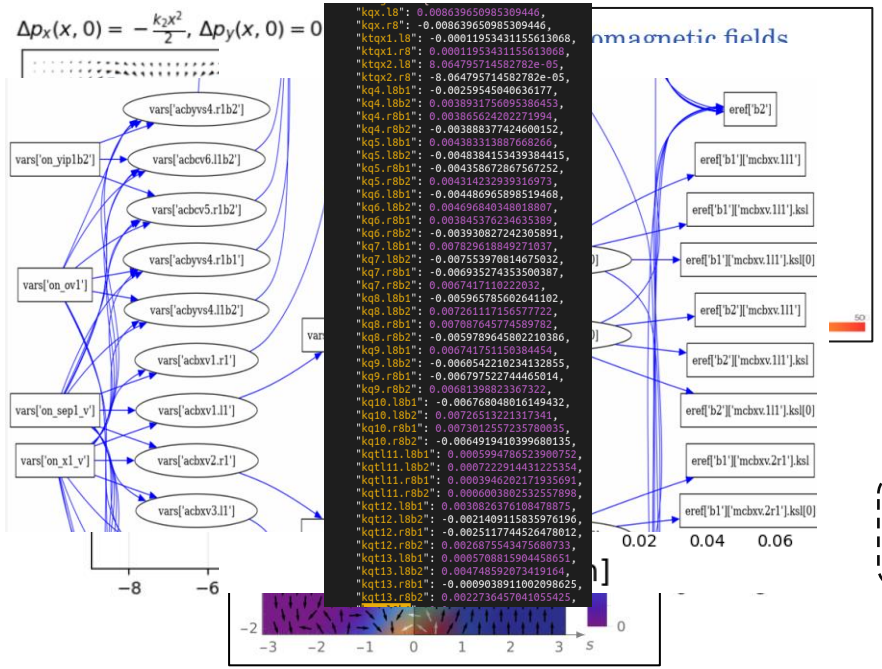
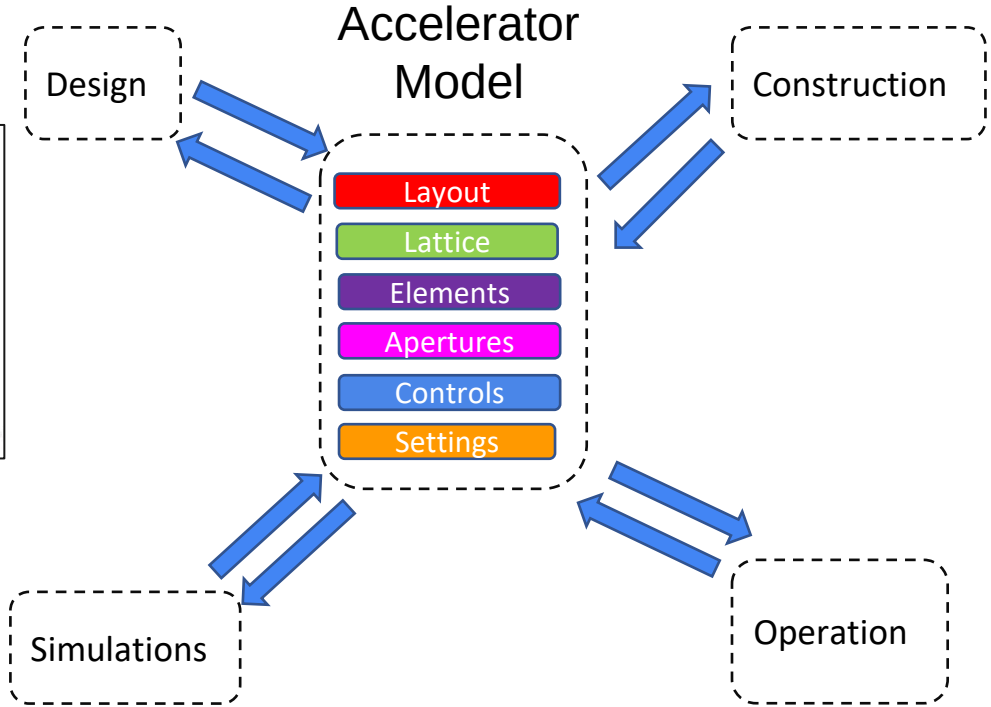
Integrated management of accelerator models

R. De Maria, G. Iadarola

Based on discussions with S. Chemli, J. De Jonghe, V. Kain, L. Fiscarelli, A. Hauschauer, C. Petrone, P. Le Roux, P. Ledo, C. Scoero

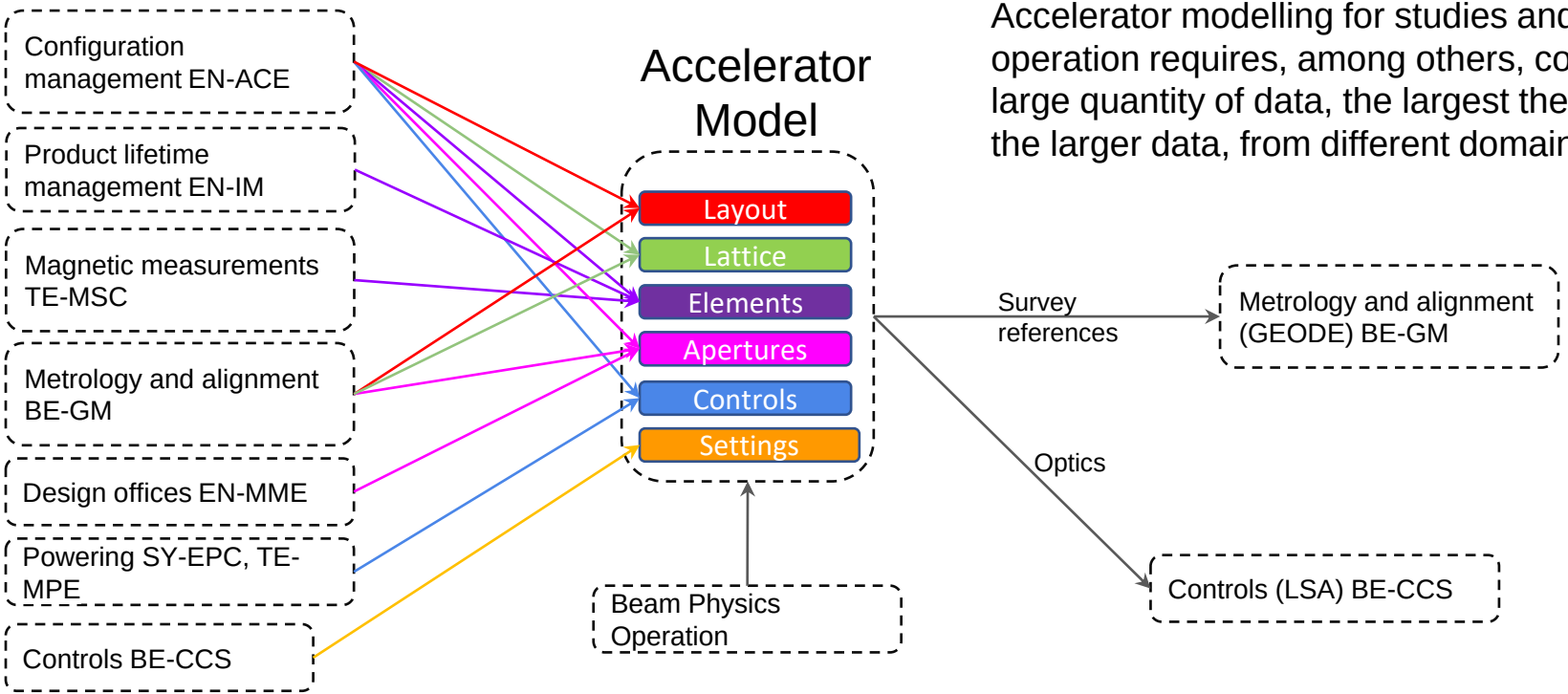
Accelerator models





Accelerator physicists and operators inject or extract information into models to design, construct, operate and optimize accelerators.

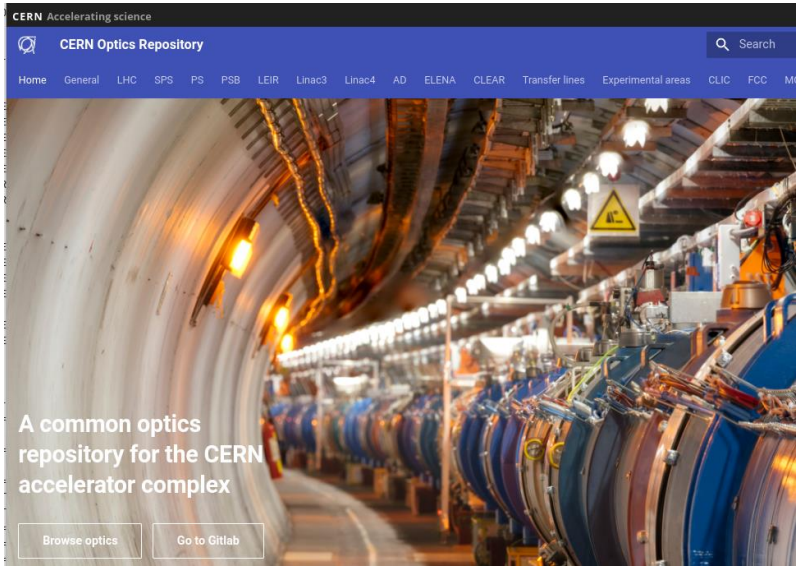
Accelerator data domains

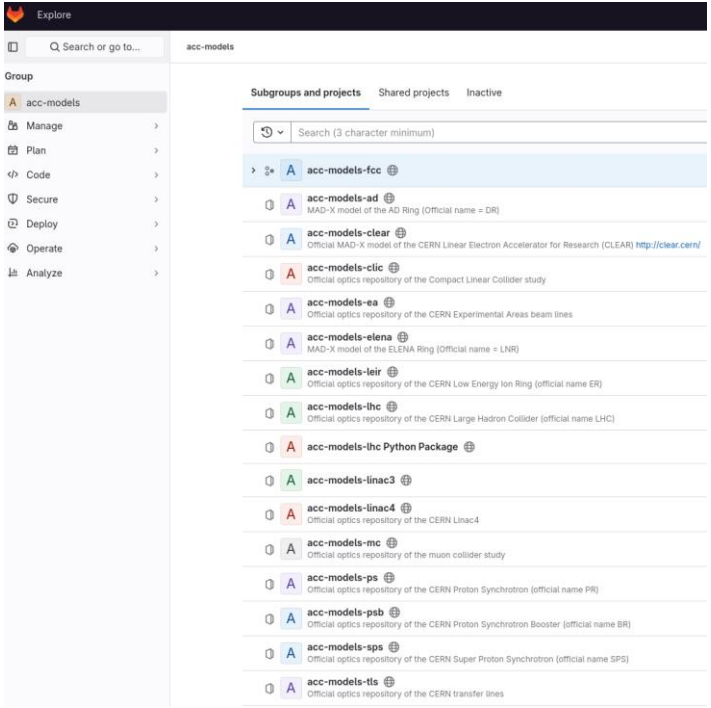


Accelerator modelling for studies and operation requires, among others, collecting a large quantity of data, the largest the machine, the larger data, from different domains.

A digital thread connecting all the sources is key to coping with scale and accuracy: automatic workflows, validation, deduplication, consistency, error correction, lifetime.

acc-models

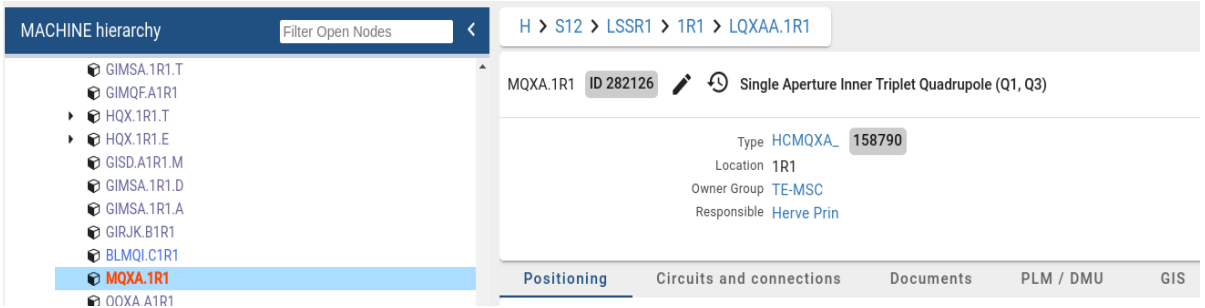


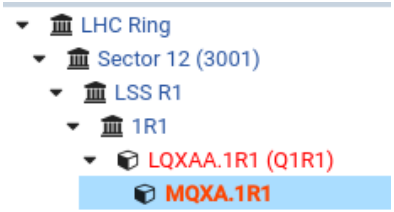


Gitlab repository and website that contains optics models for operations and studies.
Managed by BE-OP and BE-ABP/BE-EA/SY-ABT optics experts.
We aim at continuing building on top of acc-models: increase coverage, add integration with existing database and workflows, improve robustness.
We now look at the connections with the relevant data domains….

Layout database

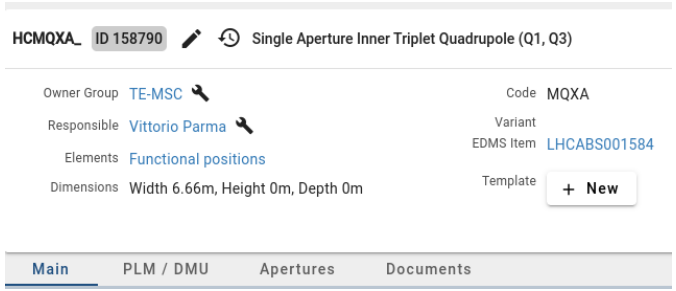
LDB contains many types of data, among which, **functional positions**, expressed as a tree of rigid transformations (but no explicit bends!), and associated circuits when relevant.





Transformations

From point	To point	S [m]	U [m]	V [m]	B [Deg]	A [Deg]	C [Deg]	Valid From	Valid till
LHC MECHANICAL START	S12 MECHANICAL START	0	0	0	0	0	0	24-11-2003	ENDLESS
S12 MECHANICAL START	LSSR1 MECHANICAL START	0	0	0	0	0	0	24-11-2003	ENDLESS
LSSR1 MECHANICAL START	1R1 MECHANICAL START	0	0	0	0	0	0	24-11-2003	ENDLESS
1R1 MECHANICAL START	LQXAA.1R1 MECHANICAL START	22.18	0	0	0	0	0	24-11-2003	LS3 1.5
LQXAA.1R1 MECHANICAL START	MQXA.1R1 MECHANICAL MIDDLE	3.97	0	0	0	0	180	08-04-2019	LS3 1.5



Functional positions are connected with **types**, which add additional info such as **apertures**.

Data is entered mostly by configuration managers, vacuum experts (LHC only) and MPE (circuits).

Data quality saves resources, and we shall see what it means and how to improve it…

Layout database data and acc-models

MACHINE hierarchy

- CTF3 Complex
- Linac 3 (L3)
- Linac 4 Complex
- ITE Transfer Line
- ITHS Transfer Line
- LT Transfer Line
- LTB Transfer Line
- LBE (Emittance meas.) line
- LBS (Spectrometer) Line
- BI Transfer Line
- PS Booster Rings (BR)
- BT Transfer Line
- BTP Transfer Line
- BTM Transfer Line
- BTY Transfer Line to Isolde
- ISOLDE Complex
- LEIR Complex
- PS Ring (PR)
- PS East Hall Complex
- F16 (TT2) Transfer Line
- FTA branch towards AD target (AD.90
- AD Complex
- FTN Transfer line to nTOF experiment
- NTF straight Forward nTOF line
- NTO Orthogonal (NEAR) - nTOF line
- NTV Vertical - nTOF line
- TT10 Transfer Line
- SPS Ring
- TT21 Transfer Line
- TT22 Transfer Line
- TT24 Transfer Line (T4)
- TT25 Transfer Line (T6)
- TT23 Transfer Line (T2)
- SPS North Area
- TT60 Transfer Line
- TT66 Transfer Line (HiRadMat)
- HiRadMat Experiment (TT66)
- TT40 Transfer Line
- TT41 (AWAKE)
- TT42 (AWAKE Laser Beam Line)
- TT43 (AWAKE Beam Electron Line)
- TI2 Injection Line
- TI8 Injection Line
- LHC Ring
- TD62 Dump Line
- TD68 Dump Line
- SM18 STRING Facility

The layout database contains data for **most of the rings and lines.** The Layout database generates MAD-X sequence for most of them (and aperture definitions for LHC and SPS), nightly. However, this data is not fully exploited in acc-models!

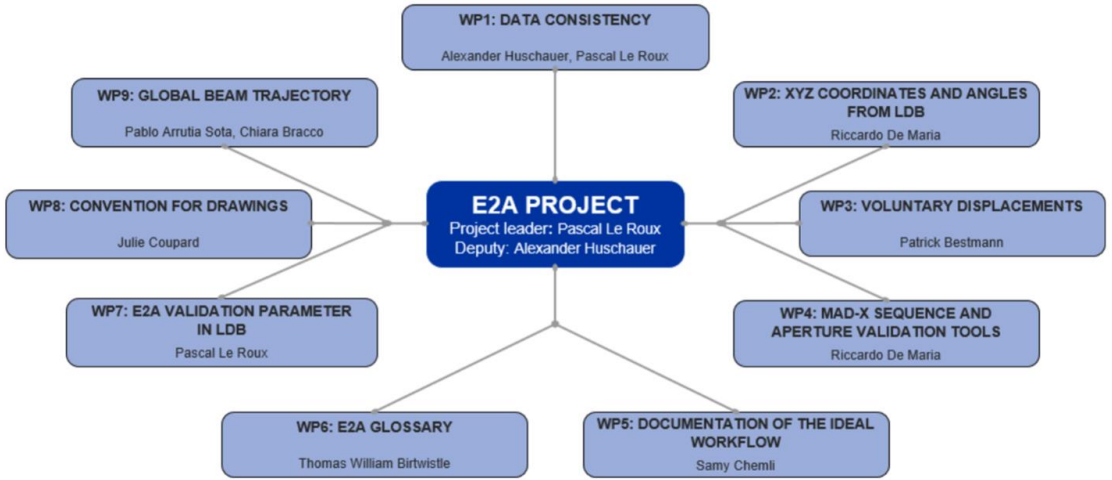
The **large majority of the LDB data is correct**, at the same time, **a model can break with a single error**.

Some data is not used immediately and validated → quality issues and gradual degradation over time.

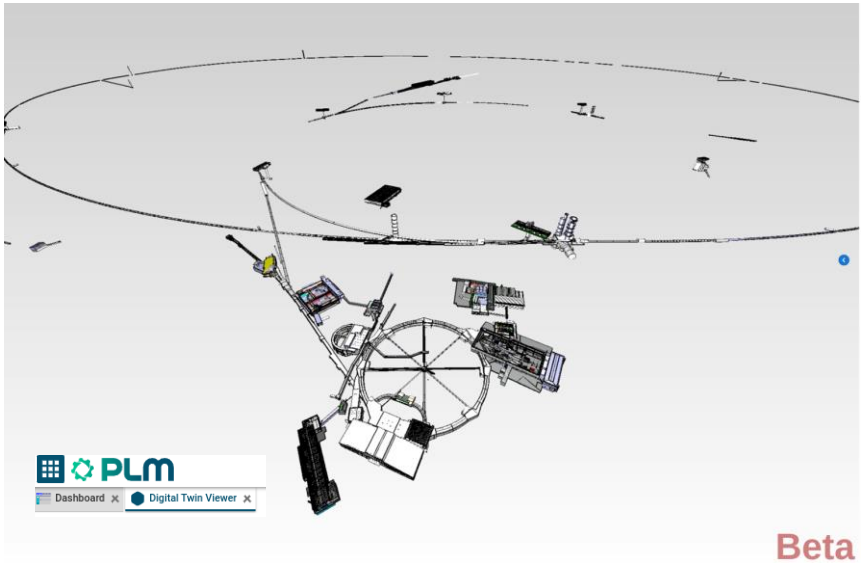
Data based on informal definitions and ad-hoc agreements → a lack of coherence between and within machines.

The layout database is the keystone of the **Engineering to Alignment** project (E2A) that aims at improving the speed and quality of beam line construction and alignment. Some WPs directly address those issues:

WP1: Data consistency
WP2: Survey references
WP4: Automatic Validation
WP7: Validation parameter
WP8: Glossary
Remarkable progress!

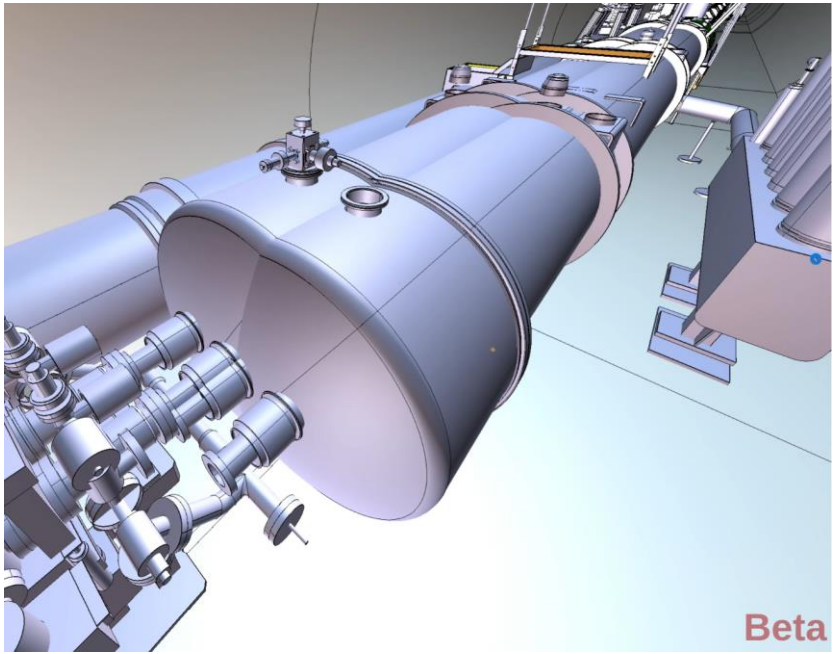


Layout visualizations



PLM team has launched a remarkable layout viewer, integrating the layout database and GEODE data with their equipment data and allowing connecting to equipment 3D models.

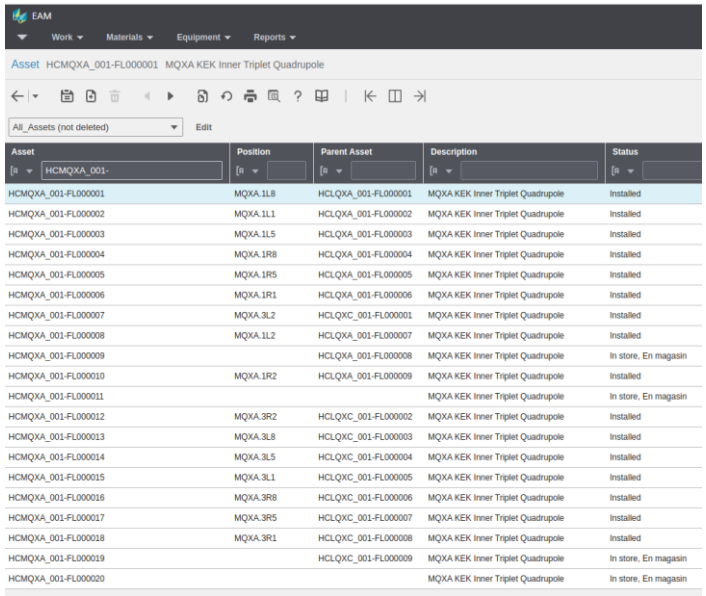
See with your own eyes, it is truly remarkable!

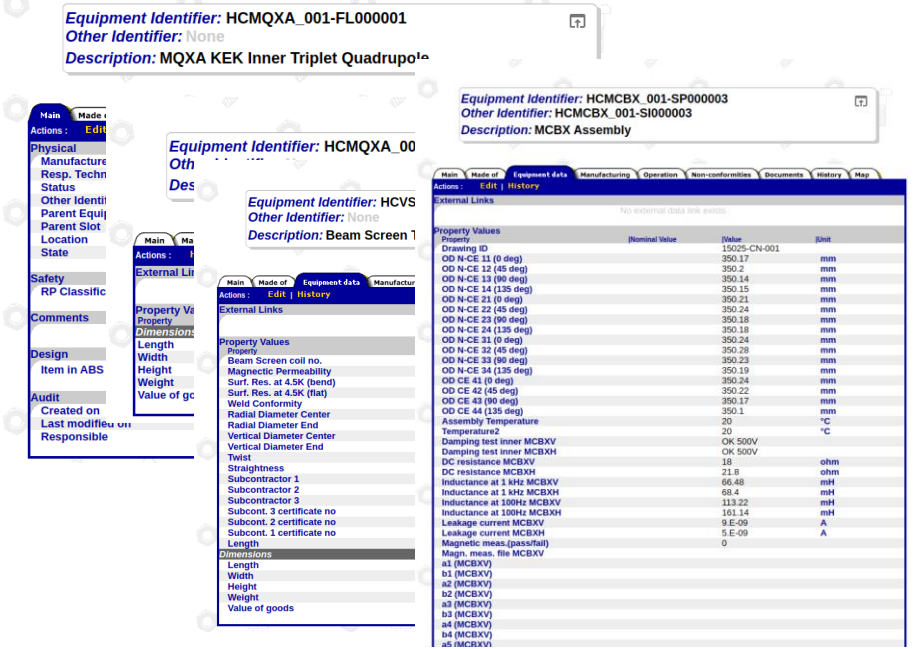


However, the data does not show as expected…
Here you see a recurring issue: missing the explicit link between the element model and the corresponding global reference points.
This is an innocent virtual artefact, but we had real installation artefacts in LS2!
Need investment in quality and focus.

Equipment data

acc-models should contain measured properties of the installed equipment. **Infor EAM** (**MTF**) contains the connections between functional positions and **assets** and some equipment data…





Effort needed to understand what is available, reliable and maintained…

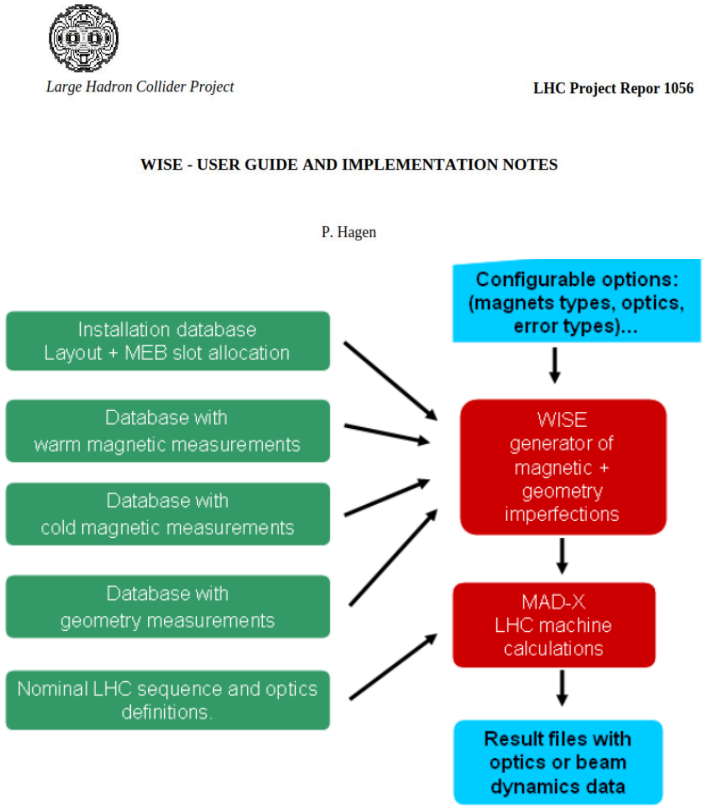
Magnetic models

Magnetic models are essential for operation, and very accurate models are especially useful for machines like the LHC that are slow and expensive to measure.

WISE was developed to integrate magnetic field model (FIDEL) in a complete workflow that considers strengths from optics, geometrical measurements and creates magnetic imperfections.

We need to revive and extend the tool for HL-LHC, other initiatives are already starting for other machines.

A good occasion to have a common approach happening at the same time as the restructuring of acc-models around Xsuite.

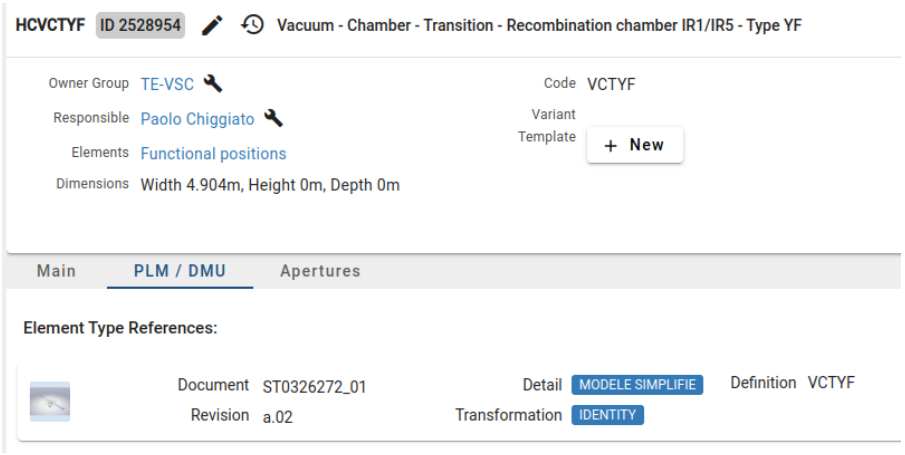


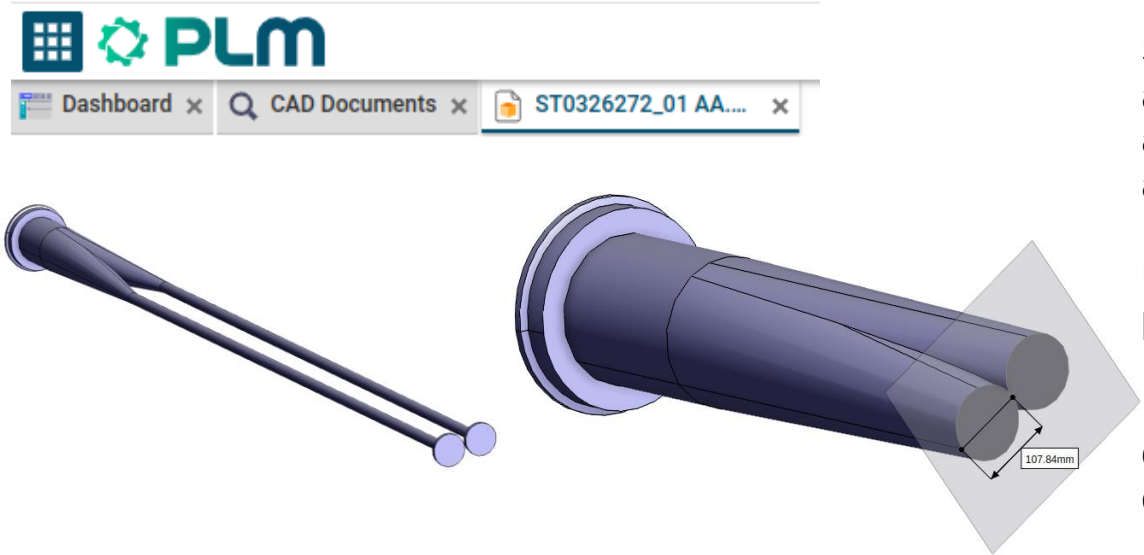
Windows Interface to Simulation of Errors

Aperture models

Aperture models are essentials to design and deploy operational configurations.

Vacuum cross-sections need to be extracted from drawings and inserted into the database.





So far, all manual, thankfully not too many aperture types. As STEP files are available, one could try to extract them automatically, pilot from Alex for PS.

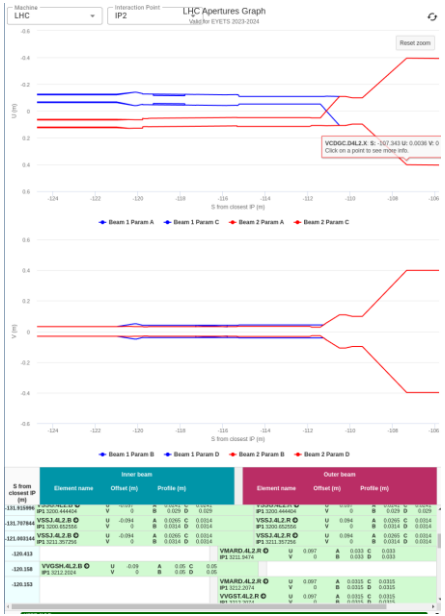
Layout database can now have arbitrary profiles using SVG Path standard.

Important to connect 3D models to types consistently by configuration manager and equipment owners!

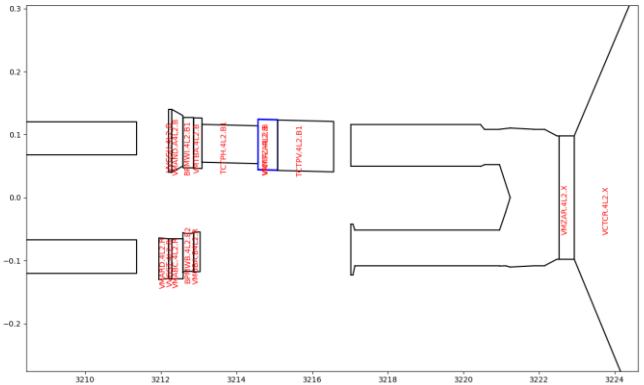
Aperture graphs

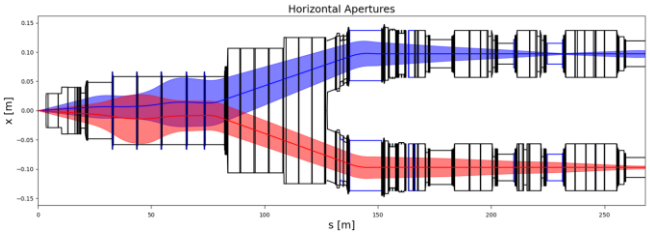
Improving aperture visualization is key to entering data correctly. Below examples of different approaches.

Present graph in LDB, angular based.



Recent approach:
pylayout: fast prototyping, Python oracle access, Python plotting, Python connection with beam dynamics. Costs and time to first release much reduced. Used by TE-VSC already for a year.





Embracing open data access API, rapid prototyping, early release cycles is paying off!

Wrap-up…

Accelerator models need to integrate data from many sources. It is a resource heavy effort!

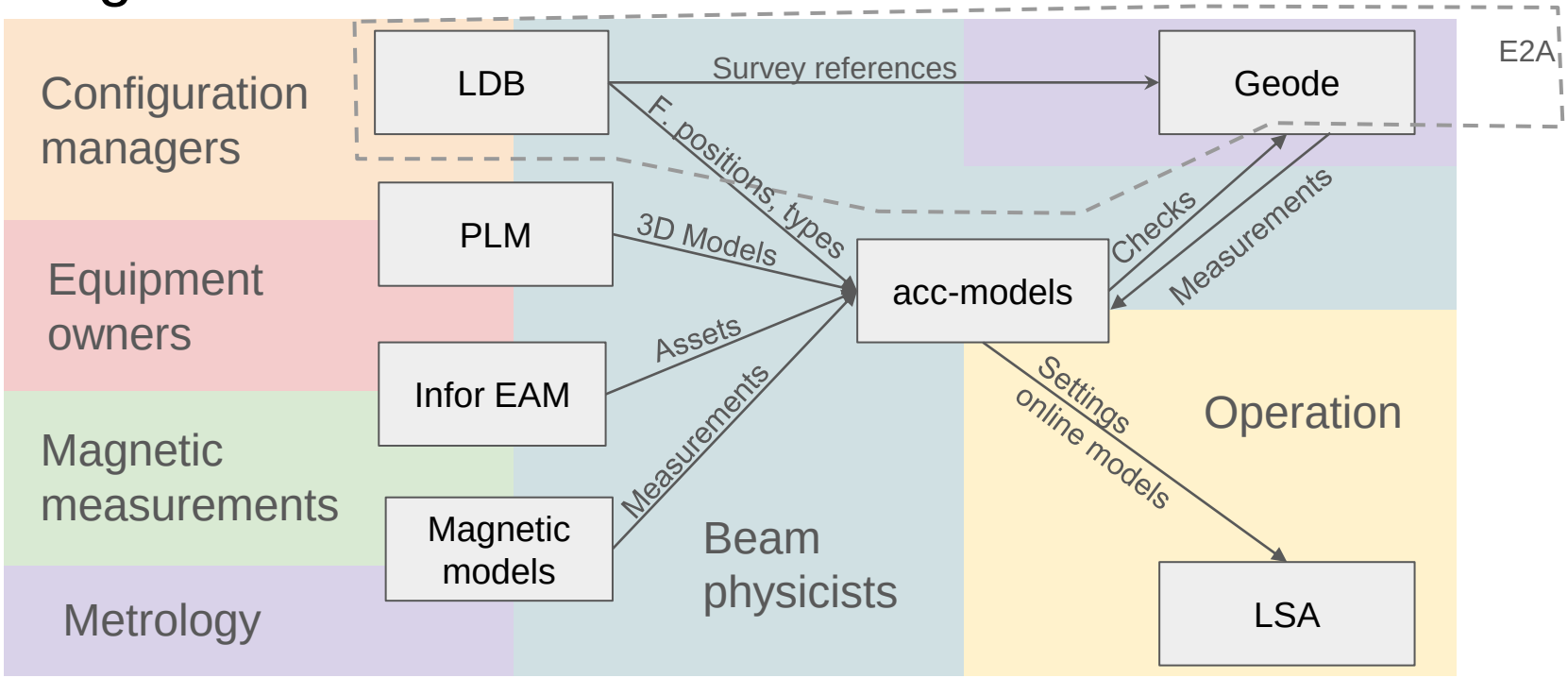
Economy of scale: join efforts, re-use and re-scope existing data sources and descope duplicated information, develop tooling to reduce constraints, minimize manual work, establish automatic testing and continuous integration.

ABP is restructuring the simulations and modelling efforts along those lines, in particular around the Xsuite framework. So far, the response has been positive.

Run 3 will be used to complete features along pilot projects (e.g. full LHC cycle developed for LHC in 2024) and LS3 to complete transitions.

We also plan to improve the integration of acc-models with the data domains.

A digital thread for acc-models



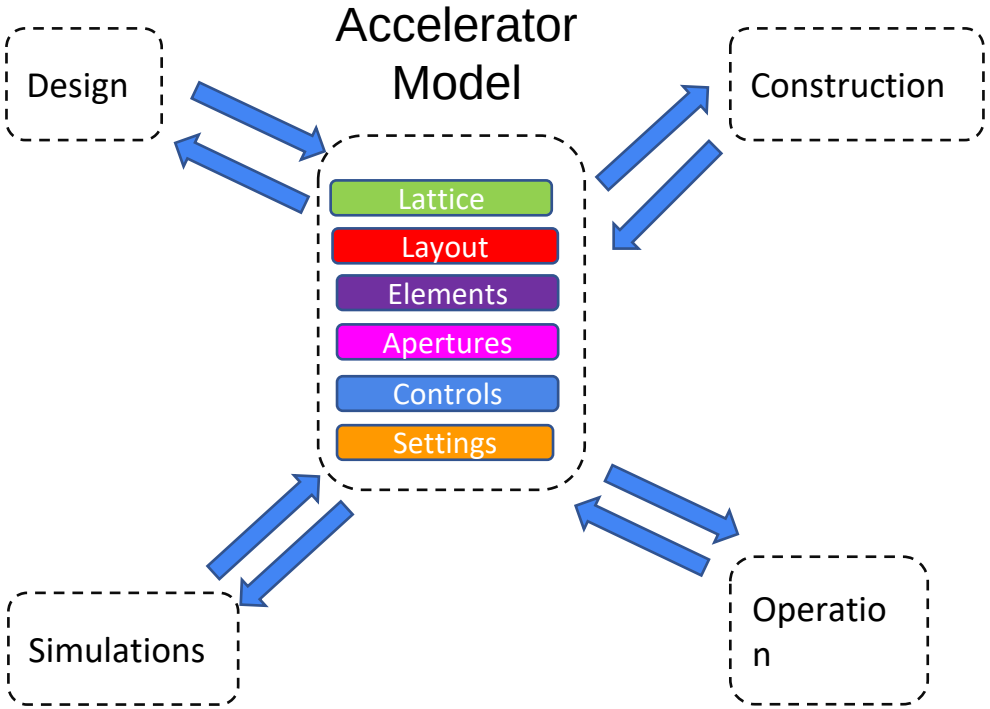
Today, each arrow represents an unstructured process driven by the needs of the users.
We ultimately miss structures in which data owners and users share responsibility and resources for ensuring data quality, checks, data flow and data lifetime.

Back-up

Accelerator models

An accelerator model contains:

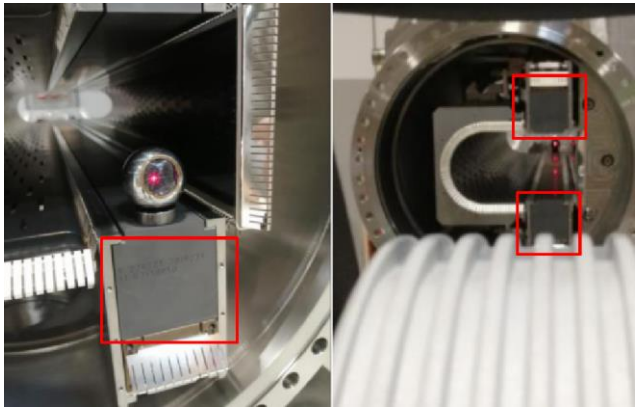
- Layout: The position of a set of physical beam elements positioned in space: magnets, cavities, BPMs, etc.
- Lattice: A sequence of tracking maps representing the physical beam elements that are needed to track the beam trajectories.
- Element physics models: parametric physics models (magnetic, electric, materials, impedance) that characterize the elements.
- Aperture model: A description of vacuum geometries around the beam.
- Control model: a set of relations between quantities that can be used to control or manipulate the parameters of beam element models.
- Settings: a specific set of values that fully specify a model during an operation cycle.



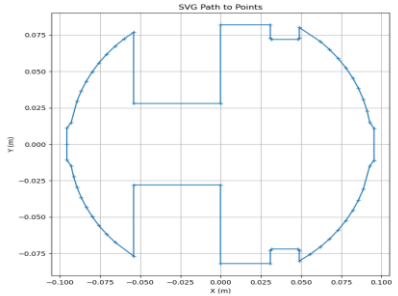
Accelerator physicists and operators inject or extract information into models to design, construct, operate and optimize accelerators.

SVG Path and editor

third modules



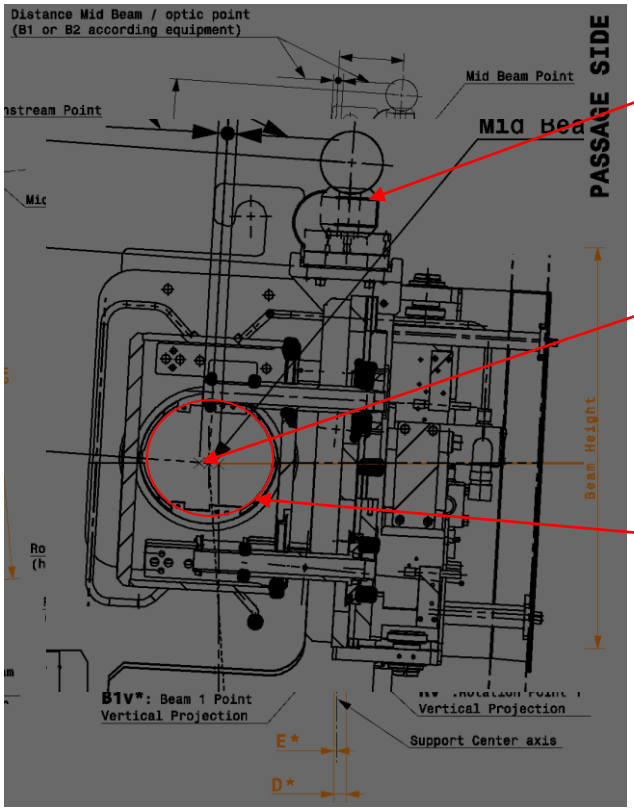
https://acc-models.web.cern.ch/svg-path-editor/#P=_m_0_4_h_78.4_a_60_60_0_01_0_120_h_-78.4_h_-4_v_-56_h_-62_v56_h-4.5_v_-120_h_4.5_v_56_h_62_v_-56_z




```
svgpath = "M -0.1 -28 L -54.1 -28 L
-54.1 -76.9 A 94 94 0 0 0 -92.9 -15
L -95.6 -11 L -95.6 0 L -95.6 10.8 L
-92.9 15 A 94 94 0 0 0 -54.1 76.9 L
-54.1 28 L -0.1 28 L -0.1 82 L 30.9
82 L 30.9 73 L 31.9 72 L 47.9 72 L
48.9 73 L 48.9 80.2 A 94 94 0 0 0
92.7 15 L 95.4 11 L 95.4 -10.8 L
92.7 -15 A 94 94 0 0 0 48.9 -80.2 L
48.9 -73 L 47.9 -72 L 31.9 -72 L
30.9 -73 L 30.9 -82 L -0.1 -82 Z"
```

```
x, y = svg_to_points(svgpath,
scale=0.001, curved_steps=10)
```

Position of a beam line elements



An accessible reference in the tunnel

A reference point related to the element and the beam line.

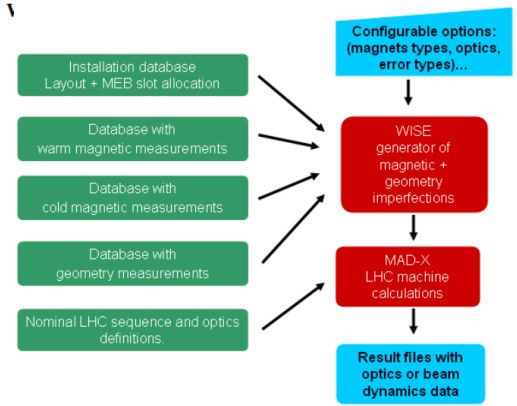
A mechanical feature to align.

… and relations between them.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics

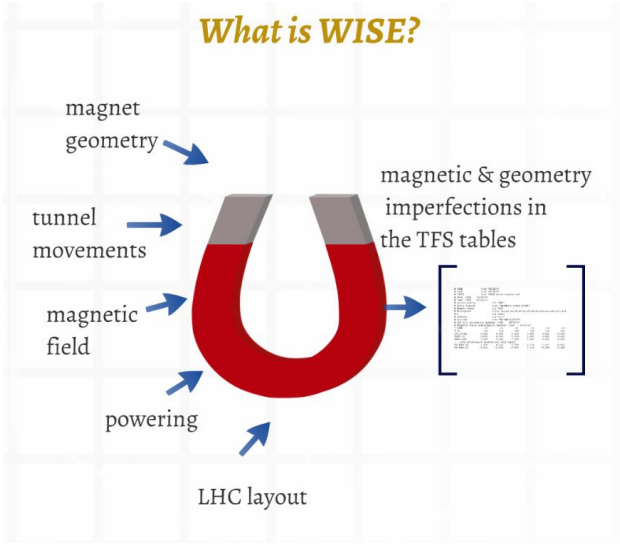
Large Hadron Collider Project

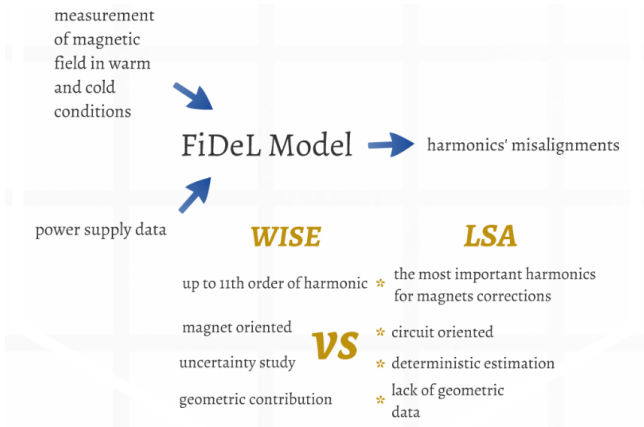
LHC Project Repor 1056



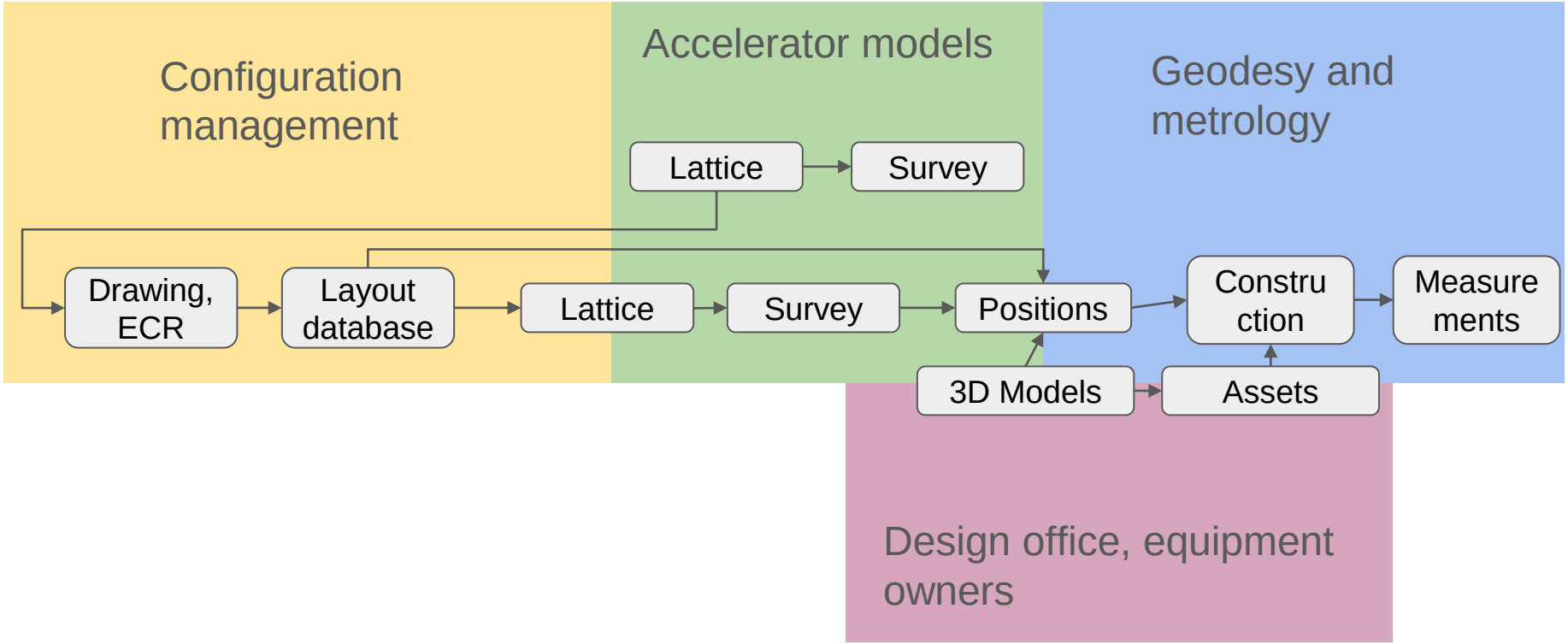
https://indico.cern.ch/event/813002/contributions/3389661/attachments/1826585/2989584/16-03-08_abs_WISE2.0.pdf

https://cds.cern.ch/record/1089857/files/lhc-project-report-1056.pdf

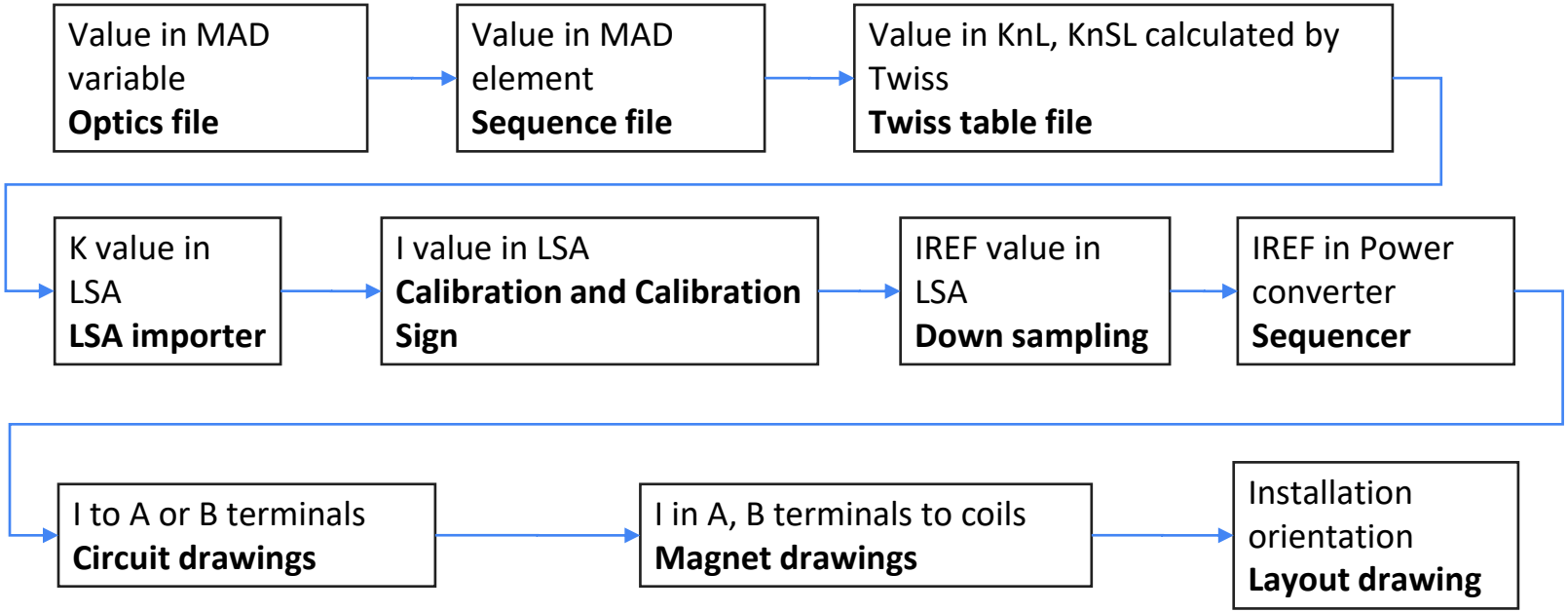




Layout


Configuration management
Accelerator models
Geodesy and metrology
Lattice
Survey
Drawing, ECR
Layout database
Lattice
Survey
Positions
Construction
Measurements
3D Models
Assets
Design office, equipment owners

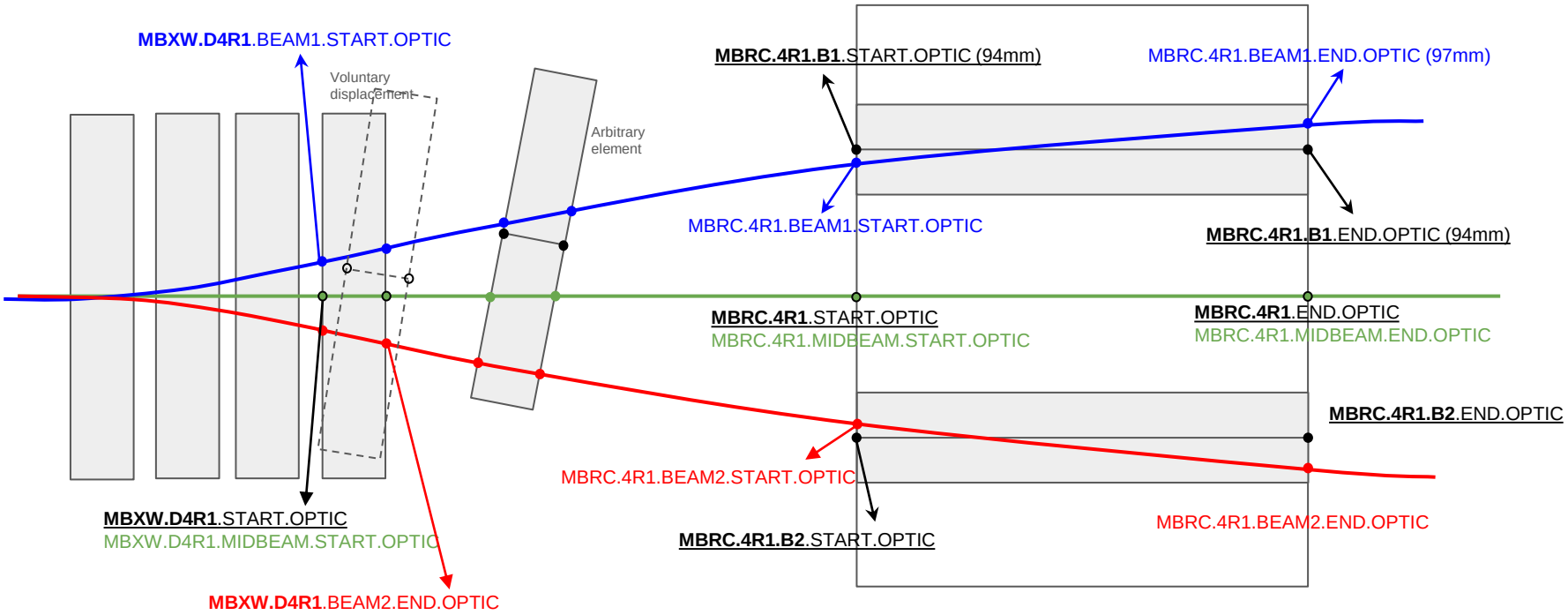
From MAD-x variables to the magnetic field seen by the beam



There are only two signs, but ten passages where it can flip!

LHC D1

LHC D2




```
MBXW.A4R1:MBXW,          at= 61.322+(0-IP1OFS.B1
MBXW.B4R1:MBXW,          at= 65.588+(0-IP1OFS.B1
MBXW.C4R1:MBXW,          at= 69.854+(0-IP1OFS.B1
MBXW.D4R1:MBXW,          at= 74.12+(0-IP1OFS.B1)
MBXW.E4R1:MBXW,          at= 78.386+(0-IP1OFS.B1
MBXW.F4R1:MBXW,          at= 82.652+(0-IP1OFS.B1
```

```
MBRC.4R1.B1:MBRC,        at= 157.9+
```

Work package leaders