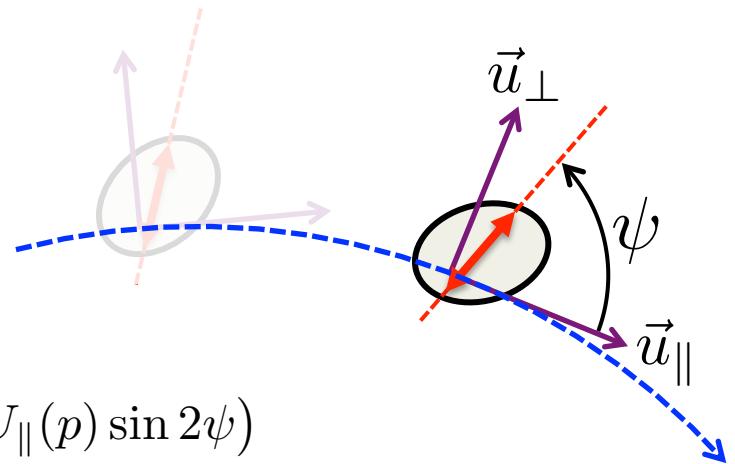


Systematics mitigation for PICO

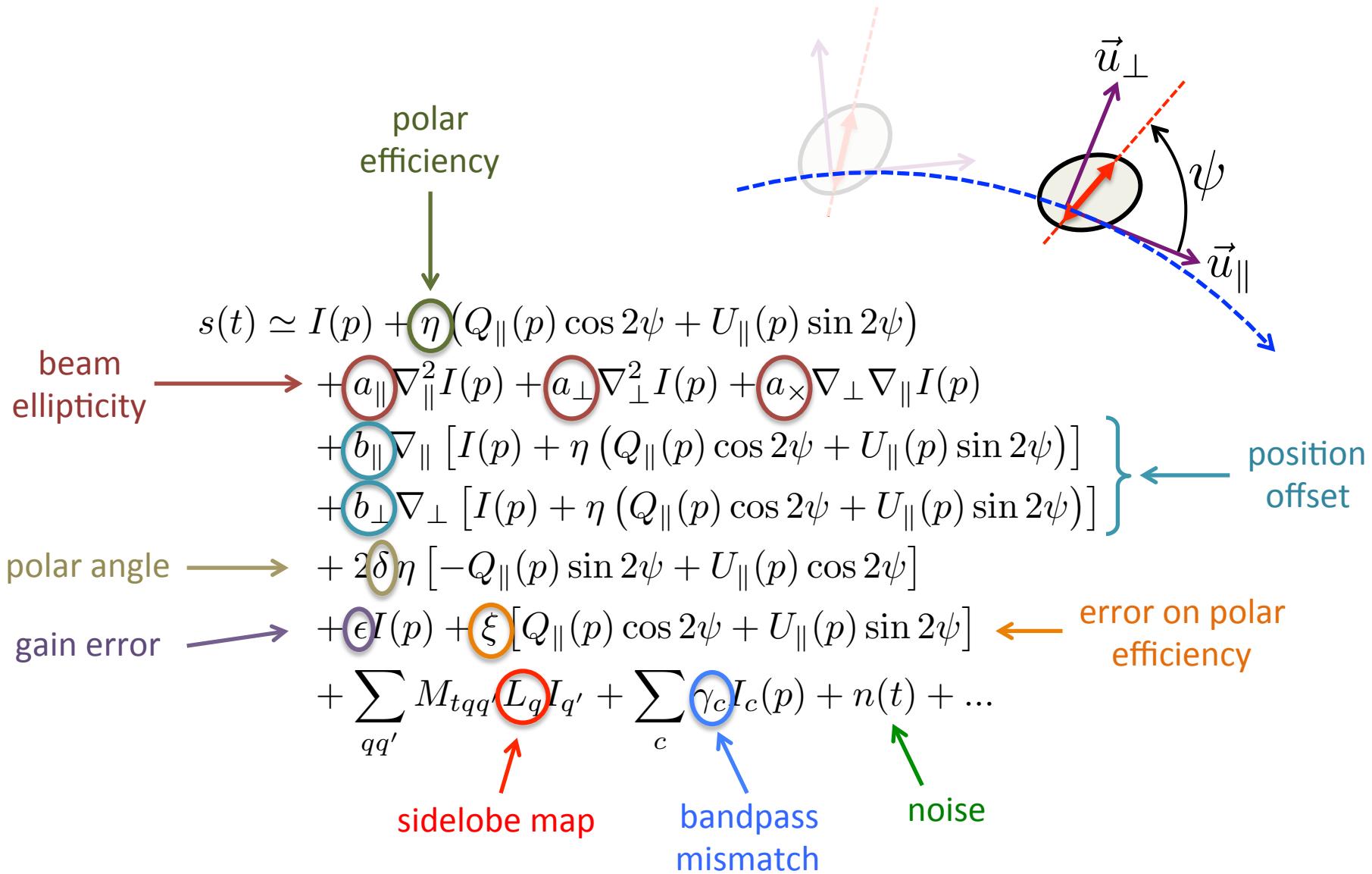
- Building an instrument that is perfect enough for systematics to be negligible is *impossible* in practice (control T to P at the level of 10^{-5}).
- Requirements would be to stringent for this to be
 - doable in a reasonable time
 - cost effective
- *Systematics must be corrected for in the data analysis pipeline.*
- *This requires the exquisite knowledge of an adequate model of the instrument.*
- While some of this knowledge can be obtained through prior calibration, the best knowledge of the instrument will be obtained from the scientific data themselves.
- (Of course, lower systematics are better so instrument design is important)

An (incomplete) model of the measurement

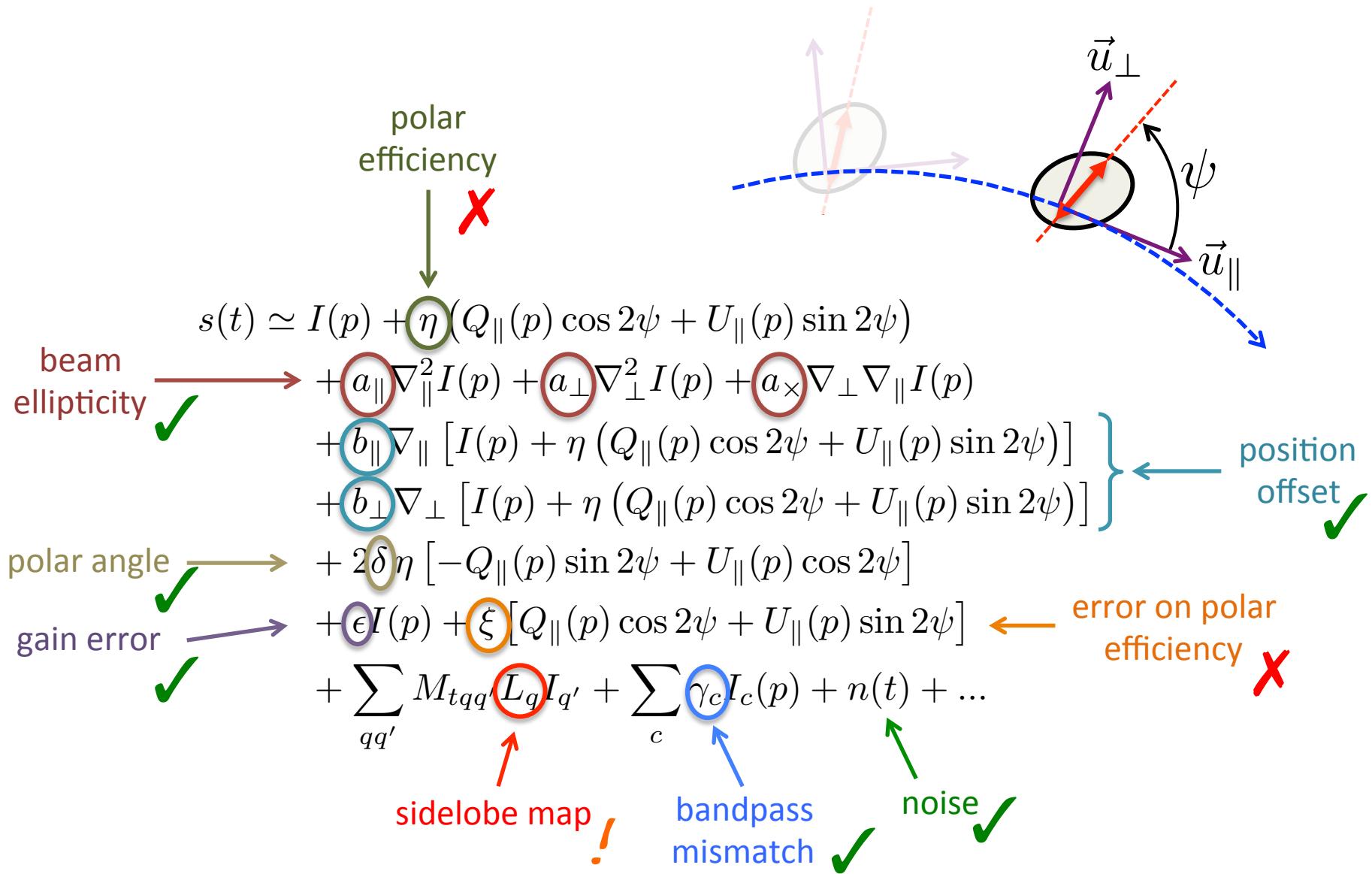


$$\begin{aligned} s(t) \simeq & I(p) + \eta (Q_{\parallel}(p) \cos 2\psi + U_{\parallel}(p) \sin 2\psi) \\ & + a_{\parallel} \nabla_{\parallel}^2 I(p) + a_{\perp} \nabla_{\perp}^2 I(p) + a_{\times} \nabla_{\perp} \nabla_{\parallel} I(p) \\ & + b_{\parallel} \nabla_{\parallel} [I(p) + \eta (Q_{\parallel}(p) \cos 2\psi + U_{\parallel}(p) \sin 2\psi)] \\ & + b_{\perp} \nabla_{\perp} [I(p) + \eta (Q_{\parallel}(p) \cos 2\psi + U_{\parallel}(p) \sin 2\psi)] \\ & + 2\delta \eta [-Q_{\parallel}(p) \sin 2\psi + U_{\parallel}(p) \cos 2\psi] \\ & + \epsilon I(p) + \xi [Q_{\parallel}(p) \cos 2\psi + U_{\parallel}(p) \sin 2\psi] \\ & + \sum_{qq'} M_{tqq'} L_q I_{q'} + \sum_c \gamma_c I_c(p) + n(t) + \dots \end{aligned}$$

An (incomplete) model of the measurement



An (incomplete) model of the measurement



An (incomplete) model of the measurement

Diagram illustrating the measurement model and its components:

$$s(t) \simeq I(p) + \eta(Q_{\parallel}(p) \cos 2\psi + U_{\parallel}(p) \sin 2\psi)$$

Annotations and components:

- polar efficiency**: Circled in red with a large red X.
- beam ellipticity**: Circled in red with a green checkmark.
- polar angle**: Circled in yellow with a green checkmark.
- gain error**: Circled in purple with a green checkmark.
- sidelobe map**: Circled in red with a red exclamation mark.
- bandpass mismatch**: Circled in blue with a blue checkmark.
- noise**: Circled in green with a green checkmark.
- position offset**: Circled in blue with a green checkmark.
- error on polar efficiency**: Circled in orange with a red X.
- all together time variations**: Circled in red with a red X.

An (incomplete) model of the measurement

The diagram illustrates a polarimeter setup. A beam enters from the left, passes through a lens, and is detected by a photodiode. A coordinate system is defined by vectors \vec{u}_\perp and \vec{u}_\parallel , with an angle ψ indicated. A dashed blue line represents the optical axis.

The measured signal $s(t)$ is given by:

$$s(t) \simeq I(p) + \eta(Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi)$$

Contributing terms include:

- beam ellipticity** (green checkmark): $+a_\parallel \nabla_\parallel^2 I(p) + a_\perp \nabla_\perp^2 I(p) + a_\times \nabla_\perp \nabla_\parallel I(p)$
- polar angle** (yellow circle): $+2\delta\eta [-Q_\parallel(p) \sin 2\psi + U_\parallel(p) \cos 2\psi]$
- gain error** (purple circle): $+\epsilon I(p) + \xi [Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi]$
- sidelobe map** (!): $+ \sum_{qq'} M_{tqq'} L_q I_{q'}$
- bandpass mismatch** (blue circle): $+ \sum_c \gamma_c I_c(p)$
- noise** (green checkmark): $+ n(t) + \dots$
- position offset** (blue bracket): $+ b_\parallel \nabla_\parallel [I(p) + \eta(Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi)] + b_\perp \nabla_\perp [I(p) + \eta(Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi)]$
- polar efficiency** (red X): $\eta(Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi)$
- error on polar efficiency** (orange X): $\epsilon I(p) + \xi [Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi]$

A red arrow points to the term $\eta(Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi)$ with a red X, indicating it is incorrect. A green checkmark is placed next to the term $b_\parallel \nabla_\parallel [I(p) + \eta(Q_\parallel(p) \cos 2\psi + U_\parallel(p) \sin 2\psi)]$.

No HWP
please!