1st Accelerator Technology Sector Workshop

Engineering Design Tools and Processes
Project Management Methodologies and Tools

Chair: Mike Lamont

Interconnecting knowledge, experience, methods, people & data to foster learning & collaboration

ATS
Accelerators and Technology Sector

Building an accelerator from engineering to alignment

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Introduction

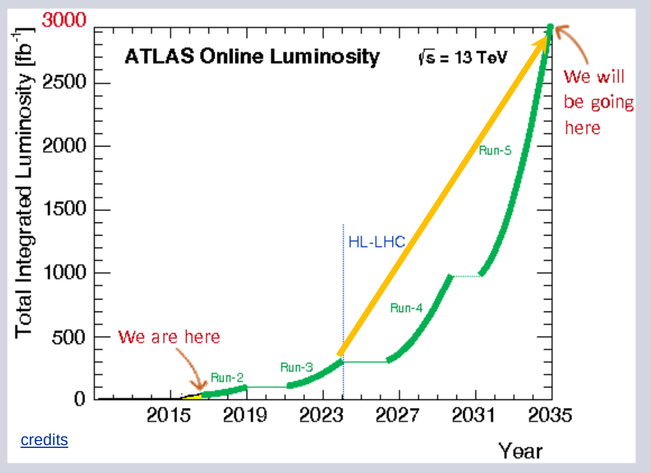
From the conception of an accelerator to the first beam, many actors from different domains need to exchange information

- at the right time,
- in a time-efficient manner,
- while ensuring consistent understanding.

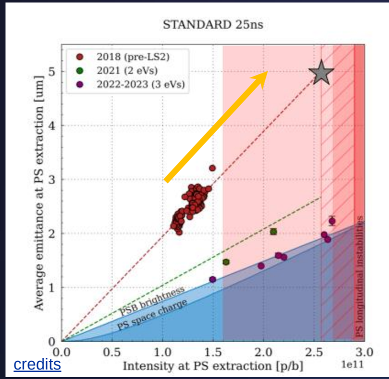
I will illustrate a selection processes that I was involved in and tools that I used for a project I know well:

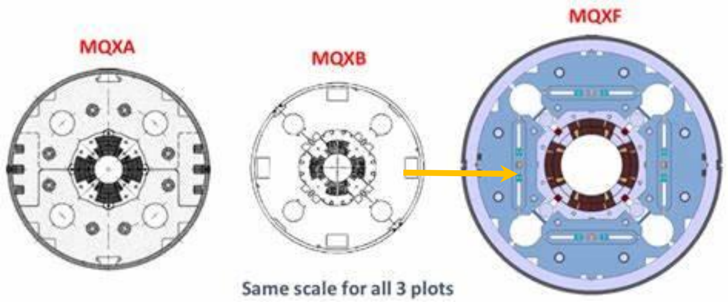
the High Luminosity LHC.

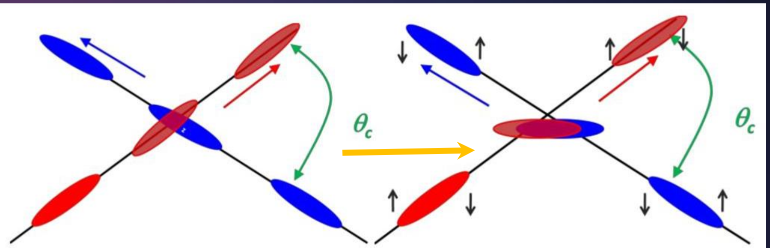
The HL-LHC project



It is well known that experiments need data at a higher and higher rate. Studies for an LHC upgrade started before LHC construction!







More protons:

LHC Injector Upgrade

Larger magnets:

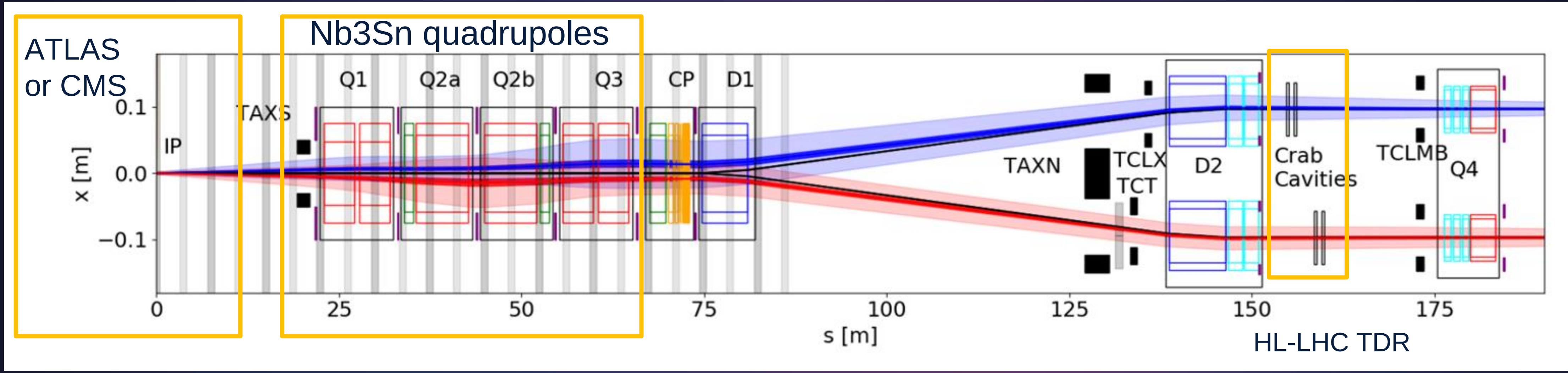
Nb3Sn magnets

Larger overlap at the interaction:

Crab cavities

Beamline equipment in a few km of the LHC will be removed and replaced, and ancillaries, civil engineering, etc…

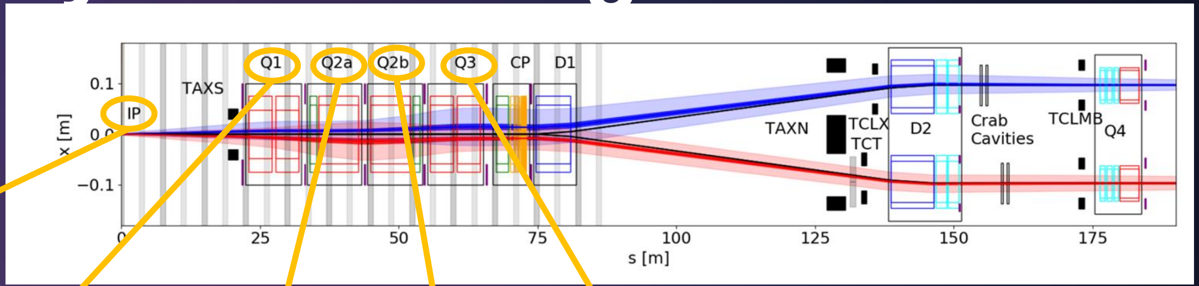
From a layout design to layout drawings

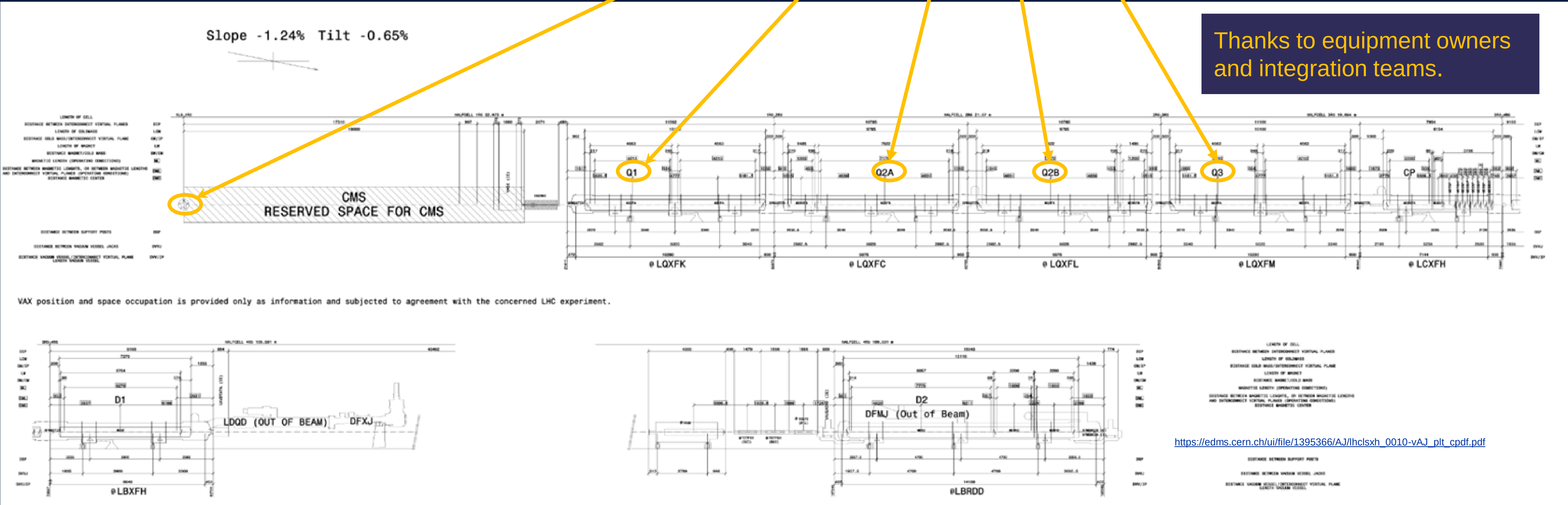


Beam physicist view the right side of the IP in HL-LHC.

MAD-X is the tool to compute the position of the beam trajectory in space and the beam physics properties: beam size, beam stability, magnetic corrections…
MAD-X models also represent a first description of the layout.

From a layout design to layout drawings

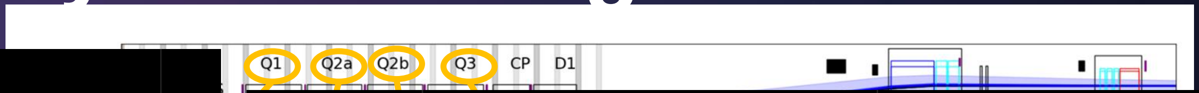


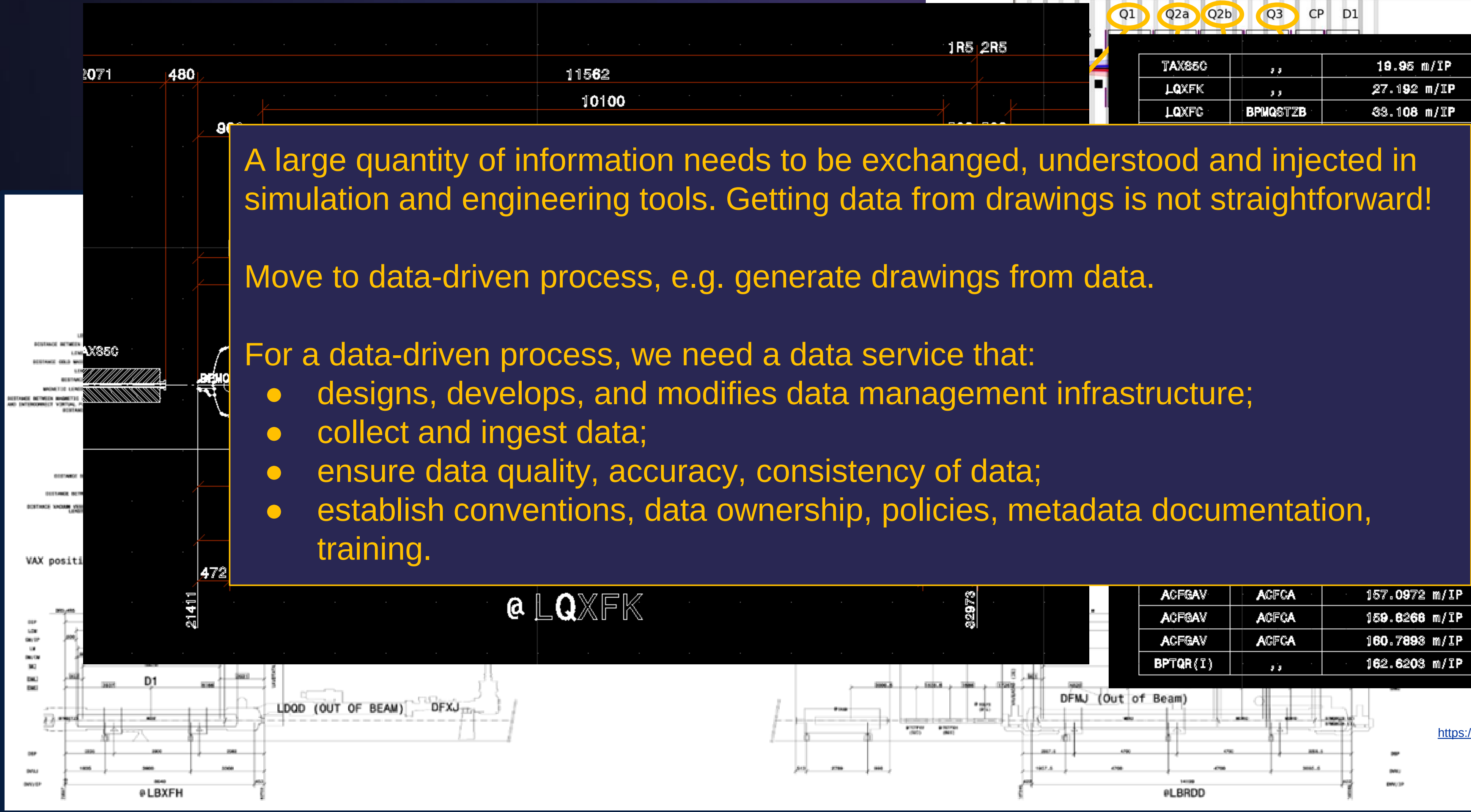


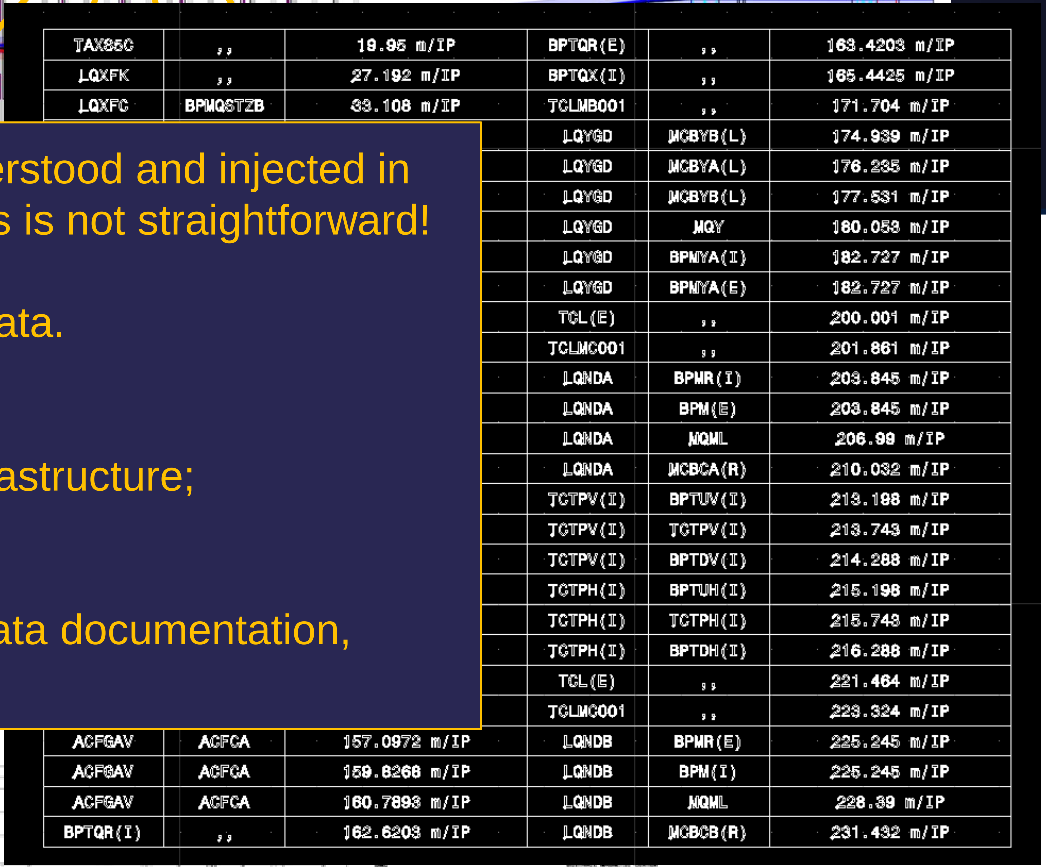
Thanks to equipment owners and integration teams.

https://edms.cern.ch/ui/file/1395366/AJ/lhclsxh_0010-vAJ_plt_cpdf.pdf

From a layout design to layout drawings







TAX85C	,,	19.95 m/IP	BPTQR(E)	,,	163.4203 m/IP
LQXFK	,,	27.192 m/IP	BPTQX(I)	,,	165.4425 m/IP
LQXFC	BPMQSTZB	33.108 m/IP	TCLMB001	,,	171.704 m/IP
			LQYGD	MCBYB(L)	174.939 m/IP
			LQYGD	MCBYA(L)	176.235 m/IP
			LQYGD	MCBYB(L)	177.531 m/IP
			LQYGD	MQY	180.058 m/IP
			LQYGD	BPMYA(I)	182.727 m/IP
			LQYGD	BPMYA(E)	182.727 m/IP
			TCL(E)	,,	200.001 m/IP
			TCLMC001	,,	201.861 m/IP
			LQNDA	BPMR(I)	203.845 m/IP
			LQNDA	BPM(E)	203.845 m/IP
			LQNDA	MQML	206.99 m/IP
			LQNDA	MCBCA(R)	210.032 m/IP
			TCTPV(I)	BPTUV(I)	213.198 m/IP
			TCTPV(I)	TCTPV(I)	213.743 m/IP
			TCTPV(I)	BPTDV(I)	214.288 m/IP
			TCTPH(I)	BPTUH(I)	215.198 m/IP
			TCTPH(I)	TCTPH(I)	215.743 m/IP
			TCTPH(I)	BPTDH(I)	216.288 m/IP
			TCL(E)	,,	221.464 m/IP
			TCLMC001	,,	223.324 m/IP
ACFGAV	ACFCA	157.0972 m/IP	LQNDB	BPMR(E)	225.245 m/IP
ACFGAV	ACFCA	159.8268 m/IP	LQNDB	BPM(I)	225.245 m/IP
ACFGAV	ACFCA	160.7893 m/IP	LQNDB	MQML	228.39 m/IP
BPTQR(I)	,,	162.6203 m/IP	LQNDB	MCBCB(R)	231.432 m/IP

A large quantity of information needs to be exchanged, understood and injected in simulation and engineering tools. Getting data from drawings is not straightforward!

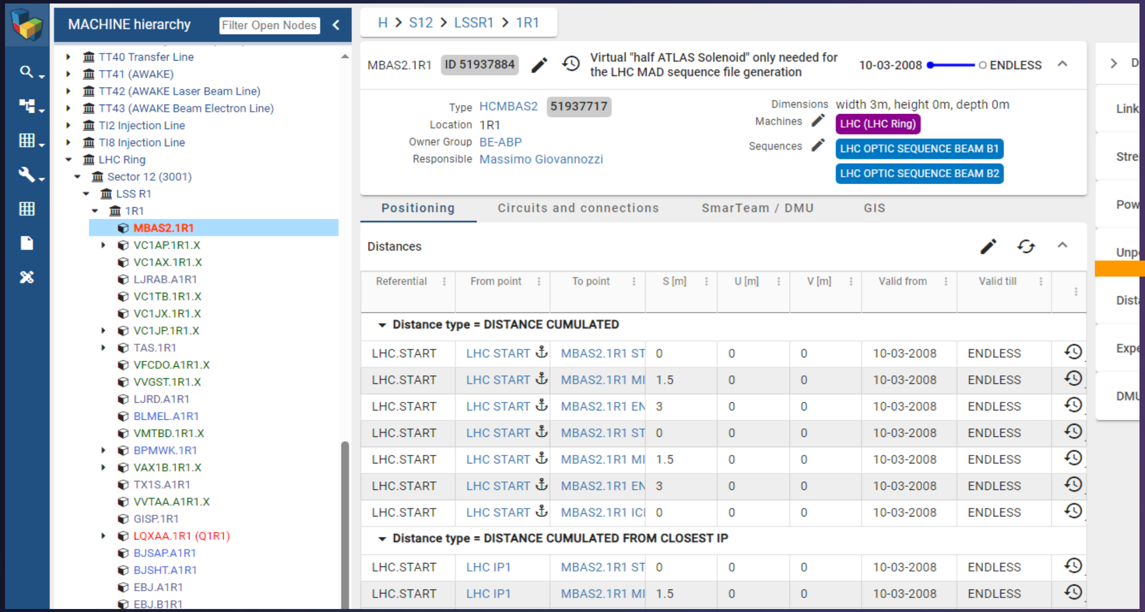
Move to data-driven process, e.g. generate drawings from data.

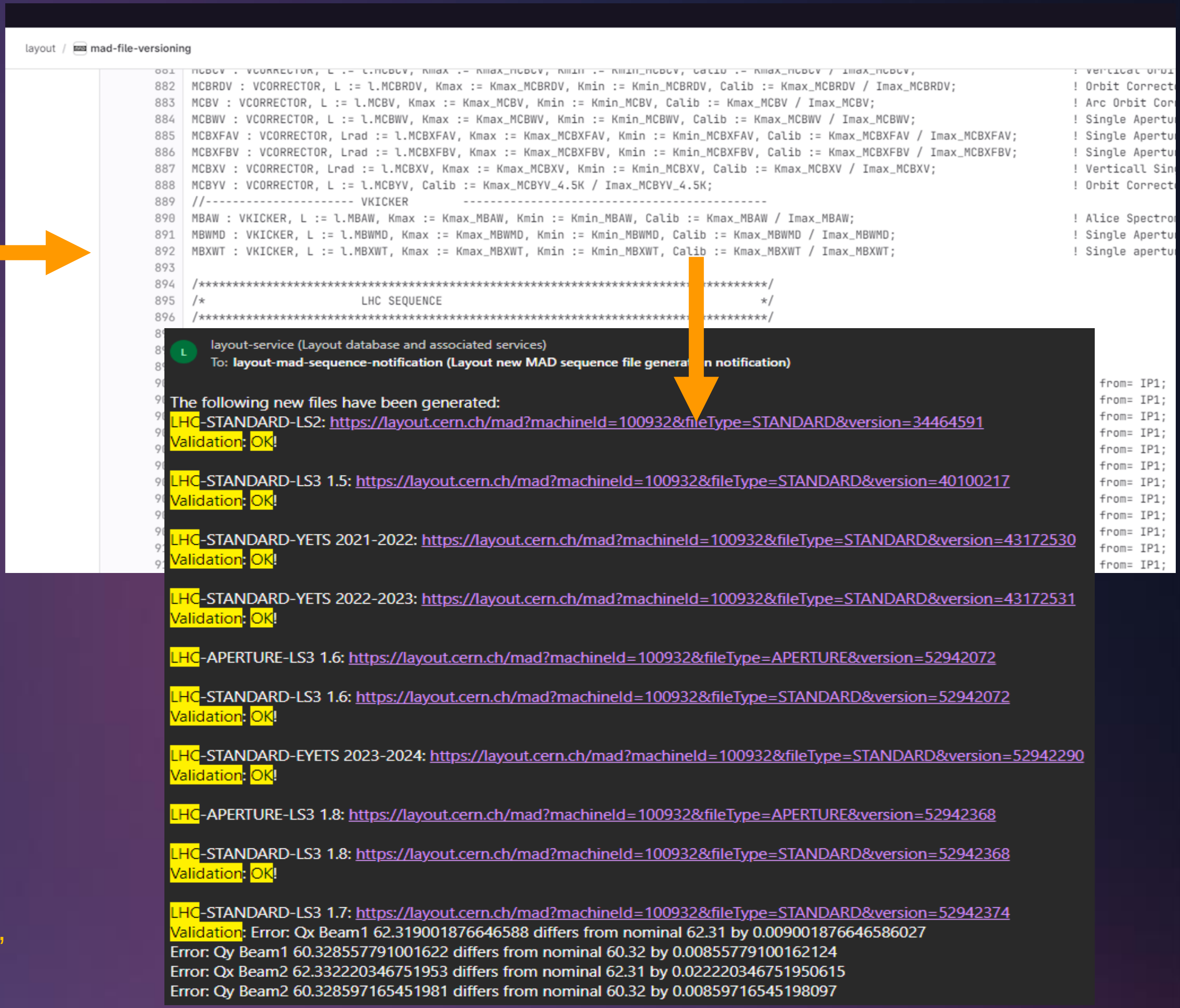
For a data-driven process, we need a data service that:

- designs, develops, and modifies data management infrastructure;
- collect and ingest data;
- ensure data quality, accuracy, consistency of data;
- establish conventions, data ownership, policies, metadata documentation, training.

https://edms.cern.ch/ui/file/1395366/AJ/lhclsxh_0010-vAJ_plt_cpdf.pdf

Layout database to automatic validation





Layout data injected by configuration manager to layout database.

Automatic pipeline to

1. transform into MAD-X code,
2. check beam optics, beam aperture,
3. create beam reference points for the equipment injected back in LDB,
4. sending e-mails if something goes wrong!

Pipeline built within the Engineering to Alignment Project (E2A), ported now to SPS, PS and with more machines coming.

Vacuum layout and beam aperture

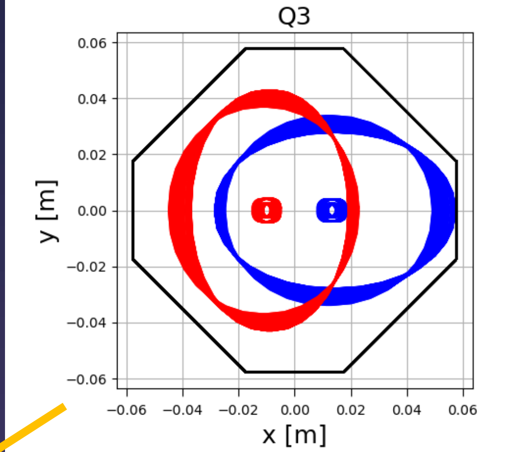
The LHC has thousands of vacuum pipes and transitions.

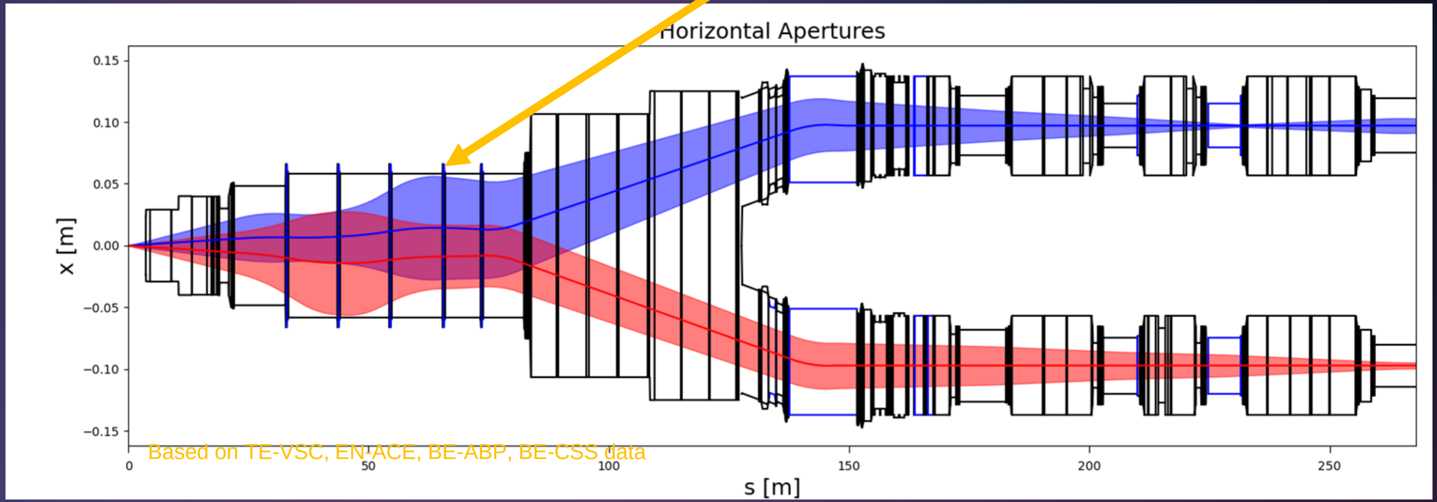
Aperture critical for performance, not only size, but smoothness matters.

Aperture geometry needs to be extracted from mechanical models and injected to beam dynamics codes.

Data-driven approach:

1. LHC vacuum expert inserts data Layout DB.
2. Layout complemented with beam size and generates views and used to cross-check.
3. Automatic checks to reduce time for insertion, identify issues quickly, to validate a vacuum layout.





Based on TE-VSC, EN-ACE, BE-ABP, BE-CSS data

Preparing an installation

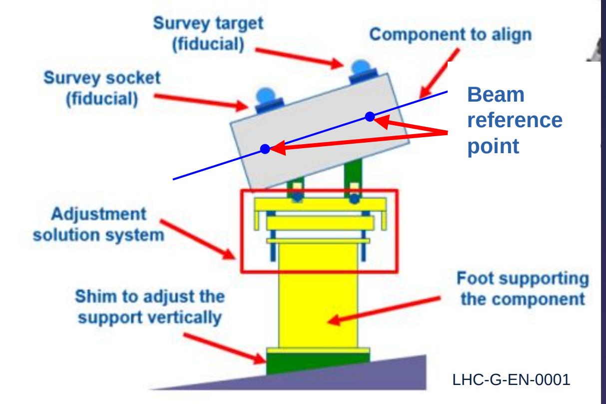
We need to calculate the expected location of the supports and alignment targets, such that the nominal beam reference points are at a defined position relative to a measured reference on the device.

This process involves survey experts, equipment owners, beam physicists, design offices, configuration managers to agree and describe an installation.

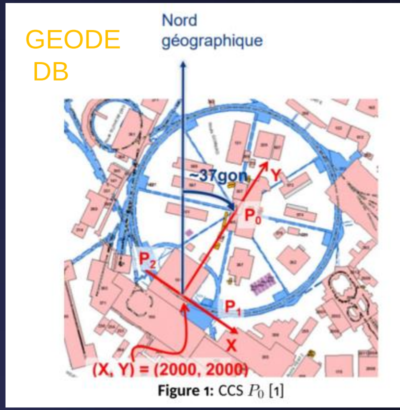
Challenges:

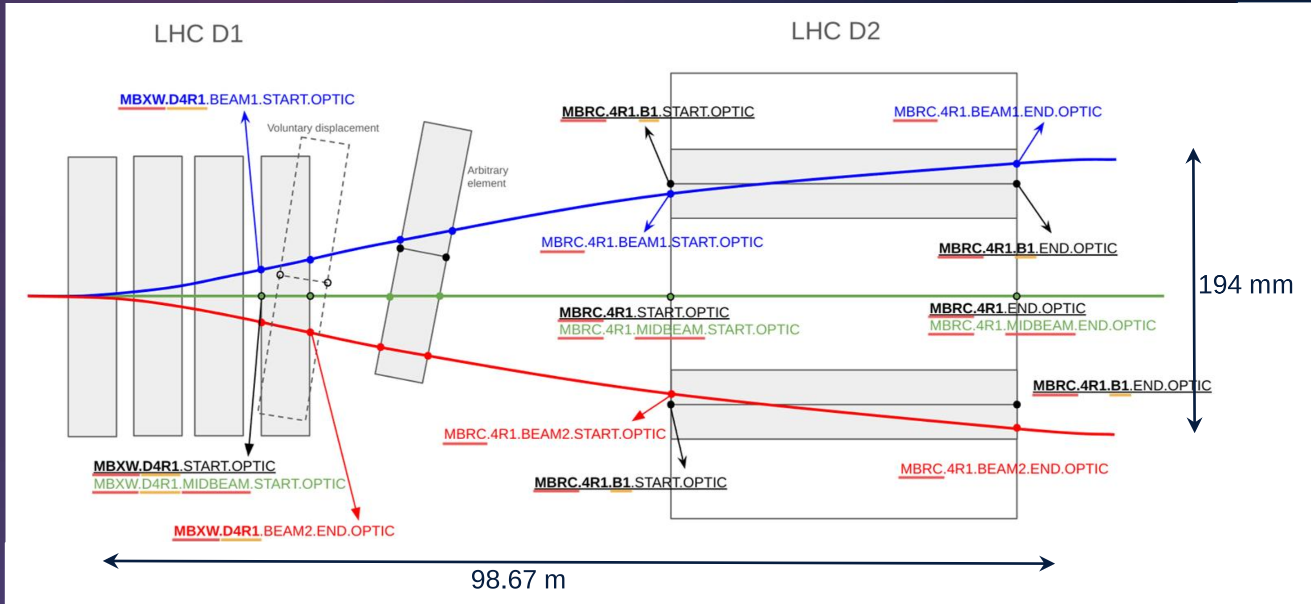
- Reference frames: data is not stored in the same reference frame and in the same place.
- Scale: transverse ~ mm, longitudinal ~10 m. Mechanical drawings cannot distinguish points.
- Lifecycle: if reference points, mechanical features can change at different times, models, and drawings could become obsolete, some time subtly.

Here we miss a completely automated data-driven process!

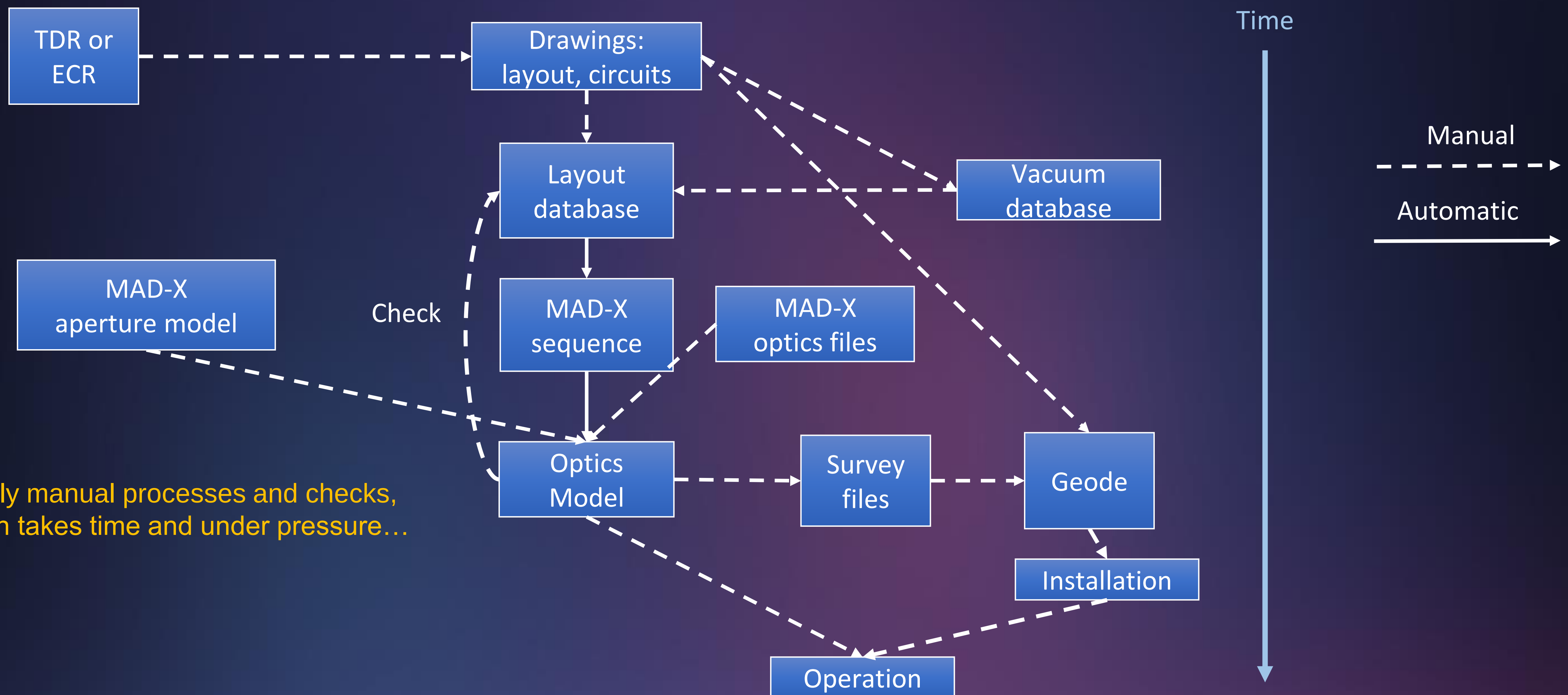


CERN COORDINATE SYSTEM (CCS)



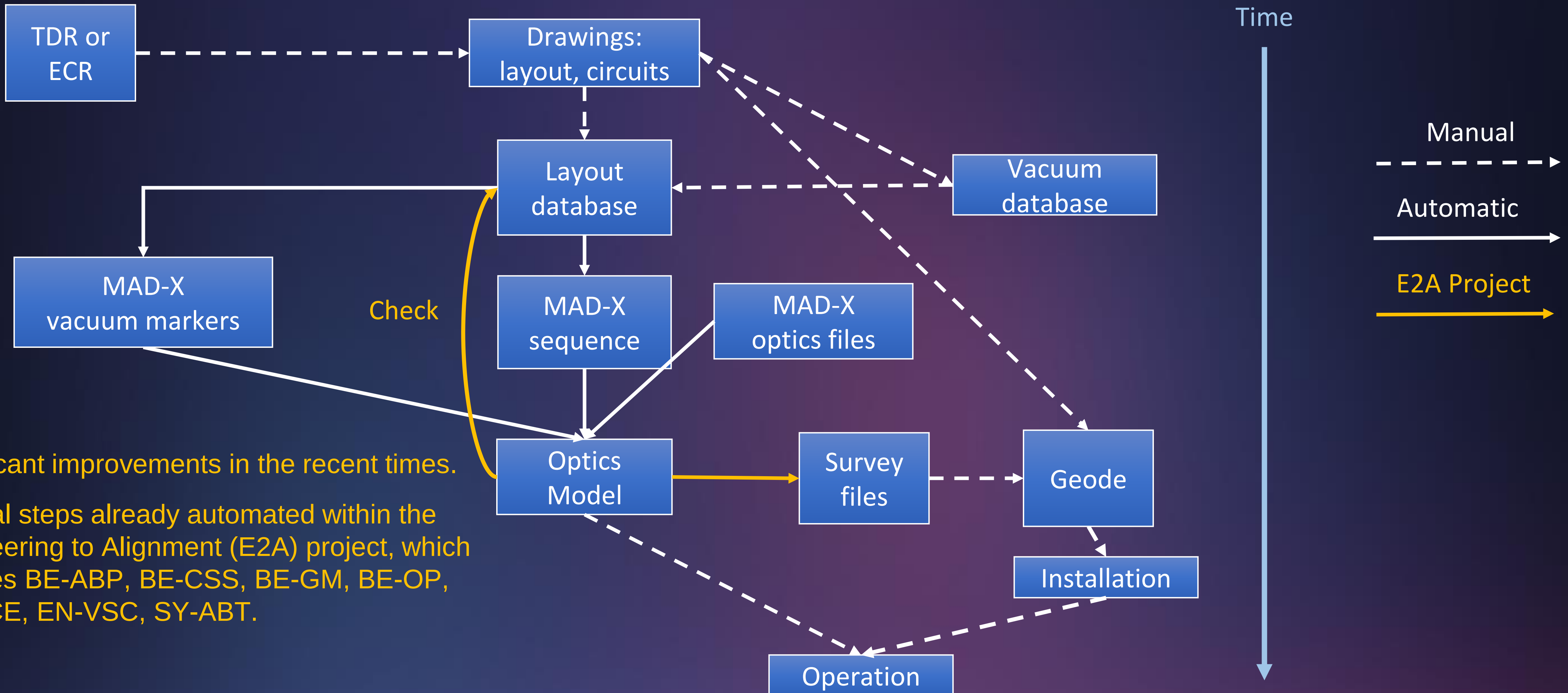


Bird-eye view of the process and tools: past



Mostly manual processes and checks, which takes time and under pressure…

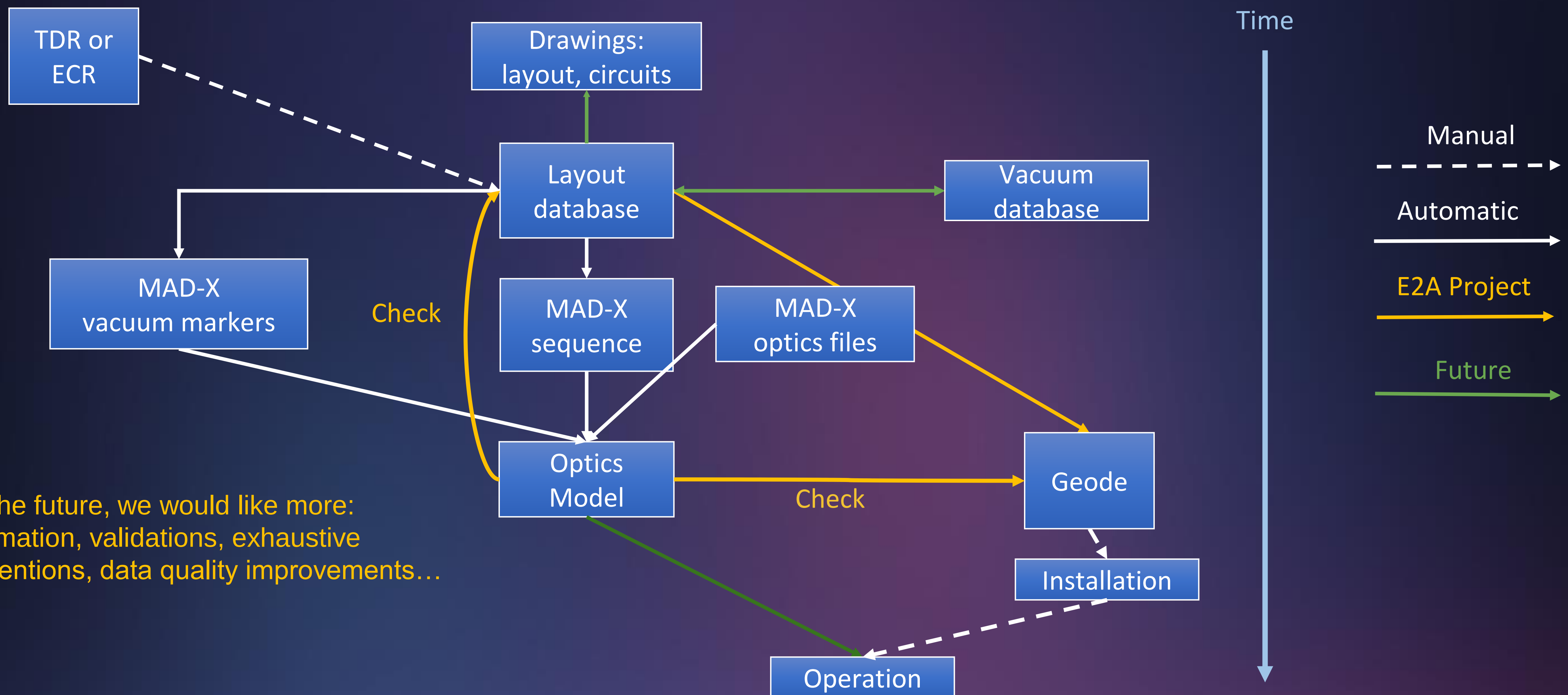
Bird-eye view of the process and tools: present



Significant improvements in the recent times.

Several steps already automated within the Engineering to Alignment (E2A) project, which involves BE-ABP, BE-CSS, BE-GM, BE-OP, EN-ACE, EN-VSC, SY-ABT.

Bird-eye view of the process and tools: future



For the future, we would like more: automation, validations, exhaustive conventions, data quality improvements…

Challenges

Building an accelerator requires a large amount of information between many actors with diverse expertise.

Challenges:

1. Some processes start too late, too coupled.
2. Coherence and completeness of data sources slows down processes significantly.
3. We are getting fewer and the projects are getting larger.

Moving to data-driven processes

How to do better:

1. Establish a single source of truth, favour data sharing and avoid duplication.
2. Do not be afraid to change, decouple processes, reduce data dependencies.
3. Establish explicit written conventions and improve conventions to simplify processes.
4. Favour early data ingestion, immediate testing, fast validation and correction cycles.

In addition:

- Clarify data management roles and process orchestrators.

Teams in the E2A project are executing this agenda. Within limited resources, we are already seeing tangible improvements. As we progress, we see many opportunities and would like to do more.