MAX PLANCK INSTITUTE
FOR THE SCIENCE OF LIGHT

Quantum
Radiation
Group

Low noise twin-beams

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european social fund in the czech republic
EUROPEAN UNION
MINISTRY OF EDUCATION, YOUTH AND SPORTS
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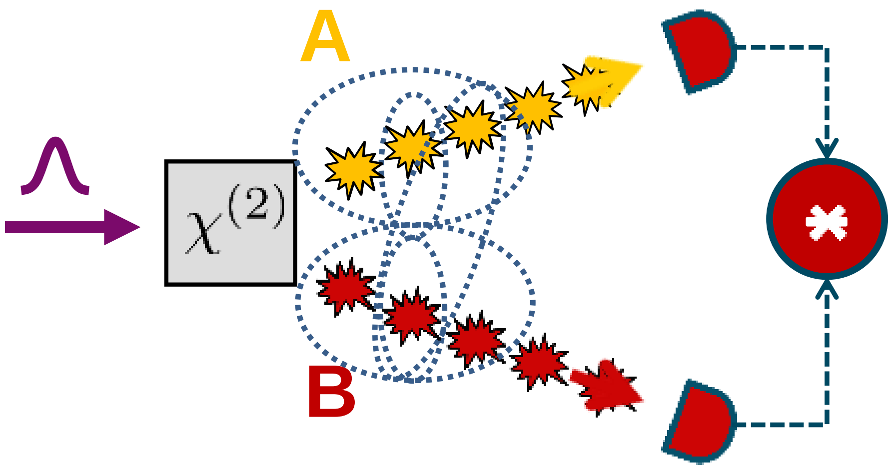
INVESTMENTS IN EDUCATION DEVELOPMENT

Outline

- Motivation
- Experimen
t
- Preliminary results
- Conclusions

Twin-beam squeezing



$$|\Psi\rangle = \sum_{n=0}^{\infty} C_n |n_A, n_B\rangle$$

$$g^{(2)} = 2 + \frac{1}{N}$$

$$\frac{\mathrm{Var}(N_A - N_B)}{\langle N_A + N_B \rangle}$$

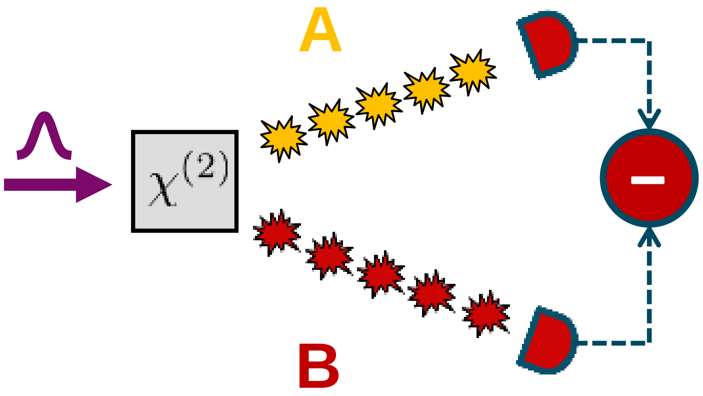
NRF $\quad$ R $\quad$ σ

Why Is It Important?

- Quantum metrology
- Quantum imaging
- Light-matter interaction

The Problem

Theory: at any parametric gain $N_A = N_B$



$$\frac{\mathrm{Var}(N_A - N_B)}{\langle N_A + N_B \rangle} = 1 - \eta = \mathrm{const}$$

Experiment: $\frac{\mathrm{Var}(N_A - N_B)}{\langle N_A + N_B \rangle} \neq \mathrm{const}$ at any parametric gain

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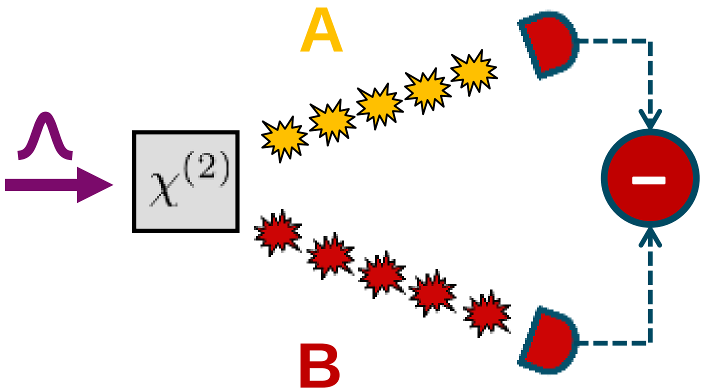
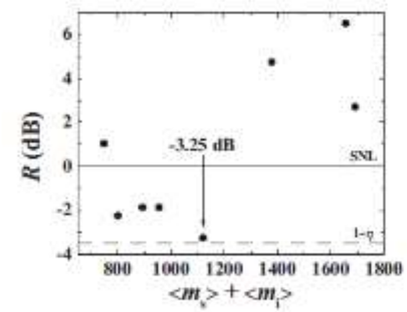
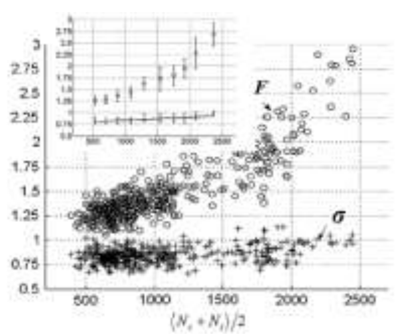
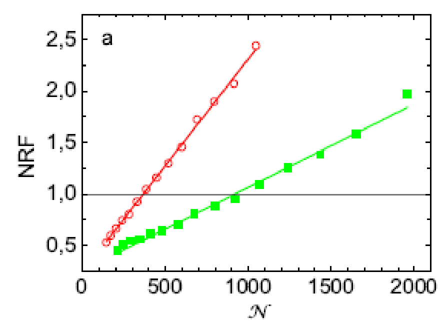




M. Bondani et al. Phys. Rev. A **76**, 013833 (2007).



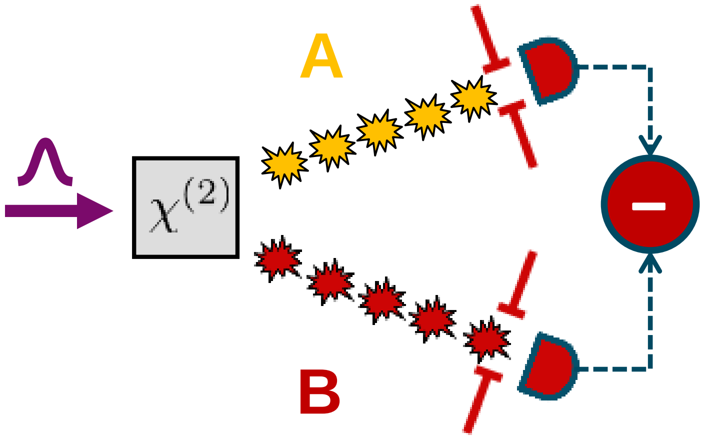
G. Brida et al. Phys. Rev. Lett **102**, 213602 (2009)

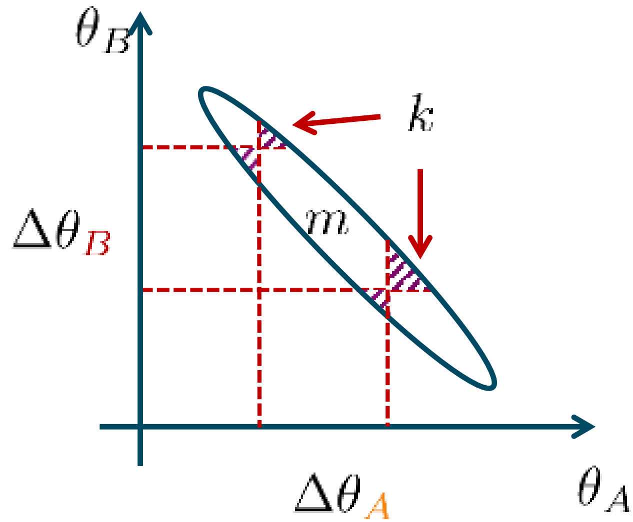


$\langle N_{mode}^{max} \rangle \approx 900$

I. N. Agafonov et al. Phys. Rev. A **82**, 011801 (2010)

The Reason





Beam **A** : m modes

Beam **B** : m modes

+ k unmatched modes

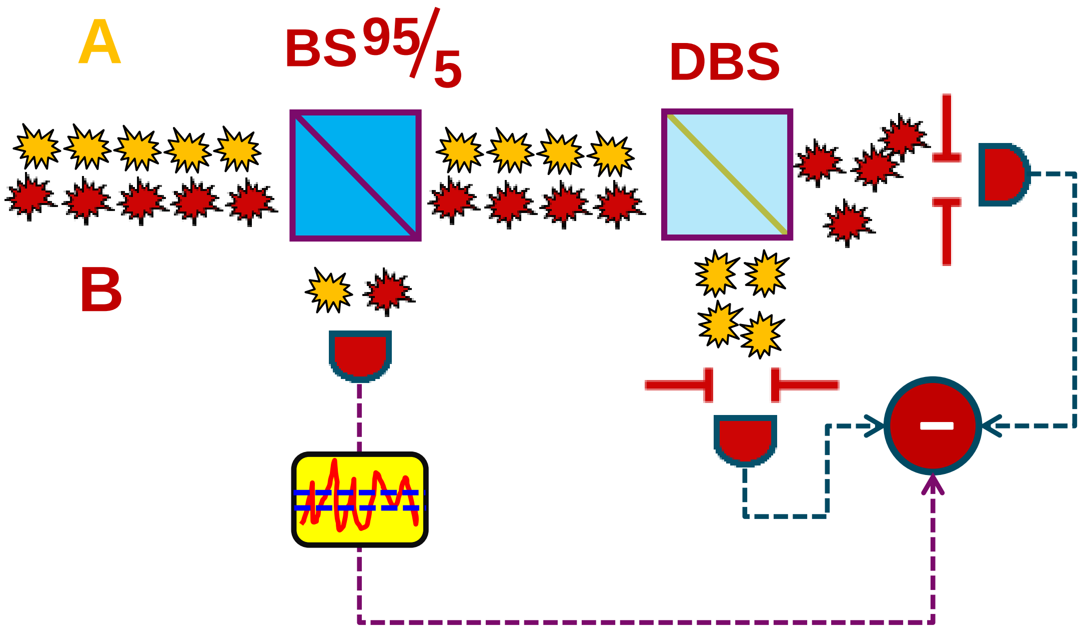
Due to the thermal statistics in single mode of PDC radiation:

$$VarN = \langle N \rangle + \langle N \rangle^2$$

$$NRF_{meas} = 1 - \frac{m}{m+k}\eta + \frac{k}{m+k} N_{mode}$$

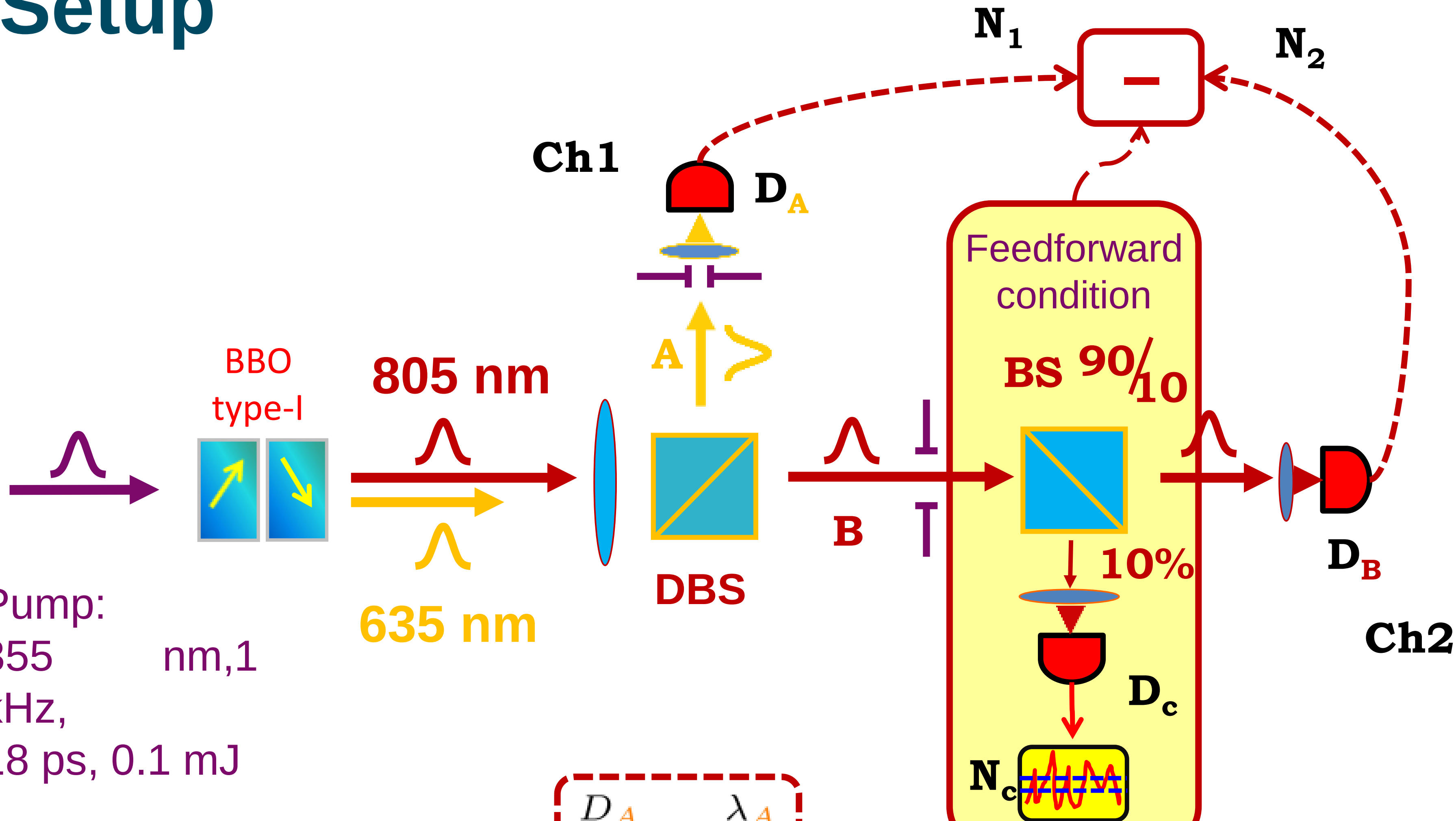
Solution

To suppress thermal fluctuations of PDC radiation via feed forward technique



$$NRF_{meas} = 1 - \frac{m}{m+k}\eta + \frac{k}{m+k}N_{mode}$$

Setup



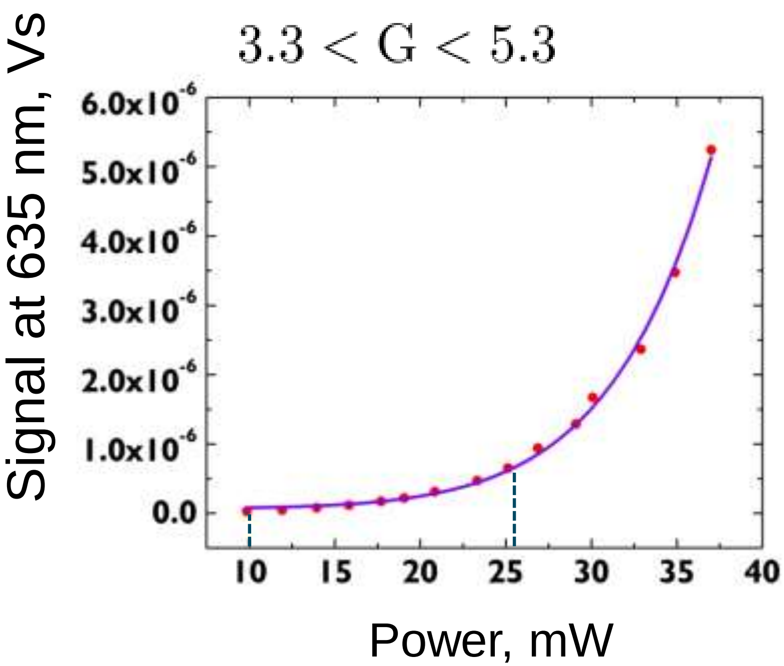
Pump:
355 nm, 1 kHz,
18 ps, 0.1 mJ

$$\frac{D_A}{D_B} = \frac{\lambda_A}{\lambda_B}$$

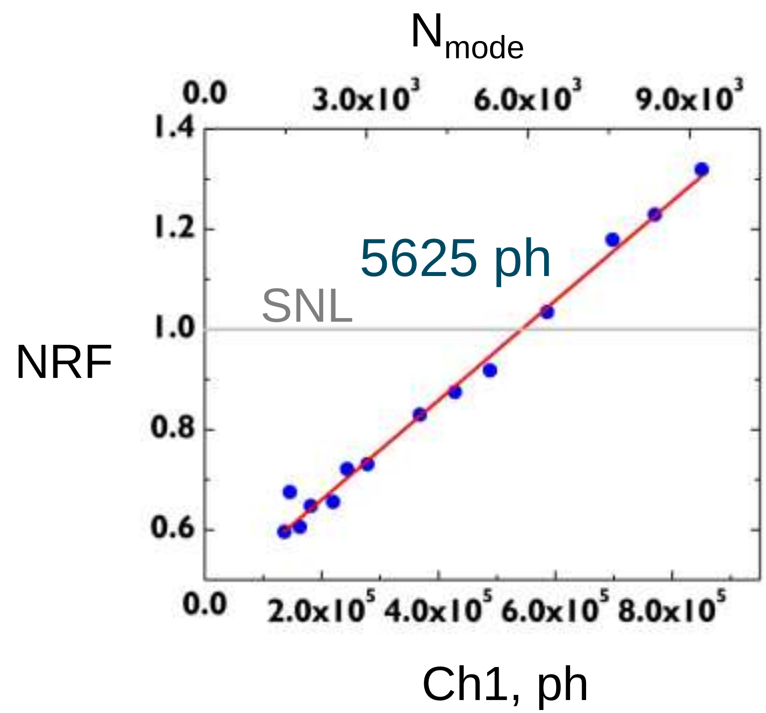
$$NRF \equiv \frac{Var(N_A - N_B)}{\langle N_A + N_B \rangle}, \text{ if } N_c \in \text{range}$$

Parametric gain

$$3.3 < G < 5.3$$



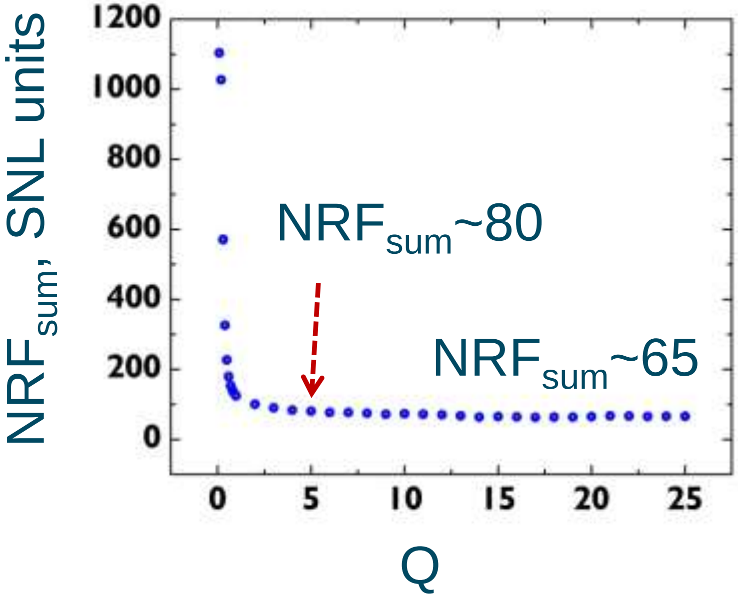
$$180 < N_{\text{mode}} < 9200$$



Width of the Range

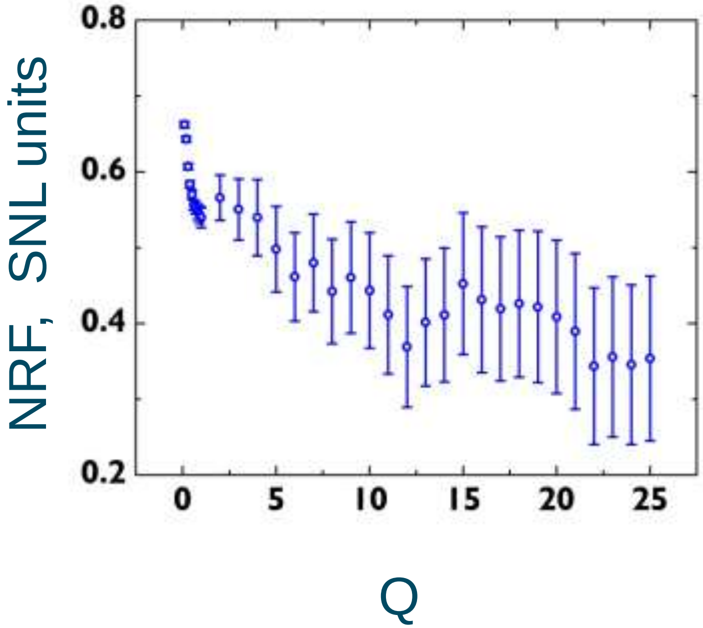
P_{pump}=16.3 mW

$$\mathrm{NRF_{sum}} \equiv \frac{\mathrm{Var}(N_A+N_B)}{\langle N_A+N_B\rangle}$$



N_{mode}=1091 photon

$$\mathrm{NRF} \equiv \frac{\mathrm{Var}(N_A-N_B)}{\langle N_A+N_B\rangle}$$



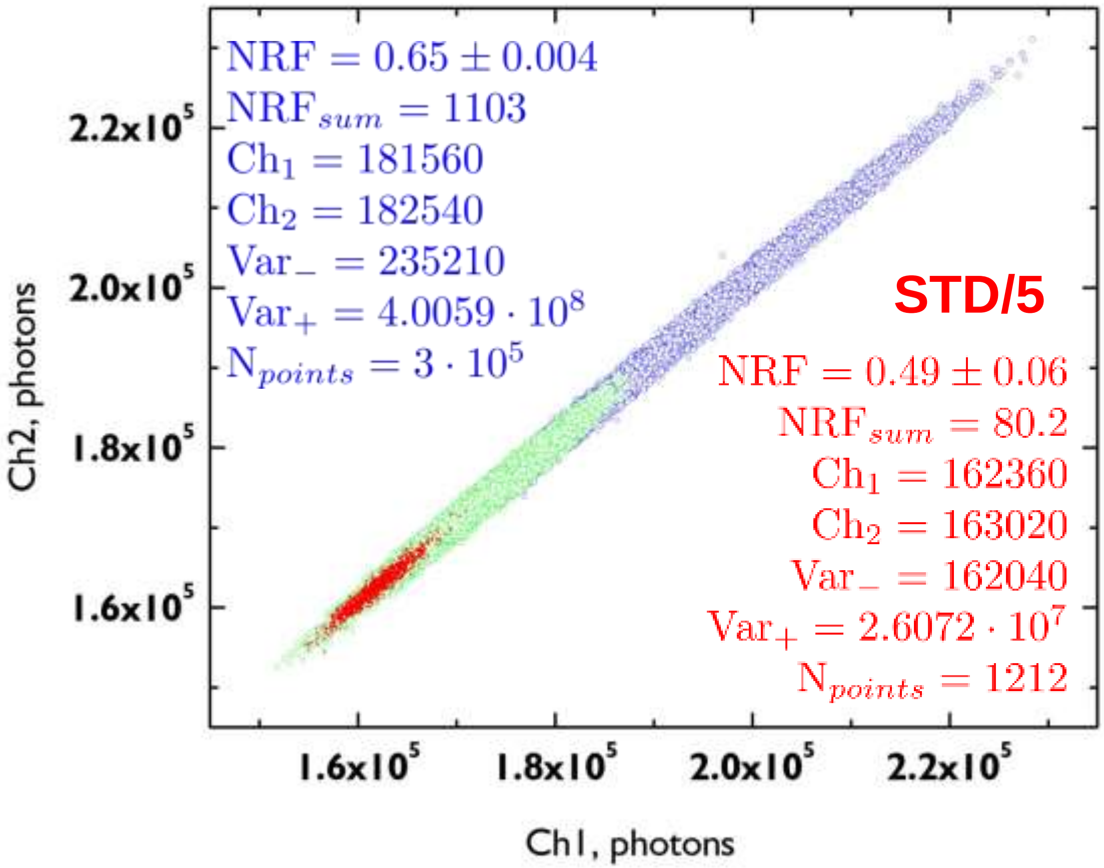
Q: $\quad \text{selected range} \equiv \text{Mean} \pm \frac{\text{STD}}{2\text{Q}}$

Optimal width of range is around STD/5

Ch2 vs Ch1

Position 0.88 mean:

STD/0.1



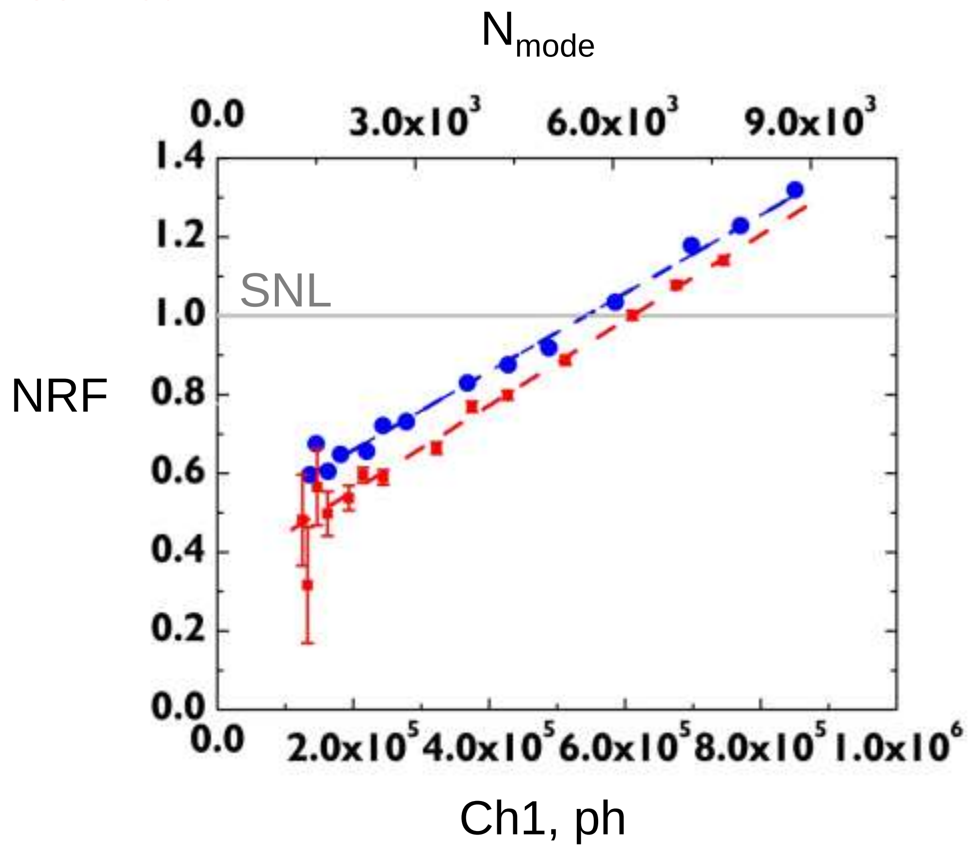
STD/0.5

$NRF = 0.57 \pm 0.006$
$NRF_{sum} = 226$
$Ch_1 = 173440$
$Ch_2 = 174270$
$Var_- = 295370$
$Var_+ = 7.8612 \cdot 10^7$
$N_{points} = 136880$

Preliminary results:

Width of range: STD/5

Position: 0.88 mean

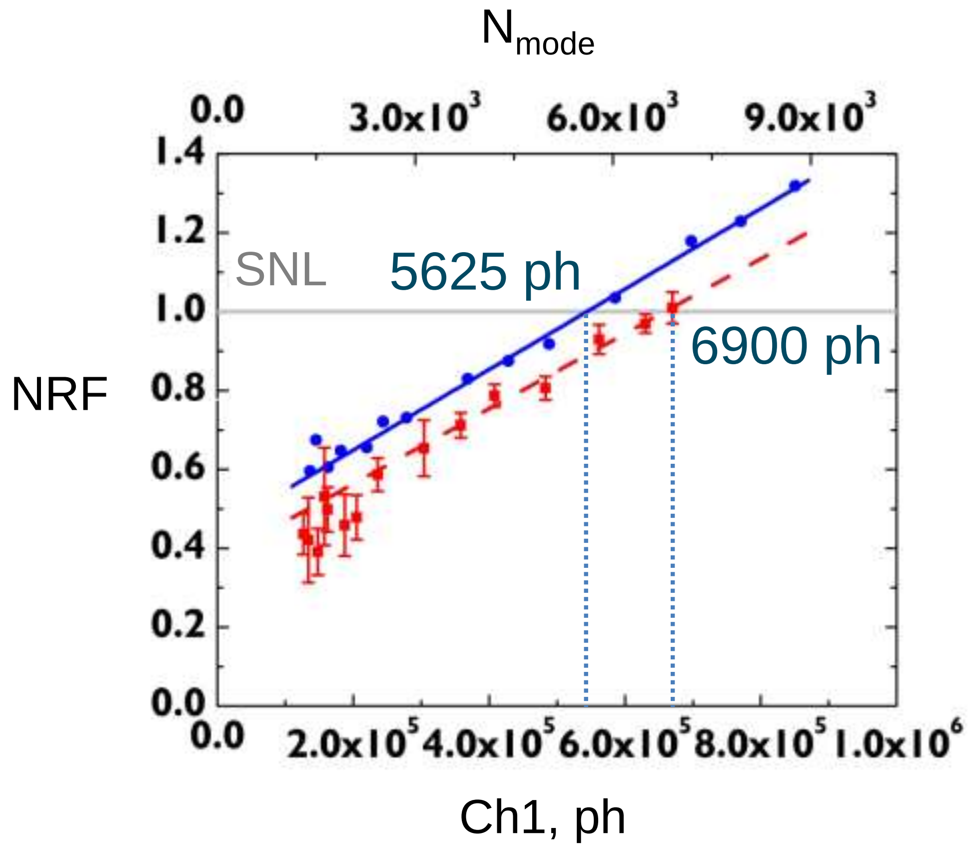


$$NRF_{meas} = 1 - \frac{m}{m+k}\eta + \frac{k}{m+k}N_{mode}$$

Preliminary results:

Width of range : STD/5

Best Position



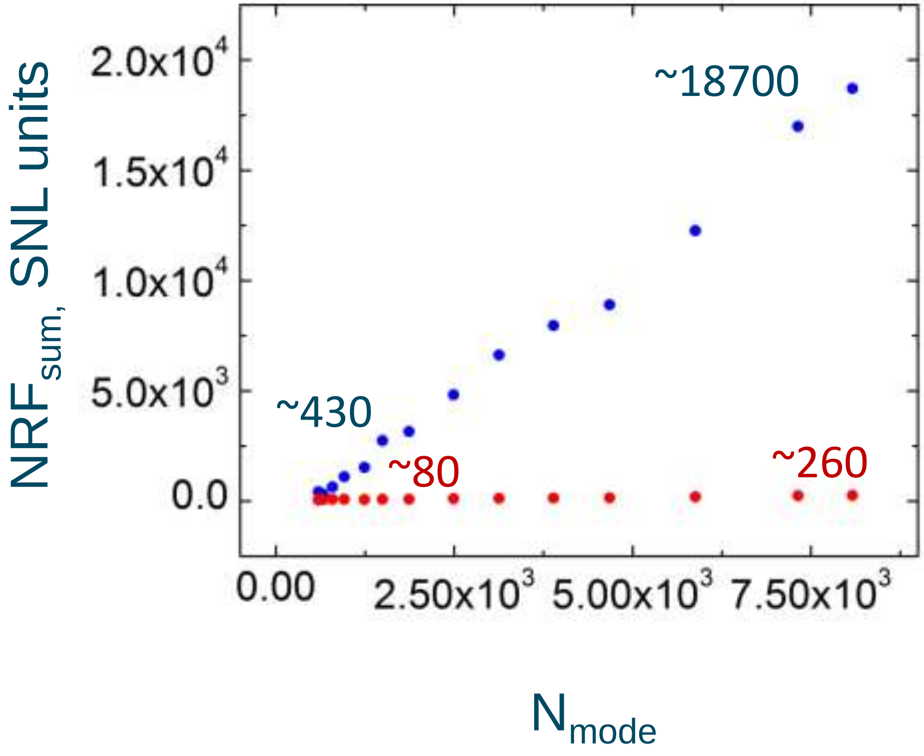
$$NRF_{meas} = 1 - \frac{m}{m+k}\eta + \frac{k}{m+k}N_{mode}$$

Preliminary results:

Width of range : STD/5

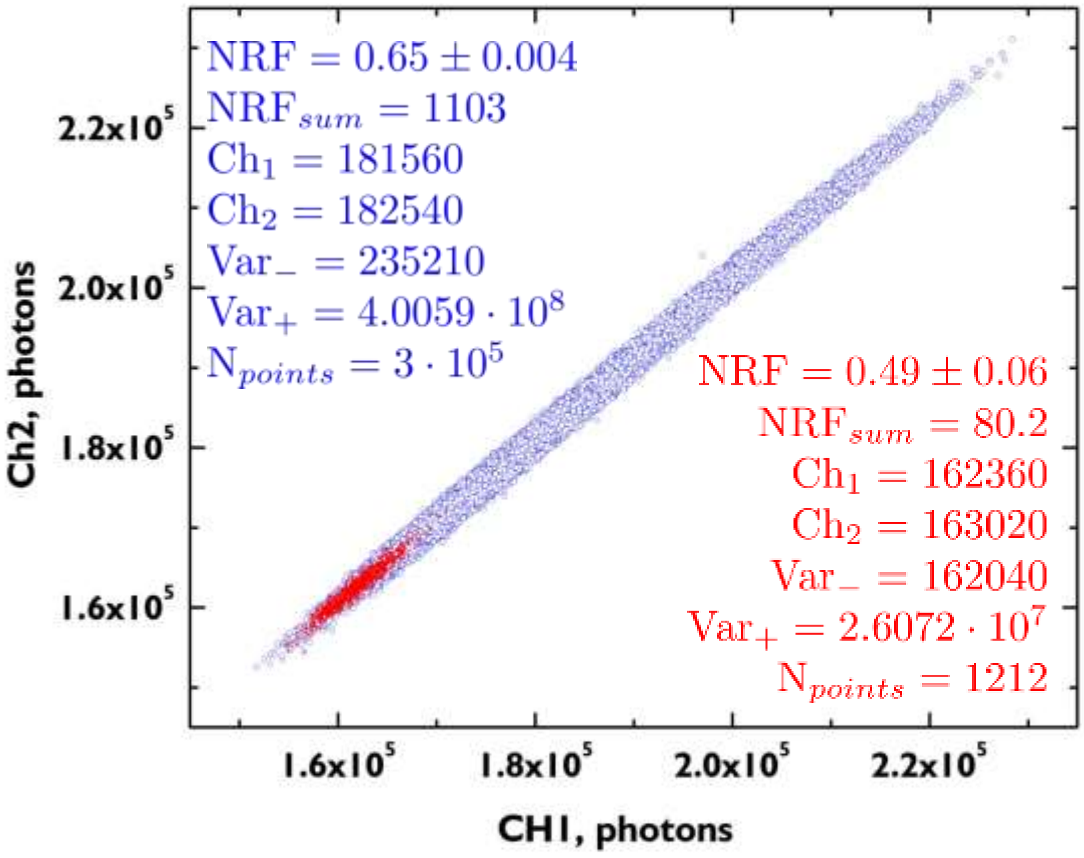
Best Position

$$\mathrm{NRF}_{\mathrm{sum}} \equiv \frac{\mathrm{Var}(N_A+N_B)}{\langle N_A+N_B \rangle}$$



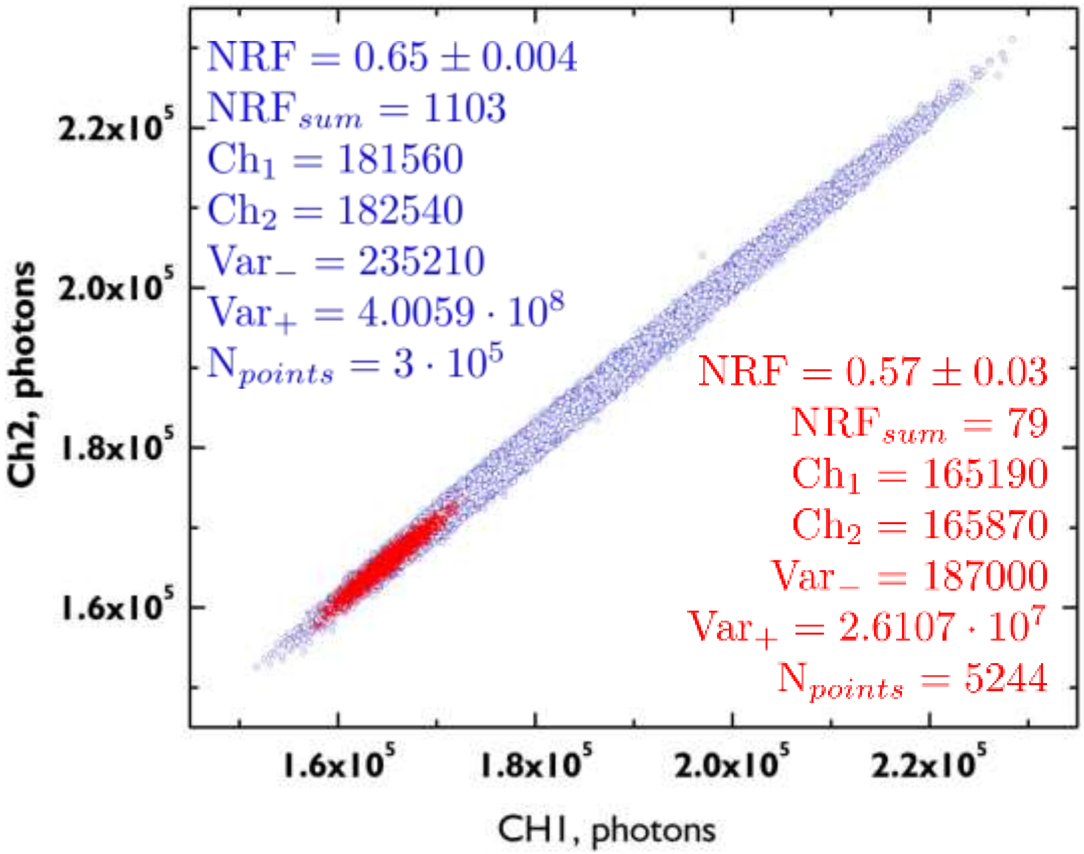
Scan of the position of the condition with the fixed width STD/5:

Position 0.88 mean, Width of range STD/5



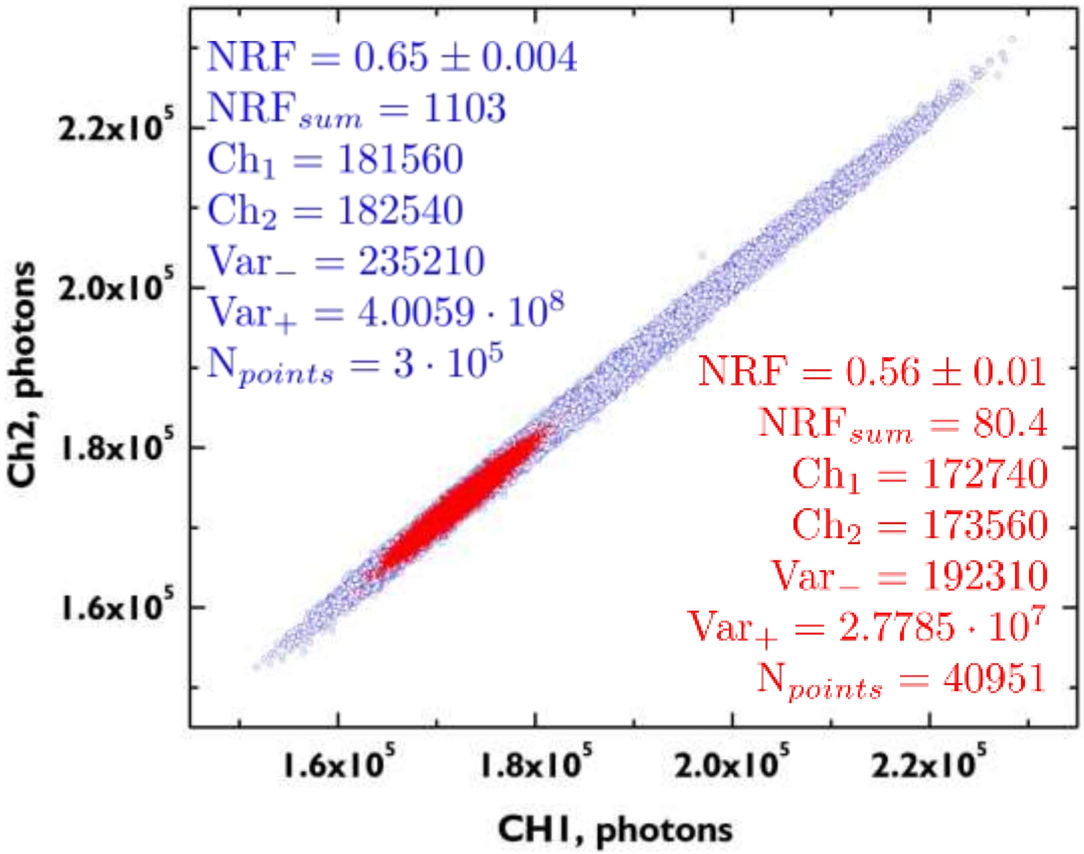
N_{mode}=1091 photons

Position 0.9 mean, Width of range STD/5



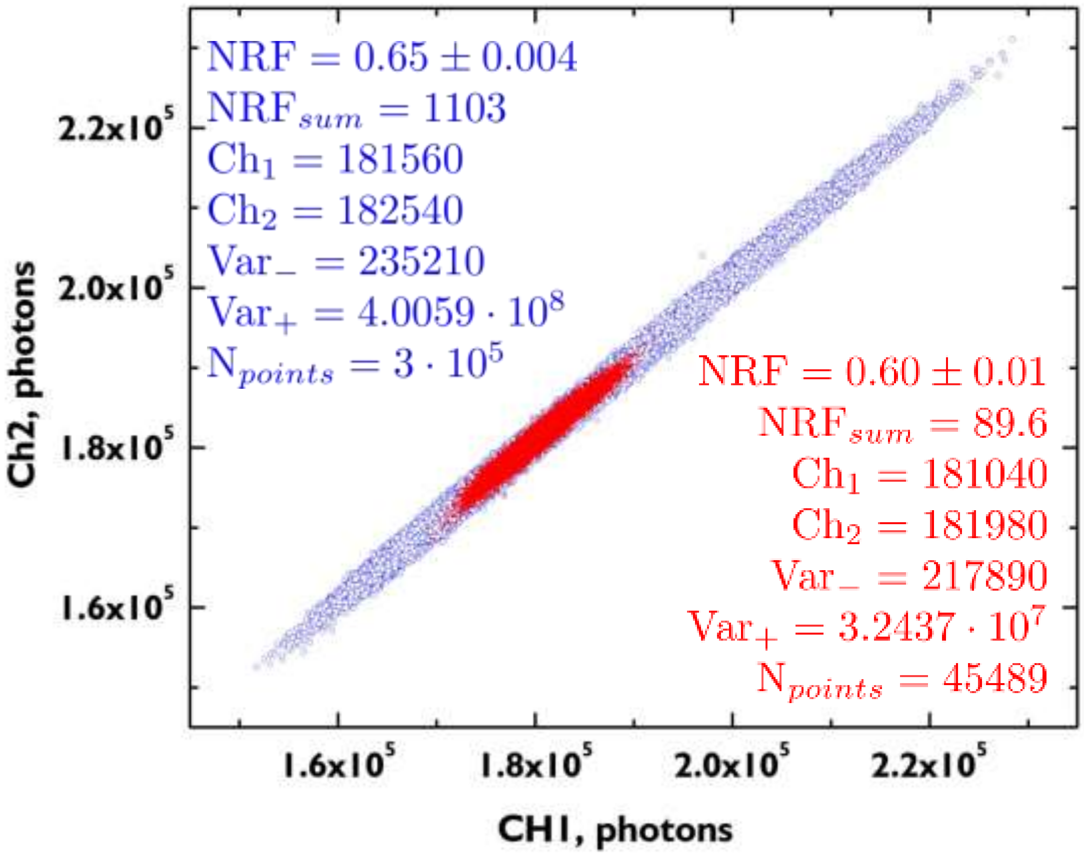
N_{mode}=1091 photons

Position 0.95mean, Width of range STD/5



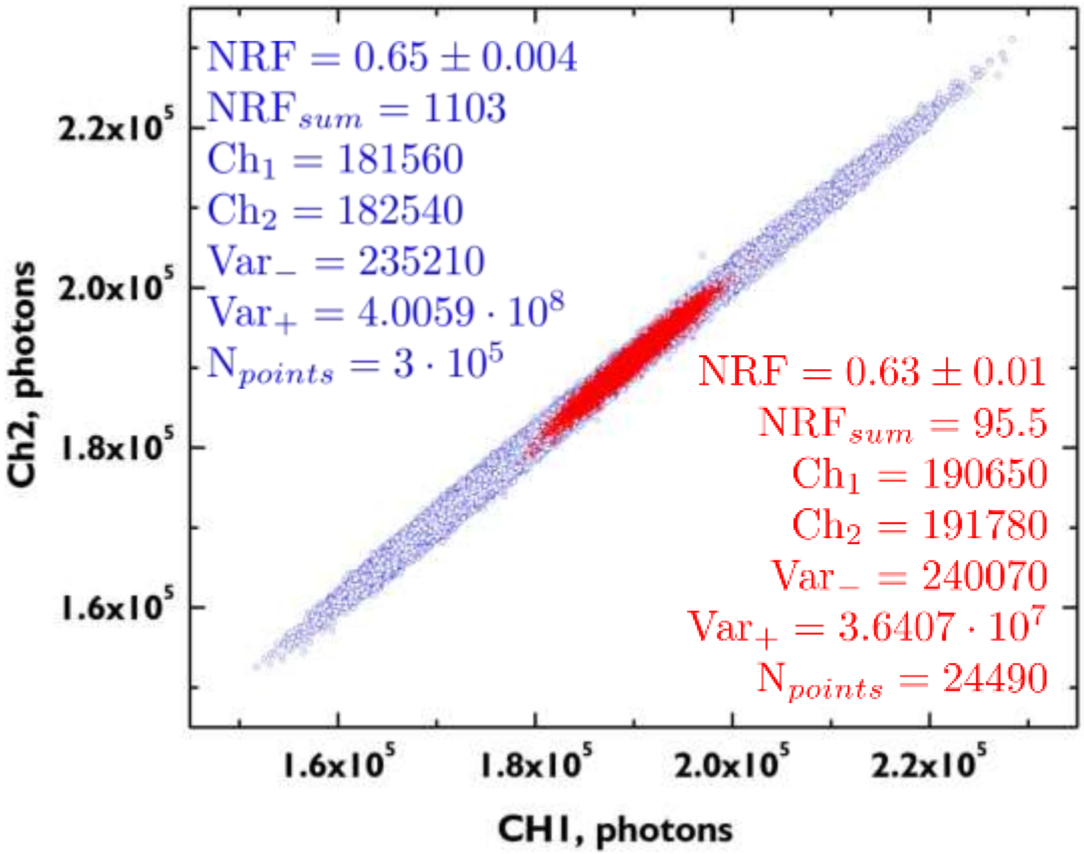
N_{mode}=1091 photons

Position 1 mean, Width of range STD/5



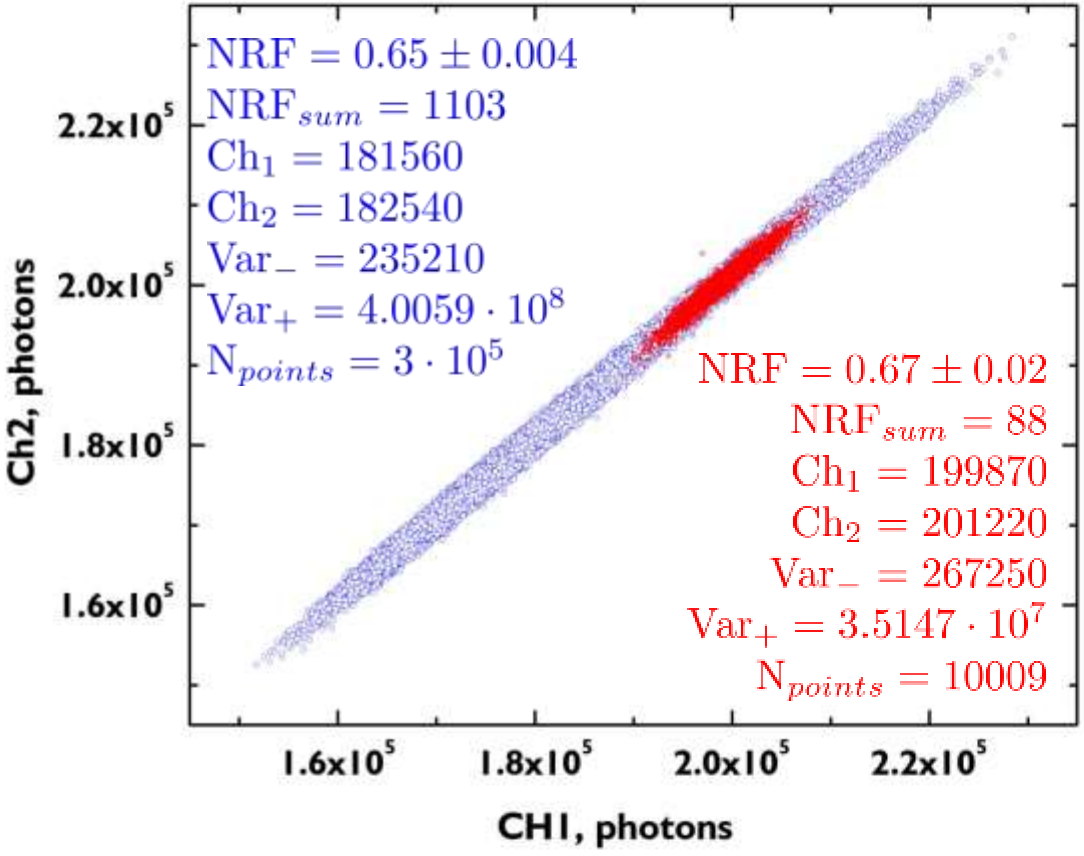
N_{mode}=1091 photons

Position 1.05 mean, Width of range STD/5



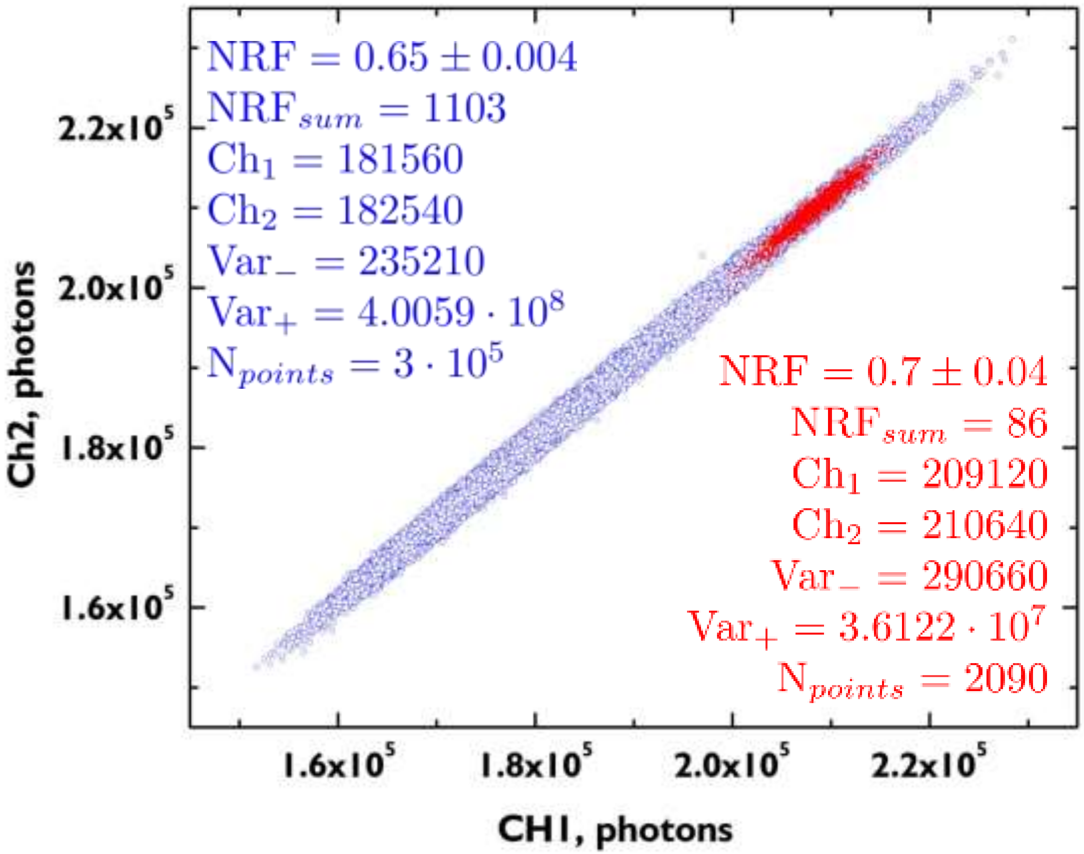
N_{mode}=1091 photons

Position 1.1 mean, Width of range STD/5



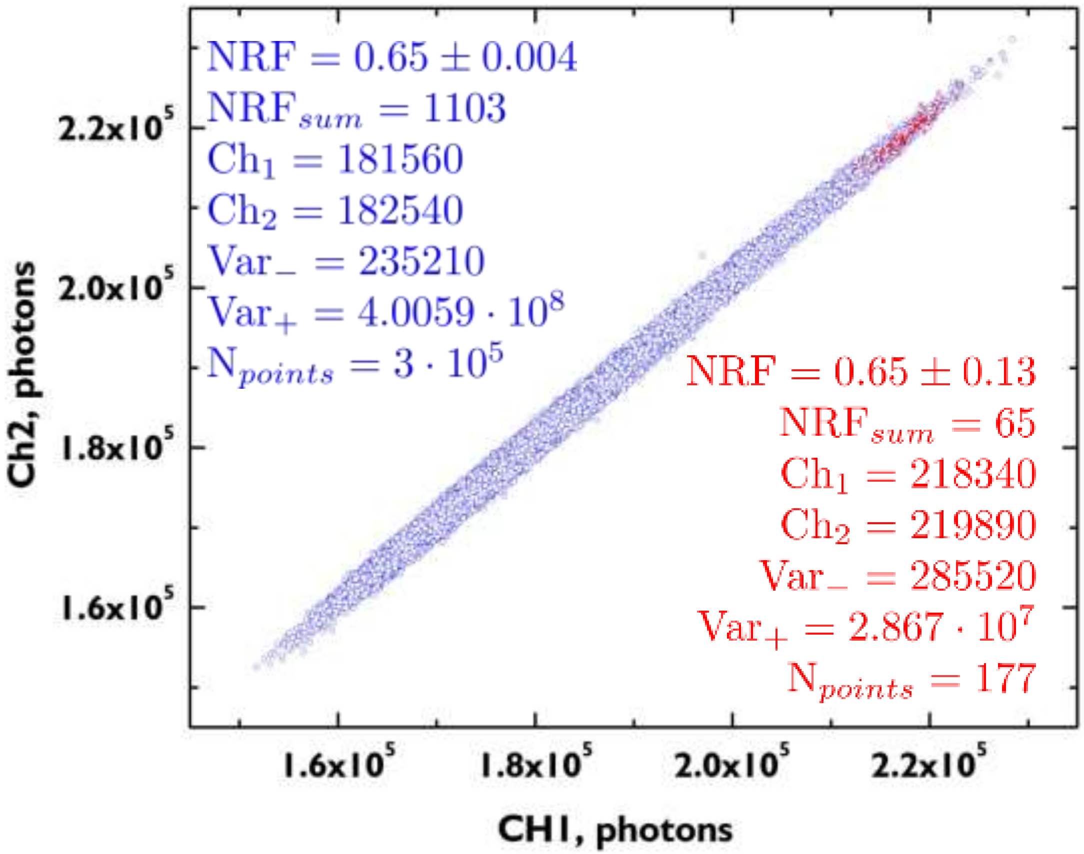
N_{mode}=1091 photons

Position 1.15 mean, Width of range STD/5



N_{mode}=1091 photons

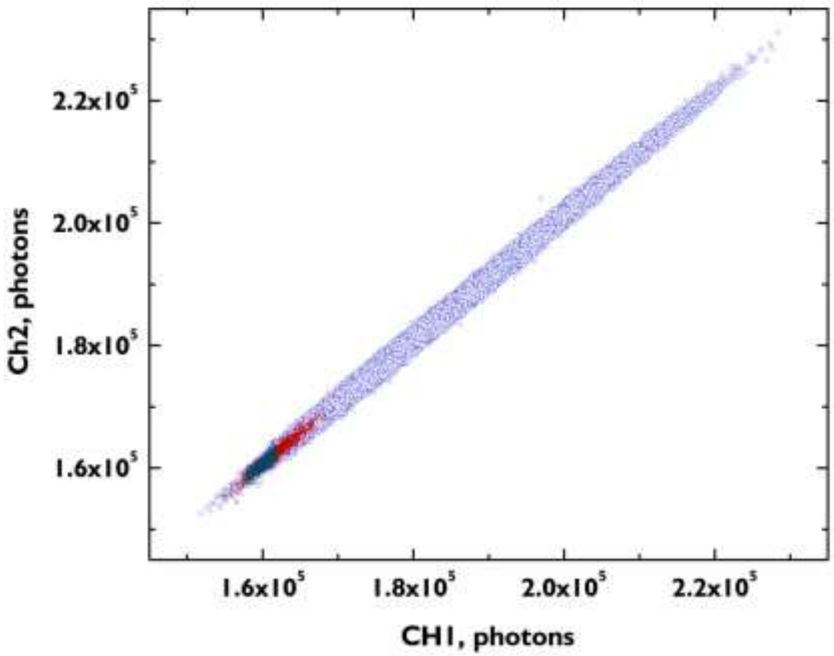
Position 1.2 mean, Width of range STD/5

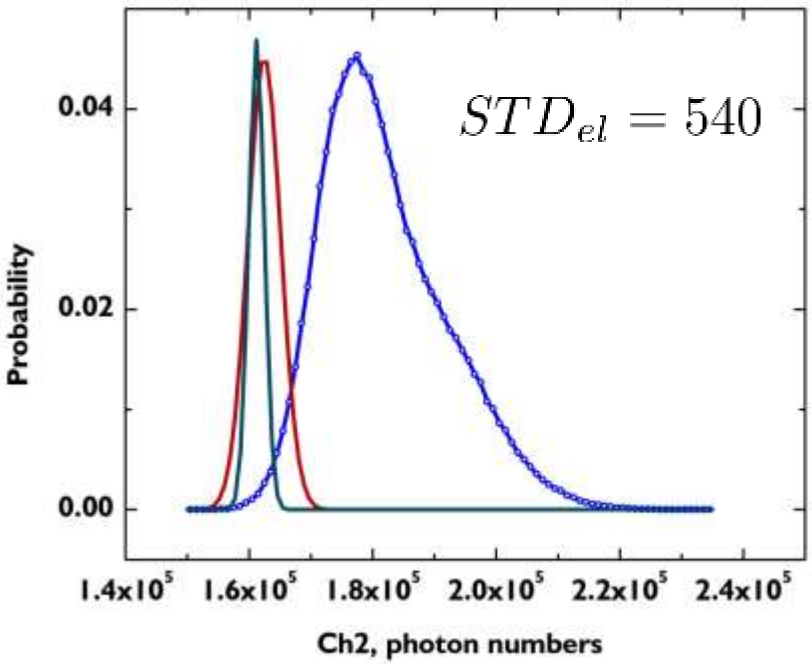


N_{mode}=1091 photons

Classical and **nonclassical** noise suppression in Ch2
Width of range STD/5. Position 0.88 mean

N_{mode}=1091 photons





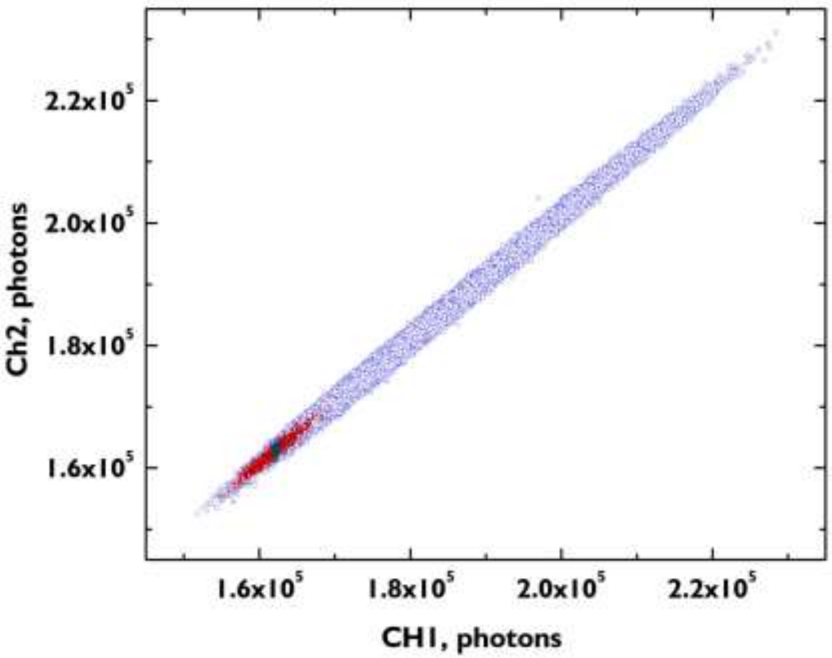
Unconditional distribution

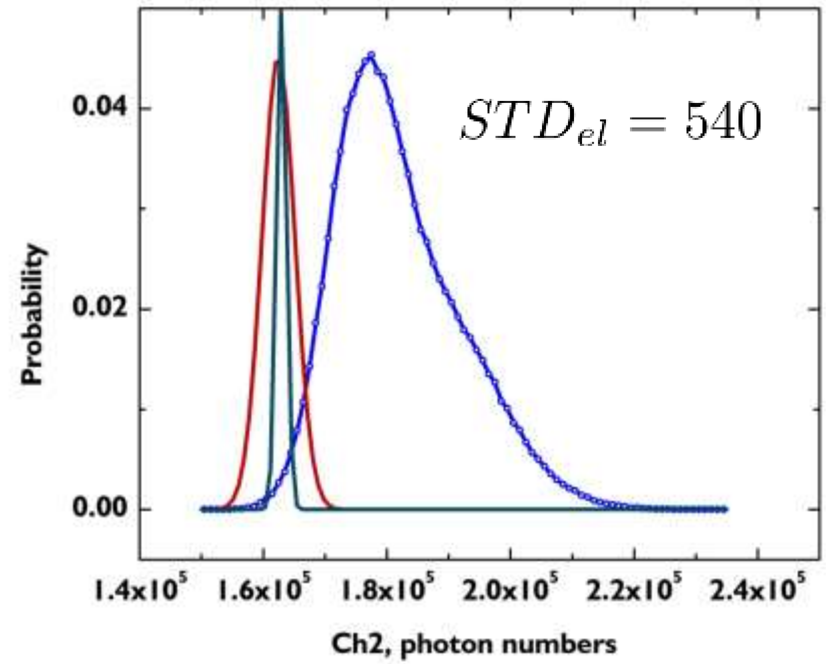
Classical Conditional distribution (D_c)

Nonclassical Conditional distribution (Ch1)

Classical + nonclassical noise suppression in Ch2
Width of range STD/5. Position 0.88 mean

N_{mode}=1091 photons





Unconditional distribution

Classical — Conditional distribution (D_c)

Double condition: Classical + Nonclassical — Conditional distribution (Ch1)

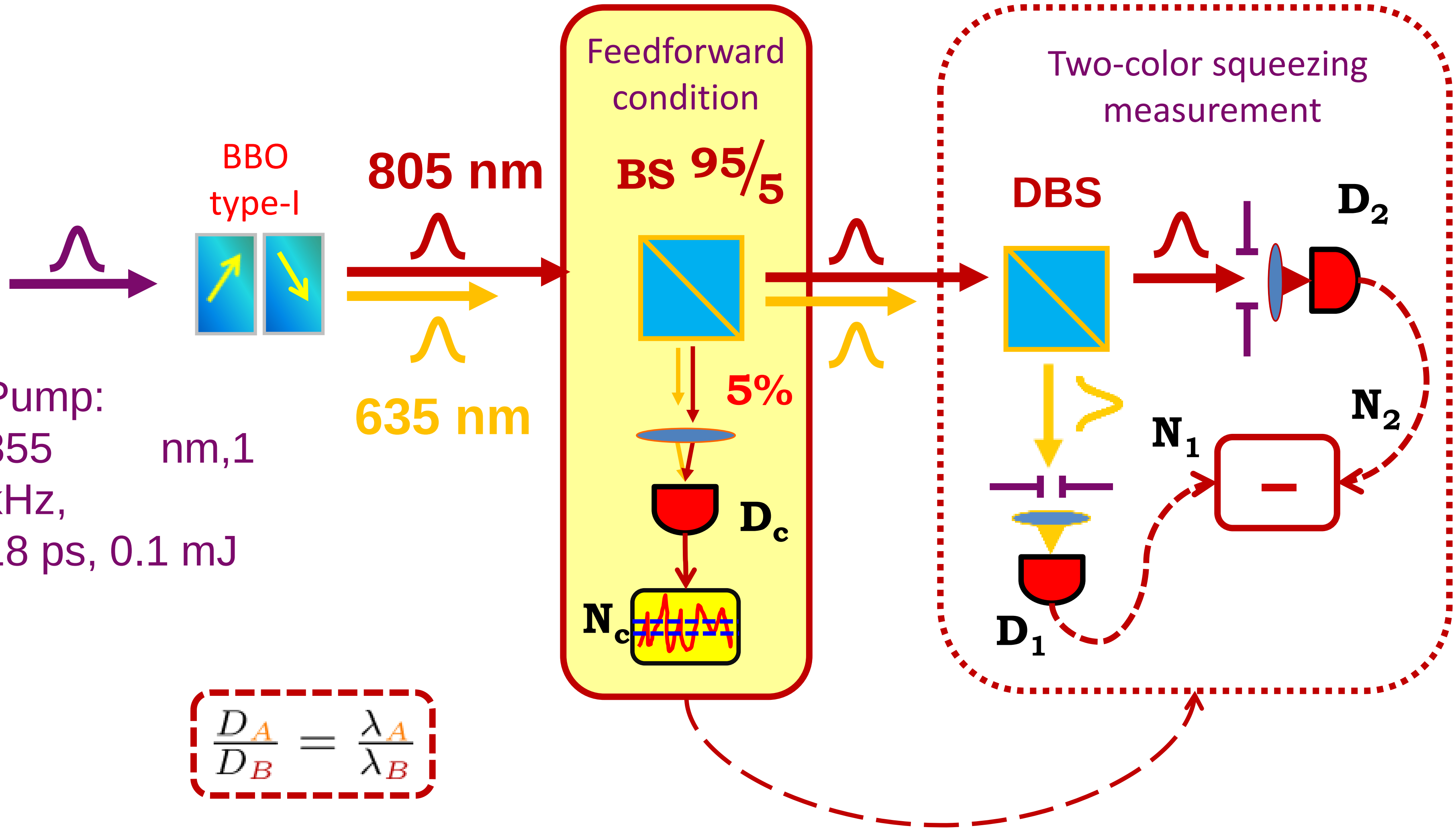
Conclusions

Bright twin-beams were generated.

Feedforward technique allows to improve the observable degree of two-mode squeezing and to suppress the fluctuatio in each beam.

It is not the end

Setup: condition in both beams



$$\frac{D_A}{D_B} = \frac{\lambda_A}{\lambda_B}$$

$$NRF \equiv \frac{Var(N_A - N_B)}{\langle N_A + N_B \rangle}, \text{ if } \; N_c \in \text{range}$$

Preliminary results:

Width of range : STD/5 Position: 0.83 mean

$$NRF_{meas} = 1 - \frac{m}{m+k}\eta + \frac{k}{m+k}N_{mode}$$

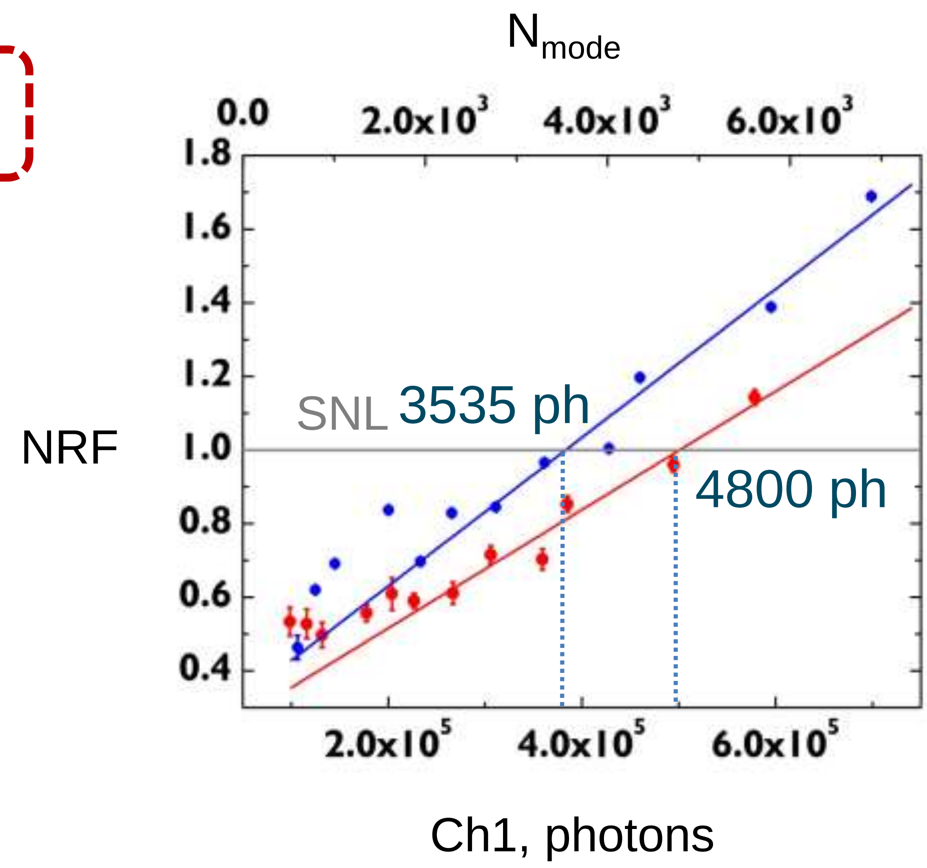
Obtained fits:

No condition

$$\mathrm{NRF} = 0.227 + 2.02 \cdot 10^{-6} \cdot x$$

With condition $\approx$ $\vee$

$$\mathrm{NRF} = 0.194 + 1.61 \cdot 10^{-6} \cdot x$$



The influence of the last term is suppressed while the constant part is almost remained

Conclusions

We have observed the suppression of the influence of thermal fluctuations in two-mode squeezing measurement.

The end

Thank You