



# Detecting Chiral Magnetic Effect in heavy ion collision via Deep Learning

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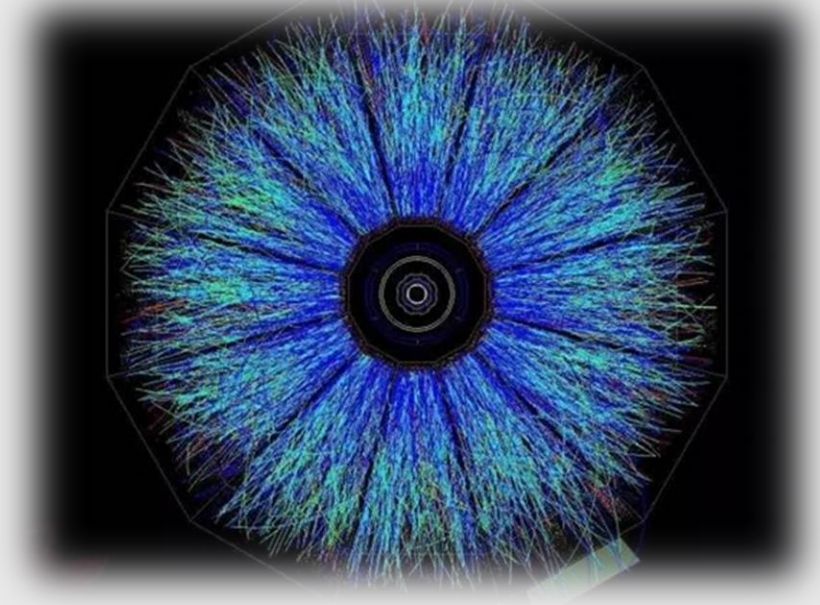
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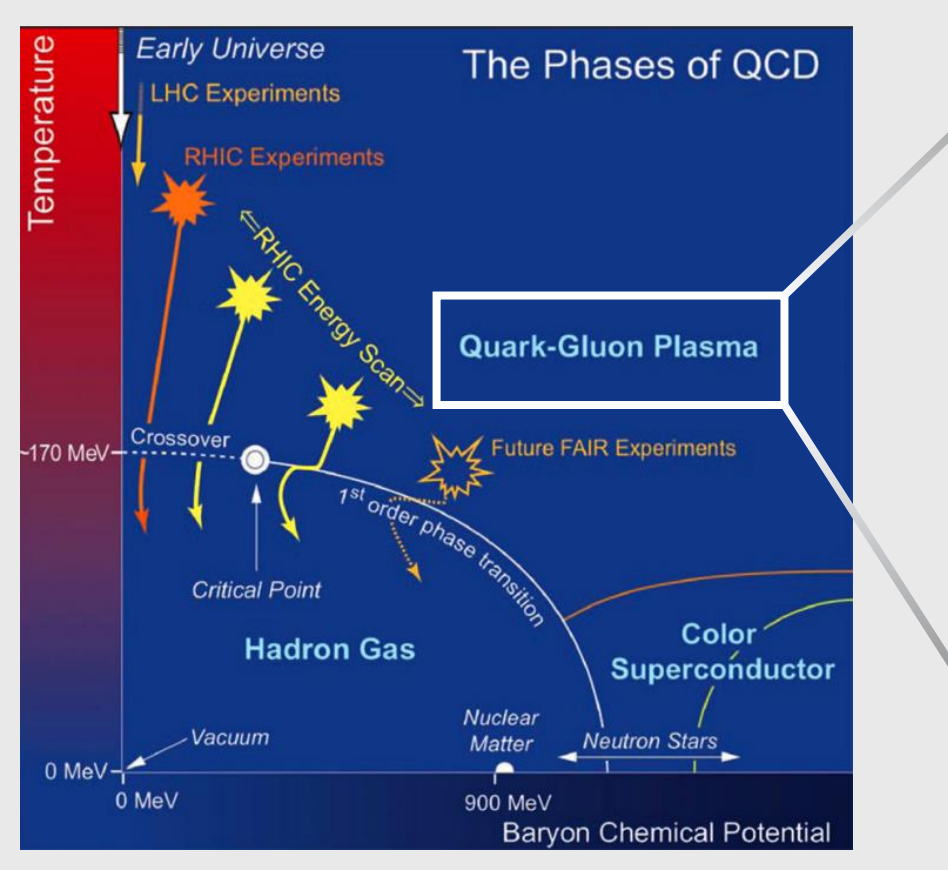
arXiv:2105.13761

## Heavy Ion Collision (HIC):

Ultra relativistic system+  
Strong interactions



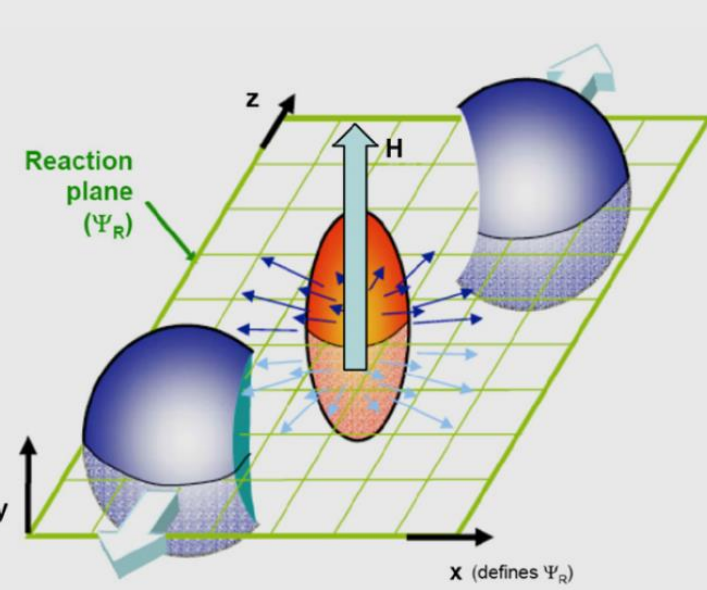
Final state of HIC



QCD phase diagram

From STAR collaboration

## Chiral Magnetic Effect (CME) in HIC:



Center magnetic field  
 $10^{18} \sim 10^{20}$  Gauss  
@ collision instant  
Largest ever found

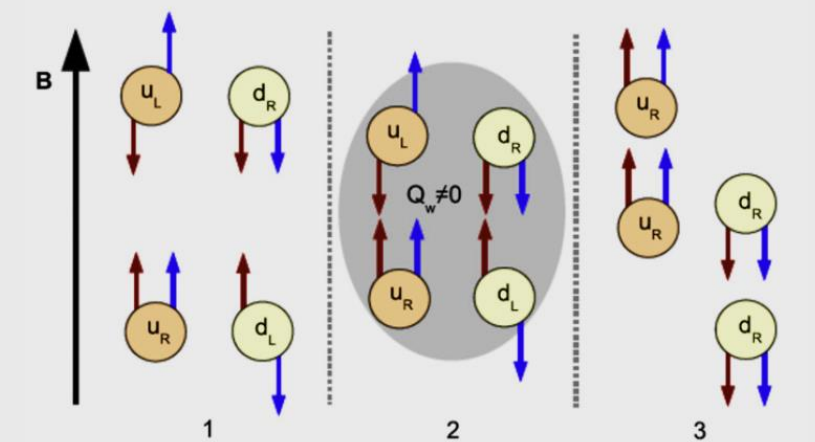
Chiral anomaly  
+ external magnetic field

$$\vec{J}_5 = \frac{e^2 \mu_5}{2\pi^2} \vec{B}$$

Chiral Magnetic Effect (CME)

Evolution

**Charge Separation (CS)**  
w.r.t the reaction plane



**Chiral anomaly:**  
 $\mu_5 \neq 0$ , topological non-trivial bubbles

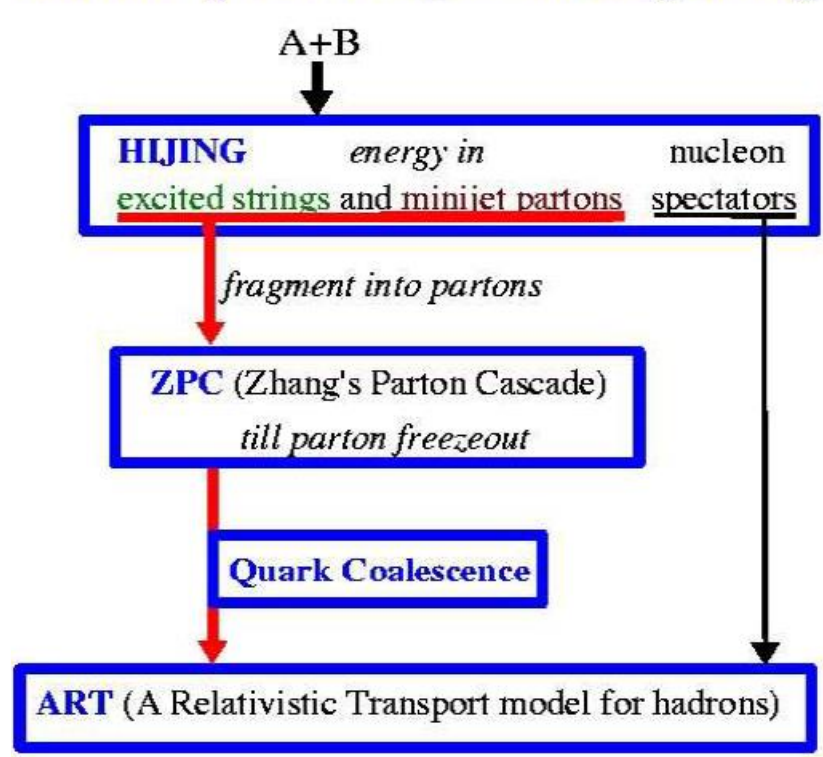
PhysRevD.78.074033

K Fukushima, DE Kharzeev, HJ Warringa

## Training data (Au+Au):

- Generated using the AMPT model
- CME added by hand (up to a ratio  $f$ )
- Supervised learning:
  - No CS: '0'
  - CS: '1'
- Extracting  $\pi^\pm$  transverse momentum spectra:  $\rho^\pm(p_T, \phi)$

Structure of AMPT model with string melting

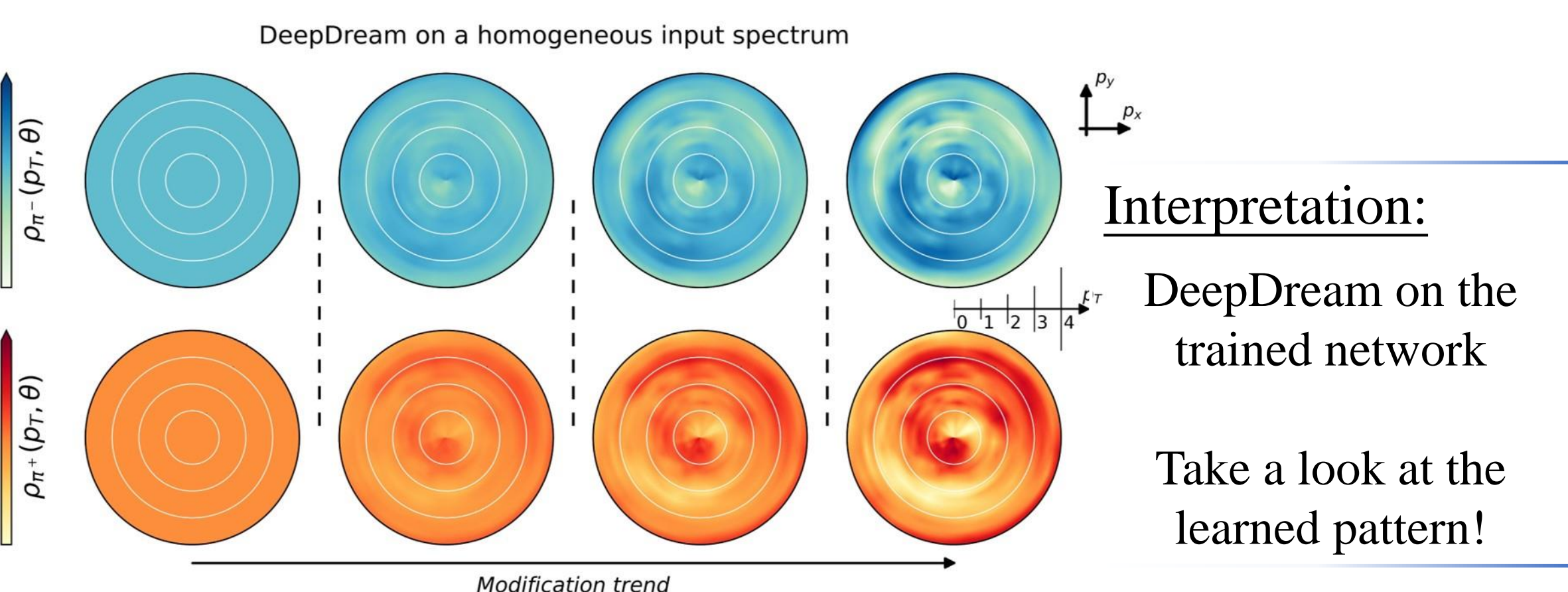
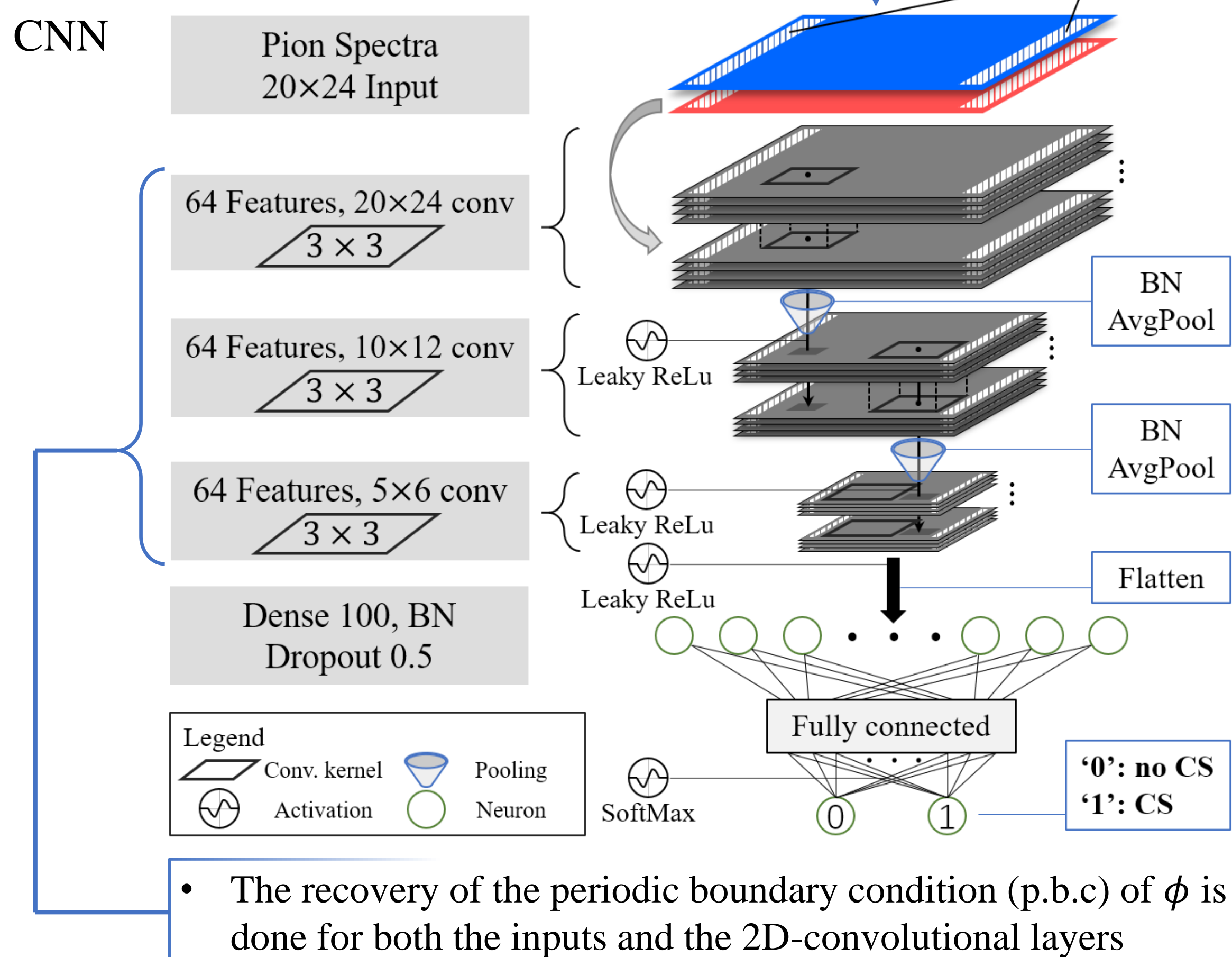


Zi-Wei Lin et al., arXiv:nucl-th/0411110v3

More detailed pre-treating to the training data:

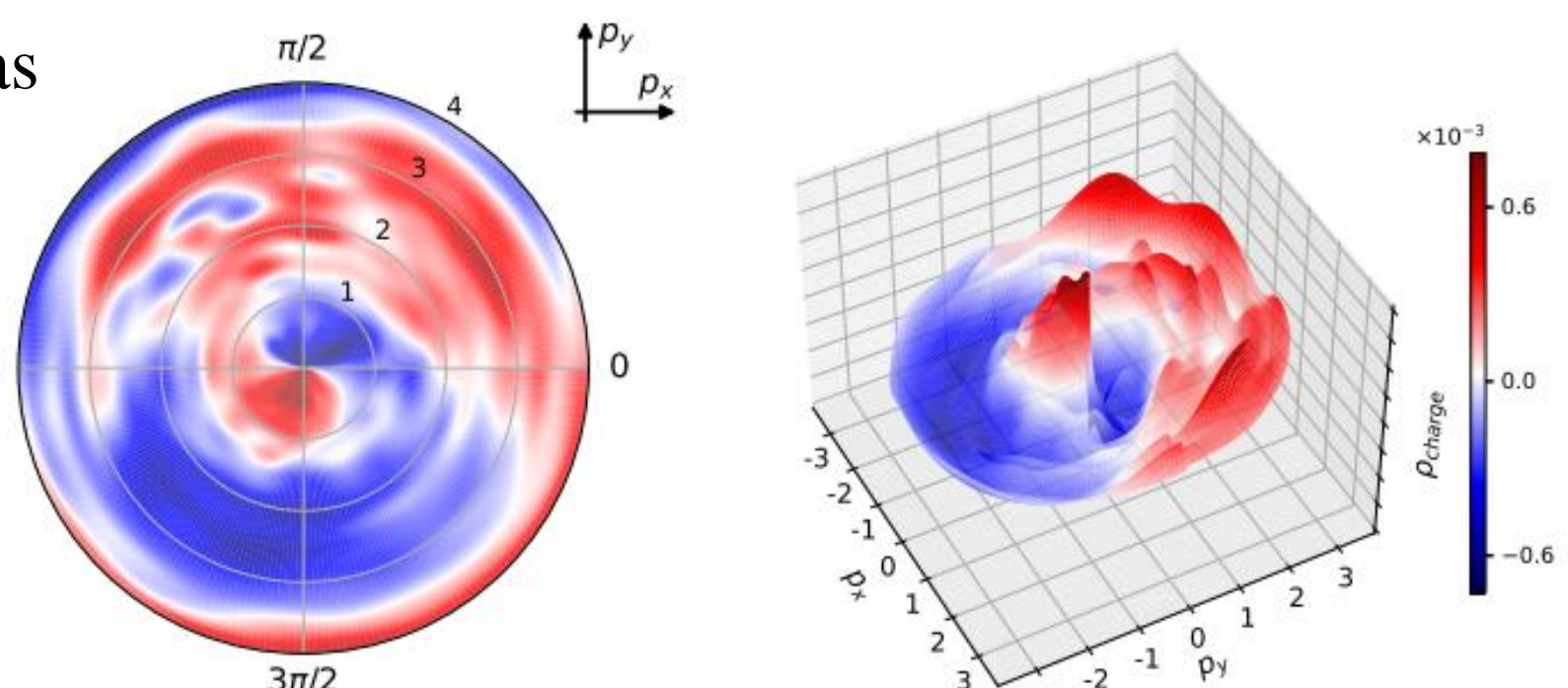
- Normalization
- Symmetrization
- Combination of events with same collision condition and dominant chirality

## Architecture:



The dipole-mode of CS has already shown up in the DeepDream visualization.

**Lookout:** is the quadrupole-mode in the figure a physical result?



## But there is challenge...

### CS observables

- $\gamma, \Delta\gamma$
- Event-shape-engineering
- $\Delta S$
- Invariant mass
- Spectator event plane
- ...

### V.S. background contamination

- Transverse momentum conservation
- + Local charge conservation
- + Elliptic flow  $v_2$
- + ...

$\gamma$  contains ~90% signal of elliptic flow!

## Application of deep learning (DL):

A better, cleaner observable / pattern for CS & CME

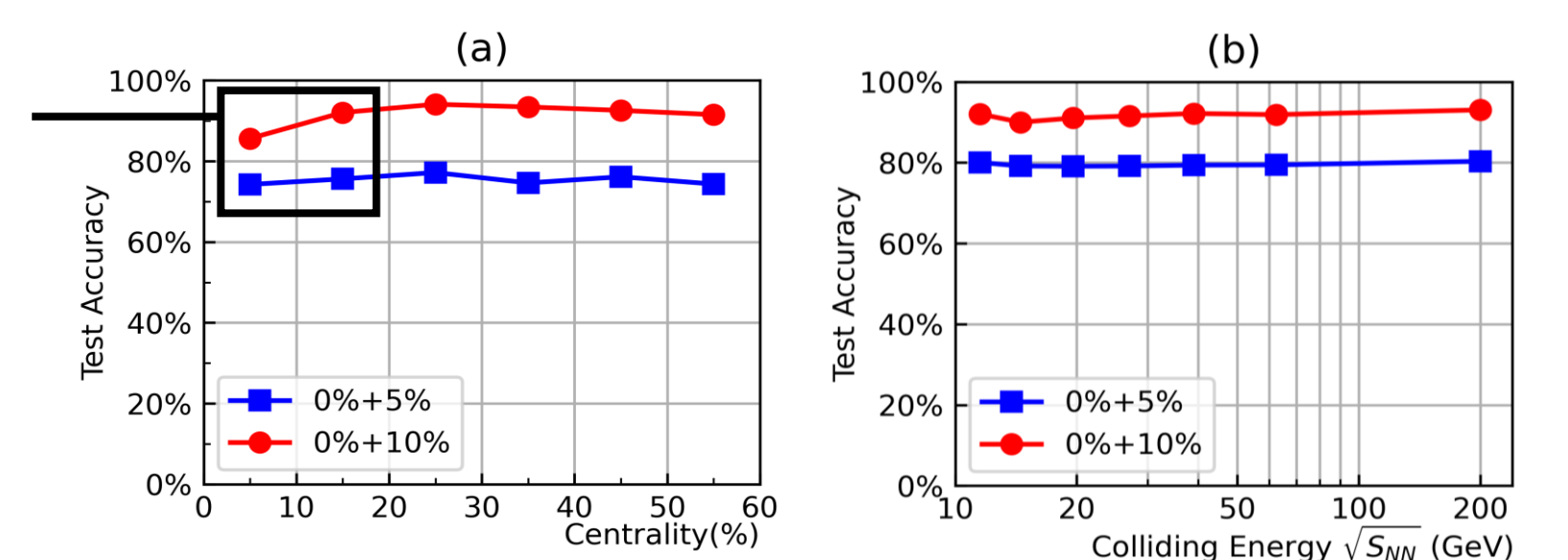
## Test results:

### Accuracy

NN	0+5%	0+10%
Acc. on f=0+5% test set	~80%	--
Acc. on f=0+10% test set	--	~92%

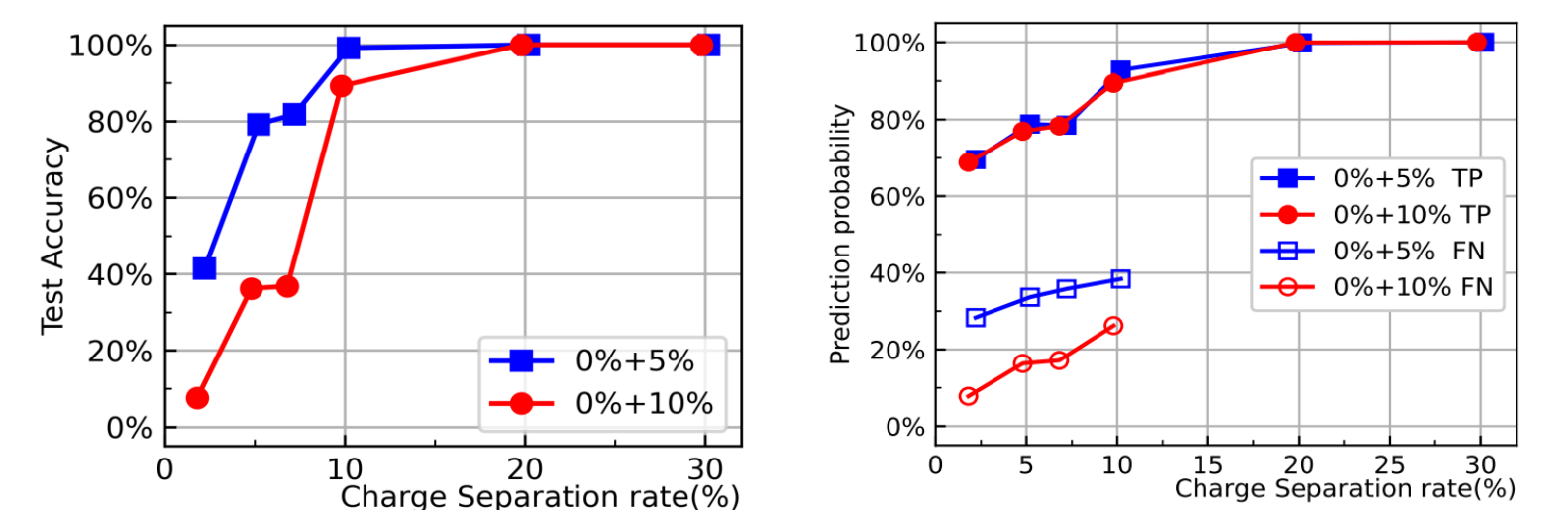
### Robustness

Data of these two centralities are not learned, but generalized by the NN itself.



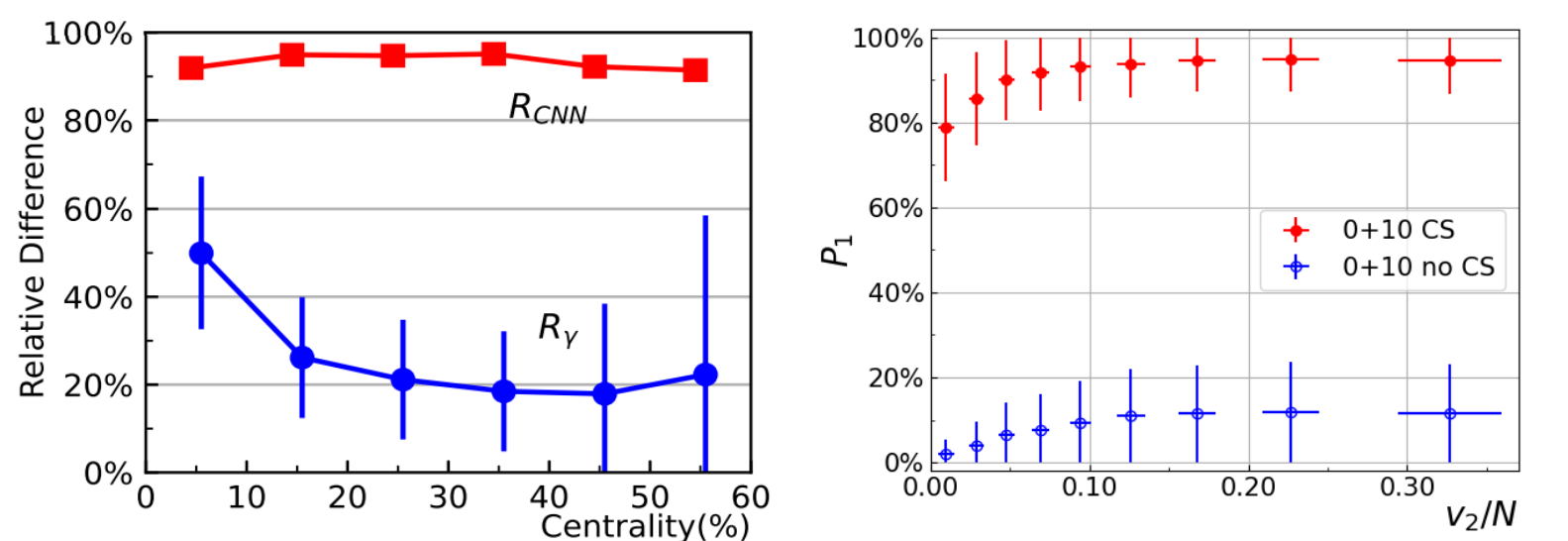
### Correlation of the out put and CS ratio $f$

The prediction value ( $P_1$ , second output of SoftMax) is positively related with  $f$ .



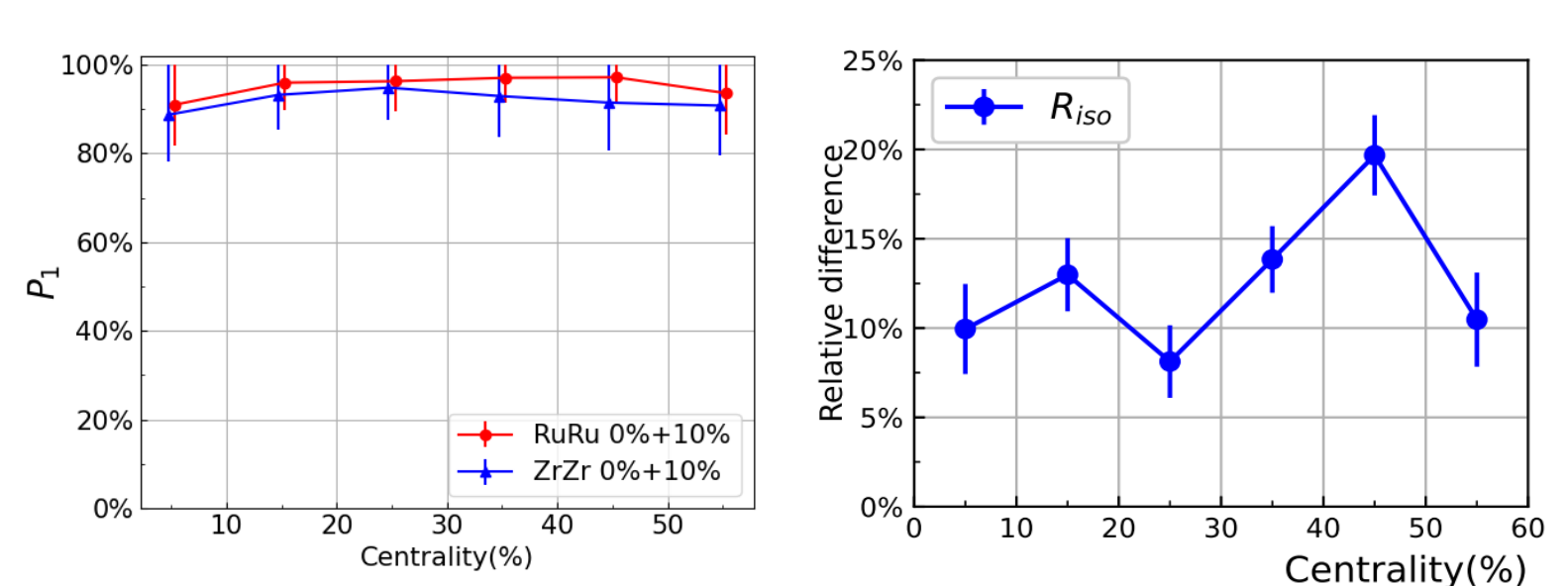
### Comparison to other observables and background

The prediction of NN exceeds the usual observable  $\Delta\gamma$ , and is robust against the main background, the elliptic flow  $v_2$ .



### Transference to other collision systems

$Au + Au$ ,  
 $^{96}Ru + ^{96}Ru$  &  
 $^{44}Ru + ^{44}Ru$  &  
 $^{96}Zr + ^{96}Zr$  &  
 $^{40}Zr + ^{40}Zr$   
 $R_{iso}$  meets the theoretical results.



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