# Parameter estimation
# with correlated photon pairs

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Jena, October 22, 2025

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# Motivation

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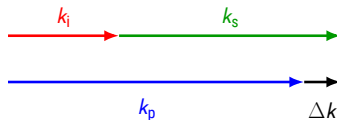Friedrich-Schiller-Universität Jena

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# SPDC

### Energy conservation



$$\omega_p = \omega_s + \omega_i$$

### Momentum conservation



$$\vec{k_p} = \vec{k_s} + \vec{k_i} - \vec{\Delta k}$$

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# Transmittance model

Conventional approach:

$$N_{\text{tot}}^{\text{ref}} = \eta_{\text{idl}} \, N_{\text{g}} + N_{\text{noise}}^{\text{ref}}$$
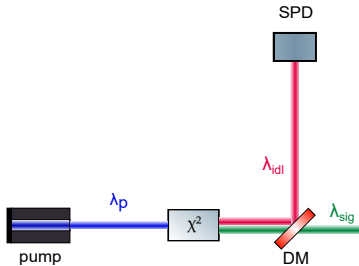
$$N_{\text{tot}}^{\text{sam}} = T \, \eta_{\text{idl}} \, N_{\text{g}} + N_{\text{noise}}^{\text{sam}}$$

Coincidence approach:

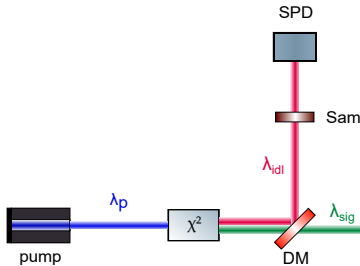$$N_{\text{cc}}^{\text{pure,sam}} = T \, \eta_{\text{idl}} \, \eta_{\text{sig}} \, N_{\text{g}},$$

$$N_{\text{cc}}^{\text{pure,ref}} = \eta_{\text{idl}} \, \eta_{\text{sig}} \, N_{\text{g}}$$

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# Conventional approach



$$N_{tot}^{ref} = \eta_{idl} N_g + N_{noise}^{ref}$$

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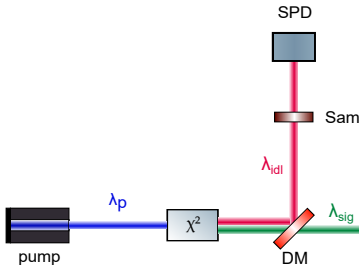
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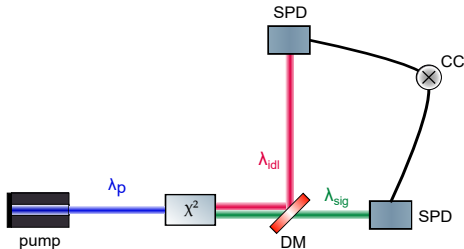5/14

# Conventional approach



$$N_{\text{tot}}^{\text{ref}} = \eta_{\text{idl}} N_{\text{g}} + N_{\text{noise}}^{\text{ref}}$$

$$N_{\text{tot}}^{\text{sam}} = T \, \eta_{\text{idl}} N_{\text{g}} + N_{\text{noise}}^{\text{sam}}$$

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# Conventional approach



$$N_{tot}^{ref} = \eta_{idl} N_g + N_{noise}^{ref}$$

$$N_{tot}^{sam} = T \eta_{idl} N_g + N_{noise}^{sam}$$

$$\Rightarrow T = \frac{N_{tot}^{sam} - N_{noise}^{sam}}{N_{tot}^{ref} - N_{noise}^{ref}}$$

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# Coincidence approach



$$N_{cc,tot}^{ref} = \eta_{idl}\, \eta_{sig}\, N_g + N_{ac}^{ref}$$

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# Coincidence approach



$$N_{cc,tot}^{ref} = \eta_{idl}\,\eta_{sig}\,N_g + N_{ac}^{ref}$$

$$N_{cc,tot}^{sam} = T\,\eta_{idl}\,\eta_{sig}\,N_g + N_{ac}^{sam}$$

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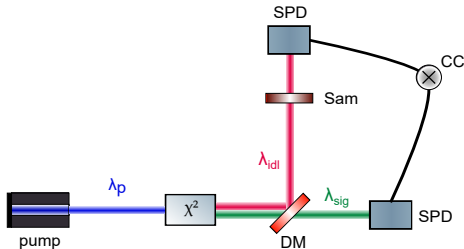
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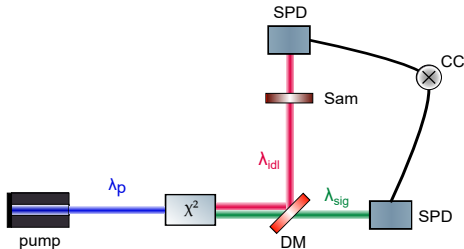
# Coincidence approach



$$N_{cc,tot}^{ref} = \eta_{idl}\, \eta_{sig}\, N_g + N_{ac}^{ref}$$

$$N_{cc,tot}^{sam} = T\, \eta_{idl}\, \eta_{sig}\, N_g + N_{ac}^{sam}$$

$$\Rightarrow T = \frac{N_{tot,cc}^{sam} - N_{ac}^{sam}}{N_{tot,cc}^{ref} - N_{ac}^{ref}}$$

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# Transmittance model

**Conventional approach:**

$$\text{Var}(T) = (\eta_{\text{idl}}\, N_{\text{g}})^{-2}\left[\text{Var}(N_{\text{tot}}^{\text{sam}}) + \text{Var}(N_{\text{noise}}^{\text{sam}}) + T^2\left[\text{Var}(N_{\text{tot}}^{\text{ref}}) + \text{Var}(N_{\text{noise}}^{\text{ref}})\right]\right]$$

**Coincidence approach:**

$$\text{Var}(T) = (\eta_{\text{sig}}\, \eta_{\text{idl}}\, N_{\text{g}})^{-2}\left[\text{Var}(N_{\text{tot,cc}}^{\text{sam}}) + \text{Var}(N_{\text{ac}}^{\text{sam}}) + T^2\left[\text{Var}(N_{\text{tot,cc}}^{\text{ref}}) + \text{Var}(N_{\text{ac}}^{\text{ref}})\right]\right]$$

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# Transmittance model

**Conventional approach:**

$$\mathrm{Var}(T) = \left(\eta_{\mathrm{idl}}\, N_{\mathrm{g}}\right)^{-2} \left[ \mathrm{Var}\big(N_{\mathrm{tot}}^{\mathrm{sam}}\big) + \mathrm{Var}\big(N_{\mathrm{noise}}^{\mathrm{sam}}\big) + T^2 \left[ \mathrm{Var}\big(N_{\mathrm{tot}}^{\mathrm{ref}}\big) + \mathrm{Var}\big(N_{\mathrm{noise}}^{\mathrm{ref}}\big) \right] \right]$$

**Coincidence approach:**

$$\mathrm{Var}(T) = \left(\eta_{\mathrm{sig}}\, \eta_{\mathrm{idl}}\, N_{\mathrm{g}}\right)^{-2} \left[ \mathrm{Var}\big(N_{\mathrm{tot,cc}}^{\mathrm{sam}}\big) + \mathrm{Var}\big(N_{\mathrm{ac}}^{\mathrm{sam}}\big) + T^2 \left[ \mathrm{Var}\big(N_{\mathrm{tot,cc}}^{\mathrm{ref}}\big) + \mathrm{Var}\big(N_{\mathrm{ac}}^{\mathrm{ref}}\big) \right] \right]$$
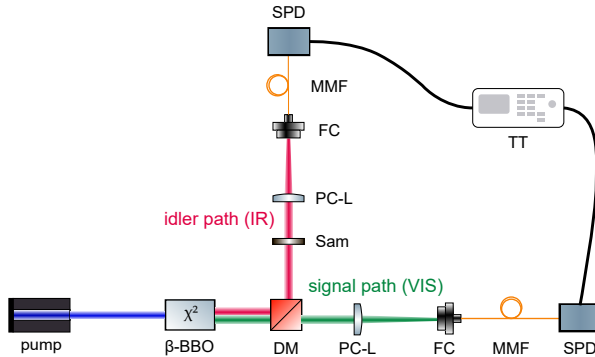
# Photon statistics

Coherent light:

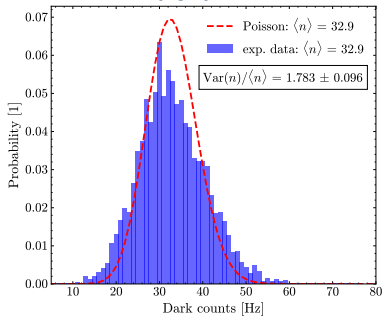$$\mathcal{P}(n) = \frac{\langle n \rangle^n}{n!} \, e^{-\langle n \rangle}$$

Thermal light:

$$\mathcal{P}_m(n) = \frac{(n + m - 1)!}{(m - 1)! \, n!} \, \frac{\langle n \rangle^n}{(1 + \langle n \rangle / m)^m \, (\langle n \rangle}$$
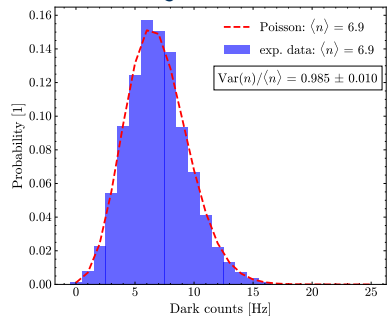
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# Experimental setup

# Dark counts



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# Single counts



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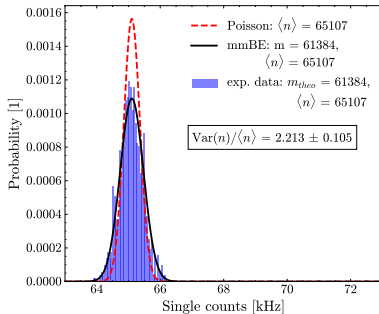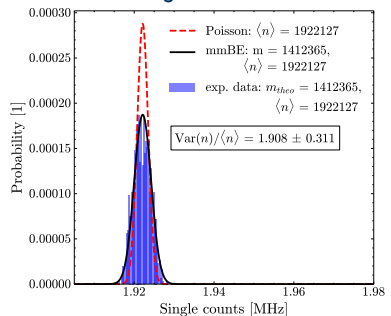
# Slide title in Palatino Linotype Font

## block environment (lower-case b)

itemize:

- First Level
  - Second Level
    - Third Level has no item mark

## Block environment (upper-case B)

enumerate:

1. First Level
   1.1 Second Level
      1.1.1 Third Level

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# Font types

| | |
|---|---|
| Normal | Lorem ipsum dolor sit amet, consectetur adipiscing elit. |
| **Bold** | **Lorem ipsum dolor sit amet, consectetur adipiscing elit.** |
| *Italic* | *Lorem ipsum dolor sit amet, consectetur adipiscing elit.* |
| ***BoldItalic*** | ***Lorem ipsum dolor sit amet, consectetur adipiscing elit.*** |

$$e^{i\pi} + 1 = 0 \tag{1}$$

Equations like eq. (1) use the beamer default font computer modern.

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# Summary and Outlook

## Git repository

public accessible:

`https://git.tpi.uni-jena.de/mstnhsr/latexbeamer_corporatedesign`

## Feedback

marc.steinhauser@uni-jena.de

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