Heavy Flavor Physics with ATLAS

Personal Perspective

Qipeng Hu (LLNL)

EF07 Meeting
July 1st, 2020

Heavy flavor program in ATLAS heavy ion group

Heavy flavor efforts in ATLAS heavy ion group:

> 2~3 analyzers for HF hadron
>
> 2~3 analyzers for HF jets
>
> + full support from the entire heavy ion group

- Small ATLAS high-lumi. *pp* B-physics group; stronger connection, heavy ion studies sometimes benefit HEP studies
- Strong ATLAS high-lumi. *pp* heavy flavor jet tagging group

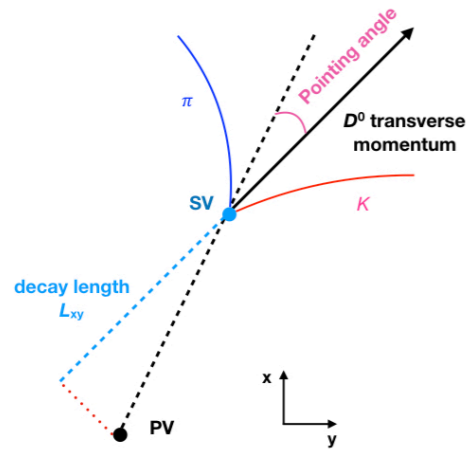ATLAS HF program has been focusing on the semi-leptonic decay muons recently

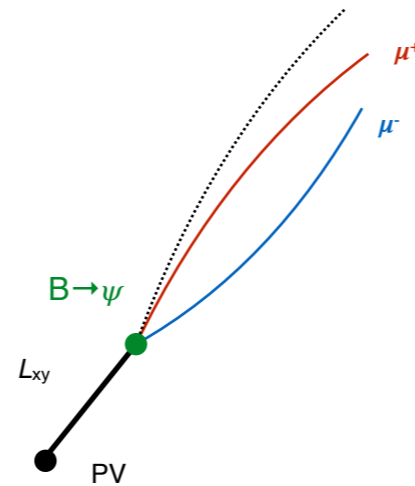Significant efforts in HF jets with good progress

Small group trying to make big contribution
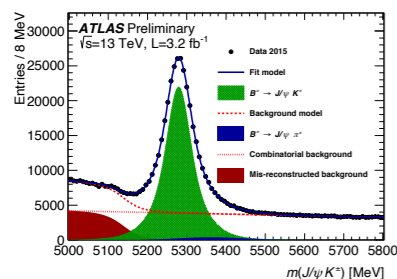
Tools for studying HF hadrons

B/D meson
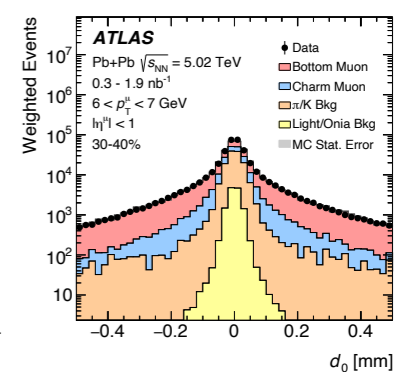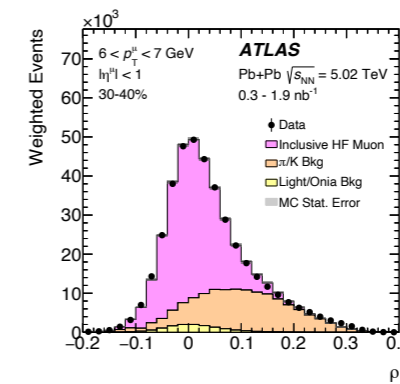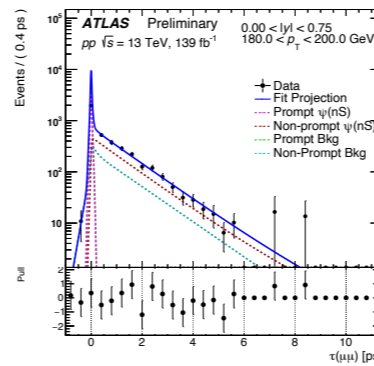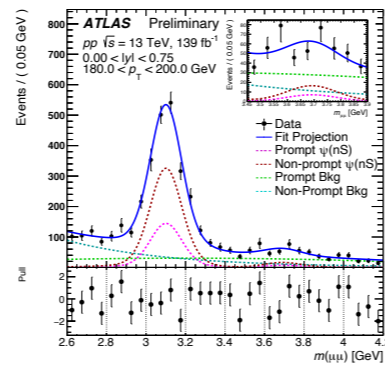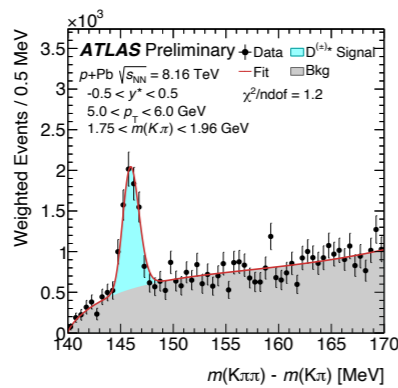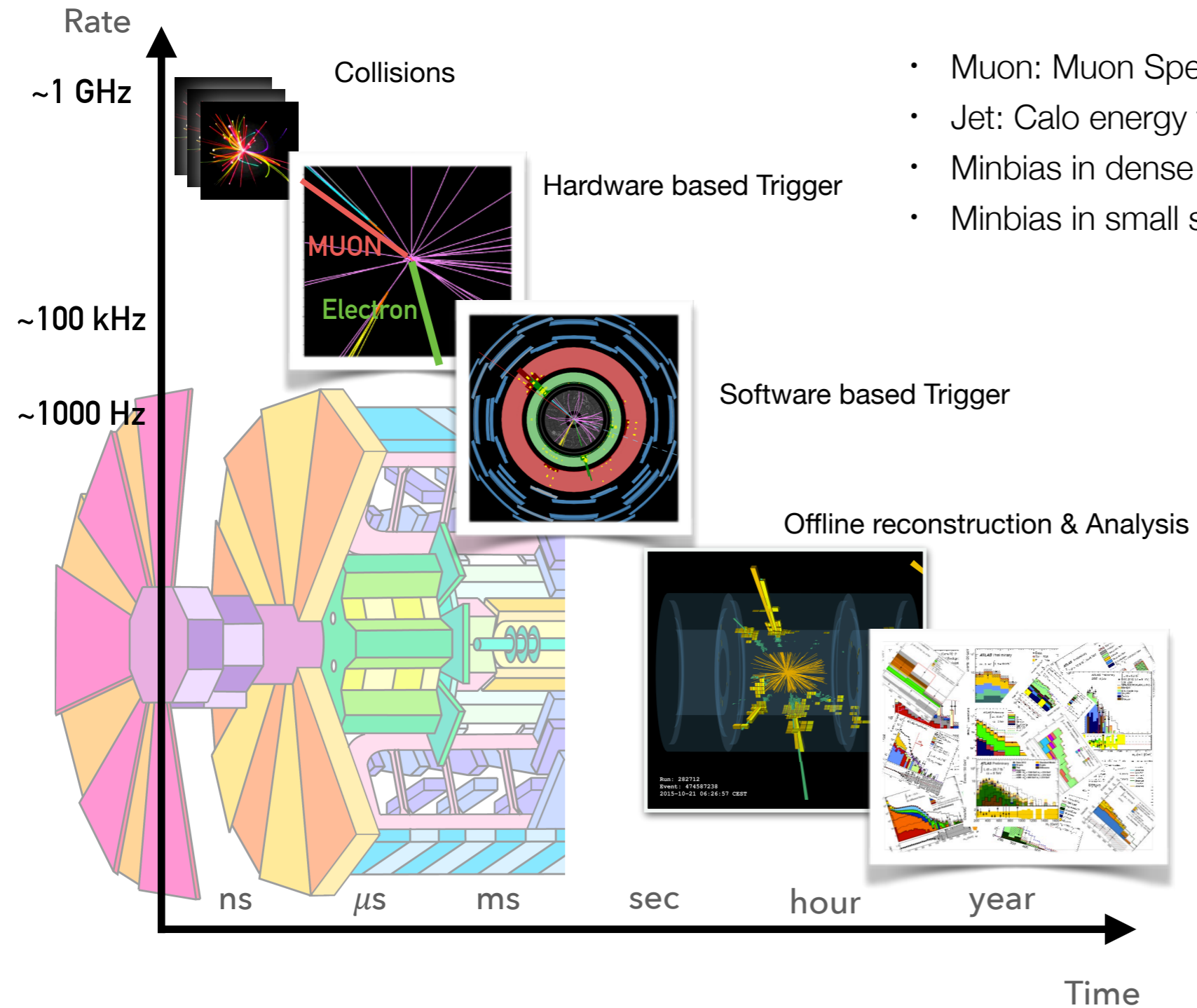

non-prompt charmonium

B/D decay muon
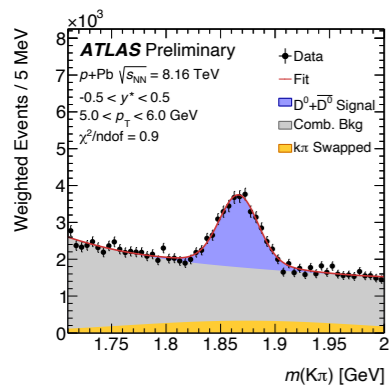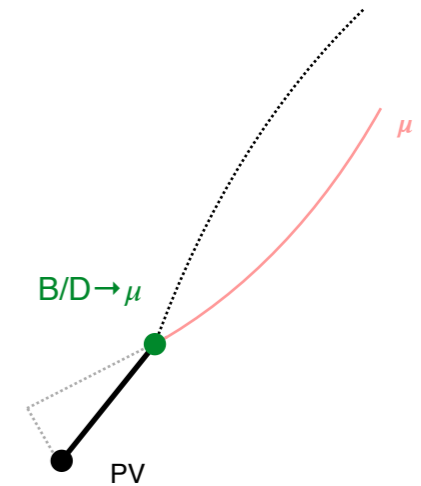
$D^0 \to K + \pi$

$D^* \to D^0 + \pi_s \to K + \pi + \pi_s$

$B \to J/\psi + K$

- Only probe high p_T open beauty
- No access to low p_T due to trigger threshold

- Measure open charm and beauty at the same time
- Hard to extend to high p_T due to W decay background

ATLAS trigger system

Rate

~1 GHz

~100 kHz

~1000 Hz

Collisions

Hardware based Trigger

MUON

Electron

Software based Trigger

Offline reconstruction & Analysis

ns   μs   ms   sec   hour   year

Time

- Muon: Muon Spectrometer tracklet
- Jet: Calo energy tower
- Minbias in dense environment: Calo energy sum
- Minbias in small system: MinBias Scintillator hits / random

ATLAS tracking system
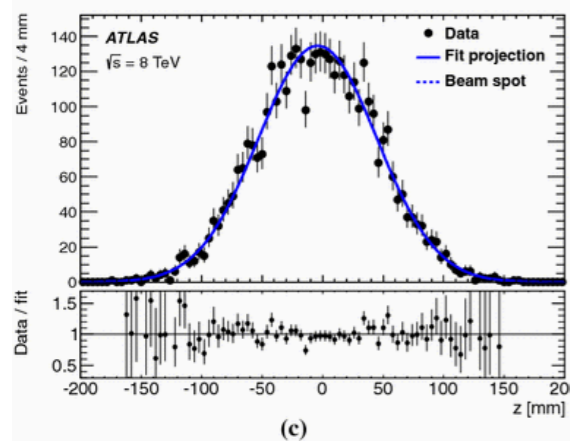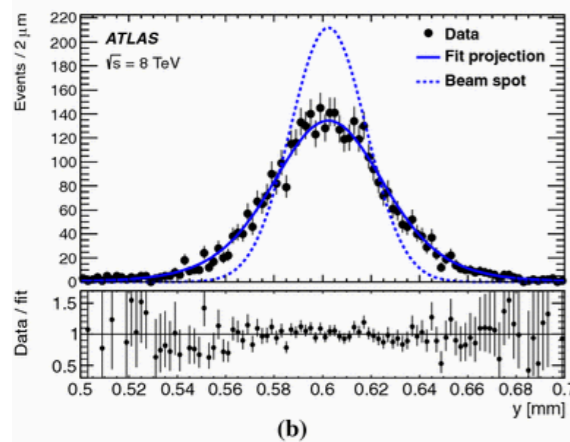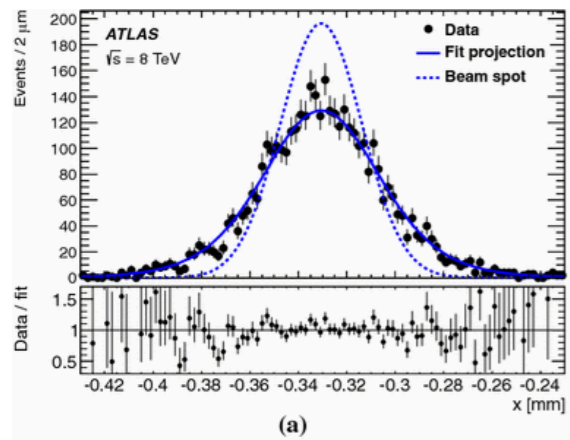
PV resolution vs. beam
spot in *pp* collisions

Impact parameter resolution
in *pp* collisions

Tracking efficiency
in Pb+Pb collisions

5

ATLAS muon system

by J. J. Goodson

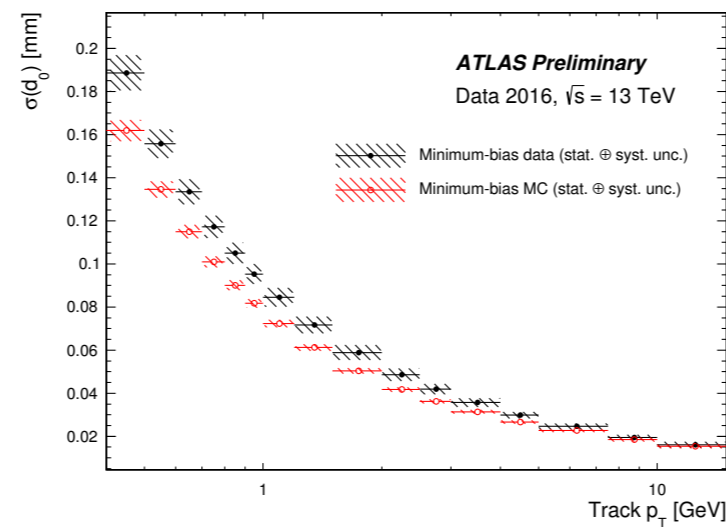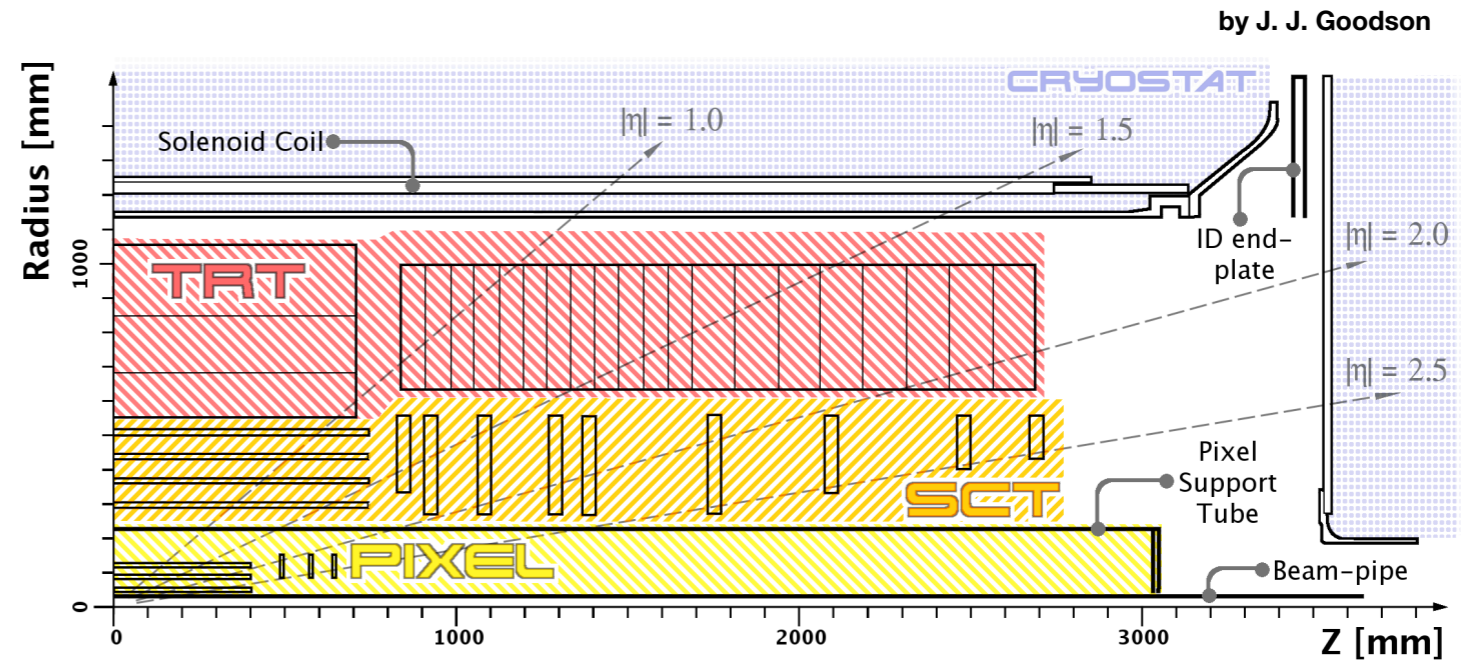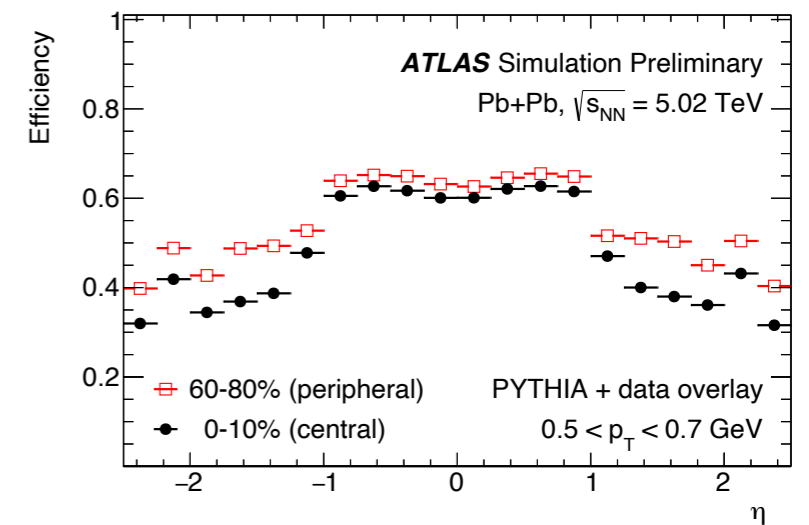**1** Monitored Drift
Tube Chambers

2 Cathode-Strip
Chambers

3 Resistive Plate
Chambers

4 Thin Gap
Chambers
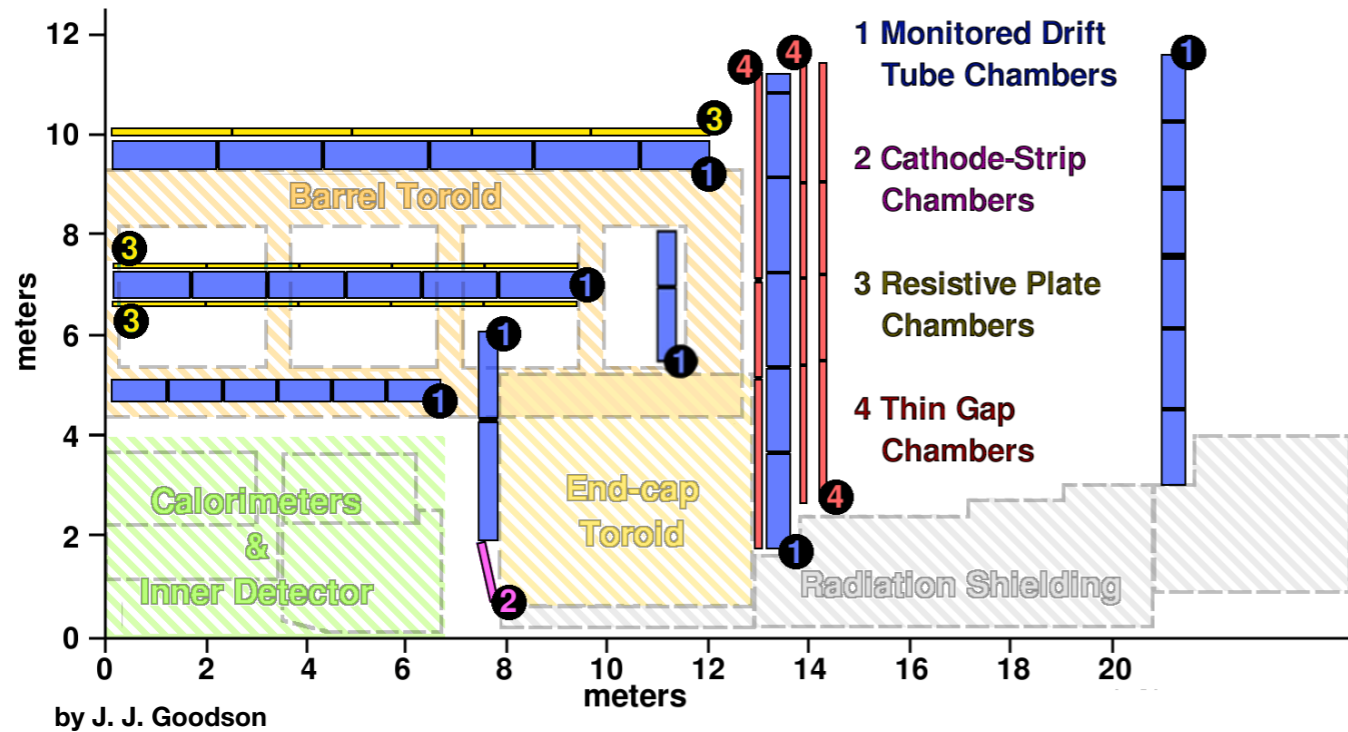
Precision chambers
- MDTs $|\eta| < 2.5$
- CSCs $2.0 < |\eta| < 2.7$

Fast trigger chambers
- RPCs $|\eta| < 1.05$ (barrel)
- TGCs $1.05 < |\eta| < 2.4$ (end-cap)

For muon with $p_T = 5$ GeV, $\eta = 0$:
- ID p_T resolution ~ 2%, dominated by multiple-scattering
- MS p_T resolution ~ 6%, dominated by energy loss fluctuation

ATLAS RPC acceptance ~ 80% overall

Selected results — muons

Systematics limited for yield measurements
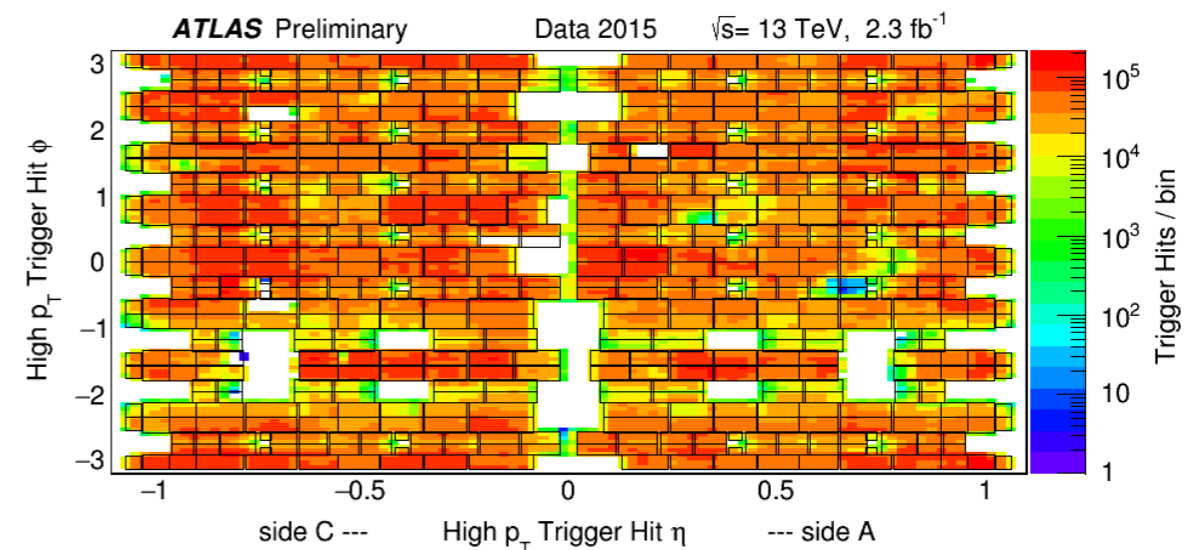
Statistics limited for flow measurements, would be benefiting from more luminosity, especially in small systems

- HF muon in *pp* can be compared to NLO *p*QCD calculations, large contamination from W at high p_T

- Charm/bottom discrimination using impact parameter allows probing charm and bottom at the same time

- Charm/bottom muon azimuthal anisotropy measured in *pp* and Pb+Pb with good precision, especially for bottom muon; same measurement in *p*+Pb would be valuable to constrain models

- HF muon can be used to tag jets, events, or correlation with other HF probes


7
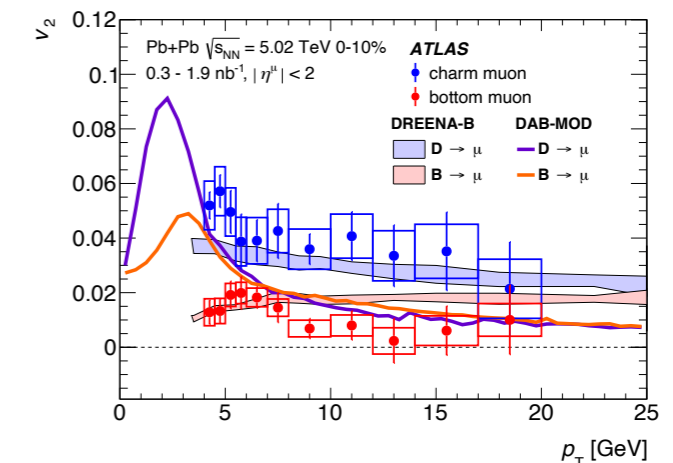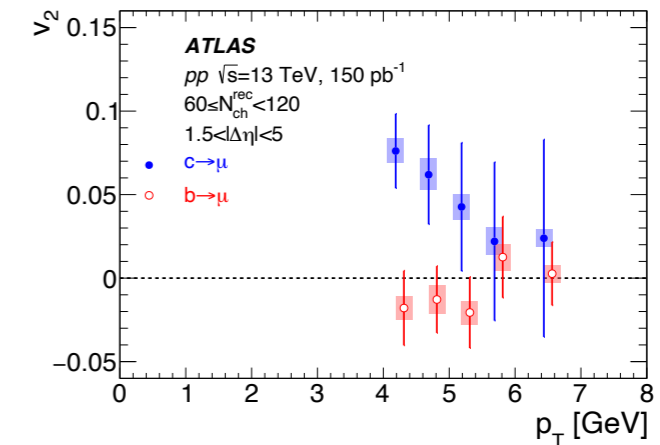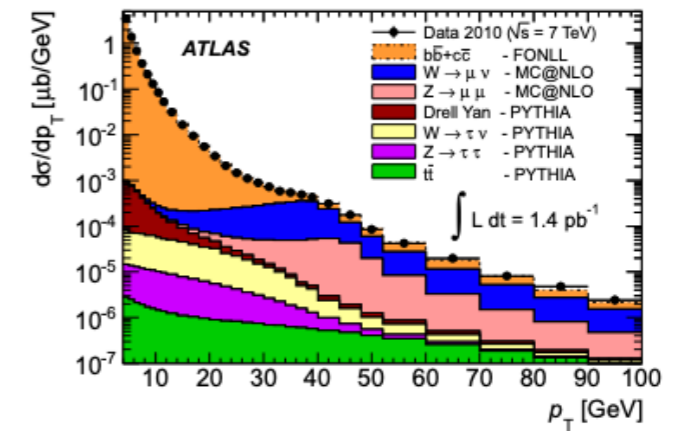
Selected results — non-prompt ψ

Small systematics

Straight forward background subtraction method

Usually limited by statistics, benefiting from more luminosity

- Full Run2 13 TeV *pp* data, 139 fb^{-1}

- FONLL over-predicts the production rates at high p_T, likely from FF at high p_T

- Non-prompt J/ψ R_{AA} and v_2 measured in 2015 Pb+Pb data

- Could be extended to higher p_T with full Run2 data to be compared to HF jets measurements

8
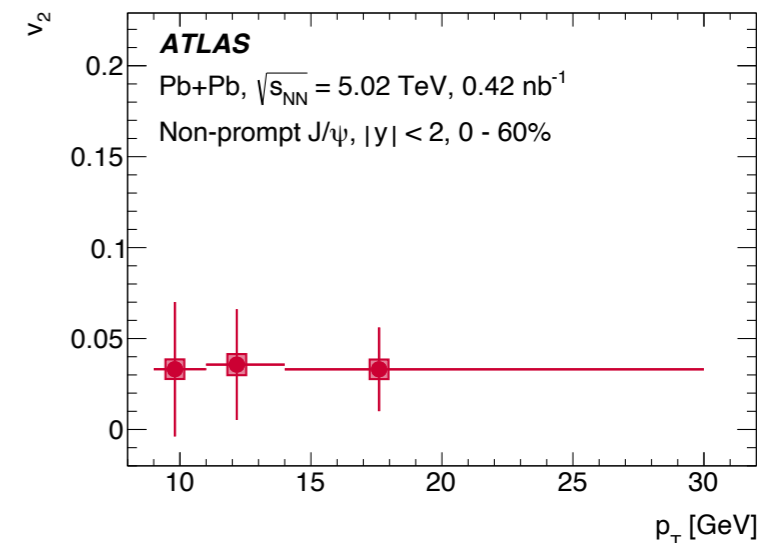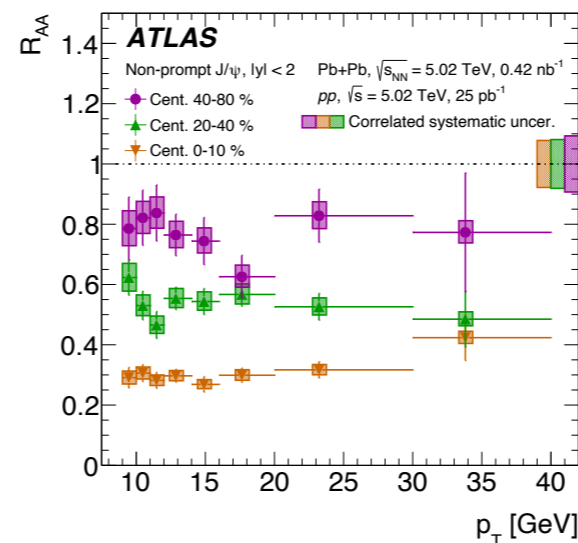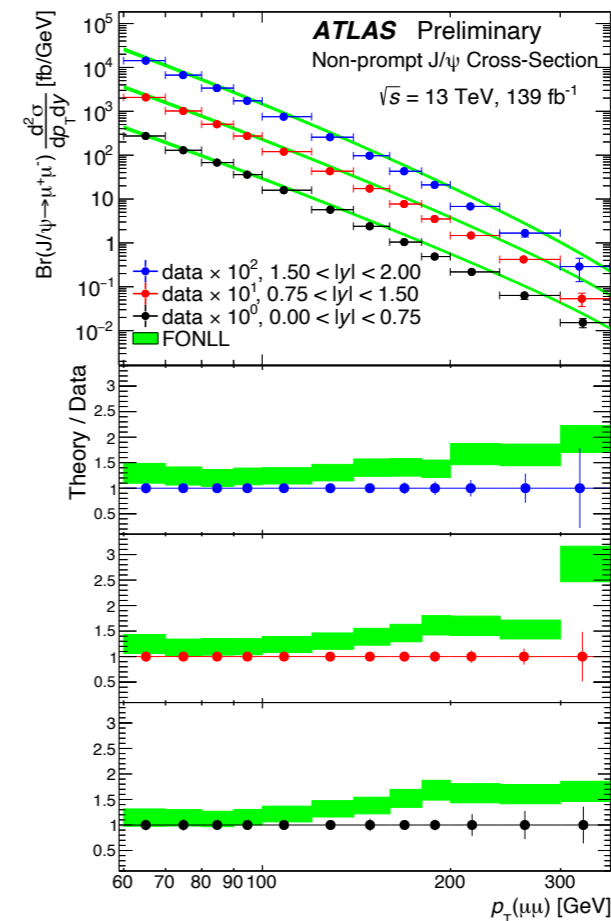
Selected results — *D* meson

Based on MinBias or random triggers at low p_T

No PID in ATALAS, heavily rely on tight cut on the decay topology

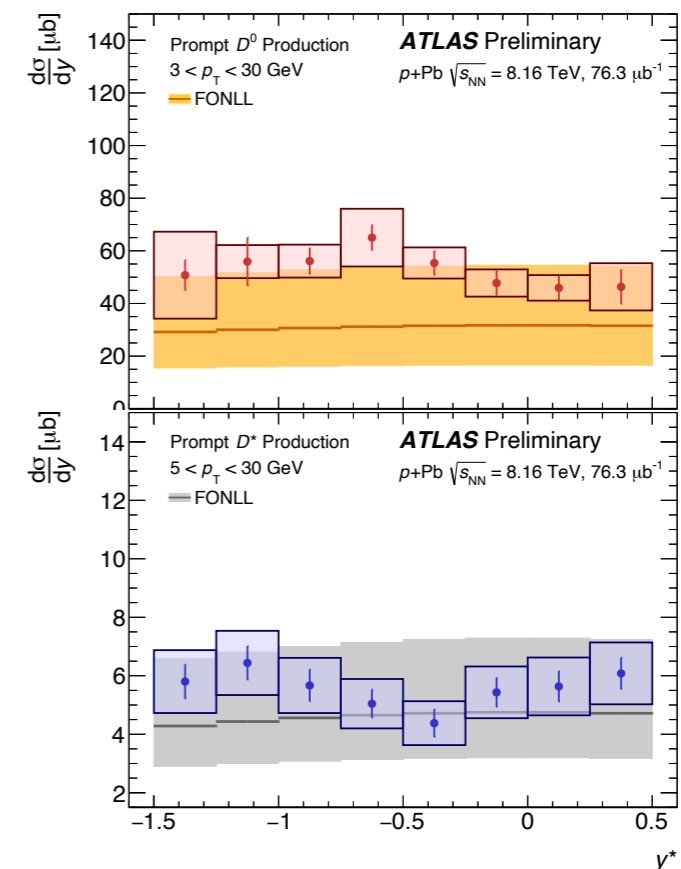Usually systematic limited

- *D** cross section in 7 TeV *pp* data

- Can be compared to NLO *p*QCD calculations

- *D** and *D*^{0} cross sections in 8.16 TeV *p*+Pb

- Comparable with FONLL w/o any nuclear effects

They show the detector feasibility for *D* meson analysis
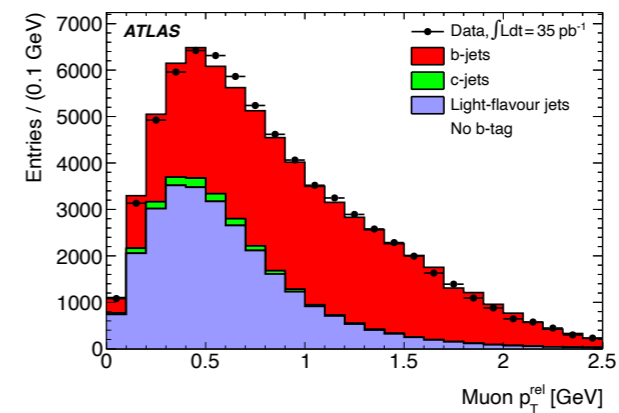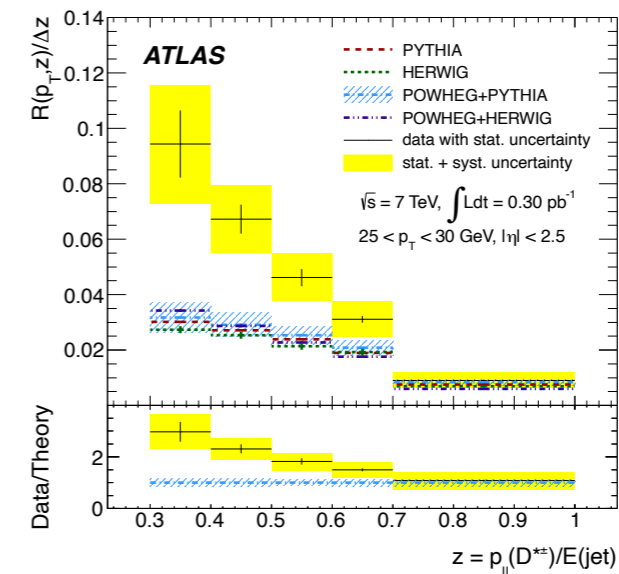
Large MinBias data (1/4 of full rate) collected in 2018 Pb+Pb runs, ideal for studying *D* mesons
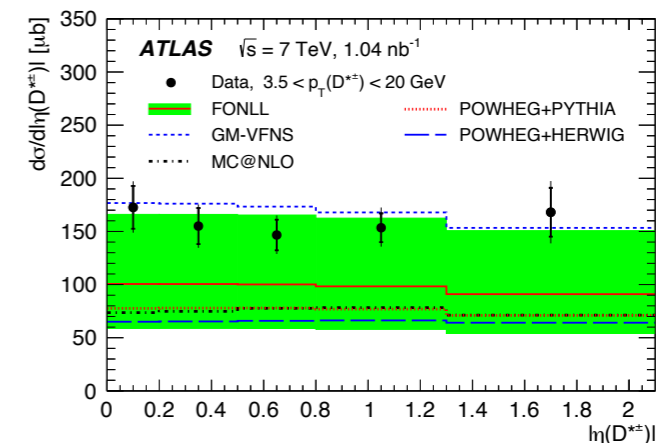
Heavy flavor jets
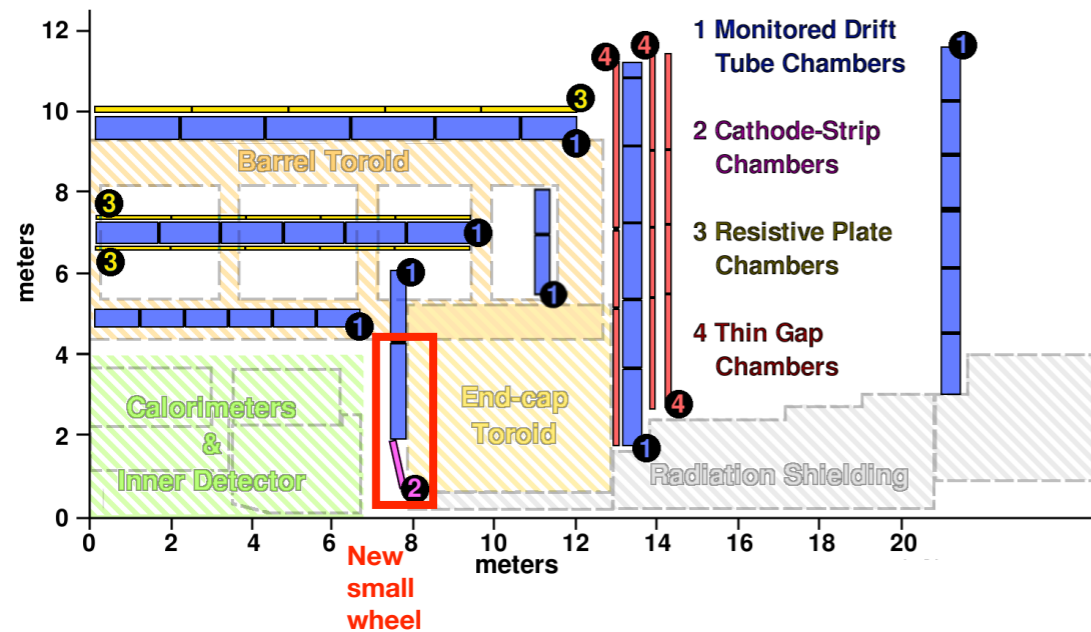
HF jets can be tagged by HF hadron probes or SV based multi-variable tagger

- D^* in jets obtained from 2010 7 TeV *pp* data

- Mis-modeling of production of small-z D^* in jets

- HF muons were used to tag HF jets based on relative p_T in *pp* collisions, can be implemented in heavy ion collisions

- Multi-variable based b-tagging is being testing/optimizing for *p*+Pb and Pb+Pb data

Detector upgrades

1 Monitored Drift Tube Chambers

2 Cathode-Strip Chambers

3 Resistive Plate Chambers

4 Thin Gap Chambers

Phase-I upgrade

New small wheel

Largely reduces fake muon trigger rate at forward, allows access to lower p_T threshold muon triggers

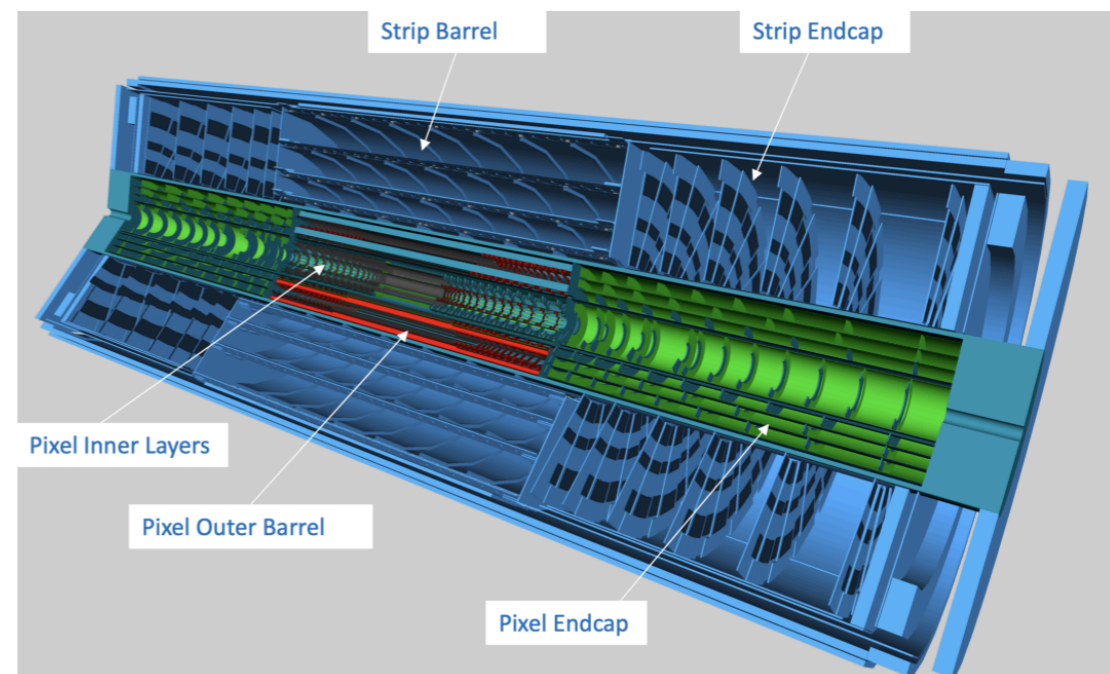Available in Run3 (one side or both)

Phase-II upgrade

ITK, $-4 < \eta < 4$

Bigger, faster and better

Benefit correlation studies and improve momentum resolution for tracks/muons

~ 2027

Summary

- ATLAS has a small HF team, but it has full feasibilities for all HF studies

- Currently focusing on completing the series of HF muon analyses; also interested in HF jets and baryons

- Most results are currently limited by statistics, would benefit from more luminosity

more influential results

better detector
more data

more people join the game