Particle multiplicity in jets at CMS

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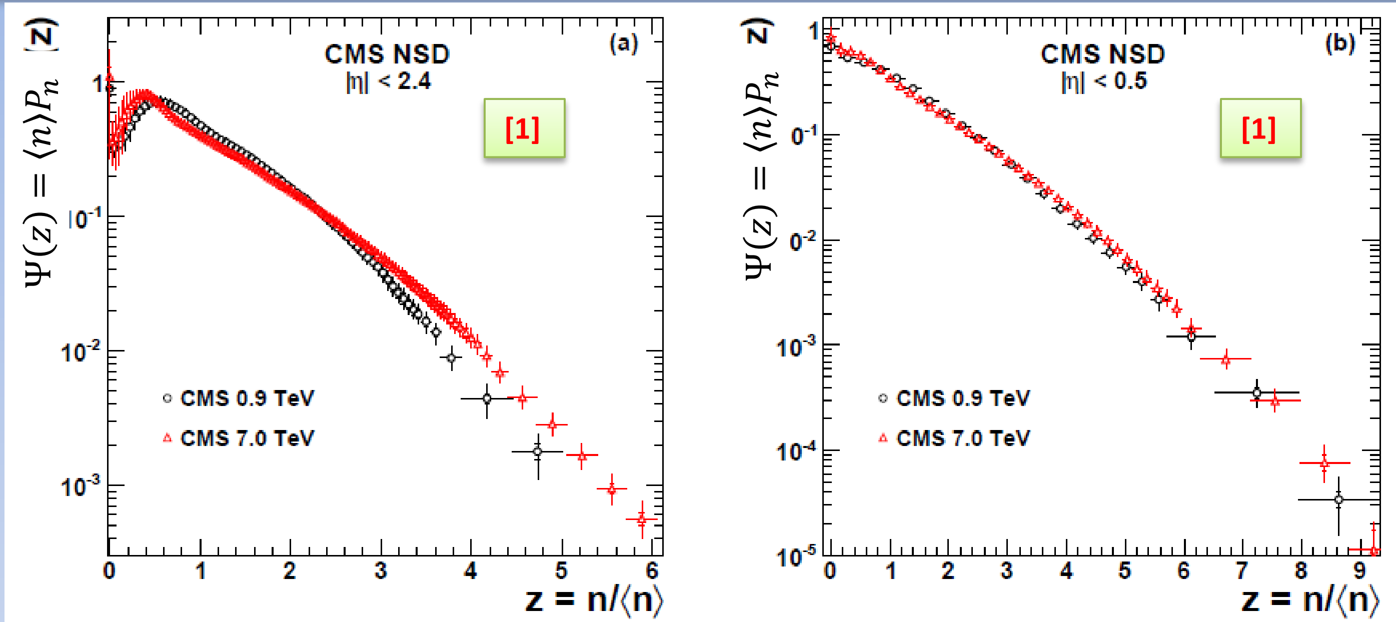
Particle correlations – the main subject of the dynamics in content of multiplicity measurement. Local conservation of quantum numbers in the hadronization process leads to short range correlations in rapidity.

For the final hadrons the widths of the multiplicity distribution in pp-collisions are larger than Poisson distribution and it indicates positive correlation between charged particles.

The nature of the particle correlation in jet compared to the event reflects clearer the fundamental laws.

But these correlations are partially hidden by Underlying Event (UE), by Initial and Final State Radiations (ISR and FSR). Particle correlations depend on type of parton produced the jet. From experimental point of view the main source of uncertainty is PileUp.

KNO-violation



KNO-scaling is true for events with a small $|\eta| < 0.5$.

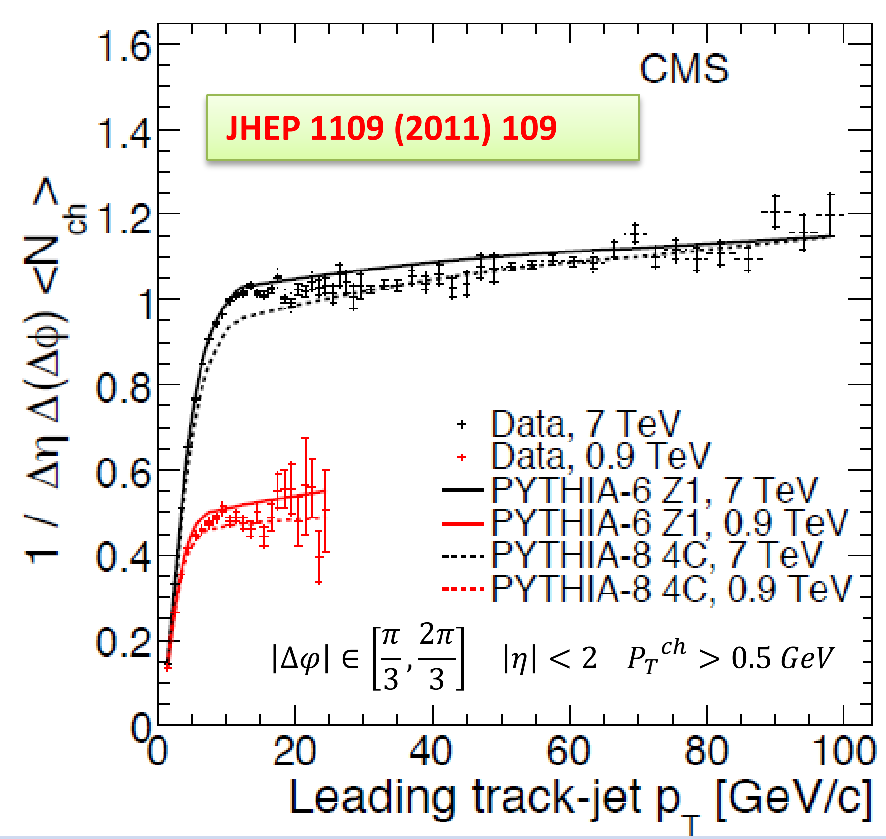
KNO-scaling is violated for $|\eta| < 2.4$

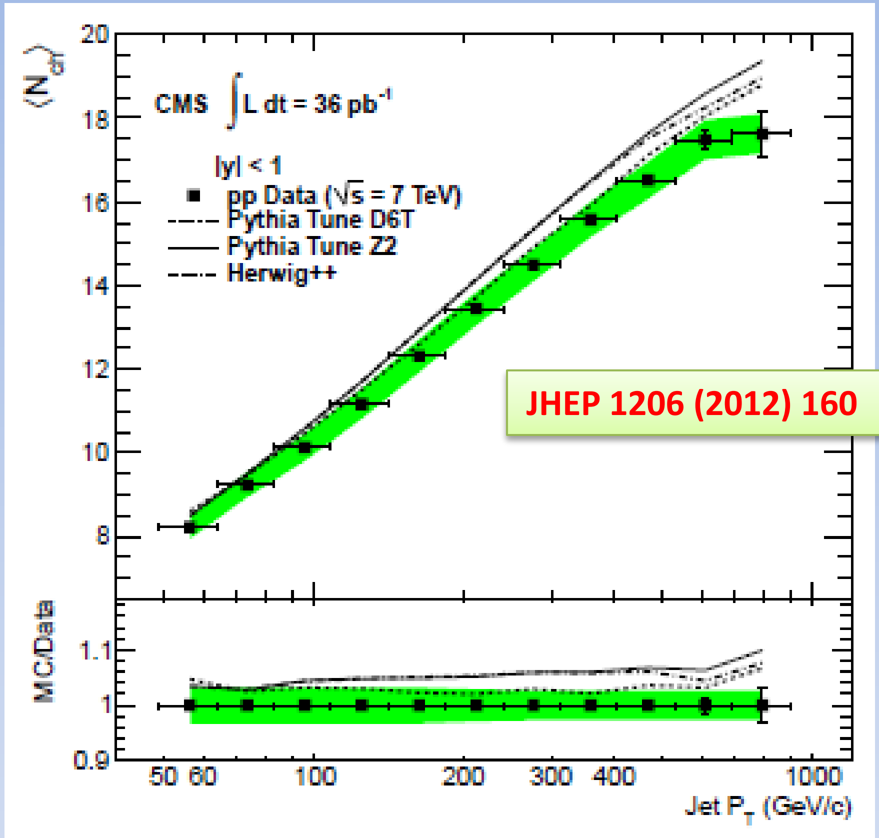
Does the KNO scaling holds in jets?

This observation allow us to expect to have unexpected results on the subject the multiplicity in jet.

[1] Charged particle multiplicities in pp interactions at $\sqrt{s} = 0.9, 2.36$ and 7 TeV. CMS collaboration, JHEP01 (2011)079

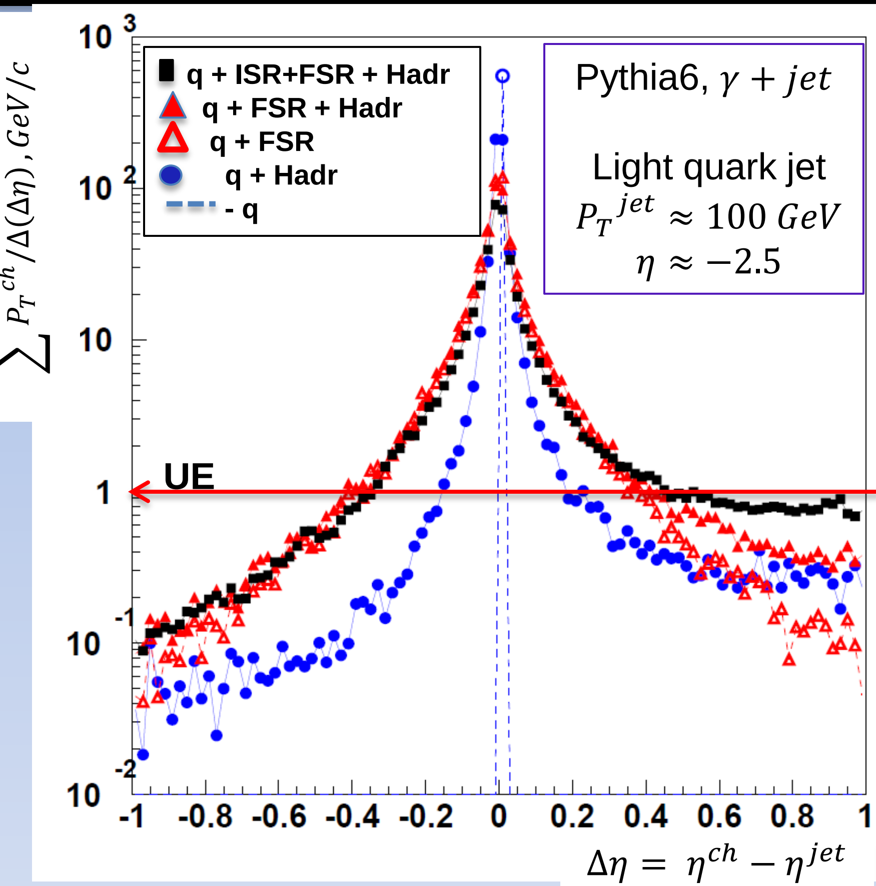
UE charge multiplicity in jets



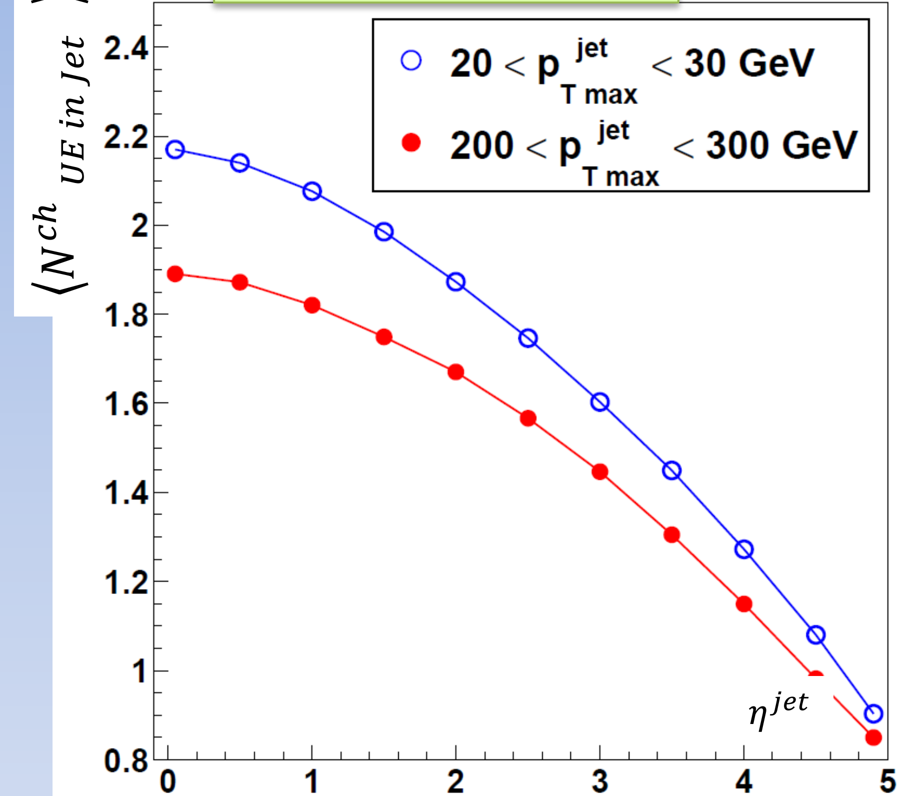


"Underlying Event" = products of Beam Remnants + Multiple Parton Interactions.
Jet tracks = signal + UE
Energy rate of UE is match lower in Jet region than in full event
due to kinematics and "by construction" of jet as a group of collimated tracks.

UE, ISR and FSR in jets



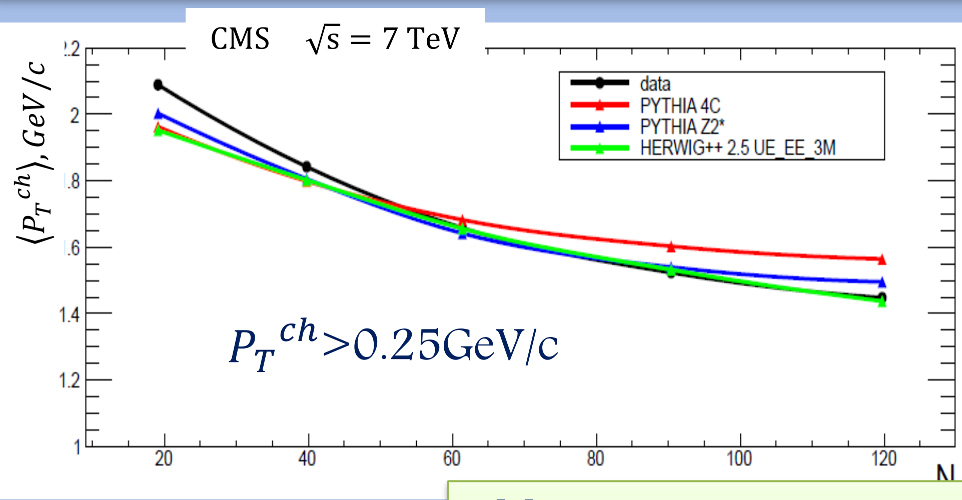
UE multiplicity in jet

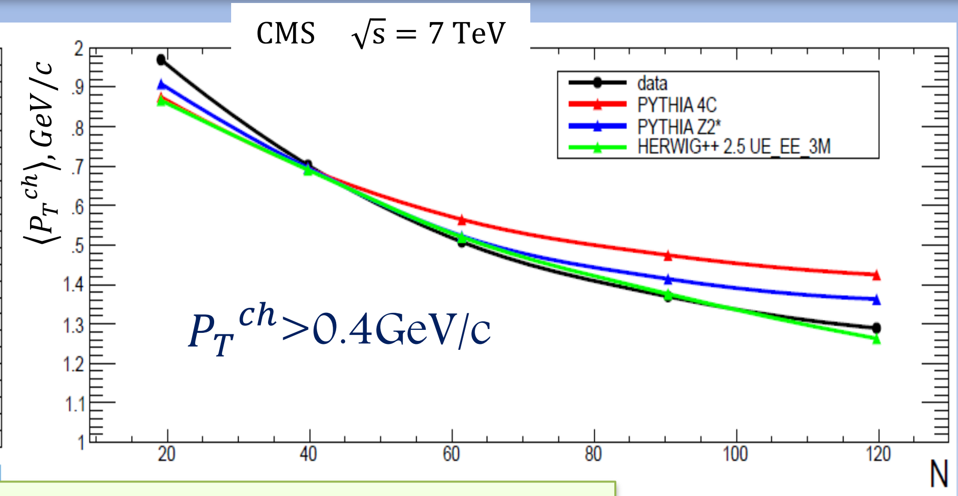


Mean UE energy per Jet ($\Delta\eta < 0.5$)
$\approx 0.5 - 1$ GeV

ISR and FSR reduce the effect of final particle correlations
because ISR and FSR does not correlate to the parton – origin of jet.
UE, ISR and FSR are inseparable parts of jet.

Jet properties vs multiplicity in event





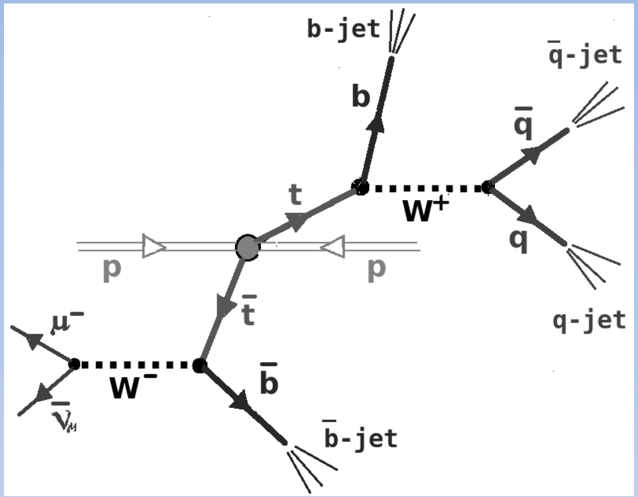
Mean transverse momentum of **charged tracks in jet** with $|\eta|<2.4$ vs multiplicity N in event.

AN 12-240, JHEP(2013)

Mult. Domain
Total
$10 < N \leq 30$
$30 < N \leq 50$
$50 < N \leq 70$
$80 < N \leq 110$
$110 < N \leq 140$

This dependence can be associated mainly to ISR and FSR which increase with increasing multiplicity N in event.

Three type of jets in Semi-leptonic $t\bar{t}$ – channel



- Two identified b-jets
- Two light quark jets identified as product of W
- N gluon jets

In the task of Multiplicity in Jets (**JM**) semi-leptonic $t\bar{t}$ – channel is useful due to

- ✓ Background is about 18%;
- ✓ Equivalence to the 2-jets e^+e^- -channel : $e^+e^- \to \frac{Z_0}{\gamma} \to q\bar{q}$;
- ✓ Separation the Light Quark Jets with 95% purity (see next slide).

For the task of **JM** it is not possible to discriminate quark and gluon jets by using inner jet constituent parameters (used in Q-G-discriminators) due to its correlations with **JM**.

Separation the Light Quark Jets in Semi-leptonic $t\bar{t}$ – channel (Pythia6)

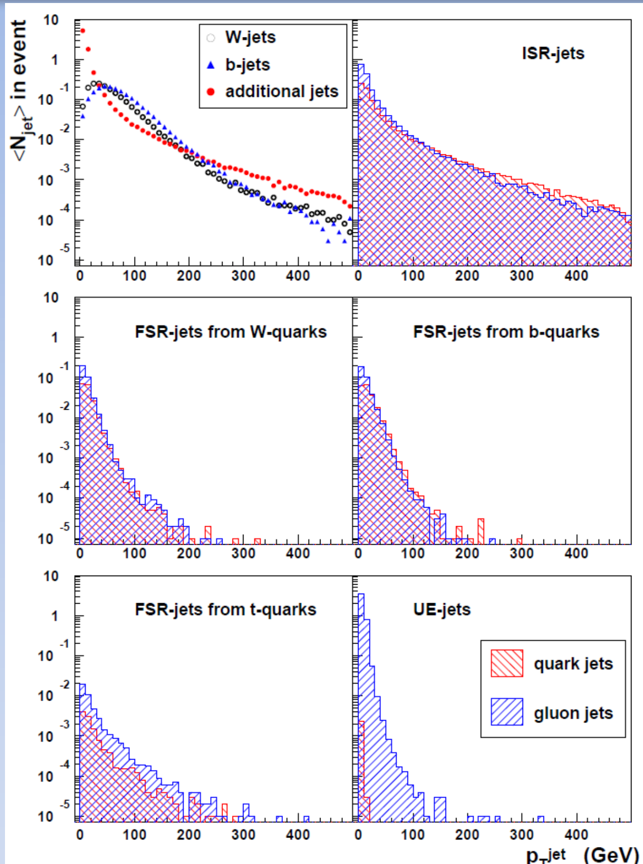


Fig.1.

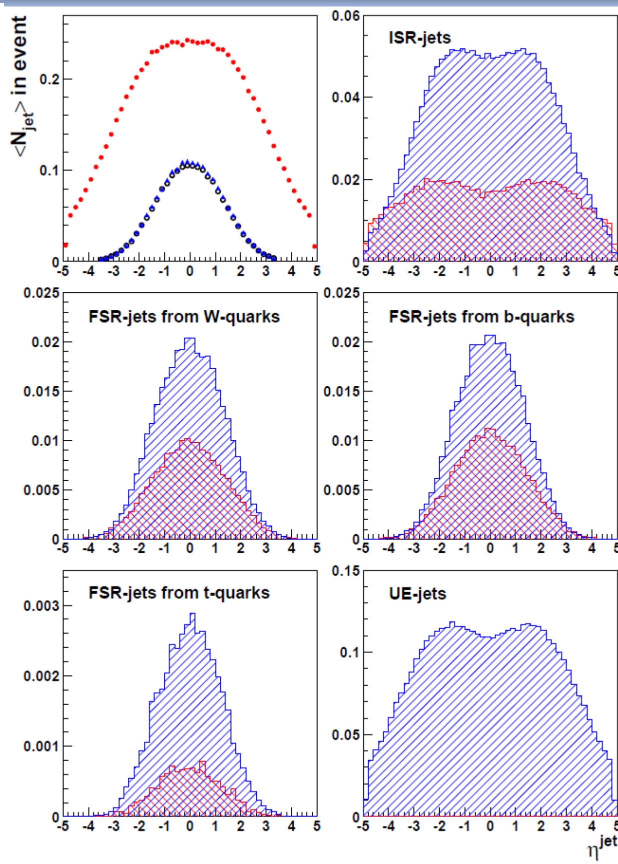


Fig.2.

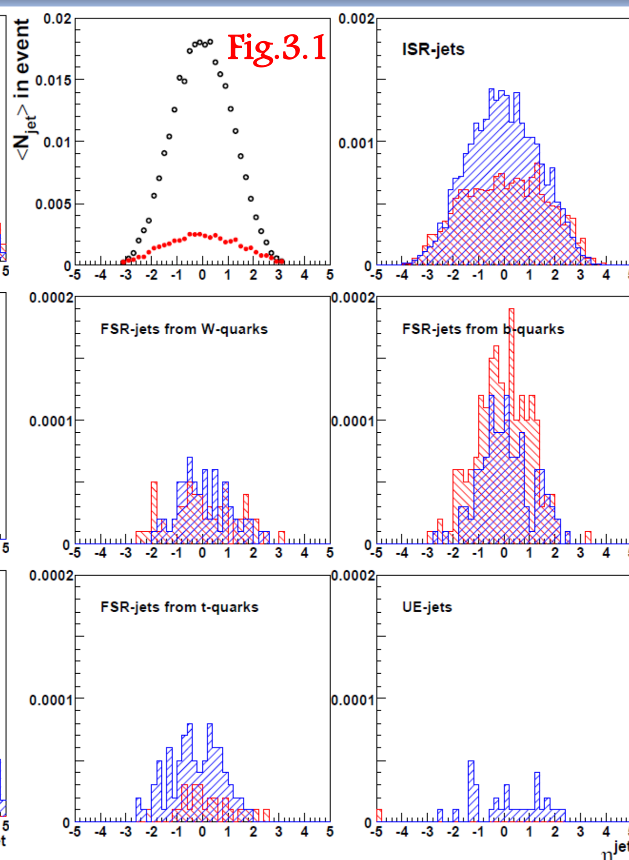
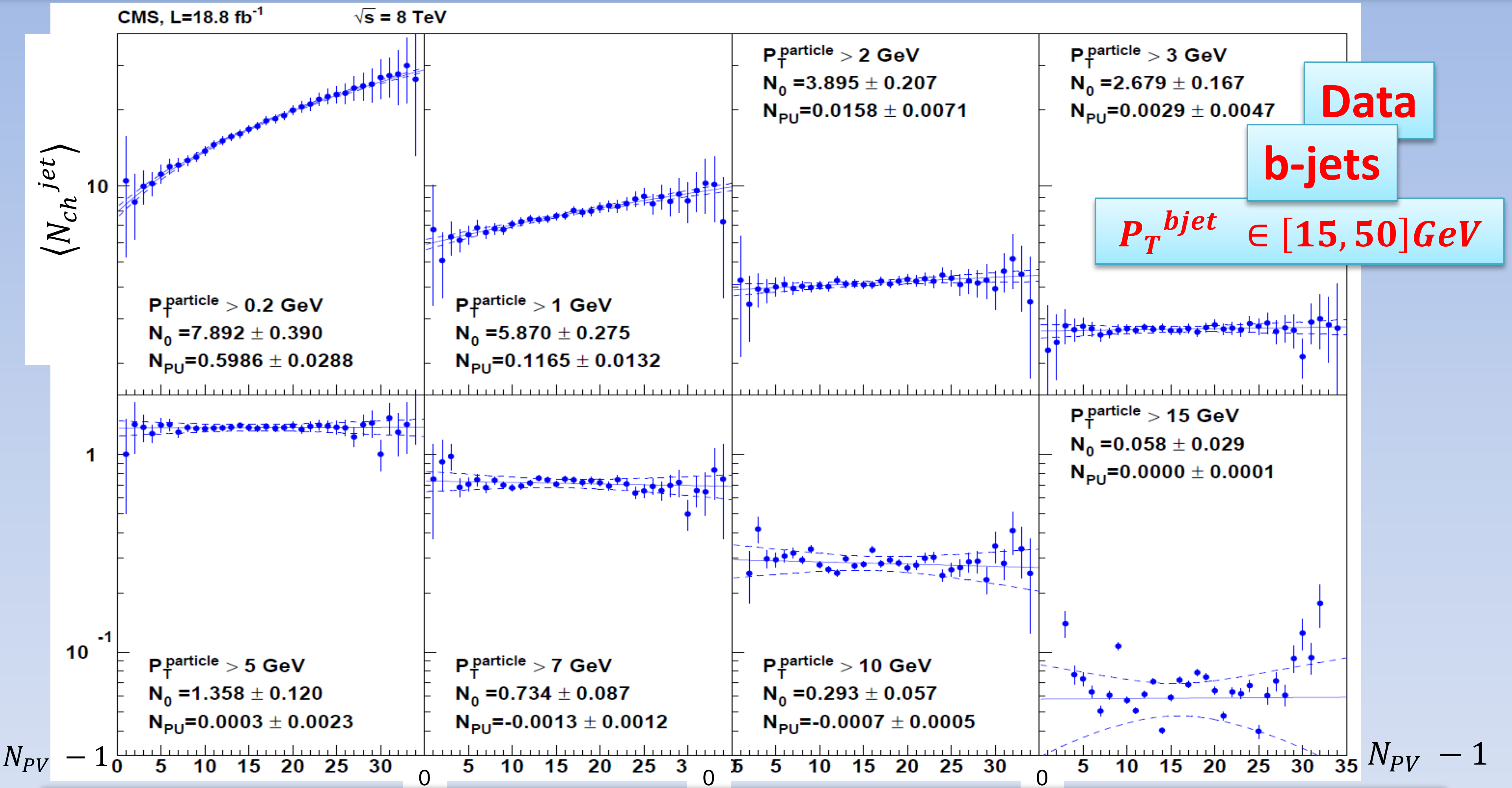


Fig.3.

In Semi-leptonic $t\bar{t}$ – channel we have separation the Light Quark Jets with **95%** purity (**Fig.3.1**) by using kinematics constraints:

- ✓ invariant mass of light quark jets $|M_{j_1 j_2} - M_W| < 10\ GeV$
- ✓ rapidity-distance $|\eta_{j_1} - \eta_{j_2}| < 1.5$ and maximum $P_T^{\,j_{1,2}}$.

PU subtraction: extrapolation to 1 PV



After extrapolation to 1 PV mean values include “strange” tracks from the decays of signal strange particles + background (material interactions, magnetic field)

PU subtraction: Track-PV matching

3D-distance method

$\min(d) < 3 * err(d)$ *and* $d < 0.4\ cm$

IP method

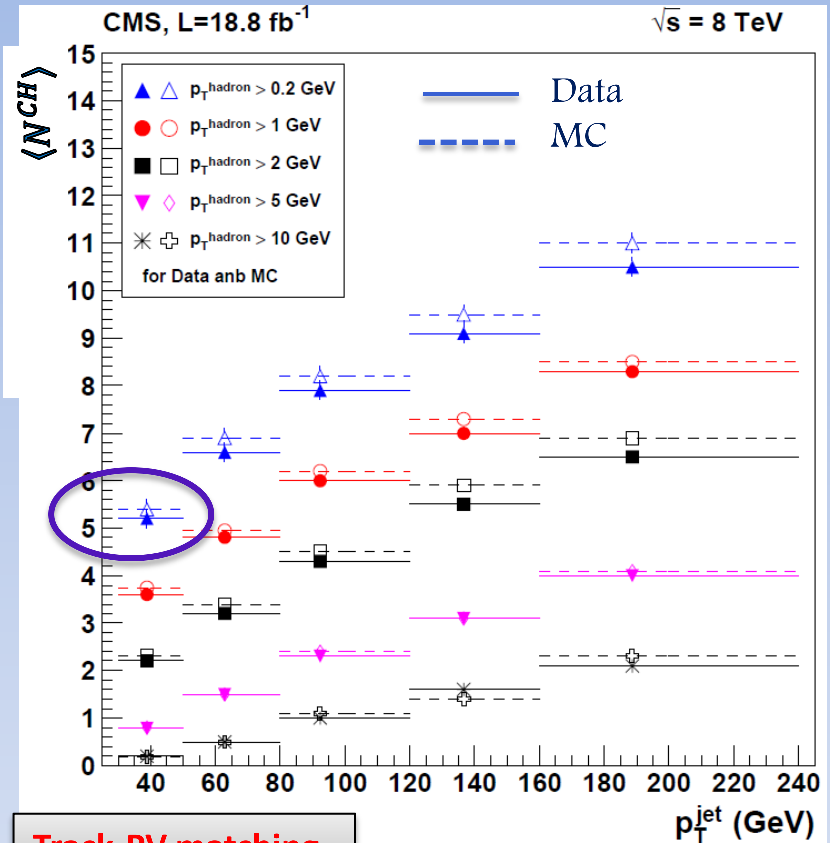
$\min(d_z) < 3 * err(d_z)$ *and* $d_z < 0.4\ cm$
$\min(d_0) < 3 * err(d_0)$ *and* $d_0 < 0.2\ cm$

	Data	MC	
3D or IP	78.7%	78.8%	Signal + PU tracks
Not 3D and **not** IP	21.3%	21.2%	"Strange" tracks
All	**148637**	**793768**	

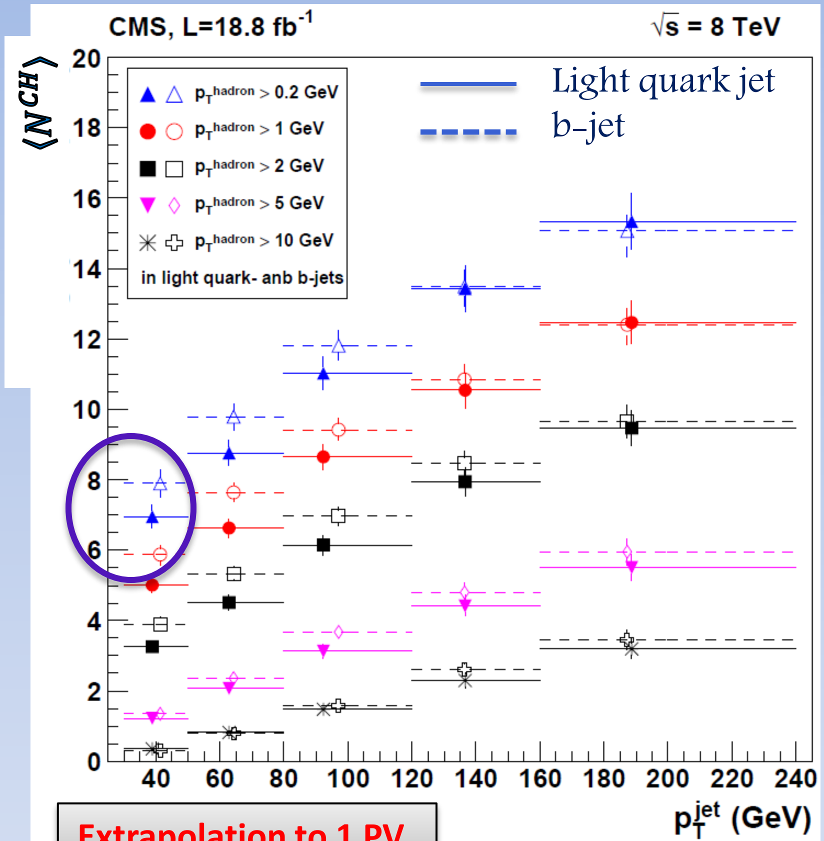
	Data/MC, %
3D and **not** IP	0.6/1.4
3D and IP	94/93.6
not 3D and IP	5.5/5.0
3D or IP	**100/100**

3D-method selection is harder, then IP-method
3D-conditions includes IP-conditions:
3D and not IP: 0.6%($d < 0.4\ cm$), 0.16%($d < 0.2\ cm$)

Mean track multiplicity in PF-jet vs. $p_{T,min}^{track}$ and P_T^{jet}



Track-PV matching

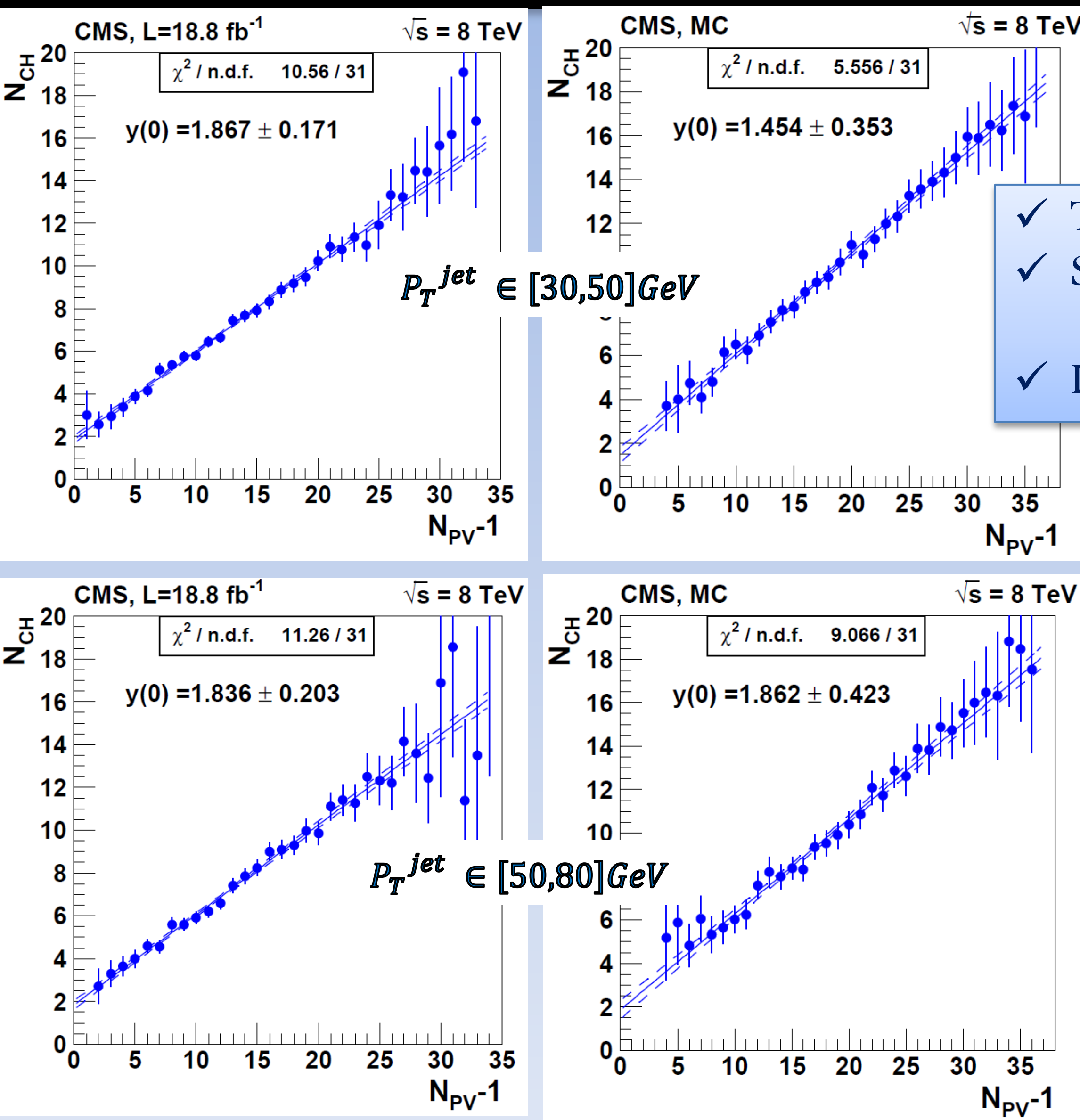


Extrapolation to 1 PV

MC and Data points are drawn by the same colors. MC a bit to the left than the data.

Systematic excess MC over the data is observed for small $P_{T,min}^{track}$

"Strange" jet content (tracks w/o PV)



- ✓ Tracks from strange particle decays
- ✓ Signal tracks w/o PV (fake track–PV matching)
- ✓ Interactions with material.

Conclusion

Multiplicity in jet (JM) will allow us to get an important information about particle correlations.

UE, ISR and FSR are inseparable parts of each jet. This is the background that hides some of particle correlations in jet.

For the task of JM one need to take into account the dependence of the JM on the multiplicity in event.

Using semi-leptonic $t\bar{t}-$ channel it is possible to separate light quark from W-decay with 95% purity to study JM in pure quark jets.

The measurement of strange mesons and baryons yields in jet is possible with CMS by fully exploiting the low-momentum track reconstruction capabilities of CMS.