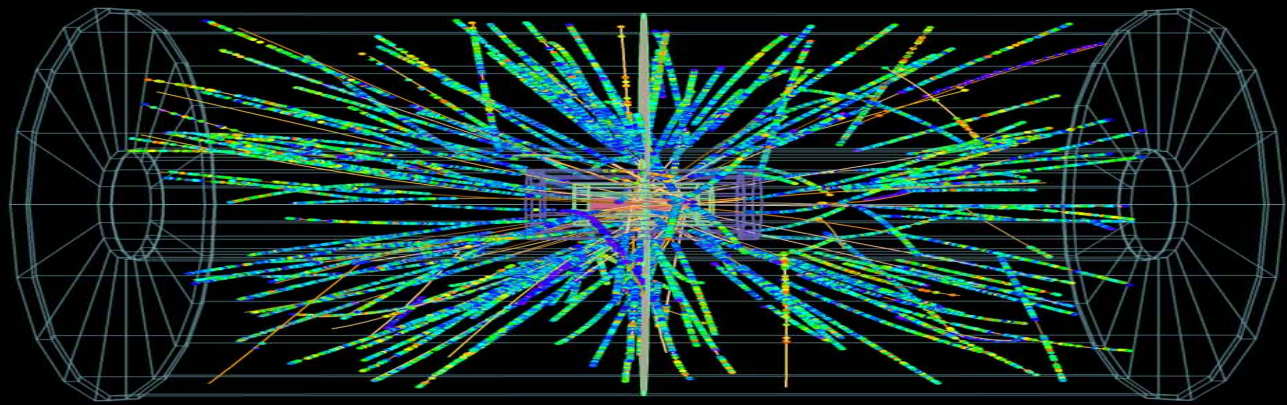

# Charged Hadron Spectra in p+Pb collisions at 8 TeV

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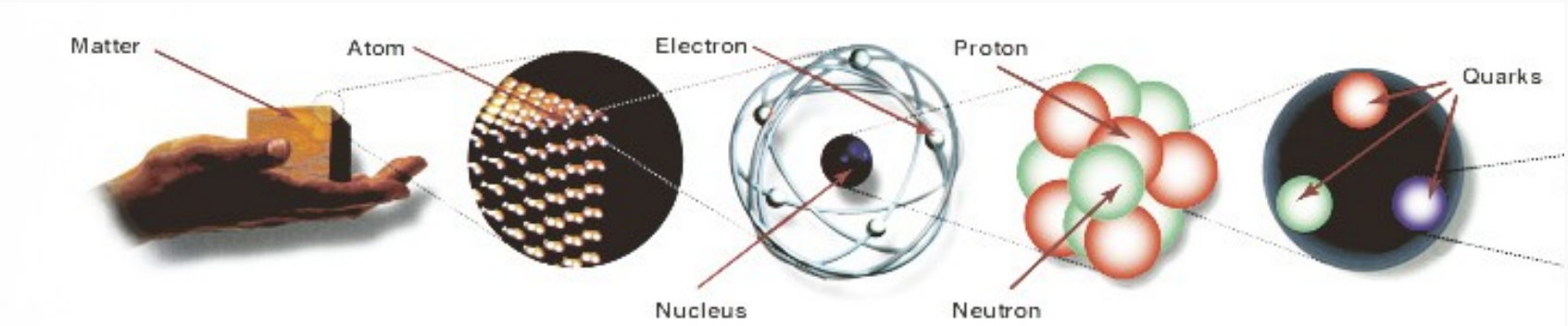
# Contents

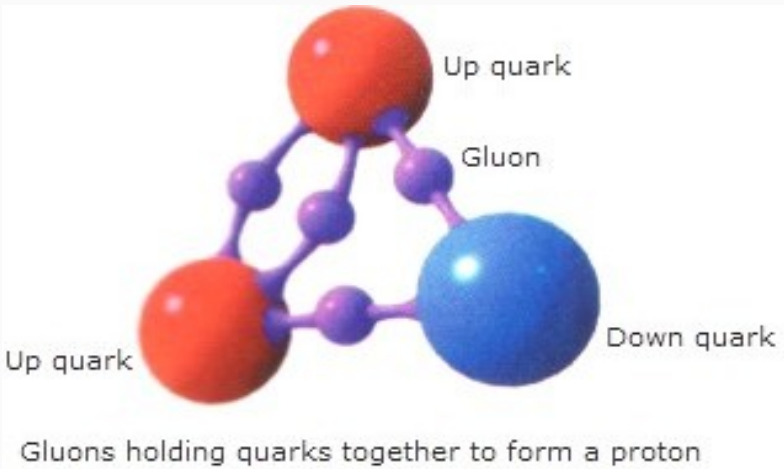
# Motivation: Why study heavy ion collisions?

What's the *hottest* thing you can imagine?

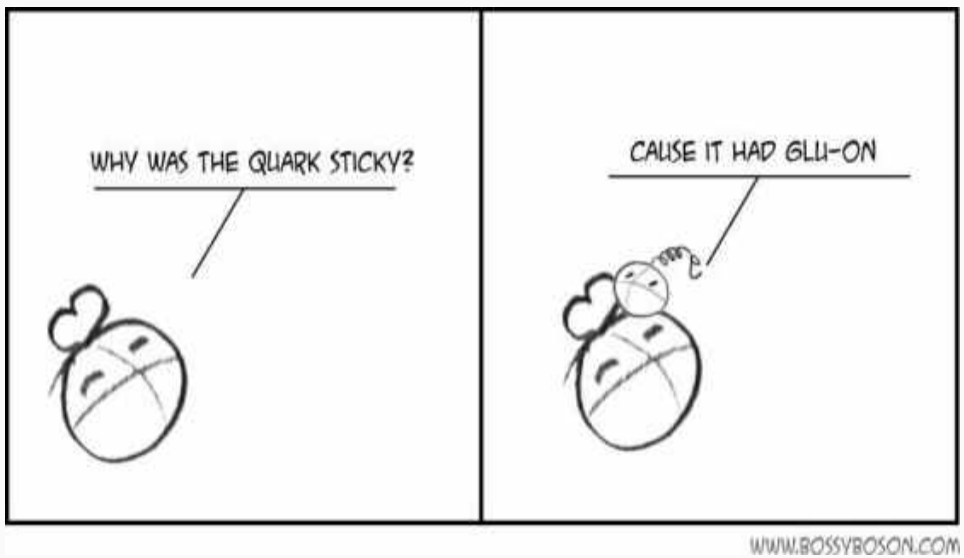
# Matter and Quark-Gluon Plasma

QGP: Extremely *hot* and dense state of **matter** where **quarks** and **gluons** are free to move!

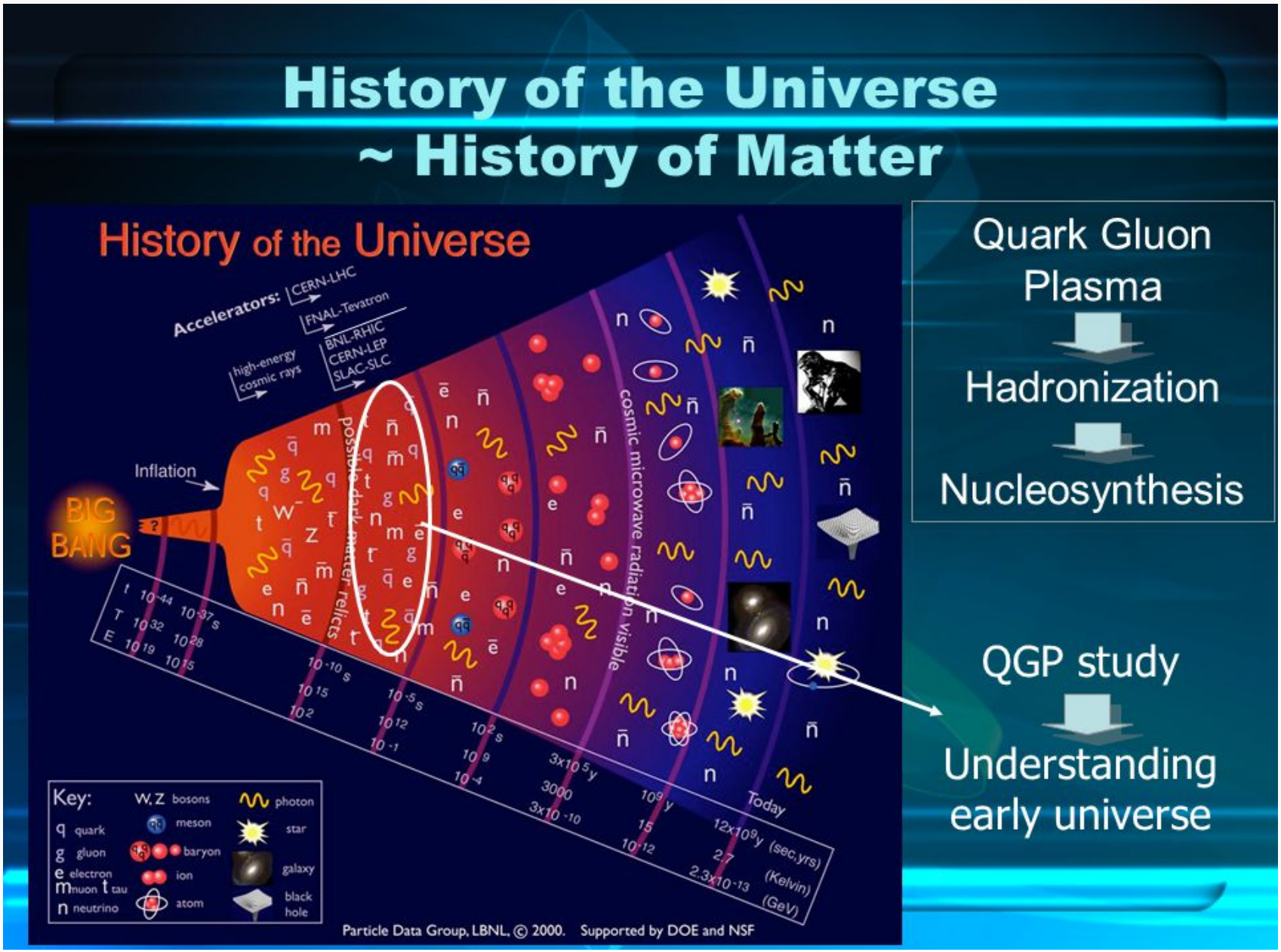



Gluons holding quarks together to form a proton

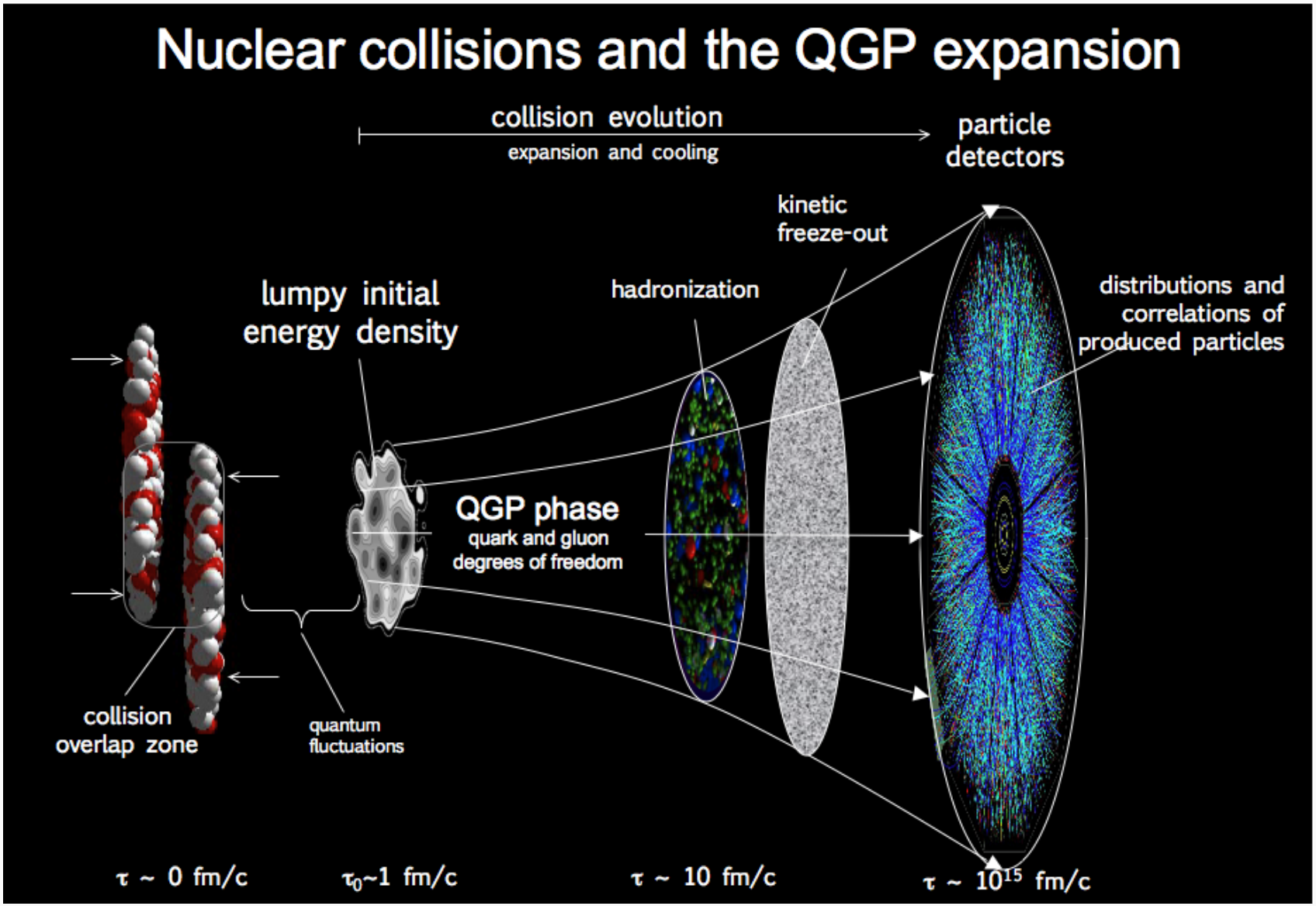


# QGP: The Primordial Soup



# Setup: How to study Quark-Gluon Plasma?
# -From HI collisions

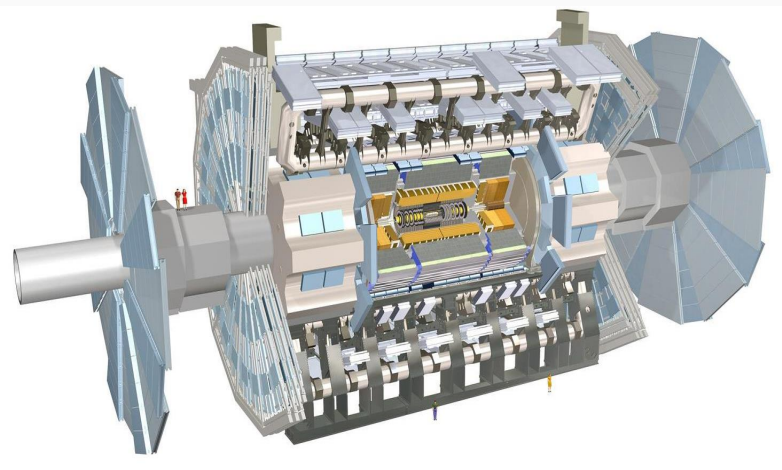
# Heavy-Ion Collisions

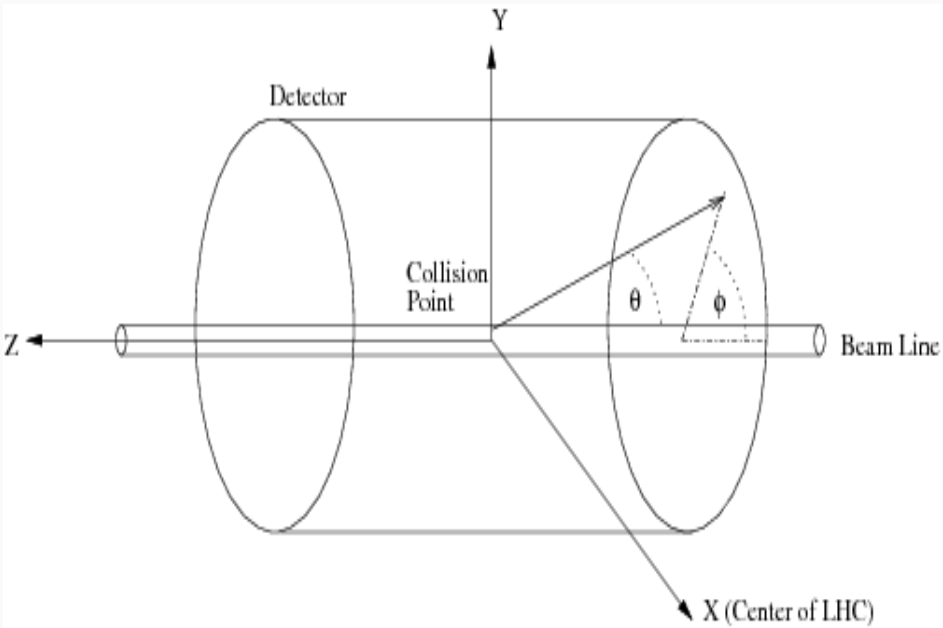


# Colliders and Detectors: ATLAS

- ATLAS follows right-handed coordinate system.
- Measure positions of particles after collision using $\theta$ (from z-axis) and $\phi$ (from x-axis in transverse plane).
- Transverse Momentum ($p_T$): a very important quantity to measure.

The ATLAS Detector (cylindrically symmetric)



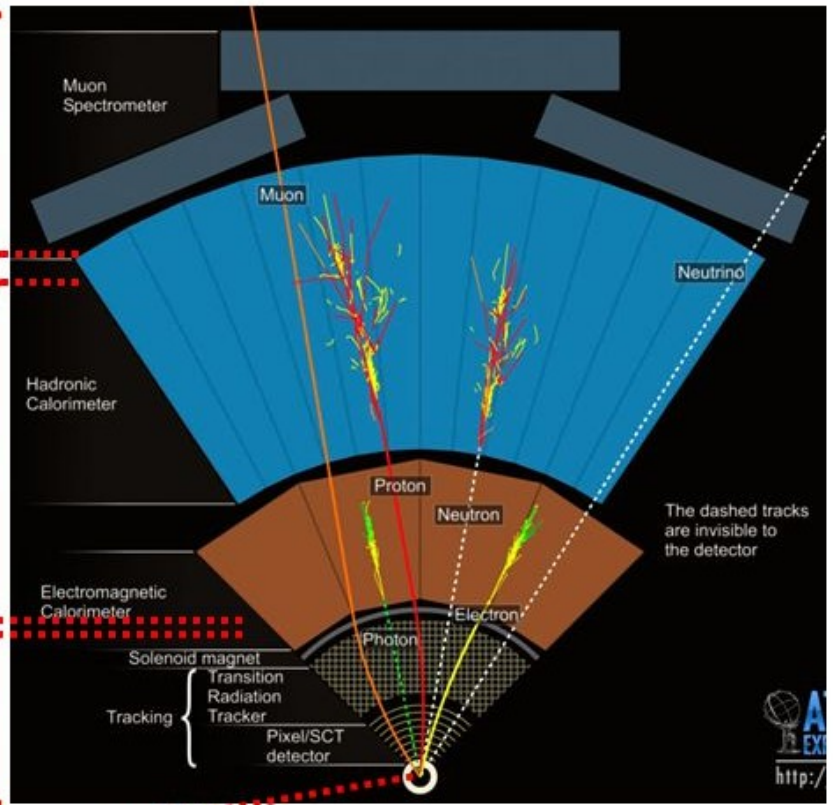


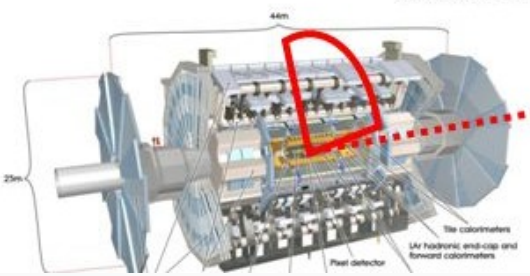
# Colliders and Detectors

Measure p of muons
Tracking

Measure E of all particles
Calorimeters convert absorbed energy in light

Measure p of charged particles
Silicon & gas based tracking detectors in B field



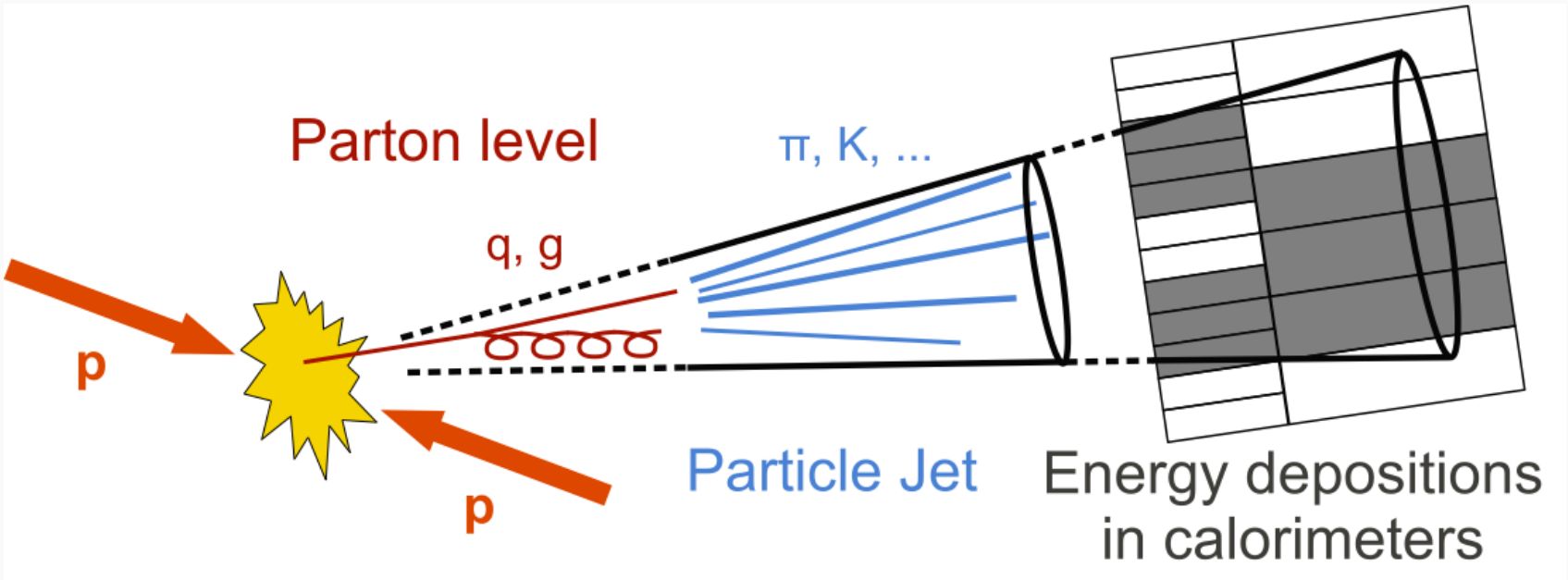



# Analysis: Evaluation of charged hadron spectra in p+Pb

# Why do we want to measure charged hadron spectra?

- Production of *hadrons* (particles composed of quarks) is modified in HI collisions compared to pp collisions.
- This modification is a result of energy loss in the hot medium.
- We're interested in the $p_T$ distribution of the tracks made by *hadrons*.
- High $p_T$ tracks are coming from jets.

# Analysis: Jets



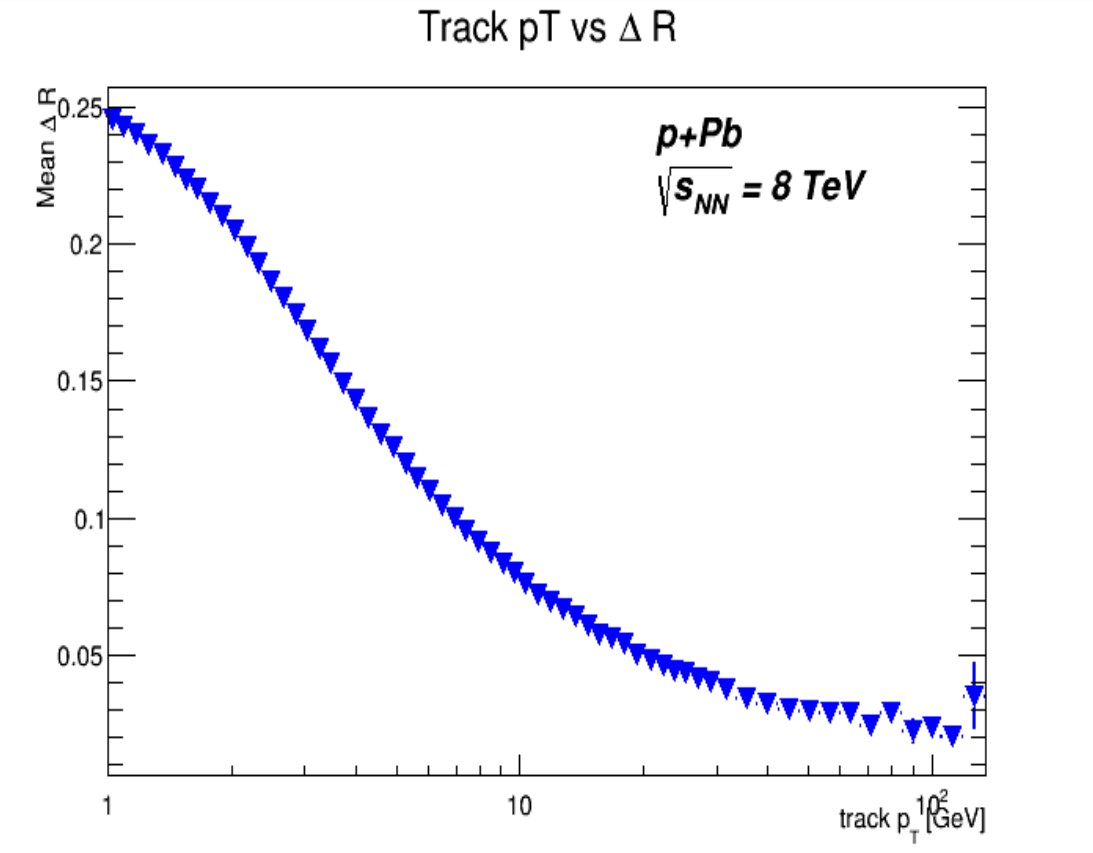

- **Jet**: A spray of hadrons depositing energy in the calorimeter.
- *Track* with high $p_T$ is part of a jet, which is found by a trigger and the event is recorded.
- *Need to record events but can't record everything!*
- We need triggers!

# Triggers and Analysis

- Trigger: A system or a software or both that selects events which potentially contain interesting physics. (”rare” or important events)
- Many types of triggers:
  - MinBias: Selects *basically* all events.
  - Jet Trigger: Selects events with jets.
  - Many other types of triggers...
- All events in my dataset were selected using MinBias and Jet triggers.
- The main goal is to combine measurements from all the triggers, in order to make a spectrum to high $p_T$.

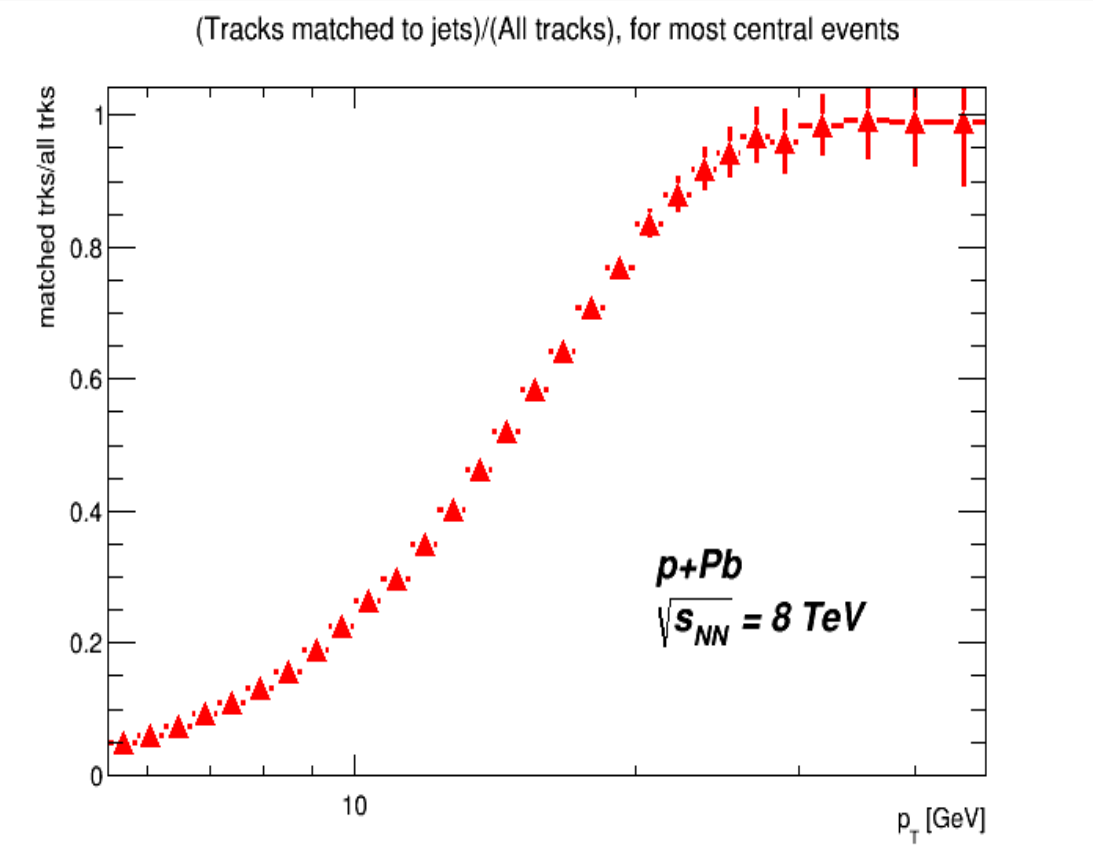
# Results

# Results: $\Delta R$



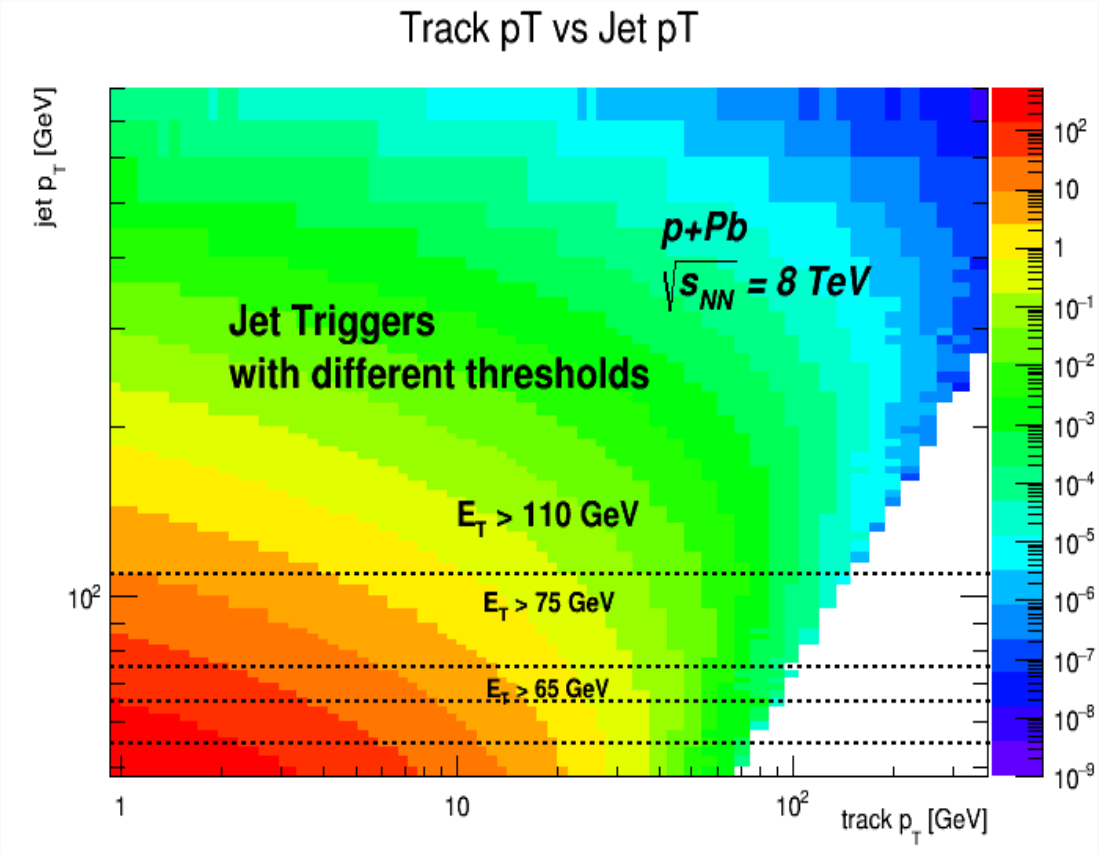

- $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$
- $\eta =$ pseudorapidity = $-ln \tan(\theta/2)$
- Matching: High $p_T$ tracks are sitting near to jet axis, within 0.05.

# Results: Ratio



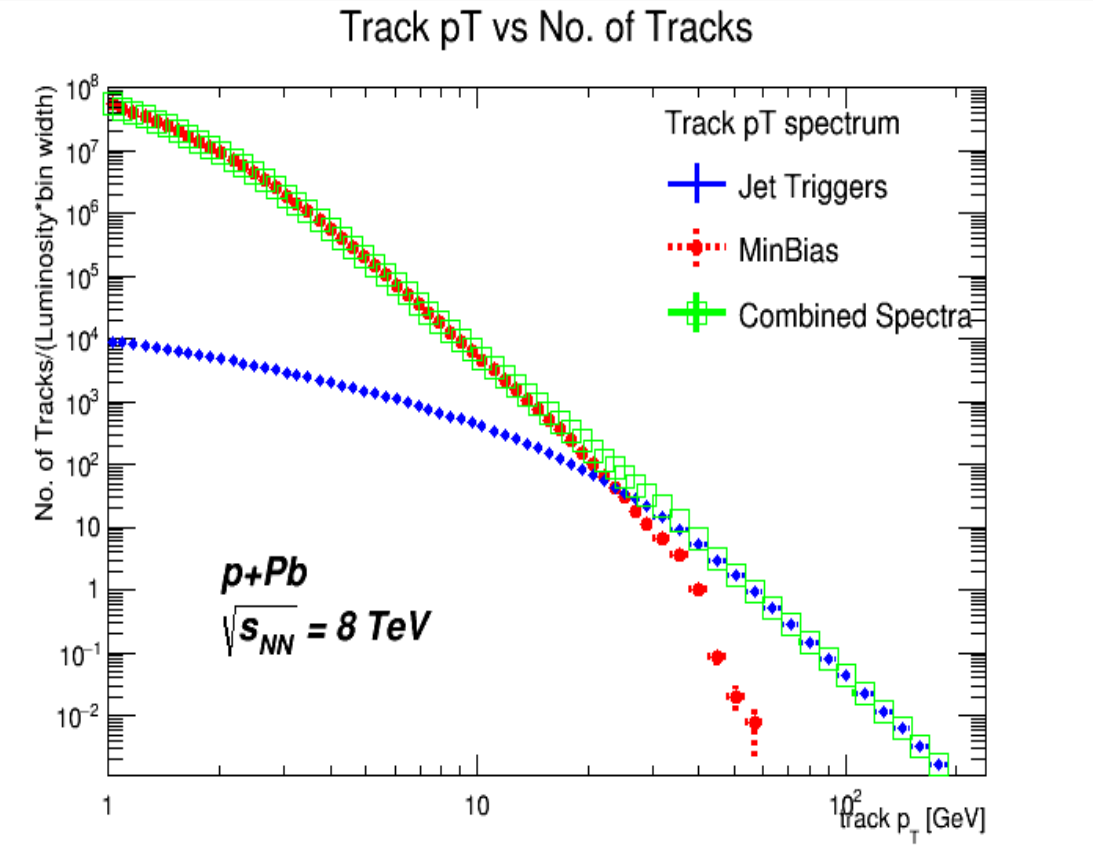

- Matching: Looking at tracks within $\Delta R \leq 0.4$
- MinBias: Doesn't use jets. But ratio at high $p_T$ goes to 1.
- Confirms the initial assumption: More than 99% of the tracks are part of a jet at high $p_T$.

# Results: Correlation between track $p_T$ and jet $p_T$




- Combination of several triggers with different energy thresholds.
- More tracks and jets at low $p_T$.
- Record all events with high $p_T$. (They're *rare*.)
- Energy conservation in high $p_T$ region.
- Histogram properly normalized, so we don't see the triggers in the plot.

# Results




- Spectrum for jet triggers, MinBias triggers and combined.
- Combined spectra: *Unbiased*. Seamless transition.
- Ten orders of magnitude measurement!!!
- Use of jet triggers allows to measure spectrum at high $p_T$.

# Conclusion

# Conclusion

- These are the *first* real results of p+Pb collisions at 8 TeV recorded with the ATLAS detector in Nov-Dec, 2016. Groundbreaking! ;)
- Lot more work is needed to work out losses and systematic uncertainties.
- By comparing the hadron spectra in p+Pb relative to pp, we can study the properties and effects of QGP.
- Learned about ROOT, triggers and physics of heavy ions.

# Take Home

Quark-Gluon Plasma is currently a HOT topic and still a lot has to be discovered about it!


Thank You!