PAUL SCHERRER INSTITUT

PSI

T. Schmidt:: ID Group :: Paul Scherrer Institut

Experience with short-period, small gap undulators at the SwissFEL Aramis beamline

FEL19, Hamburg, August 28, 2019

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Outline

Aramis undulator beamline small gap operation

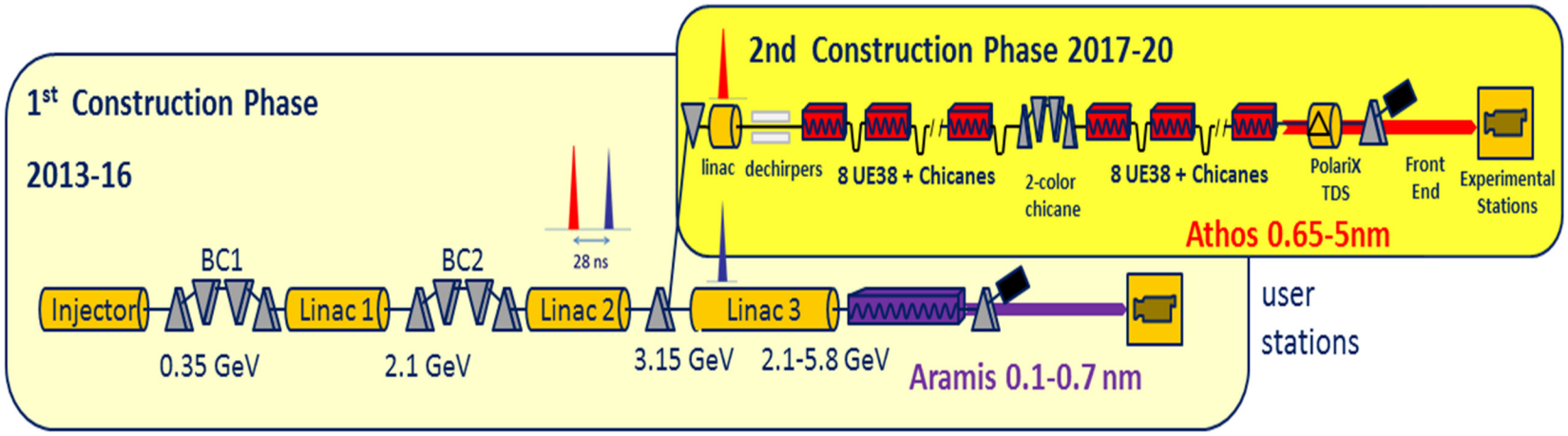
Instrumentation for spontaneous synchrotron radiation

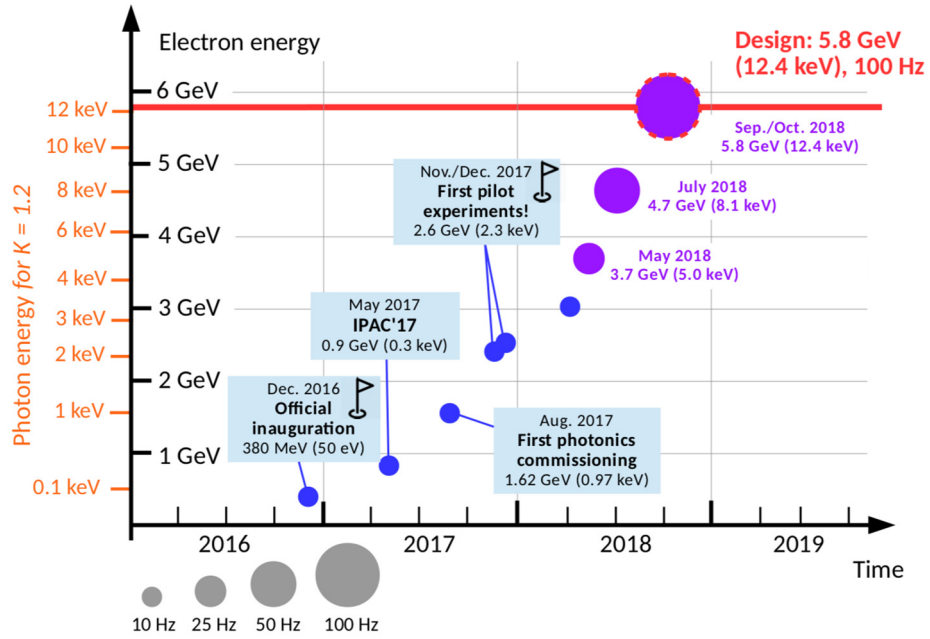
The experience with the Aramis undulators

- orbit
- alignment
- K calibration

LInk to other papers in the conference or posters

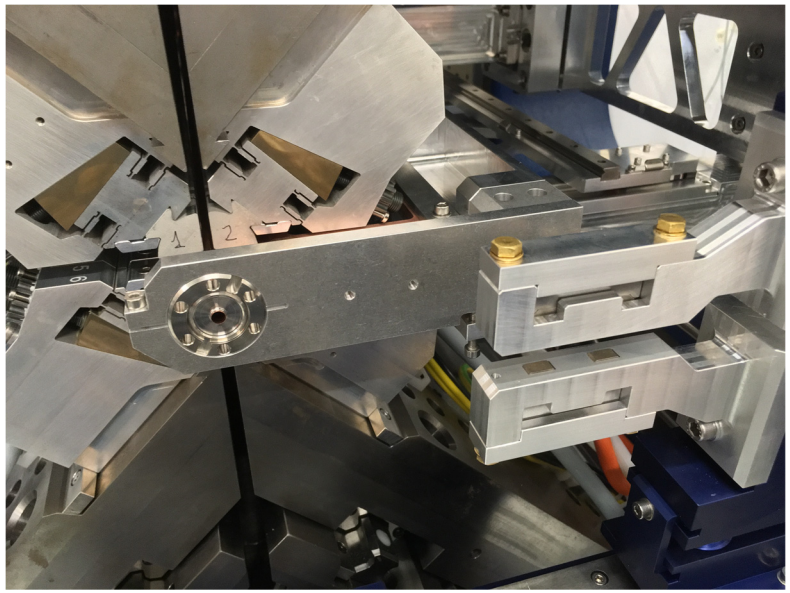
SwissFEL ramp-up phase

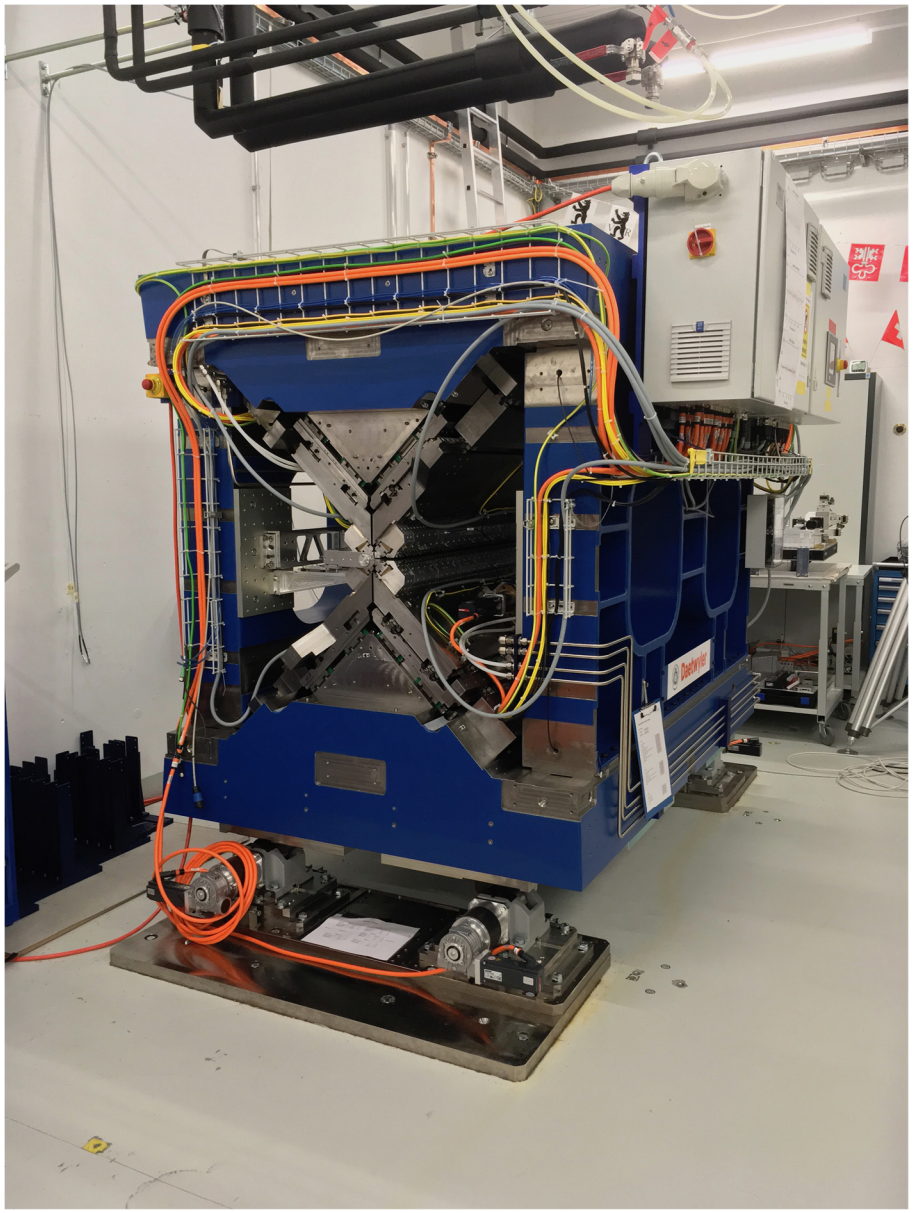




Athos switchyard
two bunch acceleration
first light in undulators:
end 2019
pilot experiments:
summer 2020

Athos UE38 APPLE X





16 modules

2m 50 periods

λ_U = 38mm

K = 3.8 – 1

gap = 6.5mm diameter

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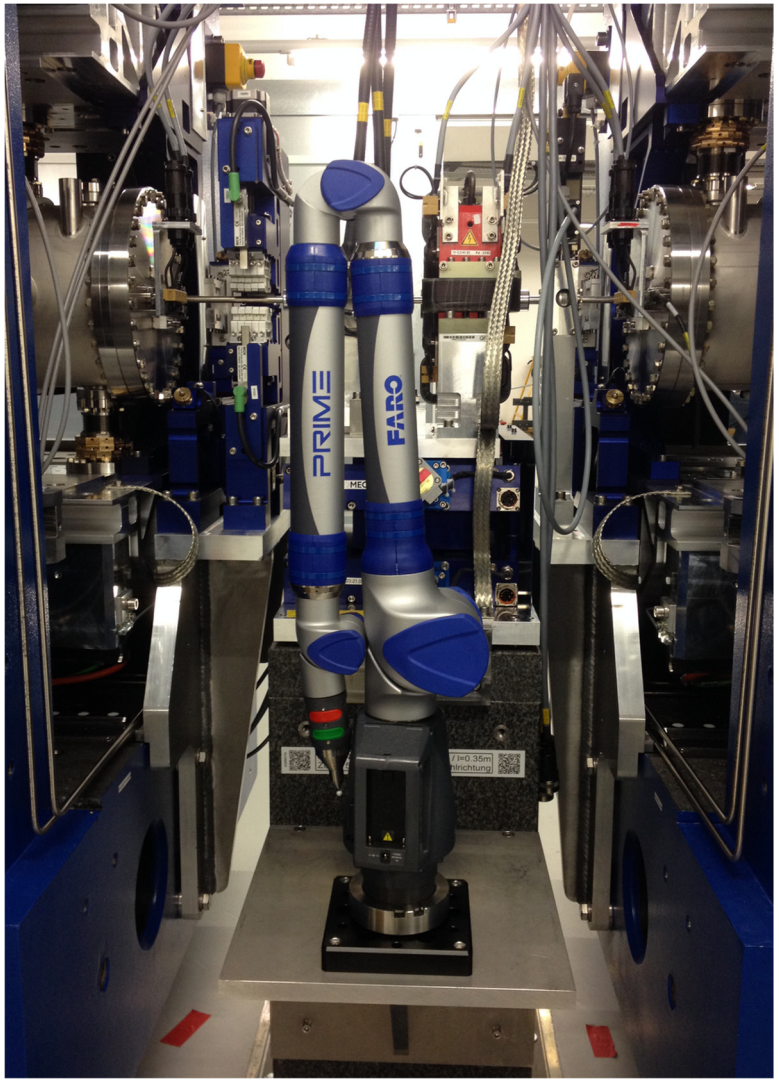
Aramis Undulator Line

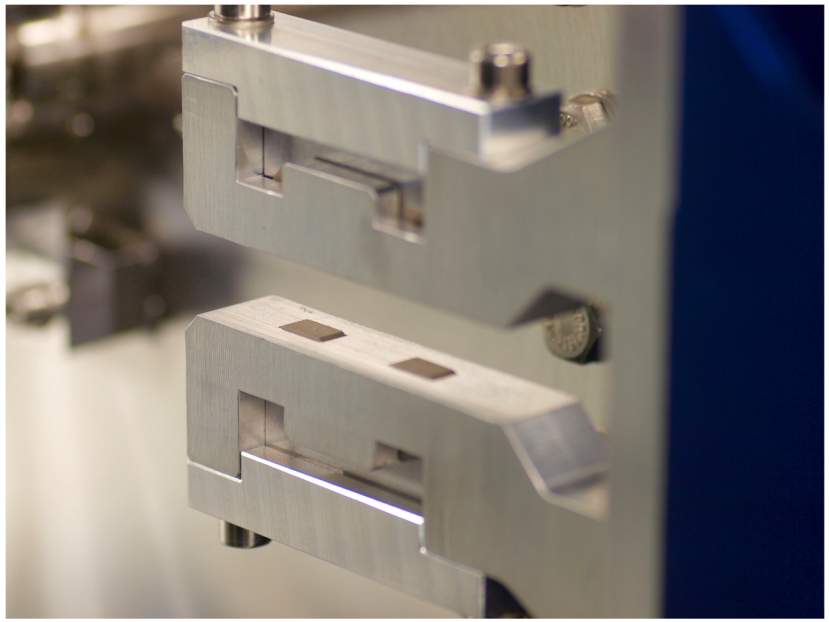
Undulator Intersection

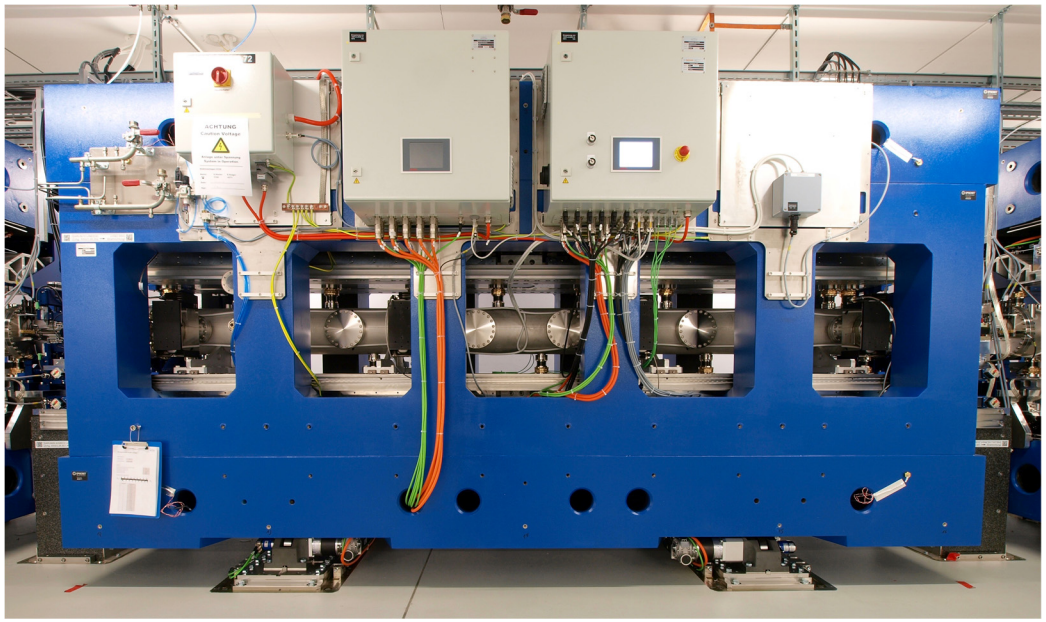
Alignment Quads, Phase Matcher, BPM and Quadrupole, Valve



Intersection Alignment Quads

Alignment Quads for Undulator beam based alignment





aligned to beam axis in lab

pneumatic in and out

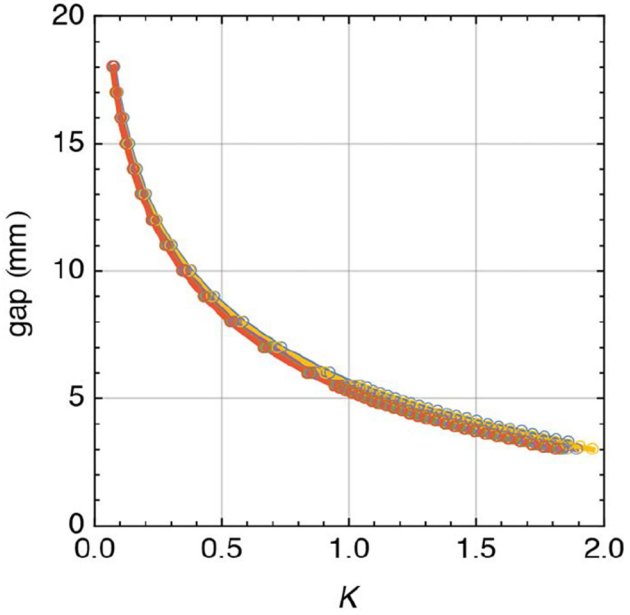
1st setup in beam

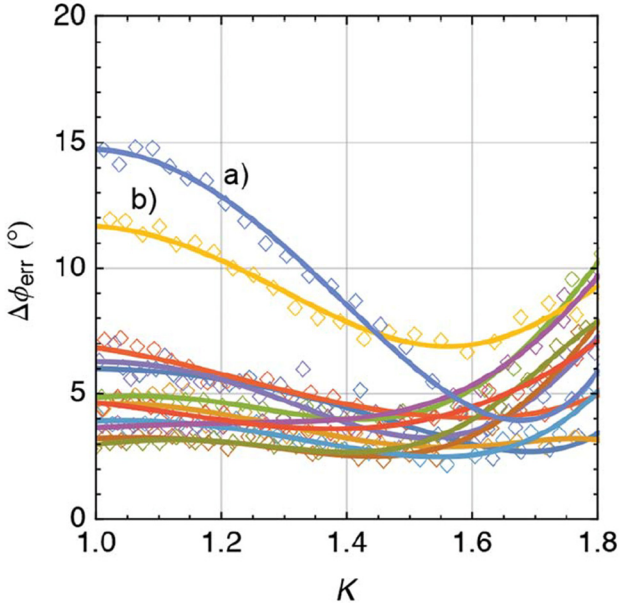
5 axis cam-shaft mover:

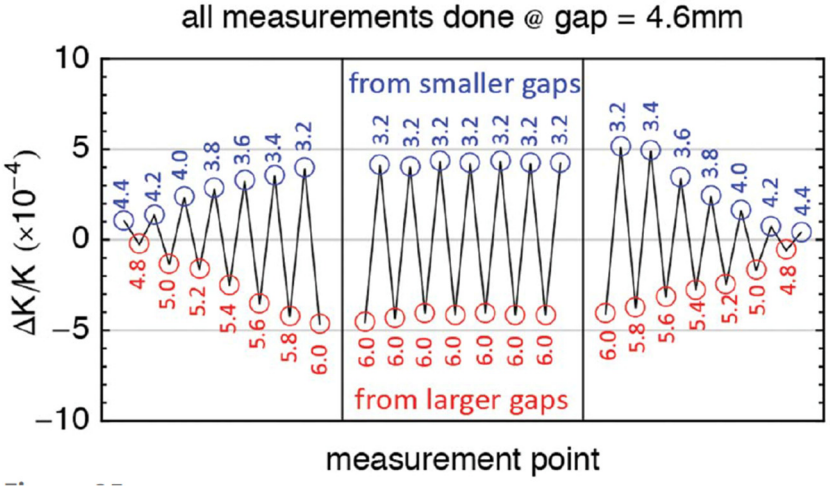
remotely controlled, µm precision

(hor., **vert.**, **pitch,** yaw, roll)

Aramis U15 magnetic performance







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Magnetic assessment and modelling of the Aramis undulator beamline

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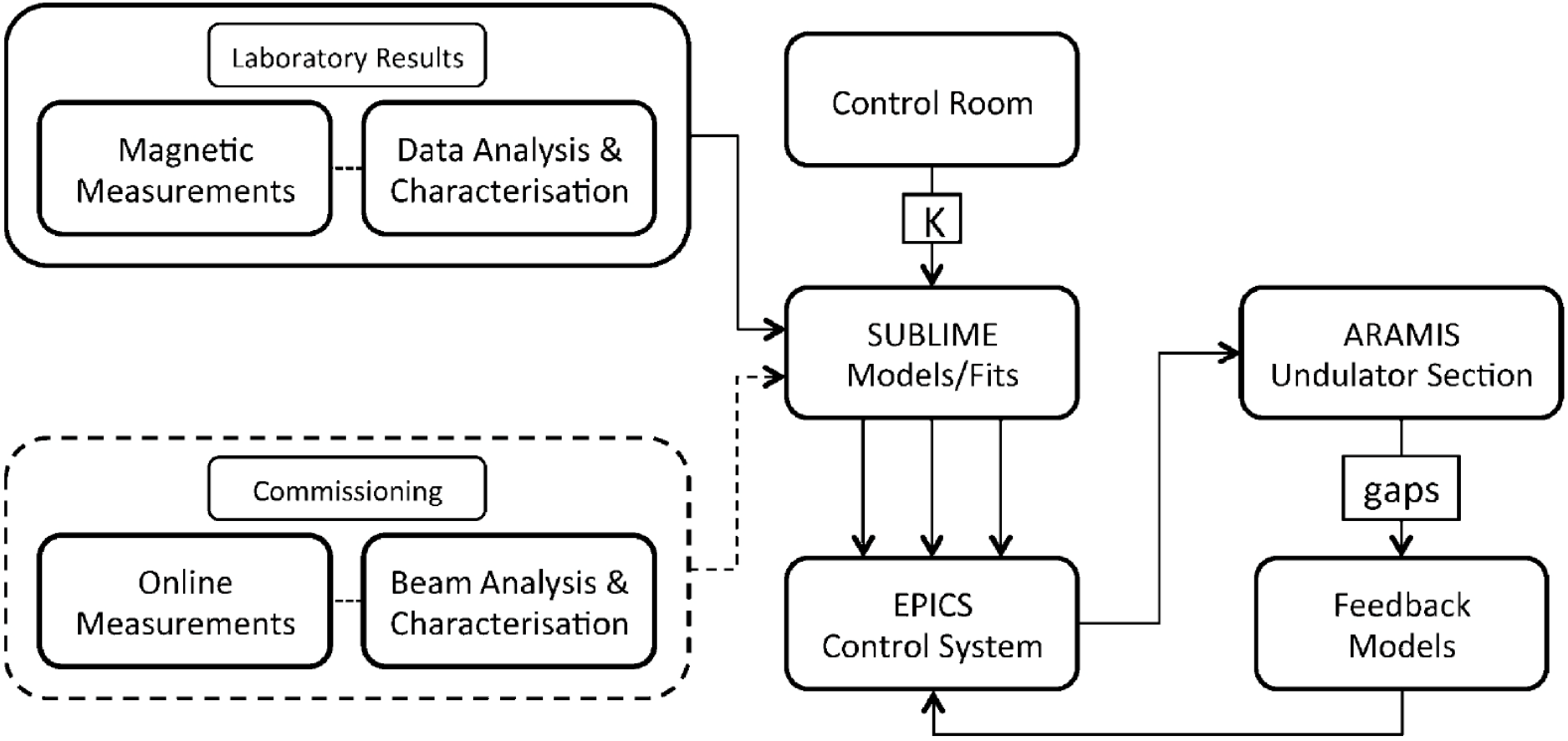
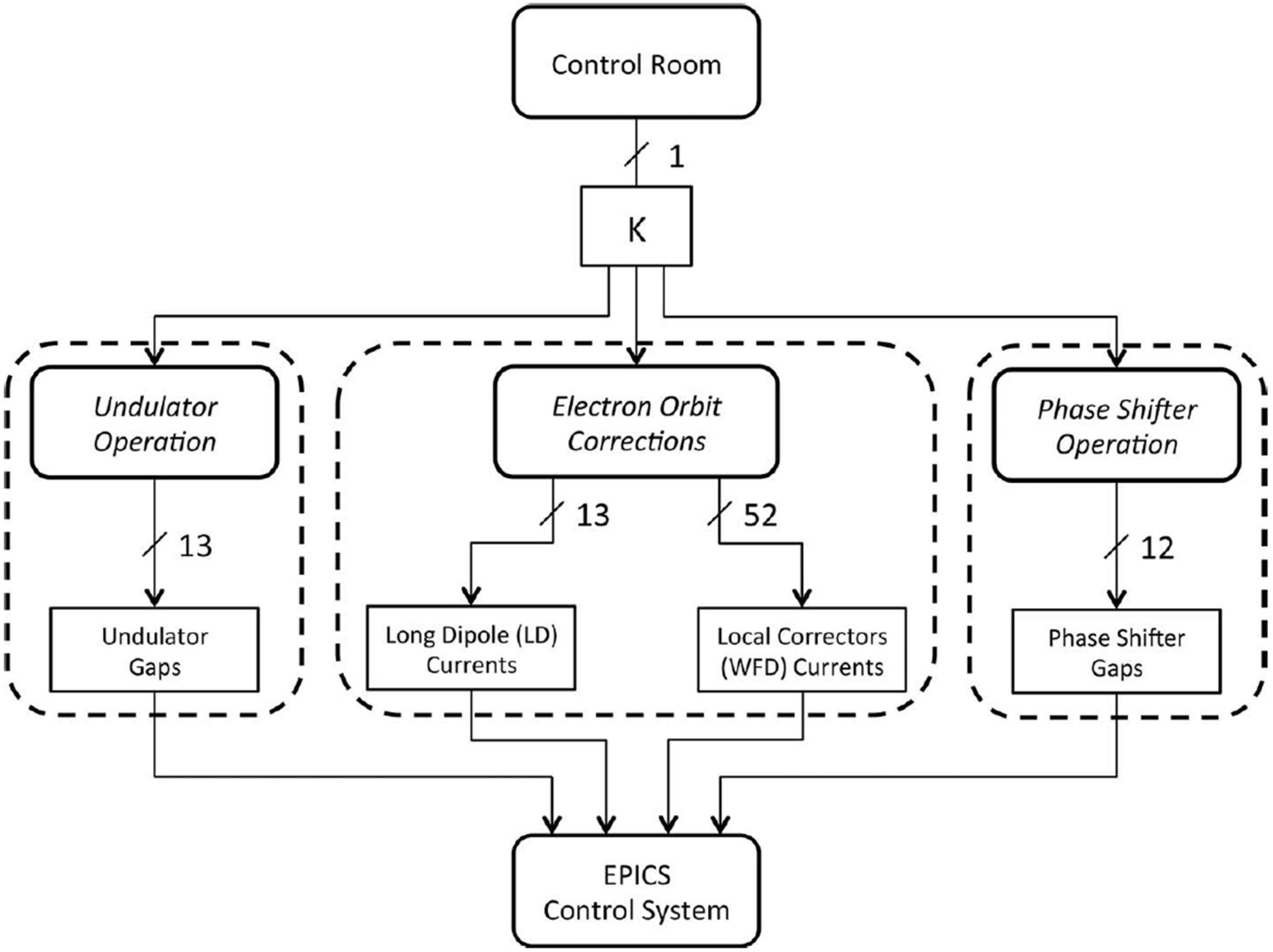
Within the SwissFEL project at the Paul Scherrer Institute (PSI), the hard X-ray line (Aramis) has been equipped with short-period in-vacuum undulators, known as the U15 series. The undulator design has been developed within the institute itself, while the prototyping and the series production have been implemented through a close collaboration with a Swiss industrial partner, Max Daetwyler AG, and several subcontractors. The magnetic measurement system has been built at PSI, together with all the data analysis tools. The Hall probe has been designed for PSI by the Swiss company SENIS. In this paper the general concepts of both the mechanical and the magnetic properties of the U15 series of undulators are presented. A description of the magnetic measurement equipment is given and the results of the magnetic measurement campaign are reported. Lastly, the data reduction methods and the associated models are presented and their actual implementation in the control system is detailed.

Aramis U15 operational concept

SUBLIME: aramiS Undulator BeamLIne ModEl

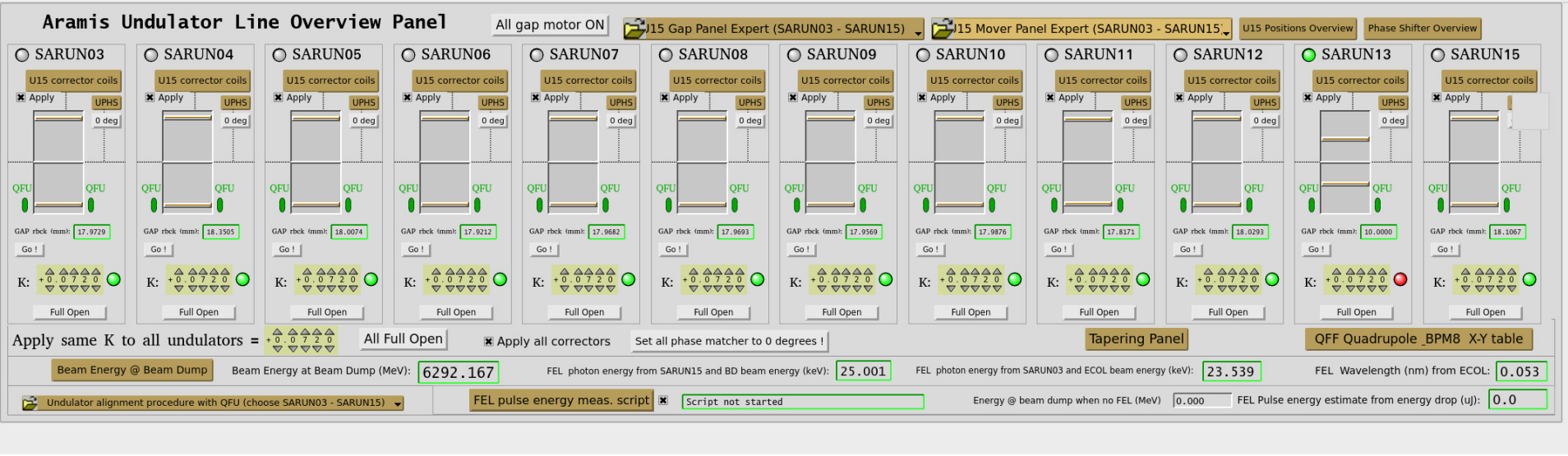


Aramis U15 operational concept

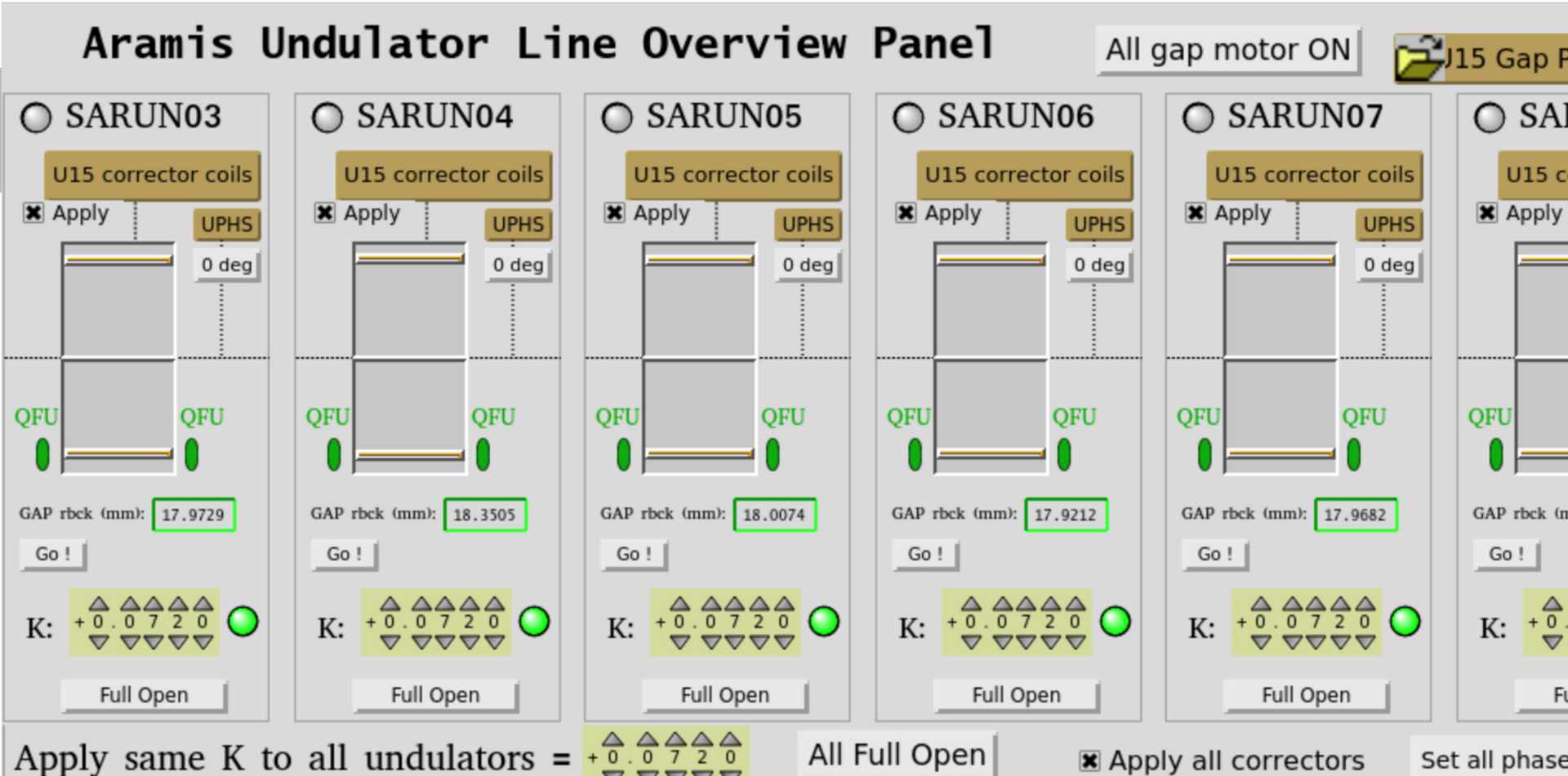


Aramis U15 operational concept

ID control panel

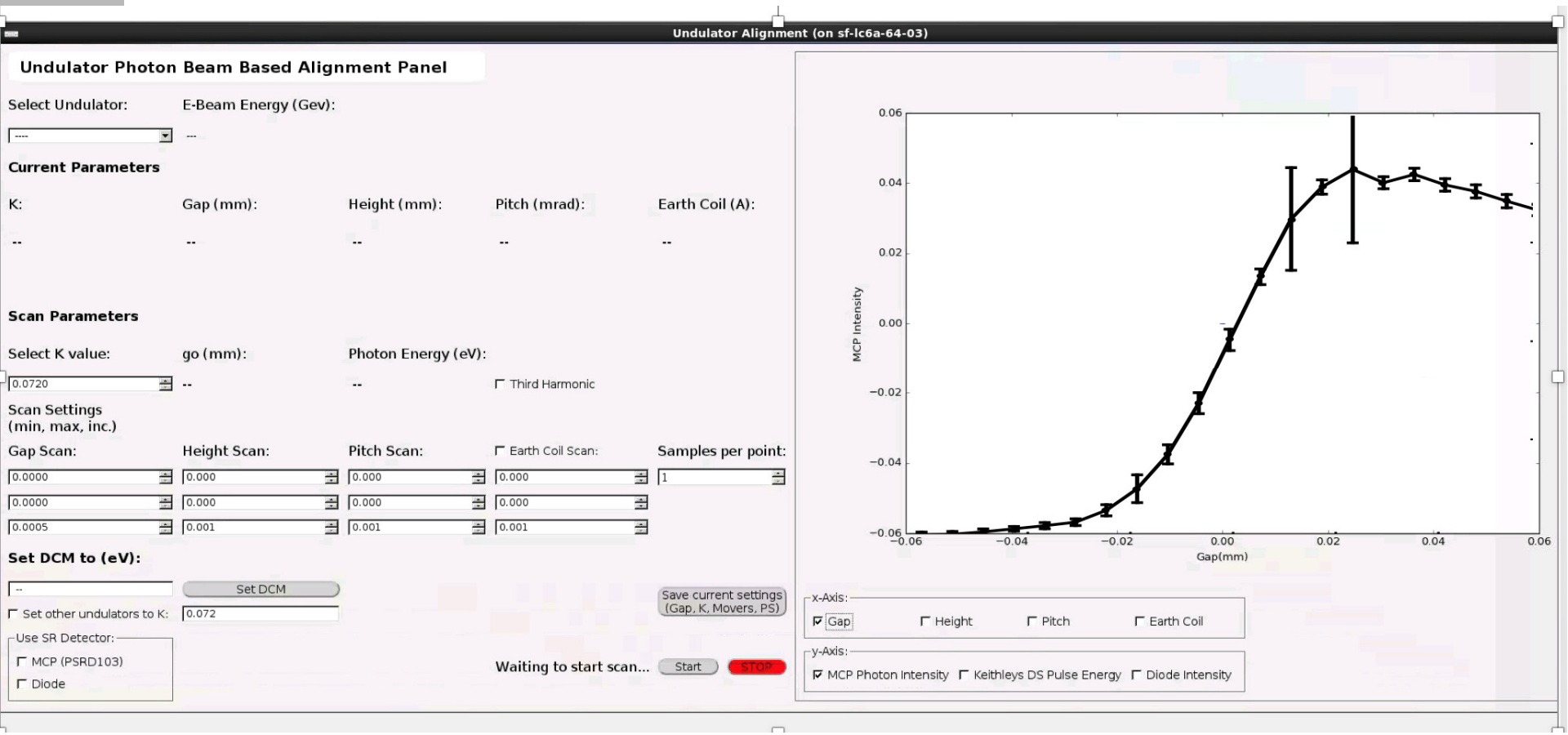


Aramis U15 operational concept



Aramis U15 operational concept

Undulator optimisation panel



Finding a straight electron orbit

1 – 2 / year

1) Straight orbit first – beam based BBA

2) Align Undulator modules to it – also BBA with Q_A

3) Improve Undulator alignment with photons (spont. rad.)

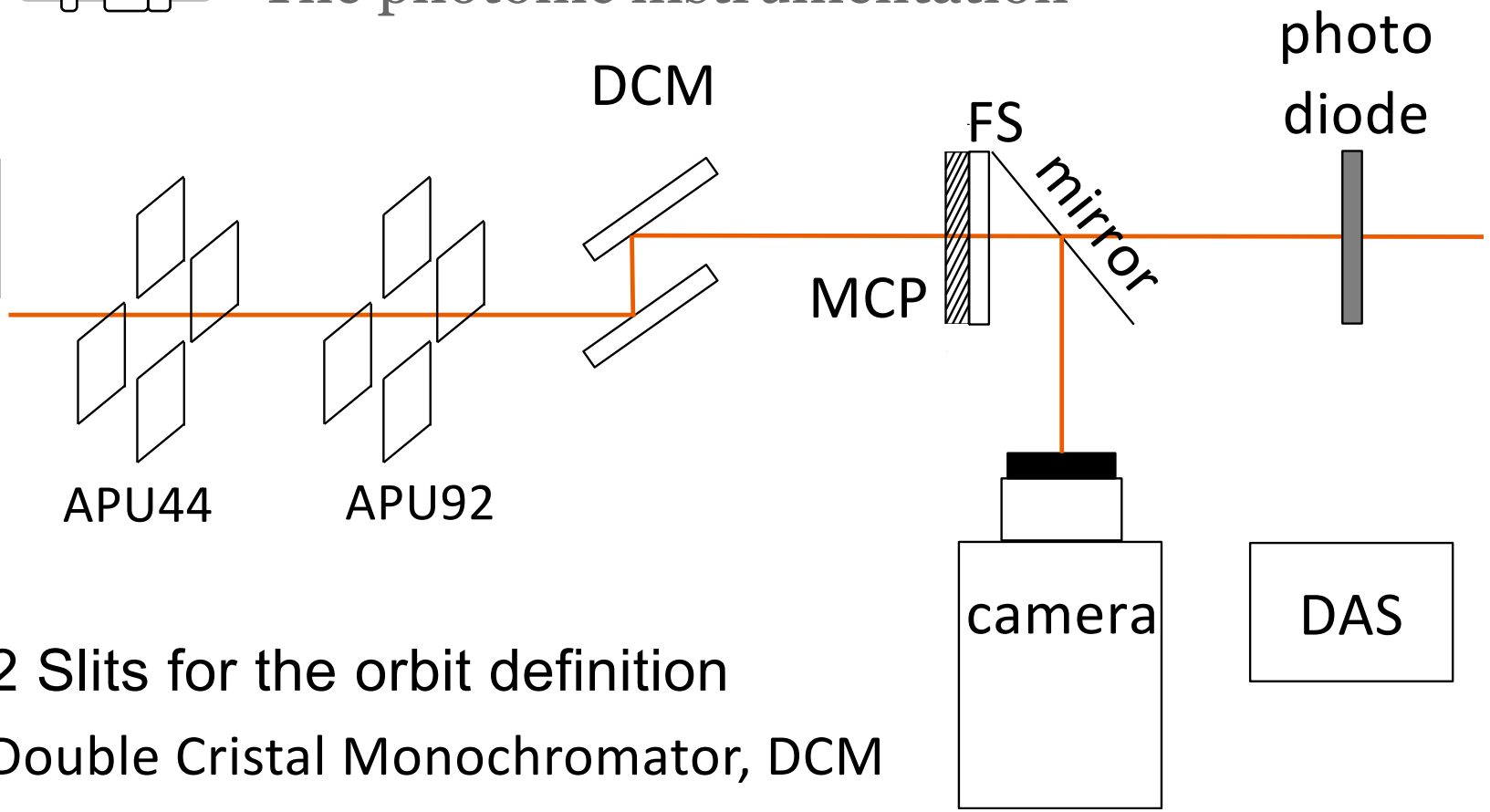
special bunch compression setup:

minimise projected energy spread

4) Optimise with FEL signal (PSICO)

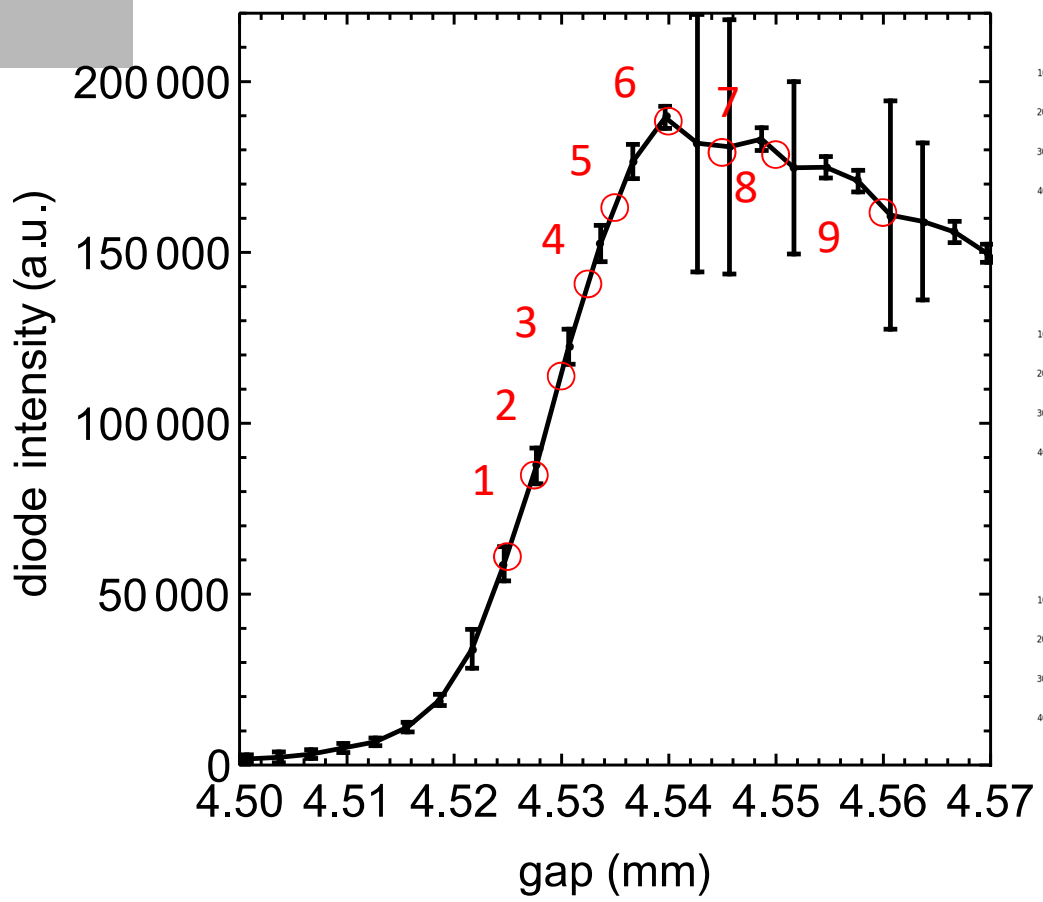
dayly

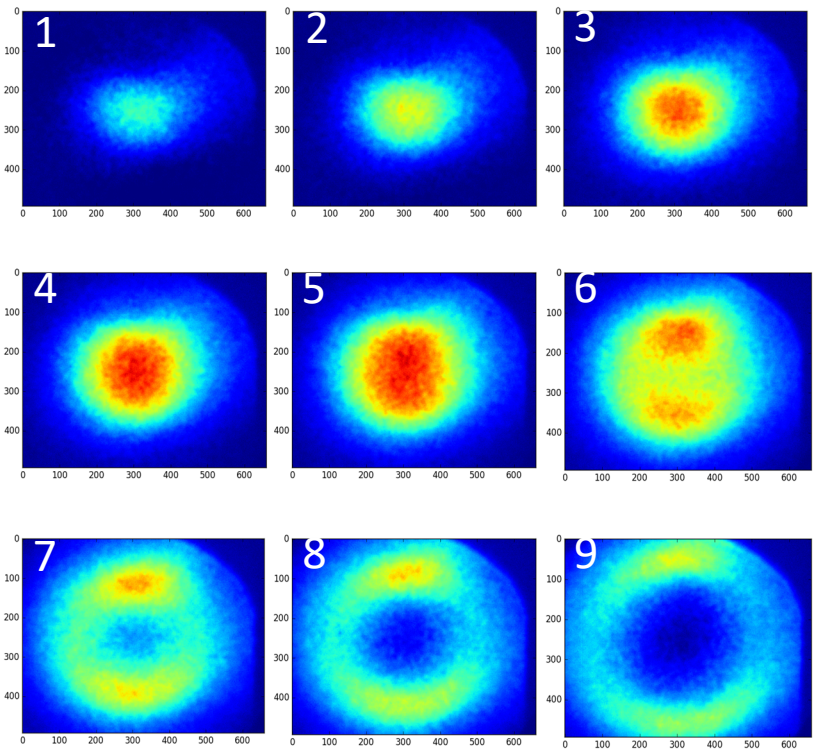
The photonic instrumentation



- 2 Slits for the orbit definition
- Double Cristal Monochromator, DCM
- Silicon Photo Diode
- Multi Channel Plate, Double stage
  MCP operated @ 1.5kV

Blue edge - gap scan : example

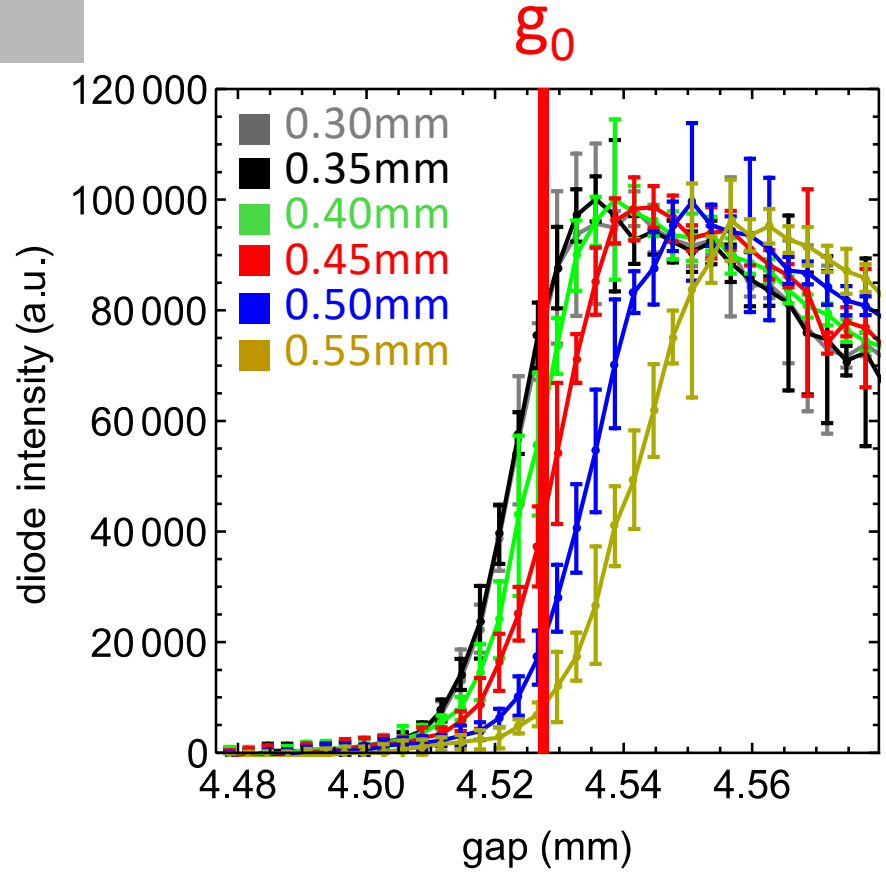


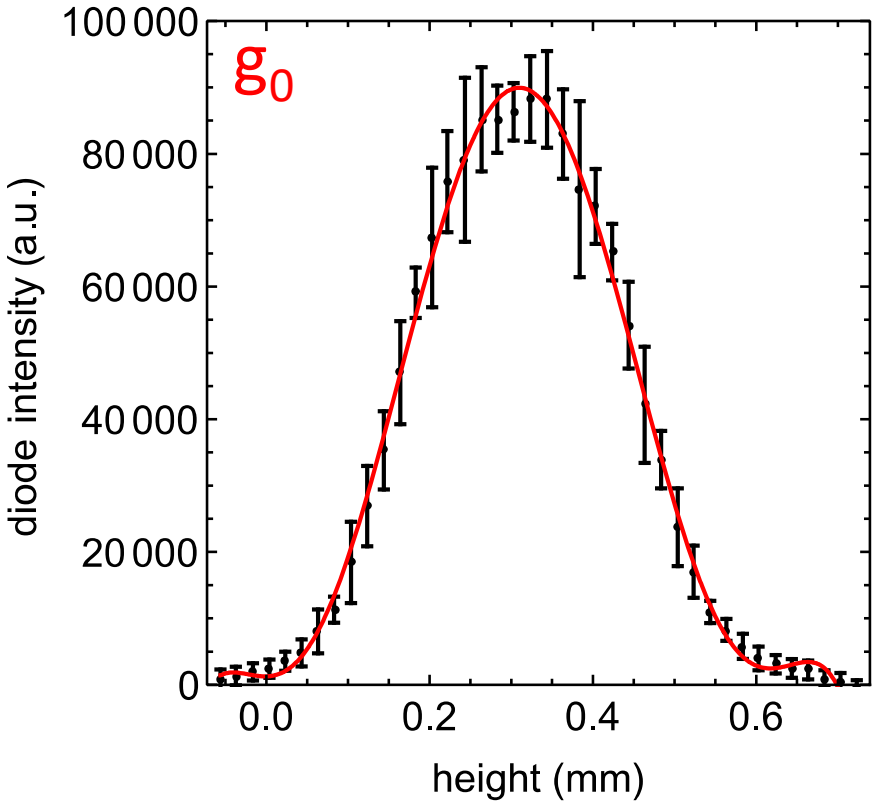


Alignment : height

Mono: 2395eV

1st harmonic

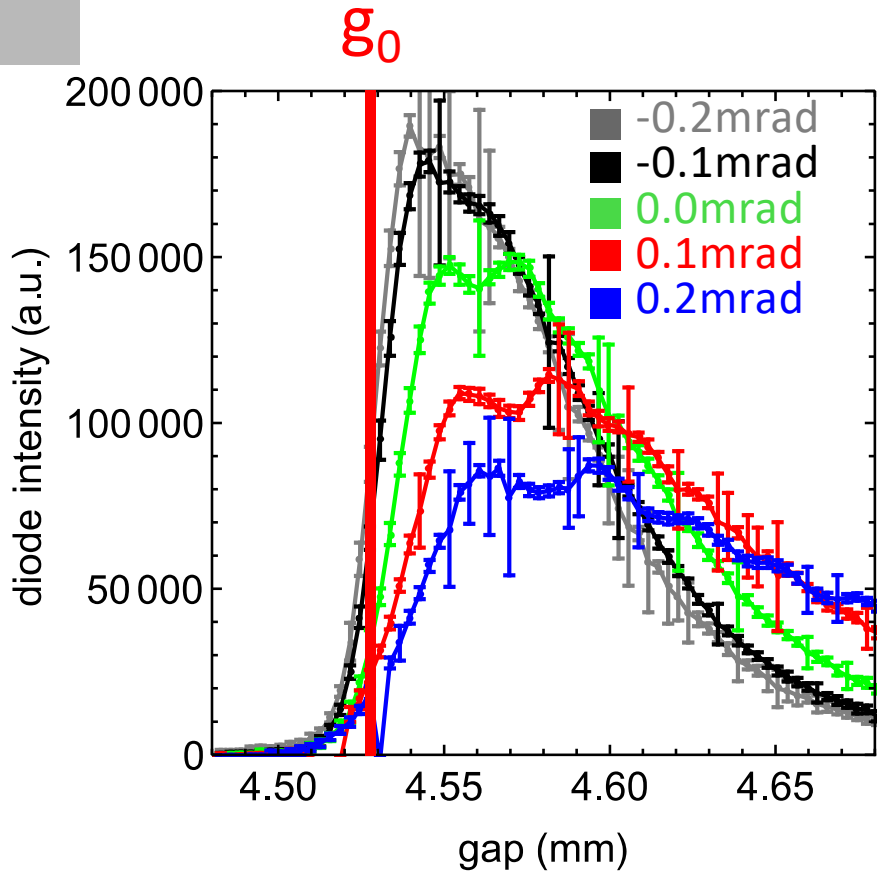


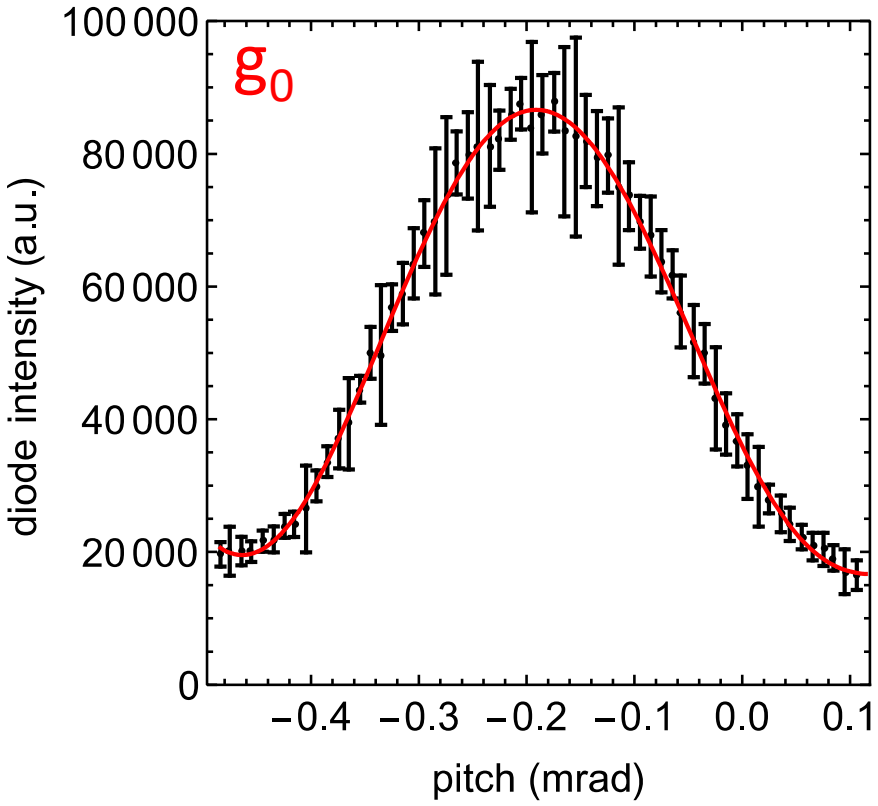


Alignment : pitch

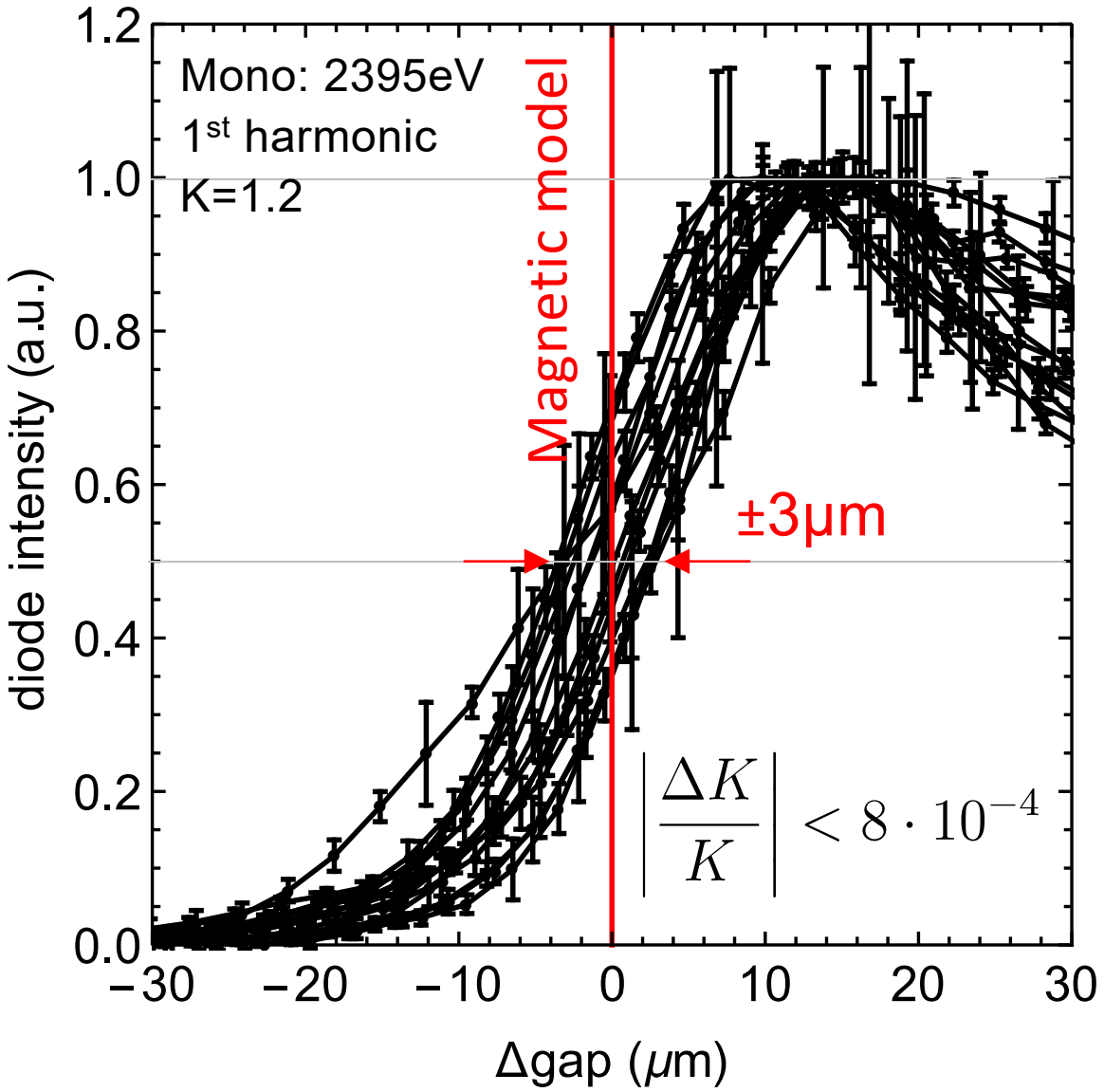
Mono: 2395eV

1st harmonic



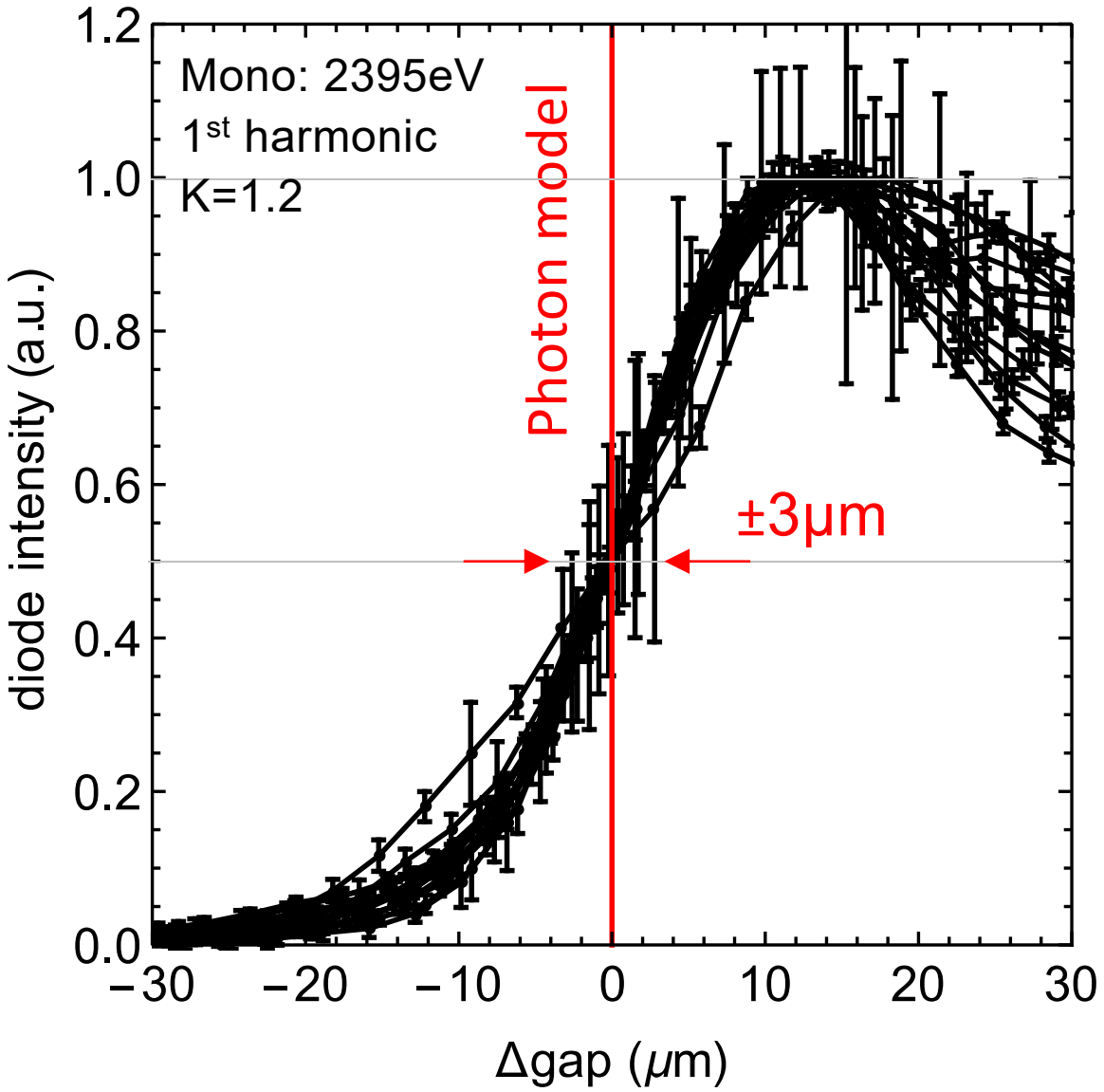


K-calibration : *March 2018*



SARNU03
SARUN04
SARUN05
SARUN06
SARUN07
SARUN08
SARUN09
SARUN10
SARUN11
SARUN12
SARUN13
SARUN14
SARUN15

K-calibration : *March 2018*



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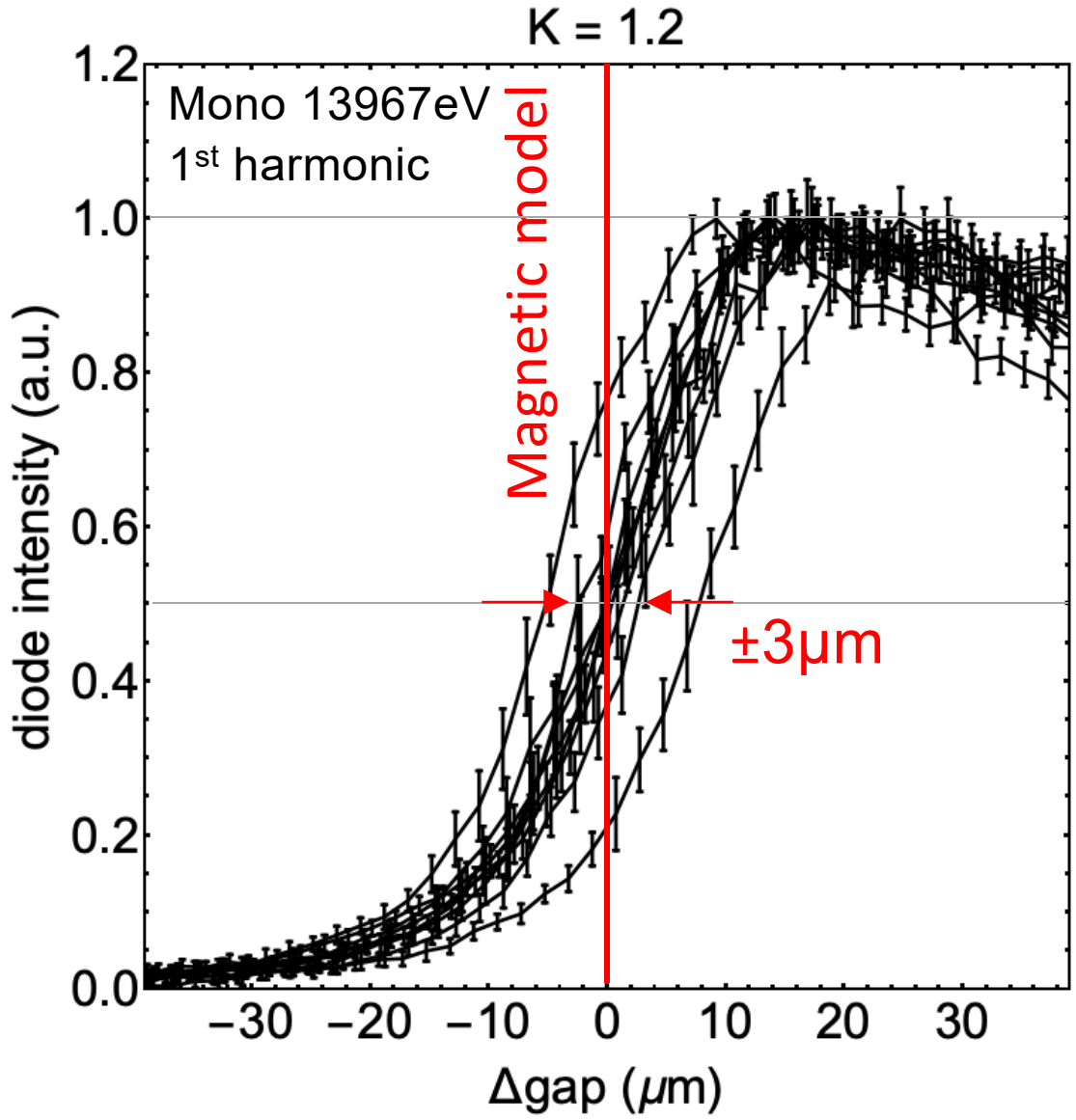
SARUN14
SARUN15

Blue edges of measured modules – K=1.2



SARNU07
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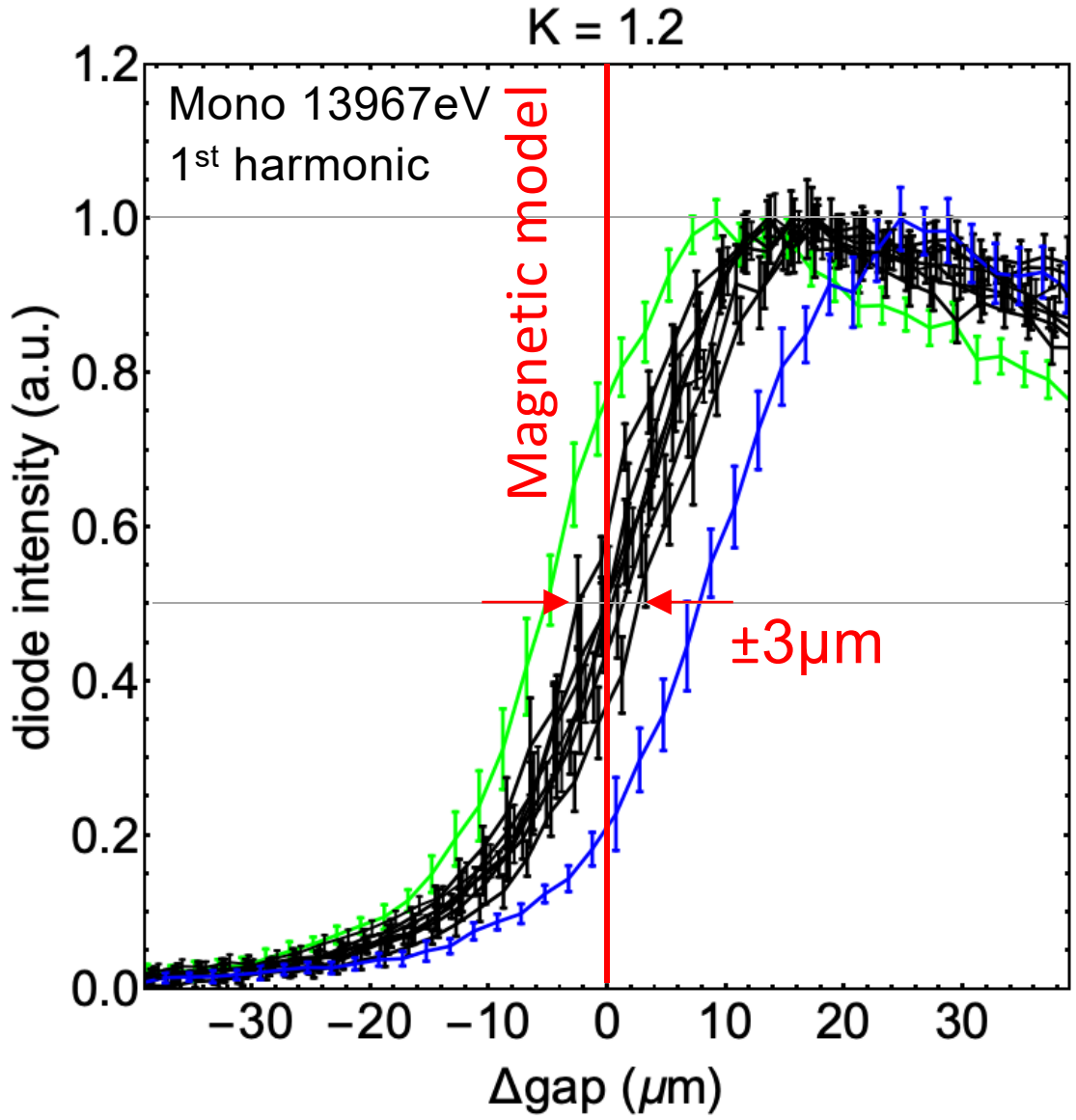
SARUN14
SARUN15

Blue edges of measured modules – K=1.2



SARNU07
SARUN08
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SARUN10
SARUN11
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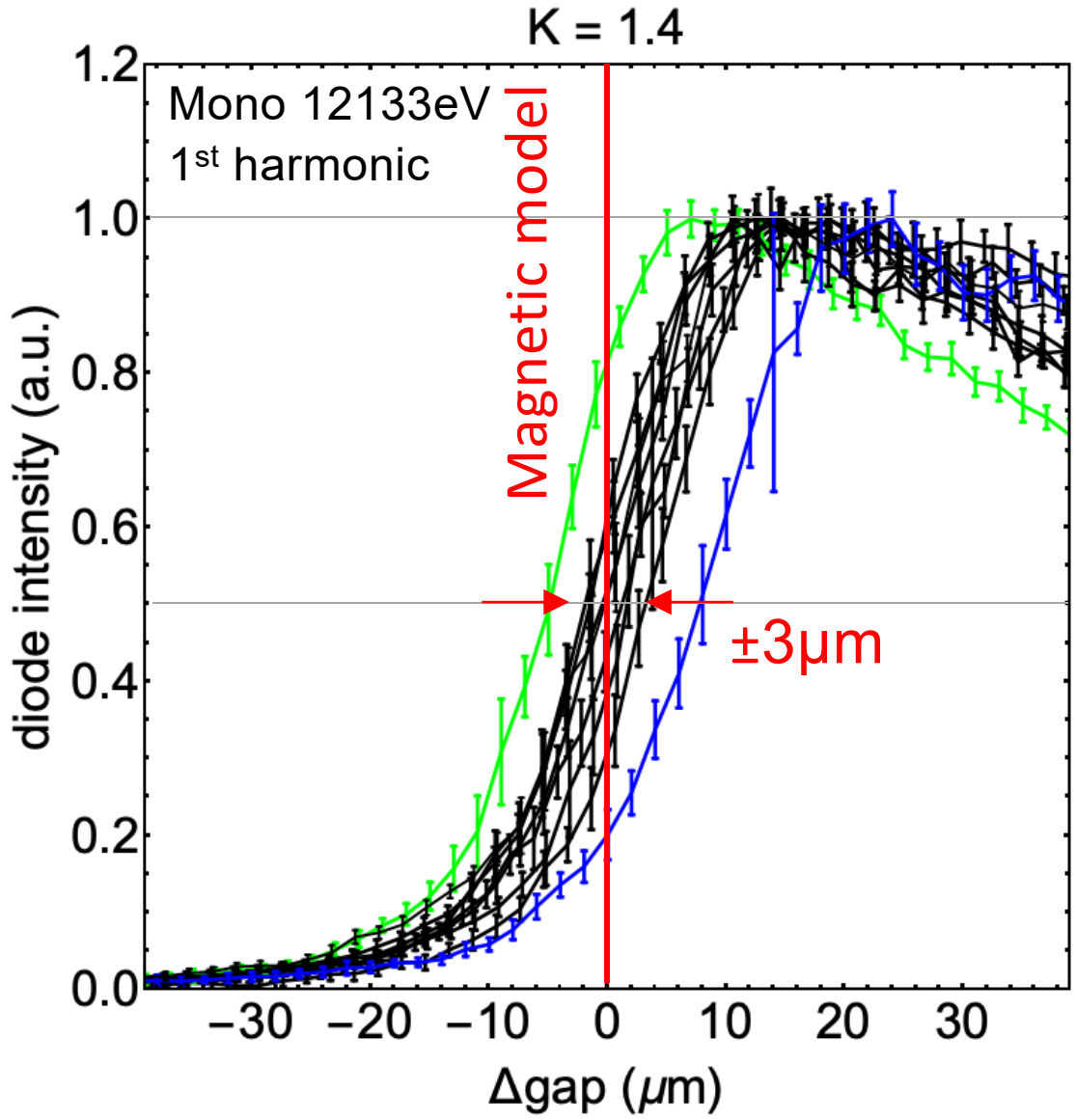
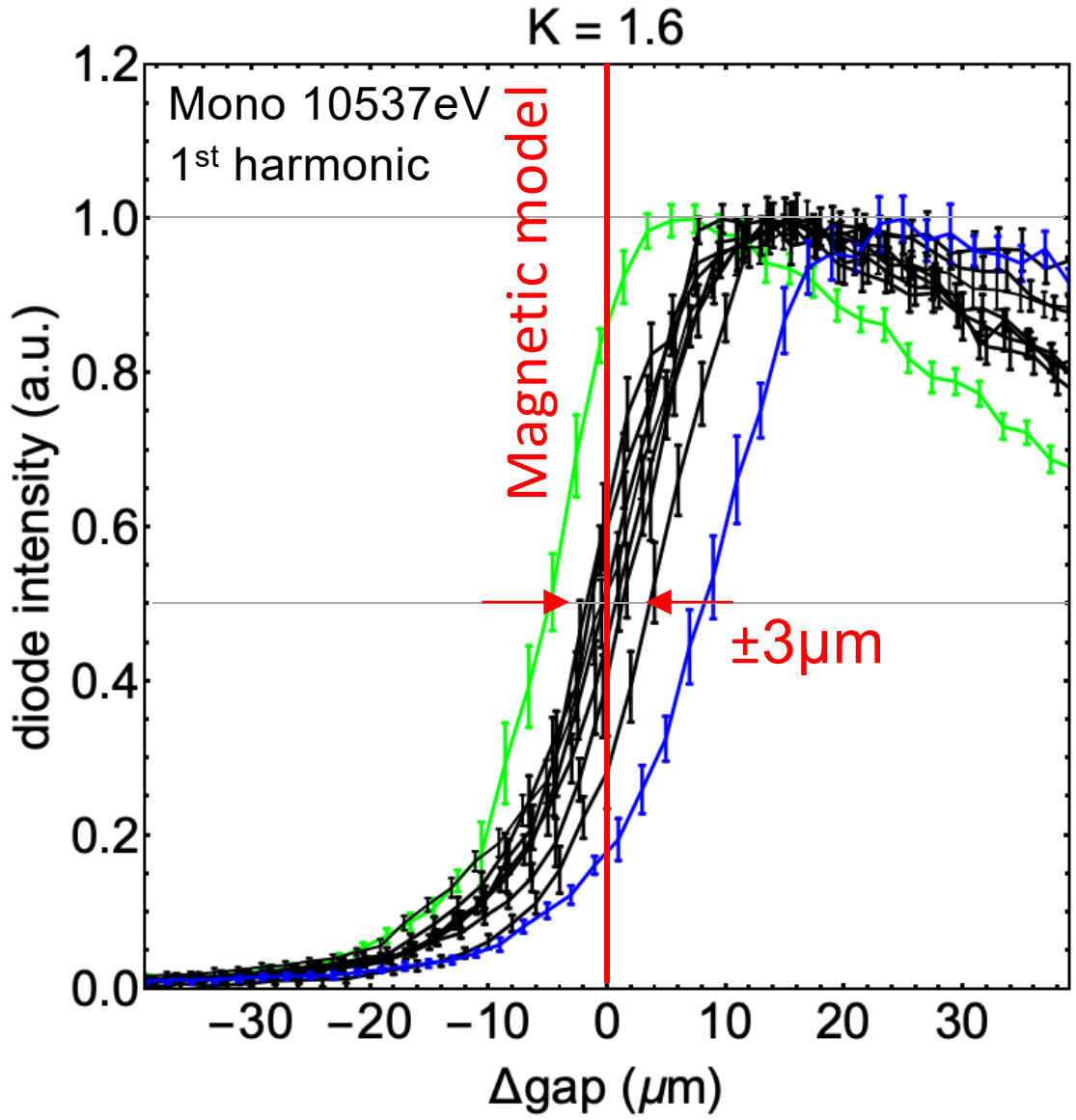
SARUN13
SARUN14
SARUN15

Blue edges of measured modules – K=1.4



SARNU07
SARUN08
SARUN09
SARUN10
SARUN11
SARUN12
SARUN13
SARUN14
SARUN15

Blue edges of measured modules – K=1.6



SARNU07
SARUN08
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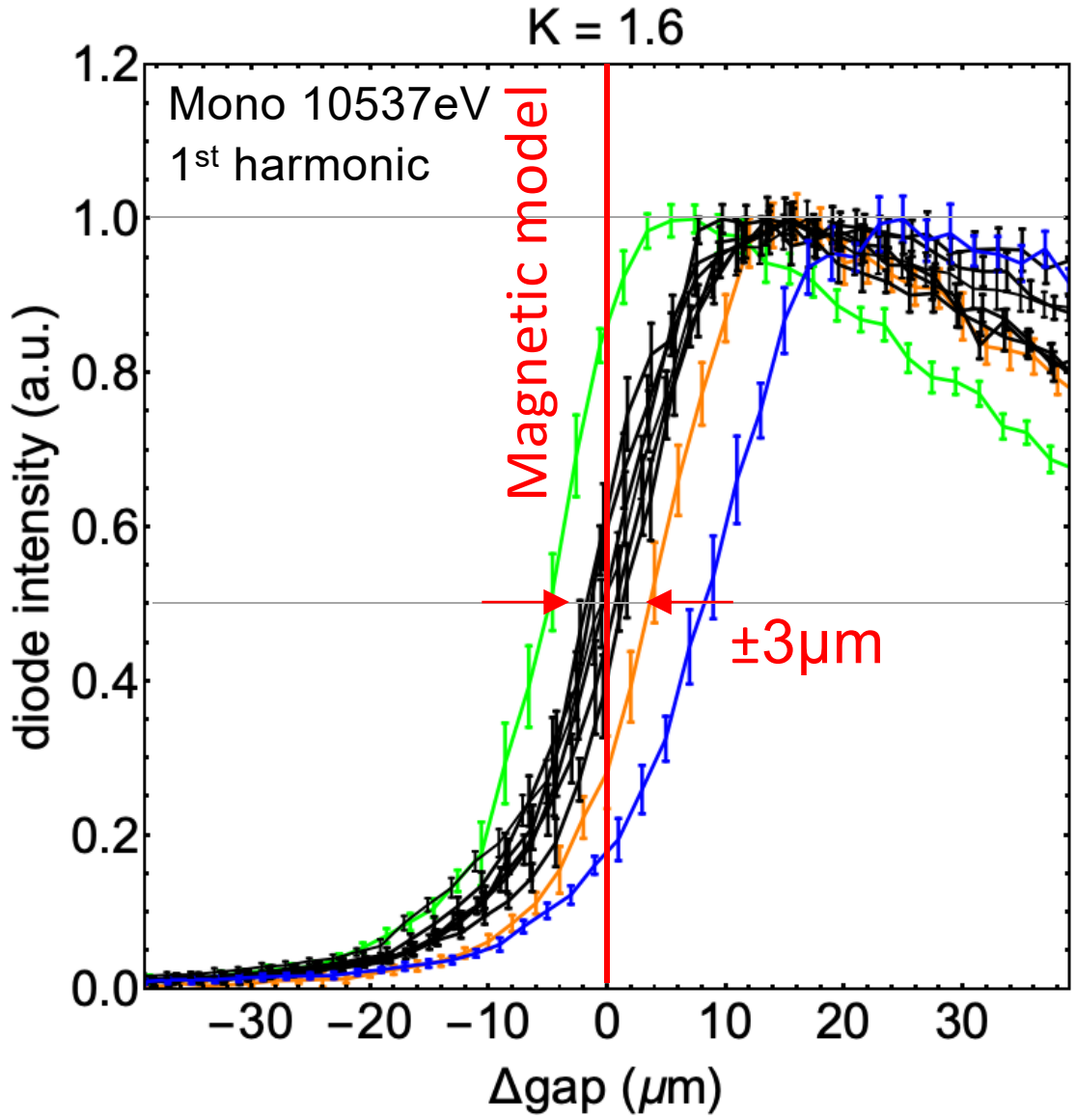
SARUN10
SARUN11
SARUN12
SARUN13
SARUN14
SARUN15

Blue edges of measured modules – K=1.6



SARNU07
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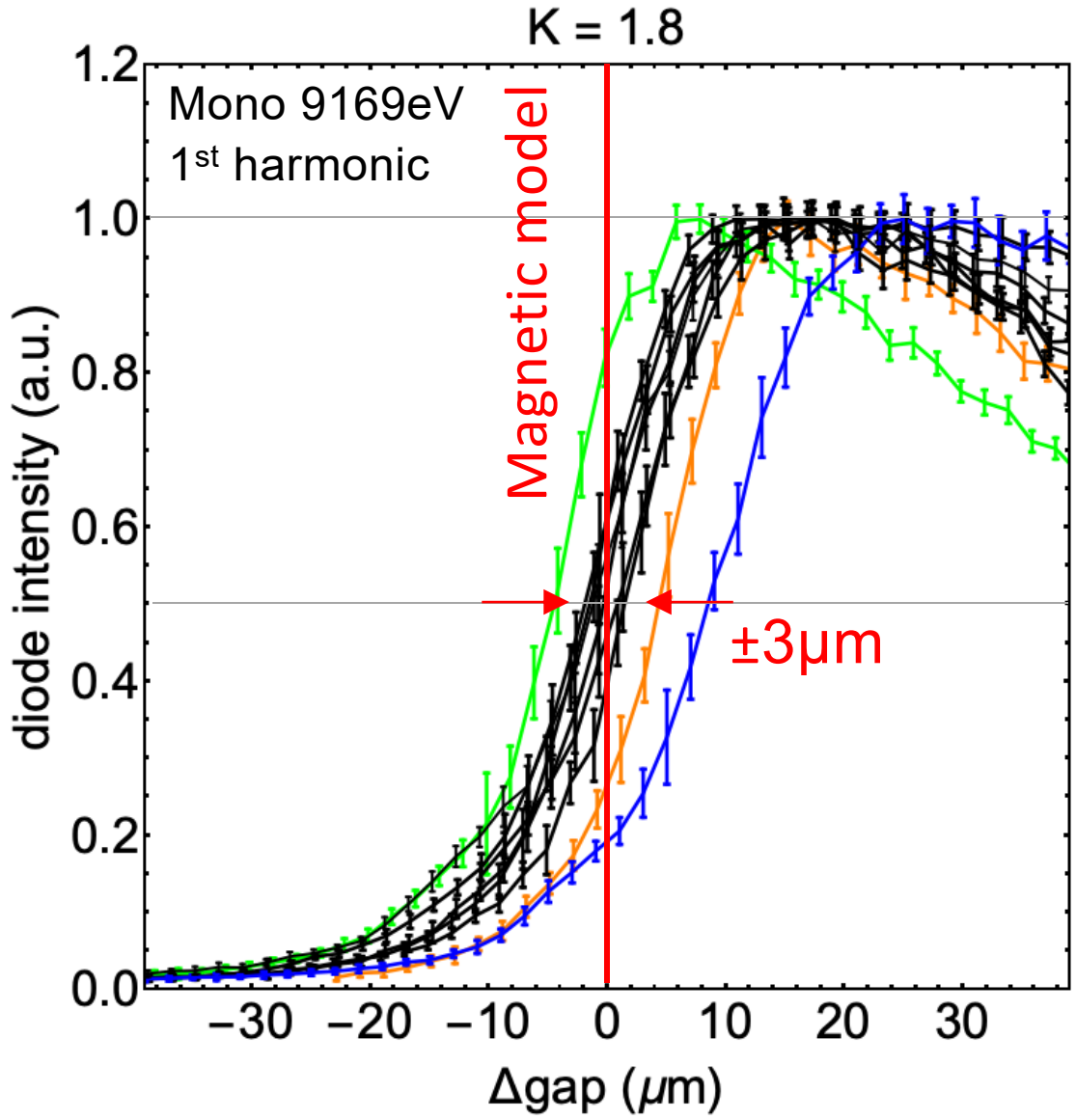
SARUN13
SARUN14
SARUN15

Blue edges of measured modules – K=1.8



SARNU07
SARUN08
SARUN09
SARUN10
SARUN11
SARUN12
SARUN13
SARUN14
SARUN15

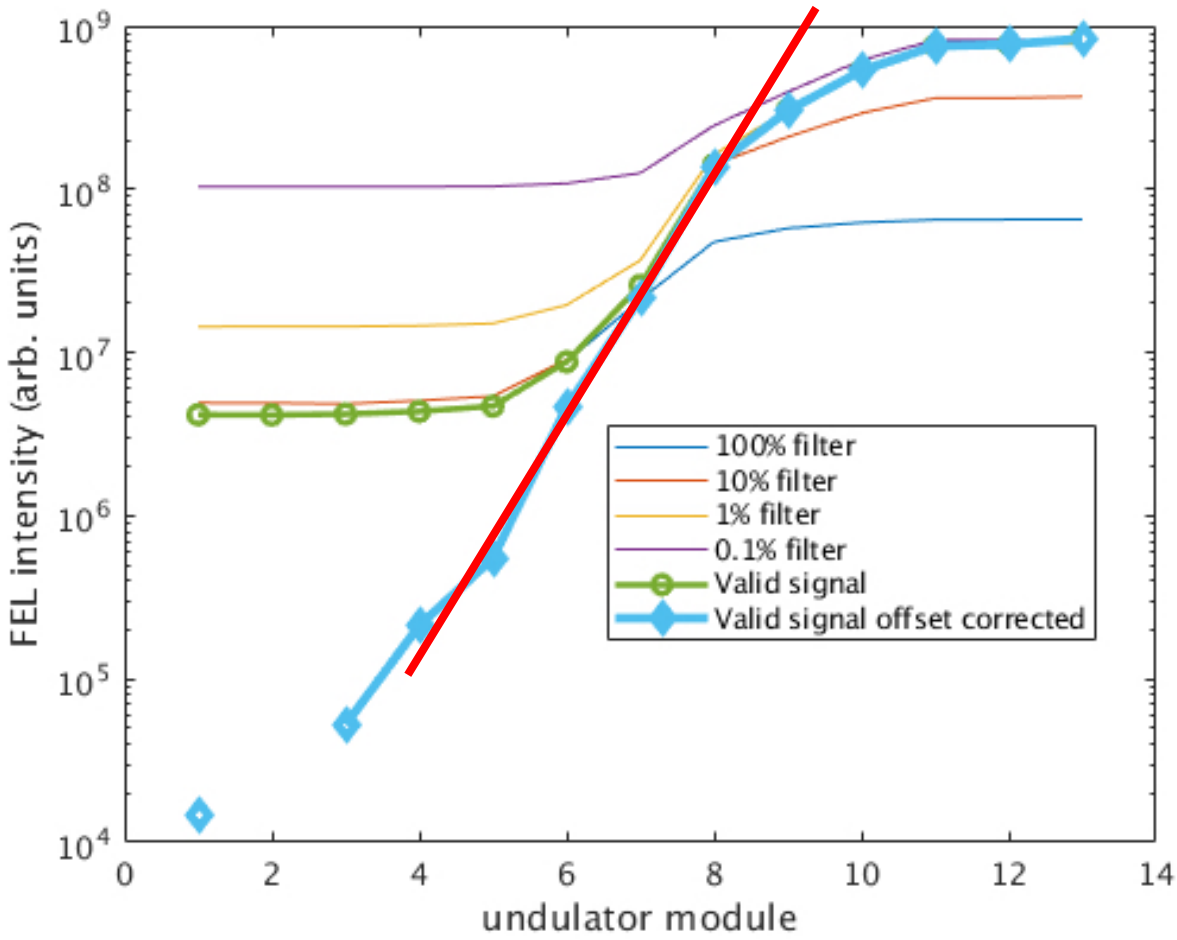
Summary table of calibration errors in Gap

K	SARUN07	SARUN08	SARUN09	SARUN10	SARUN11	SARUN12	SARUN13	SARUN14	SARUN15
				gap setting error (µm)					
1.0	2.4	-2.4	-5.6	-2.1	-1.1	-0.7	1.1	8.4	-0.1
1.1	2.6	-2.2	-5.3	-2.7	-0.8	-1.1	1.4	8.0	0.1
1.2	2.2	0.0	-5.8	-2.4	-0.8	-1.3	1.0	7.2	-0.2
1.3	2.7	0.9	-5.7	-2.5	-1.3	-1.7	1.1	7.2	-0.7
1.4	2.7	1.4	-5.6	-2.0	-1.1	-1.8	0.8	6.7	-1.1
1.5	3.3	0.7	-5.9	-2.1	-0.7	-1.9	0.4	7.4	-1.2
1.6	3.0	0.9	-5.7	-1.8	-1.0	-1.8	0.2	7.5	-1.2
1.7	3.3	0.8	-5.5	-1.7	-1.2	-2.6	0.6	7.6	-1.4
1.8	3.7	1.1	-5.4	-2.0	-1.2	-2.5	0.3	8.1	-2.0
Average:	2.9	0.1	-5.6	-2.2	-1.0	-1.7	0.7	7.6	-0.9

Summary table of calibration errors in K

K	SARUN07	SARUN08	SARUN09	SARUN10	SARUN11	SARUN12	SARUN13	SARUN14	SARUN15
					ΔK/K x10^-4				
1.0	-5.9	5.7	13.6	5.2	2.6	1.6	-2.6	-20.3	0.1
1.1	-6.4	5.4	13.2	6.6	2.1	2.7	-3.4	-19.9	-0.3
1.2	-5.7	-0.1	14.7	6.2	2.0	3.2	-2.5	-18.4	0.4
1.3	-7.1	-2.5	15.0	6.6	3.4	4.4	-2.8	-18.8	1.7
1.4	-7.3	-3.7	15.2	5.4	2.9	4.7	-2.2	-18.0	3.0
1.5	-9.0	-1.9	16.2	5.7	1.8	5.2	-1.1	-20.2	3.2
1.6	-8.1	-2.4	15.4	4.9	2.8	5.0	-0.6	-20.3	3.3
1.7	-8.7	-2.1	14.3	4.6	3.0	6.8	-1.5	-19.9	3.6
1.8	-9.5	-2.9	13.9	5.3	3.2	6.3	-0.7	-20.9	5.2
Average:	-7.5	-0.5	14.6	5.6	2.6	4.4	-1.9	-19.6	2.3

Gain Curves

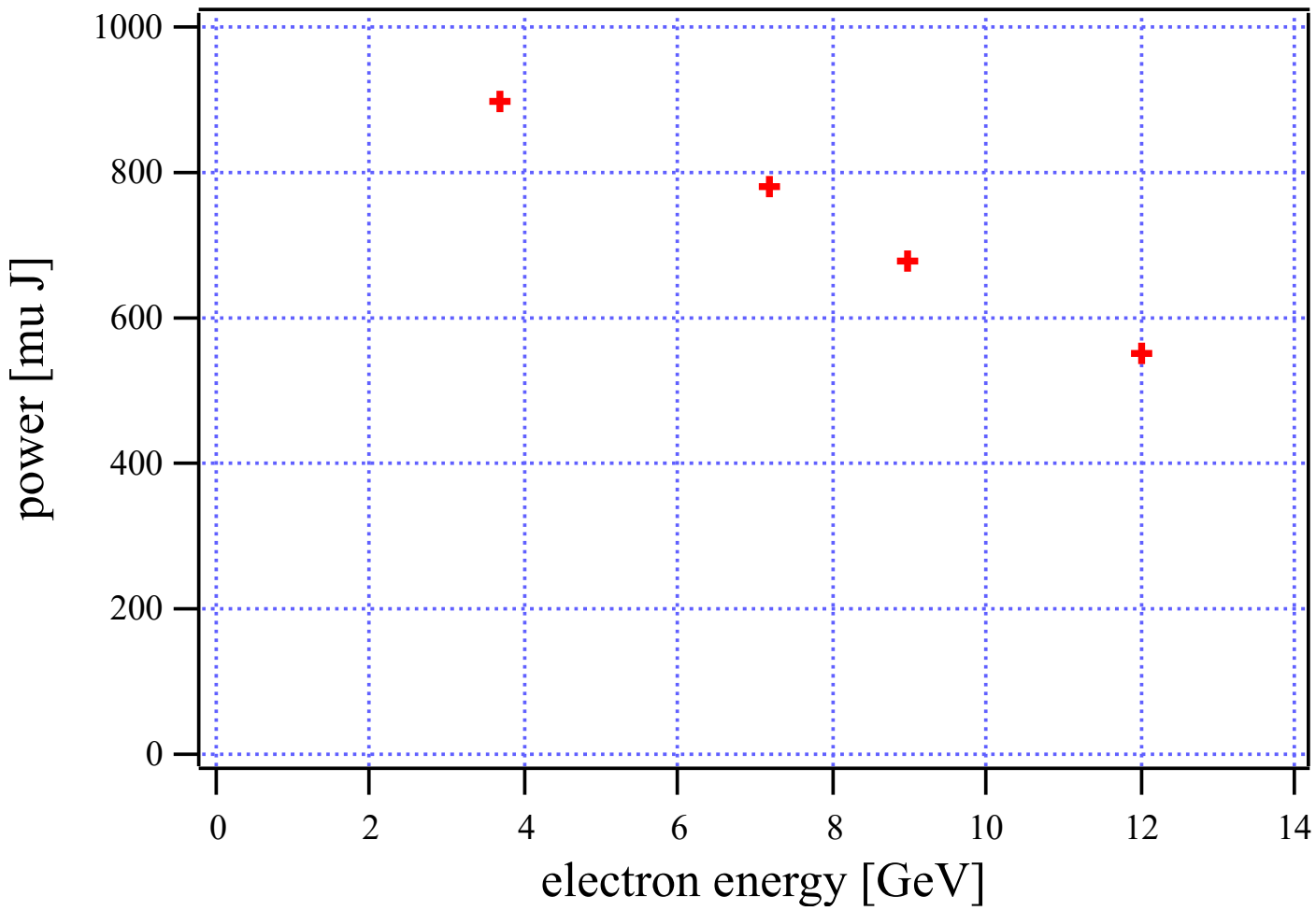


Gain curve measured march 10th 2019

5.8 GeV, 200 pC, K = 1.2

L_g = 2.2 m

Power achievements



Conclusions

- Basis is a straight orbit
- The undulator alignment procedure is straightforward

  1 shift required for all modules
- K calibration:
  - time consuming
  - the optic acceptance does not allow to collect the total flux
  - stability of the calibration

    to be repeated 1 – 2 / year

- room for improvements

Acknowledgments

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M. Calvi, R.Ganter, L.Huber, M.Brügger, A.Keller, M.Locher, M.Schmidt, S.Danner
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F. Löhl, T. Schietinger,
Controls: A. Alarcon
Operation: C.Kittel, N.Hiller, D.Voulot
Photon Diagnostic: C.Arrel, P.Juranic, L.Patthey
Optics: U. Wagner, R.Follath

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