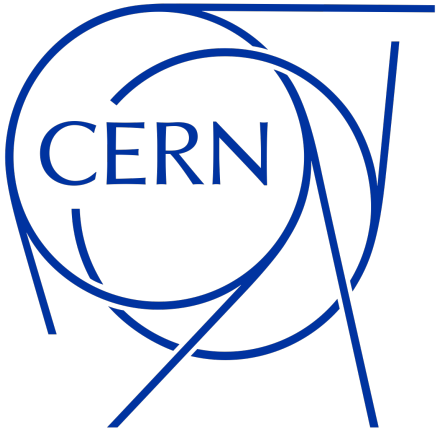


Untangling the Cables: Streamlining Muon Detector Operation

Jonas Kann (RWTH Aachen, Germany)

Supervisors: Andrea Contu, Vladimir Chulikov, Barbara Sciascia

29th of August, 2024

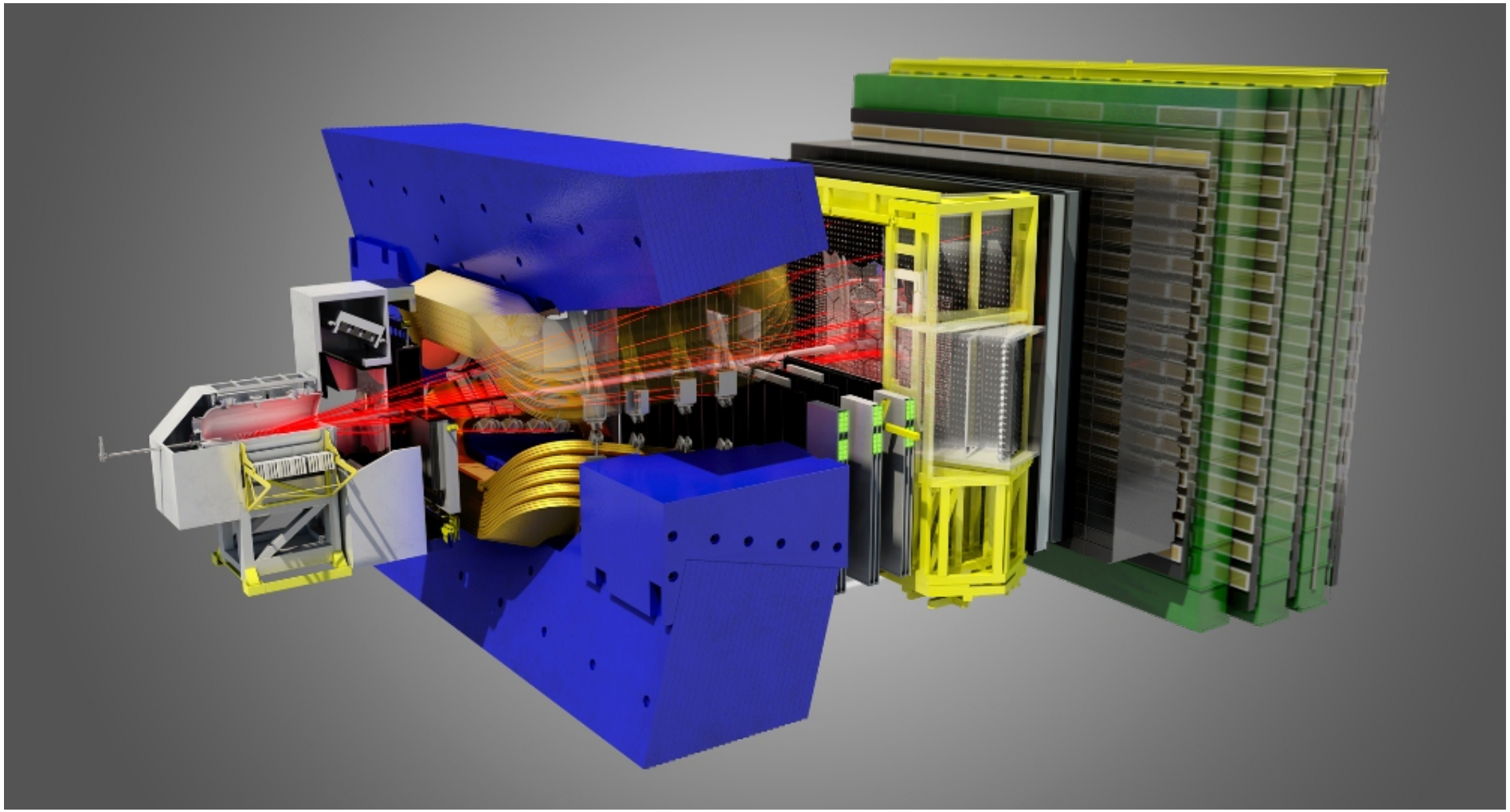
Outline

- Introduction - The muon system
- “The Cabling Problem“
- The solution - A relational database
- Applications - Database Integration
- Conclusion and Prospects

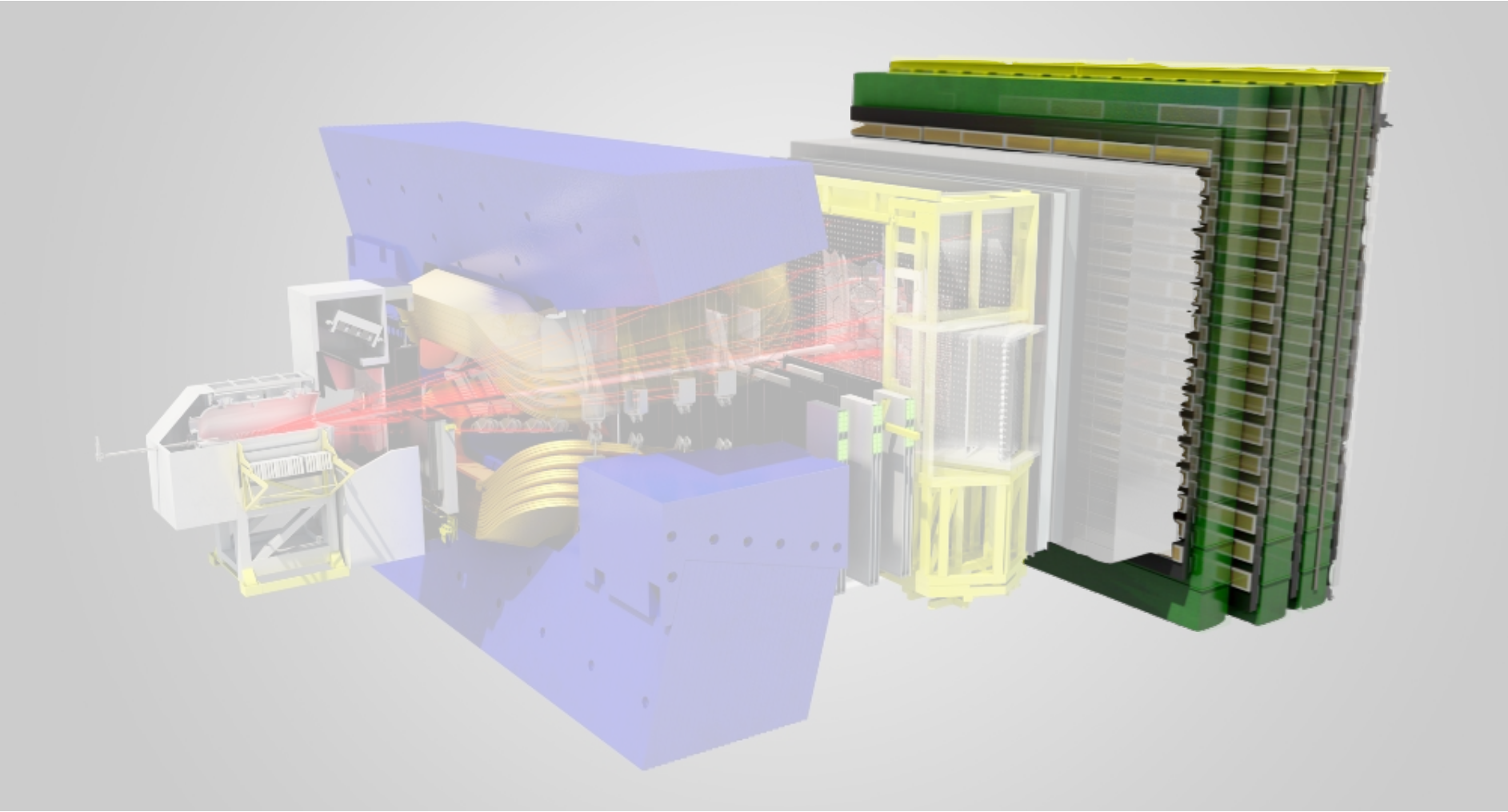
Introduction

The muon system

The muon system



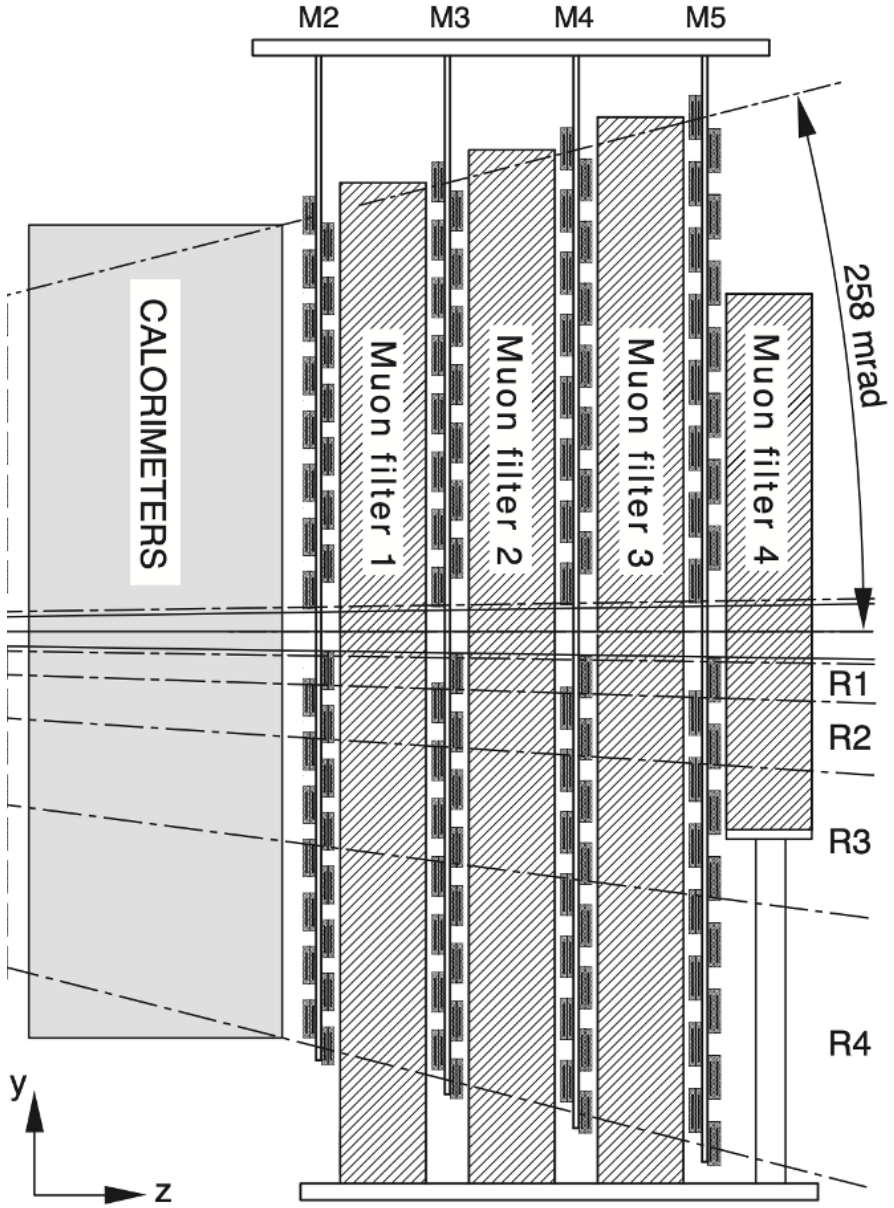
The muon system



The muon system

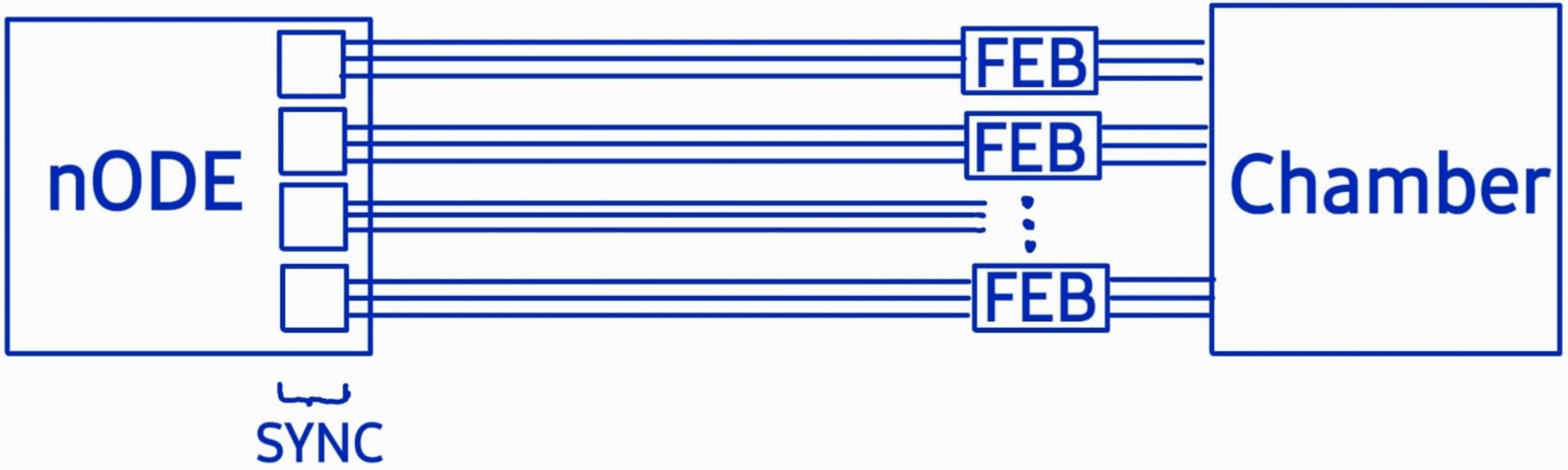
- Largest subsystem in the LHCb detector
- Subdivided into quadrant, station and region
- Based on Multi Wire Proportional Chambers (MWPC)
- Stations alternate with iron filters
- Mainly used for particle identification but tracking is possible
- Muons at final stage of many B meson decays

➔ Good performance of the muon system is crucial for LHCb physics

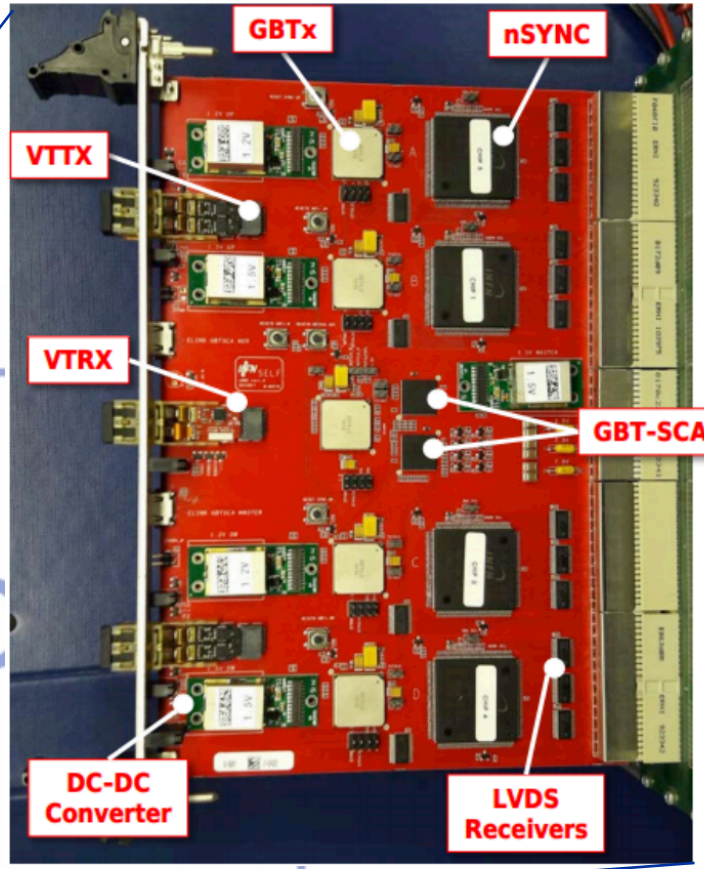


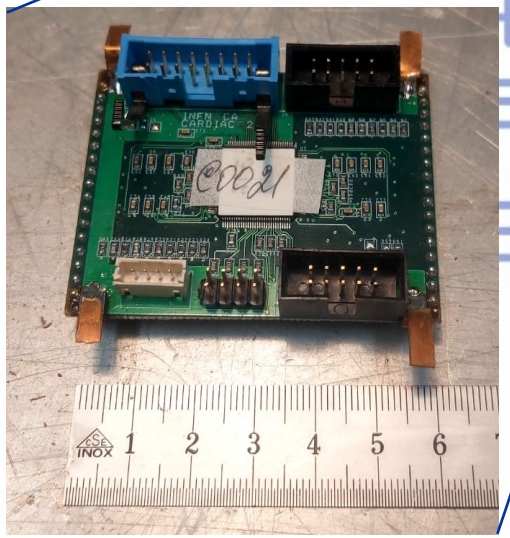
The DAQ Chain

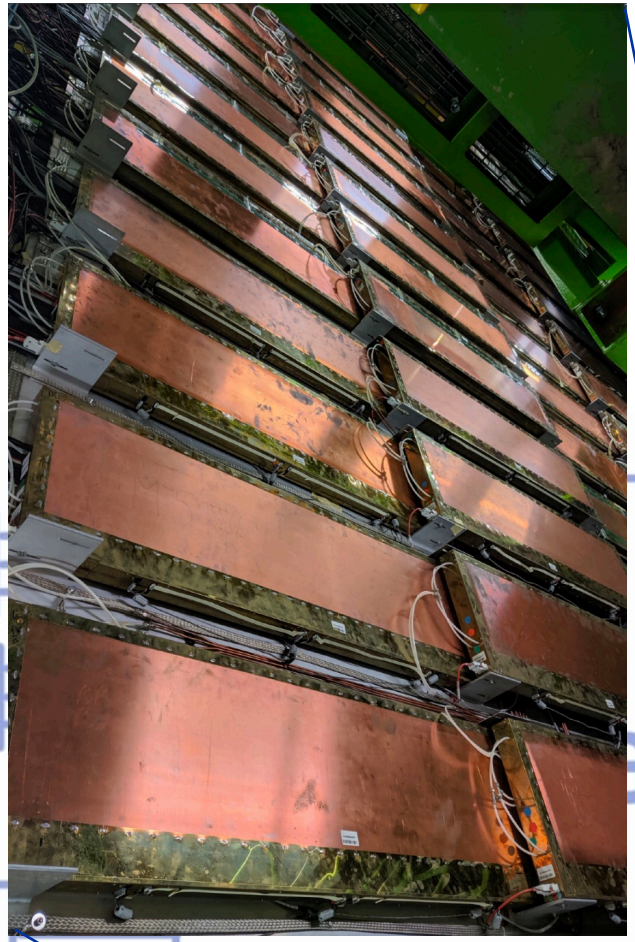
- 1104 chambers (MPWC)
- Up to 14 FEBs per chamber
- 144 nODE with 4 SYNC each
- Up to 48 used channels per SYNC and 8 channels per FEB



The DAQ Chain

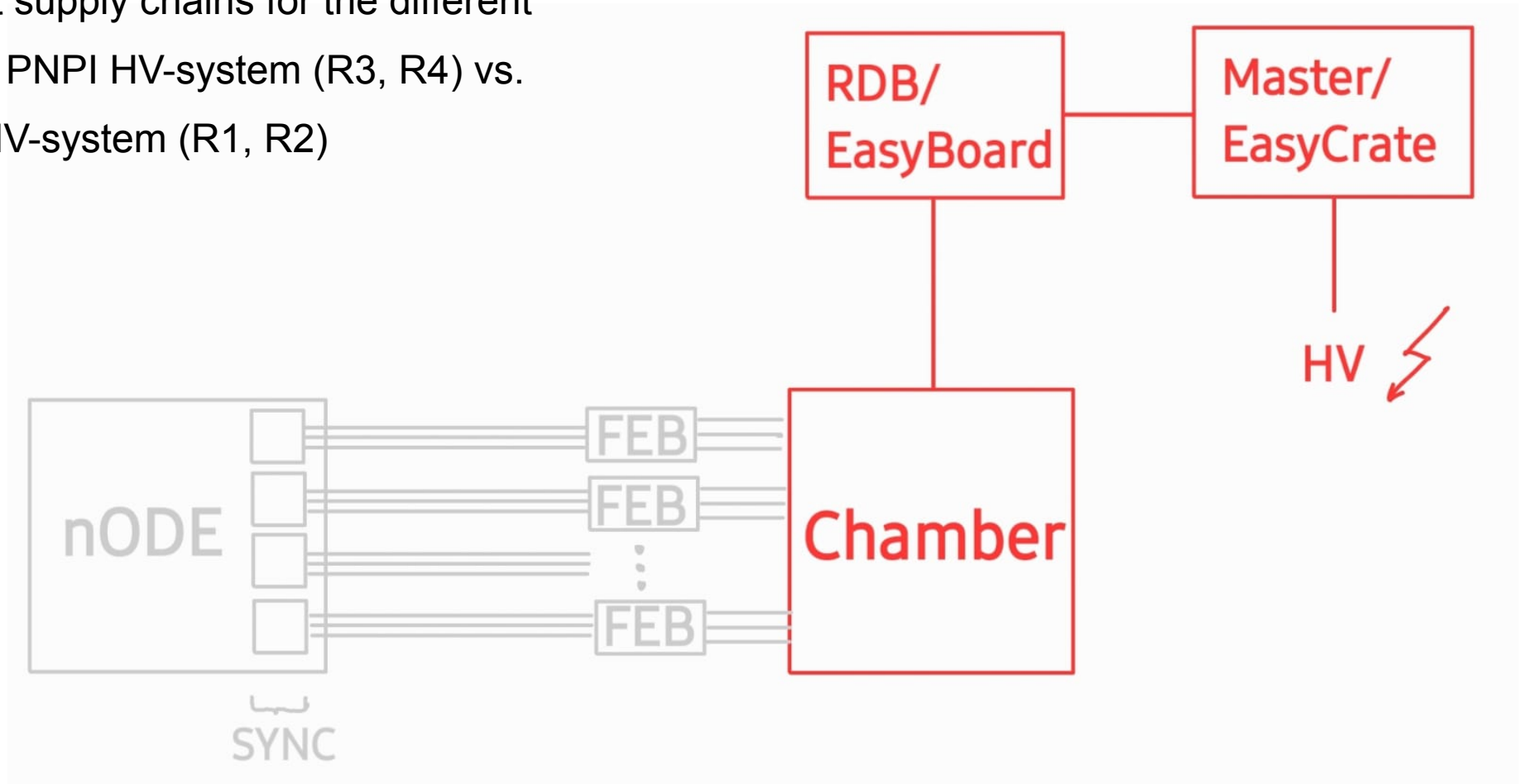




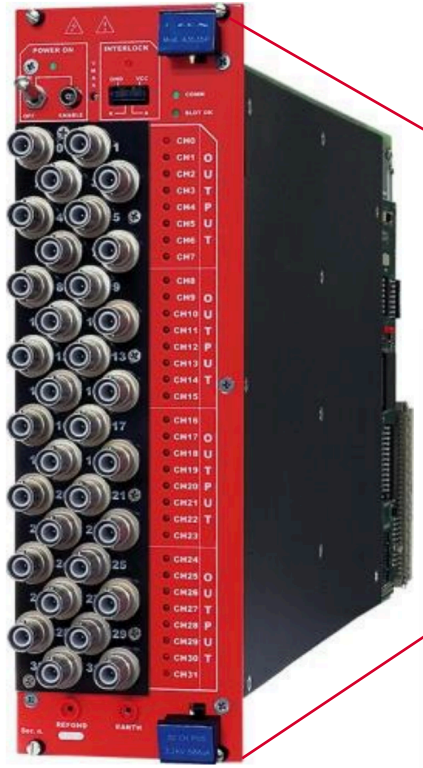


The HV Chain

- MWPC must be supplied with high voltage
- Different supply chains for the different regions, PNPI HV-system (R3, R4) vs. CAEN HV-system (R1, R2)



The HV Chain



RDB/
EasyBoard

Master/
EasyCrate

nODE

FEB

FEB

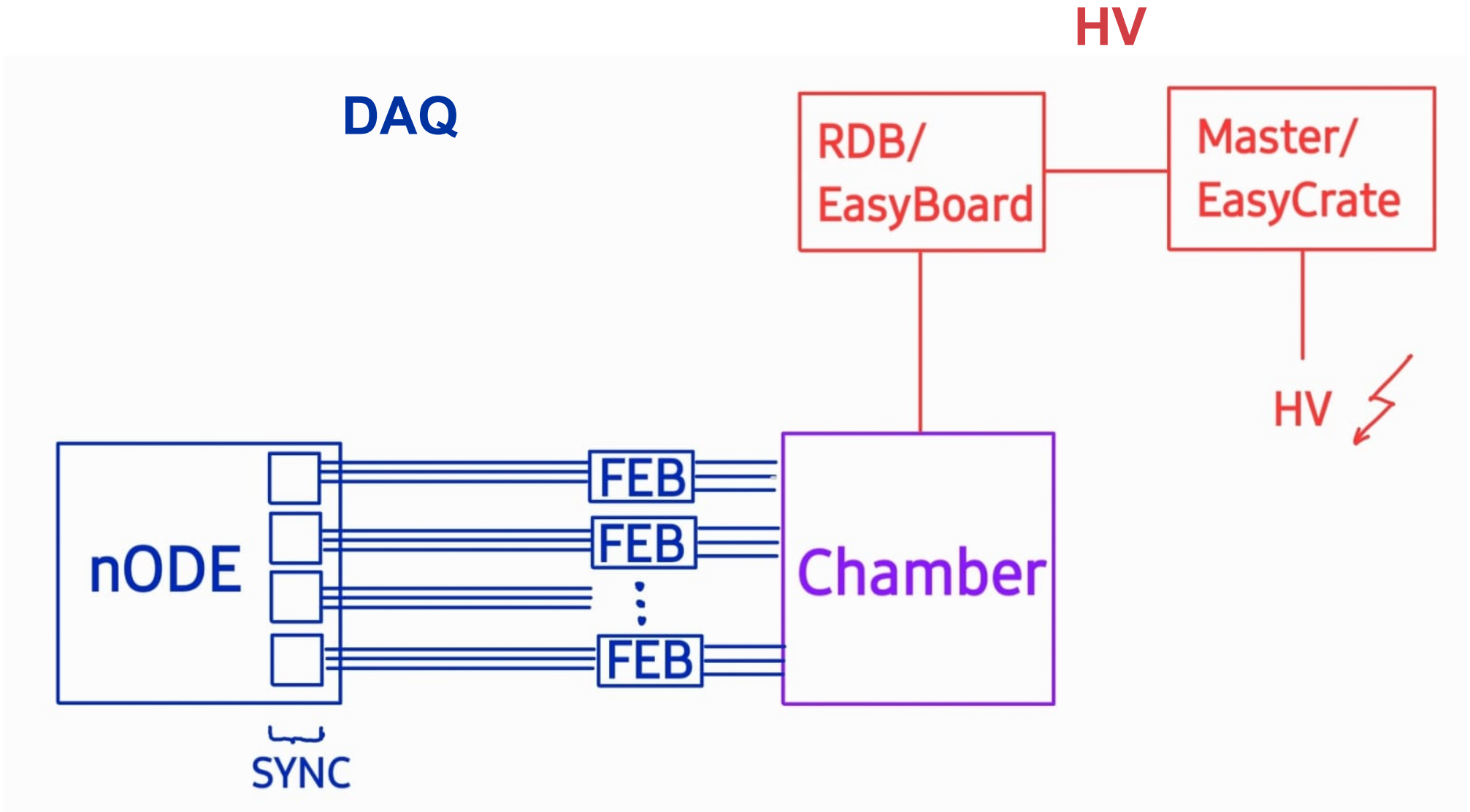
FEB

Chamber

SYNC

“The Cabling problem“

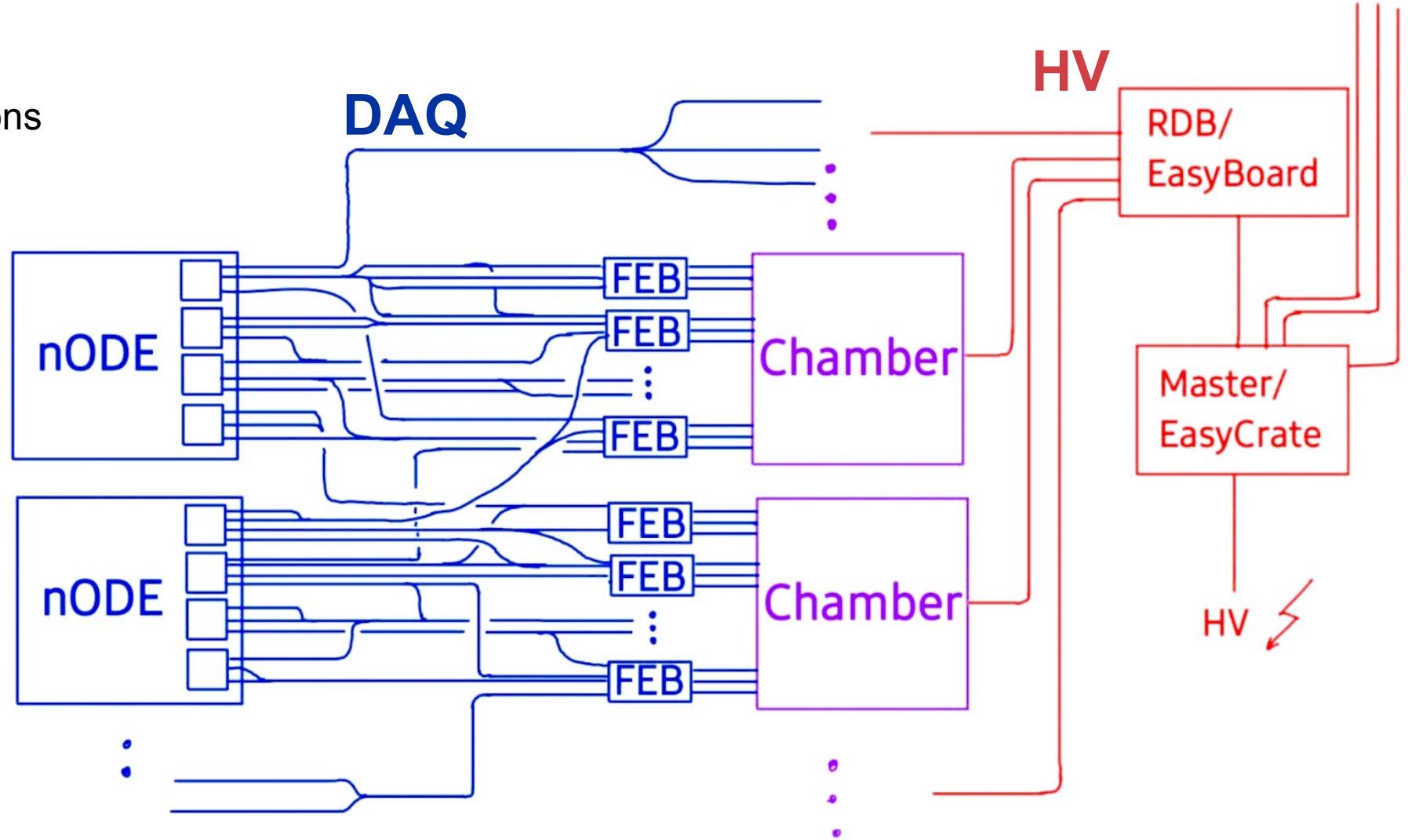
This is a lie…


HV
DAQ
RDB/
EasyBoard
Master/
EasyCrate
HV
nODE
FEB
FEB
FEB
Chamber
SYNC

This is a ~~lie~~ less of a lie…

- Rather messy cabling
- In total: ~50 000 connections
- Not a one-to-one mapping between the different components
- Hard to maintain…
- **BUT** well-defined relationships between different physical components

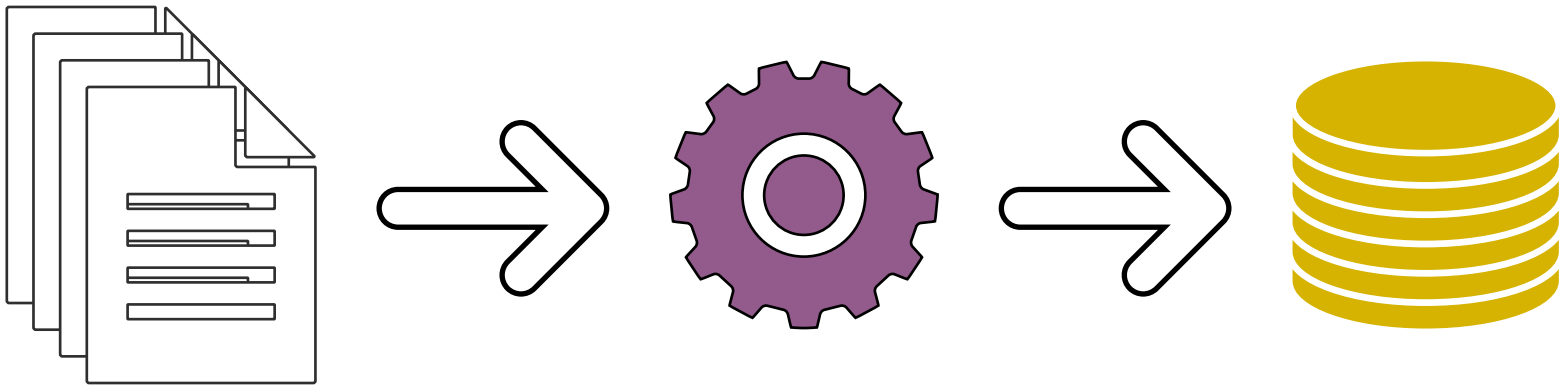
➔ Organize data in a relational database!



The solution

A relational database

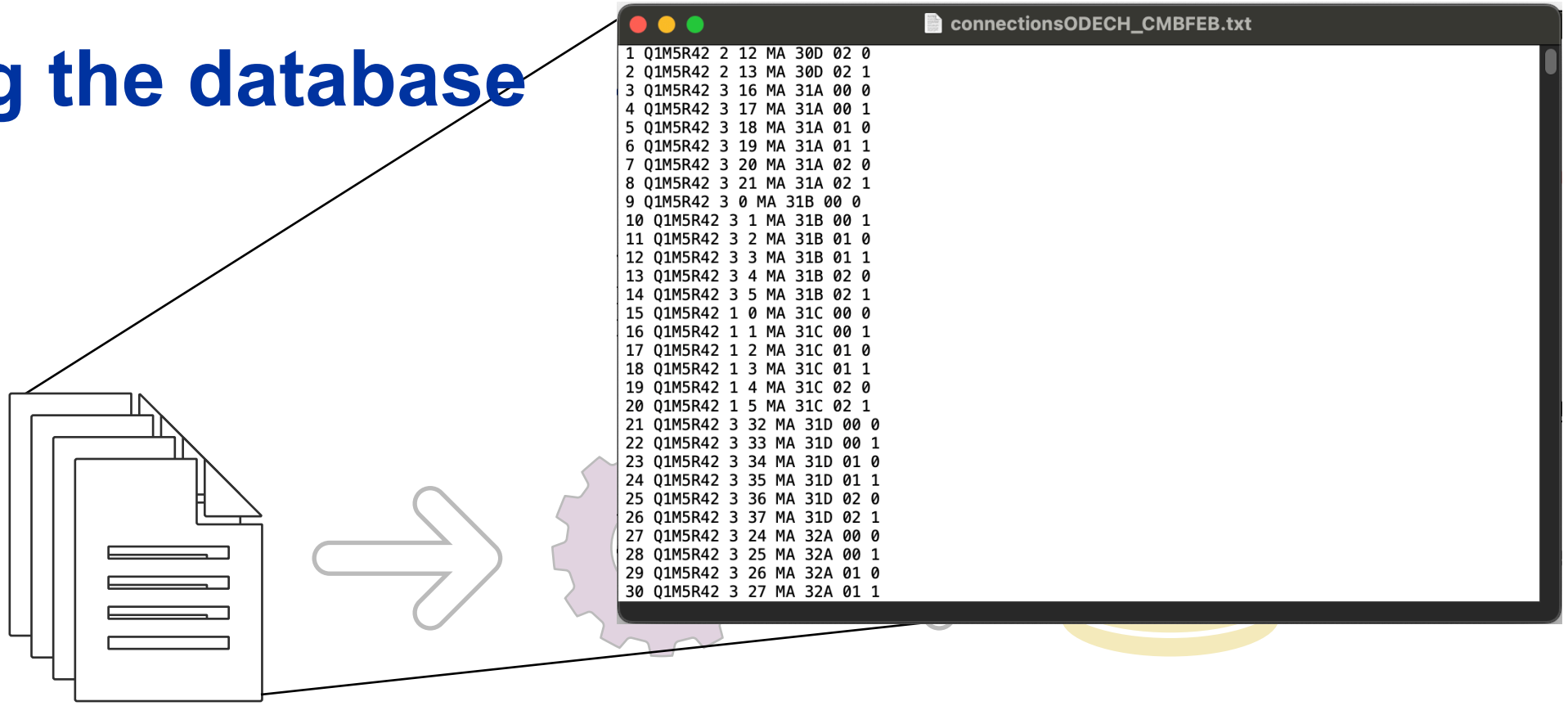
Building the database



.txt files

Relational Database

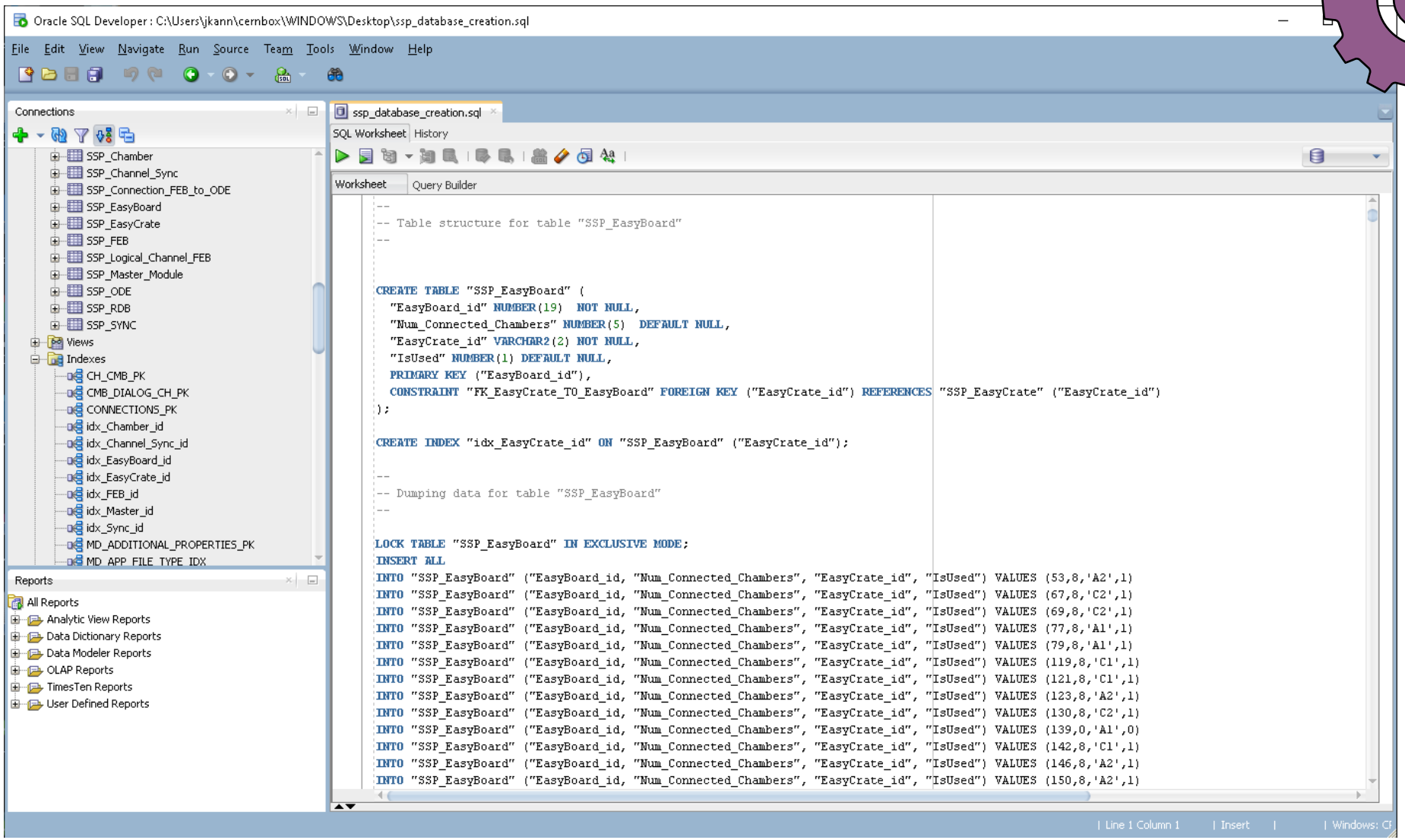
Building the database



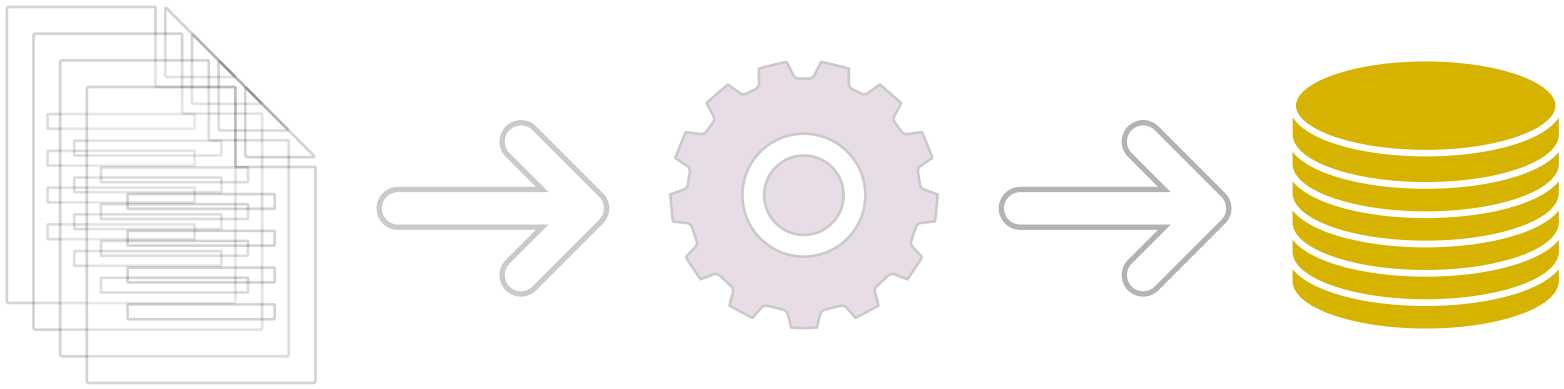
.txt files

Relational Database

Building the database



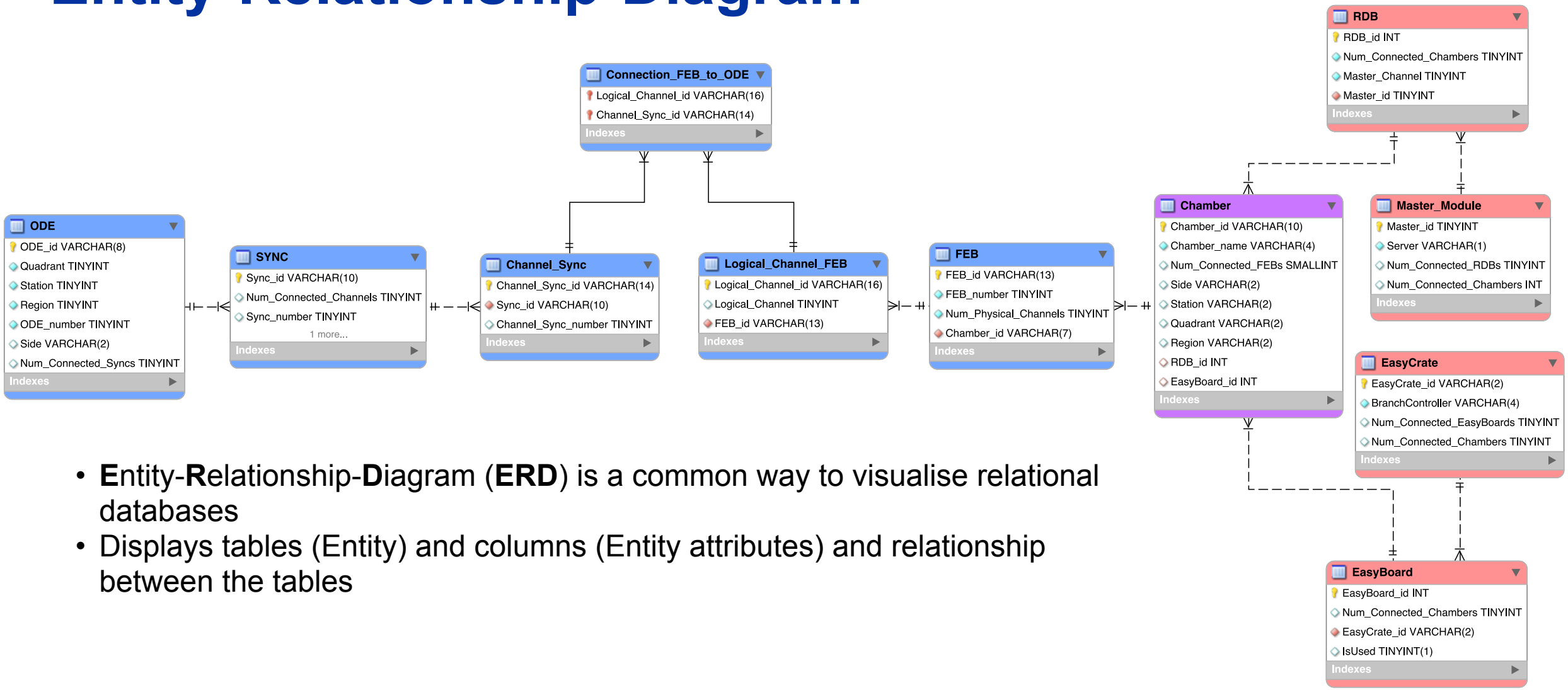
Building the database



.txt files

Relational Database

Entity-Relationship-Diagram

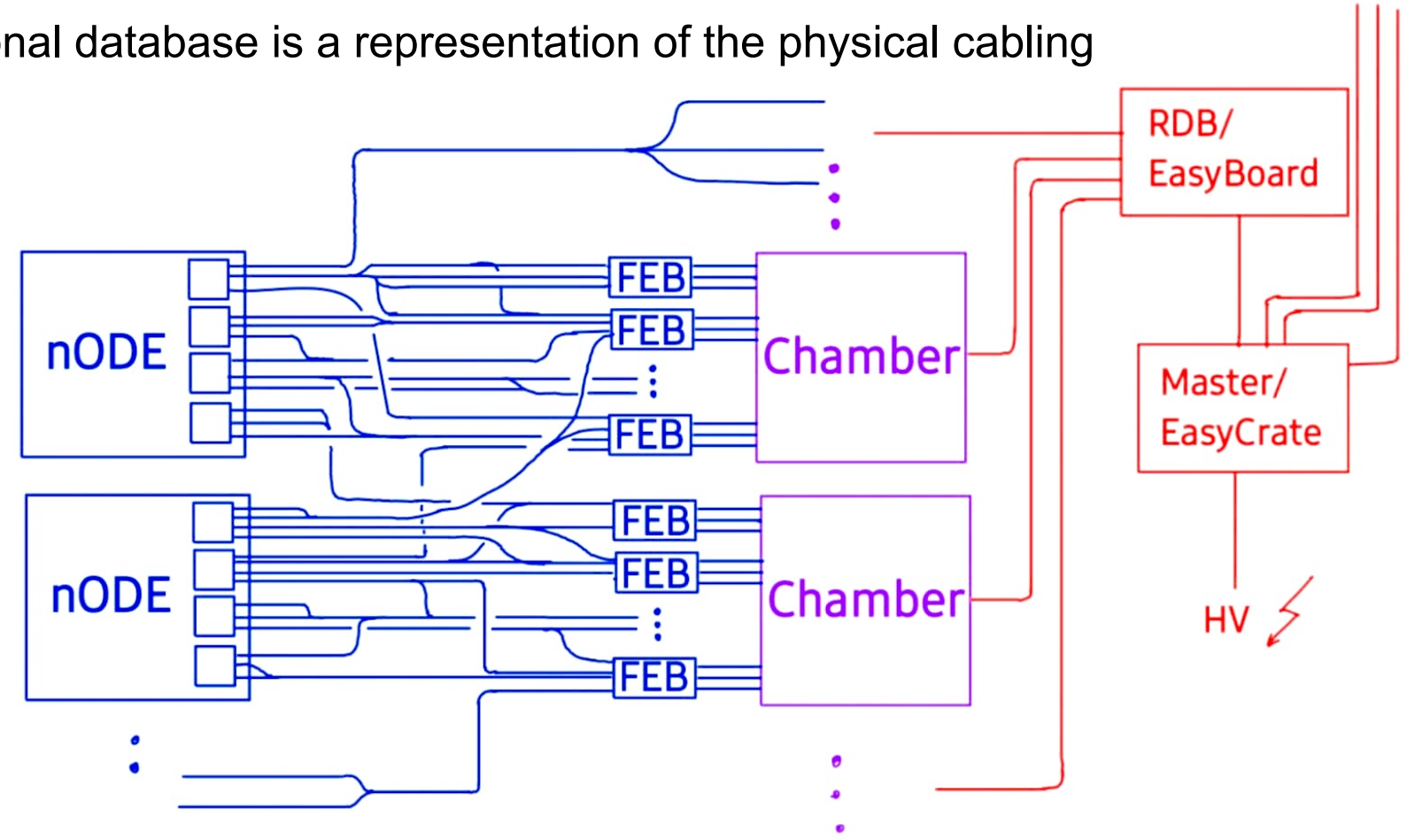


- **E**ntity-**R**elationship-**D**iagram (**ERD**) is a common way to visualise relational databases
- Displays tables (Entity) and columns (Entity attributes) and relationship between the tables

Entity-Relationship-Diagram

- In comparison: ERD similar to actual cabling of the electronic components

➔ Relational database is a representation of the physical cabling



Applications

Integration of the database

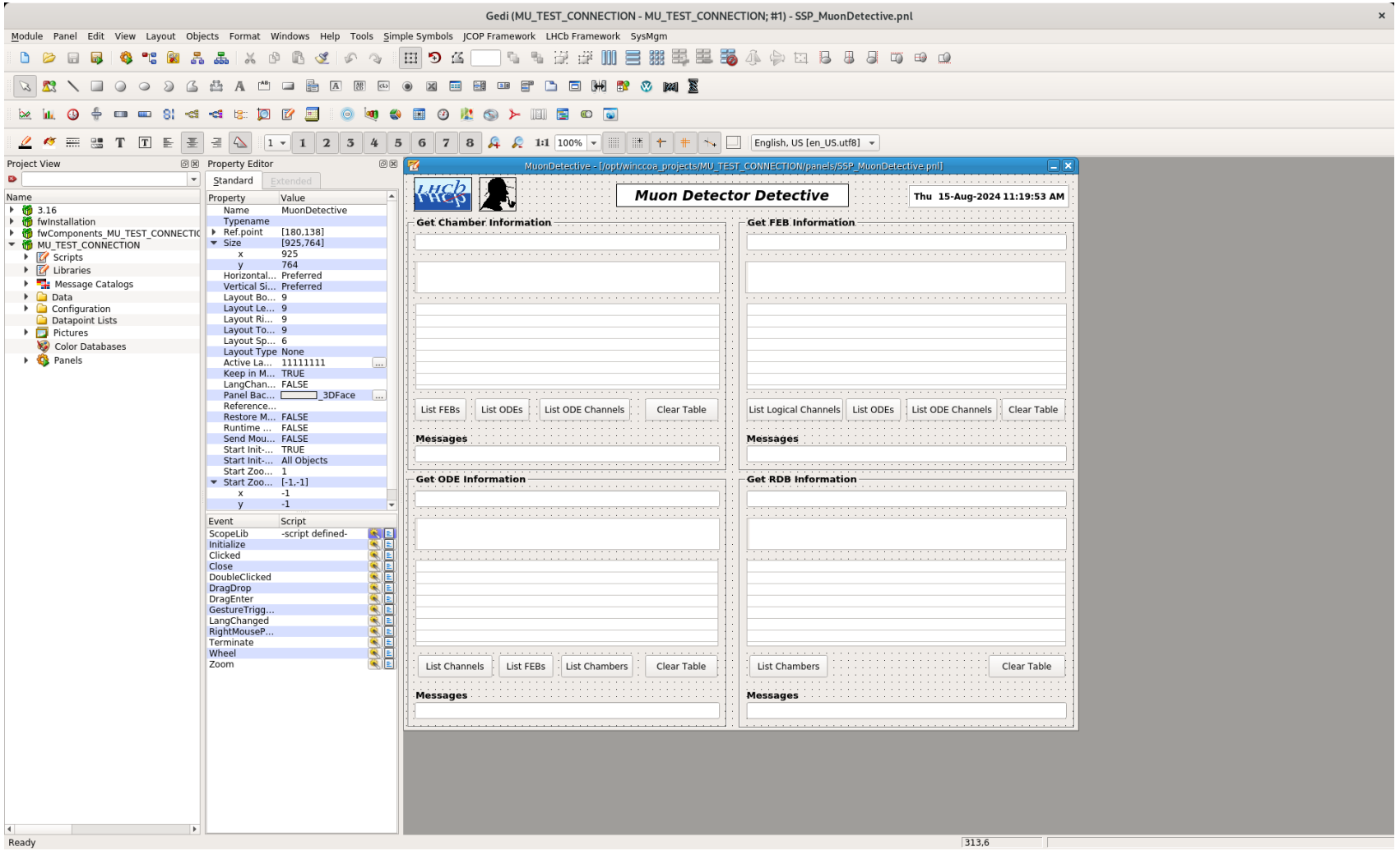
Control room ready

- Database is finished
- Next: Making it accessible for improved muon operation

➔ Design a GUI that allows users to obtain information from the database

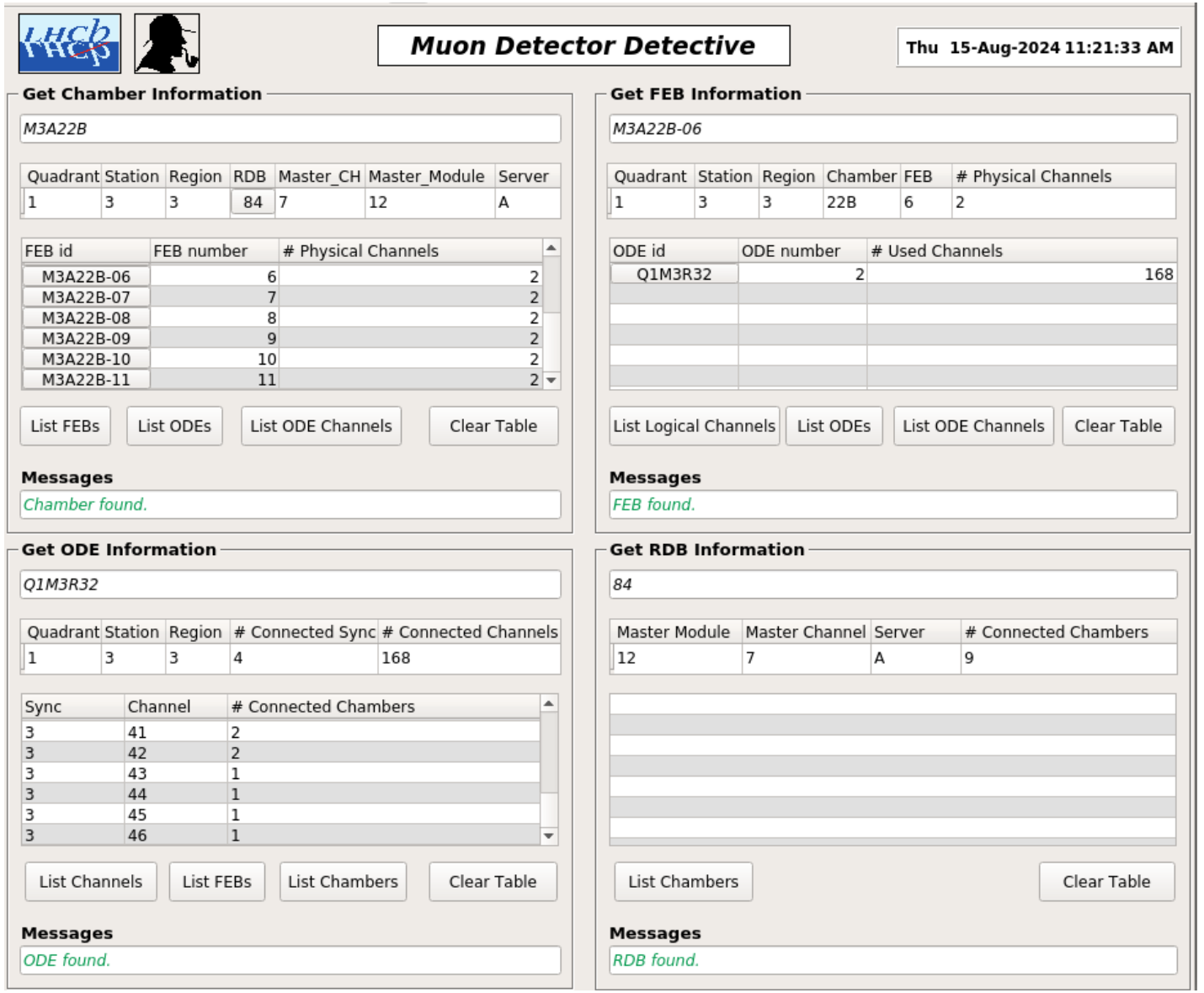
- Tool for this is the WinCC SCADA System
- Used in the control room to maintain the detector

WinCC Editor



Running Muon Detector Detective (MDD) panel

- Running panel allows users to enter different components by their identifier
- In return gets information about the component
- Opportunity to list relevant channels or connected devices for that component



Conclusions and Prospects

Conclusion

- Database is finished and running
- WinCC panel is working as expected
- MDD panel is useful for muon operation enhancing troubleshooting in case of occurring errors

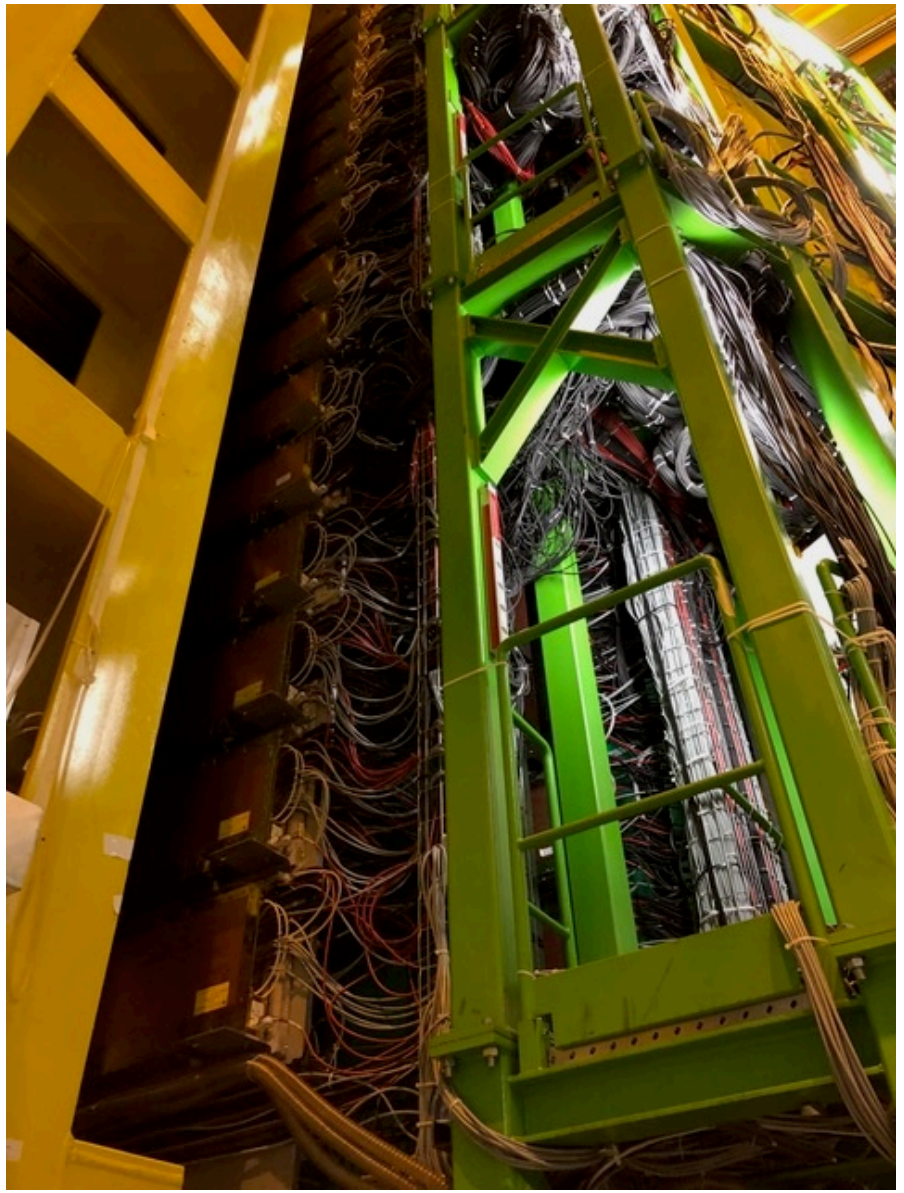
Prospects

- Connect the panel to the other panels of the muon ECS
- Add new functionalities to the panel (e.g. masking channels, setting time delays)
- Possibly include other electronic components into the database (e.g. Intermediate Boards)

Thank you for your attention! Any questions?

Acknowledgements

Special thanks to Andrea Contu, Vladimir Chulikov and Barbara Sciascia for their guidance and mentorship.



References

[1] Paolucci L.; The LHCb Muon Detector Upgrades. ICHEP 2022

[2] LHCB Technical Design Report 23

[3] Albicocco, P.; et al.; A Method Based on Muon System to Monitor LHCb Luminosity. Symmetry 2022, 14, 860

[4] Maev, O.; Piquet Training for Run 3 - HV system. 26.07.2022

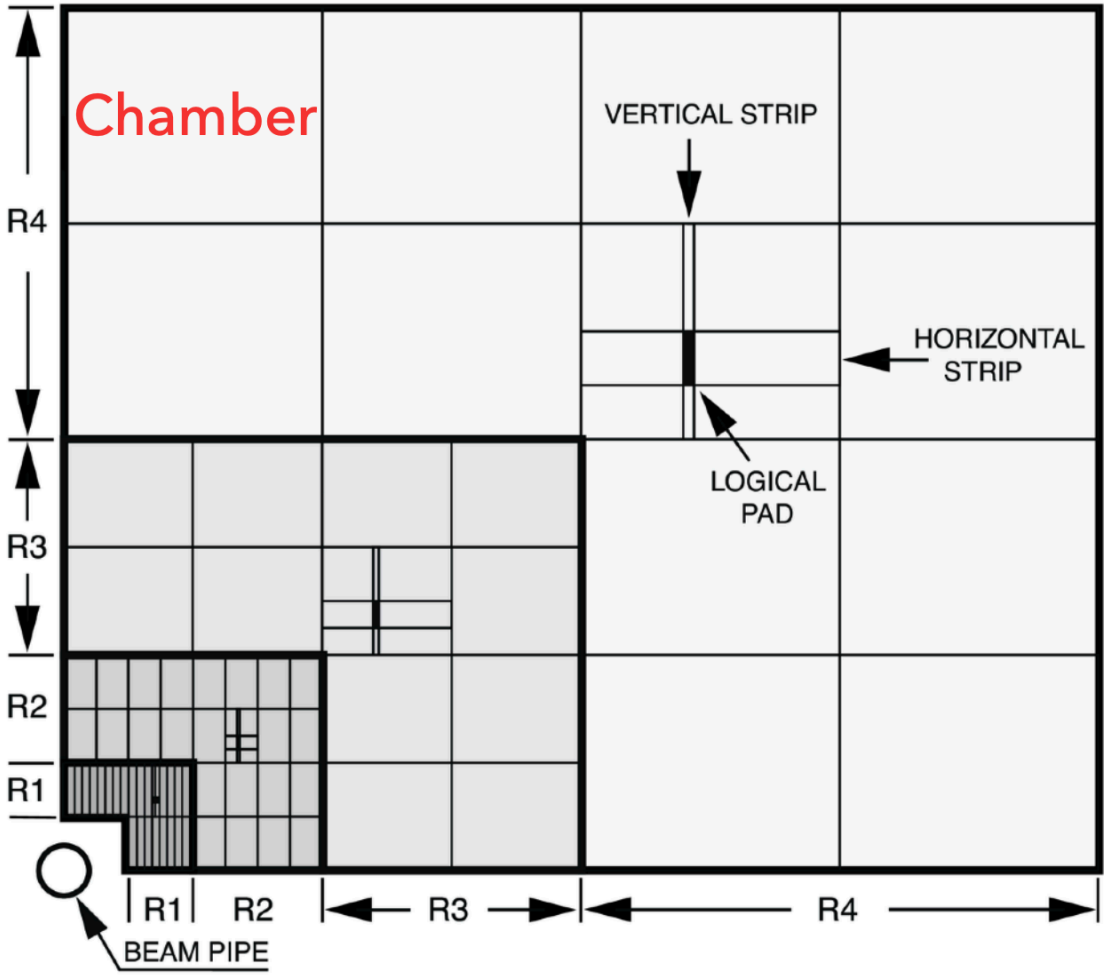
[5] Karan R.; Difference Between Primary Key And Foreign Key, Shiksha

[6] Cadeddu S., Ciambrone P.; Muon Front-End Data Format, 2017

Backup Slides

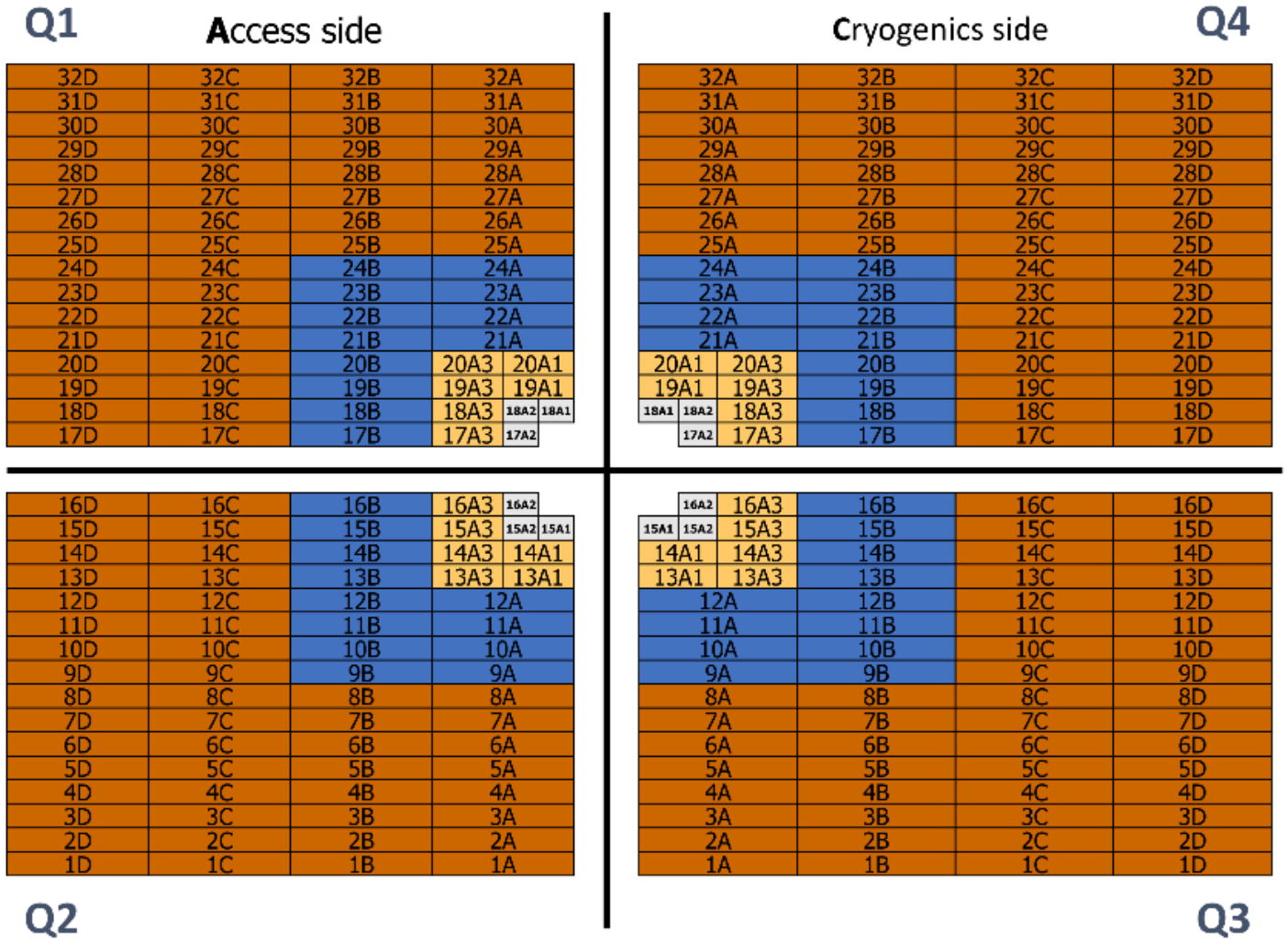
More on the muon detector geometry

- Four gaps per MPWC
- Different regions have different detector granularity
- Vertical and horizontal readout strips for two-dimensional tracking
- Strips produce binary “hit” or “no hit” information



Source: Paolucci L.; The LHCb Muon Detector Upgrades. ICHEP 2022

Layout of the chambers



Q1			
32D	32C	32B	32A
31D	31C	31B	31A
30D	30C	30B	30A
29D	29C	29B	29A
28D	28C	28B	28A
27D	27C	27B	27A
26D	26C	26B	26A
25D	25C	25B	25A
24D	24C	24B	24A
23D	23C	23B	23A
22D	22C	22B	22A
21D	21C	21B	21A
20D	20C	20B	20A3 20A1
19D	19C	19B	19A3 19A1
18D	18C	18B	18A3 18A2 18A1
17D	17C	17B	17A3 17A2

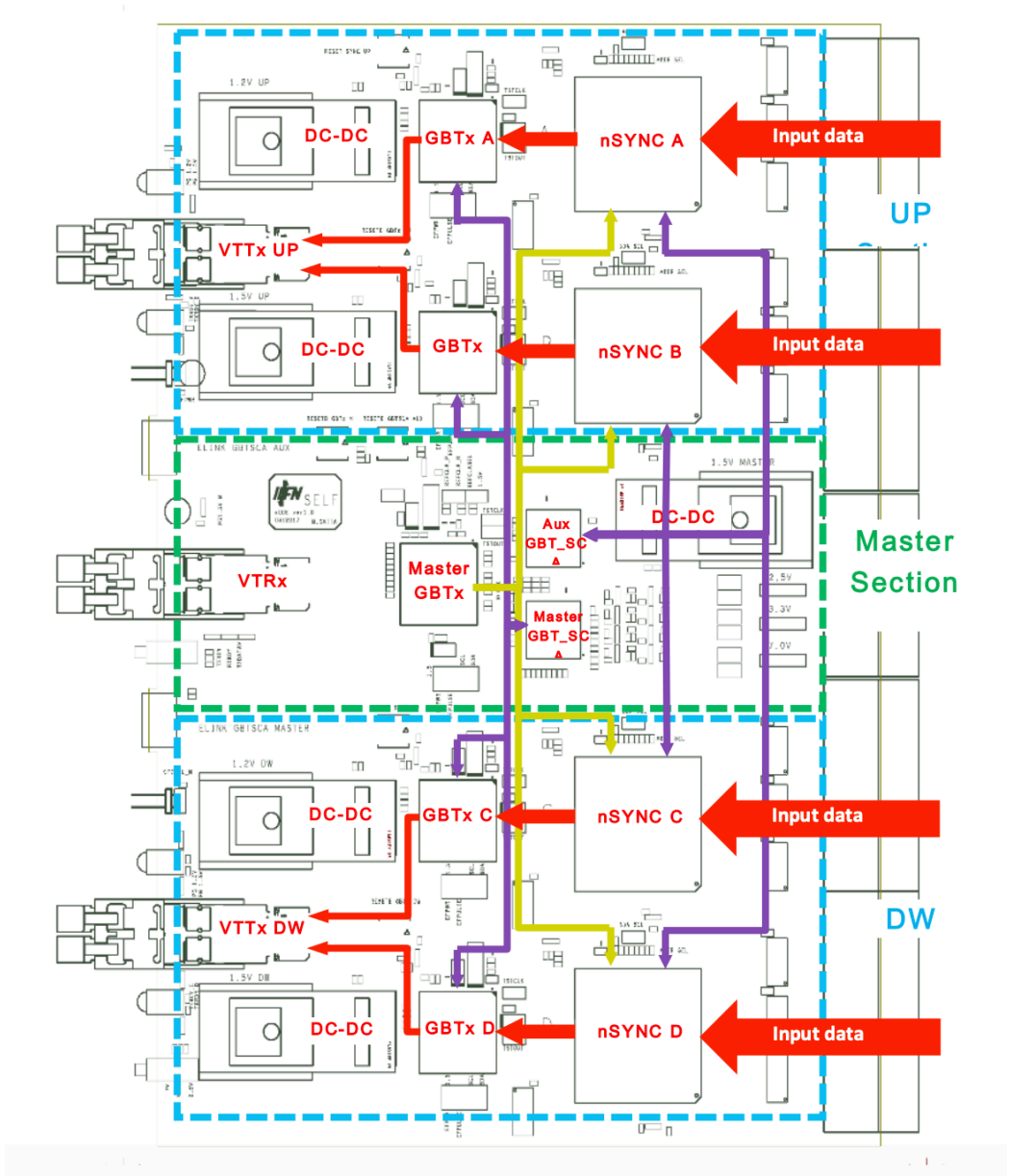
Q4			
32A	32B	32C	32D
31A	31B	31C	31D
30A	30B	30C	30D
29A	29B	29C	29D
28A	28B	28C	28D
27A	27B	27C	27D
26A	26B	26C	26D
25A	25B	25C	25D
24A	24B	24C	24D
23A	23B	23C	23D
22A	22B	22C	22D
21A	21B	21C	21D
20A1 20A3	20B	20C	20D
19A1 19A3	19B	19C	19D
18A1 18A2 18A3	18B	18C	18D
17A2 17A3	17B	17C	17D

Q2			
16D	16C	16B	16A3 16A2
15D	15C	15B	15A3 15A2 15A1
14D	14C	14B	14A3 14A1
13D	13C	13B	13A3 13A1
12D	12C	12B	12A
11D	11C	11B	11A
10D	10C	10B	10A
9D	9C	9B	9A
8D	8C	8B	8A
7D	7C	7B	7A
6D	6C	6B	6A
5D	5C	5B	5A
4D	4C	4B	4A
3D	3C	3B	3A
2D	2C	2B	2A
1D	1C	1B	1A

Q3			
16A2	16A3	16B	16C 16D
15A1 15A2	15A3	15B	15C 15D
14A1	14A3	14B	14C 14D
13A1	13A3	13B	13C 13D
12A		12B	12C 12D
11A		11B	11C 11D
10A		10B	10C 10D
9A		9B	9C 9D
8A		8B	8C 8D
7A		7B	7C 7D
6A		6B	6C 6D
5A		5B	5C 5D
4A		4B	4C 4D
3A		3B	3C 3D
2A		2B	2C 2D
1A		1B	1C 1D

The nODE board

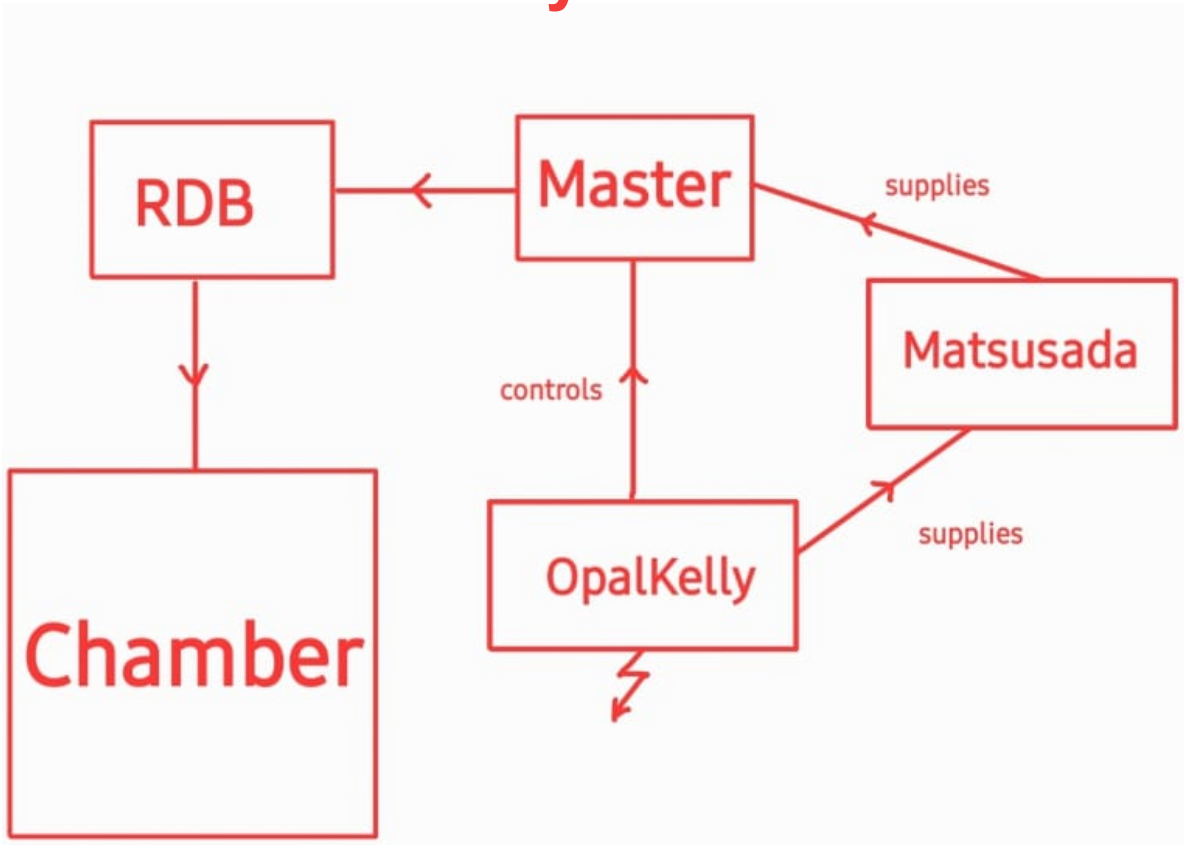
- Four nSYNC chips already discussed
- GBTx is a serializer-de-serializer chip receiving and transmitting serial data at 4.8 Gb/s (one per SYNC)
- GBT-SCA to provide the slow-controls interface to the front-end electronics
- VTTx transmits data from nSYNC to the TELL40 boards
- VTRx transmits TFC and ECS information to SOL40 boards



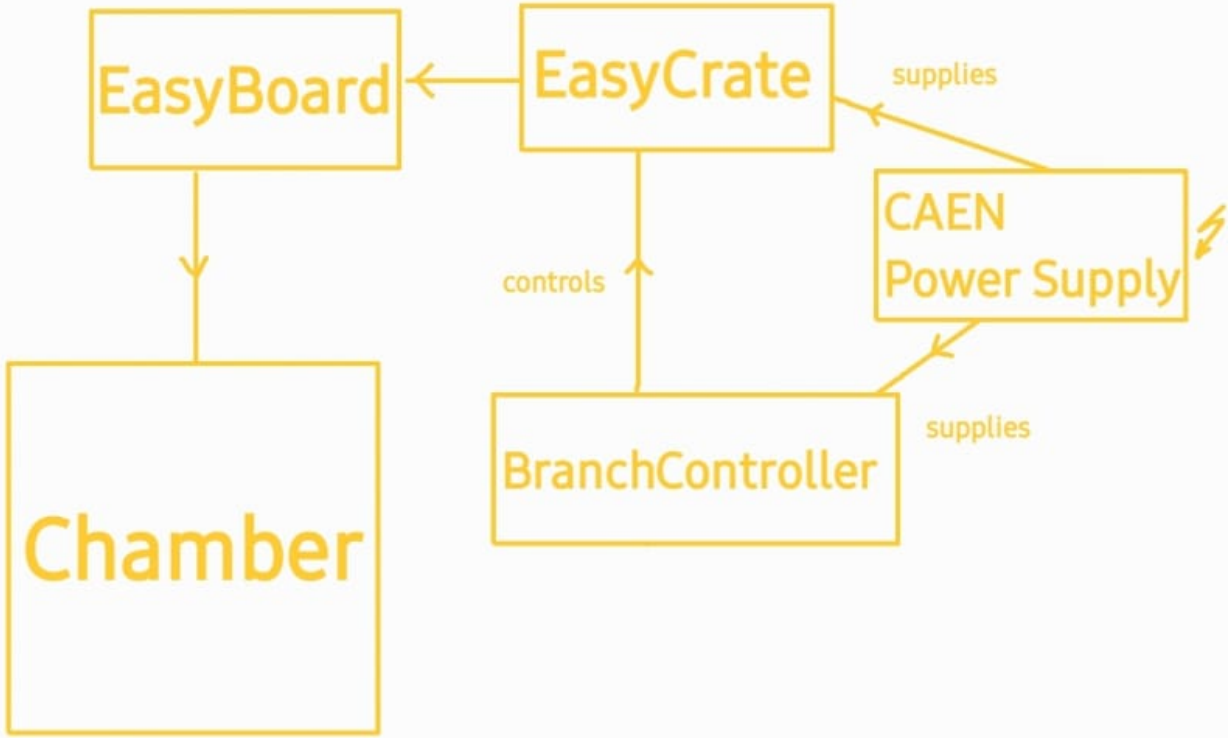
Source: S. Cadeddu, P. Ciambrone; Muon Front-End Data Format

More accurate scheme of HV system

PNPI HV system



CAEN HV system



More numbers…

DAQ

- 144 nODE → 576 available SYNCs but only 560 SYNCs used
- 48 channels per SYNC → 27648 channels in total but only 24288 used
- 1104 chambers with up to 14 FEB, up to 8 channels per FEB
- Total number of FEBs: 5616, total number of logical FEB channels: 34176
- Number of Connections between FEB and SYNC: **49152**

HV

- 112 RDBs, each connected to 9 chambers
- 16 Master modules, each connected to 7 RDBs
- 18/20 EasyBoards used, each connected to 8 chambers
- 4 EasyCreates, each connected to 9 EasyBoards

Primary key and Foreign key

- Primary keys serve as unique identifiers for the elements in a table
- Foreign keys link data in one table to the data in another table by pointing to a unique value (often the primary key) in the other table

➔ Create a way of cross-referencing two tables

TABLE - ORDERS

ORDER-ID	PRODUCT	TOTAL	CUSTOMER-ID ← FOREIGN KEY
101	PRINTER	124	4
102	MOUSE	232	2
103	LAPTOP	323	3
104	HEADPHONE	556	5
105	MOUSE PAD	417	1

RELATIONSHIP

TABLE - CUSTOMERS

PRIMARY KEY →

CUSTOMER-ID	FIRST NAME	LAST NAME	AGE	CITY
1	LYANNA	MORMONT	16	PARIS
2	SHELDON	COOPER	42	ZURICH
3	MANNY	DELGADO	23	BOGOTA
4	RAJESH	KAPOOR	44	NOIDA
5	JON	SNOW	35	LONDON

Source: Shiksha, Difference Between Primary Key And Foreign Key

Entity-Relationship-Diagram Notation

One

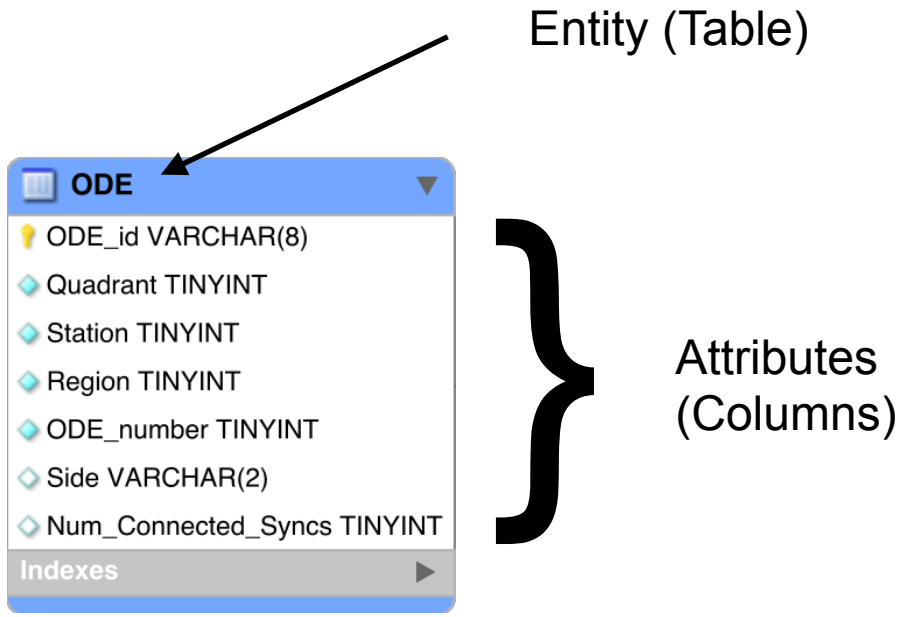
Many

One (and only one)

Zero or one

One or many

Zero or many



- Dotted line: non-identifying relationship
- Solid line: identifying relationship

Additional Work

- Designing a new panel to mask/unmask nODE channels
- Query channels for specific ODE from database
- Get information about the masking state from a specific config file
- Change masking state of channels via click in the panel, do backup and then update config file