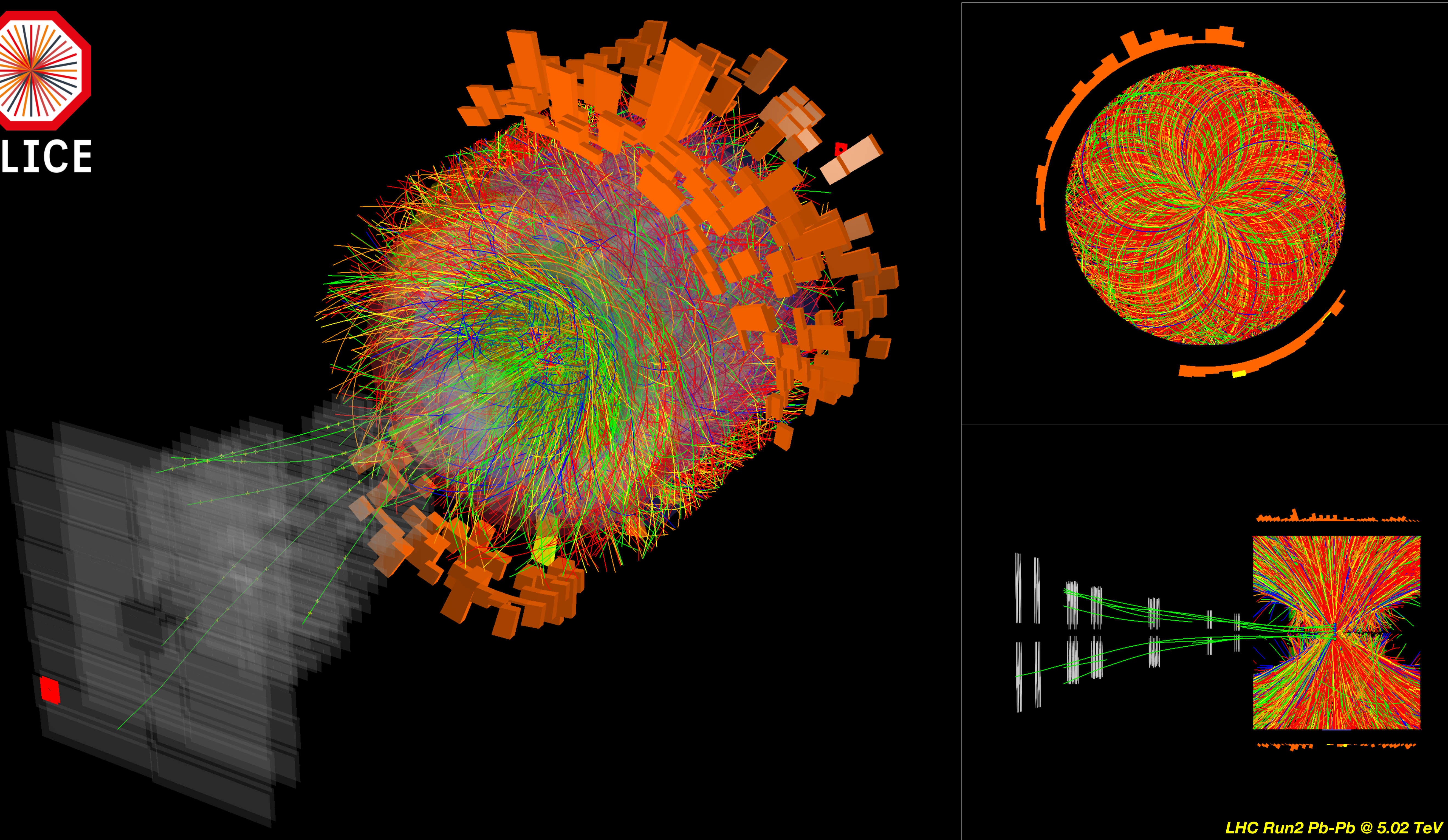


Muon Spectrometry at Forward Rapidities in ALICE

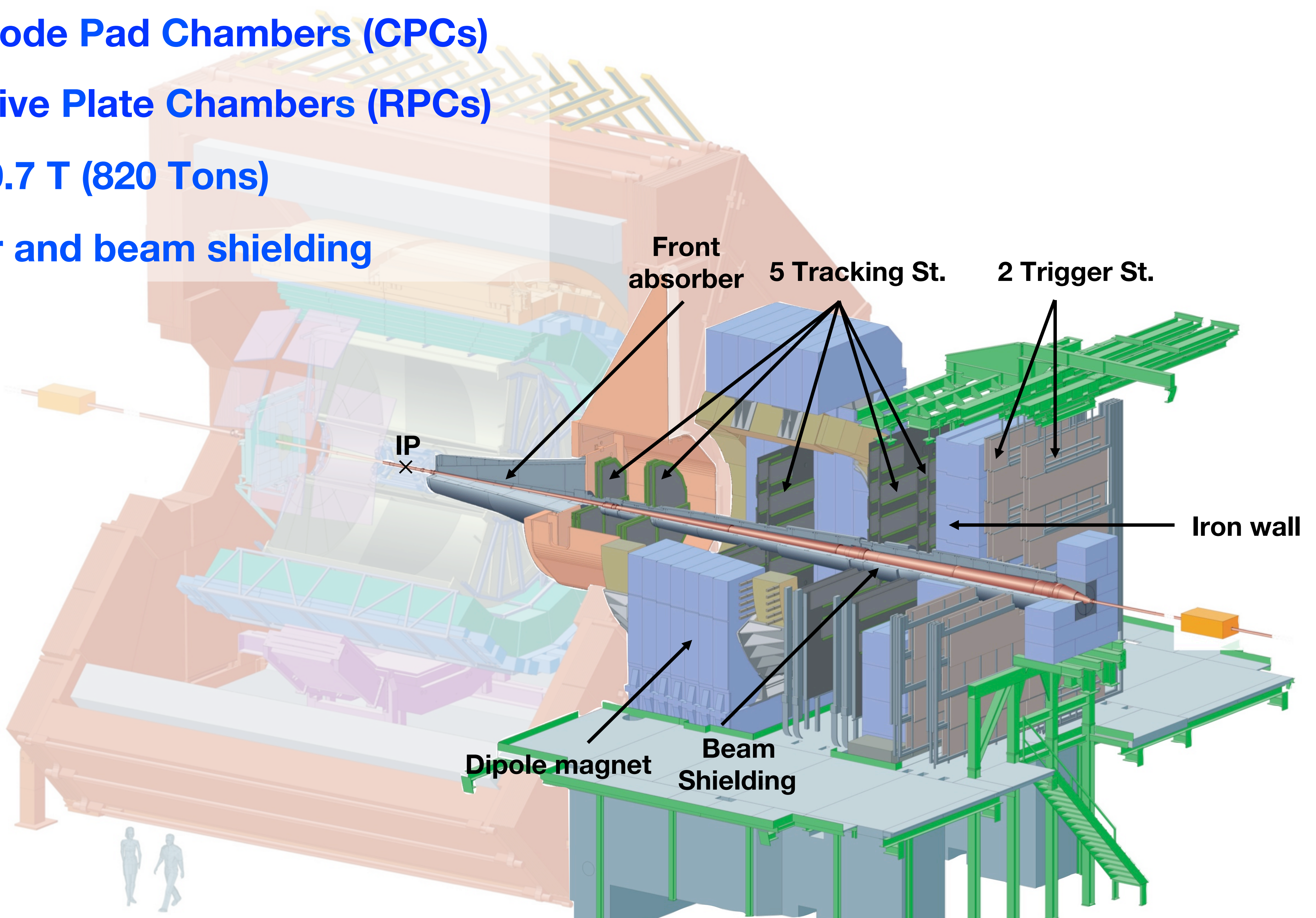
A. Ferrero

EPS-HEP2019, Ghent, July 11th 2019

The Present ALICE Muon Spectrometer

The ALICE Muon Spectrometer:

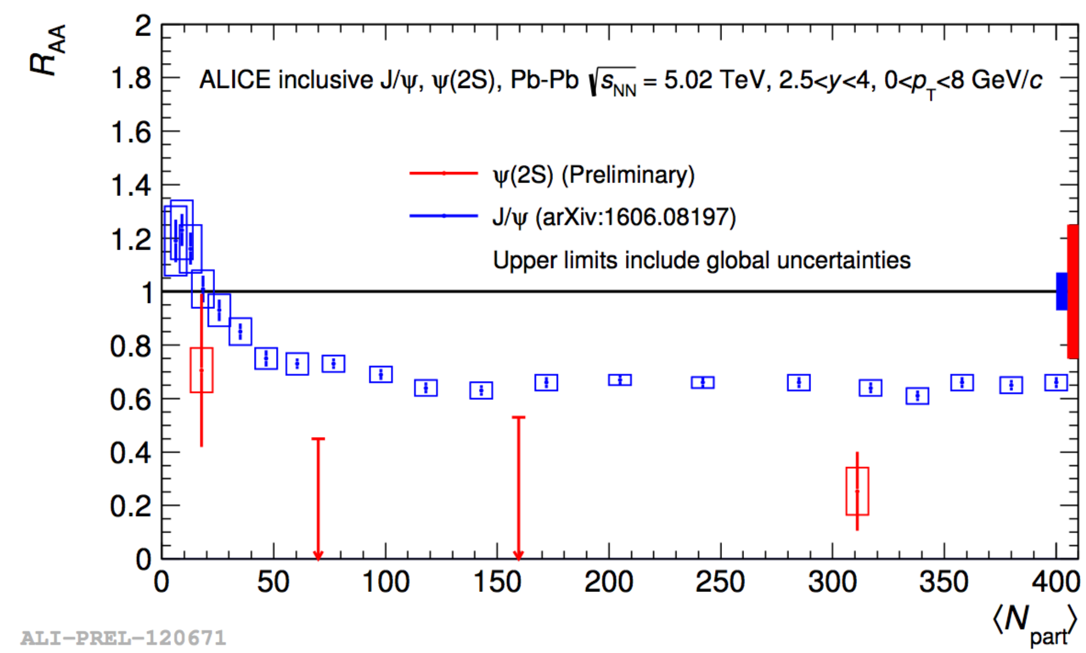
- **Muon spectrometer acceptance: $2.5 < \eta < 4$**
- **Tracking: Cathode Pad Chambers (CPCs)**
- **Trigger: Resistive Plate Chambers (RPCs)**
- **Warm dipole: 0.7 T (820 Tons)**
- **Front absorber and beam shielding**

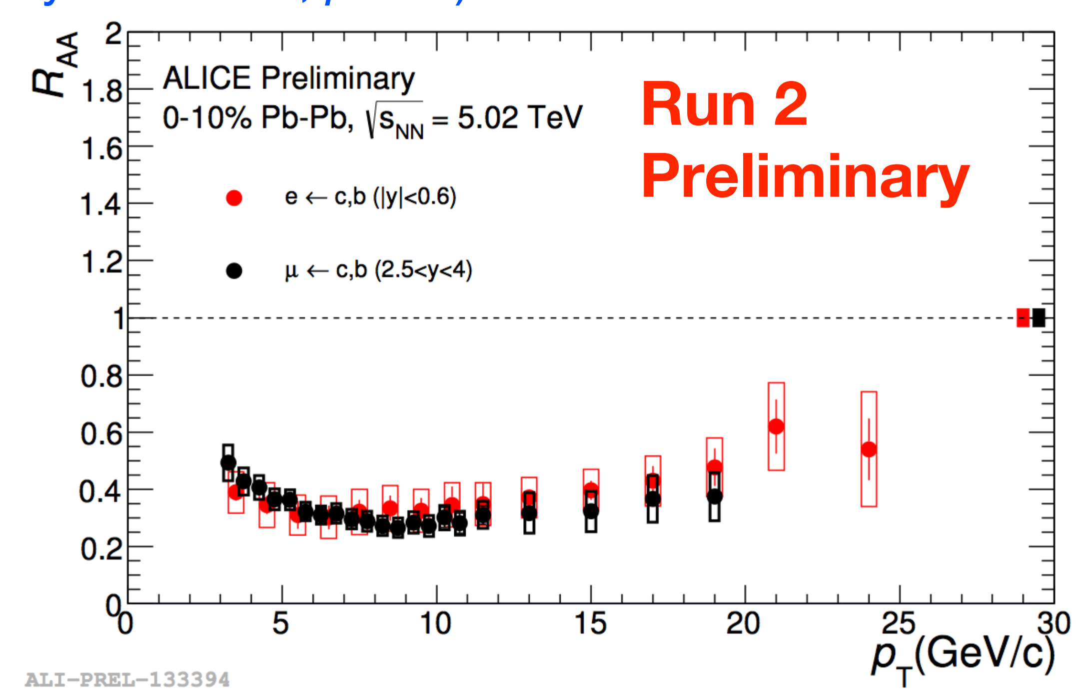


Physics with the Upgraded Muon Spectrometer

- Better statistics (one order of magnitude wrt Run 2)
  - Pb-Pb collected luminosity: **1 nb^{-1} (Run 2) -> 13 nb^{-1} (Run 3 and 4)**
  - Benefit for rare signals: Ψ (2S), Υ,…
- J/Ψ, Ψ(2S)
  - Present Muon Arm: Inclusive J/Ψ measurement
  - New: Separation prompt / non-prompt (B -> J/Ψ + X)
  - New: Improved Ψ (2S) due to the increase of S/B
- Heavy Flavor
  - Present Muon Arm: No charm/beauty separation (large systematics, p_T> 3)
  - New: Open charm/beauty in semi-leptonic decays:
  - New: B measurement using non-prompt J/Ψ down to p_T ~ 0 GeV/c
- Low mass vector mesons (ρ, ω, ϕ)
  - Much improved mass resolution
  - Important increase of S/B

J/Ψ: arXiv:1606.08197

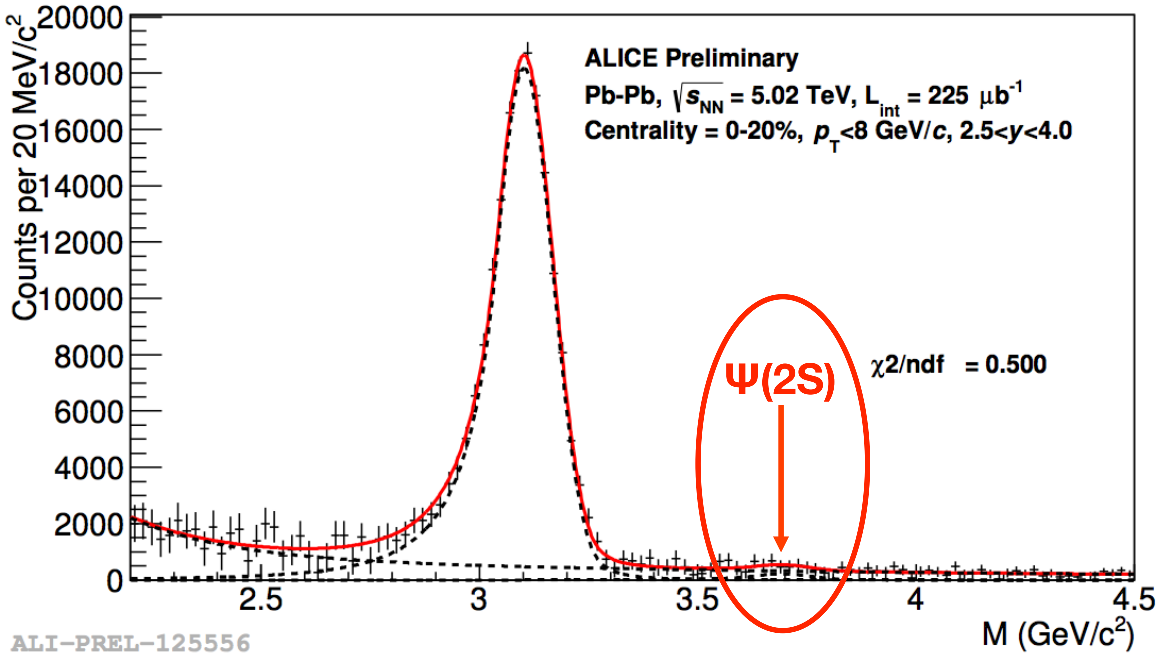


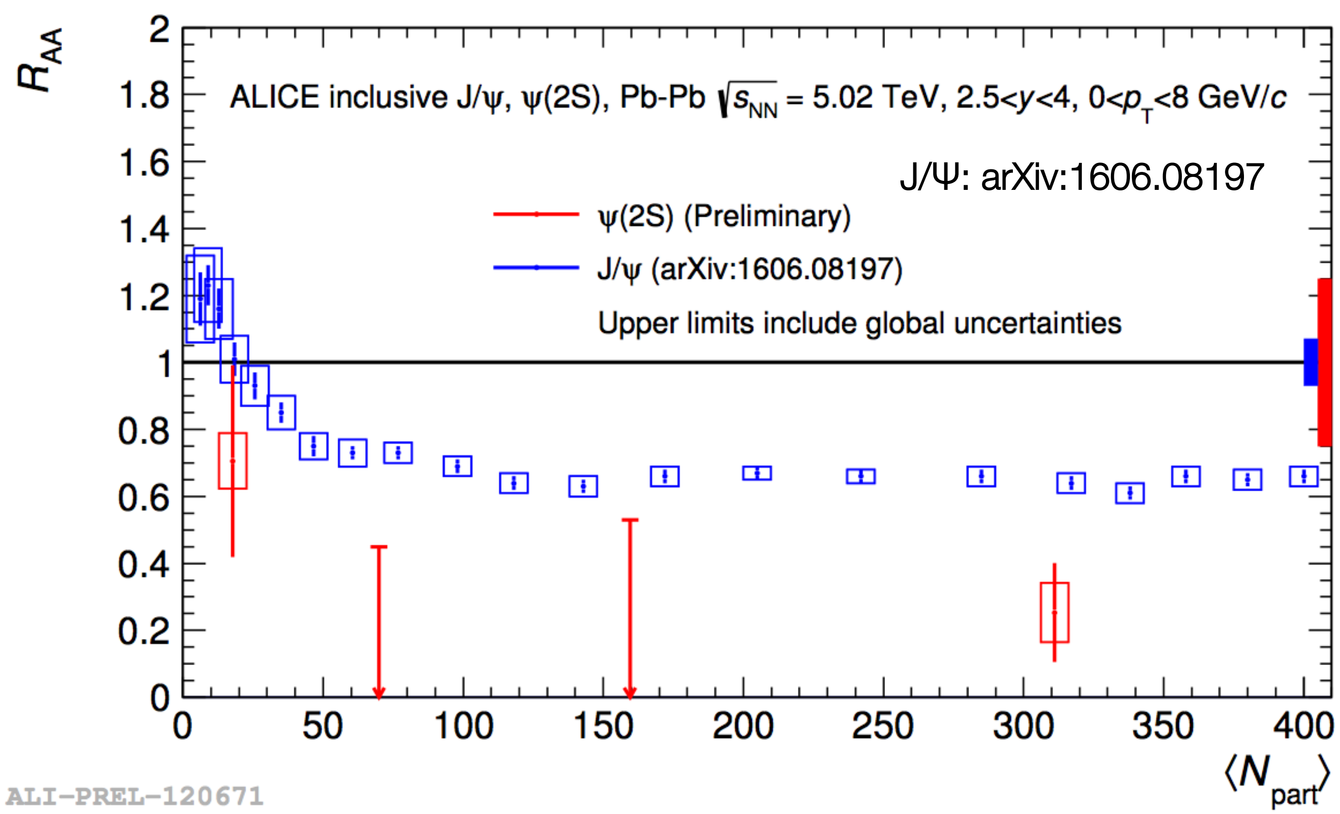


Ψ(2S) Suppression Compared to J/Ψ

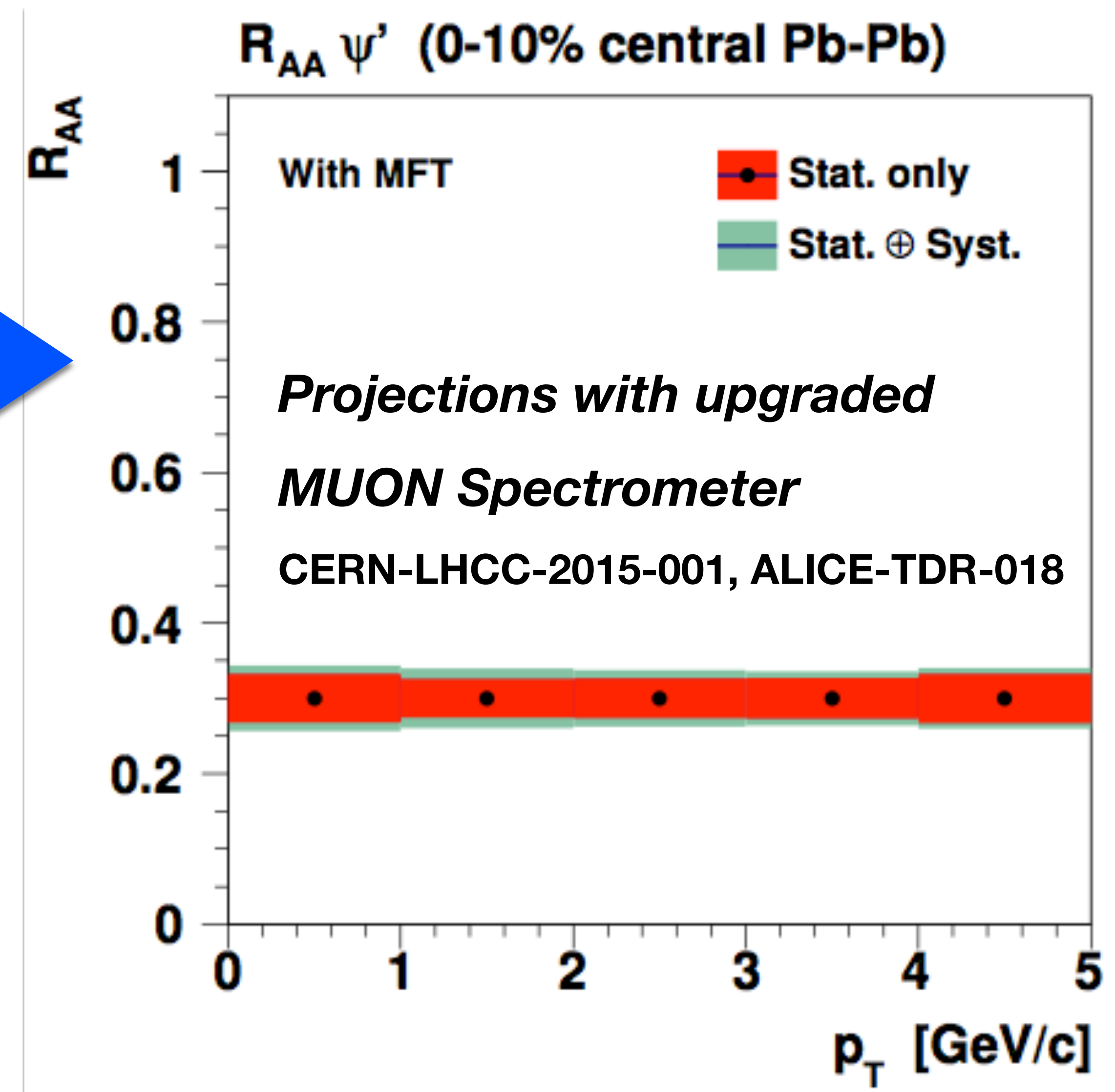
Preliminary Run2 results
(x3 expected with full stat.)

- Difficult analysis
- First preliminary results in Pb-Pb
- Need more statistics and better S/B



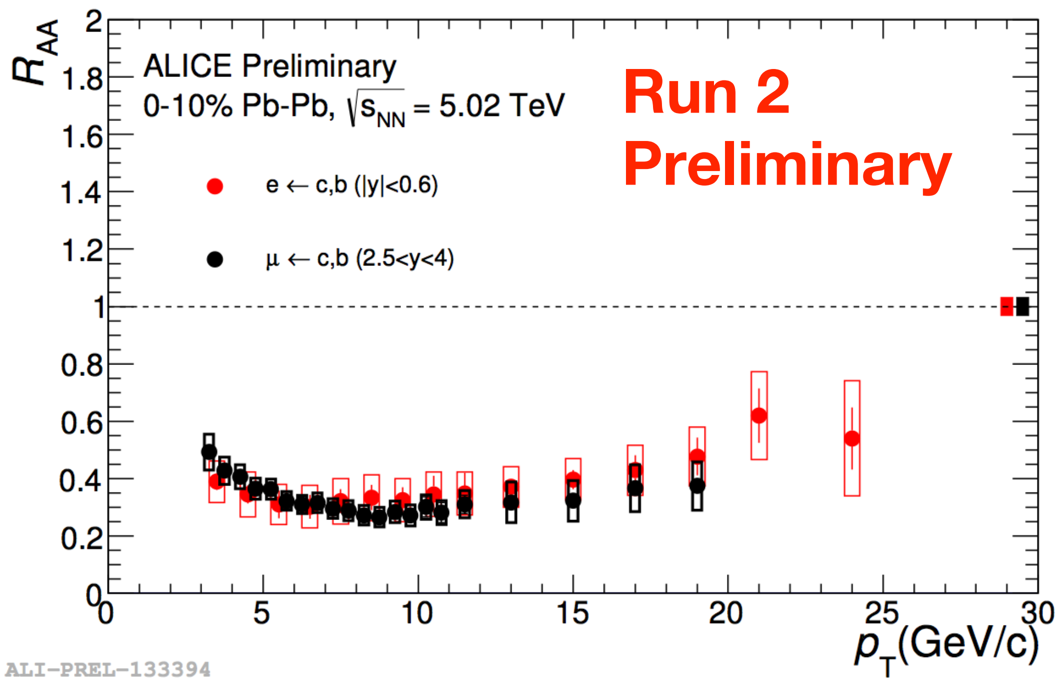


Projections with upgraded Muon Spectrometer

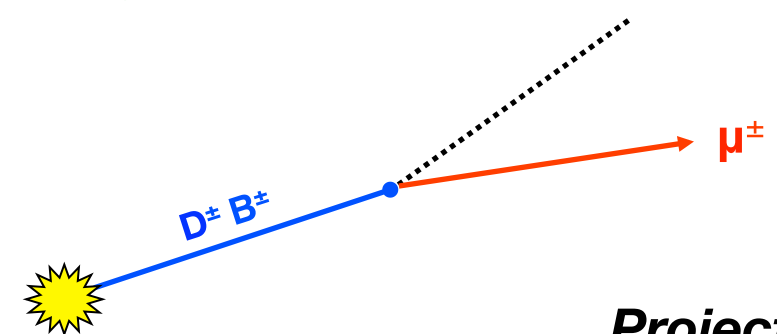


Heavy Flavor in Pb-Pb at 5.02 TeV

- Strong suppression of heavy-flavor decay leptons
  - **No separation between charm and beauty** (beauty dominates from p_T > ~5 GeV/c)
  - Similar suppression at central (electrons) and forward rapidity (muons)

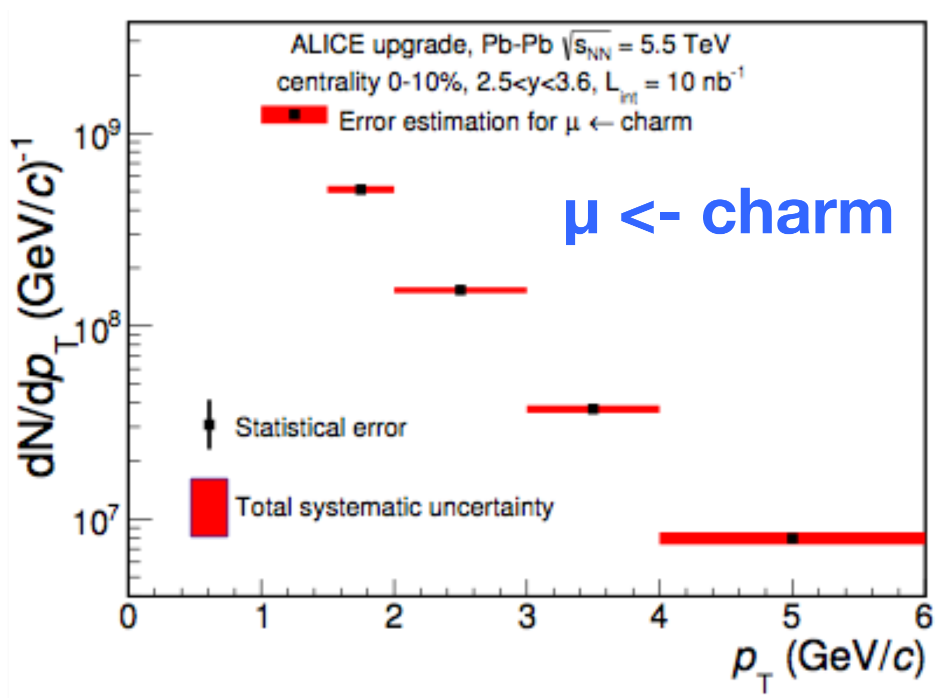


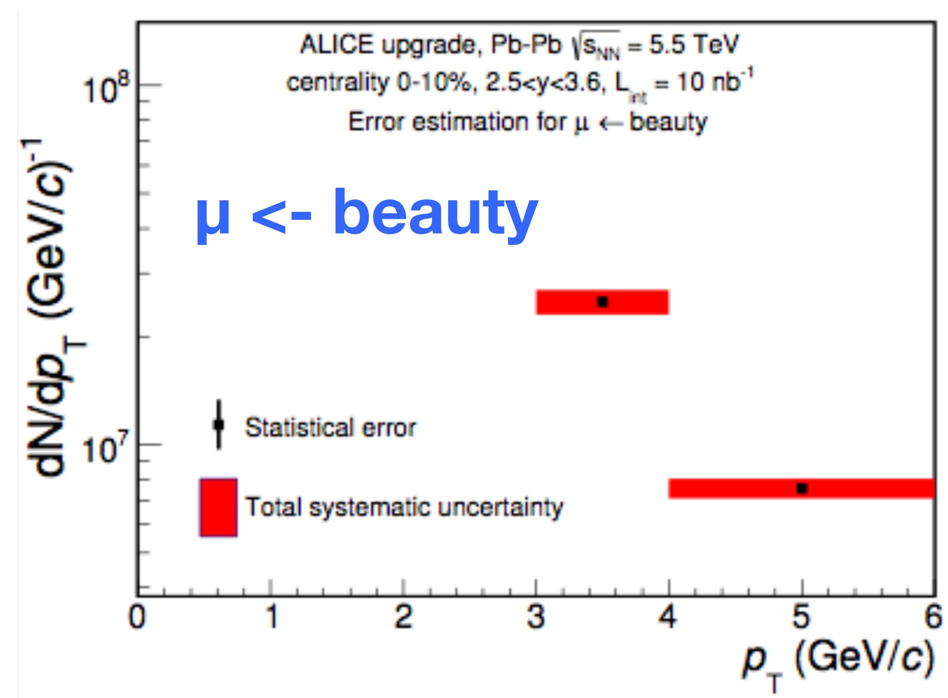
Displaced secondary vertex reconstruction with upgraded Muon Spectrometer



Projections with upgraded MUON Spectrometer

CERN-LHCC-2015-001, ALICE-TDR-018





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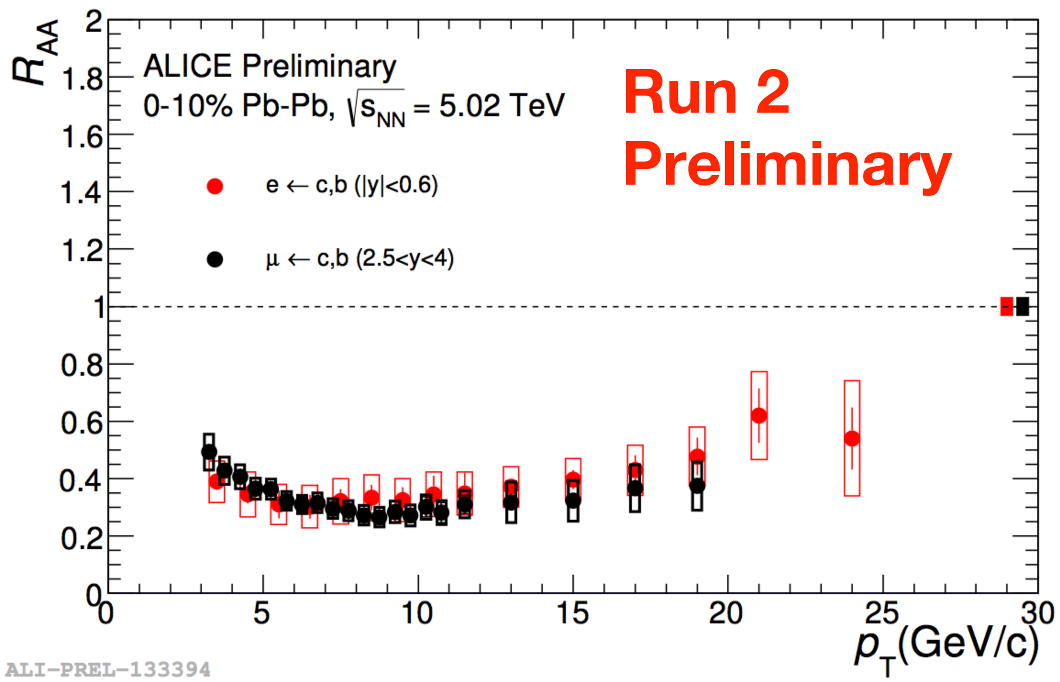
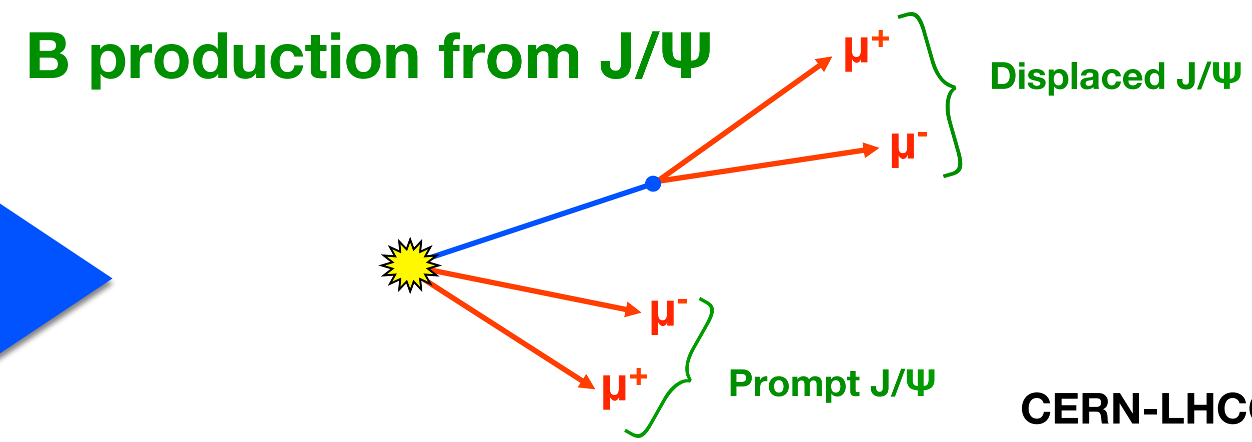
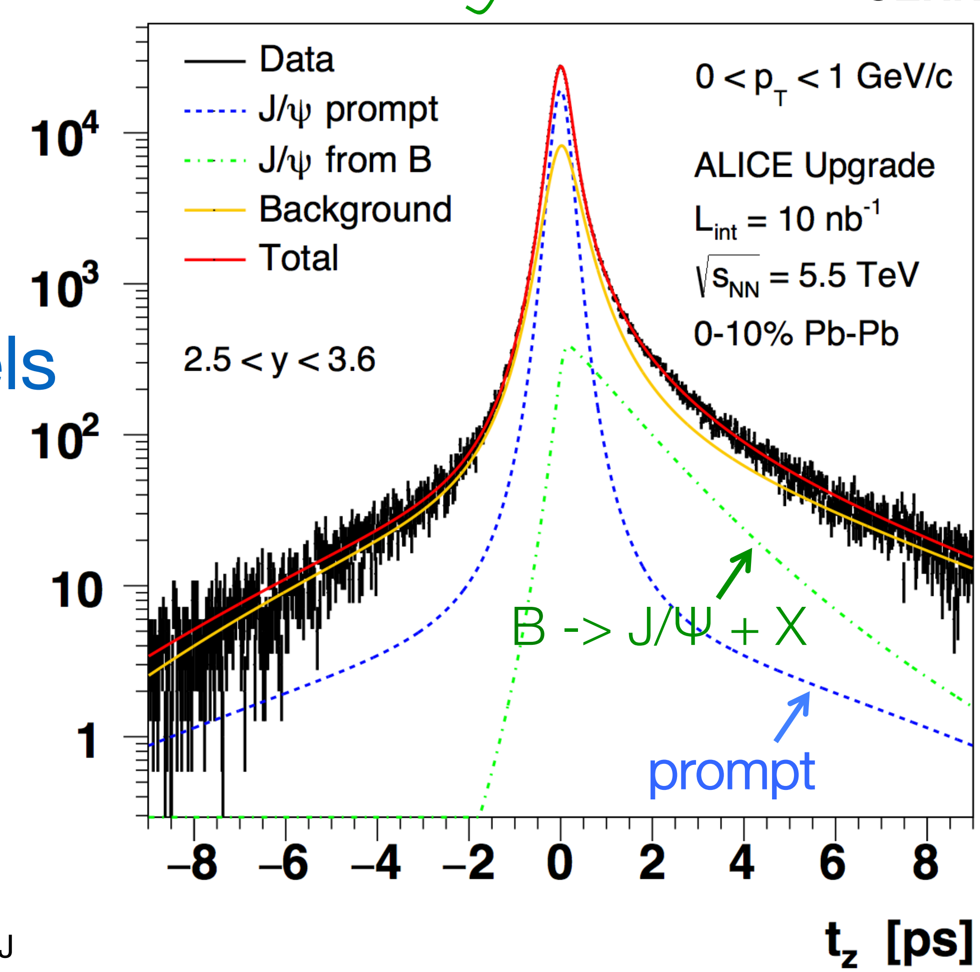




CERN-LHCC-2015-001

ALICE-TDR-018

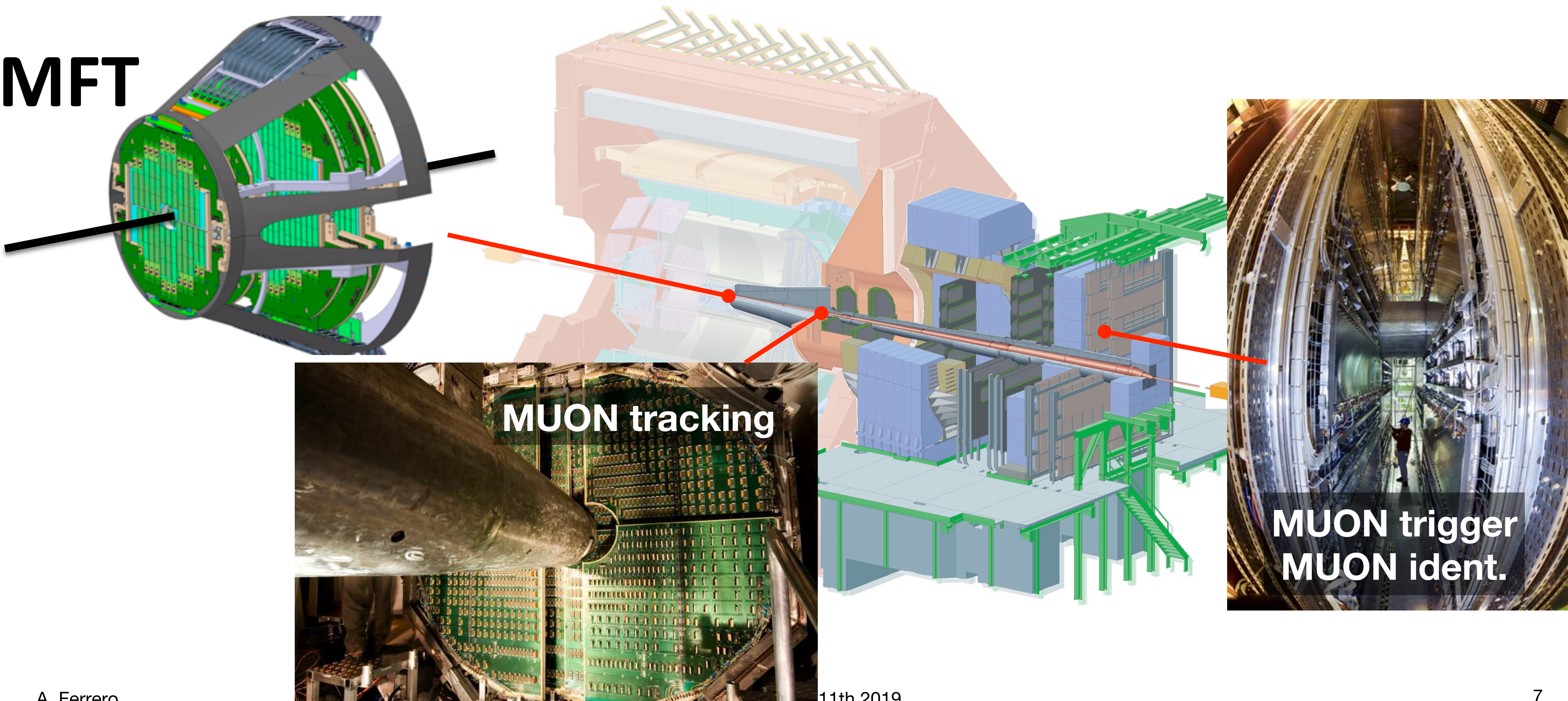


Complementary to semi-muonic channels

Access to B hadrons down to ~0 p_T

The Upgraded MUON Spectrometer

- After the LS2 (2019/2020) => **13 nb^{-1} Pb-Pb (x 10 / Run 2)**
  - Present LHC luminosity in Pb-Pb: $L=10^{27}$ $cm^{-2}s^{-1}$ (8 kHz of interaction) => **DAQ @ 1 kHz**
  - Upgraded Pb-Pb luminosity: $L=6\ 10^{27}$ $cm^{-2}s^{-1}$ => 50 kHz of interaction rate => **DAQ @ 100 kHz**
- New Muon Forward Tracker (MFT) => improved physics program
- Need to upgrade the FEE & readout of MUON Tracking and Identifier



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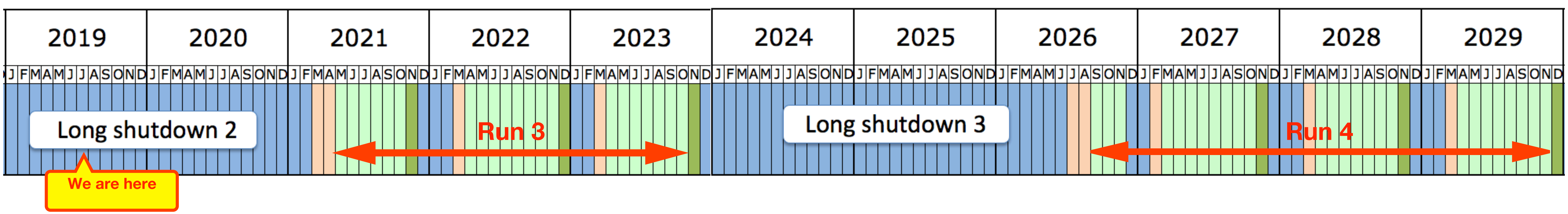
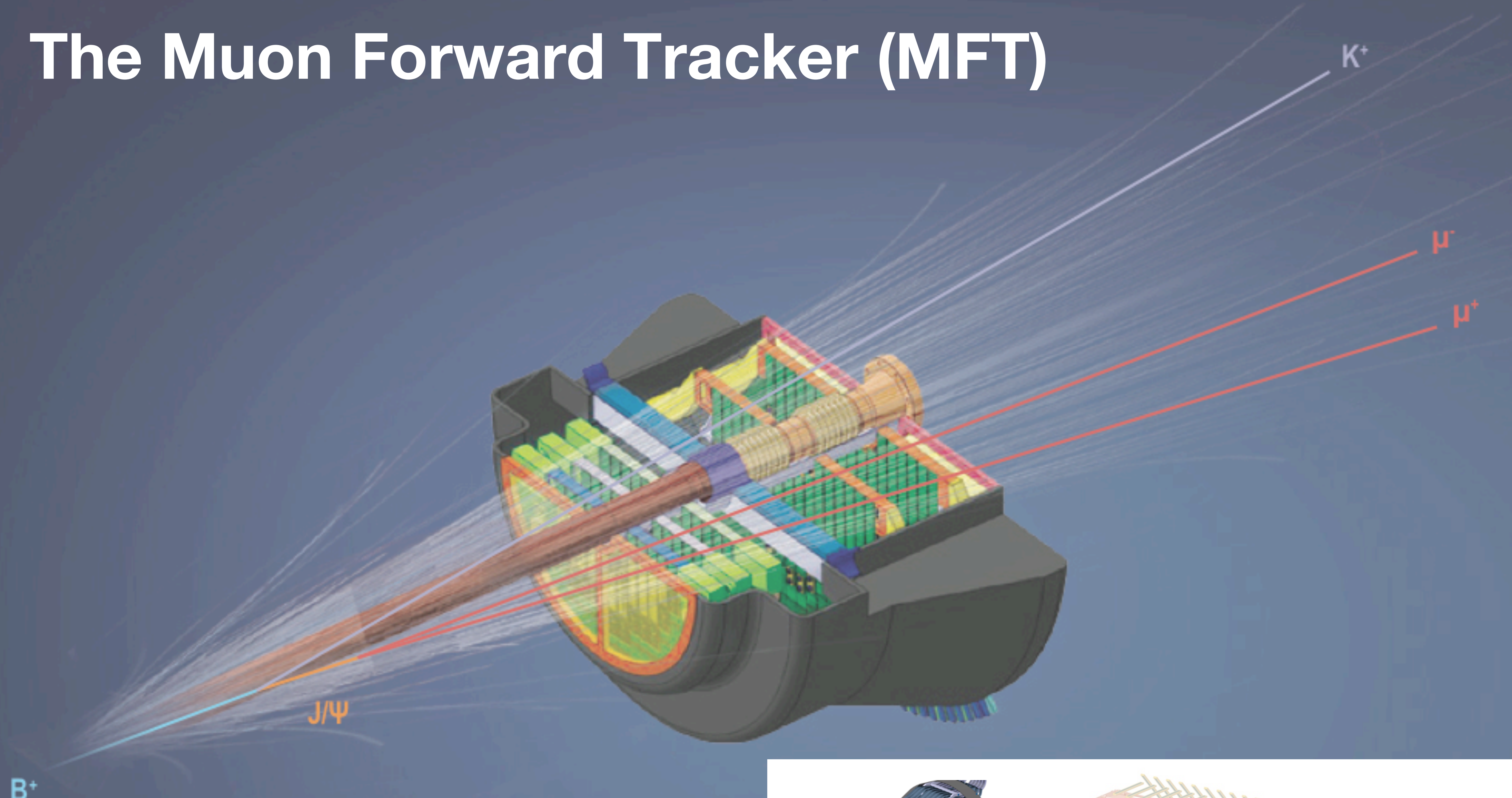
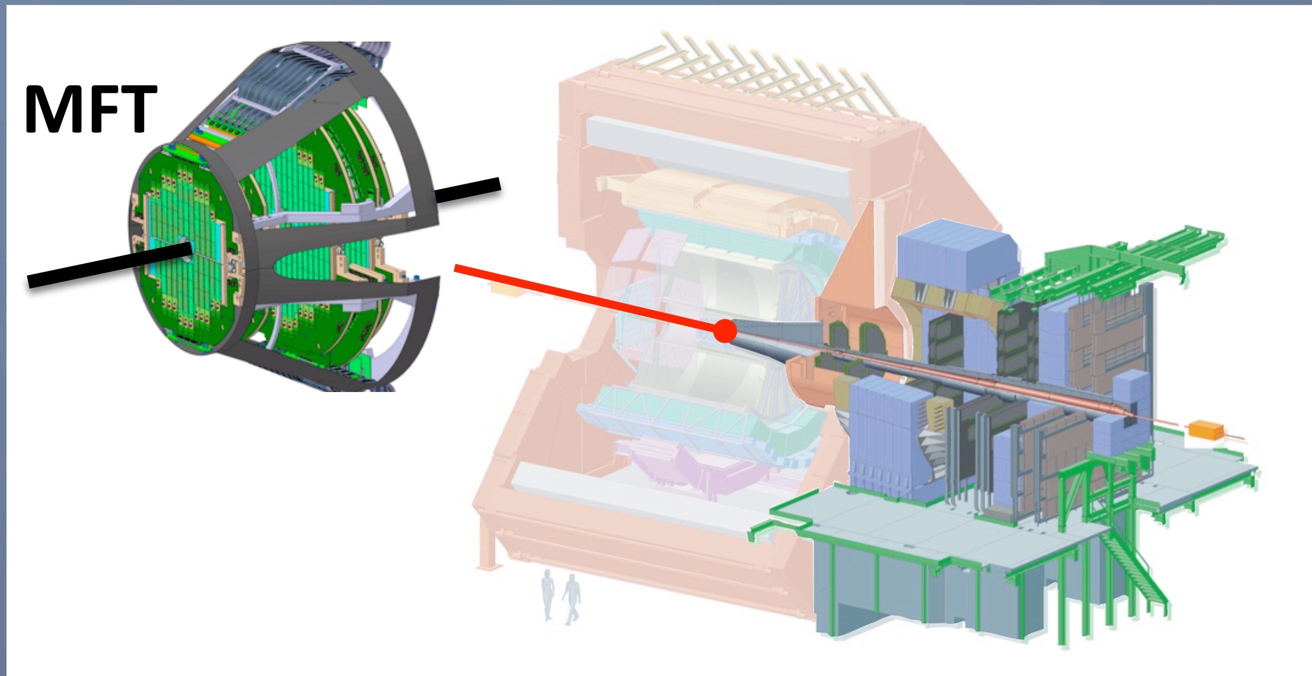


The Muon Forward Tracker (MFT)



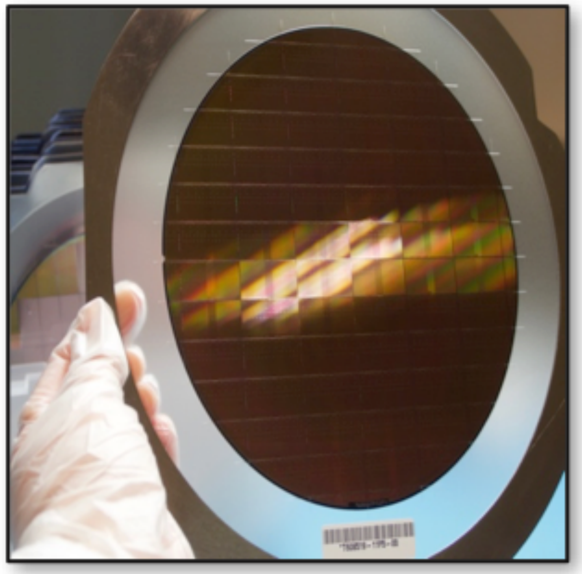


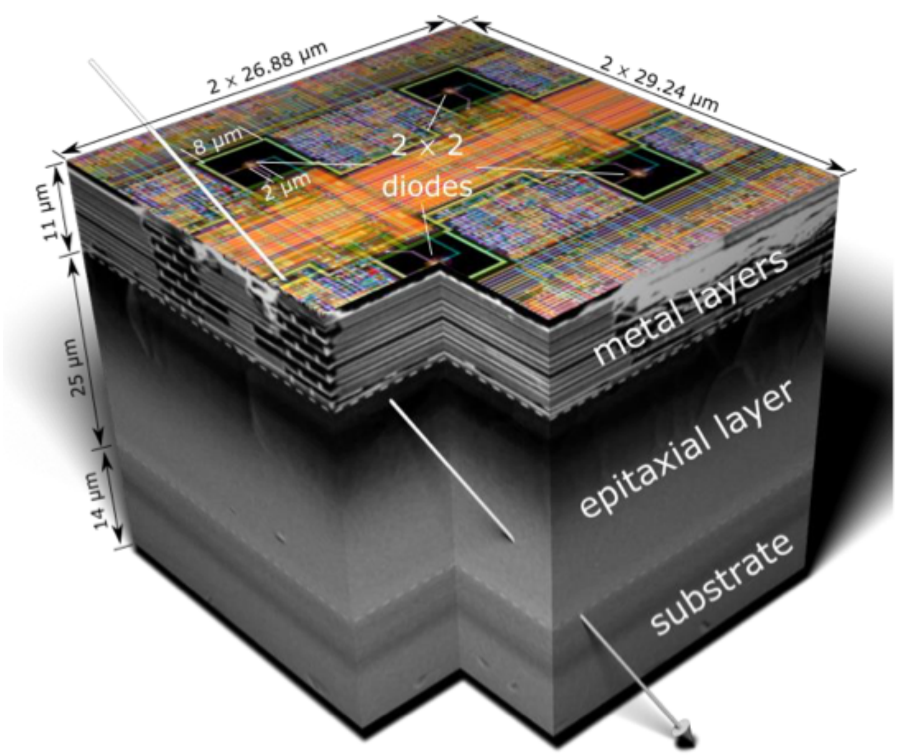
ALICE MFT

- Tracker located in front of the Muon Arm
  - High spatial resolution (~5 µm)
  - Secondary vertex capabilities
- 5 planes of CMOS sensors (ALPIDE)
  - Technology: Tower Jazz 0.18 microns
  - Pixel size: 29x27 μm^2
  - Thickness: ~0.7% X/X_0 per plane
  - ~1000 sensors, ~0.4 m^2
  - 460 mm from nominal interaction point

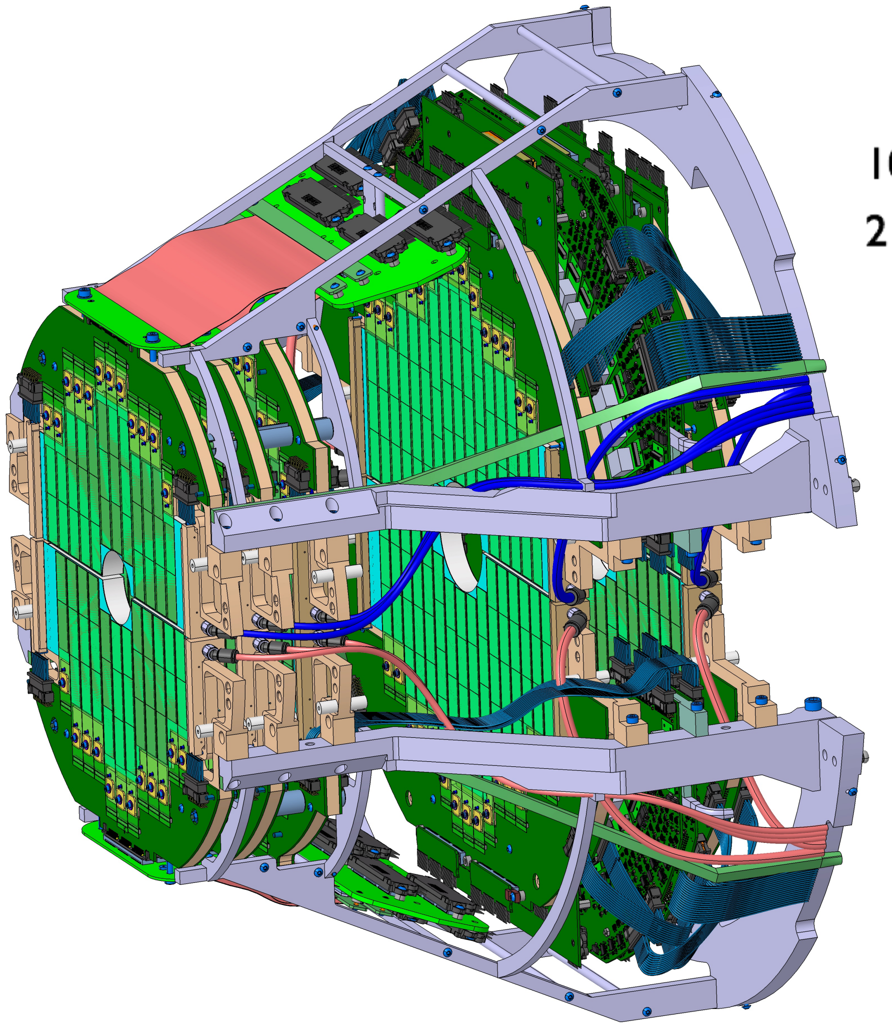
See Y. Morales' talk earlier this morning

ALPIDE Wafer (Production finished)



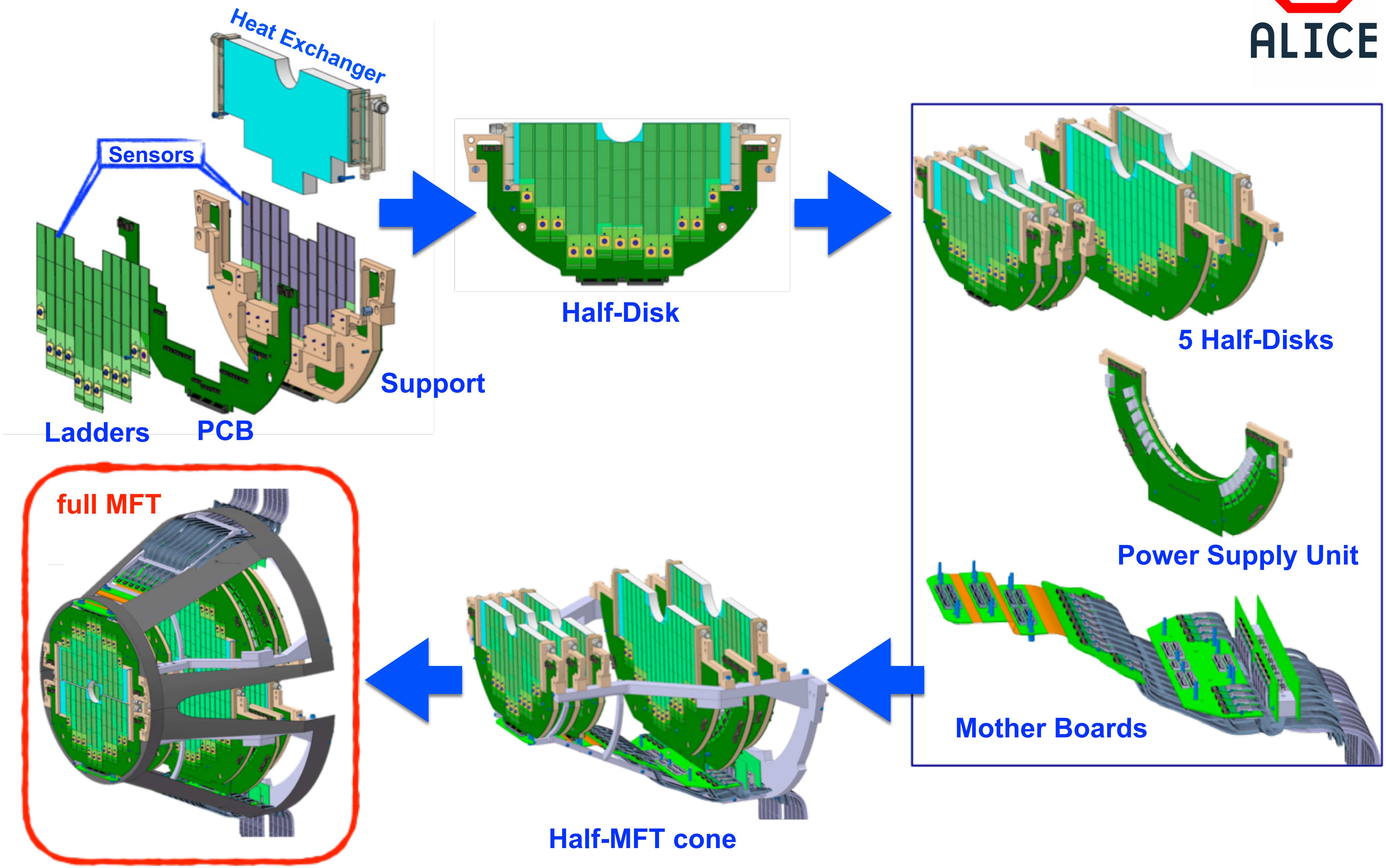


CMOS Pixel



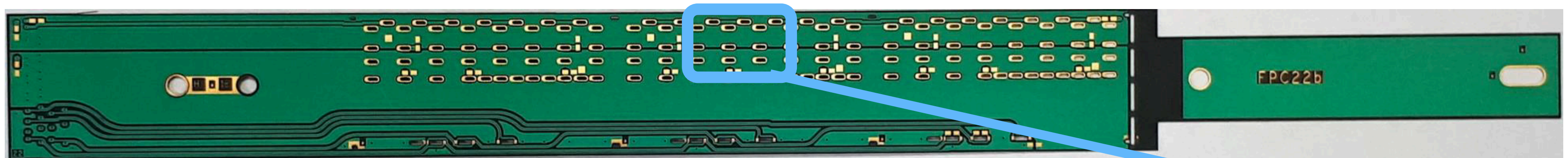
10 half-disks
2 detection planes each

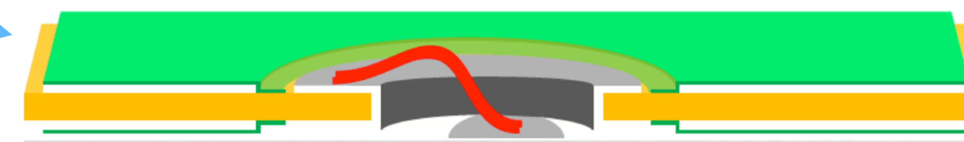
MFT Assembly

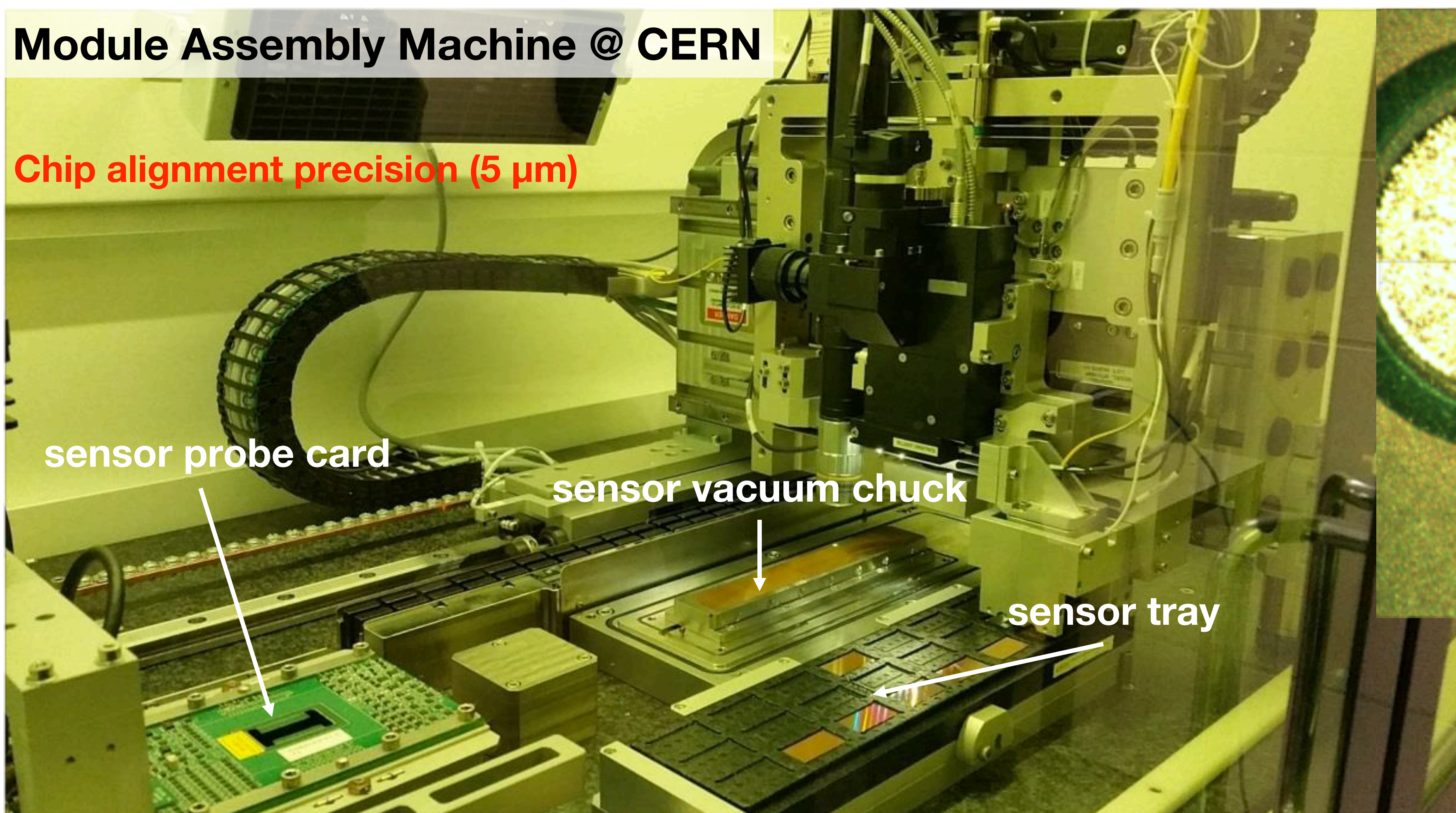


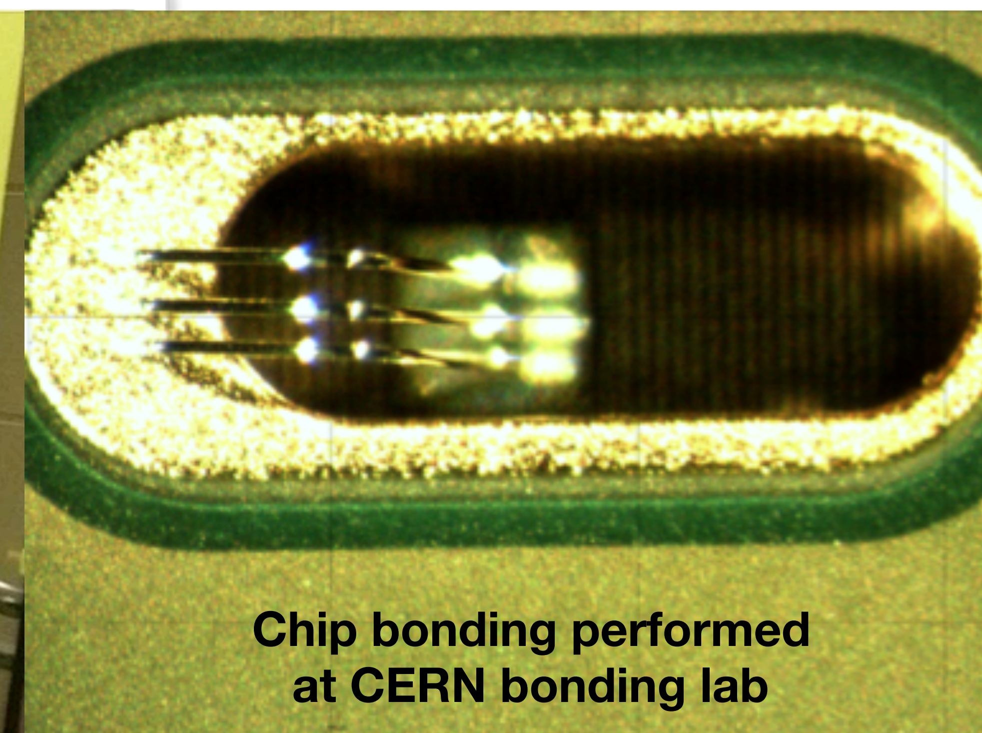
ALICE MFT Ladders

- Ladders
  - It ensures data, slow control, reverse back bias and power supply from/to the chips
  - Al FPC chosen. Produced @ CERN



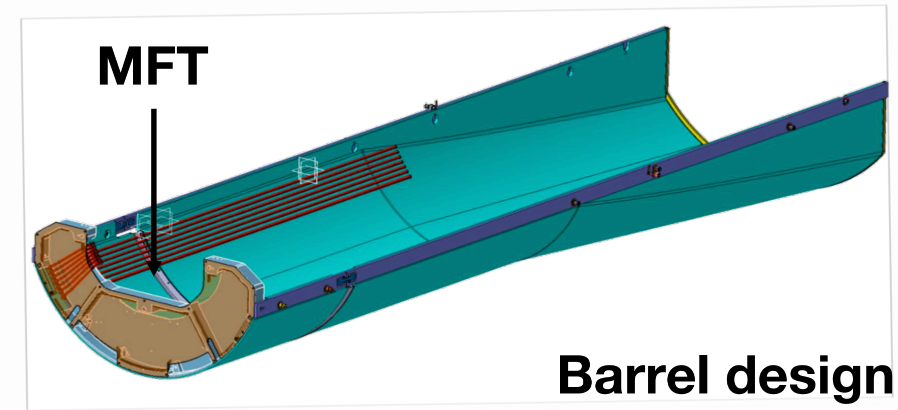


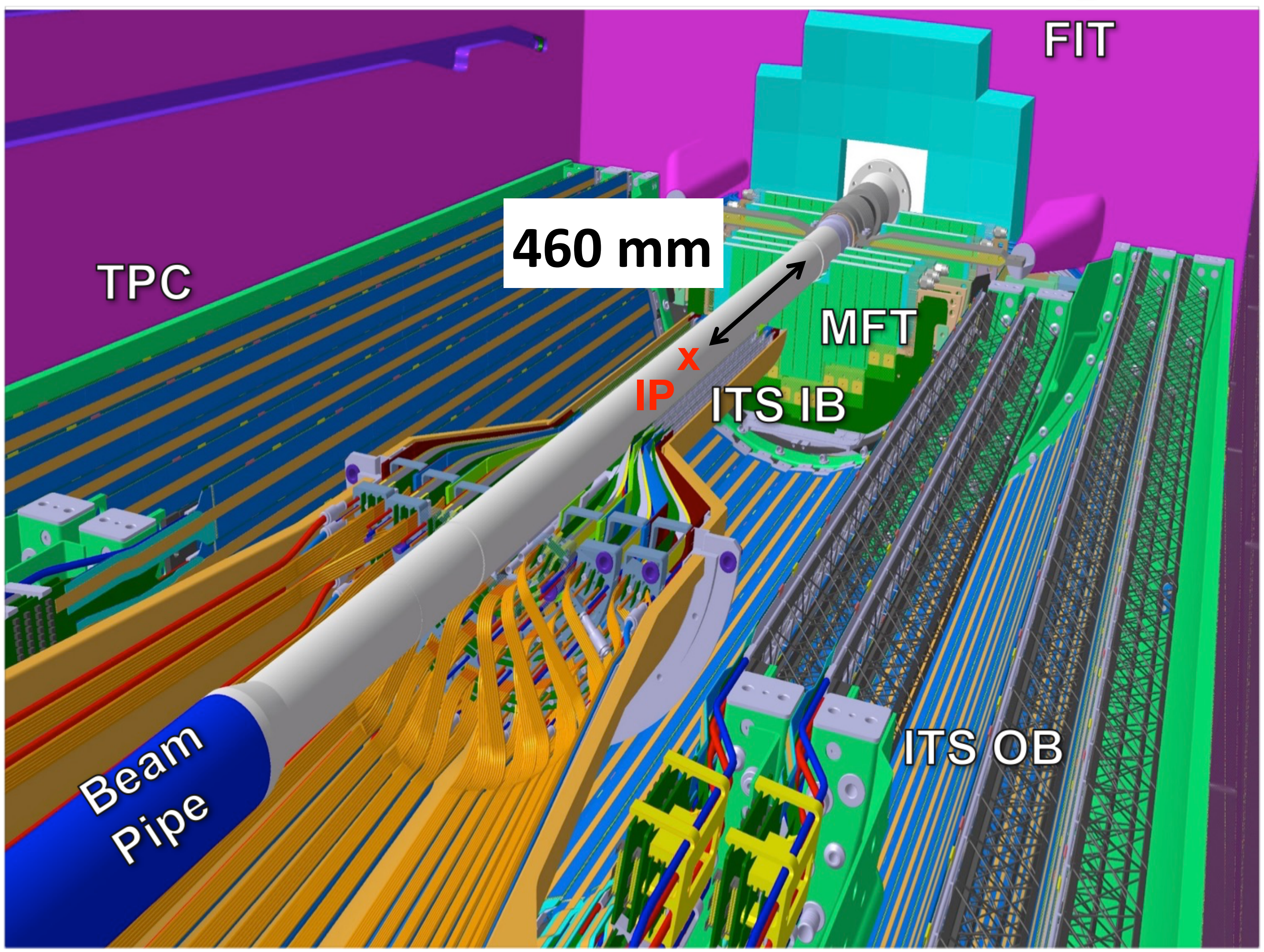




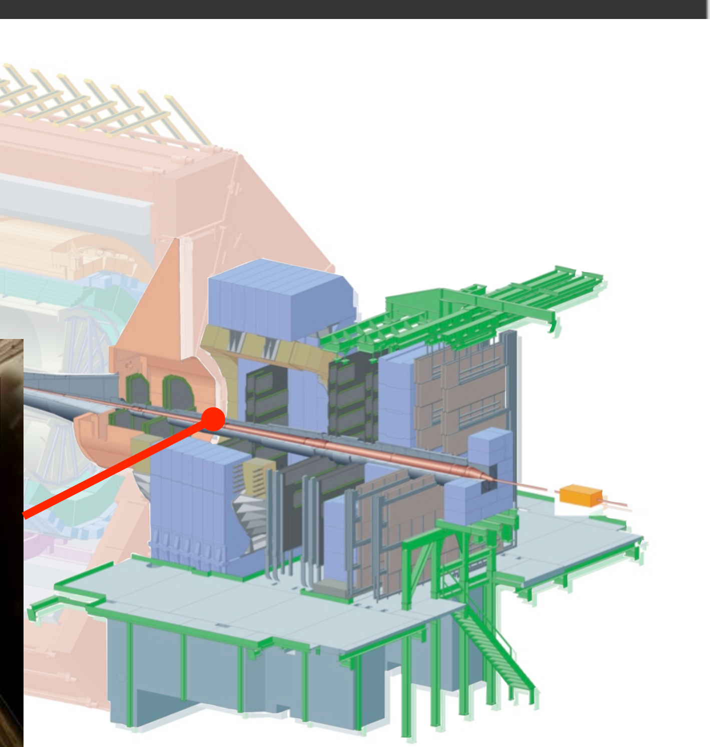
MFT Integration

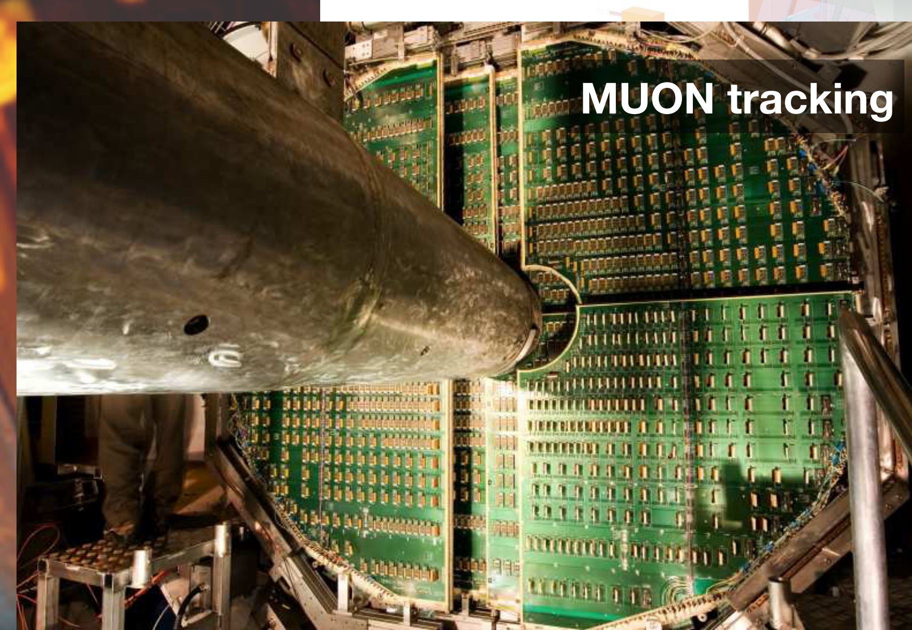
- MFT Barrel
  - Insertion & positioning
  - Cooling/LV/Readout connections





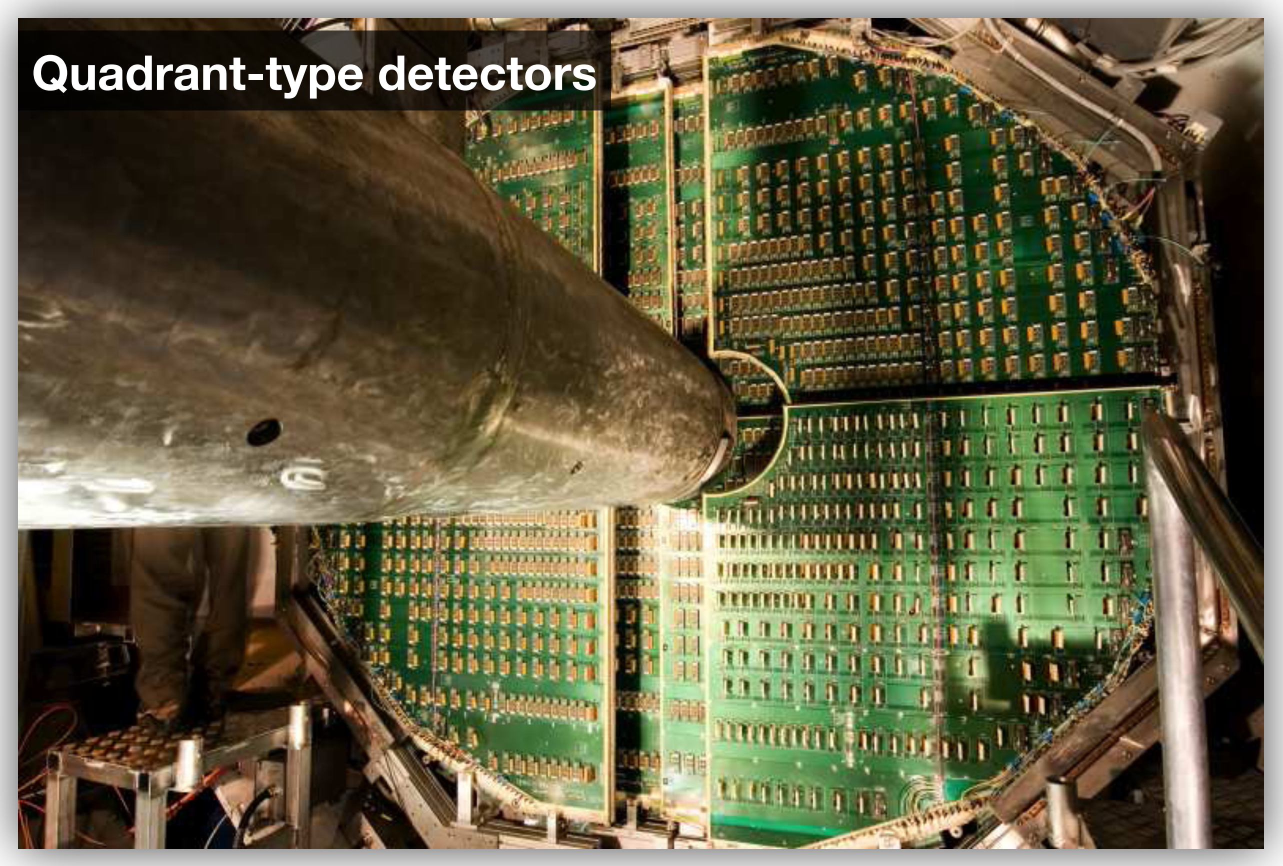
The Muon Tracking Upgrade

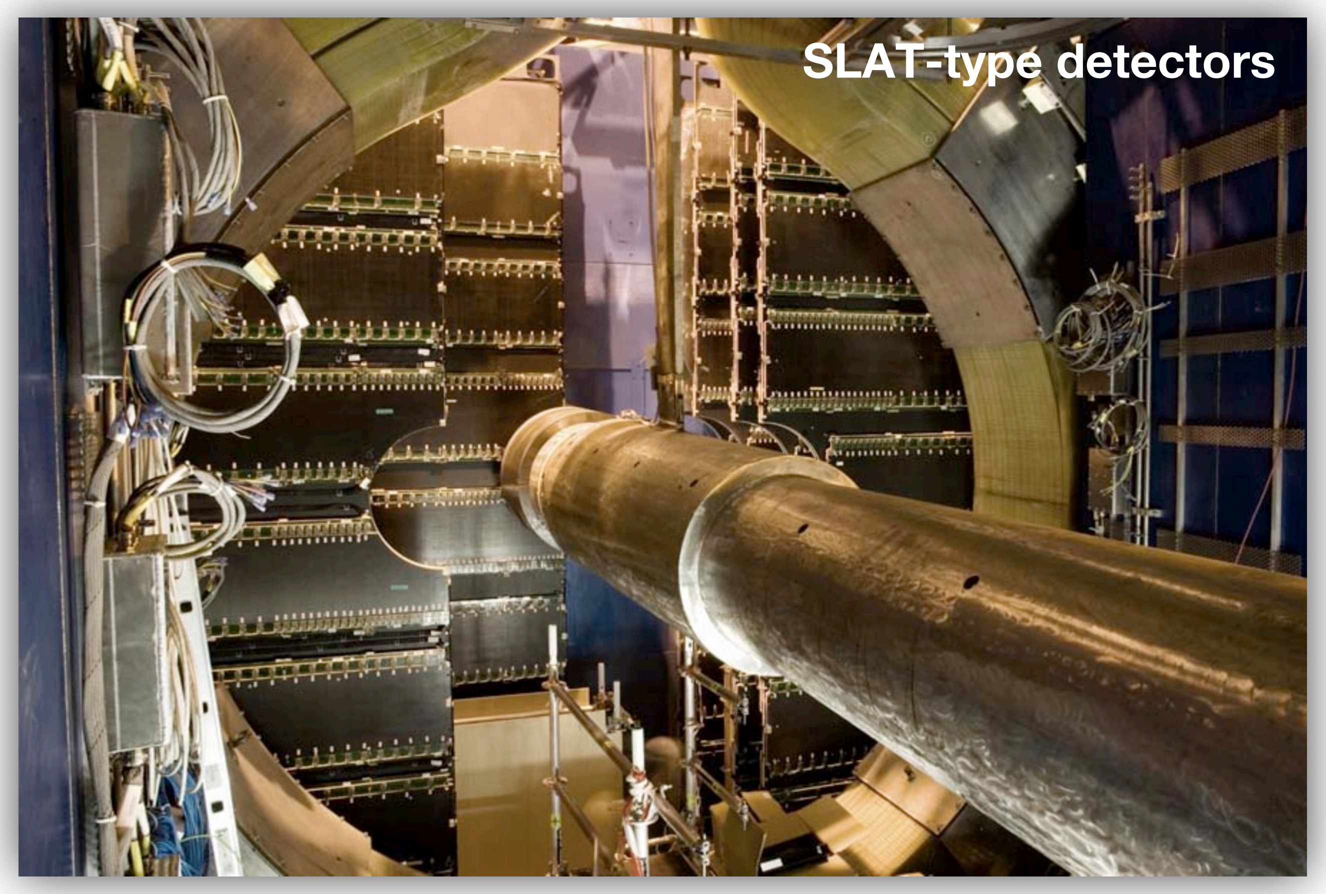




The Muon Tracking

- 10 planes of Cathode Pad Chambers (CPC) arranged in 5 stations
  - Stations 1&2 quadrant type (3 pad segm.)
  - Stations 3, 4, 5 slats type (3 pad segm.)
- CPC
  - Gas mixture Ar/CO_2 80:20, gap 5 mm (4.2 mm St. 1)
  - Gain of ~10^4, HV ~ 1650 V
  - Spatial resolution of ~100 μm and ε ~100%
- 156 detection elements, 1.1 M channels

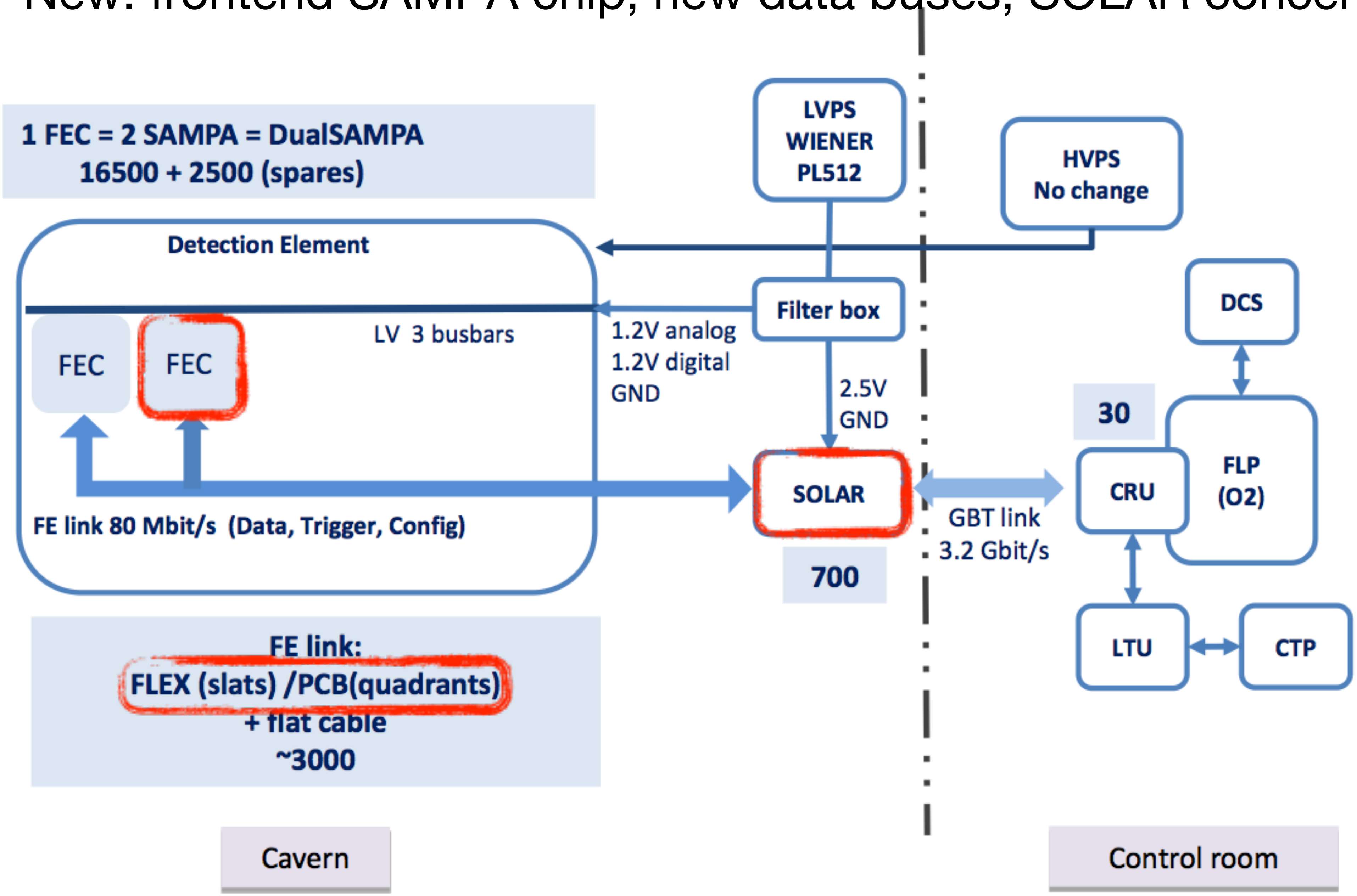




Only the CPC readout electronics will be upgraded during LS2

MUON Tracking Upgrade

- Replacement of the current electronics (FEE, Data bus, Readout)
- New: frontend SAMPA chip, new data buses, SOLAR concentrator card, CRU

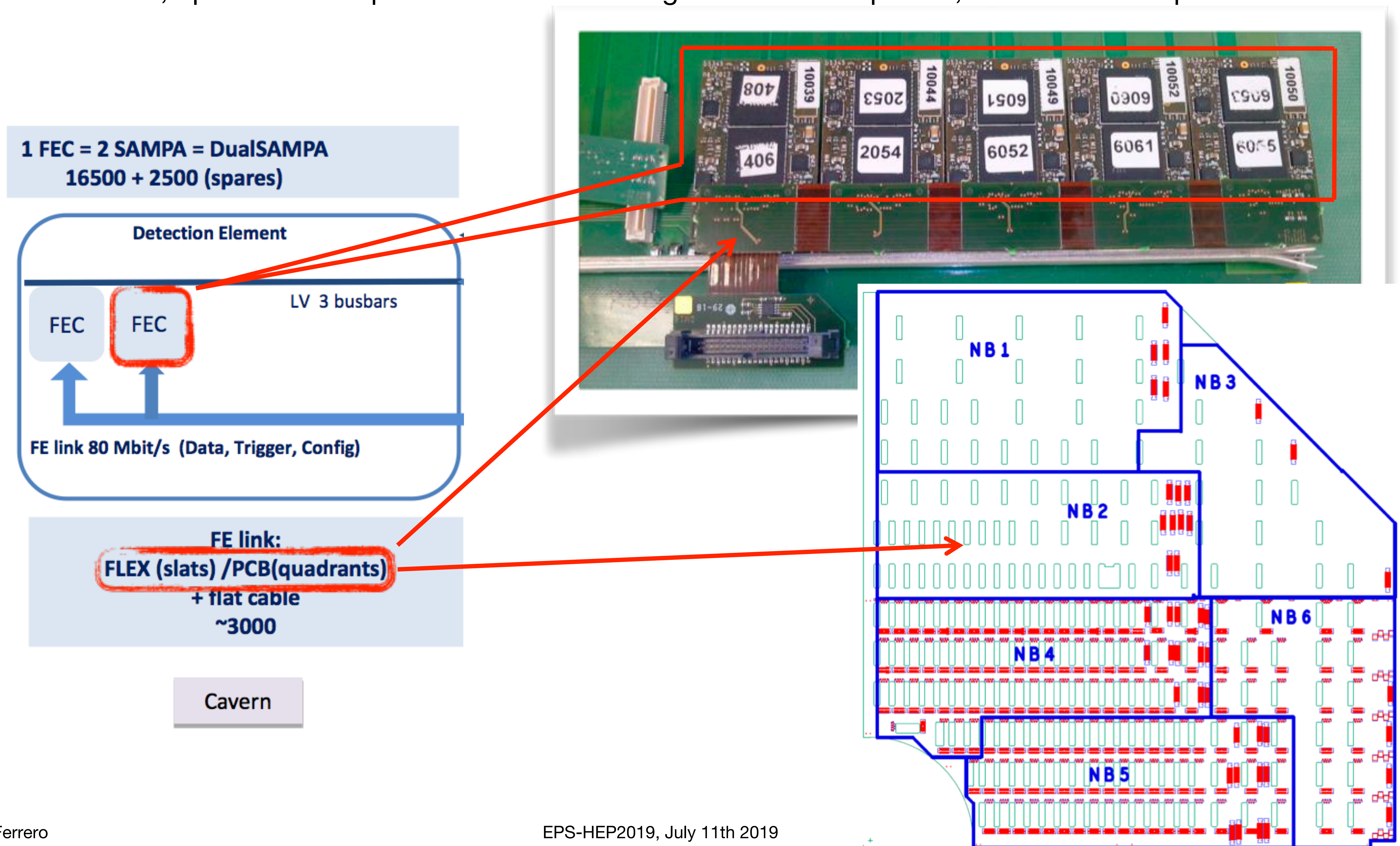


SAMPA: Brazil
CRU: Hungary, India

FEC: Orsay
FLEX: Cagliari
SOLAR : Saclay
CRU: India (Kolkata,Aligarh)
LV: South Africa

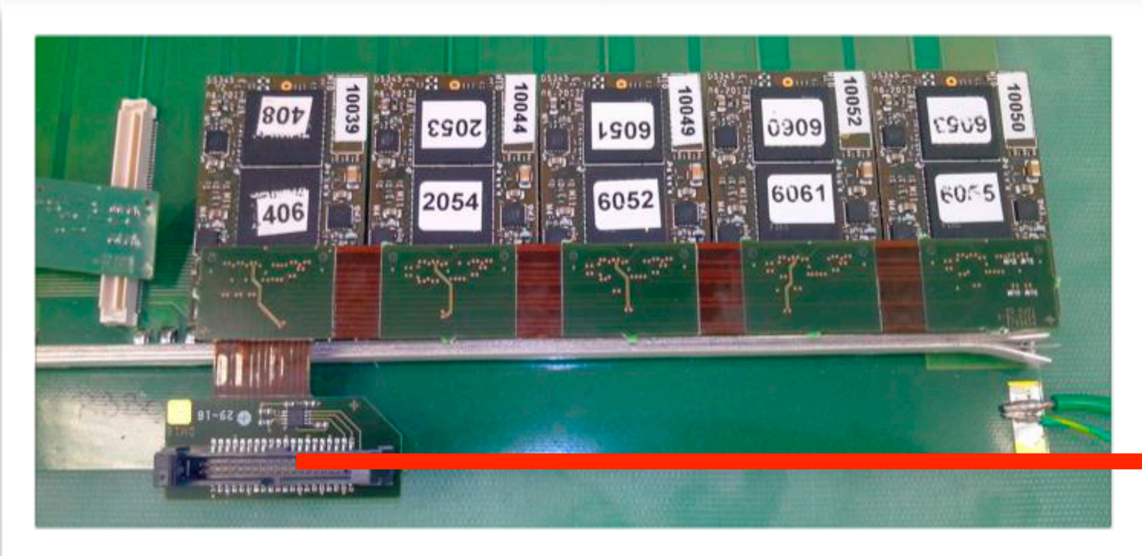
DualSAMPA Frontend Electronics

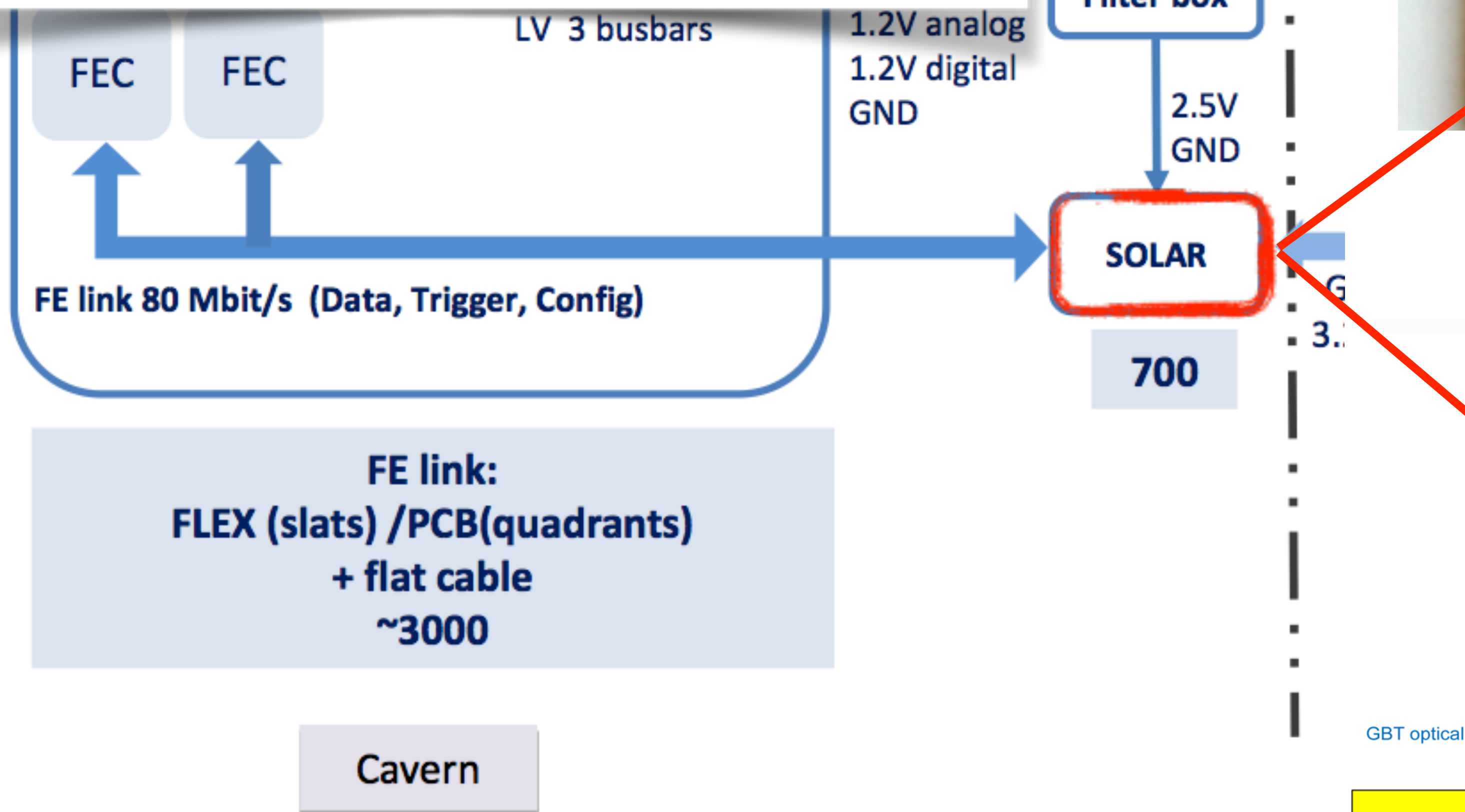
- DualSAMPA FEE based on new SAMPA ASICs
  - On-chip **zero suppression** and **continuous readout** (up to 1.28 Gbps)
  - 10 bits, up to 20 Msamples/s ADCs with Charge Sensitive Amplifiers, 32 channels/chip

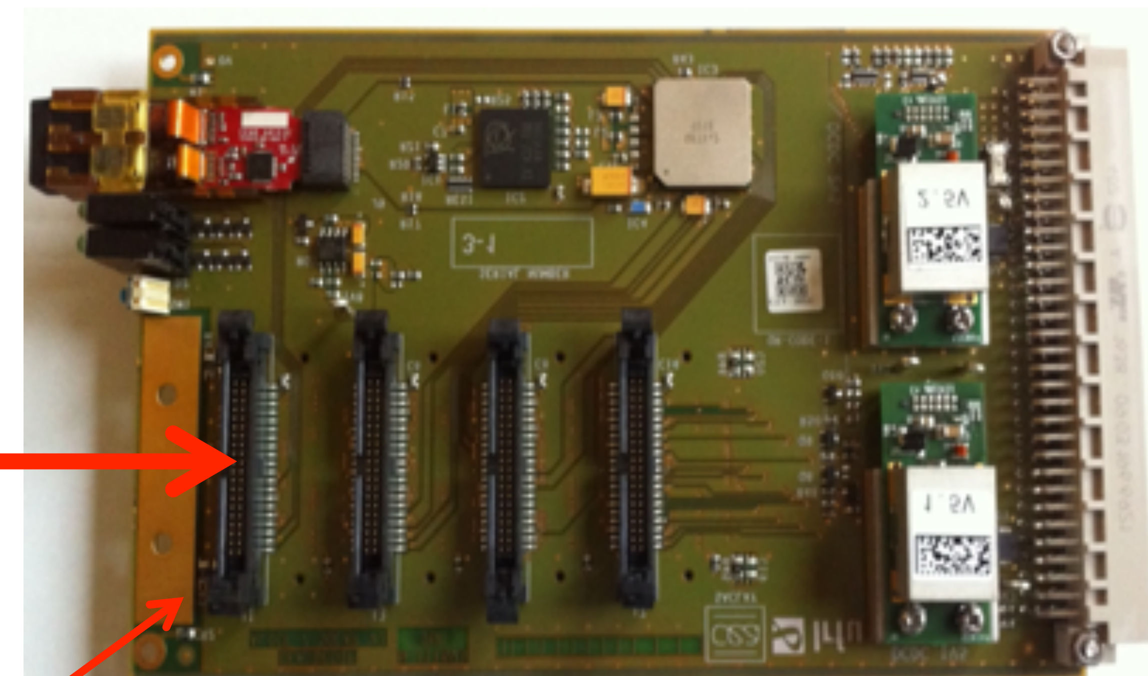


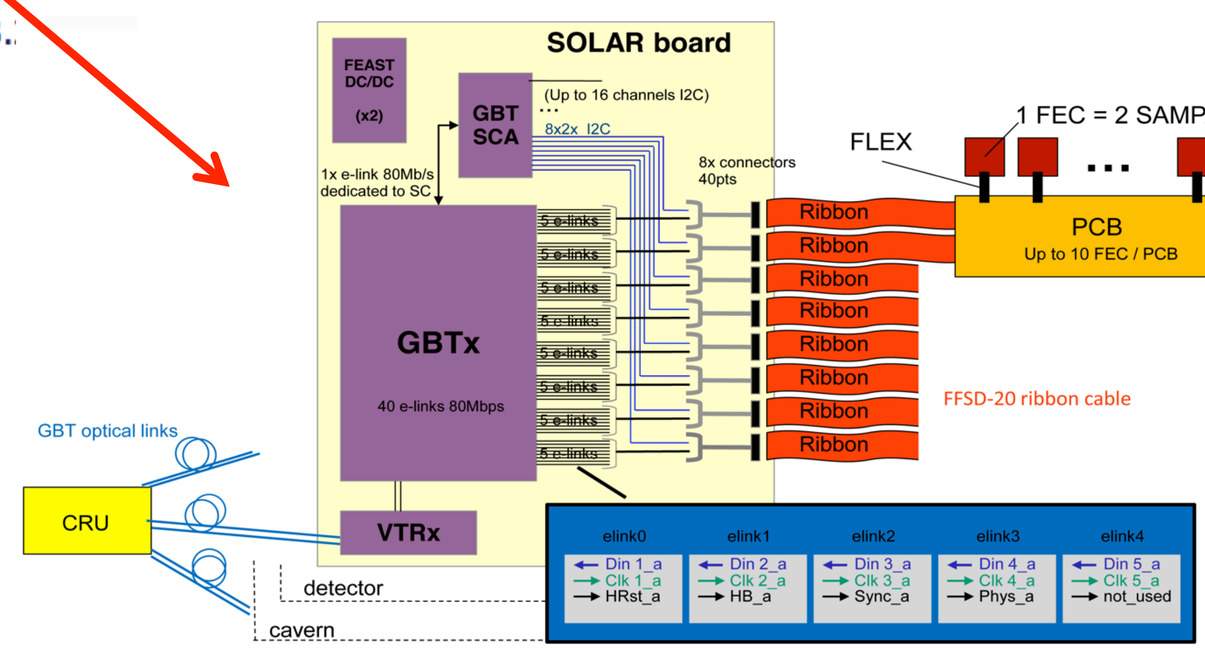
SOLAR Data Concentrator Board

- Data from 80 SAMPA chips collected and transferred via optical uplink
- Based on GBTx chip from CERN









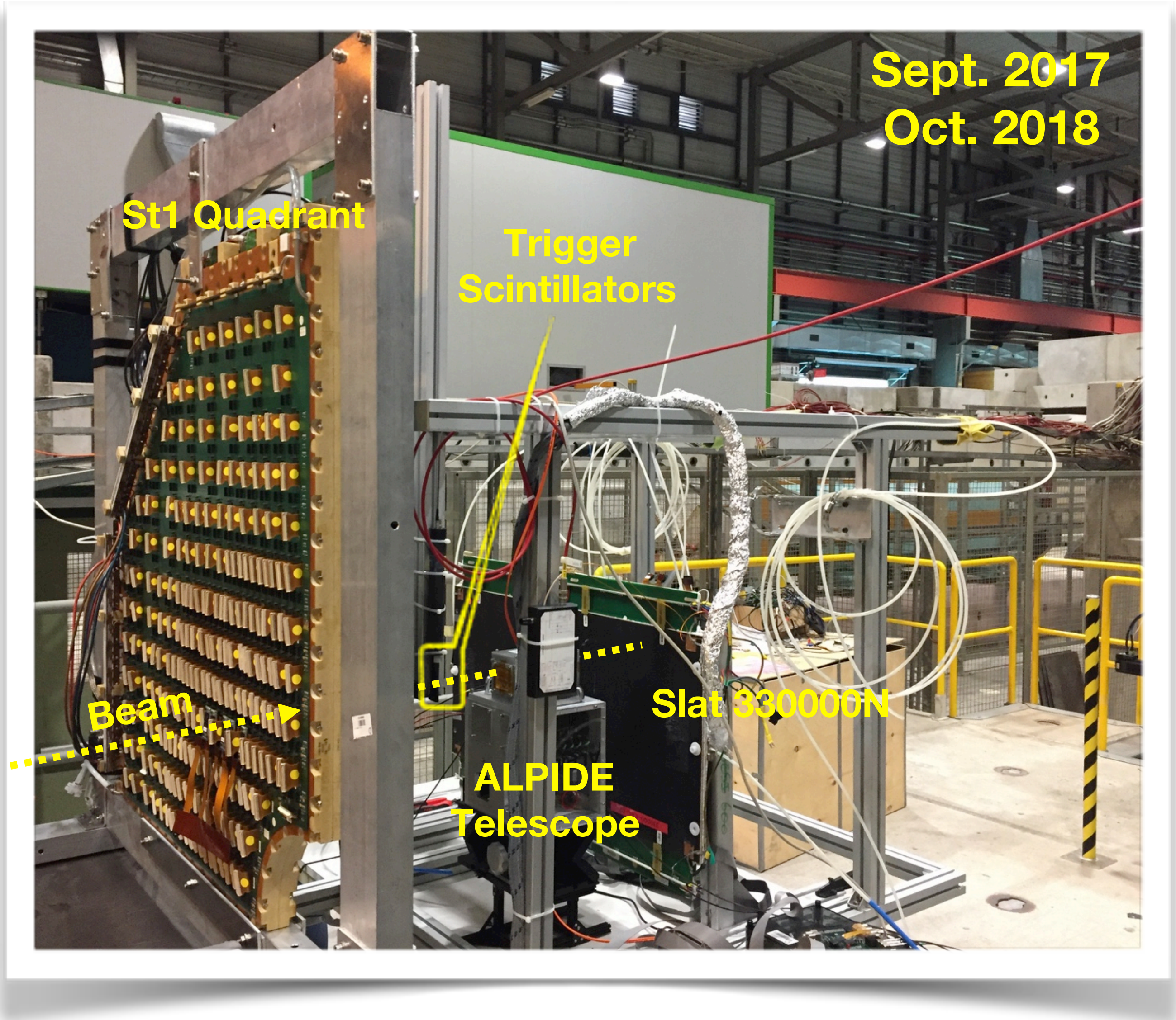
Alice-MCH christophe.flouzat@cea.fr bernard.paul@cea.fr

Testbeam Results

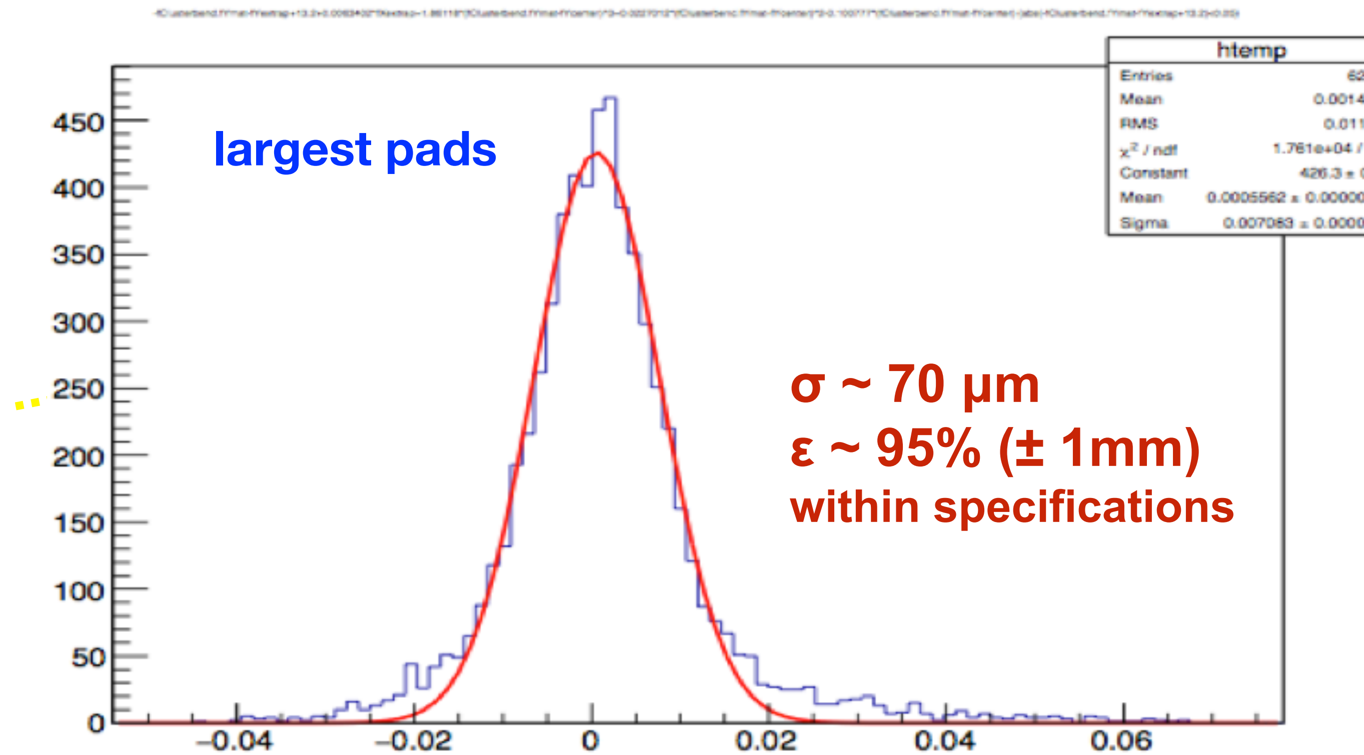
Validation of the full readout chain

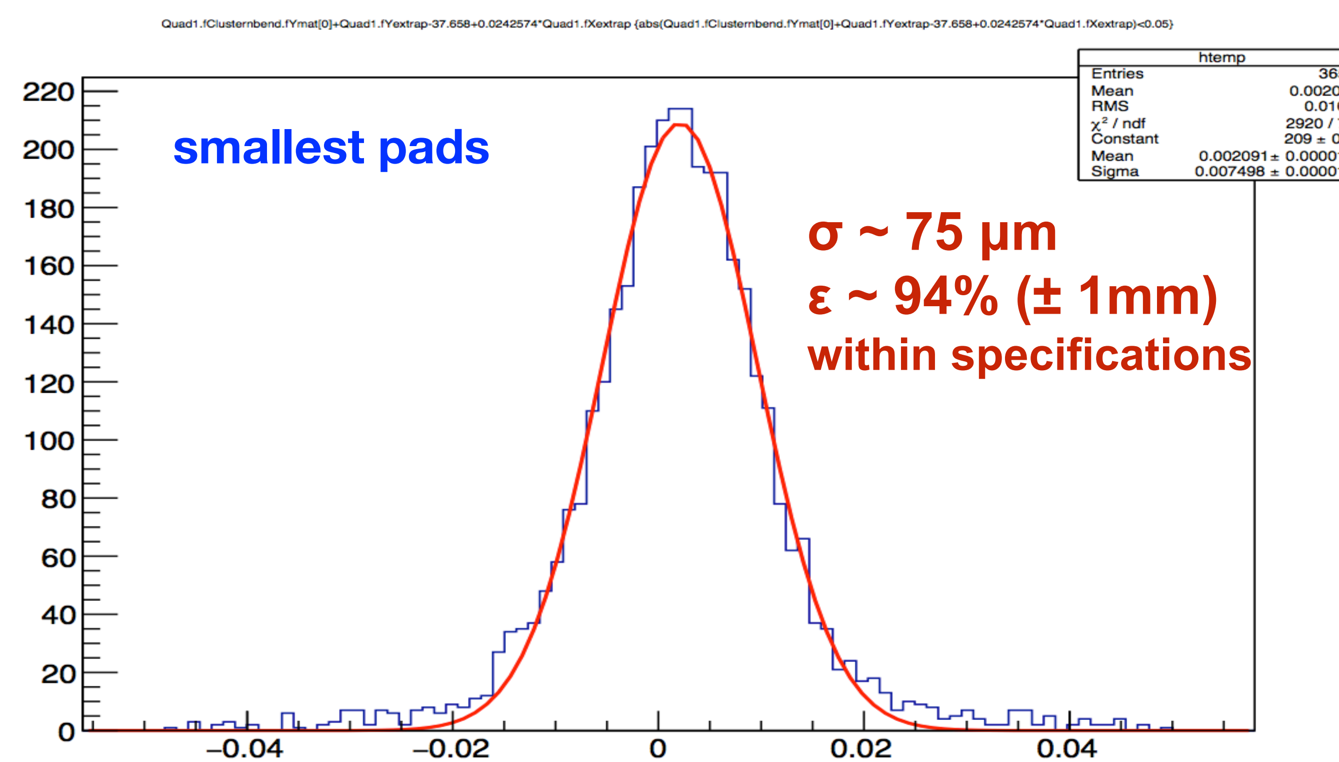
@ SPS in Sept. 2017 / Oct. 2018

20 GeV/c muon beam

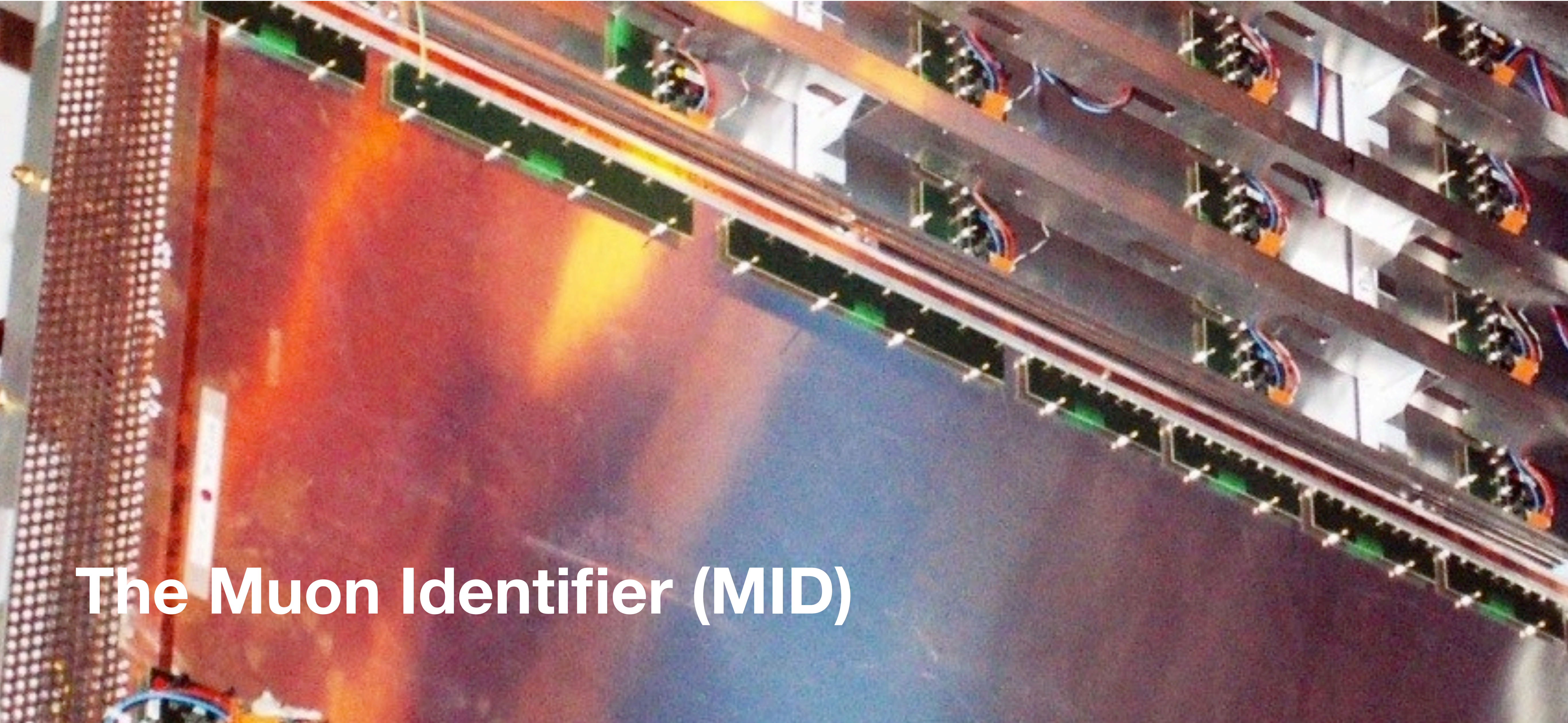


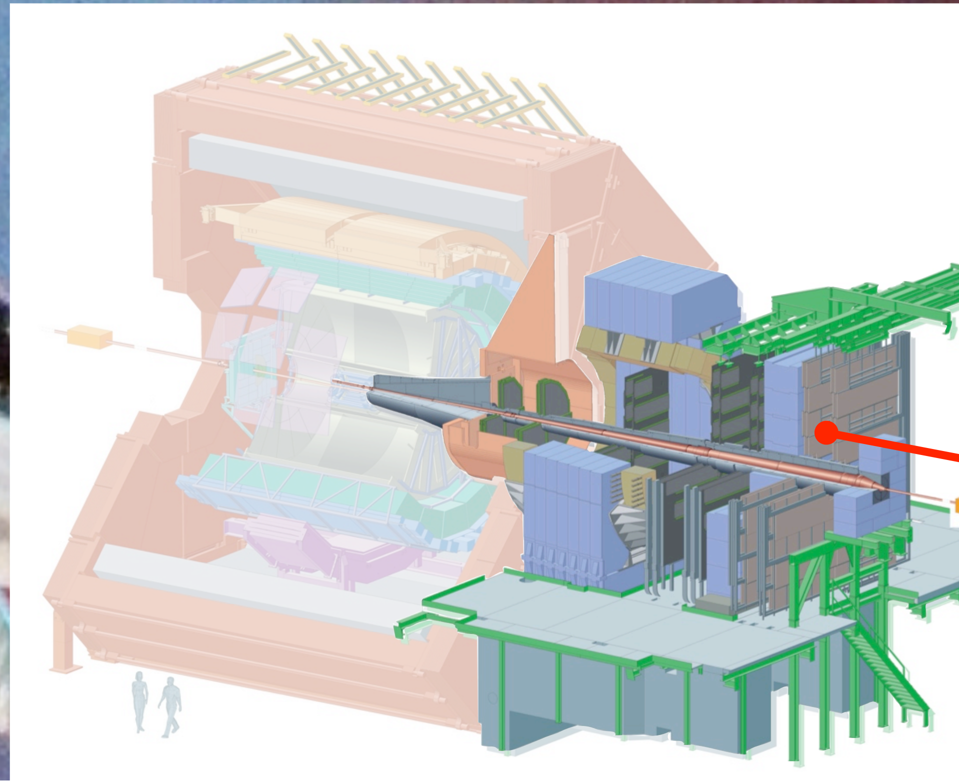
Spatial Resolution

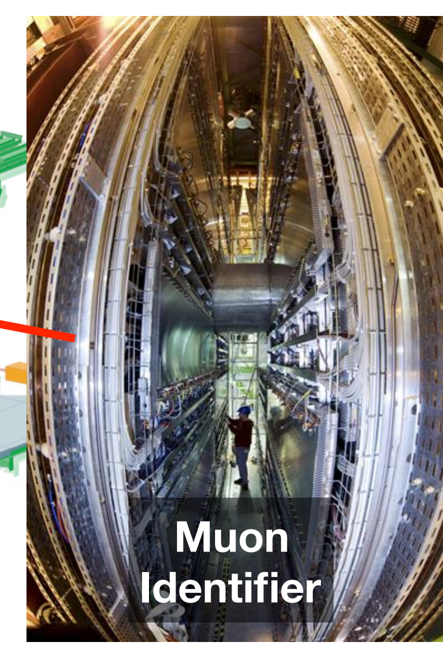




The Muon Identifier (MID)

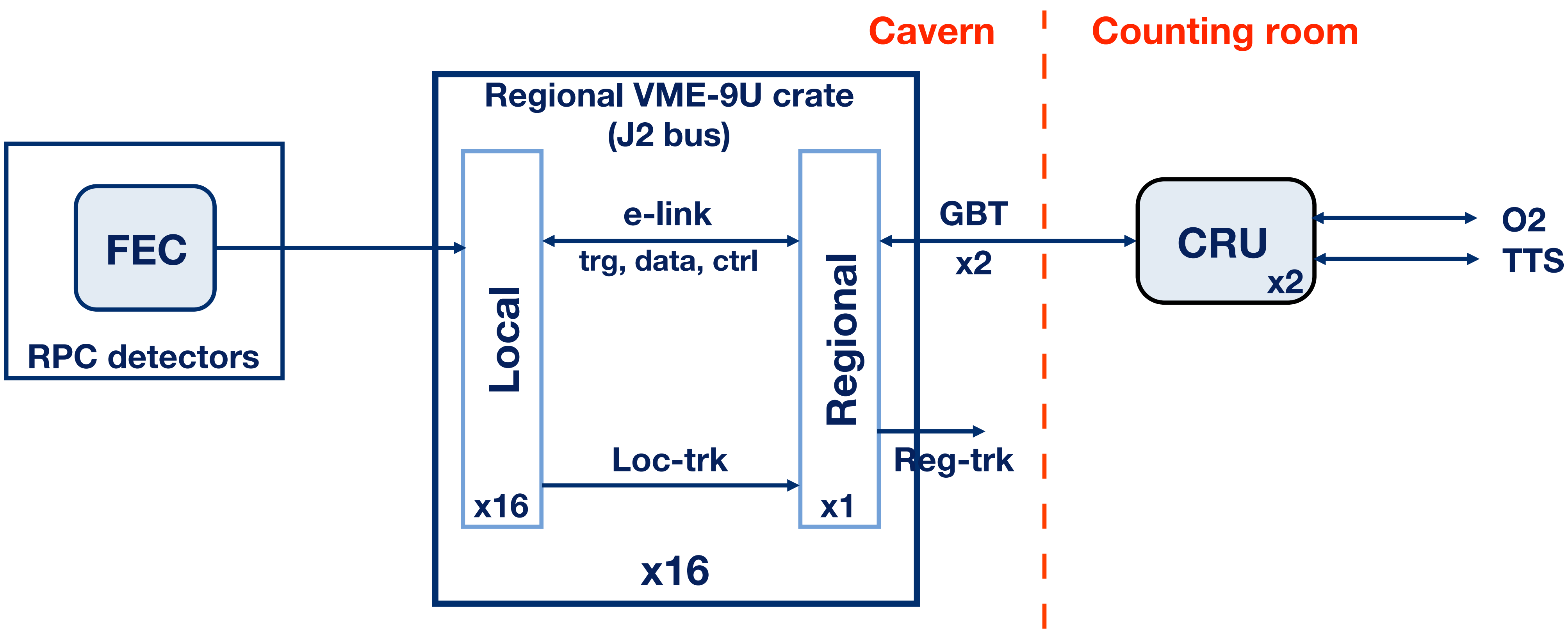






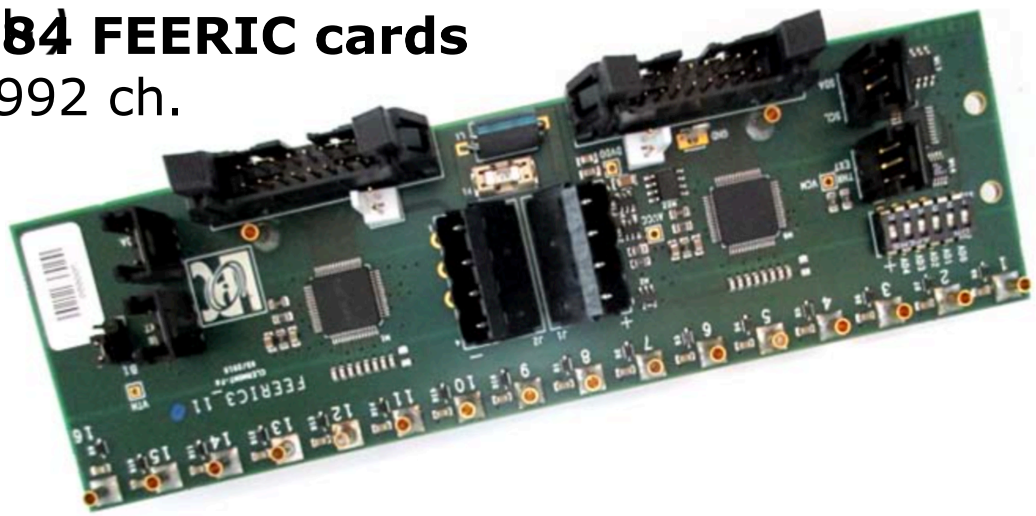
The Muon Identifier Upgrade

- No hardwired trigger anymore => <u>continuous readout mode</u>
  - Replacement of the current readout electronics (Regional, Local, J2-bus)
- Slow down the aging of the RPCs after LS2
  - Solution: Front-end electronics <u>with amplification</u>

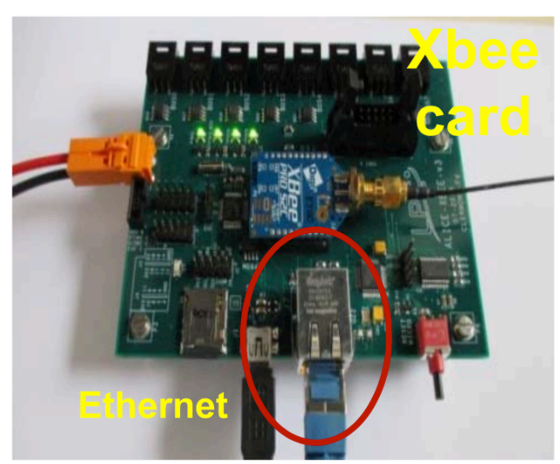


MID FEE Upgrade: The FEERIC project

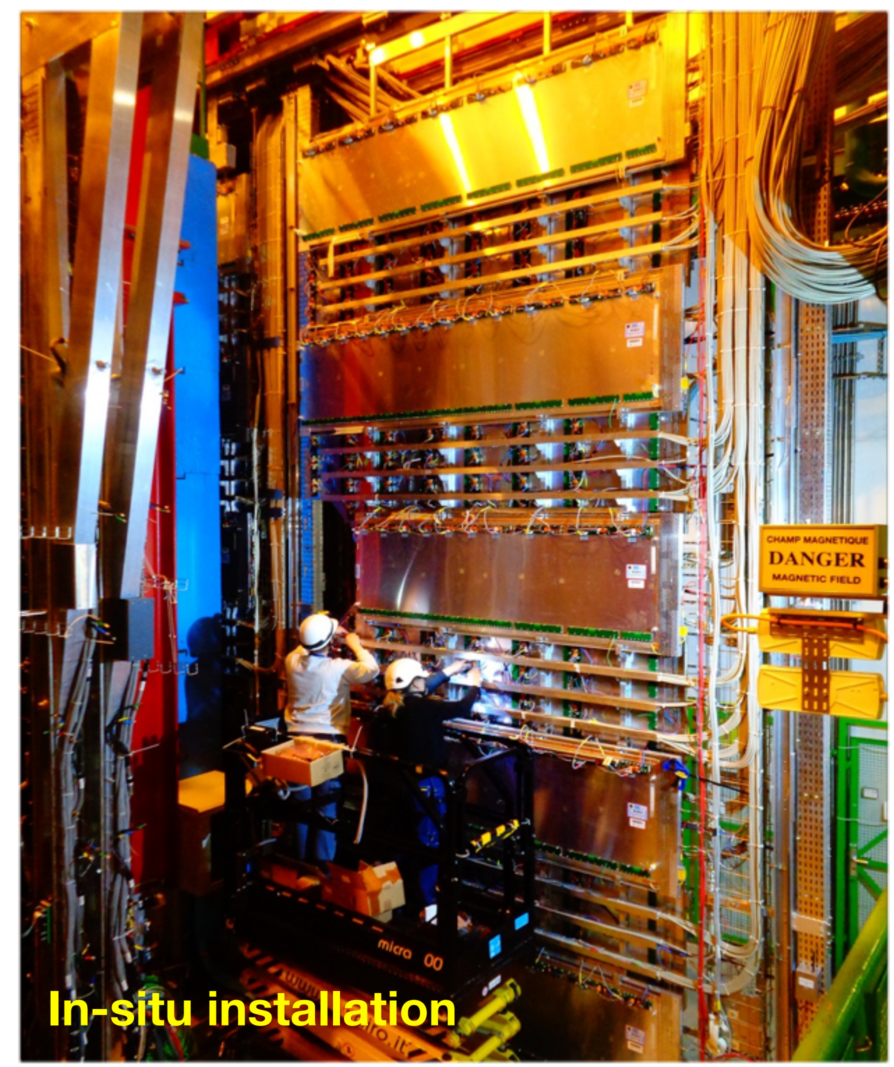
- ***Goal: slow down RPC aging after LS2***
  - FE **with amplification** (**FEERIC**) for RPCs
  - **2384 FEERIC cards**
    20992 ch.



- ***Factor 4 less charge released in the RPC gas => reduced aging***
- ***New wireless threshold distribution***
  - Threshold setting per FEERIC card
  - ZIGBEE protocol from master to node

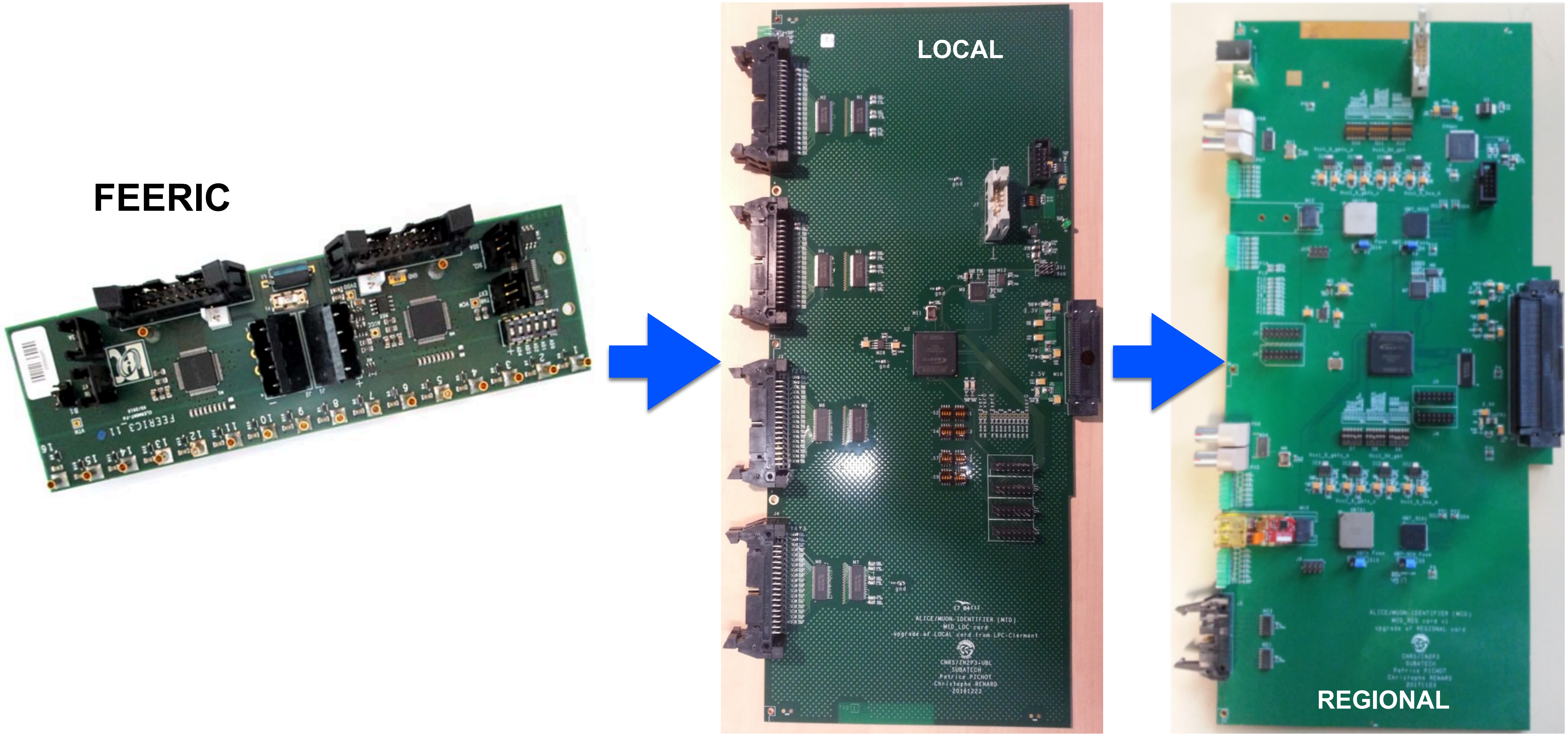


- ***Project status***
  - **Production and installation completed**
  - **Commissioning from 2nd half of 2019**



MID Readout Upgrade

- ***Replacement of the 234 Local cards and of the 16 Regional cards presently in operation***
- ***Readout electronics for continuous mode***
  - Regional card interfaced with CRU via 2 GBTs
- ***Production ongoing***



Summary and Schedule

- **Muon Forward Tracker (MFT)**
  - **New** detector for **displaced vertex reconstruction** and **improved S/B** for di-muon resonances
  - Production and assembly: **first half MFT -> June 2019, second half MFT -> December 2019**
  - Commissioning and installation: **Surface -> December 2019, Cavern -> April 2020**

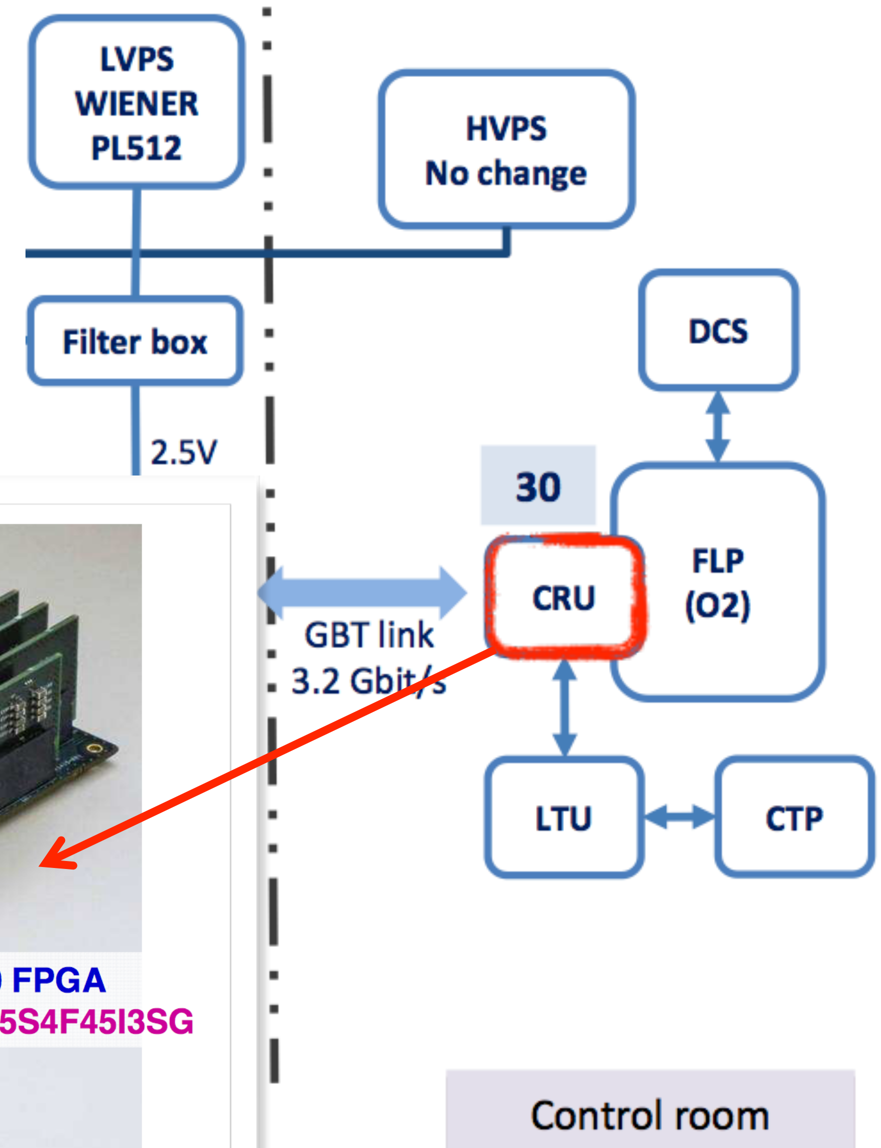
- **Muon Tracking**
  - Electronics production**: DualSAMPA -> 03/2020, SOLAR -> 10/2019**
  - Stations 1 & 2 readout replacement: **November 2019 to July 2020**
  - Stations 3, 4, 5 readout replacement: **August 2019 to June 2020**
  - Readout commissioning in parallel with installation

- **Muon Identifier**
  - FEERIC readout and threshold boards already installed, commissioning ongoing
  - Local and regional boards: **January 2019 to October 2019**

Backup Slides

Common Readout Unit (CRU)

- Up to 24 bi-directional front-end links based on the Versatile Link and the GigaBit Transceiver (GBTx) chip
- Common development with LHCb
- First-level processing: **data compression and formatting**



SAMPA: Brazil
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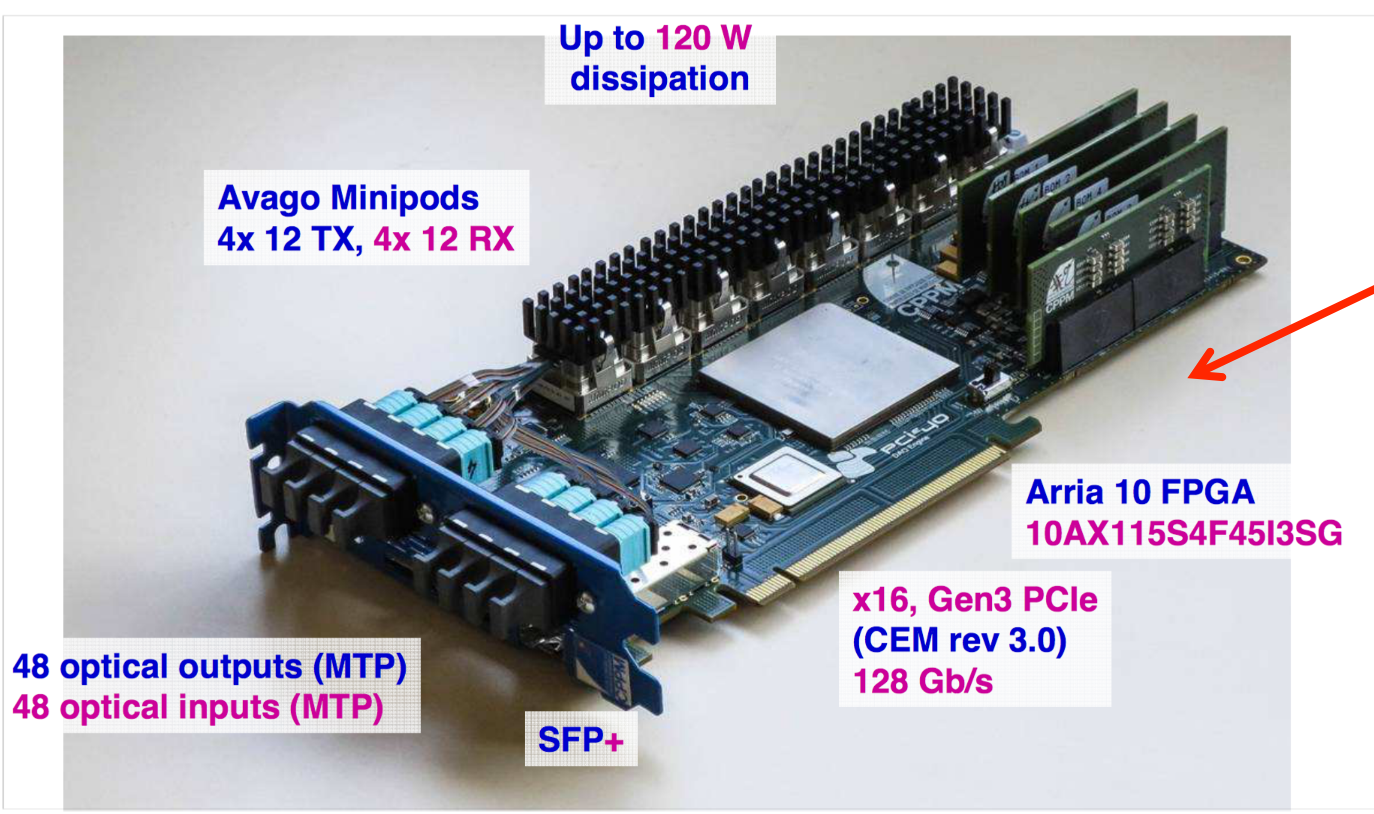

DualSampa to SOLAR

- Quadrants St.1,2
  - 6 (St1) or 8 (St2) PCBs per cathode
  - Prototypes already tested
  - St 1: end of prod by Nov.
  - St 2: end of prod by Sept.
- Slats St. 3,4,5
  - 5 DualSampa per flex (hybrid circuit)
  - Tendering done. Company about to be chosen
  - Pre-series by mid May
  - Prod by end of June