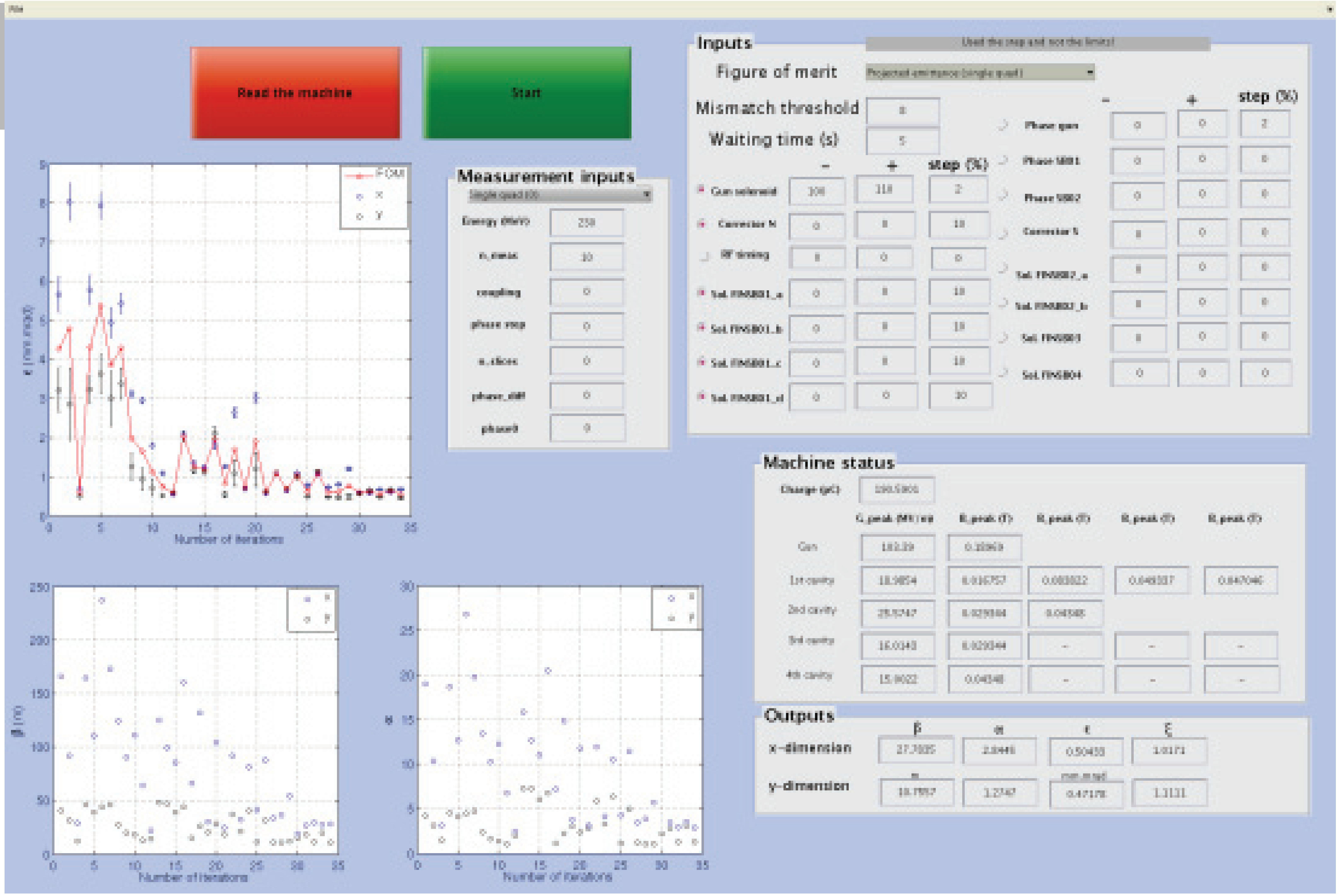
Rasmus Ischebeck

Diagnostics for FELs and ERLs

CERN Accelerator School: Free Electron Lasers and Energy Recovery Linacs

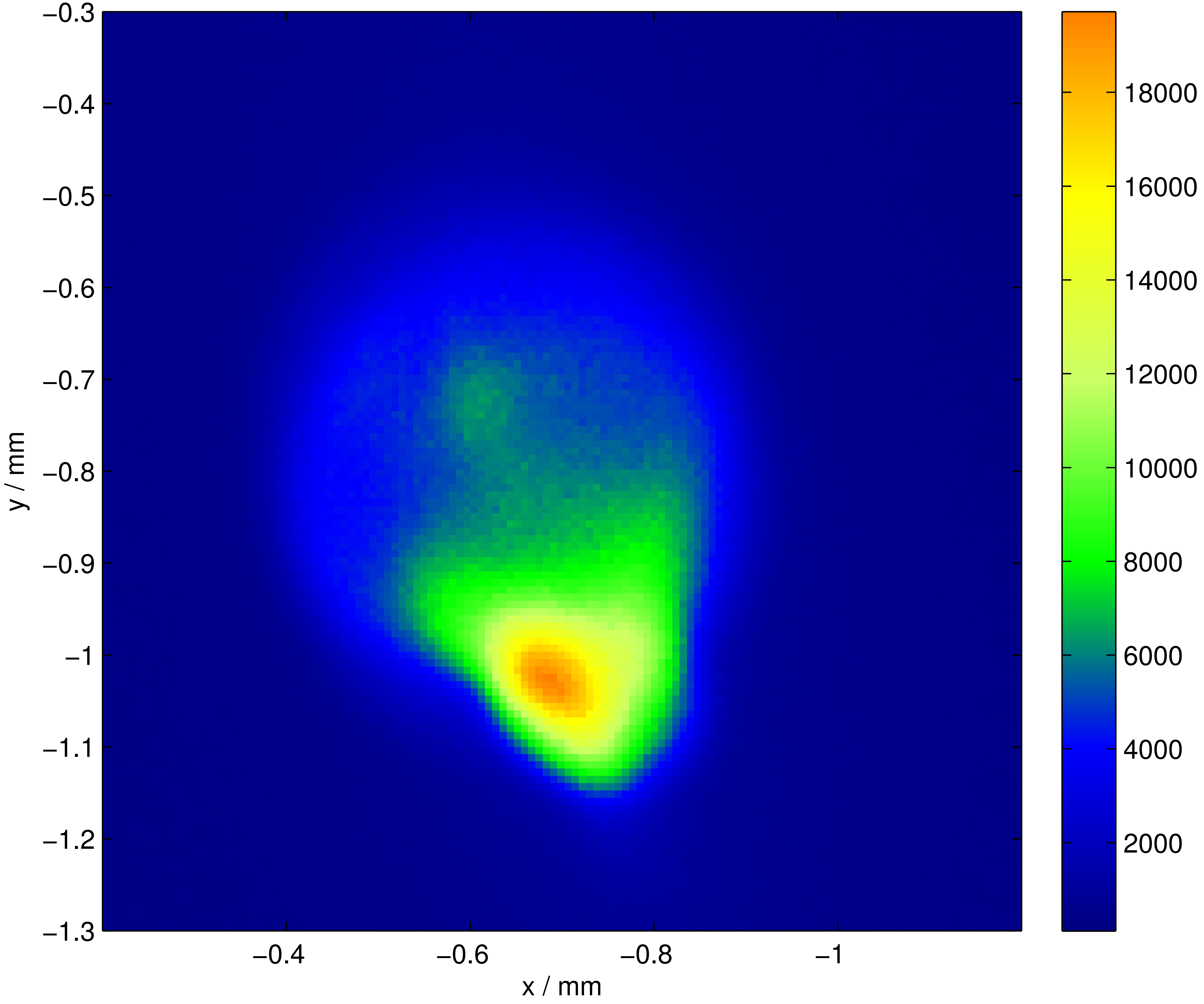
2016-06-08

Usage of Diagnostics: Measurement and Optimization of Beam Parameters



- Optimization of the emittance from a photocathode gun
- Figure of merit: emittance measured on screen
- Optimization of magnetic fields in the gun, and of RF parameters

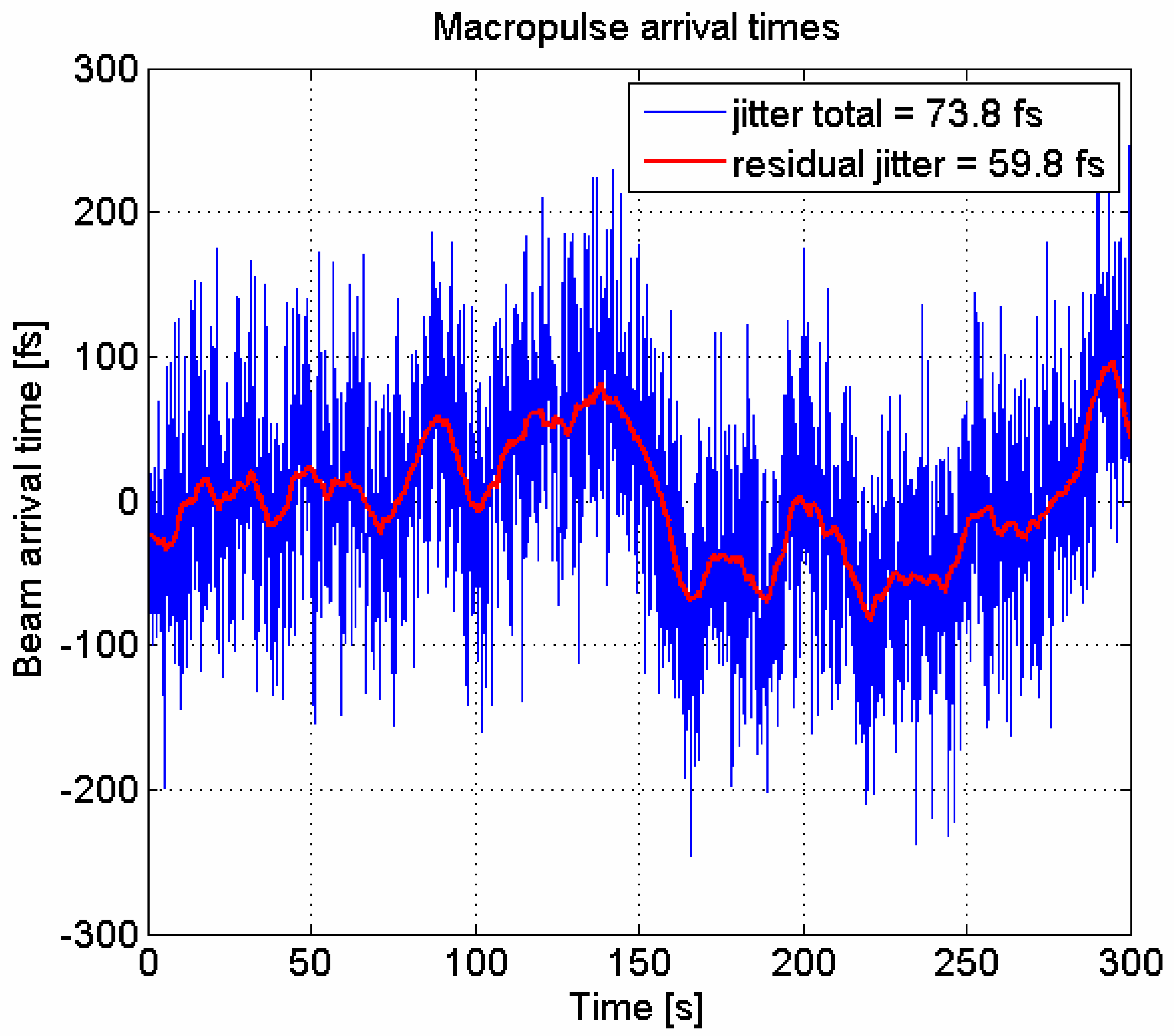
Usage of Diagnostics: Find Errors



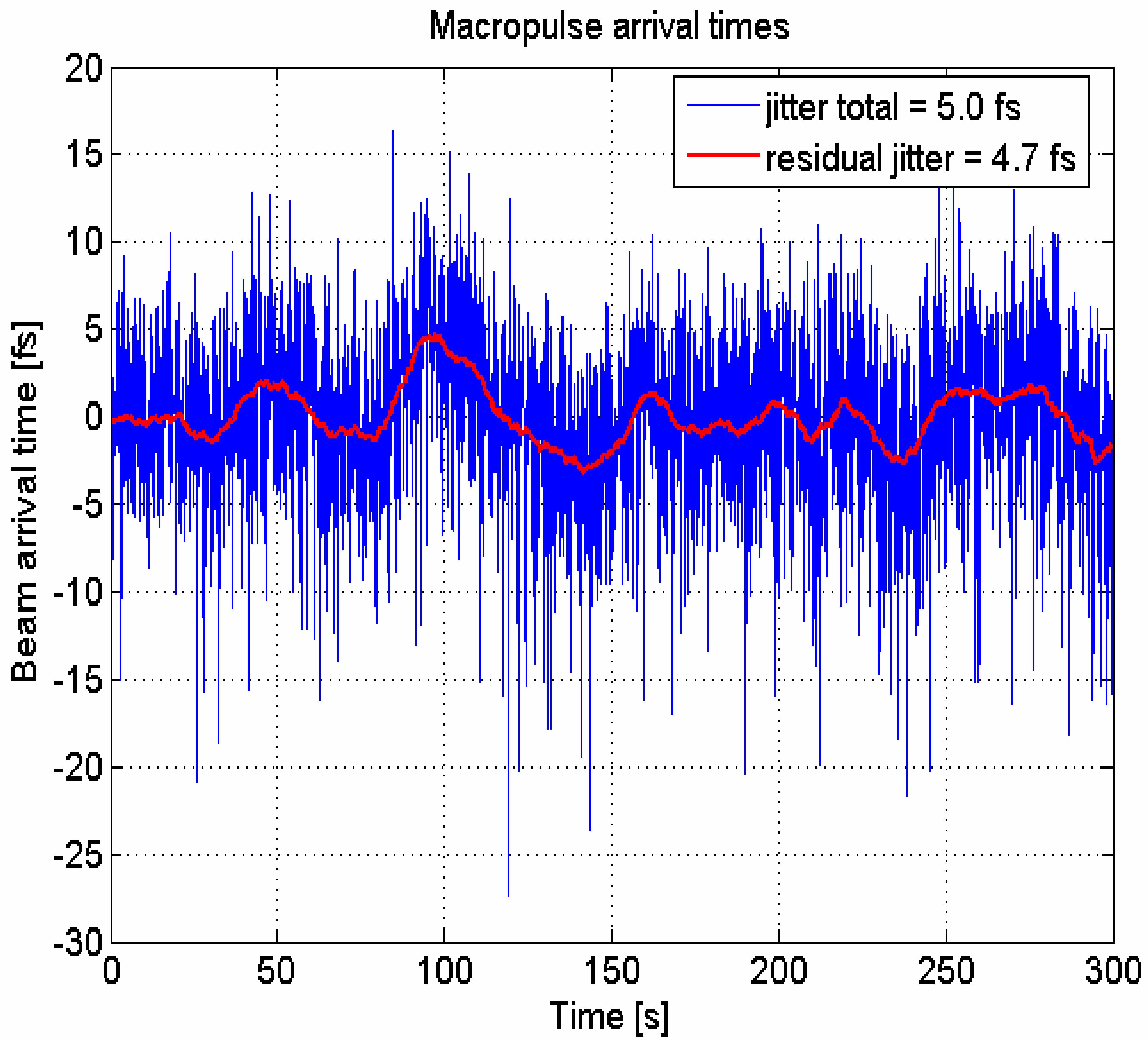
- Asymmetry in the beam caused by mis-alignment

Usage of Diagnostics: Stabilization of Systems

No Beam Based Feedback
Learning Feed Forward ON
rms = 74 fs

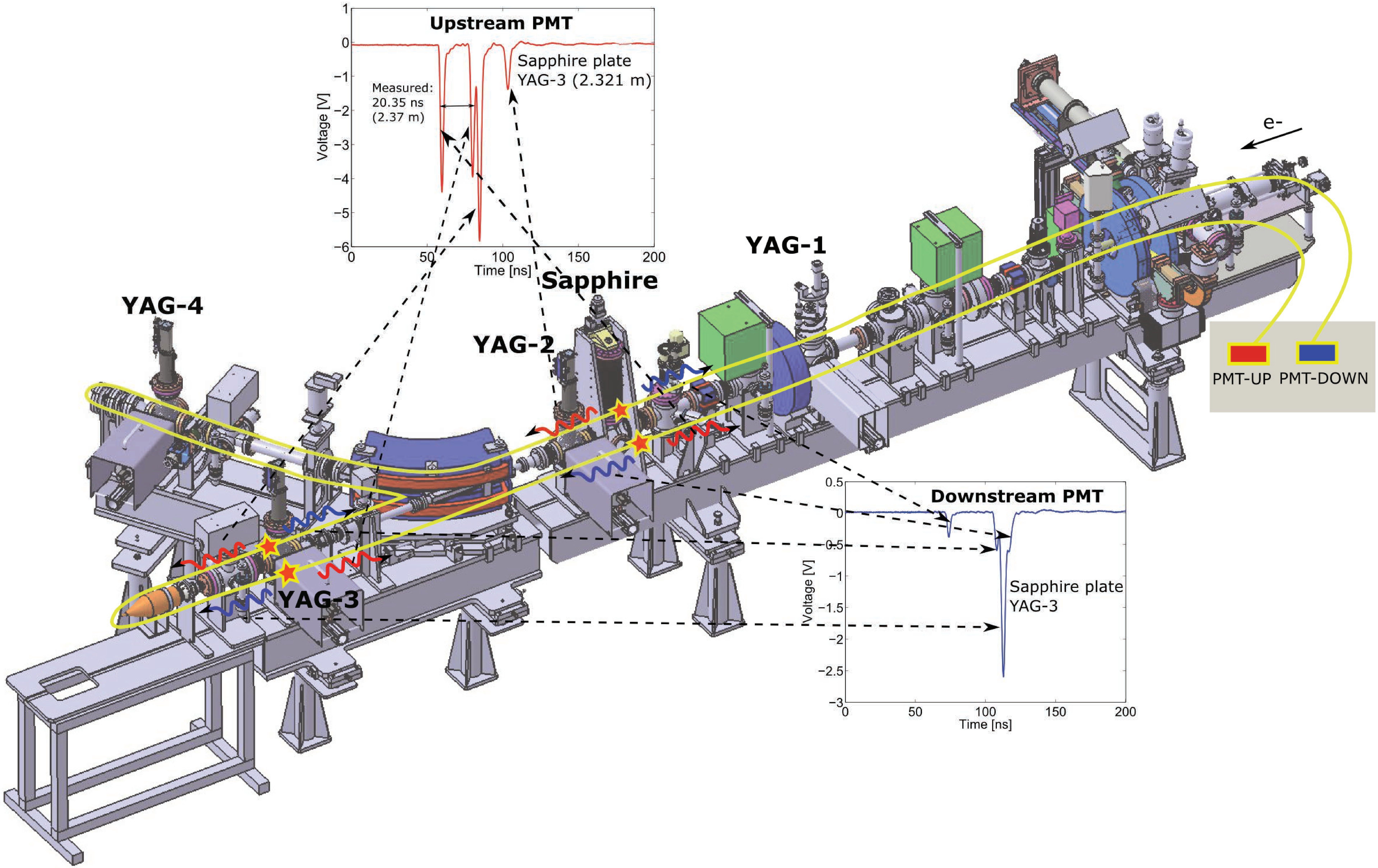


With Beam Based Feedback
running in ACC1 and ACC39
rms = 5 fs



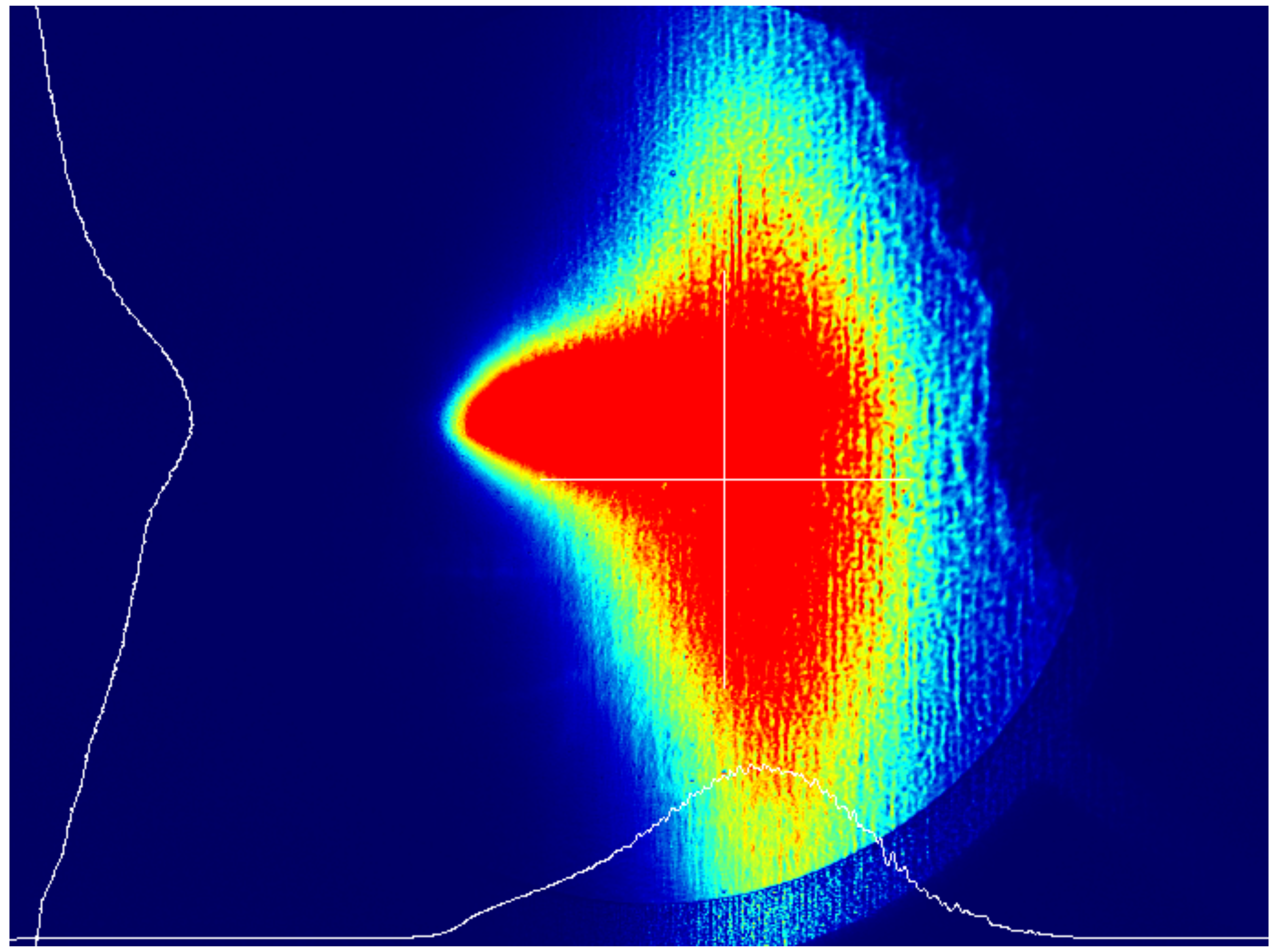
Waldemar Koprek, DESY

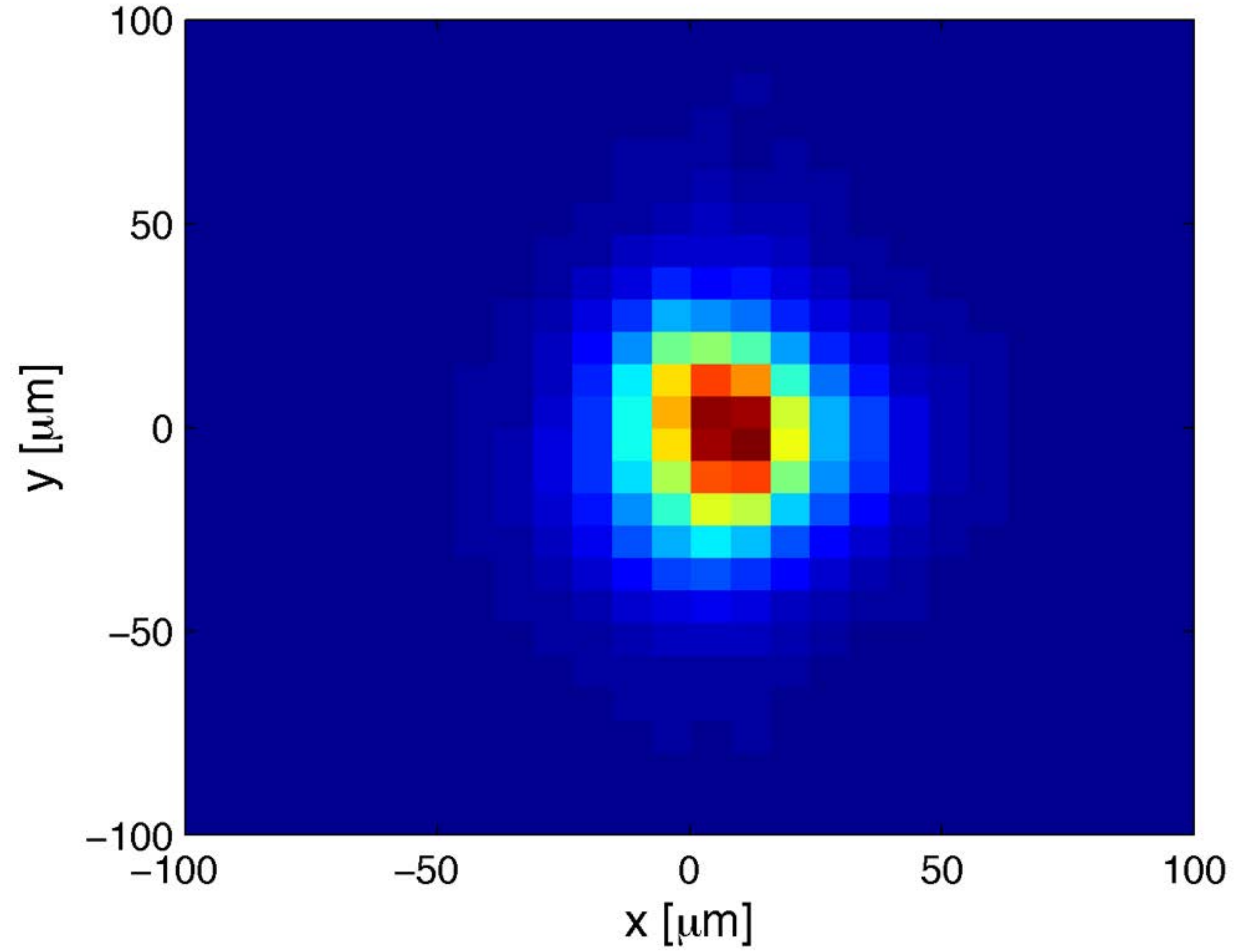
Usage of Diagnostics: Personnel and Machine Safety

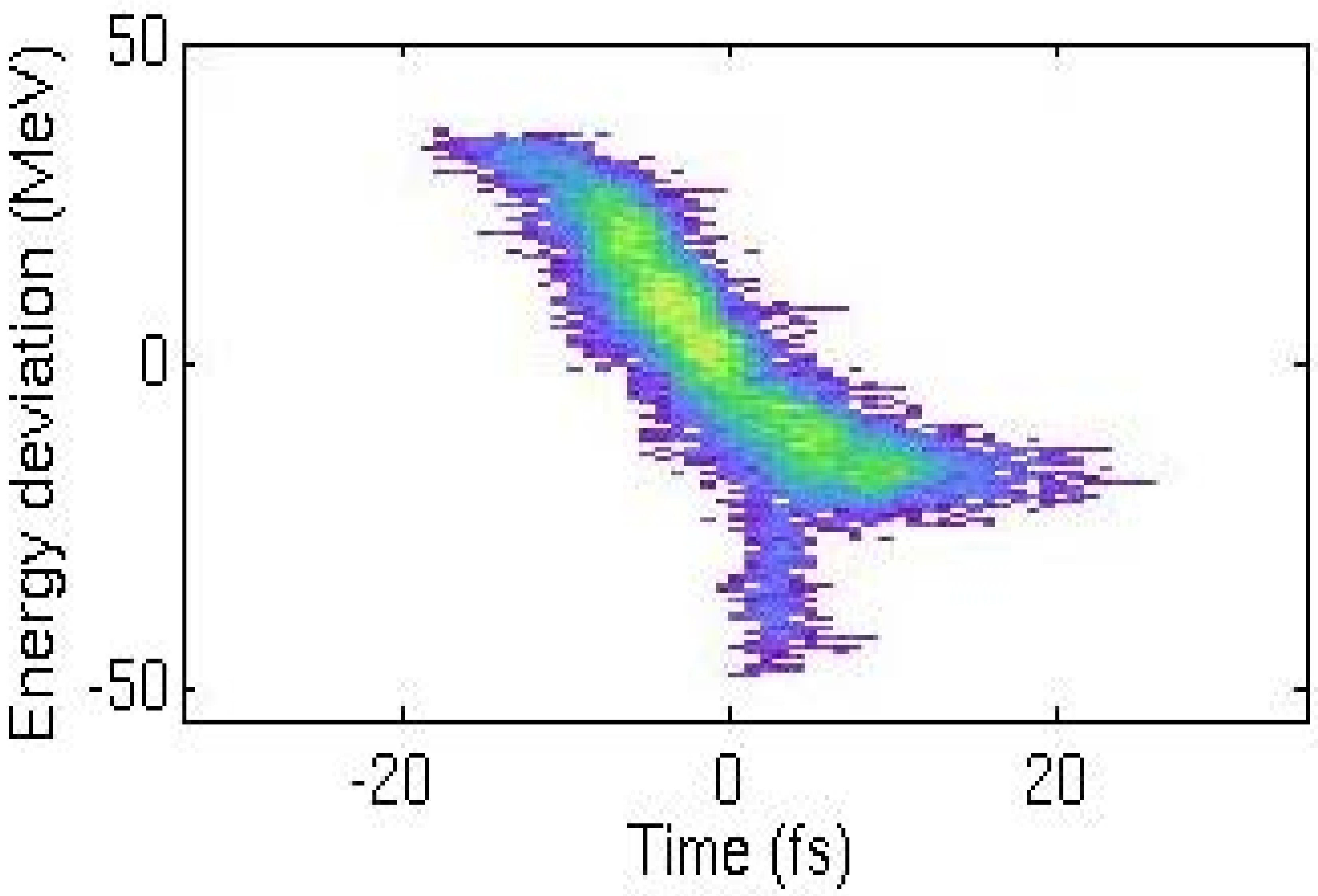


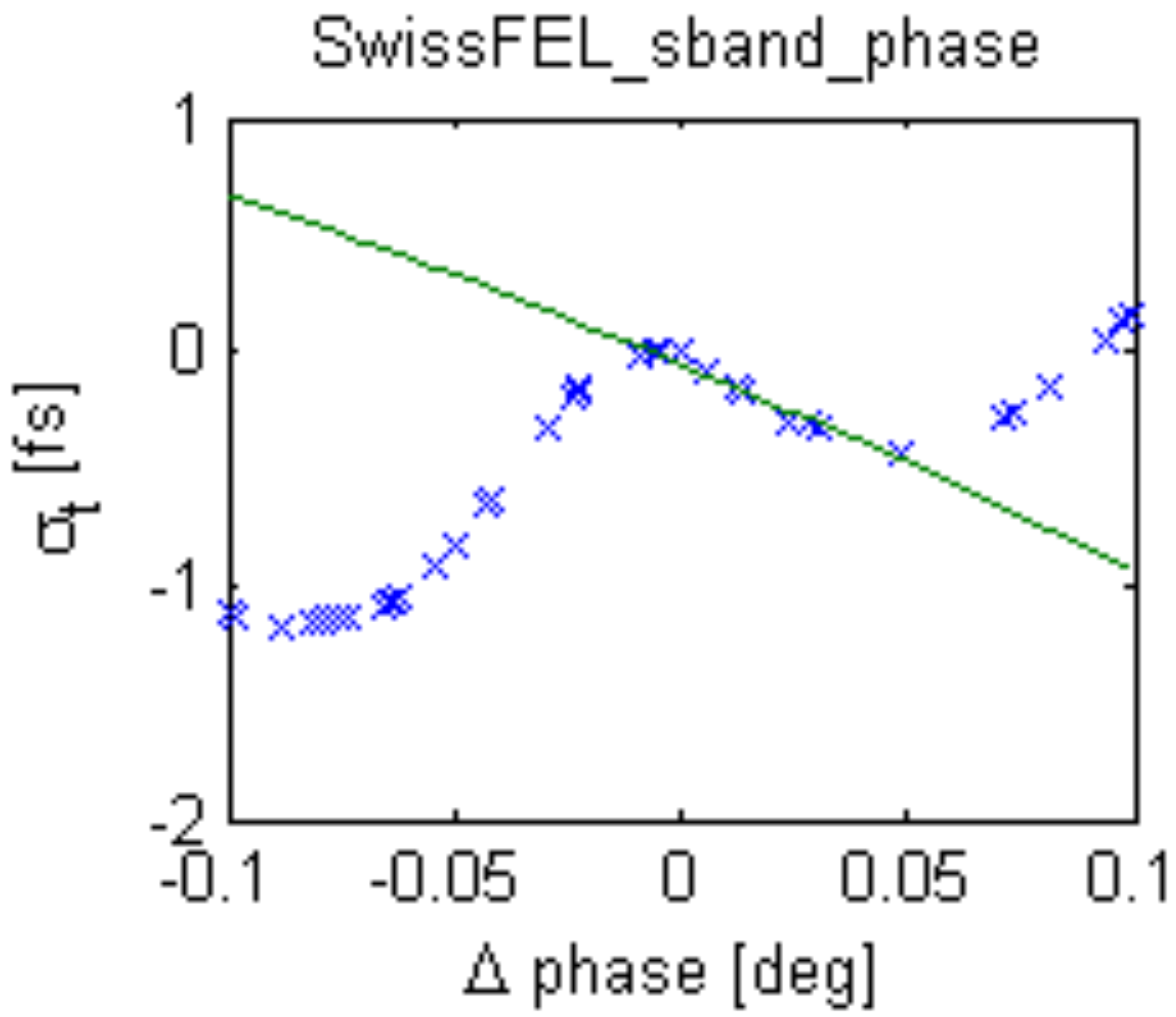
I. Chaikovska, CERN

Diagnostics at FELs — Unique Challenges



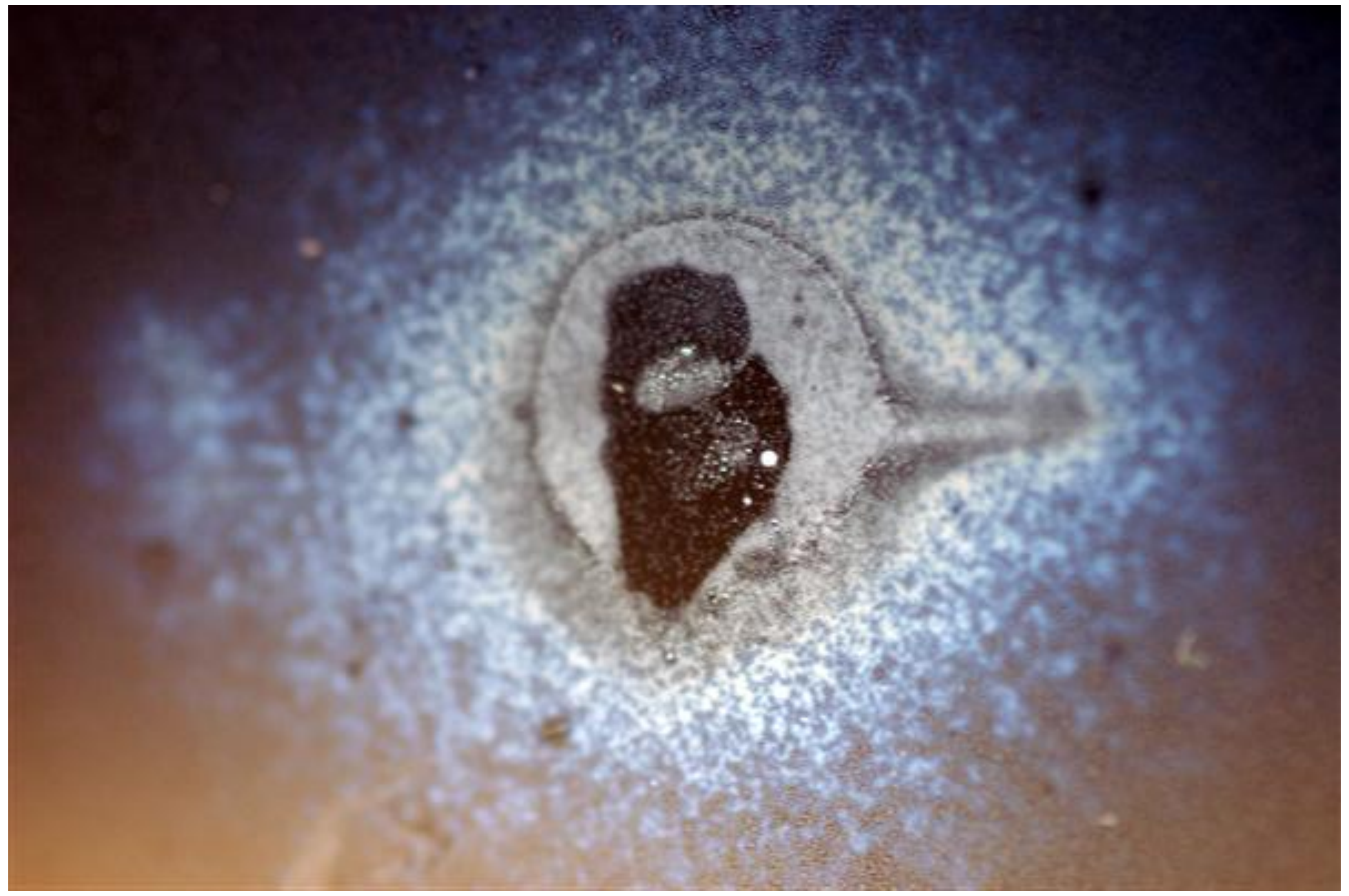


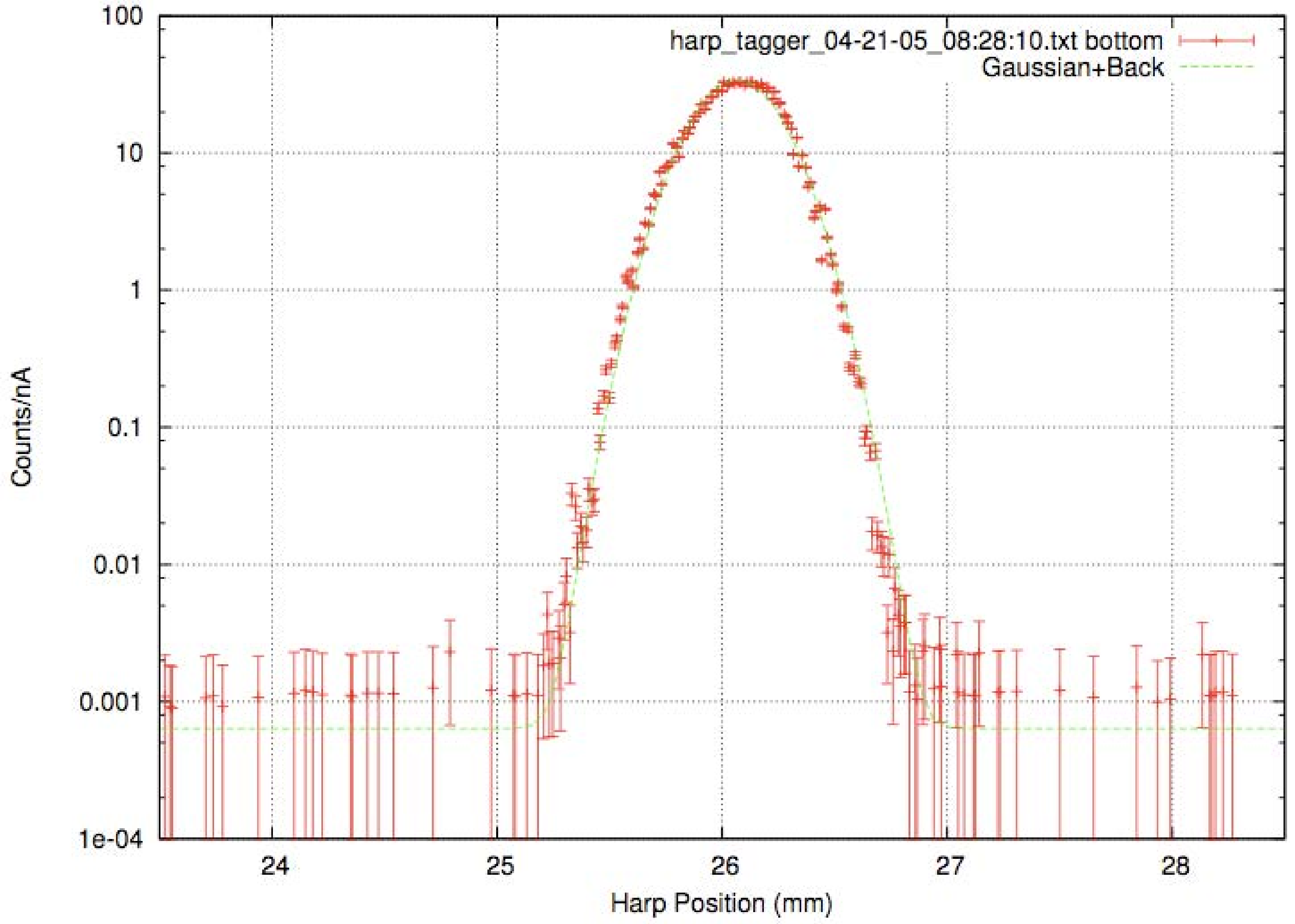


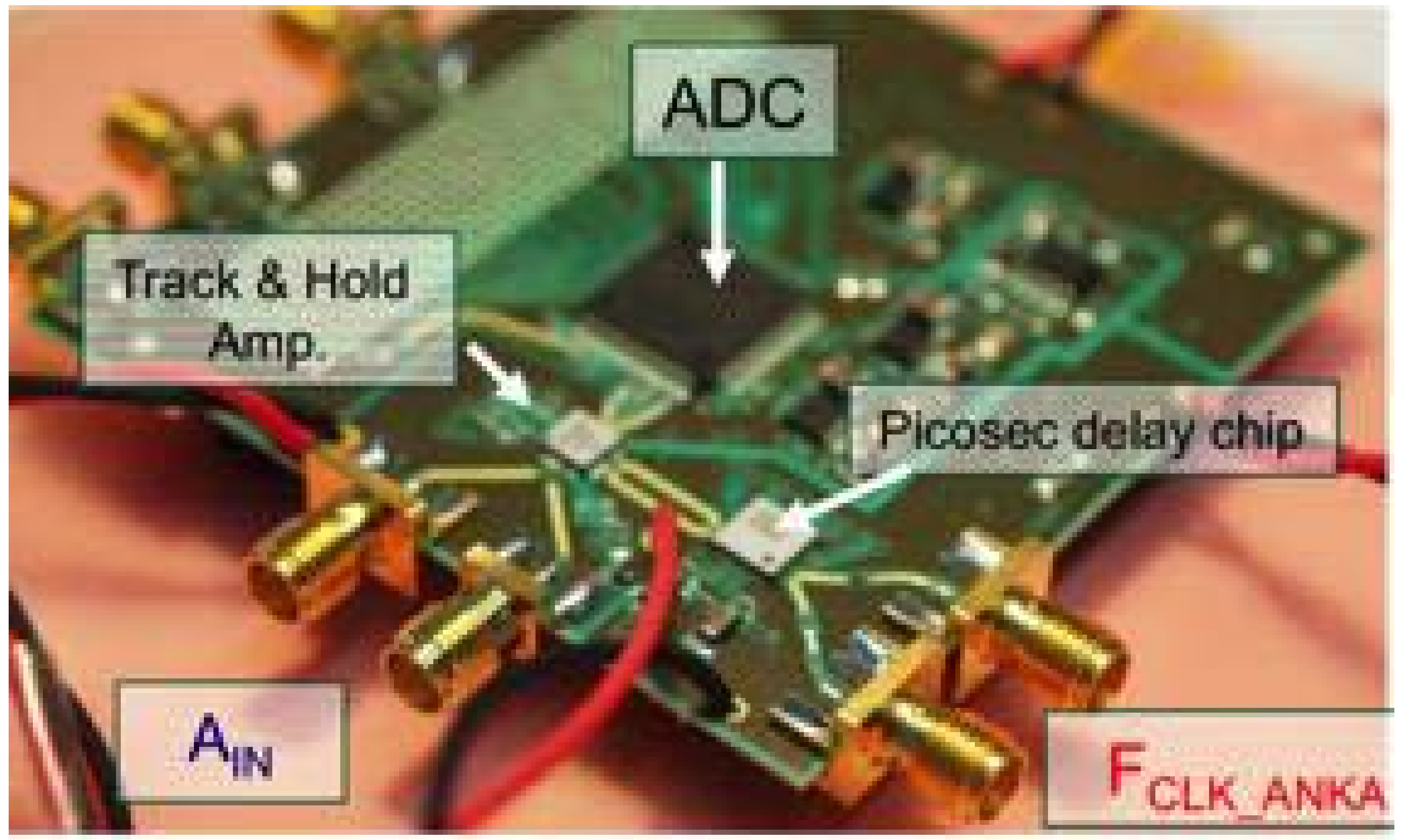


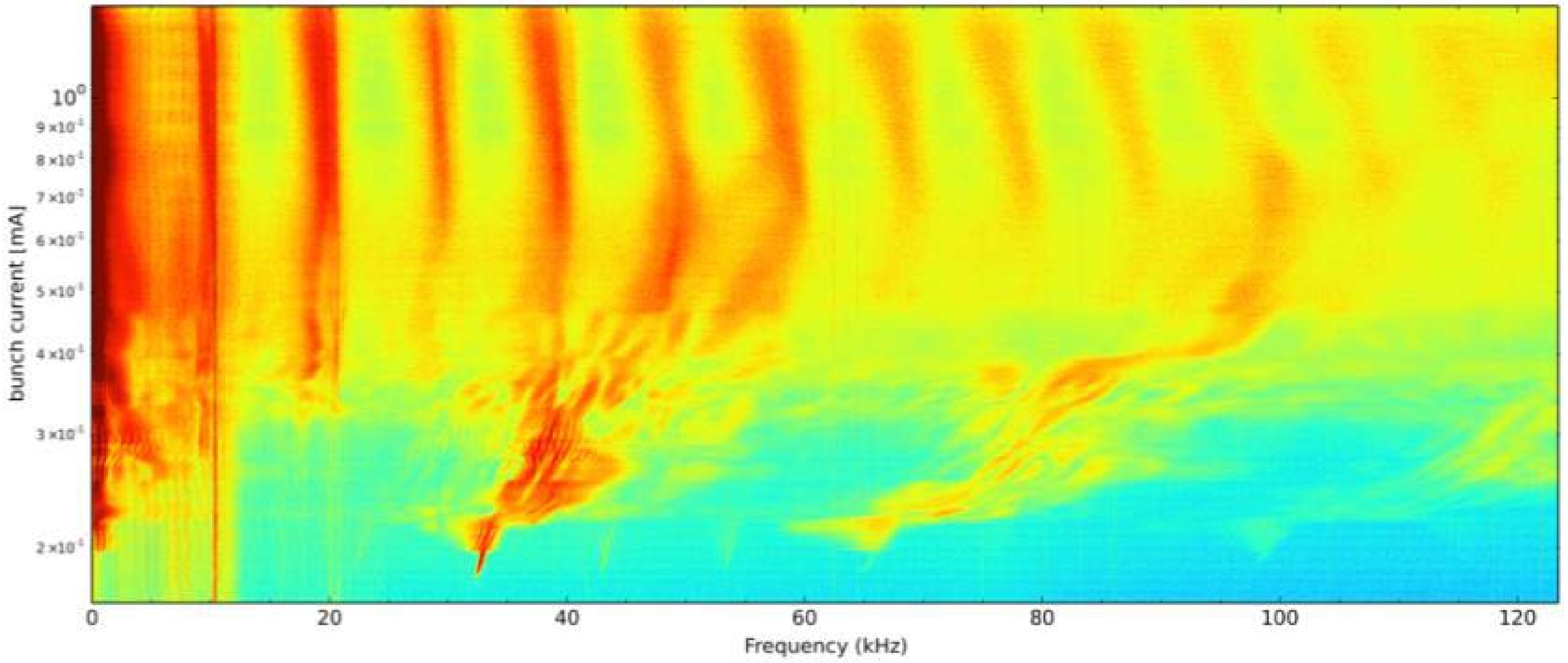
Yuji Otake, SPring-8, Patrick Krejcik, SLAC, Bolko Beutner, PSI

Diagnostics at ERLs and High-Repetition Rate FELs



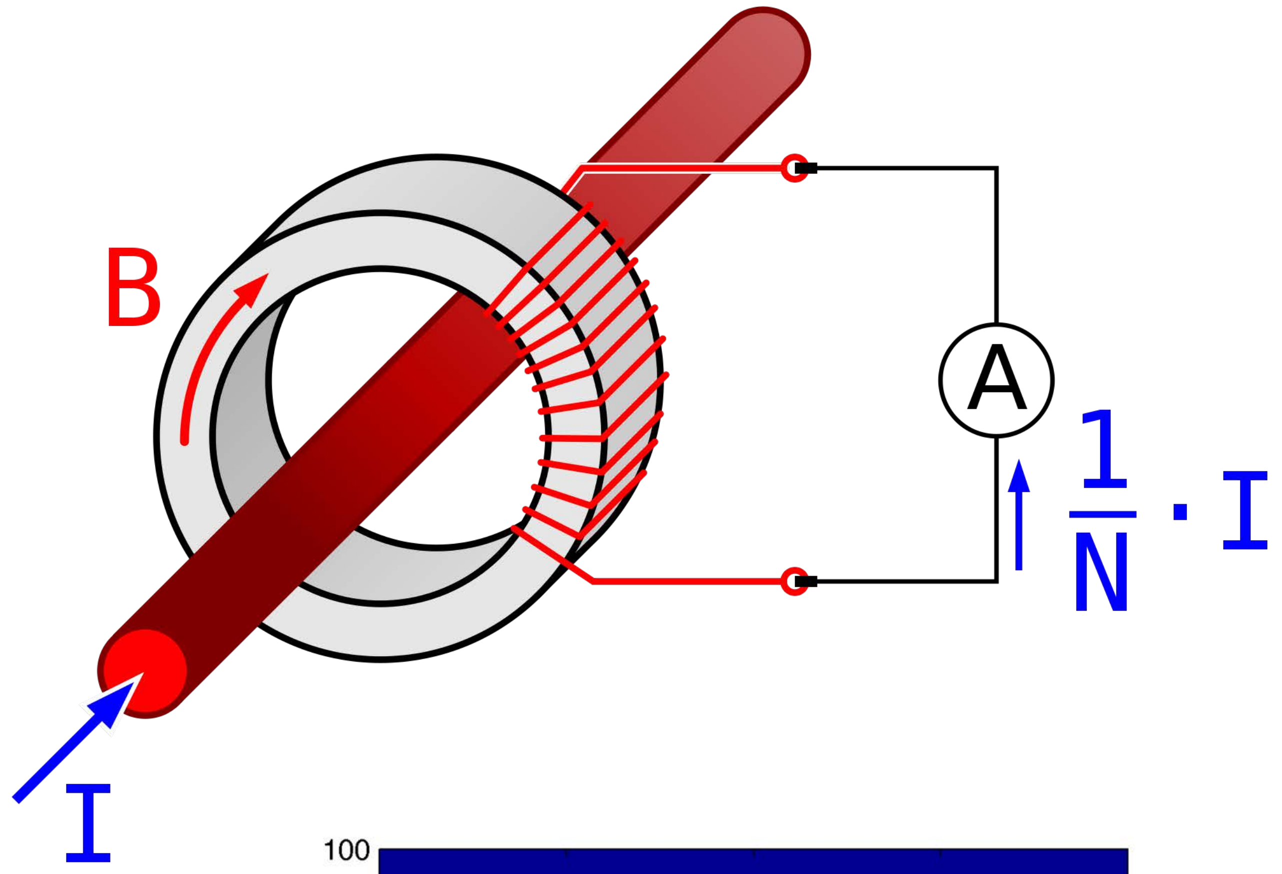




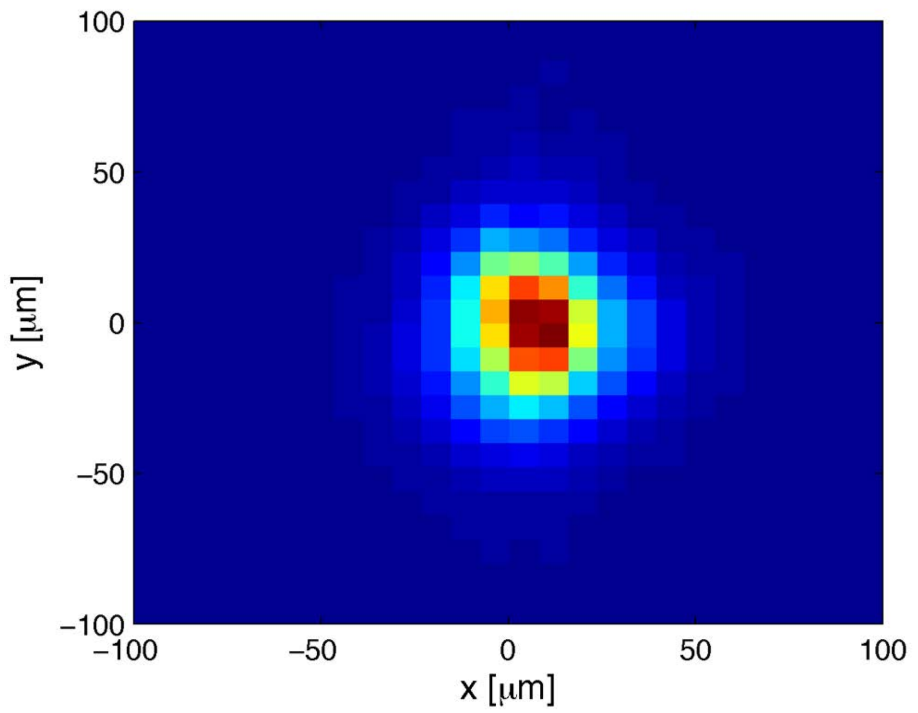


A. Freyberger, Vitali Judin, Michele Caselle

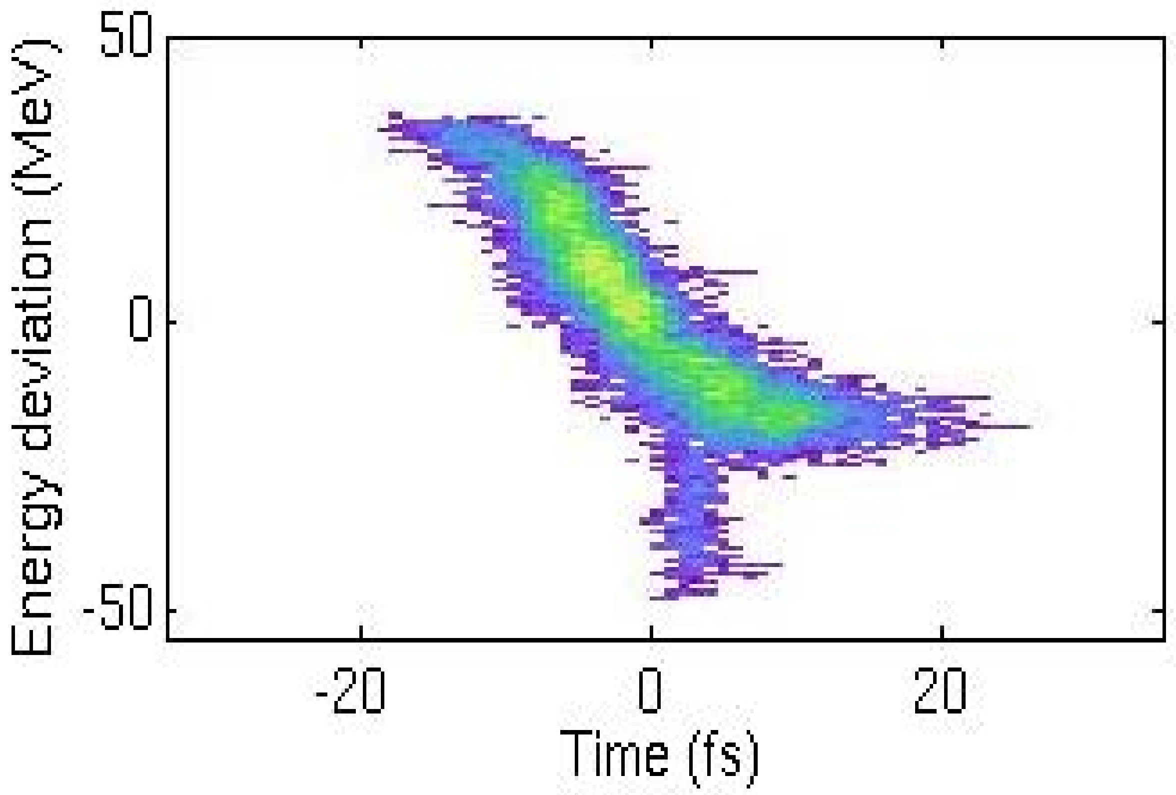
Diagnostics at FELs



- Integral Measurements

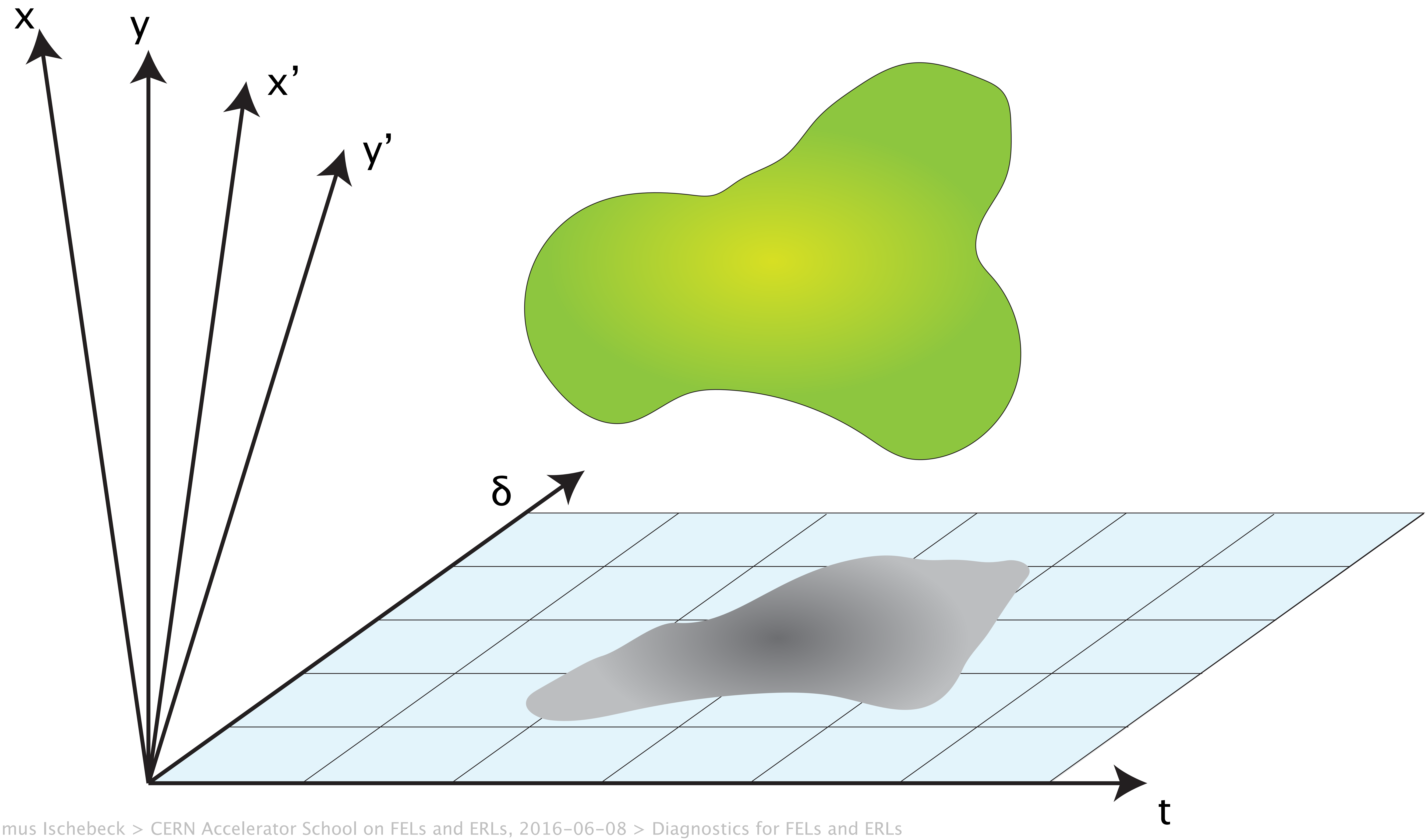


- Transverse Diagnostics



- Time-Resolved Diagnostics

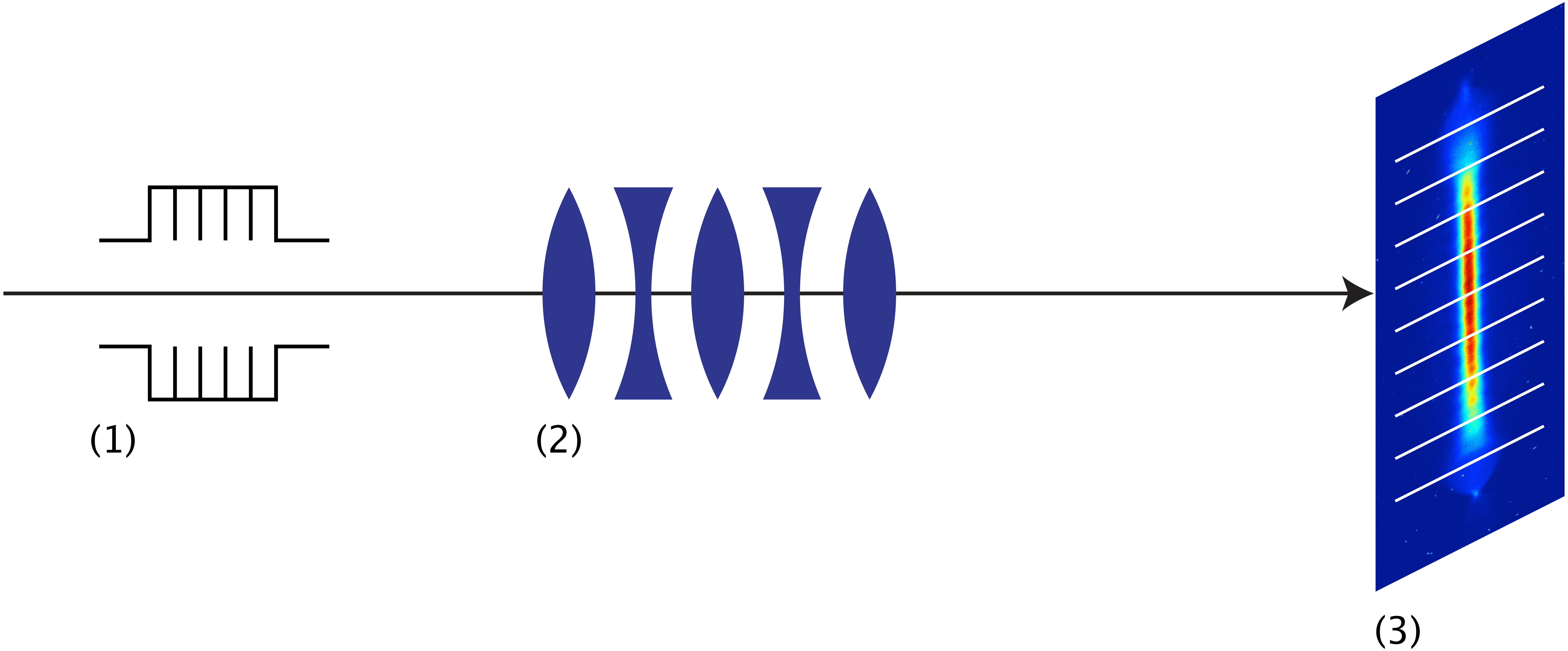
Wikimedia Commons, Patrick Krejcik, SLAC


x
y
x'
y'
δ
t

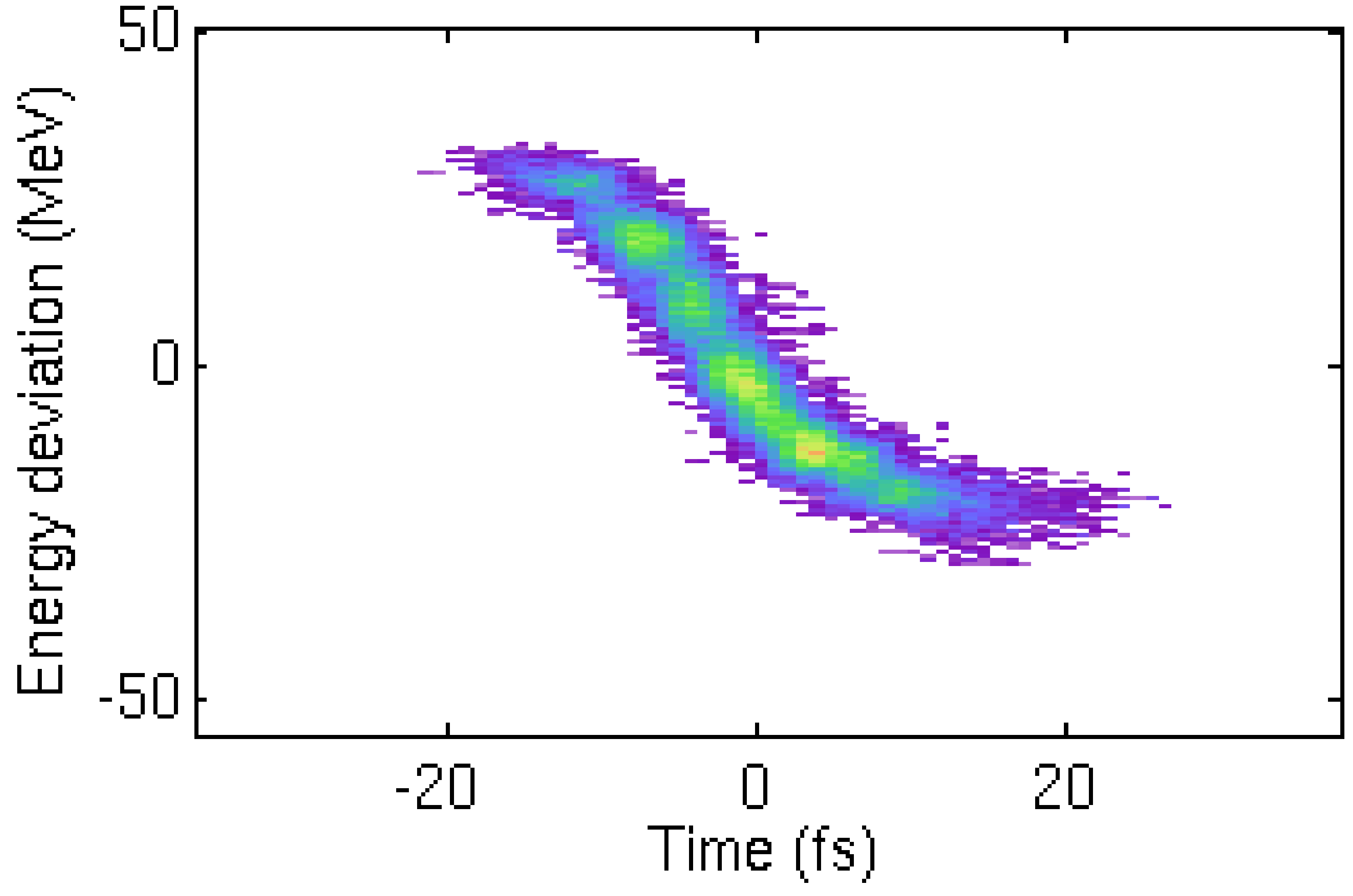
Phase Space Transformations

Patrick Krejcik, IBIC 2013

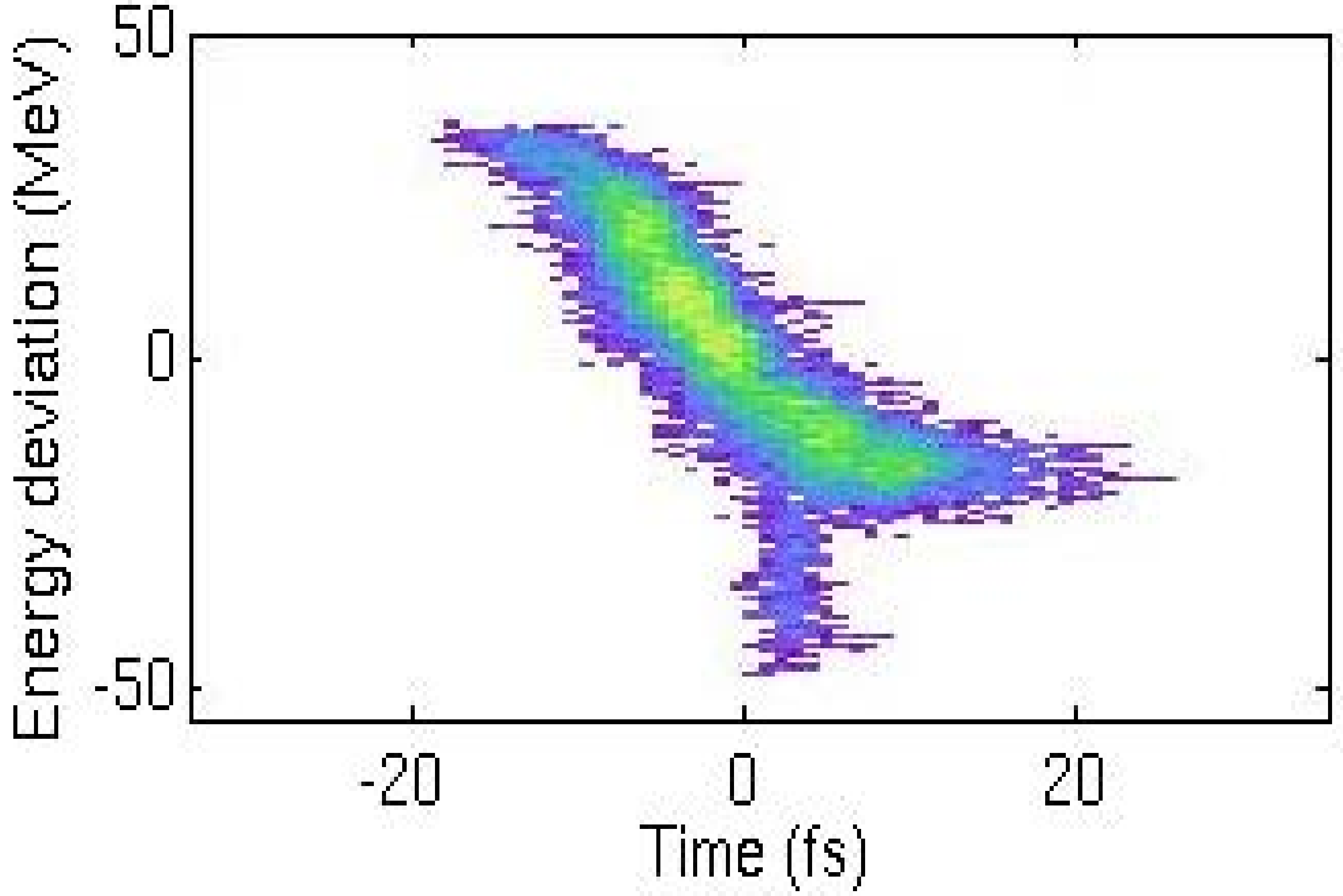

QFDM03
tesla
QFDM03
SINLH01-MQUA020


(1)
(2)
(3)

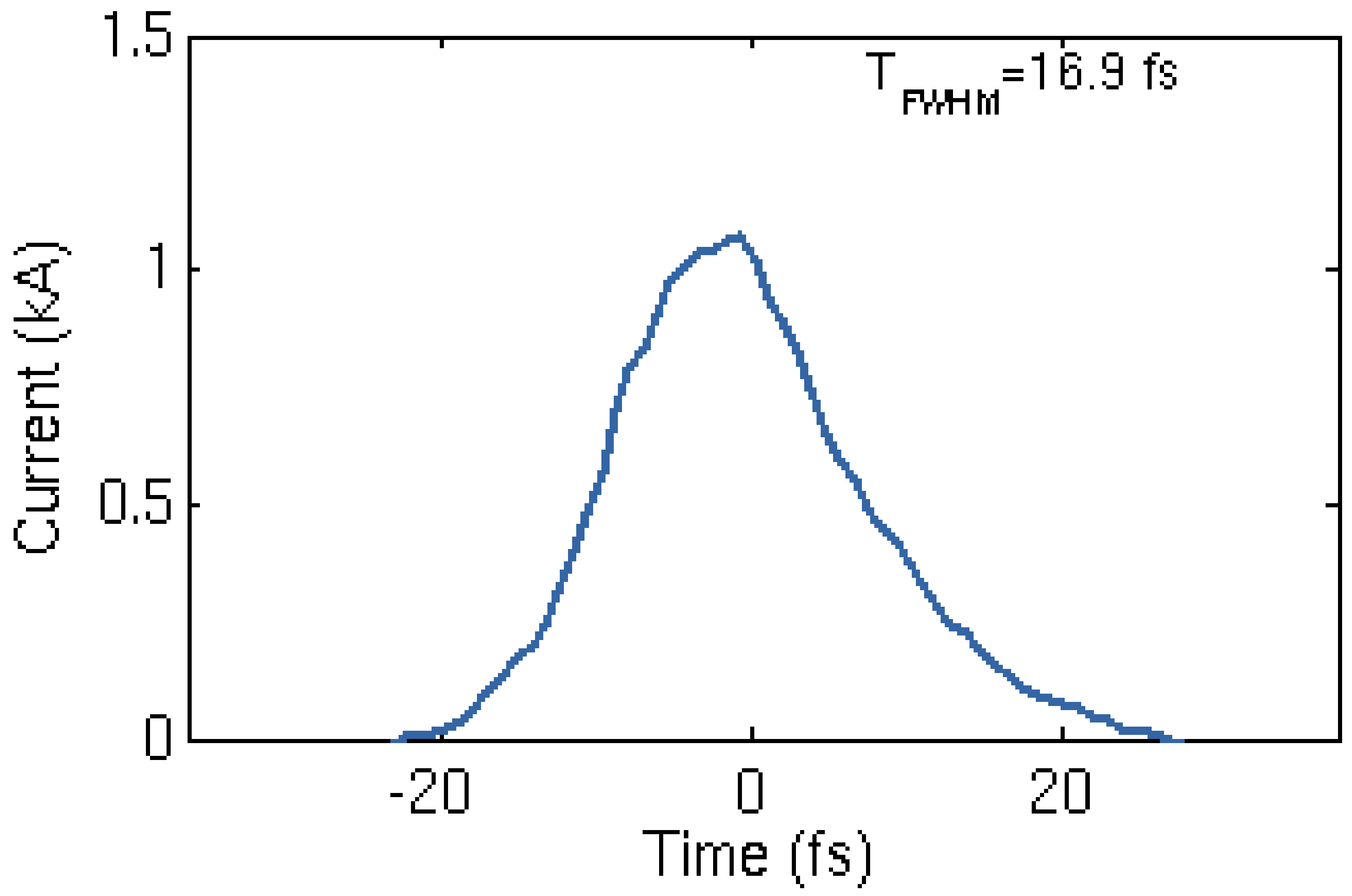
Lasing off



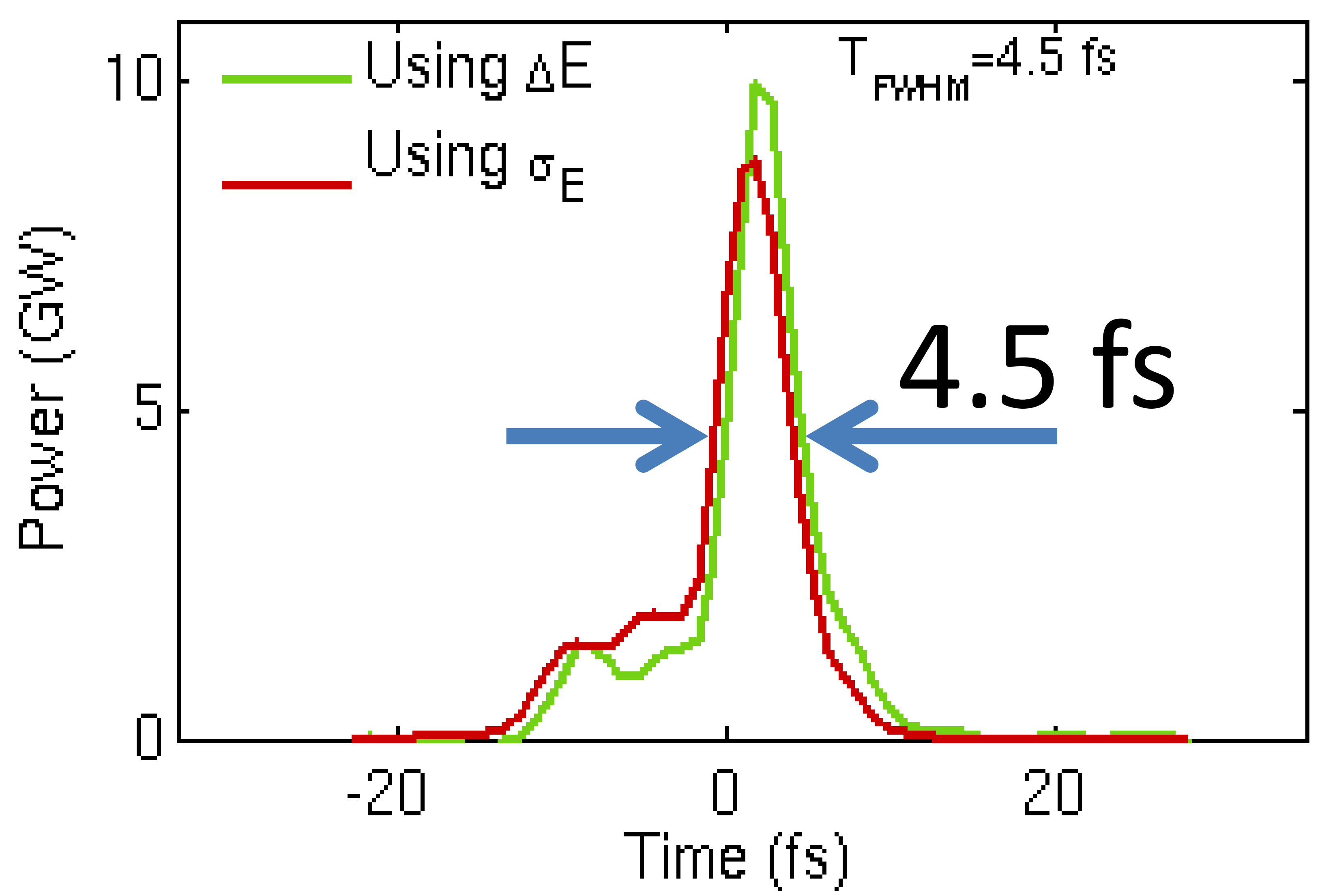
Lasing on



electrons



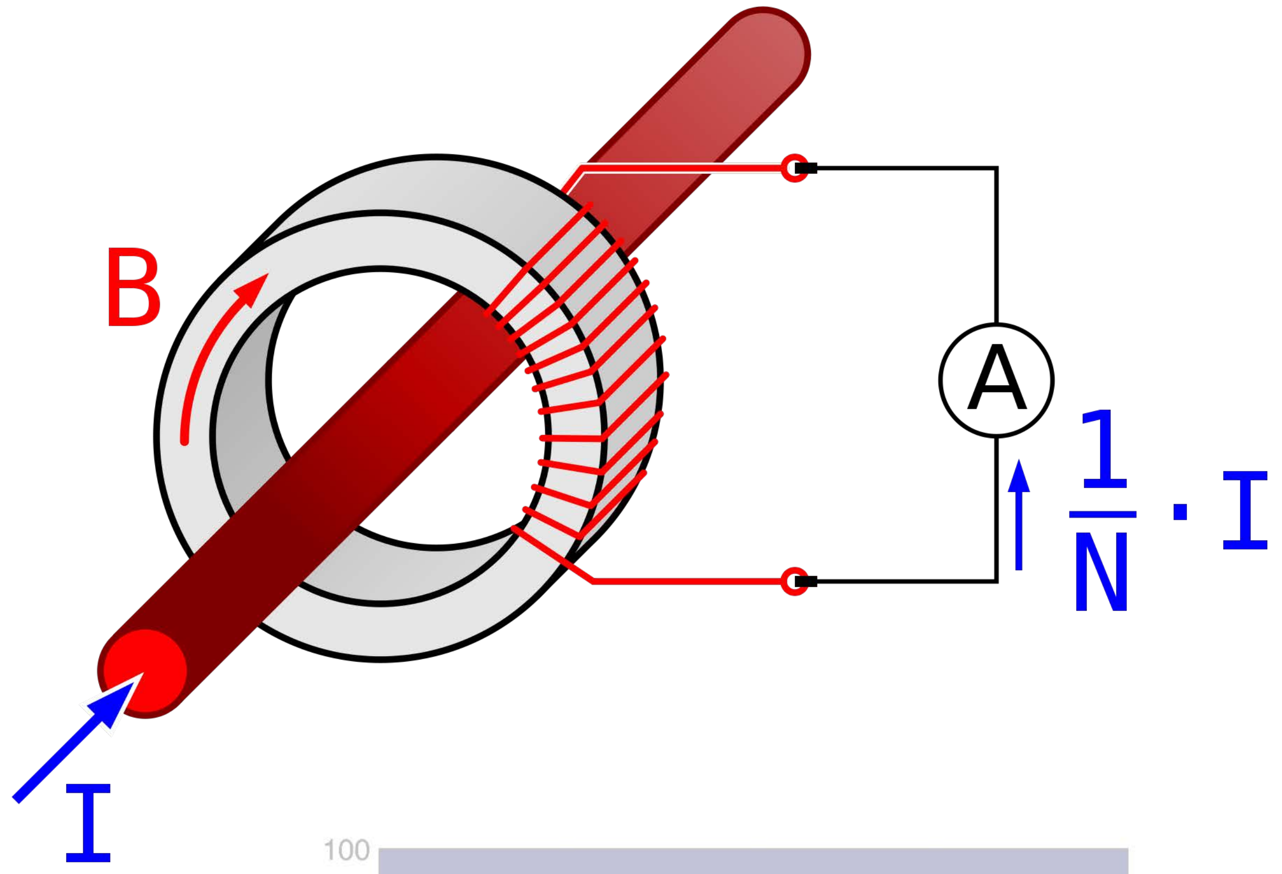
X-rays

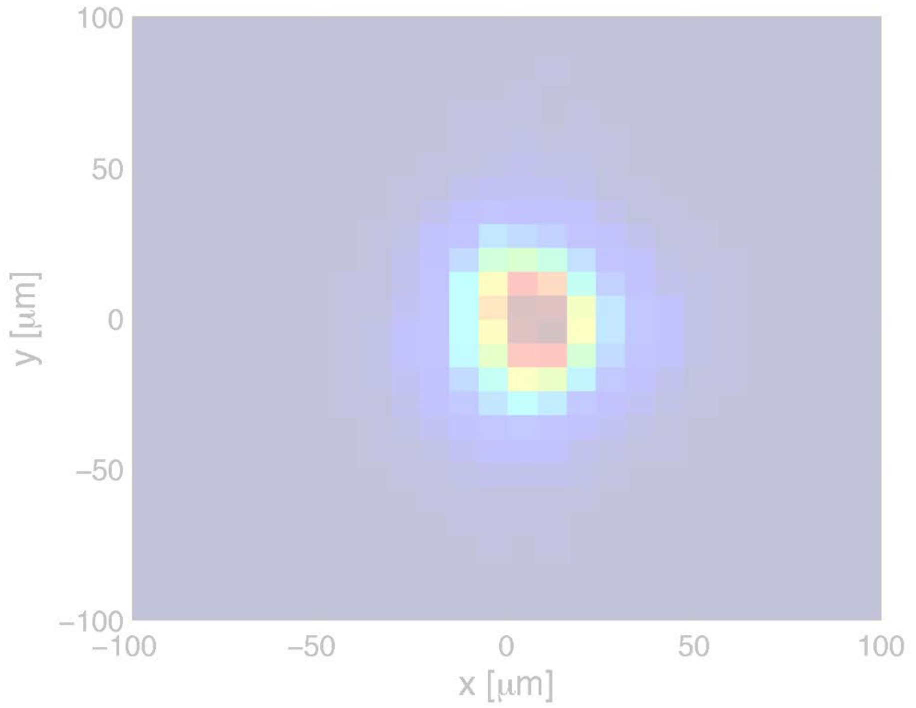


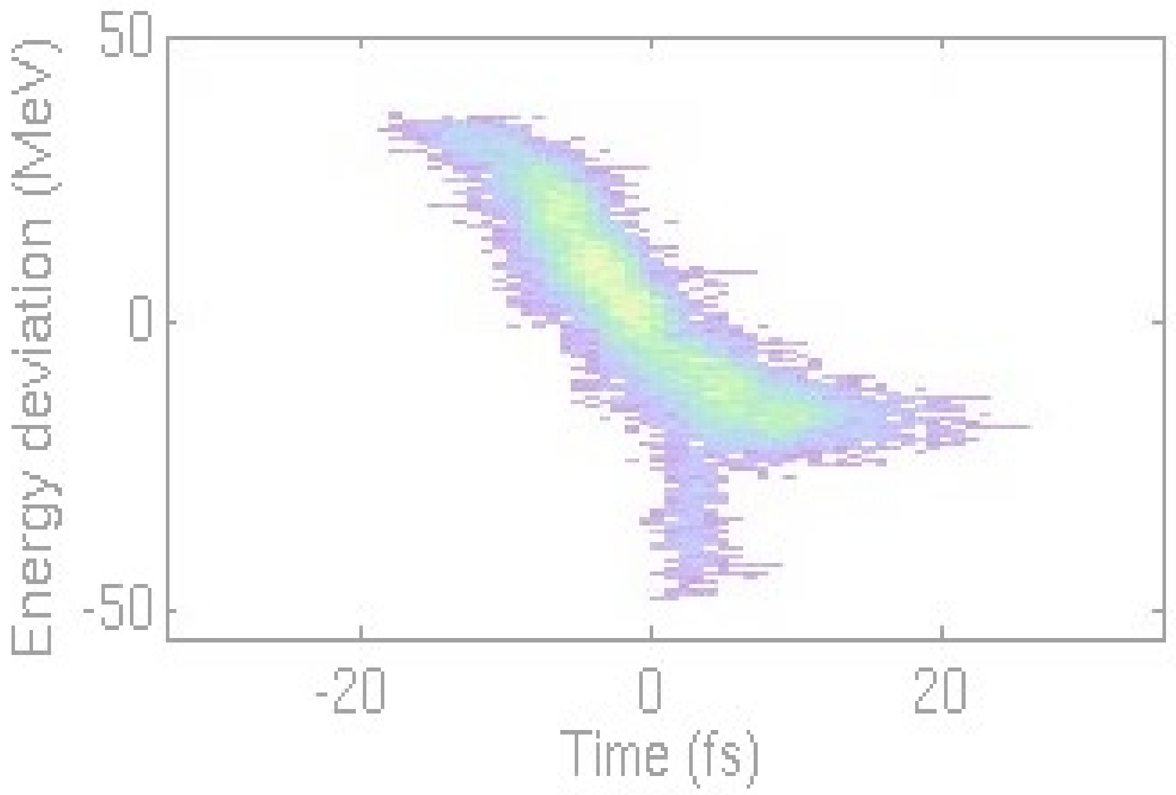
Patrick Krejcik, IBIC 2013


atk

Diagnostics at FELs





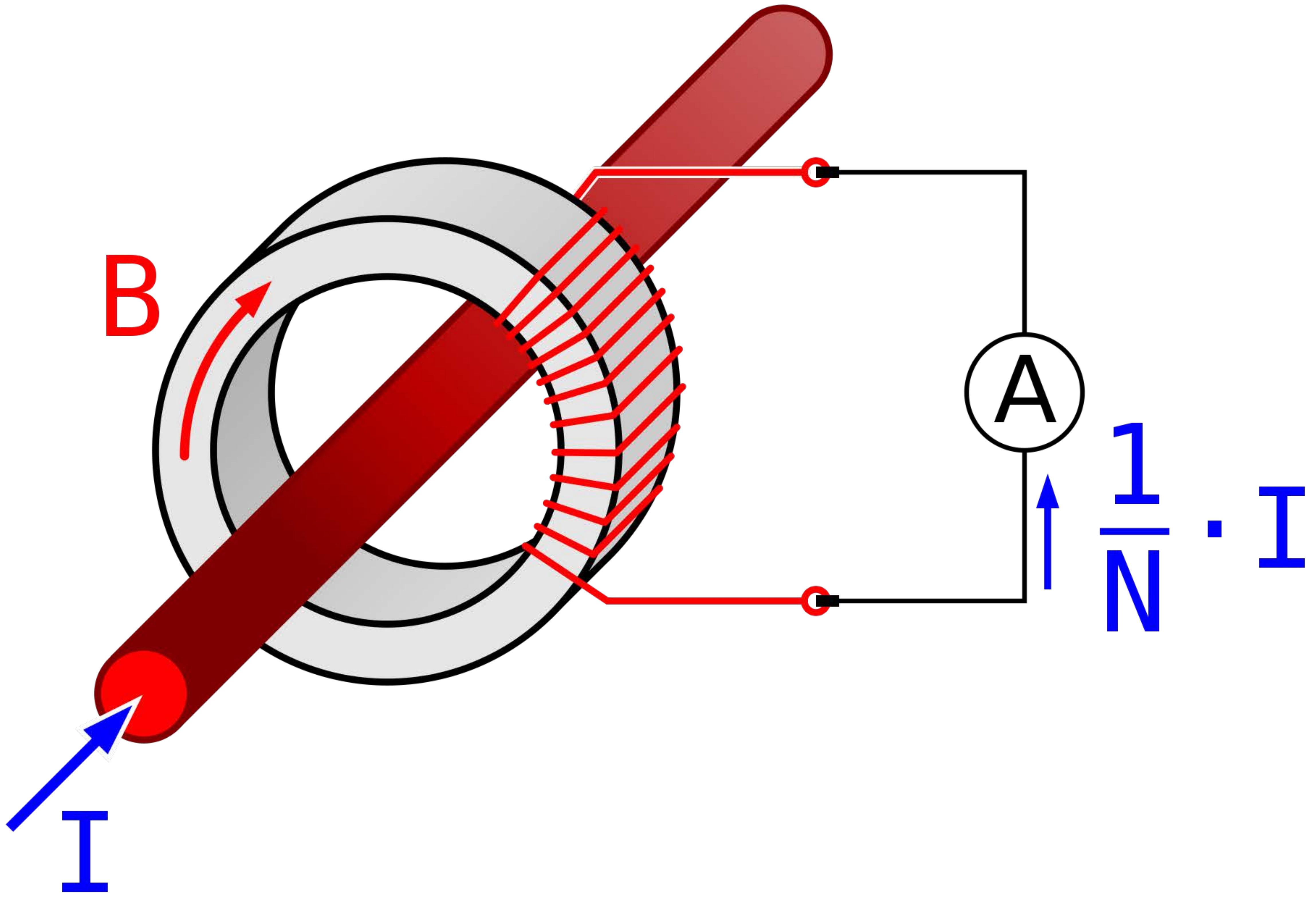


- Integral Measurements
- Transverse Diagnostics
- Time-Resolved Diagnostics

Wikimedia Commons, Patrick Krejcik, SLAC

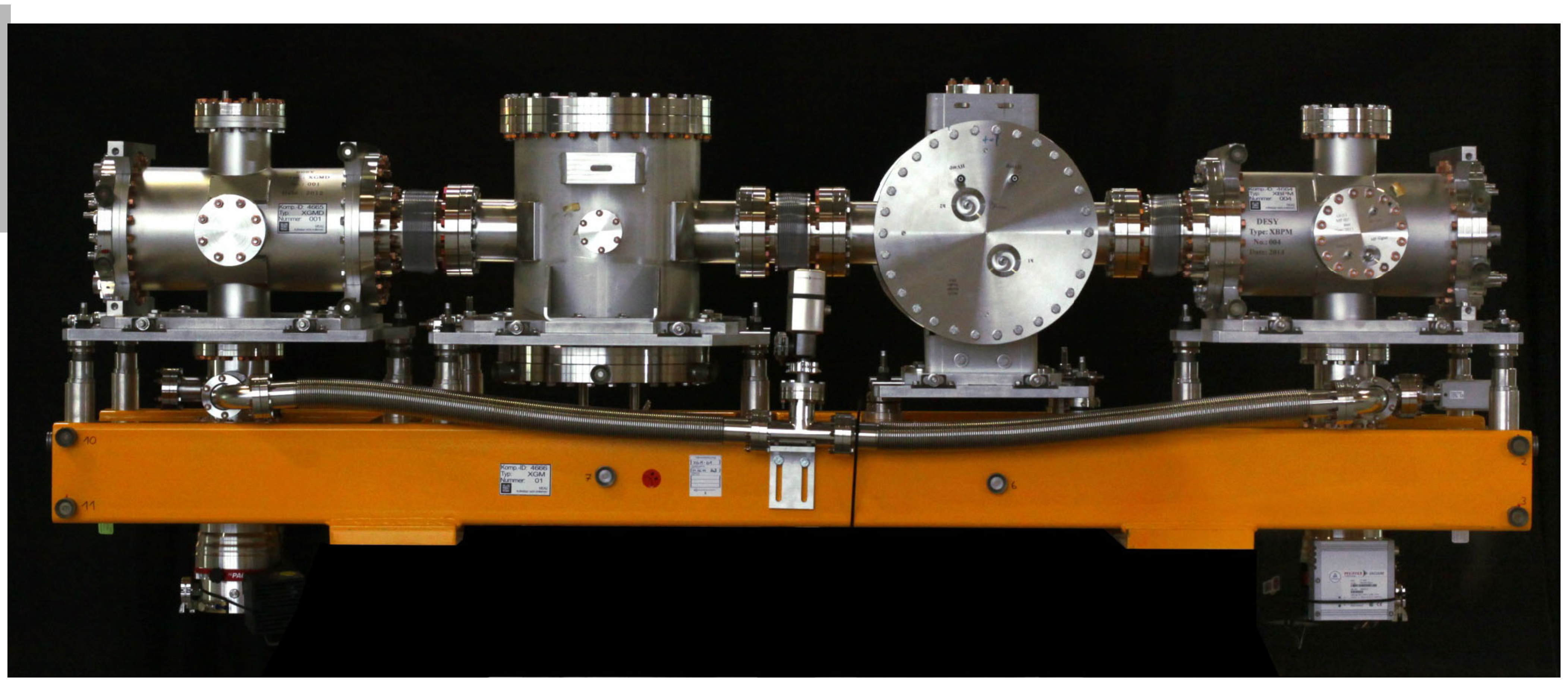
Integral Measurements

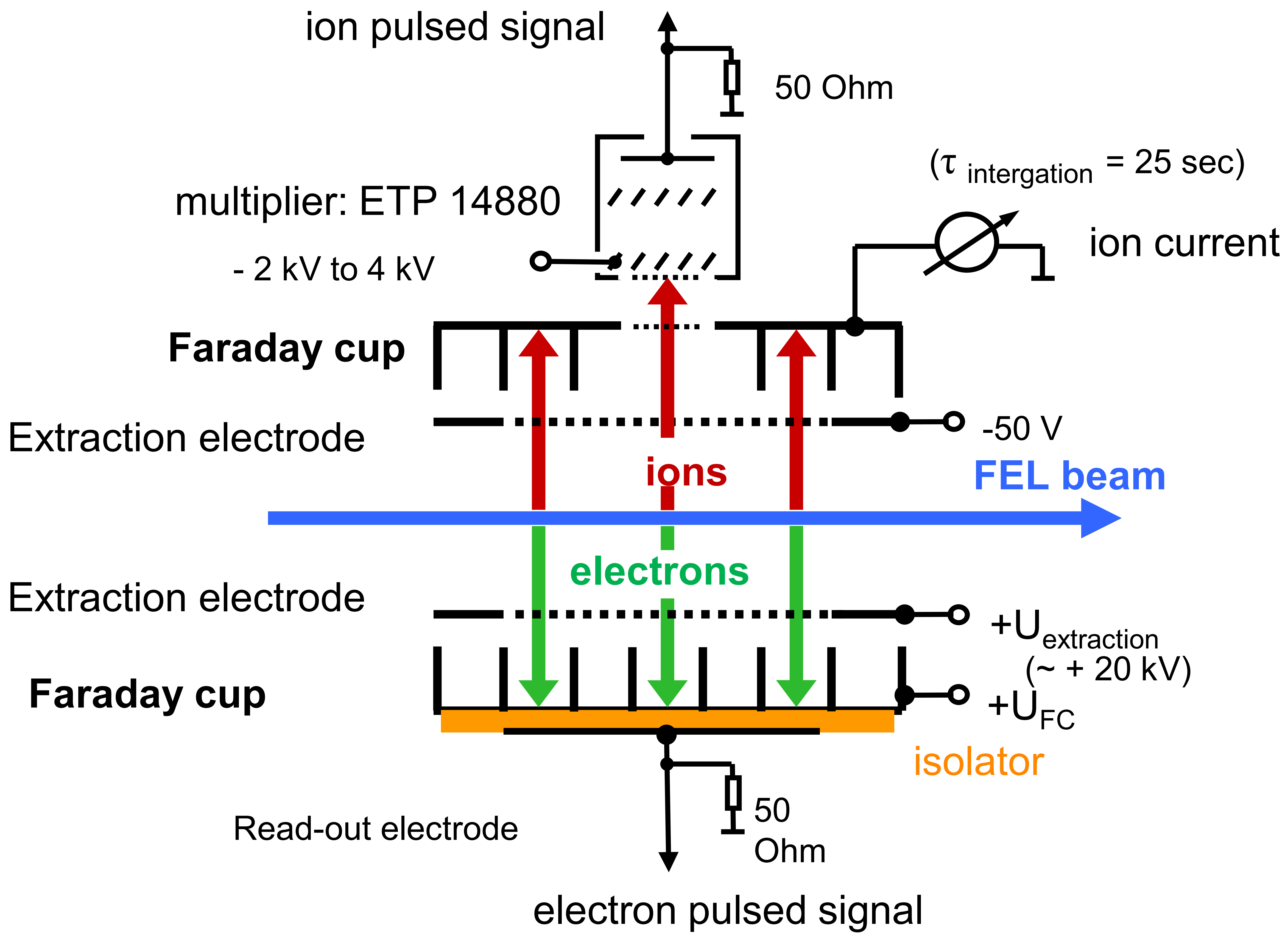
Current Transformer



Wikimedia Commons

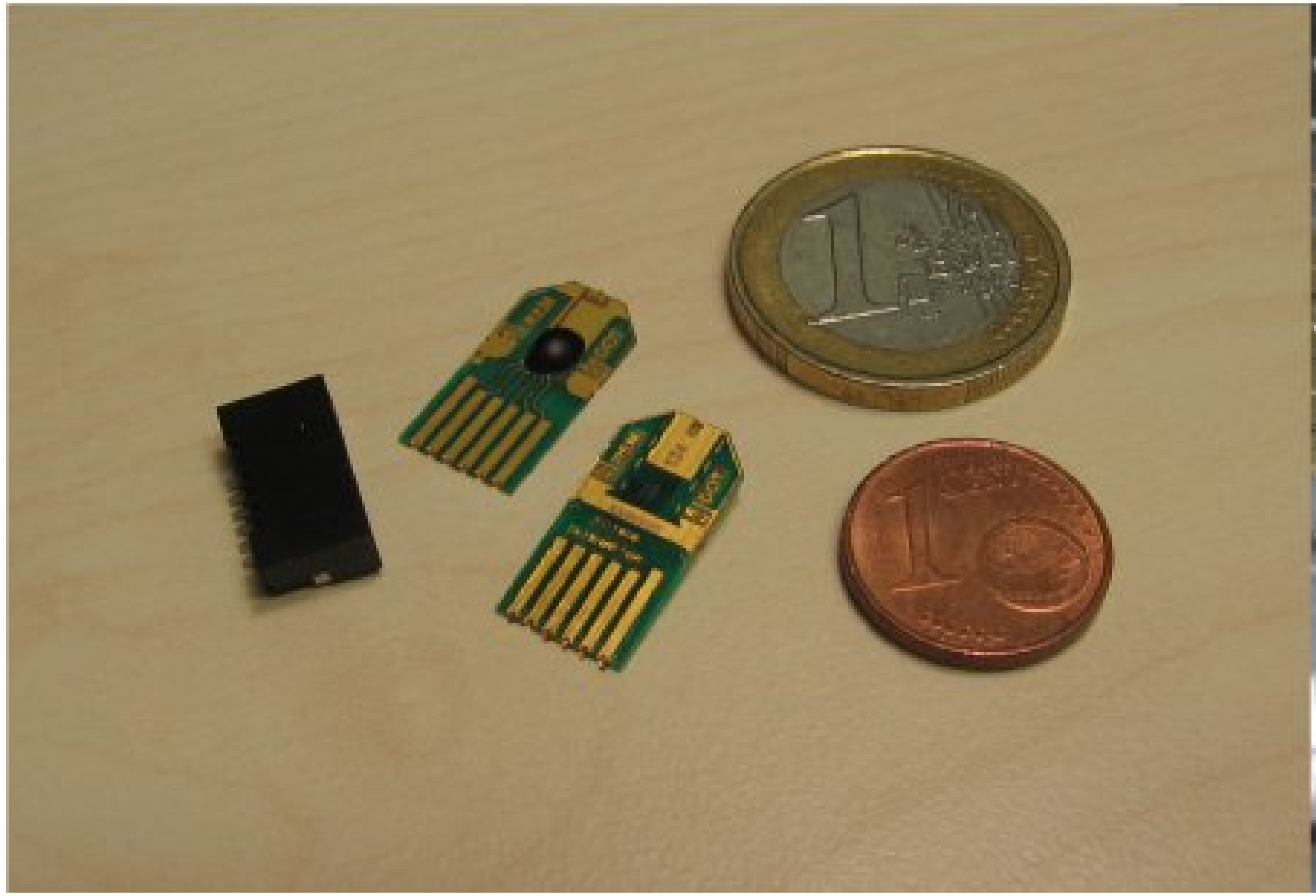
Photon Pulse Energy

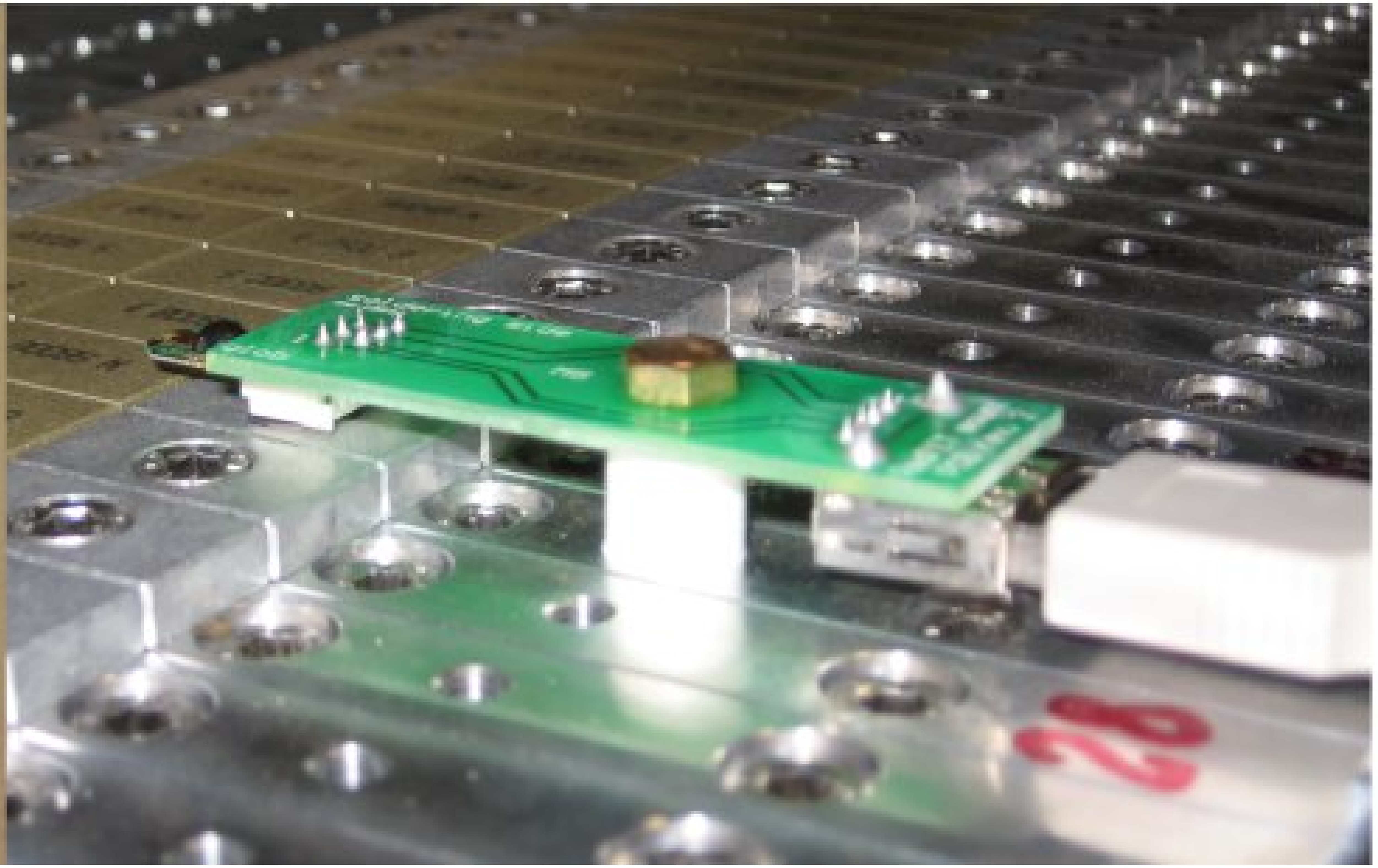




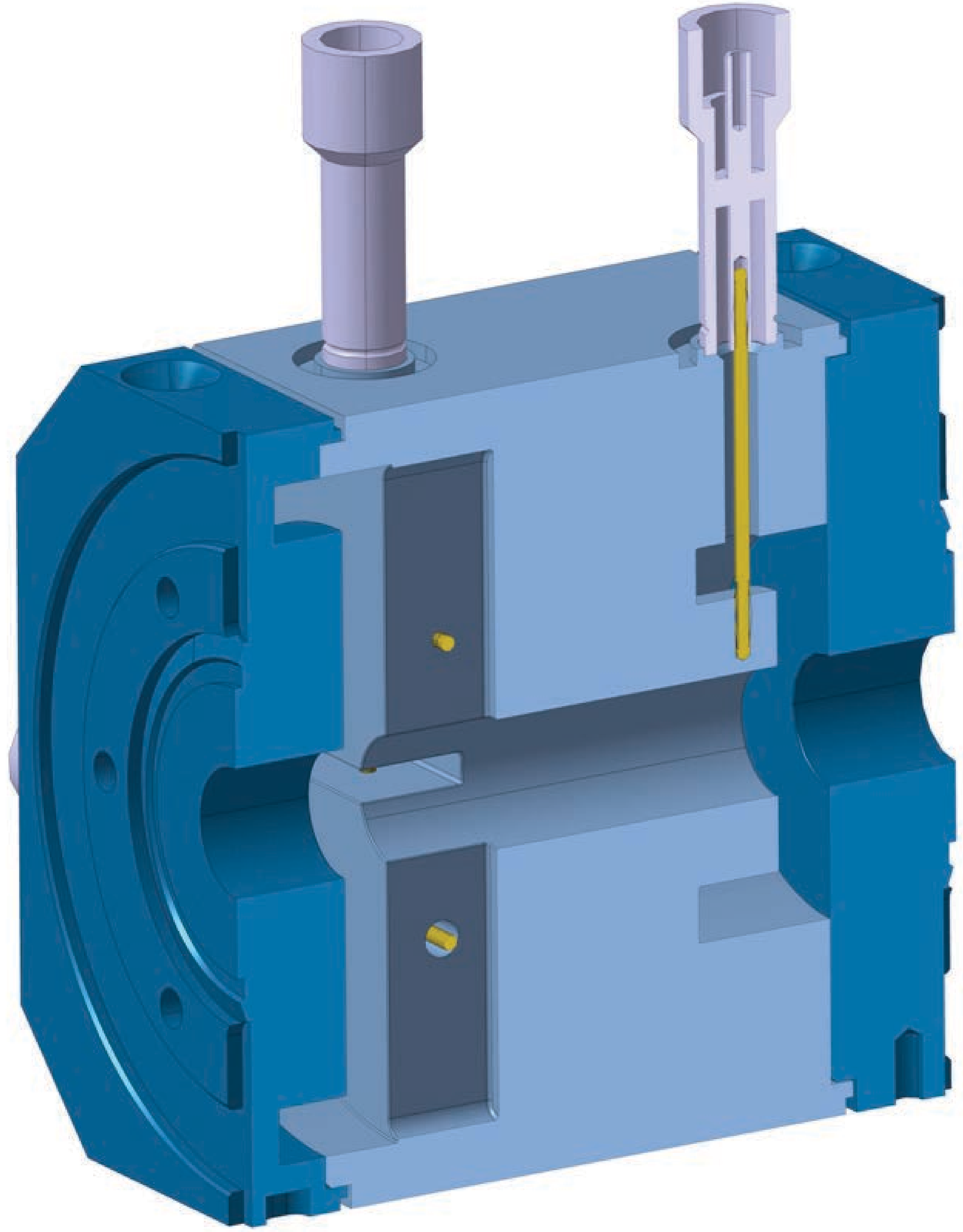
Kai Tiedtke

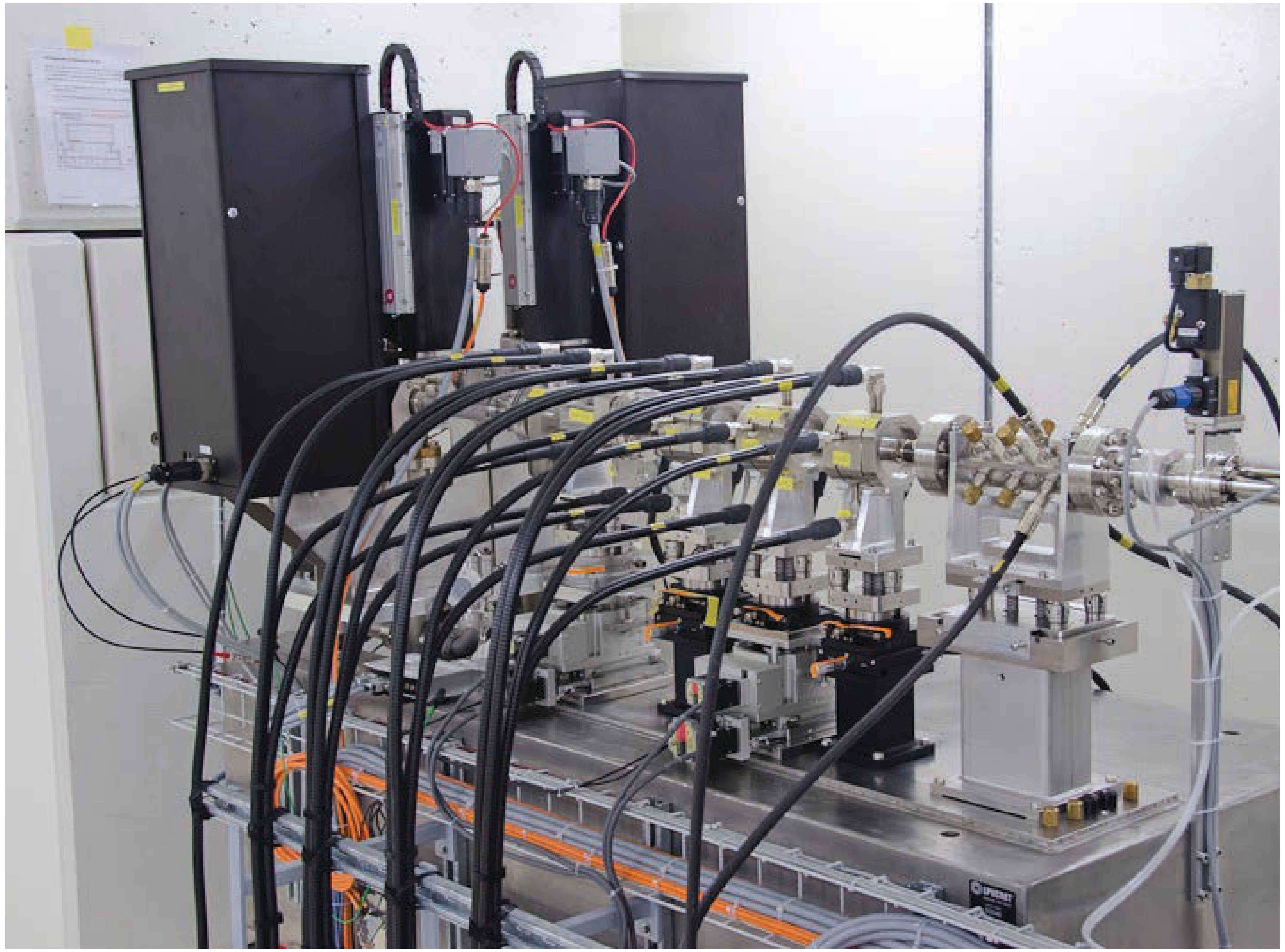

FERMI@Elettra
RadFET Reader
Power
LAN
status
read
INTLK
RadFET
D
C
B
A



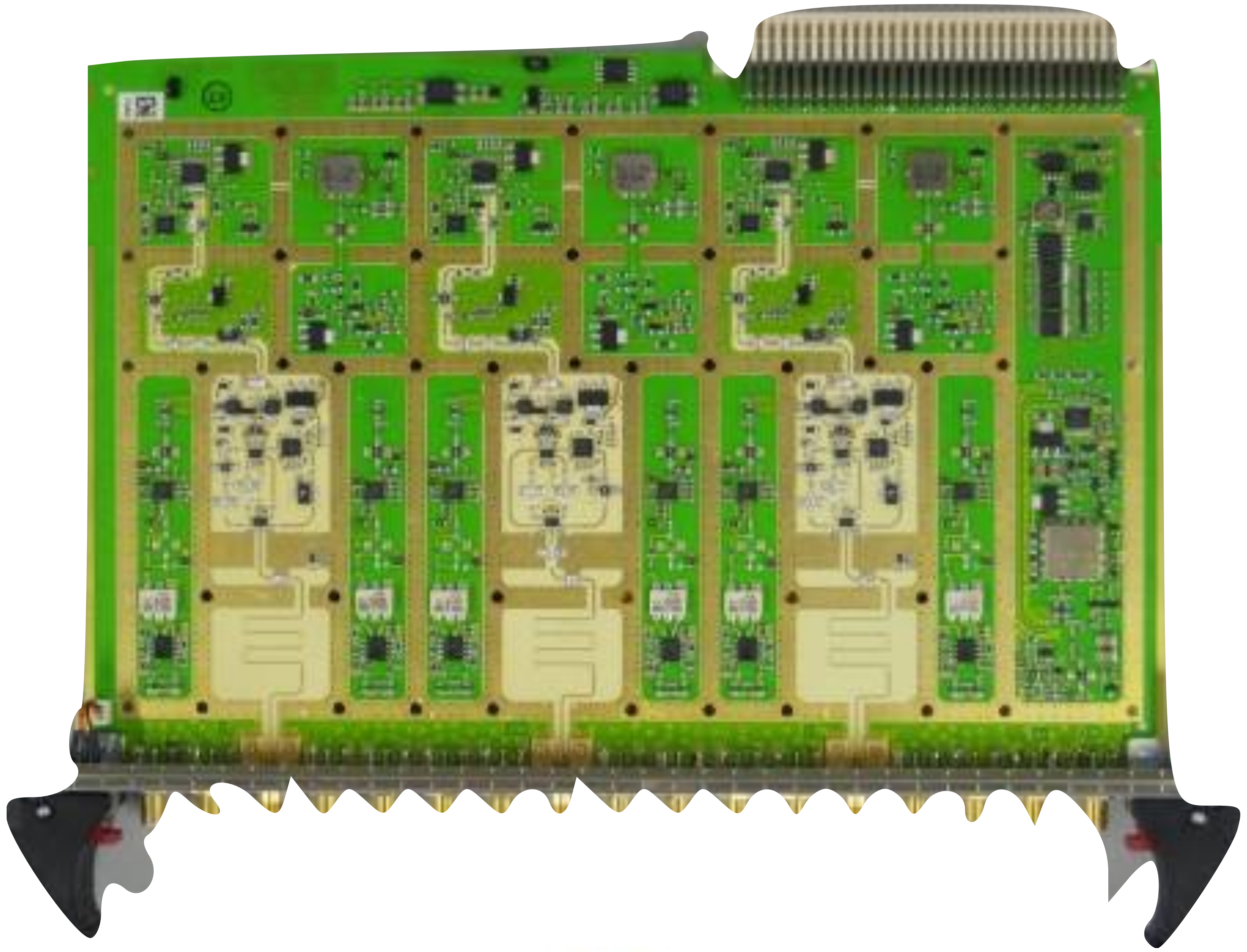


Transverse Diagnostics



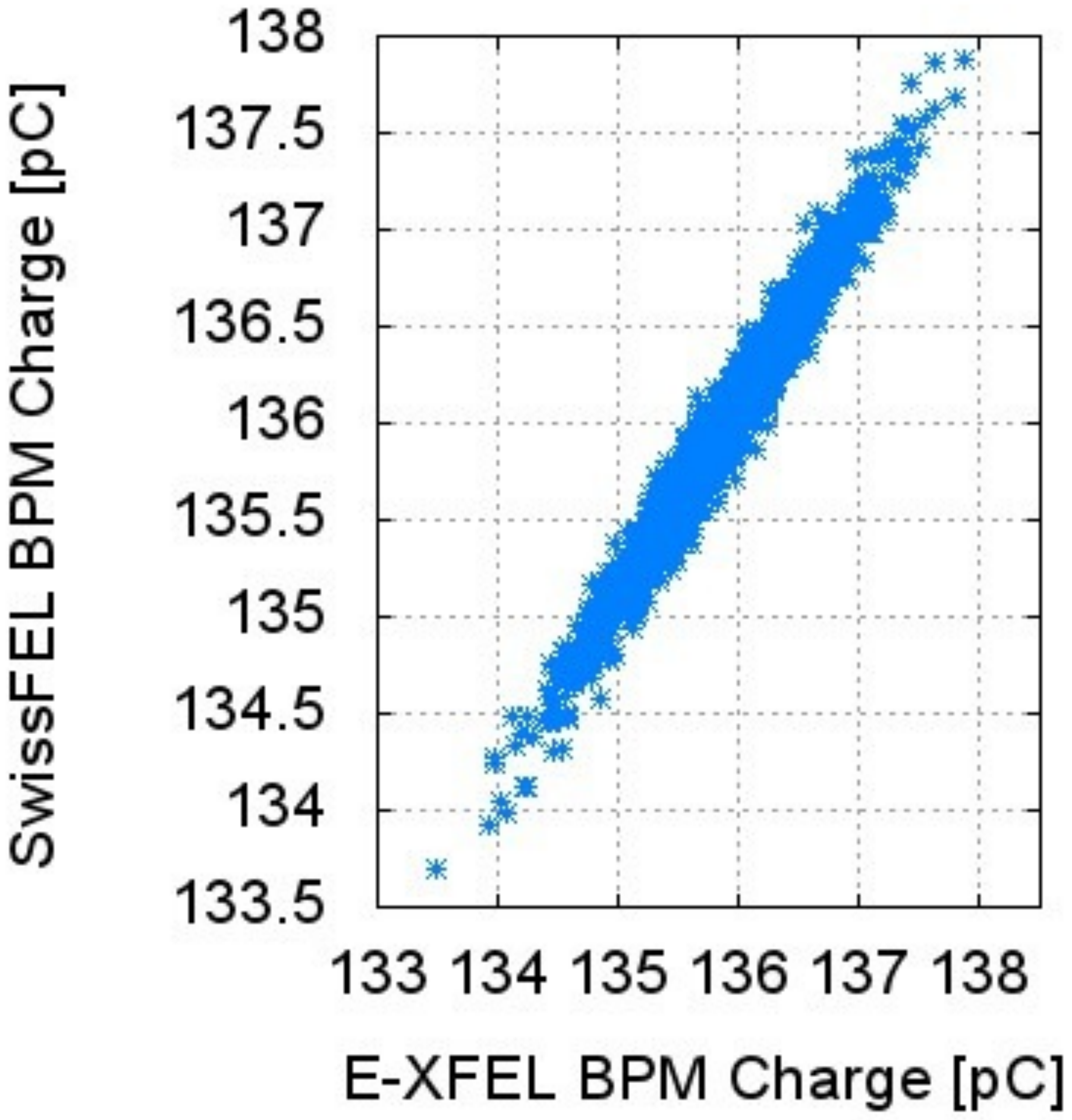


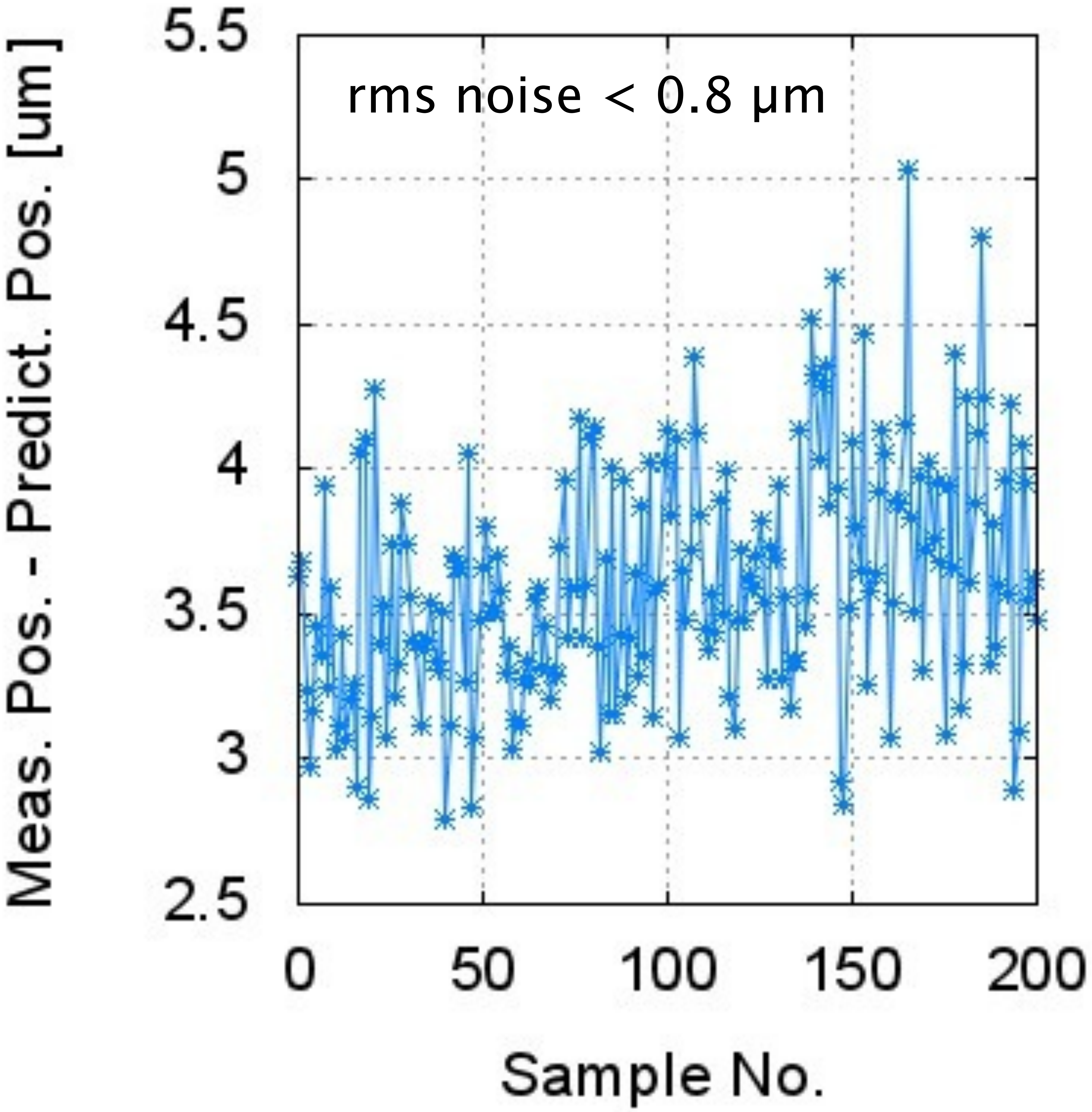
Boris Keil



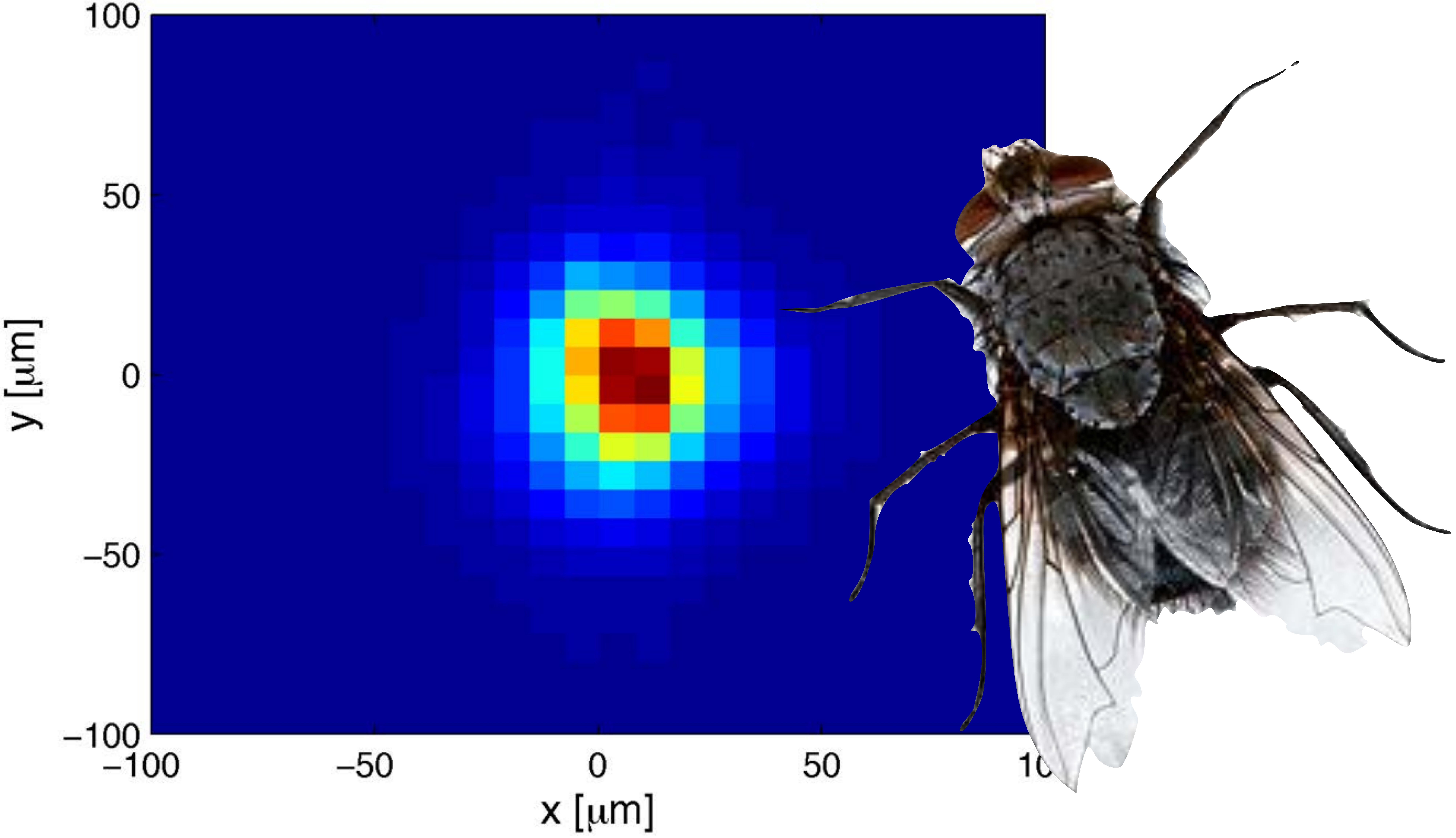
Boris Keil

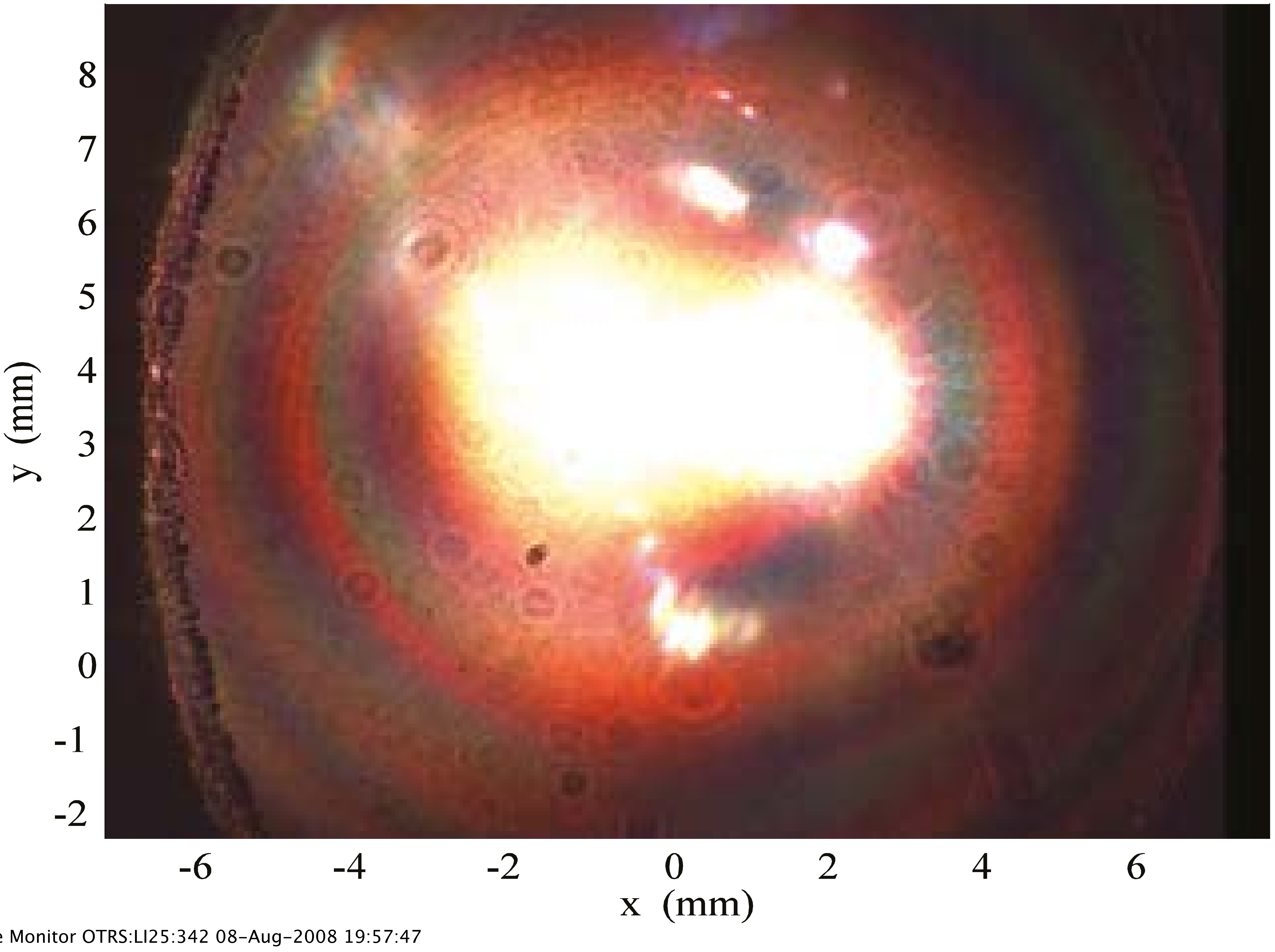
- Low charge: Position-noise · charge = const = 15pC·µm
- Q=135pC: Noise <0.8µm RMS, ±1mm range.
- Charge noise <0.1% (<0.1pC RMS at Q=135pC).



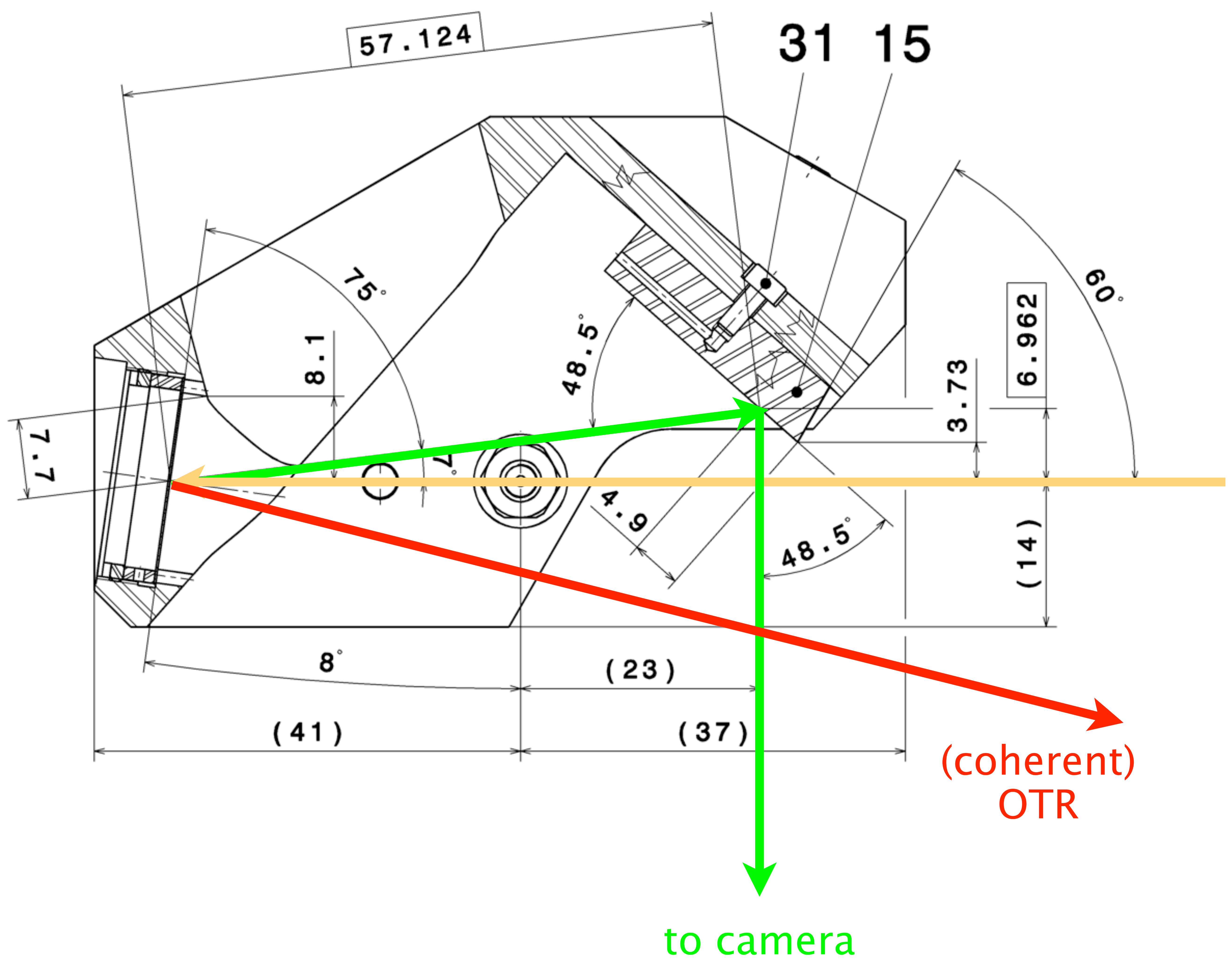


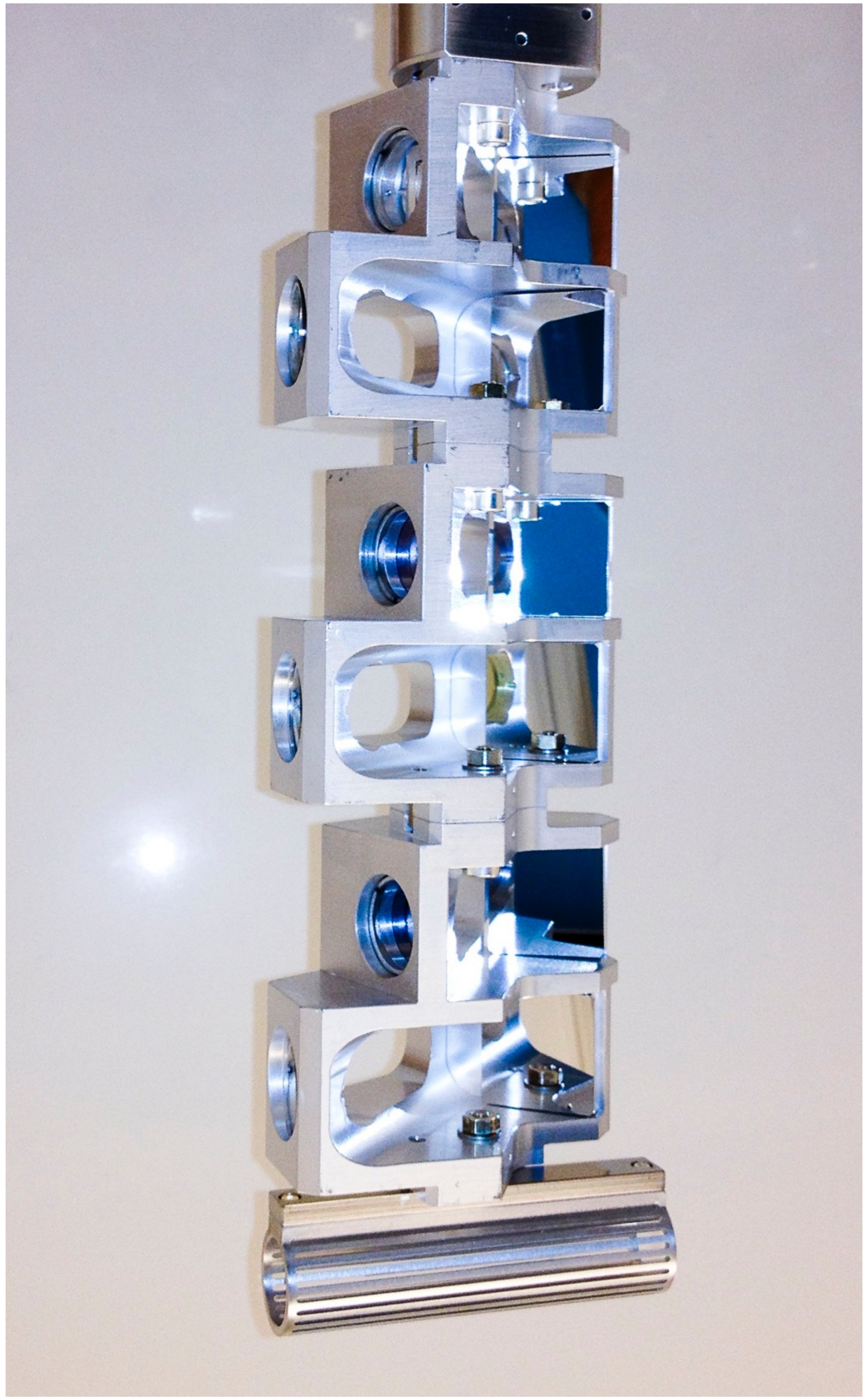
Boris Keil

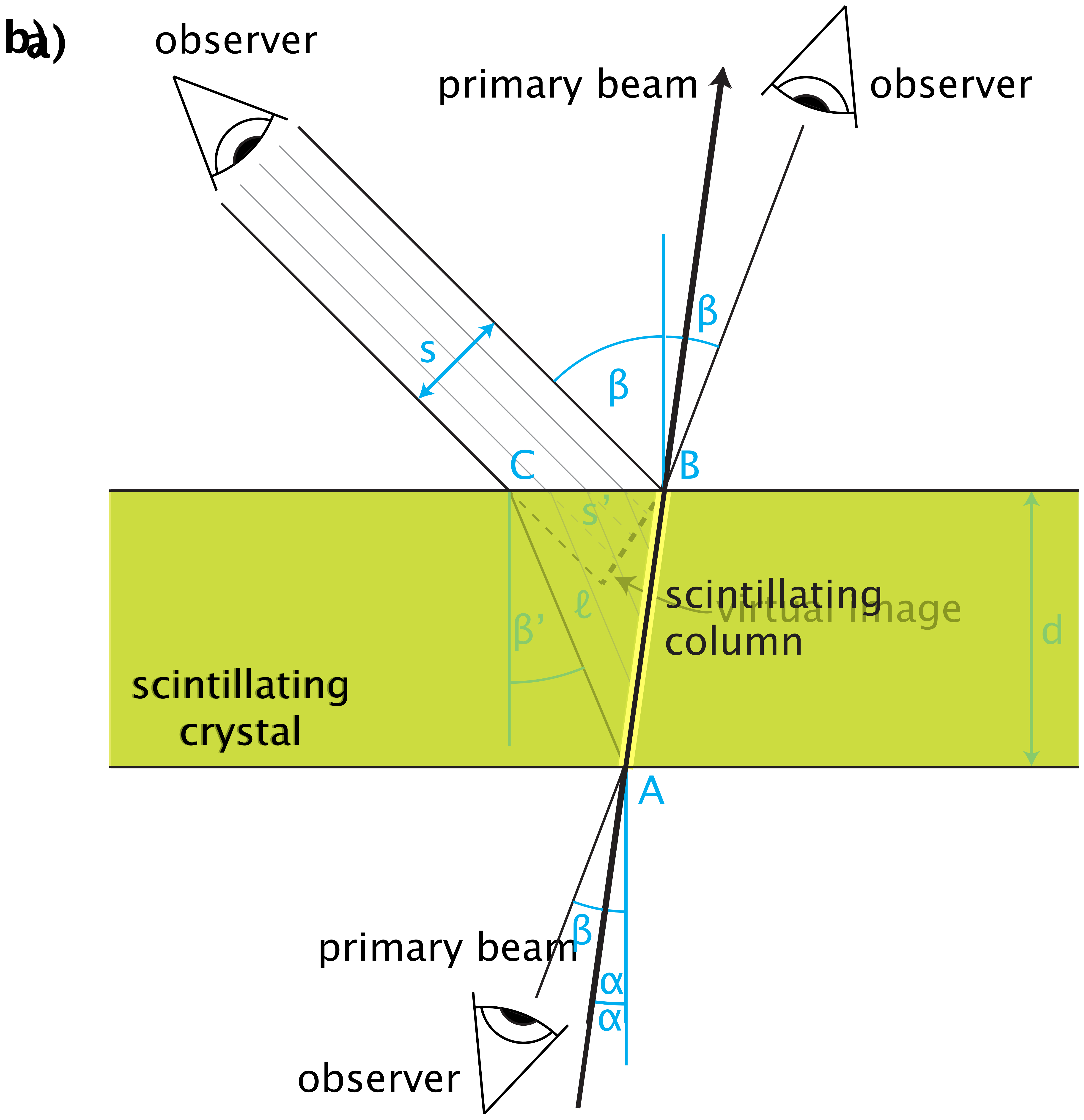

100
50
0
−50
−100
−100
−50
0
50
10
y [µm]
x [µm]



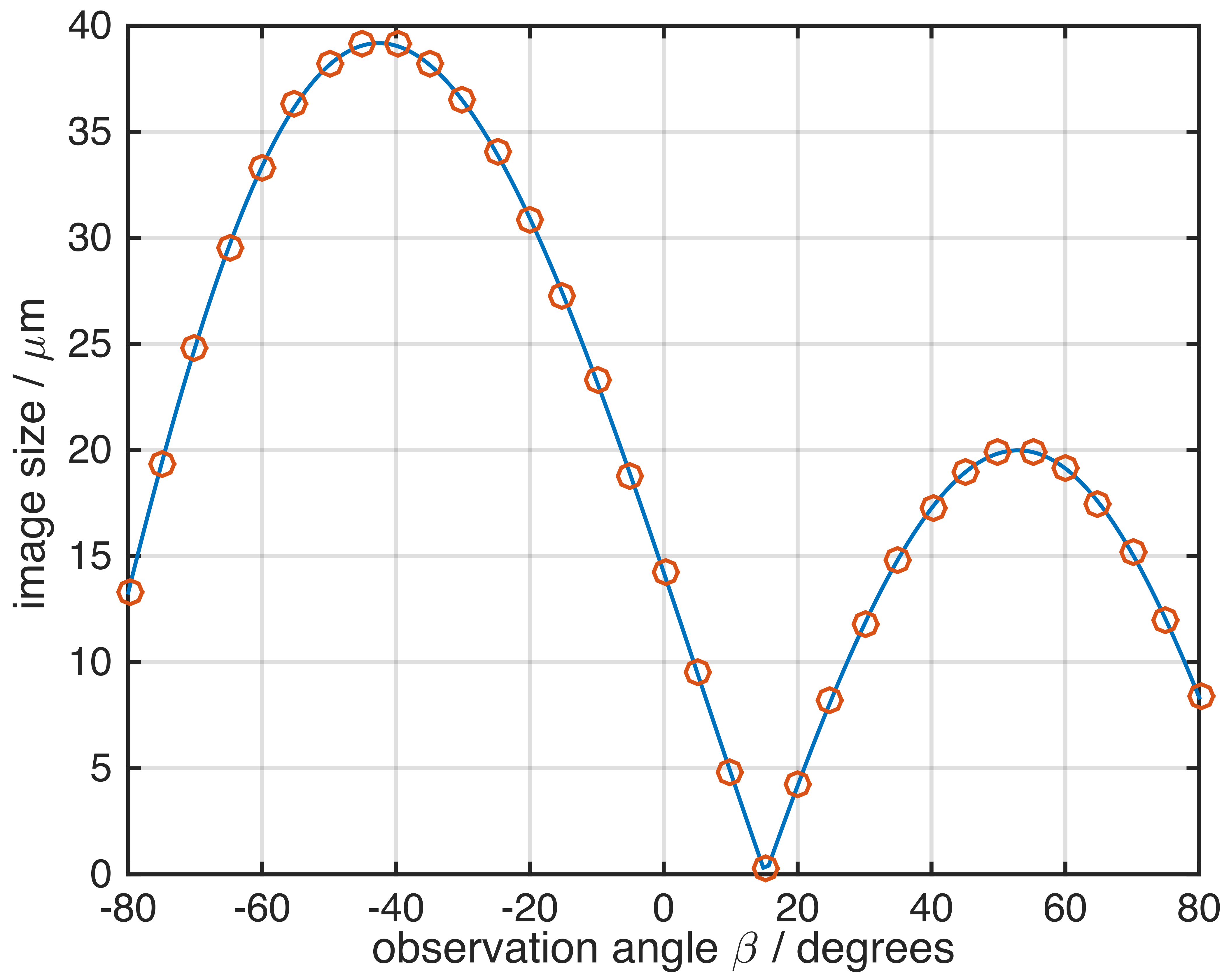
Daniel Ratner, Proceedings of FEL 2013


57.124
31 15
75°
60°
48.5°
8.1
3.73
6.962
7.7
4.9
48.5°
(14)
8°
(23)
(41)
(37)
(coherent)
OTR
to camera

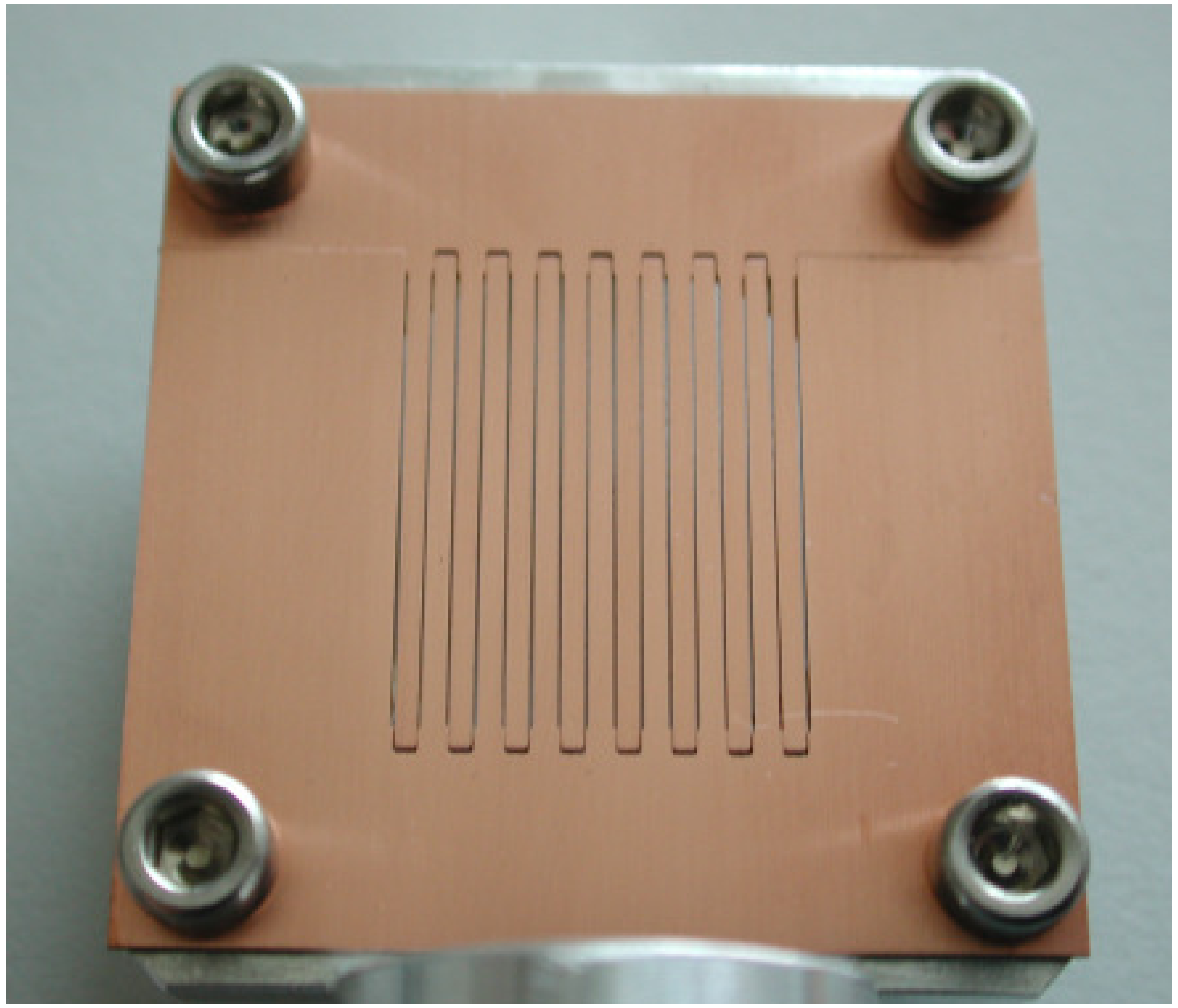


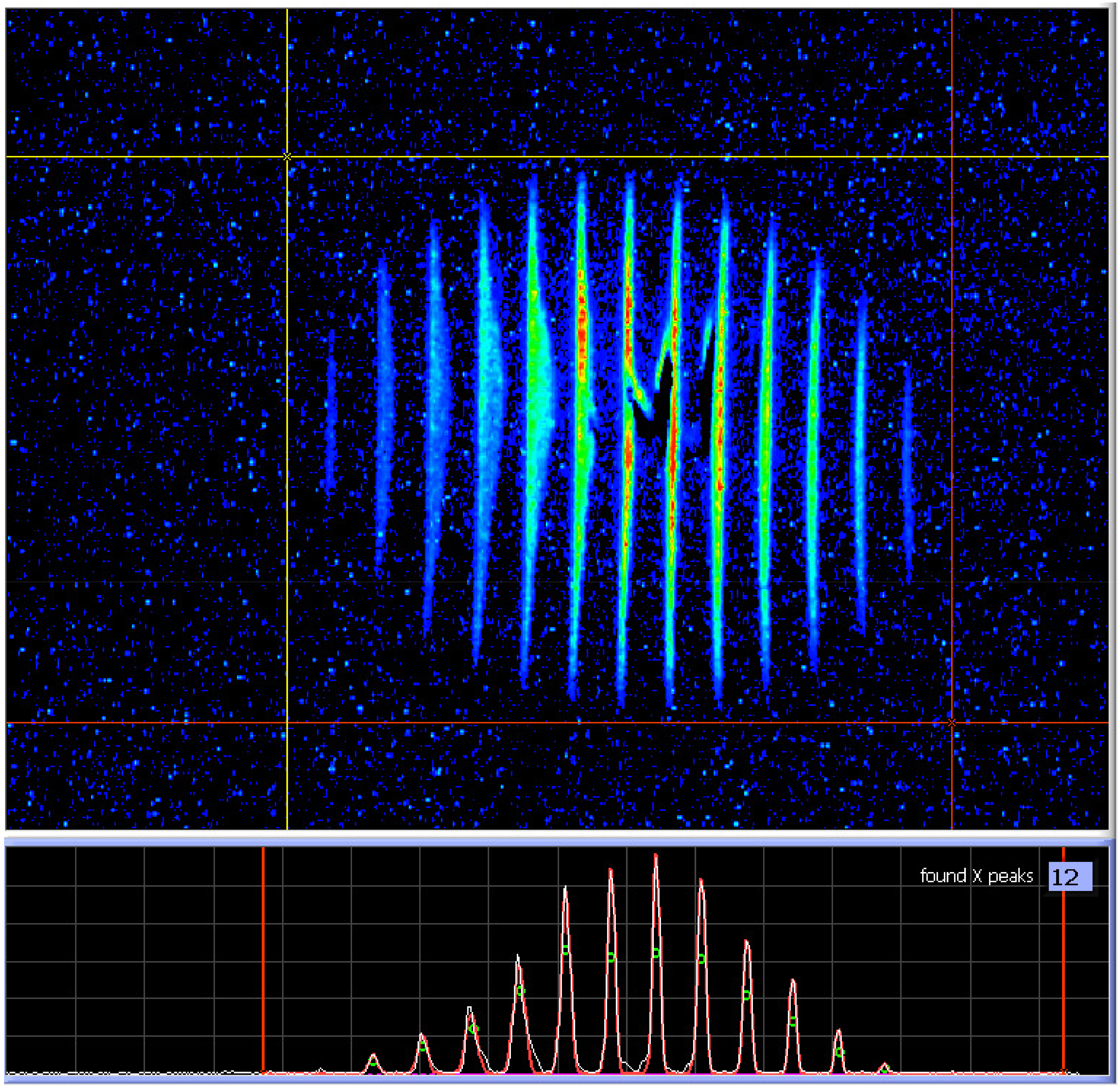


ba)
observer
primary beam
observer
β
s
β
C
B
s'
scintillating column
virtual image
ℓ
β'
d
scintillating crystal
A
primary beam
β
α
α
observer

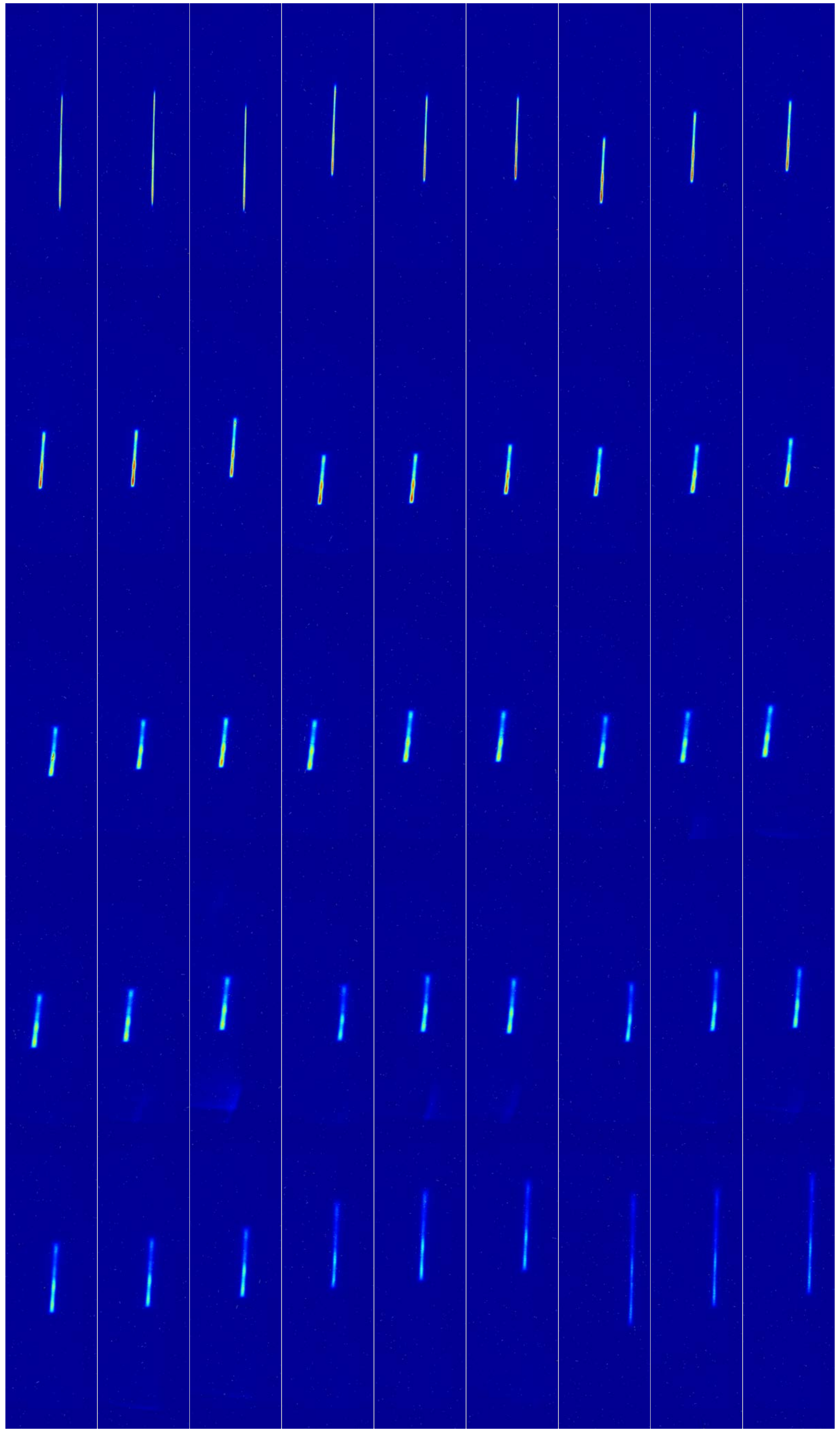


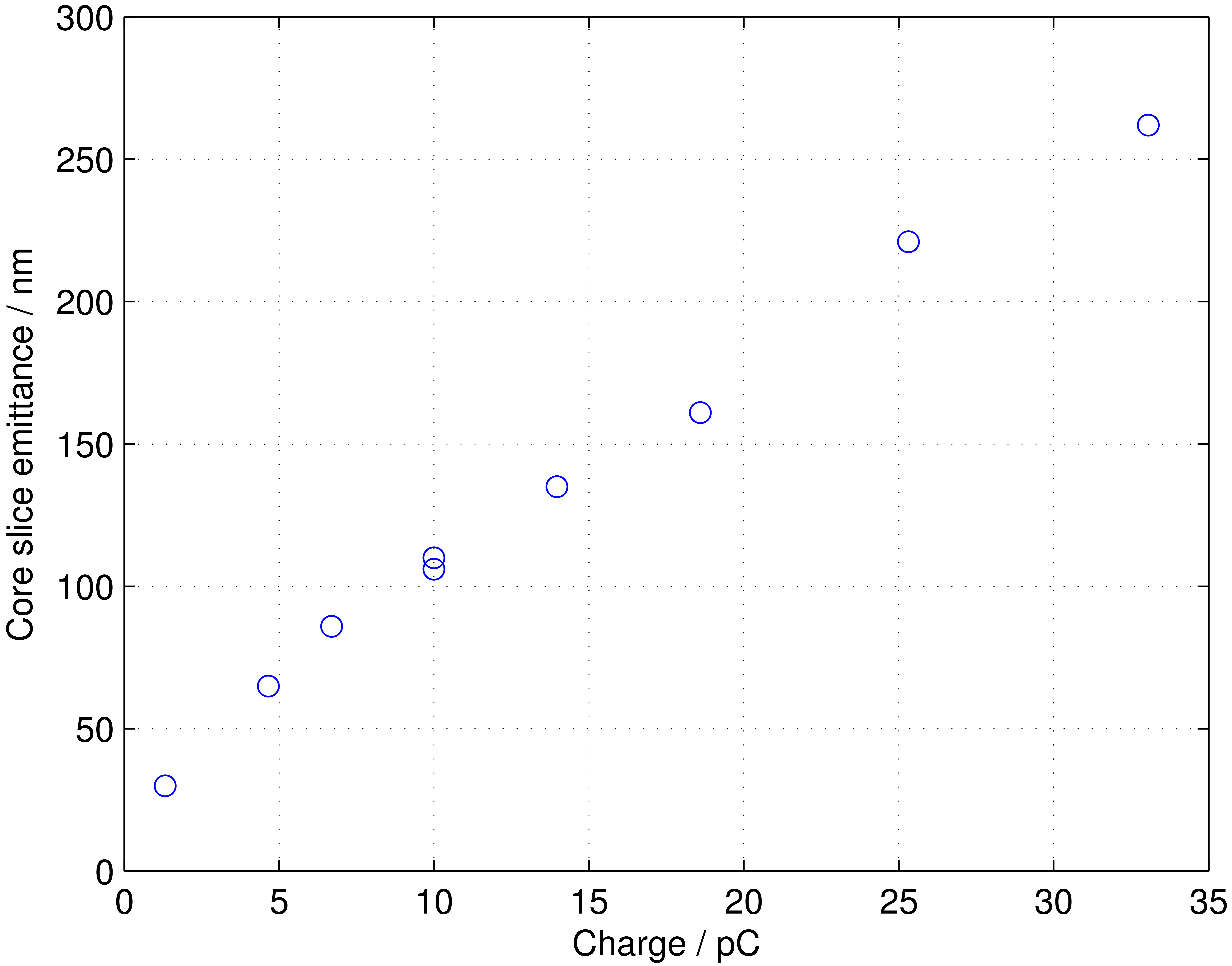
40
35
30
25
20
15
10
5
0
image size / μm
-80
-60
-40
-20
0
20
40
60
80
observation angle β / degrees



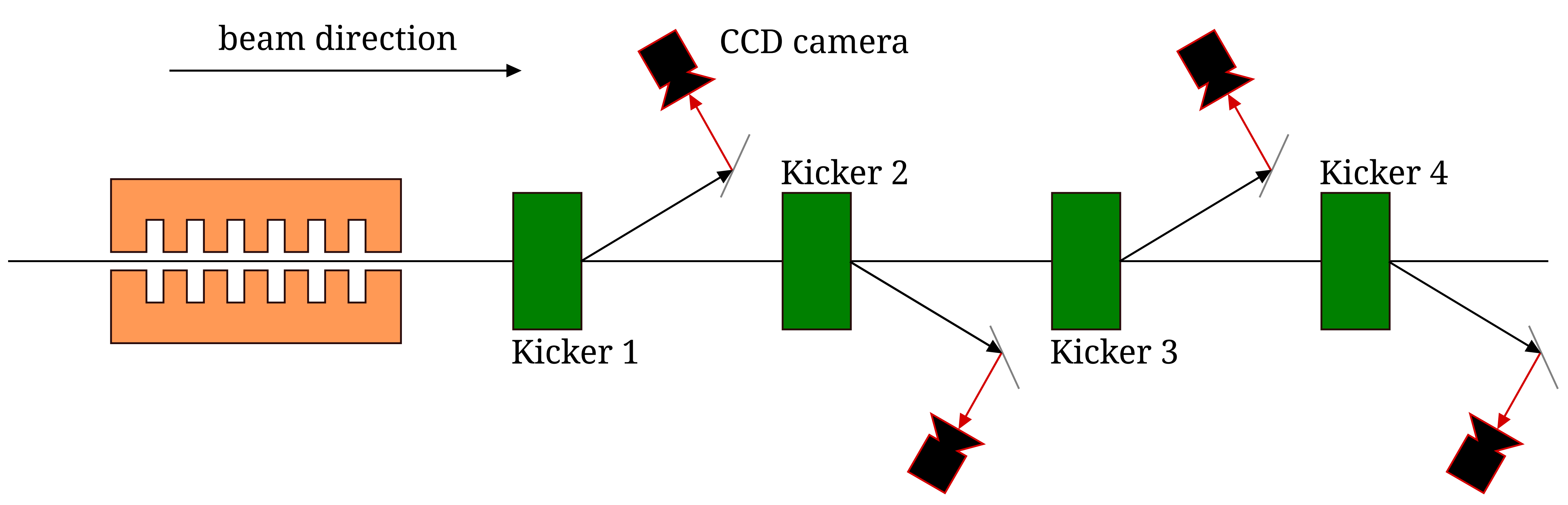


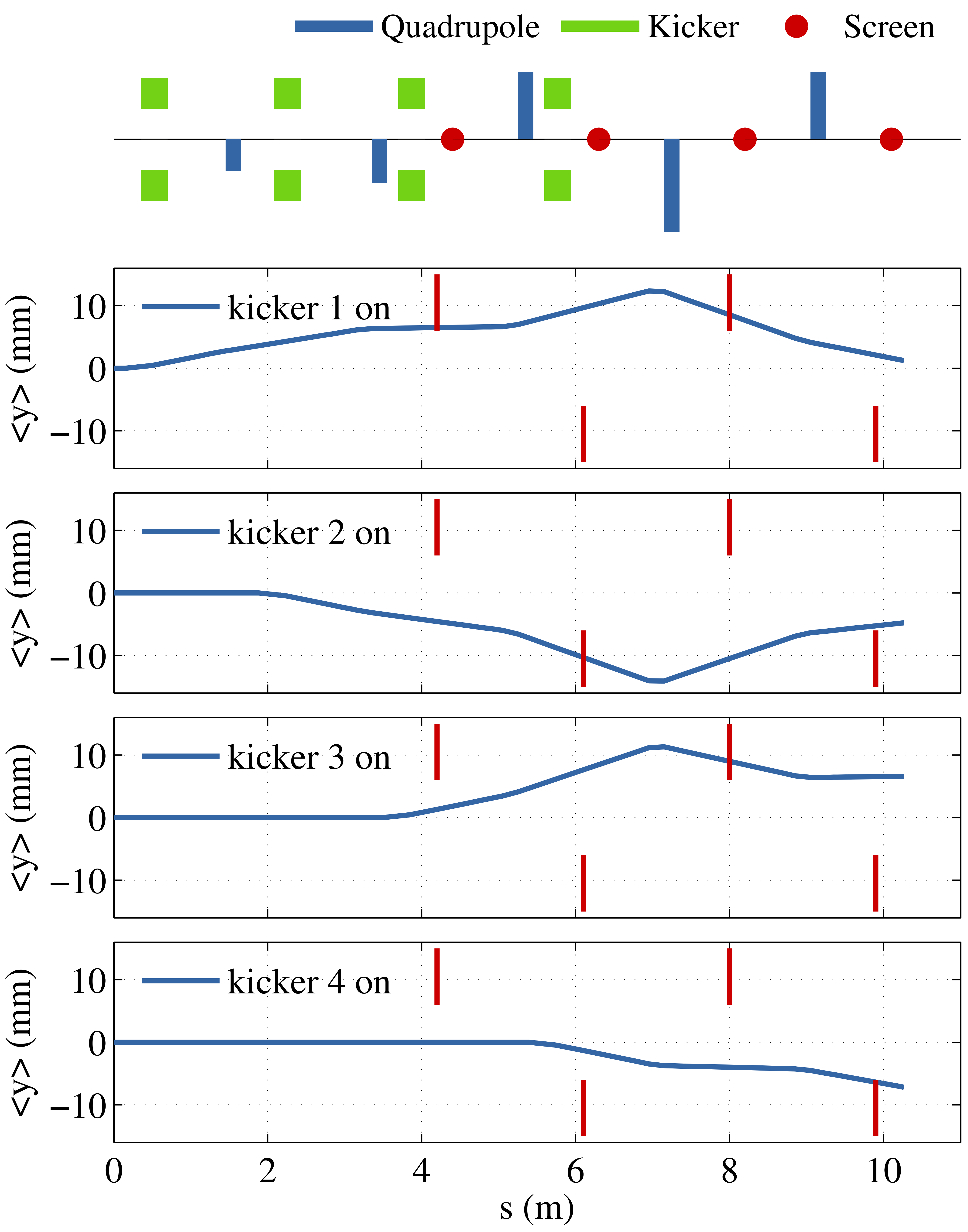
Pavel Evtushenko



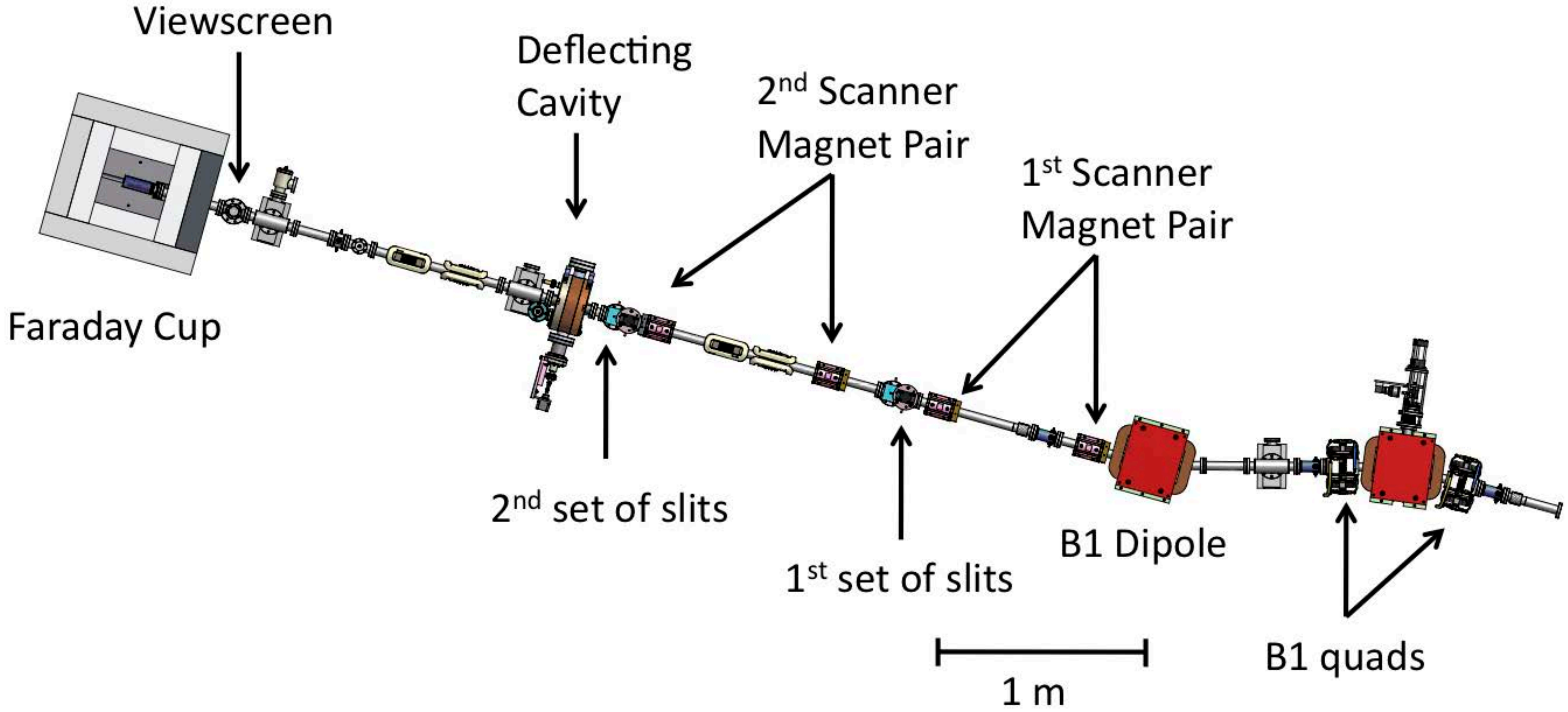

Core slice emittance / nm
Charge / pC
0
50
100
150
200
250
300
0
5
10
15
20
25
30
35

Eduard Prat

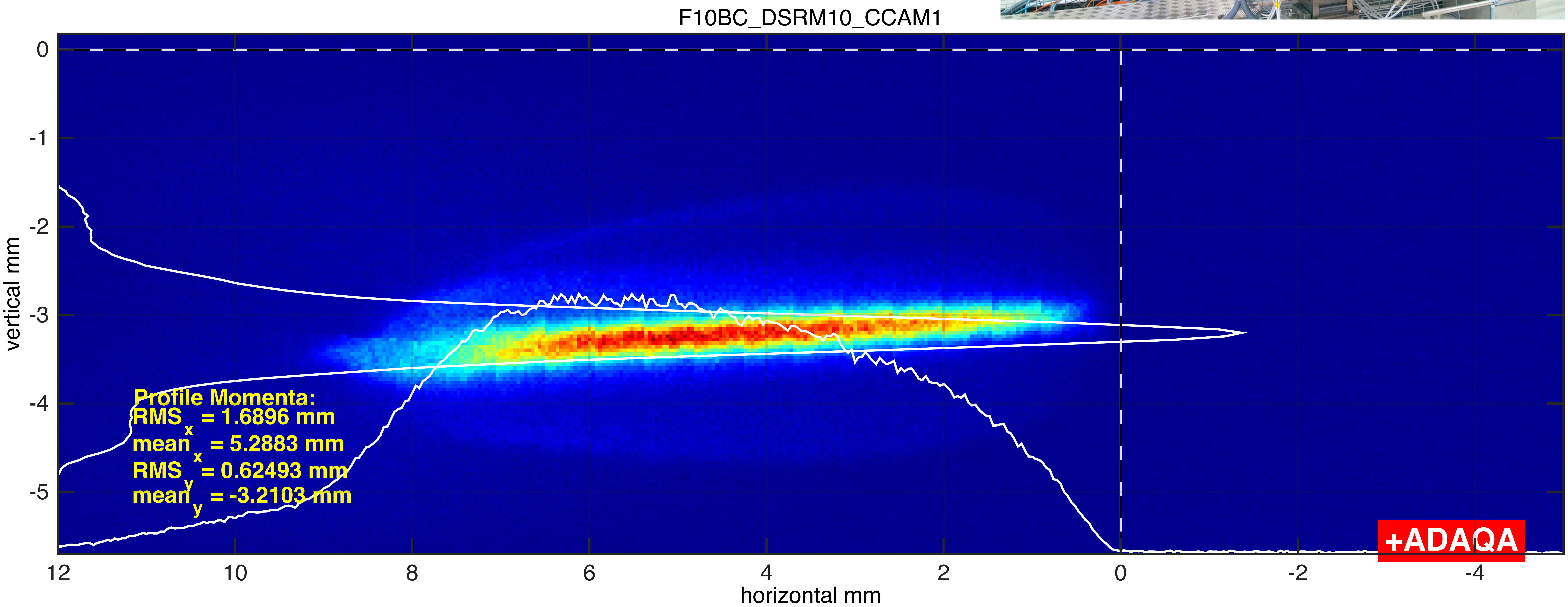




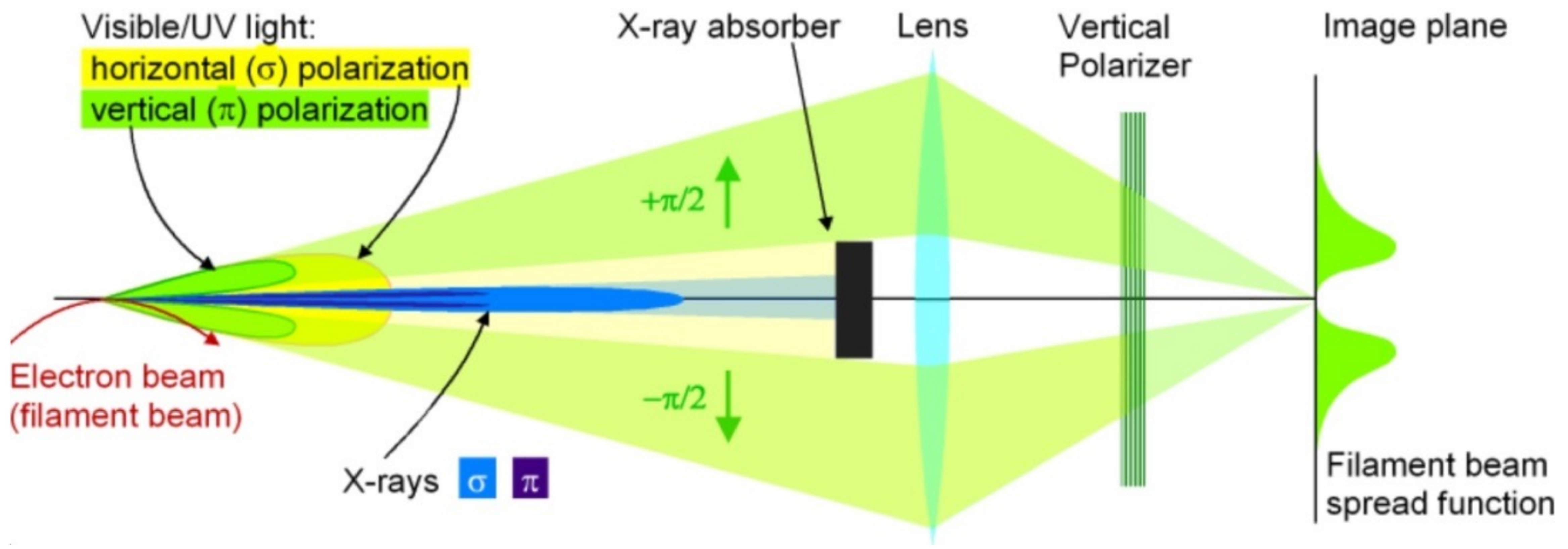
J. Wychowaniak et al., Proceedings of FEL 2014

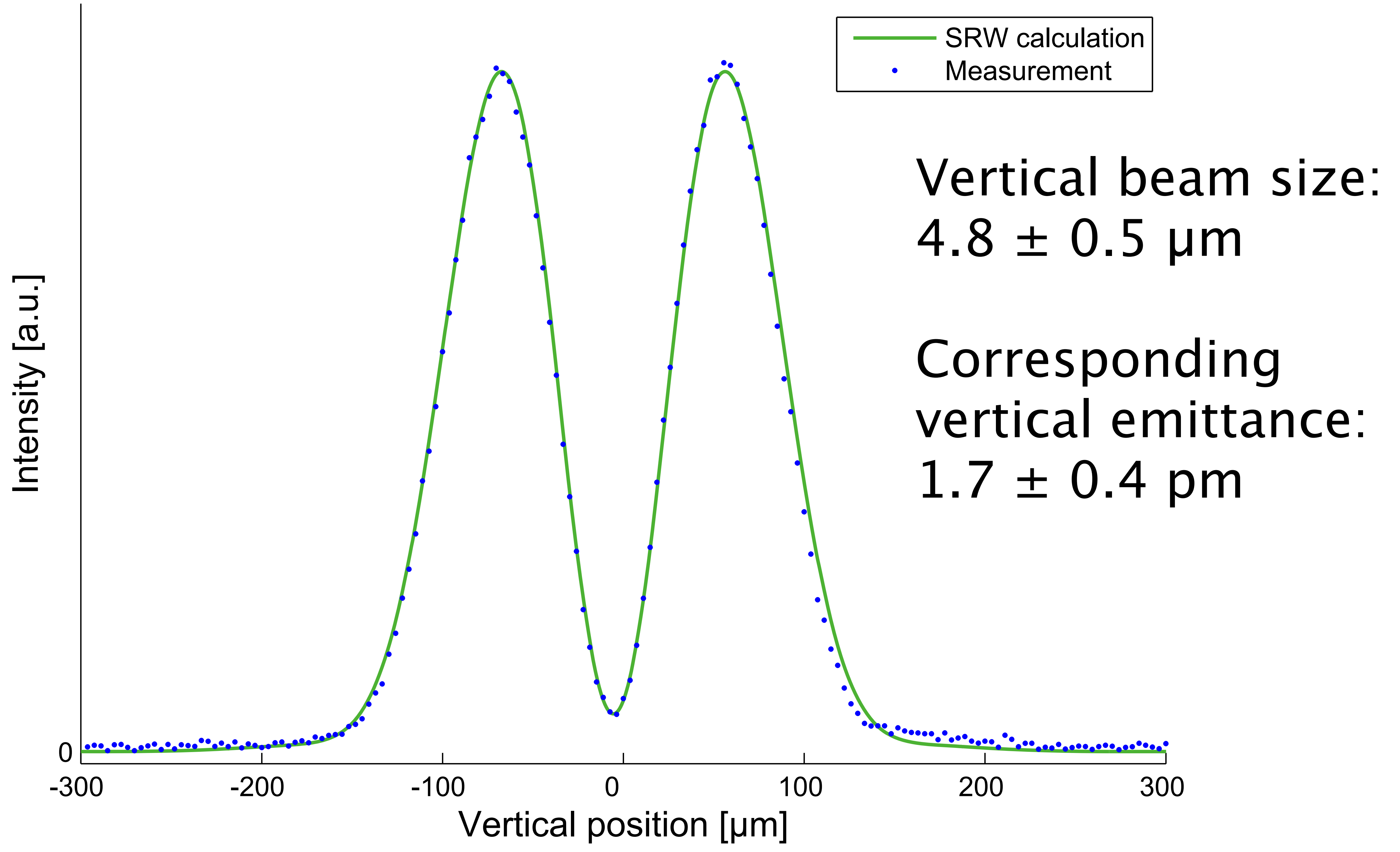


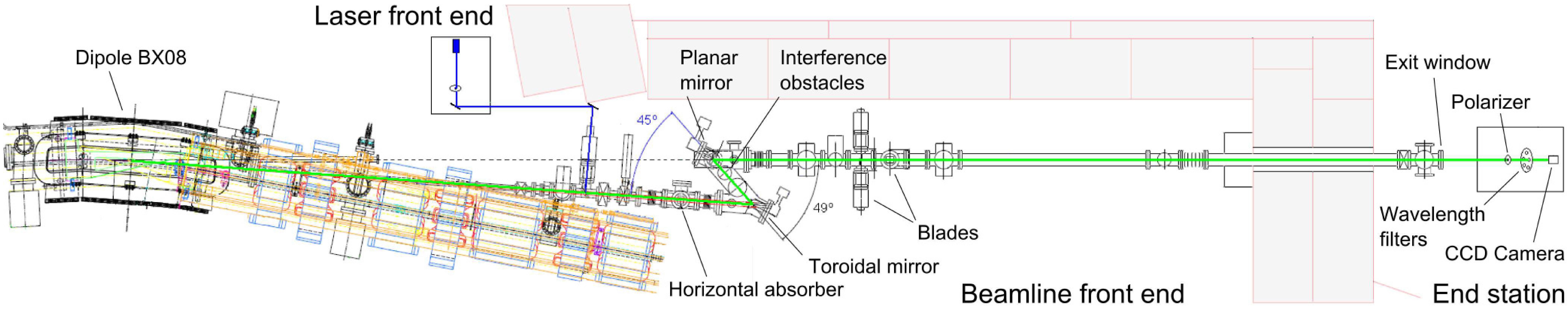
C. Gulliford et al., Proceedings of PAC 2013



Gian Luca Orlandi





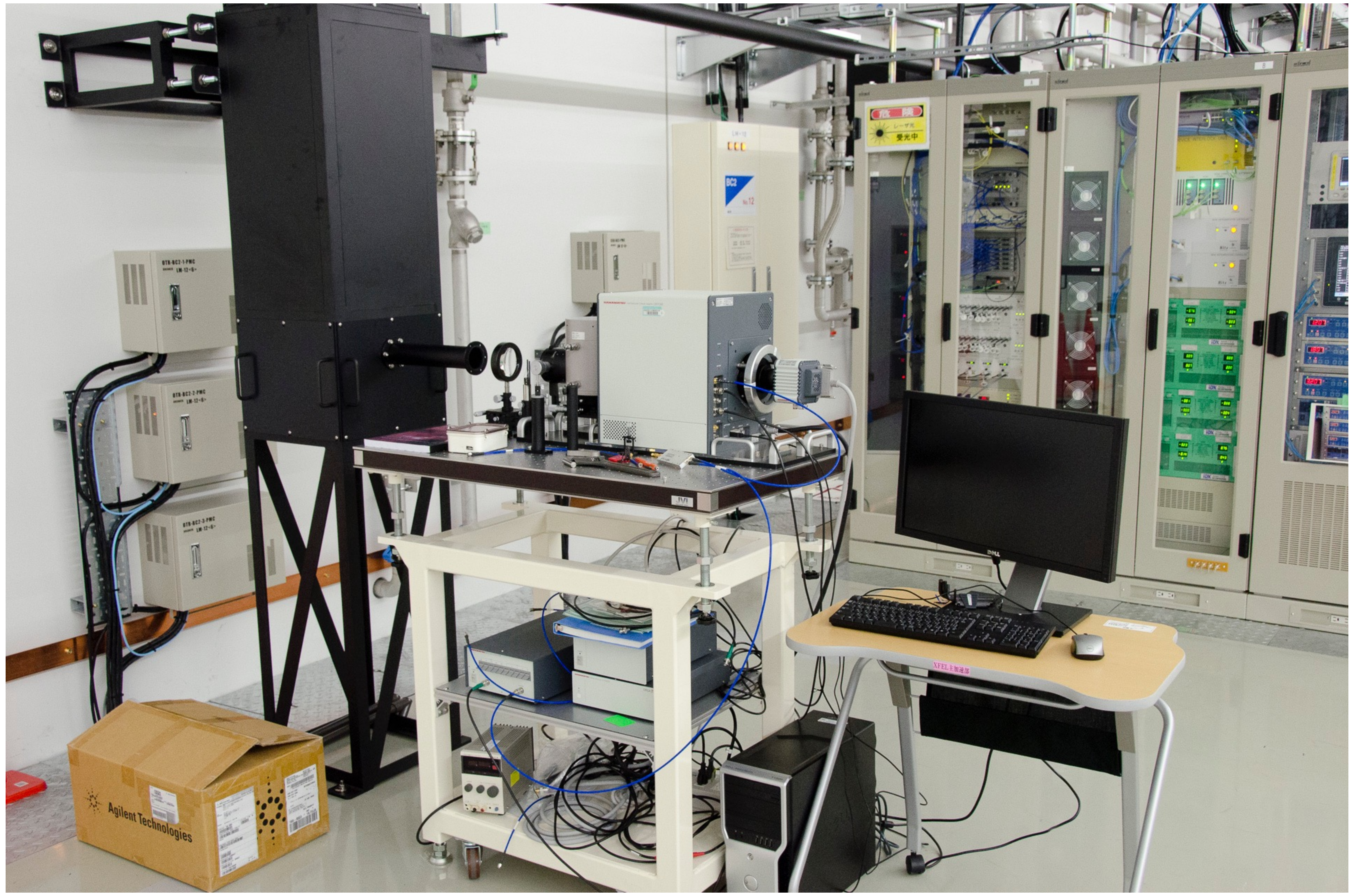


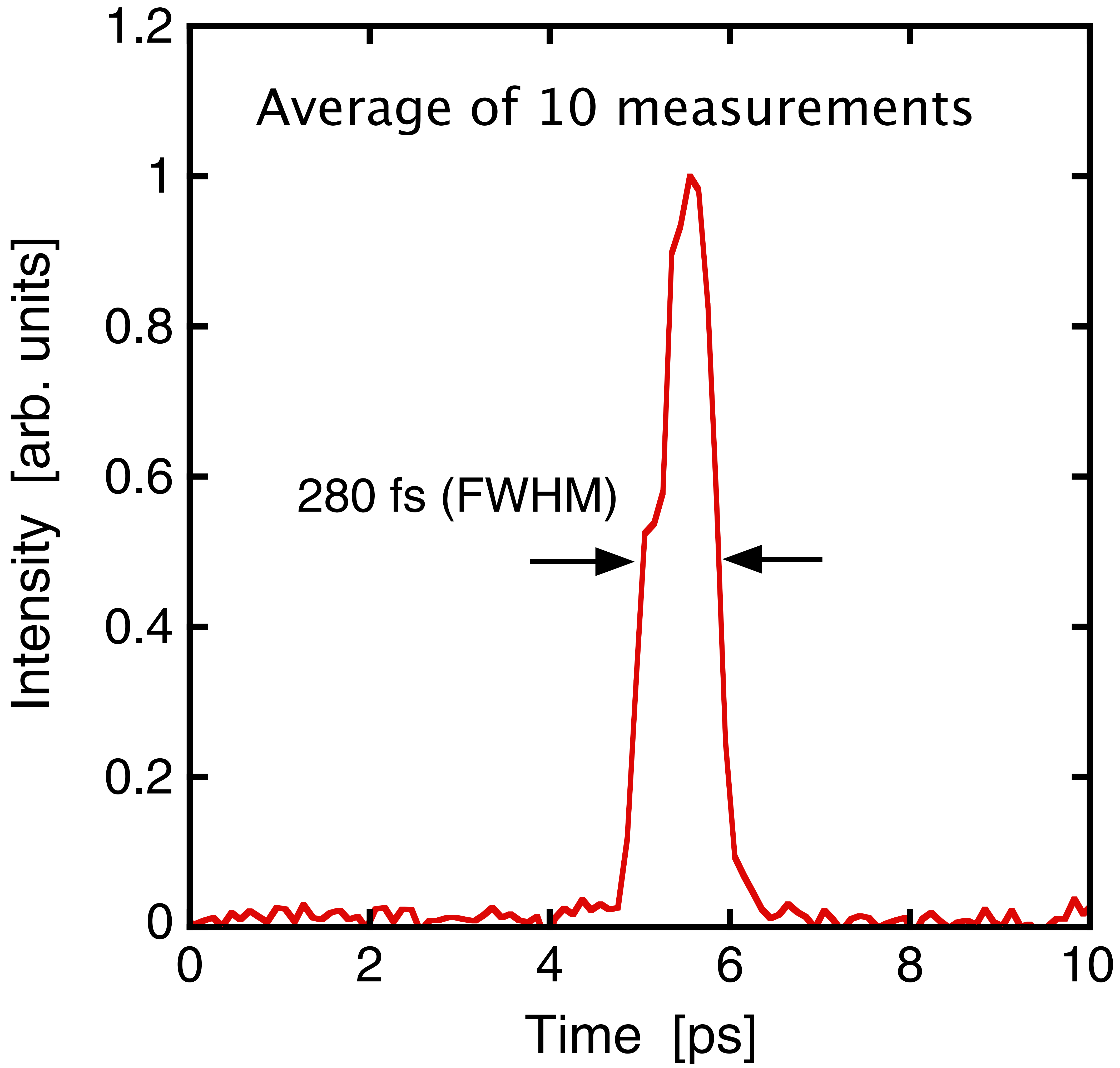
Angela Saa Hernandez, ALERT 2014 Workshop, and J. Breunlin et al., Proceedings of IPAC2014

Time-Resolved Instrumentation

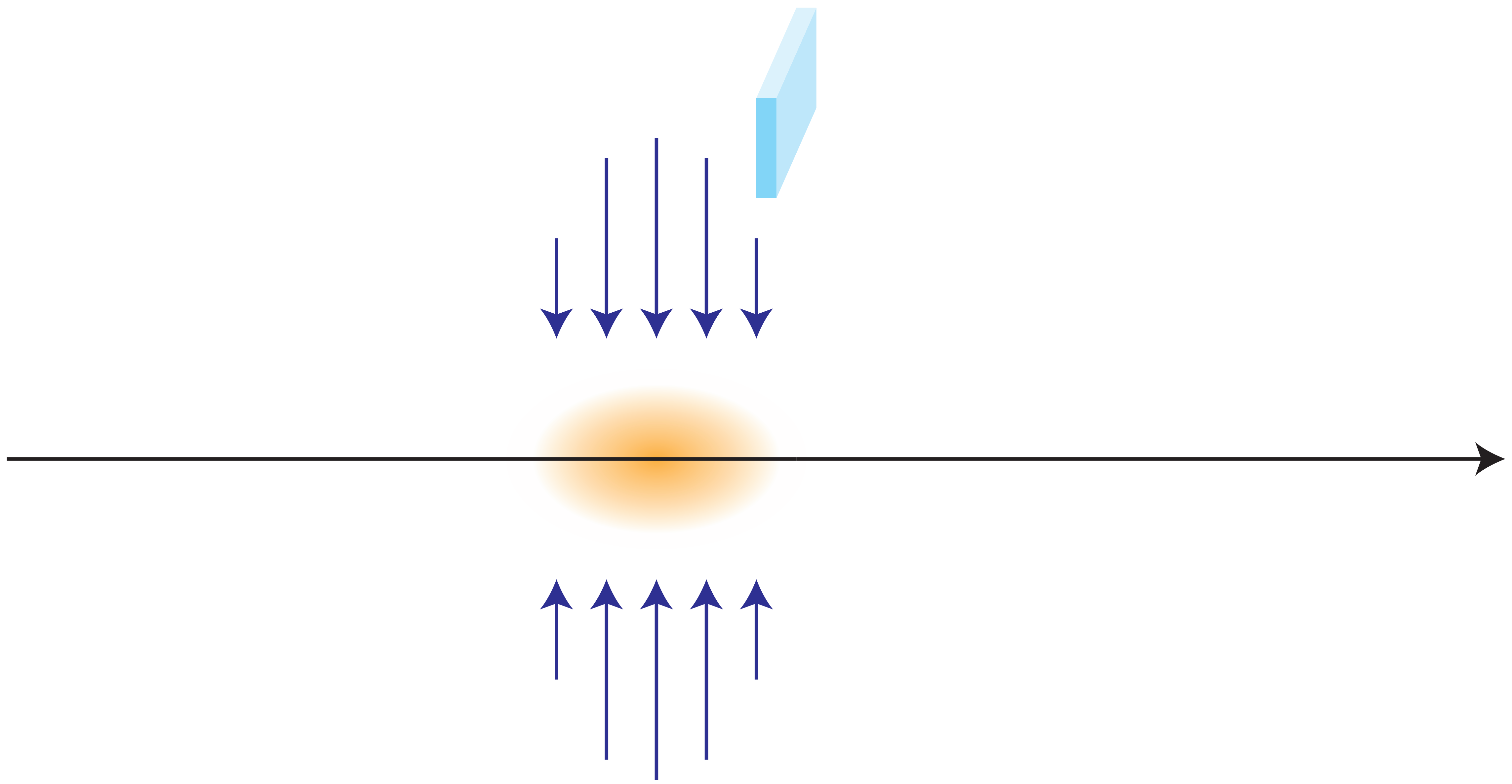
Wikimedia Commons

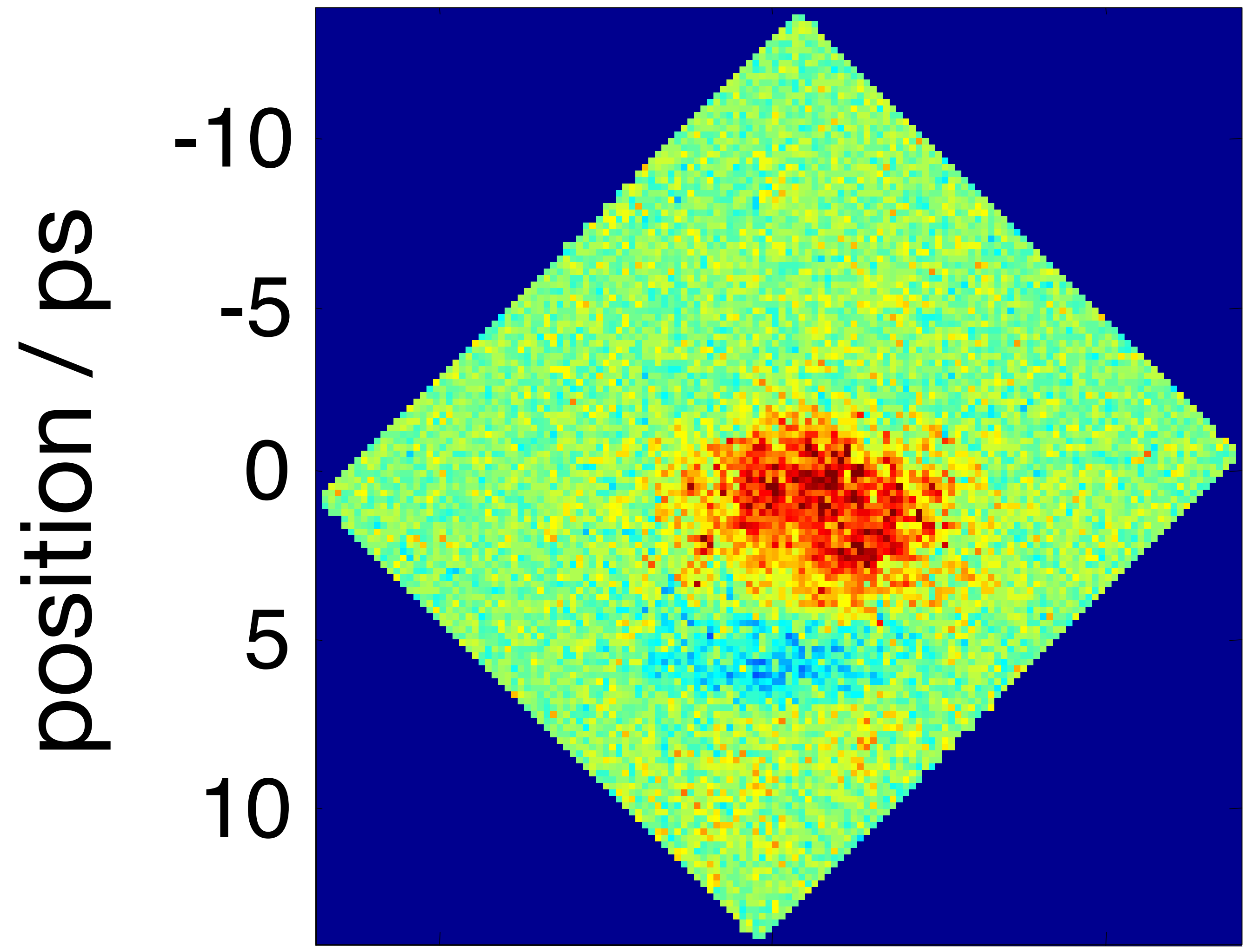
Volker Schlott

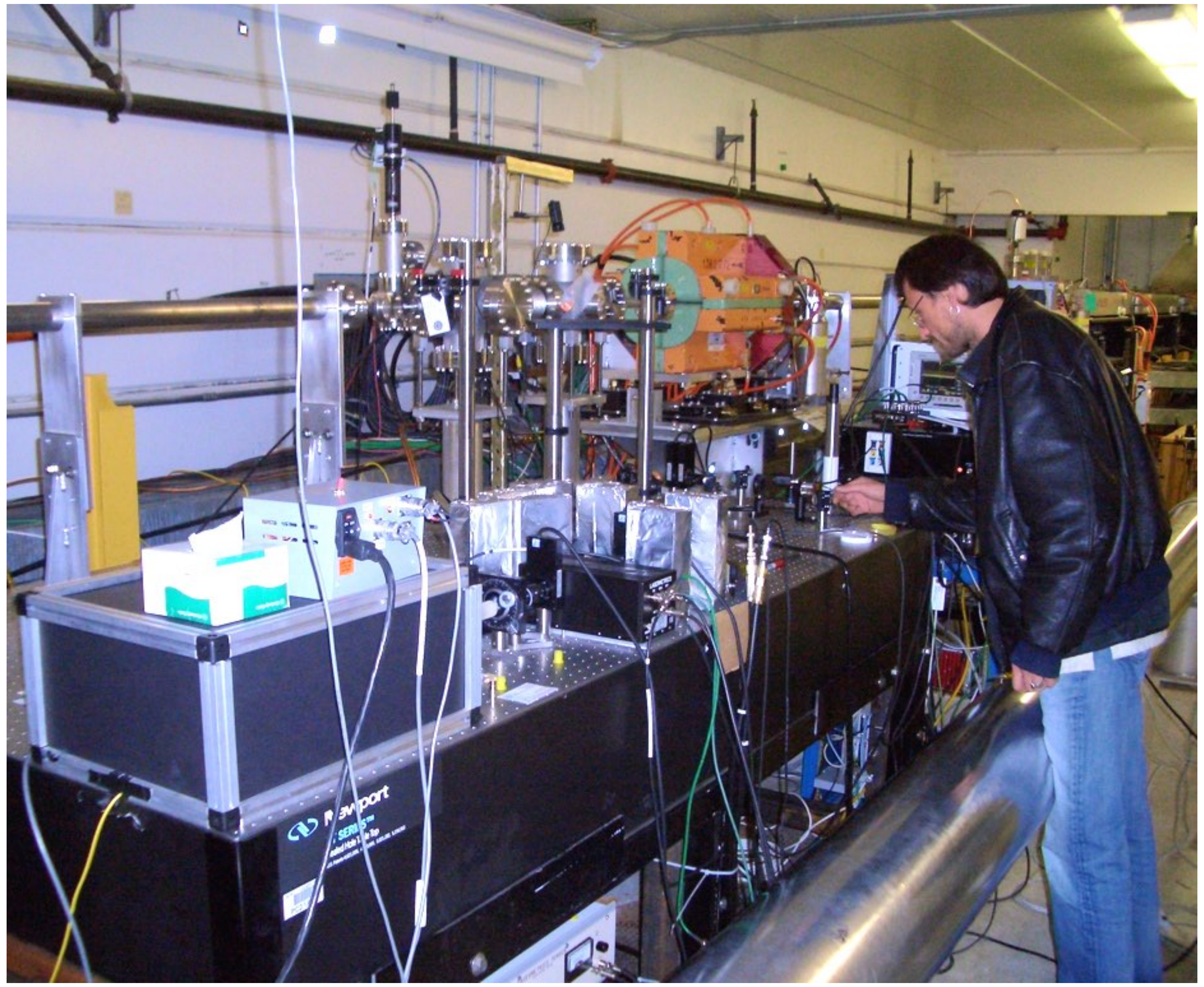




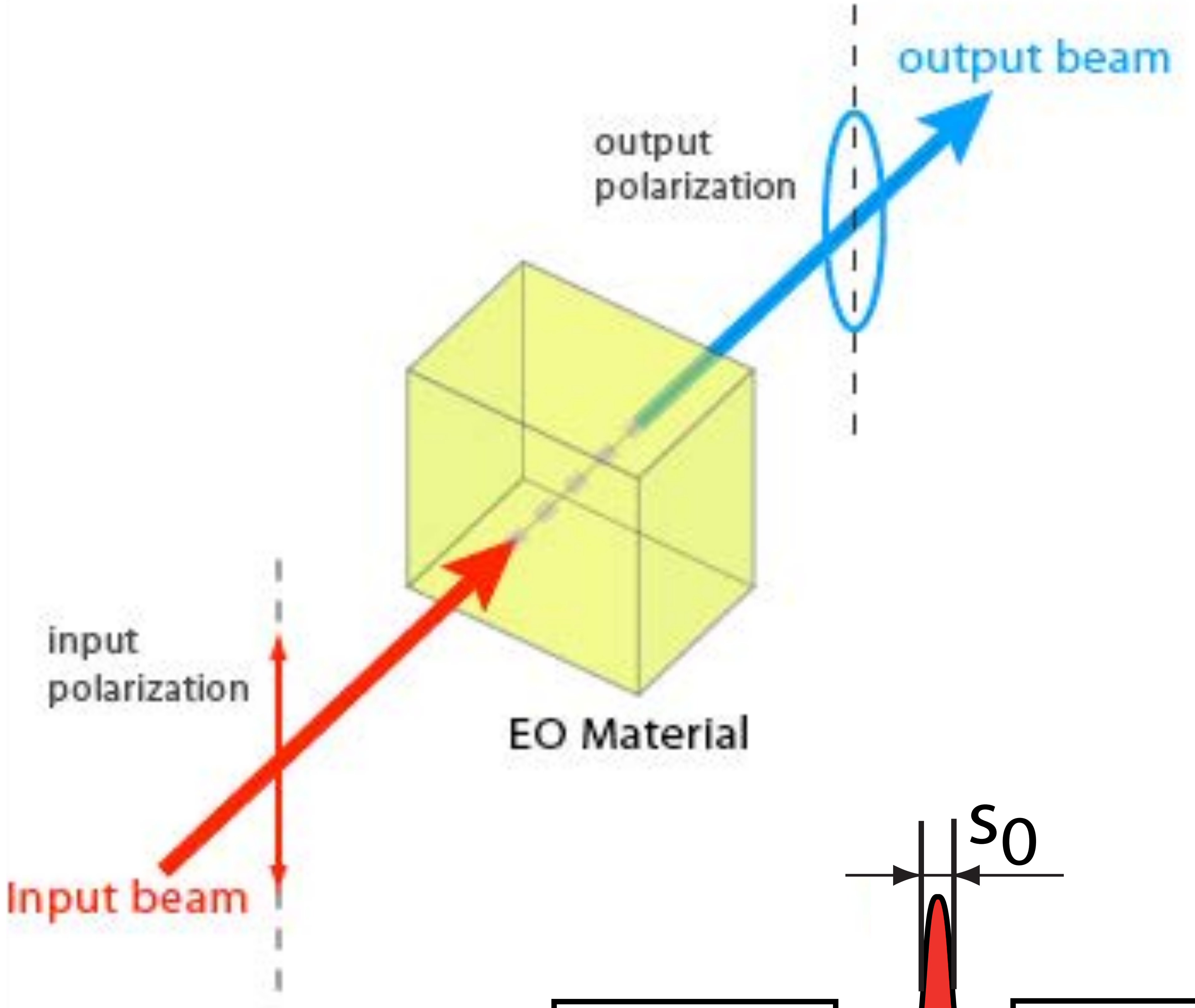
Yuji Otake et al., PRST-AB 16, 042802 (2013)

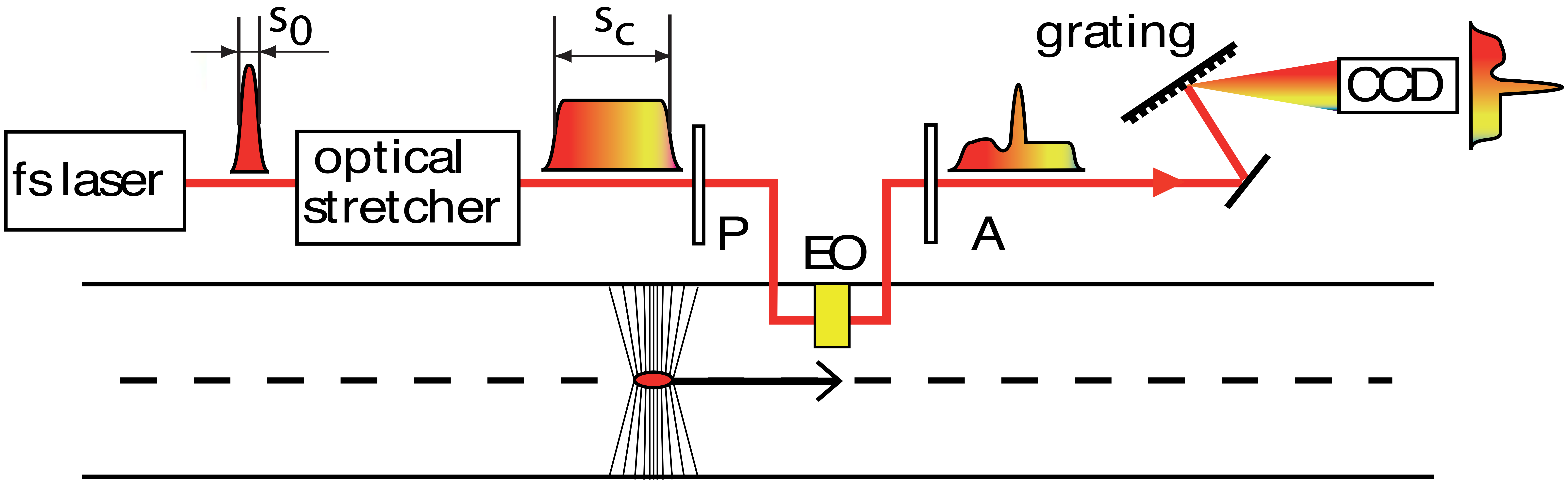




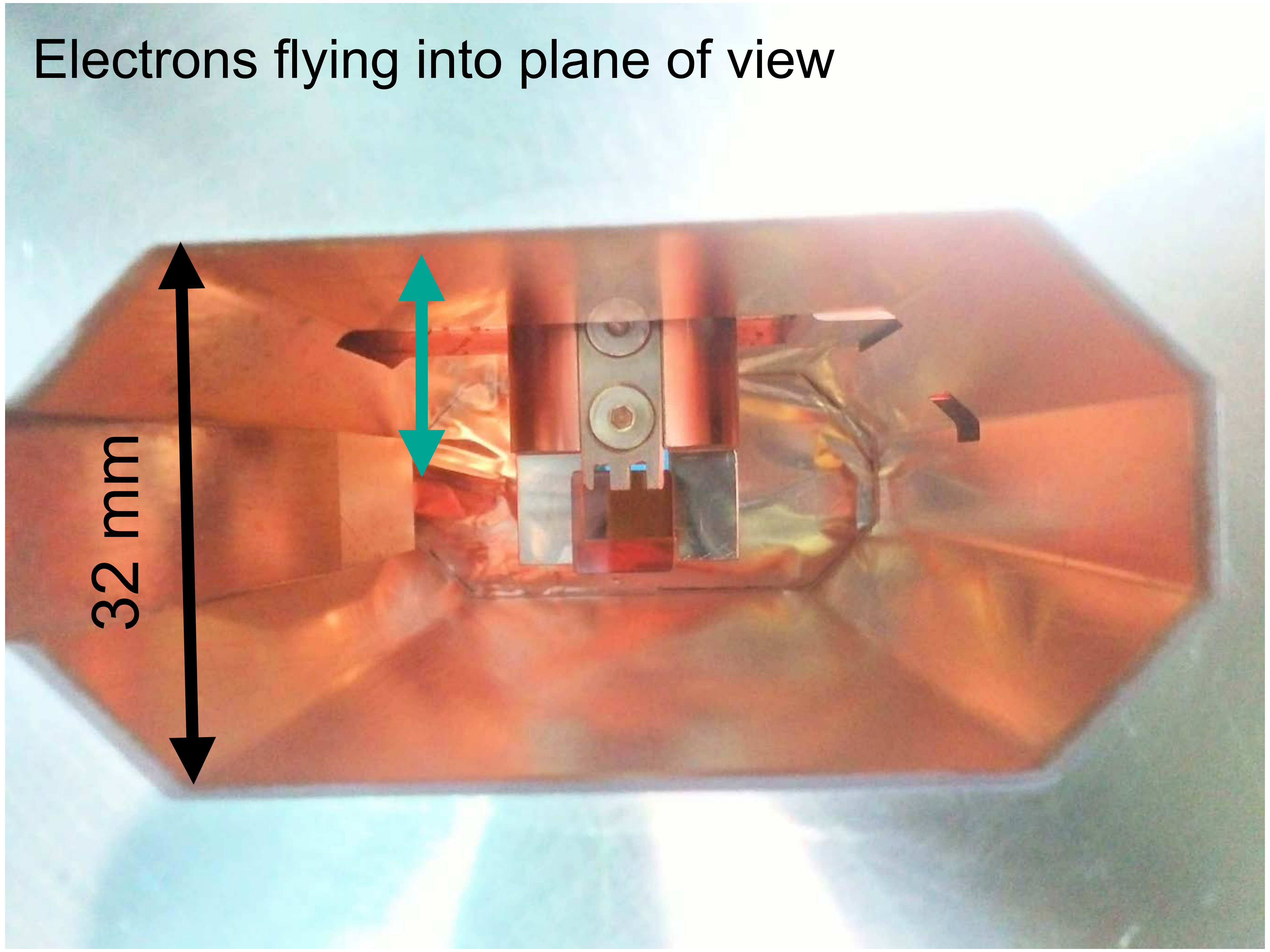


Adrian Cavalieri et al., PRL 94, 114801 (2005)

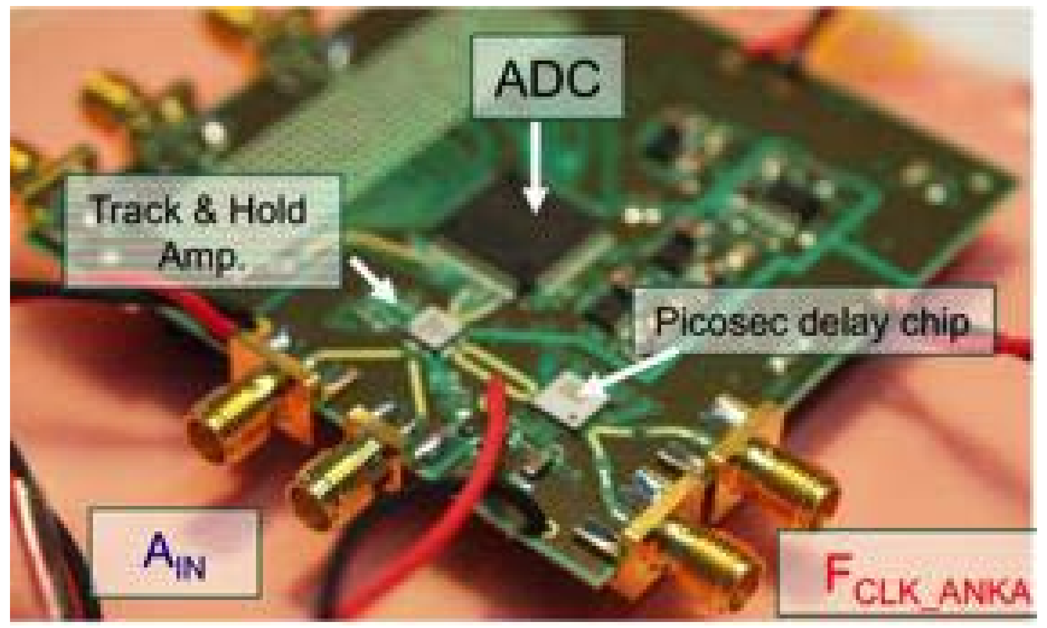


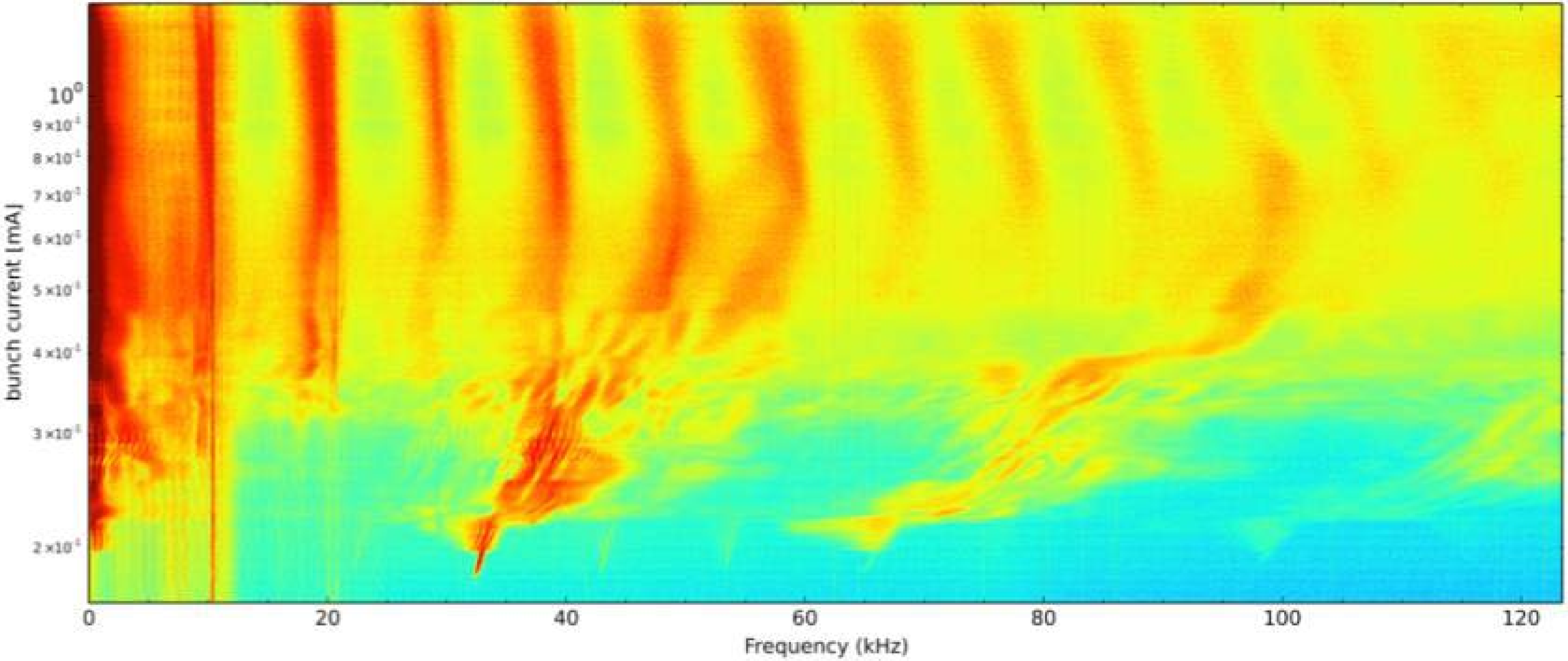


Bernd Steffen, AFS Inc.

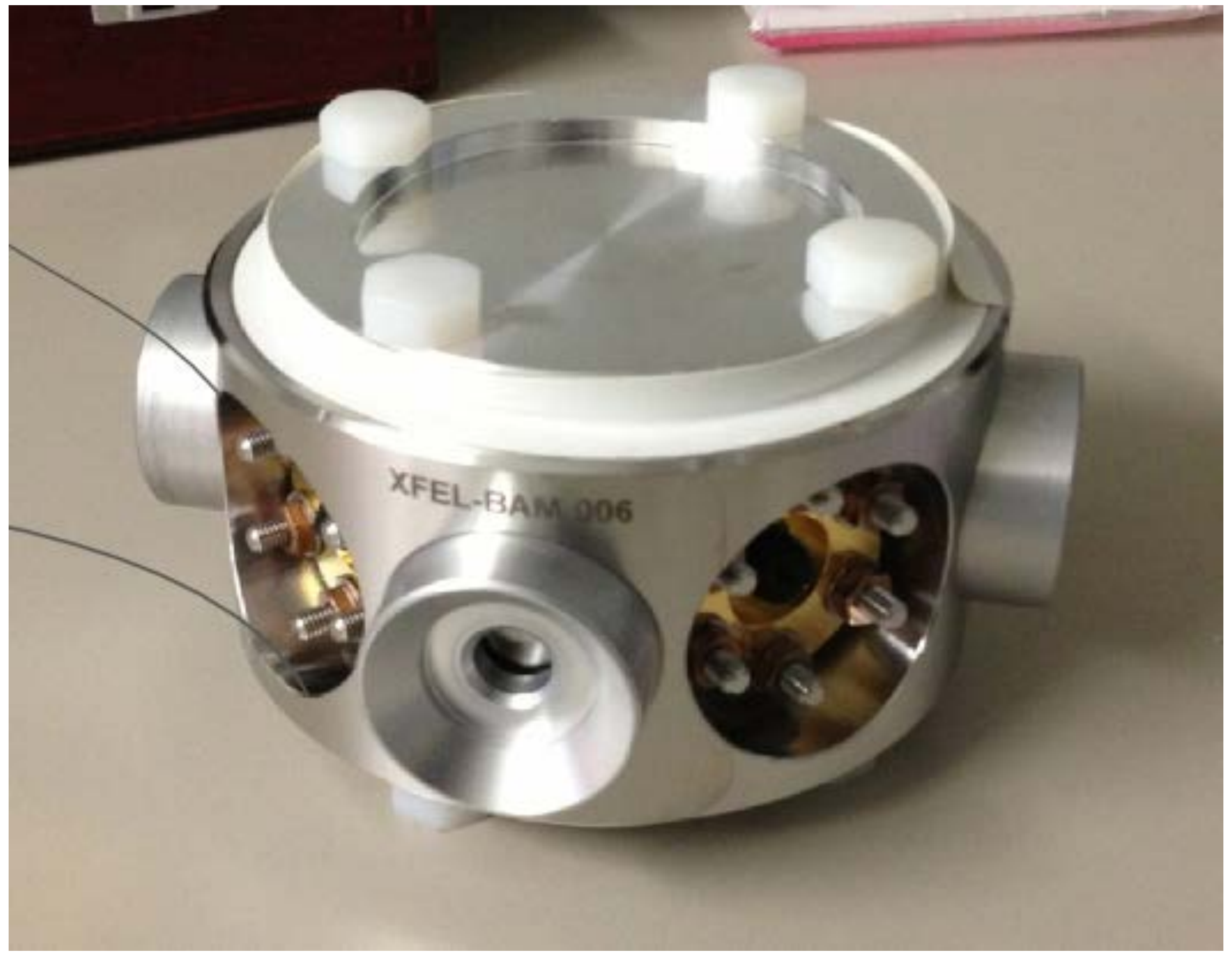


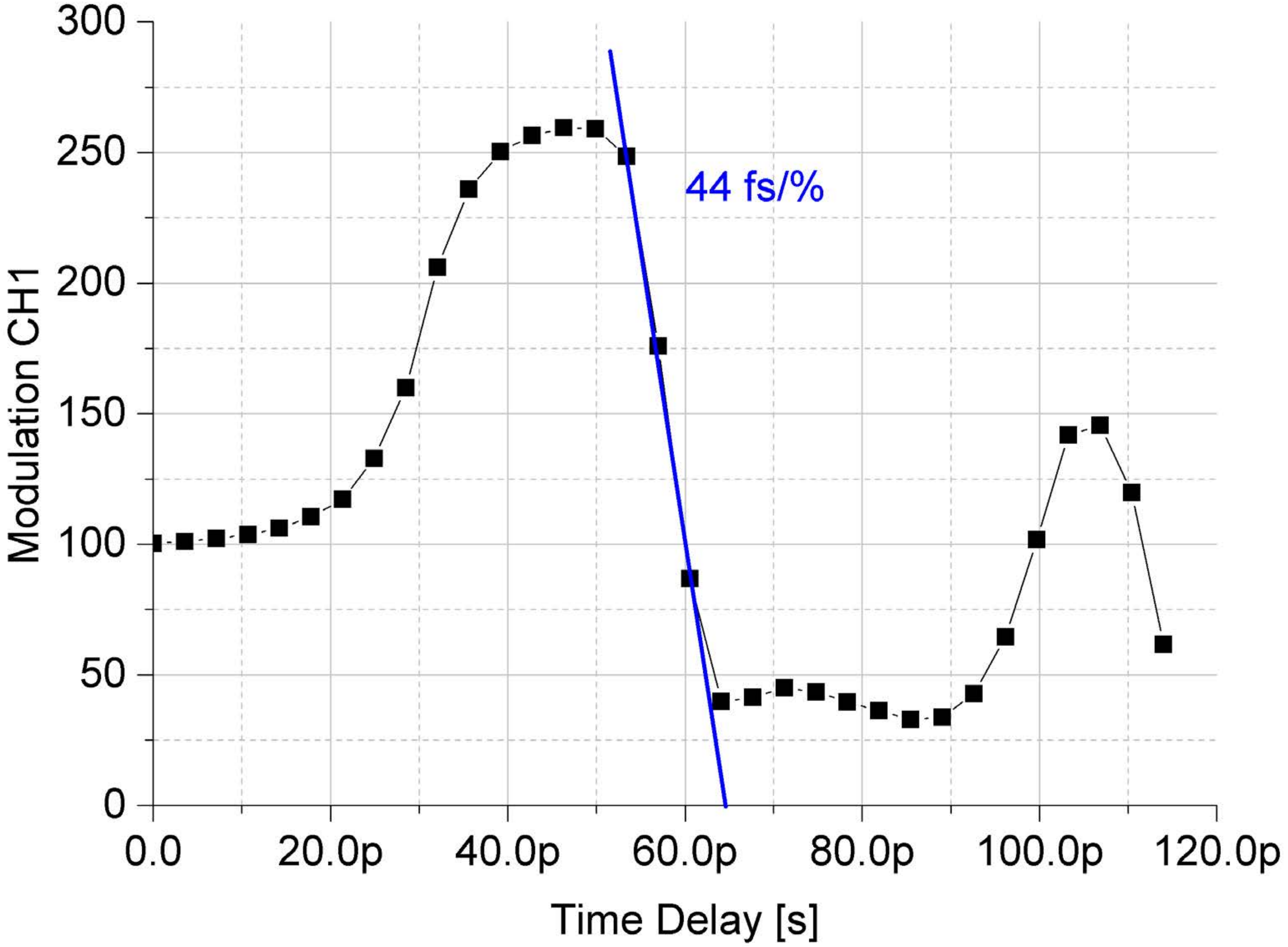
Nicole Hiller et al., Proceedings of IPAC 2014

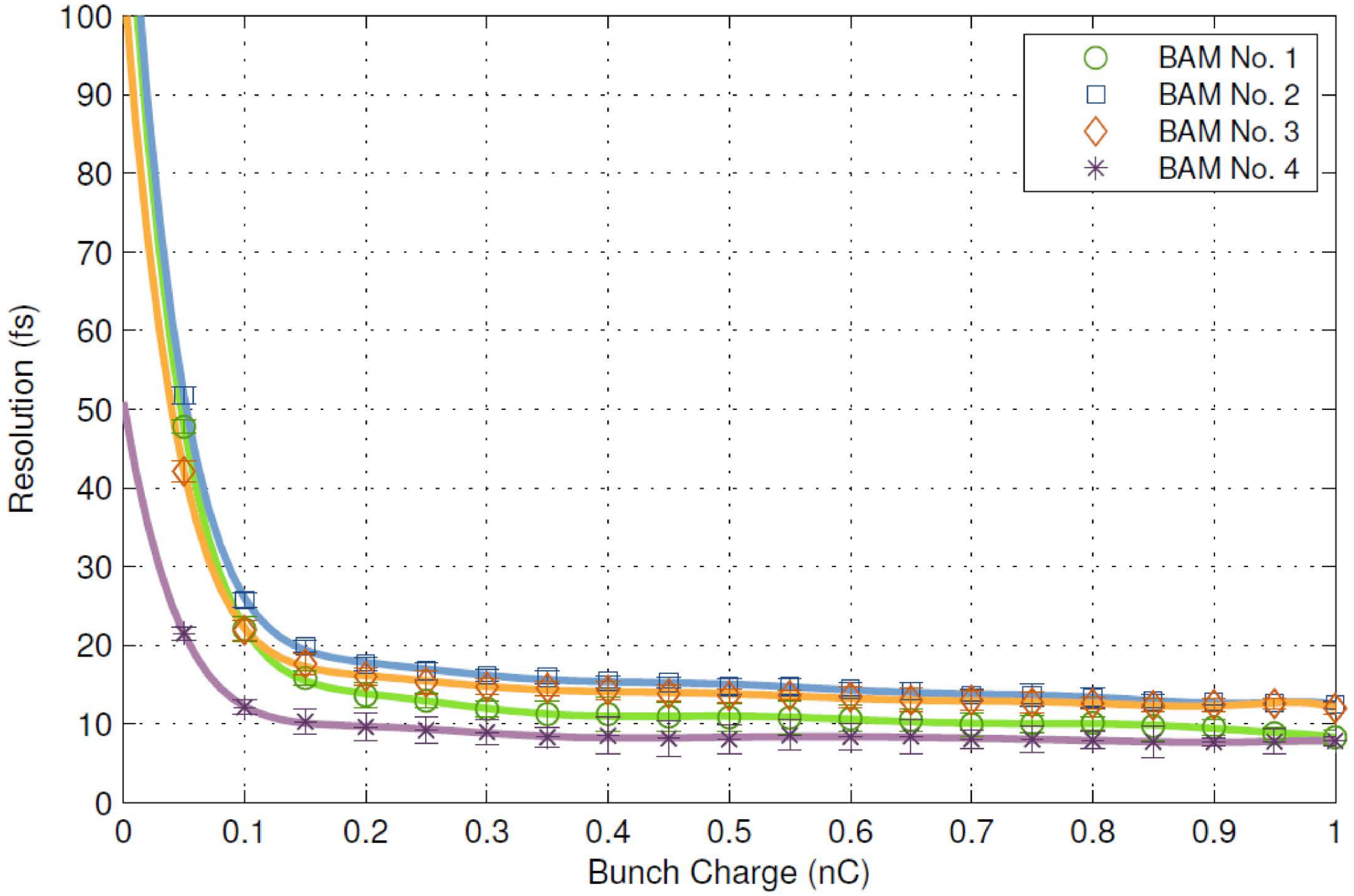




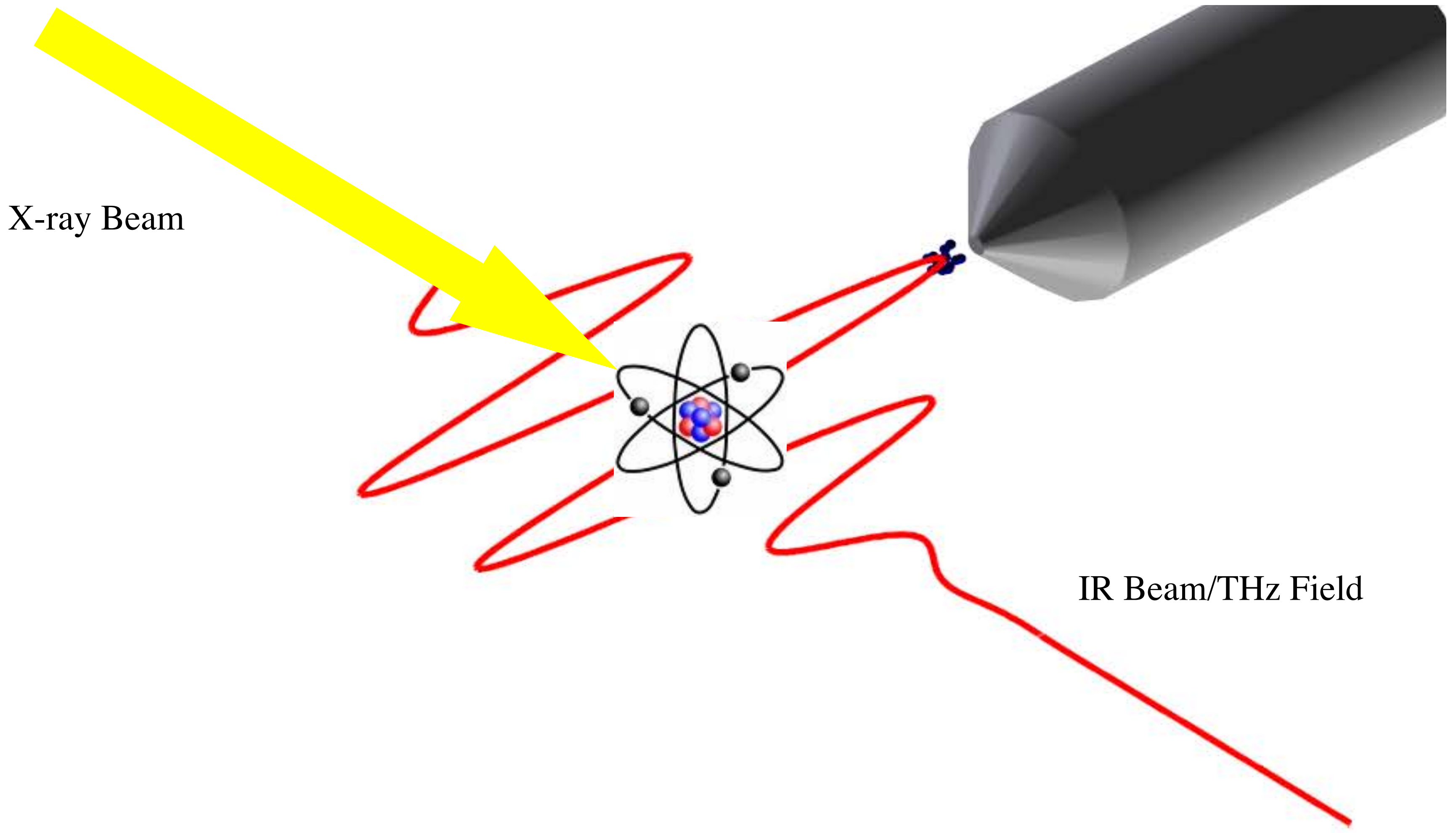
Vitali Judin et al, Proceedings of IPAC 2014, and Michele Caselle et al., JINST 9, C01024 (2014)

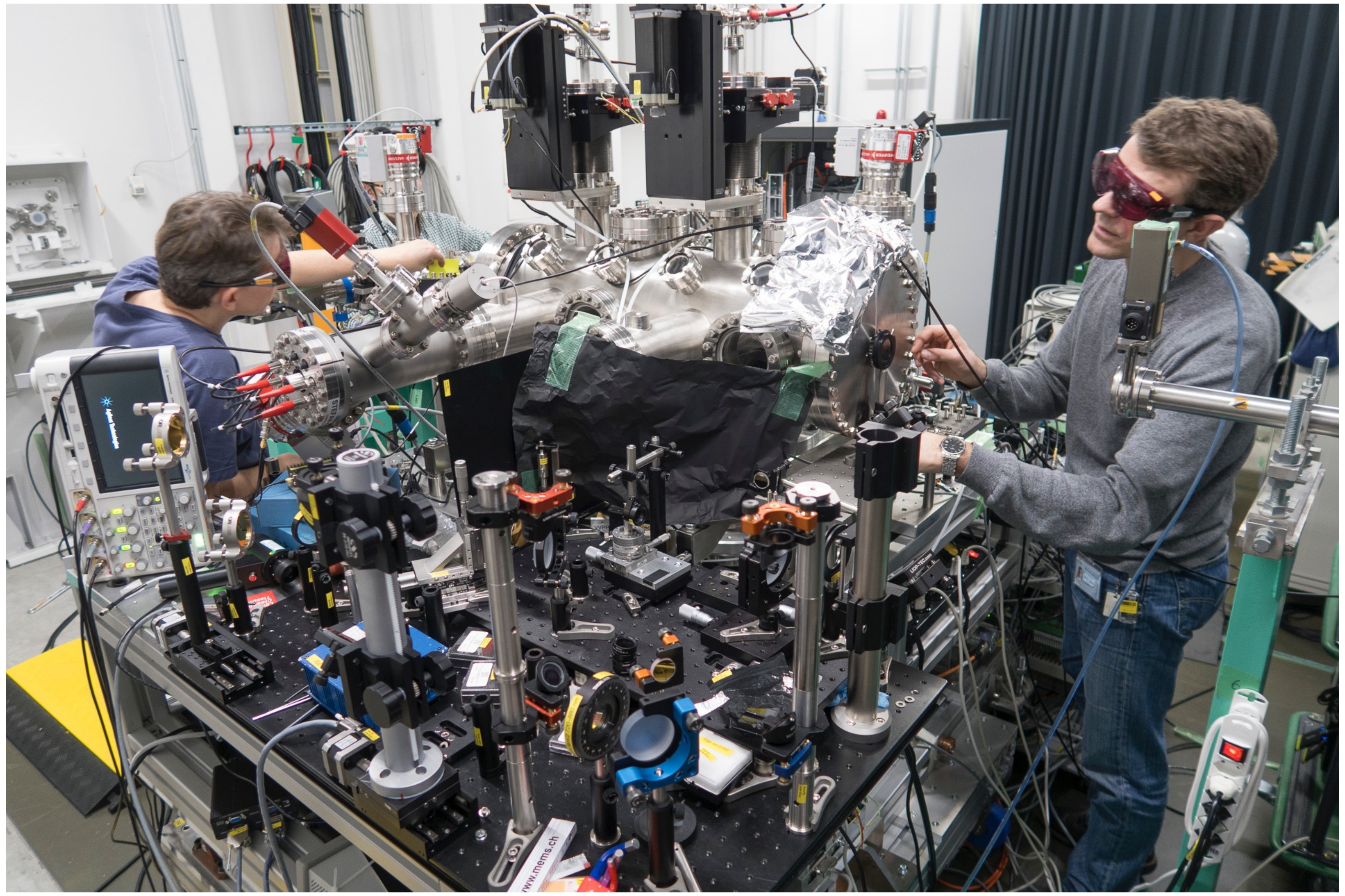


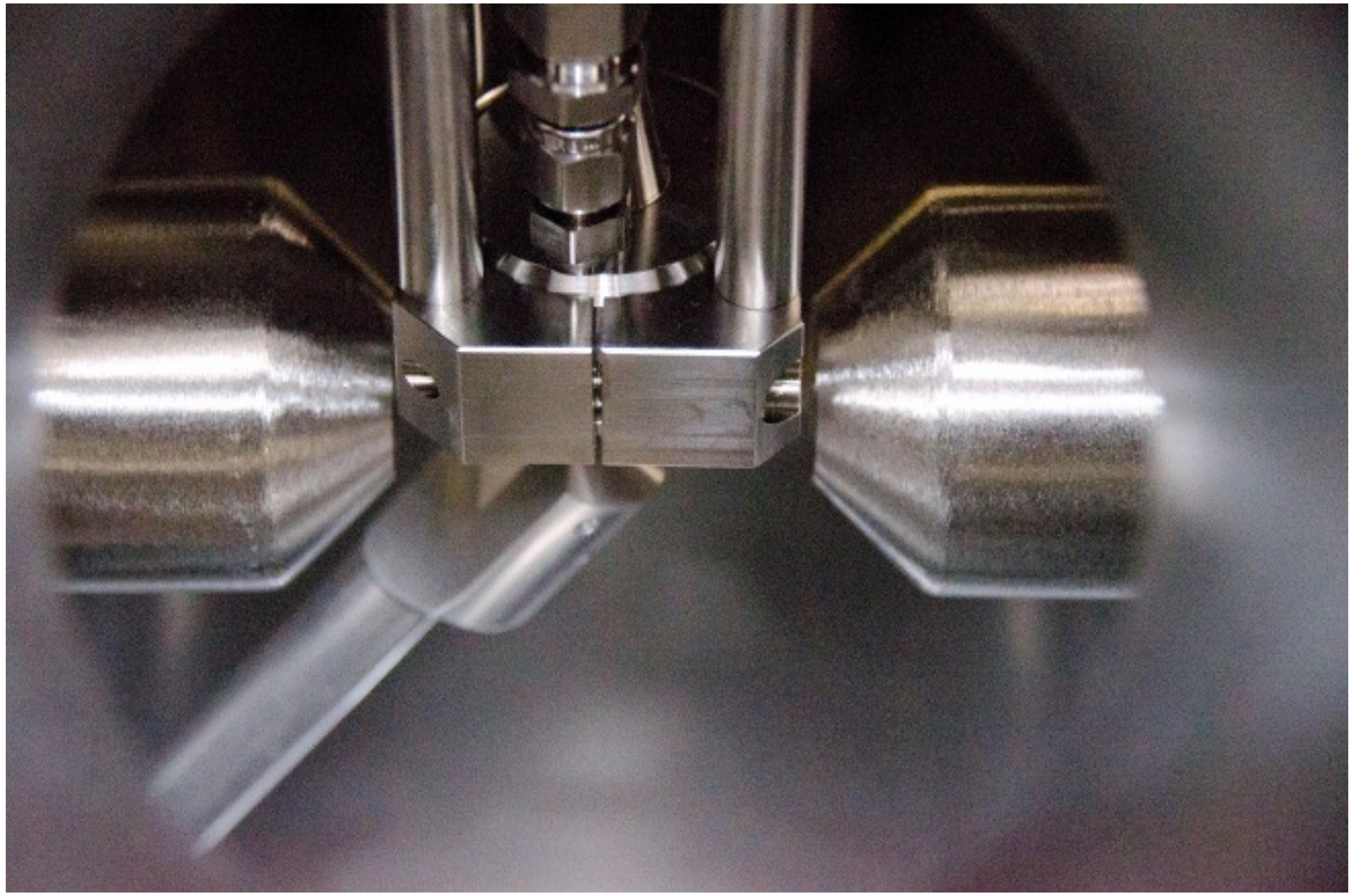


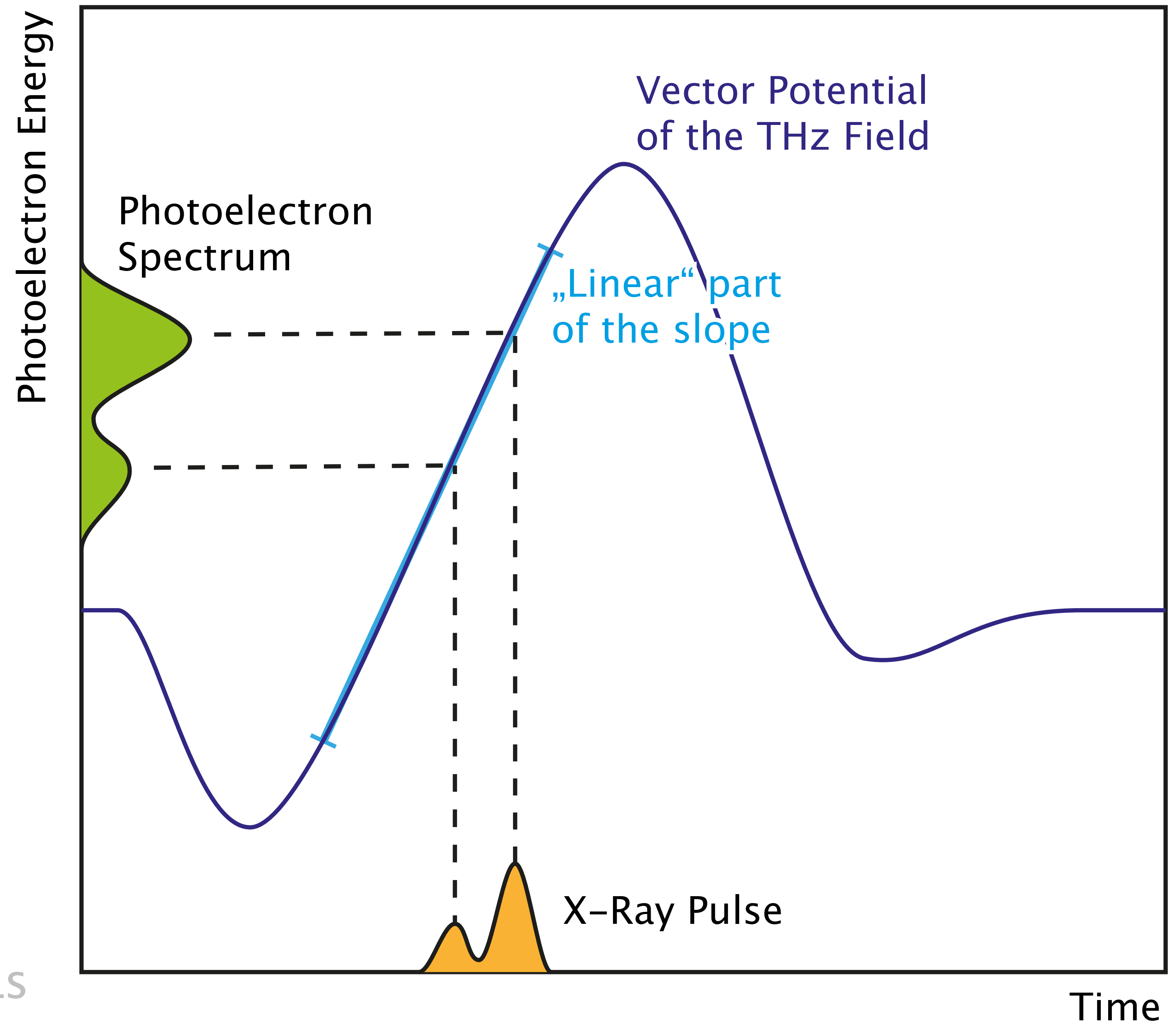


Marie Kristin Czwalinna, Proceedings of FEL2014









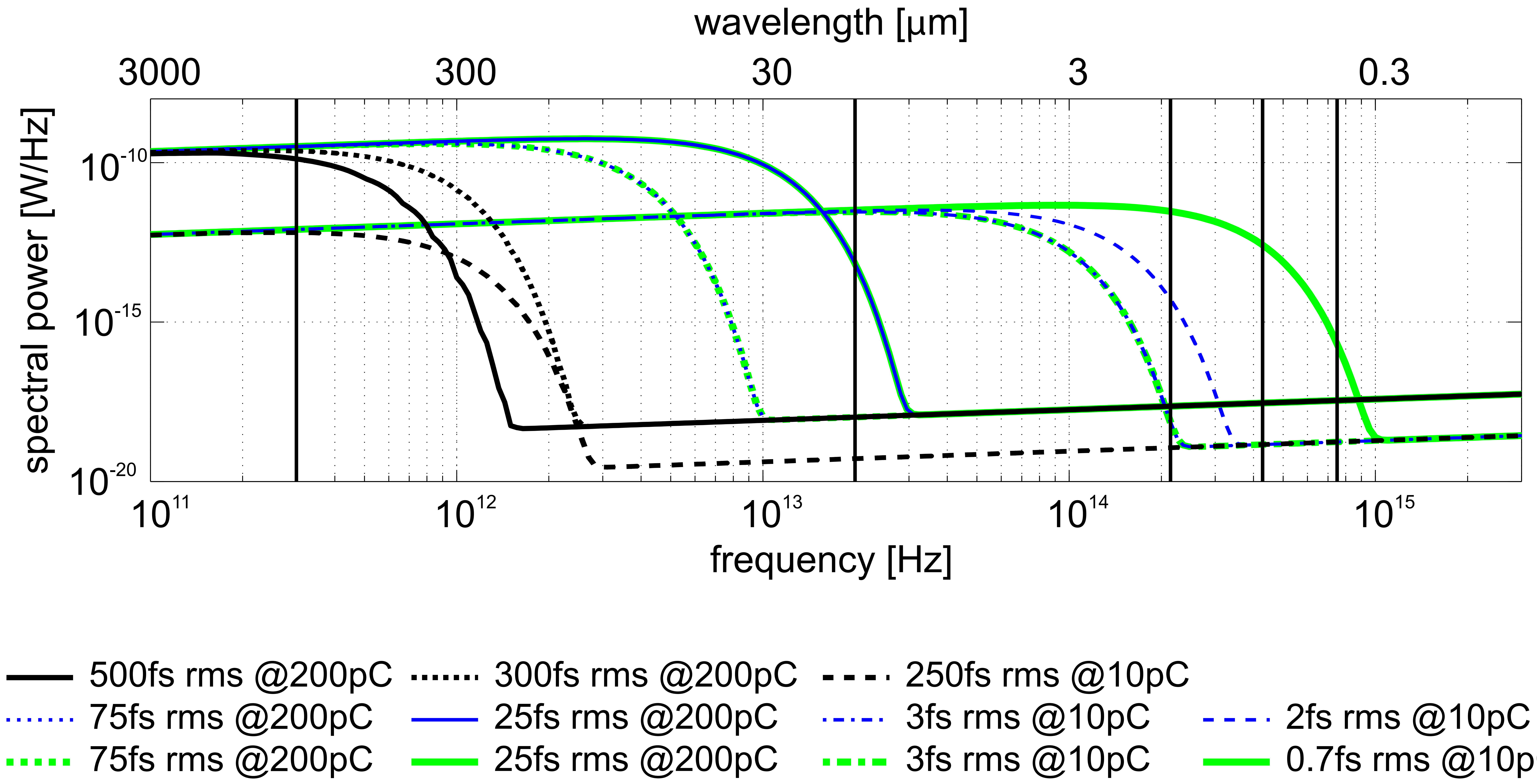
Pavle Juranić

Wolfram Helml, Nature Photonics 8 (2014)

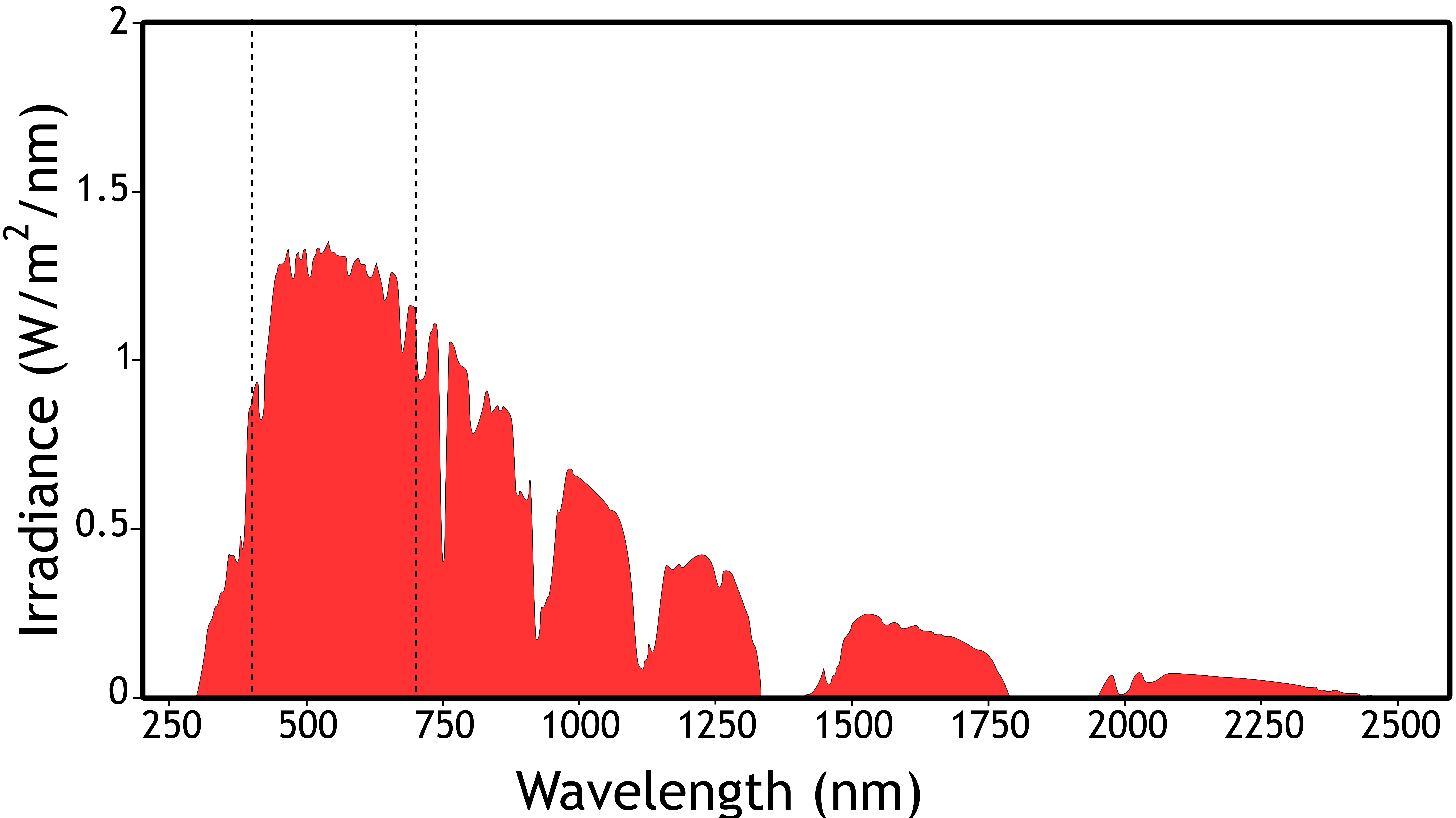
Spectral Techniques

St. Jakobi organ, Hamburg, Wikimedia Commons

a)
ρ
W
z
off-crest
acceleration
b)
ρ
W
z
magnetic
chicane
c)
ρ
W
z
d)
−E
z
low energy
high energy

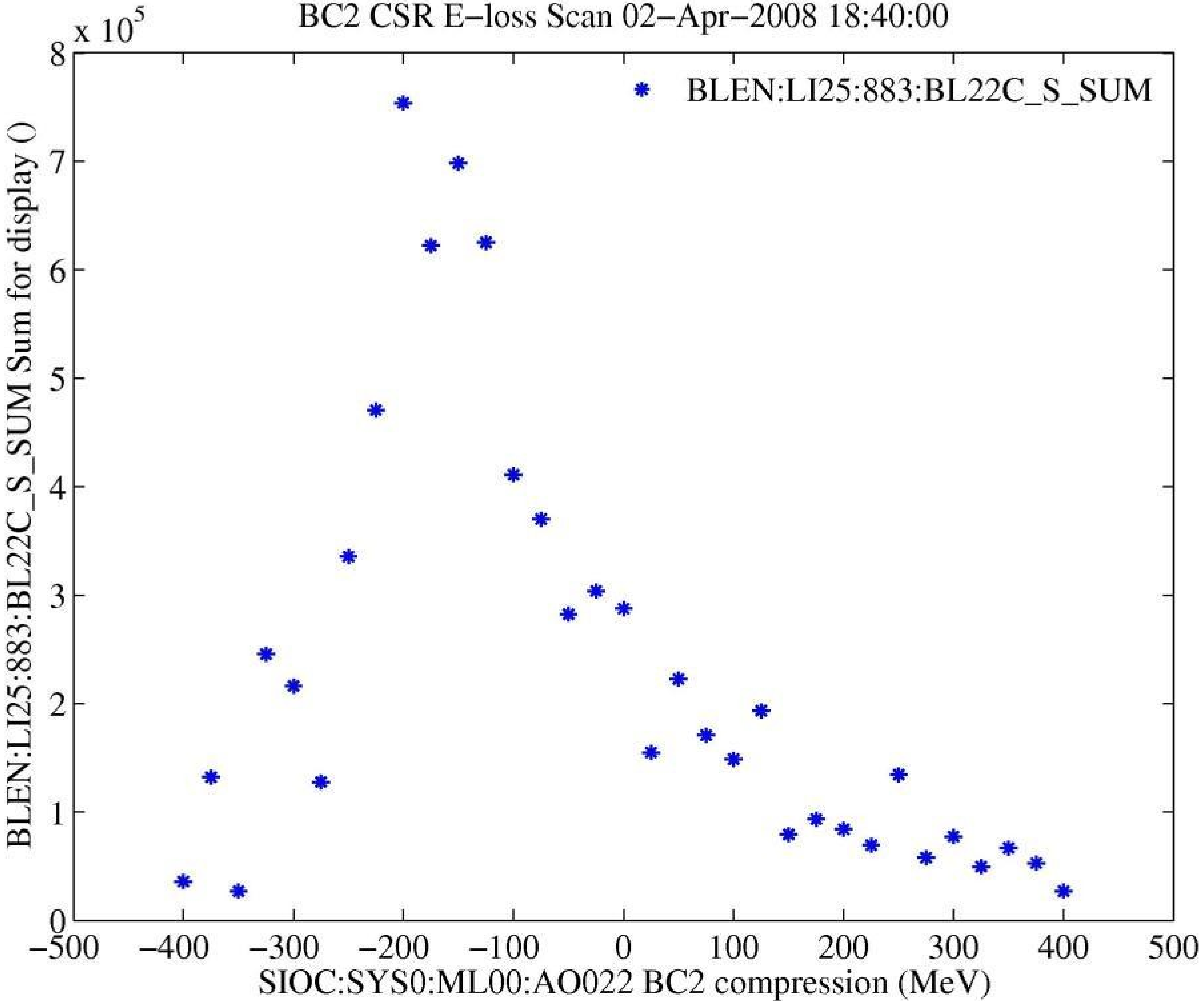


Franziska Frei, Proceedings of FEL2014

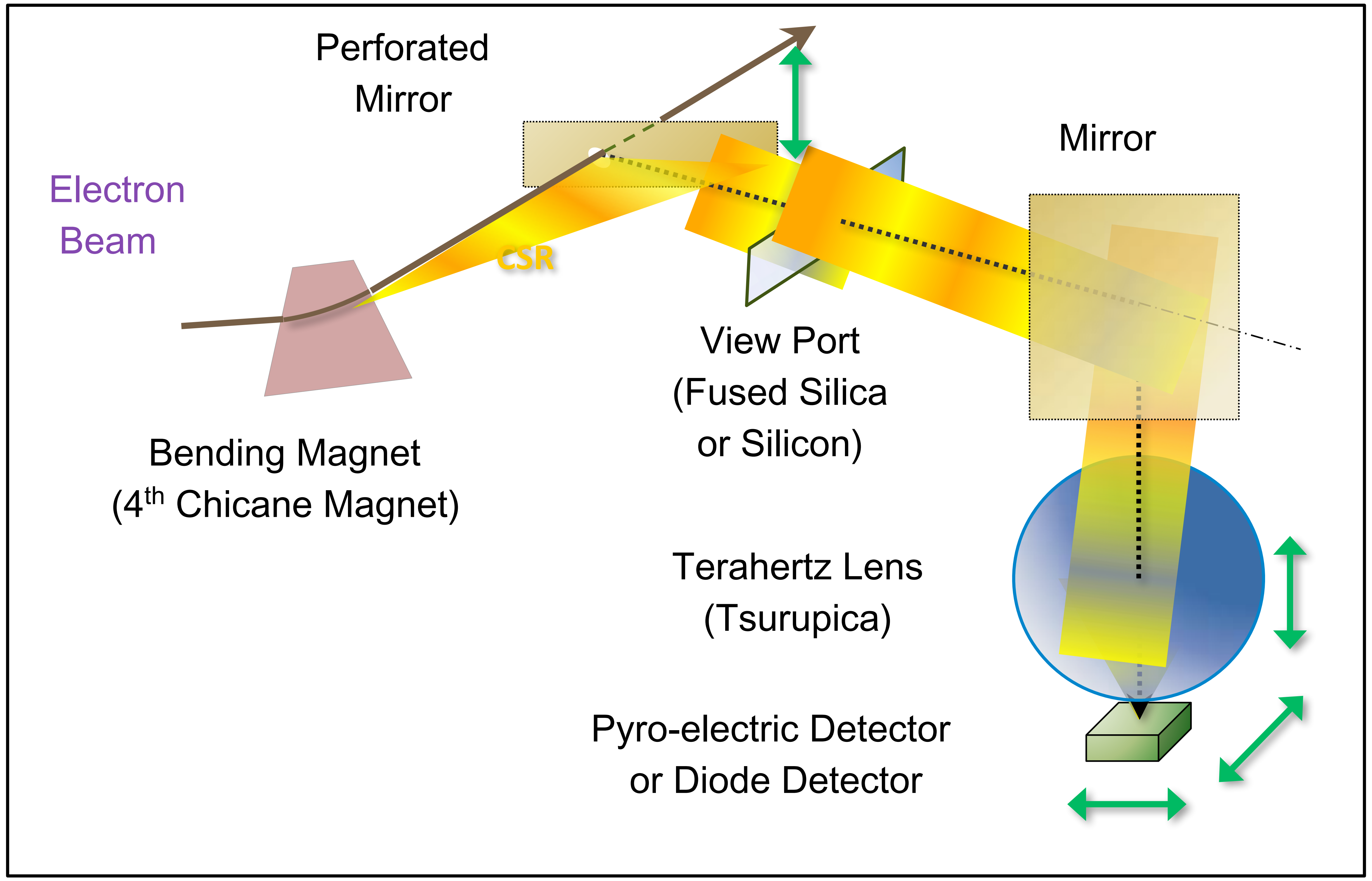


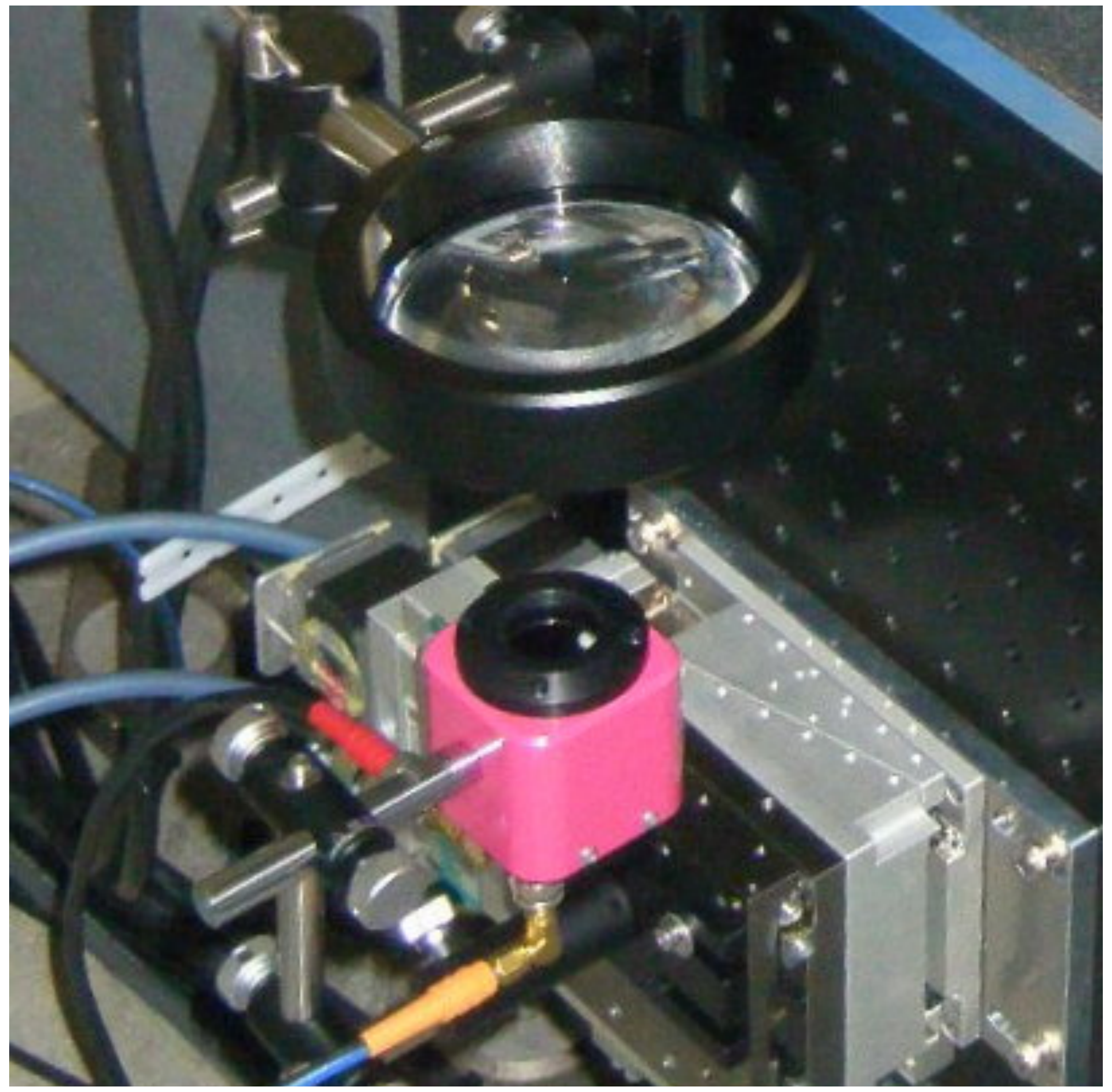
Wikimedia Commons

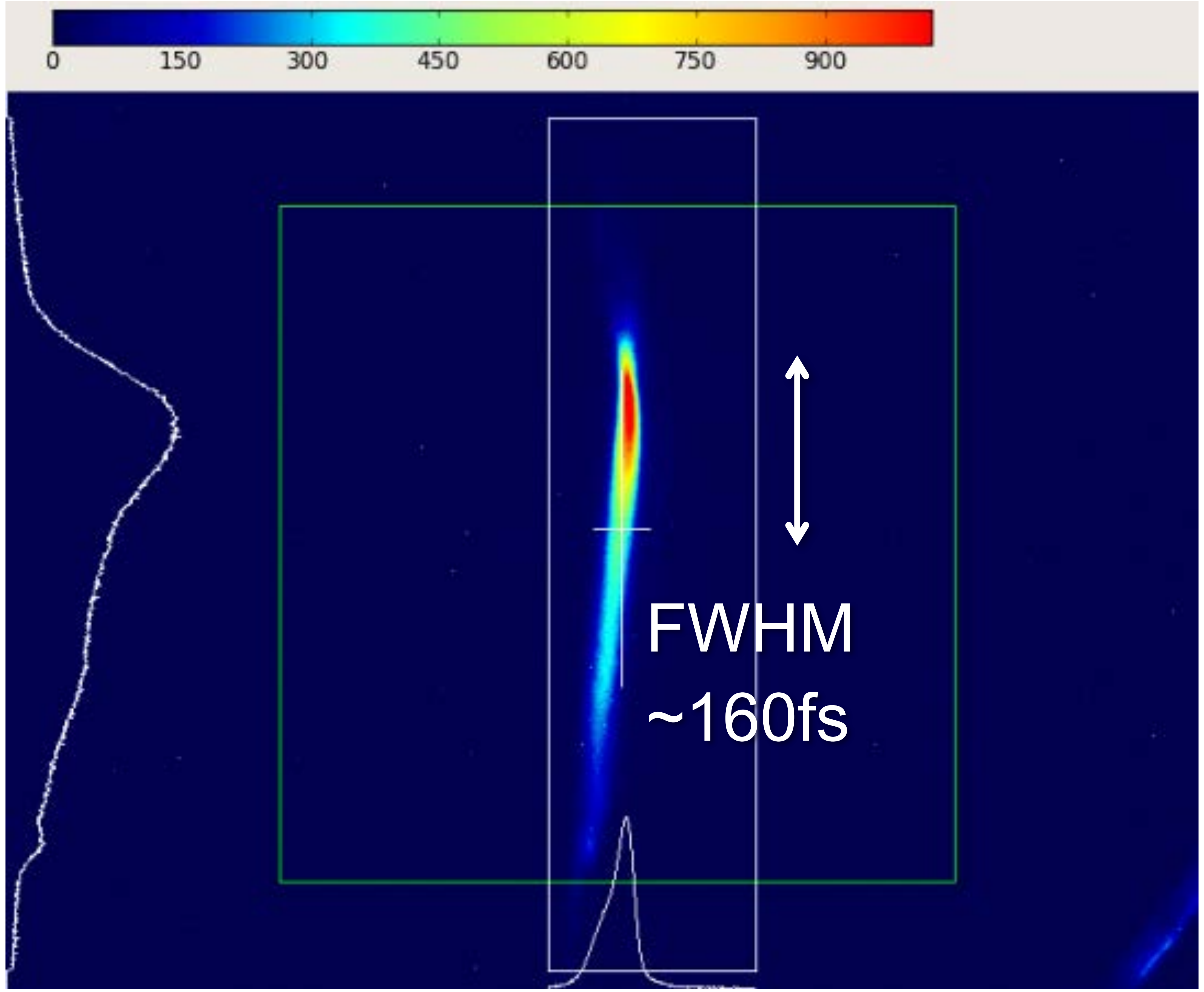

z
y
x


BC2 CSR E−loss Scan 02−Apr−2008 18:40:00
x 10^5
BLEN:LI25:883:BL22C_S_SUM
BLEN:LI25:883:BL22C_S_SUM Sum for display ()
SIOC:SYS0:ML00:AO022 BC2 compression (MeV)
8
7
6
5
4
3
2
1
0
−500
−400
−300
−200
−100
0
100
200
300
400
500

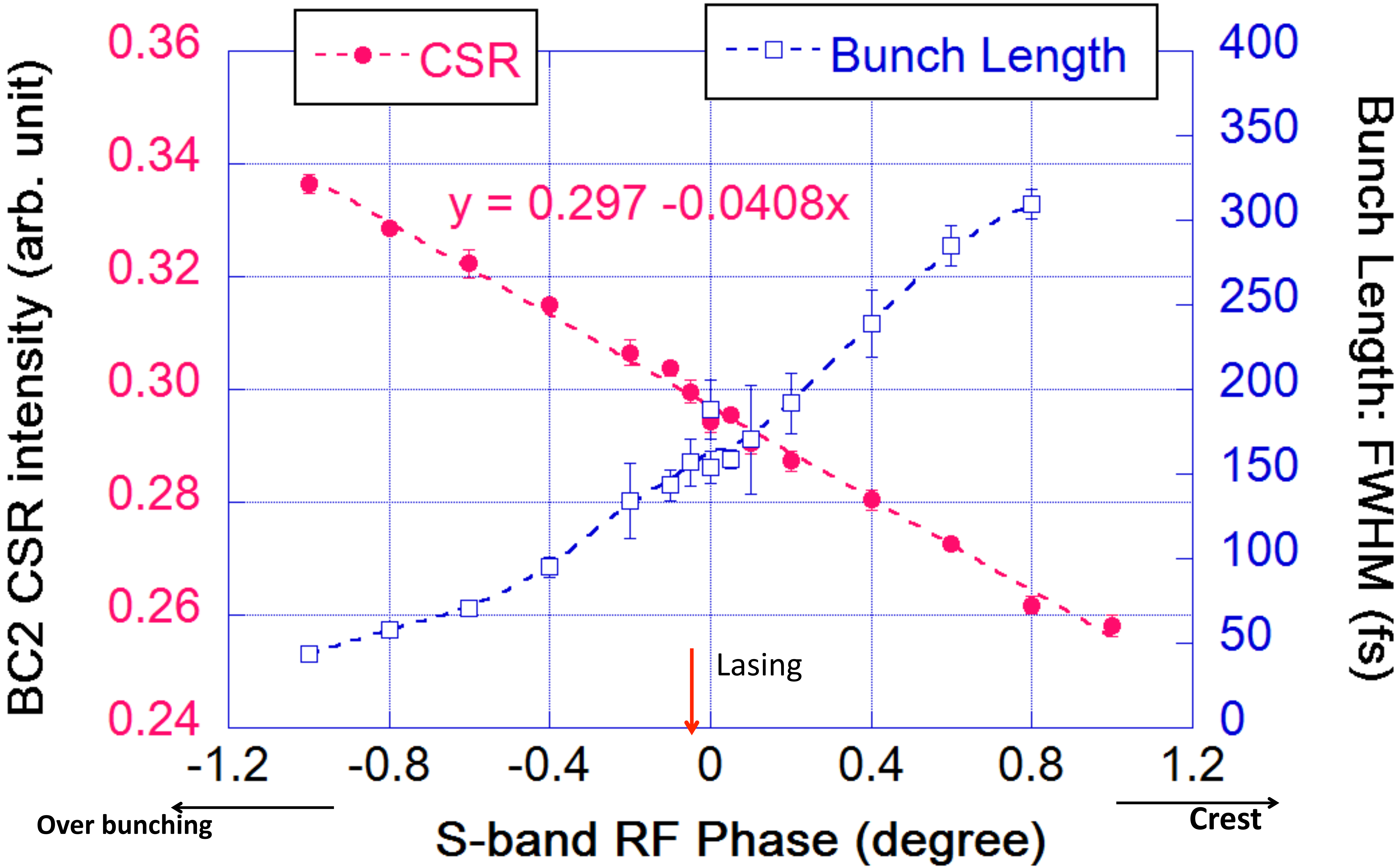
Joe Frisch


Perforated Mirror
Electron Beam
CSR
Mirror
View Port (Fused Silica or Silicon)
Bending Magnet (4th Chicane Magnet)
Terahertz Lens (Tsurupica)
Pyro-electric Detector or Diode Detector

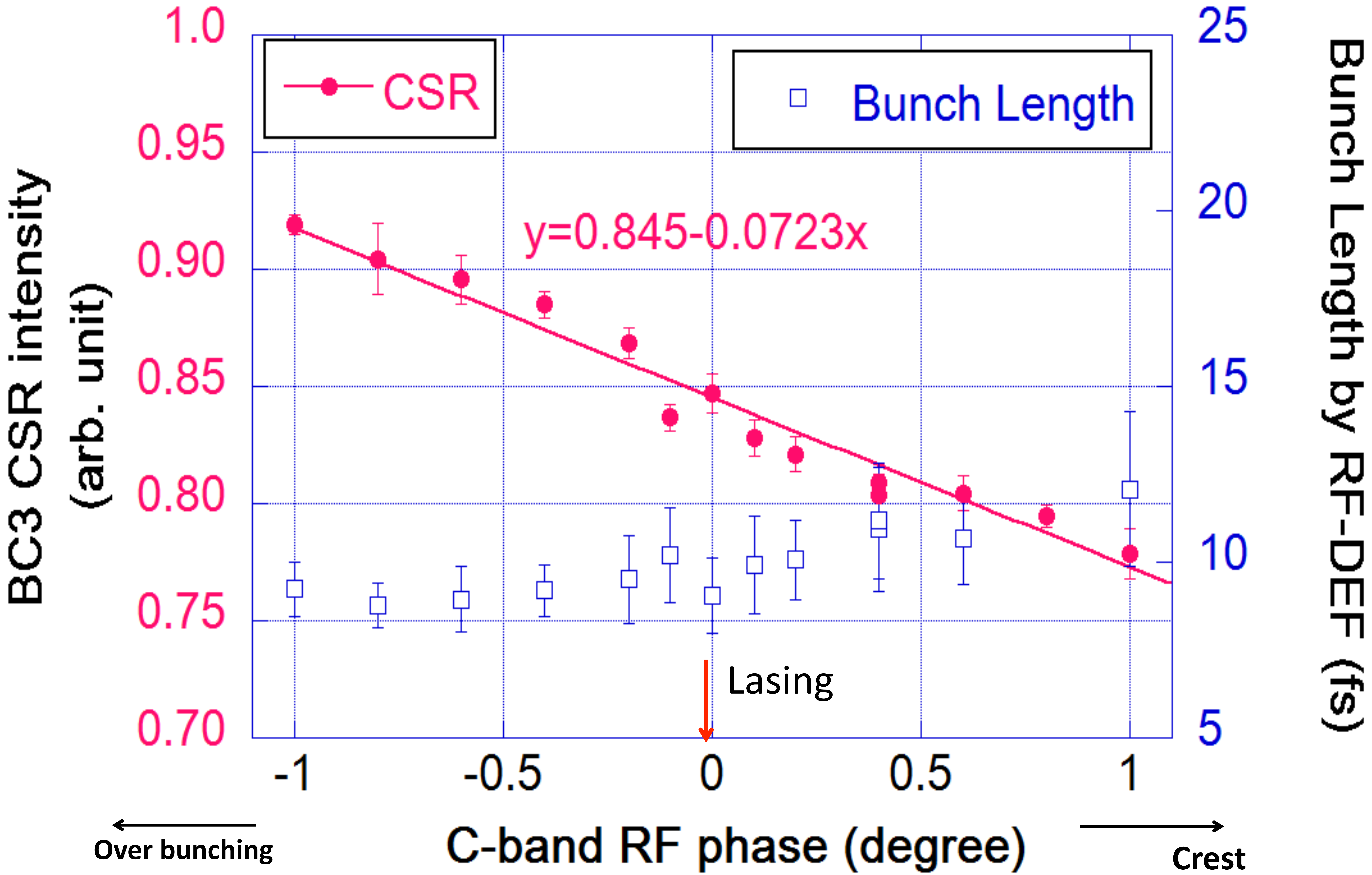



0
150
300
450
600
750
900
FWHM ~160fs

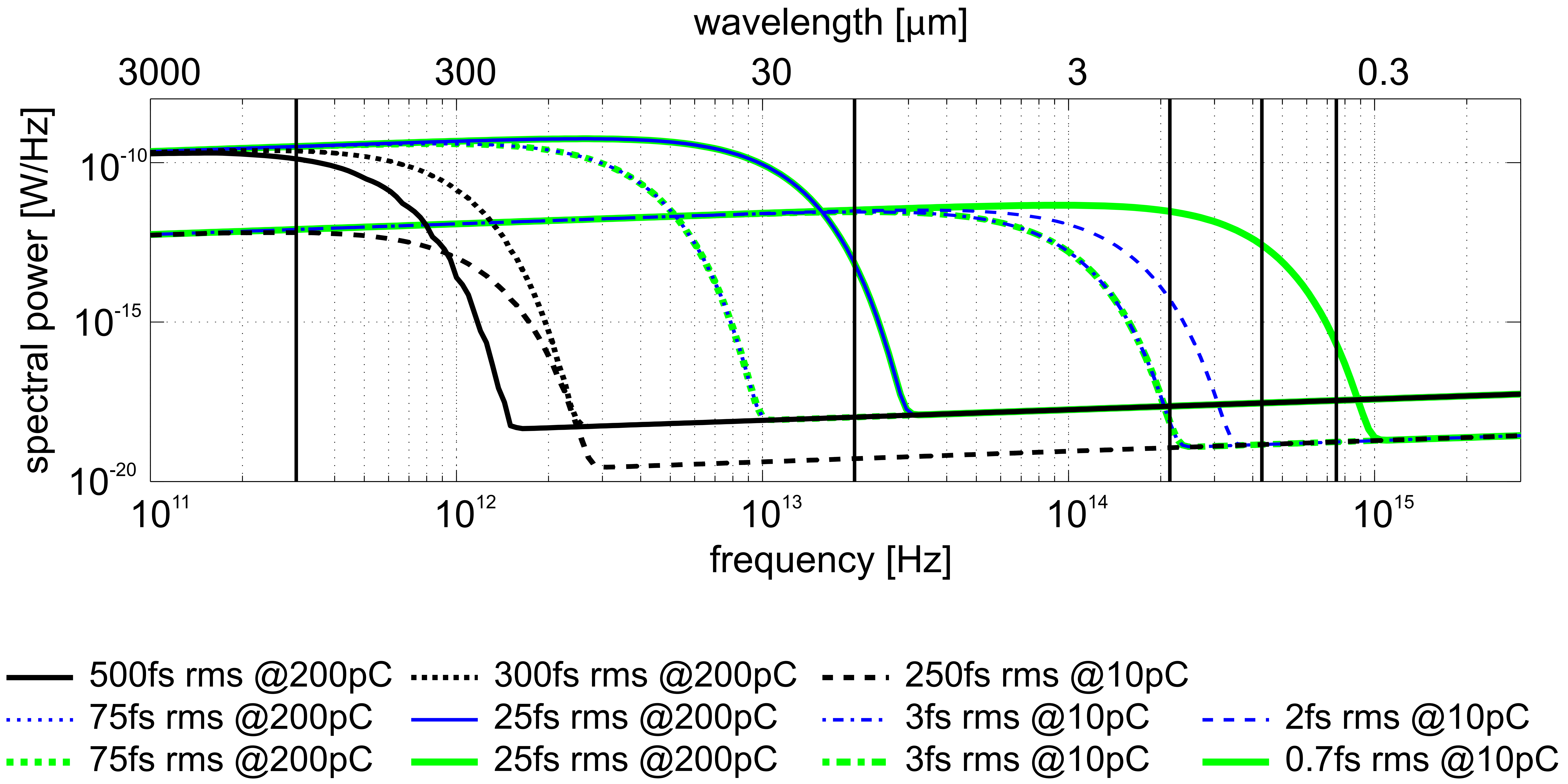
Yuji Otake


CSR
Bunch Length
y = 0.297 -0.0408x
BC2 CSR intensity (arb. unit)
Bunch Length: FWHM (fs)
0.36
0.34
0.32
0.30
0.28
0.26
0.24
400
350
300
250
200
150
100
50
0
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
Lasing
Over bunching
Crest
S-band RF Phase (degree)

Yuji Otake

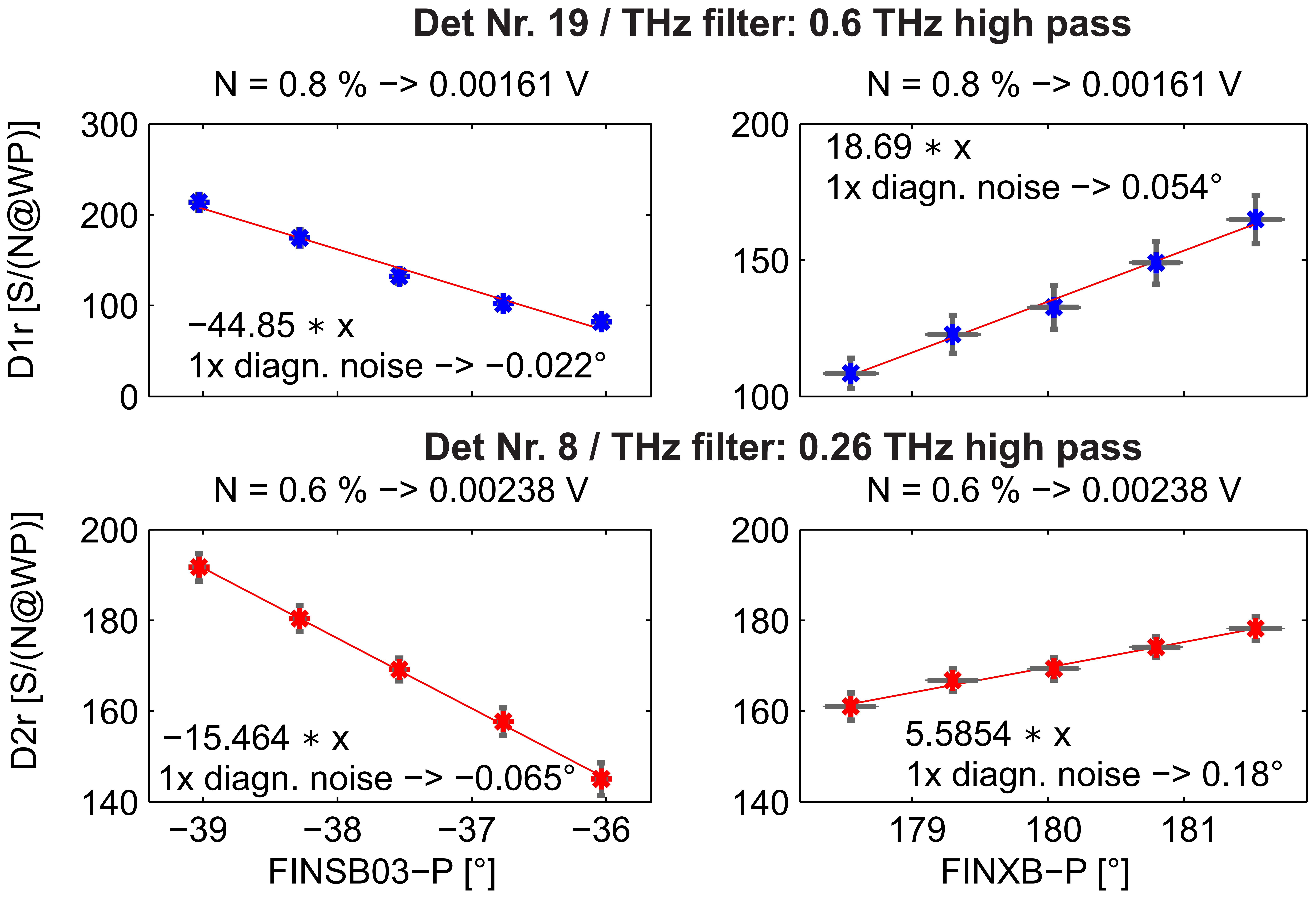

CSR
Bunch Length
y=0.845-0.0723x
BC3 CSR intensity (arb. unit)
Bunch Length by RF-DEF (fs)
Lasing
1.0
0.95
0.90
0.85
0.80
0.75
0.70
25
20
15
10
5
-1
-0.5
0
0.5
1
Over bunching
C-band RF phase (degree)
Crest

Yuji Otake

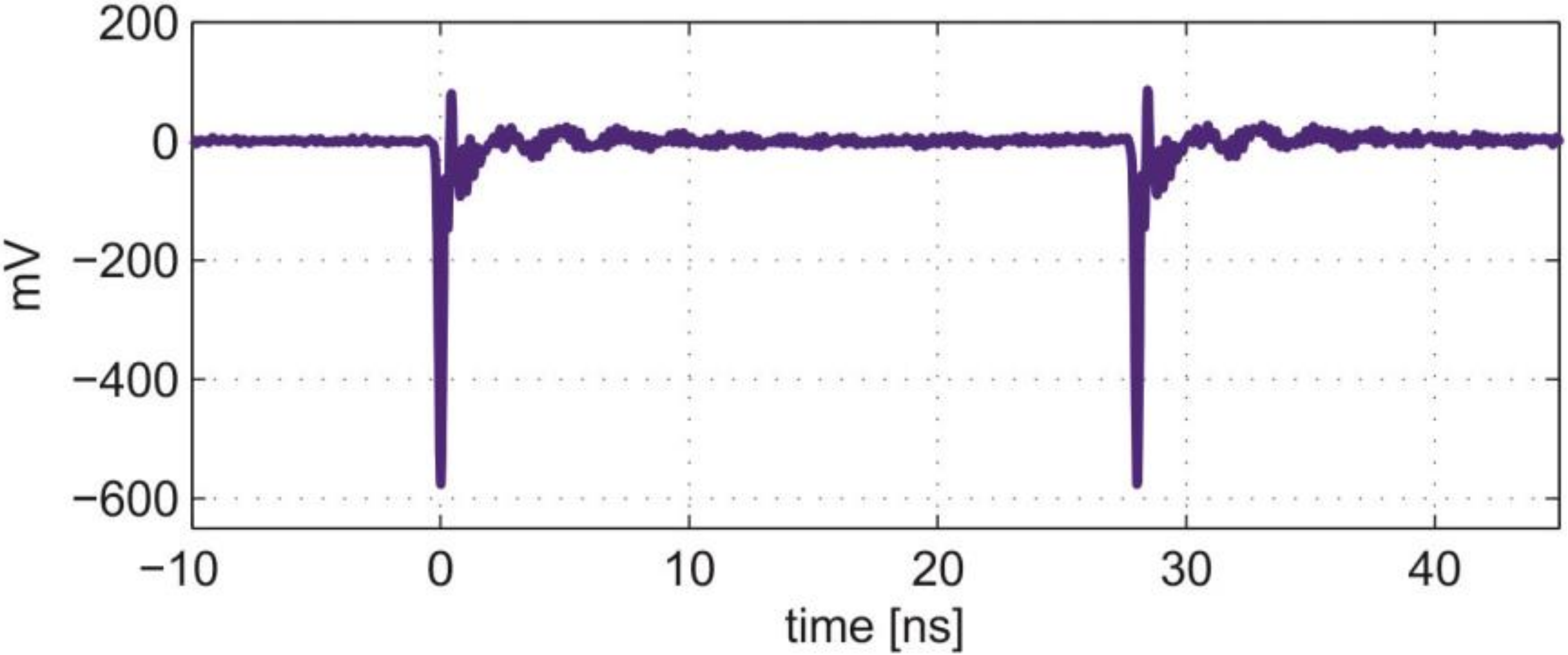


Franziska Frei, Proceedings of FEL2014

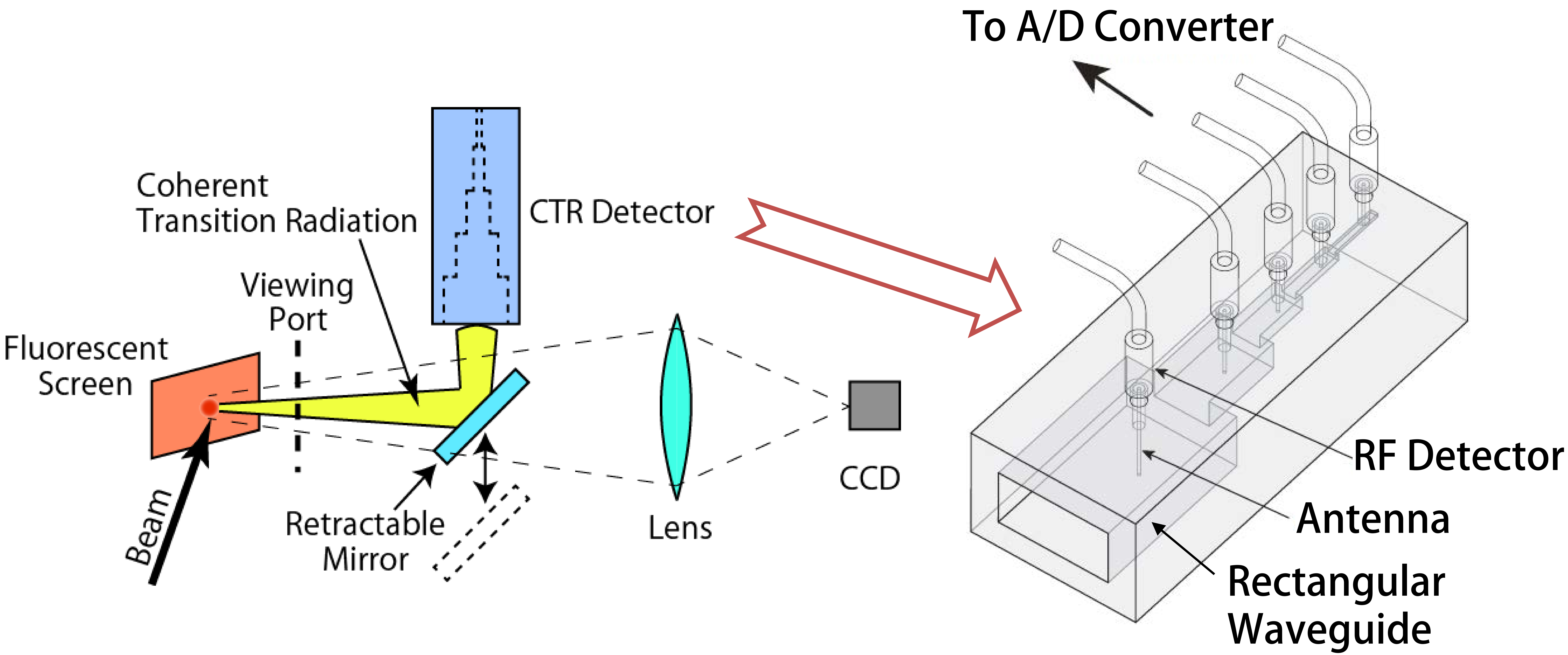
Peter Peier, Franziska Frei



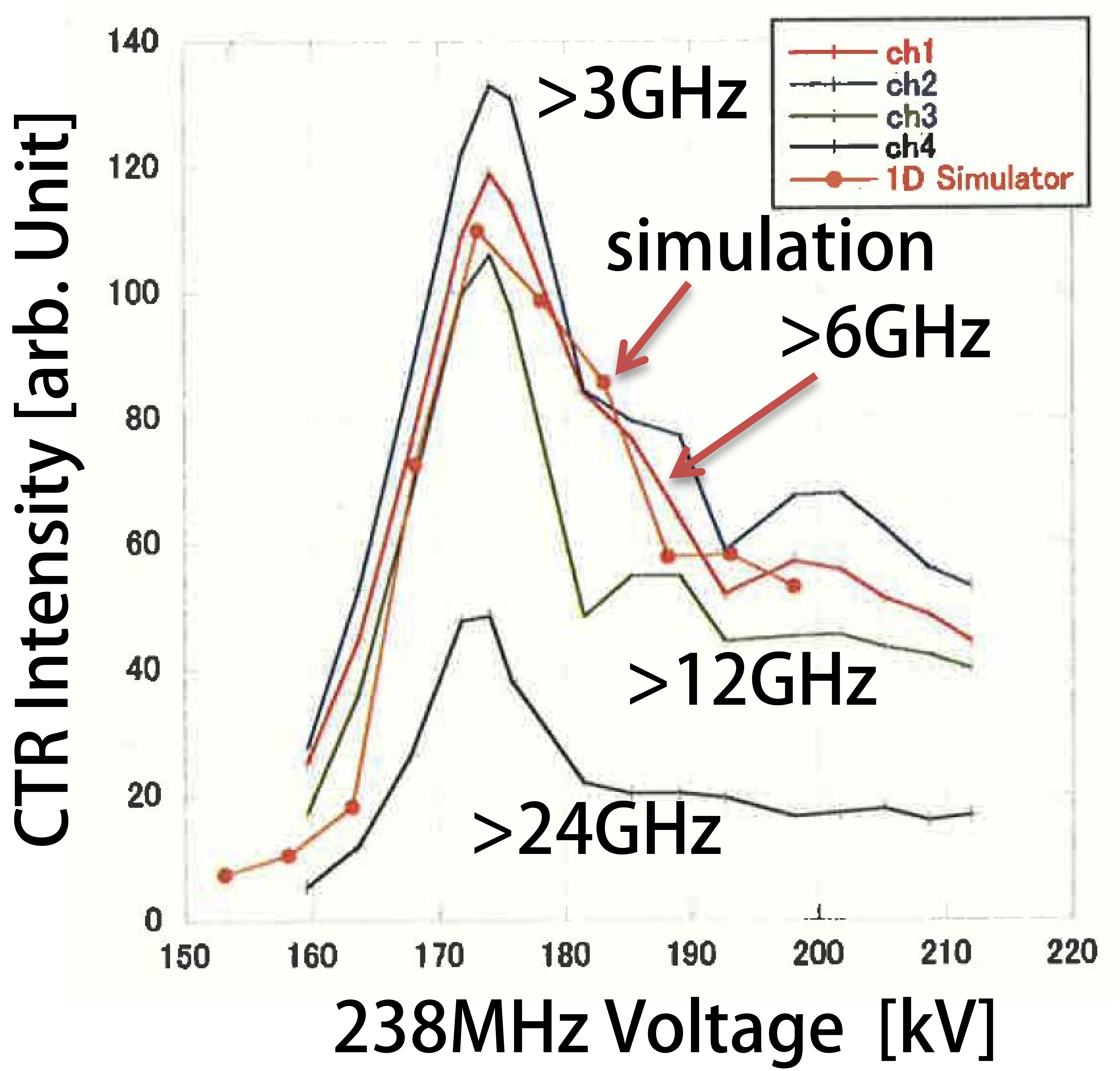
Franziska Frei, Proceedings of FEL2014



Franziska Frei

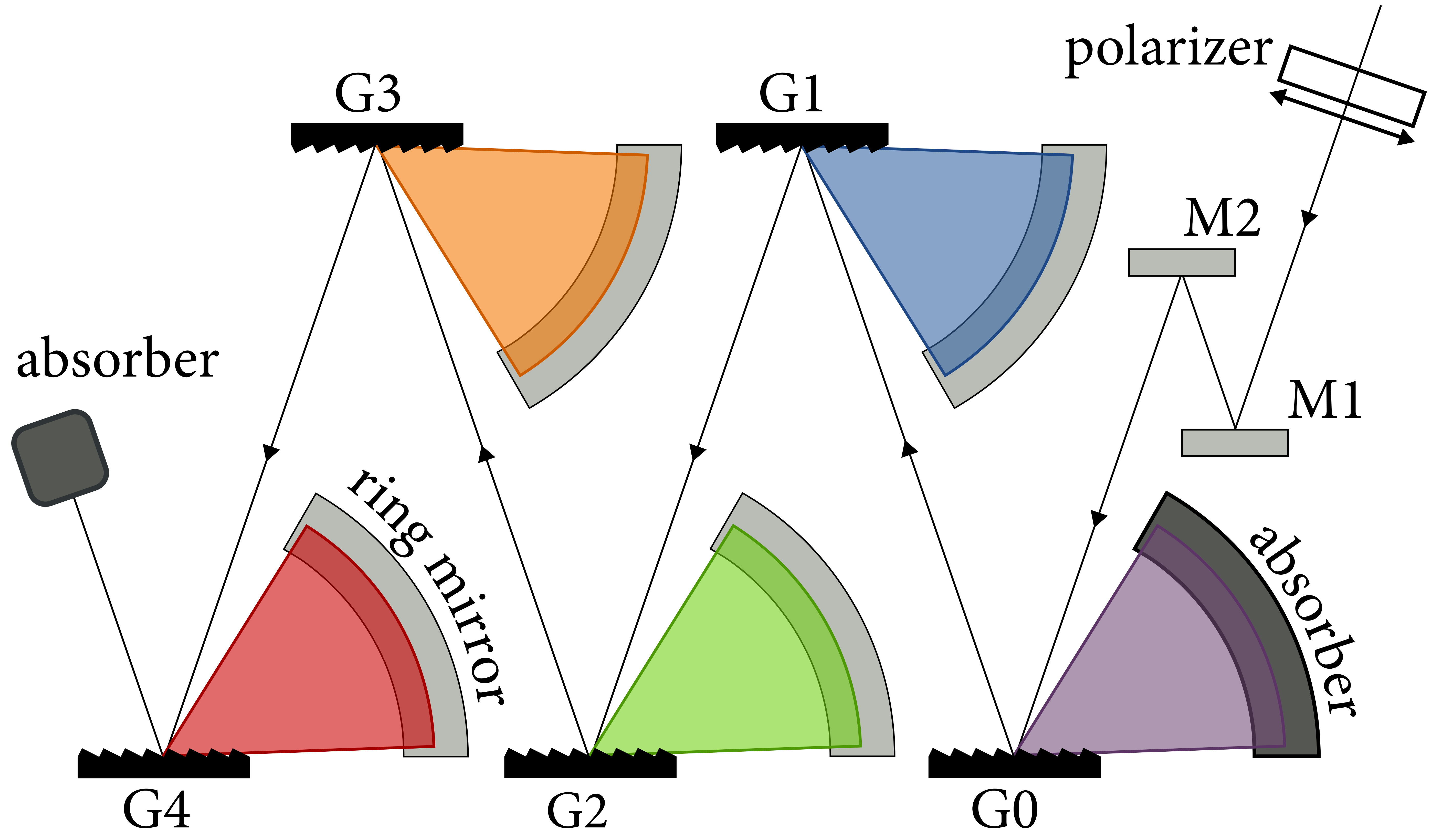


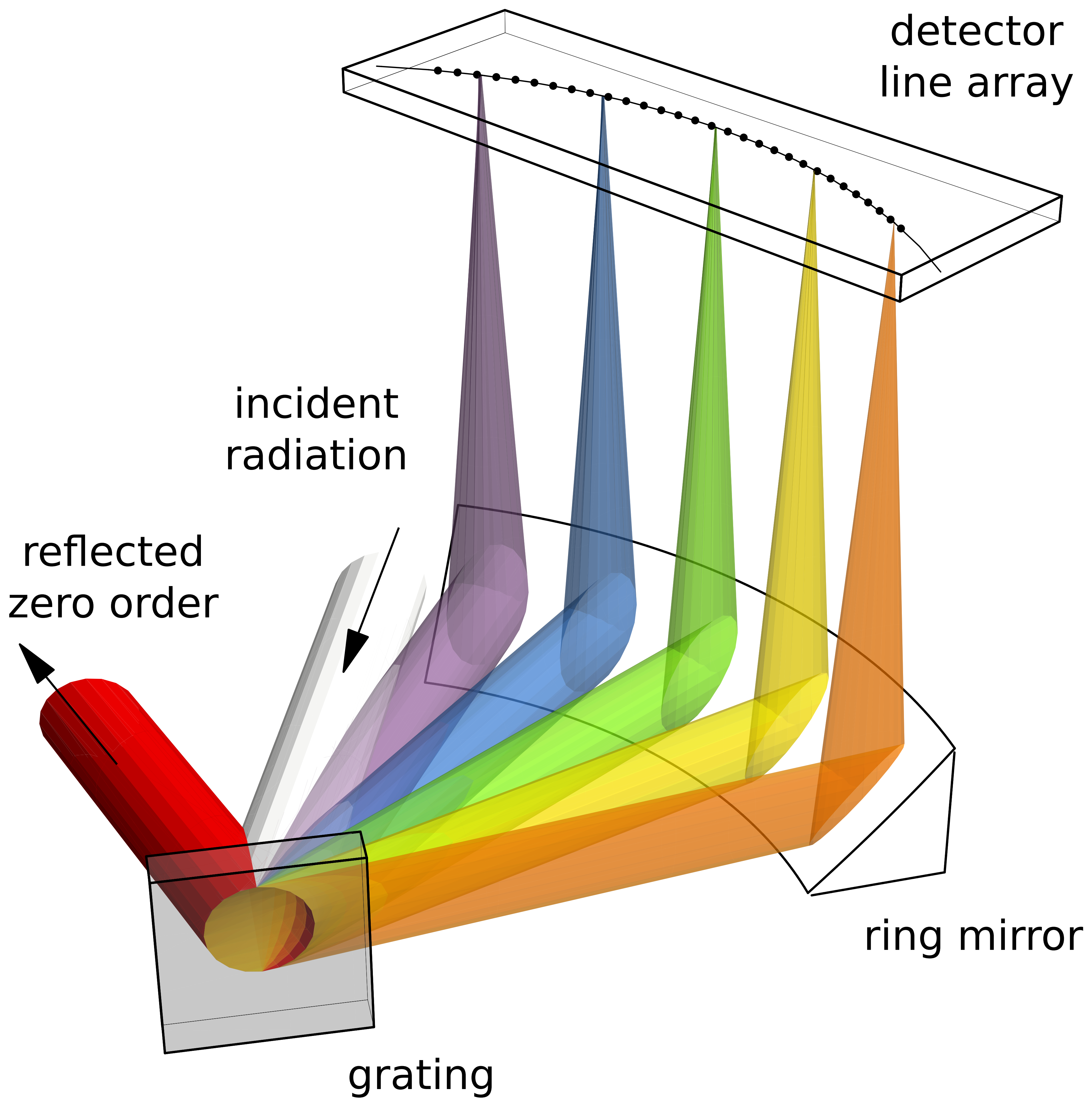
Hirokazu Maesaka



Hirokazu Maesaka

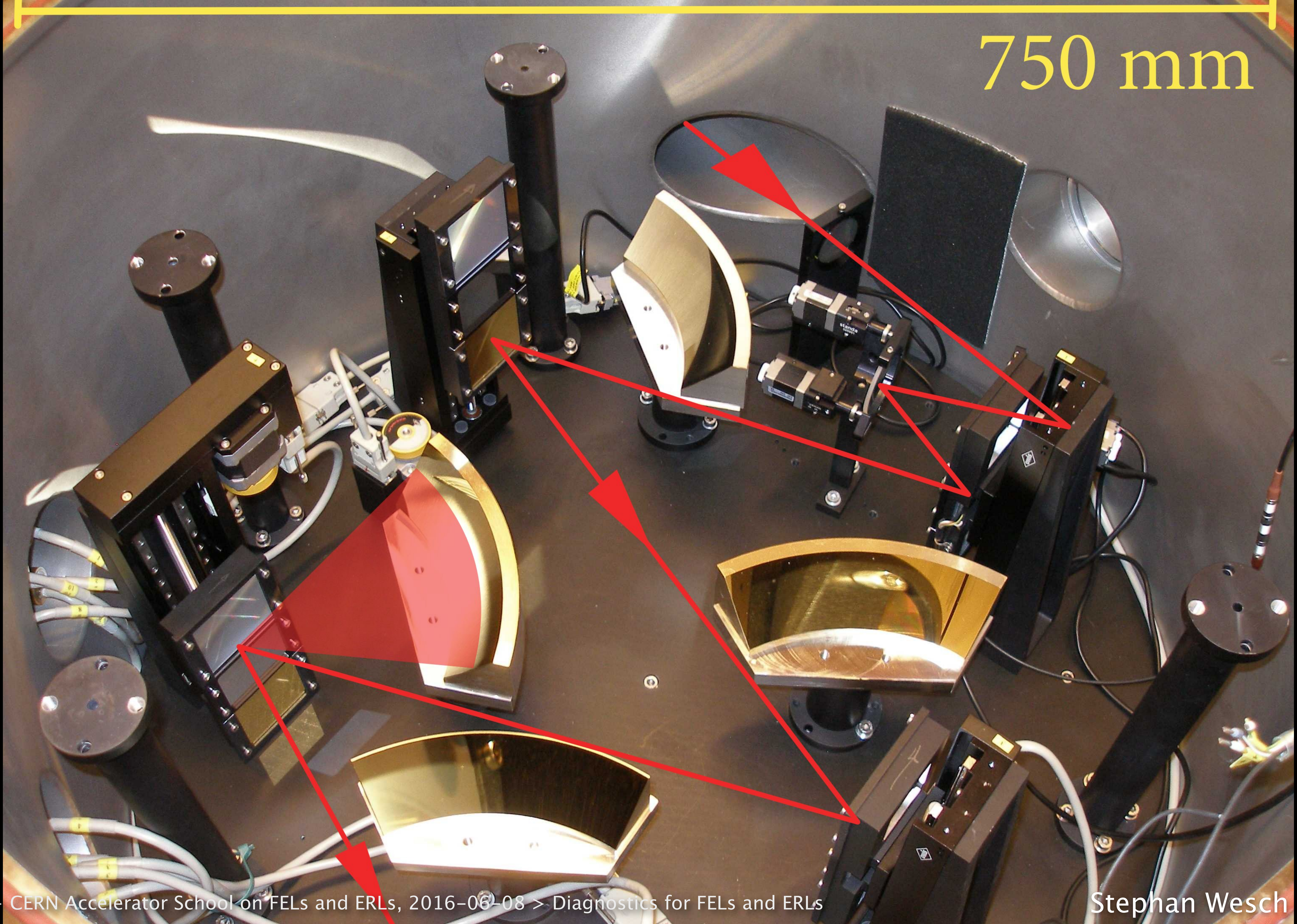
Each stage acts as dispersive element + filter for next stage

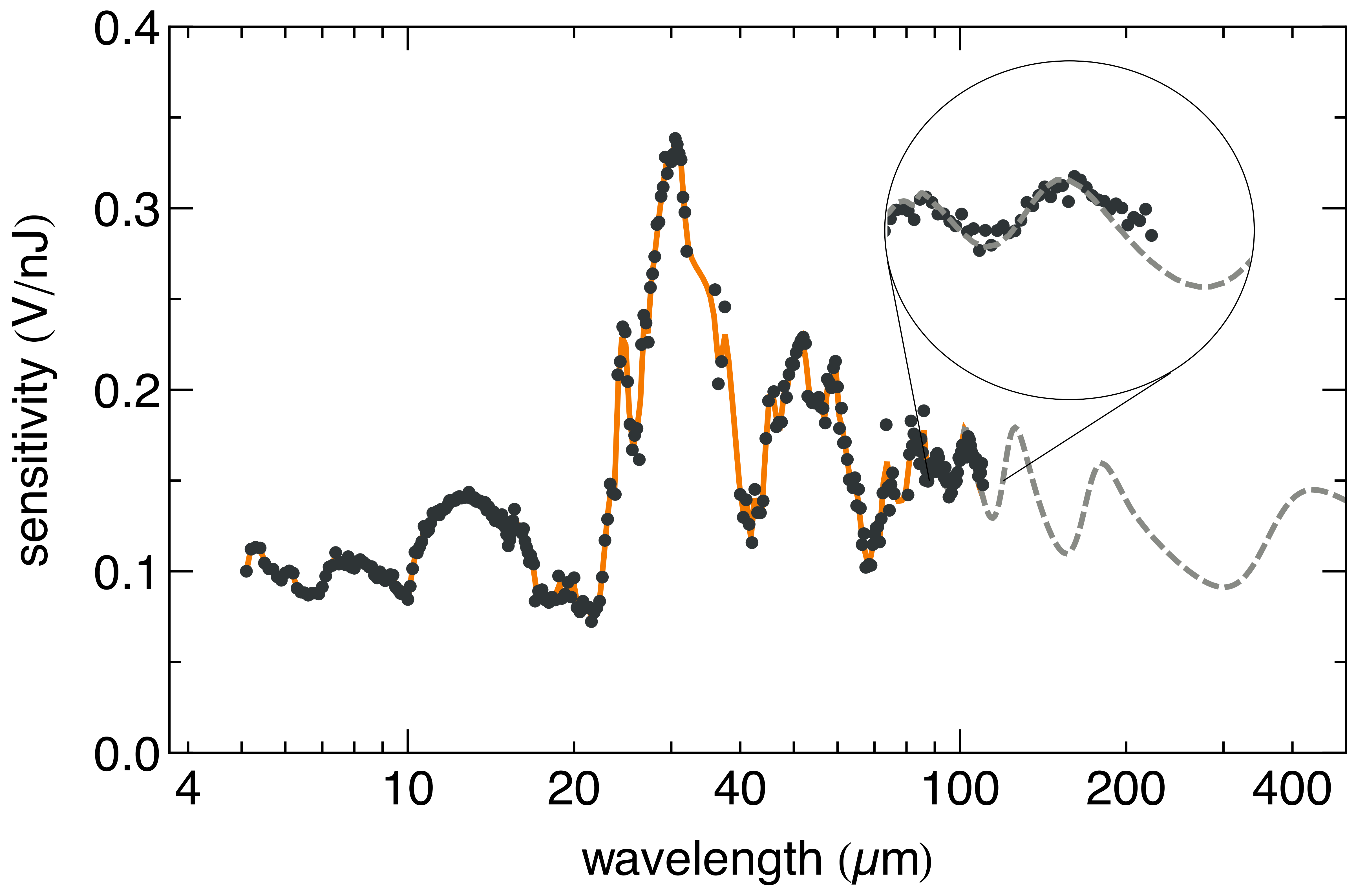


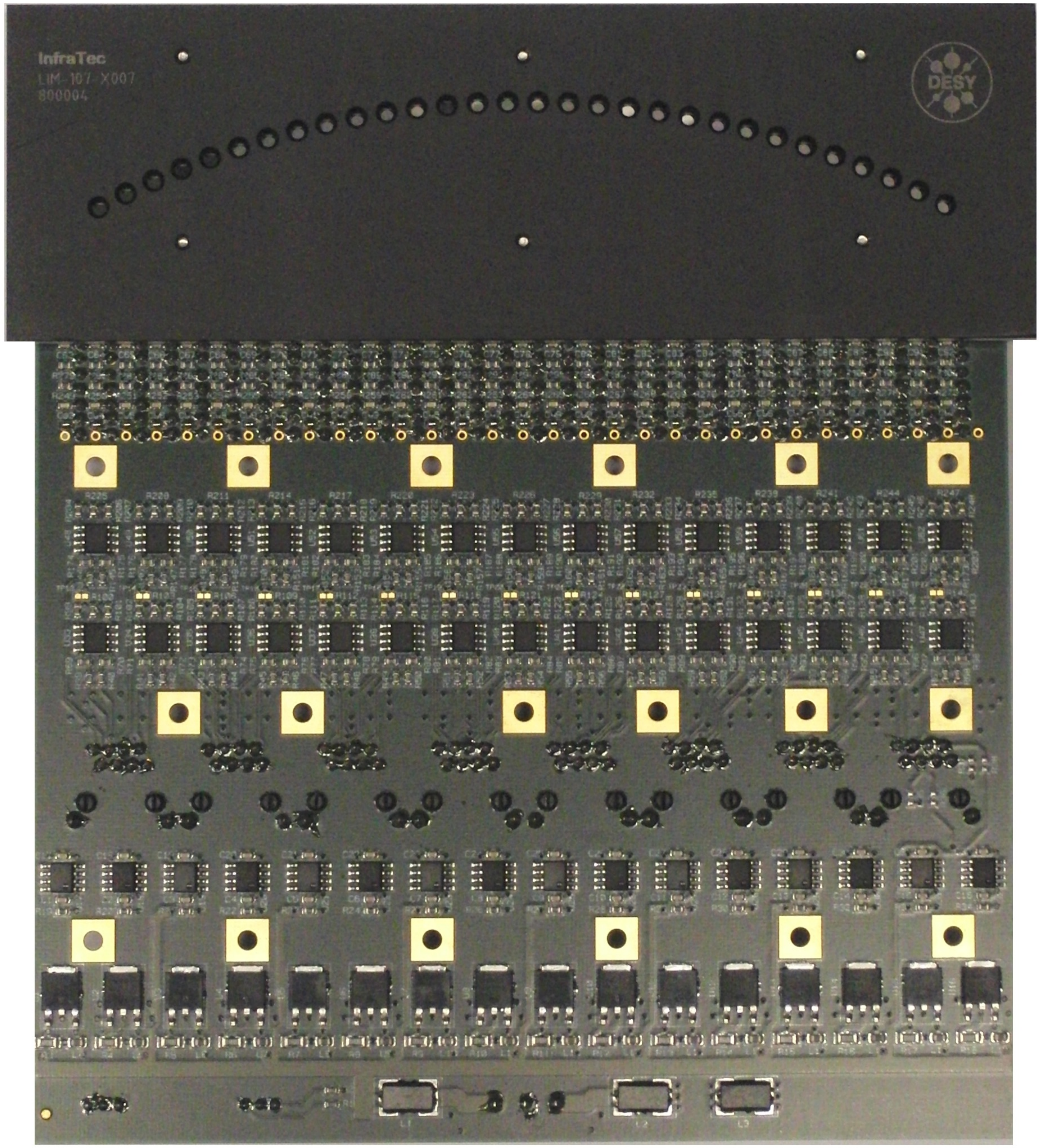


- Parallel readout
- 4 Stages cover one order of magnitude in λ

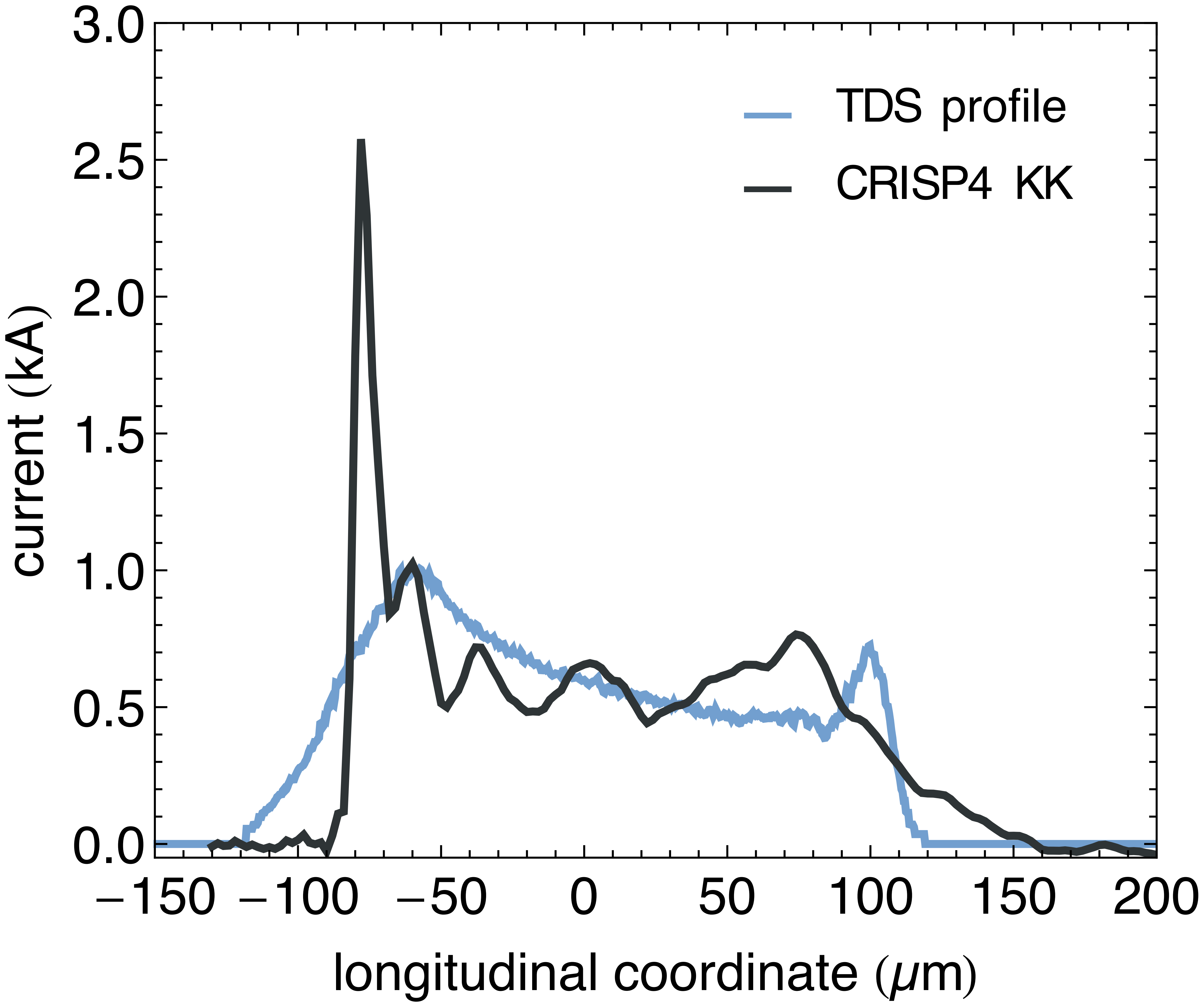
Stephan Wesch

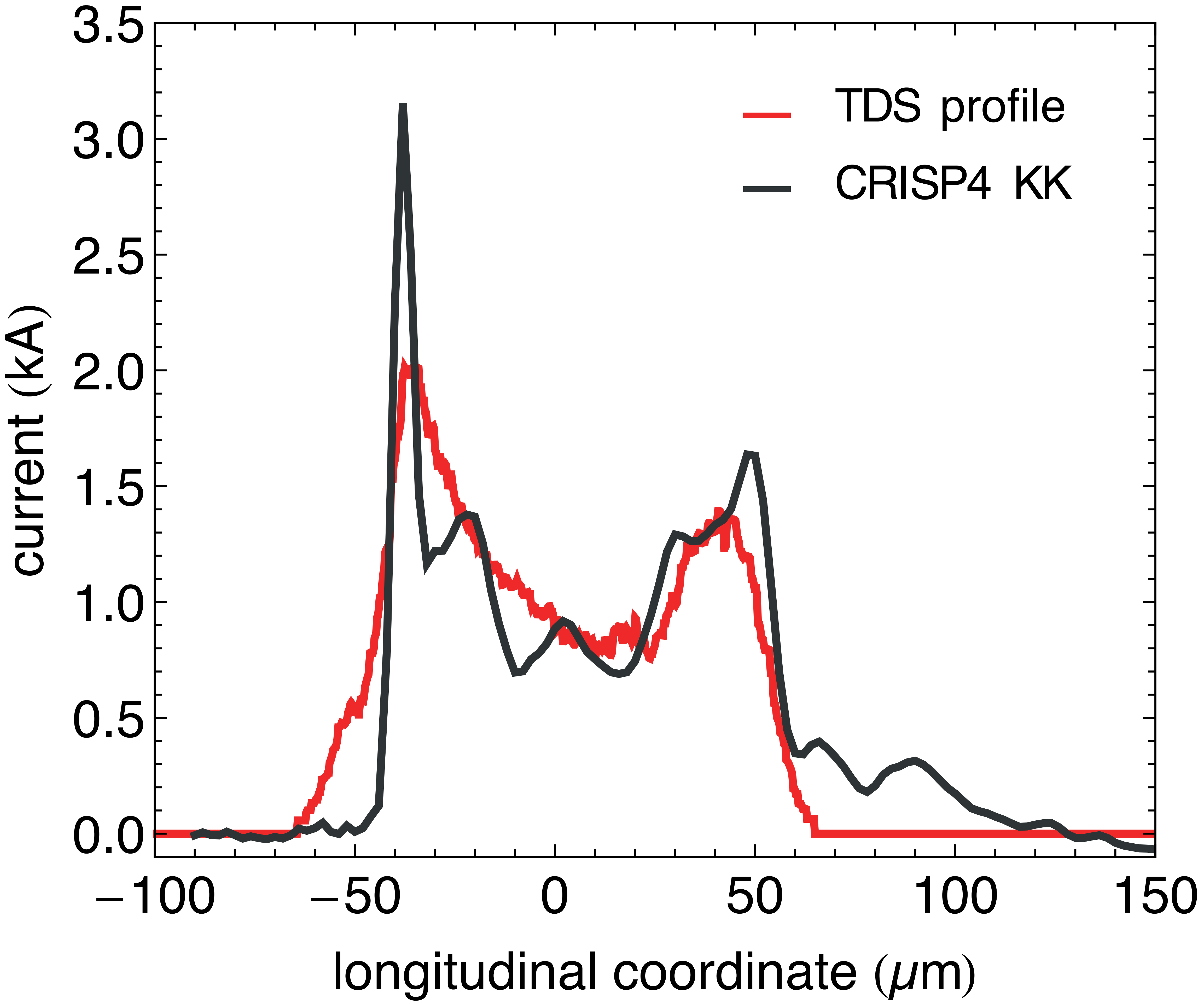

750 mm
Stephan Wesch





Stephan Wesch





Stephan Wesch

PAUL SCHERRER INSTITUT

> Thank you for slides, graphics, photos, movies and plots provided by:
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