Summary of 'Polarisation Task Force' Meeting of 21 September 2009

Michael Roney

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21 September 2009

An Exciting Programme!

- Search for CP violation in tau decays
- tau EDM – discovery very exciting given electron EDM
- g-2 complements muon g-2 – hint(?)
- Search for LFV – background suppression
- Discover LFV - study Lorentz structure of LVF process
- low energy window on precision neutral current measurements
  - opportunity to re-visit a lingering 3 sigma effect left over from LEP/SLC: high luminosity + polarisation

Some Background:

Adrian Bevan convened a meeting of parties known to have an interest in the case for polarisation.

EVO meeting 21^{st} Sept. 2009

Meeting indico page:

http://agenda.infn.it/conferenceDisplay.py?confId=1701

Some Background:

The items on the agenda:

- Overview: financial implications and a technical constraint on the accelerator
- Polarisation for g-2 and other non-LFV tau physics
- Polarisation for Tau Physics as a background suppression tool [including LFV]
- Other physics measurements relevant to the polarisation
- Discussion: tasks for TDR

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Overview

- Polarisation is in the baseline design of SuperB
- Impact on cost and performance of having one polarised beam is difficult to accurately assess
- Roughly 15-20% cost in funds and in luminosity performance (from Tuesday's discussion) ~equivalent of running an extra year
- Must be installed at beginning or costs much higher – won't be done
- Opens a rich and unique physics programme with potential for extremely high impact discovery: low risk for potentially high return
- ➔ a discovery in this sector would be SuperB legacy

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τ anomalous magnetic moment (g-2)

g-2 influence both the angular distribution and the τ polarization. Measure the Re(F2) and Im(F2) of the (g-2) from factor

$$\Delta a_\mu = a_\mu^{\rm exp} - a_\mu^{\rm SM} \approx (3 \pm 1) \times 10^{-9}$$

Complements muon g-2 hint at NP…

$\Delta a_\tau / \Delta a_\mu \sim m_\tau^2 / m_\mu^2$. **NP effects→ Δa_τ~ 10^{-6}**

	Snowmass points predictions						SuperB
	1 a	1 b	2	3	4	5	exp. resolution
$\Delta a_\mu \times 10^{-9}$	3.1	3.2	1.6	1.4	4.8	1.1	
$\Delta a_\tau \times 10^{-6}$	0.9	0.9	0.5	0.4	1.4	0.3	~1-2

without beam polarization, expected worse by factor $\approx$ 10, and worse systematics

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τ Electric Dipole Moment: discriminates w/ angular distributions and/or polarisation

Studies for Valencia: w/ 80±1% polarisation, 80% acceptance, realistic tracking efficiencies

statistical sensitivity of 10×10^{-20}

Systematic errors are x10 smaller

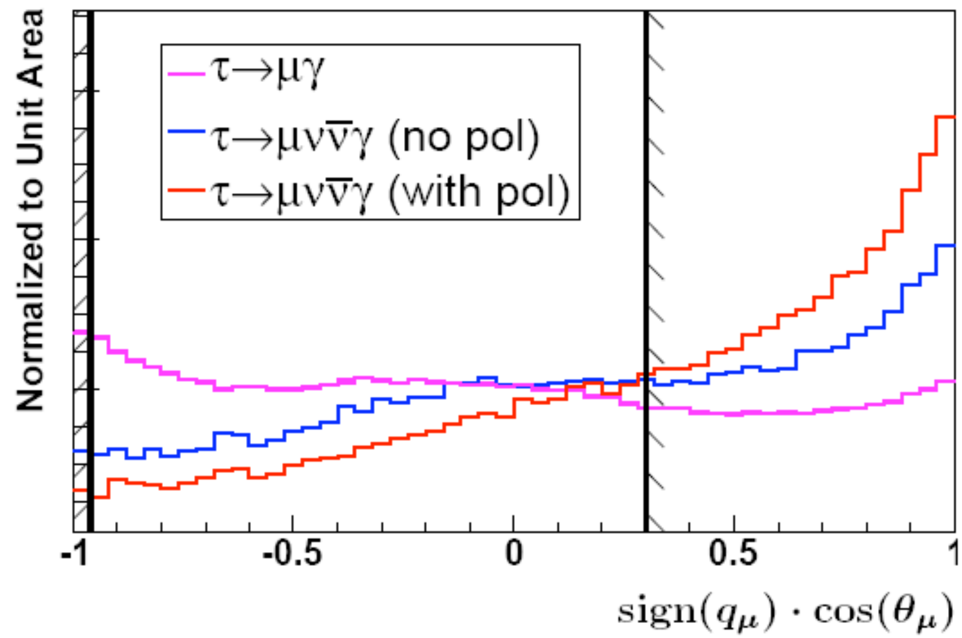
- 100x more precise than current no.

(cannot control syst errors without polarisation)

- electron EDM null measurements + a discovery of tau EDM → amazing/unexpected window on NP!

LFV analyses novel additional handle on backgrounds

This is with equal left and right handed couplings for signal



Irreducible background is from ISR photons produced in tau-pairs. Polarisation will alter ISR photon angular distribution providing additional discrimination

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More stringent LFV limits might be possible

LFV analyses novel additional handle on backgrounds

Work done on Tau Physics with Beam Polarization

tau LFV

- S.Banerjee has added two models of $\tau \to \mu\gamma$ production (SUSY production with full beam polarizazion and spin correlation)
- R.Cenci updated PacTauUser to FastSim V0.1.1
- A.L. imported latest *BABAR* tau generators (working, not yet released)
  - kk2f V00-02-29 → V00-02-32
  - tauola V00-01-20 → V00-01-21
  - koralb V03-01-16 → V03-01-18
- A.Cervelli generated events to simulate beam polarization effects for LFV search $\tau \to \mu\gamma$ (see his plots)

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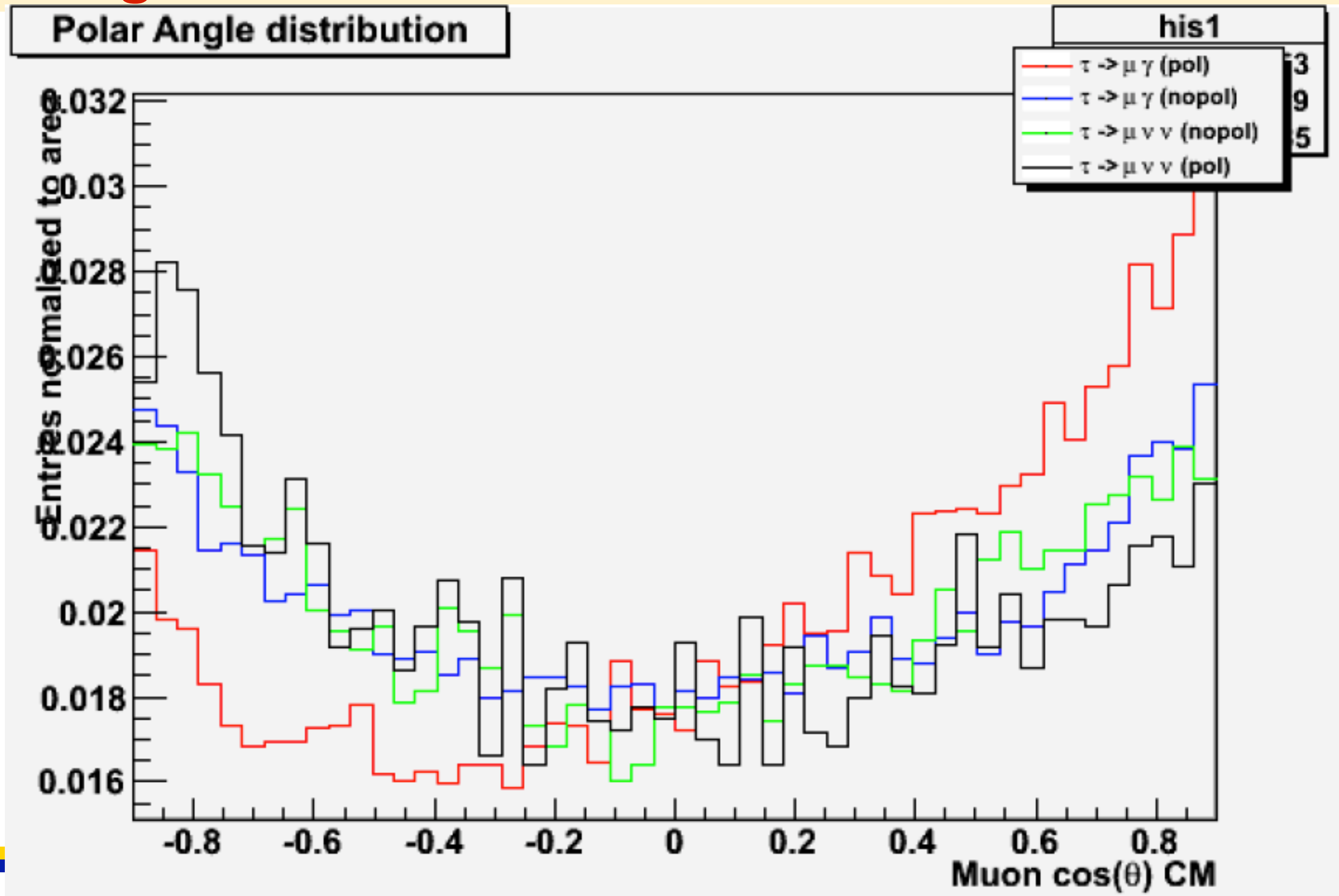
LFV analyses novel additional handle on backgrounds



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CPV in Tau decays

Small effect expected in the SM: $\sim 10^{-12}$.

Observation of CP asymmetry would be a clear sign of new physics: modulo K^0K^0 mixing effects in some decays.

Limited experimental investigations so far...

e.g. $K_s\pi\nu$: could get to $\sim 10^{-5}$ precision on charge asymmetry.

- Channel has been measured by CLEO using $13fb^{-1}$ of data.
- Probably not the best place to look (I think that the Ref is D. London et al. but will try and chase it up).
- This area could benefit from having people think about it a little...

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Exciting Discovery Programme!

- All but the last have been explored, to some extent, and presented at our workshops. These are the ~low risk – high gain studies: 'Wouldn't it be wonderful if…' CPV seen; LFV discovered and studied; etc
- Still work to be done on those
- but the neutral current component is another class of physics that until now hasn't be presented in the context of polarization at SuperB

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$e^+e^- \to f\,\bar{f}$ Diff. Cross section

at LEP: 15M hadronic Z decays, unpolarised
at SLC: 0.5M hadronic Z decays, polarised e-
at SuperB: Z-term ~30M hadronic Z, polarised

$$\frac{2s}{\pi}\frac{1}{N_c^{\rm f}}\frac{d\sigma_{\rm ew}}{d\cos\theta}(\mathrm{e^+e^-}\to \mathrm{f\bar{f}}) =$$

$$\underbrace{|\alpha(s)Q_{\rm f}|^2\,(1+\cos^2\theta)}_{\sigma^\gamma}$$

$$\underbrace{-8\Re\left\{\alpha^*(s)Q_{\rm f}\chi(s)\left[\mathcal{G}_{\rm Ve}\mathcal{G}_{\rm Vf}(1+\cos^2\theta)+2\mathcal{G}_{\rm Ae}\mathcal{G}_{\rm Af}\cos\theta\right]\right\}}_{\gamma\text{–Z interference}}$$

$$\underbrace{\begin{array}{c}+16|\chi(s)|^2\left[(|\mathcal{G}_{\rm Ve}|^2+|\mathcal{G}_{\rm Ae}|^2)(|\mathcal{G}_{\rm Vf}|^2+|\mathcal{G}_{\rm Af}|^2)(1+\cos^2\theta)\right.\\ \left.+8\Re\left\{\mathcal{G}_{\rm Ve}\mathcal{G}_{\rm Ae}{}^*\right\}\Re\left\{\mathcal{G}_{\rm Vf}\mathcal{G}_{\rm Af}{}^*\right\}\cos\theta\right]\end{array}}_{\sigma^{\rm Z}}$$

with:

$$\chi(s) = \frac{G_{\rm F}m_{\rm Z}^2}{8\pi\sqrt{2}}\frac{s}{s-m_{\rm Z}^2+is\Gamma_{\rm Z}/m_{\rm Z}},$$

where θ is the scattering angle of the out-going fermion with respect to the direction of the e^-.

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$e^+e^- \rightarrow f\,\bar{f}$ Diff. Cross section

$$\mathcal{G}_{Vf} = \sqrt{\mathcal{R}_f}\,(T_3^f - 2Q_f\mathcal{K}_f \sin^2\theta_W)$$
$$\mathcal{G}_{Af} = \sqrt{\mathcal{R}_f}\,T_3^f\,.$$

In terms of the real parts of the complex form factors,

$$\rho_f \equiv \Re(\mathcal{R}_f) = 1 + \Delta\rho_{se} + \Delta\rho_f$$
$$\kappa_f \equiv \Re(\mathcal{K}_f) = 1 + \Delta\kappa_{se} + \Delta\kappa_f\,,$$

the effective electroweak mixing angle and the real effective couplings are defined as:

$$\sin^2\theta_{eff}^f \equiv \kappa_f \sin^2\theta_W$$
$$g_{Vf} \equiv \sqrt{\rho_f}\,(T_3^f - 2Q_f \sin^2\theta_{eff}^f)$$
$$g_{Af} \equiv \sqrt{\rho_f}\,T_3^f\,,$$
$$\frac{g_{Vf}}{g_{Af}} = \Re\left(\frac{\mathcal{G}_{Vf}}{\mathcal{G}_{Af}}\right) = 1 - 4|Q_f|\sin^2\theta_{eff}^f\,.$$

The quantities $\Delta\rho_{se}$ and $\Delta\kappa_{se}$ are universal corrections arising from the propagator self-energies, while $\Delta\rho_f$ and $\Delta\kappa_f$ are flavour-specific vertex corrections.

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$e^+e^- \to f\,\bar{f}$ Diff. Cross section

$$\frac{2s}{\pi}\frac{1}{N_c^f}\frac{d\sigma_{ew}}{d\cos\theta}(e^+e^- \to f\bar{f}) =$$

at LEP: 15M hadronic Z decays, unpolarised
at SLC: 0.5M hadronic Z decays, polarised e-
at SuperB: Z-term ~10'sM hadronic Z, polarised

$$\underbrace{|\alpha(s)Q_f|^2(1+\cos^2\theta)}_{\sigma^\gamma}$$

$$\underbrace{-8\Re\left\{\alpha^*(s)Q_f\chi(s)\left[\mathcal{G}_{Ve}\mathcal{G}_{Vf}(1+\cos^2\theta)+2\mathcal{G}_{Ae}\mathcal{G}_{Af}\cos\theta\right]\right\}}_{\gamma\text{–Z interference}}$$

$$\underbrace{\begin{array}{c}+16|\chi(s)|^2\left[(|\mathcal{G}_{Ve}|^2+|\mathcal{G}_{Ae}|^2)(|\mathcal{G}_{Vf}|^2+|\mathcal{G}_{Af}|^2)(1+\cos^2\theta)\right.\\ \left.+8\Re\left\{\mathcal{G}_{Ve}\mathcal{G}_{Ae}{}^*\right\}\Re\left\{\mathcal{G}_{Vf}\mathcal{G}_{Af}{}^*\right\}\cos\theta\right]\end{array}}_{\sigma^Z}$$

$$g_L^{tree} = \sqrt{\rho_0}\,(T_3^f - Q_f\sin^2\theta_W^{tree})$$
$$g_R^{tree} = -\sqrt{\rho_0}\,Q_f\sin^2\theta_W^{tree}\,,$$

or, equivalently in terms of vector and axial-vector couplings:

$$g_V^{tree} \equiv g_L^{tree}+g_R^{tree} = \sqrt{\rho_0}\,(T_3^f - 2Q_f\sin^2\theta_W^{tree})$$
$$g_A^{tree} \equiv g_L^{tree}-g_R^{tree} = \sqrt{\rho_0}\,T_3^f\,.$$

$e^+e^- \to f\,\bar{f}$ Diff. Cross section

$$\frac{2s}{\pi}\frac{1}{N_c^{\rm f}}\frac{d\sigma_{\rm ew}}{d\cos\theta}(\mathrm{e^+e^-} \to \mathrm{f\bar{f}}) \;=$$

$$\underbrace{|\alpha(s)Q_{\rm f}|^2\,(1+\cos^2\theta)}_{\sigma^\gamma}$$

$$\underbrace{-8\Re\left\{\alpha^*(s)Q_{\rm f}\chi(s)\left[\mathcal{G}_{\rm Ve}\mathcal{G}_{\rm Vf}(1+\cos^2\theta)+2\mathcal{G}_{\rm Ae}\mathcal{G}_{\rm Af}\cos\theta\right]\right\}}_{\gamma\text{–Z interference}}$$

$$\underbrace{\begin{array}{c}+16|\chi(s)|^2\left[(|\mathcal{G}_{\rm Ve}|^2+|\mathcal{G}_{\rm Ae}|^2)(|\mathcal{G}_{\rm Vf}|^2+|\mathcal{G}_{\rm Af}|^2)(1+\cos^2\theta)\right.\\ \left.+8\Re\left\{\mathcal{G}_{\rm Ve}\mathcal{G}_{\rm Ae}{}^*\right\}\Re\left\{\mathcal{G}_{\rm Vf}\mathcal{G}_{\rm Af}{}^*\right\}\cos\theta\right]\end{array}}_{\sigma^{\rm Z}}$$

$$g_{\rm L}^{\rm tree} \;=\; \sqrt{\rho_0}\,(T_3^{\rm f} - Q_{\rm f}\sin^2\theta_{\rm W}^{\rm tree})$$

$$g_{\rm R}^{\rm tree} \;=\; -\sqrt{\rho_0}\,Q_{\rm f}\sin^2\theta_{\rm W}^{\rm tree}\,,$$

or, equivalently in terms of vector and axial-vector couplings:

$$g_{\rm V}^{\rm tree} \;\equiv\; g_{\rm L}^{\rm tree}+g_{\rm R}^{\rm tree} \;=\; \sqrt{\rho_0}\,(T_3^{\rm f} - 2Q_{\rm f}\sin^2\theta_{\rm W}^{\rm tree})$$

$$g_{\rm A}^{\rm tree} \;\equiv\; g_{\rm L}^{\rm tree}-g_{\rm R}^{\rm tree} \;=\; \sqrt{\rho_0}\,T_3^{\rm f}\,.$$

$e^+e^- \rightarrow f\,\bar{f}$ Diff. Cross section

Asymmetries at Z-pole:

$$A_{\mathrm{FB}} = \frac{\sigma_{\mathrm{F}} - \sigma_{\mathrm{B}}}{\sigma_{\mathrm{F}} + \sigma_{\mathrm{B}}}$$

$$A_{\mathrm{LR}} = \frac{\sigma_{\mathrm{L}} - \sigma_{\mathrm{R}}}{\sigma_{\mathrm{L}} + \sigma_{\mathrm{R}}} \frac{1}{\langle|\mathcal{P}_{\mathrm{e}}|\rangle}$$

$$A_{\mathrm{LRFB}} = \frac{(\sigma_{\mathrm{F}} - \sigma_{\mathrm{B}})_{\mathrm{L}} - (\sigma_{\mathrm{F}} - \sigma_{\mathrm{B}})_{\mathrm{R}}}{(\sigma_{\mathrm{F}} + \sigma_{\mathrm{B}})_{\mathrm{L}} + (\sigma_{\mathrm{F}} + \sigma_{\mathrm{B}})_{\mathrm{R}}} \frac{1}{\langle|\mathcal{P}_{\mathrm{e}}|\rangle}.$$

A_{FB} is Problematic at SuperB because of pure QED FB asymmetry – requires polarised beam – need to evaluate polarisaiton precision required

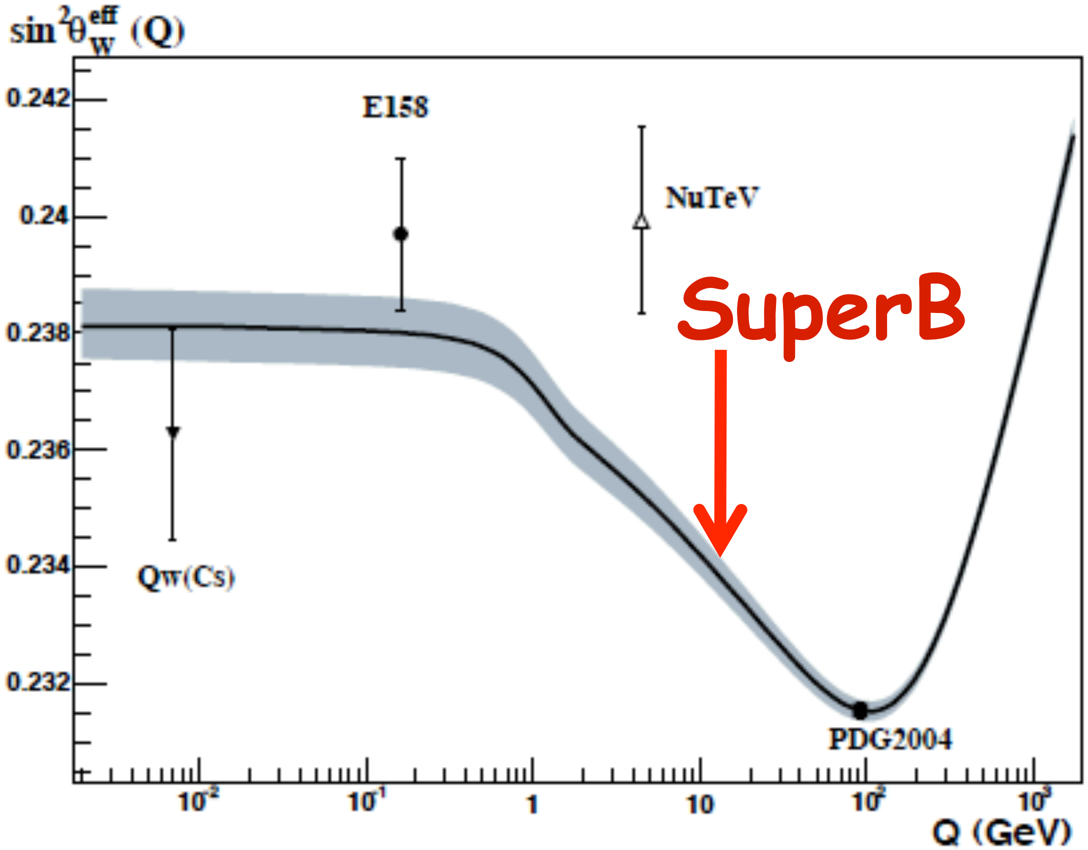

FIG. 2: Predicted variation [18] of $\sin^2 \theta_W^{eff}$ as a function of momentum transfer Q (solid line) and its estimated theoretical uncertainty (shaded area). Results of prior low energy experiments [6, 16] (closed triangle, shown at an arbitrarily higher Q) and [7] (open triangle) are overlaid together with the Z^0 pole value [16] (square) and this measurement (circle).

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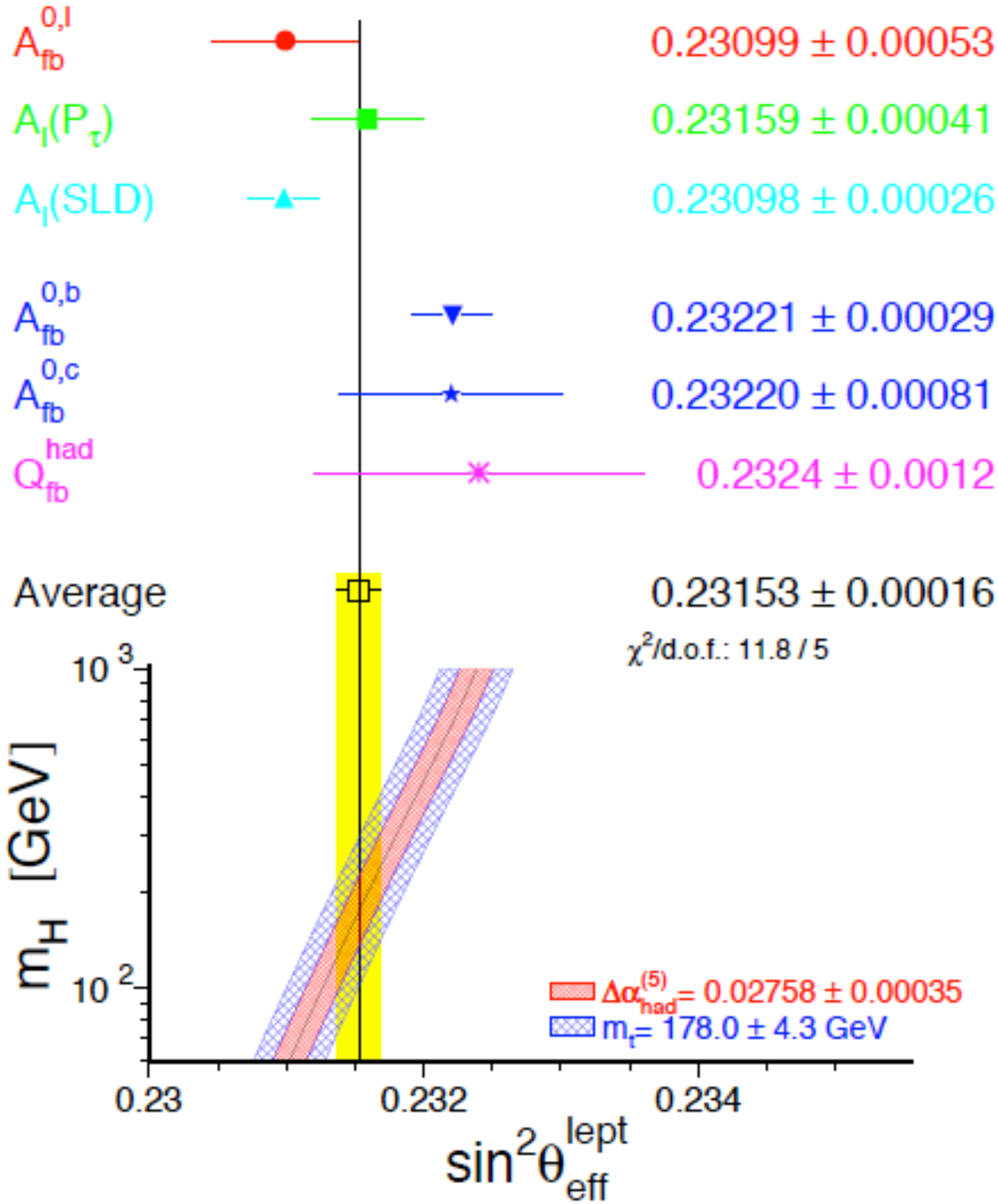

$A_{fb}^{0,l}$ 0.23099 ± 0.00053
$A_l(P_\tau)$ 0.23159 ± 0.00041
A_l(SLD) 0.23098 ± 0.00026
$A_{fb}^{0,b}$ 0.23221 ± 0.00029
$A_{fb}^{0,c}$ 0.23220 ± 0.00081
Q_{fb}^{had} 0.2324 ± 0.0012
Average 0.23153 ± 0.00016
χ^2/d.o.f.: 11.8 / 5
10^3
10^2
m_H [GeV]
$\Delta\alpha_{had}^{(5)}$ = 0.02758 ± 0.00035
m_t = 178.0 ± 4.3 GeV
0.23
0.232
0.234
$\sin^2\theta_{eff}^{lept}$

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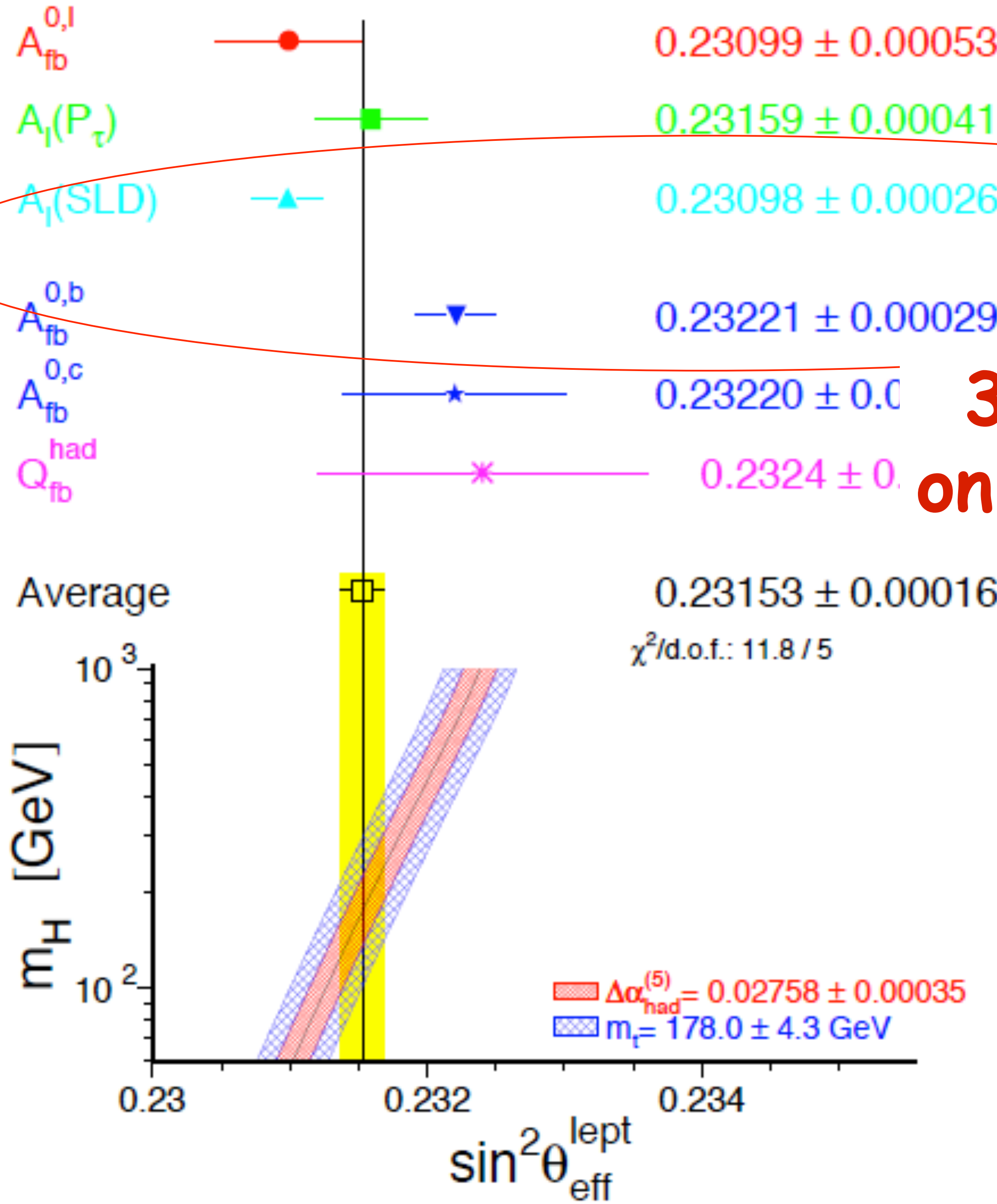

3.2σ comparing only A_{LR} and $A^{0,b}_{fb}$

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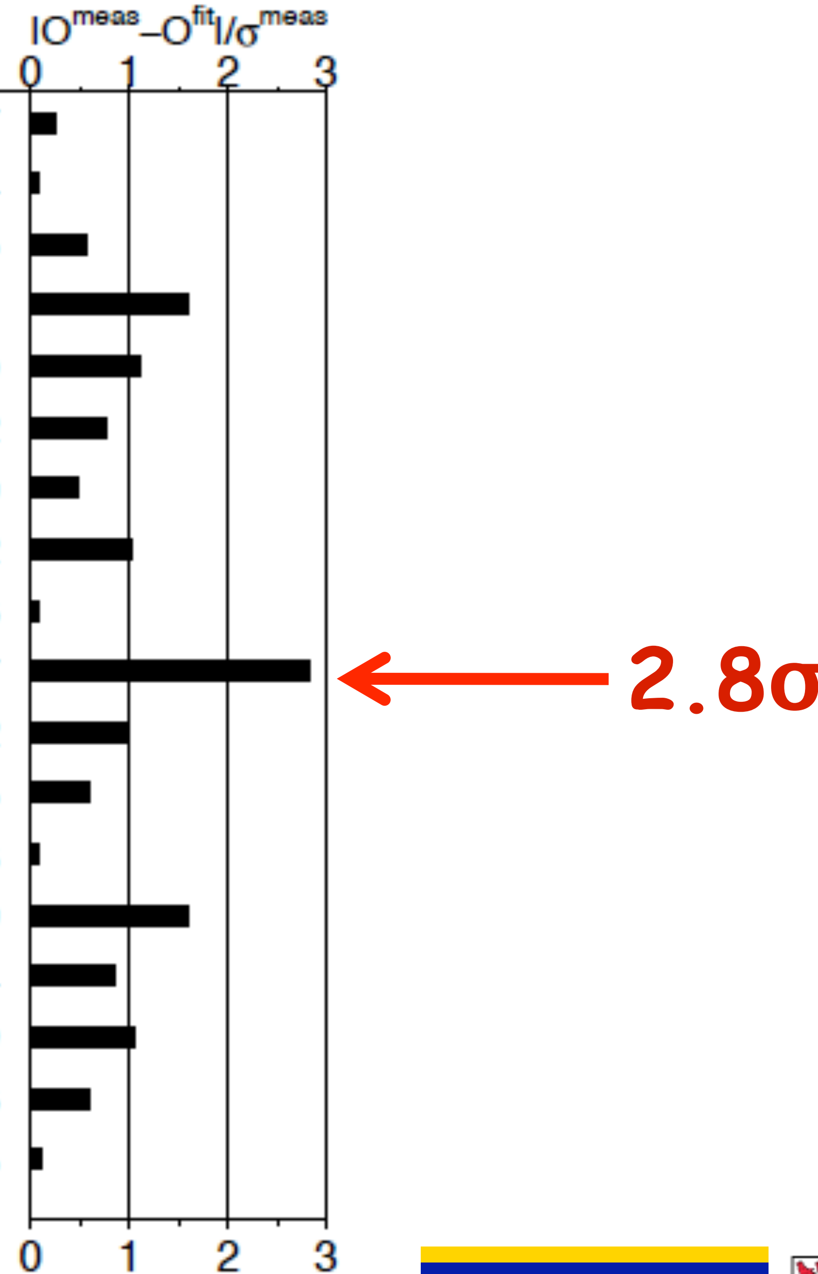
	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ_{had}^0 [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21562
R_c	0.1721 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1037
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.389
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.5



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NC Lepton universality:

- Neutral current universality: a reminder

$g_e^A / g_\mu^A = 0.9981 \pm 0.0013$

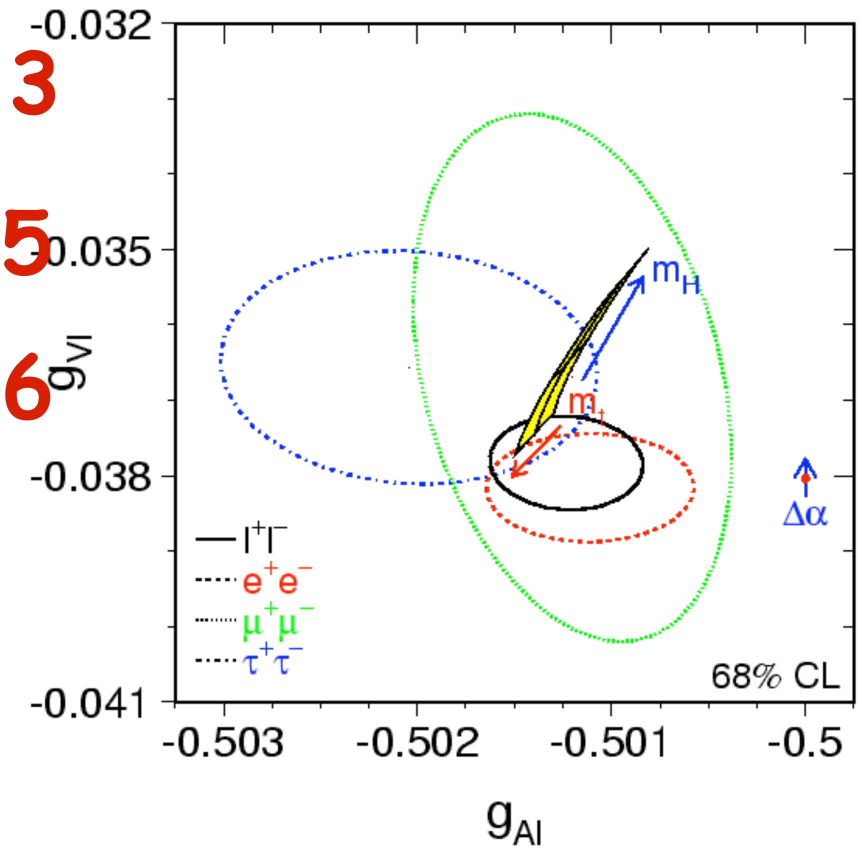
$g_e^A / g_\tau^A = 0.9981 \pm 0.0015$

$g_\mu^A / g_\tau^A = 0.9983 \pm 0.0016$

$g_e^V / g_\mu^V = 1.040 \pm 0.065$

$g_e^V / g_\tau^V = 1.043 \pm 0.030$

$g_\mu^V / g_\tau^V = 1.003 \pm 0.068$



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Neutral Current Physics Programme

- Precision measurement of $\sin^2\vartheta^{eff}_W$ at 10.58GeV
  - with muon – probe running, NuTeV result
  - with muons and taus – probe NC universality at low Q^2
  - with charm
  - with b’s: probe residual 3σ effect from LEP AFB
    - as 4S is pure vector this would be continuum B measurement while running on the 4S

Work list from meeting…

- homework NP theories are we sensitive to with CPV
- what NP theories have left or right-handed LFV decays
- improvements to g-2 and EDM sensitivities – NP theories at our sensitivities
- evaluate the NC sensitivities with 75/ab at SuperB
- need to examine impact of QED A_{FB}
- what are requirements of systematic precision of polarisation determination: work with machine folks

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Summary…

- We have a very rich and unique programme with polarisation
- low risk/cost with potential for amazing physics discoveries that could define SuperB’s ultimate impact
- Also, bread-and-butter neutral current physics programme that can shine light on a couple of >2sigma effects and provide sensitivity to different kind of new physics
- still work to do on the physics side… help wanted!