QCD at the LHC: early results

Arthur M. Moraes

University of Glasgow

Outline:

I. Introduction:

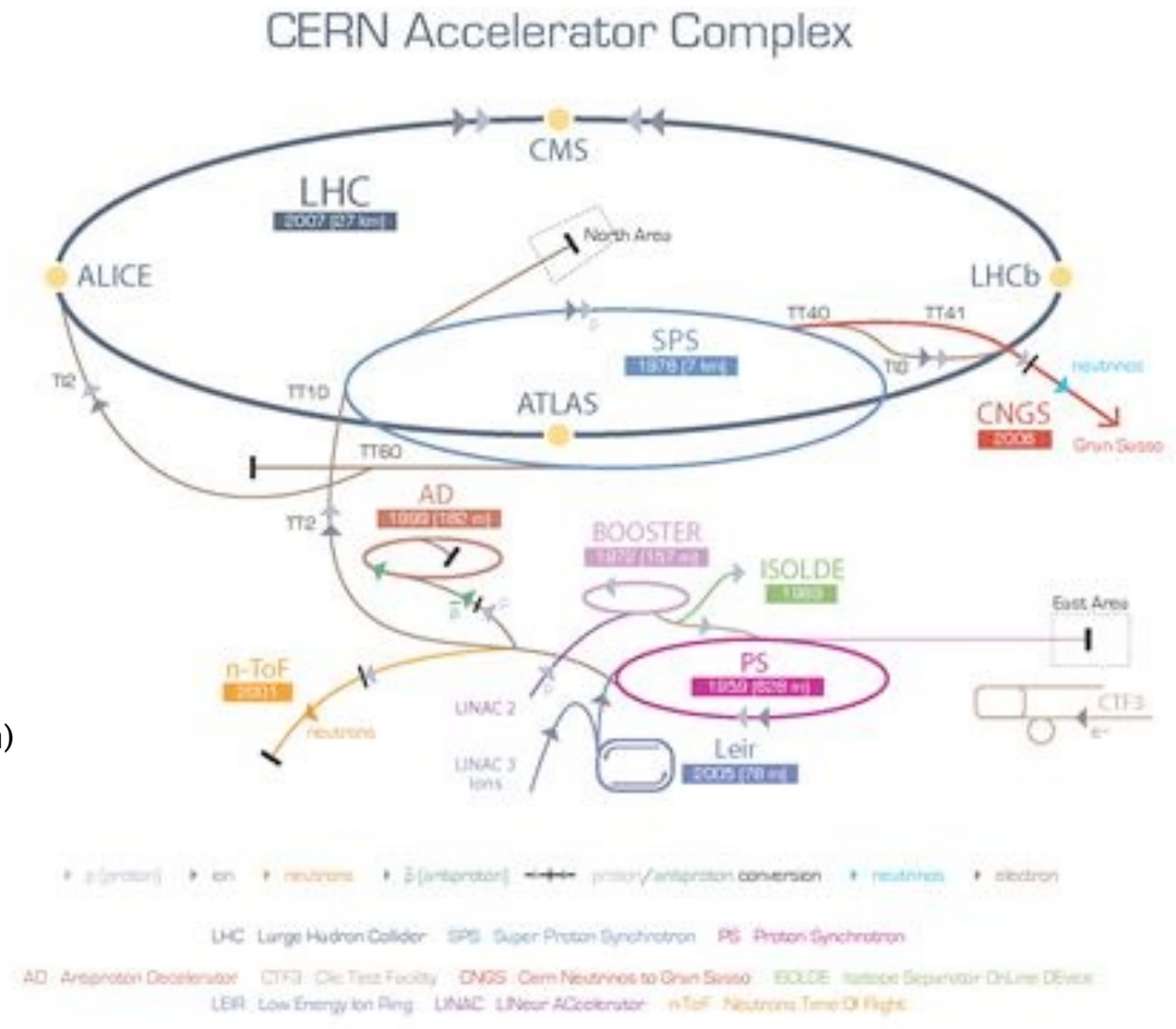
- The Large Hadron Collider – LHC
- ATLAS / CMS / ALICE

II. QCD measurements with early data:

- Minimum bias events
- Track-based underlying event
- First look at energetic jets:
  - Inclusive jet production
  - Dijet distributions
  - Internal jet structure
  - Charged particle flow

III. Summary

The Large Hadron Collider

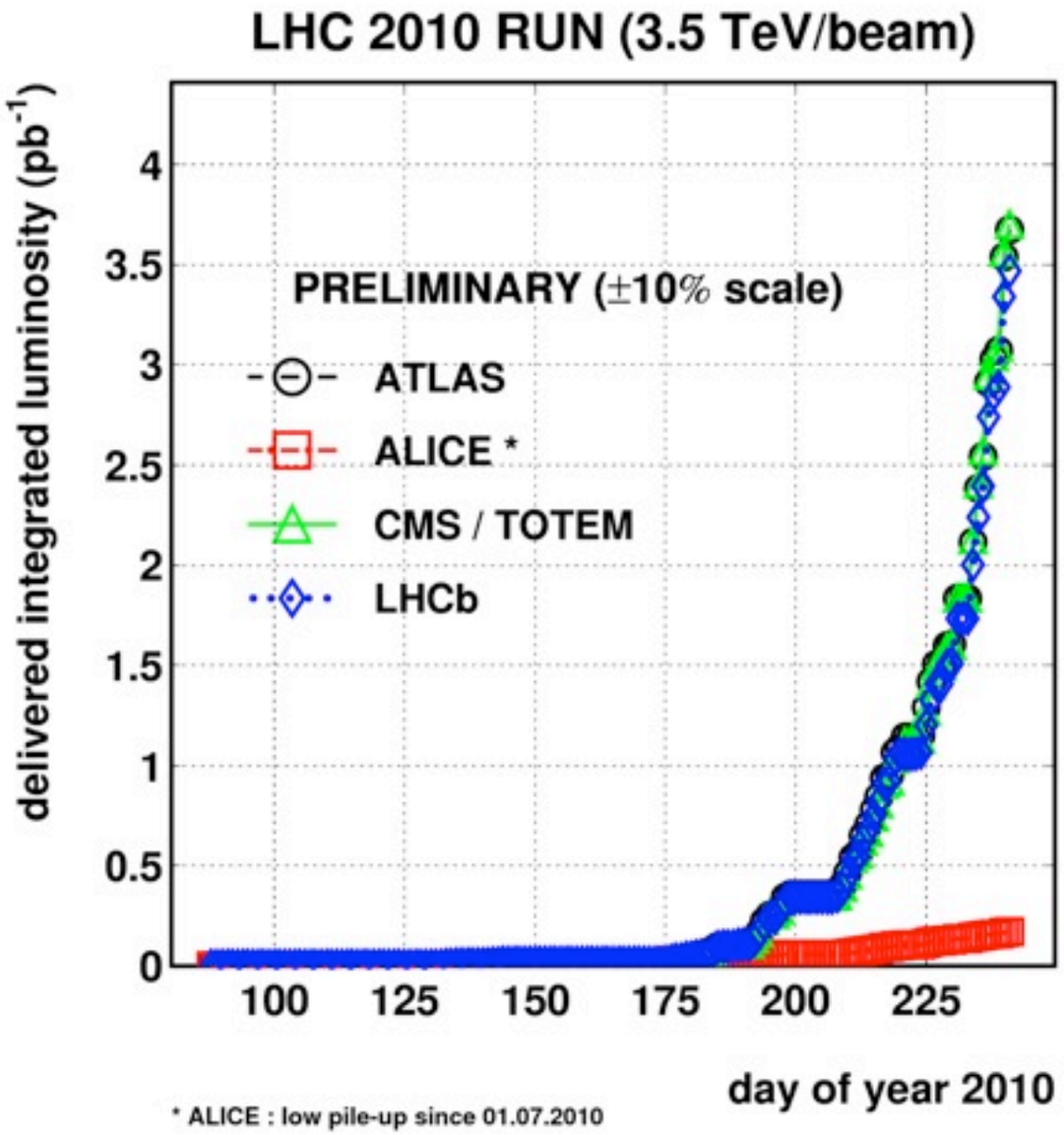


- Design specifications:
  - p-p collisions at **$\sqrt{s}$=14TeV** (x7 wrt Tevatron)
  - design luminosity **10^{34} cm^{-2}s^{-1}** (x100 wrt Tevatron)
  - bunch crossing every 25 ns (**40 MHz**)

- **Current operation:**
  - Re-started p-p collisions in November 2009: pp collisions at $\sqrt{s}$=0.9 (2.36)TeV
  - **it has been running for the past few months on "physics mode" at $\sqrt{s}$=7TeV**
    - **expect to collect hundreds (?) of pb^{-1}, before "long" shutdown for upgrades.**
    - **moderate pile-up early on.**

The Large Hadron Collider

Total collisions at 7 TeV (16/09/2010)**: ~250 billion** (per experiment)

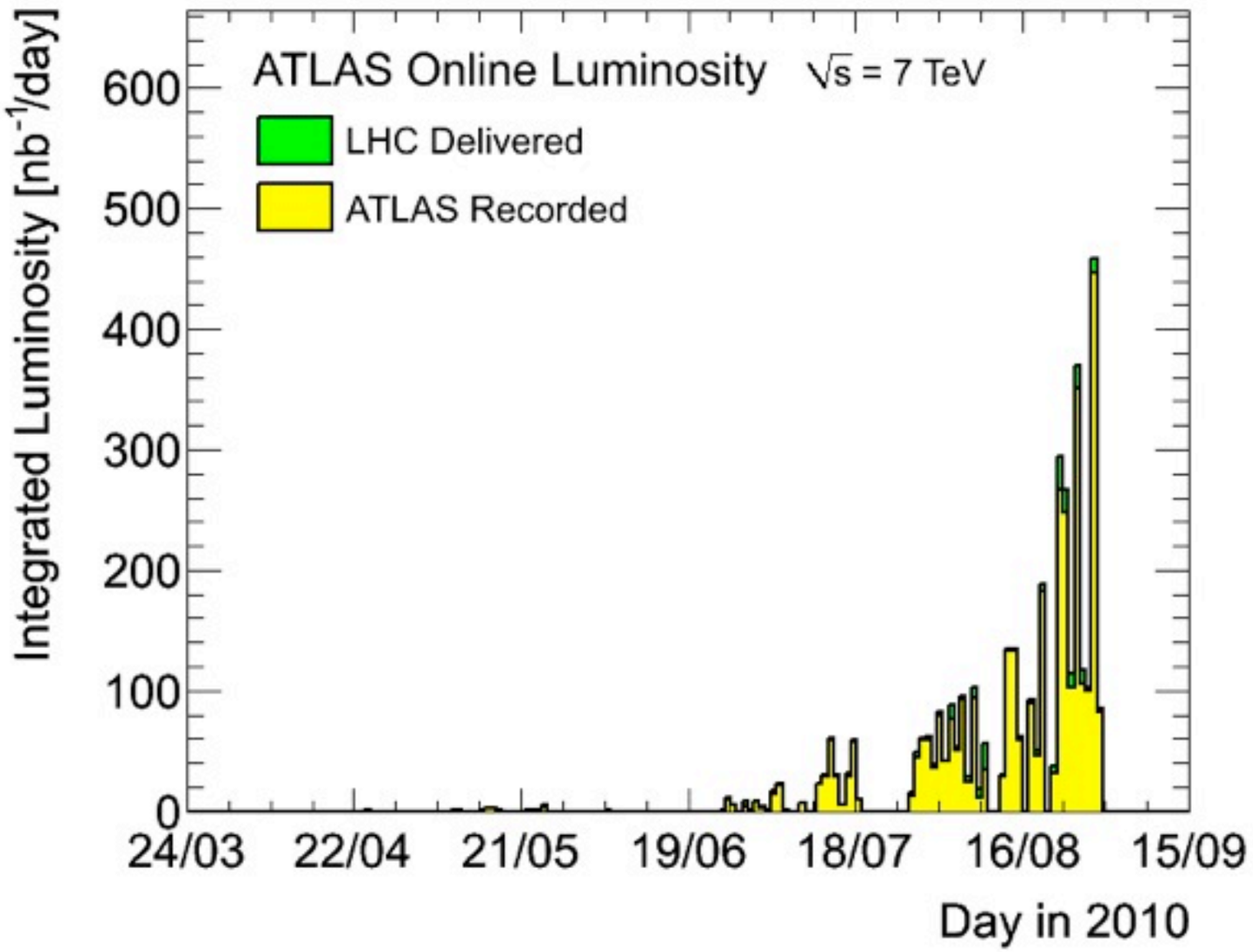


- Ramping-up the luminosity:
  - beam set-up is continuously being improved allowing steep rise in data accumulation.
- Recent configuration for collisions:
  - 36 bunches per beam;
  - $>10^{11}$ protons per bunch;
  - peak luminosity ~ 10^{31} cm^{-2} s^{-1}
- **Plans for 2010-11 run:**
  - **peak luminosity ~ 10^{32} cm^{-2} s^{-1}**
  - **up to 800 bunches per beam**
  - **record ~1fb^{-1} of integrated luminosity.**

LHC News: http://lhc.web.cern.ch/lhc/News.htm

The Large Hadron Collider

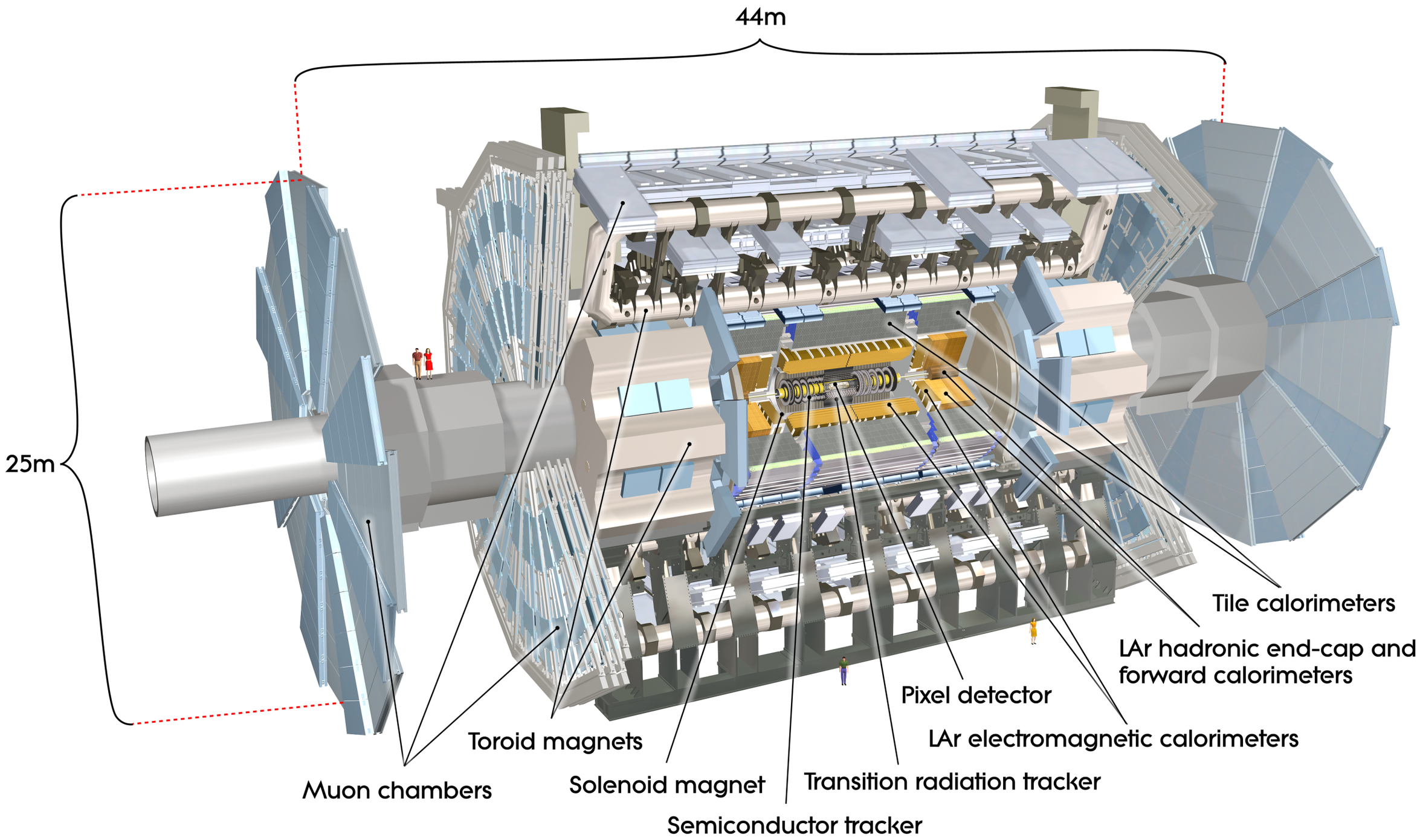
Total collisions at 7 TeV (16/09/2010)**: ~250 billion** (per experiment)



- Ramping-up the luminosity:
  - beam set-up is continuously being improved allowing steep rise in data accumulation.
- Recent configuration for collisions:
  - 36 bunches per beam;
  - $>10^{11}$ protons per bunch;
  - peak luminosity ~ 10^{31} cm^{-2} s^{-1}
- **Plans for 2010-11 run:**
  - **peak luminosity ~ 10^{32} cm^{-2} s^{-1}**
  - **up to 800 bunches per beam**
  - **record ~1fb^{-1} of integrated luminosity.**

LHC News: http://lhc.web.cern.ch/lhc/News.htm

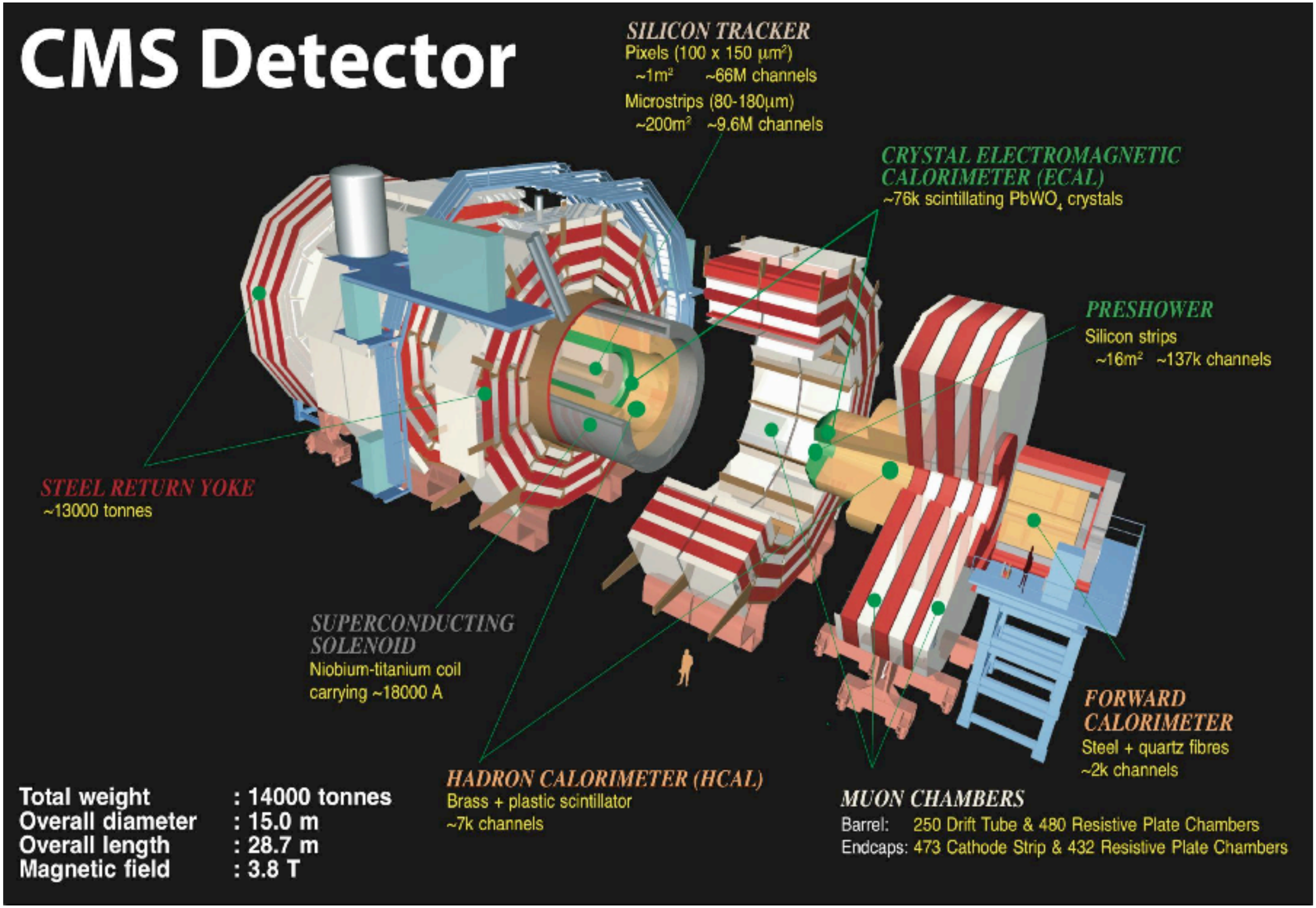
ATLAS: A Toroidal LHC ApparatuS



The ATLAS Collaboration,
G. Aad *et al.*, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003

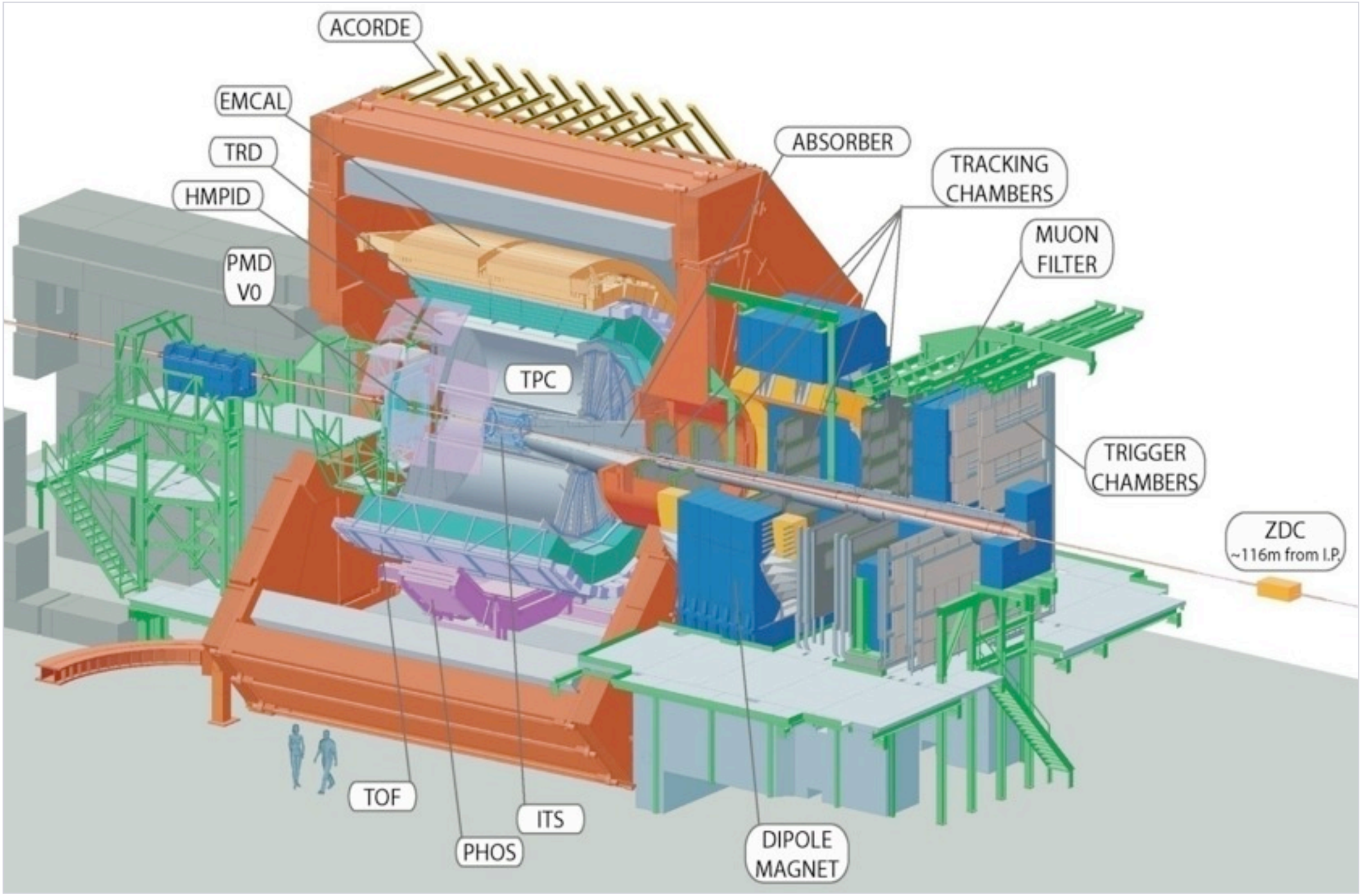
CMS: Compact Muon Solenoid

University of Glasgow

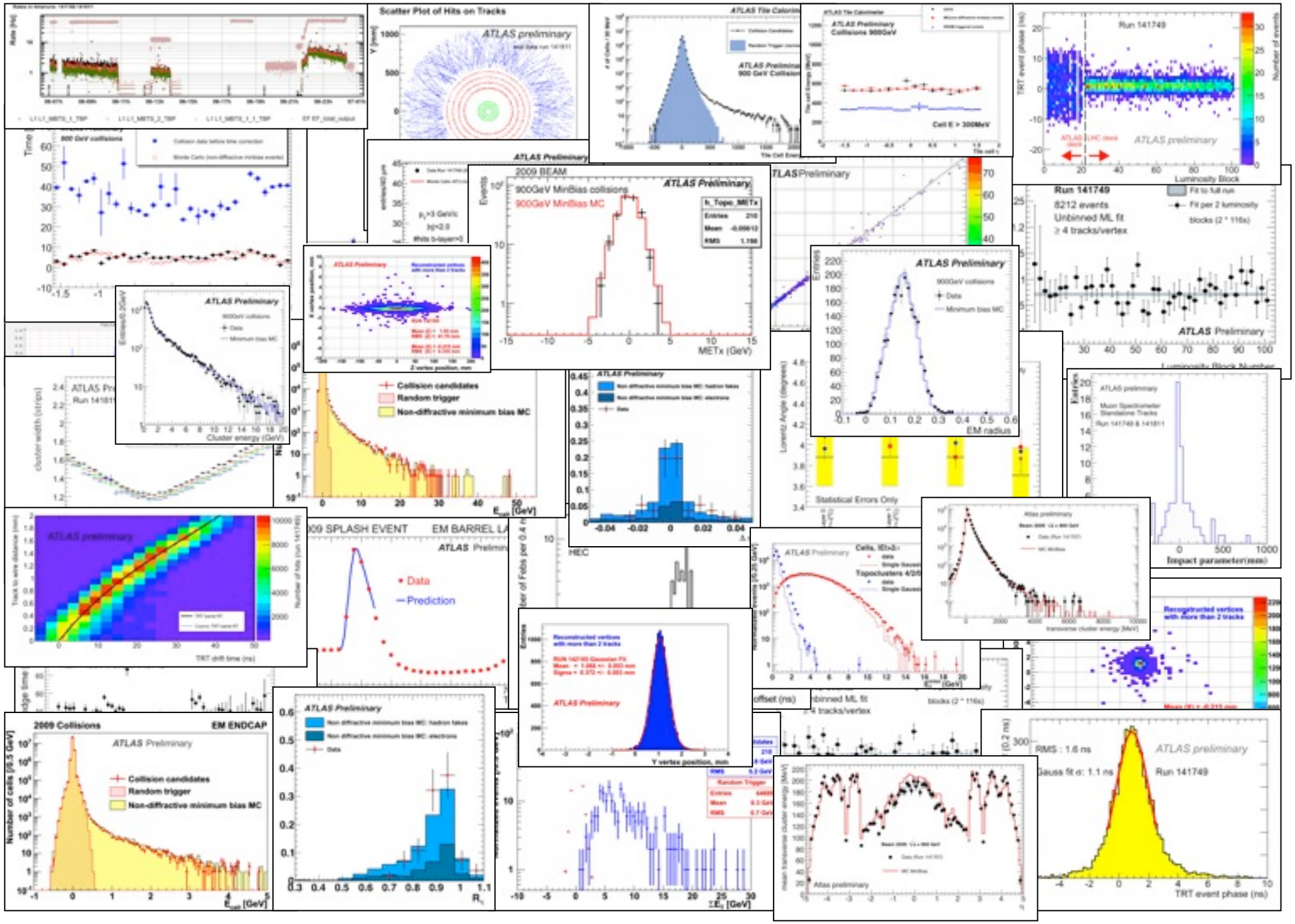


ALICE: A Large Ion Collider Experiment

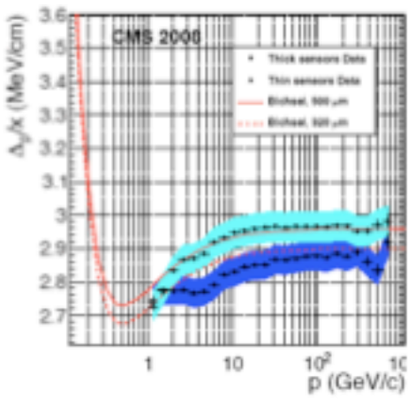
University of Glasgow

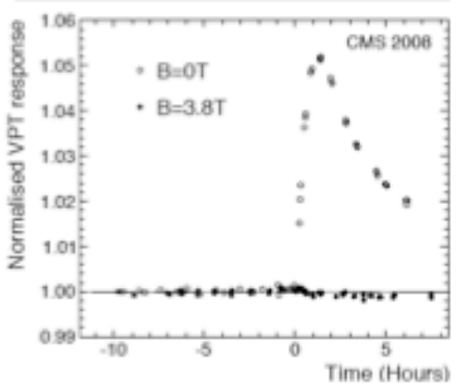


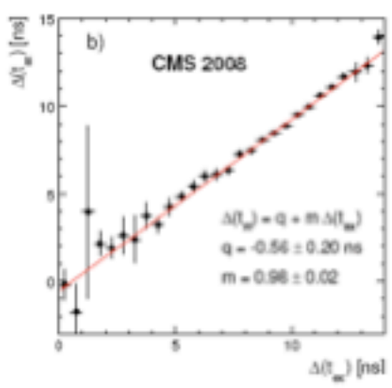
...some examples of (preliminary) detector performance results

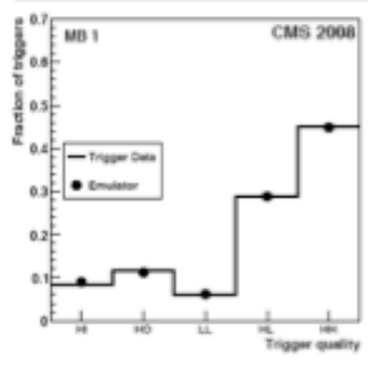


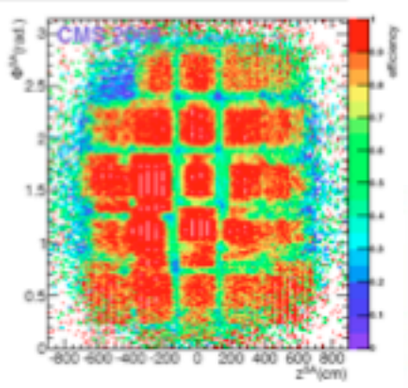
...some examples of (preliminary) detector performance results

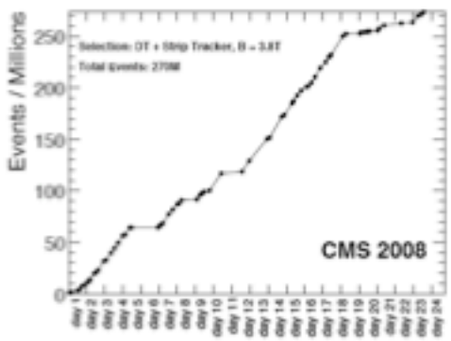


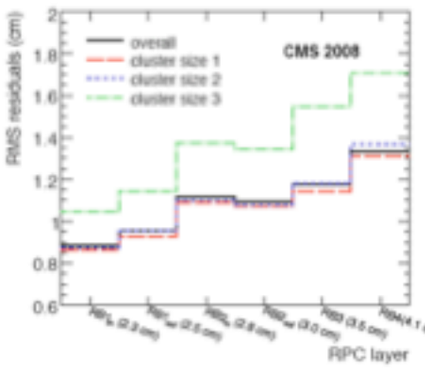


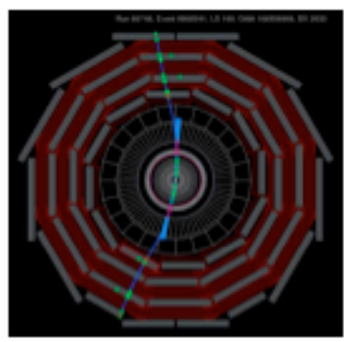


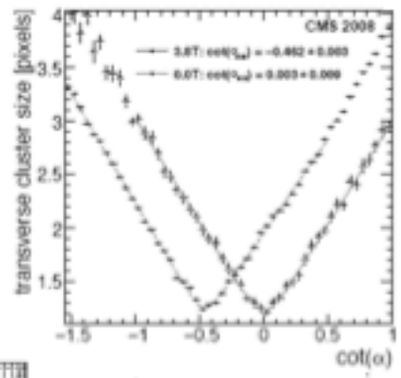


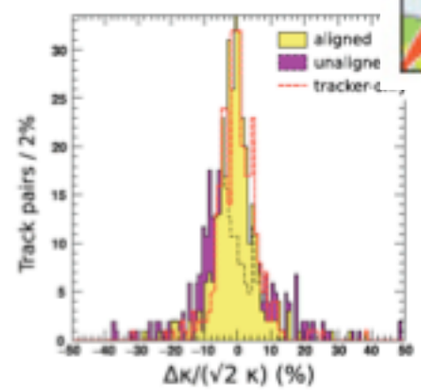


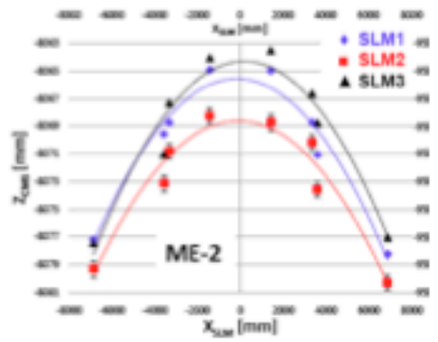


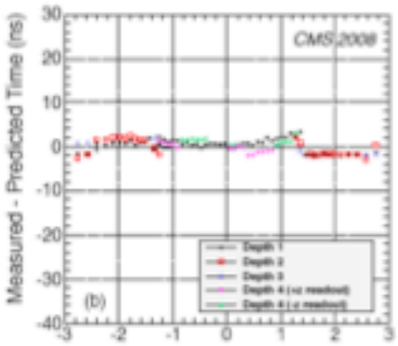


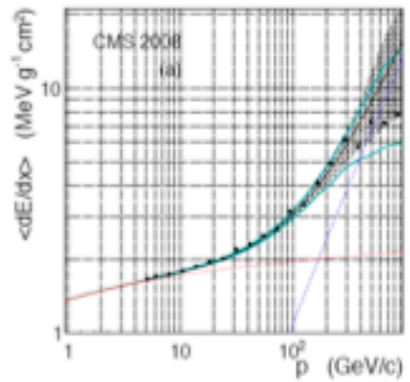


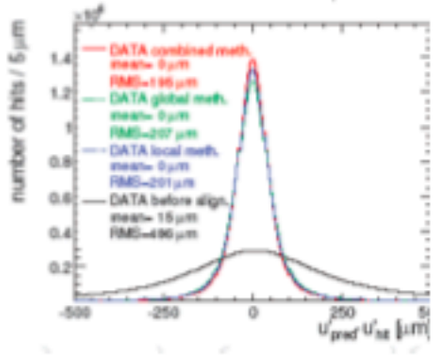


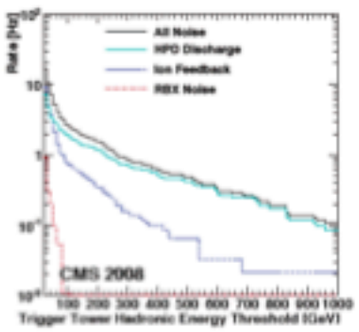


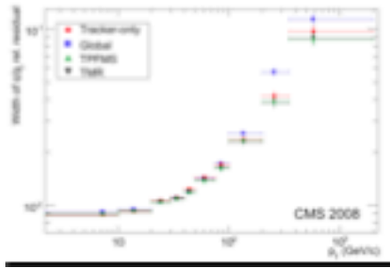


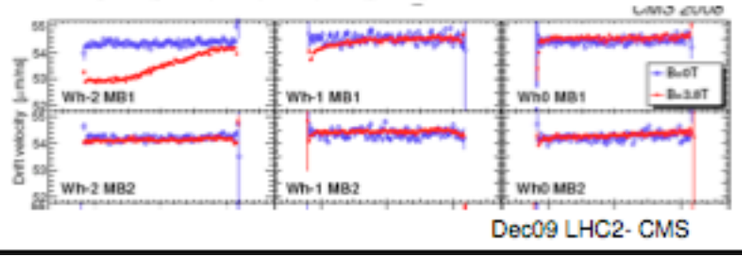


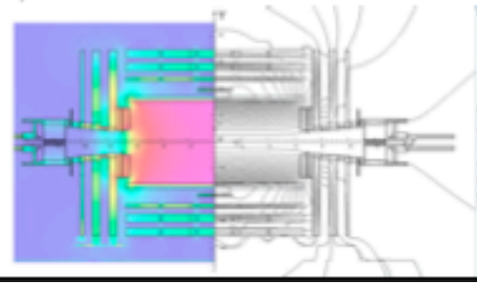


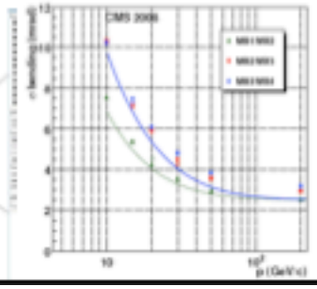












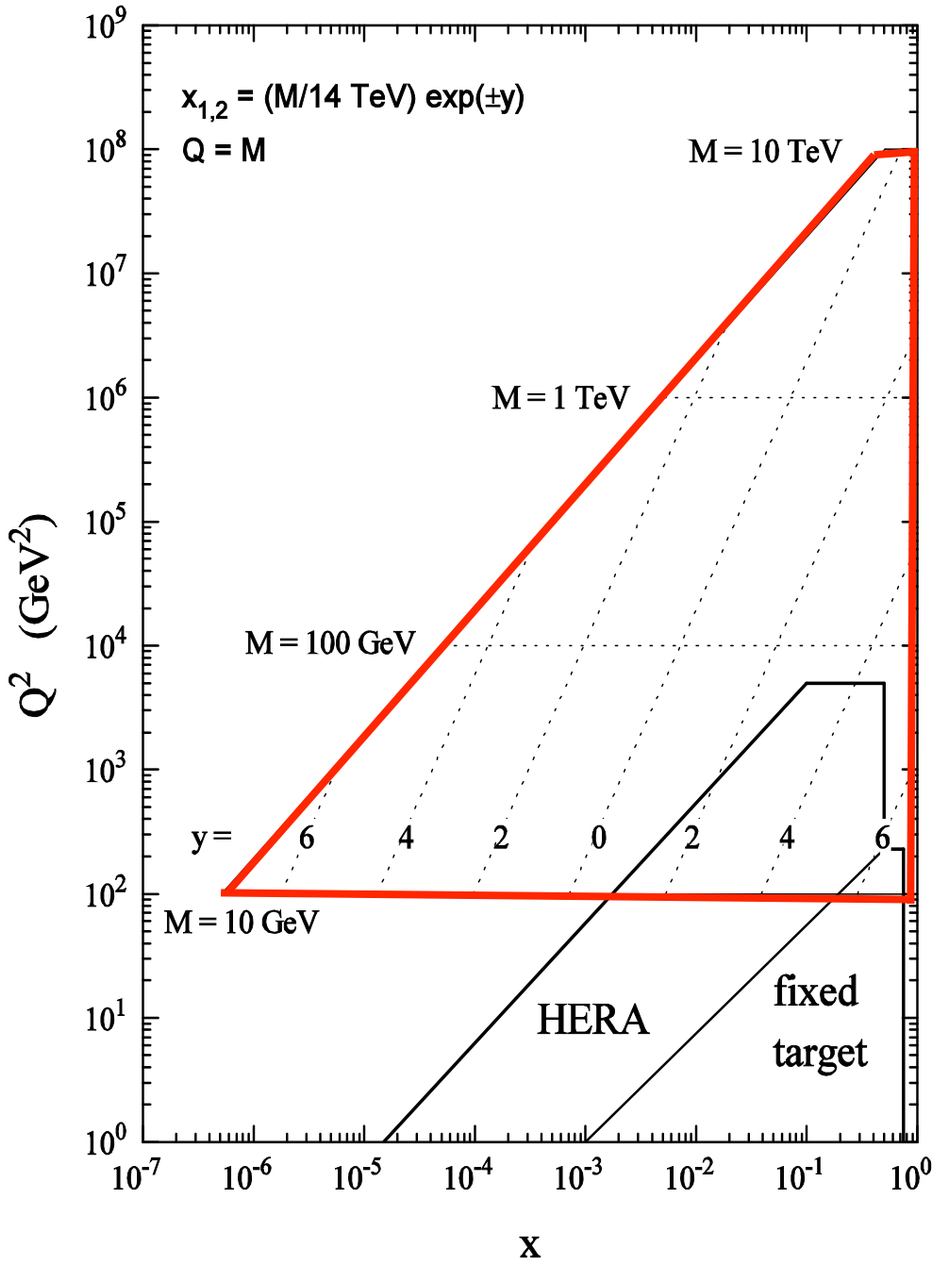
LHC Parton Kinematics

- Essentially all physics at LHC are connected to the interactions of quarks and gluons (small & large transferred momentum).

- Experience at the Tevatron is very useful, but scattering at the LHC is not necessarily just "rescaled" scattering at the Tevatron.
  - dominance of gluon on sea quark scattering;
  - large phase space for gluon emission and thus for the production of extra jets;
  - intensive QCD background!

- **This requires a solid understanding of QCD.**

- The kinematic acceptance of the LHC detectors allows a large range of **x** and **Q^2** to be probed (ATLAS & CMS coverage: $|\eta| < 5$).



LHC Parton Kinematics

- Essentially all physics at LHC are connected to the interactions of quarks and gluons (small & large transferred momentum).

- Exp… scatte… "resca…

- s…

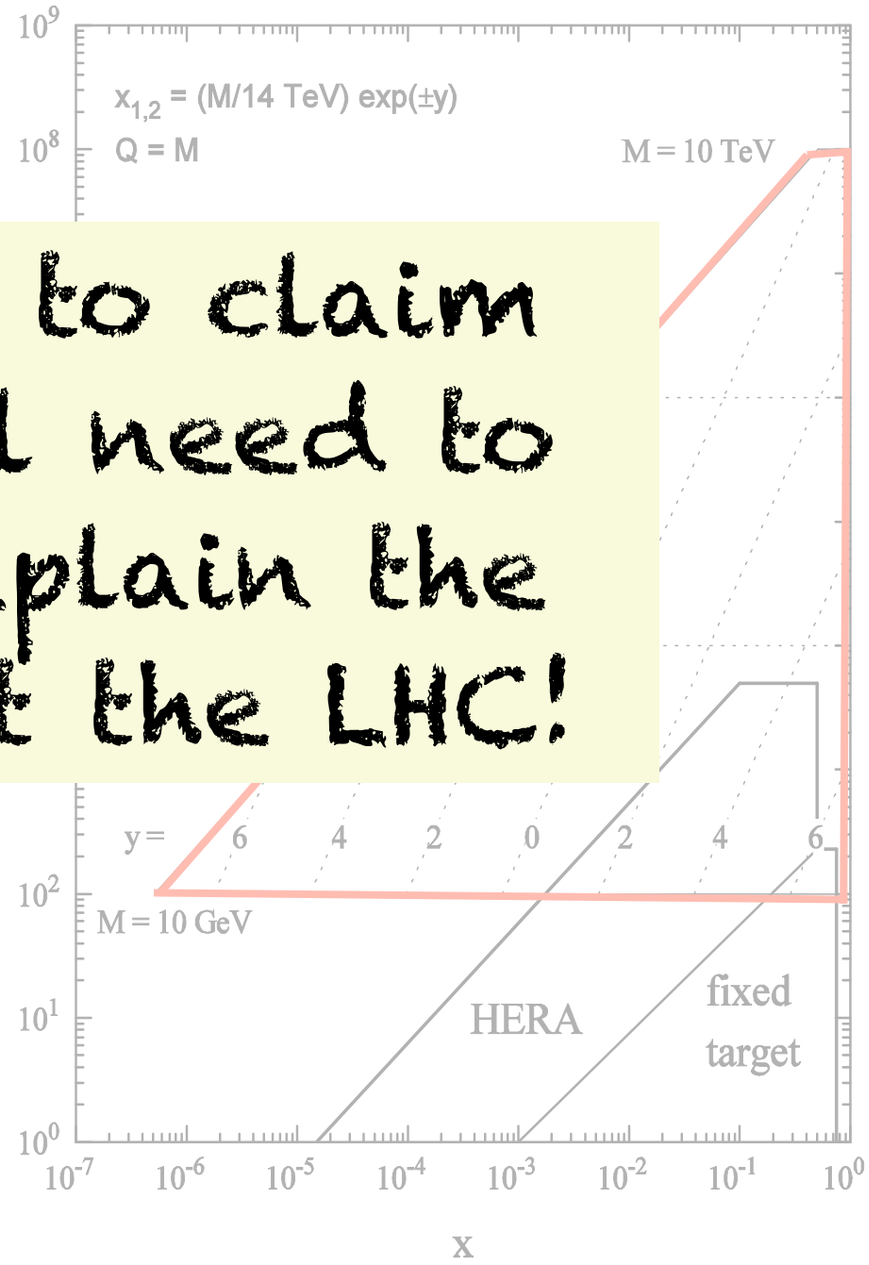
- t…

- …

Before we are able to claim discoveries, we will need to understand and explain the QCD environment at the LHC!

- **This requires a solid understanding of QCD.**

- The kinematic acceptance of the LHC detectors allows a large range of **x** and **Q^2** to be probed (ATLAS & CMS coverage: $|\eta| < 5$).



QCD results from ATLAS (public):

Soft QCD

Charged-particle Multiplicities in pp Interactions at √s=900 GeV Measured with the ATLAS Detector at LHC

Charged-particle Multiplicities in pp Interactions at √s=7 TeV Measured with the ATLAS Detector at LHC

Track-based Underlying Event Measurements in pp Collisions at √s=0.9 TeV and 7 TeV with the ATLAS Detector at LHC

Charged-particle Multiplicities in pp Interactions at √s=0.9 TeV and 7 TeV in a Diffractive-limited Phase Space Measured with the ATLAS detector at LHC and a New PYTHIA6 Tune

Charged particle multiplicities in pp interactions for track PT > 100 MeV at √s=0.9 and 7 TeV measured with the ATLAS detector at the LHC

Charged particle multiplicities in pp interactions at √s=2.36 TeV measured with the ATLAS detector at the LHC

Studies of Diffractive Enhanced Minimum Bias Events in ATLAS

NEW Track-based underlying event measurements in pp collisions at √s= 900 GeV and 7 TeV with the ATLAS Detector at the LHC

NEW Angular correlations between charged particles from proton-proton collisions at sqrt(s) = 900 GeV and sqrt(s) = 7 TeV measured with ATLAS detector

Jet Physics

Observation of Energetic Jets in pp Collisions at √s=7 TeV using the ATLAS Experiment at the LHC

Measurement of differential cross section and fragmentation of jets from tracks in proton-proton collisions at centre-of-mass energy √s=7 TeV with the ATLAS detector

Measurement of jet production in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS Detector

NEW Measurements of multijet production cross sections in proton-proton collisions at 7 TeV center-of-mass energy with the ATLAS Detector

NEW Azimuthal Decorrelations in Dijet Events at sqrt(s)=7 TeV

NEW Measurement of dijet production with a jet veto in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector

Available from: https://twiki.cern.ch/twiki/bin/view/Atlas/StandardModelPublicResults

QCD results from CMS (public):

University of Glasgow

Analysis	Approved Plots	CDS Entry	Luminosity
Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 0.9 and 2.36 TeV	TWiki QCD09010	PAPER QCD-09-010	0.001/nb
First Measurement of the Underlying Event Activity in Proton-Proton Collisions at 900 GeV at the LHC	TWiki QCD10001	PAS QCD-10-001	
Two-particle correlations and cluster properties from two-particle angular correlations in p+p collisions at sqrt(s) = 0.9, 2.36 and 7 TeV	TWiki QCD10002	PAS QCD-10-002	
Measurement of Bose–Einstein Correlations in 0.9 and 2.36 TeV proton-proton Collisions with the CMS Experiment	TWiki QCD10003	PAS QCD-10-003	
Charged particle multiplicities in pp interactions at sqrt(s) = 0.9, 2.36, and 7.0 TeV	TWiki QCD10004	PAS QCD-10-004	
Measurement of the Underlying Event Activity with the Jet Area/Median Approach at 0.9 TeV	TWiki QCD10005	PAS QCD-10-005	
Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 7 TeV	TWiki QCD10006	PAPER QCD-10-006	0.001/nb
Strange Particle Production in pp collisions at sqrt(s) = 0.9 and 7 TeV	TWiki QCD10007	PAS QCD-10-007	
Measurement of the Underlying Event Activity at the LHC	TWiki QCD10010	PAS QCD-10-010	
Measurement of the Inclusive Jet pT spectra in pp Collisions at 7 TeV	TWiki QCD10011	PAS QCD-10-011	60/nb
Measurement of the 3-jet to 2-jet Cross Section Ratio in pp Collisions at 7 TeV	TWiki QCD10012	PAS QCD-10-012	76/nb
Hadronic Event Shapes in pp Collisions at 7 TeV	TWiki QCD10013	PAS QCD-10-013	78/nb

Available from: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsQCD

QCD results from ALICE (public):

University of Glasgow

Latest General ALICE Publications

- Alignment of the ALICE Inner Tracking System with cosmic-ray tracks . March 6, 2010
- pseudorapidity density at sqrt(s) = 900 GeV (EPJC). December 3, 2009
- ALICE@LHC . August 14, 2008
- PPR Vol II. September 13, 2006
- PPR Vol I. October 20, 2004

All General ALICE Publications

Alignment of the ALICE Inner Tracking System with cosmic-ray tracks

(March 6, 2010) ALICE collaboration 2010 JINST 5 P03003 Received 22 december 2009 , accepted for publication 8 february 2010 Published 3 march 2010 http://iopscience.iop.org/1748-0221/5/03/P03003
Read more

ALICE (A Large Ion Collider Experiment) is the LHC (Large Hadron Collider) experiment devoted to investigating the strongly interacting matter created in nucleus-nucleus collisions at the LHC energies. The ALICE ITS, Inner Tracking System, consists of six cylindrical layers of silicon detectors with three different technologies; in the outward direction: two layers of pixel detectors, two layers each of drift, and strip detectors. The number of parameters to be determined in the spatial alignment of the 2198 sensor modules of the ITS is about 13,000. The target alignment precision is well below 10 μm in some cases (pixels). The sources of alignment information include survey measurements, and the reconstructed tracks from cosmic rays and from proton-proton collisions. The main track-based alignment method uses the Millepede global approach. An iterative local method was developed and used as well. We present the results obtained for the ITS alignment using about 10^5 charged tracks from cosmic rays that have been collected during summer 2008, with the ALICE solenoidal magnet

Title: *"Evaluation of the SPD efficiency with first data"*
Author List: V. Altini, G.E. Bruno, D. Elia, R. Ferretti, V. Manzari and A. Mastroserio
Journal: ALICE Internal Note
Details Download

Title: *"The Shuttle: The ALICE Framework for the Extraction of the Conditions Data"*
Author List: Chiara Zampolli, Federico Carminati, Alberto Colla
Journal: Proceedings Of Science
Details Download

Title: *"The ALICE TPC: Status and Perspectives (Proceedings of 26th Winter Workshop on Nuclear Dynamics 2010, Ochos Rios, Jamaica)"*
Author List: H.R. Schmidt, GSI Darmstadt
Journal: Journal of Physics Conference Series (JPCS)
Details Download

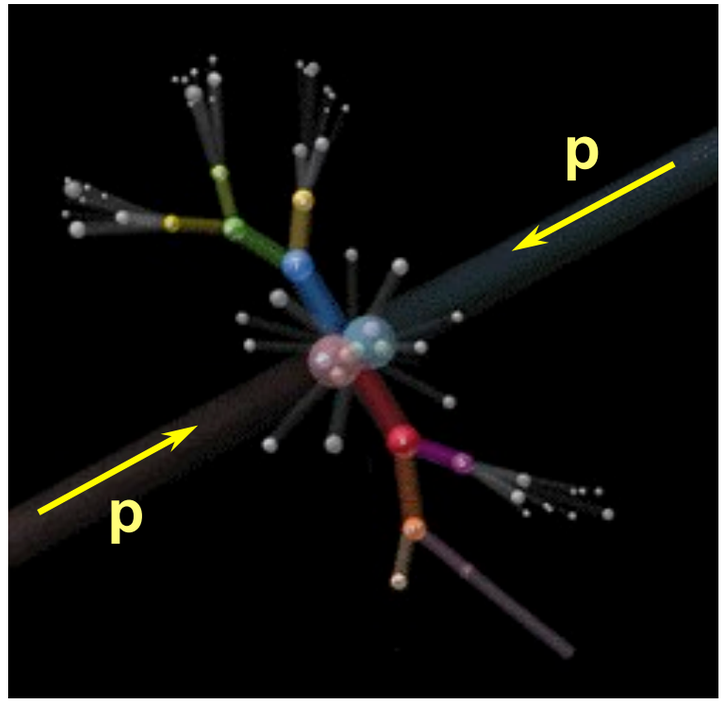
Title: *"The commissioning of the ALICE time-of-flight detector and results from the 2008 cosmic-ray data taking "*
Author List: ALICE-TOF
Journal: NIM
Details Download

Title: *"Alignment of the ALICE Inner Tracking System with cosmic-ray tracks"*
Author List: ALICE collaboration
Journal: JINST 5 P03003
Details Download

Available from:
http://aliceinfo.cern.ch/Collaboration/Documents/editorialNews.html
http://aliceinfo.cern.ch/Collaboration/Documents/Publications/index.html

Hadron-hadron collisions

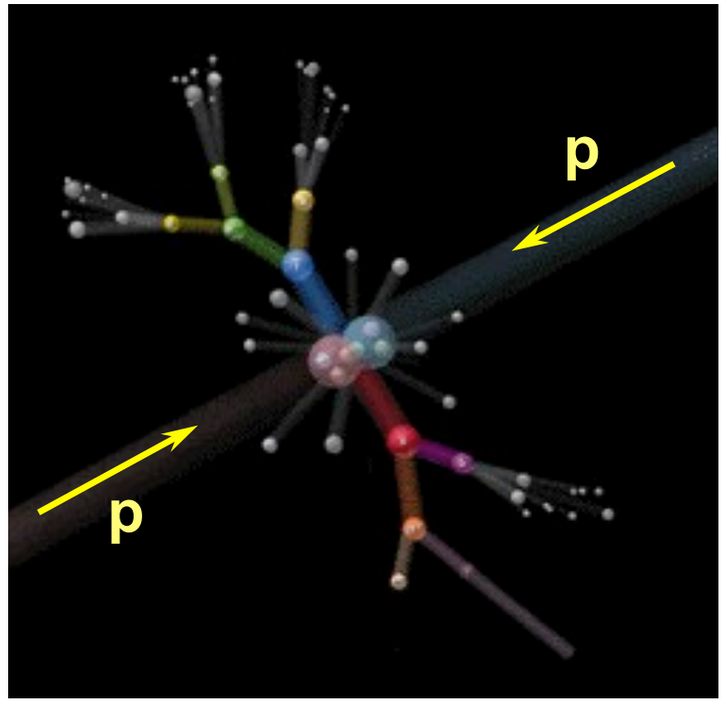
- Essentially all physics at high-energy hadron colliders are connected to the interactions of quarks and gluons (small & large transferred momentum).
  - Hard processes (high-p_T): well described by perturbative QCD
  - Soft interactions (low-p_T): require non-perturbative phenomenological models

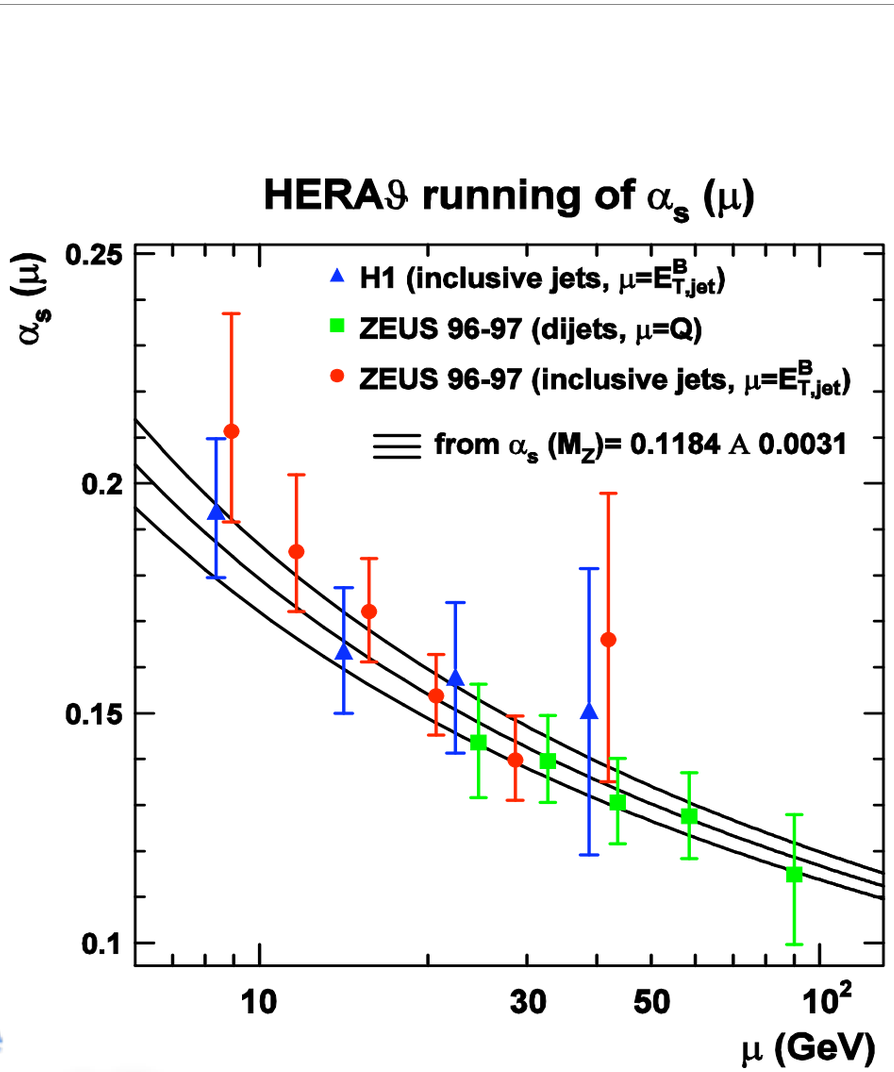


Hadron-hadron collisions

University of Glasgow

- Essentially all physics at high-energy hadron colliders are connected to the interactions of quarks and gluons (small & large transferred momentum).
  - Hard processes (high-p_T): well described by perturbative QCD
  - Soft interactions (low-p_T): require non-perturbative phenomenological models





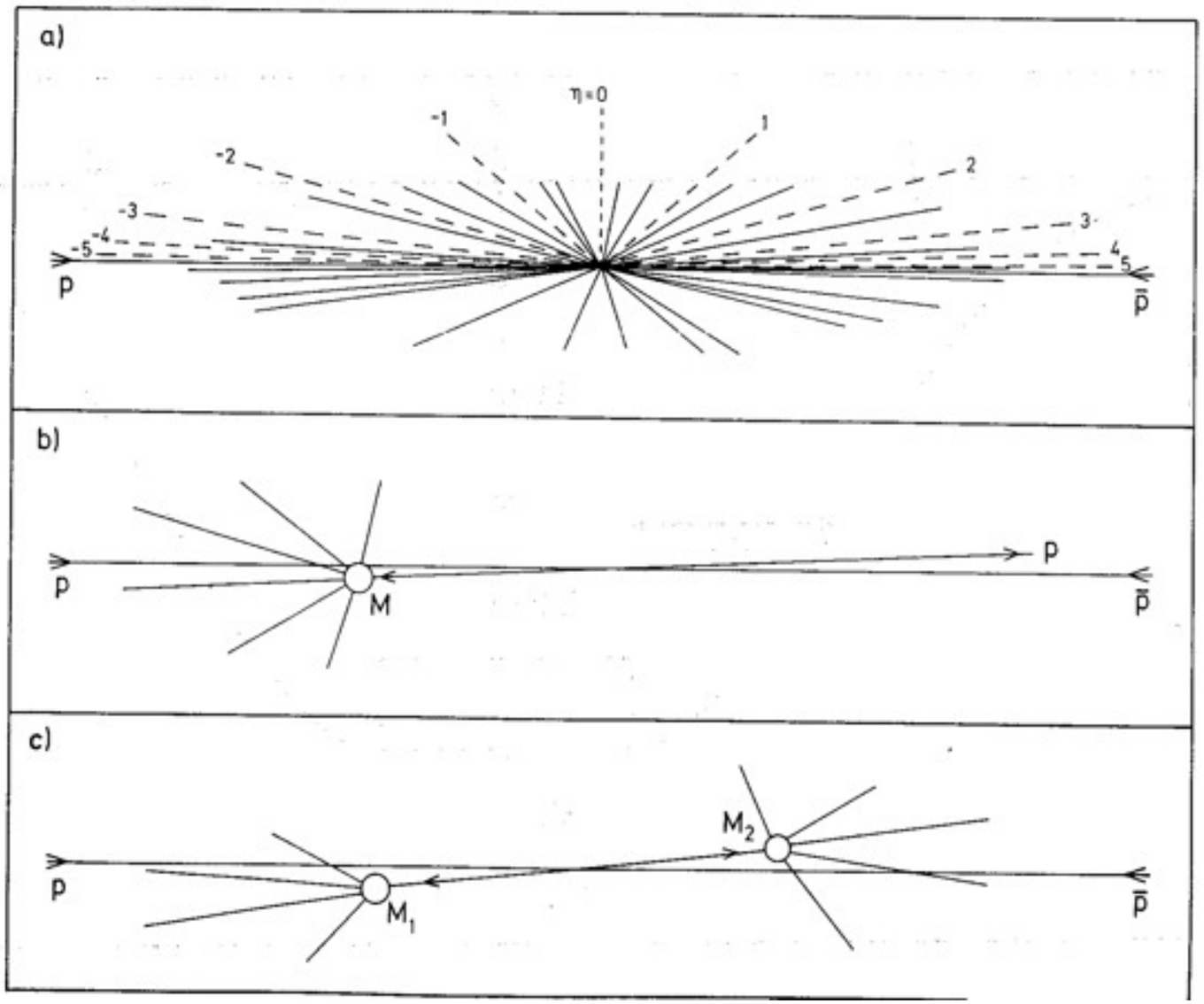
Soft Interactions: Problems with strong coupling constant, $\alpha_s(Q^2)$, saturation effects,...

- **Inelastic hadronic events** are dominated by **"soft"** partonic interactions.

On average, inelastic hadron-hadron collisions have low transverse energy, low multiplicity.

Measuring "minimum bias" events

- Selecting high-energy hadron collisions (strategy developed by UA5)



Non-diffractive inelastic

Single diffractive

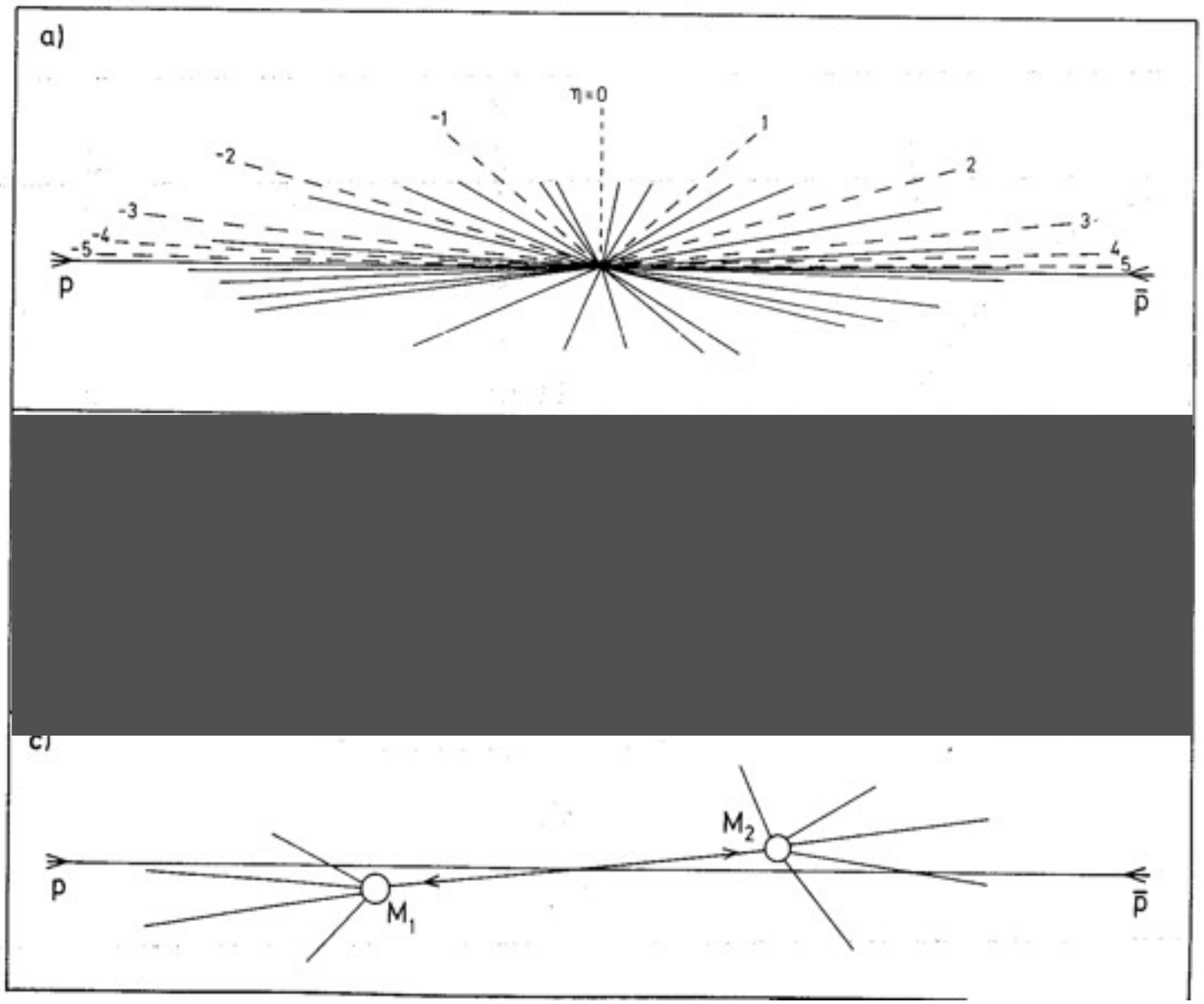
Double diffractive

Phys. Rep. **154**, 247(1987)

Z. Phys. C **43**, 357(1989)

Measuring "minimum bias" events

- Selecting high-energy hadron collisions (strategy developed by UA5)



Non-diffractive inelastic

~~Single diffractive~~

Double diffractive

Minimum bias

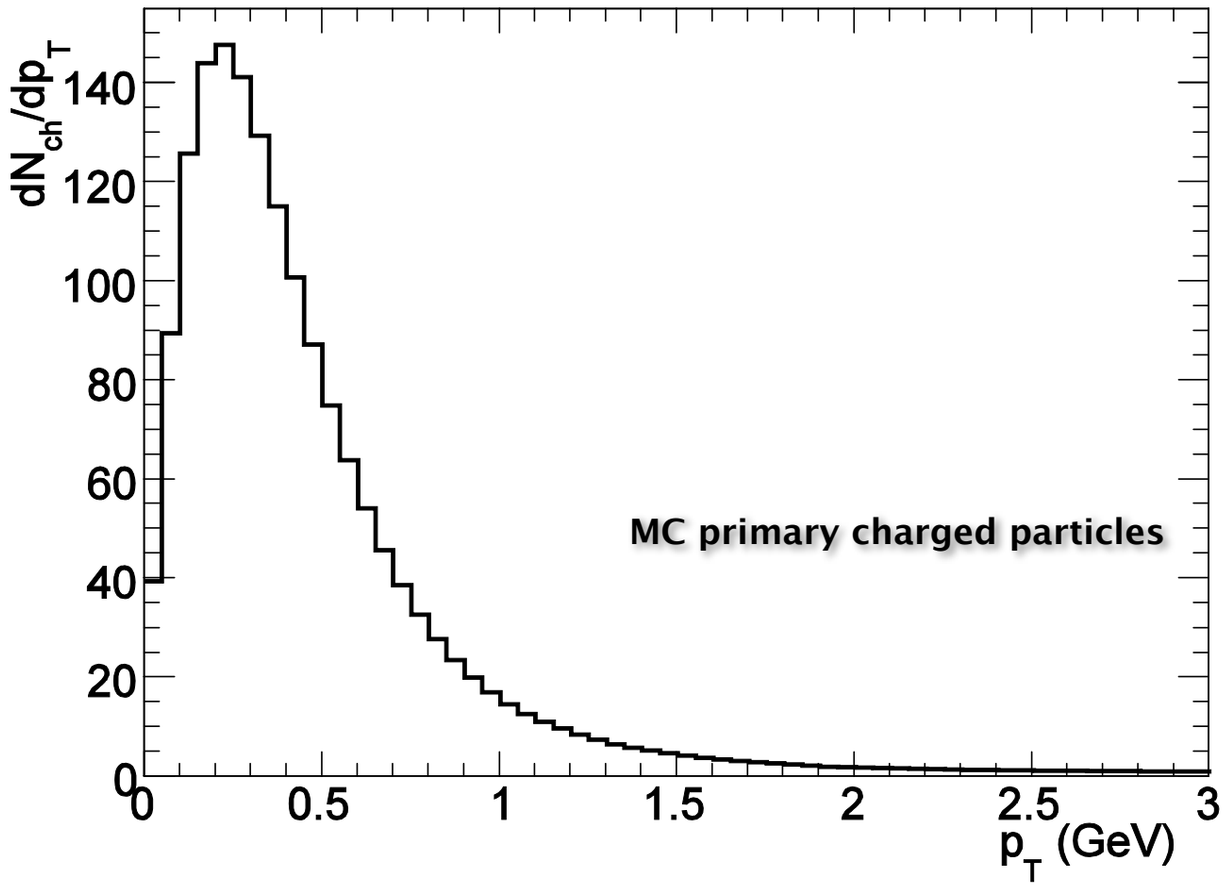
Phys. Rep. **154**, 247(1987)

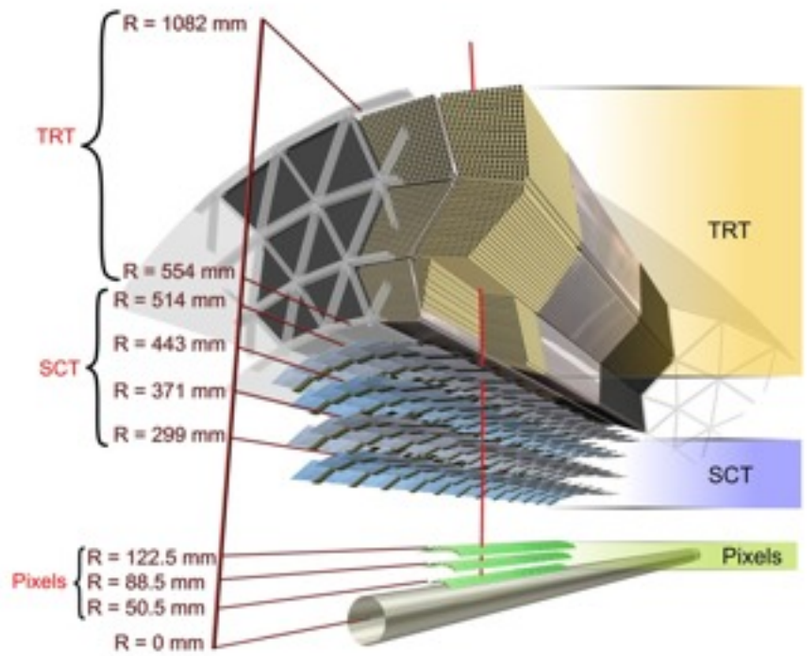
Z. Phys. C **43**, 357(1989)

Reconstructing minimum bias events

University of Glasgow

- The goal is to reconstruct the event and recover all charged particles;
  - main limitation: soft track reconstruction!
  - "typical" reconstruction: low p_T cut set to 500MeV;



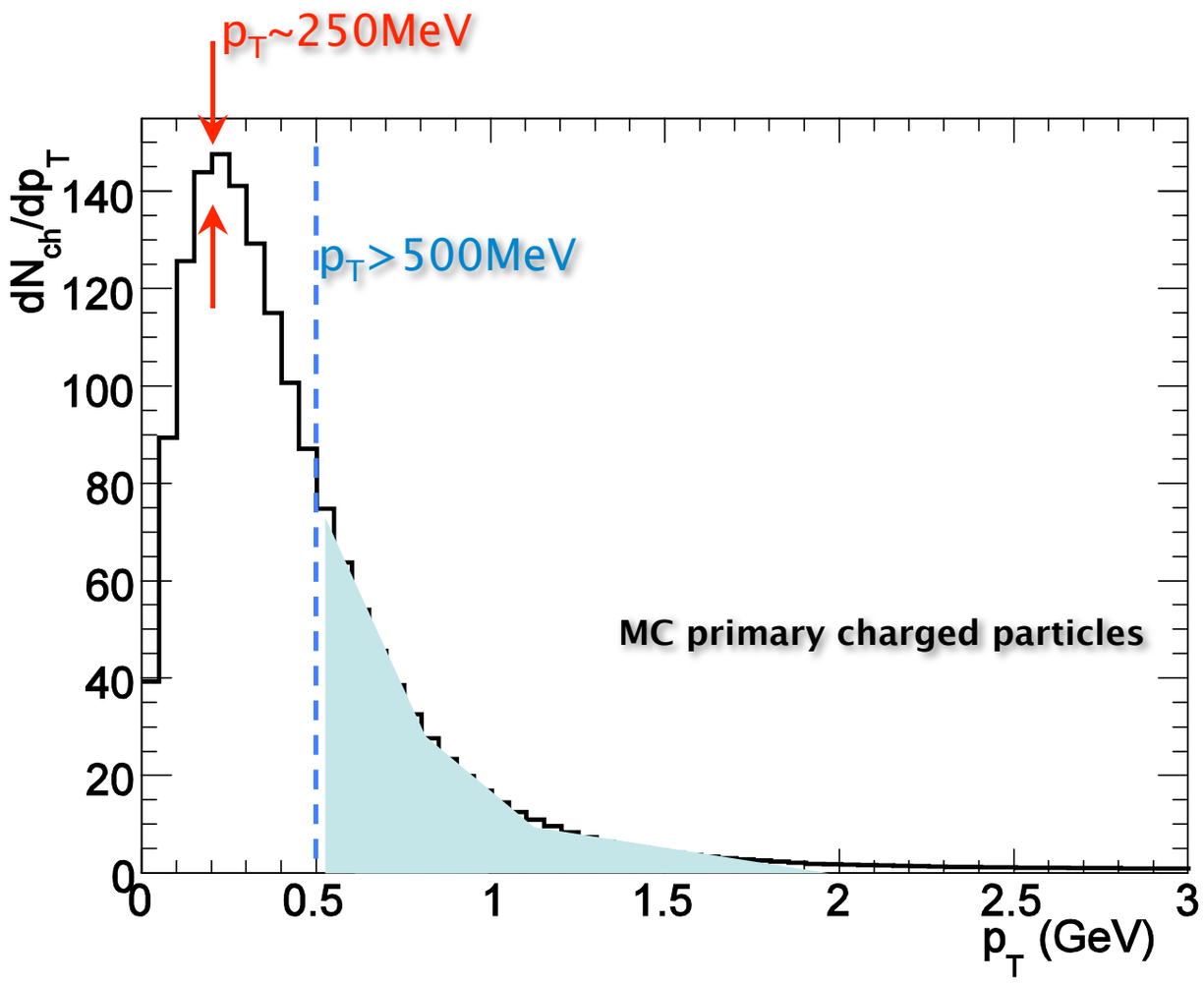


(schematic view of the ATLAS ID)

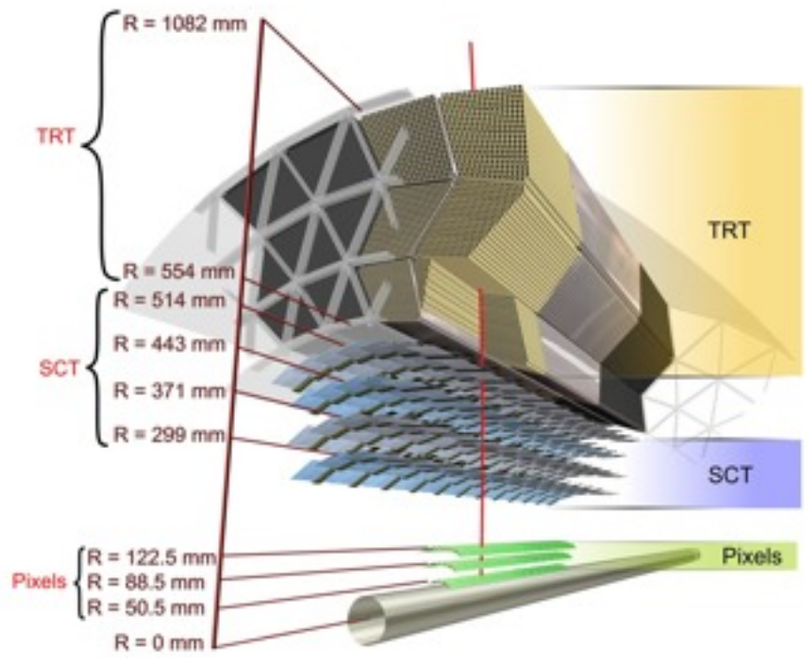
Reconstructing minimum bias events

University of Glasgow

- The goal is to reconstruct the event and recover all charged particles;
  - main limitation: soft track reconstruction!
  - "typical" reconstruction: low p_T cut set to 500MeV;

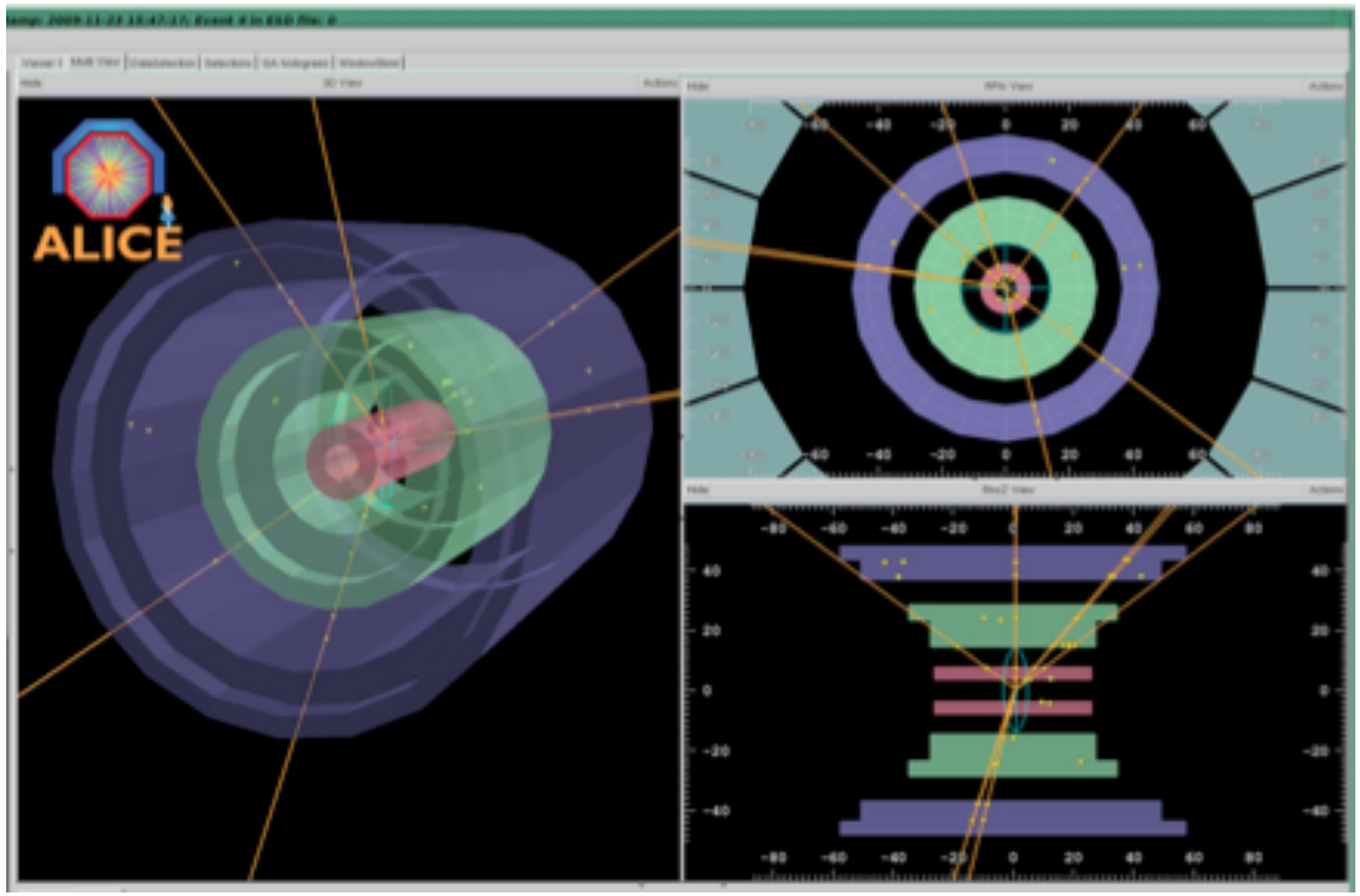


- Several strategies already available to push this limit to p_T ~ 100 MeV;
- Avoid large extrapolation factors for measurements such as $dN_{ch}/d\eta$.



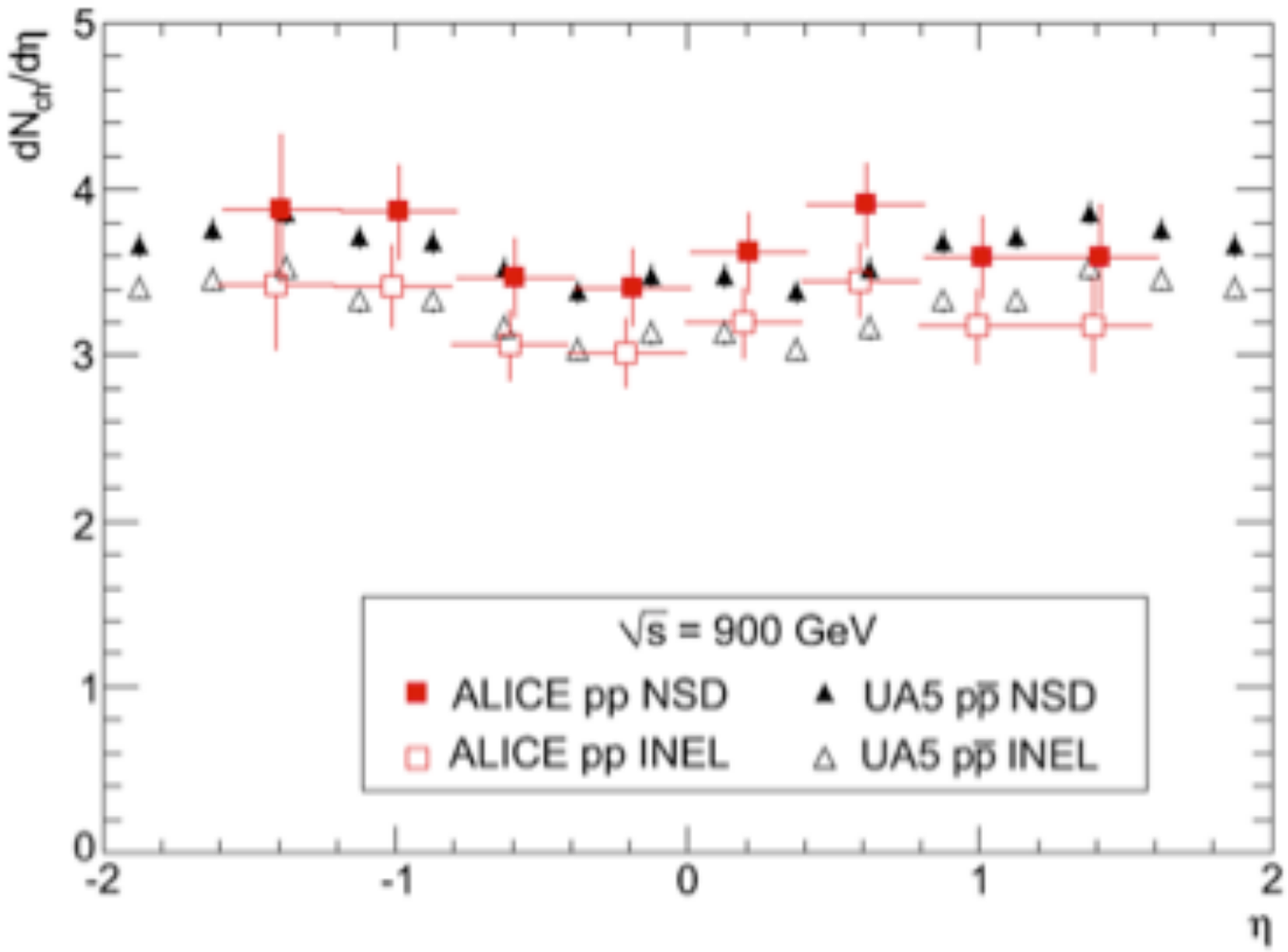
(schematic view of the ATLAS ID)

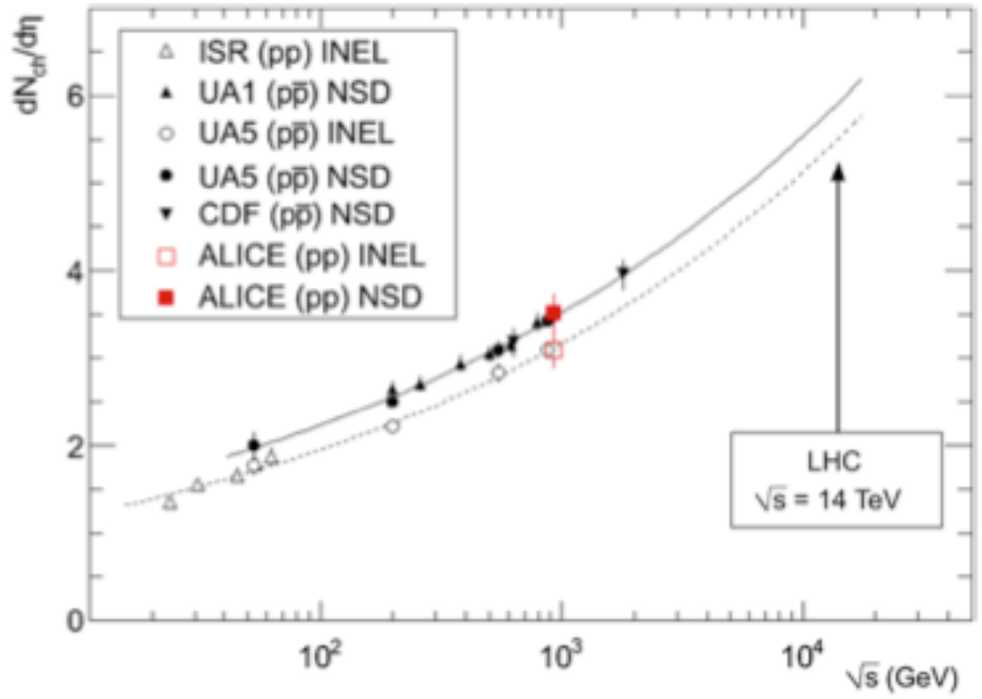
Measuring "minimum bias" events at the LHC



- pp collision at **√s=900GeV**
- First physics publication with LHC data: Eur. Phys. J. C **65** (2010) 111–125
  - 284 collision events!
  - Very early study...relied quite heavily on MC corrections (cross-section, systematic estimates, etc.)

ALICE - Minimum Bias measurements

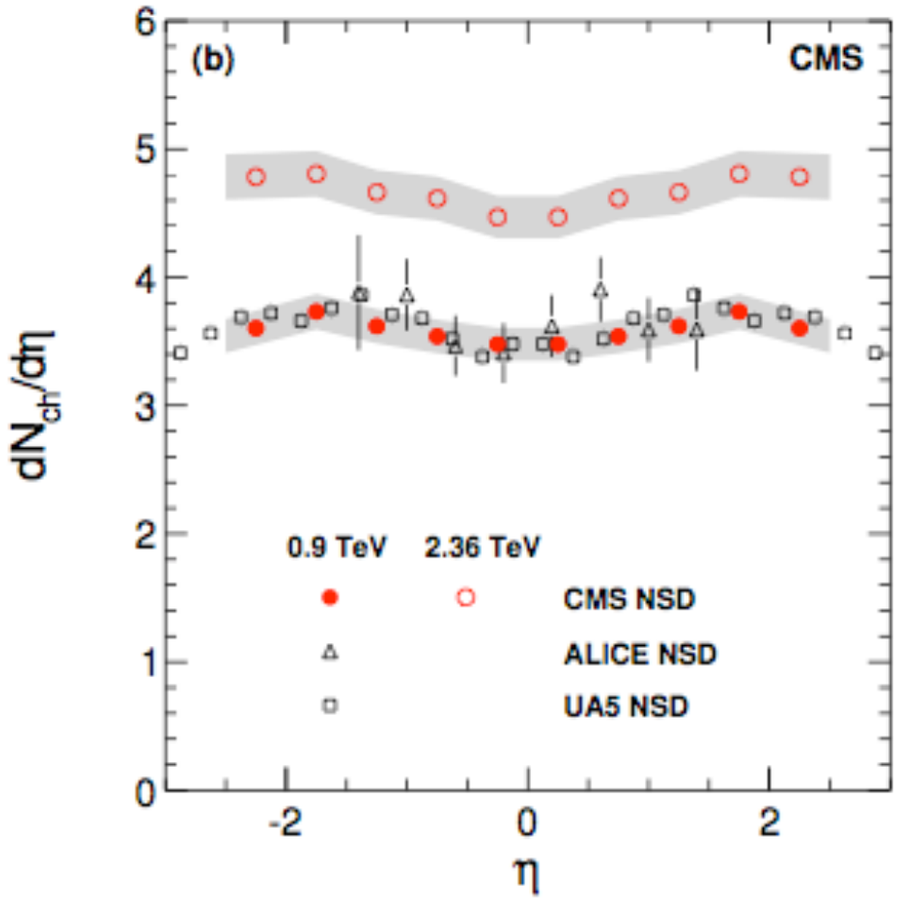


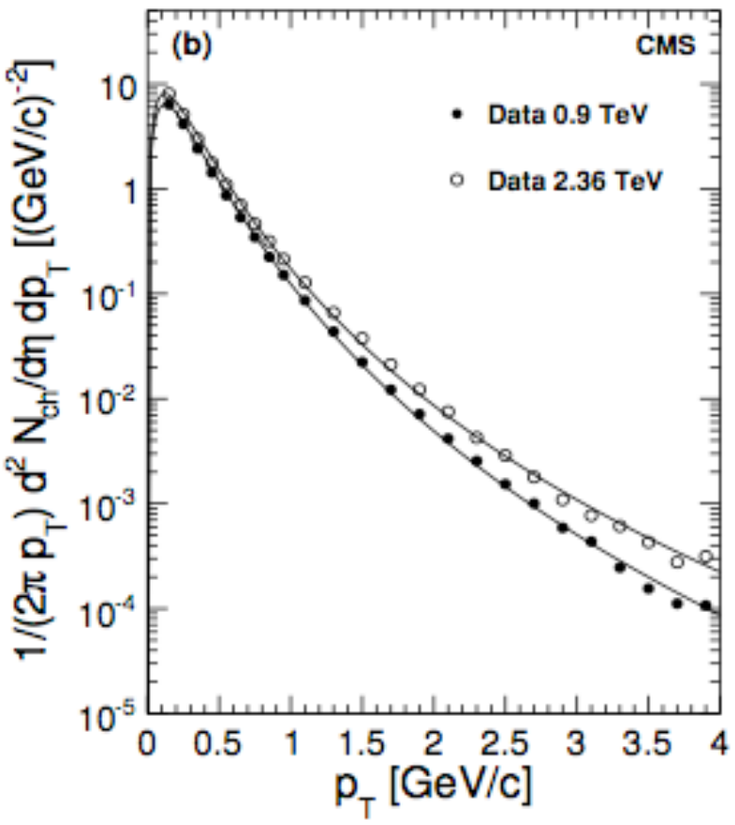


Uncertainty	
Tracklet selection cuts	negl.
Material budget	negl.
Misalignment	0.5%
Particle composition	negl.
Transverse-momentum spectrum	0.5%
Contribution of diffraction (INEL)	4%
Contribution of diffraction (NSD)	4.5%
Event-generator dependence (INEL)	4%
Event-generator dependence (NSD)	3%
Detector efficiency	4%
SPD triggering efficiency	2%
Background events	negl.
Total (INEL)	7.2%
Total (NSD)	7.1%

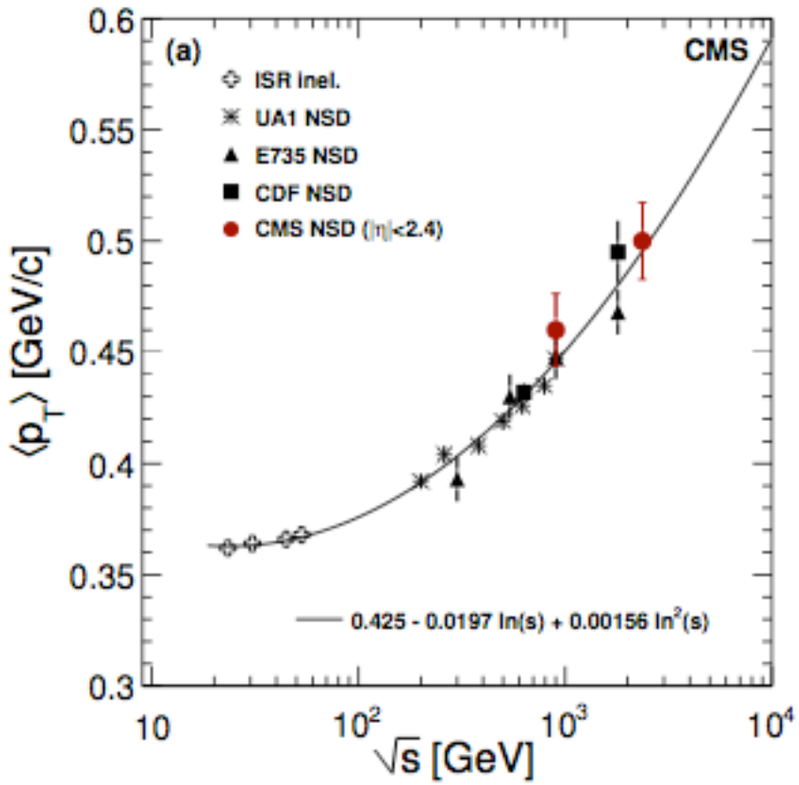
- Eur. Phys. J. C **65** (2010) 111–125

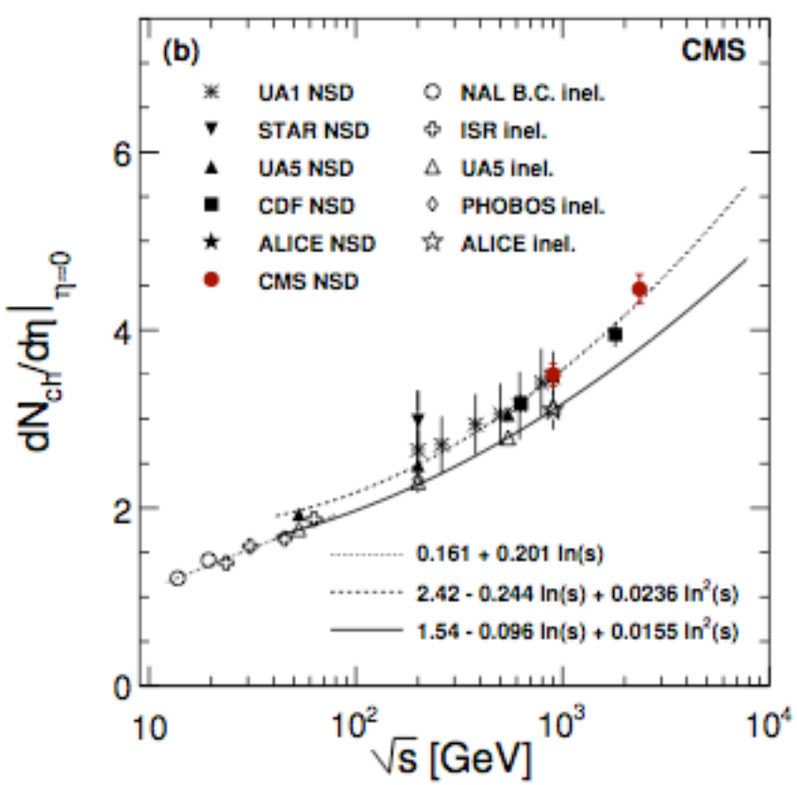
CMS - Minimum Bias measurements





- Results directly comparable to ALICE and previous experiments.
- At the time of publication, it was the highest energy measurement
- JHEP **02** (2010) 041





ATLAS – Minimum Bias measurements

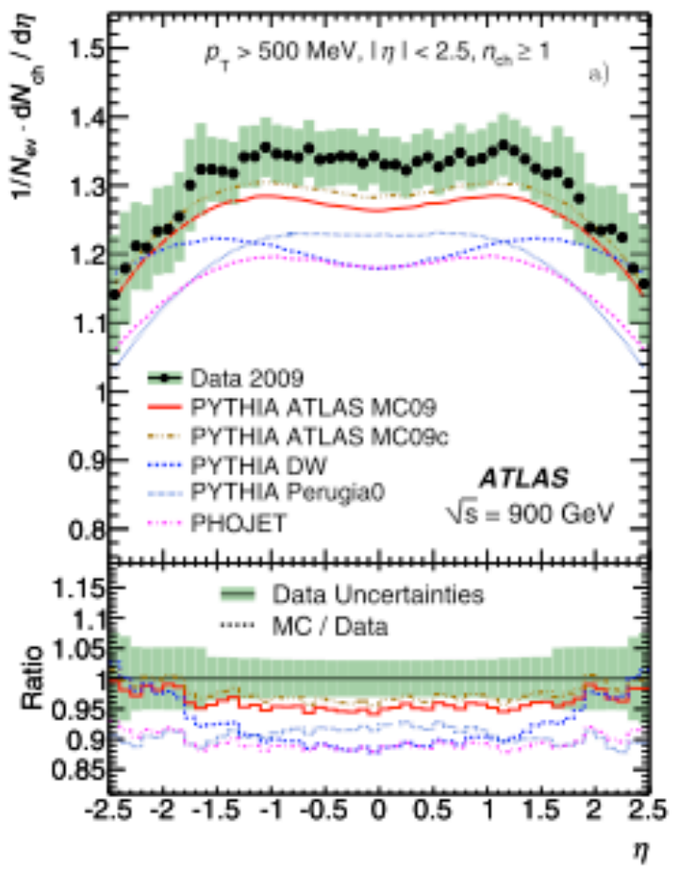
University of Glasgow

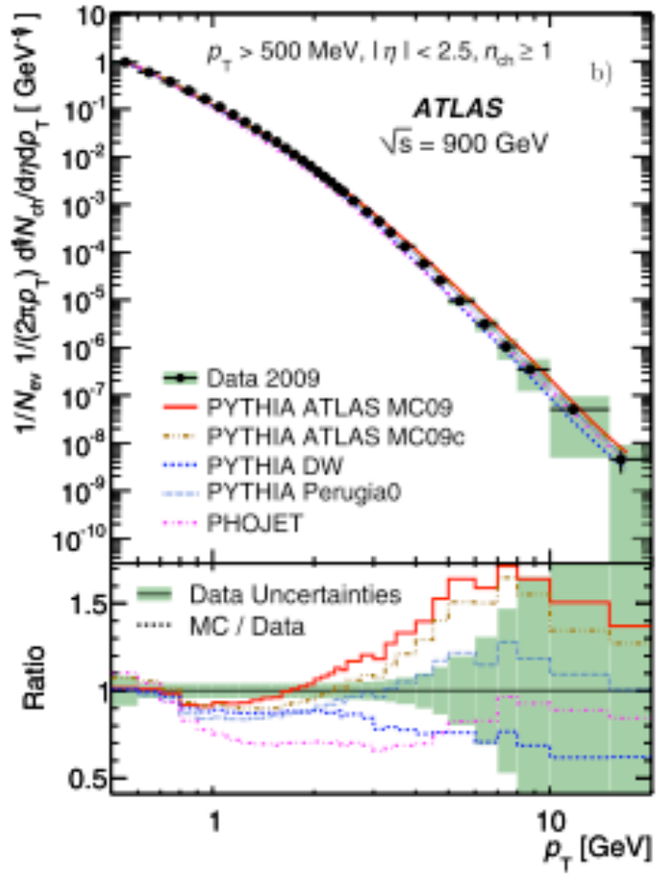
- ATLAS presented measurements for an inclusive inelastic sample (avoiding model-dependent corrections).
  - Require ≥ 1 MBTS counter to fire on either side
  - At least one primary vertex reconstructed
  - No additional primary vertices
  - Require ≥ 1 track (p_T>500MeV, |η|<2.5)

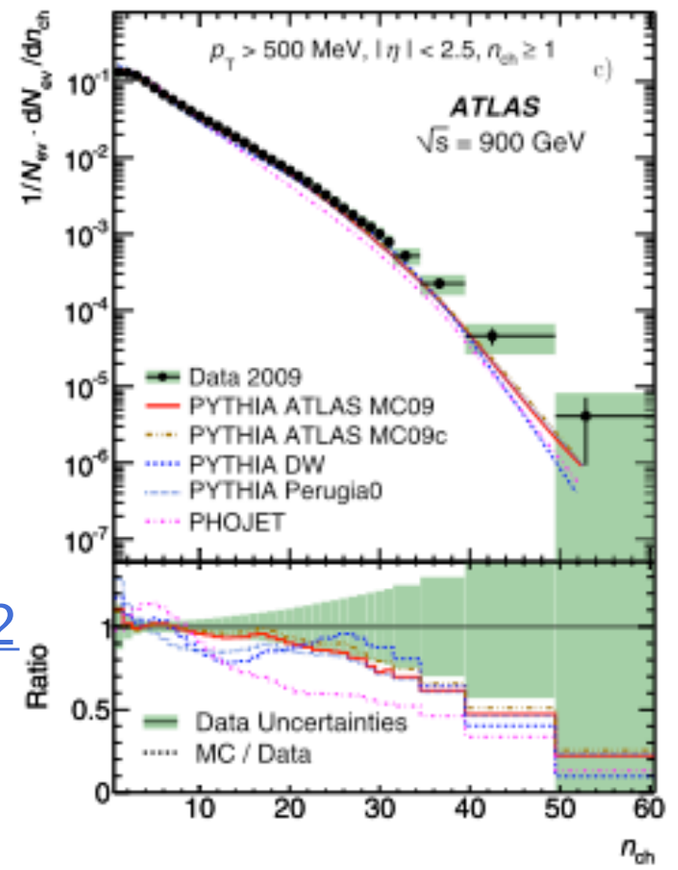
- Results are NOT directly comparable to ALICE, CMS and previous experiments.

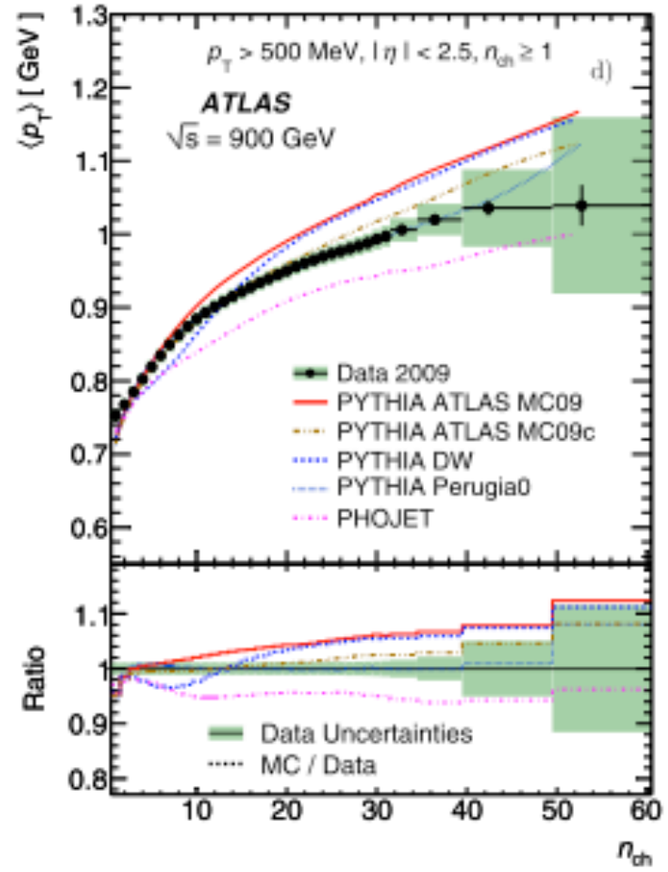
- The charged particle densities in η and p_T are not "perfectly" described by any of the MC tunes.

- Phys. Lett. B **688** (2010) 21–42

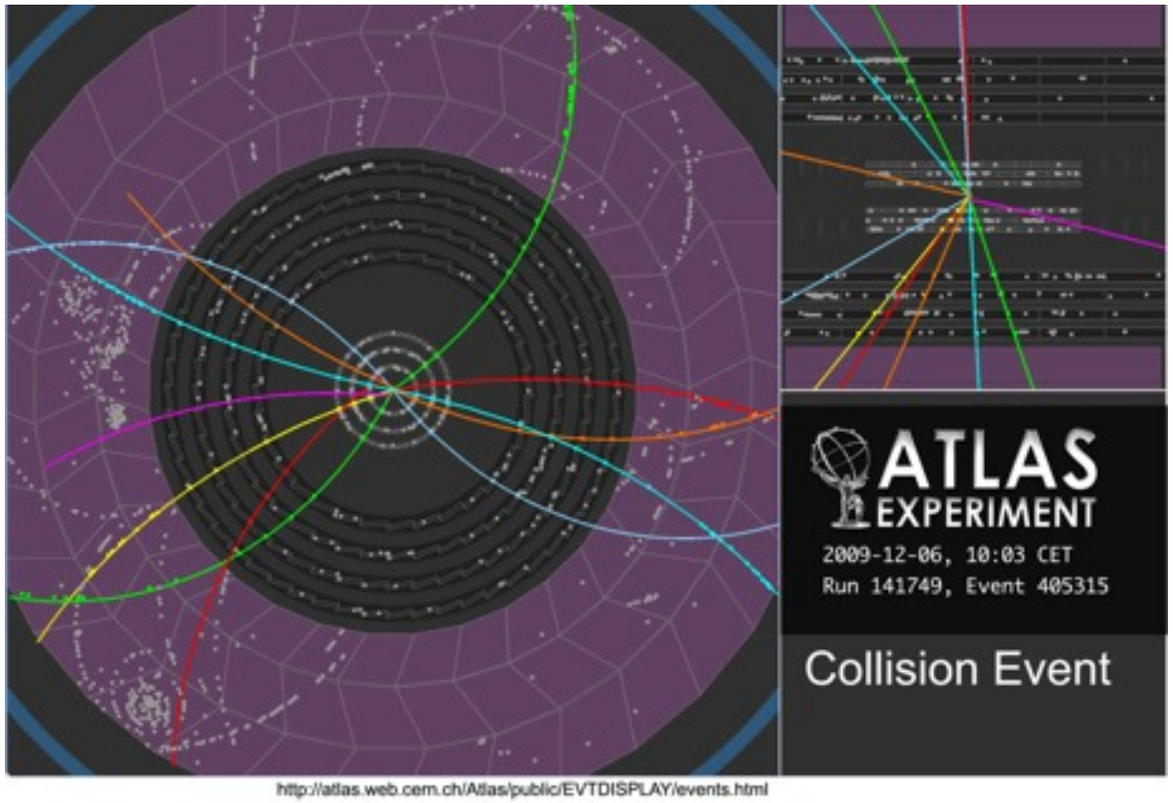








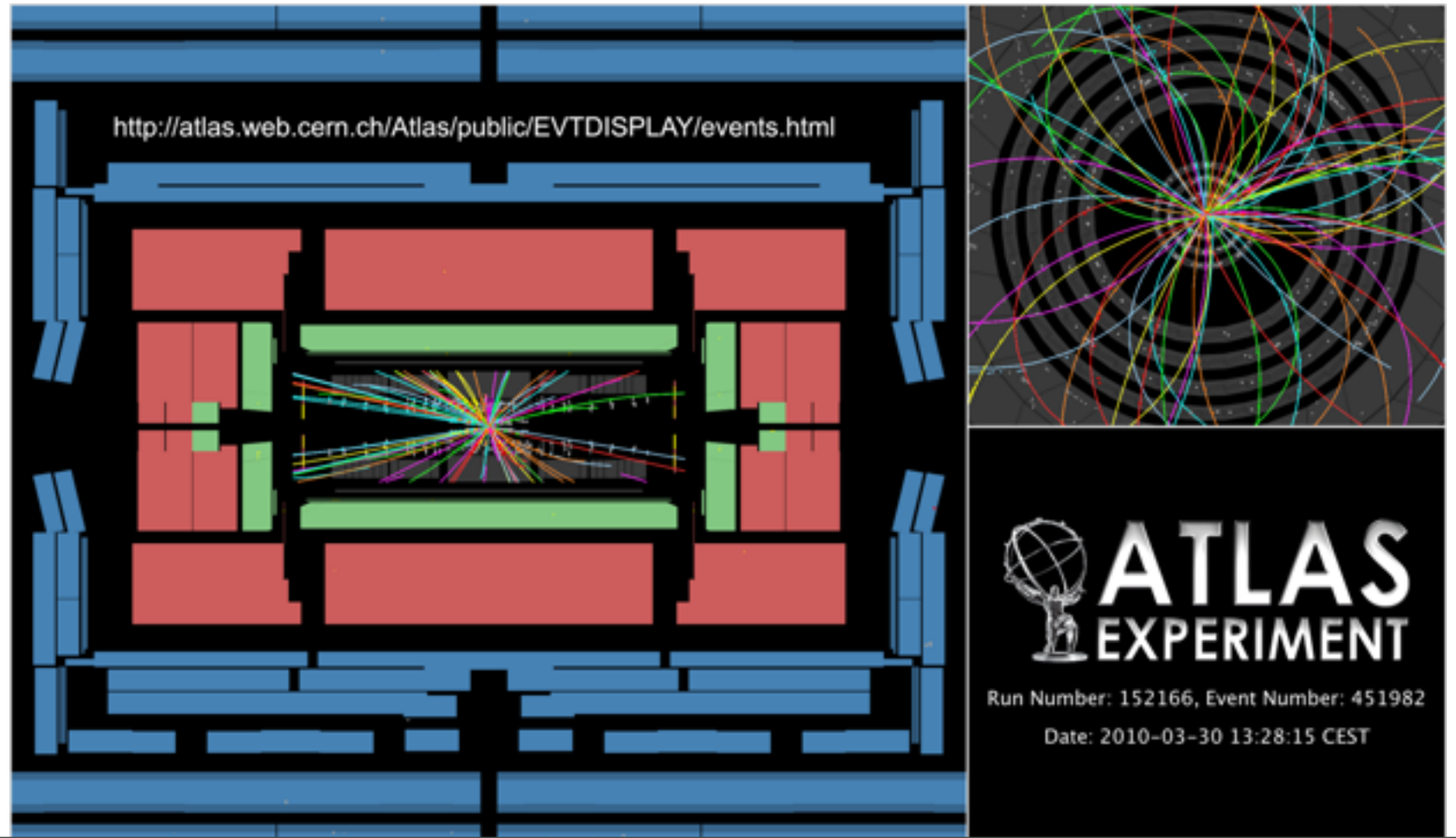
Minimum bias measurements at √s=7TeV



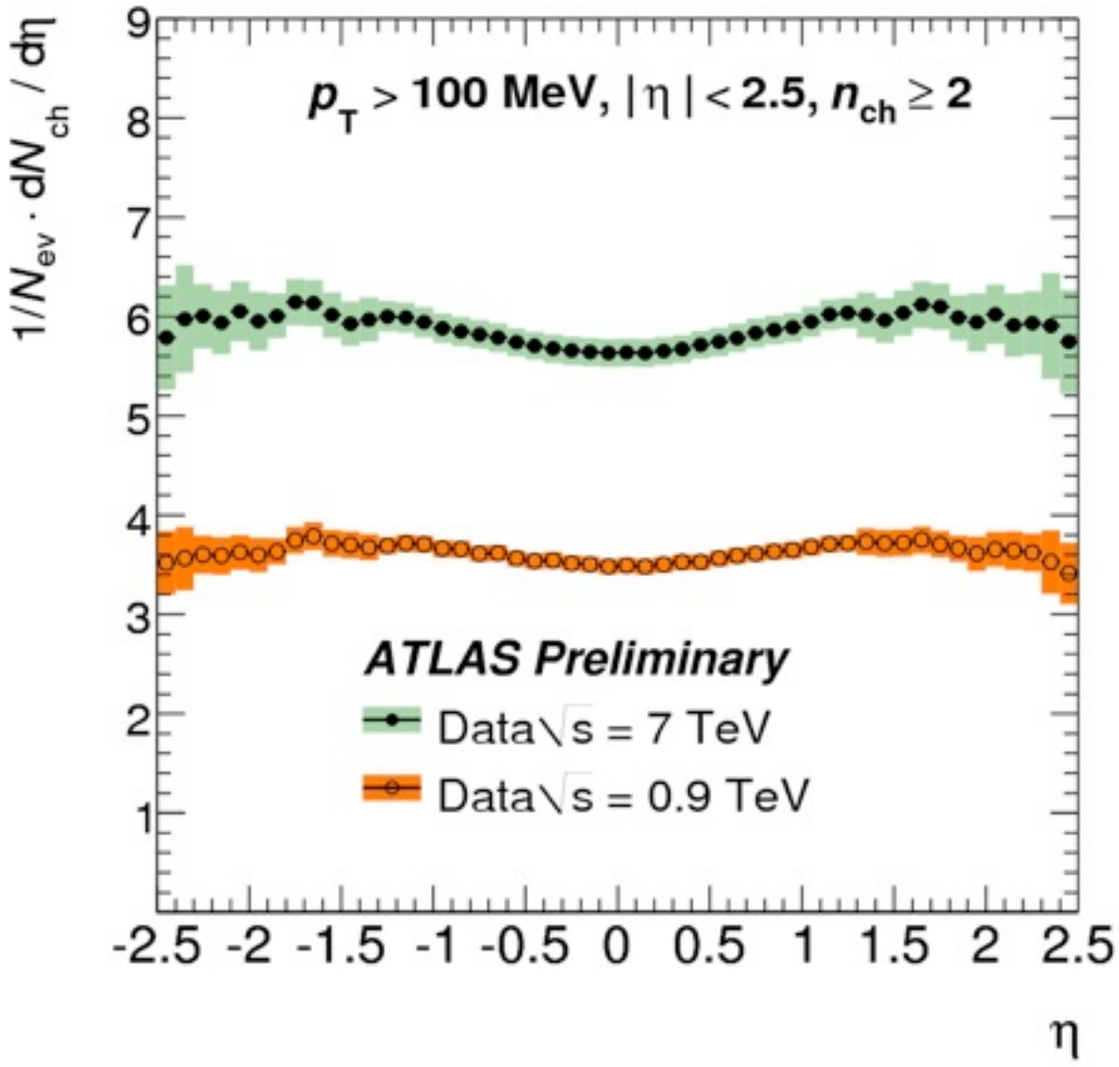
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

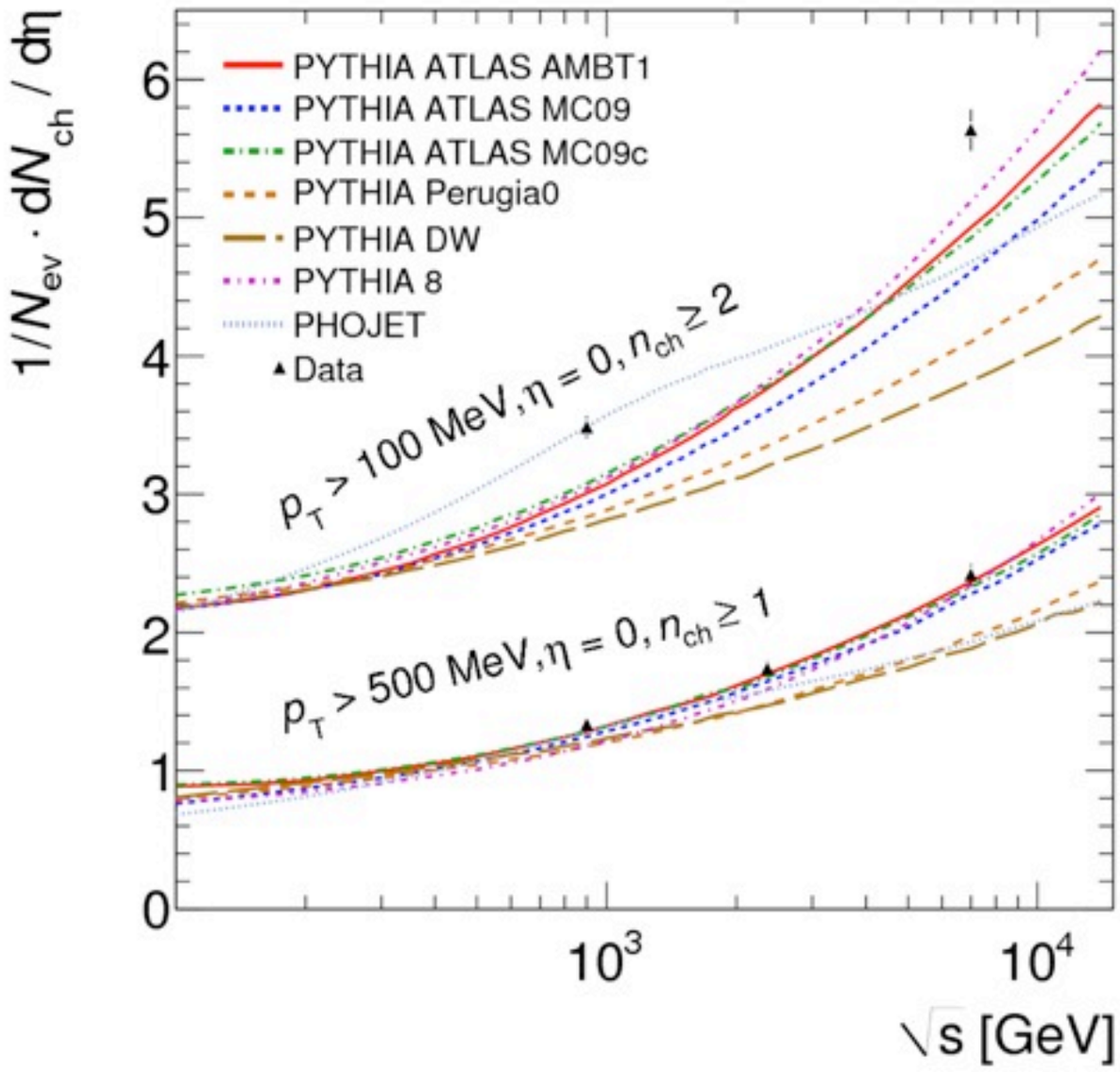
- ATLAS: pp collision at **√s=900GeV**

- ATLAS: pp collision at **√s=7TeV**



ATLAS: Charged particle distributions for tracks with p_T > 100MeV

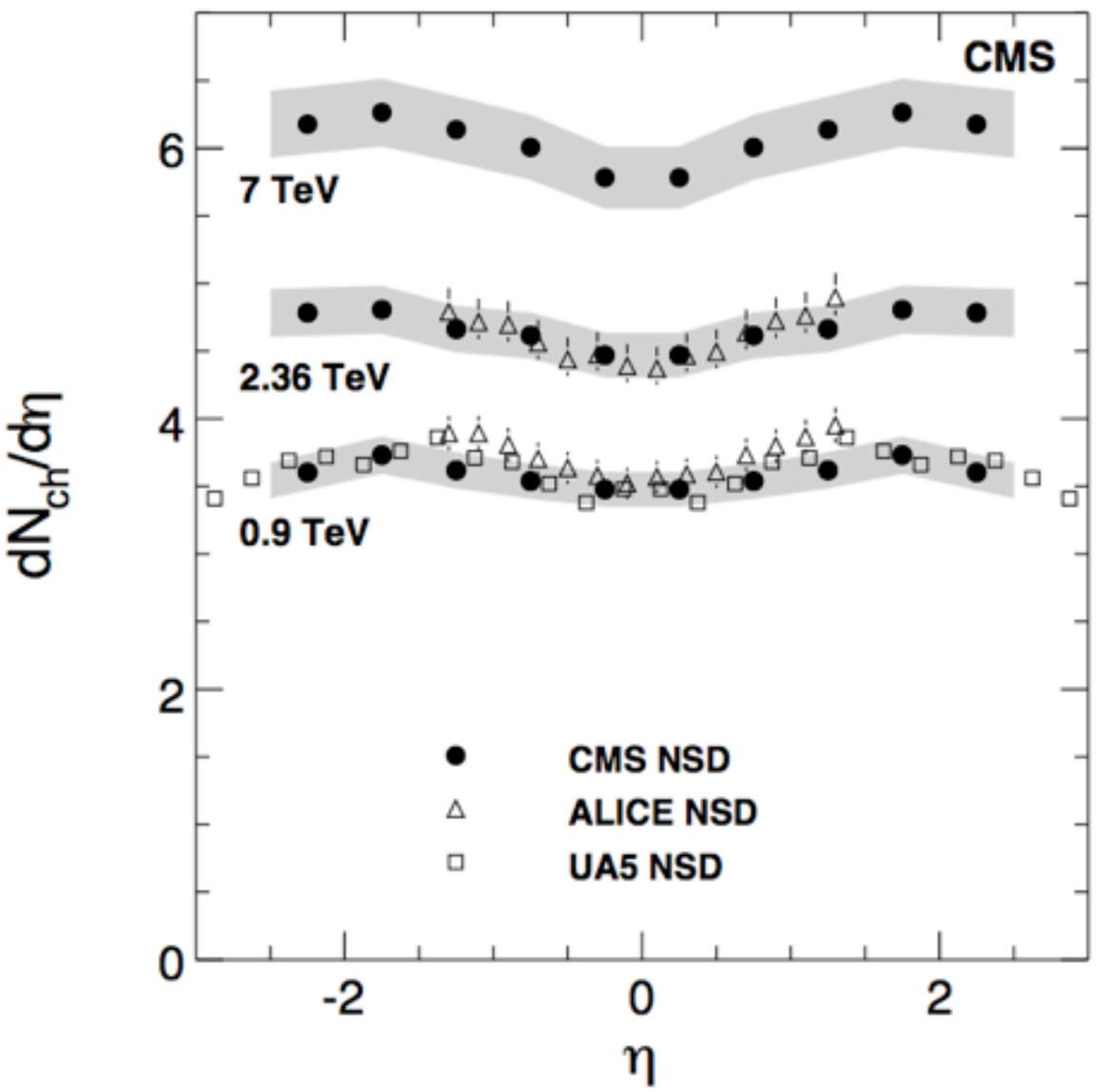


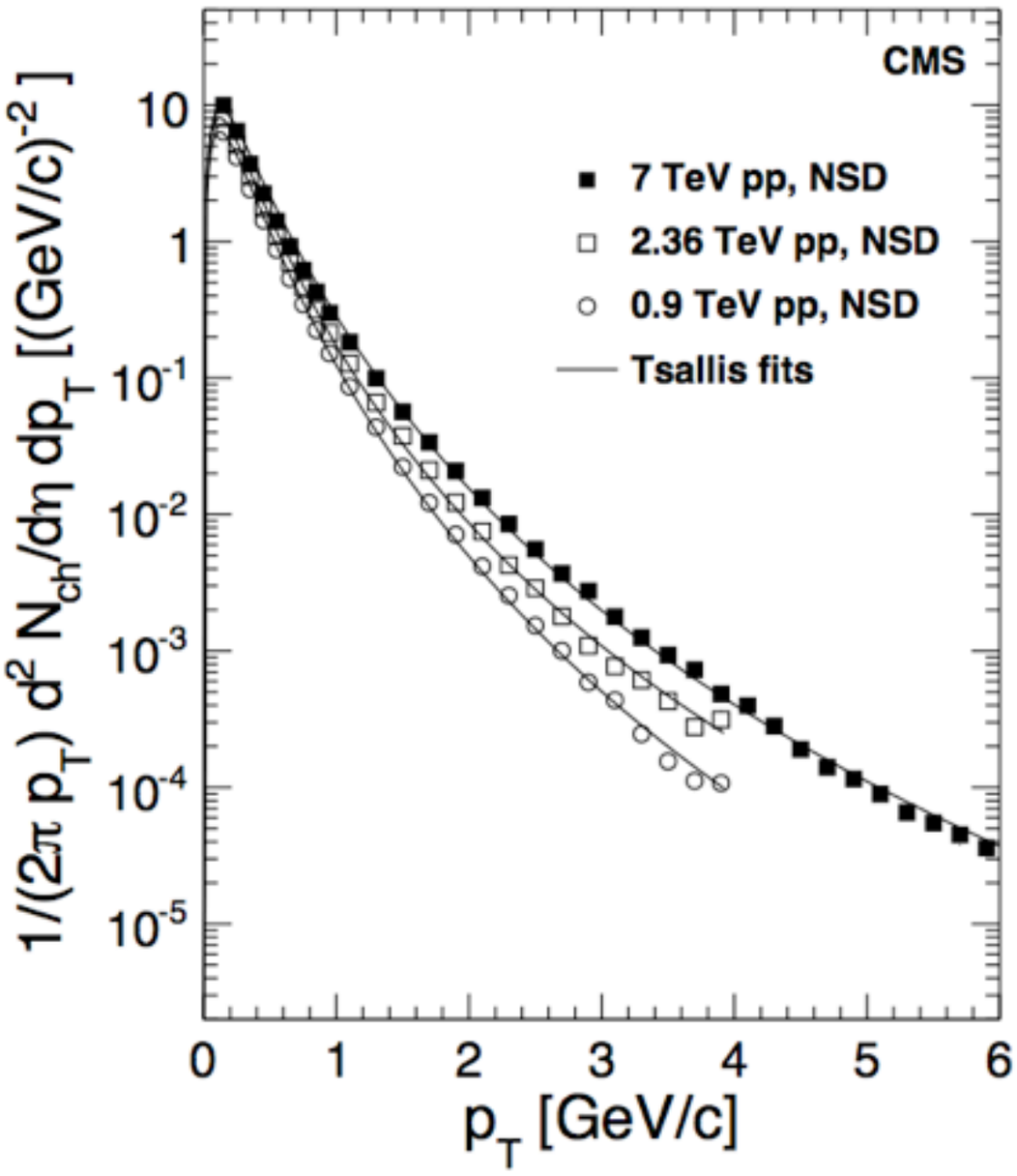


- Major improvement: track p_T threshold reduced from 500MeV to 100MeV (probing softer particle production). Measurements at 7TeV were made over a much larger sample (~10M events) than in the previous analysis.

ATLAS-CONF-2010-046

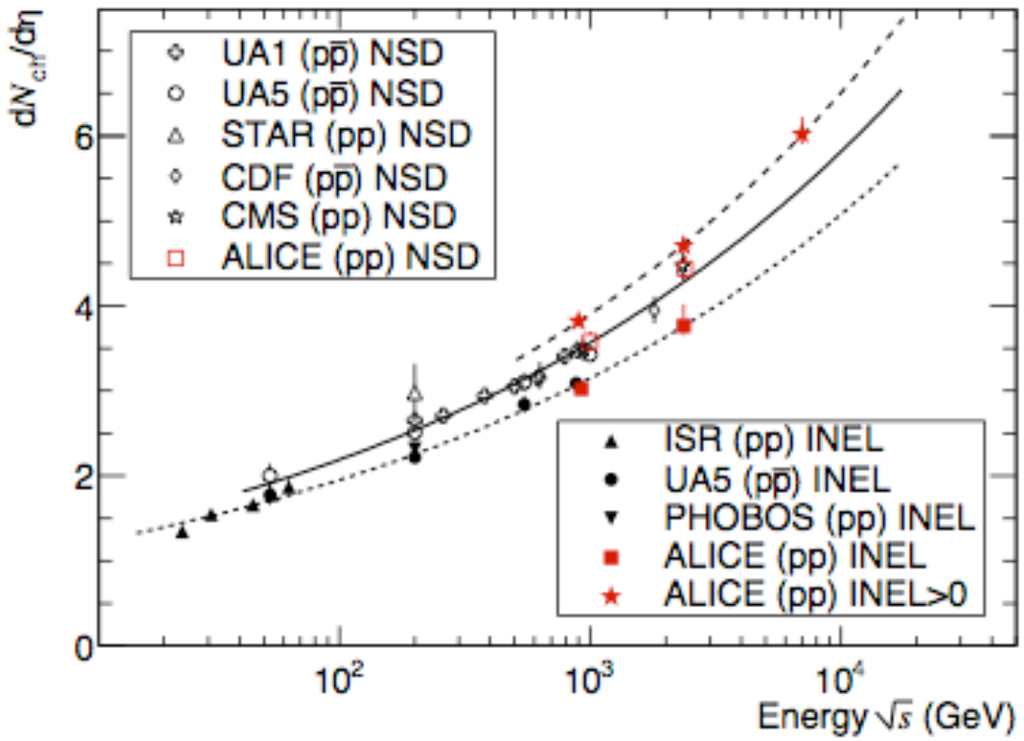
CMS: Minimum bias measurements at √s=7TeV

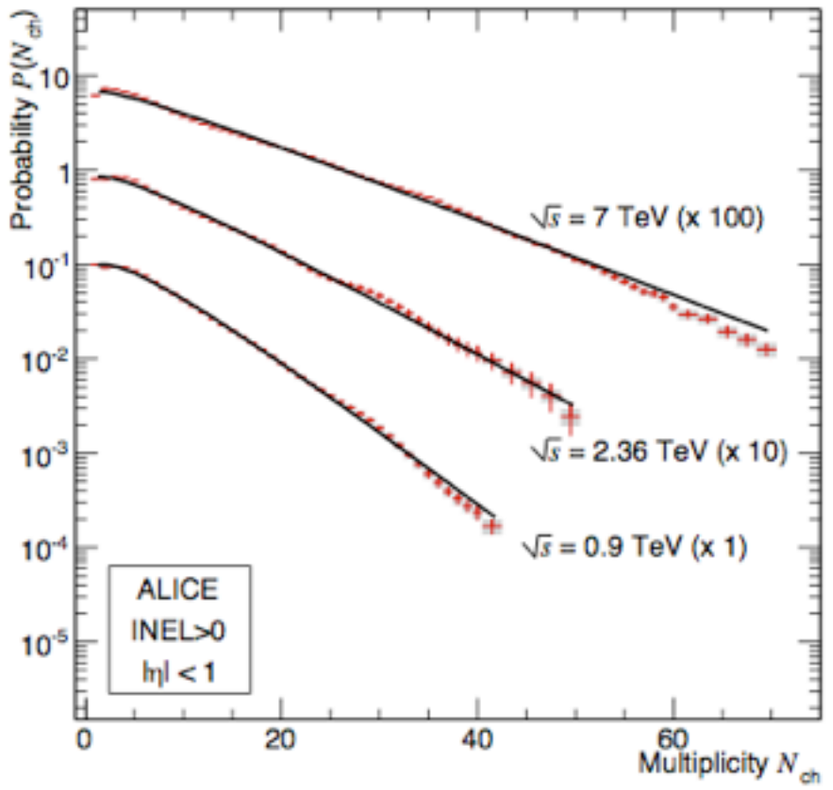




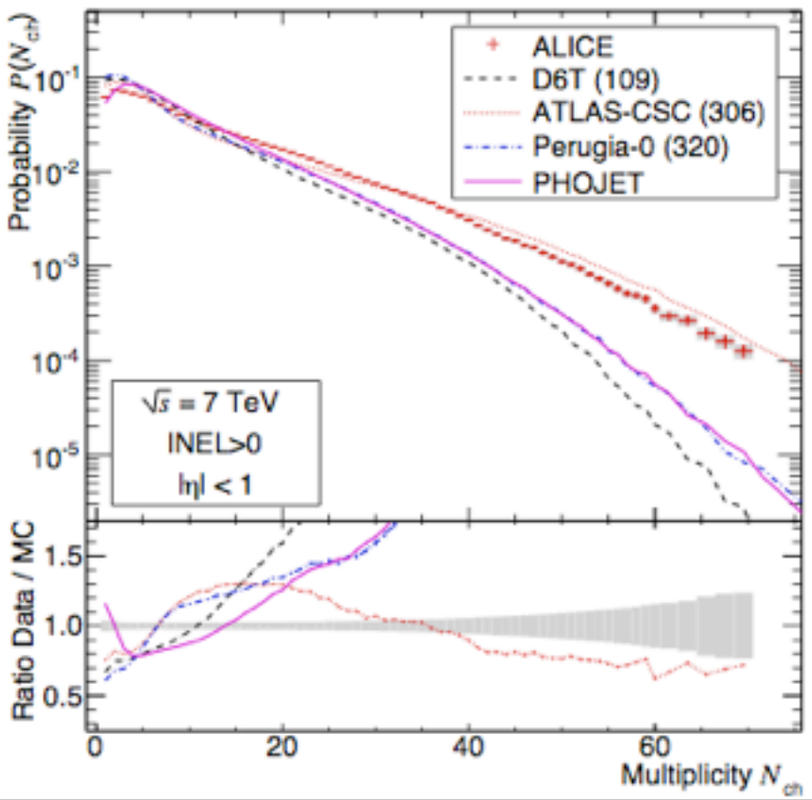
- Measurements at different c.m. energies are crucial for an accurate understanding (prediction) of the evolution of inelastic hadronic processes.

ALICE: Minimum bias measurements at √s=7TeV

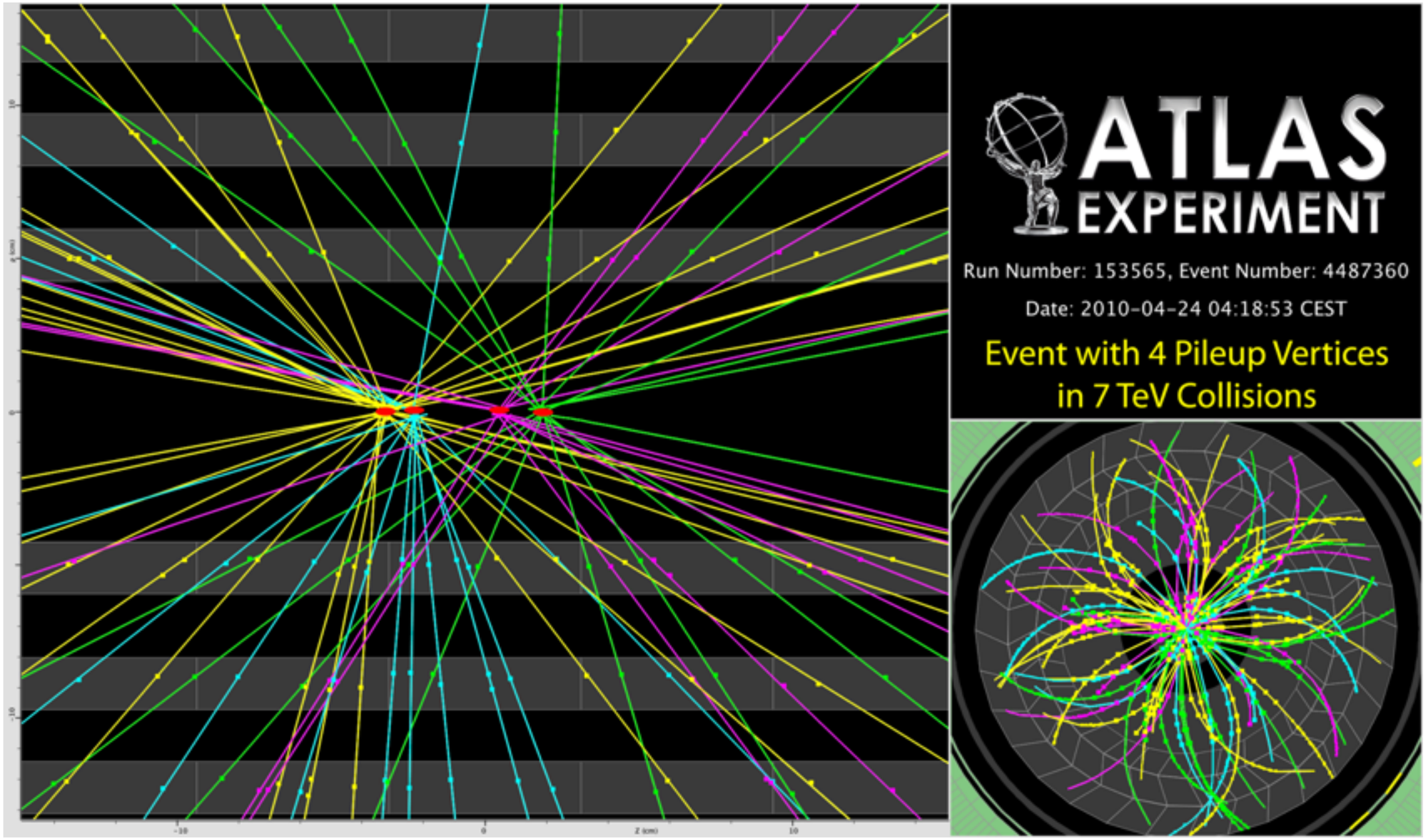




- ALICE presented measurements for an inclusive inelastic sample using an event selection similar to that employed by ATLAS.



ATLAS event with 4 pile-up vertices in 7 TeV collisions



...going forward to higher luminosities

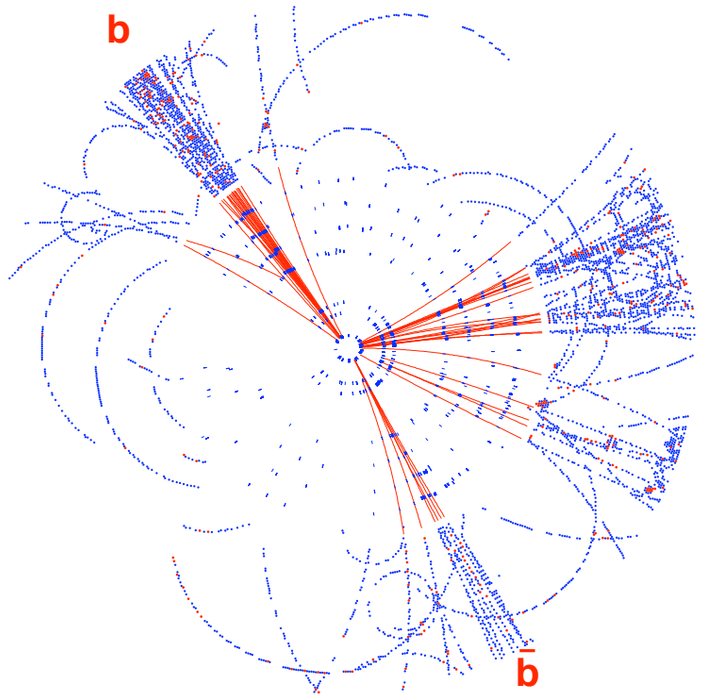
University of Glasgow

ATLAS Barrel Inner Detector

$H \rightarrow b\bar{b}$

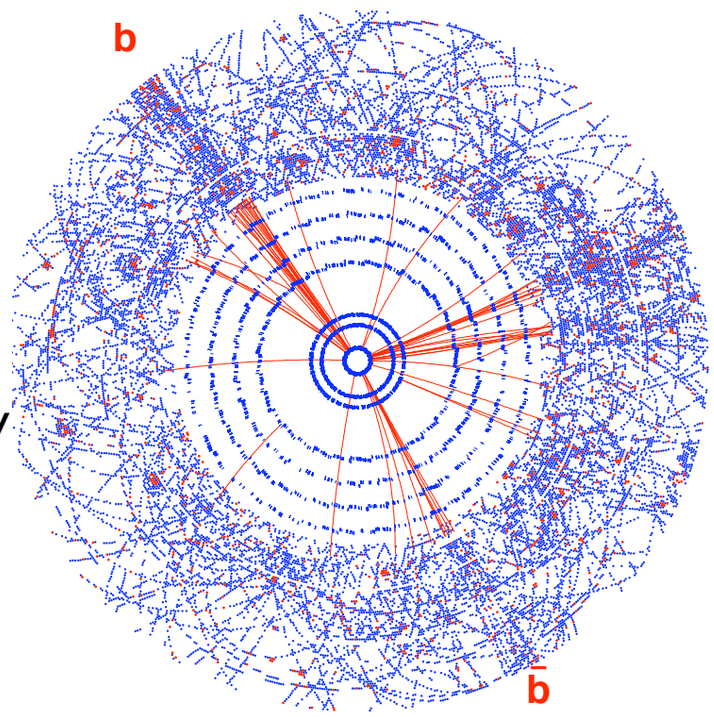
Low-luminosity

$L=10^{33}\ cm^{-2}s^{-1}$



$L=10^{34}\ cm^{-2}s^{-1}$

High-luminosity
(LHC design)

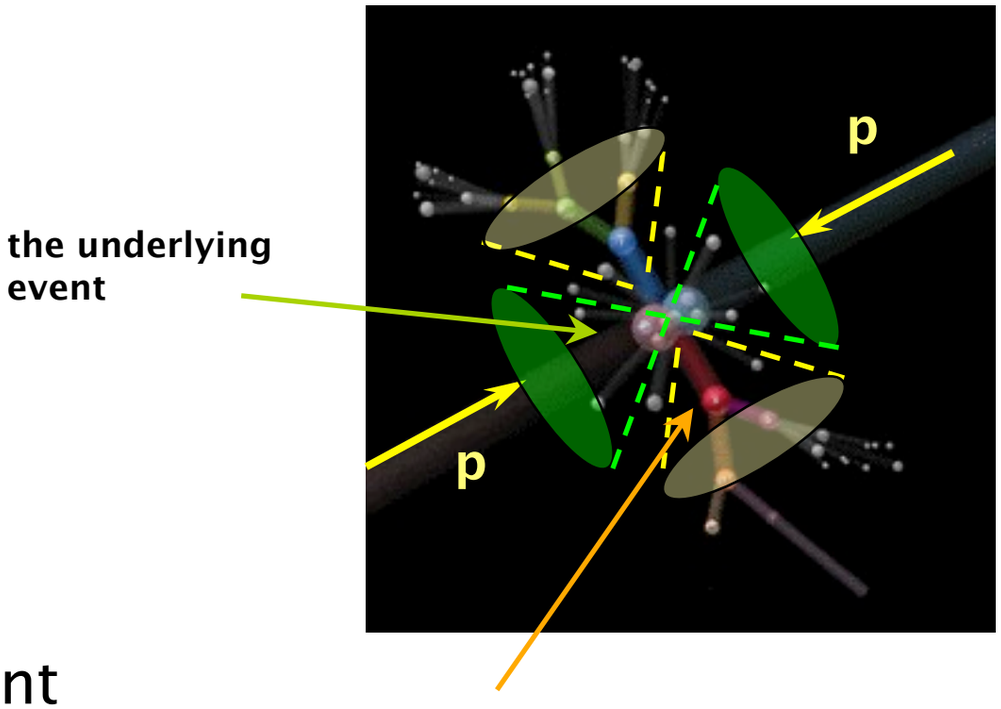


- **Understanding of single inelastic collisions is essential.**
- **High-luminosity environment: can have up to 23 – 25 minimum bias pp collisions per bunch-crossing, ie ~1000 extra tracks!**
- **SLHC: from 2017(?), luminosity 10x greater than design value ($L_{SLHC} = 10^{35}\ cm^{-2}\ s^{-1}$)**
  - **higher event rates**
  - **better statistics & signal significance**
  - **sensitivity for smaller cross-sections**
- **Understanding multiple pp collisions will be essential for most of the discovery channel both in the Higgs and Supersymmetry sectors!**

Measuring the Underlying Event

- **The underlying event:** All particles from a single particle collision except the process of interest.

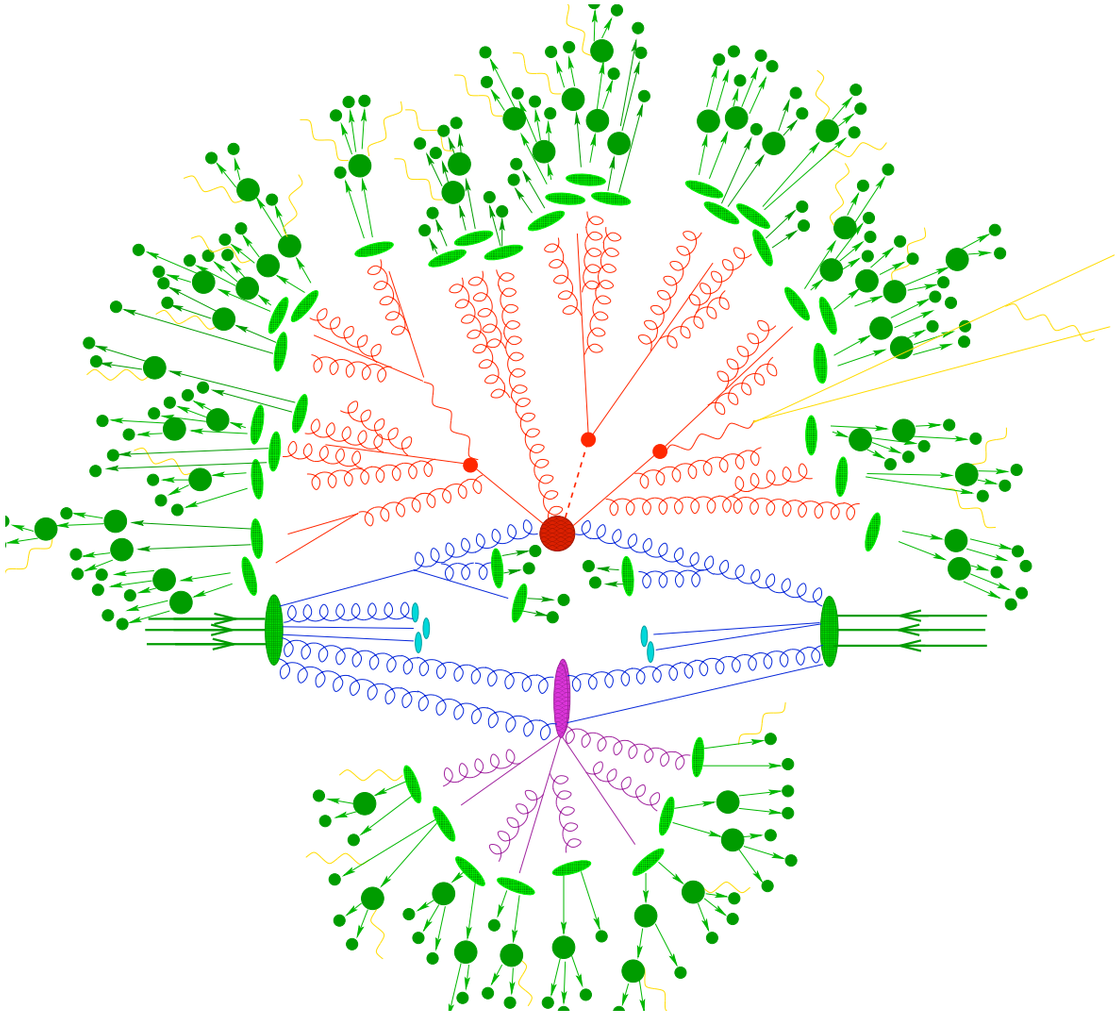
  – Sometimes, the underlying event can also be defined as everything in the collision except the hard process (high-Q^2).



- **Common mis-conception**: in the pre-Tevatron era, the activity in the underlying event (particle multiplicity, p_T^{sum}, ...) was assumed to be **"approximately"** the activity measured in minimum bias events.

Phys. Rev. D65, 092002 (2002).

More detailed look into the underlying event...



- Influenced by contributions from:
  - parton showers (ISR/FSR)
  - multiparton interactions

    (cross-section raises faster than originally thought!)
  - beam remnants
  - colour field connecting hard-scatter to beam remnants

    (this appears to be essential to get correlation $\langle p_T \rangle - n_{chg}$ correctly described)

- **Experimental challenge:** define observables that allow us to "isolate" individual components of the underlying event!

- **Modelling challenge:** vary model parameters consistently so most (if not all) observables can be properly described

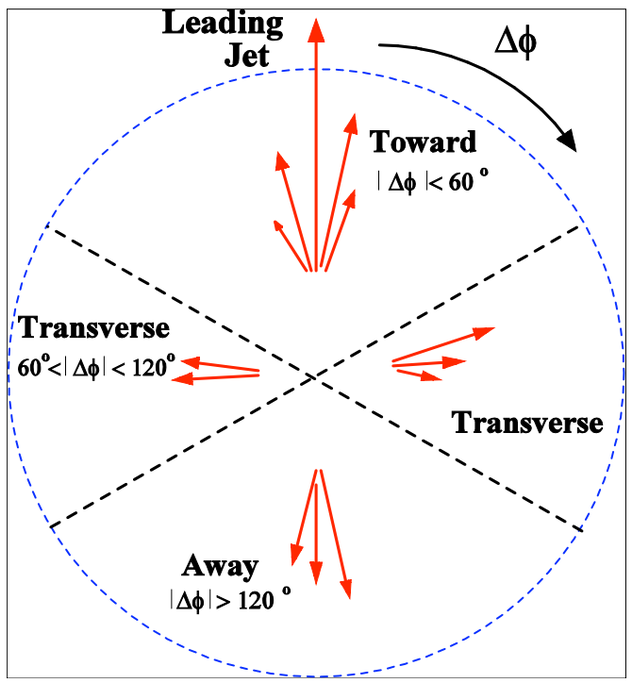
The underlying event in pp collisions at √s = 14 TeV (simulation)

University of Glasgow

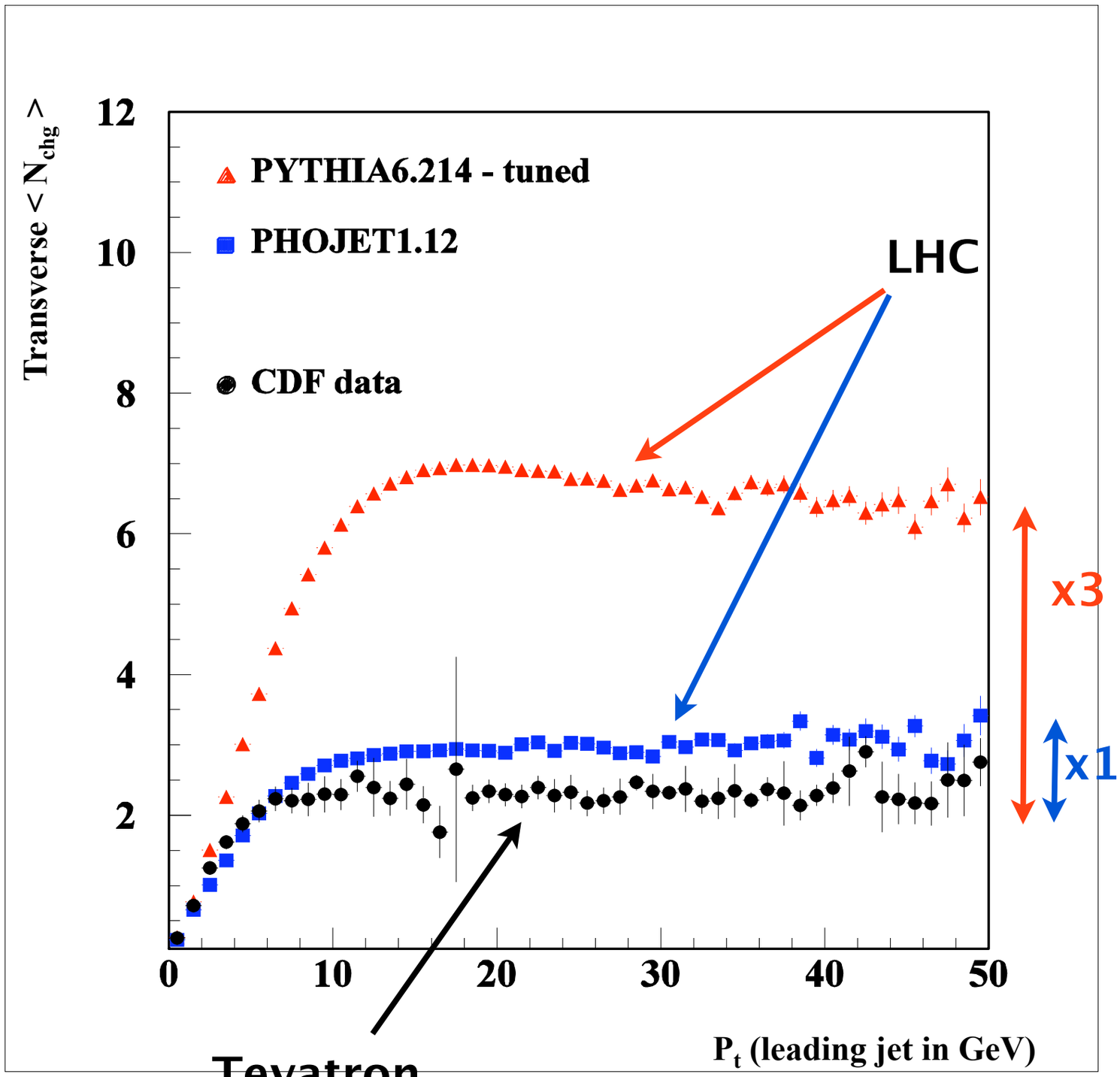
CDF – Run I "Style"

Charged particles:
p_t>0.5 GeV and |η|<1

Cone jet finder: R=0.7

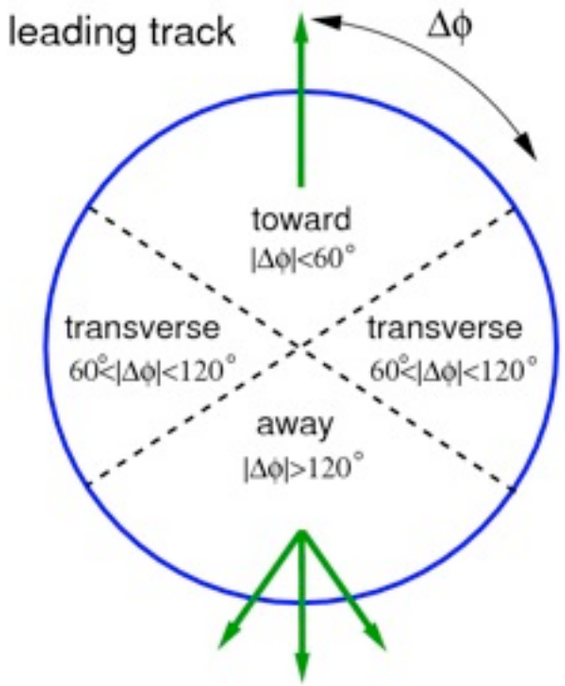


UE particles come from region transverse to the leading jet.

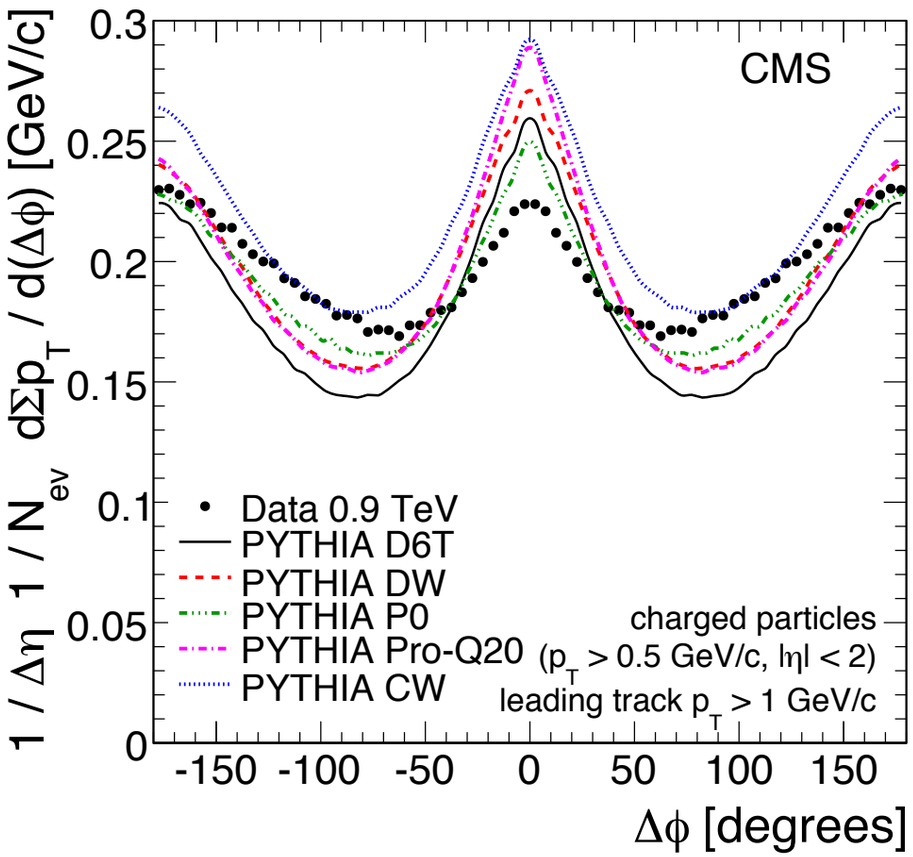


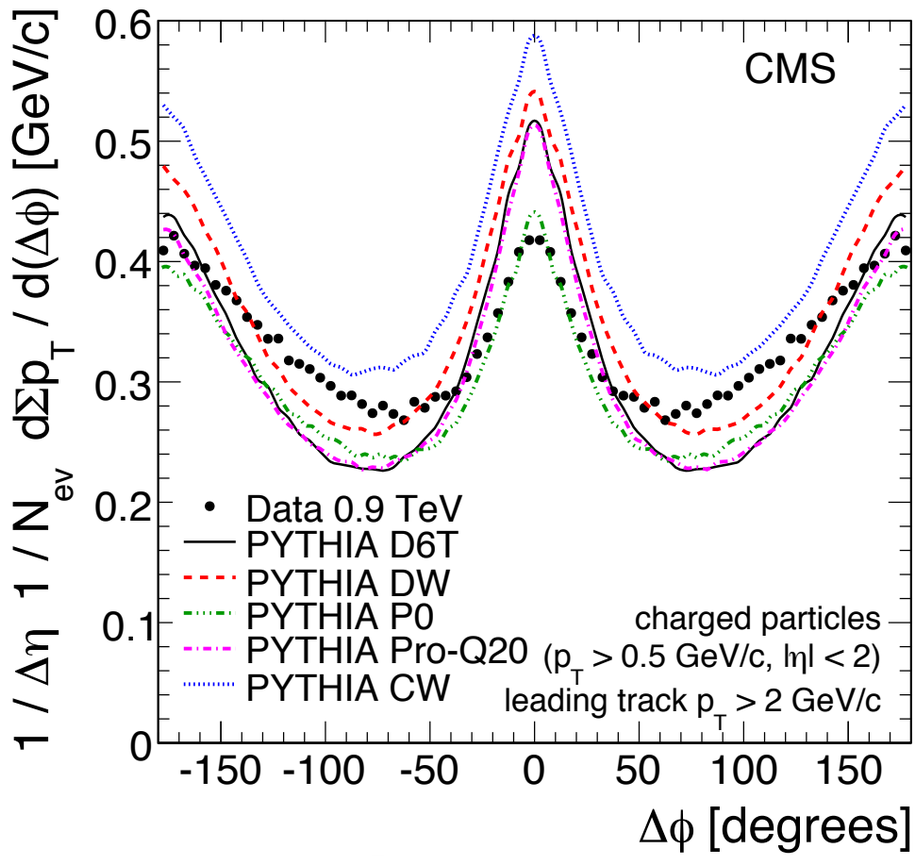
EPJ C 50, 435 (2007)

Measuring the underlying event at the LHC: CMS measurement

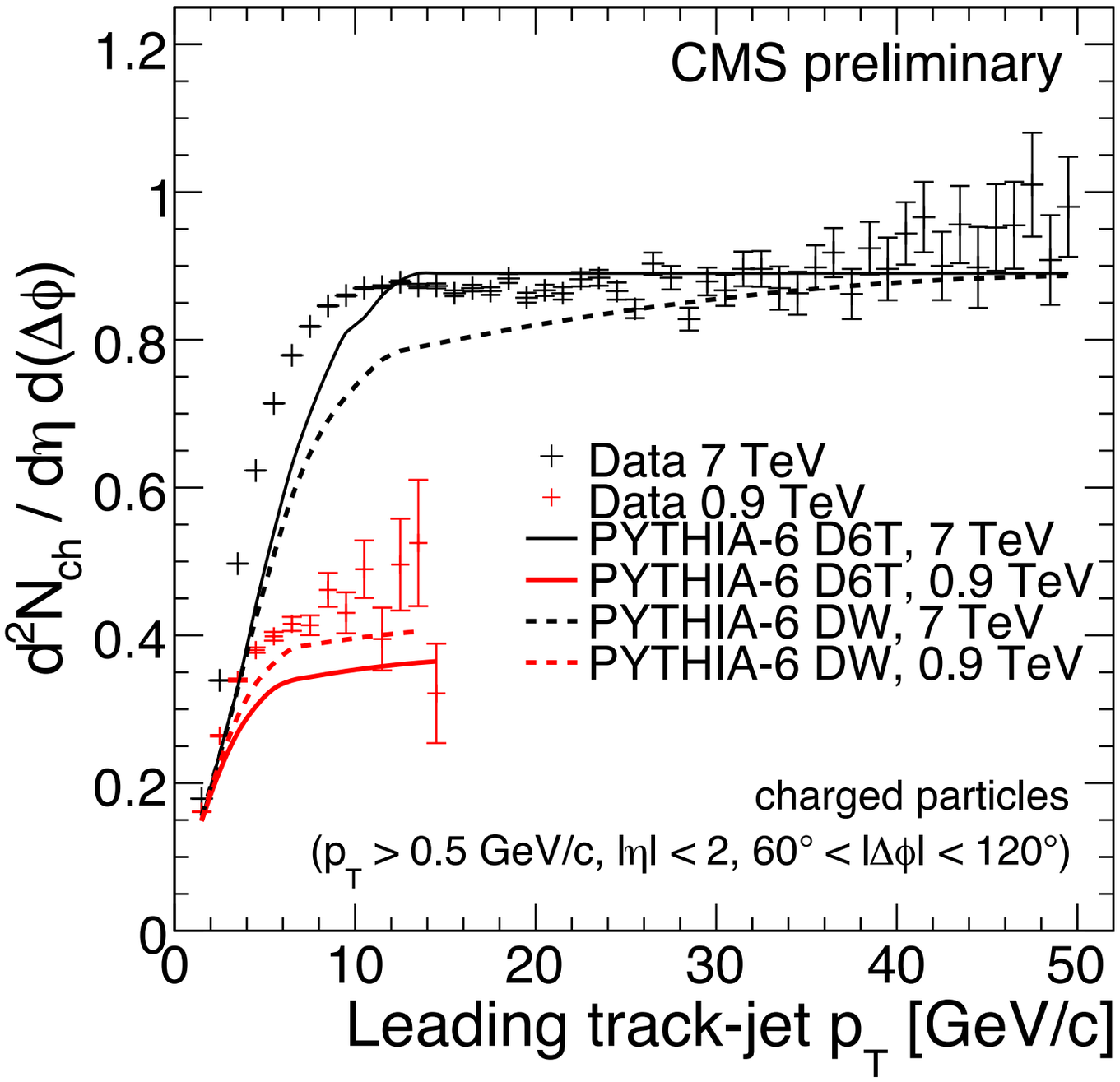


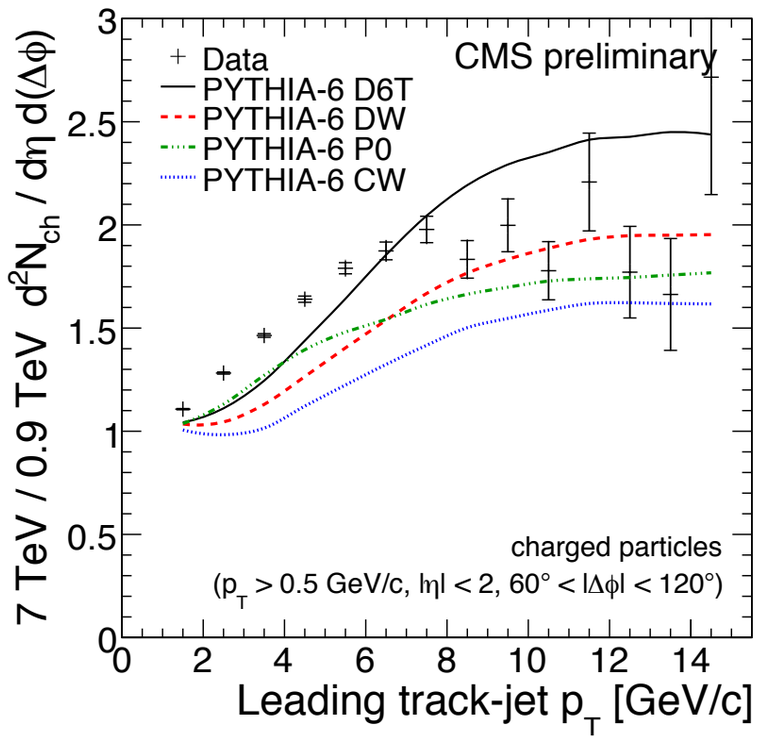
- CERN-PH-EP/2010-014
- Uncorrected data. MC after full simulation.
- Reconstructed track distribution in regions defined by the leading track in the event.
- pp collisions at $\sqrt{s}$=900GeV





Measuring ehe underlying event at the LHC: CMS measurement



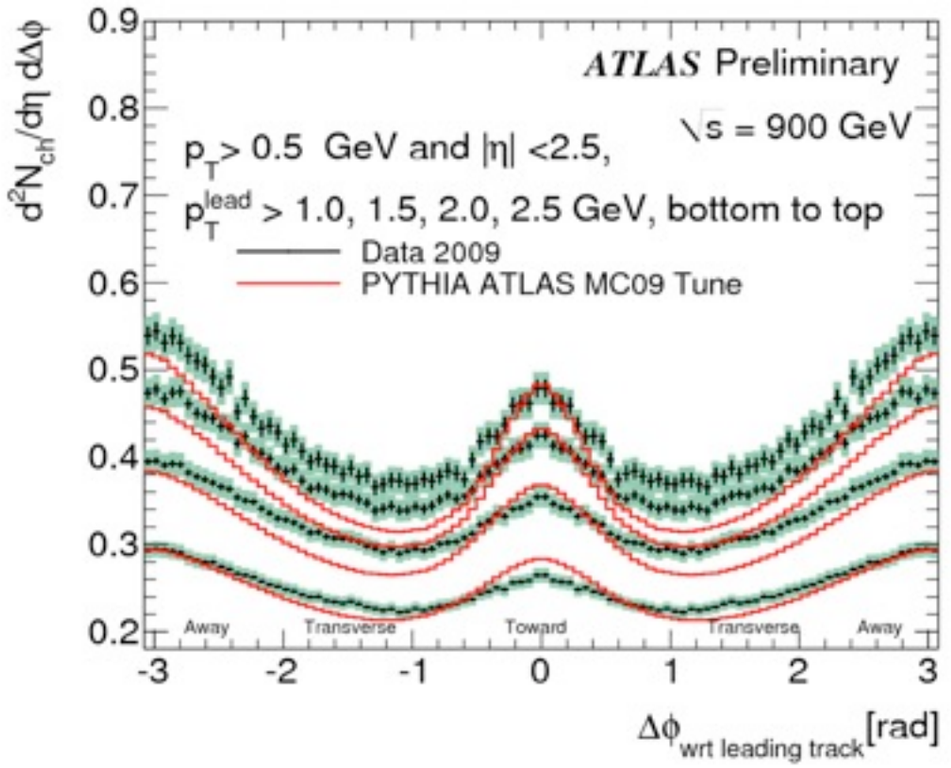


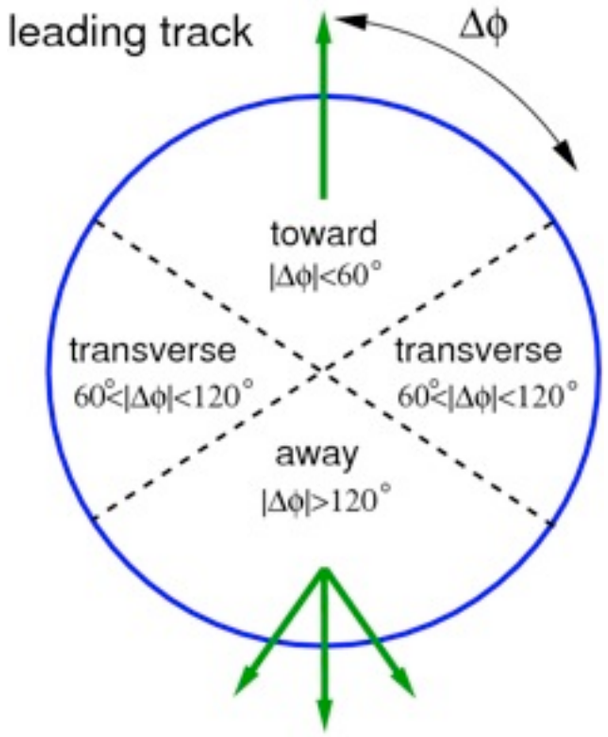
- Uncorrected data. MC after full simulation.
- pp collisions at $\sqrt{s}$=900GeV and 7TeV
- Leading **track-jet** used as reference
- **PAS QCD-10-010**

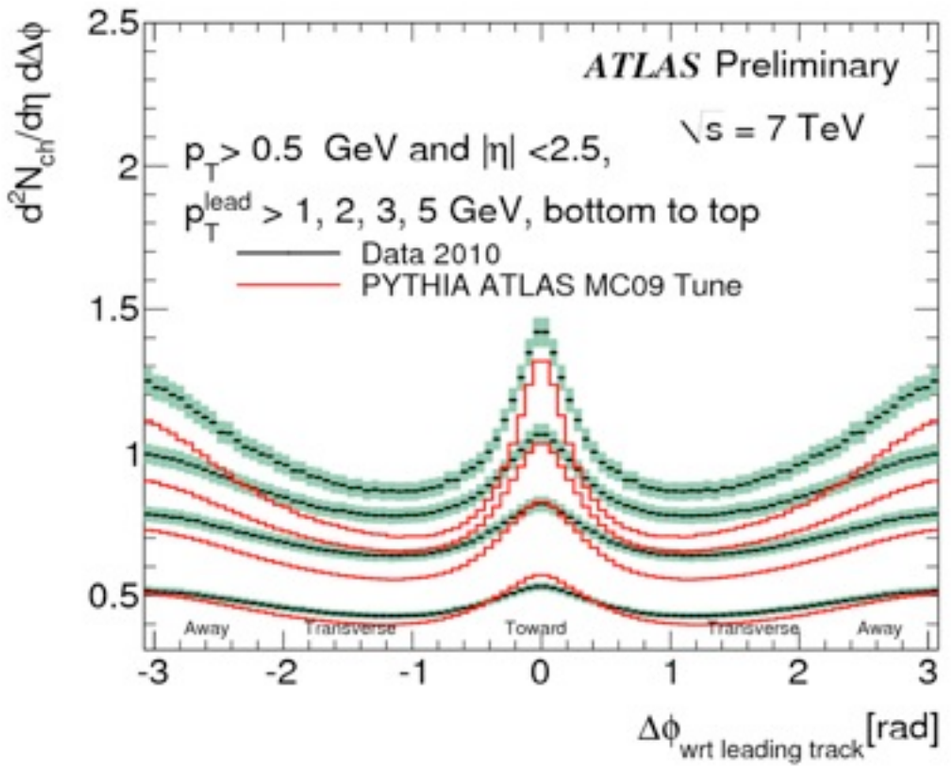
Measuring ehe underlying event at the LHC: ATLAS measurement

University of Glasgow

- Event selection:
  - full 900GeV sample (same as used for Minimum Bias)
  - 7 TeV
  - L1_MBTS_1 ≥ 1 hit
  - At least one primary vertex reconstructed
  - No additional primary vertices with 4 or more associated vertex tracks
  - At least one selected track with p_T > 1.0 GeV



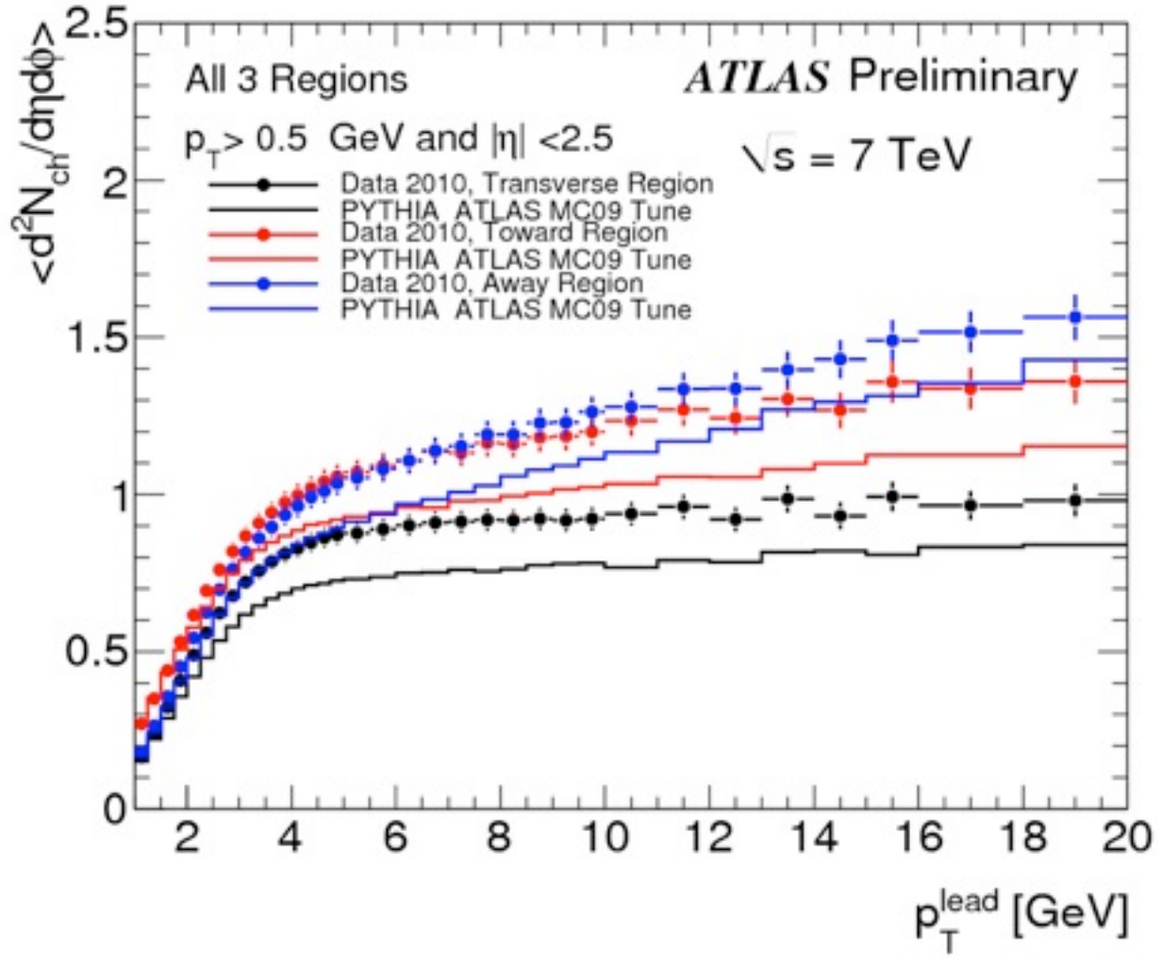


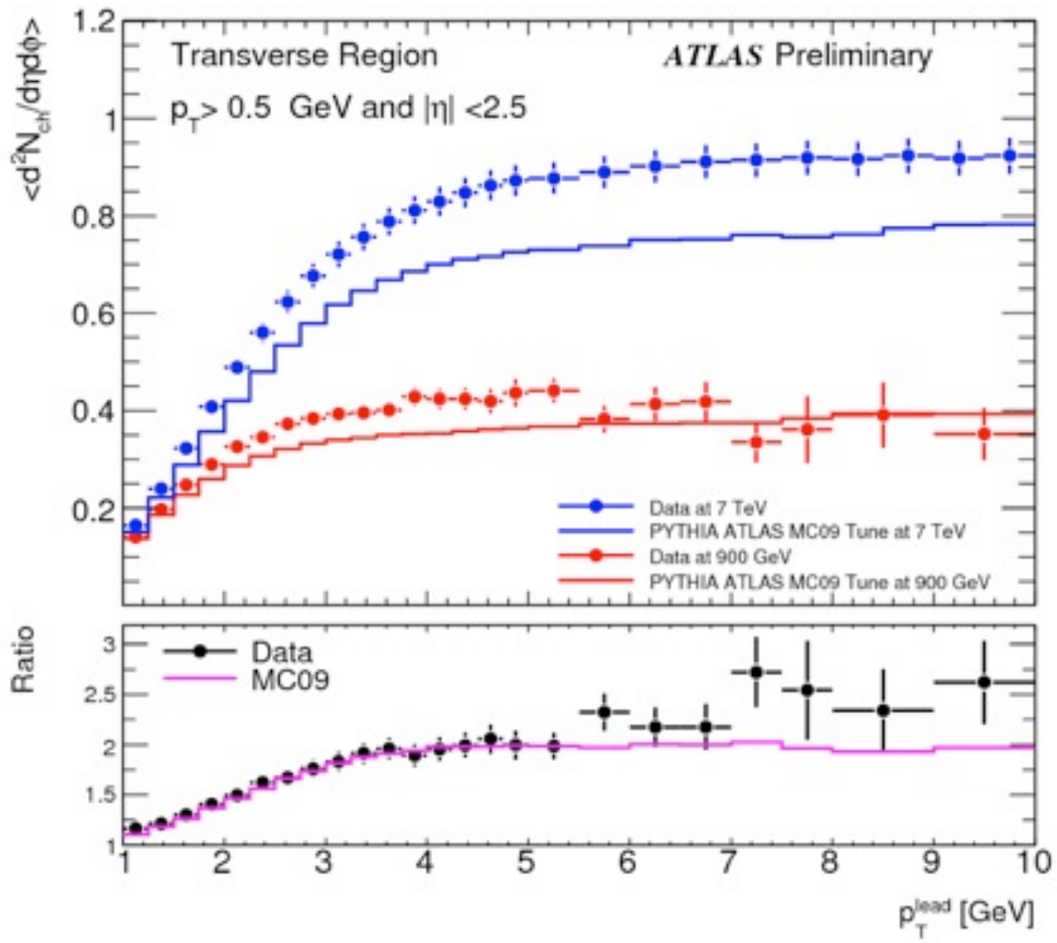


ATLAS-CONF-2010-081

Measuring ehe underlying event at the LHC: ATLAS measurement

University of Glasgow

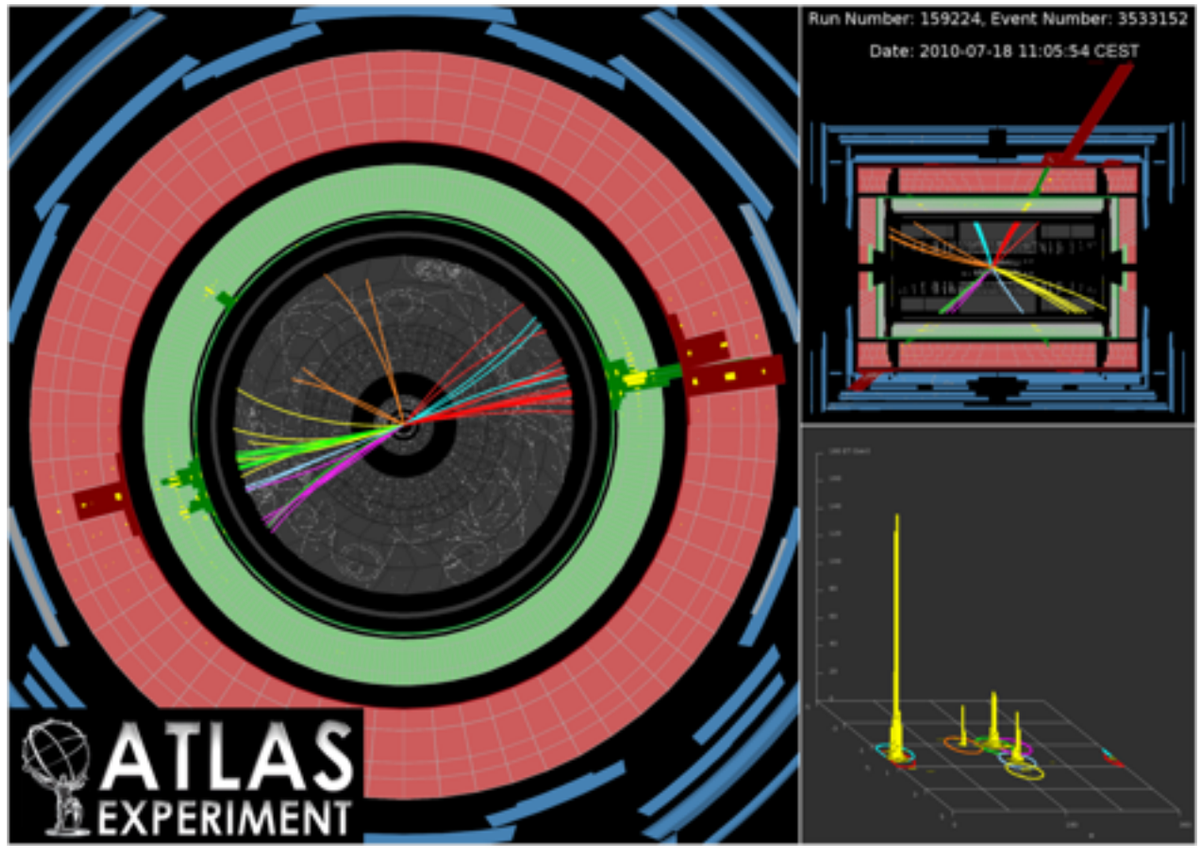




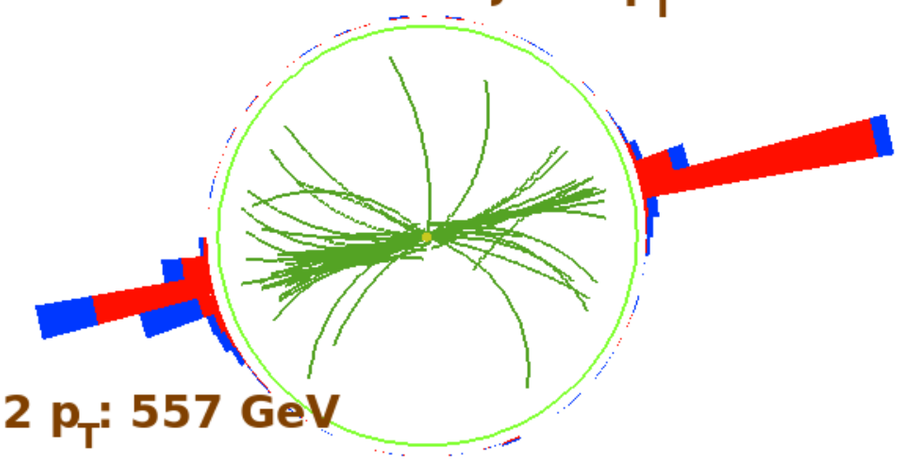
- The number density is higher than predicted by any of the MC tunes.
- The difference is more significant at 7 TeV (energy extrapolation!).
- Comparing number and sum p_T densities for 900GeV and 7 TeV measurements: crucial information for a better understanding on how to model the energy extrapolation!

ATLAS-CONF-2010-081

Measuring Jets at the LHC



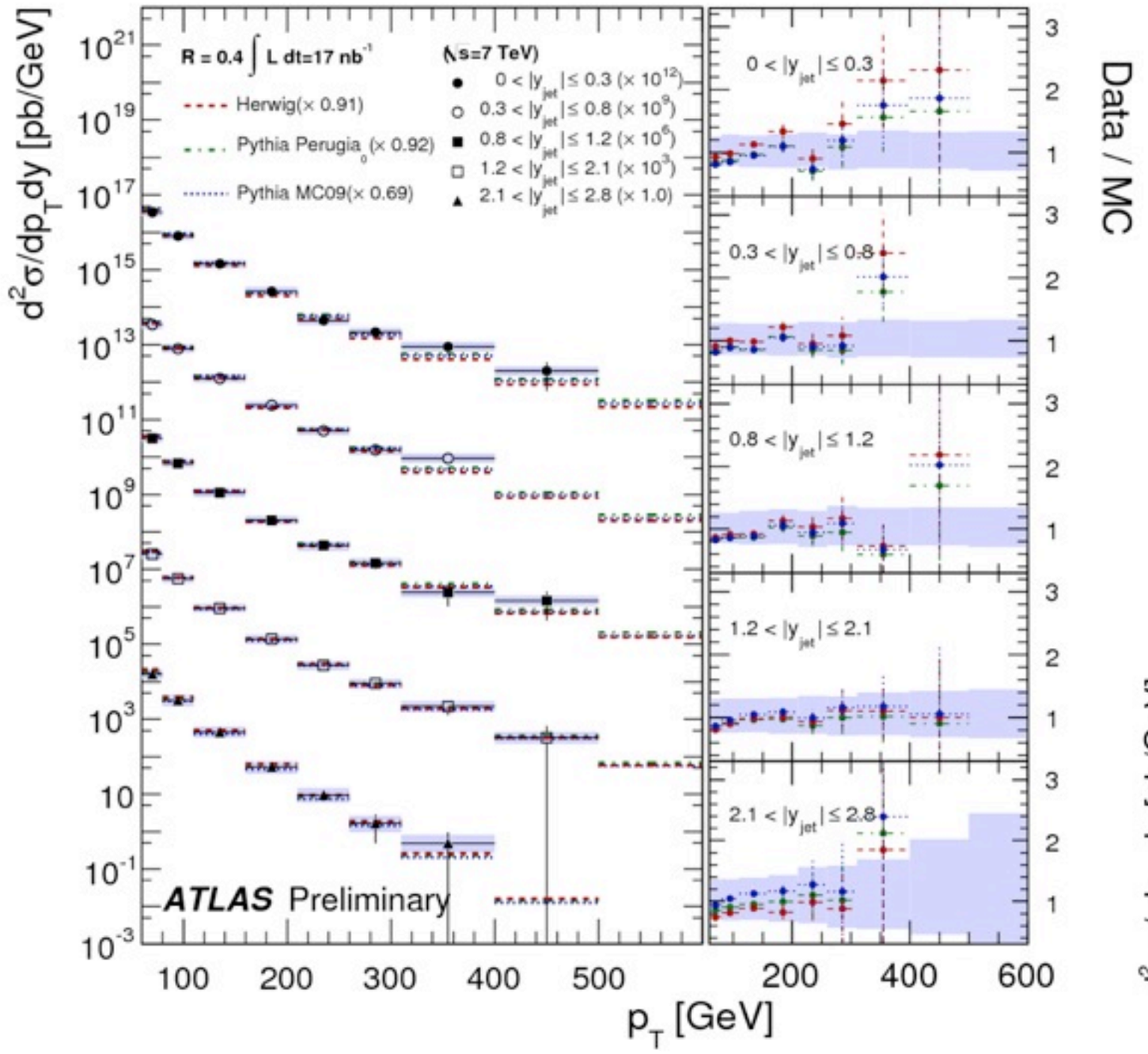
Run : 138919
Event : 32253996
Dijet Mass : 2.130 TeV

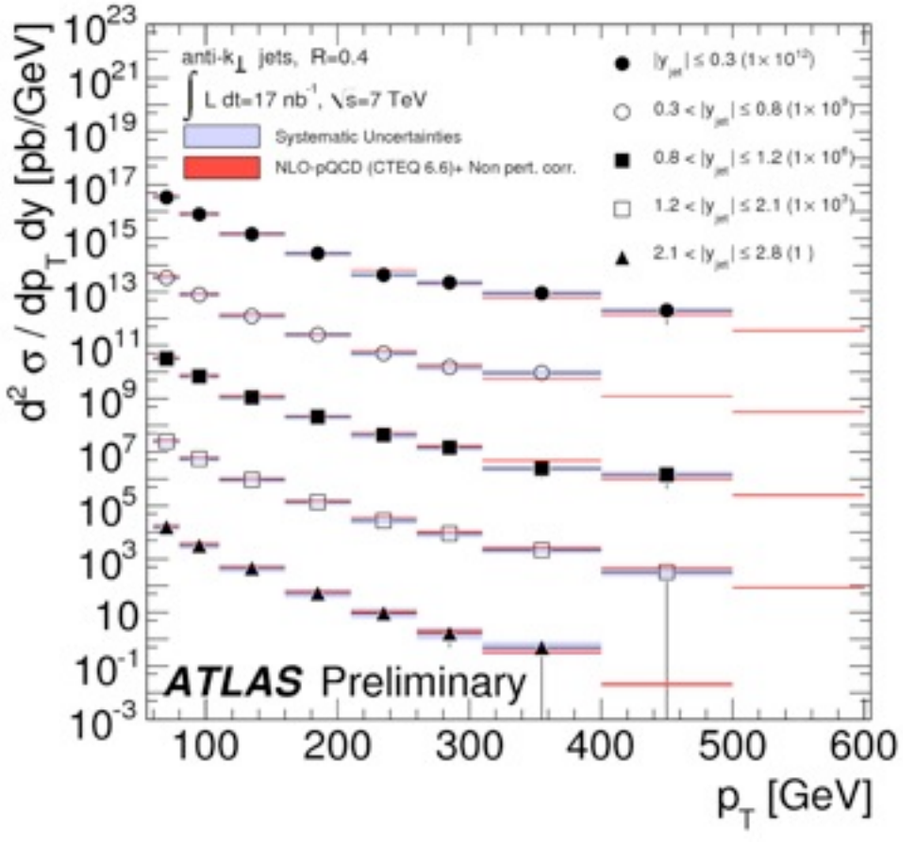


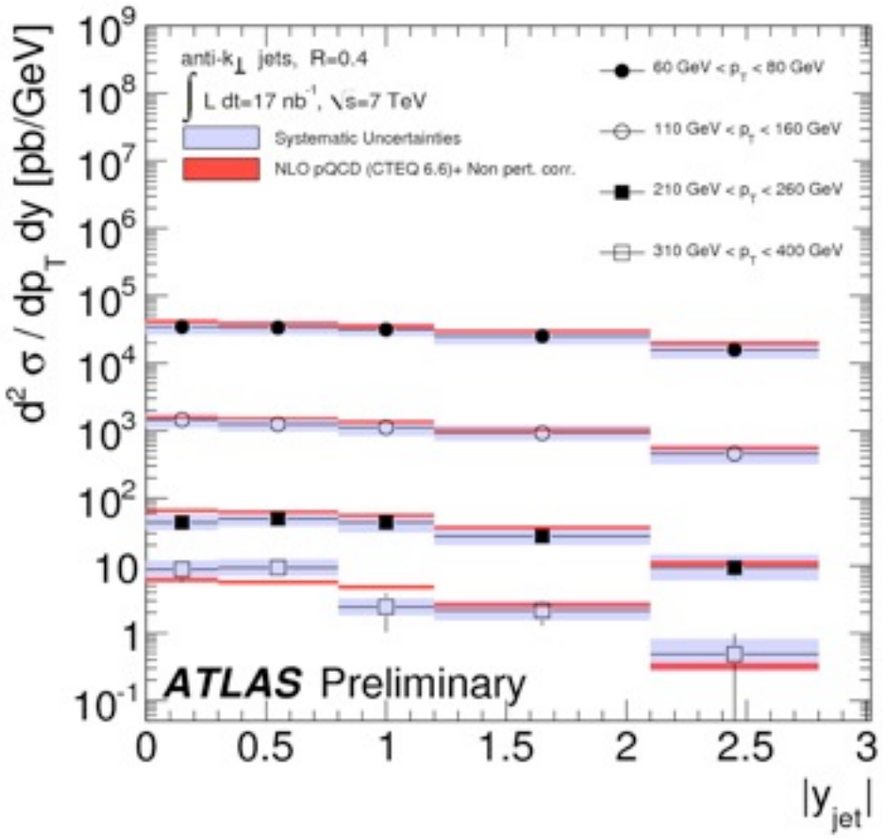
- ATLAS: event with a very high p_T leading jet
  - the highest p_T jet has a p_T of 1.12 TeV, the second leading jet has p_T of 480 GeV.

- CMS: Dijet Mass 2.13 TeV

Inclusive jet production: ATLAS



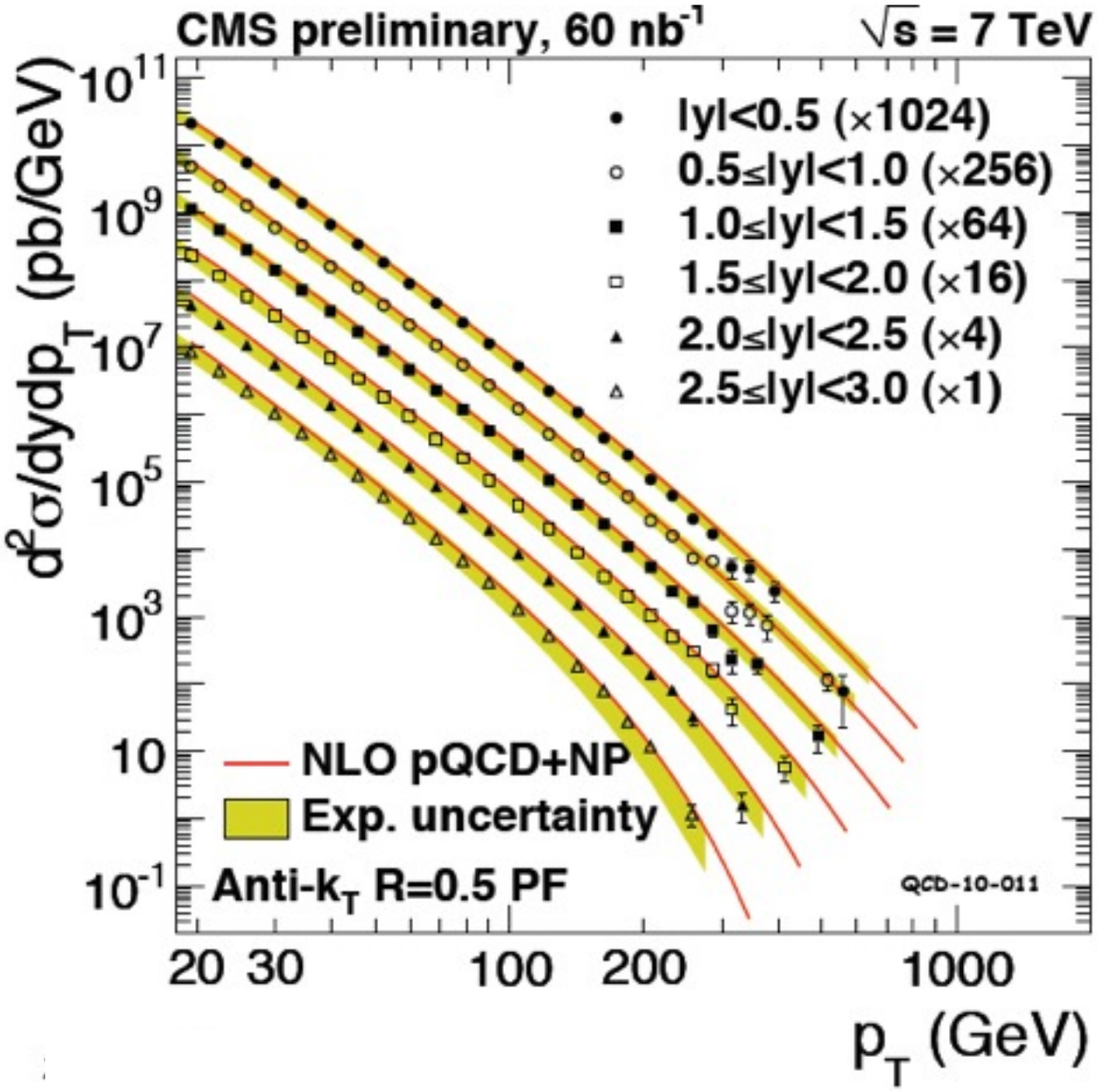




anti-k_T (0.4 and 0.6),
jet p_T > 60 GeV,
|y| < 2.8

ATLAS-CONF-2010-050

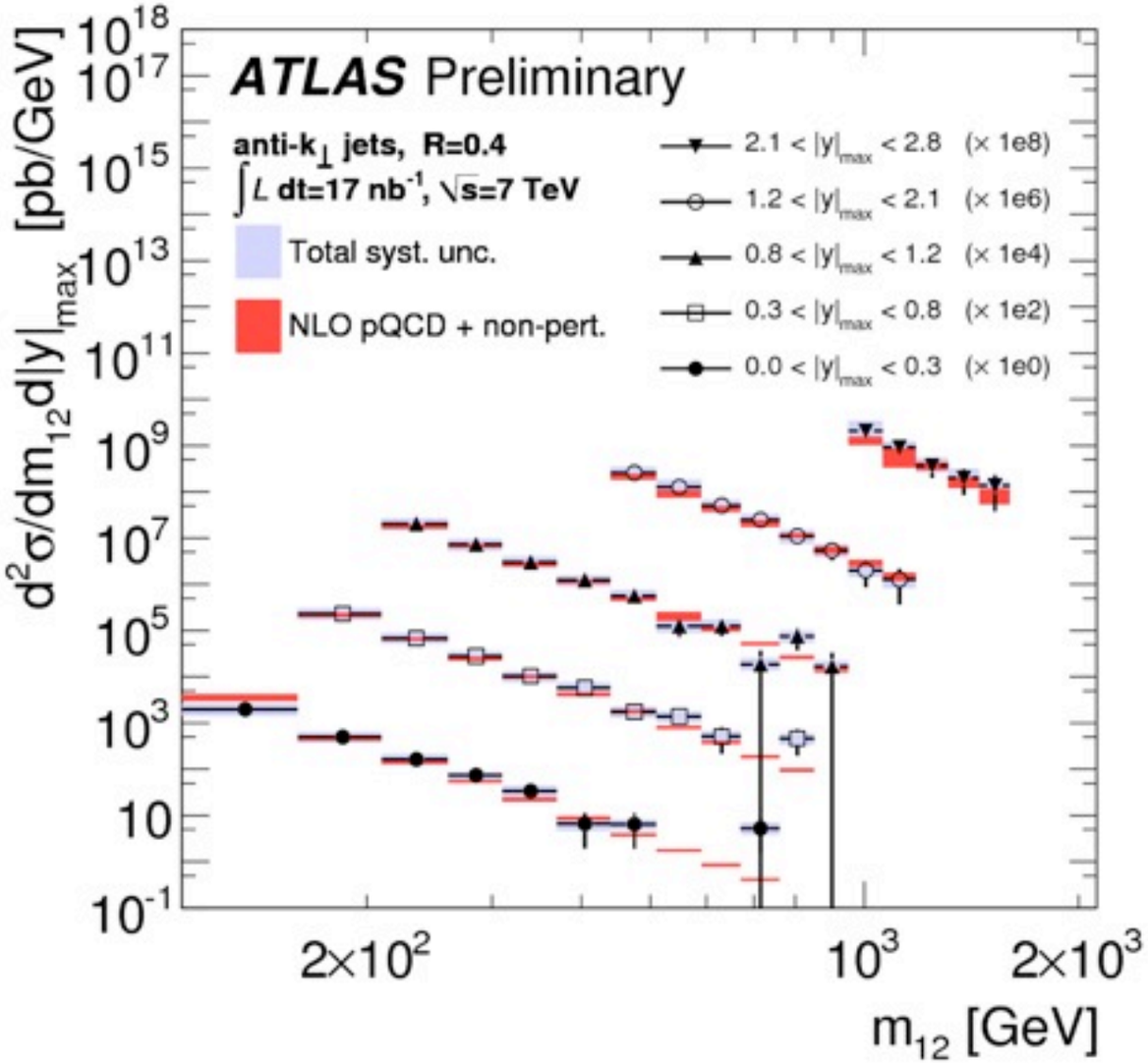
Inclusive jet production: CMS

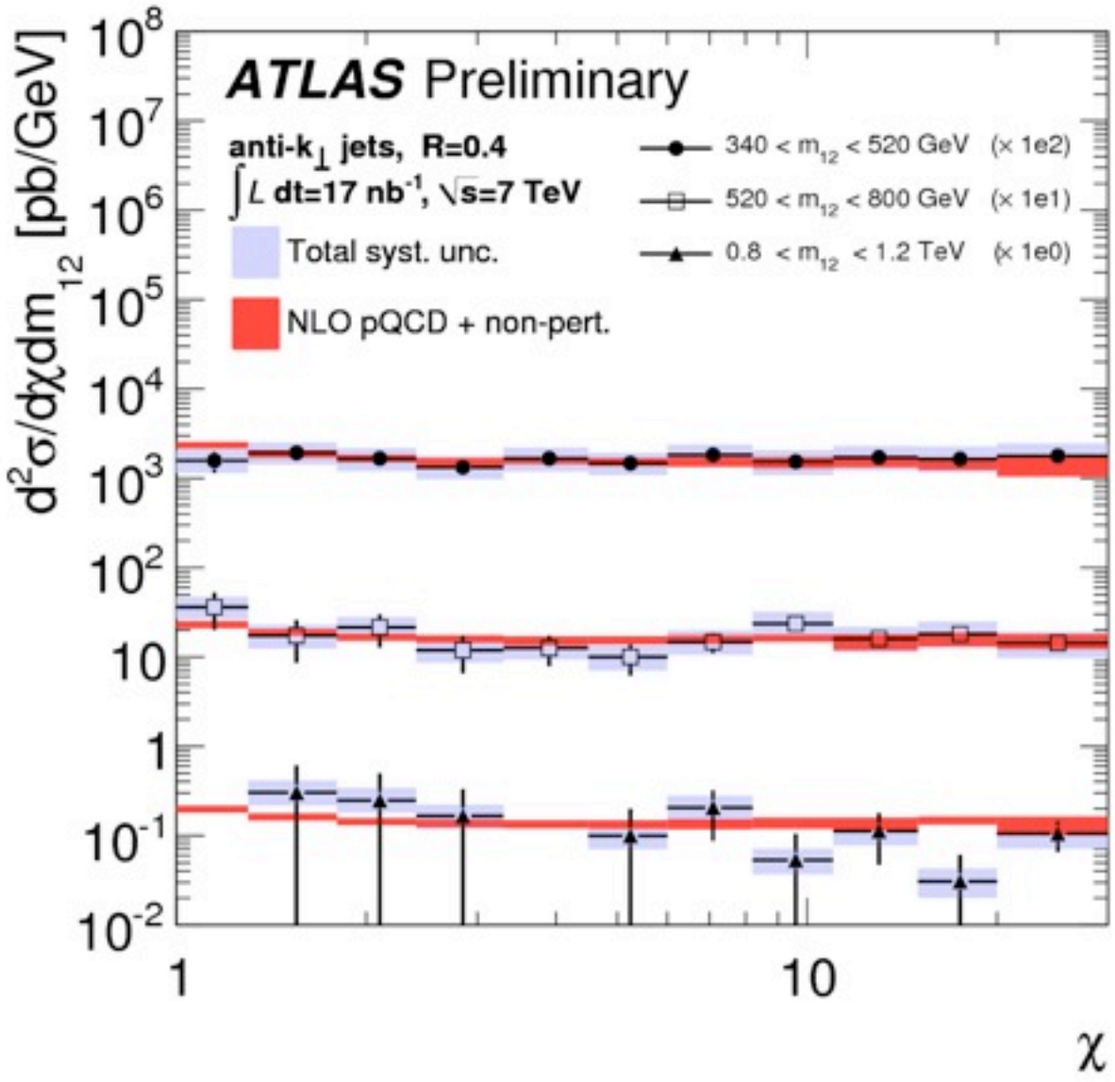


- Events are collected from a combination of Minimum Bias and jet triggers.
- Inclusive jet cross section unfolded to the particle level.
- Main systematics for inclusive jet cross section, as for most other jet analyses:
  - jet energy scale (5%),
  - jet resolutions (10%) and
  - luminosity (11%).
- Inclusive jet p_T spectra are in good agreement with NLO theory.

CMS-QCD-10-011

Dijet Mass and X Distribution: ATLAS



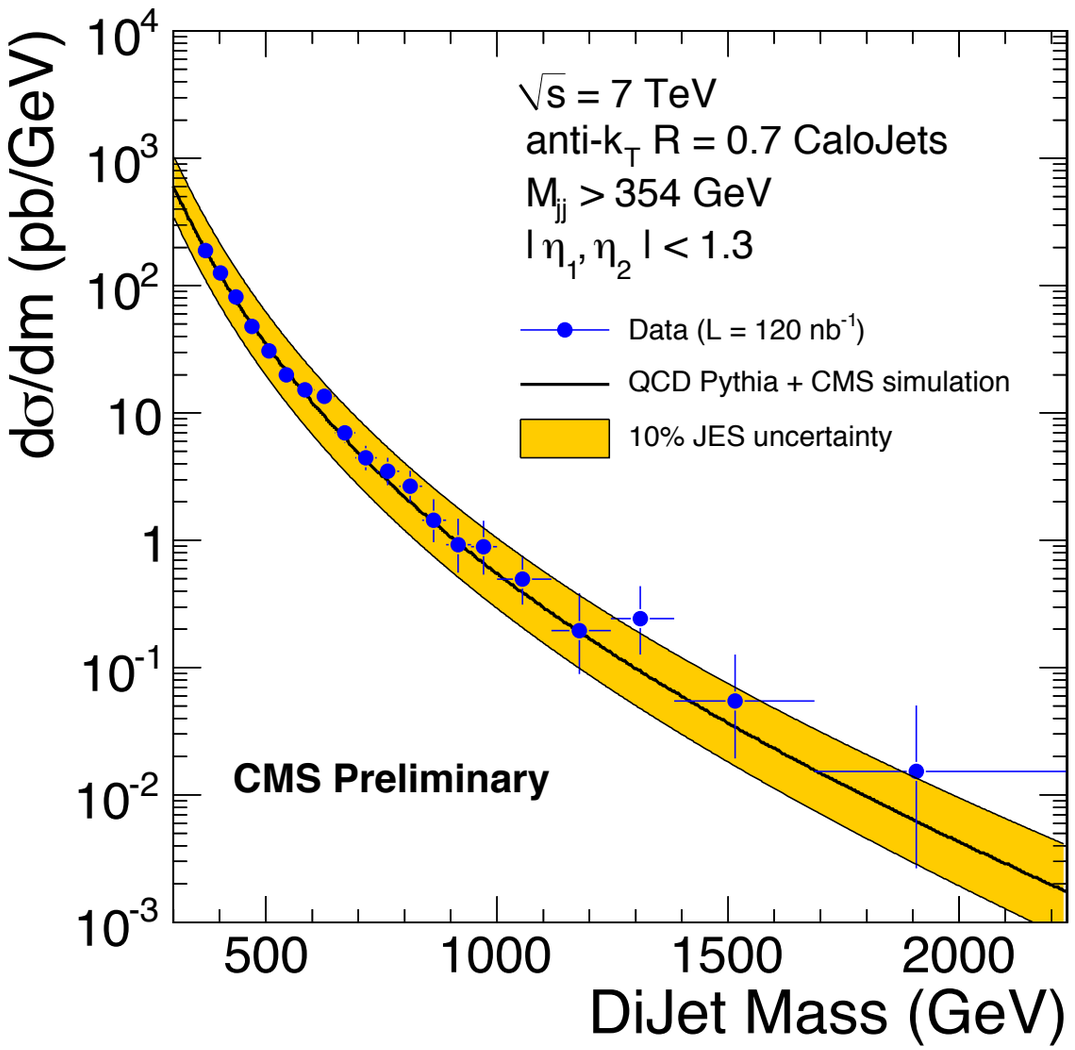


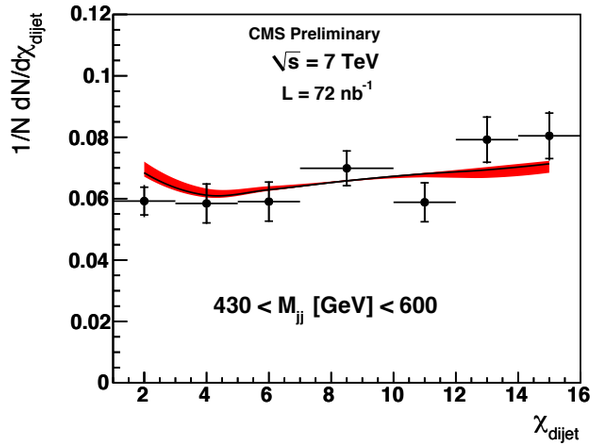
anti-k_T,
lead. jet p_T > 60 GeV,
second lead. jet p_T > 30 GeV,
|y| < 2.8

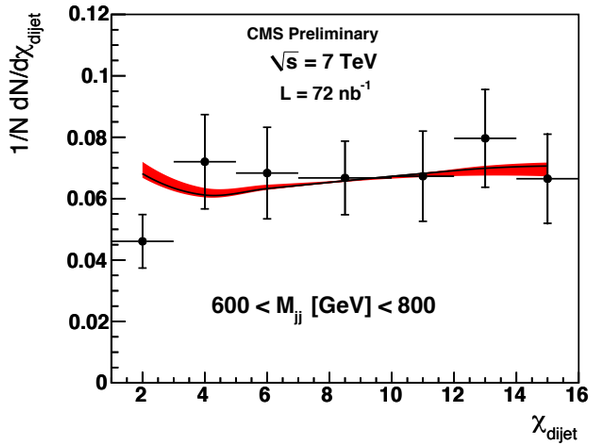
$\chi = \exp(|y1-y2|) \sim (1+\cos\theta^*)/(1-\cos\theta^*)$

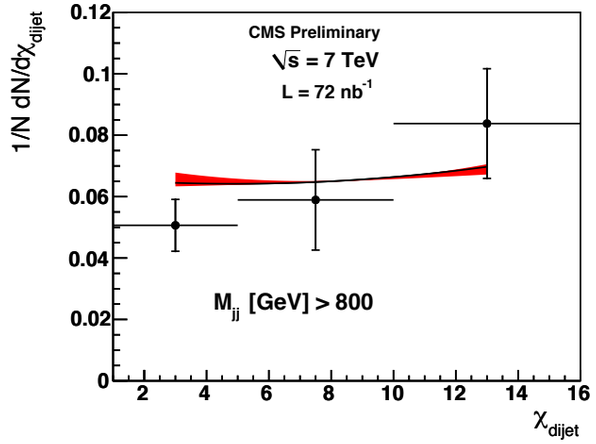
- χ can be used to look for signs of new physics (excess at low χ).

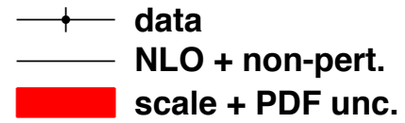
Dijet Mass and X Distribution: CMS









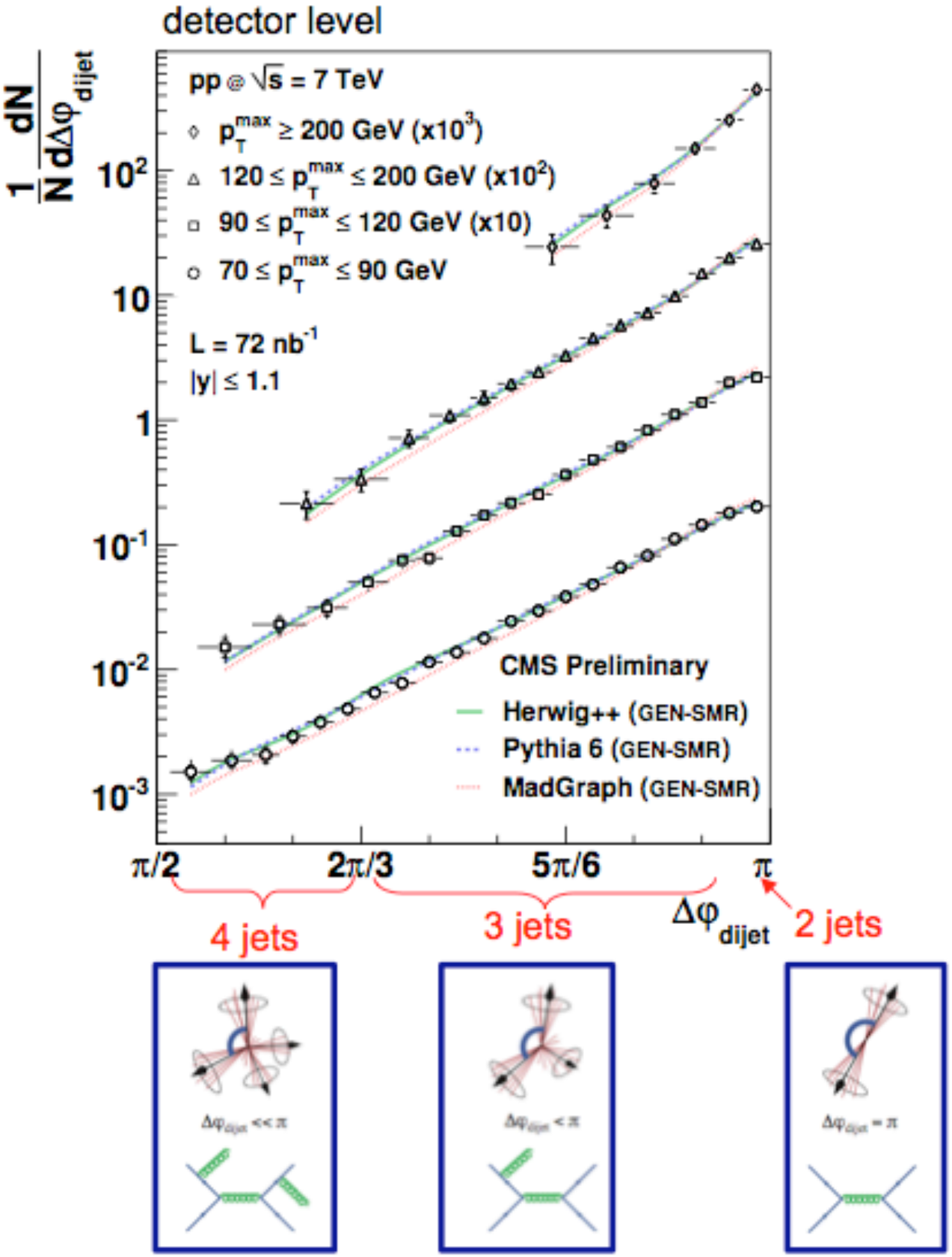


- TeV (dijet) mass range being probed!
- Results presented agree with SM predictions (both from ATLAS and CMS).

CMS-EXO-10-001

CMS-QCD-10-015

Dijet azimuthal decorrelation: CMS

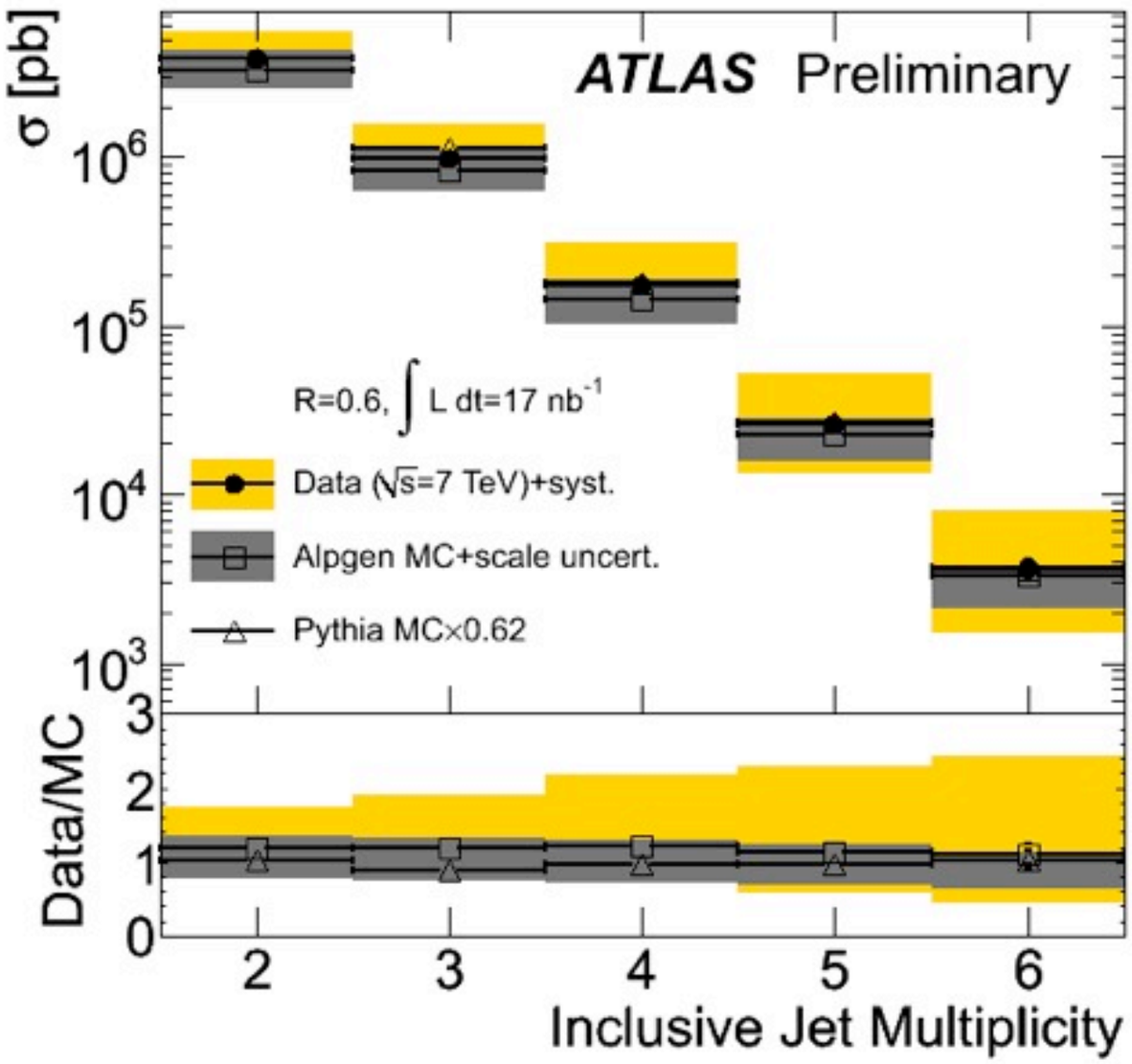


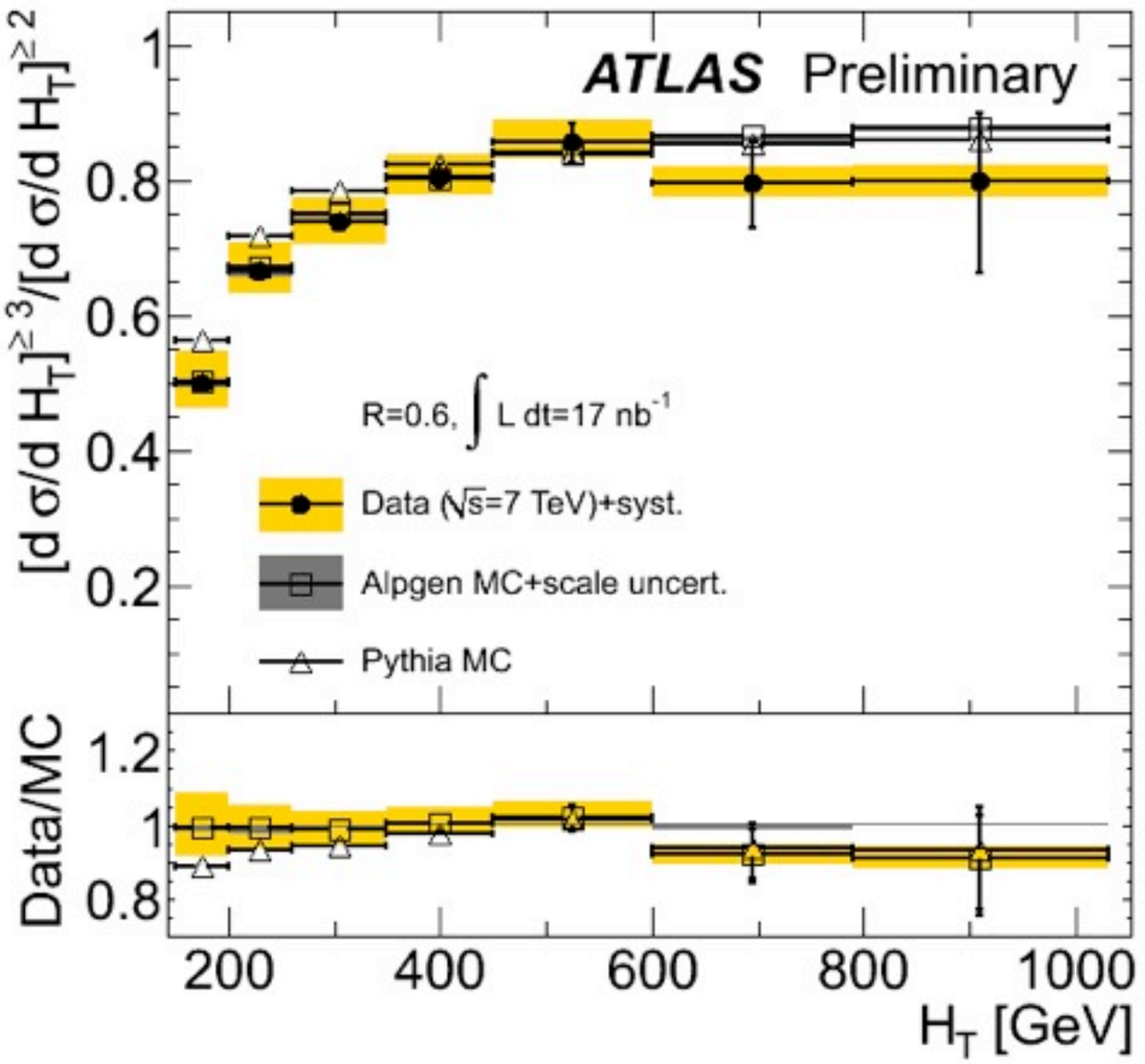
$$\Delta\varphi_{dijet} = \left|\varphi_{jet1} - \varphi_{jet2}\right|$$

sensitive to higher order QCD radiation effects

CMS-QCD-10-015

Multijet production: ATLAS

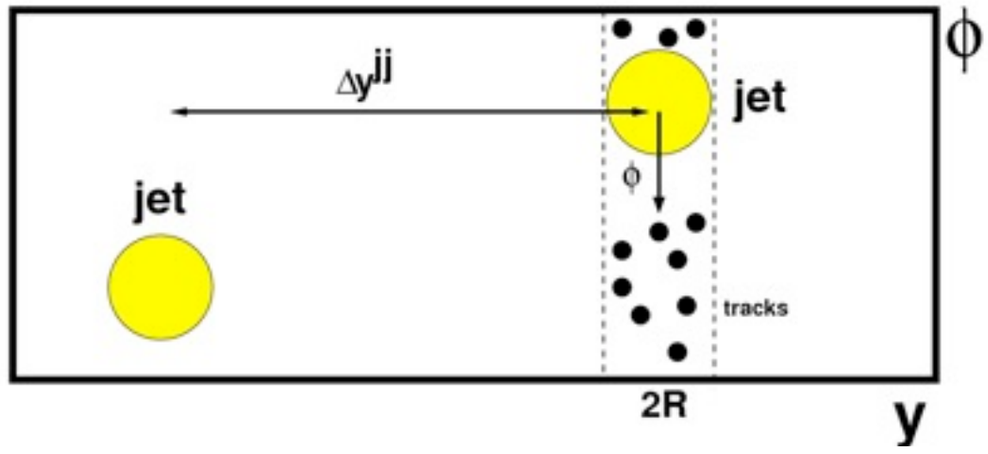




anti-k_T,
p_T > 30 GeV,
|y| < 2.8

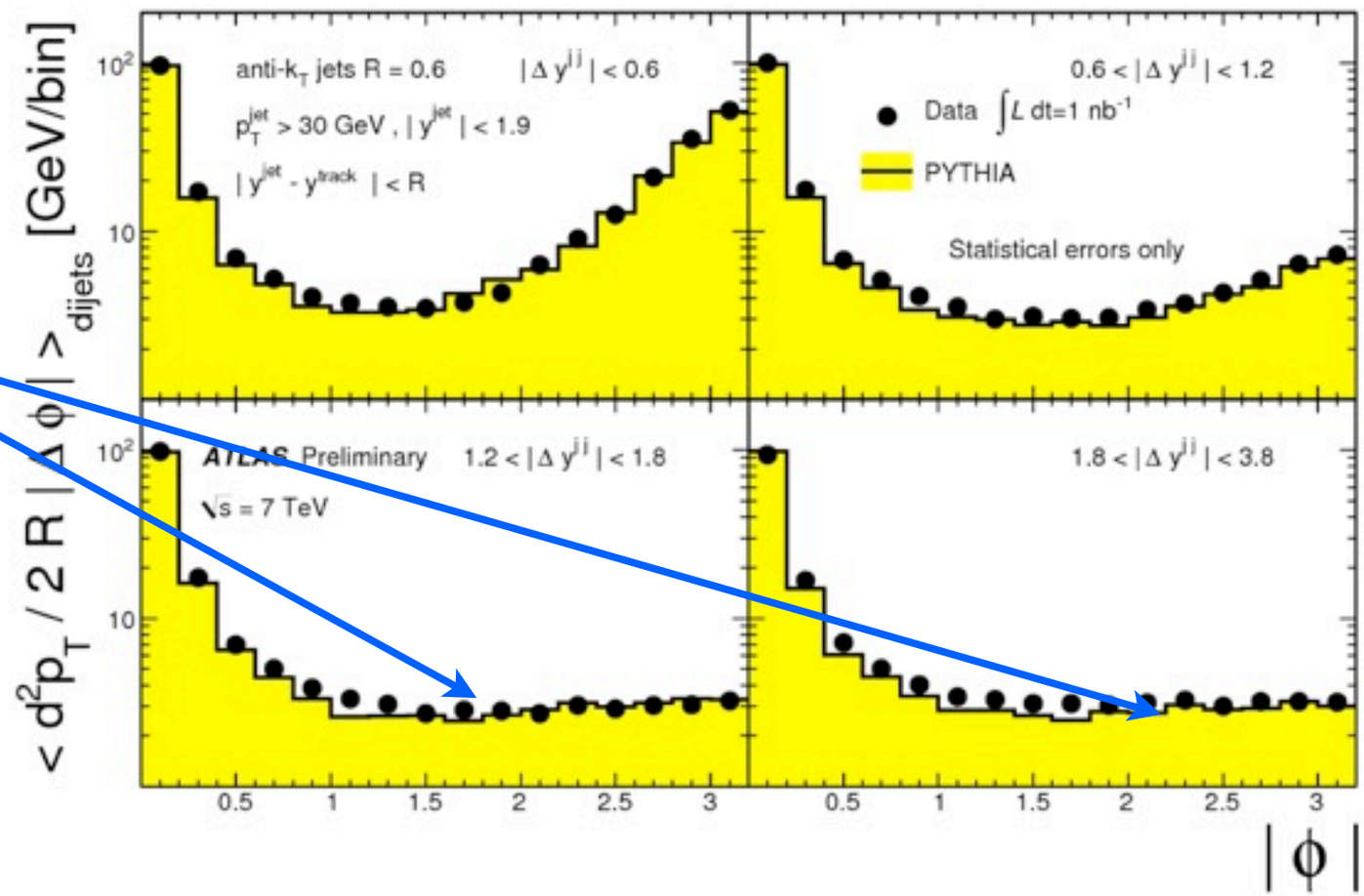
Charged Particle Flow: ATLAS

- independent information (from tracks) on the final state topology.



- $|y^{jet}|<1.9$, so tracks are within the Inner Detector acceptance ($|y|<2.5$)

plateau of remaining hadronic activity



...other results already available (public notes)

- Study of diffractive enhanced (and limited) samples (ATLAS)
- Angular correlation between charged particles (ATLAS)
- Measurement of the UE with the Jet Area approach (CMS)
- MC tuning to early LHC data (ATLAS & CMS)
- Strange particle production (CMS)
- Hadronic event shapes (ATLAS)
- Measurement of dijet production with a jet veto (ATLAS)
- Two particle correlations (CMS)
- Anti-proton to proton ratio (ALICE)
- Measurement of Bose-Einstein correlations (ALICE & CMS)
- ...

...many more to come!

Summary

- **The search for "New Physics" at the LHC has begun with studies aimed at understanding the detector and the hadronic environment in LHC collisions.**

- **Data and QCD predictions are** (generally) **in good agreement.**

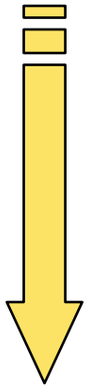
- **"Early" measurements ≠ "Easy" measurements!** Remember: brand new physics environment & new technologies.

  - Performance of trigger systems and detectors have been the focus of this early round of data taking / analysis.
  - Increasing effort is now being shifted to physics analyses.
  - Early characterisation of minimum bias events with track measurements has been successfully performed for both $\sqrt{s}$=900 GeV (2.36 TeV) and 7 TeV.
  - First measurements of the underlying event have also been made.
  - Jet studies are quickly evolving from performance to physics results (check ATLAS and CMS contributions recently presented at ICHEP, HCP and other conferences).
  - Very promising start of a new era of collider physics...discoveries are "just" in the horizon!

Backup

SM at the LHC: what can be done with early data?

- **Goals of SM physics studies with early data:**
  - Use W, Z and top to calibrate the detector & triggers.
  - Control **W**, **Z**, **top** and **QCD multi-jets** to properly estimate the background for physics beyond the SM
  - Improve current SM measurements to provide stringent consistency tests of the underlying theory.



few pb^{-1}
$L \sim 10^{30}$ to 10^{31} cm^{-2} s^{-1}

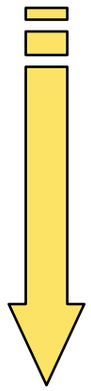
several fb^{-1}
$L \sim 10^{32}$ to 10^{33} cm^{-2} s^{-1}

SM at the LHC: what can be done with early data?

University of Glasgow

Goals of SM physics studies with early data:

- Use W, Z and top to calibrate the detector & triggers.
- Control **W**, **Z**, **top** and **QCD multi-jets** to properly estimate the background for physics beyond the SM
- Improve current SM measurements to provide stringent consistency tests of the underlying theory.



few pb^{-1}
$L \sim 10^{30}$ to 10^{31} cm^{-2} s^{-1}

several fb^{-1}
$L \sim 10^{32}$ to 10^{33} cm^{-2} s^{-1}

☑ Extensive test beam characterization of prototypes and final modules. Also used for validation of G4 simulations.

☐ 'In situ' detector calibration:
- ☑ Cosmics runs;
- ☑ Single beam and beam gas runs during LHC commissioning;
- ☐ Calibration with physics processes;
  - Procedure valid for all sub-detectors, ECAL, HCAL, inner trackers, Muon Chambers.

ongoing...

☐ Need to **"re-discover" the SM** at the LHC before claiming any discovery of new physics!