EIC FST Simulation

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On Behalf of LANL EIC Group

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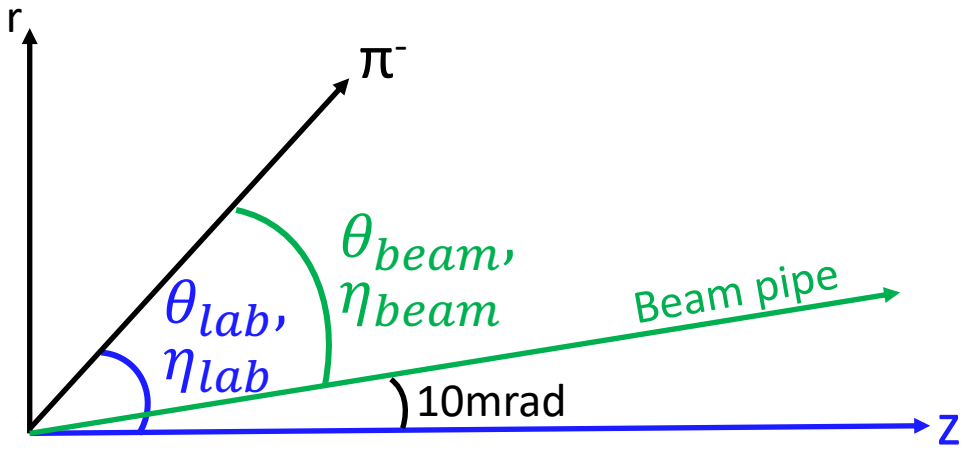
Outline

- Pseudorapidity correction for the beam pipe
- More FST designs
- Momentum resolutions
- DCA resolutions
- Vertex resolutions

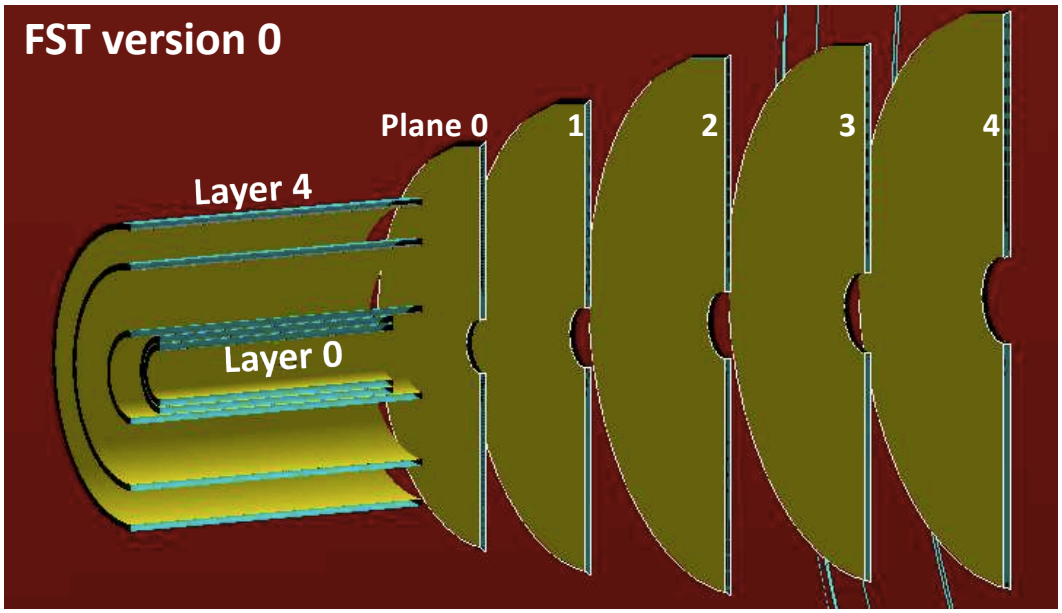
Pseudorapidity Correction



η_{beam} w.r.t. to the ion beam pipe	η_{lab} w.r.t to lab frame
1	0.985
1.5	1.49
2	1.96
2.5	2.49
3	2.90

Detector Initial Design in Fun4all

Babar magnet with a peak at 1.4 T magnetic field



Barrel layer

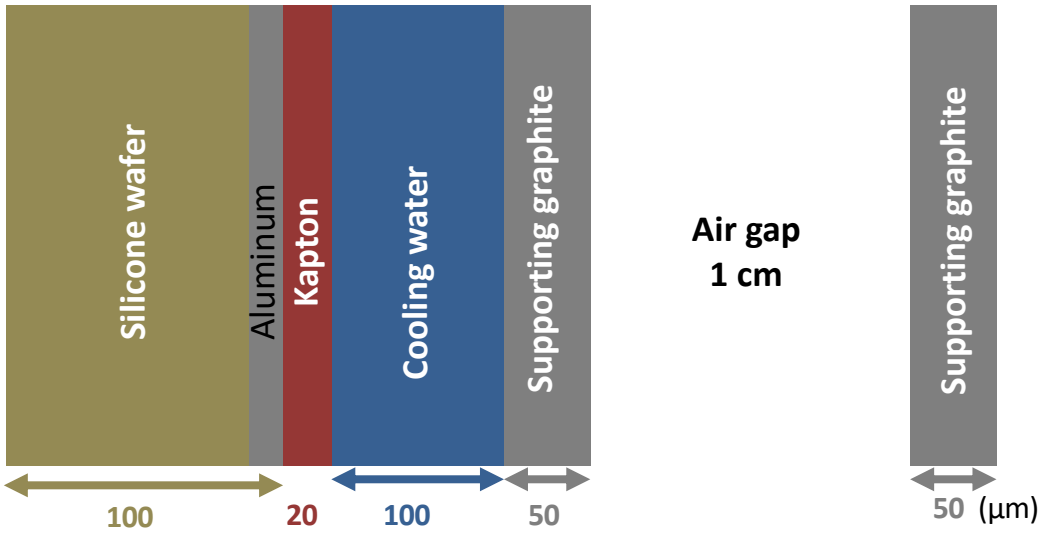
Layer	Half length (cm)	r (cm)
0	20	3.64
1	20	4.81
2	25	5.98
3	25	16
4	25	22

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	30
1	53	4.5	35
2	77	5	36
3	101	6	38.5
4	125	6.5	45

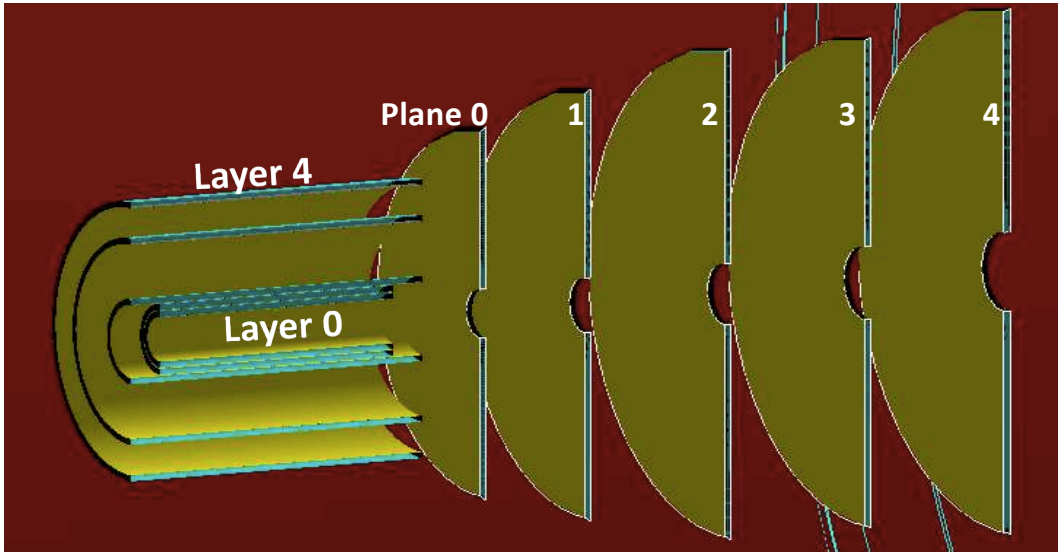
Detector Initial Design in Fun4all

Material sublayers of the plane detectors
(arbitrary scale)



Updated Versions of FST Design

Version 0



Barrel layer

Layer	Half length (cm)	r (cm)
0	20	3.64
1	20	4.81
2	25	5.98
3	25	16
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Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	30
1	53	4.5	35
2	77	5	36
3	101	6	38.5
4	125	6.5	45

100um thick silicon wafer in both barrel and FST

Version 1: modify the outer radius of the plane 0 and 1

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	**25**
1	53	4.5	**36**
2	77	5	36
3	101	6	38.5
4	125	6.5	45

100um thick silicon wafer in the layer 3 & 4 of the barrel, 50um thick silicon wafer in the rest of barrel and FST

Version 2: move the last plane (plane 4) from Version 0 far back to z=2.7m to improve detector performance at large pseudorapidity

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	30
1	53	4.5	35
2	77	5	36
3	101	6	38.5
4	**270**	6.5	45

100um thick silicon wafer in the layer 3 & 4 of the barrel, 50um thick silicon wafer in the rest of barrel and FST

New FST Design: Version 3

Version 1

Barrel layer

Layer	Half length (cm)	r (cm)	Pixel pitch (um)	Silicon thickness (um)
0	20	3.64	20	50
1	20	4.81	20	50
2	25	5.98	20	50
3	25	16	20	100
4	25	22	20	100

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)	Pixel pitch (um)	Silicon thickness (um)
0	35	4	25	20	50
1	53	4.5	36	20	50
2	77	5	36	20	50
3	101	6	38.5	20	50
4	125	6.5	45	20	50

Version 3

Barrel layer

Layer	Half length (cm)	r (cm)	Pixel pitch (um)	Silicon thickness (um)
0	20	3.64	20	**35**
1	20	4.81	20	**35**
2	25	5.98	20	**35**
3	25	16	20	**35**
4	25	22	20	**35**

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)	Pixel pitch (um)	Silicon thickness (um)
0	35	4	25	20	50
1	53	4.5	36	20	50
2	77	5	36	20	50
3	101	6	38.5	**36.4**	**100**
4	125	6.5	45	**36.4**	**100**

- Lesser material budget at the barrel detector
- Different silicon sensor option at last two planes of FST

New FST Design: Version 4

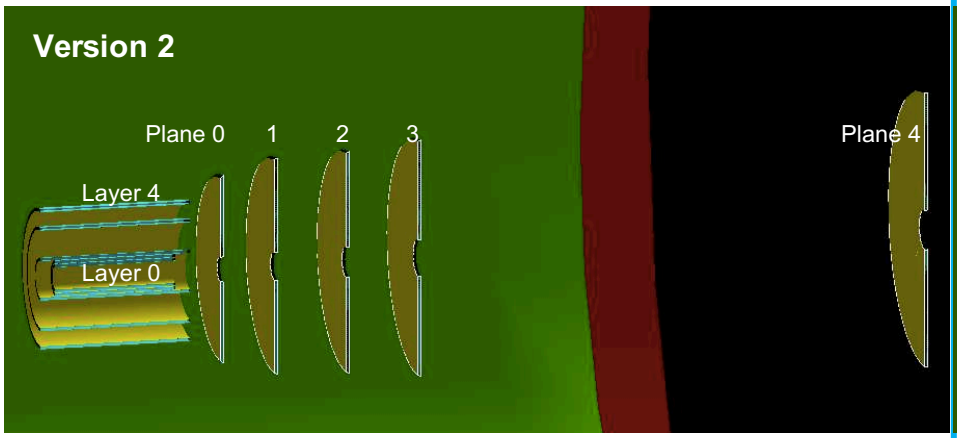
Version 2

Barrel layer

Layer	Half length (cm)	r (cm)	Pixel pitch (um)	Silicon thickness (um)
0	20	3.64	20	50
1	20	4.81	20	50
2	25	5.98	20	50
3	25	16	20	100
4	25	22	20	100

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)	Pixel pitch (um)	Silicon thickness (um)
0	35	4	30	20	50
1	53	4.5	35	20	50
2	77	5	36	20	50
3	101	6	38.5	20	50
4	270	6.5	45	20	50



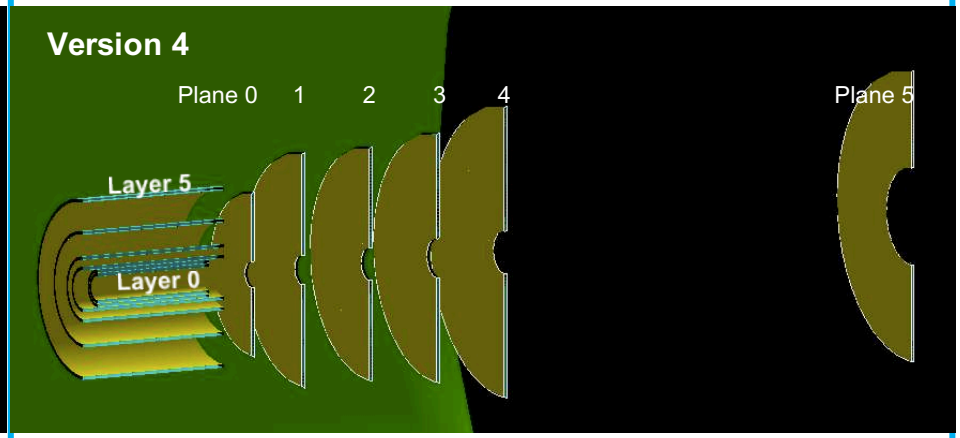
Version 4

Barrel layer

Layer	Half length (cm)	r (cm)	Pixel pitch (um)	Silicon thickness (um)
0	20	3.64	20	50
1	20	4.81	20	50
2	25	5.98	20	50
3	25	9.2	20	100
4	25	17	20	100
5	25	27	20	100

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)	Pixel pitch (um)	Silicon thickness (um)
0	35	4	25	20	50
1	53	4.5	36	20	50
2	77	5	36	20	50
3	101	6	38.5	20	50
4	125	6.5	45	20	50
5	270	15	45	20	50

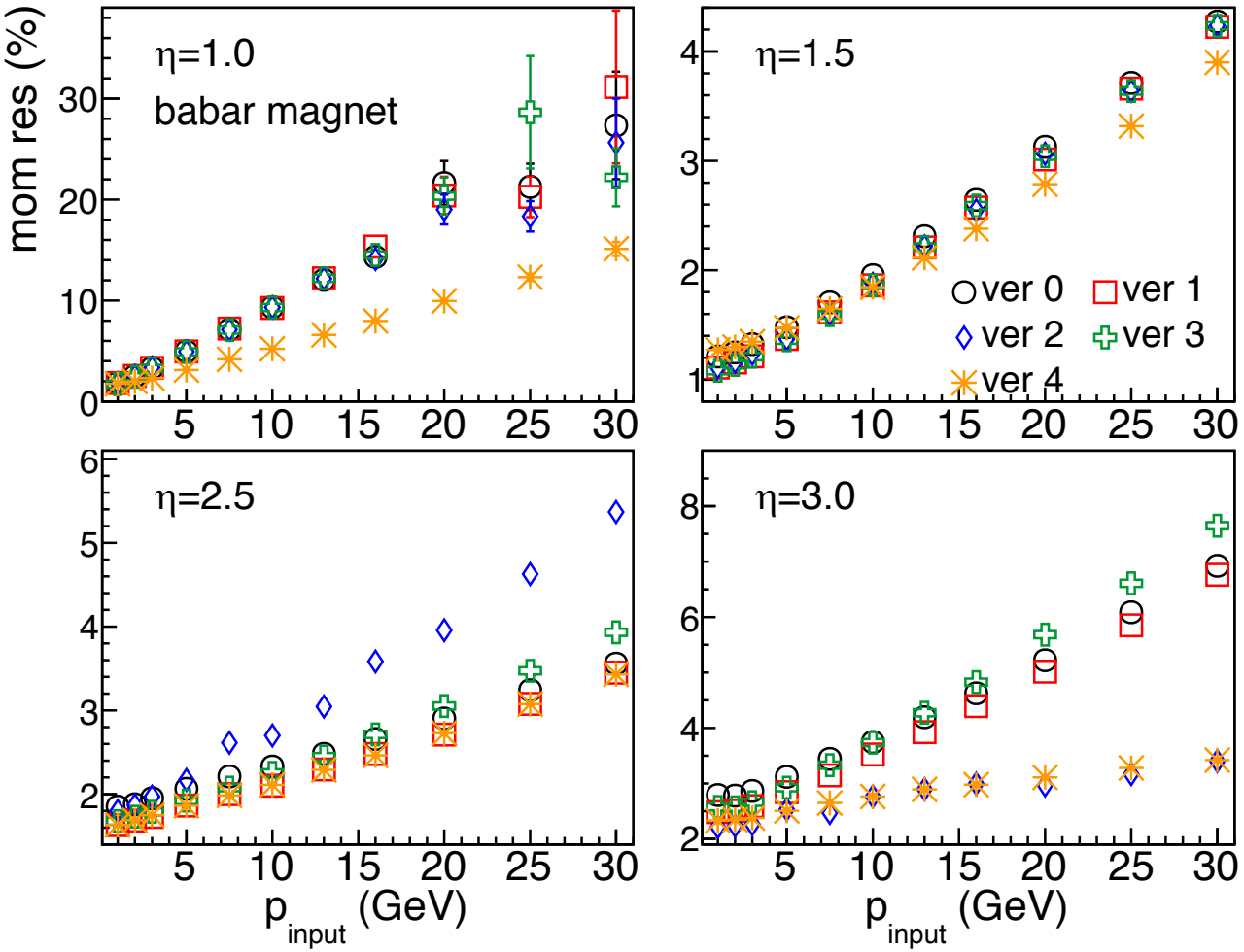


Simulation Setup

- Event configuration:
  - single π- per event.
  - Vertex (0,0,0), 20um smearing in both x and y direction
  - 50k events in each p⊗η bin.
- Track configuration:
  - Momentum: 1-30 GeV with varying increments
  - Pseudorapdity: 1-3 with a 0.5 increment.
  - Hit efficiency at 95%.
- Magnetic Field
  - Babar Magnet peaks at 1.4T
  - Beast Magnet peaks at 3T

Comparison between different FST design w/ Babar magnet

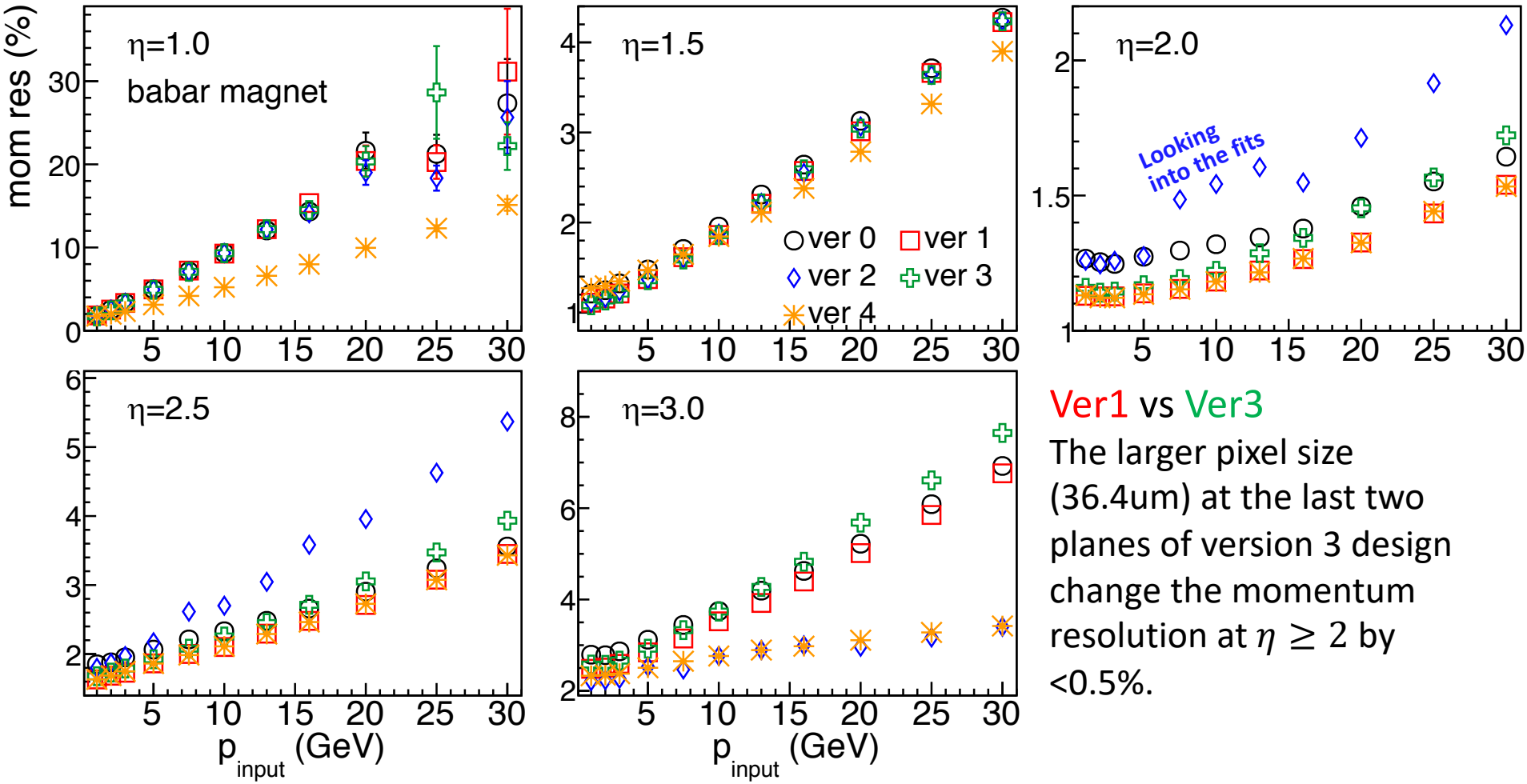
Momentum Resolution (1-30GeV) Compare Designs with Babar Magnet



Ver0 vs ver1

Ver1 gives slightly smaller resolution because of lesser material budget

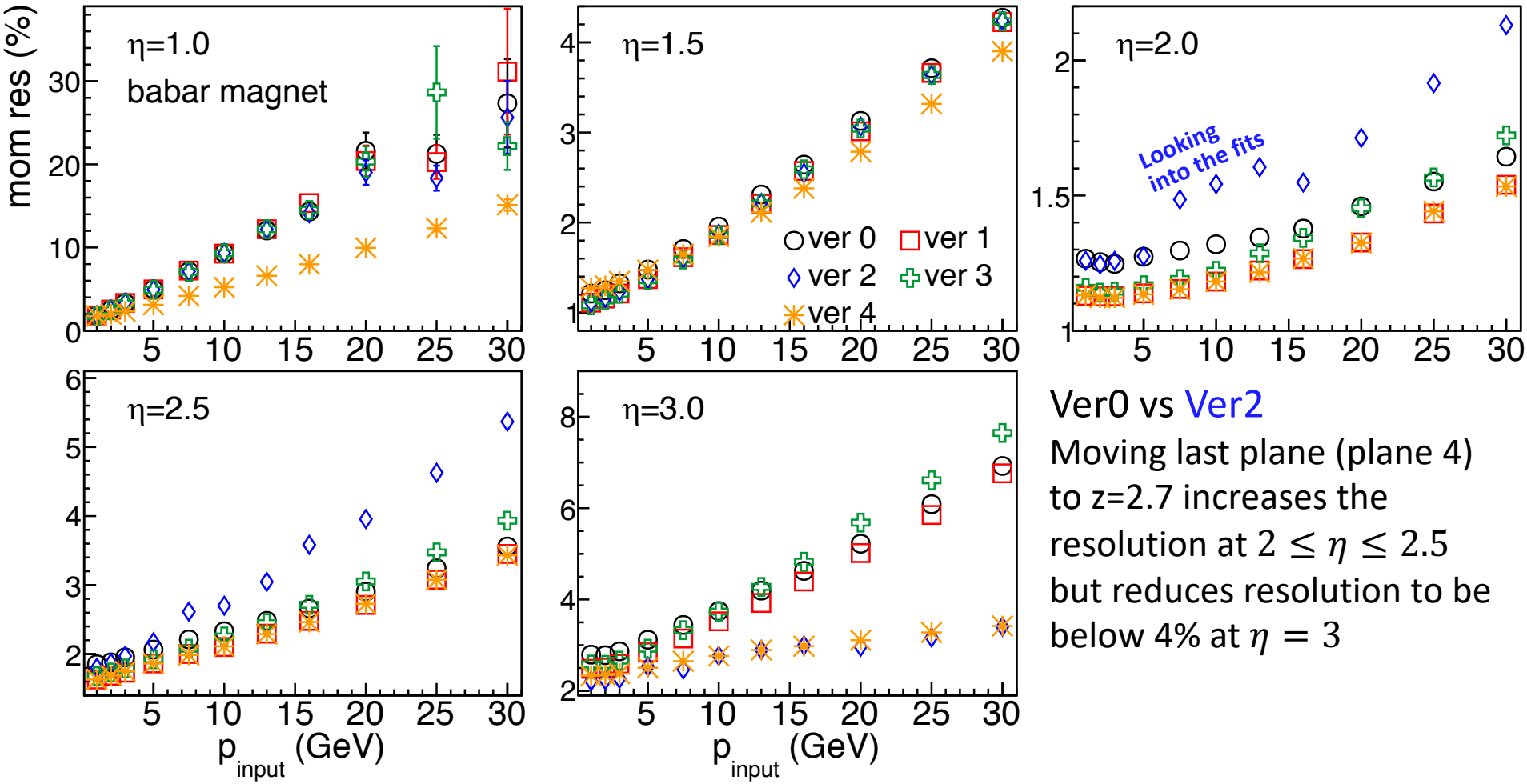
Momentum Resolution (1-30GeV) Compare Designs with Babar Magnet



Ver1 vs Ver3

The larger pixel size (36.4um) at the last two planes of version 3 design change the momentum resolution at $\eta \geq 2$ by <0.5%.

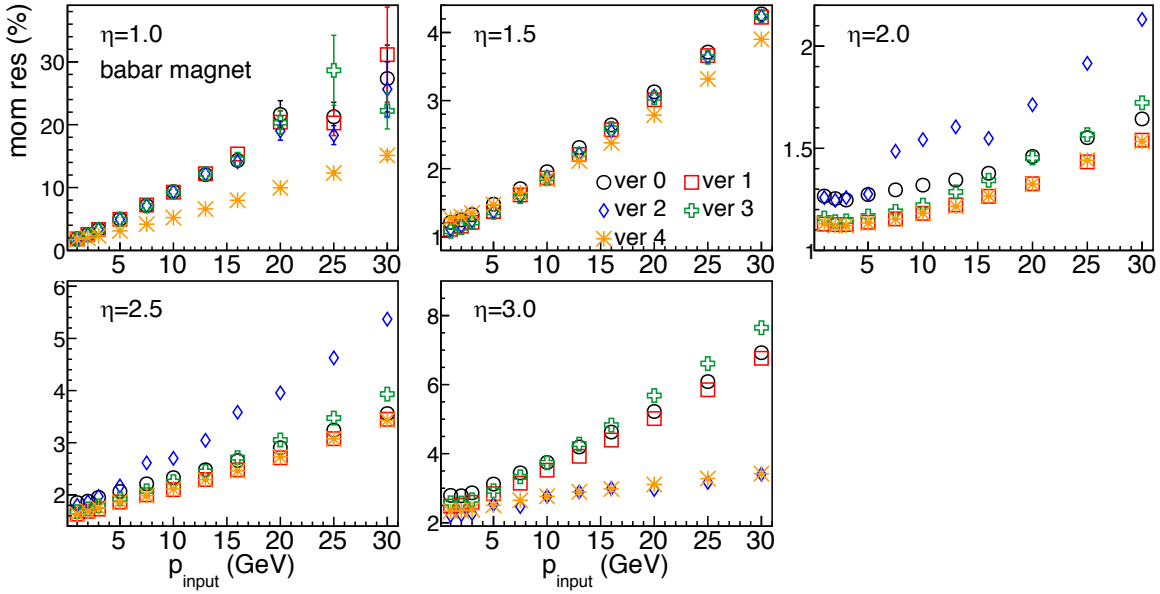
Momentum Resolution (1-30GeV) Compare Designs with Babar Magnet



Ver0 vs Ver2

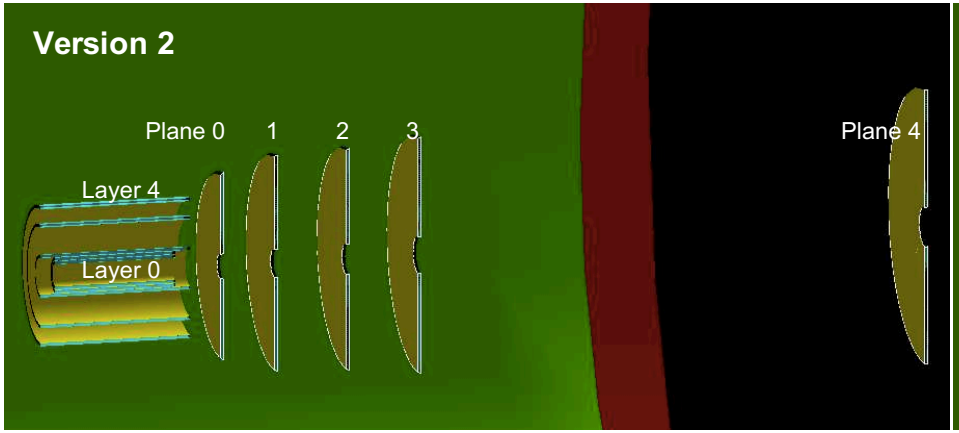
Moving last plane (plane 4) to z=2.7 increases the resolution at $2 \leq \eta \leq 2.5$ but reduces resolution to be below 4% at $\eta = 3$

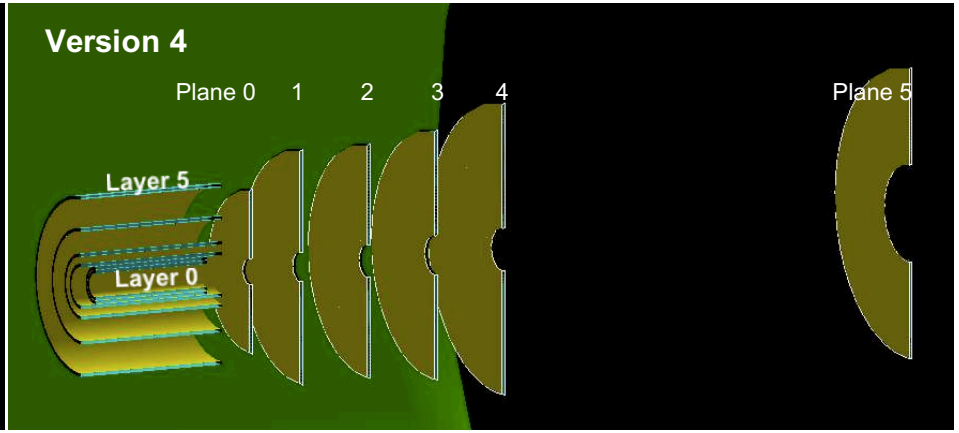
Momentum Resolution (1-30GeV) Compare Designs with Babar Magnet

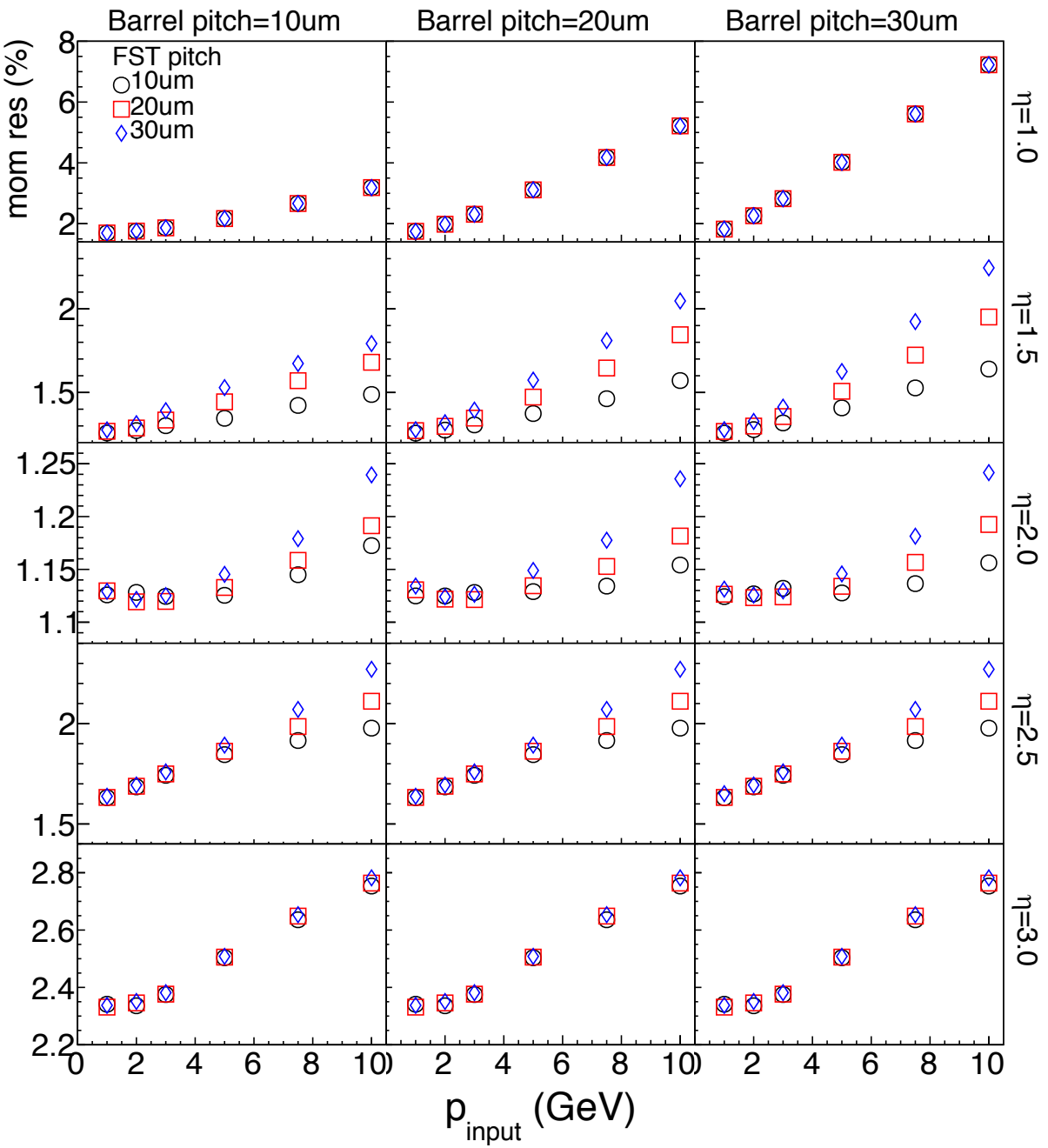


Ver2 vs Ver4

- Additional plane 5 of ver4 gives equivalent performance as ver4 at large η
- Updated barrel geometry with additional outer layer improve the resolution significantly at $\eta = 1$







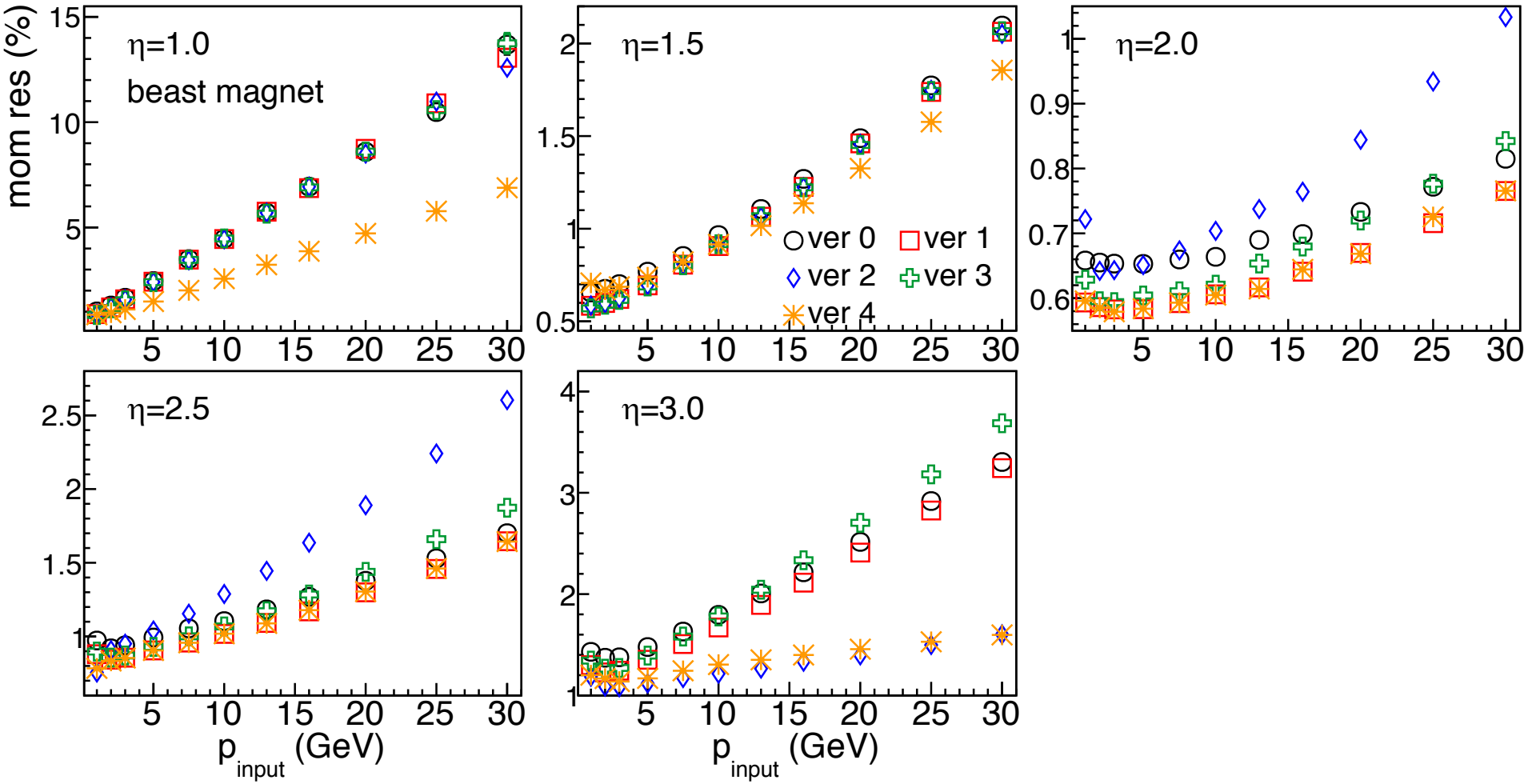
Momentum Resolutions Compare Pixel Pitch

Version 4 with Babar Magnet

- $\eta = 1$: the momentum resolution heavily depends on the pixel pitch of the barrel detector
- $\eta = 1.5$: depends on the pixel pitch of both barrel and FST
- $2 \leq \eta \leq 2.5$: depends on the pixel pitch of the FST
- $\eta = 3$: no significant pixel pitch dependency shown

Comparison between different FST design w/ Beast magnet

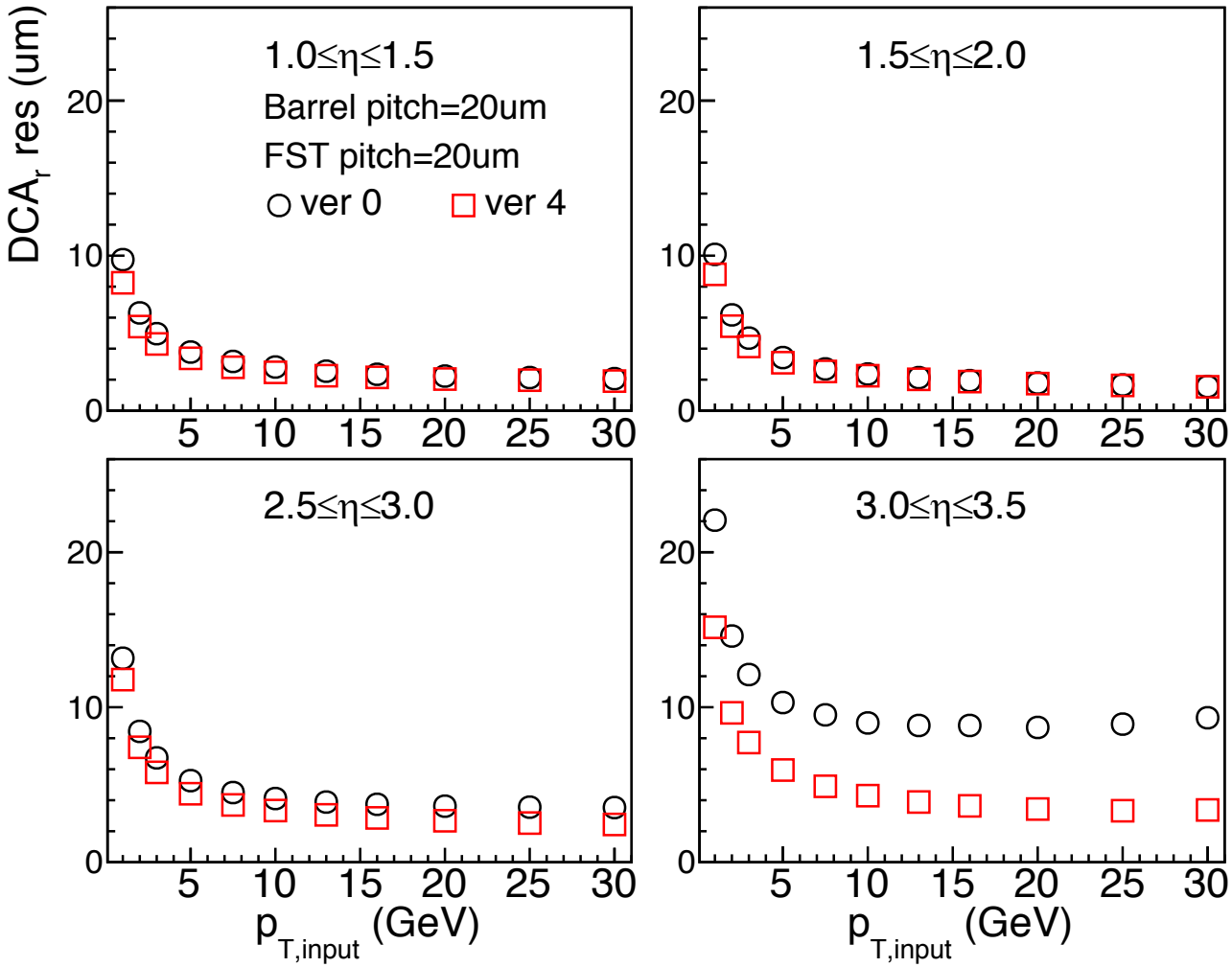
Momentum Resolution (1-30GeV) Compare Designs with BeAST Magnet



Simulation Setup for DCA Resolution Study

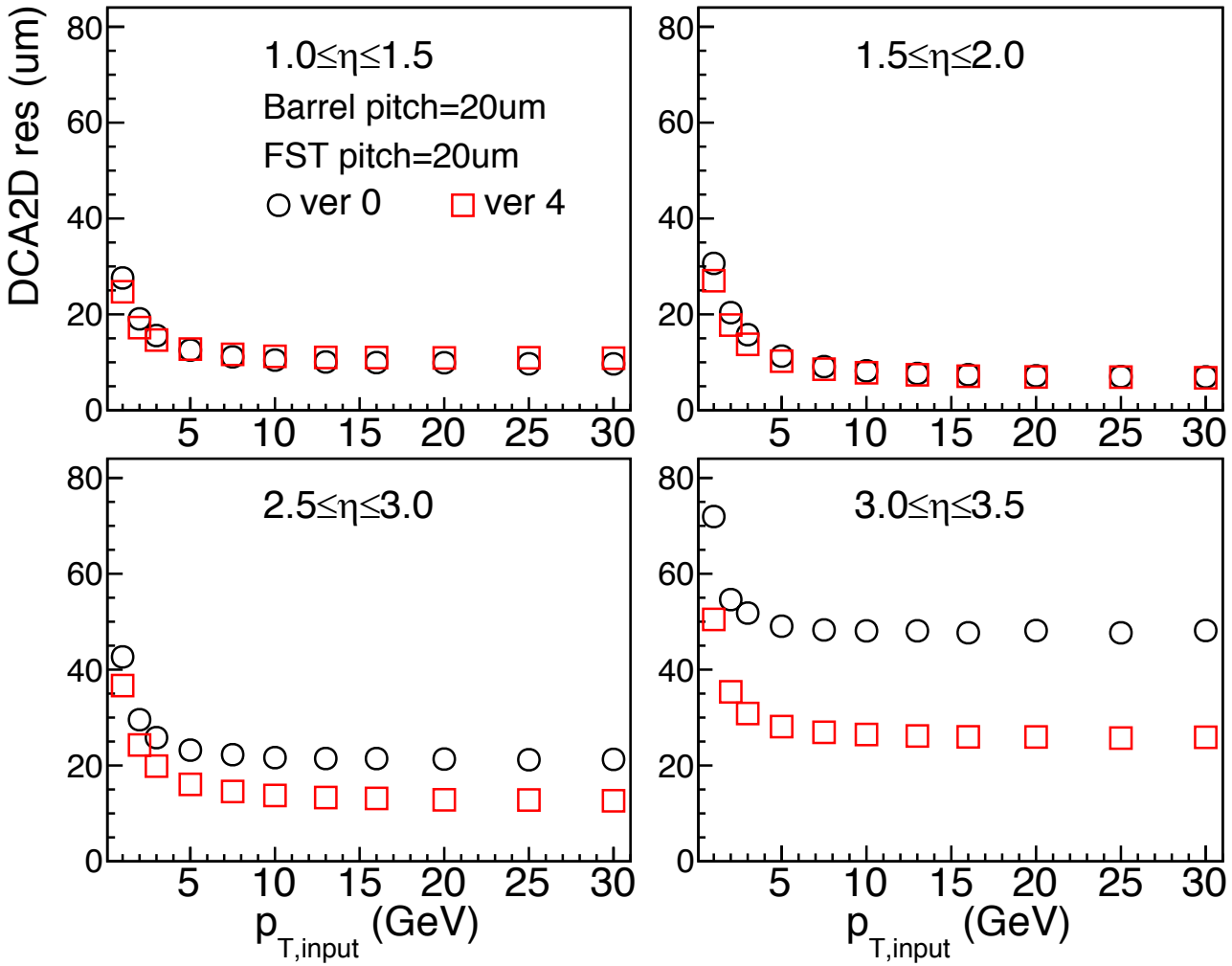
- Event configuration:
  - 10 π- per event.
  - Vertex (0,0,0)
  - 50k events in each p⊗η bin.
- Track configuration:
  - Momentum: 1-30 GeV with varying increments
  - Pseudorapdity: 1-3.5 with a 0.5 interval
  - Hit efficiency at 95%.
- Magnetic Field
  - **BeAST** Magnet peaks at 3T

DCA_r Resolutions



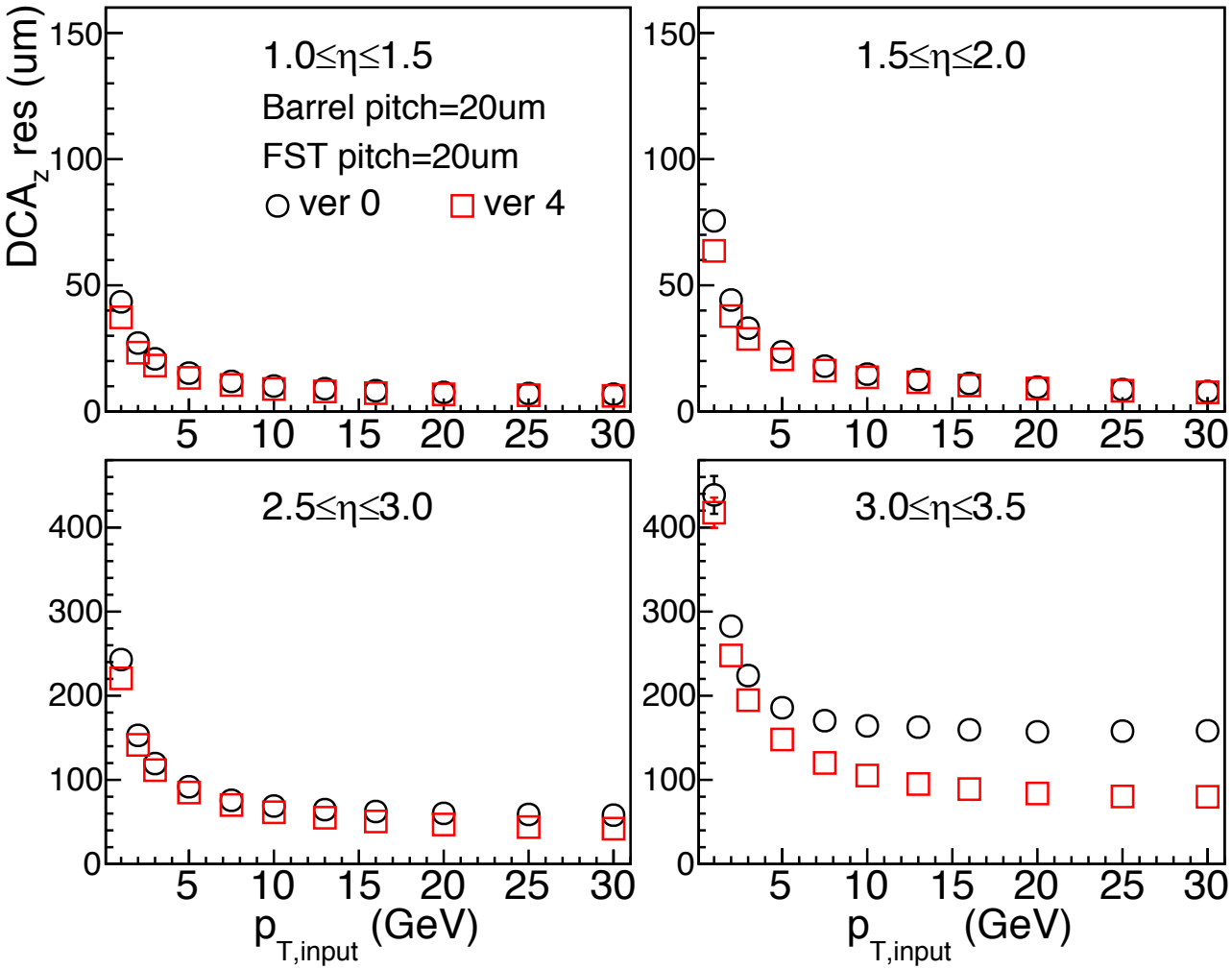
- $DCA_r = (pca - vtx) \cdot p_T$
- DCA resolution depends on track pseudorapidity.
- Version 4 gives better DCA resolution than version 0 especially at $\eta \geq 3$

DCA2D Resolutions



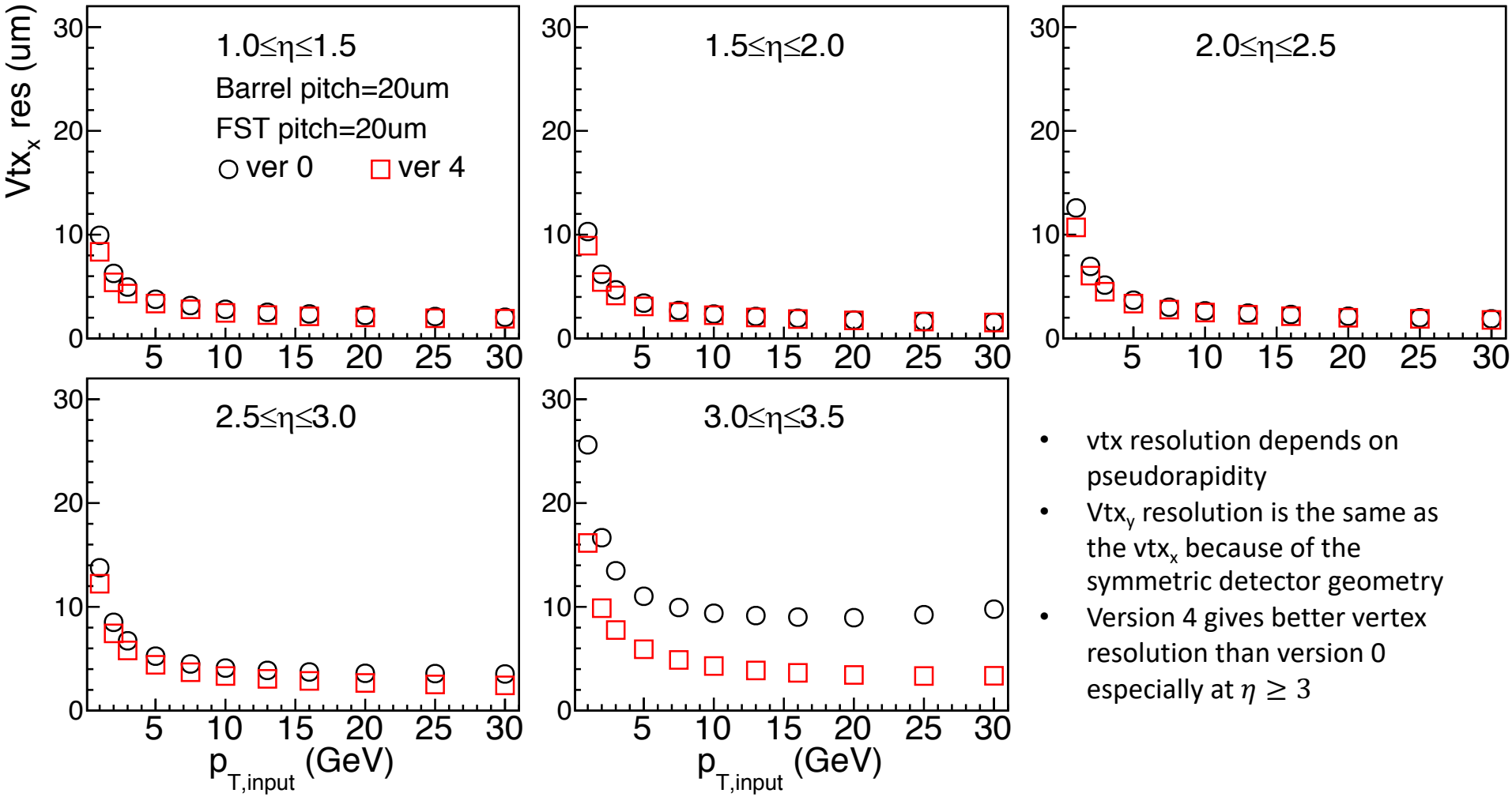
- $DCA_{2D} = (pca - vtx) \cdot (p_T \times z)$
- DCA resolution depends on pseudorapidity
- Version 4 gives better DCA resolution than version 0 especially at $\eta \geq 3$

DCA_z Resolutions



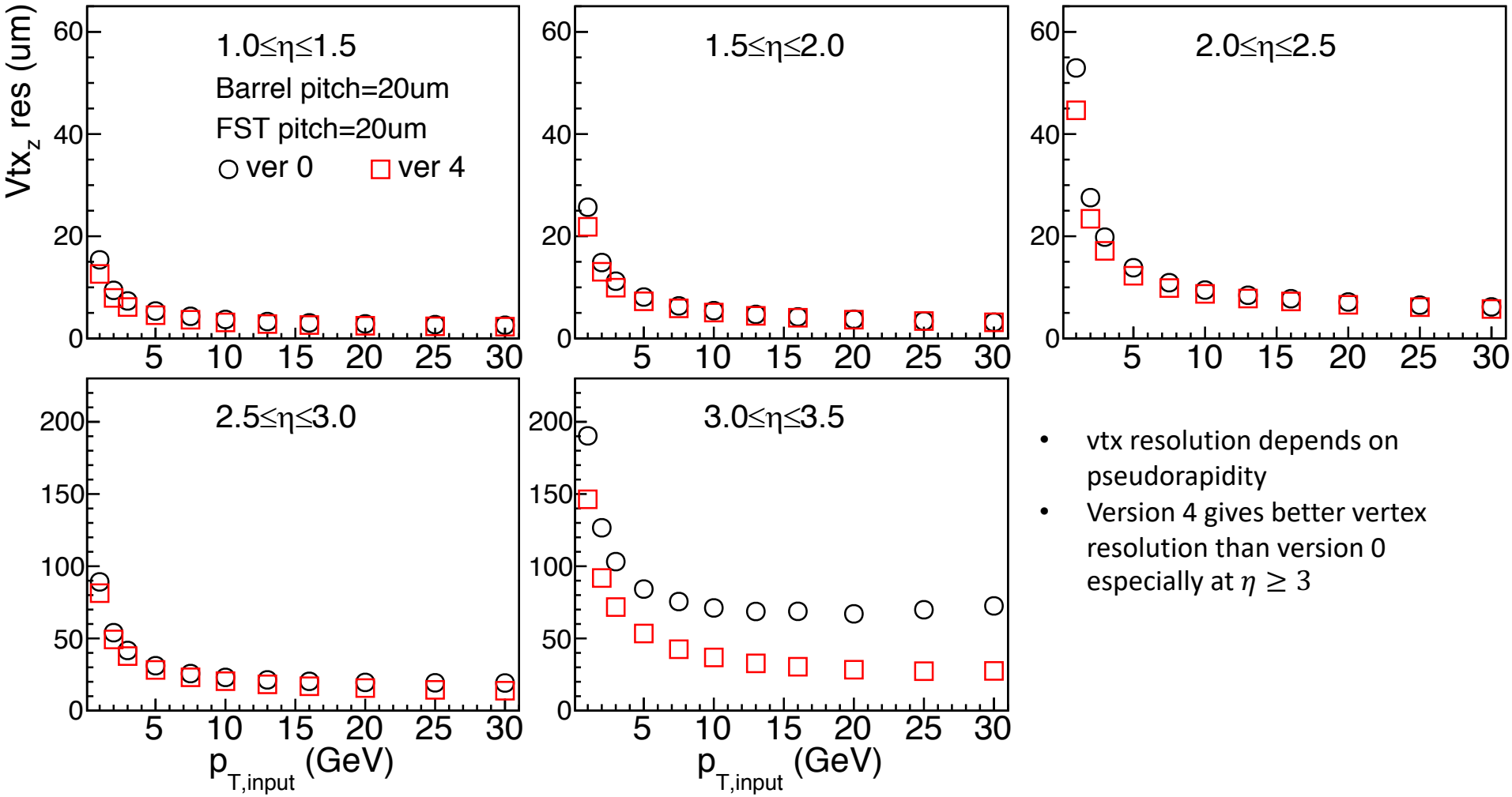
- $DCA_z = (pca - vtx) \cdot p_z$
- DCA resolution depends on track pseudorapidity。
- Version 4 gives better DCA resolution than version 0 especially at $\eta \geq 3$

Vtx_x Resolution



- vtx resolution depends on pseudorapidity
- Vtx_y resolution is the same as the vtx_x because of the symmetric detector geometry
- Version 4 gives better vertex resolution than version 0 especially at $\eta \geq 3$

Vtx_z Resolution

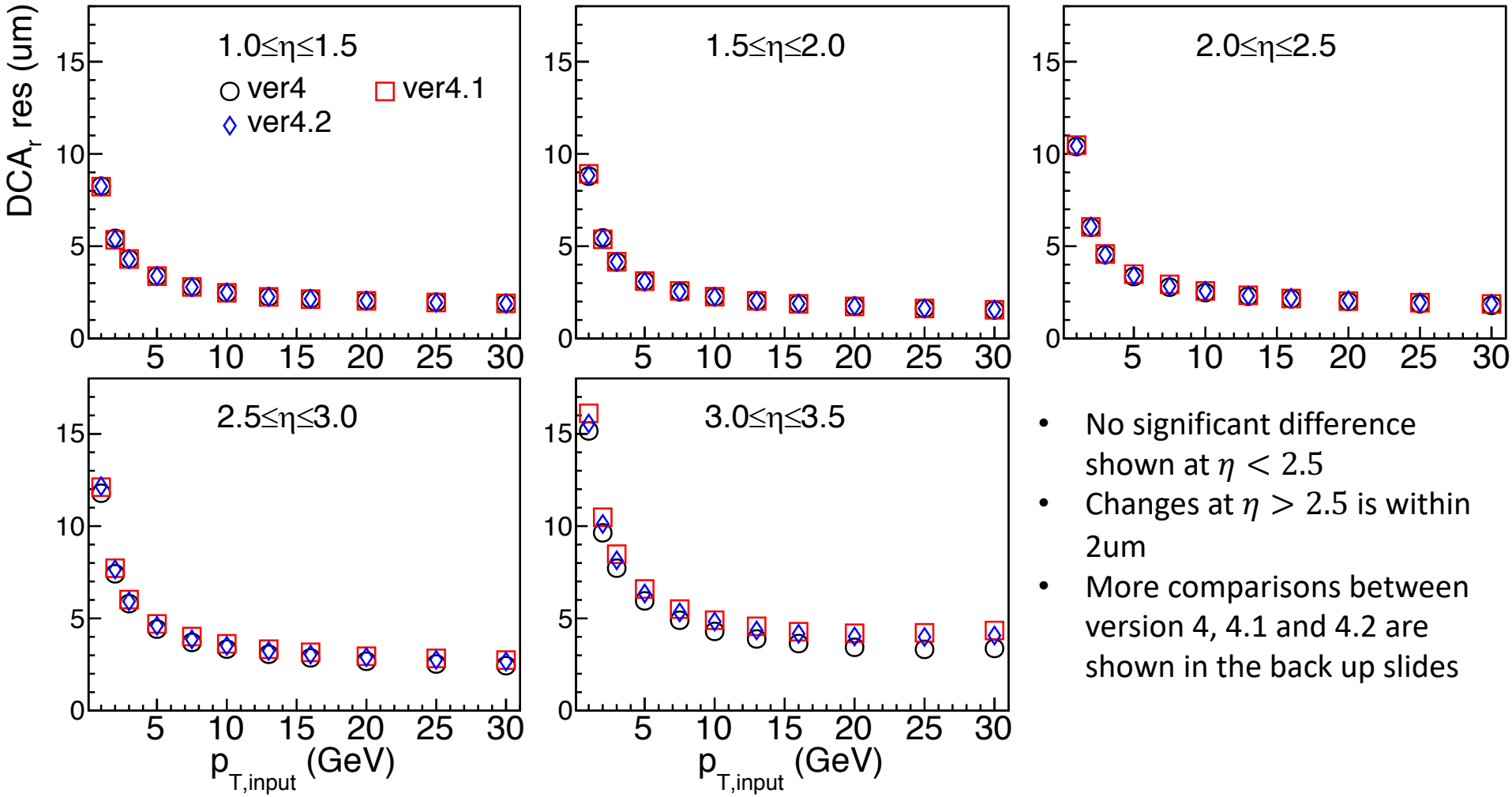


- vtx resolution depends on pseudorapidity
- Version 4 gives better vertex resolution than version 0 especially at $\eta \geq 3$

Fine tuned FST configuration: version 4.1 and 4.2

Version 4					
Plane	z (cm)	inner radius (cm)	outer radius (cm)	pixel Pitch (μm)	silicon thickness (μm)
0	35	4	25	20	50
1	53	4.5	36	20	50
2	77	5	36	20	50
3	101	6	38.5	20	50
4	125	6.5	45	20	50
5	270	15	45	20	50
Version 4.1					
Plane	z (cm)	inner radius (cm)	outer radius (cm)	pixel Pitch (μm)	silicon thickness (μm)
0	35	4	25	20	50
1	53	4.5	36	20	50
2	77	5	36	20	50
3	101	6	38.5	36.4	100
4	125	6.5	45	36.4	100
5	270	15	45	36.4	100
Version 4.2					
Plane	z (cm)	inner radius (cm)	outer radius (cm)	pixel Pitch (μm)	silicon thickness (μm)
0	35	4	25	20	50
1	53	4.5	36	20	50
2	77	5	36	20	50
3	101	6	38.5	20	50
4	125	6.5	45	36.4	100
5	270	15	45	36.4	100

DCA_r Resolution Comparing Version 4, 4.1 and 4.2



- No significant difference shown at $\eta < 2.5$
- Changes at $\eta > 2.5$ is within 2um
- More comparisons between version 4, 4.1 and 4.2 are shown in the back up slides

Summary

A series of studies have been done for the FST simulation:

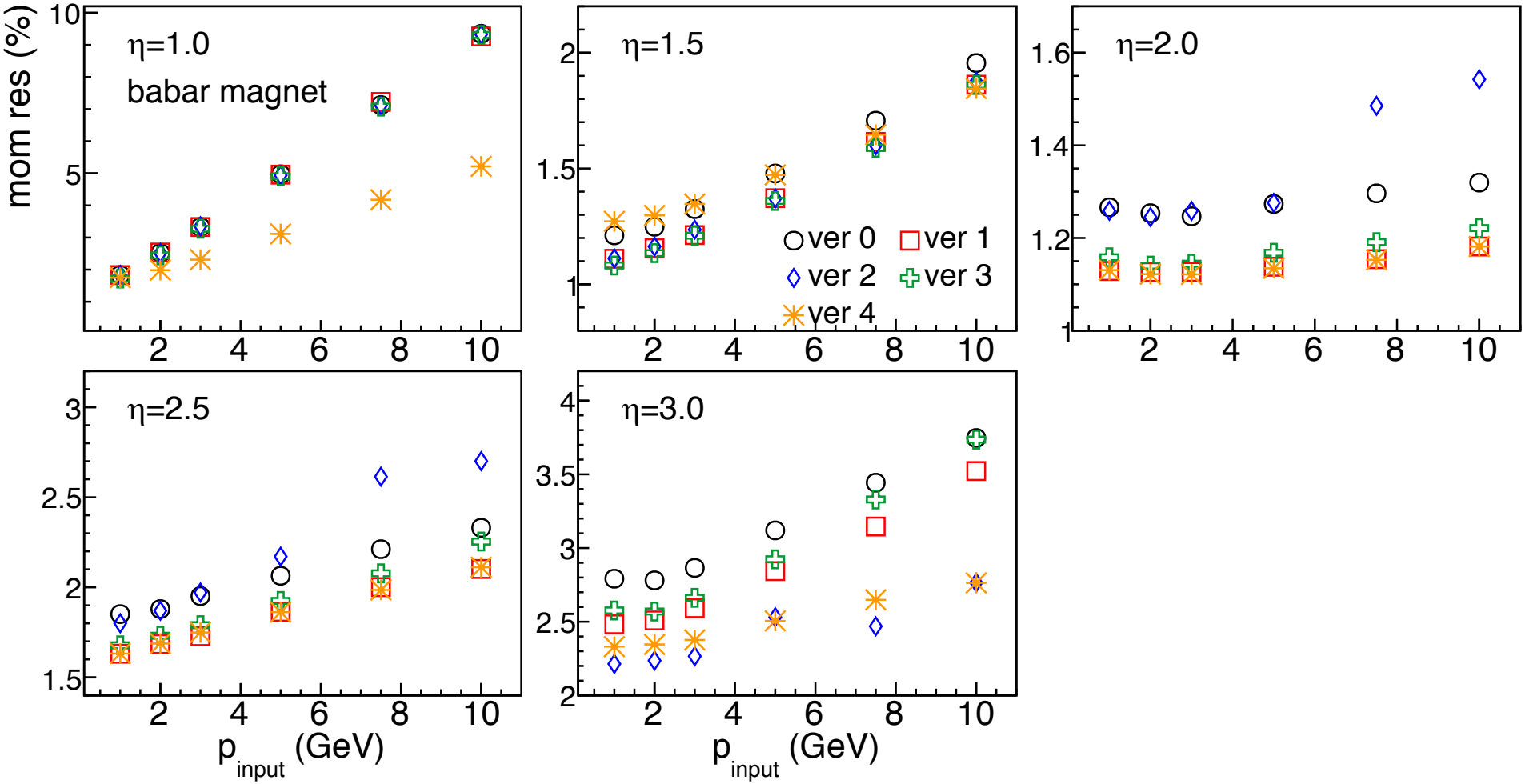
- Different FST designs shows effect of pixel pitch size and material budgets in momentum resolution
- The version 4 designs with additional layer of barrel and plane detectors improve the momentum and DCA resolution in both small and large pseudorapidity
- Use of larger pixel size and thicker silicon wafer in the last few planes of FST shows limited effect on momentum and DCA resolutions.

Plan

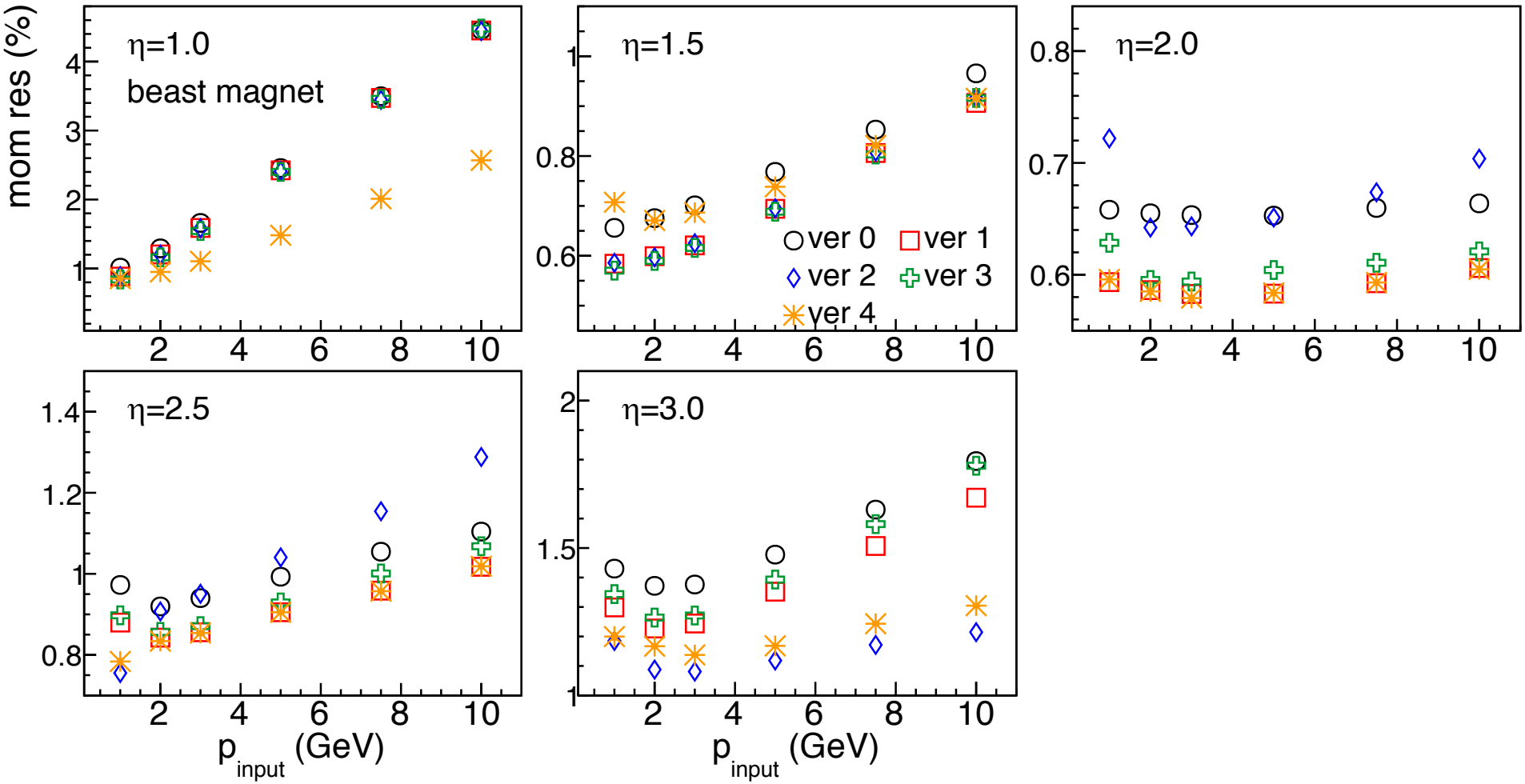
- Submit the LANL EIC FST technical note to the tracking working group convenor by the end of this week.
- Will report the studies which include the forward GEM tracker in the tracking evaluation in upcoming meetings.

Back Up

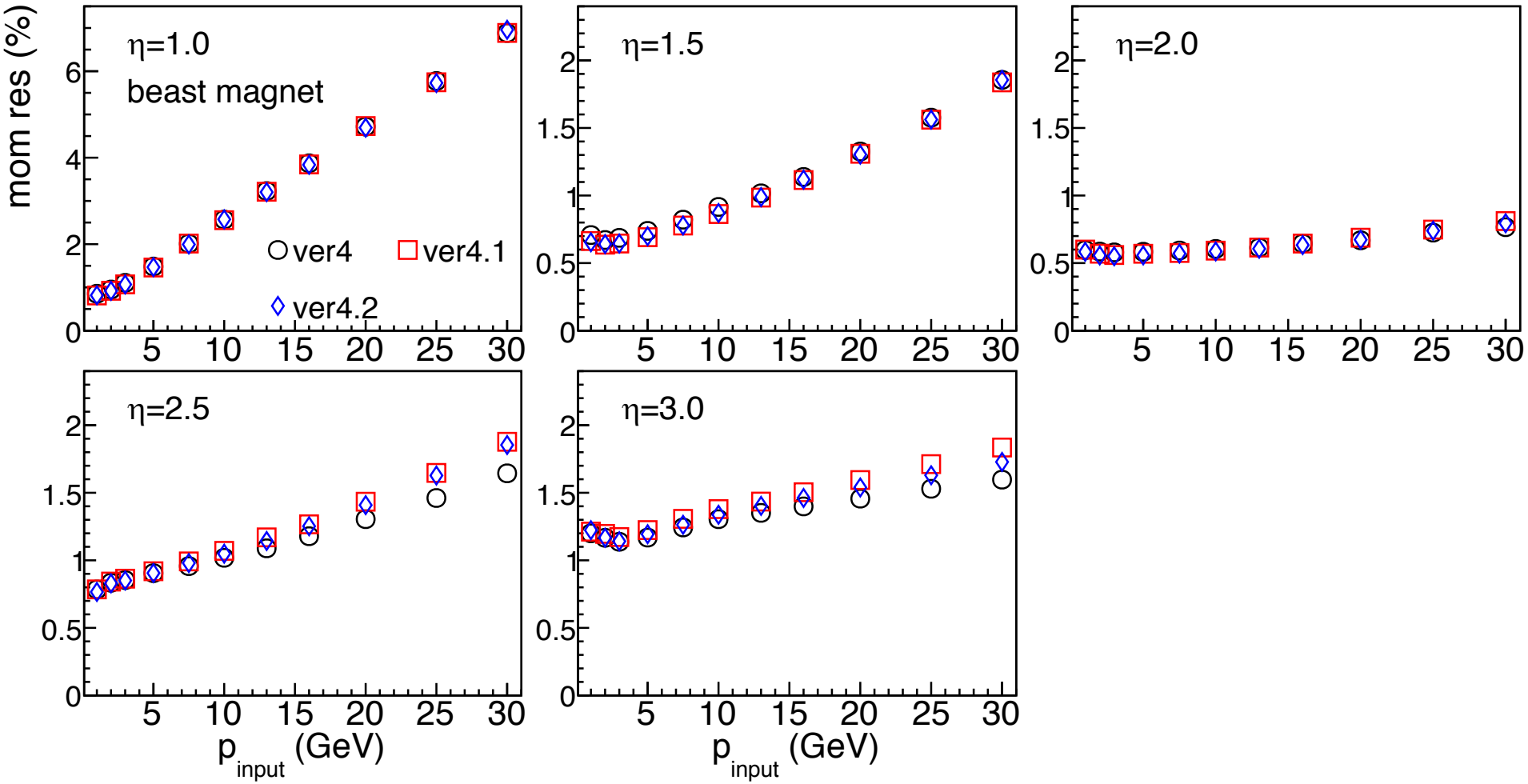
Momentum Resolution (1-10GeV) Compare Designs with Babar Magnet



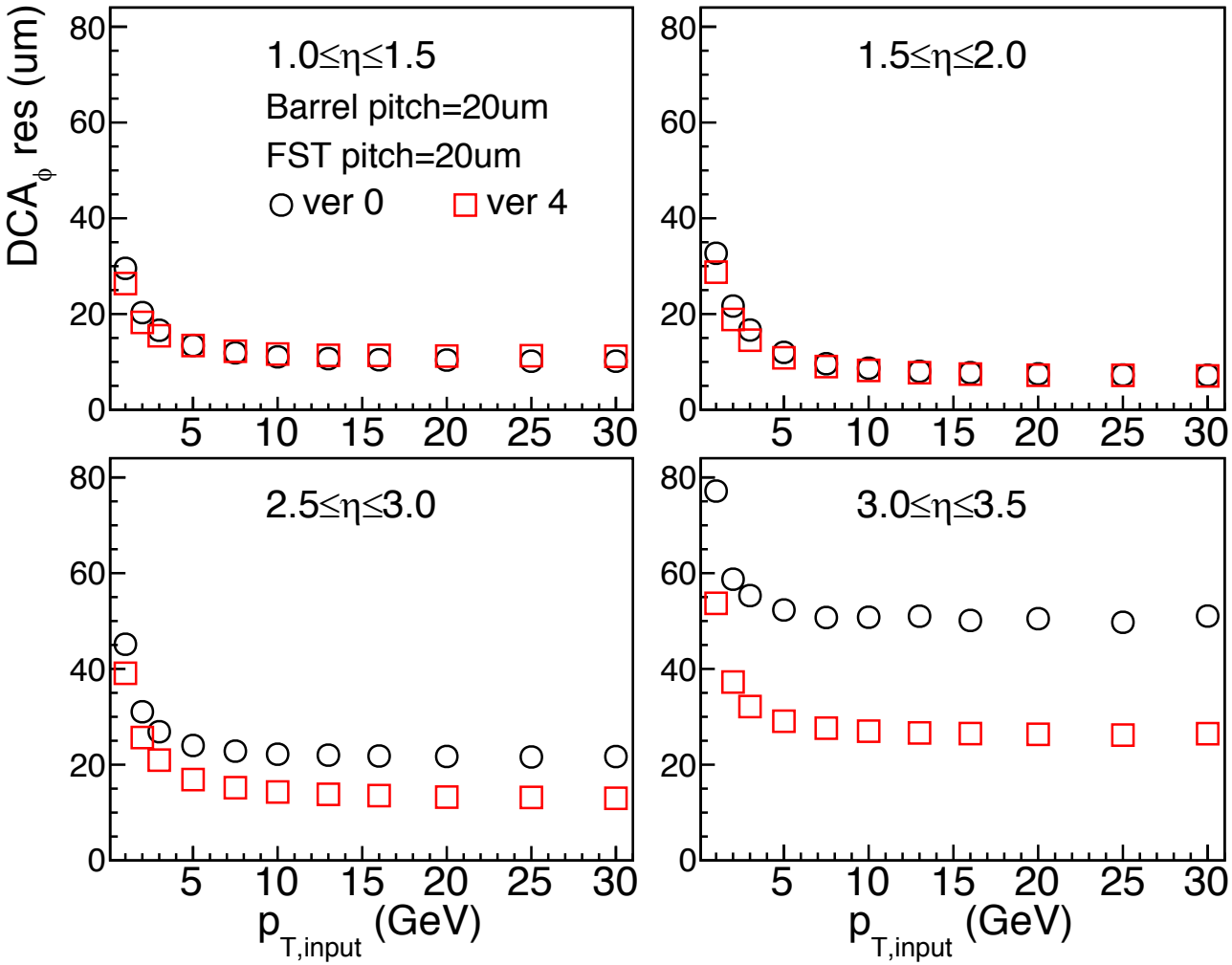
Momentum Resolution (1-10GeV) Compare Designs with BeAST Magnet



Momentum Resolution
Comparing Version 4, 4.1 and 4.2

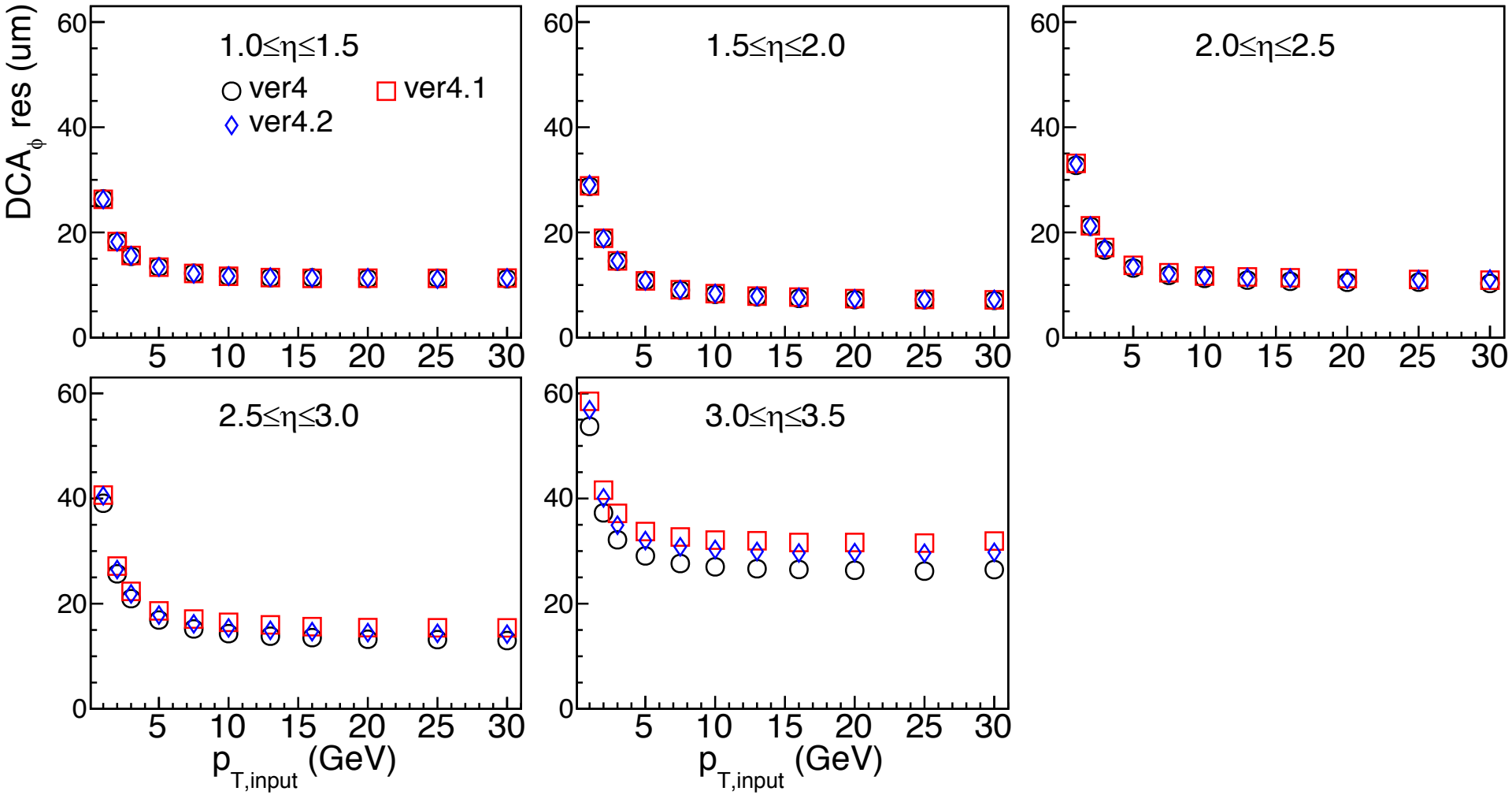


DCA_ϕ Resolutions

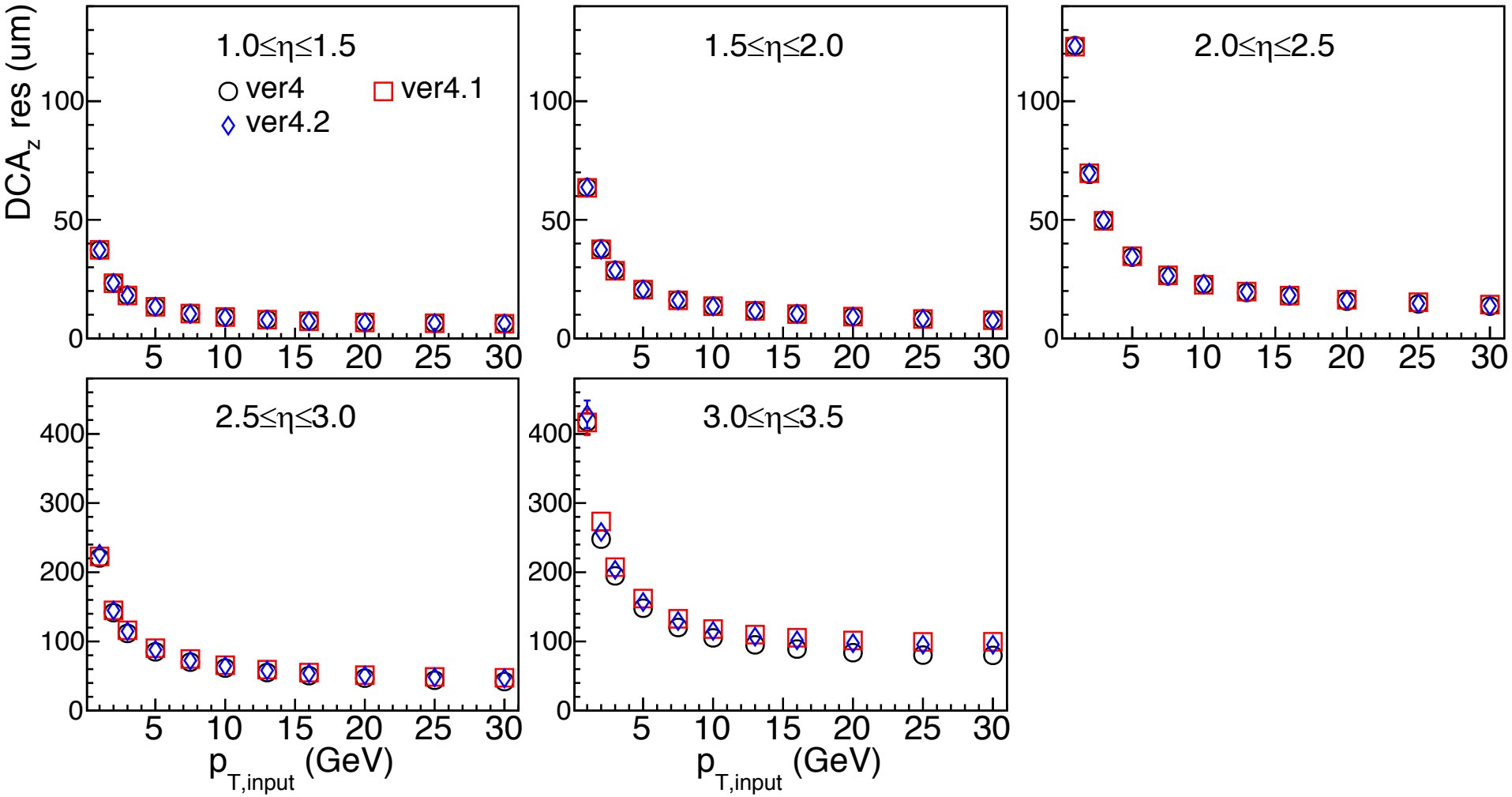


- $DCA_\phi = (pca - vtx) \times p_T$
- DCA resolution depends on track pseudorapidity
- Version 4 gives better DCA resolution than version 0 especially at $\eta \geq 3$

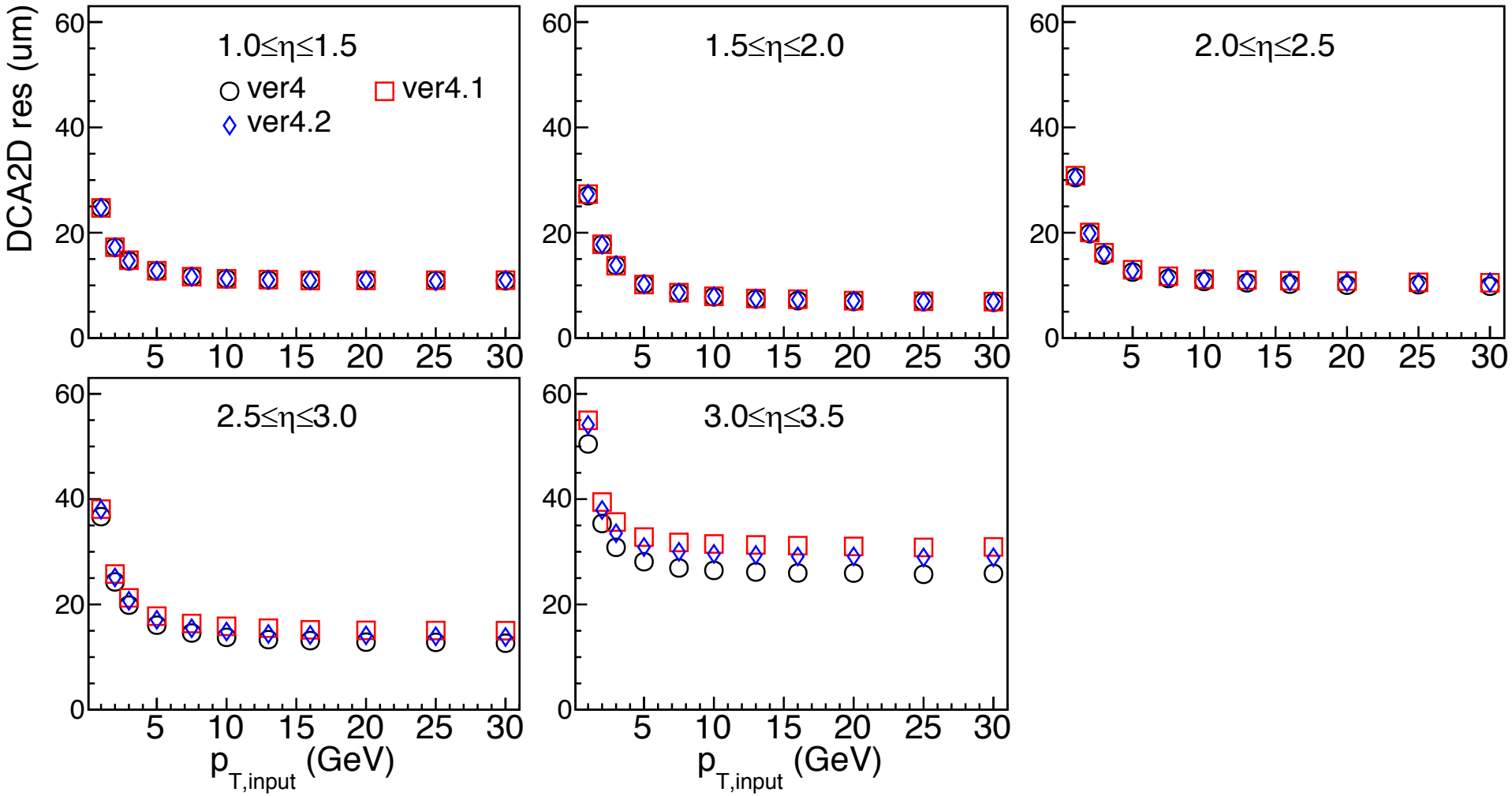
DCA_ϕ Resolution
Comparing Version 4, 4.1 and 4.2



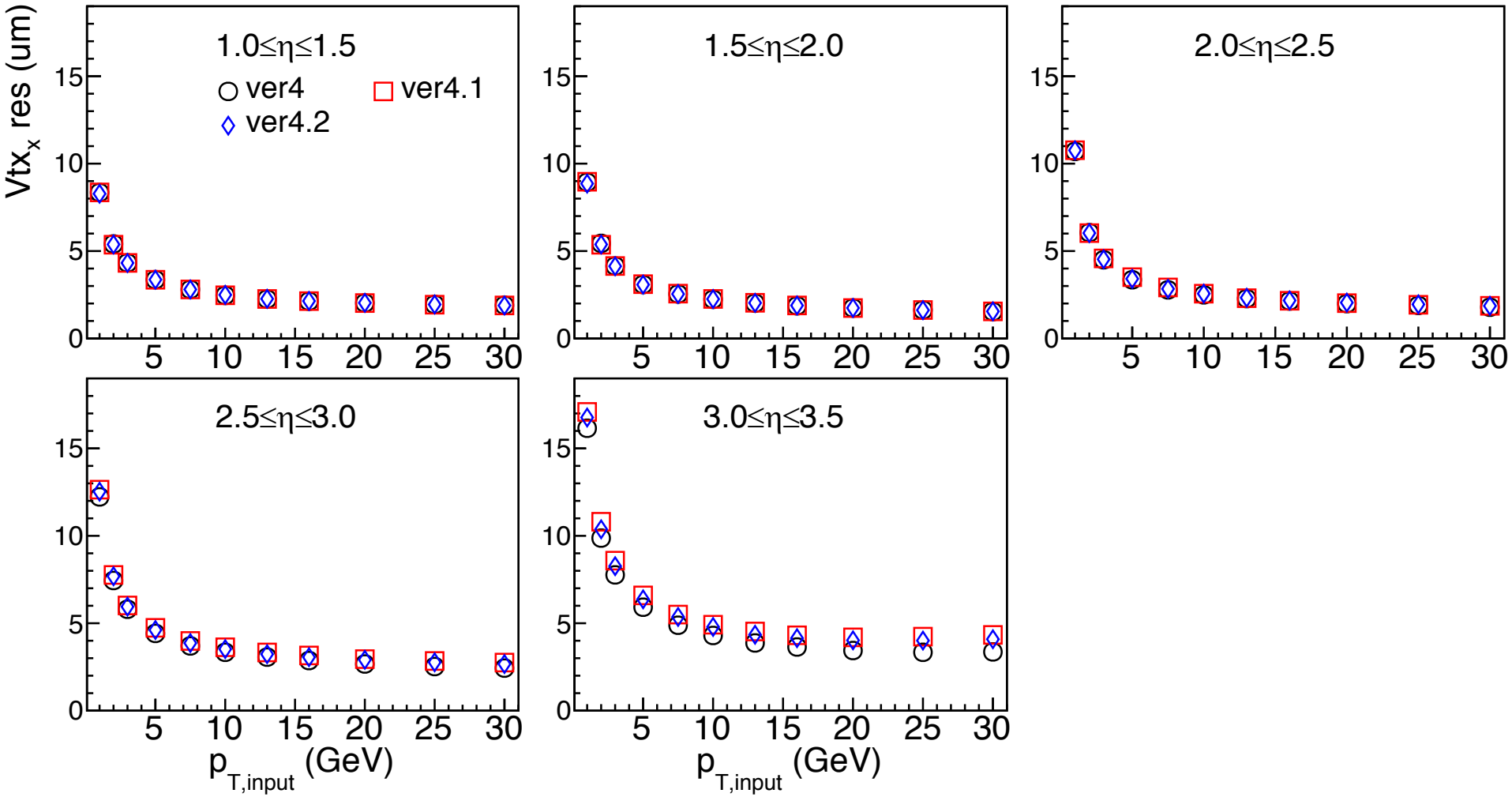
DCA_z Resolution
Comparing Version 4, 4.1 and 4.2



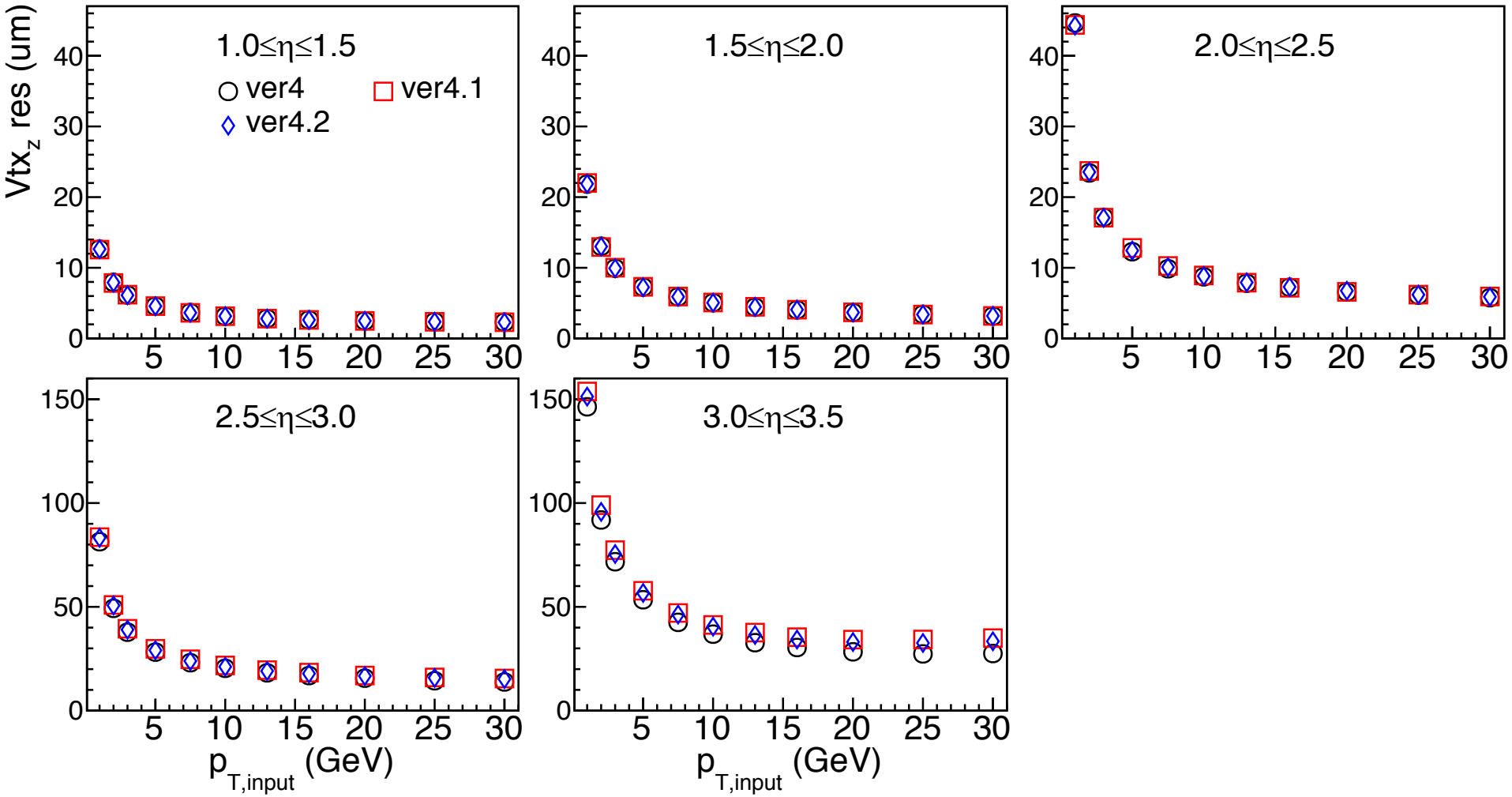
DCA2D Resolution
Comparing Version 4, 4.1 and 4.2



Vtx_x Resolution
Comparing Version 4, 4.1 and 4.2

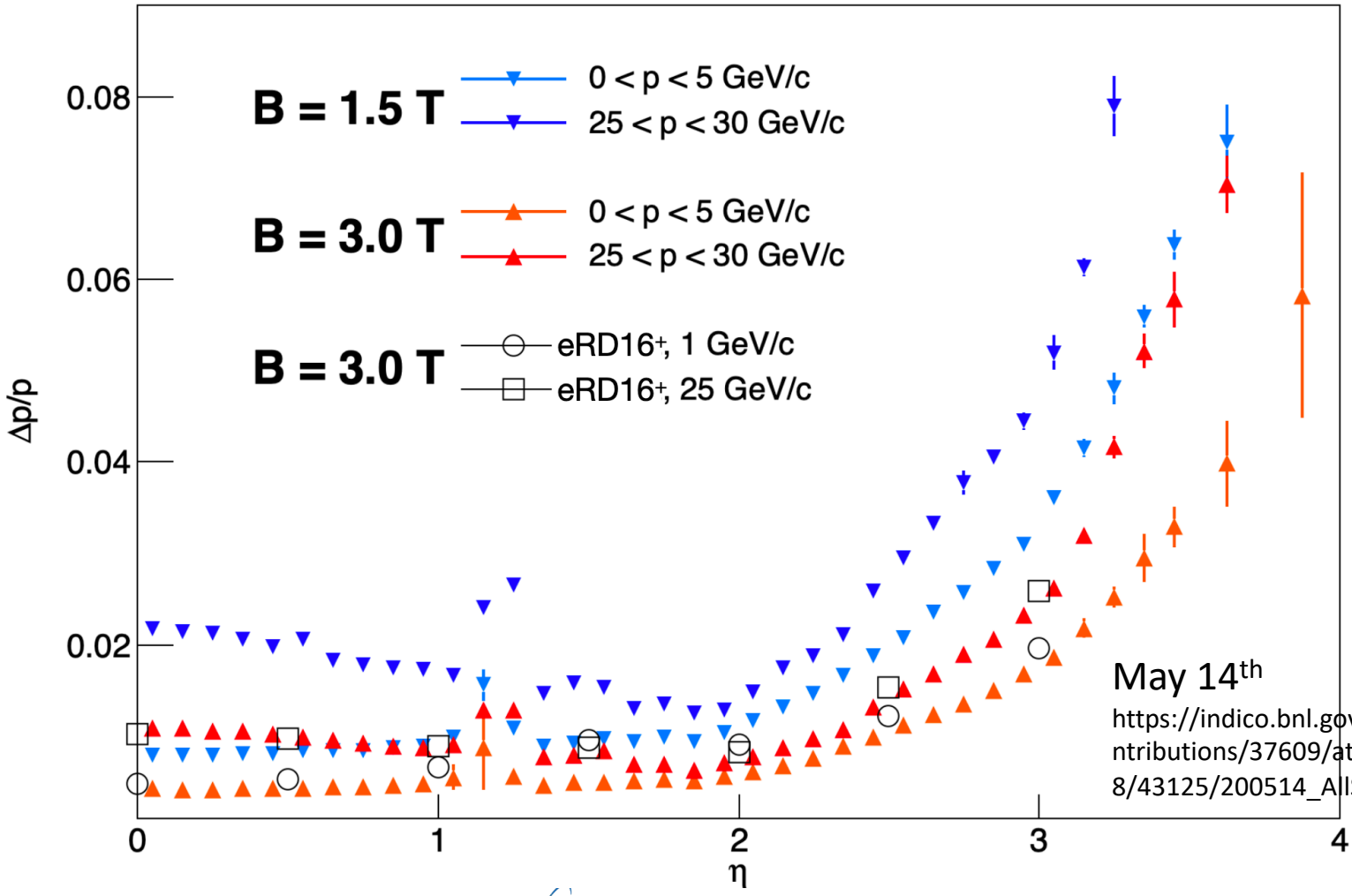


Vtx_z Resolution
Comparing Version 4, 4.1 and 4.2



Back Up

π^-



May 14th

https://indico.bnl.gov/event/7894/contributions/37609/attachments/28098/43125/200514_AllSi_in_Fun4All_2.