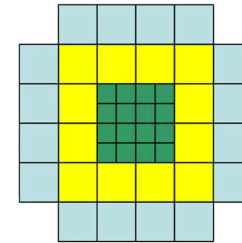
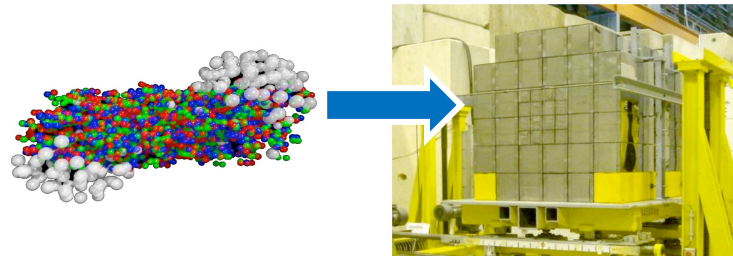


CONVOLUTION NEURAL NET FOR CENTRALITY: CONCEPT STUDY

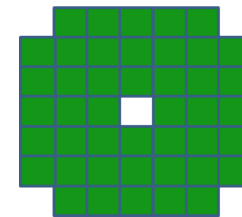
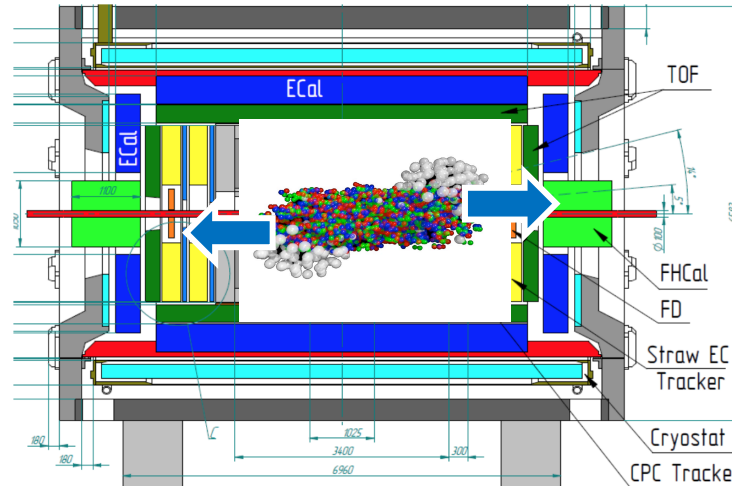
Andrey Seryakov & Denis Uzhva
Laboratory of ultra-high energy physics
St. Petersburg State University
a.seryakov@spbu.ru

CENTRALITY BY HADRONIC CALORIMETERS

NA61/SHINE

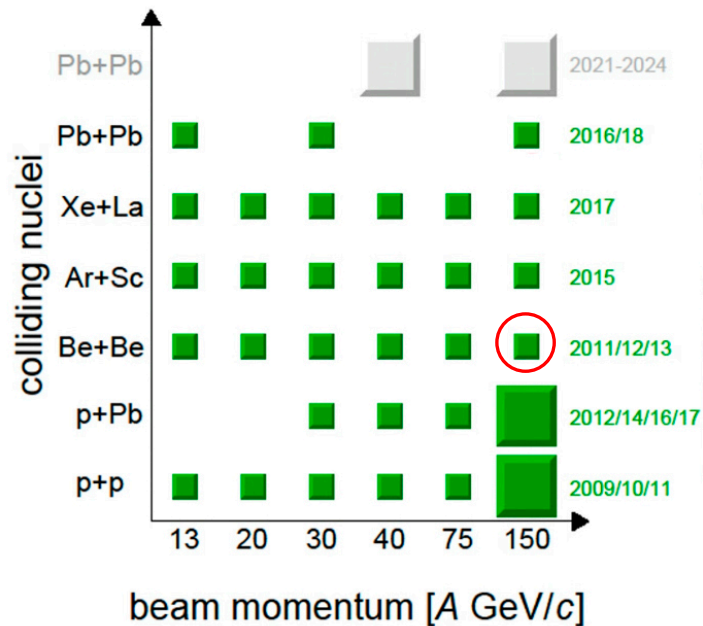


MPD | NICA



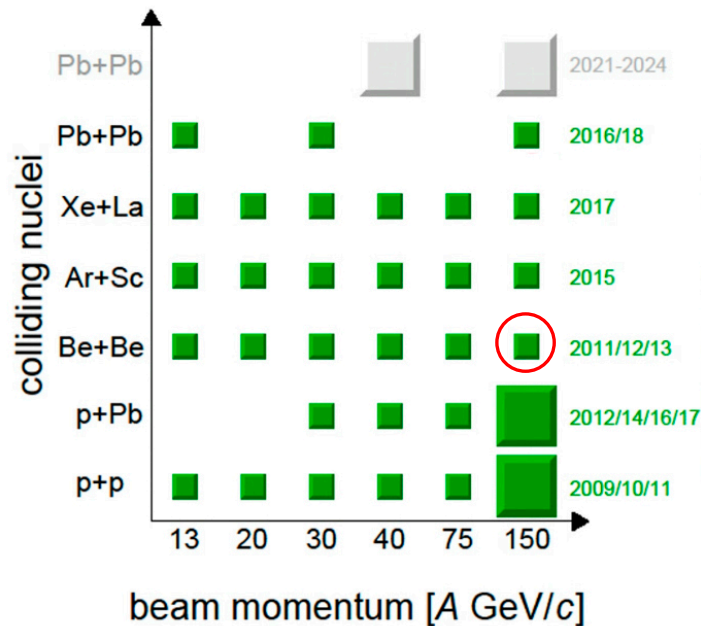
CONCEPT STUDY

- $7\text{Li}+9\text{Be}$ SHIELD 80k events
- GEANT4 PSD NA61 / SHINE



CONCEPT STUDY

- 7Li+9Be SHIELD 80k events
- GEANT4 PSD NA61/SHINE

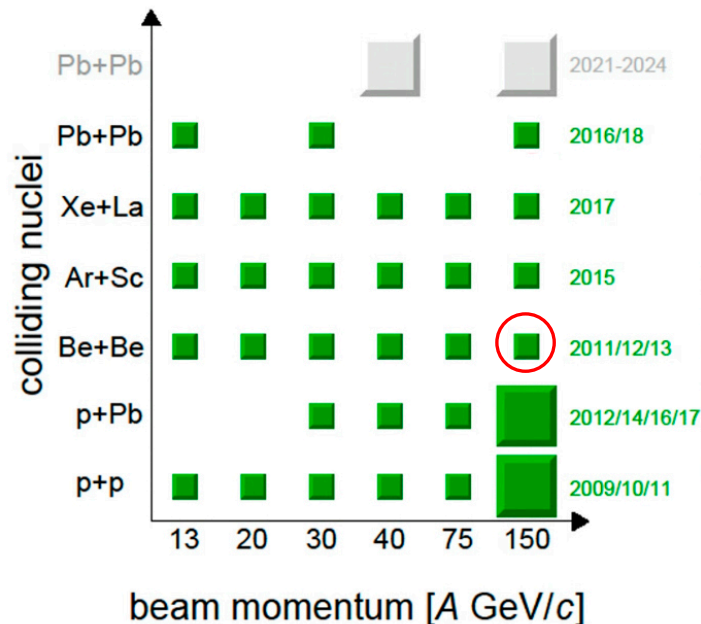


Why this system?

- **Very challenging due to high fluctuations** Universe 2019, 5(5), 126

CONCEPT STUDY

- 7Li+9Be SHIELD 80k events
- GEANT4 PSD NA61/SHINE

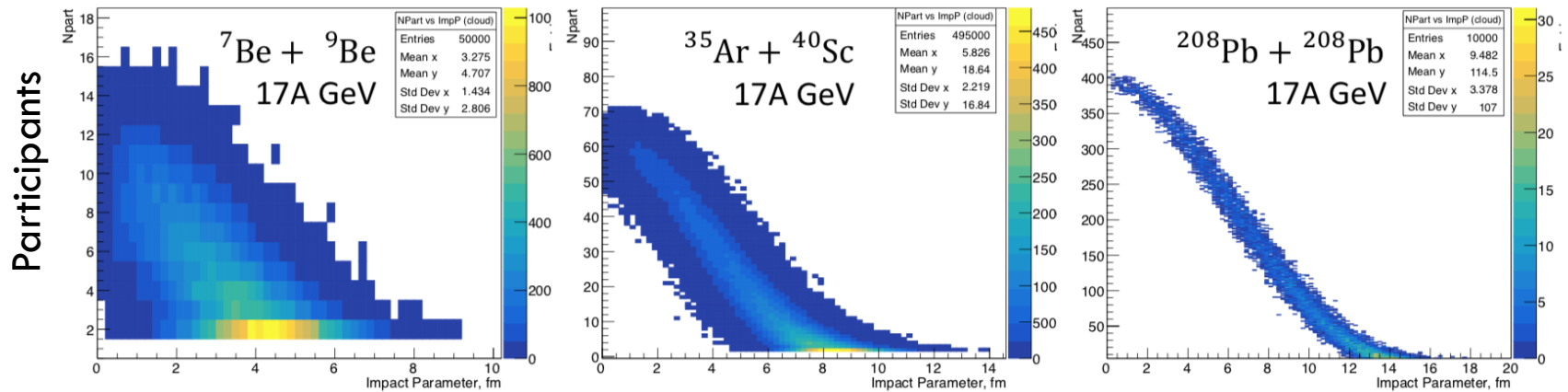


Why this system?

- **Very challenging due to high fluctuations** Universe 2019, 5(5), 126
- **Small. Hope to be able to distinguish single spectators**

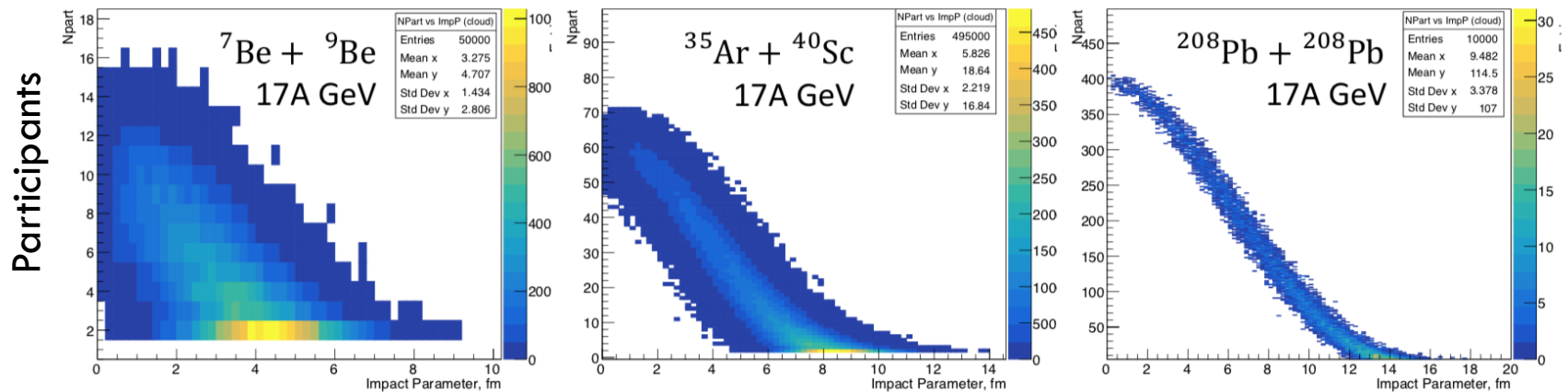
CONCEPT STUDY

- $7\text{Li} + 9\text{Be}$ SHIELD 80k events
- GEANT4 PSD NA61/SHINE



CONCEPT STUDY

- $7\text{Li} + 9\text{Be}$ SHIELD 80k events
- GEANT4 PSD NA61/SHINE

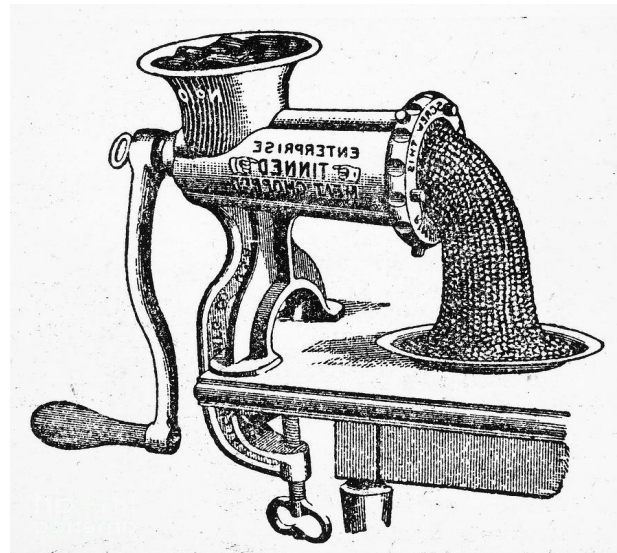


Impact parameter isn't a meaningful quantity!

We will define centrality based on:

- Forward energy
- N forward spectators

CALORIMETER FOR CENTRALITY

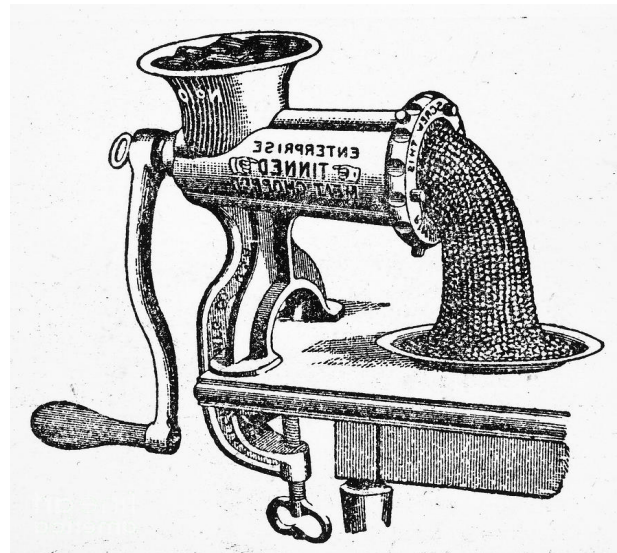


CALORIMETER FOR CENTRALITY



Forward energy:

- Spectators
- Produced hadrons



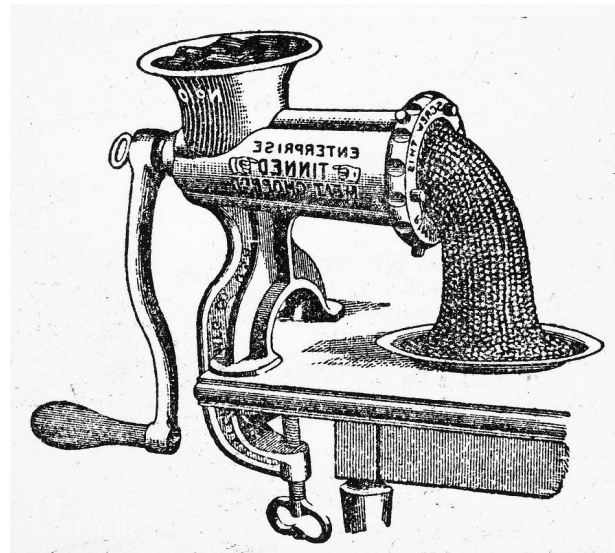
CALORIMETER FOR CENTRALITY



Forward energy:

- Spectators
- Produced hadrons

- resolution
- energy leakages
- electronic and other effects



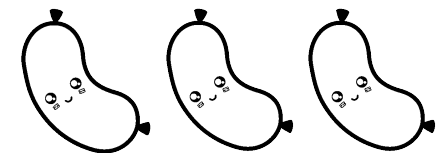
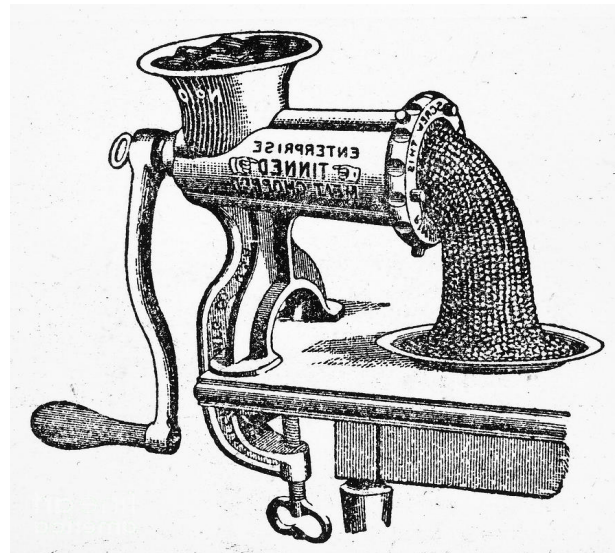
CALORIMETER FOR CENTRALITY



Forward energy:

- Spectators
- Produced hadrons

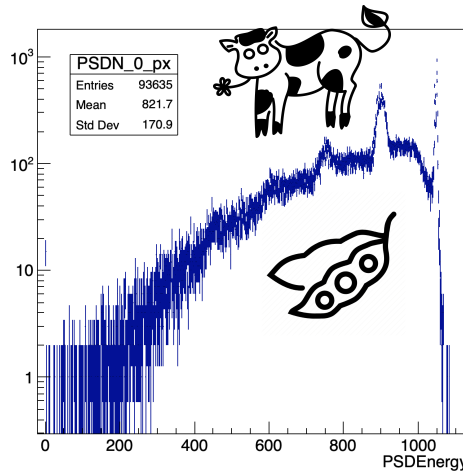
- resolution
- energy leakages
- electronic and other effects



Measured energy

CALORIMETER FOR CENTRALITY

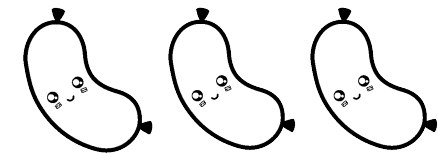
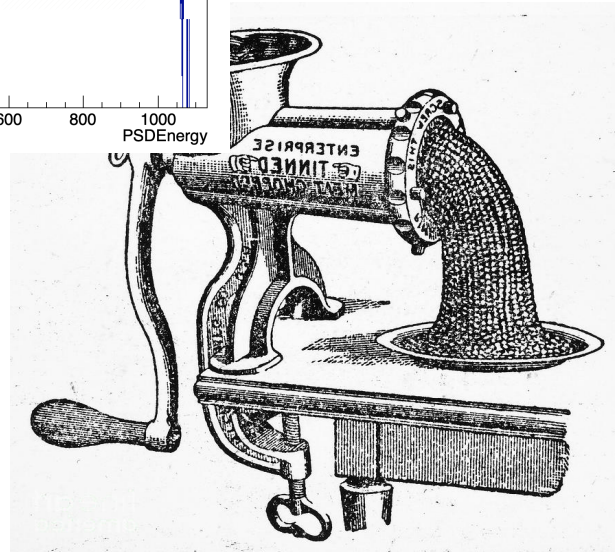
Pure SHIELD Li+Be
forward energy



Forward energy:

- Spectators
- Produced hadrons

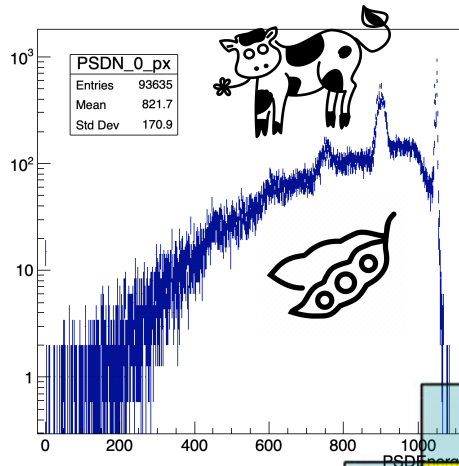
- resolution
- energy leakages
- electronic and other effects



Measured energy

CALORIMETER FOR CENTRALITY

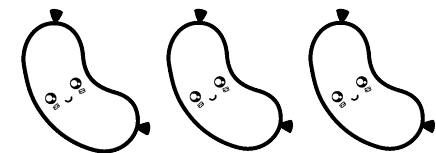
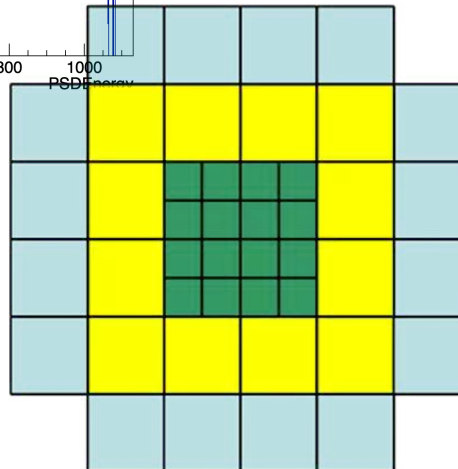
Pure SHIELD Li+Be
forward energy



Forward energy:

- Spectators
- Produced hadrons

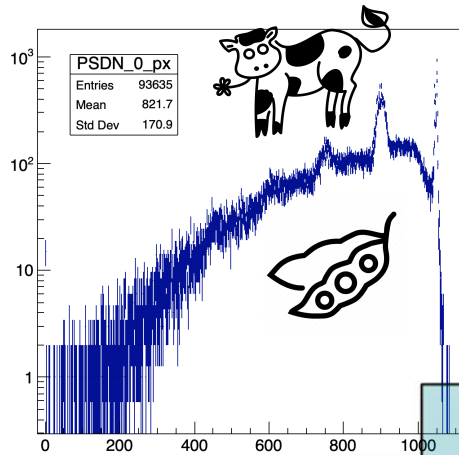
- resolution
- energy leakages
- electronic and other effects



Measured energy

CALORIMETER FOR CENTRALITY

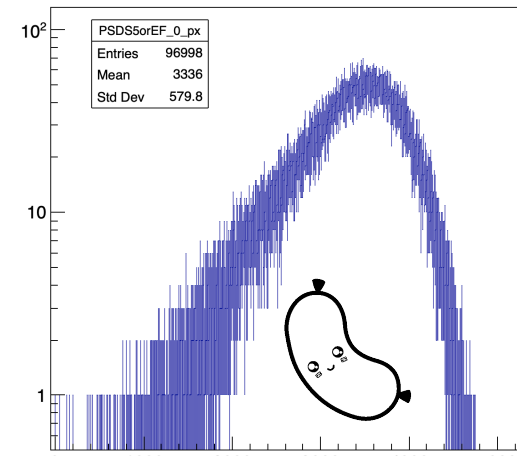
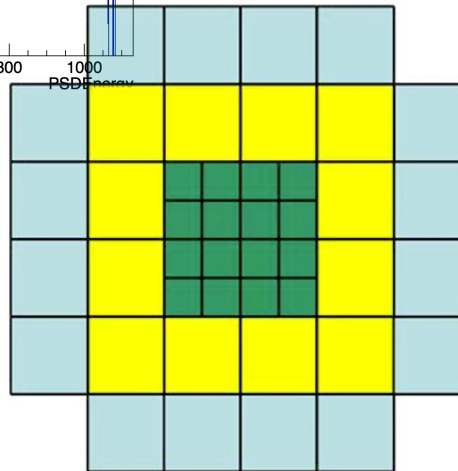
Pure SHIELD Li+Be
forward energy



Forward energy:

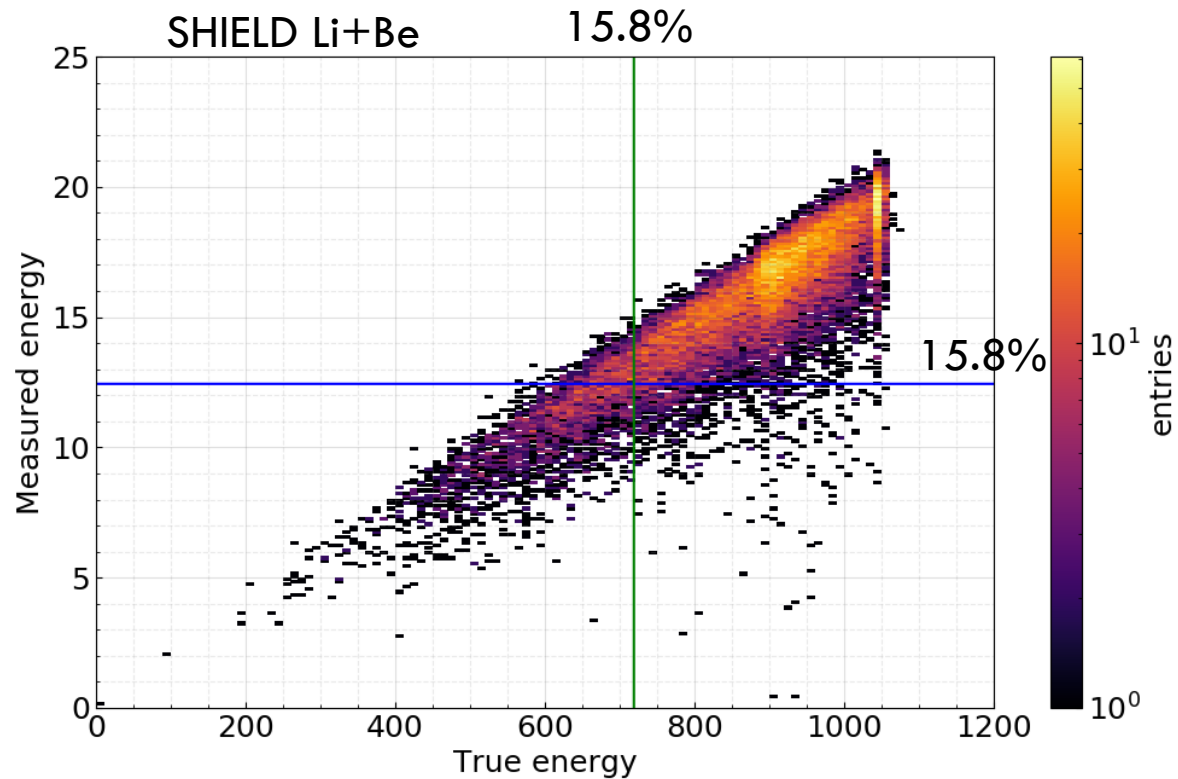
- Spectators
- Produced hadrons

- resolution
- energy leakages
- electronic and other effects

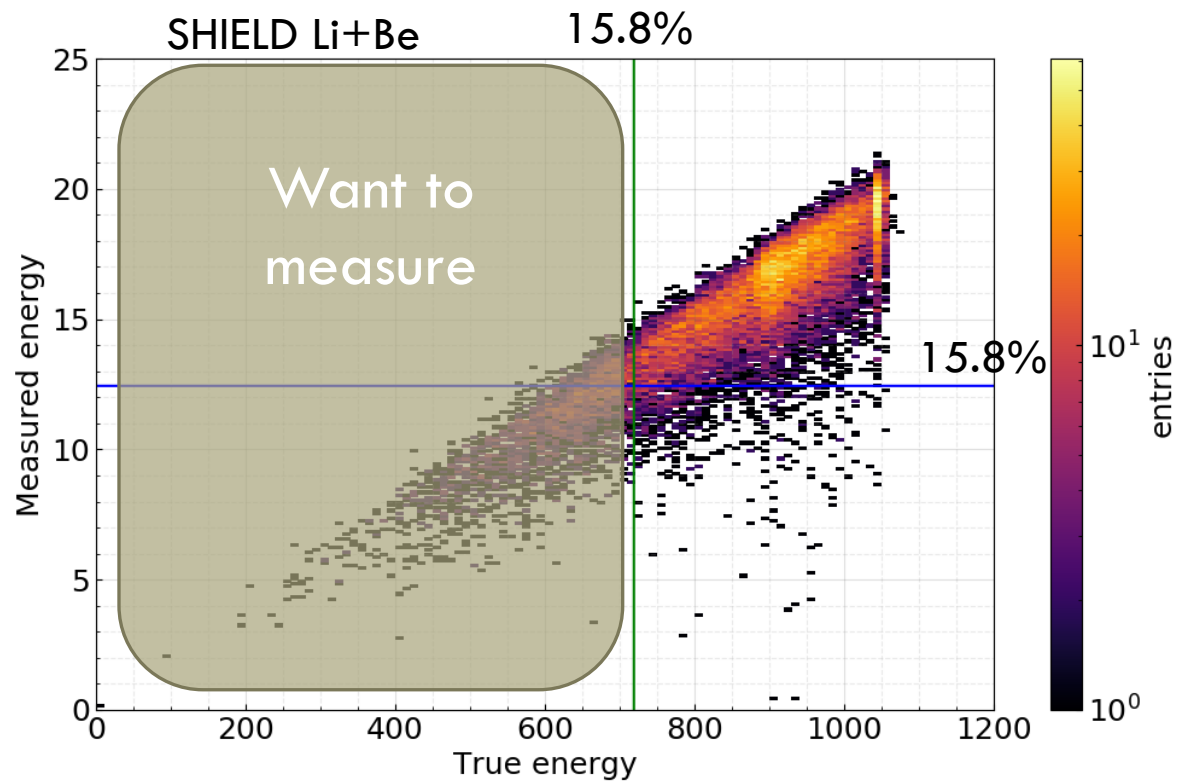


Measured energy
(SHIELD Li+Be + GEANT4 PSD)

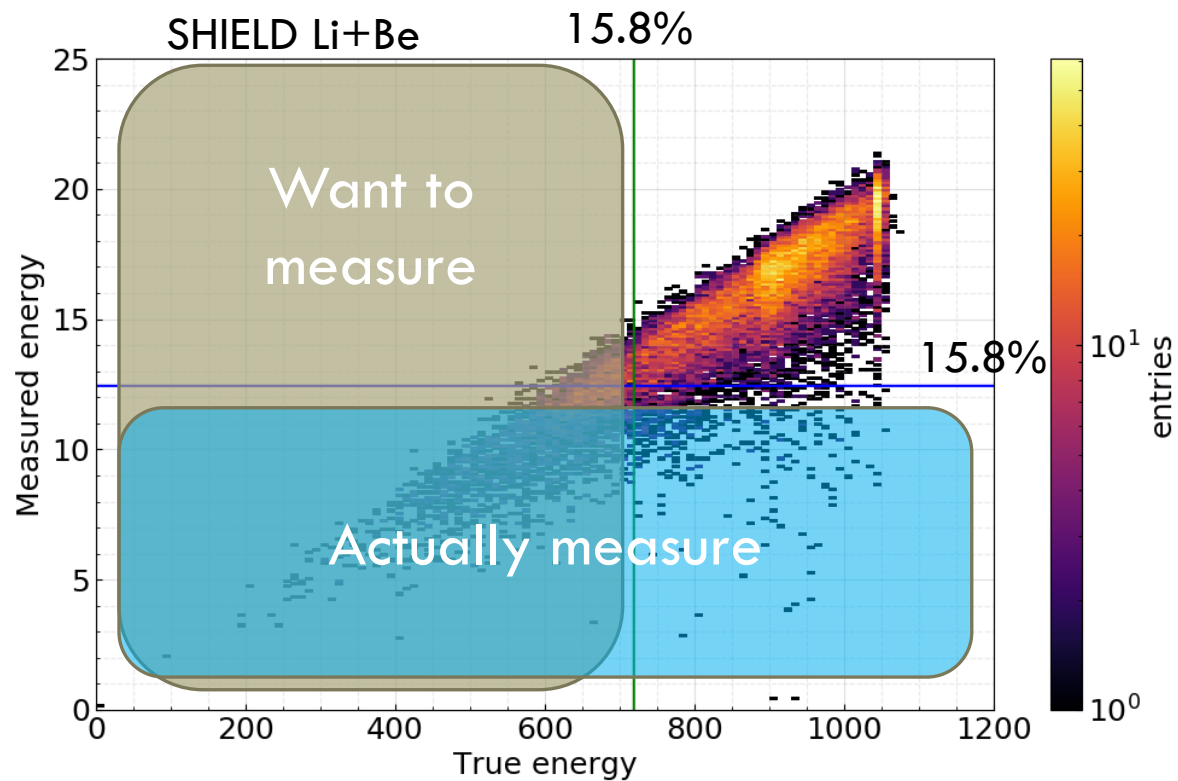
FORWARD VS MEASURED



FORWARD VS MEASURED

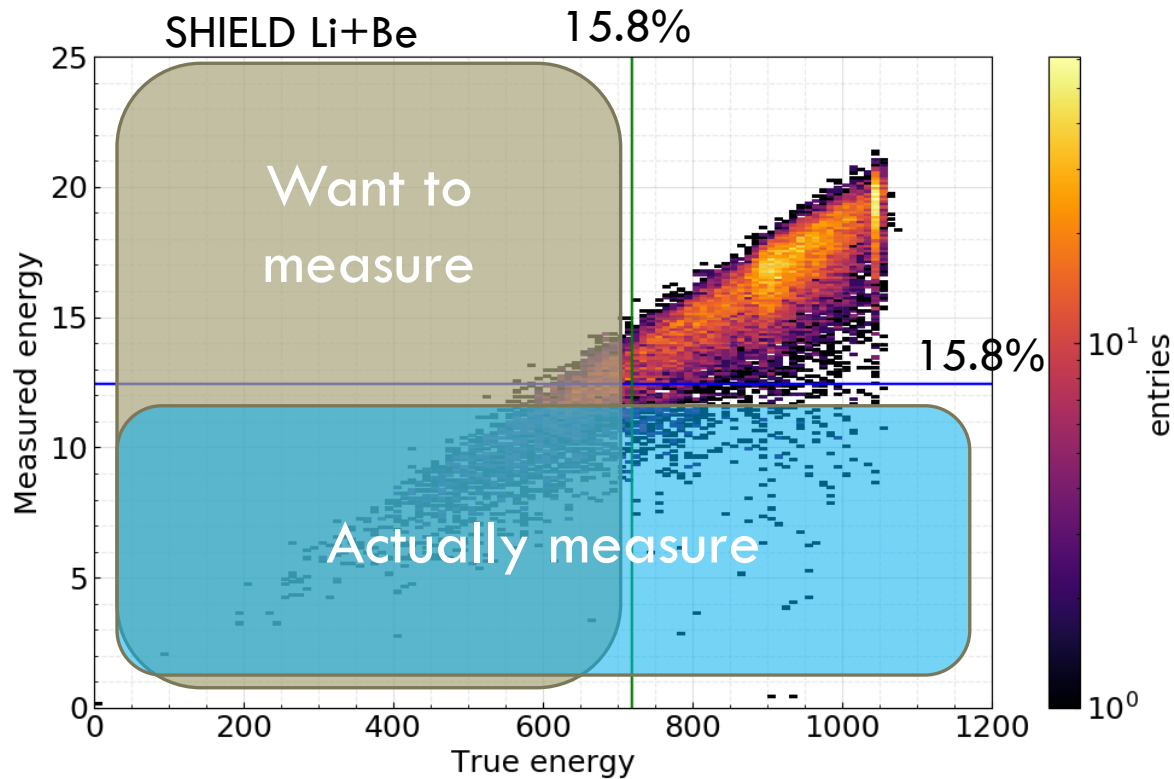


FORWARD VS MEASURED

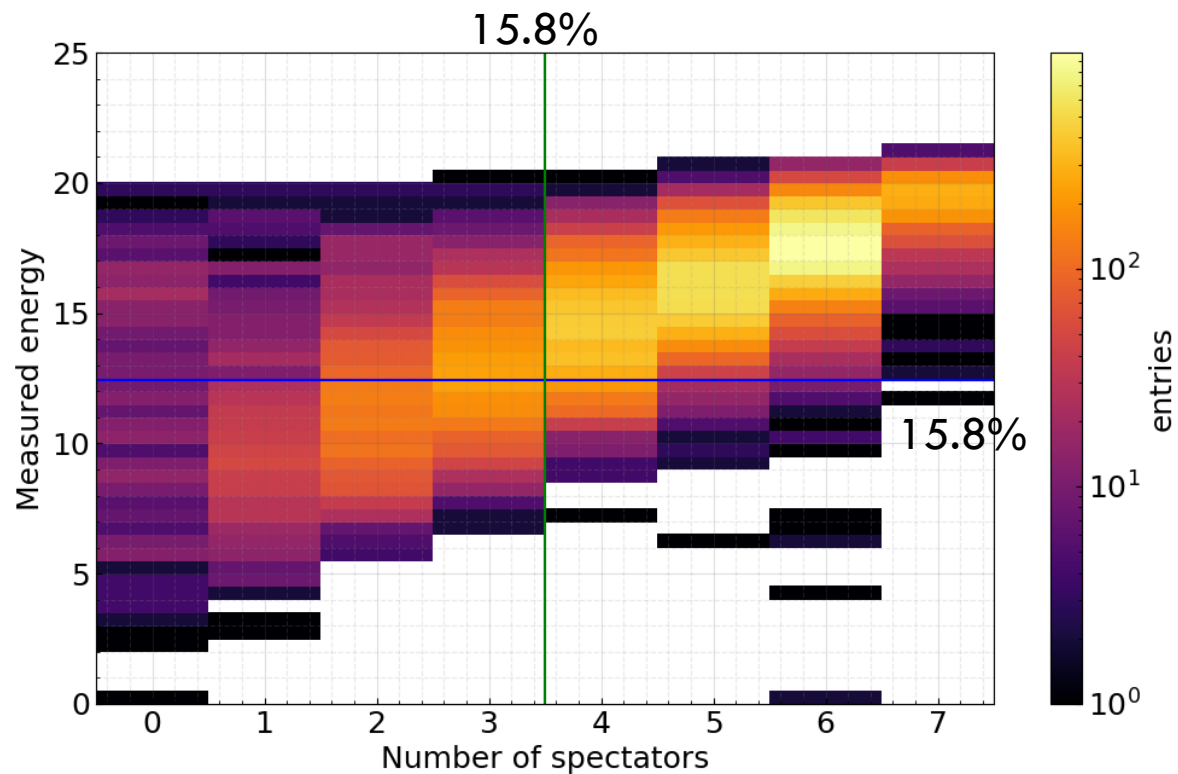


FORWARD VS MEASURED

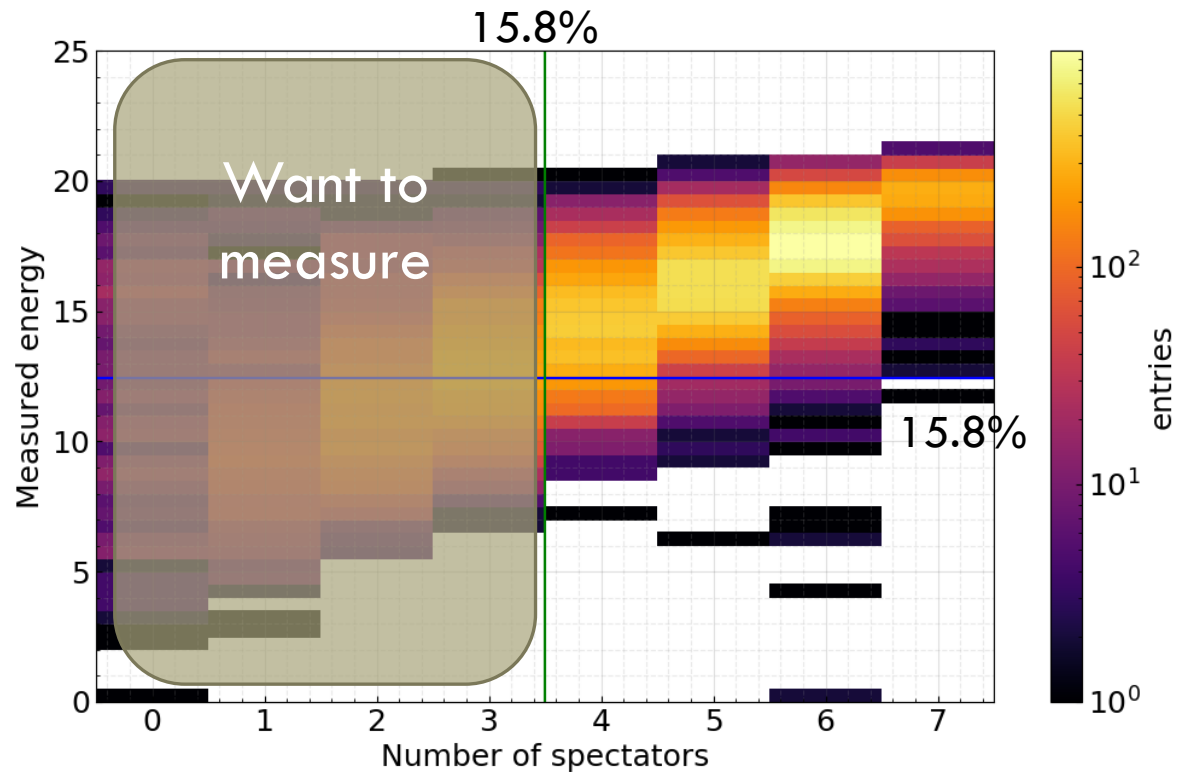
	True	Measured	Bias
$\langle N \rangle$	19.59	18.56	5.3%
$\omega[N]$	1.88	2.65	41%



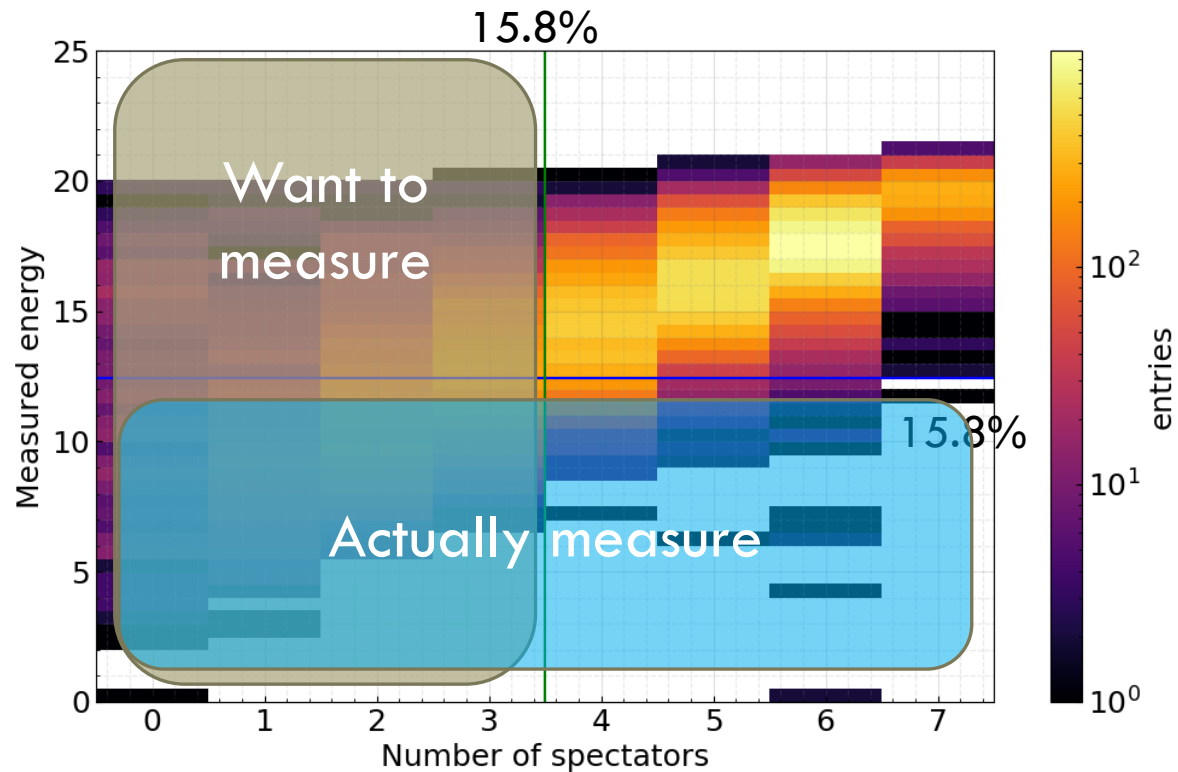
FORWARD SPECTATORS VS MEASURED



FORWARD SPECTATORS VS MEASURED

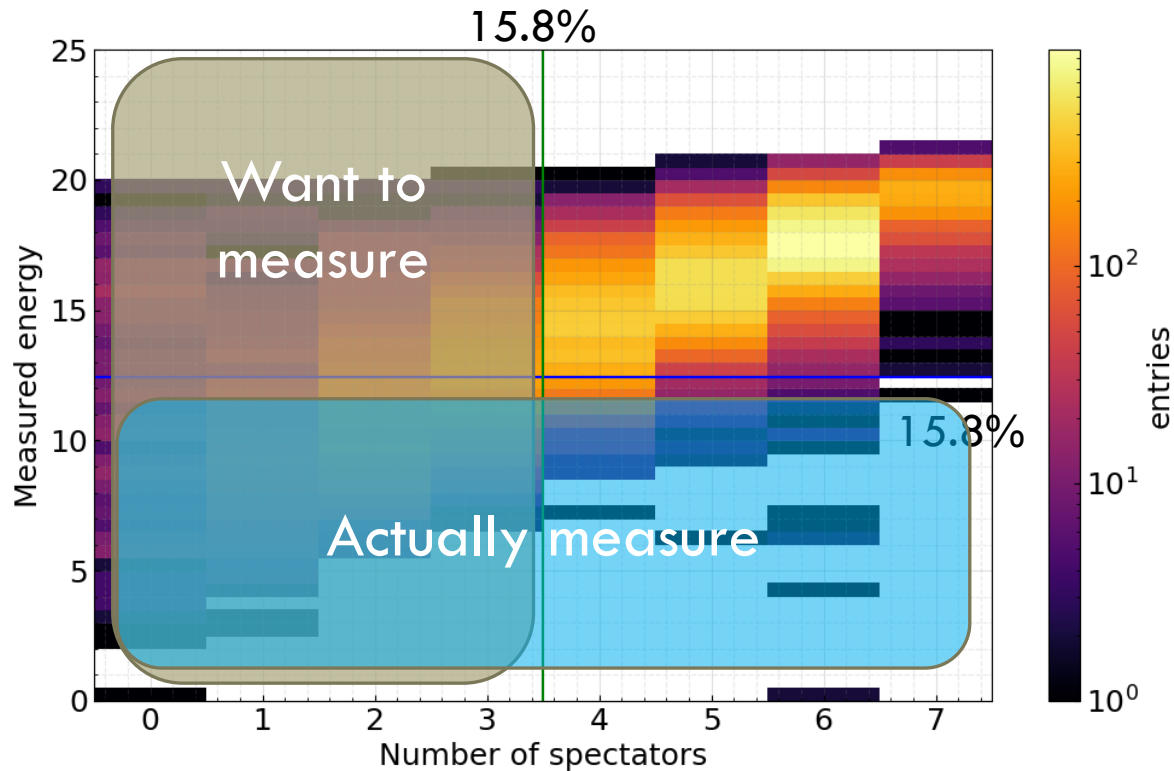


FORWARD SPECTATORS VS MEASURED



FORWARD SPECTATORS VS MEASURED

	True	Measured	Bias
$\langle N \rangle$	15.69	18.56	18.3%
$\omega[N]$	3.67	2.65	28%



CAN WE DO IT BETTER?

CONVOLUTIONAL NEURAL NETS

Classification



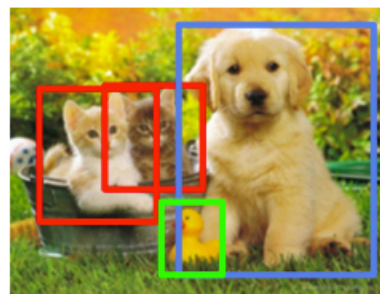
CAT

**Classification
+ Localization**



CAT

Object Detection



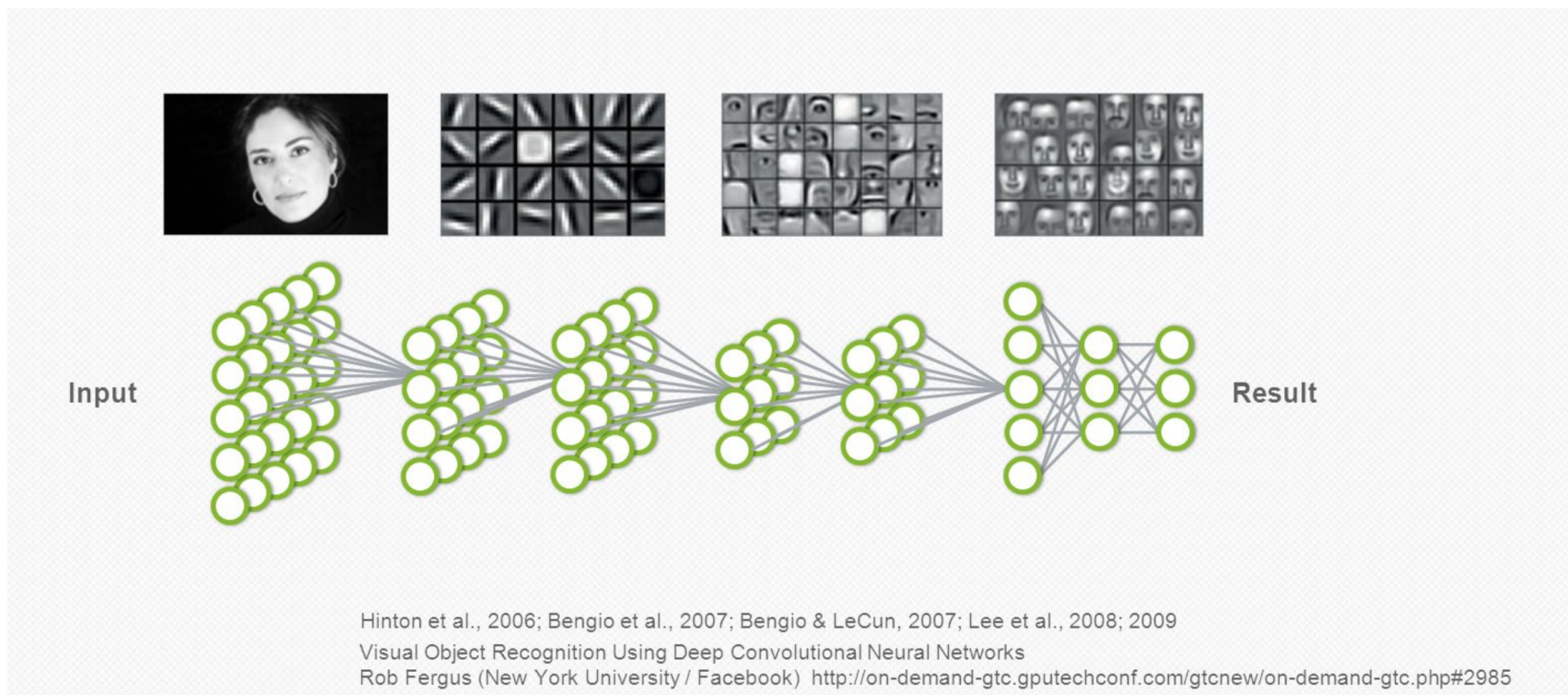
CAT, DOG, DUCK

**Instance
Segmentation**

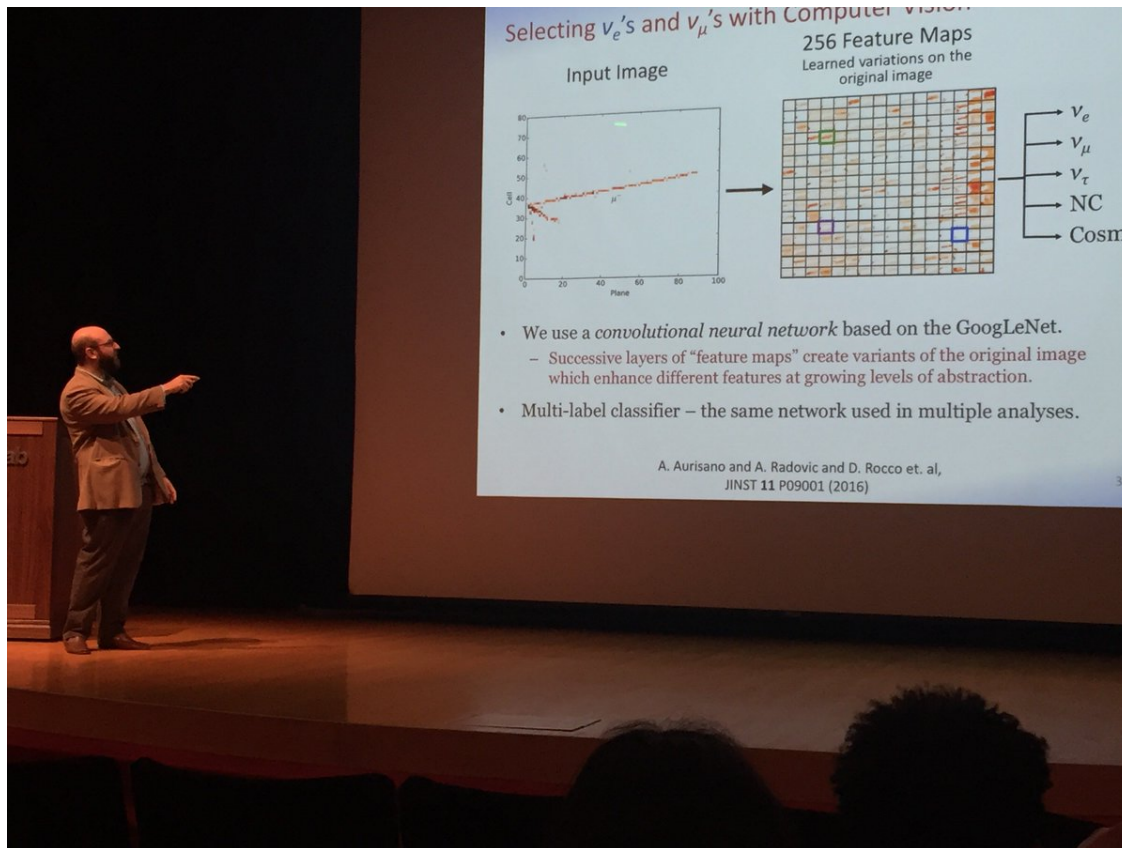


CAT, DOG, DUCK

CONVOLUTIONAL NEURAL NETS



CONVOLUTIONAL NEURAL NETS



Selecting ν_e 's and ν_μ 's with Computer Vision

Input Image 256 Feature Maps
Learned variations on the original image

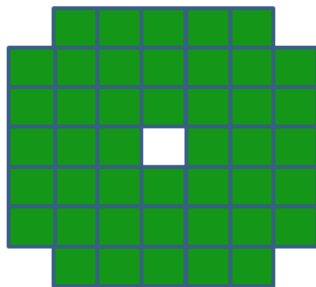
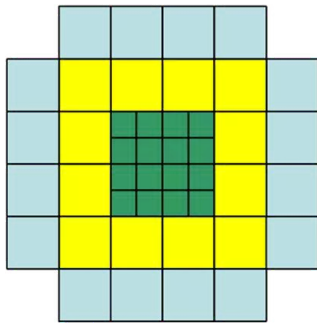
ν_e
 ν_μ
 ν_τ
 NC
 Cosmi

- We use a *convolutional neural network* based on the GoogLeNet.
 - Successive layers of “feature maps” create variants of the original image which enhance different features at growing levels of abstraction.
- Multi-label classifier – the same network used in multiple analyses.

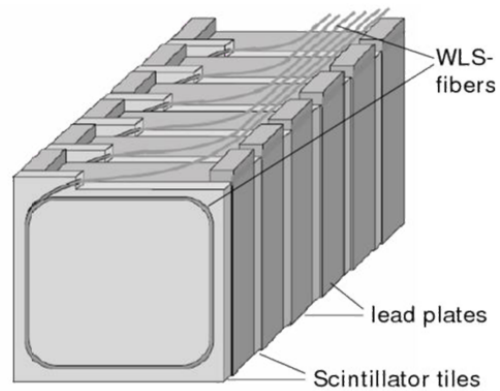
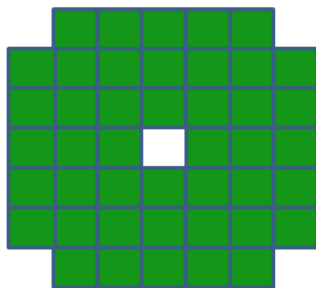
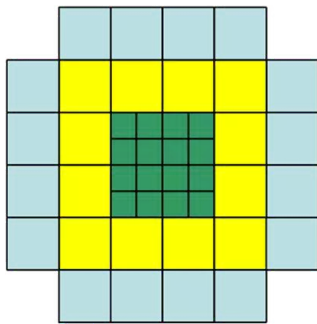
A. Aurisano and A. Radovic and D. Rocco et. al,
 JINST 11 P09001 (2016) 38

JETP seminar “First Oscillation Results from NOvA”, 2018

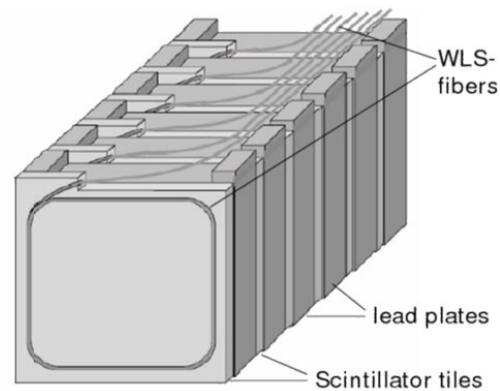
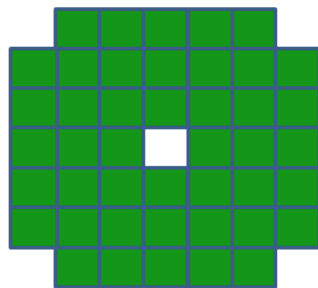
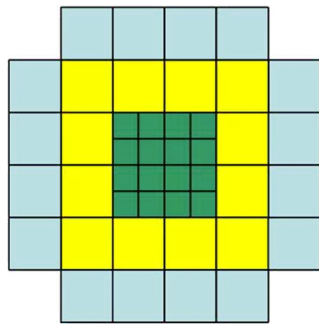
CALORIMETER AS A PICTURE



CALORIMETER AS A PICTURE



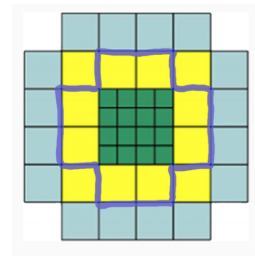
CALORIMETER AS A PICTURE



A 3D picture!
 NA61/SHINE PSD
 44 modules X 10 sections

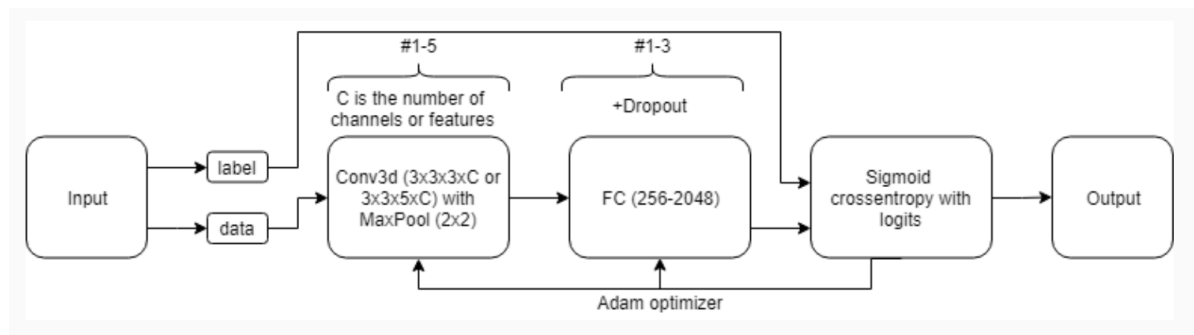
CNN FOR CENTRALITY

SHIELD Li+Be 80k min.bias events: 60k for training and 20k for test
 We use 24 calorimeter modules (as the collaboration does)

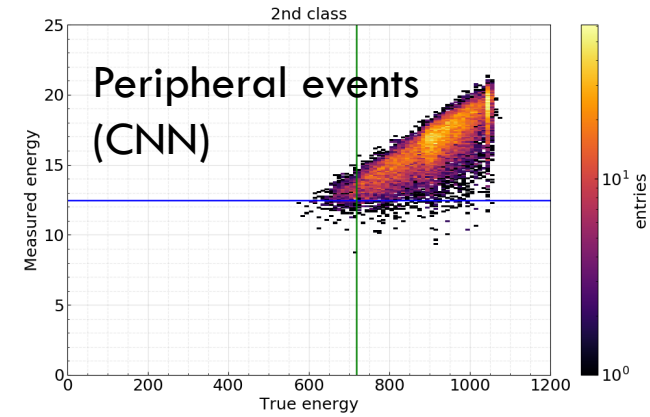
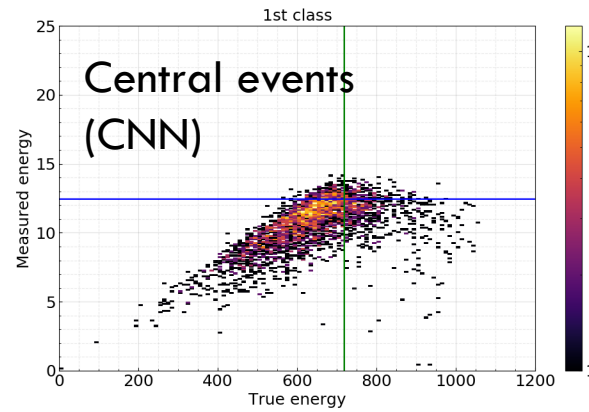
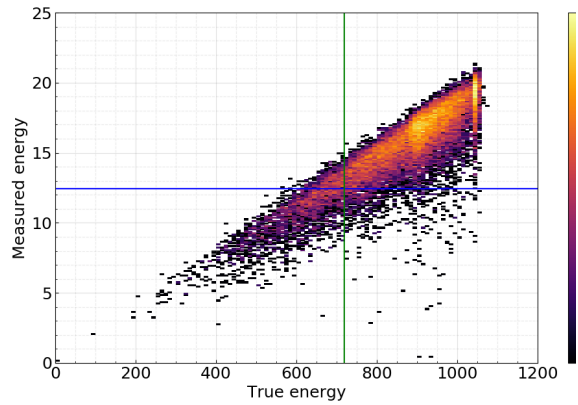


2 CNN from TensorFlow library

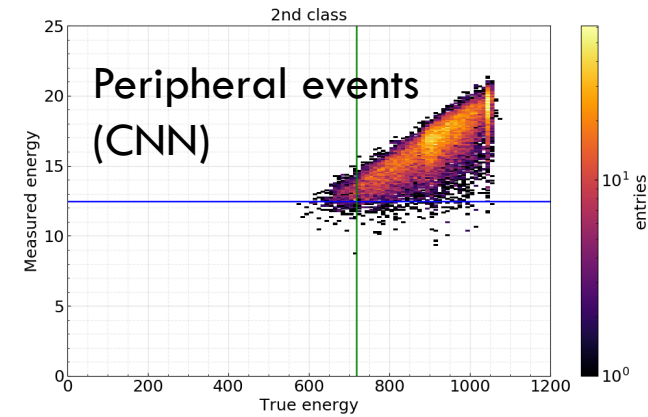
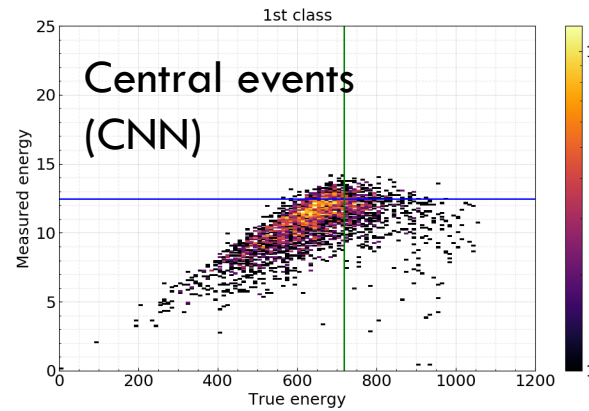
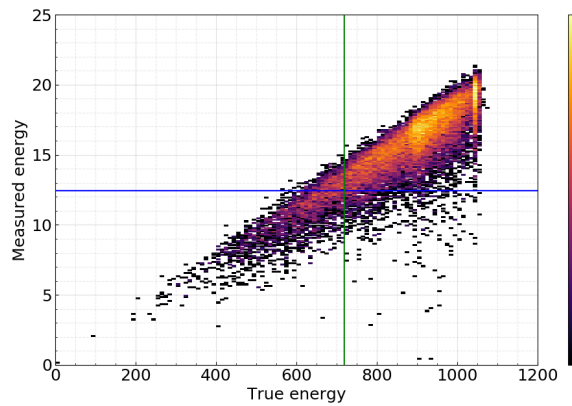
- for forward energy
- for forward spectators



RESULTS: FORWARD ENERGY

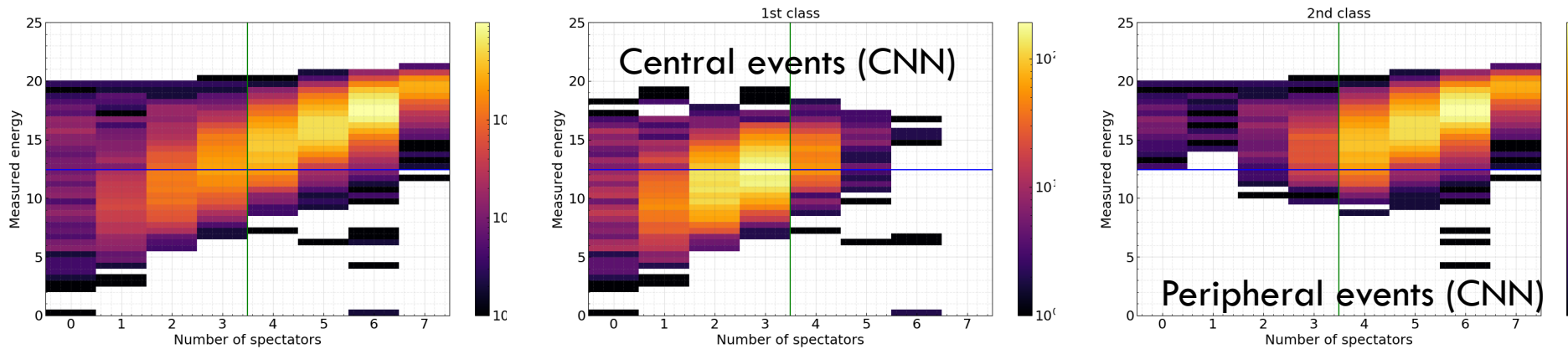


RESULTS: FORWARD ENERGY

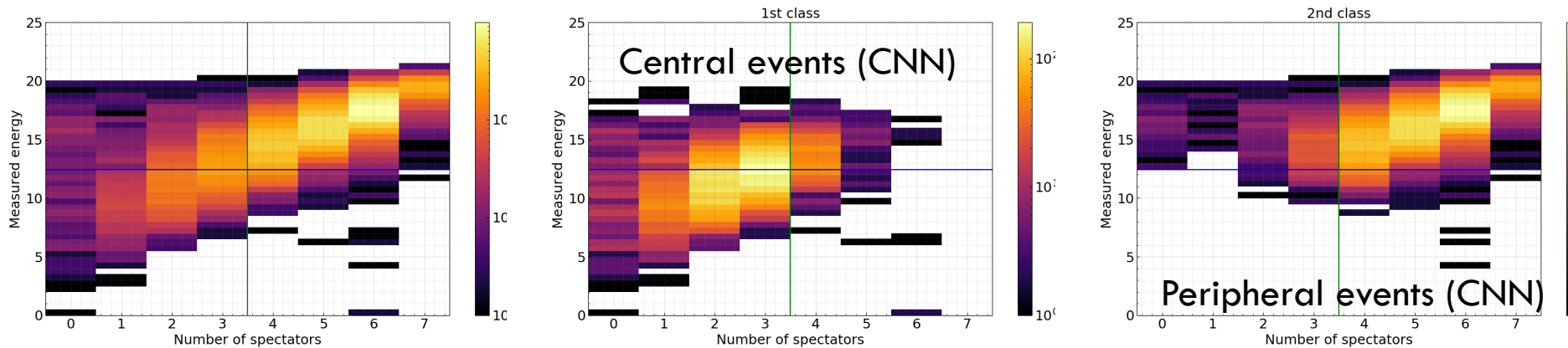


	True	Measured	Bias		CNN	Bias
$\langle N \rangle$	19.59	18.56	5.3%		18.69	4.6%
$\omega[N]$	1.88	2.65	41%		2.49	32%

RESULTS: FORWARD SPECTATORS



RESULTS: FORWARD SPECTATORS



	True	Measured	Bias		CNN	Bias
$\langle N \rangle$	15.69	18.56	18.3%		16.36	4.3%
$\omega[N]$	3.67	2.65	28%		2.49	10%

CONCLUSIONS AND PLANS

- CNN helps to reduce systematic biases from calorimeter effects especially in the spectator based centrality method

Forward energy based centrality

biases	Without CNN	With CNN
$\langle N \rangle$	5.3%	4.6%
$\omega[N]$	41%	32%

Forward spectators based centrality

biases	Without CNN	With CNN
$\langle N \rangle$	18.3%	4.3%
$\omega[N]$	28%	10%

CONCLUSIONS AND PLANS

- CNN helps to reduce systematic biases from calorimeter effects especially in the spectator based centrality method
- Different MC is needed for a cross-check

Forward energy based centrality

biases	Without CNN	With CNN
$\langle N \rangle$	5.3%	4.6%
$\omega[N]$	41%	32%

Forward spectators based centrality

biases	Without CNN	With CNN
$\langle N \rangle$	18.3%	4.3%
$\omega[N]$	28%	10%

CONCLUSIONS AND PLANS

- CNN helps to reduce systematic biases from calorimeter effects especially in the spectator based centrality method
- Different MC is needed for a cross-check
- we are looking forward to test our methods for heavy systems on both collider and fixed-target mode

Forward energy based centrality

biases	Without CNN	With CNN
$\langle N \rangle$	5.3%	4.6%
$\omega[N]$	41%	32%

Forward spectators based centrality

biases	Without CNN	With CNN
$\langle N \rangle$	18.3%	4.3%
$\omega[N]$	28%	10%

DZIĘKUJĘ

NICA days. 2019



St Petersburg
University



This research was funded by the Russian Science Foundation grant number 17-72-20045.

a.seryakov@spbu.ru

Accuracy of the CNN

CNN shows better results in accuracy, especially in the task of N_{spec} classification

	Forward energy	N_{spec}
Cut-based	93.0%	86.7%
CNN	93.7%	92.8%

FORWARD ENERGY: SHIELD VS EPOS

