

Status of b-tagging in ATLAS



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On behalf of the ATLAS b-tagging group

12/08/2010
Implications of first LHC data workshop @ MIT

b-tagging overview

b hadron properties :

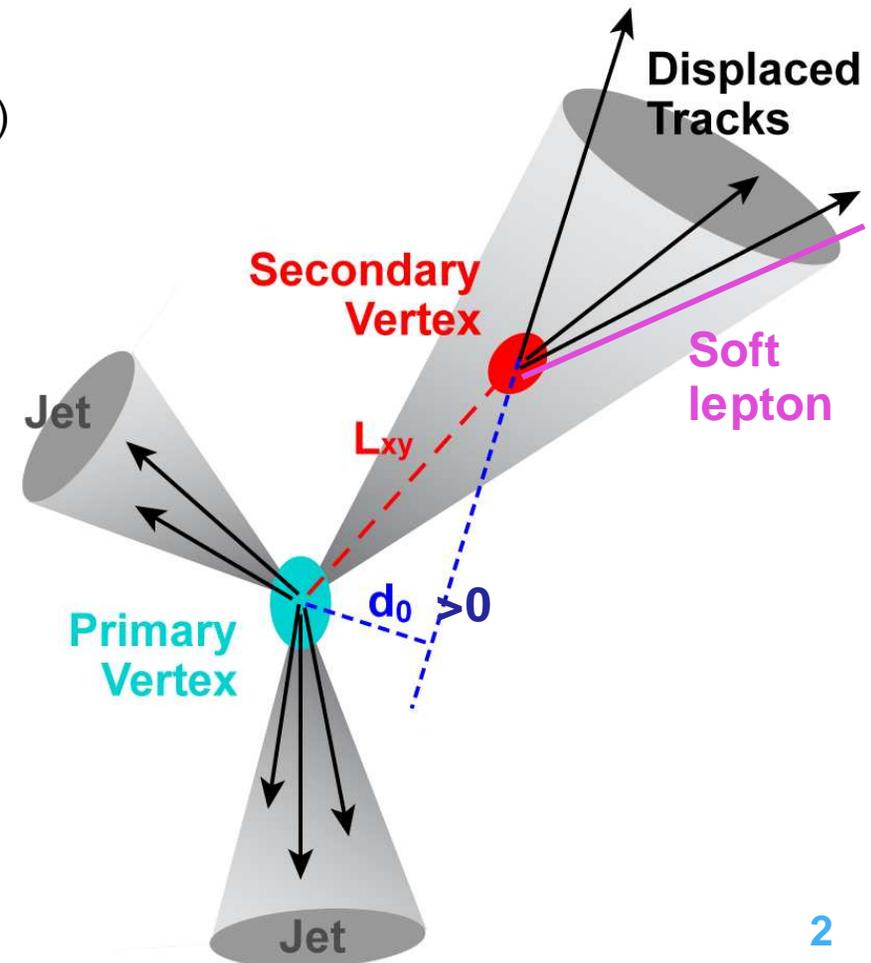
- Long lifetime (~ 1.5 ps, $c\tau=450$ μm)
 - a b hadron in a jet ($p_T=50\text{GeV}$) flies $\sim 5\text{mm}$ in the transverse plane before decaying
- Hard fragmentation
 - Keep 70% of the momentum of the initial b quark
- High mass (5GeV)
 - Decay products with large p_T
- Semi-leptonic decay (in $\sim 40\%$ of b-jets)
 - $\text{Br}(b \rightarrow l \rightarrow X) + \text{Br}(b \rightarrow c \rightarrow l \rightarrow X) = 11\% + 10\%$ ($l=e, \mu$)

Experimentally :

- **Secondary vertex (SV)** displaced from **primary vertex**
- **Larger transverse impact parameter d_0 of tracks in jets from SV**
 - Signed w.r.t. jet axis
 - Significance S_{d_0}

$$S_{d_0} = \frac{d_0}{\sigma_{d_0}}$$

- **Soft leptons**

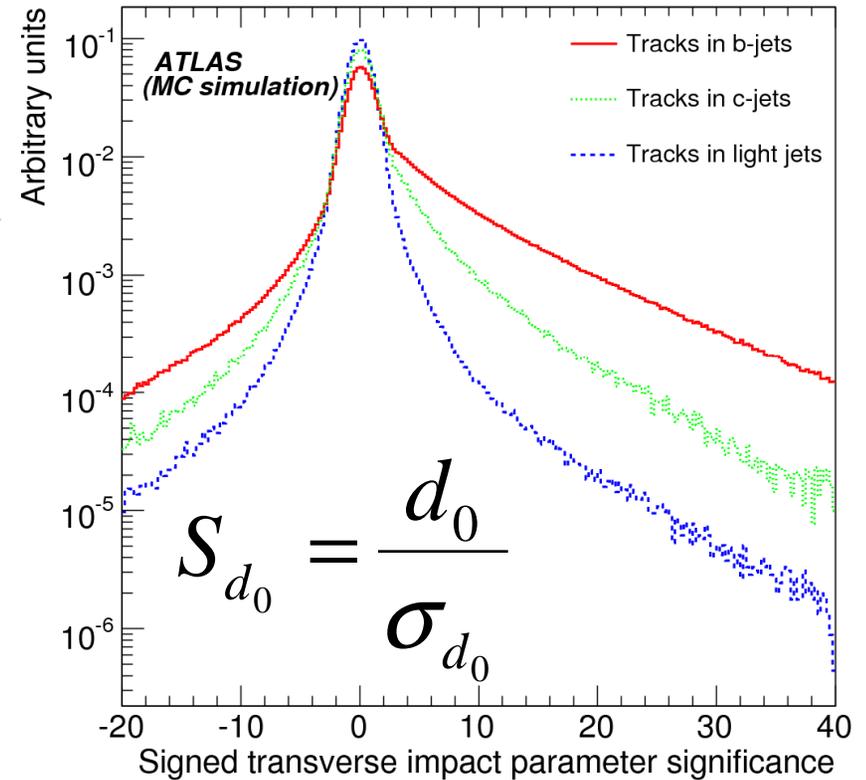
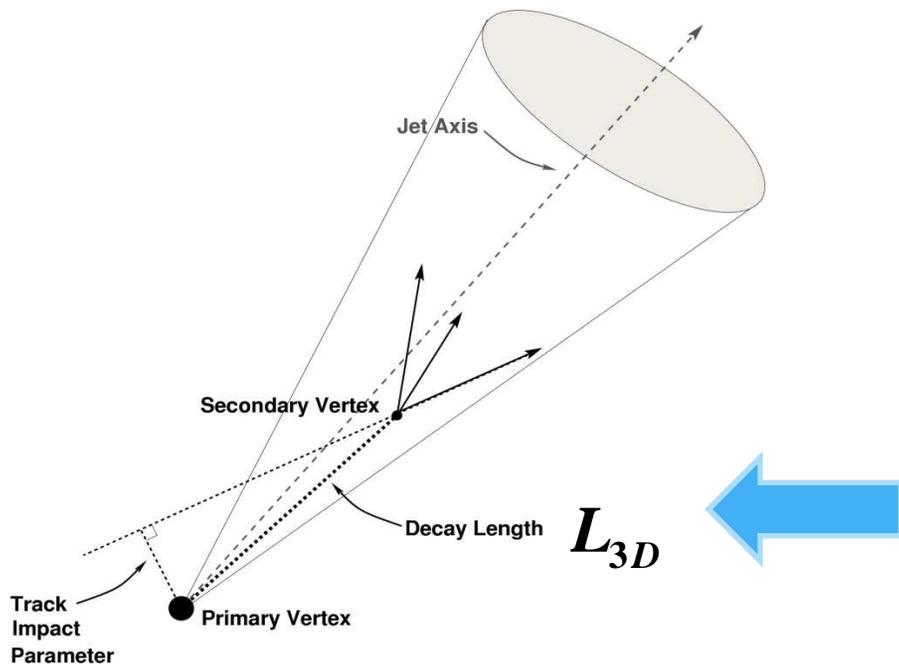


ATLAS b-tagging algorithms for first data

MC @ 14 TeV, taken from the ATLAS performance book (see ref. on last slide)

Based on track impact parameters :

- TrackCounting and JetProb
 - Discriminating variable : signed transverse impact parameter significance S_{d_0}



Based on displaced secondary vertices :

- SV0
 - Discriminating variable : signed decay length significance $S_{L_{3D}}$

$$S_{L_{3D}} = \frac{L_{3D}}{\sigma_{L_{3D}}}$$

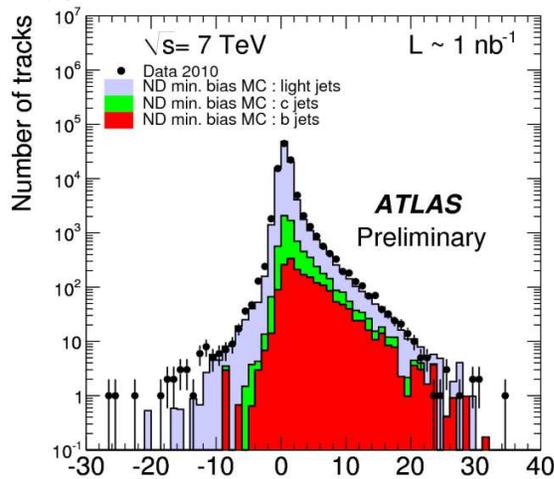
Plots shown in the following slides :
7 TeV data, 1nb^{-1} , minimum bias trigger

TrackCounting

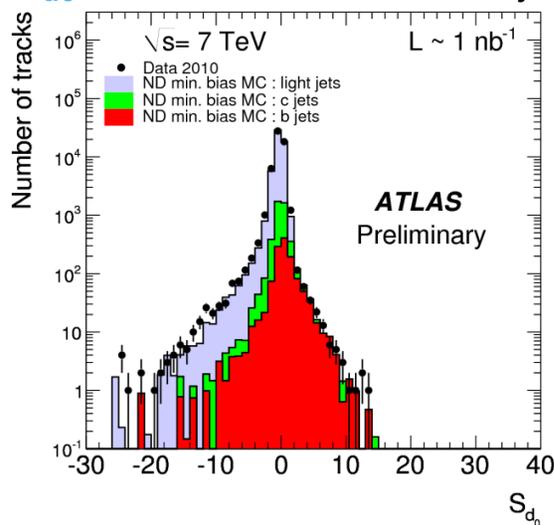
TrackCounting

- Requires only a minimum number of good quality tracks with S_{d0} exceeding a given threshold
- Discriminating variable : S_{d0} of the 2nd track, tracks being ordered in decreasing S_{d0}

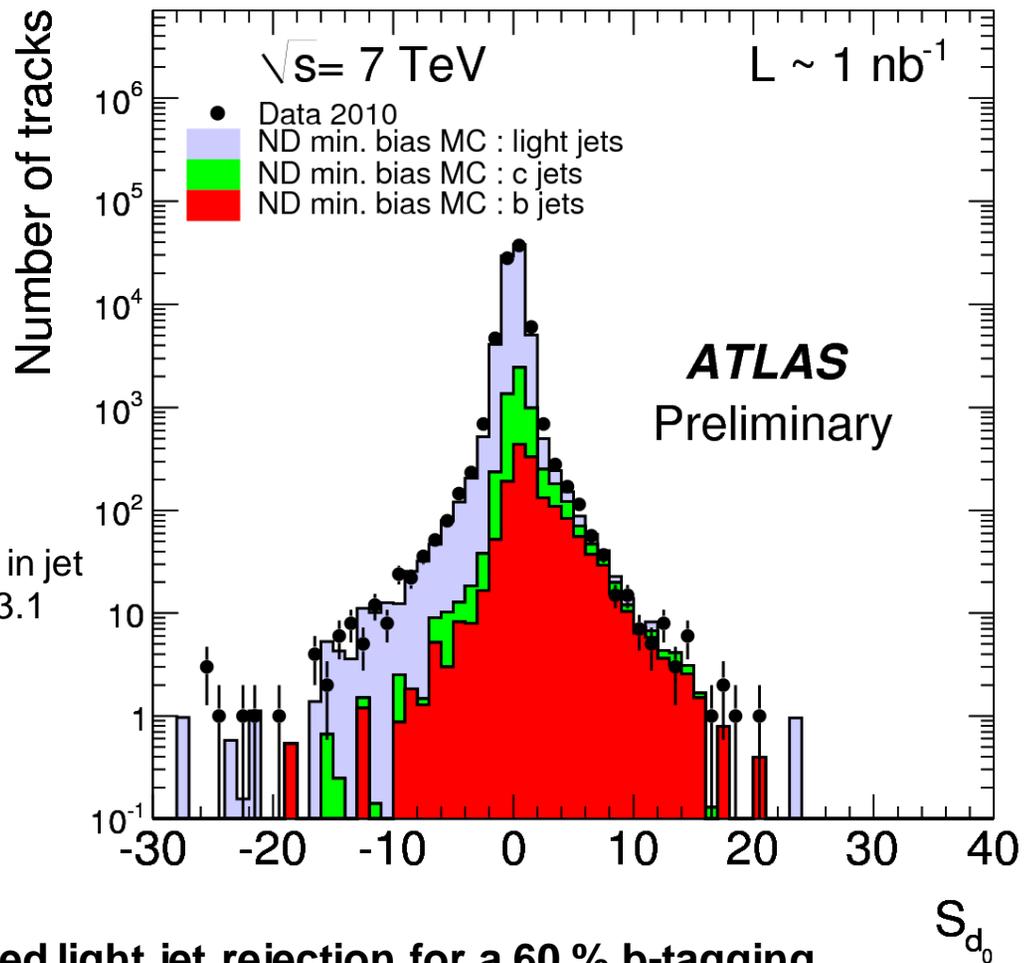
S_{d0} of the 1st track : not well discriminating



S_{d0} of the 3rd track : few jets*



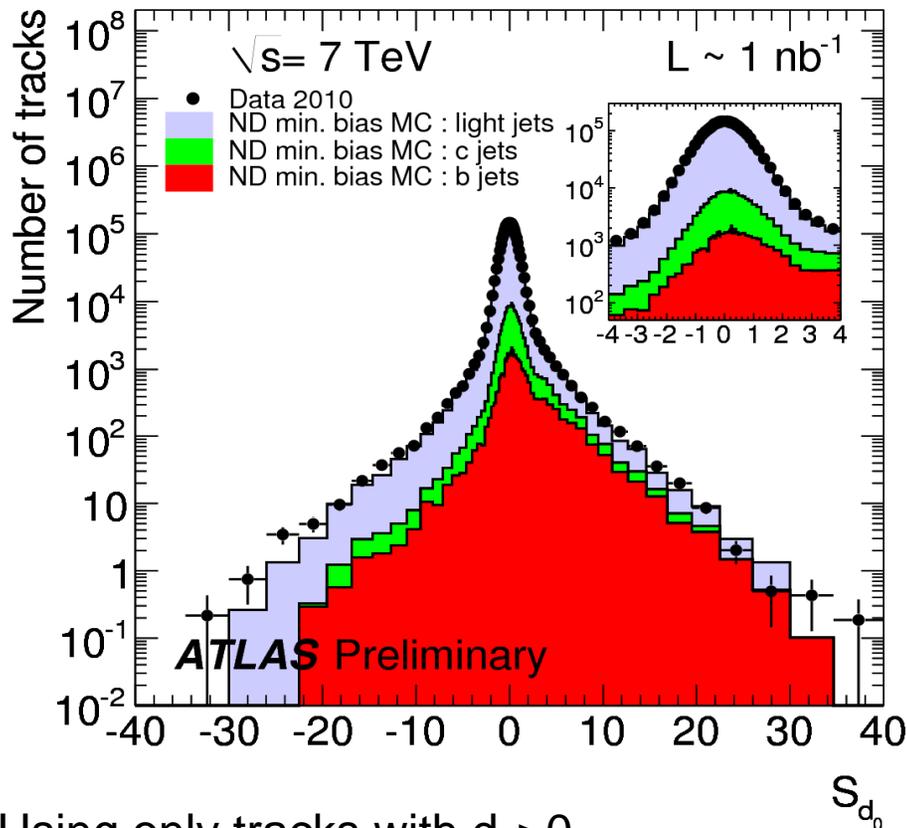
*Average track in jet multiplicity : 3.1



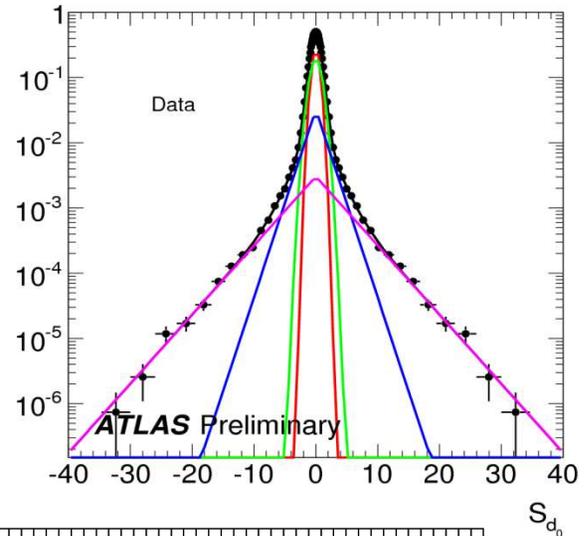
- Expected light jet rejection for a 60 % b-tagging efficiency from MC @ 7 TeV (ttbar) : ~30

JetProb : Track Probability

Computes the **probability for tracks in jet to be prompt**
 Using a calibration function describing prompt tracks extracted from data

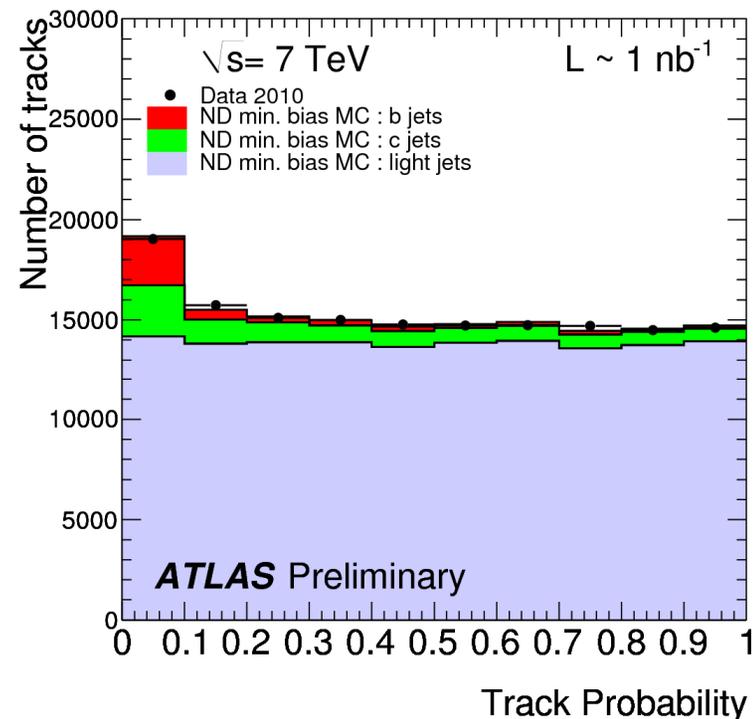


$d_0 < 0$
 symmetrized



- Using only tracks with $d_0 > 0$
- Removing tracks reconstructed as coming from long-lived particles and material interactions

$$P_i = \int_{-\infty}^{-|d_0^i / \sigma_{d_0}^i|} \mathcal{R}(x) dx$$

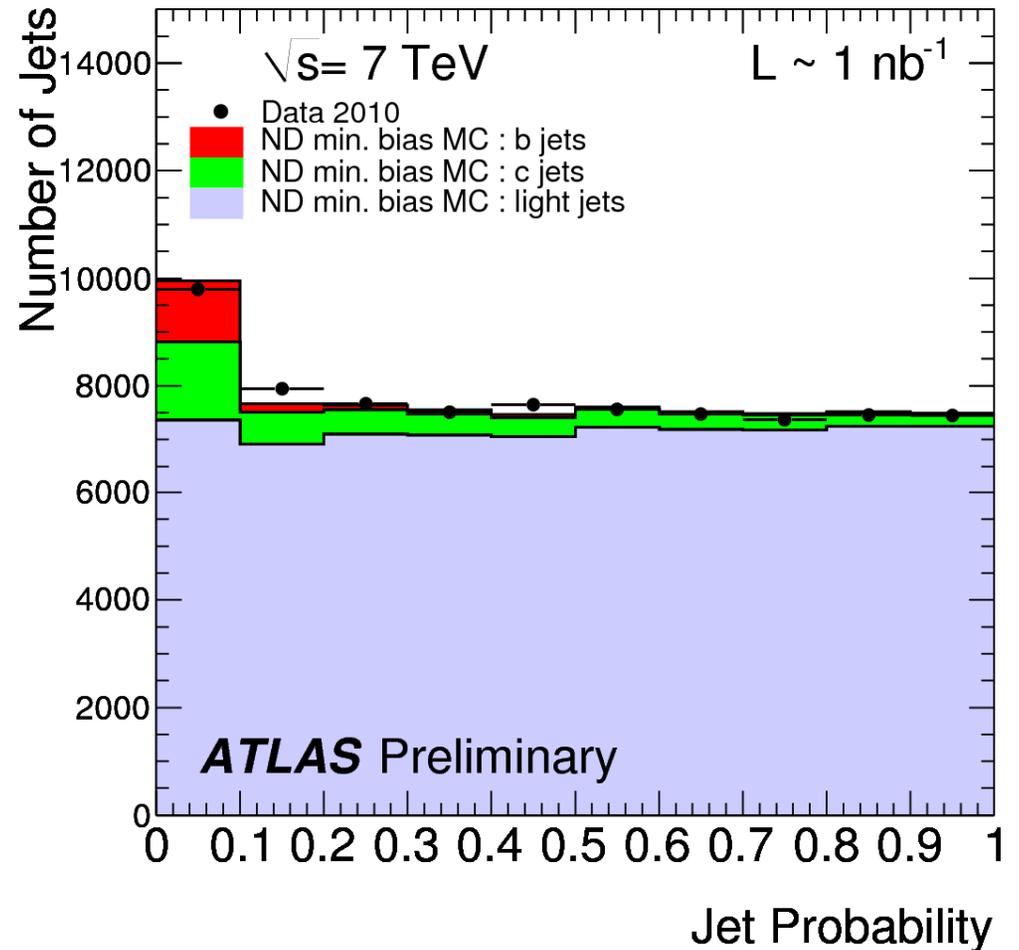
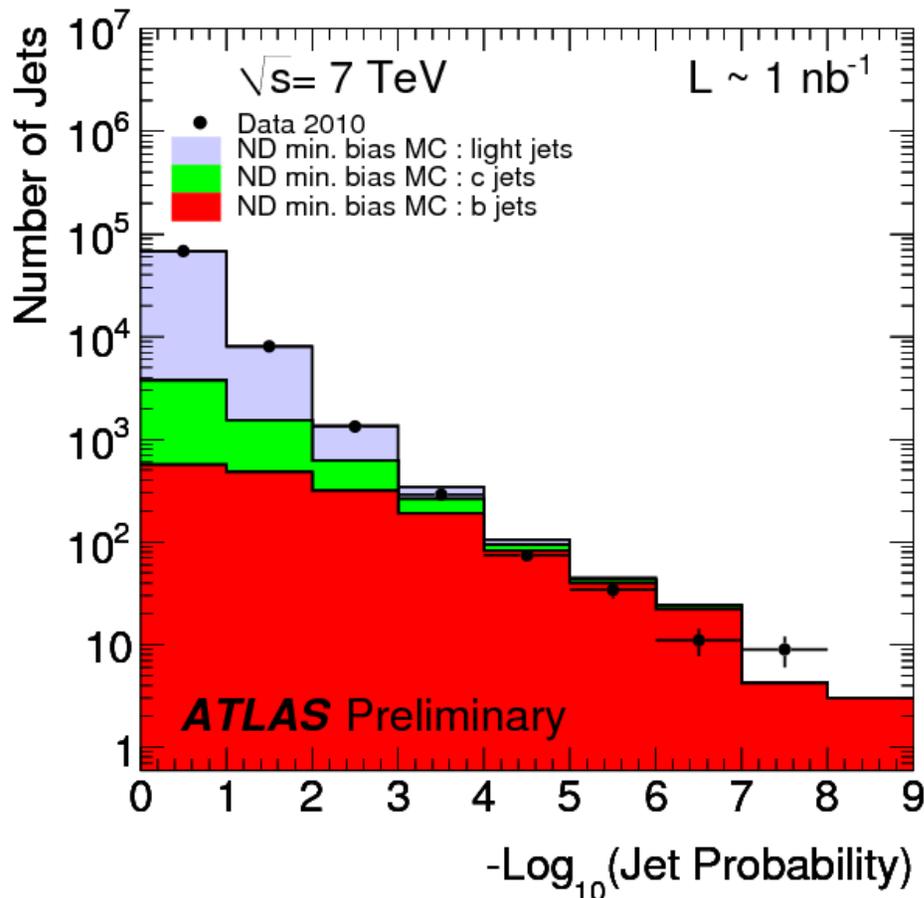
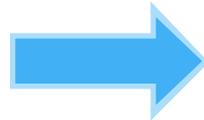


JetProb : Jet Probability

Computes the **probability for a jet to stem from light quark fragmentation**

$$P_{jet} = P_0 \sum_{j=0}^{N_{trk}-1} \frac{(-\ln P_0)^j}{j!}$$

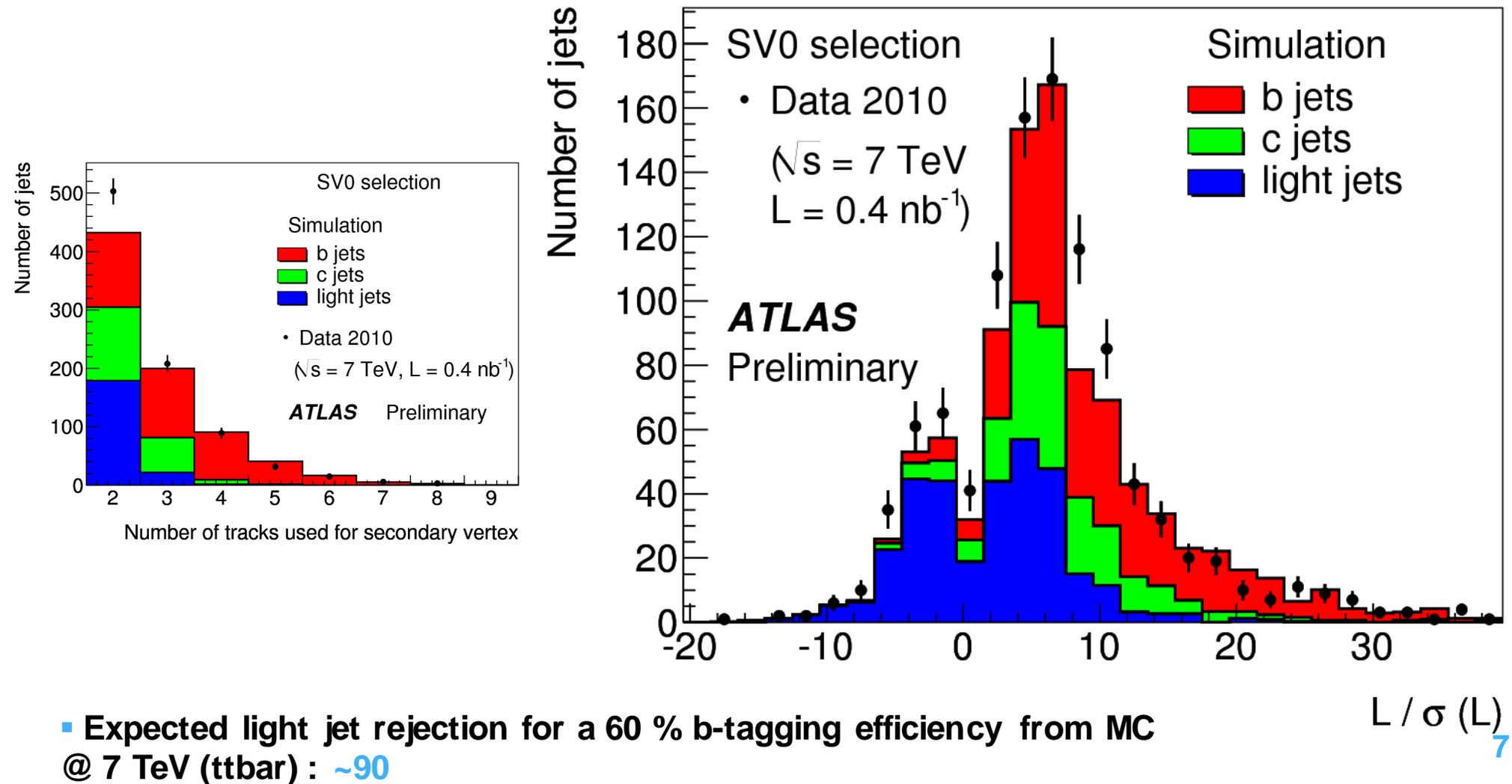
where : $P_0 = \prod_{i=1}^{N_{trk}} P_i$



- Expected light jet rejection for a 60 % b-tagging efficiency from MC @ 7 TeV (ttbar) : **~30**

SV0 (1)

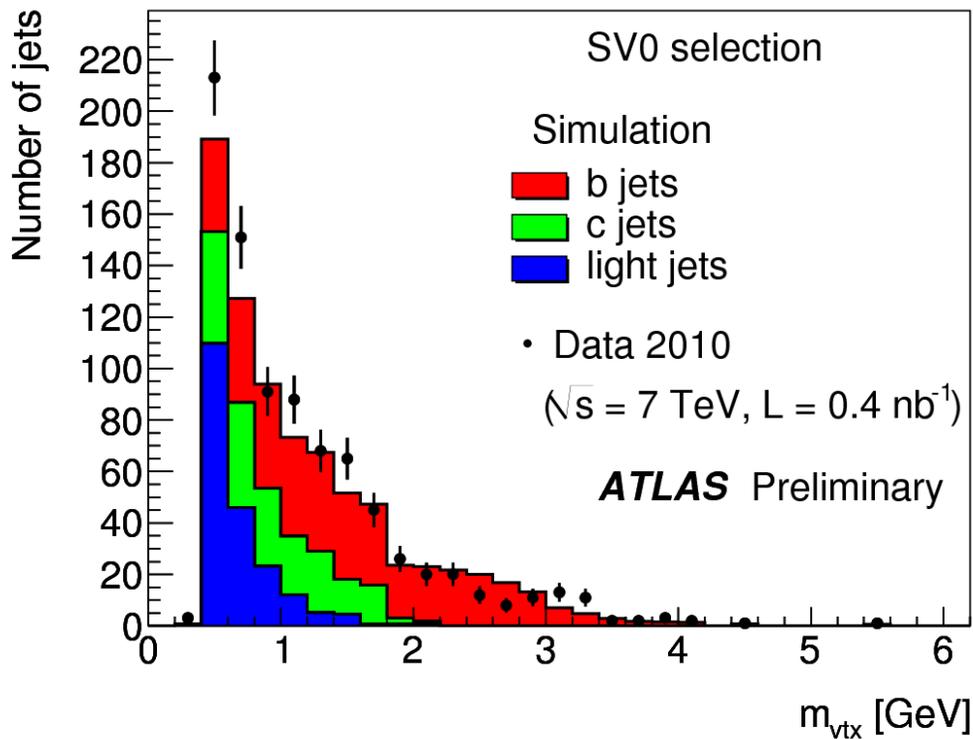
- Secondary vertex reconstructed in ~60% of b-jets
- Plots are normalized to the total number of jets in data
- Discrepancies between data and MC can be explained by :
 - Different flavour composition
 - Different SV reconstruction efficiencies



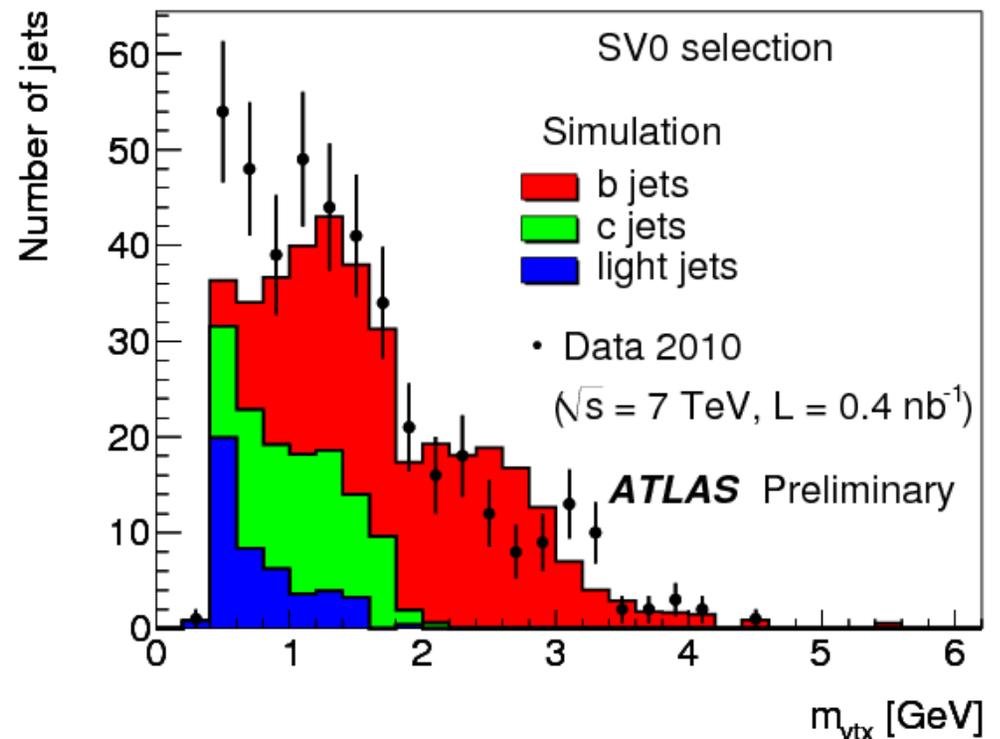
SV0 (2)

- Vertex mass \rightarrow cutting on S_{L3D}

- Using all jets with $S_{L3D} > 0$



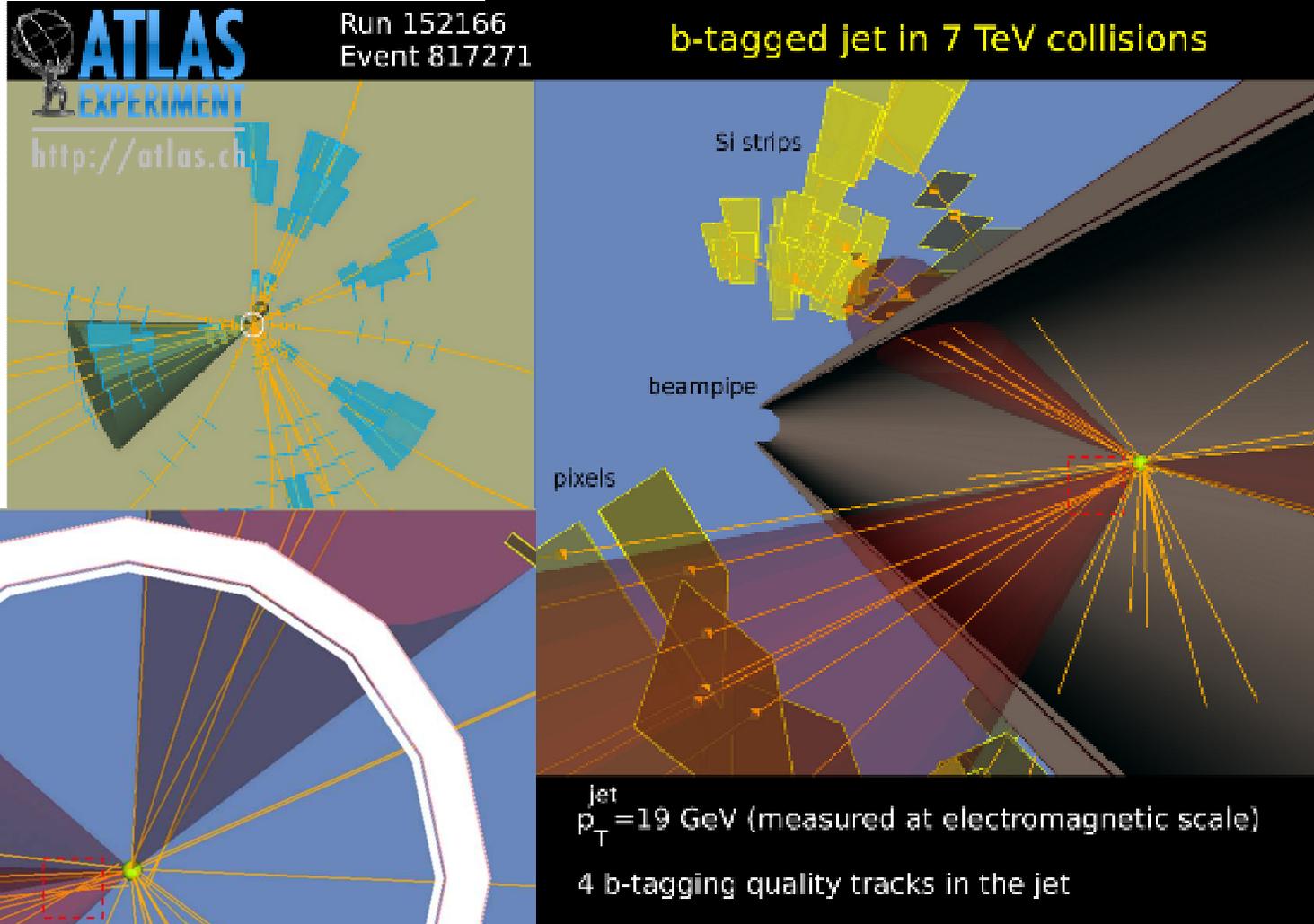
- Using all jets with $S_{L3D} > 7$



- Large enhancement of b fraction when cutting on S_{L3D} demonstrates the power of the algorithm

b-jet candidate in data @ 7TeV

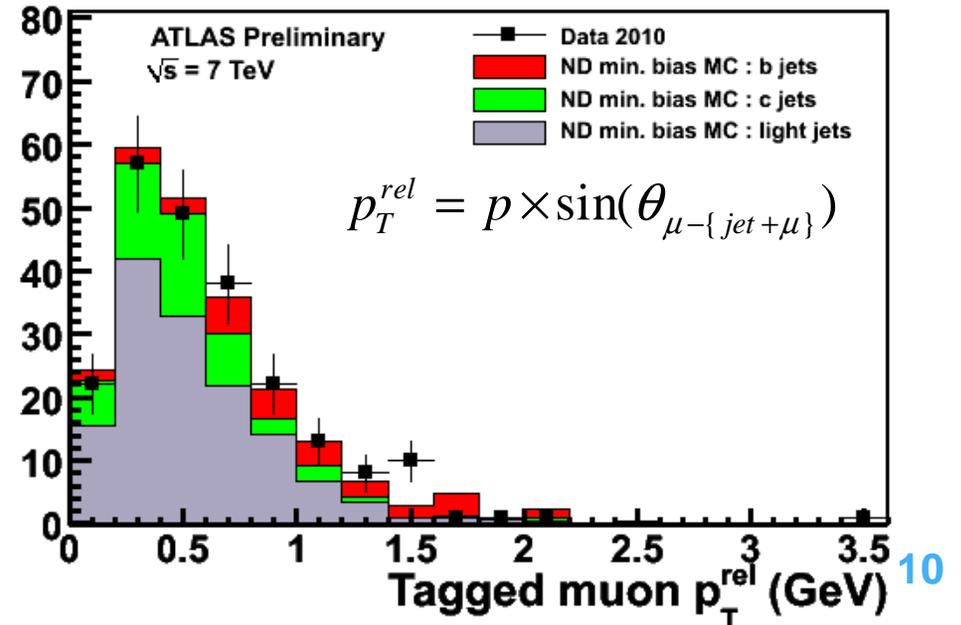
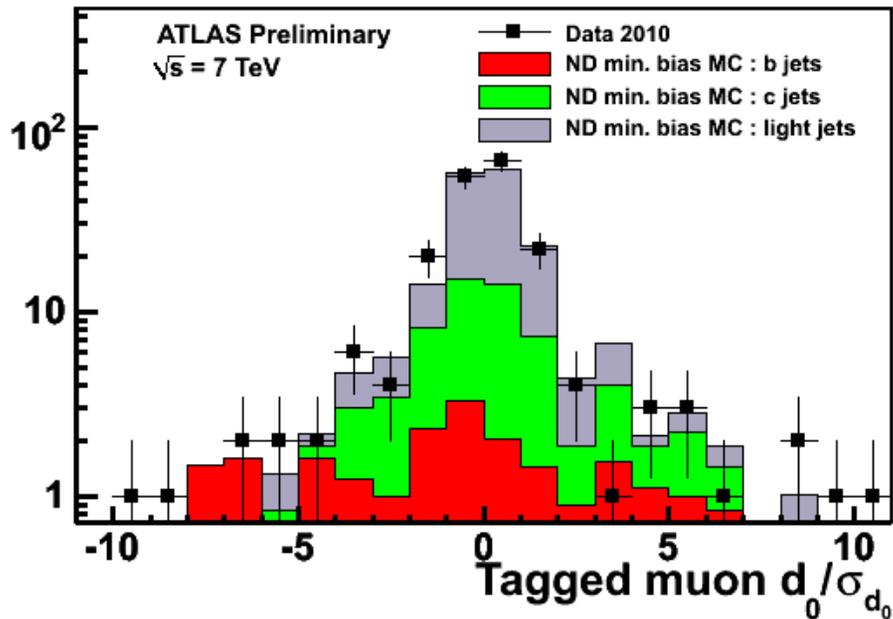
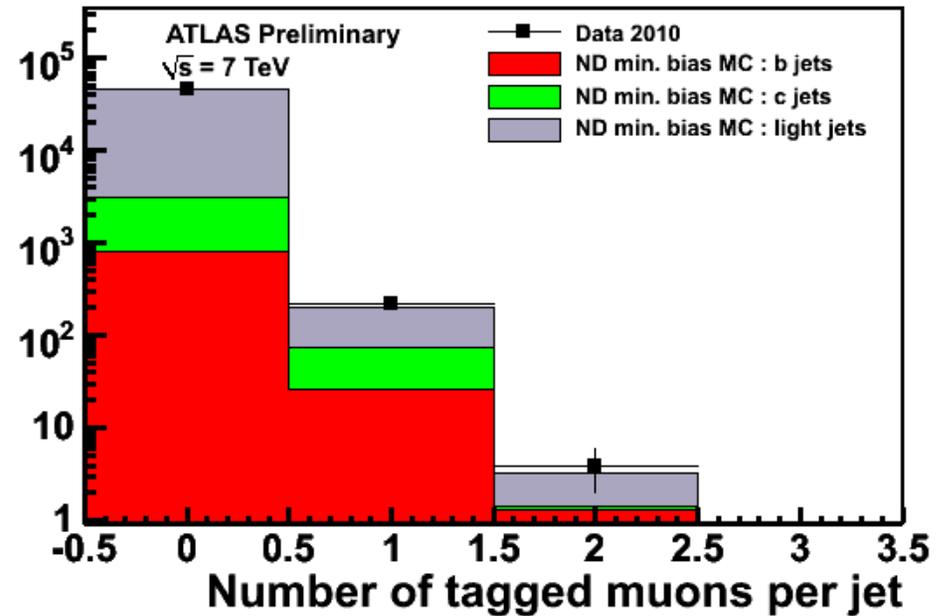
Jet :
 $p_T=31.3$ GeV
(calibrated)
 $\eta=-0.14$
 $\phi=-0.37$



Light jet probability (JetProb) : $9 \cdot 10^{-5}$
Displaced vertex reconstructed with 4 tracks (5.8 mm from PV in transverse plane).
Vertex mass : 3.9 GeV

Muons

- Muon tagging :
 - Tagged muon :
 - $p_T > 4$ GeV
 - $|d_0| < 4$ mm
 - $\Delta R(\text{Muon-Jet}) < 0.4$
- Muons in jets play a key-role in the b-tagging calibration in early data (see next slides)



b-tagged jet with muon

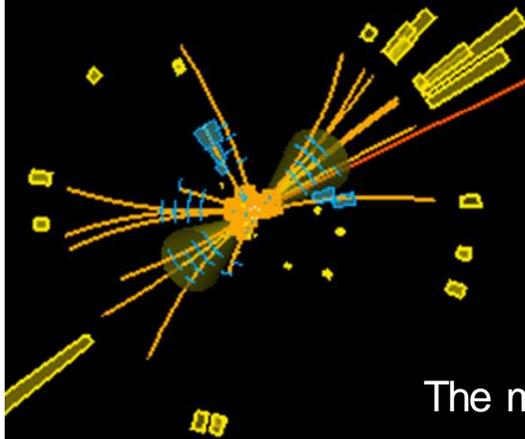
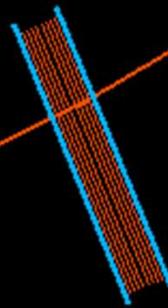
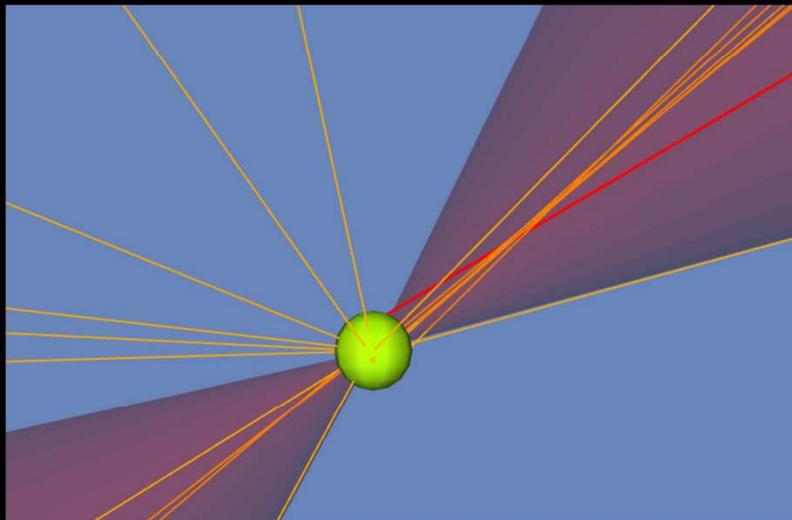


<http://atlas.ch>

Run 152409
Event 4349994

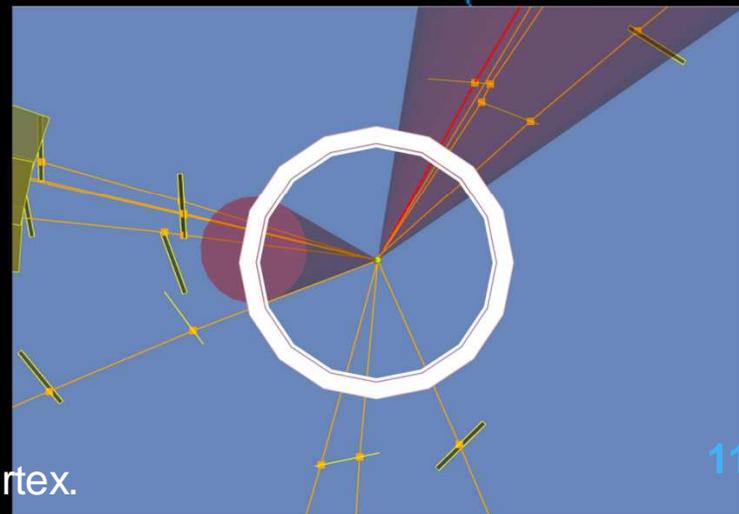
b-tagged jet in 7 TeV collisions

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



Muon $p_T = 6$ GeV
Muon $d_0 = 610$ μm
Muon $d_0/\sigma_{d_0} = 15$

The muon is part of the SV0 secondary vertex.

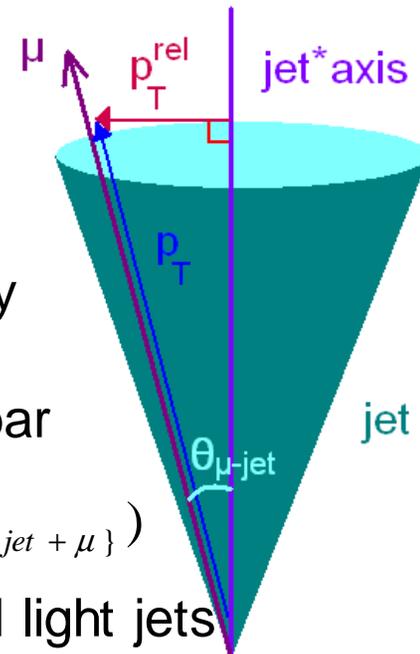


Perspectives : b-tagging calibration in data

- Efficiency of the algorithms have to be measured in data : **Started this Summer**

- Two methods for early data : p_T^{rel} and System8

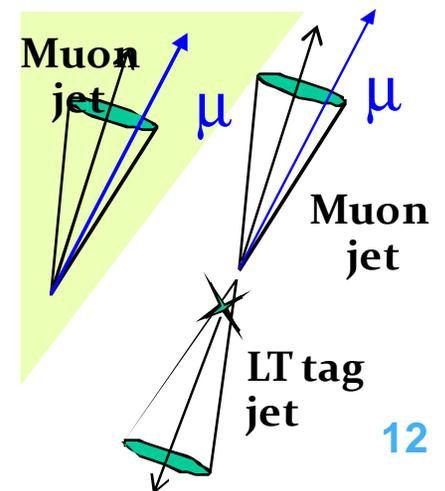
- Based on jets with muons
 - Measurement of the semileptonic jets b-tagging efficiency
 - Use a scale factor extracted from MC to obtain the efficiency for all jets
 - Works for jets with p_T up to ~ 80 GeV (above need to use $t\bar{t}$ samples, more stat. needed)



$$p_T^{\text{rel}} = p \times \sin(\theta_{\mu-\{\text{jet} + \mu\}})$$

- p_T^{rel} :
 - Uses templates of the p_T^{rel} of the muon distributions in b, c and light jets
 - Fits them to the shape extracted from data before and after tagging
 - Extracts the fraction of b jets before and after tagging

- System8 :
 - Uses 2 samples with different b fractions and 2 taggers (soft muon tagger and a lifetime tagger to be calibrated)
 - Builds a system of 8 equations
 - b-tagging efficiency of the lifetime tagger is an unknown that is obtained by solving the system



Results expected soon

Perspectives



Run Number: 158582, Event Number: 27400066

Date: 2010-07-05 07:53:15 CEST

The commissioning steps for early taggers were passed successfully

Summer-Autumn 2010 : few dozens of pb^{-1}

- b-tagging calibration in data
- $b\bar{b}$ cross-section measurement
- $t\bar{t}$ cross-section measurement using b-tagging

End of 2010 ($\sim 200\text{pb}^{-1}$):

- Commissioning of more sophisticated tagging algorithms based on likelihood ratios reaching significantly higher light jet rejection :
 - up to ~ 700 for a 50% b-tagging efficiency
 - up to ~ 200 for a 60% b-tagging efficiency

Reference material

- **List of CONF Notes for 7 TeV Data :**

[Tracking Studies for b-tagging with 7 TeV Collision Data with the ATLAS Detector](#) (ATLAS-CONF-2010-070)

[Impact parameter-based b-tagging algorithms in the 7 TeV collision data with the ATLAS detector: the TrackCounting and JetProb algorithms](#) (ATLAS-CONF-2010-041)

[Performance of the ATLAS Secondary Vertex b-tagging Algorithm in 7 TeV Collision Data](#) (ATLAS-CONF-2010-042)

- **List of CONF Notes for 900 GeV Data :**

[Tracking studies for b-tagging with 900 GeV collision data with the ATLAS detector](#) (ATLAS-CONF-2010-003)

[Performance of the ATLAS Secondary Vertex b-tagging Algorithm in 900 GeV Collision Data](#) (ATLAS-CONF-2010-004)

[First look at the JetProb b-tagging algorithm in the 900 GeV collision data with the ATLAS detector](#) (ATLAS-CONF-2010-010)

- **ATLAS Performance book :**

[ATLAS, G. Aad et al., Expected Performance of the ATLAS Experiment -Detector, Trigger and Physics, \(2009\), 0901.0512](#)