Search for Contact Interactions (second PRELIMINARY request)

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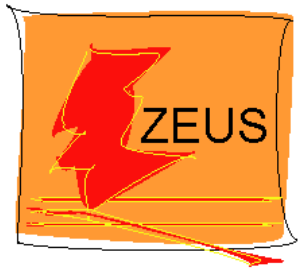

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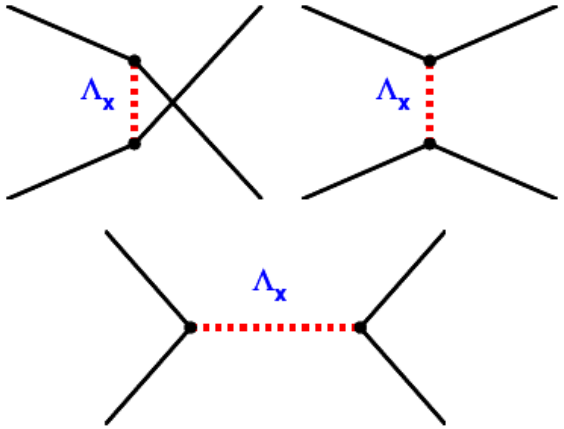
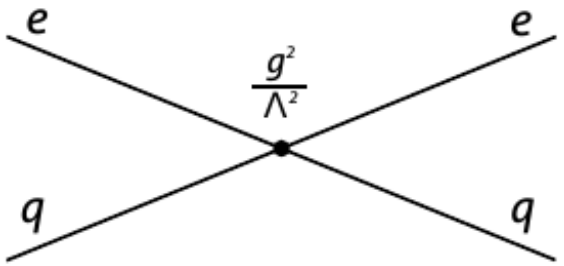
- Contact Interactions
- Limits extraction
- Comperison of results
- Results (General CI models)
- Results (LQ models)

Contact Interaction

An investigation of possible effects due to the virtual exchange allows to search for evidance of new particles with mass much higher than the center of mass energy.



$\Lambda_x \gg \sqrt{s}$



$$\mathcal{L}_{\mathrm{CI}} = \sum_{\substack{k,j=L,R \\ q=u,d,s,c,b}} \eta_{kj}^{eq} (\bar{e}_k \gamma^\mu e_k)(\bar{q}_j \gamma_\mu q_j)$$

NC cross section:

$$M_{ij}^{eq}(t) = -\frac{4\pi\alpha_{em} e_q}{t} + \frac{4\pi\alpha_{em}}{\sin^2\Theta_W \cdot \cos^2\Theta_W} \cdot \frac{g_i^e g_j^q}{t - M_Z^2} + \eta_{ij}^{eq}$$

$$\begin{aligned} \eta_{ij}^{eu} &= \eta_{ij}^{ec} = \eta_{ij}^{et}, \\ \eta_{ij}^{ed} &= \eta_{ij}^{es} = \eta_{ij}^{eb}, \end{aligned}$$

CC cross section:

$$\frac{d^2\sigma_{CC}^{e^- p}}{dx dQ^2} = (1-P)\frac{1}{\pi}\sum_{i=1}^{2}[u_i(x,Q^2) + (1-y)^2 \bar{d}_i(x,Q^2)] \times \left[\frac{G_F}{\sqrt{2}} \frac{M_W^2}{M_W^2 + Q^2} - \frac{\eta_i^{evud}}{4}\right]^2$$

Contact Interaction

Combined QCD + CI Fit (PDF fit together with CI parameters fit):

In HERAPDF2.0 appoach:

$$xg(x) = A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{C'_g}$$
$$xu_v(x) = A_{u_v} x^{u_v}(1-x)^{C_{u_v}}(1+E_{u_v}x^2)$$
$$xd_v(x) = A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}}$$
$$x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}}(1-x)^{C_{\bar{U}}}(1+D_{\bar{U}}x)$$
$$x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}}(1-x)^{C_{\bar{D}}}$$

$$\sigma_{NLO}^{SM+CI} = \sigma_{NLO}^{SM} \frac{\sigma_{LOEW}^{SM+CI}}{\sigma_{LOEW}^{SM}}$$

Reason for the simultaneous fit procedure:

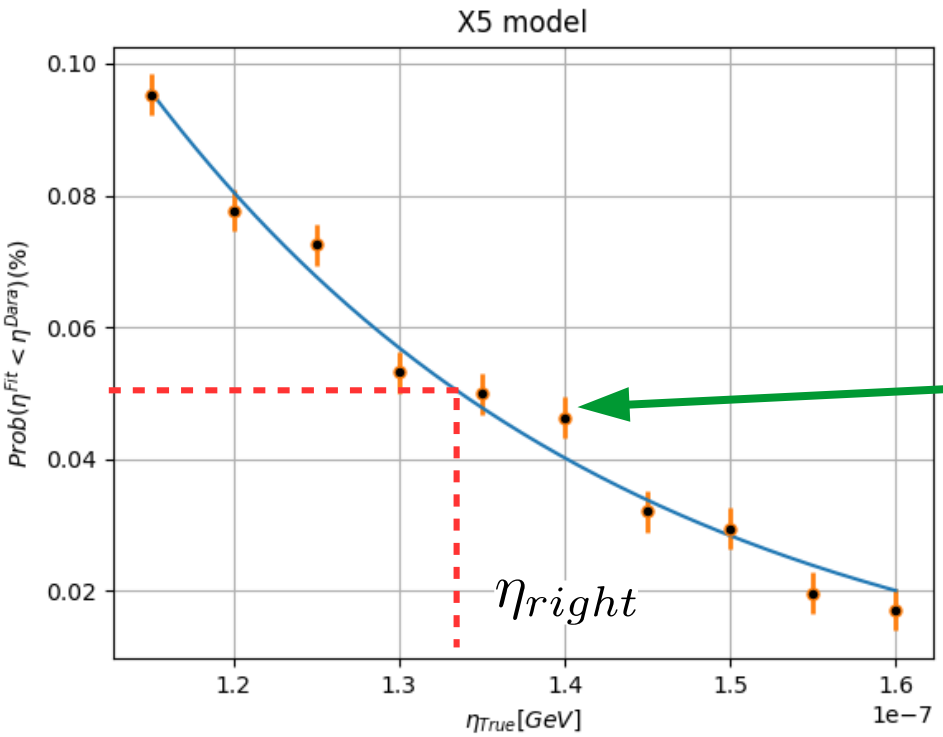
➔ BSM signal in the data could affect the PDF fit and result in biased PDFs

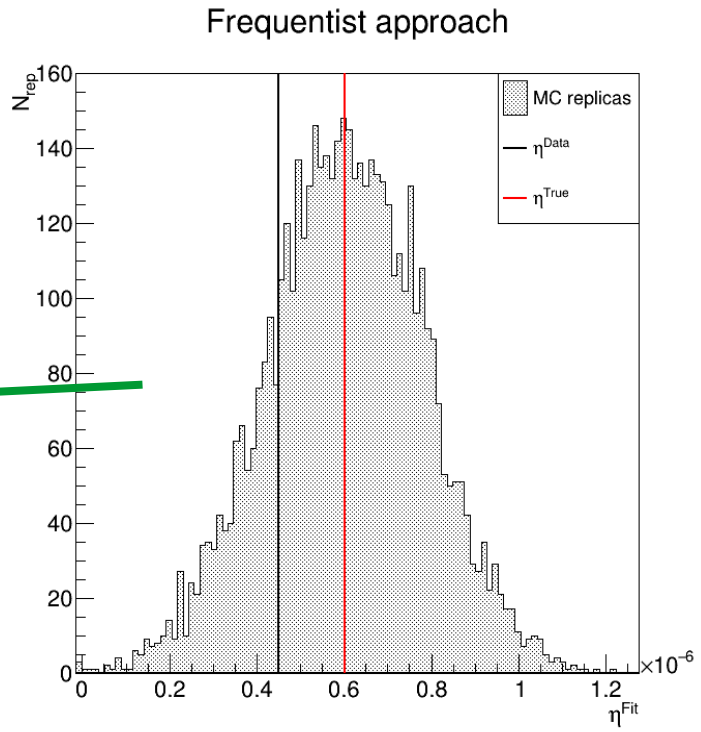
➔ This cannot be avoided for the analysis of HERA data by using another available PDF set

➔ Use of the biased PDFs in the BSM analysis would result in overestimated limits.

QCD + CI fit ➔ $\eta_{ij}^{eq} = \epsilon_{ij}^{eq}\,\eta = \epsilon_{ij}^{eq}\,\frac{4\pi}{\Lambda^2}$.

Limits extraction





$$\chi^2_{MC} = \frac{\sum_i \left[m^i + \sum_j \gamma^i_j m^i s_j - \mu^i_{0,MC} \right]^2}{\left(\delta^2_{i,stat} + \delta^2_{i,uncor} \right) \left(\mu^i_{0,data} \right)^2} + \sum_j s^2_j$$

$$\mu^i = \left[m^i_0 + \sqrt{\delta^2_{i,stat} + \delta^2_{i,uncor}} \cdot \mu^i_0 \cdot r_i \right] \cdot \left(1 + \sum_j \gamma^i_j \cdot r_j \right)$$

m^i - theory predictions,

μ^i - cross section from data or MC replicas

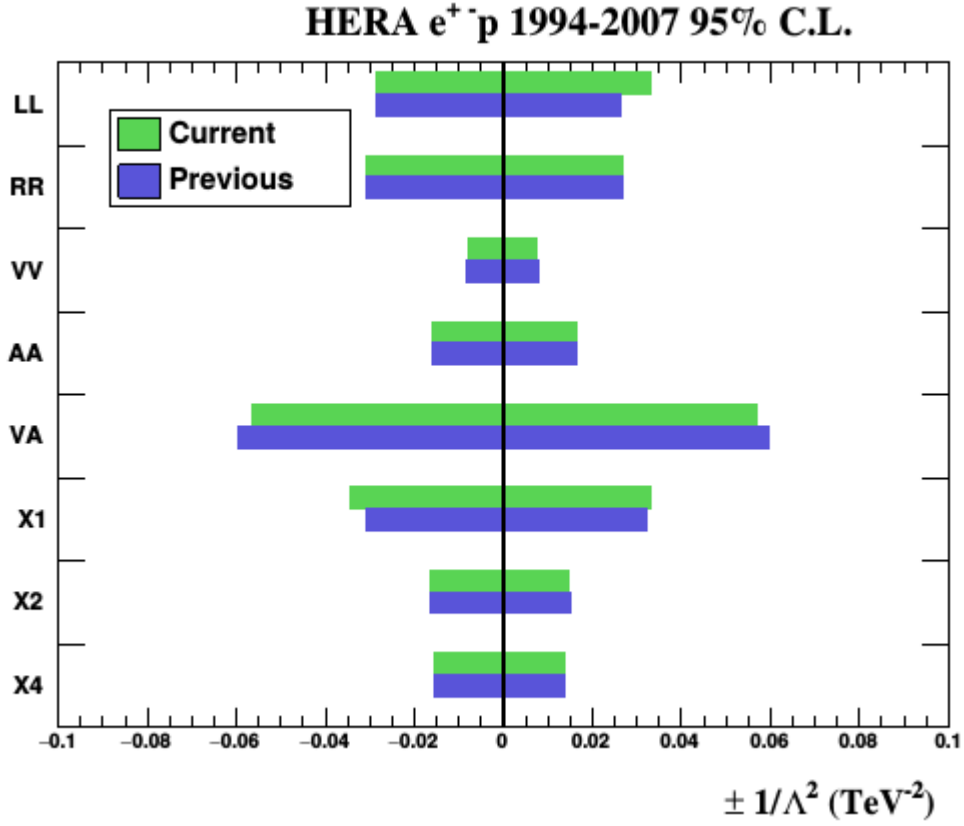
Comparison of the expected limits

95% C.L. limits (TeV)			$\eta^{Data}_{CI_{PDF}}$ (TeV^{-2})
Model	Λ^-	Λ^+	
LL	5.9	5.5	0.302
RR	5.7	6.1	0.334
VV	11.2	11.6	0.040
AA	7.9	7.8	0.213
VA	4.2	4.2	0.664
X1	5.4	5.5	0.493
X2	7.8	8.3	0.086
X4	8.0	8.6	-0.023

Current research.

95% C.L. limits (TeV)			$\eta^{Data}_{CI_{PDF}}$ (TeV^{-2})
Model	Λ^-	Λ^+	
LL	5.9	6.2	0.308
RR	5.7	6.1	0.341
VV	11.0	11.4	0.043
AA	7.9	7.8	0.324
VA	4.1	4.1	0.679
X1	5.7	5.6	0.680
X2	7.8	8.2	0.091
X4	8.0	8.6	-0.026

Previous research.



Good agreement of the expected limits.

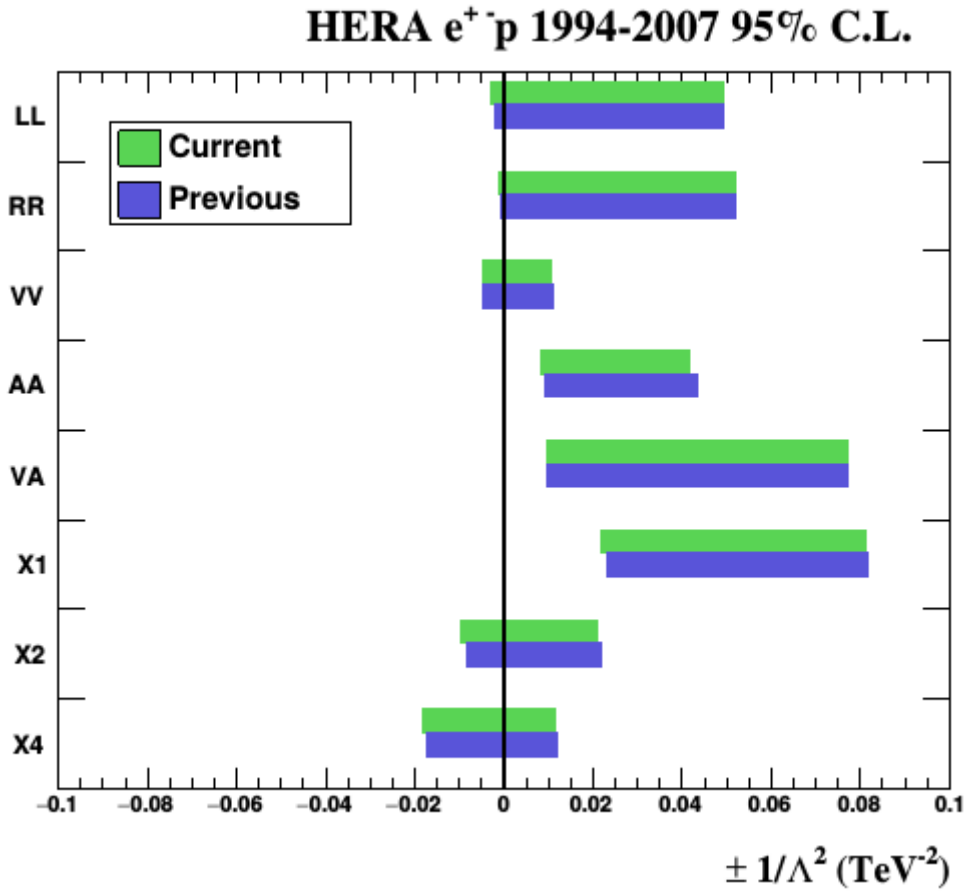
Comparison of the measured limits

95% C.L. limits (TeV)			$\eta^{Data}_{CI_{PDF}}$ (TeV^{-2})
Model	Λ^-	Λ^+	
LL	18.9	4.5	0.304
RR	27.2	4.4	0.337
VV	14.5	9.7	0.040
AA	-	4.9-11.1	0.314
VA	-	3.6-10.2	0.664
X1	-	3.51-6.75	0.667
X2	10.1	6.9	0.086
X4	7.38	9.36	-0.029

Current research.

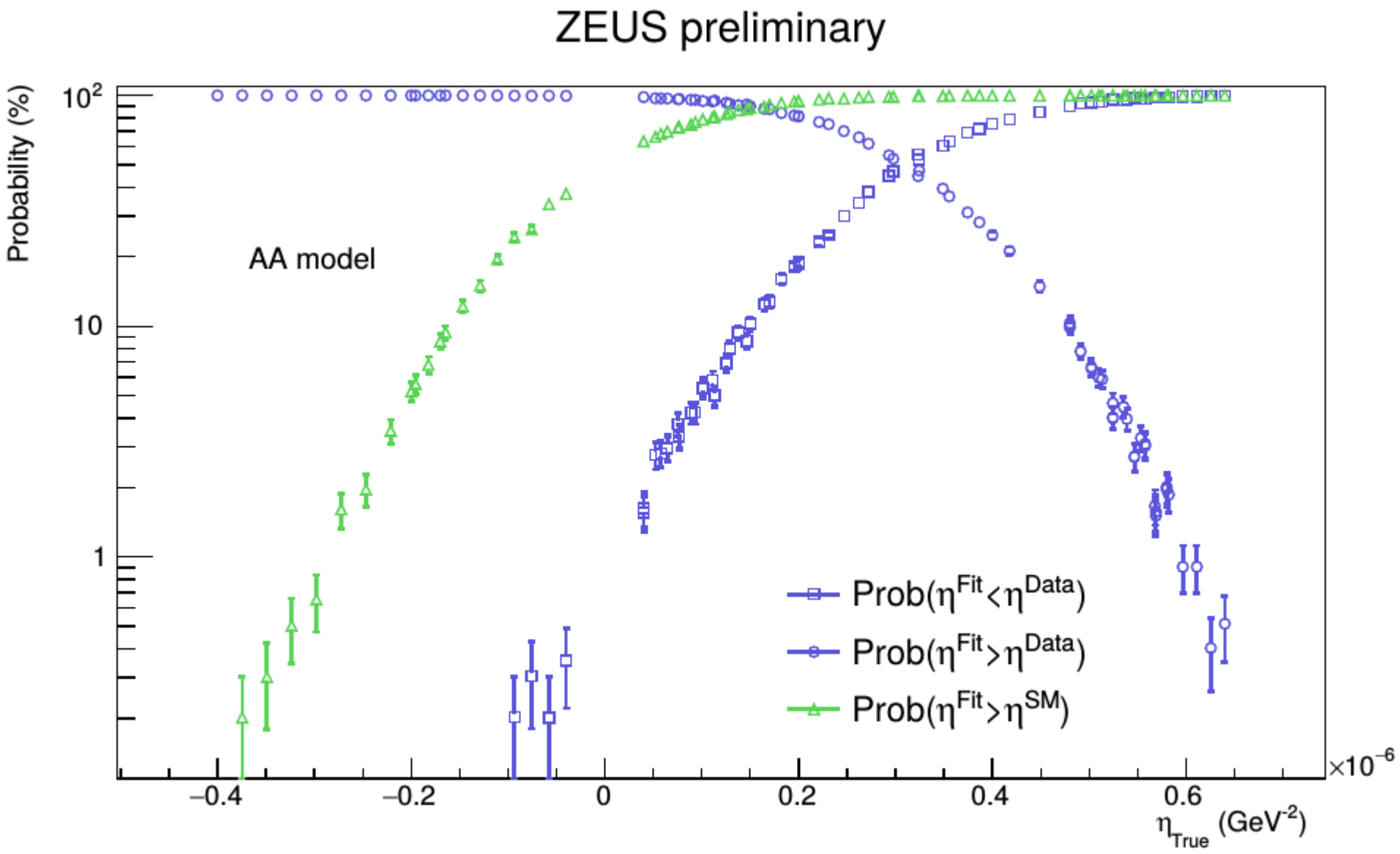
95% C.L. limits (TeV)			$\eta^{Data}_{CI_{PDF}}$ (TeV^{-2})
Model	Λ^-	Λ^+	
LL	22.0	4.5	0.308
RR	32.9	4.4	0.341
VV	14.7	9.5	0.043
AA	-	4.8-10.4	0.324
VA	-	3.6-10.1	0.679
X1	-	3.5-6.6	0.680
X2	10.8	6.8	0.091
X4	7.6	9.2	-0.026

Previous research.

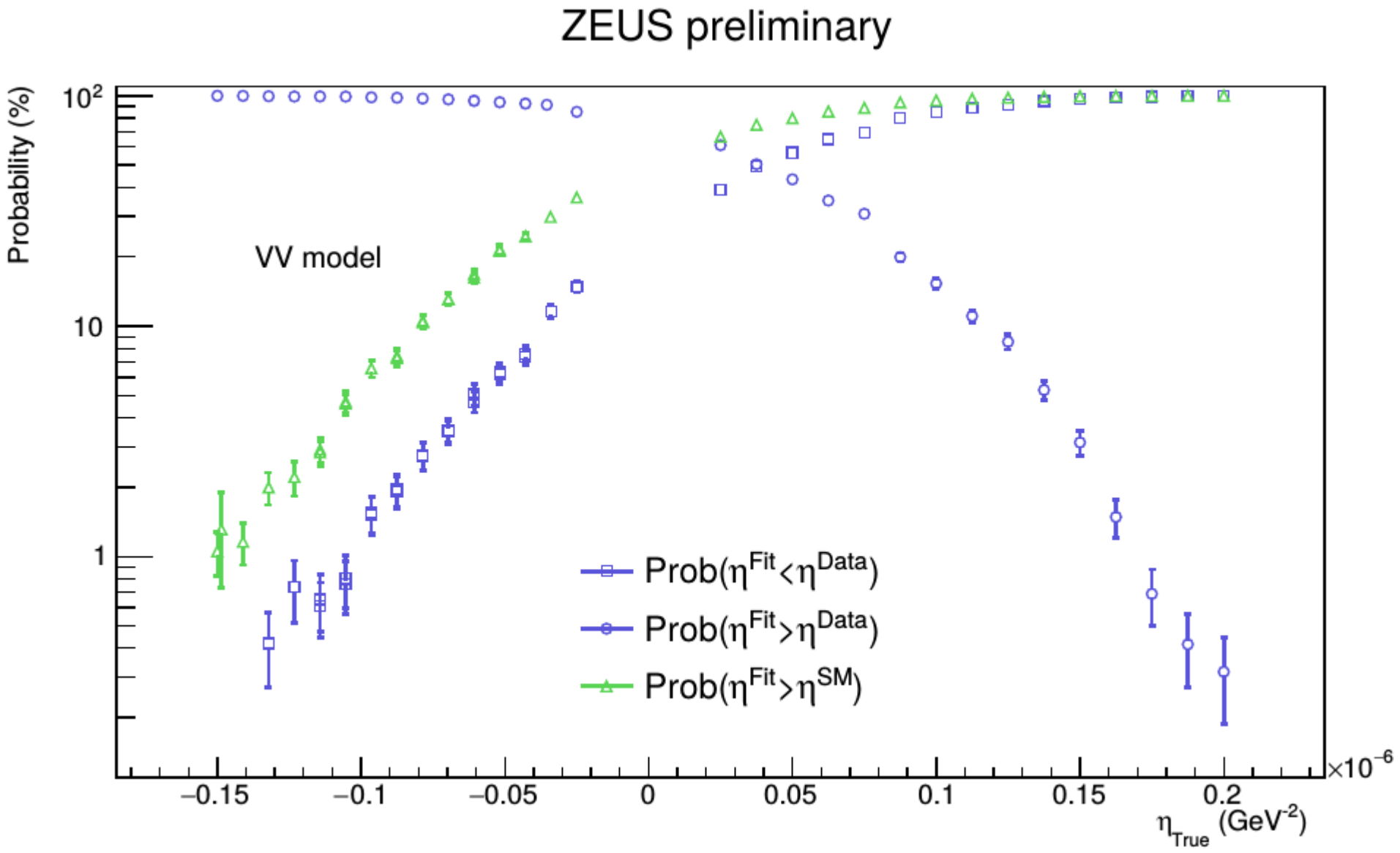


Good agreement of the measured limits.

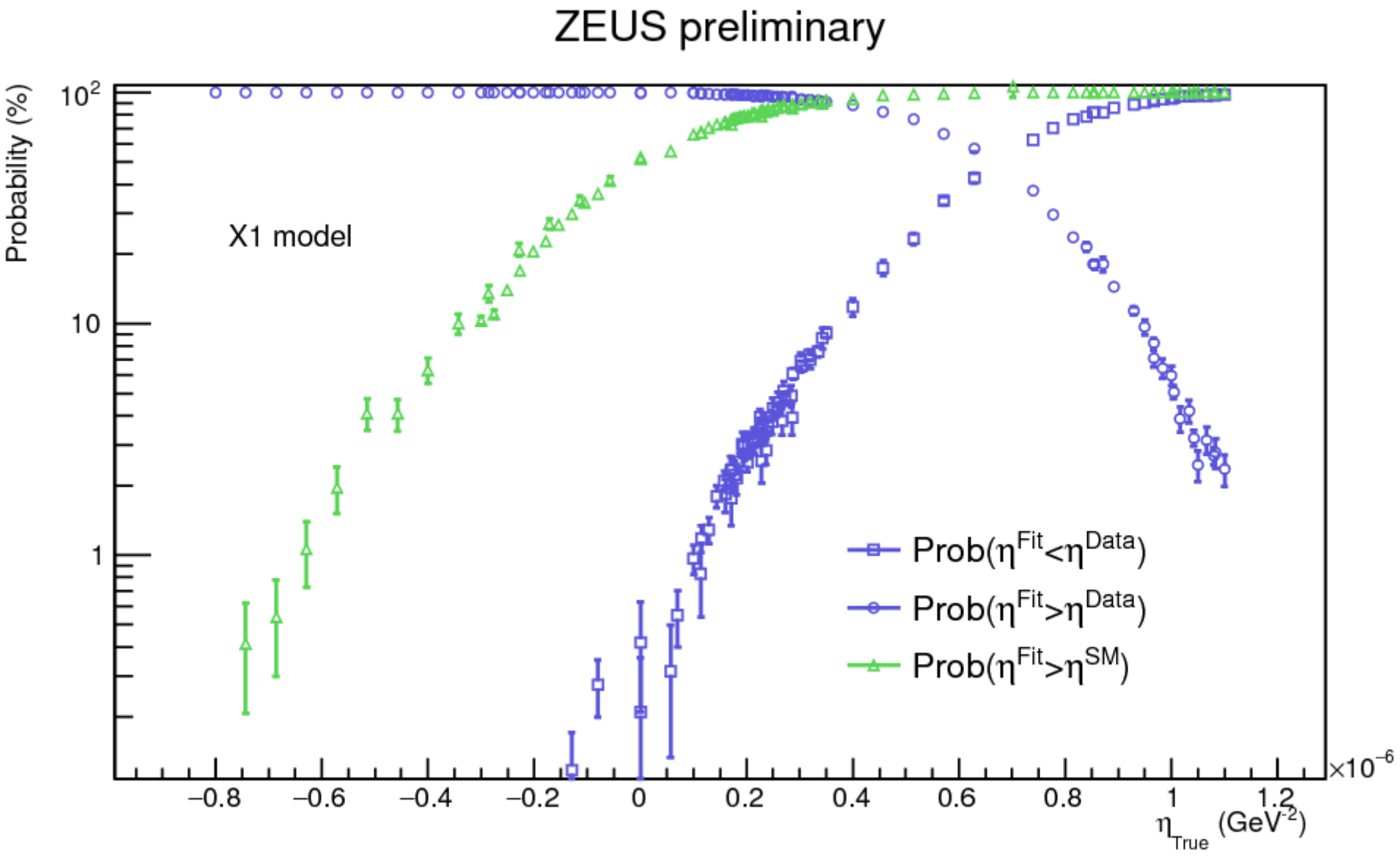
Results (General CI)



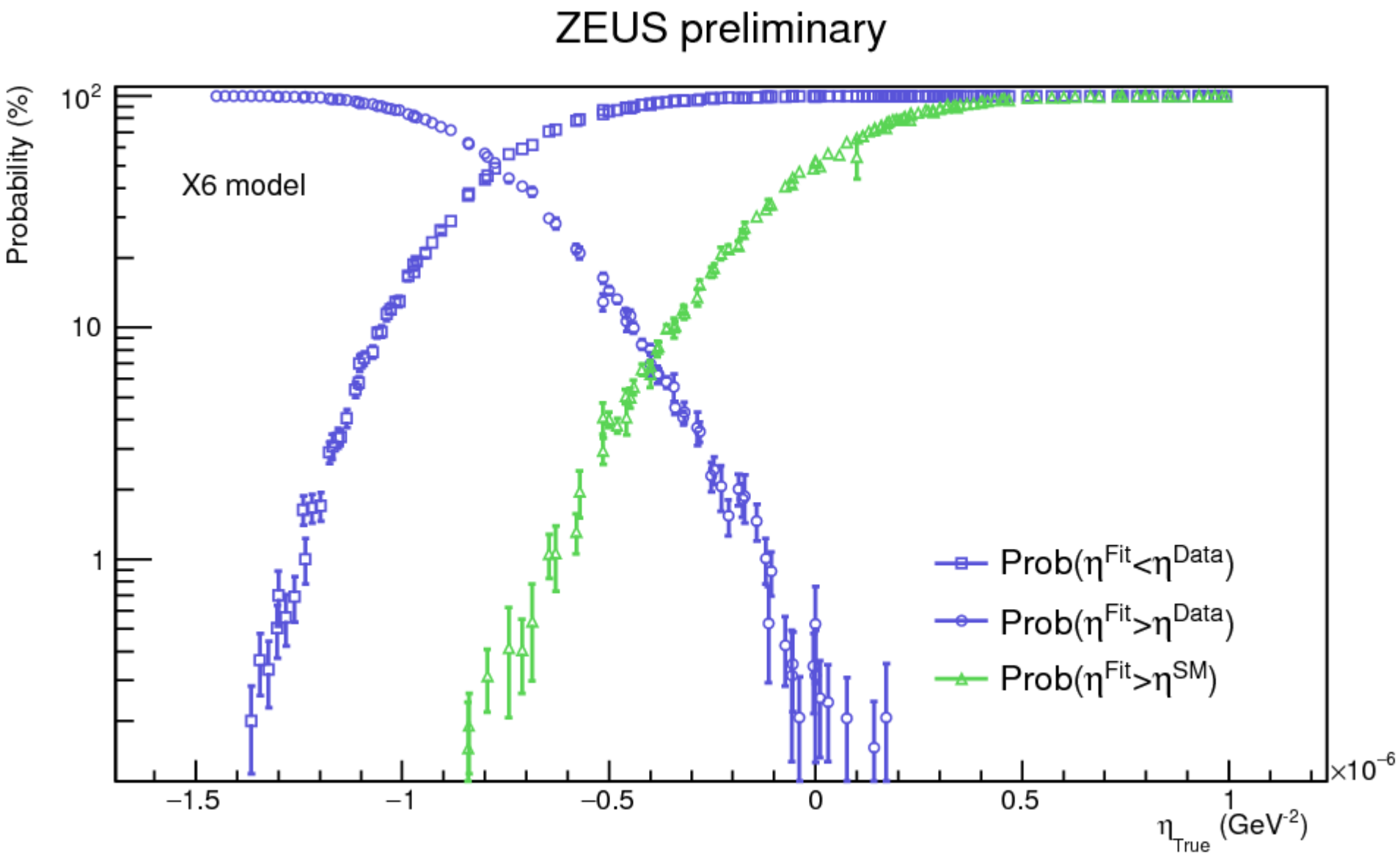
Results (General CI)



Results (General CI)



Results (General CI)



Results (General CI)

ZEUS preliminary

HERA $e^{\pm}p$ 1994-2007 data

Coupling structure		$\eta^{\text{Data}}_{\text{CI+PDF}}$	95% C.L. intervals (TeV^{-2})				p_{SM}
			Measured		Expected		
Model	$[\epsilon_{LL}, \epsilon_{LR}, \epsilon_{RL}, \epsilon_{RR}]$	(TeV^{-2})	$\eta^{\min}$	$\eta^{\max}$	$\eta^{\min}$	$\eta^{\max}$	(%)
LL	[+1, 0, 0, 0]	0.305	-0.035	0.609	-0.367	0.319	6.6
RR	[0, 0, 0, +1]	0.337	-0.017	0.648	-0.390	0.337	5.5
LR	[0, +1, 0, 0]	-0.086	-0.512	-0.25	-0.388	0.313	34
RL	[0, 0, +1, 0]	-0.027	-0.436	0.314	-0.397	0.302	41
VV	[+1, +1, +1, +1]	0.040	-0.058	0.135	-0.101	0.097	26
AA	[+1, −1, −1, +1]	0.314	0.102	0.518	-0.200	0.207	0.6
VA	[+1, −1, +1, −1]	-0.594 0.678	-0.888 0.092	 0.960	-0.723	 0.719	5.8 2.8
X1	[+1, −1, 0, 0]	0.666	0.275	1.030	-0.435	0.418	0.4
X2	[+1, 0, +1, 0]	0.089	-0.113	0.269	-0.206	0.184	24
X3	[+1, 0, 0, +1]	0.158	-0.021	0.319	-0.183	0.166	6.7
X4	[0, +1, +1, 0]	-0.030	-0.231	0.144	-0.194	0.170	38
X5	[0, +1, 0, +1]	0.080	-0.125	0.264	-0.212	0.188	27
X6	[0, 0, +1, −1]	-0.765	-1.120	-0.349	-0.454	0.415	0.3

Results (General CI)

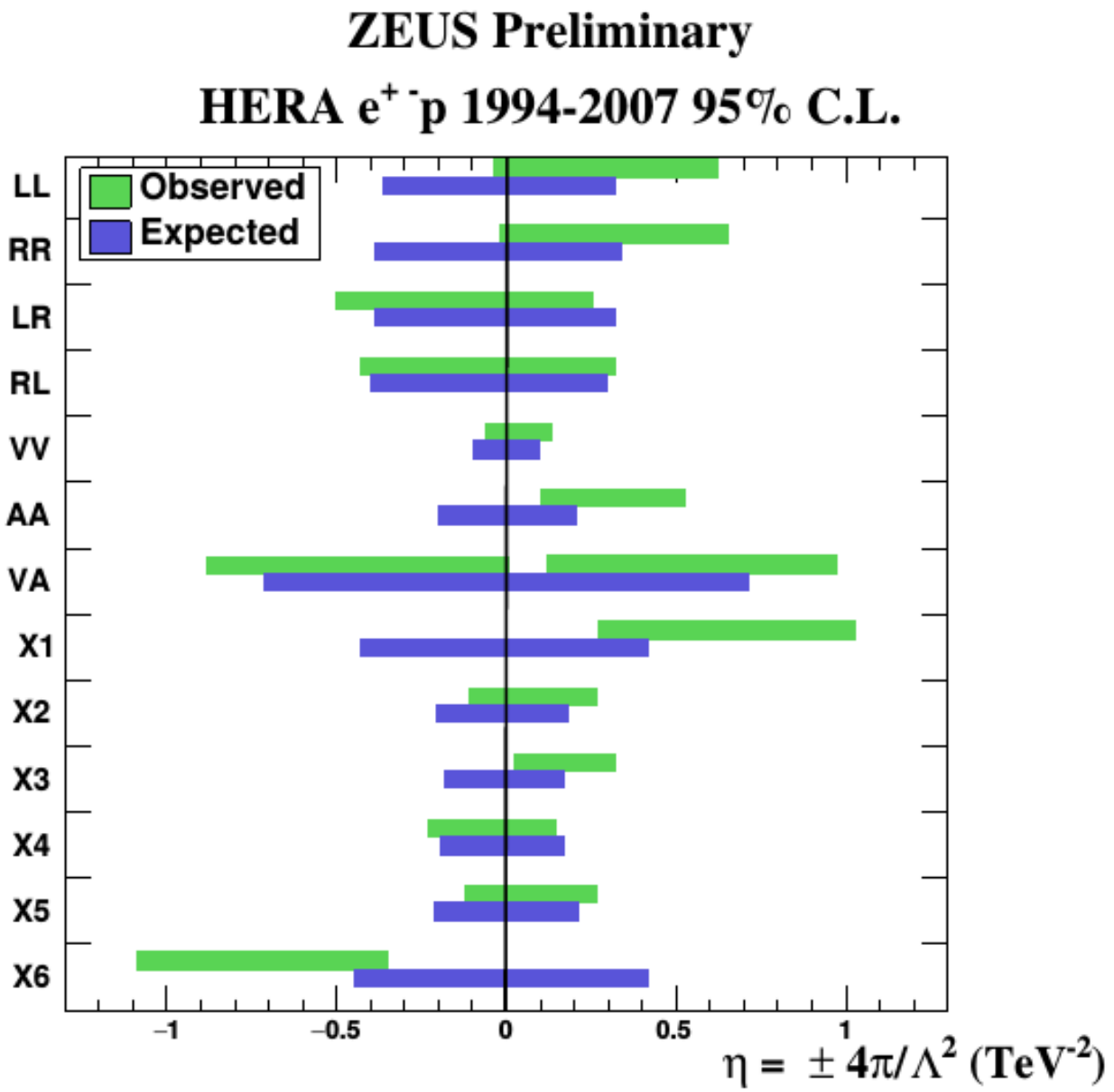
ZEUS preliminary

HERA $e^{\pm}p$ 1994-2007 data

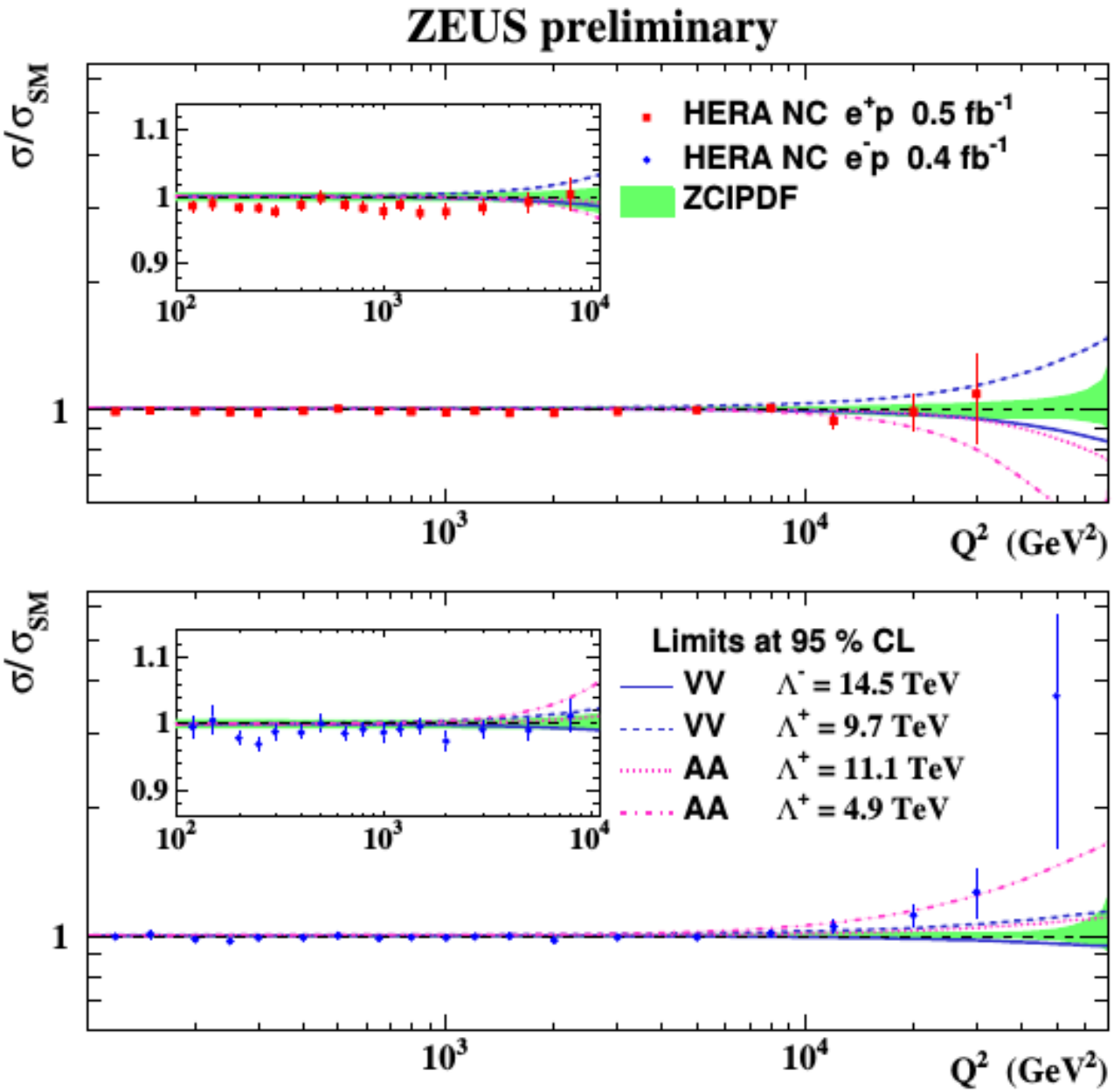
Coupling structure		95% C.L. limits (TeV)			
		Measured		Expected	
Model	$[\epsilon_{LL},\epsilon_{LR},\epsilon_{RL},\epsilon_{RR}]$	Λ^-	Λ^+	Λ^-	Λ^+
LL	$[+1, 0, 0, 0]$	18.9	4.5	5.9	6.3
RR	$[0, 0, 0, +1]$	27.2	4.4	5.7	6.1
LR	$[0, +1, 0, 0]$	5.0	7.1	5.7	6.3
RL	$[0, 0, +1, 0]$	5.4	6.3	5.6	6.5
VV	$[+1, +1, +1, +1]$	14.7	9.7	11.2	11.4
AA	$[+1, -1, -1, +1]$	-	5.0 - 11.1	7.9	7.8
VA	$[+1, -1, +1, -1]$	3.76	3.6 - 10.2	4.2	4.2
X1	$[+1, -1, 0, 0]$	-	3.5 - 6.8	5.4	5.5
X2	$[+1, 0, +1, 0]$	10.1	6.9	7.8	8.3
X3	$[+1, 0, 0, +1]$	24.4	6.3	8.3	8.7
X4	$[0, +1, +1, 0]$	7.4	9.4	8.0	8.6
X5	$[0, +1, 0, +1]$	10.1	6.9	7.7	7.7
X6	$[0, 0, +1, -1]$	3.4 - 6.0	-	5.3	5.5

$$\eta_{ij}^{eq} = \epsilon_{ij}^{eq}\,\eta = \epsilon_{ij}^{eq}\,\frac{4\pi}{\Lambda^2}\,.$$

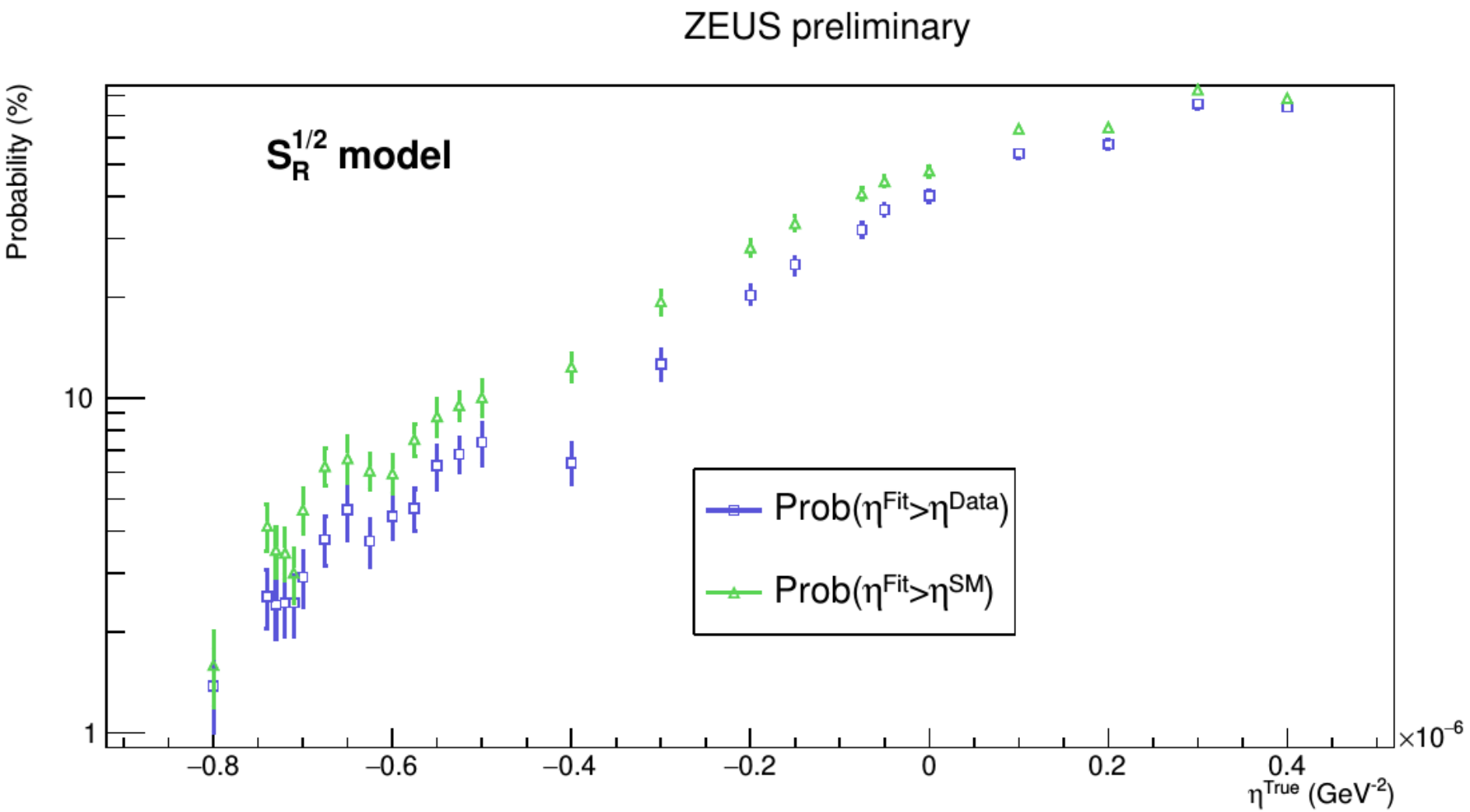
Results (General CI)



Results (General CI)



Results (LQ models)



Results (LQ models)

ZEUS preliminary

HERA $e^{\pm}p$ 1994-2007 data

Model	Coupling Structure	$\eta^{\text{Data}}_{\text{CI+PDF}}$ (TeV^{-2})	p_{SM} (%)	M_{LQ}/λ_{LQ} (TeV) 95% C.L. limit	
				Measured	Expected
$S_{\circ}^{L}$	$a_{LL}^{eu} = +\frac{1}{2}$	-0.24		0.95	1.26
$S_{\circ}^{R}$	$a_{RR}^{eu} = +\frac{1}{2}$	0.52		4.68	0.96
$\tilde{S}_{\circ}^{R}$	$a_{RR}^{ed} = +\frac{1}{2}$	-1.9		0.39	1.83
$S_{1/2}^{L}$	$a_{LR}^{eu} = -\frac{1}{2}$	0.03		1.02	0.99
$S_{1/2}^{R}$	$a_{RL}^{ed} = a_{RL}^{eu} = -\frac{1}{2}$	0.08		0.94	0.87
$\tilde{S}_{1/2}^{L}$	$a_{LR}^{ed} = -\frac{1}{2}$	0.60		0.60	0.46
S_{1}^{L}	$a_{LL}^{ed} = +1,\ a_{LL}^{eu} = +\frac{1}{2}$	0.89		1.36	1.72
$V_{\circ}$	$a_{LL}^{ed} = a_{RR}^{ed} = -1$	-0.19		1.67	2.41
$V_{\circ}^{L}$	$a_{LL}^{ed} = -1$	-0.26		1.50	2.22
$V_{\circ}^{R}$	$a_{RR}^{ed} = -1$	0.98		2.35	-
$\tilde{V}_{\circ}^{R}$	$a_{RR}^{eu} = -1$	-0.26		0.41	2.01
$V_{1/2}^{L}$	$a_{LR}^{ed} = +1$	-0.30		0.99	1.12
$V_{1/2}^{R}$	$a_{RL}^{ed} = a_{RL}^{eu} = +1$	-0.04		1.46	1.52
$\tilde{V}_{1/2}^{L}$	$a_{LR}^{eu} = +1$	-0.02		1.87	1.93
V_{1}^{L}	$a_{LL}^{ed} = -1,\ a_{LL}^{eu} = -2$	-0.04		3.64	2.96

Results (LQ models)