

# 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 :

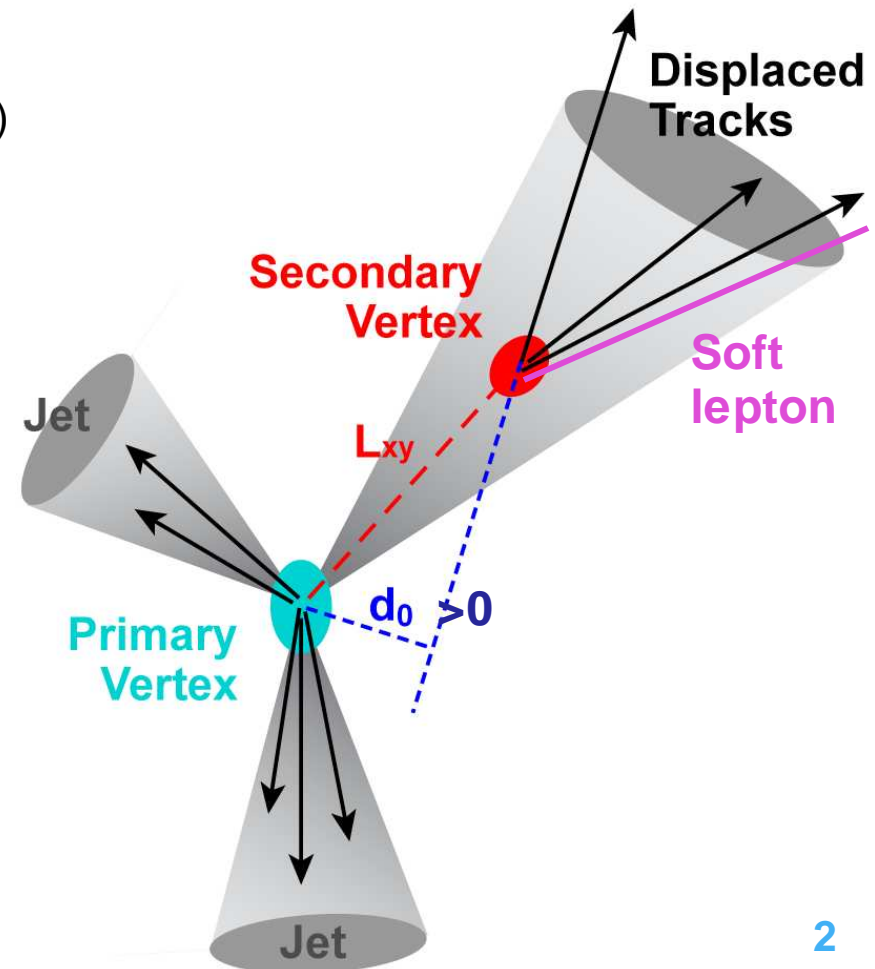
- Long lifetime ( $\sim 1.5$  ps,  $c\tau=450$   $\mu\text{m}$ )
  - a b hadron in a jet ( $p_T=50\text{GeV}$ ) flies  $\sim 5\text{mm}$  in the transverse plane before decaying
- Hard fragmentation
  - Keep 70% of the momentum of the initial b quark
- High mass (5GeV)
  - Decay products with large  $p_T$
- 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**

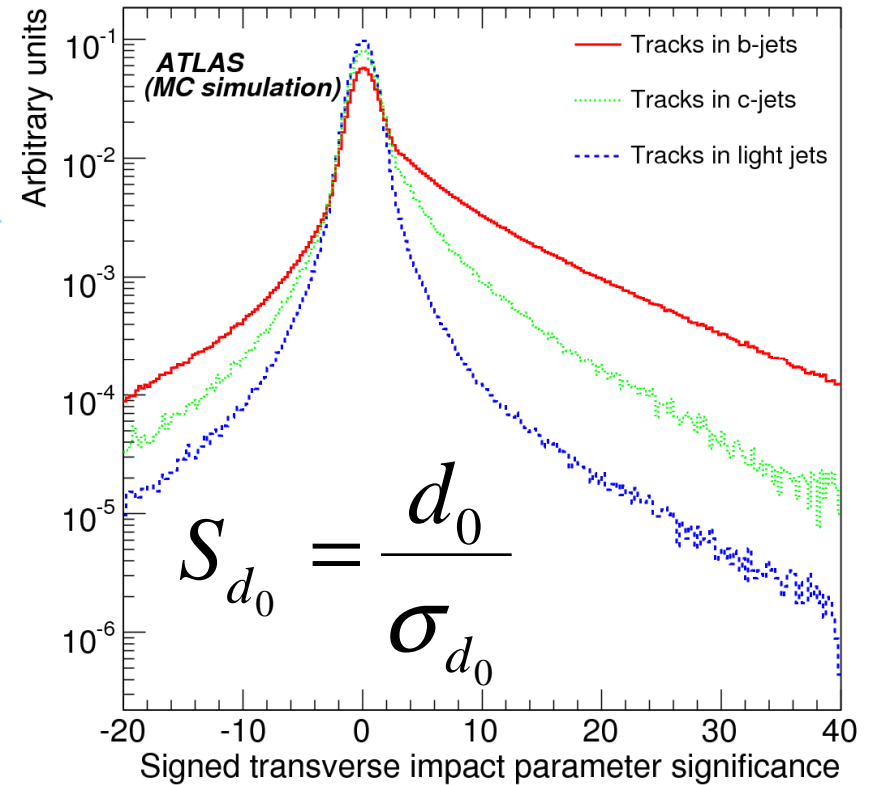
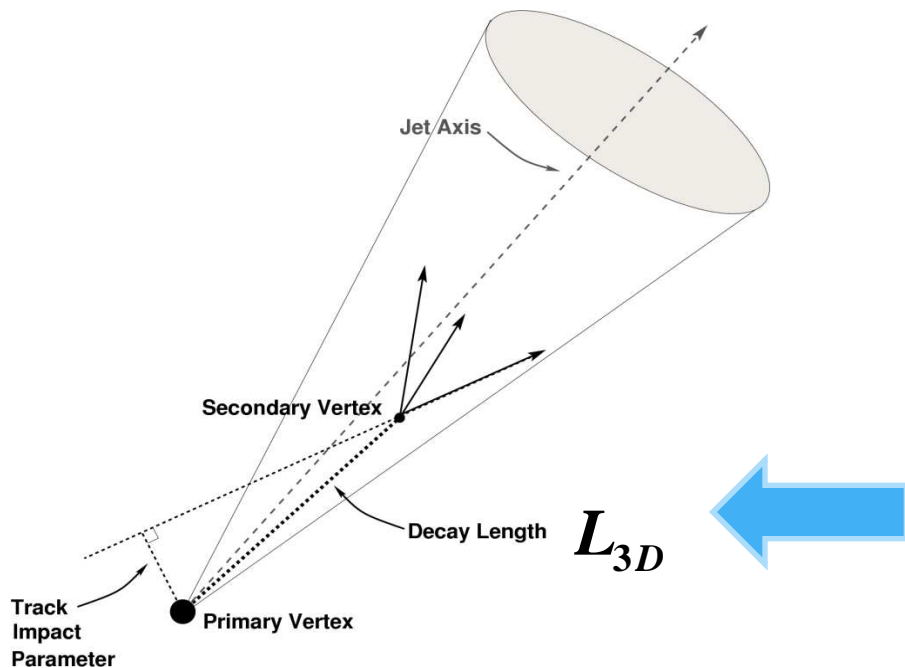


# ATLAS b-tagging algorithms for first data

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  $S_{L_{3D}}$

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

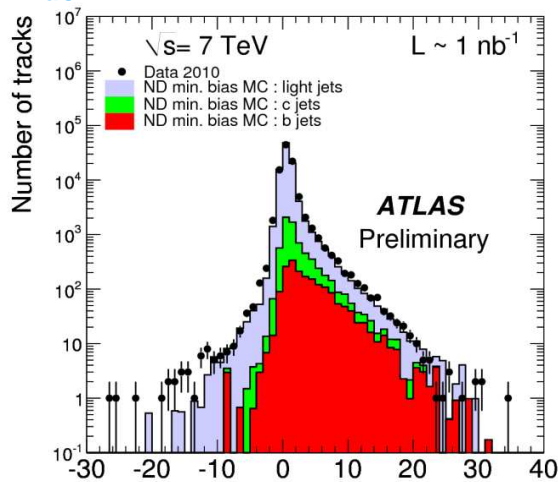
Plots shown in the following slides :  
 7 TeV data,  $1\text{nb}^{-1}$ , minimum bias trigger

# TrackCounting

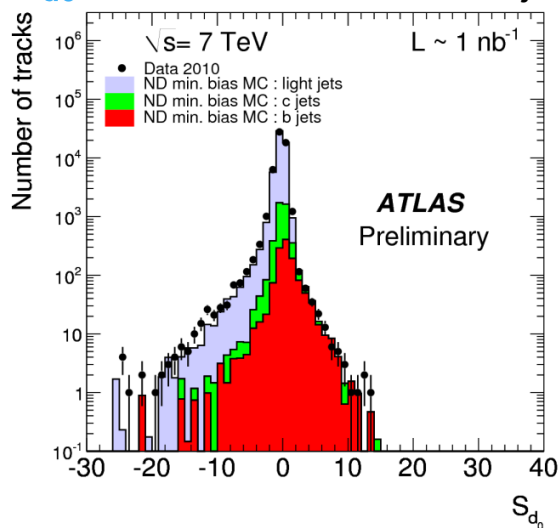
## TrackCounting

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

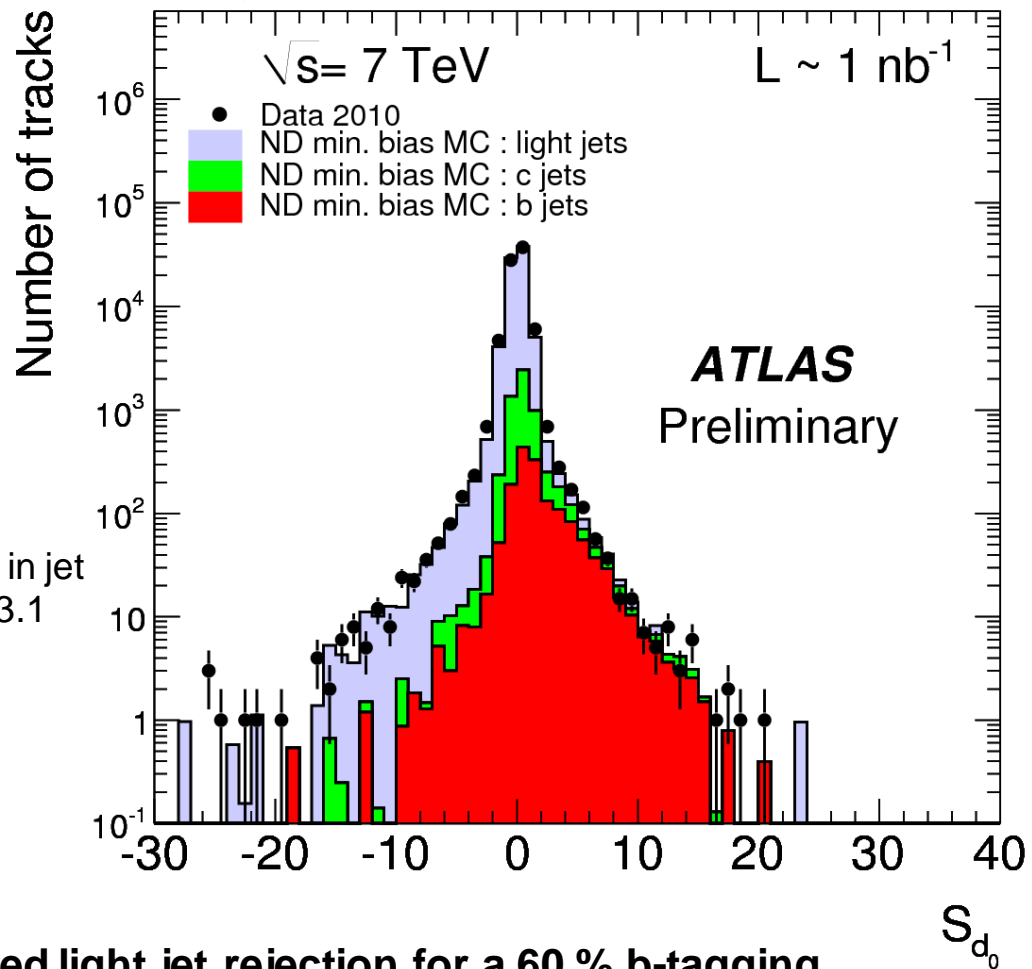
$S_{d0}$  of the 1<sup>st</sup> track : not well discriminating



$S_{d0}$  of the 3<sup>rd</sup> track : few jets\*



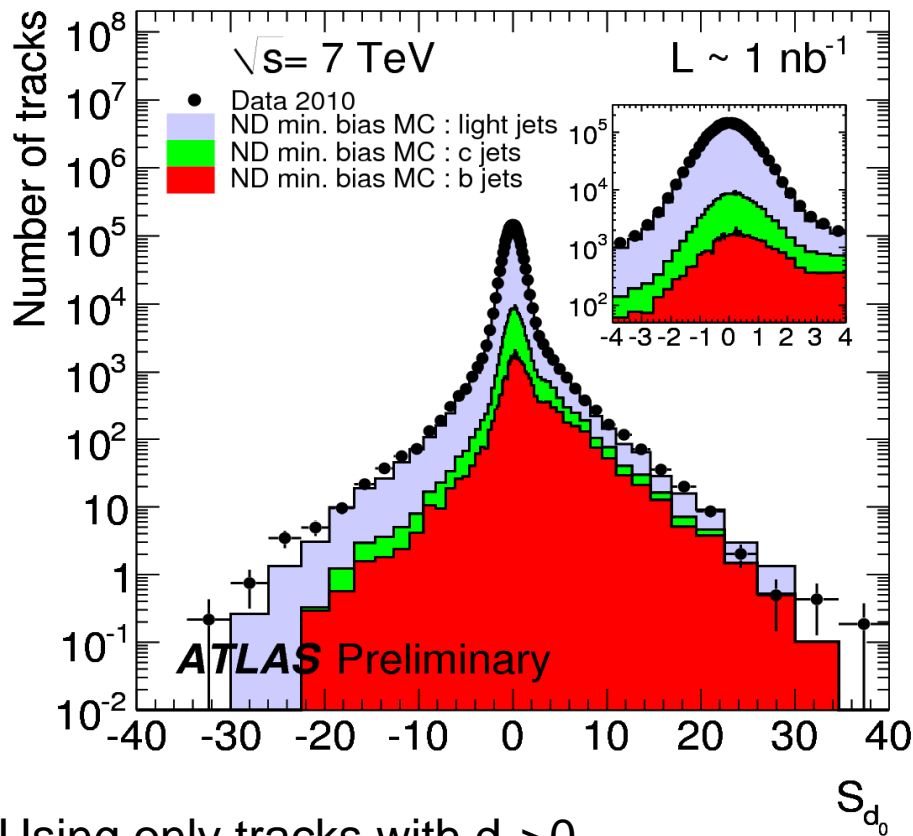
\*Average track in jet multiplicity : 3.1



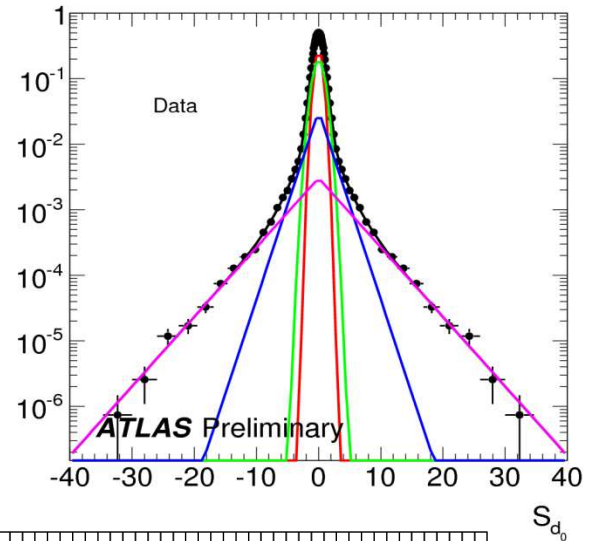
- Expected light jet rejection for a 60 % b-tagging efficiency from MC @ 7 TeV (ttbar) : ~30

# JetProb : Track Probability

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

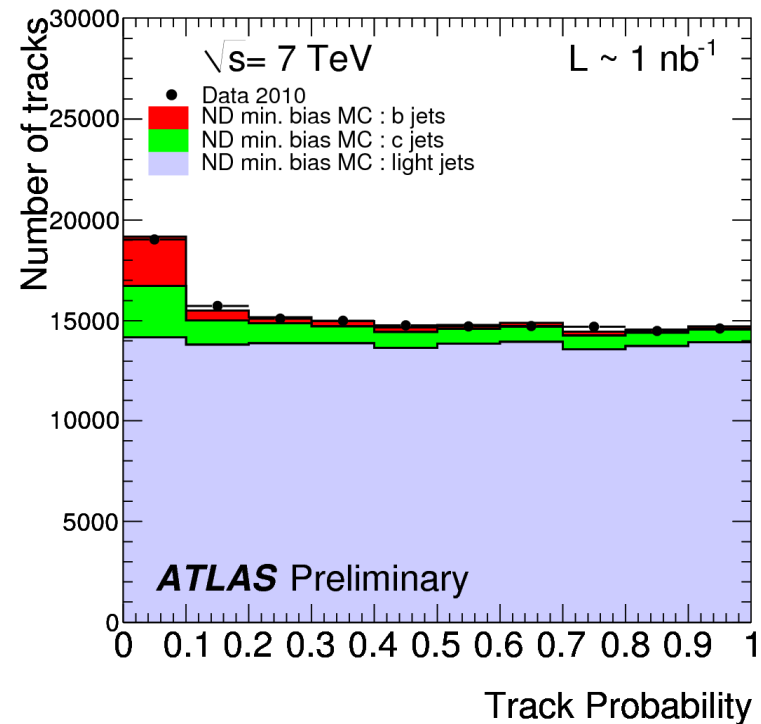


$d_0 < 0$   
 symmetrized



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

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

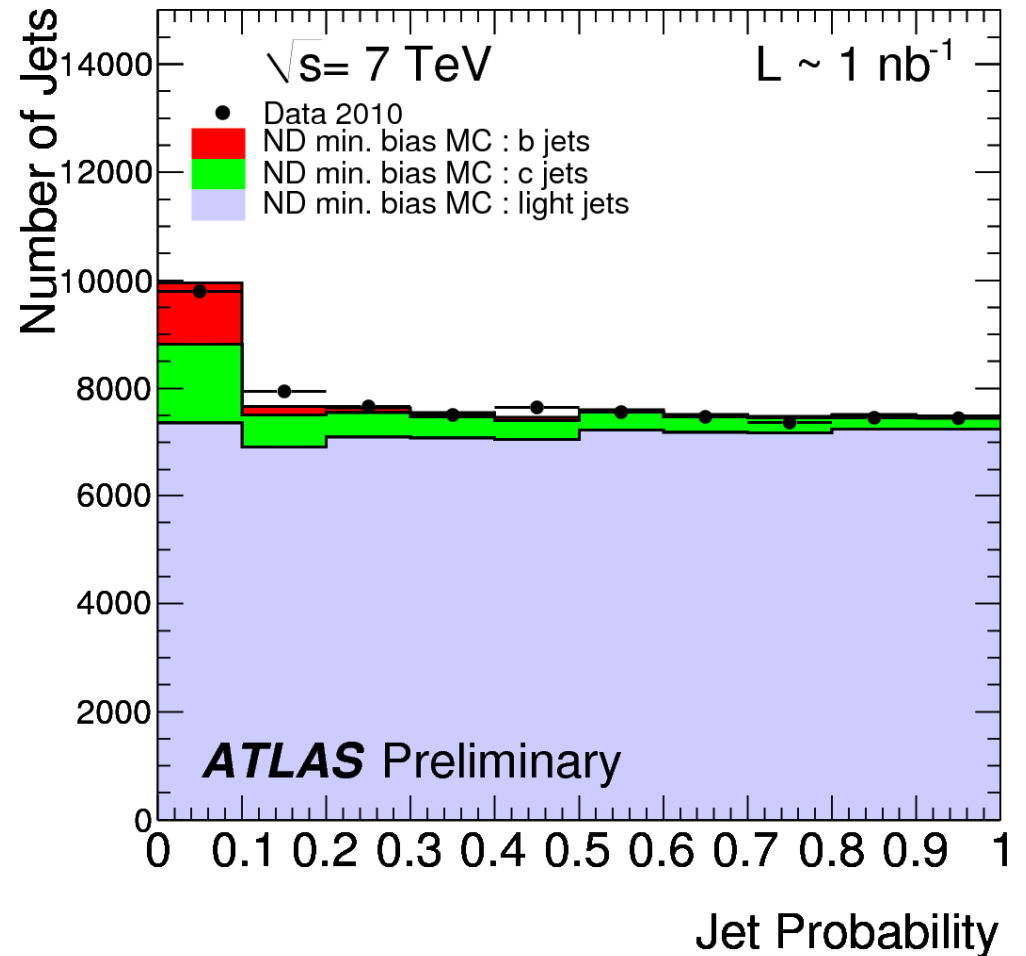
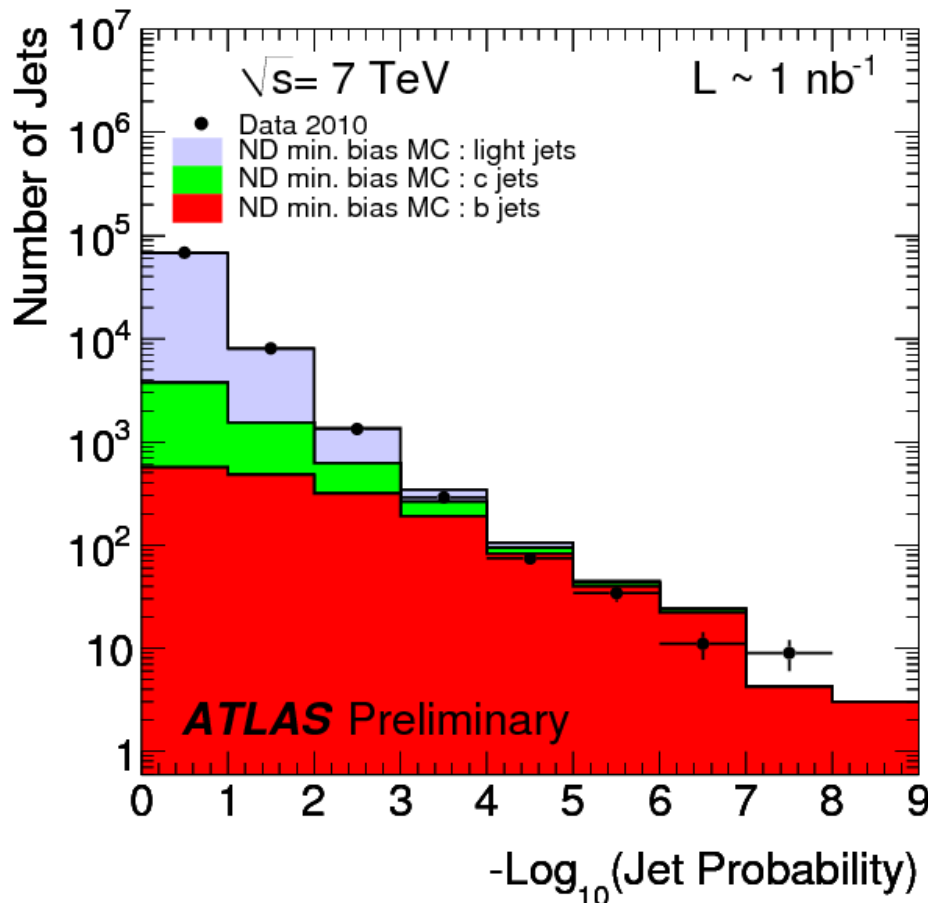


# JetProb : Jet Probability

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

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

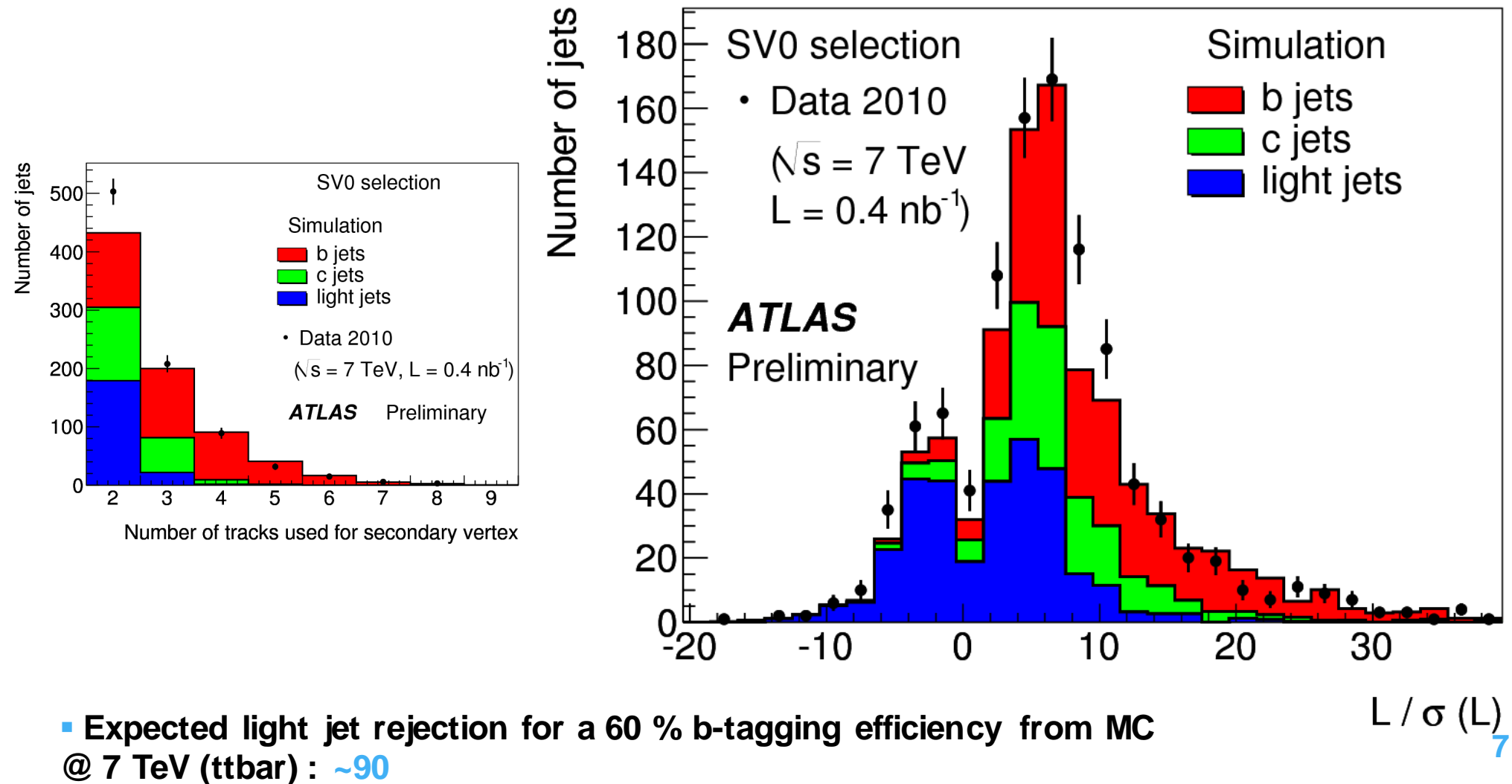
where :  $P_0 = \prod_{i=1}^{N_{trk}} P_i$



- 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

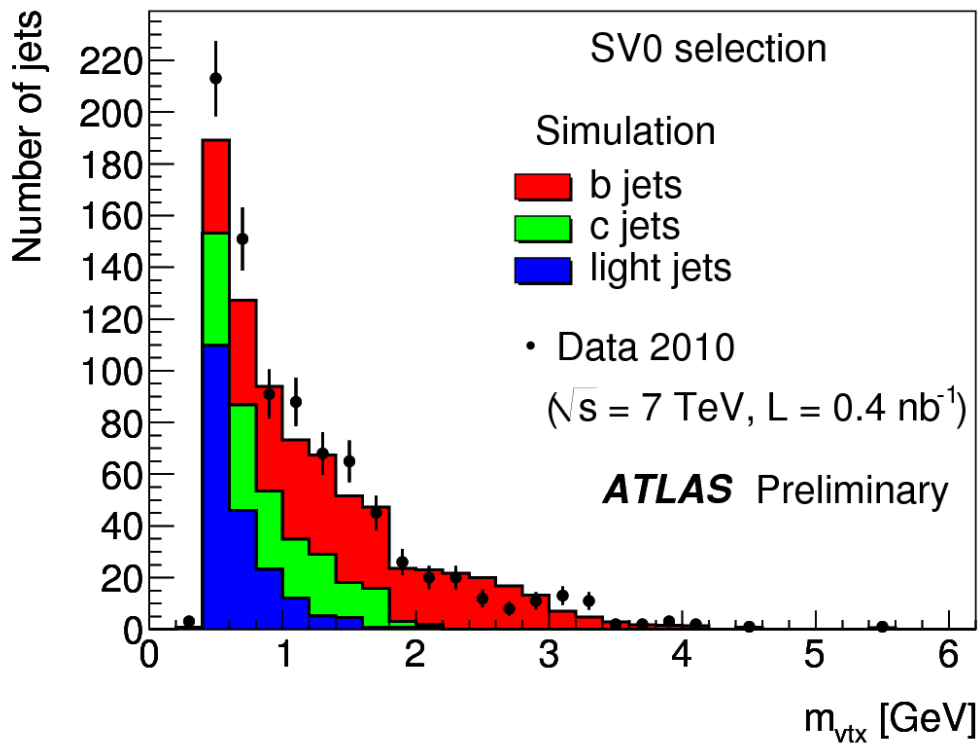


- Expected light jet rejection for a 60 % b-tagging efficiency from MC @ 7 TeV (ttbar) : ~90

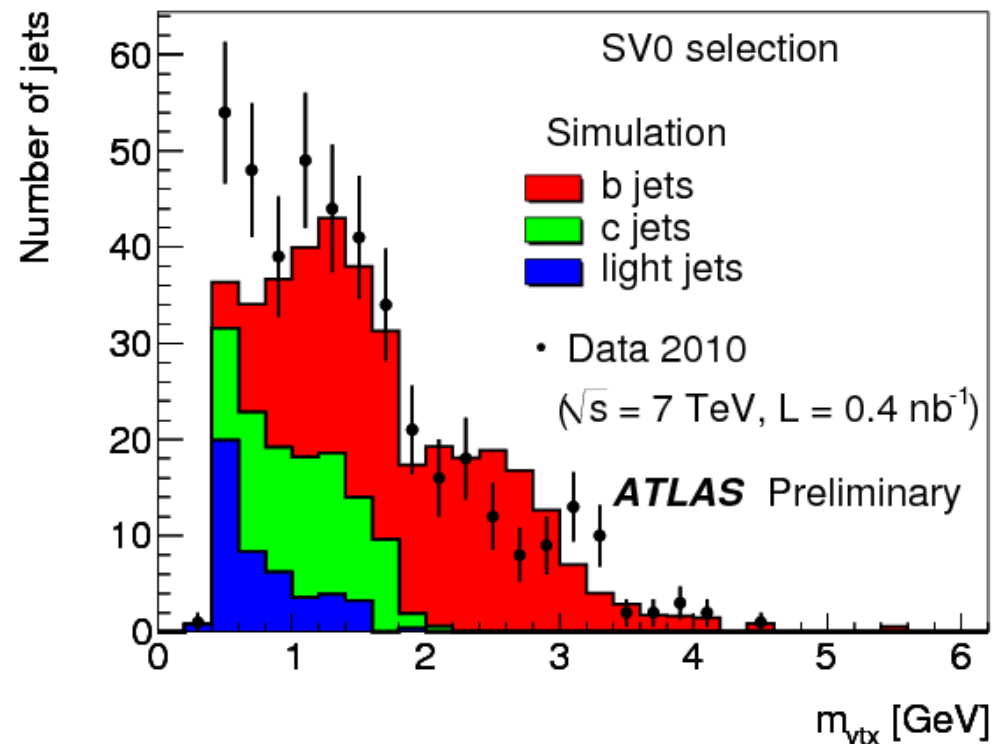
# SV0 (2)

- Vertex mass  $\rightarrow$  cutting on  $S_{L3D}$

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



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

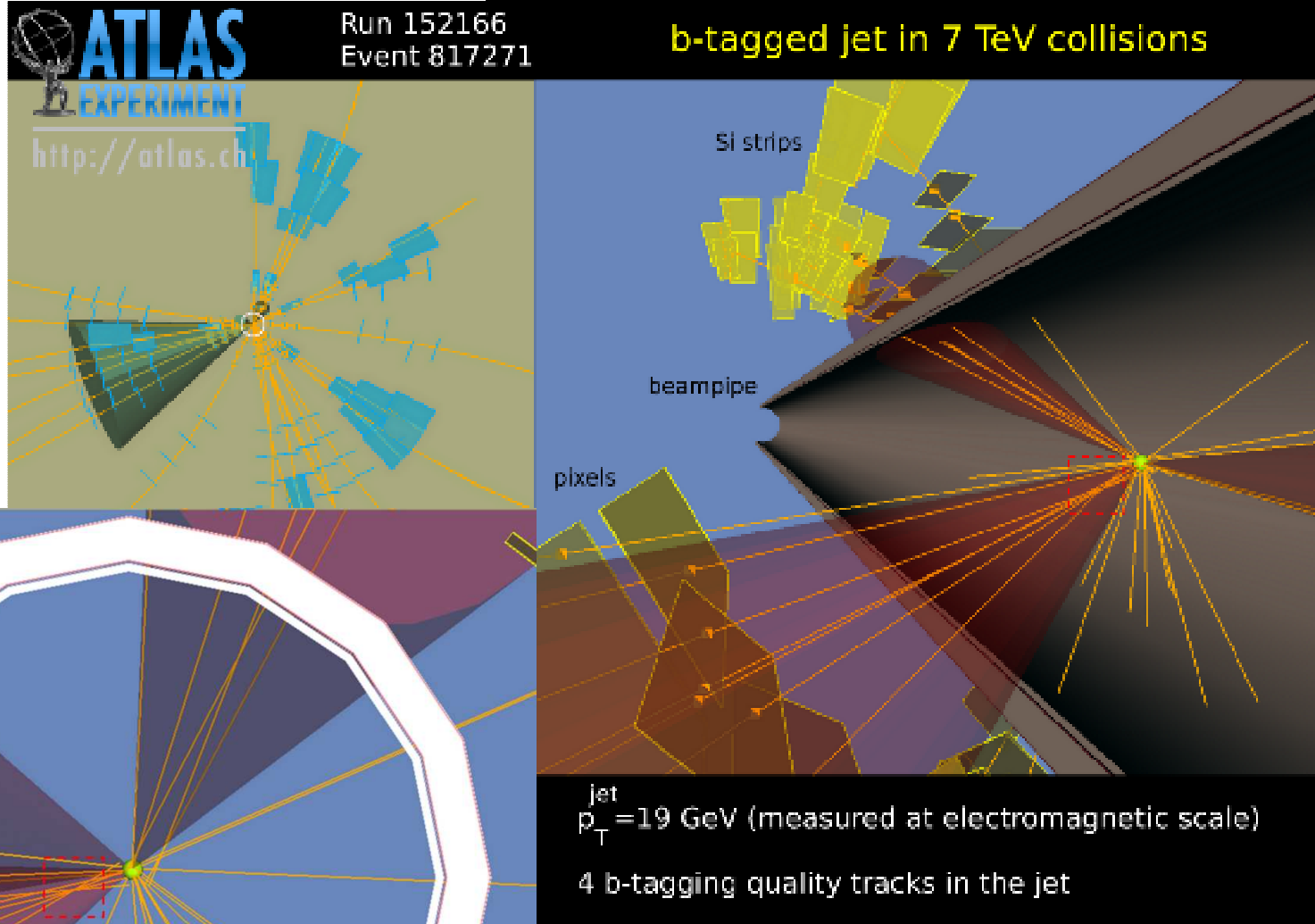


- Large enhancement of b fraction when cutting on  $S_{L3D}$  demonstrates the power of the algorithm



# b-jet candidate in data @ 7TeV

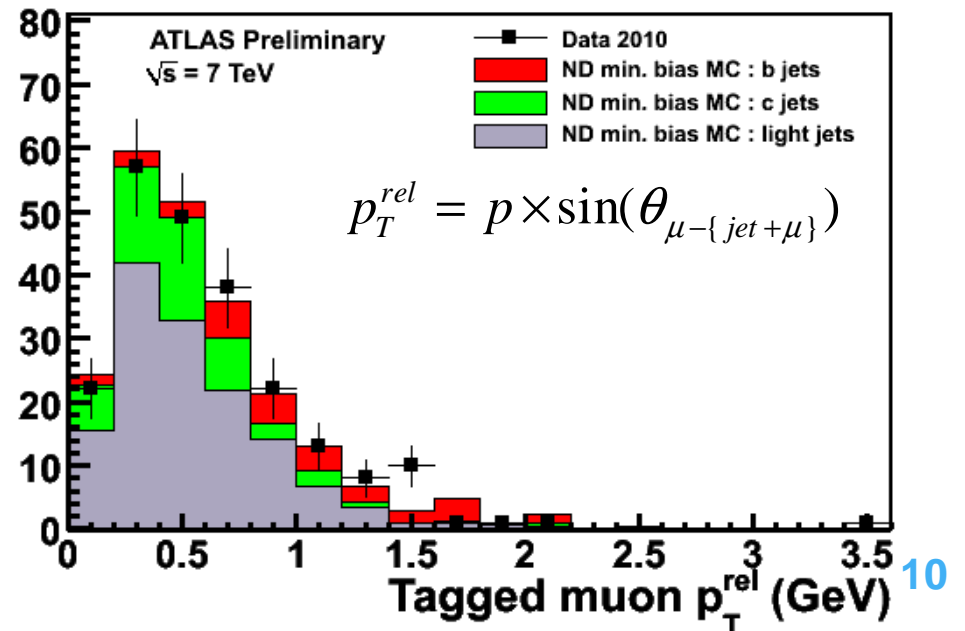
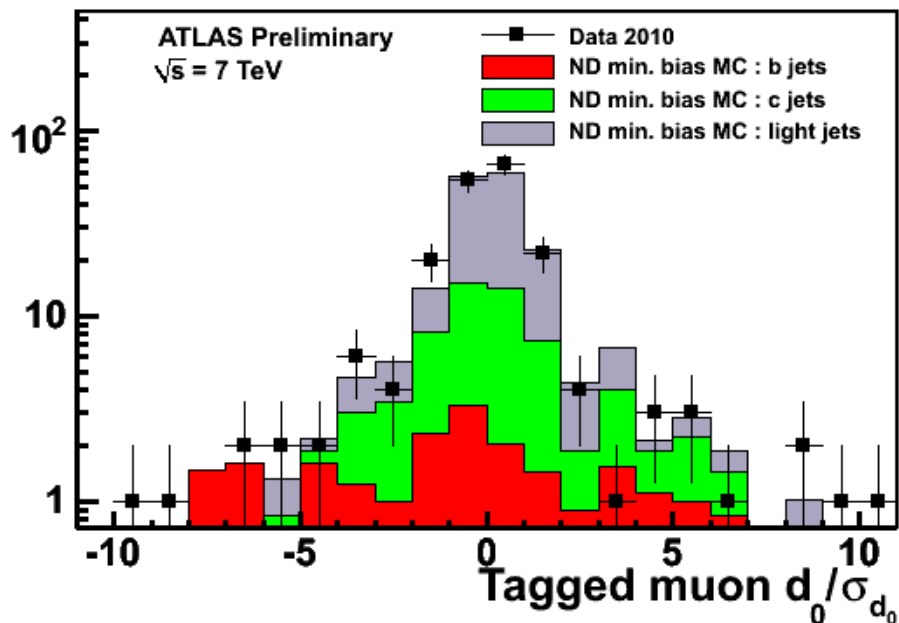
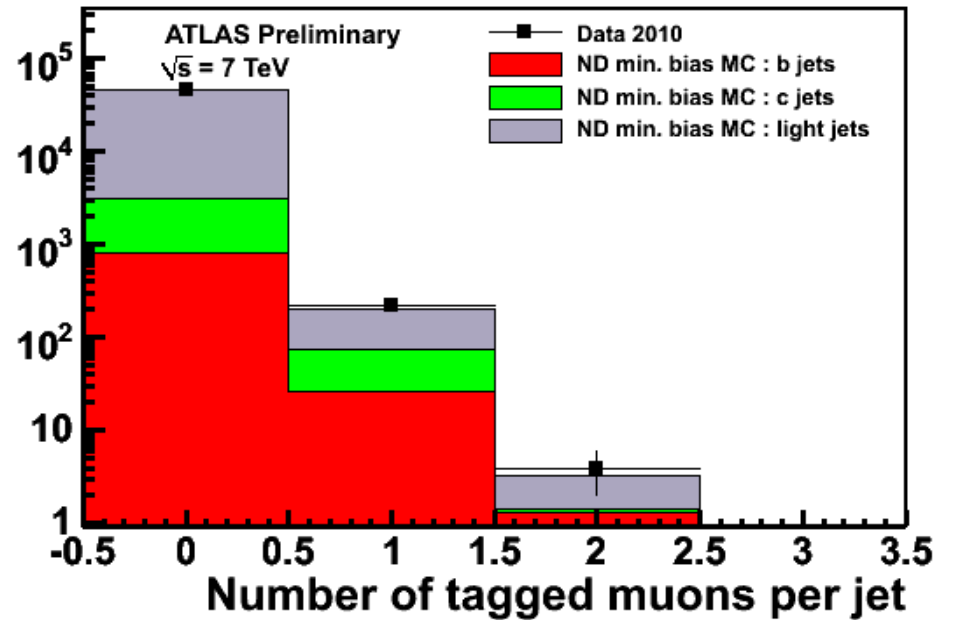
Jet :  
 $p_T=31.3$  GeV  
(calibrated)  
 $\eta=-0.14$   
 $\phi=-0.37$



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

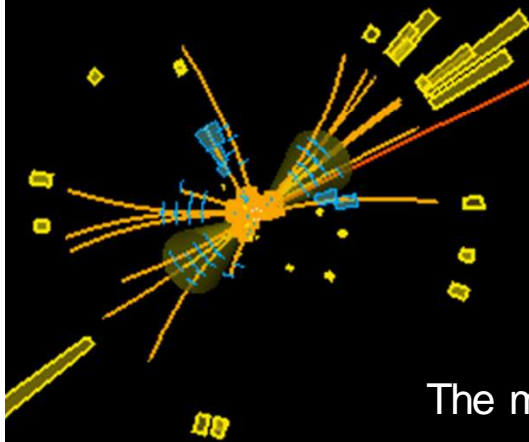
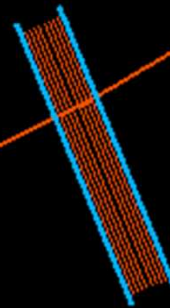
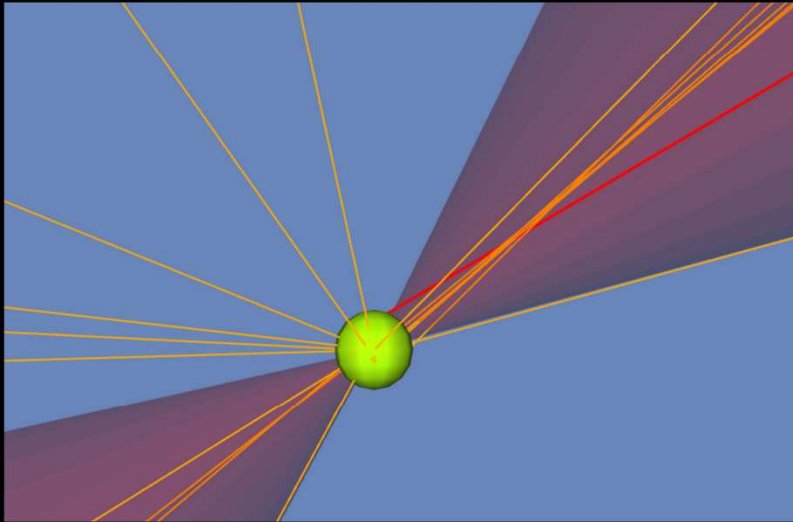


<http://atlas.ch>

Run 152409  
Event 4349994

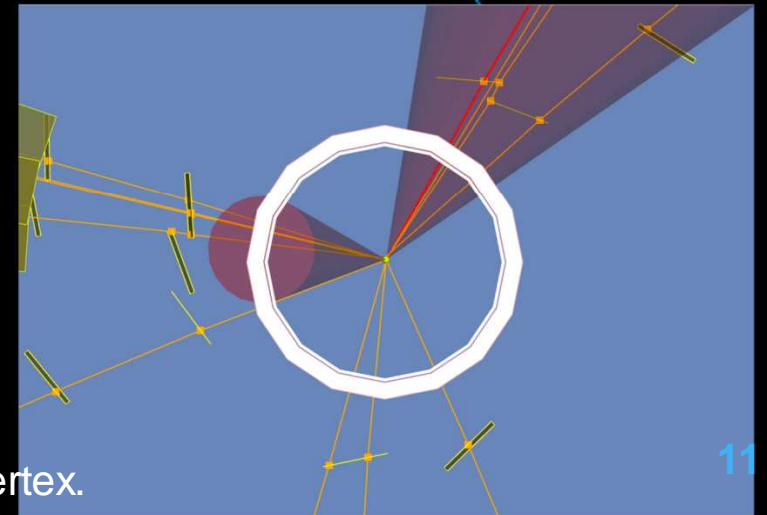
b-tagged jet in 7 TeV collisions

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



Muon  $p_T = 6$  GeV  
Muon  $d_0 = 610$   $\mu\text{m}$   
Muon  $d_0/\sigma_{d_0} = 15$

The muon is part of the SV0 secondary vertex.



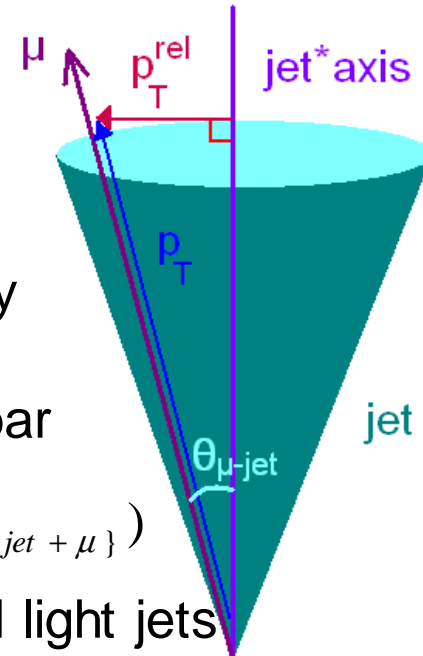
# Perspectives : b-tagging calibration in data

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

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

- Based on jets with muons

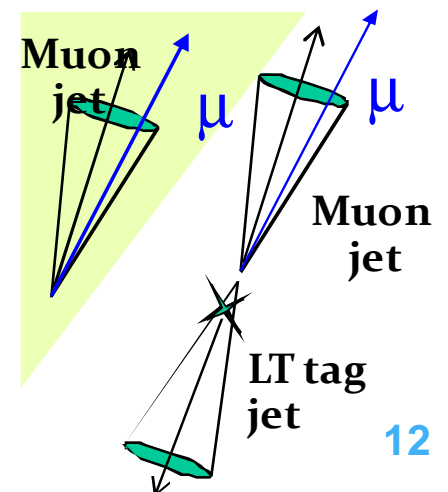
- Measurement of the semileptonic jets b-tagging efficiency
- Use a scale factor extracted from MC to obtain the efficiency for all jets
- Works for jets with  $p_T$  up to  $\sim 80$  GeV (above need to use  $t\bar{t}$  samples, more stat. needed)



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

- $p_T^{\text{rel}}$  :
  - Uses templates of the  $p_T^{\text{rel}}$  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  $\text{pb}^{-1}$

- 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  $\sim 700$  for a 50% b-tagging efficiency
  - up to  $\sim 200$  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](#)