

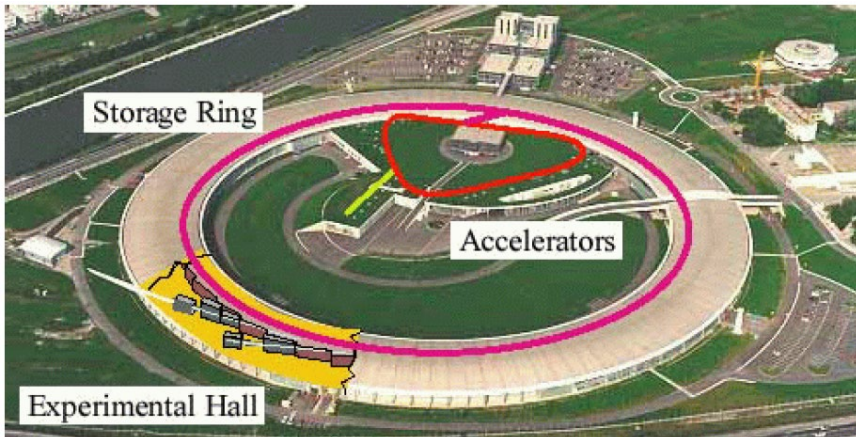
Experimental platforms for dynamic studies with MHz X-ray radioscopy at ID19 of ESRF

Bratislav Lukić

Alexander Rack, Amitay Cohen, Georg Ganzenmueller, Arnaud Sollier, Simon Bland, William Proud, David Chapman, Daniel Eakins



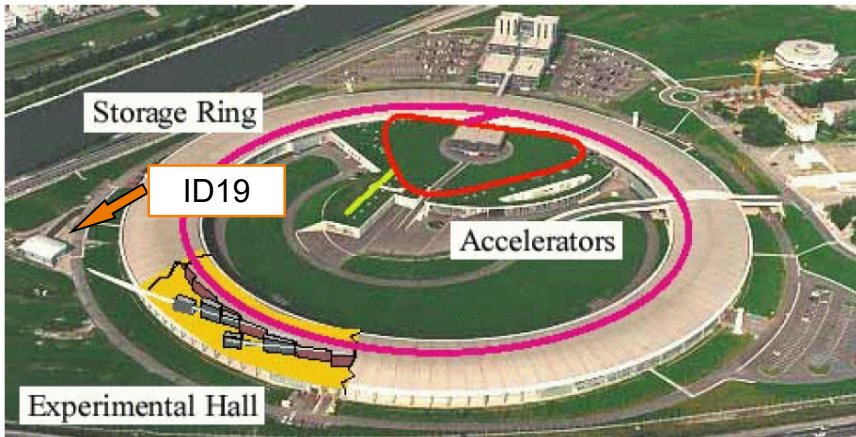
ID19: A VERSATILE PLATFORM FOR FULL-FIELD HARD X-RAY MICROIMAGING



PhD thesis, Daniel Lübbert (1999)

- Historically first long-beamline of ESRF (operation 1995)

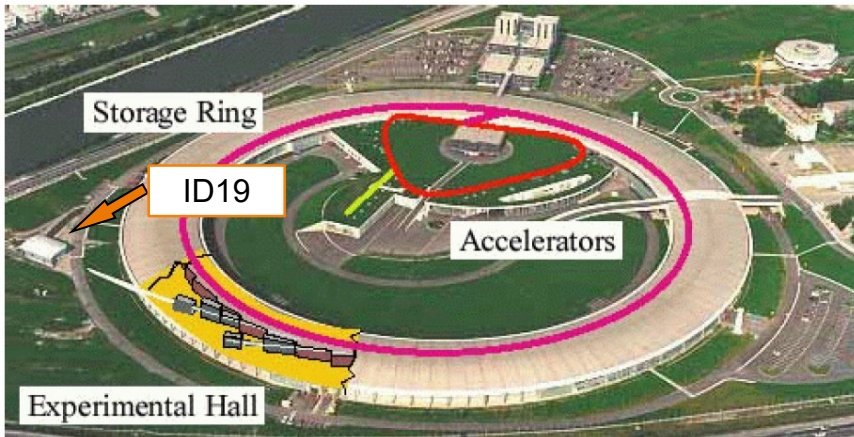
ID19: A VERSATILE PLATFORM FOR FULL-FIELD HARD X-RAY MICROIMAGING



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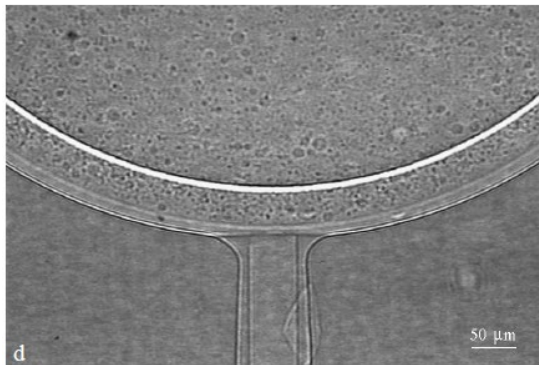
- Historically first long-beamline of ESRF (operation 1995)
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ID19: A VERSATILE PLATFORM FOR FULL-FIELD HARD X-RAY MICROIMAGING

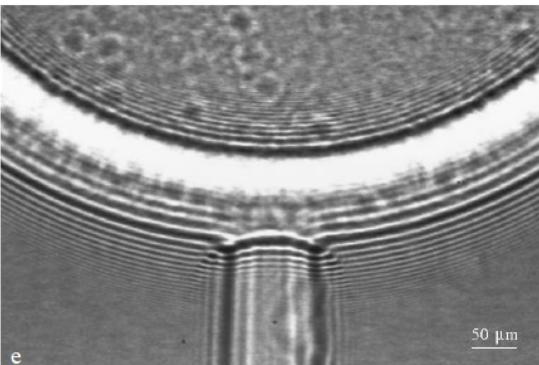


PhD thesis, Daniel Lübbert (1999)

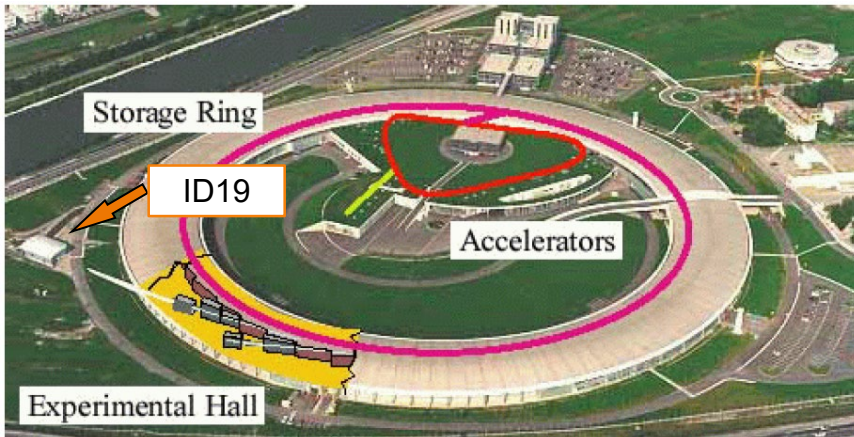
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PhD Thesis Peter Cloetens, 1999

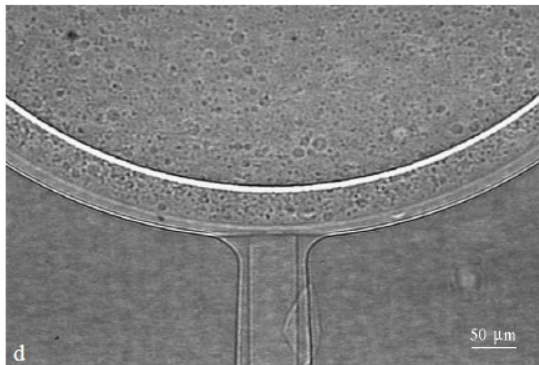


ID19: A VERSATILE PLATFORM FOR FULL-FIELD HARD X-RAY MICROIMAGING

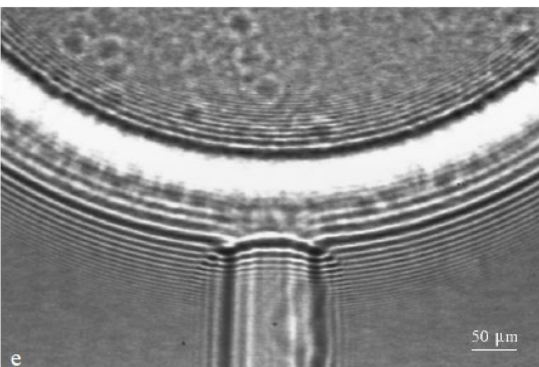
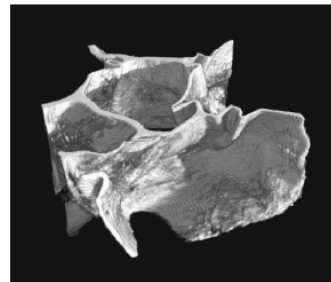


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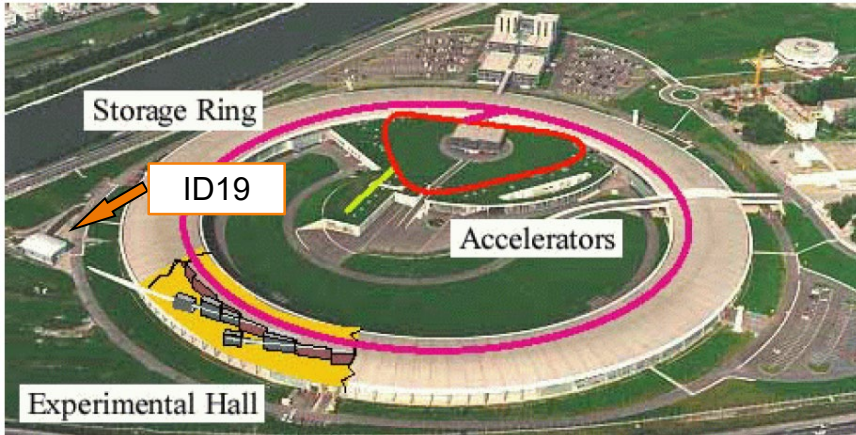
- Historically first long-beamline of ESRF (operation 1995)
- White-topography beamline (until early 00s)
- Phase-contrast imaging (since 1999s)
- Versatile Microtomography end-station (since 2000s)



PhD Thesis Peter Cloetens, 1999
Cloetens et al., APL (1999)

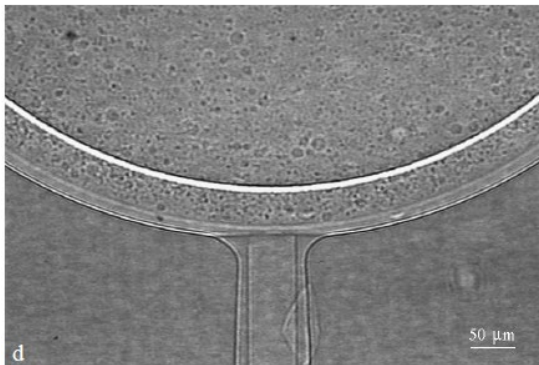


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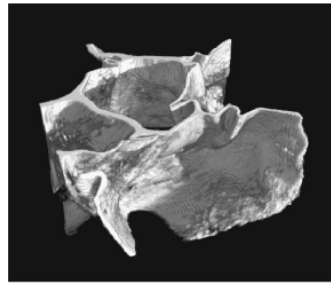


PhD thesis, Daniel Lübbert (1999)

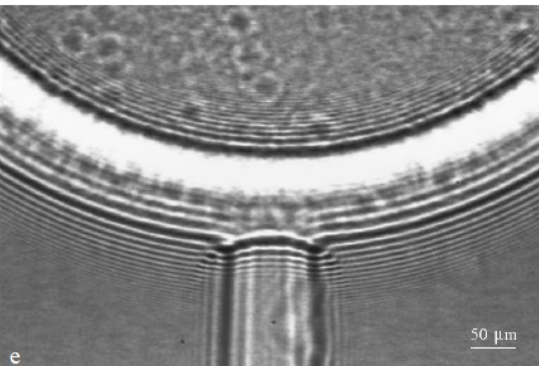
- Historically first long-beamline of ESRF (operation 1995)
- White-topography beamline (until early 00s)
- Phase-contrast imaging (since 1999s)
- Versatile Microtomography end-station (since 2000s)
- (Ultra) Fast real-time X-ray imaging (since 2010s)



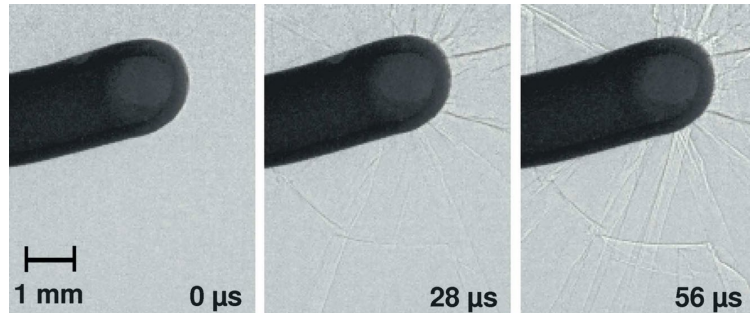
PhD Thesis Peter Cloetens, 1999
Cloetens et al., APL (1999)



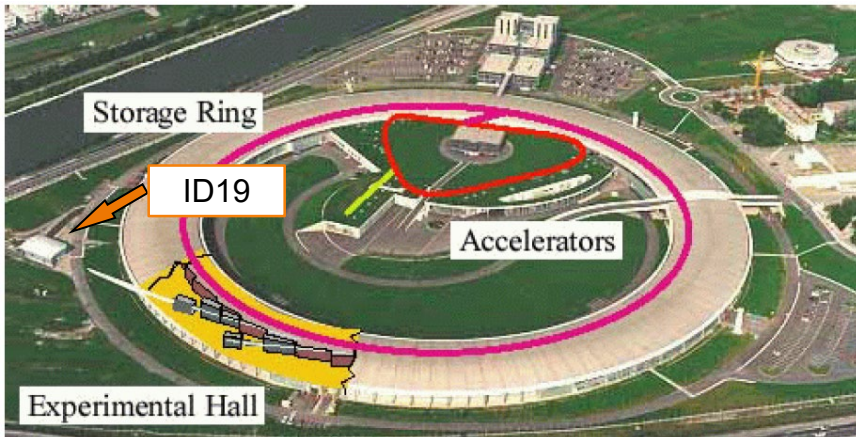
(a)



Rack et al., JSR (2014)

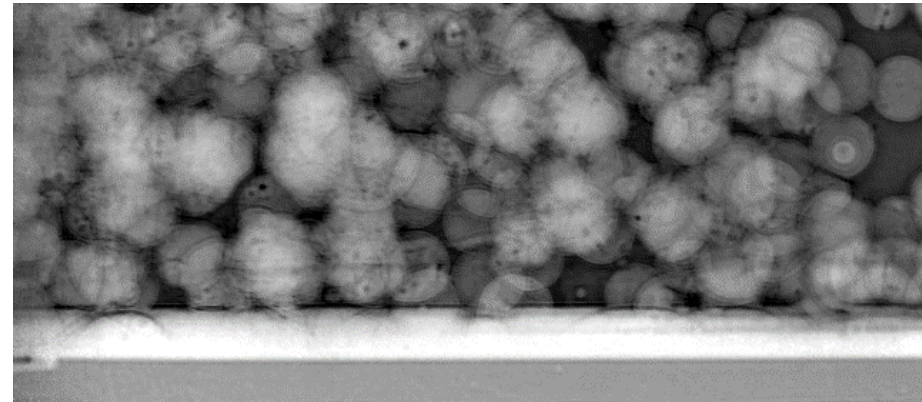


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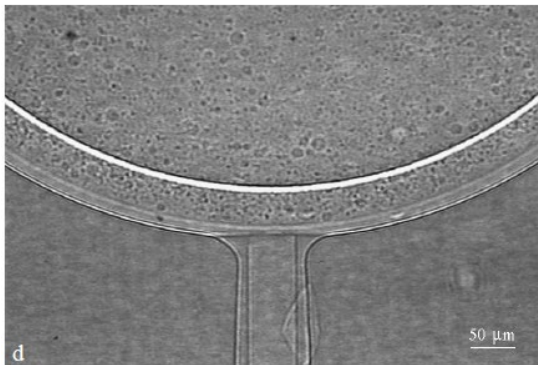
PhD thesis, Daniel Lübbert (1999)

- Historically first long-beamline of ESRF
- White-topography beamline
- **Phase-contrast imaging**
- **Versatile Microtomography** end-station
- **(Ultra) Fast real-time X-ray imaging (XRI)**

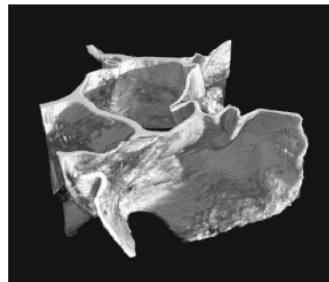


The dance of glass spheres on a loud speaker

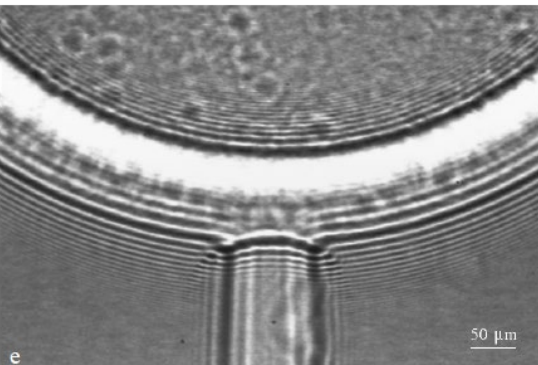
- 4 m propagation dist., 18.0 keV
- 100 000 images/s (Photron SA-Z)
- 2.4 μ s exposure time ID19 with EBS: 2020



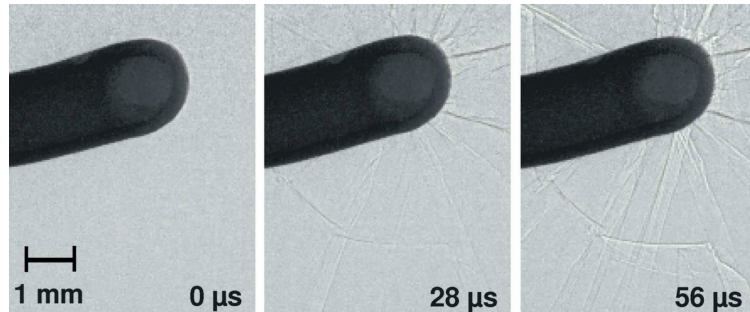
PhD Thesis Peter Cloetens, 1999
Cloetens et al., APL (1999)



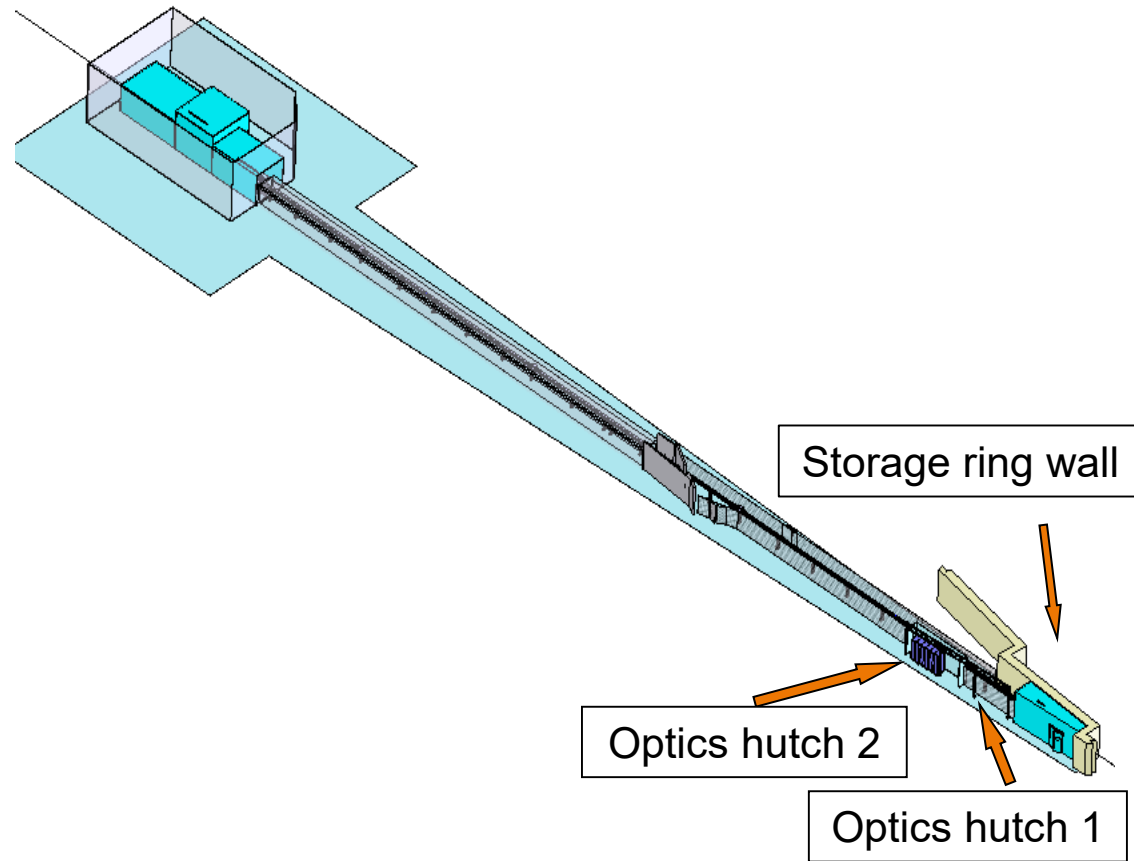
(a)



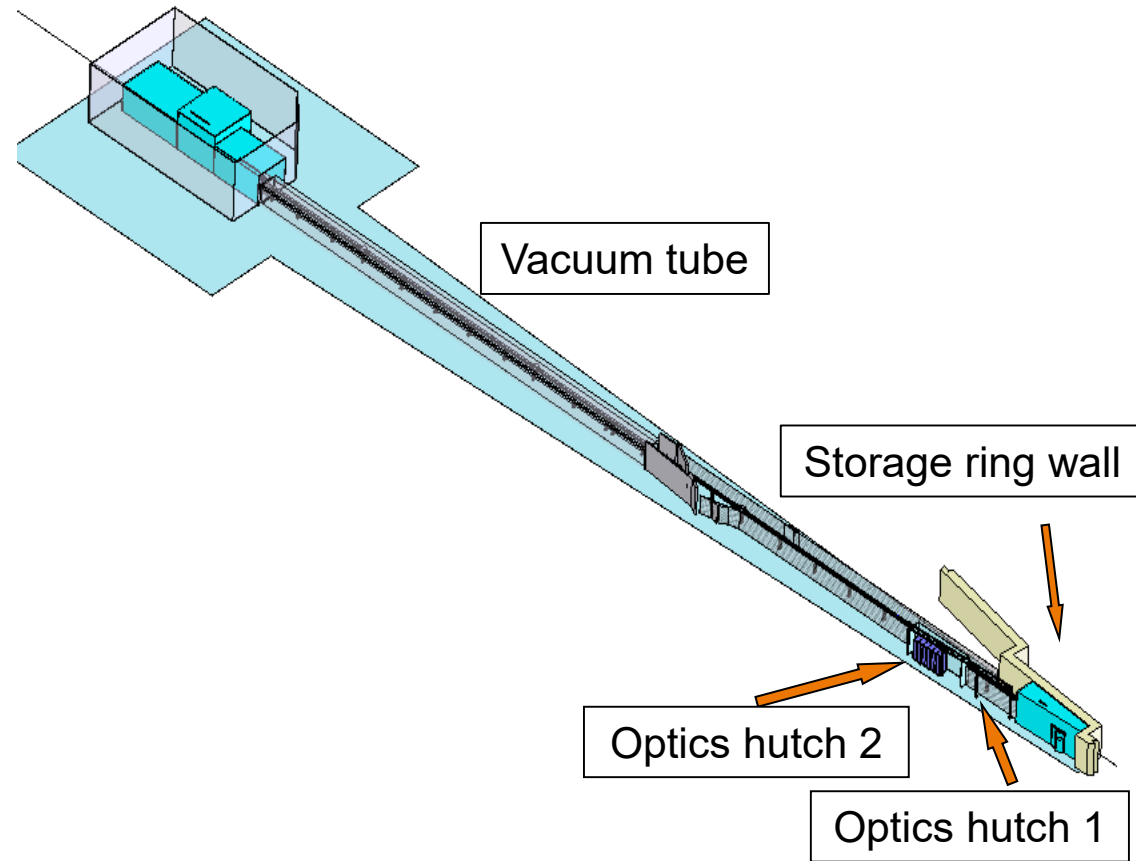
Rack et al., JSR (2014)



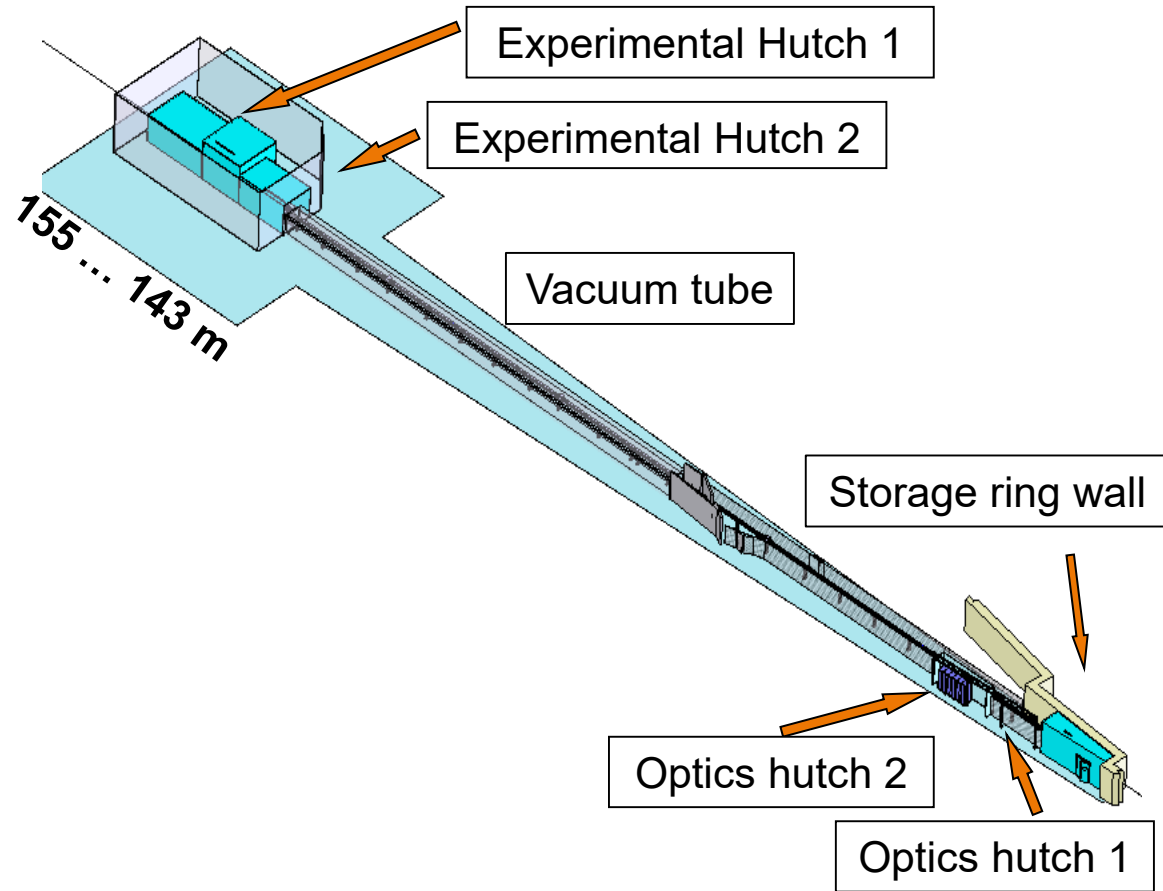
ID19: LAYOUT AND X-RAY INSTRUMENTATION



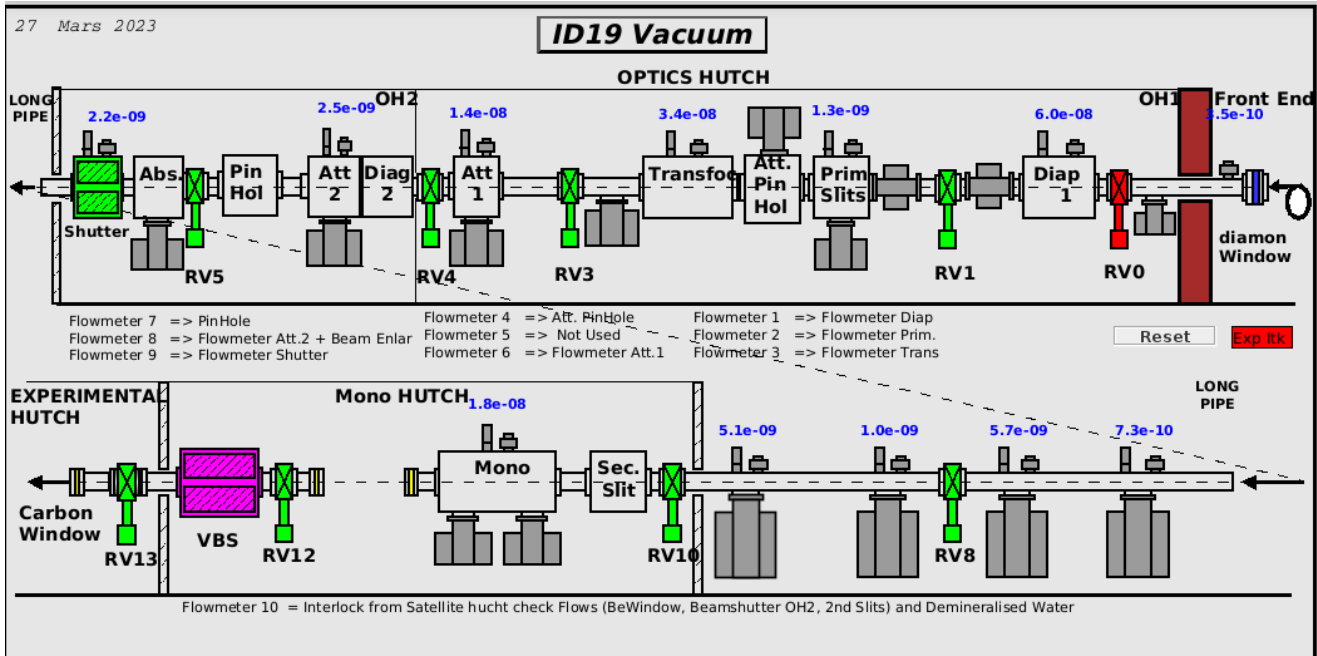
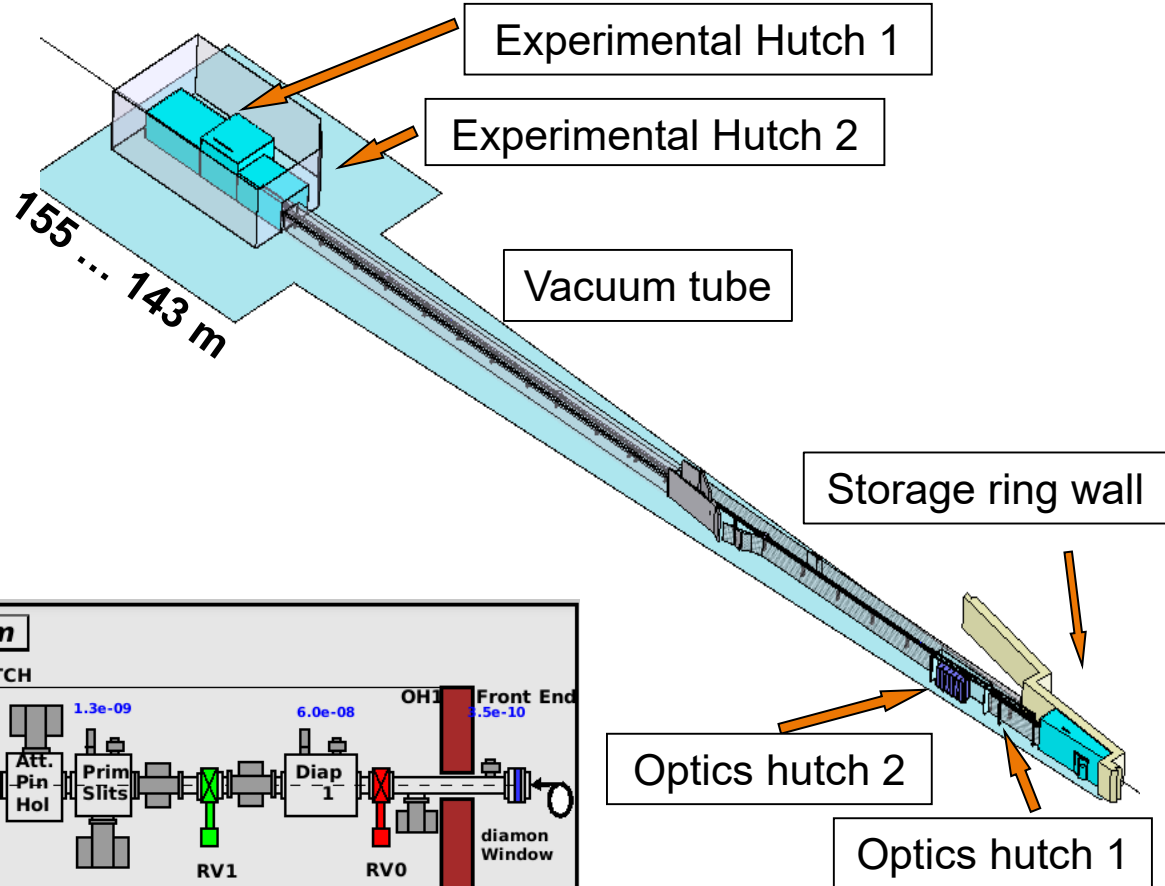
ID19: LAYOUT AND X-RAY INSTRUMENTATION



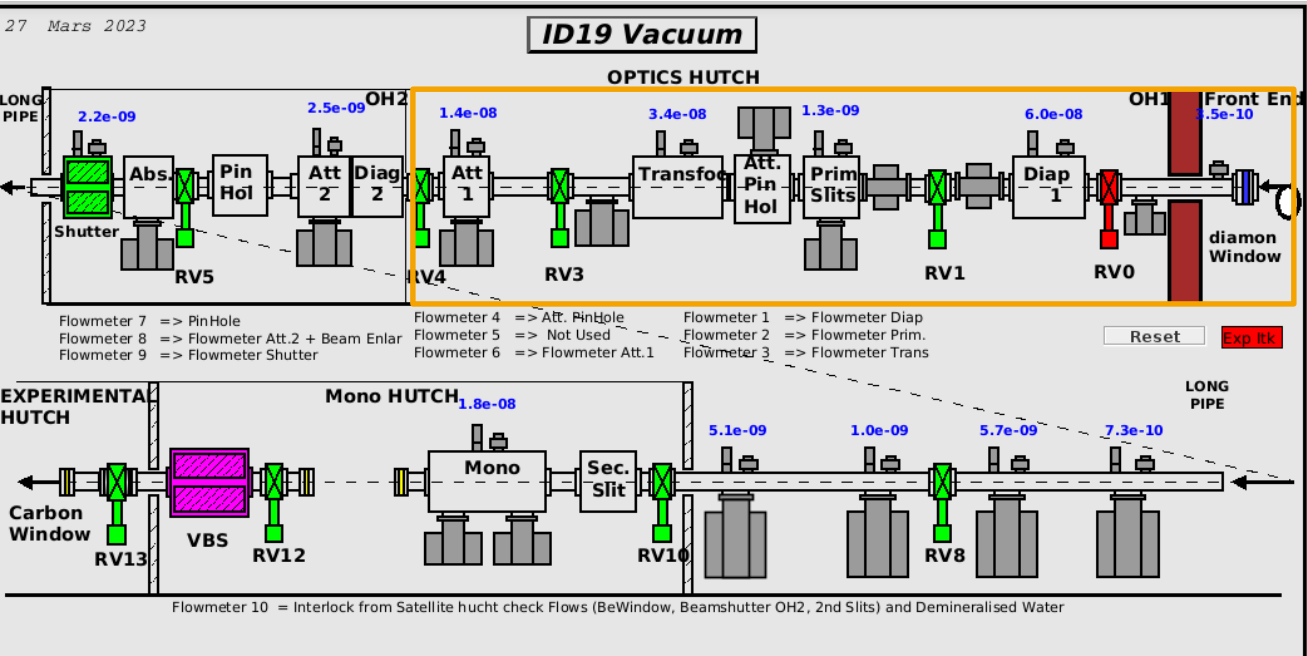
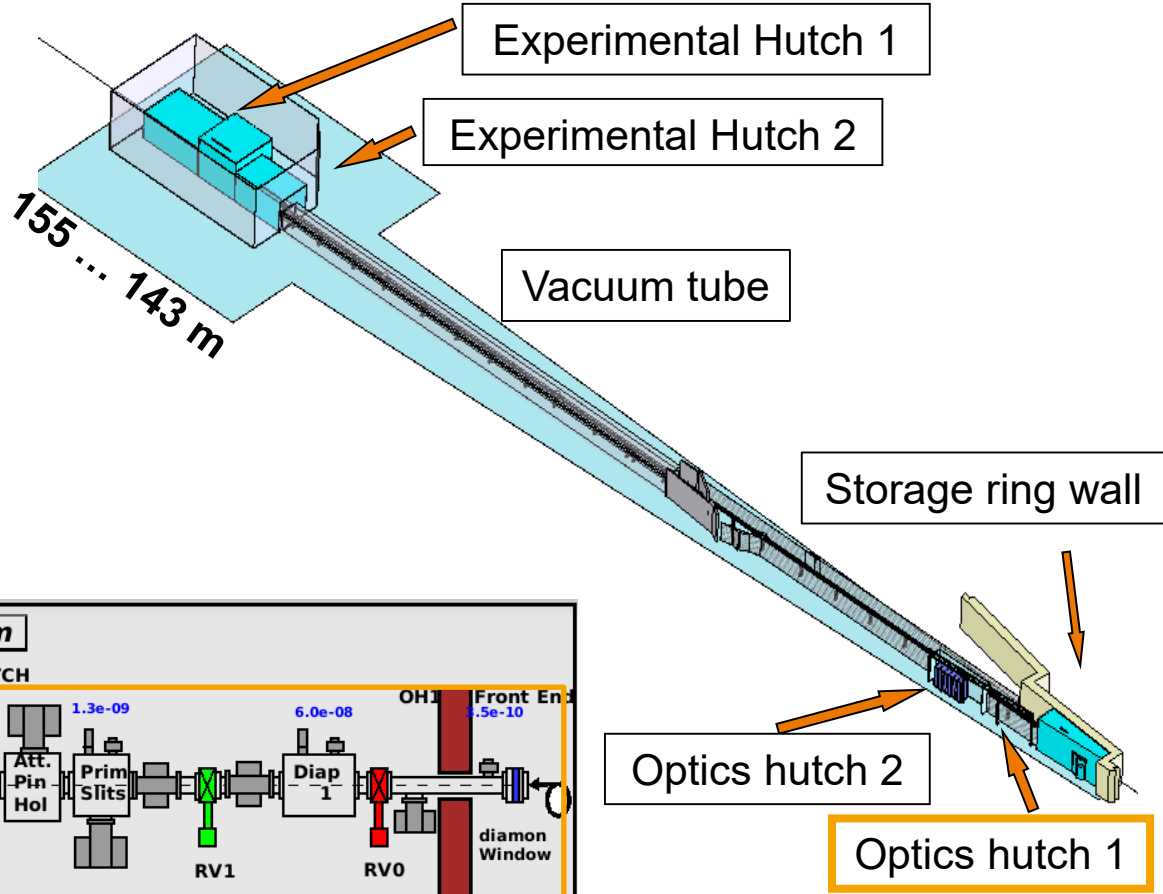
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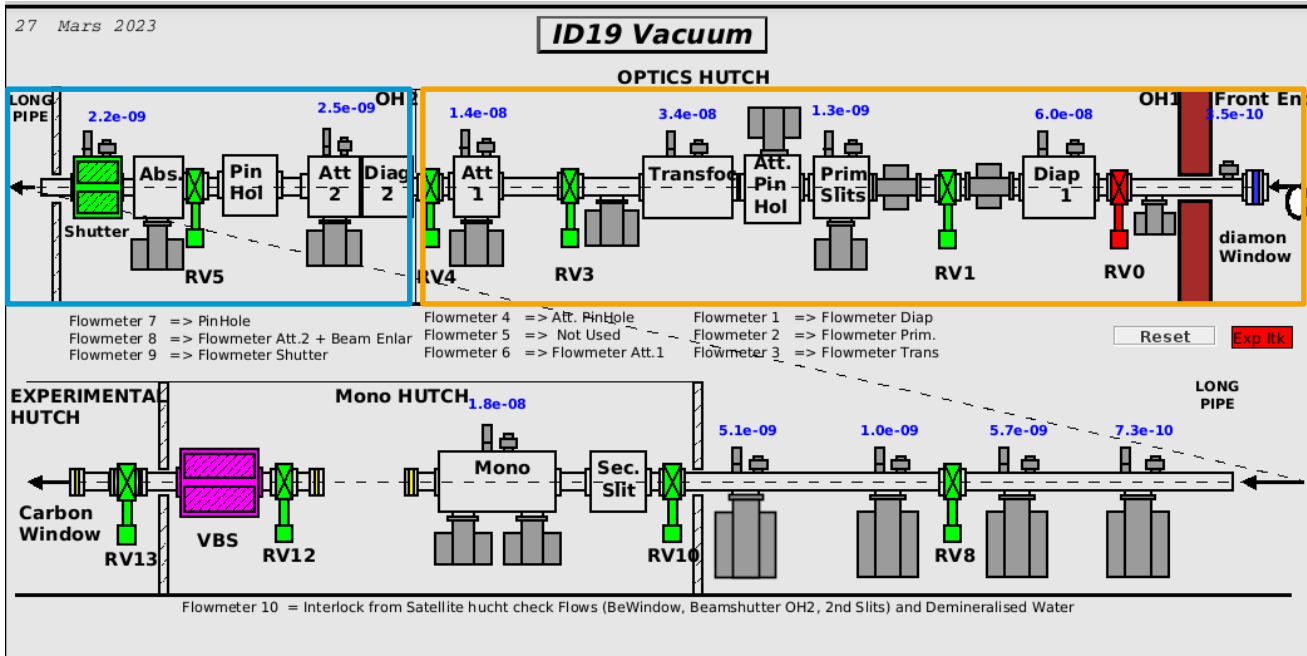
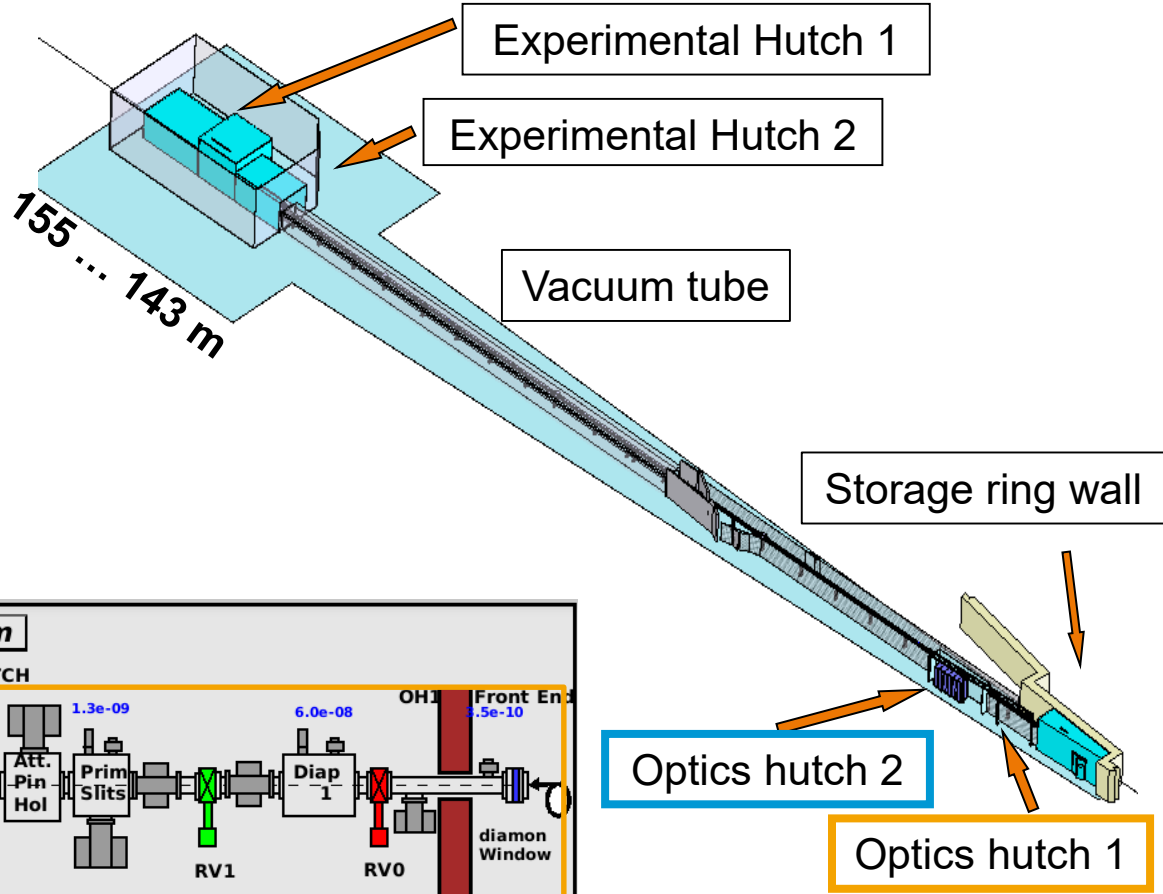
ID19: LAYOUT AND X-RAY INSTRUMENTATION



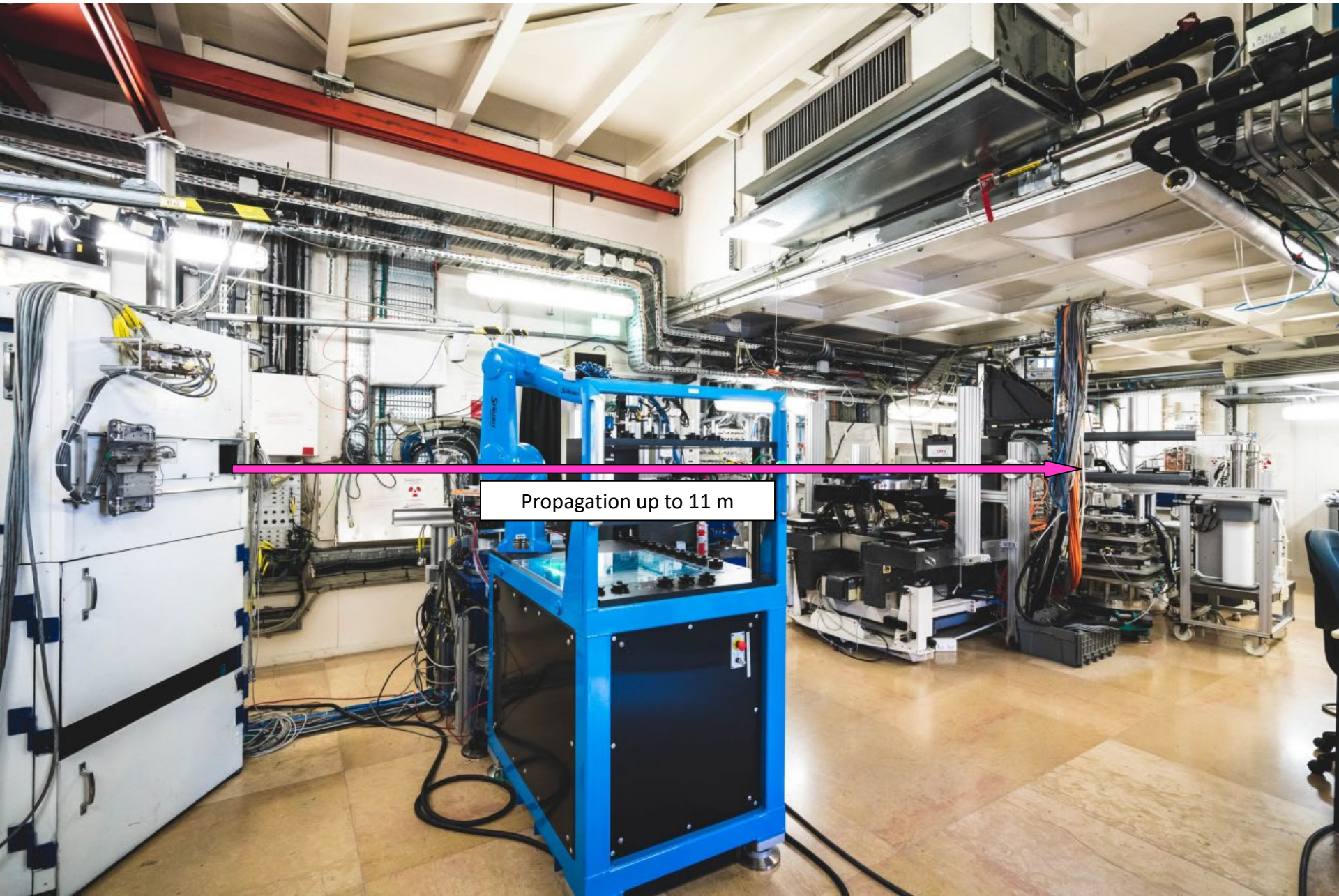
ID19: LAYOUT AND X-RAY INSTRUMENTATION



ID19: LAYOUT AND X-RAY INSTRUMENTATION



ID19 EXPERIMENTAL HUTCH 2



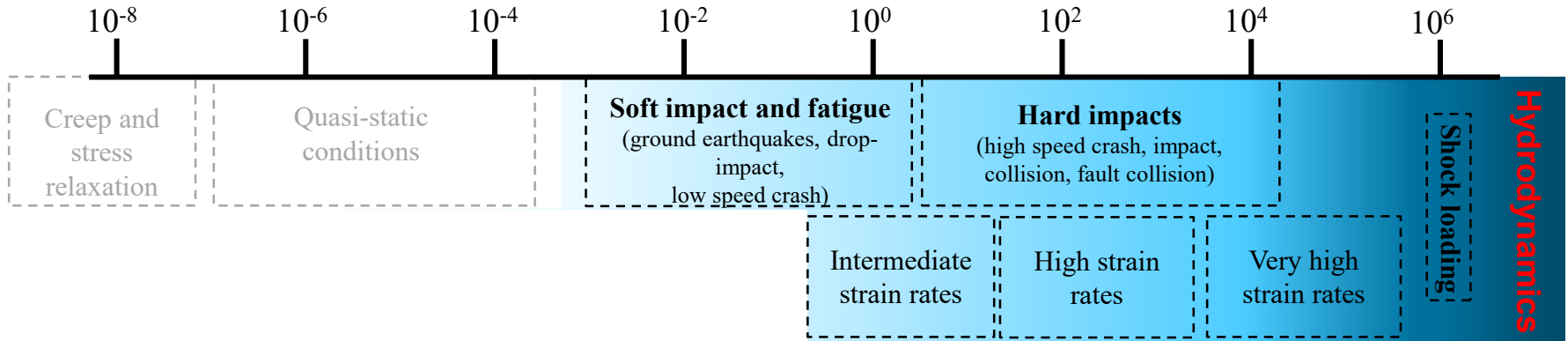
Propagation up to 11 m

- ID19: A versatile platform for full-field hard X-ray microimaging
- **Dynamic studies on materials: Motivation**
- **(Ultra-) Fast X-ray radioscopy at ID19**
- **Shock and High rate instruments for dynamic studies on materials**

- ID19: A versatile platform for full-field hard X-ray microimaging
- **Dynamic studies on materials: Motivation**
- (Ultra-) Fast X-ray radiography at ID19
- Shock and High rate instruments for dynamic studies on materials

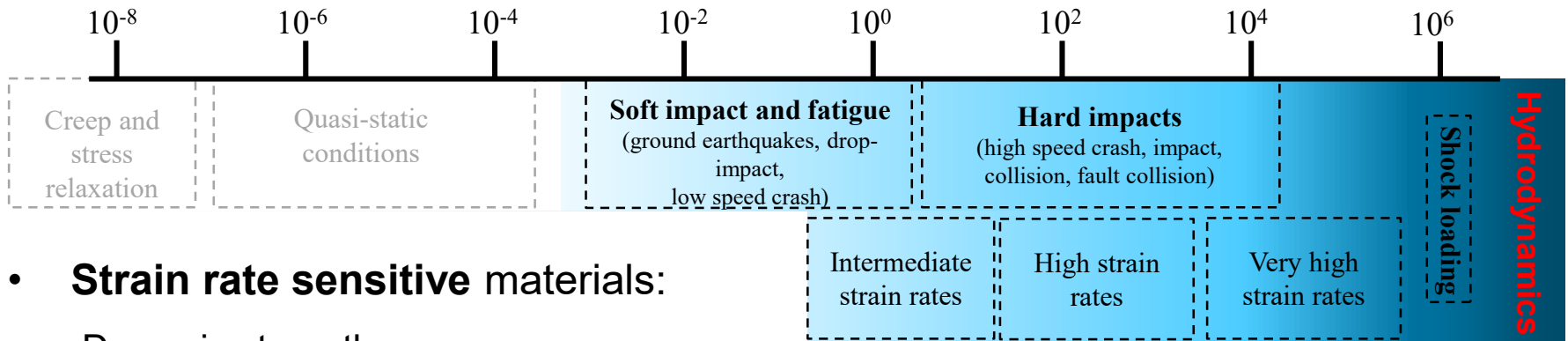
MATERIALS UNDER HIGH STRAIN RATE AND BEYOND

Strain rate: $\dot{\epsilon}$ (s^{-1})



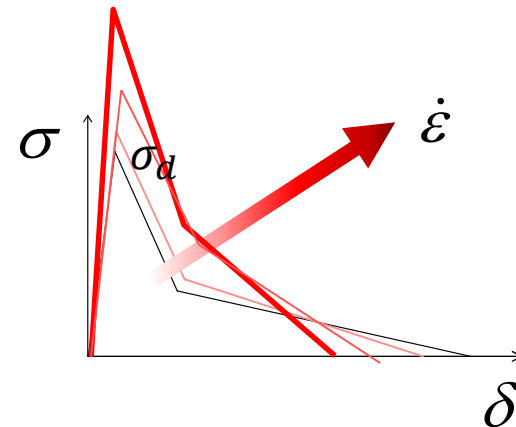
MATERIAL SENSITIVITY TO STRAIN RATES ON MACRO-SCALE

Strain rate: $\dot{\epsilon}$ (s^{-1})



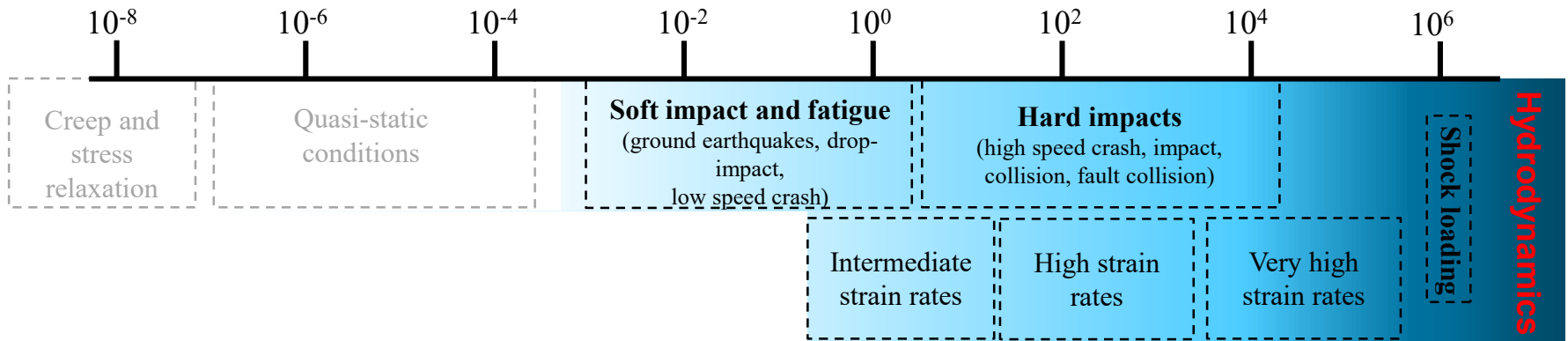
- **Strain rate sensitive materials:**
 - Dynamic strength
 - Dynamic fracture energy
 - Dynamic stiffness
 - Dynamic dislocation and plasticity

Macroscopic example:



STRAIN RATE EFFECTS ON MICROSCALE

Strain rate: $\dot{\epsilon}$ (s^{-1})

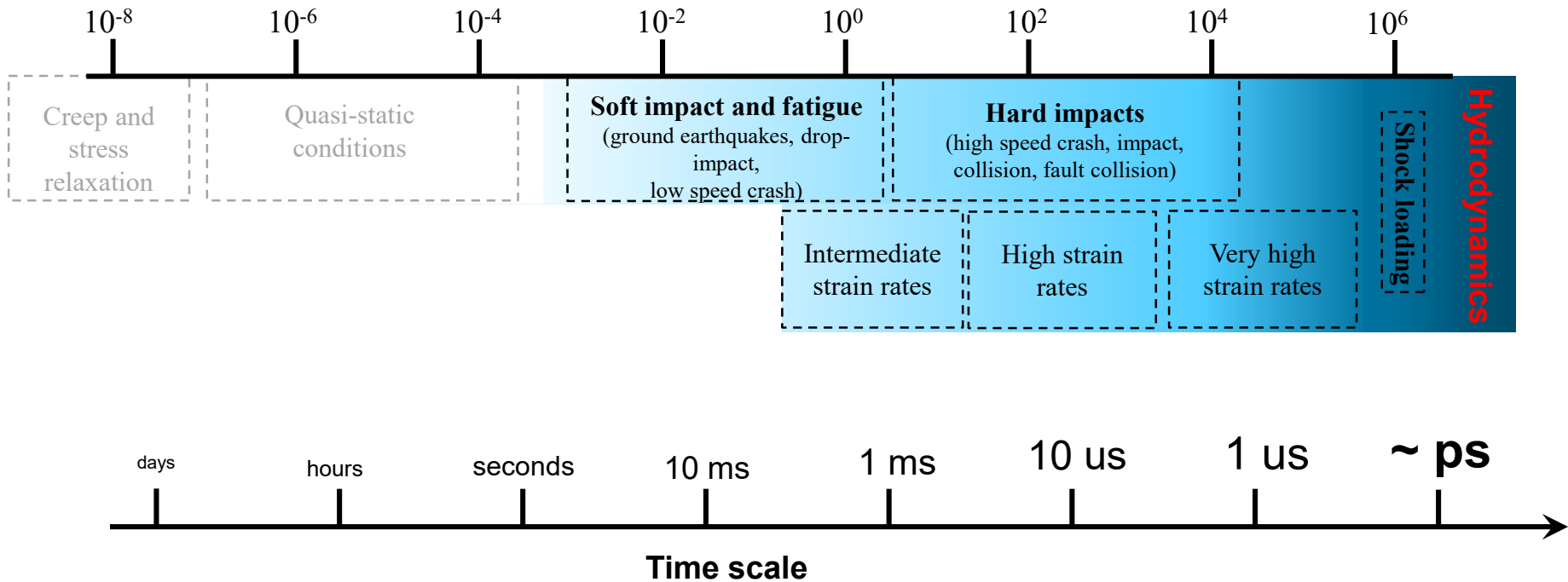


- **Fast microstructural changes**

- Phase change (stable and/or unstable)
- Adiabatic heating
- Internal damage and dislocations
- Void collapse and/or nucleation
- Multiple-fracture and fragmentation
- Dynamic crack propagation
- Hydrodynamic instabilities and mixing

MICROSCOPIC TIME SCALES

Strain rate: $\dot{\epsilon}$ (s^{-1})



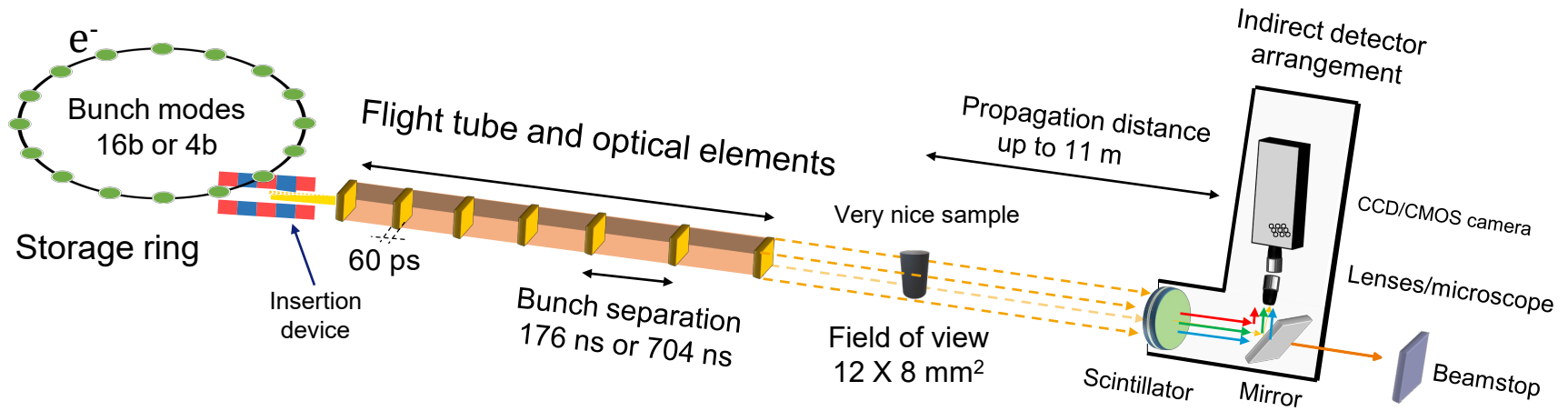
→ Need for sub-surface measurements at spatio-temporal microscale

- ID19: A versatile platform for full-field hard X-ray microimaging
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- **(Ultra-) Fast X-ray radiography at ID19**
- Shock and High rate instruments for dynamic studies

(ULTRA-) HIGH SPEED X-RAY PHASE CONTRAST IMAGING AT ID19

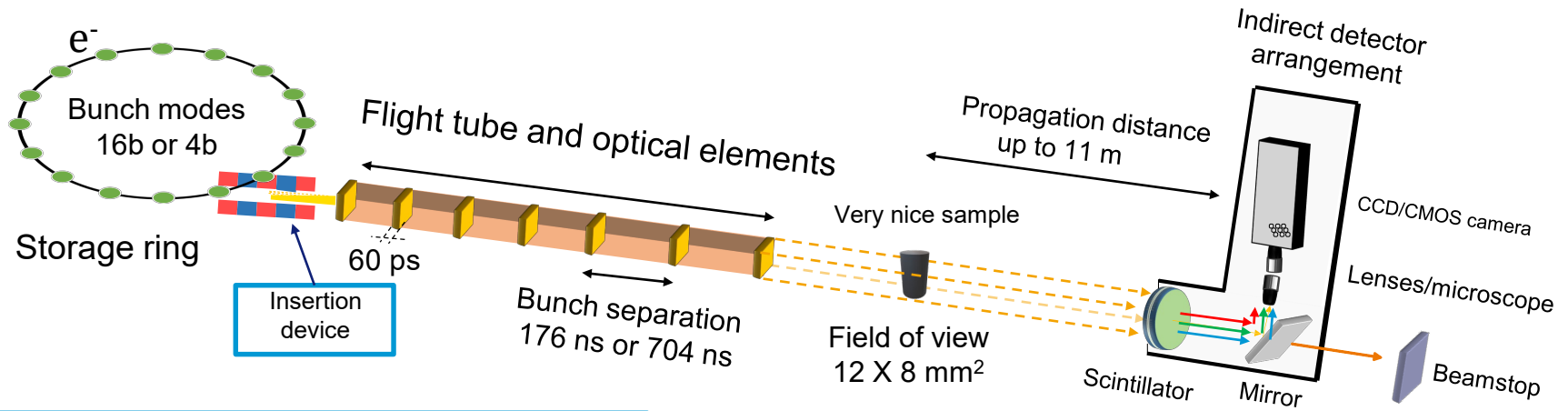
Olbinado et al. Opt. Express (2017)

- General overview of a bunch imaging at ID19:

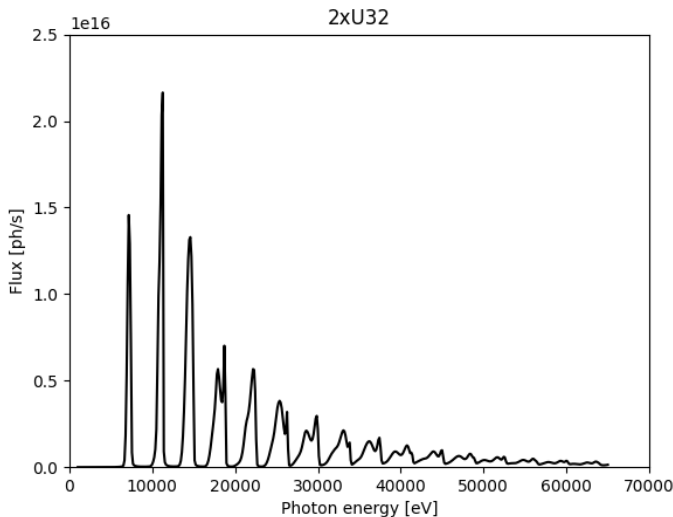


(ULTRA-) HIGH SPEED X-RAY PHASE CONTRAST IMAGING AT ID19

- General overview of a bunch imaging at ID19:



- Single- or Multi- bunch microimaging source

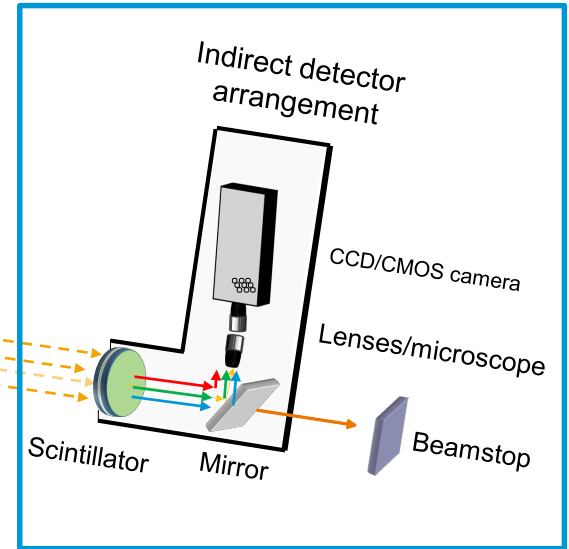
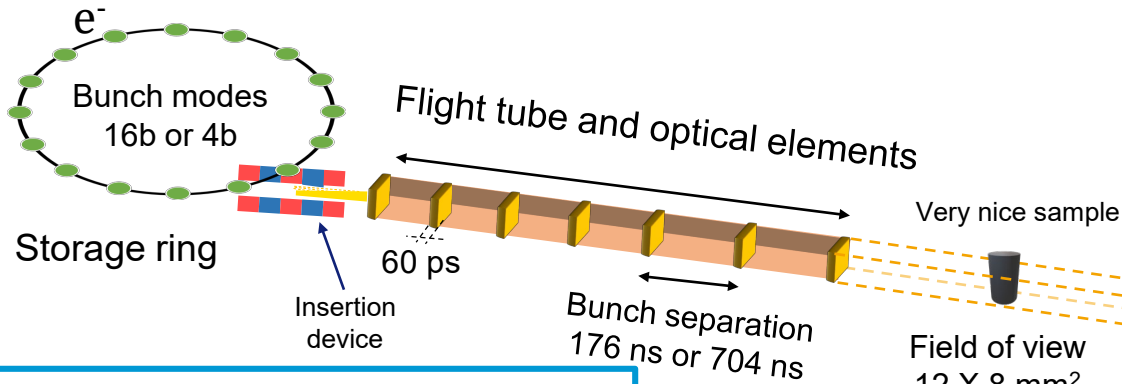


Flux calculation with XOP v2.4

(ULTRA-) HIGH SPEED X-RAY PHASE CONTRAST IMAGING AT ID19

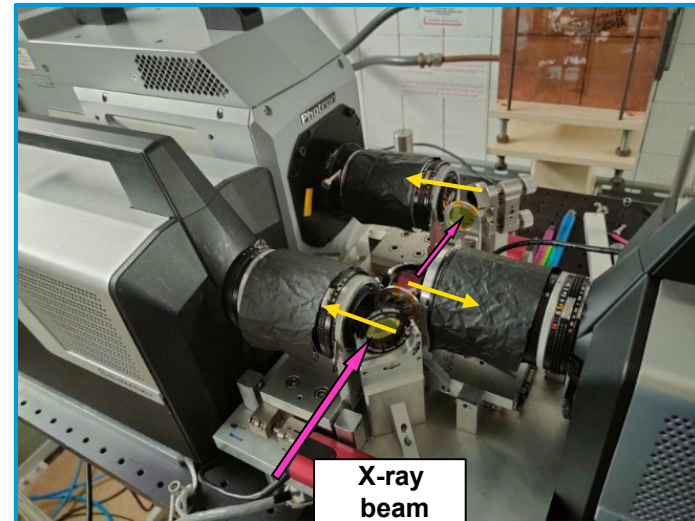
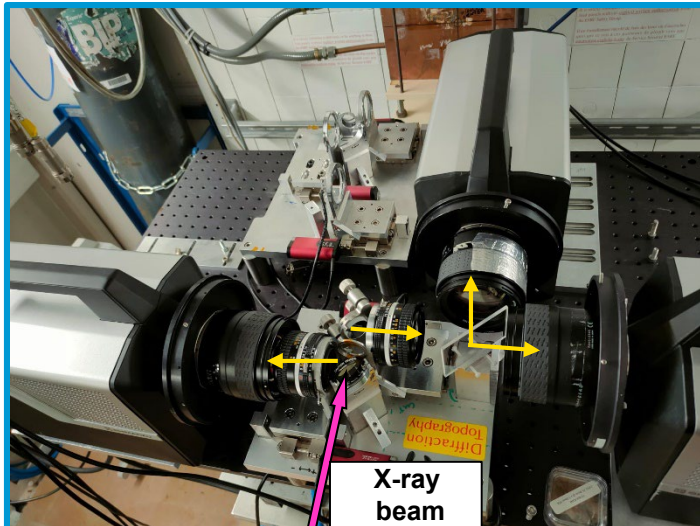
Escariza et al. Appl. Opt. (2018)

- General overview of a bunch imaging at ID19:



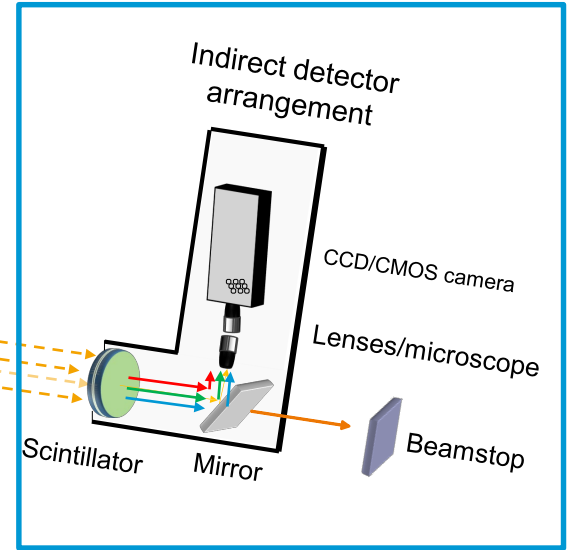
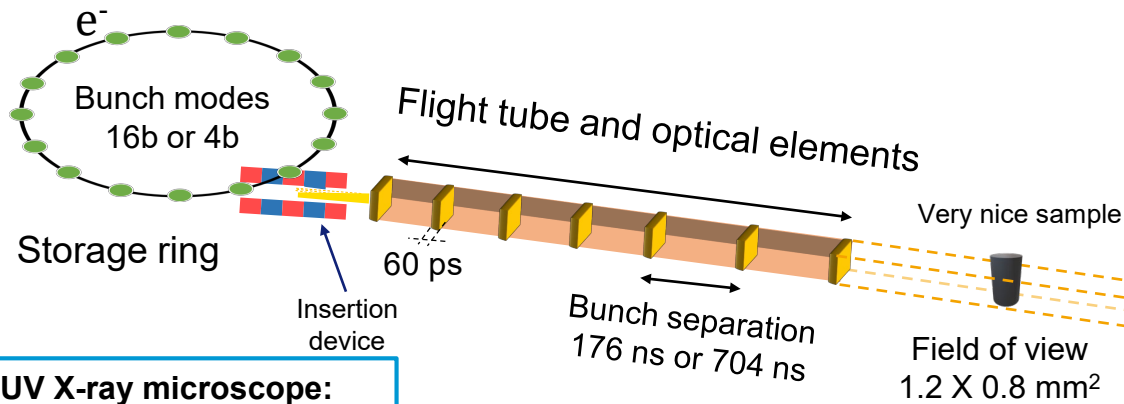
Triple detector tandem:

- 10 - 64 $\mu\text{m}/\text{px}$
- kfps to Mfps (upto 5.68 Mfps)
- 128 - 1000s images
- Versatile trigger and interlacing



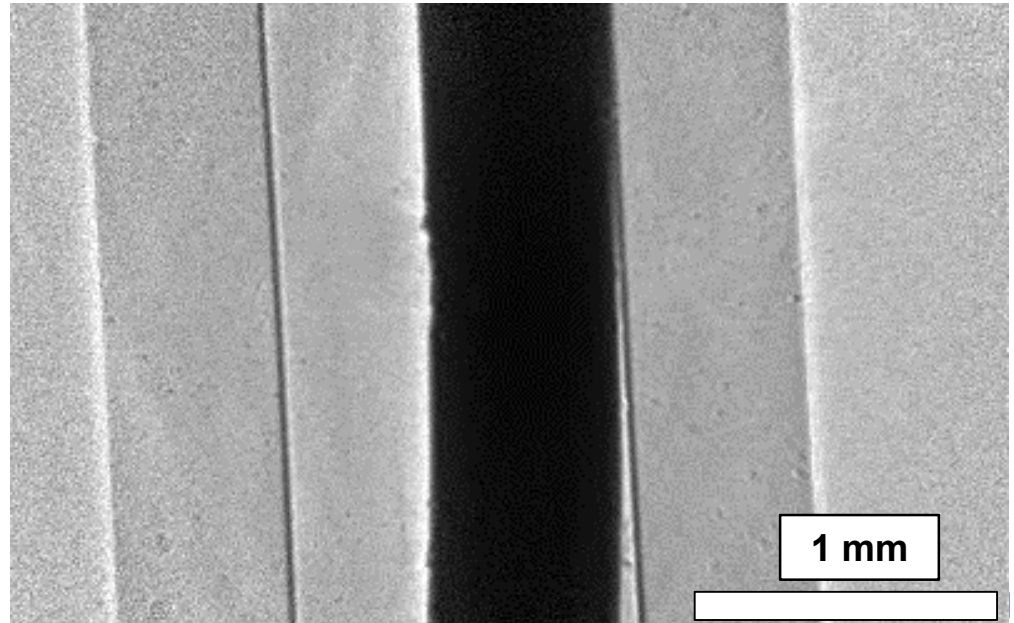
(ULTRA-) HIGH SPEED X-RAY PHASE CONTRAST IMAGING AT ID19

- General overview of a bunch imaging at ID19:



NUV X-ray microscope:

- 3.2 $\mu\text{m}/\text{px}$
- 1.8 Mfps
- 128 images



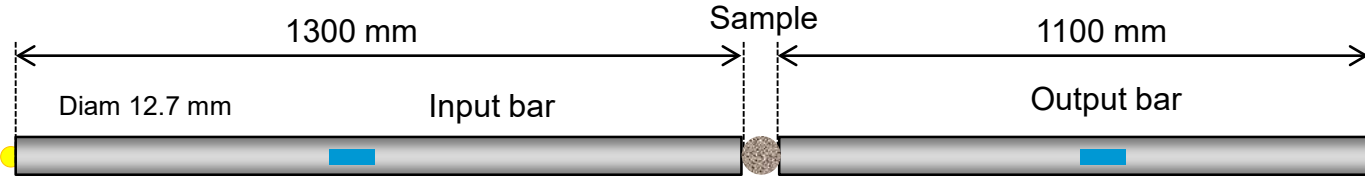
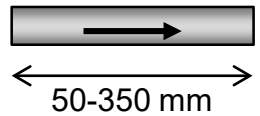
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- (Ultra-) Fast X-ray radiography at ID19
- **Shock and High rate instruments for dynamic studies on materials**

SPLIT HOPKINSON BARS: ULTRA FAST IMAGING OF MATERIALS UNDER HIGH STRAIN RATES

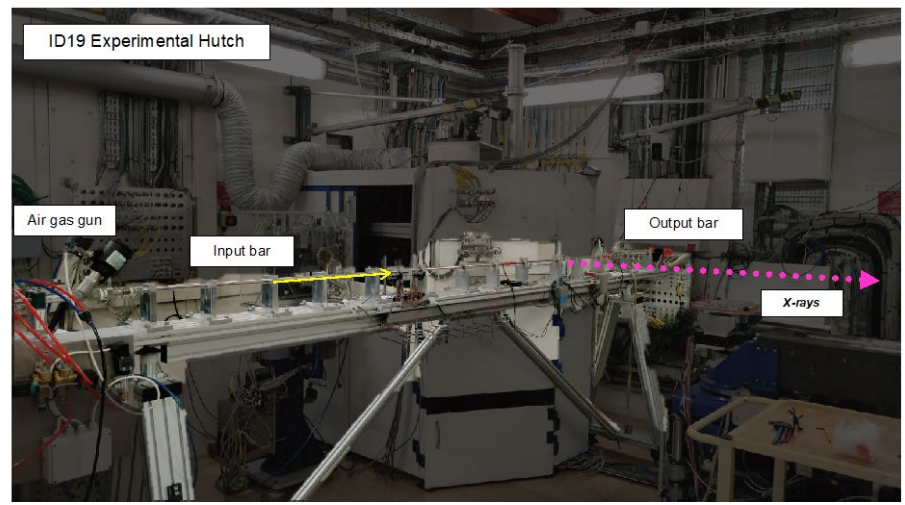
Cohen et al JINST (2018)

Lukic et al., JDBM (2021) $v < 20 \text{ m/s}$

Striker



- Aluminium bars ($F_{\text{max}} = 20 \text{ kN}$); Steel bars ($F_{\text{max}} = 40 \text{ kN}$)
- Loading from 8 – 350 μs
- Strain rate up to 1000s^{-1}
- Wide range of materials
- Versatile loading :
 - High rate Compression
 - Bending
 - Dynamic Fracture (Mode I, II, IIIa)
 - Sheer-Compression
 - Spalling
 - Confined compression



Please visit posters:

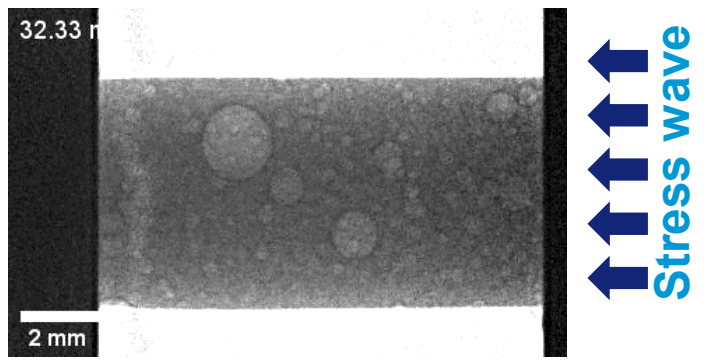
P1 - Ambikadevi et al.

P6 - Forquin et al.

P9 - Le Barbenchon et al.

P16 - Rodriguez Serano et al.

P19 - Sadat et al.



SPLIT HOPKINSON TENSION BAR



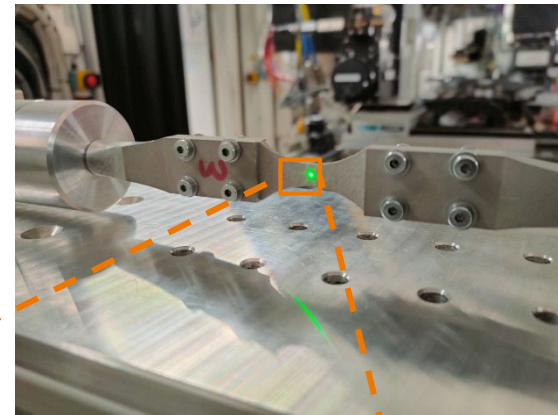
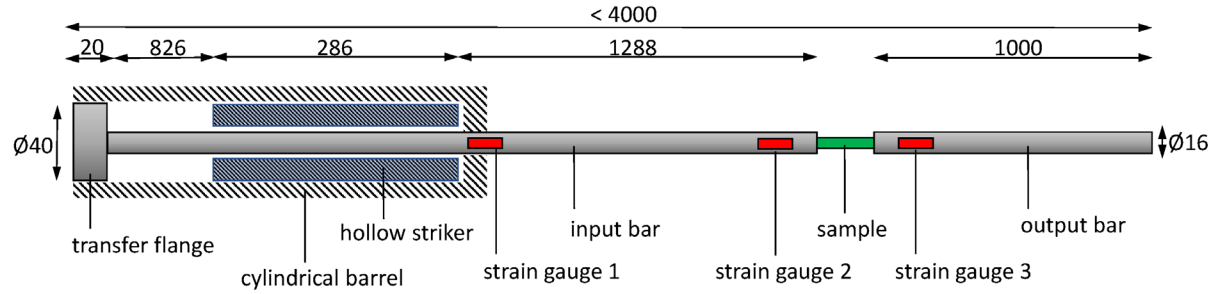
INATECH
INSTITUT FÜR NACHHALTIGE
TECHNISCHE SYSTEME

Georg Ganzenmueller

Fraunhofer

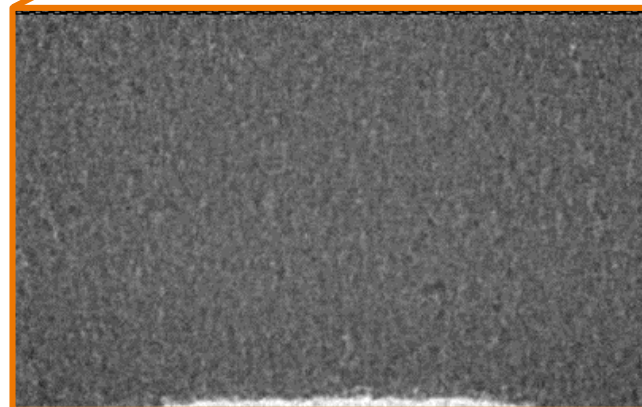
- Aluminium bars (D 16mm)
- Loading duration 400 us
- Strain rate up to 500-1000s⁻¹
- Special transition grip design
- Wide range of materials (composites, metals)

Jakkula et al., Inst. (2022)



Do not miss the talk:

- G. Ganzenmueller
Thursday @ 9:00



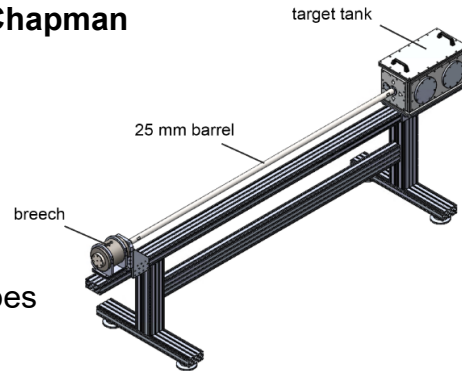
Force

MESO-SCALE GAS LAUNCHER: ULTRA FAST IMAGING OF MATERIALS SHOCK LOADING

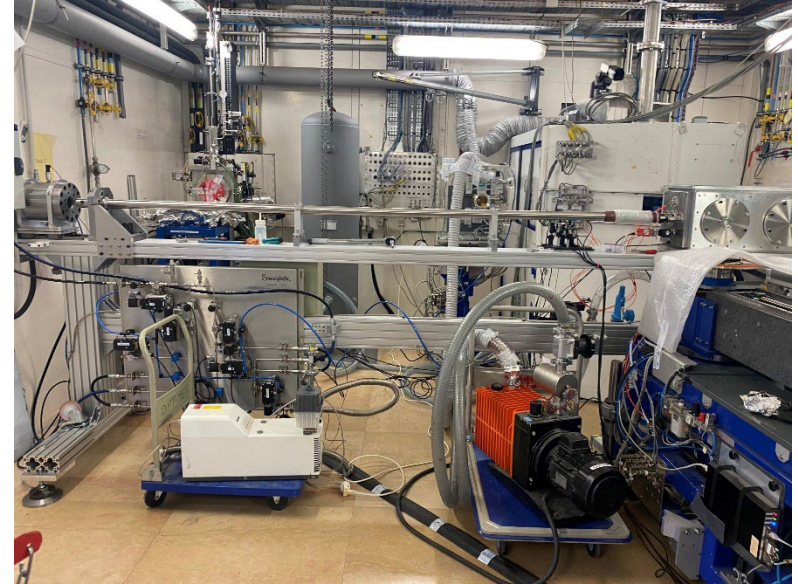


UNIVERSITY OF
OXFORD

D. Eakins and D. Chapman



- Impact speed to 100 – 900 m/s
- Multiple feedthrough for point probes
- Sample catcher for post-mortem
- Versatile sample mounting
- Applications:
 - Impact compression
 - Plate impact, Taylor impact
 - Shock spall
 - Dynamic fragmentation
 - Cold welding



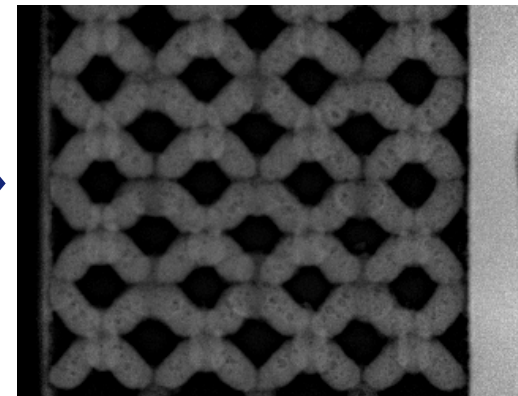
Closely follow talks:

- T. Virazels @ 16:20
- M. Arrigoni @ 16:40
- J.-R. Burie @ 17:00
- S. Neogi Thursday @9:20

Posters:

P12 – Pilvelait et al.

Compression of AM lattice



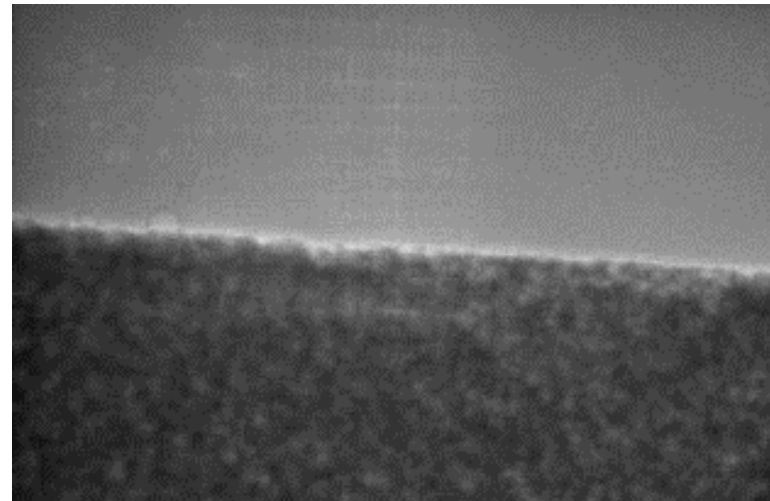
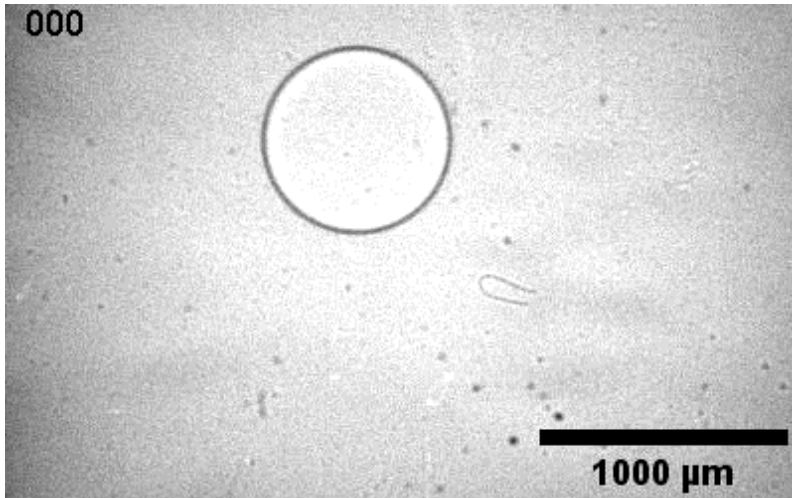
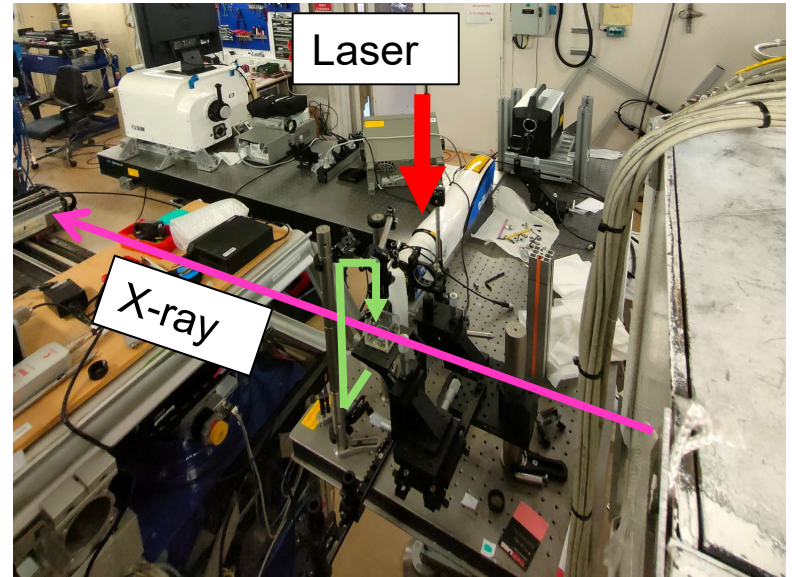
Escauriza et al. Appl. Opt. (2018)

PULSED LASER: ULTRA FAST IMAGING OF ABLATION AND CAVITATION STUDIES



Arnaud Sollier

- Quantel Q-smart
 - Nd :YAG pulsed laser 10 ns
 - Energy: 900mJ in 1064nm
 - Doubling crystal for 532 nm and 400 mJ
 - Extensive opto-mechanical components
 - Optical mirrors, splitters and calorimeter
-
- Applications:
 - Material processing
 - Cavitation and shock studies in fluids
 - Surface treatment
 - Ablation

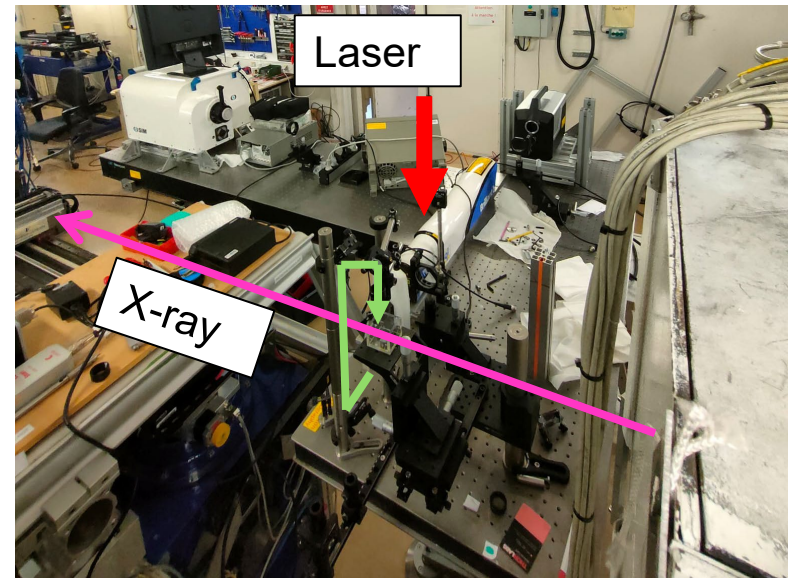


Bokman et al. CAV2024



Arnaud Sollier

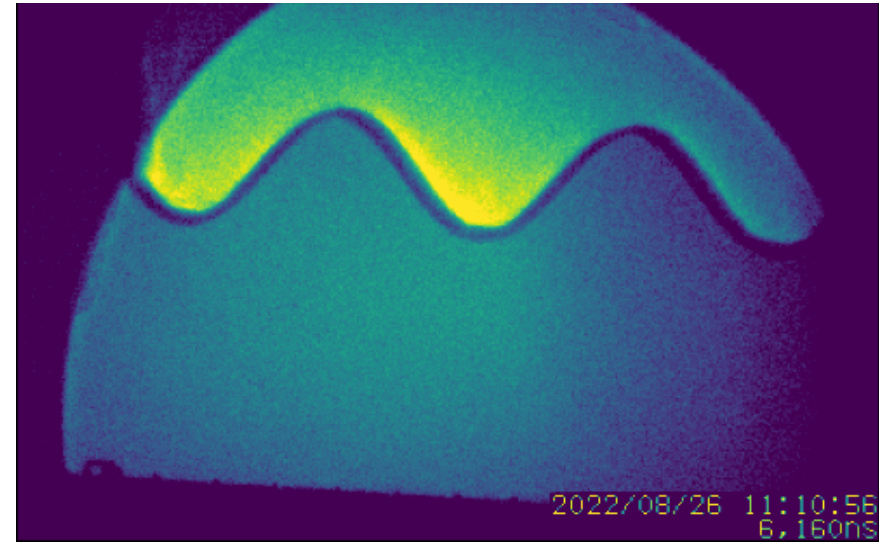
- Quantel Q-smart
 - Nd :YAG pulsed laser 10 ns
 - Energy: 900mJ in 1064nm
 - Doubling crystal for 532 nm and 400 mJ
 - Extensive opto-mechanical components
 - Optical mirrors, splitters and calorimeter
-
- Applications:
 - Material processing
 - Cavitation and shock studies in fluids
 - Surface treatment
 - Ablation



Fluid dynamics meets Synchrotron X-ray high-speed imaging

ESRF - Grenoble - France
21 - 22 March 2024

- Compact pulsed power generator
- Ultra-low HV trigger jitter <math>< 10\text{ ns}</math>
- Energy: 400 J (30kV)
- Full discharge <math>< 2\text{ }\mu\text{s}</math>
- Versatile wire array – Shock geometry shaping
- Generated pressure ($P > 400\text{ MPa}$)
- Interface acceleration acceleration $M \sim 2$



Strucka et al. Phys. Fluids (2024)

Maler et al. J.Appl.Phys. (2024)

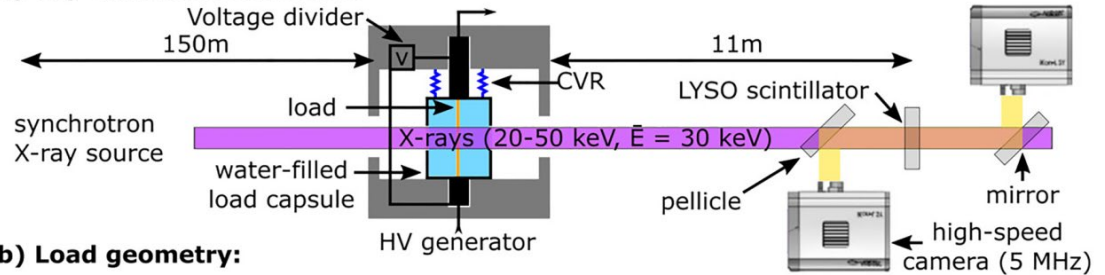
Maler et al. Phys.Plasmas (2022)

Yanuka et al. Phys.Plasmas (2019)

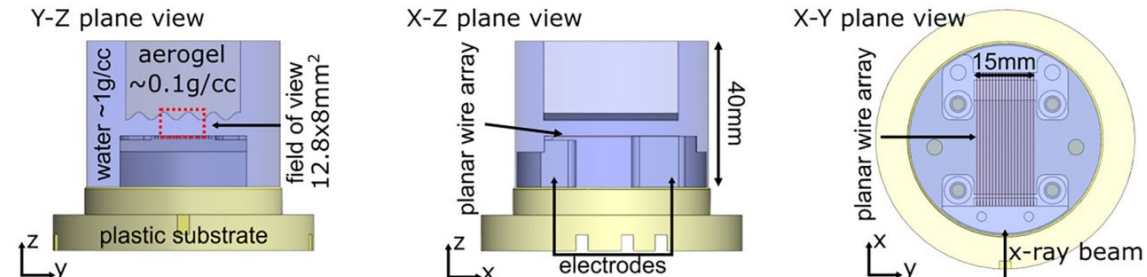
Theocharous et al. Rev. Sci. Instrum. (2019)

Yanuka et al. J. Appl. Phys. (2018)

a) Experimental schematic:



b) Load geometry:



Absolutely don't miss the talk ! :

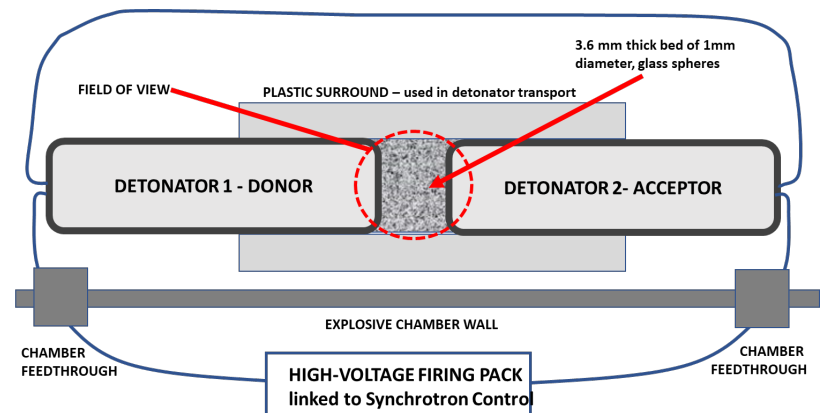
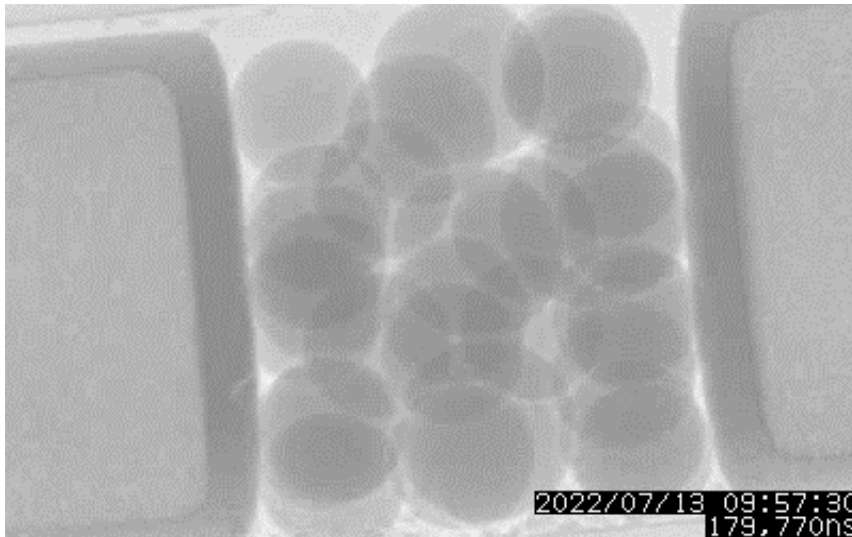
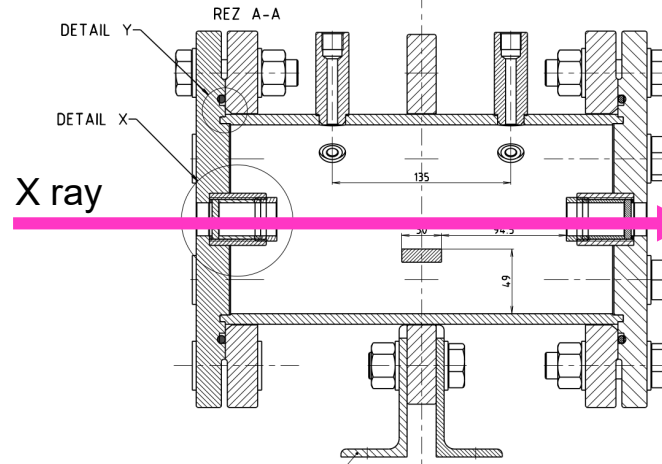
- **J. Strucka**
Thursday @ 9:40

Imperial College London

William Proud

- Compatible with energetic materials
- 6 feedthrough ports for point diagnostics
- 8 mm stainless steel walls
- Certified against 10 g Semtex explosive

[under commissioning]



ID19 Shock Block Allocation Group :



UGA
Université
Grenoble Alpes



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RENNES 1



U
Univerzita
Pardubice



**Lawrence Livermore
National Laboratory**

Fraunhofer

ONERA
THE FRENCH AEROSPACE LAB

TECHNION
Israel Institute
of Technology

ETH zürich



**TU BERGAKADEMIE
FREIBERG**
TECHNISCHE UNIVERSITÄT
BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

**ENSTA
BRETAGNE**

**MINES
ParisTech** | **PSL**

first light



**MANCHESTER
1824**
The University of Manchester

INATECH
INSTITUT FÜR NACHHALTIGE
TECHNISCHE SYSTEME



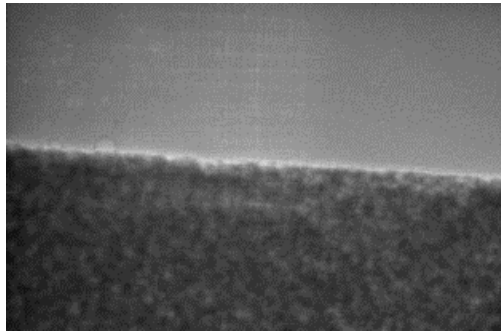
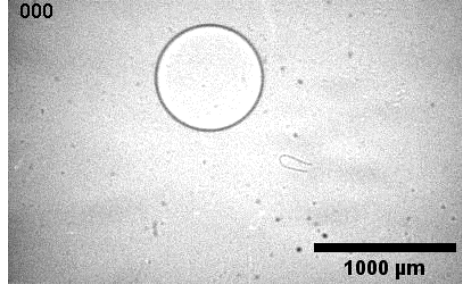
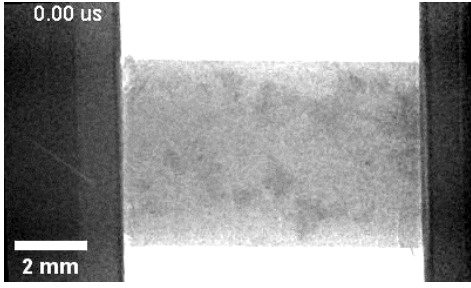
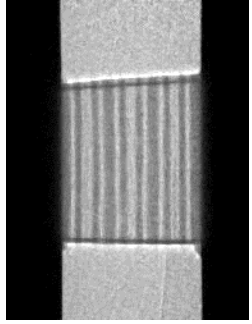
**UNIVERSITY OF
Southampton**

**Arts
et Métiers**
Sciences et
Technologies

HZDR
HELMHOLTZ ZENTRUM
DRESDEN ROSENDORF

BROWN

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**Thank you
for your attention**

Bratislav Lukić
lukic@esrf.fr

