Operational Experience from PETRA III

...and NEG-related Tests for PETRA IV

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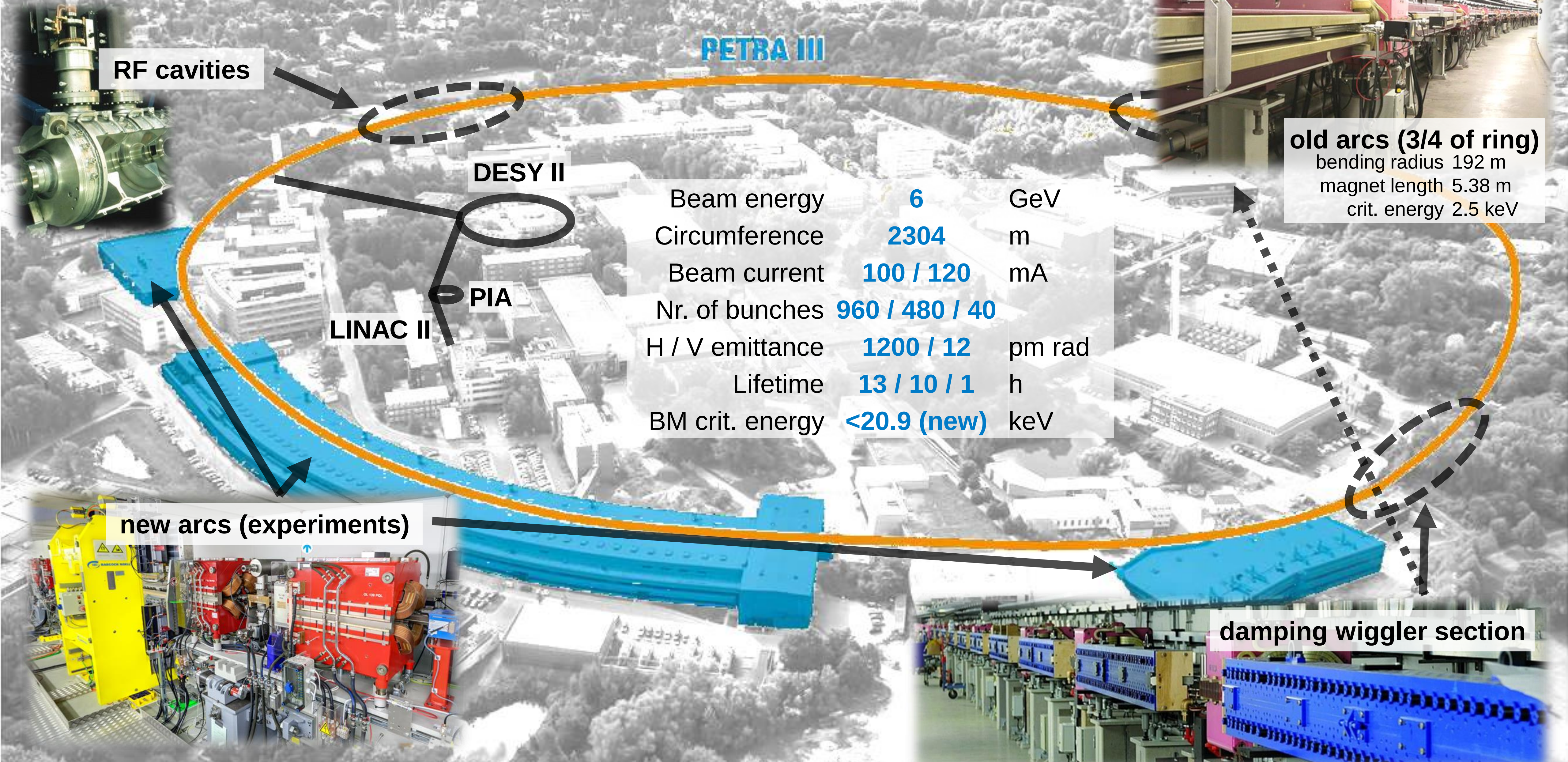
HELMHOLTZ

PETRA IV. NEW DIMENSIONS

DESY.

Outline

Overview of PETRA III

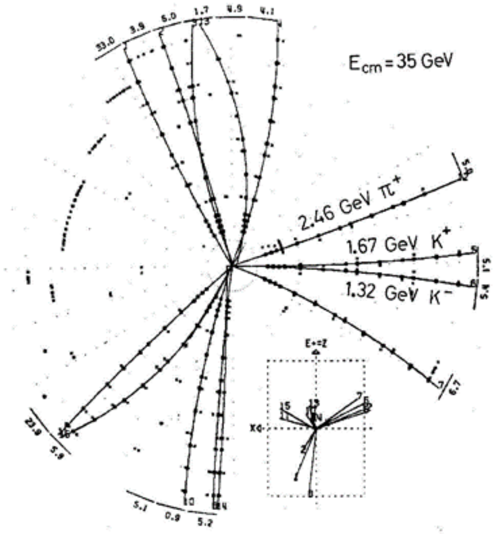


Beam energy	6	GeV
Circumference	2304	m
Beam current	100 / 120	mA
Nr. of bunches	960 / 480 / 40	
H / V emittance	1200 / 12	pm rad
Lifetime	13 / 10 / 1	h
BM crit. energy	<20.9 (new)	keV

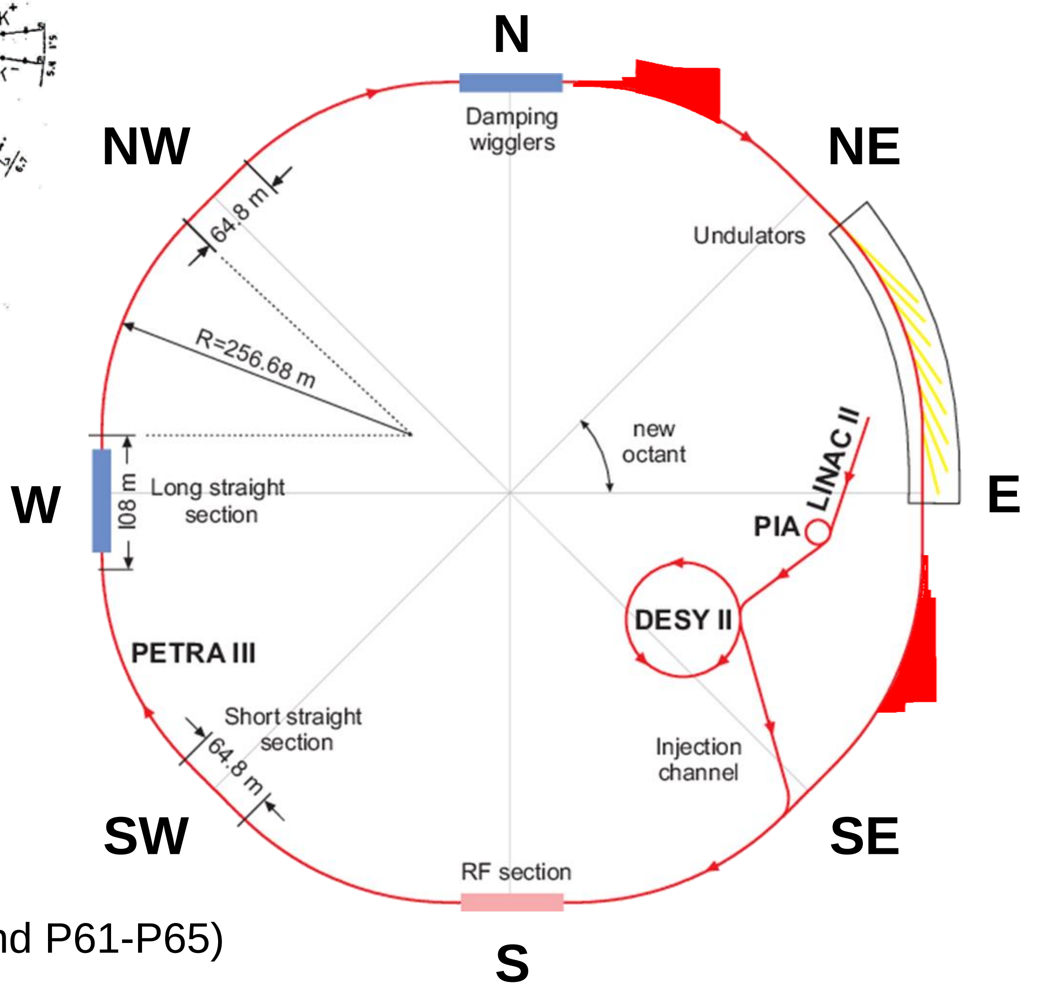
https://photon-science.desy.de/facilities/petra_iii/index_eng.html

Overview of PETRA III

Historical Sketch



- 1978 – 1986 electron – positron collider
  - 1979 Gluon was found!
- 1989 – 2007 Pre-accelerator for HERA
- 2007 – 2008 Conversion into a synchrotron light facility
  - Max-von-Laue hall was built in the east (beamlines P1 to P14)
- 2009 – 2012 e^+ operation
  - Mitigate operational instabalities due to dust
- Since 2013 e^- operation
  - Regular user operation
- 2014 – 2015 Extension north and east
  - Paul Ewald and Ada Yonath hall were built (beamlines P21-P25 and P61-P65)
- 2021 “Superlumi” beamline added (P66)

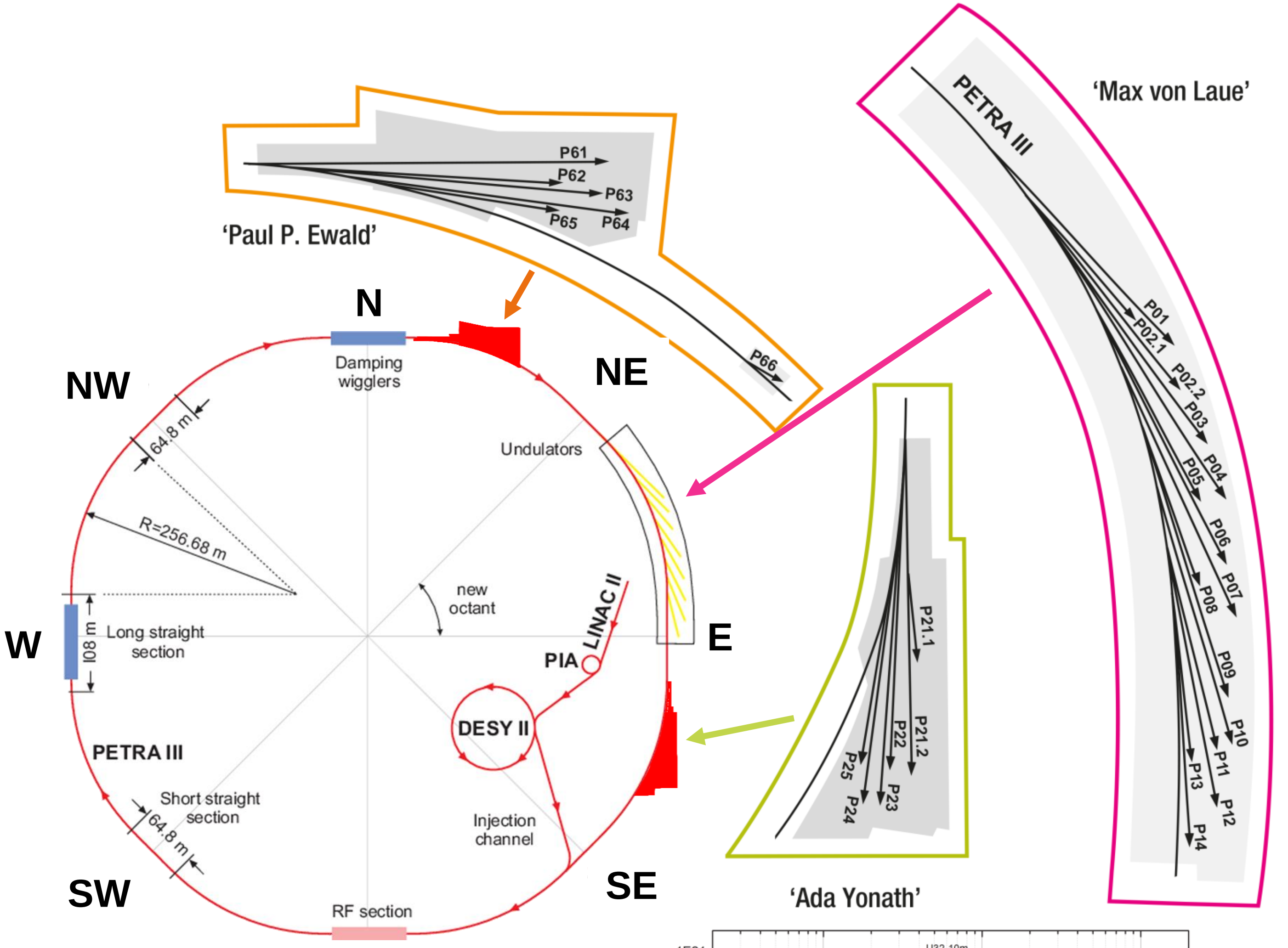


Overview of PETRA III

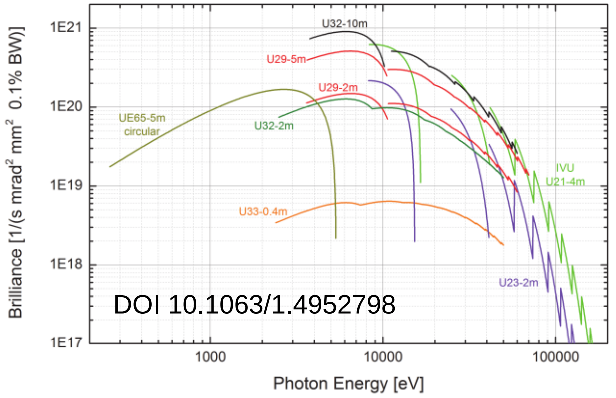
Beamlines

- 25 beamlines available...

P01 Dynamics	5 m
P02.1 Powder Diffraction and Total Scattering Beamline	5 m
P02.2 Extreme Conditions Beamline	2 m
P03 MiNaXS	2 m
P04 XUV Beamline	APPLE
P05 Imaging Beamline	2 m
P06 Hard X-Ray Micro/Nano-Probe	2 m
P07 High Energy Materials Science	in-vac
P08 High Resolution Diffraction	2 m
P09 Resonant Diffraction / HiPhaX	2 m
P10 Coherence Applications	5 m
P11 High-throughput MX	2 m
P12 BioSAXS	2 m
P13 Macromolecular Crystallography I	2 m
P14 Macromolecular Crystallography II	2 m
P21 Swedish Materials Science	2 m
P22 HAXPES	in-vac
P23 In situ X-ray Diffraction and Imaging	2 m
P24 Chemical Crystallography	2 m
P25 Medical Imaging, Powder Diffraction and Innovation	2 m
P61 High Energy wiggler beamline/LVP	DW
P62 SAXSMAT	2 m
P63 OperandoCat (under construction)	
P64 Advanced XAFS	2 m
P65 Applied XAFS	2 m
P66 Superlumi	BM



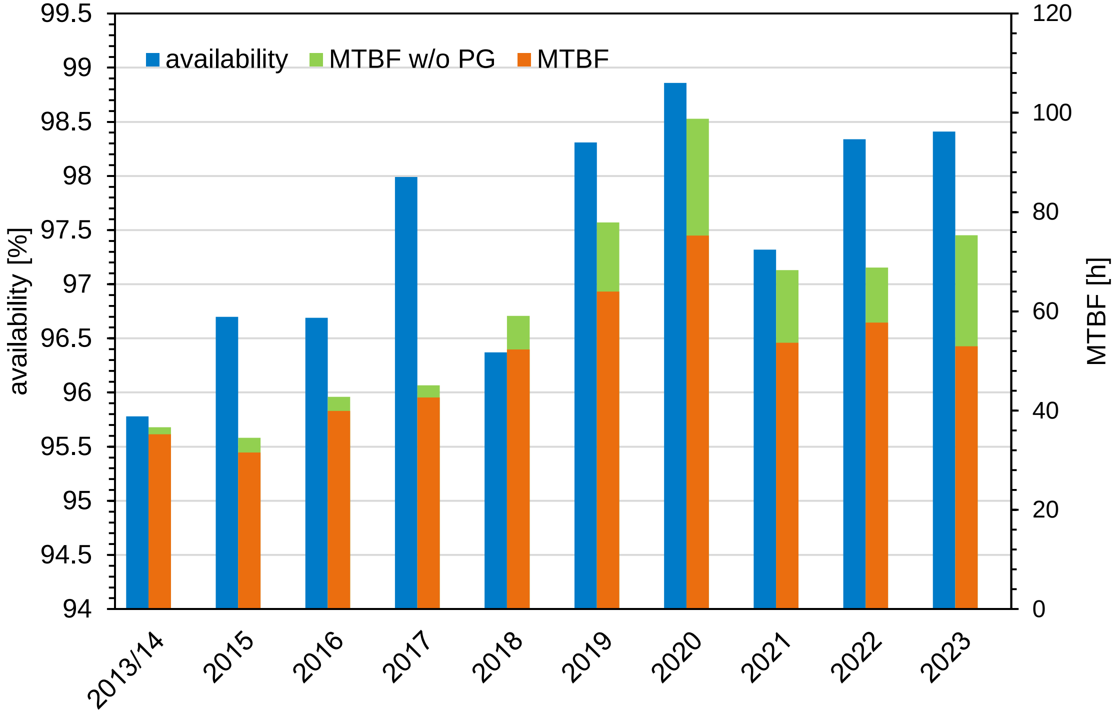
- **18 x 2 m** short regular IDs
- **3 x 5 m** long regular IDs
- **2 x 4 m** long in-vacuum undulators
- **1 x 5 m** long APPLE II undulator



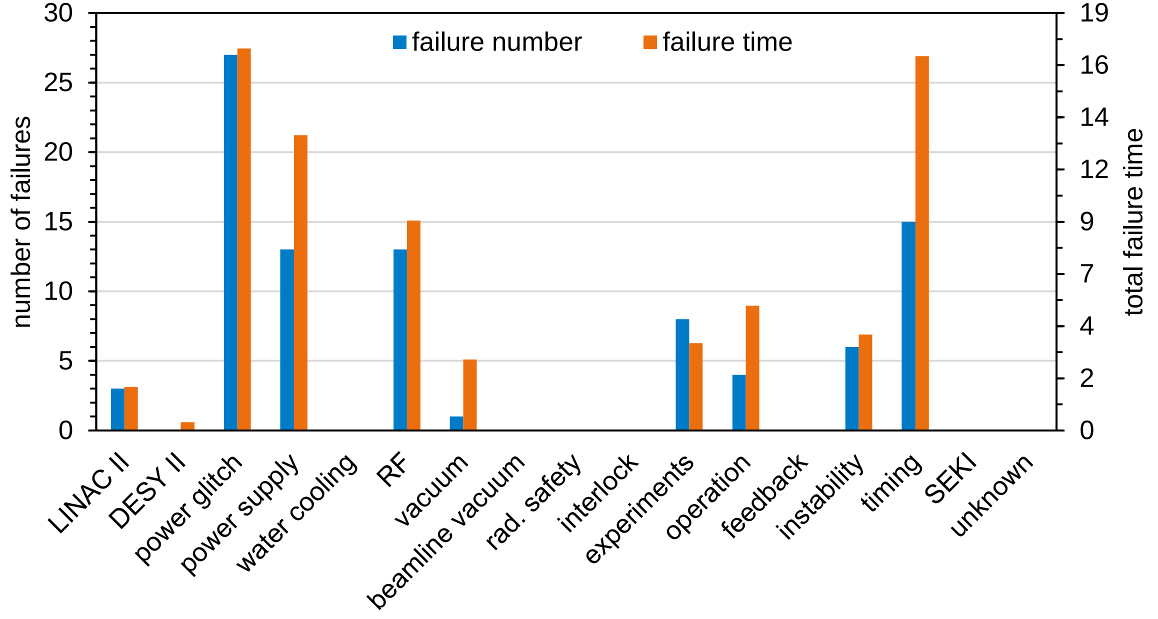
Availability

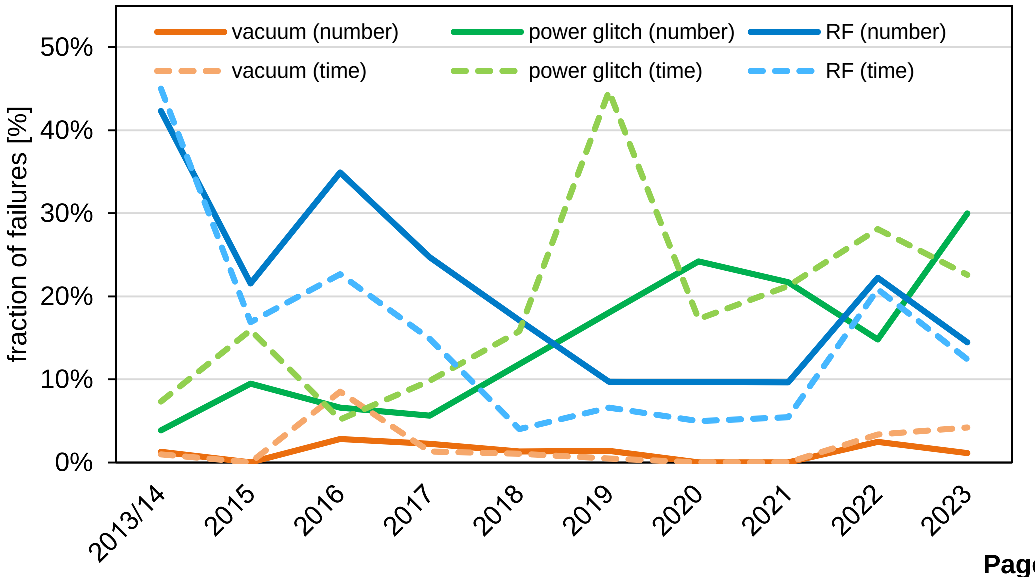
Overview 2014-2024

- Since 2018 power glitches have an increasing impact on the availability
  - >60 h MTBF goal is achieved if power glitches are neglected
- 10 vacuum failures during user operation since 2014
  - Few major events with >2 h downtime in 2016 and 2023



failures in 2023...



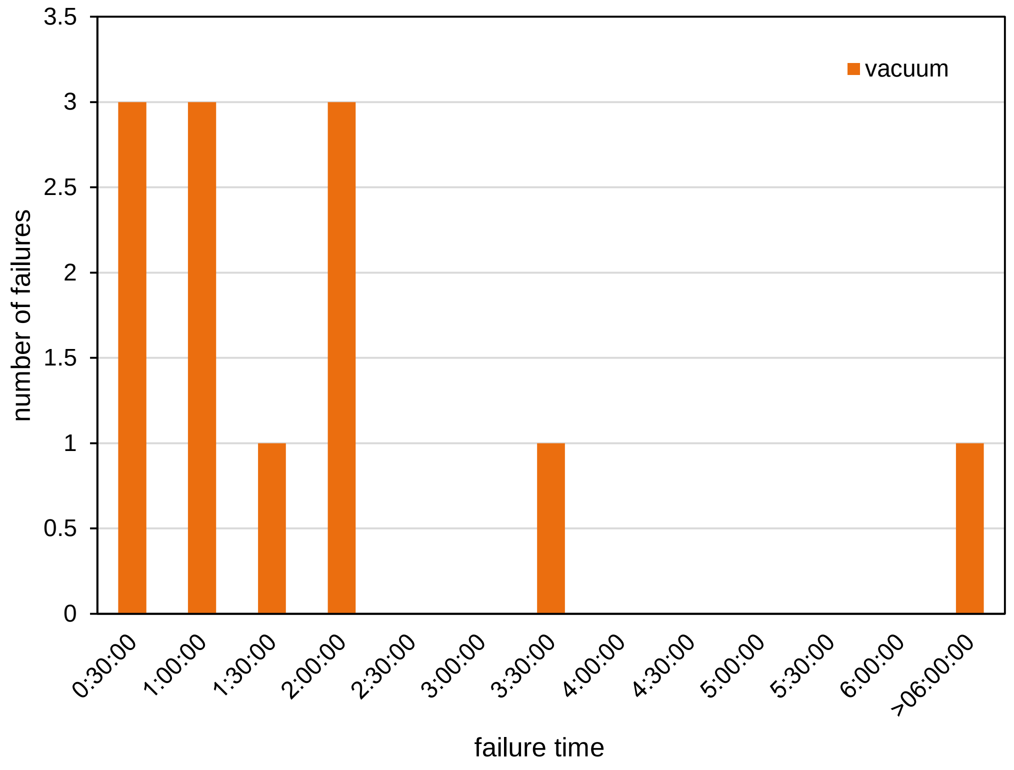


Availability

Overview 2014-2024

- List of vacuum failures...

Date	Duration	Failure Description
2013 KW32	00:43:06	2 SIPs with cable defects (radiation damage)
2013 KW41	01:46:16	vacuum sensor defect
2016 KW21	00:49:00	SIP power supply defect
2016 KW24	00:23:00	SIP cable defect
2016 KW27	11:14:00	leaks at the quartz window in diagnosis beamline and the bellow of a beam trap
2017 KW41	00:44:00	SIP power supply defect
2017 KW47	00:19:00	SIP power supply defect
2018 KW19	01:35:00	Shutter interlock in damping wiggler section
2019 KW37	00:23:00	SIP interlock in diagnosis beamline
2022 KW23	01:34:00	pump cart in diagnosis beamline
2022 KW25	01:09:00	pump cart in diagnosis beamline defect
2023 KW43	03:16:00	leak at beampipe water cooling channel



Date	Other Events Description
2016 KW38	leak at beam stop bellow (→ planned vent)
2018 KW10	missteering causing a leak at undulator flange connection due to warmup (→ planned vent)
2018 KW13	accidental vent due to ripped ceramic insulation at current monitor
2023 KW11	missteering causing a leak at undulator flange connection due to warmup (no vent necessary)
2023 KW28	leak at extractor gauge feedthrough (→ planned vent)

Failures

Quartz window in diagnosis beamline and beam trap bellows (2016 KW27+KW38)

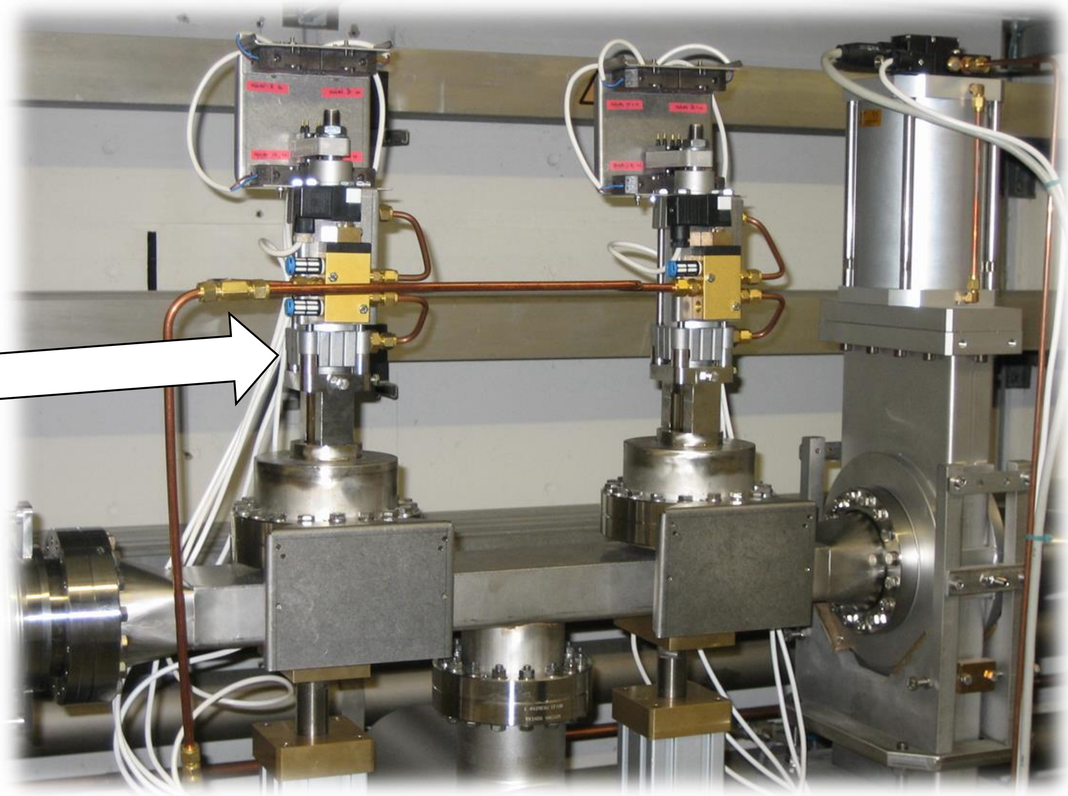
- Two major leaks >10^{-6} mbar l/s occurred simultaneously (unrelated)

  1) DN40 quartz window leak at the metal-glas joint, no visible damage, installed few weeks earlier

  2) During the intervention an unusual pressure history observed in another sector (leaky bellow at beam trap)

⇒ Two sectors had to be vented and parts replaced

- Another beam stop had to be replaced 11 weeks later
  - Similar problem:
    bellow again leaky!
    (>4x 10^{-6} mbar l/s)



Failures

Ripped ceramic insulation at current monitor (2018 KW13)

- Brazed ceramic-metal joint at current monitor ripped apart probably because of warmup during operation
  - **Monitor was not used anymore, risk factor left in the machine!**
  - No/insufficient temperature monitoring
  - Installed close to experimental area / beamlines
  - Three adjacent sectors affected, 7 vacuum sections vented to 1000 mbar
- Replayced by simple dummy pipe
- Other unused parts were removed as well, e.g. two spare kickers

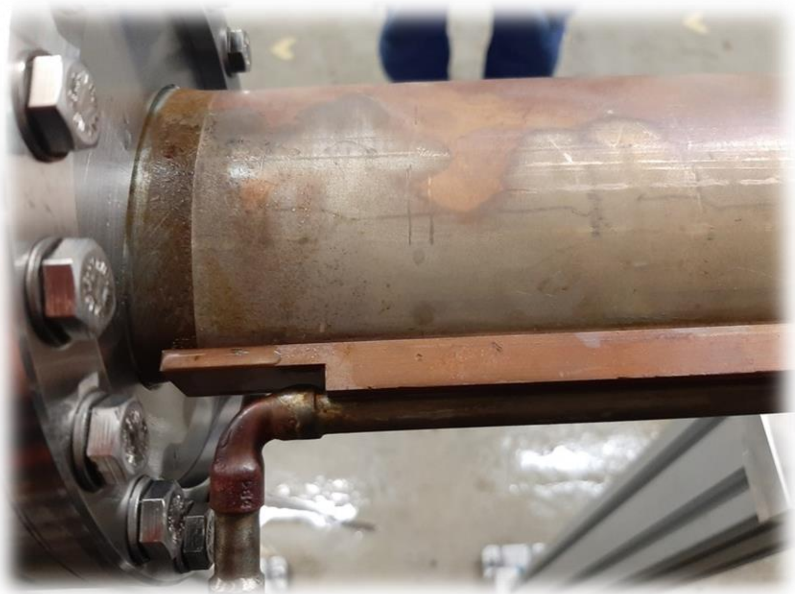
Failures

Water-leak at beam pipe cooling channel (2023 KW43)

- Water leak spontaneously occurred at cooling pipe due to erosion
  - Probably caused by too strong bending of inlet/outlet in 2009!

⇒ New cooling pipe clamped on the existing beam pipe

- Additional survey for wrong bending at water inlets was done
  - ⇒ No other locations found

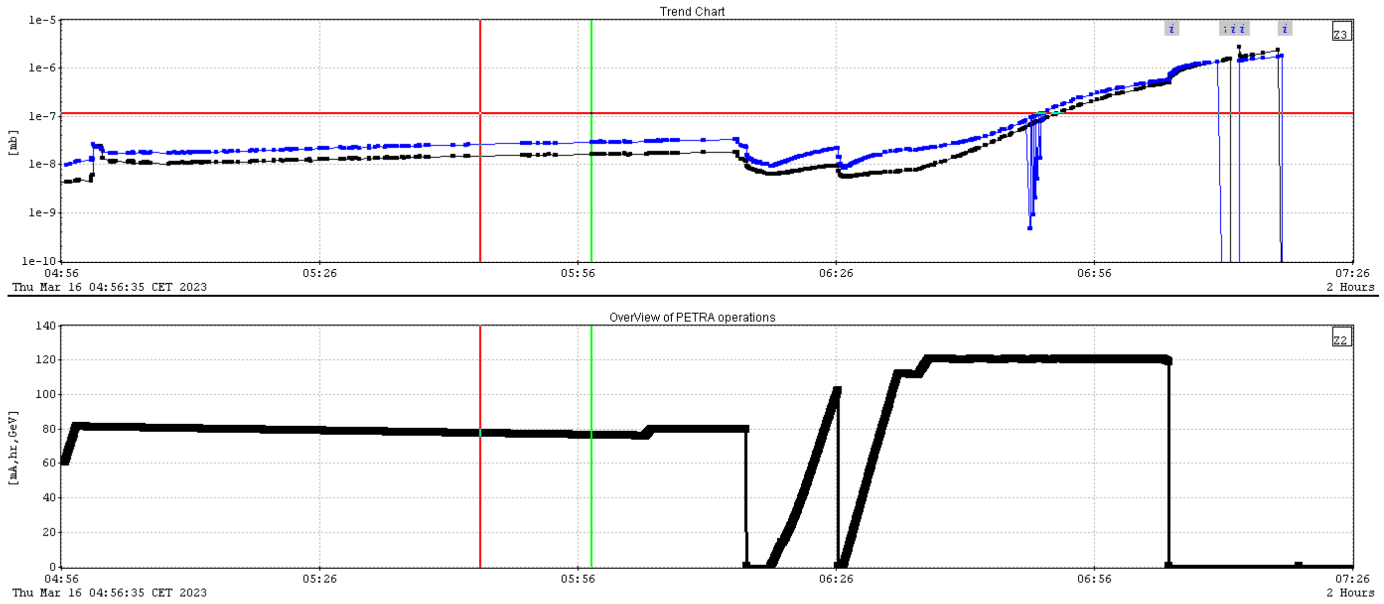


Failures

Undulator flange warmup (2023 KW11)

- High currents during setup and missteering led to warmup of undulator flange connection; BPM interlock improperly set.
  - Beam losses at the flange indicated by light activation
  - Large leak temporarily fixed by further tightening the nuts

⇒ During design phase consider as many orbits as possible



Failures

Interlocks from SIP failures

- Repeated shutter interlock events until 2018

⇒ Updated valve interlock to mitigate influence from individual SIP failures, thus increasing redundancy

- Interlock happens if...

before Average pressure of sector exceeds $5x10^{-7}$ mbar

after 2 pumps per sector have to exceed $5x10^{-7}$ mbar

⇒ **Significantly less interlocks since 2018!**

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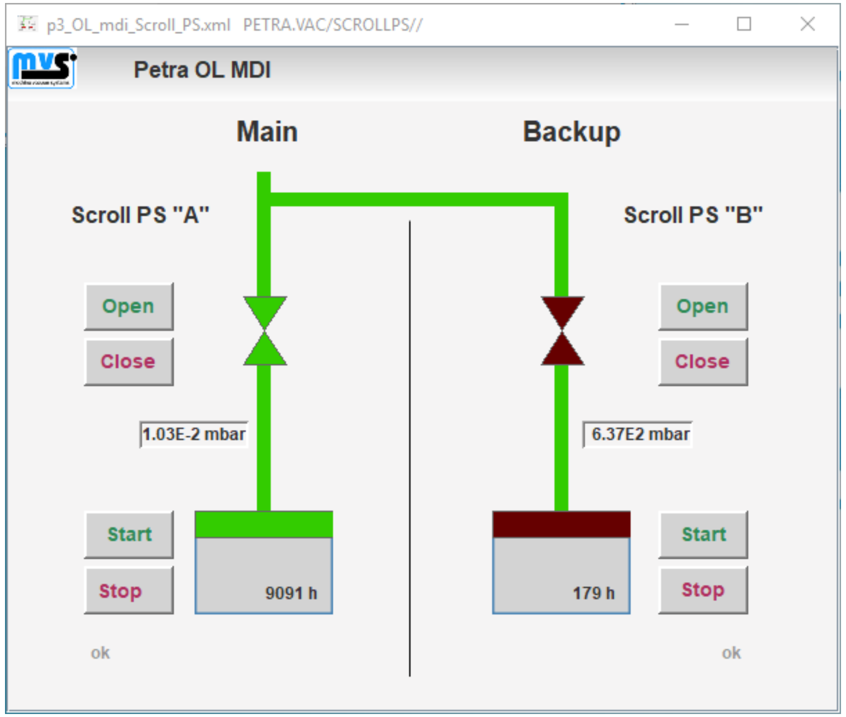
Failures

Pump cart in diagnosis beamline

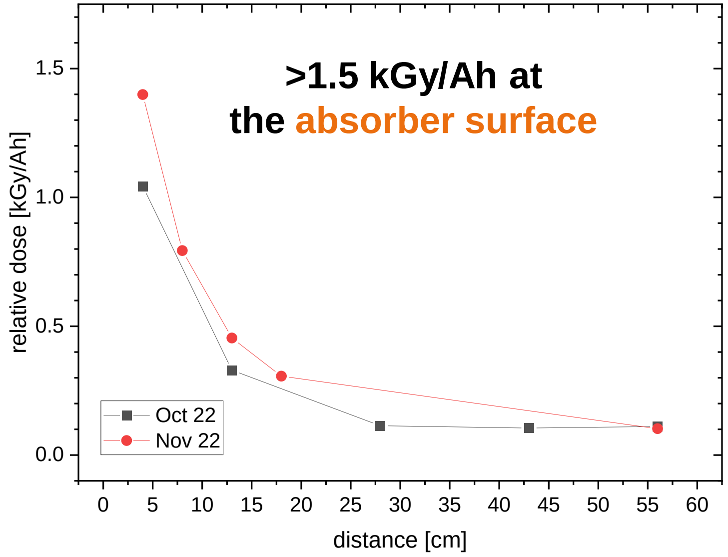
- Repeated failures of a pump cart within diagnosis beamline in 2022 (inside tunnel) that led to individual interlocks (~5 times in 2 weeks)
  - Probably due to some electronics issue
  - PLC was changed in the process without success
  - Radiation background in the vicinity only few Gy within 74 Ah of operation, probably not the cause
- Used for pumping a rotational stage feedthrough, no HV needed!

⇒ Pump cart replaced by a pair of scroll pumps (1 for redundancy)

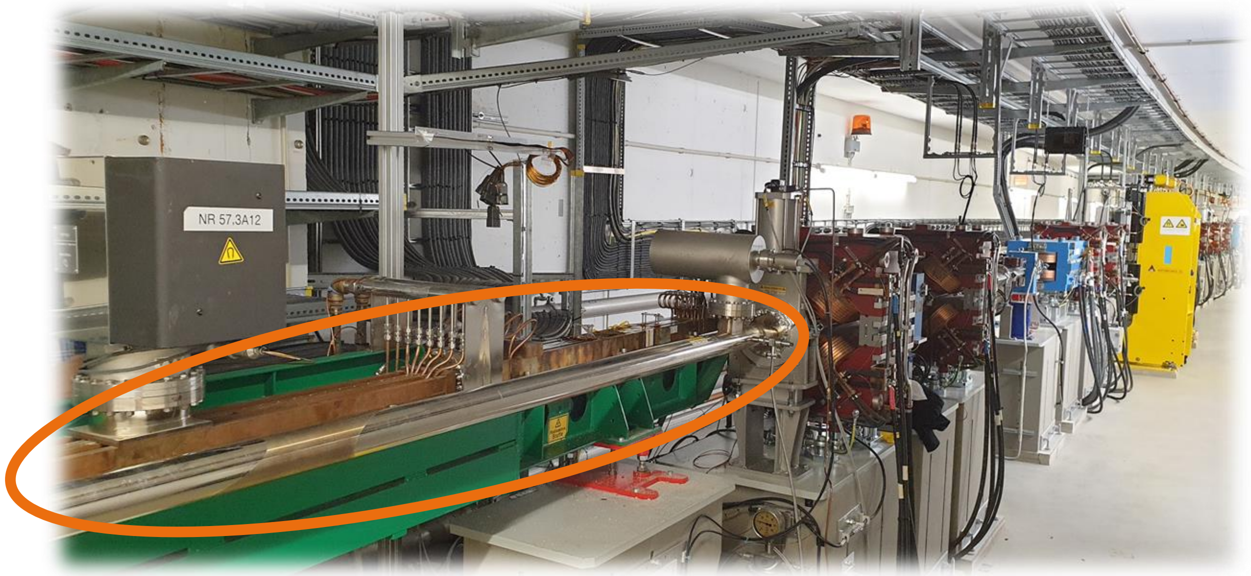


Failures

Cable defects due to synchrotron radiation



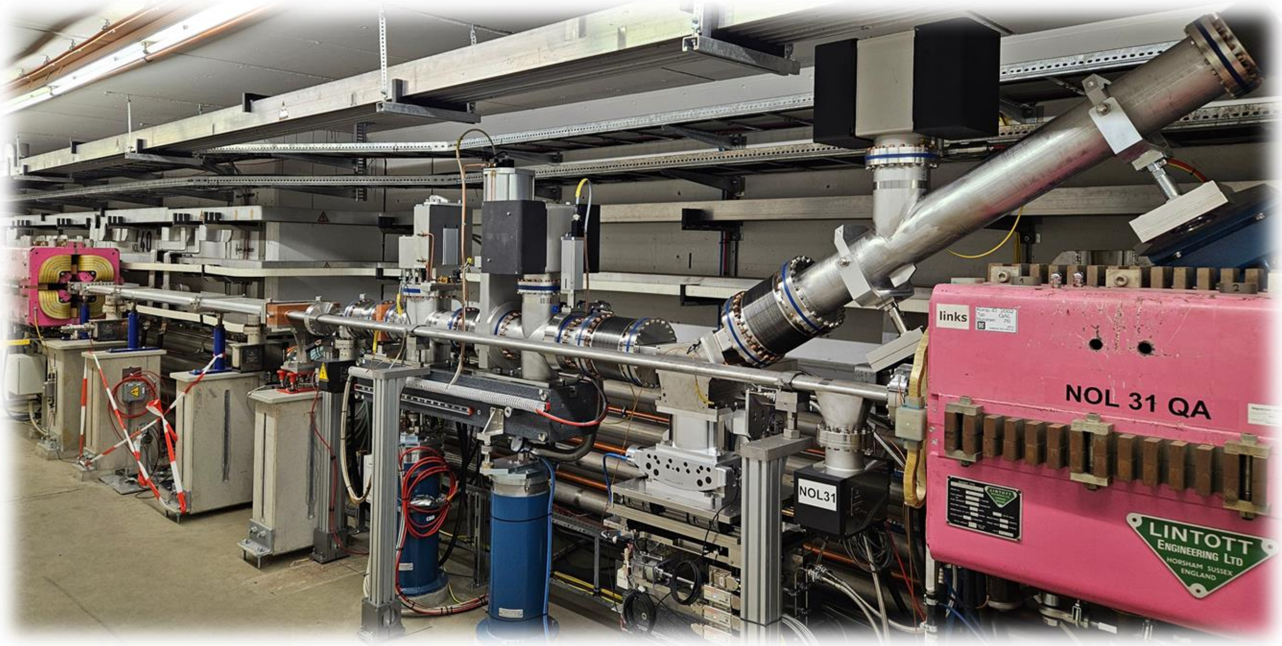
- Very high synchrotron radiation loads especially within wiggler sections
  - Estimated dose up to 2 MGy/year – e.g. on the surface of the last absorber of the damping wiggler section
- Cable insulation is falling apart, even at larger distances (ground)
  - Scattered photons are filling the tunnel during operation!
- Soldered cable joints at Pt-100 temperature sensors coming off, probably due to irradiation
  - Predominanty occurs at high radiation area
  - A dedicated cable strain relief would help!

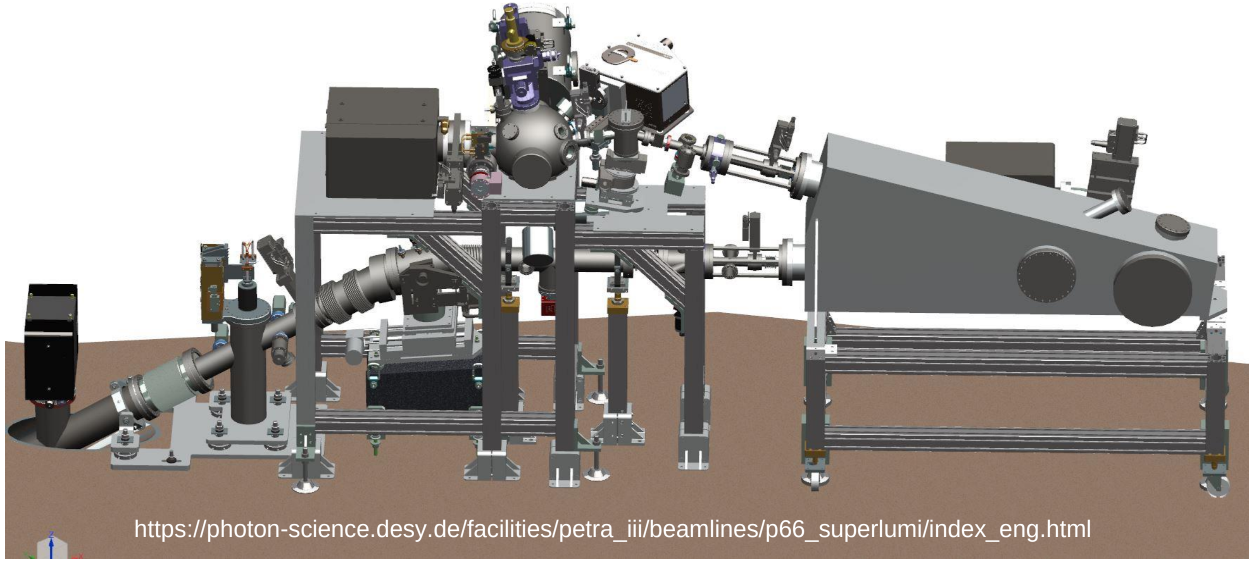


Modifications

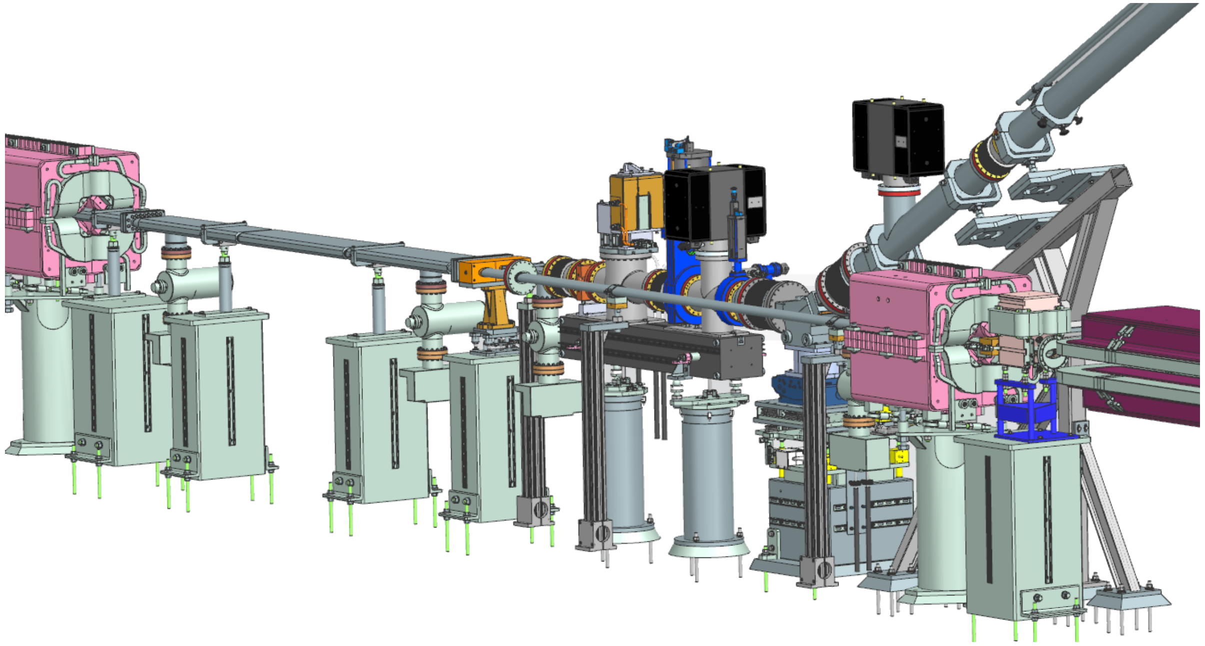
“Superlumi” beamline (2021)

- New beamline added (P66) in the northeast
  - VUV luminescence spectroscopy
  - Photon-stimulated desorption
  - Time-resolved spectroscopy
- Synchrotron radiation from bending magnet





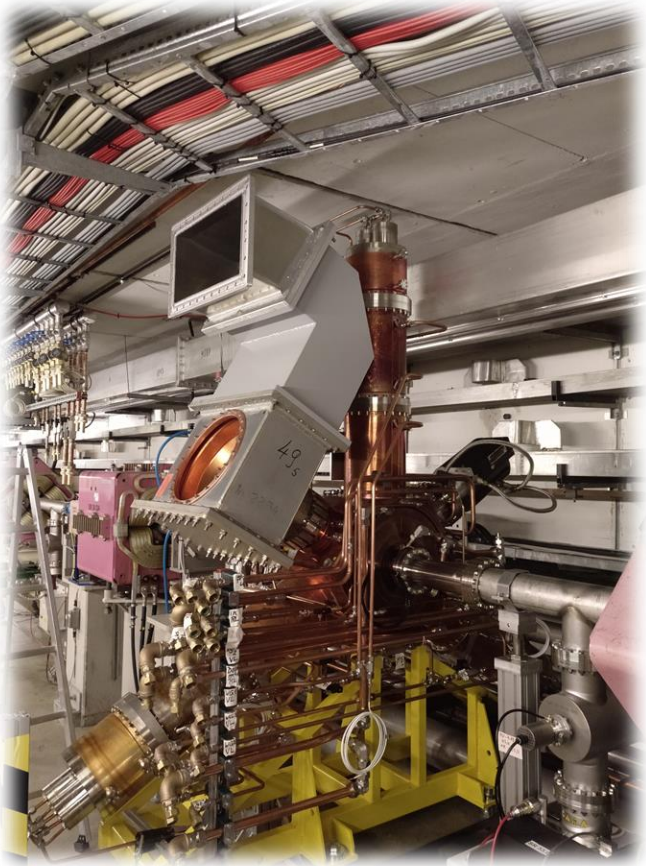
https://photon-science.desy.de/facilities/petra_iii/beamlines/p66_superlumi/index_eng.html



Modifications

PETRA IV HOM damped cavity (2023)

- A preliminary HOM damped cavity for PETRA IV developed by MHF-e was installed within the PETRA III with help of MVS

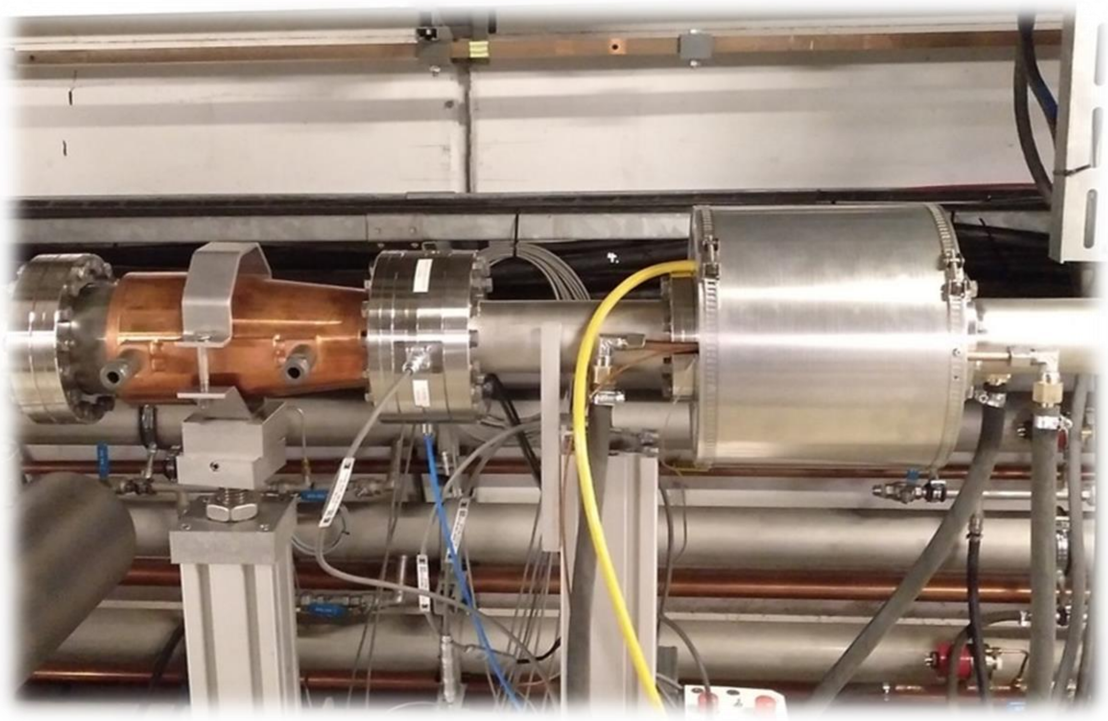


References
M. Ebert, “Proposal of an RF-System for PETRA IV”, Technical note, DOI 10.3204/PUBDB-2019-02036

Modifications

PETRA IV current monitor

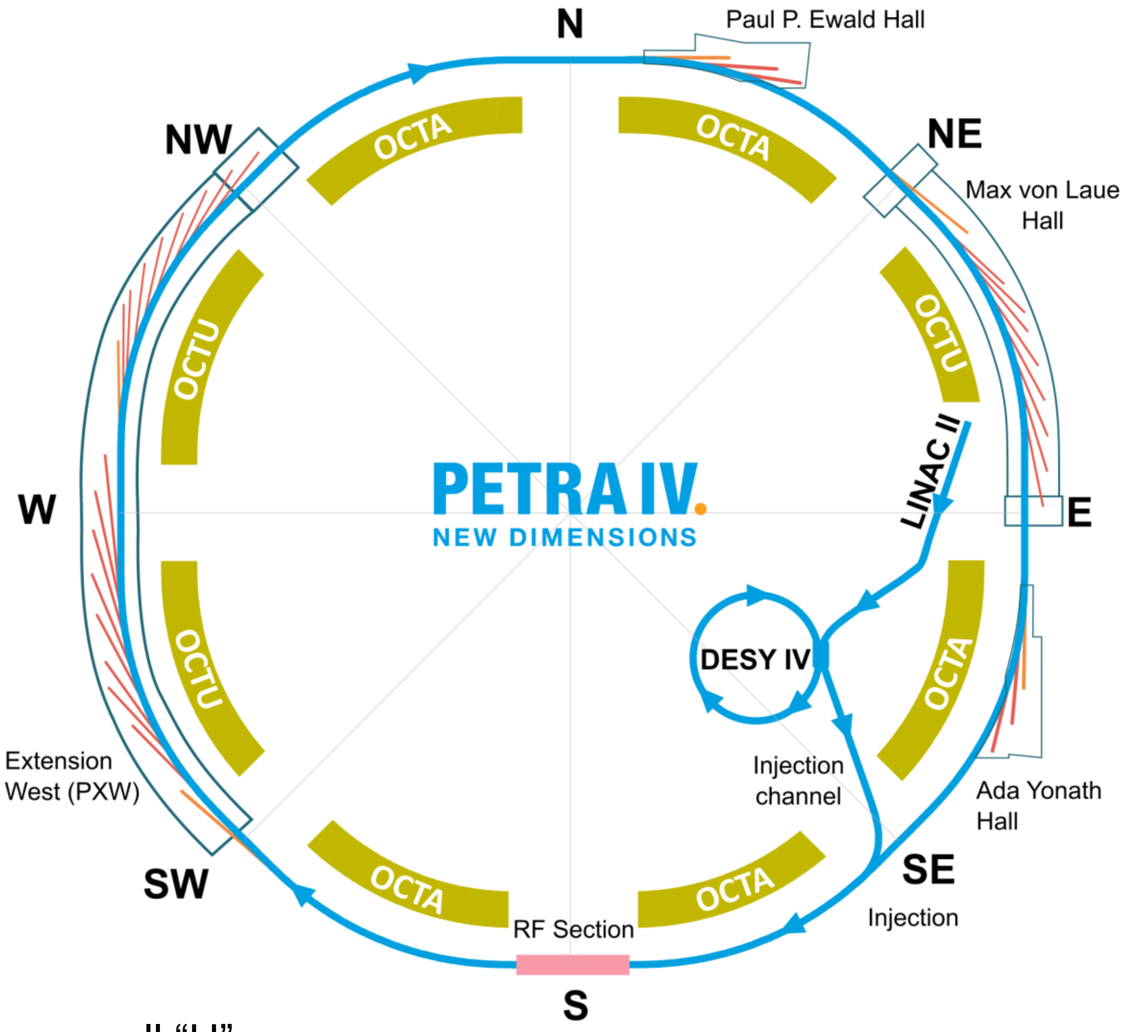
- Current monitors for PETRA IV are developed by MDI and installed with help of MVS
- First installed current monitor resulted in air leak shortly after commissioning due to flange warmup
  - Replacement during regular maintenance
- New versions are first tested at MVS by performing warmup cycles



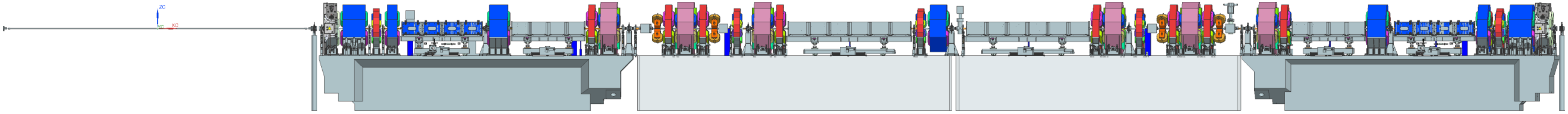
NEG-related Tests for PETRA IV

Overview of PETRA IV

- Hybrid 6-bend achromat (H6BA) lattice
  - 72 arc cells
  - 32 beamlines (3 canted undulator cells)
  - ~40 distributed damping wigglers
  - 4 “short” and 4 “long” straight sections
- Several existing beamlines and IDs to be reused
- Additional beamlines in new extension hall west
- Currently in TDR phase
- A prototype girder is being set up



side view of 23 m long arc cell “U”

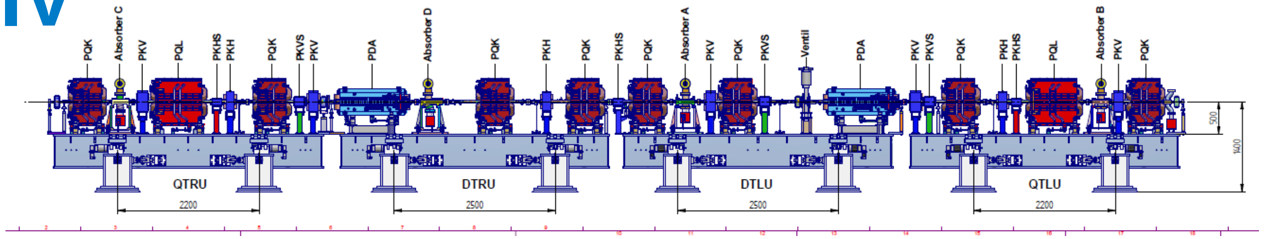


NEG-related Tests for PETRA IV

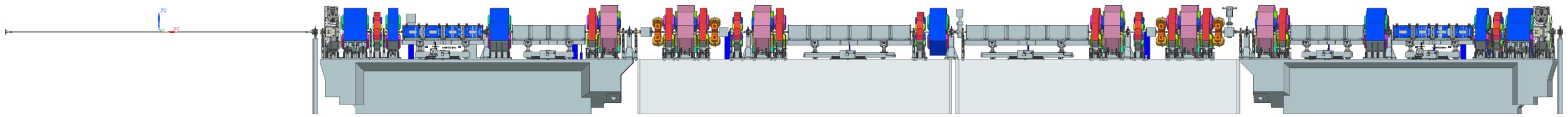
Overview of PETRA IV

- PETRA IV will replace PETRA III in the existing tunnel
- Very little space for bellows, flange connections and additional pumps

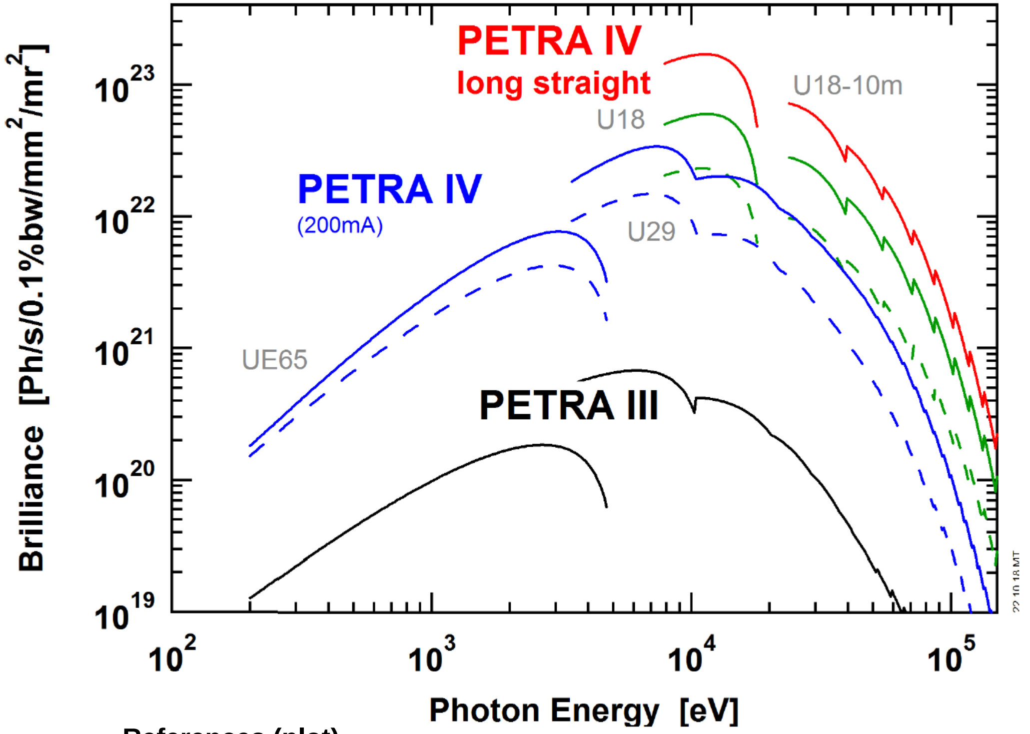
PETRA III DBA cell (new octant)



PETRA IV H6BA cell "U"



Parameter	Unit	PETRA IV Brightness	PETRA IV Timing	PETRA III
Beam energy	GeV	6	6	6
Circumference	m	2304	2304	2304
Beam current	mA	200	80	100
Nr. of bunches		1600	80	960 (40)
Bunch charge	nC	0.96	7.7	0.8 (7.7)
Hor. emittance	pm rad	< 20	< 40	1200
Ver. emittance	pm rad	2-10	5-20	12
Lifetime	h	> 10	> 5	13 (1)
BM crit. energy	keV	4.5 - 7	4.5 - 7	<20.9 (new)

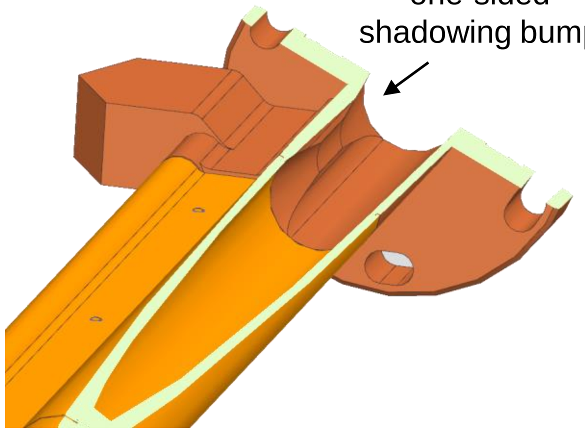


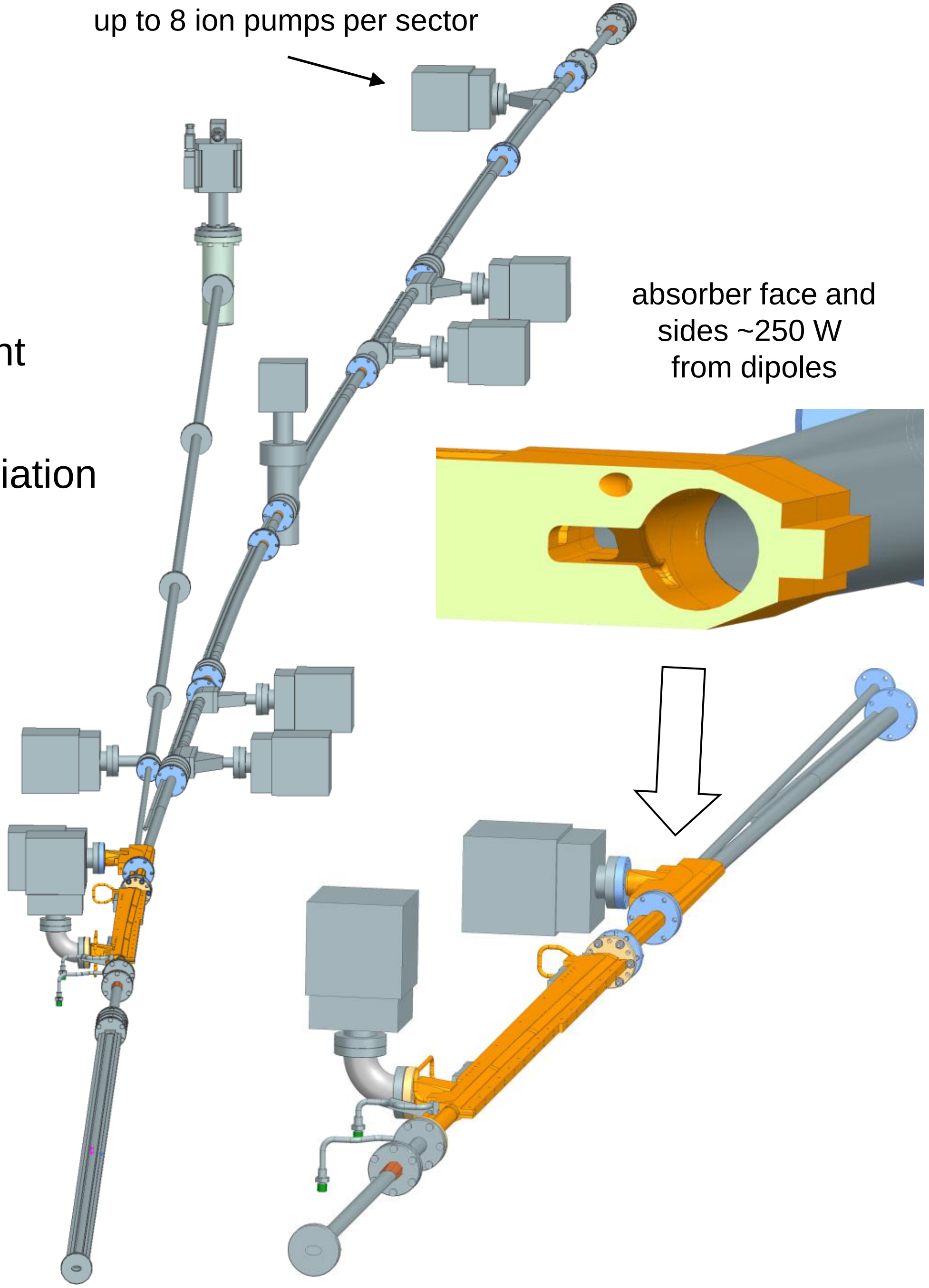
References (plot)
I. Agapov et al., DOI 10.18429/JACoW-IPAC2019-TUPGW011

NEG-related Tests for PETRA IV

Overview of PETRA IV

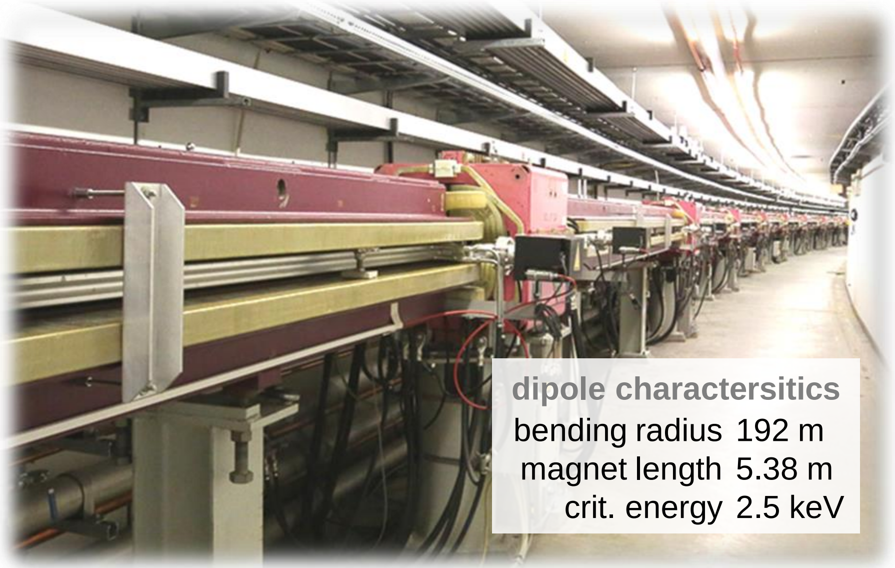
- Within arcs ~90 % of the vacuum system will be NEG coated
  - Simple 20 mm round beampipe profile, 13x20 mm within high-gradient quads and 7x20 mm within ID
  - One-sided shadowing bumps to protect BPMs and bellows from irradiation
  - Pump stages at transition to uncoated straight sections
- NEG characterization ongoing for in-house fabricated samples with different compositions and morphologies
  - Pumping speed and capacity
  - Electron-stimulated desorption
  - Resistivity
  - Thickness profile



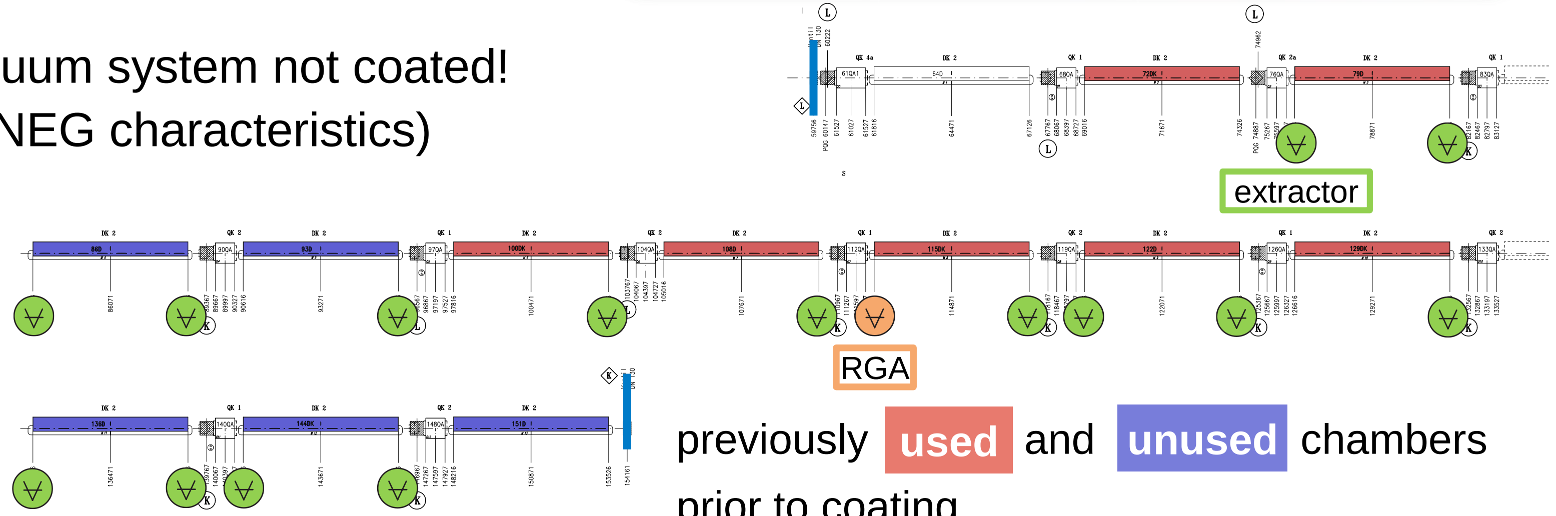


NEG-related Tests for PETRA IV

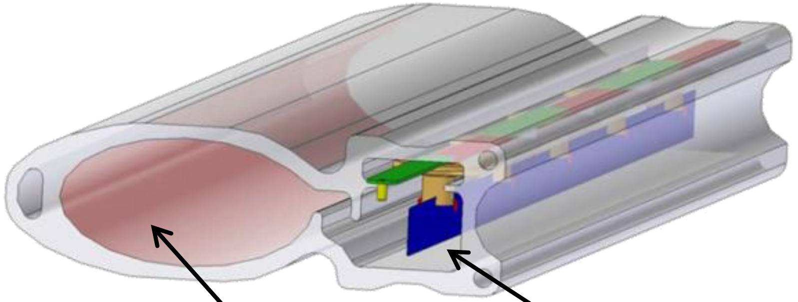
Partial NEG coating in PETRA III arcs

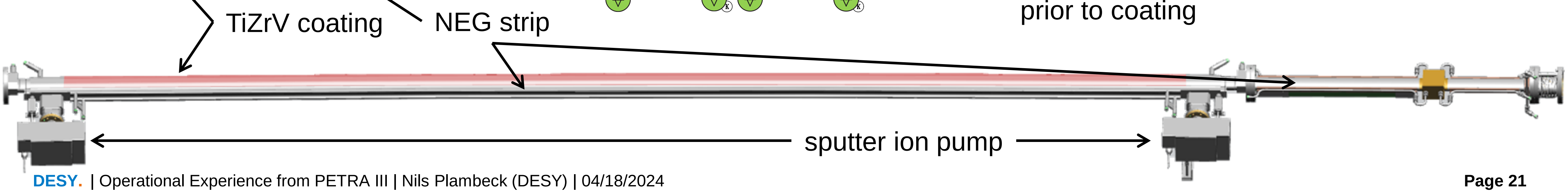


- 12 partially TiZrV coated dipole chambers, various gauges and an RGA installed end of 2018
  - Total length of the sector ~94 m
  - >55 % of total flux >7 eV absorbed within coating and <2 % on NEG strip within antechamber
- Setup not ideal / tradeoff: ~60 % of vacuum system not coated! (ensure regular operation vs. studying NEG characteristics)



previously used and unused chambers prior to coating





NEG-related Tests for PETRA IV

Partial NEG coating in PETRA III arcs

- No initial bakeout, no in-situ NEG activation (coating or strip)
- **Comparison of conditioning** behavior between

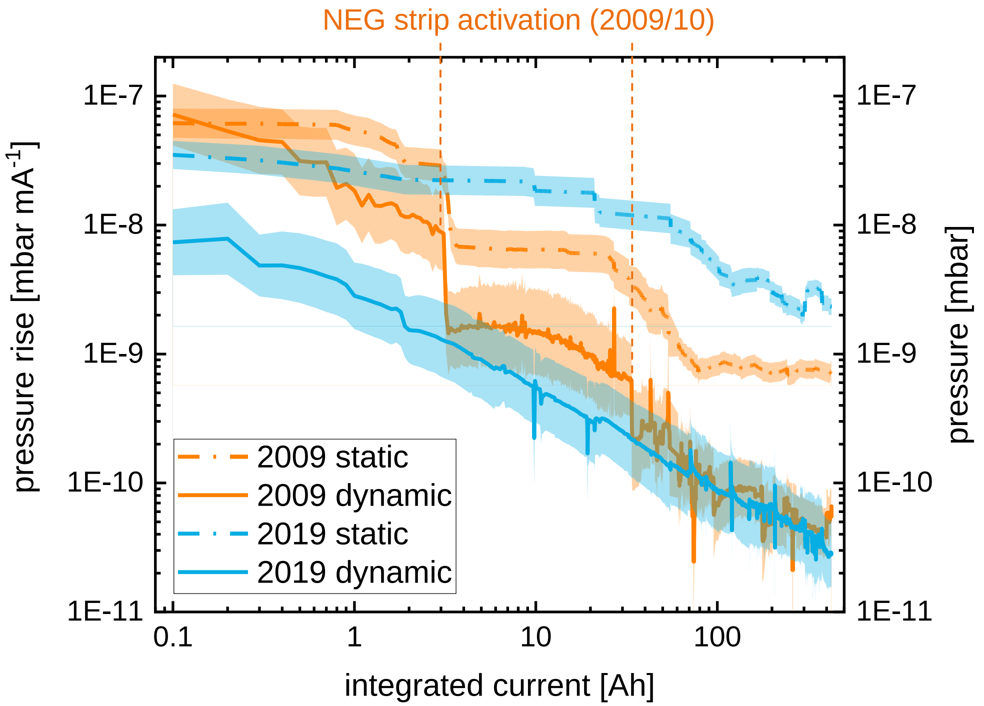
  2019 with inactive coating and NEG strip

  and 2009 without coating but (active) NEG strip

  and adjacent sector without NEG coating (Appendix)

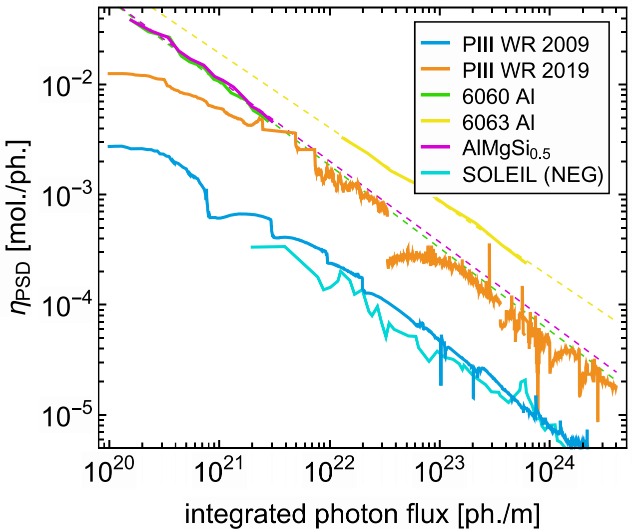
⇒ **Pressure rise 2019 similar to 2009 with active NEG strips!**

- Reduction of PSD or additional pumping due to active NEG coating?
- No difference between “used” and “unused” chambers



Estimated effective PSD

~1x10^{-4} vs. ~7x10^{-4} after 3.5x10^{22} ph/m



References (plot):
6060 Al: M. Andritschky et al., CERN-LEP-VA-89-32 (1989)
6063 Al: S. Ueda et al., Vacuum, 41(7–9), 1928-1930 (1990)
AlMgSi$_{0.5}$: A. G. Mathewson et al., CERN-AT-VA-90-10 (1990)
SOLEIL: C. Herbeaux et al., Proc. EPAC08, 3696-3698 (2008)

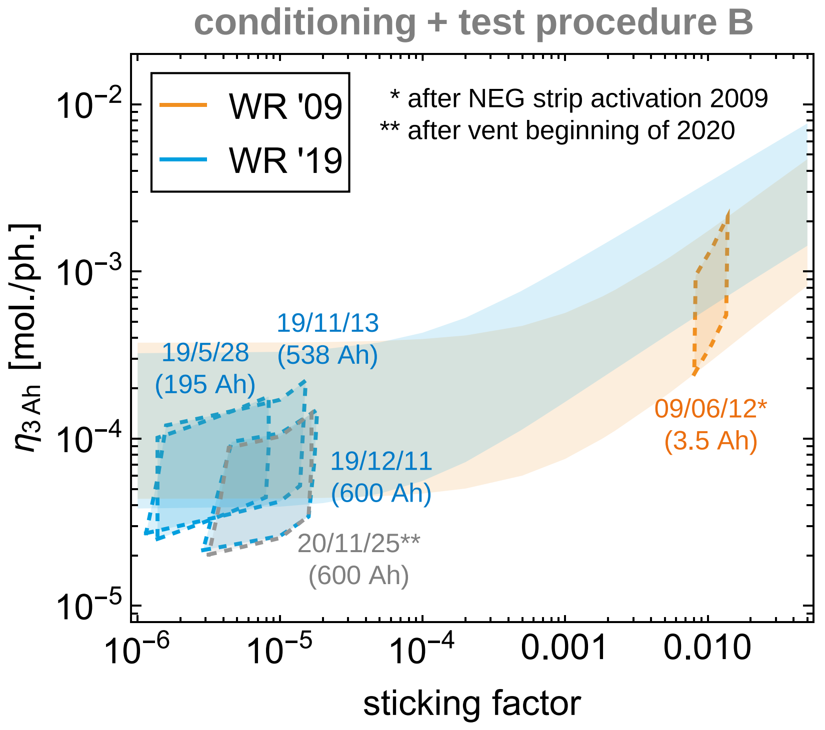
NEG-related Tests for PETRA IV

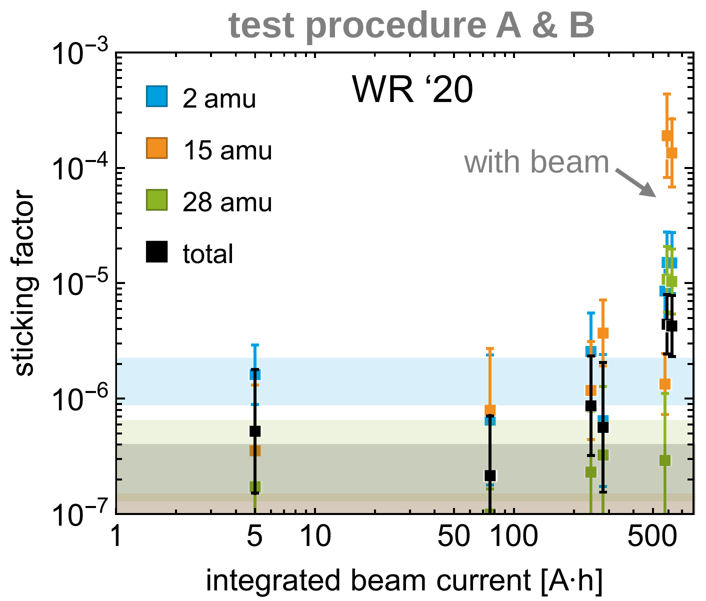
Partial NEG coating in PETRA III arcs

- Data extensively analyzed via 1D pressure matrix calculations using VACLINE/CALCVAC
  - ⇒ Relate PSD to NEG sticking factor and SIP pumping speed
  - ⇒ Recorded pressures seem to be overestimated (also indicated by adjacent sector)

- Additional tests performed with successive...
  - A. Switch-off of SIPs around RGAs during shutdown
  - B. Switch-off of SIPs around RGAs during operation
  - C. Increase of beam current with SIPs switched off

⇒ **No clear indication of additional NEG sticking probability!**



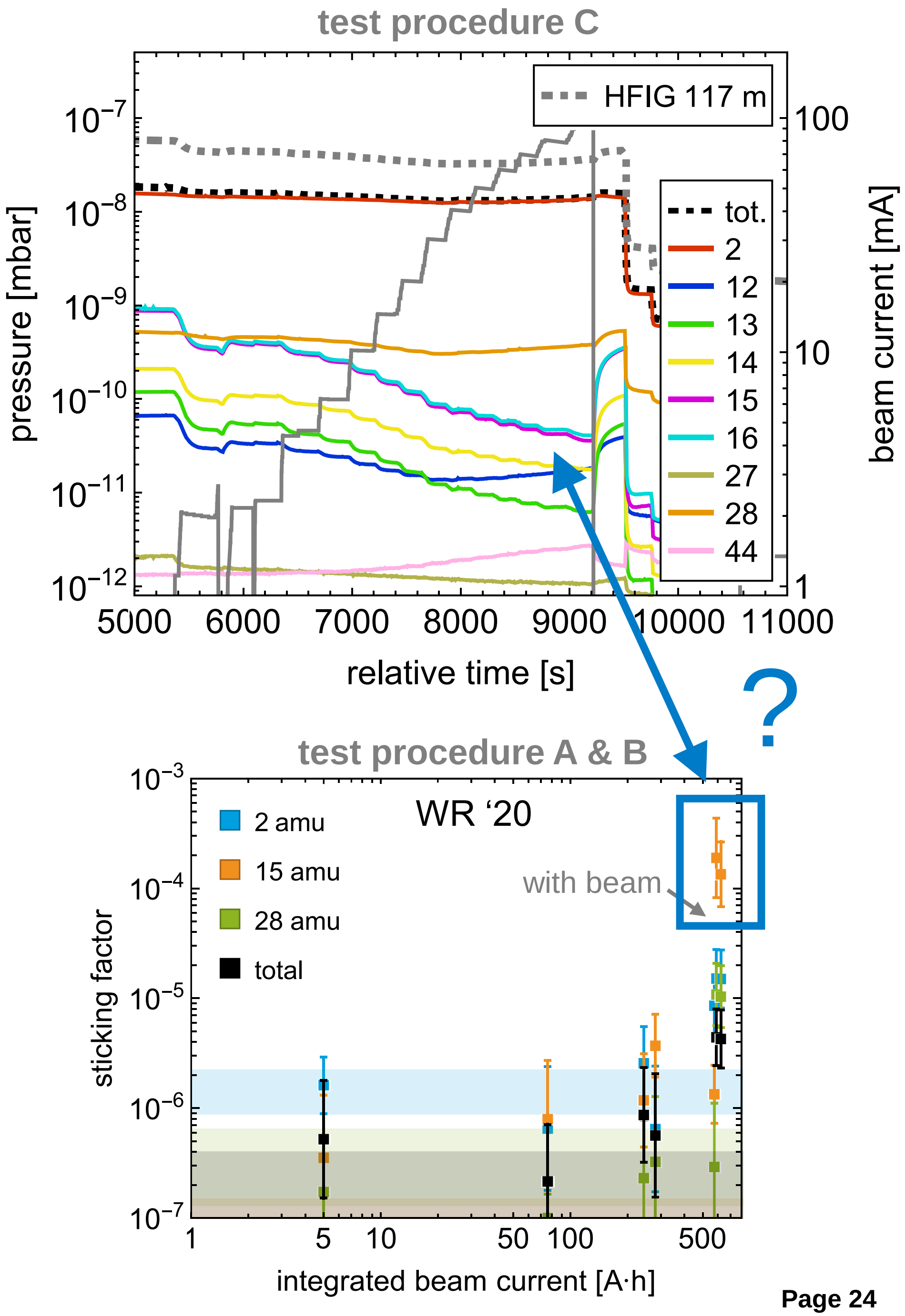


NEG-related Tests for PETRA IV

Partial NEG coating in PETRA III arcs

- **But:** A small difference is indicated if the beam is operated, especially for methane (fragments)
  - For methane tests with increasing beam current in 2020 indicate sticking factors of 3...7x10^{-7} per mA assuming that
    - outgassing is constant $q(I) = q_0$
    - sticking linearly increases with current $sf(I) = sf_0 + \sigma \cdot I$
  - However, as the methane pumping mechanism was not understood enough data analysis was finally stopped

⇒ **No clear indication of persistent additional NEG sticking probability!**



NEG-related Tests for PETRA IV

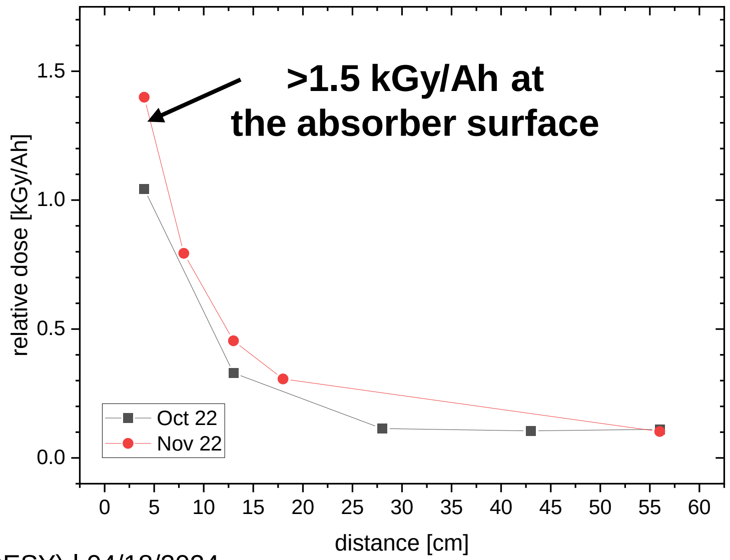
Synchrotron radiation induced damage

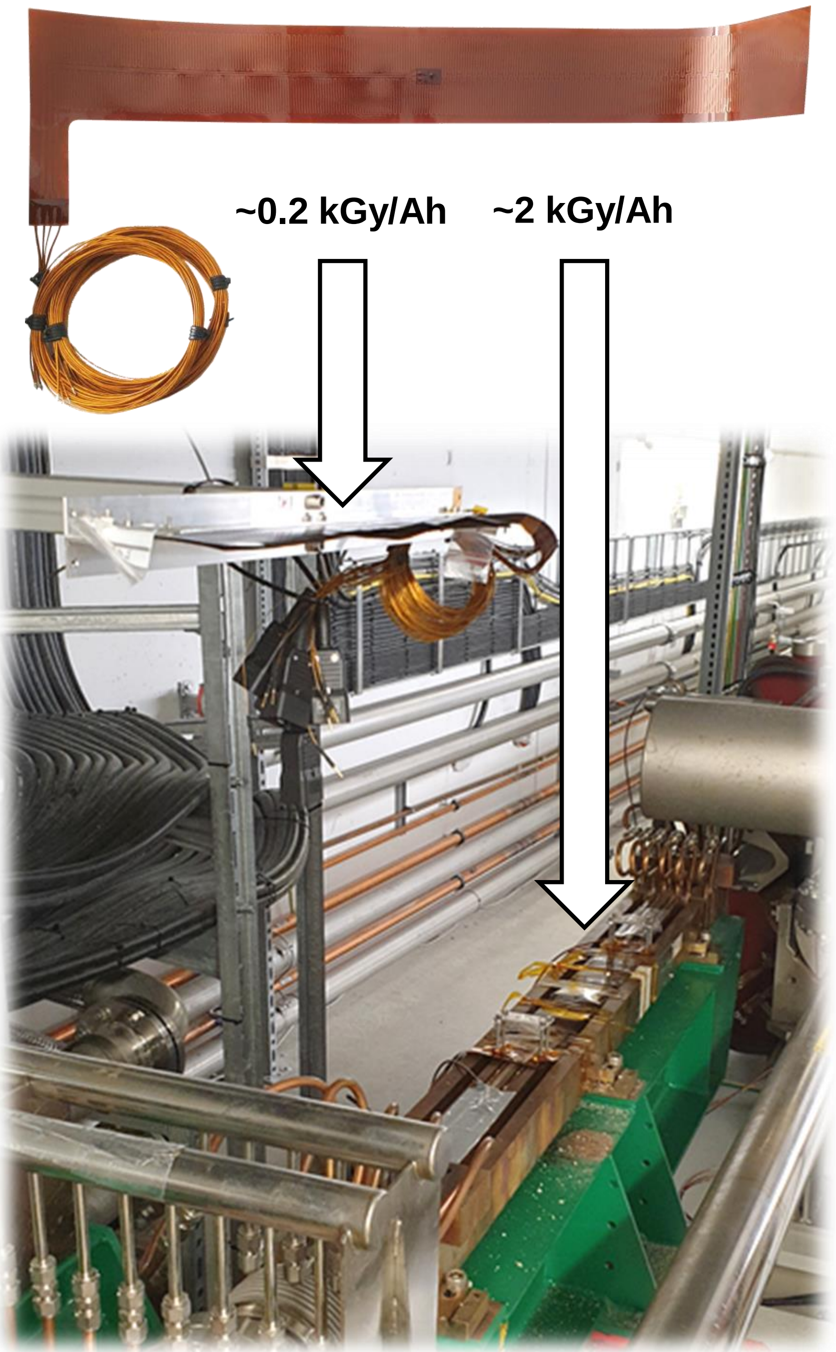
- Various equipment currently tested at high-load synchrotron radiation absorbers at PETRA III damping wiggler section, e.g.
  - Thin-foil heaters with integrated temperature sensors (polyimide, 0.2 mm)
  - Titanium-sublimation pump power supplies
  - Epoxy based thermal bond...

- Radiation dose was measured via TLD-800 thermoluminescence dosimeters (maximum dose per measurement ~25 kGy)

- Very high doses >100 kGy per month of regular operation at absorber surface

✓ Foil heaters without failure up to now (> 2 MGy)





Conclusions...

... and future plans

- PETRA III availability > 97 % since years with MTBF > 50 h, improvement possible
  - Power glitches play a major role on availability next to power supplies and RF
- Very few (severe) vacuum issues since 2015 prove the system rigidity
- Beam-induced activation of partly NEG coated sectors in 2018 is not clearly measurable
  - Fraction of uncoated areas may be too high
  - During operation additional pumping is slightly indicated

Future plans

- Extended operation until end of 2029 at least → refurbishment of hardware will be required
  - Replacement of ion pump power supplies, gauge controllers, cables... especially within pre-accelerator chain
- Further progress of the PETRA IV project including mockup

Thank you!

Contact

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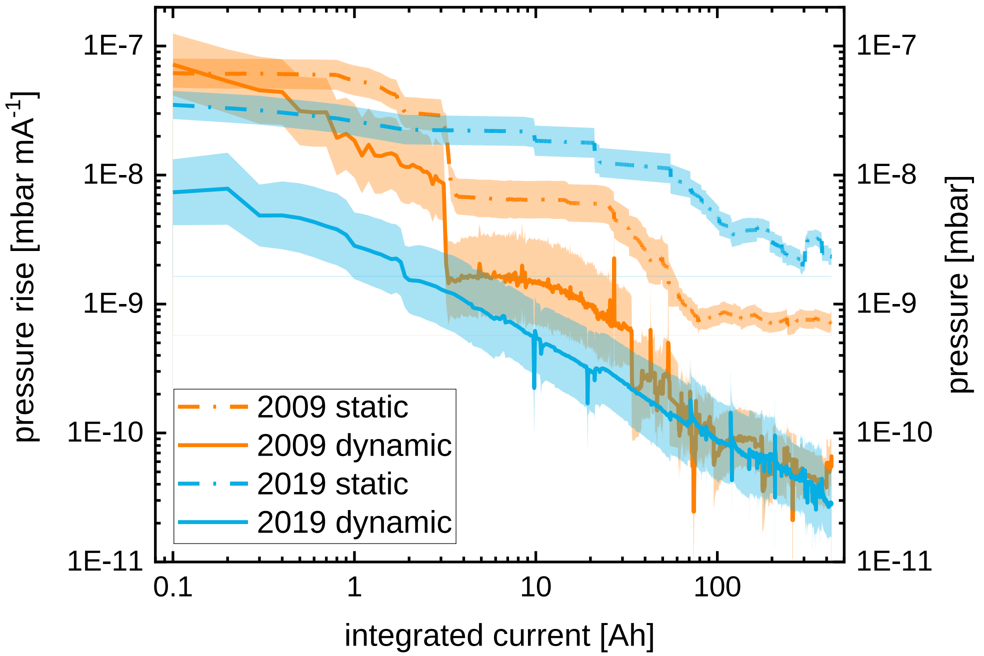
Appendix

NEG-related Tests for PETRA IV

Partial NEG coating in PETRA III arcs

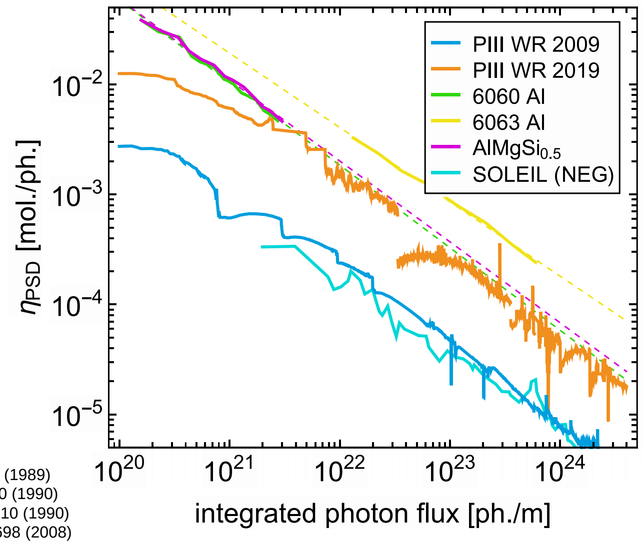
- 12 partially TiZrV coated dipole chambers installed end of 2018
  - Total length of the sector ~94 m
  - ~70 % of total flux >7 eV absorbed within coating and <0.5 % on NEG strip within antechamber
  - Setup not ideal / tradeoff: ~60 % of the vacuum system not coated! (ensure regular operation vs. studying NEG characteristics)
- No prior bakeout, no in-situ NEG activation (coating or strip)

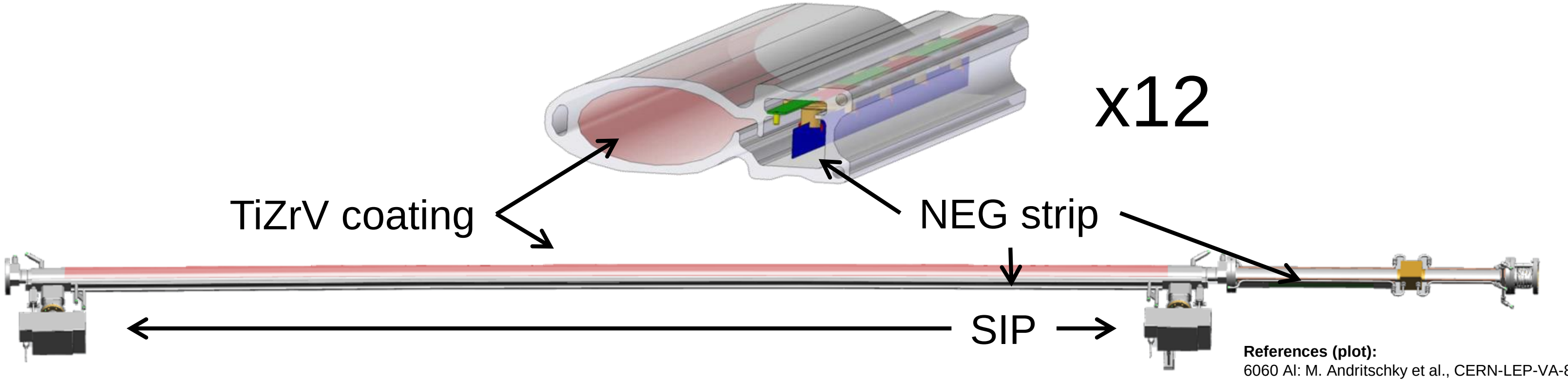
⇒ Pressure rise 2019 **with inactive coating and NEG strip** similar to 2009 **without coating but active NEG strip**



Estimated effective PSD

~1x10^{-4} vs. ~7x10^{-4} after 3.5x10^{22} ph/m





References (plot):

6060 Al: M. Andritschky et al., CERN-LEP-VA-89-32 (1989)

6063 Al: S. Ueda et al., Vacuum, 41(7–9), 1928-1930 (1990)

$AlMgSi_{0.5}$: A. G. Mathewson et al., CERN-AT-VA-90-10 (1990)

SOLEIL: C. Herbeaux et al., Proc. EPAC08, 3696-3698 (2008)

NEG-related Tests for PETRA IV

Partial NEG coating in PETRA III arcs: PSD estimates

- Similar conditioning behavior of adjacent sectors apart from offset (factor ~2.5)
- Photon-stimulated desorption (PSD) may be estimated from
  a) time until saturation after NEG strip regeneration [1]

     $\Rightarrow \eta_{3\ \mathrm{Ah},2009} \approx 3.3 \cdot 10^{-4}$

     $\Rightarrow \eta_{3\ \mathrm{Ah},2019} \approx 5 \cdot 10^{-5}$
     (one chamber accidently activated after 70 Ah)

  b) total pressure rise [2]

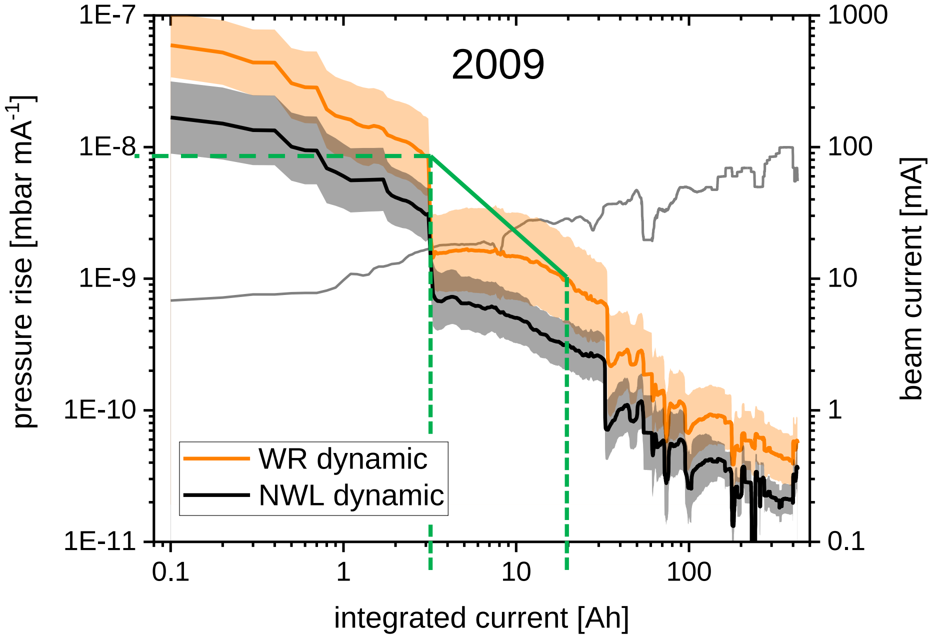
     $\Rightarrow \eta_{3\ \mathrm{Ah},2009} \approx 7.5 \cdot 10^{-4}$

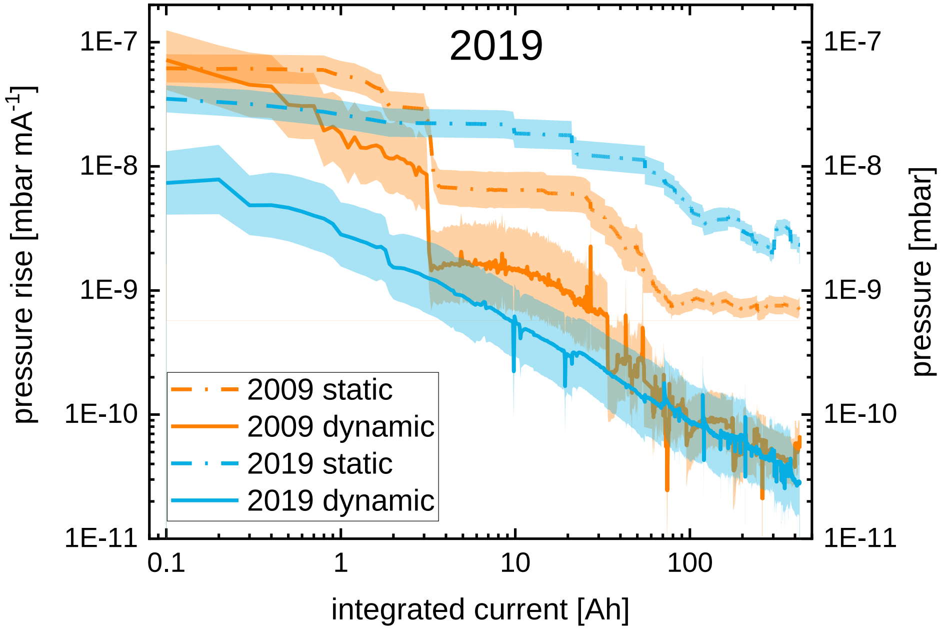
     $\Rightarrow \eta_{3\ \mathrm{Ah},2019} \approx 1.1 \cdot 10^{-4}$

Assumptions:

- NEG strip saturation by 0.7 mbar l/m (e.g. between 3 and 12 Ah)
- Conditioning slope -0.92 in 2009 and -0.72 in 2019
- SIP pumping speed 30 l/s and 2.7 m separation

⇒ Significantly less PSD or additional pumping due to NEG coating





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[1]

$$\delta Q\left[\frac{\mathrm{mbar\ l}}{\mathrm{s}}\right] = 10\,k\,T\,\eta_0\,\dot{N}_{ph}\,I\,\Delta L\left(\frac{t[\mathrm{Ah}]}{t_0[\mathrm{Ah}]}\right)^{-\alpha} \text{ and } \int \delta Q\,dt = Q_0$$

with $t = t[\mathrm{Ah}]\,\frac{3600\ \mathrm{s}}{I[\mathrm{A}]}$ a

nd $\dot{N}_{ph}$=3.2x10^{15} $\frac{\mathrm{ph}}{\mathrm{s\ mA\ m}}$

$$\Rightarrow \eta_{t_0} = \frac{Q_0\left[\frac{\mathrm{mbar\ l}}{\mathrm{m}}\right]}{10\,k\,T\,\dot{N}_{ph}\,3600} \cdot t_0[\mathrm{Ah}]^{-\alpha}\begin{cases} \ln\left(\frac{t_2}{t_1}\right)^{-1}, \alpha = 1 \\ \frac{(1-\alpha)}{(t_2[\mathrm{Ah}]^{1-\alpha} - t_1[\mathrm{Ah}]^{1-\alpha})}, \alpha \neq 1 \end{cases}$$

[2]

$$\delta Q\left[\frac{\mathrm{mbar\ l}}{\mathrm{s}}\right] = 10\,k\,T\,\eta\,\dot{N}_{ph}\,I\,\Delta L = p[\mathrm{mbar}]\,S\left[\frac{\mathrm{l}}{\mathrm{s}}\right]$$

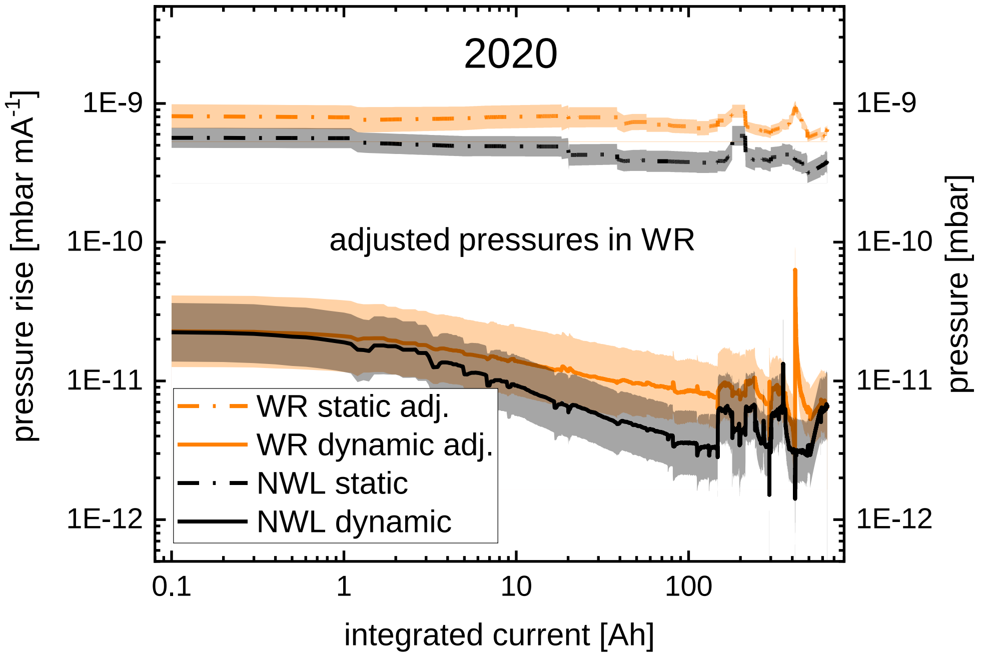
$$\Rightarrow \eta = 100\,\frac{p_{rise}\left[\frac{\mathrm{mbar}}{\mathrm{mA}}\right] S\left[\frac{\mathrm{l}}{\mathrm{s}}\right]}{k\,T\,\dot{N}_{ph}\Delta L}$$

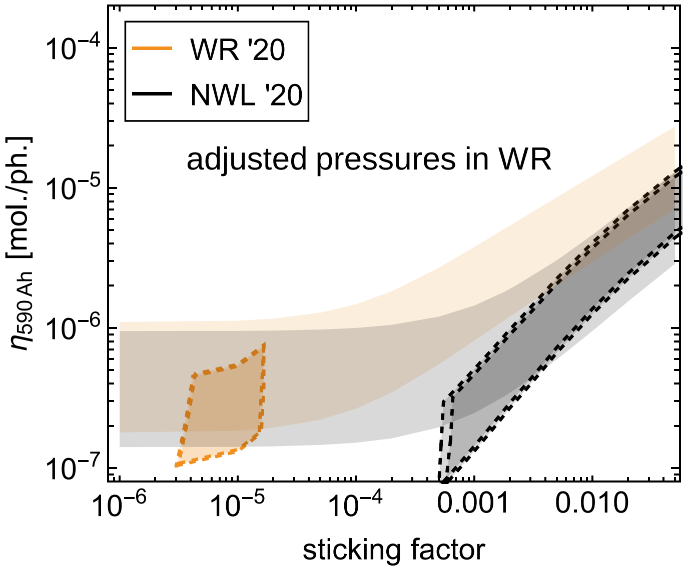
NEG-related Tests for PETRA IV

Conditioning after vent with N_2 beginning of 2020

- Adjacent sectors vented to 100 mbar for 30 min with N_2 in 2020
  - NEG strips in NWL previously activated to some degree
  - NEG coating in WR without clear indication of activation
- Very low pressures after re-comissioning
  - Physical error sources have an increasing impact
    (e.g. outgassing from RGA and SIP; change of bunch pattern...)
- For adjusted pressures in WR (factor 2.5) conditioning curves are initially in-line
- For the NEG coated sector sf<<10^{-4} similar to 2019
- Significantly higher sf indicated in NWL (NEG strip)
  - $7x10^{-4}$ < sf < $3x10^{-3}$
  - sf>$4x10^{-3}$ unlikely because corresponding PSD too high

  ⇒ Probably NEG strips were partially regenerated under UHV conditions

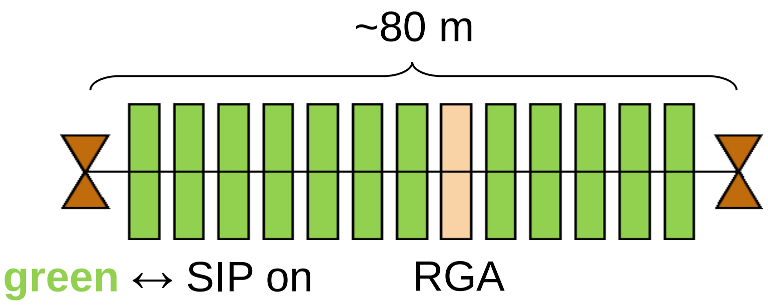




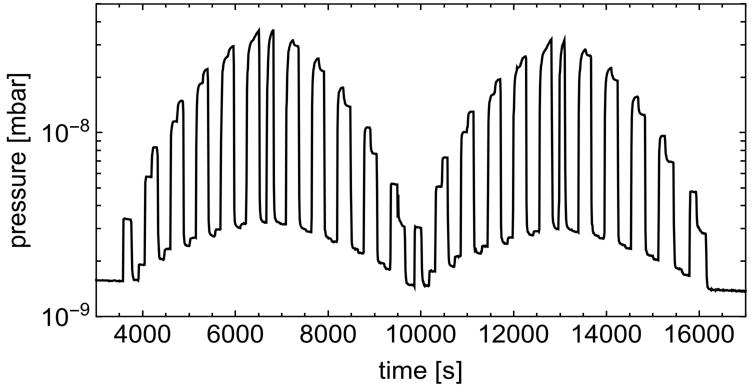
NEG-related Tests for PETRA IV

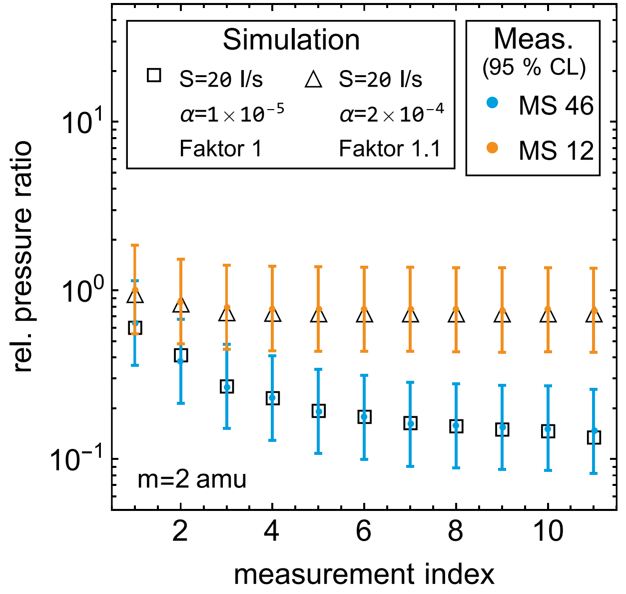
Successive switch-off of SIPs during shutdown (or operation)

- For each step $\frac{p_{on}}{p_{off} - p_{on}}$ where SIP on/off corresponds to SIP at RGA
  - Time intervall of 2 or 5 min between each switch-off (and on)
  - Several measurement rows in order to enable calculation of average and error as well as potentially observe systematic variations
- Measured pressure ratios are fitted against simulations and/or analytical formulas



Example measurement with 4 rows à 22 steps





Analytical model:

$q - s \cdot p(x) + c \cdot \frac{d^2 p(x)}{dx^2} = 0$ with $p'\left(\frac{L}{2}\right) = 0$ and $-c \cdot p'(0) = p(0) \cdot S_{SIP}$

$$\Rightarrow p = \frac{q}{s} \cdot \left(1 - \frac{\cosh\left(\sqrt{\frac{s}{c}} \cdot \left(x - \frac{L}{2}\right)\right)}{\frac{\sqrt{s \cdot c}}{S_{SIP}} \cdot \sinh\left(\sqrt{\frac{s}{c}} \frac{L}{2}\right) + \cosh\left(\sqrt{\frac{s}{c}} \frac{L}{2}\right)}\right)$$

$$\Rightarrow p(s=0) = \frac{q\,L}{2\,S_{SIP}} + \frac{q\,L}{2c} x - \frac{q}{2c} x^2$$

Simulations:

Consider S-sf pairs for which Chi-square ratio $X^2/X^2_{min} < 5$ with $\chi_\nu^2 = \frac{\chi^2}{n-1} = \frac{1}{n-1} \sum \frac{(r_i - s_i)^2}{\Delta r_i^2}$, where “r” ist the ratio from measurement and “s” from simulation.

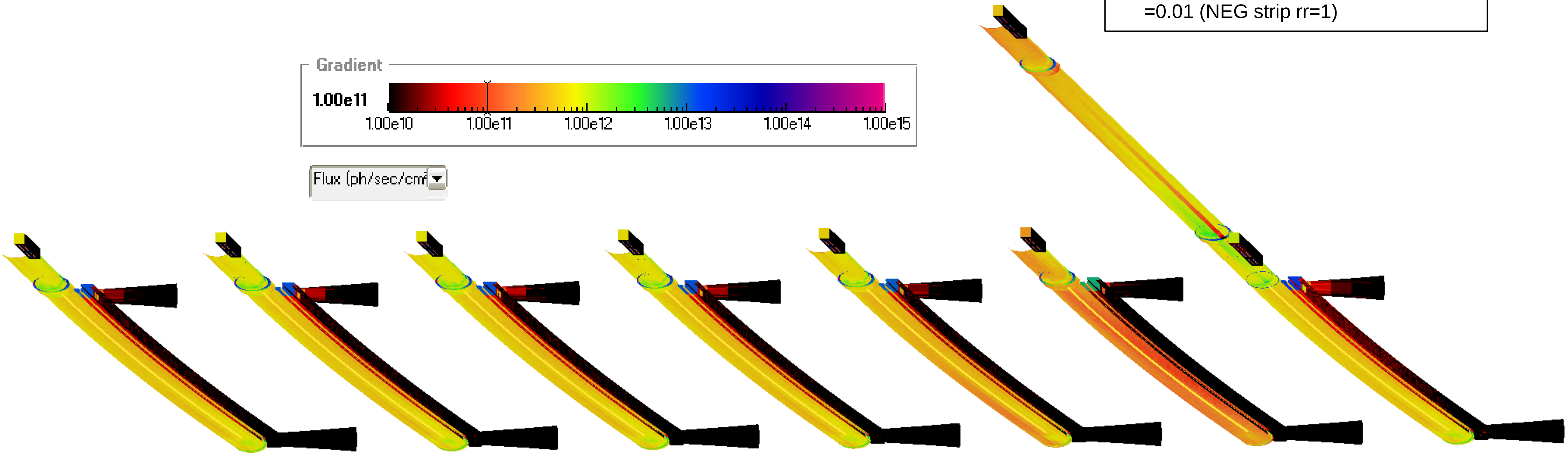
NEG-related Tests for PETRA IV

Expected synchrotron radiation distribution

- The photon distribution was simulated with SynRad+ in order to judge influence from scattered photons on NEG strip and pressure reading
  - Total flux and power per dipole 1.8x10^{16} ph/s/mA and 2.7 W/mA
  - 2 % of photons and 0.1 % of power absorbed at NEG strips
  - 55 % of photons and 65 % of total power absorbed at NEG coating
  - <10^{-3} % of photons at SIPs/gauges

Assumptions:

- Reflectivity tables for $Ti_{0.25}Zr_{0.25}V_{0.5}$ calculated from refractive index
- Use internal material files for Cu, Al and steel
- Rough scattering with roughness ratio =0.01 (NEG strip rr=1)



Pumping Speed Measurements at DESY (MVS)

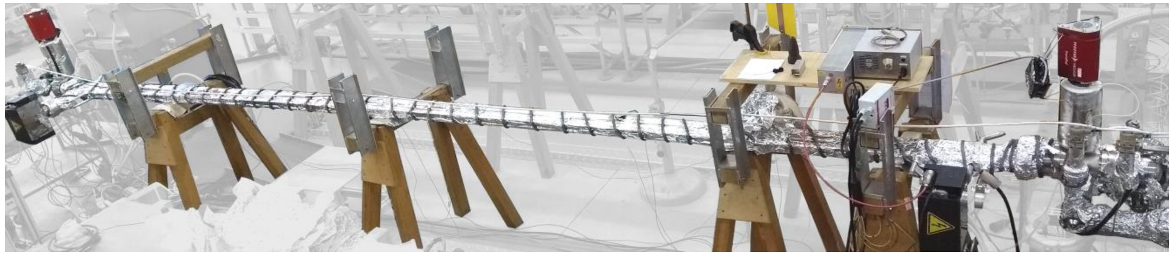
PETRA III dipole chamber

1) Test of standard dipole chamber with activated NEG-strip

initial sf of NEG-strip		H_2	CO
		w/o MS	
	from p1/p2	0.0036 - 0.0039	0.0087 - 0.0094
	from p3/p1	0.007 - 0.014	0.08 - 0.30

2) Test of dipole chamber with activated NEG-strip and without active -coating

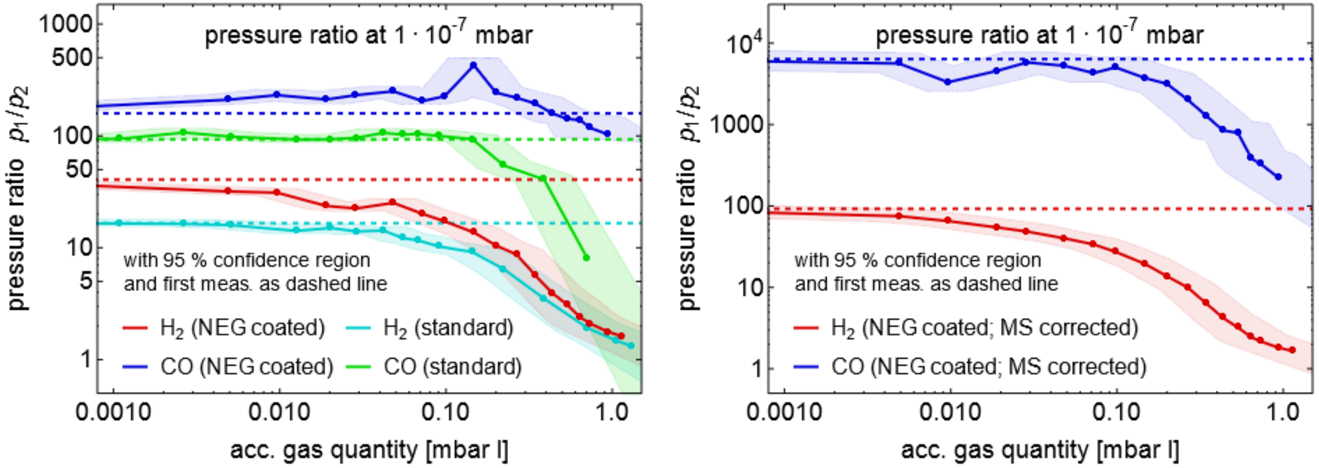
initial sf of NEG-strip		H_2	CO
		w/o MS	
	from p1/p2	0.0040 - 0.0044	0.0078 - 0.0084
	from p3/p1	0.0047 - 0.0087	0.018 - 0.036
		w/ MS	
	from p1/p2	0.0047 - 0.0052	0.019 - 0.025
	from p3/p1	0.0049 - 0.0090	0.019 - 0.04



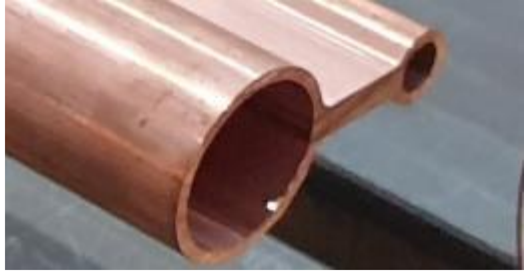
3) Test of dipole chamber with activated NEG-strip and with active -coating

initial sf of coating (on top of NEG-strip)		H_2	CO
		w/o MS	
	from p1/p2	0.0002 - 0.0003	0.0003 - 0.0005
	from p3/p1	<0.0005	0.002 - 0.014
		w/ MS	
	from p1/p2	**0.0004 - 0.0006**	**>0.013**
	from p3/p1	<0.0005	0.003 - 0.015

change of transmission factor with increasing saturation

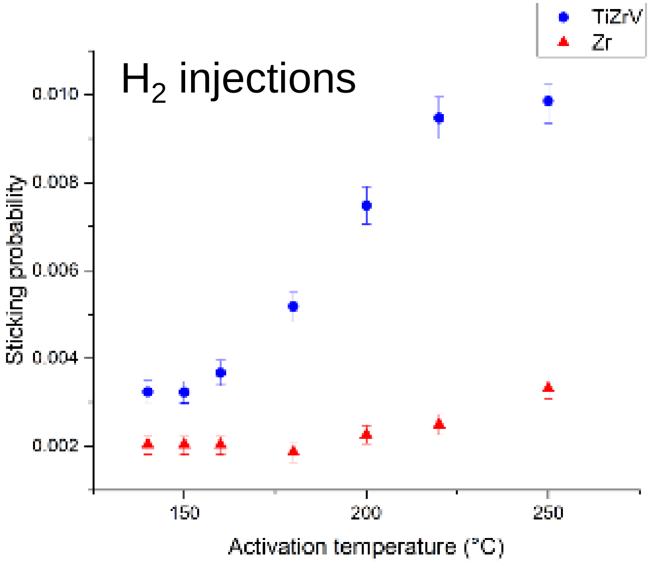


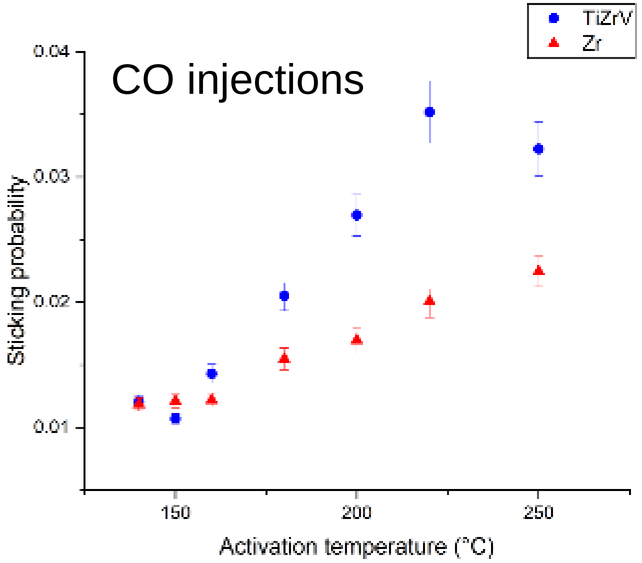
NEG Coating: Development of Film Properties



Focus on TiZrV and Zr coated Copper tubes

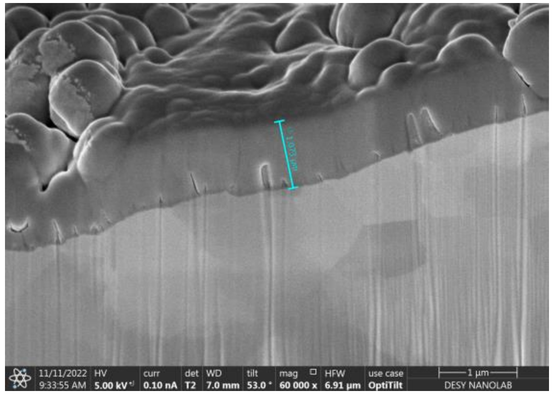
- Test program includes several topics:
  - Comparison between dense and columnar NEG samples with both TiZrV and Zr prepared at DESY
  - Bent copper chambers (OFS-Cu):
    - Chambers of various lengths (1.5 – 2.5 m) and bend radii (32 – 104 m) needed for PETRA IV
    - Bending tests after deposition show no effect on coating morphology
    - Spacer design is being worked on for samples bent before deposition
  - New Cu-OFS profile with a side cooling channel has been delivered





- Preliminary results:
  - Pumping properties within expectations for columnar
    - Pure Zr lower capacity and sticking factor

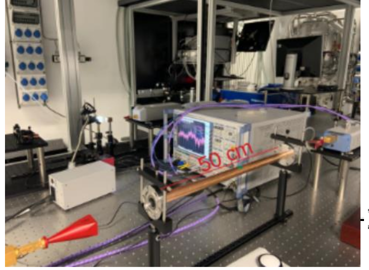
- Resistivity:
  - 5.4 μΩm for TiZrV, 8.5 μΩm for Zr
  - Measured with thick (5 um) thick samples
  - Thin (1um) NEG layers nearly indistinguishable from bulk Cu



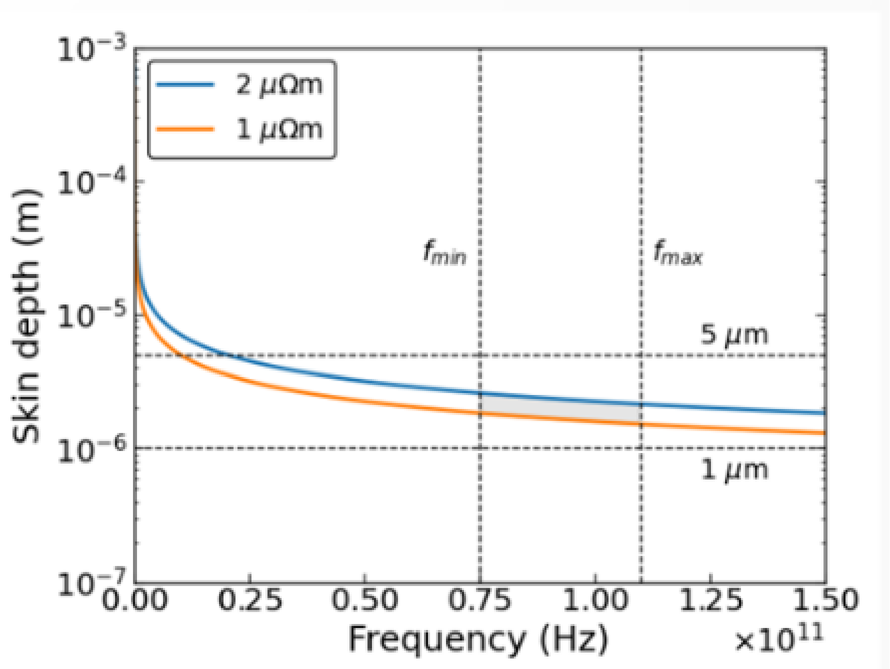
	TiZrV		Zr	
T_{act} (°C)	C_{CO} (CO/cm^2)	C_{CO} (ML)	C_{CO} (CO/cm^2)	C_{CO} (ML)
200	7.87×10^{18}	1.57	2.16×10^{18}	0.43
220	9.73×10^{18}	1.95	2.30×10^{18}	0.46
250	1.20×10^{19}	2.40	5.07×10^{18}	1.01

NEG Coating

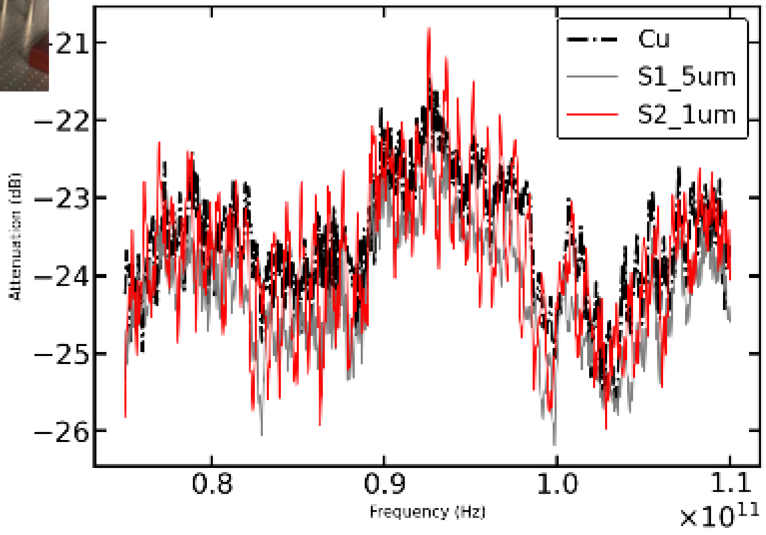
Resistivity measurements



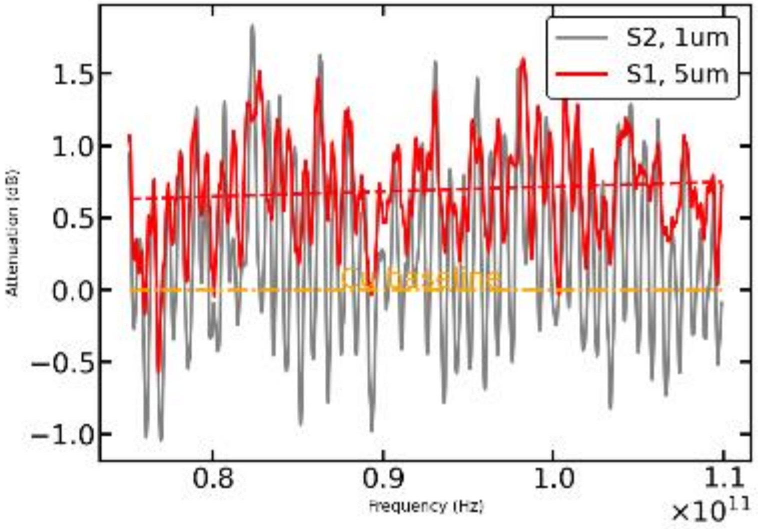
- TiZrV: Estimated resistivity 5.4 µΩm, thin sample indistinguishable from bulk Cu
- Zr: Estimated resistivity 8.5 µΩm, thin sample marginally visible in the measurement



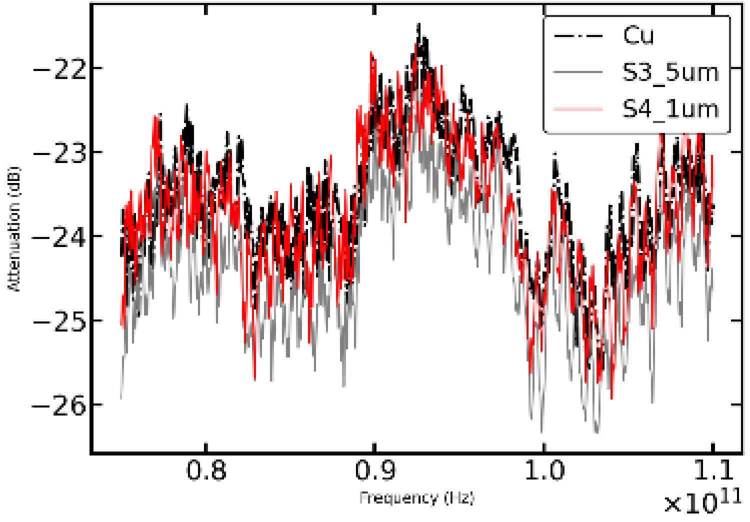
Raw data - TiZrV



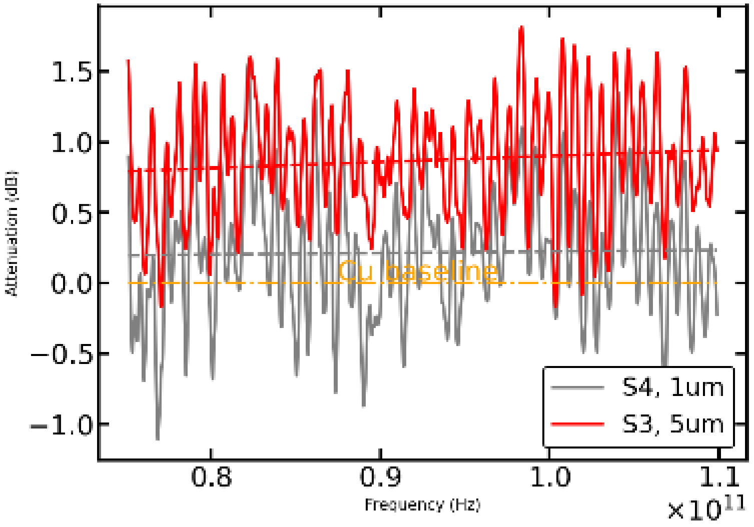
Fitted data - TiZrV



Raw data - Zr



Fitted data - Zr



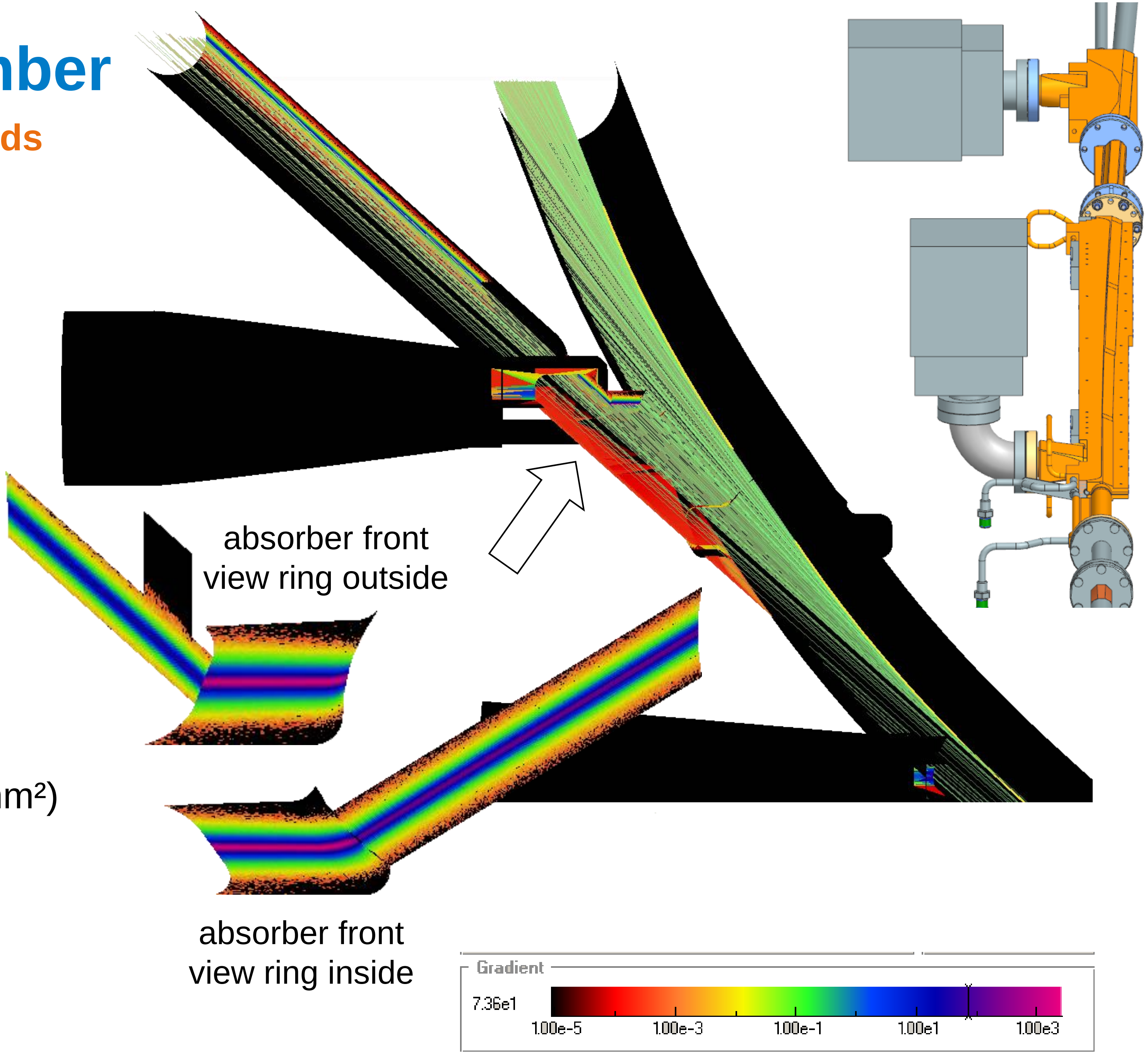
PETRA IV Extration Chamber

Expected synchrotron radiation power loads

- Power loads from SynRad:

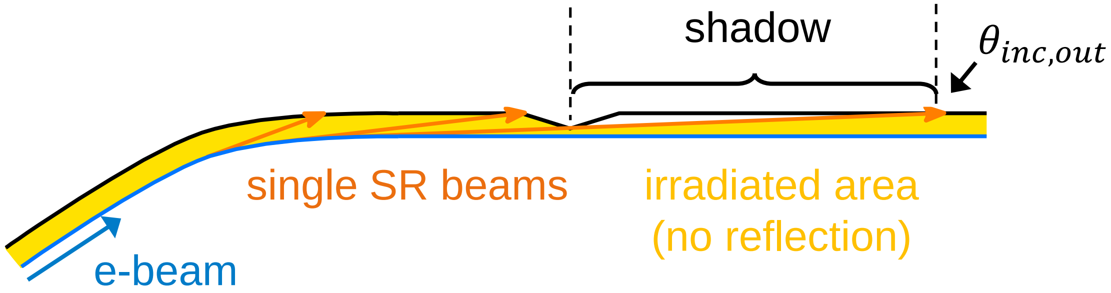
Position	Power [W]
full absorber ch.	254
abs. front and sides	252
abs. front face	174
post. beam pipe	400
photon pipe	45.7 (45 on texture)

- Textures used as input for ANSYS
- Consistent with 1D-calculation
  (175 W total on front face, max. 29.2 W/mm²)

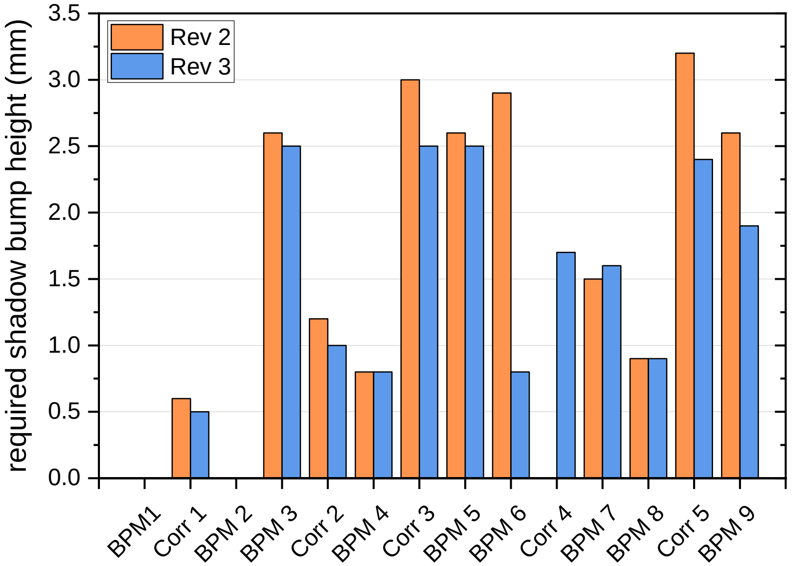


PETRA IV Shadowing Bumps

Required bump heights



- Required bump heights reduced to ≤2.5 mm in revision 3
- Bump at BPM 6 and Corrector 4 split up into two smaller bumps



Position	shadow length in mm	th. bump height in mm	tolerances in mm			req. bump height in mm
			production	alignment	girder	
BPM 1	shadowed by increased diameter					
Corrector 1	166.2	0.2	0.1	0.2		0.5
BPM 2	integrated into photon extraction chamber					
BPM 3	204.0	1.6	0.1	0.2	0.5	2.5
Corrector 2	171.2	0.7	0.1	0.2		1.0
BPM 4	123.8	0.5	0.1	0.2		0.8
Corrector 3	183.5	2.1	0.1	0.2		2.5
BPM 5	209.2	1.7	0.1	0.2	0.5	2.5
BPM 6	54.1	0.5	0.1	0.2		0.8
Corrector 4	174.6	1.4	0.1	0.2		1.7
BPM7	197.8	0.7	0.1	0.2	0.5	1.6
BPM 8	55.0	0.5	0.1	0.2		0.9
Corrector 5	177.3	2.0	0.1	0.2		2.4
BPM 9	225.8	1.0	0.1	0.2	0.5	1.9