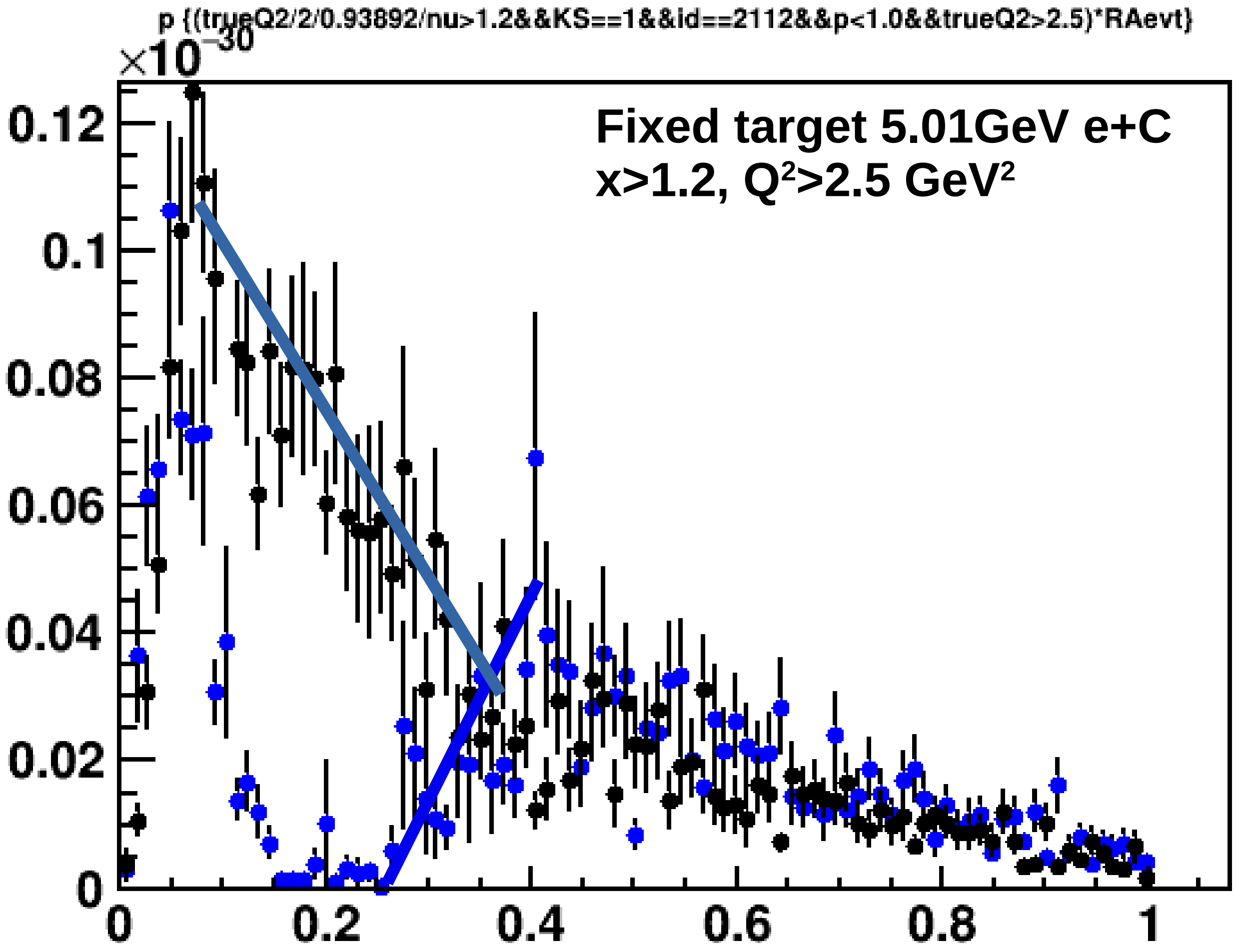

eGENIE (used for light ions and low energies) allows a single hadron-hadron scatter instead of a full cascade, but is otherwise similar to BeAGLE in terms of FSI.

Transport FSI: Excess nucleons at low end of recoil peak.

Washing out the peak.

# Low momentum excess washes out peak

Blue is no IntraNuclear Cascade
Black is full BeAGLE

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p (GeV)

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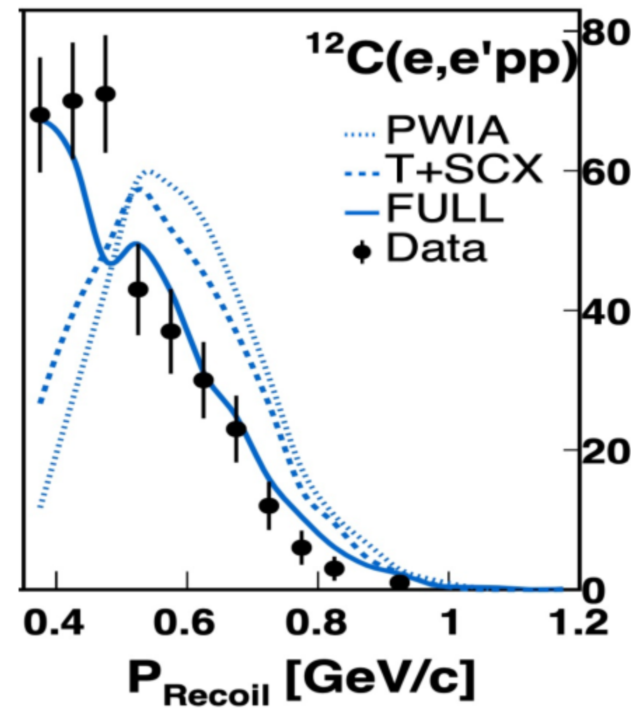
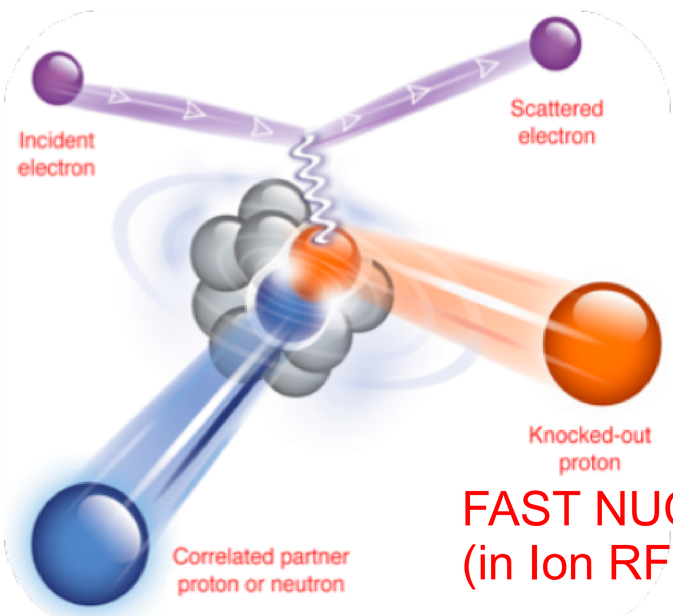
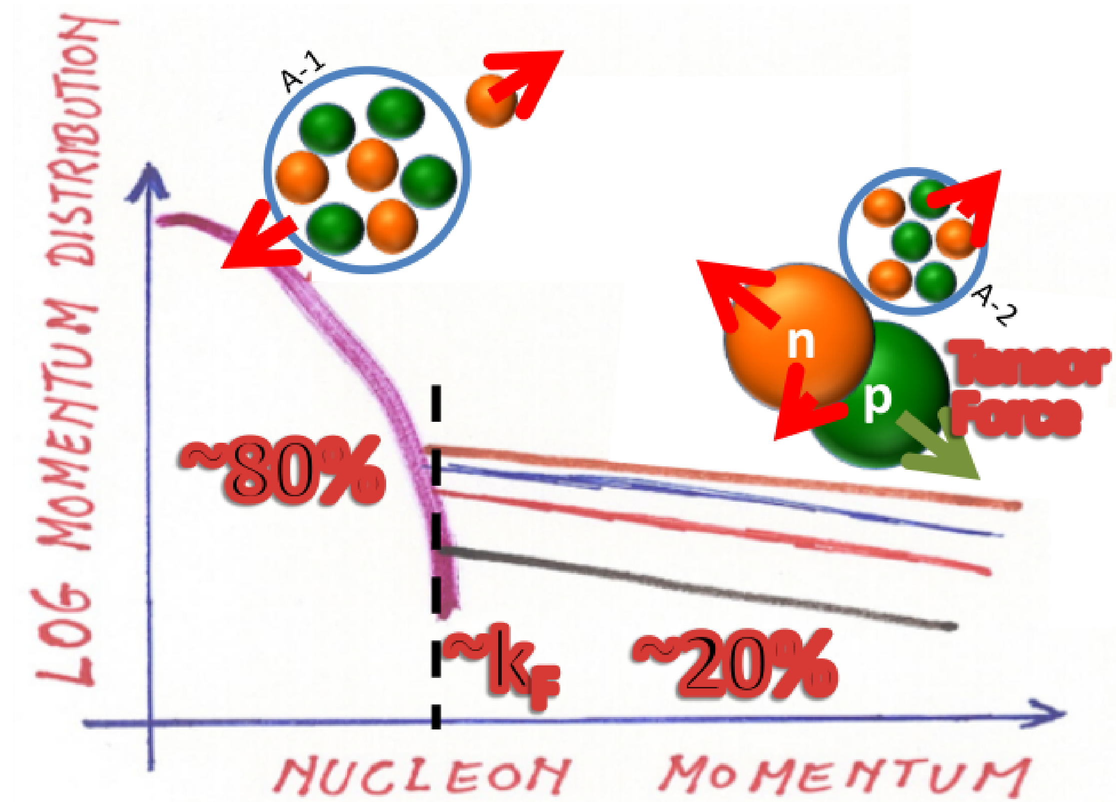


# Short-range correlations (quasielastic)

## Probing Correlations Using Hard Knockout Reactions




FAST NUCLEON
(in Ion RF)




Correlated SLOW RECOIL NUCLEON
Probes Intranuclear Cascade (final state interaction)