REU Program
SJY Group
Cyclotron Institute
National Science Foundation
Department of Energy

# DETERMINATION OF IMPACT PARAMETER FOR FERMI ENERGY HEAVY ION COLLISIONS USING THE HIPSE EVENT GENERATOR

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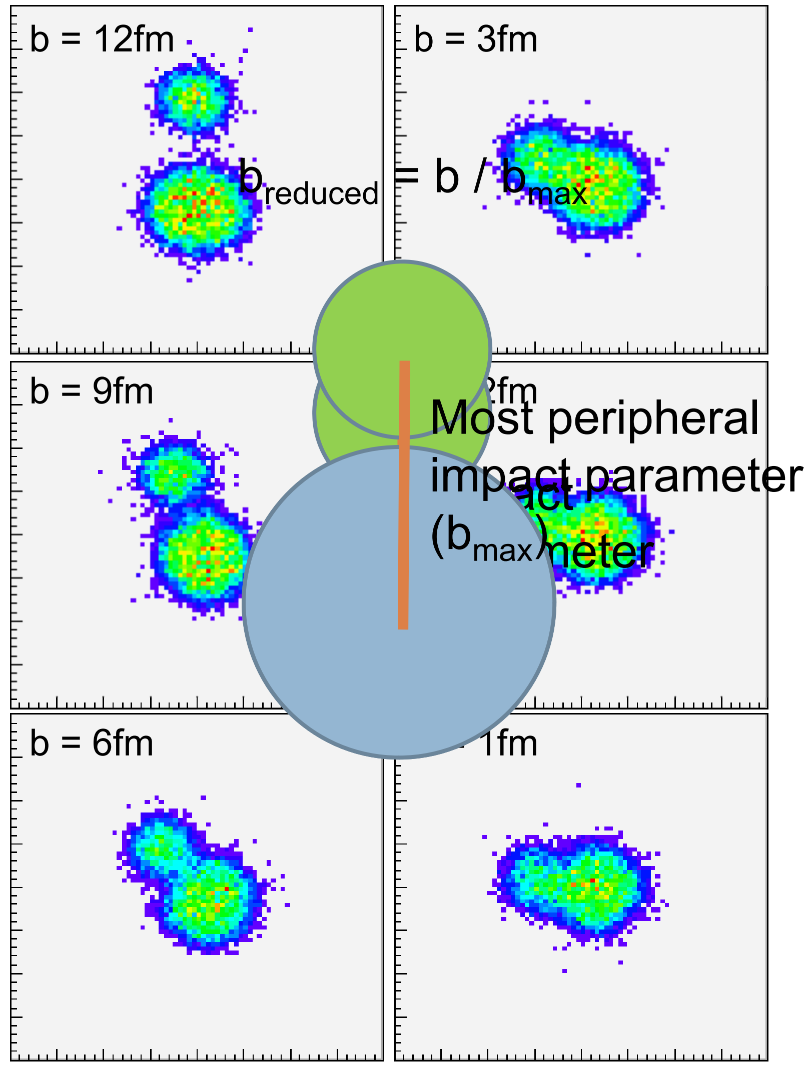
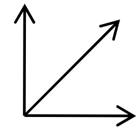
# Objective

- What is impact parameter
- Impact parameter is an important quantity (for making cuts, determining event mechanism, etc.)
- Cannot be experimentally observed
- Seek to deduce event impact parameter from knowable quantities

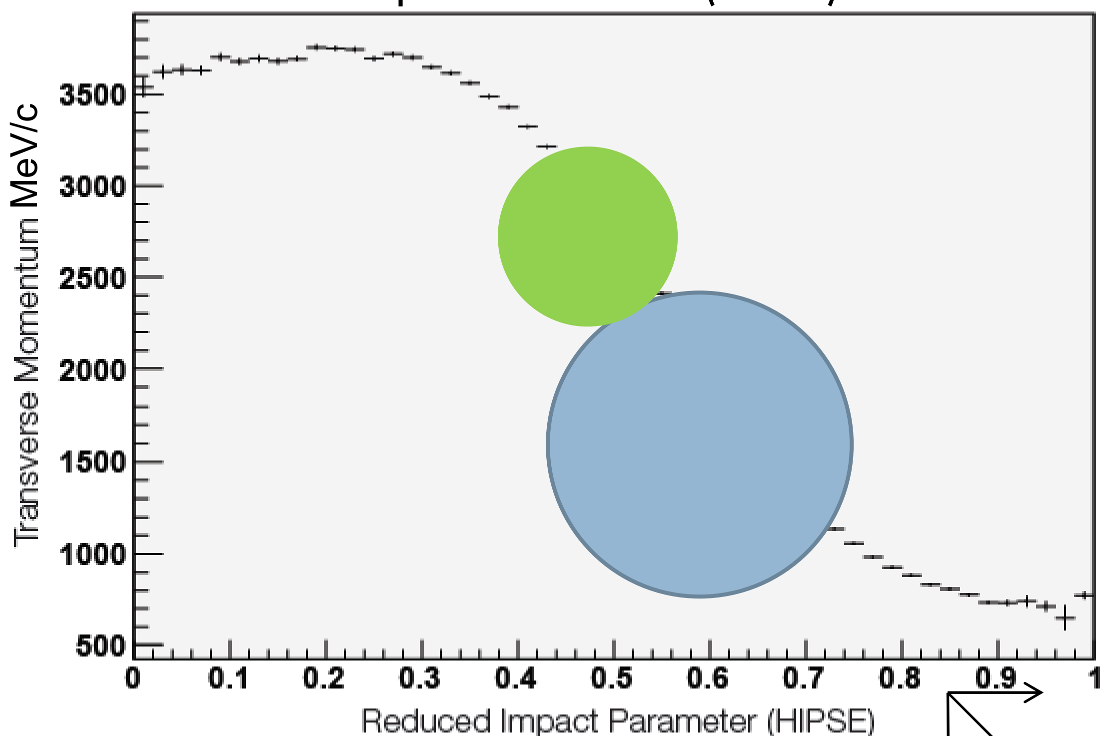


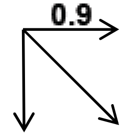

Video clip courtesy of August Keksis,
32 MeV/u $^{48}Ca$ + $^{124}Sn$, BUU Code

# Objective



Event Transverse Momentum versus  Reduced Impact Parameter (HIPSE)



# Outline

- Introduction
  - HIPSE
  - NIMROD Filter
  - Neural Network
- Bin Mapping Approach
  - Method
  - Results
- Neural Network
  - Method
  - Results

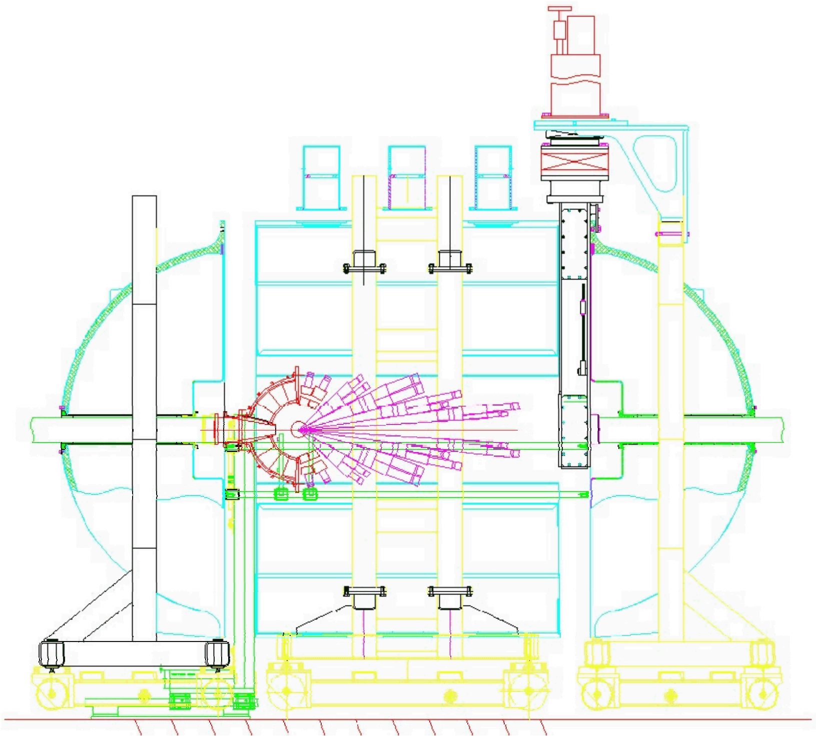
# Introduction - HIPSE

- HIPSE event generator
- Heavy-Ion Phase-Space Exploration
- Parameterized to replicate experimental data taken on the INDRA detector
- Hot fragments de-excited with statistical model SIMON
- Allows for correlation of impact parameter with different observables (since HIPSE provides impact parameter)

D. Lacroix *et al.*, *Phys. Rev. C 69, 1 (2004).*

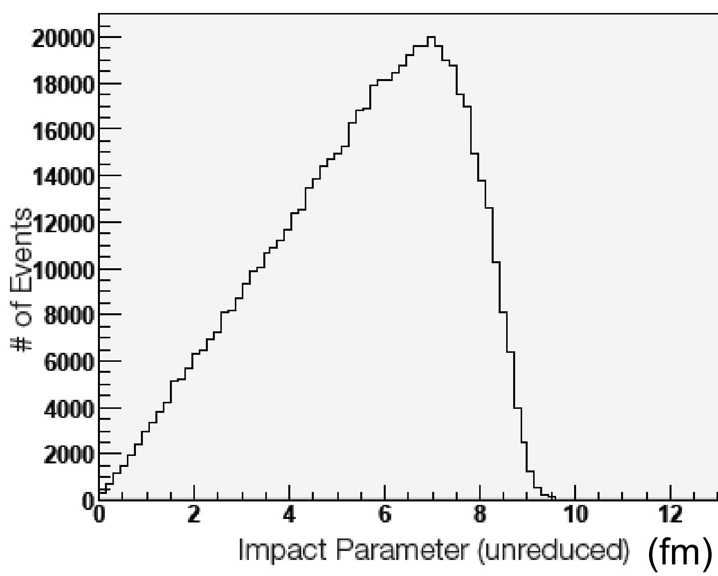
# Introduction – NIMROD Filter

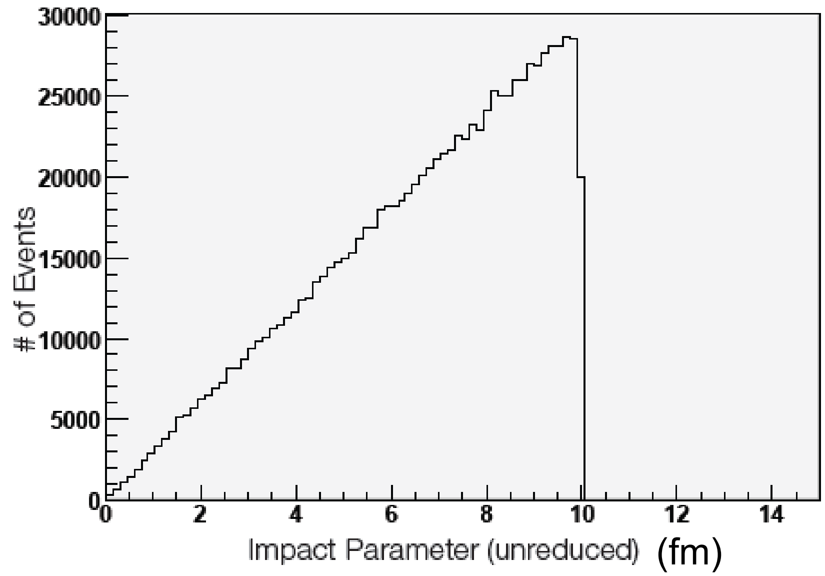
- NIMROD filter
- Filters data to approximate experimental data taken on NIMROD
  - For example, angular resolution becomes discrete, some particles don't have enough energy to be detected
- Because we want to use this method for data taken on NIMROD (July-August 2008)



# Introduction – NIMROD Filter

Distribution of events sorted by impact parameter with (left) and without (right) NIMROD filter



# Introduction – Neural Network

- Neural Network allows for multiple correlations to be considered for estimating the output for a given set of inputs
- Trained using simulated data
- Can then applied to experimental data

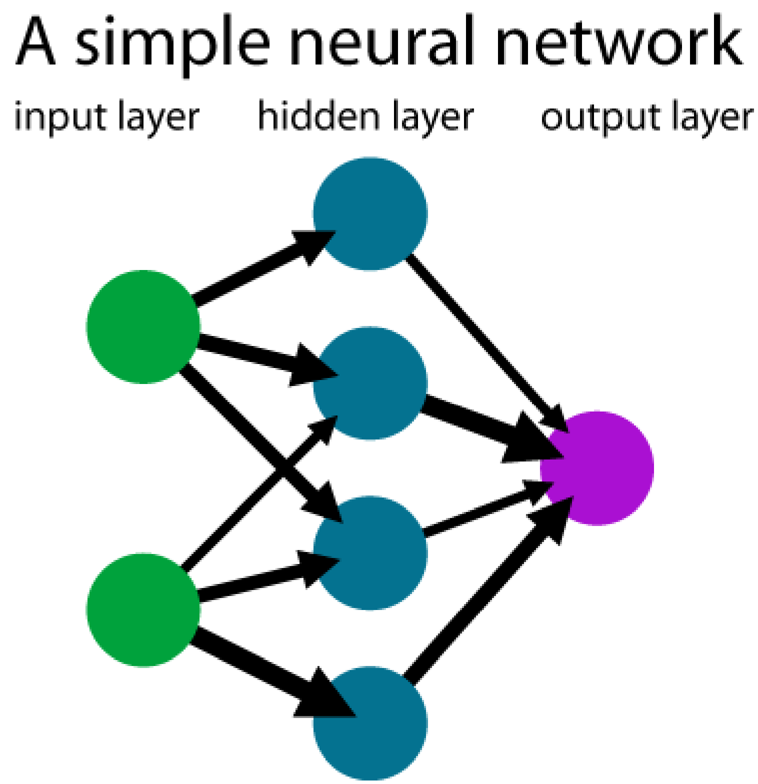
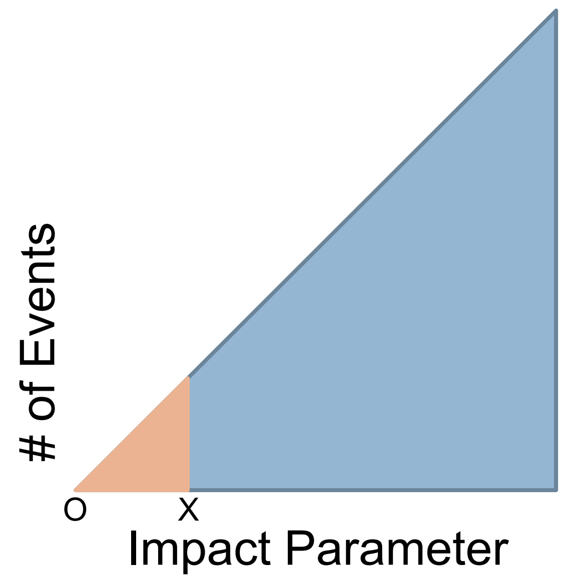
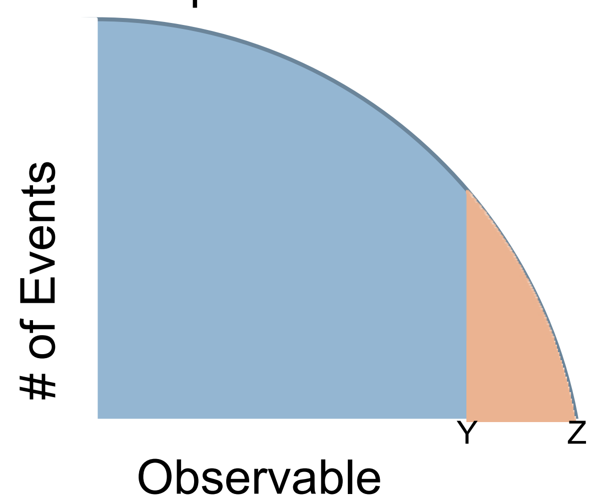



Image courtesy of Wikipedia:
http://en.wikipedia.org/wiki/Image:Neural_network_example.png

# Bin Mapping Approach – Method

- Geometrical impact parameter distribution separated into portions
- Percentage of each portion calculated
- Distribution of the global observable is binned such that the integral percentage of each bin is equal to the corresponding percentage of the impact parameter portion
- Bins from the observable distribution now mapped to distinct impact parameter ranges



# Bin Mapping Approach – Method

- Three approaches:
  - Impact parameter distribution is separated into four or five evenly spaced portions to which observable distributions are mapped.
  - Observable distribution is separated into four or five evenly spaced portions to which impact parameter distribution is mapped.
  - Observable distribution is binned by hand to avoid discontinuities. Impact parameter distribution is then mapped to these bins.
- Estimates compared with HIPSE values

# Bin Mapping Approach – Method

- Systems
  - $^{70}Zn$ on $^{70}Zn$ at 35MeV/u
  - $^{64}Zn$ on $^{64}Zn$ at 35MeV/u
  - $^{64}Ni$ on $^{64}Ni$ at 35MeV/u
  - $^{64}Zn$ on $^{64}Ni$ at 35MeV/u

# Bin Mapping Approach – Method

- Quantities examined
- All quantities examined with Z-V cut: $\Sigma Z_{frag} x V_{||frag} > ½ Z_{proj} x V_{proj}$
  - Event transverse momentum* and velocity (avg. and total)
  - Event parallel momentum and velocity (avg. and total)
  - Transverse energy
  - Average detector angle (theta)
  - Neutron multiplicity*
  - Charged particle multiplicity*
  - Total particle multiplicity
  - Mid-rapidity charge (amount of charge per event with $-V_{proj} < V_{particle} < V_{proj}$ in center of mass frame)
  - Forward charge (theta < 35°)
  - Backward charge (theta > 70°)*
  - Heavy (Z > 2) / light (Z ≤ 2) fragment ratio
  - Intermediate (6 > Z > 2) / light (Z ≤ 2) fragment ratio

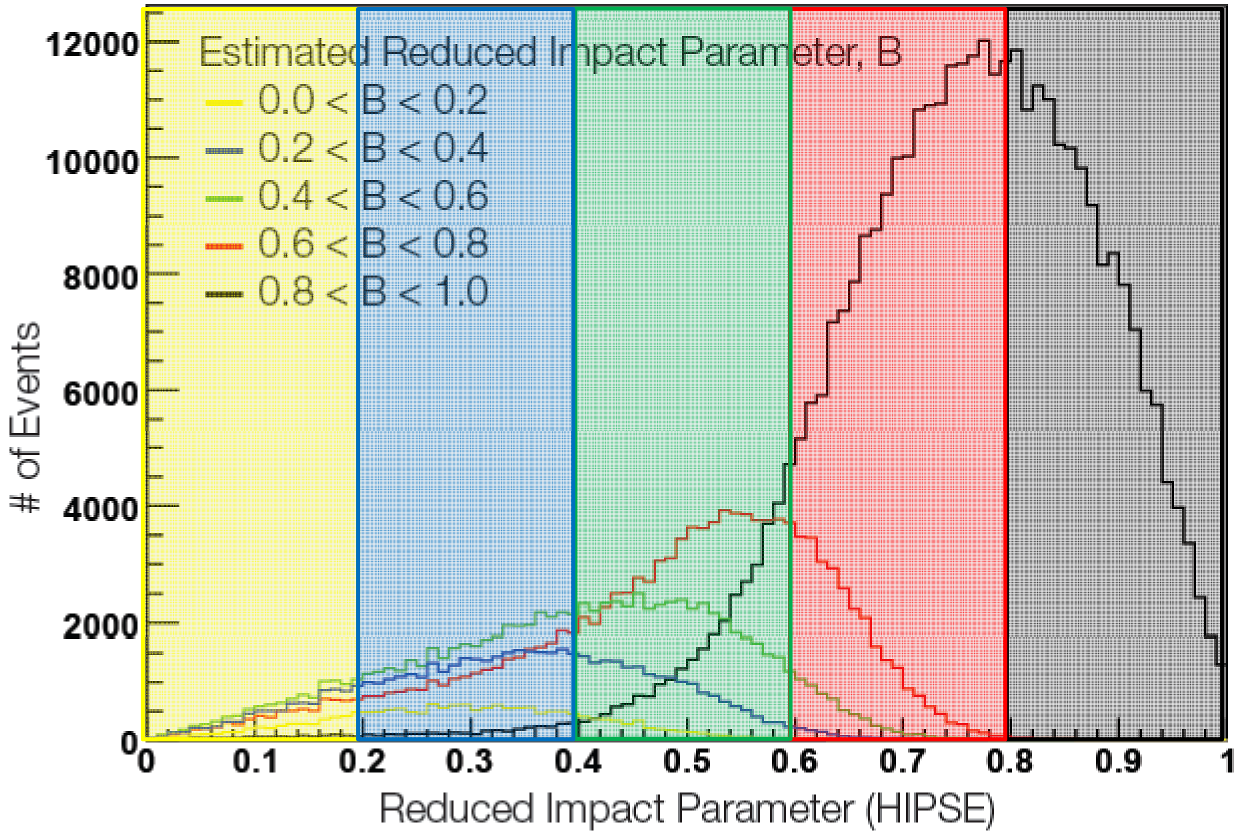
*marked quantities also examined without the cut

# Bin Mapping Approach – Results

- Examples of poor separation:
  - Mid-rapidity charge
  - Total parallel momentum
- Examples of good separation:
  - Total particle multiplicity
  - Neutron multiplicity
  - Charged particle multiplicity
  - Event total transverse momentum

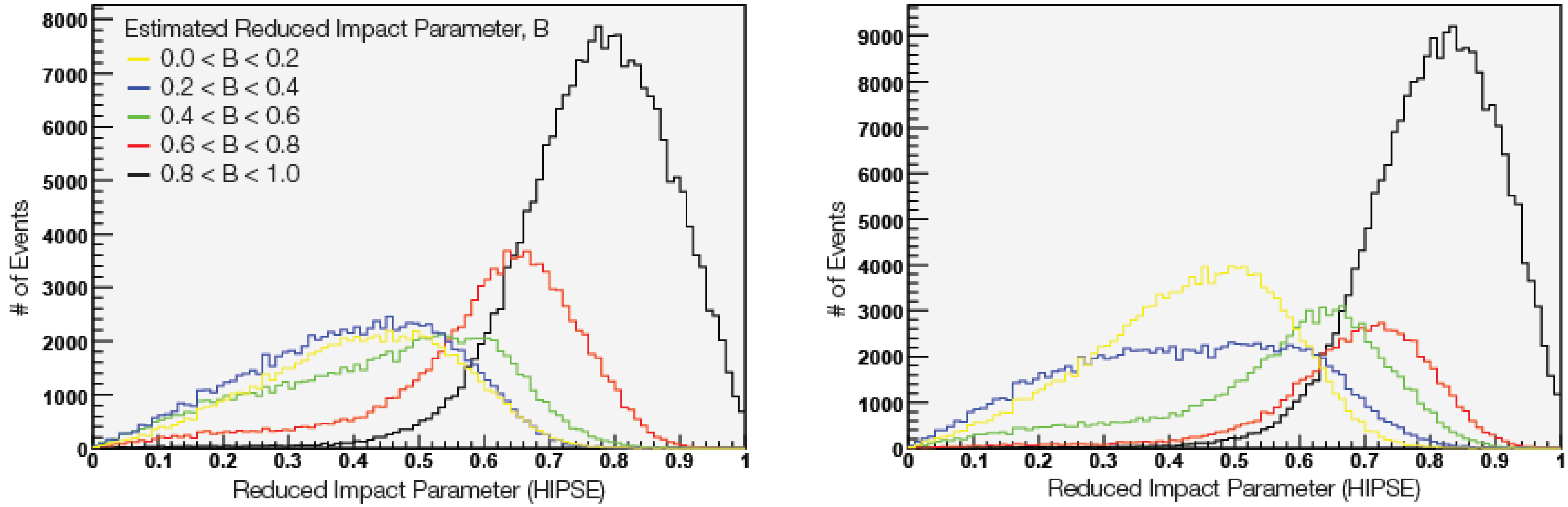
# Bin Mapping Approach – Results

Example - Separation of impact parameter by total transverse momentum without Z-V cut



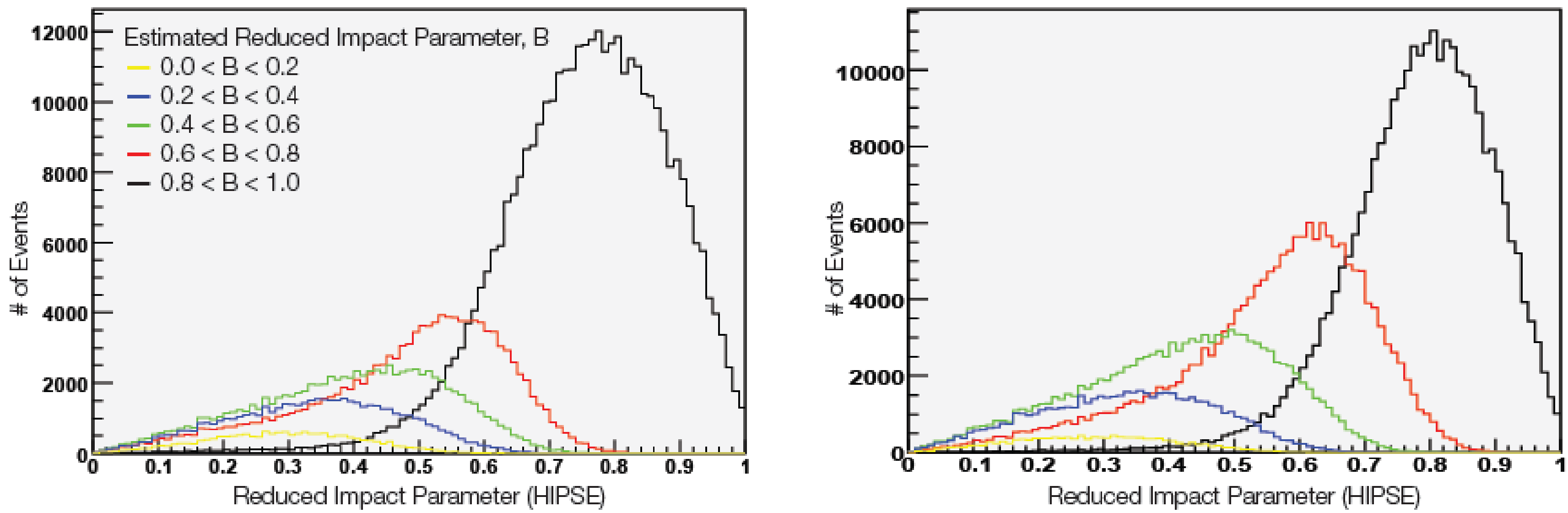
# Bin Mapping Approach – Results

Separation of impact parameter by mid-rapidity charge (left) and total parallel momentum (right)



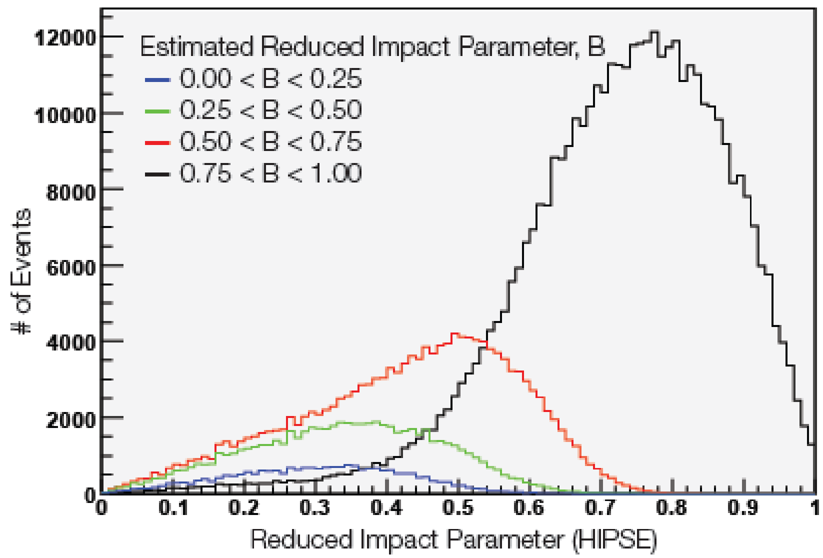
# Bin Mapping Approach – Results

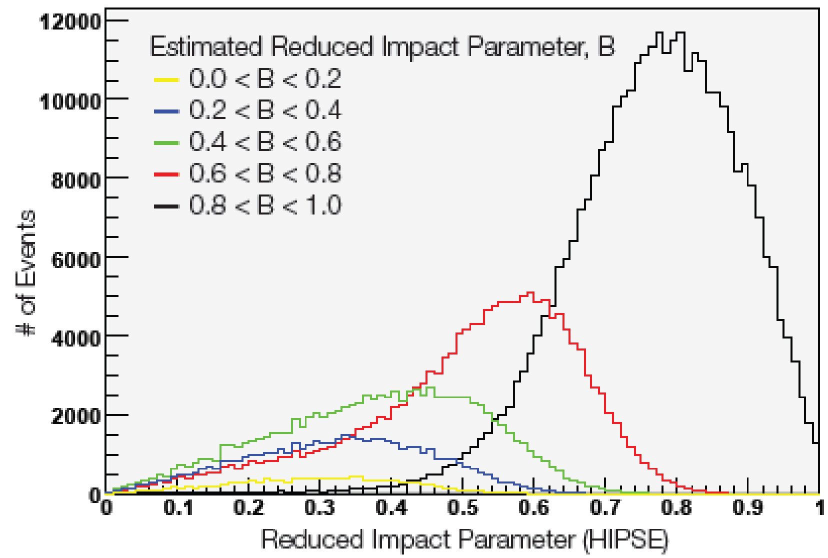
Separation of impact parameter by total particle multiplicity (left) and neutron multiplicity (right)



# Bin Mapping Approach – Results

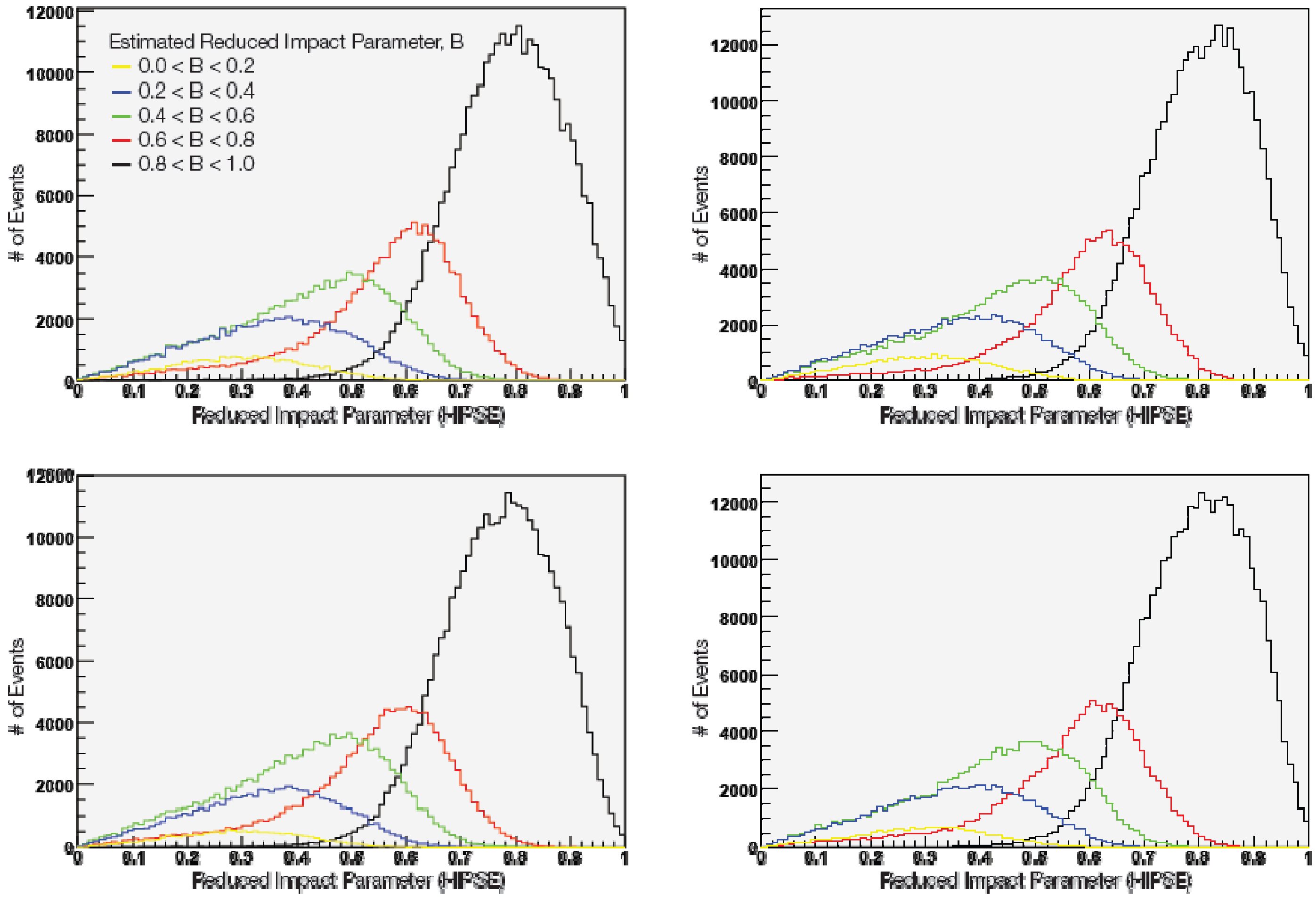
Separation of impact parameter by charged particle multiplicity using four bins (left) and five bins (right)



# Bin Mapping Approach – Results

Separation of impact parameter by total transverse momentum without Z-V cut $^{70}Zn$ on $^{70}Zn$ (top left), $^{64}Zn$ on $^{64}Zn$ (top right), $^{64}Ni$ on $^{64}Ni$ (bottom left), $^{64}Zn$ on $^{64}Ni$ (bottom right), all at 35MeV/u



# Neural Net Approach – Method

- Trained with:
  - Charged particle multiplicity
  - Neutron multiplicity
  - Event total transverse momentum
  - Intermediate / light fragment ratio
- Set up to yields most probable bin number to be compared to binned HIPSE values

http://cern.root.ch , Class: TMultiLayerPerceptron

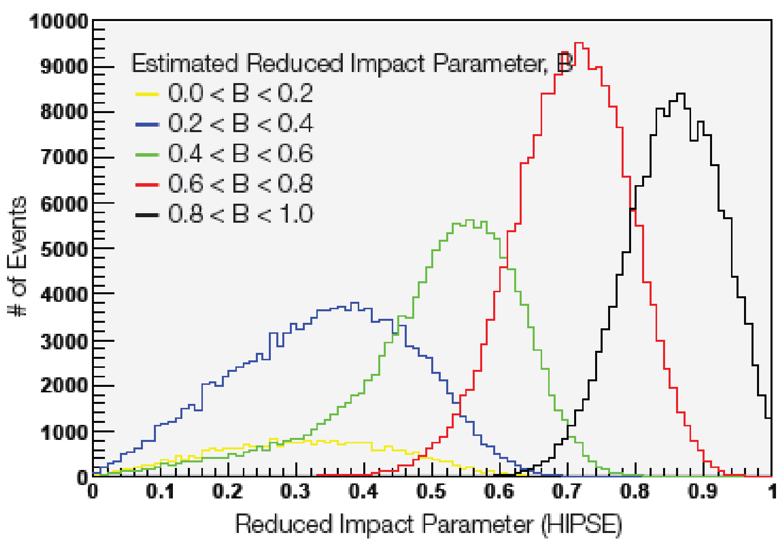
https://twiki.cern.ch/twiki/bin/view/Atlas/PhysicsAnalysisWorkBookNeuralNetwork

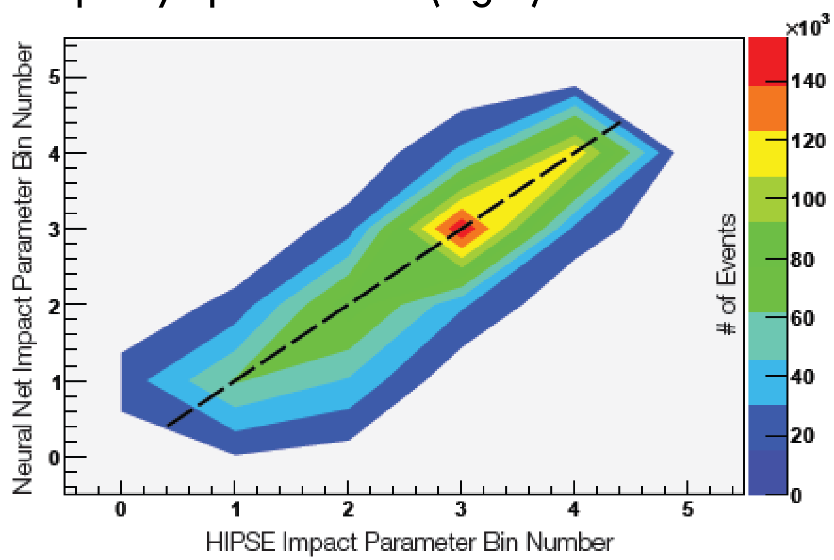
# Neural Net Approach – Results

- Neural Net
  - Separation proved better than previous method
  - Still some overlap at low impact parameter (understandable)
  - Values placed in one of five equally spaced bins (due to the nature of this net) and compared with similarly binned HIPSE values

# Neural Net Approach – Results

Separation of impact parameter using the Neural Net(left) and distribution of Neural Net generated impact parameters versus HIPSE generated impact parameters (both divided into five equally spaced bins (right)



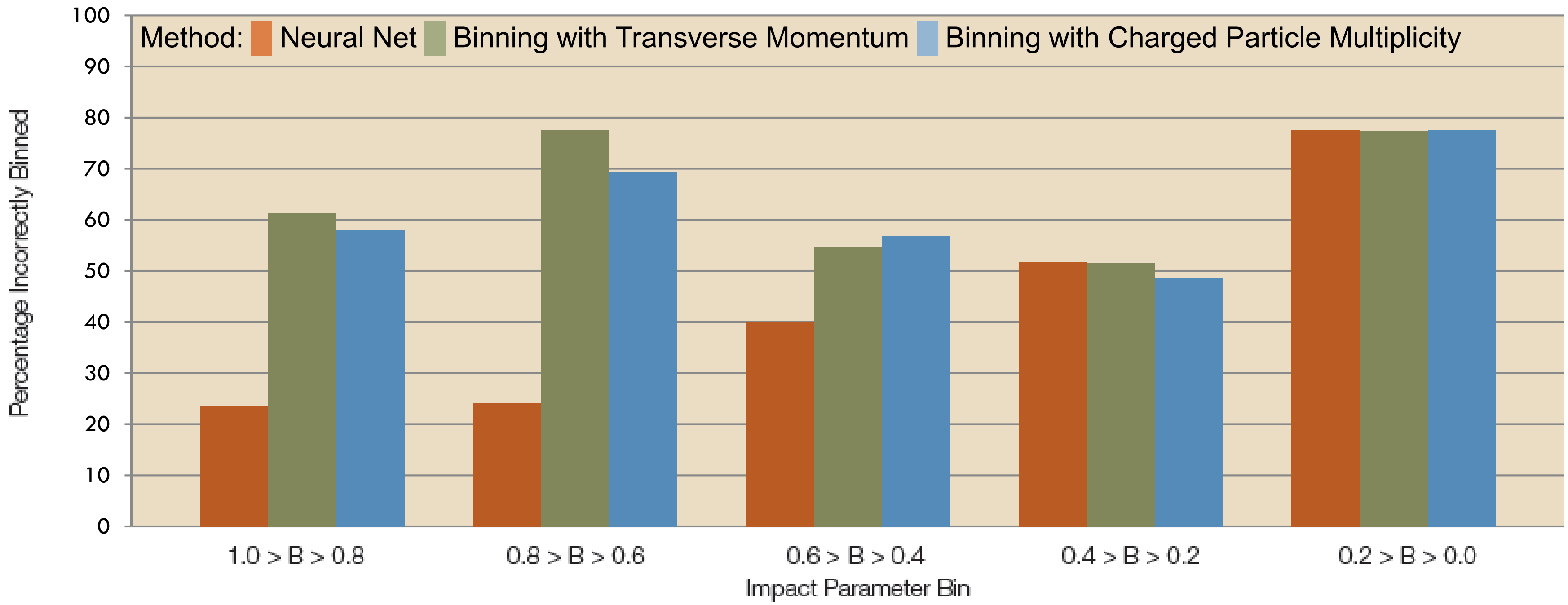



# Conclusions

- Total transverse momentum and charged particle, neutron, and total particle multiplicities suitable for impact parameter determination via binning method
- Neural Net useful tool to better impact parameter determination
- Continuing research would allow for additional quantities to be examined, and for promising quantities to be integrated into the training of the neural net

# Conclusions

Percentage of events incorrectly binned (by bin) for: the Neural Net, mapping with transverse momentum, and mapping with charged particle multiplicity



# Acknowledgements

- References:
  - C. Ogilvie *et al.*, *Phys. Rev. C 40, 654 (1989).*
  - D. Lacroix *et al.*, *Phys. Rev. C 69, 1 (2004).*
  - F. Haddad *et al.*, *Phys. Rev. C 55, 1371 (1997).*
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