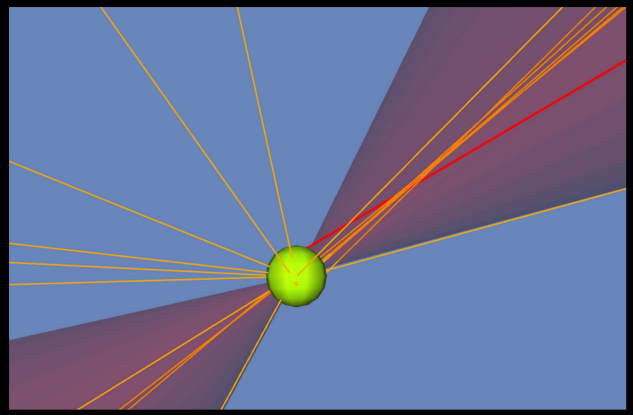
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

ATLAS EXPERIMENT
http://atlas.ch

Run 152409
Event 4349994

b-tagged jet in 7 TeV collisions

p_T^{jet} =49 GeV
6 b-tagging quality tracks in the jet, including one muon

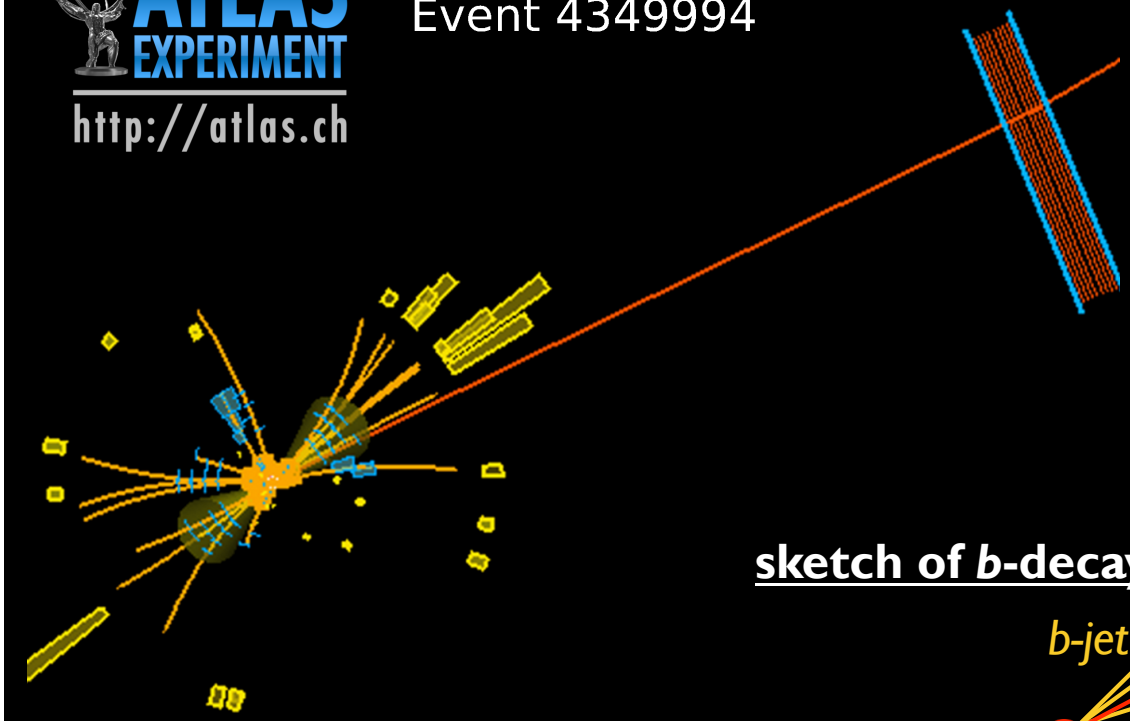


Performance of Track and Vertex Reconstruction and *b*-Tagging Studies with ATLAS

Johanna Fleckner, *CERN / University of Mainz*
on behalf of the ATLAS Collaboration

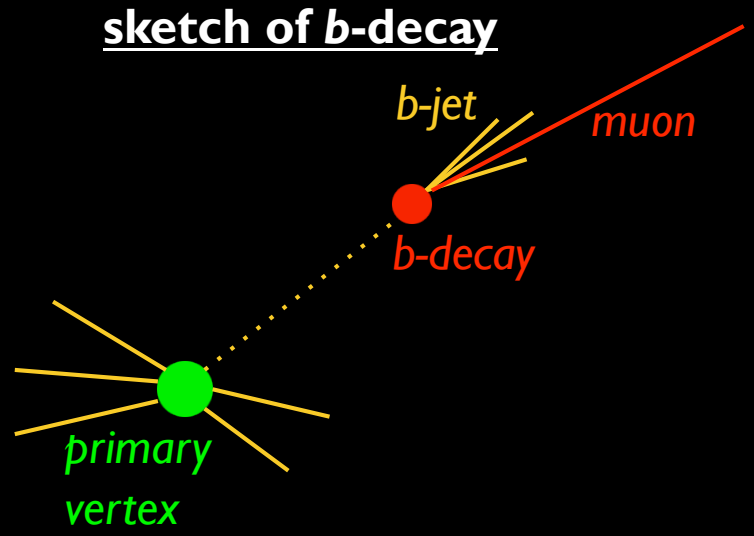
FSP 101 ATLAS

b-tagged jet with one muon

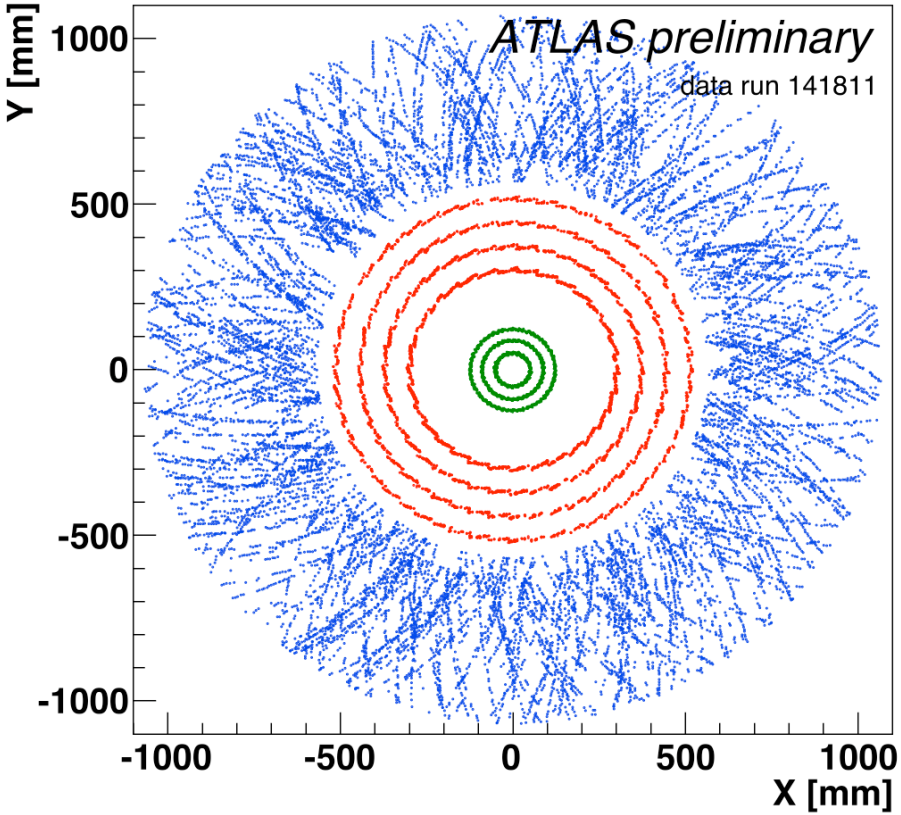


needed to tag this event:

- tracking
  - momentum resolution
  - transverse impact parameter
- primary vertexing
- *b*-tagging algorithms

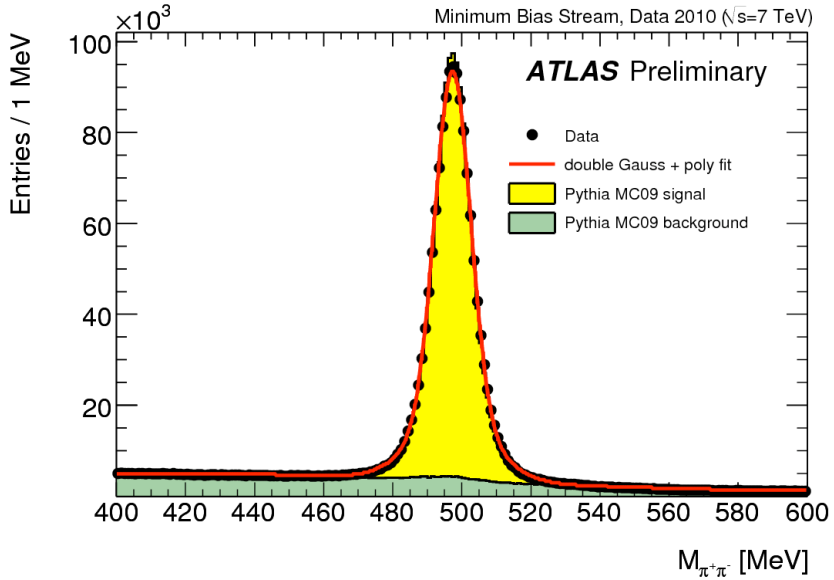


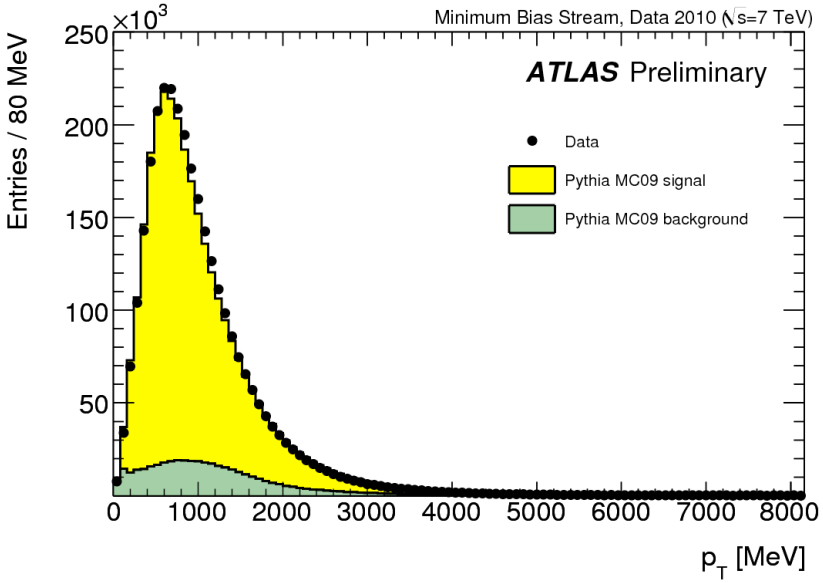
The ATLAS Inner Detector



- Pixel detector:
  - 80M channels
  - $\sigma(R\Phi)$ = 10 μm
    $\sigma(z)$ = 115 μm
- Semi Conductor Tracker (SCT):
  - 6,3M channels
  - $\sigma(R\Phi)$ = 17 μm
    $\sigma(z)$ = 580 μm
- Transition Radiation Tracker (TRT):
  - 350.000 channels
  - $\sigma(R\Phi)$ = 130 μm (barrel)

Estimating Track Momentum Resolution





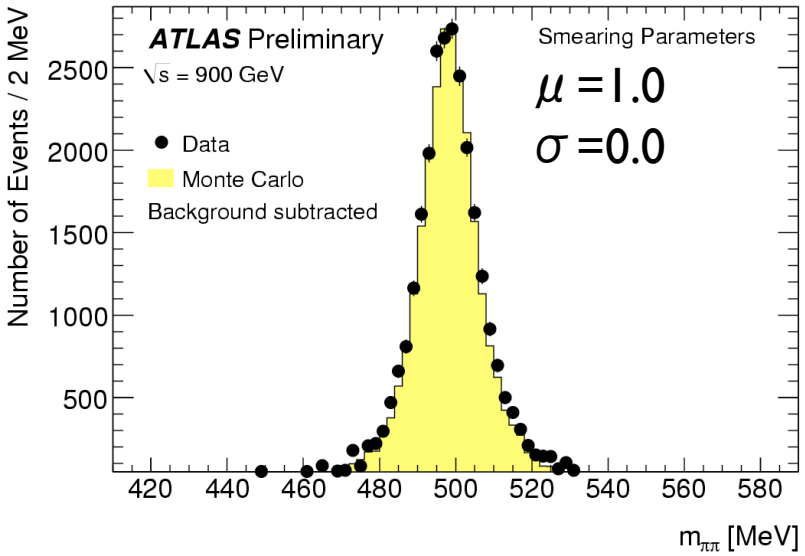
- using known particle properties
- mass distribution sensitive to
  - p_T resolution (mass peak width)
  - p_T scale (mass peak position)
- K^0_S mass spectrum parameterization:

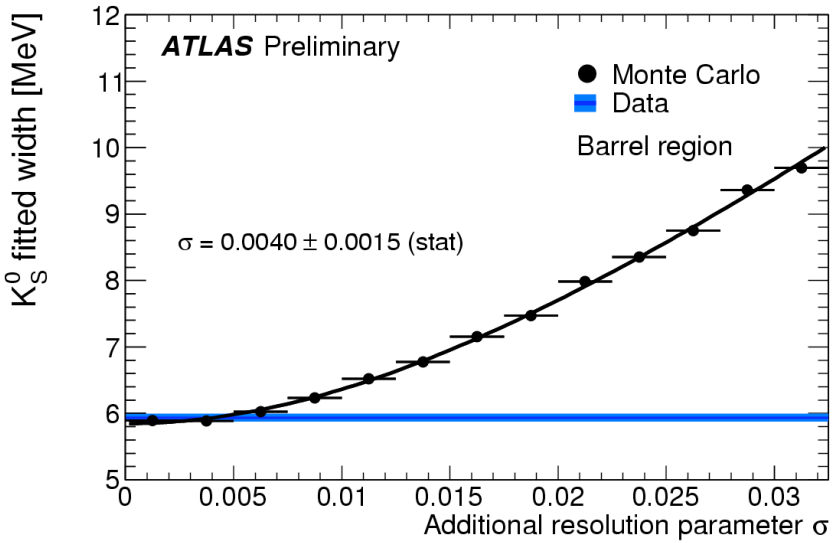
$$f(m) = t + a \cdot m + b \cdot m^2 + N \cdot e^{-\frac{(x_m - m)^2}{s^2}}$$

- more information on reconstruction of known particle decays in ATALS by R. di Nardo (poster)

Track Momentum Resolution cont'

@ 900 GeV





- rescale K^0_S p_T in Monte Carlo to fit data:

$$\frac{1}{p'^{MC}_T} = \frac{1}{p^{MC}_T}(1+\delta)$$

μ: shift of mean
σ: broadening of width

$$\text{with} \quad P(\delta;\mu,\sigma) = \frac{1}{\sqrt{2\pi}\sigma}\exp[-\frac{(\mu-1-\delta)^2}{2\sigma^2}]$$

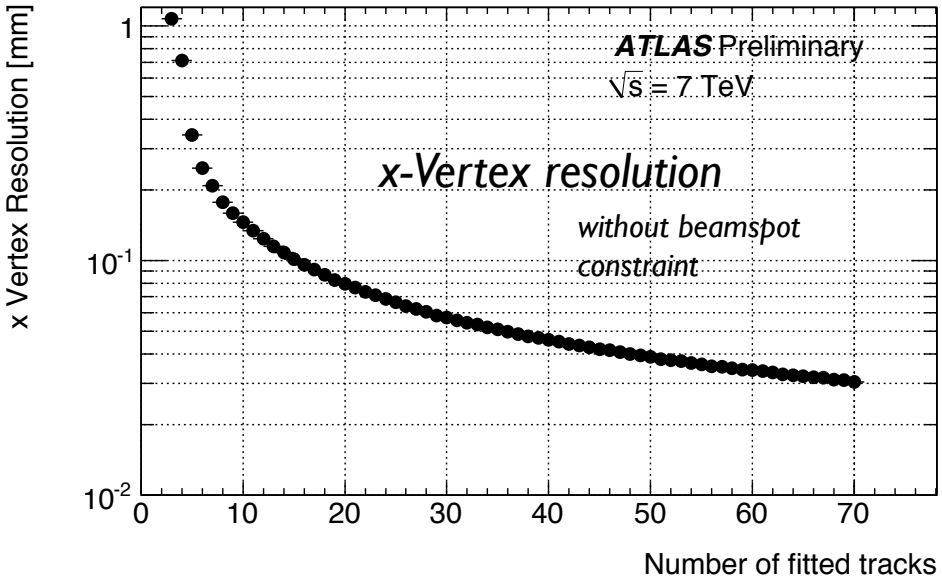
- best fit values in the barrel:
(consistent with no change)

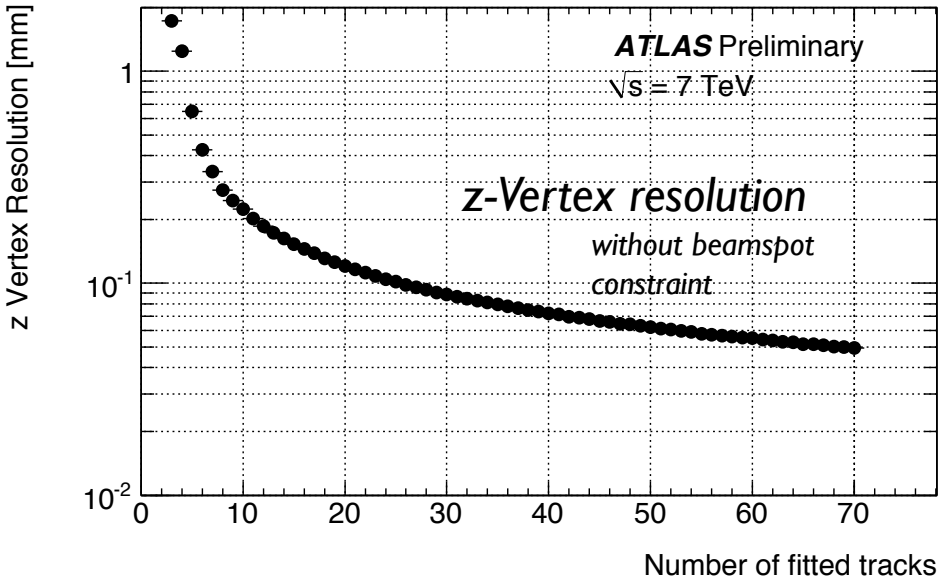
$$\mu_{Barrel} = 1.0004 \pm 0.0002 \text{ (stat)}$$

$$\sigma_{Barrel} = 0.0040 \pm 0.0015 \text{ (stat)}$$

- good agreement between data and nominal Monte Carlo for low momentum
  - studies ongoing for resonances with higher mass (and p_T)

Primary Vertex Reconstruction



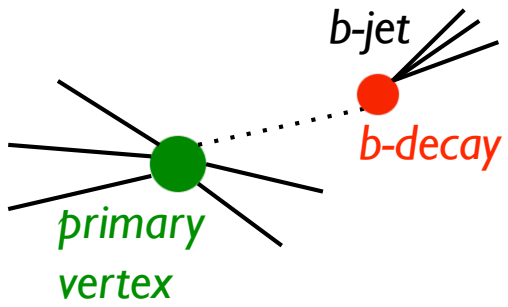


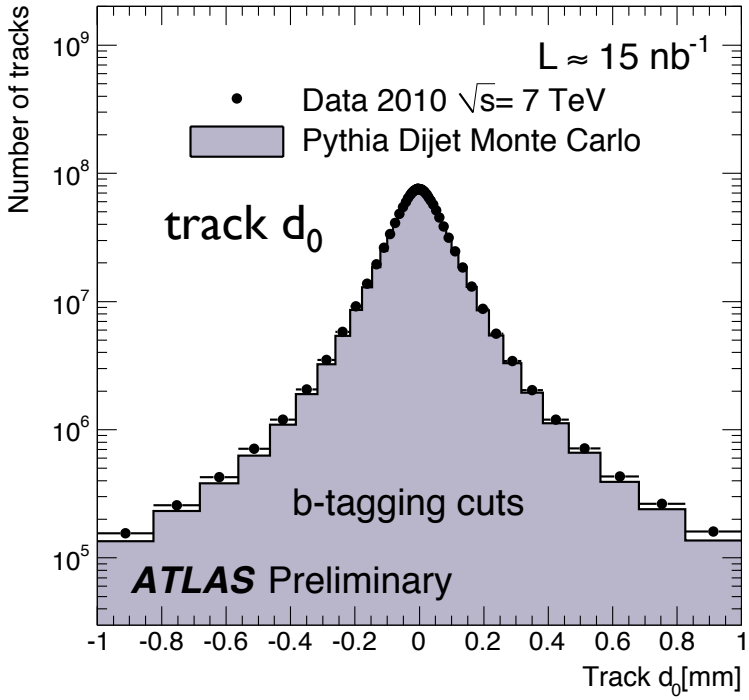
- *iterative finding* Algorithm
  - progressive down-weighting of outlying tracks
- resolution determination: *split vertex method*
  - split tracks in vertex randomly in two
  - fit both vertices independently
  - separation gives intrinsic resolution
- vertex resolution in data for $n_{tracks} \cong 50$: (typical number in dijet events)
  - along x-axis: 40 μ m
  - along z-axis: 60 μ m

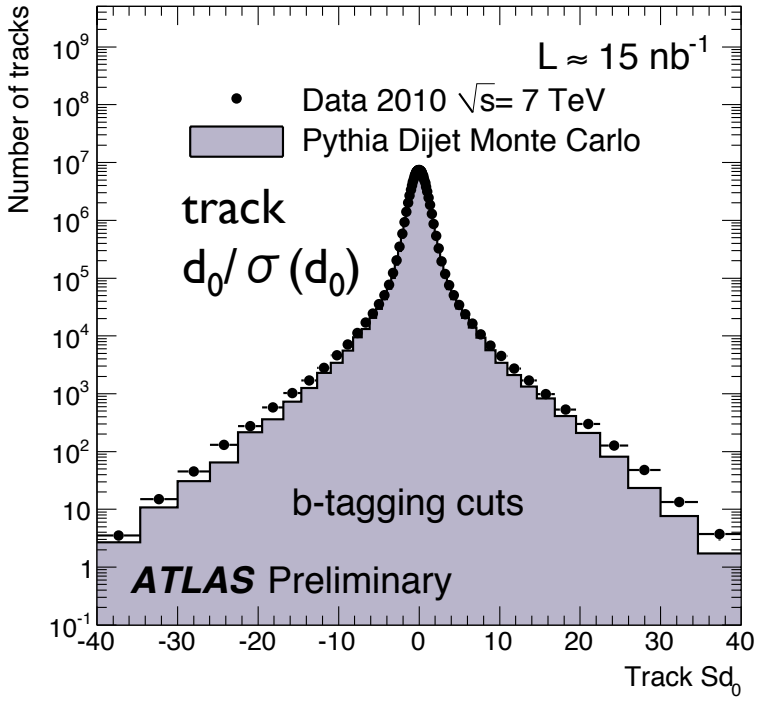
Transverse Impact Parameter

- Most *b*-tagging algorithms rely on the measurable life time and displaced decay vertex of *b*-hadrons
  - need well measured tracks
  - study the transverse track impact parameter

sketch of *b*-decay



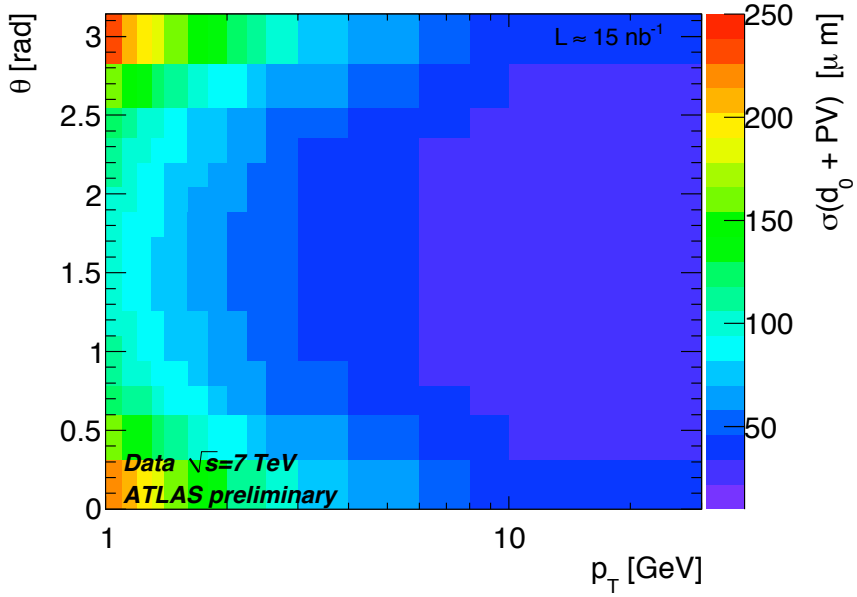


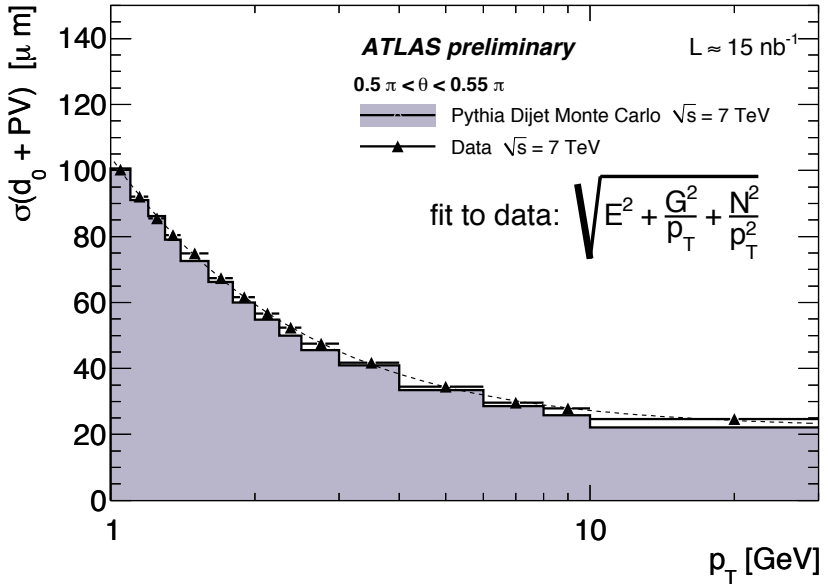


Transverse Impact Parameter Resolution

- d_0 is the d_0^{track} resolution convolved with primary vertex resolution
- d_0 resolution in bins of p_T and θ : fit core of distribution with Gaussian
- resolution clearly depends on p_T and θ
- for fixed theta:

$$\sigma(d_0) = \sqrt{E^2 + \frac{G^2}{p_T} + \frac{b^2}{p_T^2 \sin\theta}}$$

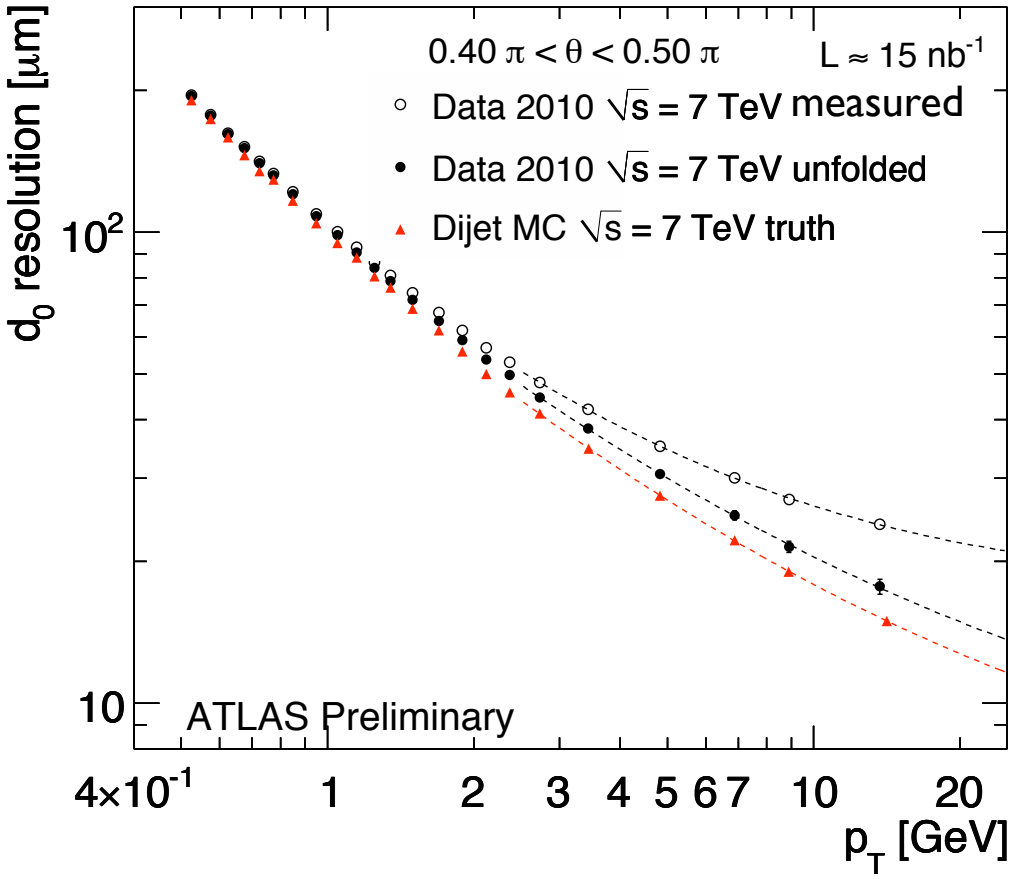




Unfolding of track d_0 resolution

- d_0^{track} can be unfolded in an iterative way

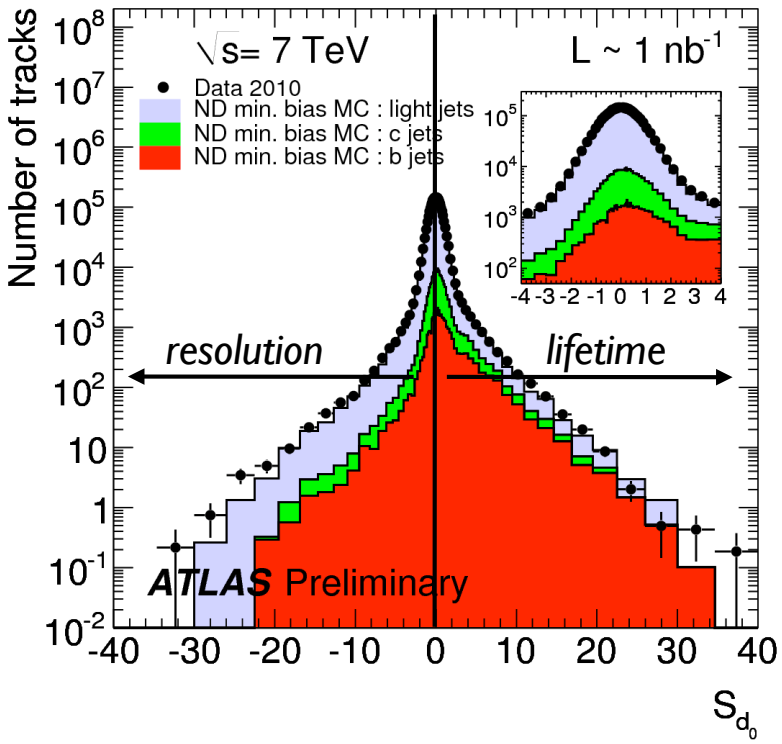
$$R_{\text{meas}}(d_0) = \int \exp\left[-\frac{1}{2}\frac{d_0^2}{\sigma^2_{d_0,\text{trk}} + \sigma^2_{d_0,\text{PV}}}\right] \cdot \overbrace{P(\sigma_{d_0,\text{PV}})}^{\text{PV uncertainty}} \, \mathrm{d}\sigma_{d_0,\text{PV}}$$



- Low p_T:
  - Good agreement between unfolded and resolution expected from nominal simulation
- High pT:
  - discrepancies due to remaining misalignment
- more details on alignment in ATLAS:
  - previous talk by A. Limosani
  - poster by J. Wang

The Jet Probability Tagger (JetProb)

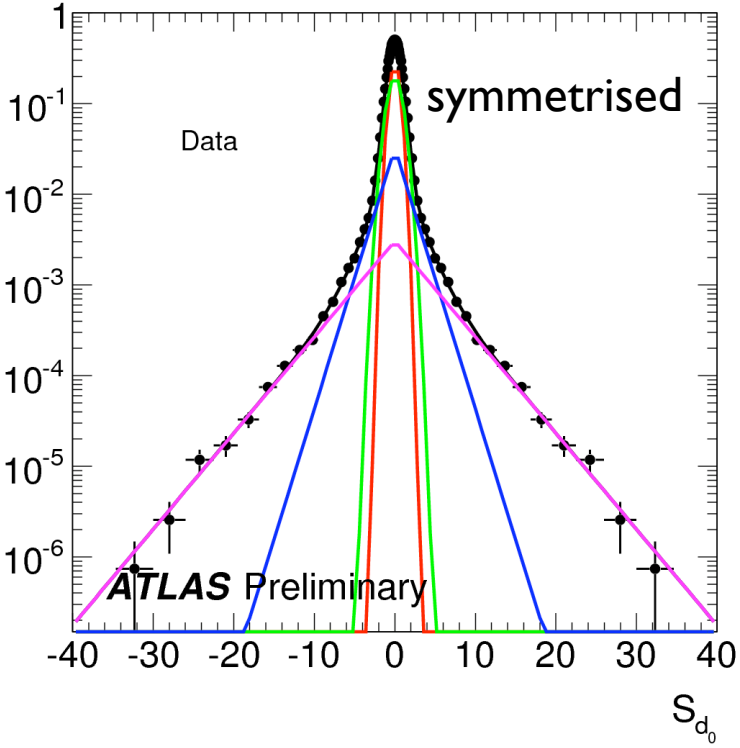
- probability for the jet to be compatible with the light jet hypothesis
- d_0 significance signed wrt jet axis (S_{d0})
- resolution function calculated in data for S_{d0}:



negative

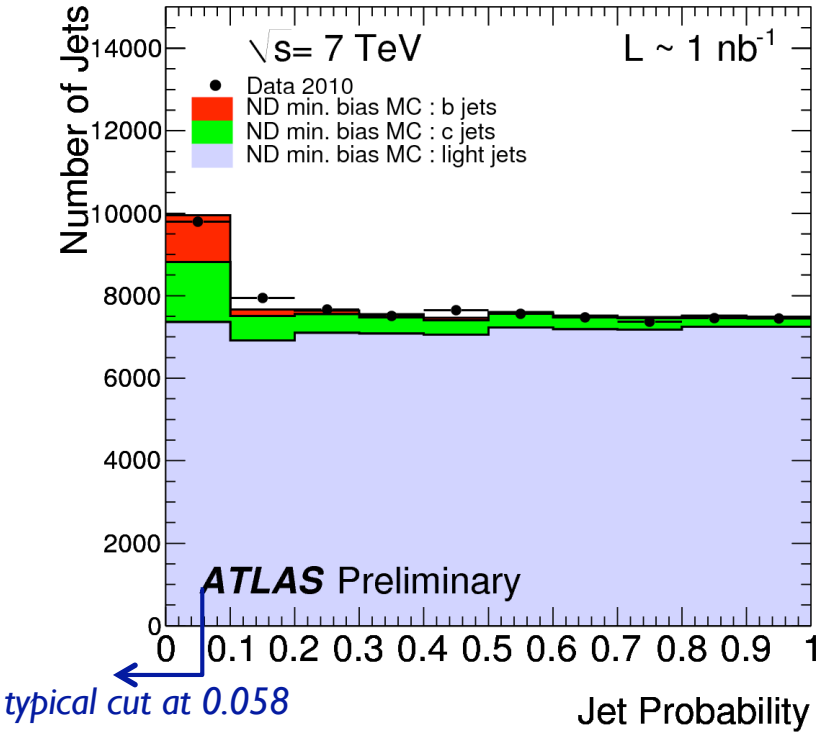
tail

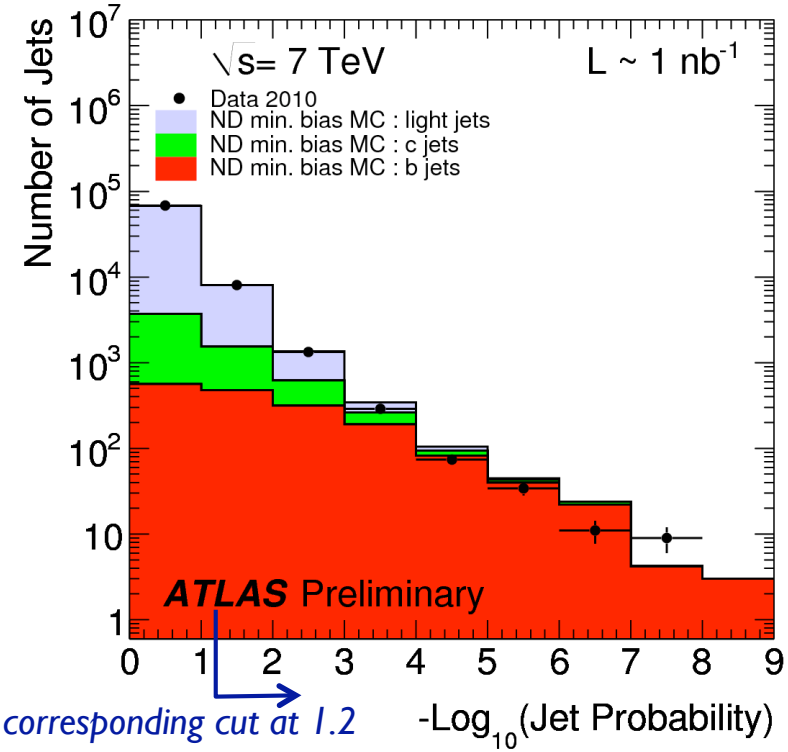
Resolution function *R*:



Results from the JetProb Tagger

1. **track probability:**
   for each track calculate probability to come from primary vertex using resolution Function *R*
2. **jet probability:**
   combine probabilities from all tracks in jet to a jet probability



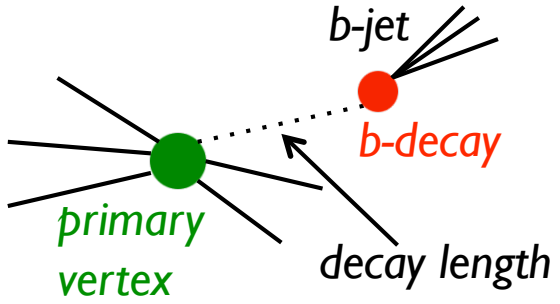


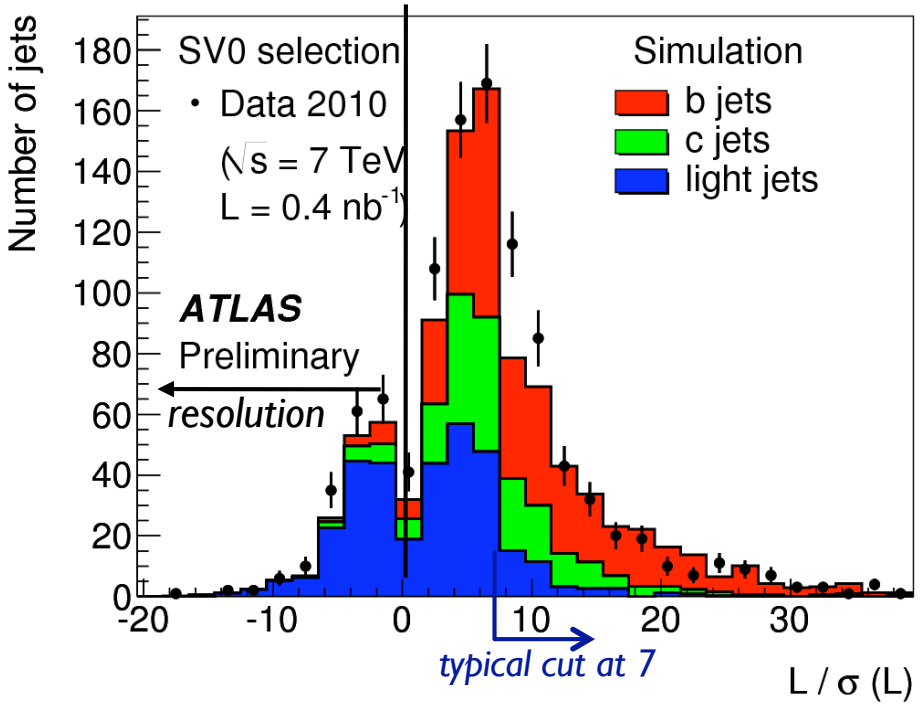
- good agreement between data and Monte Carlo

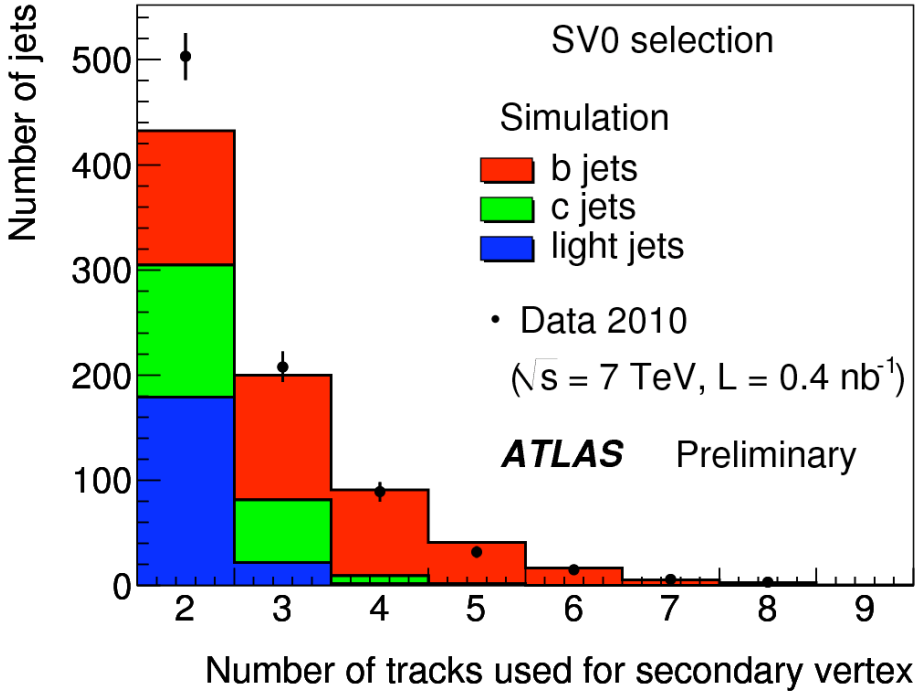
The Secondary Vertex Tagger SV0

- explicit reconstruction of *b*-hadron decay vertex
- decay length significance is discriminating variable

sketch of *b*-decay



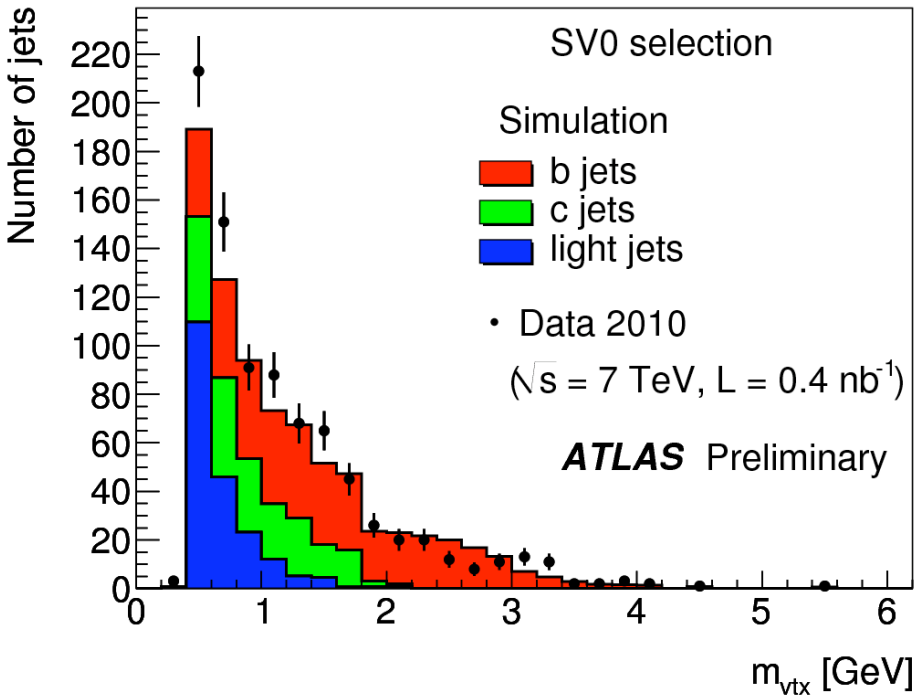




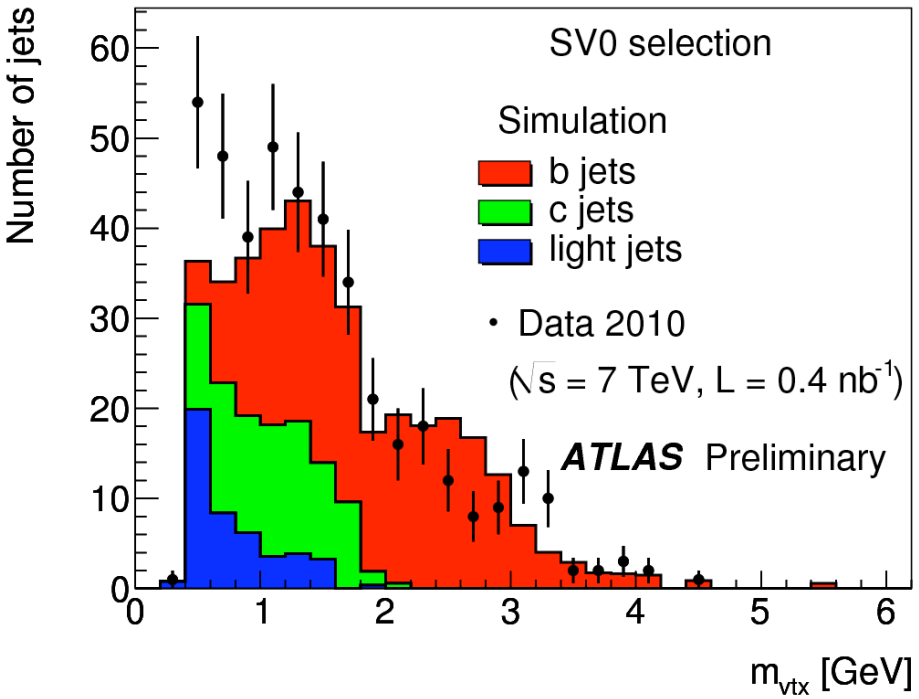
Results from the SV0 Tagger

- cut on positive decay length significance $L/\sigma(L)$
  - clear enhancement of heavy flavour in the mass of the secondary vertex m_{vtx}

$L/\sigma(L) > 0$



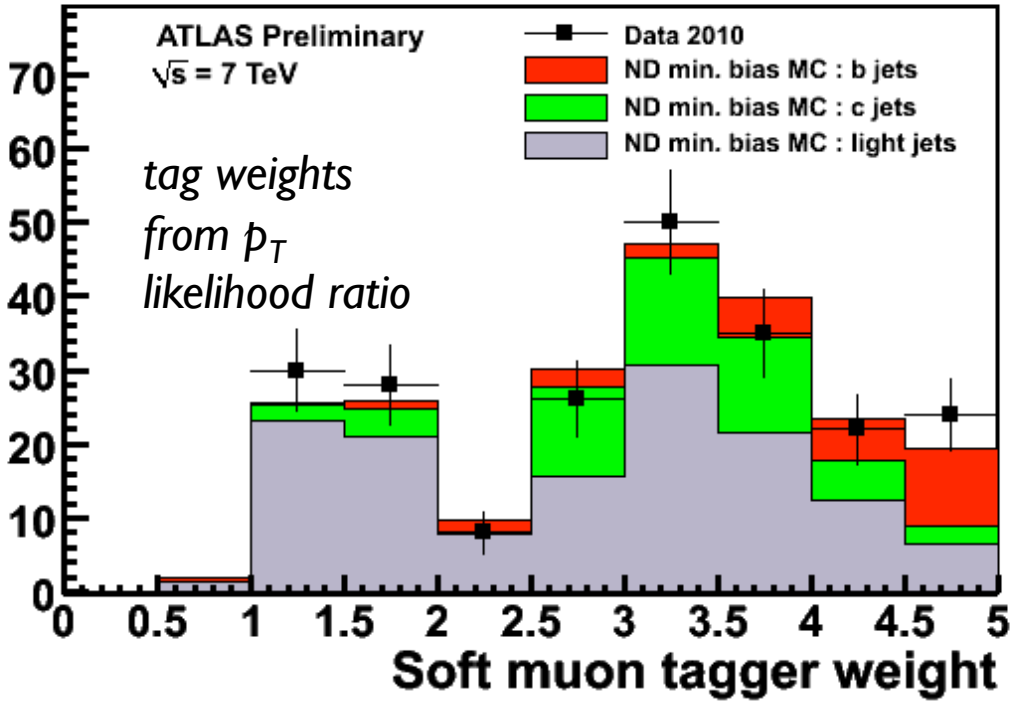
$L/\sigma(L) > 7$



- reasonable agreement between data and Monte Carlo

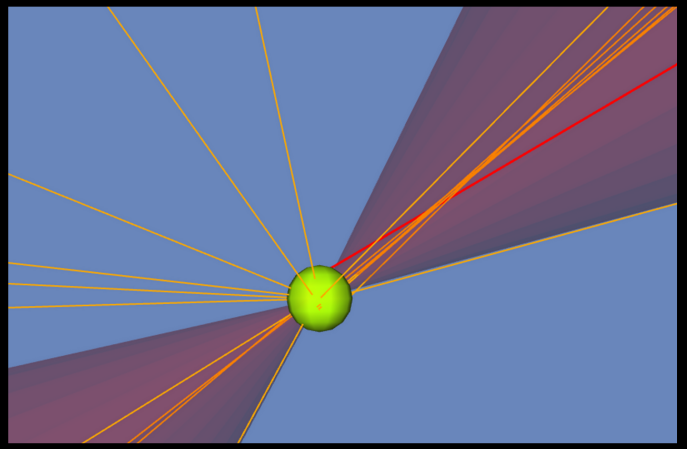
The Soft Muon Tagger

- exploits semi-leptonic decay of *b*- and *c*-hadrons to muons:
  $BR(b \to \mu\nu X) + BR(b \to c \to \mu\nu X) \approx 20\%$
- associates good reconstructed muons to jets
  - tag weights from likelihood ratio based on p_T distribution wrt jet axis
  - to be used for calibration of the lifetime tagging algorithms



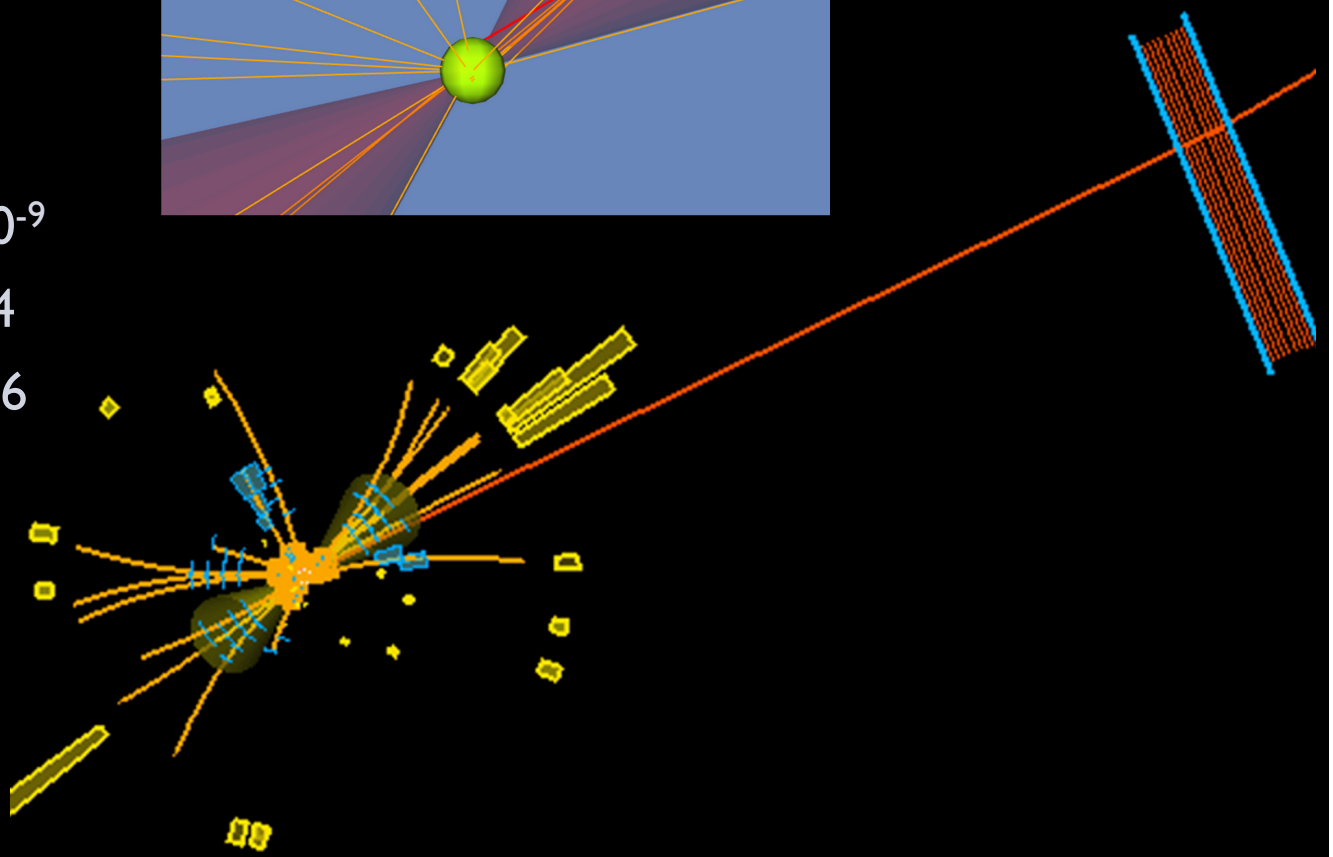
b-tagged jet with one muon

Run 152409
Event 4349994



tagger weights:

- Jet Prob: 10^{-9}
- SV0 L/σ (L): 24
- soft muon weight: 4.6



Summary

- Presented track and vertex performance and first *b*-tagging studies in ATLAS
  - reconstruction of known decays K^0_S
    - determine transverse momentum resolution and scale at low p_T
  - primary vertex reconstruction
  - transverse impact parameter resolution
    - unfolded from primary vertex uncertainty
  - three *b*-tagging algorithms used for early data analyses
  - good agreement with Monte Carlo prediction

- Inner Detector performs very well in first data
  - solid foundation for ATLAS tracking and *b*-tagging

backup slides

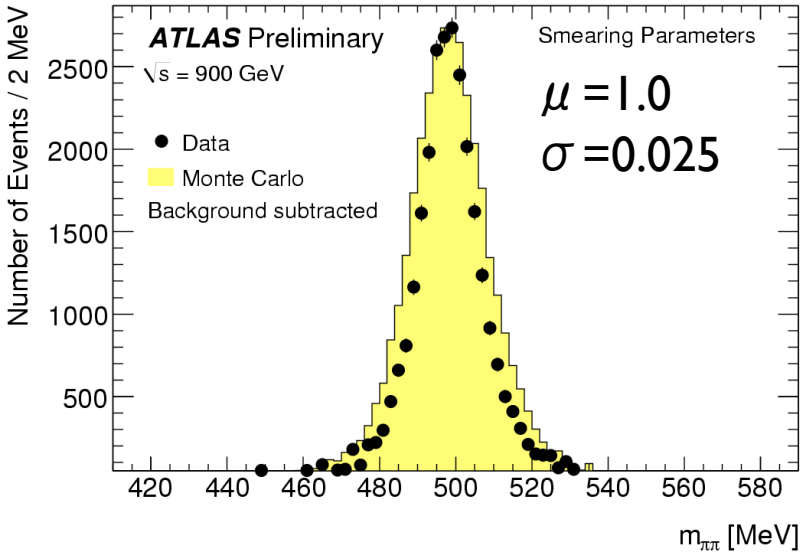
Reconstruction of K^0_S

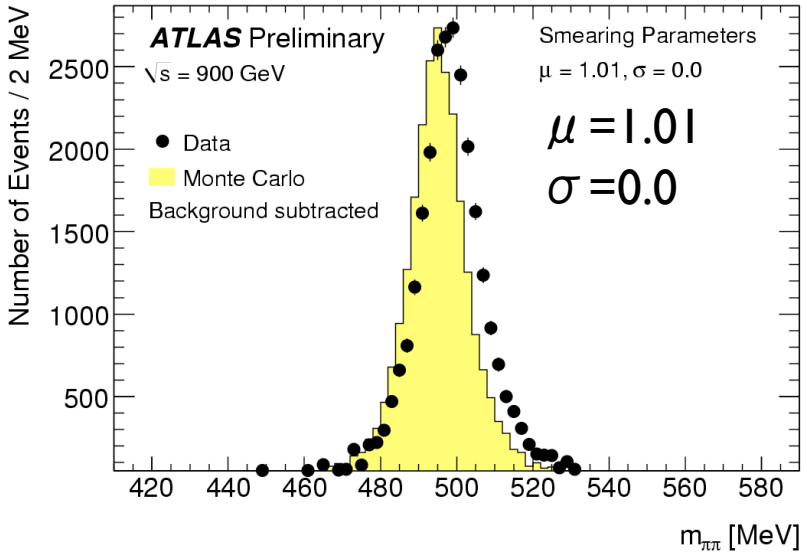
- reconstruction requirements:
  - vertex-fit: chi^2 < 15
  - 1 pixel hit, 6 SCT hits
  - d_0<50 mm, z_0<500 mm
  - transverse flight distance to PV > 0.2 (4) mm
  - cosine of angle in transverse plane between K momentum and K flight direction > 0.99 (0.999)
  - relative pT scale: $1 - \frac{p_T^{MC}}{p_T^{reco}}$

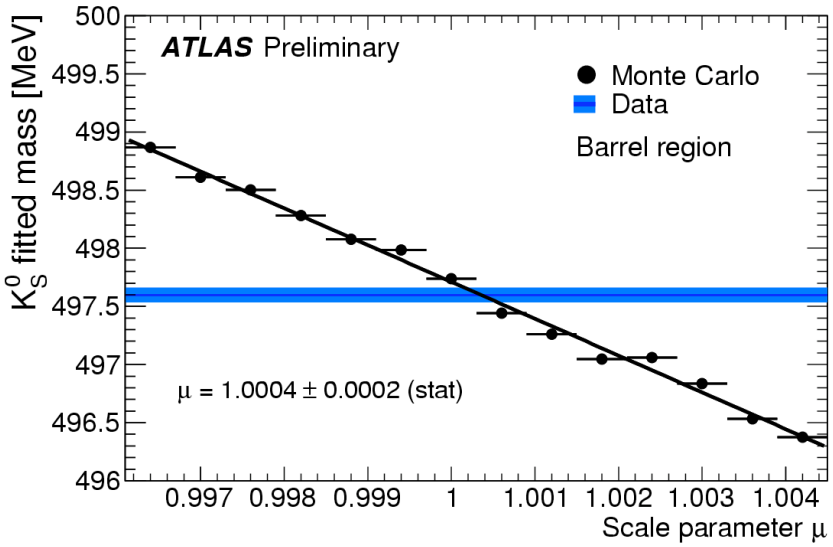
    and resolution: $p_T \times \sigma(1/p_T)$
- CONF notes:
  - ATLAS-CONF-2010-009
  - ATLAS-CONF-2010-033

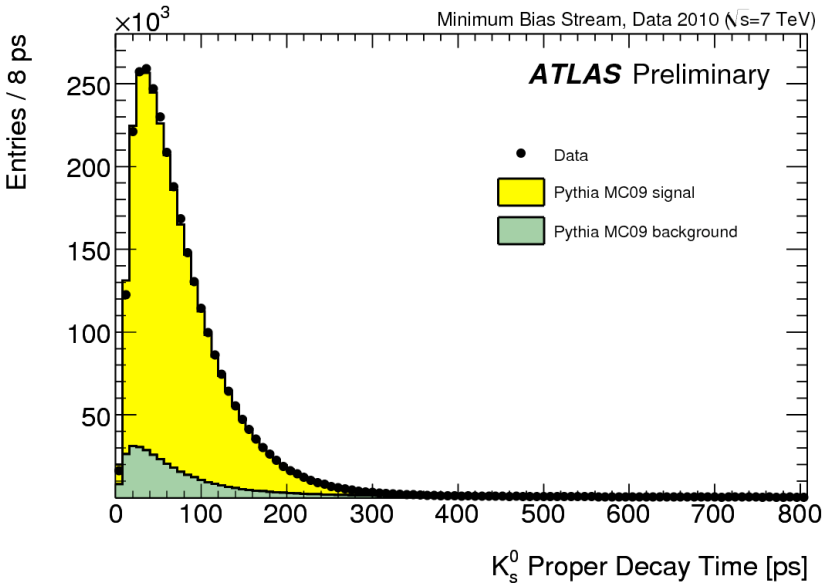
Estimating Track Momentum Resolution cont'

@ 900 GeV









Primary Vertex Reconstruction

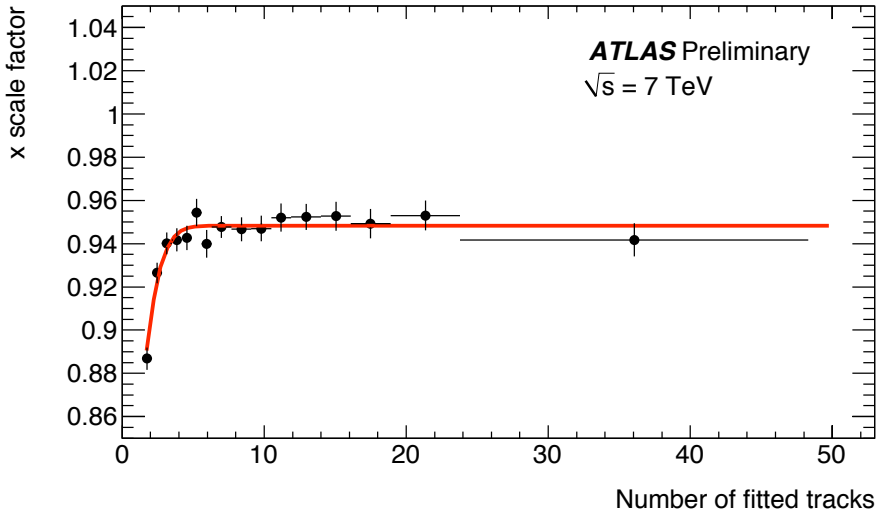
- estimating scale factors to compensate incorrect error description

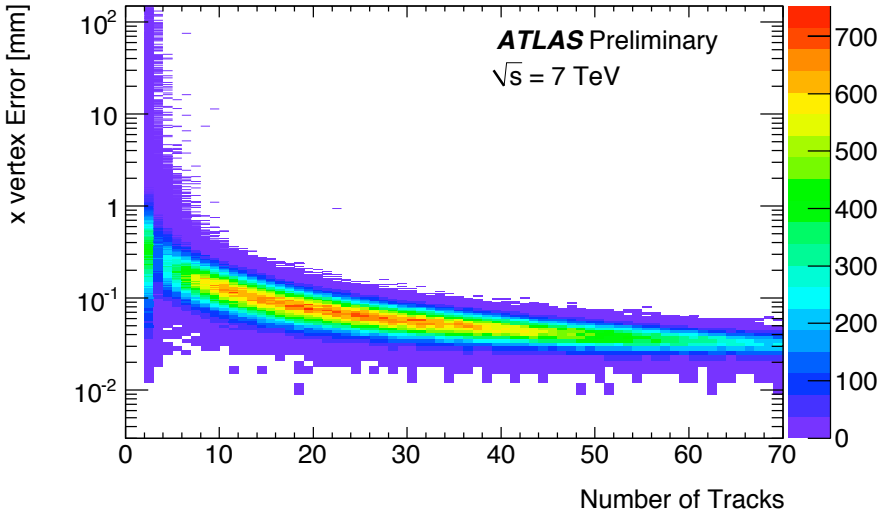
$$\sigma_{x_{\mathrm{PV}},\mathrm{true}} = K_x \sigma_{x_{\mathrm{PV}},\mathrm{fit}},$$

- pull for split vertices:

$$\mathrm{pull}_x = \frac{(x_{1,\mathrm{PV}} - x_{2,\mathrm{PV}})}{\sqrt{\sigma^2_{x_{1,\mathrm{PV}},\mathrm{fit}} + \sigma^2_{x_{2,\mathrm{PV}},\mathrm{fit}}}}.$$

- ATLAS-CONF-2010-069





Unfolding of track d_0 resolution

- d_0 can be unfolded in an iterative way
  - 1st iter.: $d_0 \rightarrow d_0 \left[1 + \frac{\sigma^2_{d_0 .\mathrm{PV}}}{\sigma^2_{d_0 .\mathrm{trk}}} \right]^{-1/2}$ ith iter.: $d_0^{(i)} \equiv d_0^{(i-1)} \left[1 + \frac{K^2_{\mathrm{PV}}}{K^2_{\mathrm{trk}}} \frac{\sigma^2_{d_0 .\mathrm{PV,fit}}}{\sigma^2_{d_0 .\mathrm{trk,fit}}} \right]^{-1/2}$
- d_0^{track} resolution in central barrel at 15 GeV:
  - convolved: 24 μ m
  - unfolded: 18 μ m
  - MC truth: 15 μ m

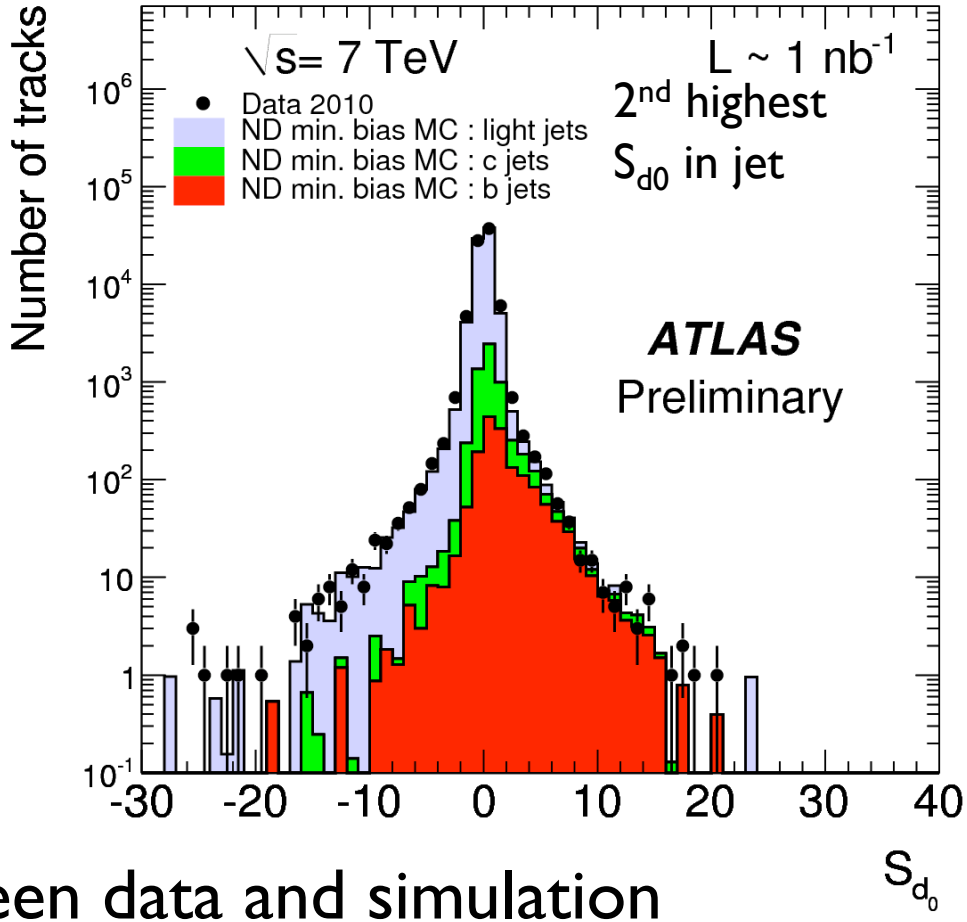
b-Tagging Cuts and Definitions

- track requirements:
  - Pt > 1 GeV
  - nHitsSi >= 7
  - nHitsPix >= 2
  - nHitsBlayer >= 1
  - $|d_0| < 1$mm
  - $|z_0 * \sin(\Theta)| < 1.5$ mm
- tracking note:
  - ATLAS-CONF-2010-070
- b-Tagging notes:
  - ATLAS-CONF-2010-041
  - ATLAS-CONF-2010-042
- sign for the transverse impact parameter wrt jet axis:

$$\mathrm{sign}(d_0) = \mathrm{sign}\left[(\vec{P}_j \times \vec{P}_t) \cdot \left(\vec{P}_t \times (\vec{X}_{pv} - \vec{X}_t)\right)\right]$$

The Track Counting Tagger

- d_0 significance signed wrt jet axis (S_{d0}) sensitive to *b*-hadron lifetime
- orders tracks in the jet according to their S_{d0}
- uses the 2nd highest S_{d0} as discriminating variable to identify *b*-jets

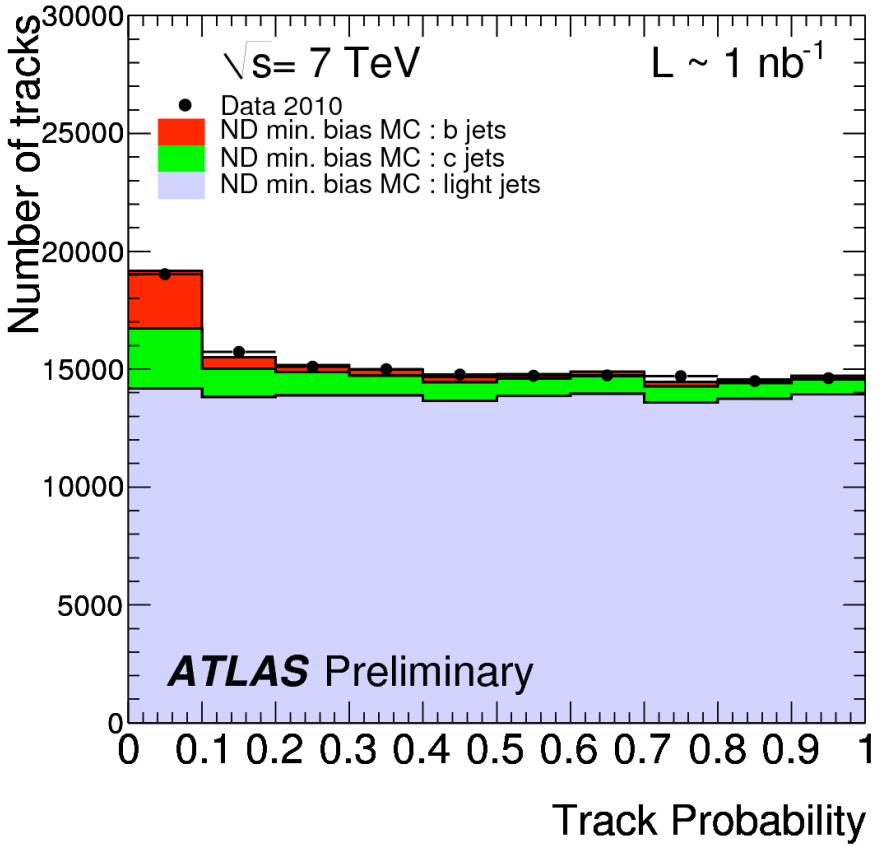


- fairly good agreement between data and simulation

JetProb Probability Calculation

1. track probability:

$$P_{\mathrm{trk},i} = \int_{-\infty}^{-\left|d_0^i/\sigma_{d_0}^i\right|} \Re(x)\,dx$$



2. jet probability:

$$P_{\mathrm{jet}} = P_0 \sum_{j=0}^{N-1} \frac{(-\ln P_0)^j}{j!}, \quad P_0 = \prod_{i=1}^{N} P_{\mathrm{trk},i}$$

The Soft Muon Tagger

- selection cuts:
  - $\Delta(R_{match})<0.5$
  - $|d_0|>4mm$
  - $p_T>4GeV$
  - Comb'Muons: chi2/ndf < 10
    LowPt: chi2/ndf: cut at 5 σ
  - https://twiki.cern.ch/twiki/bin/view/Atlas/FlavourTaggingPublicResultsCollisionData
- likelihood ratio used to identify *b*-jets
  - taken from simulation