Upgrades and performances of ALICE on muon detection at forward rapidities for LHC Run 3

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for the ALICE collaboration

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Outline

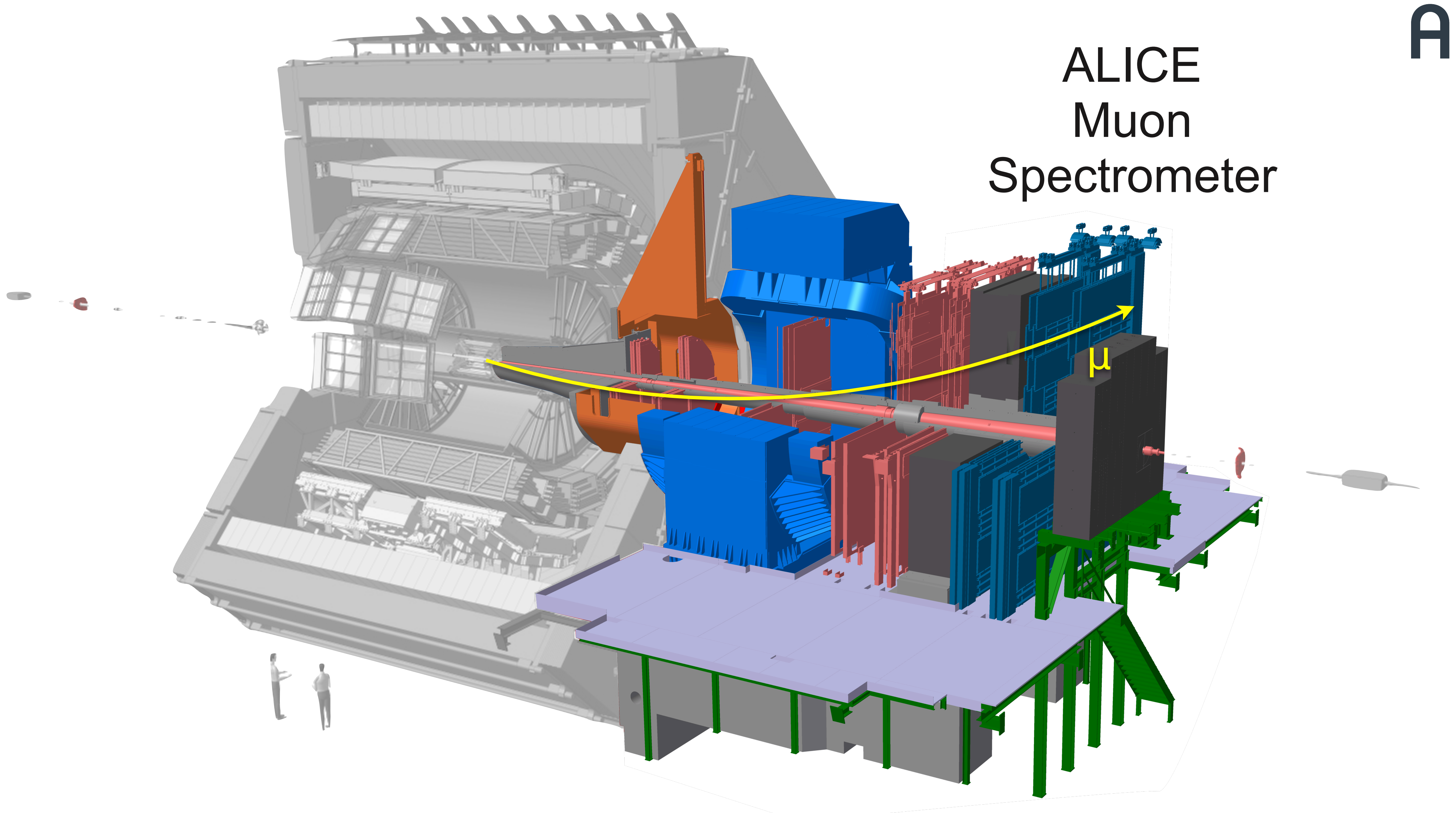
- Muon detection at forward rapidities with ALICE:
  - Physics case
  - Limitations of runs 1 and 2 set-up

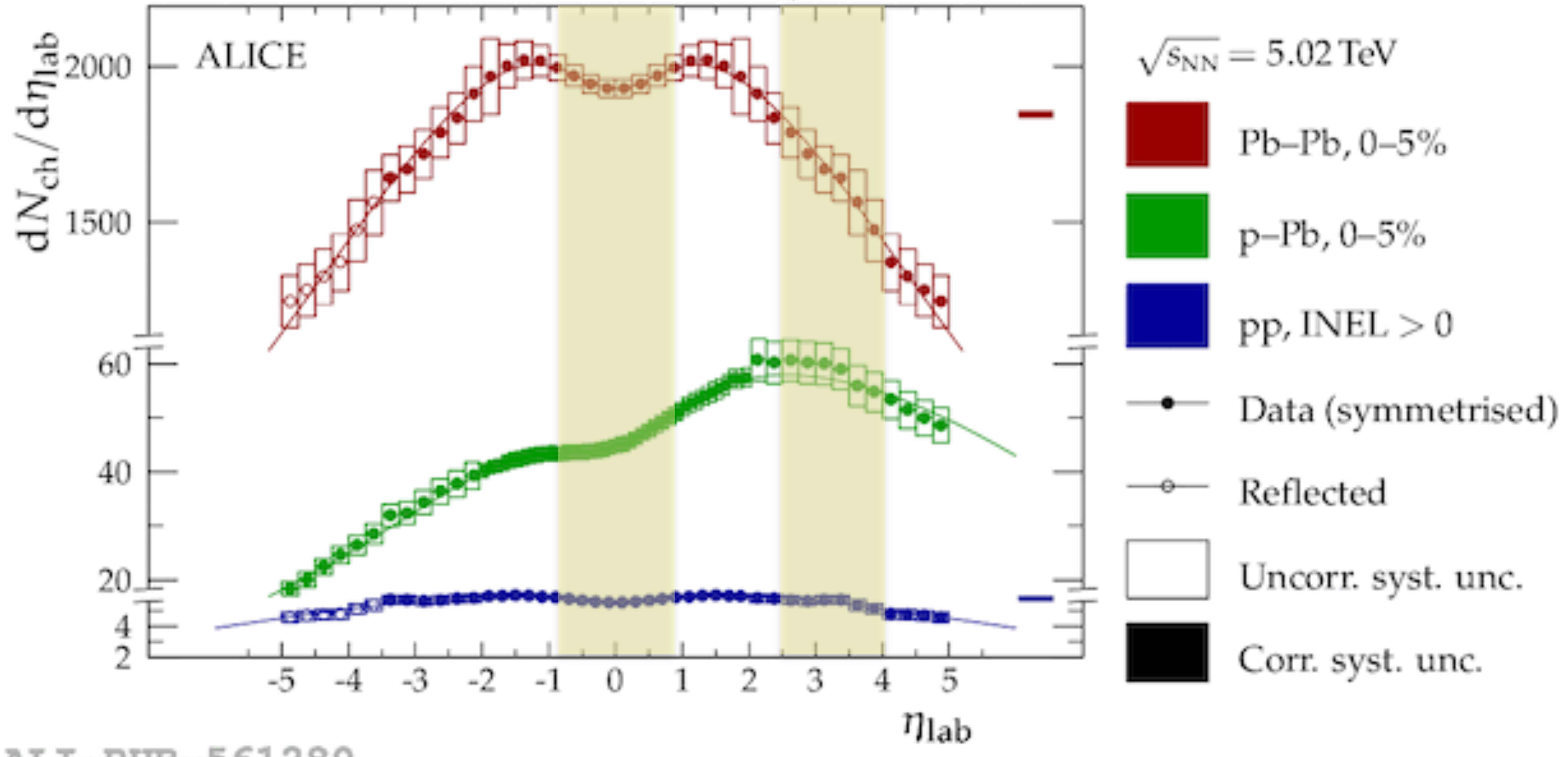
- Upgrades of muon detection for runs 3 and 4:
  - Upgrade of existing detectors
  - Installation of a new detector (Muon Forward Tracker)

- First performance results:
  - Data taking
  - Performance on charm/beauty separation

Probing QGP at forward rapidities with ALICE

- ALICE (LHC,CERN):
  - Designed to study quark-gluon plasma (QGP)
  - Collisions: Pb-Pb, p-Pb, Xe-Xe, pp
- Forward rapidity:
  - Detector: Muon Spectrometer
    $2.5 < \eta < 4$ / $2° < \theta_\mu < 9°$
  - Different region of the QGP
    Complementary to central barrel ($|\eta|<0.9$)
- Heavy flavours:
  - Created early in the collision
    Production by hard processes
  - Experience the full collision
    Sensitive to the medium (QGP or not)
- Quarkonia:
  - Historical probe for QGP
    Matsui & Satz - *Phys.Lett.B* 178 (1986) 416-422
  - Suppression/regeneration in QGP
    Debye screening / kind of QGP thermometer
  - Acceptance down to $p_T = 0$

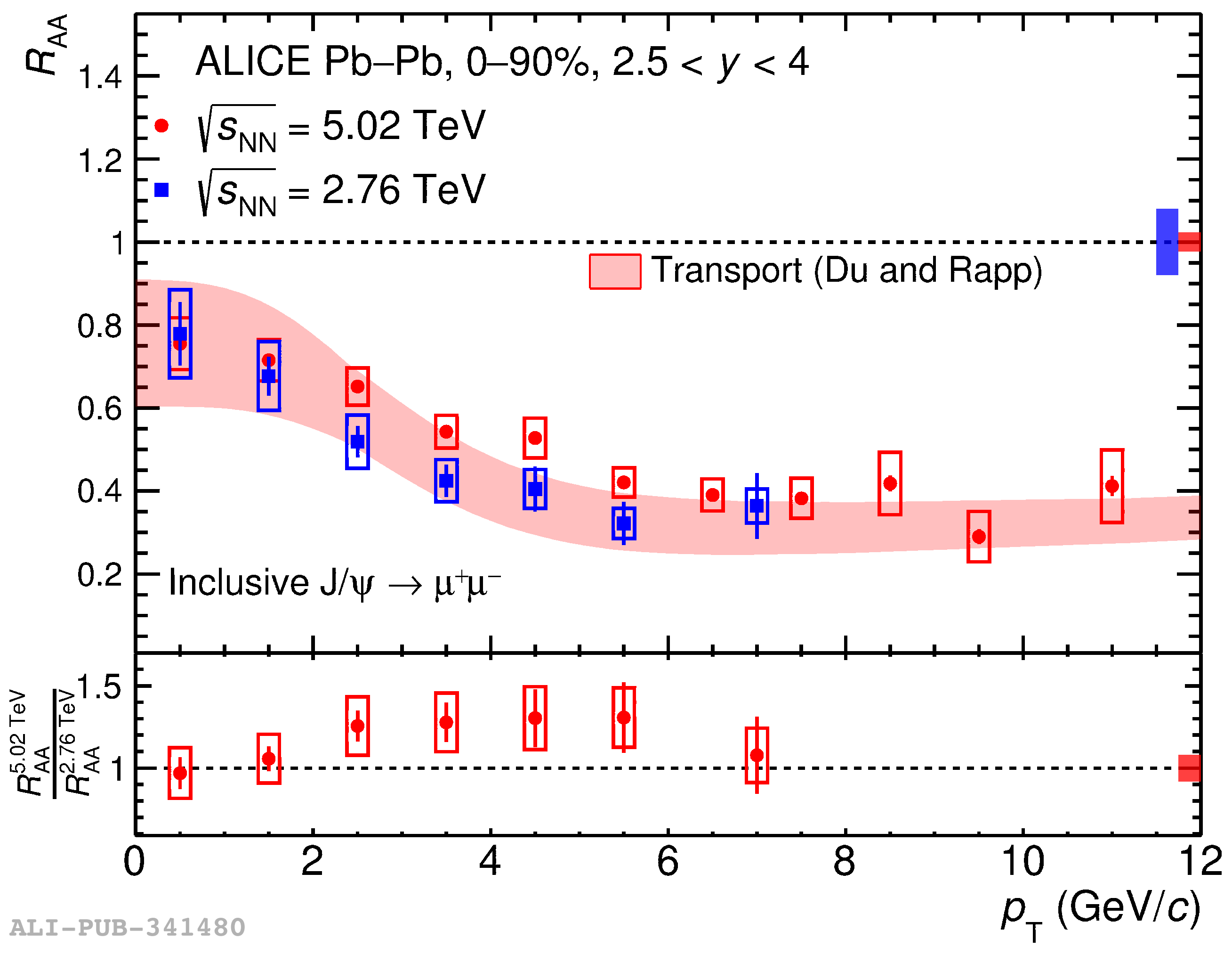


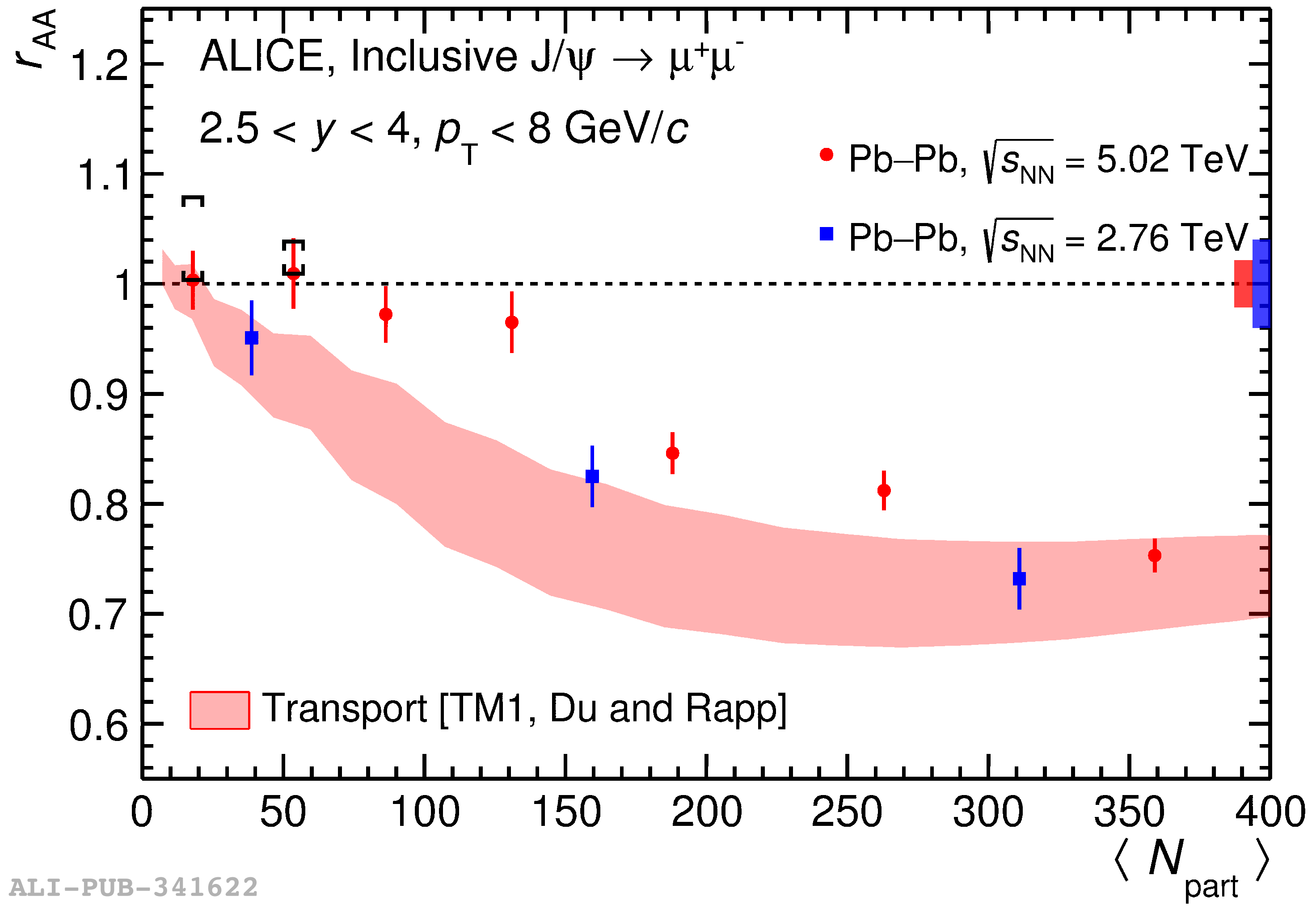


ALI-PUB-561280

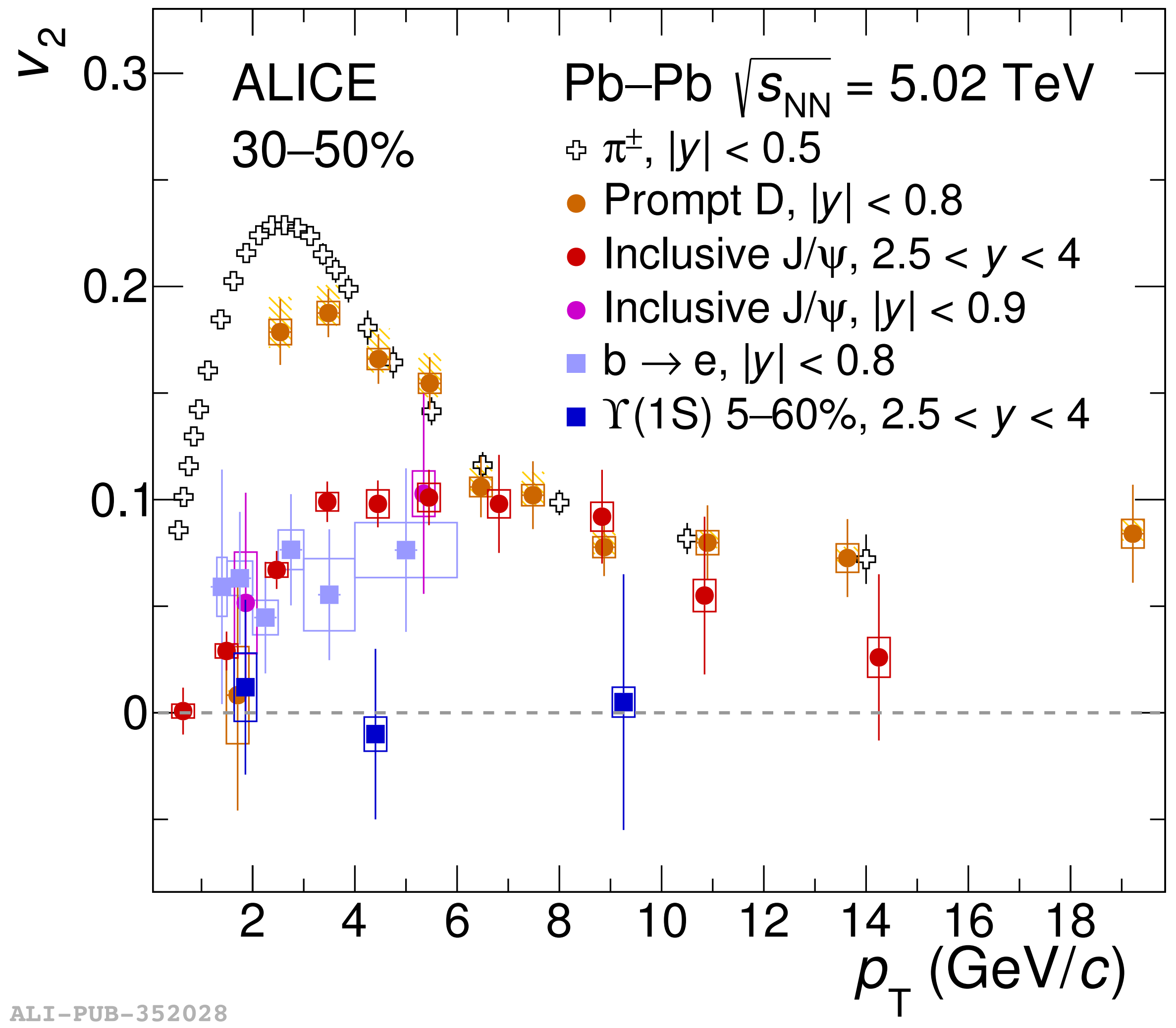
Selection of results on quarkonia for Runs 1 and 2

- J/ψ suppression vs regeneration in Pb-Pb

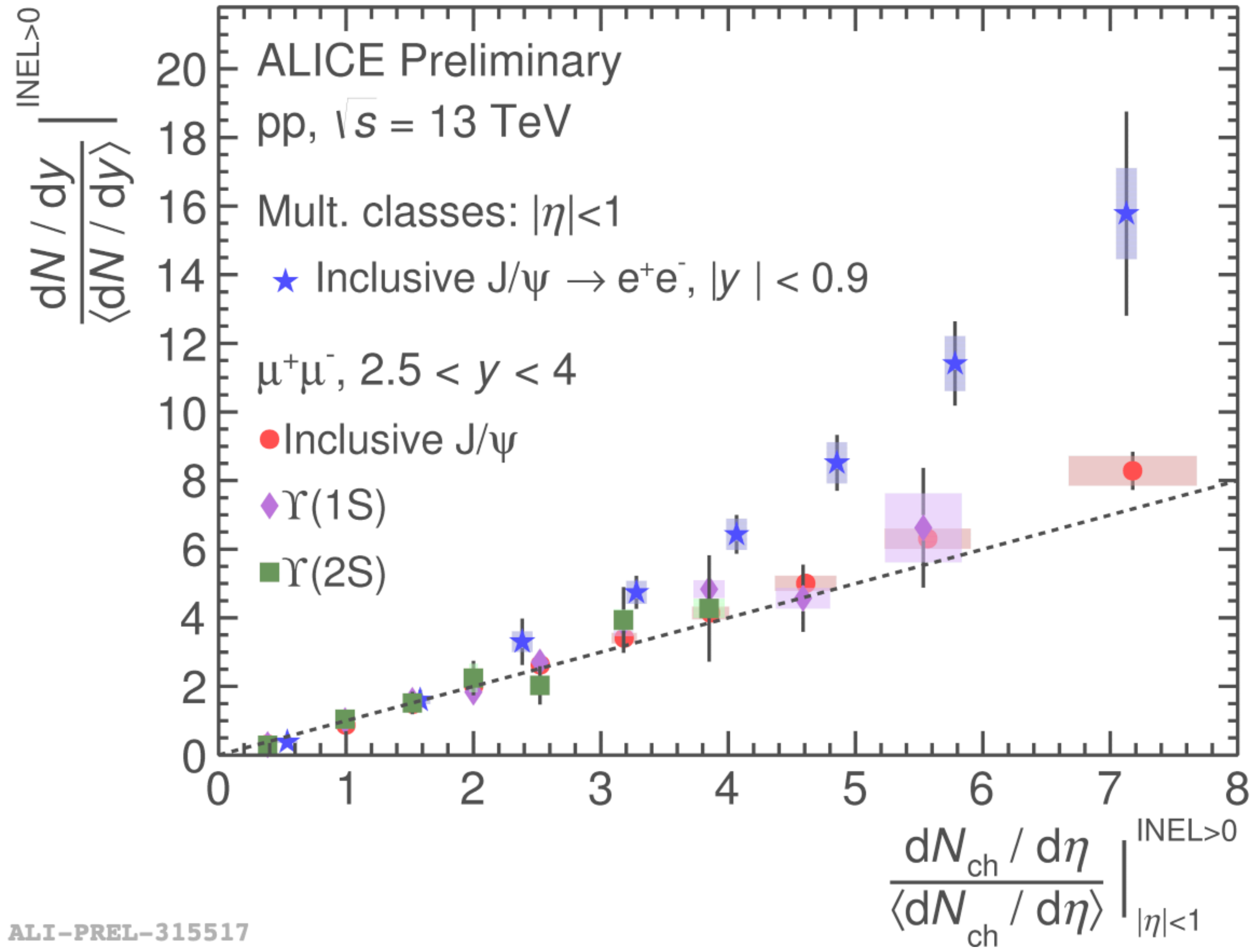




- J/ψ thermalisation ($v_2 \neq 0$) in Pb-Pb



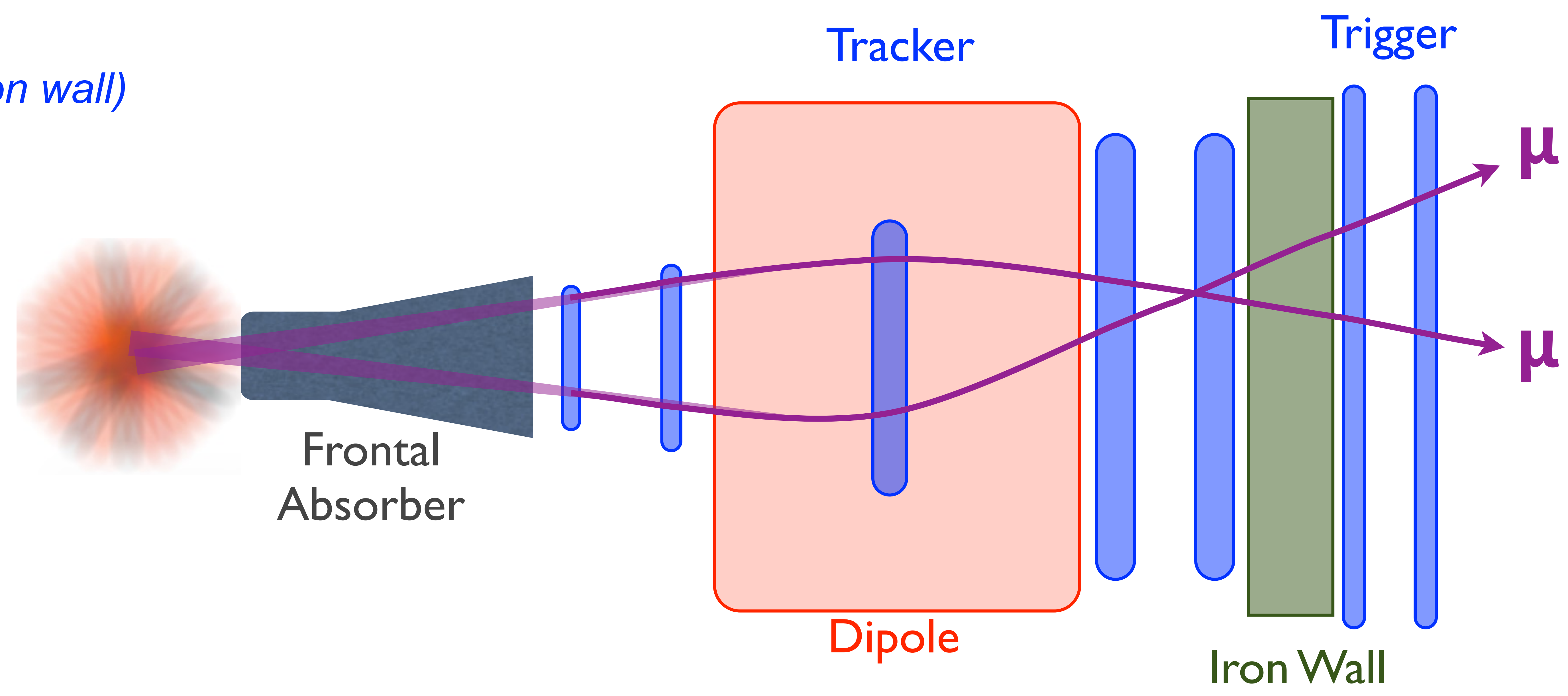
- Collective effects on J/ψ production in high multiplicity pp



and many more…

Limitation of the Muon Spectrometer

- Muon filter:
  - Frontal absorber: 60 X_0
  - Muons: p_{min} = 4 GeV/c *(including the iron wall)*
  - ⇨ limited spatial resolution around the IP region



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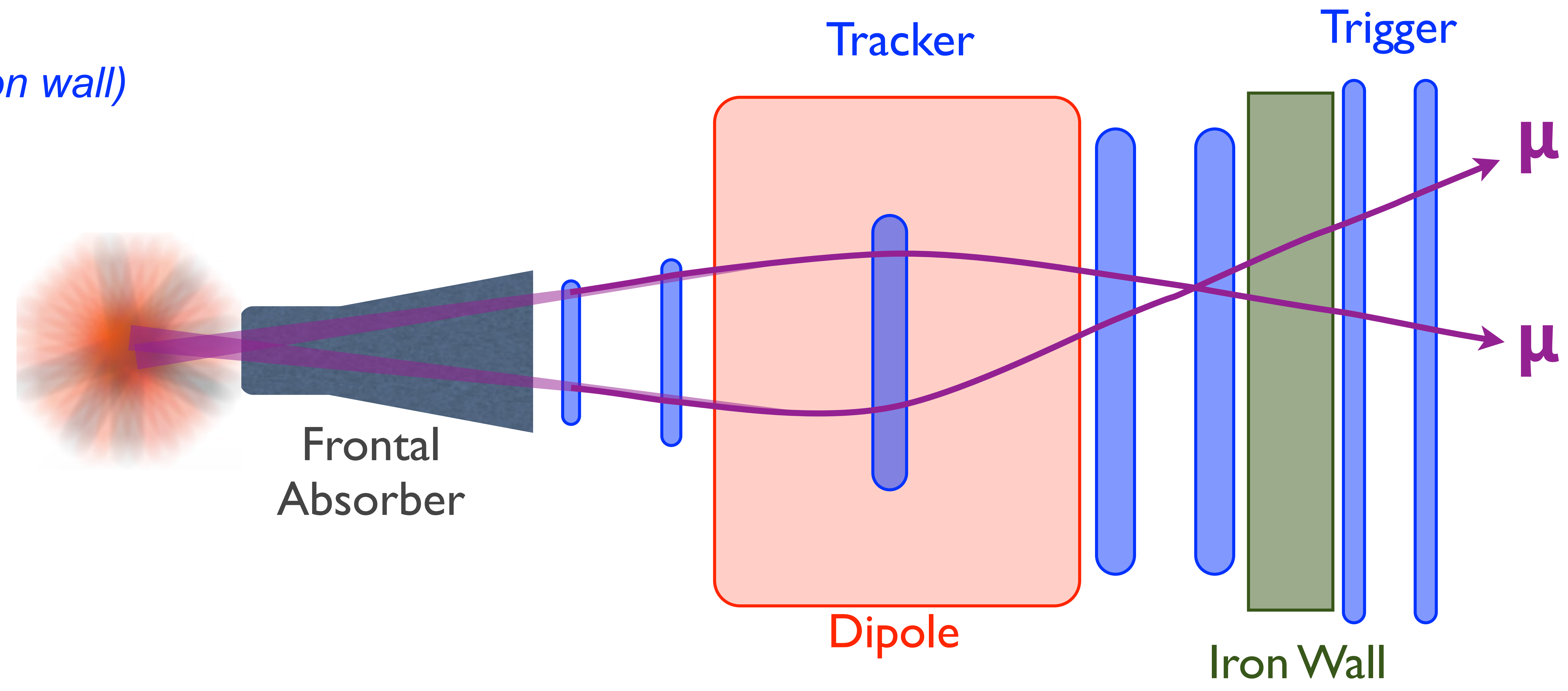
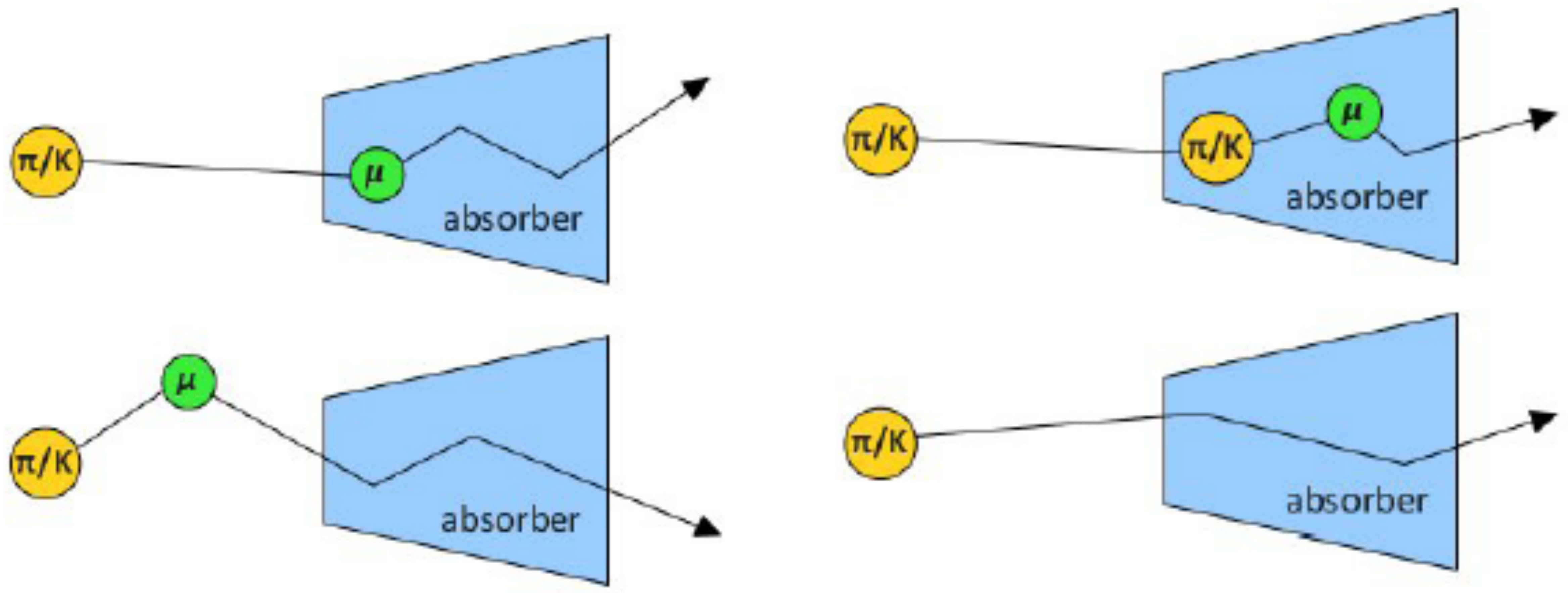


- Inclusive measurement:
  - No charm/beauty separation
    open heavy flavour
    J/ψ: B feed-down (est. ~20%)
  - Hadronic background



	$\pi^\pm$	$K^\pm$	D^0	$D^\pm$	$B^\pm$	J/ψ
$c\tau$ (μm)	7.8×10^6	3.7×10^6	123	312	491	~ 0

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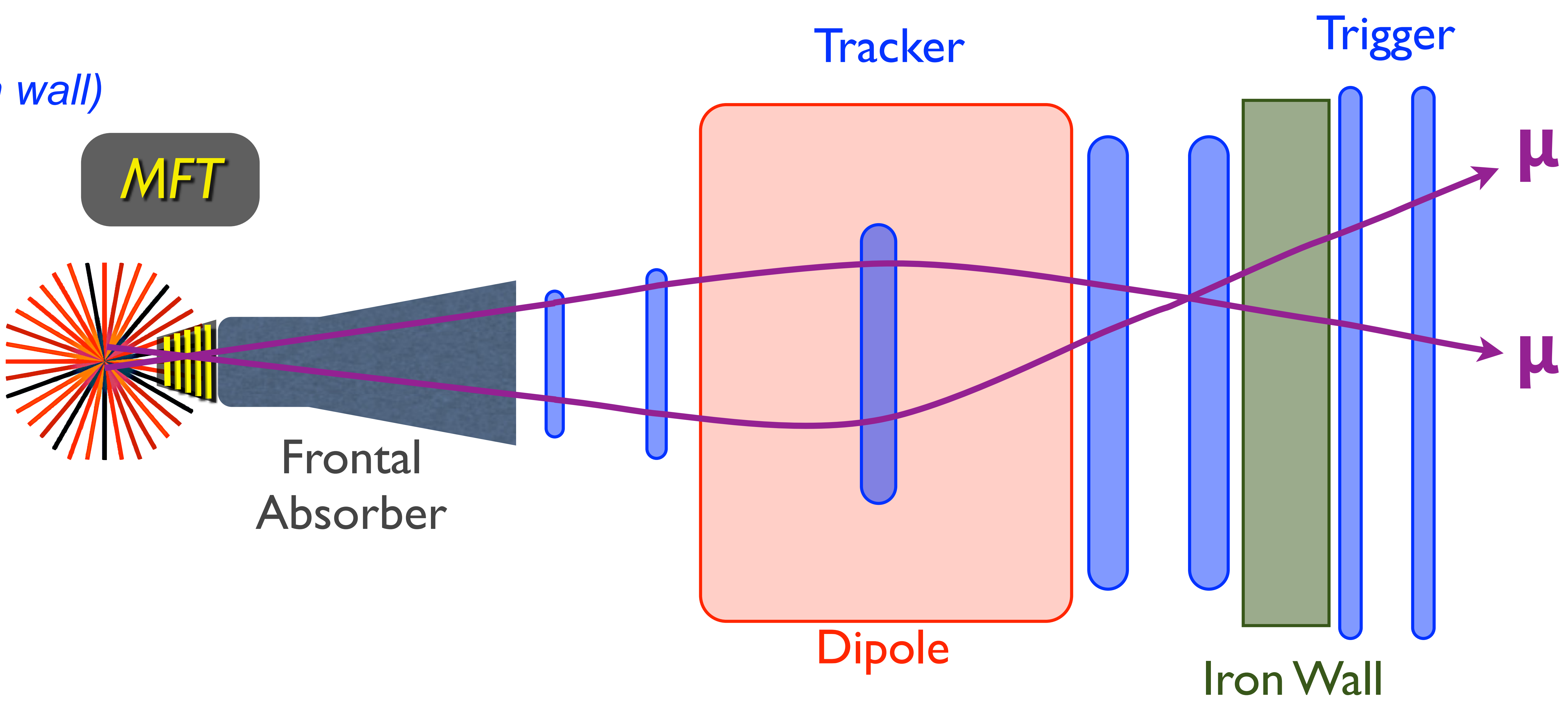

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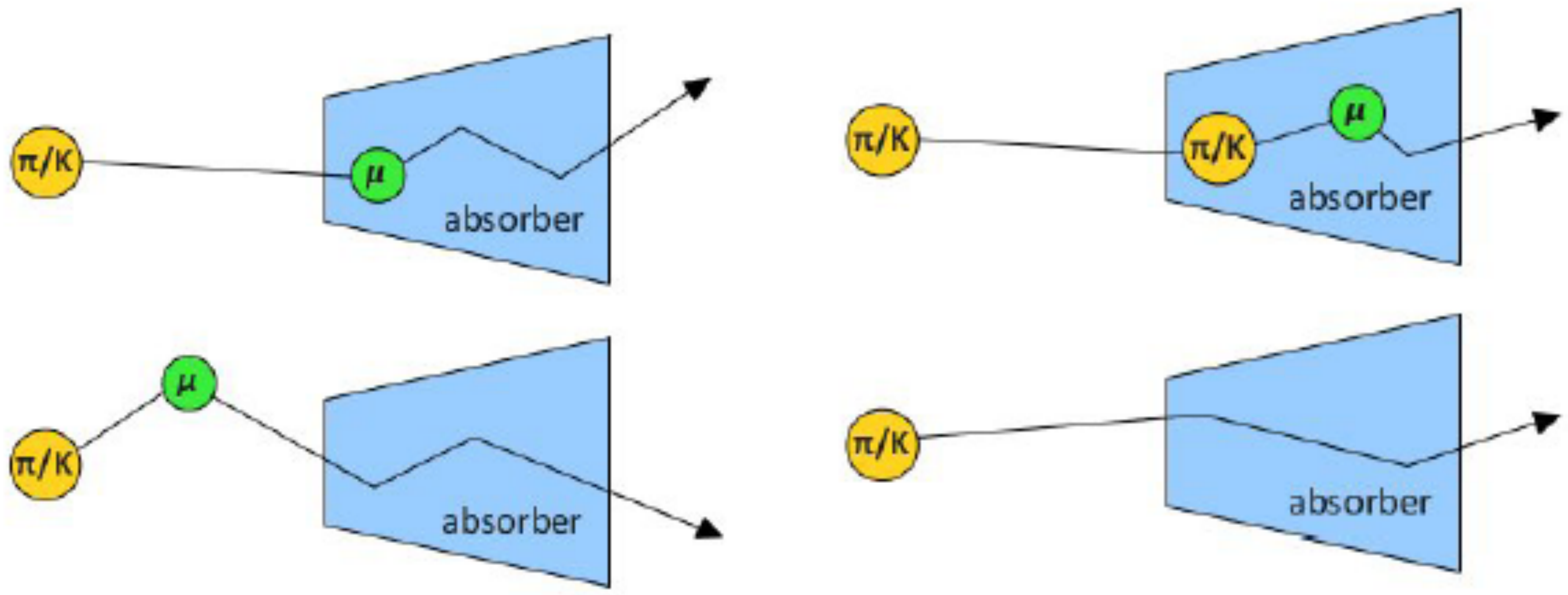

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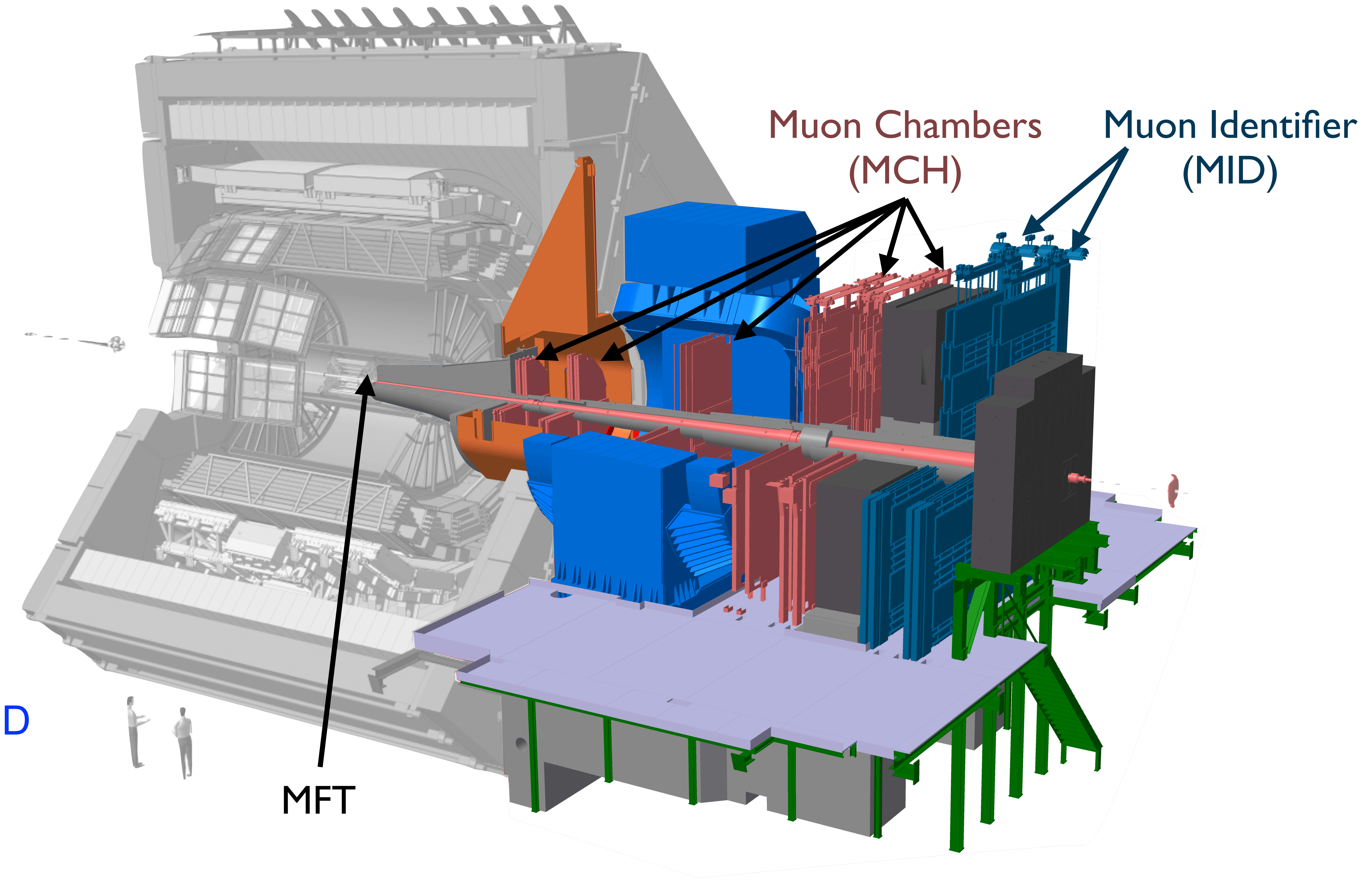
⇨ Need for a high spatial resolution tracker in front of the muon absorber and capabilities of track matching with the muon spectrometer.

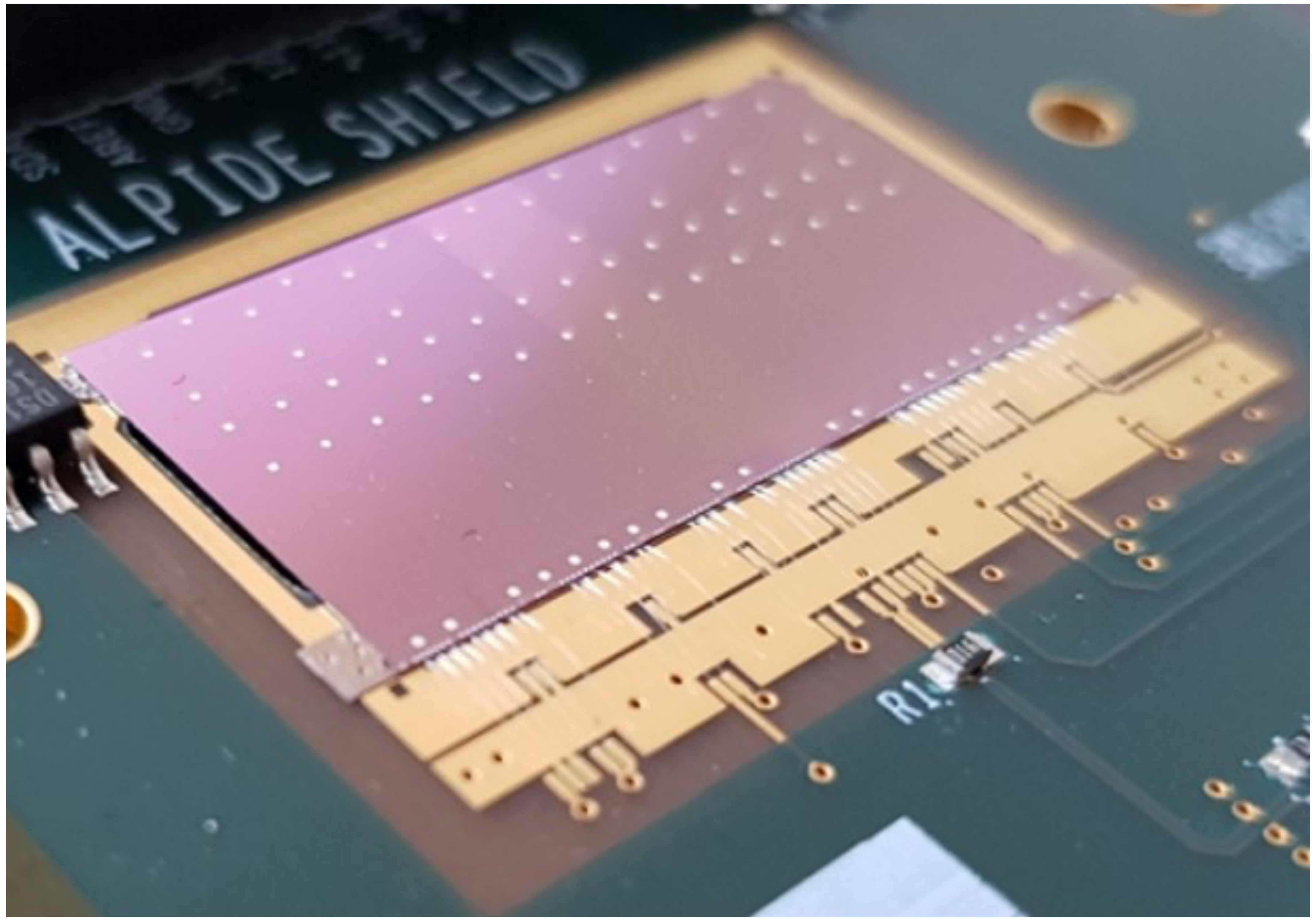
Upgrades of the muon detectors for Runs 3 and 4

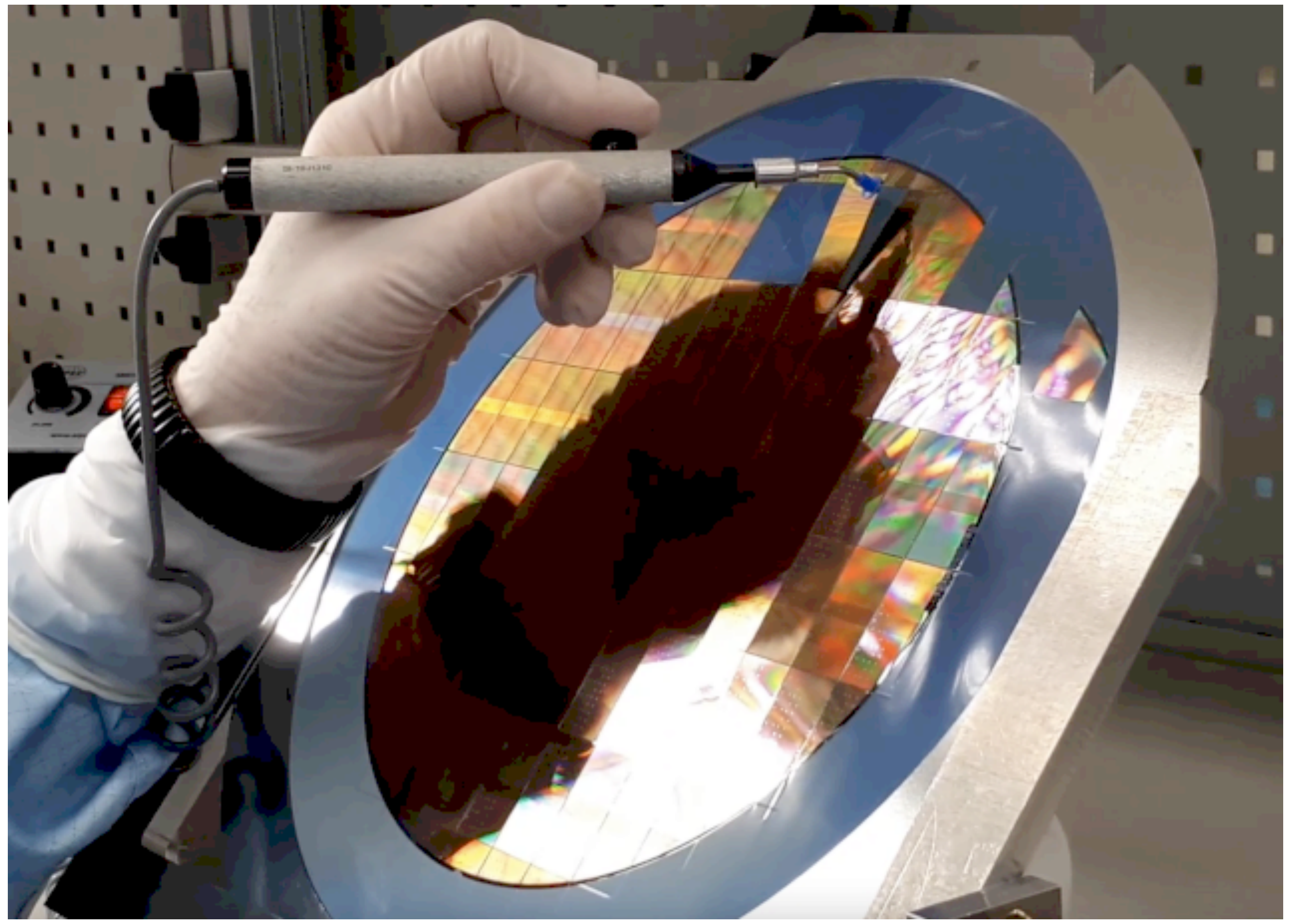
- <u>Targeted Luminosities</u>:
  - 13 nb^{-1} of Pb-Pb data
  - about 200 pb^{-1} pp
  - about 0.5 pb^{-1} p-Pb
- Data taking:
  - From trigger mode to continuous mode
    - ⇨ Muon Trigger (MTR) → Muon Identifier (MID)
  - From ~5 kHz to 50 kHz in Pb-Pb
    - ⇨ Upgrade of readout (MCH + MID)
- Muon Forward Tracker (MFT):
  - New detector
  - Measurement of displaced vertices
  - Background (π,K) discrimination for MCH+MID



MFT in a nutshell

- ALPIDE silicon pixel sensors:
  - Monolithic Active Pixel Sensor technology
  - Chip size (l x w x h): 30 mm x 15 mm x 50 µm
    1024x512 pixel matrix
  - Spatial resolution: 5 µm
    Pixel size: 27 µm x 29 µm
  - Integration time: 5 µs
  - Same chips as the ALICE ITS





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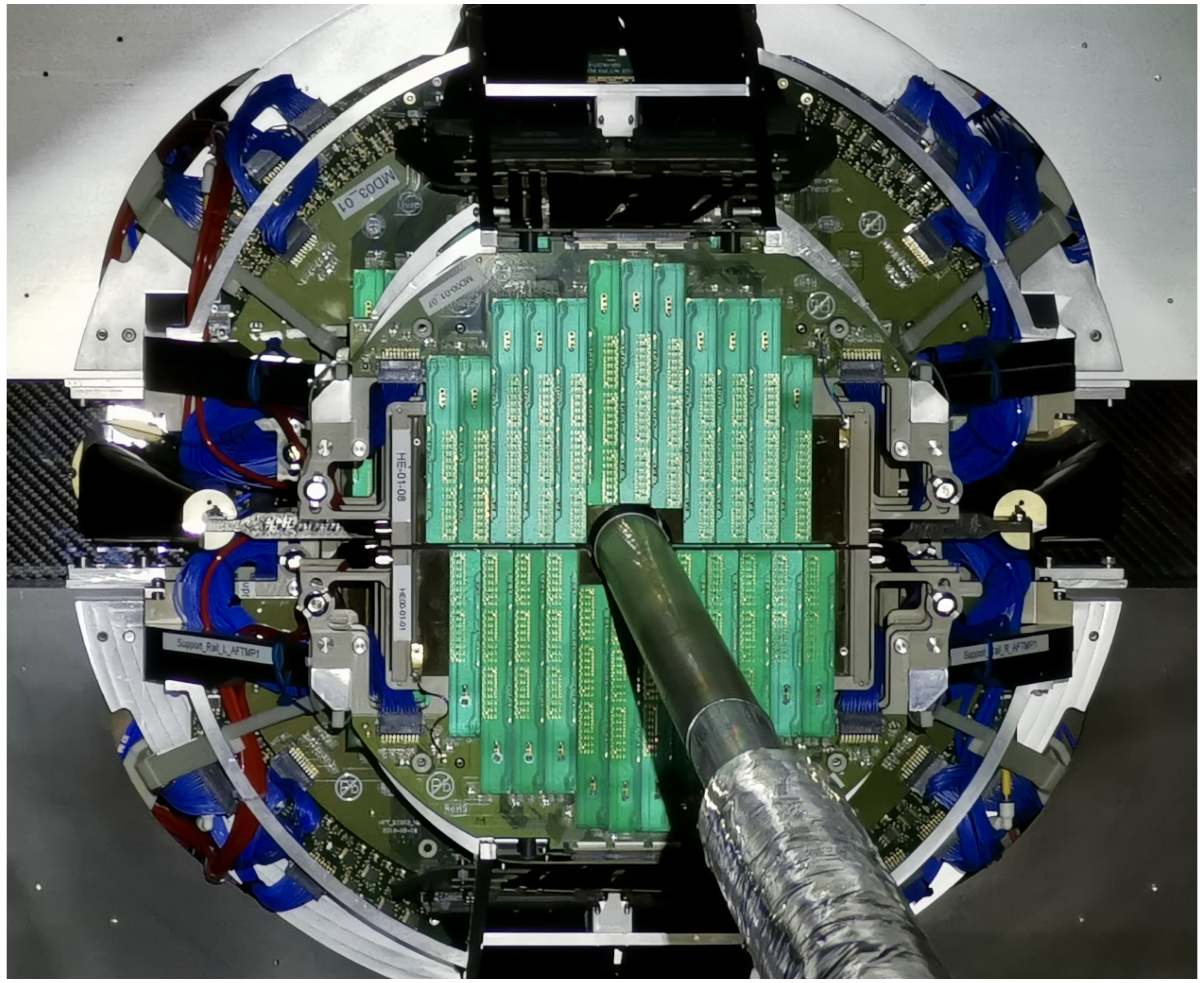
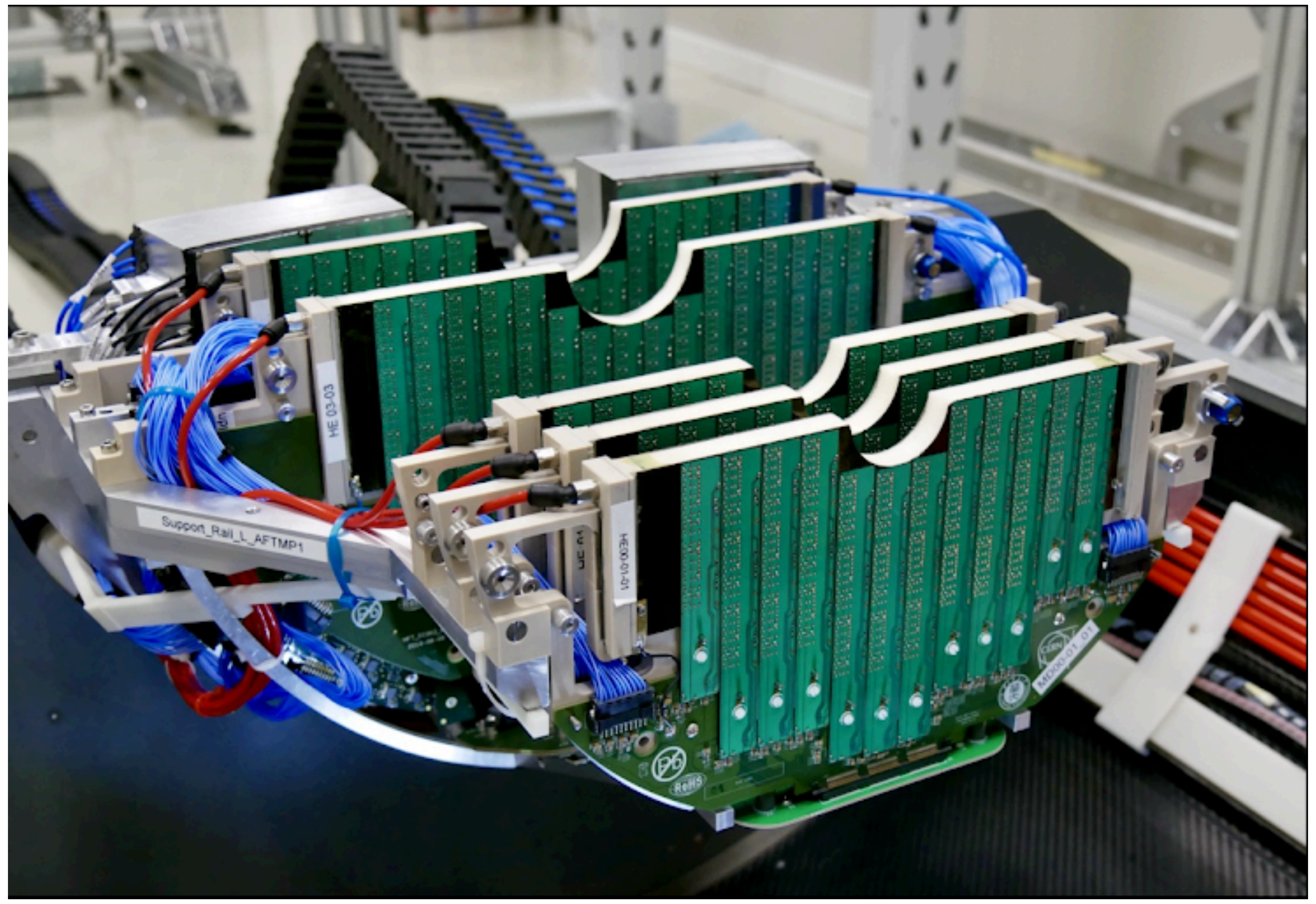


- MFT design:
  - 936 ALPIDEs on 280 ladders (between 2 and 5 chips per ladder)
  - 10 double-sided half-disks
    84% of redundancy between front and back sides
  - Position:
    First/last planes: 46 cm/76.8 cm from the interaction point (IP)

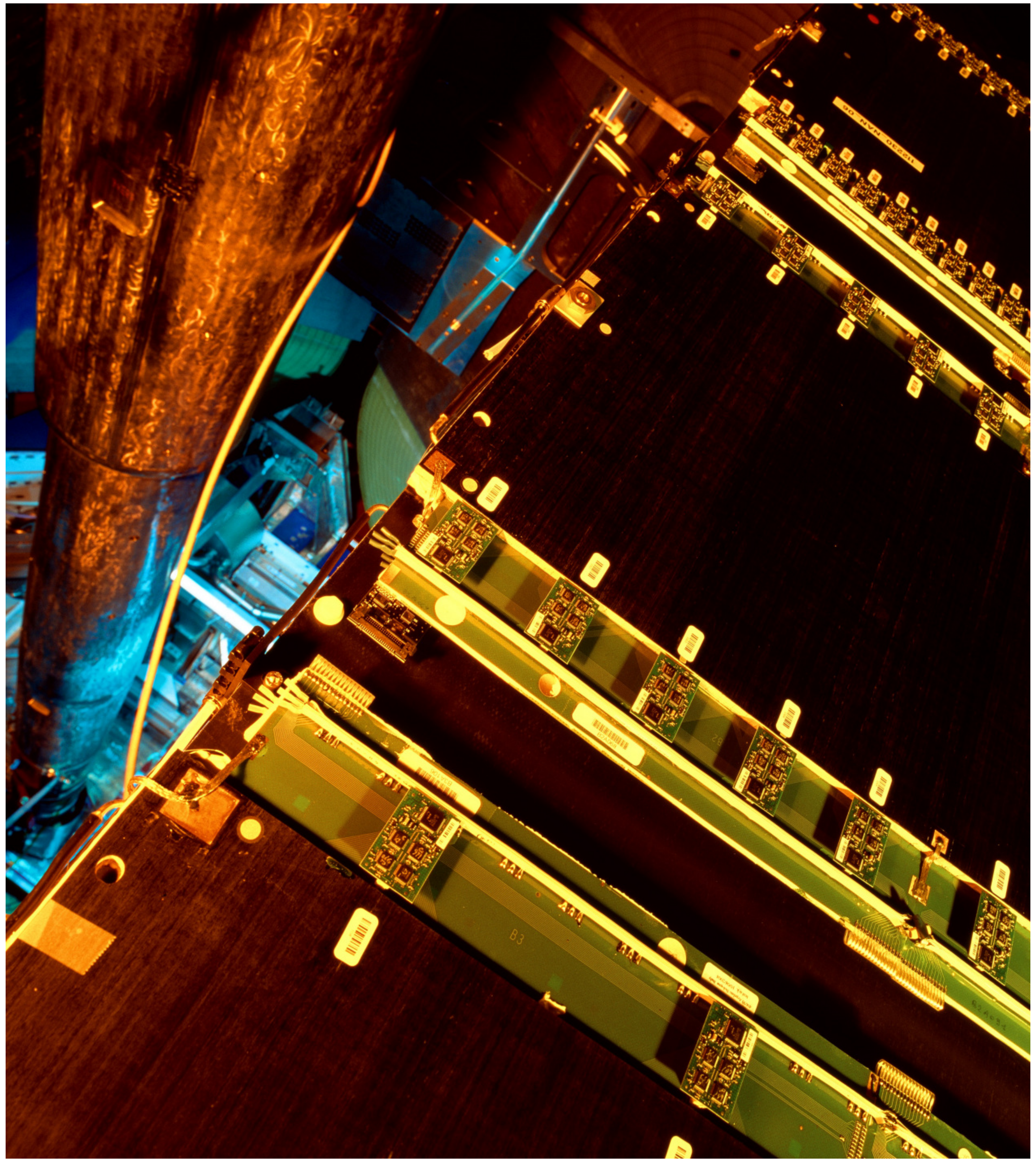
- Reconstructed tracks:
  - Acceptance:
    $2.4 < \eta < 3.6$ (limitation at high rapidity because of the beam pipe)
  - Pointing resolution at IP region:
    ~ 100 μm (to be compared to $\gamma\beta c\tau_B \approx 5$ mm)



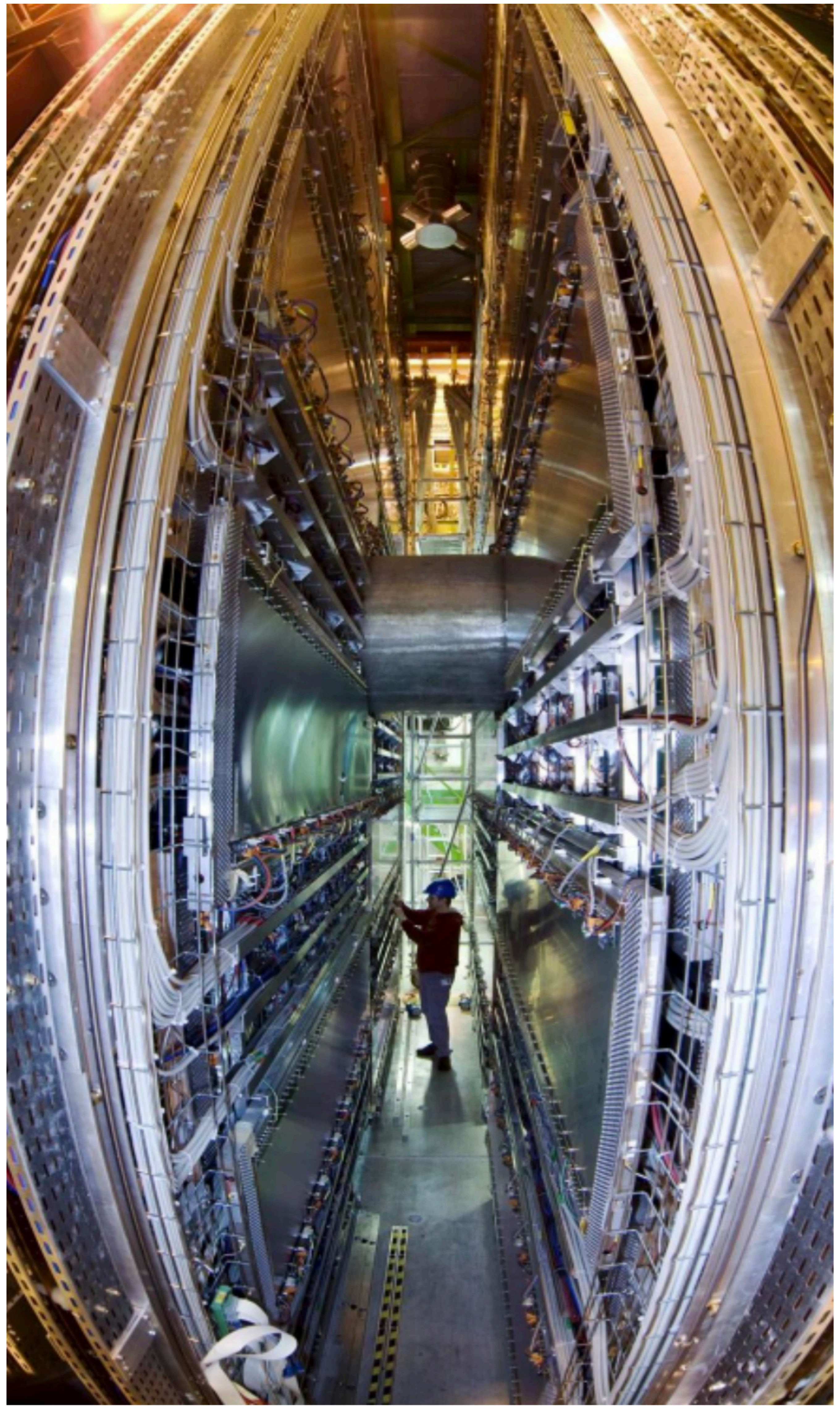
Upgrade of the Muon Tracker

- Detection:
  - Same Cathode Pad Chambers (CPC)
    1.1 million channels spread over 10 detection planes

- New readout chain:
  - To cope with higher rates and continuous readout
  - New FEE boards: Dual-Sampa
    Record of the analog signal from pads
    New amplification, filtering and compression of data
    Chip developed by Sao Paulo to meet both MCH and TPC requirements
  - New concentrator boards: SOLAR
    Based on GBT links protocol to communicate with ALICE DAQ through CRU boards
    (protocol common to many ALICE detectors)



Upgrade from the Muon Trigger to the Muon IDentifier



- Detection:
  - Same Resistive Plane Chambers (RPC)
    72 detection elements over 4 planes
- Readout boards:
  - Same local and regional boards
    Already used as a trigger detector for Runs 1 and 2 (response every 25 ns)
- New Front End Electronics:
  - Higher particle flux because of the increase of collision rate
    ⇨ Need to lower gain (lower HV) in order to improve the rate capability of the RPCs and to prevent ageing effects
  - New FEE boards:
    Based on FEERIC chip
    Higher amplification gain to compensate the decrease of HV

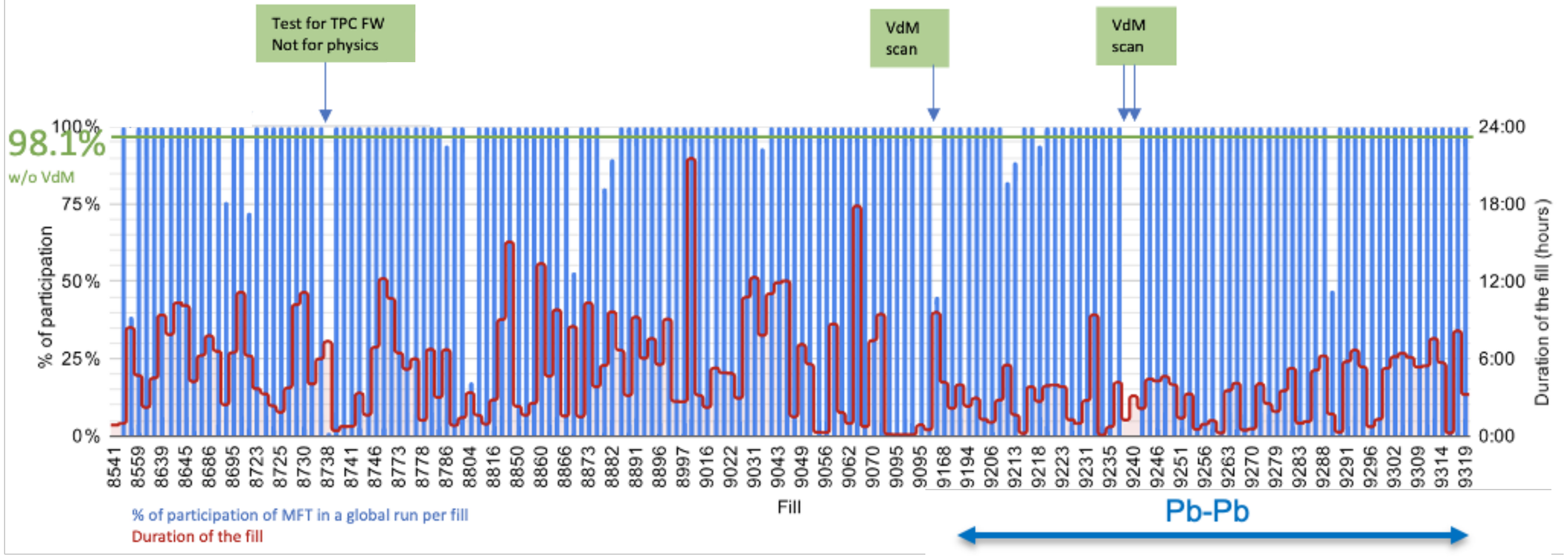
Run 3 data taking with the muon detectors

- Data taking in 2023
  - About 780h of total data taking
    Van der Meer scans and TPC tests excluded
  - Pb-Pb: about 220h of data taking

  - Improvement in efficiency with time:
    Automation of procedures (configuration, calibration and recoveries)
    Better diagnosis of faulty components

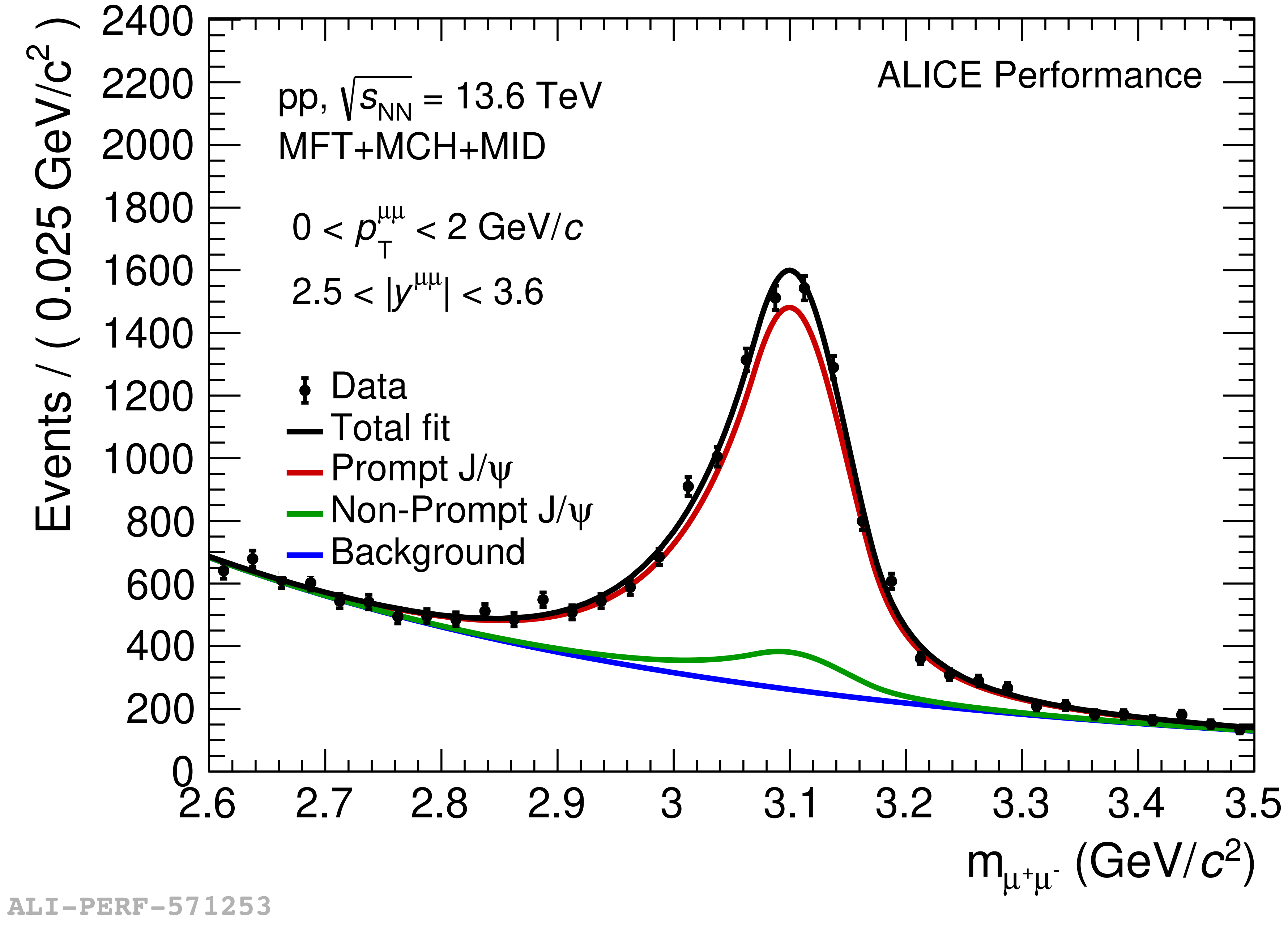
  - 2024 has started on the same pace

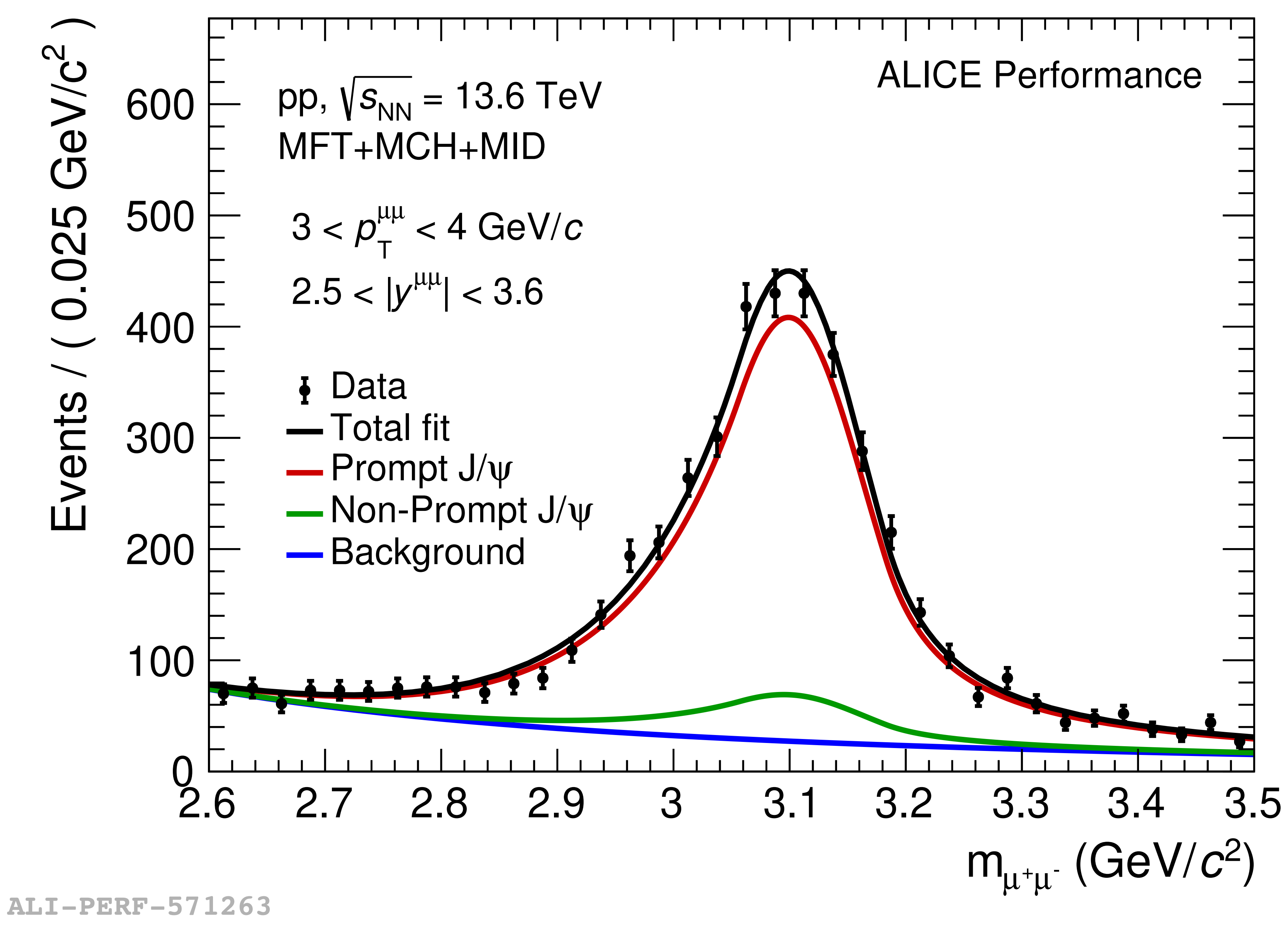
	Full 2023	Pb-Pb period
MCH	100 %	100 %
MID	99.5%	99 %
MFT	98.1%	99 %
MCH+MID+MFT	97.6%	98.1%



First performance results

- Track matching between MFT and MCH+MID tracks:
  - Based on χ^2 cut in pp (low track multiplicity)
  - Machine learning techniques in Pb-Pb (under development)
- Measurement of J/ψ from matched tracks:
  - Clear signal down to $p_T = 0$





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- Measurement of J/ψ from matched tracks:
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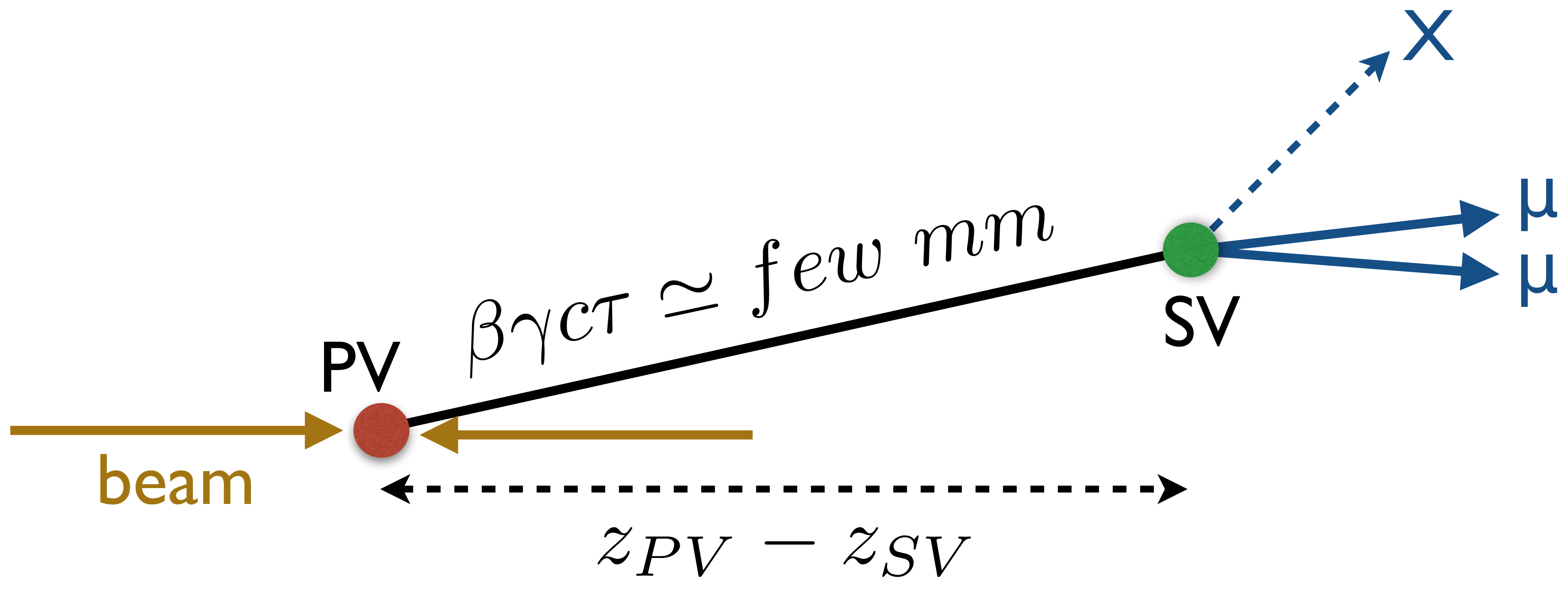
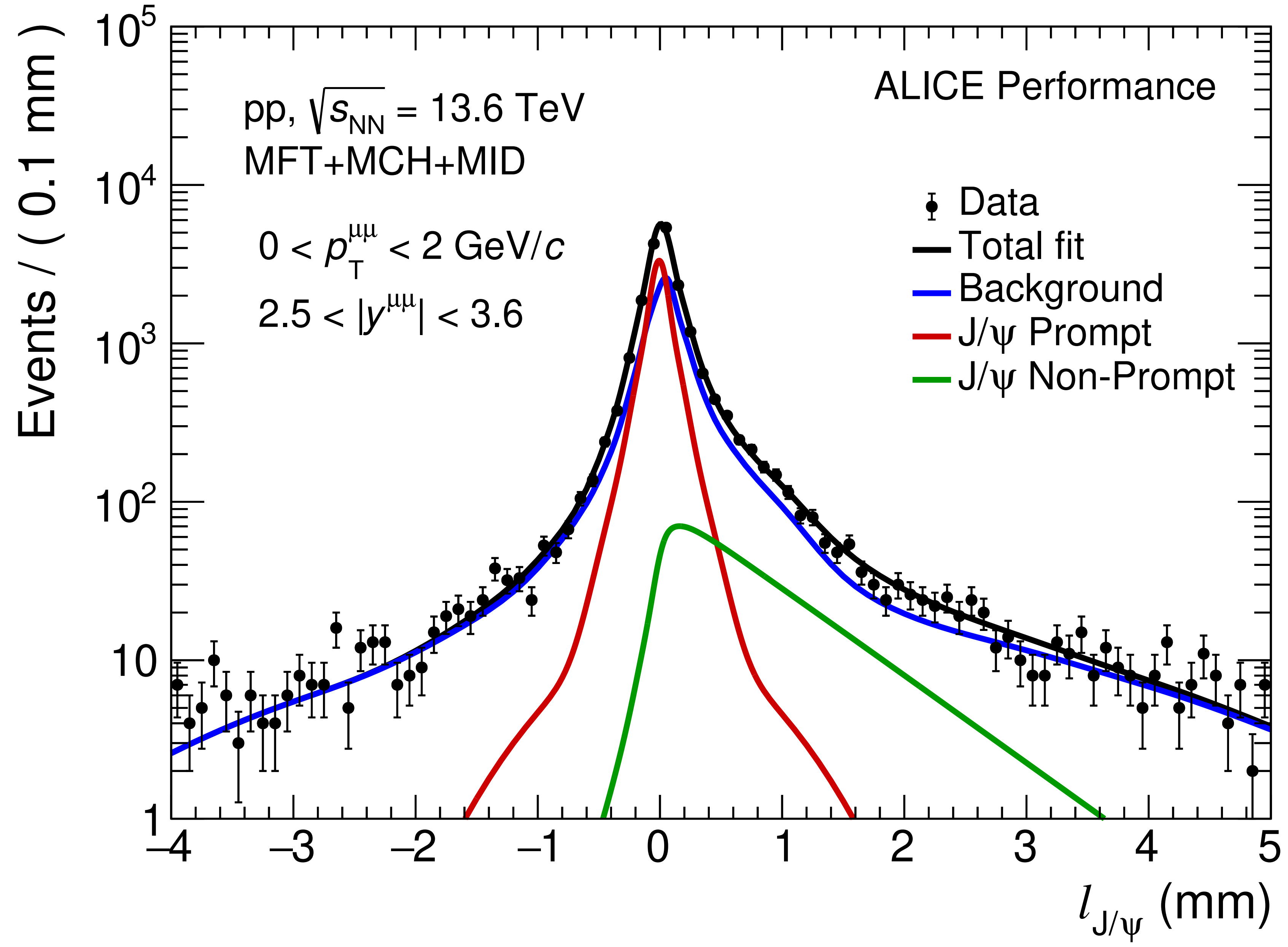
- Separation of J/ψ contributions:
  - From primary vertex (prompt) and B meson decay (non-prompt)
  - Based on the measurement of pseudo-proper decay length (l_z)



$$l_z = \frac{(z_{PV} - z_{SV}) \cdot Mc^2}{p_z c}$$



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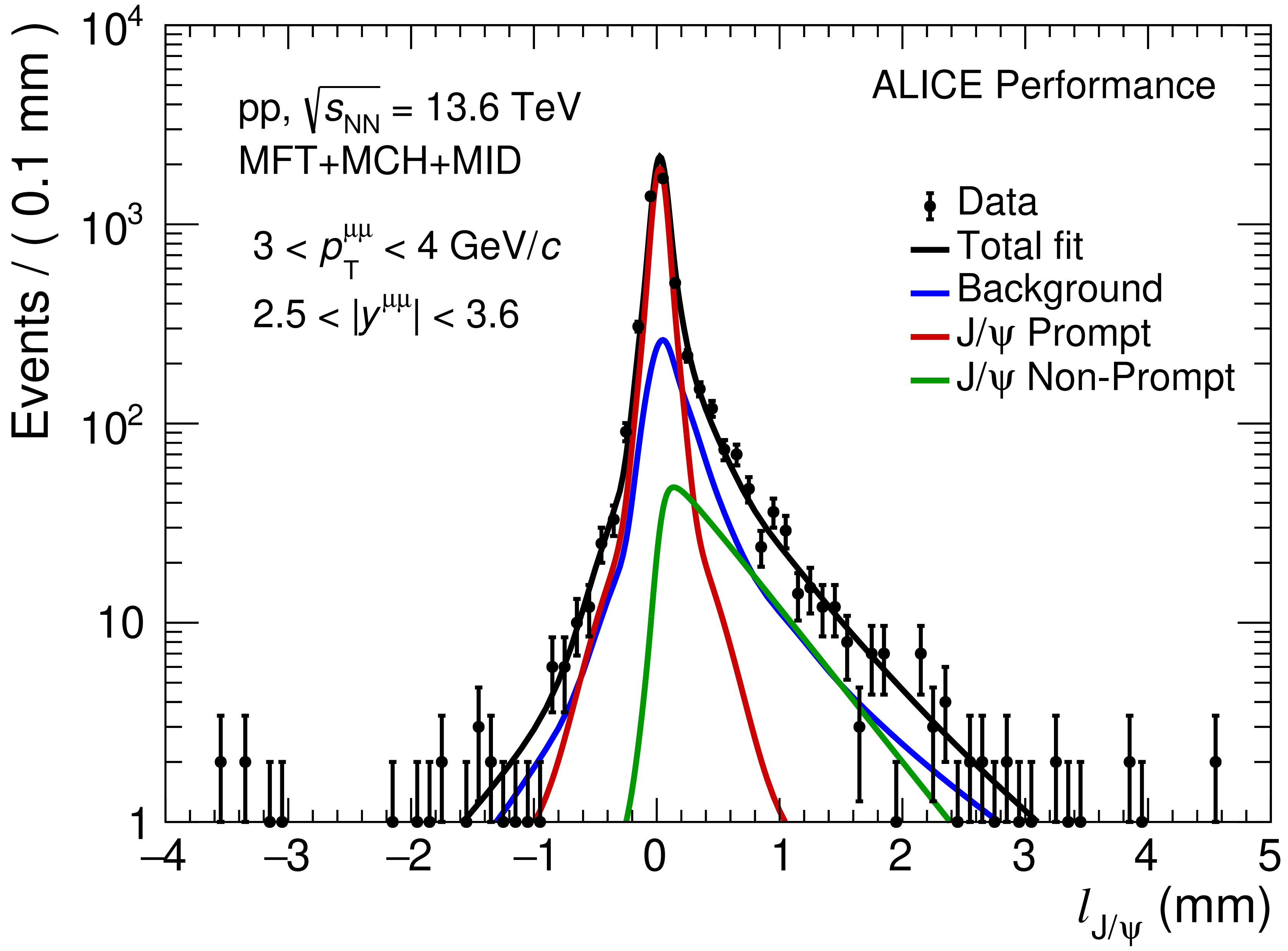

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Conclusion

- Upgrade of muon detection at forward rapidities in ALICE
  - New readout for MCH and MID to cope with the collision rate increase in Runs 3 and 4
  - New detector MFT

    Silicon pixel detector used to increase pointing resolution at the interaction point region

- Extension of the physics program at forward rapidities
  - Charm/Beauty separation
  - Lower background
  - But also:
    - Multiplicity/Centrality estimation (complementary to ALICE-ITS)
    - Measurement of the reaction plane for studies of flow

- Outcome of current data taking
  - Stable data taking with MCH, MID and MFT
  - First results of charm/beauty separation

Thank you