Electroweak physics @ LHeC

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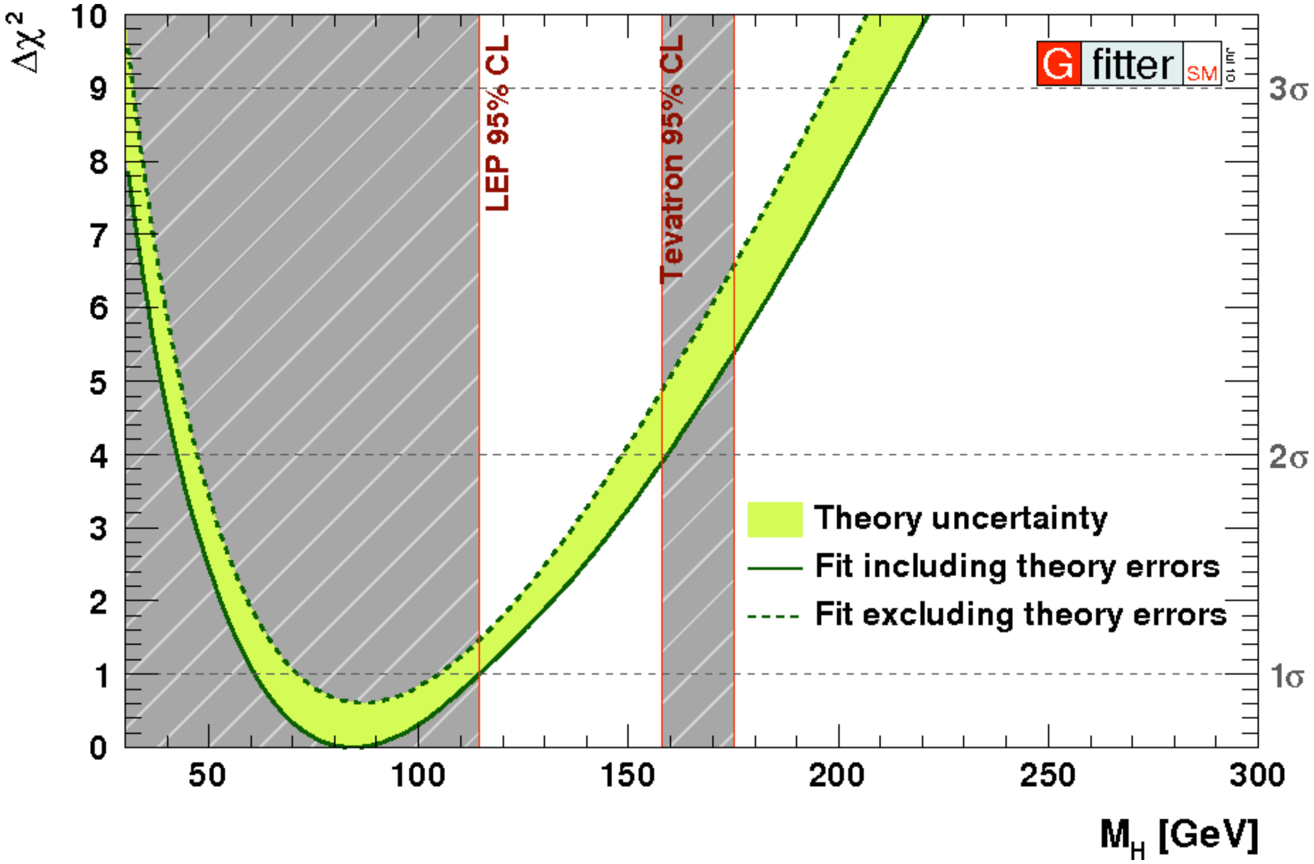
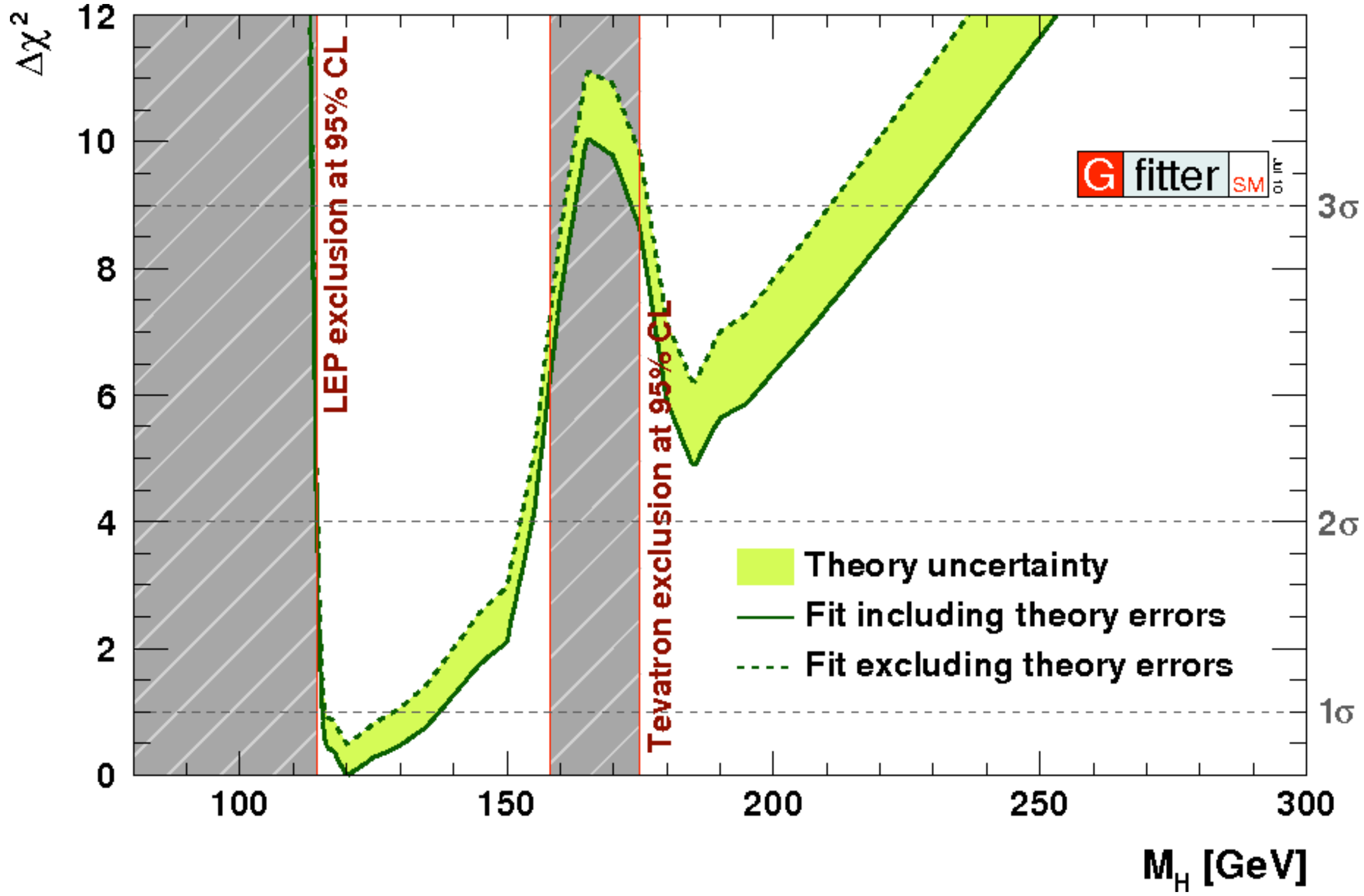
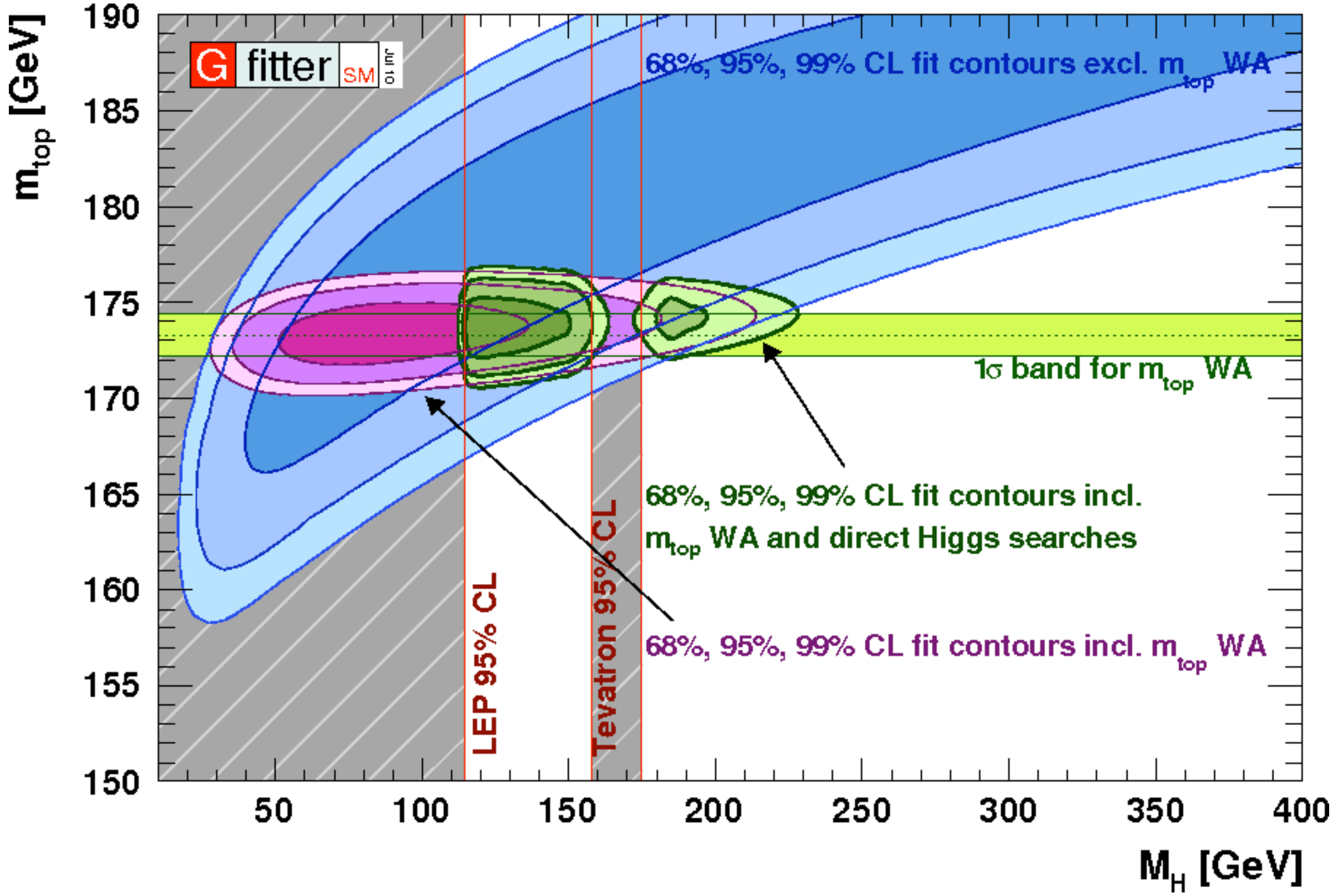
Electroweak fit and Higgs mass in 2010





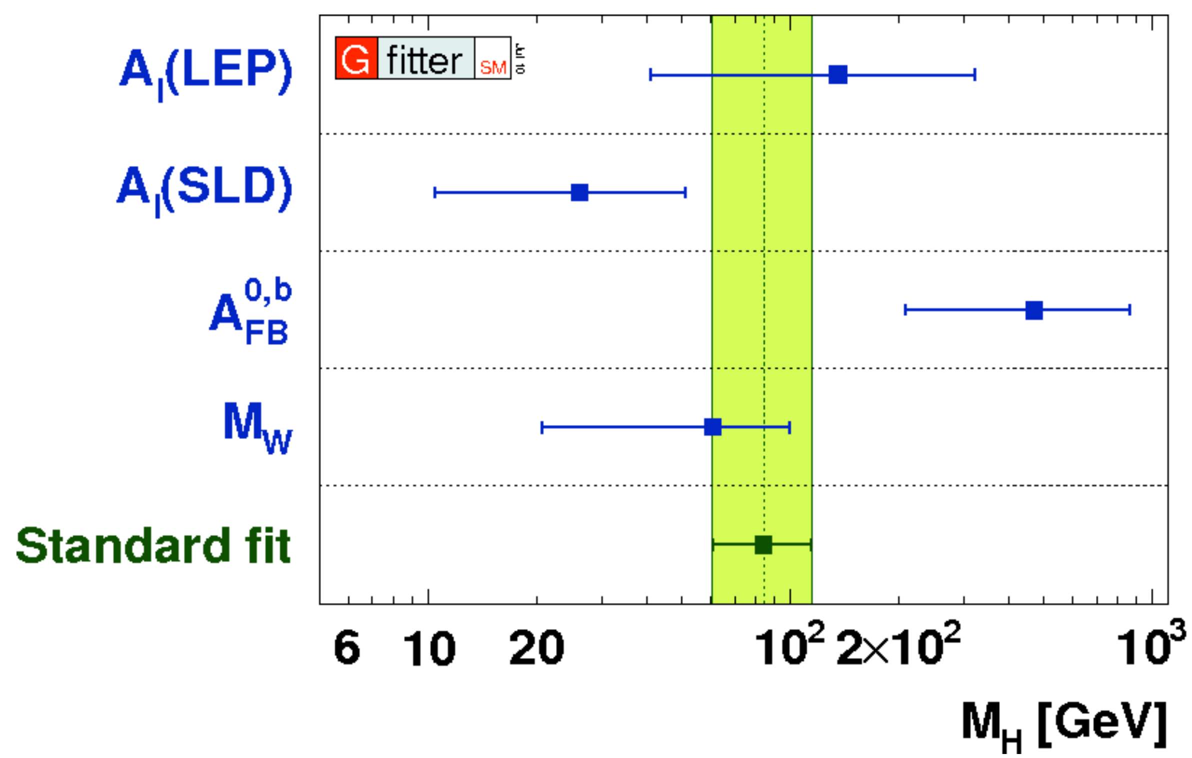
without/with results of direct searches

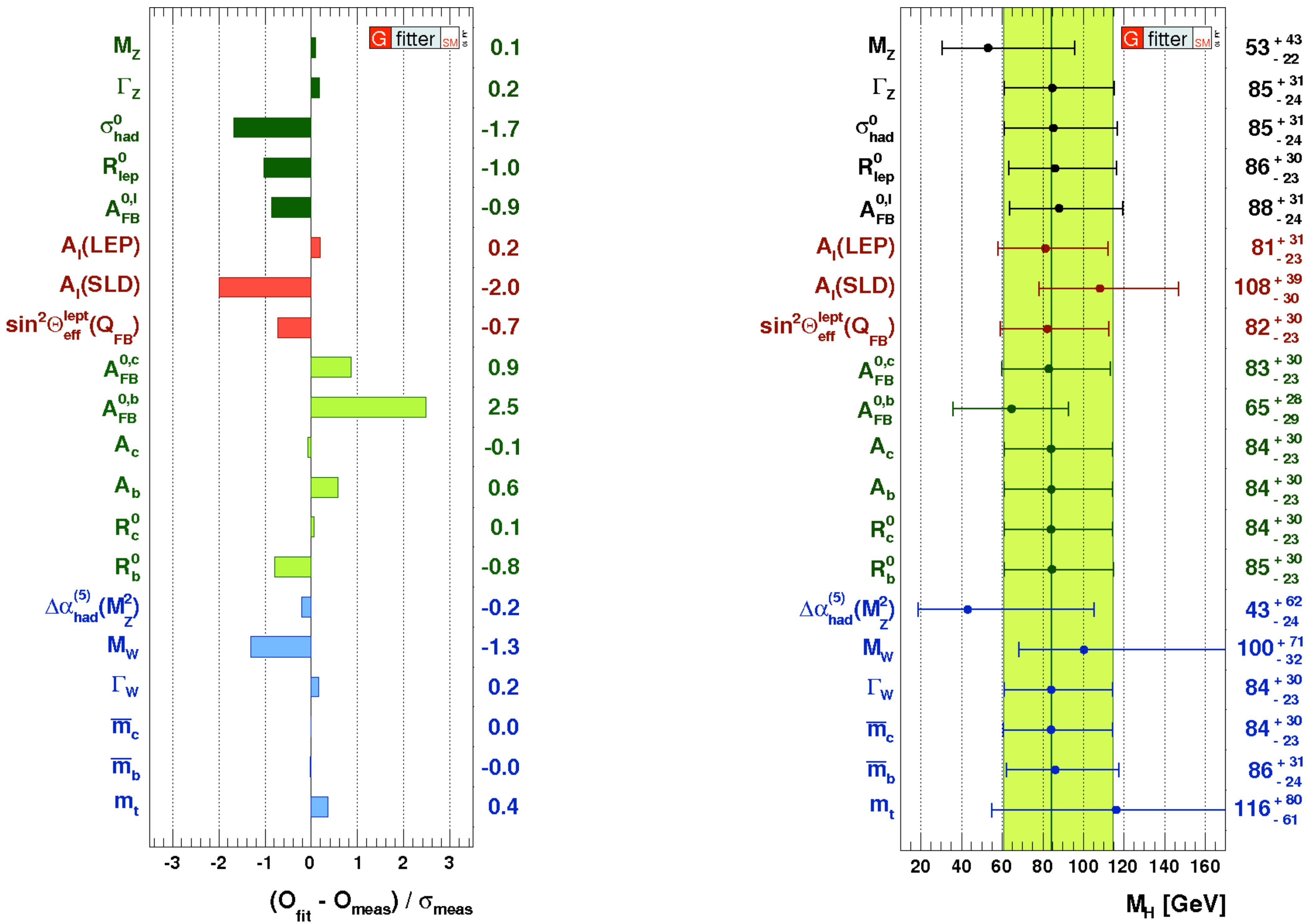
m_H<185GeV (95%CL)



Interplay m_{top}-M_H

Higgs sensitivity of the most important observables

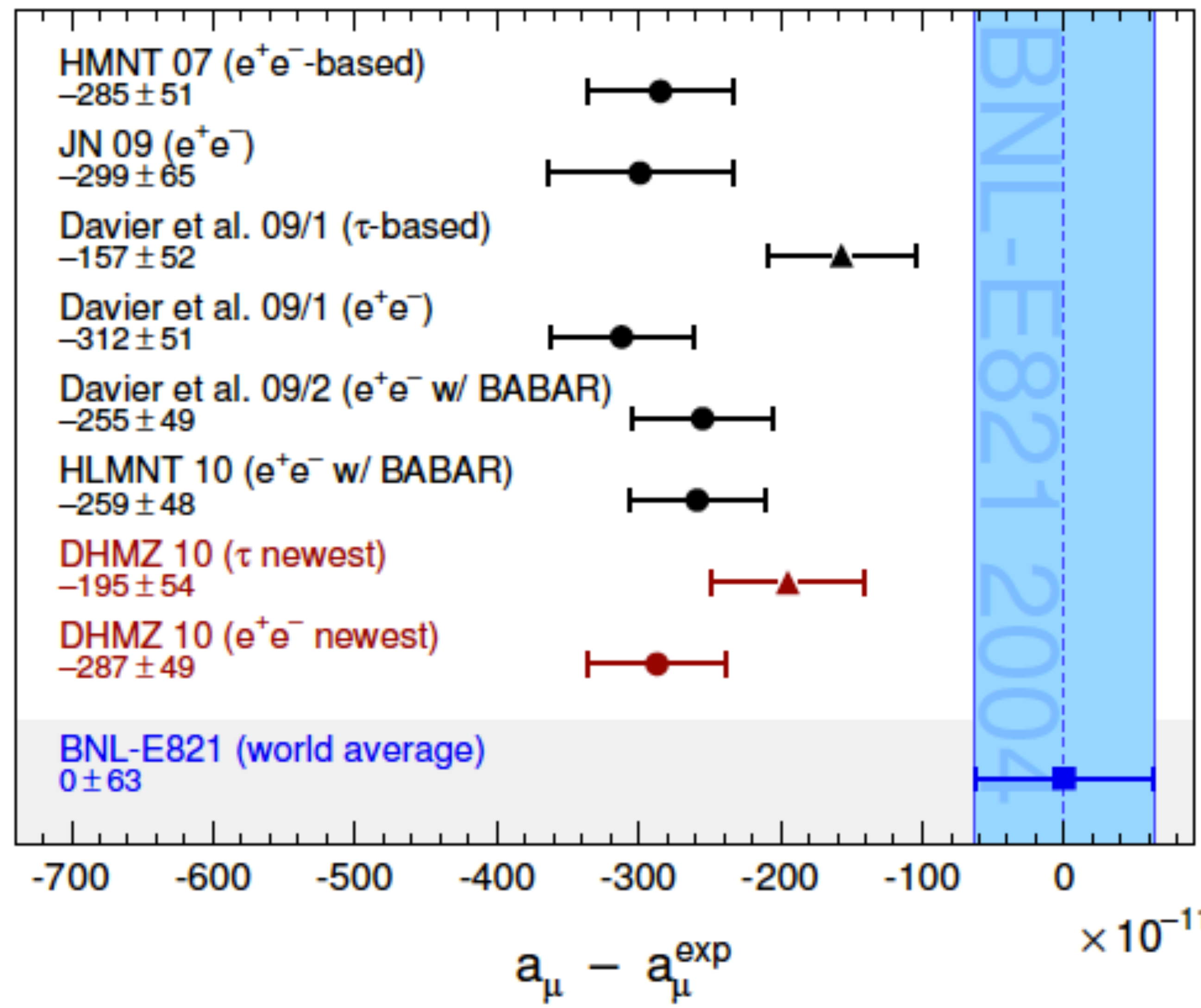



G fitter SM
M_Z 0.1
Γ_Z 0.2
σ^0_had -1.7
R^0_lep -1.0
A^{0,l}_FB -0.9
A_l(LEP) 0.2
A_l(SLD) -2.0
sin²Θ^lept_eff(Q_FB) -0.7
A^{0,c}_FB 0.9
A^{0,b}_FB 2.5
A_c -0.1
A_b 0.6
R^0_c 0.1
R^0_b -0.8
Δα^(5)_had(M_Z²) -0.2
M_W -1.3
Γ_W 0.2
m̄_c 0.0
m̄_b -0.0
m_t 0.4
-3 -2 -1 0 1 2 3
(O_fit - O_meas) / σ_meas
G fitter SM
M_Z 53 +43 -22
Γ_Z 85 +31 -24
σ^0_had 85 +31 -24
R^0_lep 86 +30 -23
A^{0,l}_FB 88 +31 -24
A_l(LEP) 81 +31 -23
A_l(SLD) 108 +39 -30
sin²Θ^lept_eff(Q_FB) 82 +30 -23
A^{0,c}_FB 83 +30 -23
A^{0,b}_FB 65 +28 -29
A_c 84 +30 -23
A_b 84 +30 -23
R^0_c 84 +30 -23
R^0_b 85 +30 -23
Δα^(5)_had(M_Z²) 43 +62 -24
M_W 100 +71 -32
Γ_W 84 +30 -23
m̄_c 84 +30 -23
m̄_b 86 +31 -24
m_t 116 +80 -61
20 40 60 80 100 120 140 160
M_H [GeV]

g-2 of the muon

3.6σ discrepancy
(2.4σ using tau data)

In the right ballpark for many NP explanations: SUSY, extra Z'



$$a_\mu(\hat{Z}) = (480 \times 10^{-11}) \frac{\hat{g}^2}{g^2} \frac{M_Z^2}{M_{\hat{Z}}^2} \left(3\hat{Q}_L\hat{Q}_R - \hat{Q}_L^2 - \hat{Q}_R^2\right)$$

$$a_\mu^{\rm SUSY} \simeq ({\rm sgn}\,\mu) \times (130 \times 10^{-11}) \left(\frac{100\,{\rm GeV}}{M_{\rm SUSY}}\right)^2 \tan\beta$$

right signμ , light charginos

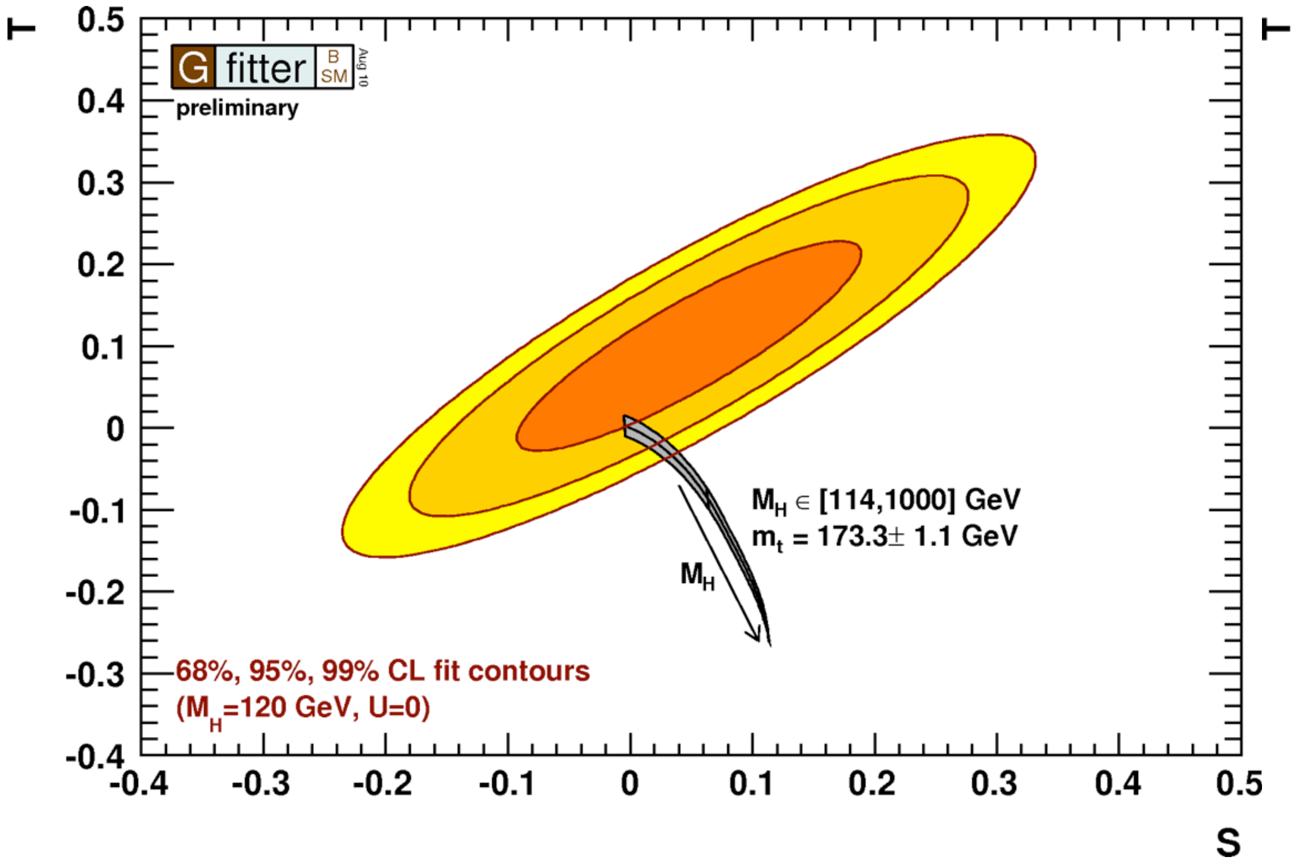
The future of EWPT

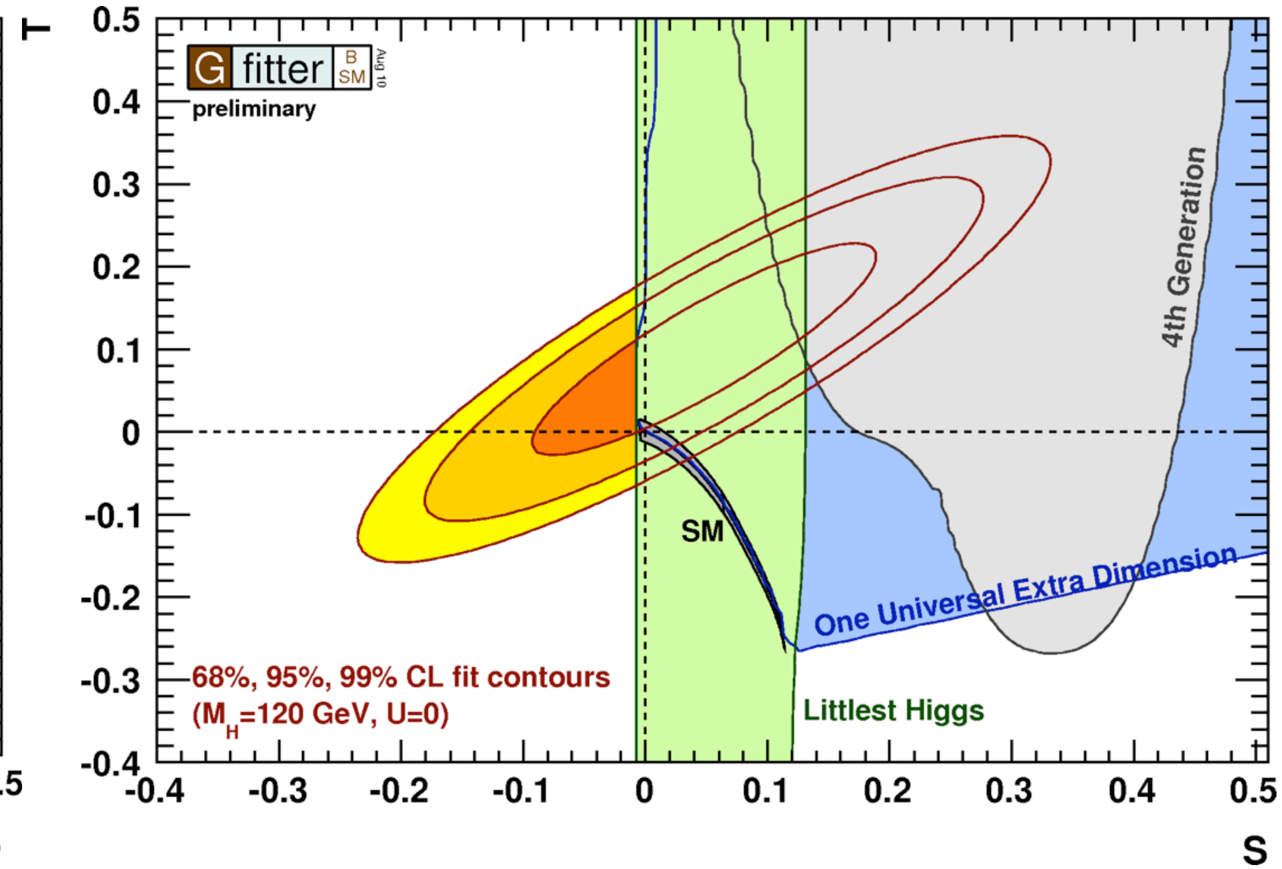
Quantity	Expected uncertainty			
	Present	LHC	ILC	GigaZ (ILC)
M_W [MeV]	23	15	15	6
m_t [GeV]	1.1	1.0	0.2	0.1
$\sin^2\theta^{\ell}_{\rm eff}$ $[10^{-5}]$	17	17	17	1.3
R^0_ℓ $[10^{-2}]$	2.5	2.5	2.5	0.4
$\Delta\alpha^{(5)}_{\rm had}(M_Z^2)$ $[10^{-5}]$	22 (7)	22 (7)	22 (7)	22 (7)
$M_H(= 120\ {\rm GeV})$ [GeV]	$^{+53}_{-40}$ $\left(^{+50}_{-37}\right)$ $\left[^{+37}_{-30}\right]$	$^{+44}_{-35}$ $\left(^{+42}_{-33}\right)$ $\left[^{+30}_{-25}\right]$	$^{+42}_{-33}$ $\left(^{+39}_{-31}\right)$ $\left[^{+27}_{-24}\right]$	$^{+26}_{-23}$ $\left(^{+20}_{-18}\right)$ $\left[^{+8}_{-8}\right]$
$\alpha_s(M_Z^2)$ $[10^{-4}]$	28	28	28	7

Marginal improvement @ LHC and some low energy experiments, but either NP or the Higgs will be discovered. Expected sensitivity to SM parameters estimates sensitivity to NP.

Oblique parameters

Parameterize NP in W,Z propagators only. Good approximation for many scenarios





Electroweak physics @ HERA

Polarized CC cross section

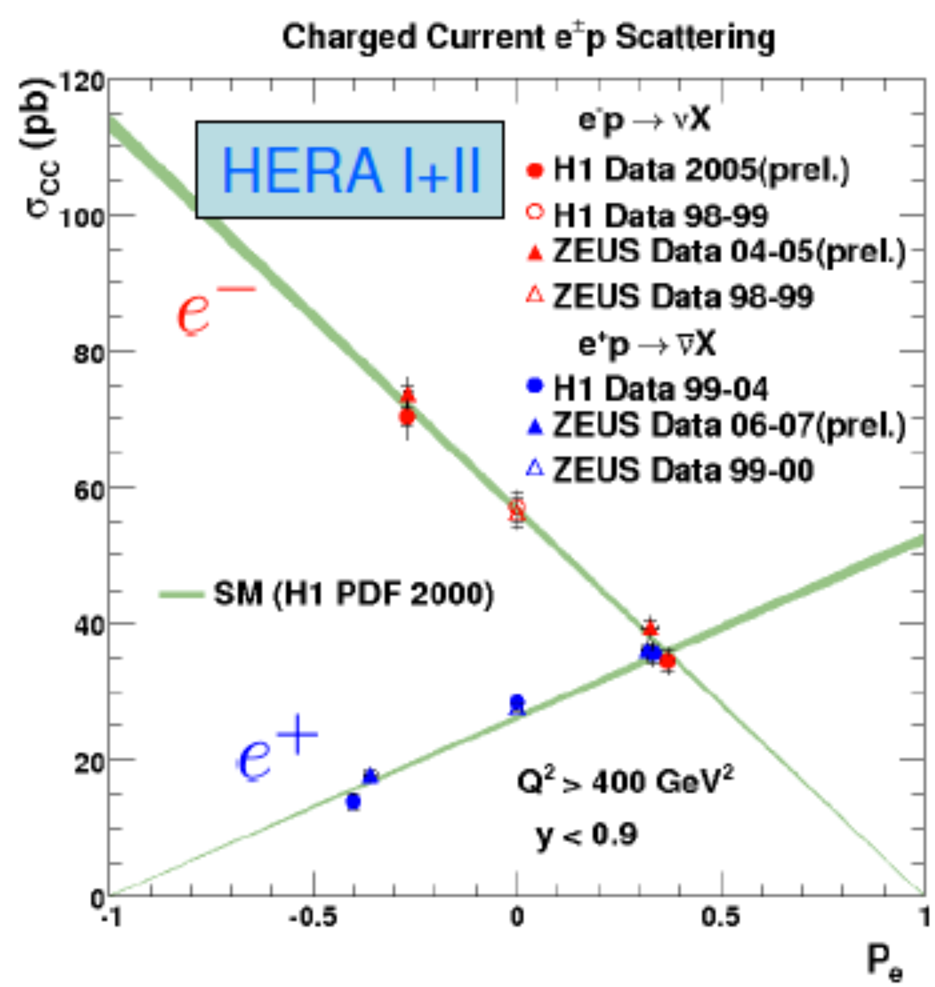
In the SM the charged current is purely LH

$$P_e = \frac{N_R - N_L}{N_R + N_L} \qquad \sigma^{\pm}_{CC}(P_e) = (1 \pm P_e)\sigma^{\pm}_{CC}(P_e = 0)$$

linear dependence on P_e

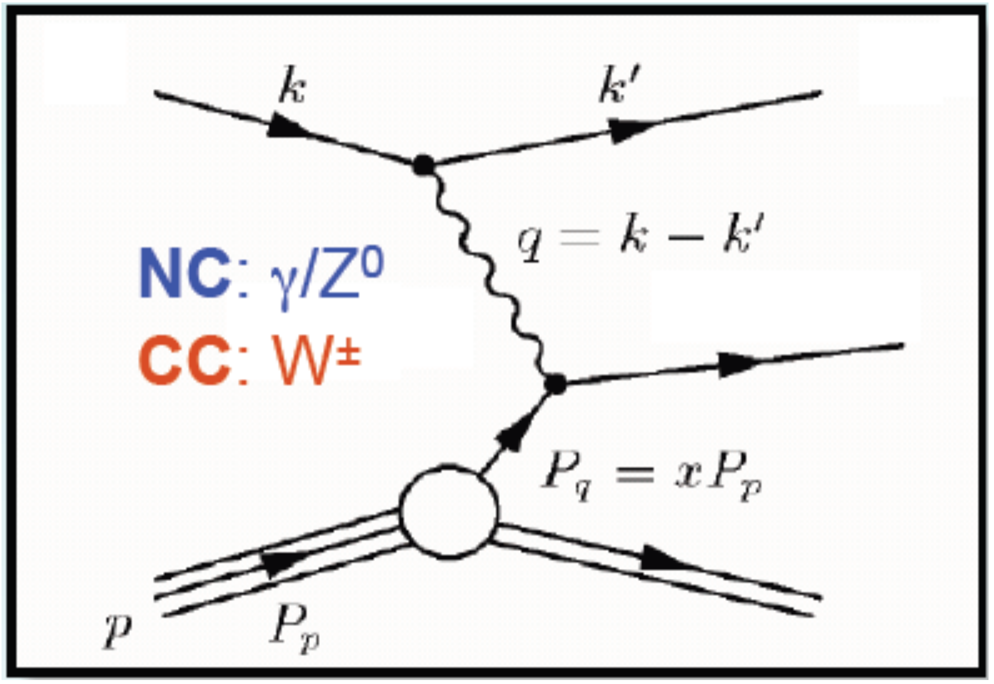
Limits on W_R

$$M_{W_R} > 208 \text{ @ } 95\ \%\ \text{C.L.}$$



These constraints on RH currents will become much stronger at LHeC, and start competing with low energy ones. *They are independent of PDFs*

Electroweak physics @ HERA



$$\frac{d^2\sigma^{CC}(e^\pm p)}{dx dQ^2} = (1 \pm P_e)\frac{G_F^2}{4\pi x}\left(\frac{M_W^2}{M_W^2 + Q^2}\right)^2\left[Y_+ F_2^\pm - Y_- x F_3^\pm - y^2 F_L^\pm\right],$$

G_F absorbs dominant ew corrections, M_W can be fitted at the same time of pdfs (with NC cross sections): Hera finds $\delta M_W \sim 1$ GeV

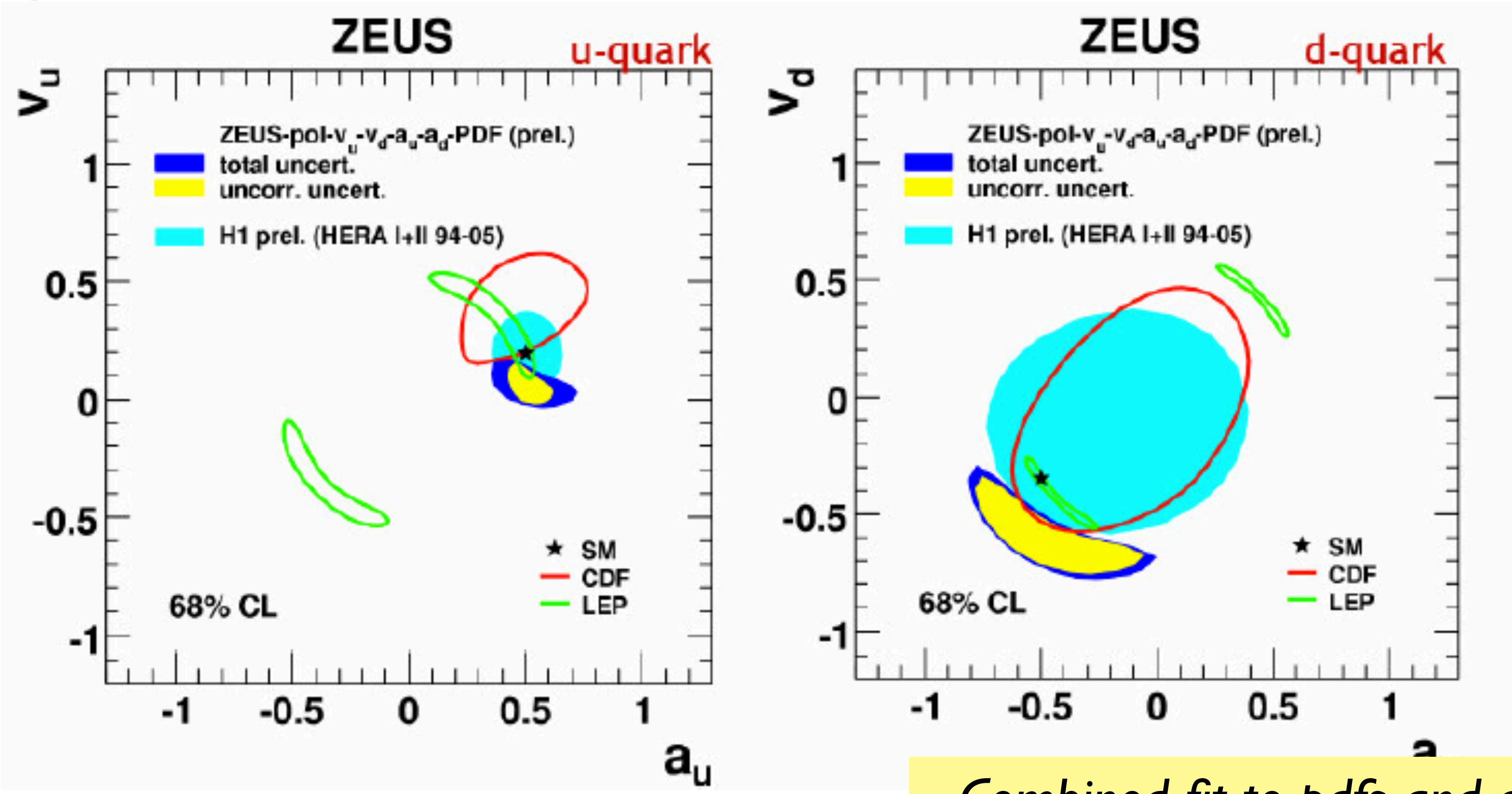
LHeC will improve this, but it won't be a precision determination: $\delta M_W \sim 0.2$GeV (Gwenlan)

Electroweak physics @ HERA

NC couplings to light quarks

unpol: $\sigma(e^+) - \sigma(e^-) \quad \rightarrow \quad a_e\, k_Z\, xF_3^{\gamma Z} \propto e_q a_q$

pol: $\sigma(P_R) - \sigma(P_L) \quad \rightarrow \quad a_e\, k_Z\, F_2^{\gamma Z} \propto e_q v_q$



Improvements: $v_q \rightarrow$ polarization
$a_q \rightarrow$ luminosity

Combined fit to pdfs and couplings, fixing lepton couplings and other parameters to SM value

Electroweak physics @ LHeC

- EW interactions at high Q^2 : choose high energy and high luminosity
- lepton polarization is crucial
- higher precision: Hera strategies need to be revised
- pdfs systematics (hidden assumptions, parameterization, etc) likely to be important
- Pilot study by C.Gwenlan on NC couplings, it would be nice to complete it for CDR

C.Gwenlan

LHeC scenarios studied

config.	E(e)	E(N)	N	$\int L(e^+)$	$\int L(e^-)$	|Pol|	$L/10^{32}$	P/MW	years	type
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	0.5	0.5	0.4	0.5	30	1	eD
G	50	2.7	Pb	0.1	0.1	0.4	0.1	30	1	ePb

Scenario D:

$E(e^\pm)$ = 100 GeV

E(p) = 7 TeV

($\sqrt{s}$ = 1.673 TeV)

$P_e = \pm 0.9$

… simulated LHeC data (M. Klein); mainly looked at **scenario D** (since it was produced first!)
… but also looked briefly at A, B, C, E as well as D

LHeC simulated data

C.Gwenlan

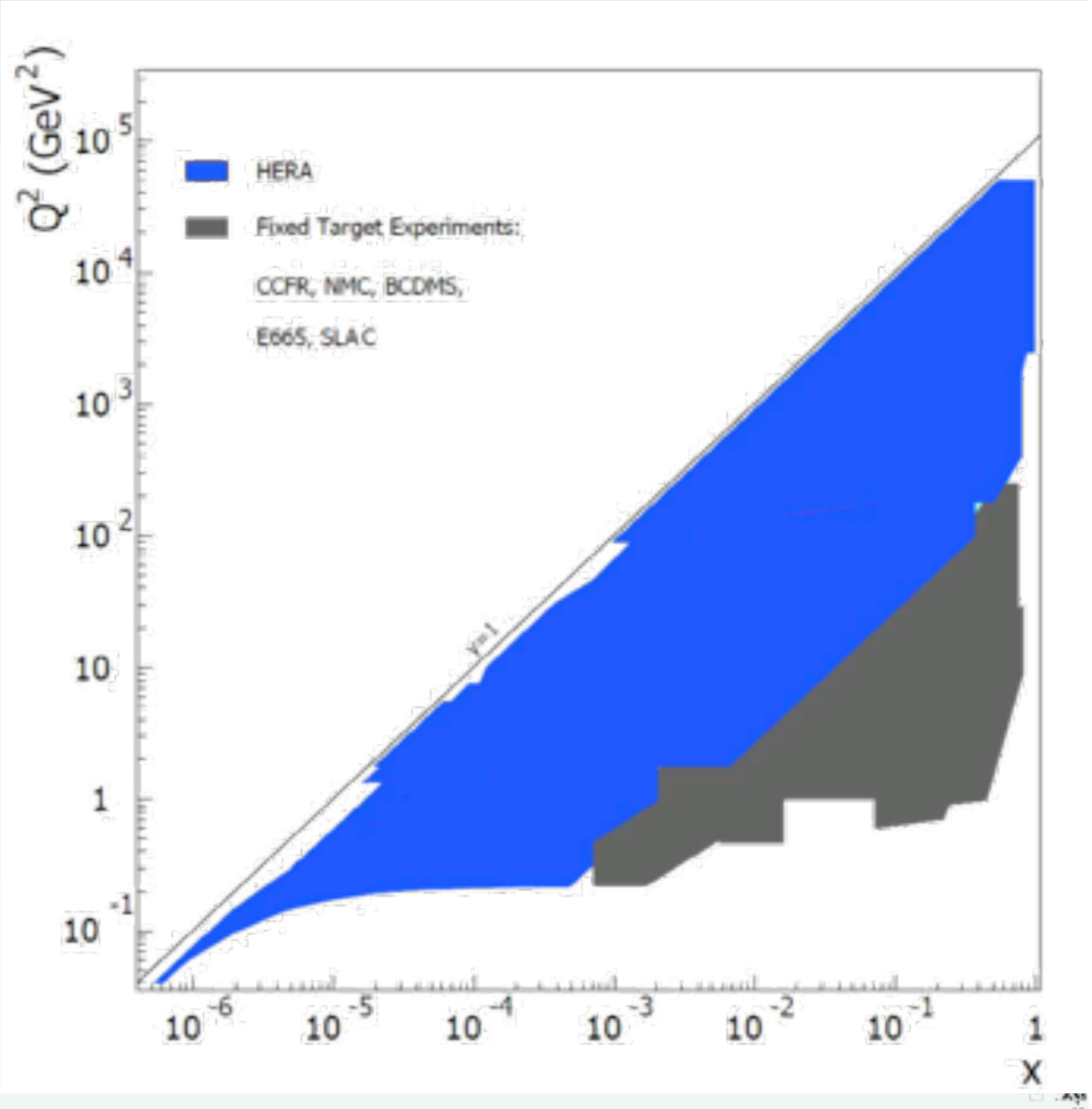
numbers based on scenario D:

pseudo-data spans kinematic region:

$2 < Q^2 < 10^6$ GeV^2; $2 \times 10^{-6} < x < 0.8$

typical uncertainties:

- » statistical: typically < 1%
  (but ranges from 0.1% at lowest Q^2 to as large as ~10−50% at highest Q^2, x)
- » uncorrelated systematic: 0.7%
- » correlated systematic: typically 1-3%



also included in fit:

1% luminosity and polarisation uncertainties (as additional correlated systematics)

C.Gwenlan

NLO QCD and electroweak fit

Study presented here is based on new **ZEUS NLO QCD fit** to HERA-I and HERA-II data

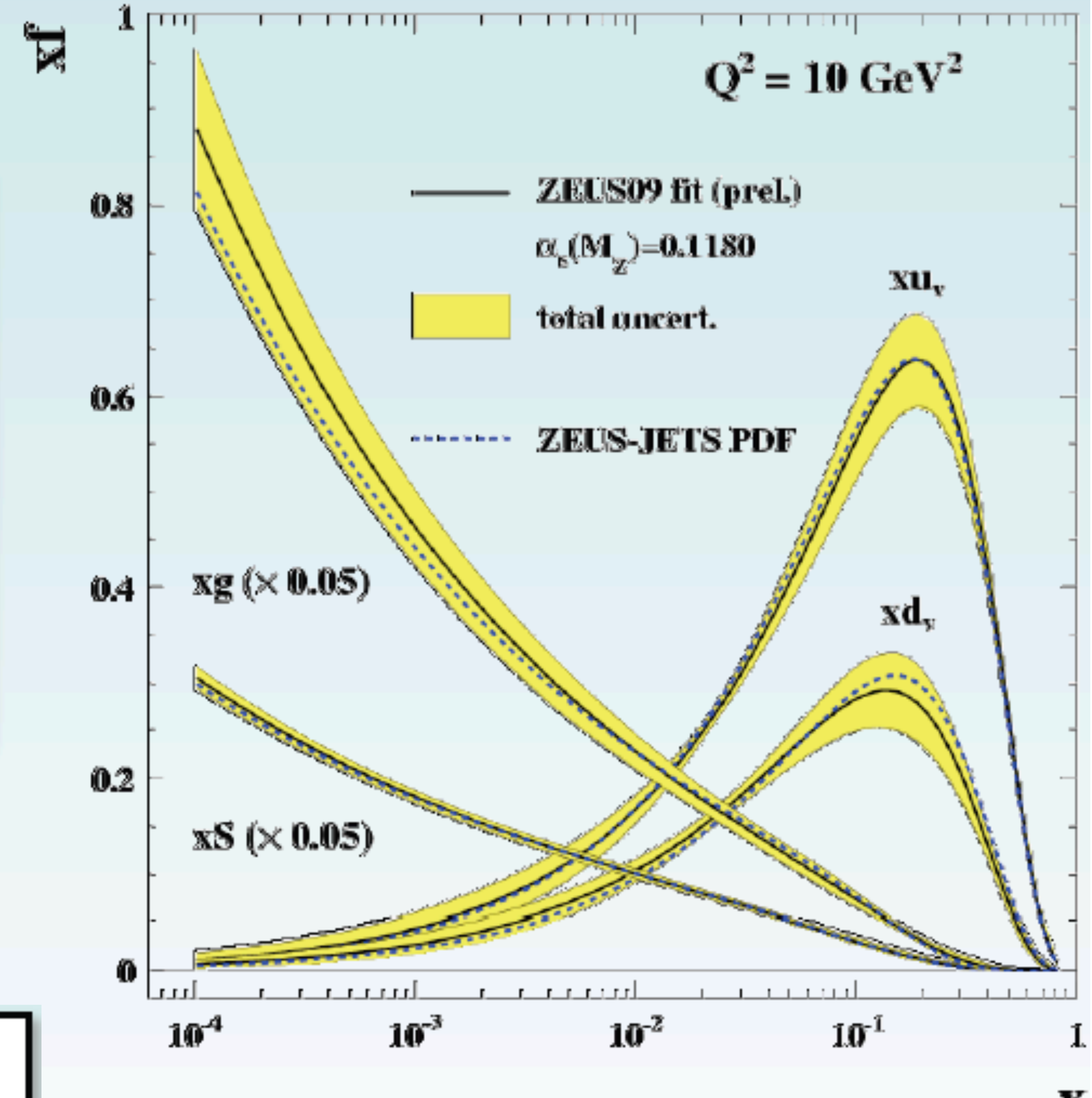
Data included in ZEUS fit:

- **HERA-I:**
  - CC and NC inclusive e±p
  - DIS inclusive jet and dijet γp
- **HERA-II**
  - CC e±p **(polarised)**
  - NC e-p **(polarised)**

correlated uncertainties:
treated using the Offset method

LHeC NC/CC simulated data added to this in a **combined fit** for the PDFs and electroweak parameters

ZEUS09 fit (c.f. central values of HERA-I fit)



Proton PDFs

$Q^2 = 100\ GeV^2$

scenario D

» only PDF parameters free
(LHeC **NC** and **CC** $e^{\pm}p$ included)

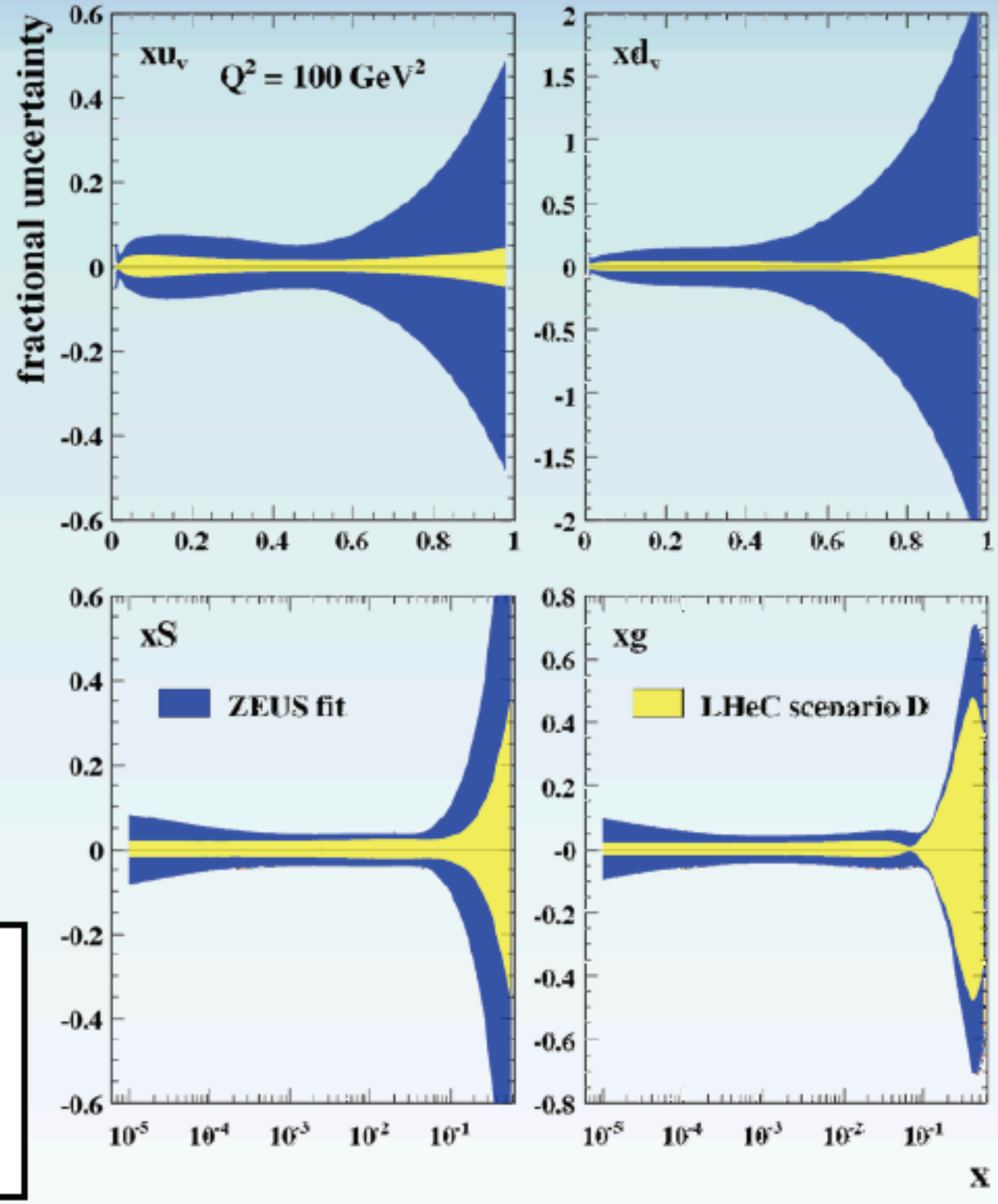
PDF uncertainties:

- **NC $e^{\pm}p$**: direct constraints on **quark densities**; indirect on **gluon** via scaling violations
- **CC $e^{\pm}p$: constraints on quarks → flavour decomposition**
  (e^-: mostly u; e^+: mostly d)

→ results encouraging!

However, should also consider:

- **flexibility of parameterisation?**
- **model uncertainties?**



Combined fit to pdfs and quark-Z couplings

» fit with PDF and electroweak parameters simultaneously free

- neutral current axial and vector quark couplings (a_u, v_u, a_d, v_d)

the following results currently have only the LHeC NC (CC will not change things by much)

caveats to comparisons:

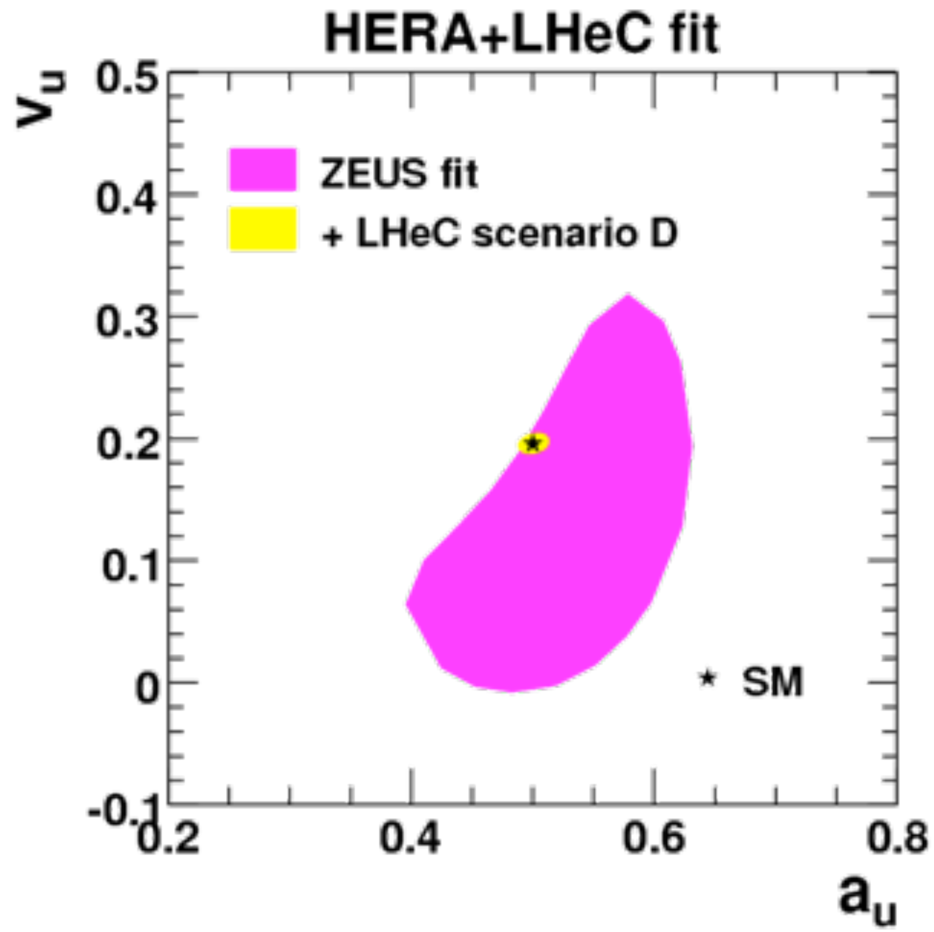
- **not all** HERA-II data yet included in ZEUS fit (NC e^+p still to come)
- best HERA PDF+EW constraints will come from a **future HERA-II combination** of H1+ZEUS data

» still some **improvement to come from HERA** (but difficult to quantify)

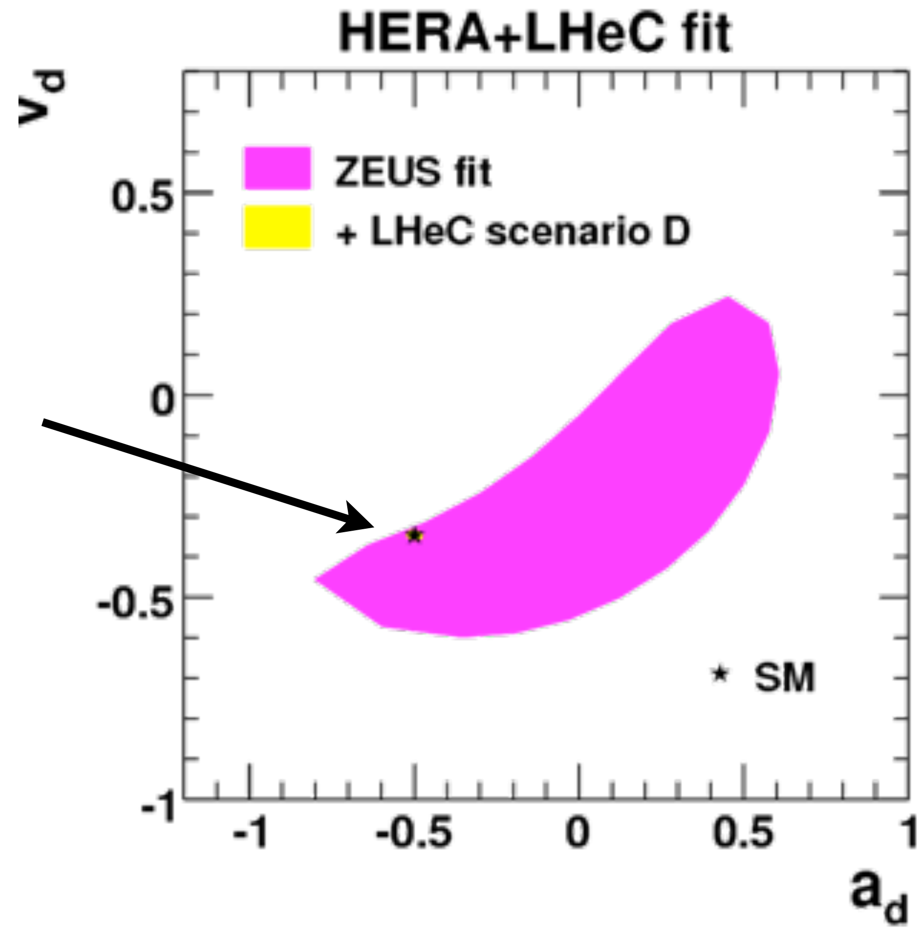
LHeC scenario D

comparison with **ZEUS fit** (base to which LHeC pseudo-data added)

» still to come: HERA-II NC e^+p data in ZEUS fit; **H1+ZEUS combined HERA-II** results



u-type quark couplings

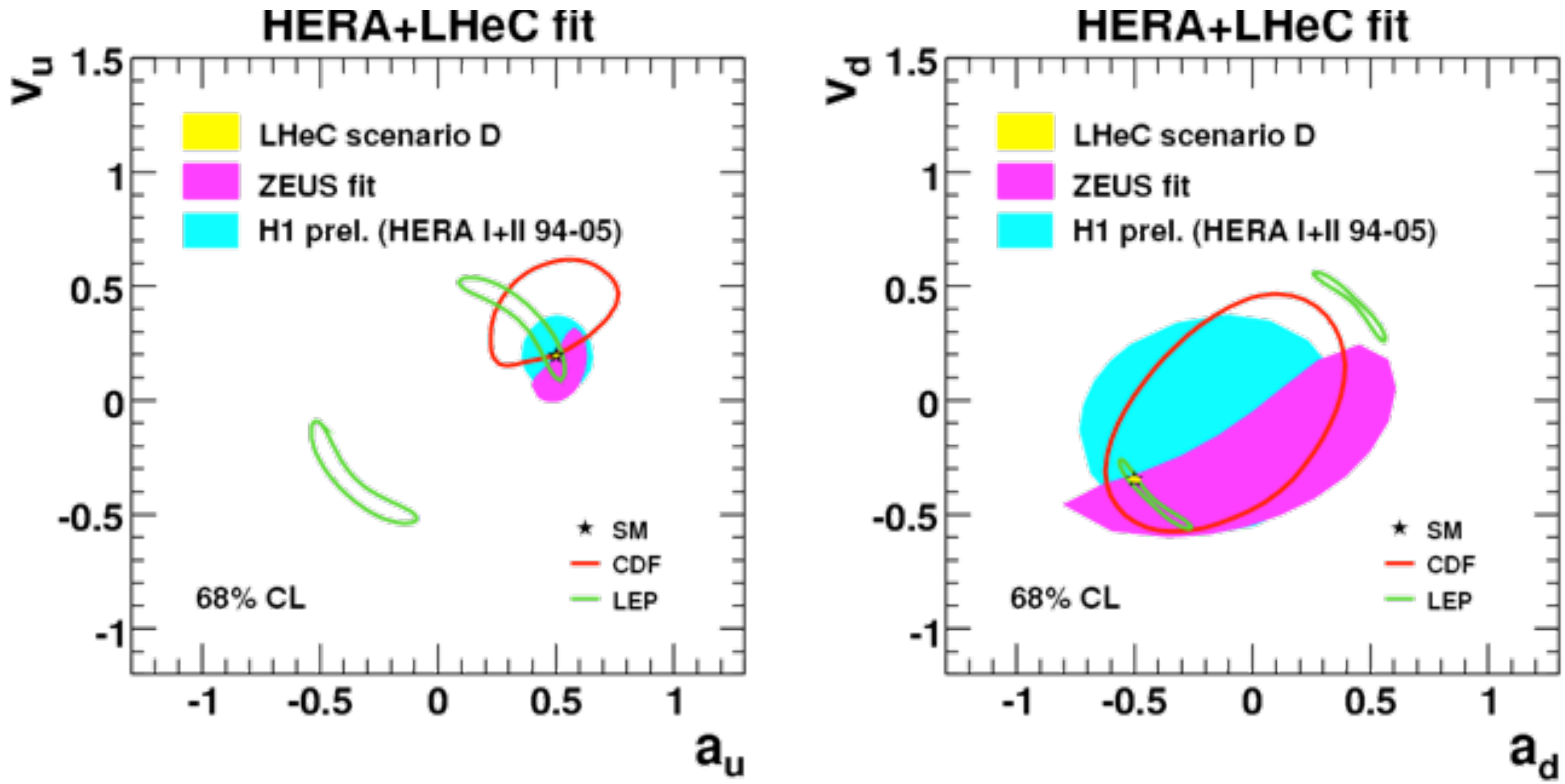


d-type quark couplings

LHeC scenario D

comparison with **other experiments**

» still to come: HERA-II NC e^+p data in **ZEUS fit**; **H1+ZEUS combined HERA-II** results

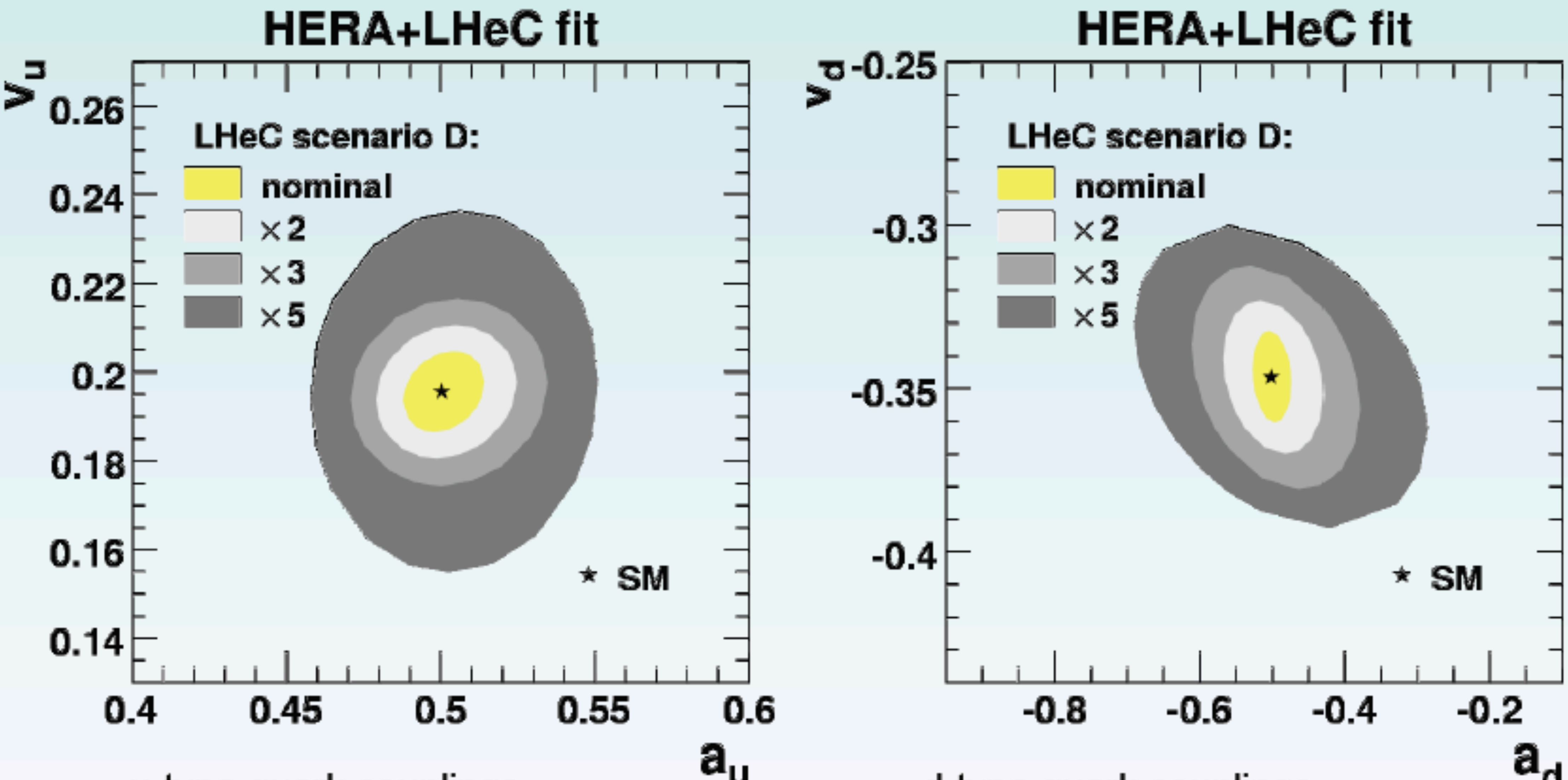


neutral current quark couplings

scenario D:
$P_e = \pm 0.9$

What if assumed level of statistical and systematic precision **not achieved**?

» reducing **luminosity** and increasing all **systematic uncertainties** by factors of × 2, 3, 5



u-type quark couplings

d-type quark couplings

neutral current quark couplings

scenario D:
$P_e = \pm 0.9$

What if assumed level of statistical and systematic precision **not achieved**?

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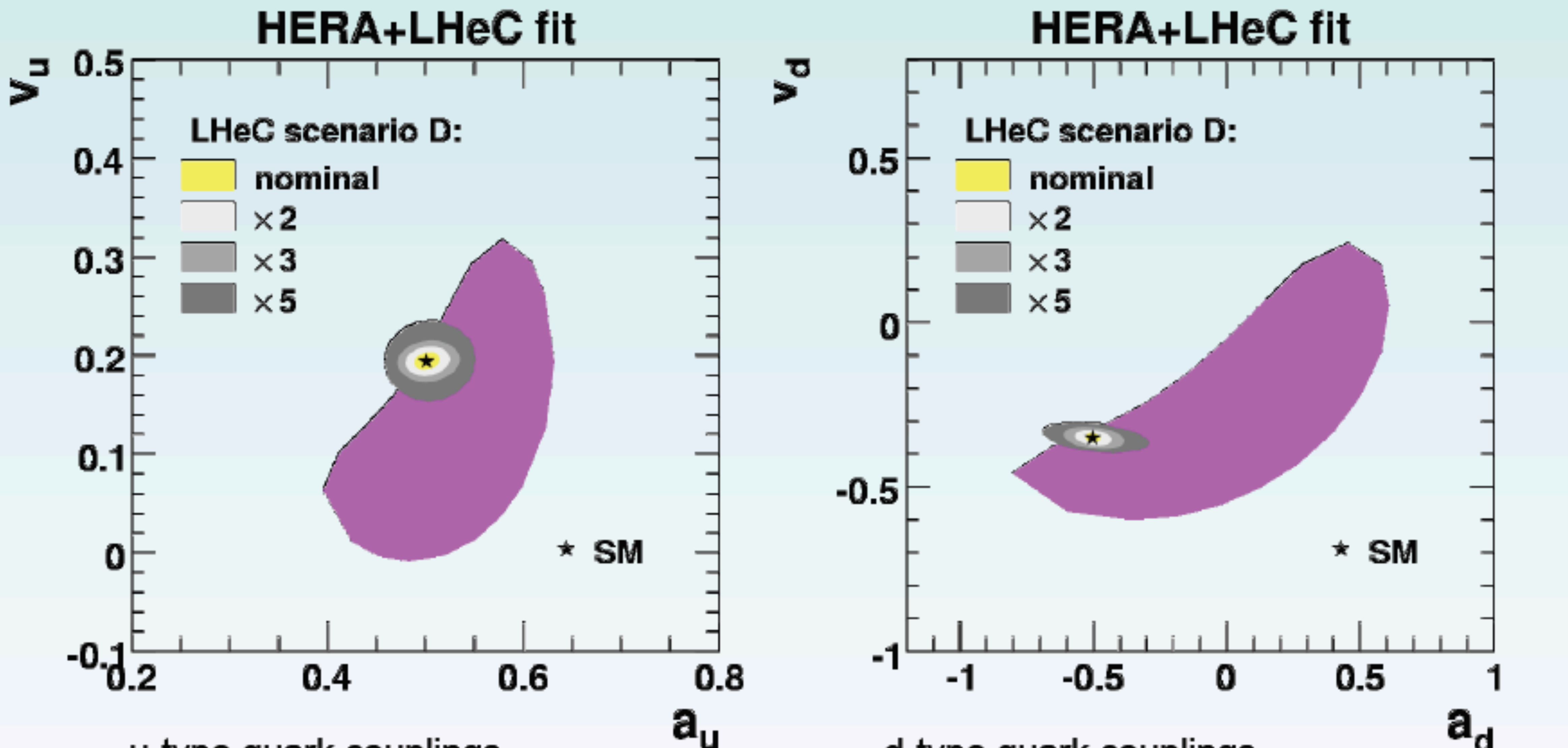


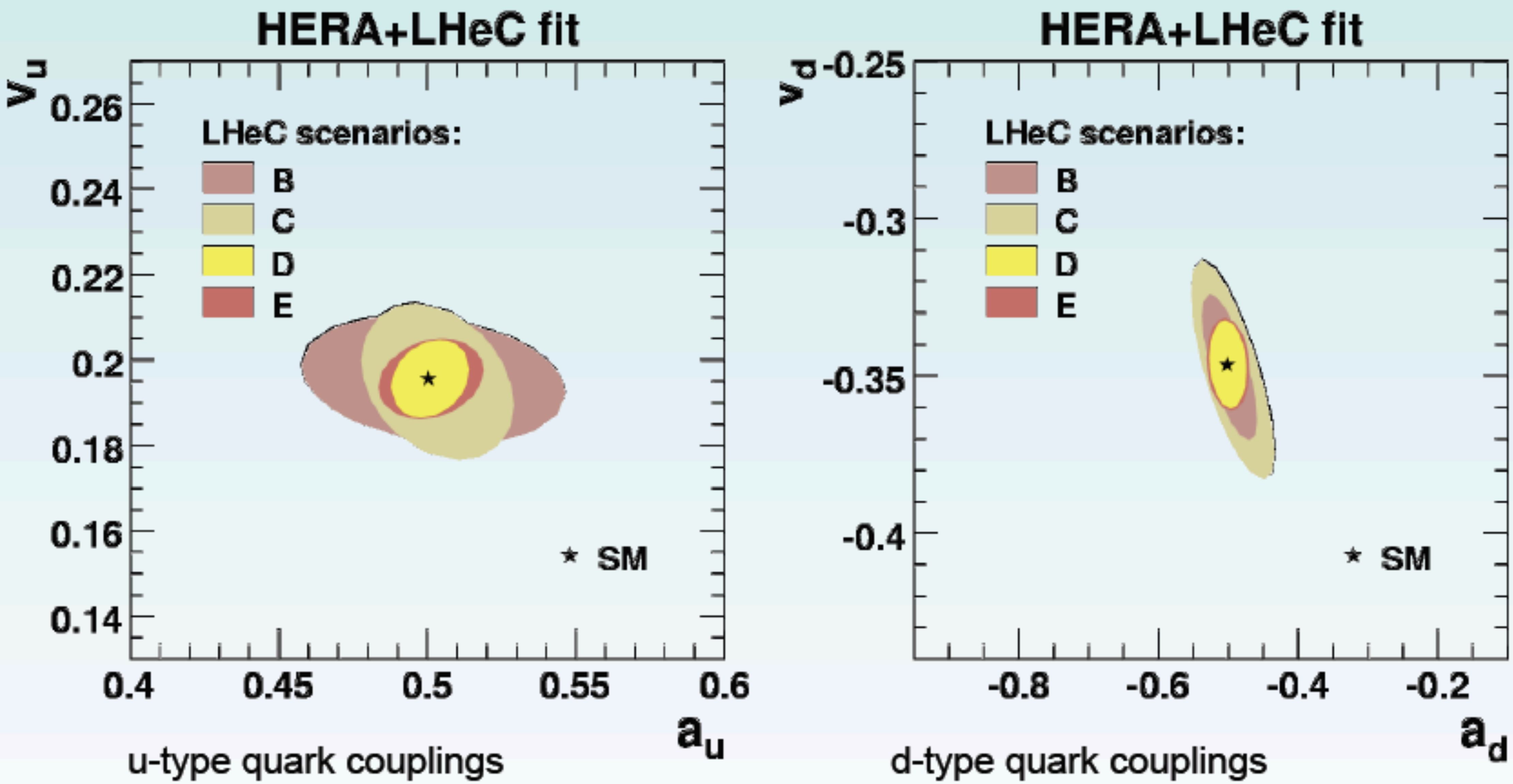
u-type quark couplings

d-type quark couplings

neutral current quark couplings

polarisations:
$P_e = \pm 0.4$ **(B,C)**
$P_e = \pm 0.9$ **(D,E)**

other scenarios: **B**, **C**, (**D**) and **E**



→ factors of **×10−40 improvement** (depending on exact coupling and scenario) wrt Hera

Comments on quark couplings fit

- ✓ Interesting results, O(1%) determination of light quark couplings, much better than LEP etc
- ✓ The strategy followed here is analytic continuation of Hera: lepton couplings well measured elsewhere, can be fixed to SM value, fit for quark NC couplings (+pdfs) Translates into roughly $\delta\sin^2\theta_W \sim 5\ 10^{-3}$
- ✓ But at 1% that might not be appropriate. Can we still look at $\sin^2\theta_W$? it will help gauge the constraining power of LHeC. In the context of New Physics, easy to consider oblique corrections S,T, U (covering large class of models).
- ✓ Some assumptions on pdfs might affect results.
- ✓ By itself, a better determination of quark NC couplings will constrain some exotic scenarios that modify *only* light quark couplings (non-universal Z', R-parity violating susy) After LHC? LHC measurements that can put similar constraints?

Conclusions

- Electroweak measurements @ LHeC will be favored by high Q^2, lepton polarization, high luminosity.
- Pdfs dependence can be to large extent avoided by simultaneous fit.
- Preliminary study shows interesting resolution on quark couplings
- Hope to have some additional study for CDR