High Precision Laser Polarization Measurement

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Combined Polarimetry Requirement

SOLID

Table 2.2: Error budget in A_{PV}^{EW} at $x = 0.4$ for the test of the Standard Model

Source: SOLID PAC 35 addendum

Source	Uncertainty in %
Statistics	0.3
Polarimetry	0.4
Q^2	0.2
Radiative Corrections	0.3
Total	0.6

MOLLER

Background Process	Fractional Error (%)
Signal Statistics	2.08
Absolute value of Q^2	0.5
beam (second order)	0.4
beam polarization	0.4
$e + p(+\gamma) \rightarrow e + X(+\gamma)$	0.4
beam (first order)	0.3
$e + p(+\gamma) \rightarrow e + p(+\gamma)$	0.3
$\gamma^{(*)} + p \rightarrow \pi + X$	0.3
Transverse polarization	0.2
neutrals (soft photons, neutrons)	0.1
Total	1.02

Table 3.2: Summary of systematic errors

Source: K. Paschke

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Compton Systematics at 11 GeV

Relative Error (%)	electron	photon
E_{beam}	0.03	0.03
Laser Polarization	0.20	0.20
Radiative Corrections	0.1	0.1
False Asymmetries	0.01	0.01
Background	0.05	0.05
Deadtime / Pileup	0.2	0.1
Analyzing power	0.15	0.40
Total	0.34	0.47

correlated

uncorrelated

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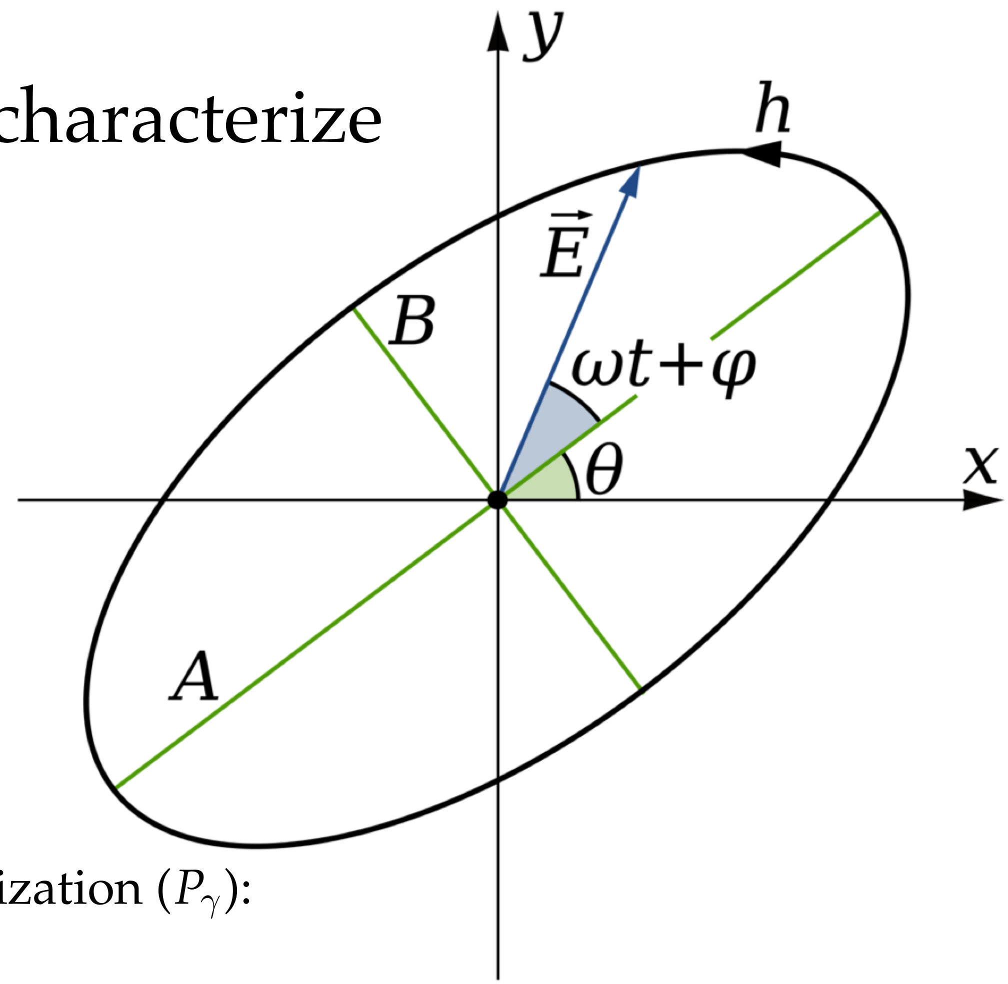
1. Laser polarization is the <u>largest</u> correlated systematic.

2. My understanding is that, at present, the laser polarization is known to **0.35% to 2%**. This is mainly due to our understanding of the "transfer function."

Quick Review of Polarized Light

In general, four numbers characterize the polarization of light.



Source: http://en.wikipedia.org/wiki/File:Polarisation_ellipse.svg

1. total intensity: $I_0 \propto \left\langle |\vec{E}|^2 \right\rangle_{\text{time}}$

2. angle of linear polarization: θ

3. degree of linear (P_L) or circular polarization (P_γ): related to eccentricity of elipse

4. depolarization: $D = \sqrt{1 - P_L^2 - P_\gamma^2}$
($D = 0$ for monochromatic coherent light)

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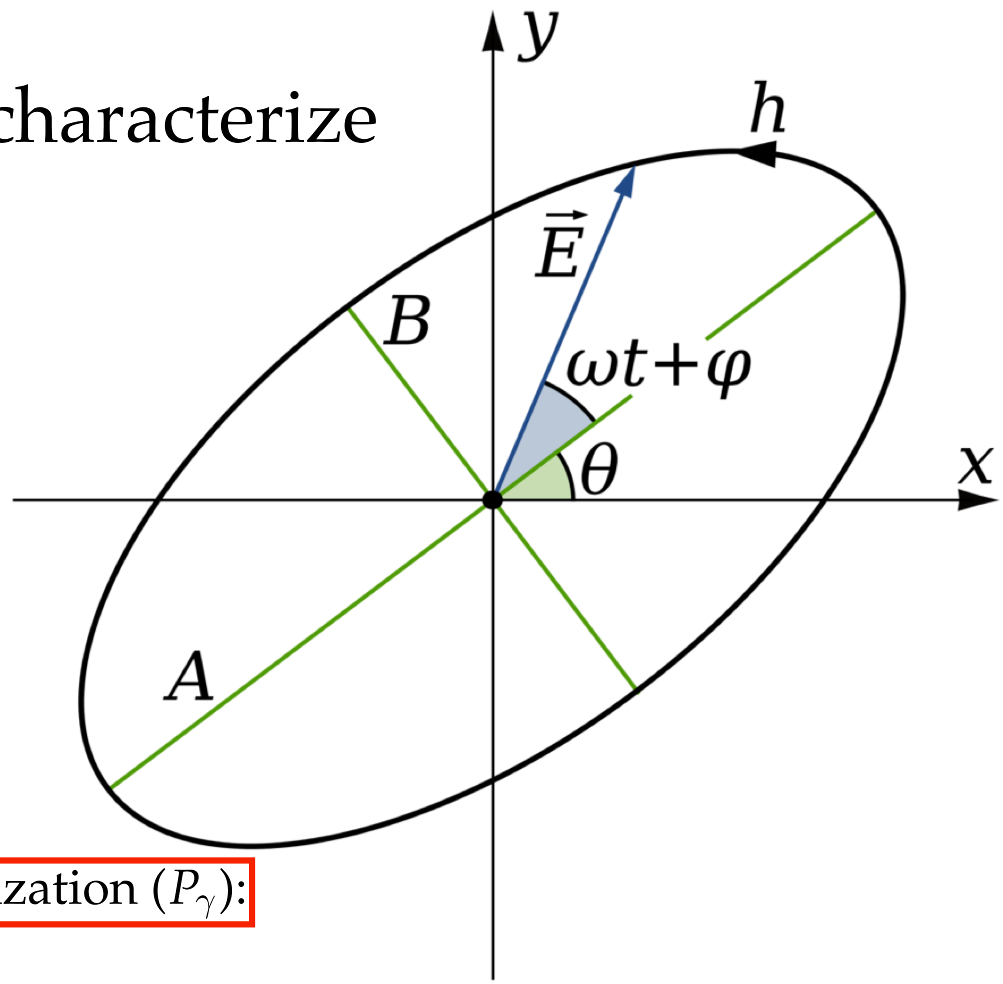

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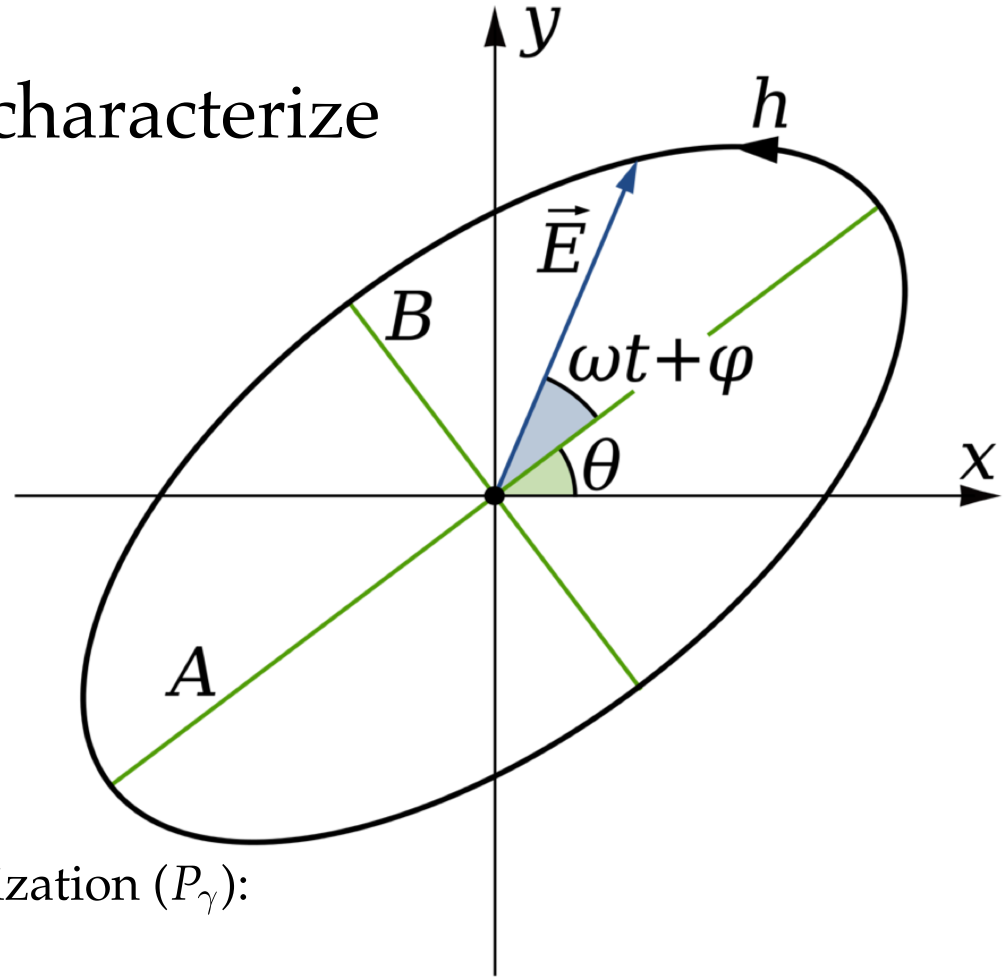

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For $D = 0$, $P_\gamma = (99.5 \pm 0.2)\%$ corresponds to $P_L = (10 \pm 2)\%$.

Measuring the Polarization

Rotating linear polarizer (currently used)

1. sensitive to residual linear polarization
2. insensitive to sign of circular
3. slow rotation - measurements no faster than 1 Hz, but at present much slower

Rotating quarter waveplate (currently used)

1. relatively insensitive to residual linear polarization
2. sensitive to sign of circular polarization
3. slow rotation - measurements no faster than 1 Hz, but at present much slower

Photoelastic Modulator w/ Lockin Detection (proposed or something like it)

1. first harmonic can be made sensitive to sign of circular polarization
2. second harmonic can be made sensitive to residual linear polarization
3. very fast measurements (100 Hz or more)

Possible Issues at 0.2% Precision

Cavity Setup

1. no direct measurement inside of cavity - transfer function
2. put a retractable beam sampler and polarization analyzer inside the cavity?
3. temporal stability of polarization inside the cavity?
4. change of polarization when cavity is locked relative to unlocked cavity?

RF Pulsed Laser

1. time-dependent polarization? (fast photodiodes up to 2 GHz exist)
2. high peak power (beam samplers and/or high damage threshold optics)

Some Things That I Think Are Important

1. Measure extinction ratio of polarization analyzer
2. Measure the depolarization of the light (i.e validate D is nearly zero)
3. Continuous online relative sign monitoring
4. Continuous measurement of circular polarization
5. Fast analysis of polarization
6. Measure the polarization changing properties of <u>everything</u>
   (e.g. vacuum windows, cavity mirrors, polarization optics, analysis optics, beam samplers, etc.)
7. Measure & control the orientation of the analyzer axes with respect to the Compton Interaction Point
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<u>Take-home message:</u>

With dedicated effort & attention to detail, 0.2% precision is not totally unreasonable!