Universiteit Antwerpen

The CMS "ridge" in pp: Possible MPI interpretation (and others)

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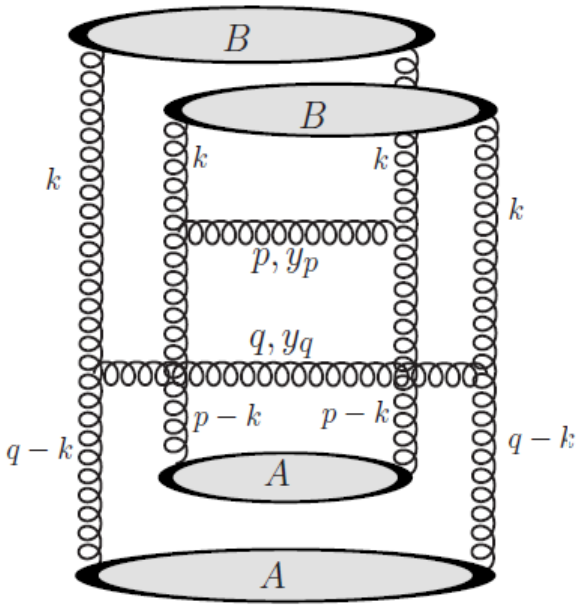
+ Pierre Van Mechelen

MPI@LHC 2010: 2nd International Workshop on
Multiple Partonic Interactions at the LHC

Glasgow, 29th of November to the 3rd of December 2010

Color-Glass-Condensate

Dumitru et al.
[arXiv:1009.5295]



Transverse momentum Flowing in the blobs: $|p_\perp - k_\perp|$ and $|q_\perp - k_\perp|$

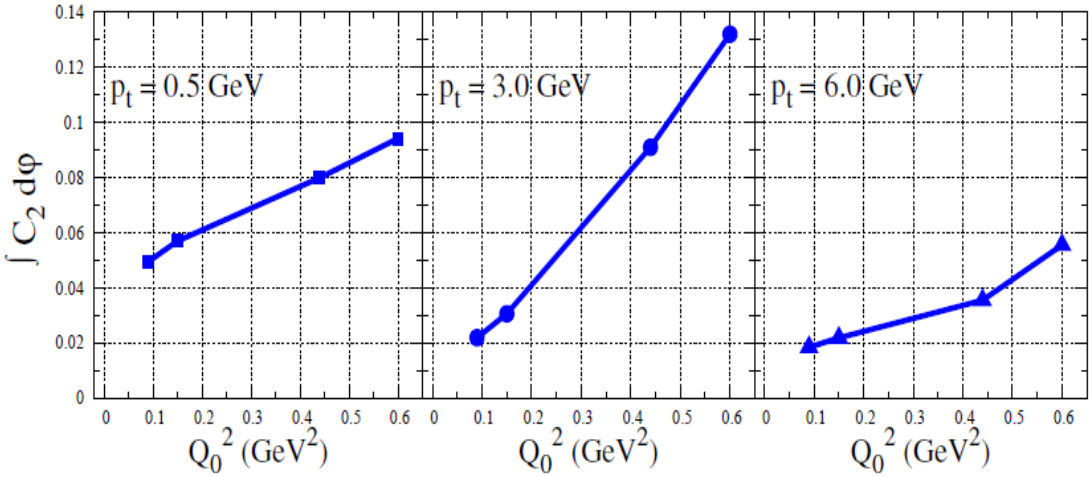
"Saturated" gluons peaking at:

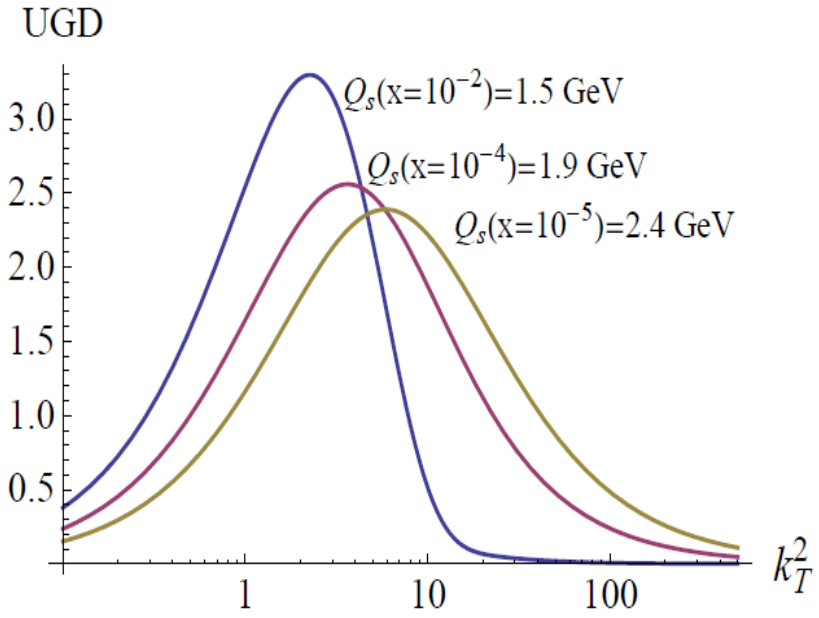
$$\langle k_t^2 \rangle \sim Q_s^4(x)$$
$$\langle n \rangle \sim Q_s^2(x)$$

→ $|p_\perp - k_\perp| \sim Q_s$ and $|q_\perp - k_\perp| \sim Q_s$.

→ **Δϕ correlations:**

$$C_2(p_\perp, y_p, q_\perp, y_q) \equiv \frac{dN}{dy}\left[\frac{\frac{dN_2}{d^2p_\perp dy_p d^2q_\perp dy_q}}{\frac{dN}{d^2p_\perp dy_p}\frac{dN}{d^2q_\perp dy_q}} - 1\right]$$



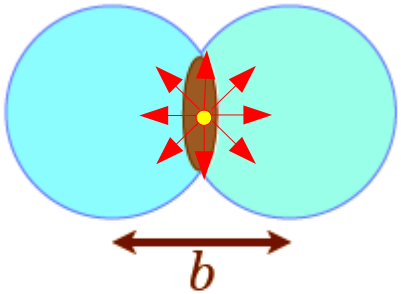


→ **Similar effect as in CMS data**

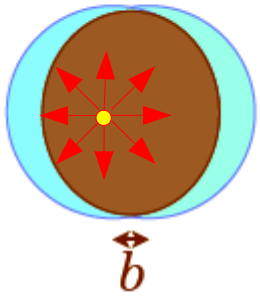
Other ref.: Jalilian-Marian [arxiv:1011.1601]
Bautista et al. [arXiv:1011.1870]
Tribedy, Venugopalan [arXiv:1011.1895]

Heavy Ion: Is it Elliptic Flow (v_2) ?

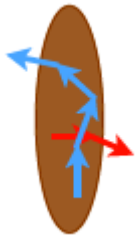
"Peripheral" (large impact parameter)



"Central" (Samall impact parameter)



Including Final state interactions with the medium give preferred direction:

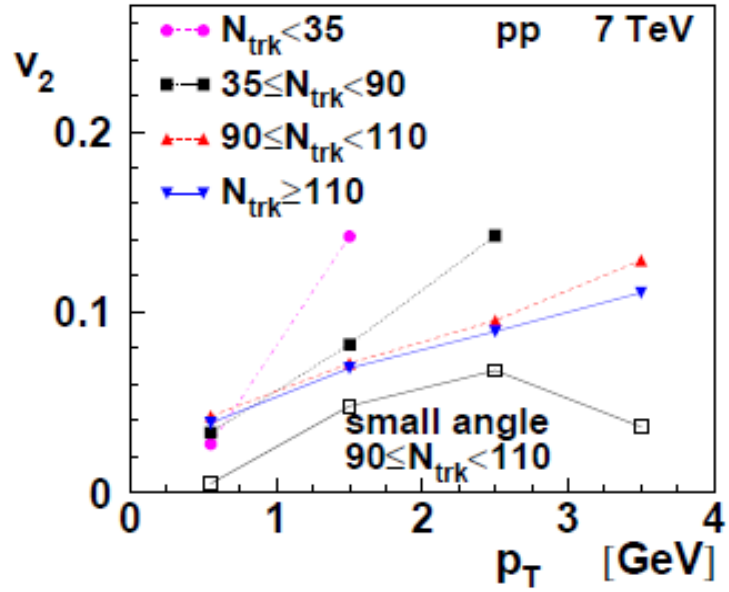


$$\frac{dN}{dp_T} = \frac{dN}{2\pi p_T\, dp_T}\left[1 + 2v_1\cos(\varphi - \Phi_R) + 2v_2\cos 2(\varphi - \Phi_R) + \cdots\right]$$

$$v_n = \langle \cos n(\varphi - \Phi_R) \rangle$$

Bozek [arXiv1010.0405]:

Assuming some models on non-flow part:



Near-side long-range 2-particle angular correlations in PYTHIA 6.4

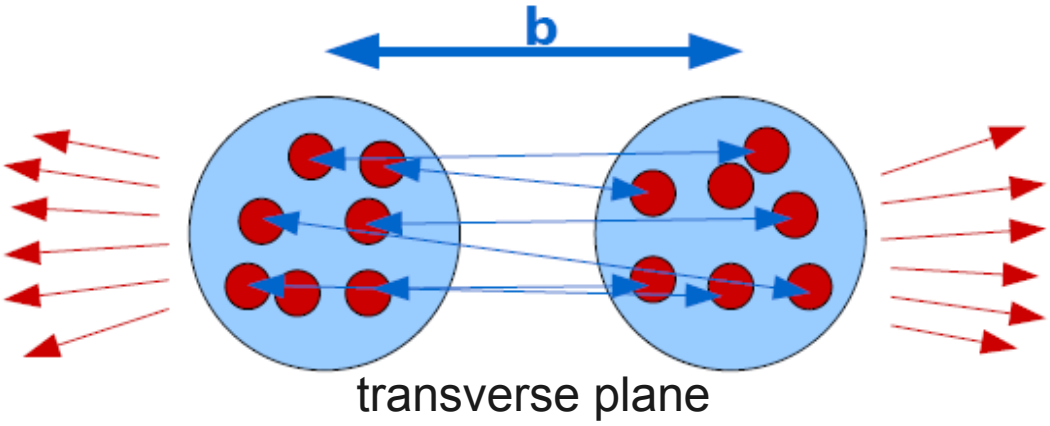
Pierre Van Mechelen

Angular momentum conservation in multiple parton interactions

Semi-classical intuition:

Multiple parton interactions may generate long-range, near side angular correlations

- Protons separated by impact vector ***b***
- All parton collisions will tend to lie in the plane defined by incoming proton momenta ***p*** and impact vector ***b***
  → resulting particles have similar φ
- Initial state partons have different x_{Bj}
  → resulting particles have different η



- Sizeable effect expected for events with many MPI (large multiplicity) and for particles with moderate p_T (because of the $1/p_T^4$ dependence of the partonic cross section)

Comments

- Need to consider quantum mechanics of the problem
- Argument does not hold for central collisions, which in principle dominate the high-multiplicity sample
- Azimuthal correlation of MPIs was studied experimentally, e.g. in γ + 3 jet events, but no correlation was found (however the hardness and centre-of-mass energy of the MPIs was quite different)

Azimuthal angle of multiple parton interactions in PYTHIA

PYTHIA does not take into account angular momentum conservation in MPI!

- MPI approach of PYTHIA uses impact parameter model to calculate the number of MPI, but the azimuth of the scattering plane is chosen randomly for each MPI
  → no long-range near-side angular correlations in PYTHIA!
- Private modification of PYTHIA aligns MPI to scattering plane of hardest interaction, but with a impact-parameter dependent smearing:

$$\phi_i = \phi_{hardest} + \mathrm{Gauss}(\mu = 0, \sigma = 1)\arctan(b_{avg}/b)$$

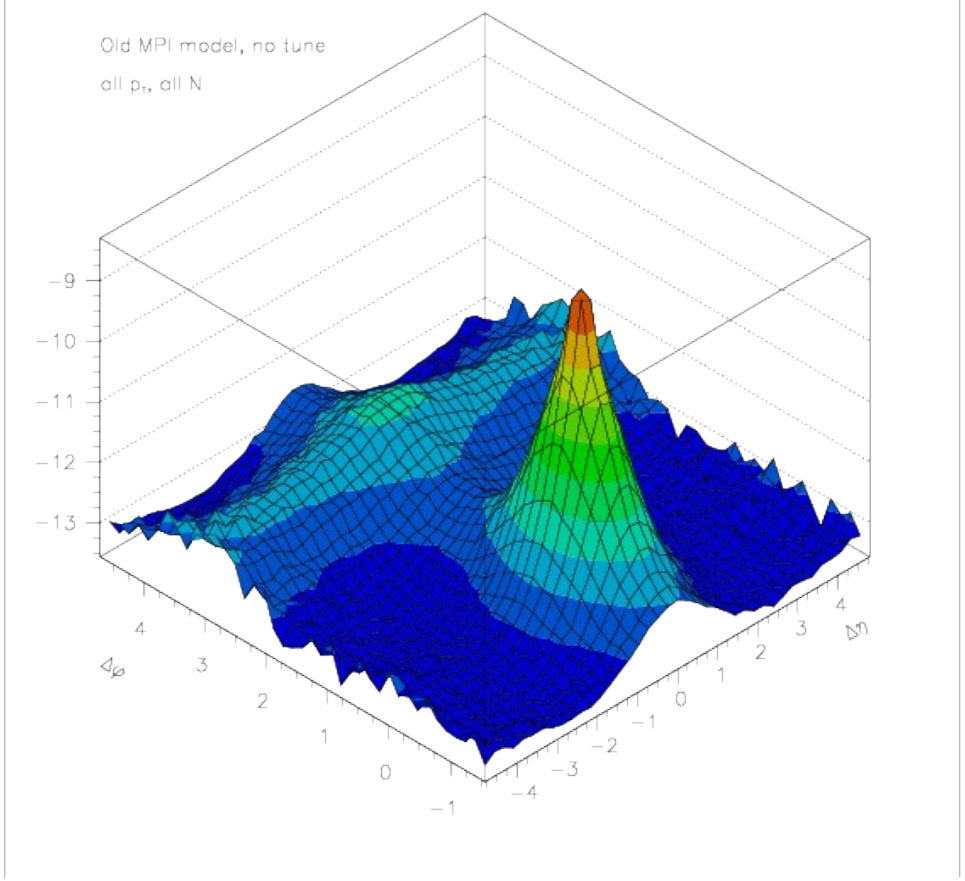
  → this is just a first attempt; a more sophisticated mode, taking into account the topology of the MPIs, has also been used
- PYTHIA 6 has two MPI models:
  - "Old" model: calculates hadronic overlap to obtain number of MPIs
  - "New" model: adds parton showers to MPIs, colour reconnections, ...
- Some numbers for new model (Perugia 2010 tune)

	nch(|η|<2.4) < 10	nch(|η|<2.4) > 110
average number of MPI	0.6	14
mean normalized impact parameter	1.33	0.26

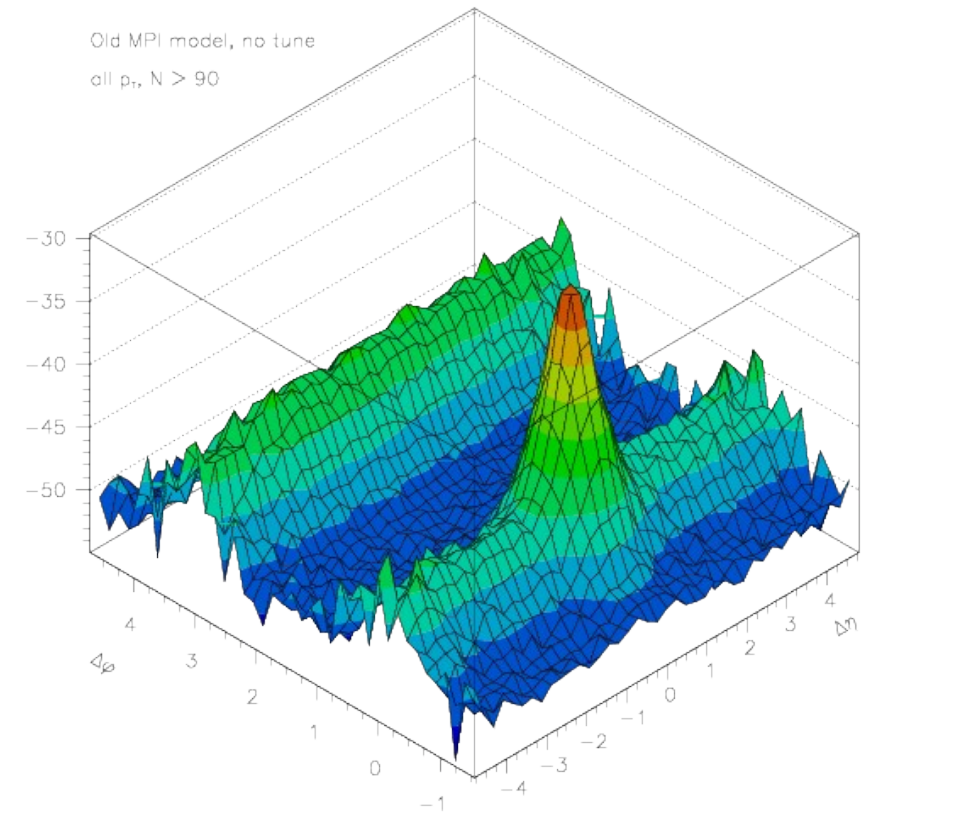
→ "normalized" = w.r.t. average impact parameter in minimum bias events

Old MPI model – no tune

All pT, all N



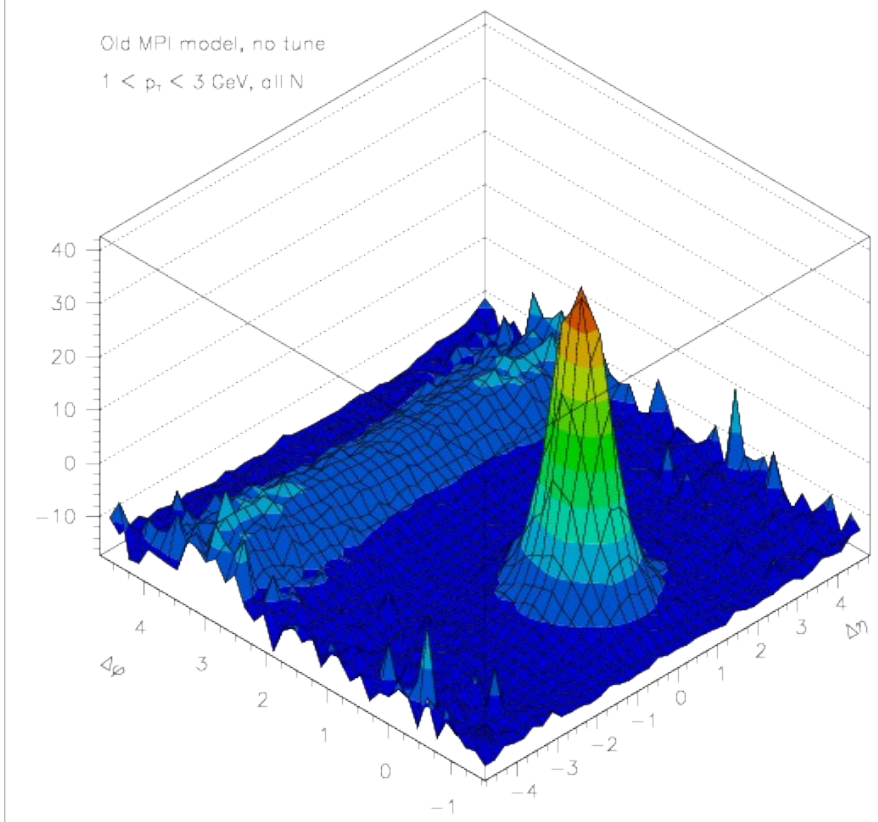
All pT, N > 90



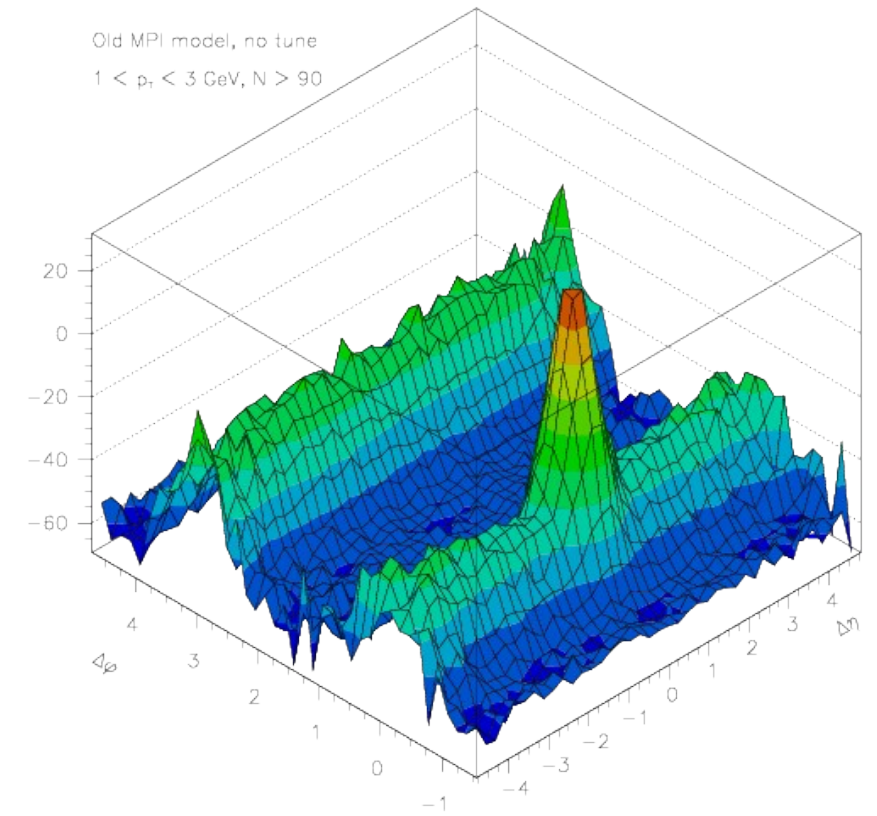
➔ In old MPI model, near-side ridge appears at large multiplicity, even for all pT

Old MPI model – no tune

1 < pT < 3 GeV, all N



1 < pT < 3 GeV, N > 90



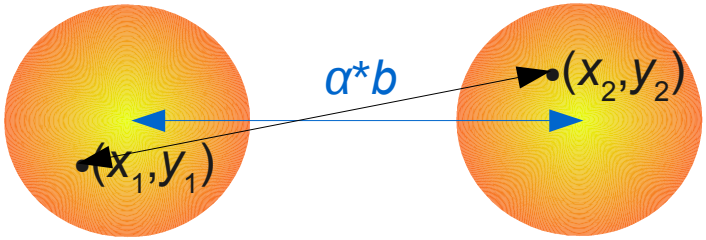
→ In old MPI model, near-side ridge appears at large multiplicity, also for 1 < pT < 3 GeV

New MPI model – Perugia 2010 tune – scaled impact parameter

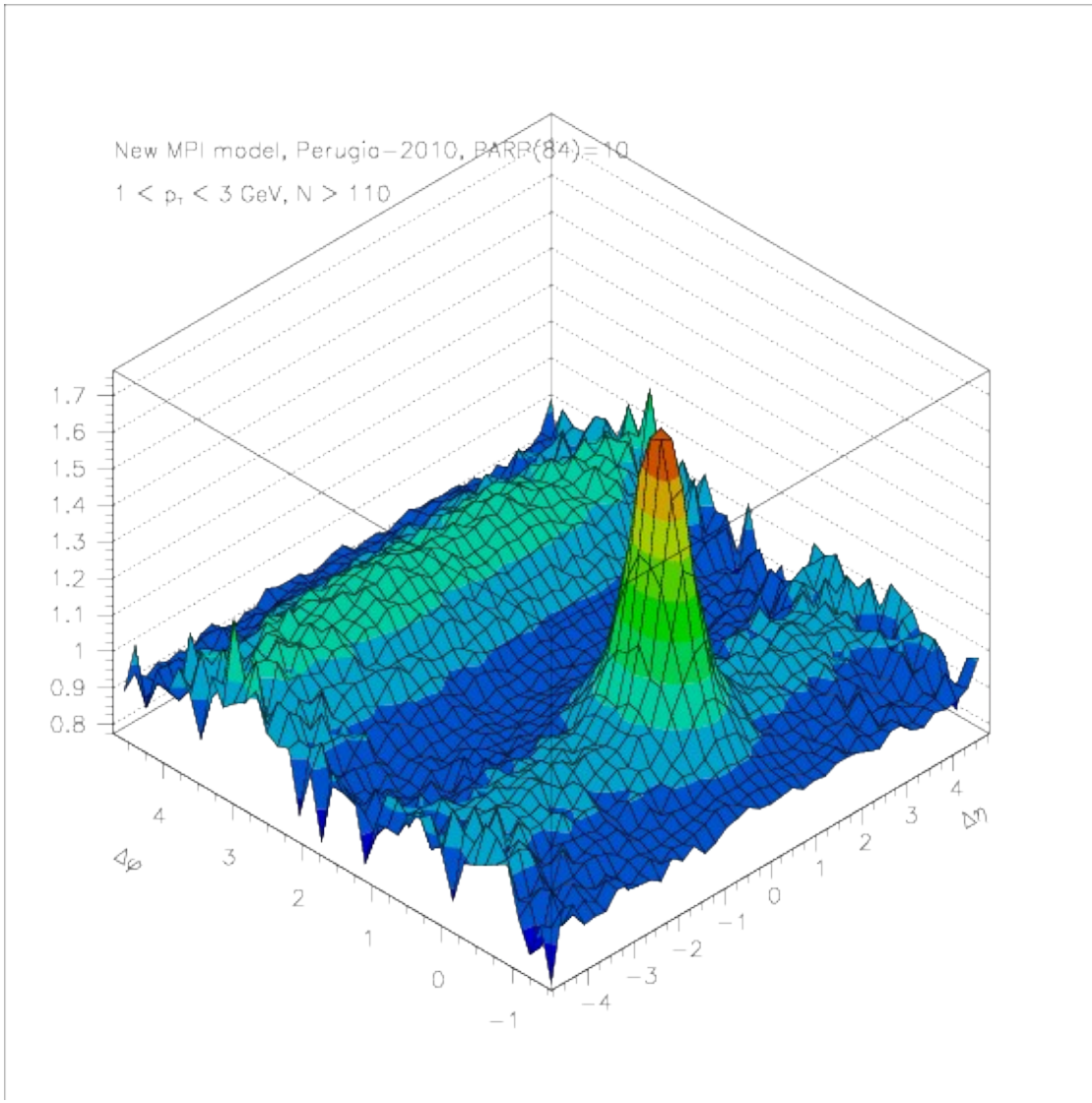
Parton showers, colour reconnections, primordial pT all switched on

New method to include azimuthal correlations:

- Sample gaussian profiles of proton separated by impact parameter * scale factor (=10 here)



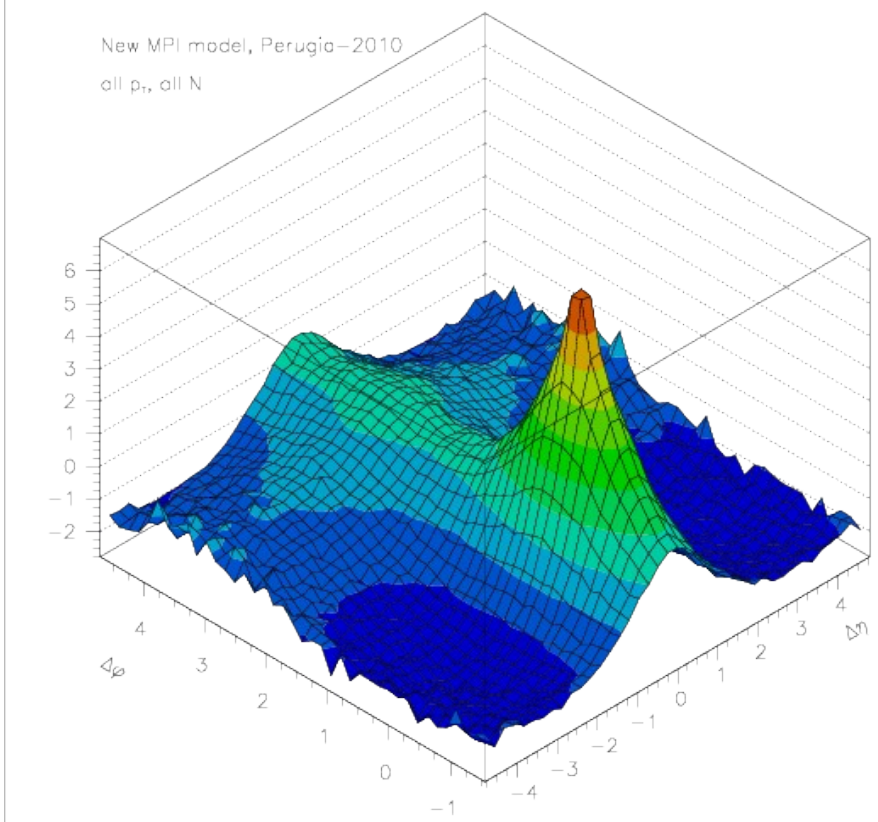
$$\phi_i = \phi_{hardest} + \arctan\left(\frac{y_2 - y_1}{(x_2 + \alpha * b) - x_1}\right)$$



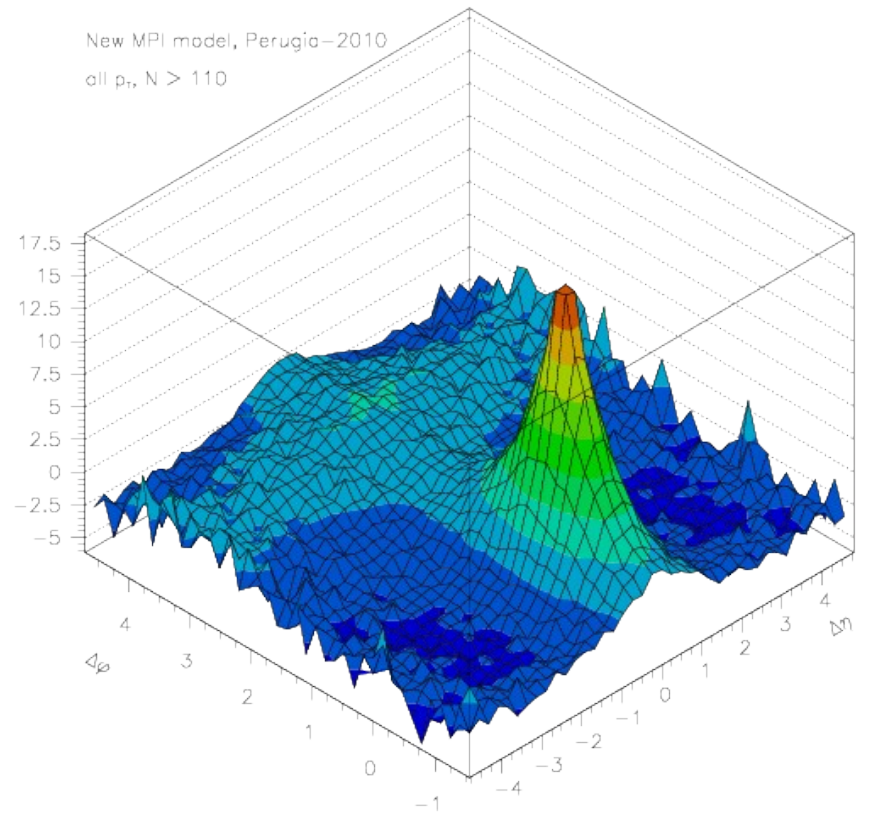
BACKUP SLIDES

New MPI model – Perugia 2010 tune

All pT, all N



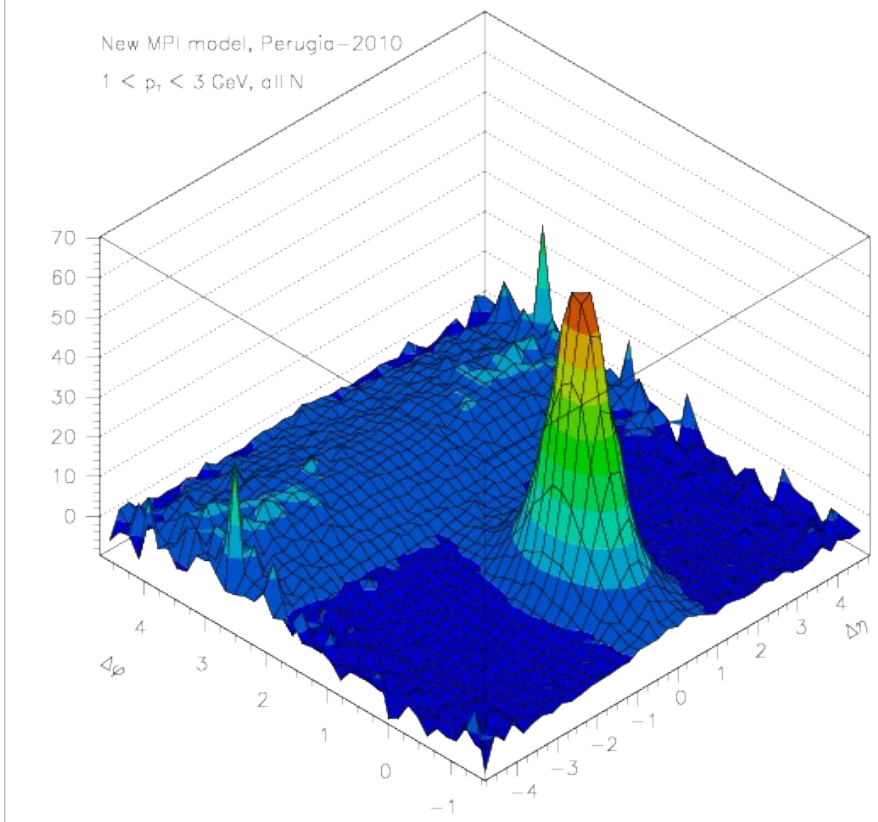
All pT, N > 110



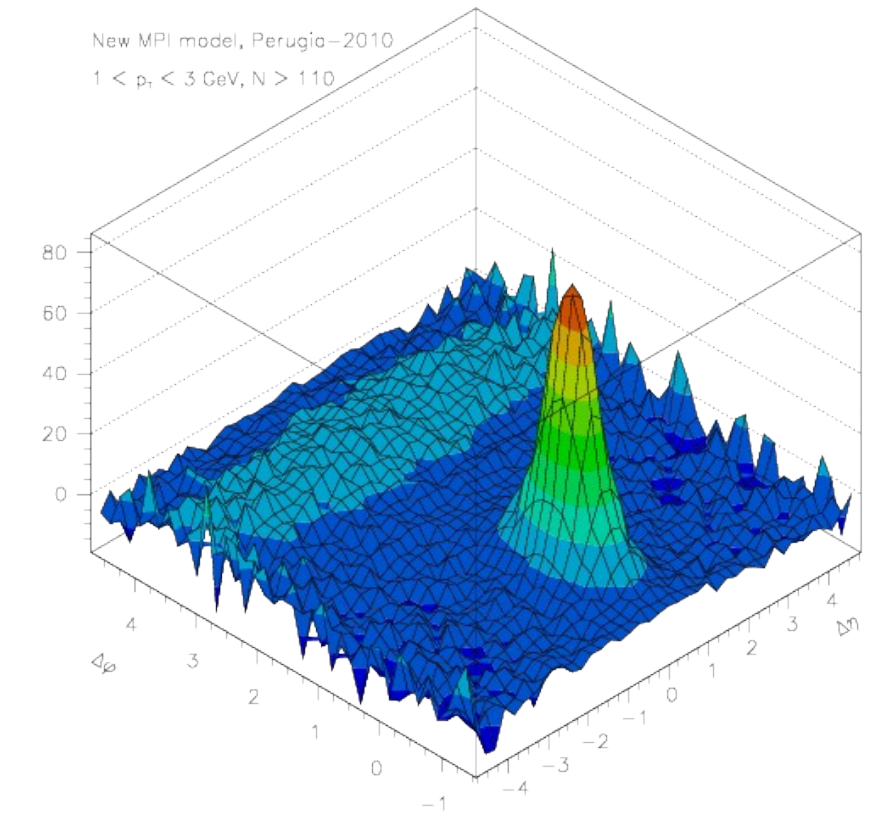
➔ No ridge visible in new MPI model

New MPI model – Perugia 2010 tune

1 < pT < 3 GeV, all N



1 < pT < 3 GeV, N > 110

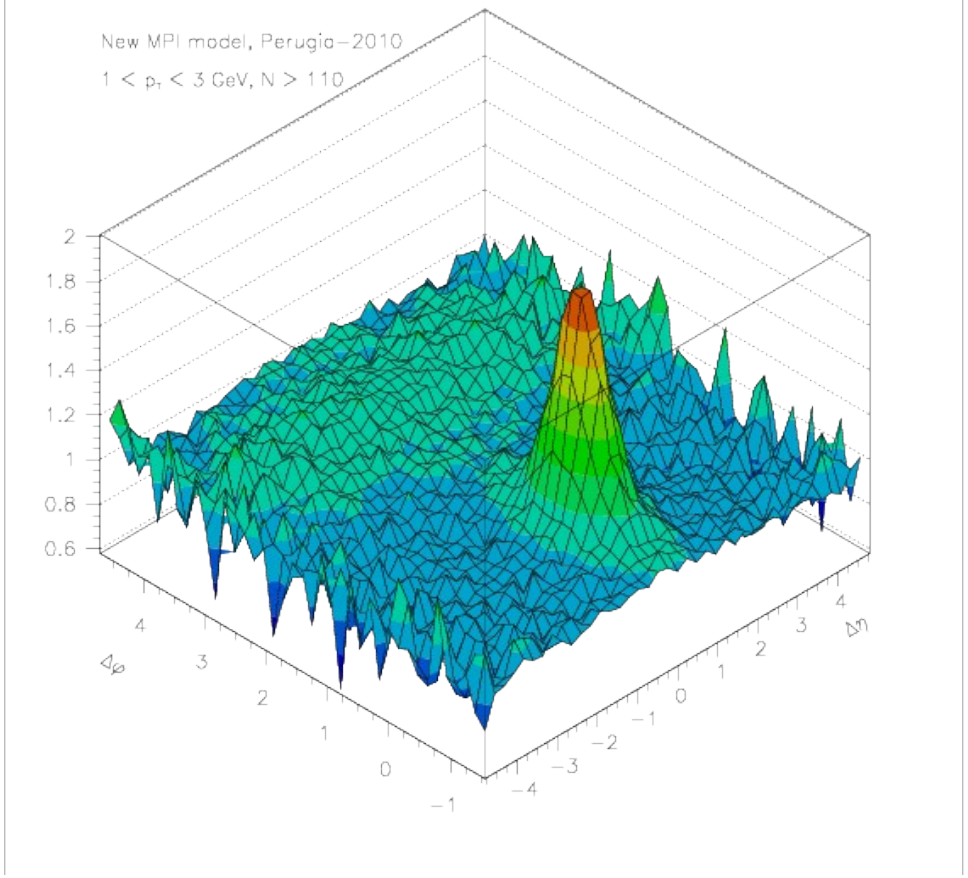


➔ No ridge visible in new MPI model, also not for 1 < pT < 3 GeV

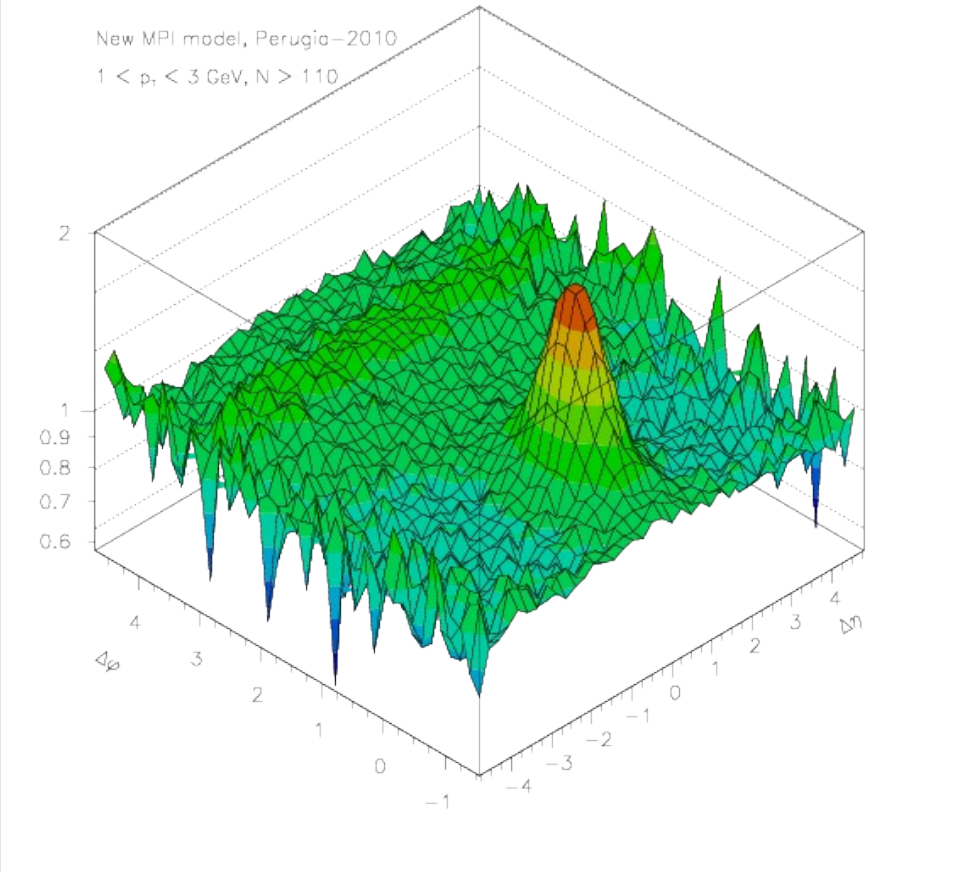
New MPI model – Perugia 2010 tune – no parton showers in MPI, colour reconnections or primordial pT

MSTP(84) = MSTP(85) = MSTP(91) = MSTP(95) = 0

1 < pT < 3 GeV, N > 110, linear scale



1 < pT < 3 GeV, N > 110, logarithmic scale

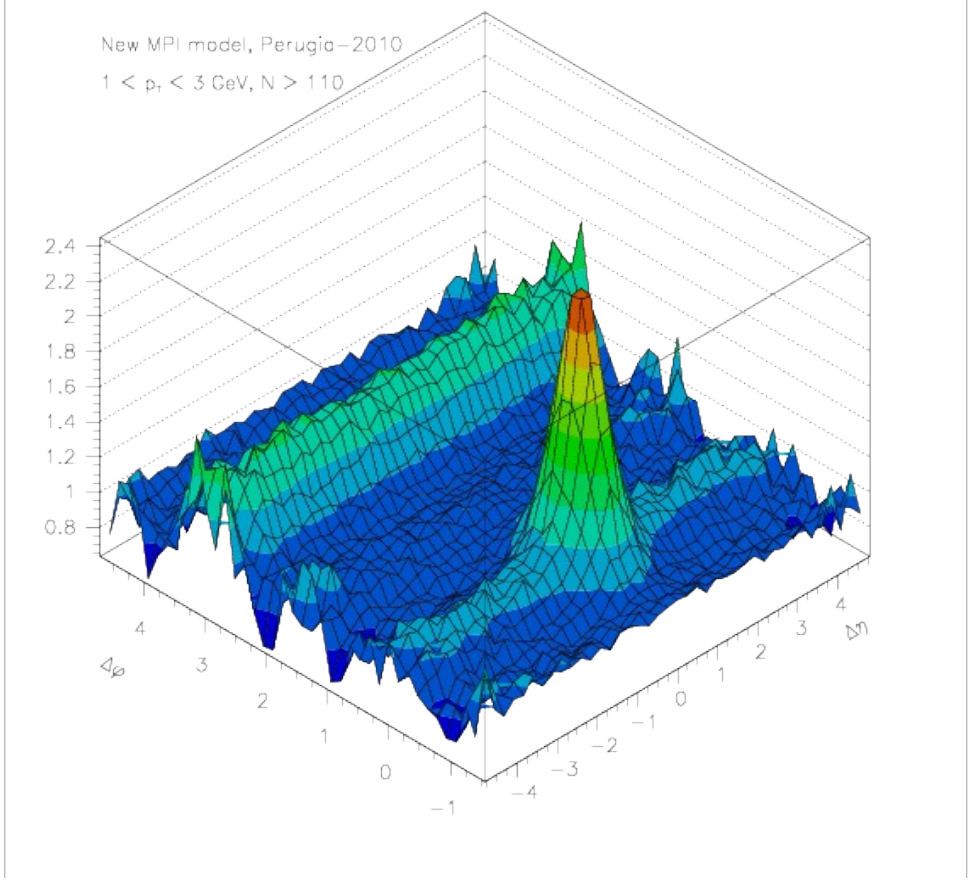


➔ No ridge visible in new MPI model, also not when disabling ISR/FSR in all but hardest interaction, colour reconnections and primordial pT

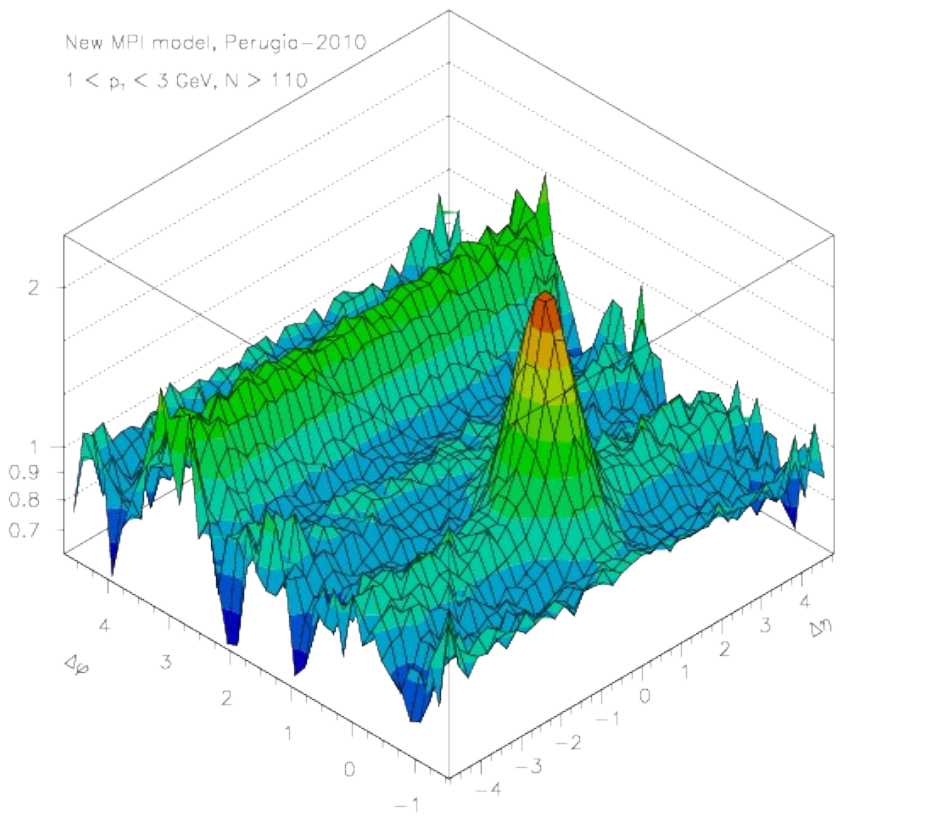
New MPI model – Perugia 2010 tune – no parton showers, colour reconnections or primordial pT

MSTP(61) = MSTP(71) = MSTP(84) = MSTP(85) = MSTP(91) = MSTP(95) = 0

1 < pT < 3 GeV, N > 110, linear scale



1 < pT < 3 GeV, N > 110, logarithmic scale

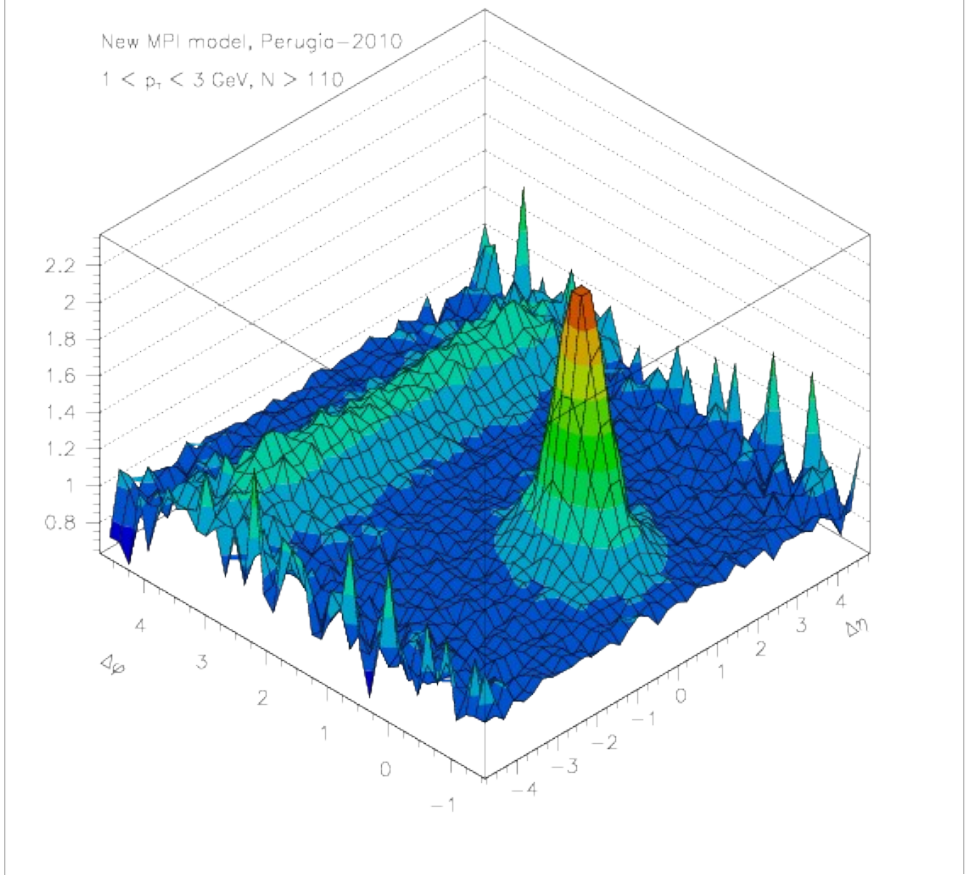


→ Ridge reappears in new MPI when also disabling parton showers of primary interaction! Additional ridge at Δφ = 90°!!

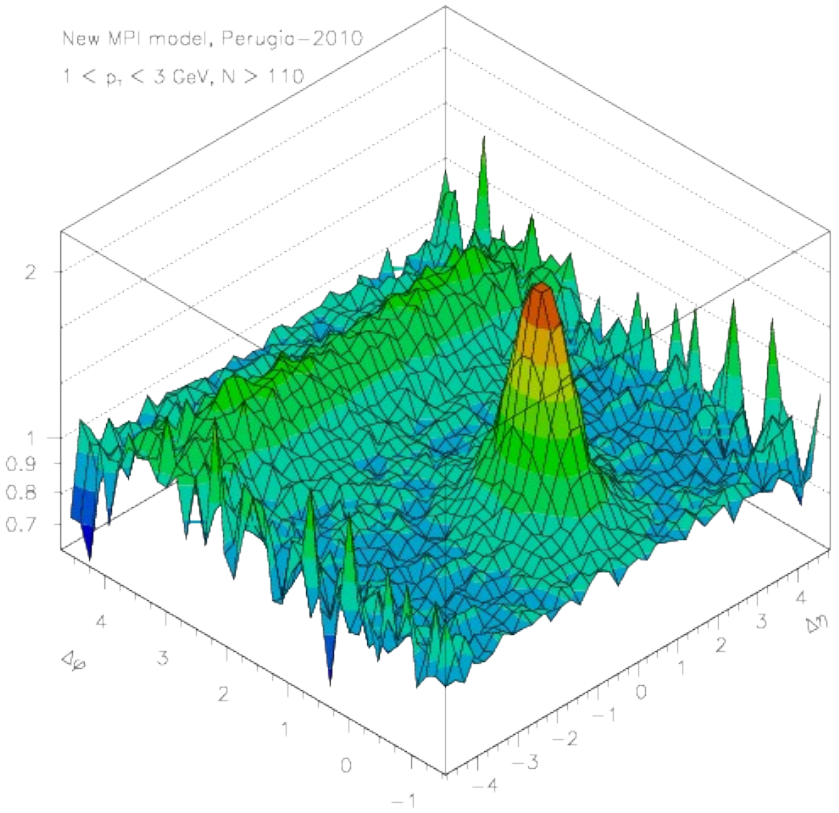
New MPI model – Perugia 2010 tune – no parton showers, colour reconnections or primordial pT

PYTHIA without correlated MPIs
MSTP(61) = MSTP(71) = MSTP(84) = MSTP(85) = MSTP(91) = MSTP(95) = 0

1 < pT < 3 GeV, N > 110, linear scale



1 < pT < 3 GeV, N > 110, logarithmic scale



➔ Sanity check: no (double) ridge in original PYTHIA with new MPI model and parton showers (primary and MPI), colour reconnections and primordial pT switched off

DIPSY MC

Avsar et al.
[arXiv:1009.5643]

MC implementation of dipole model
(~ LO BFKL gluon evolution)

→ Large event-by-event fluctuations in gluon multiplicity + transverse plane correlations