UNIVERSITY OF BIRMINGHAM | SCHOOL OF PHYSICS AND ASTRONOMY

Detector benchmarks and optimisation studies in Fun4All

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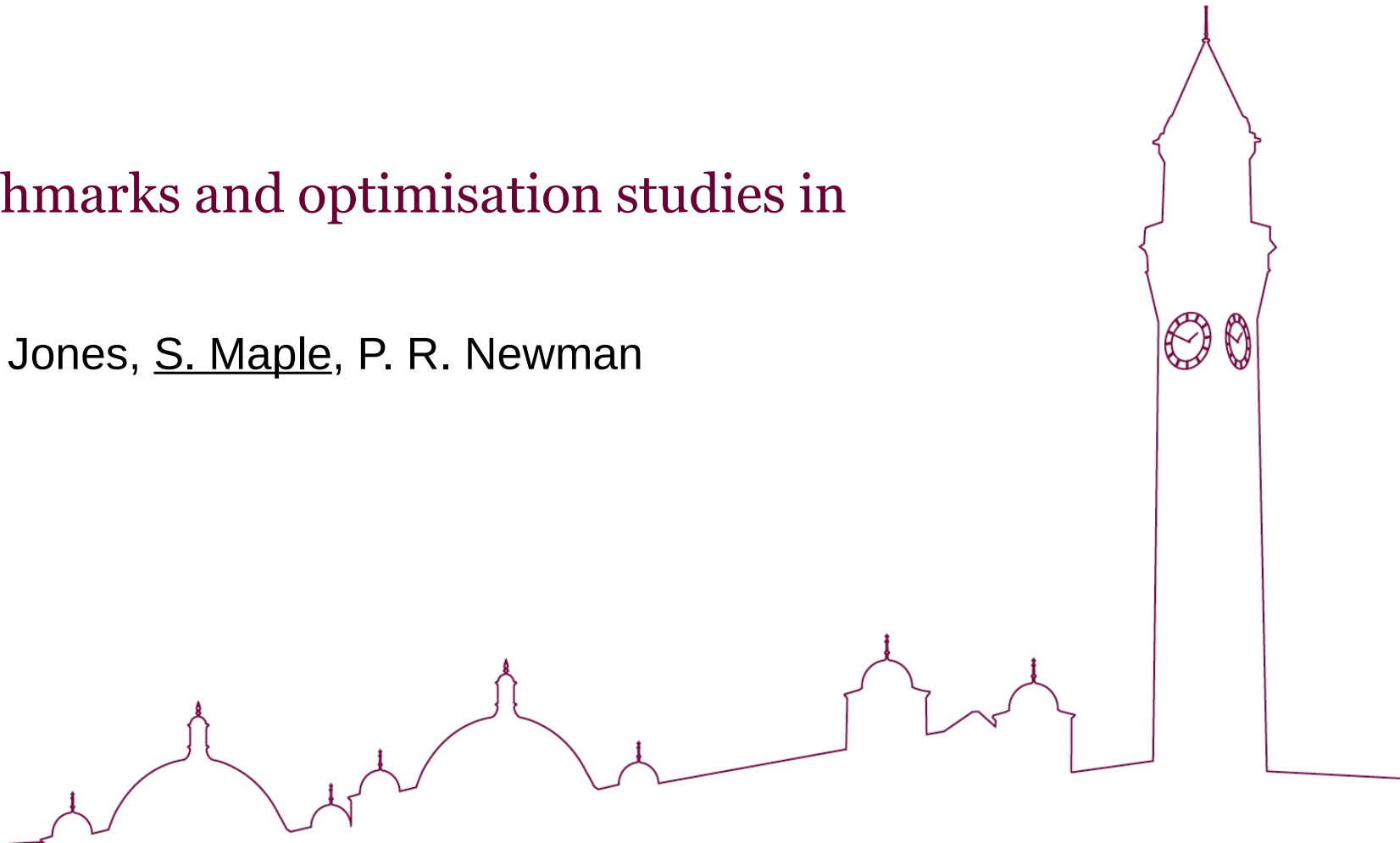


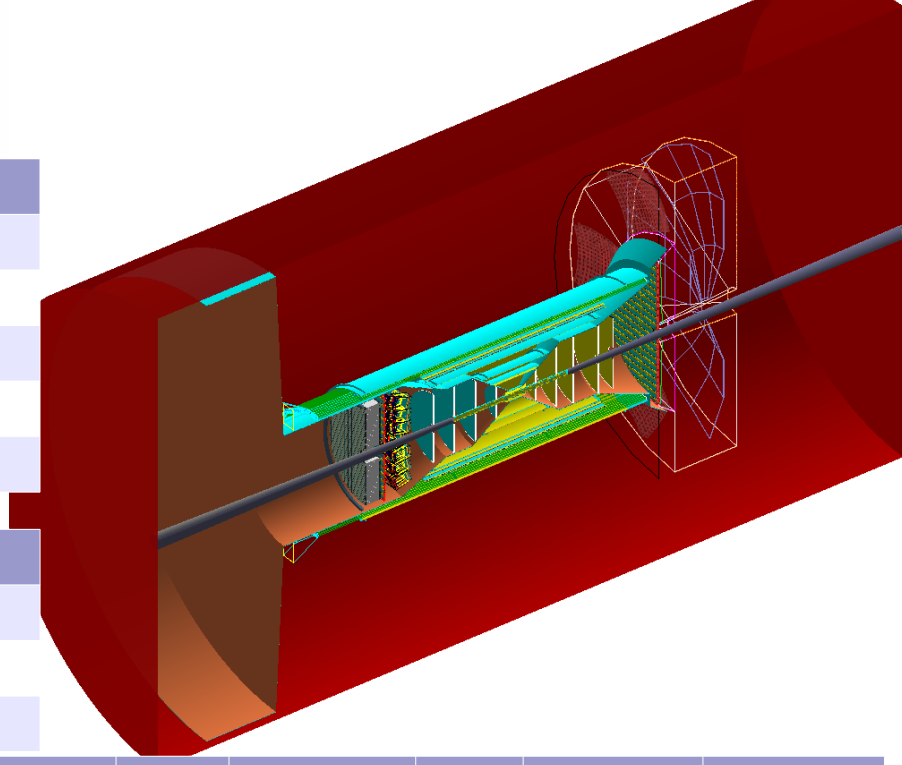
Overview

- Software and Simulation WGs working towards implementation of ECCE detector in the two supported frameworks (Fun4All and DD4hep based stacks)
- This work represents some initial studies done in Fun4All
- Detector geometry taken from https://github.com/ECCE-EIC/macros
  - Removed all elements outside of the tracker
- Benchmarked dp/p and DCA_T/DCA_z and compared against results shown by Xuan at https://indico.bnl.gov/event/15489/contributions/62761/
  - Field map at: https://github.com/sPHENIX-Collaboration/calibrations/blob/master/Field/Map/sPHENIX.2d.root
  - PWG requirements from https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Common
- After benchmarking the following changes have been applied:
  - Fieldmap rescaled from 1.4T to 1.5T
  - X/X_0 for sagitta layers updated from 0.05% X/X_0 to 0.55% X/X_0

Simulation setup

Region	Layer	Technology	Radius/cm	Min z/cm	Max z/cm	Pitch/μm
barrel	1	MAPS	3.3	-13.5	13.5	10
	2		4.35	-13.5	13.5	10
	3		5.4	-13.5	13.5	10
	4		21	-27	27	10
	5		22.68	-30	30	10

Region	Layer	Technology	Radius/cm	Min z/cm	Max z/cm	Pitch/μm
barrel	1	μRWELL	33.14	-40	40	400
	2		51	-106	106	400
	3		77	-197	145	400

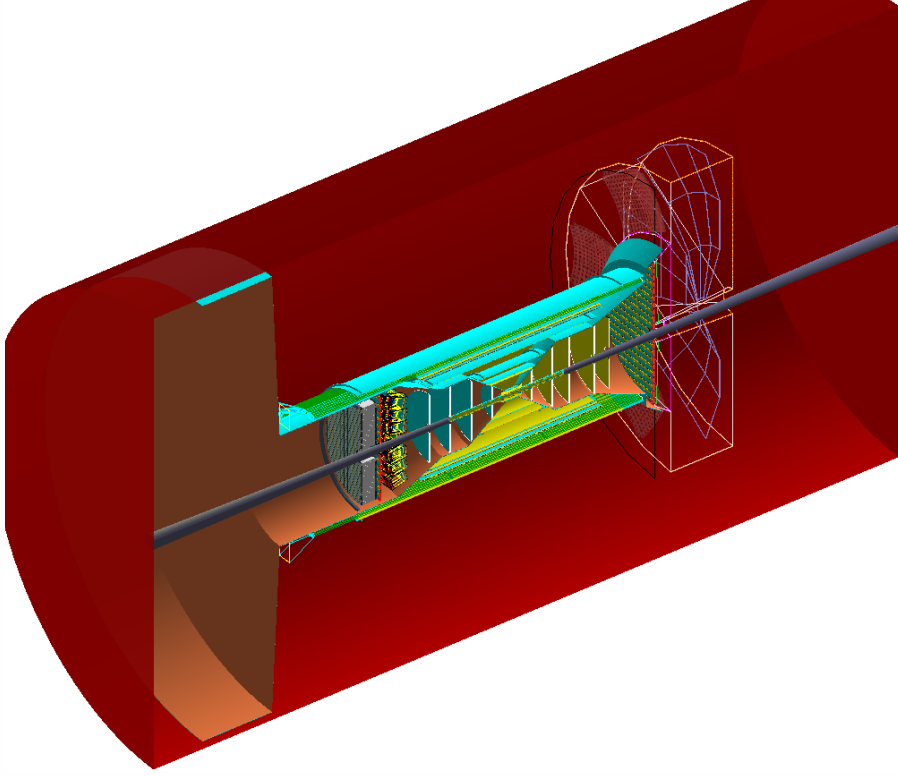


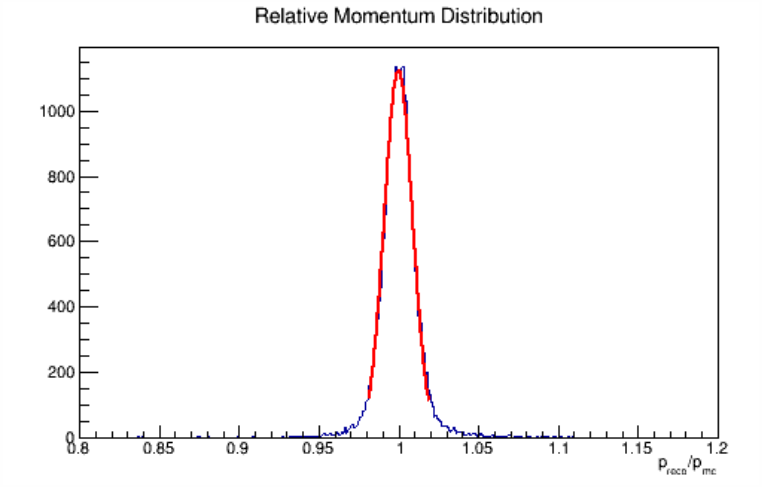
Region	Disk	Technology	z/cm	Inner r/cm	Outer r/cm	Pitch/μm
e-endcap	1	MAPS	-25	3.5	18.5	10
	2		-52	3.5	36.5	10
	3		-79	4.5	40.5	10
	4		-106	5.5	41.5	10

Region	Disk	Technology	z/cm	Inner r/cm	Outer r/cm
h-endcap	1	MAPS	25	3.5	18.5
	2		49	3.5	36.5
	3		73	4.5	40.5
	4		106	5.5	41.5
	5		125	7.5	43.5

Simulation procedure

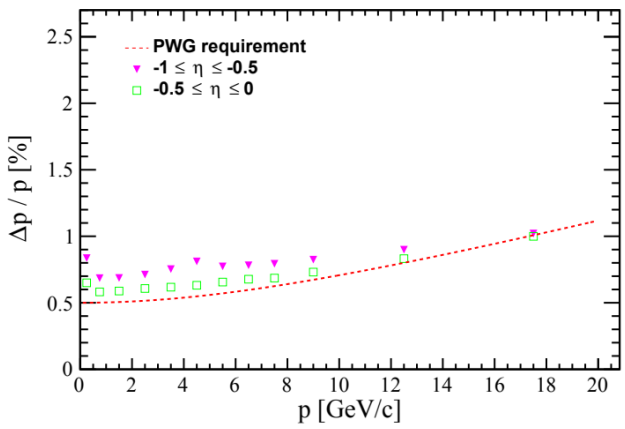
- Negative pions generated uniformly in p_T for $0 < p_T < 20$ GeV over η range $-3.5 < \eta < 3.5$
- Tracks reconstructed, momentum and DCA binned in η and p_T
- Resolution extracted from fit applied over ±2σ range to p_{rec} and DCA distributions

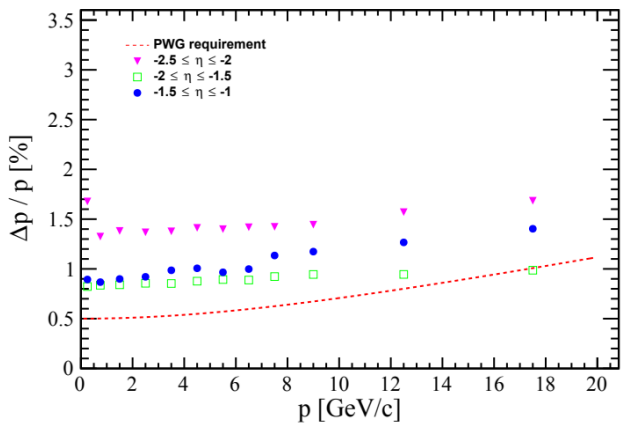


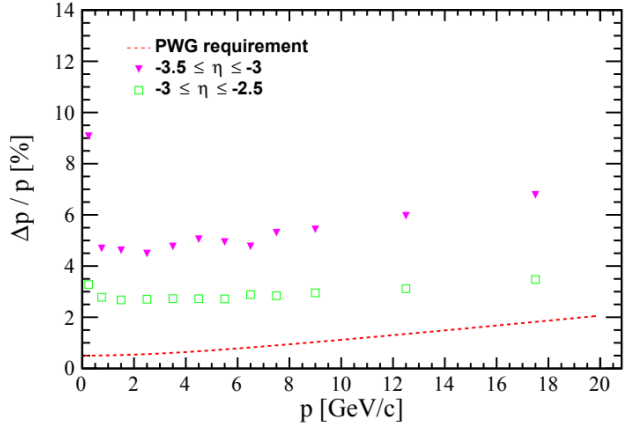


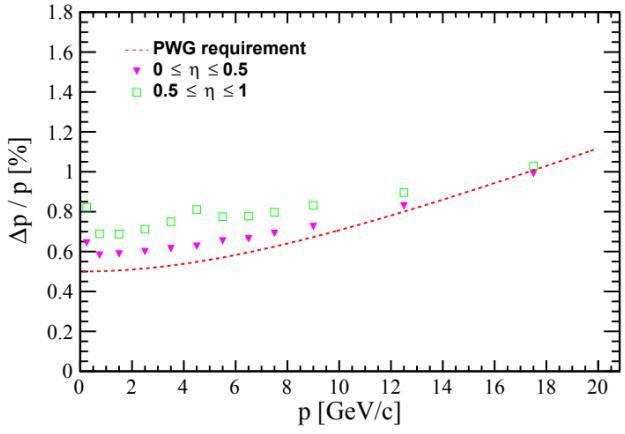
Benchmarks for dp/p

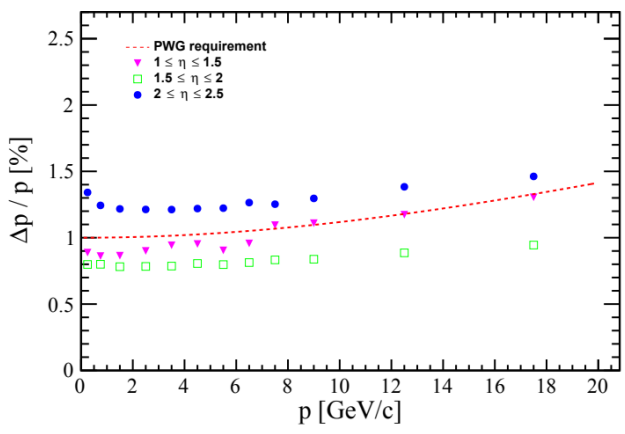
- Note: uses the described setup with 1.4T field map

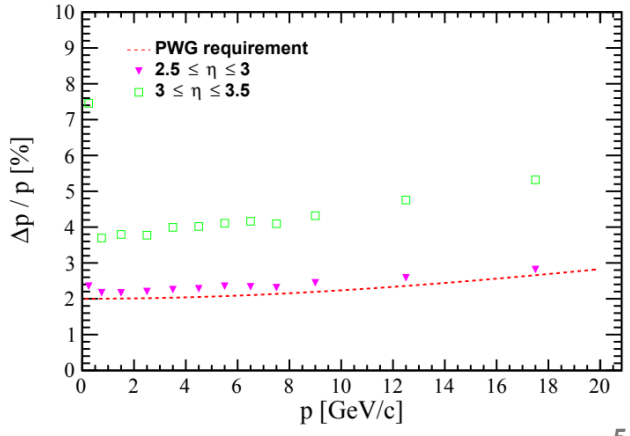






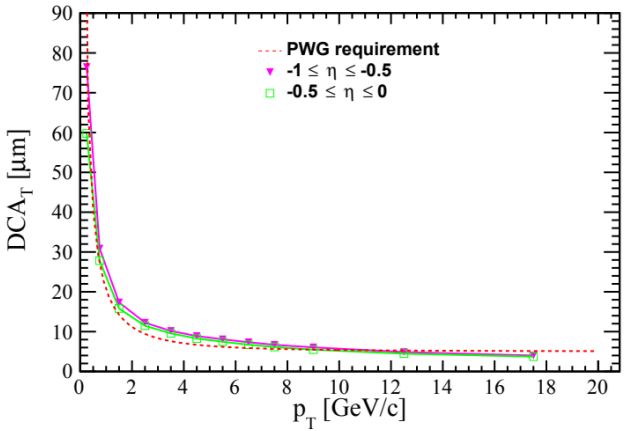


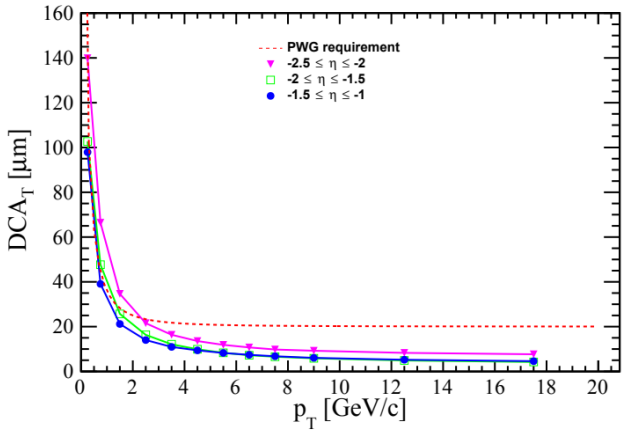


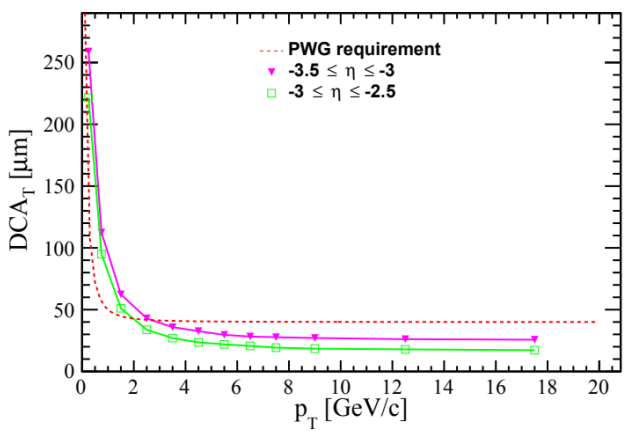


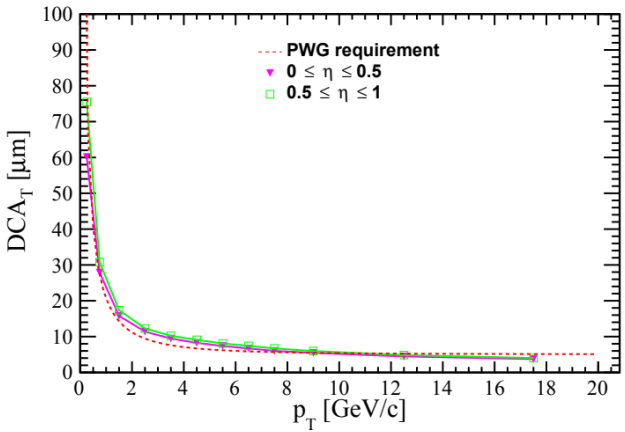
Benchmarks for DCA_T

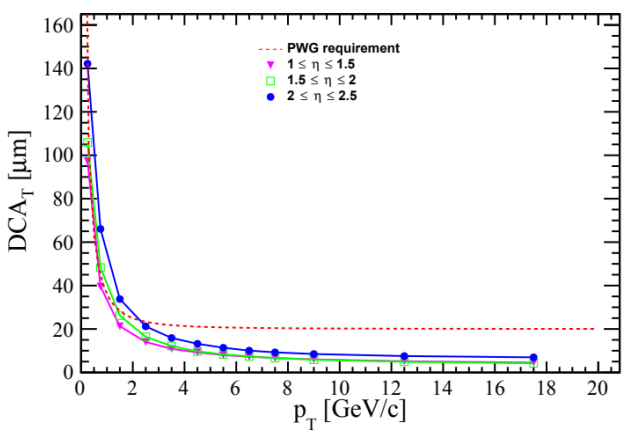
- Resolutions for both DCA_T and dp/p are quite consistent with prior ECCE studies

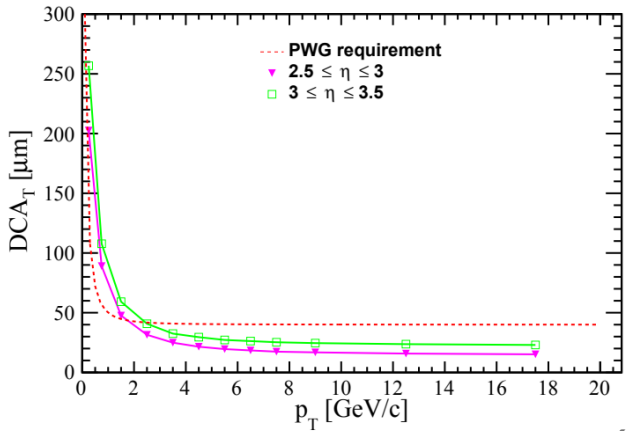






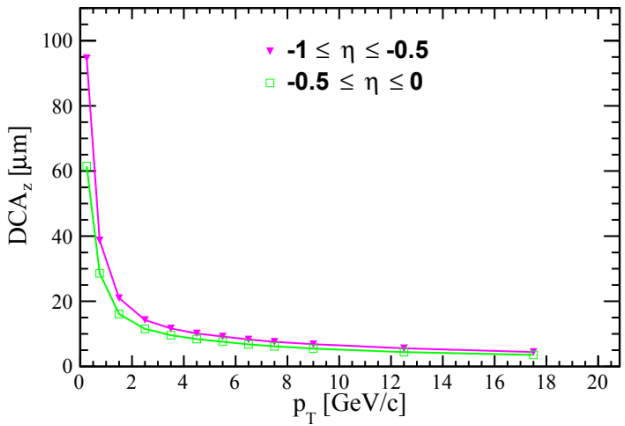


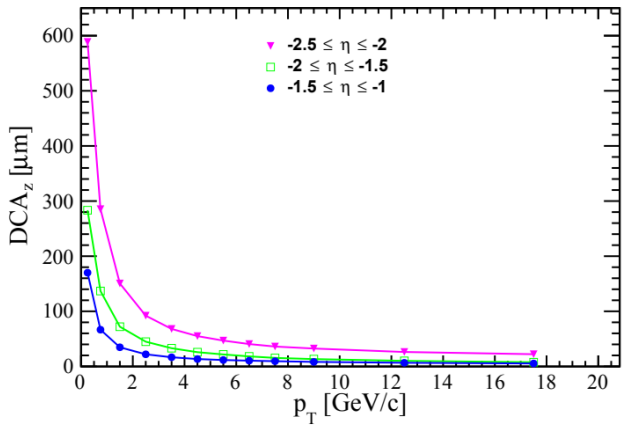


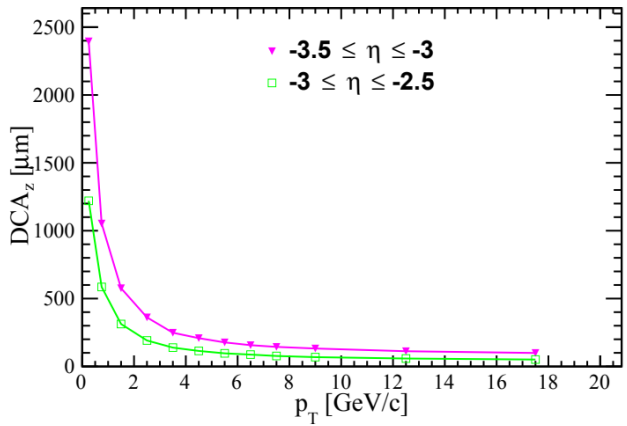


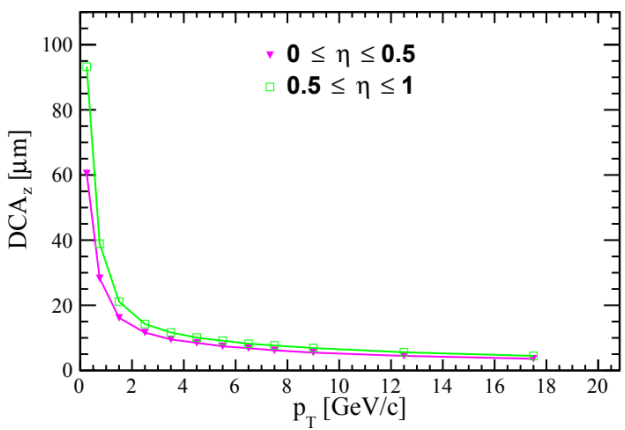
Benchmarks for DCA_z

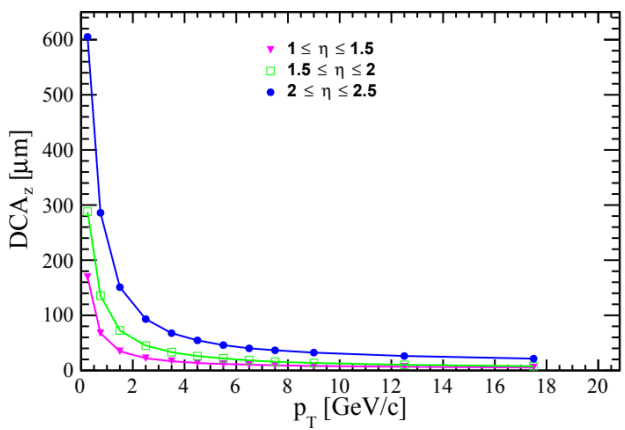
- No formal PWG requirement in my table → is this still the case?

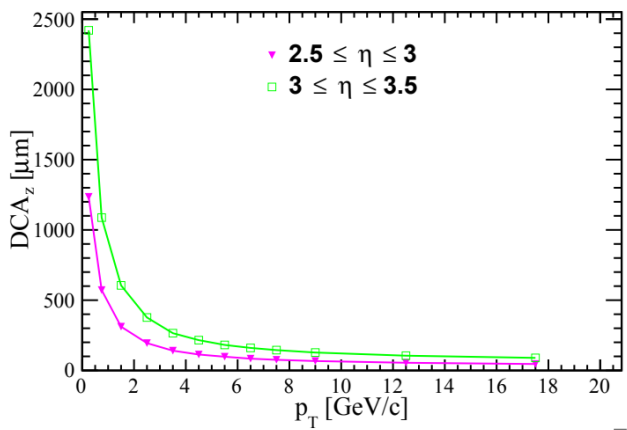






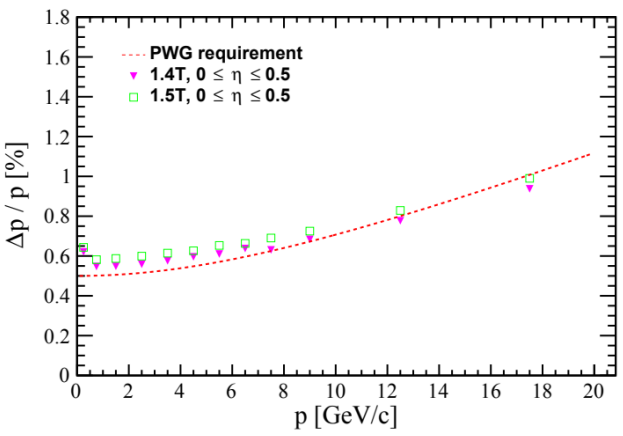


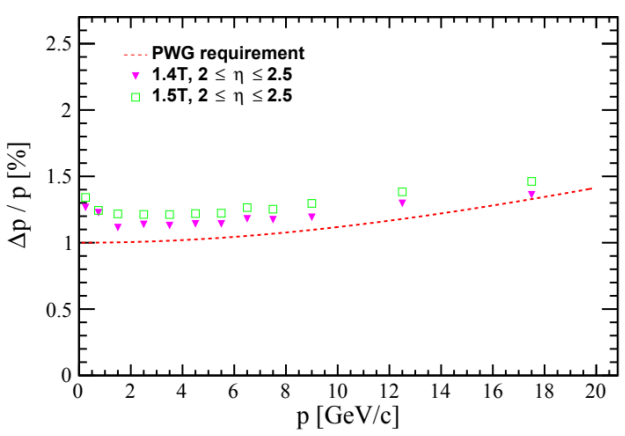


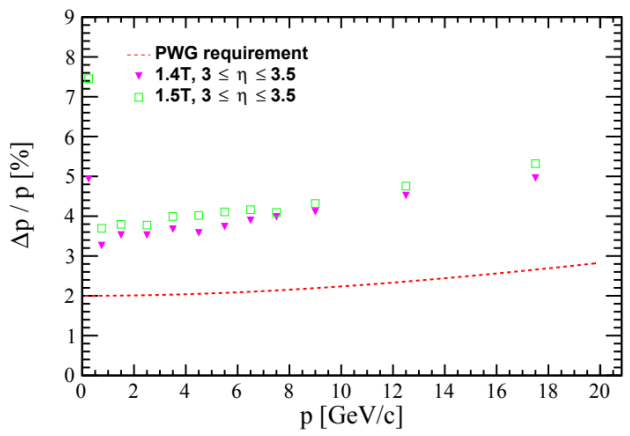


Rescaling B field: 1.4T → 1.5T

- Using a higher B field can improve momentum resolution: what performance do we see for a 1.5T field?
  - Note: the field map used in ECCE full simulations was an sPHENIX field map rescaled by 1.4/1.5, I simply removed the rescaling → If this implementation of a 1.5T field is not realistic then I can revert to 1.4T for future studies

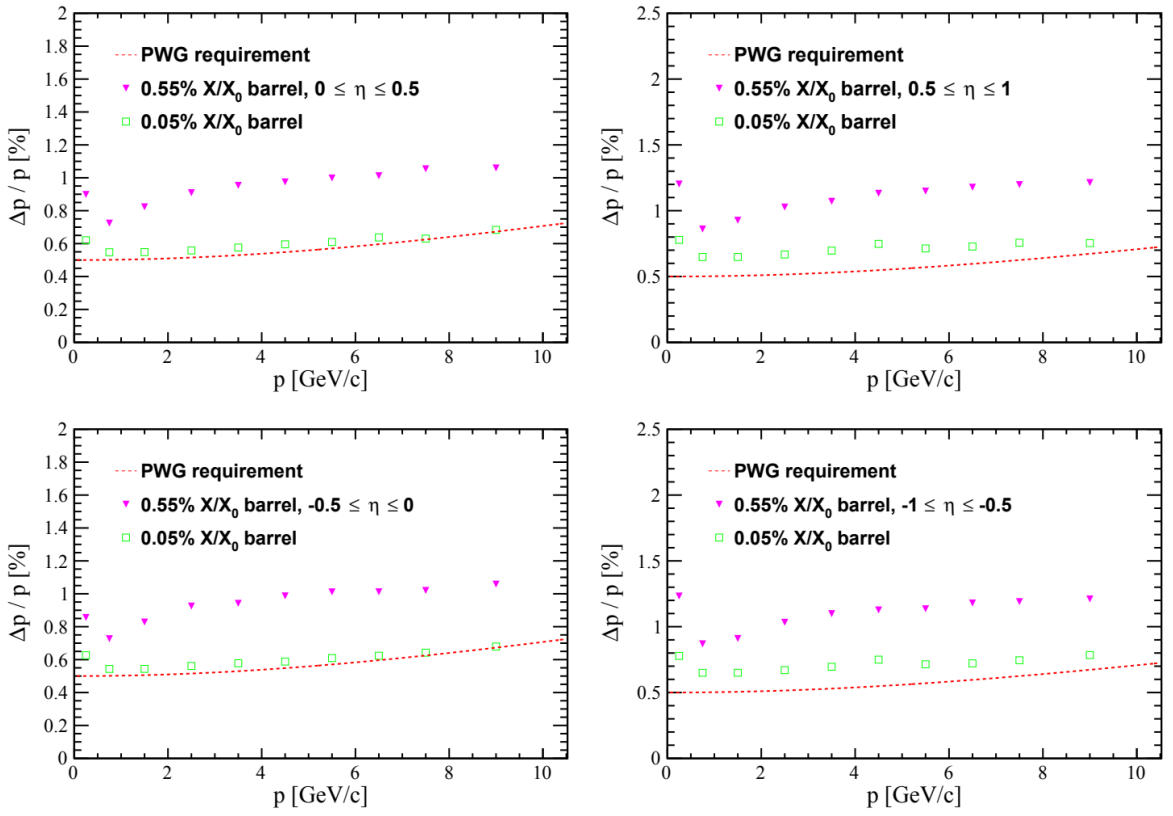






Increased material in sagitta layers

- Updated the material of layer 4 and 5 of the barrel MAPS to reflect estimated material budget from SC
  - Barrel layer 4 and 5 go from 0.05% X/X_0 → 0.55% X/X_0 per layer
- Note: both sets of results are produced using the 1.5T field map



Comments on performance requirements

- These requirements come from September 2020: are they still representative?
- Can also find a “Detector Matrix” at https://physdiv.jlab.org/DetectorMatrix/
  - Are these more up to date?

η	Nomenclature			Tracking			
				Resolution	Allowed	minimum-pT	Si-Vertex
-6.9 to -5.8	↓ p/A	Auxiliary Detectors	low-Q2 tagger	σθ/θ < 1.5%; 10-6 < Q2 < 10-2 GeV2			
-5.0 to -4.5						300 MeV pions	
-4.5 to -4.0			Instrumentation to separate charged particles from photons			300 MeV pions	
-4.0 to -3.5						<100MeV pions, 135MeV kaons	
-3.5 to -3.0		Central Detector	Backward Detector	σp/p ~ 0.1%⊕0.5%	~5% or less X	<100MeV pions, 135MeV kaons	
-3.0 to -2.5						<100MeV pions, 135MeV kaons	σ_xy ~ 30/pT μm + 40 μm
-2.5 to -2.0				σp/p 0.1%⊕0.5%		<100MeV pions, 135MeV kaons	σ_xy ~ 30/pT μm + 20 μm
-2.0 to -1.5				σp/p 0.05%⊕0.5%		<100MeV pions, 135MeV kaons	
-1.5 to -1.0						<100MeV pions, 135MeV kaons	
-1.0 to -0.5			Barrel	σp/p ~0.05%×p+0.5%		<100MeV pions, 135MeV kaons	σxyz ~ 20 μm, d0(z) ~d0(rΦ) ~ 20/pTGeV μm + 5 μm
-0.5 to 0.0						<100MeV pions, 135MeV kaons	
0.0 to 0.5						<100MeV pions, 135MeV kaons	
0.5 to 1.0						<100MeV pions, 135MeV kaons	
1.0 to 1.5			Forward Detectors	σp/p ~0.05%×p+1.0%		<100MeV pions, 135MeV kaons	σ_xy ~ 30/pT μm + 20 μm
1.5 to 2.0						<100MeV pions, 135MeV kaons	
2.0 to 2.5						<100MeV pions, 135MeV kaons	
2.5 to 3.0				σp/p ~ 0.1%×p+2.0%		<100MeV pions, 135MeV kaons	σ_xy ~ 30/pT μm + 40 μm
3.0 to 3.5						<100MeV pions, 135MeV kaons	σ_xy ~ 30/pT μm + 60 μm

Summary

- Fun4All implementation up and running with results in agreement with published ECCE plots
- Higher material in the Sagitta layers deteriorates resolutions as expected
  - Need input from EIC SC/eRD104 on services reduction and optimised material estimates

Next Steps

- Change radii of vertex layers to account for beam pipe bake out
- Once DD4hep implementation becomes available I will begin work on performance simulations using that