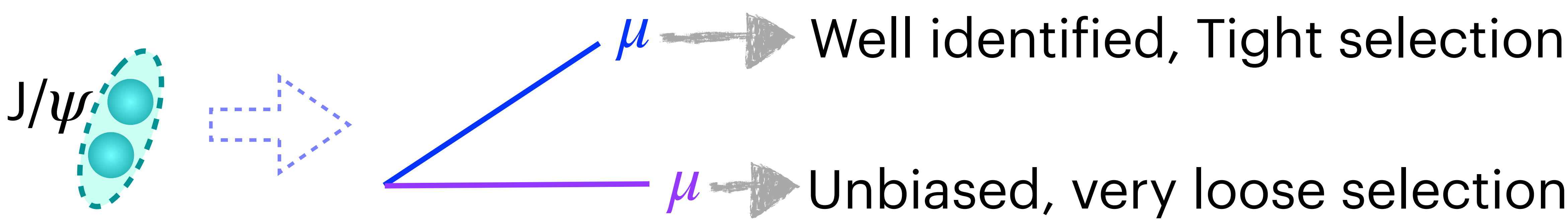
Tag-and-Probe efficiency study for muons in Alice

Rencontres QGP France

Batoul DIAB - 03/05/2022

The Tag-and-Probe method

- Tag-and-Probe (T&P) is a data-driven efficiency calculation technique
- Simulations are not ideal → need data calibration
- based on the decays of known resonances, e.g. J/ψ



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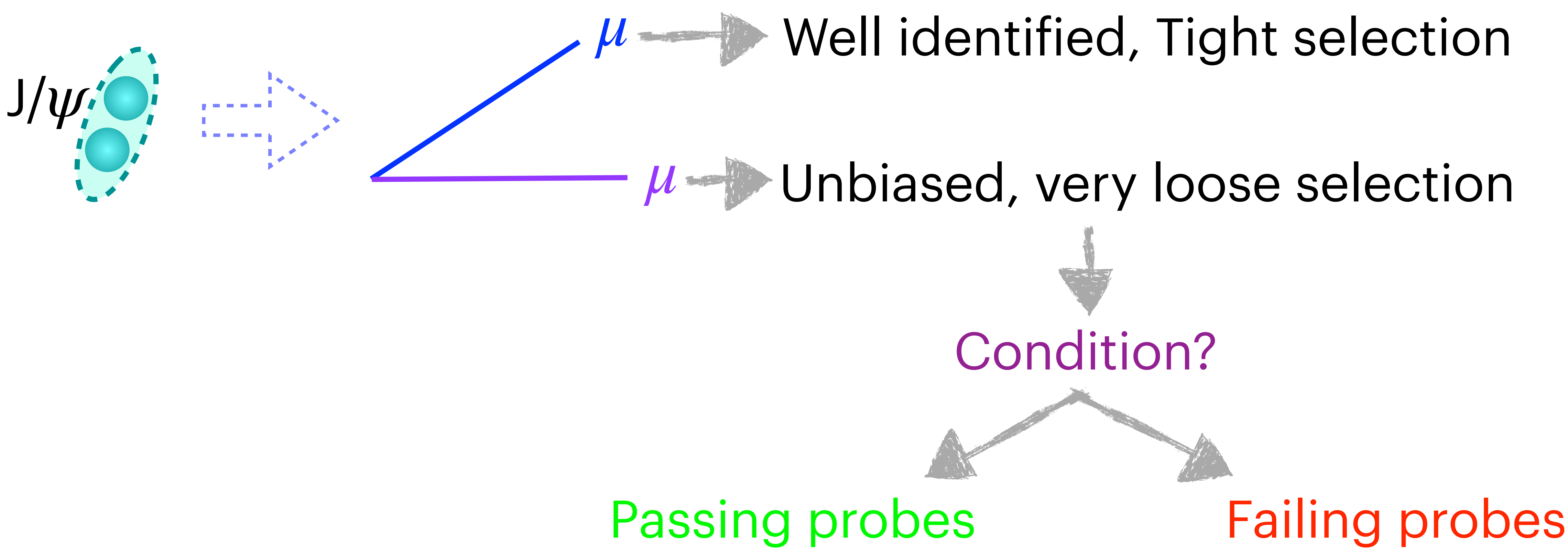

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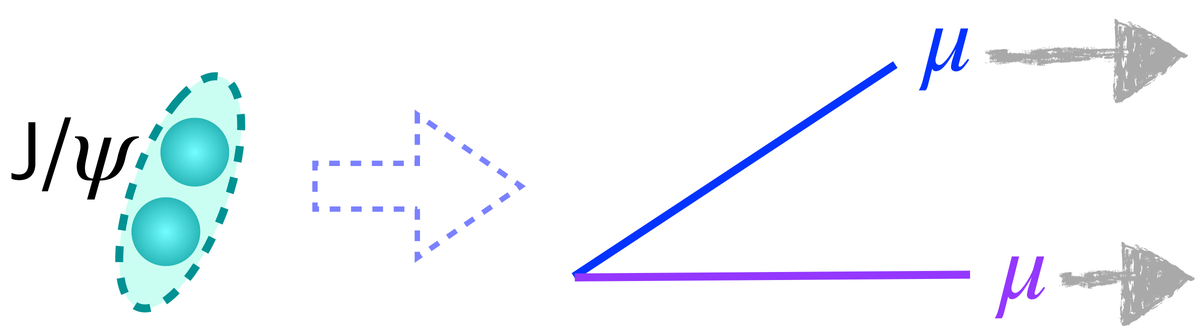


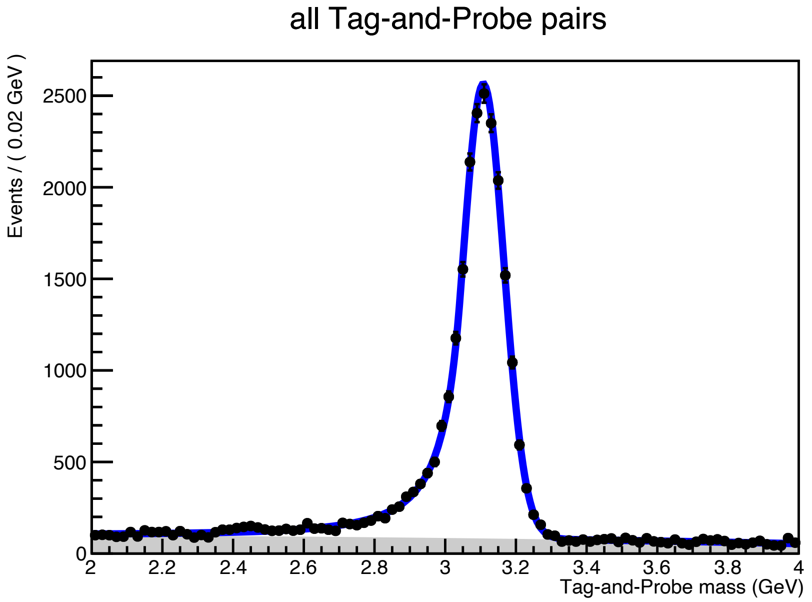
Well identified, Tight selection

Unbiased, very loose selection

Condition?

Passing probes

Failing probes



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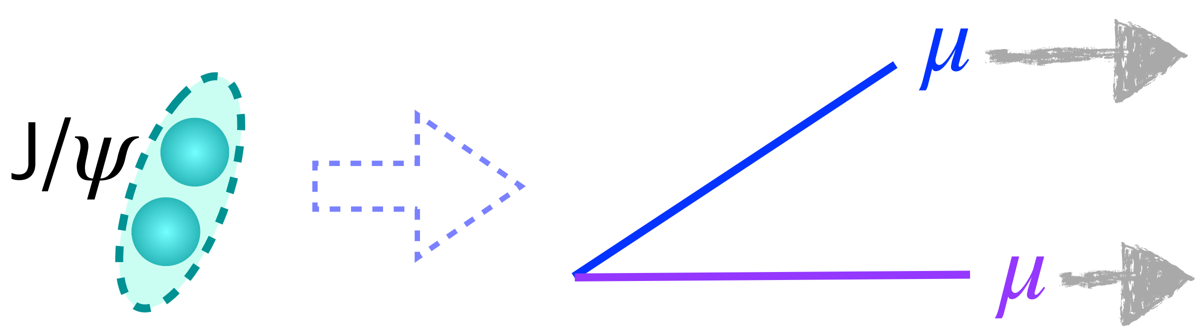

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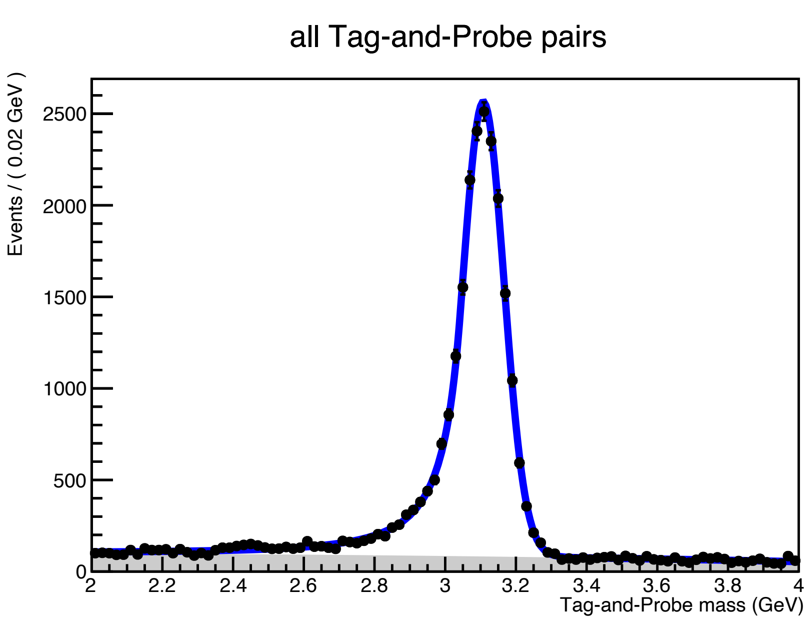
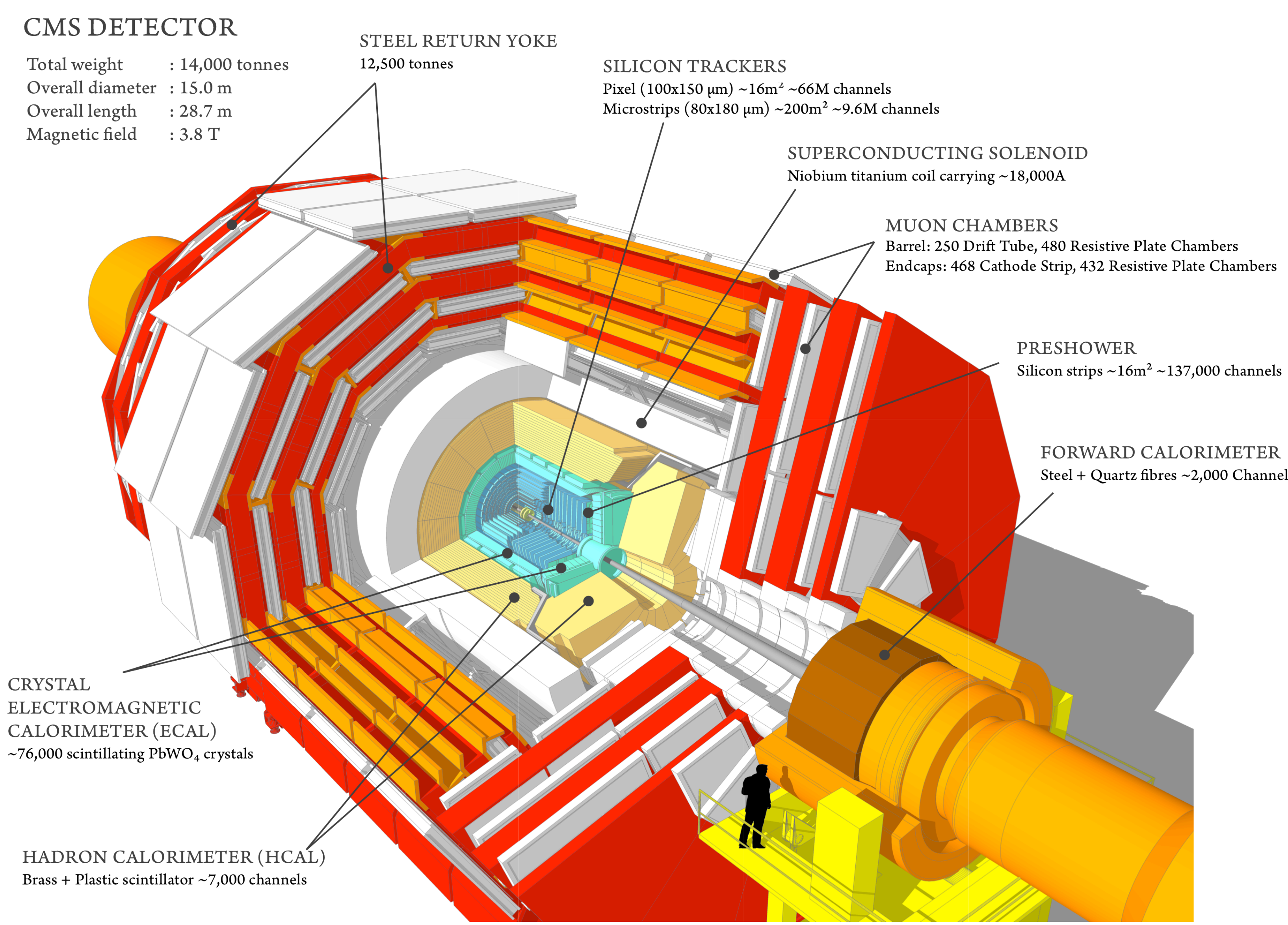


$$\varepsilon = \frac{\text{probes passing condition}}{\text{all probes}}$$

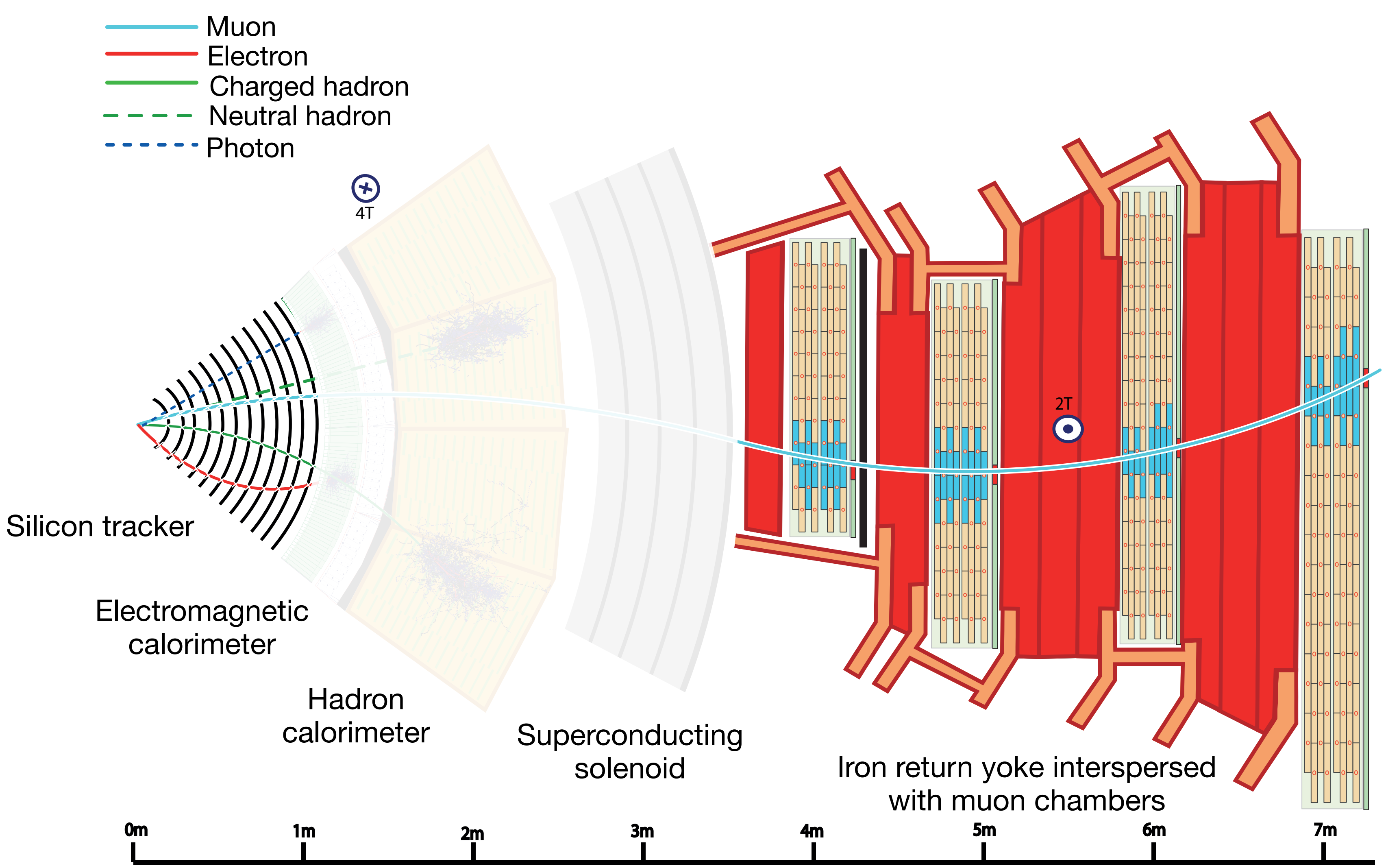
The CMS detector

- The Compact Muon Solenoid is a general purpose detector
- Made of many subsystems for different particles
- shaped like a cylindrical onion
- Most subsystems have mid and forward rapidity layers



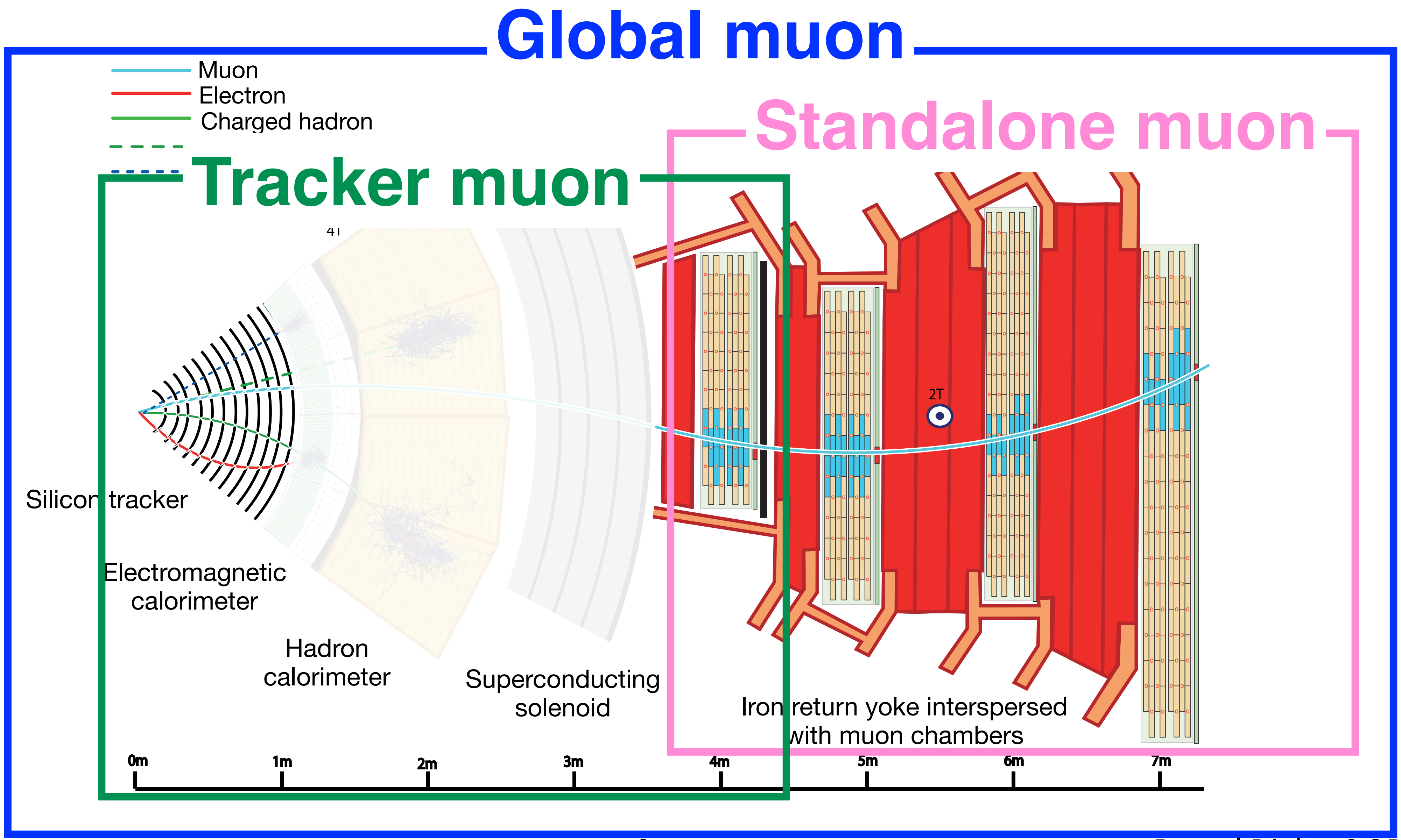
Muon systems in CMS

- Muons are measured in two subsystems in CMS
- The silicon tracker: very precise momentum determination but busy environment
- The muon chambers: very clean signal
- Together they give very precise and clean muon detection
- $p_T > 3$ GeV for $|\eta| < 1.2$, $p_T > 1.5$ GeV for $2.1 < |\eta| < 2.4$



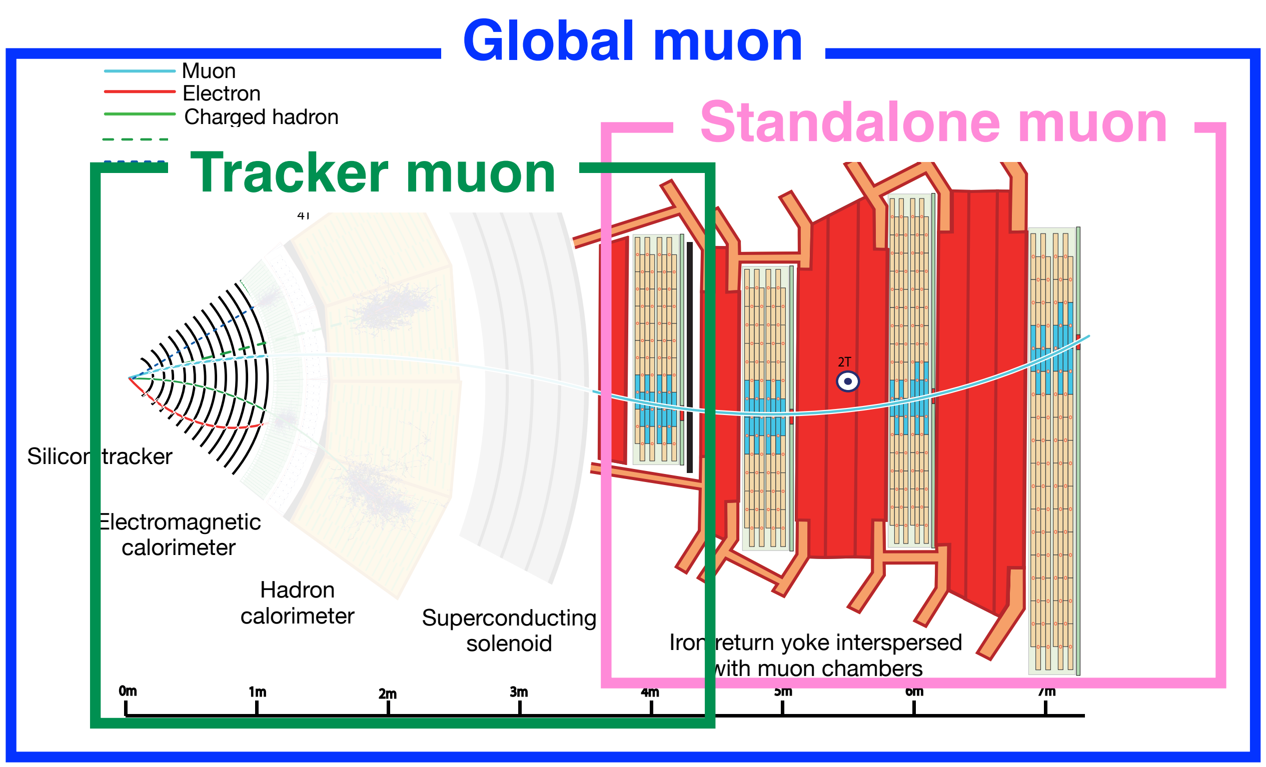
Tag-and-Probe in CMS

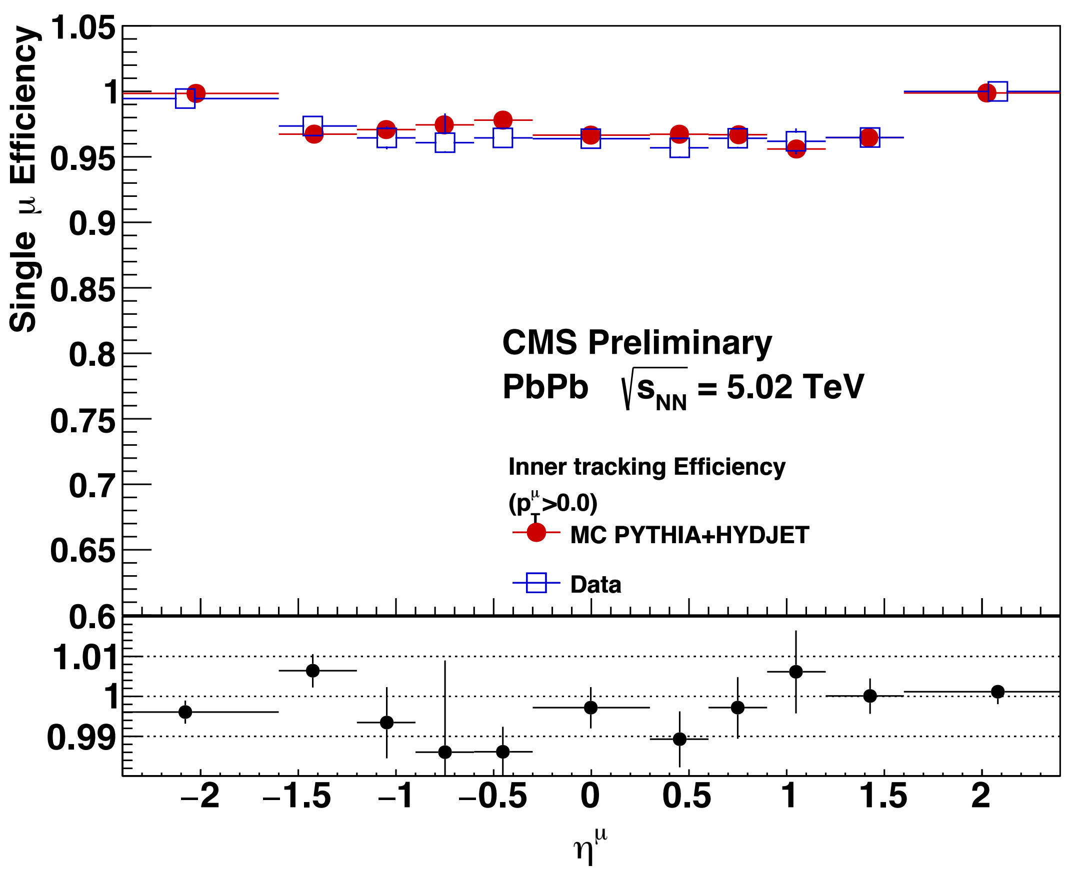
- Three types of muons are defined in CMS
- Standalone muons: reconstructed in the muon chambers
- Tracker muons: tracker + first layer in the muon chambers
- Global Muons: tracker + muon chambers
- Works in favor of efficiency measurements like Tag-and-Probe



Tag-and-Probe tracking efficiency

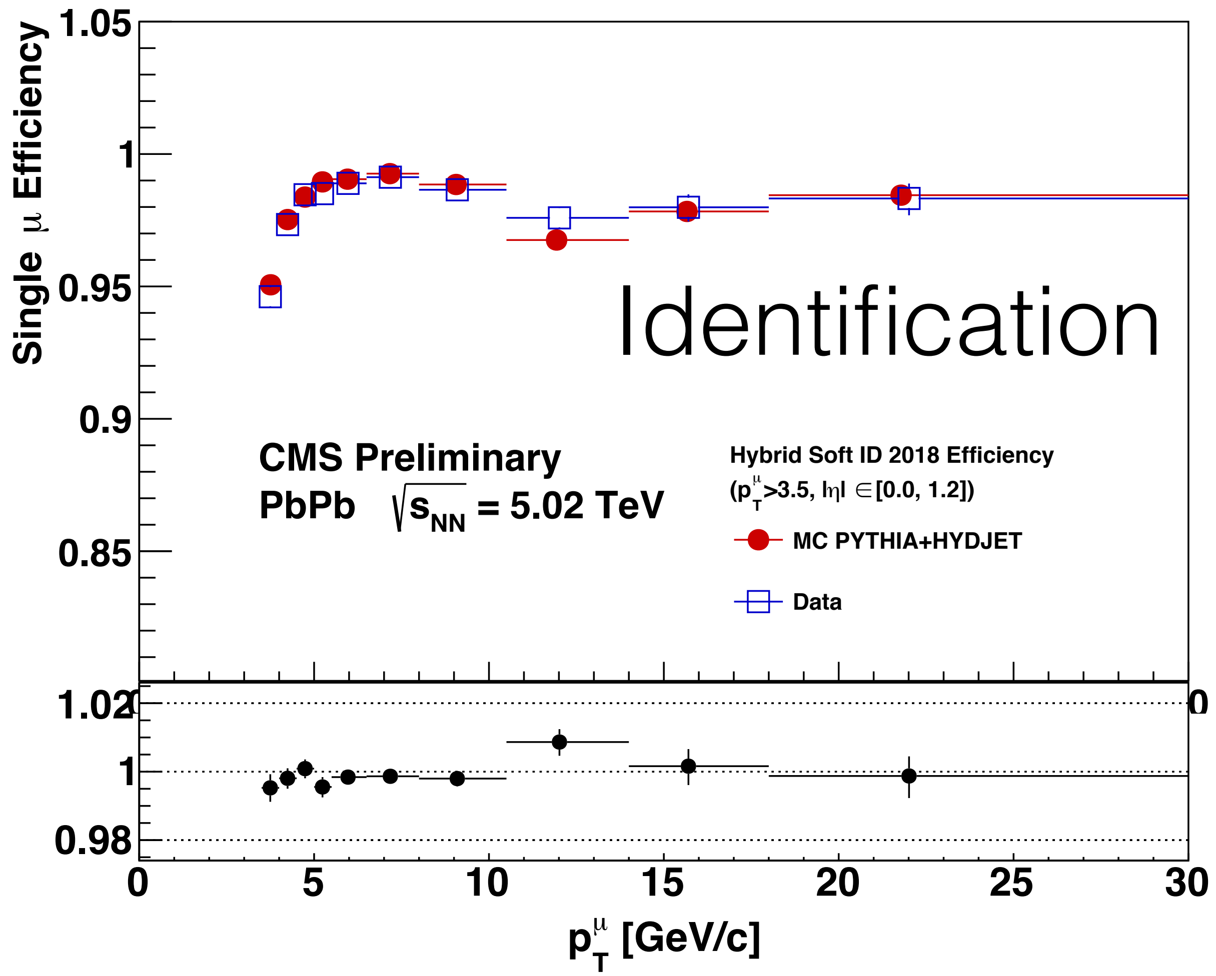
- For the tracking efficiency we can look at standalone muons and check if they are reconstructed in the tracker as well (Global muons)
- For 2018 PbPb run: very good efficiency that only depends on rapidity
- Small differences between data and simulation

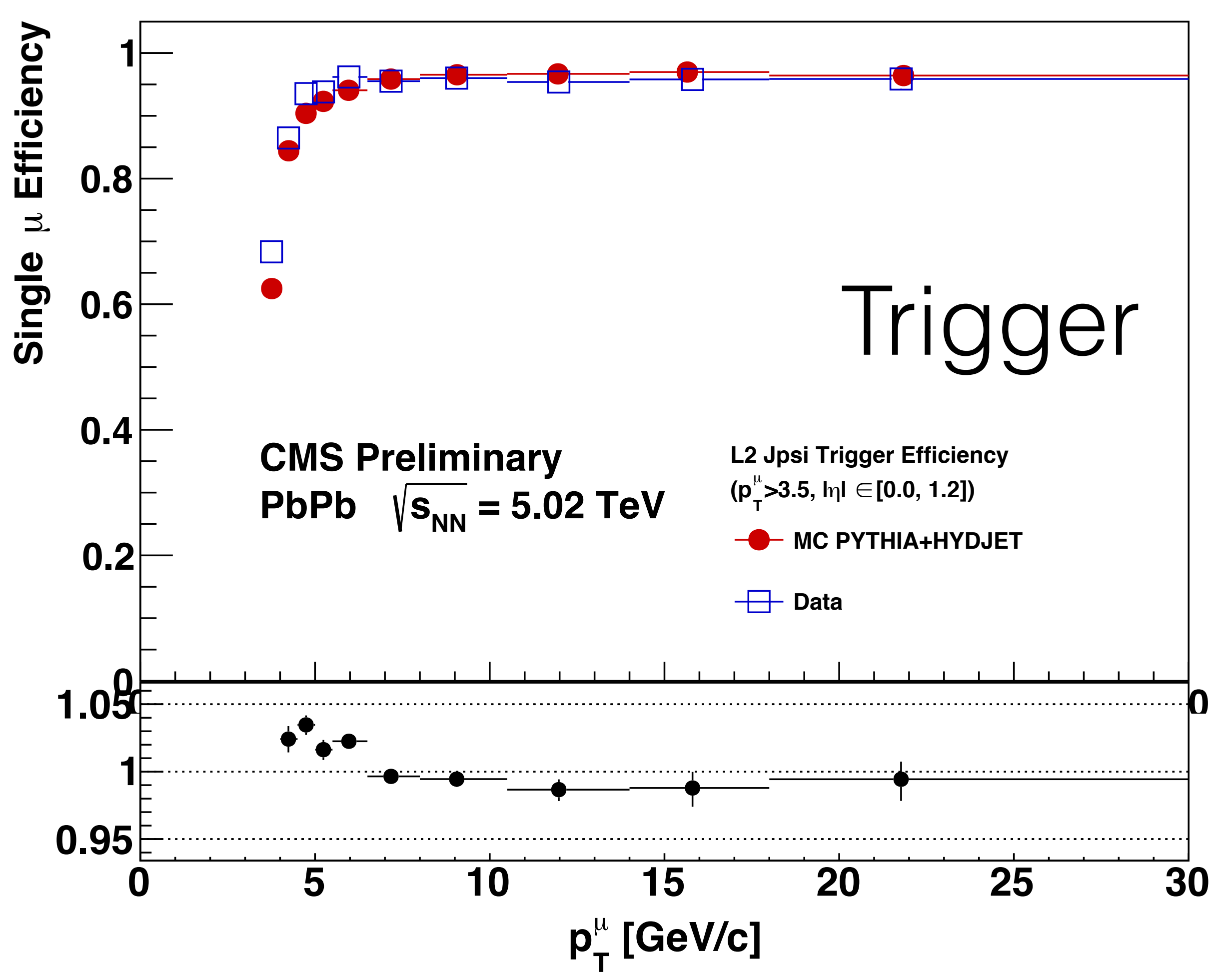




Other Tag-and-Probe efficiency

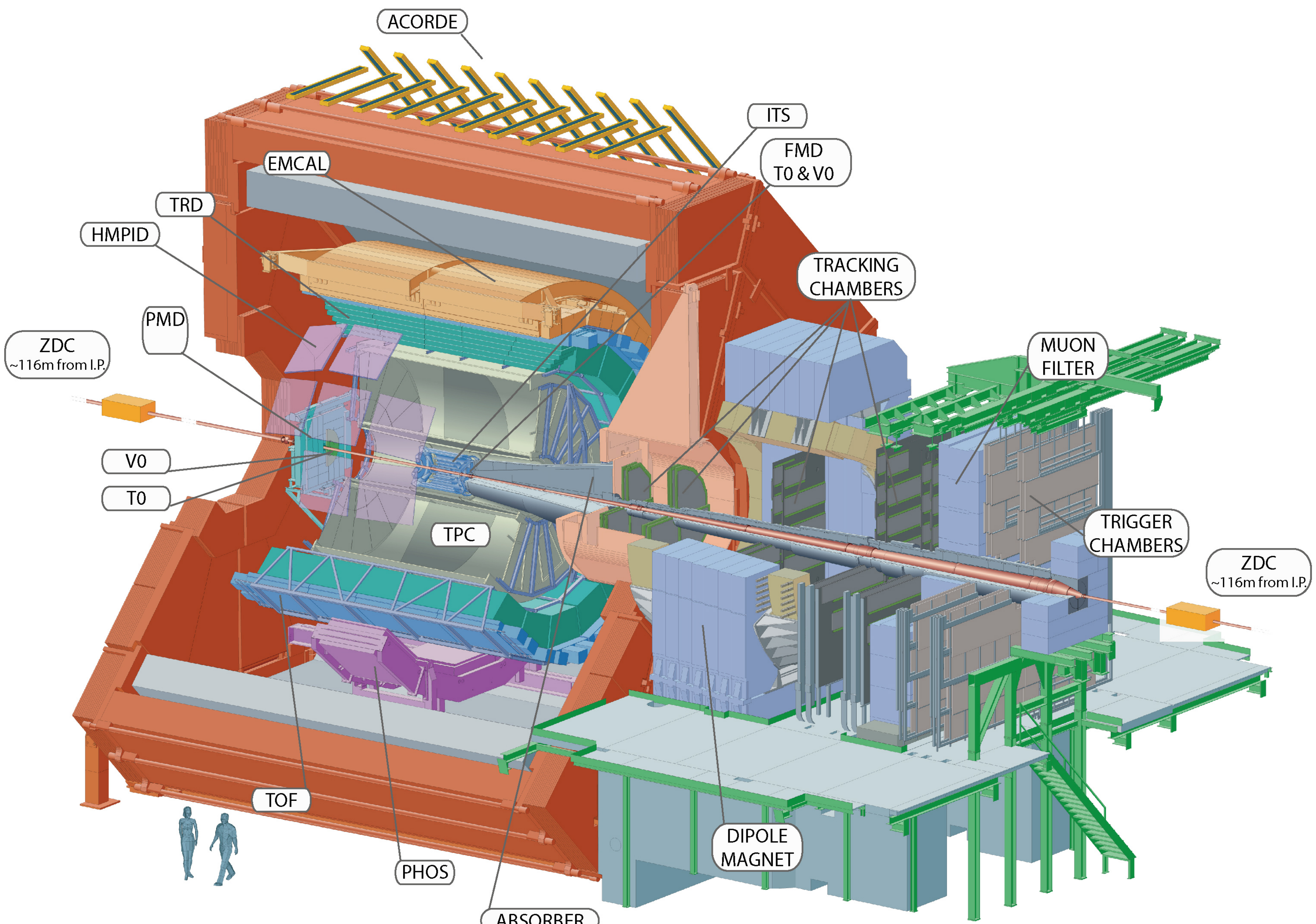
- Other efficiencies can also be measured with T&P
- muon identification: take global muons and check if they pass the ID
- trigger: take global muons that pass the ID and check if they are matched to the trigger filter
- To cover all data/simulation differences T&P efficiecies are computed and applied in layers





The ALICE detector

- A Large Ion Collider Experiment optimized for collisions of heavy nuclei at ultra-relativistic energies
- Goal: studying the physical properties of the Quark-Gluon Plasma
- Made of many detectors: ensemble of cylindrical detectors in the barrel + a muon spectrometer in the forward region



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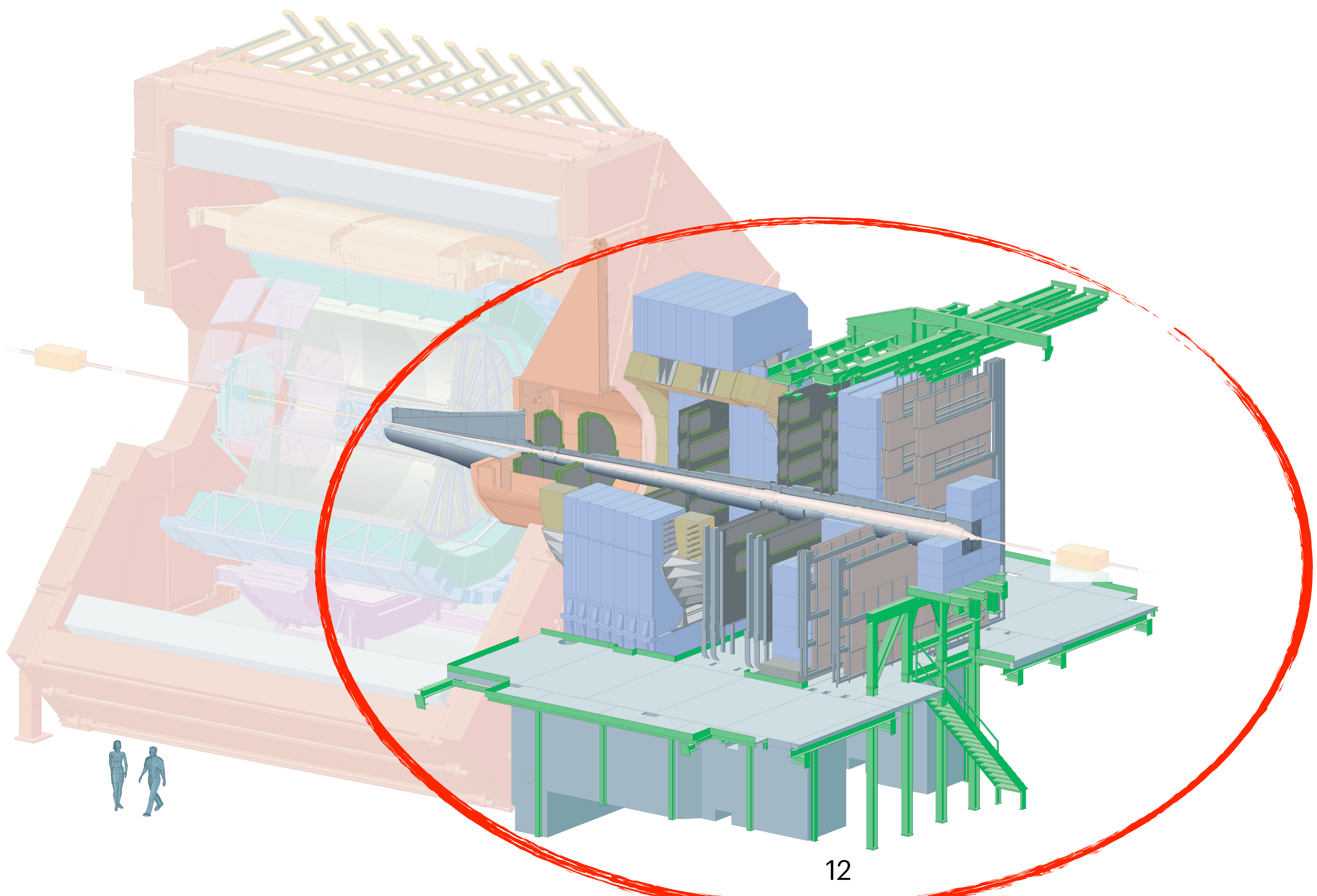
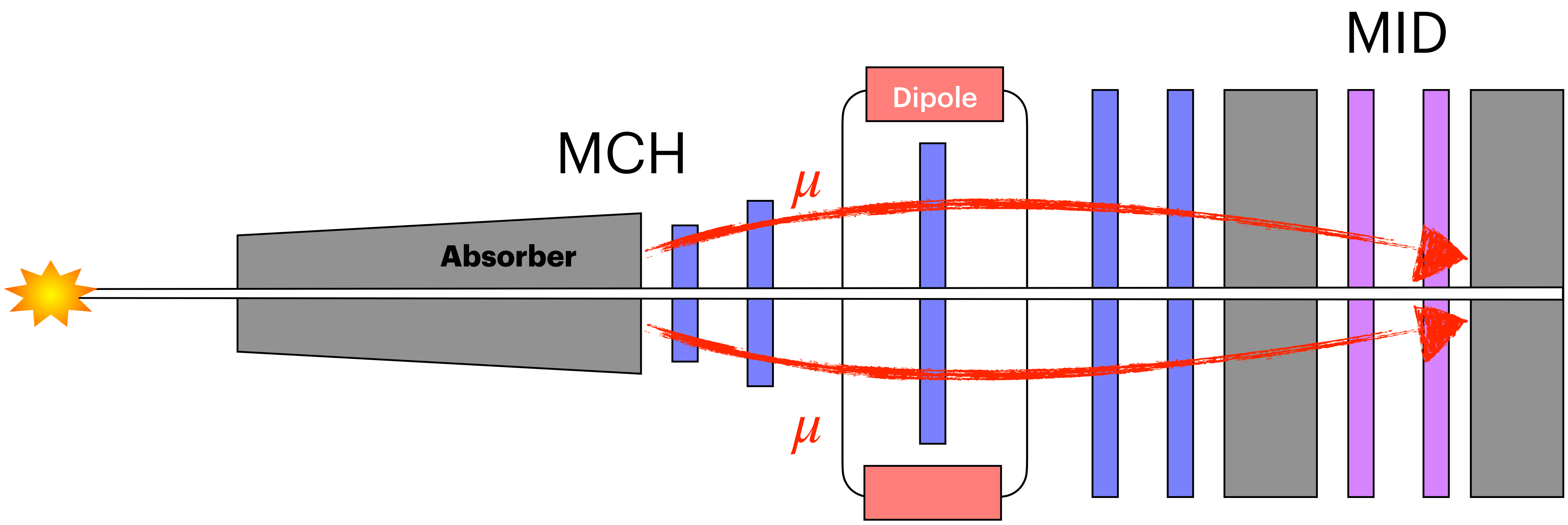


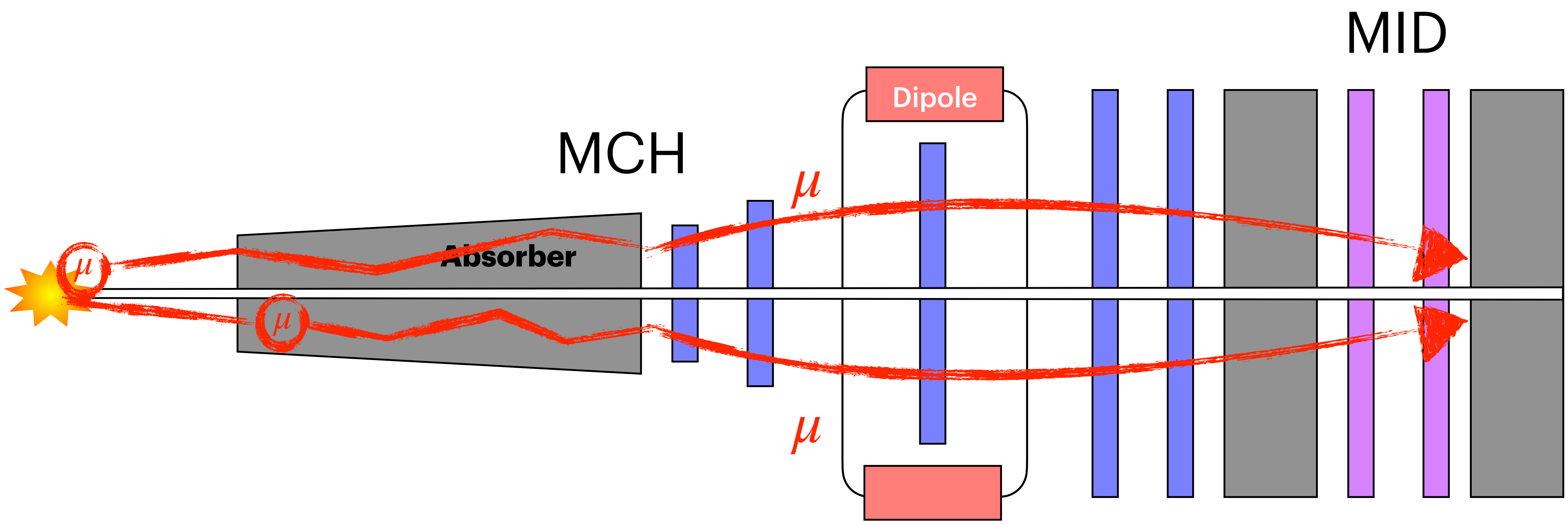
Muons in ALICE Run 2

- MCH: Muon CHambers, tracking stations
- MID: Muon ID, trigger stations
- Front absorber: suppresses particles except for muons
- Muon measurements in $-4 < \eta < -2.5$
- Resonances can be detected down to zero transverse momentum



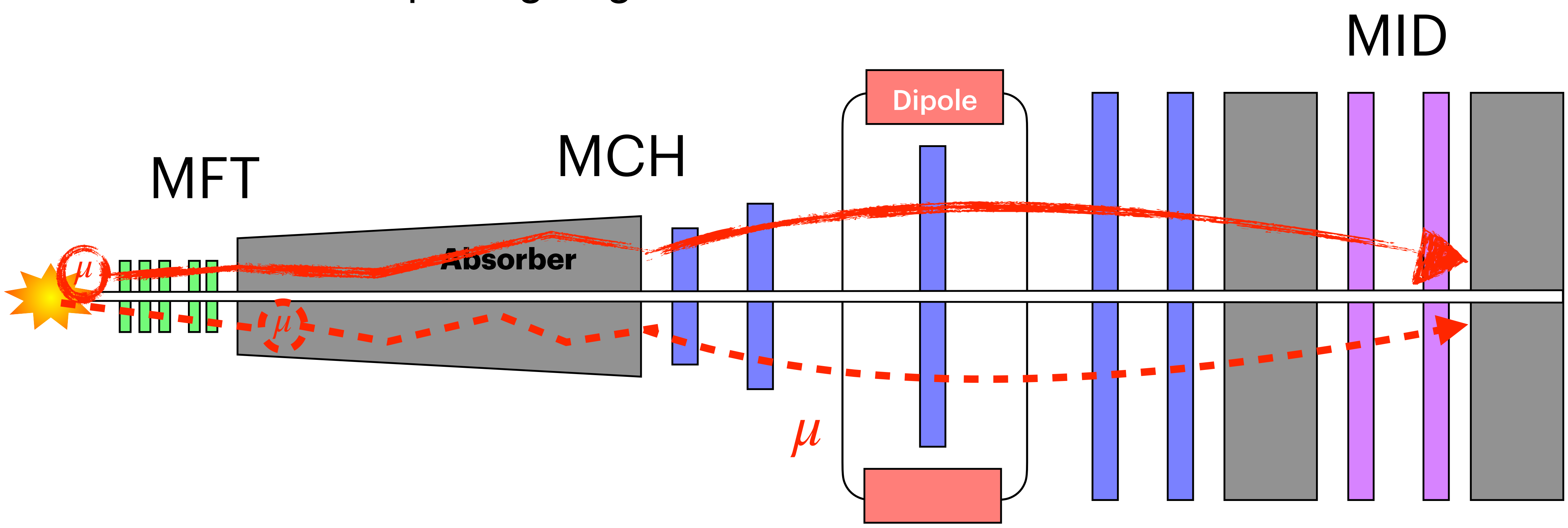
Muons in ALICE Run 2

- Muons can come from the interaction point or from decay in flight
- Limitations of the muon spectrometer:
  - High background from π/K decays
  - No secondary vertex reconstruction
  - Limited mass resolution



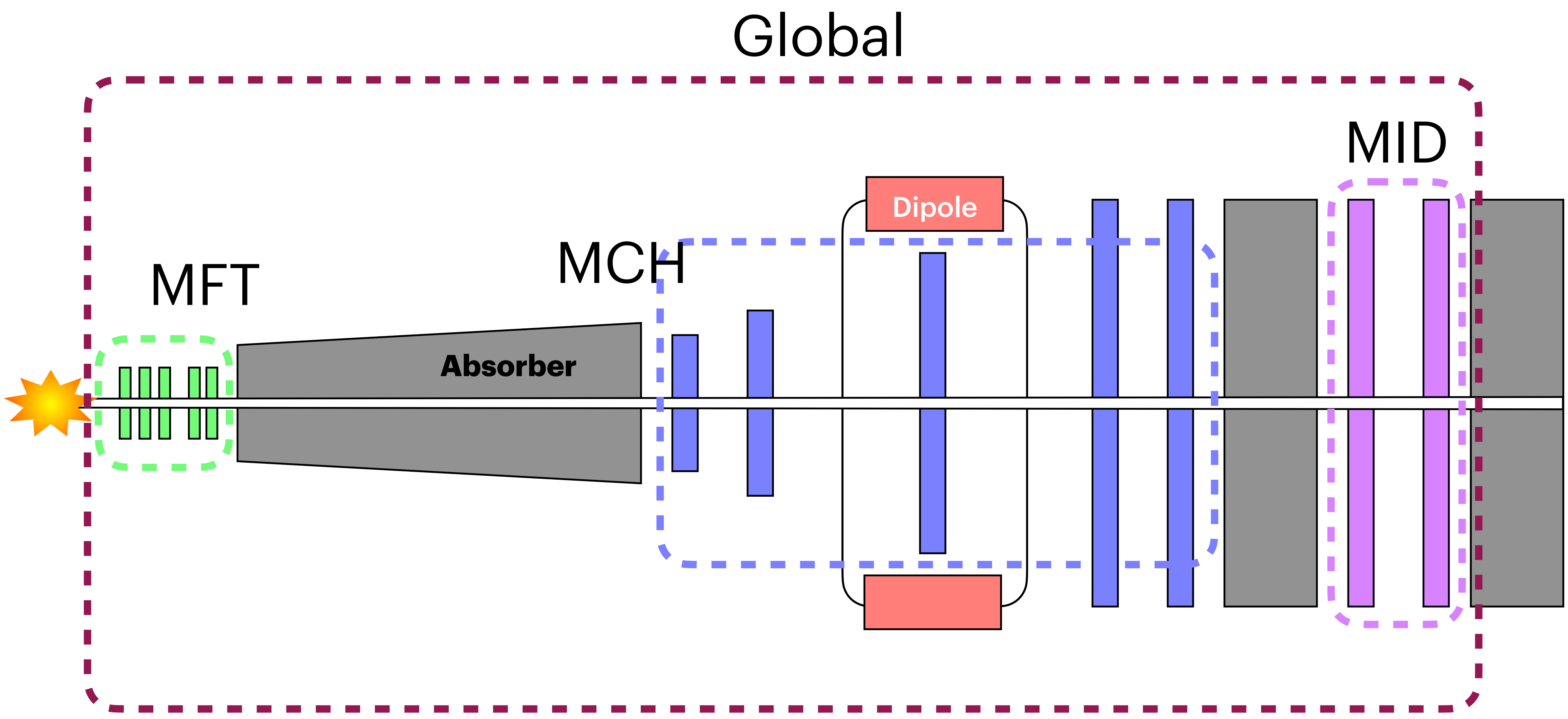
Muons in ALICE Run 3

- The Muon Forward Tracker is added for run 3
- Granular silicon detector placed in front of the absorber at 40 cm from the interaction point
- Improvements:
  - The S/B ratio
  - Precise determination of production vertex
  - Better dimuon opening angle resolution



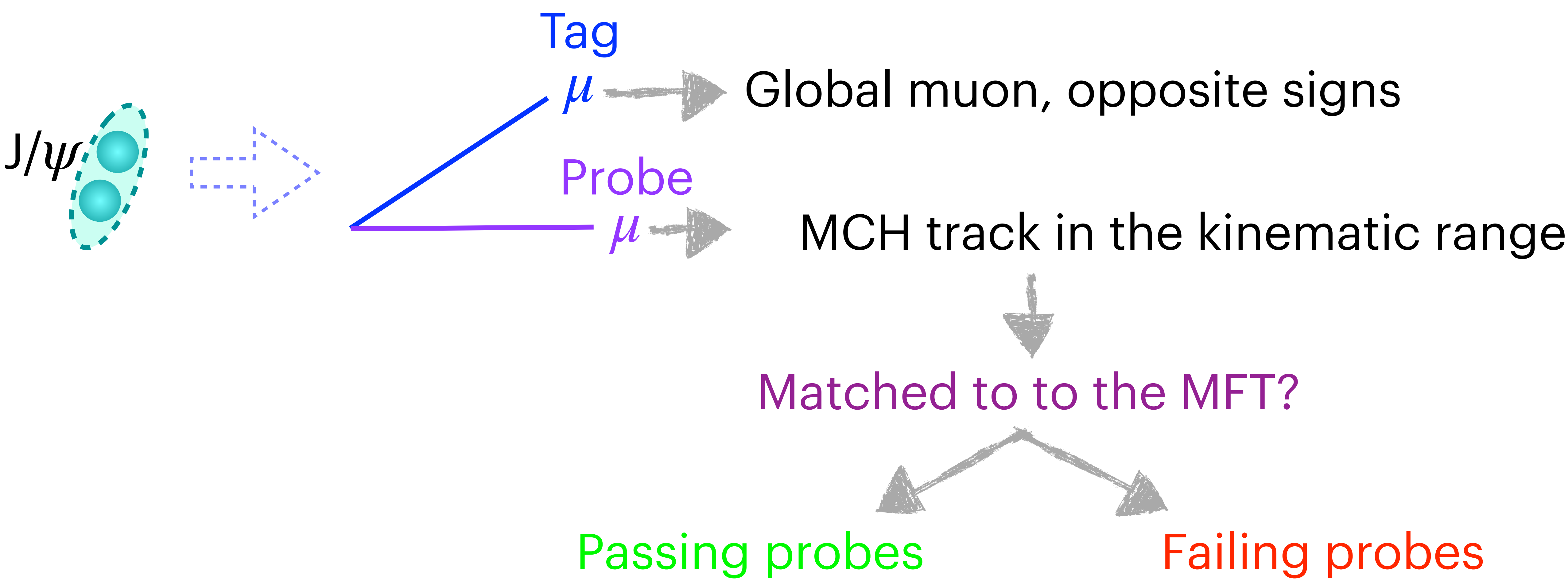
Tag-and-Probe in ALICE

- In Run 3 analyses will use global muons: reconstructed in the three subsystems (MFT, MCH and MID)
- An important part of the reconstruction: matching between MCH and MFT
- The efficiency is going to be calculated in simulation
- T&P studies are needed for calibration



The starting point

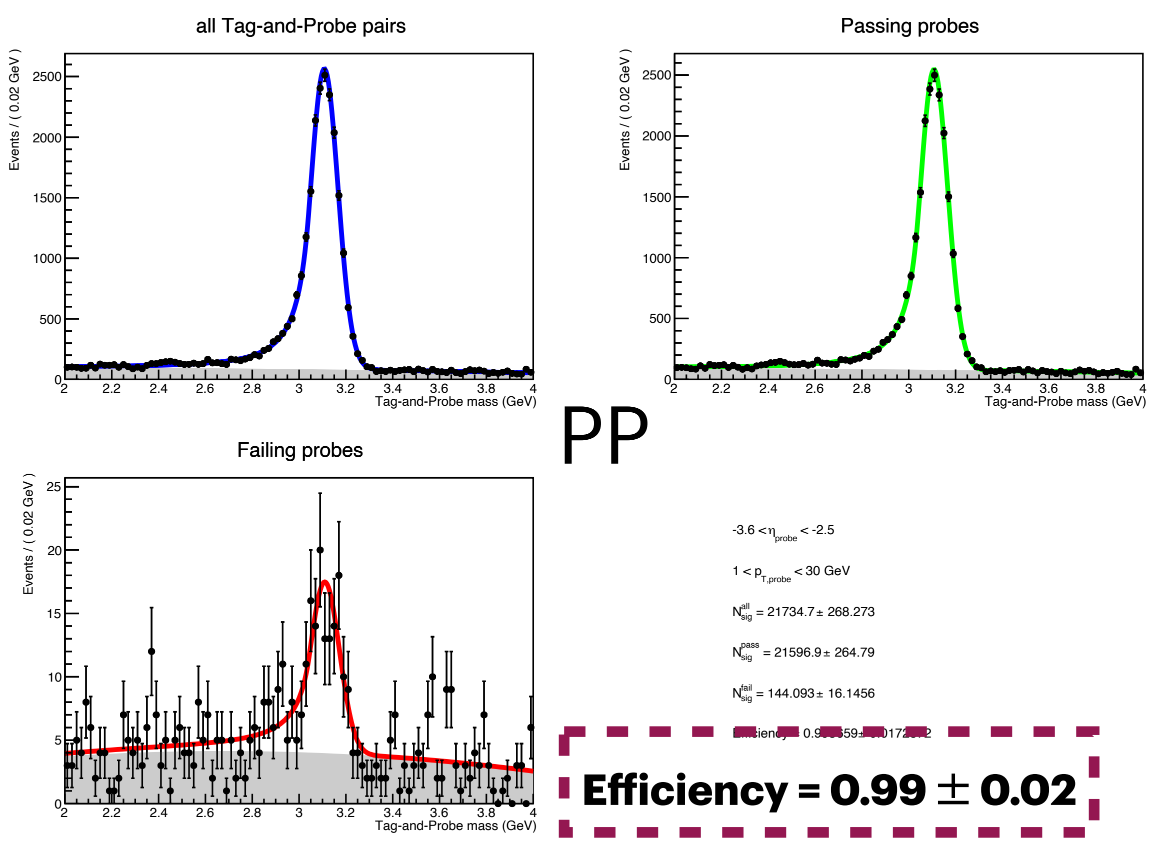
- For now we only have MC simulation
- Using the nonprompt J/ψ simulations in pp and PbPb

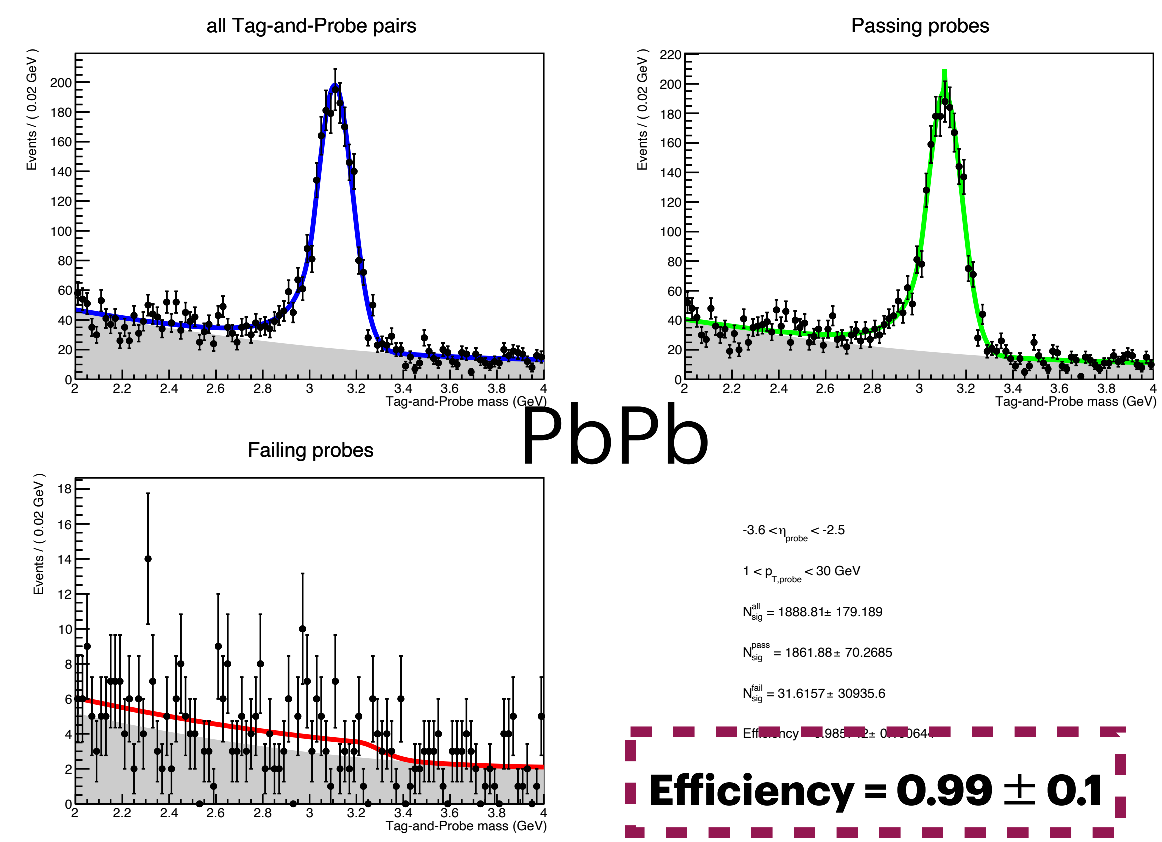


- All kinematic quantities (p_T, η, M…) are taken from the MCH tracks
- No additional criteria are applied on the quality of the tracks (e.g χ^2)
- In PbPb there is no centrality spectrum correction. Centrality is flat here which does not realistically represent data

Tag-and-probe fits

- Fits on the invariant mass of the T&P pairs, done with the rooFit package
- The fits are done for three categories: all probes, passing probes and failing probes but only all and passing fits are taken into account in the efficiency calculations
- For the signal: two Crystal Ball functions and for the background: 1st order Chebychev polynomial
- The fits definitely need more work but they give a good estimate for now
- An unrealistic efficiency of 0.99 for both pp and PbPb

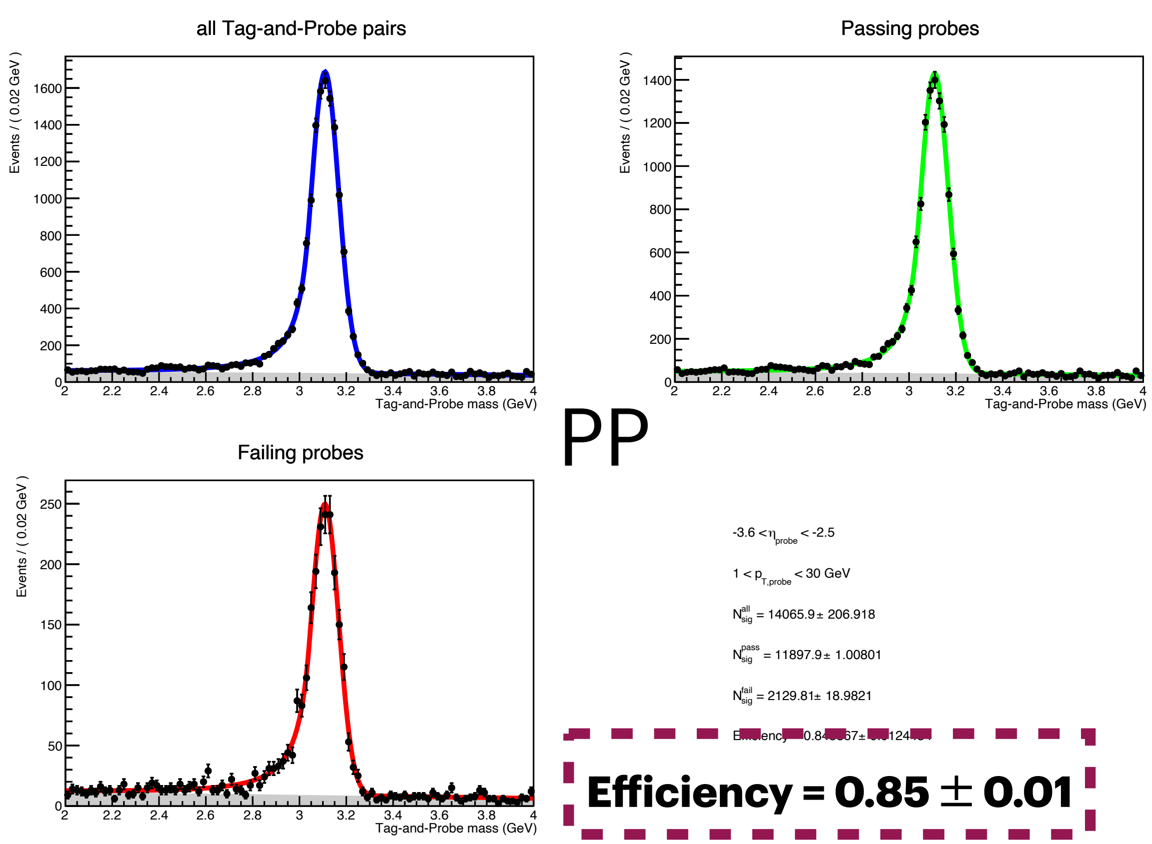




Tag-and-probe fits

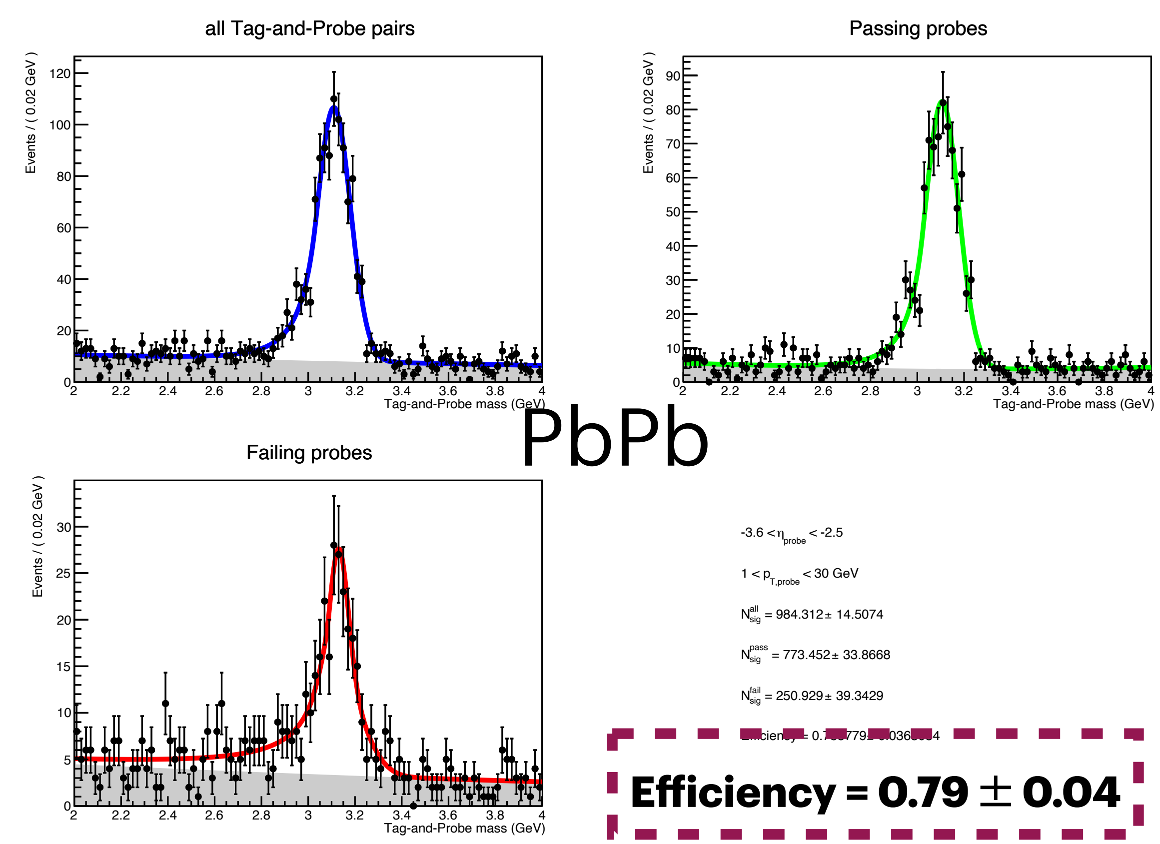
- It is not enough for the MCH to have a match in the MFT. It needs to be the right match
- In MC this information is available (🛑 will not be available in data)
- In these fits the match is required to be the correct one for both the tag and the passing probes
- A decrease in the efficiency from 0.99 to 0.85 in pp and 0.79 in PbPb (would even be lower in PbPb when the centrality distribution is corrected)
- The main challenge is not the inefficiency itself but the mismatching

PP



Efficiency = 0.85 ± 0.01

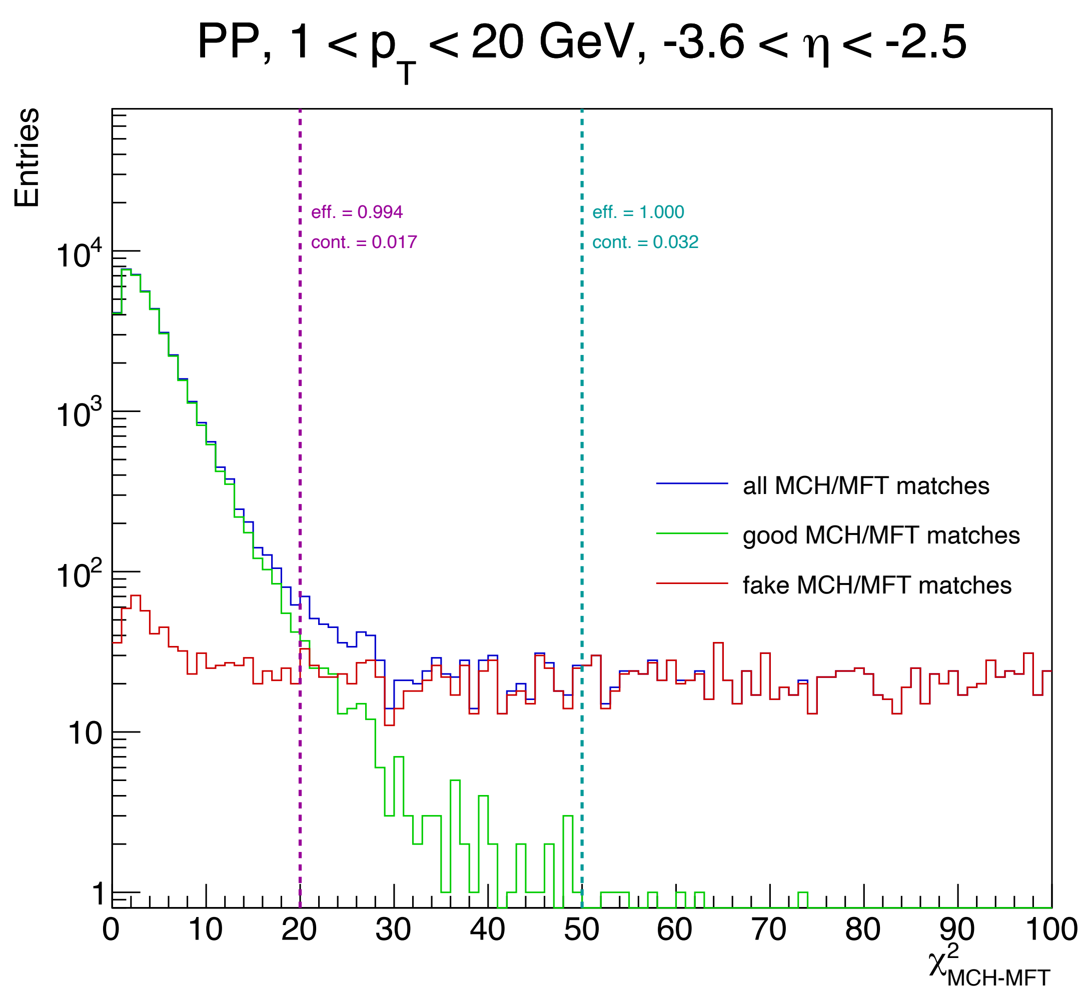
PbPb

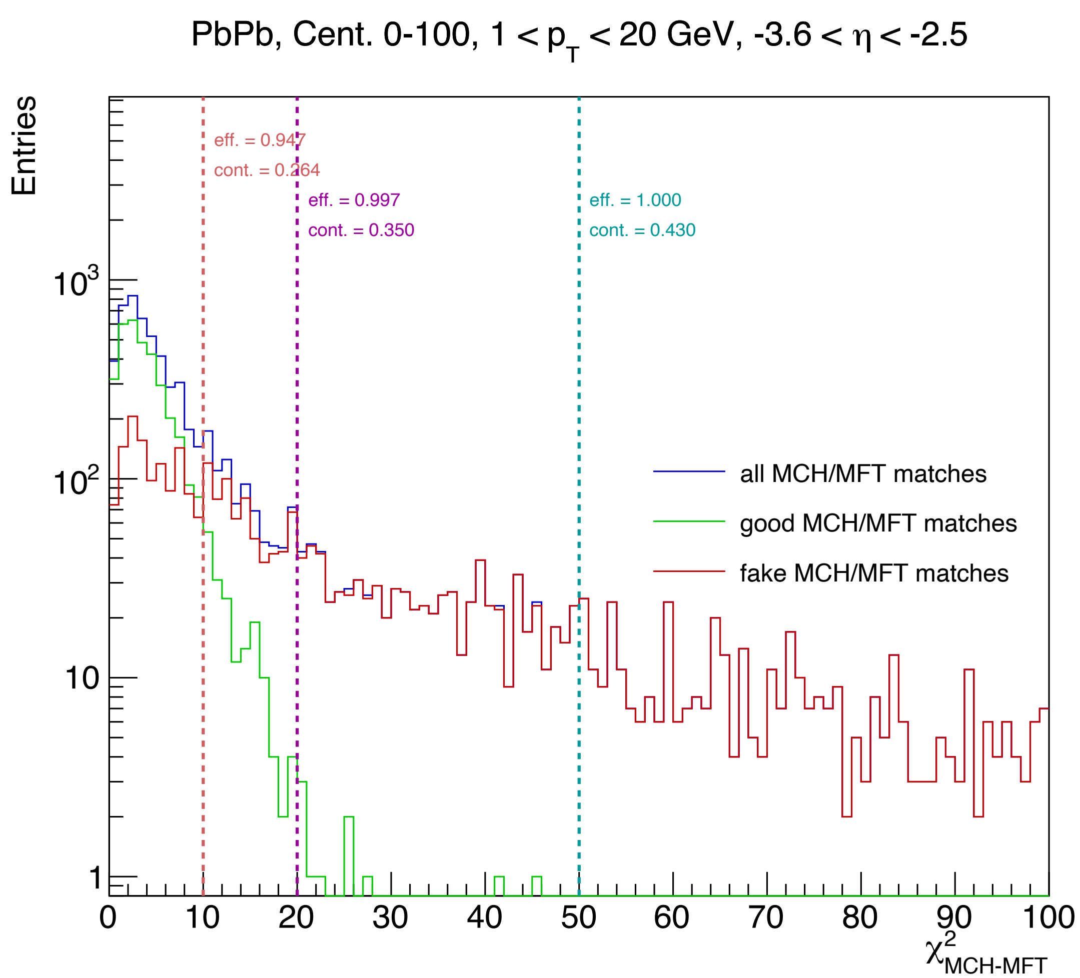


Efficiency = 0.79 ± 0.04

Challenges for fake match rejection

- Need a discriminator that exist in data as well as MC
- Let's start by looking at the χ^2 of the MCH/MFT match in MC for good and bad matches and look for a pattern
- In PP: big peak of good matches at low χ^2, almost flat distribution of bad matches
- Harder to separate in PbPb
- With a simple cut on the χ^2 we need to know the inefficiency and the contamination
- Not a good solution especially in PbPb
- Machine learning will be used to reject fake matches





Summary

- The Tag-and-Probe method will be used for the first time for muons in ALICE
- The focus will be the matching between the muon chambers and muon forward tracker
- The work started but still very preliminary
- Many challenges will be faced but they don't only concern Tag-and-Probe

Thank you