Minimum bias and underlying event measurement with the CMS detector

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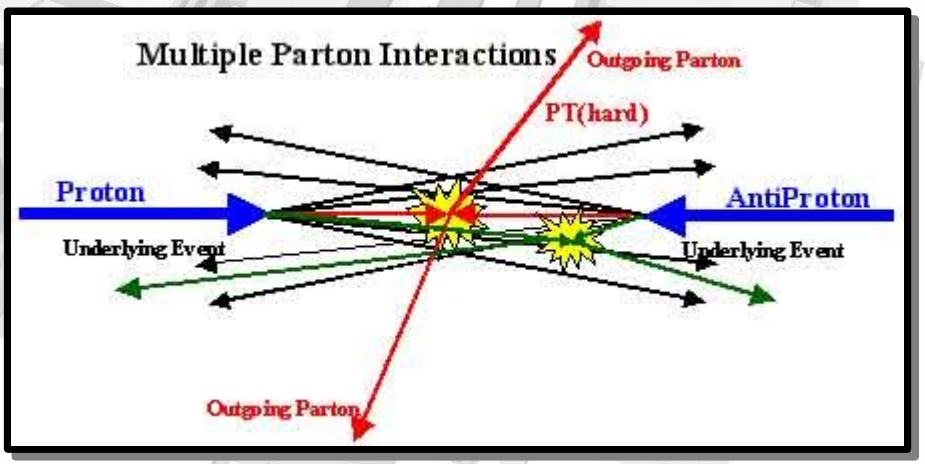
[based on a talk by Livio Fano of the CMS Minimum Bias and Underlying Event group]

Outline:

- Definitions and models
- Monte Carlo tunes
- Measurement plan
- Preparing the analysis
  - Computing, Software and Analysis Challenge 2006



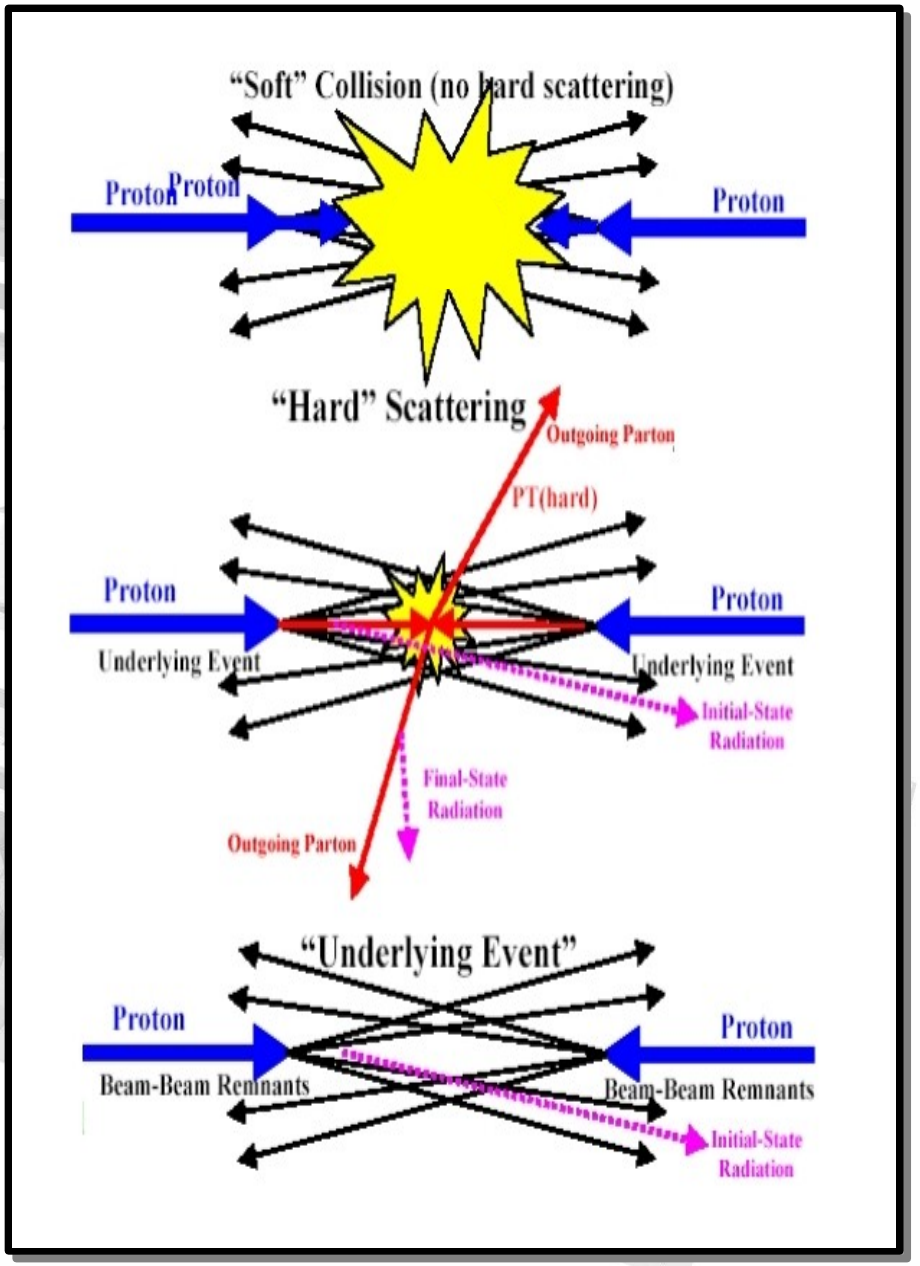
Definition and models: Minimum bias

- events collected with a completely inclusive trigger
  - generic single proton-proton interaction
  - elastic, inelastic and diffractive interactions (100 mb at LHC)
- general properties of interactions:
  - $\langle N_{int} \rangle \propto \mathscr{L}_{inst} * \sigma$ ☞ important dependence on specific luminosity
  - low transverse energy
  - low multiplicity
- At Tevatron, 1% of minimum bias events contain a jet with ET > 10 GeV
  - expect 12% at LHC

- Note: Minimum bias only collected together with triggered event
  - ☞ Minimum bias constitutes Pile-Up

Definition and models: Underlying event

- everything except hard-scattering component of collision
  - initial and final state radiation
  - spectators
  - beam-beam remnants
  - ...
- Underlying event is related to hard scattering
  - same primary vertex
  - correlated with energy of main interaction
  - color and flavor connected
- Note: Underlying event ≠ Minimum bias
  - ☞ but both have similar phenomenolgy



Pythia 6.2 tuning

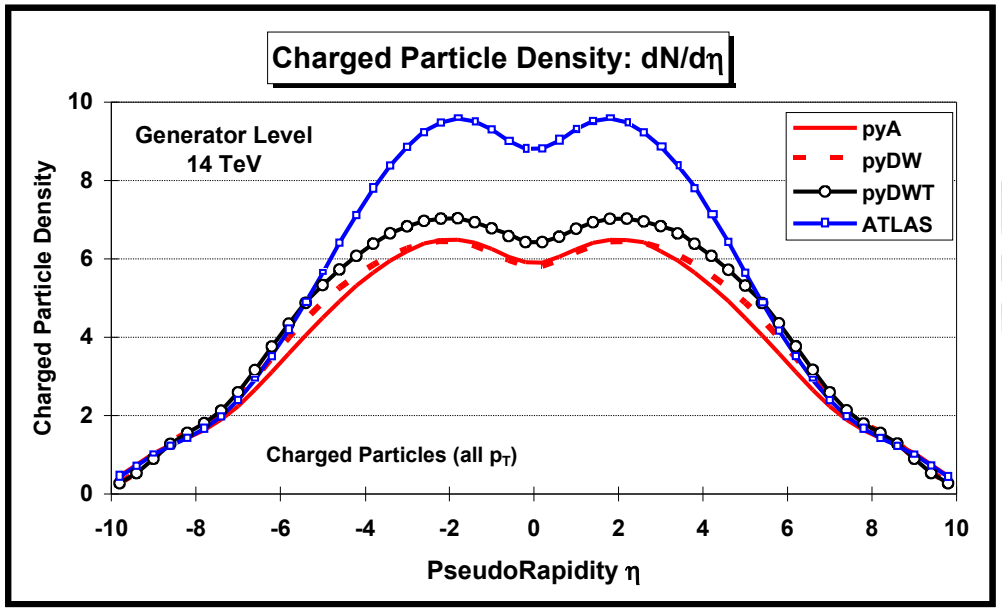
Currently, only Pythia can be tuned to simultaneously describe CDF and UA5 data.

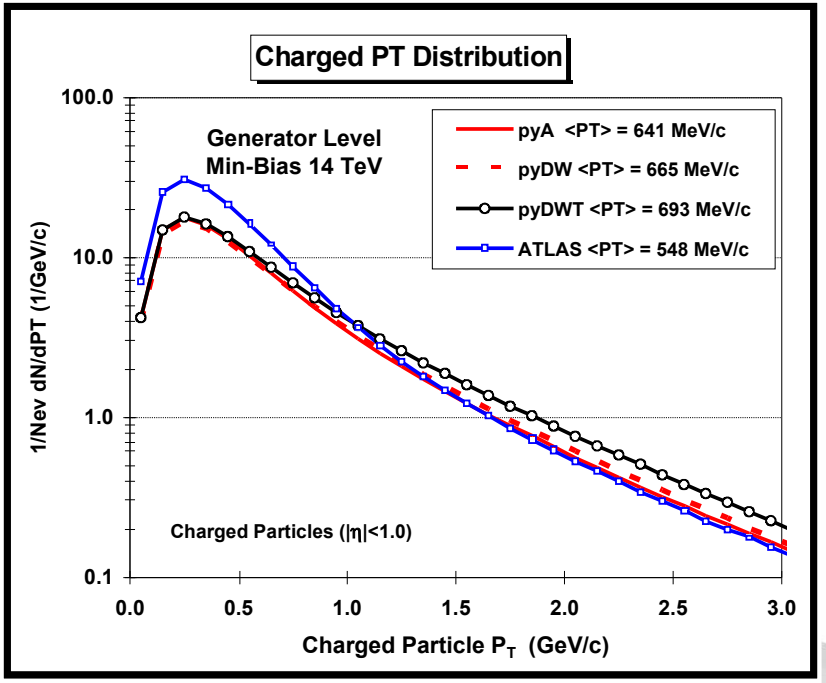
- Pythia tune A (R. Field):
  - describes the underlying event in CDF Run 1 and 2
- Pythia tune DW (R. Field):
  - similar to tune A
  - fits CDF $P_T(Z)$ distribution
  - uses DØ preferred value of PARP(67) (from dijet $\Delta\phi$ distribution)
- Pythia tune ATLAS:
  - uses default value of multiple parton interaction energy dependence parameter PARP(90)=0.16
- Pythia tune DWT (R. Field):
  - identical to tune DW at 1.96 TeV
  - using ATLAS energy extrapolation to 14 TeV (P_T cutoff) ☞ PARP(90)=0.16

Parameter	Tune A	Tune DW	Tune DWT	ATLAS
MSTP(81)	1	1	1	1
MSTP(82)	4	4	4	4
PARP(82)	2.0 GeV	1.9 GeV	1.9409 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4	0.5
PARP(85)	0.9	1.0	1.0	0.33
PARP(86)	0.95	1.0	1.0	0.66
PARP(89)	1.8 TeV	1.8 TeV	1.96 TeV	1.0 TeV
PARP(90)	0.25	0.25	0.16	0.16
PARP(62)	1.0	1.25	1.25	1.0
PARP(64)	1.0	0.2	0.2	1.0
PARP(67)	4.0	2.5	2.5	1.0
MSTP(91)	1	1	1	1
PARP(91)	1.0	2.1	2.1	1.0
PARP(93)	5.0	15.0	15.0	5.0

	σ(MPI) at 1.96 TeV	σ(MPI) at 14 TeV
Tune A	309.7 mb	484.0 mb
Tune DW	351.7 mb	549.2 mb
Tune DWT	351.7 mb	829.1 mb
ATLAS	324.5 mb	768.0 mb

Evaluation of different tunes (Rick Field)

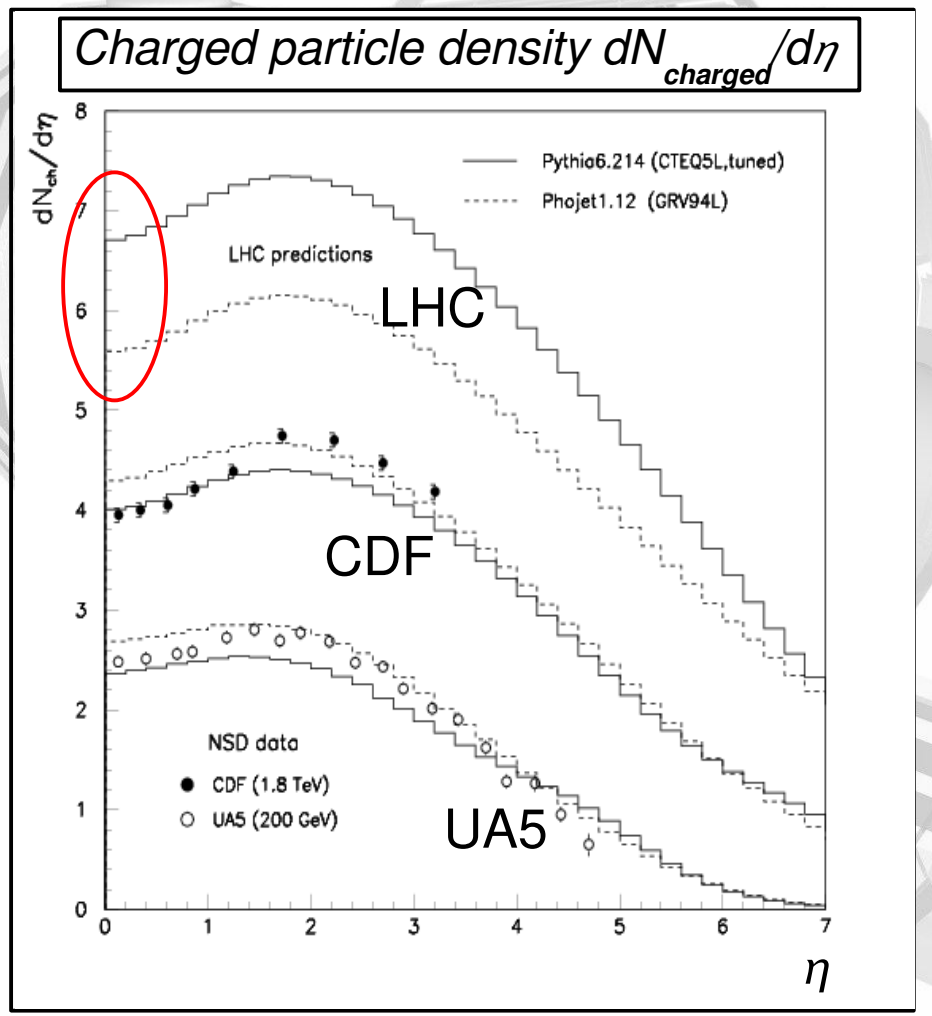


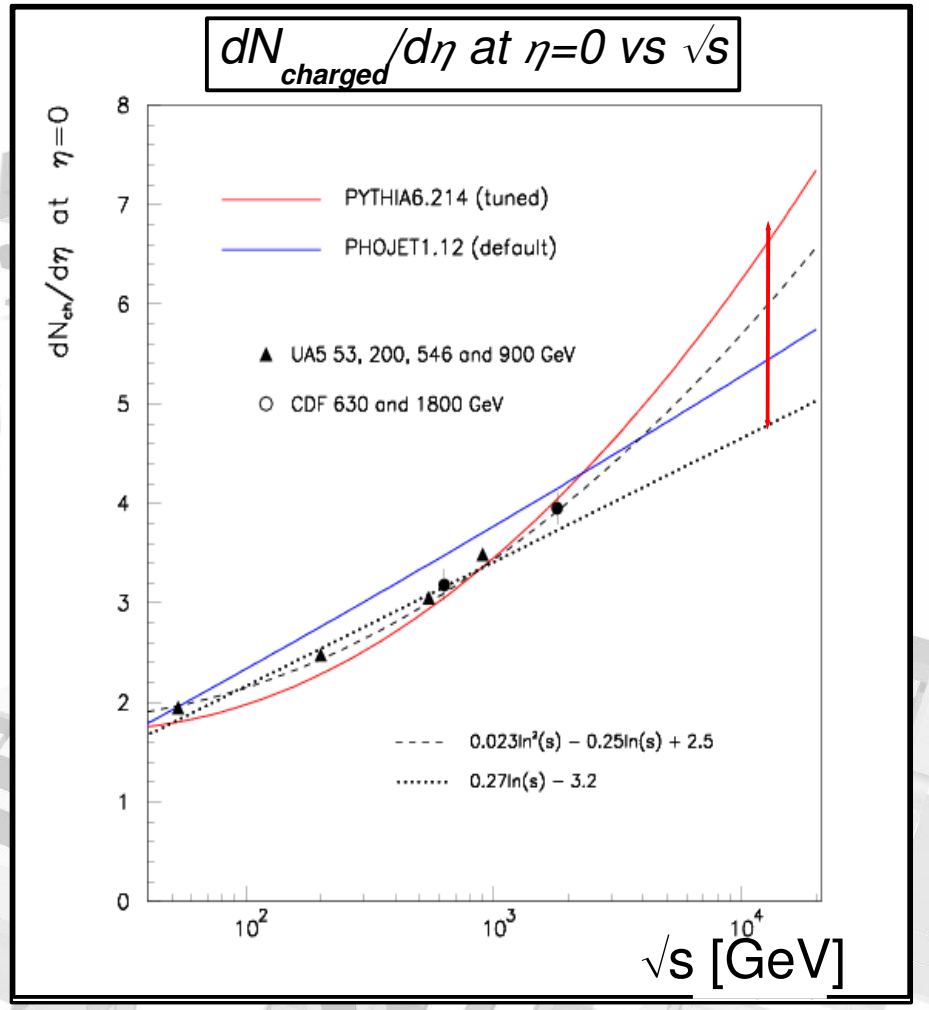


R. Field at MC4LHC workshop:

- Pythia tune A: not enough "soft" energy in the "underlying event"
- ATLAS tune: too many "soft" particles
  - $<P_T>$ of charged particles too low and not in agreement with CDF Run 2 data
  - tune in agreement with $<N_{charged}>$ at Tevatron
  - tune not in agreement with $<PT_{sum}>$ at Tevatron
- **Pythia tune DWT** identical to tune DW at 1.96 TeV but using ATLAS energy extrapolation to 14 TeV (P_T cutoff) ☞ PARP(90)=0.16

Measurement plan: Minimum bias

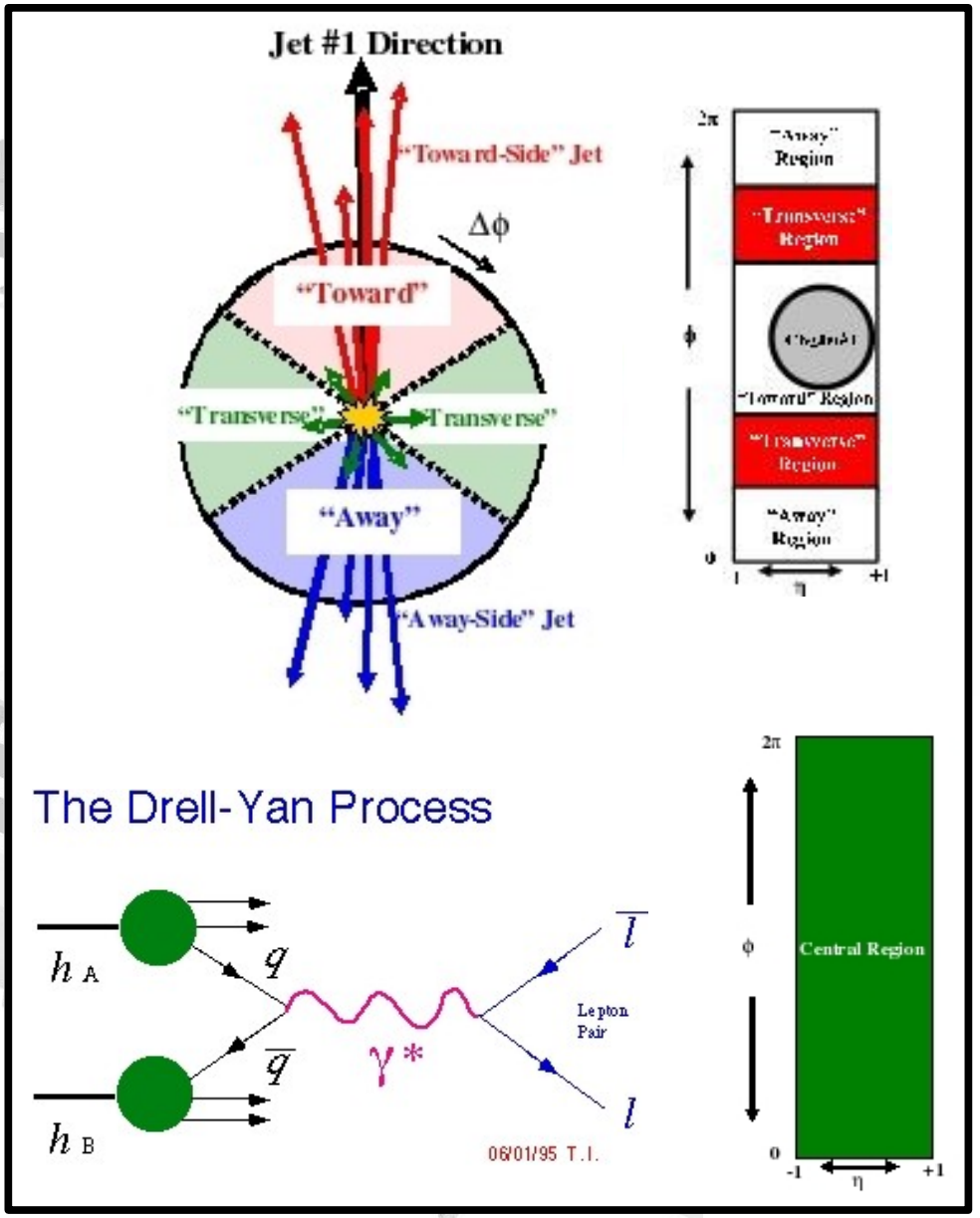




- Pythia 6.214 tunes from CDF (1.8 TeV) and UA5 (200 and 900 GeV) measurements predict 4 to 7 charged particles with $\Delta\eta$=1 around η=0 for $\sqrt{s}$=14 TeV
  - ☞ large systematic uncertainty
- main observables for minimum bias data: **$dN_{charged}/d\eta$, $dN_{charged}/dP_T$**

Measurement plan: Underlying event

- following CDF analysis (Rick Field)
- UE measurement employing charged jets
  - run iterative cone algorithm on massless charged tracks
    - ☞ "charged jet"
  - leading jet defines direction in ϕ plane
  - transverse region sensitive to UE
- employing Drell-Yan-muon pair production
  - everything but the muon pair is the UE
  - observables defined in entire ϕ plane
- Main observables:
  - charged particle density: $\mathbf{dN/d\eta d\phi}$
  - energy density: $\mathbf{dPT_{sum}/d\eta d\phi}$
  - fluctuation: $\mathbf{dN_{charged}/dP_T}$



Testing the analysis workflow

- **Computing, Software and Analysis Challenge 2006 (ongoing):**
  - 50 million event exercise to test the workflow and dataflow associated with the data handling and data access model of CMS
    - prompt reconstruction at Tier-0 (CERN)
    - distribution of Analysis Object Data to participating Tier-1's (e.g. FZK)
    - Physics jobs on skimmed data on participating Tier-2's (e.g. DESY)
- **Monte Carlo samples:**
  - of interest to this analysis:
    - 25 million minimum bias events
    - 2.2 million Drell-Yan events
    - 1.2 million dijet and Z+jet events

Base objects – Generator level

Particles

no η cut

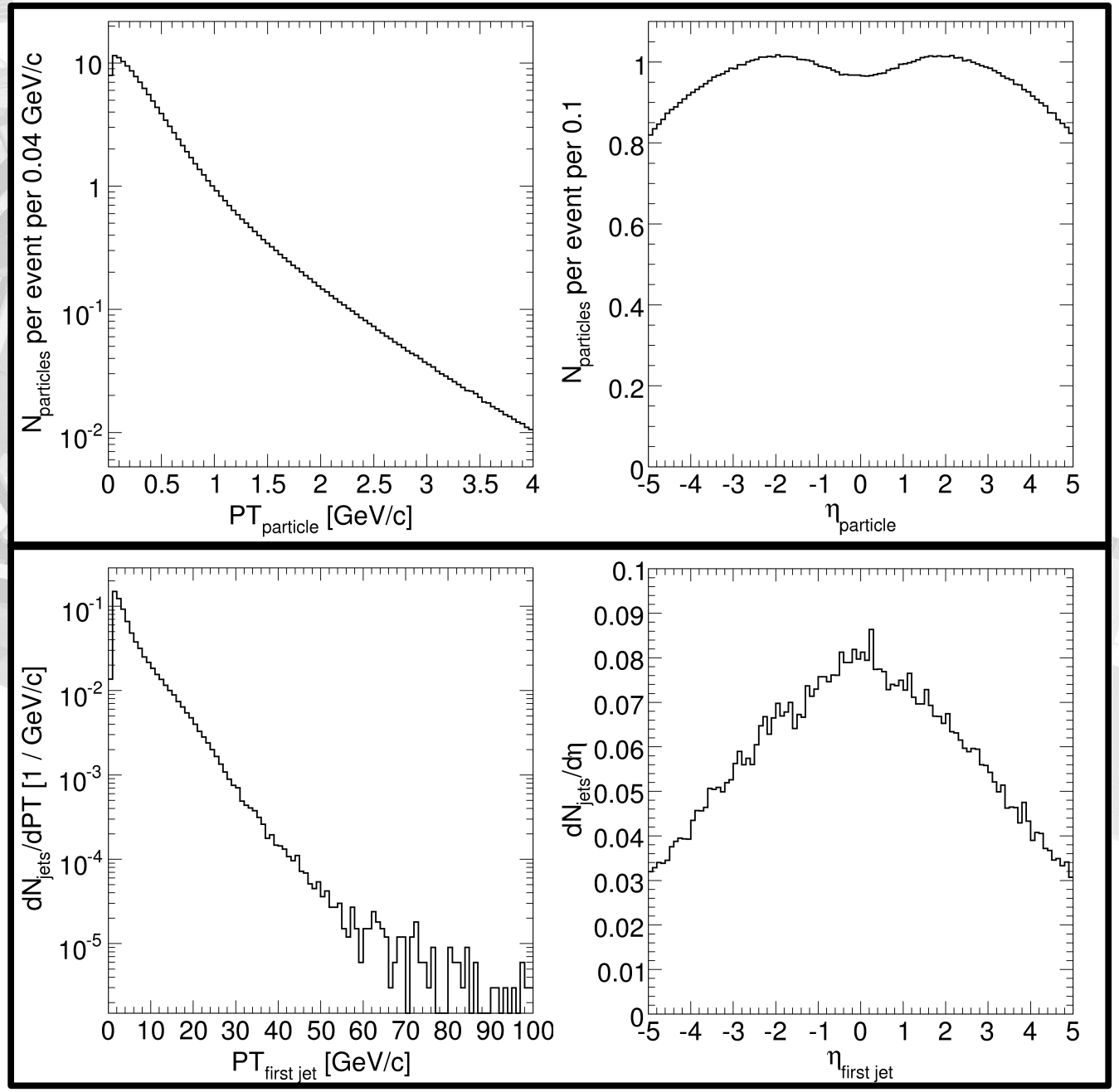
no P_T cut

Leading charged jet

cone radius 0.7

$PT_{particle} > 0.5$ GeV/c

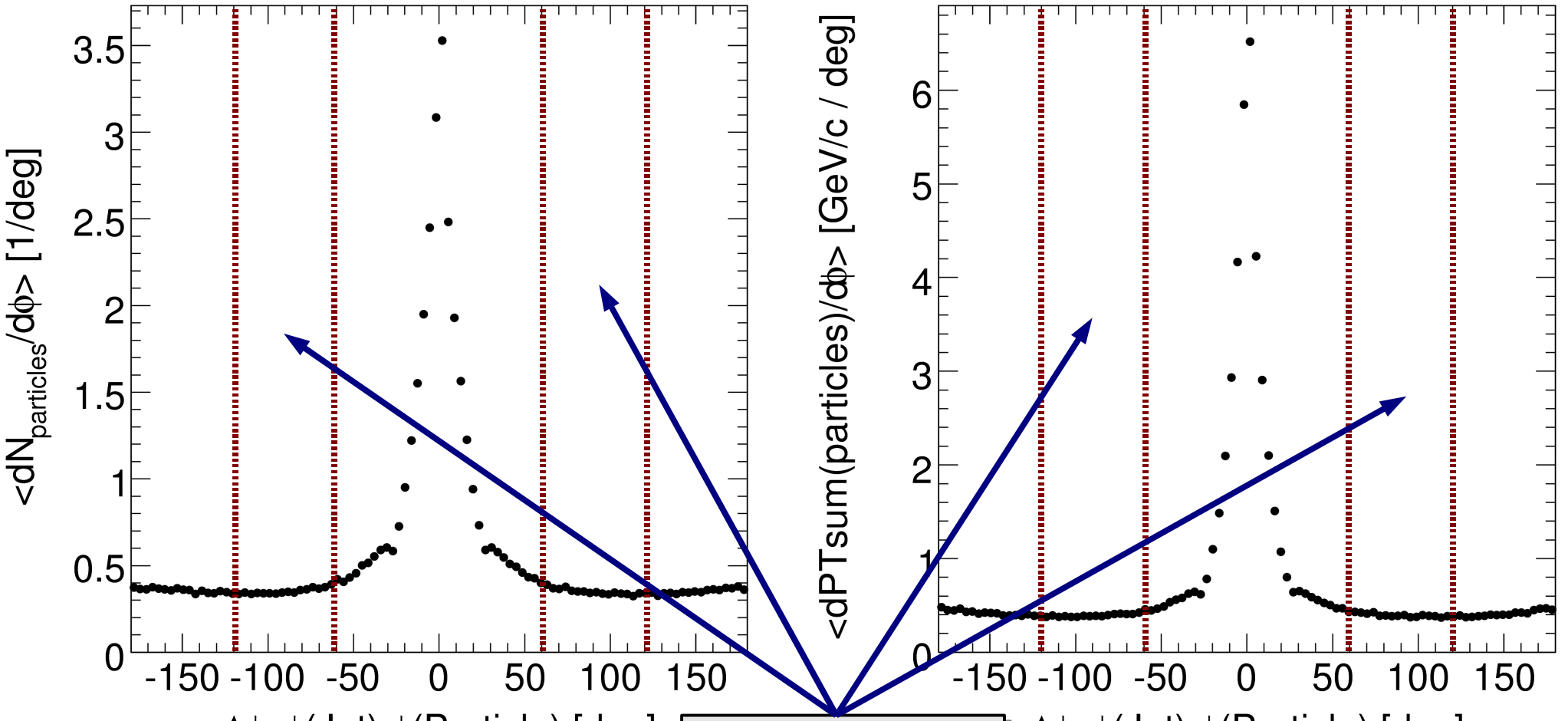
no η cut



MB and UE event observables – Gen level

$PT_{particle} > 0.5$ GeV/c $-1 < \eta_{particle} < 1$

$PT_{jet} > 1$ GeV/c $-1 < \eta_{jet} < 1$



Summary

- **CMS:**
  - MB tuning performed and a reference configuration for MB production for CMS was released and validated
    - *CMSNOTE 2006/067 - PTDR vol.2*

- **This analysis:**
  - Goal: Measure minimum bias and underlying event properties
  - Next steps:
    - running the analysis in the new CMS framework
    - estimate track reconstruction performances during the startup (assuming pixelless seeding and not-aligned detector)