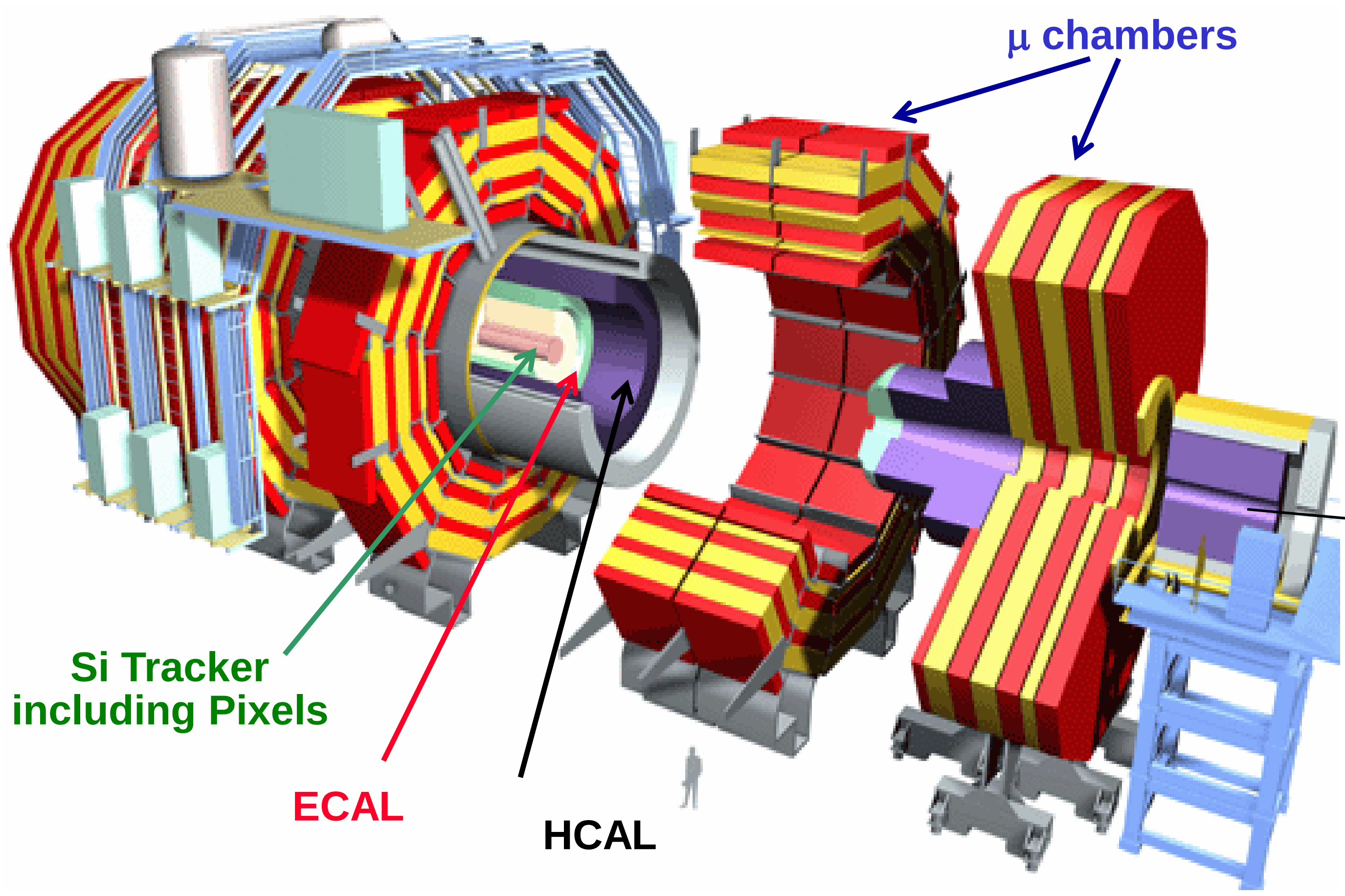
Charged hadron multiplicity and transverse energy densities in PbPb collisions from CMS

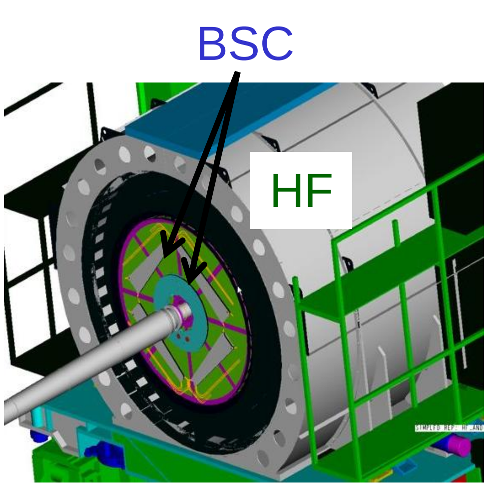
Krisztián Krajczár

for the CMS Collaboration

CMS

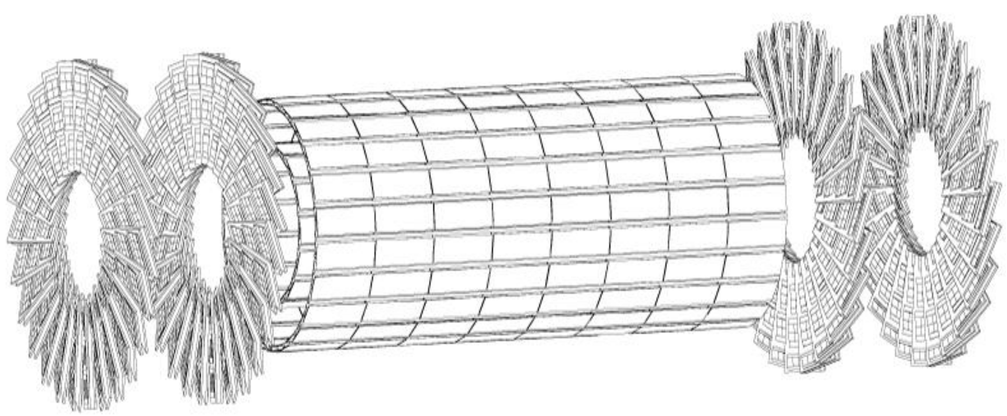
- Compact Muon Solenoid
  - Large acceptance tracker, hermetic calorimetry, excellent muon spectrometer

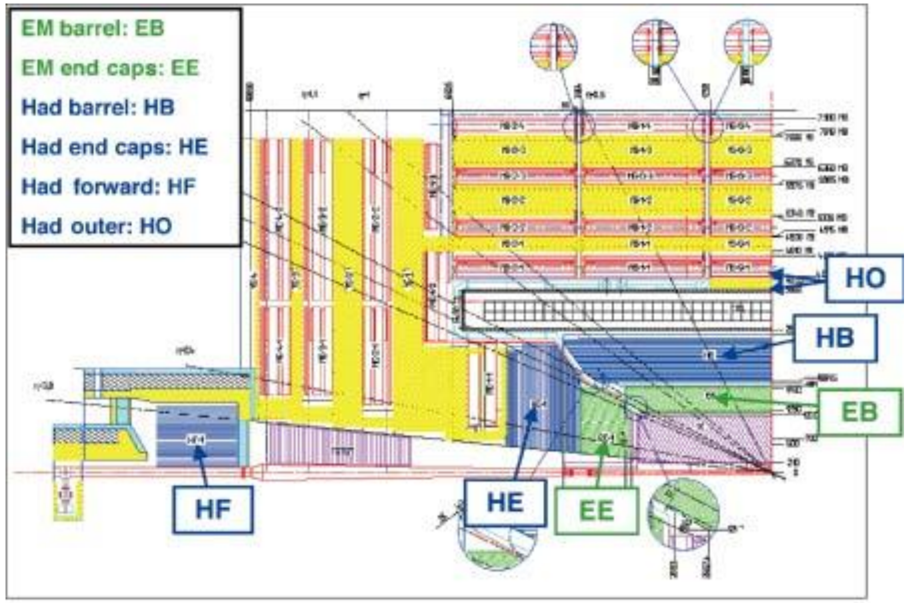




Tracker and calorimeter systems

- Tracker: multiple layer silicon detector, $|\eta|<2.5$
  - Layers composed of pixels or strips cells
  - Pixels: 66M, each cell has a surface of 100x150 μm^2
- Calorimeters: $|\eta|<5.2$:
  - ECAL, HCAL
  - Used: $|\eta|<1.2$ and $3.2<|\eta|<4.9$





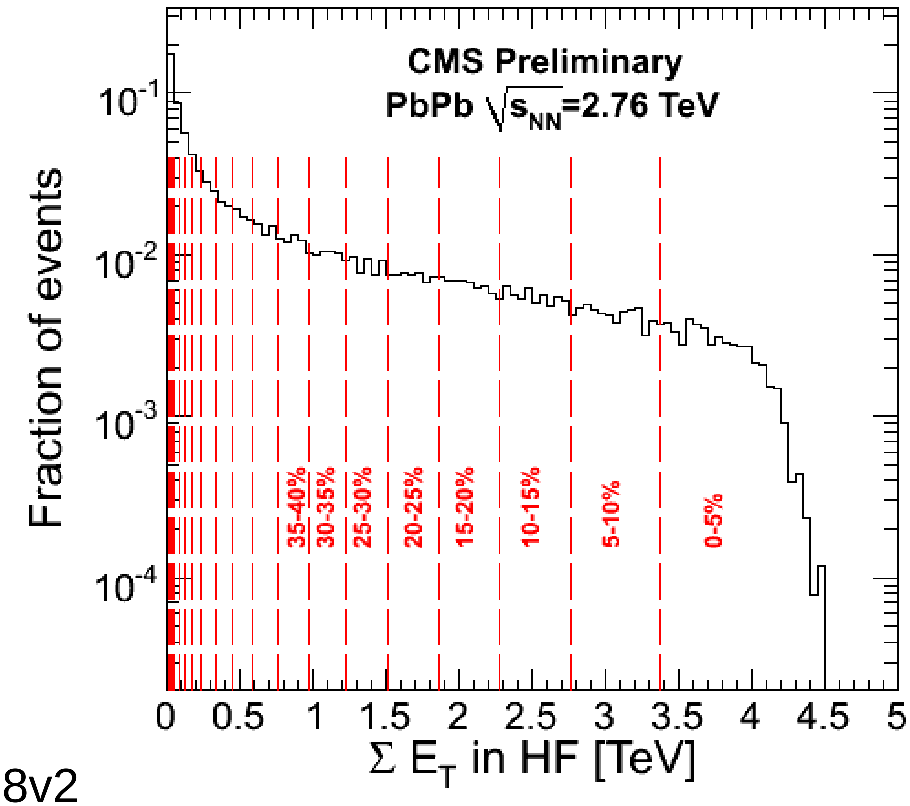
Data, simulation

- Data:
  - 100k minimum bias events recorded with B=0 T ($dN_{ch}/d\eta$)
  - 2M minimum bias events with B=3.8 T ($dE_T/d\eta$)
- Simulations:
  - 100k AMPT events, default tune
  - 100k HYDJET events, default tune

AMPT: Z-W. Lin, C. M. Ko, B.-A. Li et al., Phys. Rev. C72 (2005) 064901
HYDJET: I. Lokhtin and A. Snigirev, Eur. Phys. J. C45 (2006) 211-217

Event selection, centrality

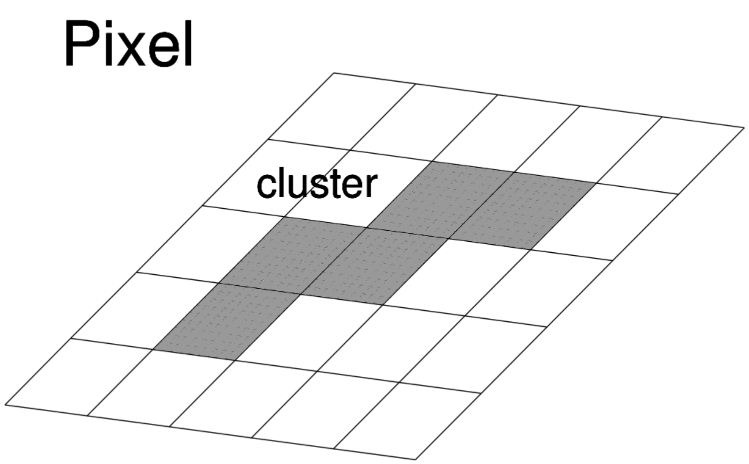
- Minimum bias data:
  - Double sided HF or BSC, vertex
  - 99% hadronic efficiency (B=0 T)
  - 1% UPC contamination (B=0 T)
- Collision centrality:
  - determined via total transverse energy in HF

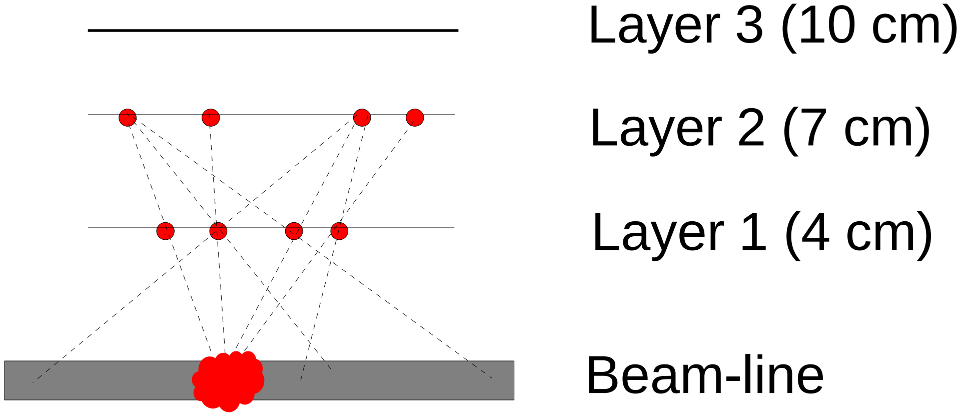


UPC: Djuvstrand and Nystrand, arXiv:1011.4908v2

$dN_{ch}/d\eta$: Measurement methods

- Two methods
- Cluster counting:
  - Determines multiplicity via single layer occupancy
- Tracklets:
  - Uses all pairs of layers to create cluster-pairs
- Vertexing: done for each method separately



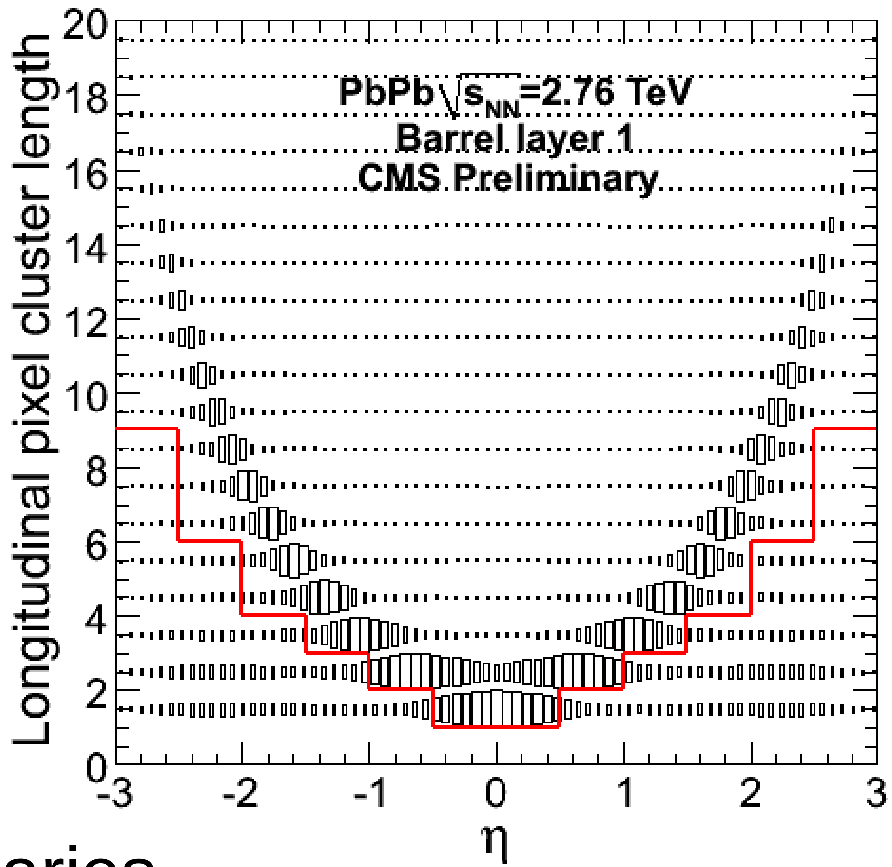


Cluster counting

- Vertex:
  - From the compatibility of cluster length with a primary vertex hypothesis
- Cluster selection:
  - Primary clusters:

    cluster length ~ |sinh(η)|

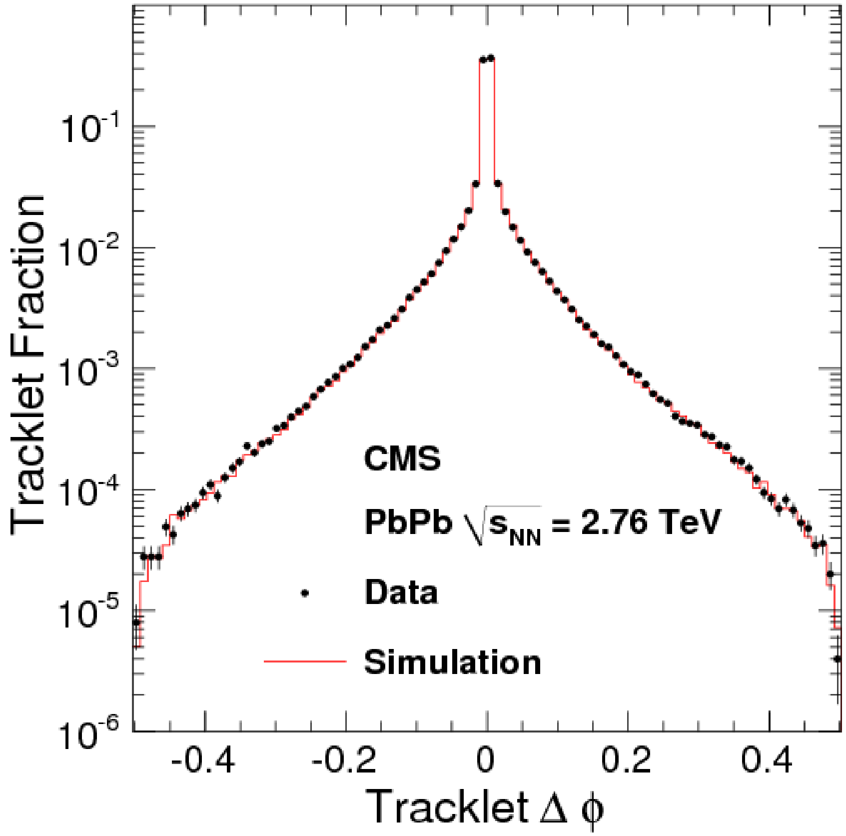
    Not strictly true for clusters due to background



- Further corrections:
  - Background mimicking primaries
  - Layer 1: 10%, layer 2: 20%, layer 3: 30%

Tracklet method

- Vertex:
  – Clusterize tracklets along the beam line
- Tracklet reconstruction:
  – Input: clusters passing the cluster selection
  – Sort tracklets in ΔR; cluster is matched multiple times, keep the tracklet with the smallest ΔR



- Typical correction: <15%
- Data-MC: agreement over 5 orders of magnitude

$dE_T/d\eta$: Measurement method

- Uses the co-called particle flow objects
  Calorimeter information together with tracking
  See Matthew Nguyen's talk (448, Friday)

- Non-linear calorimeter response at low energies
- The low-p_T particle spectra is not yet included
  → 0-2.5% centrality for $|\eta|<1.2$
  → 0-80% for $|\eta|>3.2$

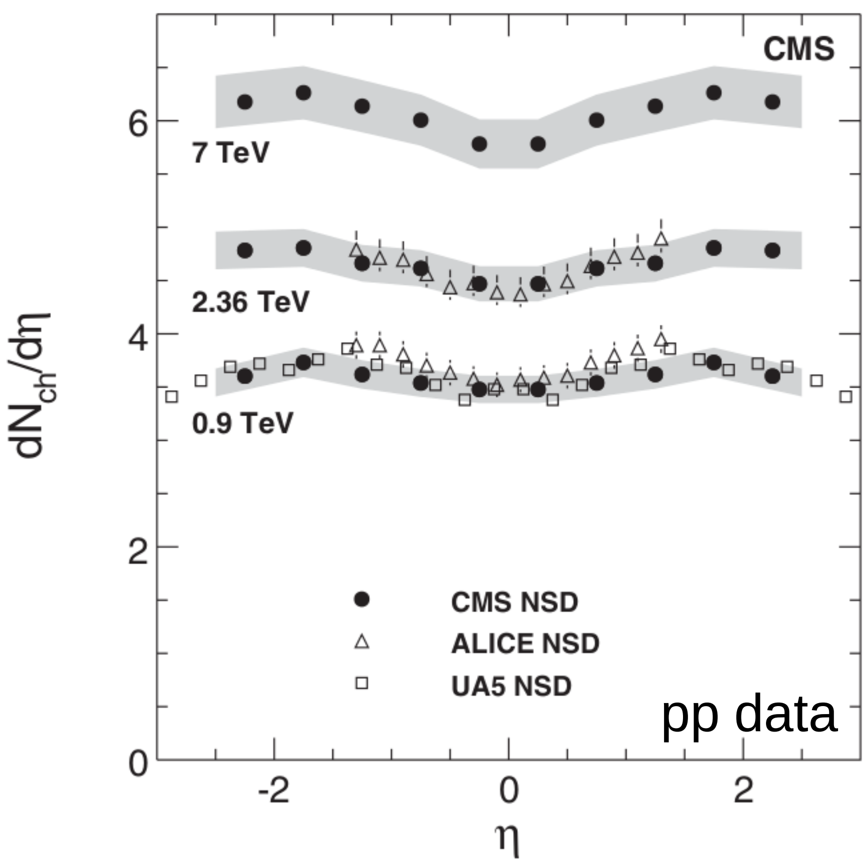
- 50-100% of the transverse energy is captured

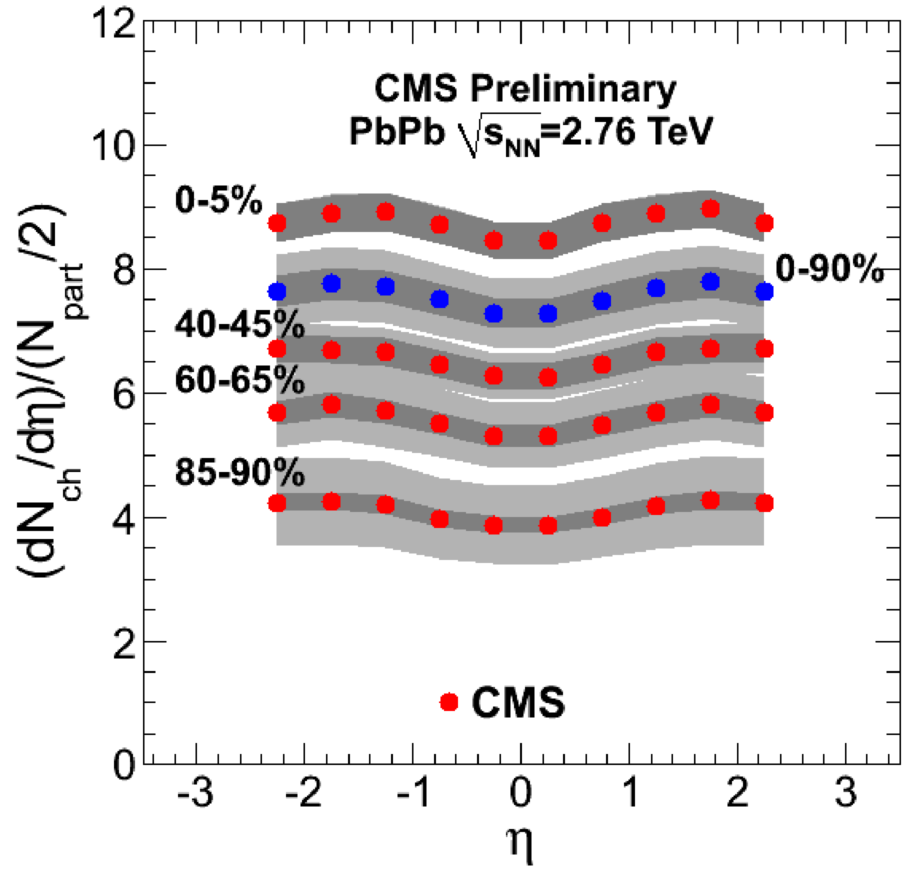
More details on Magdalena Malek's poster (443)

Results

Measured $dN_{ch}/d\eta$

- The results from the two analysis methods agree within 1% → they are averaged
- $dN_{ch}/d\eta$ is ~flat over $|\eta|<2.5$ (<10% variation)

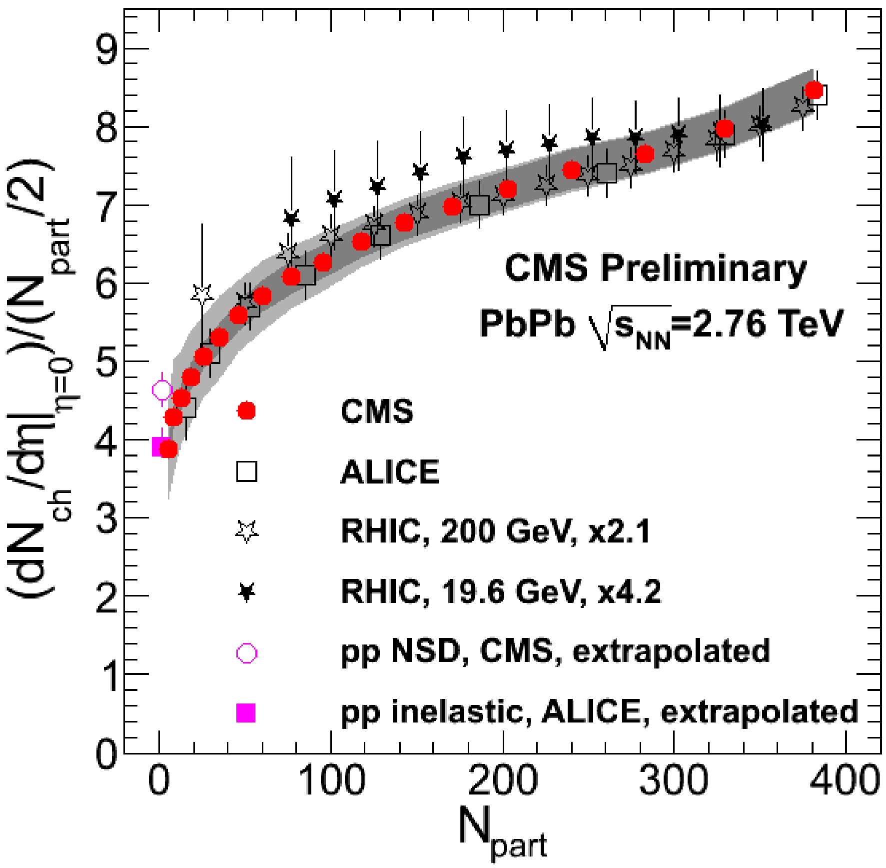


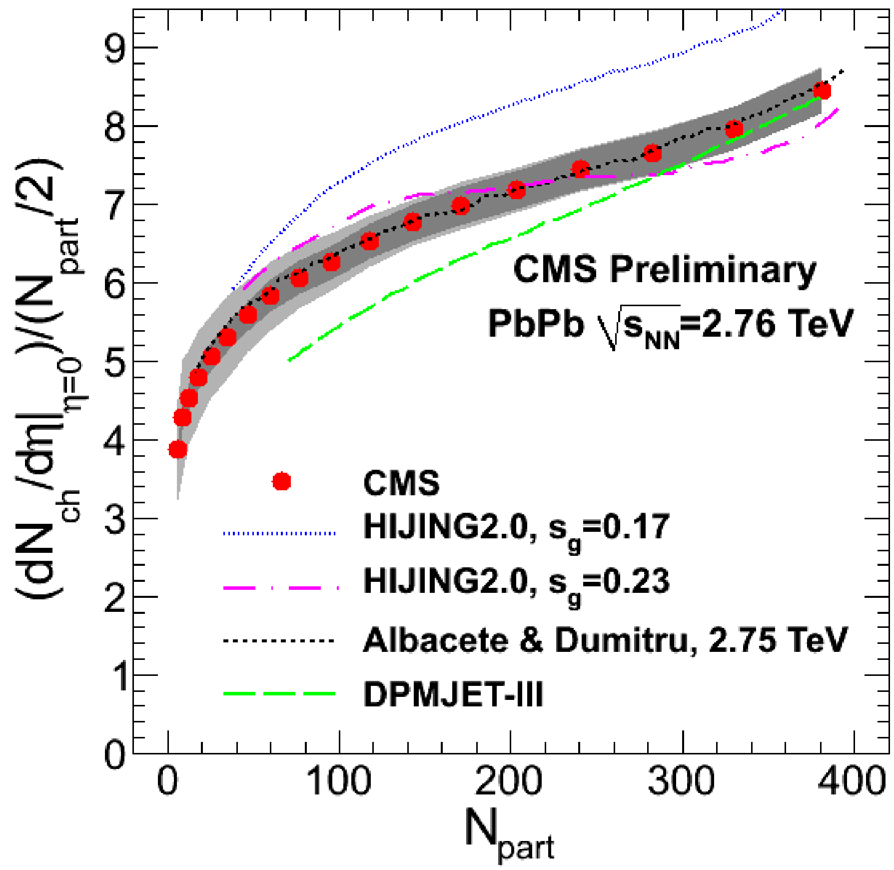


NSD pp data: Phys. Rev. Lett. 105 (2010) 022002

Measured $(dN_{ch}/d\eta)/(N_{part}/2)$

- Similar dependence for all $\sqrt{s_{NN}}$
- Provides contraints on soft+hard, parton saturation, Regge-Gribov approaches

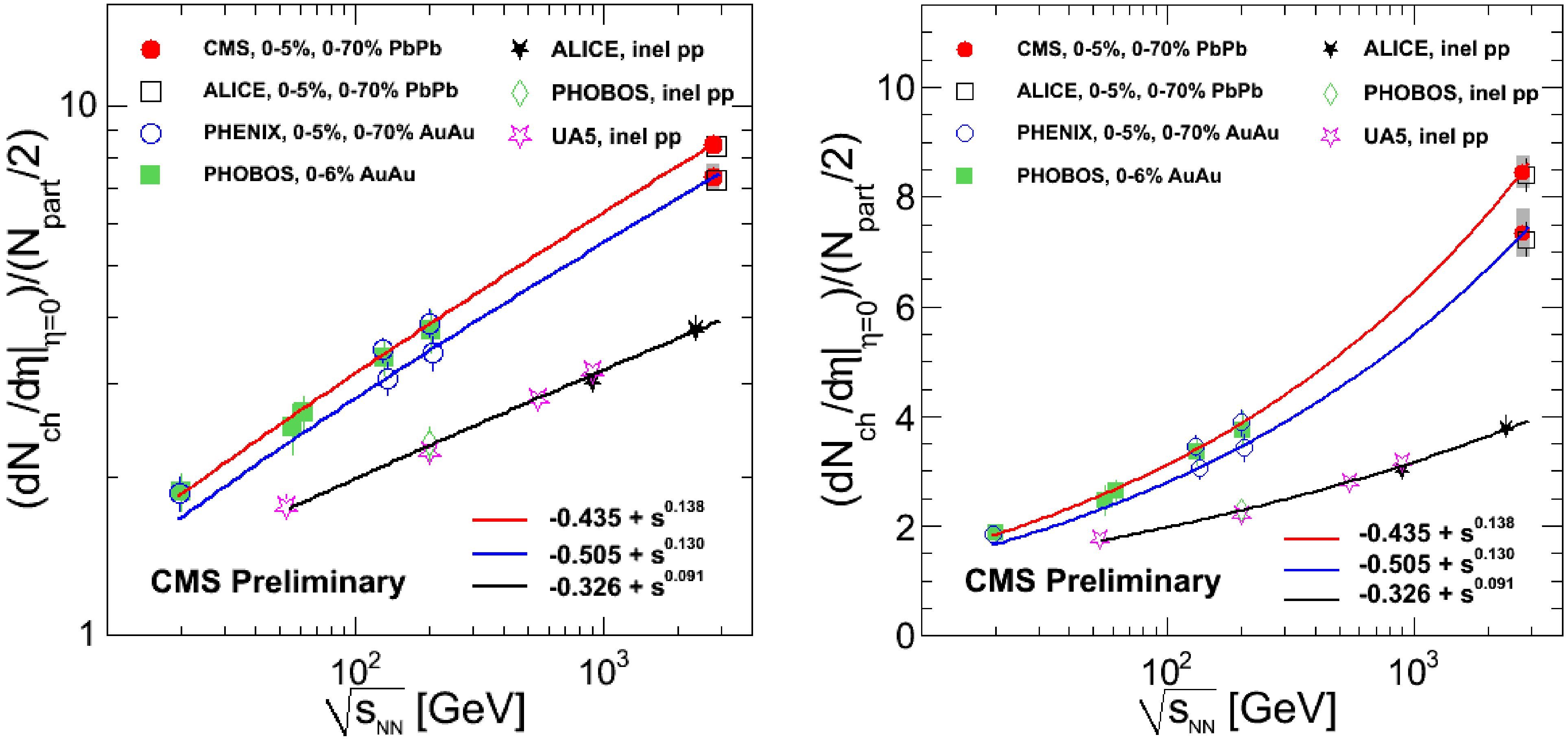




RHIC: Phys. Rev. C71 (2005) 034908, ALICE: Phys. Rev. Lett. 106 (2011) 032301

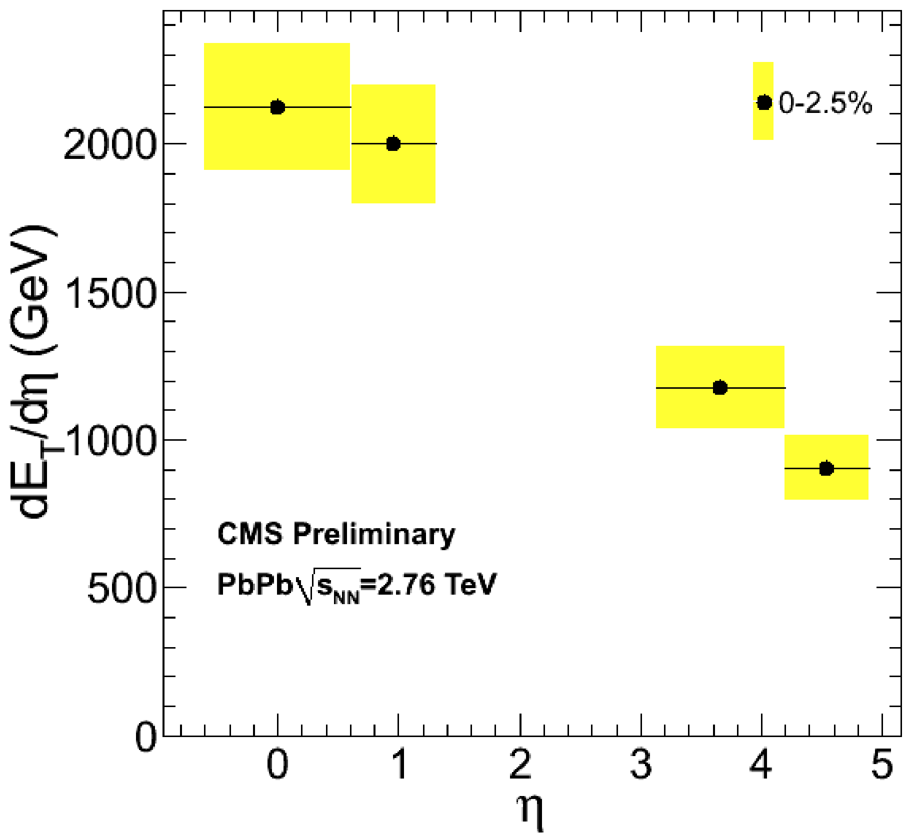
$dN_{ch}/d\eta$: Collision energy dependence

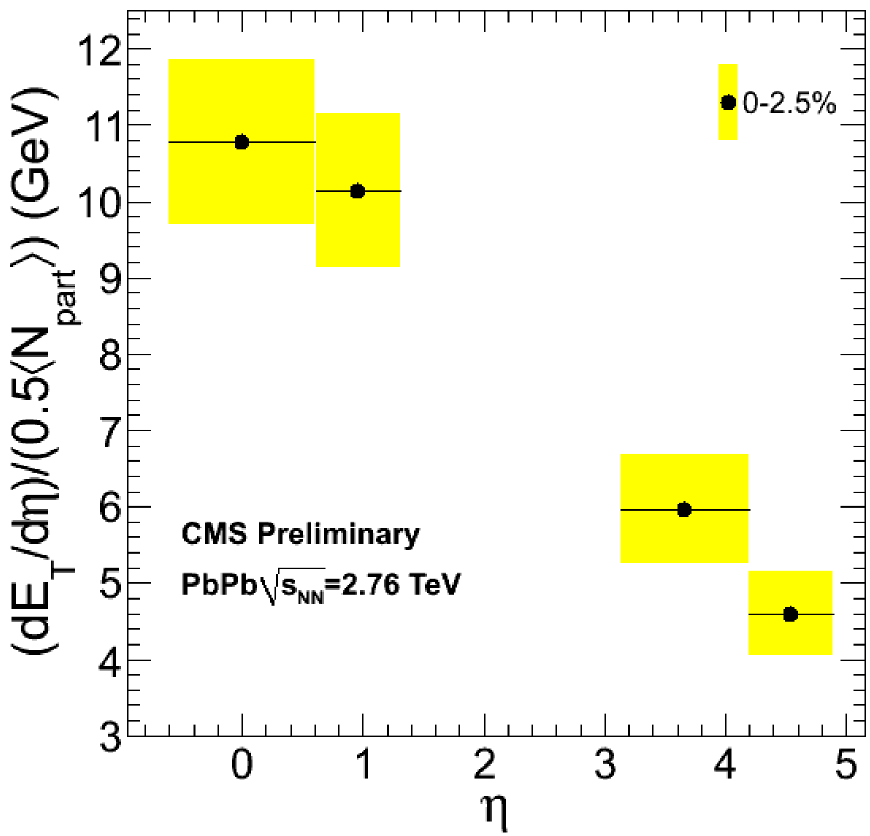
In accordance with a power law dependence with exponents $s^{0.13}$ (PbPb) and $s^{0.09}$ (pp)



Measured $dE_T/d\eta$, 0-2.5%

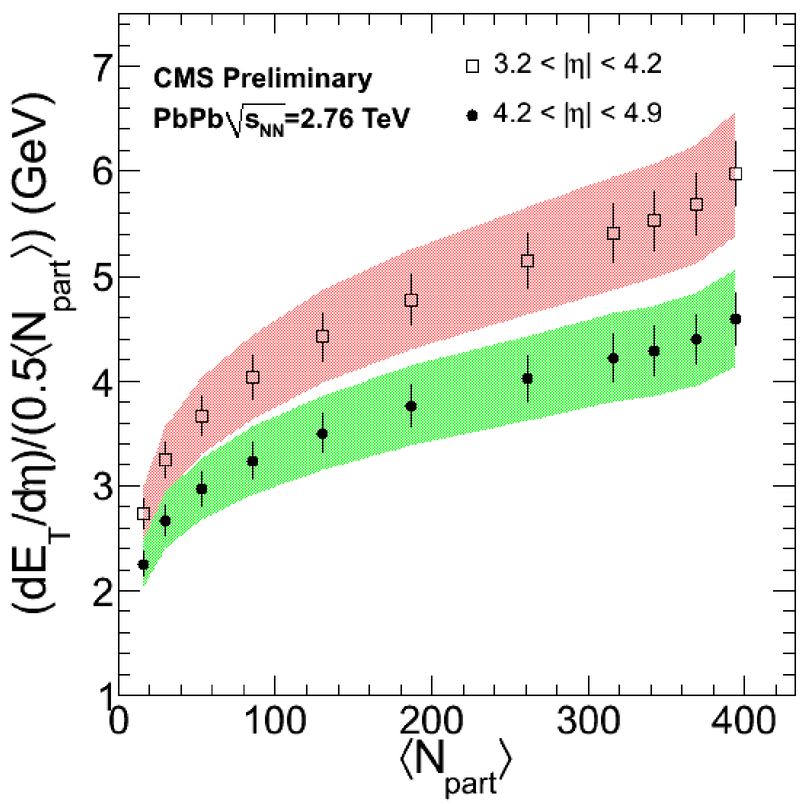
- E_T: 2 TeV deposit for central pseudorapidities
  More than 3xRHIC (0.6 TeV)
- Yield falls by a factor of 2 from η=0 to η=4

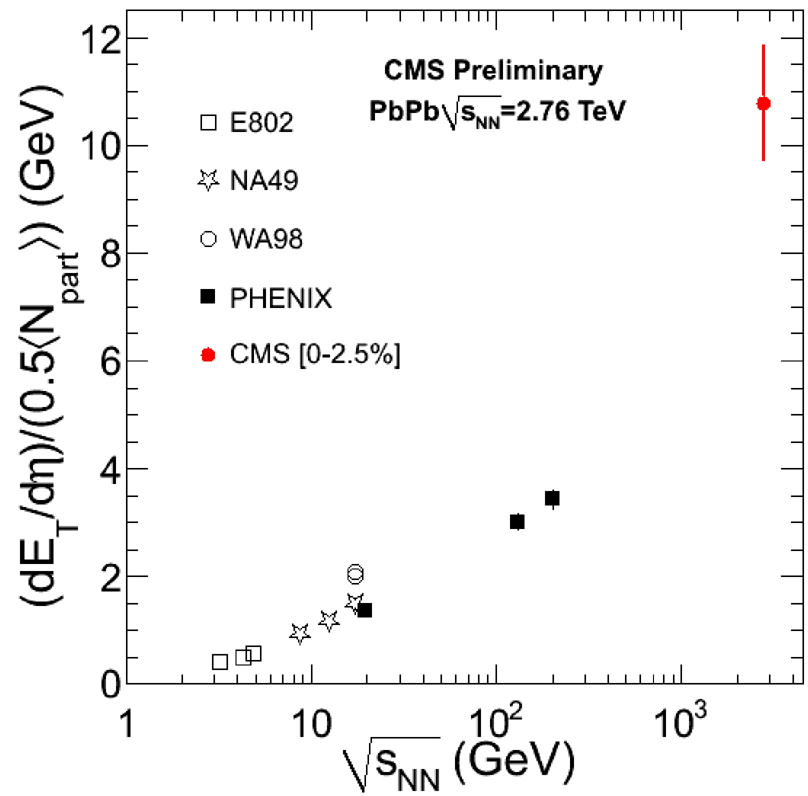




Measured $(dE_T/d\eta)/(N_{part}/2)$

- Sideward S shape
- $\sqrt{s_{NN}}$: More rapid rise than logarithmic
- Increase from 0.2 TeV:
  3.4±0.4 compared to 2.2±0.1 for multiplicity





Summary of the $dN_{ch}/d\eta$ distributions

- Charged hadron density in 0-5%: 1610±55
- Small variation as a function of η (<10%)
- No plateau in the N_{part}-normalised results
- Nice extrapolation to the pp values

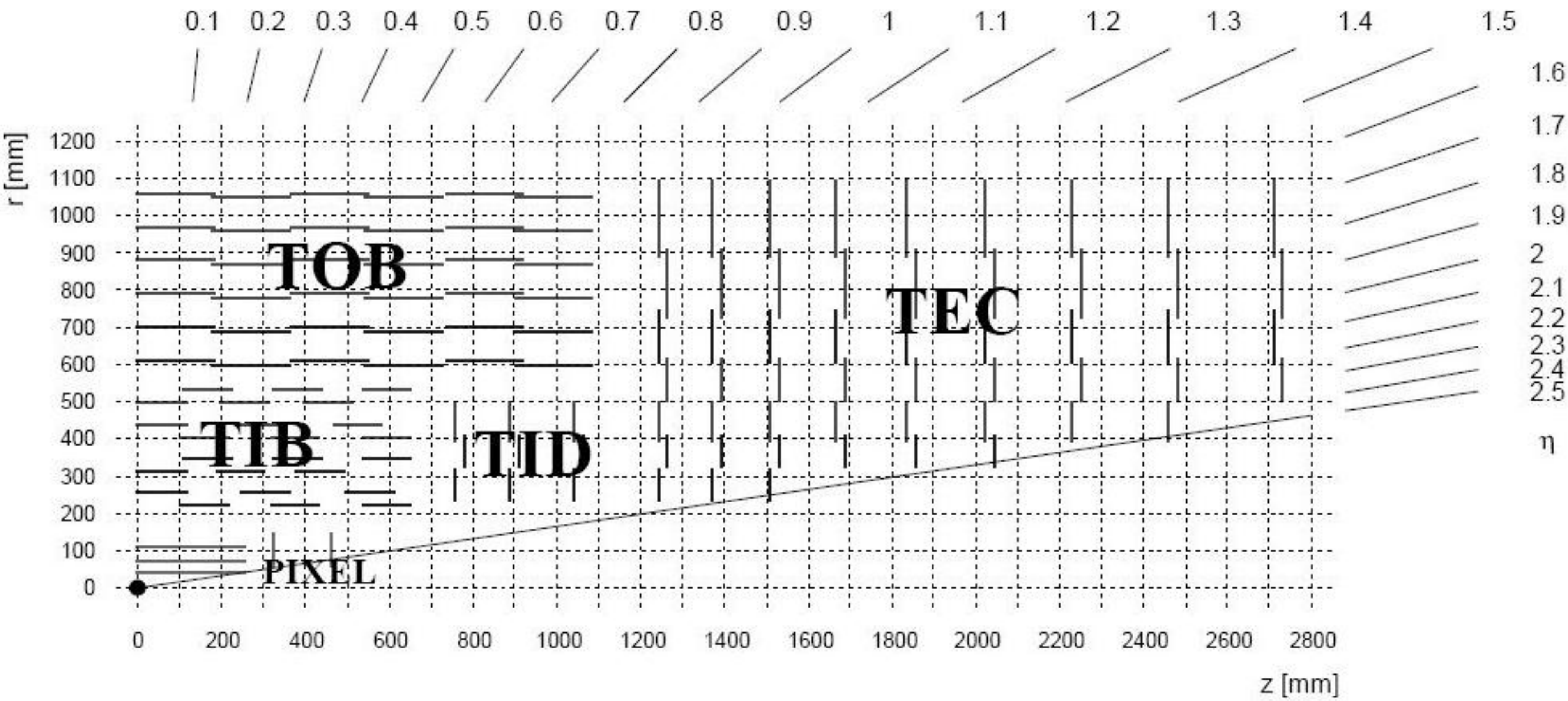
- Very good description of the data by a parton saturation approach
- Collision energy dependence follows power law behaviour

Summary of the $dE_T/d\eta$ distributions

- Central collisions: $dE_T/d\eta$ reaches 2 TeV (more than 3xRHIC)
- Yield falls by a factor of 2 from $\eta=0$ to $\eta=4$
- $\sqrt{s_{NN}}$ dependence: stronger than predicted by earlier experiments assuming logarithmic scaling
- The increase of $(dE_T/d\eta)/(N_{part}/2)$ in central collisions from 0.2 to 2.76 TeV is 3.4 ± 0.4 compared to 2.2 ± 0.1 for multiplicity

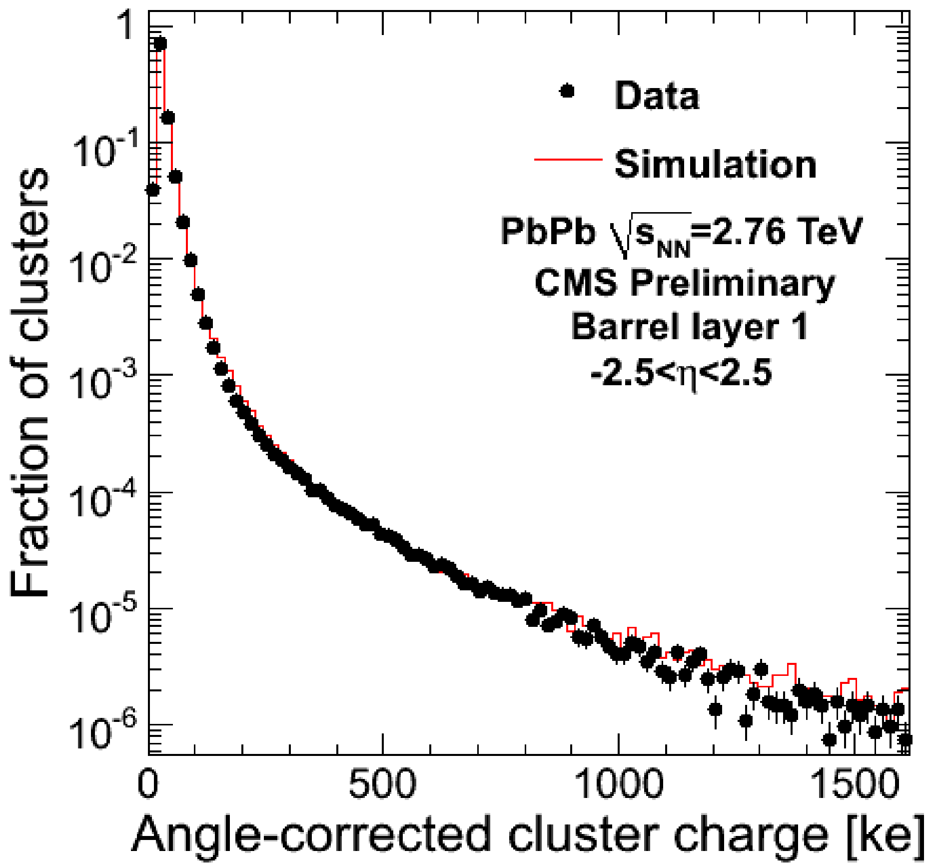
Backup slides

Tracker layout

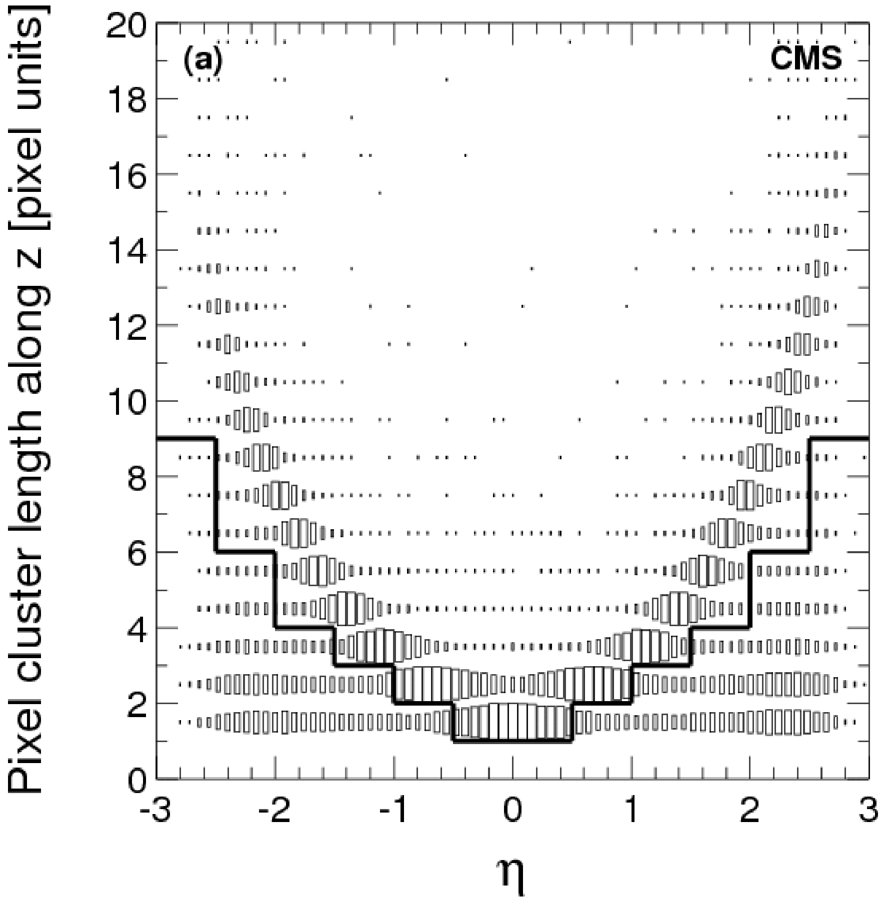


Pixel clusters in PbPb collisions

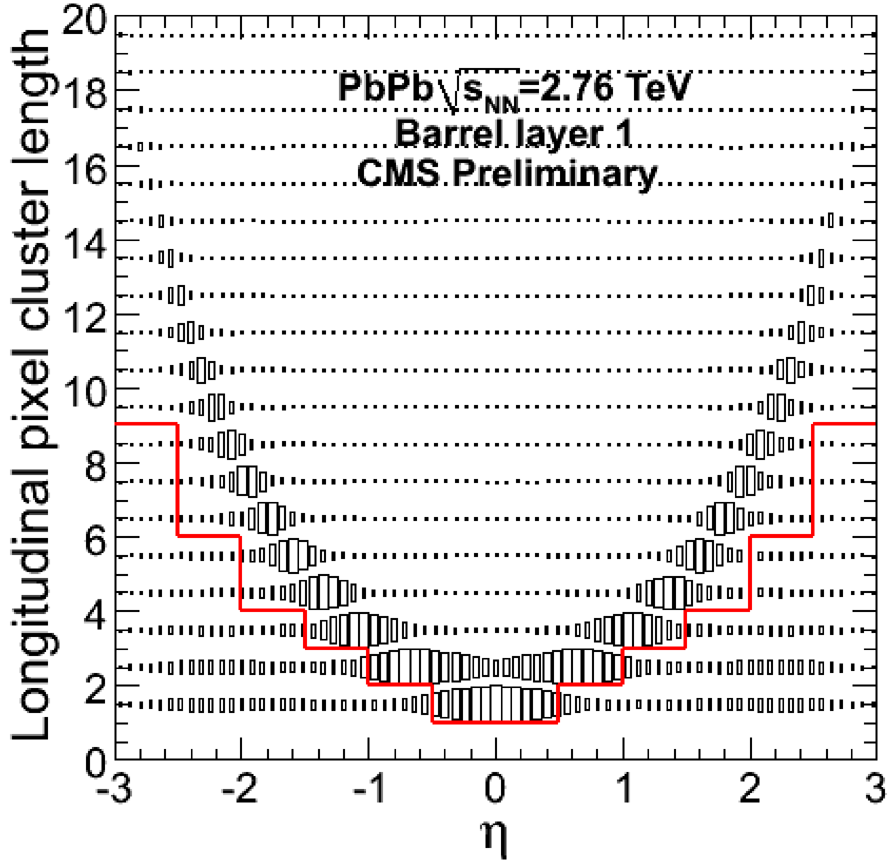
- Pixel detector:
  - Occupancy: <1% even for the 0-5% collisions
  - Efficiency: exceptionally good, >99% just as in pp
- Pixel clusters:
  - Well understood behaviour



Cluster length in pp and PbPb



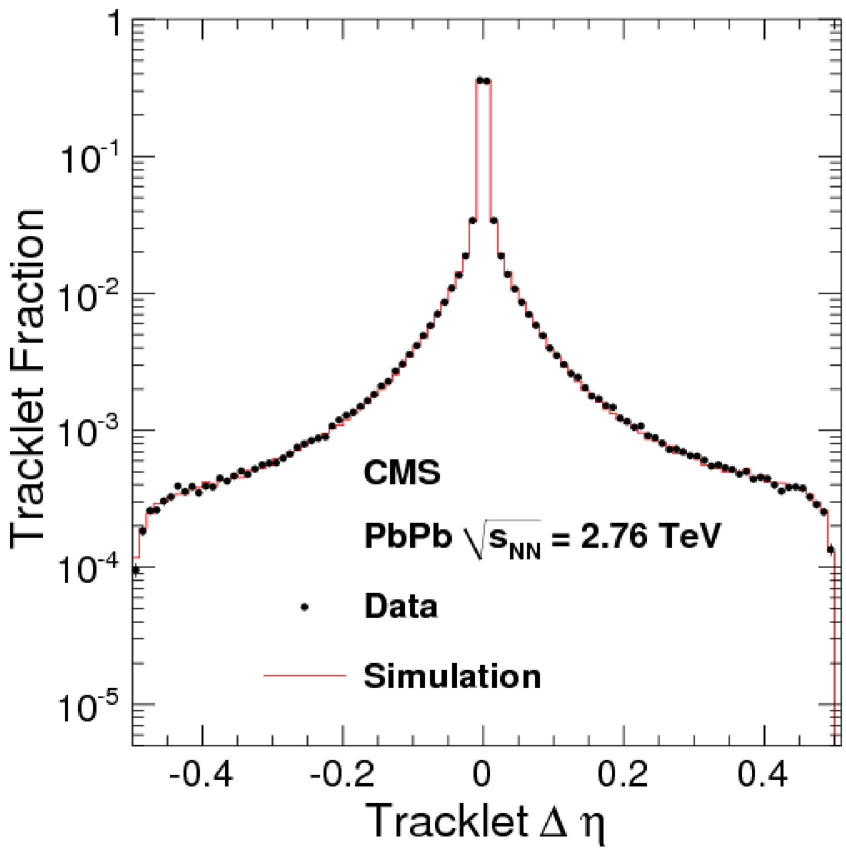
B=4 T pp data
Phys. Rev. Lett. 105 (2010) 022002

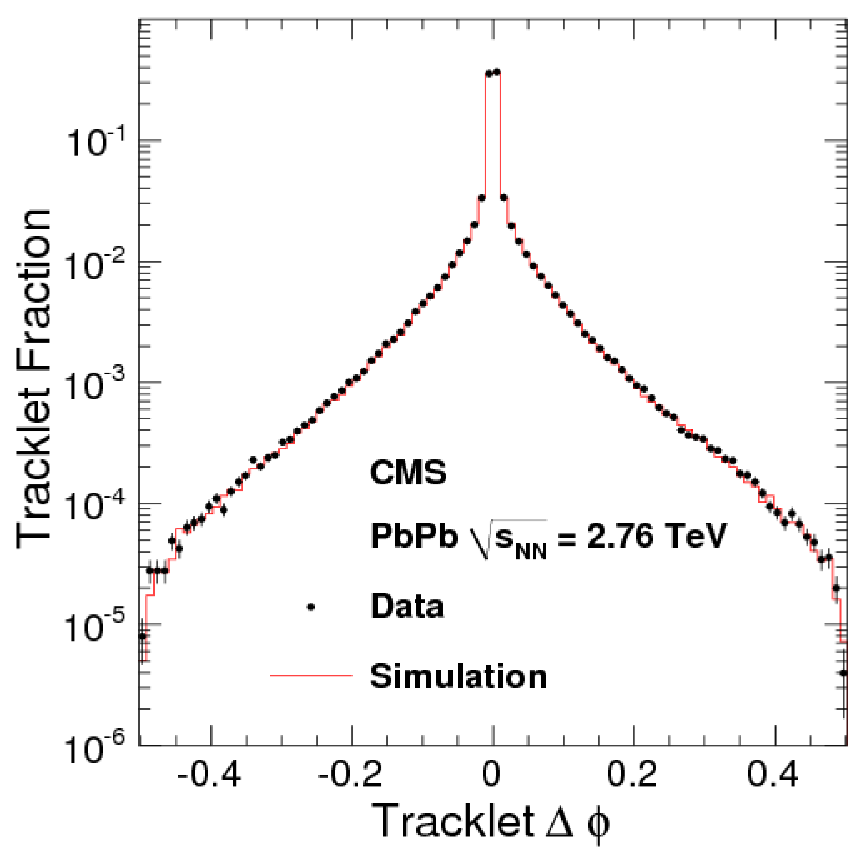


B=0 T PbPb data, slide 7

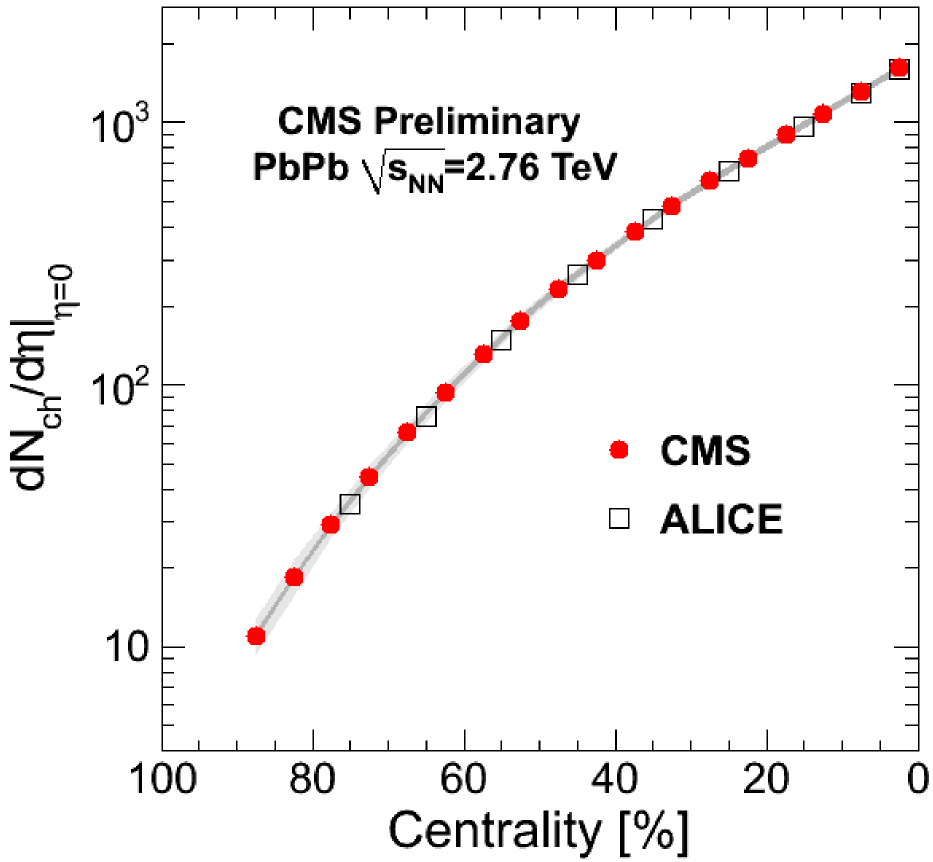
Tracklets: data-MC comparison

- Signal peaks around (Δη,Δφ)=(0,0)
- Agreement over 6 orders of magnitude





$dN_{ch}/d\eta$: pp and PbPb



NSD pp data
Phys. Rev. Lett. 105 (2010) 022002

Systematic uncertainties: $dN_{ch}/d\eta$

- Systematics for the two analysis methods

Source	Pixel Counting [%]	Tracklet [%]
Correction on event selection	-	-
Centrality (0–5% – 85–90%)	0.5–15.6	0.5–15.6
Pixel hit efficiency	0.5	1.0
Tracklet and cluster selection	3.0	0.5
Acceptance uncertainty	1.5	1.5
Correction of secondary particles	2.0	1.0
Pixel cluster splitting	1.0	0.4
Efficiency of the reconstruction	-	1.9
Misalignment, different scenarios	-	1.0
Random hits	1.0	0.2
Total non-correlated uncertainties	-	2.1
Total uncertainties	4.2–16.2	3.1–15.9

Systematic uncertainties: $dE_T/d\eta$

	$\lvert\eta\rvert < 0.6$	$0.6 < \lvert\eta\rvert < 1.3$	$3.2 < \lvert\eta\rvert < 4.2$	$4.2 < \lvert\eta\rvert < 4.9$
Energy scale	2%	2%	10%	10%
MC correction factor	9 %	9 %	4 %	4%
HF noise	–	–	2 %	2%
Vertex distribution	2%	2%	1%	2%
η symmetry	2%	2%	2%	2%
Auto correlations	1.5%	1.5%	1%	1%
PF/Calo difference	1%	1%	0.1%	0.1%
Total	10%	10%	12%	12%

N_{part}

Cent. bin	0–5%	5–10%	10–15%	15–20%	20–25%	25–30%
$\langle N_{part} \rangle$	381 ± 2	329 ± 3	283 ± 3	240 ± 3	203 ± 3	171 ± 3
Cent. bin	30–35%	35–40%	40–45%	45–50%	50–55%	55–60%
$\langle N_{part} \rangle$	142 ± 3	117 ± 3	95.8 ± 3.0	76.8 ± 2.7	60.4 ± 2.7	46.7 ± 2.3
Cent. bin	60–65%	65–70%	70–75%	75–80%	80–85%	85–90%
$\langle N_{part} \rangle$	35.3 ± 2.0	25.8 ± 1.6	18.5 ± 1.2	12.8 ± 0.9	8.64 ± 0.56	5.71 ± 0.24

Event selection efficiency

- Hadronic event selection efficiency:
  - Peripheral PbPb data
  - 2.76 TeV pp data
  - AMPT
  - Pythia Z2
- UPC study:
  - Based on Djuvstrand's and Nystrand's article: arXiv:1011.4908v2