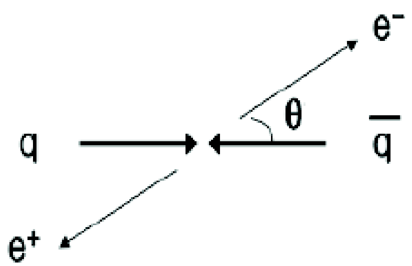
Collins-Soper frame

- Collins-Soper frame : the center of mass frame of dilepton

$$q\bar{q} \rightarrow Z/\gamma* \rightarrow \ell^{+}\ell^{-}$$



in lepton plane

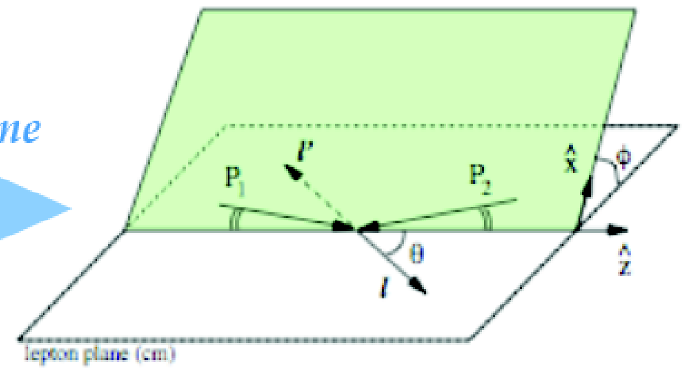


FIG. 1: The Collins-Soper frame.

- Differential cross section of cosθ and ϕ

$$\frac{\mathbf{d}\sigma}{\mathbf{dP_T^2dyd}\cos\theta\mathbf{d}\phi} \propto (1+\cos^2\theta) \longrightarrow \textit{LO term}$$

$$+ \frac{1}{2}A_0(1-3\cos^2\theta) \longrightarrow \cos^2\theta : \textit{higher order term}$$

$$+ A_1\sin 2\theta\cos\phi + \frac{1}{2}A_2\sin^2\theta\cos 2\phi + A_3\sin\theta\cos\phi \rightarrow (\theta, \phi)\ \textit{terms}$$

$$+ A_4\cos\theta \longrightarrow \textit{LO term : determine } A_{fb}$$

$$+ A_5\sin^2\theta\sin 2\phi + A_6\sin 2\theta\sin\phi + A_7\sin\theta\sin\phi \rightarrow \textit{very small terms}$$

****All higher order terms are zero at Pt=0*

Reweighting to isotropic events

- **We can verify extracted coefficients in MC by reweighting to isotropic events (flat in both cos θ and ϕ) with weight**

$$w_{iso} = \frac{1.}{\sum_{i=0}^{i=8} < A_i^{ref} > P_i(\theta, \phi)}$$

Coefficients extracted from moments

- **Reweighting can be done per individual sub-process with possibly better control on systematics due to PDFs**
- **Isotropic events can be used build required template shape in the fiducial volume (see latter)**

Building templates from MC events

- **Reweight MC events to represent desired component in the full phase-space volume**

$$r^i = \frac{P_i(\theta,\phi)}{\sum_{k=0}^{k=8} < A_k^{ref} > P_k(\theta,\phi)}$$

- **Build template as superposition of 9 individual templates (added term $(1+\cos^2\theta)$ multiplied by a constant coefficient $A_8=1$)**
- **Thanks to the linear form, fit only corrections to the known MC model.**

$$< A_i > = < A_i^{ref} > + \delta A_i$$

$$hist_{tmpl} = \sum_{i=0}^{i=8} (< A_i^{ref} > + \delta A_i)\ hist_{tmpl}^i$$

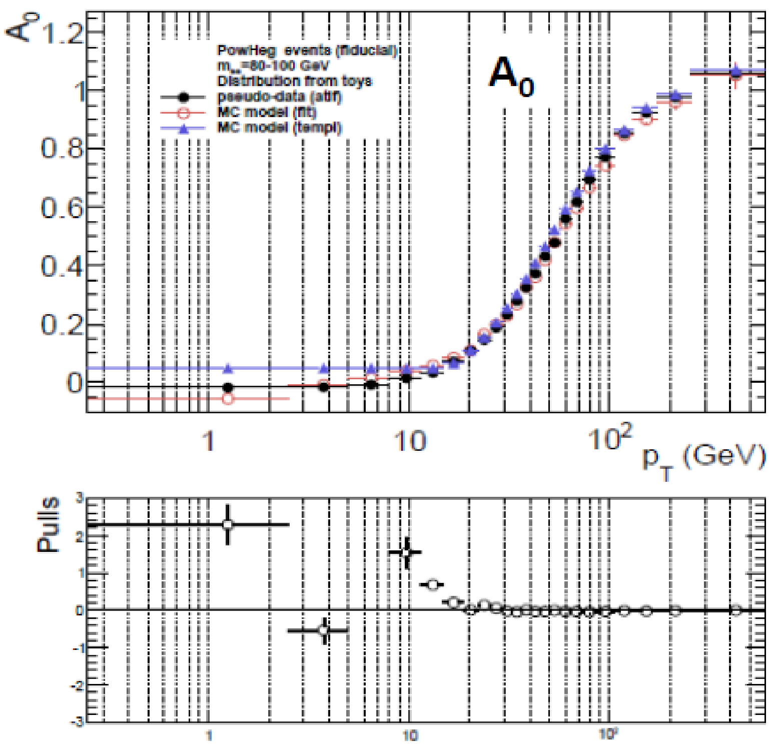
$$= hist_{ref} + \sum_{i=0}^{i=8} \delta A_i\ hist_{tmpl}^i$$

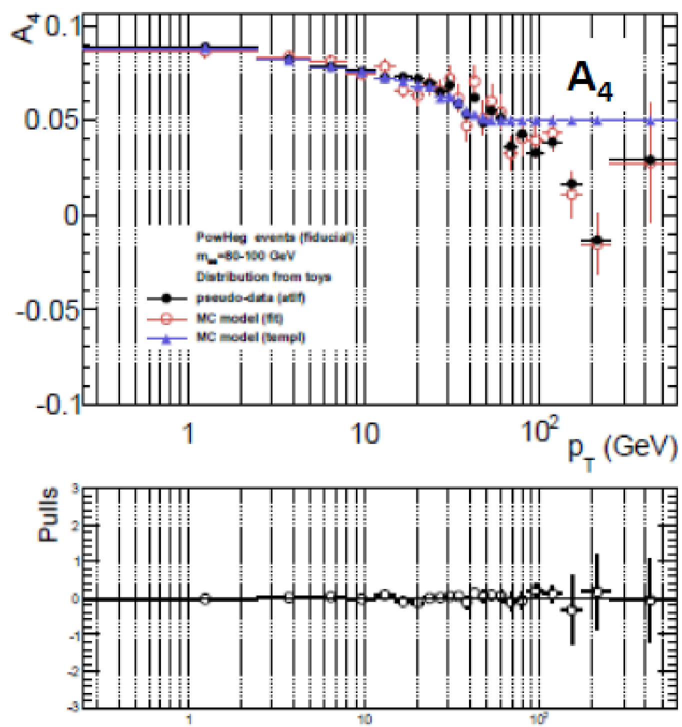
Fitting results (pseudodata)

Black: pseudo-data for A_0 (left) and A_4 (right) as a function of p_T^Z

Blue: starting values for the fit

Brown: fitted values



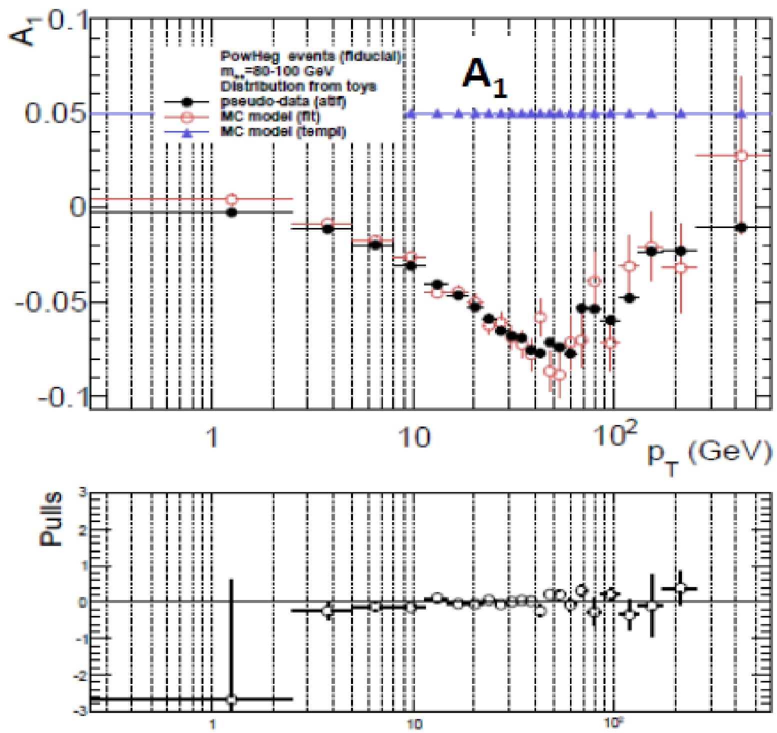


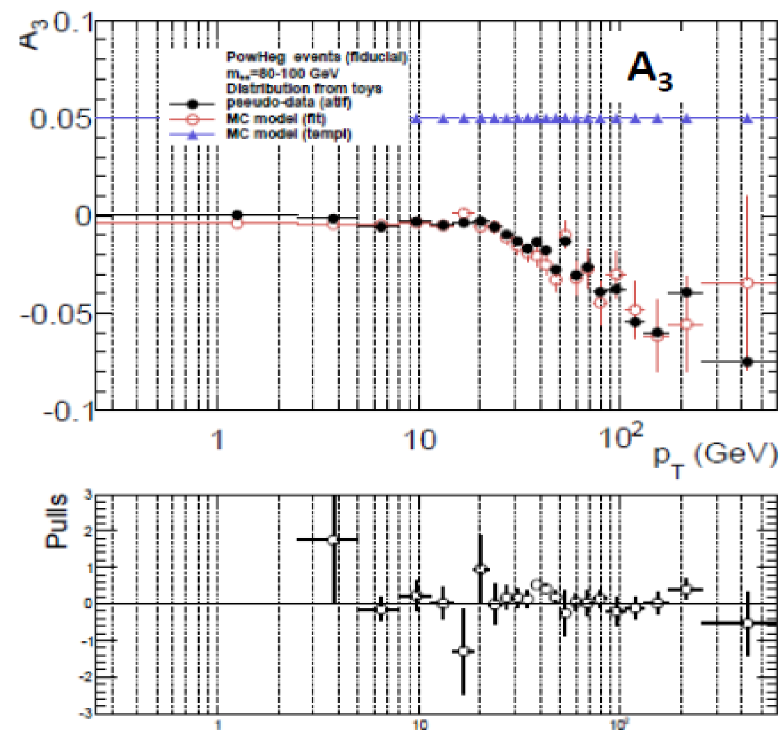
Fitting results (pseudodata)

Black: pseudo-data for A_1 (left) and A_3 (right) as a function of p_T^Z

Blue: starting values for the fit

Brown: fitted values





Example of the fit

- Fit residuals (biases) ~ 0 within errors (in well behaved p_T^Z bin)
- Stat. errors ~ 20-100% larger in fiducial region
- In all p_T^Z bins, the fit results are reasonable (χ^2/ndof < 2.5)

Fit in fiducial region ↙ true ↙ fit2D (based on 5.2M pseudo-data events)

p_T (GeV)	Ang. coeff.	A_i (Psd)	A_i (Fit2D)	δA_i^{stat} (Fit2D)	Residual	$\chi^2/ndof$
32.6 - 36.4	A_0	0.2794	0.2679 ± 0.0010	0.0107 ± 0.0000	0.0115 ± 0.0108	1.60 ± 0.01
	A_1	-0.0691	-0.0724 ± 0.0007	0.0072 ± 0.0000	0.0033 ± 0.0072	
	A_2	0.2025	0.1947 ± 0.0008	0.0093 ± 0.0000	0.0078 ± 0.0093	
	A_3	-0.0168	-0.0190 ± 0.0005	0.0043 ± 0.0000	0.0022 ± 0.0043	
	A_4	0.0589	0.0619 ± 0.0007	0.0072 ± 0.0000	-0.0030 ± 0.0072	
	A_5	-0.0010	0.0006 ± 0.0005	0.0048 ± 0.0000	-0.0016 ± 0.0047	
	A_6	0.0000	-0.0046 ± 0.0005	0.0057 ± 0.0000	0.0046 ± 0.0058	
	A_7	-0.0016	-0.0010 ± 0.0005	0.0042 ± 0.0000	-0.0006 ± 0.0042	