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University of Birmingham simulations update

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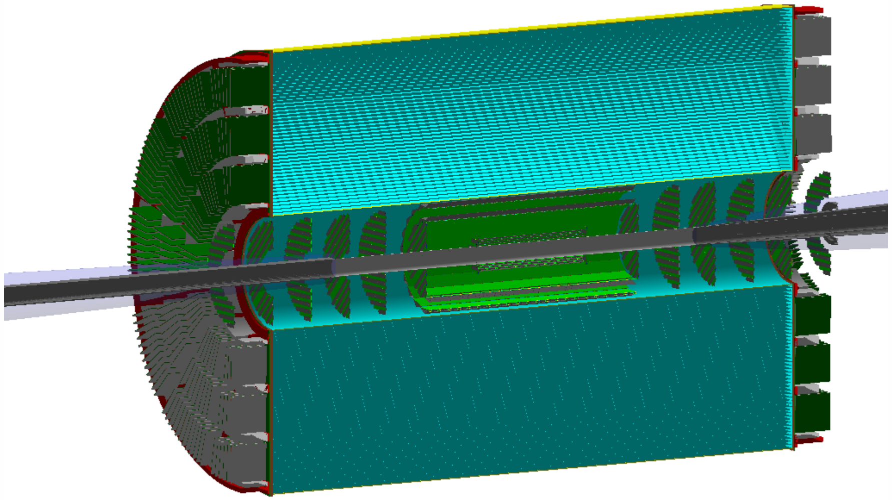
TPC hybrid baseline – Comparing to detector matrix

- Study done using pions
  - Transverse momentum range: 0 to 30 GeV/c
- This detector layout is symmetric, so only three pseudorapidity intervals were studied:
  - $-1.0 \leq \eta \leq 1.0$
  - $1.0 \leq \eta \leq 2.5$
  - $2.5 \leq \eta \leq 3.5$
- Study made for magnetic fields of 1.5 T and 3.0 T



TPC hybrid baseline detector

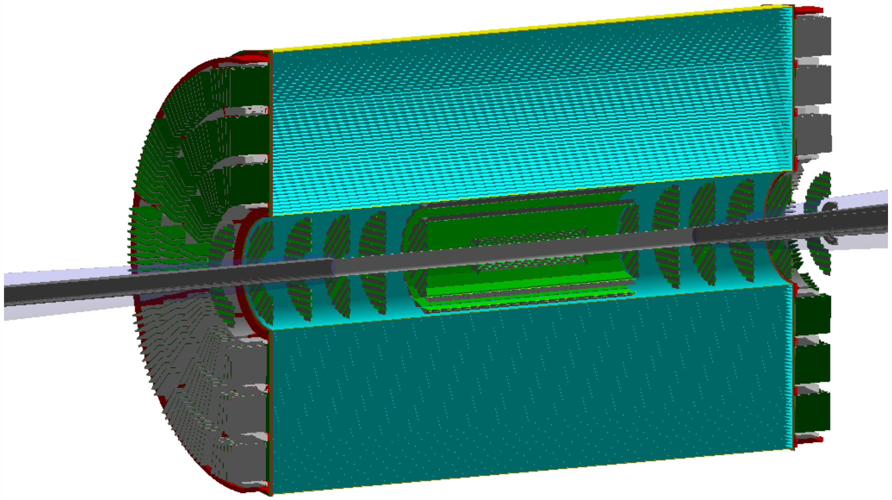
Parametrisation functions:

$$\frac{\sigma_p}{p} = A \cdot p \oplus B = \sqrt{(A \cdot p)^2 + B^2}$$

$$\frac{\sigma_{xy}}{p_\mathrm{T}} = A/p_\mathrm{T} \oplus B = \sqrt{\left(\frac{A}{p_\mathrm{T}}\right)^2 + B^2}$$

TPC parametrisation used

- Baseline EIC TPC in Fun4All, with default endcaps
- Based on the sPHENIX TPC (using sPHENIX TPC gas)
- Kapton field cage
- Simulation geometry made up of 48 layers
- Resolutions used:
  - 200 µm azimuthal (xy)
  - 500 µm longitudinal (z)

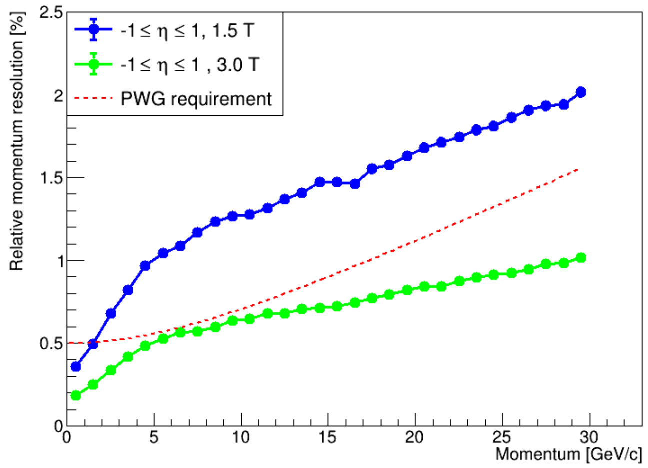


Results

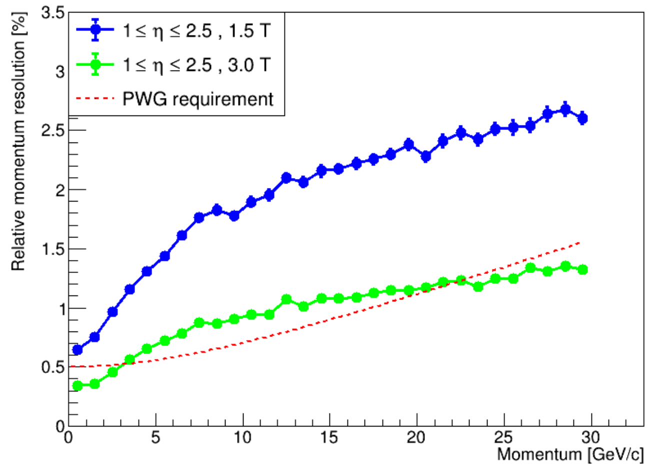
- The following slides show plots of resolutions, with curves for the PWG requirements drawn where available
- “Lower is better” in these plots, so if resolution curve is below PWG requirement curve, the results exceed the requirement
- Three intervals are shown
  - Requirements generally less strict in the backward region, so the strictest requirement is shown
  - Backup slides hold tables with all regions and requirements

Relative momentum resolution

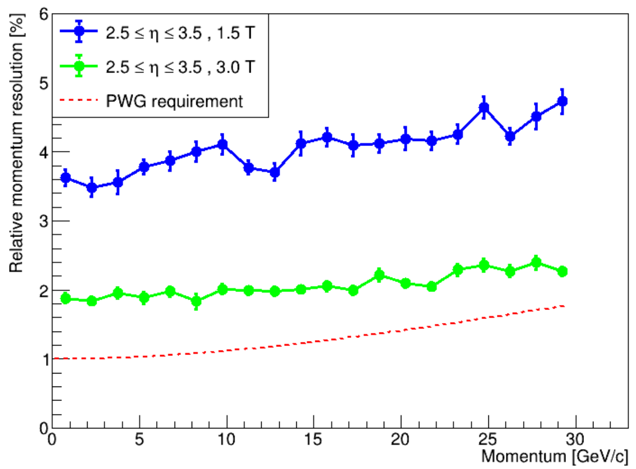
-1.0 ≤ η ≤ 1.0



1.0 ≤ η ≤ 2.5

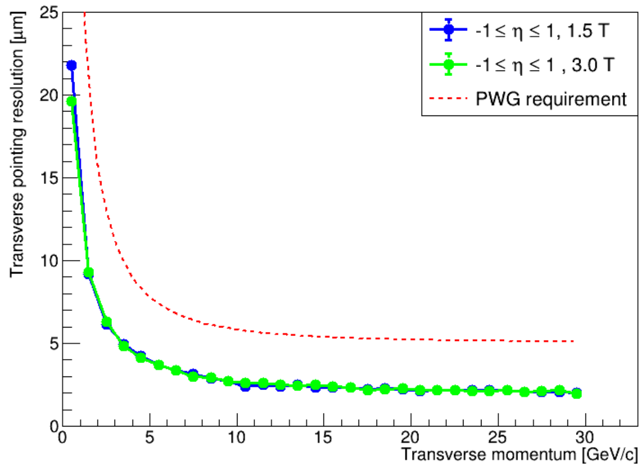


2.5 ≤ η ≤ 3.5

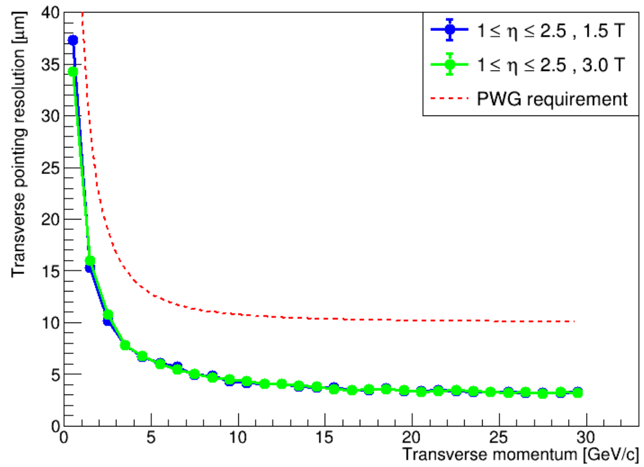


Transverse pointing resolution

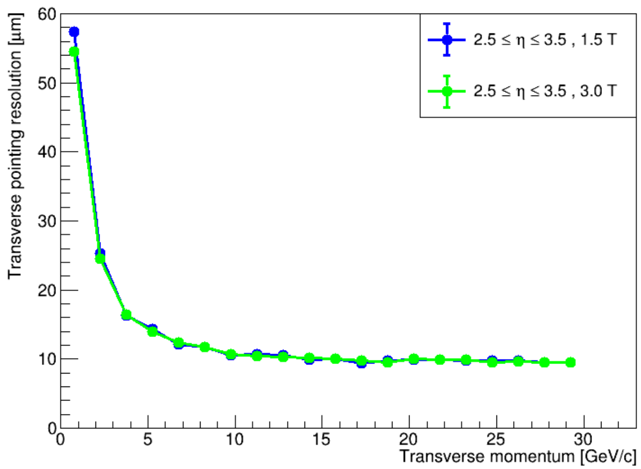
-1.0 ≤ η ≤ 1.0



1.0 ≤ η ≤ 2.5



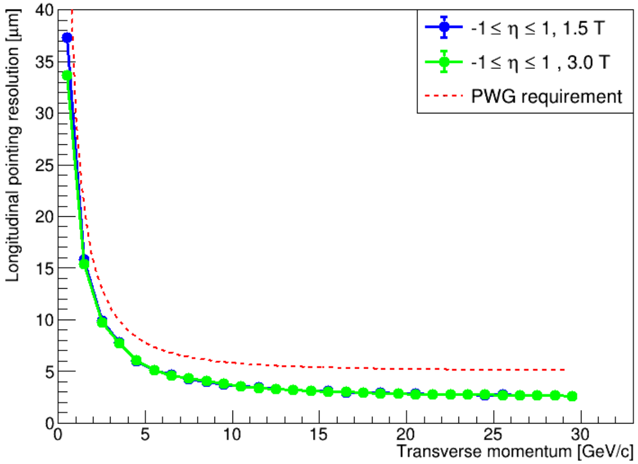
2.5 ≤ η ≤ 3.5



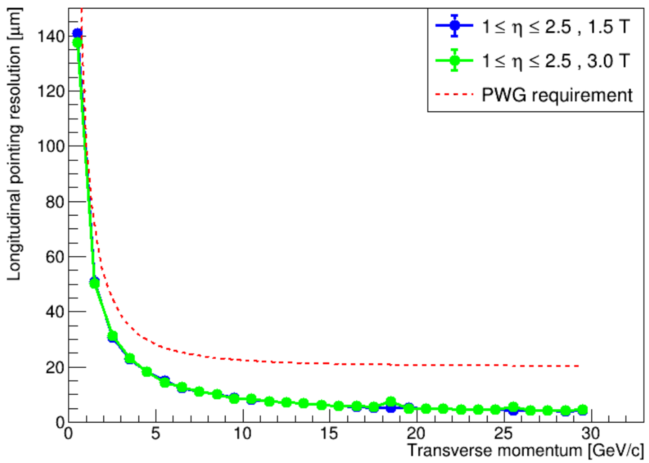
Note: currently no PWG requirement available in the most forward region

Longitudinal pointing resolution

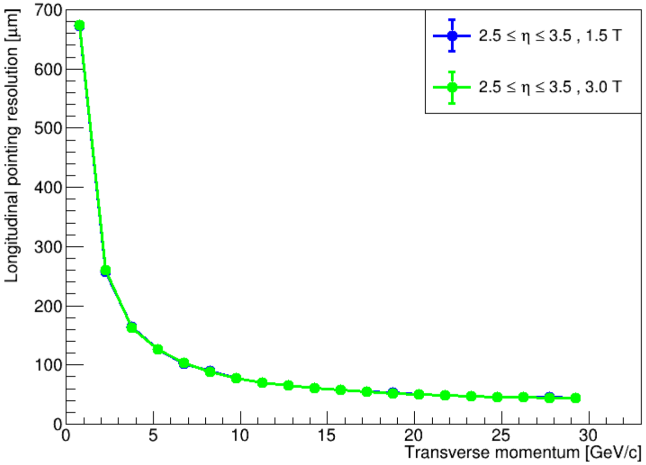
-1.0 ≤ η ≤ 1.0



1.0 ≤ η ≤ 2.5



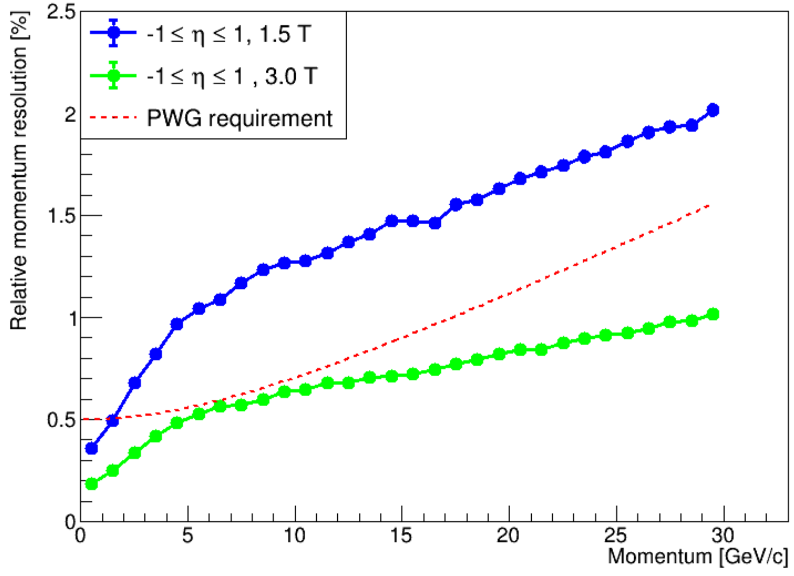
2.5 ≤ η ≤ 3.5



Note: currently no PWG requirement available in the most forward region

Notes on fitting

- Relative momentum resolution results when using a TPC do not follow the parametrisation equation
- Solution used: fit in two intervals
  - "Low-momentum region"
    - 0 to 5 GeV/c here
  - "Higher momentum region"
    - 5 to 30 GeV/c here
- Pointing resolution fits work well across the full interval



Notes

- Fits were performed according to the parametrisation functions. Resulting tables are available in the backup slides.
- The layout provides pointing resolutions that exceed the PWG requirements
- The layout does **not** provide adequate momentum resolution in most cases
  - A 1.5 T field is never enough
  - A 3 T field is enough in central regions, but not in $2.5 \leq \eta \leq 3.5$
- A 3.0 T magnetic field would help, **however** the TPC has a large outer radius
  - Need a **large-bore 3.0 T magnet** to reach the required relative momentum resolution with this layout
- In forward region, adding a far-forward tracking station (e.g. GEM or silicon) can greatly improve the momentum resolution there, due to increased lever arm length

Conclusions and next steps

- Pointing resolution with this layout (which for the silicon is using ITS3-like sensors and a 10x10 μm^2 pixel size) **matches or exceeds the current PWG requirements.**
- Relative momentum resolution **does not** generally reach the required performance
- The silicon technology is at its peak the way it is used in the simulations
  - Small adjustments can be made to the positioning of the detectors, but technology cannot be assumed to improve further
- Can the TPC be improved compared to the current Fun4All EIC TPC baseline?
  - Question for gaseous detector experts

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Backup slides

Relative momentum resolution tables

1.5 T field

Interval	Mom. interval	PWG values [%]	Fit 1.5 T [%]
$-3.5 \leq \eta \leq -2.5$	0 to 30 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.09 \pm 0.005$, $B = 3.71 \pm 0.046$
$-2.5 \leq \eta \leq -1.0$	0 to 8 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.24 \pm 0.003$, $B = 0.67 \pm 0.011$
	8 to 30 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.07 \pm 0.001$, $B = 1.81 \pm 0.020$
$-1.0 \leq \eta \leq 1.0$	0 to 5 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.21 \pm 0.002$, $B = 0.34 \pm 0.004$
	5 to 30 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.06 \pm 0.0004$, $B = 1.09 \pm 0.007$
$1.0 \leq \eta \leq 2.5$	0 to 8 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.24 \pm 0.003$, $B = 0.67 \pm 0.011$
	8 to 30 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.07 \pm 0.001$, $B = 1.81 \pm 0.020$
$2.5 \leq \eta \leq 3.5$	0 to 30 GeV/c	$A = 0.05$, $B = 1.0$	$A = 0.09 \pm 0.005$, $B = 3.71 \pm 0.046$

3.0 T field

Interval	Mom. interval	PWG values [%]	Fit 3.0 T [%]
$-3.5 \leq \eta \leq -2.5$	0 to 30 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.05 \pm 0.003$, $B = 1.90 \pm 0.024$
$-2.5 \leq \eta \leq -1.0$	0 to 8 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.11 \pm 0.002$, $B = 0.33 \pm 0.006$
	8 to 30 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.04 \pm 0.001$, $B = 0.88 \pm 0.010$
$-1.0 \leq \eta \leq 1.0$	0 to 5 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.11 \pm 0.001$, $B = 0.18 \pm 0.003$
	5 to 30 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.03 \pm 0.0002$, $B = 0.54 \pm 0.003$
$1.0 \leq \eta \leq 2.5$	0 to 8 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.11 \pm 0.002$, $B = 0.33 \pm 0.006$
	8 to 30 GeV/c	$A = 0.05$, $B = 0.5$	$A = 0.04 \pm 0.001$, $B = 0.88 \pm 0.010$
$2.5 \leq \eta \leq 3.5$	0 to 30 GeV/c	$A = 0.1$, $B = 0.5$	$A = 0.05 \pm 0.003$, $B = 1.90 \pm 0.024$

Pointing resolution tables

Transverse pointing resolution

Interval	PWG values [μm]	Fit 1.5 T [μm]	Fit 3.0 T [μm]
$-3.5 \leq \eta \leq -2.5$	N/A	$A = 49.3 \pm 0.2$, $B = 9.64 \pm 0.02$	$A = 48.5 \pm 0.2$, $B = 9.58 \pm 0.02$
$-2.5 \leq \eta \leq -1.0$	$A = 40$, $B = 10$	$A = 23.3 \pm 0.1$, $B = 3.32 \pm 0.01$	$A = 23.1 \pm 0.1$, $B = 3.31 \pm 0.01$
$-1.0 \leq \eta \leq 1.0$	$A = 30$, $B = 5$	$A = 14.1 \pm 0.1$, $B = 2.11 \pm 0.01$	$A = 13.7 \pm 0.1$, $B = 2.14 \pm 0.01$
$1.0 \leq \eta \leq 2.5$	$A = 40$, $B = 10$	$A = 23.3 \pm 0.1$, $B = 3.32 \pm 0.01$	$A = 23.1 \pm 0.1$, $B = 3.31 \pm 0.01$
$2.5 \leq \eta \leq 3.5$	N/A	$A = 49.3 \pm 0.2$, $B = 9.64 \pm 0.02$	$A = 48.5 \pm 0.2$, $B = 9.58 \pm 0.02$

Longitudinal pointing resolution

Interval	PWG values [μm]	Fit 1.5 T [μm]	Fit 3.0 T [μm]
$-3.5 \leq \eta \leq -2.5$	N/A	$A = 596.9 \pm 1.5$, $B = 41.05 \pm 0.12$	$A = 596.5 \pm 1.5$, $B = 40.79 \pm 0.12$
$-2.5 \leq \eta \leq -1.0$	$A = 100$, $B = 20$	$A = 78.3 \pm 0.2$, $B = 3.11 \pm 0.02$	$A = 78.1 \pm 0.2$, $B = 3.12 \pm 0.02$
$-1.0 \leq \eta \leq 1.0$	$A = 30$, $B = 5$	$A = 23.2 \pm 0.1$, $B = 2.64 \pm 0.01$	$A = 22.9 \pm 0.1$, $B = 2.64 \pm 0.01$
$1.0 \leq \eta \leq 2.5$	$A = 100$, $B = 20$	$A = 78.3 \pm 0.2$, $B = 3.11 \pm 0.02$	$A = 78.1 \pm 0.2$, $B = 3.12 \pm 0.02$
$2.5 \leq \eta \leq 3.5$	N/A	$A = 596.9 \pm 1.5$, $B = 41.05 \pm 0.12$	$A = 596.5 \pm 1.5$, $B = 40.79 \pm 0.12$

Full layout sketch