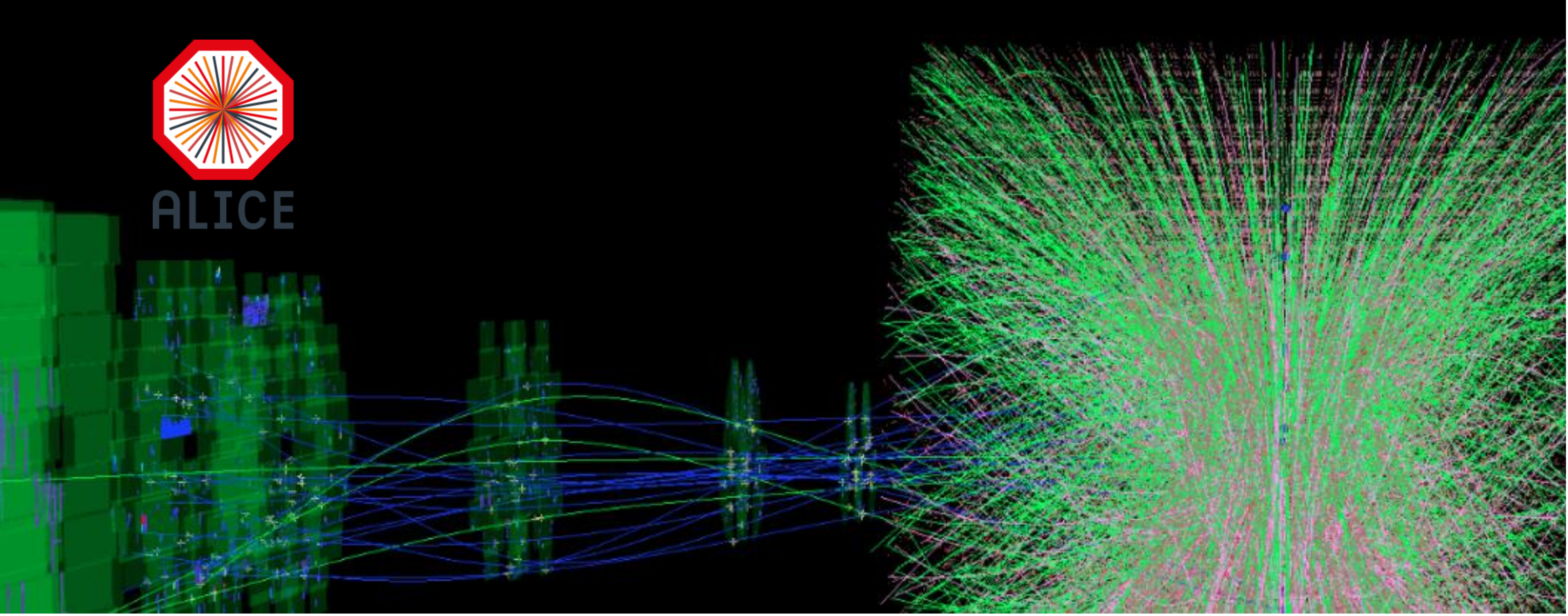

PERFORMANCE OF THE ALICE SECONDARY VERTEX B-TAGGING ALGORITHM

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CONTENT

- Motivation for b-jet studies
- Secondary vertex reconstruction
- b-jet tagging algorithm performance studies
- Unfolding corrections in p-Pb collisions
- Outlook

PROPERTIES OF b-JETS

b quarks

- $m \sim 4.2$ GeV/c^2
- High energy needed for their creation, produced in the collision, not as an effect of medium
- Expected to lose energy via elastic scatterings and radiative processes
- Their energy loss in medium is expected to be smaller than for lighter quarks and gluons (dead-cone effect)

(Yuri L. Dokshitzer and D.E. Kharzeev. *Heavy quark colorimetry of QCD matter.* Phys.Lett., B519:199–206, 2001.)

Jets

- Sprays of collimated particles coming from the fragmentation of hard-scattering partons
- Jet finding algorithms reconstruct the full jet starting from charged tracks and neutral energy

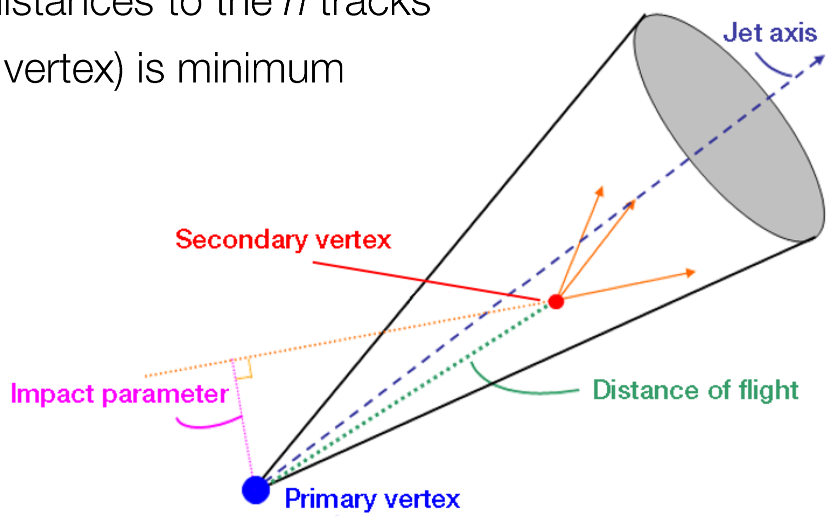
PROPERTIES OF b-JETS

<u>b-jets</u>

- Come from fragmentation of beauty quarks
- Allow studies of redistribution of the lost energy and possible modifications to b-quark fragmentation in the medium
- b-tagging algorithms exploit long lifetime ($c\tau$ ~500 μm) and large mass (~5 GeV/c^2) of B hadrons

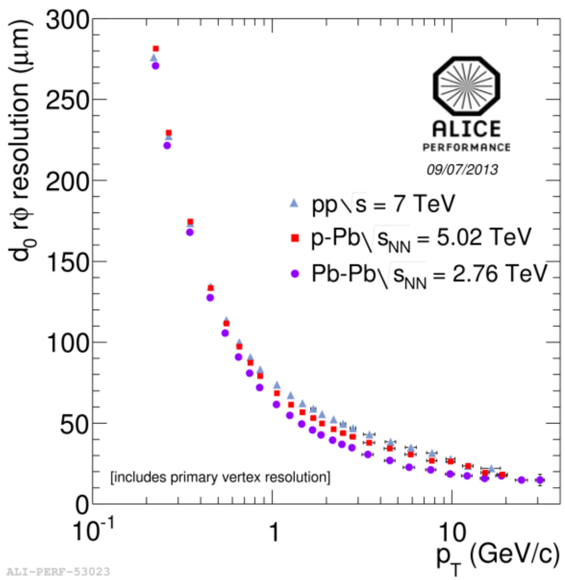
<u>Secondary vertices</u>

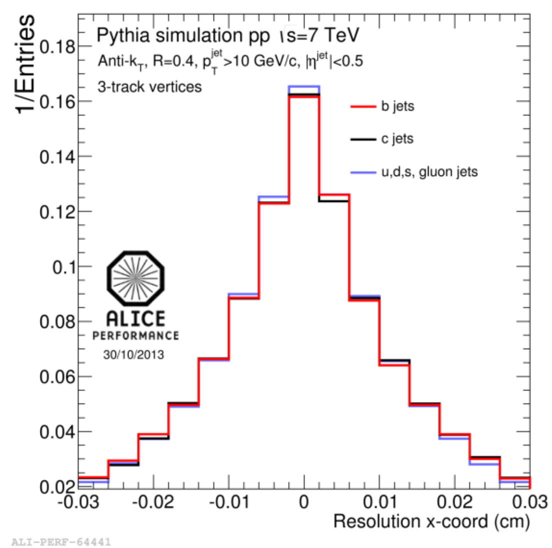
- Calculated as the point for which the sum of the distances to the *n* tracks (approximated to linear in proximity of the primary vertex) is minimum
- Secondary vertices from beauty-hadron decays:
  - Large invariant mass
  - Large secondary vertex distance of flight L_{xy}

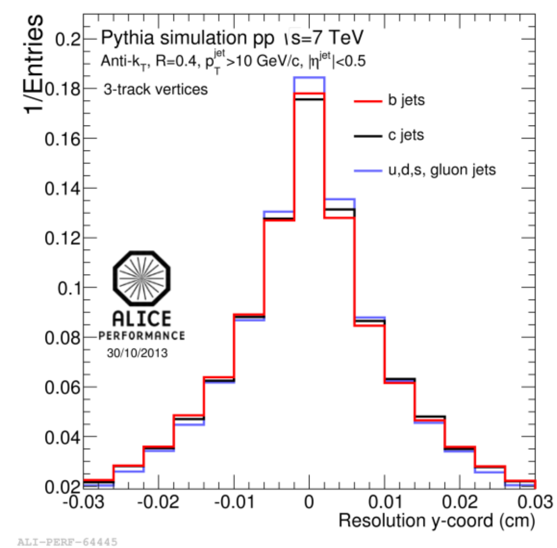


SECONDARY VERTEX RECONSTRUCTION

- Inner Tracking System (ITS) and Time Projection Chamber (TPC) are used for tracking and secondary vertex reconstruction
- Track impact parameter resolution better than 70 μm for $p_T > 1$ GeV/*c*, for all collision systems
- Resulting secondary vertex resolution ~120 μm







Track impact parameter resolution in the transverse plane vs p_T

3-prong vertex resolution (in the xy plane)

SECONDARY VERTEX RECONSTRUCTION

Jet reconstruction:

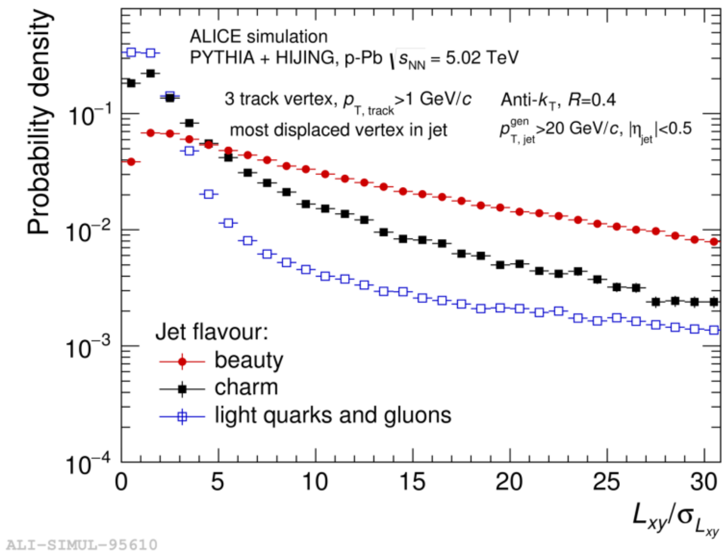
- FastJet Anti-k_T, $R = 0.4$
- $p_{T,\ track} > 0.15$ GeV/c

Secondary vertex reconstruction:

- Using 3 tracks
- Tracks in a jet $p_{T,\ prong} > 1$ GeV/c

Discriminating variables for b-tagging:

- Significance of signed secondary vertex distance of flight L_{xy}/σ_{Lxy} in the transverse plane
- Secondary vertex dispersion, $\sigma_{vtx} = \sqrt{d_1^2 + d_2^2 + d_3^2}$ where $d_{1,2,3}$ are the distances of tracks from secondary vertex



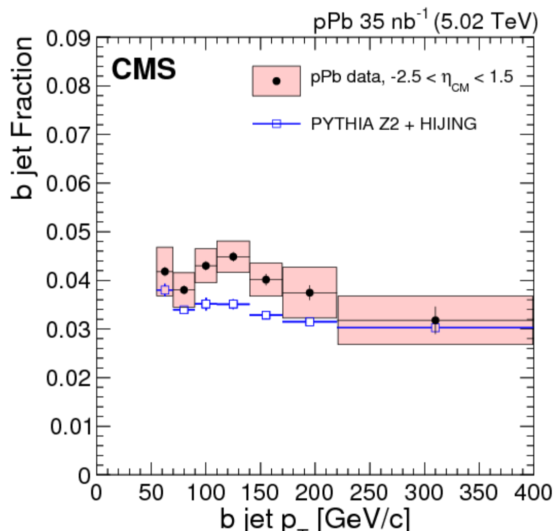
Signed flight distance significance of secondary vertex. Jets of different flavour defined in MC based in presence of B- (D-) hadron.

SECONDARY VERTEX ALGORITHM PERFORMANCE IN p-Pb COLLISIONS

- Tagging efficiency:

$$\varepsilon_b(p_T) = \frac{dN_b^{tagged} / dp_T}{dN_b / dp_T}$$

- The goal is to find the working point (cuts used in further analysis) with high purity and reasonably high efficiency at the same time
- b-jet fraction from CMS ~2-4% ⇒ cuts with mistagging rate 100 times smaller than tagging efficiency are needed to reduce background



Transverse momentum spectra of b-jets in pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV,
CMS Collaboration (Khachatryan, Vardan et al.), arXiv:1510.03373, CMS-HIN-14-007, CERN-PH-EP-2015-205.

b-jet fraction in p-Pb collisions for different rapidity ranges for $50 < p_{T,\,jet} < 200$ GeV/c from CMS experiment

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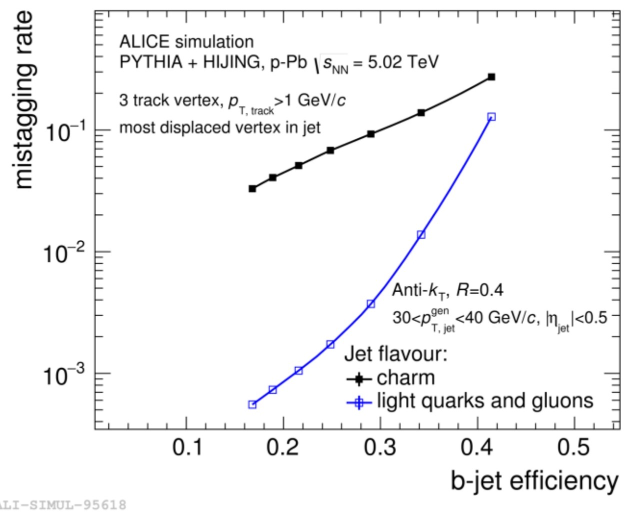
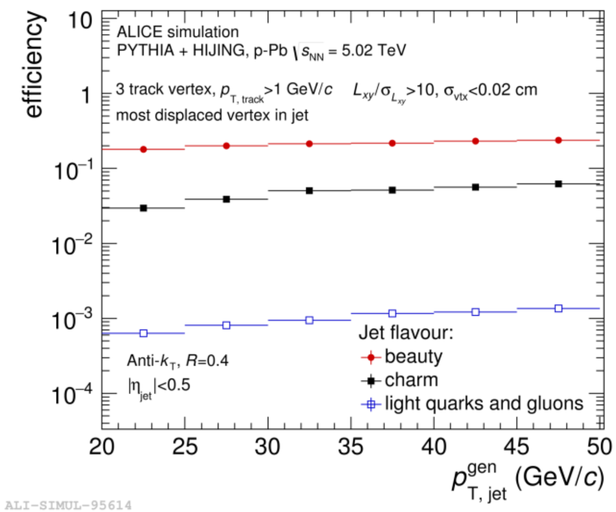
- Cut variation ⇒ different tagging and mistagging efficiencies



Tagging efficiency and mistagging rate with different cuts on L_{xy}/σ_{Lxy} of secondary vertex for $30 < p_{T,\ jet} < 40$ GeV/c.



(Mis)Tagging efficiencies of secondary vertex algorithm for $L_{xy}/\sigma_{Lxy} > 10$ and $\sigma_{vtx} < 0.02$ cm.

UNFOLDING CORRECTIONS IN p-Pb COLLISIONS

- Measured spectrum is a convolution of a true spectrum and detector response function
- True jet spectrum is found via unfolding procedure

- Singular Value Decomposition (SVD) unfolding was used

(Hocker, Andreas et al., *SVD approach to data unfolding*, Nucl.Instrum.Meth. A372 (1996) 469-481.)

- Constant background density ρ_{CMS} is subtracted from $p_{\mathrm{T,\,jet}}$:

$$\rho_{CMS} = \mathbf{median}\left\{\frac{p_{T,i}}{A_i}\right\}\cdot C$$

  - $p_{\mathrm{T},i}$ are soft clusters, found by FastJet k_{T}, A_i is the jet area, C is the correction factor for the empty clusters.

- Background fluctuations δp_{T} are calculated with MC (HIJING) via random cone method:

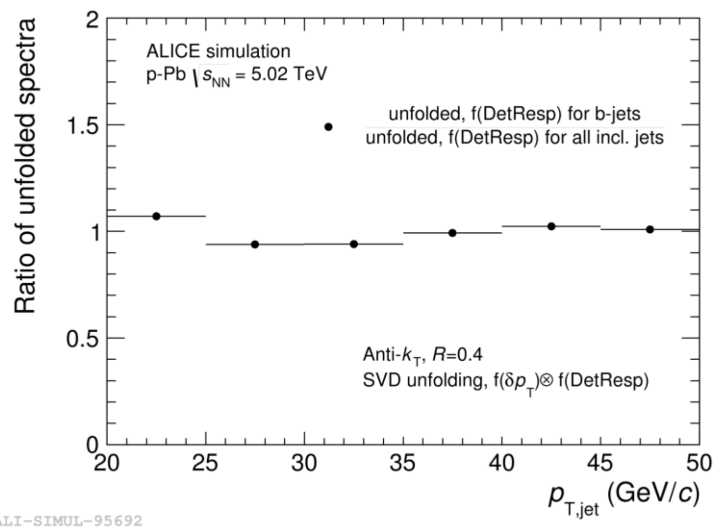
$$\delta p_T = \sum_i p_{T,i} - \rho \cdot A_{cone}$$

  - sum is over track $p_{\mathrm{T},i}$ in a cone.

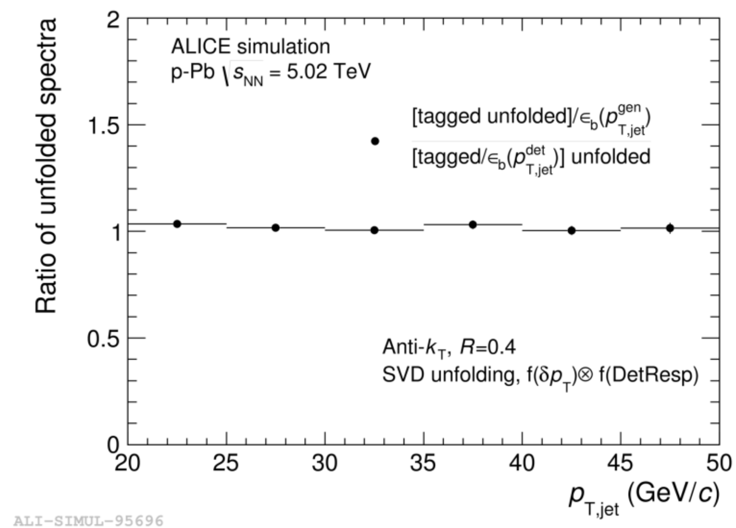
UNFOLDING CORRECTIONS IN p-Pb COLLISIONS

- MC b-jet p_T spectrum is unfolded with the **combined matrix**:
  - detector response
  - background fluctuations of jets
- Comparison of unfolding with **response matrix** for b-jets and for inclusive jets

- Tagged spectrum should be:
  - **Unfolded**
  - Corrected for **tagging efficiency** and purity
- Estimation of systematic influence of the order of corrections



Same results when unfolding spectrum with detector response matrix of inclusive and b-jets



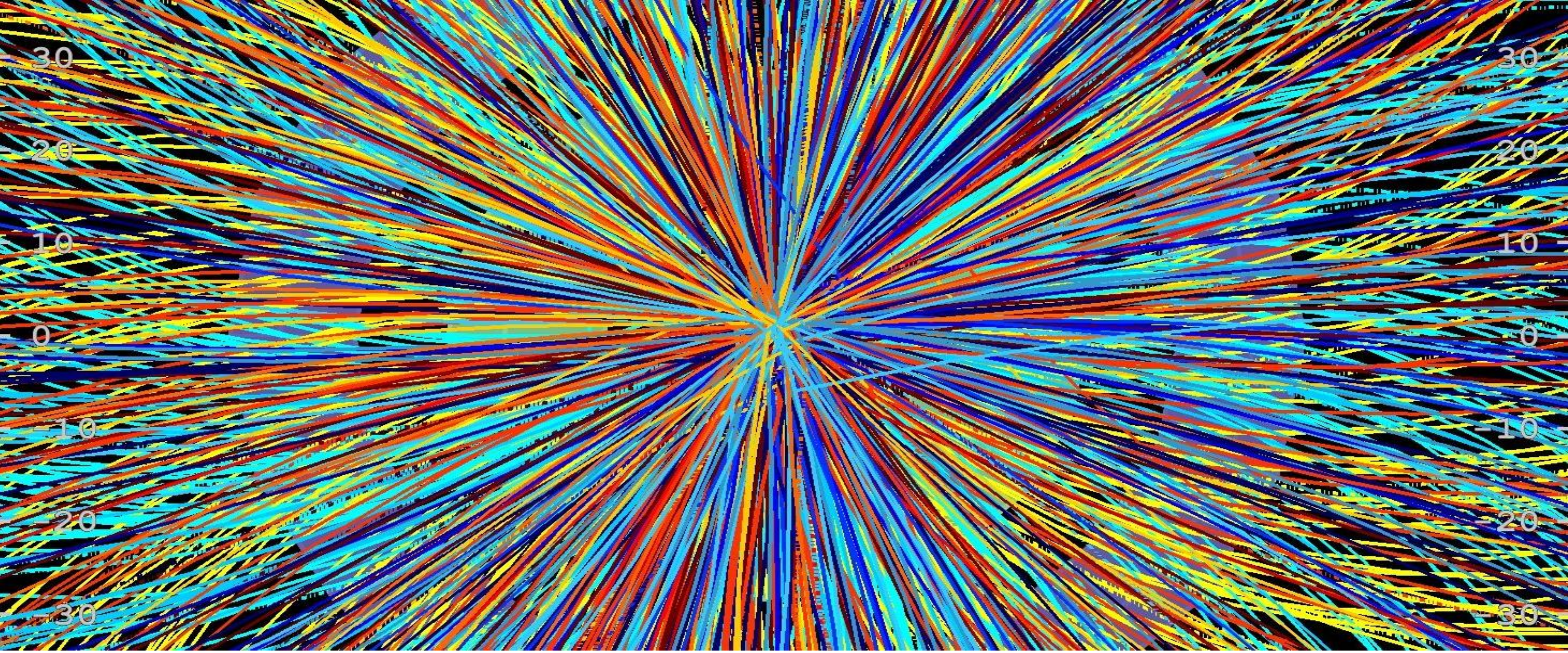
It was verified that the correction order does not give significant differences in the resulting spectrum

OUTLOOK

- Tagging cuts for secondary vertex algorithms are being optimized:
  - beauty efficiencies as large as possible
  - keeping charm and light-jet contamination small
    - b-jet fraction ~2-4% ⇒ cuts which have 100 times smaller contamination of light flavors than b-jet efficiency are needed
- Corrections for background, background fluctuations and for detector response are implemented
- b-jet spectrum can be unfolded using a detector response matrix for all inclusive jets
- Order of corrections (tagging efficiency vs unfolding) gives compatible results

Ongoing studies:

- MC and data-driven estimation of tagging purity
- Track cuts and selection for secondary vertex reconstruction in order to obtain higher purity



THANK YOU FOR YOUR ATTENTION

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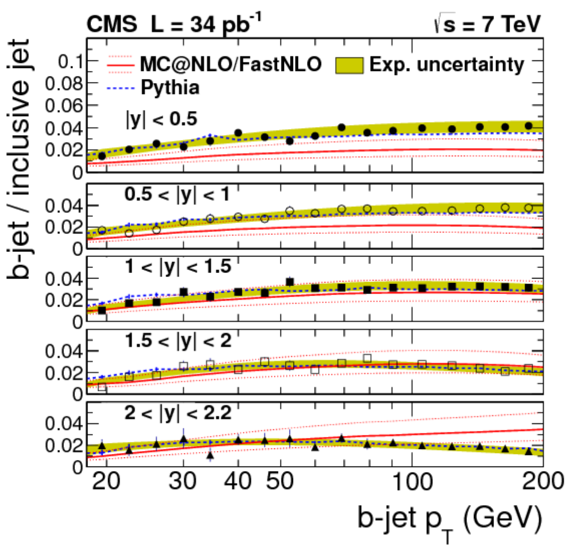
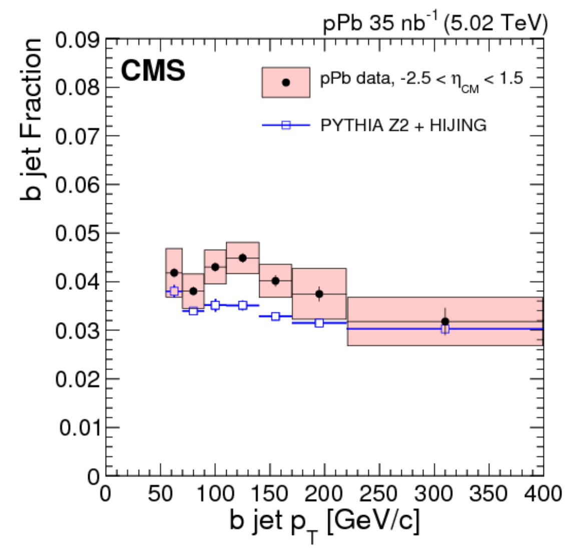
BACKUP SLIDES

b-JET FRACTION IN p-Pb AND pp FROM CMS



b-jet fraction in pp collisions for different rapidity ranges for $20 < p_{T,\, jet} < 200$ GeV/c from CMS experiment

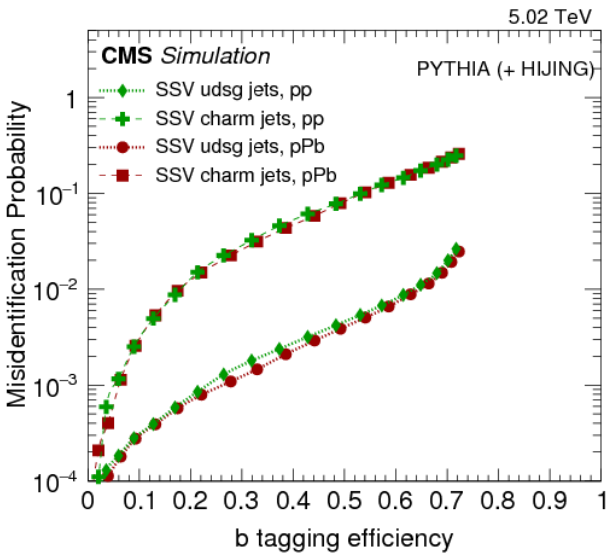


b-jet fraction in p-Pb collisions for different rapidity ranges for $50 < p_{T,\, jet} < 200$ GeV/c from CMS experiment

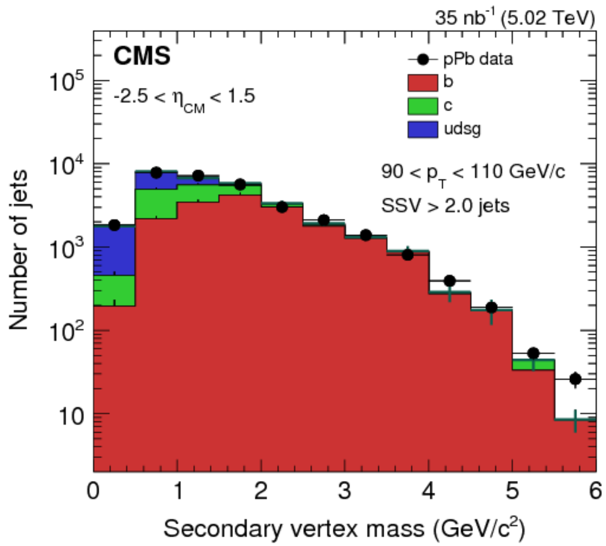
Inclusive b-jet production in pp collisions at $\sqrt{s}$ = 7 TeV, CMS Collaboration (Serguei Chatrchyan et al.) arXiv:1202.4617, JHEP 1204 (2012) 084.

Transverse momentum spectra of b-jets in pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, CMS Collaboration (Khachatryan, Vardan et al.), arXiv:1510.03373, CMS-HIN-14-007, CERN-PH-EP-2015-205.

PERFORMANCE OF b-TAGGING IN p-Pb AT CMS



Tagging efficiency and mistagging rate with different cuts on L_{xy}/σ_{Lxy} of secondary vertex in pp and p-Pb collisions.



Template fit to SSV tagged invariant mass distribution for $90 < p_{\mathrm{T,\,jet}} < 110$ GeV/*c*.

Transverse momentum spectra of b-jets in pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV,
CMS Collaboration (Khachatryan, Vardan et al.),
arXiv:1510.03373, CMS-HIN-14-007, CERN-PH-EP-2015-205.

UNFOLDING CORRECTIONS, SVD

- Measured spectrum *m(x')* is a convolution of a true spectrum *t(x)* and detector response function *A(x;x')*:

$$m(x') = \int dx A(x;x')t(x)$$

- In practice one solves the discrete equation with the spectra as histograms and the response function as a matrix: $M_m = A_{m,t} \cdot T_t$

- Given a detector response and background fluctuation matrix, the unfolding can be done with the combined matrix $C_{m,t}$. The measured spectrum M_m is the "detector" spectrum D_d distorted by background fluctuations $B_{m,d}$: $M_m = B_{m,d} \cdot D_d$
- The "detector" spectrum D_d is the true spectrum distorted by detector effects $A_{d,t}$: $D_d = A_{d,t} \cdot T_t$
- Thus, measured spectrum is:

$$M_m = B_{m,d} \cdot A_{d,t} \cdot T_t = C_{m,t} \cdot T_t$$

- Finding and inverse matrix is an ill-posed problem, since it is very sensitive to small perturbations of the data.
- Here we used SVD (singular value decomposition) as a main method for our results