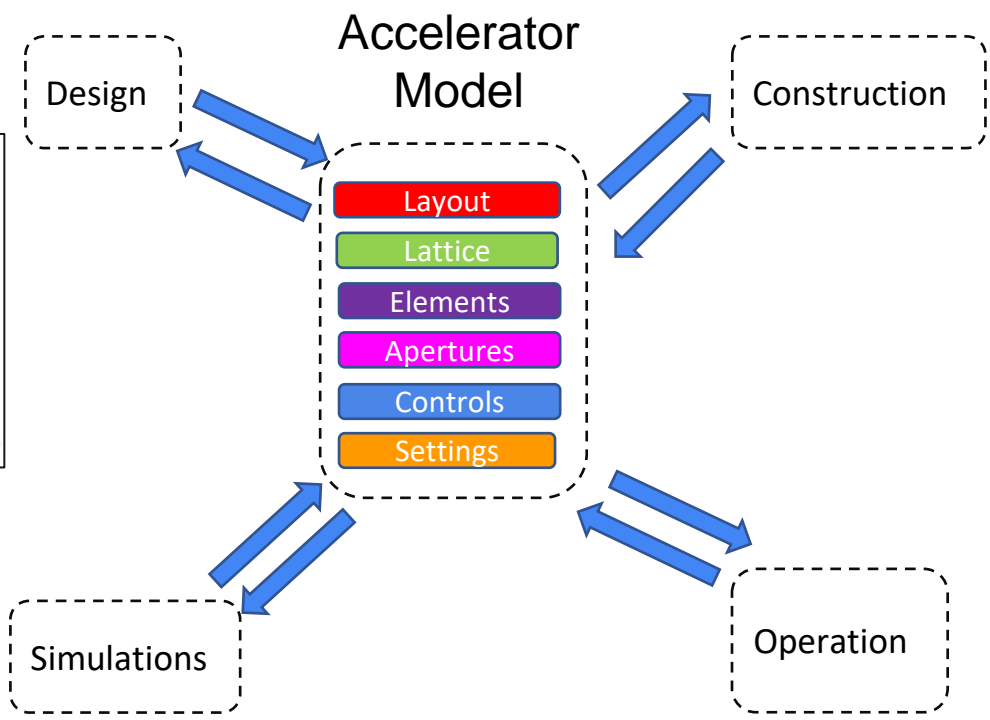
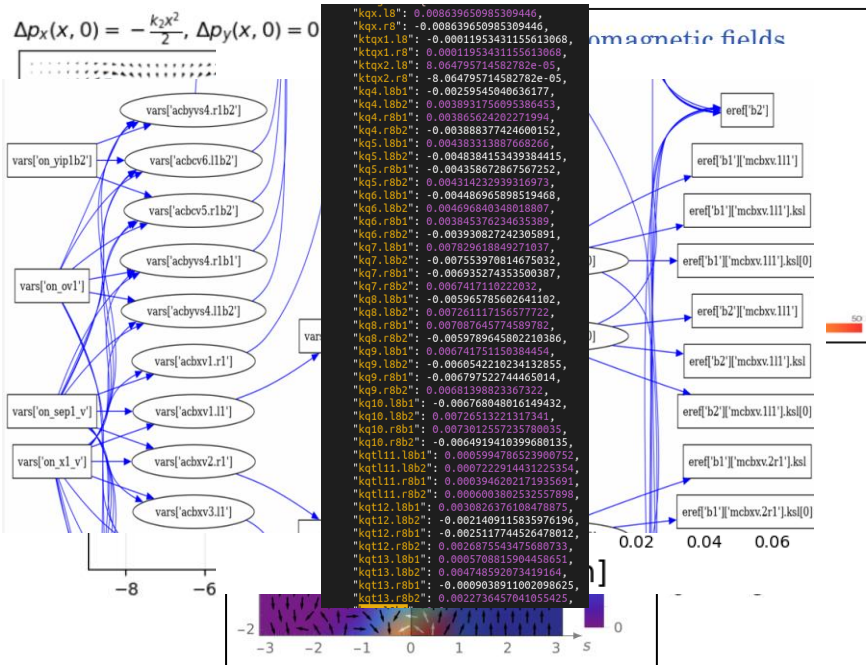


# Integrated management of accelerator models

R. De Maria, G. Iadarola

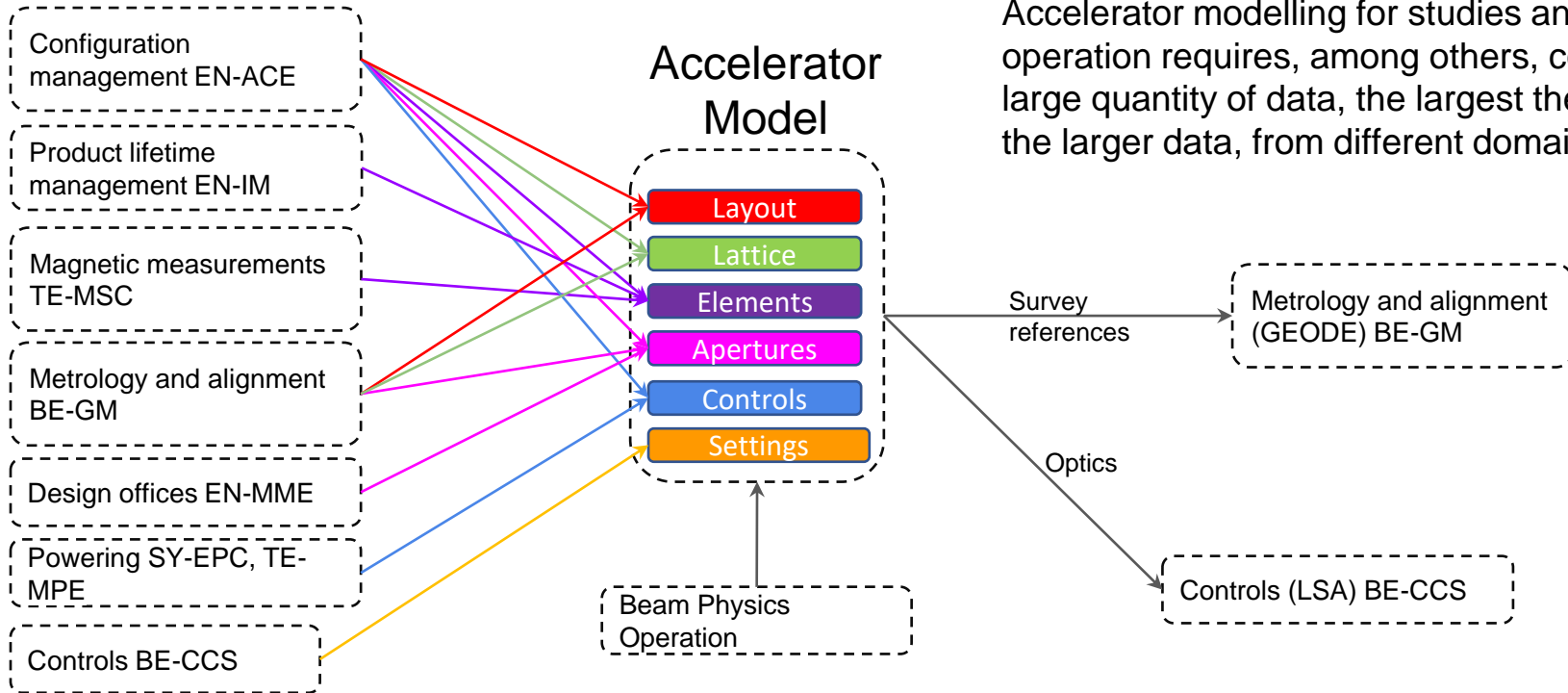
Based on discussions with S. Chemli, J. De Jonghe, V. Kain,  
L. Fiscarelli, A. Hauschauer, C. Petrone, P. Le Roux, P. Ledo, C. Scoero

# Accelerator models



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

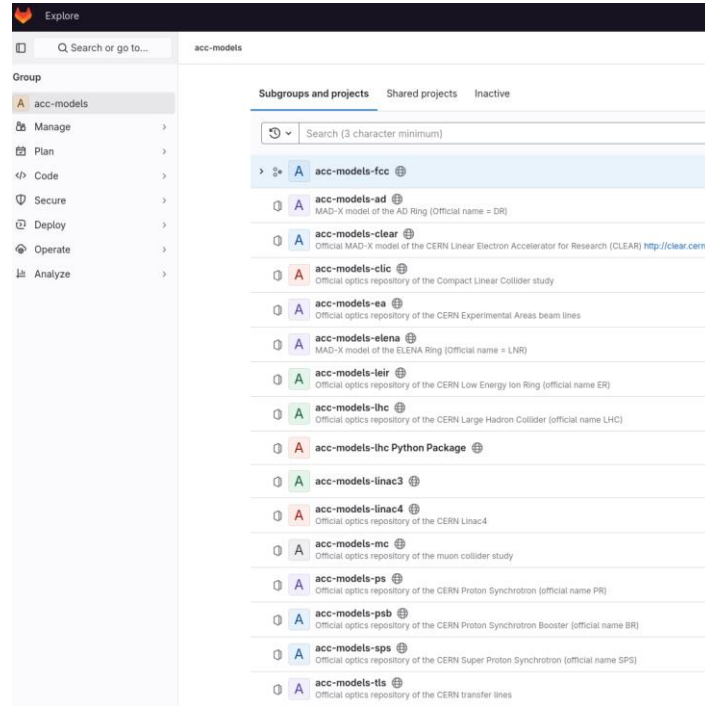
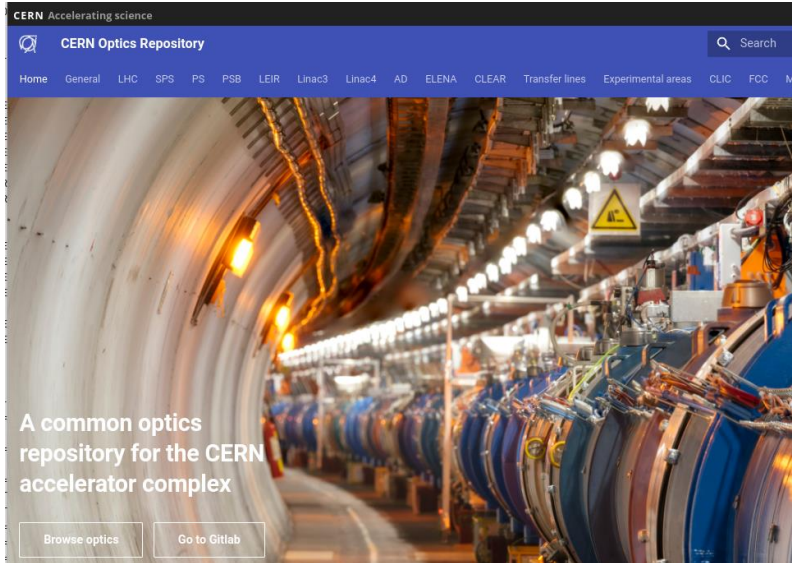
# Accelerator data domains



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

- ▼ LHC Ring
- ▼ Sector 12 (3001)
- ▼ LSS R1
- ▼ 1R1
- ▼ LQXAA.1R1 (Q1R1)
- MQXA.1R1

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

MACHINE hierarchy Filter Open Nodes <

- ◻ GIMSA.1R1.T
- ◻ GIMQFA1R1
- ▶ ◻ HQX.1R1.T
- ▶ ◻ HQX.1R1.E
- ◻ GISSD.A1R1.M
- ◻ GIMSA.1R1.D
- ◻ GIMSA.1R1.A
- ◻ GIRJK.B1R1
- ◻ BLMQI.C1R1
- ◻ **MQXA.1R1**
- ◻ OQXA.A1R1

H > S12 > LSSR1 > 1R1 > LQXAA.1R1

MQXA.1R1 ID 282126 Single Aperture Inner Triplet Quadrupole (Q1, Q3)

Type HCMQXA\_ 158790

Location 1R1

Owner Group TE-MSC

Responsible [Herve Prin](#)

Positioning Circuits and connections Documents PLM / DMU GIS

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

HCMQXA\_ ID 158790 Single Aperture Inner Triplet Quadrupole (Q1, Q3)

Owner Group TE-MSC

Responsible [Vittorio Parma](#)

Elements Functional positions

Dimensions Width 6.66m, Height 0m, Depth 0m

Code MQXA

Variant

EDMS Item [LHCABS001584](#)

Template [+ New](#)

Main PLM / DMU Apertures Documents

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)
- ▶ T12 Injection Line
- ▶ T18 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  $\rightarrow$  quality issues and gradual degradation over time.

Data based on informal definitions and ad-hoc agreements  $\rightarrow$  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

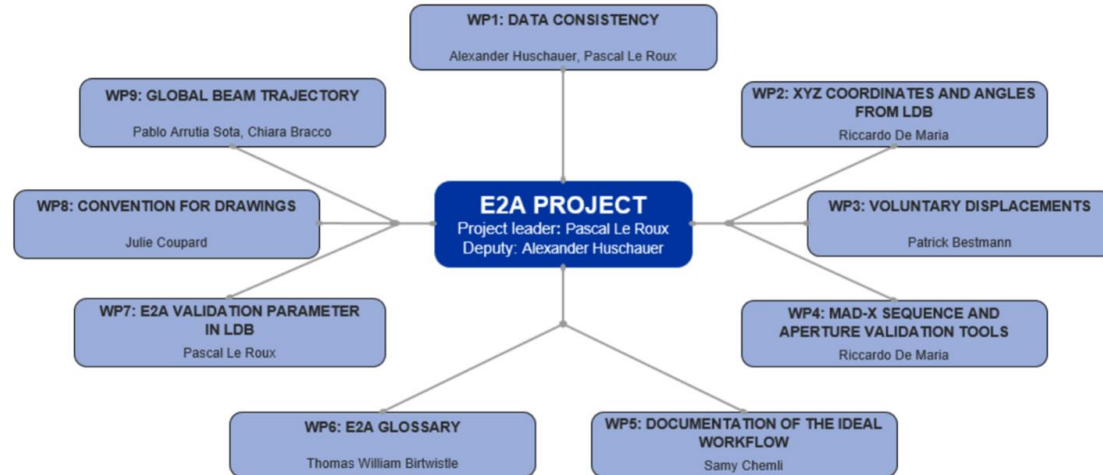
WP2: Survey references

WP4: Automatic Validation

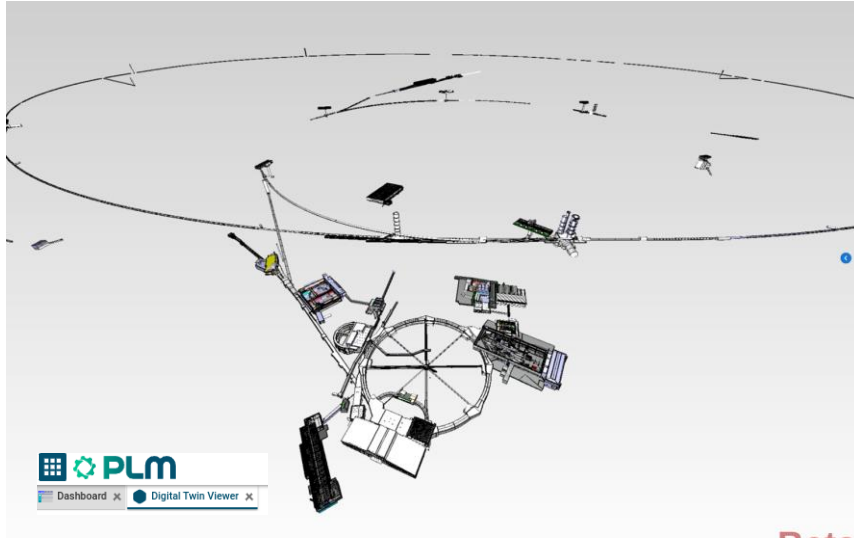
WP7: Validation parameter

WP8: Glossary

Remarkable progress!

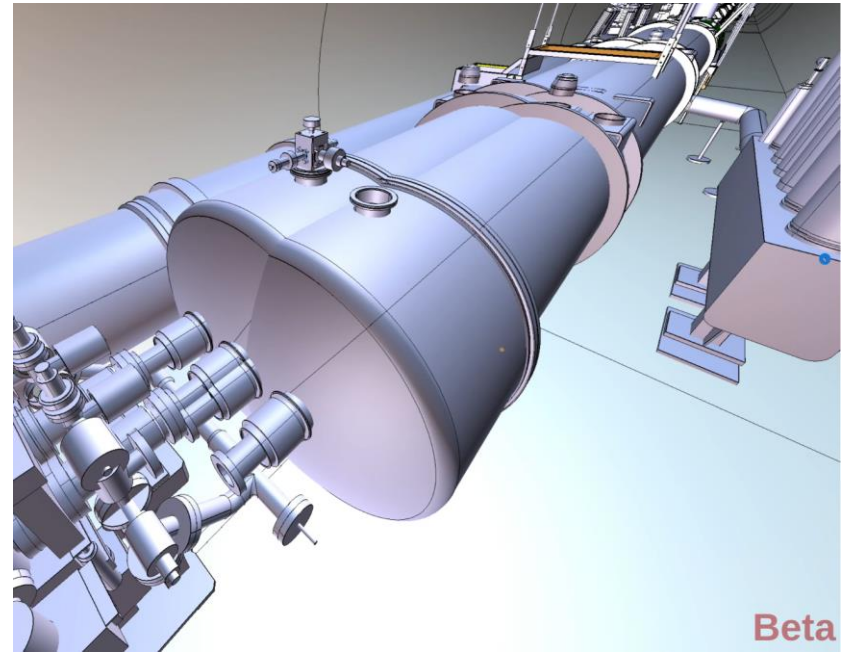


# Layout visualizations



[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!

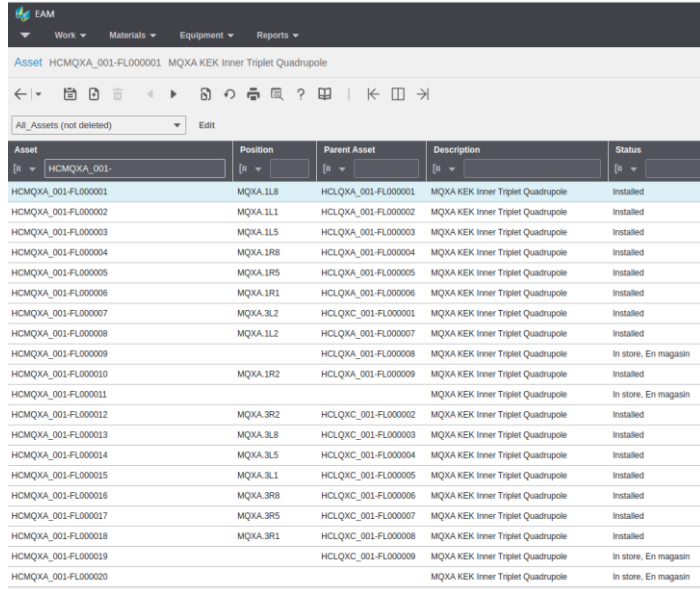


However, the data does not show as expected... Here you see a recurring issue: missing the explicit link between the element model and the corresponding global reference points. This is an innocent virtual artefact, but we had real installation artefacts in LS2! Need investment in quality and focus.



# 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...



Asset	Position	Parent Asset	Description	Status
HCMQXA_001-FL000001	MQXA.1L8	HCLQXA_001-FL000001	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000002	MQXA.1L1	HCLQXA_001-FL000002	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000003	MQXA.1L5	HCLQXA_001-FL000003	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000004	MQXA.1R8	HCLQXA_001-FL000004	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000005	MQXA.1R5	HCLQXA_001-FL000005	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000006	MQXA.1R1	HCLQXA_001-FL000006	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000007	MQXA.3L2	HCLQXC_001-FL000001	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000008	MQXA.1L2	HCLQXA_001-FL000007	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000009		HCLQXA_001-FL000008	MQXA KEK Inner Triplet Quadrupole	In store, En magasin
HCMQXA_001-FL000010	MQXA.1R2	HCLQXA_001-FL000009	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000011		HCLQXA_001-FL000010	MQXA KEK Inner Triplet Quadrupole	In store, En magasin
HCMQXA_001-FL000012	MQXA.3R2	HCLQXC_001-FL000002	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000013	MQXA.3L8	HCLQXC_001-FL000003	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000014	MQXA.3L5	HCLQXC_001-FL000004	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000015	MQXA.3L1	HCLQXC_001-FL000005	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000016	MQXA.3R8	HCLQXC_001-FL000006	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000017	MQXA.3R5	HCLQXC_001-FL000007	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000018	MQXA.3R1	HCLQXC_001-FL000008	MQXA KEK Inner Triplet Quadrupole	Installed
HCMQXA_001-FL000019		HCLQXC_001-FL000009	MQXA KEK Inner Triplet Quadrupole	In store, En magasin
HCMQXA_001-FL000020		MQXA KEK Inner Triplet Quadrupole	In store, En magasin	

Equipment Identifier: HCMQXA\_001-FL000001  
 Other Identifier: None  
 Description: MQXA KEK Inner Triplet Quadrupole

Main Made in  
 Actions: Edit  
 Physical  
 Manufacture  
 Resp. Techn  
 Status  
 Other Identif  
 Parent Equip  
 Parent Slot  
 Location  
 State  
 Safety  
 RP Classific  
 Comments  
 Design  
 Item In ABS  
 Audit  
 Created on  
 Last modified  
 Responsible

Equipment Identifier: HCMQXA\_001-FL000001  
 Other Identifier: None  
 Description: MQXA KEK Inner Triplet Quadrupole

Main Made in  
 Actions: Edit  
 External Links  
 Property Values  
 Dimensions  
 Length  
 Width  
 Height  
 Weight  
 Value of goods

Equipment Identifier: HCVS  
 Other Identifier: None  
 Description: Beam Screen 1

Main Made in  
 Actions: Edit  
 Equipment data  
 Manufacturer  
 External Links  
 Property Values  
 Property  
 Beam Screen coil no.  
 Magnetic Permeability  
 Surf. Res. at 4.5K (bend)  
 Surf. Res. at 4.5K (flat)  
 Weld Conformity  
 Radial Diameter Center  
 Radial Diameter End  
 Vertical Diameter Center  
 Vertical Diameter End  
 Twist  
 Straightness  
 Subcontractor 1  
 Subcontractor 2  
 Subcontractor 3  
 Subcontract 3 certificate no  
 Subcontract 2 certificate no  
 Subcontract 1 certificate no  
 Length  
 Dimensions  
 Length  
 Width  
 Height  
 Weight  
 Value of goods

Equipment Identifier: HCMCBX\_001-SP000003  
 Other Identifier: HCMCBX\_001-SI000003  
 Description: MCBX Assembly



Property Values	Nominal Value	Value	Unit
Drawing ID	15025-CN-001		
OD N-CE 11 (0 deg)	350.17	350.17	mm
OD N-CE 12 (45 deg)	350.2	350.2	mm
OD N-CE 13 (90 deg)	350.14	350.14	mm
OD N-CE 14 (135 deg)	350.15	350.15	mm
OD N-CE 21 (0 deg)	350.21	350.21	mm
OD N-CE 22 (45 deg)	350.24	350.24	mm
OD N-CE 23 (90 deg)	350.18	350.18	mm
OD N-CE 24 (135 deg)	350.18	350.18	mm
OD N-CE 31 (0 deg)	350.24	350.24	mm
OD N-CE 32 (45 deg)	350.28	350.28	mm
OD N-CE 33 (90 deg)	350.23	350.23	mm
OD N-CE 34 (135 deg)	350.19	350.19	mm
OD CE 43 (0 deg)	350.24	350.24	mm
OD CE 42 (45 deg)	350.22	350.22	mm
OD CE 43 (90 deg)	350.17	350.17	mm
OD CE 44 (135 deg)	350.1	350.1	mm
Assembly Temperature	20	20	°C
Temperature2	20	20	°C
Damping test inner MCBXV	OK 500V	OK 500V	
Damping test inner MCBXV	OK 500V	OK 500V	
DC resistance MCBXV	18	18	ohm
DC resistance MCBXV	21.9	21.9	ohm
Inductance at 1 kHz MCBXV	66.48	66.48	mH
Inductance at 1 kHz MCBXV	68.4	68.4	mH
Inductance at 100Hz MCBXV	113.22	113.22	mH
Inductance at 100Hz MCBXV	161.14	161.14	mH
Leakage current MCBXV	9.E-09	9.E-09	A
Leakage current MCBXV	5.E-09	5.E-09	A
Magnetic meas.(pass/fail)	0	0	
Magn. meas. file MCBXV			
a1 (MCBXV)			
b1 (MCBXV)			
a2 (MCBXV)			
b2 (MCBXV)			
a3 (MCBXV)			
b3 (MCBXV)			
a4 (MCBXV)			
b4 (MCBXV)			
a5 (MCBXV)			

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.

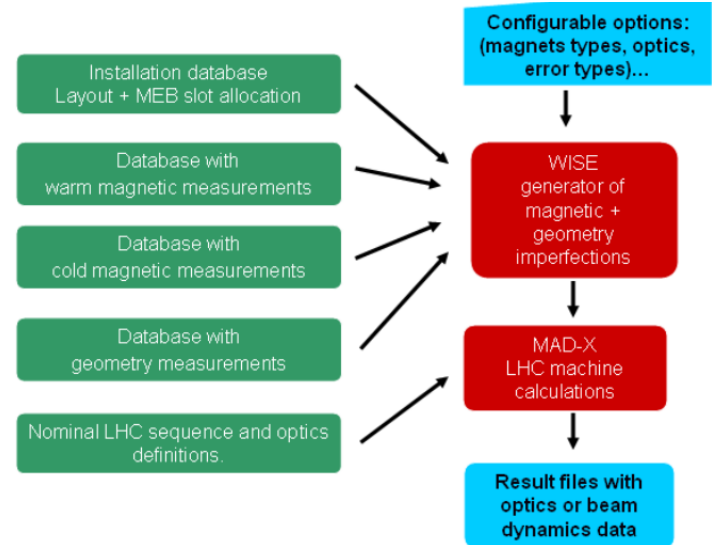


Large Hadron Collider Project

LHC Project Report 1056

## WISE - USER GUIDE AND IMPLEMENTATION NOTES

P. Hagen

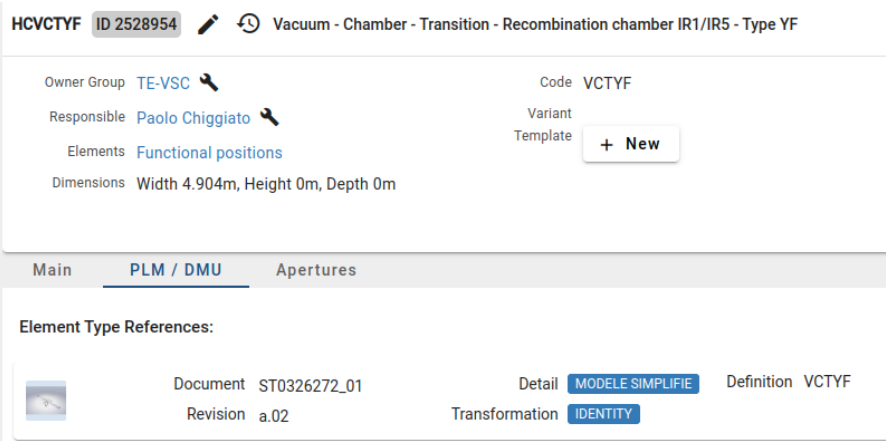
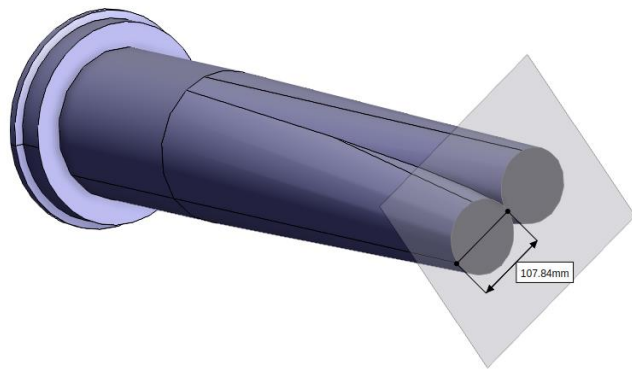
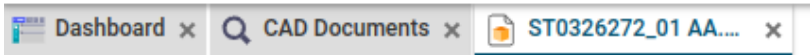


Windows Interface to Simulation of Errors

# 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

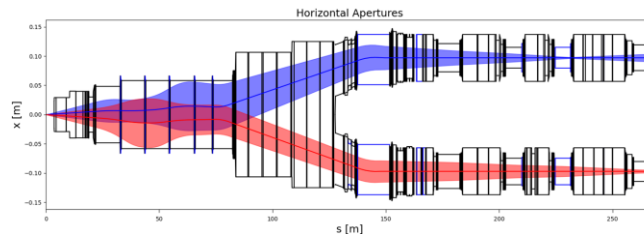
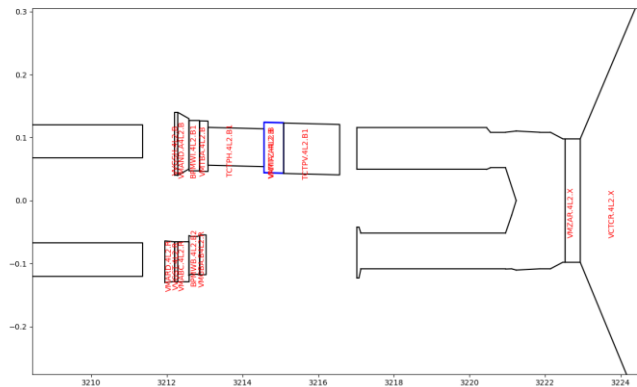
Improving aperture visualization is key to entering data correctly. Below examples of different approaches.

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!

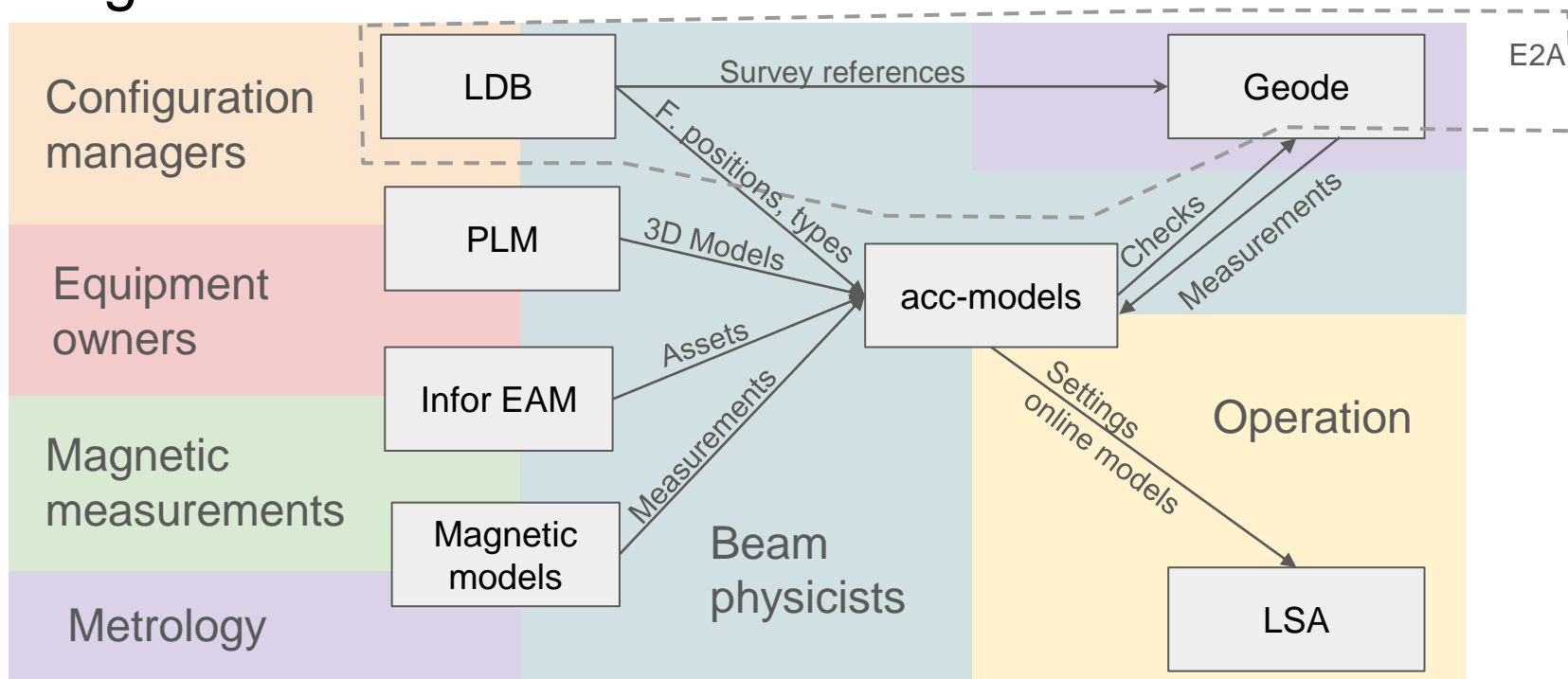
Economy of scale: join efforts, re-use and re-scope existing data sources and descope duplicated information, develop tooling to reduce constraints, minimize manual work, establish automatic testing and continuous integration.

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



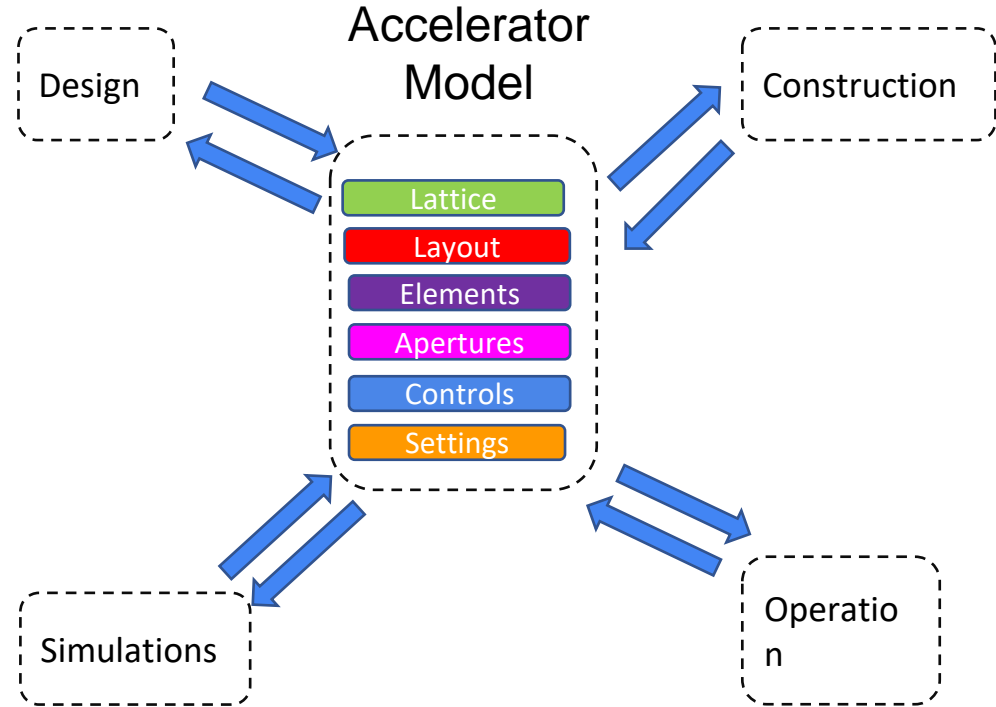
Today, each arrow represents an unstructured process driven by the needs of the users. We ultimately miss structures in which data owners and users share responsibility and resources for ensuring data quality, checks, data flow and data lifetime.

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.

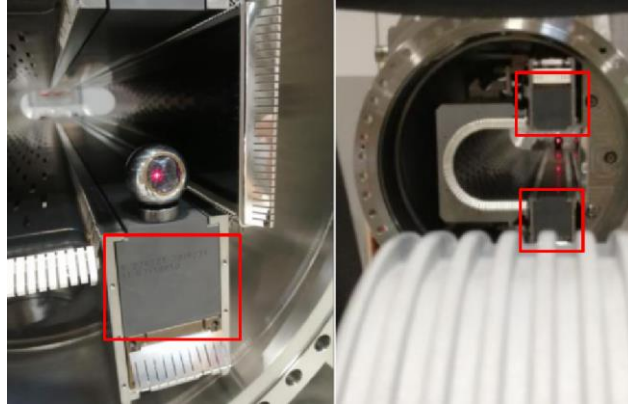


Accelerator physicists and operators inject or extract information into models to design, construct, operate and optimize accelerators.

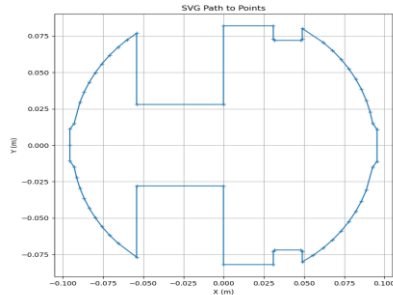


# SVG Path and editor

third modules



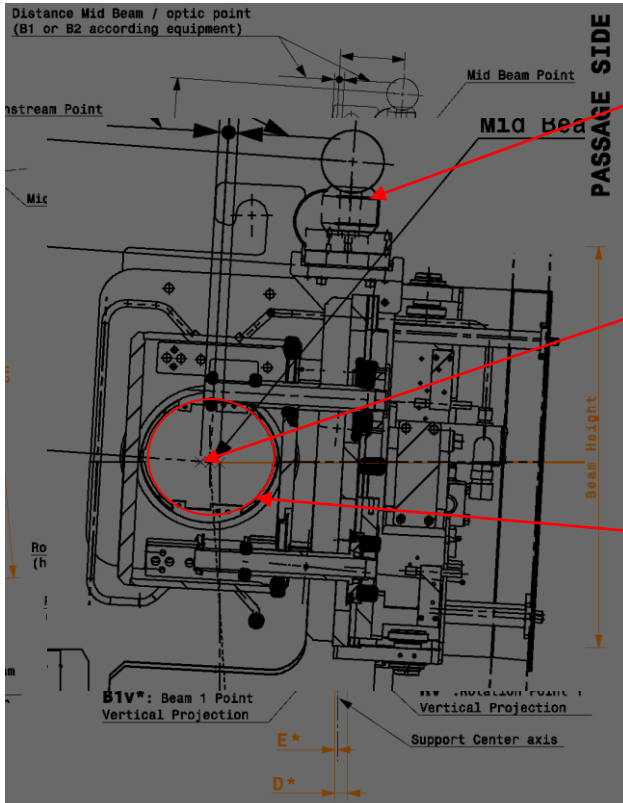
[https://acc-models.web.cern.ch/svg-path-editor/#P=m 0 4 h 78.4 a 60 60 0 01 0 120 h -78.4 h -4 v -56 h -62 v56 h-4.5 v -120 h 4.5 v 56 h 62 v -56 z](https://acc-models.web.cern.ch/svg-path-editor/#P=m%200%204%20h%2078.4%20a%2060%2060%200%2001%200%20120%20h%20-78.4%20h%20-4%20v%20-56%20h%20-62%20v%2056%20h%20-120%20h%204.5%20v%2056%20h%2062%20v%20-56%20z)



```
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.

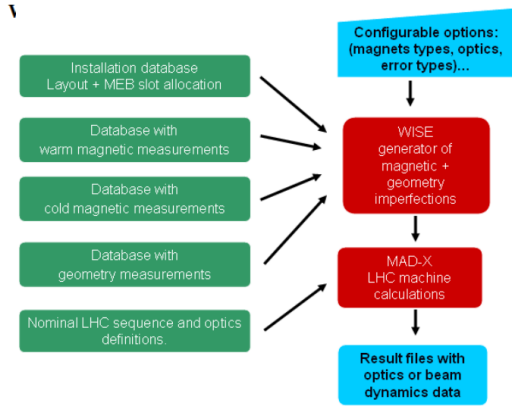


... and relations between them.



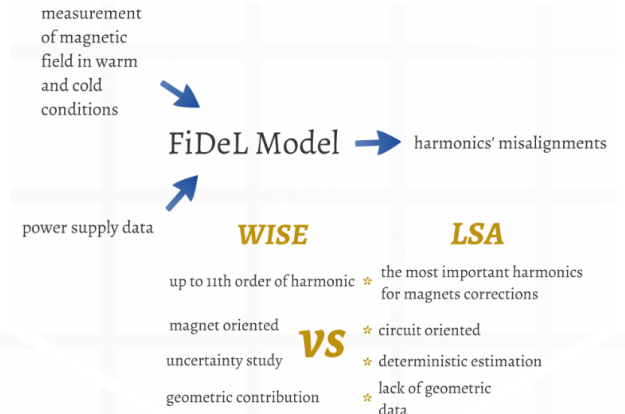
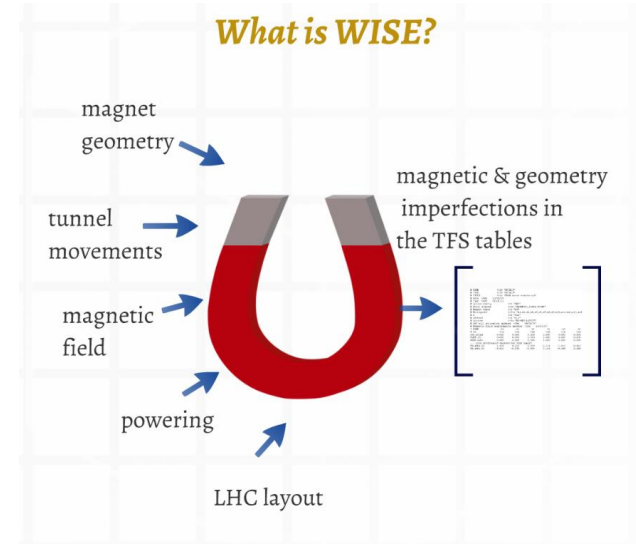
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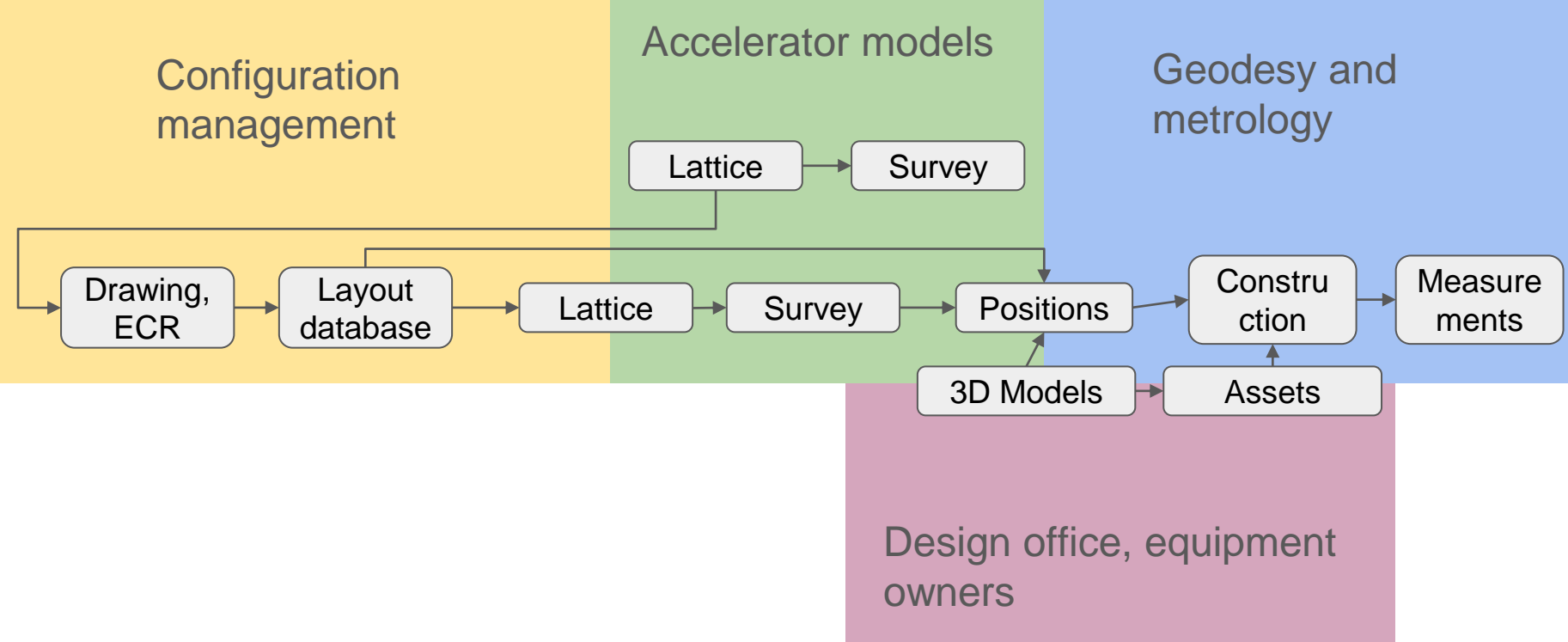


[https://indico.cern.ch/event/813002/contributions/3389661/attachments/1826585/2989584/16-03-08\\_abs\\_WISE2.0.pdf](https://indico.cern.ch/event/813002/contributions/3389661/attachments/1826585/2989584/16-03-08_abs_WISE2.0.pdf)

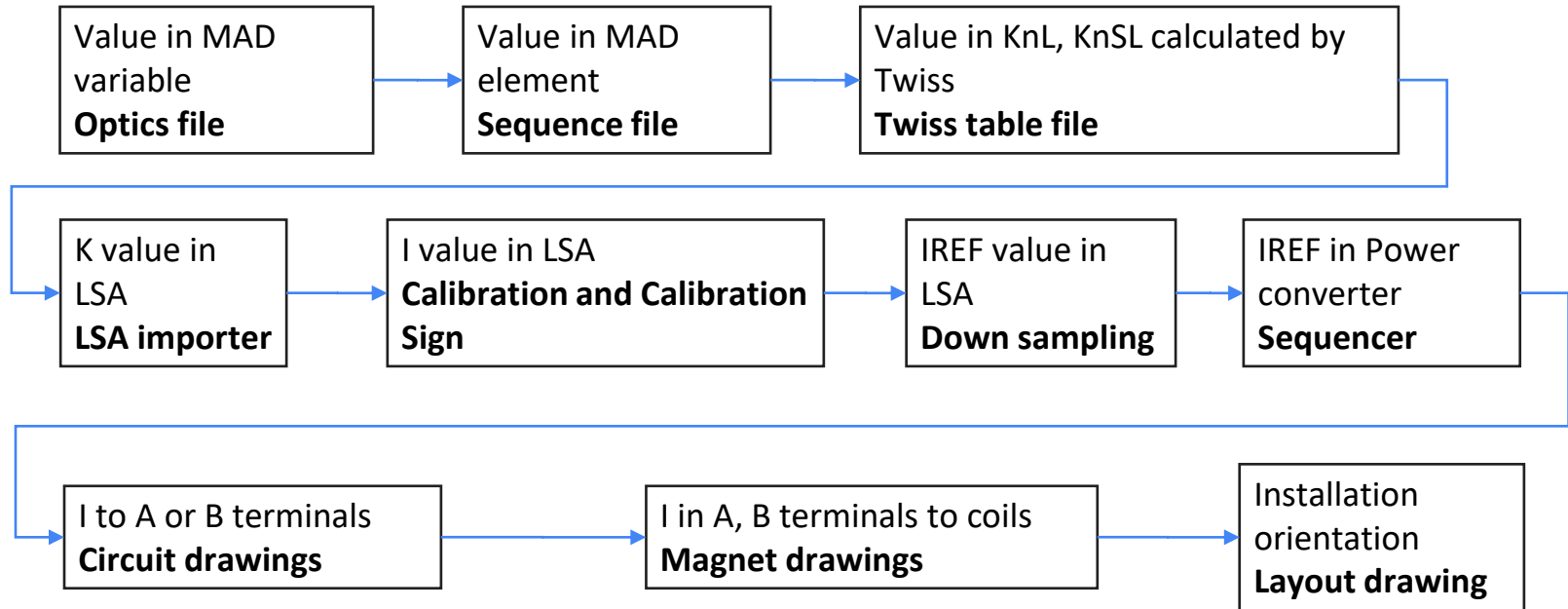
<https://cds.cern.ch/record/1089857/files/lhc-project-report-1056.pdf>



# Layout



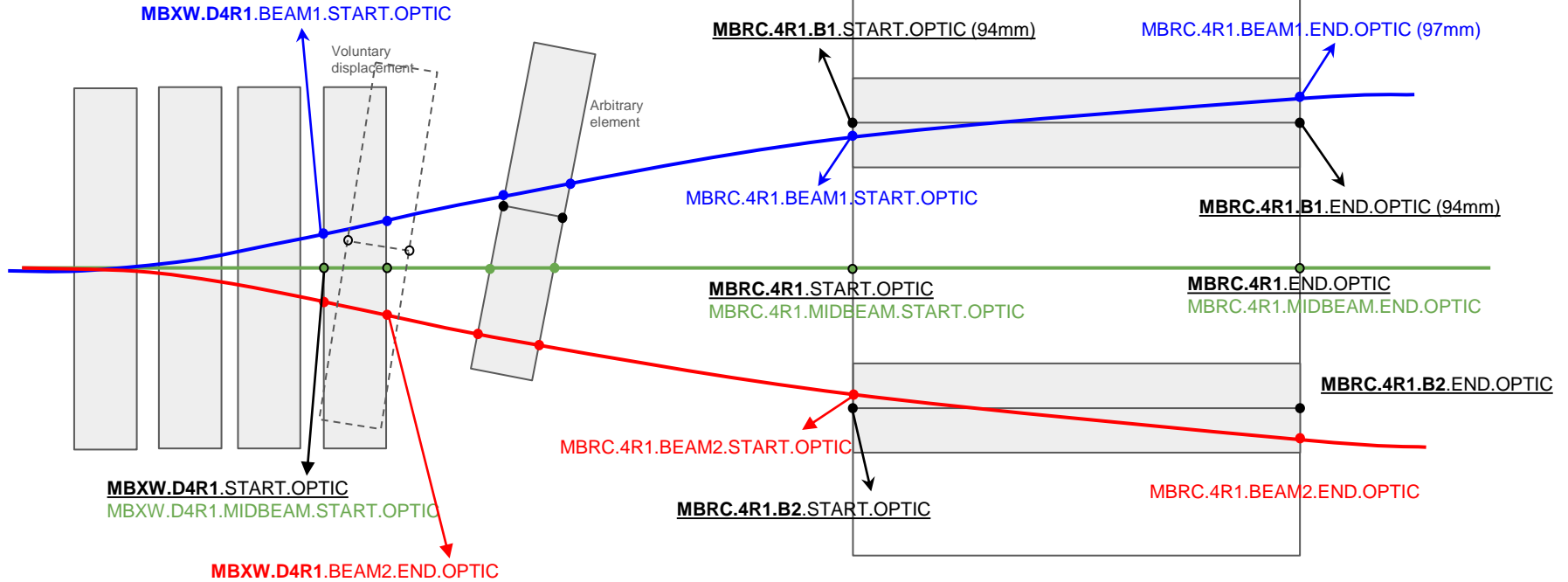
# From MAD-x variables to the magnetic field seen by the beam



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

# LHC D1

# LHC D2



BPMST.4R1.B1:BPMST002,  
 MBXW.A4R1:MBXW,  
 MBXW.B4R1:MBXW,  
 MBXW.C4R1:MBXW,  
 MBXW.D4R1:MBXW,  
 MBXW.E4R1:MBXW,  
 MBXW.F4R1:MBXW,

dL= 36.2345+(0-IP10FS.B:  
 at= 61.322+(0-IP10FS.B:  
 at= 65.588+(0-IP10FS.B:  
 at= 69.854+(0-IP10FS.B:  
 at= 74.12+(0-IP10FS.B1:  
 at= 78.386+(0-IP10FS.B:  
 at= 82.652+(0-IP10FS.B:

MBRC.4R1.B1:MBRC,

at= 157|.9+

## Work package leaders

