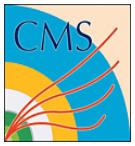


Analysis of Z + jet events in proton-lead collisions with the CMS detector

Qifei Gu

Supervisors: Lamia Benhabib, Krisztian Krajczar and Gabor Veres

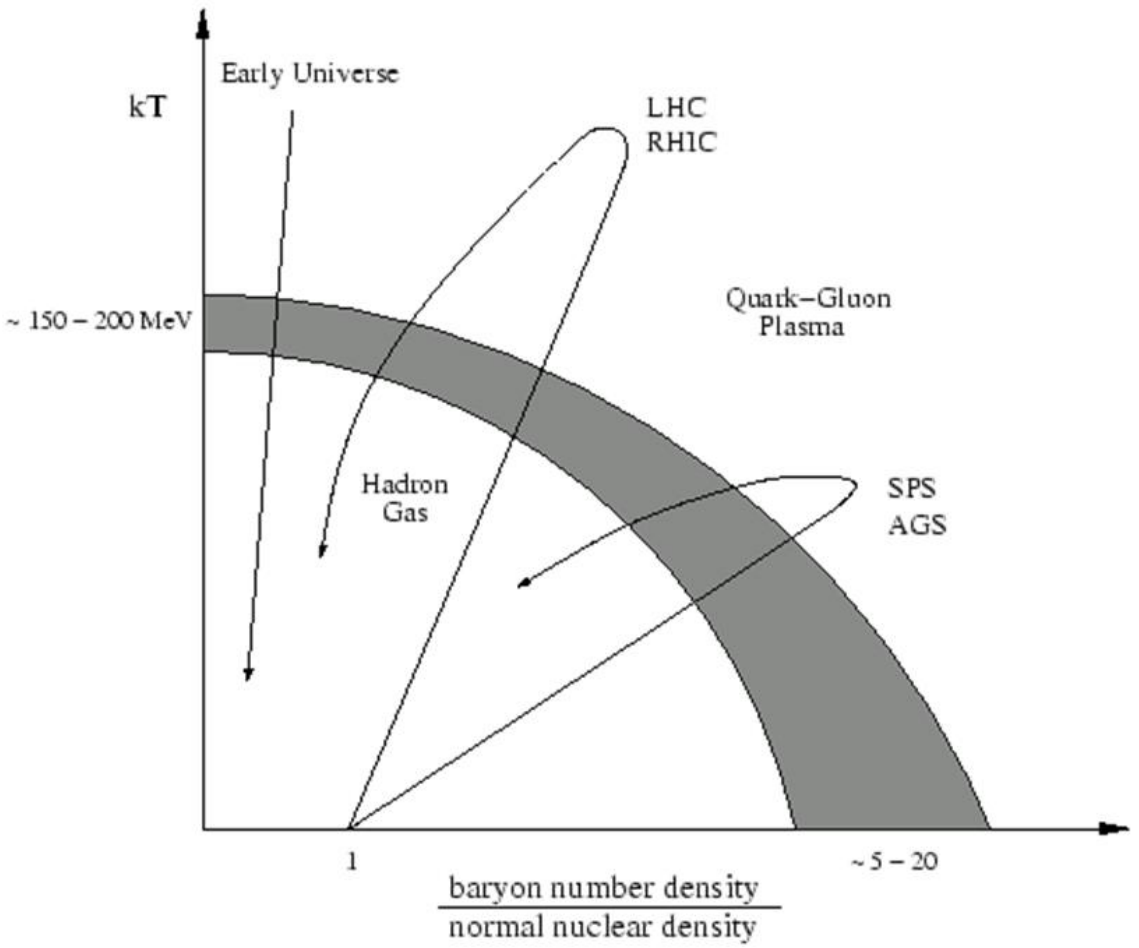
CERN Student Session
14th August 2014

Contents

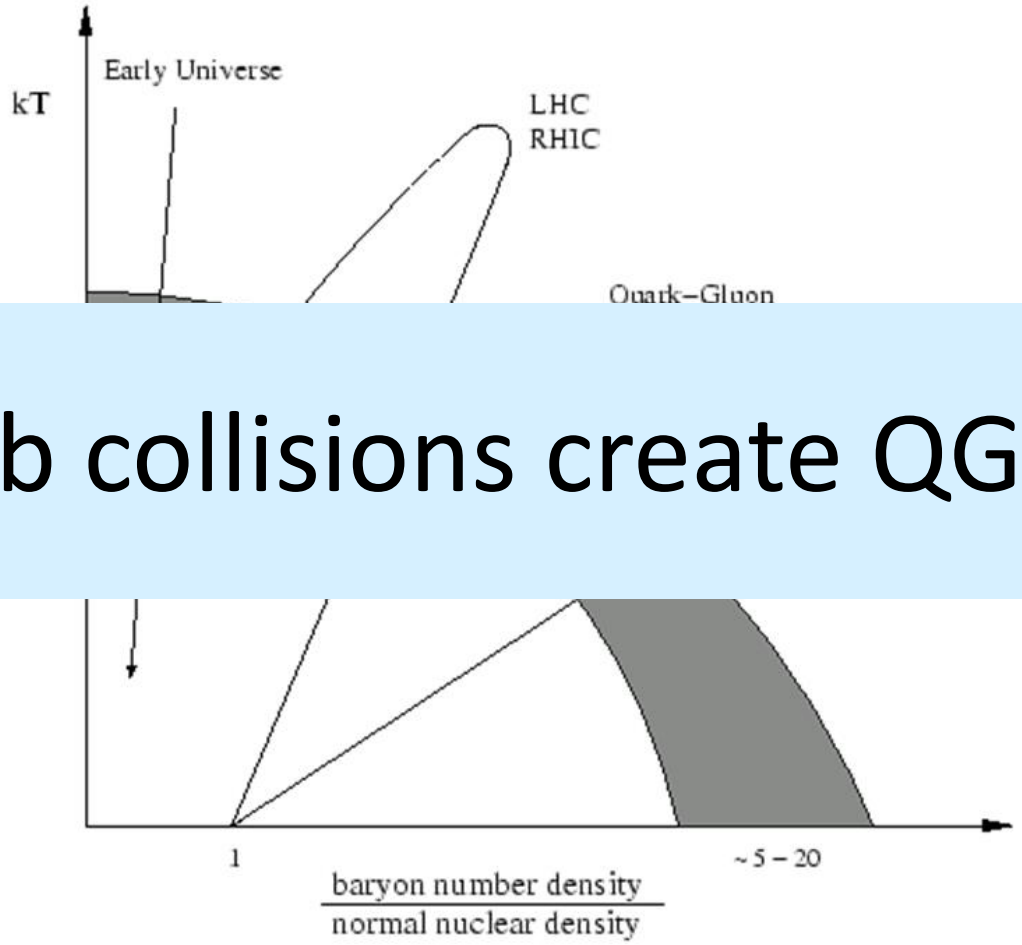
- Motivation for colliding heavy ions
- Z^0 + jet events in pPb collisions to study jet quenching
- Event selection for Z^0 + jet pair
- Preliminary results

Why collide heavy ions?

- LHC collides pPb and PbPb.
- In PbPb collisions, we have many nucleon-nucleon interactions at TeV energies.
  - We create a new state of matter, the quark-gluon plasma (QGP).
  - QGP was present in the early universe.
- Partons in the QGP subsequently hadronise to form particles and jets.
  - Use these remnants to probe the QGP.



Phase diagram for QGP [1]

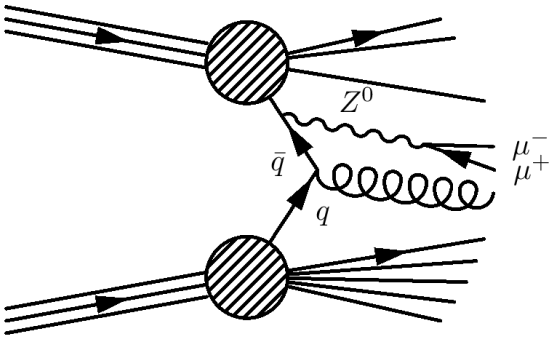


Do pPb collisions create QGP?

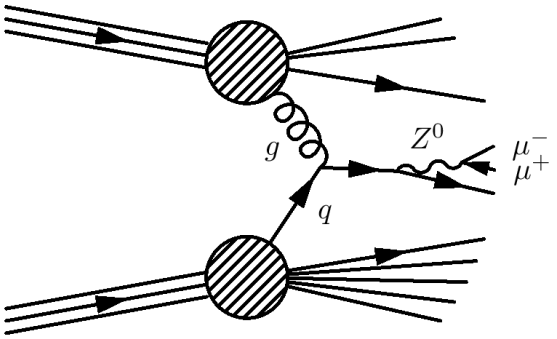
Phase diagram for QGP [1]

Z^0 + jet from pPb to study jet quenching

- The QGP is strongly interacting.
- Jets (partons) that travel through the QGP interacts with the medium, and loses energy -> jet quenching.
- Z^0 + jet event is a clear channel to study jet quenching.
  - Jets are affected by QGP but Z^0 bosons are not.
  - Clean signal for Z^0 as it decays to two oppositely charged muons.



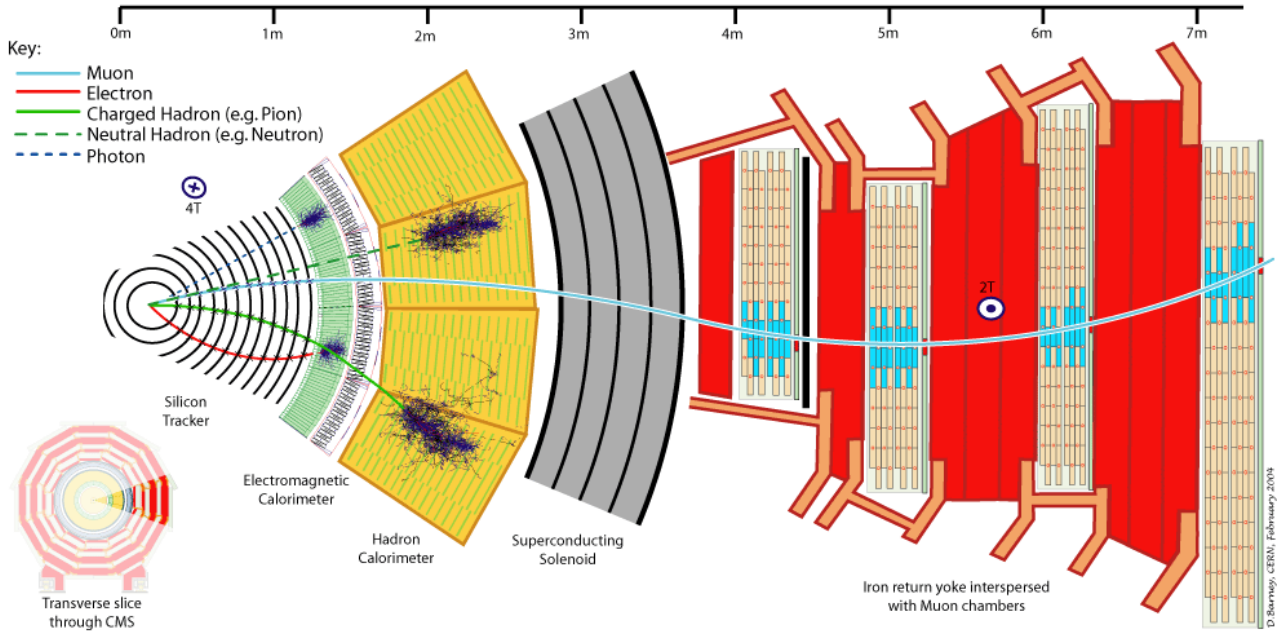
pPb->$q\bar{q}$->Z^0->μ^+ μ^- + gluon jet [2]



pPb->qg->Z^0->μ^+ μ^- + quark jet [3]

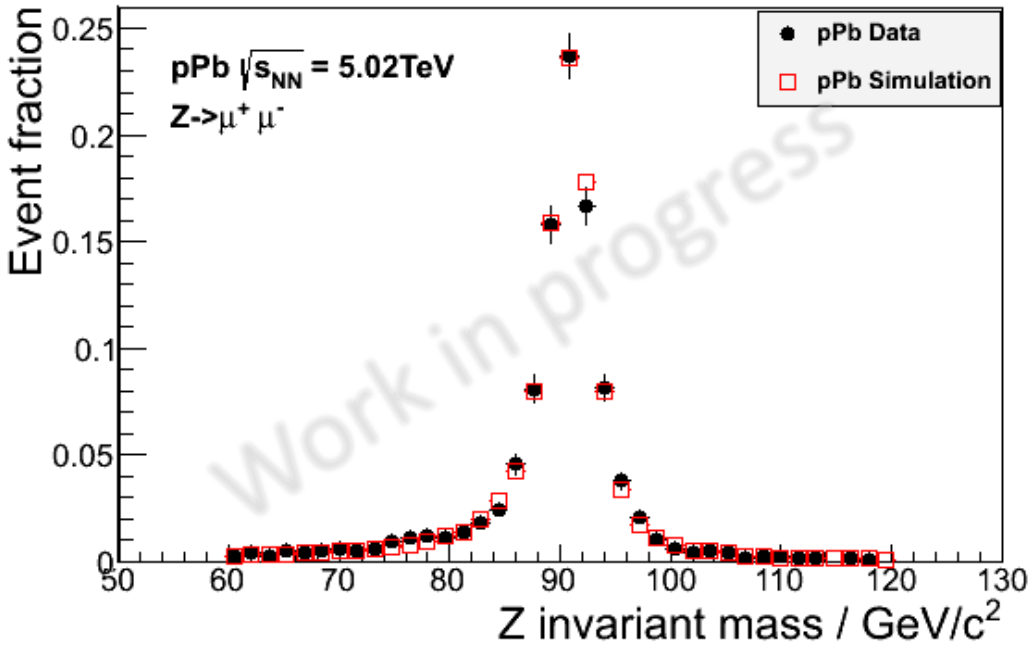
Event selection for pPb->Z^0->μ^+ μ^- + jet

- Data from pPb at $\sqrt{s_{NN}} = 5.02\ \mathrm{TeV}$ taken in Jan. and Feb. 2013.
- Z^0 reconstruction from two muons:
  - Apply standard "good muon" selections.



Slice of CMS detector [4]

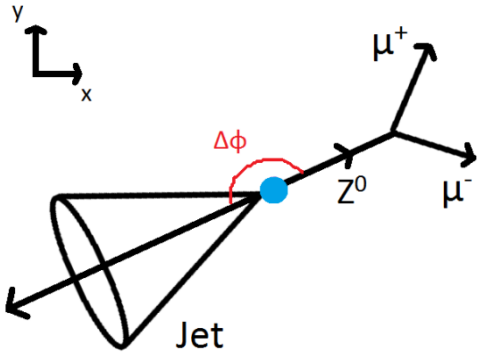
- Further selections for Z^0 :
  - Two muons oppositely charged.
  - Cut on muon transverse momentum ($p_{T,\,muon} > 20$ GeV).
  - Invariant mass of Z between 60 and 120 GeV.



- Compare data to simulation.
- Simulation - PYTHIA embedded in simulated pPb.
  - No QGP effects included.

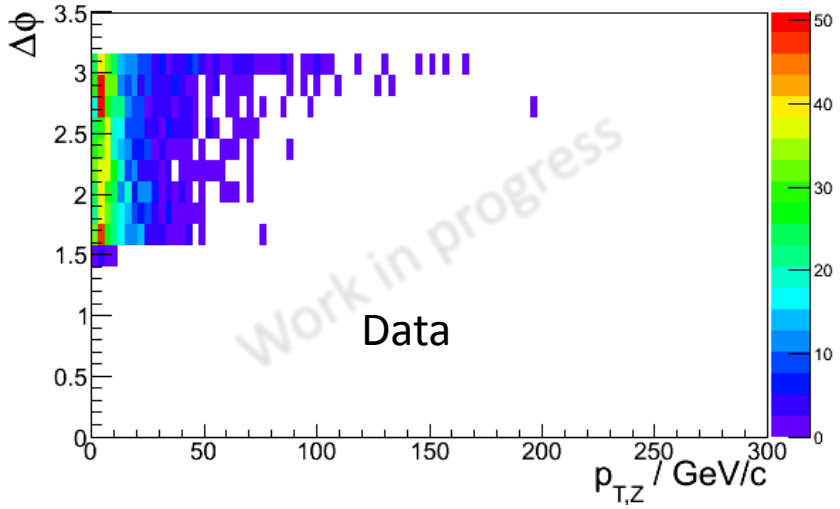
Z^0 and jet correlations

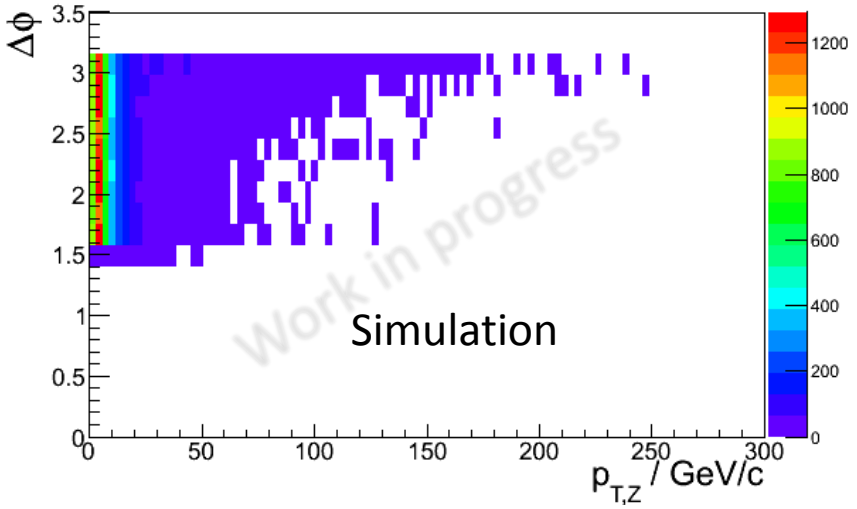
- Now have Z^0, find corresponding leading-jet* from the same interaction.
- Consider particle flow jets.
- Jets with $p_{T,\ jet} > 25$ GeV and $|\eta_{jet}| < 2.1$.

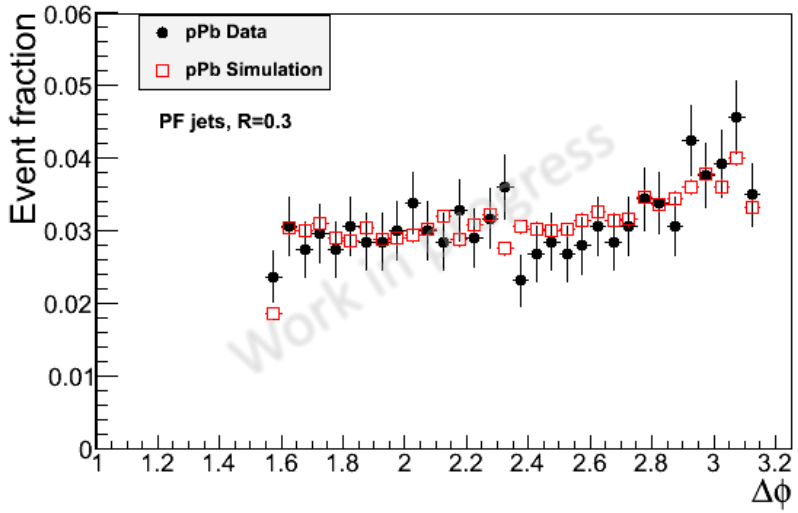


- pPb collide along the z-axis – no momentum component in transverse (xy) plane.
  - Expect correlation Z^0 + jet to have $\Delta\phi = |\phi_{jet} - \phi_Z| \approx \pi$.
- **Selection: Consider pairs that have $\Delta\phi = |\phi_{jet} - \phi_Z| > \pi/2$.**

*Jet with the highest p_T.

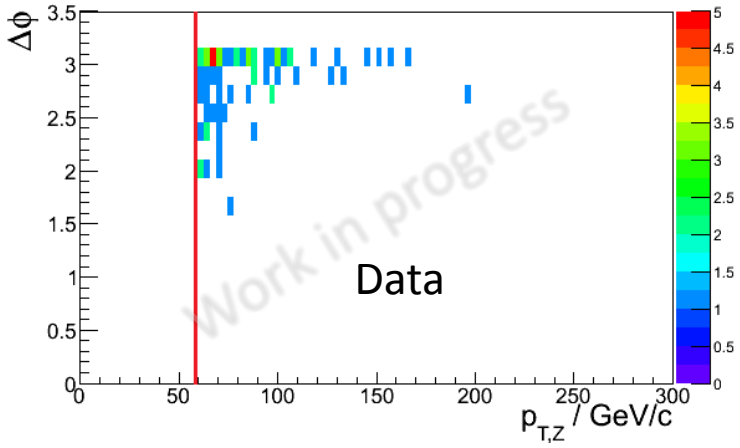


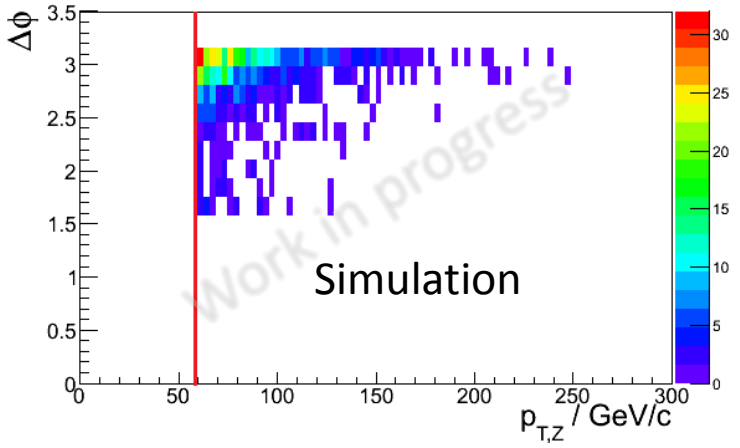


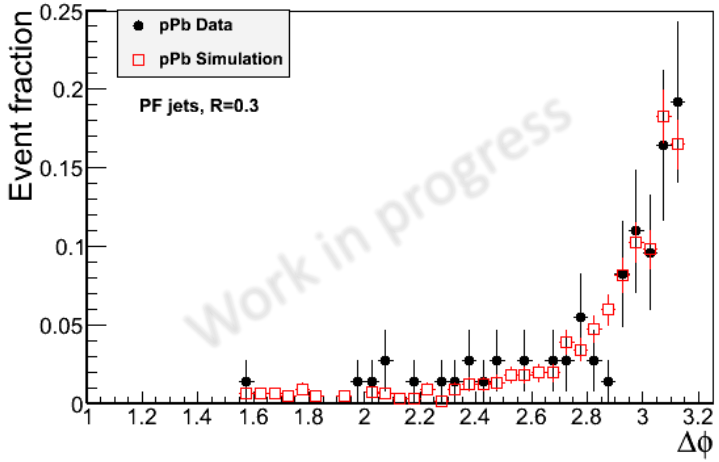


- Slight correlation between Z and jets seen at $\Delta\phi = \pi$.

Motivation for $p_{T,Z}$ > 60 GeV cut



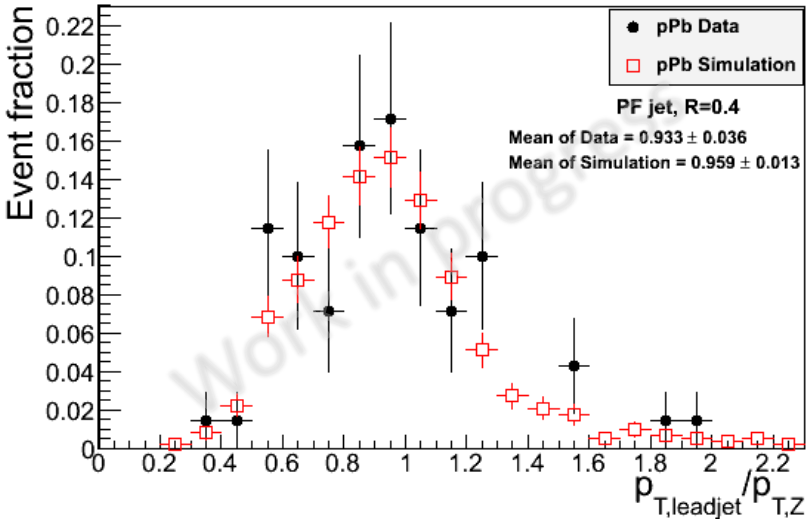


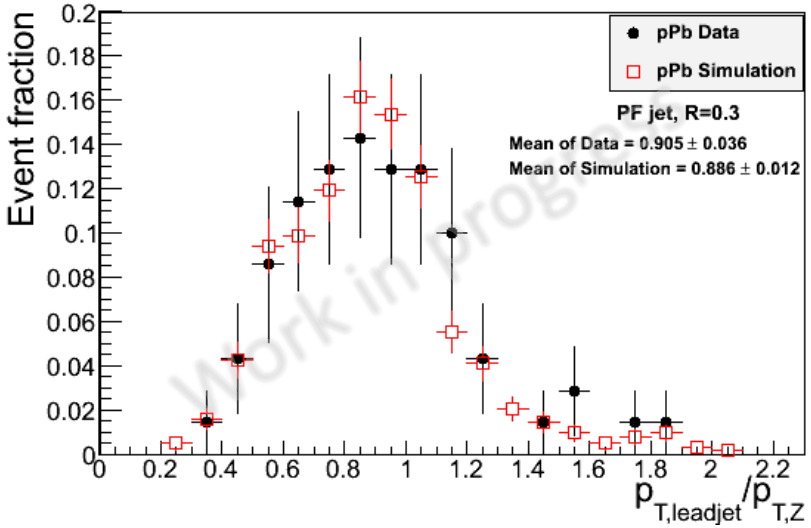


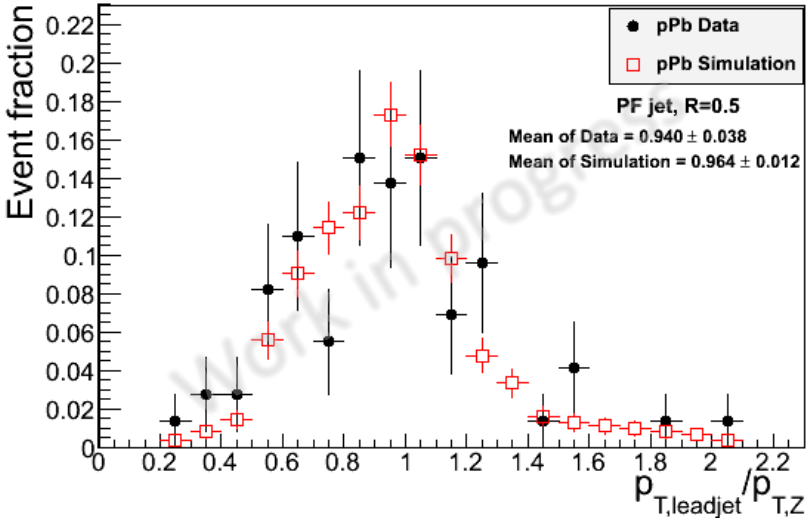
- The $p_{T,Z}$ > 60 GeV cut gives much better back-to-back correlation.

Jet quenching - p_T imbalance

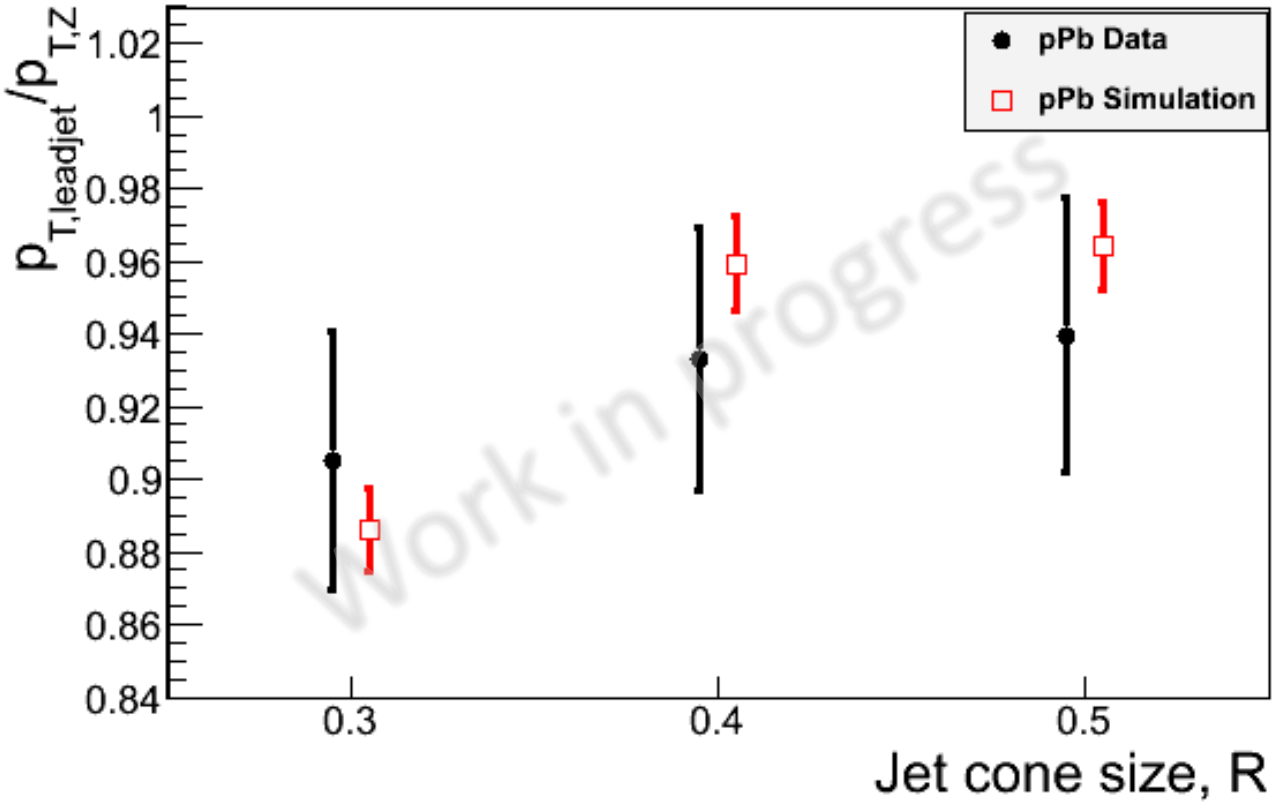
- Final selection, Z^0 and leading jets that have $\Delta\phi > 2\pi/3$.
- Calculate the p_T imbalance, $p_{T,\,jet} / p_{T,\,Z}$.







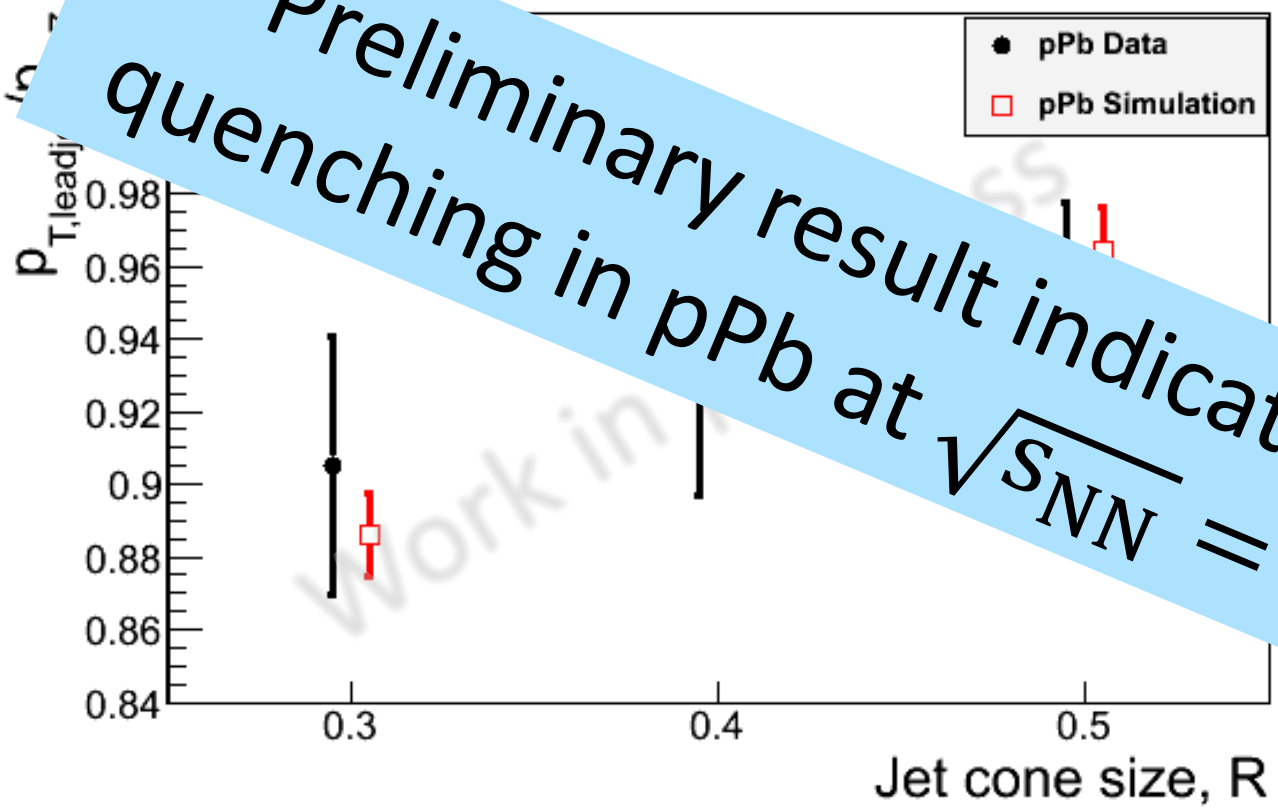
Mean p_T imbalance



Event selection summary:

- $p_{T,\,muon} > 20$ GeV
- 60 GeV < M_Z <120 GeV
- $p_{T,\,jet} > 25$ GeV
- $|\eta_{jet}| < 2.1$
- $\Delta\phi = |\phi_{jet} - \phi_Z| > \pi/2$
- $p_{T,\,Z} > 60$ GeV
- $\Delta\phi > 2\pi/3$

Mean p_T imbalance



Event selection summary:

- $p_{T,\,muon} > 20$ GeV
- 60 GeV < M_Z <120 GeV
- $p_{T,\,jet} > 25$ GeV
- $|\eta_{jet}| < 2.1$
- $|\phi_{jet} - \phi_Z| > \pi/2$

Preliminary result indicates no jet quenching in pPb at $\sqrt{s_{NN}} = 5.02$ TeV.

Further improvements

- More optimized selections to find the Z^0 + jet pair.
- Search for fake jets.
  - E.g. high p_T muons that are identified as a jet.
- Consider systematic uncertainty.
  - In muon selection.
  - Background muon contributions to Z^0.
  - Jet energy scale corrections.


Disclaimer:

All data shown are preliminary.

Not officially approved by CMS.


Thank you for your attention!

Image references

[1] QGP phase diagram:
http://www.hep.lu.se/staff/tydesjo/physics/theses/lichtml/node4.html
Feynman diagrams of Z + jet events
[2] http://www.physik.uzh.ch/~che/FeynDiag/Details.php?code=40000001
[3] http://www.physik.uzh.ch/~che/FeynDiag/Details.php?code=40000011
CMS detector slice
[4] http://upload.wikimedia.org/wikipedia/commons/8/8a/CMS_Slice.gif