New Beam Loss Detector System for EBS-ESRF

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IBIC 2018, 12/09/2018

Beam Loss Detection

Monitor and localize the particle losses around the storage ring to prevent the accelerator from damages, see "hidden" obstacles, and improve the machine parameters

- **Slow Losses:** Unavoidable, determine the beam lifetime. Time scale $\simeq 1\,\mathrm{s}$
- **Fast Losses:** Accidental, caused by traumatic events. Down to the single bunch time scale.

ESRF-EBS

European Synchrotron Radiation Facility

Extremely Brilliant Source

ESRF-EBS

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ESRF $\Rightarrow$ EBS
Lower horizontal emittance $\Rightarrow$ higher and more coherent synchrotron radiation flux

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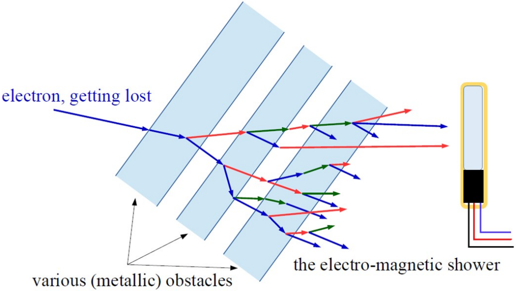
Current ESRF system is not compatible with EBS $\Rightarrow$
Design a new system for EBS and commission it on ESRF

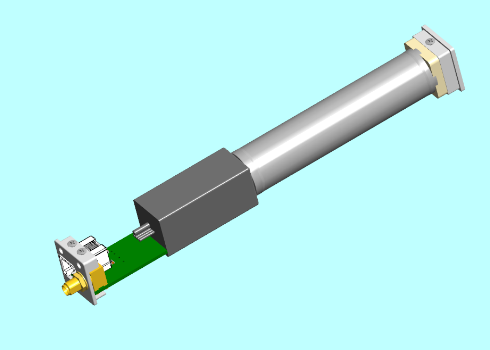
Requirements for the new system

- 6 GeV electron losses
  - Slow losses
  - Fast losses
- Compact
- System "off shelf"



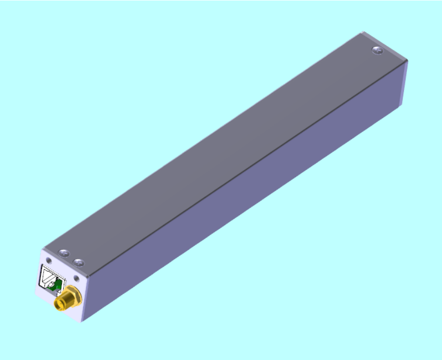
→ PMT-scintillator based detector
→ Libera BLM electronics

Detector



- PMT Hamamatsu H10721-110
  - 8 mm active area
  - Powered 5 V
  - 0-1 V gain control
- EJ-200 scintillator rod (100x22mm)
  - Wrapped in reflective foil
- Aluminum casing
- "Light" lead shielding

Detector



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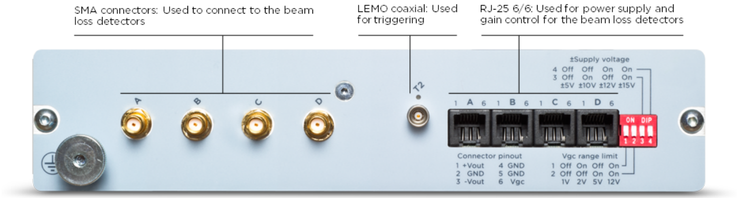
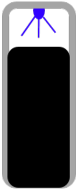


- Power and control 4 BLDs
- 4 independent 5 V power supplies
- 4 independent gain control channels and 0-31 dB attenuation
- 4 independent read out channels
- 4 independent impedance settings (50 Ω/1 MΩ)
- Trigger input
- $>$ 10 MHz bandwidth
- 8 ns ADC sample (125 MHz)

PMT Calibration

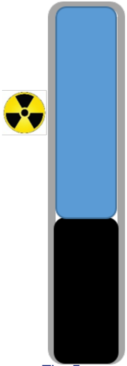
PMT output depends on sensitivity and the applied gain ⇒ Important to obtain comparable data from different PMTs

Blue LED
(In-lab)

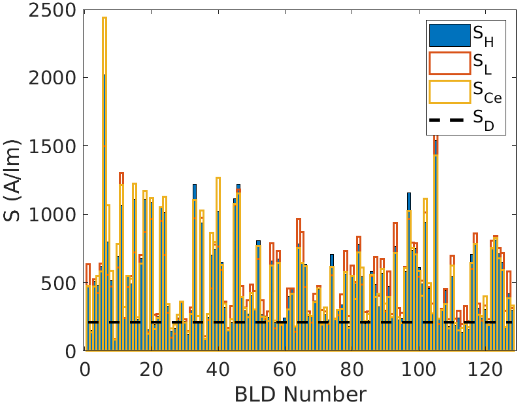


Register the PMT output and compare with the PMT specification

Ce137 Source
(In-situ)

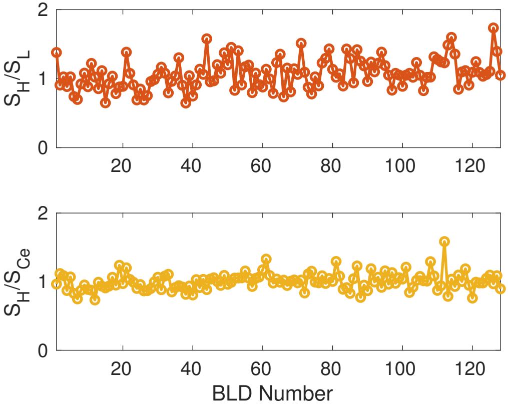


Calibration – Sensitivity



- S_H: Sensitivity individual data-sheet
- S_L: Sensitivity measured with the LED
- S_{Ce}: Sensitivity measured with the Ce137 source
- S_D: Sensitivity data-sheet

Calibration – Sensitivity



- $S_D = 210\,\mathrm{A/lm}$
- $S_{H,avg} = 483\,\mathrm{A/lm} \pm 70\%$
- $\frac{S_{H,avg}}{S_{L,avg}} = 1.06 \pm 20\%$
- $\frac{S_{H,avg}}{S_{Ce,avg}} = 1.002 \pm 12\%$

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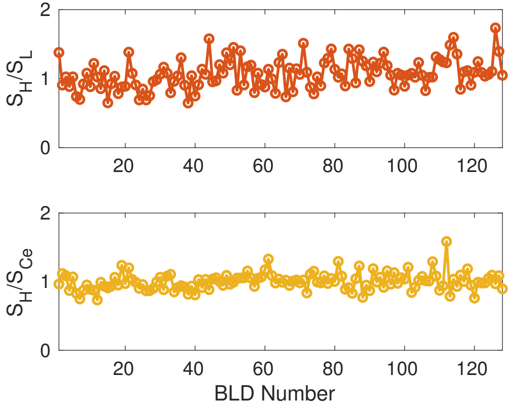

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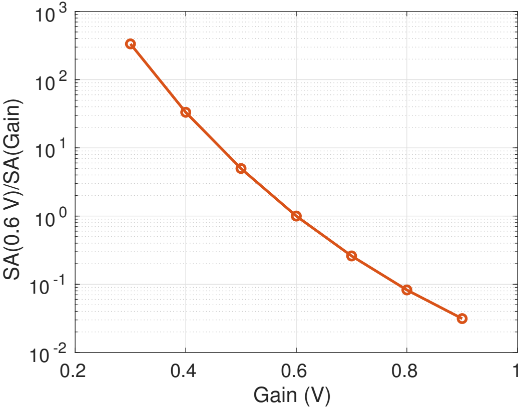
Final sensitivity: average of the three values

Calibration – Gain

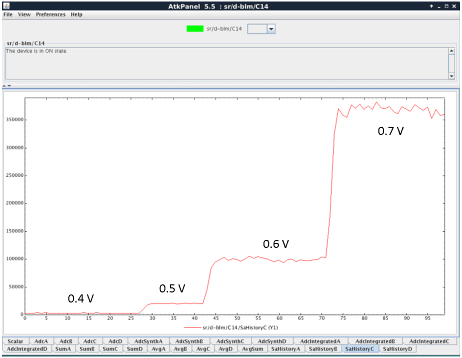
PMT output signal depends on the PMT gain



Libera BLM Calibration

$$SA_C = SA \times G \times C \times A$$

- SA_C: Calibrated Losses
- SA:Raw losses
- G: Depends on the applied gain
- C: Inverse of PMT anode sensitivity
- A: Depends on the BLD Attenuation



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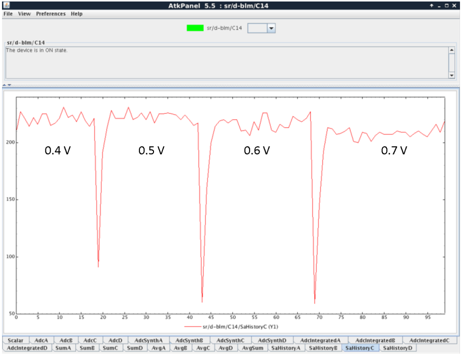

X-Rays Background

Scintillator sensitive to synchrotron radiation scattered x-rays

"Minimal-Losses" condition
→ Low current per bunch
→ High vertical emittance
⇓

Touschek effect suppressed

Scraping current from 20 to 0 mA

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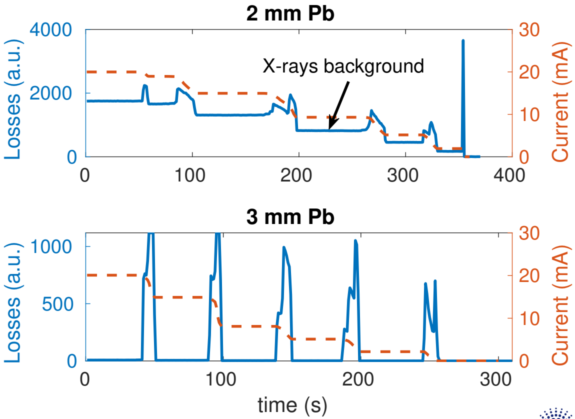

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Scintillator sensitive to synchrotron radiation scattered x-rays

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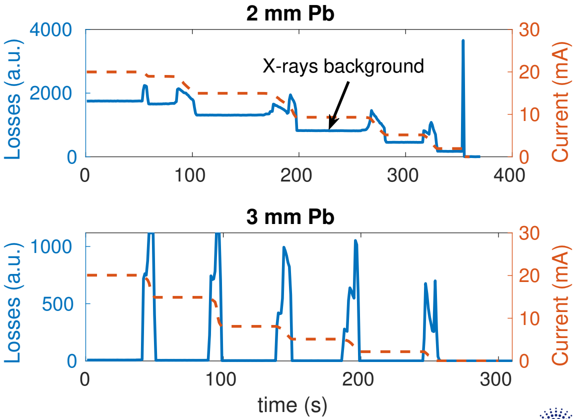
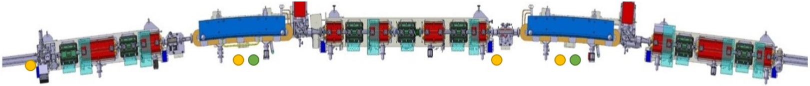
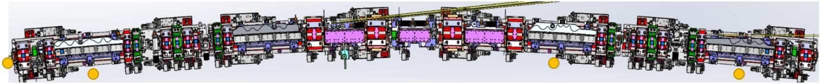
Touschek effect suppressed

3 mm lead shielding cuts the background



Location ESRF-EBS



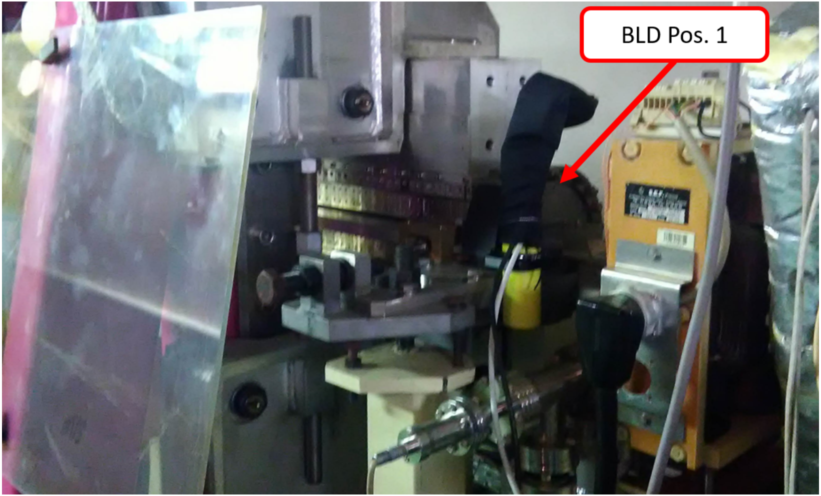


- Inner side of bending magnets
- Comparison old BLD system
- Losses @ IDs monitoring

"Old" BLD system:
64 detectors

"New" BLD system:
128 detectors

ESRF Location Example



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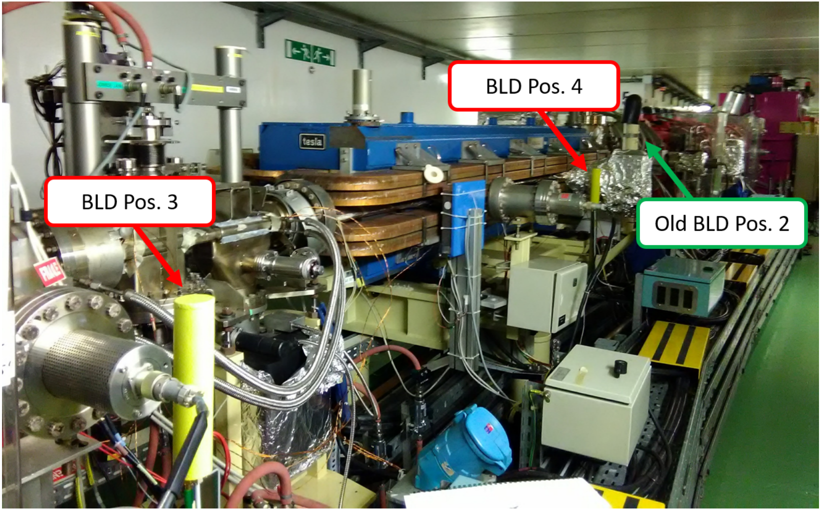
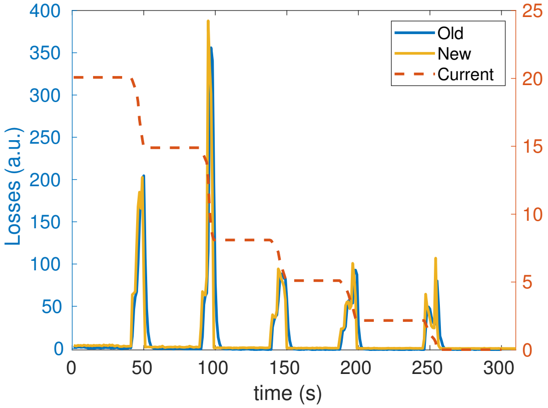


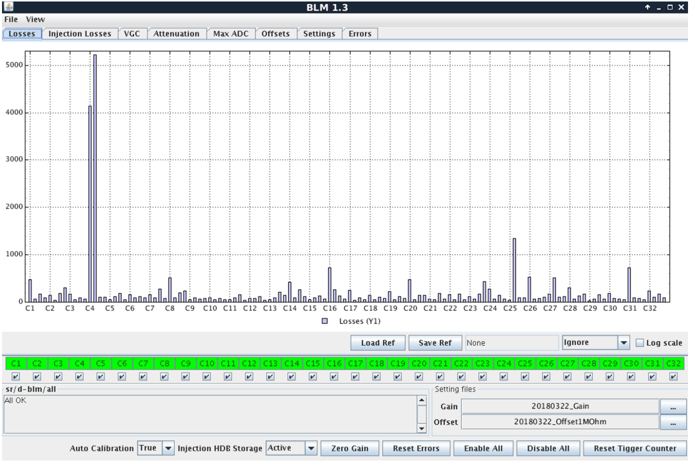
Comparison New-Old BLD system

Temporal overlap of the two systems ⇒
Possibility of comparison



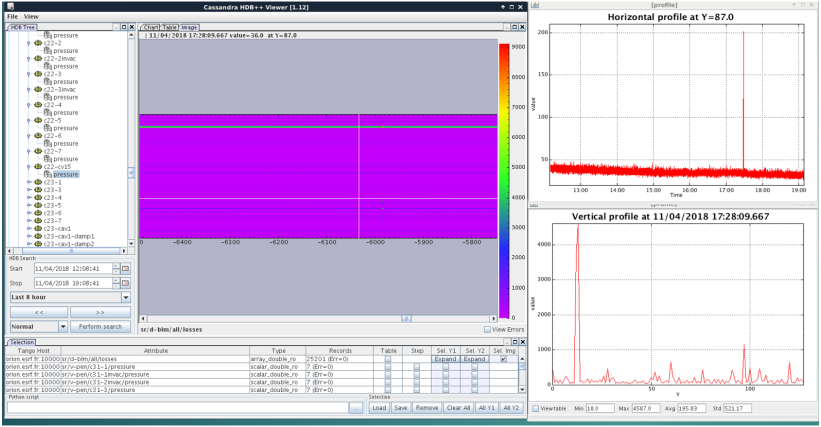
Scraping current
from 20 to 0 mA

Operation



- Auto-gain function
- Decay-mode
- Injection-mode

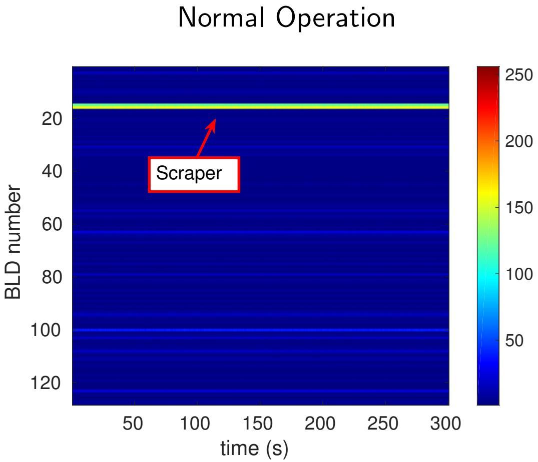
Archive


Cassandra HDB++ Viewer [1.12]
Horizontal profile at Y=87.0
Vertical profile at 11/04/2018 17:28:09.667
sr/d-blm/all/losses
Last 8 hour
Perform search

Decay-mode operation

- 1 MOhm impedance
- Not-synchronous
- Integration over $\simeq$ 130.000 turns (0.4 s)
- 1 Hz repetition rate

Useful in the control-room to monitor on-line losses distribution



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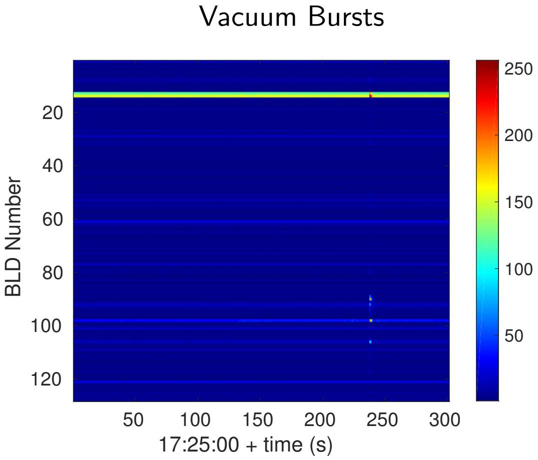

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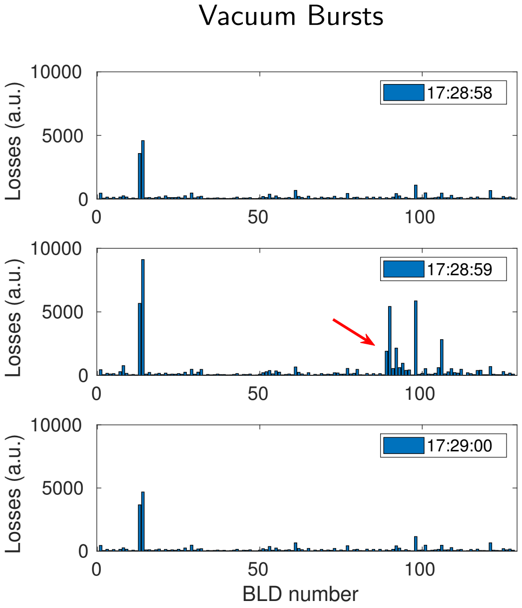

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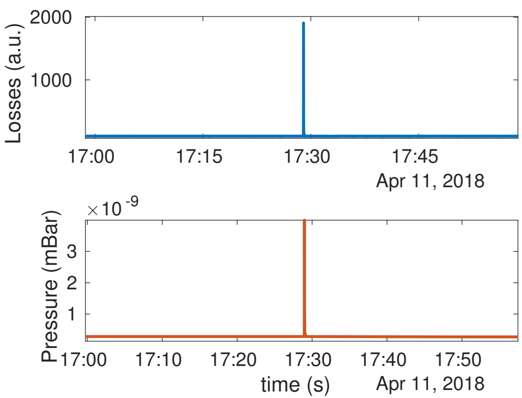
Vacuum Bursts

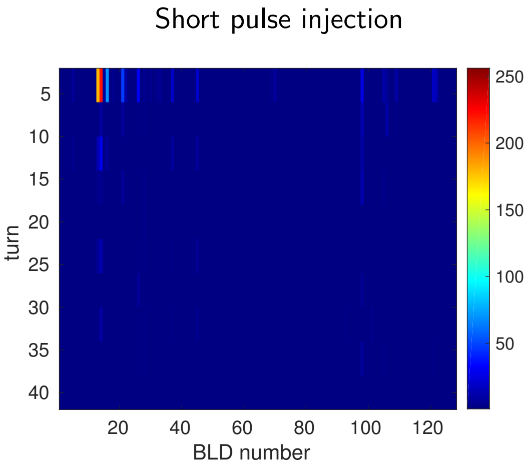


Injection-mode operation

- 50 Ohm impedance
- Synchronous data
- Average over 4 turns, sum of 10 averages
- 4 Hz repetition rate

Automatic switch when linac and injection kicker on

One value, per BLD, per shot along the injection is stored



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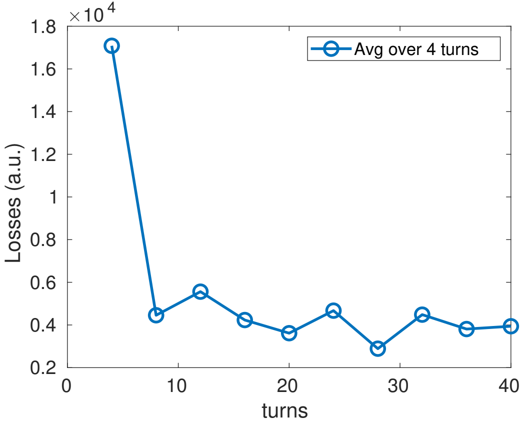
Short pulse injection



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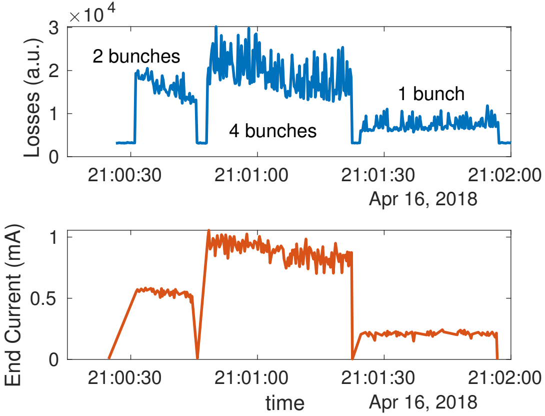
7/8+1 injection

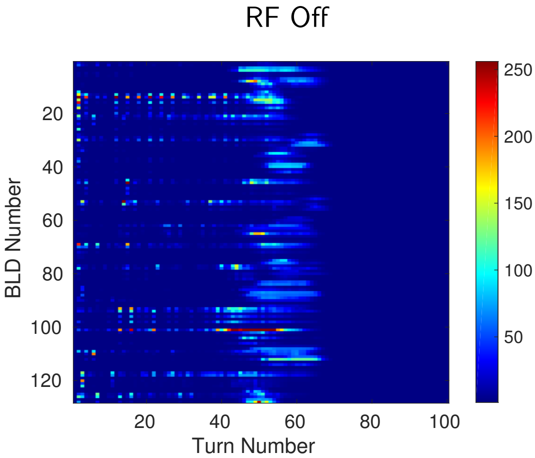


Turn-by-Turn Losses

- 50 Ohm impedance
- Synchronous data
- Sum over 1 turn
- 4 Hz repetition rate

Interesting for EBS commissioning

One shot injection and RF off



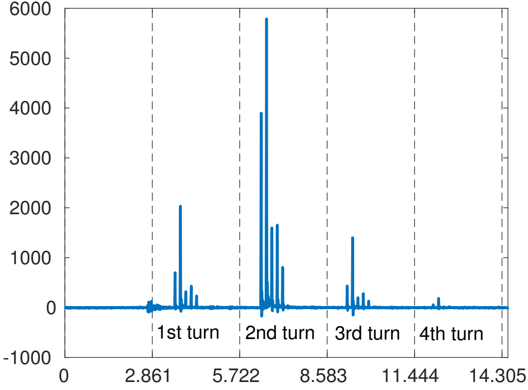
ADC Data

- 50 Ohm impedance
- Synchronous data
- 8 ns resolution
- 4 Hz repetition rate

Almost Bunch-by-Bunch losses

Data taken during injection

5 bunches injection



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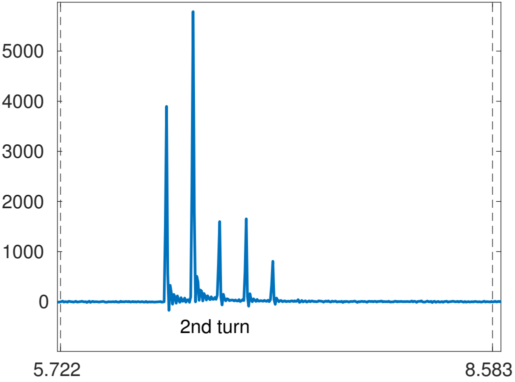

Outlooks

- New BLD system has been installed at ESRF
- PMT calibration
- Background suppression
- Location
- Operation
  - Decay-mode
  - Injection-mode
- Turn-by-Turn losses
- (Almost) Bunch-by-Bunch losses

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Ready for EBS!

ESRF-EBS

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Many thanks to K. Scheidt, N. Benoist, F. Taoutaou, J.L. Pons, P. Colomp, P. Leban, Beam Dynamics, Insertion Devices, and Operation groups!