Charged-particle nuclear modification factor in PbPb collisions using the ANGANTYR model

Robert Pierrard

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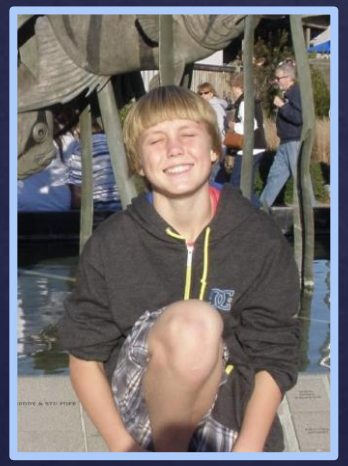
Group Context

Robert → Vanderbilt's Heavy Ion Group → CMS Collaboration → CERN



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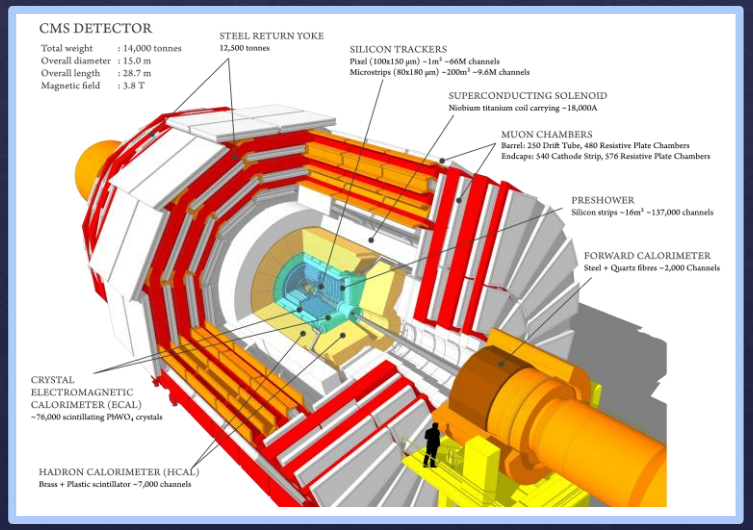
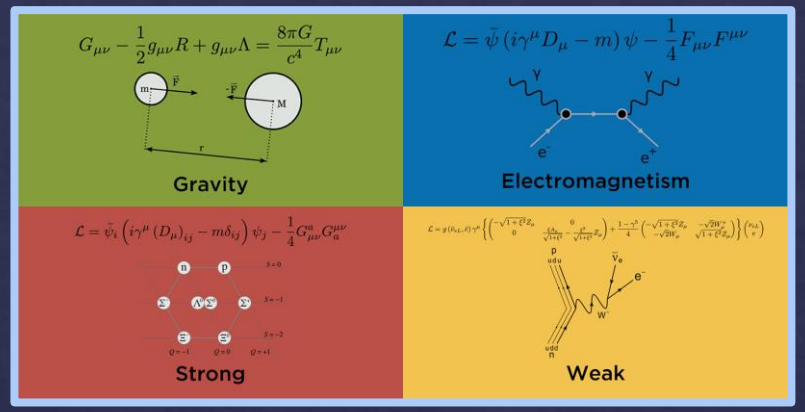
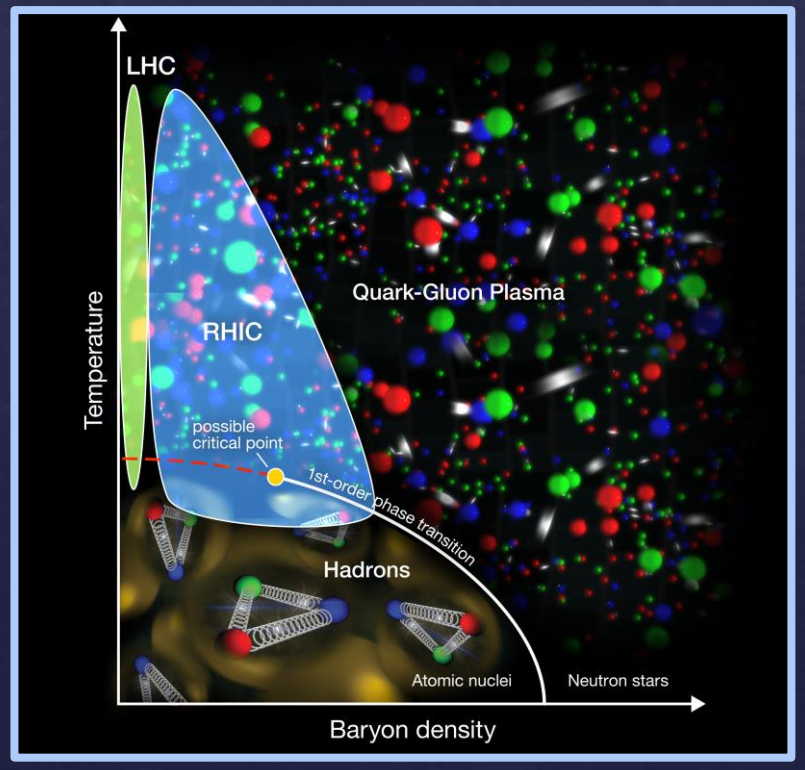




https://briankoberlein.com/blog/four-horsemen/



http://sites.coloradocollege.edu/pc357ml/2014/04/10/the-quark-gluon-plasma/

An exotic state of matter

- Quark-gluon plasma (QGP) is a state of matter where particles (quarks and gluons) are freed from the strong interaction.
- QGP is produced with immense heat or pressure.
  - $T > 150\ MeV/Particle\ \simeq 1.66 \cdot 10^{12} K$
  - Production requires smashing heavy ions (Pb or Au) together at near luminal speeds.
- Alternatively, we can simulate these collisions with various simulation programs.
  - I am using Pythia8 and more specifically the ANGANTYR model within it.

Goals

- "Help uncover the universe and how it works."
  - The strong nuclear force.
- Test a newly established model known as ANGANTYR.
- Calculate the charged particle nuclear modification factor (R_{AA}) using ANGANTYR.
- (Personally) - Develop an understanding of a computationally intensive research experience.

Methods

Use ANGANTYR model to simulate pp and PbPb collisions

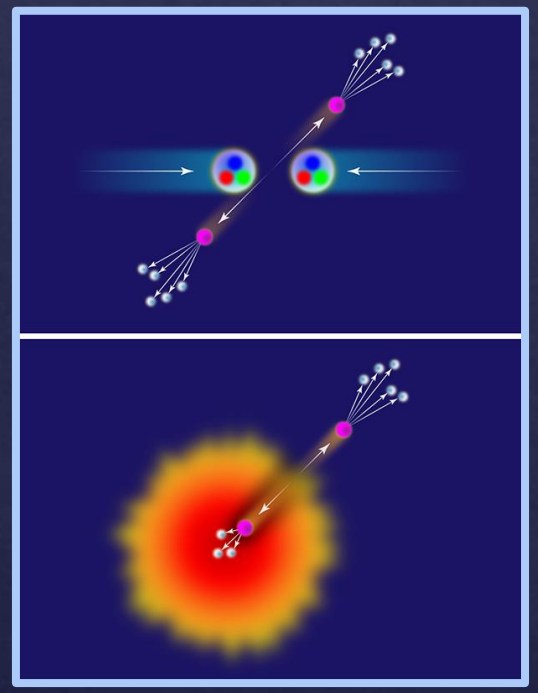
Extract relevant parameters from raw collision data

Use ROOT to process data and produce figures

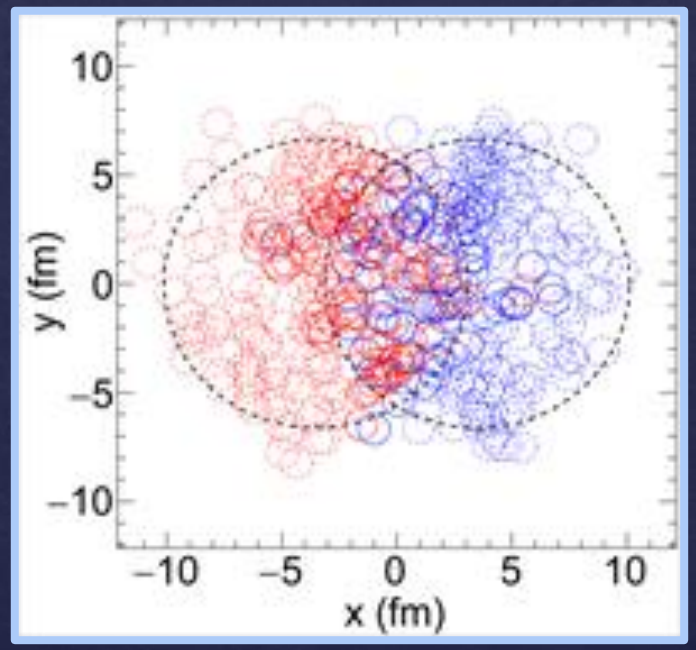
Compare data and figures from simulations with real CMS data.

Some relevant parameters

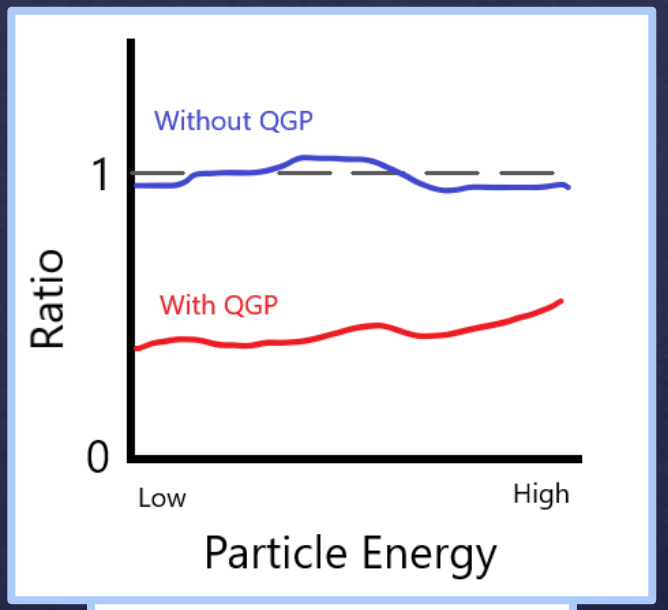
Jet Quenching



Number of Collisions



Nuclear Modification Factor (R_{AA})



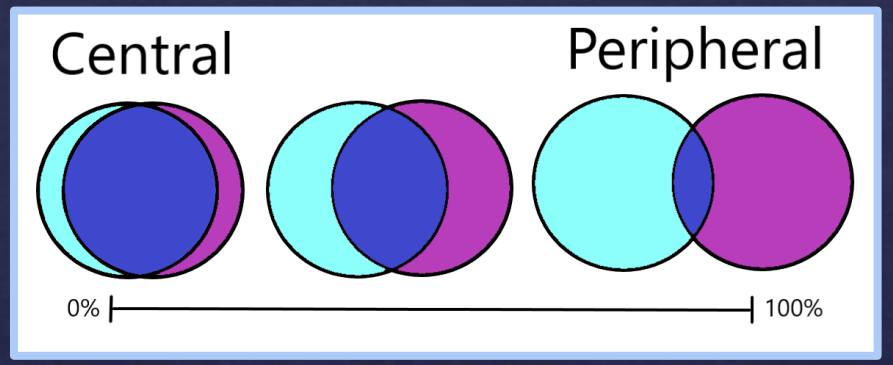
$$R_{\mathrm{AA}} = \frac{Y_{\mathrm{AA}}}{N_{\mathrm{coll}} Y_{\mathrm{pp}}}$$

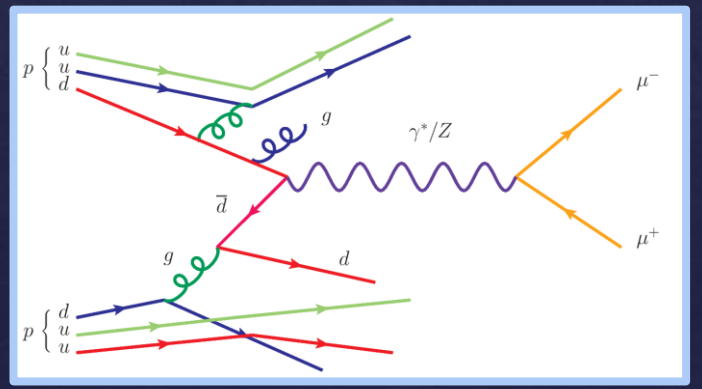
Challenges Faced

- Discovered “number of collisions” in the ANGANTYR model is incorrect
  - Used CMS data as a replacement.
- Processing extremely large datasets.
  - Provide some info on processing times and data size.
- Knowledge gap, curiosity regarding underlying physics.

Centrality	$\langle N_{\mathrm{coll}} \rangle$	T_{AA} [mb^{-1}]
0–5%	1820^{+130}_{-140}	$26.0^{+0.5}_{-0.8}$
5–10%	1430^{+100}_{-110}	$20.5^{+0.4}_{-0.6}$
10–30%	805^{+55}_{-58}	$11.5^{+0.3}_{-0.4}$
30–50%	267^{+20}_{-20}	$3.82^{+0.21}_{-0.21}$
50–70%	$65.4^{+7.0}_{-6.6}$	$0.934^{+0.096}_{-0.089}$
70–90%	$10.7^{+1.7}_{-1.5}$	$0.152^{+0.024}_{-0.021}$
0–10%	1630^{+120}_{-120}	$23.2^{+0.4}_{-0.7}$
0–100%	393^{+27}_{-28}	$5.61^{+0.16}_{-0.19}$

Centrality





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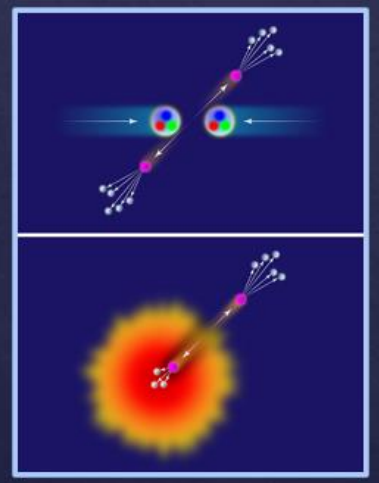
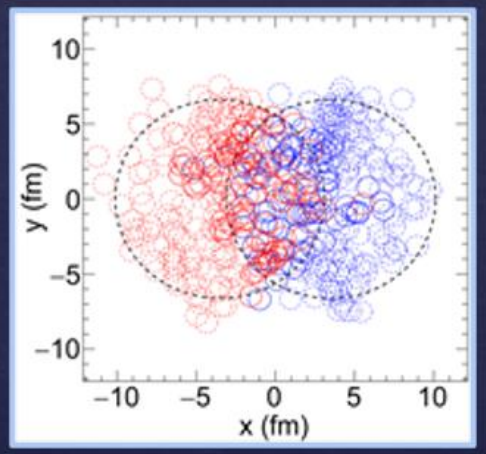
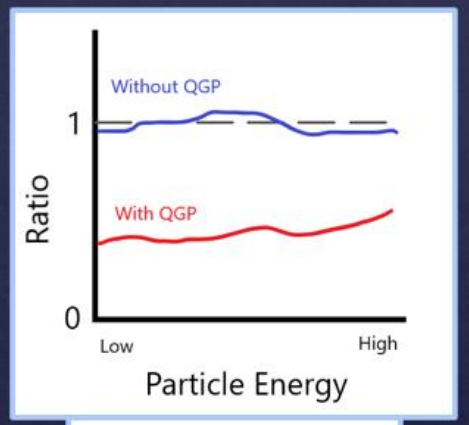


Number of Collisions

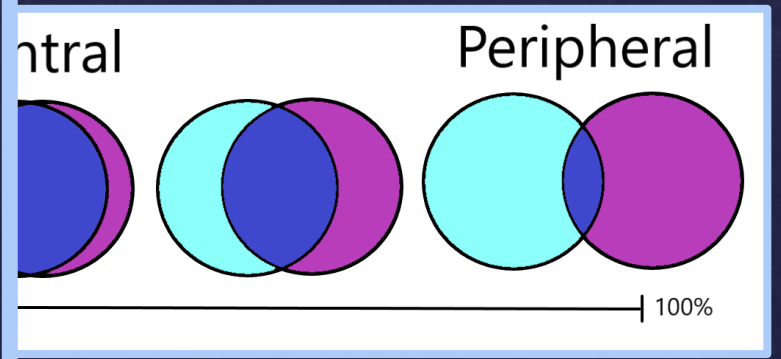


Nuclear Modification Factor (R_{AA})



$$R_{\mathrm{AA}} = \frac{Y_{\mathrm{AA}}}{N_{\mathrm{coll}} Y_{\mathrm{pp}}}$$

ntrality



Computational Requirements

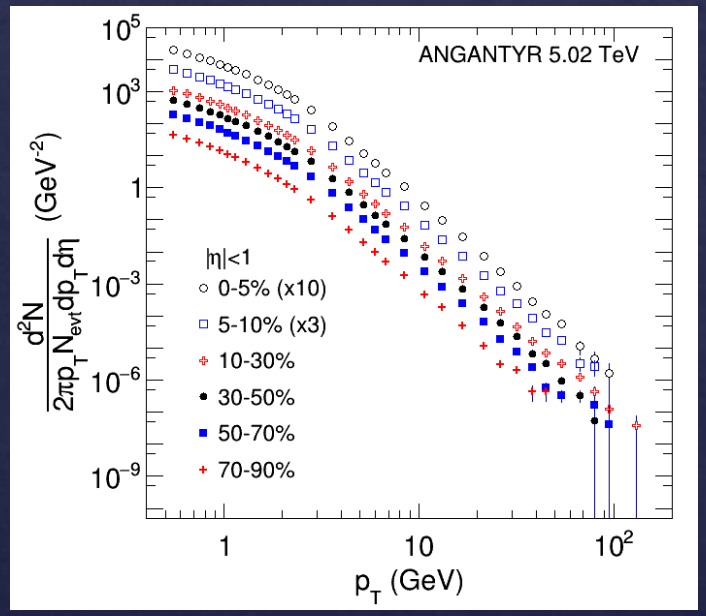
Event Generation:

- Raw data generated: 850 GB
- Total processing time: ~8,000 hours
- Number of jobs submitted: 700

+ more computation for data analysis.

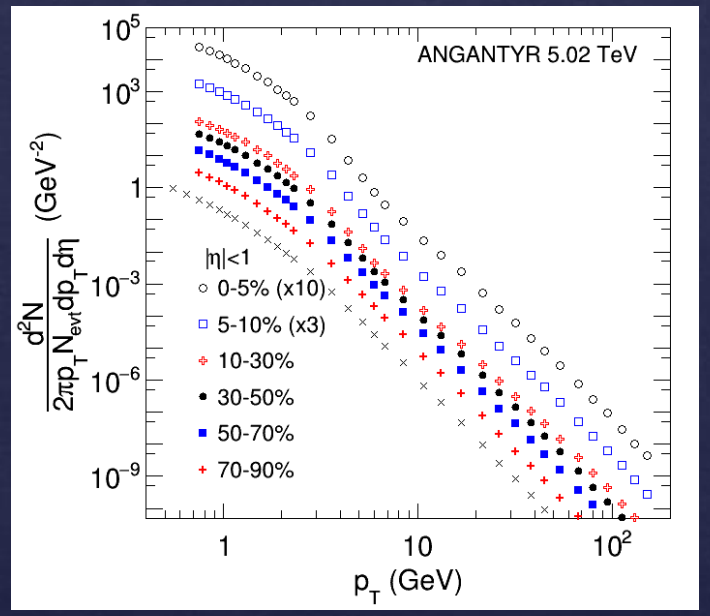
p_T Spectra Figures

Large Batch ANGANTYR

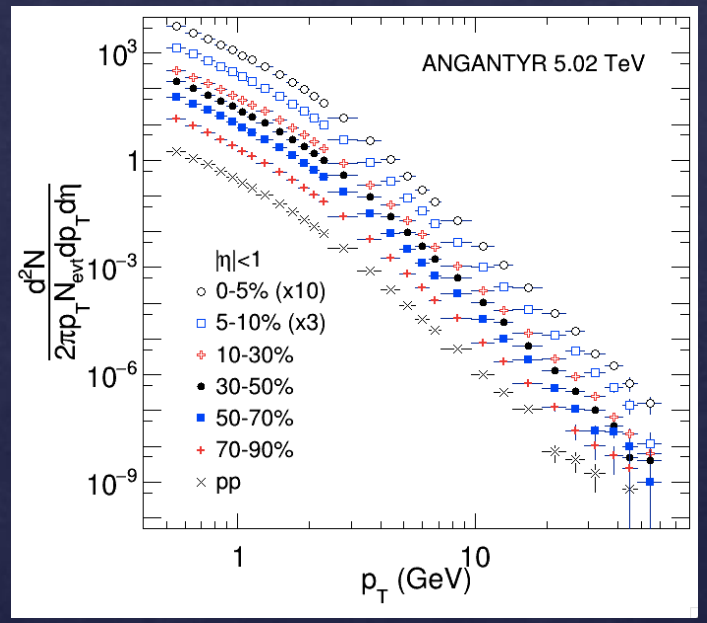


3.6 million events.

CMS Data



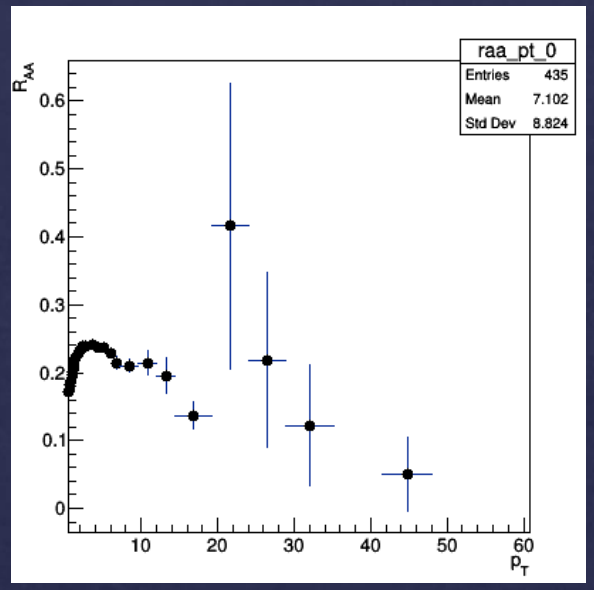
Small batch ANGANTYR

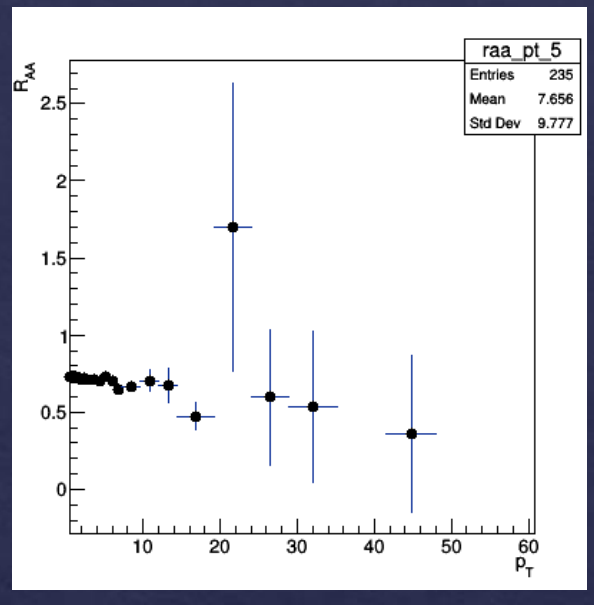


Much fewer events.

R_{AA} Figures

Small Batch ANGANTYR





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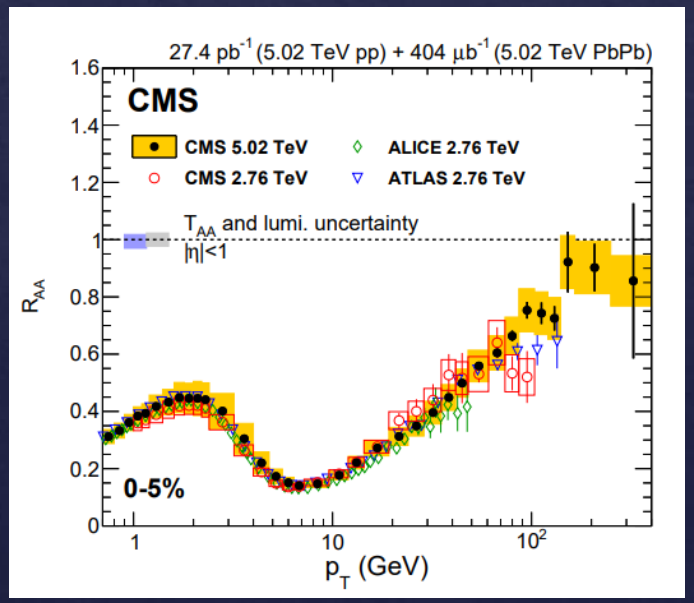

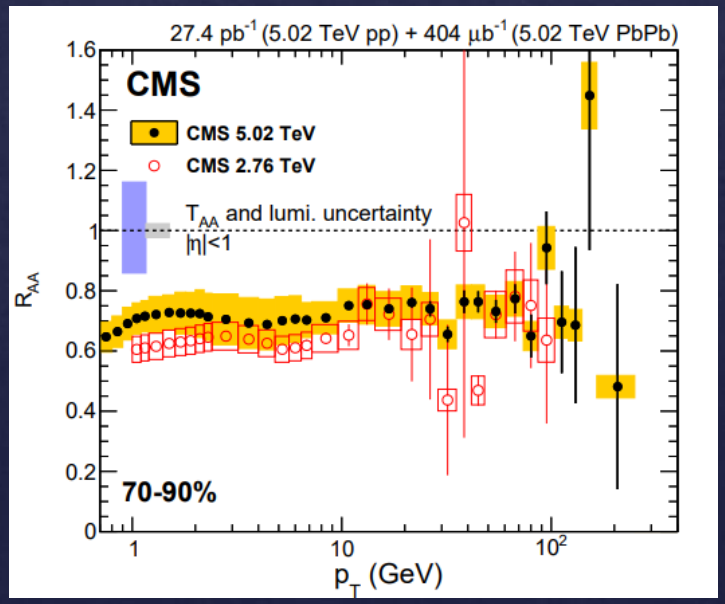

Additional Figures

- p_T spectra for pp collisions using large data set.
- R_{AA} using large data set.
- Relations between CMS figures and ANGANTYR produced figures.
  - Subtracting ANGANTYR R_{AA} from CMS R_{AA} ?
- Producing the same figures using etfwd as the centrality parameter.

Moving Forward

Summary/Context

Supplemental Slides

What is *ANGANTYR*?

- Monte-Carlo Glauber Model
- Direct extrapolation of high energy pp collisions.
- Collective effects are not simulated.