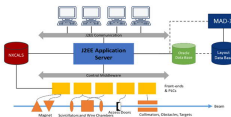




Introduction

Abstract
The CERN fixed target experimental areas are composed of more than 10m of beam lines with around 800 devices used to define and monitor the beam parameters. Each year more than 140 groups of users come to perform experiments in these areas, with a need to control and access the data from these devices. The software to allow this therefore has to be simple and robust, and be able to control and read out all types of beam devices. This contribution describes the functionality of the beam line control system, CESAR, and its evolution. This includes all the features that can be used by the beam line physicists, operators, and device experts that work in the experimental areas. It also underlines the flexibility that the software provides to the experimental users for control of their beam line, allowing them to manage this in a very easy and independent way. This contribution also covers the on-going work of providing MAD-X support to CESAR to achieve an easier way of integrating beam optics. An overview of the on-going software migration of the Experimental Areas is also given.

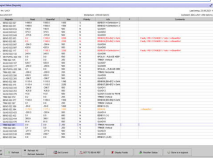
Introduction
CESAR is based on Java and constructed around an Oracle Database. It requires and sets up-called equipment knobs, mainly by subscribing to the Front-End Software Architecture (FESA) device. In addition, it provides information from other services such as from the access system database (Access DB), via the Data Interchange Protocol, and the data logging system INCA/AL. All devices are identified in the CESAR database together with their parameters, such as FESA name, element type, name, and others. This allows flexible modifications as often needed in secondary beam lines.



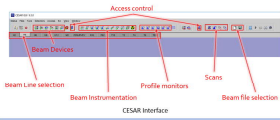
CESAR Architecture and Foreseen Connectivity.

CESAR Device Control

Magnets
In the magnets status panel, all magnets of the selected beam line are displayed together with their main parameters. It is possible to set and read the applied current values for each of the magnets and reference values can be defined in addition. This reference allows to go back to previous configurations, e.g. when steering the beam. CESAR also displays magnet faults together with the specific fault type, e.g. overvoltage.



Magnets Status (You can see the display of faults in red colour)



Interface
The CESAR interface is composed of three main panels, as depicted below the top menu, the devices panel and the beam line selection tab. The latter is used to change the selected beam line and control the devices associated with it. This functionality is reserved for super-users. The devices panel displays the main features and functionality, which is needed during setting up and tuning of beams, as well as during the operation during a physics run. On the top menu, specific panels can be opened within the devices panel, including specific modules and panels that are related to particular beam line equipment, beam line protection, user configurations and other settings. In addition, automatic user programs used for precise beam steering can be updated that allow efficient tuning of selected elements while visualizing direct feedback to the beam instrumentation.

Collimator
For collimator settings, each of the motors moving individual jaws is controlled. Collimators with four jaws are considered as two different entities, one vertical and one horizontal, for a better overview. They are used for changing intensity, shape, and energy spread of a beam. Similar to the magnet settings, one can set reference values for each of them, as can be seen.



Collimators Status

Obstacles
In order to create and absorb different particles types as well as for creating tertiary beams, different materials ("obstacles") can be placed in the beam. The Obstacles Command allows the users to control the position of each device and to add or remove different kinds of material externally as these devices are monitored. The positions are all entered in the CESAR DB, so one can directly select the desired obstacle to be placed and keep a reference, as well.

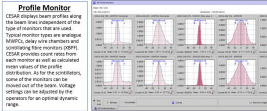


Obstacles Status

Beam Instrumentation and Scan

Scintillators
The trigger status displays counts from each scintillator along the selected beam line. In addition, it calculates normalized counts, which are normalized to the beam intensity in the upstream primary pages in order to avoid fluctuations coming from the primary beam. As they are monitored, scintillators can be moved out of beam on demand, e.g. to reduce absorption for low-momentum electrons. Furthermore, in each control room, users can connect their discriminated NIM detector signals to scalar units, which are then displayed on CESAR and allow beam operators to scan and set the beam position for a maximum number of events.

Scintillators Status



Profile monitor Status

Scan
CESAR offers the possibility to perform scans on any beam device and instrumentation. One can select the central element (e.g. magnet or collimator) and the instrumentation to perform a scan between certain values in selected steps. The scan will go through all preset values and plot the detector reading as a function of scanned parameter, e.g. a magnet current as depicted below. This scan allows to measure transmission through a beam line or to find the position of a user detector without the need of survey in the same FSC scan can be performed in different modes, i.e. one position per extraction in a fast mode for a complete scan during one extraction. There are different expert modes in addition, for instance to scan the beam divergence between two FSC monitors.



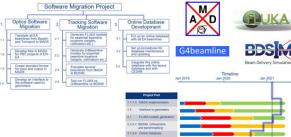
Scan Result

Software Migration Update and CESAR Future

Software Migration Project
The Software Migration project has been initiated with the goal of modernization of the offline software used for the description and design of the secondary beams at CESAR, analysed by the BE-CFA Section. A migration of the complete software chain used for the design of the secondary beamlines in both CESAR North and East Areas has been performed. The new baseline consists of MAD for beam optics and survey calculations, the in-house developed software ADEL for graphical output and matching as well as FUSION, SCOP and GEM for beam monitor interactions. The solution has been validated with the help of benchmark studies and a test of the complete software chain. It is planned to use the software in a highly integrated way, utilising the modern online database tools available at CERN, such as Layout Database and Gt4b.

The new software has become the baseline for Run 3 (2022-2025), which is expected to allow the final validation of its predictability and to reveal some aspects requiring improvement. While the major migration work has been completed according to the initial project plan, work on the adaptation of the software chain to the evolving software infrastructure at CERN as well as the integration of the beamlines into the Layout Database, the benchmarking studies and work on further automation are foreseen to continue during Run 3 and beyond.

Tests and Validation
The aforementioned tools have been tested individually. In order to assure smooth interfaces between the tools, a major part of the new software chain has been tested as a hardware modification in the North Area beamline C32. This modification consisted of moving several bending magnets and installing new detectors for the NA22 experiment. The following steps have been undertaken for the test:
(1) BEATCH files for the configurations of 2018 and 2021 have been forwarded to the EA configuration managers.
(2) The configuration managers implemented those two layout versions into the Layout Database.
(3) The tool for automatic processing of MAD-X input files from the Layout Database configuration has been successfully used.
(4) The file generated with the tool has been processed in MAD-X software, producing a Survey file for the geometries.
(5) The Survey file has been forwarded to the Metrology Group, which examined it and found it to be consistent with the existing Metrology Database entries with regards to naming convention and positions of the beamline elements.
Many of the use cases of the new software chain will be tested now thanks to the restart of beams after LS2. A large share of the North Area beamlines has still to be implemented into the Layout Database, which is planned to be completed by end of 2022.



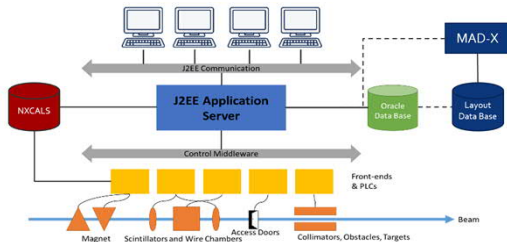
CESAR Future
The most important aspect from the configuration management point-of-view will be the connection of CESAR to the newly commissioned beam software. The project is on a good track and several new features for CESAR have already been developed, such as the Apple-to-Apple CESAR conversion and the automatic layout update with the Layout Data Base. We are thankful for the gentleness of users reaching out from the user community and from the recently established North Area Consolidation Project, which are evaluated at the moment. A frequently wished-for item is establishing an Application Programming Interface (API) for CESAR, permitting Super Users to access the CESAR functionality from within scripts. This would allow to automate even complicated steps for beam tuning with direct feedback from the beam instrumentation. In addition, connecting CESAR to the NICALS logging service will allow users to retrieve recorded values of any device in convenient way. Thinking further ahead, integrating fault reporting into CESAR, as well as the already existing Automatic Fault System API, will improve reliability analyses and save time of the operators.
In addition, the new CERN GUI Strategy working group currently reviews the existing GUI systems with the aim of streamlining and easing maintainability. This is a good opportunity to improve the graphical interface and to explore possible synergies with the other control systems of CERN, for instance by adding some useful features that have been developed for accelerator controls.

Abstract

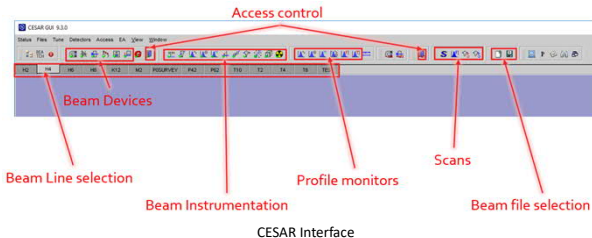
The CERN fixed target experimental areas are composed of more than 8km of beam lines with around 800 devices used to define and monitor the beam parameters. Each year more than 140 groups of users come to perform experiments in these areas, with a need to control and access the data from these devices. The software to allow this therefore has to be simple and robust, and be able to control and read out all types of beam devices. This contribution describes the functionality of the beam line control system, CESAR, and its evolution. This includes all the features that can be used by the beam line physicists, operators, and device experts that work in the experimental areas. It also underlines the flexibility that the software provides to the experimental users for control of their beam line, allowing them to manage this in a very easy and independent way. This contribution also covers the on-going work of providing MAD-X support to CESAR to achieve an easier way of integrating beam optics. An overview of the on-going software migration of the Experimental Areas is also given

Introduction

CESAR is based on Java and constructed around an ORACLE database. It acquires and sets so-called equipment knobs, mainly by subscribing to the Front-End Software Architecture FESA device. In addition, it receives information from other services such as from the access system database (Access-DB), via DIP (Data Interchange Protocol), and the data logging system NXCALs. All devices are identified in the CESAR database together with their parameters, such as FESA name, element type, beam line, and others. This allows flexible modifications as often needed in secondary beam lines



CESAR Architecture and Foreseen Connectivity.



CESAR Interface

Interface

The CESAR interface is composed of three main panels, as depicted below the top menu, the devices panel and the beam line selection tab. The latter is used to change the selected beam line and control the devices associated with it. This functionality is reserved for super users. The devices panel displays the main features and functionality, which is needed during setting-up and tuning of beams, as well as during the operation during a physics run. On the top menu, specific panels can be opened within the devices panel, including specific modules and panels that are related to particular beam line equipment, beam line protection, user configurations and other settings. In addition, automatic scan programs used for precise beam steering can be opened that allow efficient tuning of selected elements while visualising direct feedback by the beam instrumentation.



Magnets

In the magnets status panel, all magnets of the selected beam line are displayed together with their main parameters. There is the possibility to set and read the applied current values for each of the magnets and reference values can be defined in addition. This reference allows to go back to previous configurations, e.g. when steering the beam. CESAR also displays magnet faults together with the specific fault type, e.g. overheating

Magnet Status (Magnets)

Beam: H4 / LHC2
File: H4A.LHC2.017
Last time: 23.09.2021 10:50:08
Comment: ZDC.LHC2+350 GeV/c proton

Momentum: +350.00 GeV/c

Magnets	Read	BeamRef	Max	Property	Info	F	Comments
BEND-022-027	1406.9	1500.0	1500.0	S	BENDC01-H-Deflection-2		
BEND-022-031	1406.9	1500.0	1500.0	S	BENDC01-H-Deflection-3		
QUAD-022-034	375.0	375.0	500.0	N	QUAD001		
QUAD-022-041	375.0	375.0	500.0	N	QUAD002		
QUAD-022-049	375.0	375.0	500.0	N	QUAD003		
BEND-022-053	0.0	1198.0	2250.0	N	BENDC00-BI-Defl-1-Cath		Fault: IRB1-STAD001-Cath-1-BeamRef
BEND-022-053	0.0	1198.0	2250.0	N	BENDC00-BI-Defl-1-Cath		Fault: IRB1-STAD001-Cath-1-BeamRef
QUAD-022-057	204.0	204.0	500.0	N	QUAD004		
QUAD-022-067	400.0	400.0	500.0	N	QUAD005		
BEND-022-117	0.0	1198.0	2250.0	N	BENDC00-BI-Defl-2-Cath		Fault: IRB1-STAD001-Cath-2-BeamRef
QUAD-022-122	204.0	204.0	500.0	N	QUAD006		
SEXTUPOL-022-134	0.0	0.0	500.0	N	SPOL001-RELEASE-HZEP		
TRM-022-135	0.0	0.0	250.0	S	TRM001-Vertical		
QUAD-022-167	400.0	400.0	500.0	N	QUAD007		
QUAD-022-177	204.0	204.0	500.0	N	QUAD008		
SEXTUPOL-022-190	0.0	0.0	500.0	N	SPOL002-RELEASE-HZEP		
TRM-022-198	0.0	0.0	250.0	S	TRM002-Vertical		
QUAD-022-206	400.0	400.0	500.0	N	QUAD009		
QUAD-022-245	204.0	204.0	500.0	N	QUAD010		
BEND-022-309	1110.0	1110.0	1300.0	S	BENDC00-BI-Defl-3-Cath		
BEND-022-314	1110.0	1110.0	2250.0	S	BENDC00-BI-Defl-3-Cath		
QUAD-022-343	204.0	204.0	500.0	N	QUAD011		
QUAD-022-353	400.0	400.0	500.0	S	QUAD012		
QUAD-022-370	110.0	110.0	500.0	S	QUAD013-Used for FMH		
TRM-022-372	0.0	0.0	250.0	N	TRM003-Vertical		
BEND-022-377	1100.0	1100.0	1300.0	S	BENDC00-BI-Defl-4-Cath		
TRM-022-381	0.0	0.0	250.0	S	TRM004-Vertical		
BEND-022-389	50.0	50.0	1000.0	S	BENDC02-20		
BEND-022-394	1110.0	1110.0	1300.0	S	BENDC00-BI-Defl-5-Cath		collimator
QUAD-022-423	300.0	300.0	500.0	N	QUAD014		
BEND-022-432	0.0	0.0	800.0	N	BENDC01-10		
QUAD-022-444	300.0	300.0	500.0	N	QUAD015		
QUAD-022-478	0.0	0.0	500.0	N	QUAD016		
BEND-022-481	0.0	0.0	250.0	S	TRM005-Vertical		
QUAD-022-483	0.0	0.0	250.0	S	TRM006-Vertical		
QUAD-022-526	207.0	207.0	500.0	S	QUAD017		
QUAD-022-536	200.0	200.0	500.0	S	QUAD018		
BEND-022-544	0.0	0.0	800.0	S	BENDC01-14-05		

Run | Hold | Refresh | Refresh All | Refresh Selected | Set Current | SET TO BEAM REF | Display Faults | Monitor Status | Store to e-logbook

Magnets

Magnets Status (You can see the display of faults in red colour)

Collimators

For collimator settings, each of the motors moving individual jaws is controlled. Collimators with four jaws are considered as two different entities, one vertical and one horizontal, for a better overview. They are used for changing intensity, shape, and energy spread of a beam. Similar to the magnet settings, one can set reference values for each of them, as can be seen

Collimator Status (Collimators)

Beam: ZT10 / ZT10-EXP
File: ZT10A.ZT10-EXP-091
Last time: 23.09.2021 17:09:54
Comment: RD51 Calc -5.0 GeV/c

Momentum: -5.00 GeV/c

Collimators	Read Jaw 1	Read Jaw 2	BeamRef Jaw 1	BeamRef Jaw 2	Min	Max	Info	F	Comments
ZT10.XCDV010	-10.0	10.0	-10.0	10.0	-47	47	COLL01 Vertical		
ZT10.XCDV015	-39.0	39.0	-39.0	39.0	-47	47	COLL02 Horizontal		
ZT10.XCHV022	-40.1	40.1	-40.0	40.0	-50	50	COLL04 Horizontal		
ZT10.XCHV023	-40.0	40.0	-40.0	40.0	-60	60	COLL05 Vertical		

Run | Hold | Refresh | Refresh All | Refresh Selected | Set Jaw Positions | SET TO BEAM REF | Store to e-logbook

Collimators

Collimators Status

Obstacles

In order to create and absorb different particles types as well as for creating tertiary beams, different materials ("obstacles") can be placed in the beam. The Obstacles Command allows the users to control the position of each device and to add or remove different kinds of material automatically as these devices are motorised. The positions are all entered in the CESAR DB, so one can directly select the desired obstacle to be placed and keep a reference, as well.

Obstacle Status (Obstacles)

Beam: H6 / Medipix
File: H6B.Medipix.000
Last time: 23.09.2021 17:10:20
Comment: V.H6=1200GeV@30rad/Parallel through H6

Momentum: +120.00 GeV/c

Obstacles	Read	BeamRef
XCON-041-126	Air	Air - Air
XCON-041-369	Air	Air - Air

Run | Hold | Refresh | Refresh All | Refresh Selected | Move (discrete) | Move In | Move Out | Book

Obstacles

Move XCON-041-126

Select a Position

- Air - Air - 110.0 mm
- Air - Air - 115.0 mm
- Cu - Copper 400mm 39.0 mm
- Pb - Lead 400mm 45.0 mm
- Pb - Lead 400mm 45.0 mm
- Poly - Polyethylene 1m 79.0 mm

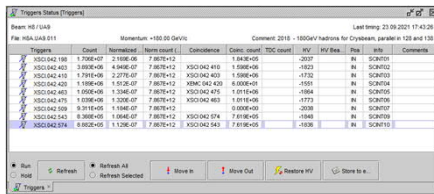
OK | Cancel

Obstacles Status



Scintillators

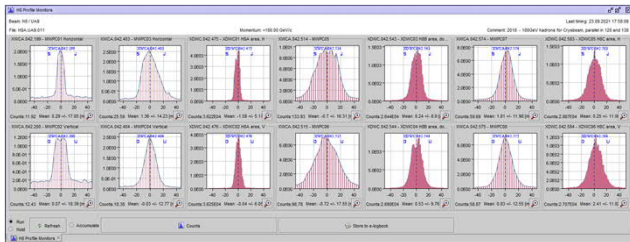
The trigger status displays counts from each scintillator along the selected beam line. In addition, it calculates 'normalised counts', which are normalised to the beam intensity on the upstream primary target in order to avoid fluctuations coming from the primary beam. As they are motorised, scintillators can be moved out of beam on demand, e.g. to reduce absorption for low-momentum electrons. Furthermore, in each control room, users can connect their discriminated NIM detector signals to scaler units, which are then displayed on CESAR and allow beam operators to scan and set the beam position for a maximum number of counts



Scintillators Status

Profile Monitor

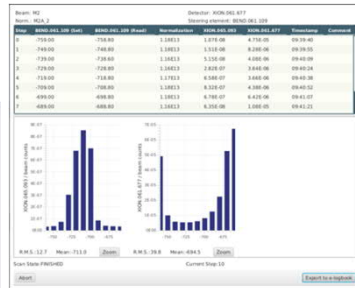
CESAR displays beam profiles along the beam lines independent of the type of monitors that are used. Typical monitor types are analogue MWPCs, delay wire chambers and scintillating fibre monitors (XBPF). CESAR provides count rates from each monitor as well as calculated mean values of the profile distribution. As for the scintillators, some of the monitors can be moved out of the beam. Voltage settings can be adjusted by the operators for an optimal dynamic range.



Profile monitor Status

Scan

CESAR offers the possibility to perform scans on any beam device and instrumentation. One can select the control element (e.g. magnet or collimator) and the instrumentation to perform a scan between certain values in selected steps. The scan will go through all preset values and plot the detector reading as a function of scanned parameter, e.g. a magnet current as depicted below. This needed allows to maximise transmission through a beam line or to find the position of a user detector without the need of survey in the zone. FISC scans can be performed in different modes, i.e. one position per extraction or in a fast mode for a complete scan during one extraction. There are different expert modes in addition, for instance to scan the beam divergence between two FISC monitors



Scan Result

Software Migration Project

The Software Migration project has been instated with the goal of modernisation of the offline software used for the description and design of the secondary beamlines at CERN, employed by the BE-EA-LE Section. A migration of the complete software chain used for the design of the secondary beamlines in both CERN North and East Areas has been performed. The new baseline consists of MADX for beam optics and survey calculations, the in-house developed software AppLE.py for graphical output and matching as well as FLUKA, BDSIM and Geant4 for beam-matter interactions. The solution has been validated with the help of benchmark studies and a test of the complete software chain. It is planned to use the software in a highly integrated way, utilising the modern online database tools available at CERN, such as Layout Database and GitLab.

The new software has become the baseline for Run 3 (2021-2025), which is expected to allow the final validation of its practicability and to reveal some aspects requiring improvement. While the major migration work has been completed according to the initial project plan, the work on the adaptation of the software chain to the evolving software infrastructure at CERN as well as the integration of the beamlines into the Layout Database, the benchmarking studies and work on further automatization are foreseen to continue during Run 3 and beyond.

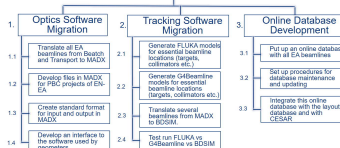
Tests and Validation

The aforementioned tools have been tested individually. In order to assure smooth interfaces between the tools, a major part of the new software chain has been tested on a hardware modification on the North Area beamline K12. This modification consisted of moving several bending magnets and installing new detectors for the NA62 experiment. The following steps have been undertaken for the test:

- (1) BEATCH files for the configurations of 2018 and 2021 have been forwarded to the EA configuration managers.
- (2) The configuration managers implemented those two layout versions into the Layout Database.
- (3) The tool for automatic production of MADX input files from the Layout Database configuration has been successfully used.
- (4) The file generated with the tool has been processed in MADX software, producing a Survey file for the geometries.
- (5) The Survey file has been forwarded to the Metrology Group, which examined it and found it to be consistent with the existing Metrology Database entries with regards to naming convention and positions of the beamline elements.

Many of the use cases for the new software chain will be tested now thanks to the restart of beams after LS2. A large share of the North Area beamlines has still to be implemented into the Layout Database, which is planned to be completed by the end of 2021.

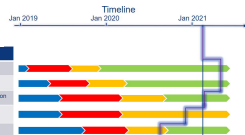
Software Migration Project



G4beamline



BDSIM
Beam Delivery Simulation



CESAR Future

The most important aspect from the configuration management point-of-view will be the connection of CESAR to the newly commissioned beam software. The project is on a good track and several new features for CESAR have been already developed, such as the Apple.py-to-CESAR conversion and the automatic layout update with the Layout Data Base. We are thankful for the plenitude of ideas reaching us from the user community and from the recently established North Area Consolidation Project, which are evaluated at the moment. A frequently requested item is establishing an Application Programming Interface (API) for CESAR, permitting Super Users to access the CESAR functionality from within scripts. This would allow to automatise even complicated steps for beam tuning with direct feedback from the beam instrumentation. In addition, connecting CESAR to the NXCALLS logging service will allow users to retrieve recorded values of any device in convenient way. Thinking further ahead, integrating fault reporting into CESAR, e.g. with the already existing Automatic Fault System AFT, will improve reliability analyses and save time of the operators.

In addition, the new CERN GUI Strategy working group currently reviews the existing GUI systems with the aim of streamlining and easier maintainability. This is a good opportunity to improve the graphical interface and to explore possible synergies with the other control systems of CERN, for instance by adding some useful features that have been developed for accelerator controls.