Commissioning of the Muon Forward Tracker and preparation of data analysis (LHC, CERN)

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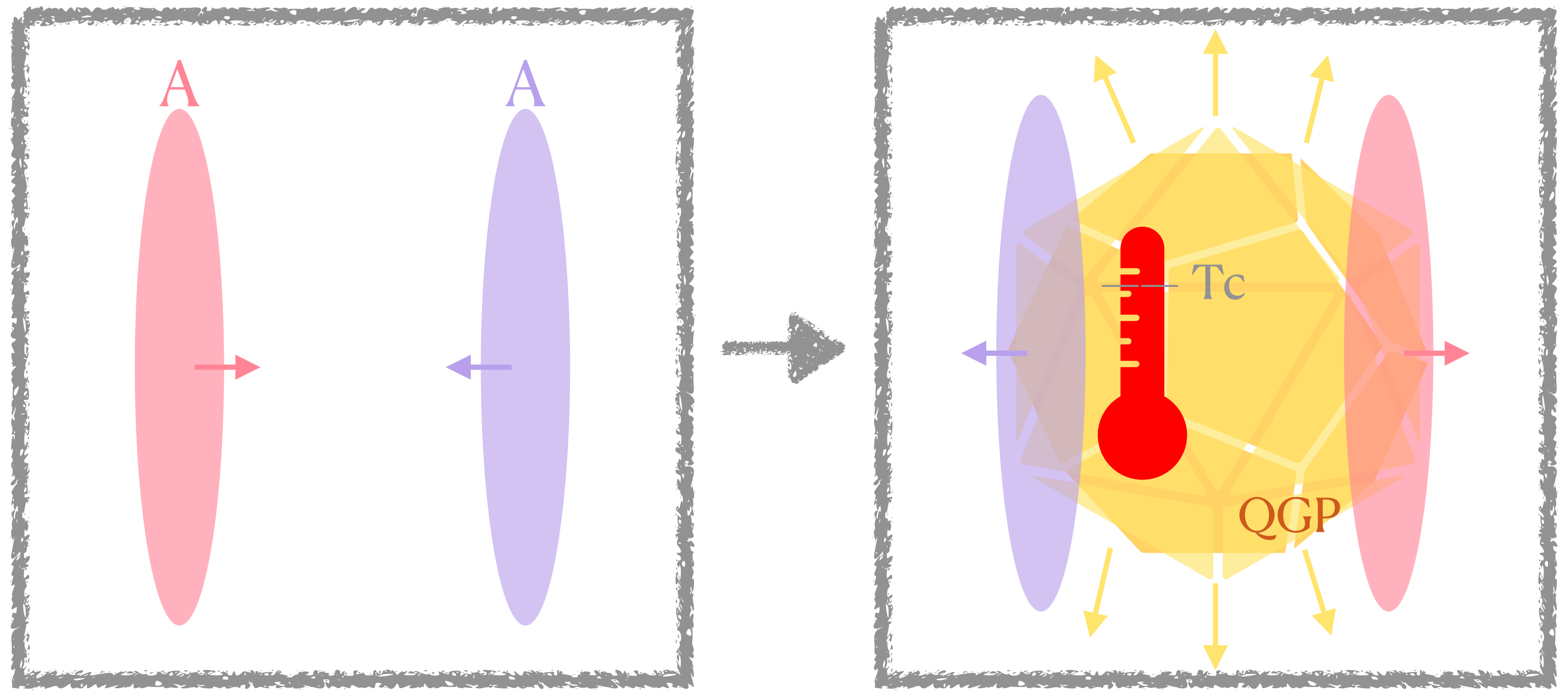
GDR QCD

10/03/2021

Heavy Flavor and Quarkonium Physics

- Heavy **quarks** serve as QGP probes.
  Because of their large masses, they are produced very early in the collision and experience the full system evolution.



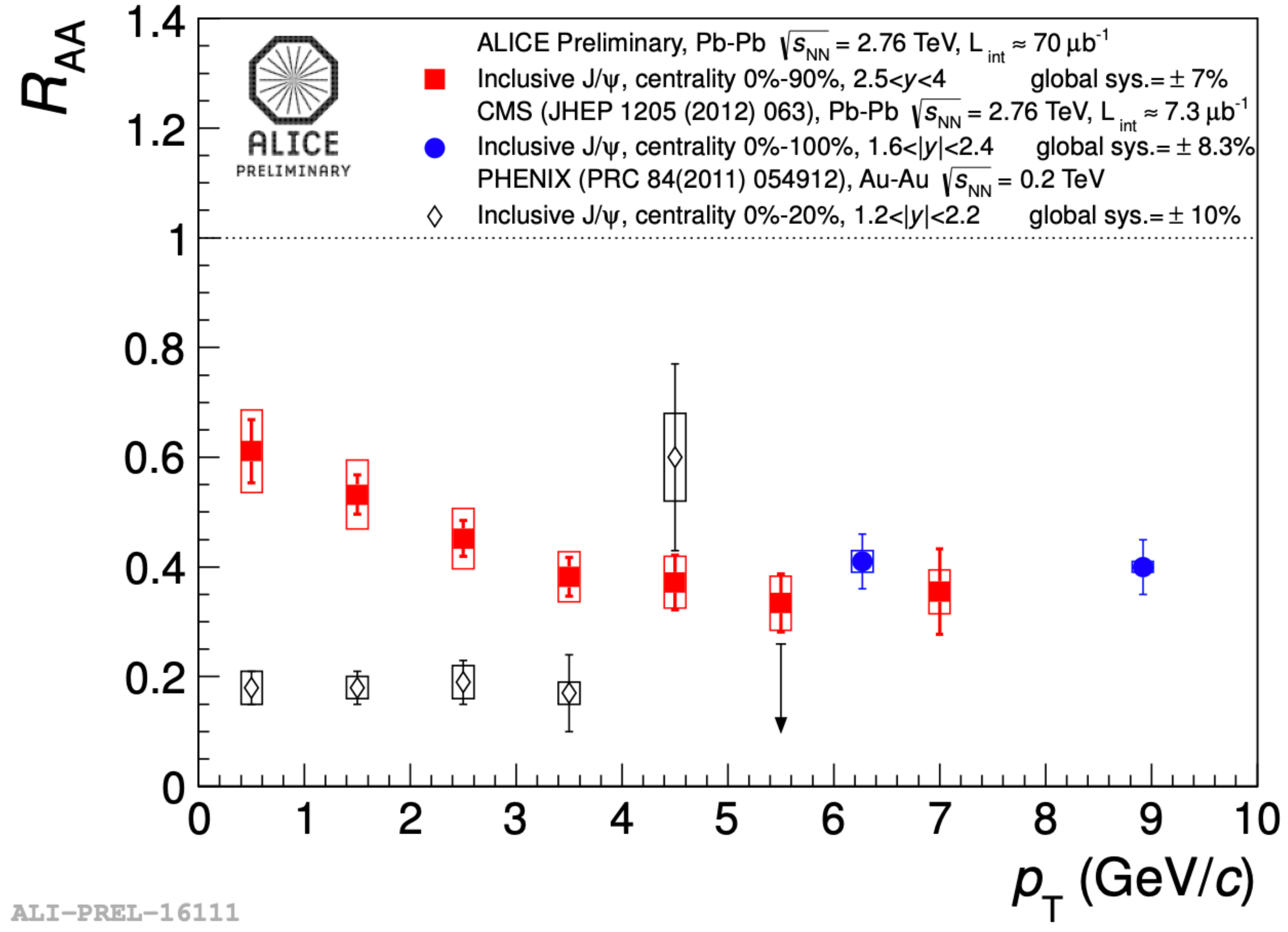
- Observables:
  The nuclear modification factor:

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \cdot \frac{dN_{AA}/dp_t}{dN_{pp}/dp_t}$$

- $R_{AA} < 1 \rightarrow$ **Suppression**
- $R_{AA} > 1 \rightarrow$ **Enhancement**

The elliptic flow coefficient (thermalization with the QGP):

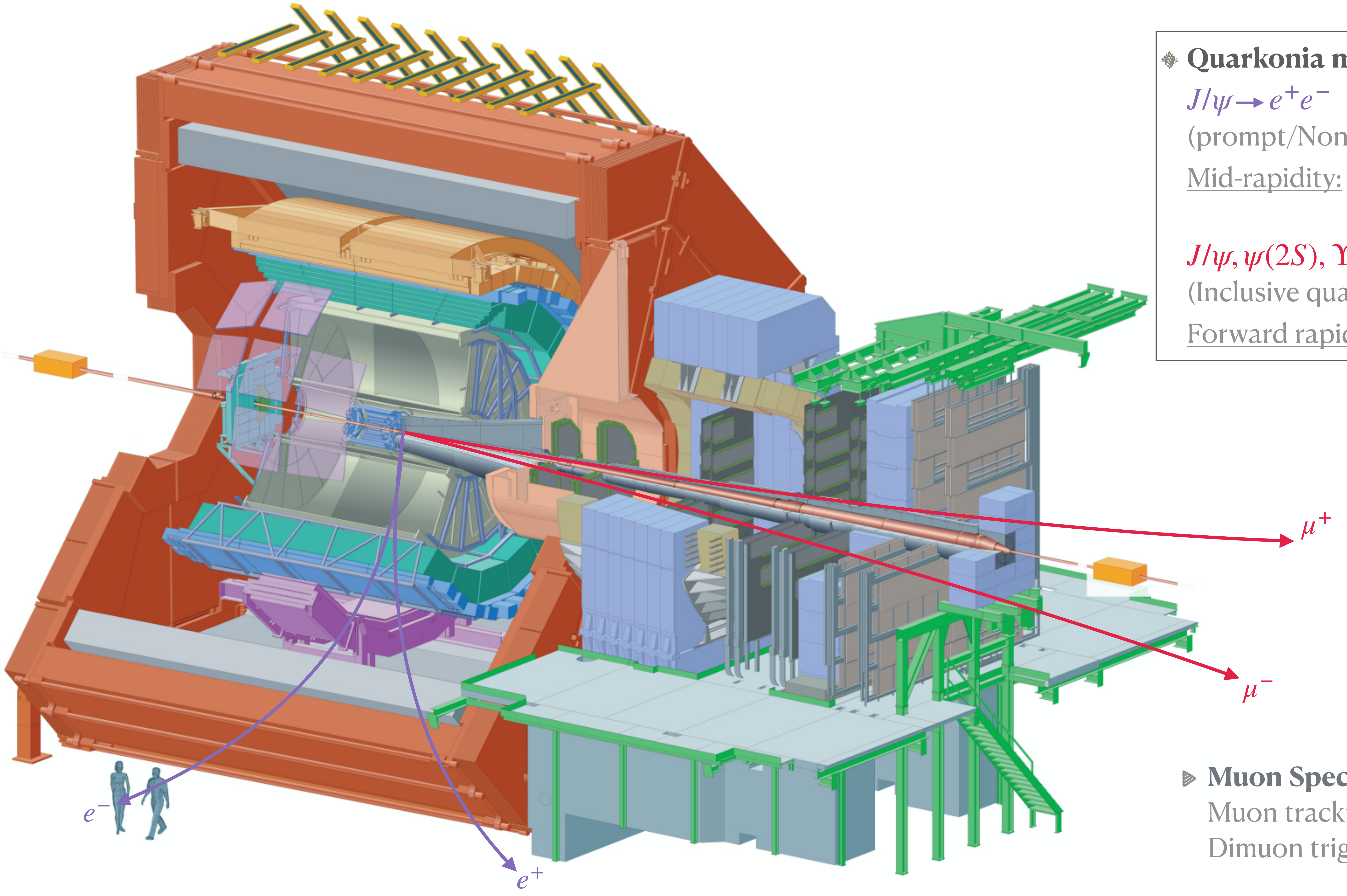
$v_2 = < cos(2(\varphi - \Psi_{RP})) >$



- High-precision + High-statistics measurements needed.

- **Time Projection Chamber:**
  Particle tracking
  Particle Identification

- **Inner Tracking System:**
  Particle tracking
  Vertex reconstruction



- **Quarkonia measurements:**
  $J/\psi \rightarrow e^+e^-$
  (prompt/Non-prompt separation)
  Mid-rapidity: $|y_{ee}| < 0.9$

  $J/\psi, \psi(2S), \Upsilon(nS) \rightarrow \mu^+\mu^-$
  (Inclusive quarkonium states)
  Forward rapidity: $2.5 < y_{\mu\mu} < 4$

- **Muon Spectrometer:**
  Muon tracking
  Dimuon trigger

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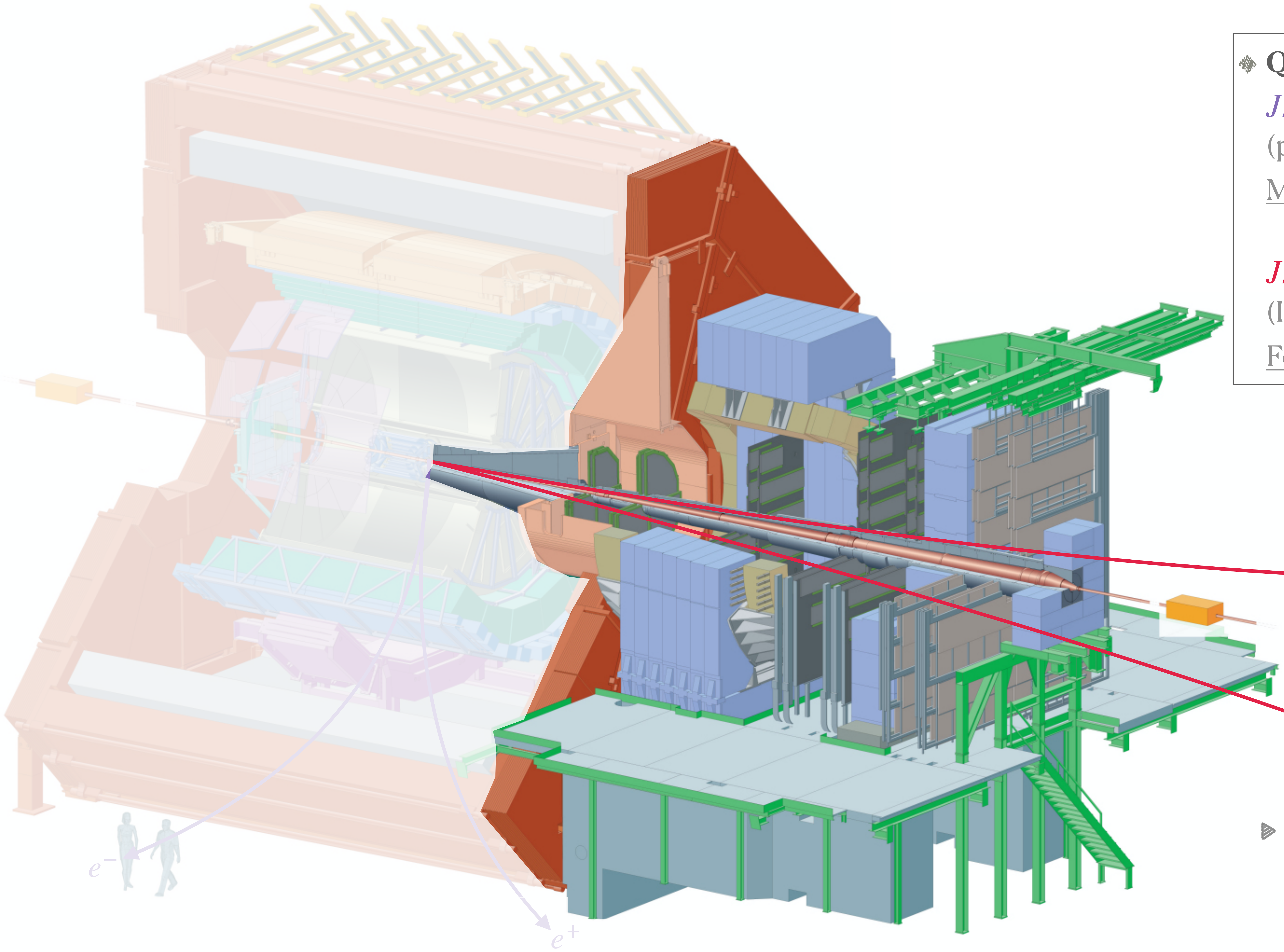

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- **Muon Spectrometer:**
  Muon tracking
  Dimuon trigger

Long Shutdown

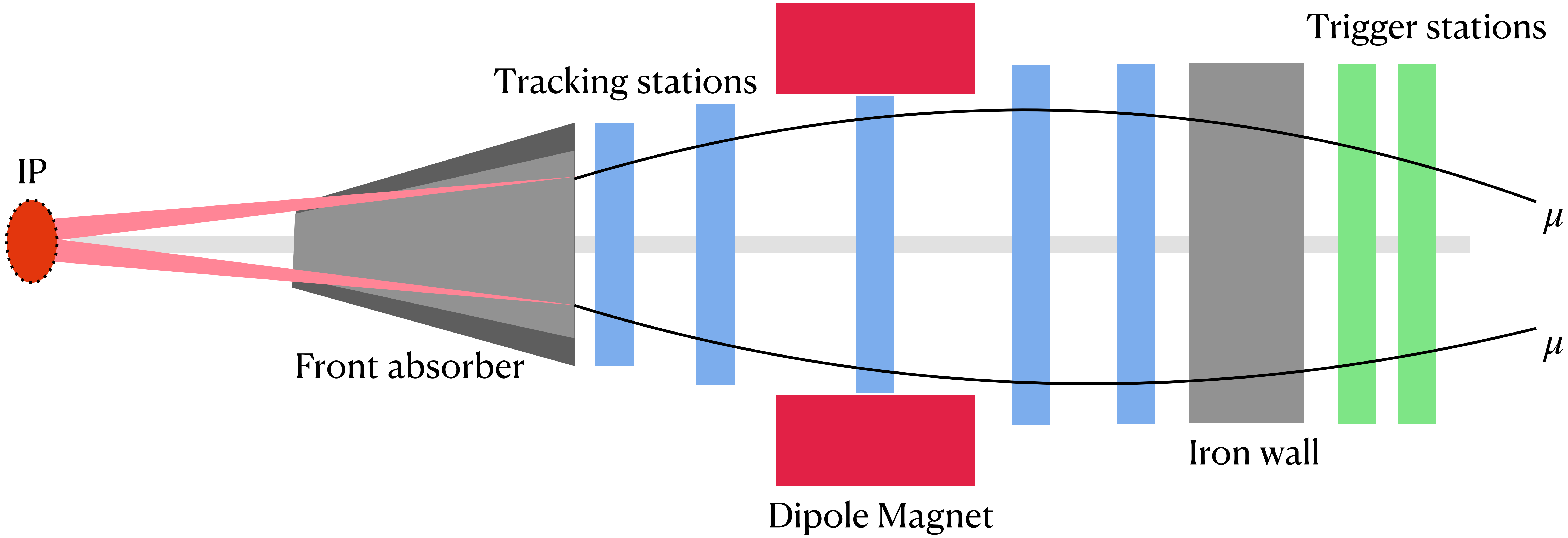
The Muon Spectrometer:

Detects muons in the pseudo-rapidity region $-4 < \eta < -2.5$ and full azimuthal angle.

- **Heavy Flavors:**
  Measuring the **energy loss** of charm and beauty quarks → probing QCD medium.
  Measuring total **beauty production** cross-section → reference for Υ suppression.

- **Charmonia:**
  Precise evaluation of $c\bar{c}$ **recombination** contribution to the production of charmonium at LHC energies.

- **Low mass vector mesons:**
  Modification of **spectral functions** of vector mesons in the medium, possibly linked to the chiral symmetry restoration.
  Dilepton thermal radiation.



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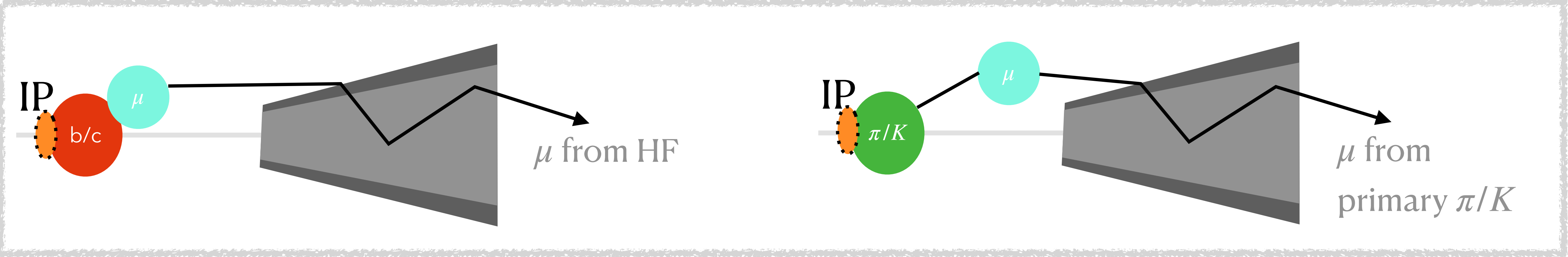

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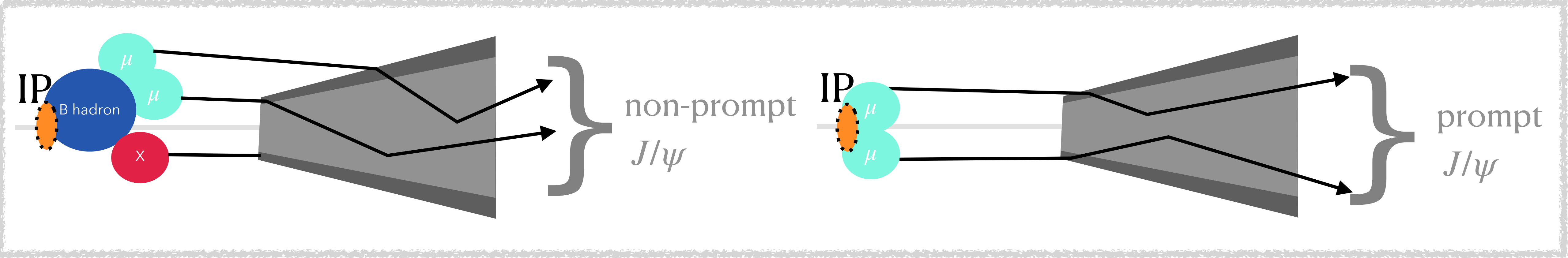

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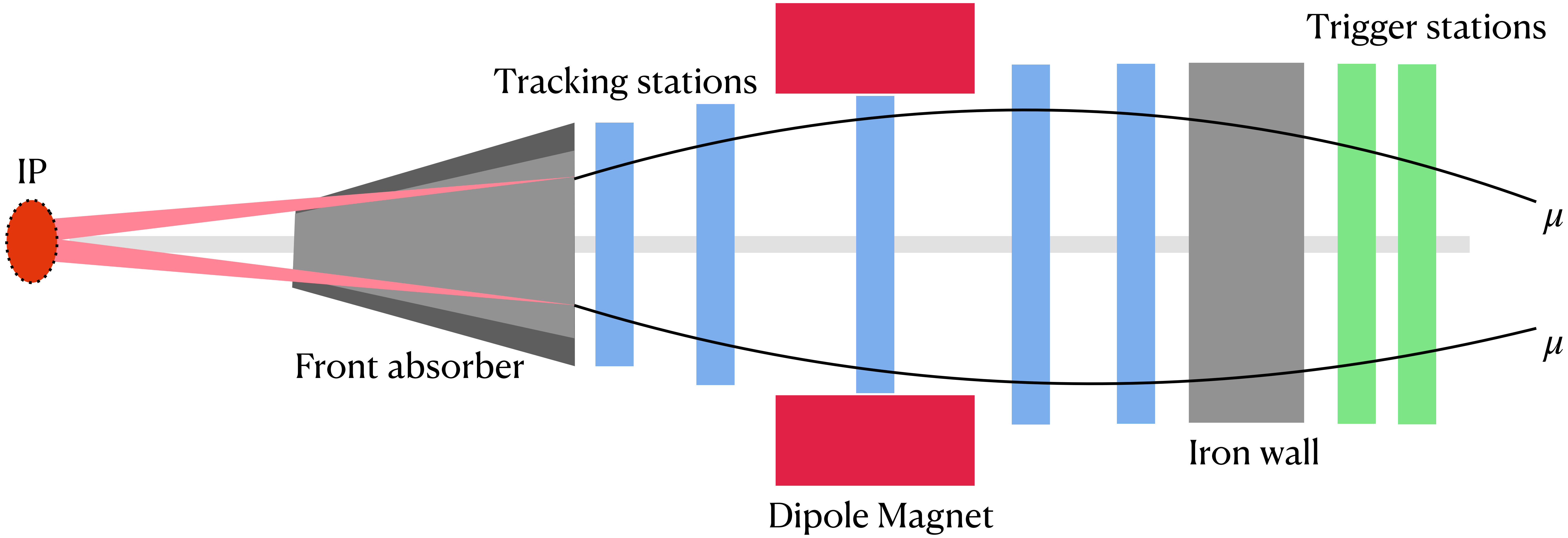
Design limitations:

High background coming from π/K decays.
Determination of muon production vertex is impossible.
Limited mass resolution for the resonances.



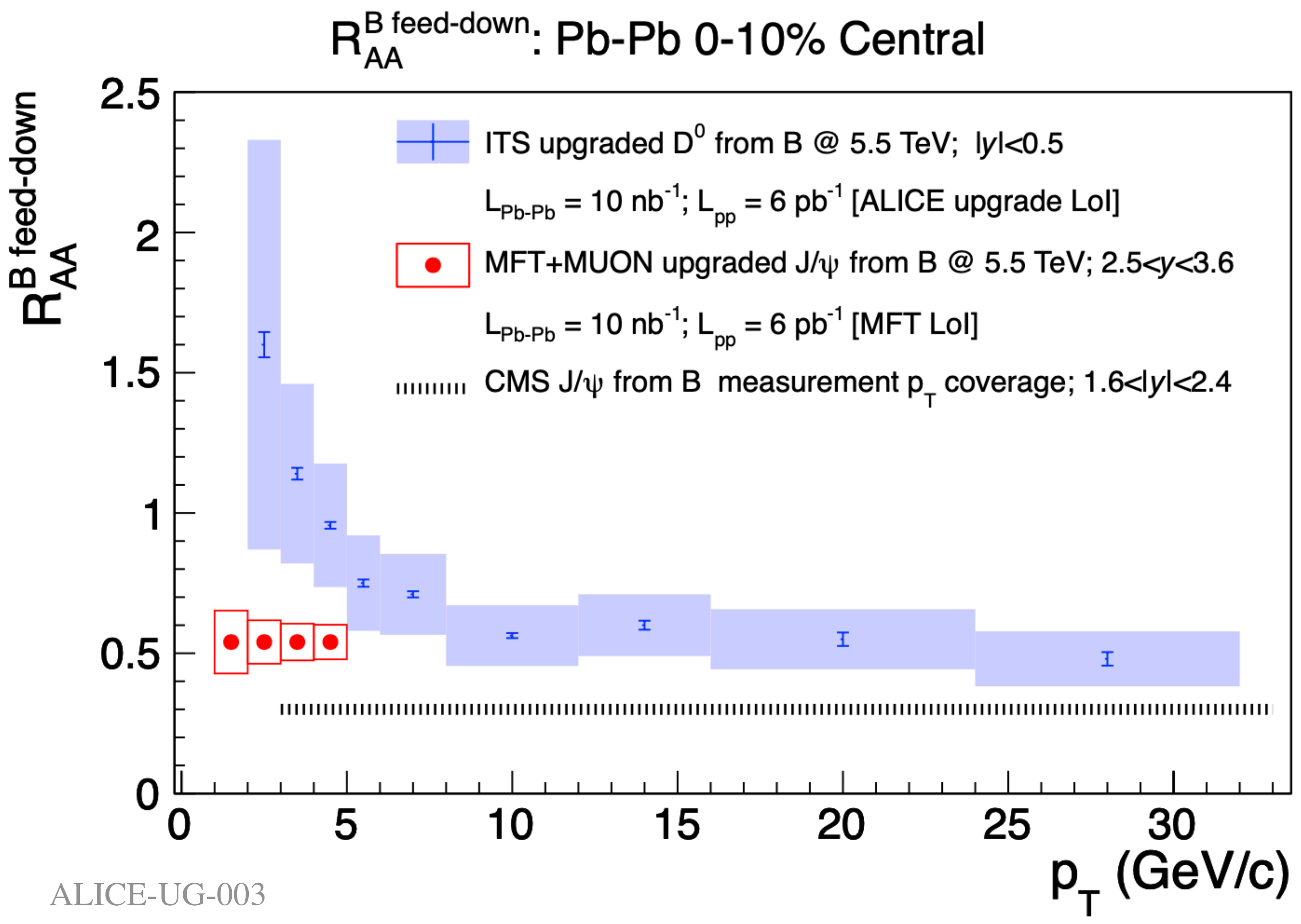
The Muon Forward Tracker:

Precise determination of production vertex.

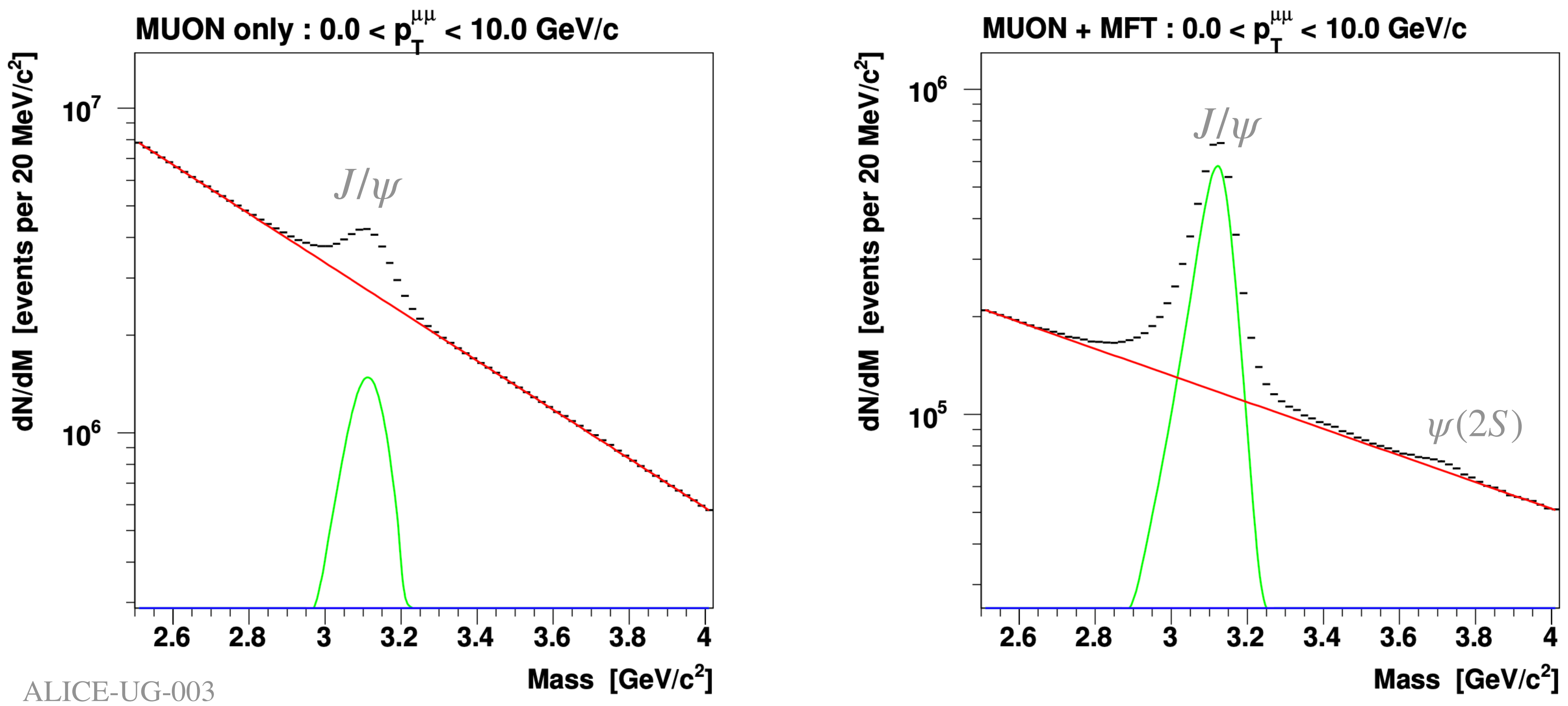
- **Heavy Flavors:**
  Less background expected → **low p_T awaited.**
  Separation between charm and beauty quarks.

- **Charmonia:**
  Improvement of the S/B → **extraction of the ψ(2S) signal.**
  Access to the **charmonia non prompt fraction.**

- **Low mass dimuons:**
  Better dimuon opening angle resolution → **better mass resolution.**



ALICE-UG-003



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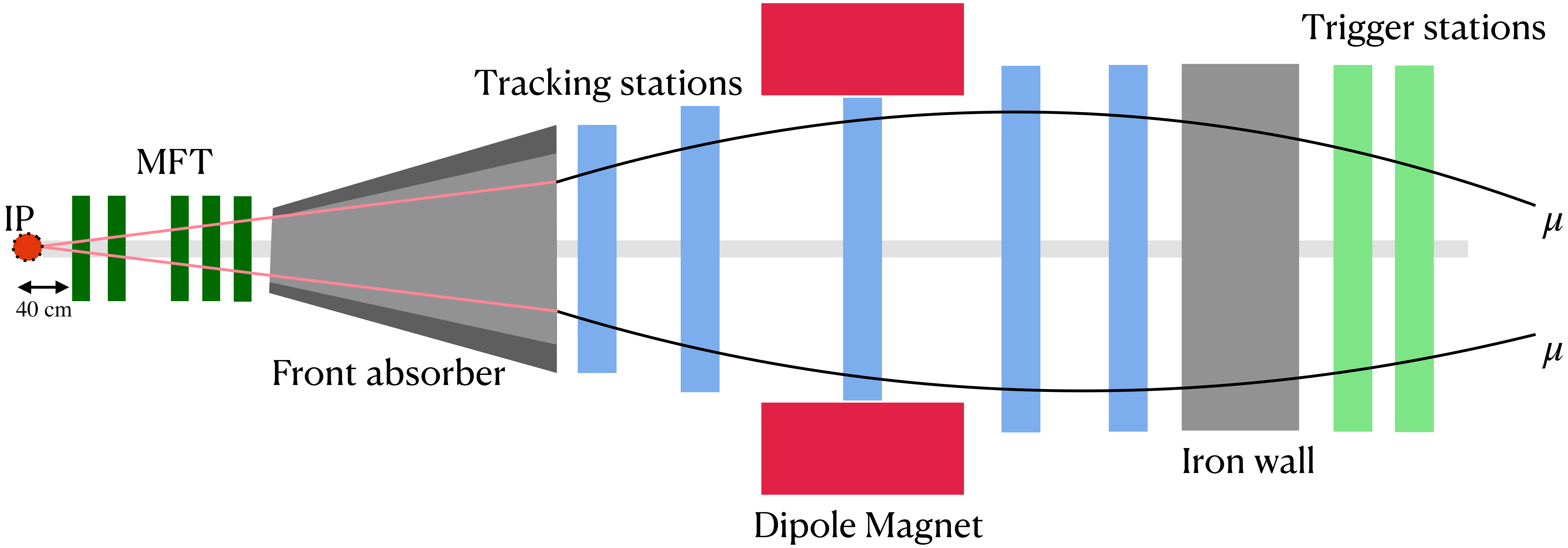
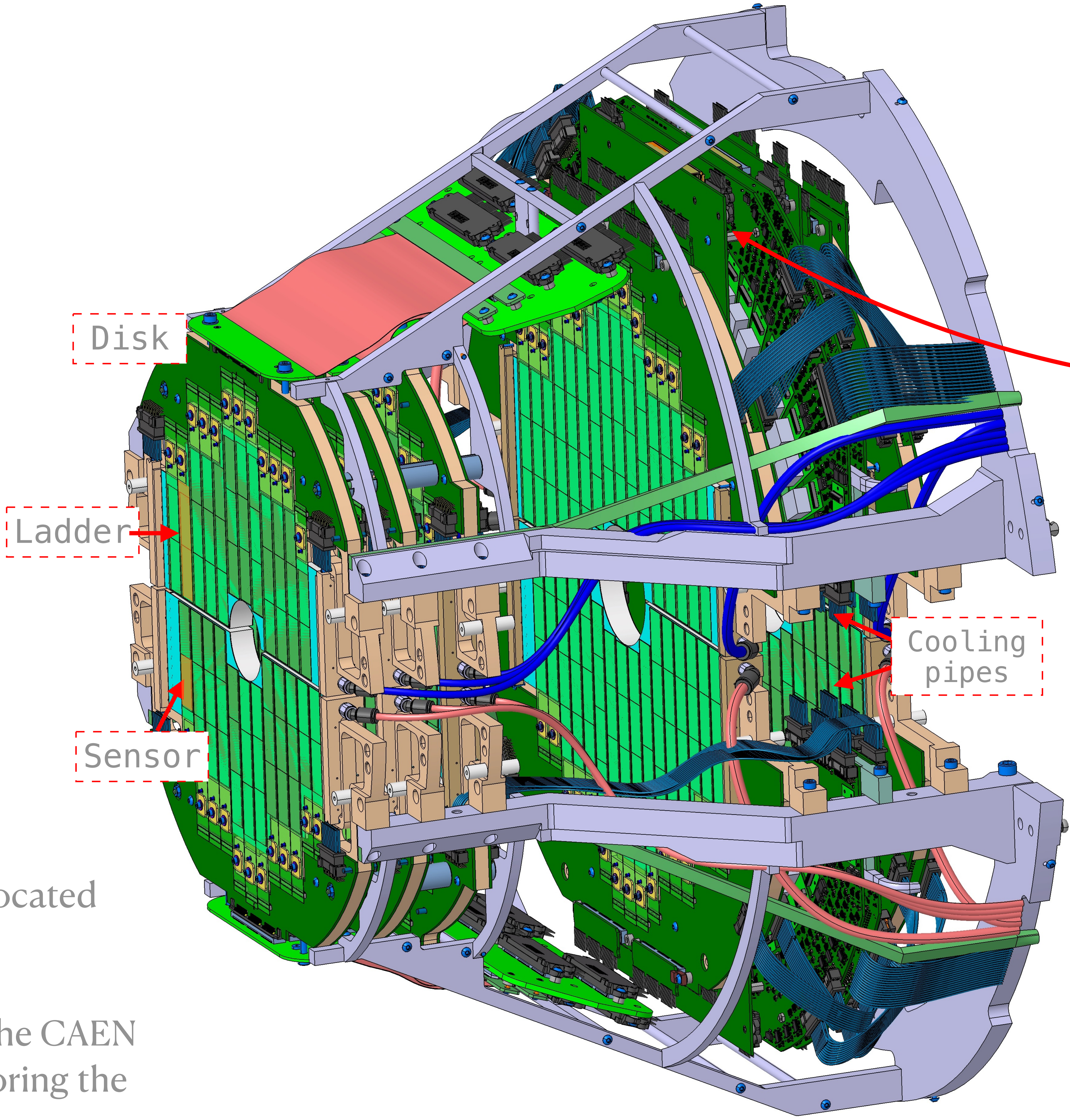
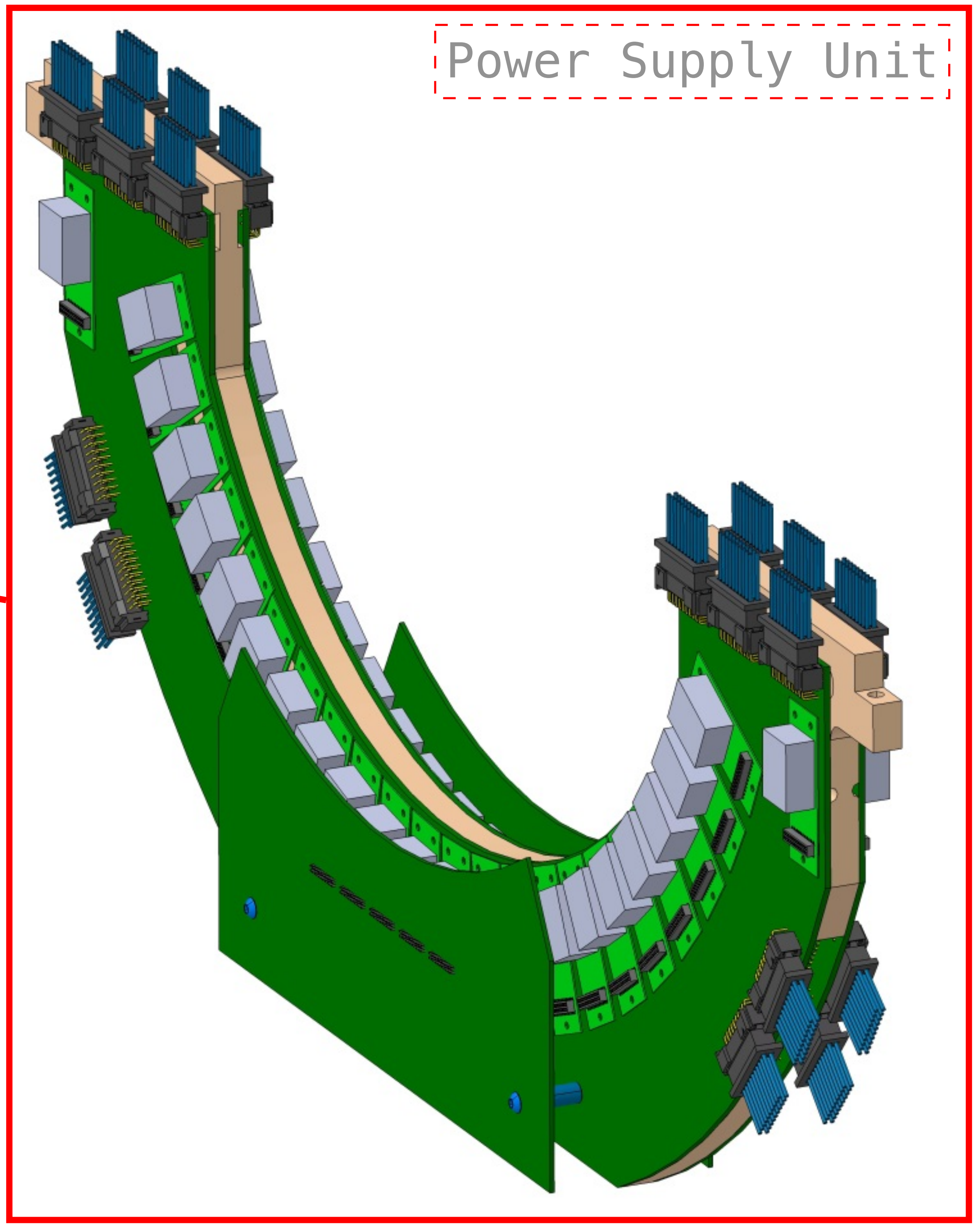


Muon Forward Tracker

- **936 silicon pixel sensors in 280 ladders.**
- **10 double-sided half disks.**
- **Nominal acceptance:** $-3.6 < \eta < -2.5$ **and full azimuthal angle.**
- **Water cooling** at 18°C.

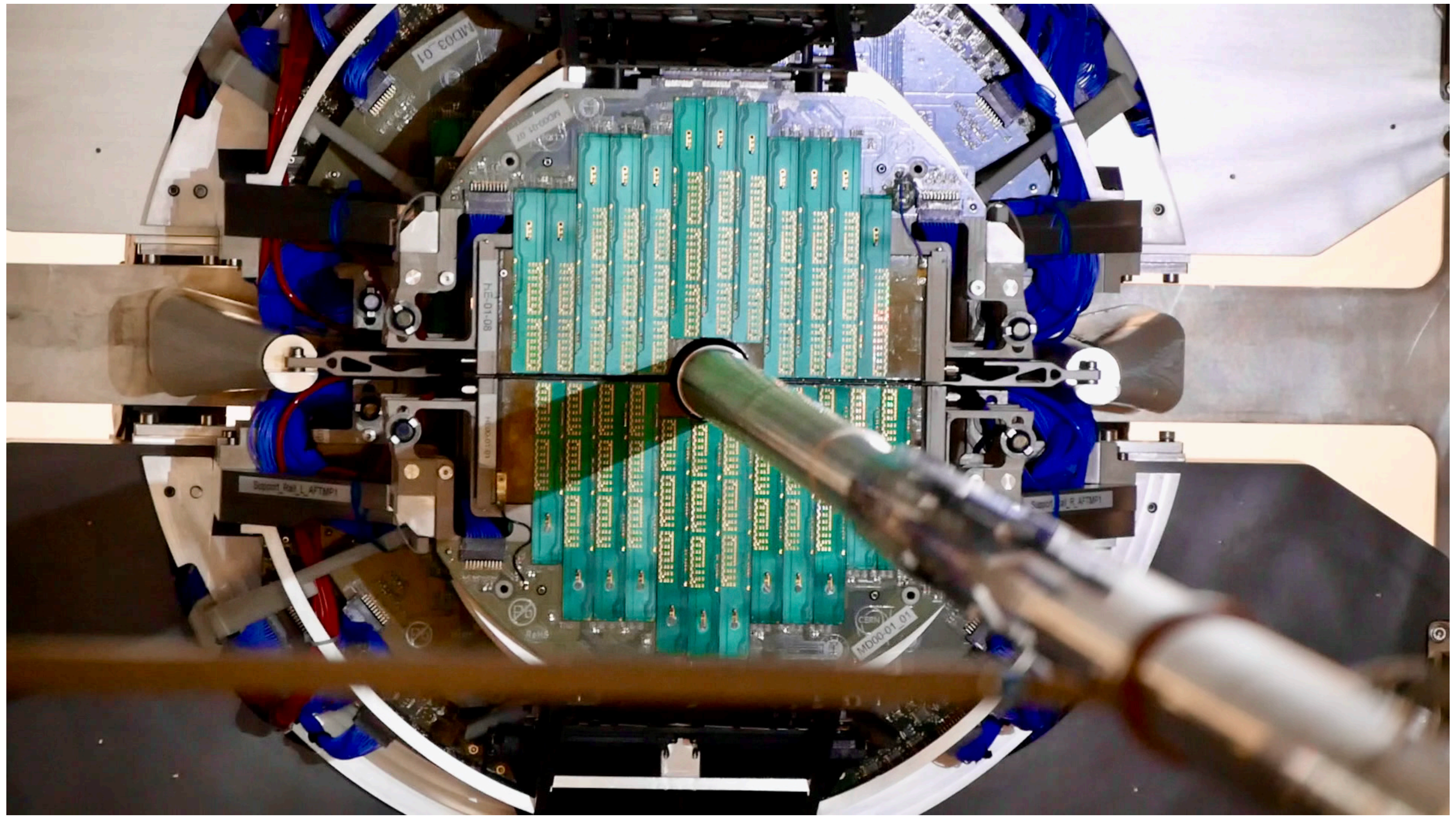




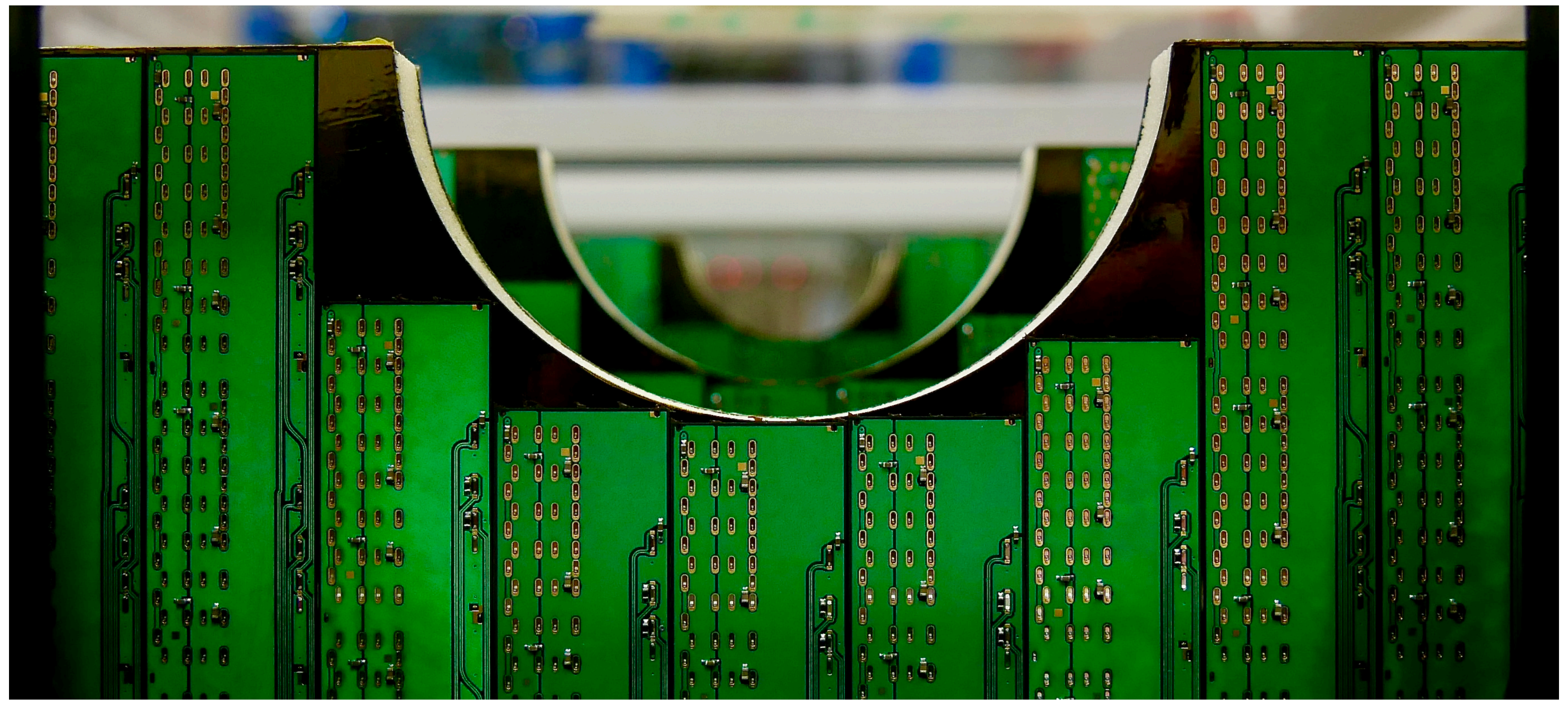
- The power supply (CAEN LV modules) is located outside the ALICE solenoid.
- **The Power Supply Unit** is connected to the CAEN LV, is responsible for powering and monitoring the detector.

Muon Forward Tracker

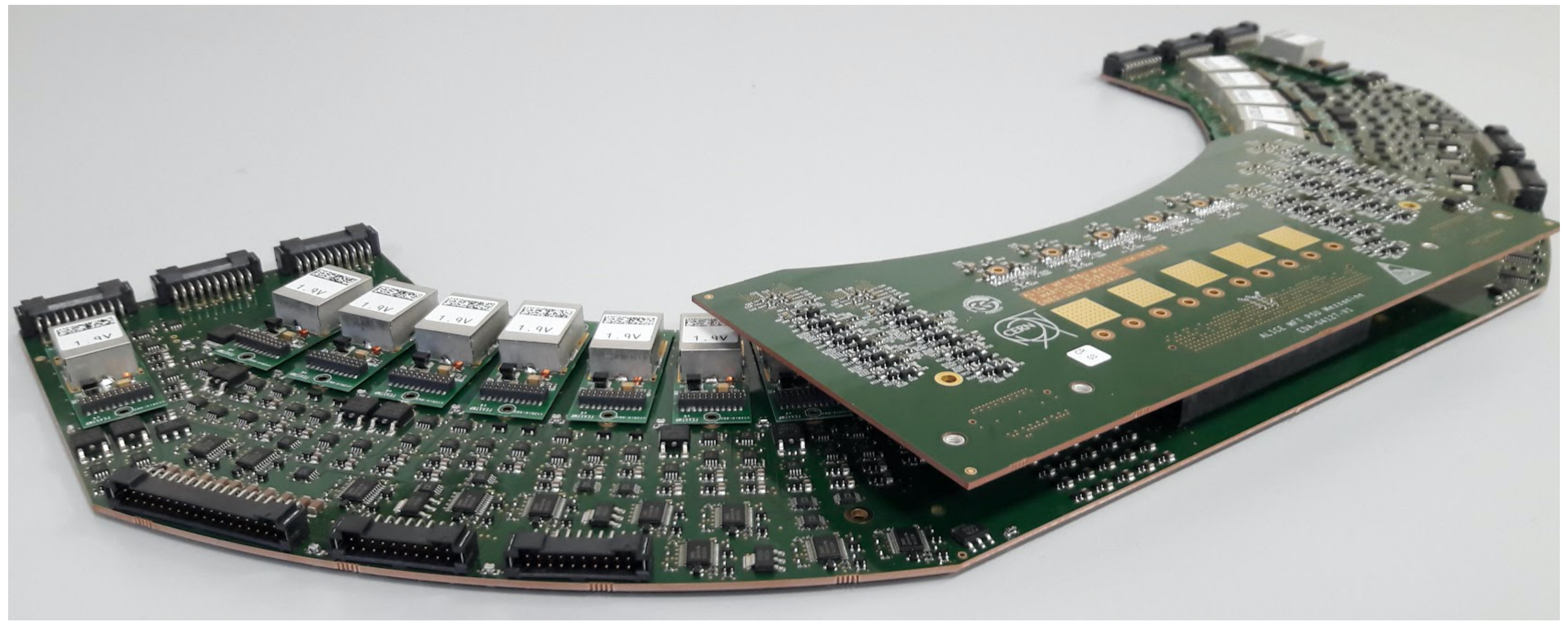
- The **MFT** detector successfully finished the surface commissioning phase in mid November .
- The detector was integrated in ALICE in December: **One of the first detectors installed in cavern.**
- In January, commissioning phase restarted in cavern. All connections were tested, and the whole detector was turned on for state verification: **Everything is functioning properly,** no problem due to transportation or different environments was observed.
- MFT pre-commissioning state is now back up and daily tests ongoing in cavern to integrate DCS FSM and prepare for **ALICE global commissioning in July.**



The MFT detector in its final position around the beam pipe inside the ALICE experiment



Rear view of half-disks of the MFT



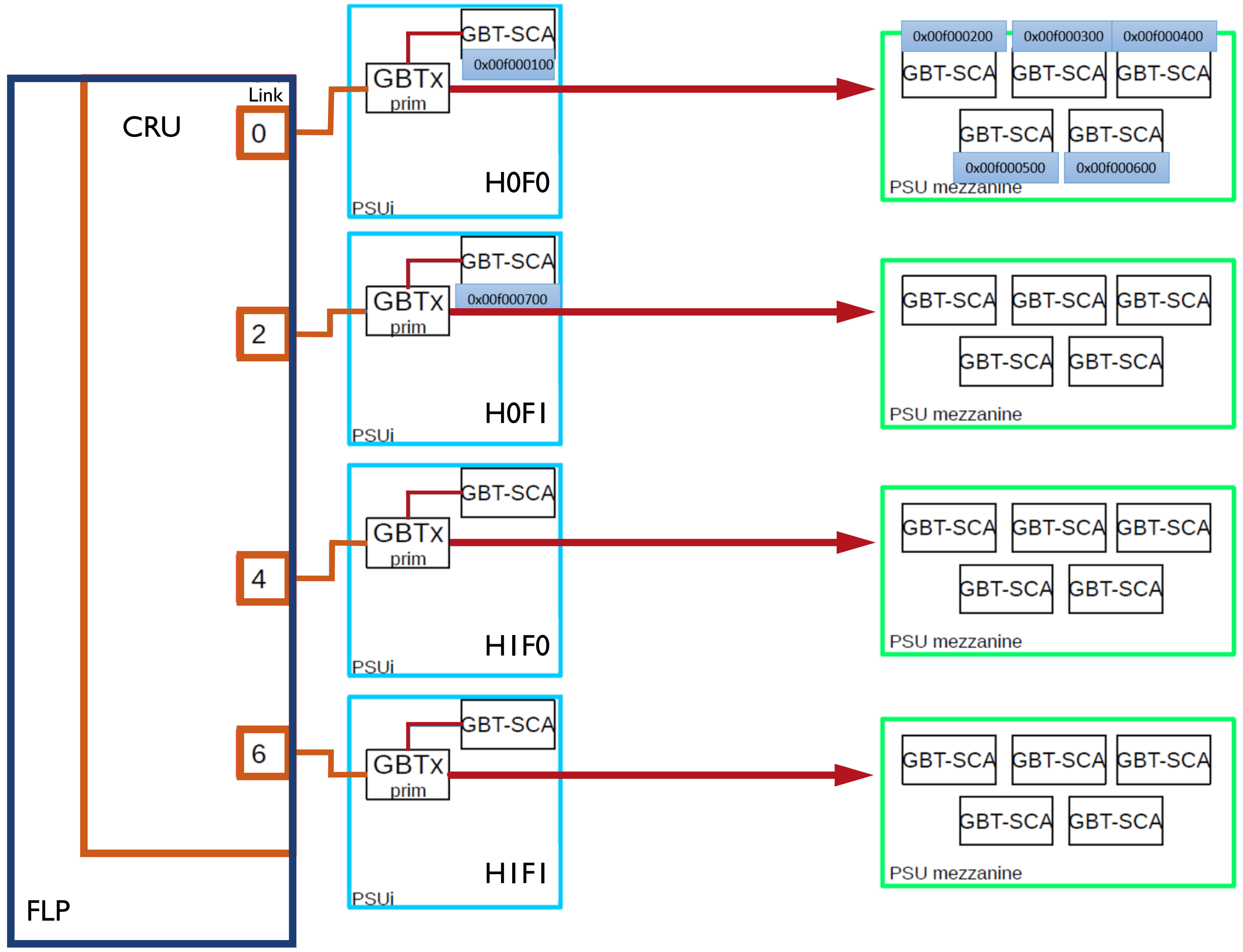
The MFT Power Supply Unit

 Rita Sadek | 10/03/2021

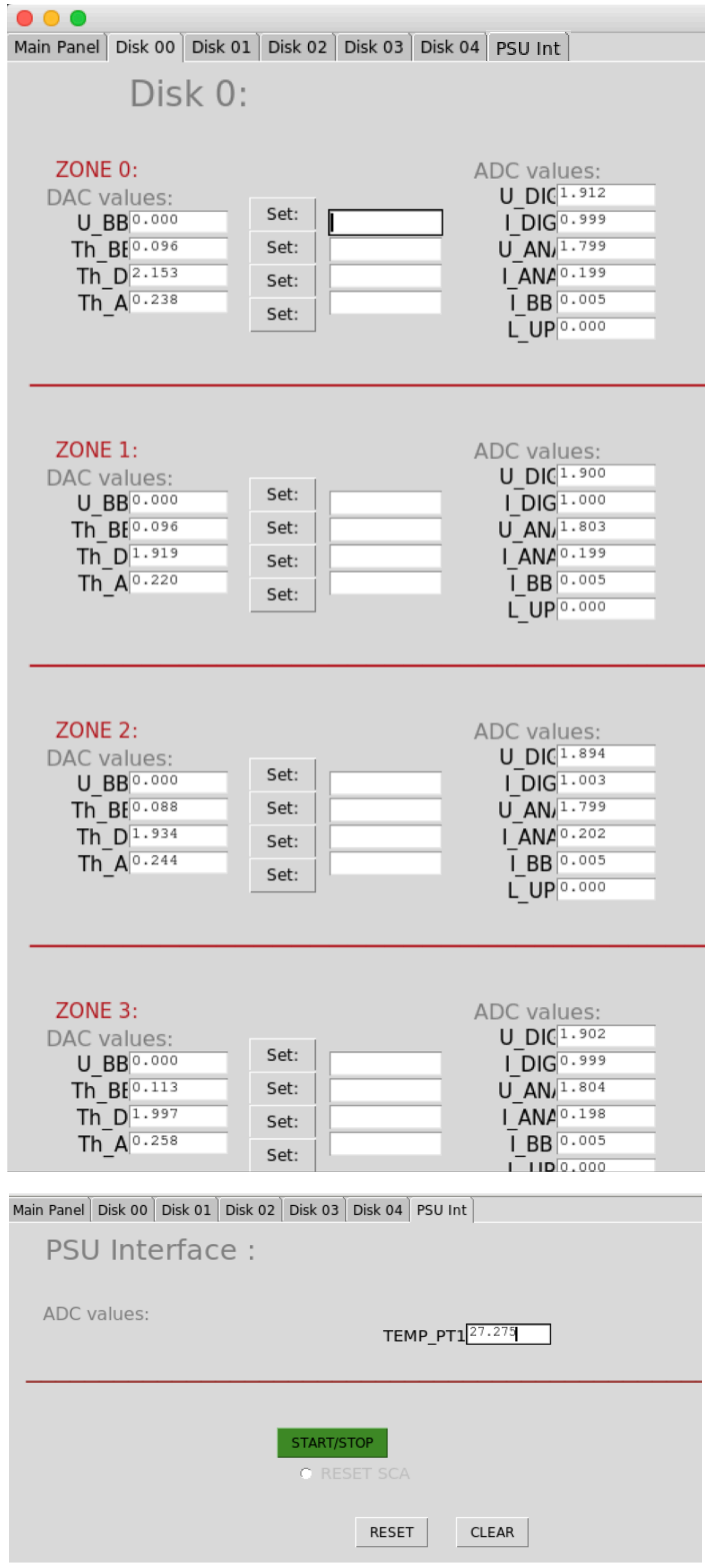
The commissioning software

- **Developed the commissioning software for detector control:** Approved and used by the MFT collaboration during all the commissioning period.

✓ Enable/Disable DC-DC control
✓ Set BackBias voltage
✓ Set threshold values (Analog, Digital and BackBias)
✓ Live monitoring of currents, voltages, temperatures, humidity
✓ Reset zones in Latch-Up state

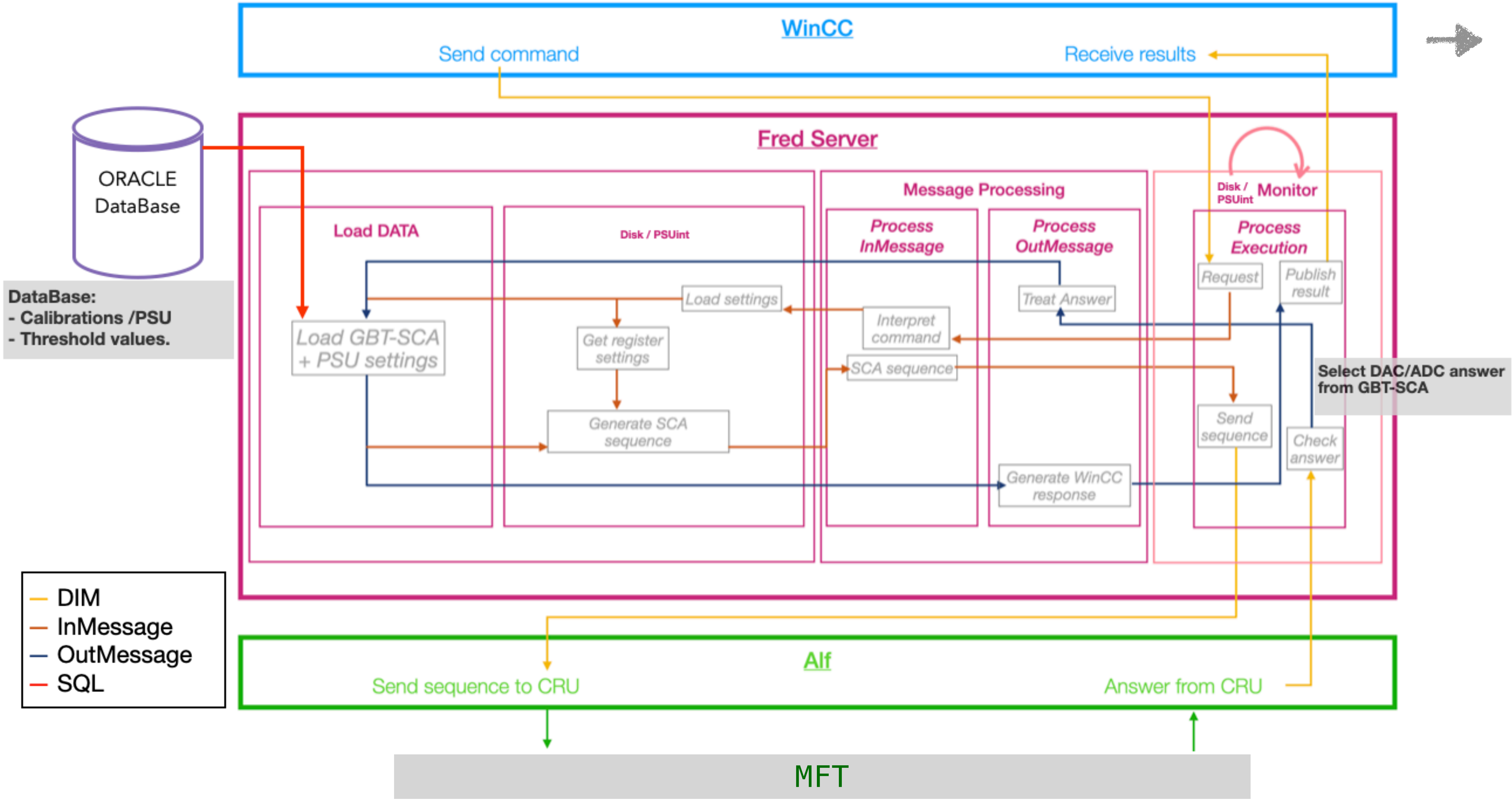


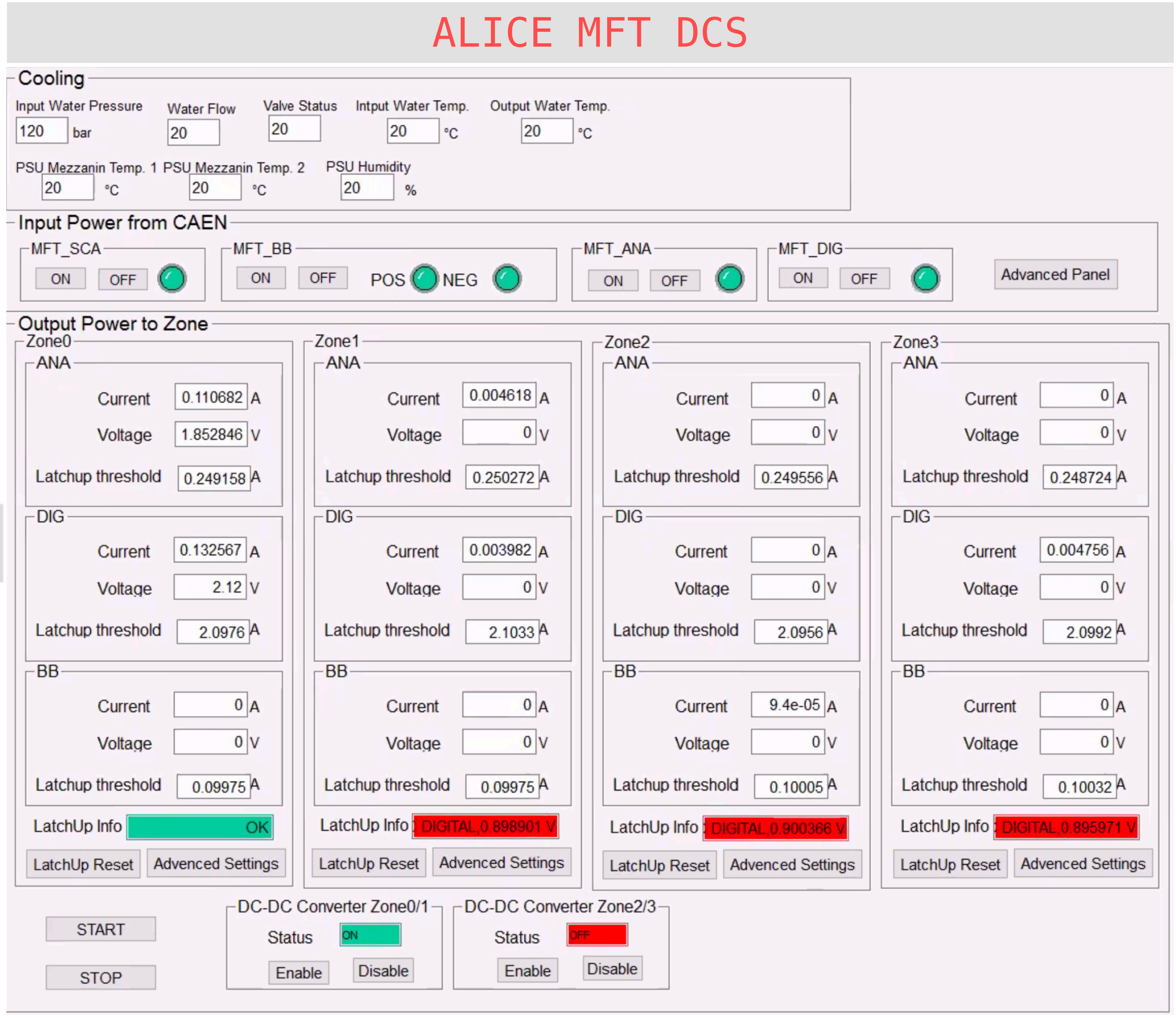
ALICE MFT commissioning panels



Detector Control System for RUN3

- **Developed PSU DCS for RUN3:**
  Integrates ALFRED environment.
  Uses CERN ORACLE database to store all calibration values.
  DataPoints created and winCC scripts developed to link this software with friendly user panels for RUN3.
- **On going tests at point2.**

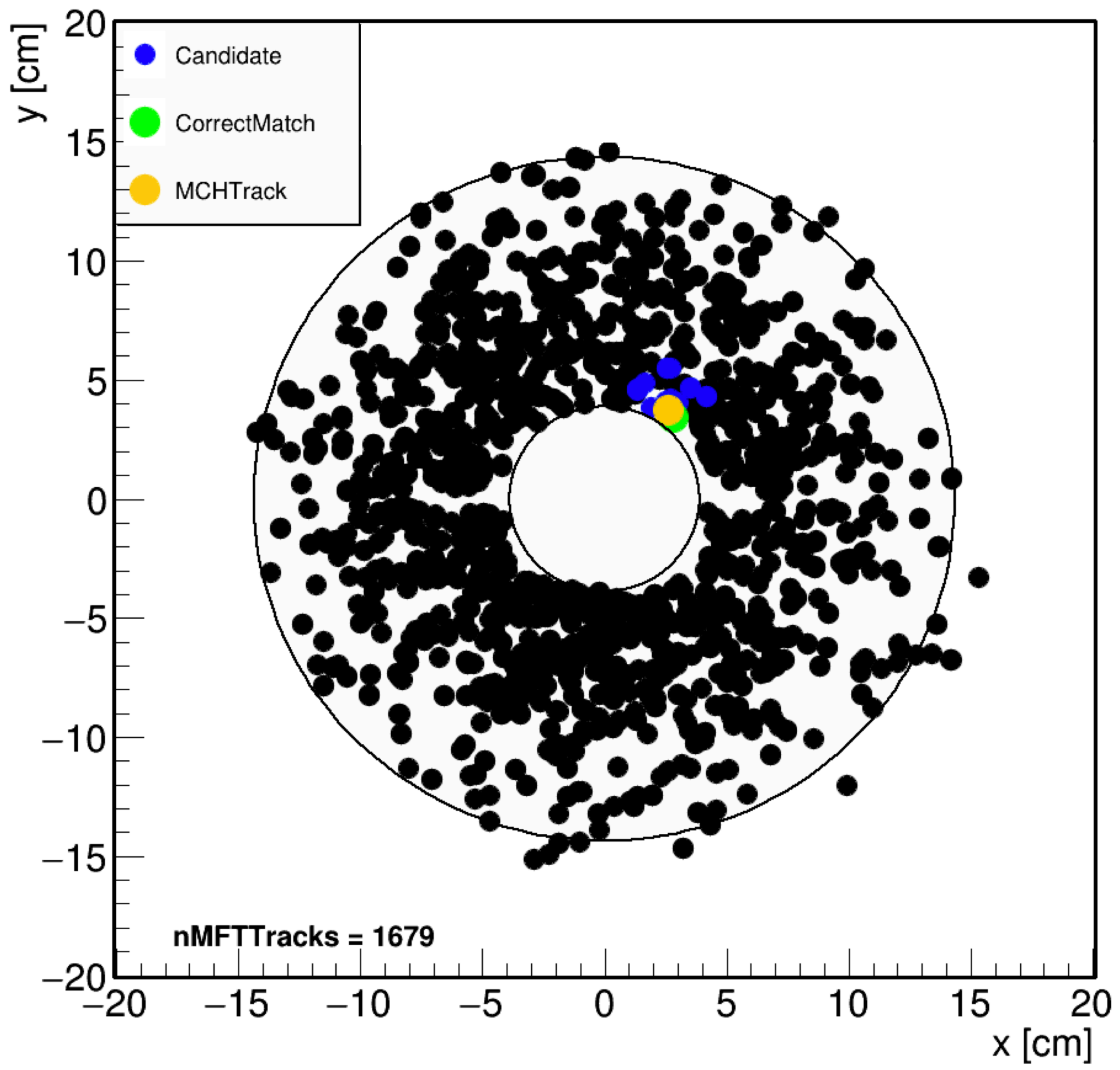




Track matching algorithm

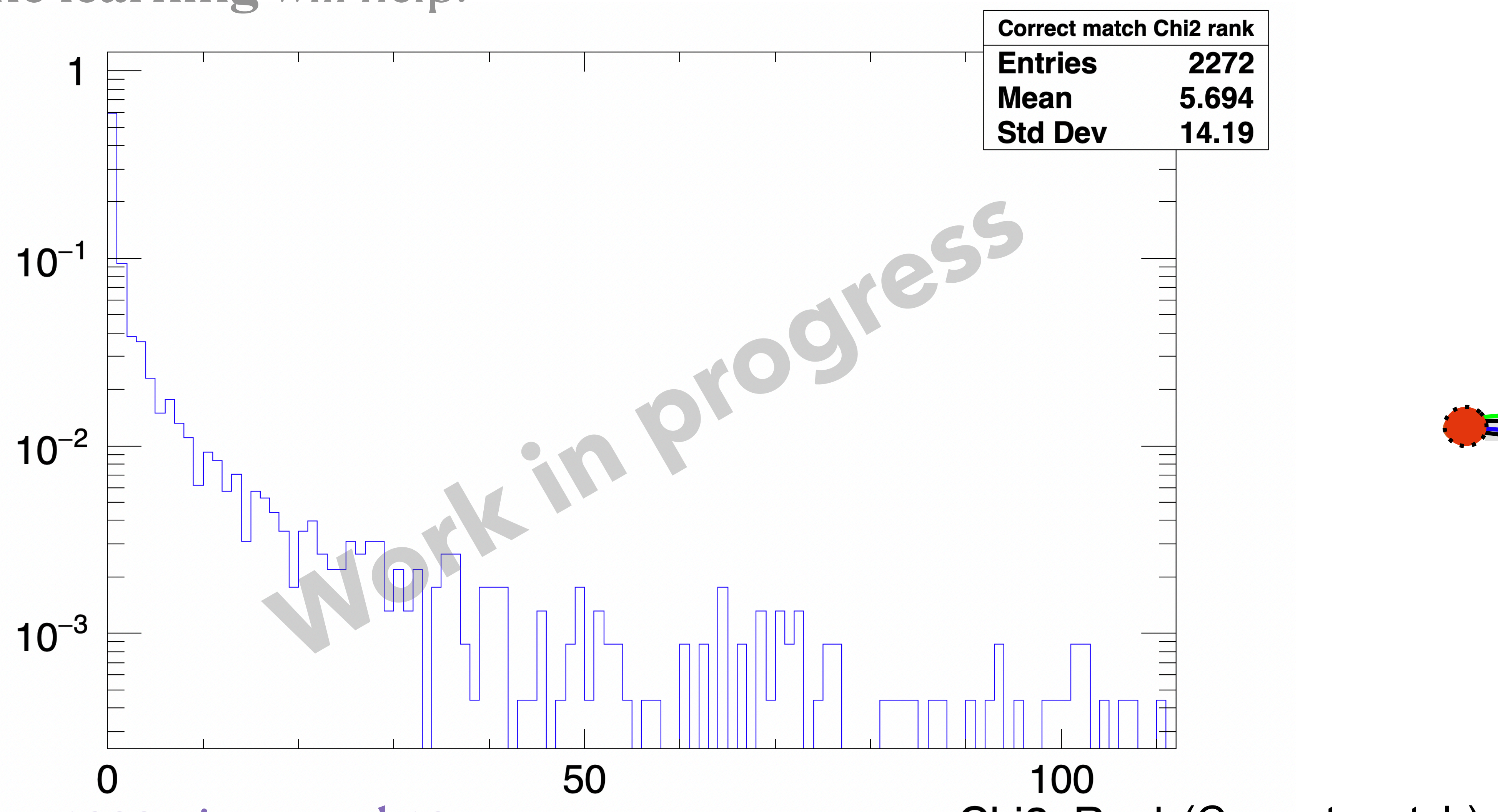
Matching Method:

- Generate events with number of muons and other particles (π, K, p, ...).
- Reconstruct MCH and MFT tracks individually.
- Extrapolate MCH tracks to a matching plane ($z = 77.5$cm).
- Apply a cut to select candidate tracks.
- Find the best match.
- Check the Monte Carlo generator if the best match is the correct match.

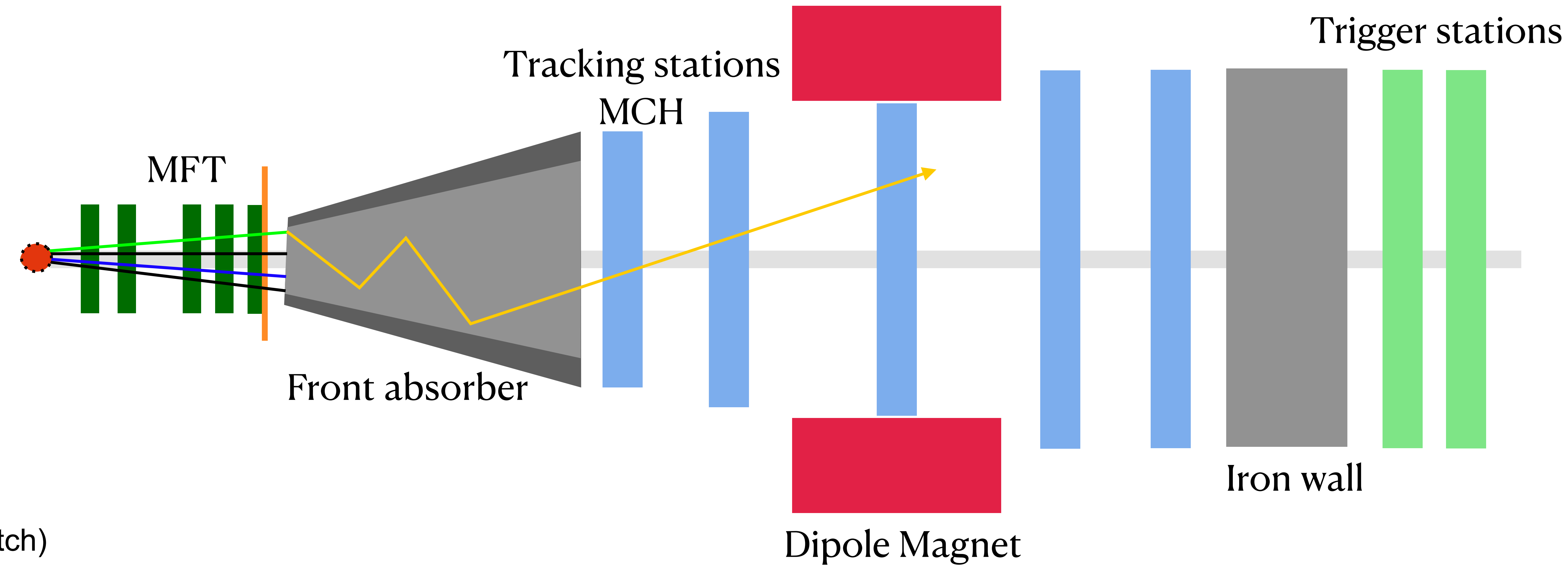


- The χ^2 score is calculated between MCH and MFT tracks coordinates.
  $\vec{S} = (x, y, \phi, \tan\lambda, q/p_t)$

- Difficulty on predicting track path in absorber, where multiple scattering takes place.
  Machine learning will help.



- 1000 pions and 10 muons



MultiLayer Perceptron

- **Neural Network** used for the classification task.

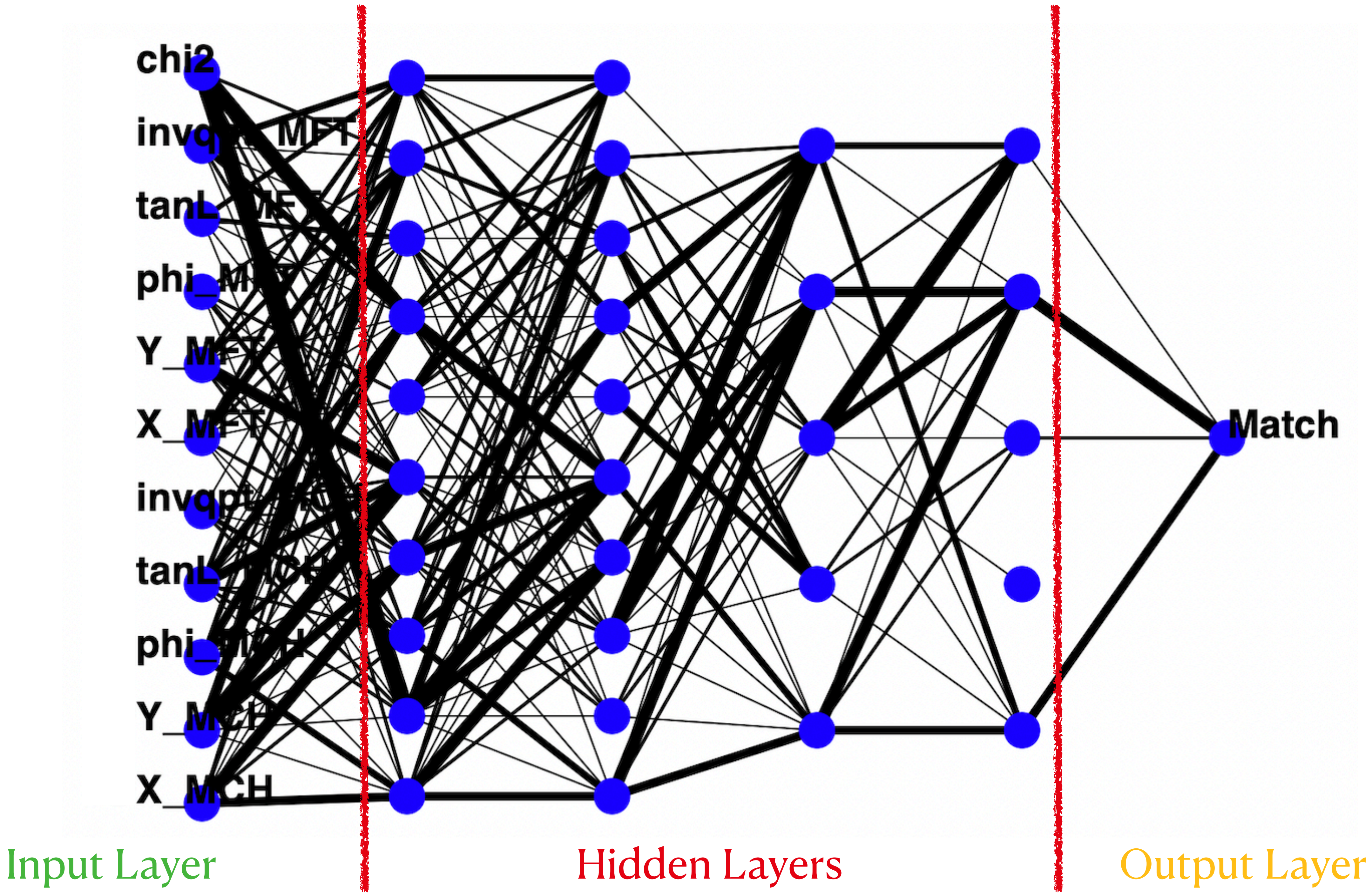
- The MultiLayer Perceptron is a feed-forward network toolkit in ROOT.
  Input layer: Normalized input vector containing coordinates of MCH and MFT tracks.
  Hidden layers: Configurable, best network structure is $10:10:5:5$.
  Output layer: Probability of a correct match.

- Method used: Stochastic minimization.

$$w_{ij}(t+1) = w_{ij}(t) + \Delta w_{ij}(t)$$
$$\Delta w_{ij}(t) = -\eta(de_p/dw_{ij} + \delta) + \epsilon \Delta w_{ij}(t-1)$$

- F score is used to judge the networks reliability:

$$F = 2.\frac{precision\,.\,recall}{precision + recall} = \frac{TruePositive}{TruePositive + 0.5(FalsePositive + FalseNegative)}$$



	ML=0	ML=1
MC=0	True Negative	Fake Positive
MC=1	Fake Negative	True Positive

Track matching with Machine Learning

The ML training sample:

- 100 events, 150 pions and 14 muons each.
  Working in a favorable environment: Lots of rare events (muons) to train Neural Network.
  Data file with 5700 inputs, divided input between 4275 training and 1425 testing samples.
  24000 iterations for training.
- Input consists of 5 MCH coordinates, 5 MFT coordinates and the χ^2 score.

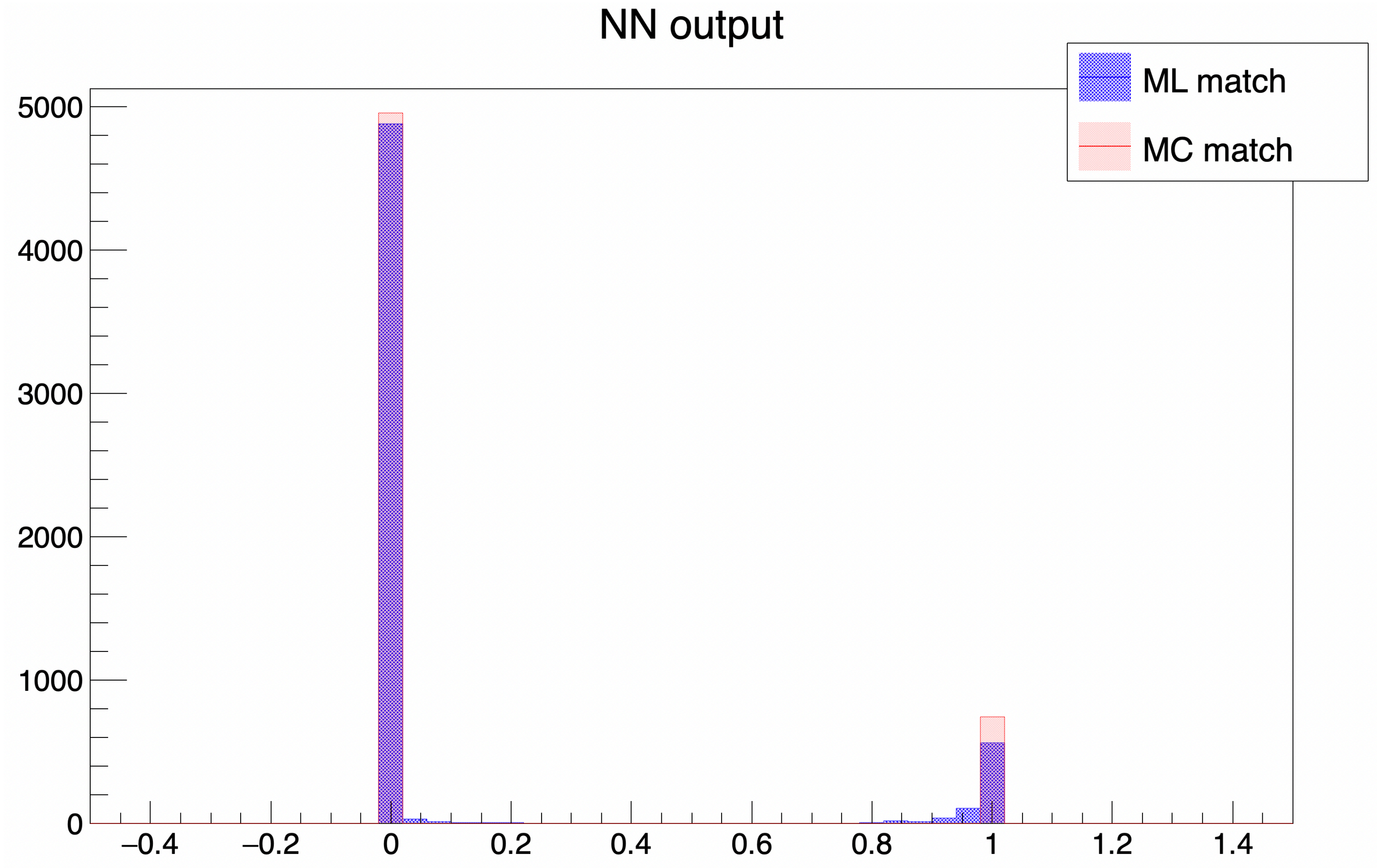
- The calculated F score for this setup: $F = 0.94$

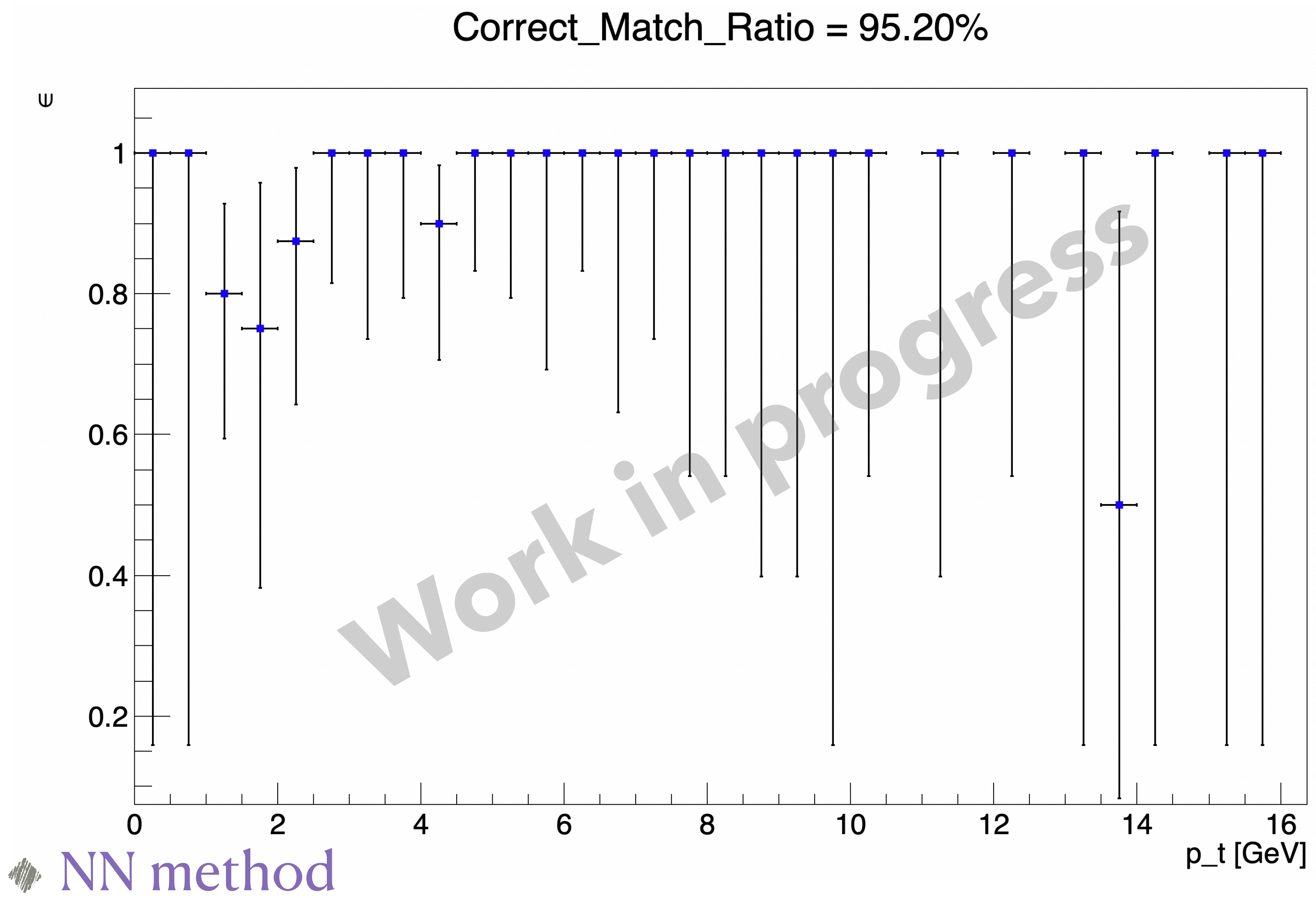
- Extraction of learned neural network, and application of score during simulations runtime.

- The correct match is then calculated, to compare the different methods used:

$$CorrectMatch = \frac{N^{rec.2.5<\eta<3.6}_{MCH\&MFT,corr}}{N^{rec2.5<\eta<3.6}_{MCH\&MFT,all}}$$

- For the **high multiplicity** challenge:
  HIJING generator for low p_T training: PbPb collisions with $0-10\,\%$ centrality.





	ML=0	ML=1
MC=0	99.0%	1.0%
MC=1	5.7%	94.3%

- NN method
  150 pions and 14 muons

Summary

Conclusion:

- **Developed a complex environment** for the detector Muon Forward Tracker control, was **approved by MFT** collaboration.
- **The software was used at CERN throughout all the commissioning period,** and allowed us to work and test the detector.
- **Finished the Detector Control System for PSU,** which will be used to control officially the detector throughout **RUN**3.
- Integration of machine learning to **further improve the track matching** algorithm.

Perspective:

- **Charm and Beauty separation.**
- Evaluation of the **performance of the MFT in its final status**.
- Start first **data analysis preparations**.

Thank you for your attention !