Muons and electrons for quarkonia with ATLAS and CMS

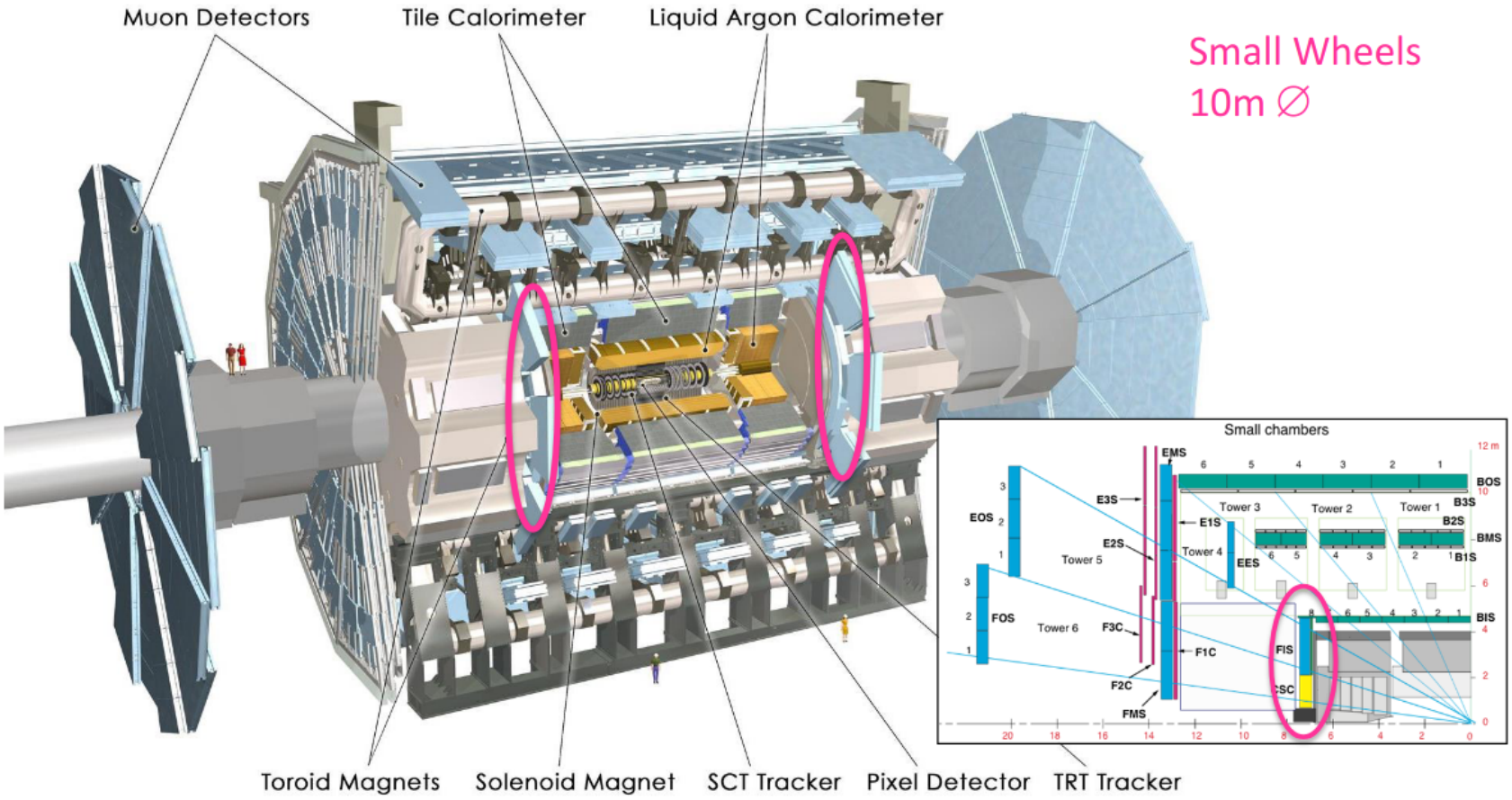
Émilien Chapon

DPhP / Irfu / CEA Saclay

Muon detection and quarkonium reconstruction at the EIC
April 25, 2022

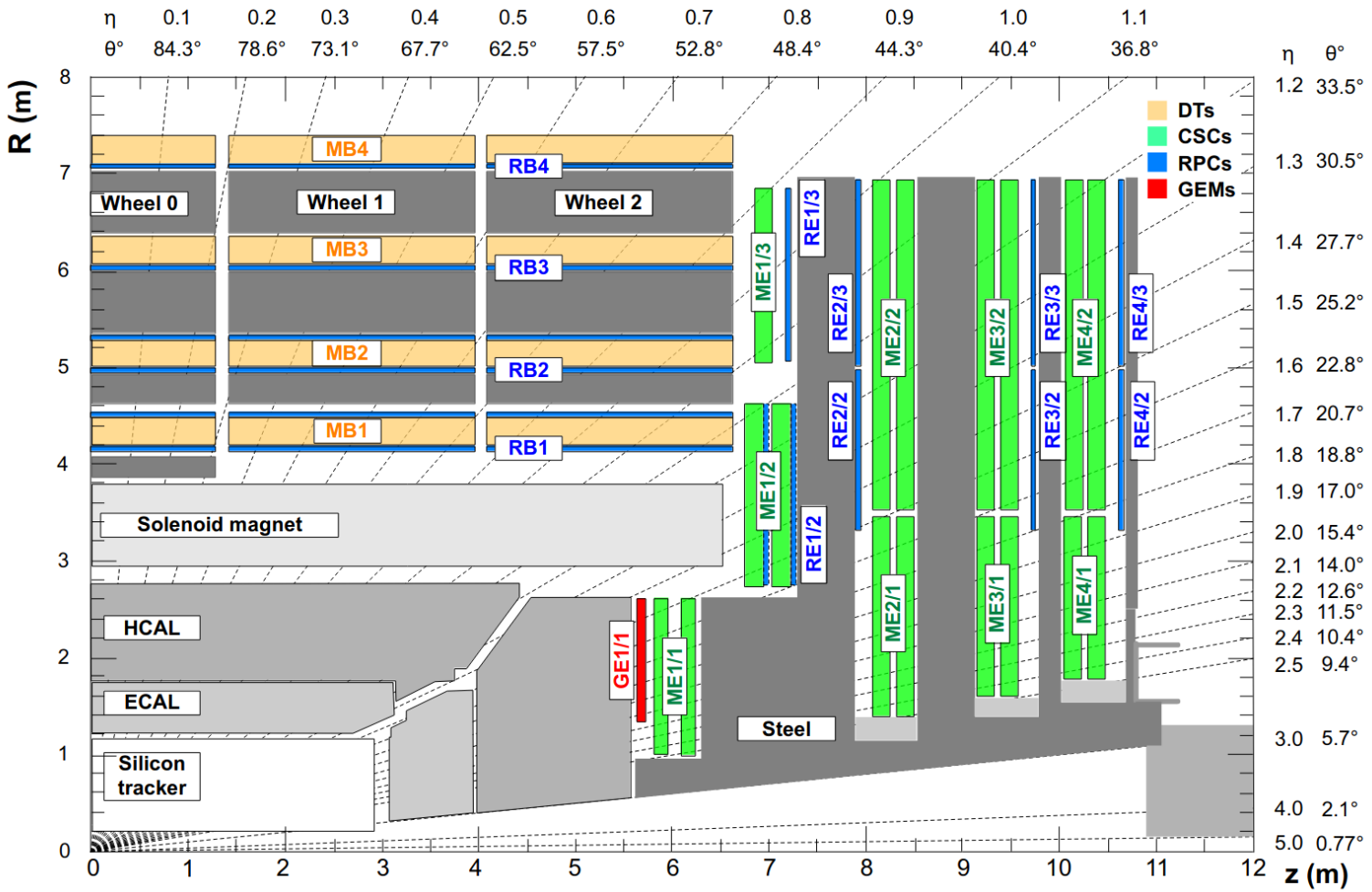
Muons

ATLAS



- Monitored drift tubes (MDT, precision)
- Cathode strip chambers (CSC, precision)
- Resistive-plate chambers (RPC, trigger)
- Thin-gap chambers (TGC, trigger)

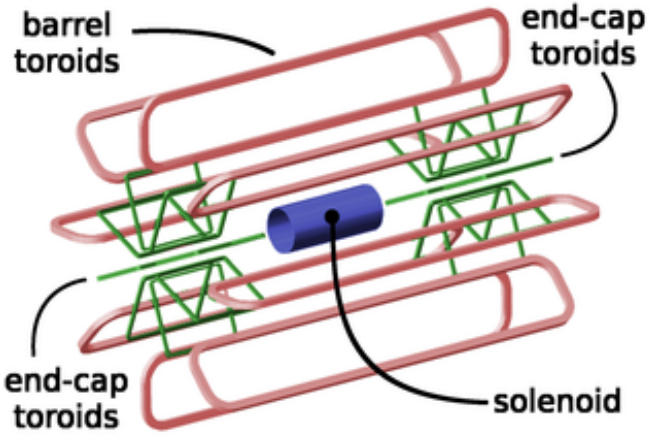
CMS

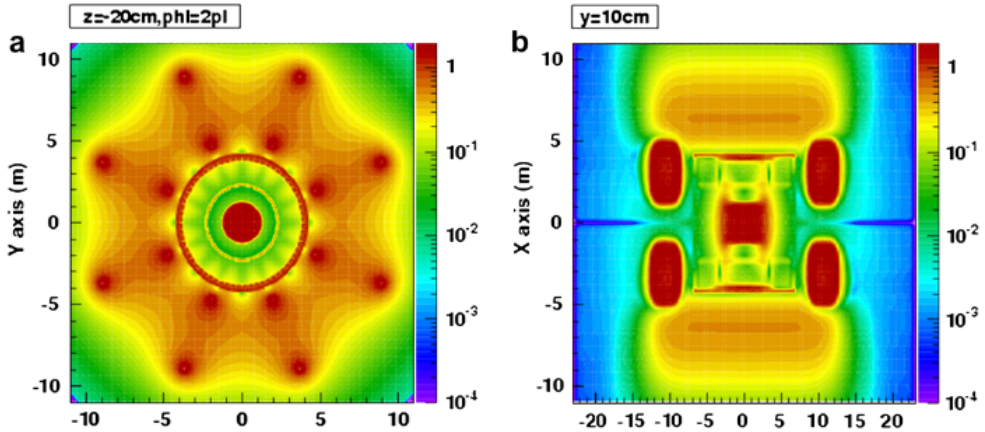


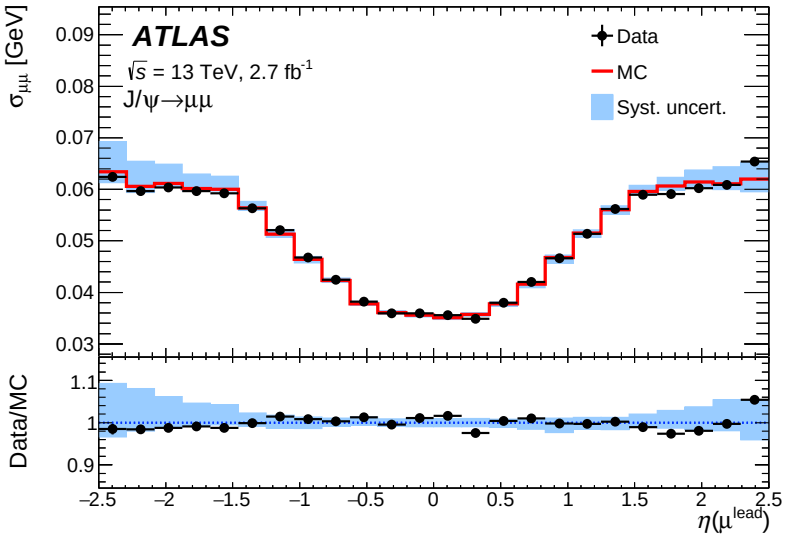
- Drift tubes (DT, precision)
- Cathode strip chambers (CSC, precision)
- Resistive-plate chambers (RPC, trigger)
- Gas electron multiplier (GEM, new for Run 3)

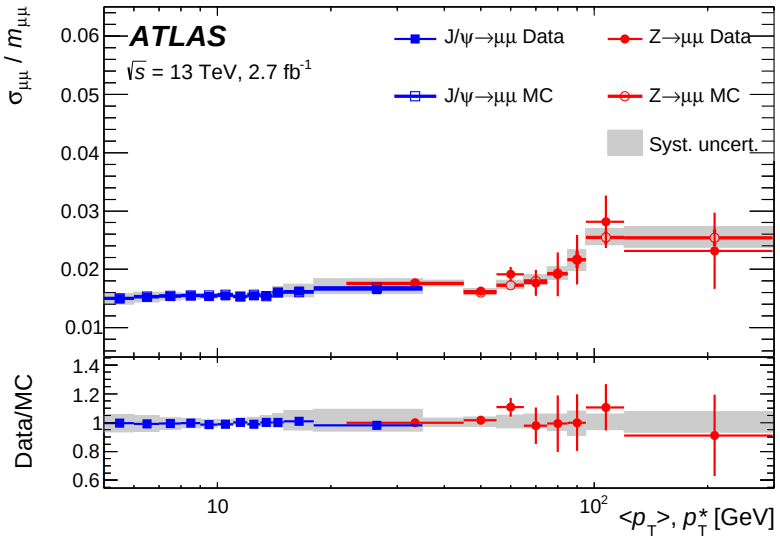
ATLAS

Physica C: Superconductivity 468 (2008) 2137, EPJC 76 (2016) 292



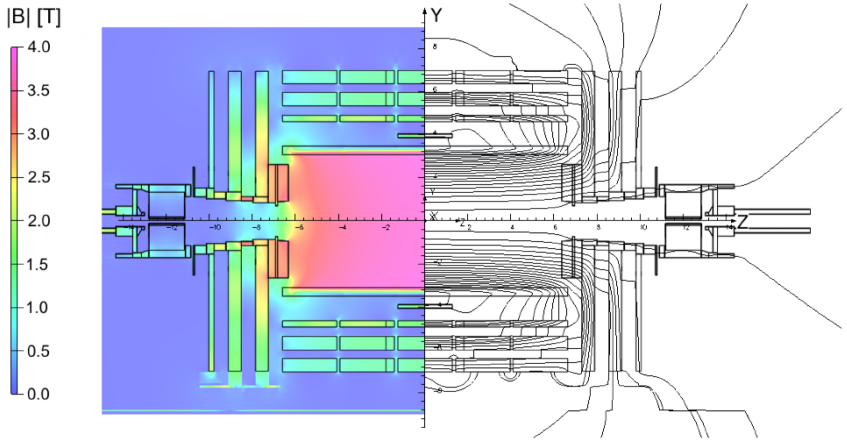


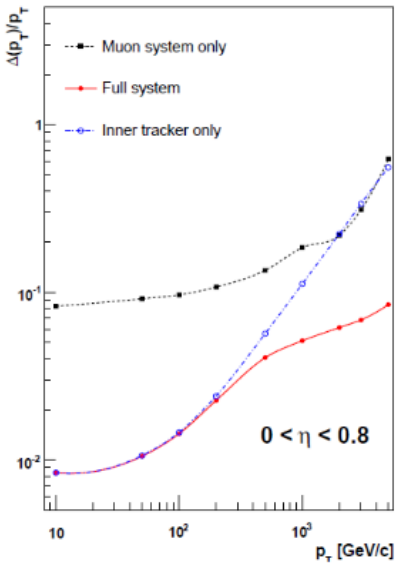


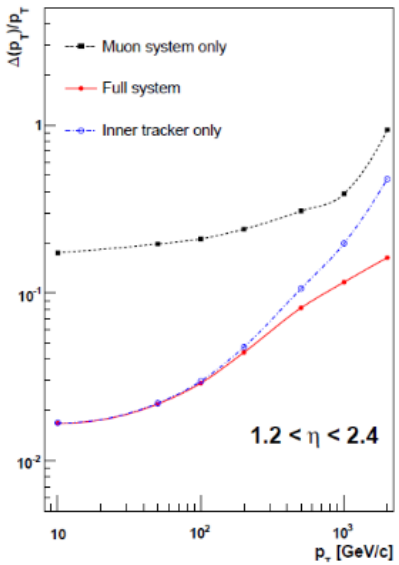


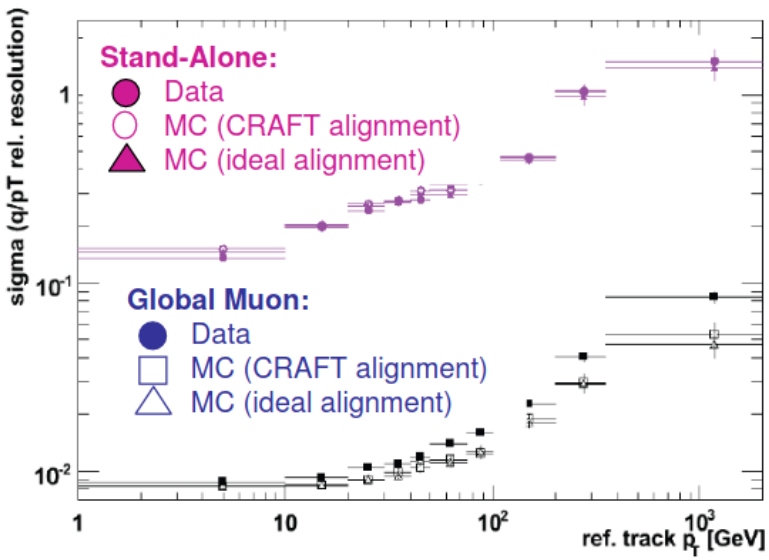
CMS

JINST 8 (2013) P11002, https://indico.cern.ch/event/51276/





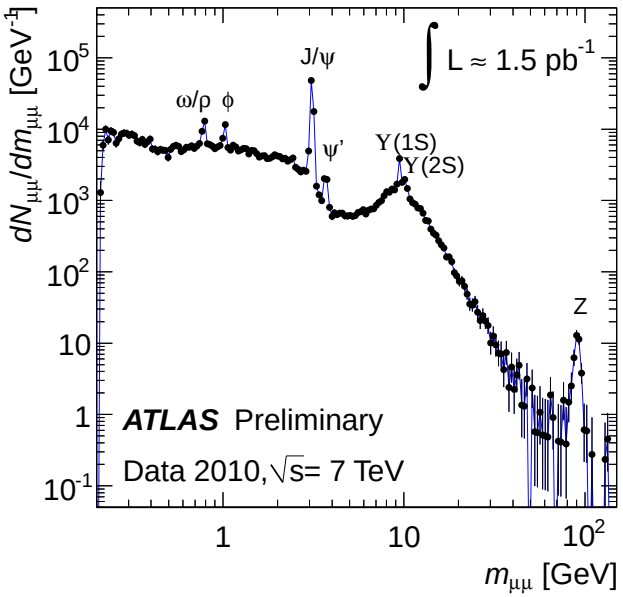


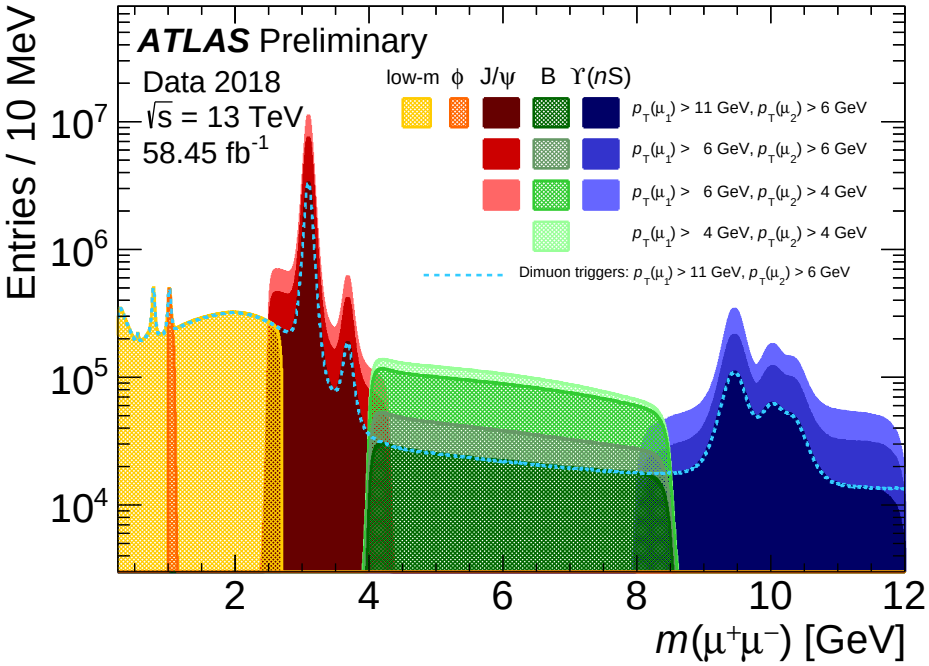


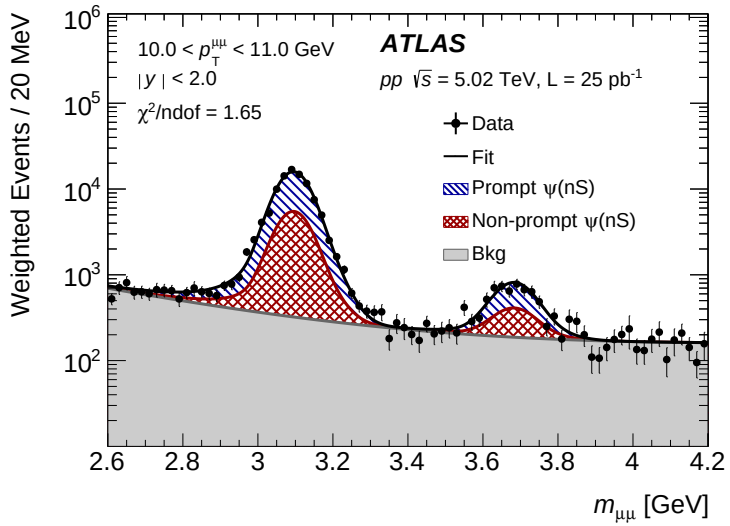
- Magnetic field $\approx 3.8\,\mathrm{T}$ in the inner detector
- Momentum resolution driven by the inner tracker at low p_T

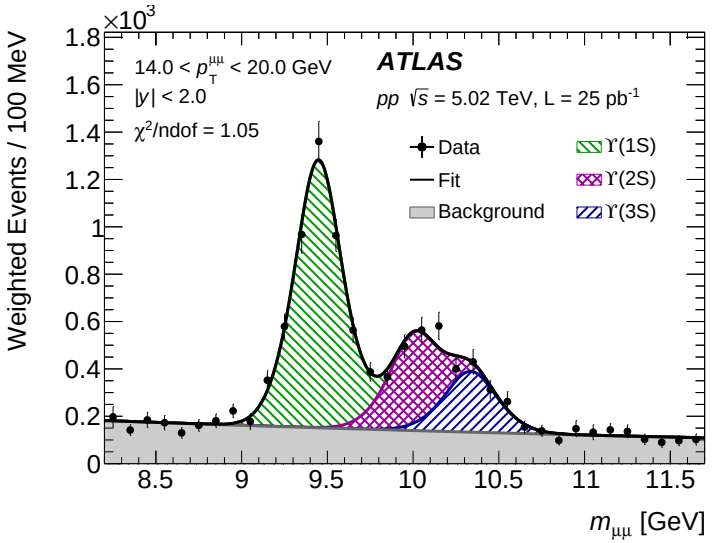
ATLAS

ATLAS-CONF-2011-003, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BPhysicsTriggerPublicResults, **EPJC 78 (2018) 171**



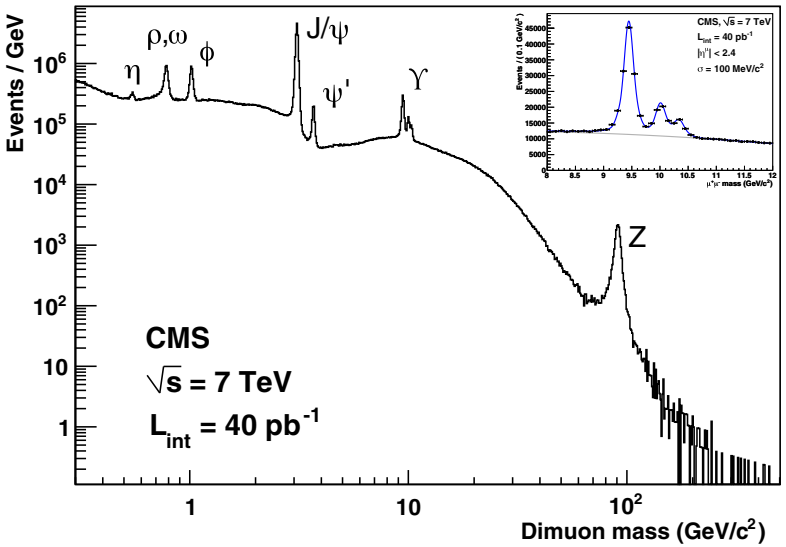


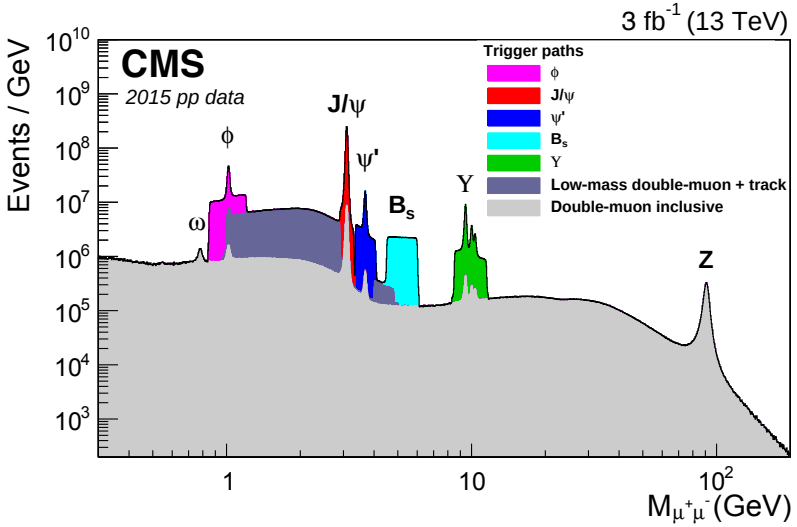


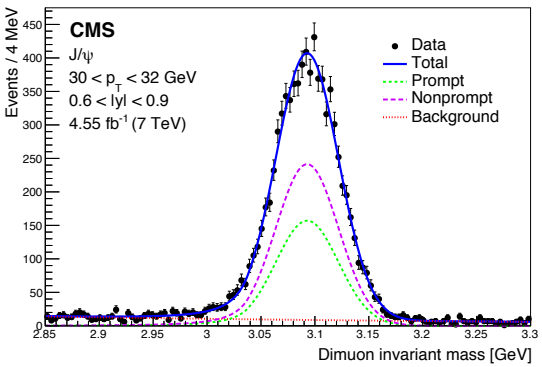


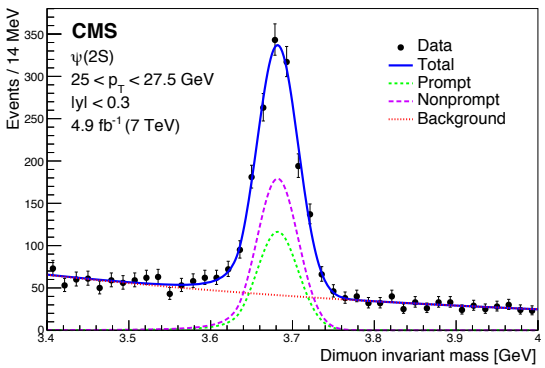
CMS

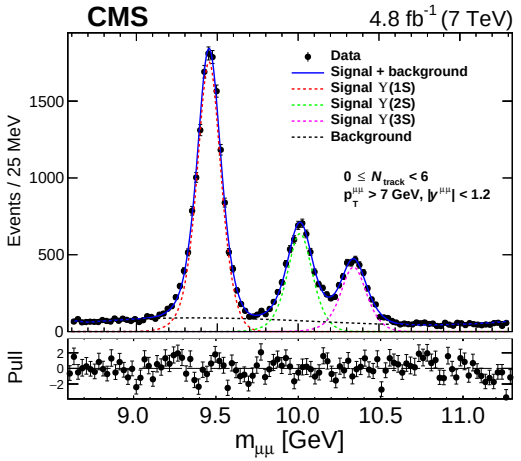
JINST 7 (2012) P10002, JINST 13 (2018) P06015, PRL 114 (2015) 191802, JHEP 11 (2020) 001







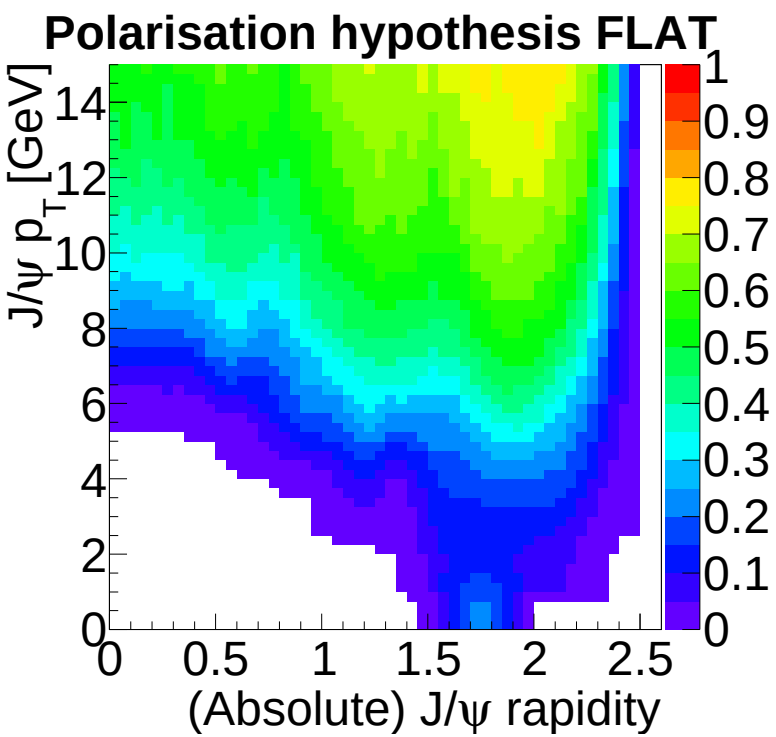


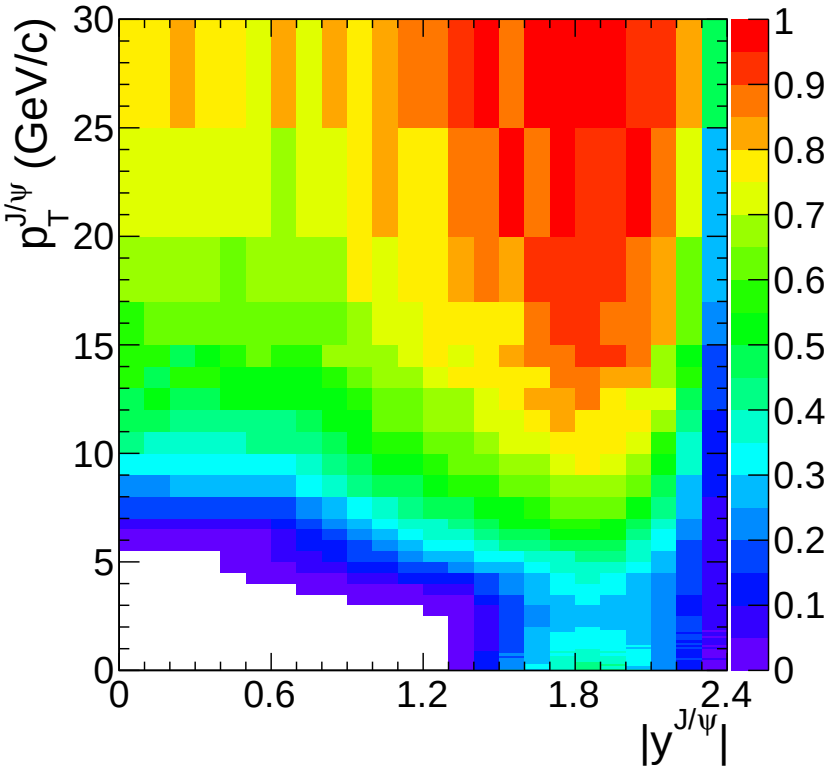


ATLAS/CMS

Nucl.Phys. B 850 (2011) 387, EPJC 71 (2011) 1575

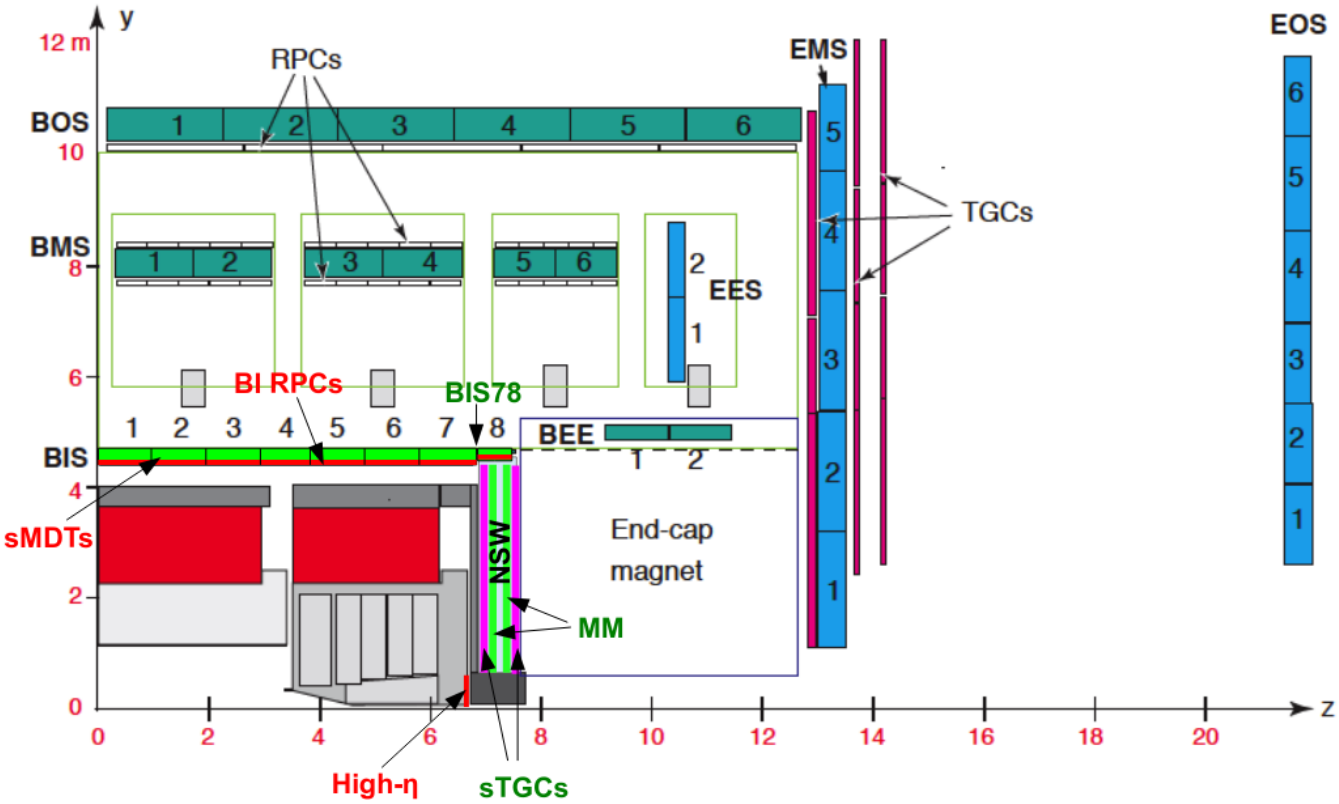
Similar acceptance at low p_T between ATLAS (left) and CMS (right) (NB: some differences expected, e.g. trigger / efficiency)





ATLAS upgrades

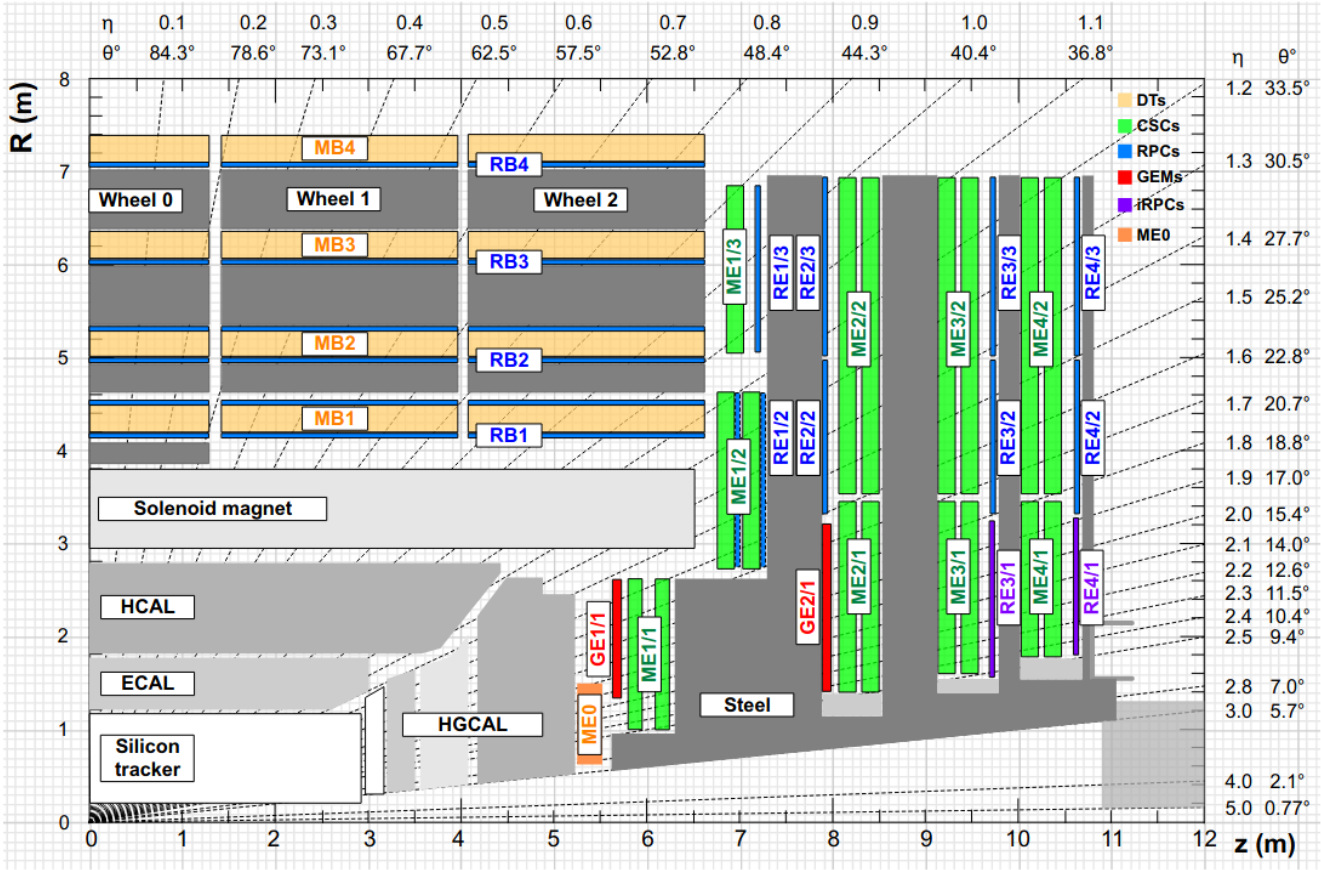
ATLAS-TDR-026



- **Phase-I (Run 3, now)**: BIS78 (barrel inner MDT and RPC), NSW (new small wheel): MM (micromegas), sTGCs (small-strip TGC)
- **Phase-II (HL-LHC, 2029+)**: sMDTs (small-diameter MDT)
- Trigger and readout electronics (higher rates, higher latency)

CMS upgrades

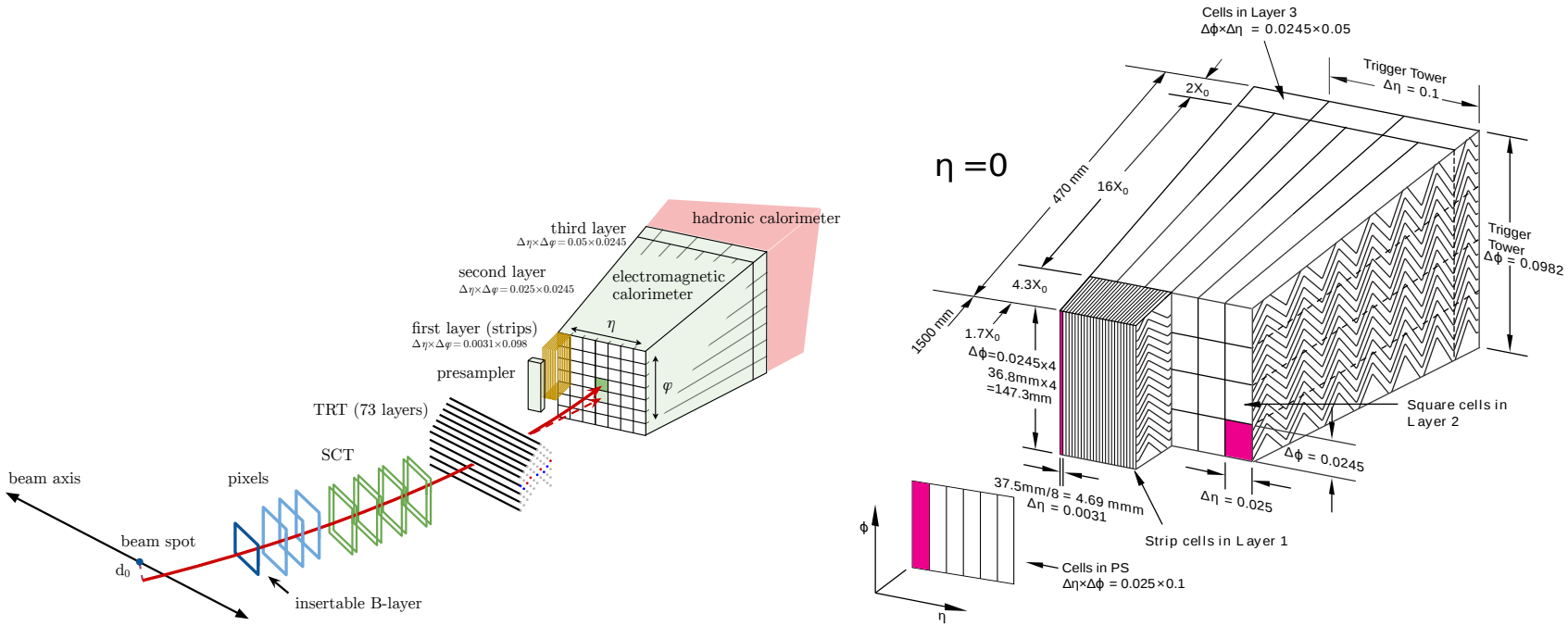
CMS-TDR-016



- New chambers in the forward region (lower trigger rates, increased acceptance): CSC (ME0), GEM (GE), improved RPC (iRPC).
- Trigger and readout electronics (higher rates, higher latency)

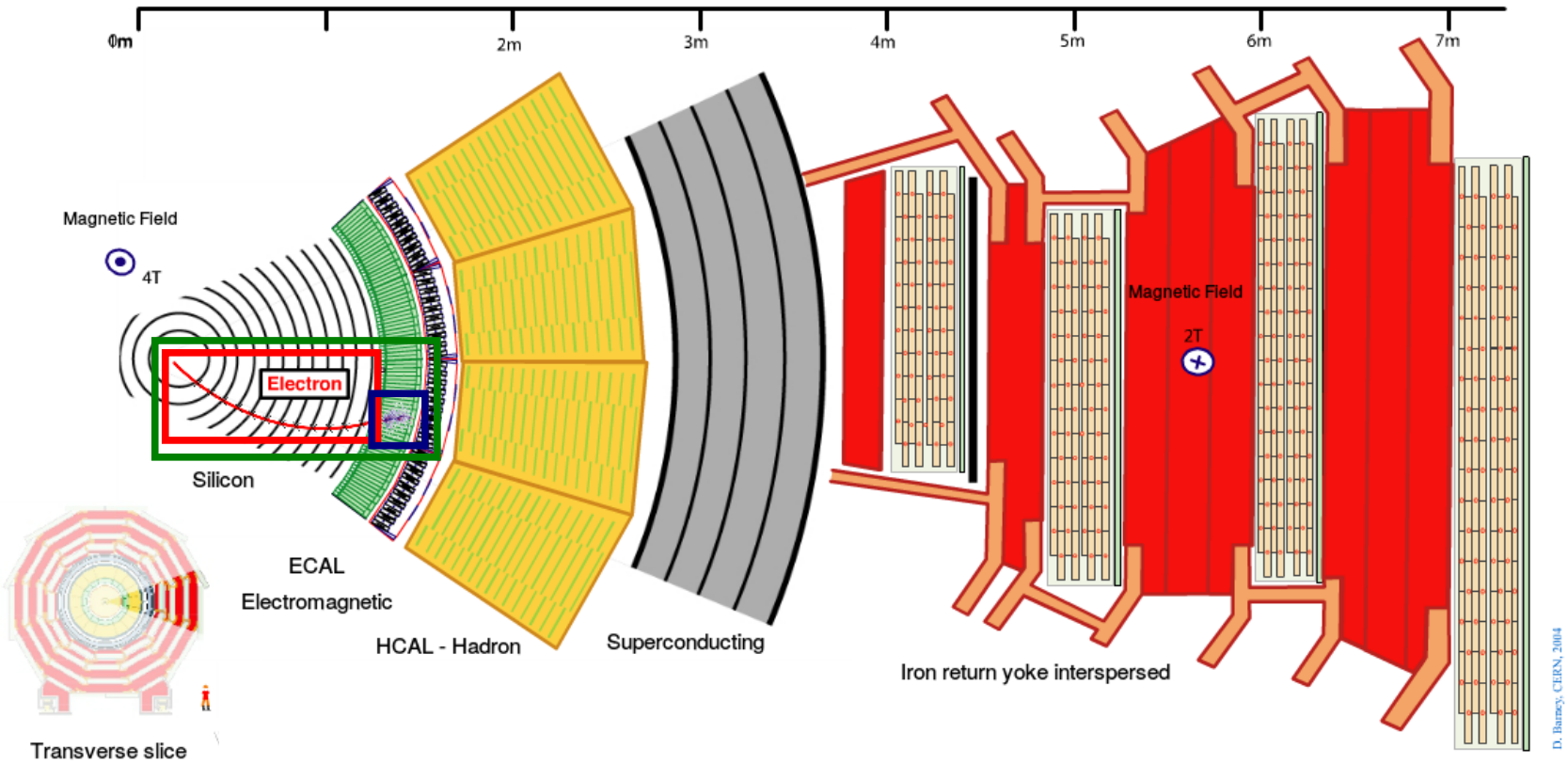
Electrons

ATLAS



Combine information from the liquid argon calorimeter and inner detectors: pixels, silicon tracker (SCT), transition radiation tracker (TRT).

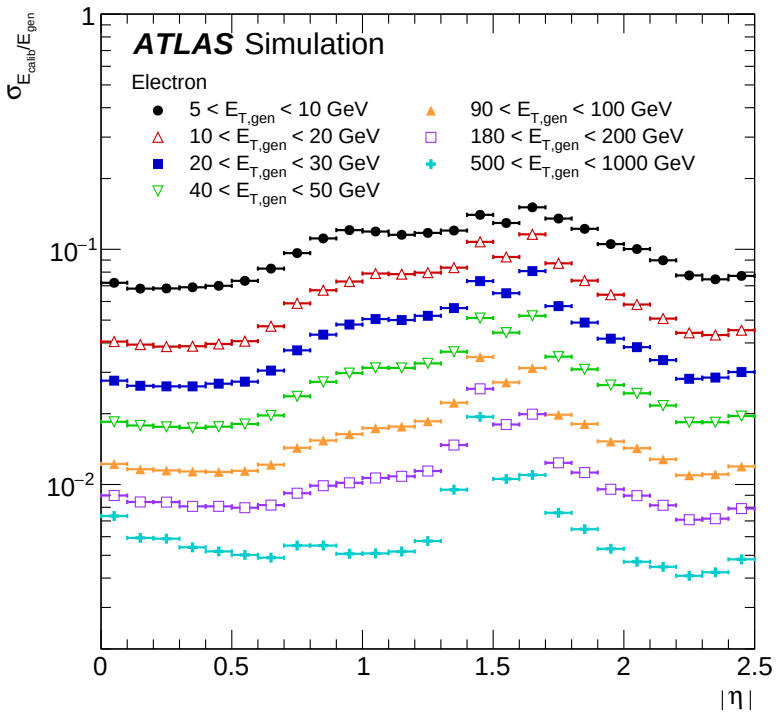
CMS

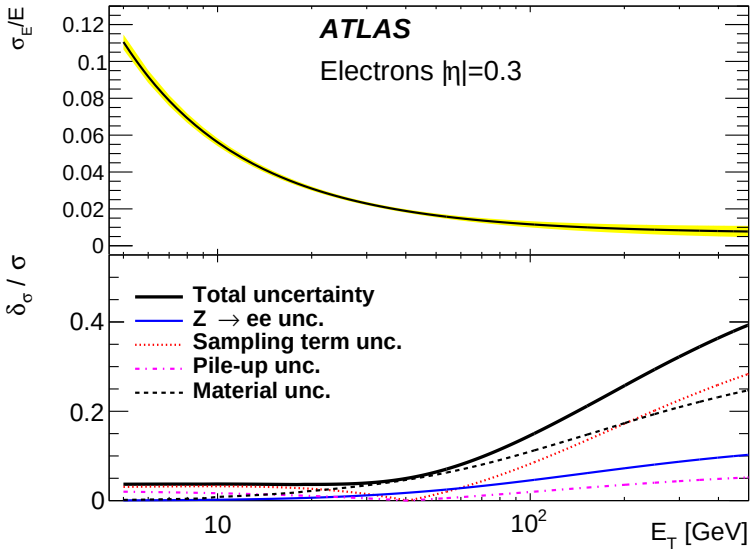


Combine information from the $PbWO_4$ calorimeter and the silicon tracker

ATLAS

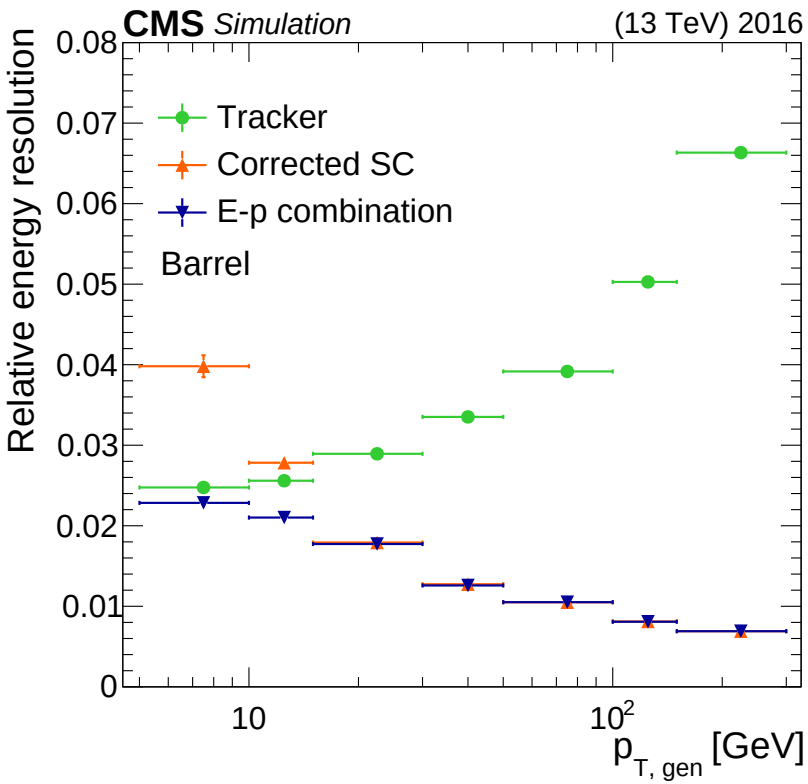
JINST 14 (2019) P03017

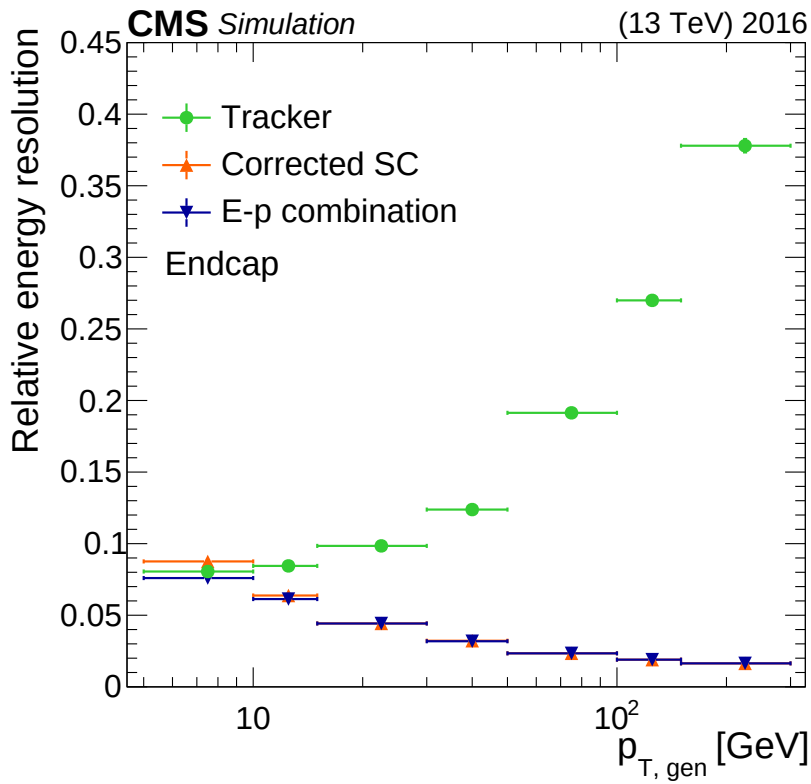




CMS

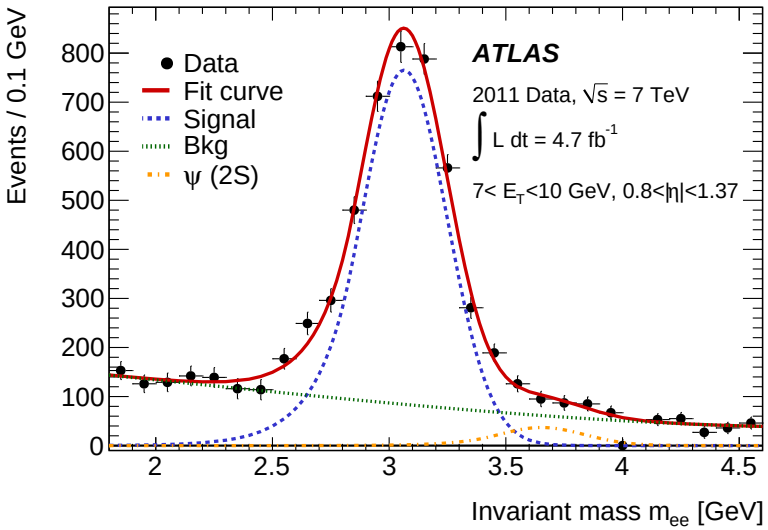
JINST 16 (2021) P05014

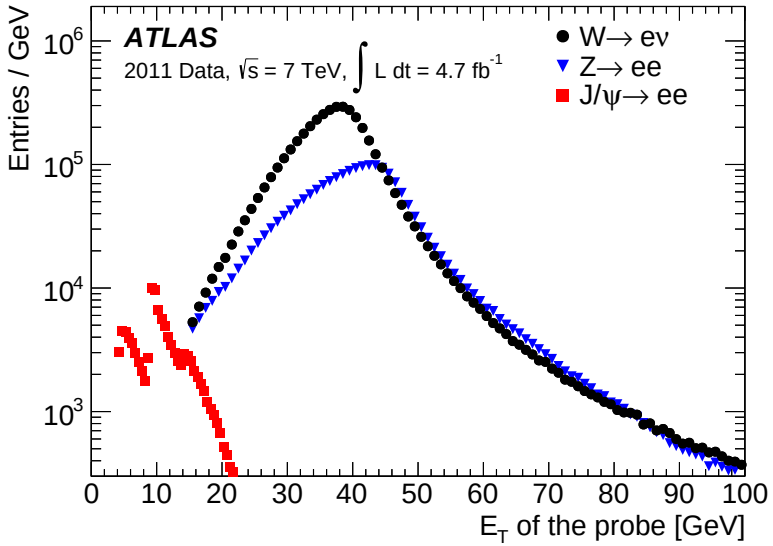




ATLAS

EPJC 74 (2014) 2941

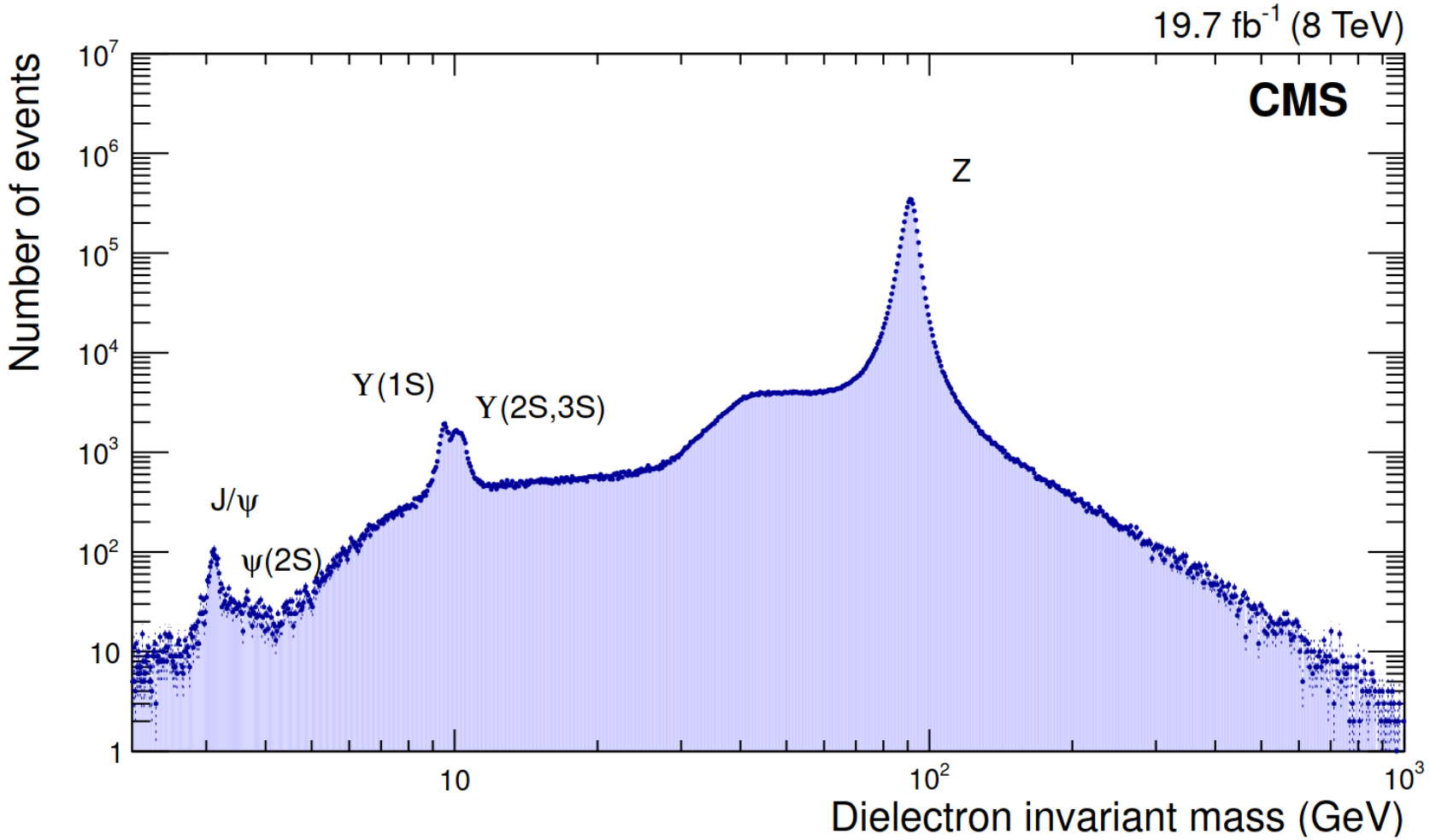




Good resolution and S/B (left), but small number of recorded events for quarkonia (right)

CMS

JINST 10 (2015) P06005



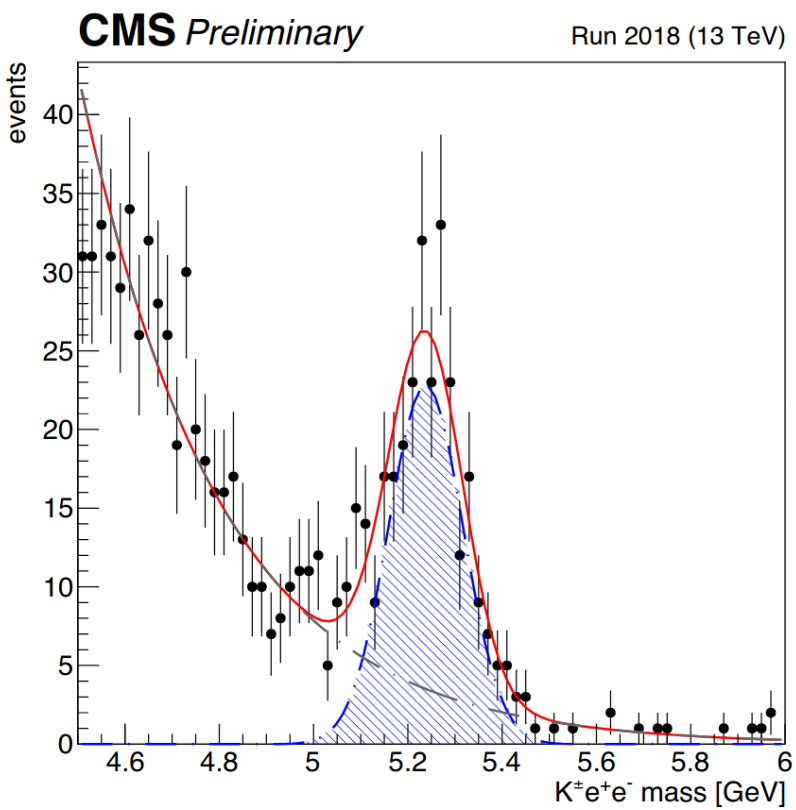
Good resolution and S/B, but small number of recorded events for quarkonia

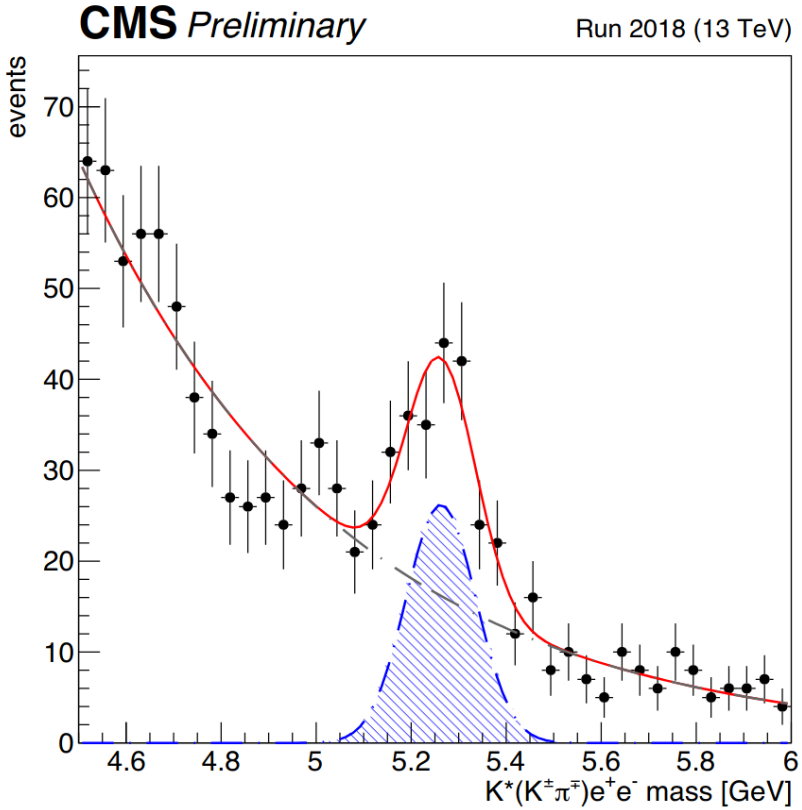
CMS special case

https://cds.cern.ch/record/2704495

Special case: "data parking"

- Record high rate of $b \to \mu + X$ events, which are only reconstructed months later
- $\approx$ 10 billion unbiased b hadron decays recorded throughout Run 2
- Targetting flavour anomalies





Comments

Quarkonia are measured only in $\mu^+\mu^-$ with ATLAS and CMS, never e^+e^- (except for performance studies: efficiency, momentum scale and resolution):

- Low-p_T muons are much easier to **trigger** than low-p_T electrons
  - Only calorimeter information available at L1 $\rightarrow$ very high rate of low E_T clusters
  - Large backgrounds for electrons (jets, photons)
- Higher **efficiency** (and / or lower background) for muons than electrons
- Similar / better **resolution** for muons at low p_T

Summary

- Muons: excellent performance at both low and high p_T (i.e. for quarkonia and for W/Z)
- Electrons: excellent performance at high p_T, very challenging triggering at low $p_T \rightarrow$ not suitable for quarkonium measurements