

Untangling the Cables: Streamlining Muon Detector Operation

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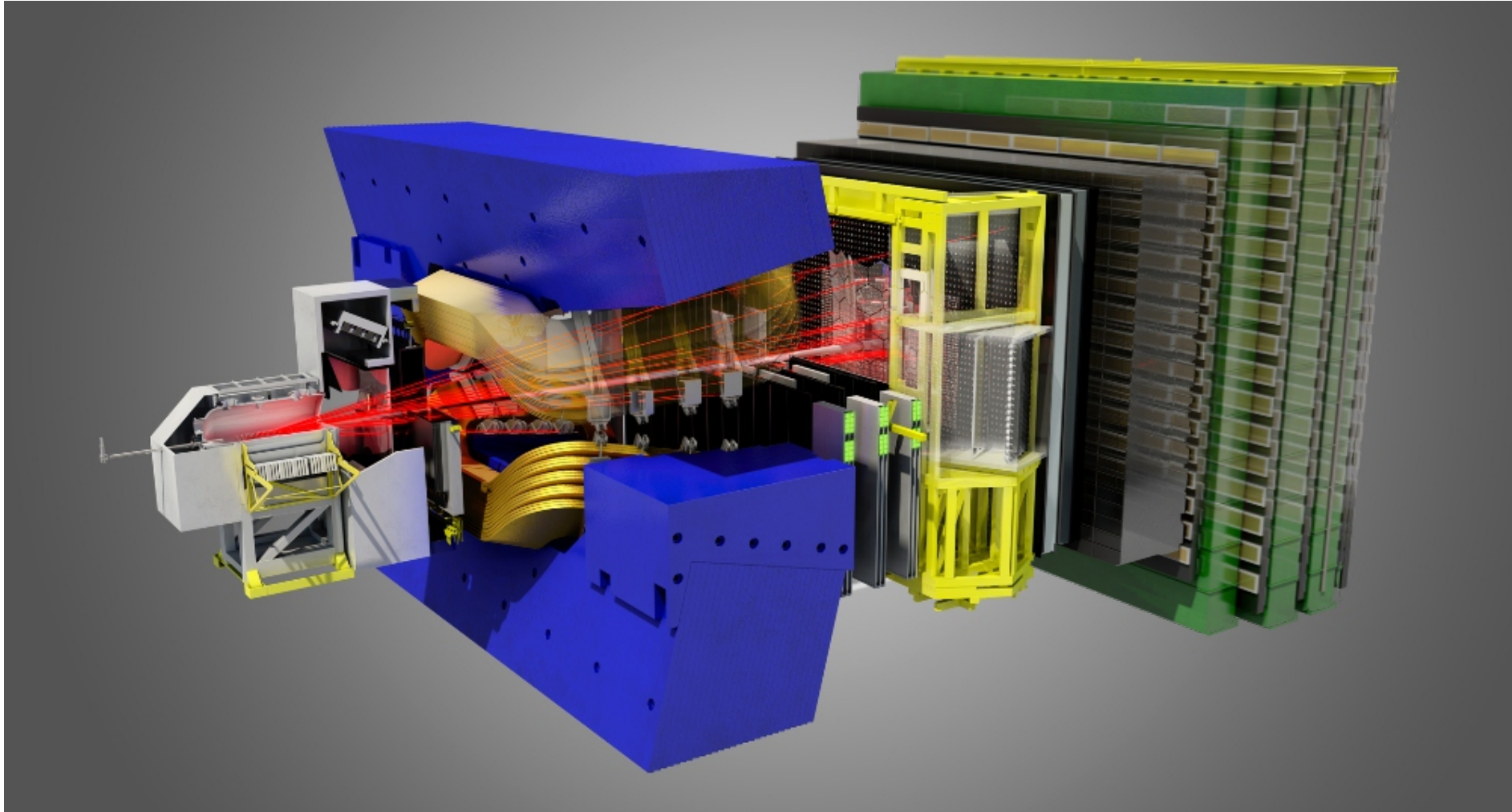
Outline

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

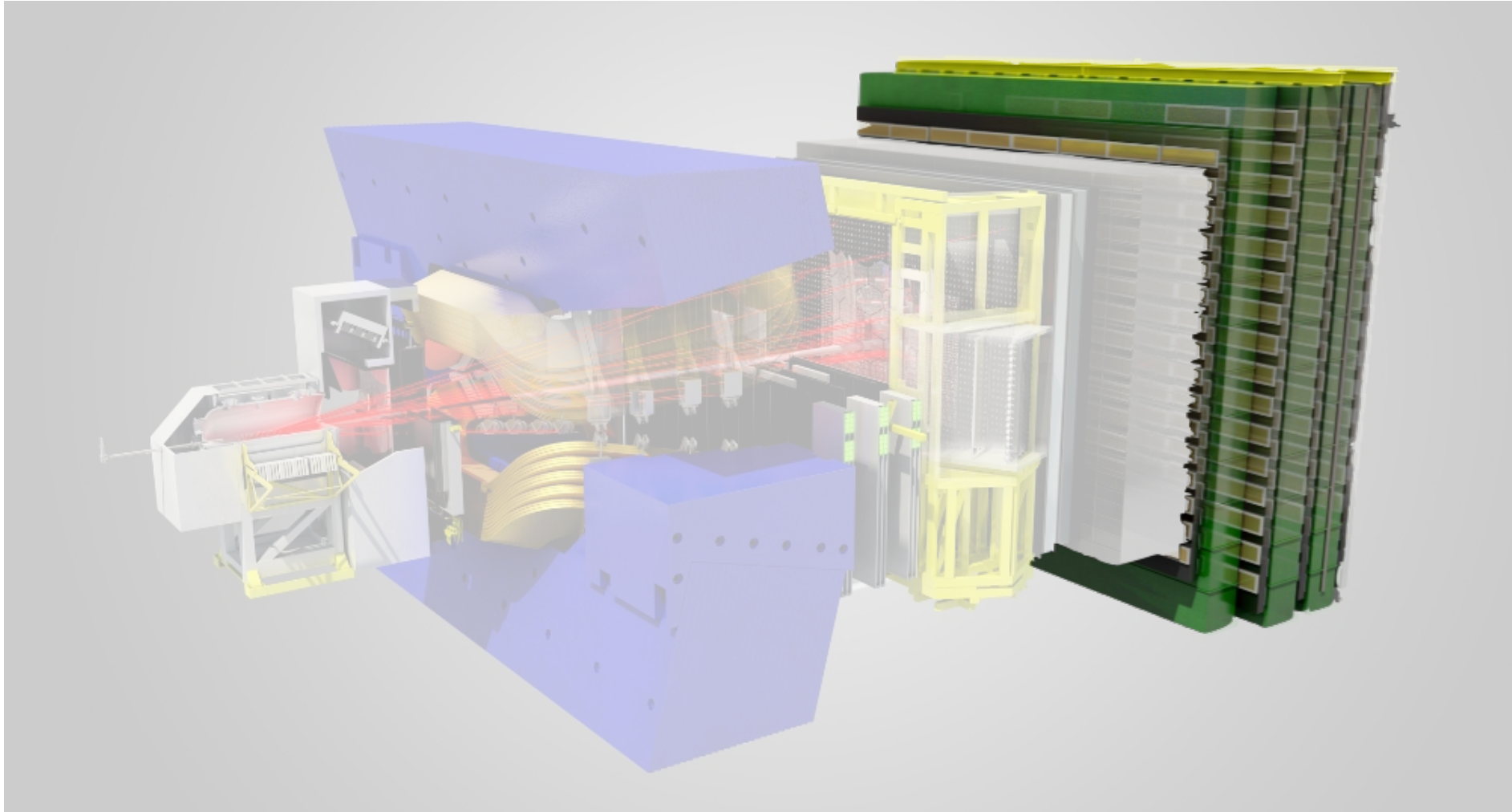
Introduction

The muon system

The muon system



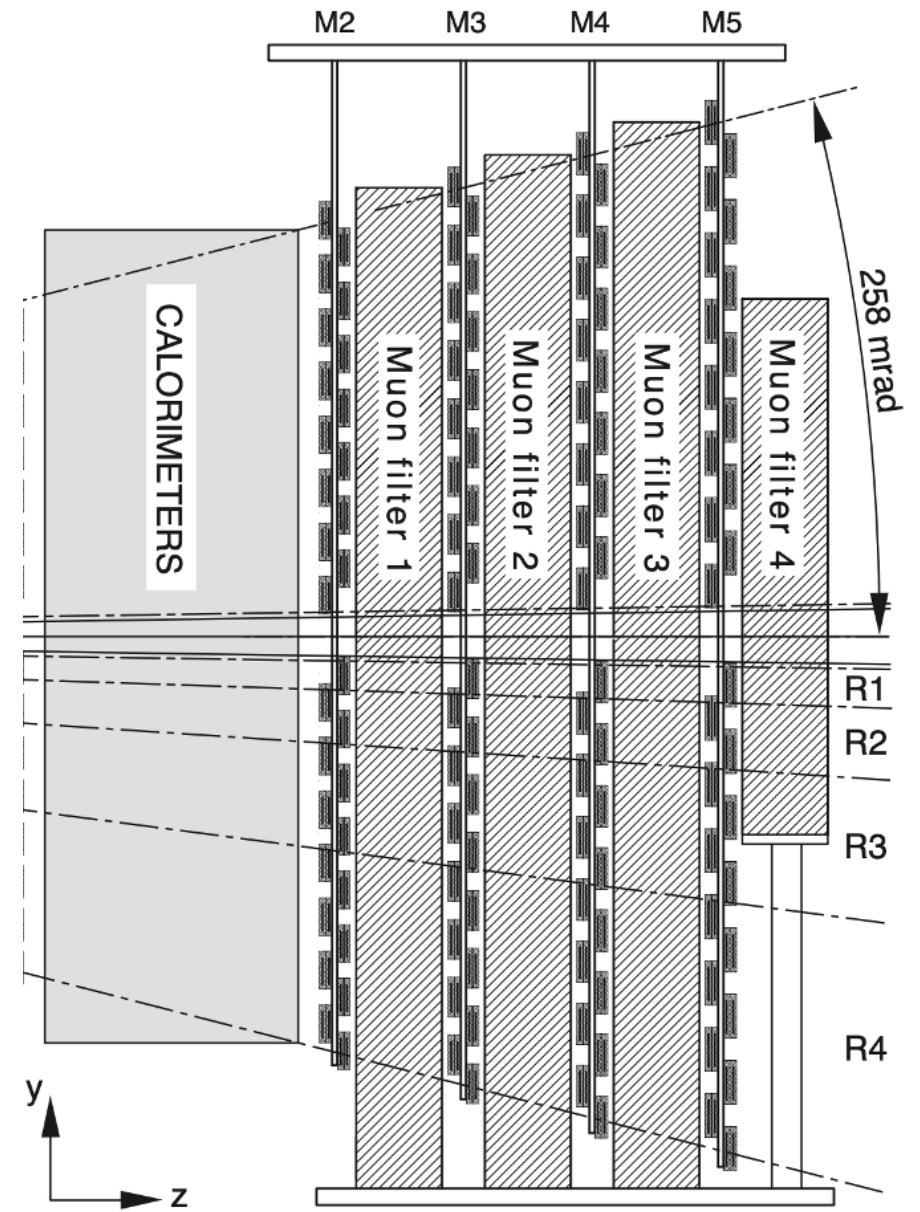
The muon system



The muon system

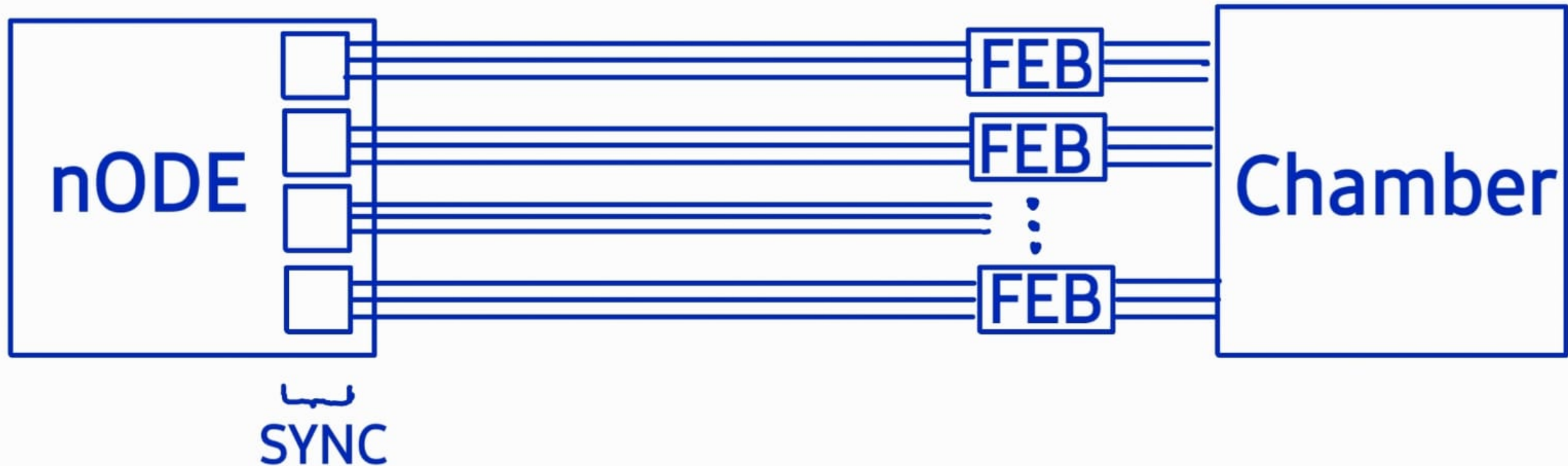
- Largest subsystem in the LHCb detector
- Subdivided into quadrant, station and region
- Based on **M**ulti **W**ire **P**roportional **C**hambers (**MWPC**)
- Stations alternate with iron filters
- Mainly used for particle identification but tracking is possible
- Muons at final stage of many B meson decays

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

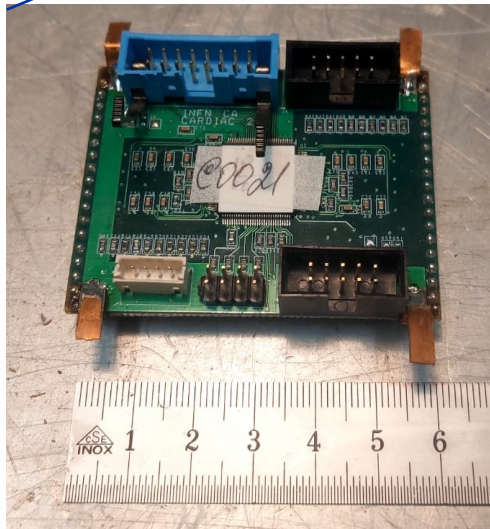
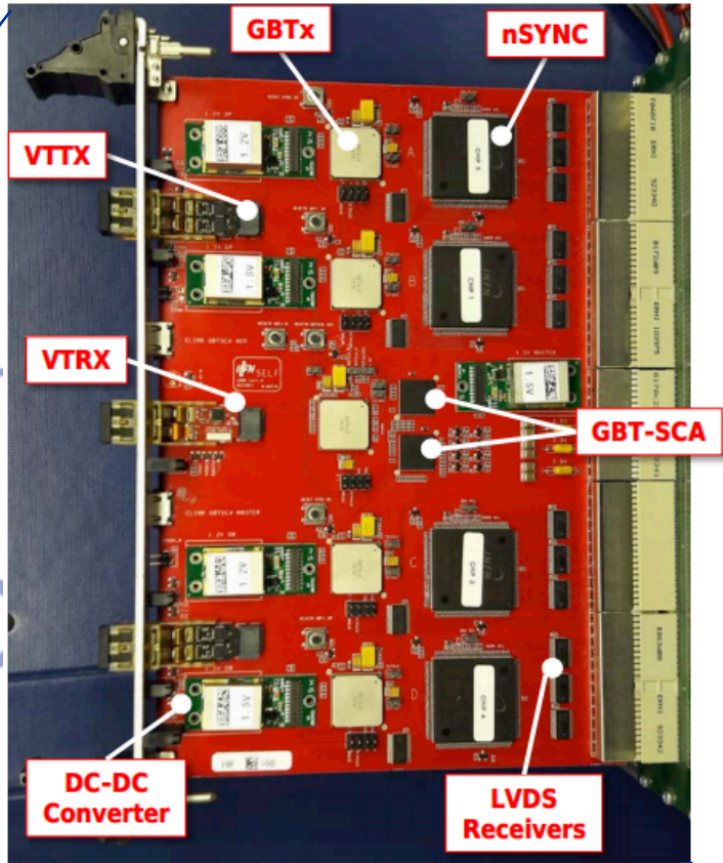


The DAQ Chain

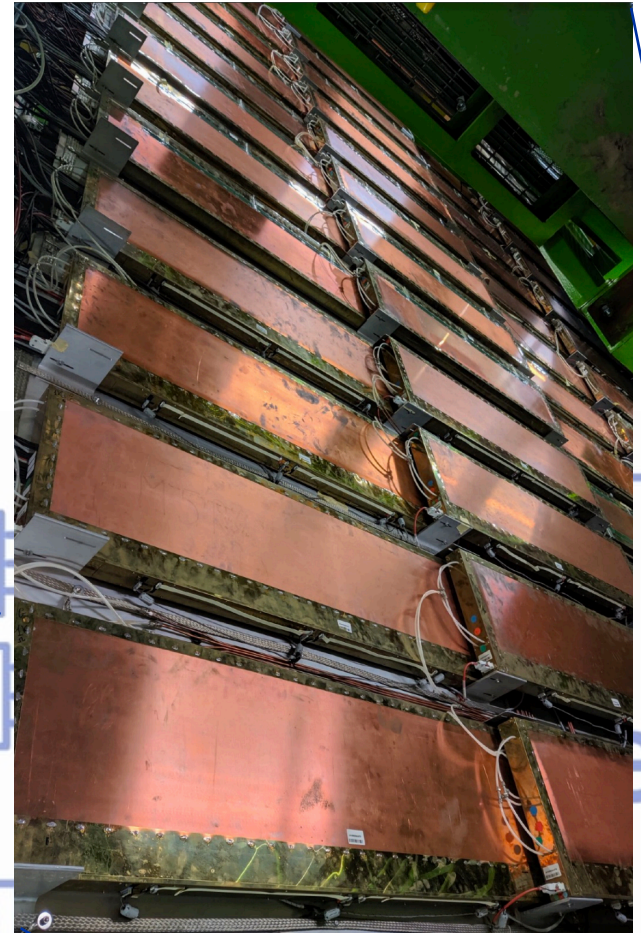
- 1104 chambers (MPWC)
- Up to 14 FEBs per chamber
- 144 nODE with 4 SYNC each
- Up to 48 used channels per SYNC and 8 channels per FEB



The DAQ Chain



FEB
FEB
FEB

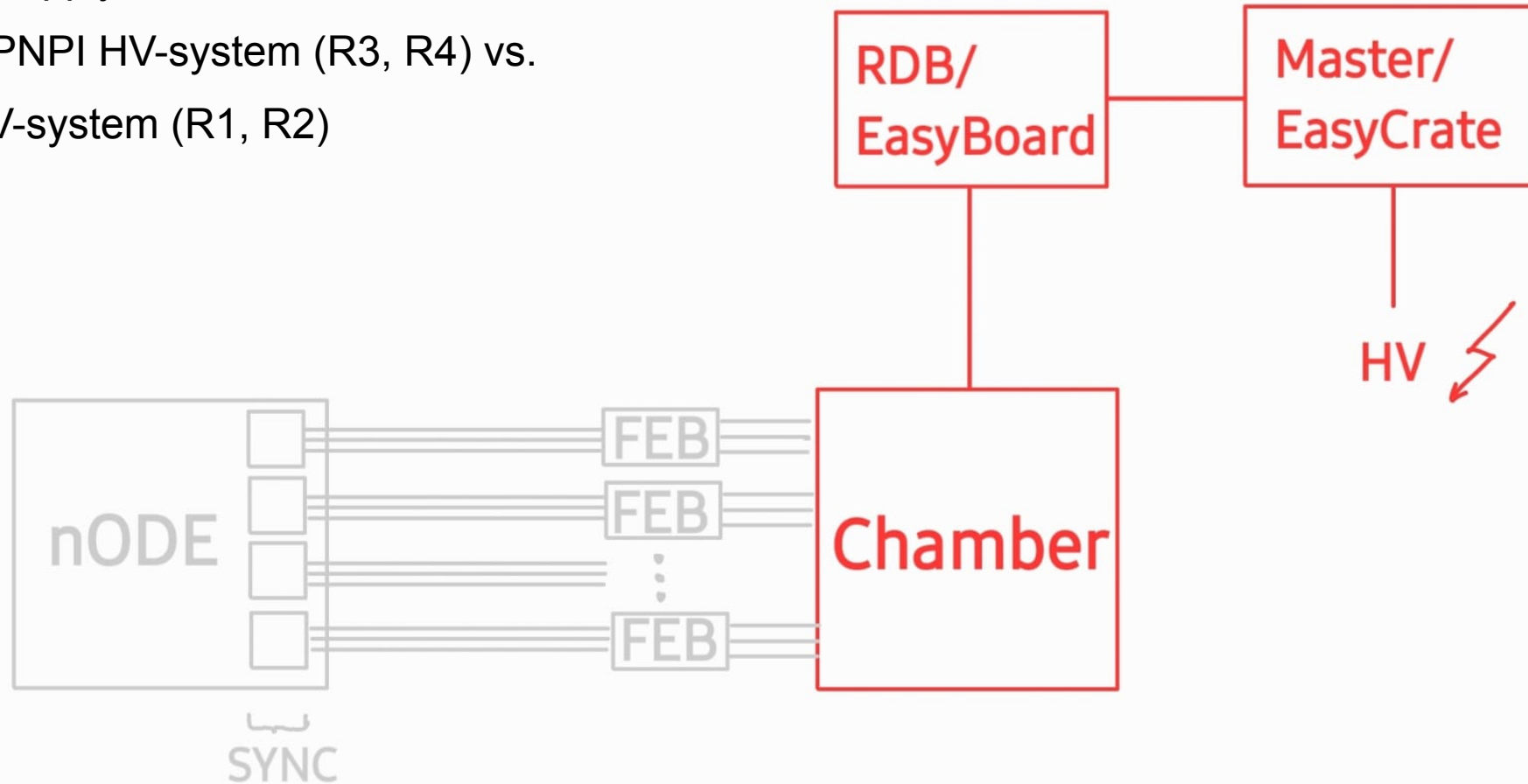


nOD

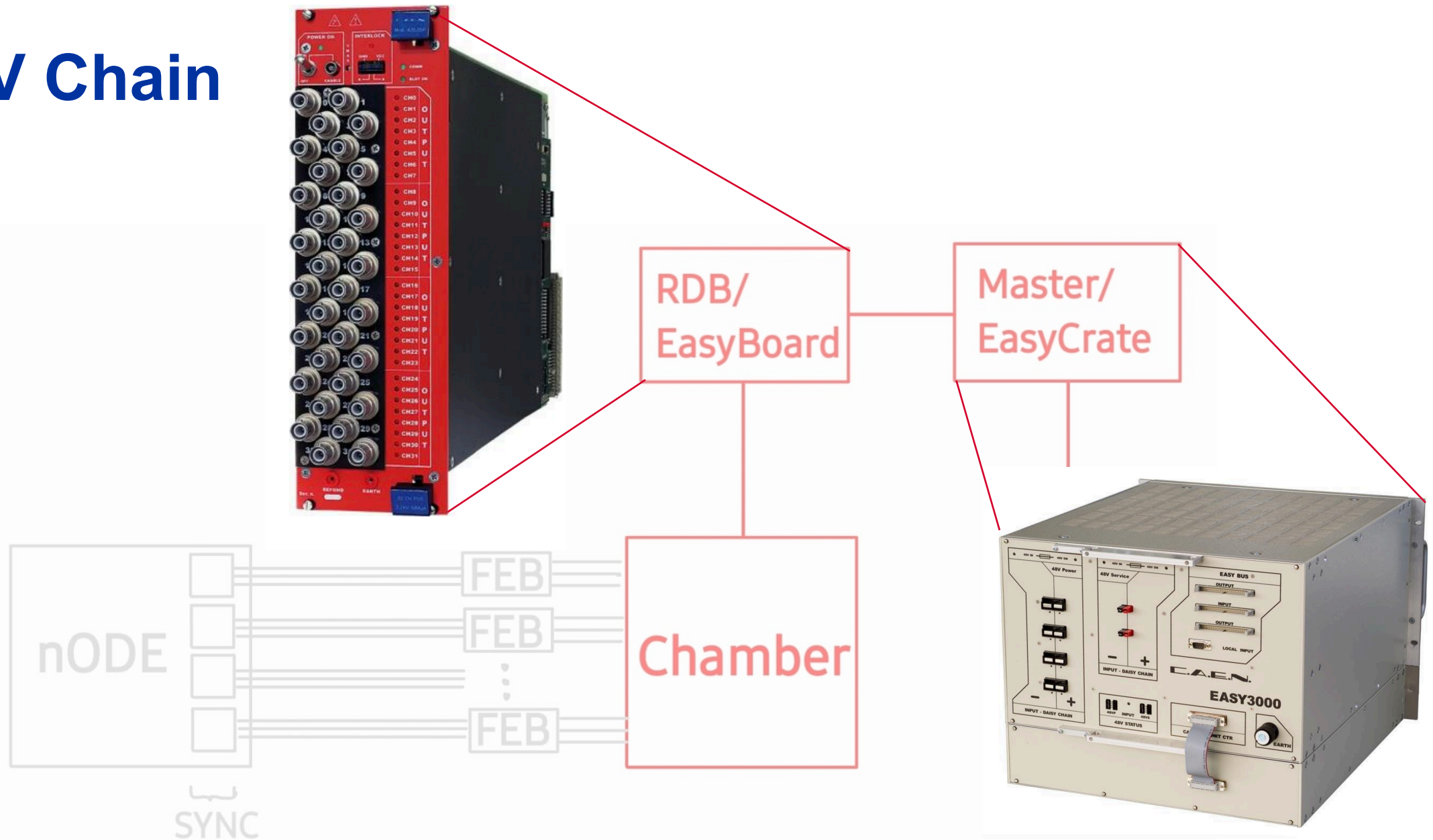
سبأ
SYNC

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)

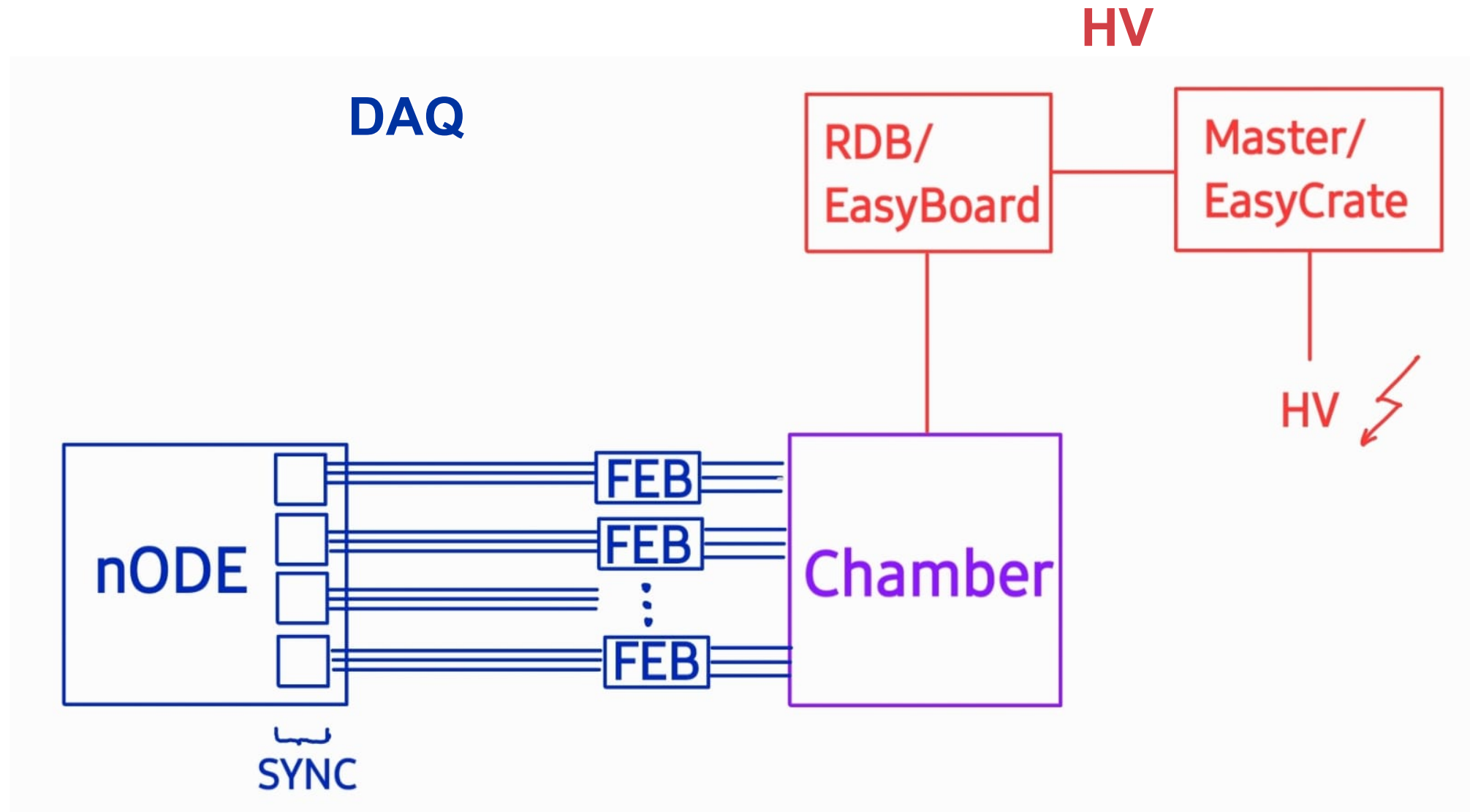


The HV Chain



“The Cabling problem”

This is a lie...

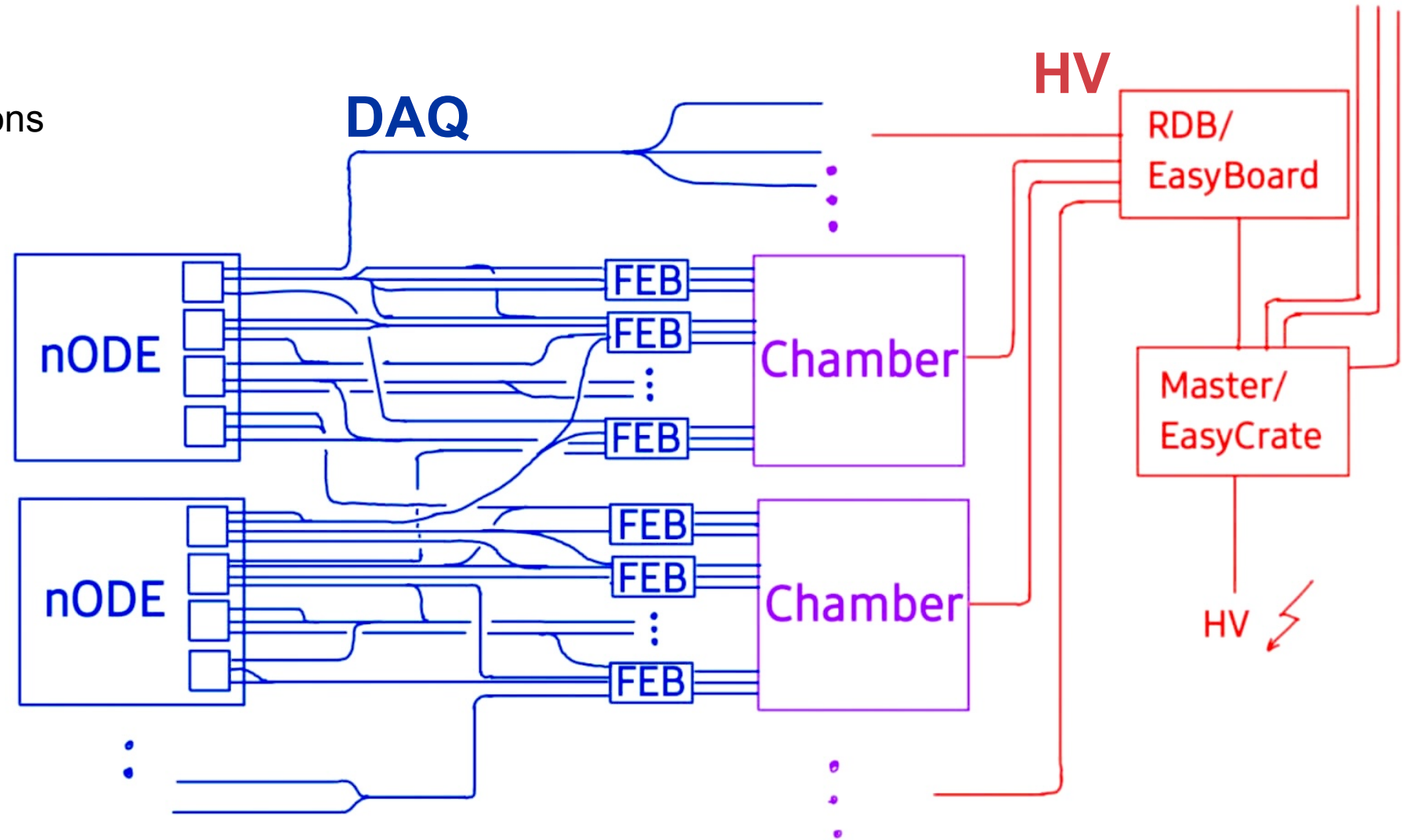


This is ~~a lie~~ less of a lie...

- 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



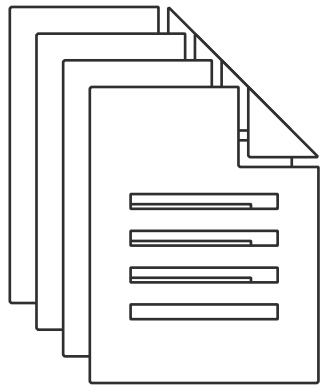
Organize data in a relational database!



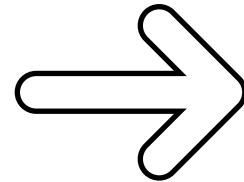
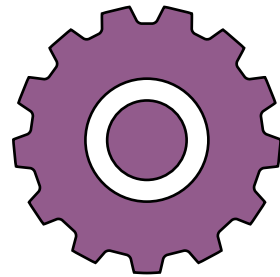
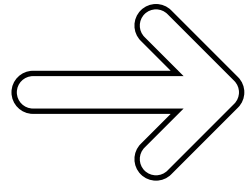
The solution

A relational database

Building the database

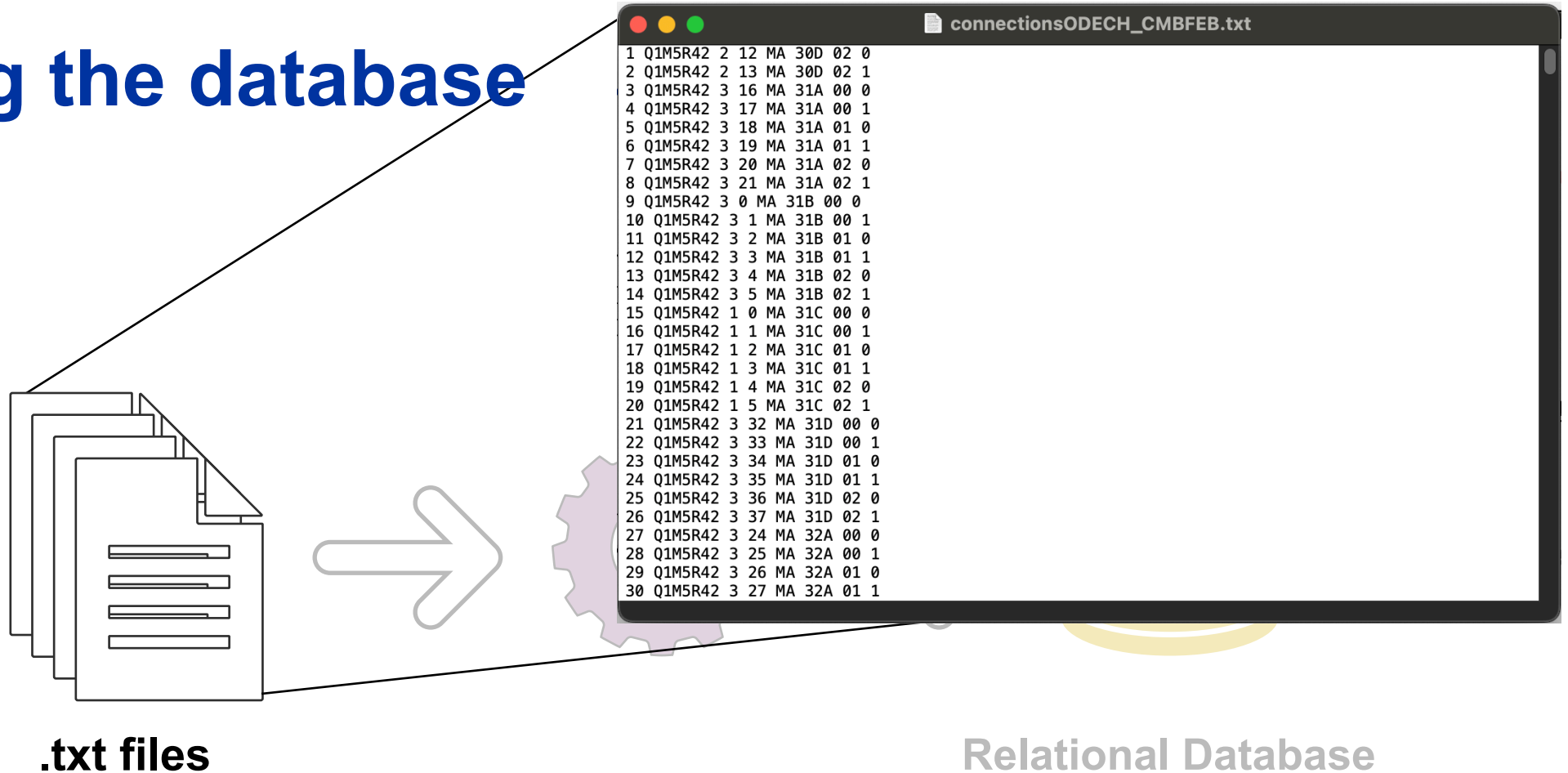


.txt files

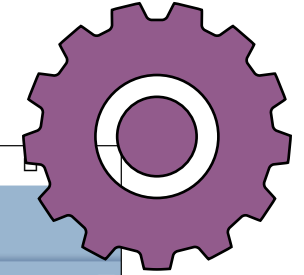


Relational Database

Building the database



Building the database



The screenshot displays the Oracle SQL Developer interface. The left pane shows a tree view of the database schema with various tables and indexes. The main window shows a SQL worksheet with the following code:

```
--
-- Table structure for table "SSP_EasyBoard"
--
CREATE TABLE "SSP_EasyBoard" (
  "EasyBoard_id" NUMBER(19) NOT NULL,
  "Num_Connected_Chambers" NUMBER(5) DEFAULT NULL,
  "EasyCrate_id" VARCHAR2(2) NOT NULL,
  "IsUsed" NUMBER(1) DEFAULT NULL,
  PRIMARY KEY ("EasyBoard_id"),
  CONSTRAINT "FK_EasyCrate_T0_EasyBoard" FOREIGN KEY ("EasyCrate_id") REFERENCES "SSP_EasyCrate" ("EasyCrate_id")
);

CREATE INDEX "idx_EasyCrate_id" ON "SSP_EasyBoard" ("EasyCrate_id");

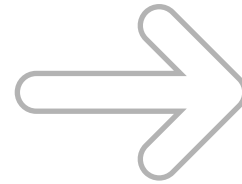
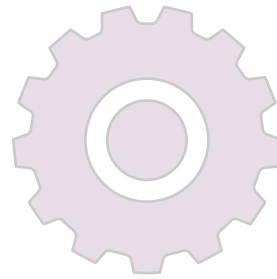
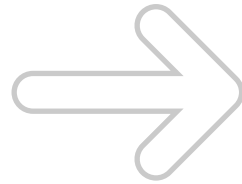
--
-- Dumping data for table "SSP_EasyBoard"
--

LOCK TABLE "SSP_EasyBoard" IN EXCLUSIVE MODE;
INSERT ALL
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (53,8,'A2',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (67,8,'C2',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (69,8,'C2',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (77,8,'A1',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (79,8,'A1',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (119,8,'C1',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (121,8,'C1',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (123,8,'A2',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (130,8,'C2',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (139,0,'A1',0)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (142,8,'C1',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (146,8,'A2',1)
INTO "SSP_EasyBoard" ("EasyBoard_id", "Num_Connected_Chambers", "EasyCrate_id", "IsUsed") VALUES (150,8,'A2',1)
```

Building the database

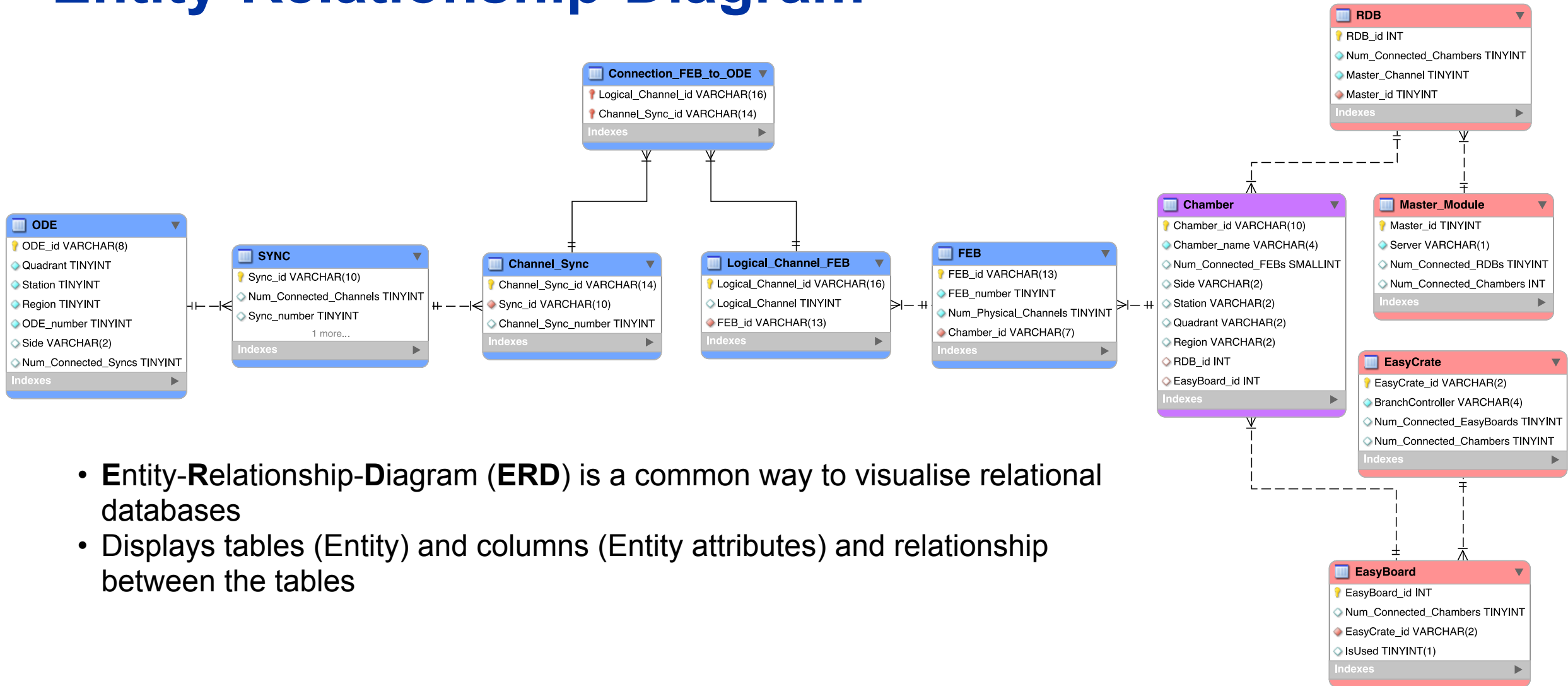


.txt files



Relational Database

Entity-Relationship-Diagram

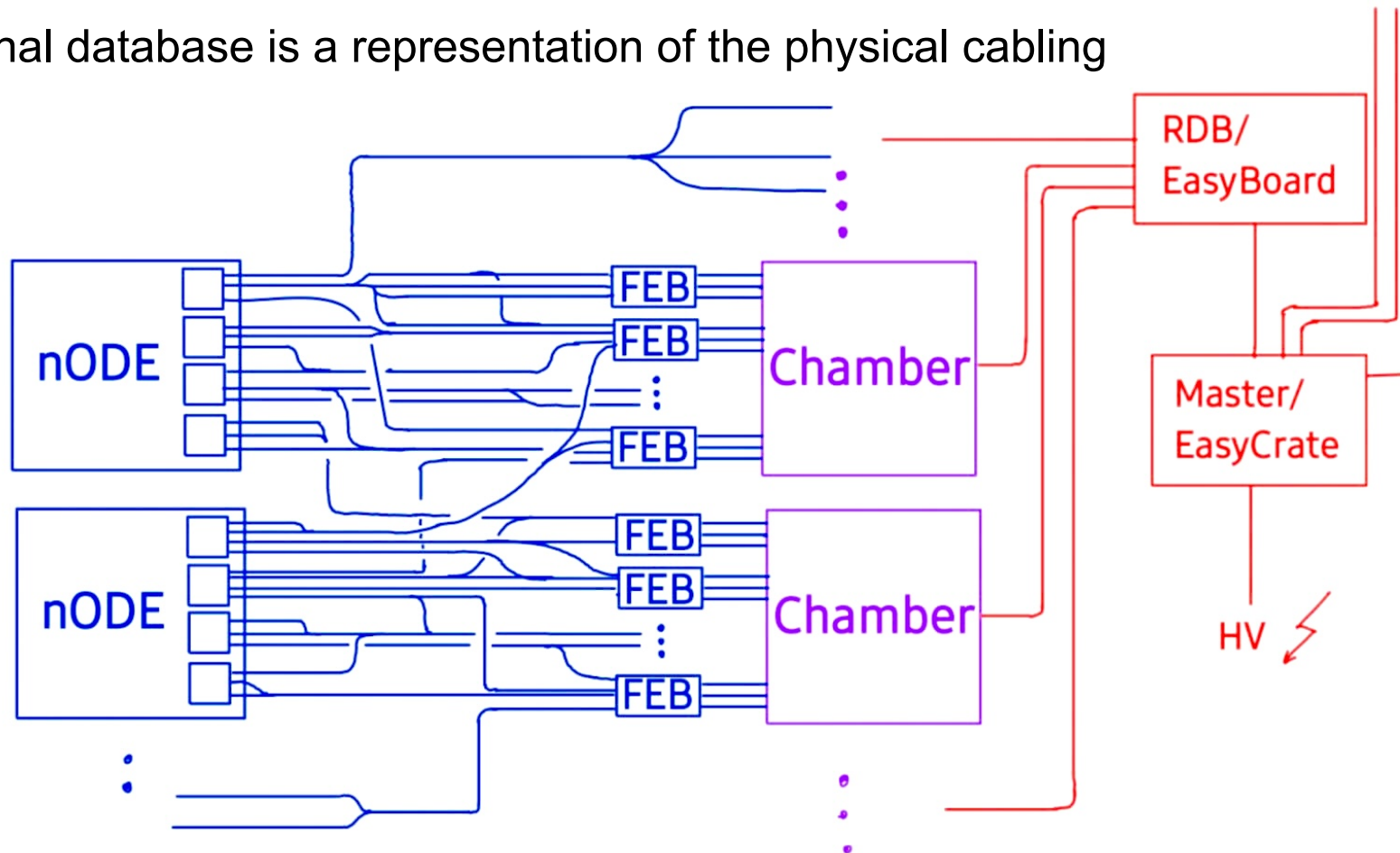


- **Entity-Relationship-Diagram (ERD)** is a common way to visualise relational databases
- Displays tables (Entity) and columns (Entity attributes) and relationship between the tables

Entity-Relationship-Diagram

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

➔ Relational database is a representation of the physical cabling



Applications

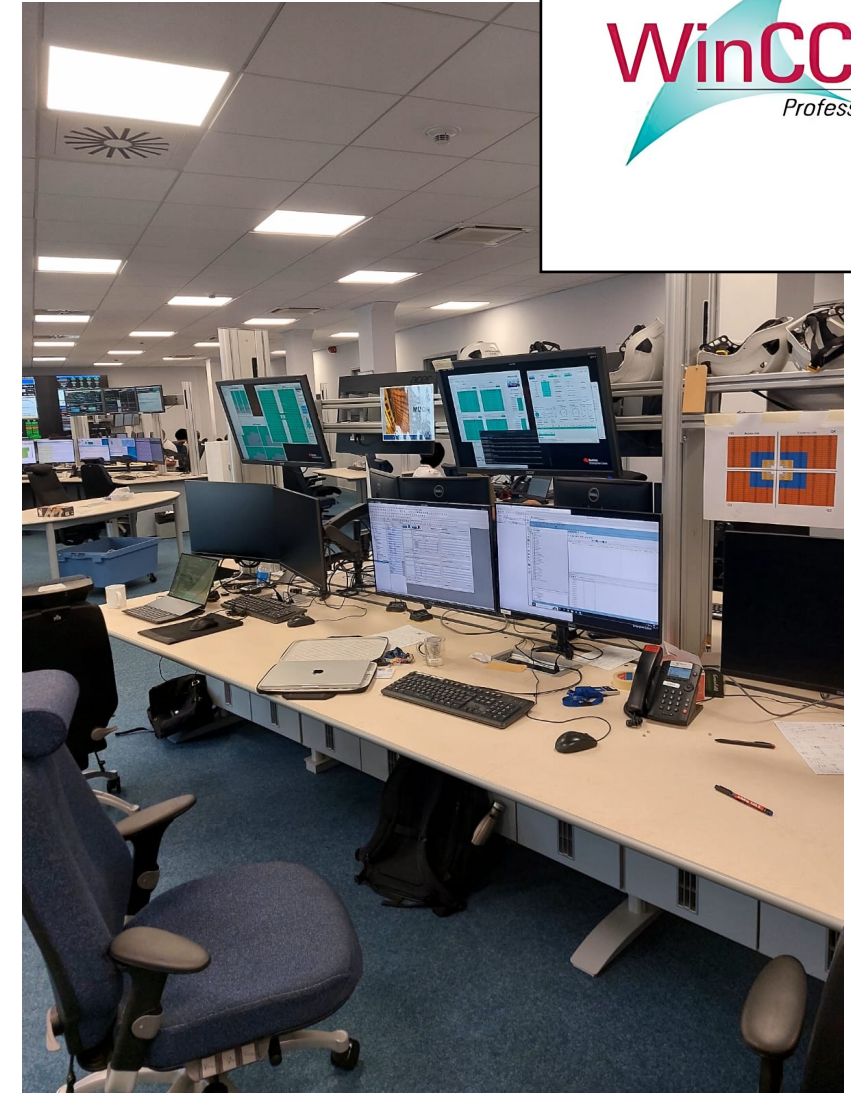
Integration of the database

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

The screenshot displays the WinCC Editor interface for a project named "Gedi (MU_TEST_CONNECTION - MU_TEST_CONNECTION; #1) - SSP_MuonDetective.pnl". The interface is divided into several panes:

- Project View:** Shows a tree structure of the project, including folders for "3.16", "fwInstallation", "fwComponents_MU_TEST_CONNECTION", "MU_TEST_CONNECTION", "Scripts", "Libraries", "Message Catalogs", "Data", "Configuration", "Datapoint Lists", "Pictures", "Color Databases", and "Panels".
- Property Editor:** Displays the properties of the selected "MuonDetective" object. The "Standard" tab is active, showing properties such as Name, Typename, Ref.point, Size, Horizontal/Vertical Size, Layout Bo., Layout Le., Layout Ri., Layout To., Layout Sp., Layout Type, Active La., Keep in M., LangChan., Panel Bac., Reference., Restore M., Runtime, Send Mou., Start Init., Start Zoo., and Start Zoo. coordinates.
- Panel Design:** The main workspace shows a panel titled "Muon Detector Detective" with a timestamp "Thu 15-Aug-2024 11:19:53 AM". The panel contains four main sections:
 - Get Chamber Information:** Includes a table for listing chambers and buttons for "List FEBs", "List ODEs", "List ODE Channels", and "Clear Table".
 - Get FEB Information:** Includes a table for listing FEBs and buttons for "List Logical Channels", "List ODEs", "List ODE Channels", and "Clear Table".
 - Get ODE Information:** Includes a table for listing ODEs and buttons for "List Channels", "List FEBs", "List Chambers", and "Clear Table".
 - Get RDB Information:** Includes a table for listing RDBs and buttons for "List Chambers" and "Clear Table".Each section also has a "Messages" area for displaying data.

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

Muon Detector Detective

Thu 15-Aug-2024 11:21:33 AM

Get Chamber Information

Quadrant	Station	Region	RDB	Master_CH	Master_Module	Server
1	3	3	84	7	12	A

FEB id	FEB number	# Physical Channels
M3A22B-06	6	2
M3A22B-07	7	2
M3A22B-08	8	2
M3A22B-09	9	2
M3A22B-10	10	2
M3A22B-11	11	2

List FEBs
List ODEs
List ODE Channels
Clear Table

Get FEB Information

Quadrant	Station	Region	Chamber	FEB	# Physical Channels
1	3	3	22B	6	2

ODE id	ODE number	# Used Channels
Q1M3R32	2	168

List Logical Channels
List ODEs
List ODE Channels
Clear Table

Get ODE Information

Quadrant	Station	Region	# Connected Sync	# Connected Channels
1	3	3	4	168

Sync	Channel	# Connected Chambers
3	41	2
3	42	2
3	43	1
3	44	1
3	45	1
3	46	1

List Channels
List FEBs
List Chambers
Clear Table

Get RDB Information

Master Module	Master Channel	Server	# Connected Chambers
12	7	A	9

List Chambers
Clear Table

Messages

Chamber found.

FEB found.

ODE found.

RDB found.

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

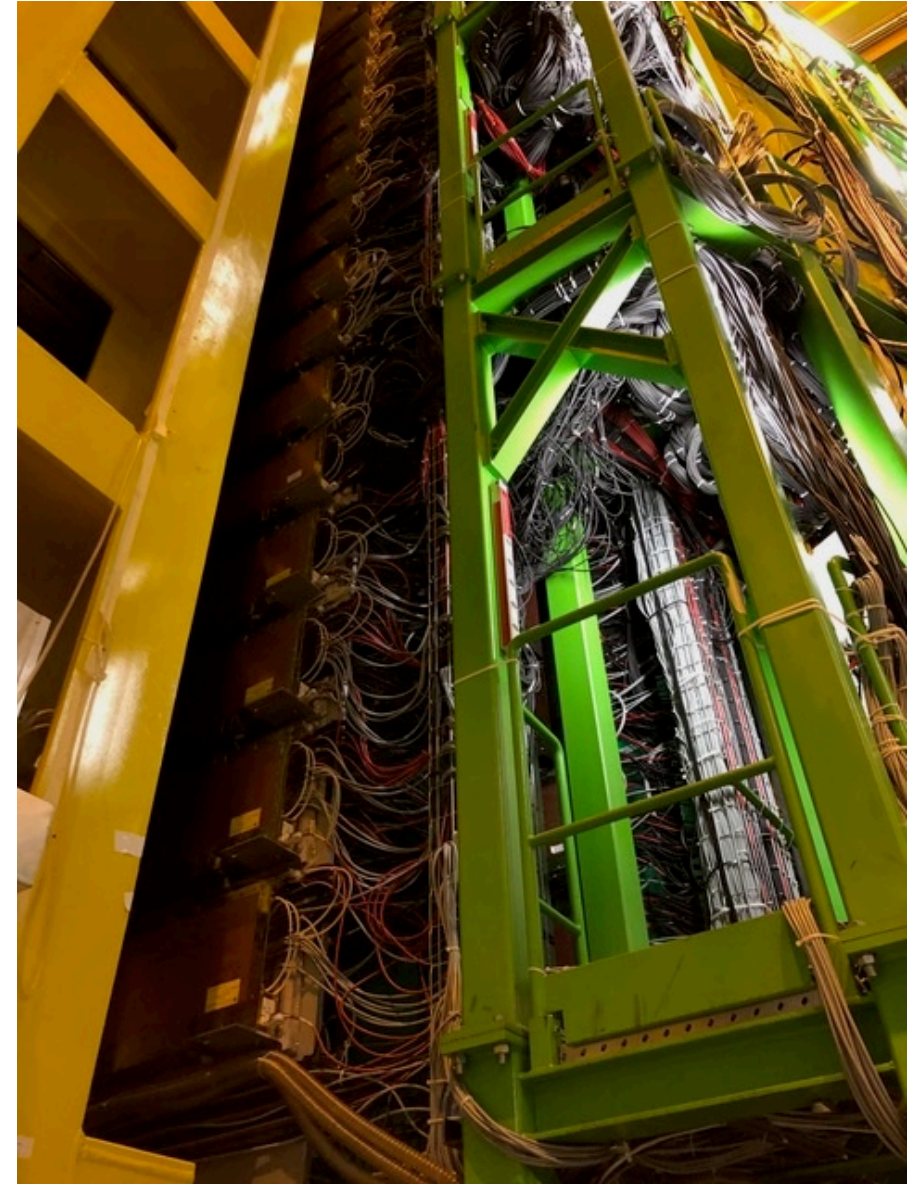
Prospects

- 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.



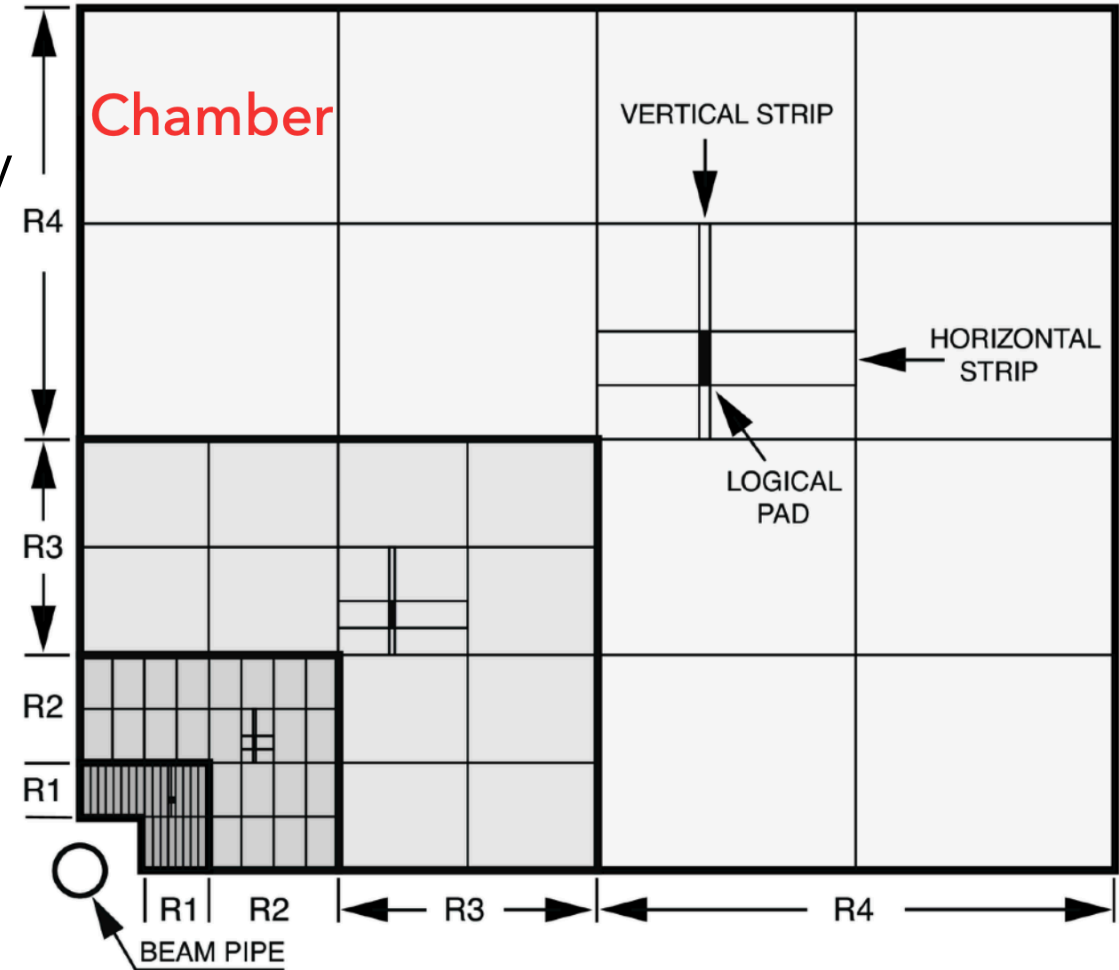
References

- [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., Ciambone 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

Access side

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	

Cryogenics side

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	

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		

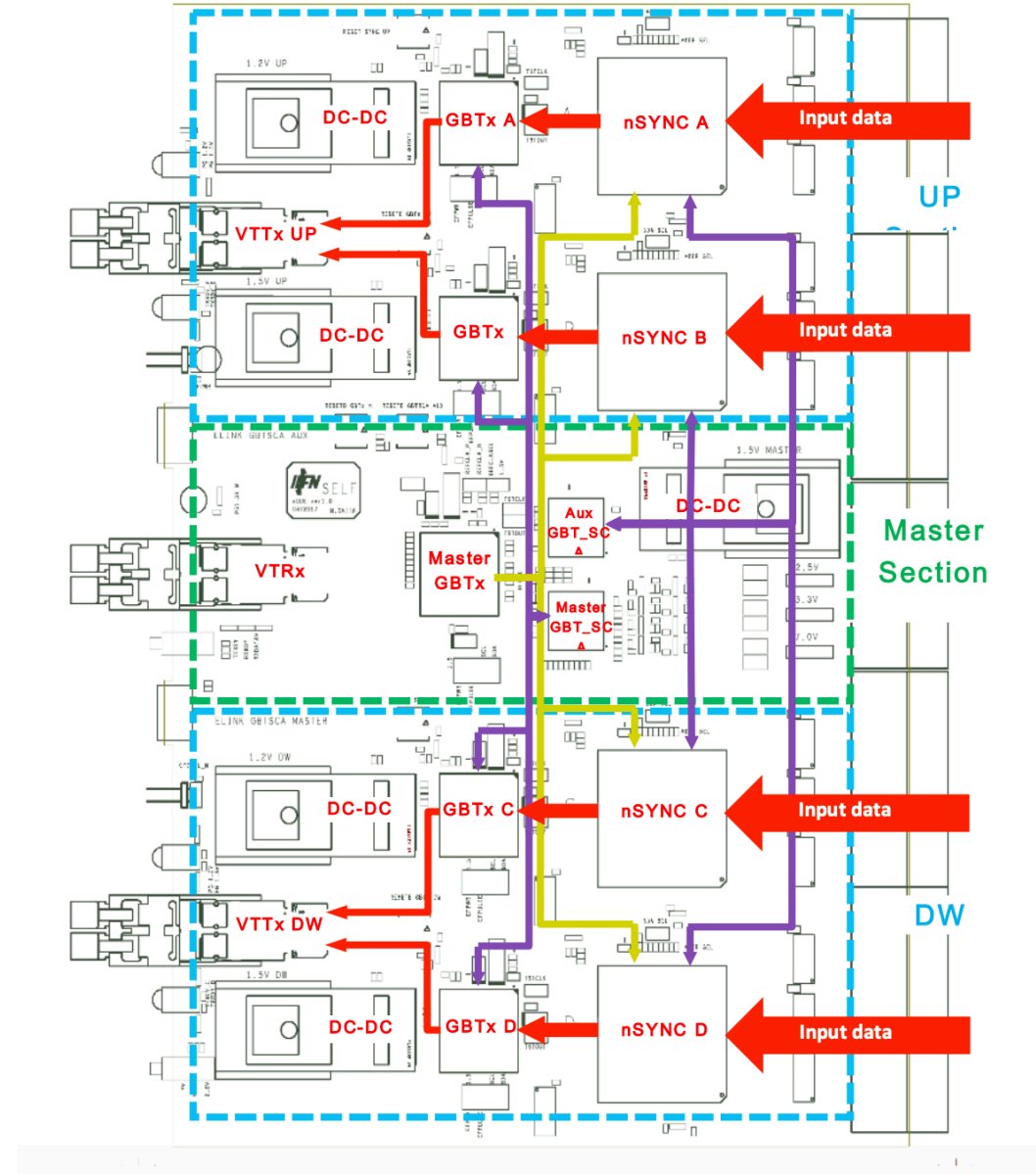
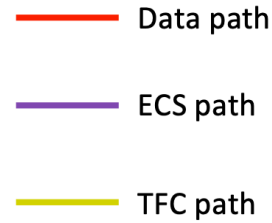
Q2

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		

Q3

The nODE board

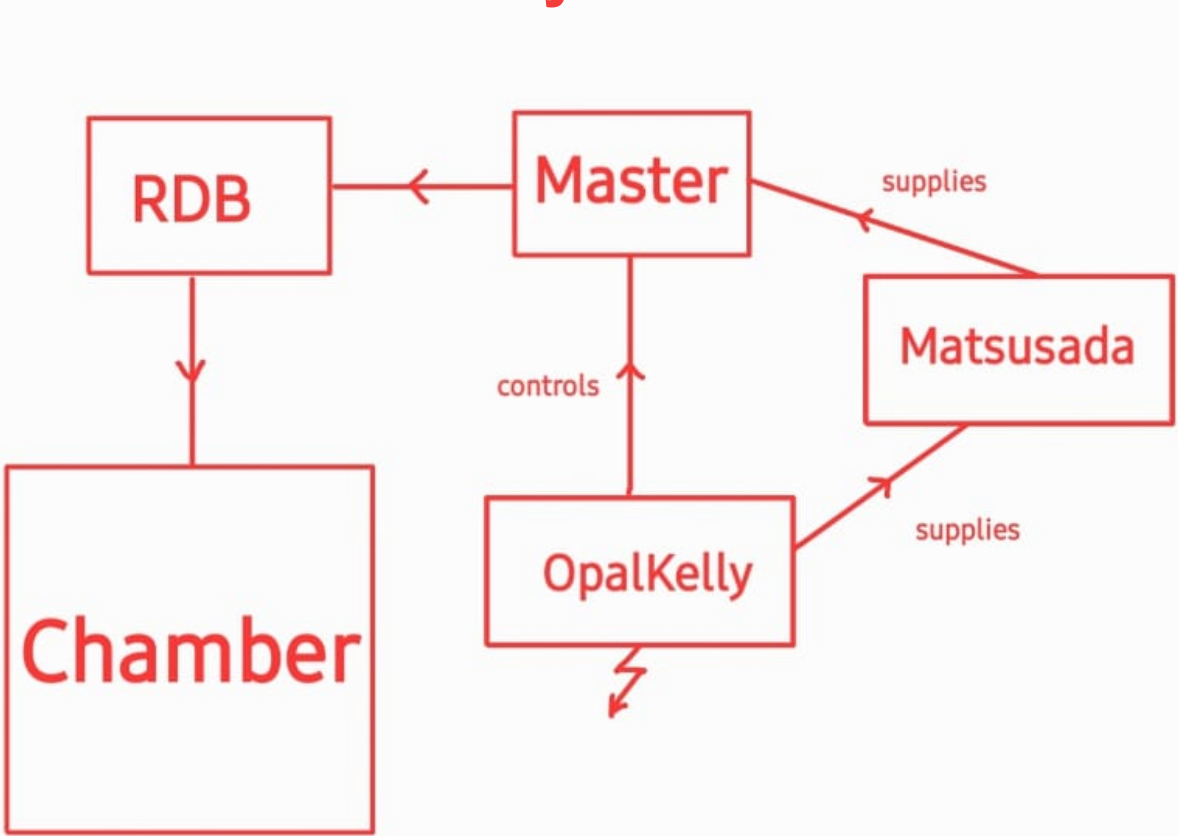
- Four nSYNC chips already discussed
- GBTx is a serializer-de-serializer chip receiving and transmitting serial data at 4.8 Gb/s (one per SYNC)
- GBT-SCA to provide the slow-controls interface to the front-end electronics
- VTTx transmits data from nSYNC to the TELL40 boards
- VTRx transmits TFC and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



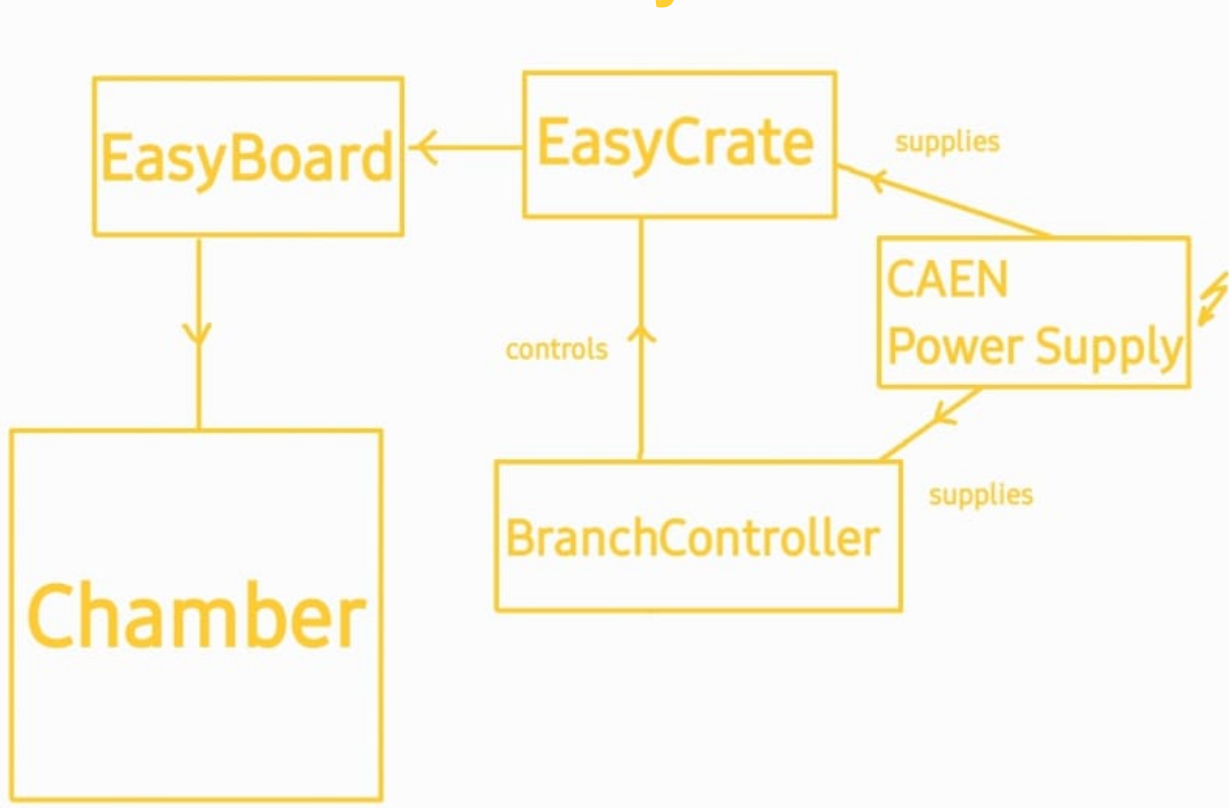
Source: S. Cadeddu, P. Ciambone; Muon Front-End Data Format

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

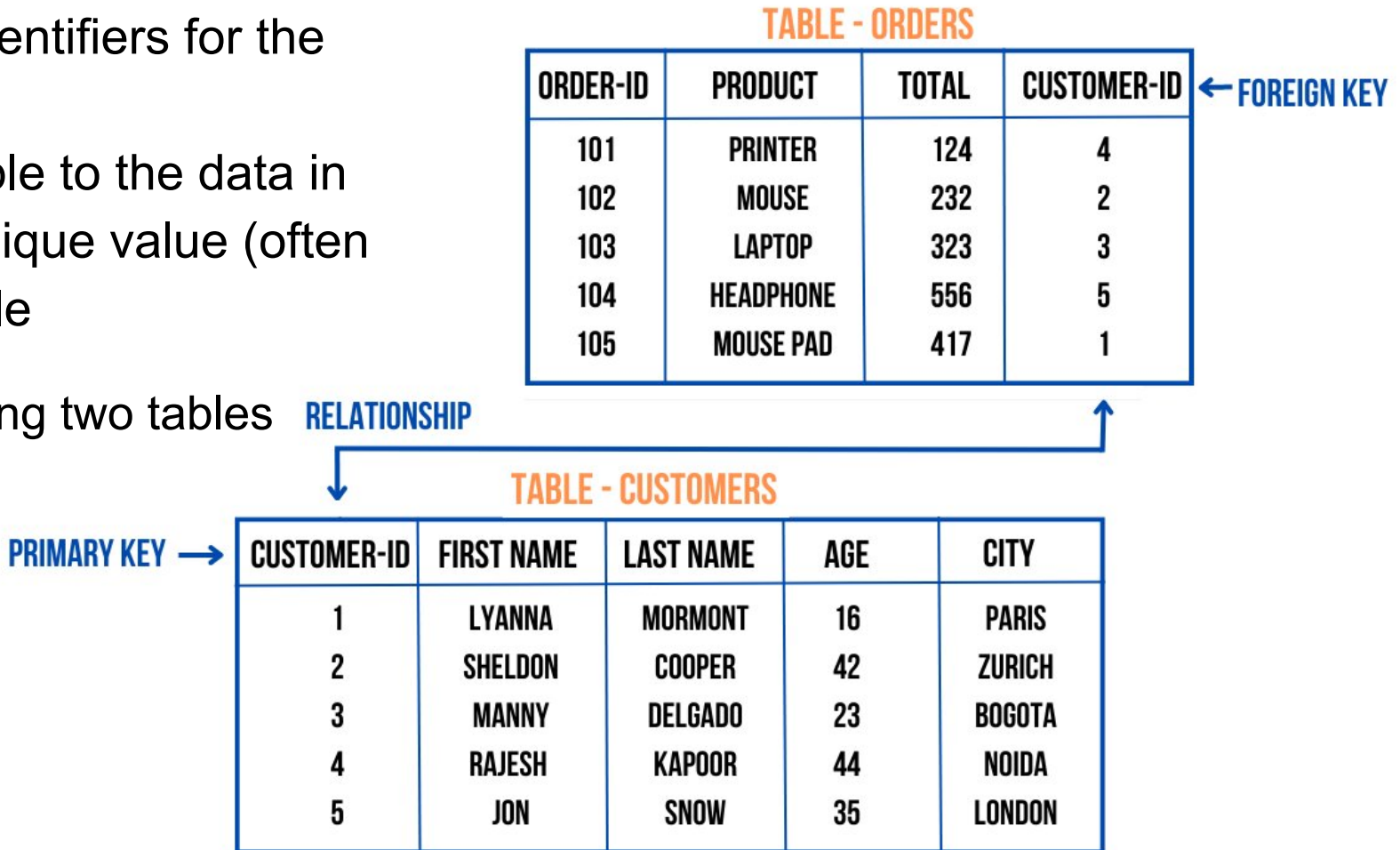
- 112 RDBs, each connected to 9 chambers
- 16 Master modules, each connected to 7 RDBs
- 18/20 EasyBoards used, each connected to 8 chambers
- 4 EasyCreates, each connected to 9 EasyBoards

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



Source: Shiksha, Difference Between Primary Key And Foreign Key

Entity-Relationship-Diagram Notation



One



Many



One (and only one)



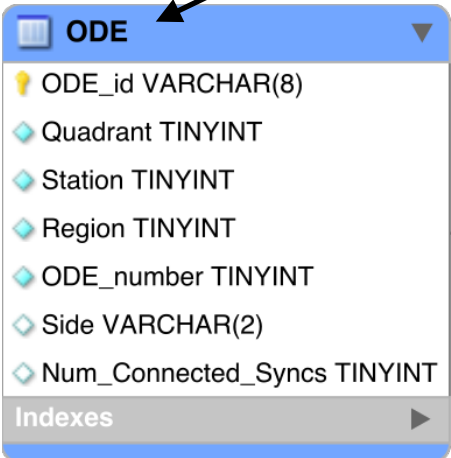
Zero or one



One or many



Zero or many



Entity (Table)



Attributes (Columns)

- 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

Masking nODE Channels

Enter nODE

Quadrant: Q1 Station: M2 Region: R1 ODE number: 1

Specify SYNC

Specify SYNC? SYNC number: 1

nODE Channels

Sync	Channel	# Connected Chambers	Active
1	0	1	Active
1	1	1	Active
1	2	1	Active
1	3	1	Masked
1	4	1	Active
1	5	1	Active
1	6	1	Masked
1	8	1	Active
1	9	1	Active

List Channels Update Config Clear Table

Messages

ODE/SYNC found.

Save changes