Automated Activation Procedures for GaAs photocathodes at Photo-CATCH*
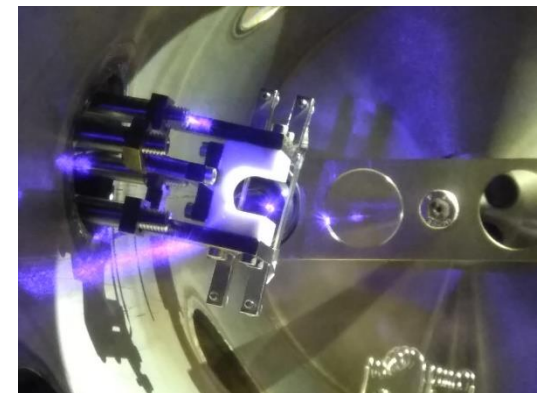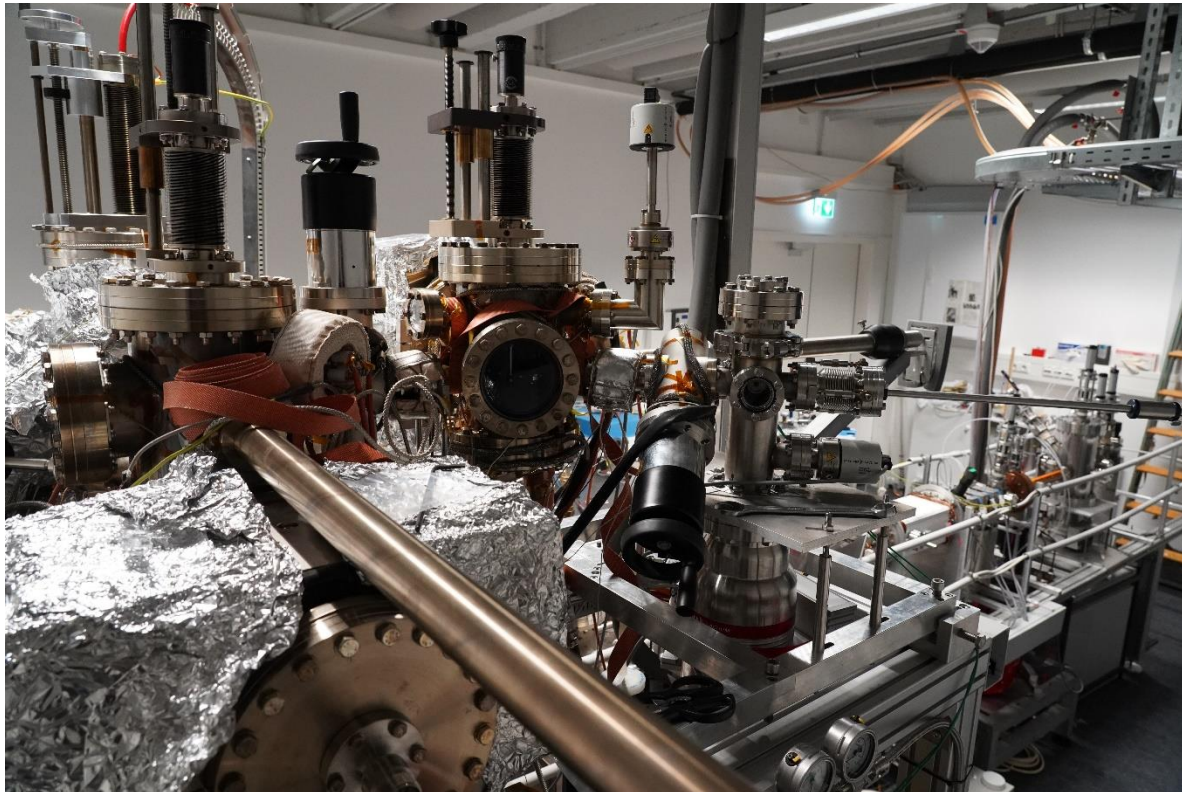
M. Herbert – T. Eggert, J. Enders, M. Engart, Y. Fritzsche, V. Wende
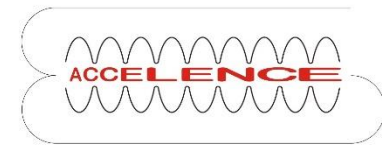
GaAs − NEA surface layer

Activation

Co-Deposition (Co-De)

Cs, O_2 off

$\rightarrow$ quantum efficiency η

I_p

O_2 on

Cs on

t

GaAs − NEA surface layer

Activation

I_p

Co-Deposition (Co-De)

Cs, O$_2$ off

→ quantum efficiency η

O$_2$ on

Cs on

t

Decay

I_p

$$\eta(t) = \eta_0 \cdot e^{-t/\tau}$$

→ Lifetime τ

t

GaAs − NEA surface layer

Activation

Decay

I_p

Co-Deposition (Co-De)

Cs, O$_2$ off

O$_2$ on

Cs on

t

→ quantum efficiency η

I_p

$$\eta(t) = \eta_0 \cdot e^{-t/\tau}$$

→ Lifetime τ

t
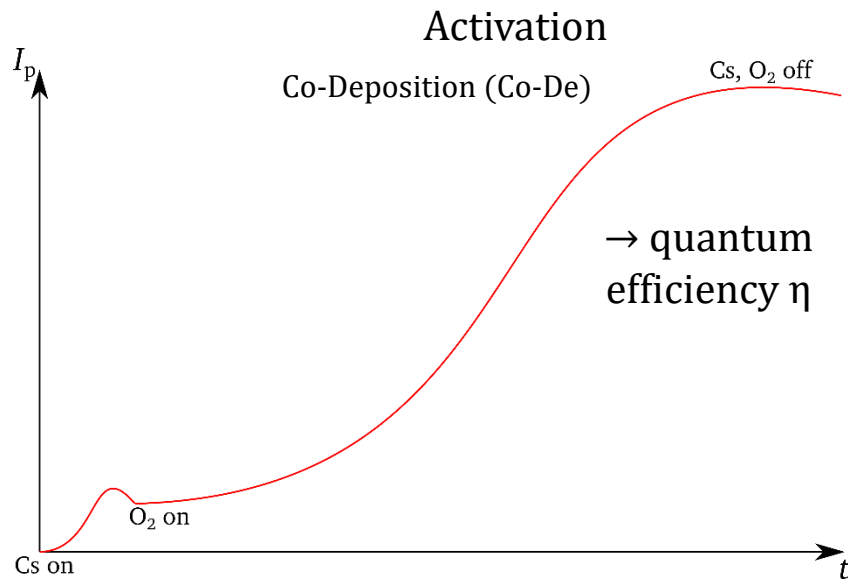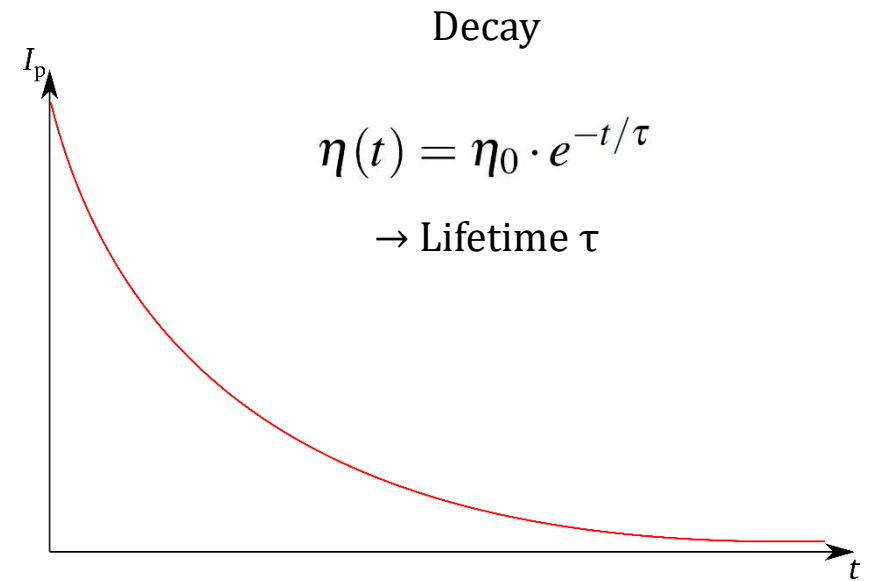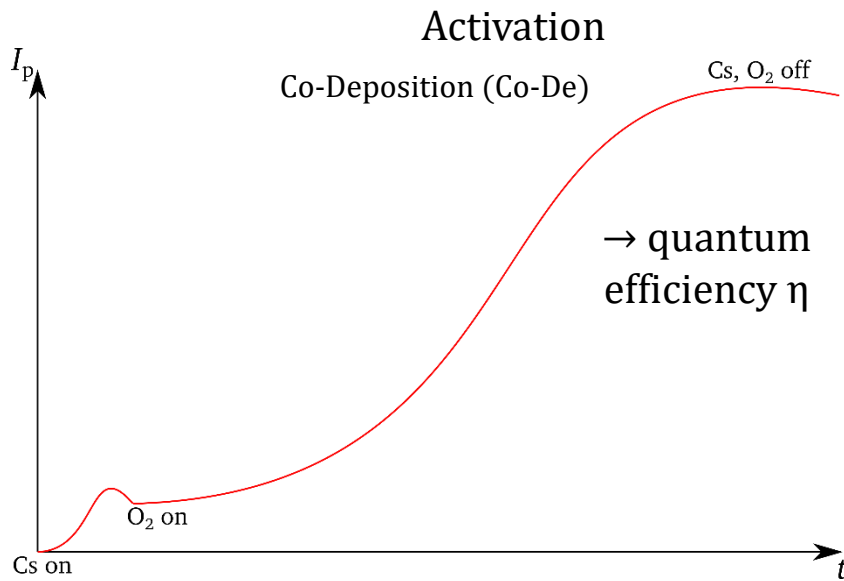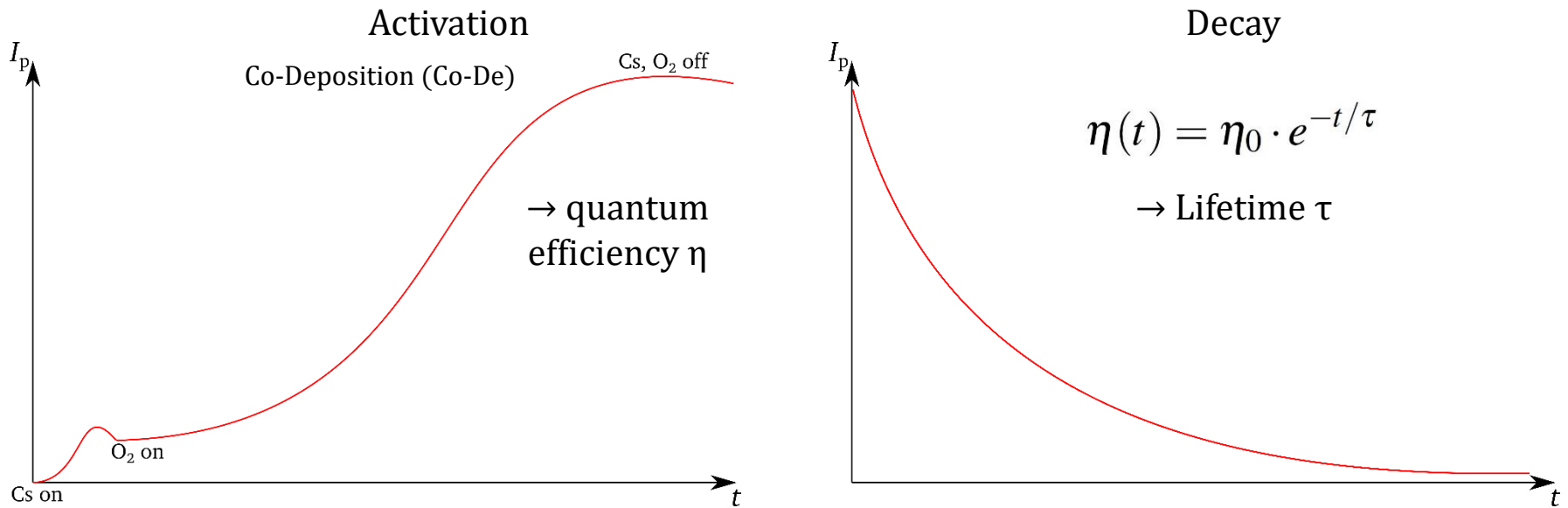
Influence on τ

Reproducible η and τ required for accelerator applications

GaAs – NEA surface layer

Activation

I_p

Co-Deposition (Co-De)

Cs, O_2 off

→ quantum efficiency η

O_2 on

Cs on

t

Decay

I_p

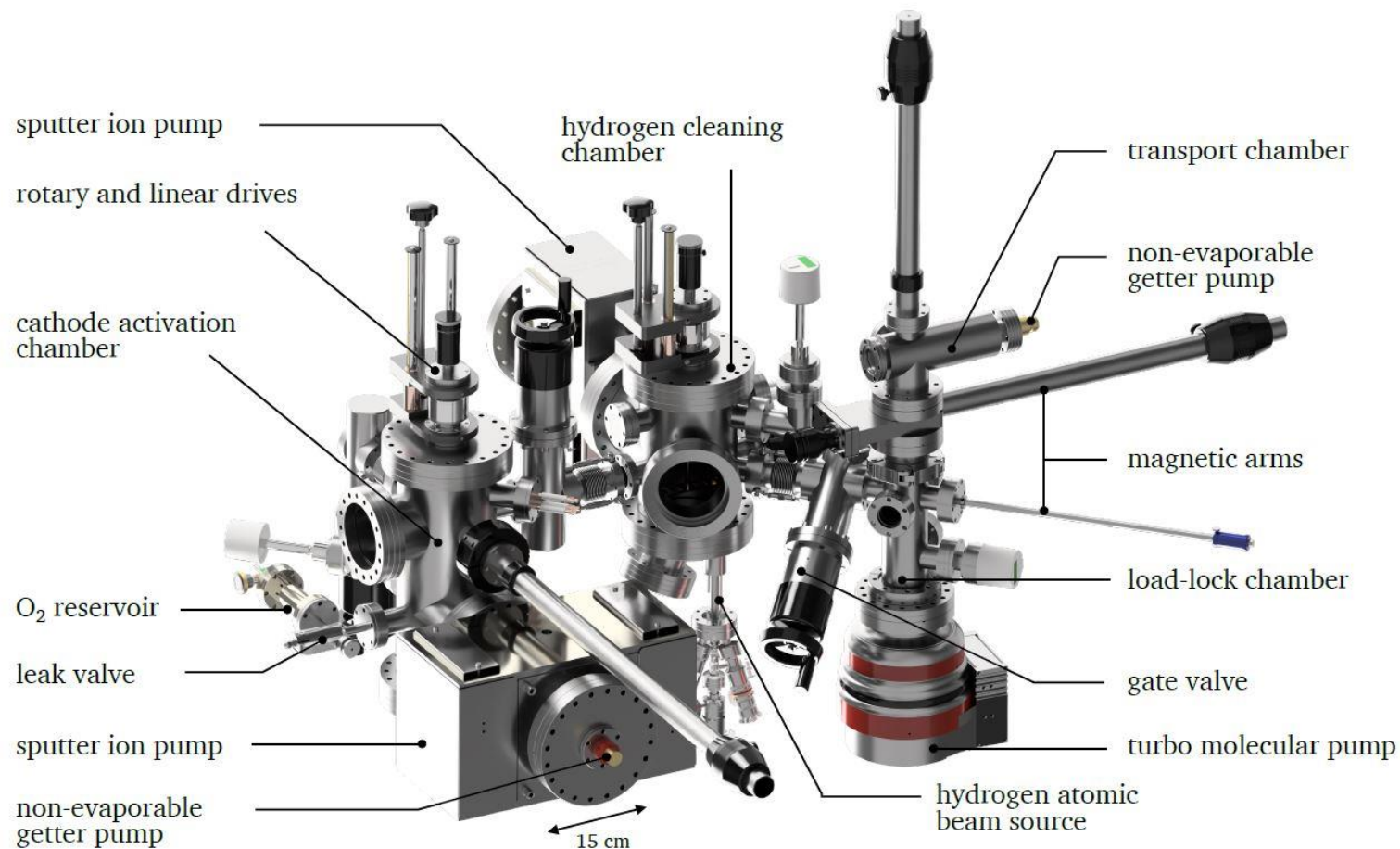$$\eta(t) = \eta_0 \cdot e^{-t/\tau}$$

→ Lifetime τ

t
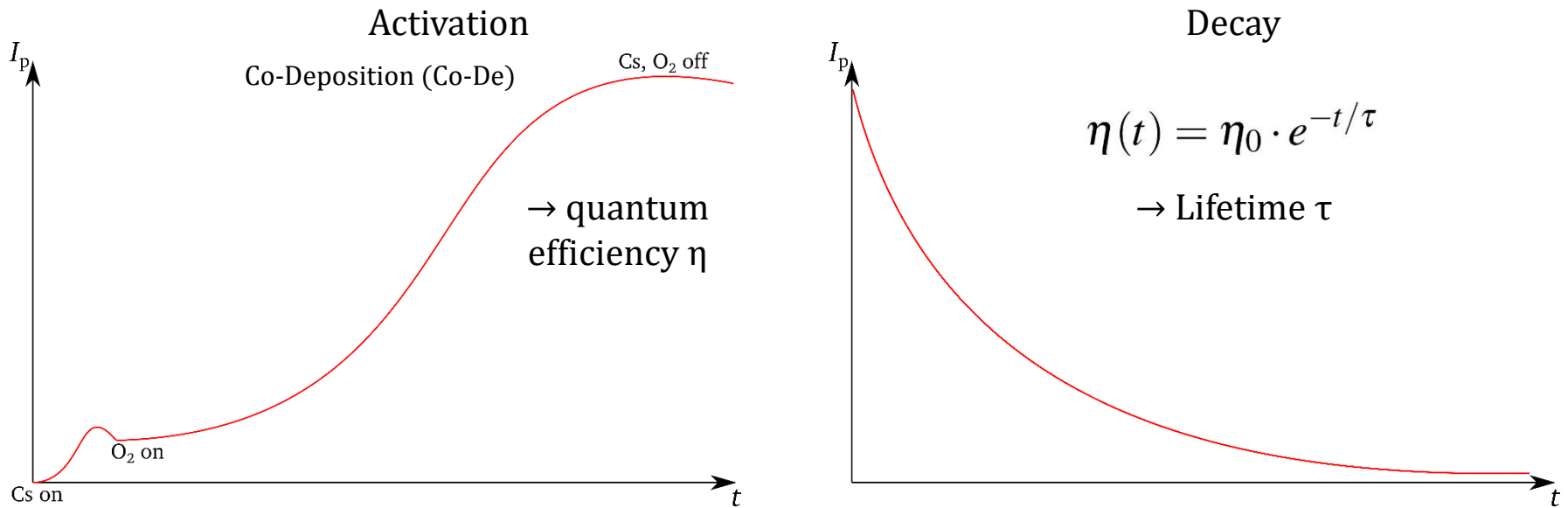
Influence on τ

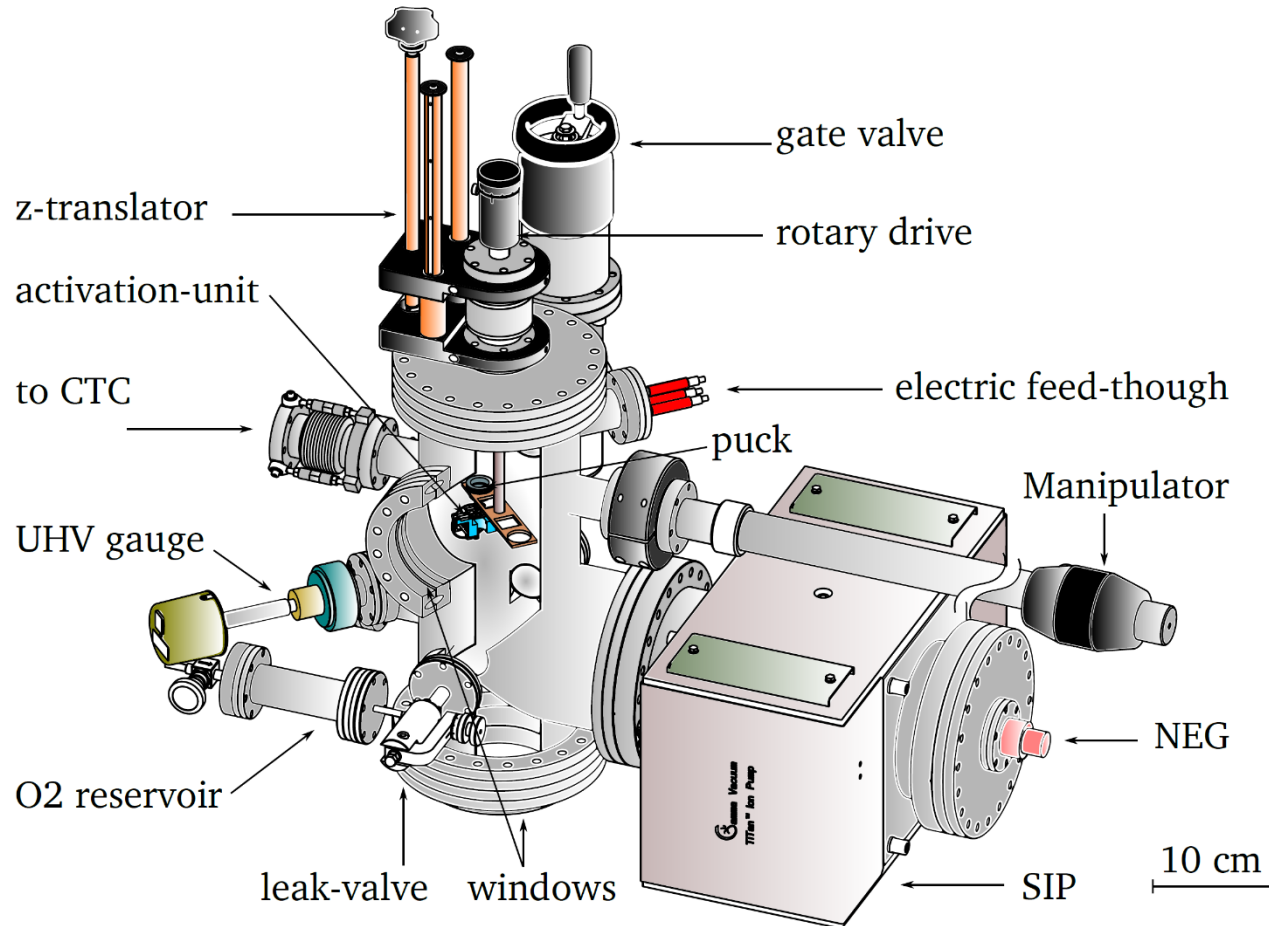Reproducible η and τ required for accelerator applications

Automated activation process

Experimental Setup @ Photo-CATCH

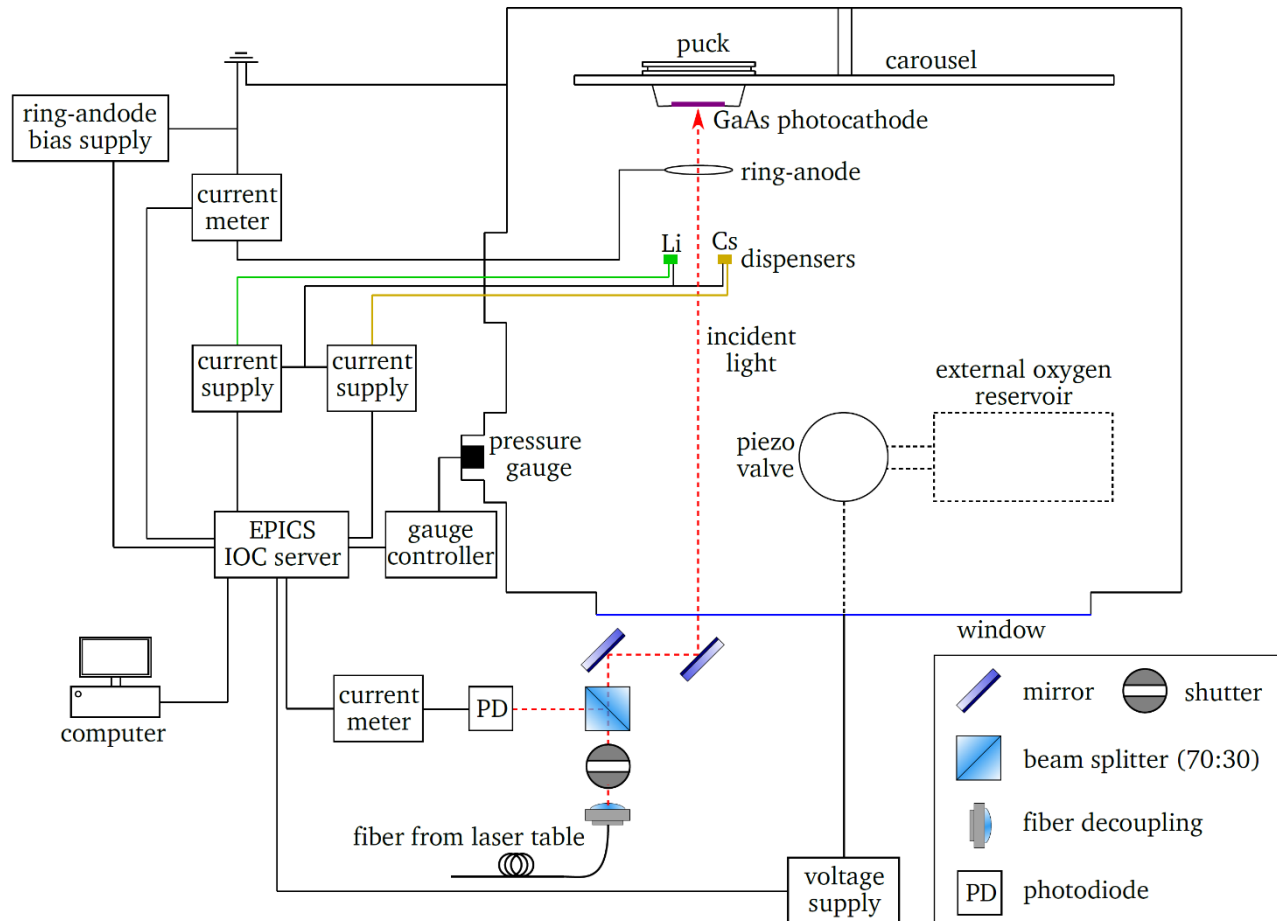N. Kurichiyanil *et al., A test system for optimizing quantum efficiency and dark lifetime of GaAs photocathodes,* Journal of Instrumentation 14 P08025 (2019)

N. Kurichiyanil, *Design and construction of a test stand for photocathode research and experiments,*
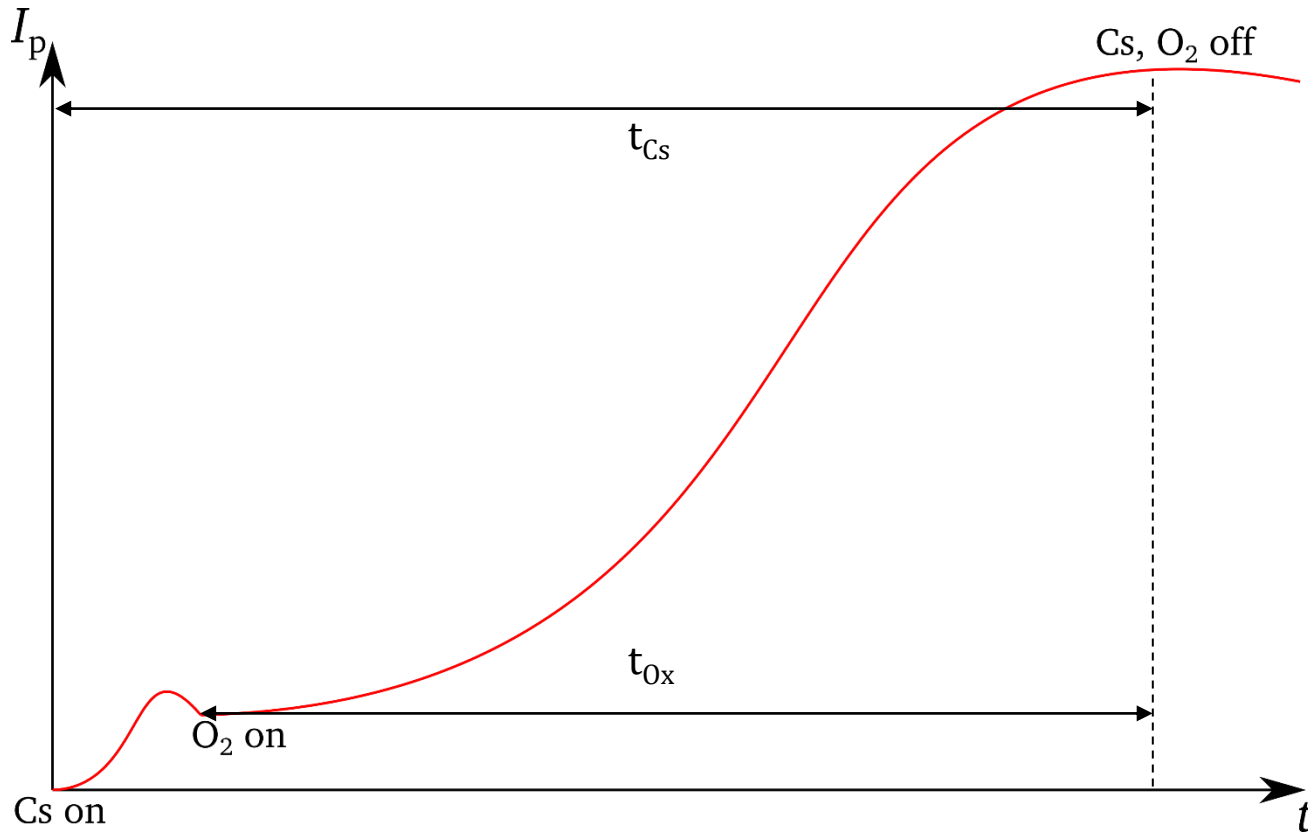Dissertation, TU Darmstadt (2017)

Experimental Setup @ Photo-CATCH

Automated Activation Scheme

Co-De scheme
(Cs + O_2)

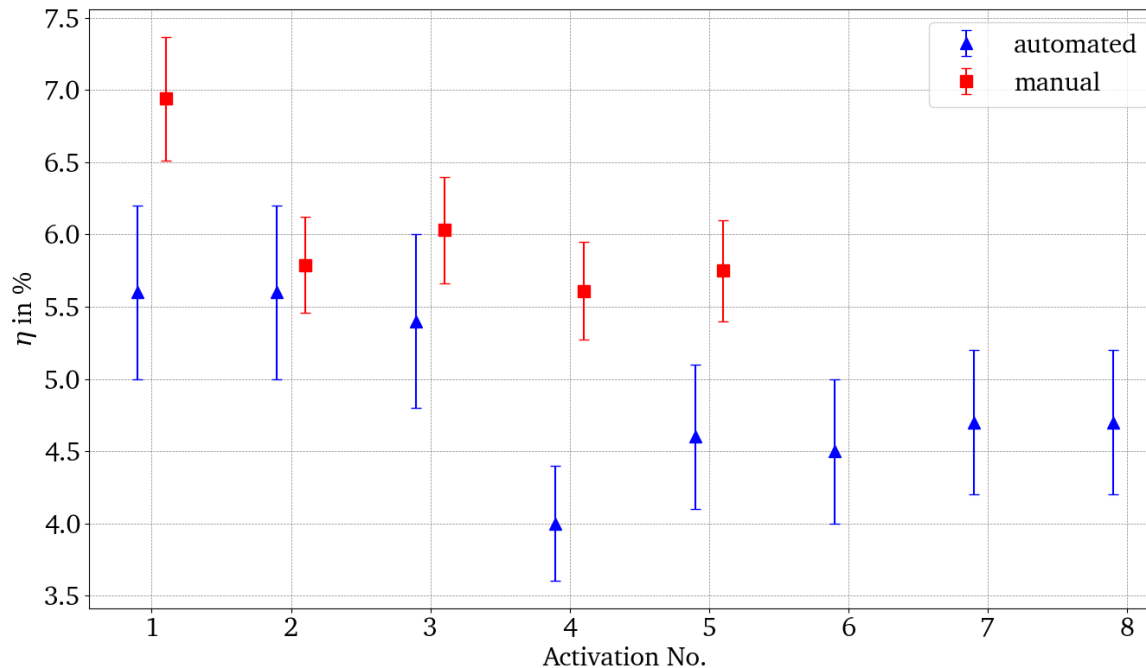$t_{Cs} = 39$ min, $t_{Ox} = 22.8$ min

Quantum Efficiency – Manual vs Automated

Manual:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (5 \pm 1)$ µW
$U_{bias} = 102$ V

Automated:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (8 \pm 2)$ µW
$U_{bias} = 102$ V

Quantum Efficiency – Manual vs Automated

Manual:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (5 \pm 1)$ µW
$U_{bias} = 102$ V

Automated:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (8 \pm 2)$ µW
$U_{bias} = 102$ V
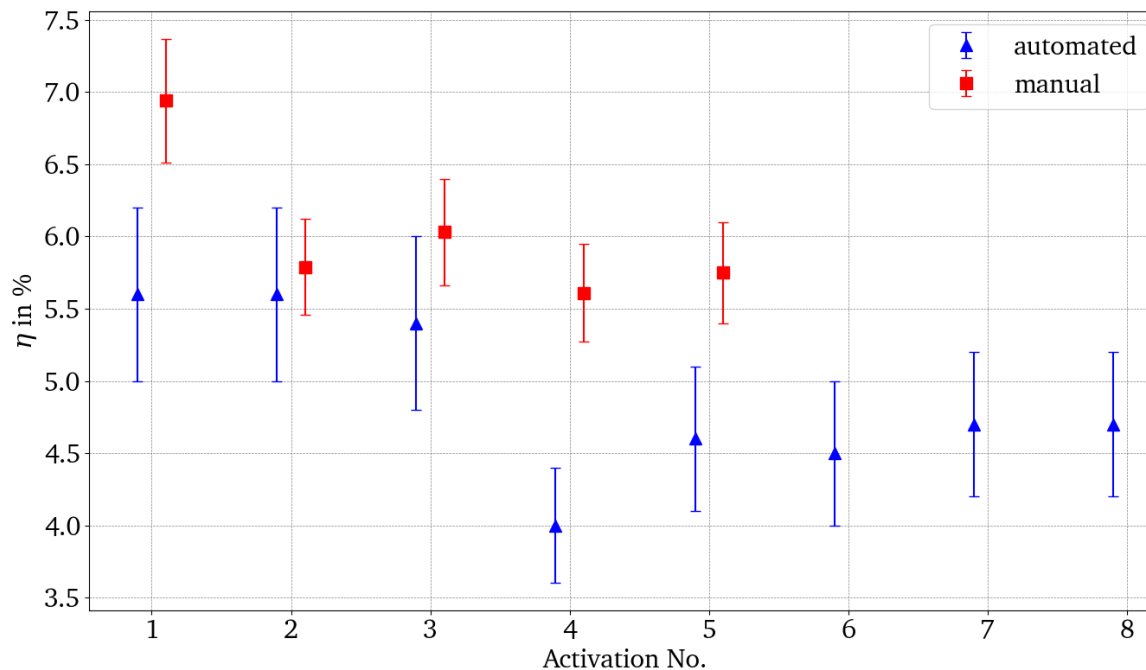
Scheme	η_{mean} (%)
Manual	6.0 ± 0.6
Auto	4.9 ± 0.8

Comparable reproducibility

Automated Activation Scheme - Oxygen Input
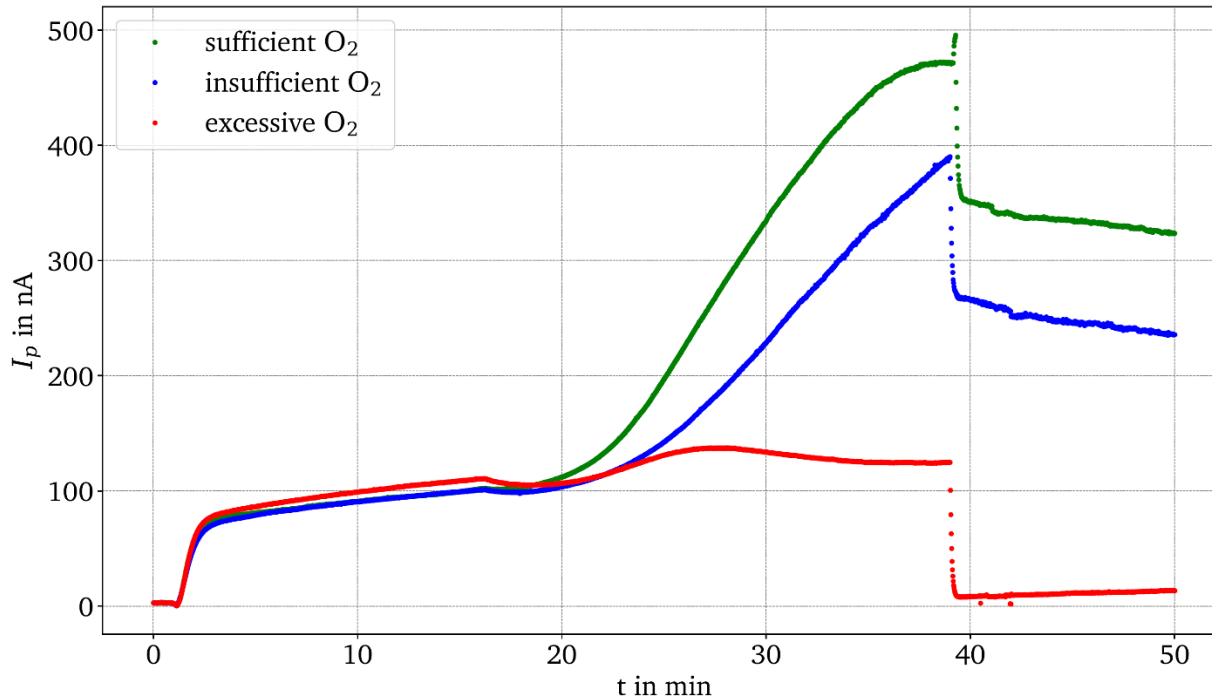
Automated Activation Scheme - Oxygen Input
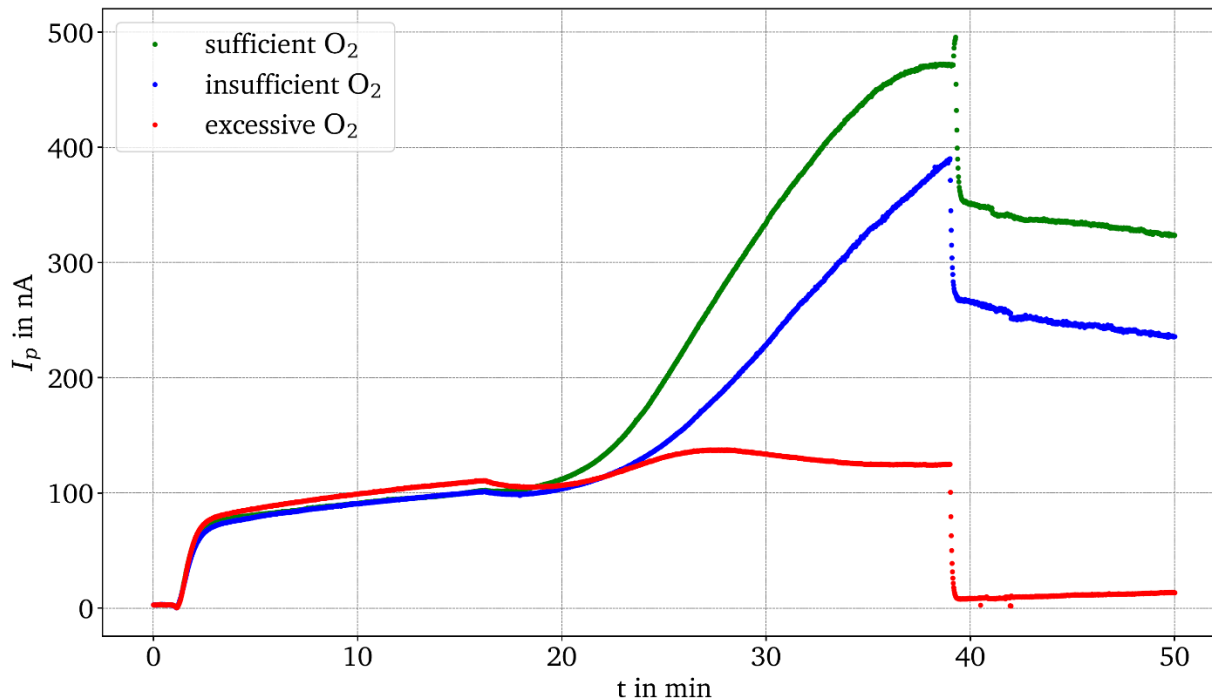
Oxygen	#	No.	η_{mean} (%)
sufficient	3	1, 2, 5	5.3 ± 0.6
insufficient	5	3, 4, 6, 7, 8	4.7 ± 0.5
excessive	1	9	0.2 ± 0.1

Automated Activation Scheme - Oxygen Input
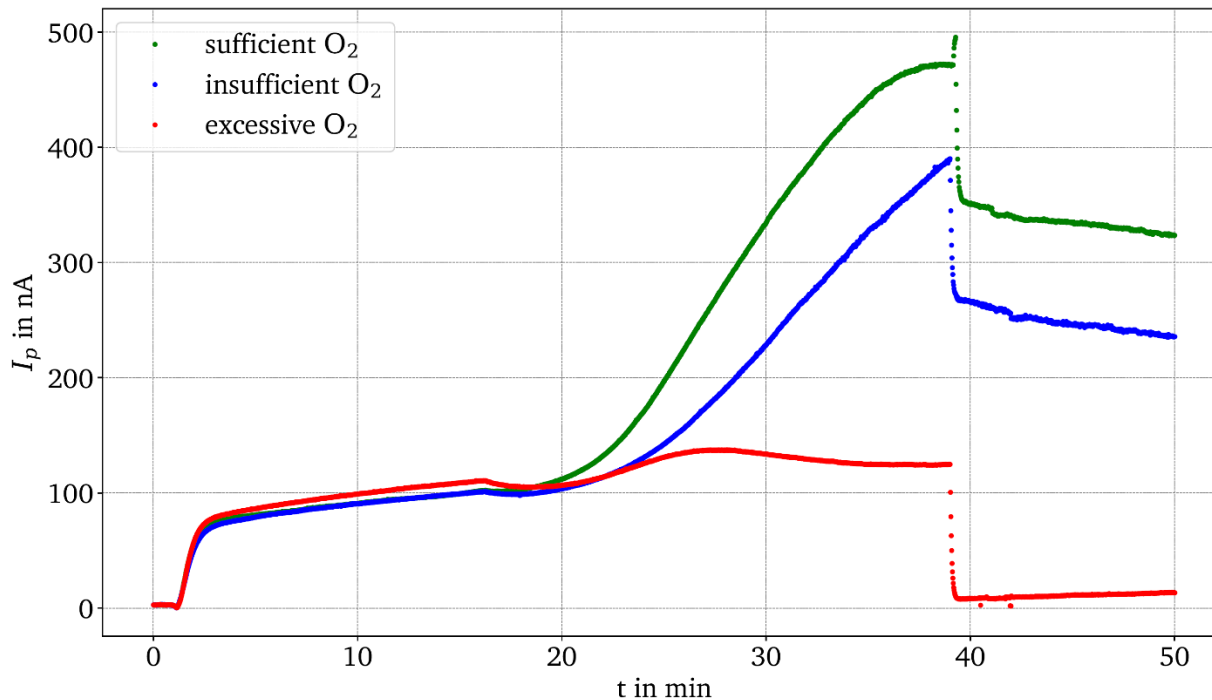
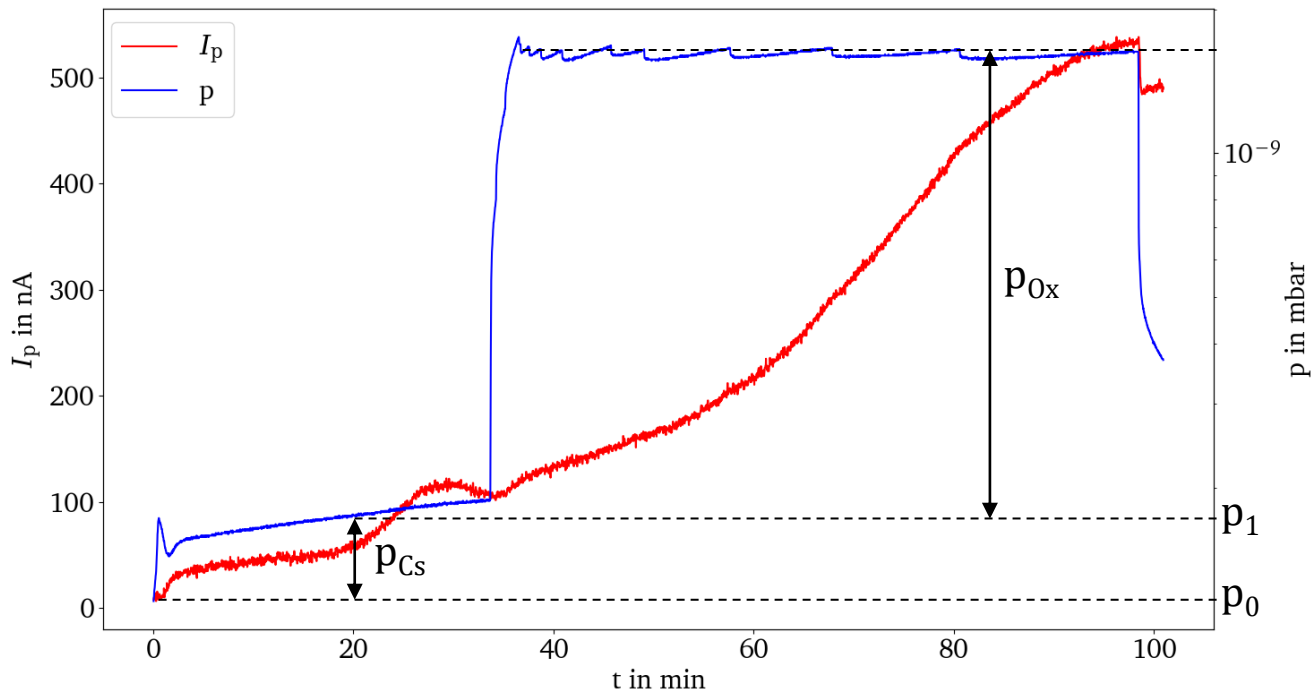| Oxygen	#	No.	η_{mean} (%)
sufficient	3	1, 2, 5	5.3 ± 0.6
insufficient	5	3, 4, 6, 7, 8	4.7 ± 0.5
excessive	1	9	0.2 ± 0.1

Reliable oxygen input required to improve reproducibility

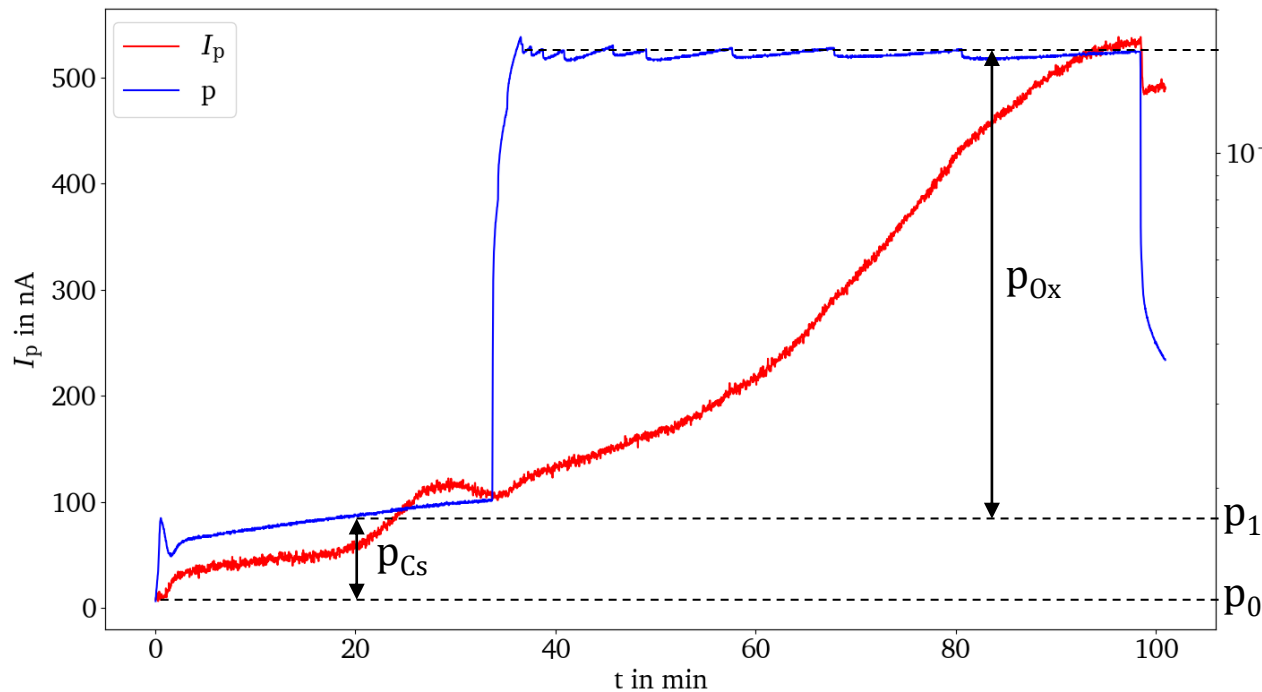# Partial Pressure Ratio
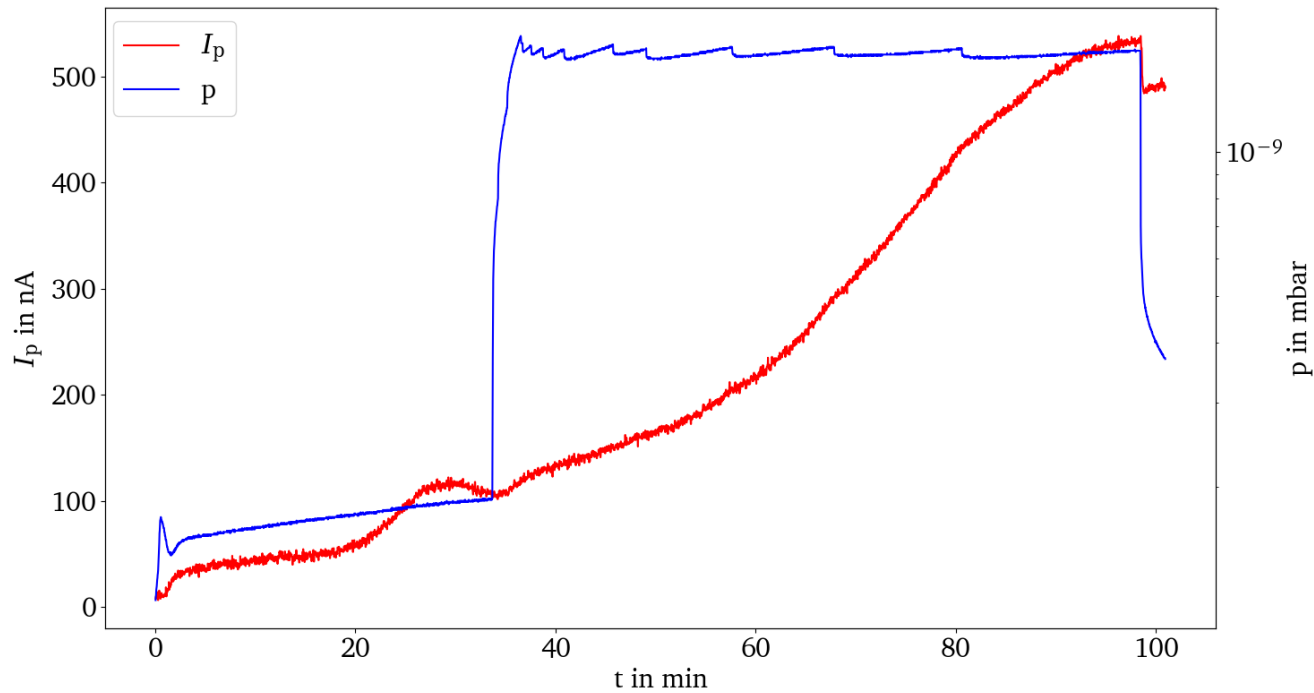
Partial Pressure Ratio

$$p_{Cs} = p_1 - p_0$$
$$p_{Ox} = p_{tot} - p_{Cs}$$

Partial Pressure Ratio

$$p_{Cs} = p_1 - p_0$$
$$p_{Ox} = p_{tot} - p_{Cs}$$
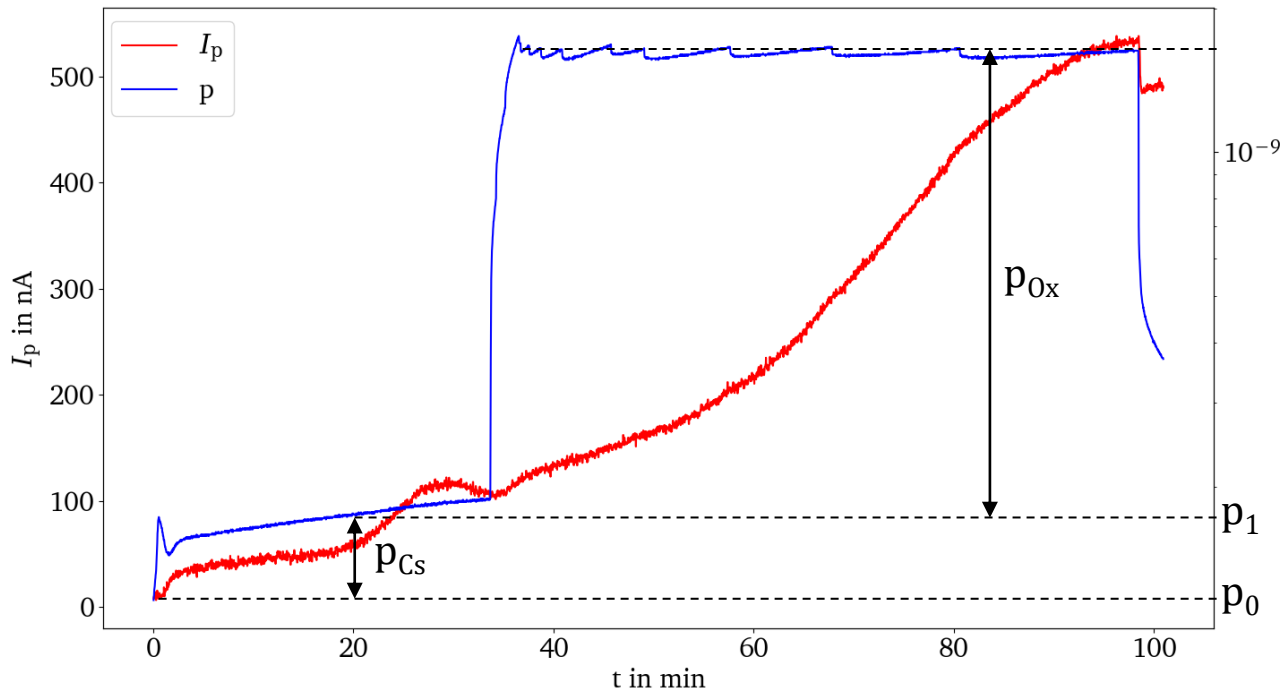
Partial pressure ratio
$$r = p_{Cs}/p_{Ox}$$

sufficient O_2: $r = r_{opt}$
insufficient O_2: $r > r_{opt}$
excessive O_2: $r < r_{opt}$

Photo-CATCH: $r_{opt} \approx 0.043$

Partial Pressure Ratio

$$p_{Cs} = p_1 - p_0$$
$$p_{Ox} = p_{tot} - p_{Cs}$$

Partial pressure ratio
$$r = p_{Cs}/p_{Ox}$$

sufficient O_2: $r = r_{opt}$
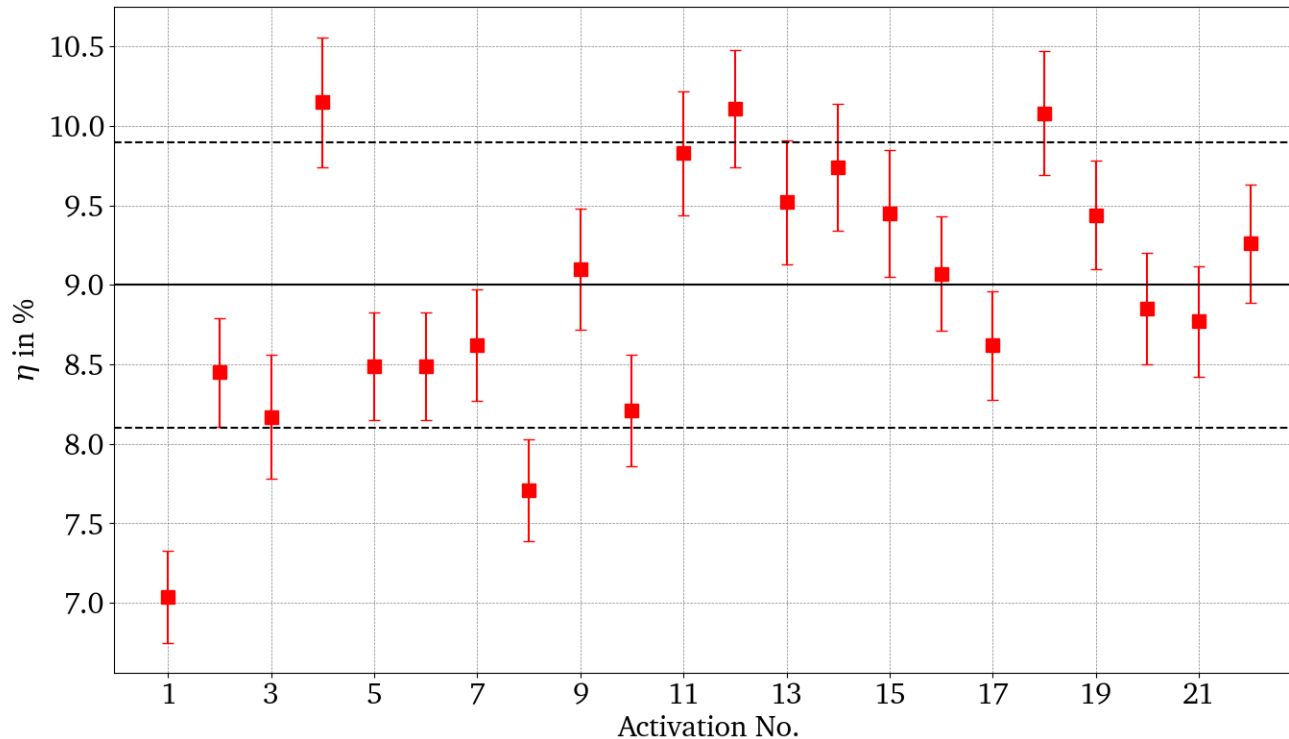insufficient O_2: $r > r_{opt}$
excessive O_2: $r < r_{opt}$

Photo-CATCH: $r_{opt} \approx 0.043$

p_{Cs}, p_{Ox}, r determined and controlled manually during activation
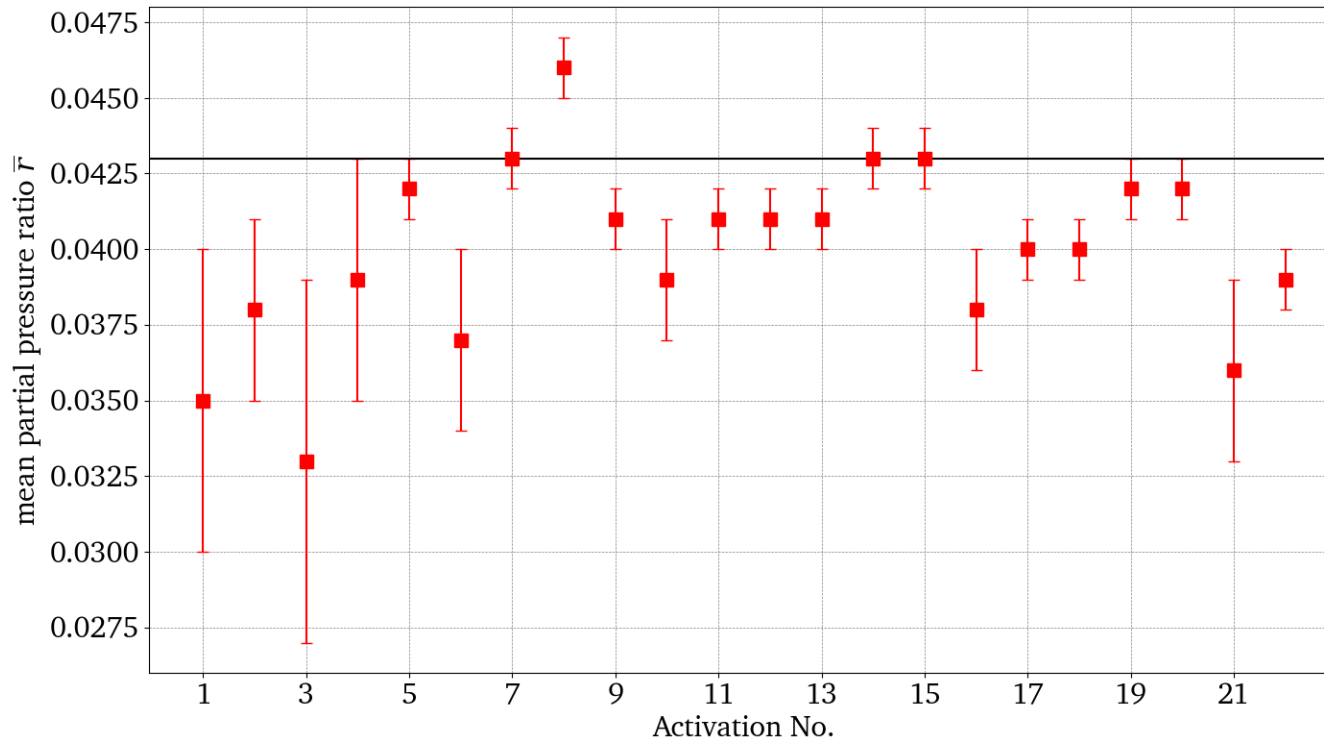
Improved procedure required

Optimized Manual Activations

$$\lambda = (785 \pm 5)\ \text{nm}$$
$$P_{laser} = (50 \pm 2)\ \mu W$$
$$U_{bias} = 102\ V$$

$$\eta_{mean} = (9.0 \pm 0.9)\ \%$$

Partial Pressure Analysis

Partial Pressure Analysis
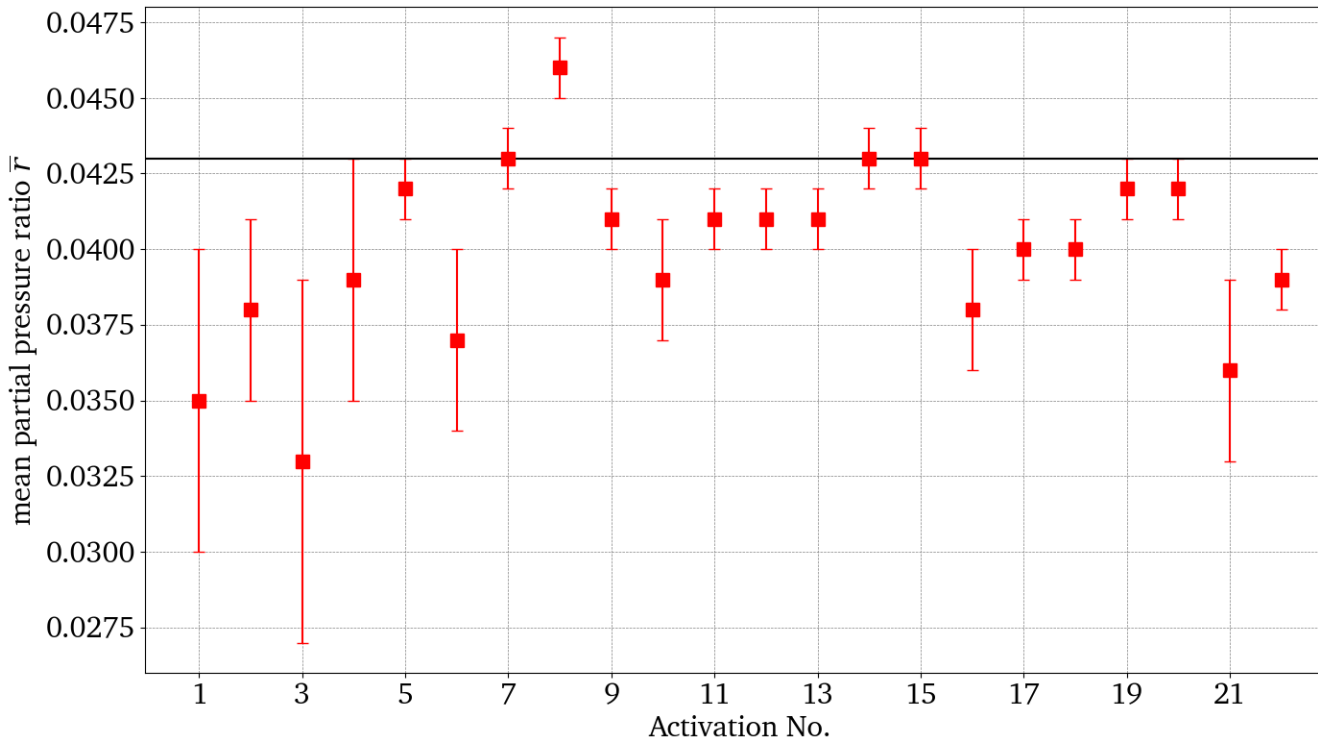
$r = r_{opt}$: 7 Activations
$r > r_{opt}$: 1 Activation
$r < r_{opt}$: 14 Activations

Manual control insufficient

Conclusion

✓ Successfull implementation of a basic automated activation scheme

✓ Reproducibility comparable to manual activation

✓ Promising basis for developing sophisticated automation
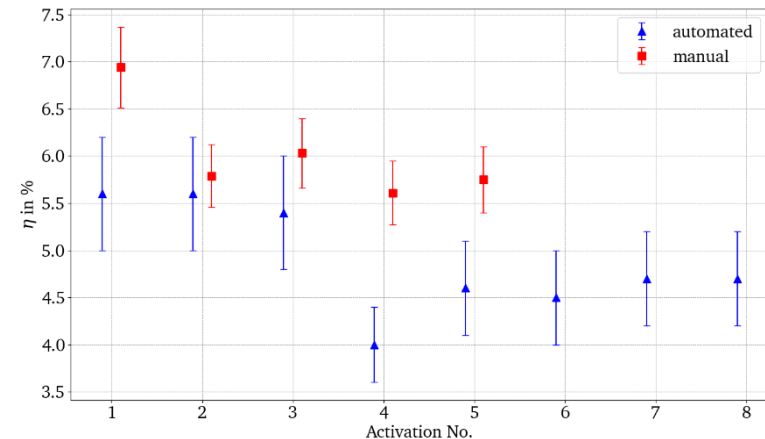
Outlook

- Further development of automated activation scheme

- Implementation of automated partial pressure ratio control

- Lifetime studies

- High-polarization cathodes
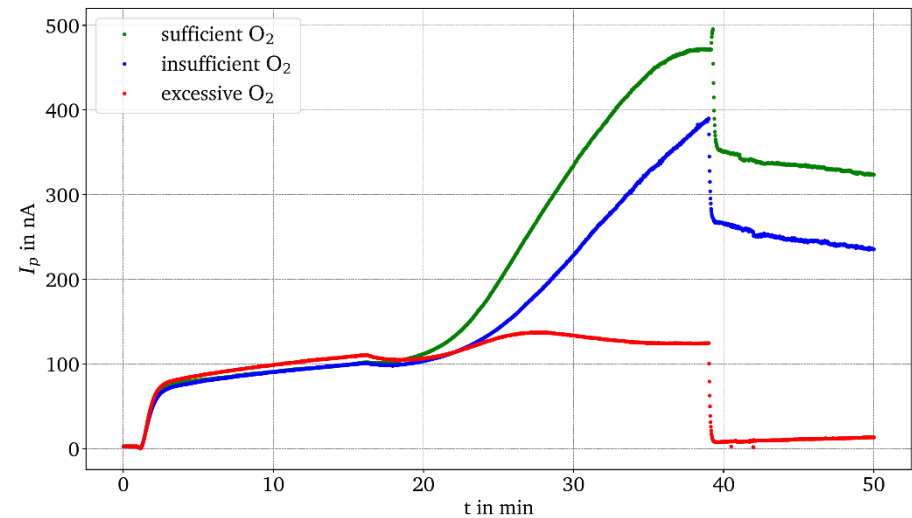
Thank you for your attention!

Quantum Efficiency – Manual vs Automated

Manual:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (5 \pm 1)$ µW
$U_{bias} = 102$ V

No.	η (%)
1	6.9 ± 0.4
2	5.8 ± 0.3
3	6.0 ± 0.4
4	5.6 ± 0.3
5	5.8 ± 0.4

Quantum Efficiency – Manual vs Automated

Manual:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (5 \pm 1)$ µW
$U_{bias} = 102$ V

No.	η (%)
1	6.9 ± 0.4
2	5.8 ± 0.3
3	6.0 ± 0.4
4	5.6 ± 0.3
5	5.8 ± 0.4

Automated:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (8 \pm 2)$ µW
$U_{bias} = 102$ V

No.	η (%)
1	5.6 ± 0.6
2	5.6 ± 0.6
3	5.4 ± 0.6
4	4.0 ± 0.4
5	4.6 ± 0.5
6	4.5 ± 0.5
7	4.7 ± 0.5
8	4.7 ± 0.5
9	0.2 ± 0.1

Quantum Efficiency – Manual vs Automated

Manual:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (5 \pm 1)$ µW
$U_{bias} = 102$ V

No.	η (%)
1	6.9 ± 0.4
2	5.8 ± 0.3
3	6.0 ± 0.4
4	5.6 ± 0.3
5	5.8 ± 0.4

Automated:
$\lambda = (780 \pm 5)$ nm
$P_{laser} = (8 \pm 2)$ µW
$U_{bias} = 102$ V

No.	η (%)
1	5.6 ± 0.6
2	5.6 ± 0.6
3	5.4 ± 0.6
4	4.0 ± 0.4
5	4.6 ± 0.5
6	4.5 ± 0.5
7	4.7 ± 0.5
8	4.7 ± 0.5
~~9~~	~~0.2 ± 0.1~~