Evaluation of the Slow Extraction Survey

iFAST-REX collaboration meeting

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February 17, 2022

Background

- Survey compiled by Florian Kühteubl & Dale Prokopovich
  - Based on the survey from the Slow Extraction Workshop 2016
- Part of the iFAST-REX collaboration
  - Project lead: P. Forck
  - Parameter collection: August - September 2021
- Collection of representative spill measurement data
  - October 2021 - January 2022
- Expansion to the Slow Extraction Workshop

Goal of the survey:

Collect the 'status quo' of SX for all facilities and use the collection as baseline for future collaborations/common developments

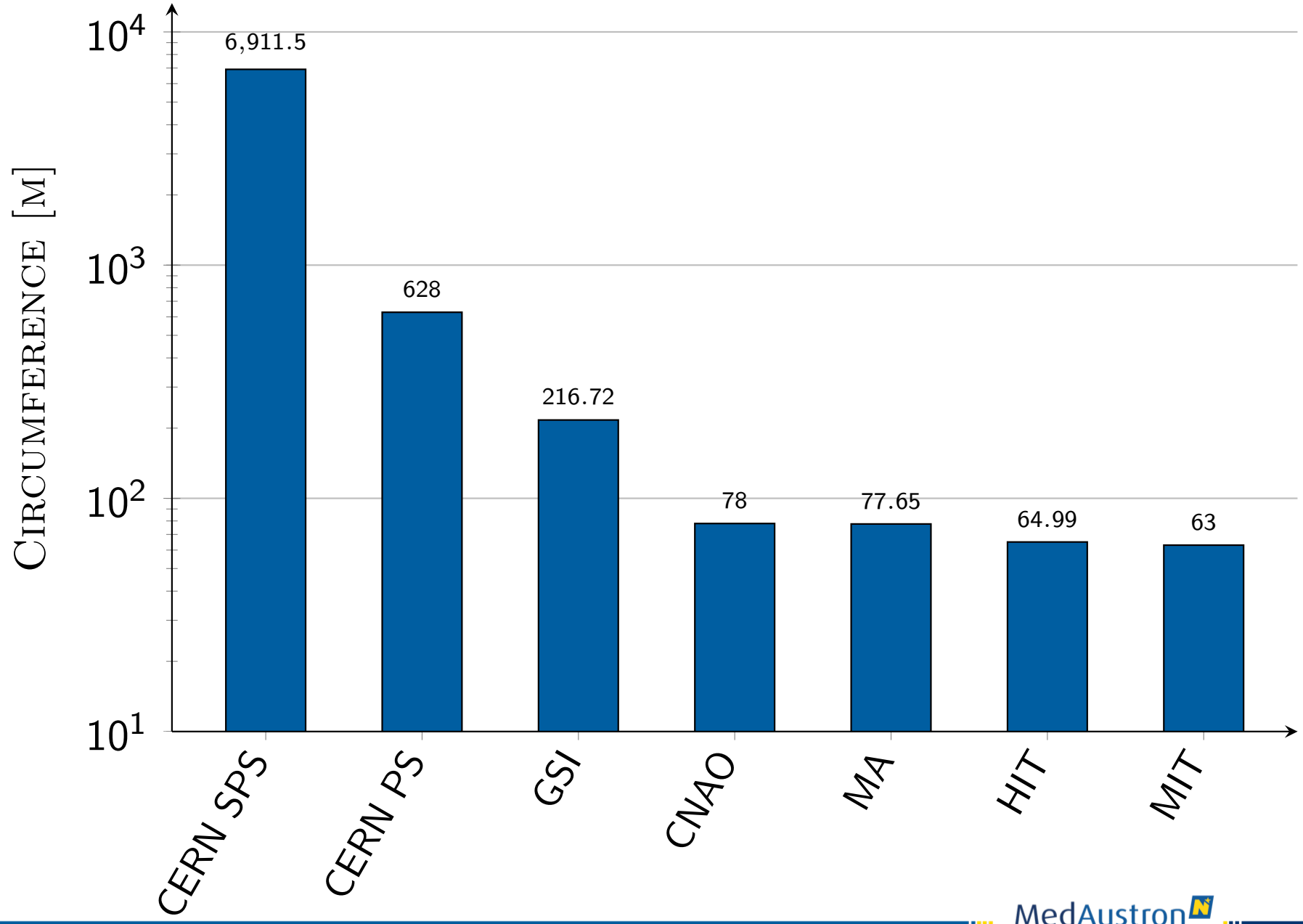
Participants

- Brookhaven National Laboratory (BNL)
- **European Organization for Nuclear Research (CERN)**
- **Centro Nazionale di Adroterapia Oncologica (CNAO)**
- Fermi National Accelerator Laboratory (Fermilab)
- **Helmholtzzentrum für Schwerionenforschung (GSI)**
- Heavy Ion Medical Accelerator in Chiba (HIMAC)
- **Heidelberger Ionenstrahl-Therapiezentrum (HIT)**
- Institute for High Energy Physics (IHEP)
- Japan Proton Accelerator Research Complex (J-PARC)
- **MedAustron (MA)**
- **Marburger Ionenstrahl-Therapiezentrum (MIT)**

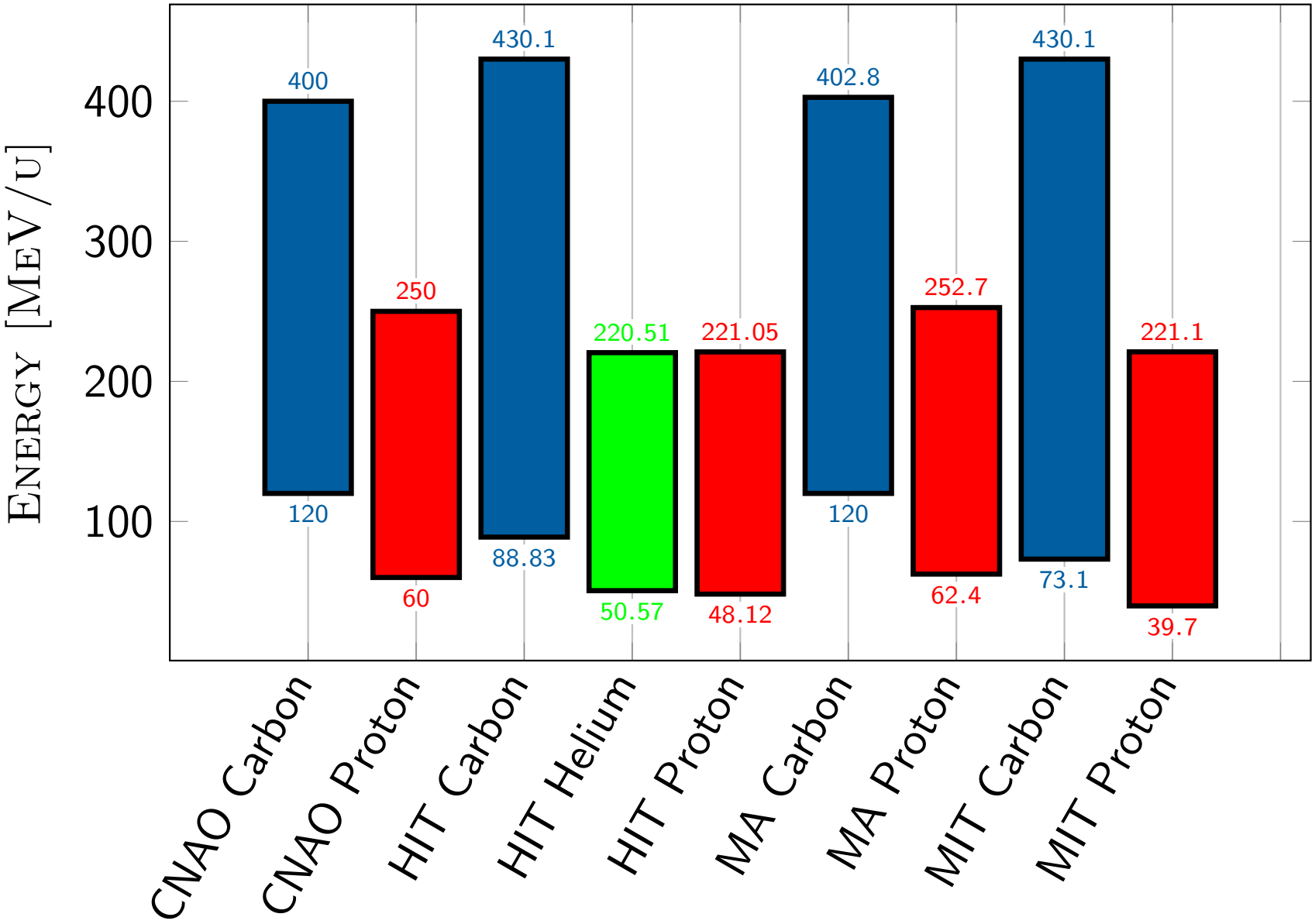
General Information

	Name	Particle type(s)	Extraction method(s)	Bunched?
CERN	PS and SPS	Proton	COSE	✗
CNAO	Synchrotron	Proton Carbon	Betatron Core RFKO	✗ ✓
GSI	SIS-18	Proton all ions until Uranium	Tune Sweep RFKO	✓or ✗ ✓
HIT	HIT-Accelerator	Proton Carbon Helium	RFKO	✓
MedAustron	Synchrotron	Proton Carbon	Betatron Core	✗
MIT	IONTRIS (Siemens)	Proton Carbon	RFKO	✓

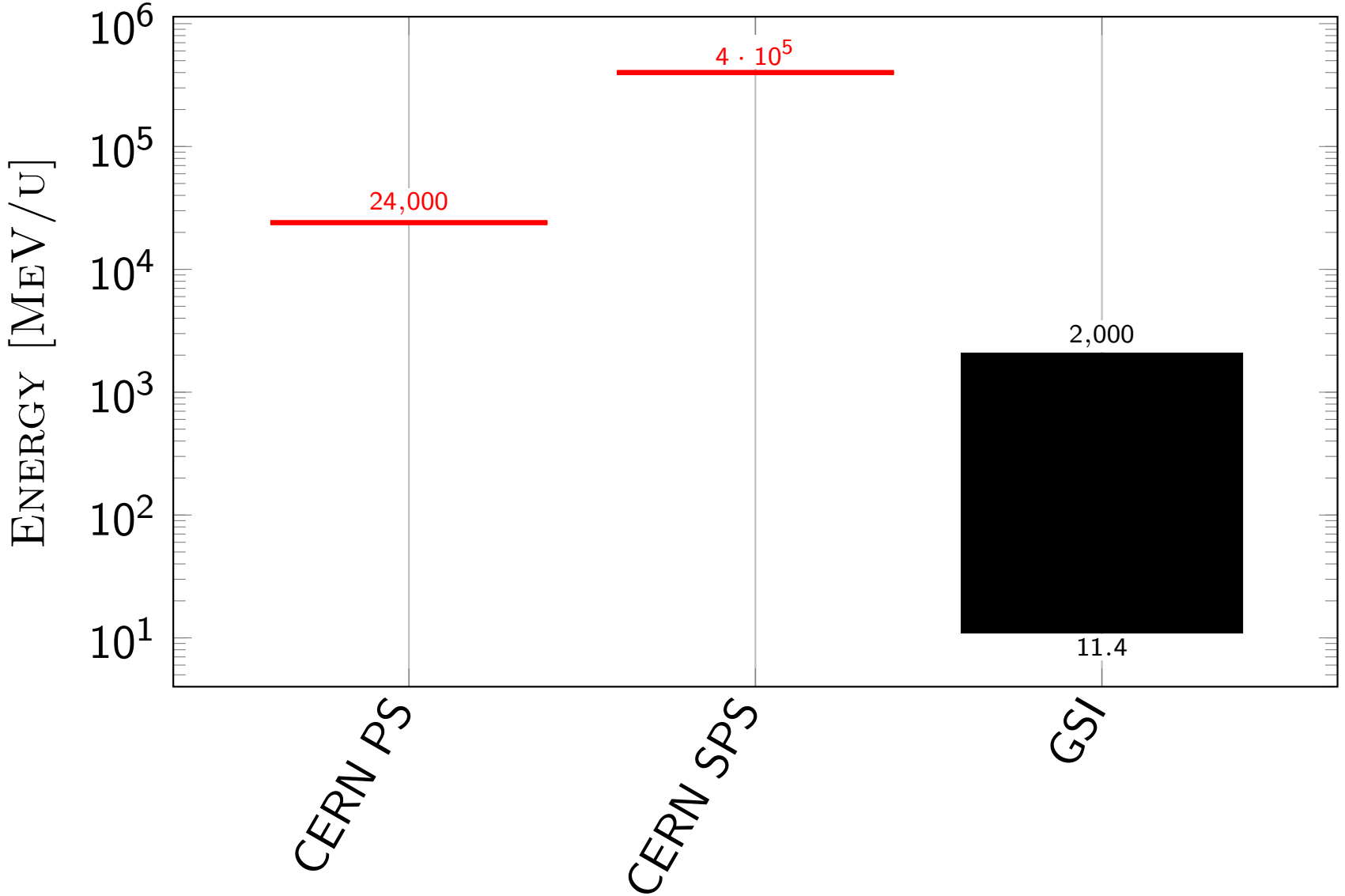
Accelerator Circumference



Energy range - medical-focused facilities



Energy range - research-focused facilities



Extraction Parameter - medical-focused facilities

			Horizontal tune $\rightarrow$ Resonance	Horizontal chromaticity	Mom. offset [‰]	Mom. spread [‰]
CNAO	Betatron	Proton	1.672 $\rightarrow$ 5/3	-4.0	-25/8.5	0.8*
		Carbon			-20/8.5	0.8*
	RFKO	Proton		-1.0	-25/8.5	0.4*
		Carbon			-10/8.5	0.25*
HIT		Carbon	1.68 $\rightarrow$ 5/3	-0.7 $\pm$ 0.05	0	$\approx$ 2
		Helium	1.685 $\rightarrow$ 5/3			N/A
		Proton	1.688 $\rightarrow$ 5/3			$\approx$ 2
MA			1.676 $\rightarrow$ 5/3	-4.0	-20/8.5	1.15**
MIT		Proton	1.715 $\rightarrow$ 5/3	N/A	0	1
		Carbon	1.698 $\rightarrow$ 5/3			1.2

* root mean square

** uniform momentum distribution, $\sigma = \sqrt{dpp^2_{total}/12}$

Extraction Parameter - research-focused facilities

		Horizontal tune $\rightarrow$ Resonance	Horizontal chromaticity	Mom. offset [‰]	Mom. spread [‰]
CERN	PS	$6.323 \rightarrow 19/3$	-1.67	3	1.7*
	SPS	$26.62 \rightarrow 80/3$	-33.5	1.5	0.87*
GSI		$4.29 \rightarrow 13/3$	-4	0	0.5

* uniform momentum distribution, $\sigma = \sqrt{dpp_{total}^2/12}$

Duty factor

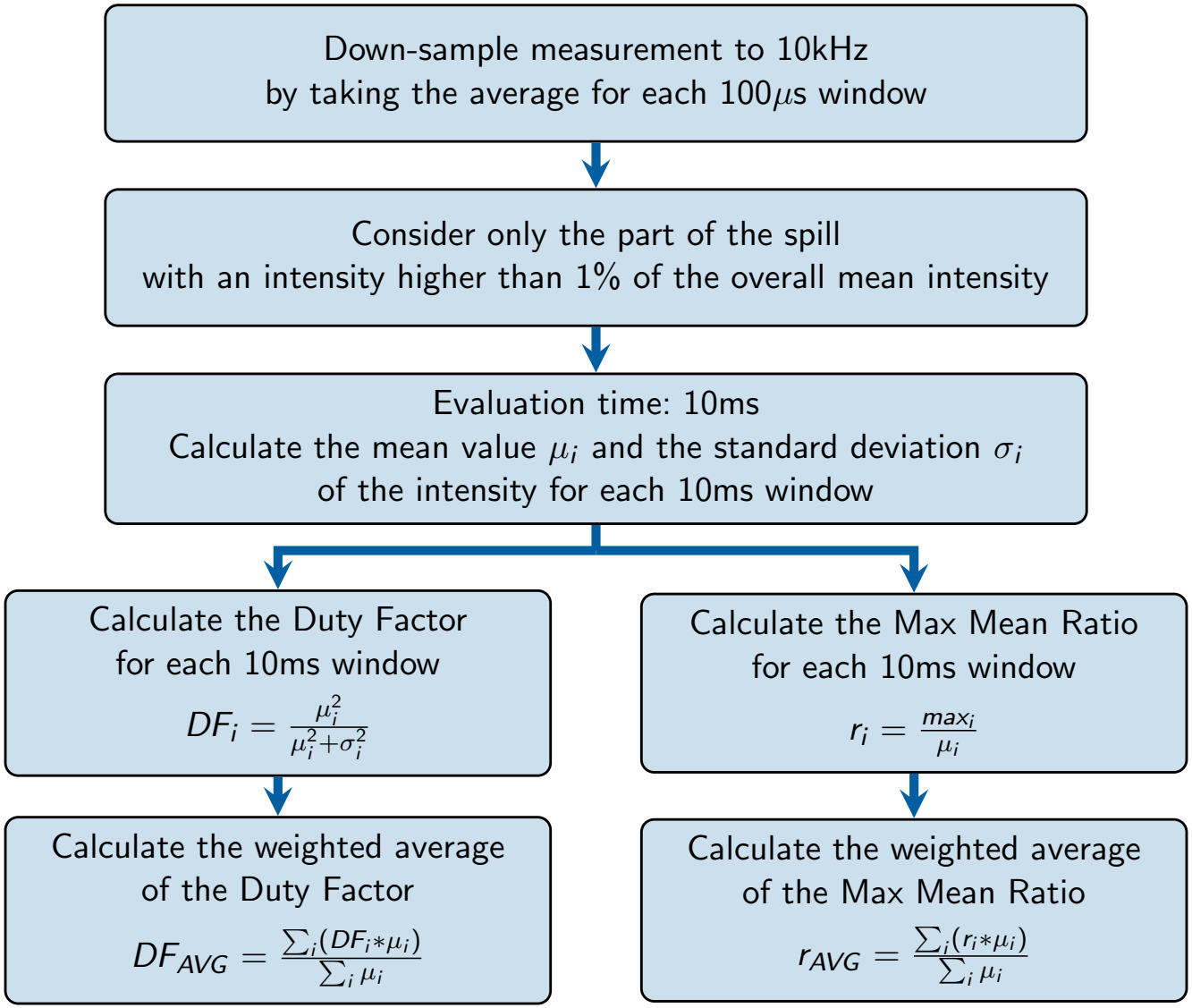
		Time resolution [μs]	Duty Factor
CERN	PS	1,000	0.9
	SPS	500	0.986
CNAO		100 - 10,000	0.4 - 0.8
GSI		10	0.5
HIT		50	0.95 - 0.97
MA		100	0.83
MIT		50	0.93

Attention:

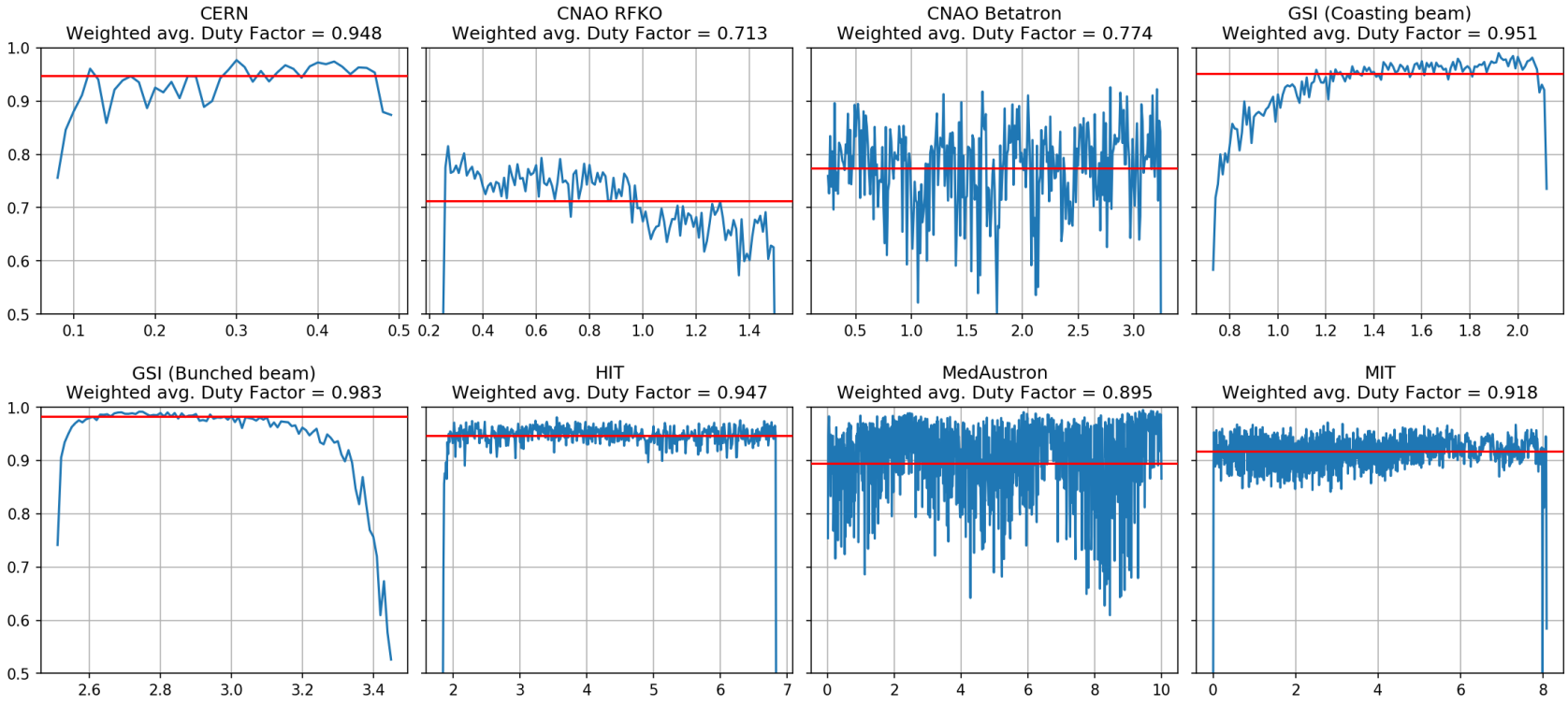
No standardized definition of duty factor!

Direct comparisons are limited!

Proposal of standardized parameter evaluation

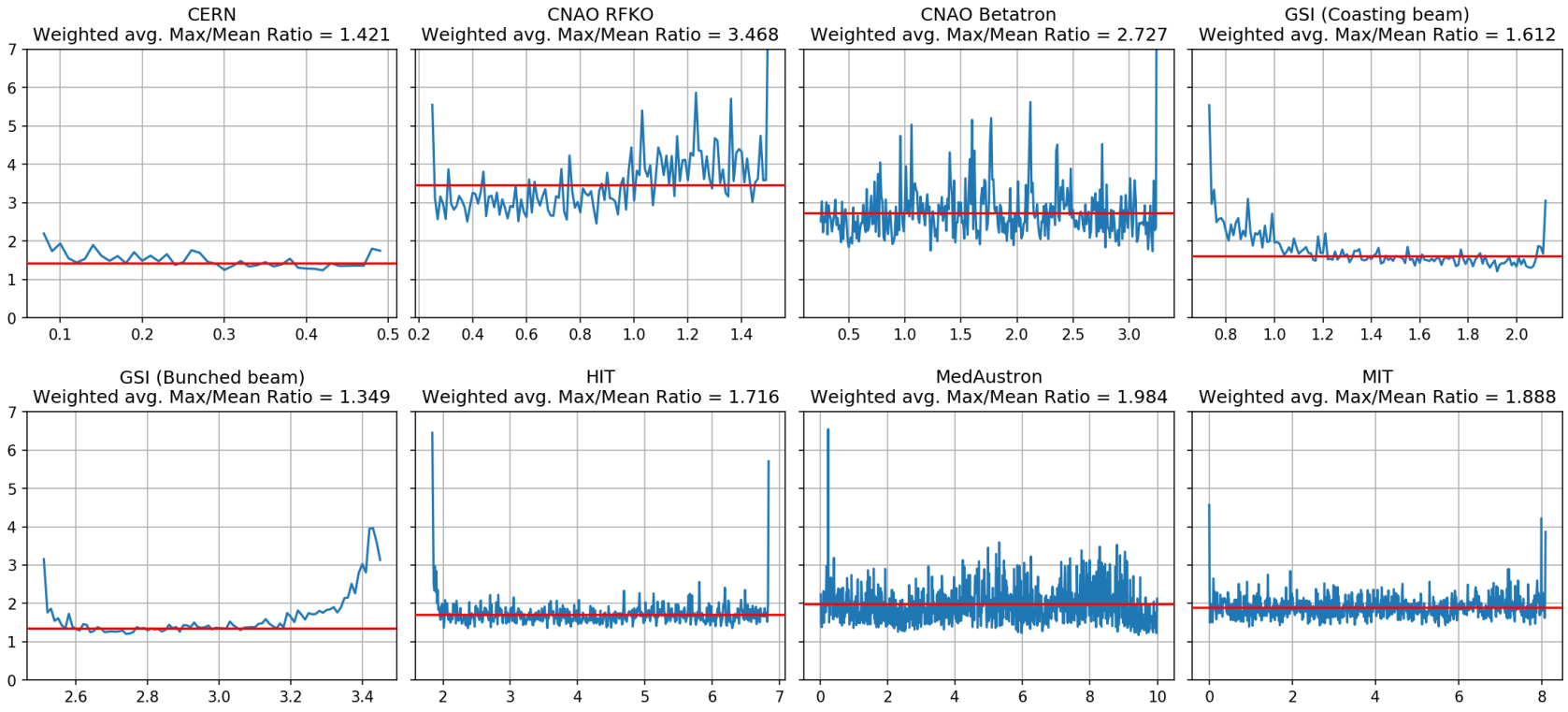


Standardized Duty Factor (Proton)



CERN PS	**CNAO** RFKO	**CNAO** Betatron	**GSI** coasting	**GSI** bunched	**HIT**	**MedAustron**	**MIT**
0.9	0.4-0.8	0.4-0.8	0.5	0.5	0.95-0.97	0.83	0.93
0.948	0.713	0.774	0.951	0.983	0.947	0.895	0.918

Standardized Max Mean Ratio (Proton)



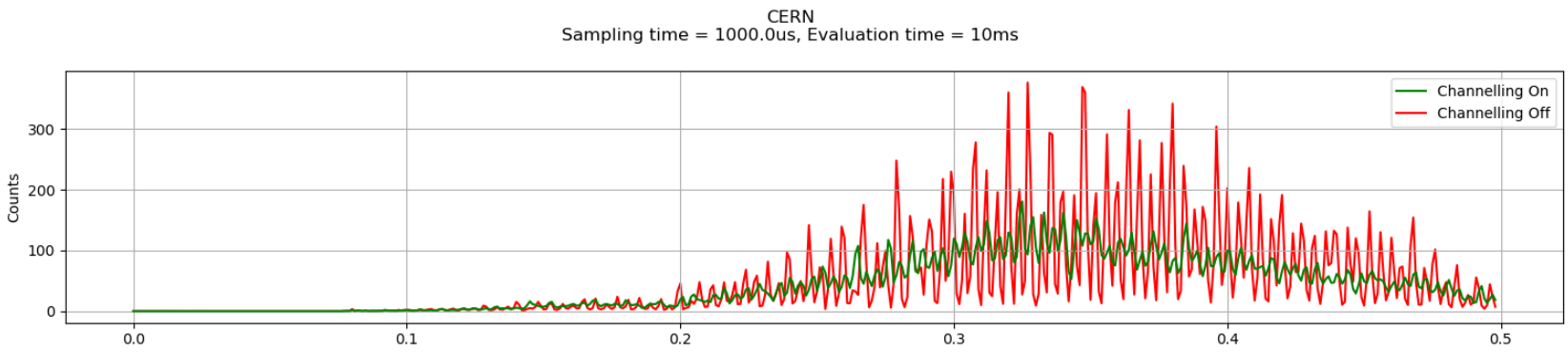
CERN PS	**CNAO** RFKO	**CNAO** Betatron	**GSI** coasting	**GSI** bunched	**HIT**	**MedAustron**	**MIT**
1.421	3.468	2.727	1.612	1.349	1.716	1.984	1.888

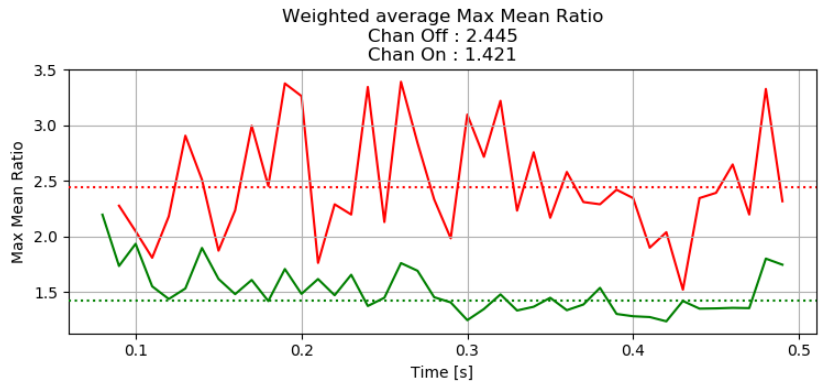
Ripple control schemes

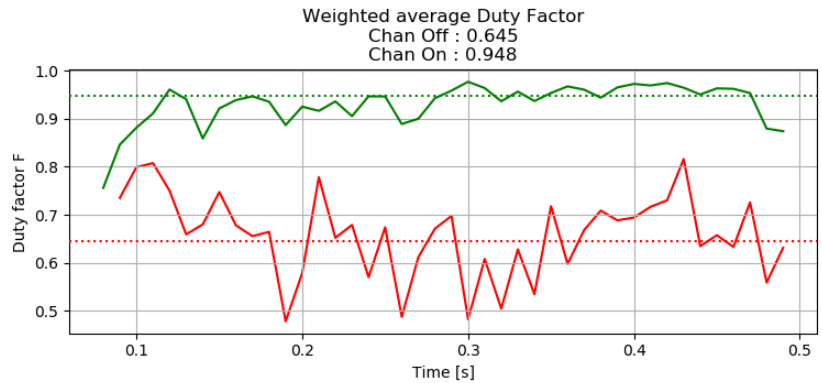
		HF empty bucket sweeping	RF channelling	Longitudinal RF noise	(Air core) quad
CERN	PS	✗	✓	✗	✗
	SPS	✗	✗	✗	✗
CNAO	Betatron	✓	✓	✗	✗
	RFKO	✗	✗	✗	✓
GSI		✗	✓- Tune wobbling	✗	✗
HIT		✗	✗	✗	✗
MA	Proton	✗	✓*	✗	✗
	Carbon	✗	(✓)	✗	✗
MIT		✗	✗	✗	(✓)

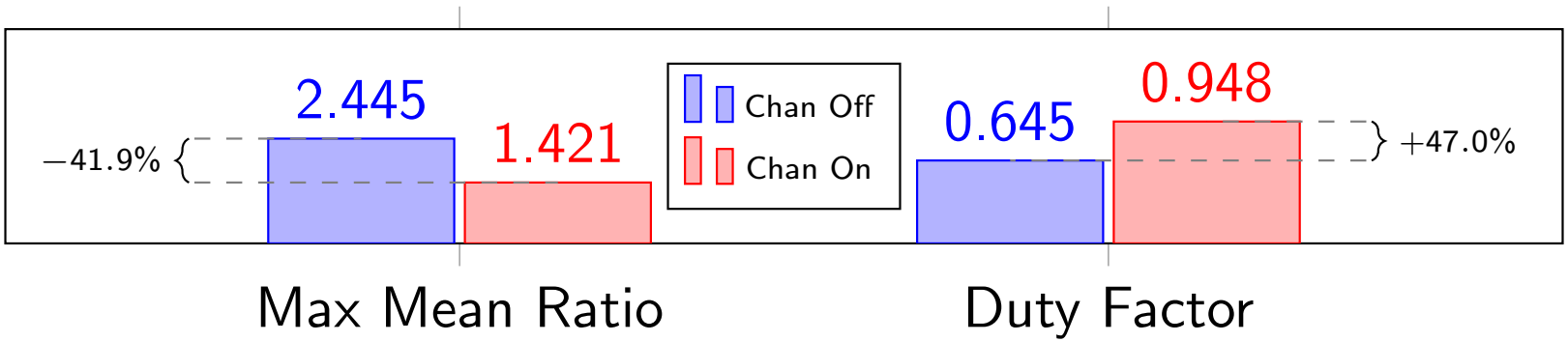
(✓) = experimental/in testing

Ripple control schemes - RF channelling (CERN)

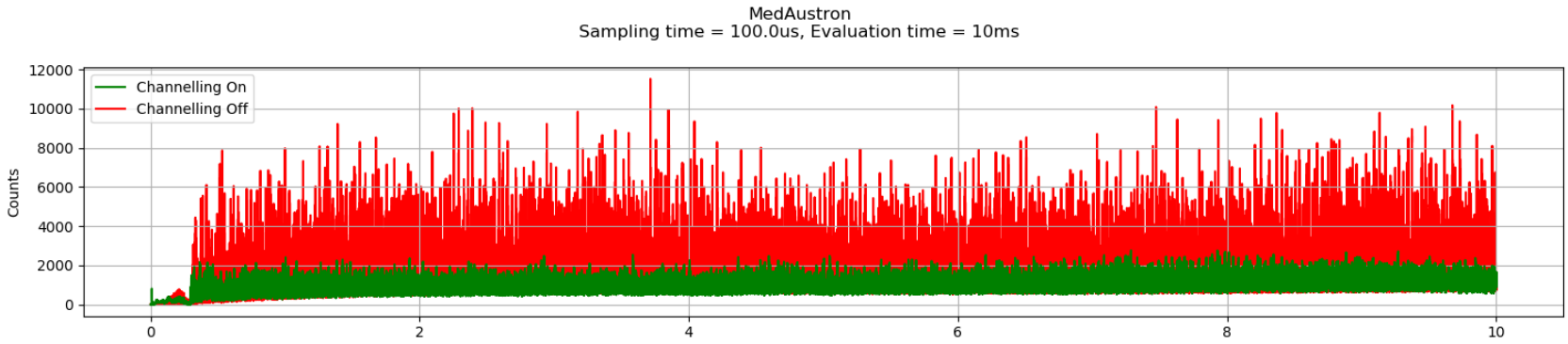


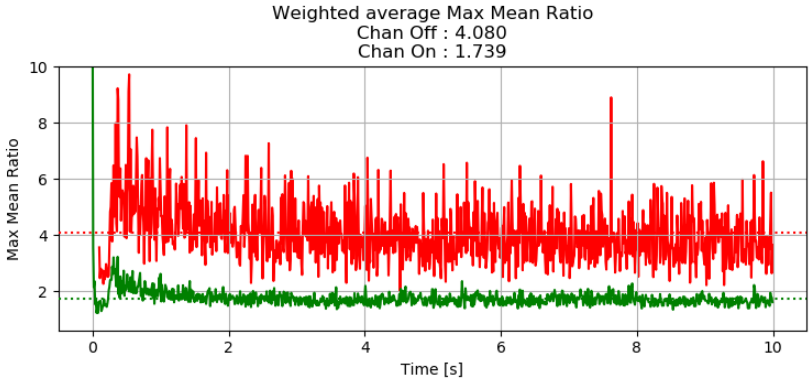


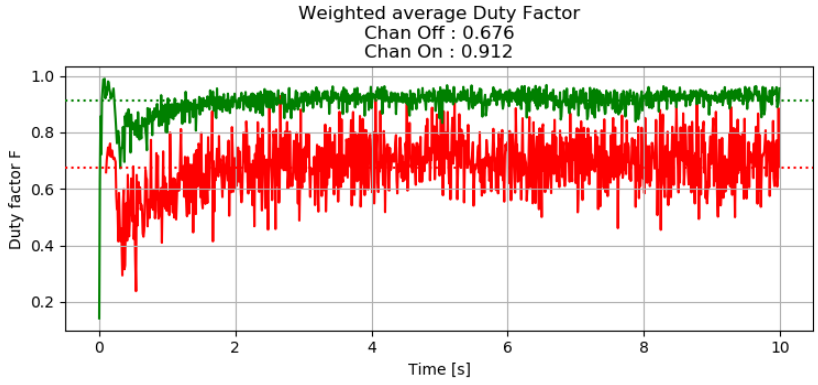


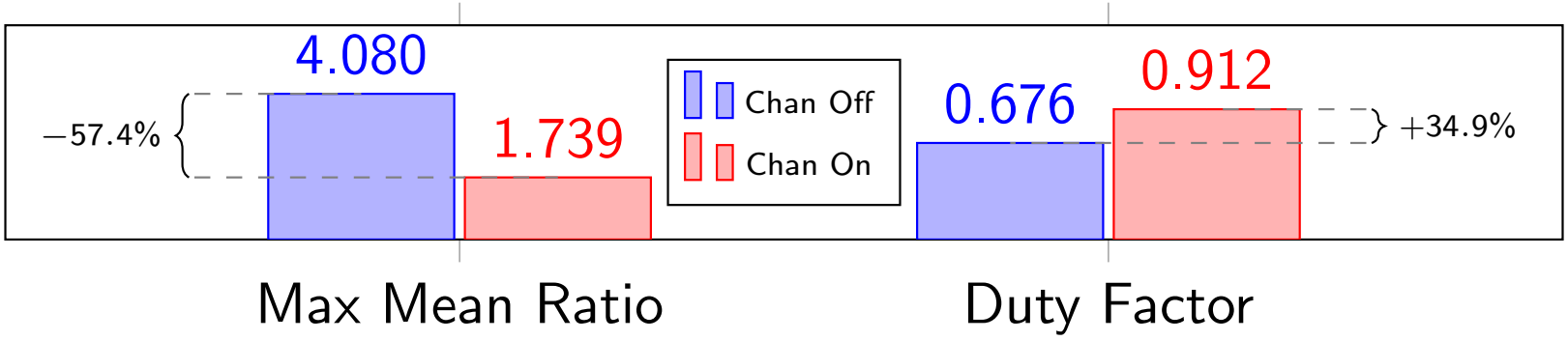


Ripple control schemes - RF channelling (MedAustron)

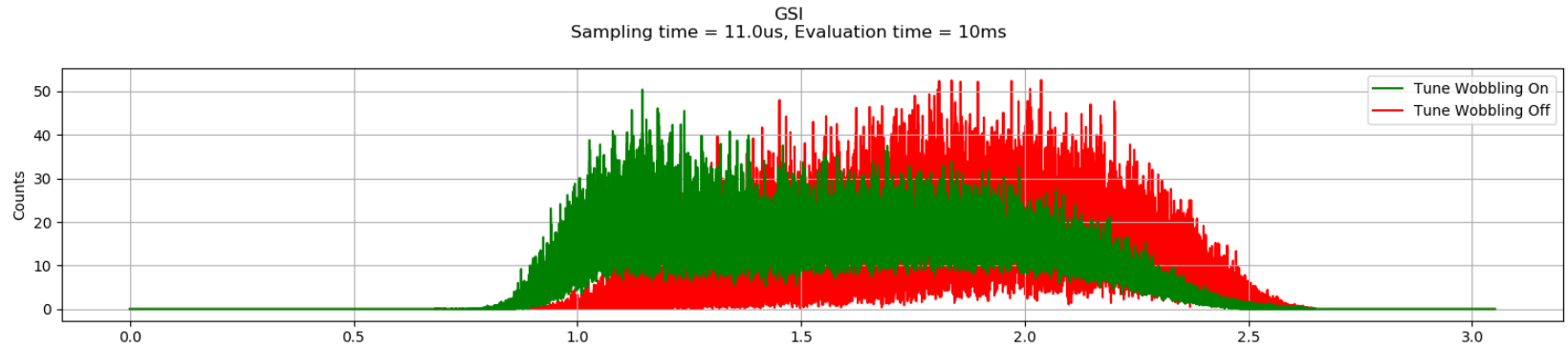


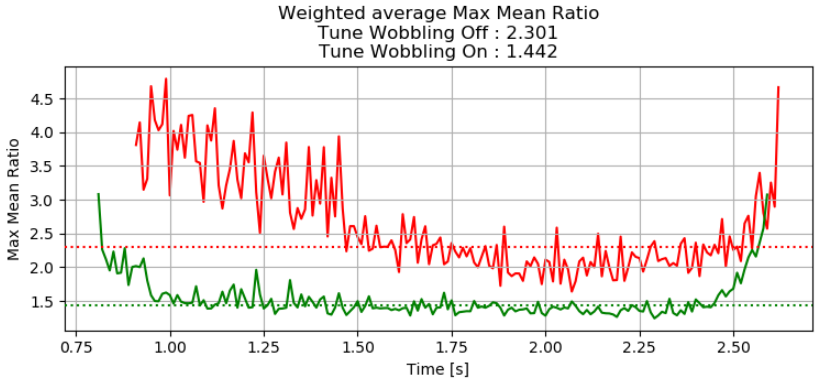


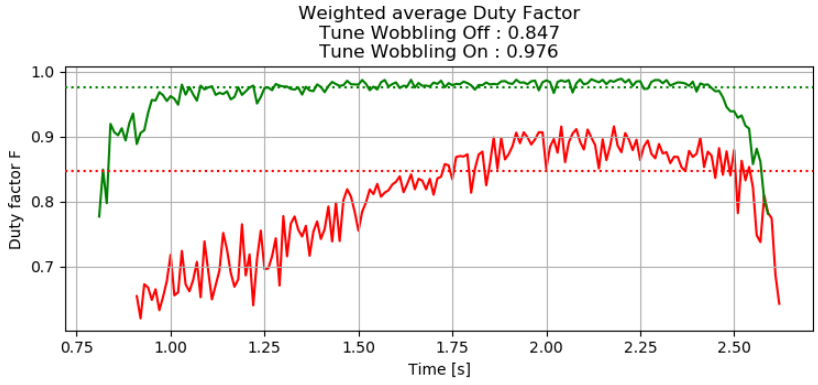


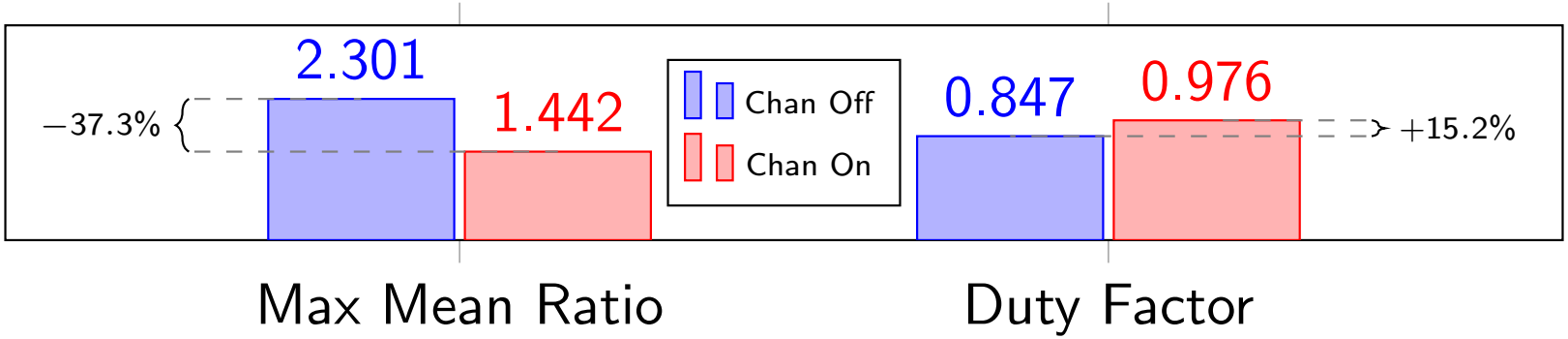


Ripple control schemes - Tune Wobbling (GSI)

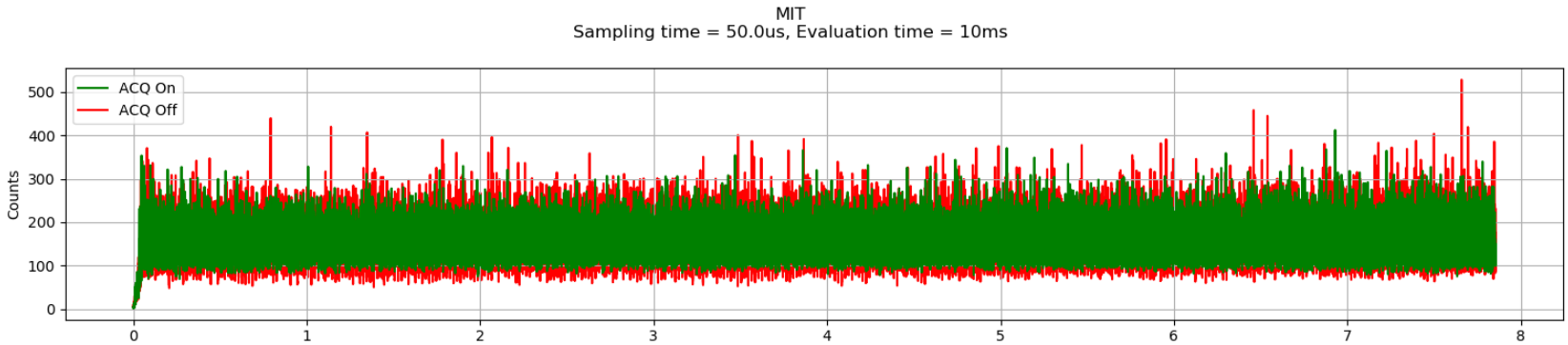


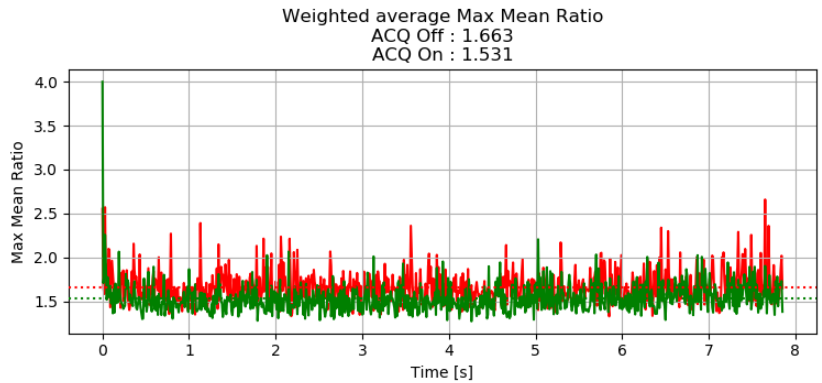


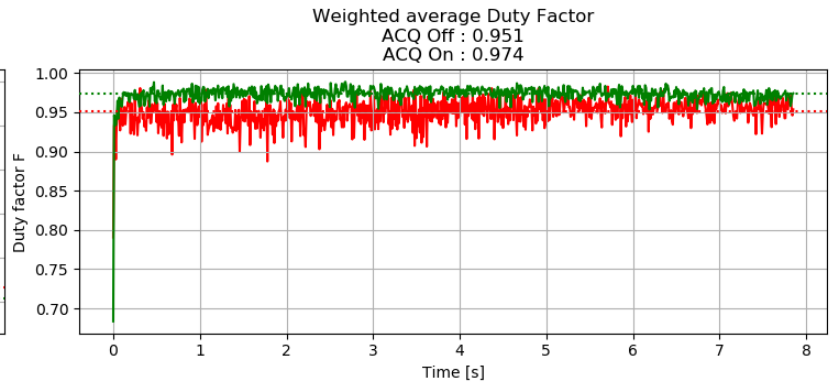


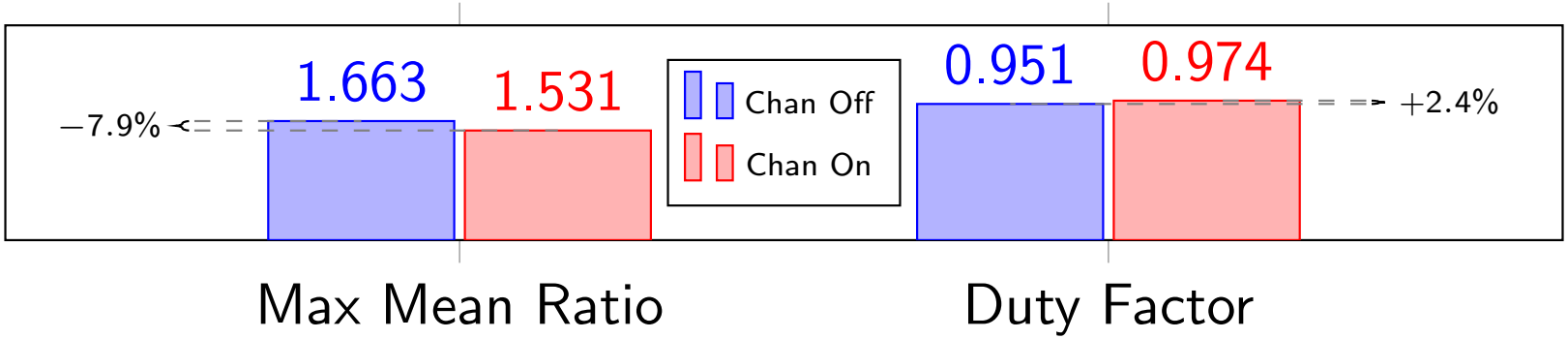


Ripple control schemes - Air Core Quad (MIT)









Outlook

- Written report containing all collected data
- Improvement of other common parameter definitions (extraction efficiency, non-delivery time, ...)
- FFT analysis of spill measurement data
- Fostering discussions between the institutions in an open dialogue

Thank you for your attention!