SuperB EW Physics Update

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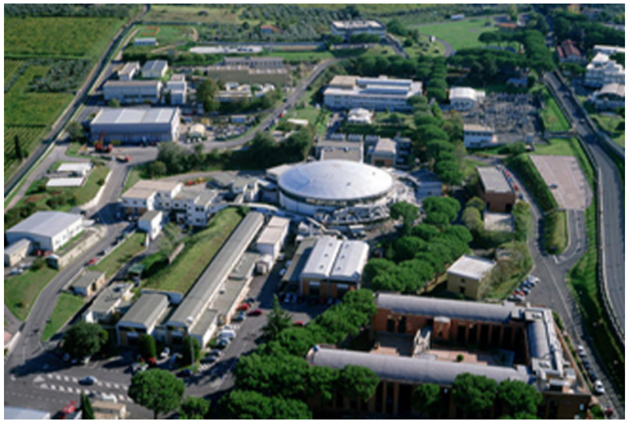
LNF



Outline

- Quick reminder of the EW programme
- Software tool studies: ZFITTER calculation of A_{LR} vs simple calculation
- Comments on cross section: what impact does beam polarisation have on the cross sections

EW programme reminders…

Polarised e- beam yields product of the neutral axial-vector coupling of the electron and vector coupling of the final-state fermion via Z-γ interference:

$$A_{LR} = \frac{4}{\sqrt{2}}\left(\frac{G_F s}{4\pi\alpha Q_f}\right) g_A^e g_V^f \langle Pol \rangle$$

$$\langle Pol \rangle = 0.5\left\{\left(\frac{N_R^{e-} - N_L^{e-}}{N_R^{e-} + N_L^{e-}}\right)_R - \left(\frac{N_R^{e-} - N_L^{e-}}{N_R^{e-} + N_L^{e-}}\right)_L\right\}$$

$$g_A^e = T_3^e = 1/2 \qquad\qquad g_V^f = T_3^f - 2Q_f \sin^2\theta_W$$

EW programme …

- A_{LR} programme -> rich precision probe of the vector coupling of e, μ, τ, c, b all within the same experiment

- Absolute vector coupling gives measure of $\sin^2\theta_W$ requires absolute polarisation and electron axial-vector coupling (g_A^e)

- Relative vector couplings are given by ratios of A_{LR} and can be expected to be statistics limited as polarisation and g_A^e cancel in the ratios

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Absolute vector couplings: $\sin^2\theta_W$

- Absolute vector coupling gives measure of $\sin^2\theta_W$: requires absolute polarisation and electron axial-vector coupling (g_A^e)
- Beam polarisation with Compton Polarimeter and tau-polarisation FB asymmetry to ~0.5% (see Sept 2011 presentation)
- g_A^e : can either assume SM ½; use LEP measurement and assume it is the same at 10.58GeV; or can check it with $A_{FB}^{\mu} \sim g_A^e g_A^{\mu}$ assuming Lept. Univ. (In principle $A_{FB}^e \sim g_A^e g_A^e$ gives this w/o assuming Lept. Univ. but A_{FB}^e dominated by QED)

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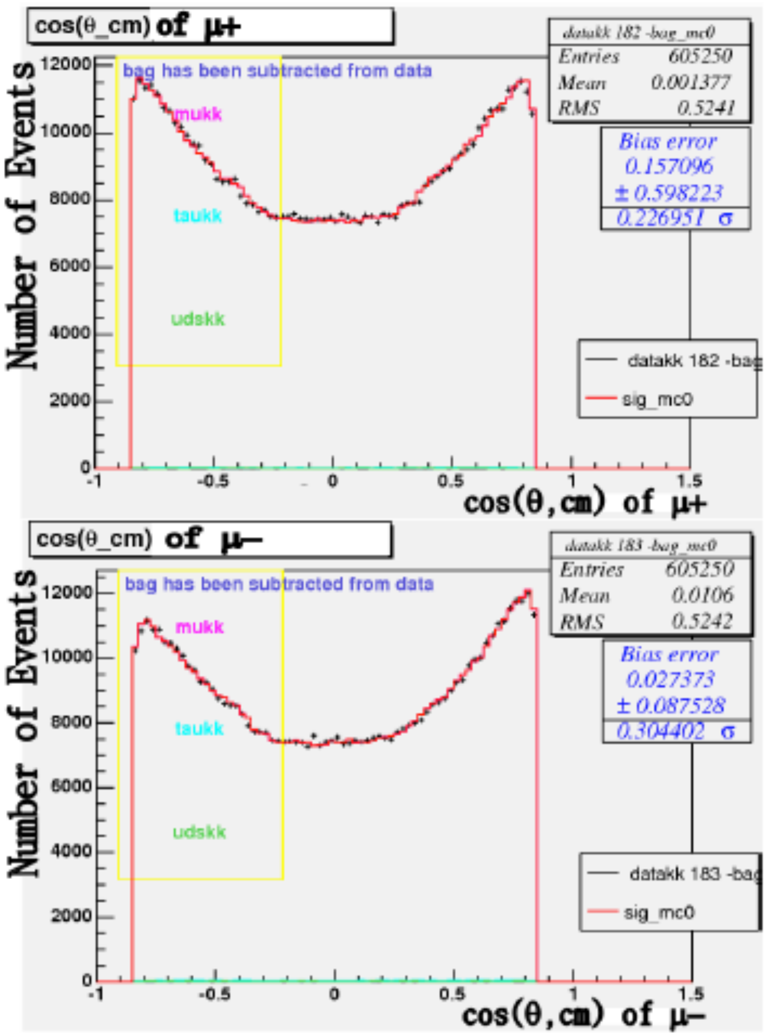
A μ-pair selection in BaBar

- Efficiency = 53.4%
- Purity = 99.6%
- Projected no. of selected mu-pair events at SuperB for 75/ab is 45.6 billion
- For 46×10^{9} stat error on for <P>= 100% is 4.7×10^{-6}



$e^+e^- \rightarrow \mu^+\mu^-$ @ $\sqrt{s}$=10.58GeV

Diagrams	Cross Section (nb)	A_{FB}	A_{LR} (Pol = 100%)
$\lvert Z+\gamma \rvert^2$	1.01	0.0028	-0.00051

σ_{ALR} =6x10^{-6} → $\sigma_{(\sin 2\theta eff)}$ =0.0002

cf SLC A_{LR} $\sigma_{(\sin 2\theta eff)}$ =0.00026

relative stat. error of 1% (pol=80%) require <~0.5% systematic error on beam polarisation

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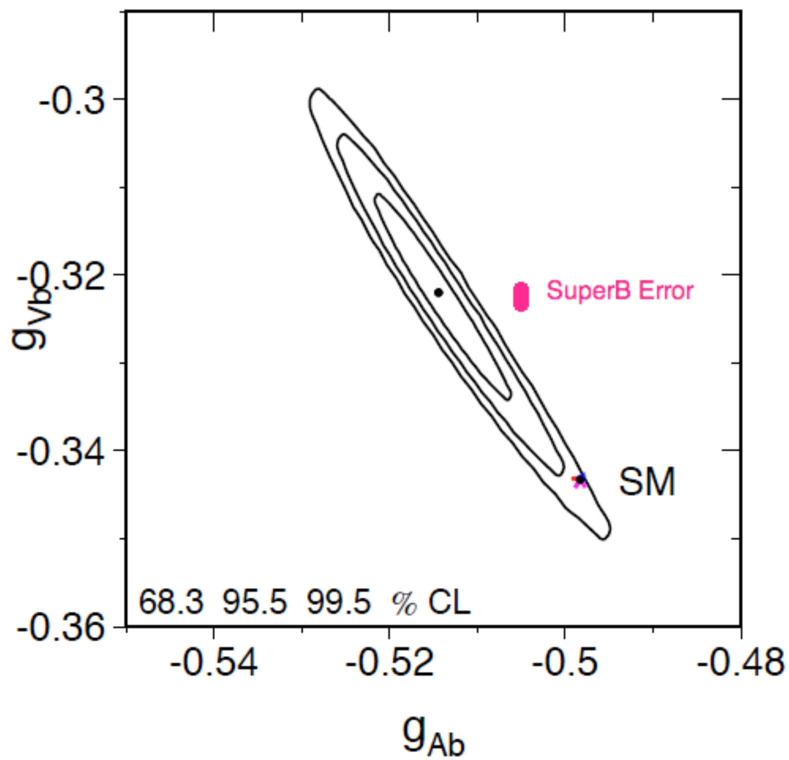
SM expectation & LEP Measurement of g_V^b

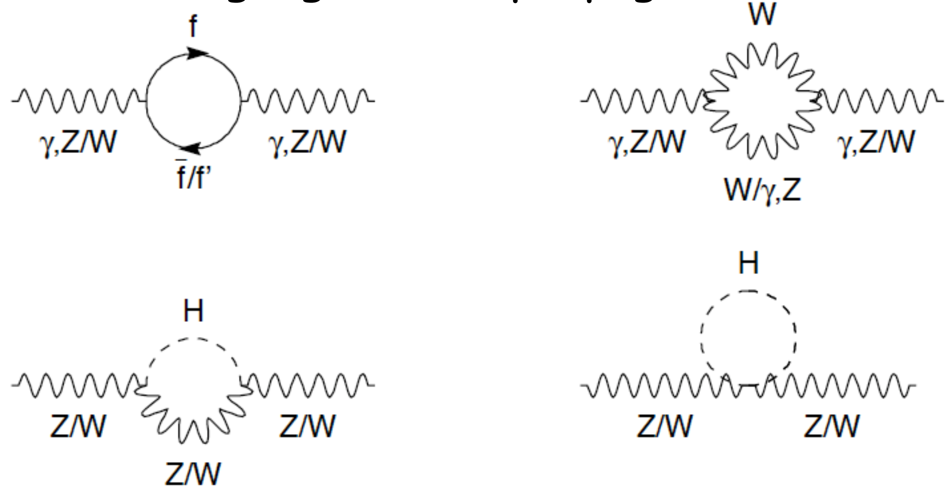
- SM: -0.34372 +0.00049-.00028
- A_{FB}^b: -0.3220±0.0077

- with 0.5% polarization systematic and 0.3% stat error, SuperB can have an error of ±0.0021



on-shell scheme...

Higher order corrections to gauge boson propagators



$$g_V^f \equiv \sqrt{\rho_f}\left(T_3^f - 2Q_f\kappa_f \sin^2\theta_W\right)$$

$$g_V^f \equiv \sqrt{\rho_f}\, T_3^f$$

on-shell scheme $\sin^2\theta_W$ in terms,

to all orders, of pole masses

$$\cos^2\theta_W = m_W^2 / m_Z^2$$

$$\rho_f \equiv 1 + \Delta\rho_{se} + \Delta\rho_f$$

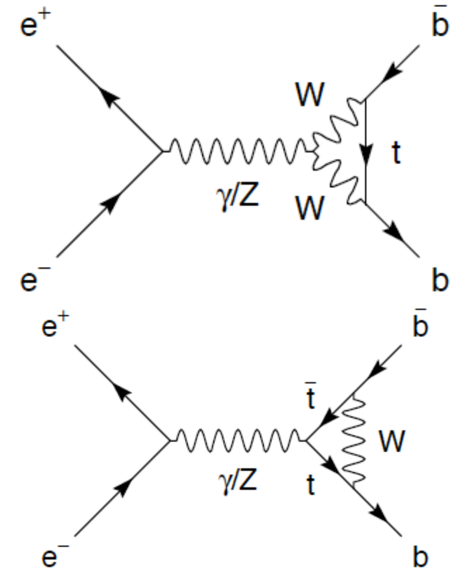
$$\kappa_f \equiv 1 + \Delta\kappa_{se} + \Delta\kappa_f$$

$$\Delta\rho_{se} = \frac{3G_F m_W^2}{8\sqrt{2}\pi^2}\left[\frac{m_t^2}{m_W^2} - \frac{\sin^2\theta_W}{\cos^2\theta_W}\left(\ln\left(\frac{m_H^2}{m_W^2}\right) - \frac{5}{6}\right) + \ldots\right]; \qquad \Delta\rho_{f\neq b} \approx 0; \quad \Delta\rho_b = -\frac{G_F m_t^2}{2\sqrt{2}\pi^2} + \ldots$$

$$\Delta\kappa_{se} = \frac{3G_F m_W^2}{8\sqrt{2}\pi^2}\left[\frac{m_t^2}{m_W^2}\frac{\cos^2\theta_W}{\sin^2\theta_W} - \frac{10}{9}\left(\ln\left(\frac{m_H^2}{m_W^2}\right) - \frac{5}{6}\right) + \ldots\right]; \quad \Delta\kappa_{f\neq b} \approx 0; \quad \Delta\kappa_b = -\frac{G_F m_t^2}{4\sqrt{2}\pi^2} + \ldots$$

on-shell scheme...

Higher order corrections to vertex in e+e- -> b-pair



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ZFitter vs simple tree A_{LR}

With mass measurements of Z and top, Higgs we have SM values for the vector couplings and rigorous predictions of the vector couplings:

at 10.58GeV	Zfitter	Zfitter (Weak Rad Corr off)	Simple Analytic no Rad Cor
muon	-0.00050	-0.00086	-0.00077
charm	-0.00478	-0.0052	-0.00547
beauty	-0.01936	-0.0200	-0.0194

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Relative vector couplings

With mass measurements of W, Z and top, we have SM values for the vector couplings and rigorous predictions of the ratios of the vector couplings:

$$g_V^{f\neq b}/g_V^{\mu} = \left(T_3^f - 2Q_f \sin^2\theta_W\right)/\left(-0.5 + 2\sin^2\theta_W\right)$$

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Relative vector couplings

take ratios of μ,τ,c,b A_{LR} so that of the electron cancels polarisation systematic errors and the electron axial-vector coupling: stat. error dominated

	SM (Mh=125GeV)	LEP	SuperB error
g_V^{μ} / g_V^{τ}	1	0.997 +/- 0.068	~2% from tau stats
g_V^{c} / g_V^{lepton}	5.223 +/-	-4.991 +/- 0.074	~1% muon stats +/-0.05
g_V^{b} / g_V^{lepton}	9.357 +/-	8.58+/- 0.16	~1% from mu stats +/- 0.08

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Cross-sections with polarised beams

- From Gudrid Moortgat-Pick (desy-10-242)

$$\begin{aligned}
\sigma_{P_{e^-}P_{e^+}} &= \frac{1+P_{e^-}}{2}\,\frac{1-P_{e^+}}{2}\,\sigma_{\rm RL} + \frac{1-P_{e^-}}{2}\,\frac{1+P_{e^+}}{2}\,\sigma_{\rm LR} \\
&= (1-P_{e^-}P_{e^+})\,\frac{\sigma_{\rm RL}+\sigma_{\rm LR}}{4}\left[1 - \frac{P_{e^-}-P_{e^+}}{1-P_{e^+}P_{e^-}}\,\frac{\sigma_{\rm LR}-\sigma_{\rm RL}}{\sigma_{\rm LR}+\sigma_{\rm RL}}\right] \\
&= (1-P_{e^+}P_{e^-})\,\sigma_0\,[1 - P_{\rm eff}\,A_{\rm LR}]\,,
\end{aligned}$$

the unpolarized cross section: $\sigma_0 = \frac{\sigma_{\rm RL}+\sigma_{\rm LR}}{4}$

the left-right asymmetry: $A_{\rm LR} = \frac{\sigma_{\rm LR}-\sigma_{\rm RL}}{\sigma_{\rm LR}+\sigma_{\rm RL}}$

and the effective polarization: $P_{\rm eff} = \frac{P_{e^-}-P_{e^+}}{1-P_{e^+}P_{e^-}}$

Polarisation of one beam has ~no impact on cross sections

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Summary

- We have a very rich EW programme that gives unprecedented precision measurements of the vector coupling via A_{LR} –for mu, tau, charm and b fermions – the best place for b's

- Ratio of vector couplings are statistics limited errors – and polarization value will impact this

BACKUP SLIDES

Tau Polarisation as Beam Polarimeter

$$P_{z'}^{(\tau-)}(\theta,P_e) = -\frac{8G_F s}{4\sqrt{2}\pi\alpha}\mathrm{Re}\left\{\frac{g_V^l - Q_b g_V^b \Upsilon_{1S,2S,3S}(s)}{1+Q_b^2\Upsilon_{1S,2S,3S}(s)}\right\}\left(g_A^\tau \frac{|\vec{p}|}{p^0} + 2g_A^e\frac{\cos\theta}{1+\cos^2\theta}\right)$$

$$+ P_e\frac{\cos\theta}{1+\cos^2\theta}$$

- Dominant term is the polarization forward-backward asymmetry whose coefficient is the beam polarization ->Oscar's slides from Elba
- Measure tau polarization as a function of θ for the separately tagged beam polarization states
- Because it's a forward-backward asymmetry it doesn't use information we'd want to use for new physics studies

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Tau Polarisation as Beam Polarimeter

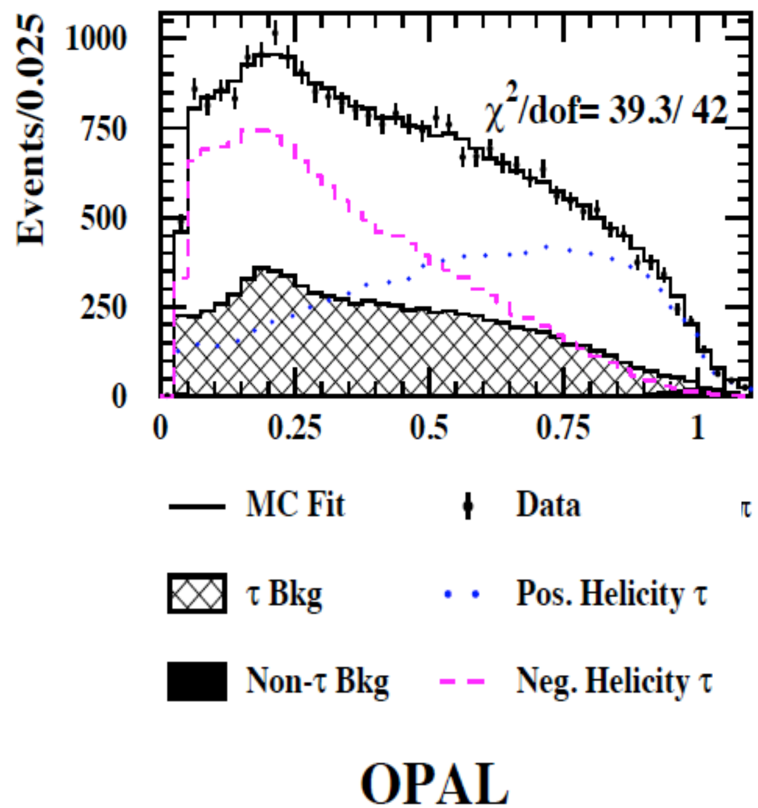
- Advantages:
  - Measures beam polarization at the IP: biggest uncertainty in Compton polarimeter measurement is likely the uncertainty in the transport of the polarization from the polarimeter to the IP.
  - It automatically incorporates a luminosity-weighted polarization measurement
  - If positron beam has stray polarization, it's effect is automatically included
- 0.5% systematic error on P_e from tau FB polarization asymmetry can be obtained using only pion decays (0.25% with other modes)
- to get to 1%, we'll need 144fb^{-1}

Tau Polarisation as Beam Polarimeter

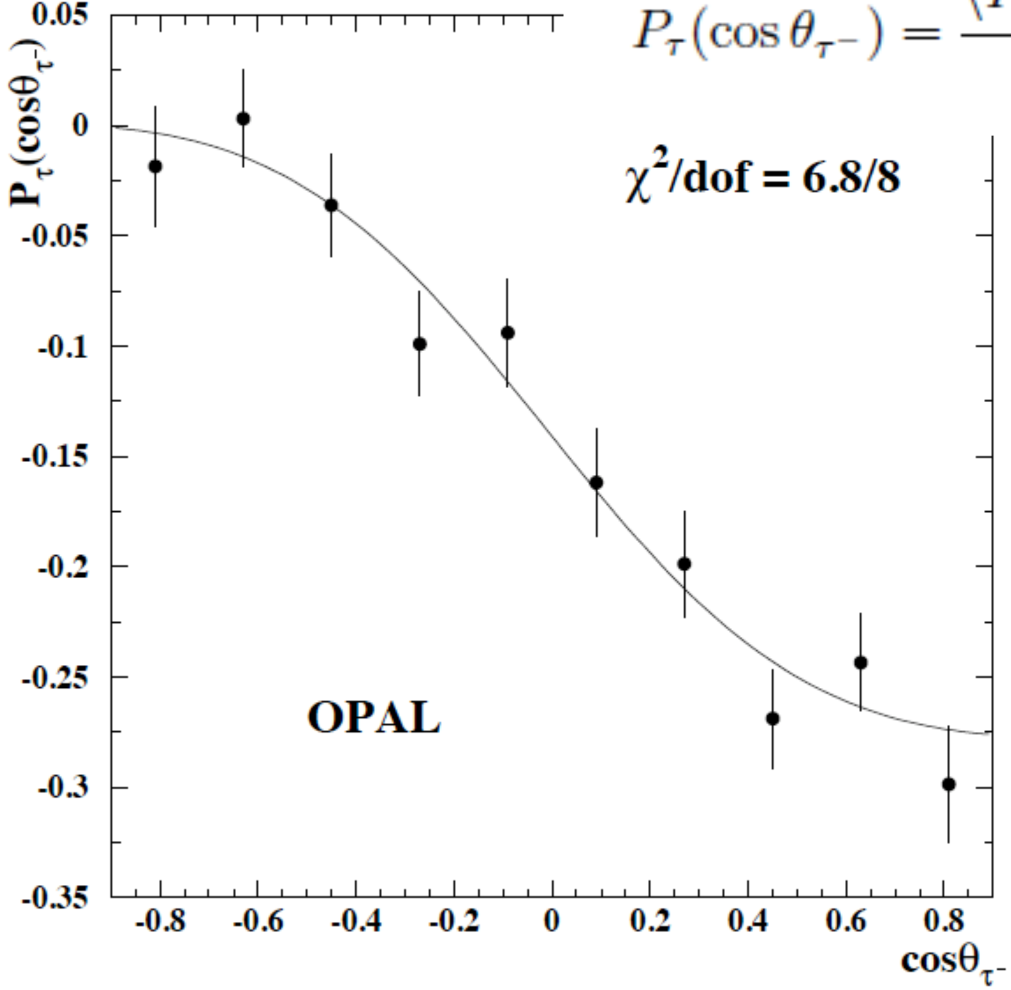
- BaBar selection was not optimized for polarisation and would expect more efficient use of data
- See no reason why the tau polarisation forward-backward asymmetry can't be used as a beam polarimeter at SuperB
- At a minimum, it would provide a cross check of the Compton polarimeter measurement
- At best, it may provide the absolute beam polarisation measurement and Compton polarimeter provides time dependence and a cross check

Tau Polarisation as Beam Polarimeter

- OPAL tau->pi nu **Eur.Phys.J. C21 (2001) 1-21**
- Events selected using vetoes against multihadron, dimuon,
  elec-pair or 2-photon events
  non-tau background (0.2%)
- Nsignal=22526
- Purity=0.74
  - main backgrounds:
    rho(16%);mu(5%);a1(2%)



Tau Polarisation as Beam Polarimeter



$$P_\tau(\cos\theta_{\tau^-}) = \frac{\langle P_\tau \rangle \ (1+\cos^2\theta_{\tau^-}) + \frac{8}{3}\mathrm{A}^{\mathrm{FB}}_{\mathrm{pol}} \ \cos\theta_{\tau^-}}{(1+\cos^2\theta_{\tau^-}) + \frac{8}{3}\mathrm{A}_{\mathrm{FB}} \ \cos\theta_{\tau^-}}$$

$\frac{8}{3}A^{FB}_{POL}$ at OPAL plays role of

P_e at SuperB

Most systematic errors cancel for this FB quantity

Tau Polarisation as Beam Polarimeter

Systematic errors expressed in 0.01 units:

	$\Delta\langle P_\tau\rangle$ and ΔA_{pol}^{FB}											
	e		μ		π		ρ		a_1		Global fit	
Momentum scale/resolution	0.4	0.2	2.1	0.1	0.8	0.1	0.3	0.1	0.4	0.2	0.24	0.13
ECAL scale/resolution	3.2	0.1	0.2	0.1	0.2	–	1.1	0.2	0.3	0.1	0.17	0.11
HCAL/MUON modelling	0.1	–	1.1	0.1	0.5	0.1	–	–	–	–	0.13	0.05
dE/dx errors	0.6	0.1	0.3	0.1	0.3	0.1	0.1	0.1	0.3	0.1	0.12	0.08
Shower modelling in ECAL	0.6	0.1	0.2	0.1	0.4	0.1	0.5	0.2	0.4	0.1	0.25	0.10
Branching ratios	0.1	–	0.1	–	0.2	–	0.2	–	0.2	0.1	0.11	0.02
$\tau \rightarrow a_1 \nu_\tau$ modelling	–	–	–	–	–	–	0.4	–	0.5	0.1	0.22	0.02
$\tau \rightarrow 3\pi \geq 1\pi^0 \nu_\tau$ modelling	–	–	–	–	–	–	–	–	1.2	0.1	0.11	0.04
A_{FB}	–	0.2	–	–	–	–	–	–	–	–	0.03	0.02
Decay radiation	–	–	–	–	–	–	–	–	0.1	–	0.01	0.01
Monte Carlo statistics	0.7	0.2	0.8	0.3	0.3	0.1	0.3	0.1	0.8	0.2	0.22	0.10
total	3.4	0.4	2.6	0.4	1.2	0.2	1.3	0.3	1.7	0.3	0.55	0.25

Pion systematic error is smallest = 0.002

8/3 factor→translates into 0.005 P_e error

Tau Polarisation as Beam Polarimeter

	$\tau \longrightarrow e\nu_e\nu_\tau$	$\tau \longrightarrow \mu\nu_\mu\nu_\tau$	$\tau \longrightarrow \pi\nu_\tau$	$\tau \longrightarrow \rho\nu_\tau$	$\tau \longrightarrow a_1\nu_\tau$
Sample size	44,083	41,291	30,440	67,682	22,161
Efficiency	92%	87%	75%	73%	77%
Background	4.6%	3.3%	26%	29%	25%
$\langle P_\tau \rangle$ (%)	-18.7 ± 2.5	-16.3 ± 2.7	-13.8 ± 1.2	-13.3 ± 1.1	-11.6 ± 2.8
A^{FB}_{pol} (%)	-8.9 ± 2.6	-10.6 ± 2.8	-11.5 ± 1.3	-10.6 ± 1.1	-7.1 ± 2.8

Statistical error is 0.013 for 22526 $\tau \rightarrow \pi\nu$ signal events

translates into error of 0.035 on P_e
To reach 0.005 error need 1.1M events

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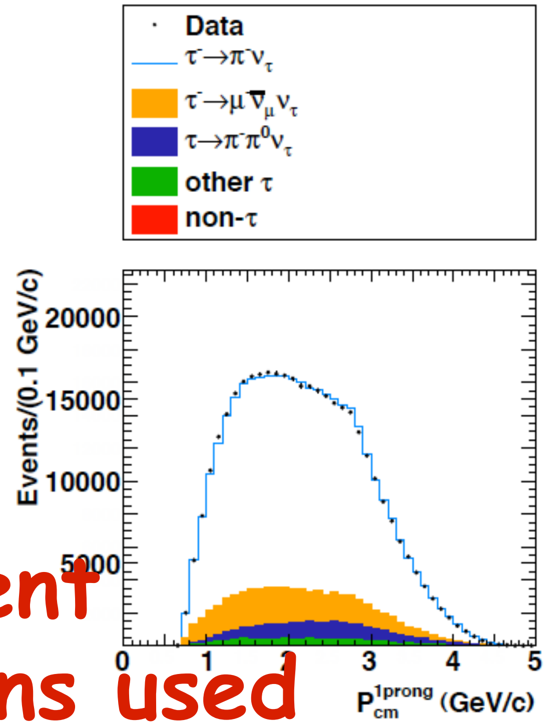
Tau Polarisation as Beam Polarimeter

- BaBar tau->pi nu selection from Phys.Rev.Lett. 105 051602 (2010)
- Tag with 3-prong, suppressed non-tau background and trigger efficiency not an issue
- Luminosity=467fb^{-1}
- Nsignal=288,400
- Purity=0.79



Seems ~ 3.6 ab^{-1} is sufficient to get to 0.005 if only pions used

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Additional Thoughts…

- OPAL used 5 channels in a global analysis and achieved a total statistical error on ApolFB of 0.0076 with systematic error of 0.0025 or total error of 0.008, or 8/3*0.008=0.021 for error on P_e. This was with the equivalent of 22526/288400*467fb^{-1} =36fb^{-1} .
- So to get to 1%, we'll need 144fb^{-1}

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