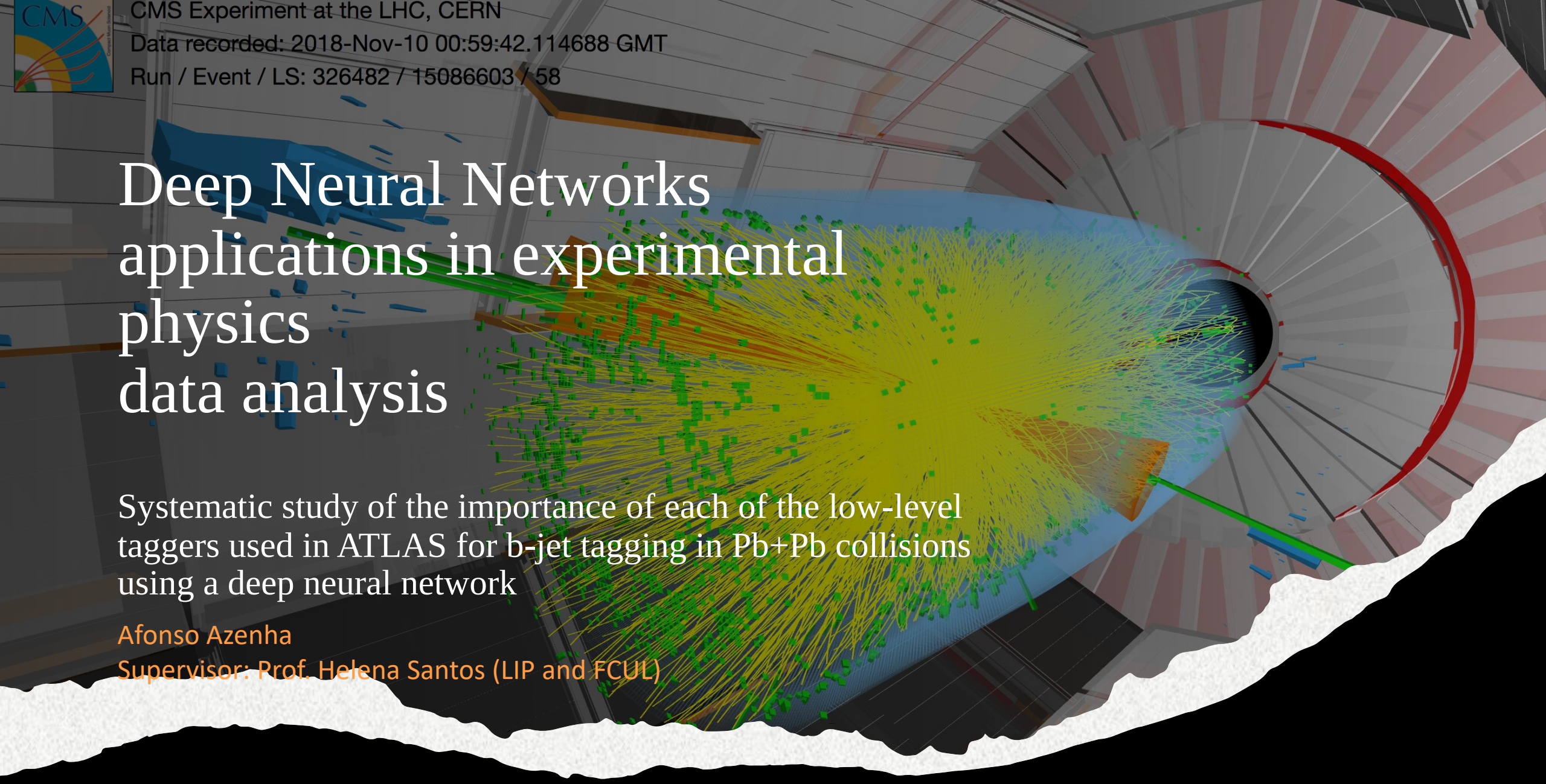

Deep Neural Networks applications in experimental physics data analysis

Systematic study of the importance of each of the low-level taggers used in ATLAS for b-jet tagging in Pb+Pb collisions using a deep neural network

Afonso Azenha
Supervisor: Prof. Helena Santos (LIP and FCUL)

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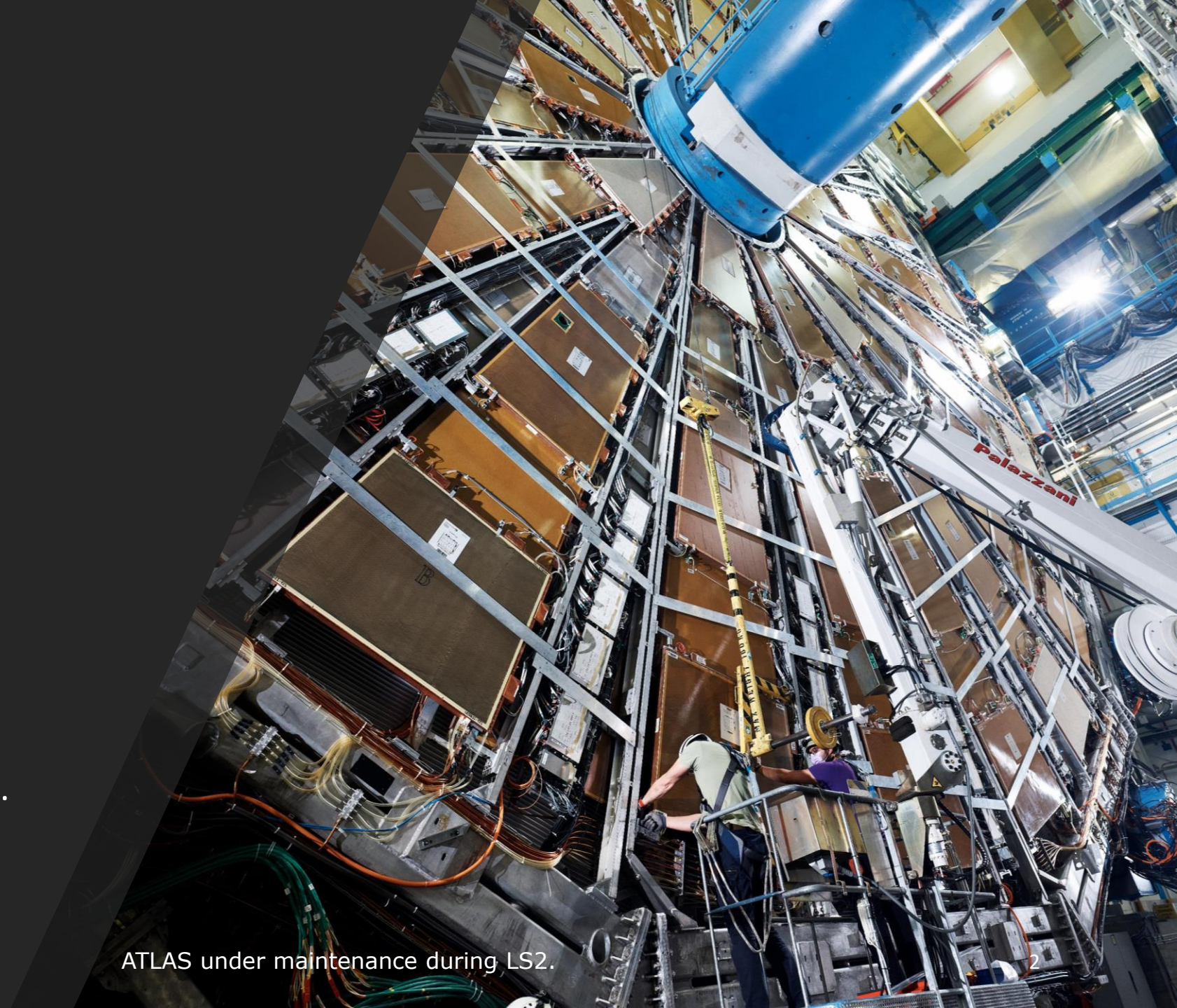
- Motivation:
  - The quark-gluon plasma;
  - Jets and b-jets;
  - b-jets and b-tagging.
- How to tag b-jets:
  - Low-level taggers (LLTs);
  - High-level taggers – DL1.
- Results:
  - Example - All LLTs case;
  - Comparison - ROC curves.

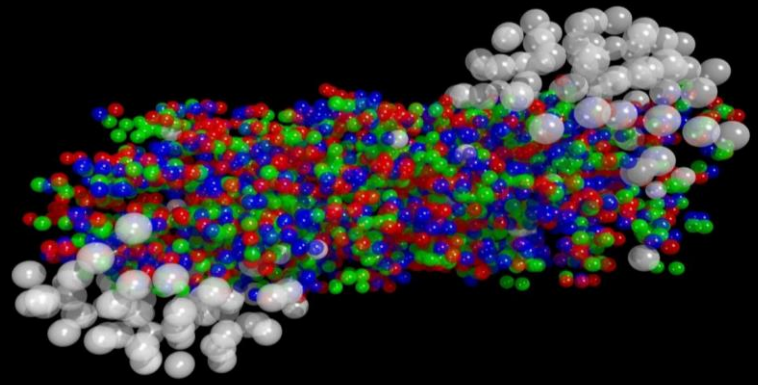


ATLAS under maintenance during LS2.

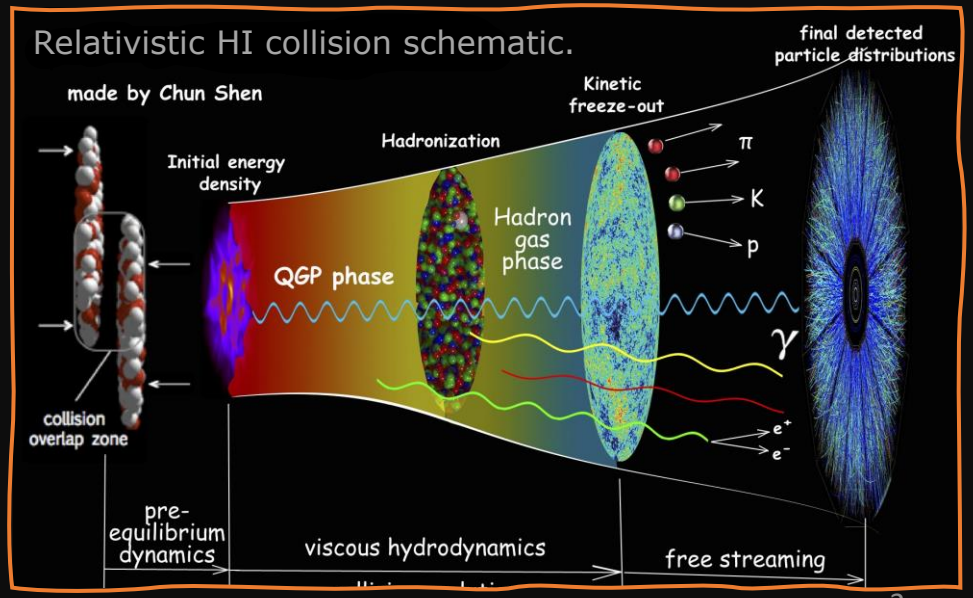
Motivation: The **quark-gluon-plasma**

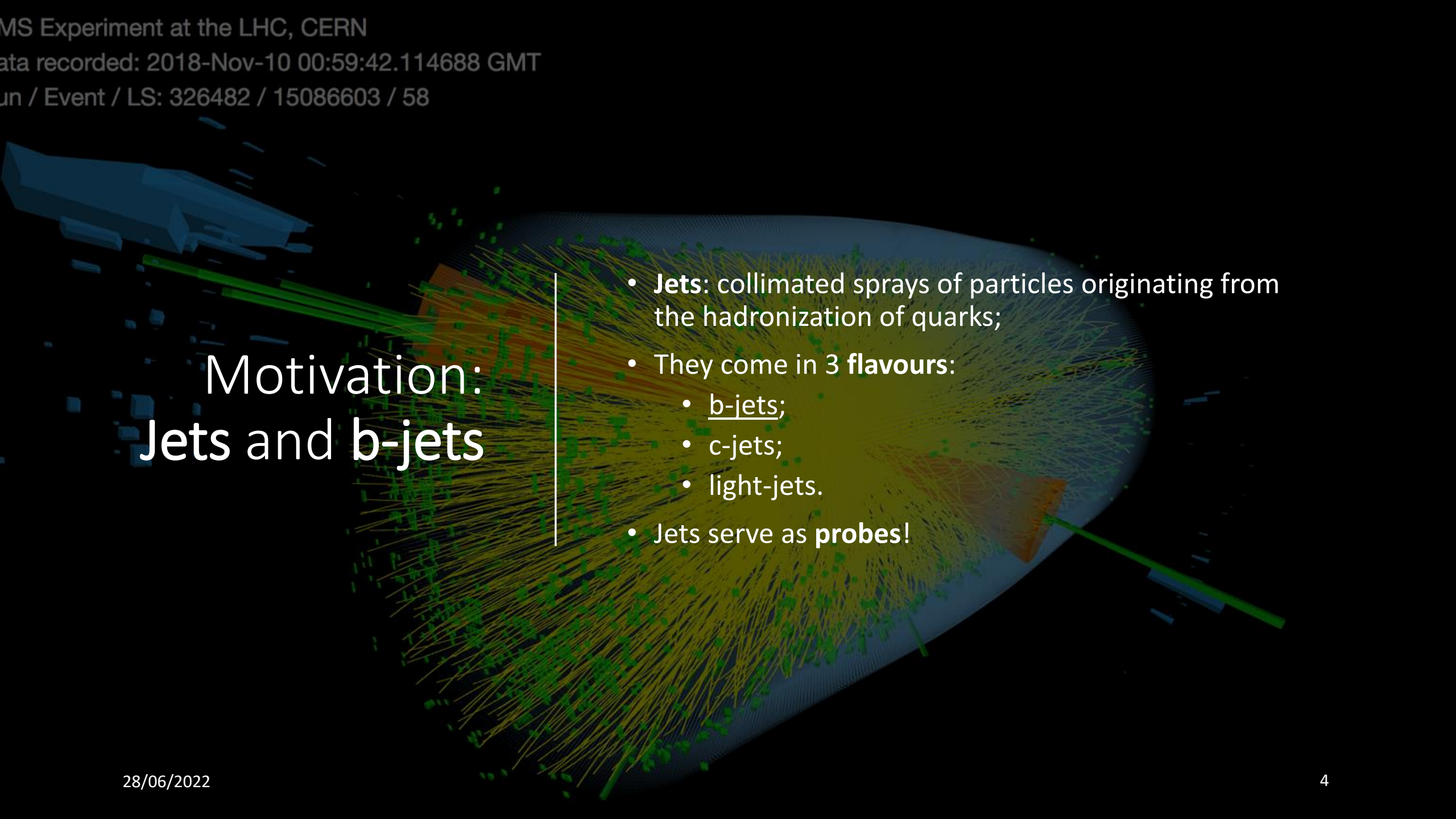
- The **quark-gluon plasma** is a ”state of matter” in which the elementary particles that make up the hadrons of baryonic matter are freed of their strong attraction for one another under extremely high energy densities.
- Existed in the Universe a tiny fraction of time after the Big Bang (10^{-12} to 10^{-6} seconds after).
- Fundamental to understand how the Universe was created!

QGP illustration.



Relativistic HI collision schematic.





Motivation: **Jets** and **b-jets**

- **Jets**: collimated sprays of particles originating from the hadronization of quarks;
- They come in 3 **flavours**:
  - b-jets;
  - c-jets;
  - light-jets.
- Jets serve as **probes**!

Motivation: b-jets and b-tagging

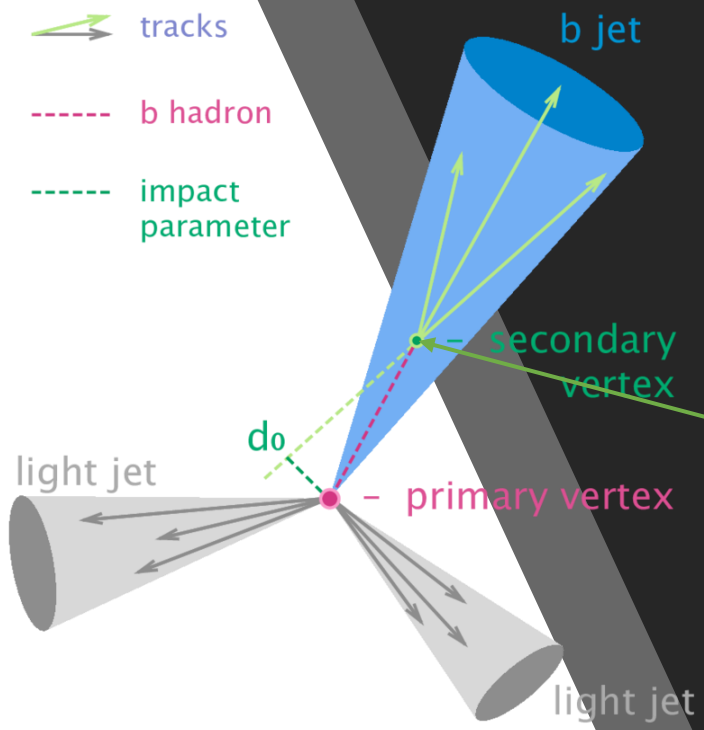


Diagram illustrating the structure of a b-jet.

b-tagging is utilized to study physics processes with b-jets in their final state:

- Standard Model Higgs sectors ($H \to b\bar{b}$, $HH \to b\bar{b}b\bar{b}$, ...);
- Top physics ($t \to W\,b$);
- Beyond Standard Model searches ($X \to bY$).

b-hadrons:

- Sufficient lifetime → they travel some **measurable** distance before decaying → displaced secondary vertex;
- High mass (few GeV) → decay products with a larger $\mathbf{p_T}$ (transverse momentum), which means b-jets:
  - Are wider;
  - Have higher multiplicities (numbers of constituent particles) and invariant masses;

How to tag b-jets: Low-level taggers (LLTs)

Exploit the jet's properties to infer its flavour.

- 3 types:
  - Algorithms based on impact parameters: **IP2D** and **IP3D;**
  - Secondary vertex finding algorithms: **SV1;**
  - Topological multi-vertex finding algorithms: **JetFitter.**

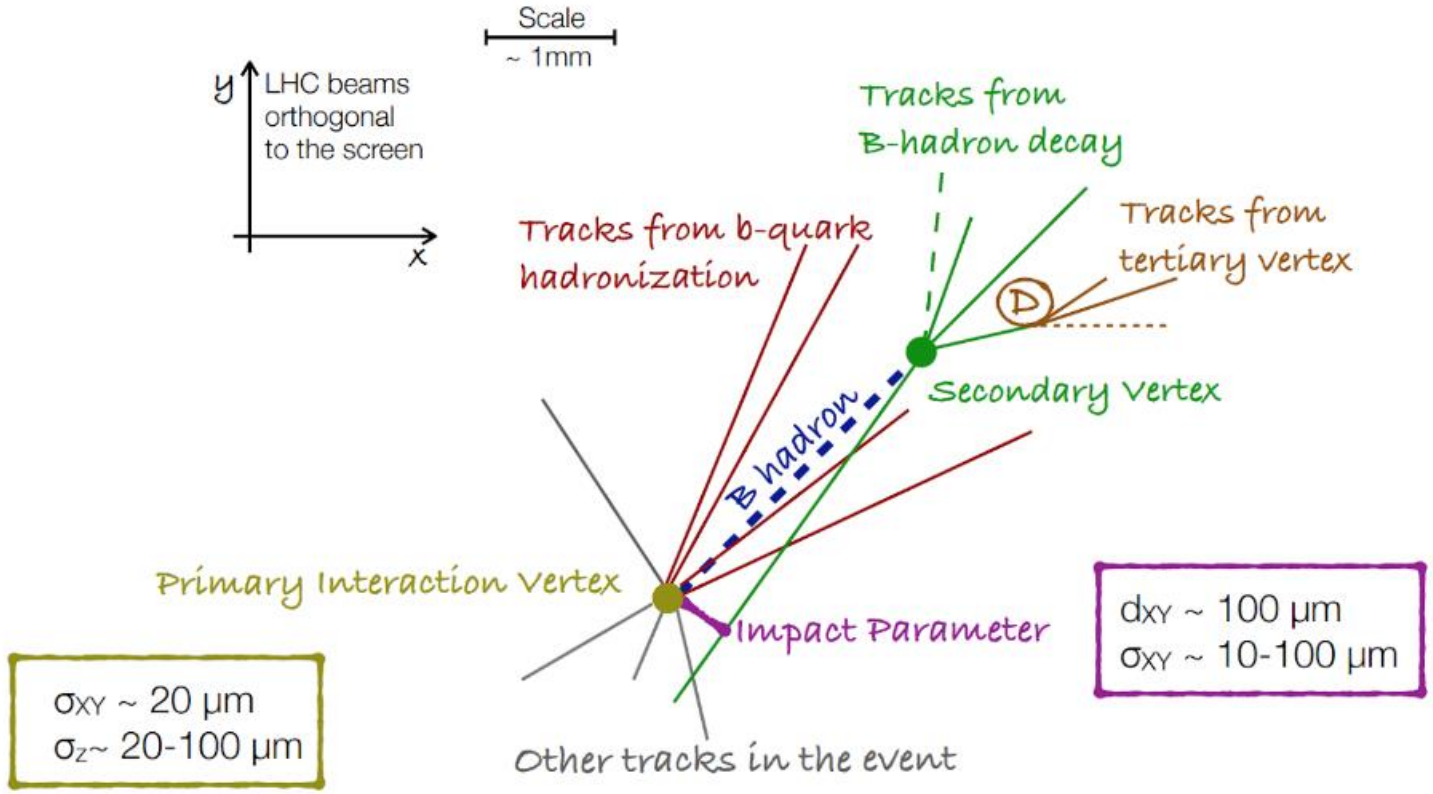
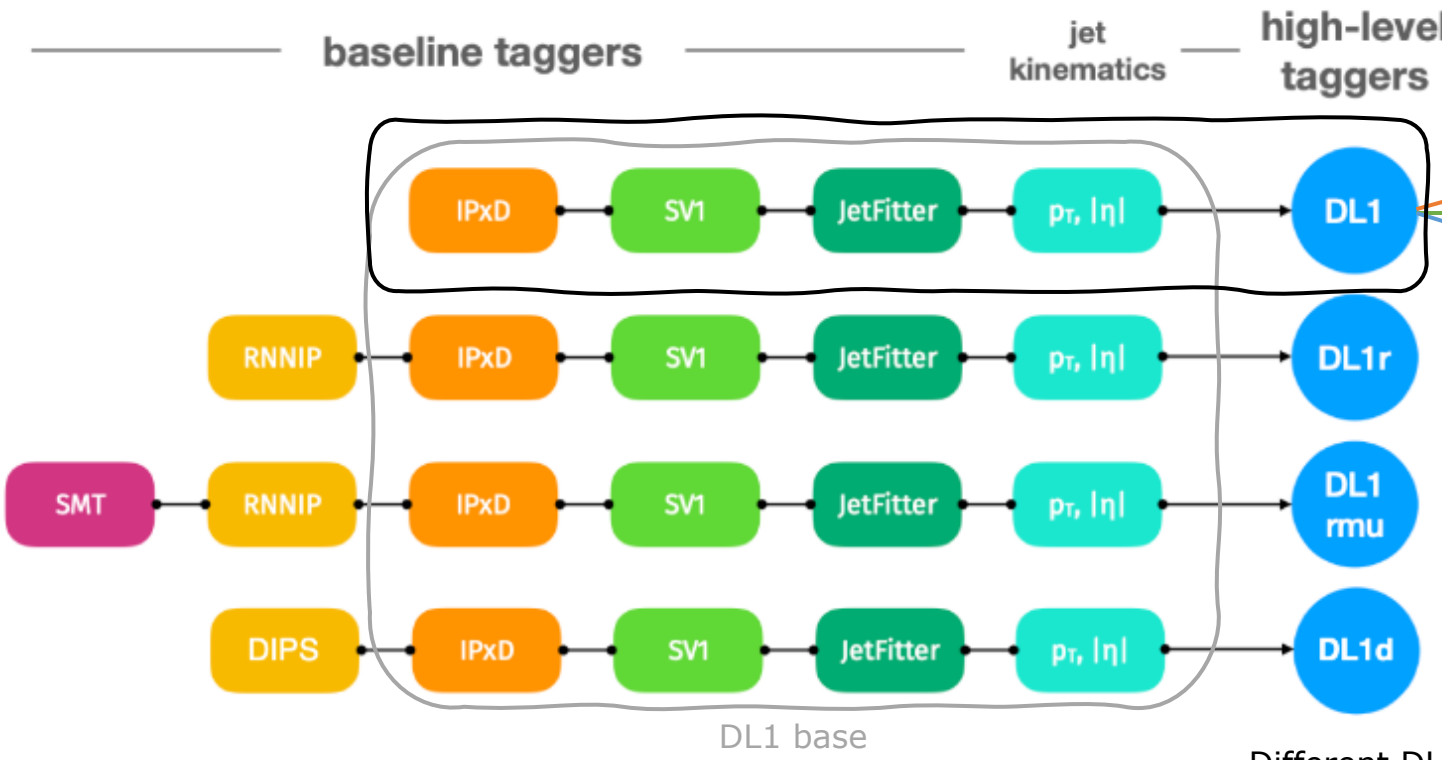


Diagram illustrating the structure of jets formed in a collision.

How to tag b-jets: High-level taggers – DL1



p_b
p_c
p_{light}

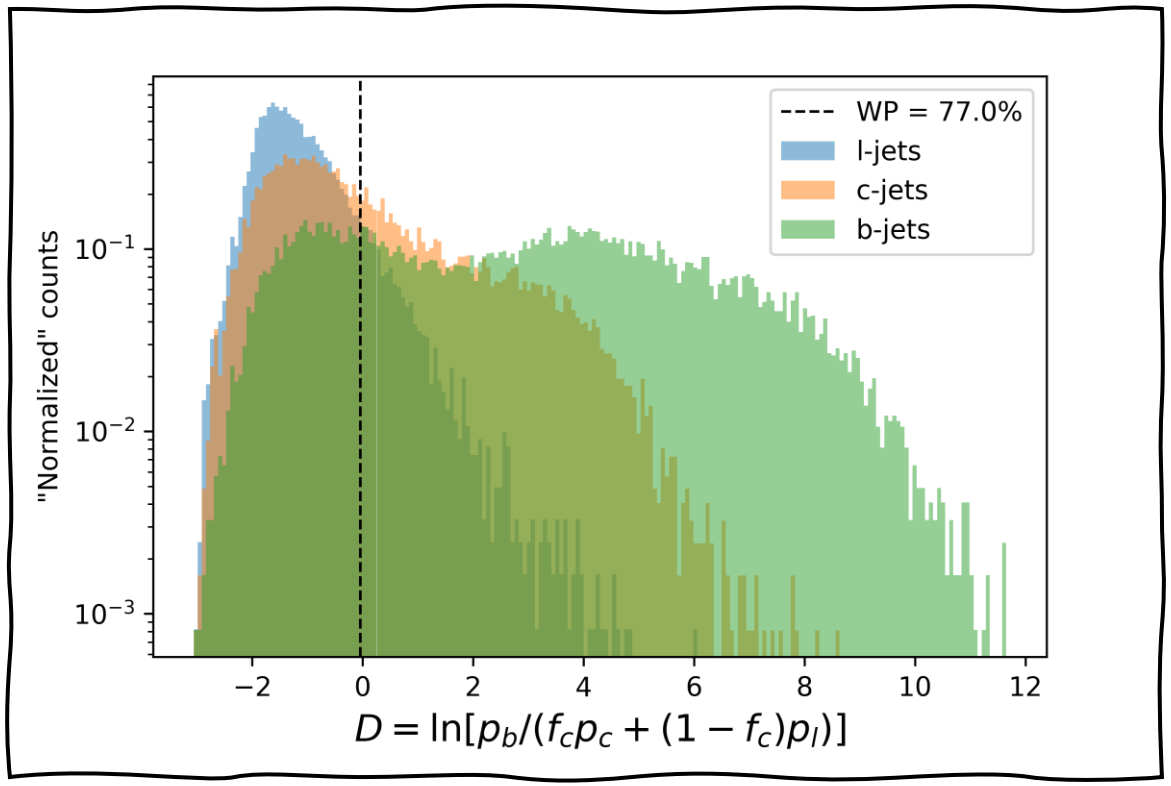
f_c : Effective c-jet fraction in background training sample

For b-tagging:

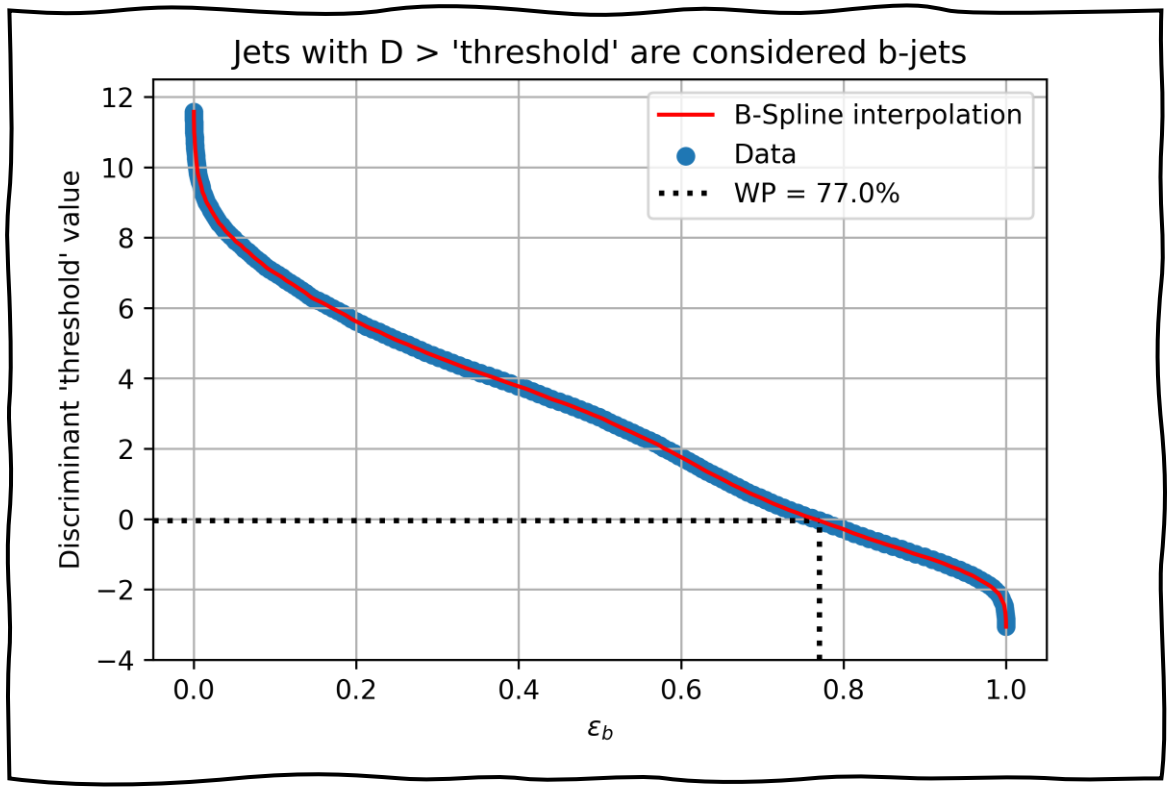
$$D_{\mathrm{DL1}} = \ln\left(\frac{p_b}{f_c \cdot p_c + (1 - f_c) \cdot p_{\mathrm{light}}}\right)$$

DL1 discriminant

Results: Example - All LLTs case

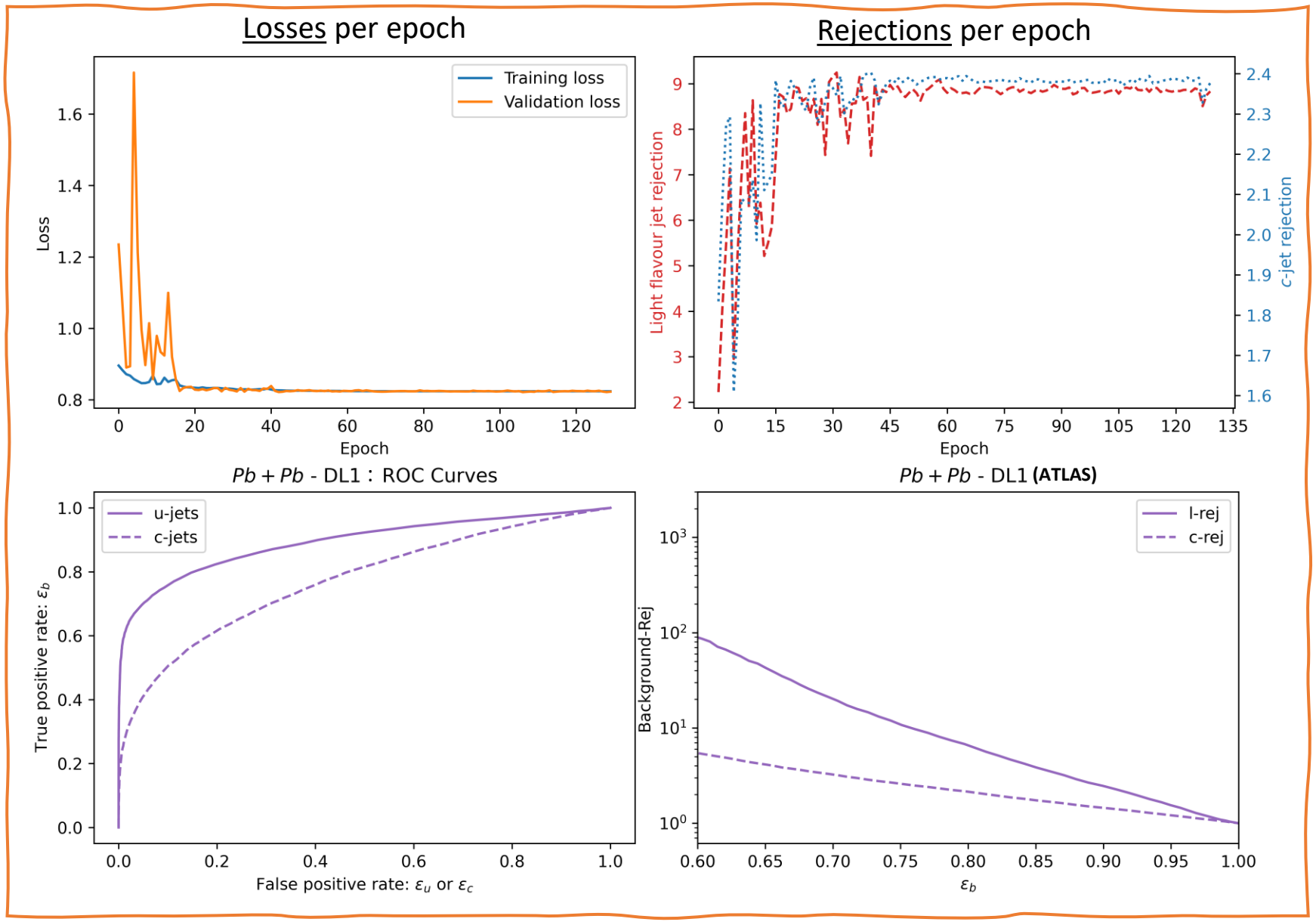


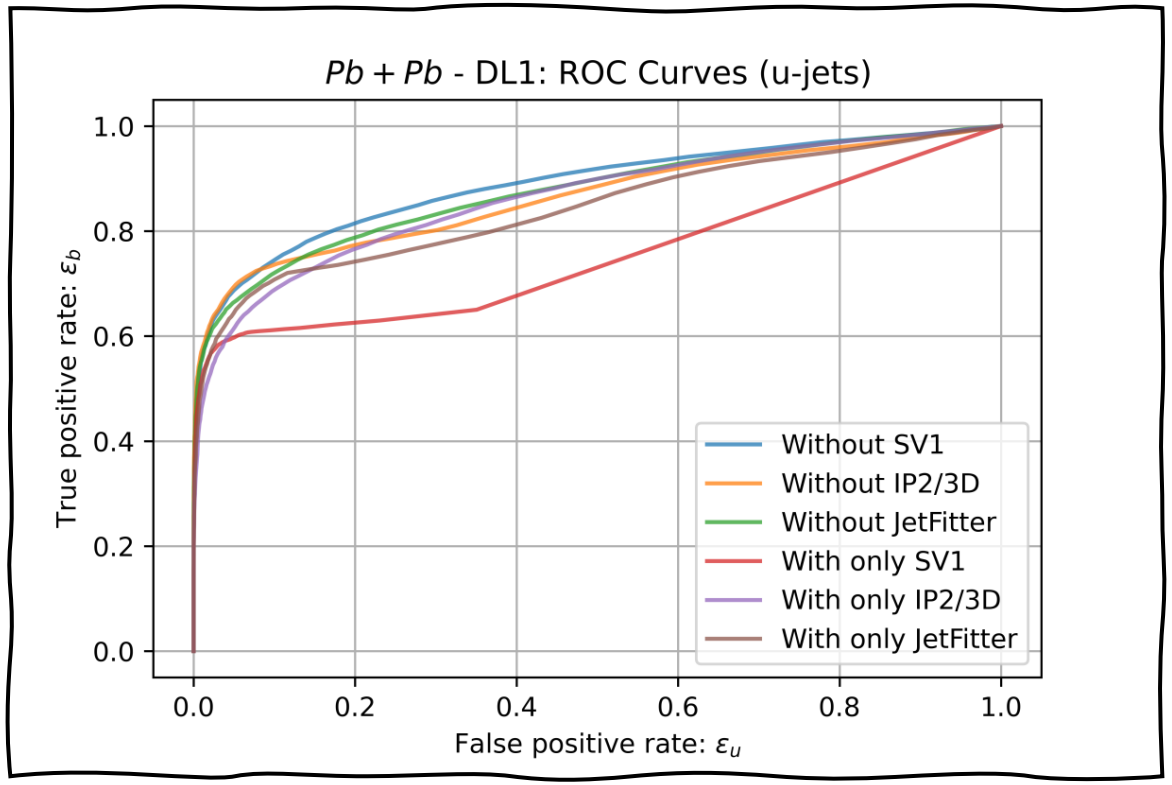
Number of jets' distribution in the discriminant values.



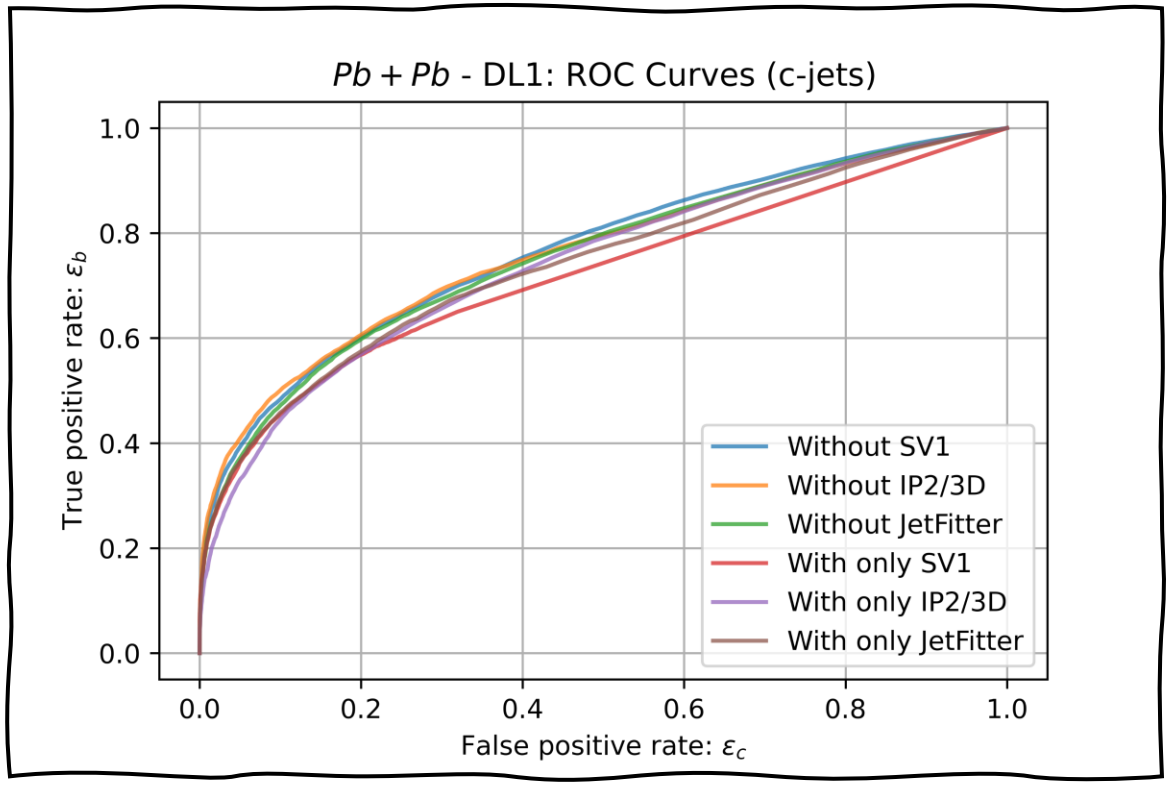
Discriminant 'threshold' value as a function of ε_b.

Results: Example - All LLTs case (cont.)





ROC curves for u-jets: Most* combinations.



ROC curves for u-jets: Most* combinations.

Results : Comparison - ROC curves

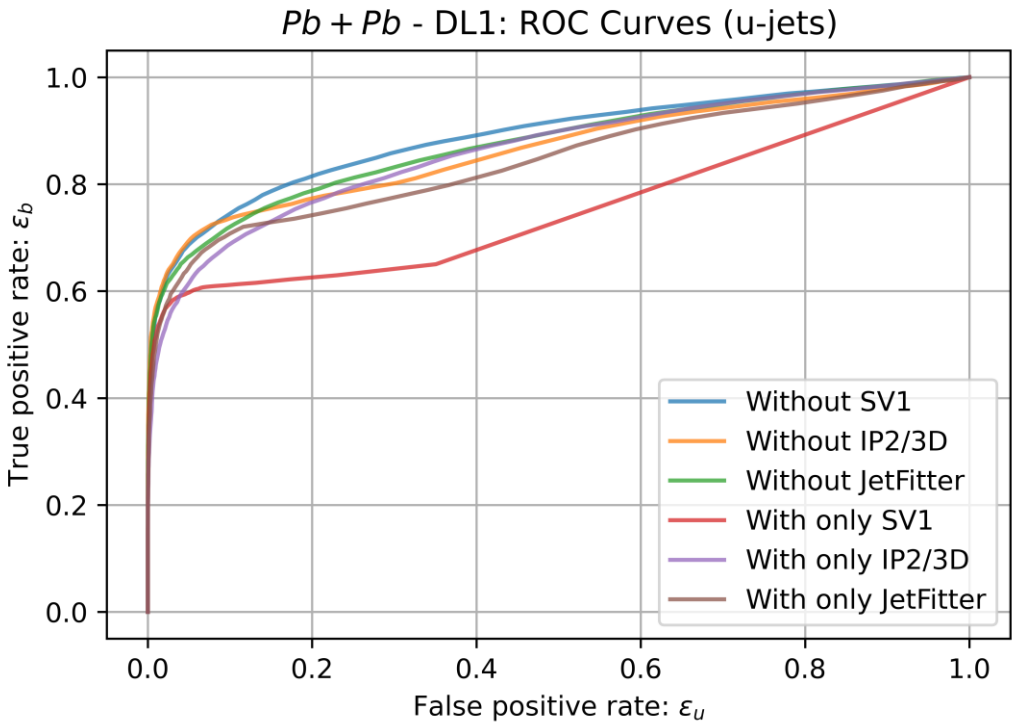
*We're missing 'All LLTs' and 'No LLTs'.

Results : Comparison - ROC curves

- Results for **light-jets**

	AUC	
	For u-jets	For c-jets
IP2(3)D Only	0.8617	0.7718
JetFitter Only	0.8432	0.7401
SV1 Only	0.7514	0.7202
Without IP2(3)D	0.8643	0.7625
Without JetFitter	0.8731	0.7559
Without SV1	0.8876	0.7659
With all LLTs	0.8911	0.7712
With no LLTs	0.5008	0.4961

Table: Area Under the Curve (AUC) values.

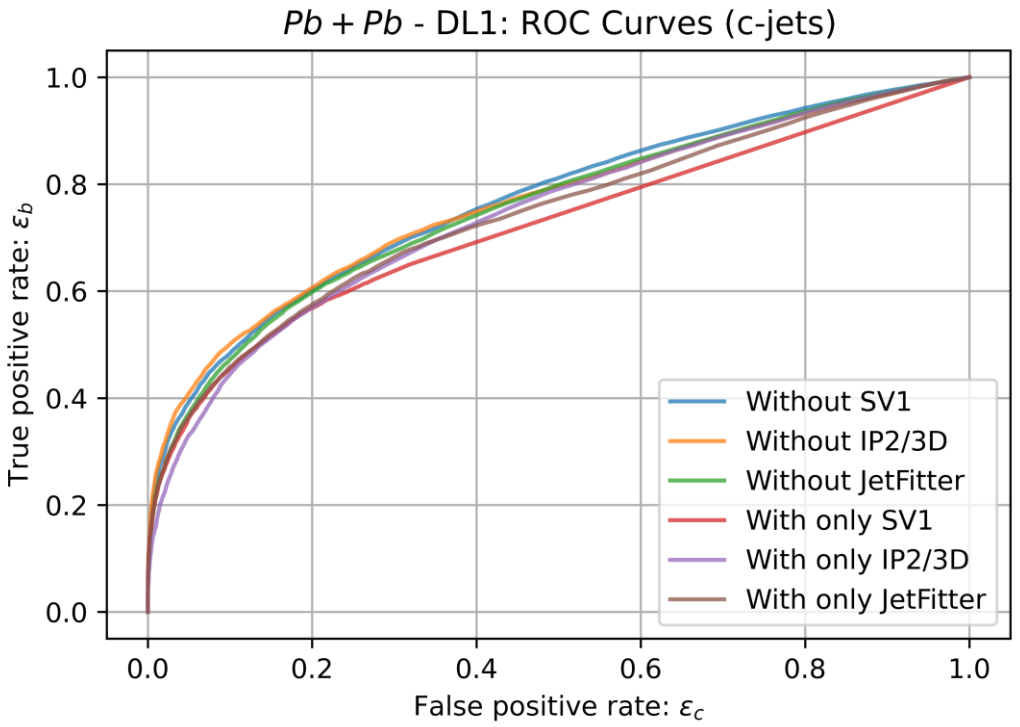


Results : Comparison - ROC curves

- Results for **c-jets**

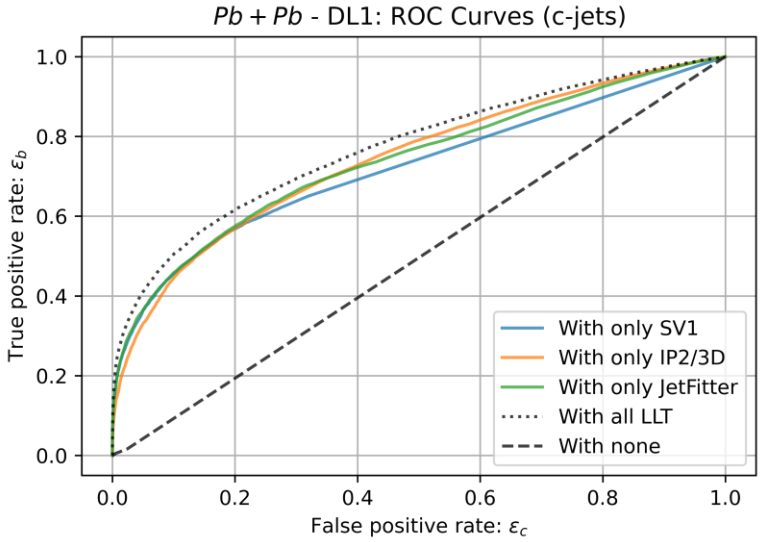
	AUC	
	For u-jets	For c-jets
IP2(3)D Only	0.8617	0.7718
JetFitter Only	0.8432	0.7401
SV1 Only	0.7514	0.7202
Without IP2(3)D	0.8643	0.7625
Without JetFitter	0.8731	0.7559
Without SV1	0.8876	0.7659
With all LLTs	0.8911	0.7712
With no LLTs	0.5008	0.4961

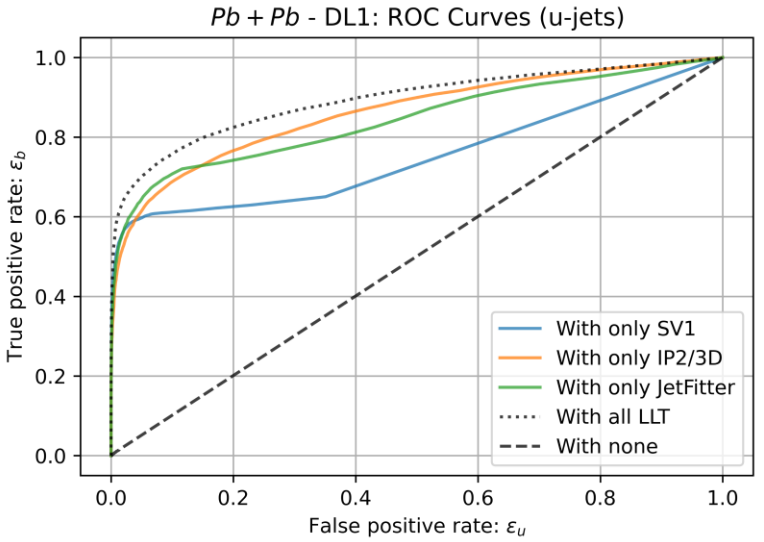
Table: Area Under the Curve (AUC) values.

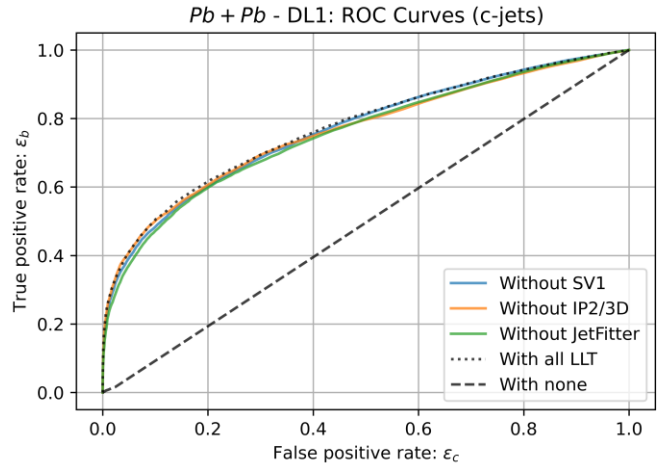


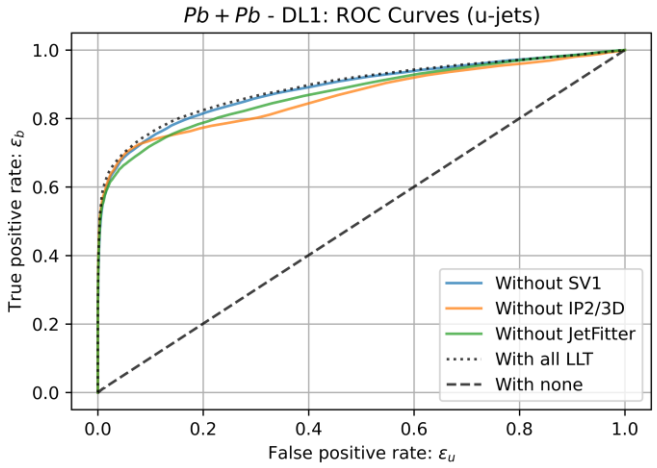
Conclusion

- This work allows for a deeper comprehension of the LLTs influence in b-tagging when working with a deep neural network. This is useful for deciding which input parameters we want to choose for DL1.



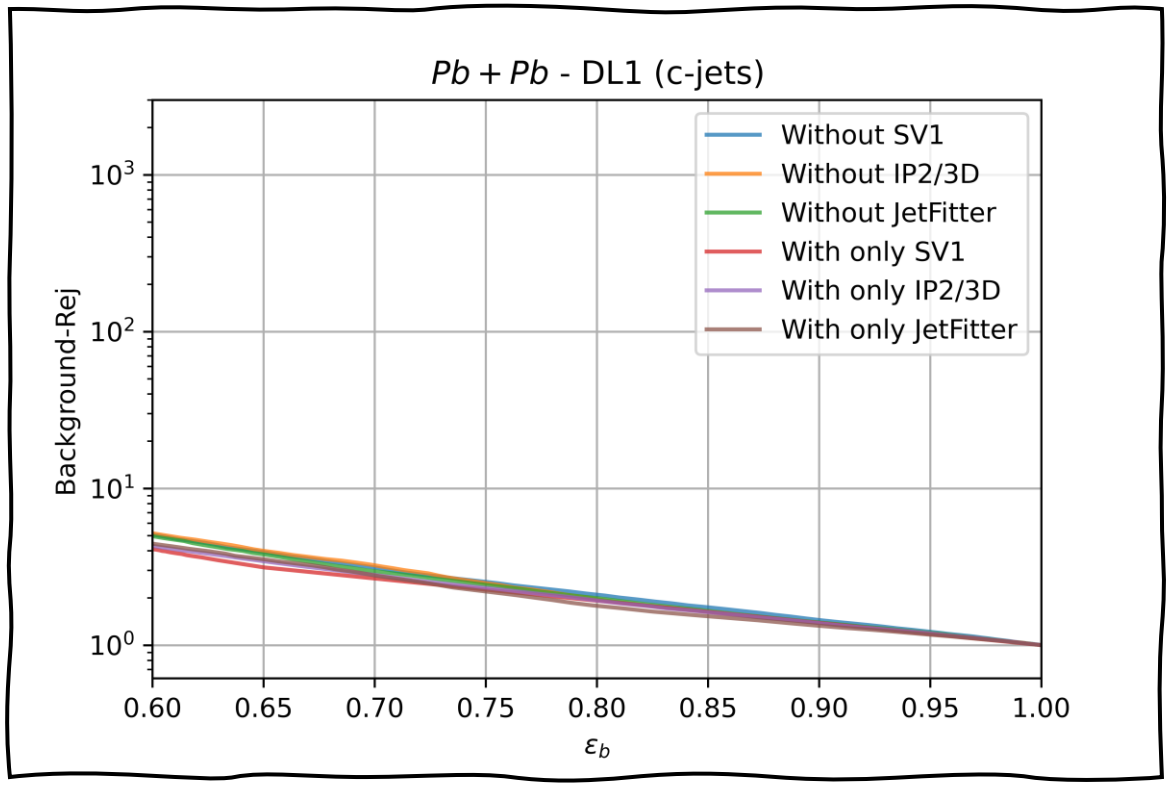


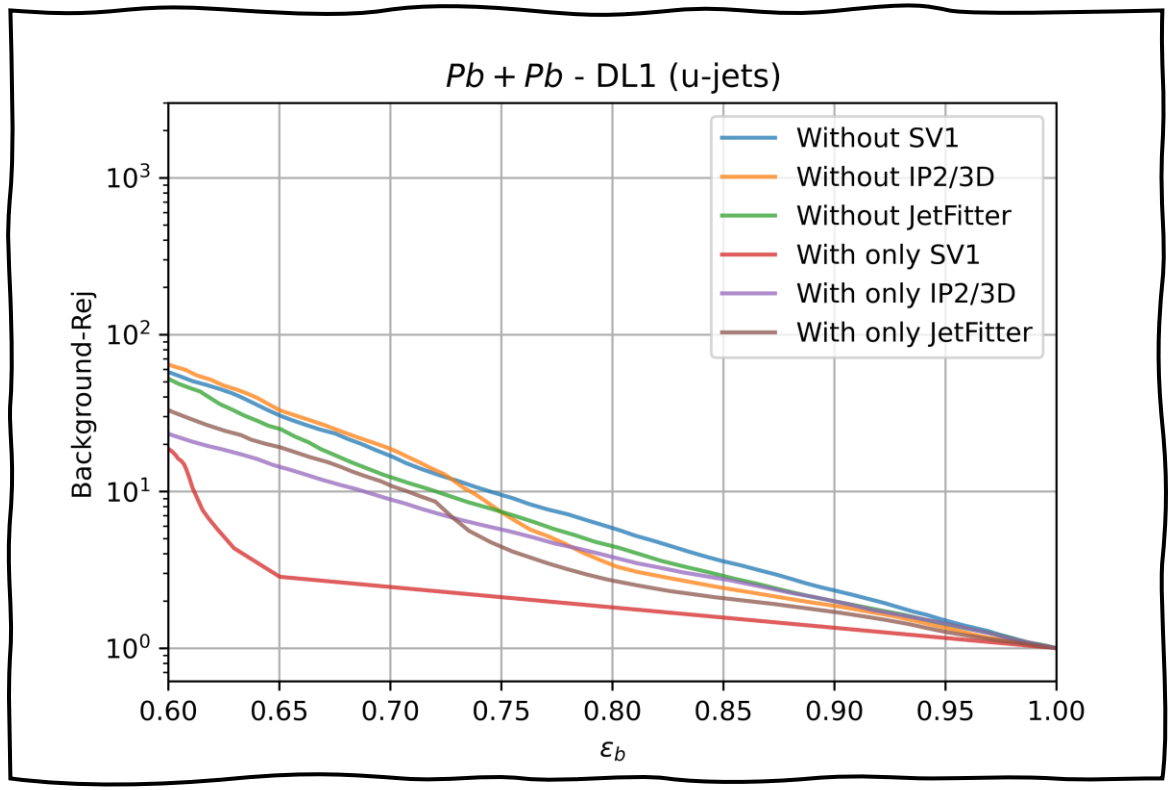




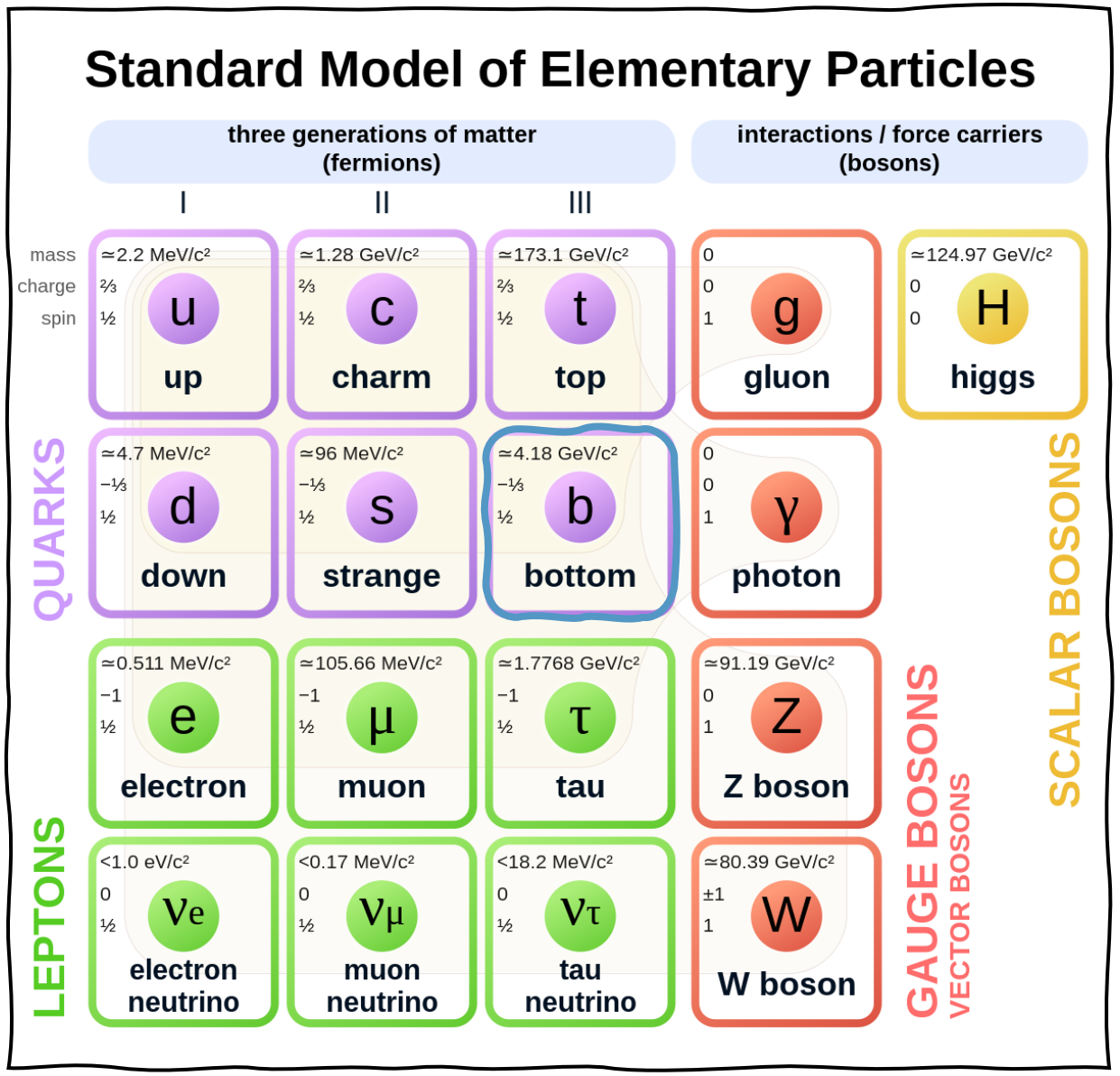
Back-up slides: More ROC curves

Results: ROC curves (ATLAS convention)

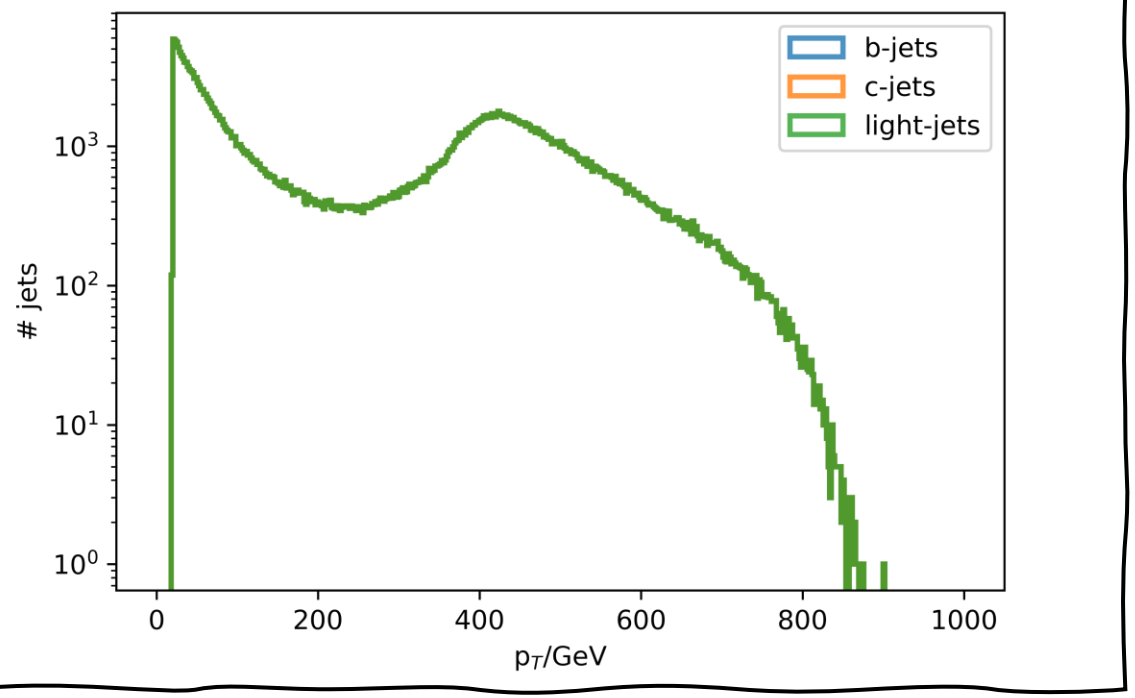




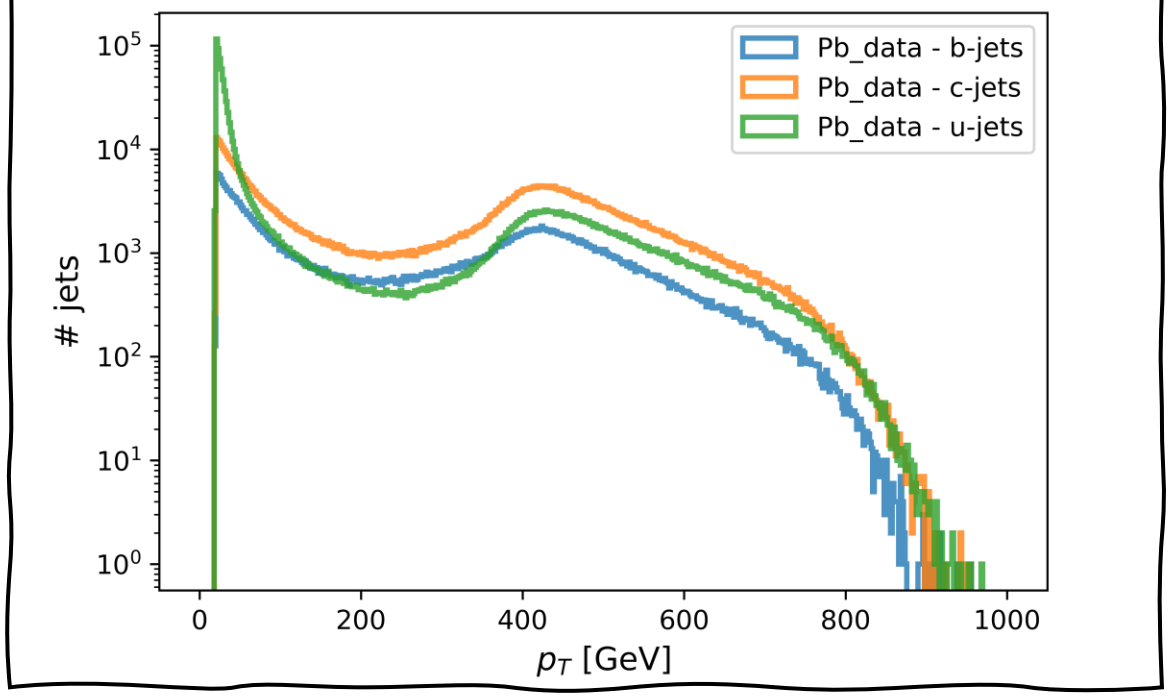
The Standard Model



Elementary particles of the Standard Model.



p_T distributions <u>after</u> down-sampling.



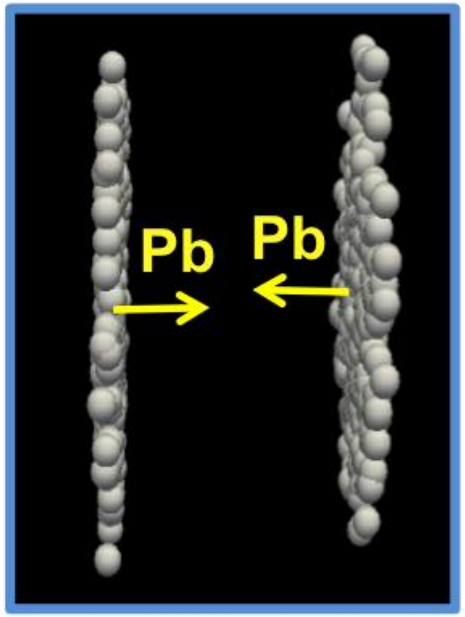
p_T distributions <u>before</u> down-sampling.

p_T distributions

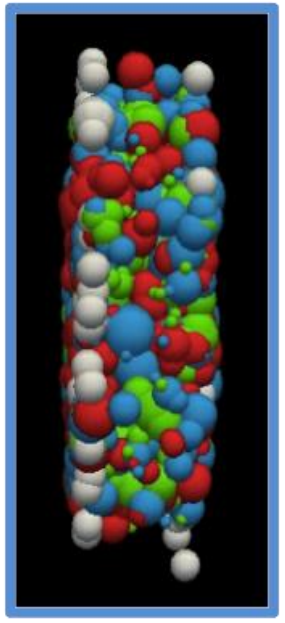
QGP Formation

time

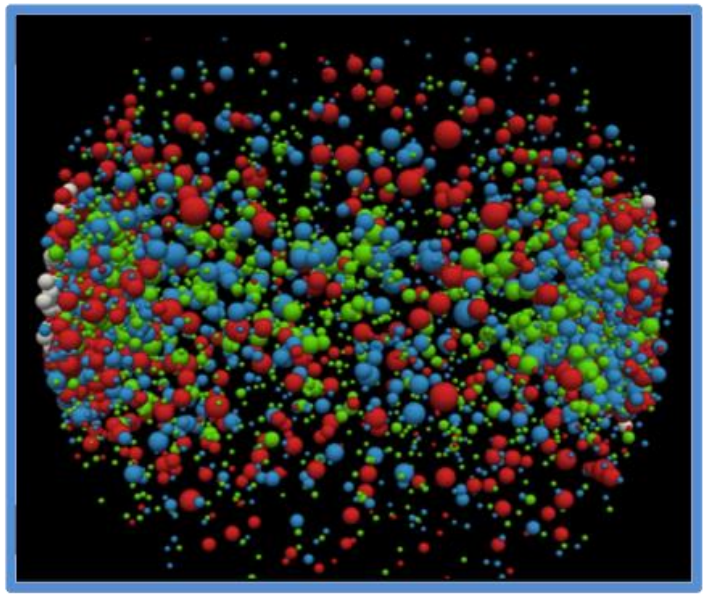
Pre-reaction



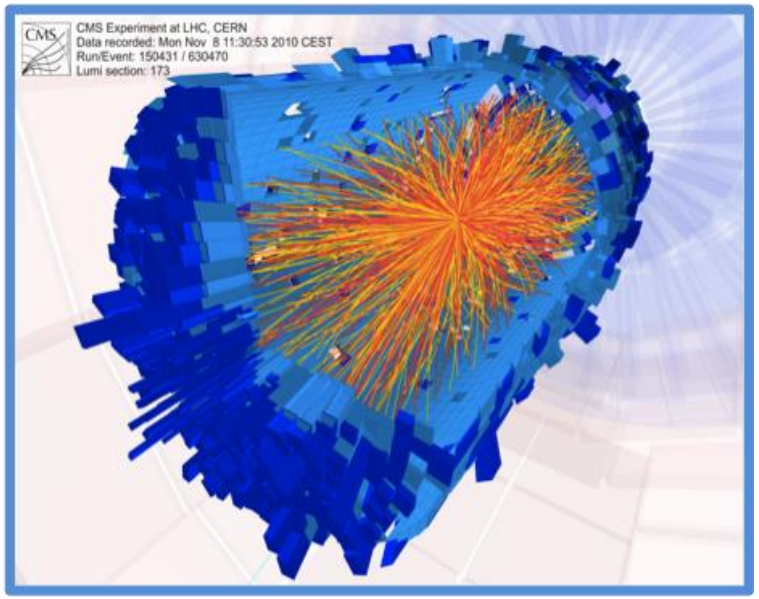
QGP



Hadronization



Detection



QGP Formation