The European Synchrotron

Overview on the diagnostics for EBS-ESRF

Laura Torino
On behalf of ESRF diagnostics group

International Beam Instrumentation Conference
Malmö, September 9, 2019

Extremely Brilliant Source – EBS

The aim of EBS is to increase the source **brilliance** and the **coherent fraction**
$\rightarrow$ **Hybrid Multi-Bend Achromat Lattice**

Requests:

- Reduce the horizontal equilibrium emittance from 4 nm to 140 pm
- Maintain the existing beamlines
- Preserve the time structure operation and a multi-bunch current of 200 mA
- Keep the present injector complex and reuse existing hardware
- Limit the downtime for installation and commissioning to less than 18 months

J. Biasci et al. Synchrotron Radiation News, vol. 27, Iss. 6, 2014
P. Raimondi, THPPA3, IPAC'17

ESRF → EBS

Credits Communication Group

Before 10 December 2018
→ ESRF

ESRF → EBS

Credits Communication Group

10 December 2018
→ ESRF Shutdown

ESRF → EBS

Credits Communication Group

After 10 December 2018
→ ESRF Dismantling

ESRF → EBS

Credits Communication Group

Before 2 December 2019
→ Tunnel Renovation

ESRF → EBS

Credits Communication Group

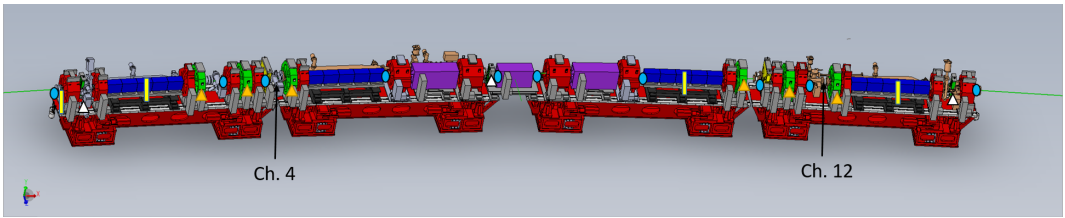
Before 2 December 2019
→ EBS installation

ESRF → EBS

Credits P. Guerin

Today
→ Installation is done
→ Cabling is completed
→ Bake-out is on-going
→ Final alignment is on-going
→ Equipment test is on-going

EBS Diagnostics



Quantity	Component
320	BPMs
5	Striplines
9	Correctors
3	Special BPM blocks
6	CTs
128	BLDs
5	Emittance Monitors
1	Bunch Purity Monitor
1	Visible light beamline

- BLD
- BPM
- ▲ Slow Correctors
- △ Fast Correctors

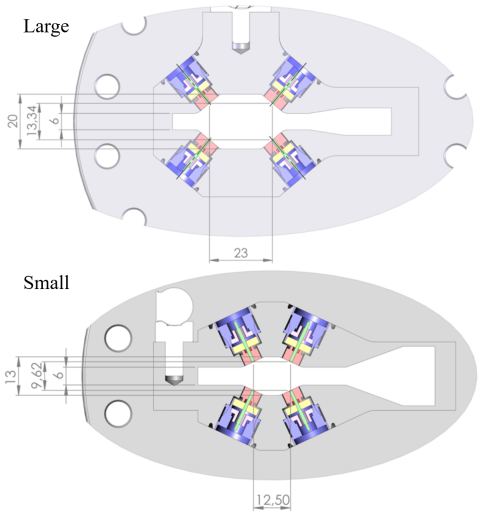
Ch. 4: Emittance monitor extraction/ Visible light extraction

Ch. 12: Emittance monitor extraction/ Shakers/ Striplines/CTs

BPM System

320 BPMs (10 per cells), two different BPMs geometries to fit the vacuum chamber:

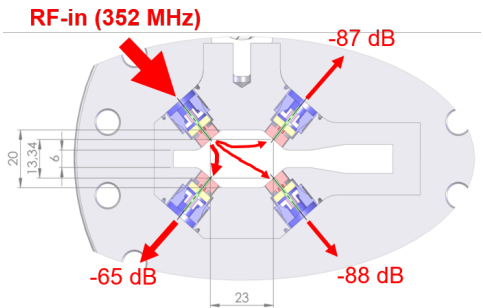
- **6 Large:** button diameter 8 mm, horizontal and vertical distance between buttons 23 mm and 13.34 mm
- **4 Small:** button diameter 6 mm, horizontal and vertical distance between buttons 12.5 mm and 9.62 mm



K.B. Scheidt, TUPB02, IBIC'18

BPM Signal Correction

Button sensitivity and **Non Linearity** due to the BPM block compactness may add offset to the measured position



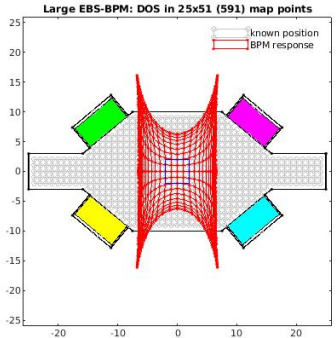
- Button Sensitivity ($C_{a,b,c,d}$) measured using the Lamberson Method

$$\rightarrow x = \frac{C_a a + C_d d - C_b b - C_c c}{C_a a + C_b b + C_c c + C_d d}$$

$$\rightarrow y = \frac{C_a a + C_b b - C_c c - C_d d}{C_a a + C_b b + C_c c + C_d d}$$

BPM Signal Correction

Button sensitivity and **Non Linearity** due to the BPM block compactness may add offset to the measured position



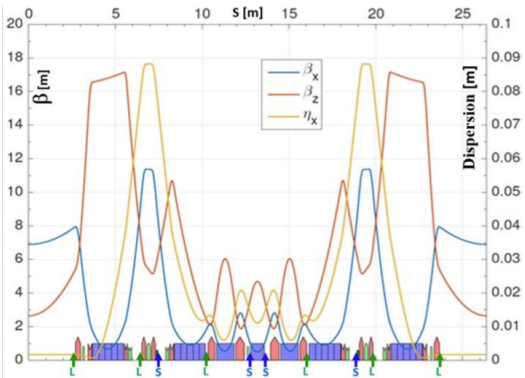
- Button Sensitivity ($C_{a,b,c,d}$) measured using the Lamberson Method
  $\rightarrow x = \frac{C_a a + C_d d - C_b b - C_c c}{C_a a + C_b b + C_c c + C_d d}$
  $\rightarrow y = \frac{C_a a + C_b b - C_c c - C_d d}{C_a a + C_b b + C_c c + C_d d}$
- Non-Linearity estimated and corrected applying a 2D polynomial generated by BPMLab
  $\rightarrow x_p = \sum_{i=0}^{N} X_i x^i + x_{off}|_\theta$
  $\rightarrow y_p = \sum_{i=0}^{N} Y_i y^i + y_{off}|_\theta$

- Polynomial depends on the BPM shape (Large or Small)
- $x_{off}|_\theta$ and $x_{off}|_\theta$ individual for each BPM block

Hybrid BPM Electronics

- 320 BPMs (10 per cell)
  - 192 with Libera-Brilliance electronics (6 per cells) → Slow/Fast Orbit Feedback
  - 128 with Libera Spark electronics (4 per cell) → Slow Orbit Feedback

K.B. Scheidt, TUPB02, IBIC'18



Data-streams, and buffers with identically synchronized sampling-rates

Hybrid BPM Electronics

- 320 BPMs (10 per cell)
  - 192 with Libera-Brilliance electronics (6 per cells) → Slow/Fast Orbit Feedback
  - 128 with Libera Spark electronics (4 per cell) → Slow Orbit Feedback

K.B. Scheidt, TUPB02, IBIC'18

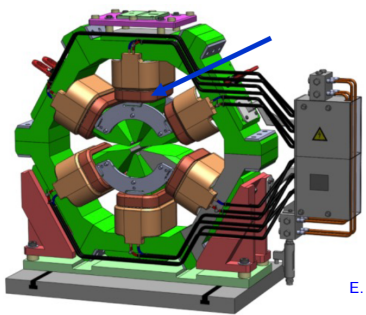
→ All the electronics has been tested on the old machine

Data-streams, and buffers with identically synchronized sampling-rates

Slow Orbit Feedback

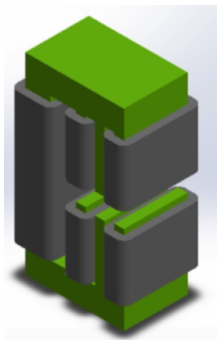
10 BPMs and 9 correctors acquire data and correct at $\simeq$1 Hz to cure the slow drifts. Different number of correctors and BPMs $\rightarrow$ correctors settings obtained using the **SVD method**

6 "Slow Correctors" $\rightarrow$ Additional winding in sextupoles



E. Plouviez et al., MOPG09, IBIC'16

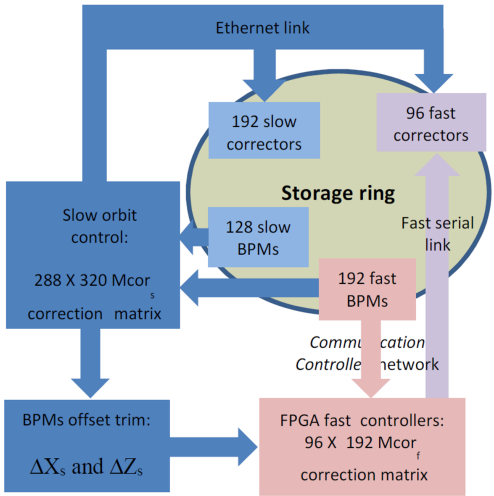
3 "Fast Correctors" $\rightarrow$ Dedicated magnets



Fast Orbit Feedback

- 96 Correctors $\times$ 192 BPMs
- 10 kHz acquisition frequency
- Corrector bandwidth 500 Hz
- 8 FPGA power supply controller boards to compute correctors settings via SVD
- Slow orbit position offset trim

Correct perturbation up to 50 Hz $\rightarrow$ First girder resonance mode



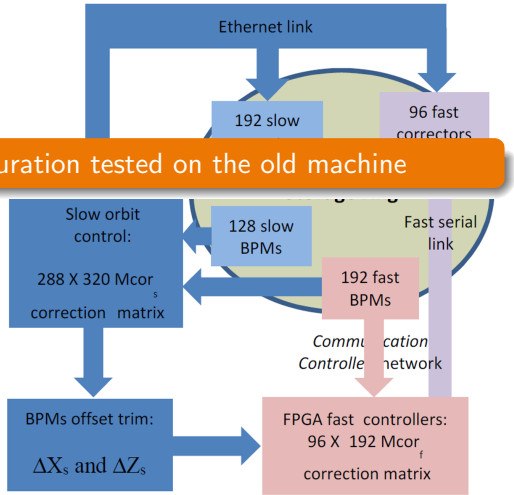
E. Plouviez et al., MOPG09, IBIC'16

Fast Orbit Feedback

- 96 Correctors $\times$ 192 BPMs
- 10 kHz acquisition frequency
- [illegible]
- [illegible]
- boards to compute correctors settings via SVD
- Slow orbit position offset trim

$\rightarrow$ Effectiveness of the feedback configuration tested on the old machine

Correct perturbation up to 50 Hz $\rightarrow$ First girder resonance mode



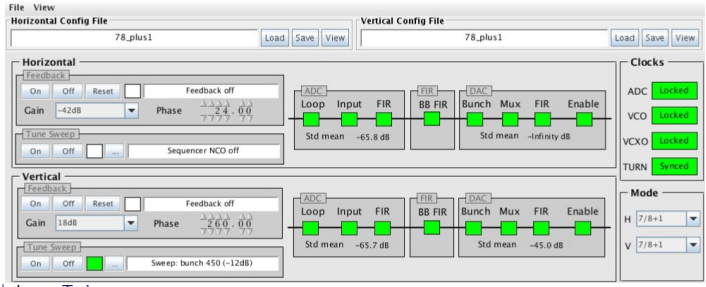
E. Plouviez et al., MOPG09, IBIC'16

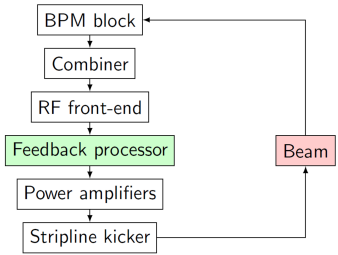
Multi-Bunch Feedback

Horizontal and Vertical Multi-Bunch Feedback
mainly to mitigate the ion instabilities during vacuum conditioning

⇓

Adopt the system developed by Diamond





EPICS to Tango wrapper
has been developed

M.G. Abbott, et al, THPHA115, ICALEPS'17

B. Roche, ARIES Workshop'18

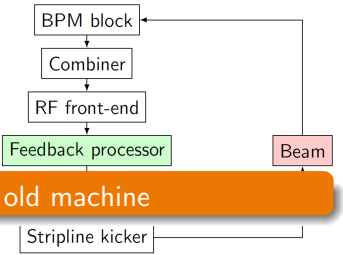
Multi-Bunch Feedback

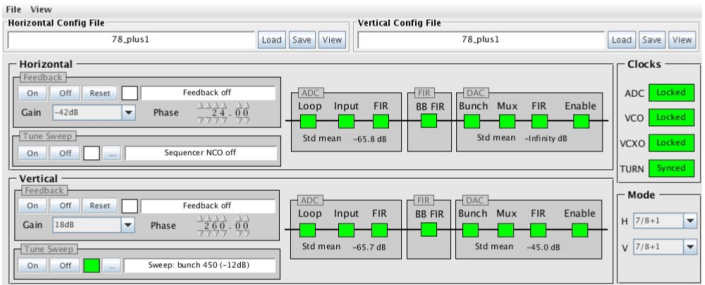
Horizontal and Vertical Multi-Bunch Feedback
mainly to mitigate the ion instabilities during vacuum conditioning

⇓

Adopt the system developed by Diamond

→ Installed and commissioned in 2017 on the old machine





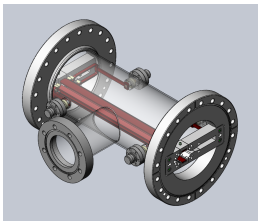
EPICS to Tango wrapper has been developed

M.G. Abbott, et al, THPHA115, ICALEPS'17

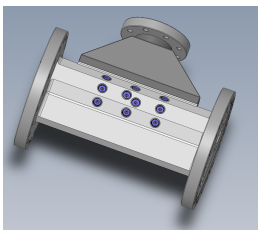
B. Roche, ARIES Workshop'18

Electromagnetic devices – Ch. 12

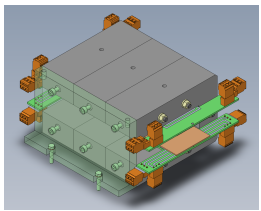
- 5 Striplines
  - 1 Filling Pattern
  - 2 Multi-Bunch Feedback
  - 2 Spares



- 3 Special BPM Blocks
  - 2 20-buttons
    → Tune meas.
    → Phase meas.
  - 1 16 buttons
    → Bump meas.



- 2 Shakers
  - Tune measurements
  - Injection damping
  - Beam blowup

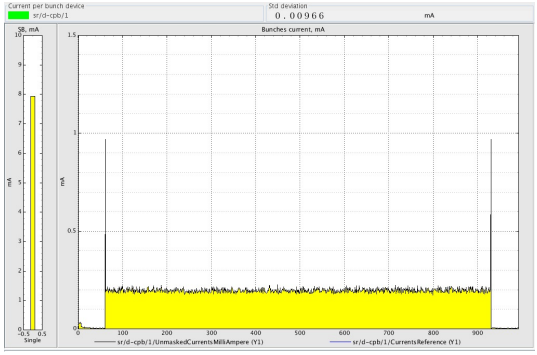


Bandwidth 1 MHz → Smaller with respect to the one of striplines but stronger excitation

E. Plouviez, et al. TUPIK041, IPAC'17

Filling Pattern and Bunch Purity

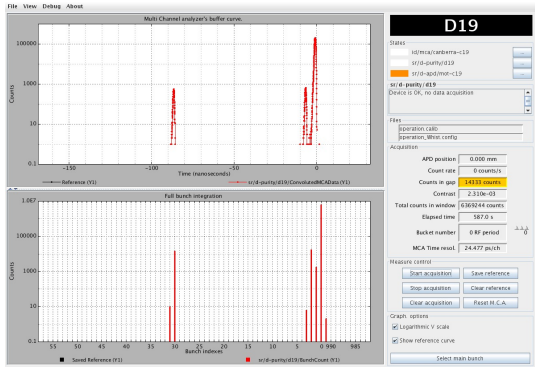
Filling Pattern → Horizontal Stripline + Oscilloscope + Data Analysis



Dynamic range: 10^3, all the beam, fast result

L. Torino, et al. MOPP002, IBIC'19

Bunch Purity → Time Correlated Single Photon Counting (X-Rays)

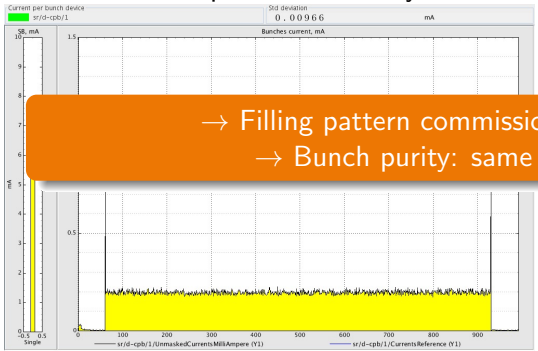


Dynamic range: 10^7, part of the beam, takes few minutes

B. Joly, et al., PM20, DIPAC'01

Filling Pattern and Bunch Purity

Filling Pattern → Horizontal Stripline + Oscilloscope + Data Analysis

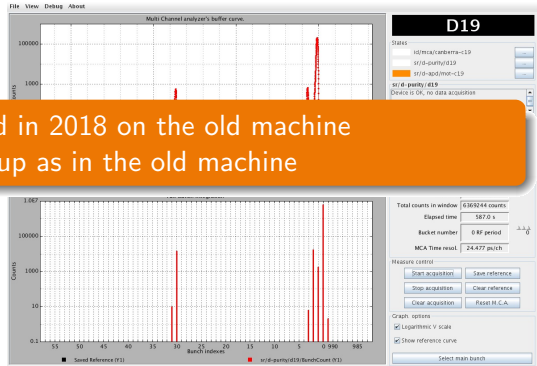


→ Filling pattern commissioned in 2018 on the old machine
→ Bunch purity: same setup as in the old machine

Dynamic range: 10^3, all the beam, fast result

L. Torino, et al. MOPP002, IBIC'19

Bunch Purity → Time Correlated Single Photon Counting (X-Rays)



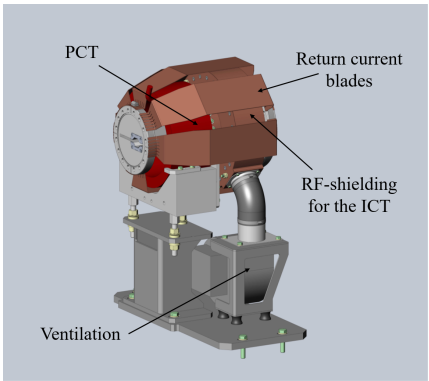
Dynamic range: 10^7, part of the beam, takes few minutes

B. Joly, et al., PM20, DIPAC'01

Current Transformers

6 Bergoz Current Monitors:

- 3 Parametric Current Transformers to measure the DC current
- 2 Integrated Current Transformers to measure the single bunch current when operating in timing mode
- 1 Fast Current Transformer to monitor the filling pattern



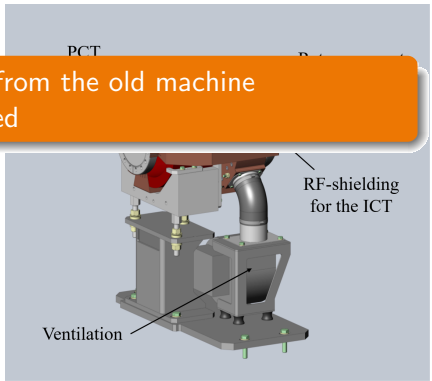
Mechanical implementation optimized to minimize impedance.

Current Transformers

6 Bergoz Current Monitors:

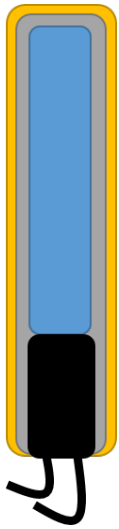
- 3 Parametric Current Transformers to measure
  - the single bunch current when operating in timing mode
- 1 Fast Current Transformer to monitor the filling pattern

→ Five out of six CTs has been re-used from the old machine
→ Software unchanged

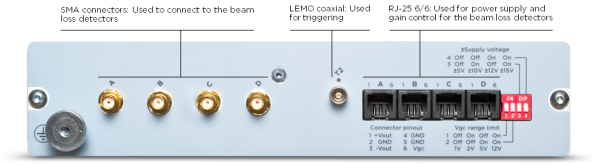


Mechanical implementation optimized to minimize impedance.

Beam Loss Monitors

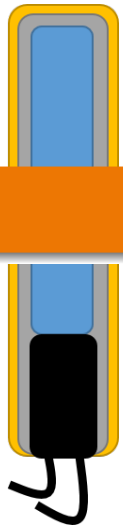


- 128 BLDs PMT+Scintillator+Lead shielding
- Power/Readout electronics Libera-BLM
- 4 BLDs per BLM (32)
- Independent gain and attenuation settings
- Relative calibrated losses
- Capability for almost BbB and full TbT losses measurements



L. Torino, et al., WEOB01, IBIC'18

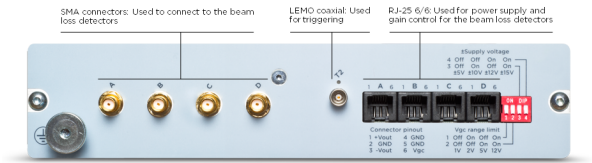
Beam Loss Monitors



- 128 BLDs PMT+Scintillator+Lead shielding
- Power/Readout electronics Libera-BLM
- 4 BLDs per BLM (32)
- Independent gain and attenuation settings

→ Commissioned in 2018 on the old machine
→ Data available for comparison

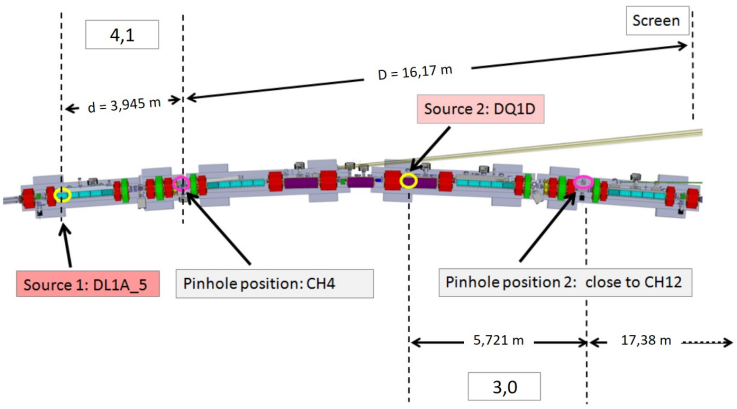
measurements

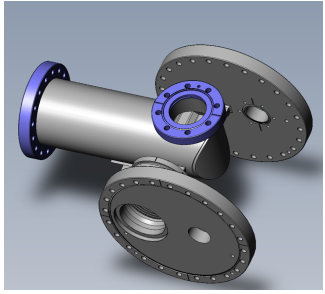


L. Torino, et al., WEOB01, IBIC'18

Emittance Monitor

5 x-rays ports available for **emittance** and **energy spread** measurements. Each of this port will be equipped with a **pinhole**.





DL1A_5 vacuum chamber modified to locate the pinhole

Emittance and Energy Spread

	Hor.	Vert.		
		$C = 4\%$	$C = 1\%$	$C = 0.1\%$
ε	150 pm	5 pm	1.3 pm	0.13 pm
σ_{DL1A_5}	15 µm	9 µm	4.7 µm	1.5 µm
σ_{DQ1D}	19 µm	4 µm	2.2 µm	0.7 µm

$E_\gamma \simeq 100$ keV. DL1A_5 preferred location for emittance measurements. Resolution 5 µm

F. Ewald, ARIES Workshop'18

Energy spread obtained from beam size measurements at different locations:

$$\delta E = \sqrt{\frac{\beta_2\sigma_1^2 - \beta_1\sigma_2^2}{\beta_2\eta_1^2 - \beta_1\eta_2^2}}$$

	B [T]	β_x [m]	β_y [m]	η [m]	M
DL1A_5	0.62	1.59	16.64	0.0007	4.1
DQ1D	0.55	1.442	3.844	0.01302	3.0

Emittance and Energy Spread

	Hor.	Vert.		
		$C = 4\%$	$C = 1\%$	$C = 0.1\%$
σ_{DL1A_5}	15 µm	9 µm	4.7 µm	1.5 µm
σ_{DQ1D}	19 µm	4 µm	2.2 µm	0.7 µm

$E_\gamma \simeq 100$ keV. DL1A_5

Pinhole workhorse to measure beam size at ESRF for more than 20 years

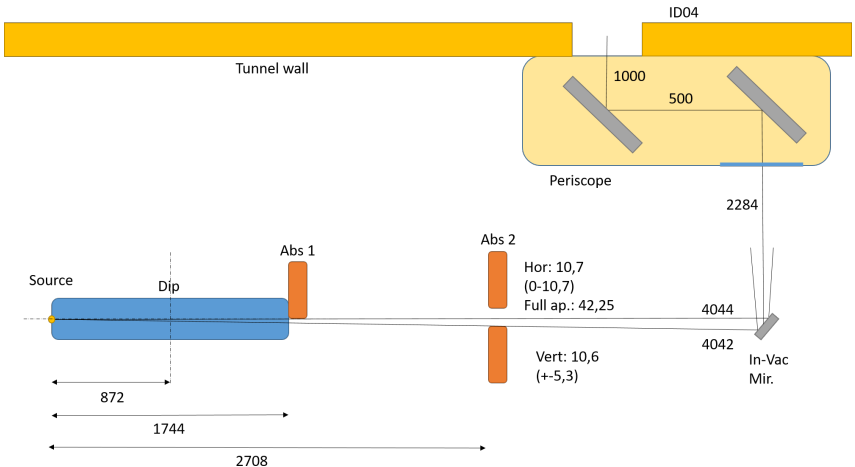
Resolution 5 µm

F. Ewald, ARIES Workshop'18

Energy spread obtained from beam size measurements at

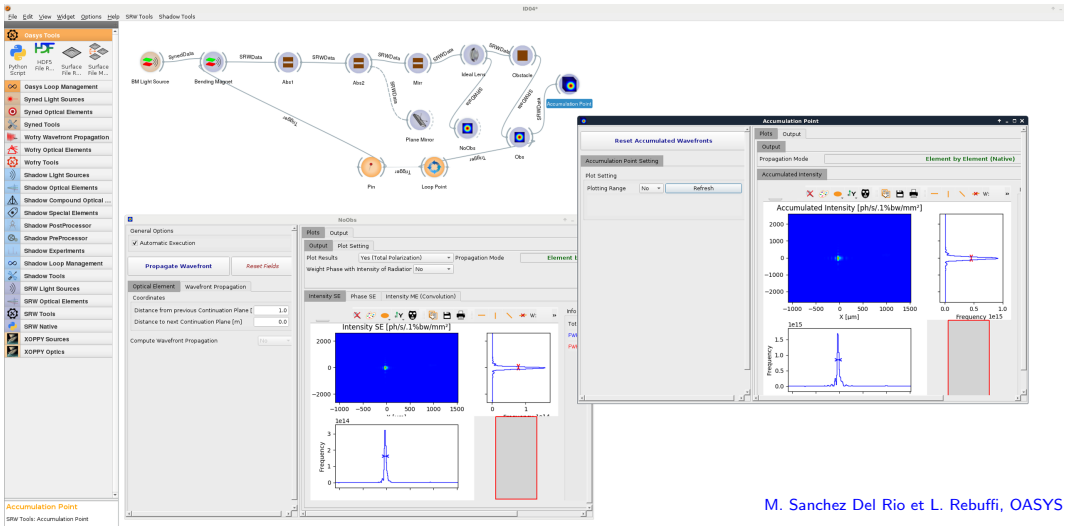
Measurement of the ultra low beam sizes still under investigation... (Berillium lenses, interferometry, diffraction masks...)

Visible Light Beamline



Bunch Length measurements using a Hamamatsu C10910 streak camera

Visible Light Beamline – Bonus



M. Sanchez Del Rio et L. Rebuffi, OASYS

Future Developments

- Extremely small sources and X-Ray beamlines are pushing on the synchrotron radiation beam position stability requirements
- Measurement of ultra low beam sizes, test of new sources and detectors

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- X-rays BPMs to be integrated to the closed orbit loop control system
- Full diagnostics x-ray beamline

Summary

- Several diagnostics elements are re-used from the old machine (as required)
- Most of the new setups has been tesed and commissioned on the old machine
- Beginning of November $\rightarrow$ Tunnel will be closed
- December 2 $\rightarrow$ Commissioning will start

Summary

- Several diagnostics elements are re-used from the old machine (as required)
- Most of the new setups has been tesed and commissioned on the old machine
- Beginning of November → Tunnel will be closed
- December 2 → Commissioning will start
  - Install diagnostics in the tunnel
  - Finalize the cable connection
  - Perform the hardware test of the distributed systems
  - Adapt the scripts to the control system upgrade
  - Commission EBS!