September 20, 2024

End of 1st PhD year Seminar

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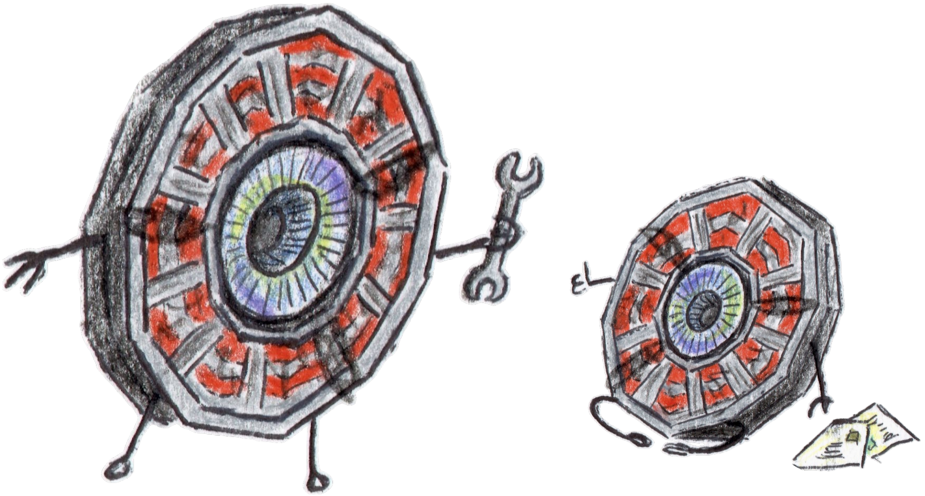
Outline

- Dimension-6 **EFT reinterpretation of same-sign WW** scattering with Run 2 data
  - status of the analysis
  - contributions to dim-6 EFT combination
- Development of **ECAL DAQ SW for Phase 2 Upgrade**
  - SW developments in the last year
  - test beam preparation
  - tests at SuperModule 36
- ECAL **Run 3 operations**
  - DAQ activities
- Other activities
  - Conferences and publications
  - Schools and courses



Marta Tornago

Dimension-6 EFT interpretation of same-sign WW scattering with Run 3 data

Outline

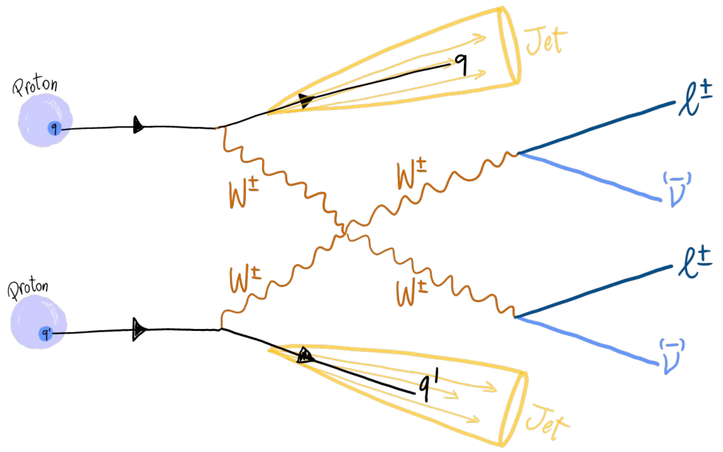
Study of the effect of **dimension-6 EFT operators** on **fully-leptonic same-sign WW** scattering with Run 2 data

State of the art:

- SM analysis + dim 8 EFT studies: 2005.01173 (SMP-19-012)
- dim 6 EFT studies at LHE: 2108.03199

Target:

- dim-6 EFT combination (CMS-AN-2024-108)



Very clean signature (very low QCD background):

- 2 forward jets
- 2 same sign charged leptons
- 2 neutrinos

Main backgrounds:

- fake leptons
- WZ (QCD and EWK)

SM Effective Field Theory (SMEFT)

The **SM** is seen as a **low-energy approximation** of a more complete theory:

- First non zero term (after SM) is **dimension 6**
- BSM effects are parametrized as additional terms to the SM lagrangian, which contain **higher order operators**
- Their intensity is gauged by **Wilson coefficients**

$$\mathcal{L}_{EFT} = \mathcal{L}_{SM} + \sum_{i,d>4} \frac{c_i}{\Lambda^{d-4}} \mathcal{O}^{(d_i)}$$

Λ – new physics scale

$\mathcal{O}^{(d_i)}$ – EFT operator of dimension d_i

c_i – Wilson coefficient

EFT events are generated privately via Madgraph5 and SMEFTsim:

- UFO model: `topU3l_MwScheme_UFO_b_massless`
- Operators considered: **cW**, **cHW**, **cHWB**, **cHbox**, **cHDD** (choice driven by combination)
  - all operators belong to the Warsaw basis

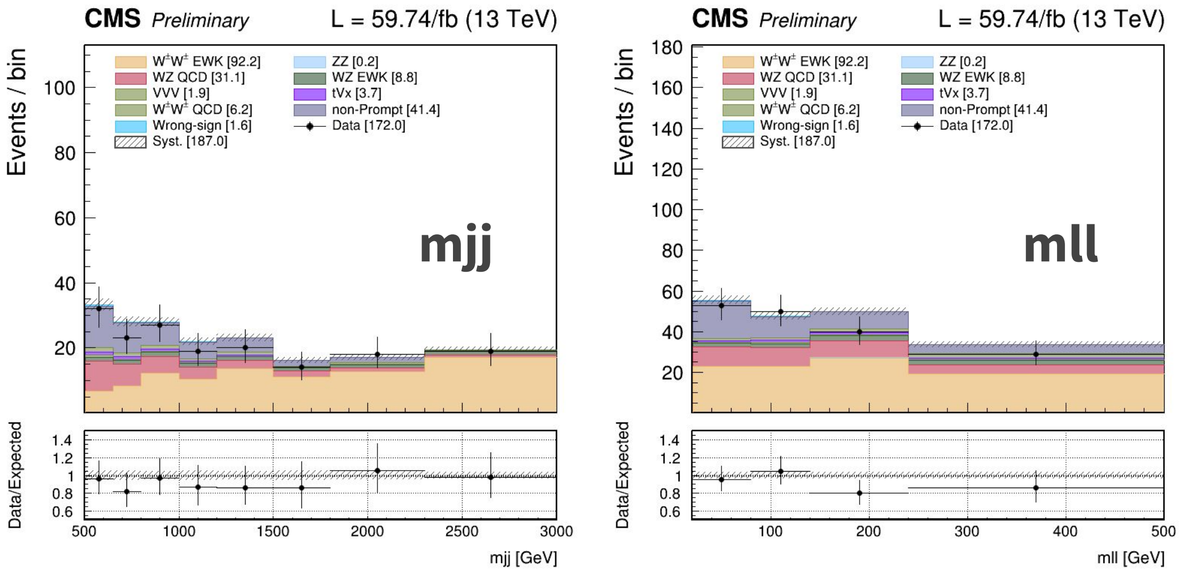
SM analysis reproduction

- Simultaneous fit of **SSWW SR**, **WZ** and **WZb CRs** + additional non-prompt for controls
  - wrt published AN: removed ZZ CR and removed non-prompt CR from fit
  - we use a **tighter, MVA-based lepton ID** + **Ultra Legacy** samples

Variable	$W^{\pm}W^{\pm}$	WZ	Nonprompt	WZb	ZZ
Number of leptons	2	3	2	3	4
p_T^{ℓ}	$> 25/20$ GeV	$> 25/10/20$ GeV	$> 25/20$ GeV	$> 25/10/20$ GeV	$p_T > 25/20/10/10$ GeV
p_T^{j}	> 50 GeV	> 50 GeV	> 50 GeV	> 50 GeV	> 50 GeV
$\|m_{\ell\ell} - m_Z\|$	> 15 GeV (ee)	< 15 GeV	> 15 GeV (ee)	< 15 GeV	< 15 GeV (both pairs)
$m_{\ell\ell}$	> 20 GeV	-	> 20 GeV	-	-
$m_{\ell\ell\ell}$	-	> 100 GeV	-	> 100 GeV	-
p_T^{miss}	> 30 GeV	> 30 GeV	> 30 GeV	> 30 GeV	-
Anti b-tagging	Applied	Applied	Inverted	Inverted	-
τ veto	Applied	Applied	Applied	Applied	-
$max(z_{\ell}^{*})$	< 0.75	< 1.0	< 0.75	< 1.0	< 0.75
m_{jj}	> 500 GeV	> 500 GeV	> 500 GeV	> 500 GeV	> 500 GeV
$\|\Delta\eta_{jj}\|$	> 2.5	> 2.5	> 2.5	> 2.5	> 2.5

SSWW signal region (2018)

- 2 leptons, away from Z mass window, VBS selections on jets, bVeto
  - Main backgrounds: **fake leptons** - **WZ QCD** - **WZ EWK**

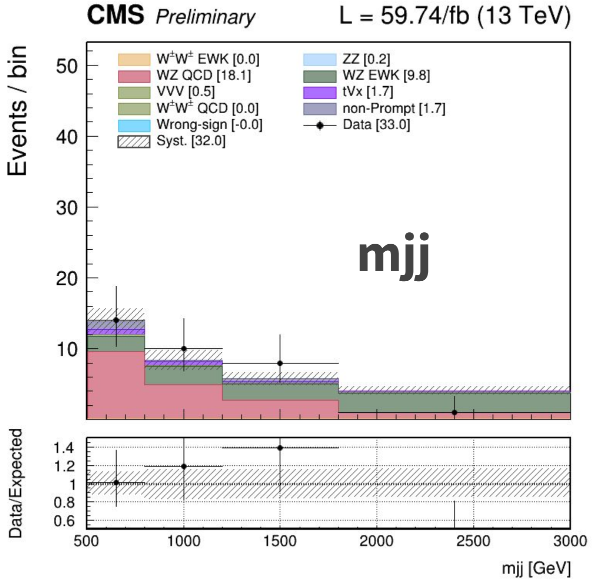


Published AN:

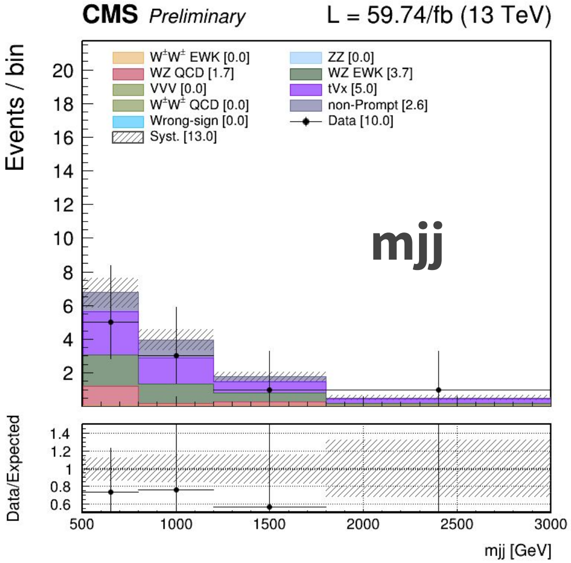
	2018
EWK WW	92.8 ± 11.4
QCD WW	5.5 ± 0.7
Intf. WW	3.7 ± 1.0
EWK WZ	7.2 ± 1.6
QCD WZ	18.5 ± 3.4
Intf. WZ	0.2 ± 0.1
ZZ	0.3 ± 0.1
Non-prompt	95.9 ± 26.7
tVX	2.3 ± 0.8
$W\gamma$	3.9 ± 1.2
Wrong sign	6.5 ± 4.3
Other bkg.	2.4 ± 1.3
Total	239.2 ± 31.7
Data	246

Control regions (2018)

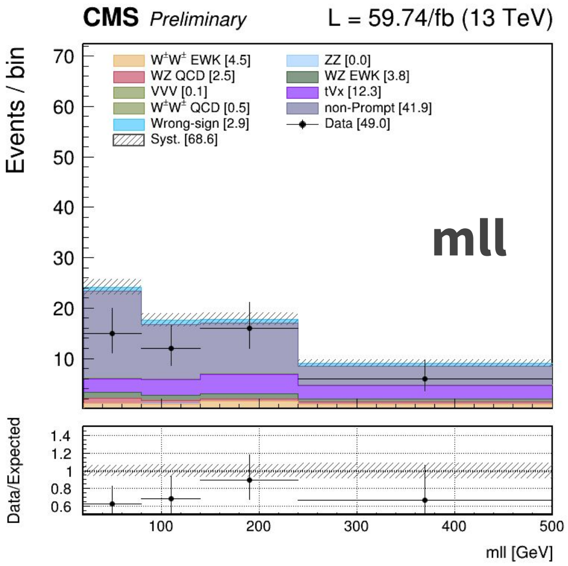
WZ: 3 leptons, Z mass window, VBS selections on jets, bVeto



WZb: 3 leptons, Z mass window, VBS selections on jets, bTag



non-prompt: 2 leptons away from Z mass window, VBS selections on jets, bVeto



SM analysis: results and WIP

- **2018 close to completion**
  - fixed some systematics last week at the combination meeting, need to finish implementing them and run the shapes again

- **2016/2017: workflow completed**, but there is some bug to fix (weights? cuts?)
  - significance much higher than expected
  - next steps: summary tables with yields, to figure out where exactly is the problem

	SSWW MC Asimov	SSWW Data Asimov	WZ MC Asimov	WZ Data Asimov
2018	10.287	10.2482	2.15454	2.07983
2017	9.63439	8.90379	2.06672	1.65507
2016 no HIPM	10.287	10.3099	2.09598	2.16041
2016 HIPM	10.0008	10.0653	2.07625	2.04662

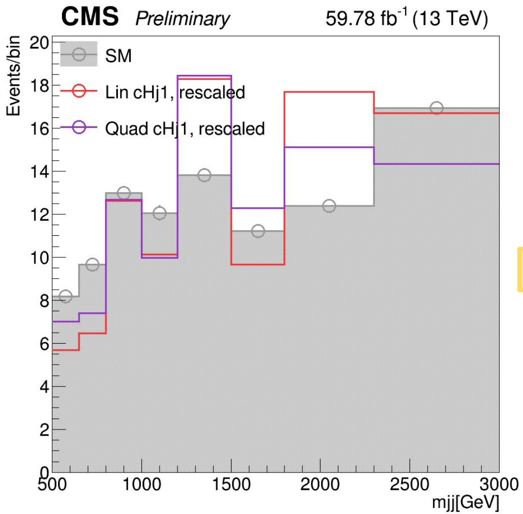
	2016	2017	2018	Combination
EWK WW (observed/expected)	4.6/5.2	7.2/7.2	7.9/7.2	11.5/11.3
EWK WZ (observed/expected)	2.6/2.7	4.4/2.8	4.6/3.7	6.8/5.3

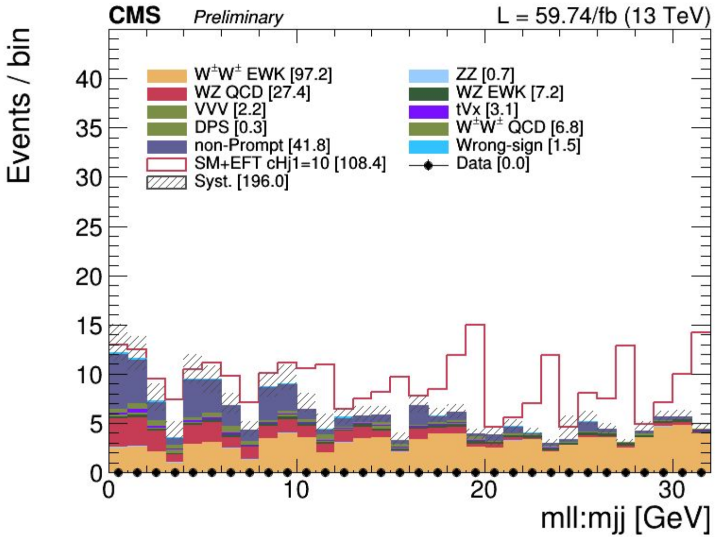
EFT contributions to SSWW observables

$$|A_{EFT}|^2 = \underbrace{|A_{SM}|^2} + \underbrace{2Re(A_{SM}A^*_{op})} + \underbrace{|A_{op}|^2}$$

EFT contributions considered only for WW (not yet for WZ)

- A pure **SM contribution**
- Additional terms with **linear** and **quadratic** dependence on the Wilson coefficient



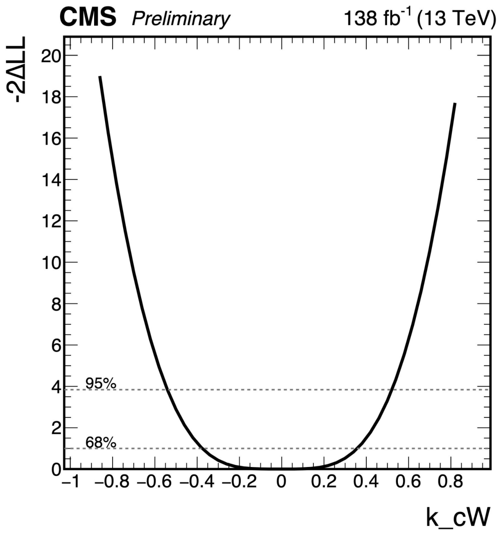


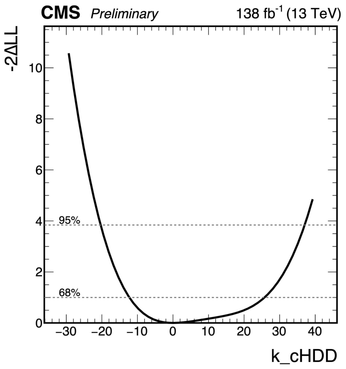
Results: EFT fits 1D

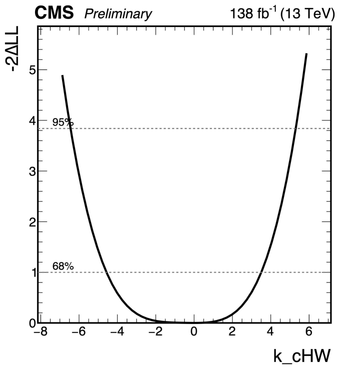
- Same regions and variables as SM. Fits are non-profiled (all other ops are set to 0)

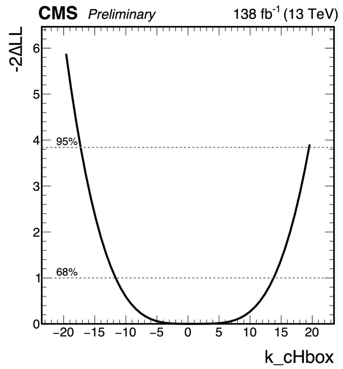
  → sensitivity hierarchy ~ LHE study

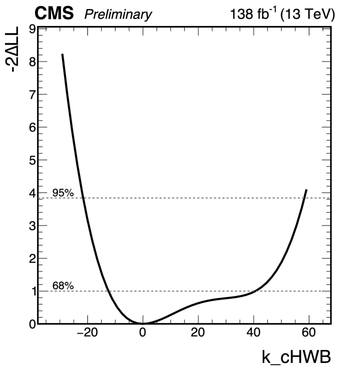
  → size of the bounds is comparable







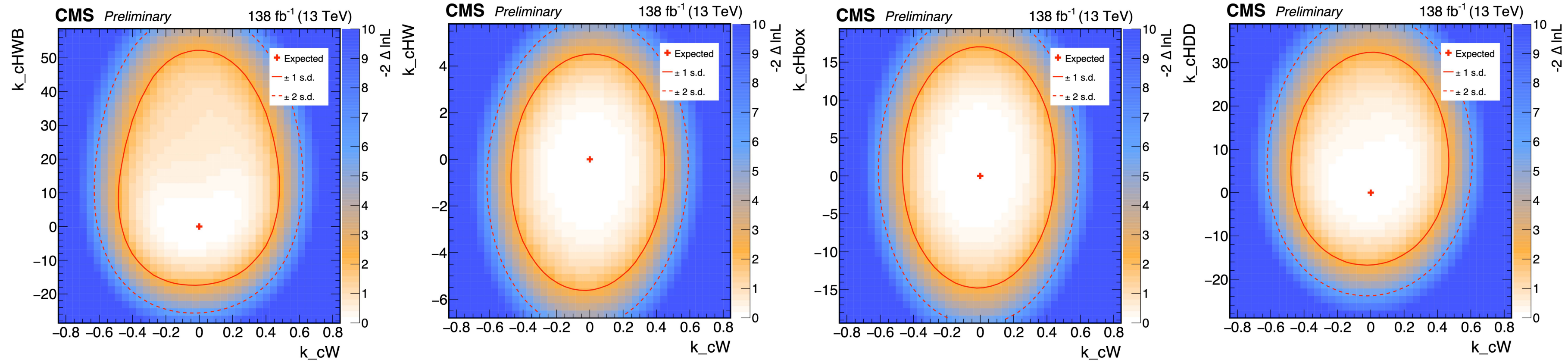




Results: EFT fits 2D

Two operators are fitted simultaneously. As for the 1D fits, all the other operators are fixed to 0 (plots for cW wrt other operators as from combination)

- Bounds are slightly larger than in the individual fits



EFT analysis: conclusions and WIP

- Our results are competitive with the other state of the art studies →

- **Full workflow in place, from nanoAOD to datacard with EFT operators**
  - some checks needed on 2016 and 2017
  - close to completion for 2018, after last systematics were decided and added in the last combination meeting

- **Target: join the combination!**
  → Moriond 2025

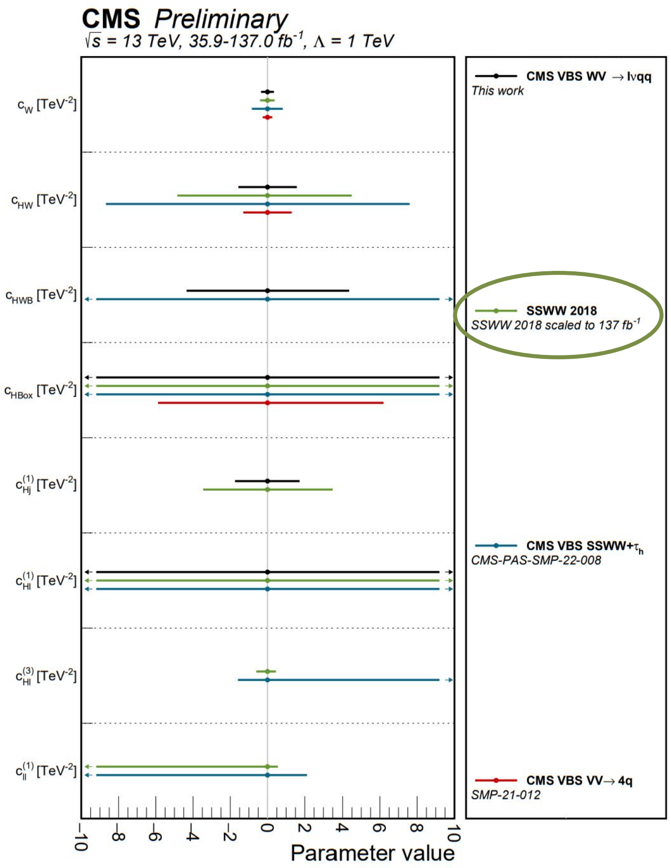
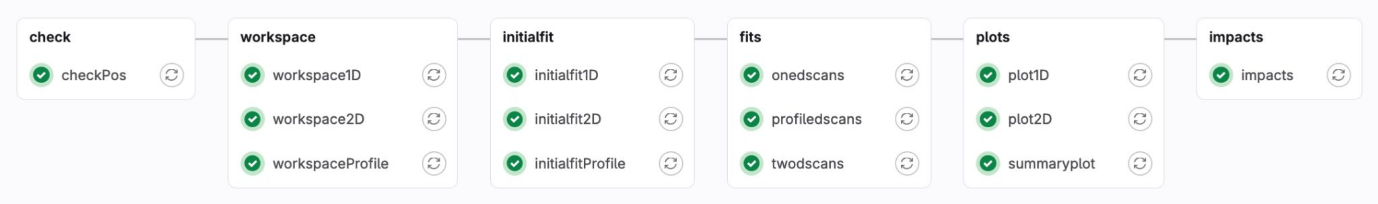


Figure by Giacomo Boldrini

Dimension-6 EFT combination

Joined the effort for the dimension-6 EFT combination of direct EFT interpretations in the EW sector [gitlab] [G. Boldrini's presentation]

- inputs from **15 analyses, 6 operators chosen**
  - SSWW grants sensitivity to 5 of them
  - during last year all 5 of them were implemented (table not up to date)!
- gitlab CI/CD pipeline testing each analysis and performing the combination → **highly automated framework**!
  - See Giorgio's presentation



	cB	cWWW	cW	cHB	cW	cHDD	cHW	cHWB	cHbox
WV	✓	✓	✓	?	?	?	?	?	?
Wγ				?	✓	?	?	?	?
VBF-W				✗	✓	✓	✗	✓	✗
VBS ZZ				○	✓	○	✓	○	✓
VBS SSWW				✗	✓	○	✓	○	✓
VBS WZ				○	✓	○	✓	○	✓
VBS ZV				✓	✓	○	✓	✓	✓
VBS WV				✓	✓	○	✓	✓	✓
VV/γ				✓	✓	✓	✓	✓	✓
VBS SSWW τ				✗	✓	✓	✓	✓	✓
VBF-Z				✗	✓	✓	✗	✓	✗
WW				✗	✓	○	✗	✓	✓
γγ→ττ				?	?	?	?	?	?
Z→ττμμ				?	?	?	?	?	?
VBF-γ				?	✓	?	?	✓	?

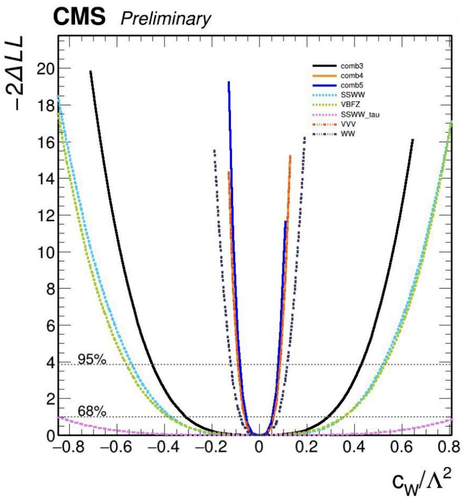
Figure by Giacomo Boldrini

Combination: in-person meetings

Joined both in-person meetings :

- **May 2024**: first results combining 5 analyses
+ developed tools and CI/CD infrastructure
  - all nuisances uncorrelated, minimal set of assumptions (→ WIP!)
  - both AnalyticAnomalousCoupling and InterferenceModel fwks tested

- **September 2024**: discussion on correlation of systematic uncertainties
+ tools for datacards editing
  - produced first guidelines for correlation
  - tested tools for datacard editing



Combined analyses:

- WW Run2
- VVV/γ Run2
- SSWW+τ_h Run 2
- VBF-Z 2017+2018
- SSWW (e,μ) 2018

- comb3: SSWW + VBF
- comb4: comb3+VVV
- comb5: comb4+WW

For example:

```
nuisances['fake_mu_EWKsub']  = {
                'name'  : 'VBFW_fake_m_EWKsub_2017',
                'kind'  : 'weight',
                'type'  : 'shape',
                'samples'  : {
                               'Fake'      : [ fakeW_EWKsubUp , fakeW_EWKsubDown ],
                              },
                'cuts':  phase_spaces_tot_mu
}
```

because I did something very different with the non-prompt estimation!

theory: QCD

Not normalized (i.e. no acceptance).
To all samples, eft included.
Problem: name of samples should be unified

```
variations = ['LHEScaleWeight[0]', 'LHEScaleWeight[1]', 'LHEScaleWeight[3]', 'LHESca
```

for sample in backgrounds:

```
 nuisances['QCDscale_'+sample] = {
            'name'  : 'QCDscale_'+sample,
            'kind': 'weight_envelope',
            'type'  : 'shape',
            'samples'  :  { sample: variations },
    }
```

Combination of nuisances - c...

prescriprions: latinos imple...

theory: QCD
pdf weight
Parton Shower
UE
TOPptReweight:
PU (splitted years)
JER
Fakes (ele and mu)
JES - to be discussed after see...
MET
Ele and mu efficiency and scales
JET PU ID
LUMI:
Still Missing raccomandations:

Development of ECAL Upgrade SW for Phase 2

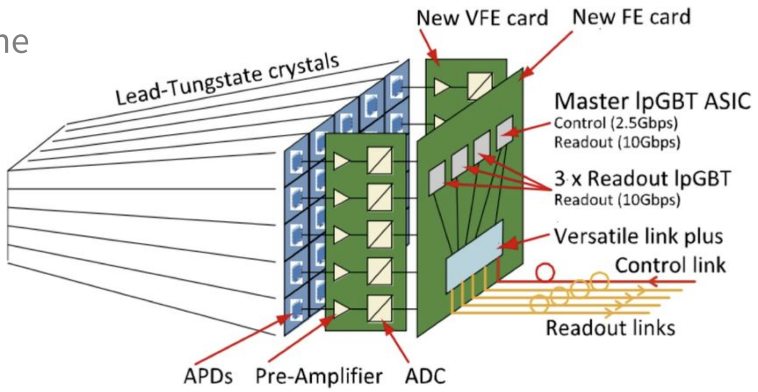
ECAL Phase 2 upgrade overview

- **Redesign of ECAL on-detector electronics** to cope with the harsher radiation levels and the higher pile-up levels:
    - higher analog bandwidth ⇒ shorter signal rising time
    - higher sampling rate (from 40 MS/s to 160 MS/s)

⇒ better discrimination of APD spikes

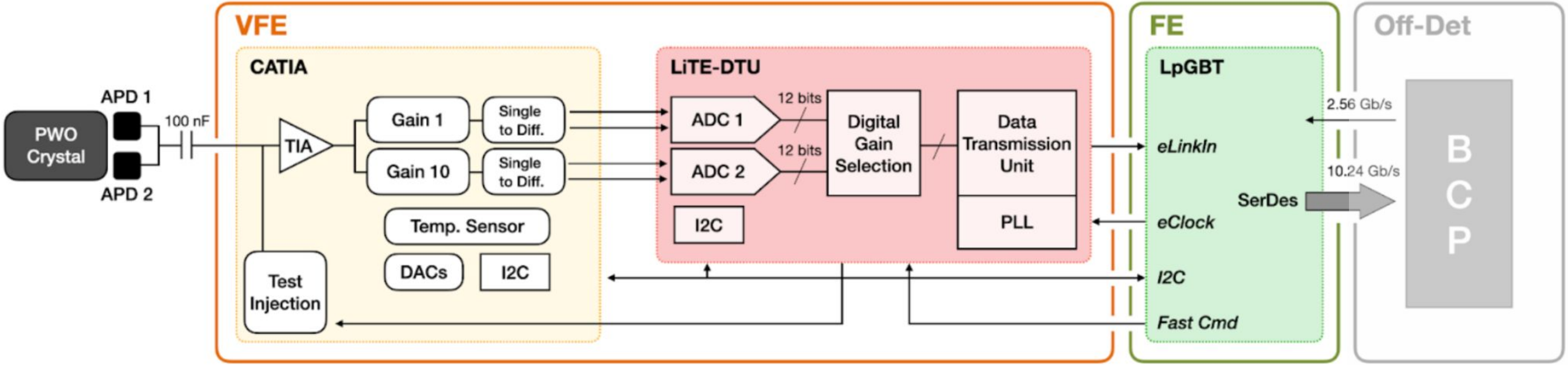
⇒ improved time resolution (30ps)

⇒ better primary vertex reconstruction



- **New common backend for ECAL and HCAL** to cope with stringent L1 requirements:
    - higher trigger rate (100 kHz → 750 kHz)
    - longer latencies (4.2 μs → 12 μs)

On-detector electronics



CATIA (analog ASIC)

2x transimpedance amplifier

LiTE-DTU (digital ASIC)

2x 12-bit ADCs sampling at 160 MHz

gain selection & data transmission unit

lossless data compression algorithm

LpGBT

radiation tolerant optical transmission system

Faster analog electronics

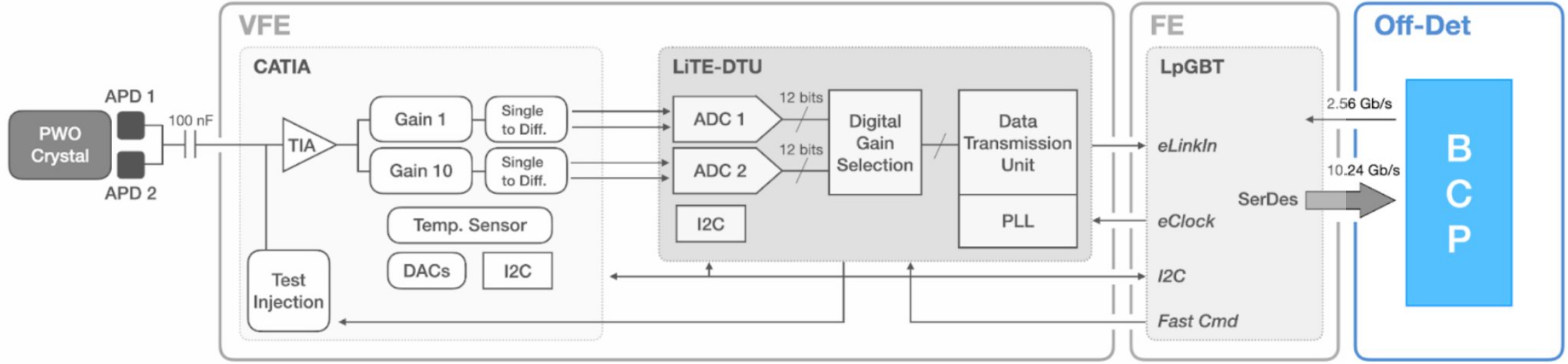
(larger analog bandwidth, sampling rate from 40 to 160 MHz, with 12-bit resolution)

→ **better noise filtering and time measurements**

Fast optical links

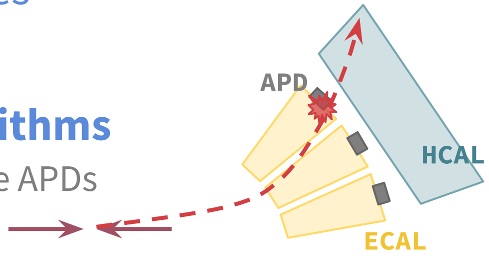
for data transmission

Off-detector electronics



Trigger objects reconstructed off-detector:
→ 25x more granular trigger primitives
(single crystal granularity)

Powerful spikes suppression algorithms
Spikes are particle ionizing in the APDs



Barrel Calorimeter Processor (BCP)
FPGA data aggregator, provides clock and control to FE and DAQ interface

- \+ decompression algorithm
- \+ trigger primitives construction
- \+ spike killing algos

Starting point: SW setup for tests and devel

2023

Set of **functions and scripts in Python + Rogue** libraries:

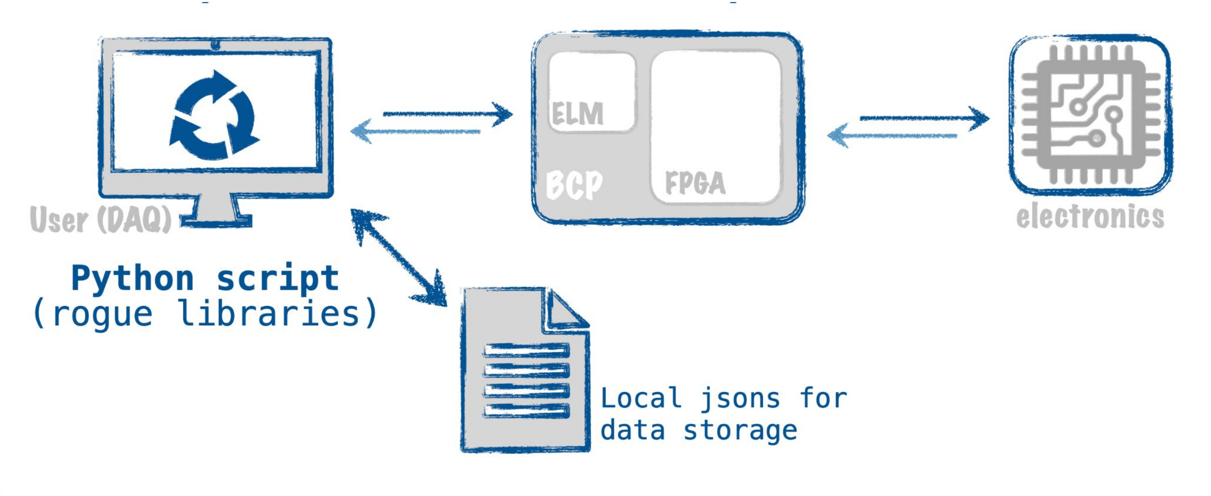
✔ easy to modify, quick implementation of new features

✘ hardly readable, not fully optimized, complex propagation of changes

status:

✔ all functionalities are in place

✔ still widely used for testing and development



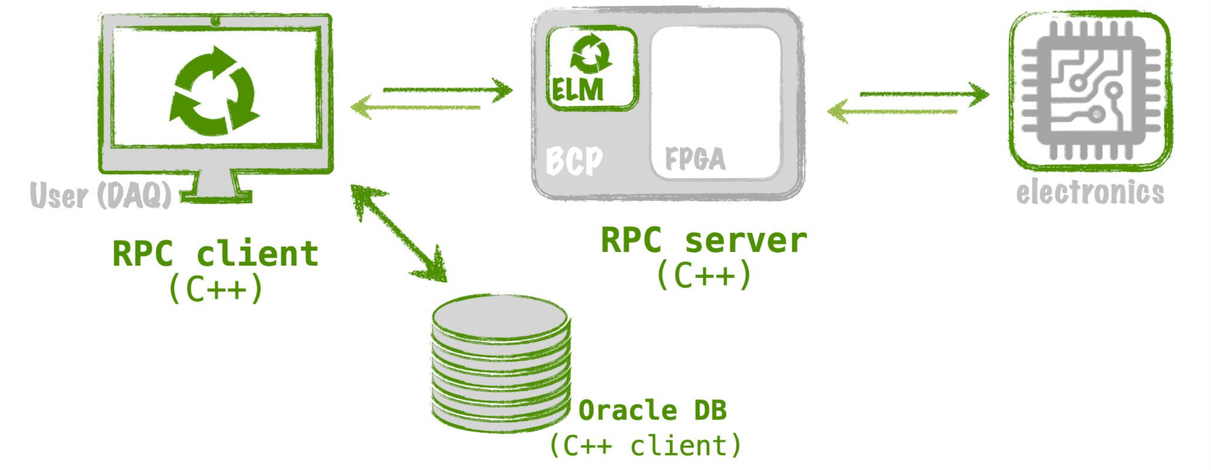
RPC: first implementation of final SW

Jan – Aug 2024

First prototype of the target SW: **custom adaptation of Wisconsin UNI's RPC service**

- Client running on DAQ/user PC, sending calls to the BCP (e.g. configureFE …)
- Server (running on ELM) receiving calls, performing actions and communicating with the electronics
- database

status:
✔ full FE and VFE configuration
✔ config storage on DB in place
✘ no BCP alignment (will be FW)



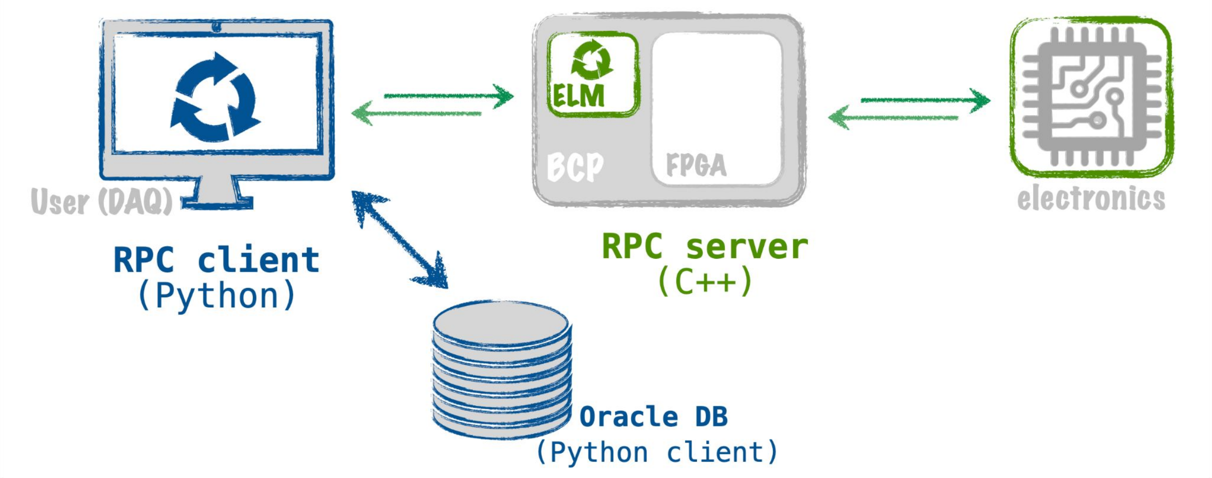
Integration of RPC in the test beam SW

Aug 2024

Also developed a third "flavor" of the SW in order to comply with Test Beam SW:
Python version of the Client + Python DB interface

Client and Server use Google **Protobuf** communication protocol ⇒ language agnostic

status:
✔ full FE and VFE configuration
✔ config storage on DB in place
✘ no BCP alignment (will be FW)



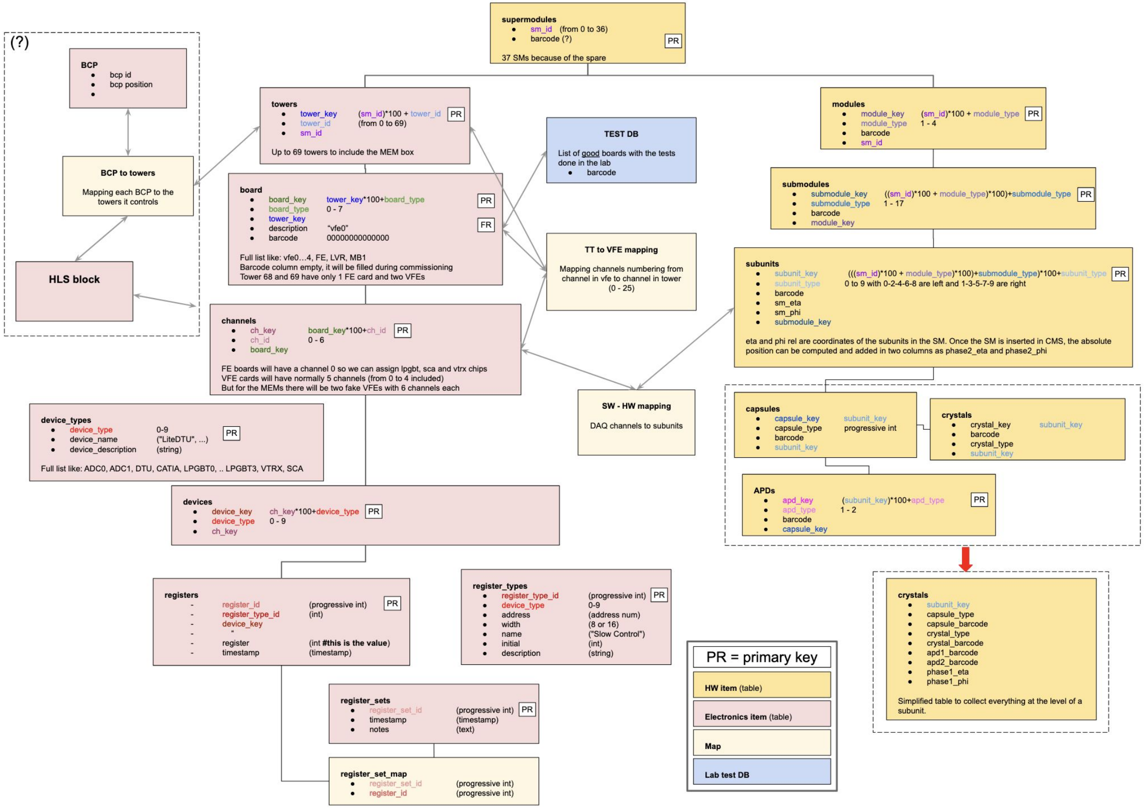
ECAL Phase2 database

Designed and built the first prototype of DB (Oracle):

- HW components (position, barcodes, properties …)
- SW components (position, barcodes, configuration registers …)
- maps (shortcuts)

✔ oracle DB exists
✔ C++ interface
✔ Python interface

ECAL Phase2 database (preliminary)

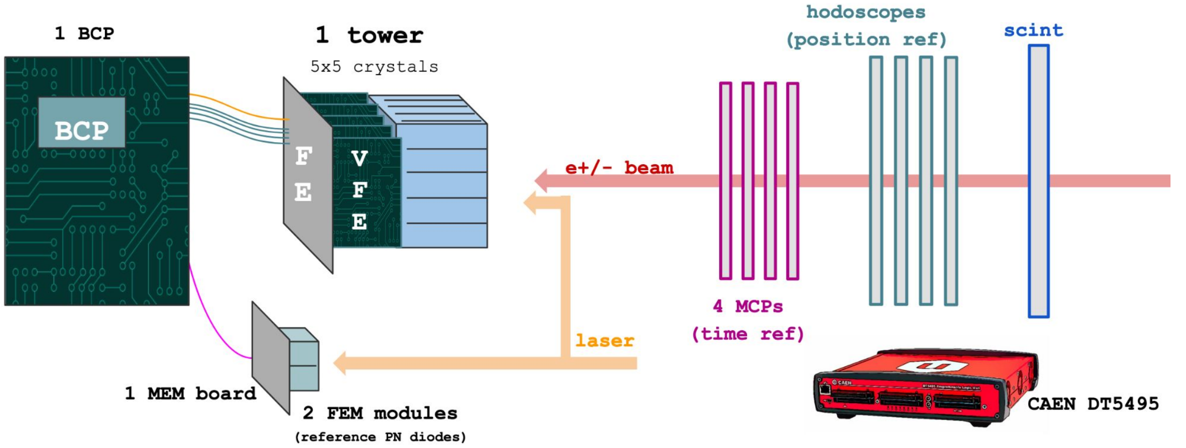


2024 Test Beam preparation (ongoing)

Currently **preparing next test beam** (16 - 27 october 2024):

- **single readout tower** to test new version of FE, VFE, LVR, LiTE DTU and CATIA
  - ✔ adapted SW to LiTE DTU v3.3, now fully integrated in the readout chain
  - ✔ SW mostly already in place
  - ✘ HW (cold box + rotating table) to be commissioned in the next weeks
  - ✘ DB undergoing upgrade to improve usability
- **New MCP commissioning**

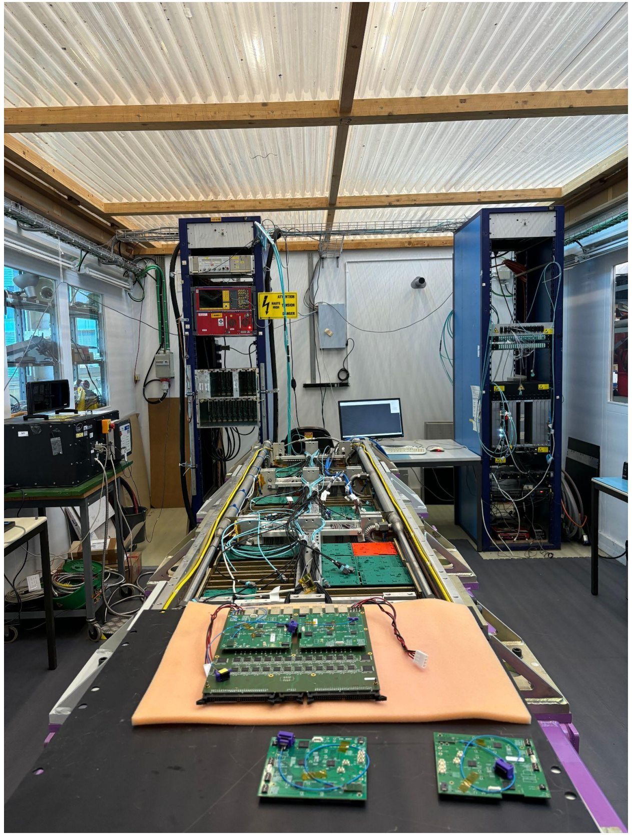
H4 test beam line at the North Area of the **CERN SPS: e^+/e^-** (**20 - 300 GeV**, $\Delta p/p < 0.5\%$)



@SM36 various tests and measurements

Many **measurement campaigns** by different groups took place at **SM36**: we (DAQ team) take care of HW setup, SW configuration and DAQ

- commissioning and integration of new electronics (e.g. LiTE DTU v3.0)
- laser monitoring upgrade tests
- LVR/VFE tests (next slides)



LVR/VFE tests

In March we received **LiTE DTU v3.0** showing uniform **extra power consumption** in both analog and digital domain (~ 30 mA each)

⇒ **investigations on the origin of the problem** (took months)

- turns out (end of July) that the **wrong process was submitted to TSMC**
  - not the fault of CERN/INFN
  - solution is to produce all chips (80k) again, correctly

⇒ studied **possible strategies to cope with increased current consumption**

- Chip fully functional: possible to use it? Would it fail sooner? see C. Borca's slides
- Proposal: **slight modification of LVR and VFE cards** (see T. Gadek's slides)
  - I run measurements at SM36 on the modified boards, to assess the feasibility of the strategy. See my slides and backup

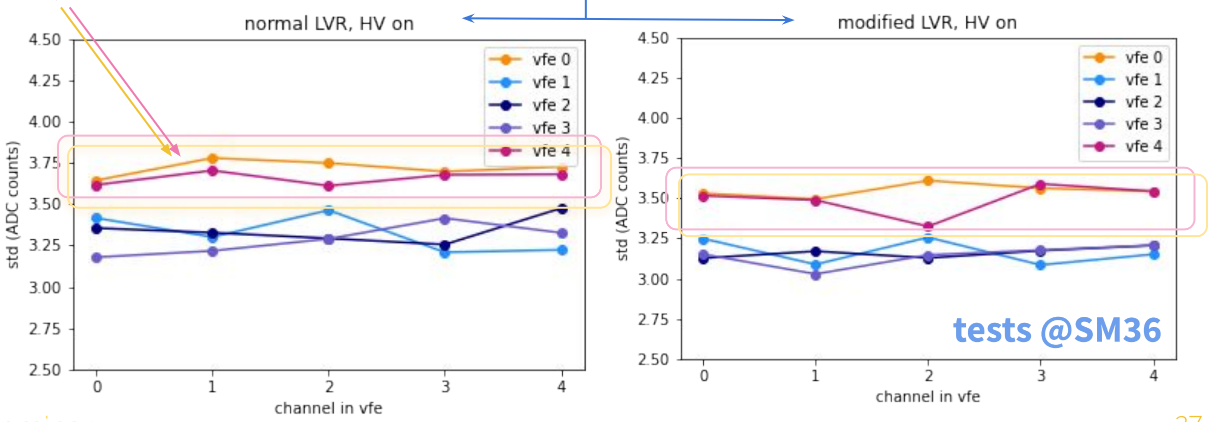
LVR/VFE tests results

- **new LVR** to cope with increased power consumption of LiTE DTUs:
  - reshuffled converters in LVR and added a big passive filter
- **new VFE** cards to mitigate the filtering dependance on the LiTE DTU power consumption
  - reduction of LiTE-DTU passive filters

tests on bench and on SM36

Results:

- noise: small increase in new VFEs, no differences with modified LVR
- current consumption lower in towers with modified VFE
- no temperature alterations
- uplink stability good

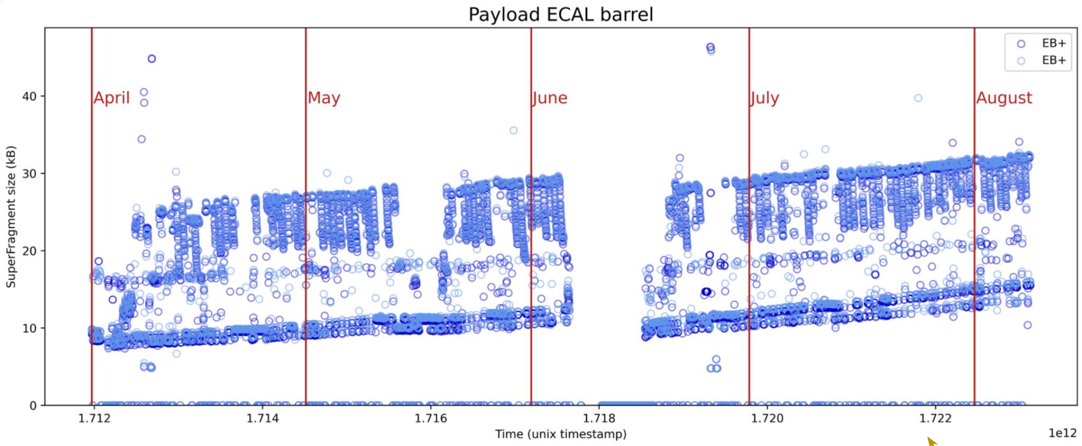


ECAL Run 3 operations

Activities overview

Took shifts for ECAL (~ 10 weeks):

- ECAL DOC
- ECAL DGL
- ECAL DAQ Expert on Call

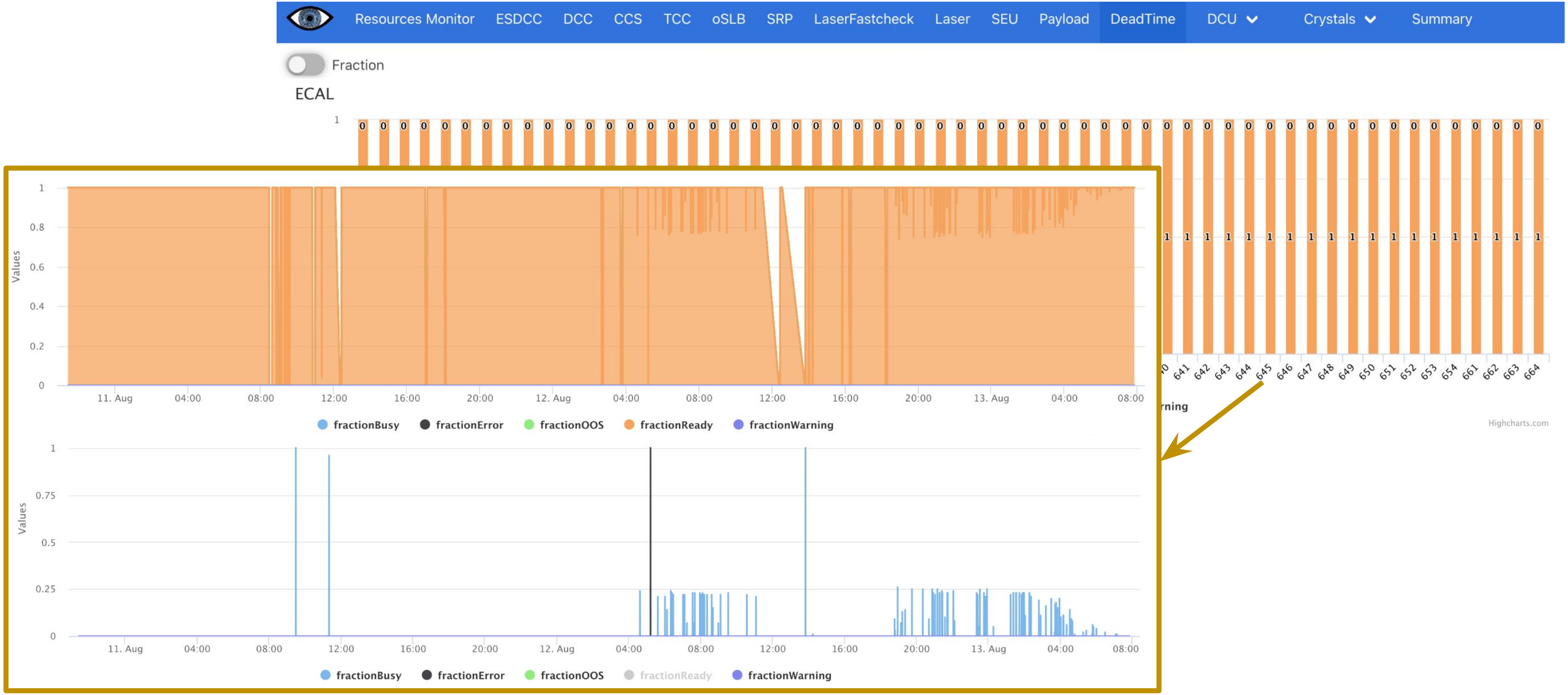


A lot of activity because of the **high ECAL deadtime** (up to 7%, normally ~ 4%).
(multiple concurring effect: very high PU, higher lumi delivered wrt foreseen ⇒ ECAL thresholds against noise are too loose … see R. Paramatti's slides)

⇒ Joined the investigations:

- developed sw tools to retrieve payload history in 2024
- developed a real time monitor (with ~7 days history) for shifters (next slide)

Dead time monitor



Other activities

Students

- **Martina Chirico** (INFN scholarship "La fisica delle particelle per scoprire l'universo"): **ECAL upgrade pedestal calibration studies** [Martina's presentation @ECAL Upgrade meeting]
  - Full setup with electronic chain mounted on the spare supermodule SM 36
  - Configuration process validated, she also found interesting bug (not concerning) in the process
    - ➔ engineers investigating!

- **Agustin Gabriel Guillenea Odella** (CERN Summer Student Programme): **SMEFT reinterpretation of SSWW using HEPData** [Agustin's presentation @SMP-VV meeting]
  - MadAnalysis framework for analysis, using DELPHES for detector simulation
  - EFT events generated through Madgraph and SMEFTsim

  → 1D constraints on cW operator!

Conferences and publications

talk @ **1st COMETA (COmprehensive Multiboson Experiment-Theory Action) General Meeting**
An Anomaly Detection strategy for new physics searches at the LHC [link]

talk @ **12th Beam Telescopes and Test Beams workshop** (BTTB 2024)
On-beam test for the LHC Phase-II CMS electromagnetic PbWO4 calorimeter [link]

talk @ **XIII International Conference on New Frontiers in Physics** (ICNFP 2024)
Upgrade of the CMS Electromagnetic Calorimeter for the High-Luminosity LHC [link]

talk @ **Upgrade Plenary** of **CMS Upgrade Week** (16-20 September 2024)
Barrel Calorimeters Upgrade status report [link]

proceeding: *A Variational AutoEncoder for Model Independent Searches of New Physics at LHC*, **Springer Lecture Notes in Computer Science (LNCS), volume 14365, 2024** - Image Analysis and Processing - ICIAP 2023 Workshops Proceedings, Part I [link]

proceeding: *Use of Anomaly Detection algorithms to unveil new physics in Vector Boson Scattering*, **EPJ Web of Conf. Volume 295, 2024** - 26th International Conference on Computing in High Energy and Nuclear Physics (CHEP 2023) [link]

Schools and courses

Schools:

- AIPHY: Artificial intelligence and modern physics: a two-way connection (end of the month)

Courses:

- Scientific computing with Python
- Physics at Colliders (starting next month)

BACKUP

EFT operators

$Q_{Hl}^{(1)}$	$= (H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_p\gamma^\mu l_p)$	$Q_{Hl}^{(3)}$	$= (H^\dagger i\overleftrightarrow{D}^i_\mu H)(\bar{l}_p\sigma^i\gamma^\mu l_p)$
$Q_{Hq}^{(1)}$	$= (H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}_p\gamma^\mu q_p)$	$Q_{Hq}^{(3)}$	$= (H^\dagger i\overleftrightarrow{D}^i_\mu H)(\bar{q}_p\sigma^i\gamma^\mu q_p)$
$Q_{qq}^{(1)}$	$= (\bar{q}_p\gamma_\mu q_p)(\bar{q}_r\gamma^\mu q_r)$	$Q_{qq}^{(1,1)}$	$= (\bar{q}_p\gamma_\mu q_r)(\bar{q}_r\gamma^\mu q_p)$
$Q_{qq}^{(3)}$	$= (\bar{q}_p\gamma_\mu\sigma^i q_p)(\bar{q}_r\gamma^\mu\sigma^i q_r)$	$Q_{qq}^{(3,1)}$	$= (\bar{q}_p\gamma_\mu\sigma^i q_r)(\bar{q}_r\gamma^\mu\sigma^i q_p)$
Q_{HD}	$= (H^\dagger D_\mu H)(H^\dagger D^\mu H)$	$Q_{H\Box}$	$= (H^\dagger H)\Box(H^\dagger H)$
Q_{HWB}	$= (H^\dagger\sigma^i H)W^i_{\mu\nu}B^{\mu\nu}$	Q_{HW}	$= (H^\dagger H)W^i_{\mu\nu}W^{i\mu\nu}$
Q_W	$= \varepsilon^{ijk}W^{i\nu}_\mu W^{j\rho}_\nu W^{k\mu}_\rho$	$Q_{ll}^{(1)}$	$= (\bar{l}_p\gamma_\mu l_r)(\bar{l}_r\gamma^\mu l_p)$

- H denotes the SU(2) Higgs doublet
- Wiμν and Bμν denote the gauge fields associate with SU(2) and U(1) symmetries respectively
- l,q denote the left-handed lepton and quark doublets
- u, d, e denote the right-handed quark and charged-lepton fields
- i, j, k denote the SU(2) indexes and sig_i the Pauli matrices

•Enter via modifications of the EW input quantities: $(Q_{Hl}^{(3)}, Q_{ll}^{(1)}, Q_{HD}, Q_{HWB})$

•Induce modifications via:

-Vff couplings $(Q_{Hl}^{(1)}, Q_{Hl}^{(3)}, Q_{Hq}^{(1)}, Q_{Hq}^{(3)})$

-Gauge couplings (Q_W)

-HVV couplings $(Q_{HD}, Q_{HW}, Q_{HWB}, Q_{H\Box})$

-Four-quark contact terms $(Q_{qq}^{(1)}, Q_{qq}^{(3)}, Q_{qq}^{(1,1)}, Q_{qq}^{(3,1)})$

LHC High Luminosity Upgrade (Phase 2)

Phase 2 will deliver to the experiments a **much larger dataset** compared to Phase 1.

To achieve this, **unprecedented instantaneous luminosities** will be provided:
(currently $\mathscr{L}$ = **2** x 10^{34} cm^{-2} s^{-1} → $\mathscr{L}$ = **7.5** x 10^{34} cm^{-2} s^{-1})

This will pose **several challenges for the CMS subdetectors**:

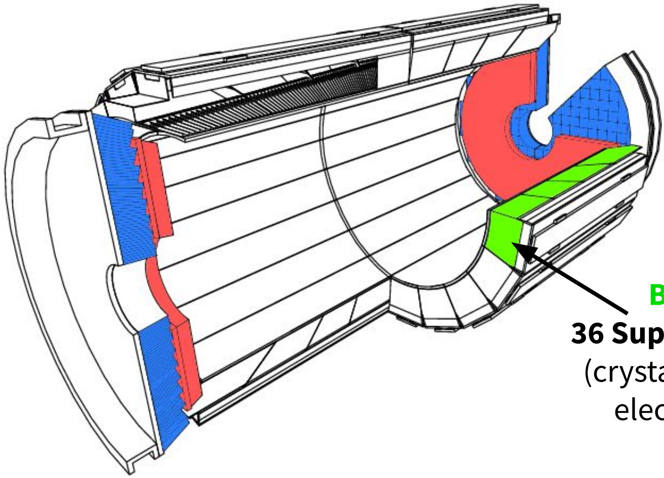
- More collisions per Bunch Crossing → **better discrimination of spurious events**
  (Pile Up 30-60 → 140-200)
- More radiation damage → **radiation tolerance**
- More stringent requirements
  - longer latencies (4.2 μs → 12 μs)
  - higher trigger rates (100 kHz → 750 kHz)

} **longer pipelines and faster readout**

The CMS Electromagnetic Calorimeter

key role in the **detection of electrons and photons** for the CMS experiment at LHC

- homogeneous, fine grained, high-resolution calorimeter
- $PbWO_4$ scintillating crystals
  - avalanche photodiodes (APD) in barrel
  - vacuum phototriodes in endcaps



Phase 2 Upgrade:

- endcaps and forward calorimeters will be replaced by HGCAL
- **barrel:**
  - **full refurbishment of electronics**
  - crystals + APDs will not change, but will be **operated at lower temperature**

Physics goals for ECAL in Phase 2

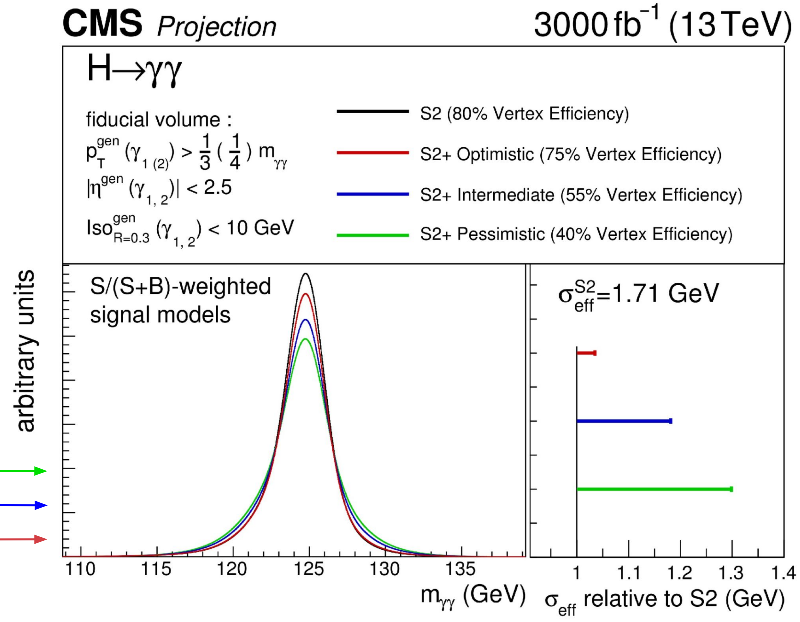
1. the goal is to **maintain the performance of Phase 1** despite the harsher datataking conditions: **target energy resolution same as Phase 1**

2. we aim at **precise time resolution** off-line **(σ_t = 30 ps)** for ***e*** **+/-** and **γ** with **E > 50 GeV** (unprecedented!)

   motivation: improvement of **H→ γγ vertex identification** at high pile-up

+ benefit from CMS **MTD** (dedicated timing detector) [CMS-TDR-020]

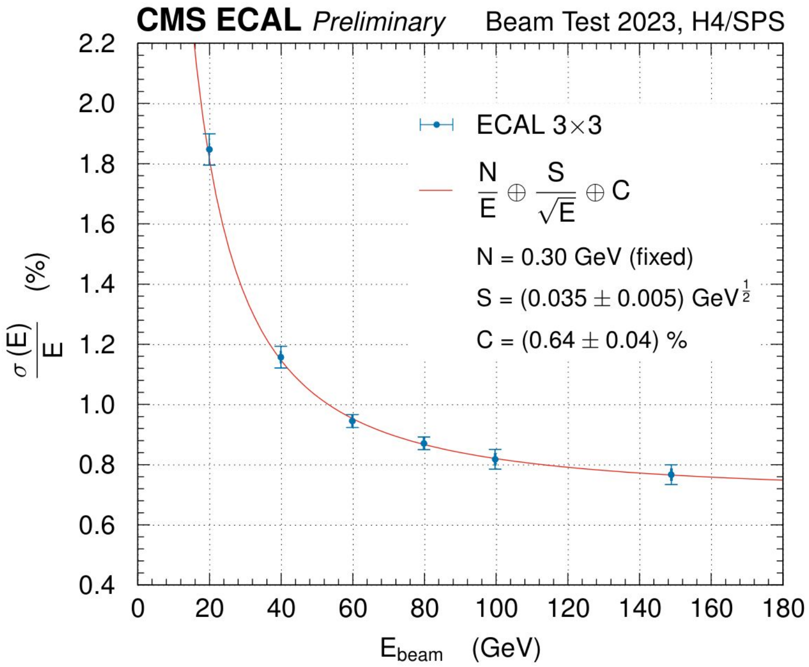
no ECAL timing
ECAL timing σ_t = 30 ps
ECAL + MTD

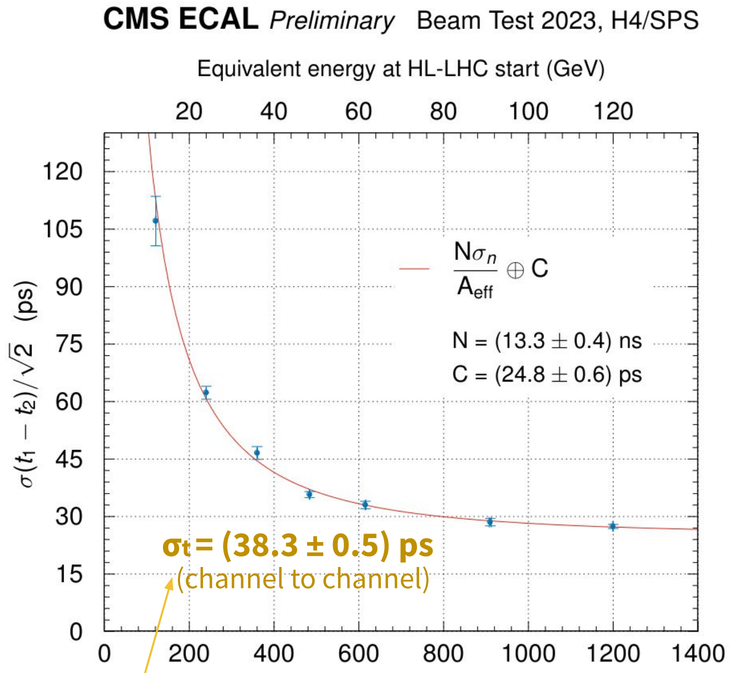


Test Beam 2023 performances

H4 test beam line at the North Area of the **CERN SPS:**

e^+/e^- (20 - 300 GeV, $\Delta p/p < 0.5\%$).





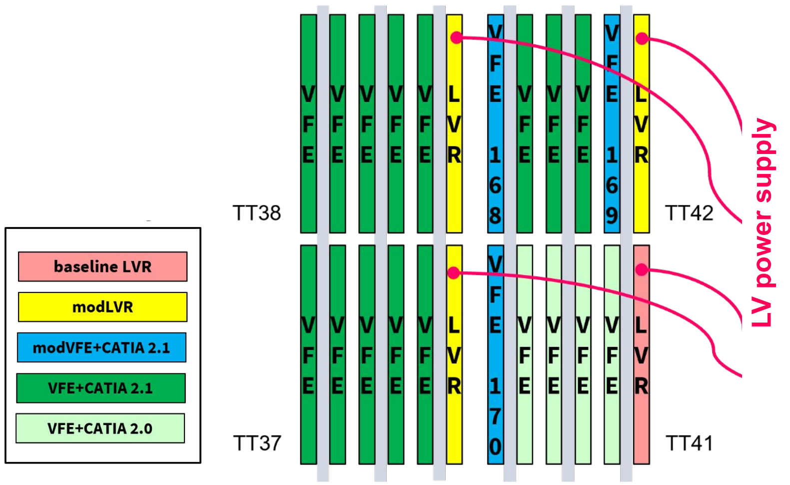
σ_t = (38.3 ± 0.5) ps
(channel to channel)

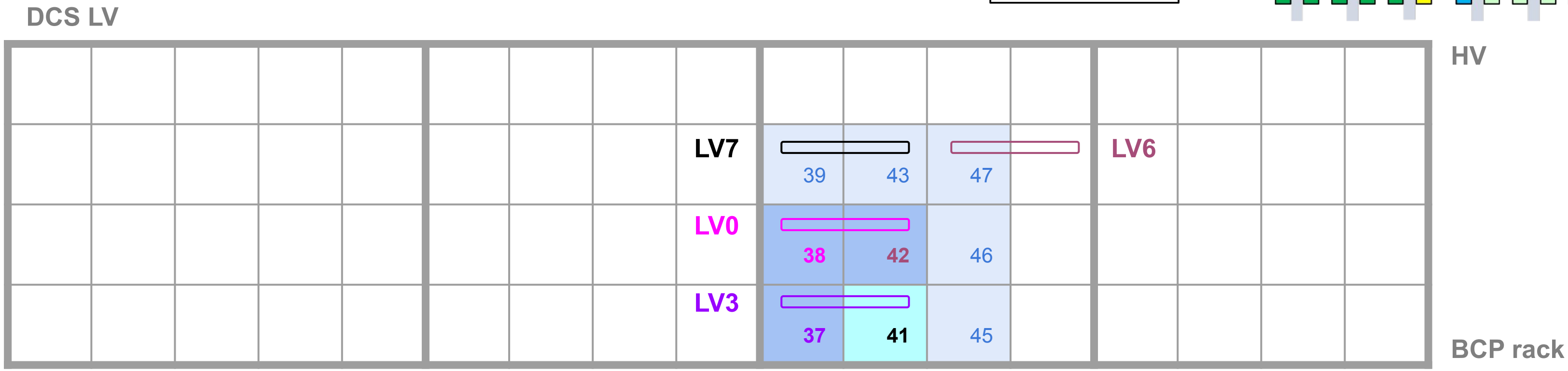
σ_n = 100 MeV
A_{eff} = 50 GeV

$$\frac{A_{eff}}{\sigma_n} = \sqrt{\frac{2}{\left(\frac{\sigma_1}{A_1}\right)^2 + \left(\frac{\sigma_2}{A_2}\right)^2}}$$

LVR tests - setup SM 36

- 9 towers powered on, 4 measured (FE 3.3)
  - 3 towers targeted for the LVR switch
  - 1 tower monitored
  - each tower has its own supply channel





LVR tests - measurements

- ✓ **Current consumption pre-calibration** (at power-on) **and post calibration**
  - ➢ taken from the Wiener power supply
- ✓ **Temperature** (every 15 minutes, 24h)
  - ➢ CATIA, 2x VFE, 2x LVR → all through lpGBT ADCs
- ✓ **Pedestals** (every 15 minutes, 24h)
- ✓ **Uplink stability** (every 15 minutes, 24h)

↻ **4 input voltage points**: 12 V, 11 V (HV on and off), 10 V, 9 V

↻ 2 datasets: **standard LVR**, **modified LVR**