Performance of tracking and b-tagging in ATLAS and CMS with first Run-2 data

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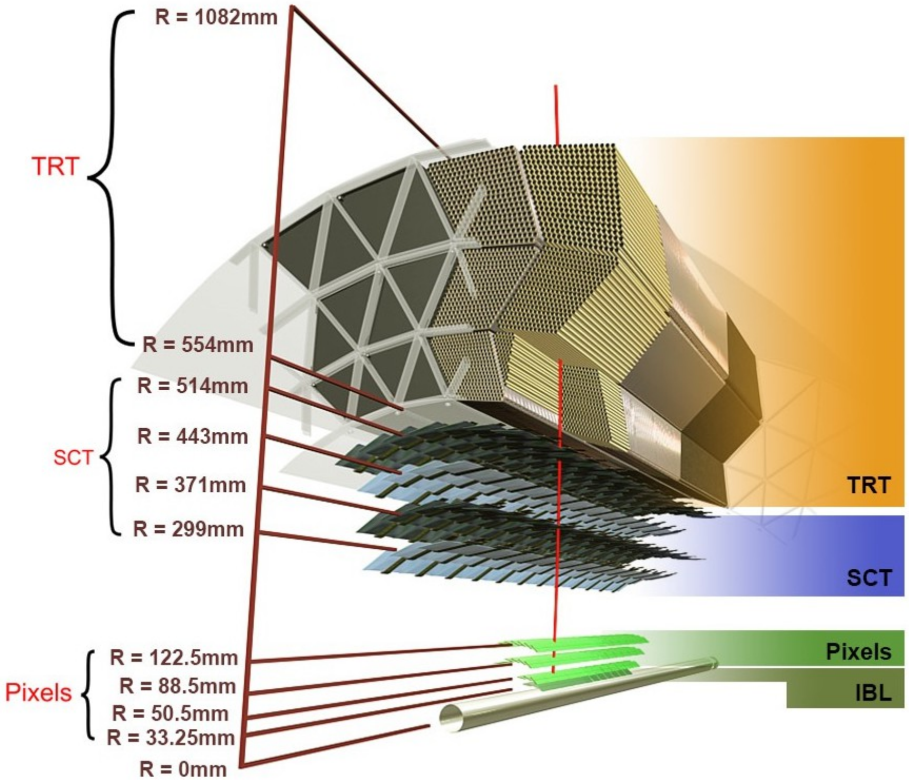
Physics Motivation

- Tracking and b-tagging crucial for physics analyses at LHC
- Tracking
  - Vertex detectors for precise measurement of trajectories of charged particles and estimation of track parameters
  - Event reconstruction and particle identification
- B-tagging builds on top of an excellent tracking performance
  - Exploits the b lifetime (cτ=450μm), looking for tracks with impact parameter significance and displaced secondary vertices
  - Needs tracking, vertexing, secondary vertexing
- Many analyses with b-jet final states
  - H physics - H->bb
  - Top and SM
  - Exotics and SUSY
  - Both selection and veto
  - Important also for the online selection in the trigger systems

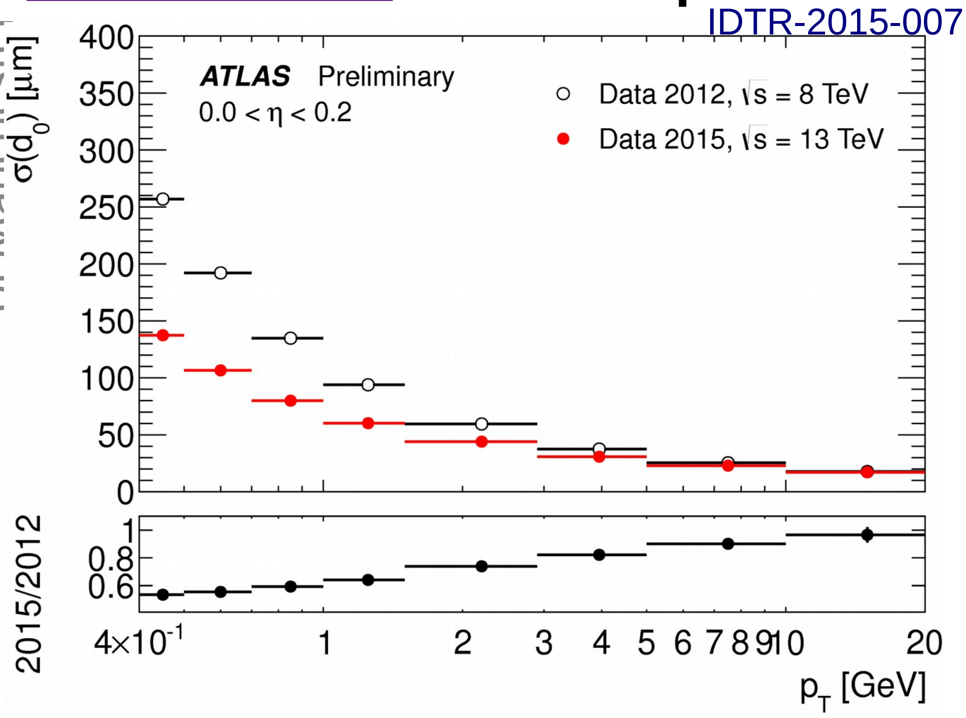
ATLAS Inner Detector

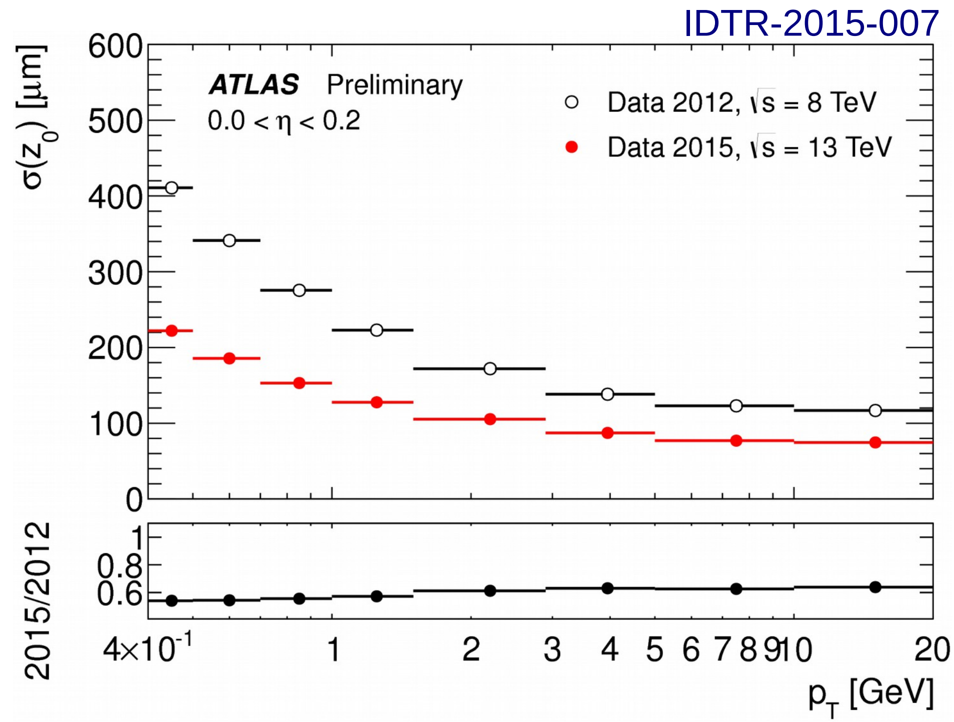
- Pixel + double-sided Si strip + transition radiation tracker
  - Innermost pixel layer (IBL) added before Run-2
    - track precision
      - Closer to the beamline (3.3cm), smaller dimensions along z
      - Impact parameters important for b-tagging
    - Reconstruction robustness
      - wrt higher pileup, detector failures, aging
- In an axial magnetic field from a solenoid of 2T
- $|\eta| < 2.5$



	channels	dimensions	<hits on track>
IBL+ Pixel	12M+ 80M	50μmx250μm 50μmx400μm	1+ 3
SCT	3.5M	~80μm	8
TRT	350k	straws R=2mm	~33

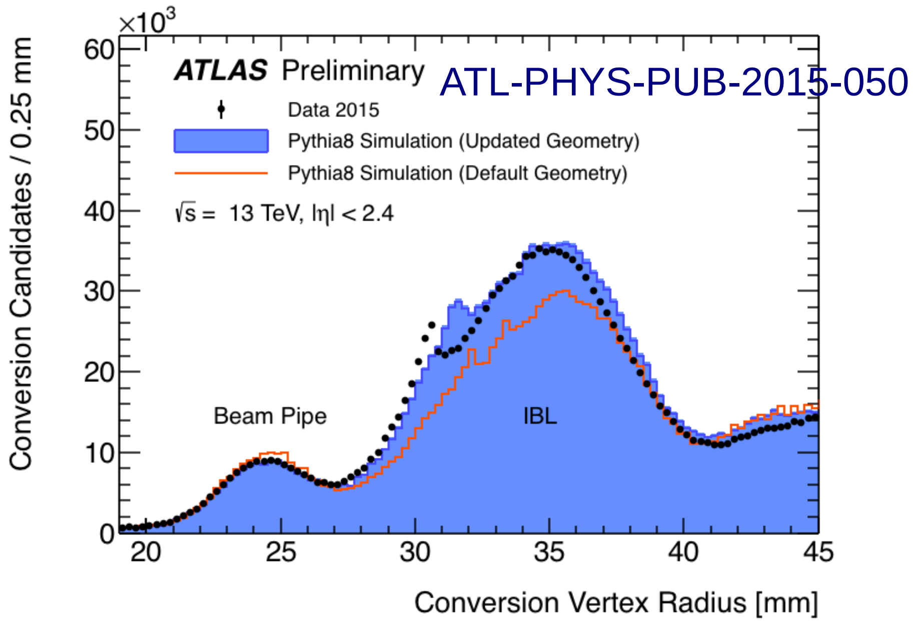
Improvements due to IBL in Run-2





- More precise estimation of impact parameters important for b-tagging

- Detailed analyses of the material distribution in the tracker lead to improved description → improvements in the tracking performance and data/MC comparisons



IBL and alignment

Calibration, alignment of the detector and determination of the beamspot position important ingredients for optimal tracking/b-tagging

- Irradiation of front-ends in 2015 → an increased current in the course of a run and correspondingly an increased temperature of staves leading to thermal bowing of the IBL staves
- 2015: time-dependent alignment introduced to mitigate the effect
- 2016: automated alignment procedure accounting for in-run changes, automatic corrections each ~2h
- Poster of Giulia Ripellino on the ATLAS ID alignment

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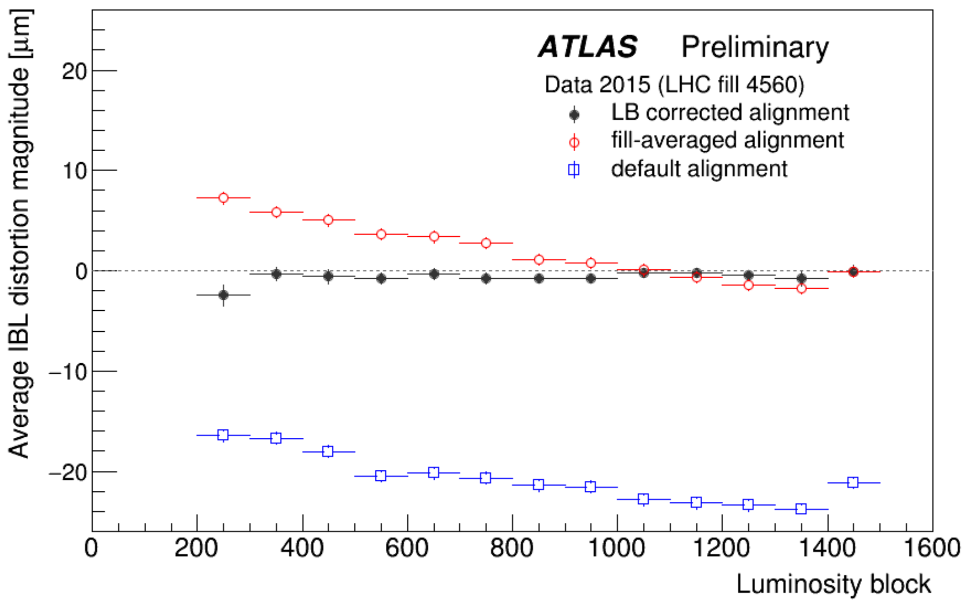

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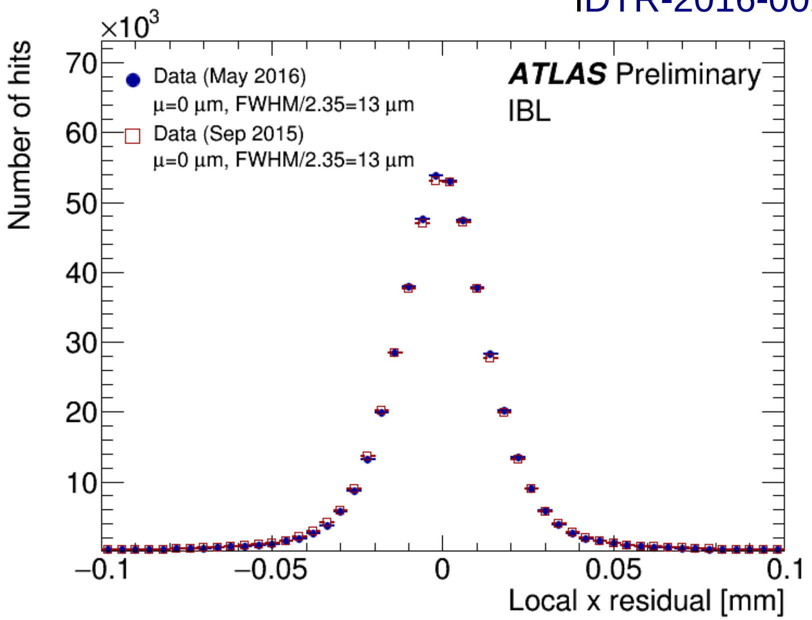


CMS Tracker

Pixel (100μm x 150μm)

- 3 barrel layers (R =4.4cm – 10.2cm)
- 2 endcap disks
- 66M channels

Strip tracker (~100μm strip pitch)

- 10 barrel layers (R=25.5cm-110cm)
- 12 endcap disks
- single sided and double sided layers
- 10M channels

|η|<2.5

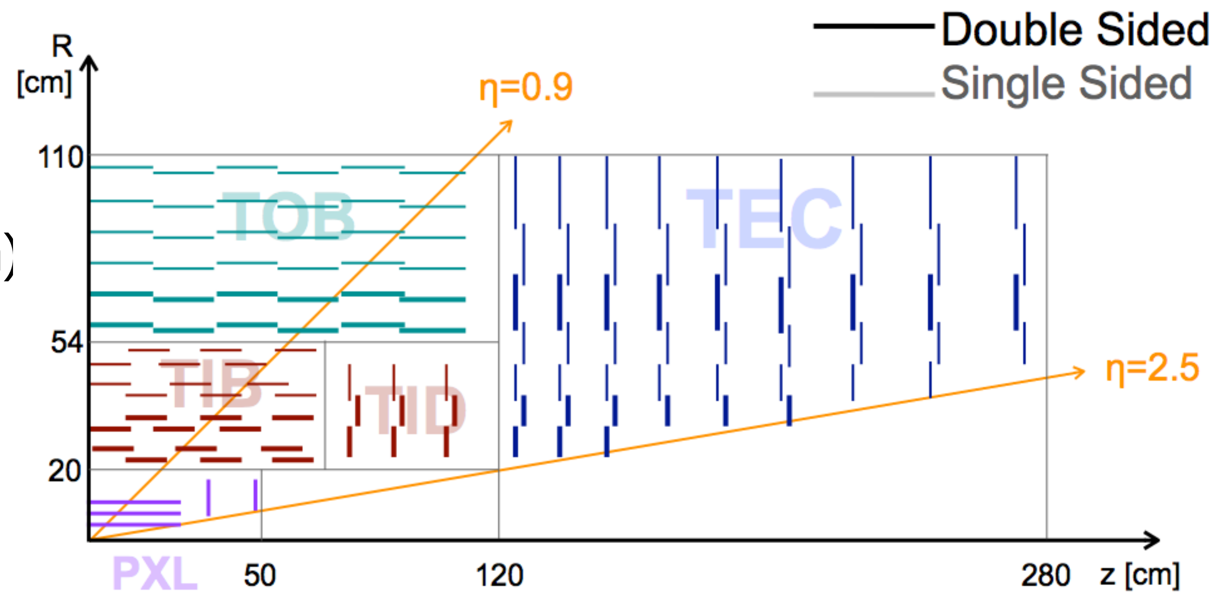
typically ~16 hits on track

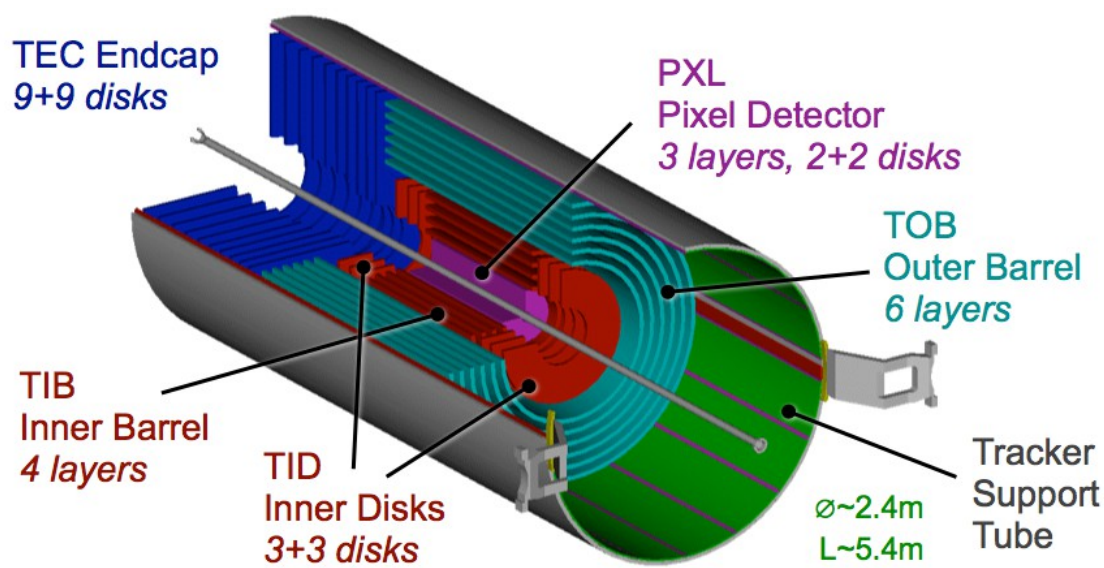
3.8T solenoidal field

with 200m² of sensitive area the largest silicon tracker

Upgrade of the pixel detector in 2016-2017 shutdown

- Reduction of material
- Additional layer In barrel and EC
- B-tagging will benefit





Track reconstruction

- ATLAS
  - Using seeds (triplets) from different layers of the detector
  - Higher purity seeds used first
  - Combinatorial track finding
  - Track scoring and ambiguity resolving
    - With NN pixel clustering and identification of clusters from multiple tracks
  - TRT extensions

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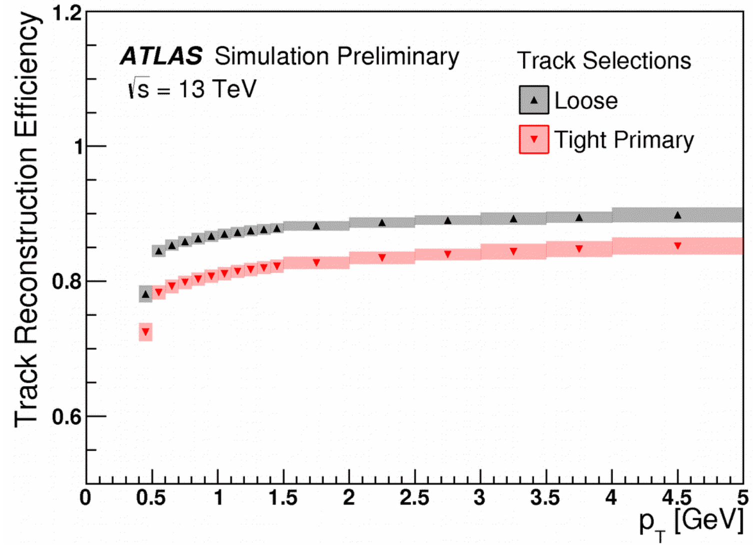
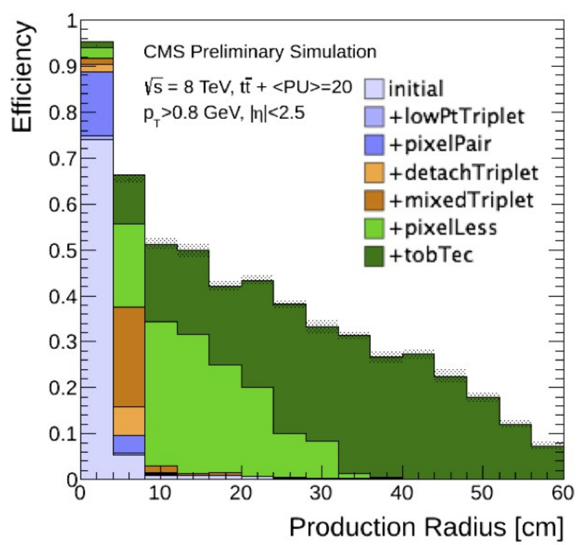
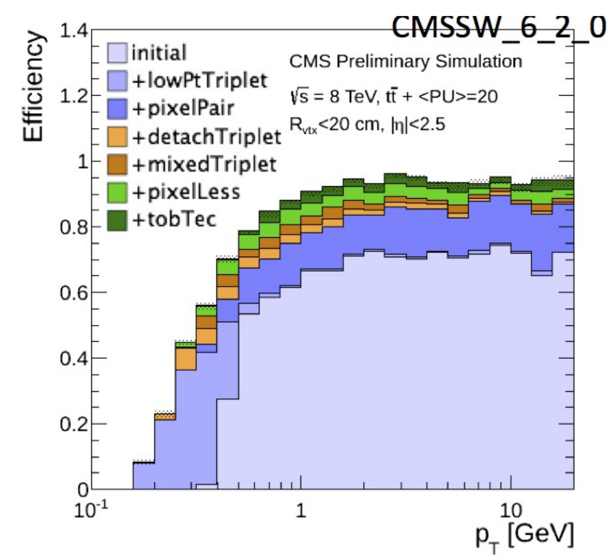


- CMS
  - Iterative tracking
    - To reduce CPU time
    - Start from higher pT, beamline compatible seeds
    - Loosen requirements in next iterations and mask hits used in previous stages





Tracking in dense environment / ATLAS

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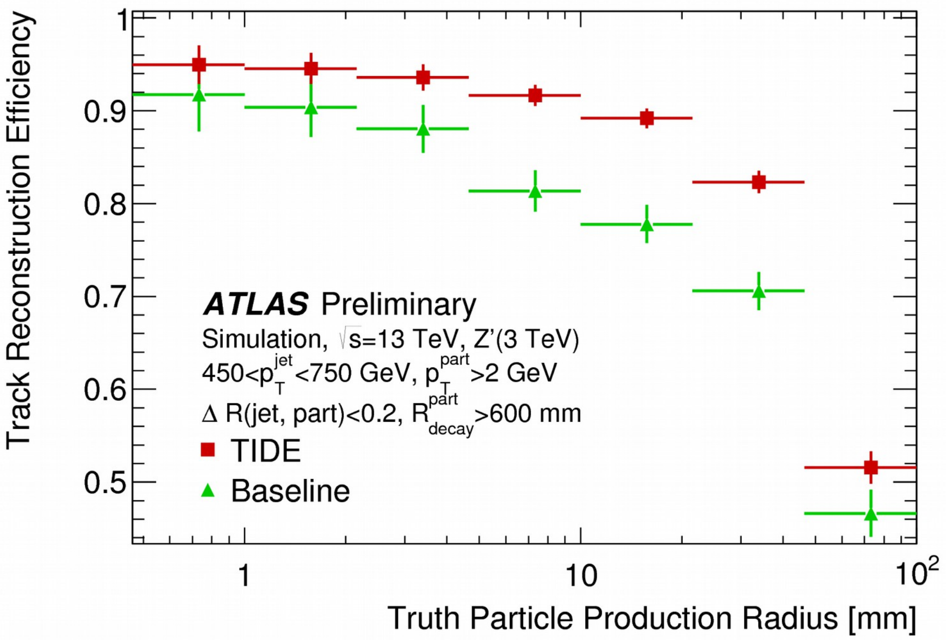
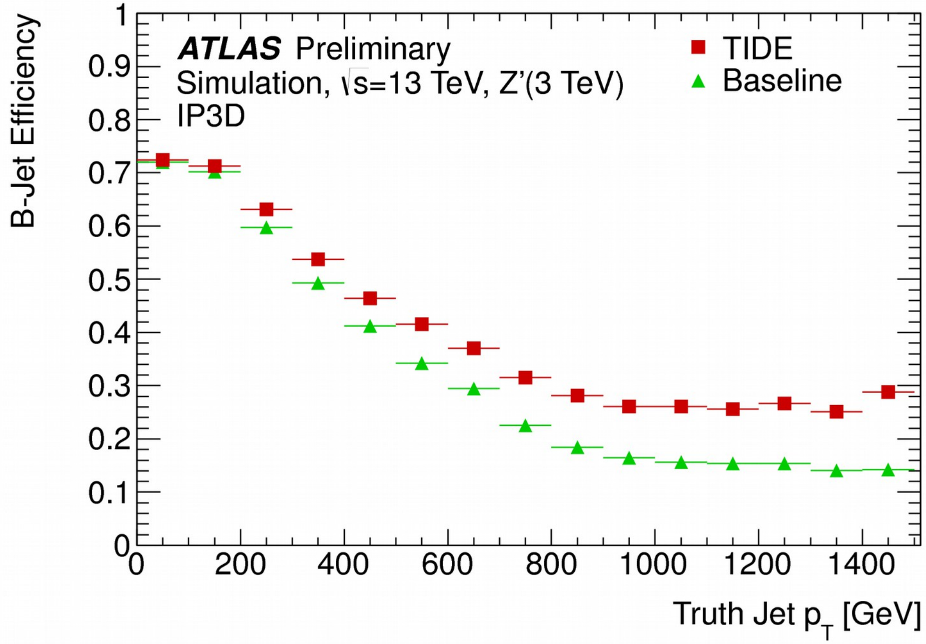
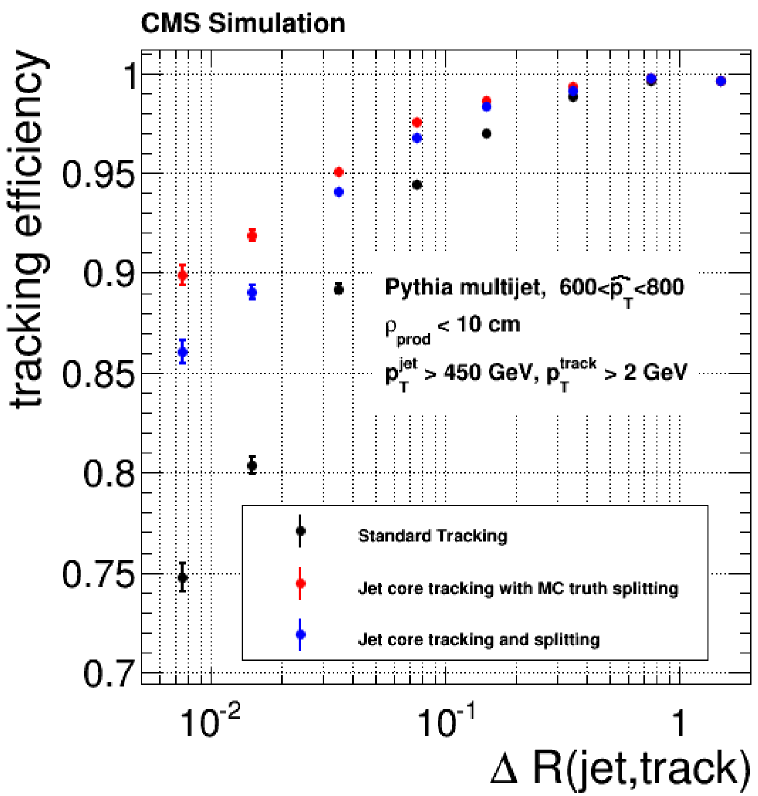




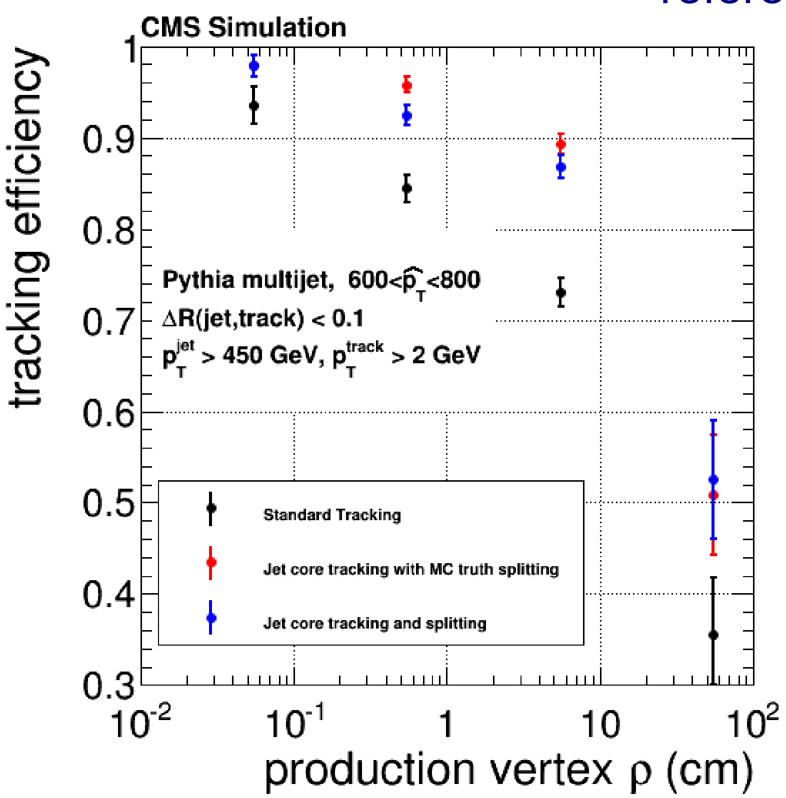
- Tracking in the dense environment such as core of jets with nearby tracks sharing clusters challenging
- AmbiguitySolver reoptimised to deal with clusters originating from multiple tracks
  - Merged clusters identified by NN clustering
  - Track information (incident angle), charge collection pattern used in the NN
  - Optimised scoring for such clusters, an increase of tracking efficiency
  - Poster of P.E. Sidebo on the robustness of NN pixel clustering

Tracking in dense environment /CMS

- JetCore tracking - another stage of the iterative tracking to obtain
  - Increase the number of seeds from pix, 2 TIB layers with high pT and beamline compatibility in the jet core
  - Pixel cluster splitter to deal with merged pixel clusters – jet direction and expected charge/shape of the cluster

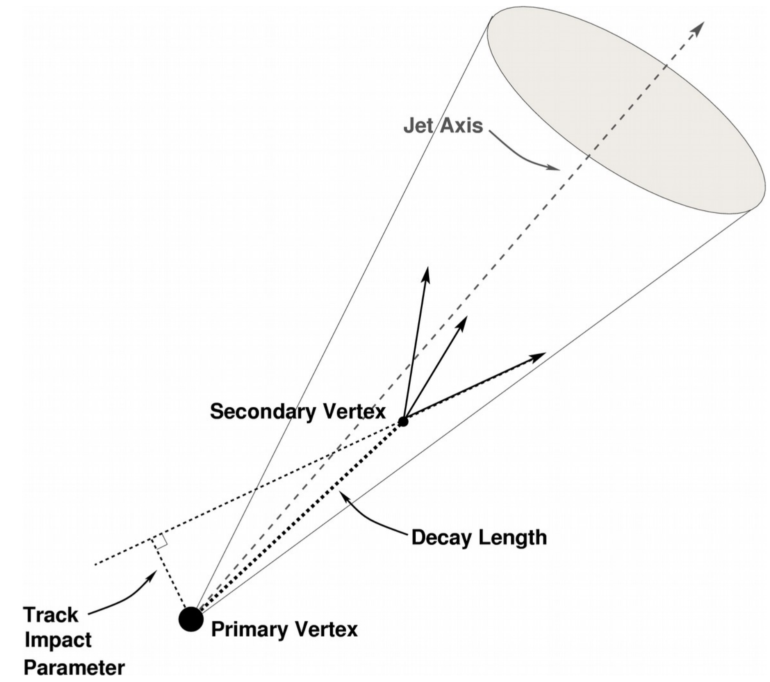


reference



B-tagging

- characteristics of B hadrons in bjet
  - tracks with large positive IP
  - Presence of secondary vertices
  - 40% of jets with e,μ

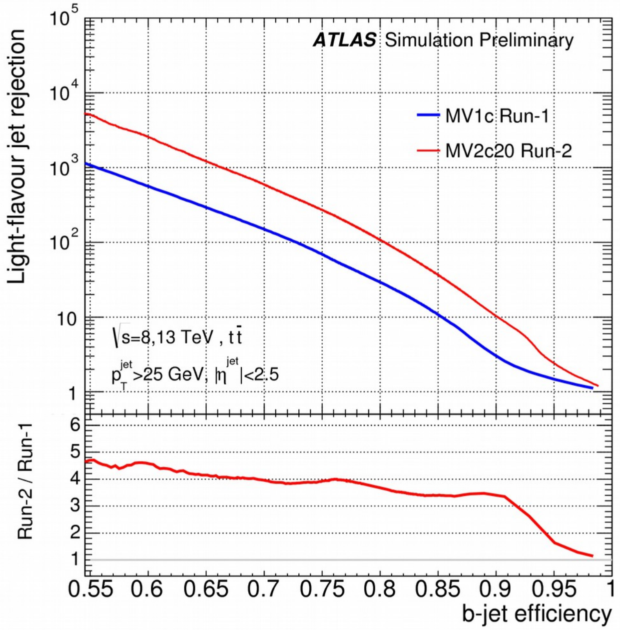


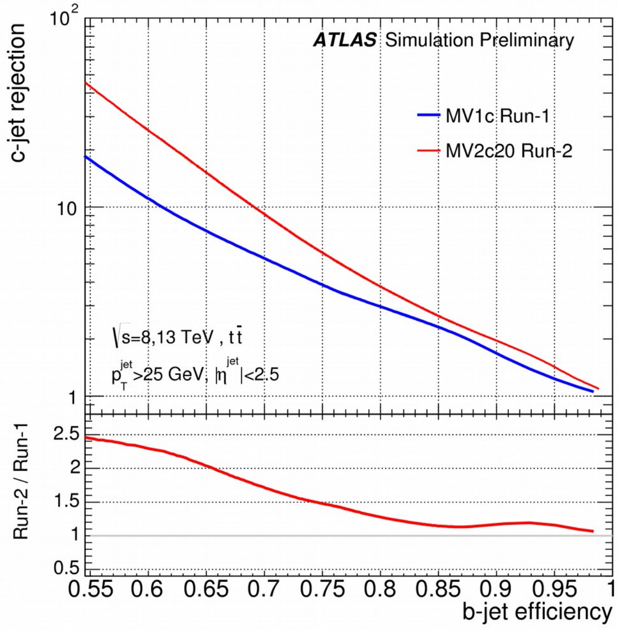
- Variety of taggers exploiting these features (and their combinations)

- ATLAS
  - IP2D, IP3D
  - SV
  - JetFitter
  - **MV2cxx**

- CMS
  - JP
  - CSVv2
  - SoftElectron,SoftMuon
  - **cMVAv2**

B-tagging performance/ ATLAS





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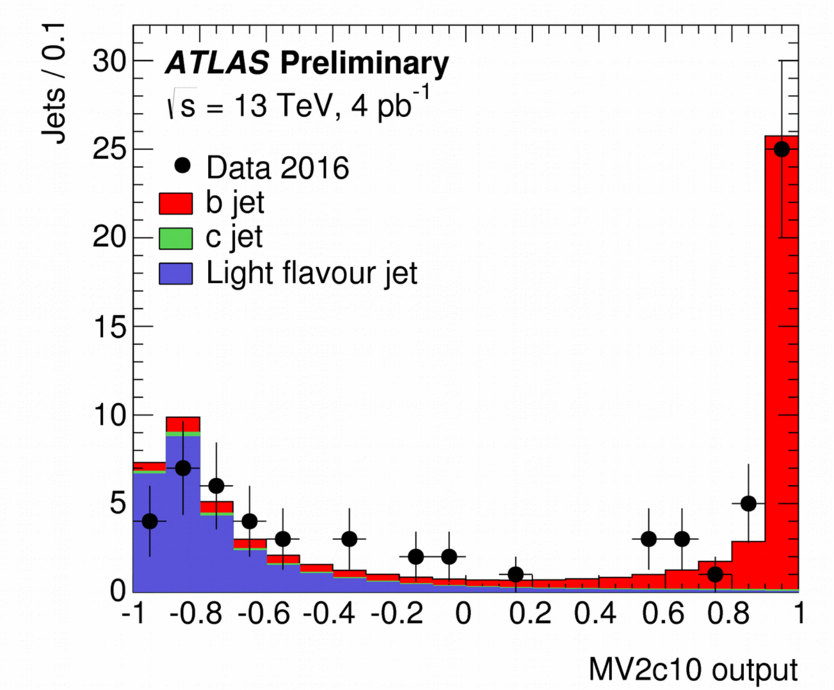
- Light/c rejection 2015 vs Run1
  - MV2(BDT) vs MV1(NN) + tracking + IBL
- Further improvements for 2016
  - IP taggers
    - Hit pattern requirements for tracks used in the IP tagger adjusted to recover highly boosted decays
  - SV taggers
    - only tracks with higher pT considered in pT>300GeV to reduce fake vtx, tracks from fragmentation
    - Pileup tracks reduced by removing low transverse IP and high longitudinal IP significance
  - MVA
    - MVA training procedure improved between 2015 and 2016
  - Significant improvement (+40%) c-jet rejection at 77% b-jet efficiency MV2c10
    - Poster of A. Calandri on developments for 2016

B-tagging performance / ATLAS

- Data-MC comparison of the MV2C10 output
  - e-μ $t\bar{t}$ selection of events for b-jet rich sample
- Discriminators on the input of the MV2C10
- First data of 2016 (4pb^{-1})



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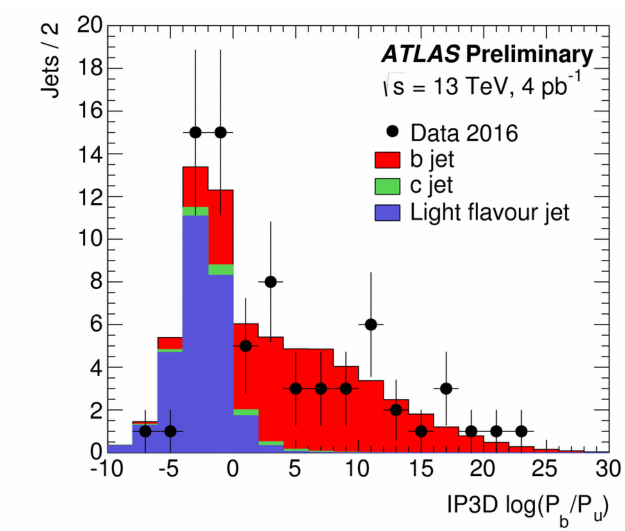
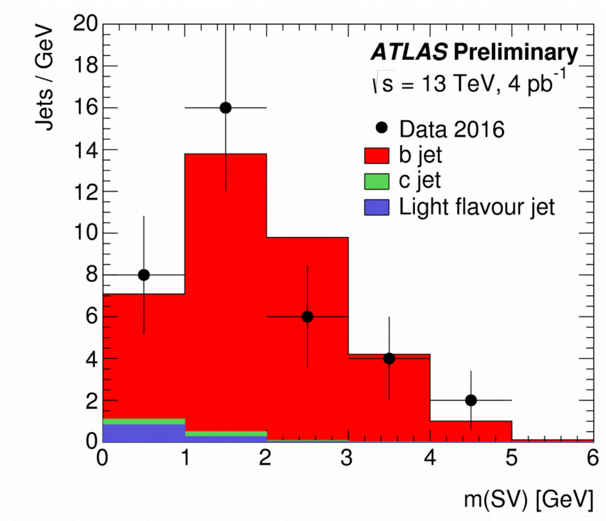
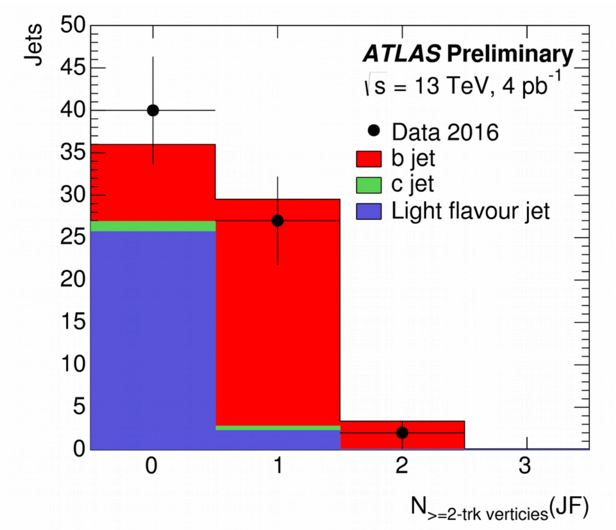


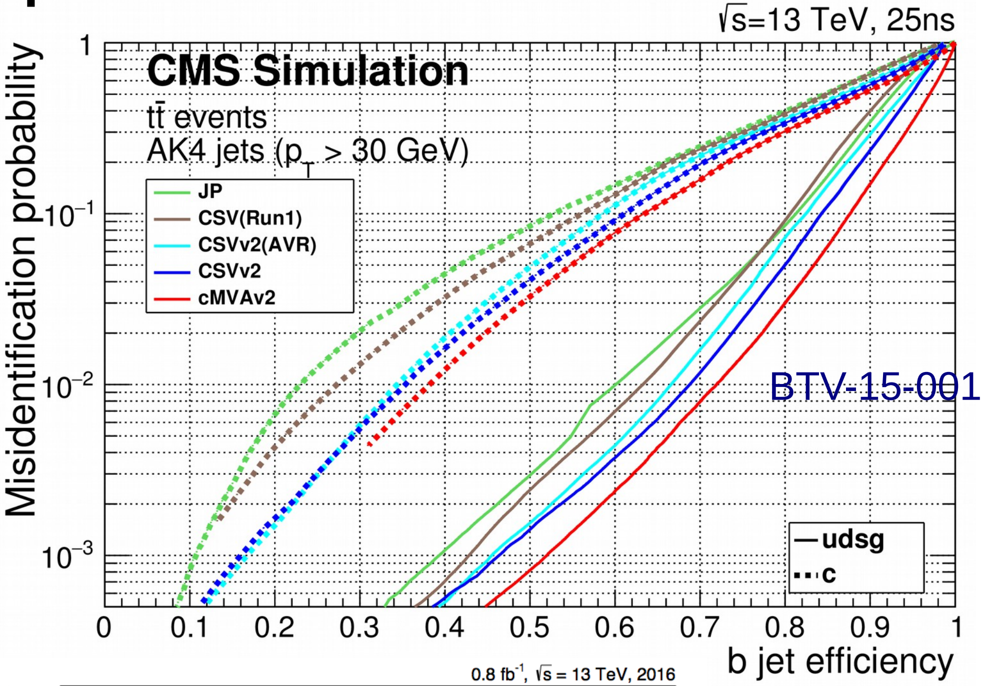




more in the backup

B-tagging performance /CMS

- CSVv2
  - Combined SV algorithm (real vtx/ pseudo vtx/ no vtx cases)
  - an improved performance wrt Run-1
    - Upgraded to multilayer perceptron to use more input variables (nSV, α(SV,jet),..)
  - CSVv2 8% better efficiency wrt CSV @1% mistag for light jets
- cMVAv2
  - outperforms CSVv2 by 4% in efficiency for the same mistag probability of light partons



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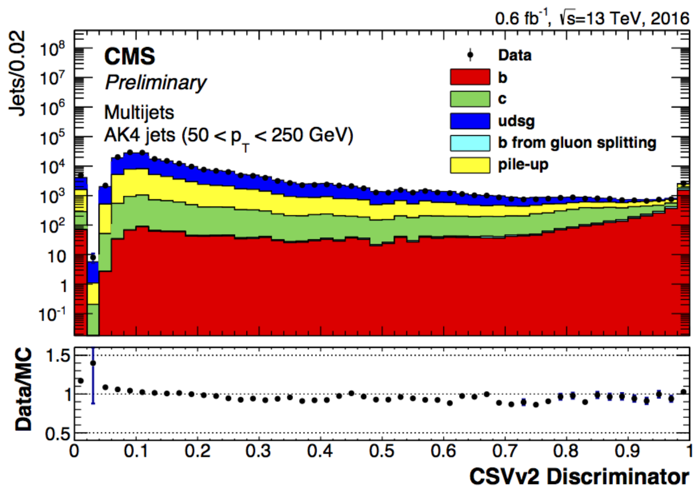

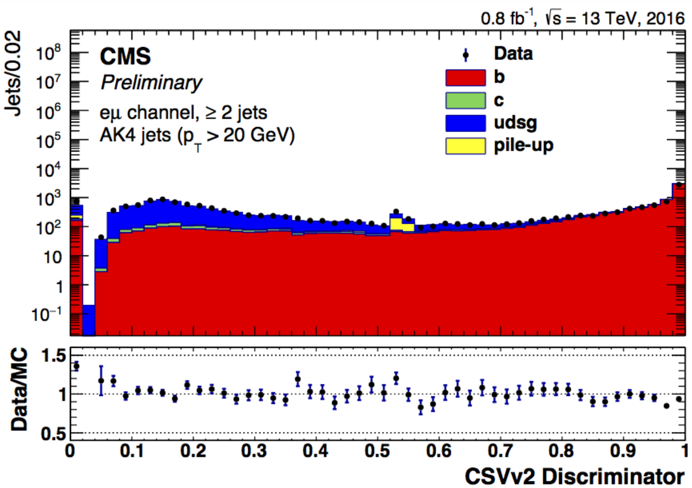

CMS DP 2016/018

- CSVv2 discriminator for AK4 jets– data 2016/MC comparison in multijet (left) and $t\bar{t}$ eμ events (right)

B-tagging scale factors (2015)/ CMS

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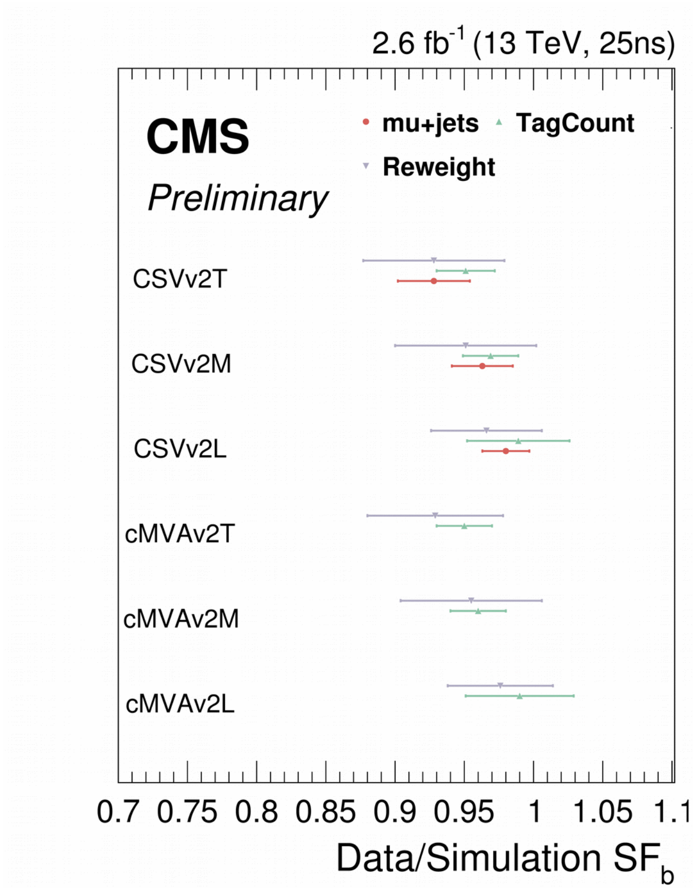

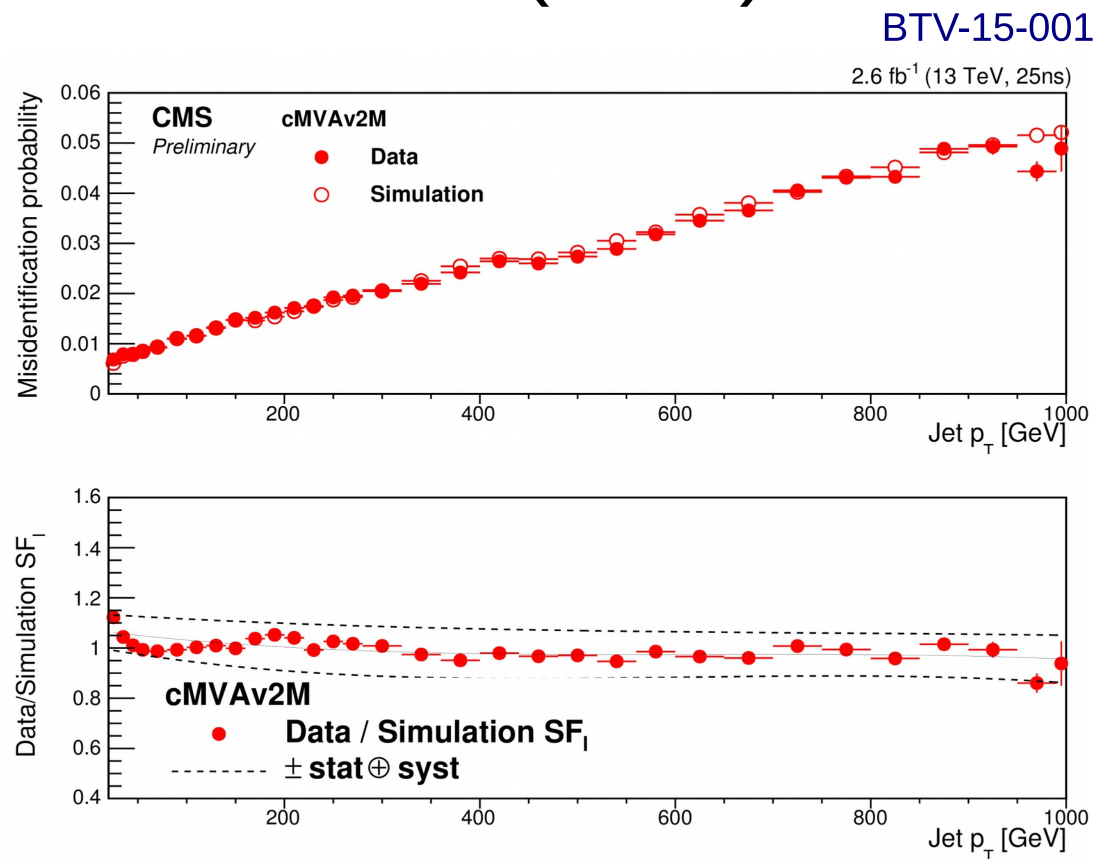

- Data/Simulation scale factors of CVSv2 and cMVAv2 for b-efficiency (left) and misidentification probability cMVAv2M (right)
  - Scale factors from μ+jet compared with $t\bar{t}$ events for CSVv2
    - TagCount and Reweight methods
    - **L**oose, **M**edium, **T**ight working points compared

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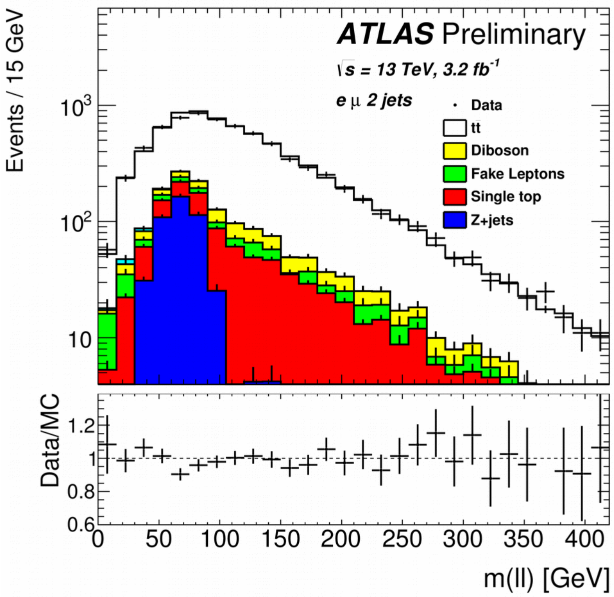
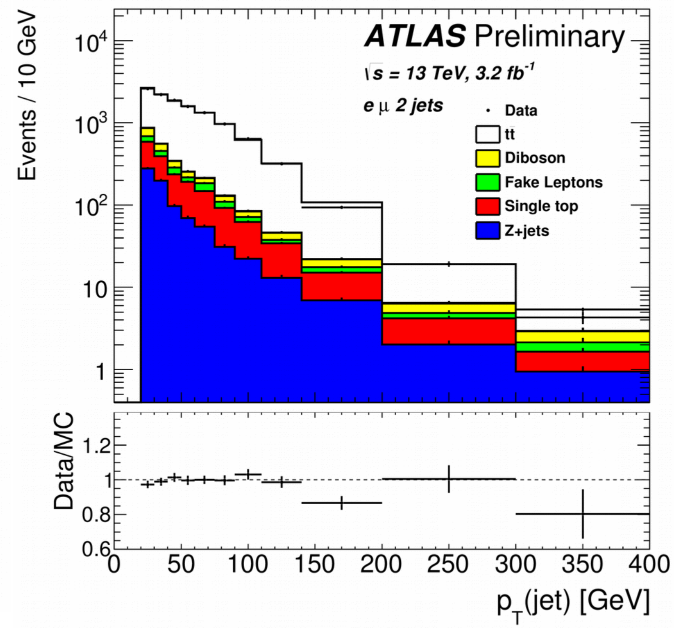
Summary and outlook

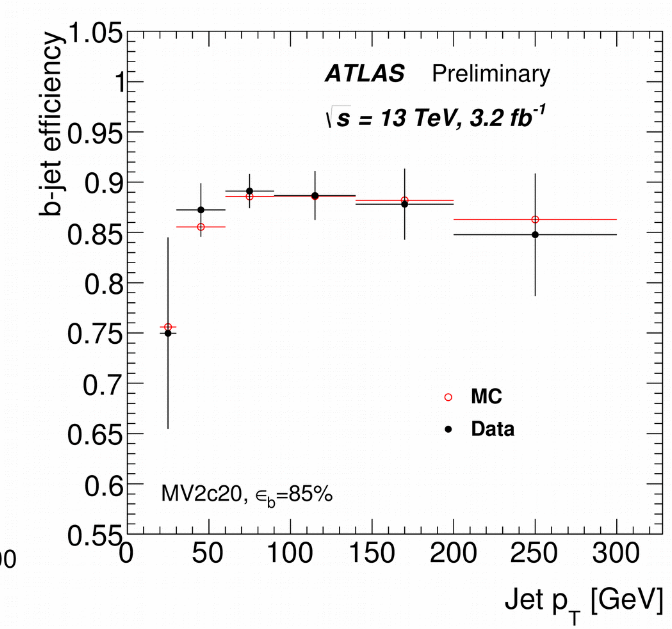
- Commissioning of tracking for 2016 proceeding well
  - Improved performance due to IBL
  - Tracking developments for better b-tagging
    - Nearby tracks / tracking in dense environment for an improved track reconstruction efficiency/precision in the core of jets
    - Alignment / beamspot / detector calibration – important role for precise track parameter estimation and reconstruction of b-decays
- B-tagging will benefit from improvements wrt Run-1 and early Run-2 performance
  - Optimisation of b-tagging discriminators
  - Multivariate techniques refined for 2016 data
  - Robust methods to calibrate b-tagging performance
- excellent performance of the LHC
  - By now the integrated lumi of 2016 almost reached the total of 2015
  - Look forward to new results from Run-2

Backup slides

B-tagging scale factors / ATLAS







Data2015/MC comparison in eμ+2jet events and b-tagging efficiency and SF for MV2c20 @85% working point

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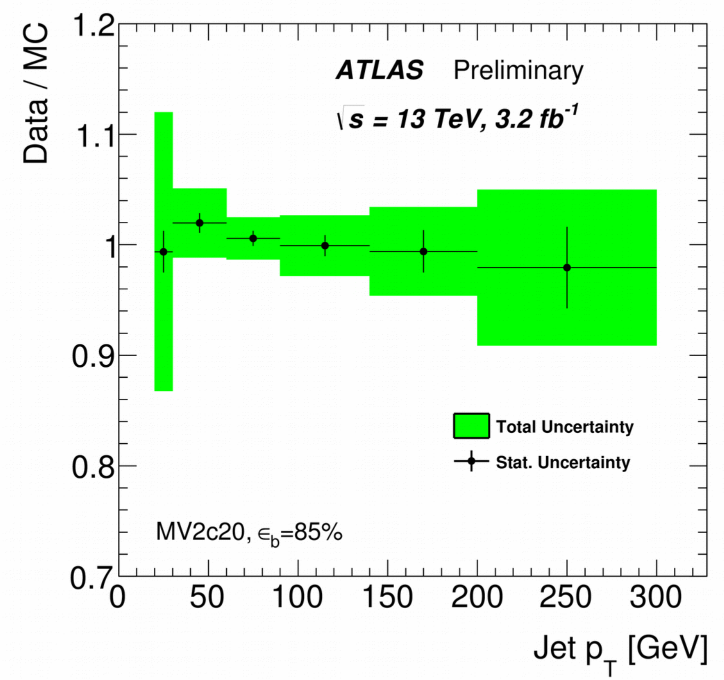

Tracking efficiency/ ATLAS

Track Reconstruction Efficiencies and Systematic Uncertainties				
Track Quality Selection	Loose		Tight Primary	
η Range	$\|\eta\| \leq 0.1$	$2.3 \leq \|\eta\| \leq 2.5$	$\|\eta\| \leq 0.1$	$2.3 \leq \|\eta\| \leq 2.5$
Track Reconstruction Efficiency	91%	73%	86%	63%
$\mathrm{Sys}_{+5\% Extra}$	0.4%	0.9%	0.5%	1.1%
$\mathrm{Sys}_{PixServExtra}$	—	2.0%	—	2.3%
$\mathrm{Sys}_{+30\% IBLExtra}$	0.2%	0.5%	0.2%	0.5%
Total Systematic Uncertainty	0.4%	2.2%	0.5%	2.6%

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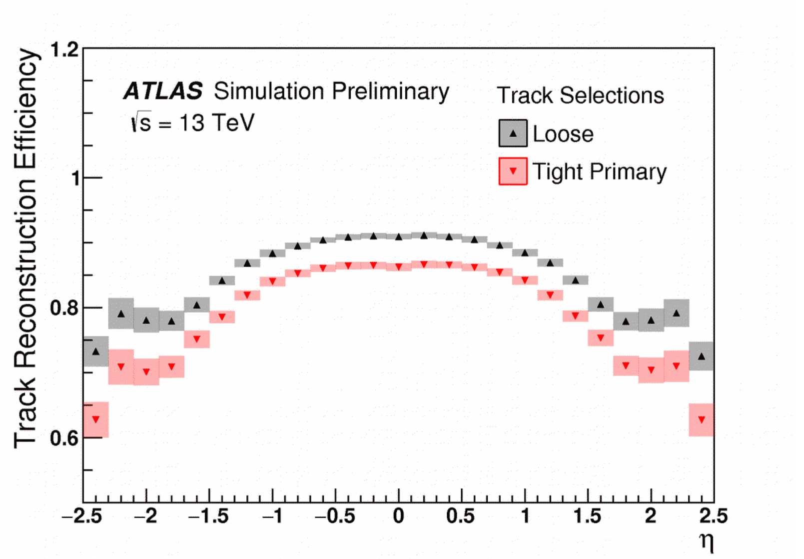

- Tracking efficiencies for 0.4GeV< p_T <20 GeV and Loose & Tight Primary selection in regions with the smallest/largest systematic uncertainties

Scale factors CSVv2 / CMS

- Data / simulation scale factors b-tagging efficiency for CSVv2