New results on underlying event physics at CMS

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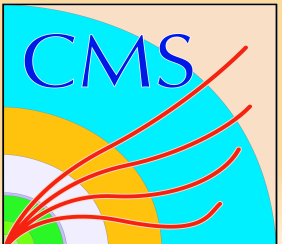
For the CMS Collaboration

MPI@LHC 2012
Geneva, December 3rd.



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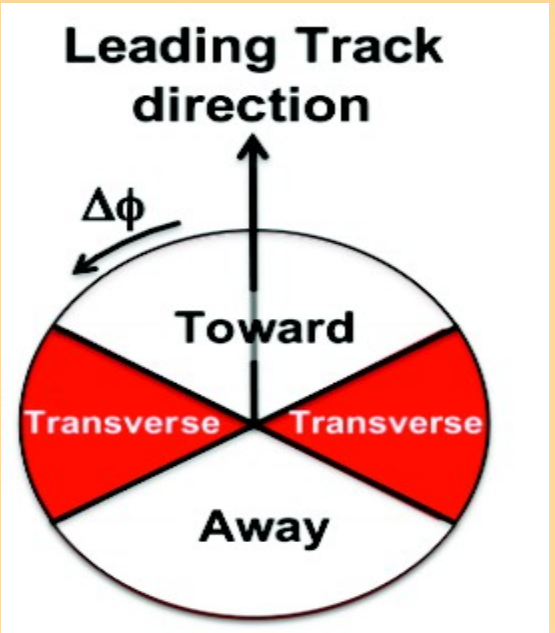
Outline

- The UE at CMS during 2012:
  - UE using the leading track.
  - Strange particles production in UE.
  - UE at forward physics.
  - Current projects.

Where to Look For the UE?

- We utilize the structure of hadron-hadron collisions to find regions sensitive to the UE activity:
  - Our leading object defines 3 regions in the η-Φ space and sets the scale.
  - Look at hadronic activity separated from the hard scattering system by a large distance in rapidity.

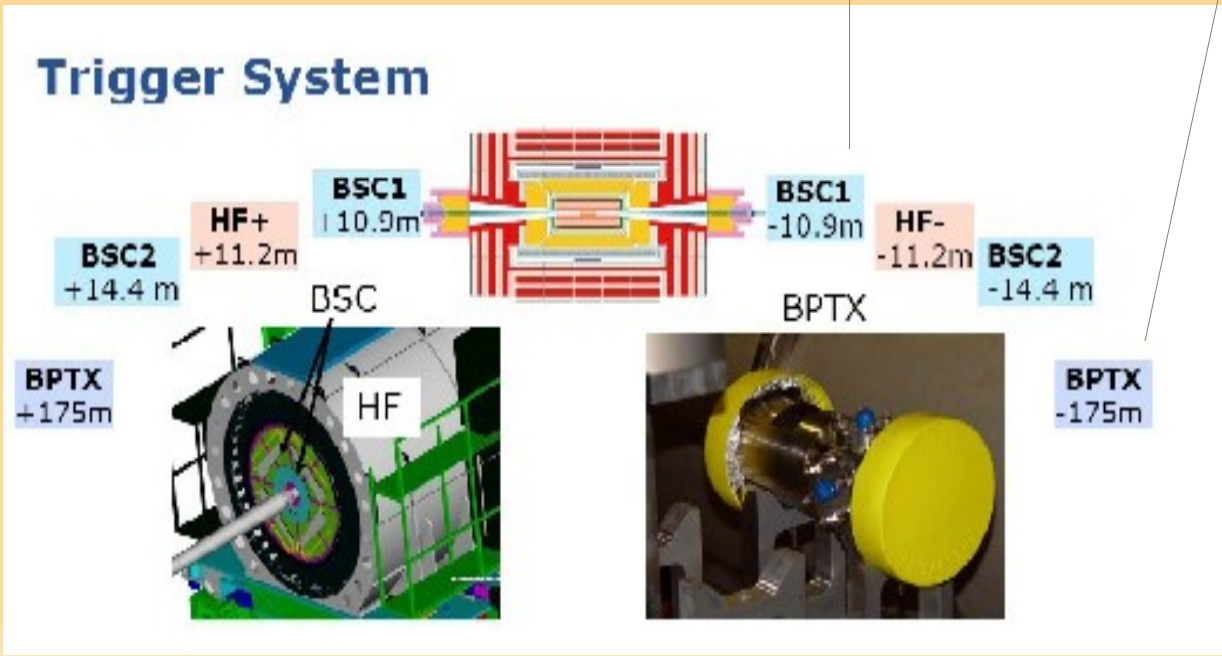


UE using the leading tracks

- Motivation: Designed to complement previous analyses done using the leading track-jet:
  - To extend the analysis already done to the leading track at 7 TeV (same data and procedure).
  - To increase the amount of data processed at 0.9 TeV.
  - To produce the common plots required by MBUEWG.

Triggering

- Using Beam Pick-up Timing eXperiment and the Beam Scintillator Counter.
- We use HLT to pick up events with at least one track in the pixel with pT > 0.2 GeV/c.



Cuts and Selections (7 TeV)

- p_T > 0.5 GeV/c.
- |η| < 0.8. (As requested by UEMBWG).

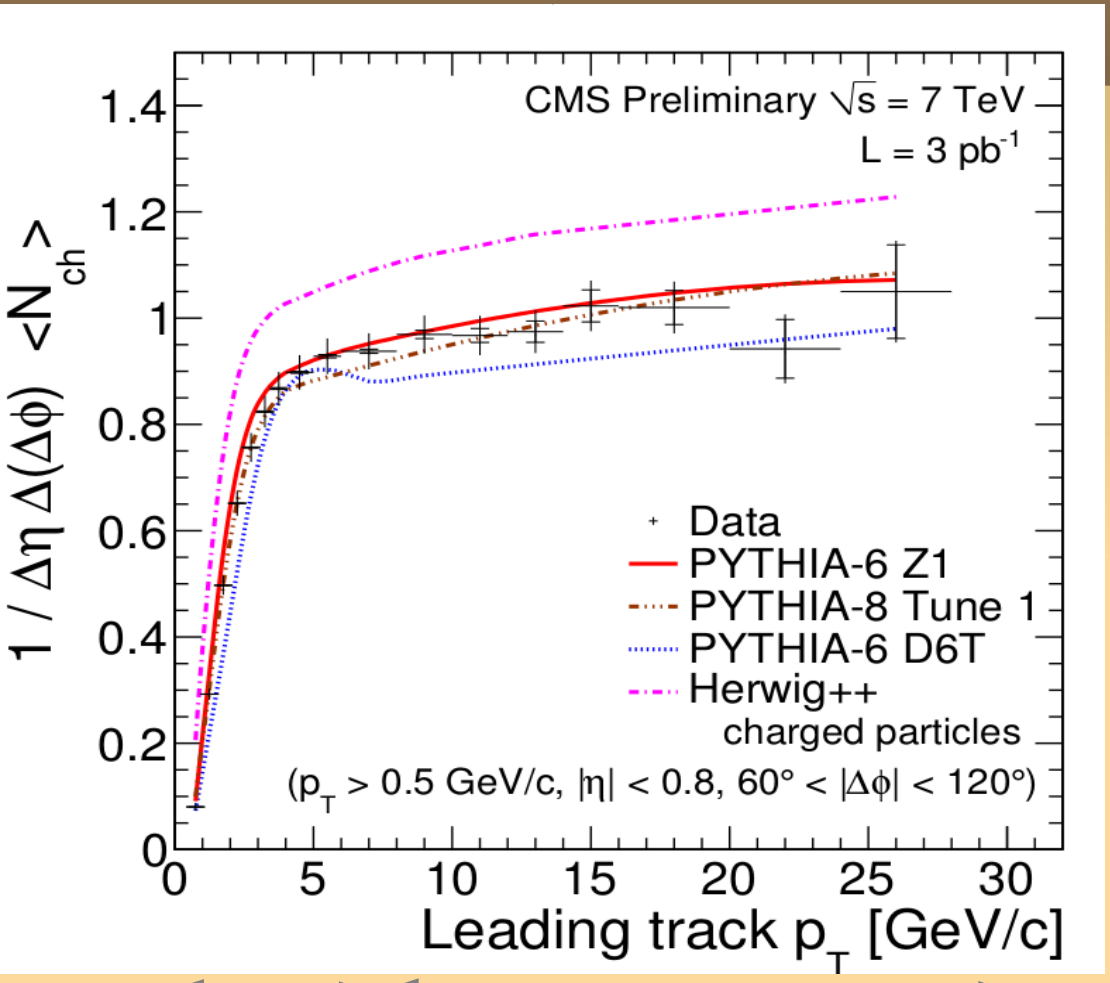
Event Selection	Data	Data[%]	MC[%]
triggered	32 880 355	100	100
+1 real Vertex	27 111 711	82.46	92.42
+ (+/-10cm) vertex z window	25 915 016	95.59	99.95
+ vertex n.d.o.f. > 4	23 449 115	90.49	87.59

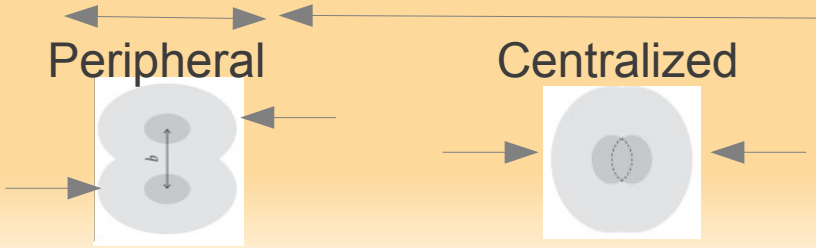
Cuts and Selections (0.9 TeV)

- $p_T > 0.5$ GeV/c.
- $|\eta| < 0.8$.

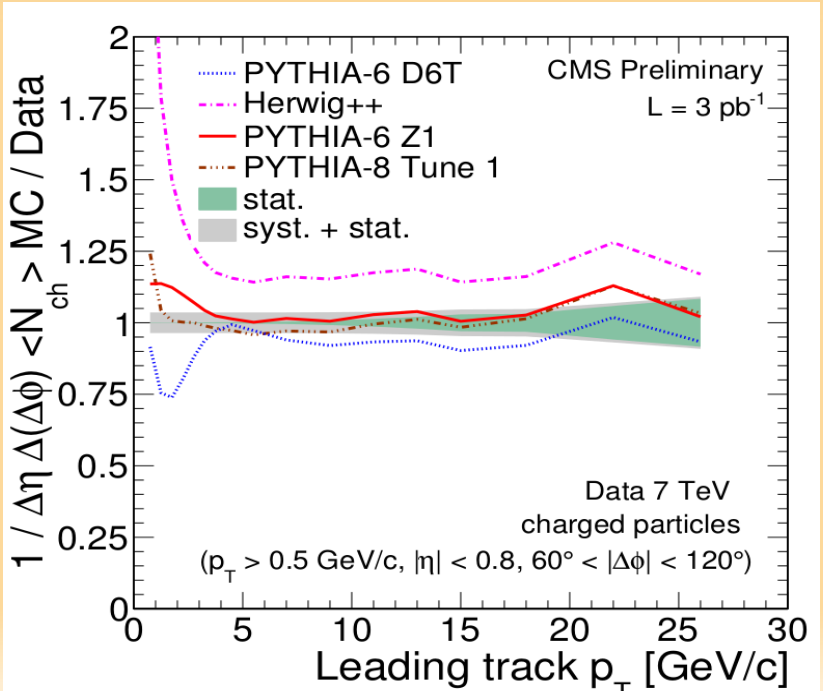
Event Selection	Data	Data[%]	MC[%]
Triggered	11 049 300	100	100
+1 real Vertex	10 124 392	91.6	90.5
+10 cm vertex z window	8 776 728	86.7	89.7
+Vertex n.d.o.f > 4	7 516 685	85.6	83.2

N_{ch} Density (7 TeV)

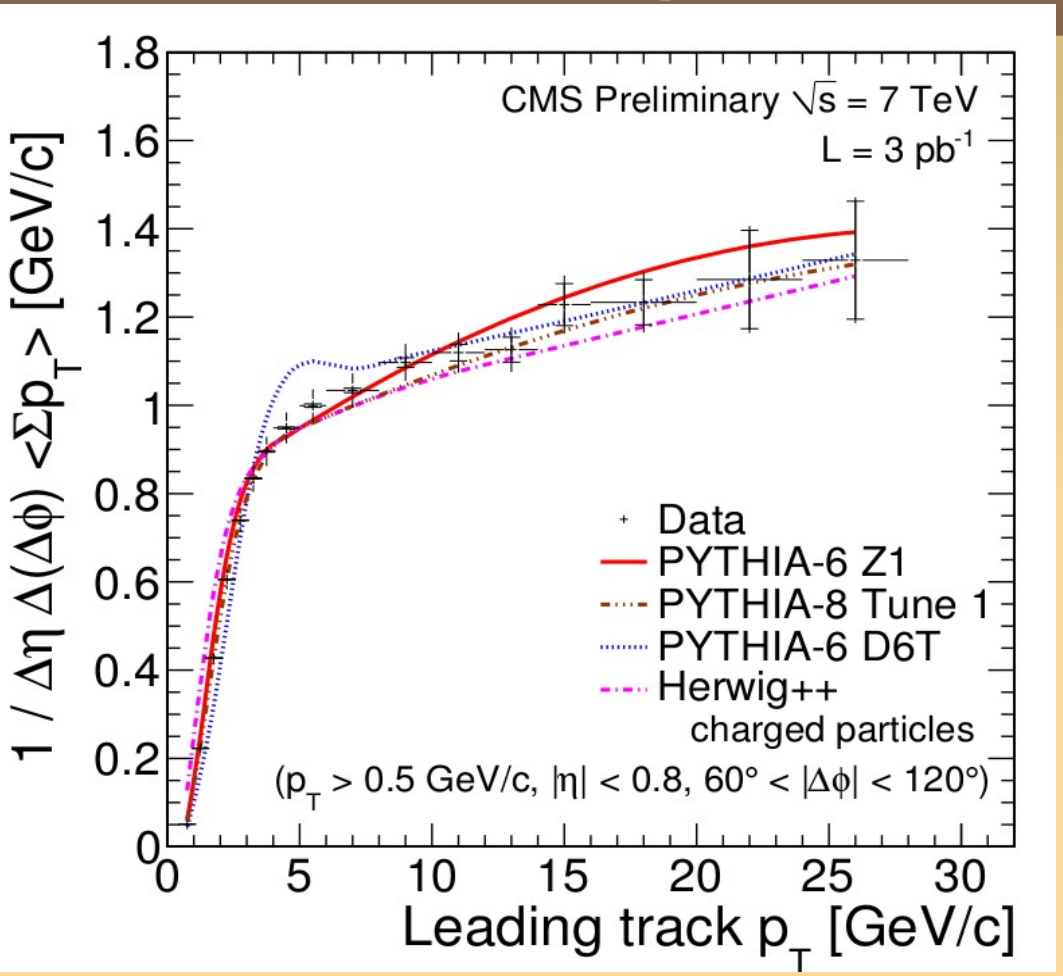


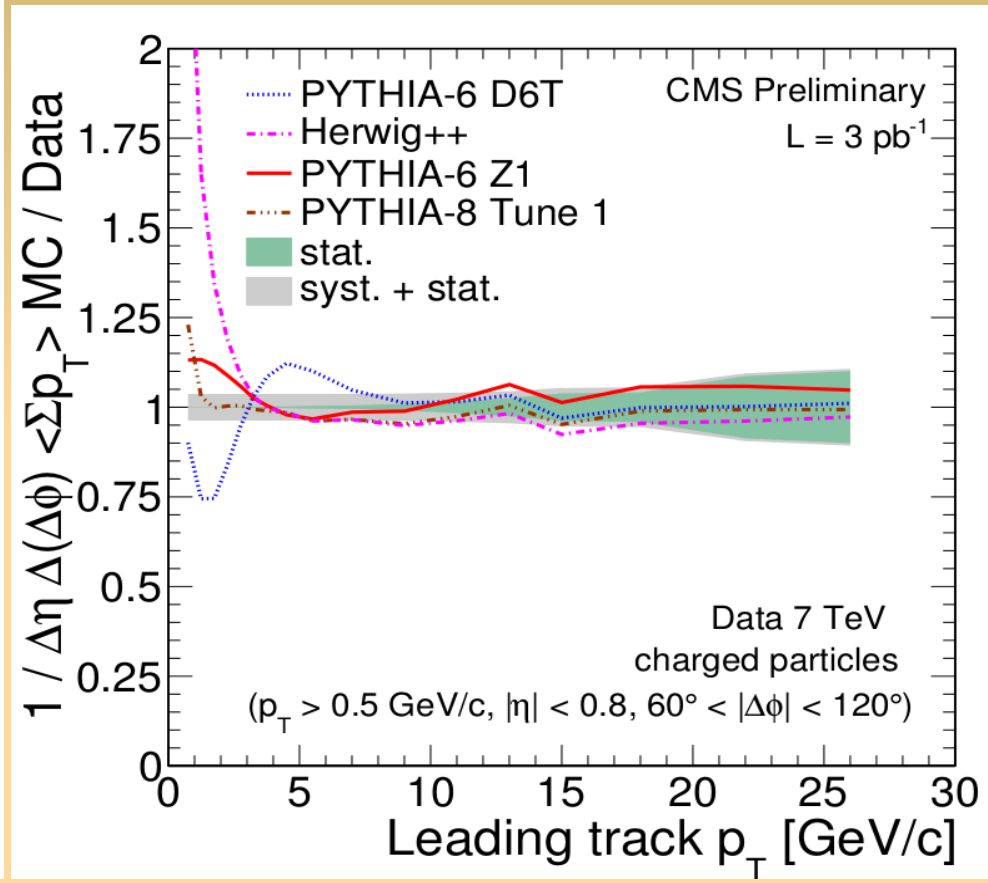


- We see the MC tunes mimic the behavior of the data with various degrees of success.

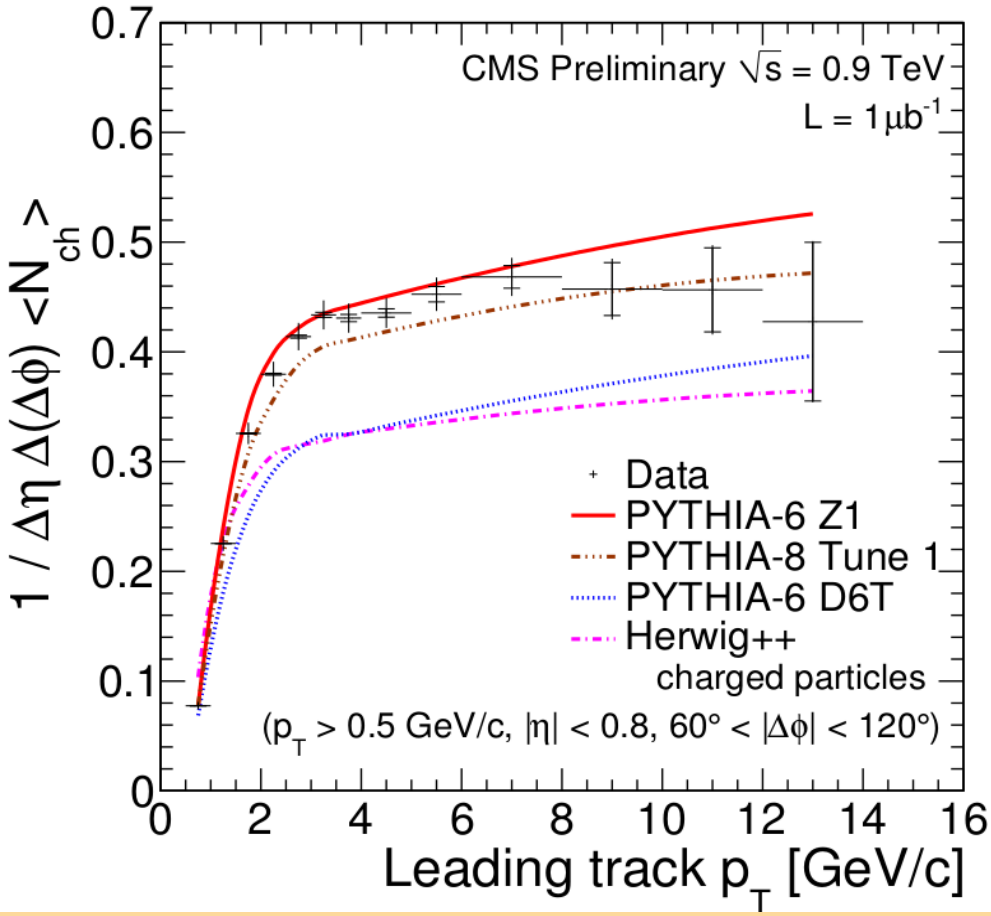


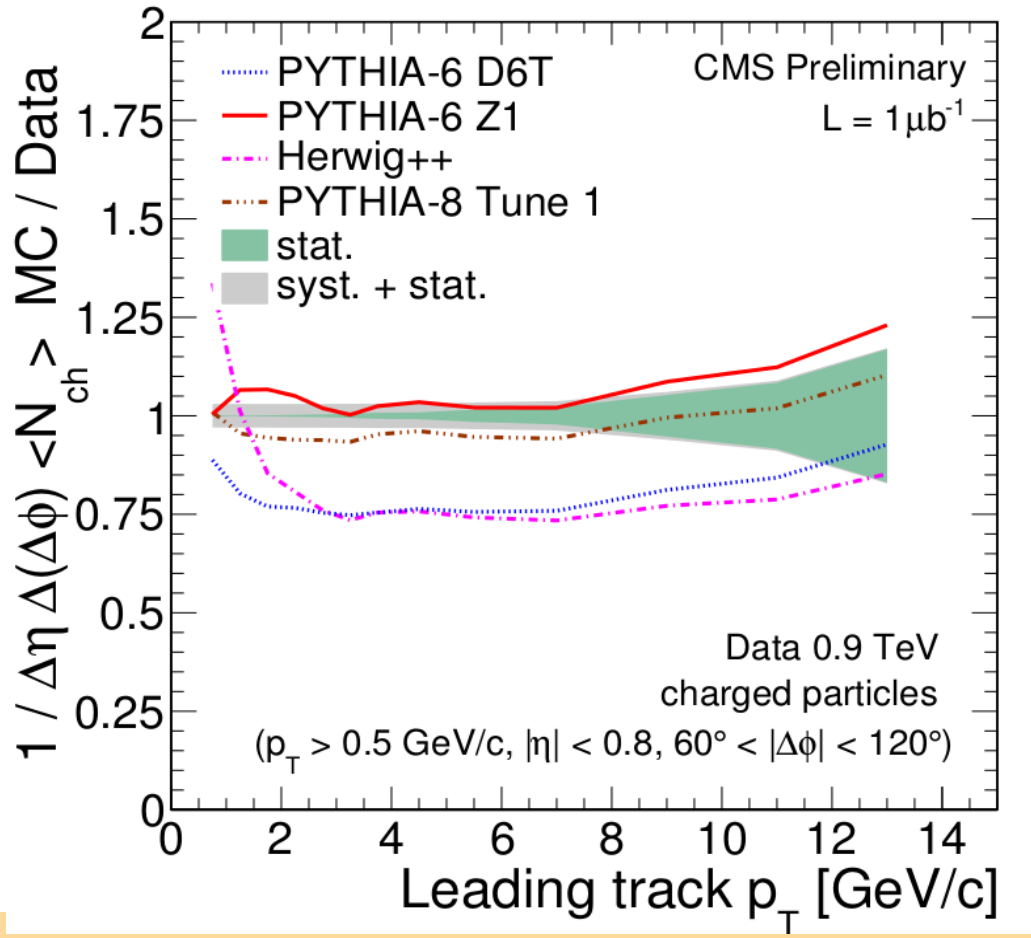
Σp_T Density (7 TeV)



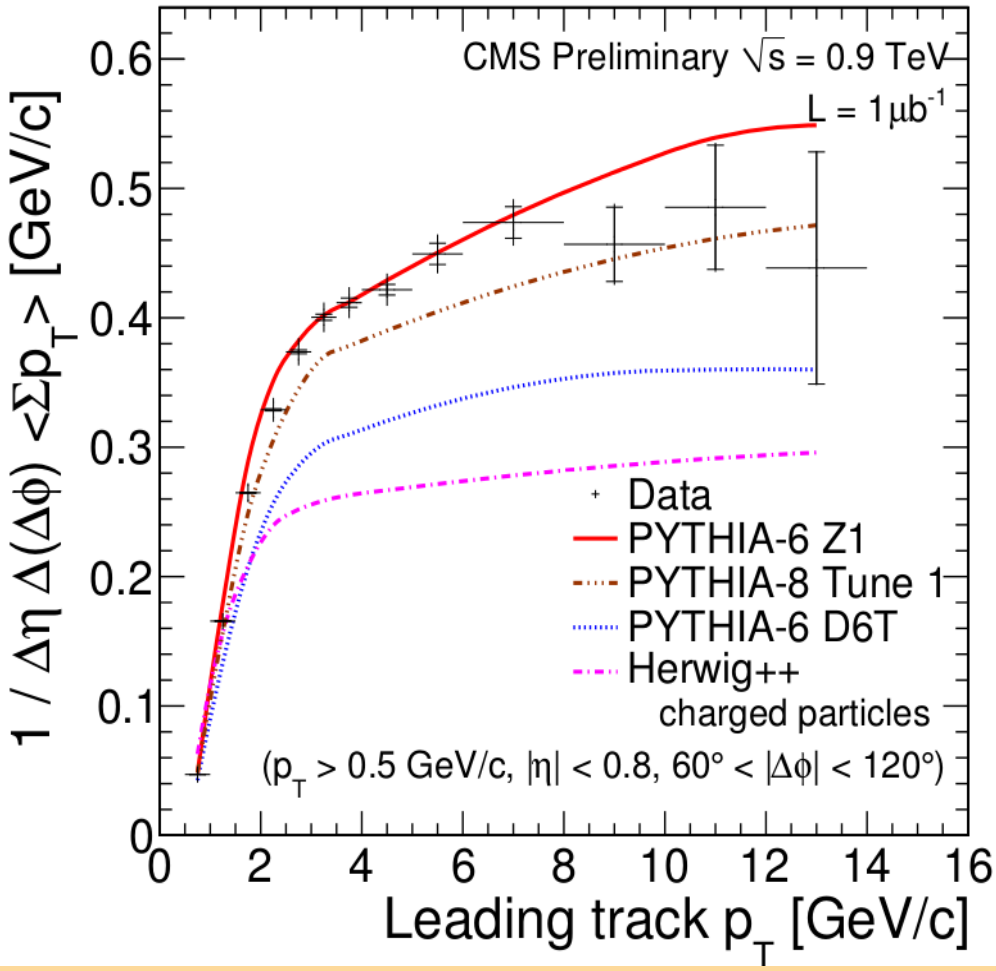


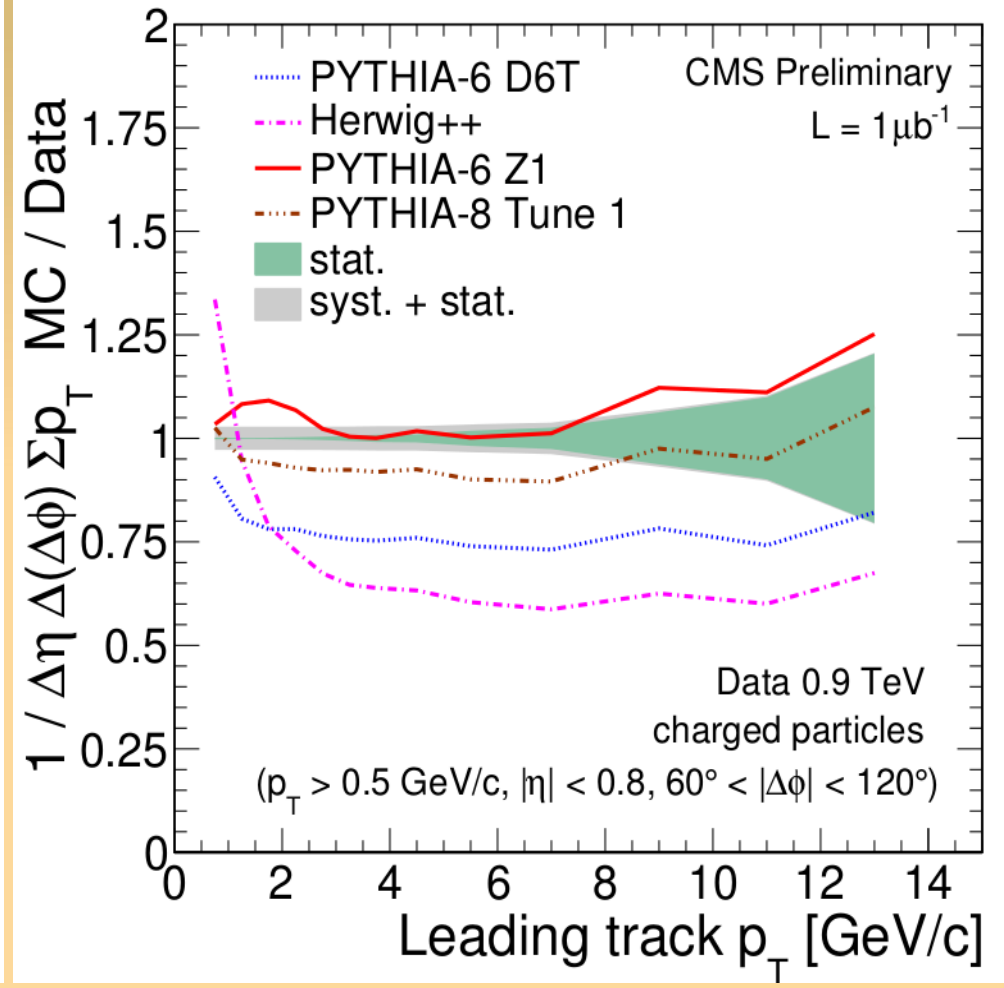
N_{ch} Density (0.9 TeV)



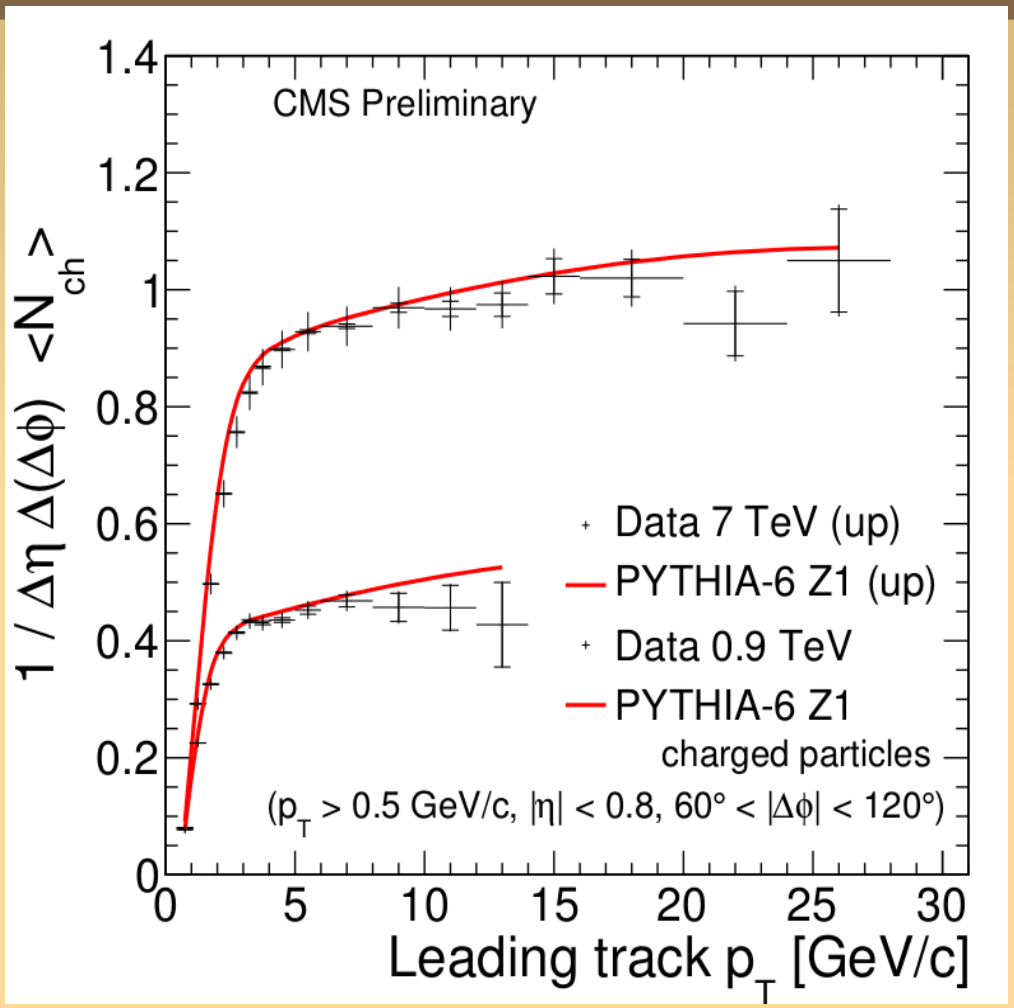


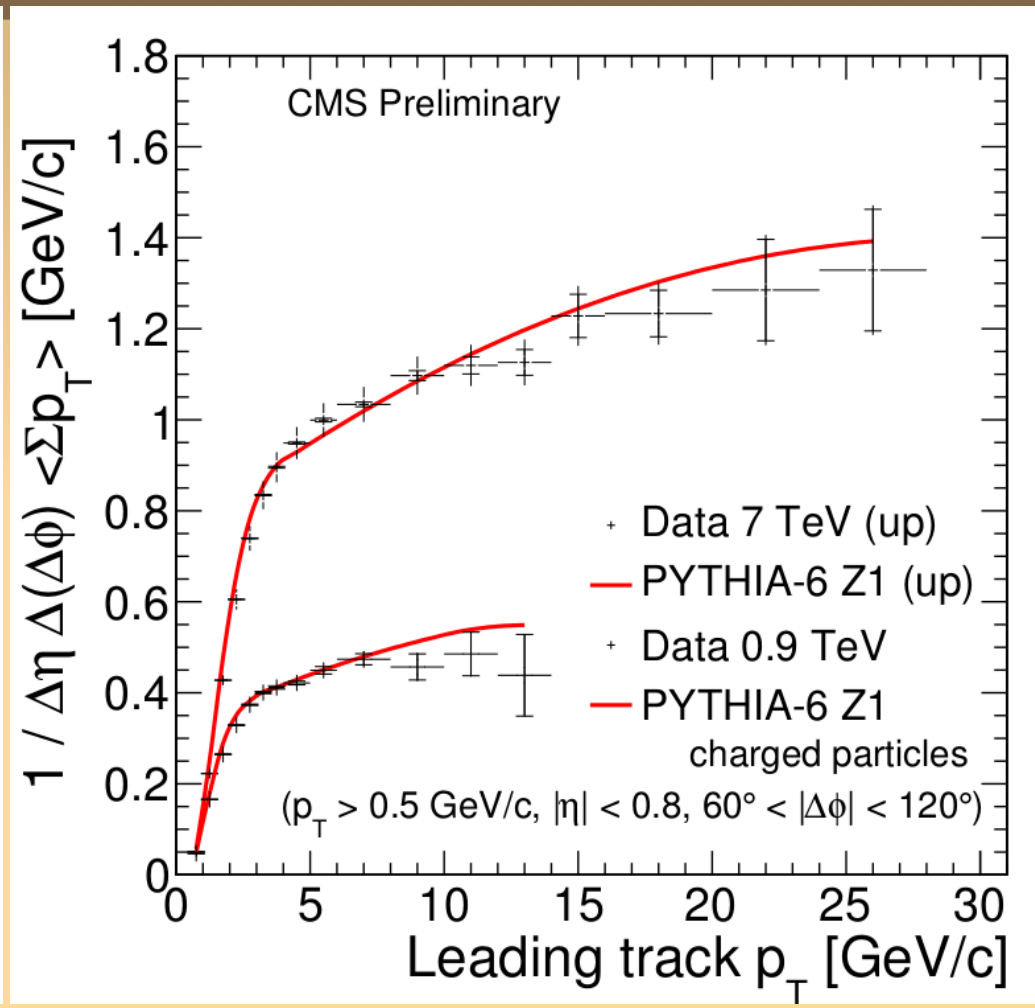
Σp_T Density (0.9TeV)



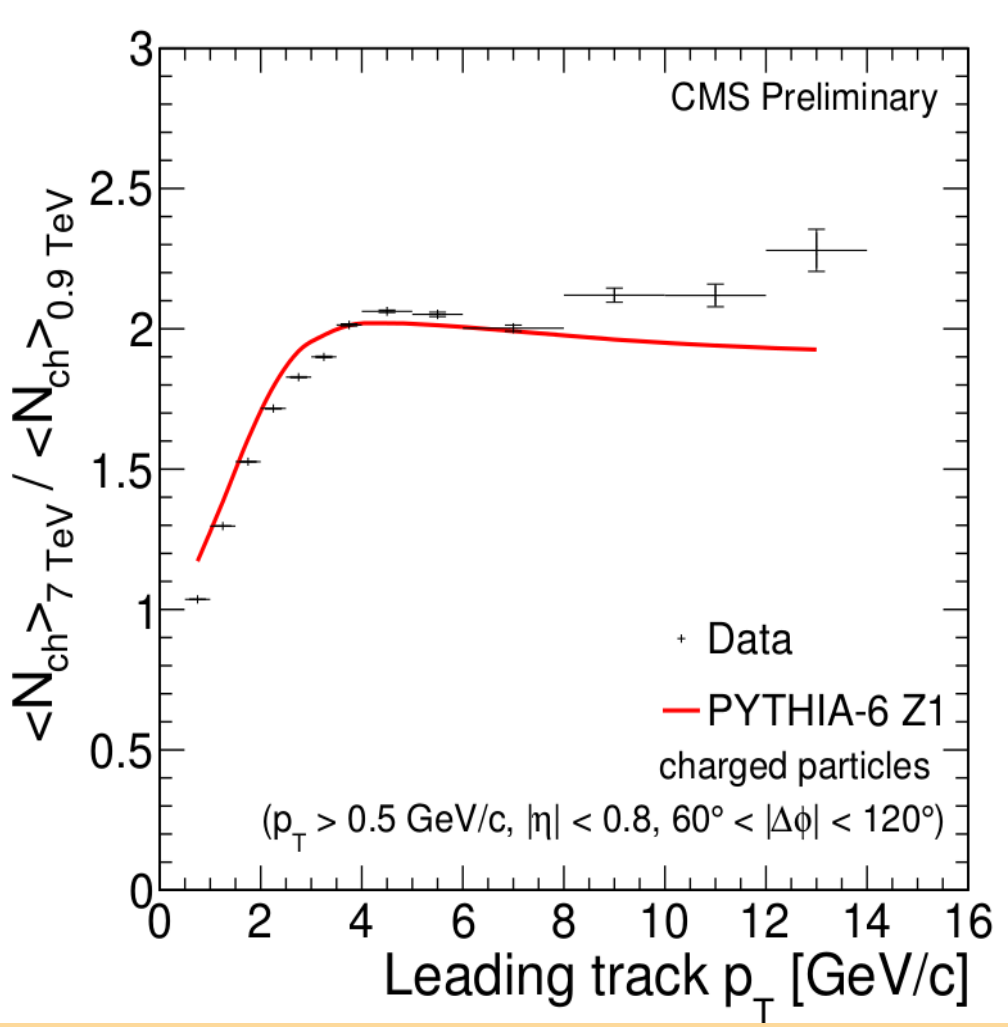


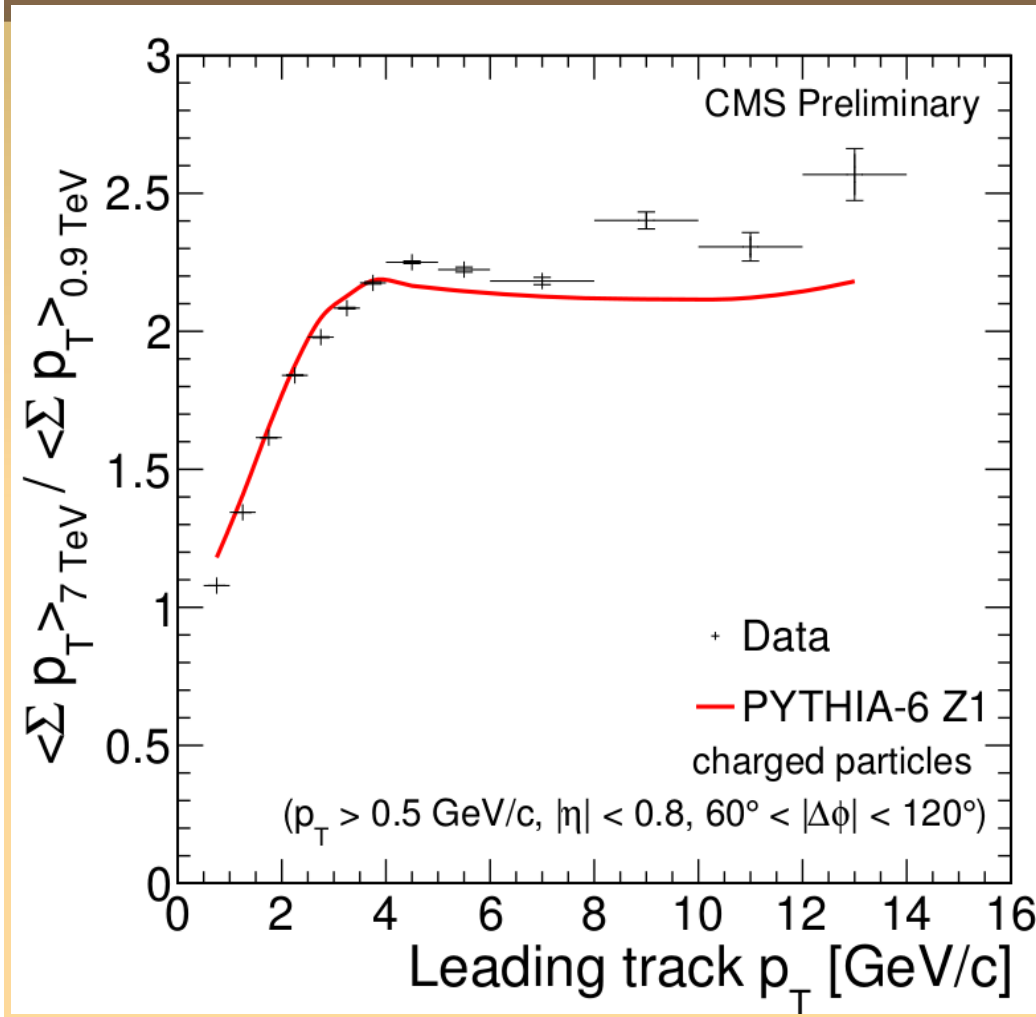
UE at the two Energies



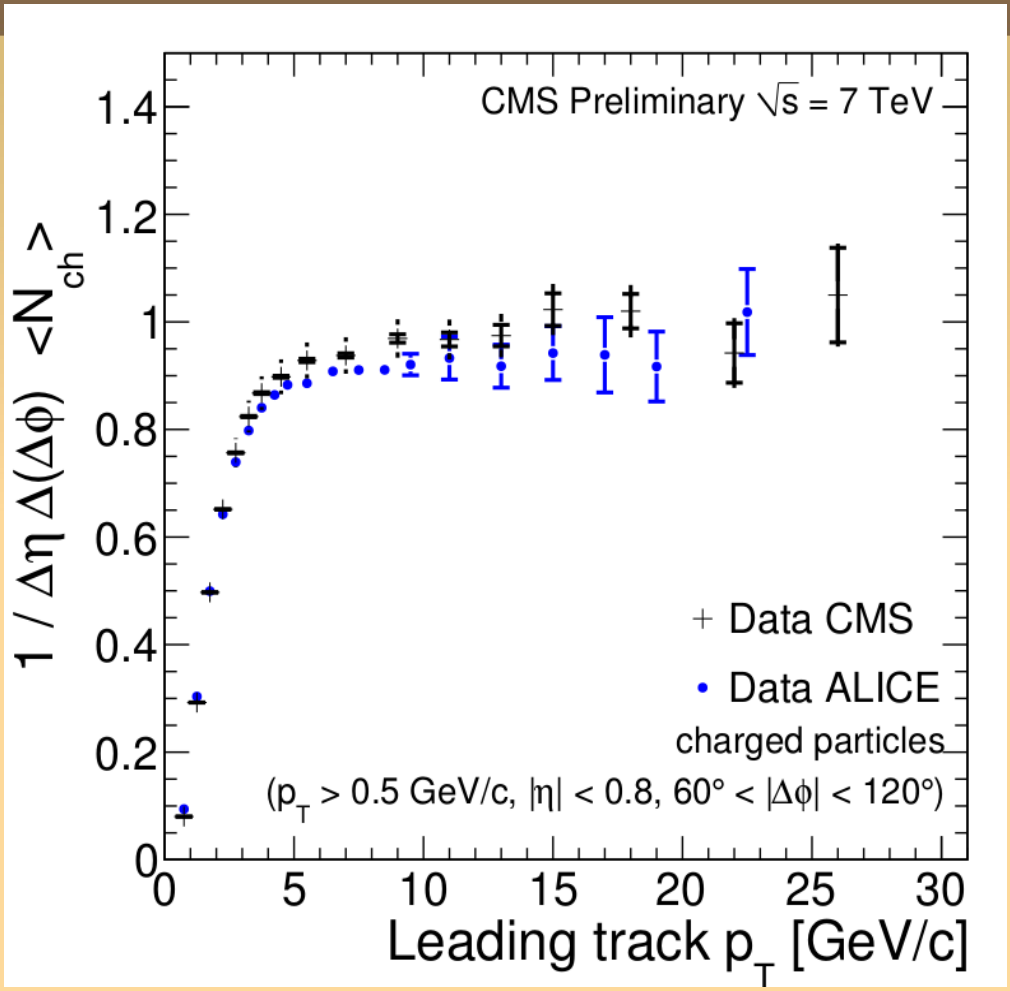


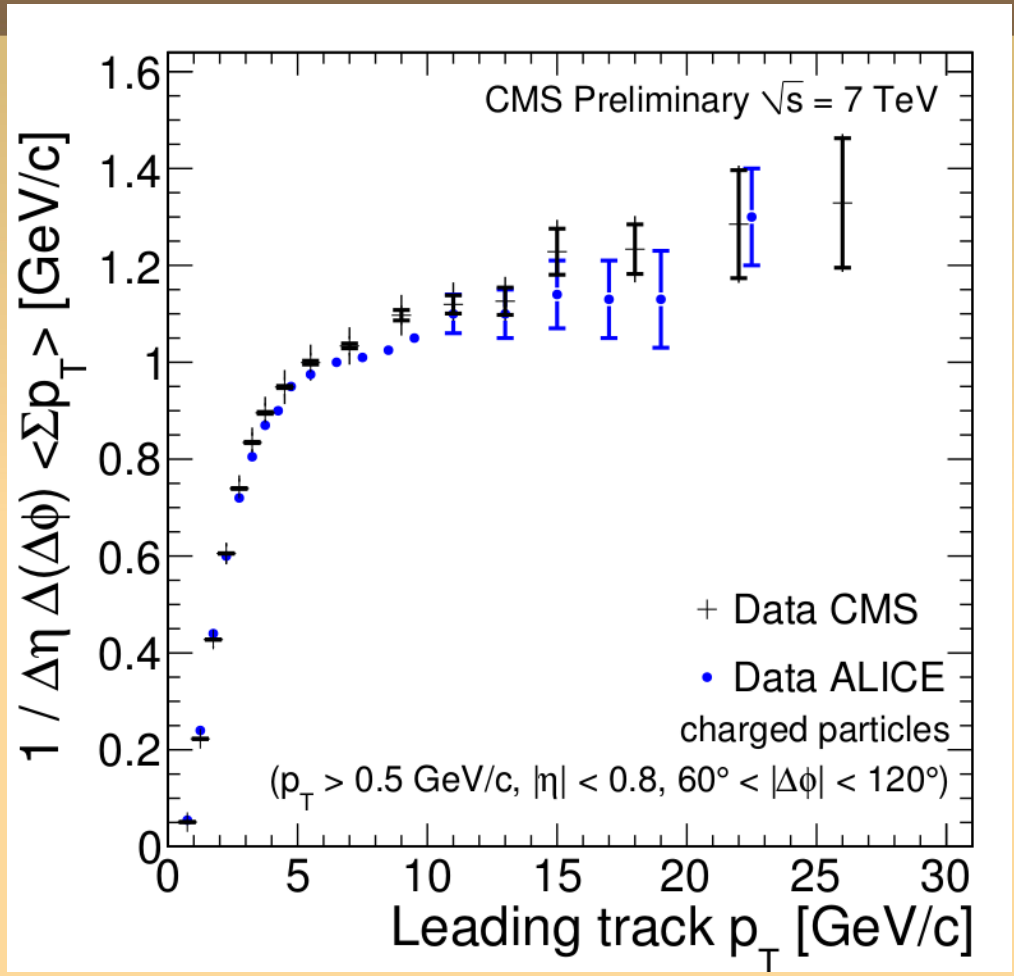
The energy ratio for the UE





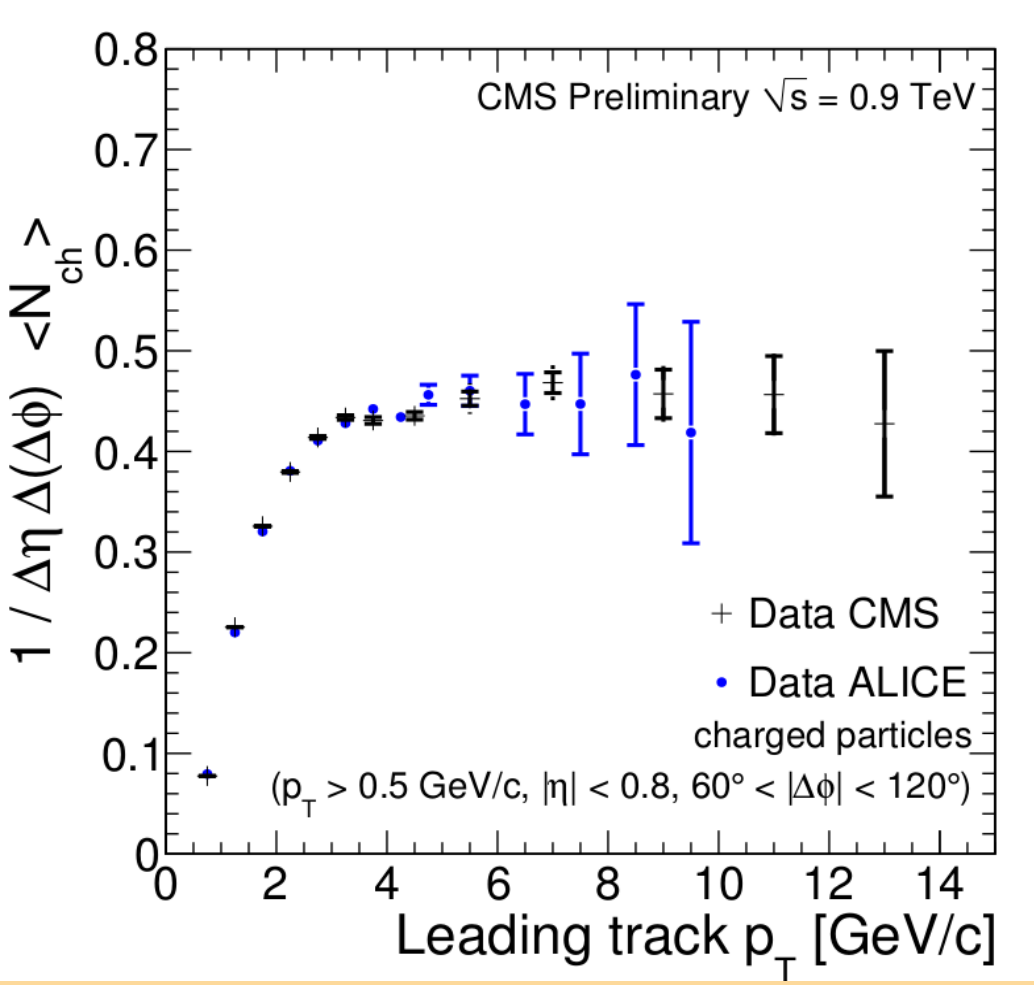
Comparison with ALICE (7 TeV)

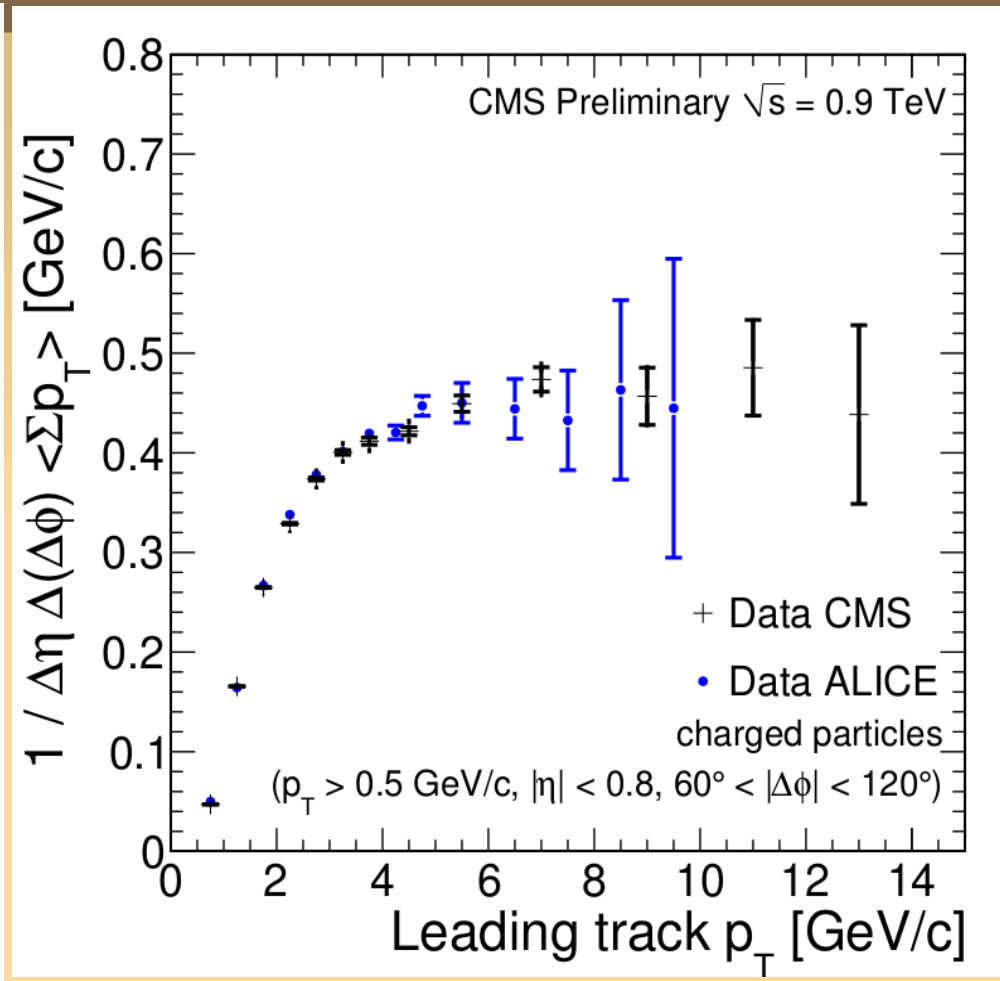




Close resemblance with better statistics.

Comparison with ALICE (0.9TeV)





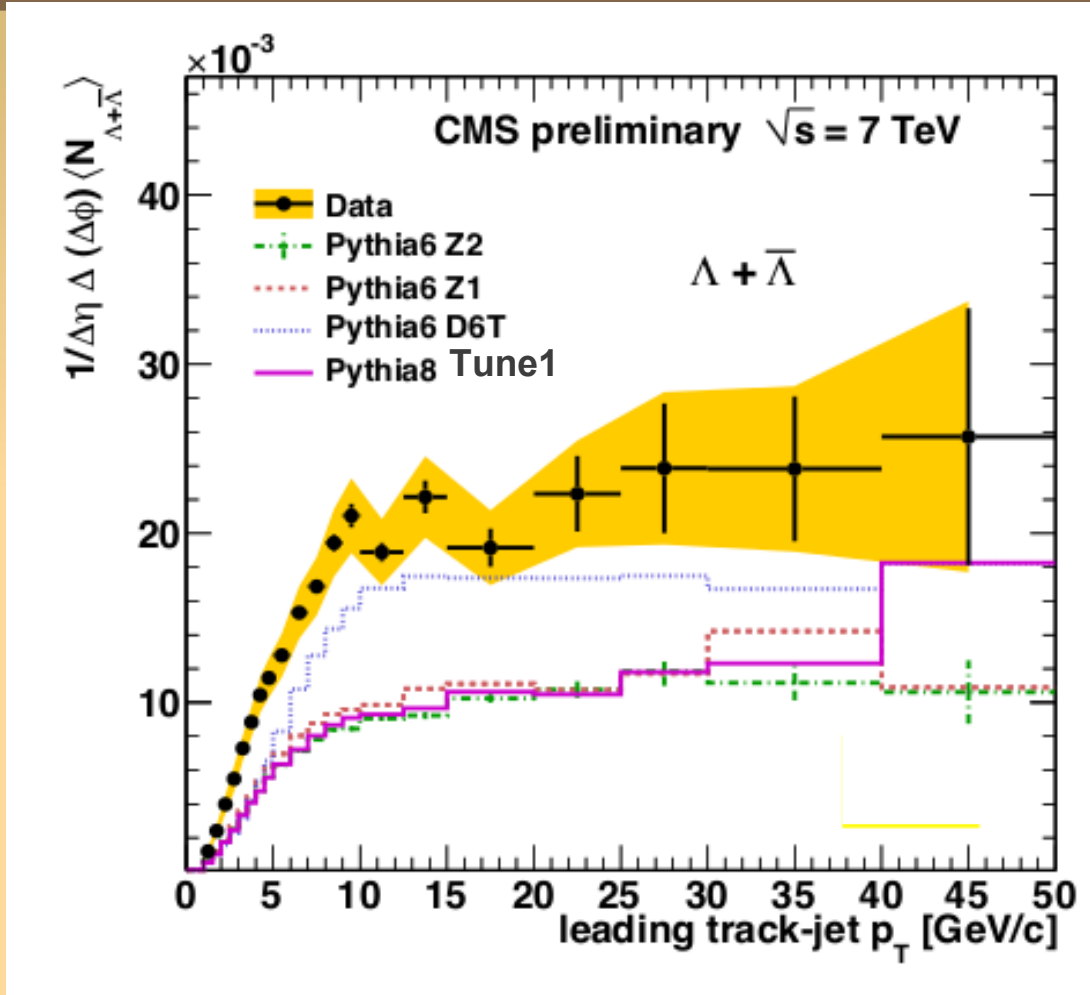
Close resemblance with better statistics.

Strange particles production in UE

- The first measurement of primary strange particle production in the UE.
- Almost identical in its analysis strategy to the previous analysis (this time using Anti-kt with radius equal to 0.5).
- Please refer to Tomas Hreus' talk for more details.

Strangeness in UE

- Similar Qualitative features as the Charged UE.
- MC was able to mimic the qualitative features, but fails in getting the plateau.
- Similar features for K^0_s.

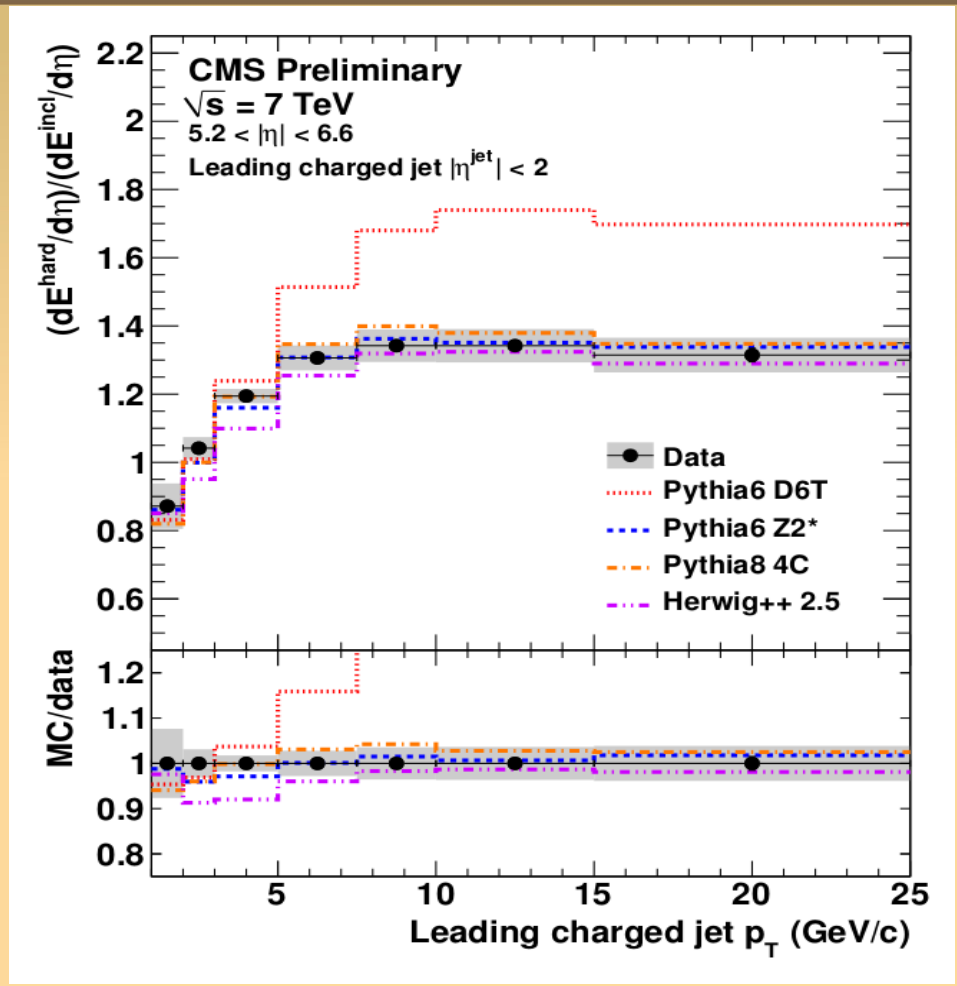


UE at forward physics

- Studies the UE at forward rapidity ($-6.6 < \eta < -5.2$) by measuring the ratio of the energy density, $dE/d\eta$, between events with a charged particle jet produced at central rapidity ($|\eta| < 2$) and inclusive events.
- Measured as a function of the leading charged jet pT at 3 COM energies: 0.9, 2.76 and 7TeV.
- See Hans Van Haevermaet's talk for details.

UE at forward physics

- Similar trigger requirements as the previous 2 analyses.
- Depends on CASTOR.
- Comparison with data reveals good agreement with all tunes except PYTHIA6 Tune D6T.



Conclusions

- CMS continues with its strong commitment to studying the UE covering various topologies and probes:
  - One more UEMBWG requirement was fulfilled.
  - First analysis for the strangeness at UE.
  - Studies of the UE at forward physics.
- Plenty of data is available for phenomenology experts; all analyses are or are about to be done in RIVET.
- Some tuning projects are on the way.

Thank You!

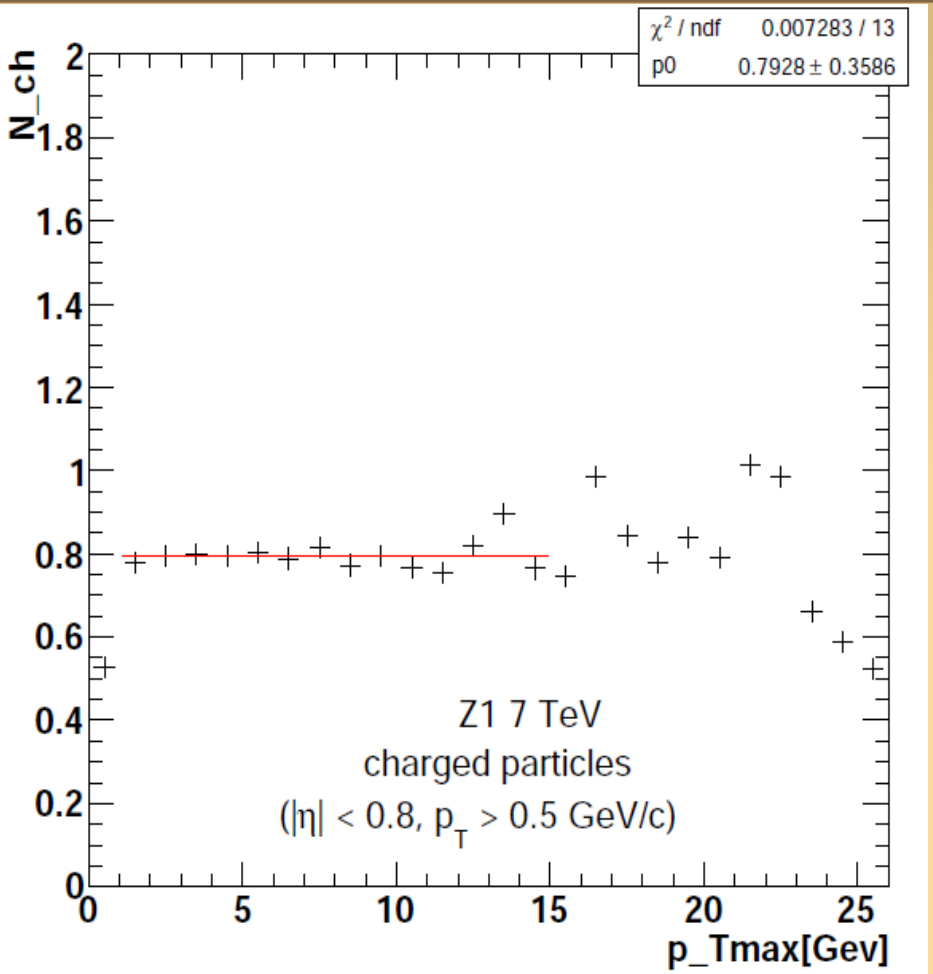
References:

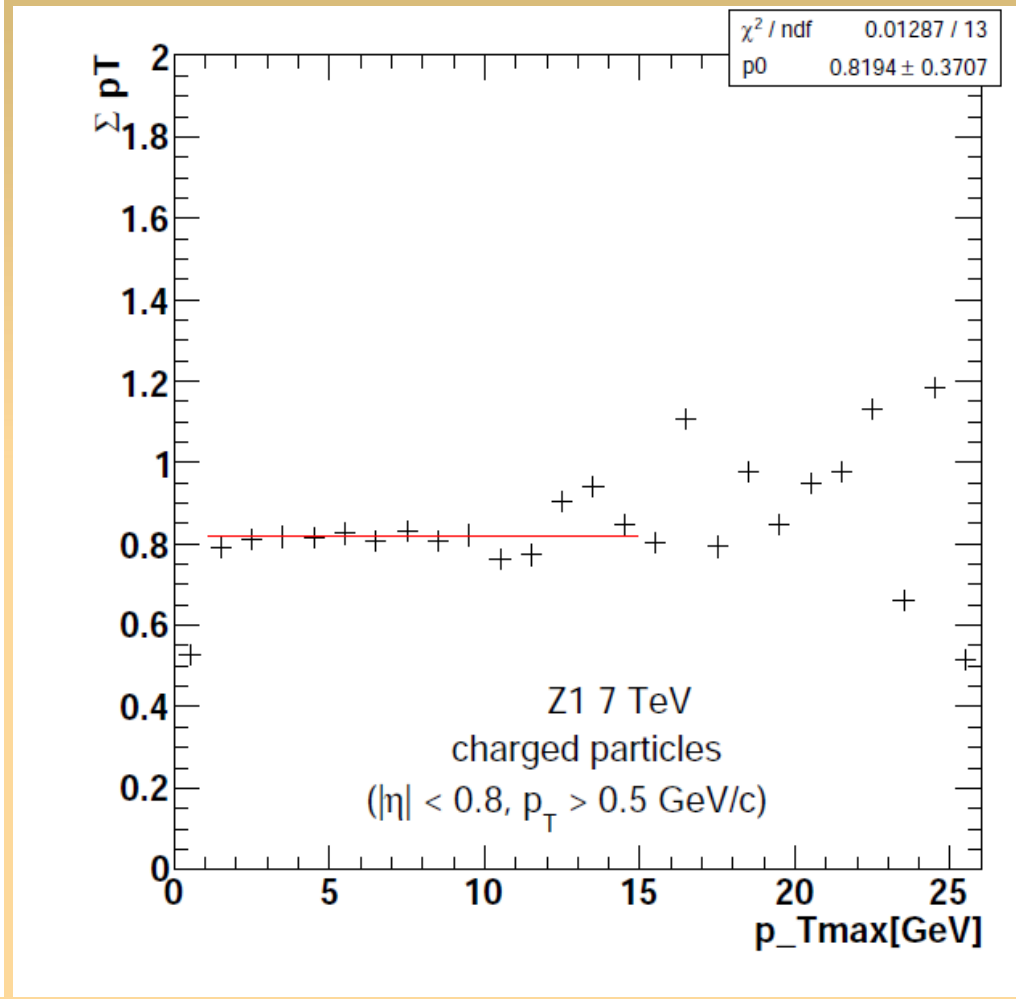
- UE using the leading track: http://cdsweb.cern.ch/record/1478982/files/FSQ-12-020-pas.pdf
- Strangeness at UE: http://cdsweb.cern.ch/record/1463352
- UE at forward physics: http://cdsweb.cern.ch/record/1373466/files/FWD-11-001-pas.pdf

Image Credit (Bottom of slide 8): DOI: 10.1103/PhysRevD.83.054012

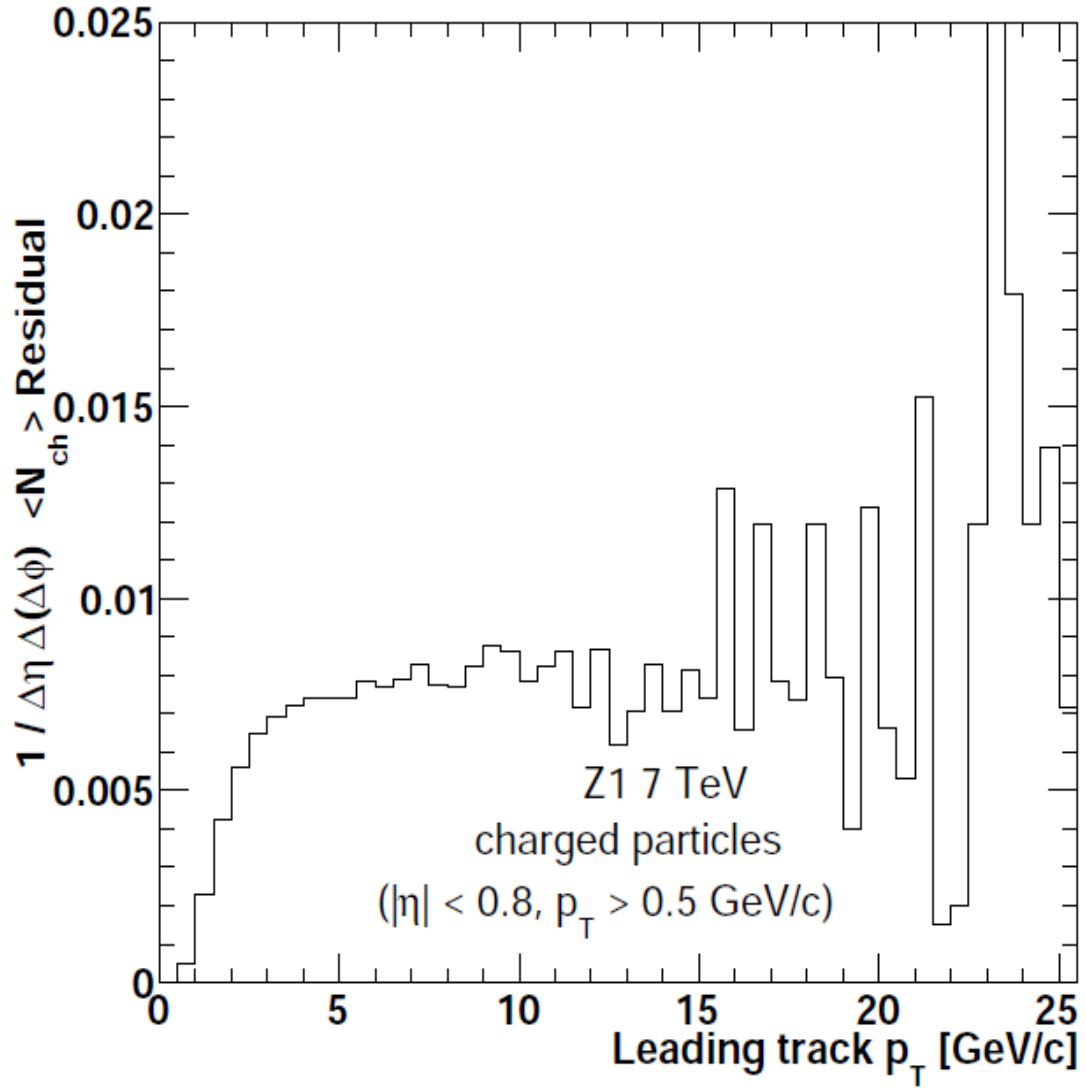
Back up slides

HLT effect


χ² / ndf 0.007283 / 13
p0 0.7928 ± 0.3586
N_ch
Z1 7 TeV
charged particles
(|η| < 0.8, p_T > 0.5 GeV/c)
p_Tmax[Gev]


χ² / ndf 0.01287 / 13
p0 0.8194 ± 0.3707
Σ pT
Z1 7 TeV
charged particles
(|η| < 0.8, p_T > 0.5 GeV/c)
p_Tmax[GeV]

Re-orientation



- Assumptions:
  - Run the code
  - Generate a random number
  - 10% of the cases will have a Re-orientation
  - Take the second leading pT track

PYTHIA parameters

Parameter	Default	Description
PARP(83)	0.5	Double-Gaussian: Fraction of total hadronic matter within PARP(84)
PARP(84)	0.2	Double-Gaussian: Fraction of the overall hadron radius containing the fraction PARP(83) of the total hadronic matter.
PARP(85)	0.33	Probability that the MPI produces two gluons with color connections to the “nearest neighbors.
PARP(86)	0.66	Probability that the MPI produces two gluons either as described by PARP(85) or as a closed gluon loop. The remaining fraction consists of quark-antiquark pairs.
PARP(89)	1.8 TeV	Determines the reference energy E_0.
PARP(82)	1.9 GeV/c	The cut-off P_{T0} that regulates the 2-to-2 scattering divergence $1/PT^4 \rightarrow 1/(PT^2+P_{T0}^2)^2$
PARP(90)	0.16	Determines the energy dependence of the cut-off P_{T0} as follows $P_{T0}(E_{cm}) = P_{T0}(E_{cm}/E_0)^{\varepsilon}$ with ε = PARP(90)
PARP(67)	1.0	A scale factor that determines the maximum parton virtuality for space-like showers. The larger the value of PARP(67) the more initial-state radiation.

1 →

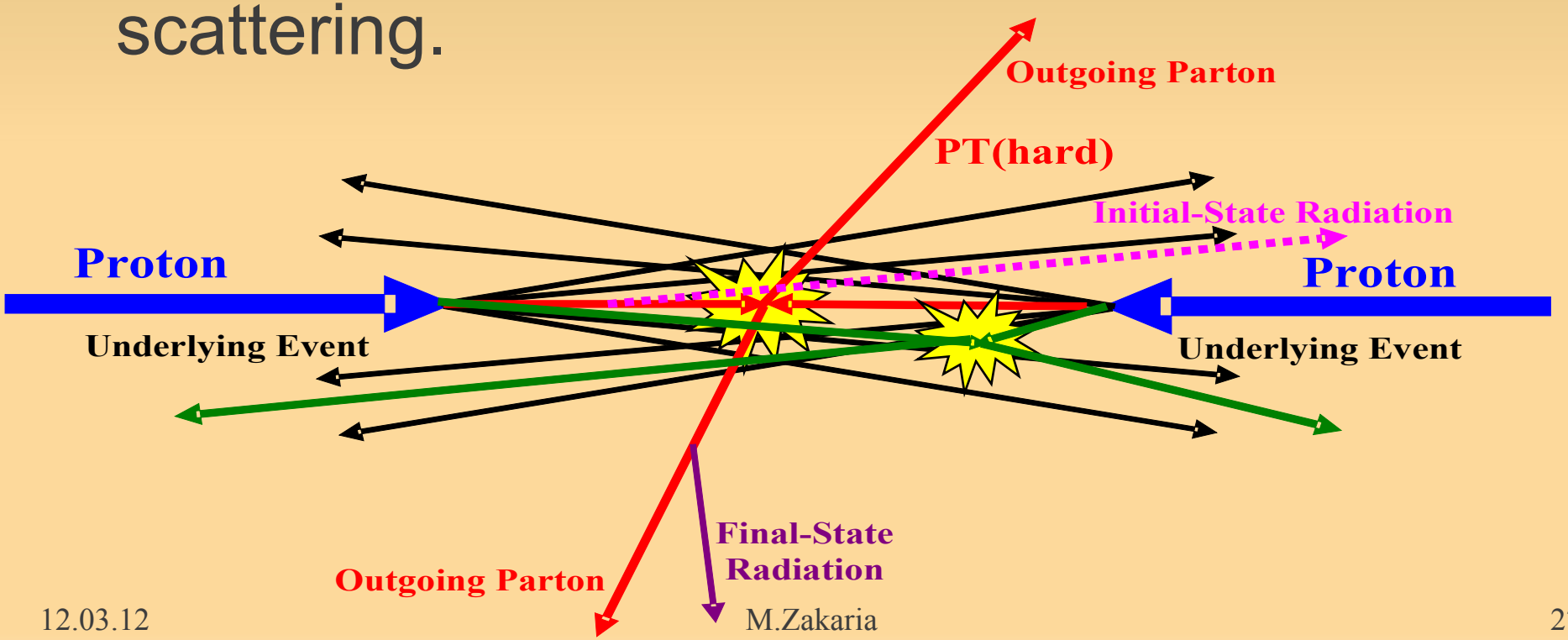
2 →

Differnet Tunes

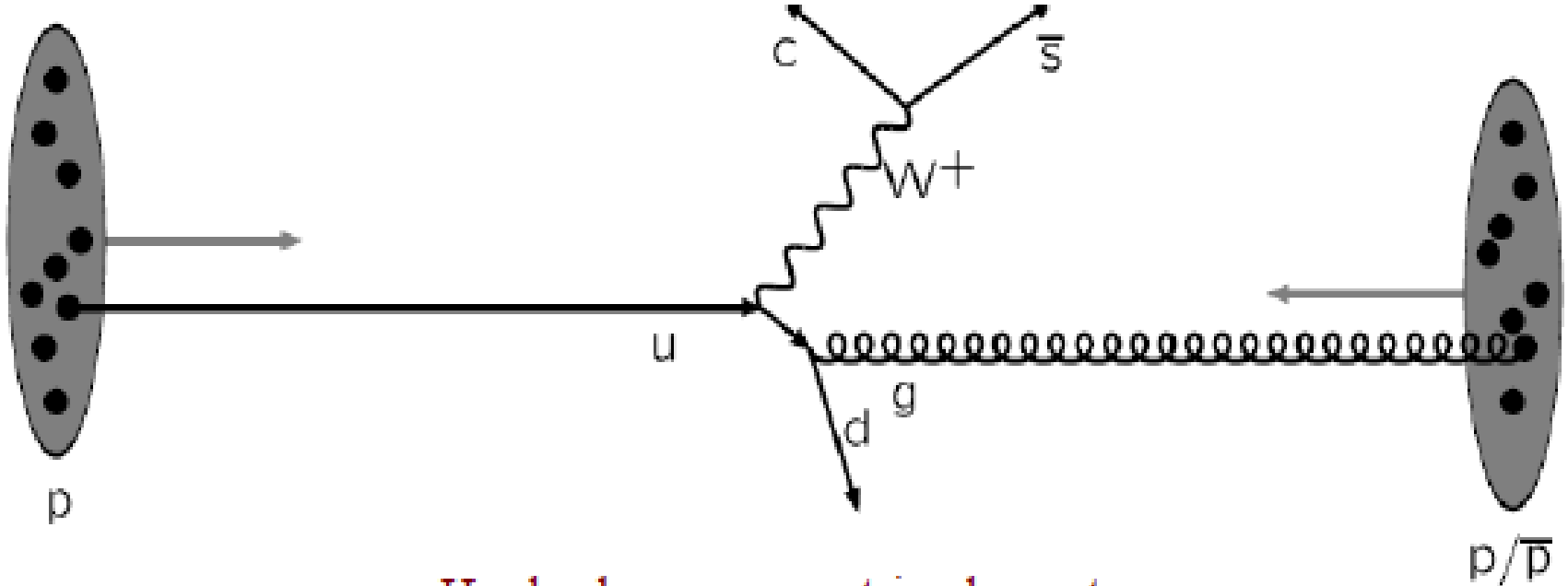
- All tunes used in this study were used to describe the UE activities at CDF.
- DW, P0 (only Minbias) , Pro-Q20 (UE + Min-bias) has ε = 0.25, 0.26, 0.22, respectively.
- D6T has ε = 0.16 and CTEQ6L.
- P0 and Pro-Q20 use LEP Fragmentation.
- P8: Only one tune (close to P0), ε = 0.25

What is the The UE?

- The Underlying Event is the part of the p-p collision that doesn't participate in the hard scattering.



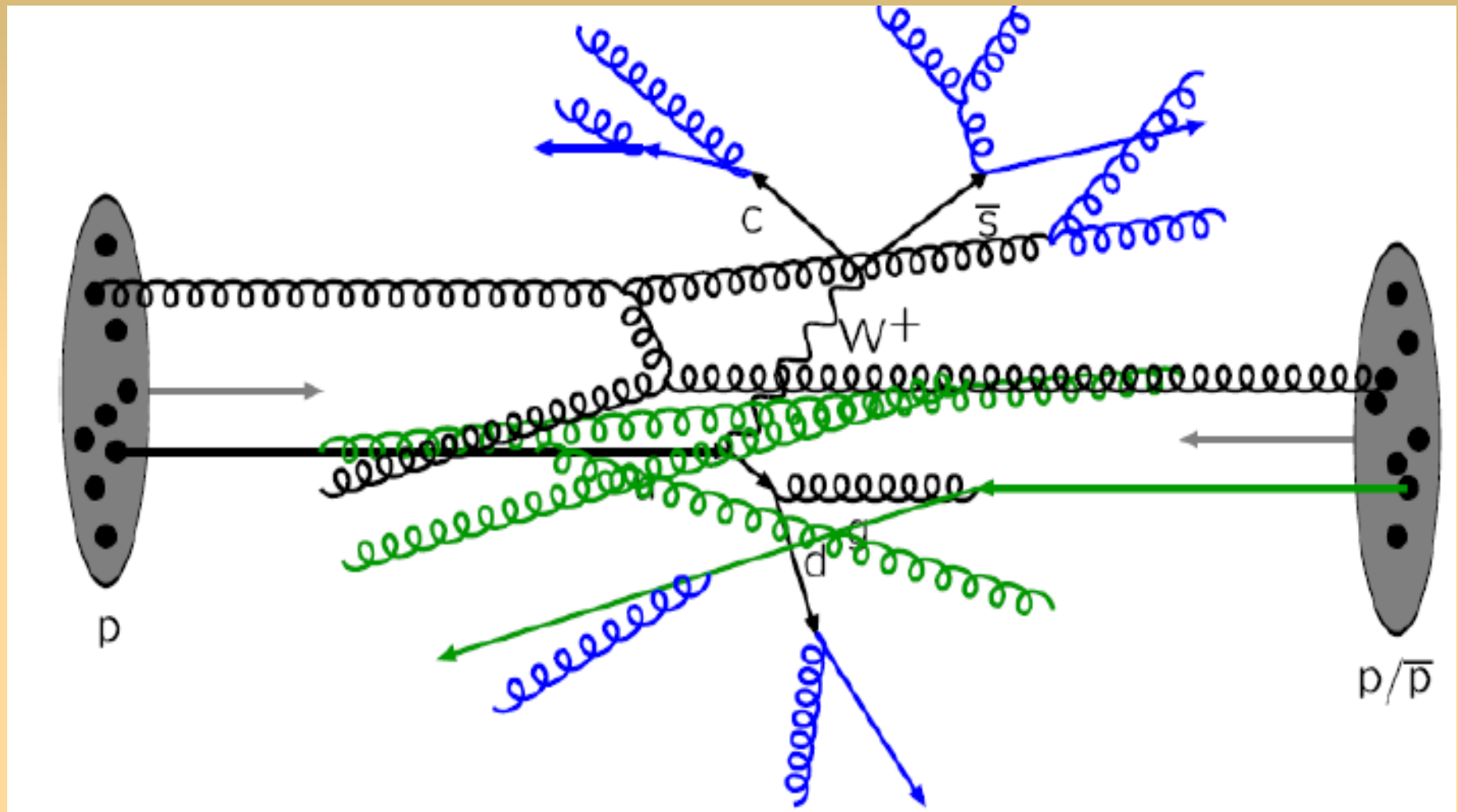
What is the The UE?



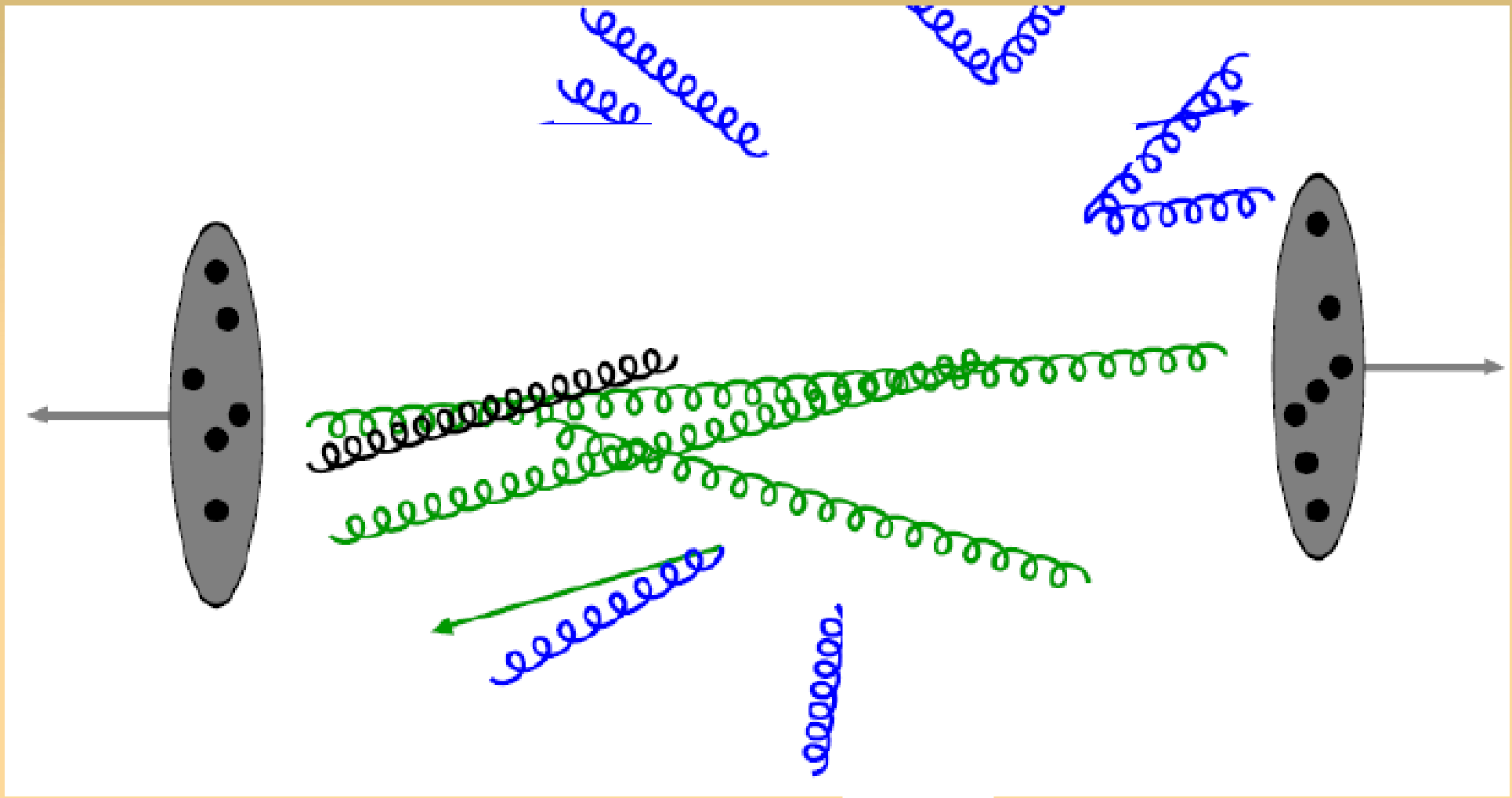
Hard subprocess: matrix elements,
Resonance decays (correlated to hard process)

Source: Martin Fechl

What is the The UE?



What is the The UE?



Motivation

- The UE is an unavoidable background for most collider observables.
- It has large effect on many physics processes (example: inclusive jet cross section).
- It helps in modelling MPI (Multiple Parton Interaction) and BBR (Beam Beam Remnants).
- New physics might be sensitive to UE!

DATA Samples

7 TeV (3 pb^{-1})

- Data I /MinimumBias/Commissioning10-Jun14thReReco v1/RECO
- Data II /MinimumBias/Run2010A-Jun14thReReco v2/RECO
- Data III /MinimumBias/Run2010A-Jul16thReReco-v1/RECO
- Data IV /MinimumBias/Run2010A-PromptReco-v4/RECO

Same samples used for QCD-10-010

0.9 TeV (1 μb^{-1})

- /MinimumBias/Commissioning10-Jun14thReReco v1/RECO

MC Samples

7 TeV

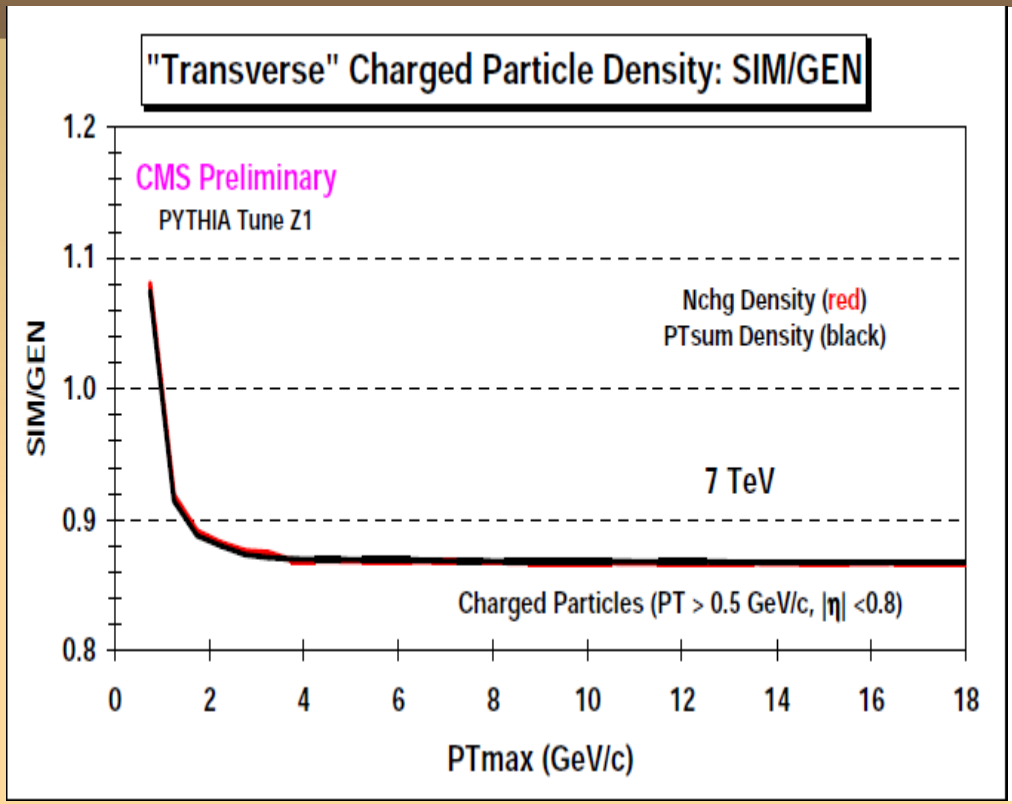
- /MinBias_TuneD6T_7TeV-pythia6/Summer10-START36_V10_SP10-v1/GEN-SIM-RECODEBUG
- /MinBias_TuneZ1_7TeV-pythia6/Summer10-START36_V10_TP-v1/GEN-SIM-RECODEBUG;

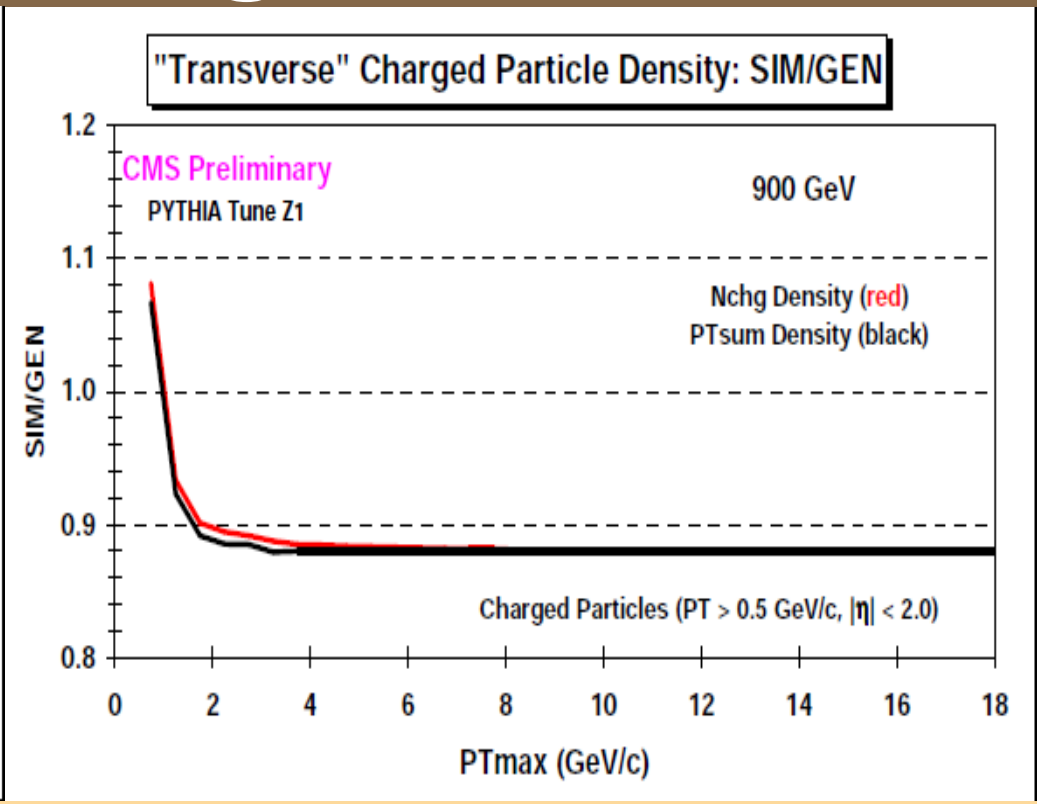
0.9 TeV

- /MinBias_TuneZ1_900GeV-pythia6/Summer10-START36_V10A-v1/GEN-SIM-RECO
- /MinBias_TuneD6T_900GeV-pythia6/Summer10-START36_V10A-v1/GEN-SIM-RECODEBUG

Added: Private production of PYTHIA8 (Tune1) and Herwig++ (Default tune)

Unfolding





- Bin-By-Bin Method.
- Done using Tune Z1.
- Hadronic level: An event is counted if it has at least one charged and stable particle with (p_T > 0.5 GeV/c and |η| < 0.8).

Triggering

- Using Beam Pick-up Timing eXperiment and the Beam Scintillator Counter.
- L1:

  L1_BscMinBiasOR_BptxPlusORMinus
- HLT:

  HLT_MinBiasPixel_SingleTrack (At least one track in the pixel with pT > 0.2 GeV/c)

How to Calculate The UE Activity?

- The UE represents the soft component of QCD processes. The transverse momentum p_T becomes too small for perturbative QCD as p_T goes to zero.
- We use MC generators: PYTHIA, SHERPA, HERWIG etc.

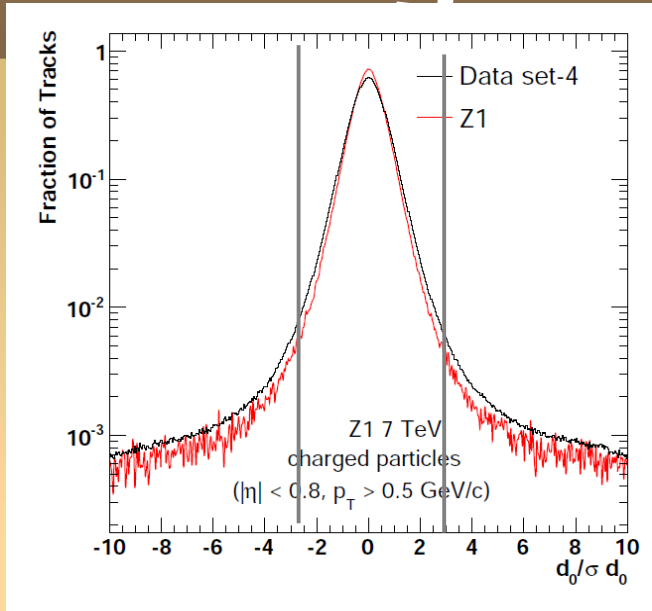
Tracking Validation

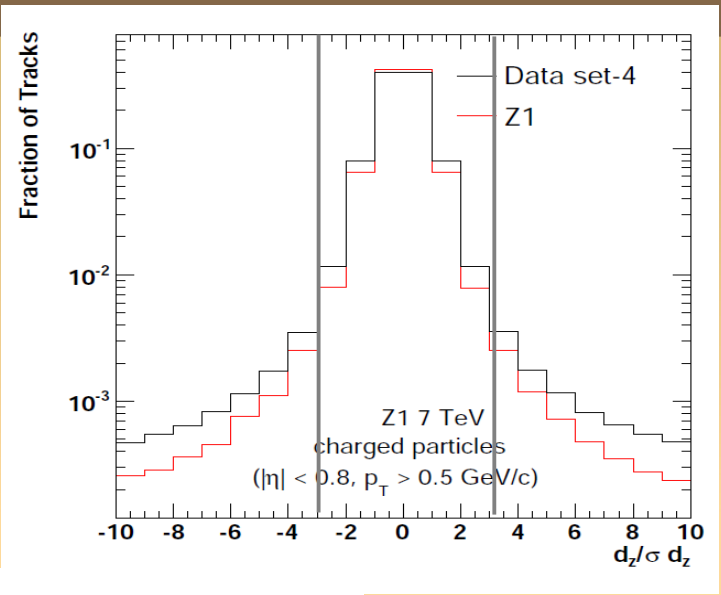
High Purity

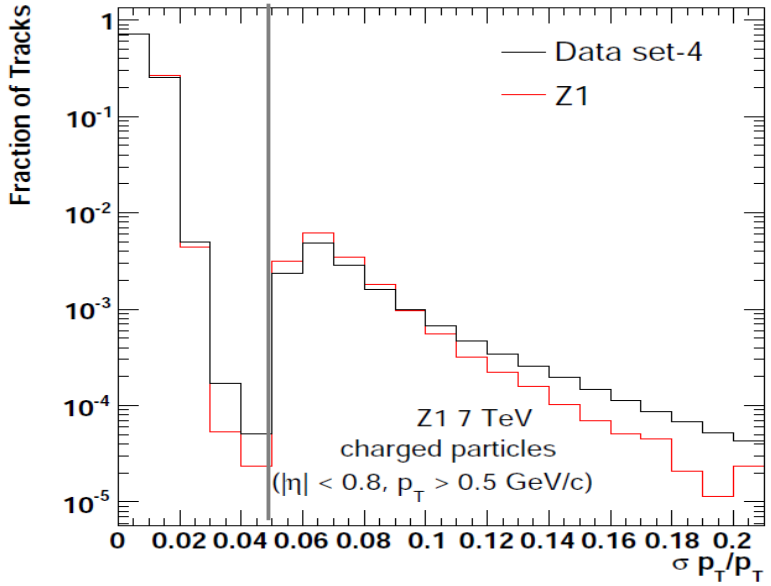
$$\frac{d_0}{\sigma(d_0)} < 3$$

$$\frac{d_z}{\sigma(d_z)} < 3$$

$$\frac{\sigma(p_T)}{p_T} < 0.05$$







How to Calculate The UE Activity

- PYTHIA regulates the cross-section by including a smooth cut-off p_{T0} which regulates the 2-to-2 scattering divergence

$$\frac{1}{\hat{p}_T^4} \rightarrow \frac{1}{(\hat{p}_T^2 + \hat{p}_{T0}^2)^2}$$

- $\hat{p}_{T0}$ can be interpreted as the inverse of the effective color screening length.

Systematic Uncertainty

	Nch (7 TeV)	Sum p_T (7 TeV)	Nch (0.9 TeV)	Sum p_T (0.9 TeV)
Tracking	%0.57	%0.57	%0.5	%0.5
Track Selection	%2.2	%5.1	%2.7	%4.6
Track Cuts	%0.5	%2.3	%2.6	%2.9
Pile Up	%0.7	%0.7	%0	%0
Vertex Ndof	%3.9	%2.2	%1.2	%1.9
Bg. Cont.	%0.8	%0.8	%0.8	%0.8
MC Model	%2	%2.2	%0.9	%0.9