NEW CERN SPS BEAM DUMP IMAGING SYSTEM

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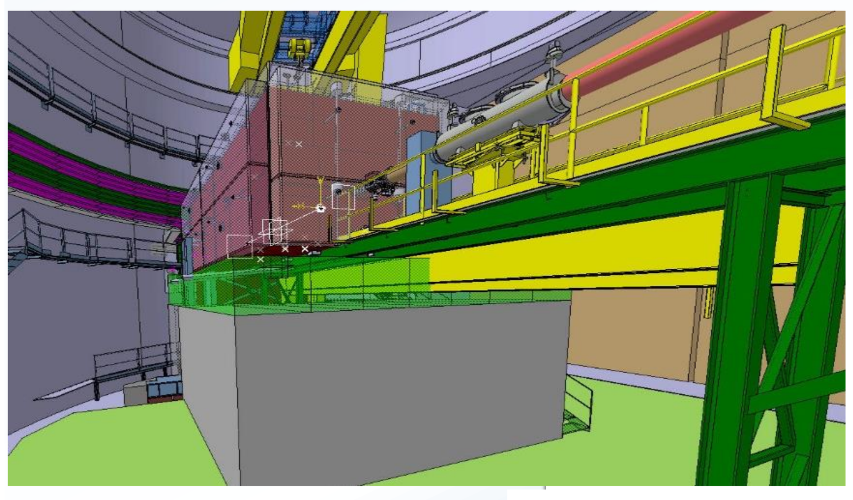
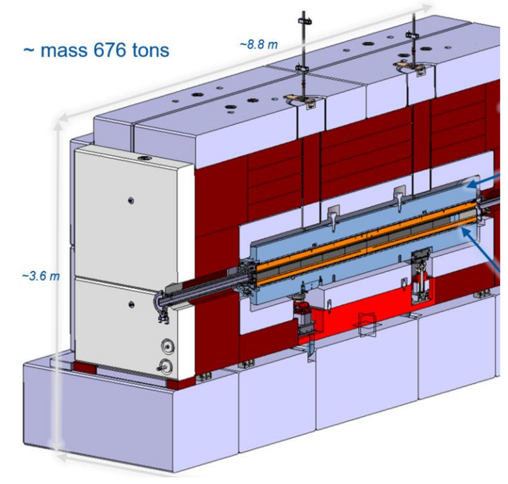
ABSTRACT

As part of the LHC injector Upgrade (LIU), the CERN SPS is now equipped with a new Beam Dumping System (SBDS) designed to cope with the high power beams fore-seen for the High Luminosity LHC (HL-LHC) era. Before reaching the dump, the proton beam (from 26 to 450 GeV) is vertically kicked and then diluted passing through a series of horizontal and vertical bumps. This prevents the dump damage, by reducing the power density per surface unit. The quality of each dump event must be recorded and verified and all parameters of the SBDS are logged and analysed from the so-called Post-Mortem dataset. An essential part of the verification is performed by a beam imaging system based on a Chromox screen imaged on a digital camera. The desired availability level of 100% (to protect the dump) and the harsh radiation environment made the design extremely challenging. For example, it implied the need for a 17 m long optical line made of high-quality optical elements, a special camera shielding (to minimise single event upsets) and a generally careful design accounting for maintenance aspects, mainly related to expected high activation levels. After giving an overview of the whole imaging system design with details on the chosen layout and hardware, this paper will discuss the DAQ and SW architecture, including the automatic, on-line, image selection for validating every dump event. This will be complemented with experimental results demonstrating the performance and reliability achieved so far.

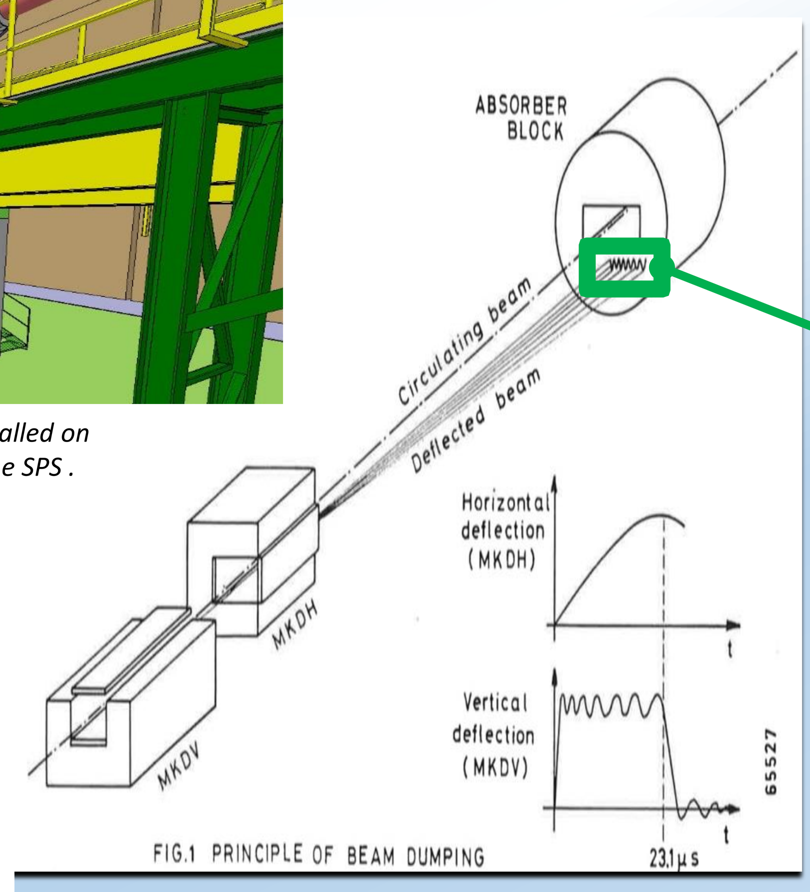
NEW SPS INERNAL DUMP

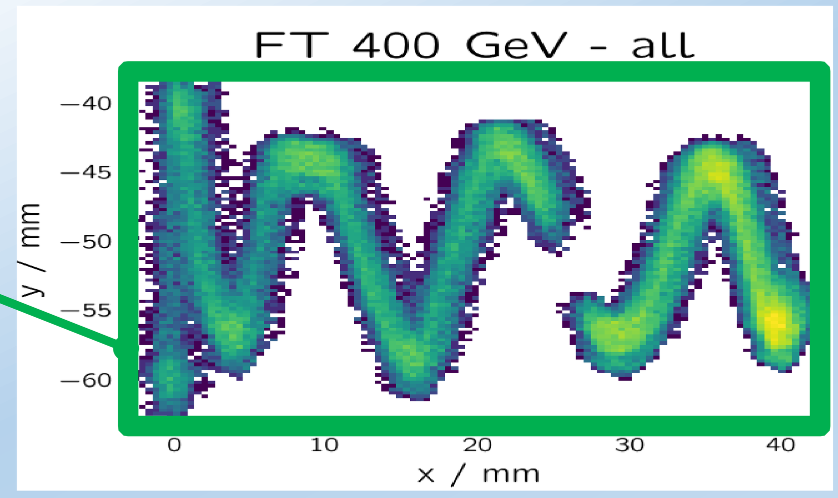


Pictures of the new SPS Dump being installed on its concrete basement in section 5 of the SPS .



BEAM DUMP SIMULATION





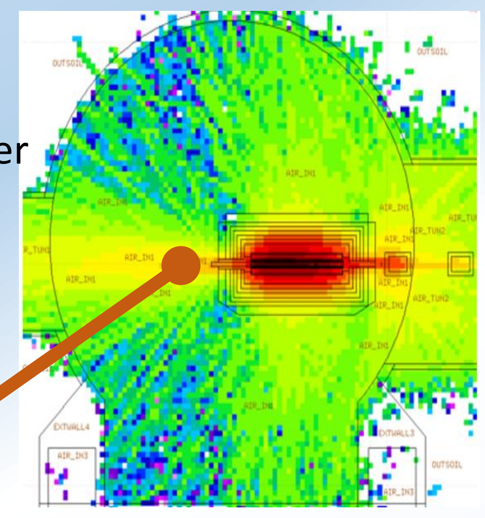
Simulation of beam dilution on the dump for a Fixed Target beam (F. Velloti)

Monitoring beam shape and position parameters at the SBDS faceplate is crucial to certify proper operation and avoid internal damage

RADIATION LEVEL

Simulations at the beam instrumentation location shows per year:

- ***TID up to 10KGy***
- ***HEH up to 1e13/cm2***



Proposed location for instrumentation ~4m upstream the front plate of the SBDS

Simulation of the radiation level after 1 year of operation. Top view at the beam level

INSTRUMENTATION SPECIFICATIONS

- ***"All beam extractions must be recorded over the full beam energy range (14 to 440GeV) and intensity range (5e9 to 8e13p) of the SPS machine"***
- ***Spatial resolution <200um H & V***
- ***Easy and fast maintenance due to radiation level***

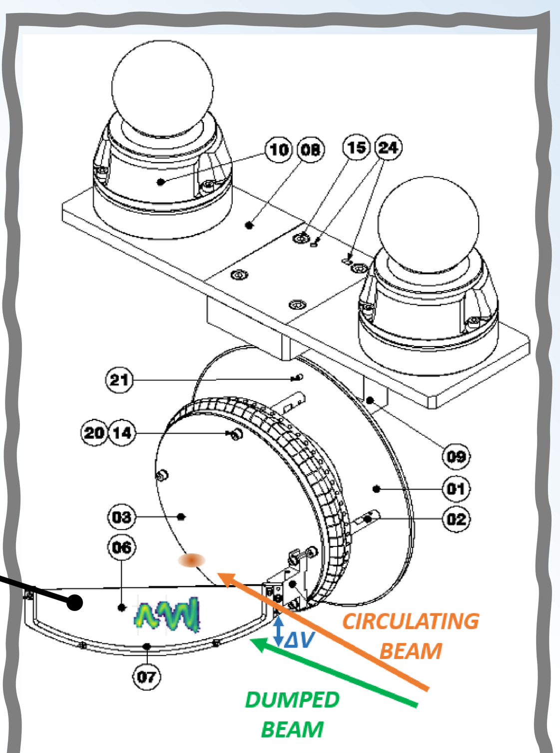
SBDS IMAGING SYSTEM

This new device will be using a **scintillation screen** installed permanently on the beam extraction patch. **The interaction of the beam particles with the screen generates photons** that are driven only with means of **high-quality mirrors** to a **shielded camera** 17m away of the **high level of radiation area**.

HARDWARE

Permanent IN-beam **Scintillation Screen** of so-called 'Chromox' type:

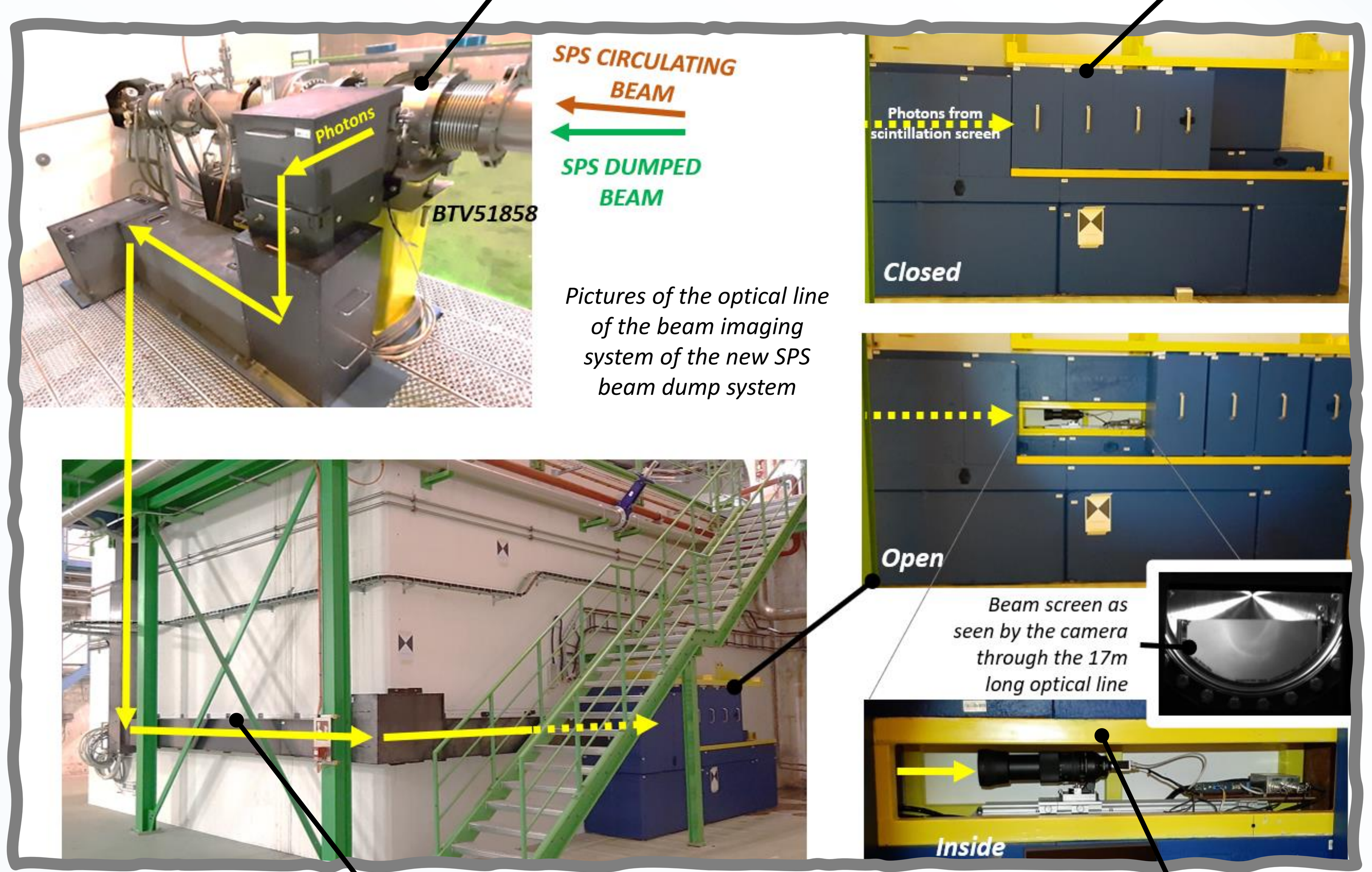
- Dump rate up to **~333 per hour**
- Worst case density on screen with dilution kicker failure: **6.5E12p/mm2**
  → **OK for the screen**
- **Impedance optimization** with RF finger design



Scintillation screen mounted on its support design for fast replacement in case of failure

Dedicated shielding:

- Needed to guaranty very **limited number of SE, <1/year and 100% availability of the camera**
- **Few tons of iron** and concrete blocks are needed to reach this performance as per the FLUKA simulation



Pictures of the optical line of the beam imaging system of the new SPS beam dump system

Optical Line designed with ZEMAX optical Studio:

- 17m long
- 5 high quality mirrors: flatness λ/5)

Digital Camera

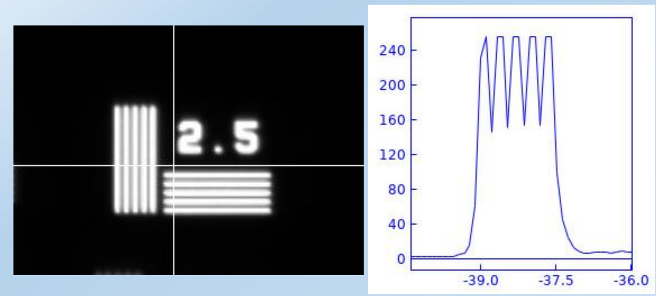
- BASLER Aca2040-35gm

Camera Lens

- F600mm focal length / NA 5.6

OPTICAL PERFORMANCES

Use of a 2.5 line-pair/mm target to validate the expected optical resolution of <200um simulated with ZIMAX tools.



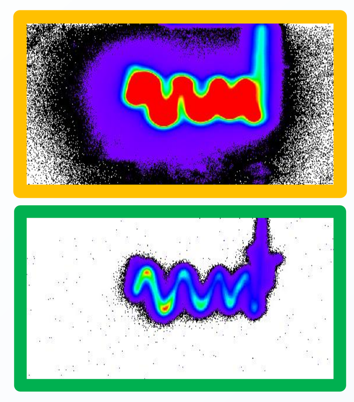
Spatial resolution [um/px]	108
Optical resolution [um] / Visibility [%]	200 / >35

SOFTWARE

The acquisition takes profit of the **long decay time property of the Chromox material**, permitting to **capture multi-images of the same events and perform an online selection**.

Acquisition process:

- **Free running camera @ 35Hz**
  continuously feeding 'Rolling' memory buffer of 100 images
- **Dump Trigger is given by the extraction kicker** (synch & asynch)
  → **start to fill a 100 images memory space with:**
  pre-trigger images: used for noise 'cleaning'
  post-trigger following images are saved for online analysis
  → **Automatic selection of 1st image not saturated**



Example of image selection. Top is first image at trigger event. Down is the 9th with values below the saturation level. This image is selected and publishes.

Internal watchdog

Periodically checks:

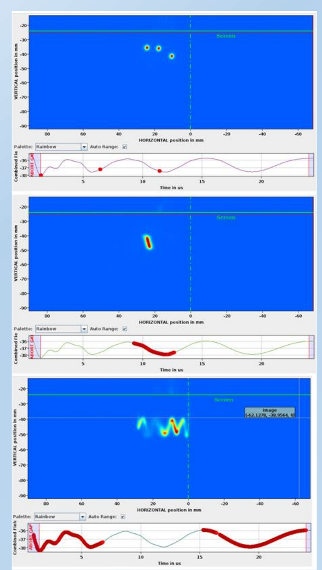
- **status of camera and Ethernet switch,**
- **consistency between the settings in FESA and the camera**

→ In case of issue: **Automatic reboot of the camera and ethernet switch**

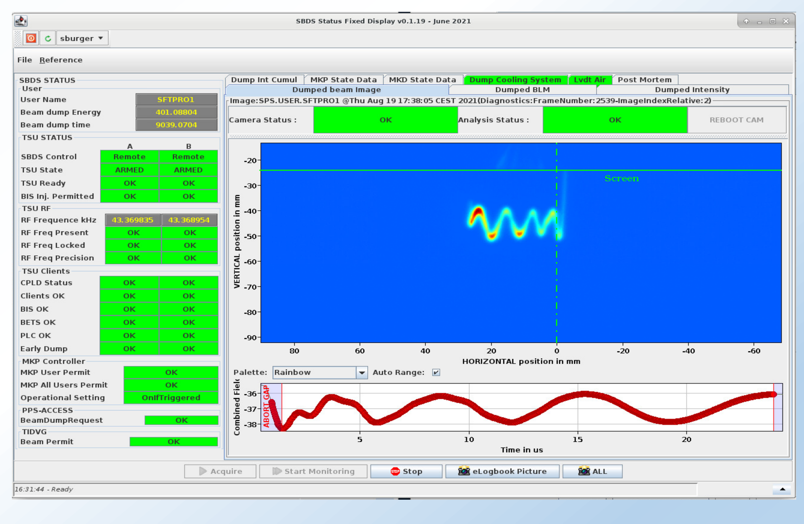
OPERATIONAL RESULTS

Commissioning

Extensively used from day 1 to evaluate the kickers transfer functions, the effect of kicker failures and the polarity of the horizontal kicker responsible for the particle density dilution at the dump block.



Images taken during SBDS commissioning confirming the good behaviour of the beam extraction system, increasing progressively the number of bunch in the machine from top to bottom plots.



SBDS Status Fixed Display showing together with all parameters required for a proper dump extraction the status of the imaging instrument and the selected image of the last event.

Operational tool

The selected image is shown online from the GUI of the SBDS Status Fixed Display.

The status of the instrumentation is part of the Interlock system.

Work is ongoing to extract this information with machine learning methodologies to assess, together with direct kicker monitoring, the occurrence of failures.

CONCLUSION

The **new SPS Beam Dump System** (SBDS) was equipped with a **dedicated beam imaging system**, designed to monitor and qualify every single beam dump event. The instrument is based on a **fixed scintillating screen** in front of the dump and a **digital camera** as detector. The **harsh radiation environment** required a challenging design with the integration of a **17 m long optical line composed of 5 high quality mirrors** (flatness of λ/5). The light is thus transported from the dump to a **radiation shielded bunker** protecting the digital camera from radiation. This monitor is a fundamental device to continuously assess the beam extraction and dump quality as well as the health of the whole system. A new **on-line image selection process** was deployed to ensure the published image for Post-Mortem analysis is not saturated. The software also includes **automatic rebooting** from internal hardware and a communication status watchdog, thus minimizing downtime. This **watchdog is also part of the global interlock system**, ensuring that no injection occurs if the monitoring is off. The commissioning of the SPS beam dumping system was performed from day one with the full availability of this new beam imaging instrumentation. It was then extensively used to evaluate dump kicker and diluter performance. **An operational GUI is available in the control room with data showing the dilution of the beam on the dump**, and work is ongoing to extract this information with machine learning methodologies to assess, together with direct kicker monitoring, the occurrence of failures.