Centrality and p_T dependence of charged particle R_{AA} in *PbPb* collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

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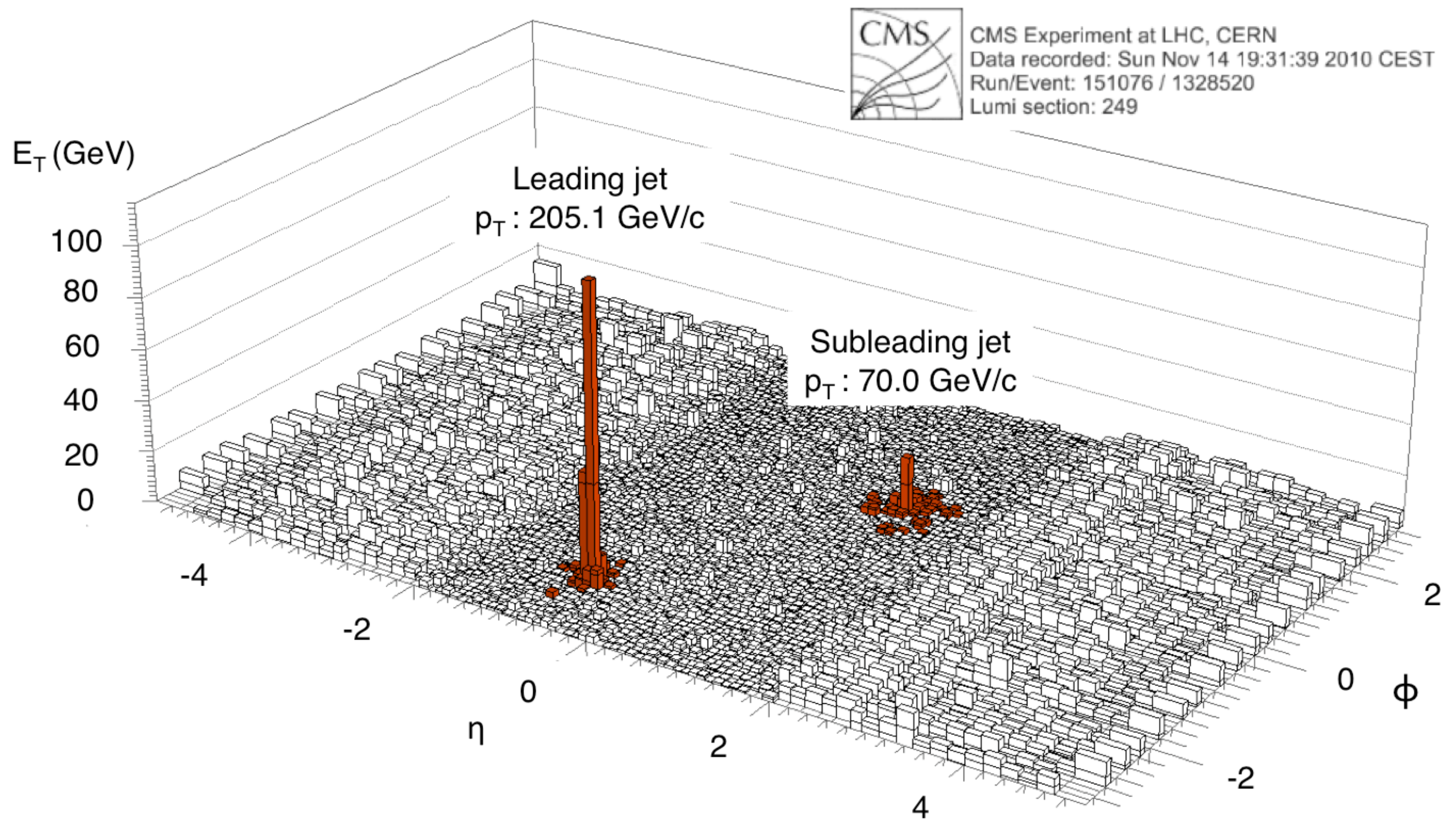
Nuclear Modification Factor

$$R_{AA} = \frac{d^2N_{AA}/dp_T d\eta}{\langle T_{AA}\rangle d^2\sigma_{pp}/dp_T d\eta} \sim \frac{\text{“QCD Medium”}}{\text{“QCD Vacuum”}}$$

- $R_{AA} > 1$ (enhancement)
- $R_{AA} = 1$ (no medium effect)
- $R_{AA} < 1$ (suppression)

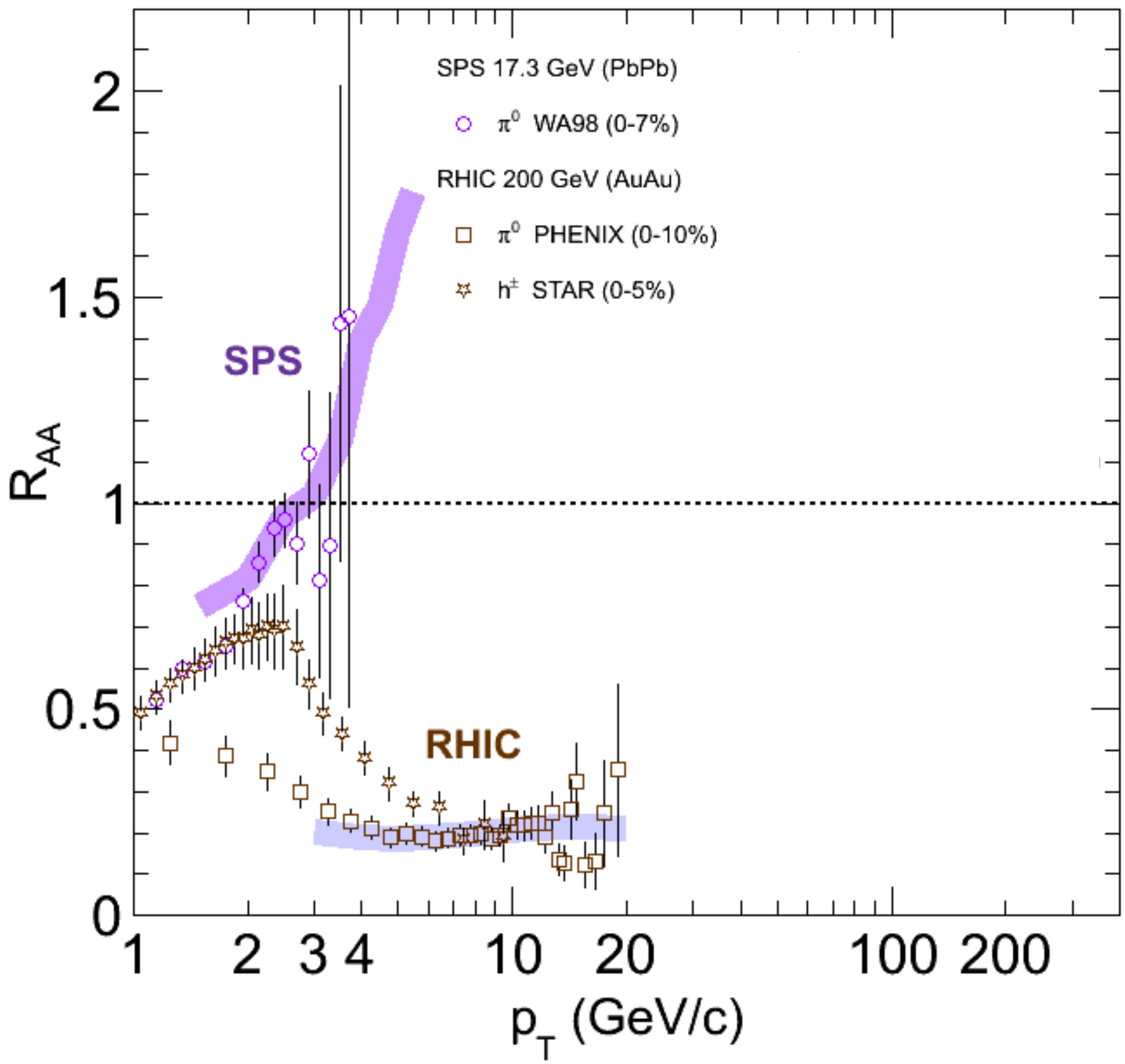
$$\langle T_{AA}\rangle = \langle N_{coll}\rangle / \sigma_{pp}^{inel}$$



arXiv:1102.1957

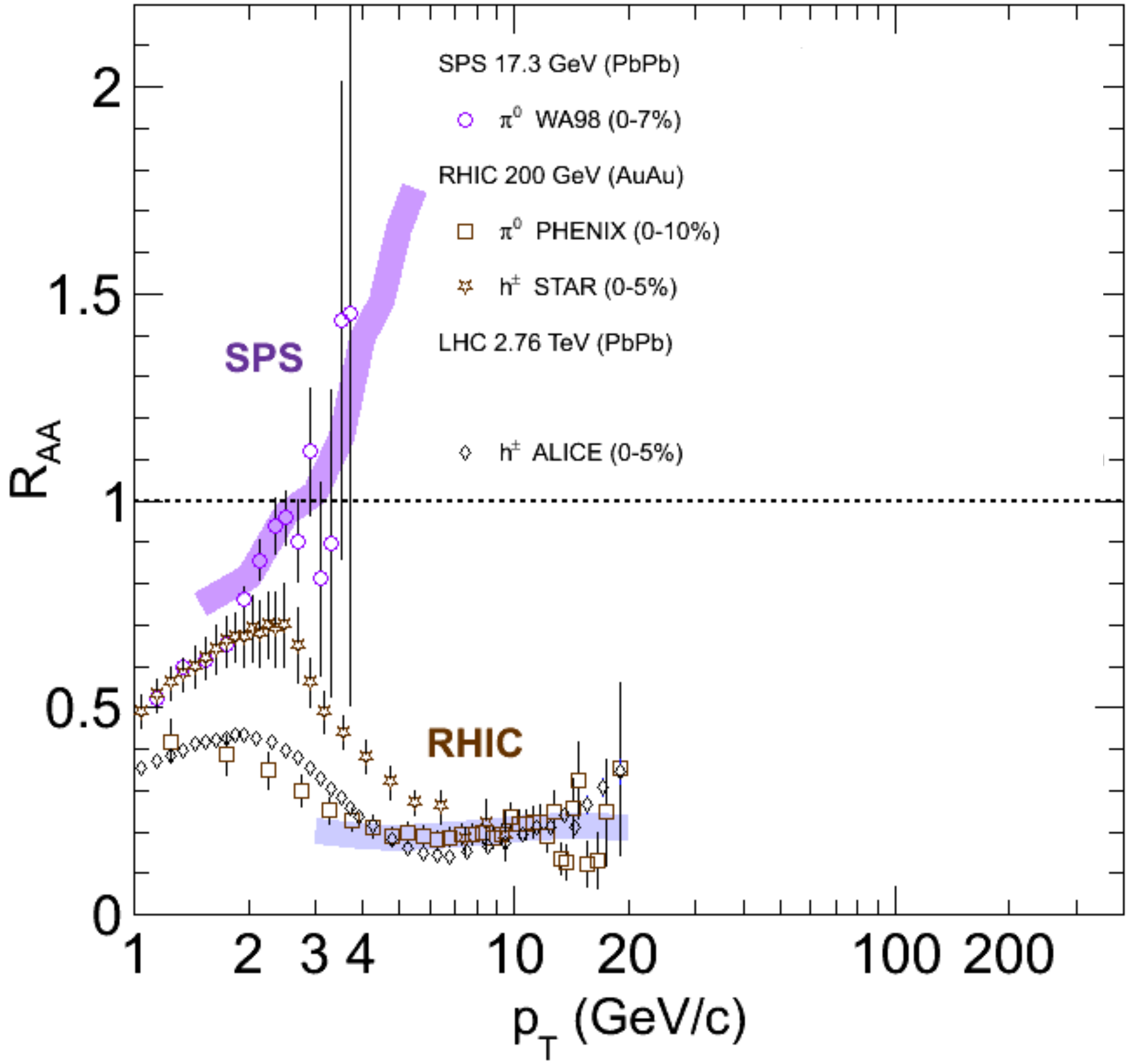
Tomographic access to medium properties via pQCD E-loss models

Current State of Knowledge



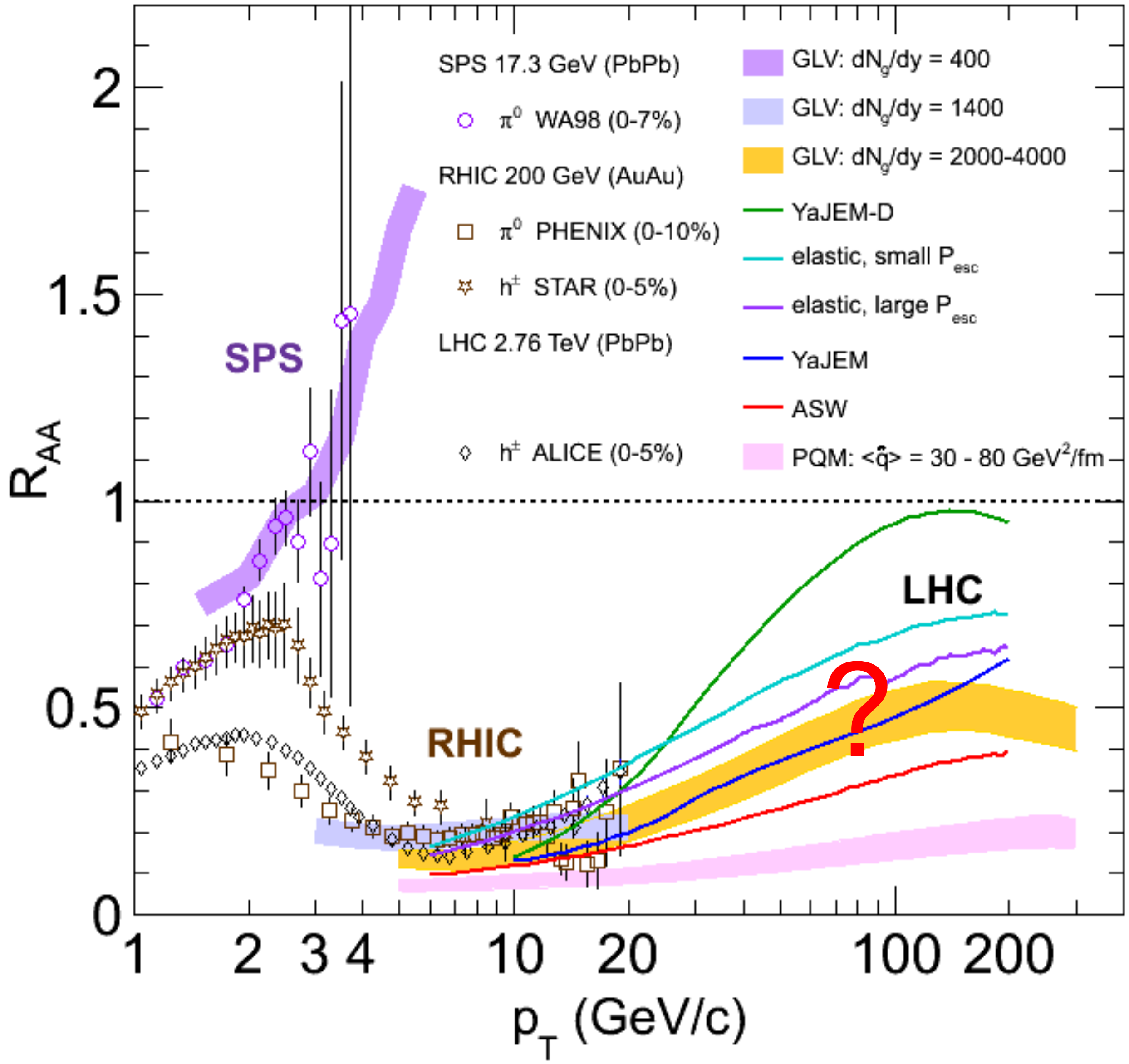
- At SPS, no suppression
- At RHIC, ~ x5 suppression above a few GeV/c
- Charged hadrons and neutral pion converging above ~8 GeV/c

Current State of Knowledge



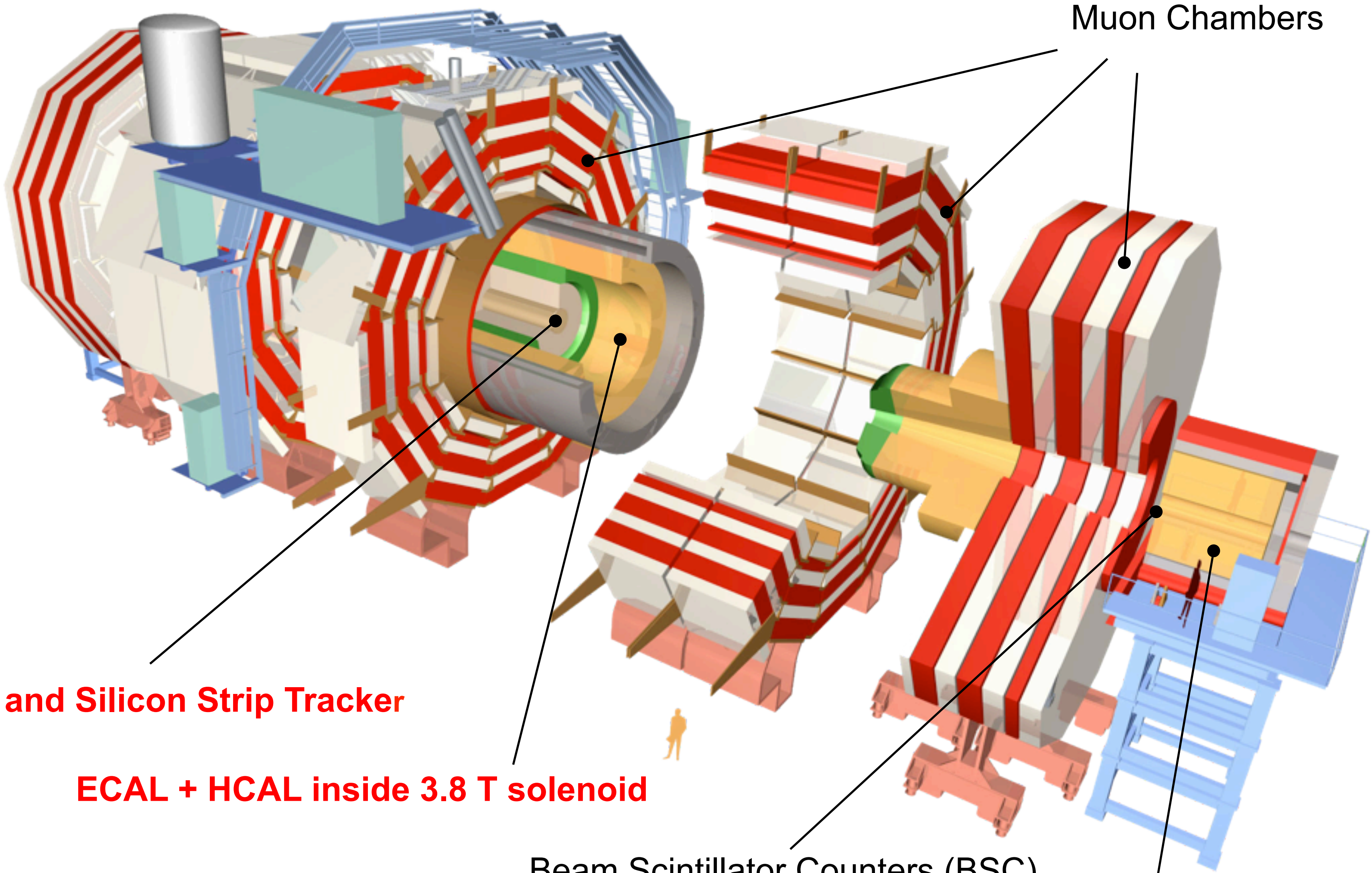
- At LHC, similar level of suppression above a few GeV/c
- (c.f. ALICE 2.76 TeV measurement of charged particle R_{AA} up to 20 GeV/c)
- Abundant high p_T charged particles beyond 20 GeV/c!

Current State of Knowledge



- R_{AA} is very sensitive to the details of the quenching parameters at high p_T
- CMS is capable of measuring single charged particle up to ~O(100) GeV/c

CMS Detector



Nuclear Modification Factor

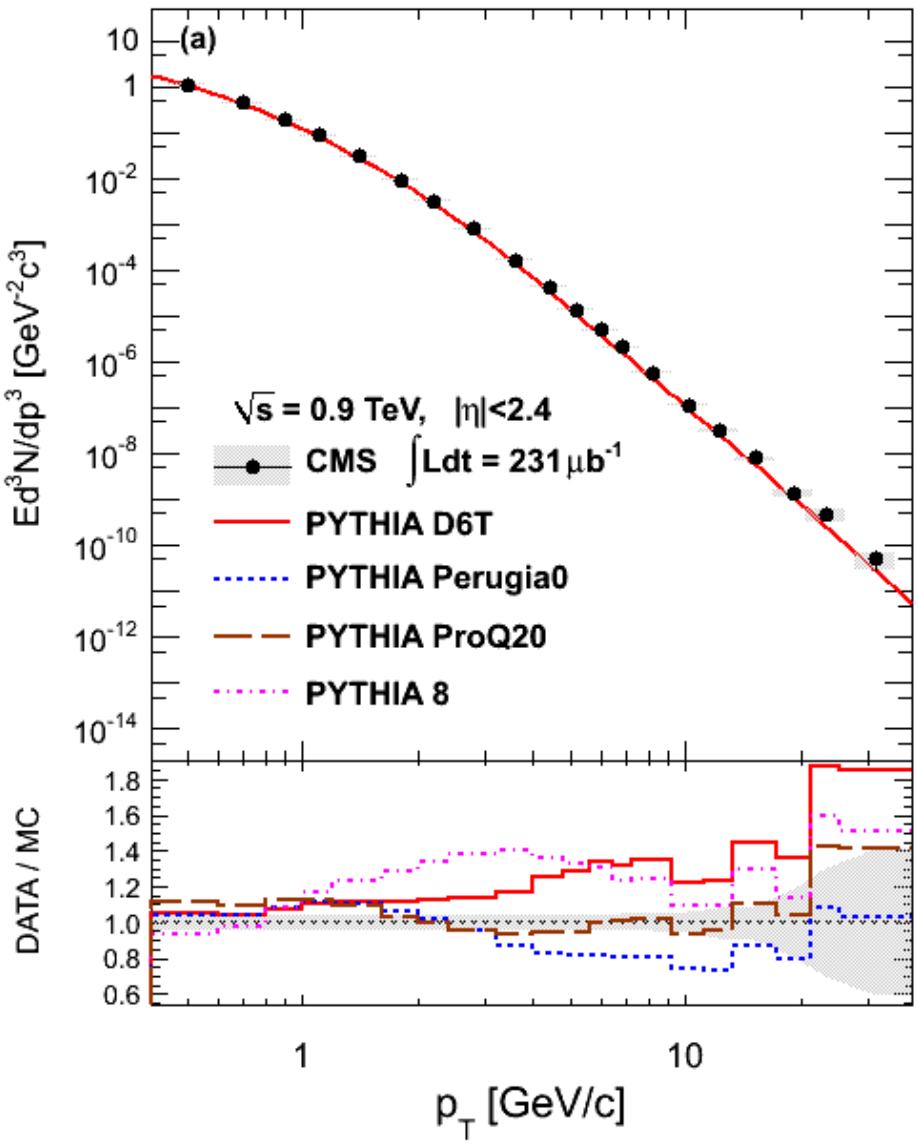
PbPb spectra (using minimum-bias and jet-triggers)

$$R_{AA} = \frac{d^2N_{AA}/dp_T d\eta}{\langle T_{AA}\rangle d^2\sigma_{pp}/dp_T d\eta}$$

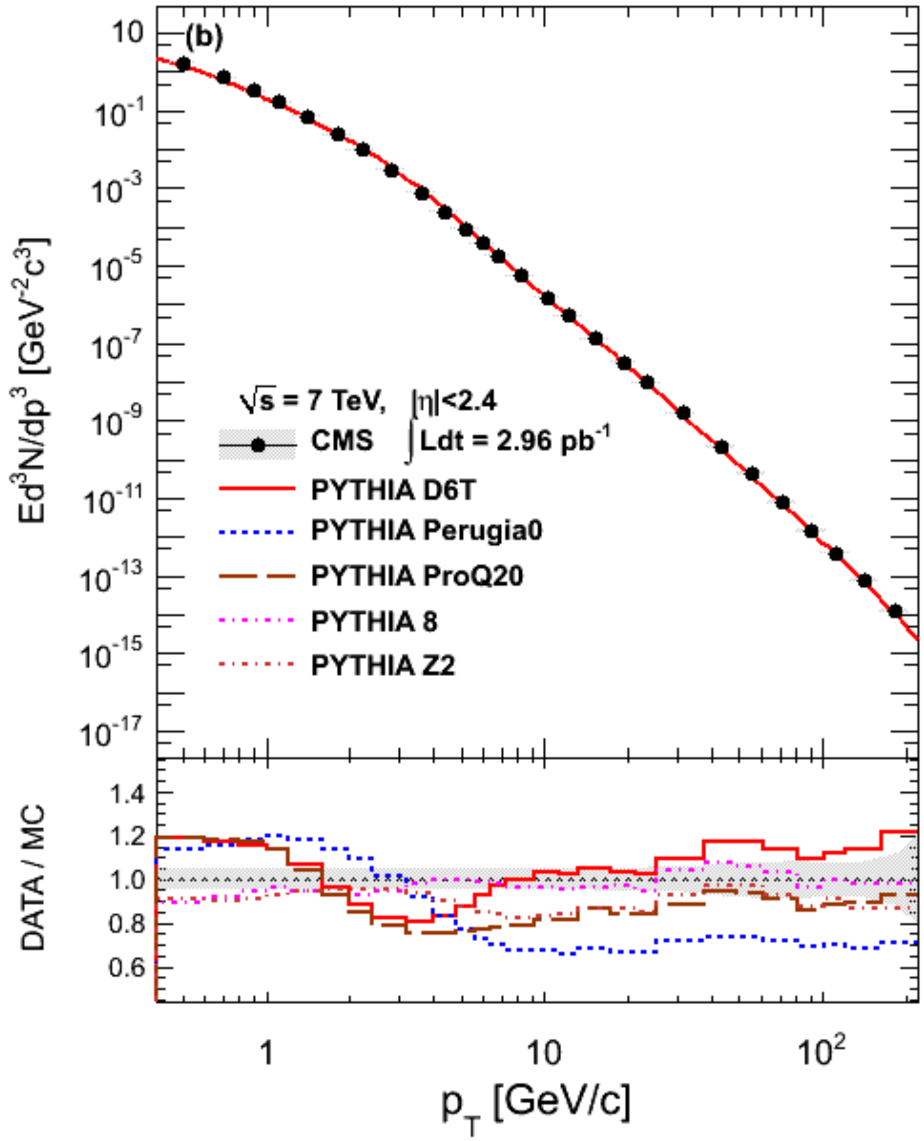
pp reference spectrum (using minimum bias and jet-triggers)

Charged Particle Spectra in *pp*

$\sqrt{s}$ = 0.9 TeV



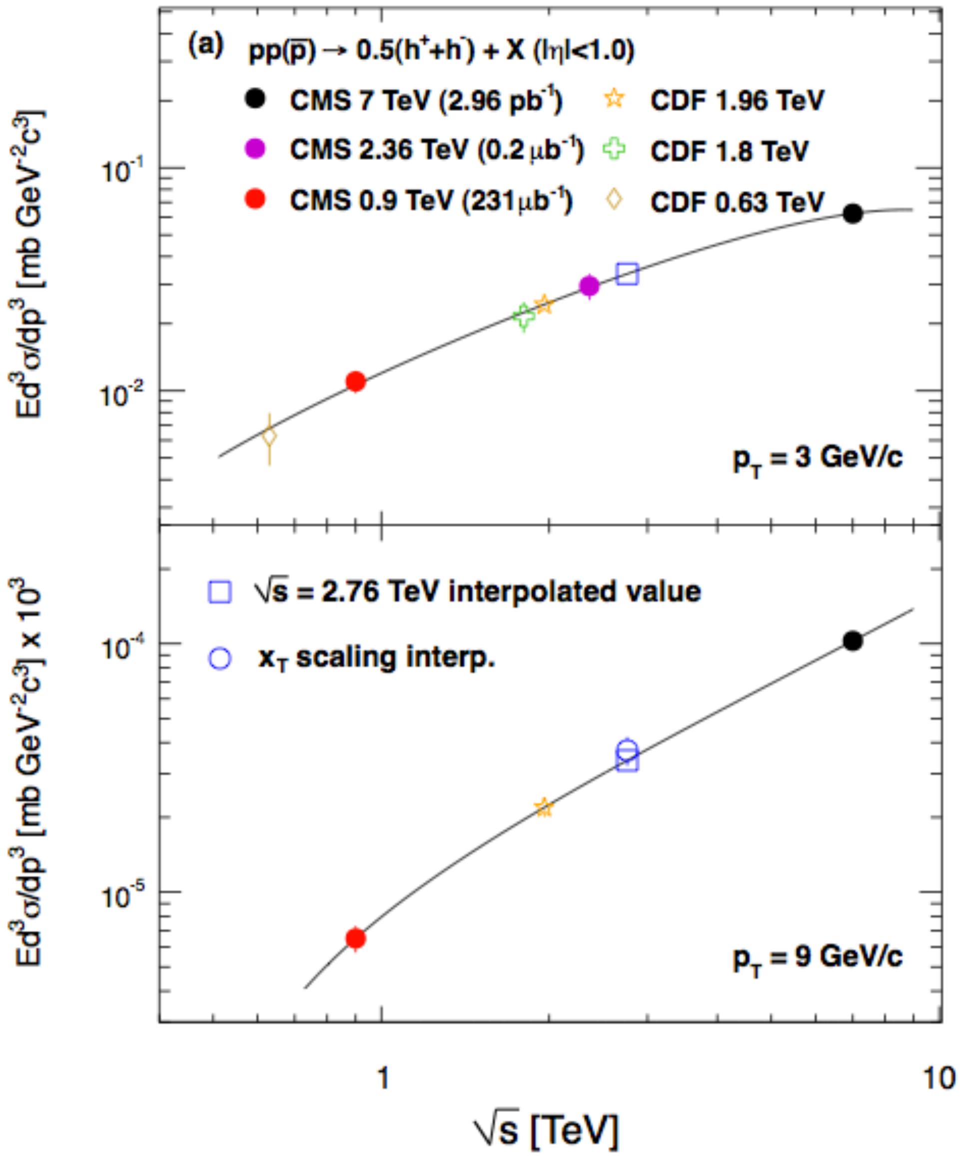
$\sqrt{s}$ = 7.0 TeV



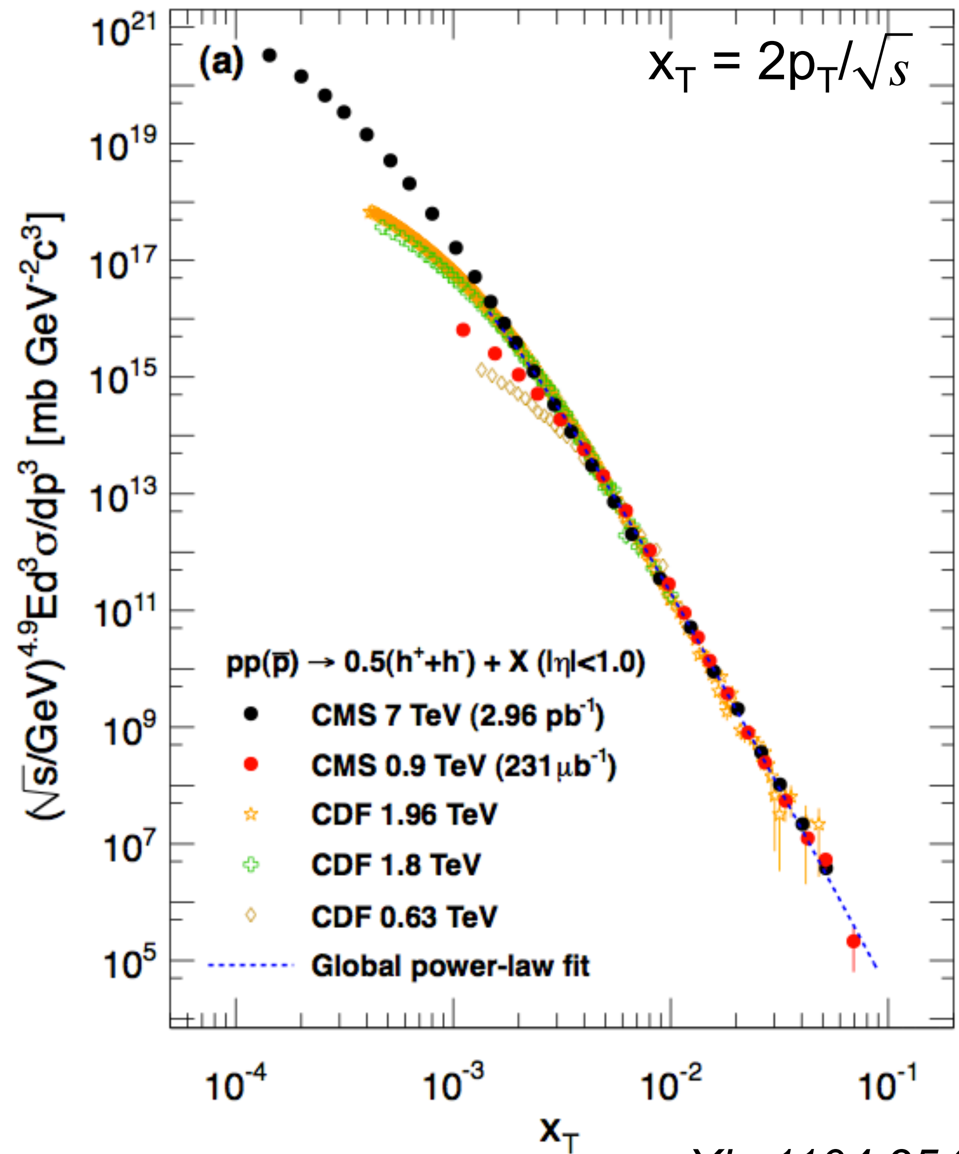
arXiv:1104.3547

Reference *pp* Spectrum

Low p_T (1-10 GeV/c)

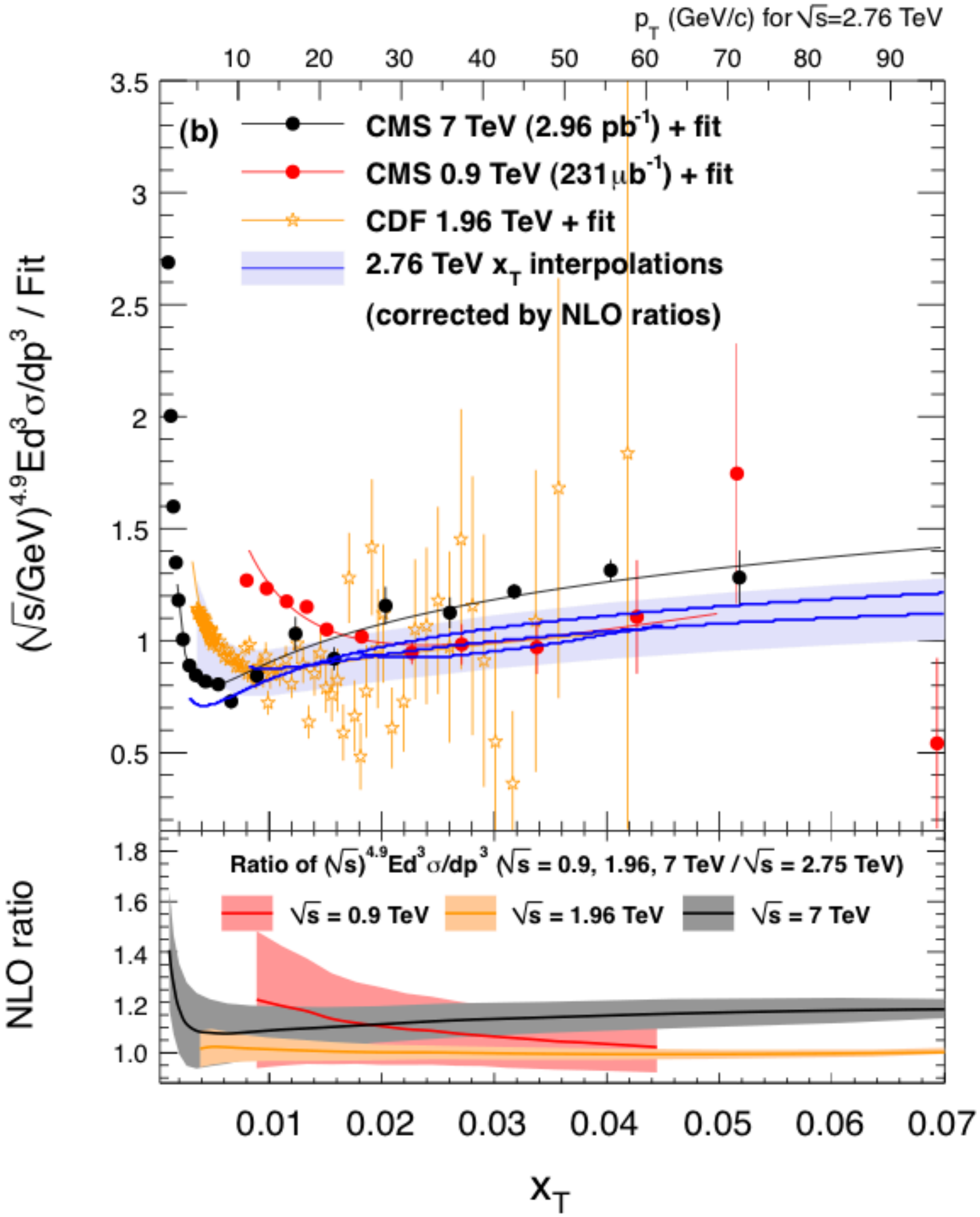


High p_T (10-100 GeV/c)



arXiv:1104.3547

x_T scaling interpolation



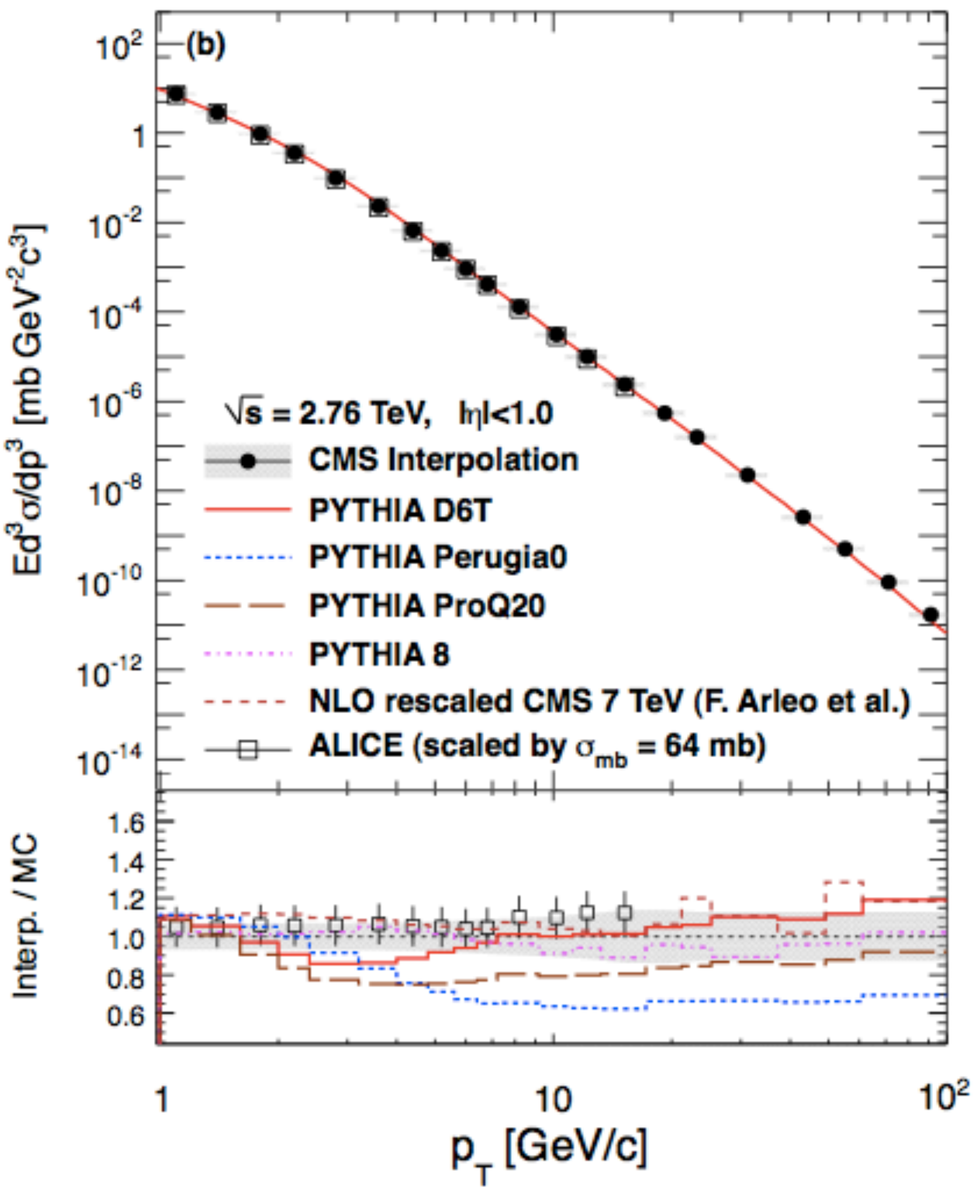
$$E\, d^3\sigma/d^3p = F(x_T)/p_T^{n(x_T,\sqrt{s})} = F'(x_T)/\sqrt{s}^{n(x_T,\sqrt{s})}$$

- Small scaling violation due to running and the evolution of PDFs and FFs.
- NLO residual corrections

arXiv:1104.3547

Reference *pp* Spectrum

arXiv:1104.3547



- Bin-to-bin interpolation (p_T<10 GeV/c) and NLO based x_T scaling up to 100 GeV/c
- Good agreement with PYTHIA8 (<10%) and NLO rescaled CMS 7 TeV measurement
- Interpolation well constrained (7-13%) by measurements at different collision energies

Nuclear Modification Factor

PbPb spectra (using minimum-bias and jet-triggers)

$$R_{AA} = \frac{d^2 N_{AA} / dp_T d\eta}{\langle T_{AA} \rangle d^2 \sigma_{pp} / dp_T d\eta}$$

pp reference spectrum (using minimum bias and jet-triggers)

Event selections

Minimum Bias Trigger:

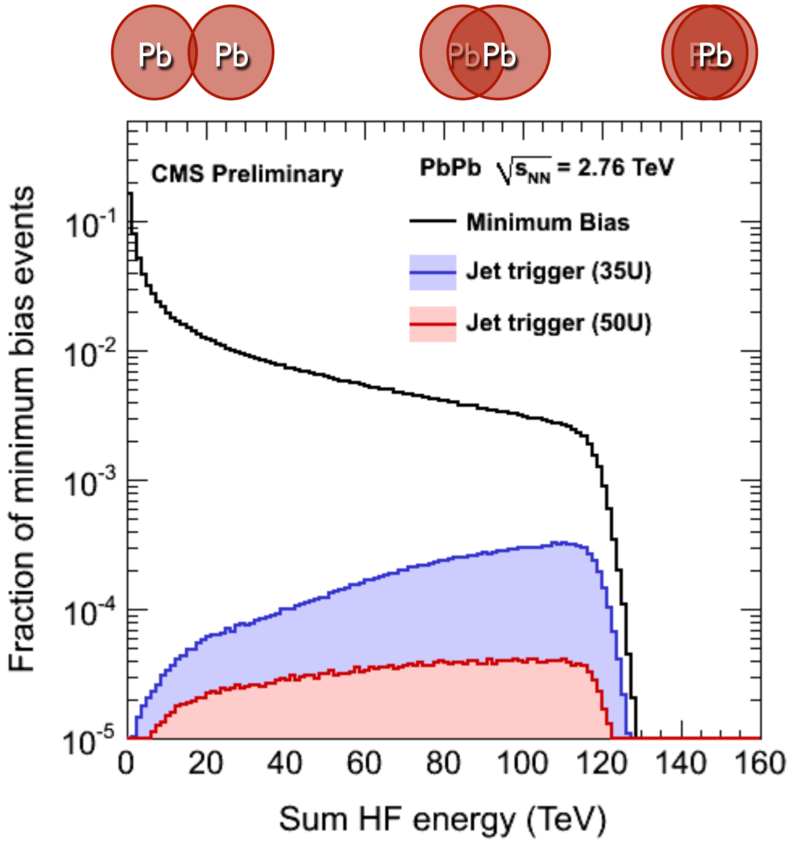
- HF or BSC firing in coincidence on both sides

Jet Triggers:

- Background subtracted uncorrected jet energies (35, 50 GeV)

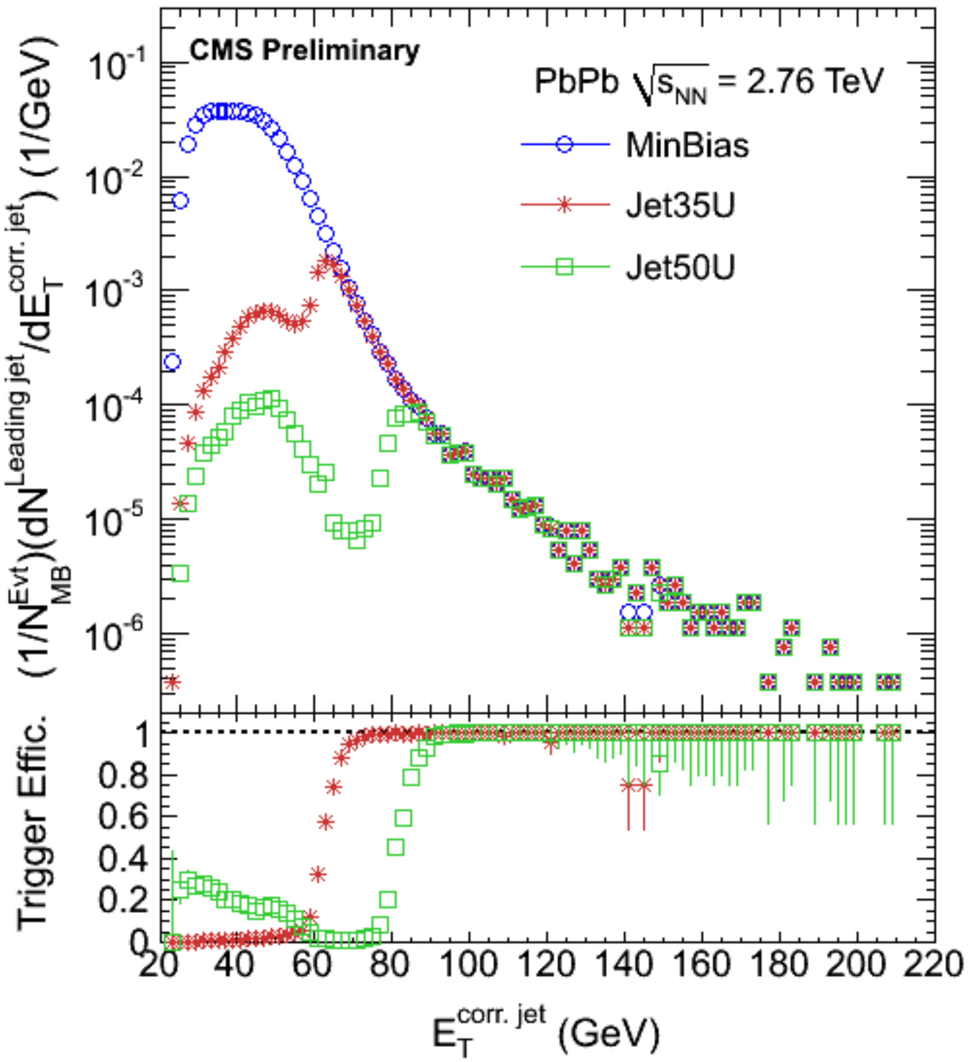
Event selection:

- Beam halo veto
- Primary vertex with at least 2 tracks
- 3 towers (E>3 GeV) in each of HF±
- Beam-scraping cleaning
- Primary vertex |z|<15 cm

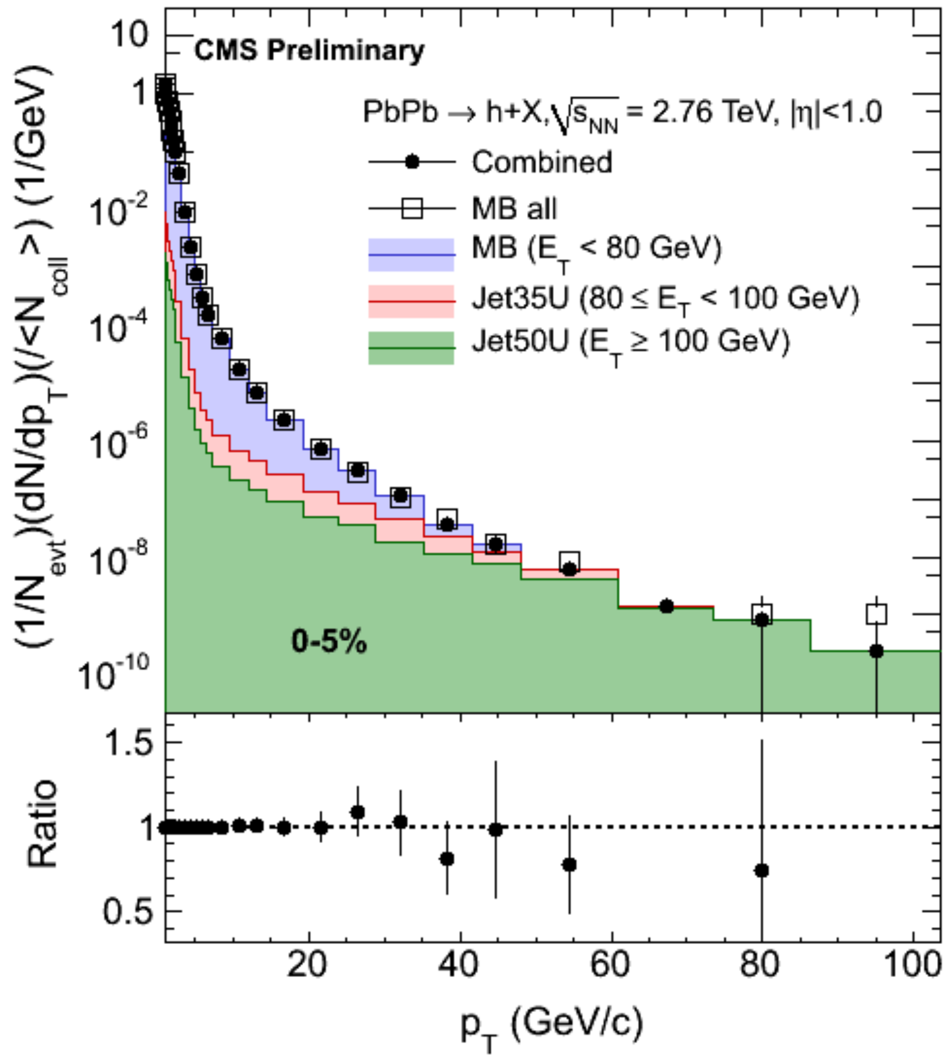


Inclusion Of Jet Triggers

Jet energy distribution

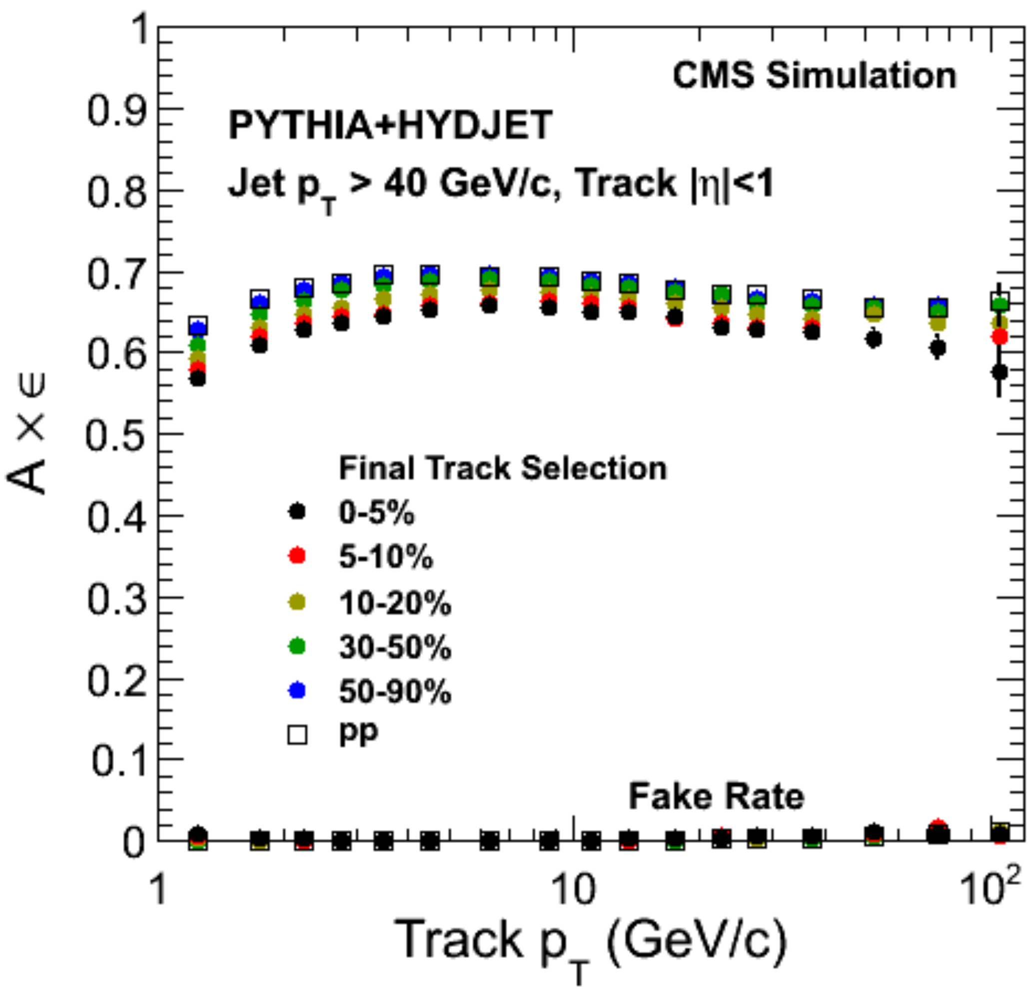


Charged particle distribution



Jet triggers are used to enhance the p_T reach and to have low fake

Tracking Performance in CMS

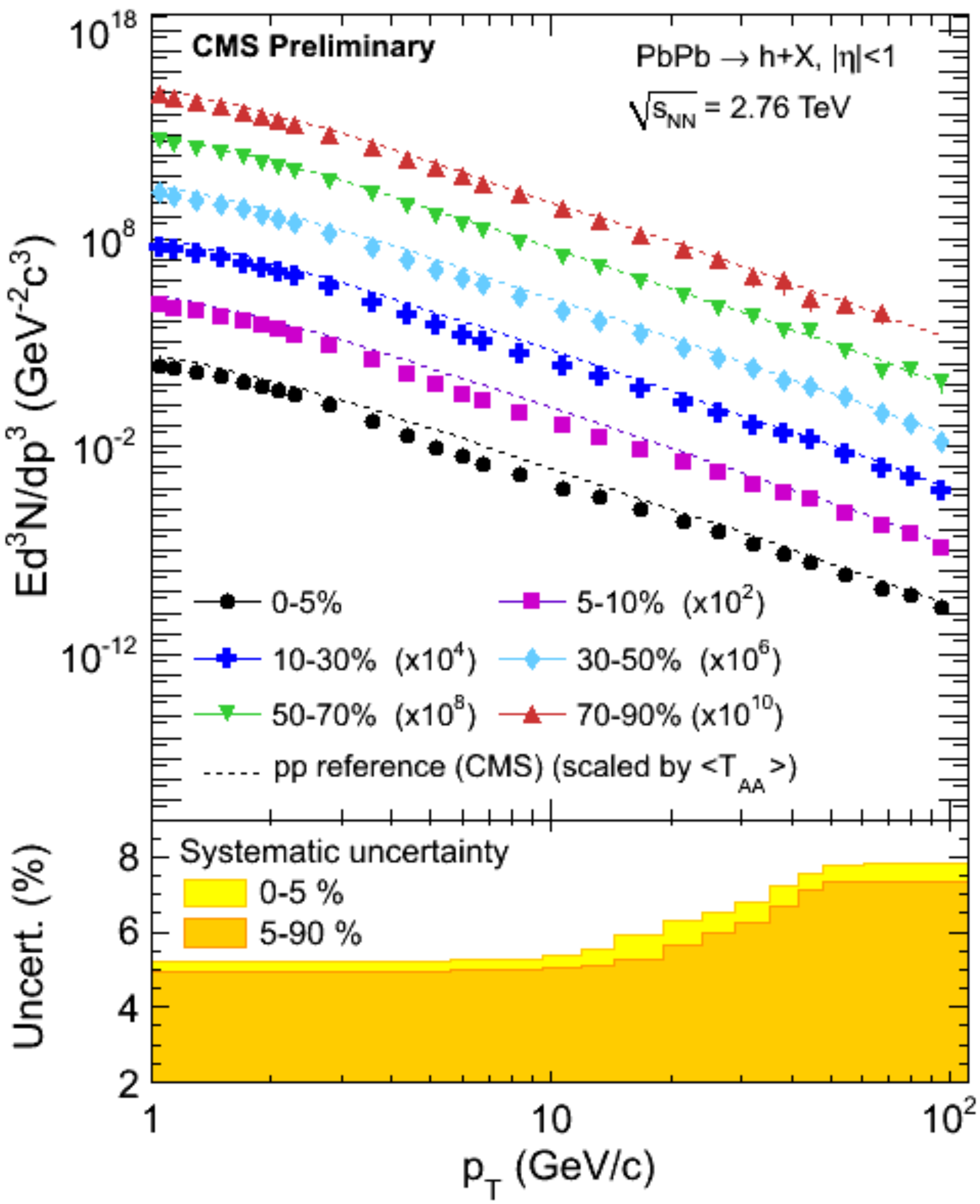


- Efficiency ~65% and fake < 3% up to 100 GeV/c
- Momentum resolution below 5% (correction <3 %) up to 100 GeV/c

Systematic Uncertainties for Spectra

Source	Uncertainty [%]
Reconstruction efficiency	3.0–4.5
Non-primary and fake tracks	2.5–4.0
Momentum resolution and binning	3.0
Normalization of jet-triggered spectra	0.0–4.0
Total for PbPb spectra	4.9–7.8

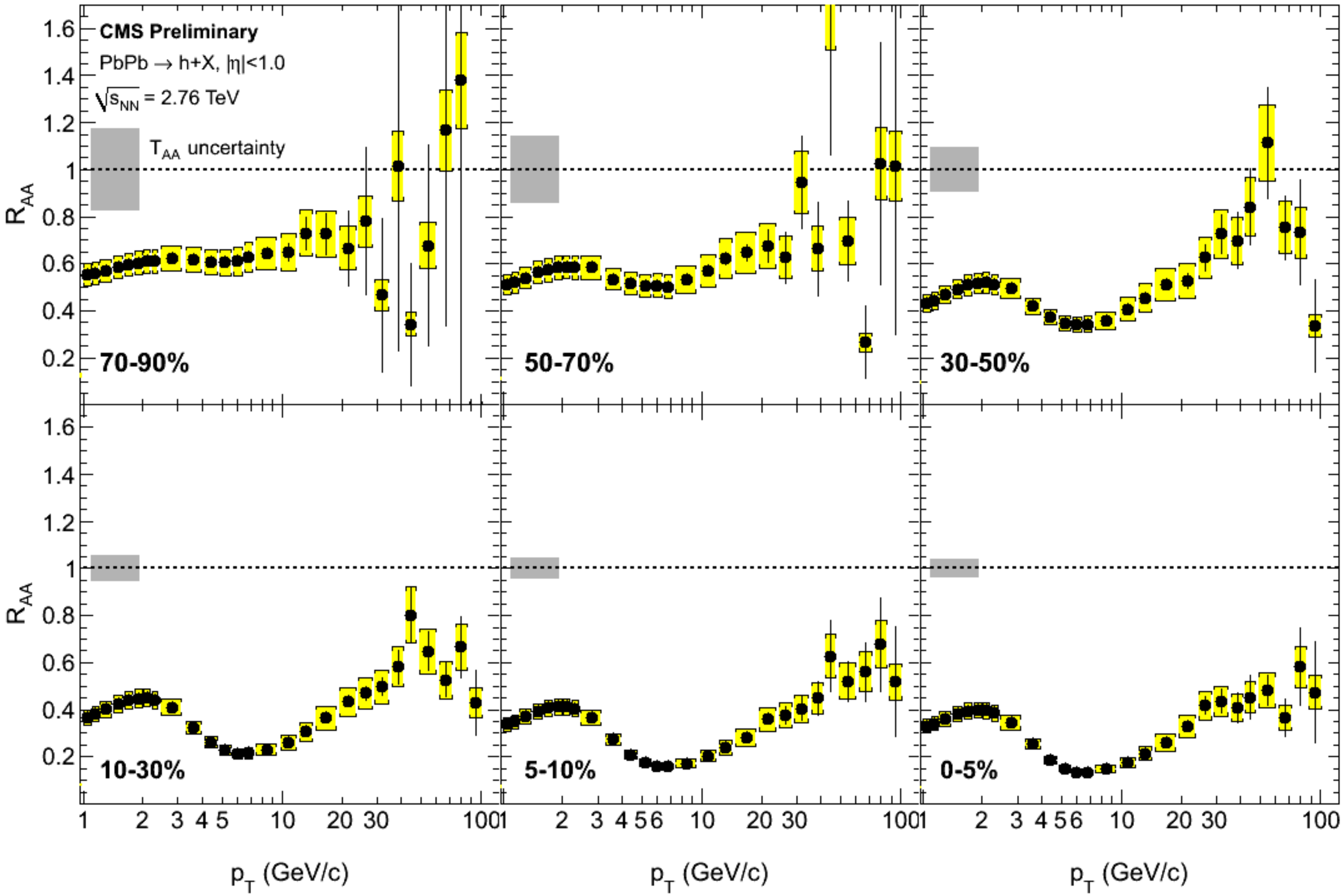
Charged Particle Spectra in *PbPb*



Systematic Uncertainties for R_{AA}

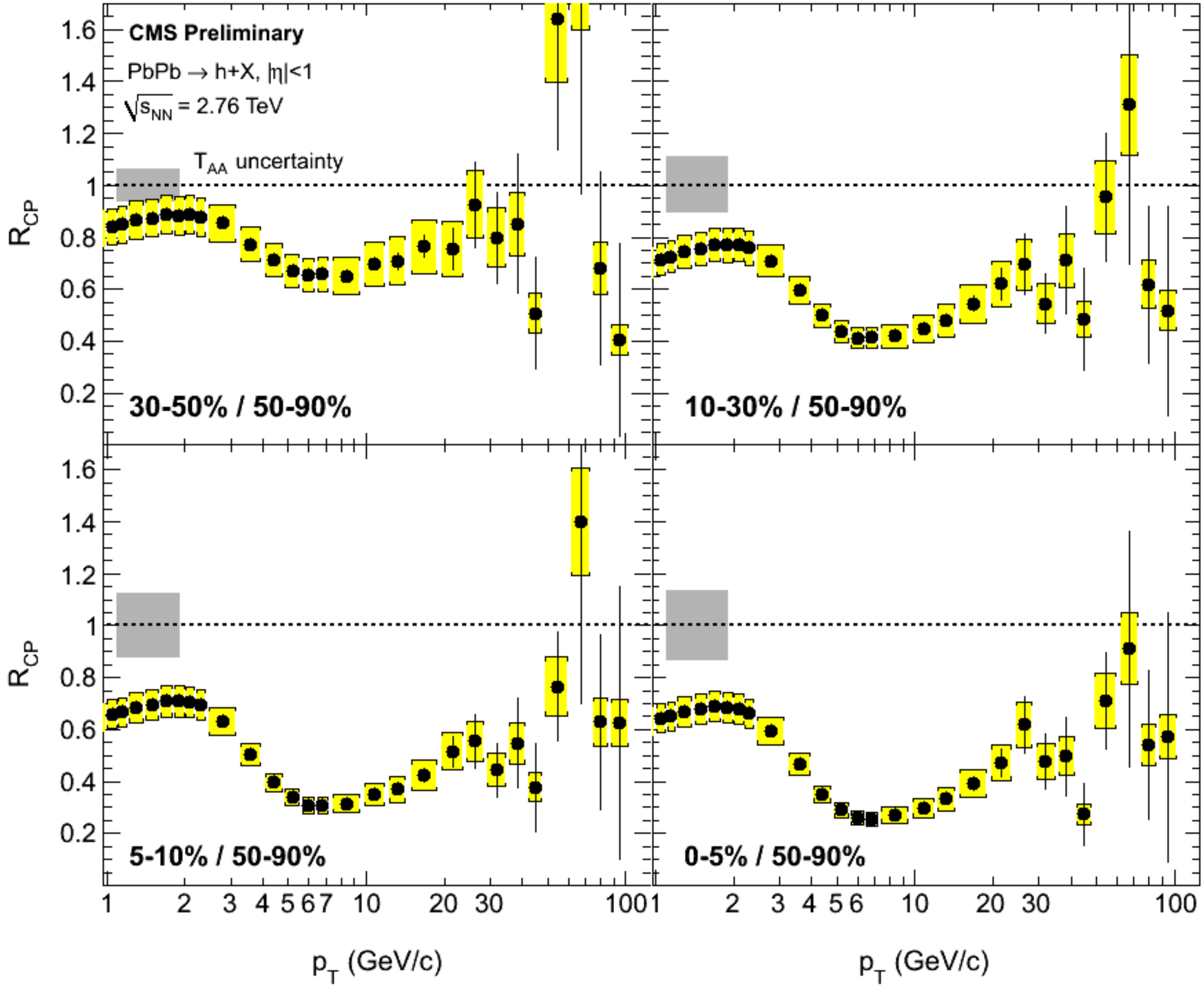
Source	Uncertainty [%]
Total for PbPb spectra	4.9–7.8
T_{AA} determination	4.1–18
Interpolated pp reference spectrum	6.8–13
Total for R_{AA}	9.3–24

$R_{AA}(p_T)$ for different centralities

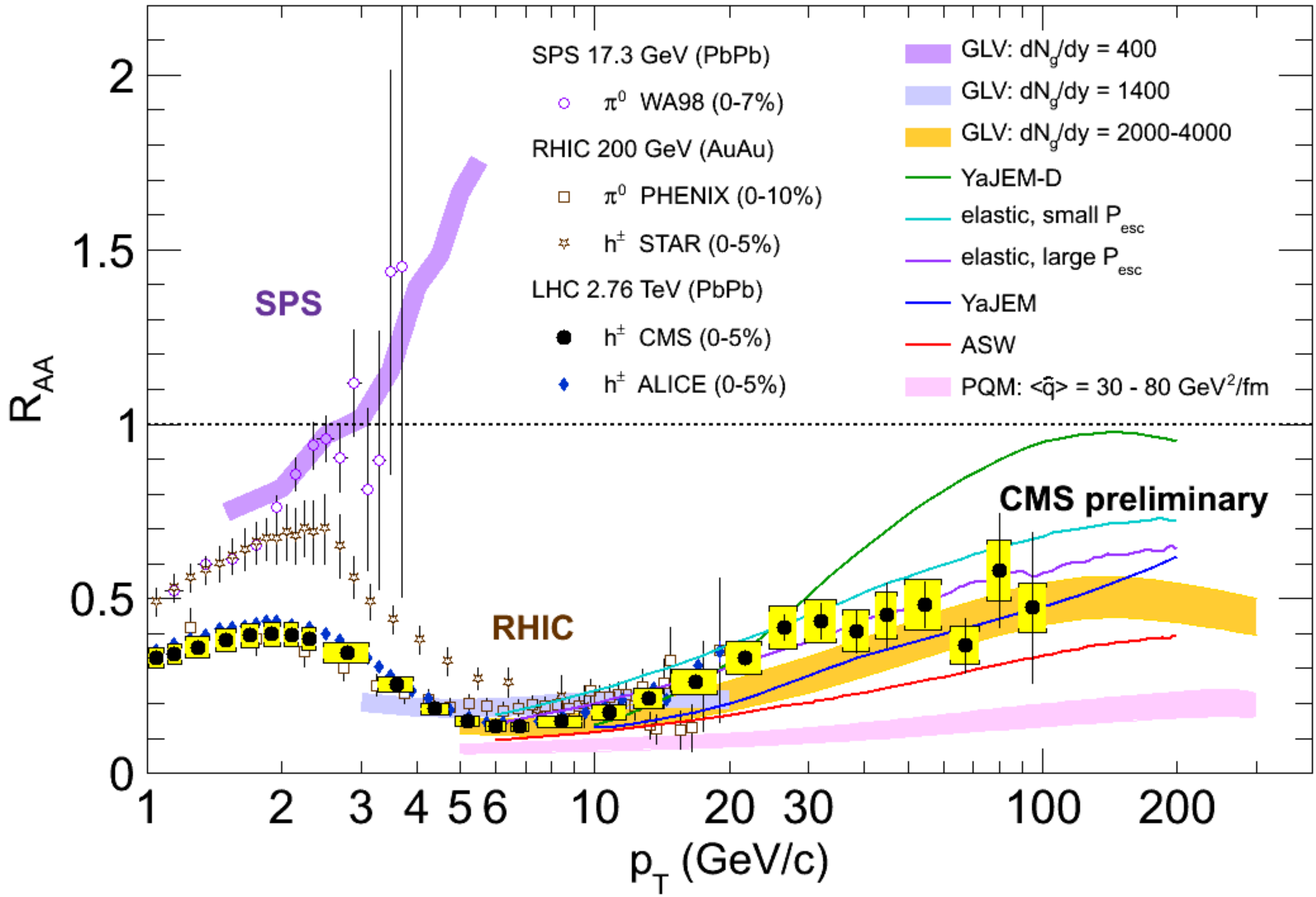


$R_{CP}(p_T)$ for Different Centralities

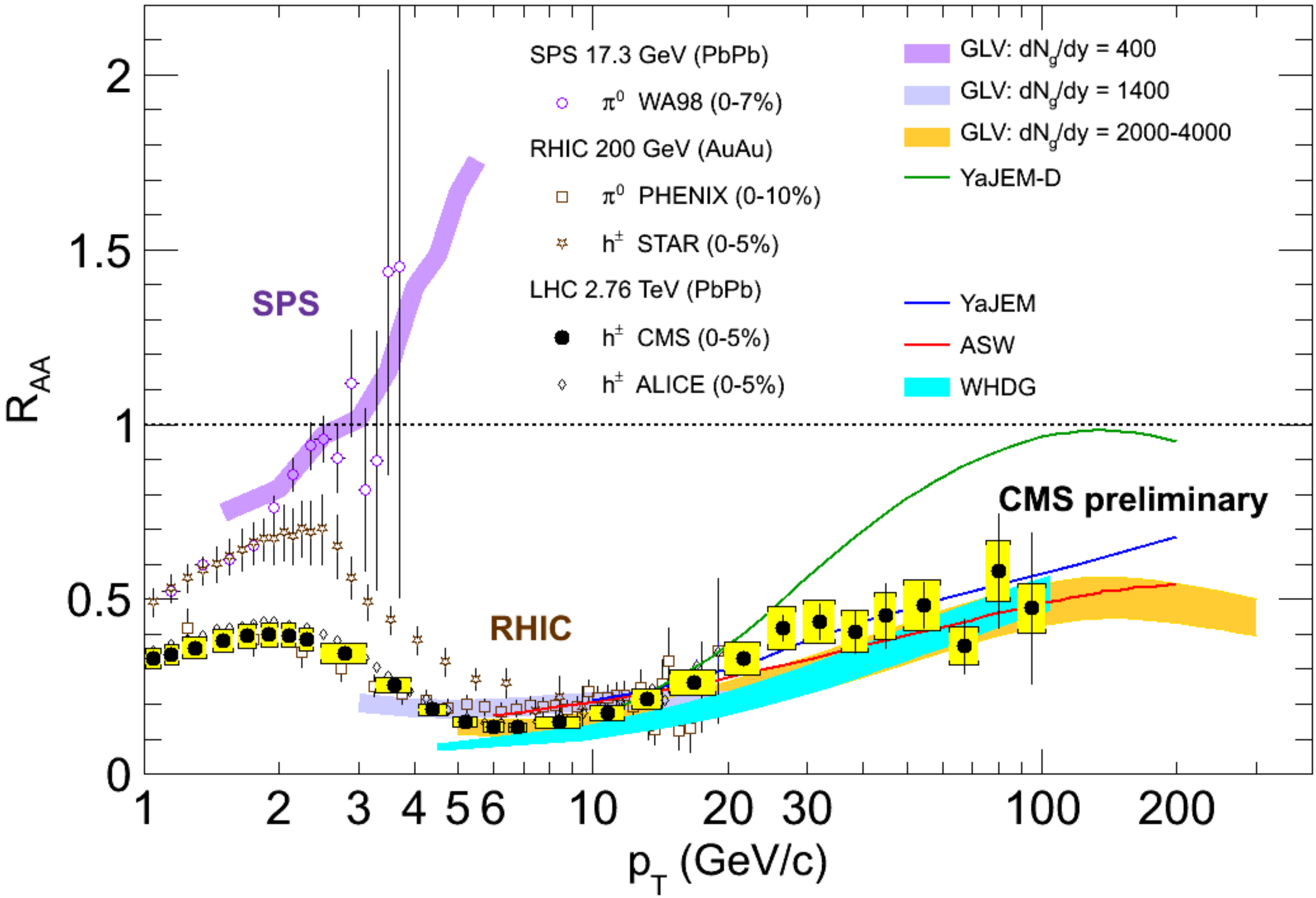
$$R_{CP} = \frac{d^2N_{AA}/dp_T d\eta / N_{coll}(\text{central})}{d^2N_{AA}/dp_T d\eta / N_{coll}(\text{peripheral})}$$



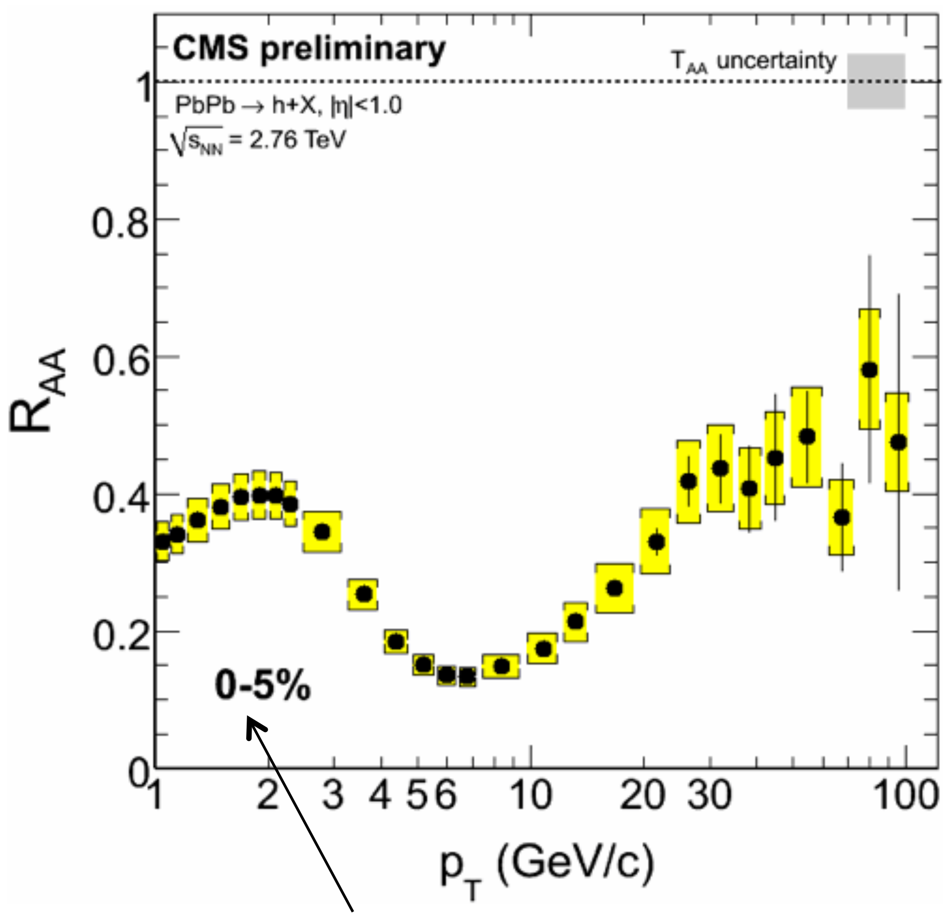
R_{AA} over two decades in p_T !

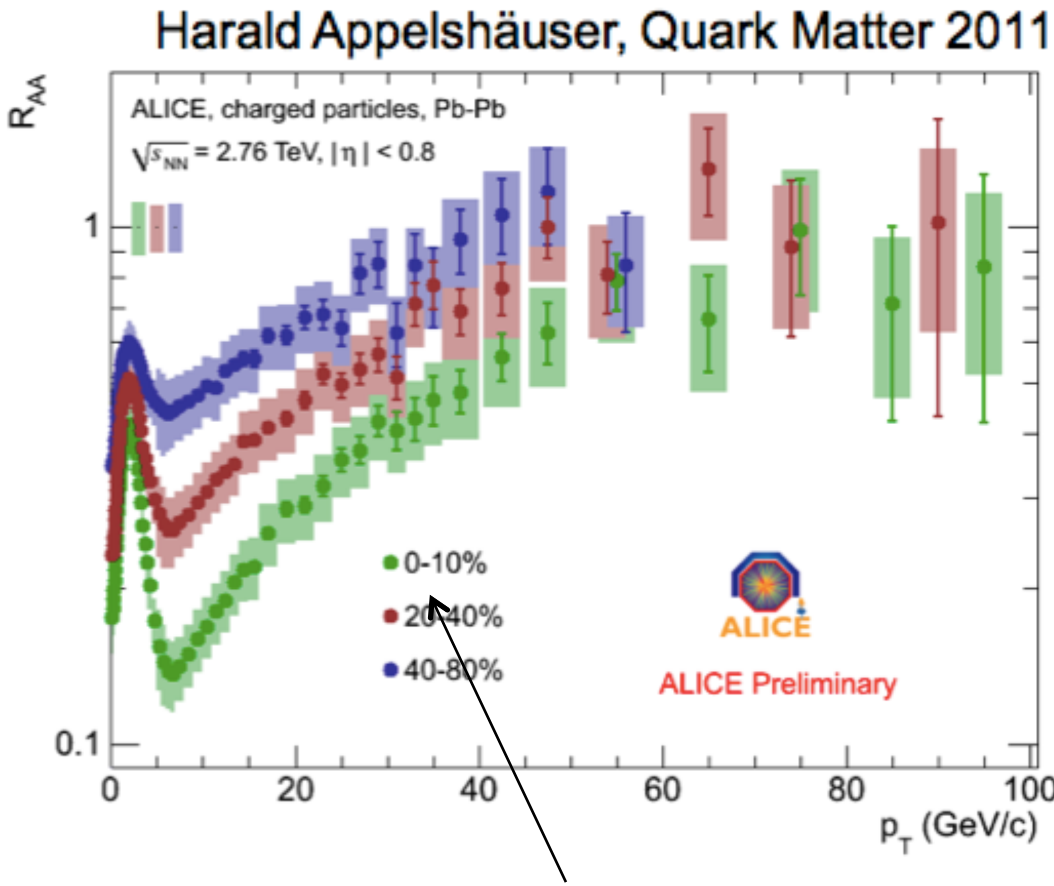


R_{AA} over two decades in p_T !

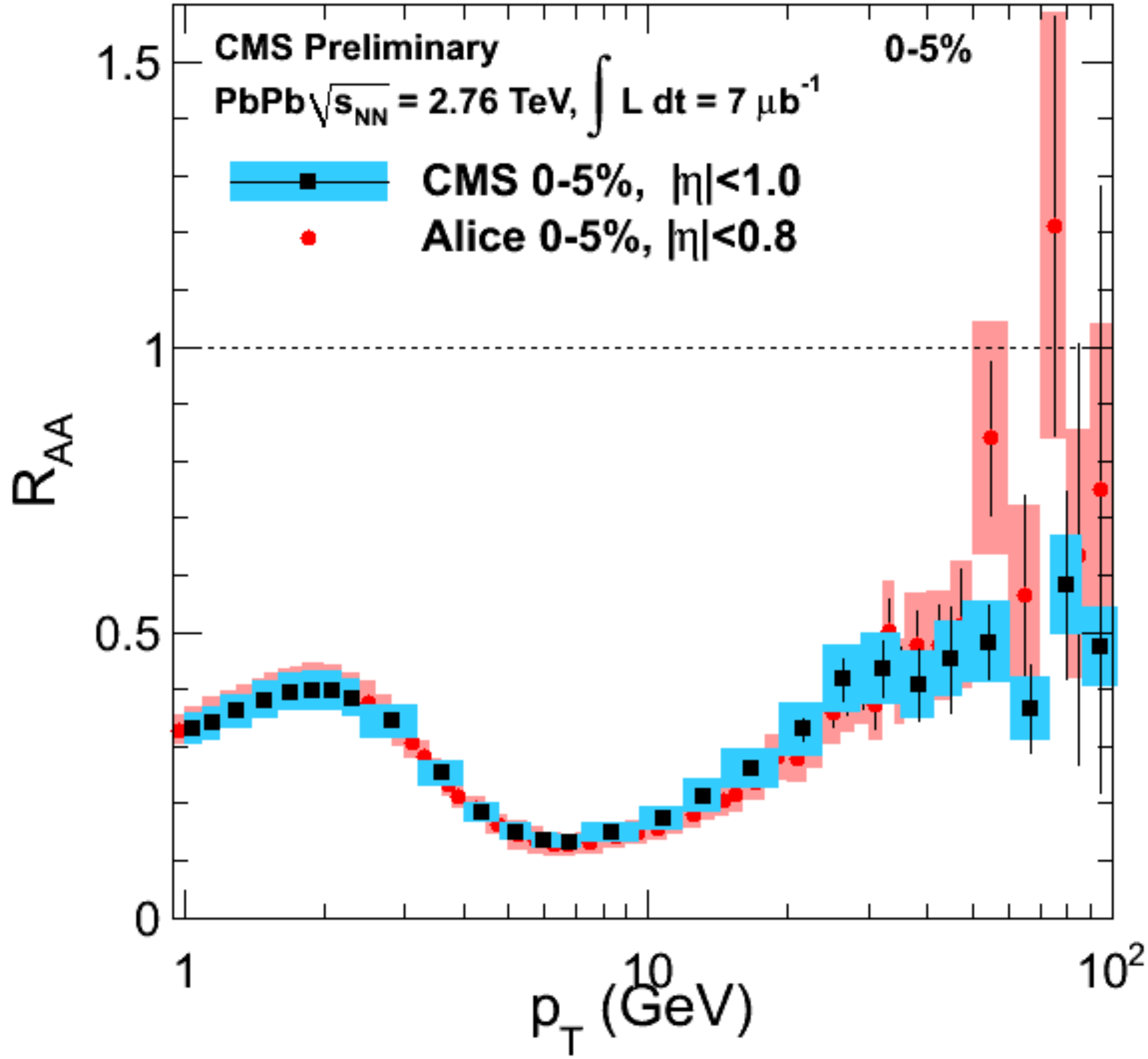


"Monday Crisis"





Comparison to ALICE R_{AA}



Summary and Conclusions

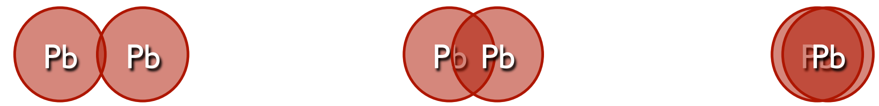
- With the pp reference spectrum constructed based on the CMS measurements, R_{AA} is measured up to 100 GeV/c.

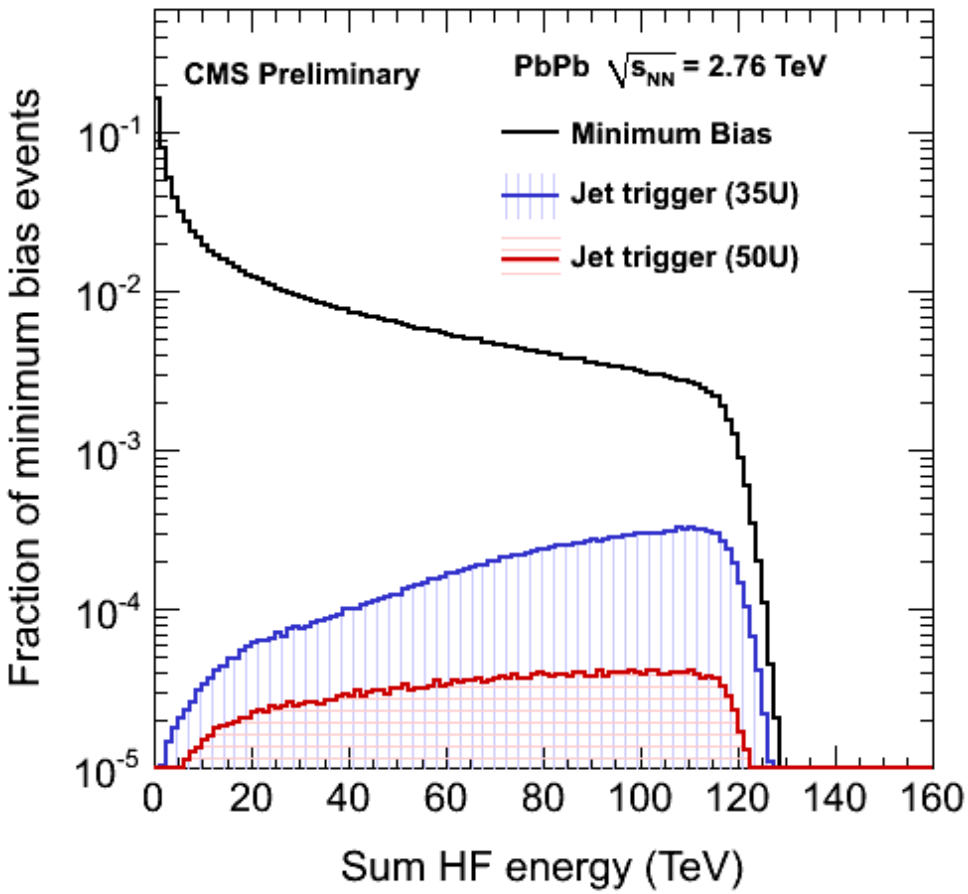
- Unambiguous suppression of charged particles above a few GeV/c and a continued rise of R_{AA} up to 0.5 (0-5%) are observed.

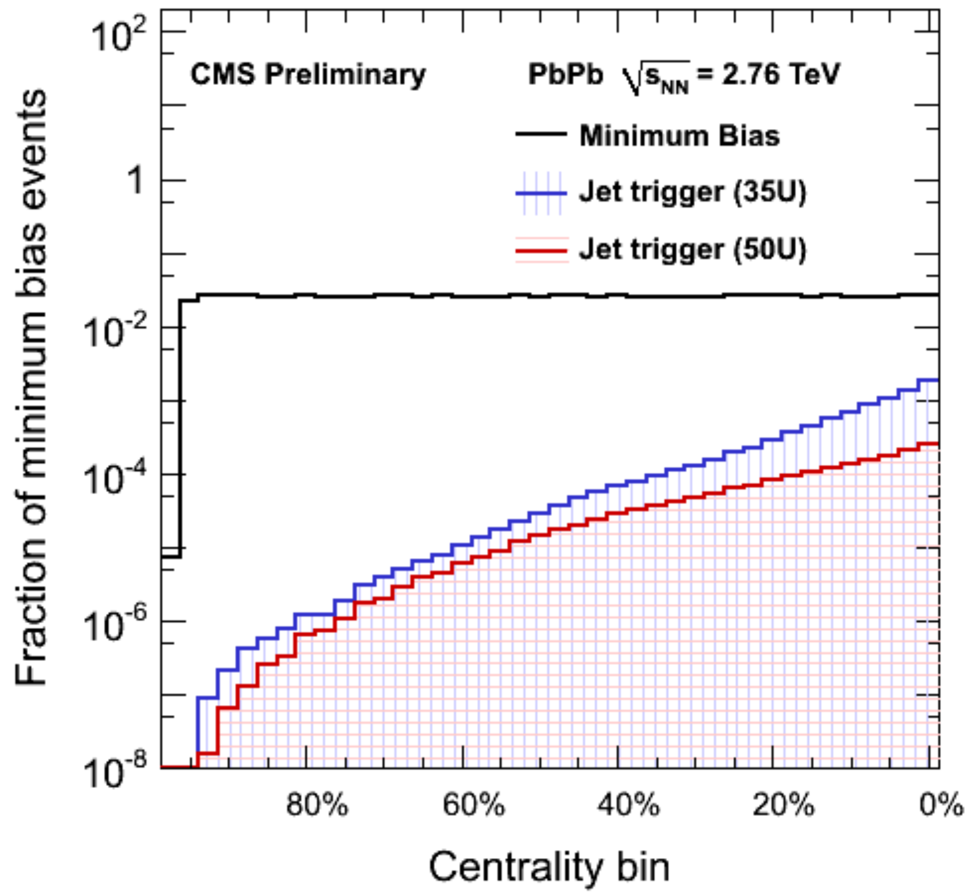
- Put strong constraints on parton energy-loss models and allow an access to medium properties (dN_g/dy and $\hat{q}$) by comparison to pQCD predictions.

Backup Slides

Collision Centrality







Events are classified according to the percentile of the Pb+Pb inelastic cross section based on total deposited HF energy

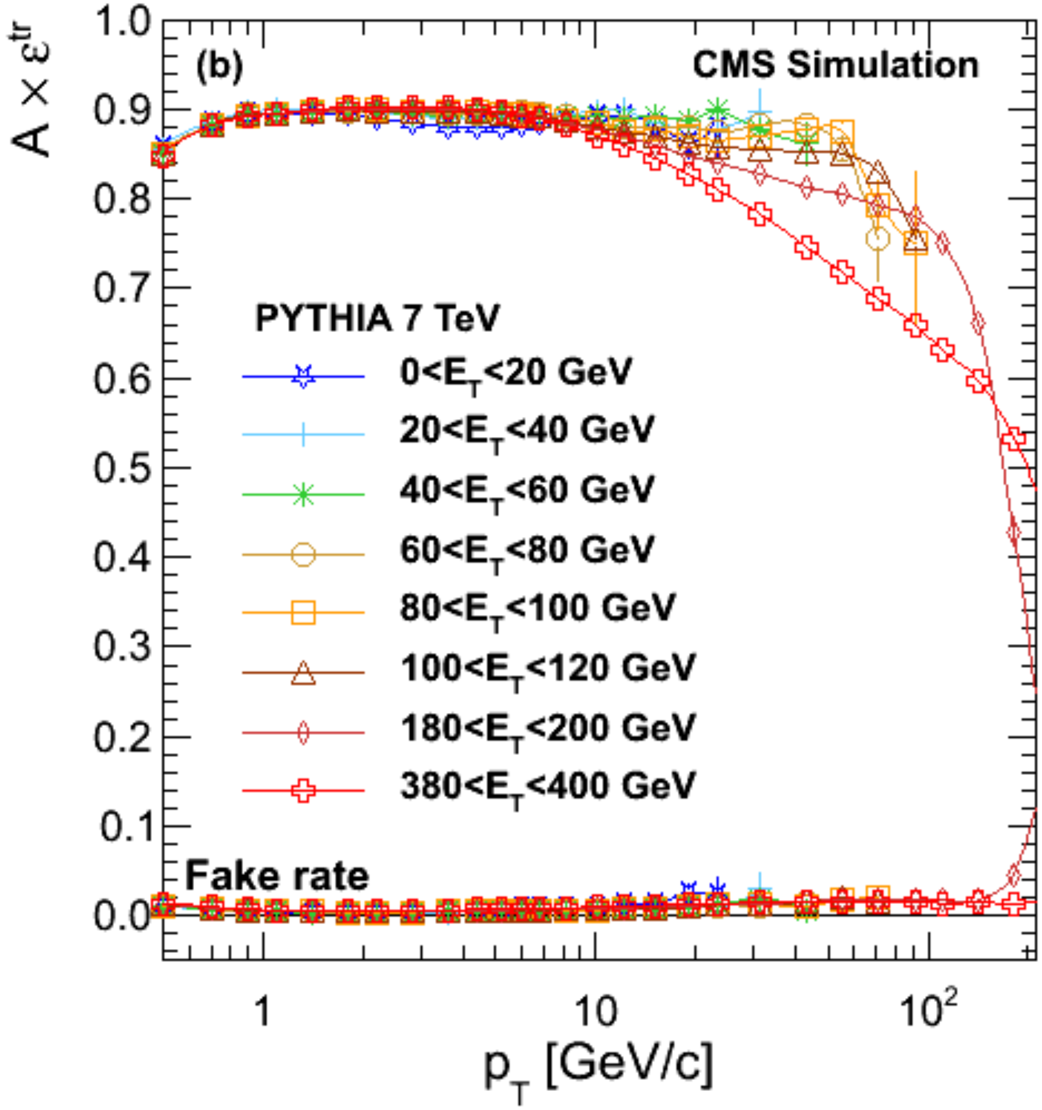
Collision Centrality

Centrality Bin	$\langle N_{part} \rangle$	r.m.s.	$\langle N_{coll} \rangle$	r.m.s.	$\langle T_{AA} \rangle$ (mb^{-1})	r.m.s.
0 - 5%	381 ± 2	19.2	1660 ± 130	166	25.9 ± 1.06	2.60
5 - 10%	329 ± 3	22.5	1310 ± 110	168	20.5 ± 0.94	2.62
10 - 30%	224 ± 4	45.9	745 ± 67	240	11.6 ± 0.67	3.75
30 - 50%	108 ± 4	27.1	251 ± 28	101	3.92 ± 0.37	1.58
50 - 70%	42.0 ± 3.5	14.4	62.8 ± 9.4	33.4	0.98 ± 0.14	0.52
70 - 90%	11.4 ± 1.5	5.73	10.8 ± 2.0	7.29	0.17 ± 0.03	0.11

- Uncertainty on N_{coll} value driven by two terms:

- Trigger and event selection efficiency
- Glauber parameters

Tracking efficiency in *pp*



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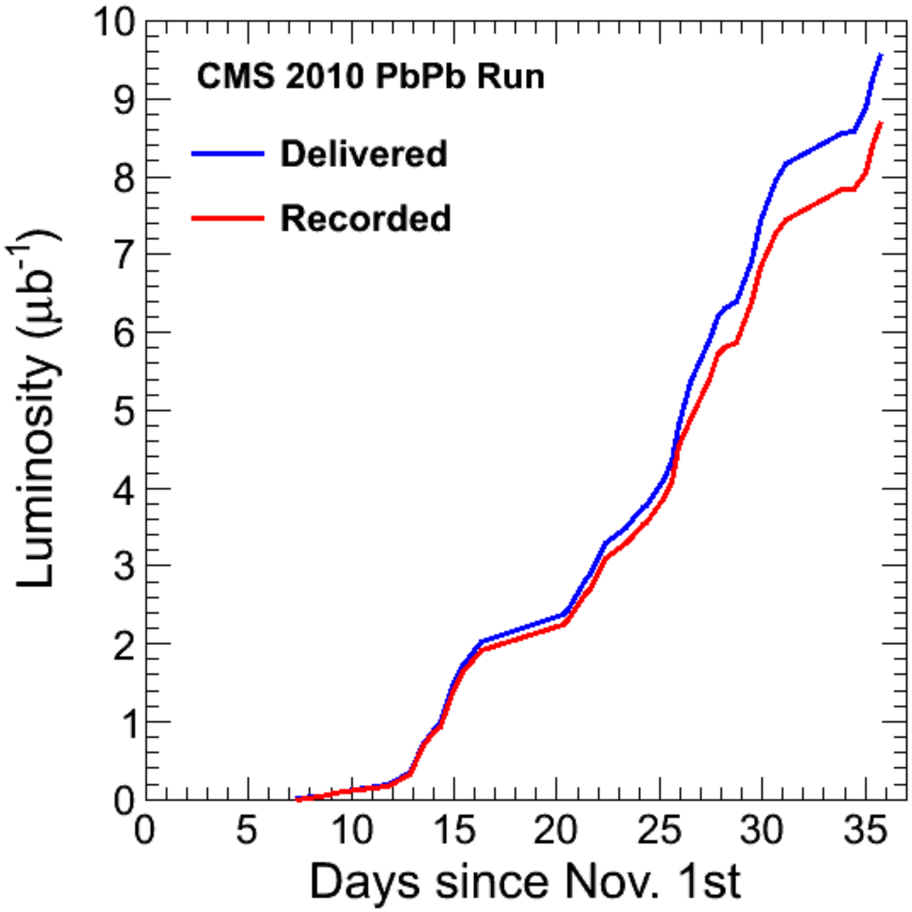
2010 Heavy Ion Run at LHC

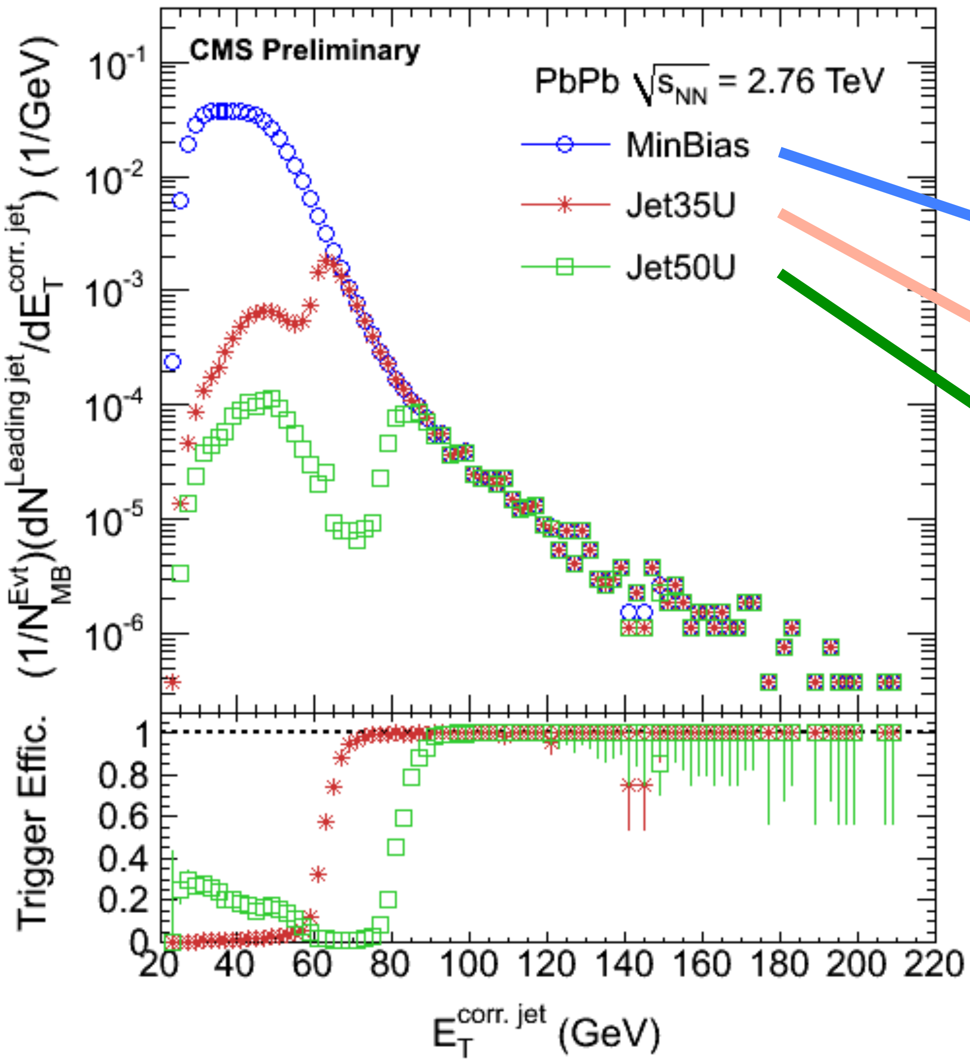
2010 has been a successful year at LHC



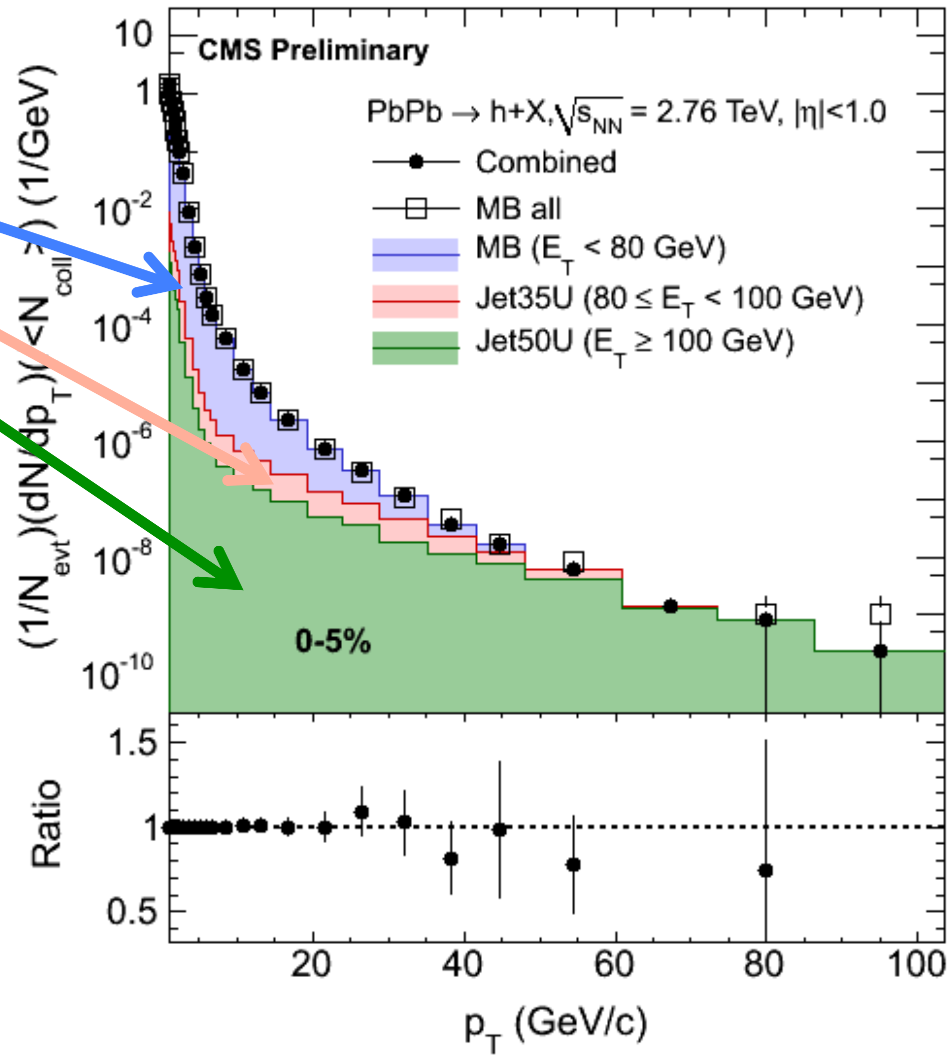
After delivering 40 pb-1 of pp data, LHC delivered over 9 μb^{-1} of PbPb data
~ 7 μb^{-1} used in this analysis

Inclusion Of Jet Triggers

Jet energy distribution

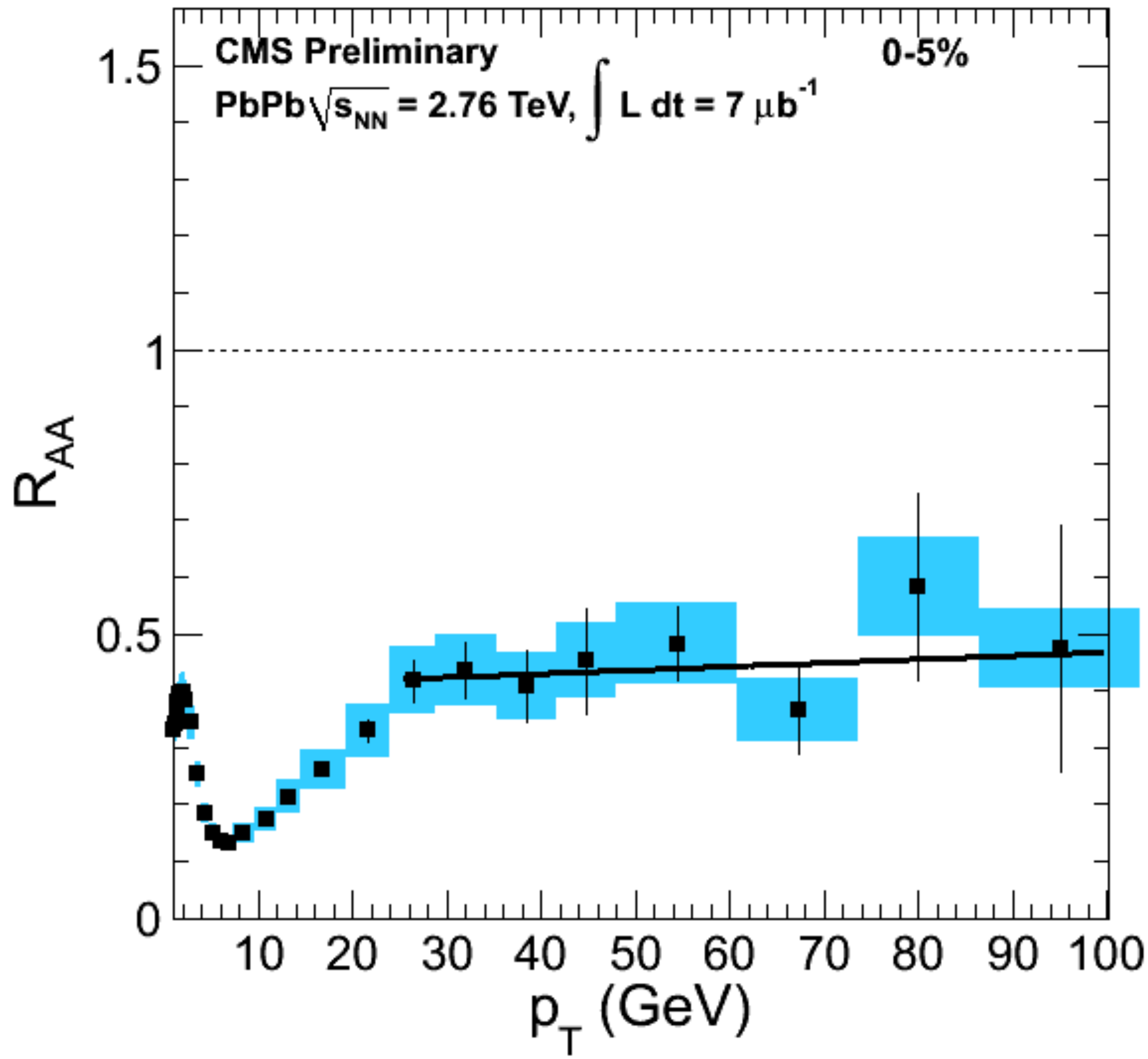


Charged particle distribution



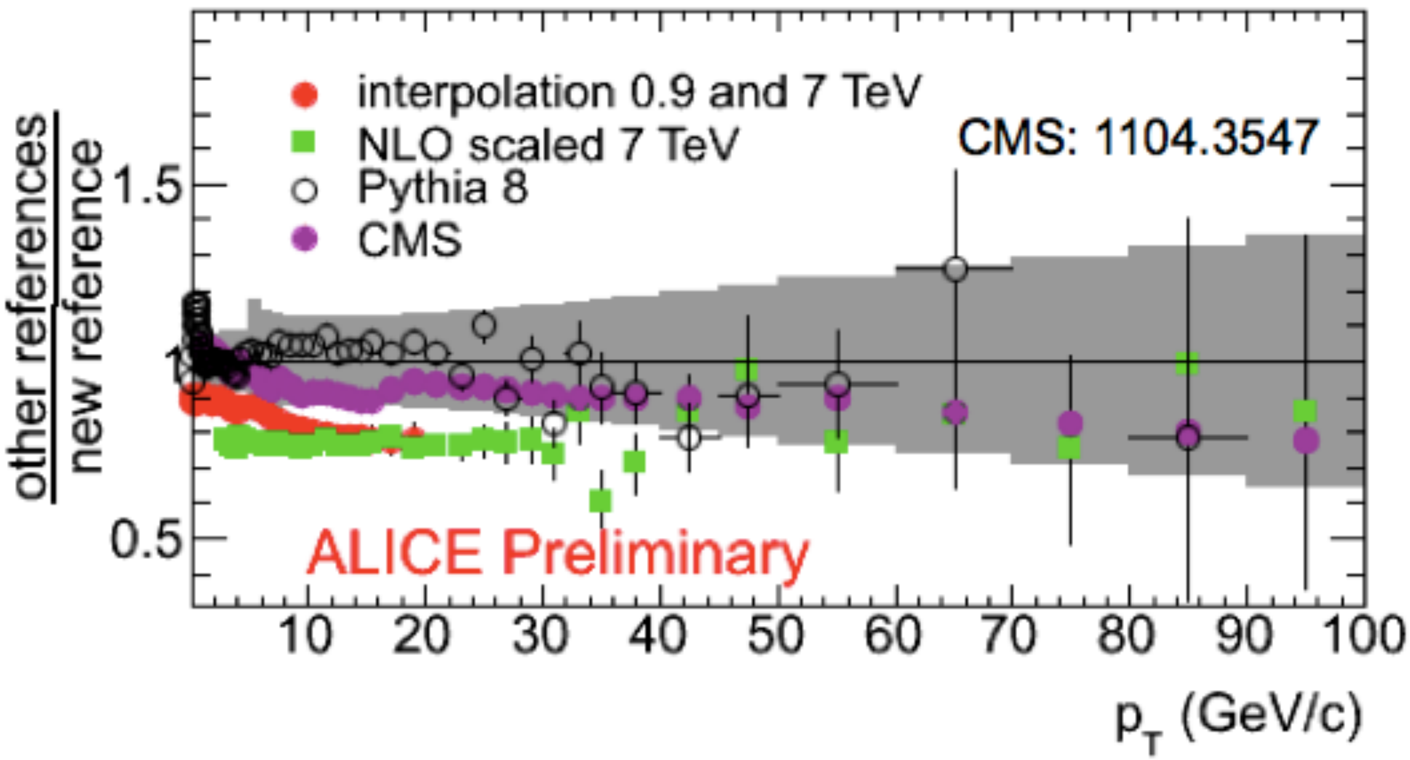
Jet triggers are used to enhance the p_T reach and to have low fake

R_{AA} (0-5%)



- Statistically not significant to tell if it's rising or flattening
- 0.00063 ± 0.0014

Reference comparison



Harald Appelshäuser, Quark Matter 2011,