Reconstruction irregularities in the ATLAS experiment

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Overview

Motivation

- Excess parity-violation could indicate new physics...
- ... or imperfections in the experiment
- Should be apparent in parity-odd observables as an asymmetry
- How to quantify 'asymmetry'?
- How to figure out its cause?

Parity-violating observables

- Spatial inversion through the origin - reverses momenta
- Parity is violated in a process if cross-section changes under $\hat{P}$

$$|M|^2 = \text{even} + \text{odd} \quad \xrightarrow{P} \quad |M|^2 = \text{even} - \text{odd}$$

Parity-violating observables

- Initial state must be symmetric
- Can only depend on momenta
- Involves alternating tensor $\epsilon_{\mu\nu\rho\sigma}$
- Asymmetry should not cancel between different processes

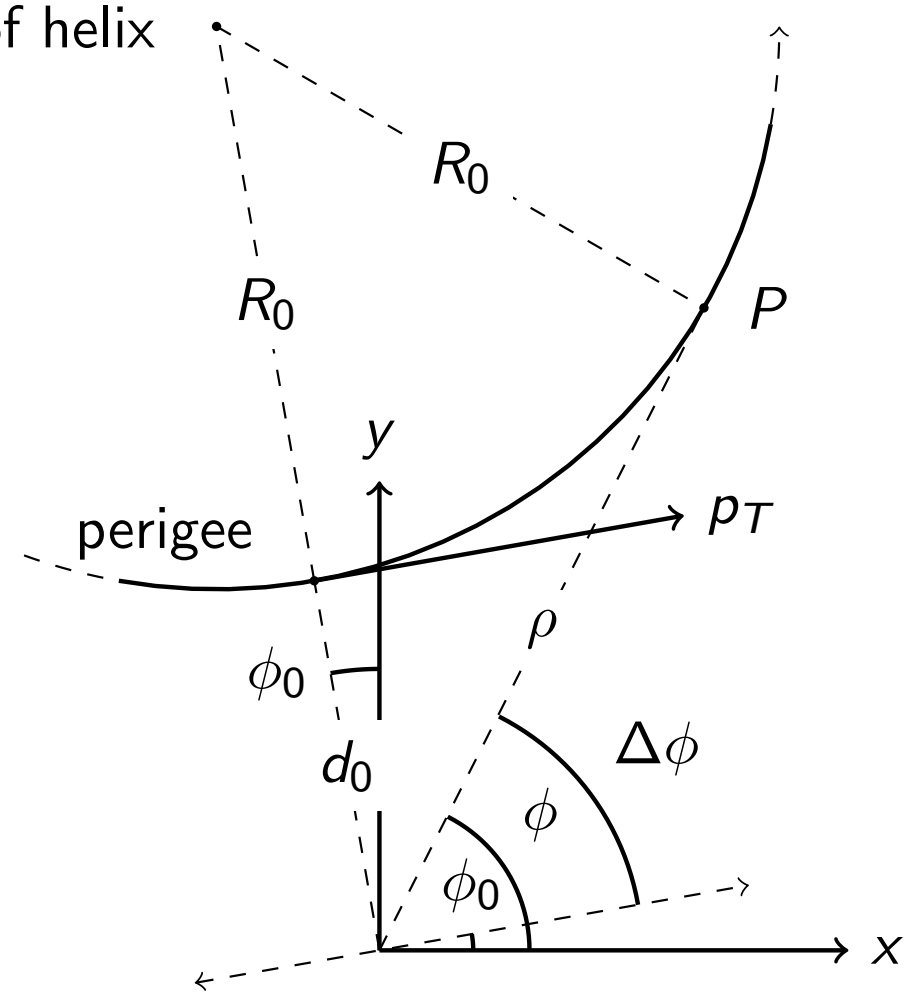
The variable D

$$((\vec{p}_a \times \vec{p}_b) \cdot \hat{z}) \, \mathrm{sgn}((\vec{p}_a - \vec{p}_b) \cdot \hat{z})$$

Avoid cancelling:

- label by energy
- label by charge (e.g. twist)
- CP-conjugate (CP violation)

Particle tracking



Parameters:

- d_0 and z_0
- ϕ_0 and θ_0 (η_0)
- q/p

Coefficients of asymmetry

- 'Forward-backward'

$$A = \frac{|N_{D>0} - N_{D<0}|}{N_{D>0} + N_{D<0}}$$

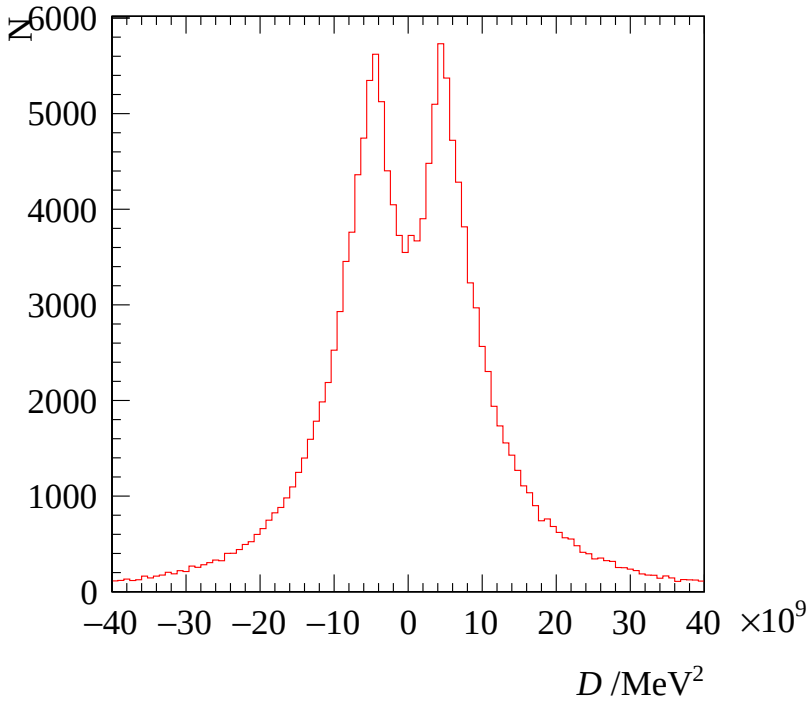
- Mean

$$\bar{D} = \sum_{i=1}^{N} \frac{1}{N} D_i, \quad \mathrm{SE}_{\bar{D}} = \frac{\sigma}{\sqrt{N}}$$

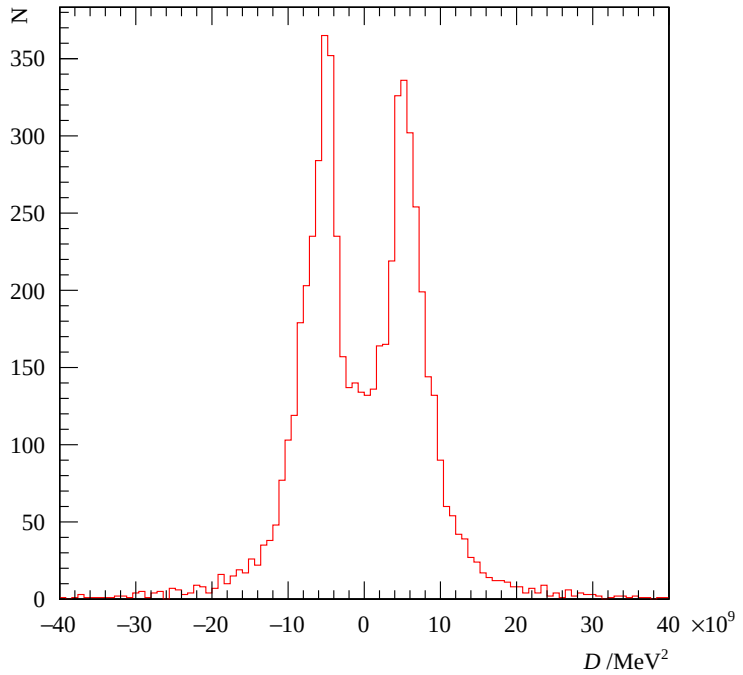
- Skewness

$$G_1 = \frac{\sqrt{N(N-1)}}{N-2} \frac{1}{\sigma^3} \sum_{i=1}^{N} \frac{1}{N} (D_i - \bar{D})^3, \quad \mathrm{var}(G_1) \approx \frac{6}{N}$$

ATLAS data



$n = 1.567 \times 10^5$



$n = 6.07 \times 10^3$

Figure: D distributions of dijet and dilepton events.

ATLAS data

	n	A	$\bar{D}/\mathrm{MeV}^2$	G_1
dijet	1.567×10^5	$(2 \pm 5) \times 10^{-3}$	$(0.5 \pm 1.9) \times 10^8$	4 ± 11
$e^{\pm}$, $\mu^{\pm}$	6.07×10^3	$(0 \pm 3) \times 10^{-2}$	$(0 \pm 3) \times 10^8$	1 ± 2

Table: Values of coefficients for $1\,\mathrm{fb}^{-1}$ of ATLAS data, divided into 10 sub-samples.

- Errors are too large!
- Especially if we want to see variation with ϕ, η
- Need lots more data to see if method works

Toy model

- Monte Carlo generator
- 'Dilepton' events (can label by charge)
- Make parity symmetric
- Looks symmetric (just as well!) ...

Toy model

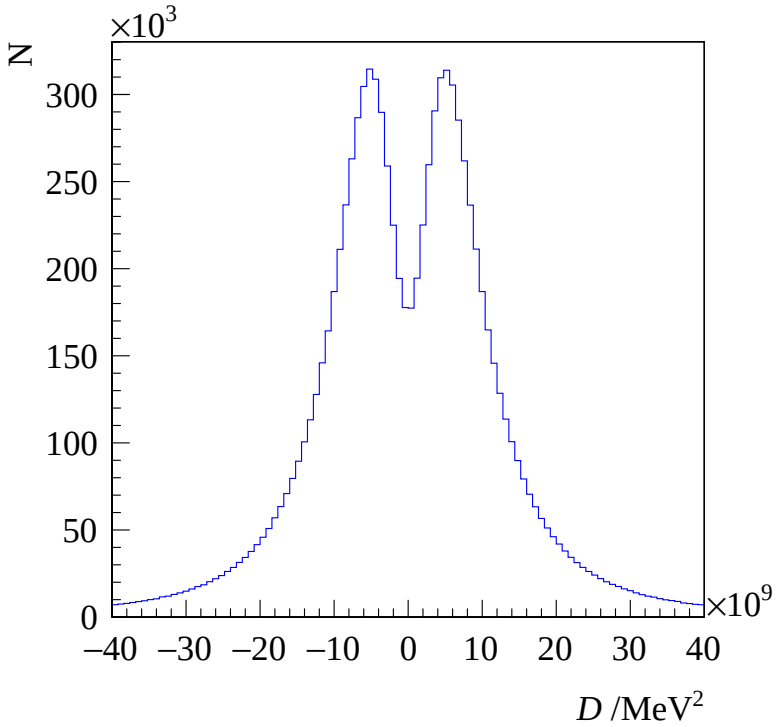


Figure: Overall D distribution for 'dimuon' events.

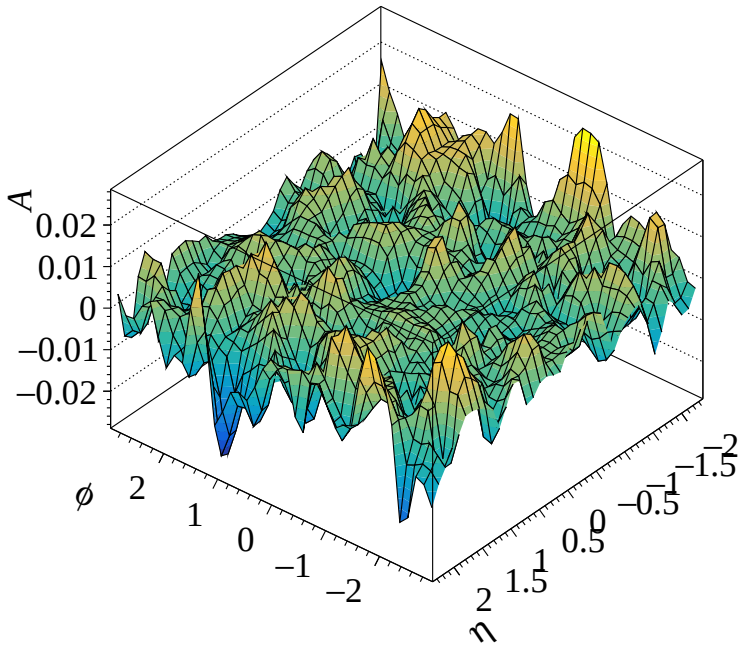


Figure: Variation of A over 20 bins in ϕ and η.

Screw model

- ... but does anything look asymmetric?
- Look at model that violates parity
- Screw model has $\Delta\phi \propto \Delta\eta$

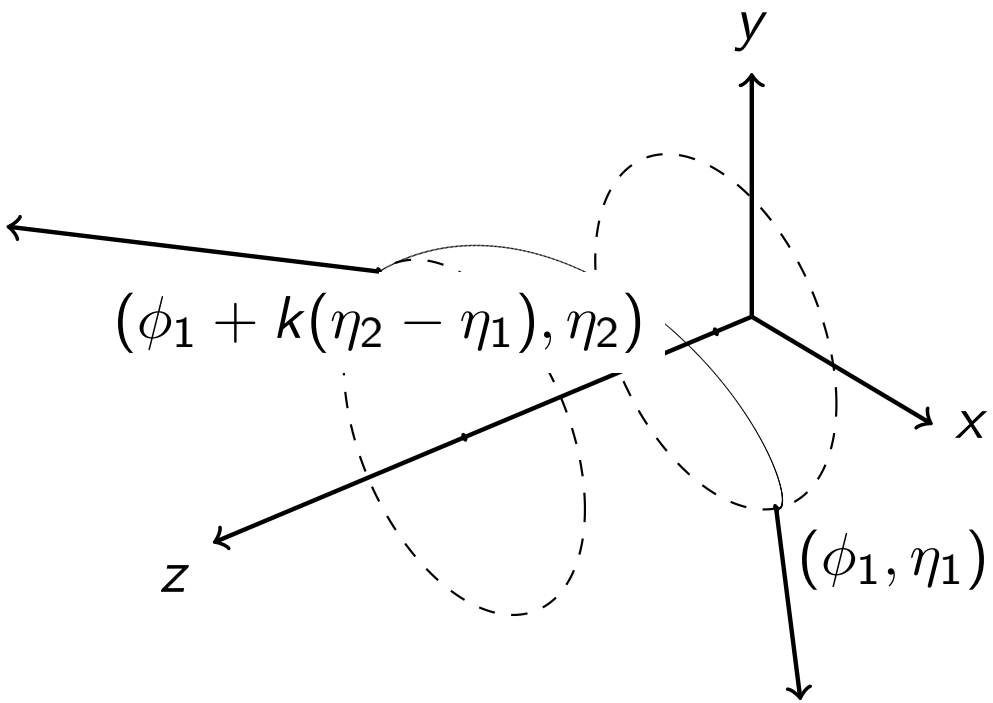


Figure: Illustration of the screw model geometry.

Screw model

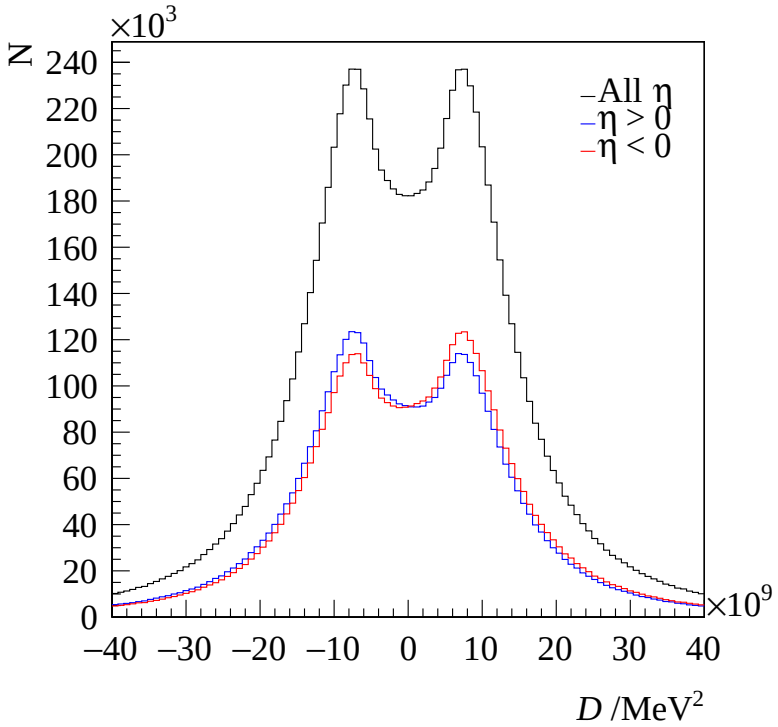


Figure: D distribution for 1×10^7 screw model events.

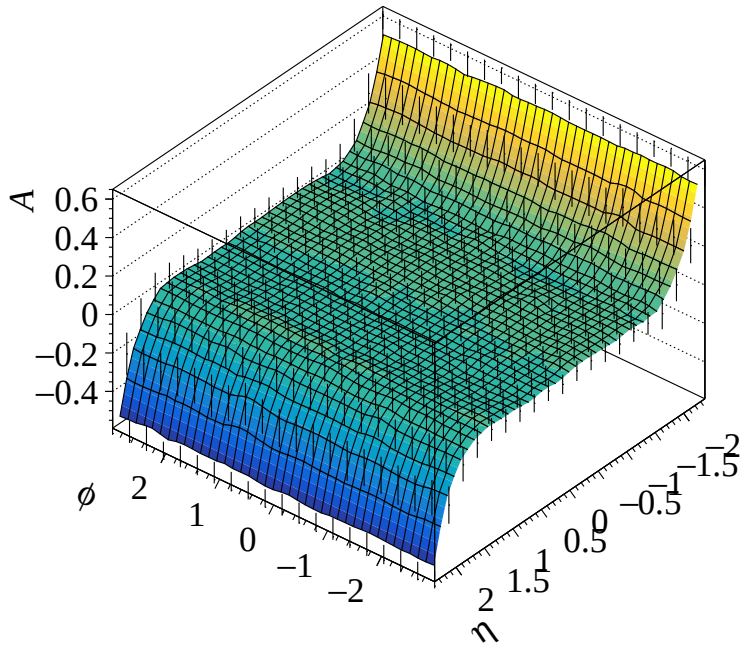


Figure: Variation of A, divided into 100 sub-samples and 20 bins.

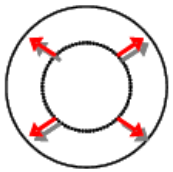
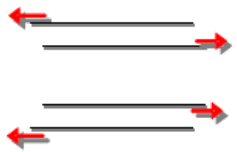
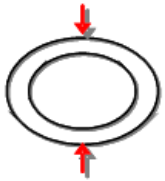
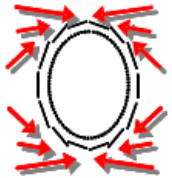
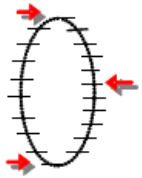
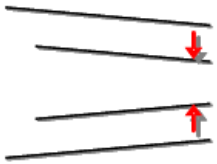
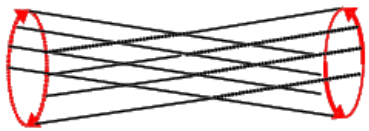
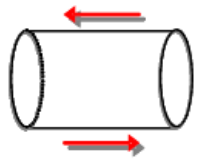
Screw model

- Need to look at variation to see asymmetry
- A, $\bar{D}$ have smaller errors than G_1
- Theoretically, the method could spot parity violation
- What about a potential detector effect?

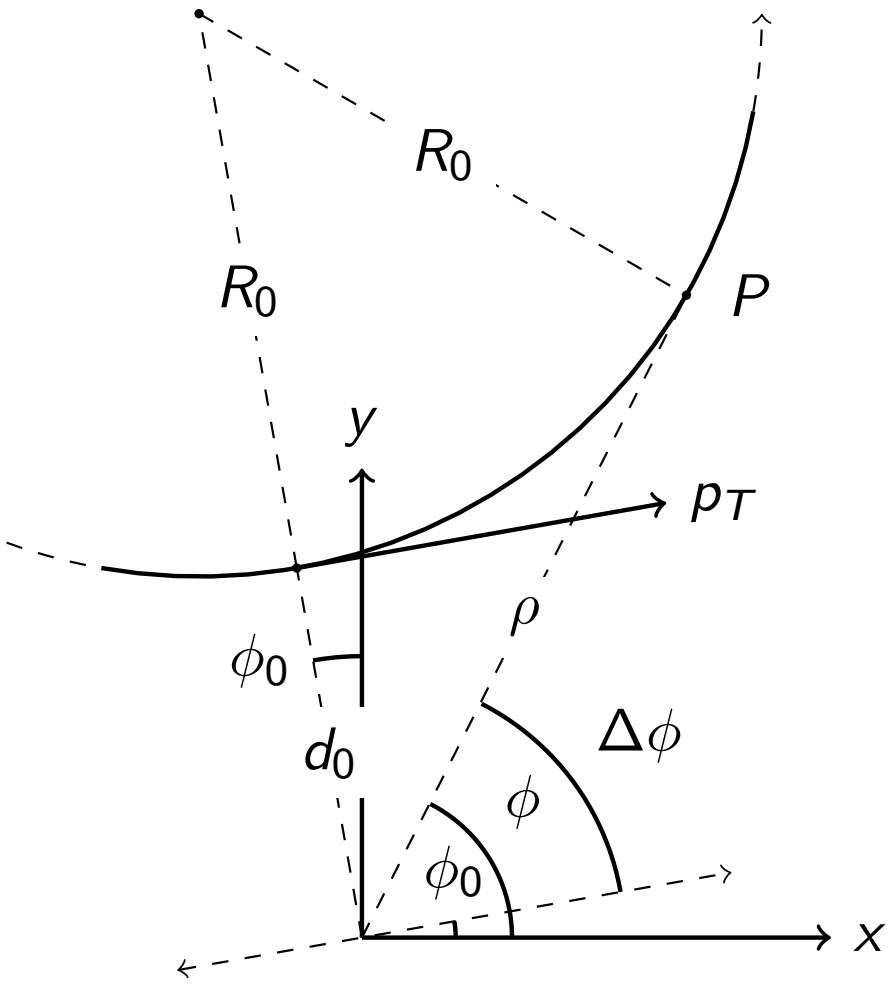
Weak modes of alignment

- Correlated distortion
- No effect on χ^2
- Bias track parameters
- A twist, where $\Delta\phi = cz$, is parity-odd
- Potential source of excess parity violation

Weak modes of alignment

	ΔR	$\Delta\phi$	ΔZ
R	**Radial Expansion** (distance scale) 	**Curl** (Charge asymmetry) 	**Telescope** (COM boost) 
ϕ	**Elliptical** (vertex mass) 	**Clamshell** (vertex displacement) 	**Skew** (z momentum) 
Z	**Conical Warping** (total momentum) 	**Twist** (vertexing) 	**Z expansion** (distance scale) 

Effect on parameters



- Neglect d_0
- Transformation

$$\Phi \to \Phi + cz$$

- Only affects $p_T = seBR_0$

$$\to p_T \left(1 + \frac{2c}{seB} p_T \sinh \eta_0\right)^{-1}$$

- Need to label by charge

Twist

- Look at a twist we can already identify/correct
- Transform p_T (and $D_\pm$) for fake data

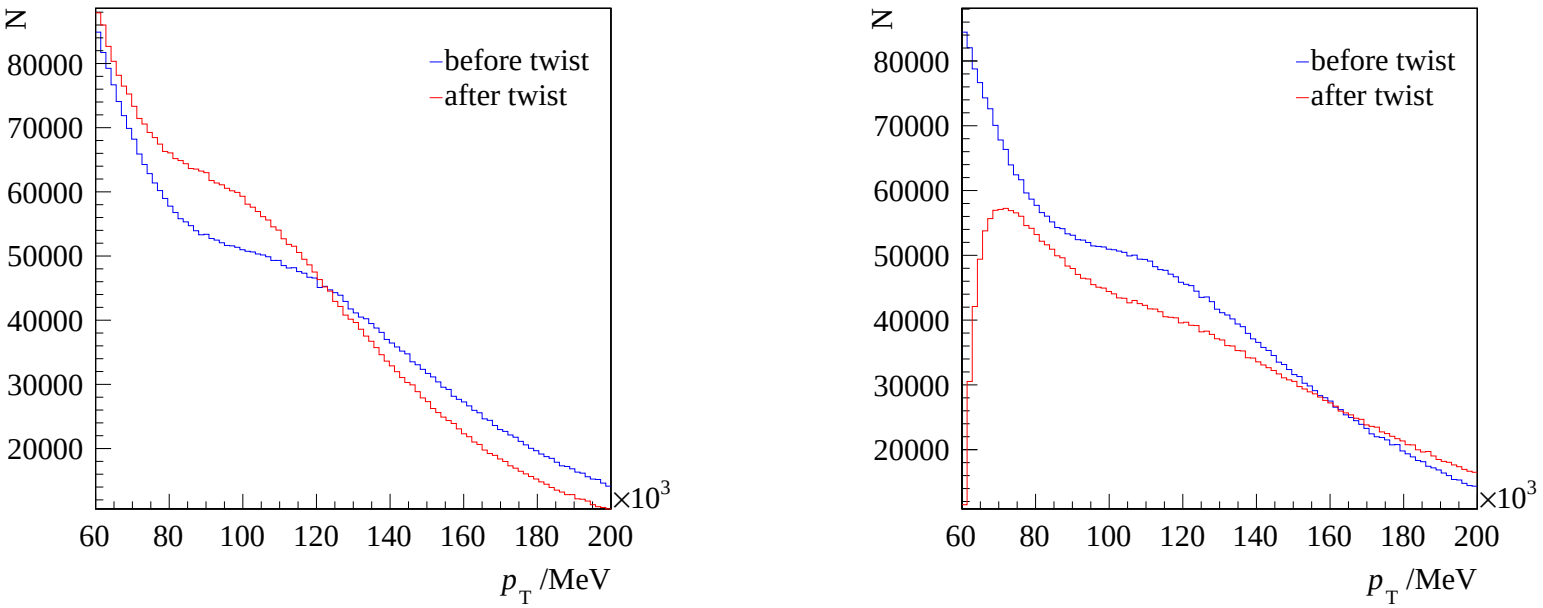


Figure: Effect on $\pm$-vely charged momentum distributions respectively, for 5×10^6 'dimuon' events in the forward region.

Does it look asymmetric?

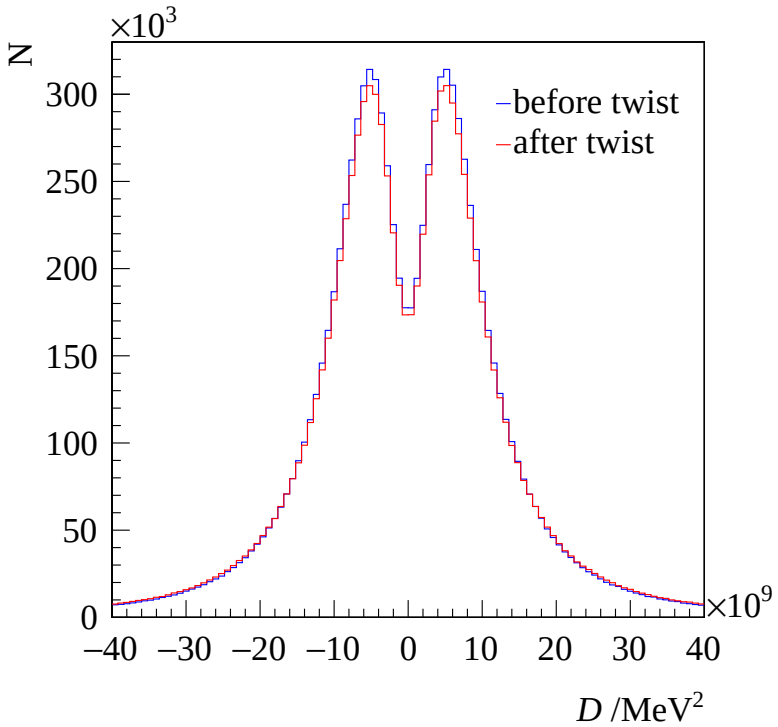


Figure: Effect of twist on $D_{\pm}$ distribution for 1×10^7 'dimuon' events.

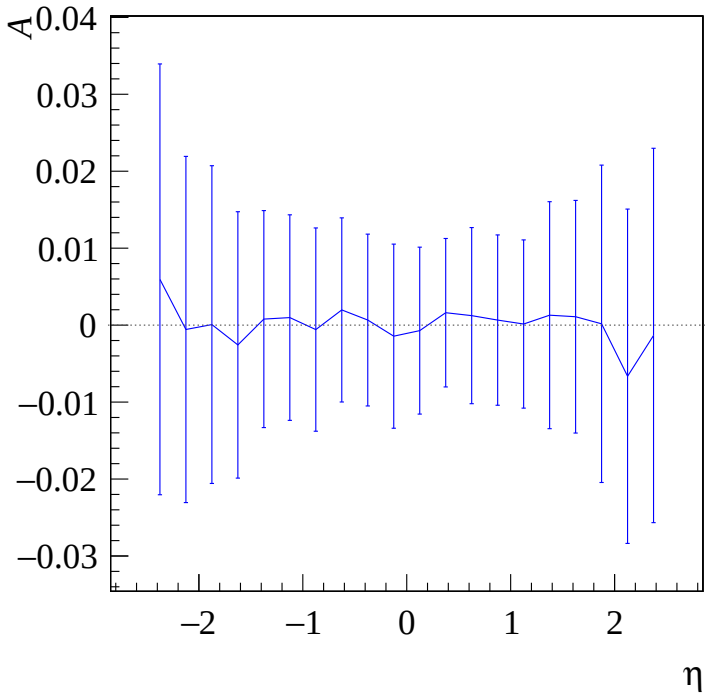


Figure: Variation of A for 1×10^7 'dimuon' events after twist, divided into 100 sub-samples.

Conclusions

- Need to choose coefficients wisely
- Coordinate variation of D distribution important
- Even for a large twist deformation, D-asymmetry is negligible
- Other detector effects responsible?
- Need more sophisticated analysis with proper detector response
- A way off from using parity-odd observables as a test for new physics