QCD - experimental part
Jets, Minimum Bias and Underlying Event

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Quinto workshop sulla fisica pp ad LHC

outline

Start with Jets, link with Giulia

- Jet reconstruction algorithms at work:
  - What the two experiments use and how they perform
- Jet energy measurement:
  - brief review of the correction strategies
  - In situ validation
- Analysis with jets:
  - Inclusive jet cross section
  - Jet Shapes
  - Event Shapes

Early measurements: Minimum Bias and Underlying Event

- Basic tools
  - triggers, tracking, particle ID…
- Minimum Bias measurement plans
- Underlying Event measurement and sensitivity to QCD models
- Monte Carlo tuning at LHC

Reconstruction Algorithms

CMS and ATLAS have implemented lots of different algorithm

Cone family (iterative, midpoint, SIS)	ATLAS	CMS
DR	0.4,0.7	0.5,0.7
Seed (if present)	1 GeV	1 GeV
Split and Merging parameter	50%	75%
Input	Towers, Clusters	Towers
Fast K_T	**ATLAS**	**CMS**
D parameter	0.4,0.6	0.4,0.6
Input	Towers, Clusters	Towers

The recombination scheme is simply the 4-vector sum of the constituents (E-scheme)

$$E_{jet} = \sum_{const} E_{const}$$

$$P^i_{jet} = \sum_{const} P^i_{const}$$

A careful study of the jet constituent drove their choice

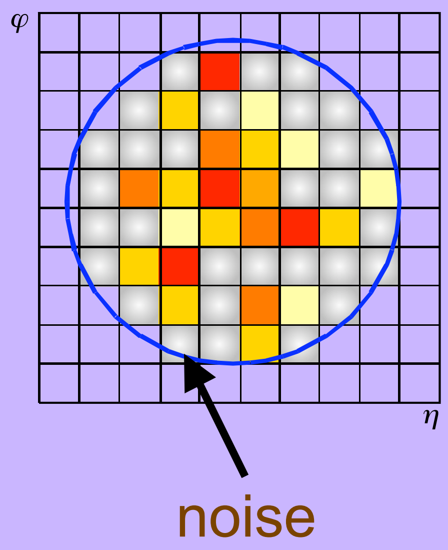
Input to the reconstruction

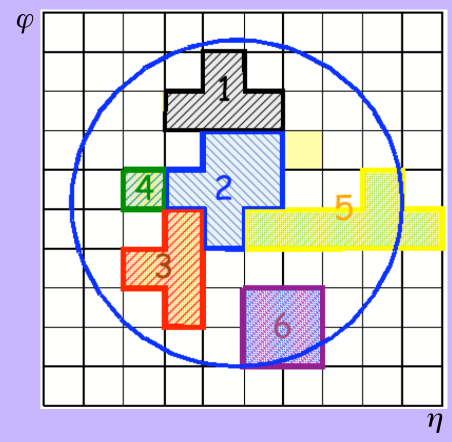
What is the input for the jet reconstruction algorithm?

- The choice is made based on granularity needs, efficiencies, sensitivity to noise, CPU requirements
- The simple choice: calorimeter pseudoprojective towers:
  - The calorimeter granularity drives the size of the tower for ATLAS ($\Delta\eta x \Delta\Phi$=0.1x0.1) and CMS (0.087x0.087 in the central region, increasing with the pseudorapidity)
- Topological cluster building implemented and widely used in ATLAS
- Additional input foreseen for CMS: tracks, Pflow objects (any 4-vector….)

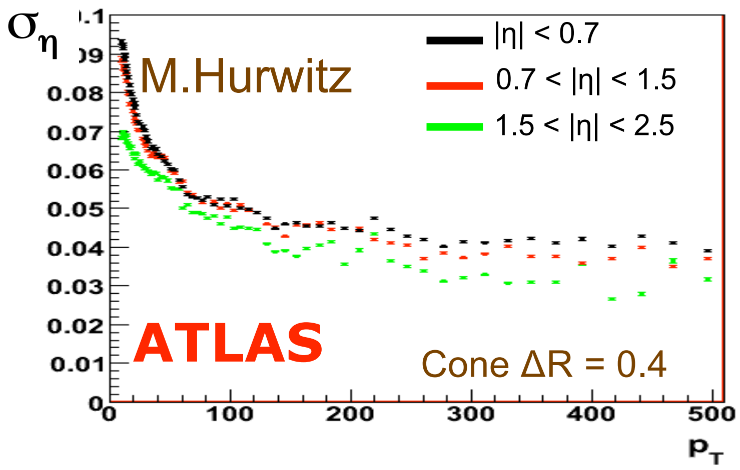
Noise suppression:

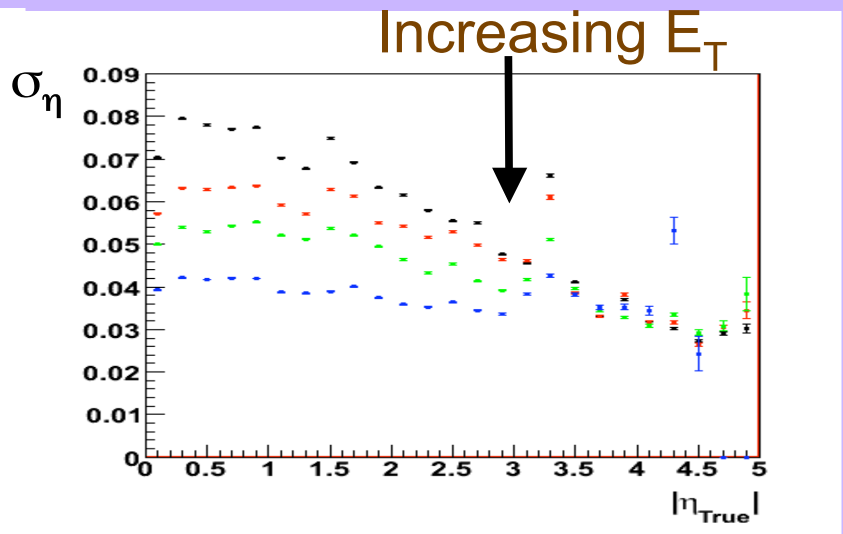
- implemented at tower level for CMS
- ATLAS: not implemented for towers. Topological clusters “based” on noise suppression

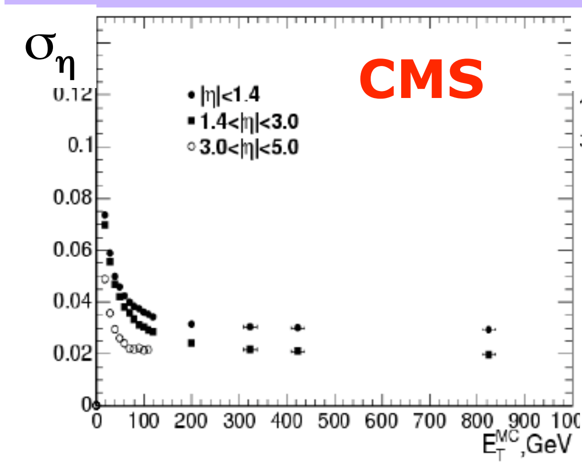


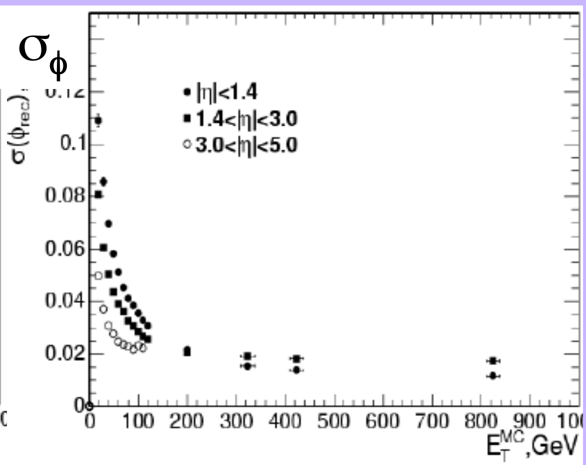


Reconstruction performances - angular resolution









Eg:
ET=100, $|\eta|$<1.
σ ~ [0.04-0.05]

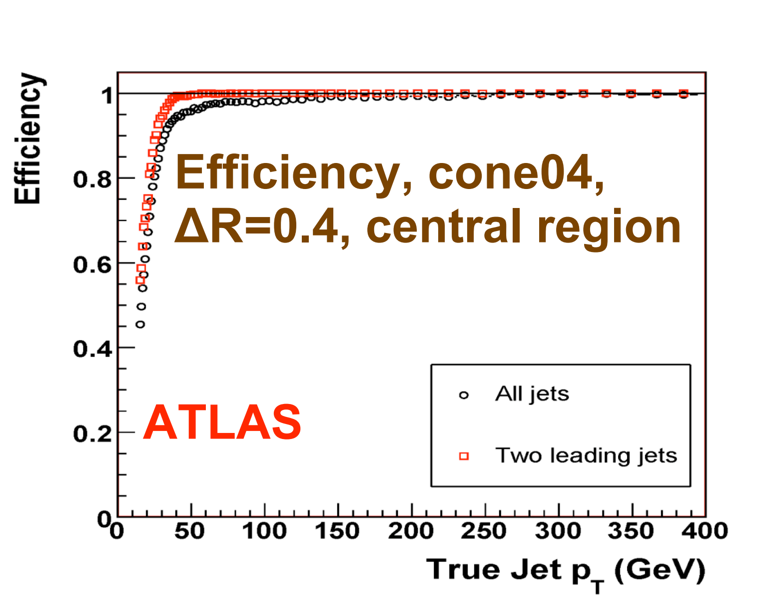
The angular resolution depends on the calorimeter granularity

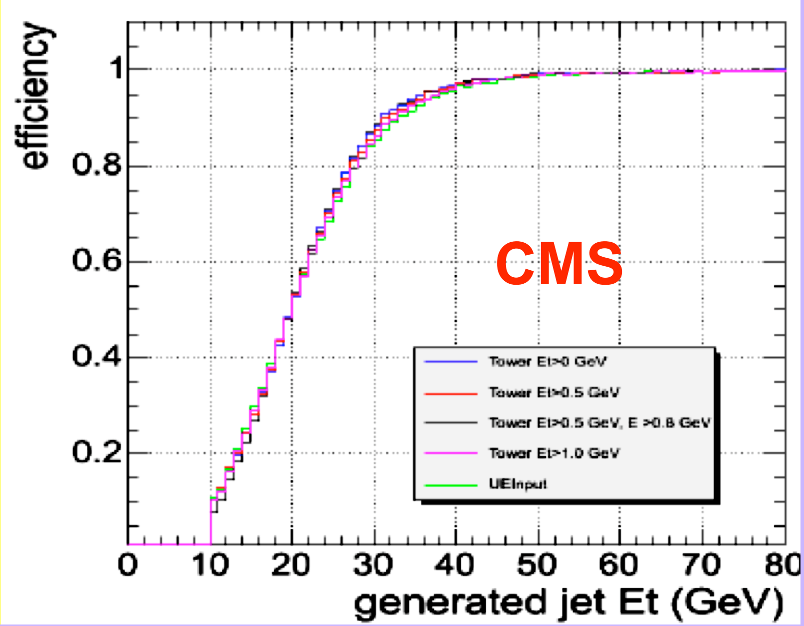
It is energy dependent

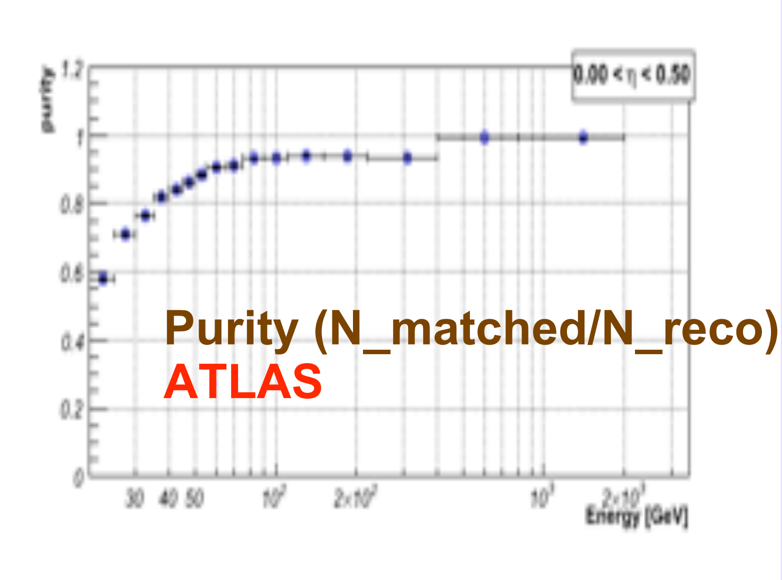
Reconstruction performances - efficiency

Reconstruction efficiencies:

- Important ingredient for, e.g., the inclusive cross section measurement
- The dependence on the jet reconstruction algorithm is found to be small







Reconstruction performances - energy measurement

The jet energy measurement is a complex task:

what enters and where

longitudinal energy leakage

detector signal inefficiencies (dead channels, HV…)

pile-up noise from (off-time) bunch crossings

electronic noise

calo signal definition (clustering, noise suppression ,…)

dead material losses (front, cracks, transitions…)

detector response characteristics (e/h ≠ 1)

jet reconstruction algorithm efficiency

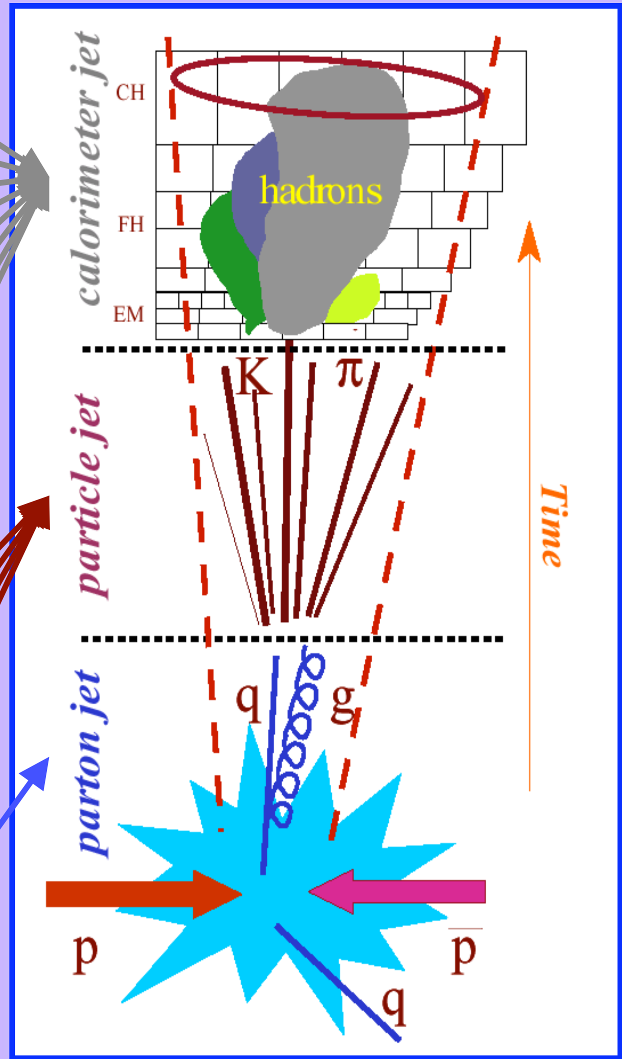
jet reconstruction algorithm efficiency

added tracks from in-time (same trigger) pile-up event

added tracks from underlying event

lost soft tracks due to magnetic field

physics reaction of interest (parton level)



Reconstruction performances - energy measurement

Both ATLAS and CMS are now trying to factorize the problem as much as possible

CMS is discussing an approach a la D0:

- first subtract pileup, then make the detector uniform, compute the absolute response using γ+jet, correct for hadronization…
- **What comes out from this is a parton level jet:**

$$E^{ptcl}_{jet} = \frac{E^{meas}_{jet} - O}{R_{jet}\, S_{jet}}$$

ATLAS applies cell level corrections for detector effects only:

- After the cell level corrections one gets the particle level jet
- Underlying event and hadronization corrections applied (if necessary) to go to the parton level jet

Inclusive Jet Cross Section

Physics motivations:

interesting per-se

("old" and "new" physics)

Background for <u>all</u> the physics channels

Uncertainties from theoretical prediction

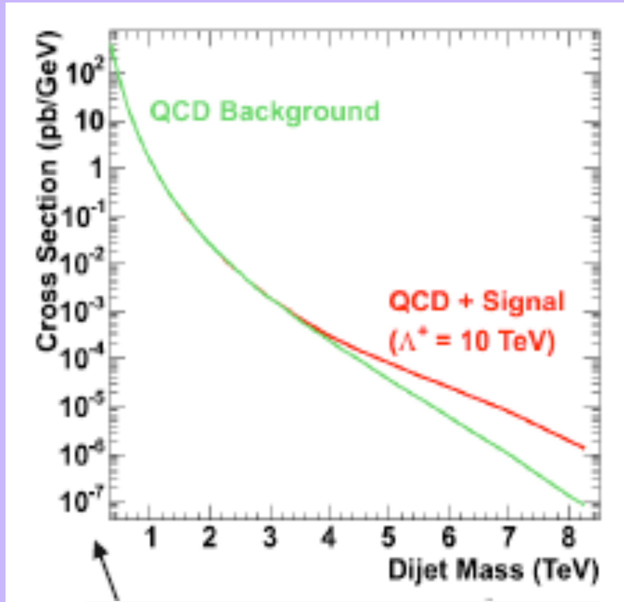
Experimental issues (100 pb^{-1}):

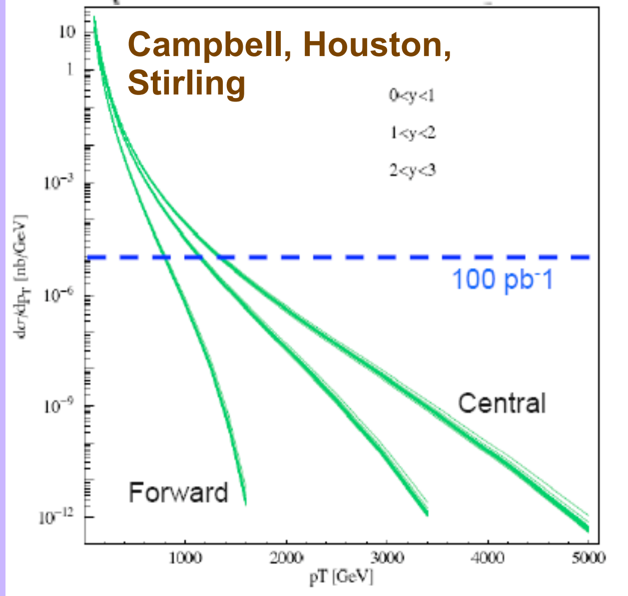
Understanding of the X axis:

- Setting the energy scale and understand its systematic (γ + jets up to ~300 GeV)
- Measure the resolution from the data (di-jet balance)
- Underlying event (tuning with tracks)
- Understand high E_T jets (how do we check the scale at high E_T?)

Understanding the Y axis (jet counting):

- Luminosity
- Jet reconstruction efficiencies
- Jet trigger efficiencies (tag and probe proved to work OK)





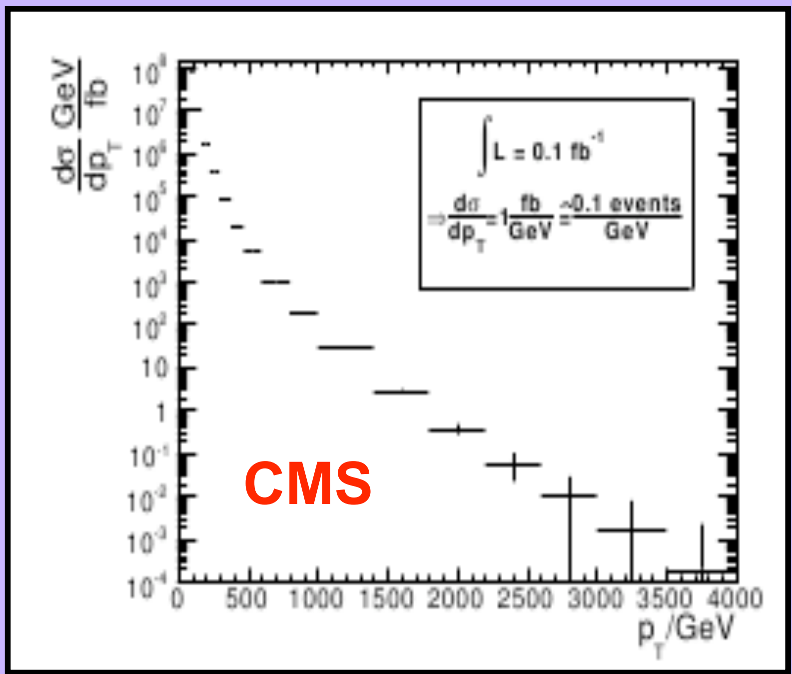
Inclusive Jet Cross Section

Not necessarily an easy measurement:

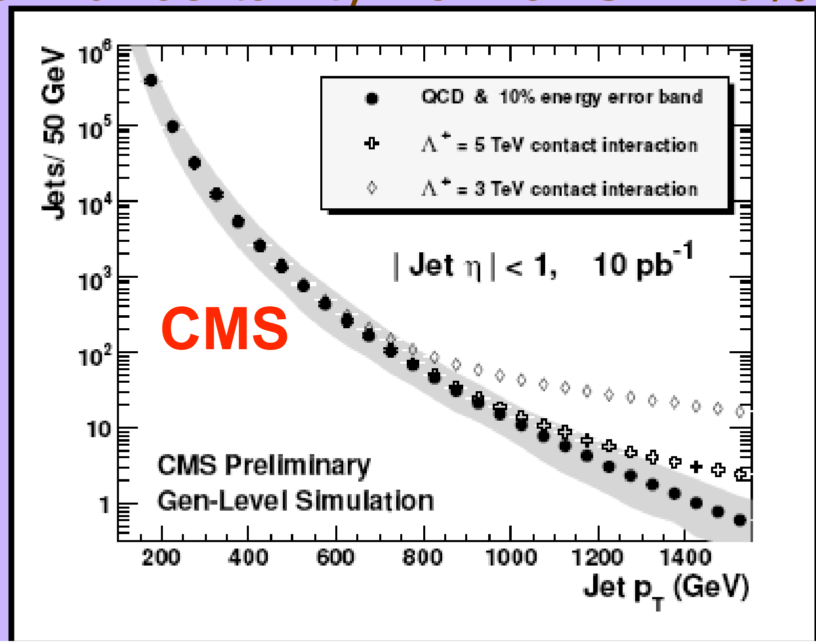
Early data taking characterized by the highest uncertainty on the jet energy scale

Up to what scale can we probe with the first data?

statistical error at 1 TeV is 1.3% with 100 pb^{-1}, 0.4% with 1 fb^{-1}



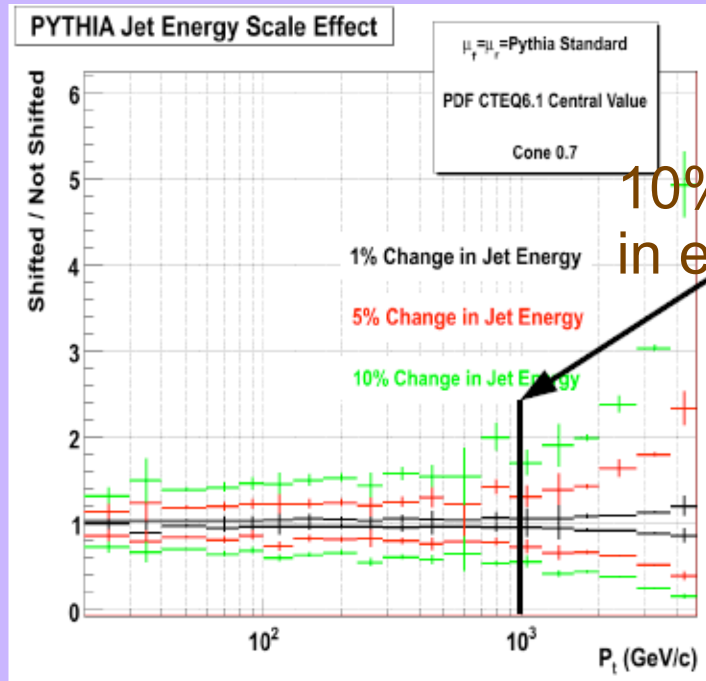
e.g, with 10 pb^{-1} we can probe contact interaction up to ~3 TeV (main uncertainty from JES ~ 10%)

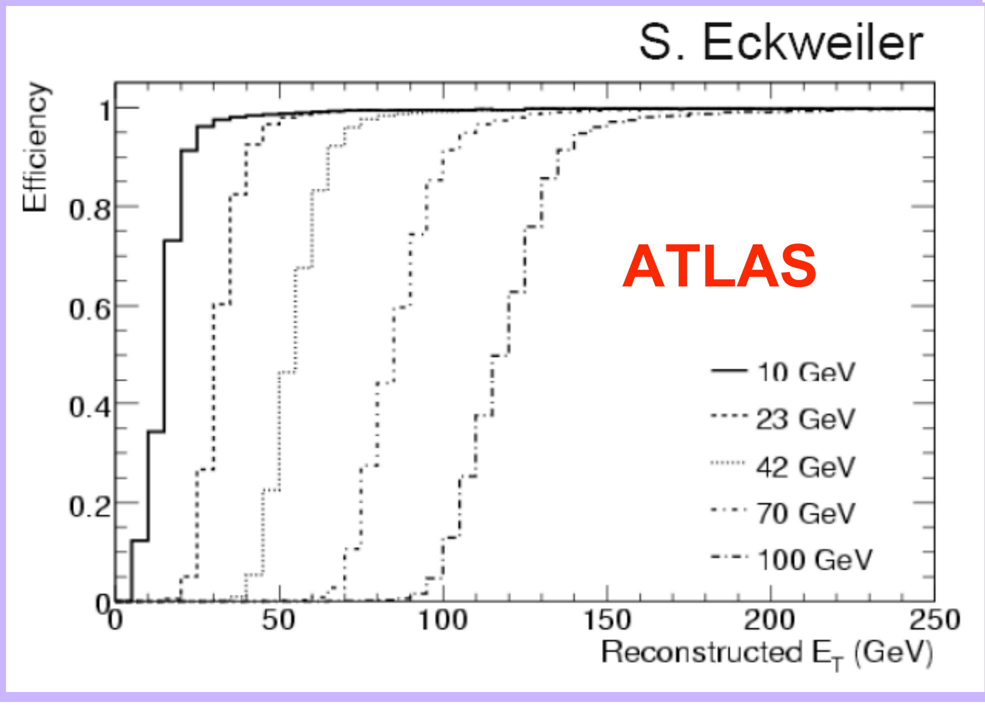


Inclusive Jet Cross Section

The uncertainty on the jet energy scale is the dominant experimental uncertainty:

- 10% error on the energy at 1 TeV means 50% error on the cross section





The jet trigger efficiency can be measured using tag and probe techniques:

- The highest E_T jet is biased
- Look if the trigger is able to see the other jets

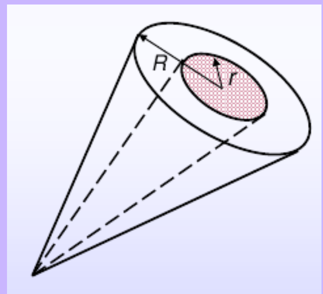
Jet Shape

Jet shapes useful to distinguish gluon and quark originating jets:

- Already used at CDF (hep-ex/0505013v2)
- One possibility is to define

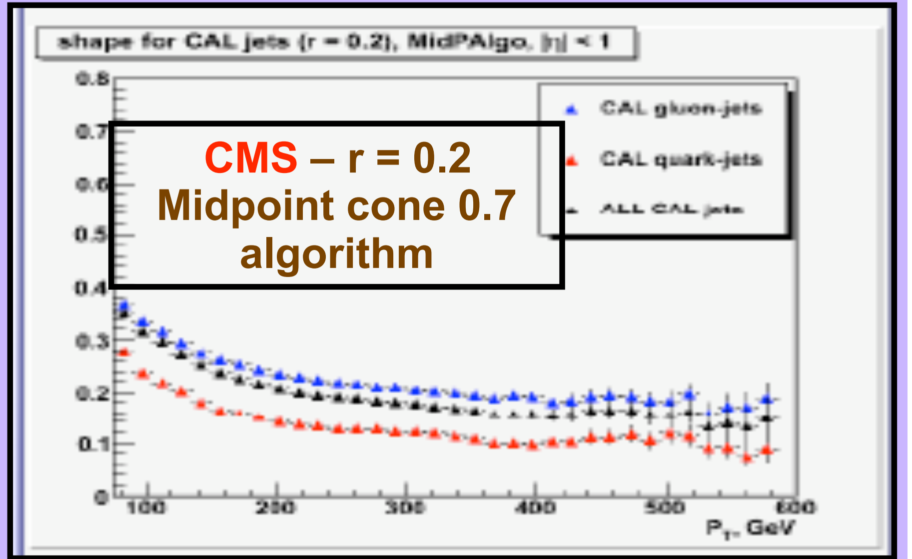
$$\psi = \frac{1}{N_{jets}} \sum_{jets} \frac{P_T(0,r)}{P_T(0,R)}$$

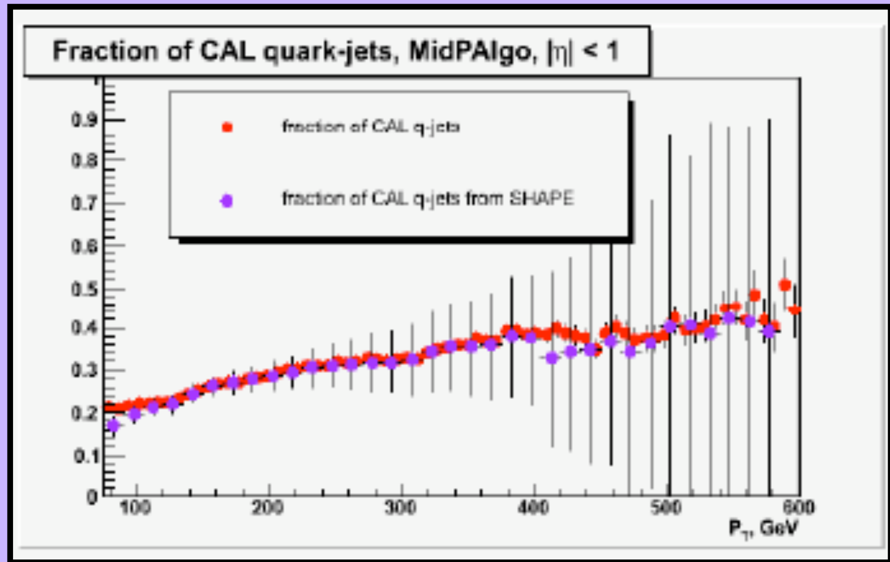
$$SH = 1 - \psi$$



$$F_q^{SH}(P_T) = 1 - \frac{SH_{all-jets}(P_T) - SH_{quark-jets}(P_T)}{SH_{gluon-jets}(P_T) - SH_{quark-jets}(P_T)}$$

Promising to estimate the relative abundance of gluon and quark jets



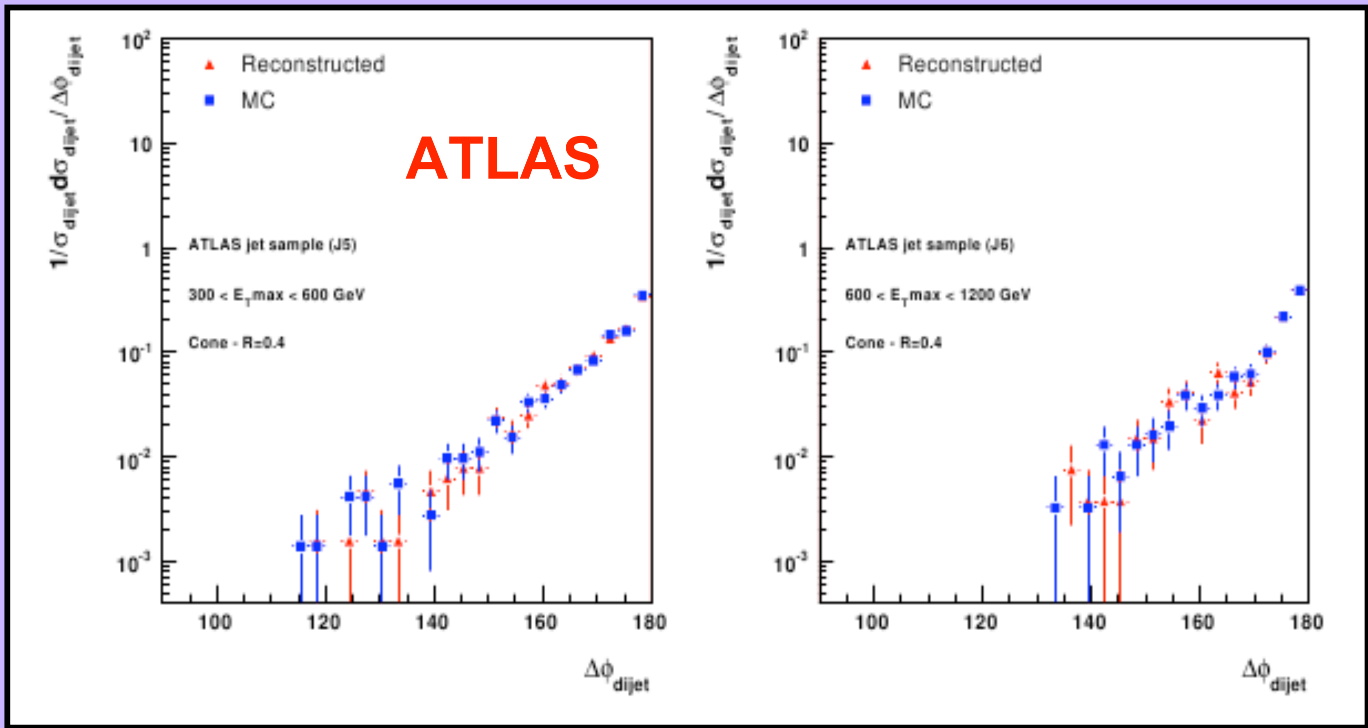


Angular decorrelation

The angular distance (Δφ) between the leading and the next to leading jet in QCD "di-jet" events is sensitive in particular to hard radiation :

- Already measured by D0 at 1.96 TeV
- Not sensitive to "reconstruction details"
- It is an important tool to tune the event generators

The quality of the jet reconstruction will allow to repeat the measurement at LHC



Event shape

Something new: a study of the event shapes at CMS

Event shapes are robust against experimental issues

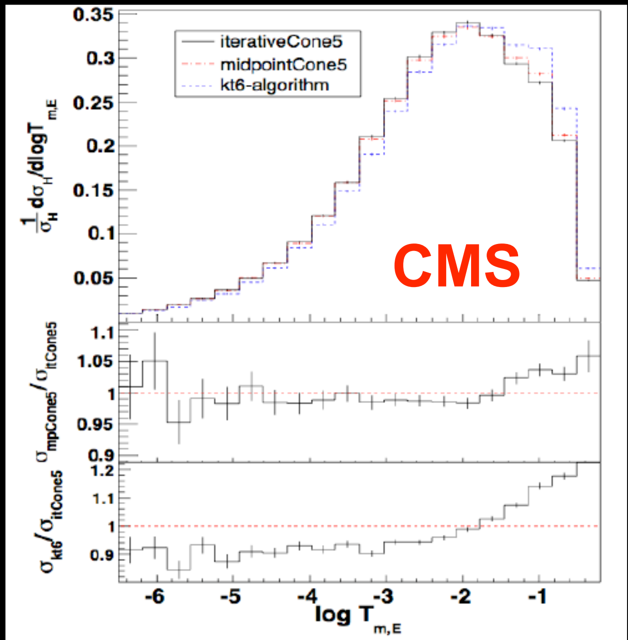
(see Giulia's talk)

- Not too sensitive against jet scale and jet resolution issues
- Not too sensitive to the jet reconstruction algorithm

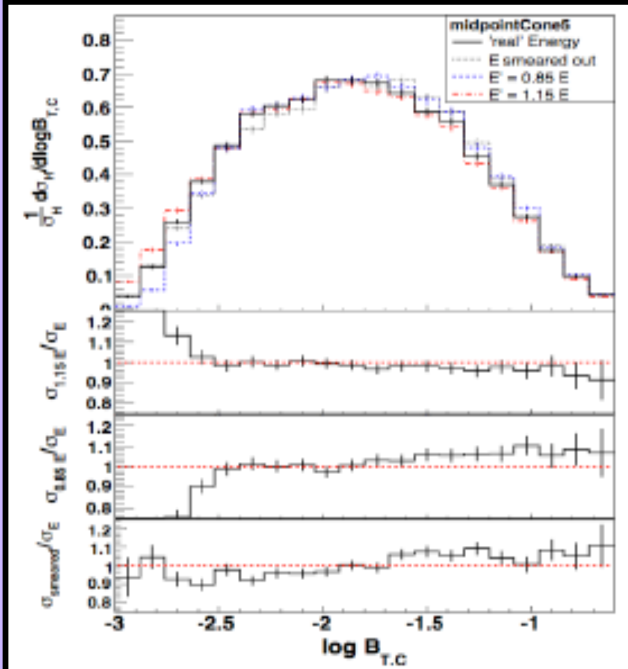
Study on a "toy" MC:

- change of ±15% in the particle jet scale
- Smearing/ No smearing

Small (o(10%)) impact on the measurement



central thrust minor with exp. suppressed forward term
50 GeV < Et[1] < 80 GeV



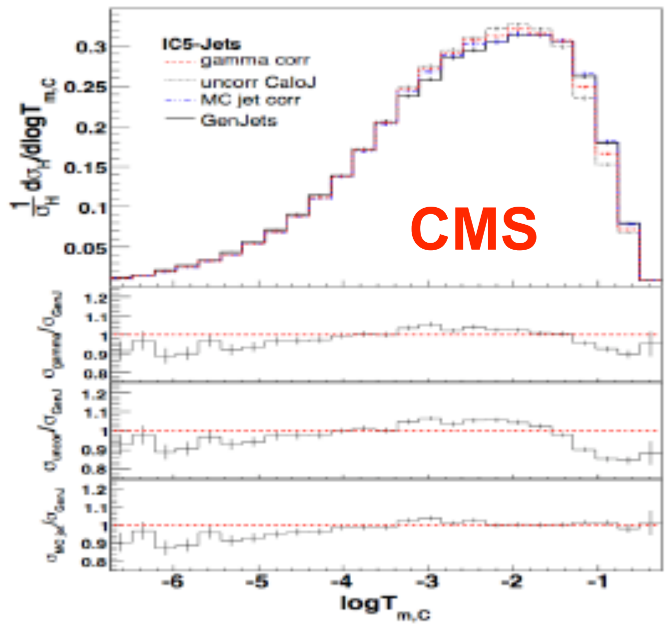
central total jet broadening
120 GeV < Et[1] < 170 GeV

Event shape

Study carried out also in full simulation:

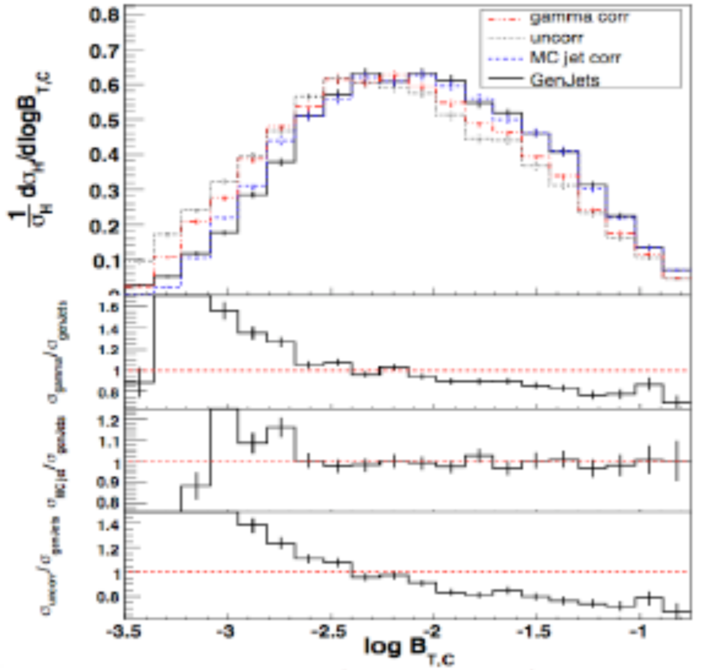
- In general, a good agreement between the particle and reconstructed jets
- global thrust shapes well reproduced at reco level
- Some of the central shapes have problems with the jet scale and resolution

Low dependency on the jet algorithm confirmed at reco level



central thrust minor

130 GeV< Et[1] <185 GeV, QCD_120_300



central total jet broadening

230 GeV < Et1<325 GeV, QCD_300_380

QCD with Jet - summary

The most used jet reconstruction algorithms are implemented in ATLAS and CMS

Long and deep studies have been done or are ongoing on their performance

Scale corrections highly factorized both in ATLAS and CMS

Jet scale is an issue for the early data. Reasonable to assume 5%-10% of systematic uncertainty

Many analysis going on both in ATLAS and CMS. The inclusive jet cross section suffers from JES uncertainty

Strategies on how to asses the jet performance with data are in place

In general, the detector reconstruction looks satisfactory with simulated data

The LHC experiments are getting ready for the jet reconstruction and analysis.

Minimum Bias and Underlying Event
Motivations

Exploring Fundamental aspects of hadron-hadron collisions

Describe QCD@LHC in the best way

Not enough to rescale conclusions from Tevatron to 14 TeV
[different Q^2, x range and energy dependence of the cutoffs]

Structure of hadrons

Factorization of interactions
spin offs on other relevant physics

Calibration of major physics tools

Low, medium and high-PT QCD affected by “surrounding” processes which affect:

Pile up understanding, jet energy, isolation performances,
vertexing, detector responce, High-PT background…

Tuning of Monte Carlo Models

Both not-perturbative and perturbative aspects

Remnants, I-FSR radiation, MPI…
(UE activity, minijet, hard scattering)

Understanding the detector

occupancies
background
…

Introduction

A proton-proton collision is a combination of "soft" and occasionally "hard" process

$$\frac{d\sigma}{dt} \sim A + B\alpha_S + C\alpha_S^{\ 2} + D\alpha_S^{\ 3} + \ldots$$

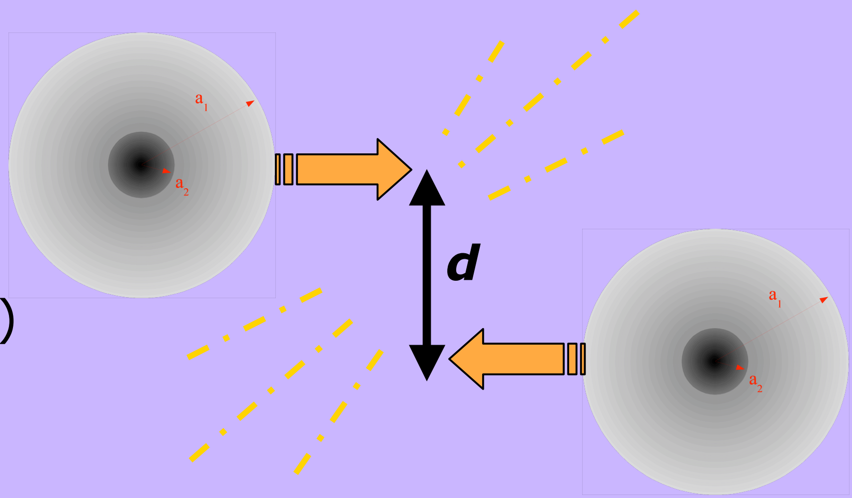
…pQCD well describe hard process

Modeling the collision:

+pQCD is applied to describe high-PT parton-parton scattering
+attempt to extend high-PT treatment to low-PT region
(using the cutoff P_{t0} to regularize the x-section)
+MPI can occour

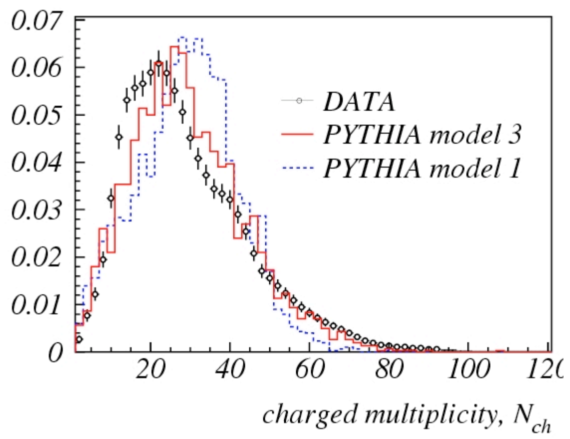
$$\sigma_{\text{int}} = \int_{P_{T_{min}}}^{s/4} \frac{d\sigma}{dp_t^{\ 2}} dp_t^{\ 2}$$

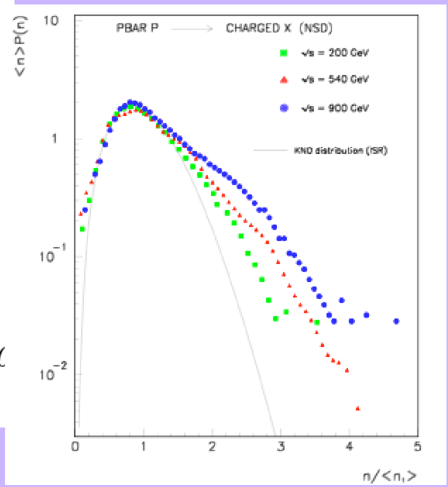
$$P_{T_{min}}^{(s)} = P_{T_{min}}^{(s')} \left(\frac{s}{s'}\right)^{\epsilon}$$



$n \sim \sigma_{\text{int}}$
Lower P_{Tmin} -> higher n (# inetractions)
Lower d -> higher probability to have
an hard-scattering

Past observation and MPI





ISR, FSR, SPECTATORS are not enough to account from the observed multiplicities, P_T spectra, KNO scaling violation (CDF, AFS, UA1…)

The Pythia solution:

[T. Sjöstrand et al. PRD 36 (1987) 2019]

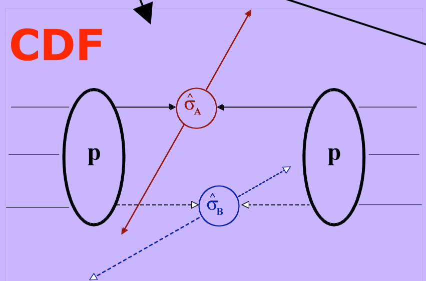
Multiple Parton Interactions (MPI)

Main Parameter: P_T cut-off P_{T0}

$$\sigma(\widehat{P}_T) \rightarrow \sigma(\widehat{P}_T) \cdot \frac{(\widehat{P}_T)^4}{((\widehat{P}_{T0})^2 + (\widehat{P}_T)^2)^2}$$

Inspired by observations of double high P_T scatterings

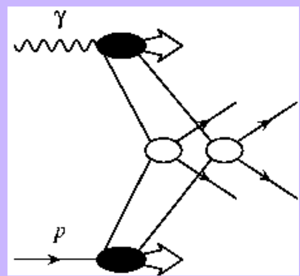
1) **CDF**



$$p\bar{p} \rightarrow \gamma / \pi^0 + 3\, jets + X$$

Phys. Rev. Lett. **79** (4) 584 (1997);
Phys. Rev. D **56** (7) 3811 (1997).

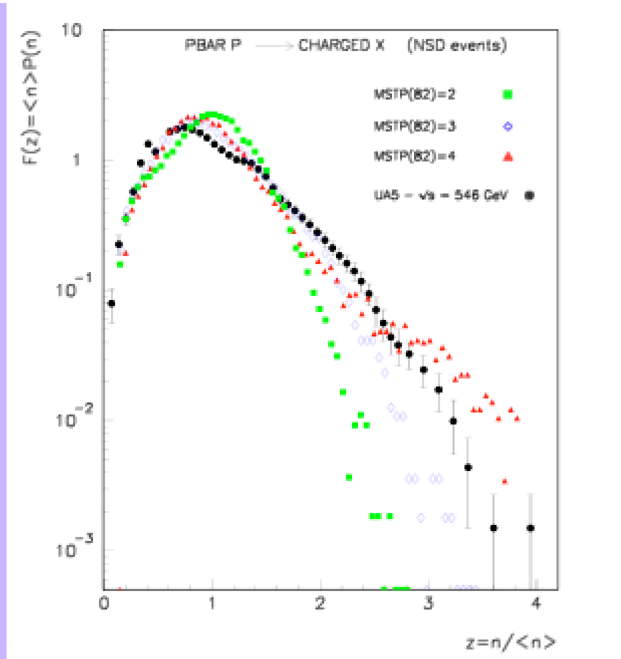
2)



Photoproduction at HERA

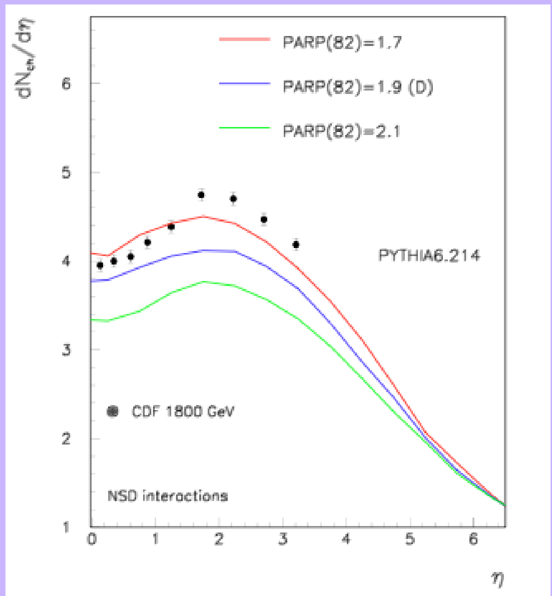
Z. Phys. C**72** (1996) 637.

Modeling the MPI (pythia)



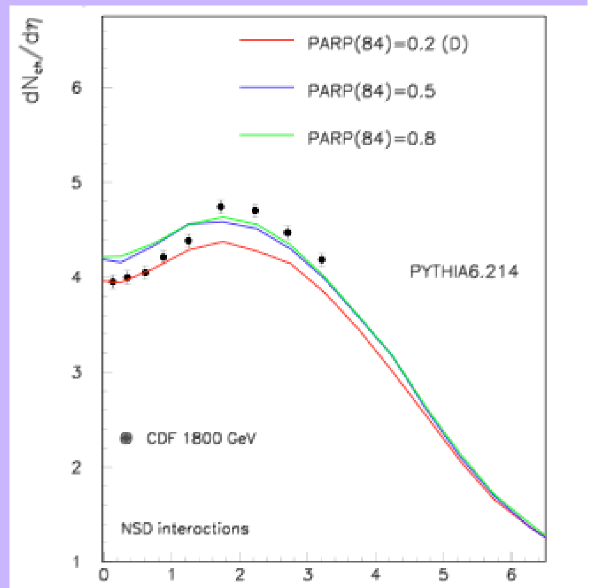
There are two options for multiple parton scattering [MSTP(82)] :

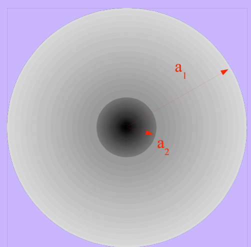
- "simple" scenario abrupt cut at pt_{min}
- "complex" scenario smooth transition



PT cut [PARP(82), PARP(90)]

$$P_{T_{min}}^{(s)} = P_{T_{min}}^{(s')}\left(\frac{s}{s'}\right)^{\epsilon}$$





Proton matter distribution [PARP(84)]

$$\rho(r) \propto \frac{1-\beta}{a_1^3}\exp\left\{-\frac{r^2}{a_1^2}\right\} + \frac{\beta}{a_2^3}\exp\left\{-\frac{r^2}{a_2^2}\right\}$$

Definitions

Minimum Bias (main component of the pileup):
Generic p-p interaction (hard, soft, SD, DD…)

σ_{tot}	$= \sigma_{Elastic}$	$+ \sigma_{SD}$	$+\sigma_{DD}$	$+\sigma_{HardCore}$	
(14 TeV)	~20 mb	~15 mb	~10 mb	~55 mb	= ~100 mb

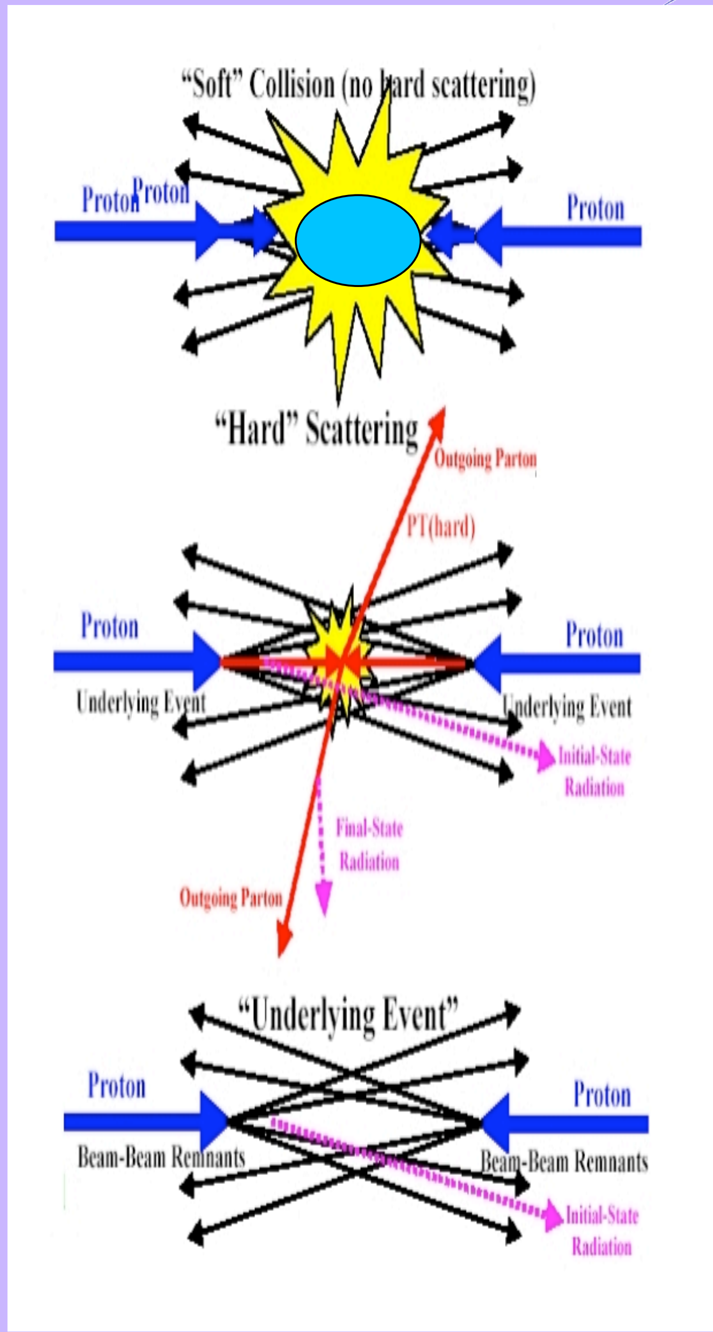
Underlying Event:
All the activity from a single p-p interaction superimposed to the hard scattering process

+ Initial and final state radiation
+ Spectators
+ beam-beam remnant
+ Multiple Parton Interactions

The UE is related to the hard scattering

+ primary vertex sharing
+ "pedestal effect"
  (events with high pt jet in the final state show an higher UE activity)
+ color and flavor connected

UE!=Minimum Bias
but phenomenological aspects are similar



pQCD models

Eg: effect on base MB observables
pp@14 TeV

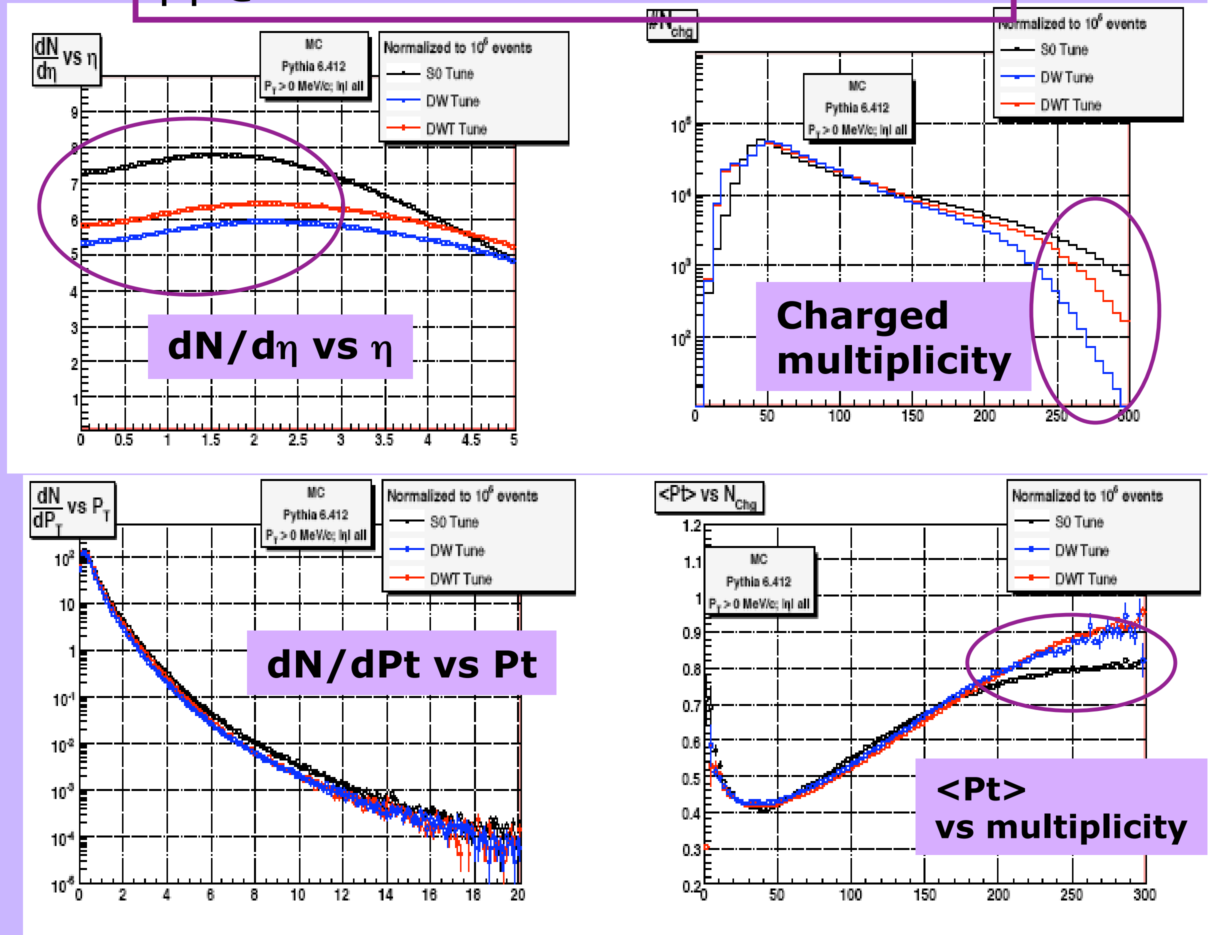
Generators setup used
(details in backup slides)

+ **Pythia Tune DW**
(from TuneA)
OLD MPI model,
IP CORRELATIONS

+ **Pythia Tune DWT**
DW and
default PT-cut-off evolution

+ **Pythia Tune S0**
New MPI, more correlations

+ HERWIG
NO MPI, reference



All these Pythia Tunes describe the UE@Tevatron, but show several **differences extrapolating to LHC energy**
Not enough to re-scale conclusions to 14 TeV
[different Q^2, x range and energy dependence of the cutoffs]

MB Triggers

+ Using forward detectors

+ Random trigger (inefficient for Nint<<1)

+ Pile up from other streams
  (jet or lepton triggers as example)

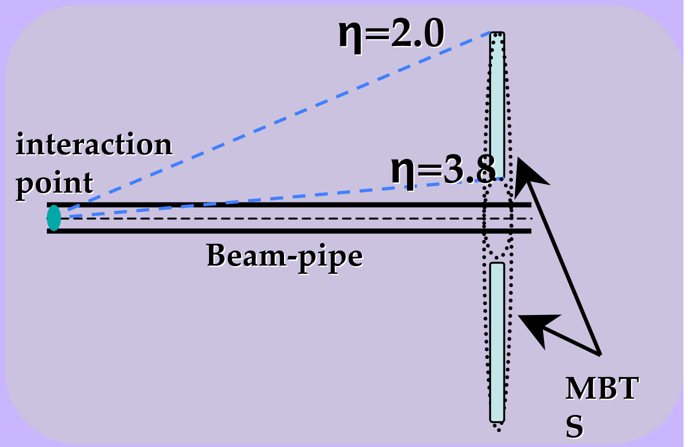
Best solution, at the moment, seems to be the one based on forward detectors

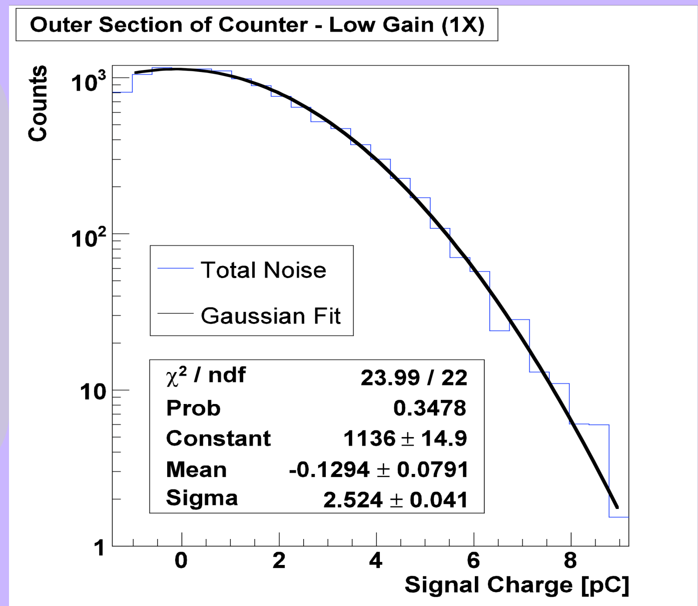
The use of pile up from other streams could introduce biases (under study)

MB Triggers - **ATLAS**

MBTS Trigger scintillation counters mounted on end of LAr calorimeter covering same radii as the inner detector

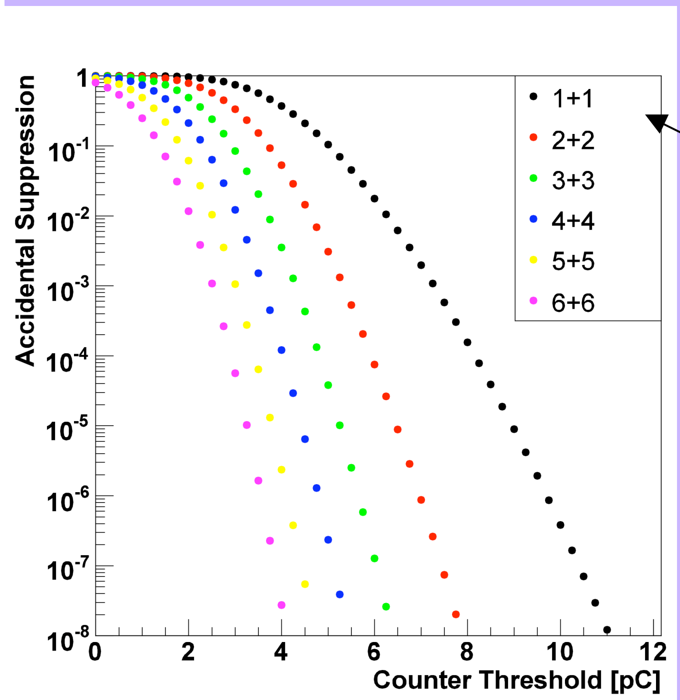
(minimum bias trigger scintillator)





Noise spectrum fits well to a Gaussian with σ=2.52pC

Beyond 9pC (almost 4σ), non-Gaussian behavior is possible



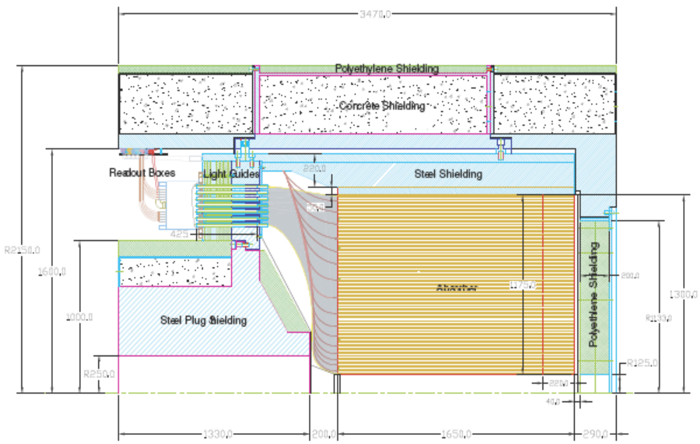
# of backward-forward coincidences

+ Accidental rate from noise must be suppressed to ~Hz, limited by EF output-rate of 100Hz

+ Suppression required of $(10^{-6})10^{-7}$ at (900 GeV) 14 TeV

MB Triggers - **CMS**

Idea: Based on Hadron Forward Calorimeter

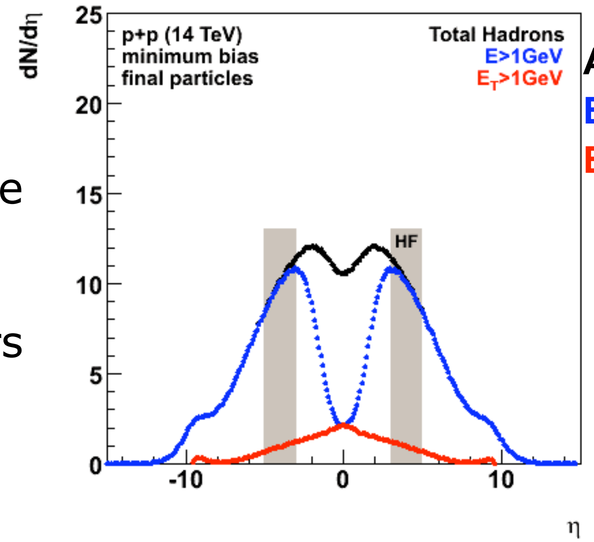


$3<|\eta|<5$

18 wedges/side

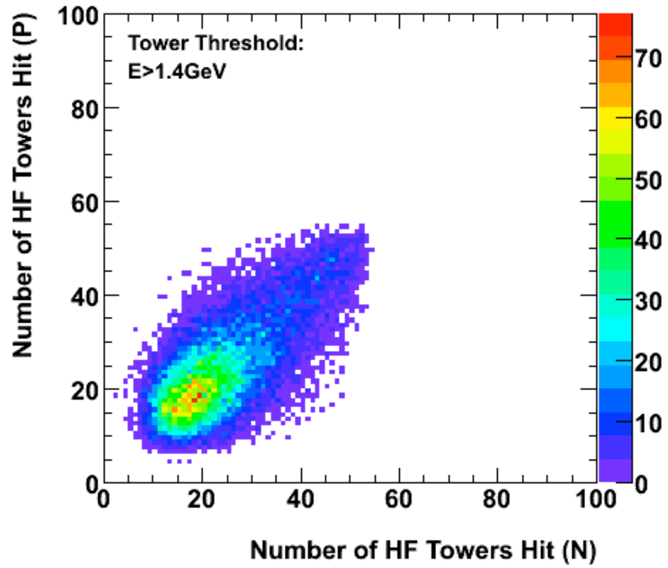
0.175x0.175 towers

Ongoing studies:
Generator level

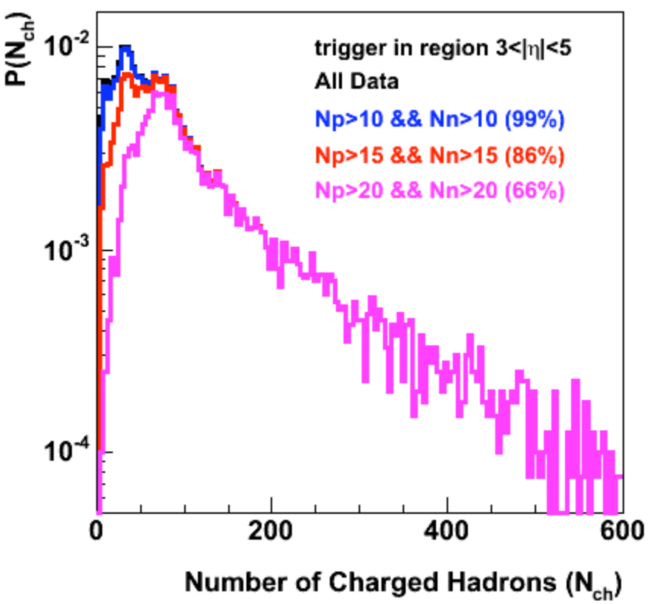


All
E>1GeV
E_T>1GeV

Using towers or single cells fired



Triggering Biases on minimum bias p+p collisions



Cut on the number of calorimeter cells

>10 cells hit

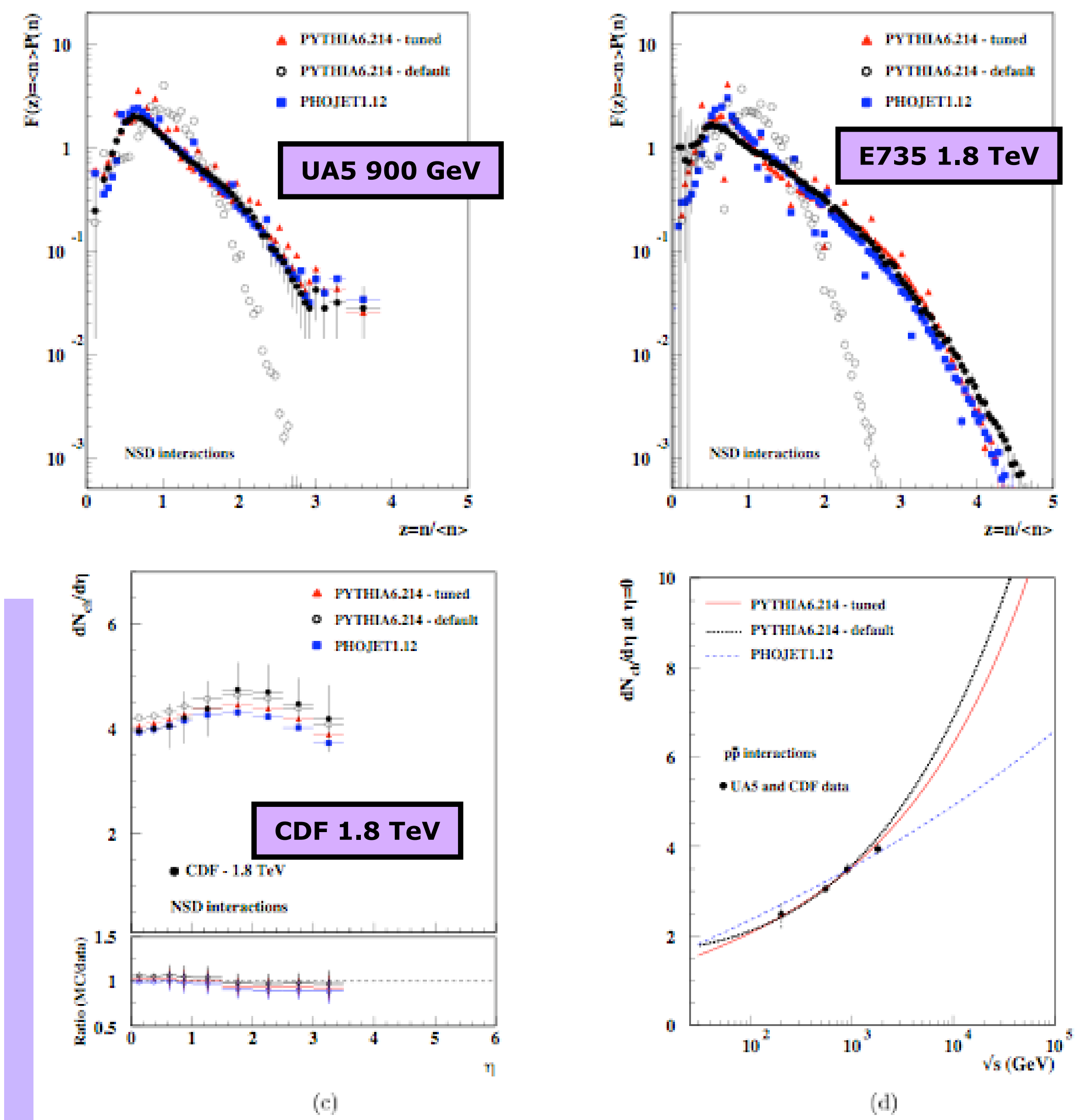
99% efficient

>10 forward cells and
>10 backward cells

>15 → 86%

>20 → 66%

MB measurement - **ATLAS** predictions

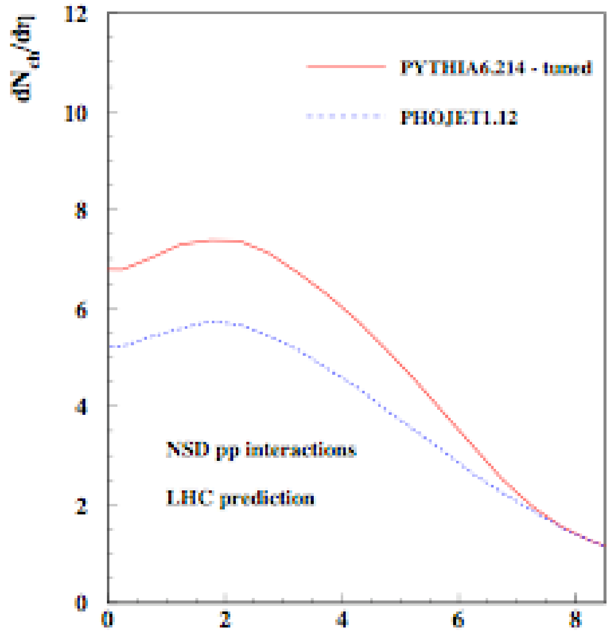


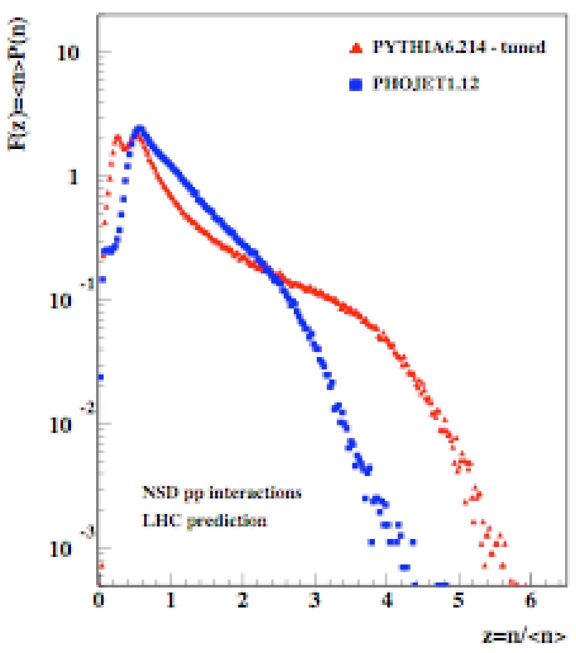
Starting from KNO scaling on past experiment:

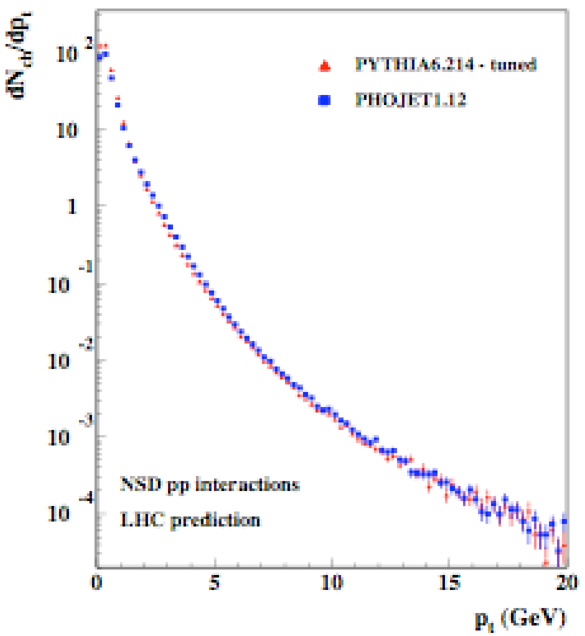
+ Observables are defined
+ Models are exploited
+ **Tune based on MB and UE observables** are chosen

Models	$\chi^2_{\text{min-bias}}$	χ^2_{UE}	χ^2_{global}
PHOJET1.12	8.15	7.35	7.95
PYTHIA6.214 - tuned	11.62	2.07	9.27
CDF tuning	26.66	1.31	20.43
ATLAS - TDR	38.98	15.03	33.09
PYTHIA6.214 - default	68.01	22.68	56.87

MB measurement plan - **ATLAS**



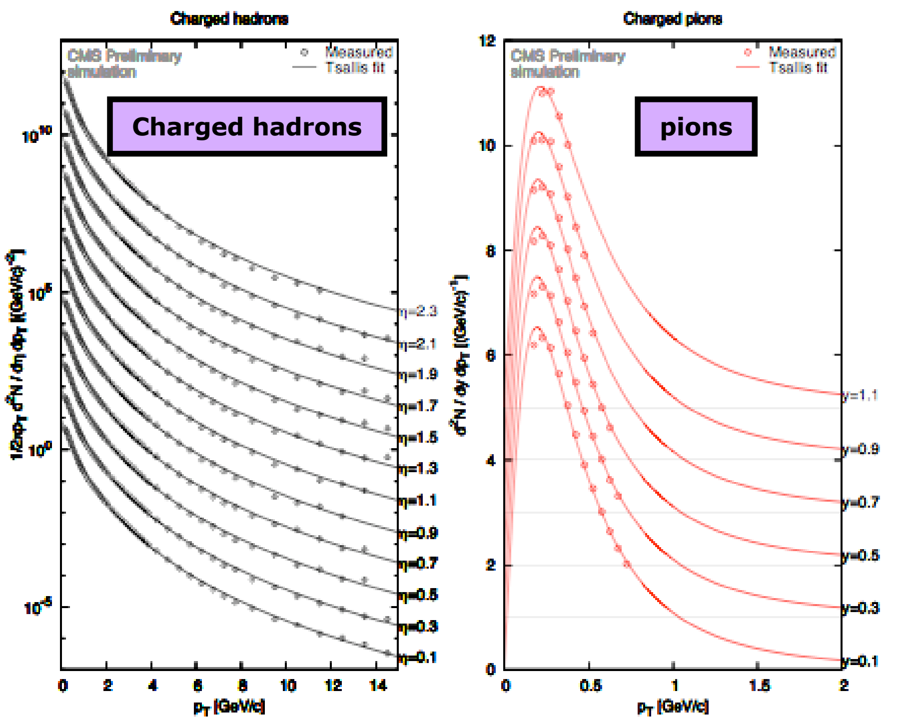


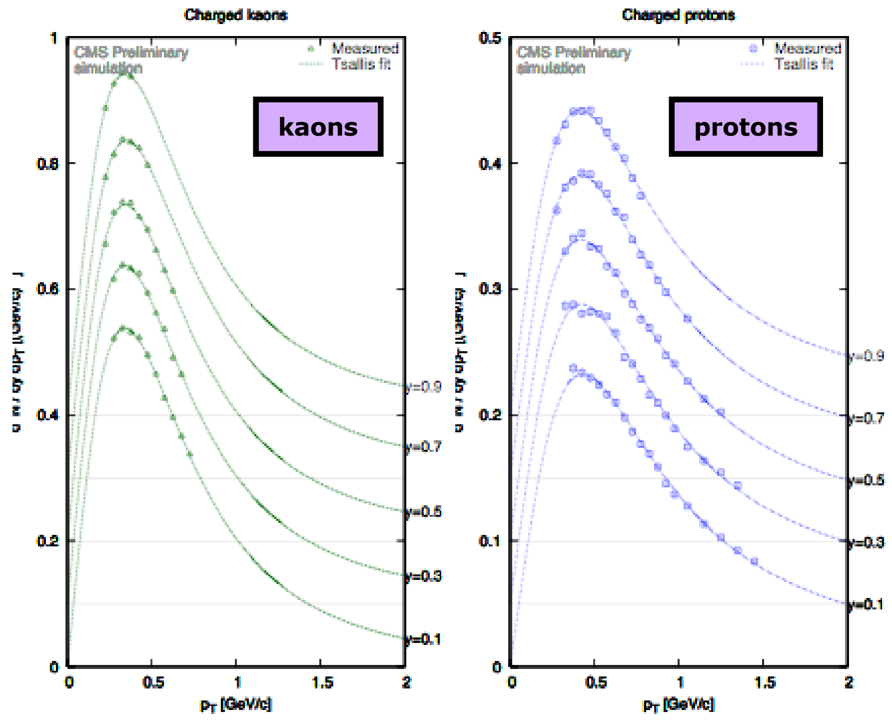


Foreseen measurements:

+ NSD events
+ charged spectra (pt, η)
+ fragmentation

MB measurement - **CMS**

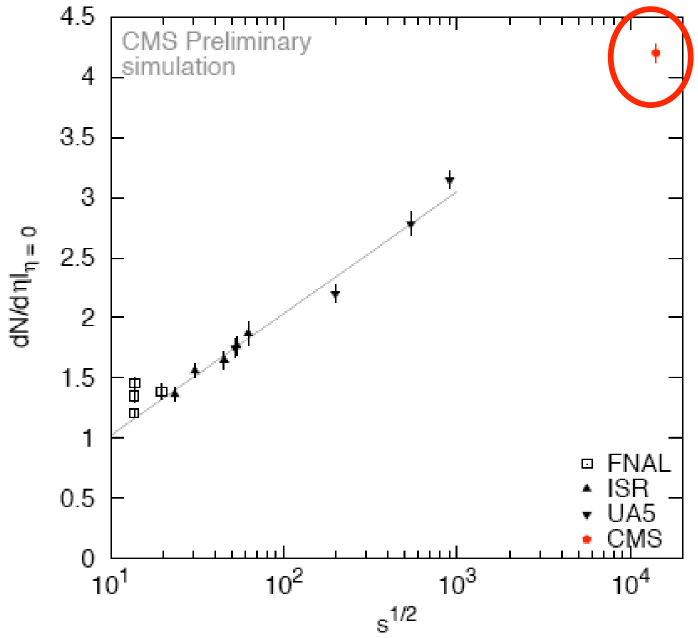


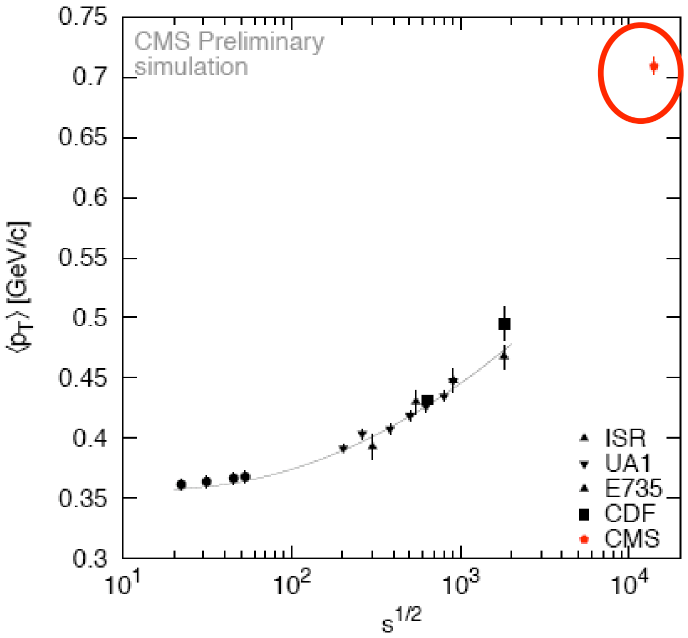


$$E\frac{d^3N}{dp^3} = \frac{dN}{dy}\,\frac{(n-1)(n-2)}{2\pi\, nT\,[nT+(n-2)m]}\,\left[1+\frac{E_T(p_T)}{nT}\right]^{-n}$$

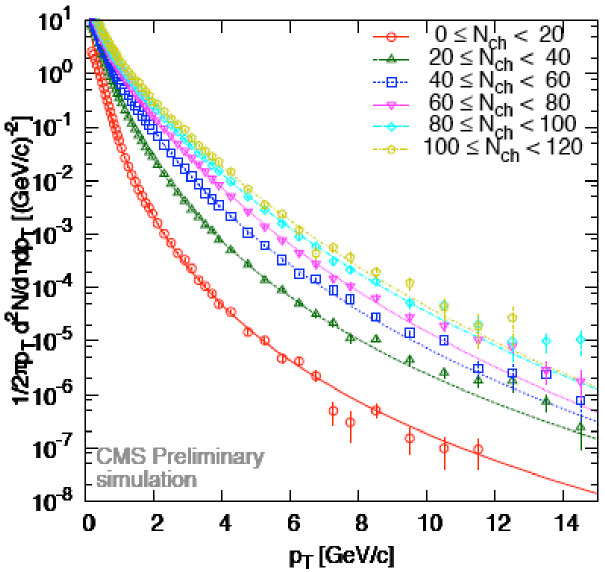
From Tsallis fit and expected performances on tracking, particle corrections are calculated and applied
(PID performed with dE/dx)

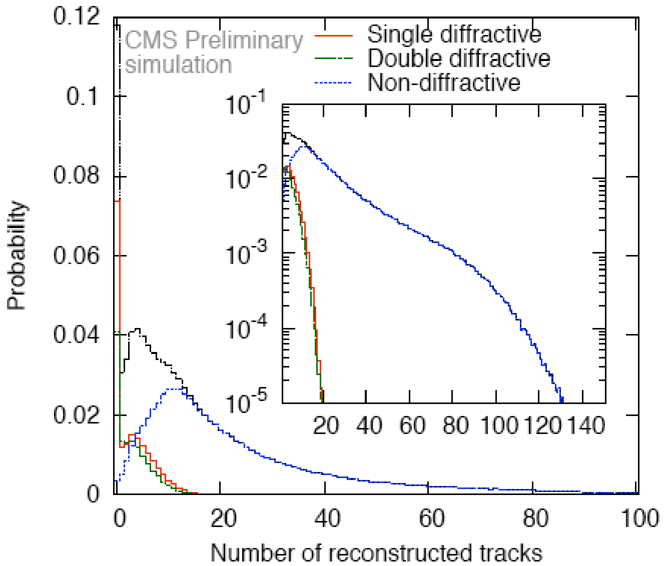
MB measurement - **CMS**





LHC expected multiplicity and average particle pT





pT distribution and particle multiplicity

UE observables definition

From charged jet

Topological structure of p-p collision from charged tracks

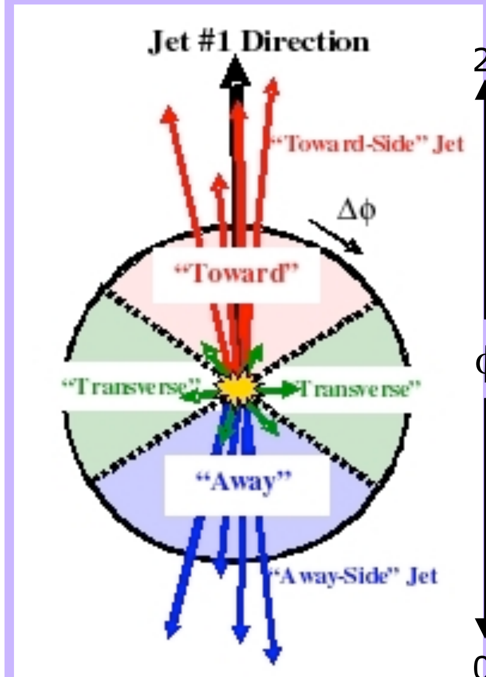
Charged jet definition -> ICA algorithm with massless tracks as input

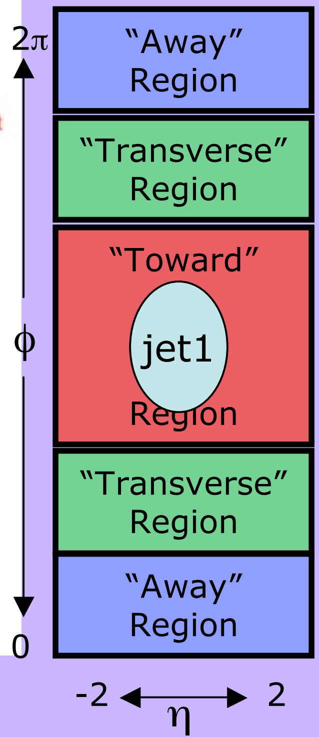
The leading Ch_jet1 defines:

+ a direction in the ϕ plane

+ the PT is used as reference for the energy scale of the interaction

The transverse region is particularly sensitive to the UE





Main observables:

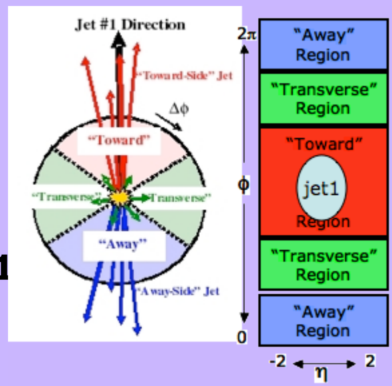
- ❖ $dN/d\eta d\phi$, charged density
- ❖ $d(PT_{sum})/d\eta d\phi$, energy density

Feasibility@LHC

UE Observables VS

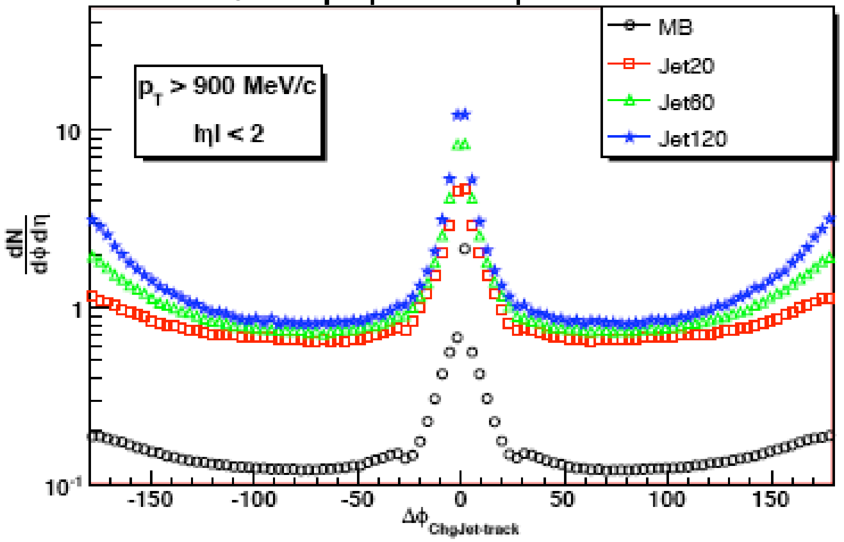
$\Delta\phi$ Leading Charged Jet - Track

Uncorrected distributions from **10pb^{-1}**



Tracks:
PT>0.9
|η|<2

$dN_{ch}/d\eta d\phi$ VS $\Delta\phi$



$dPT_{sum}/d\eta d\phi$ VS $\Delta\phi$

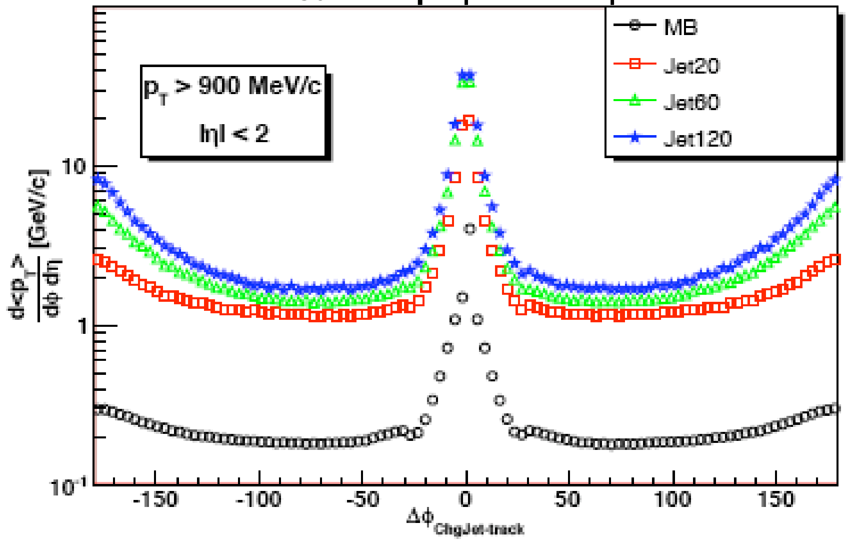
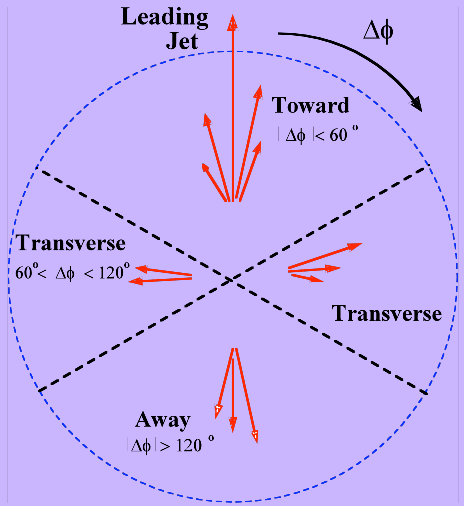
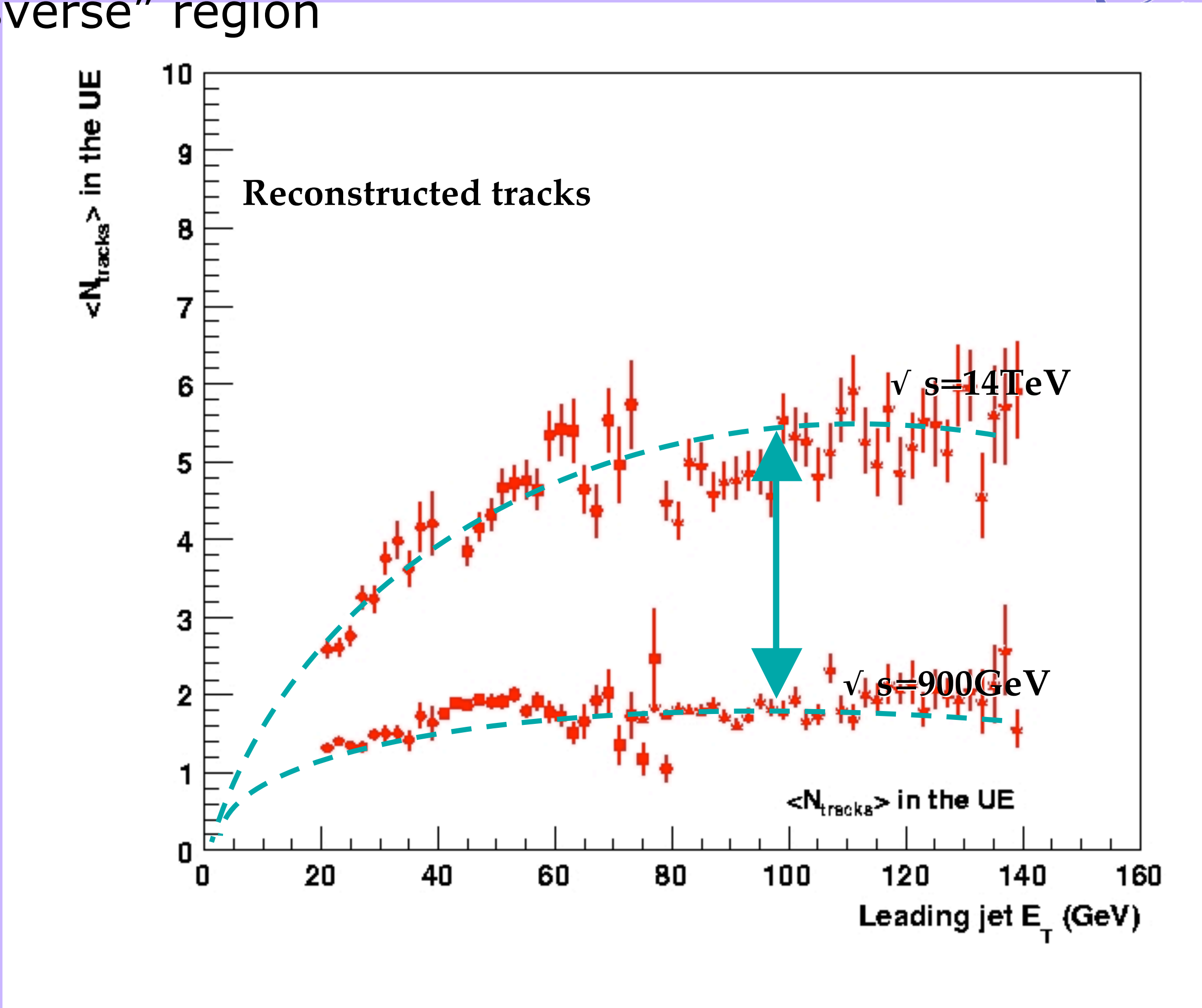


Figure 2: Density of charged particles, $dN/d\eta d\phi$ (*left*), and average charged $\sum p_t$ density (*right*) versus the azimuthal distance between charged tracks and leading charged jet. Reconstructed data from different triggers are superimposed.

ATLAS - jet events

Results in the "transverse" region

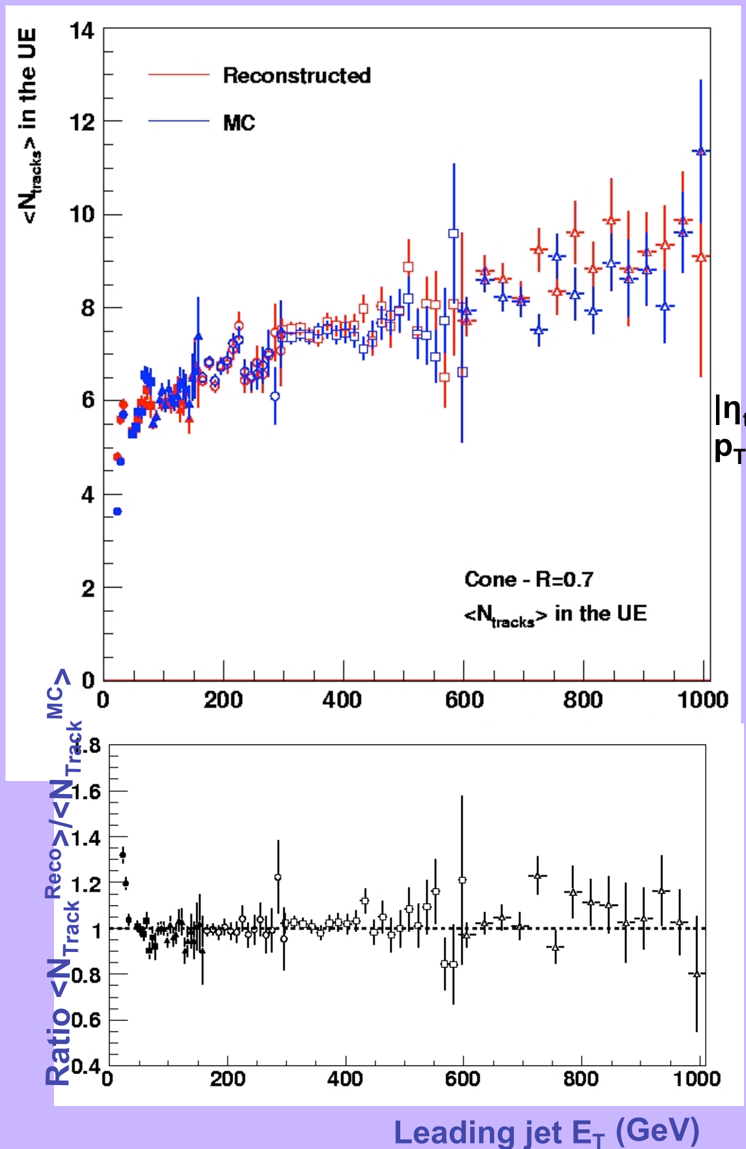




Multiplicity of charged particles with $p_T > 0.5$ GeV and $|\eta| < 1$ in region transverse to leading jet

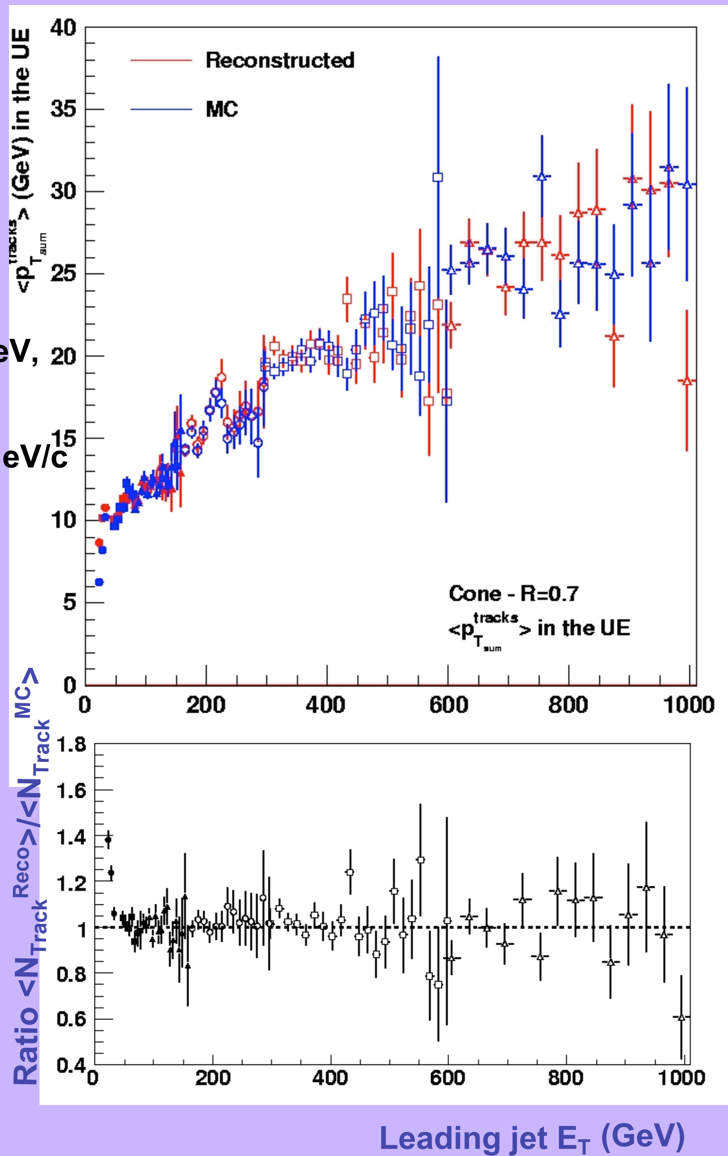
~ 15 days of data taking enough to cover up to p_T(leading jet) ~ 40 GeV

ATLAS - jet events up to TeV



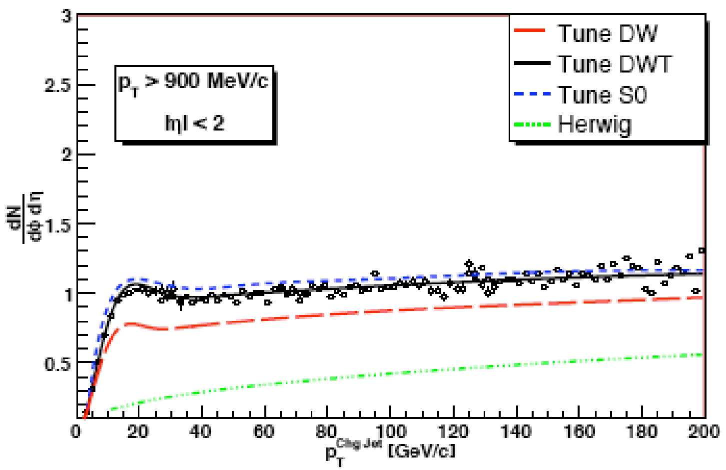
$N_{jets} > 1$,
$|\eta_{jet}| < 2.5$,
$E_T^{jet} > 10$ GeV,

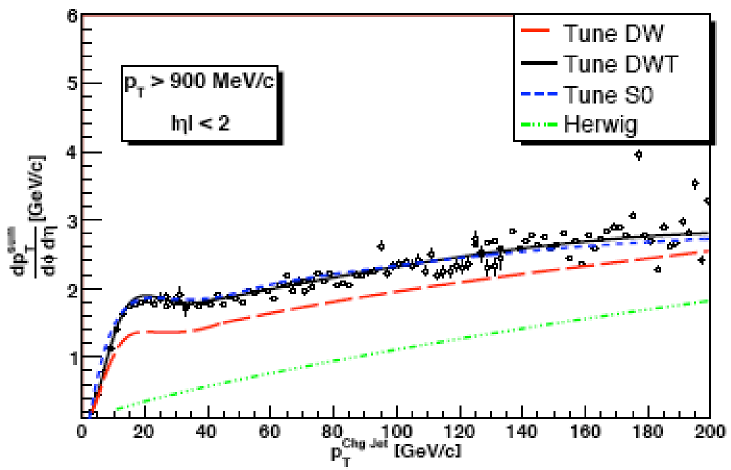
$|\eta_{track}| < 2.5$,
$p_T^{track} > 1.0$ GeV/c



Very good RECO/MC agreement

CMS - jet events - 100 pb-1



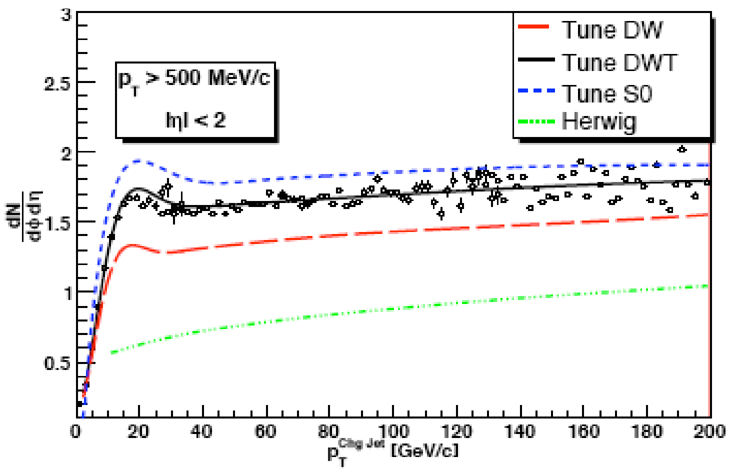


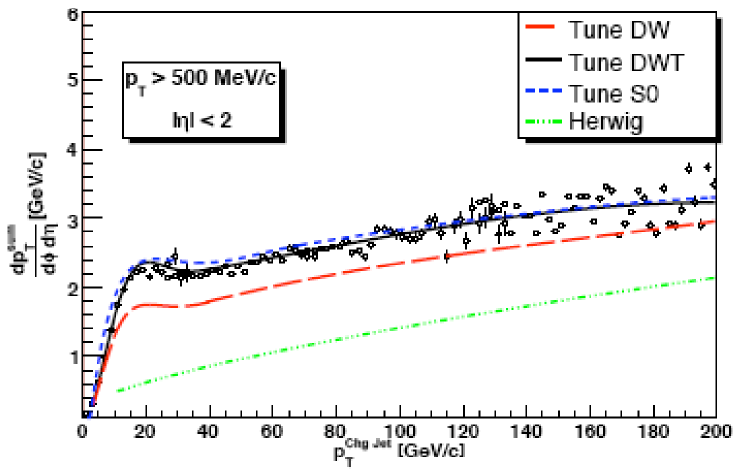
pT>900 MeV/c

dN/dηdϕ vs PT_chg

Figure 6: Same as figure 4 but for corrected distribution.

d(PT$_{sum}$)/dηdϕ vs PT_chg





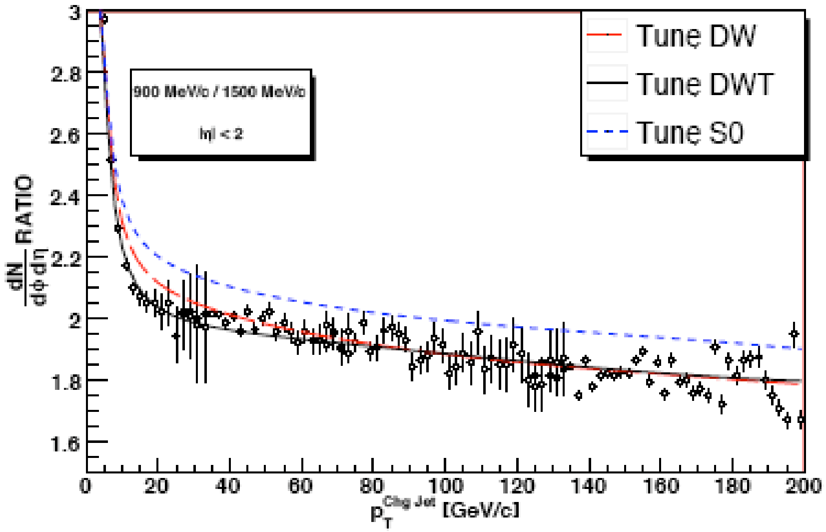
pT>500 MeV/c

Effect from correction -> get back the DWT
Good discrimination power -> DW/DWT (from 900 MeV)
S0/DWT using tracking from 500 MeV

CMS - jet events - 100 pb-1

dN/dηdϕ ratio vs PT_chg

d(PT_{sum})/dηdϕ ratio vs PT_chg



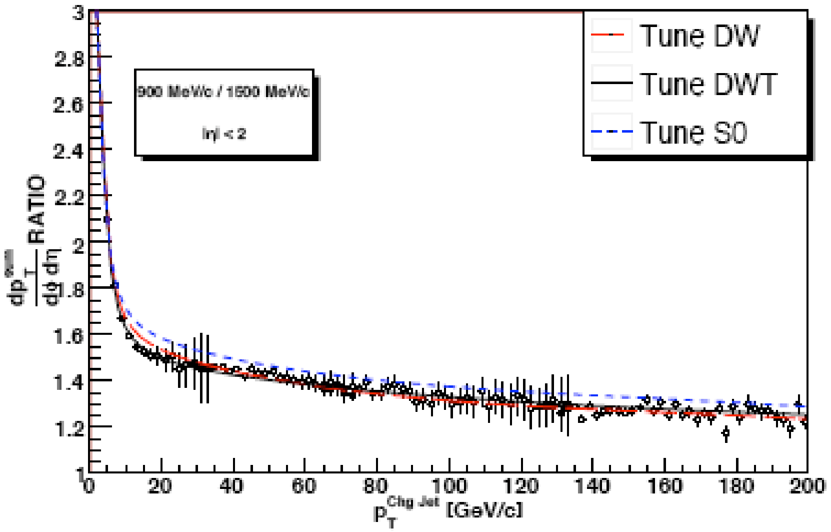


Figure 9: Ratio plots using track with $p_T > 1.5\,\mathrm{GeV/c}$ and $p_T > 0.9\,\mathrm{GeV/c}$ for density of charged particles dN/dηdϕ (*left*) and average charged $\sum p_t$ density (*right*) versus the transverse momentum of the leading charged jet.

Uncorrected data.
Ratios of observables using minimum pT of 900 MeV/c and 1.5 GeV/c

+No need to apply corrections, absorbed in the ratio
+Additional discrimination between tunes

summary

Minimum Bias measurement plans exist for both experiments

Measuring charged hadron spectra will allow to calibrate and understand soon the detectors and establishing a solid basis for exclusive physics:

Monte Carlo predictions, based on Tevatron data, greatly differ if extrapolated to LHC energy (MPI component)

Underlying Event activity is studied in the transverse region of charged jet events

(studies exist in CMS on DY events - not presented here)

Measuring UE will allows us to

tune the energy dependence models (largely related to the MPI) ->

improve the QCD understanding in pp collisions ->

fundamental for all the LHC measurements ("old" and "new" physics)

Strategy proposed by CMS:

1 pb-1 -> tools calibration (tracking, triggers, correction and response function…)

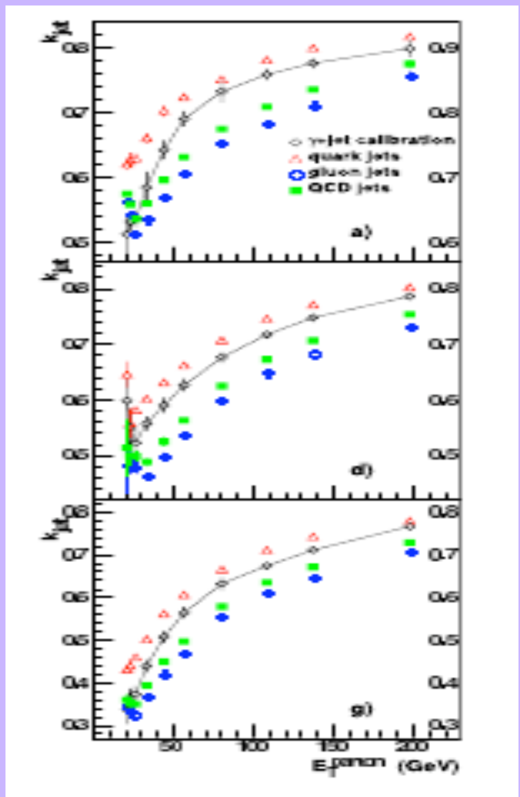
10 pb-1 -> start control of systematics and discriminating between models

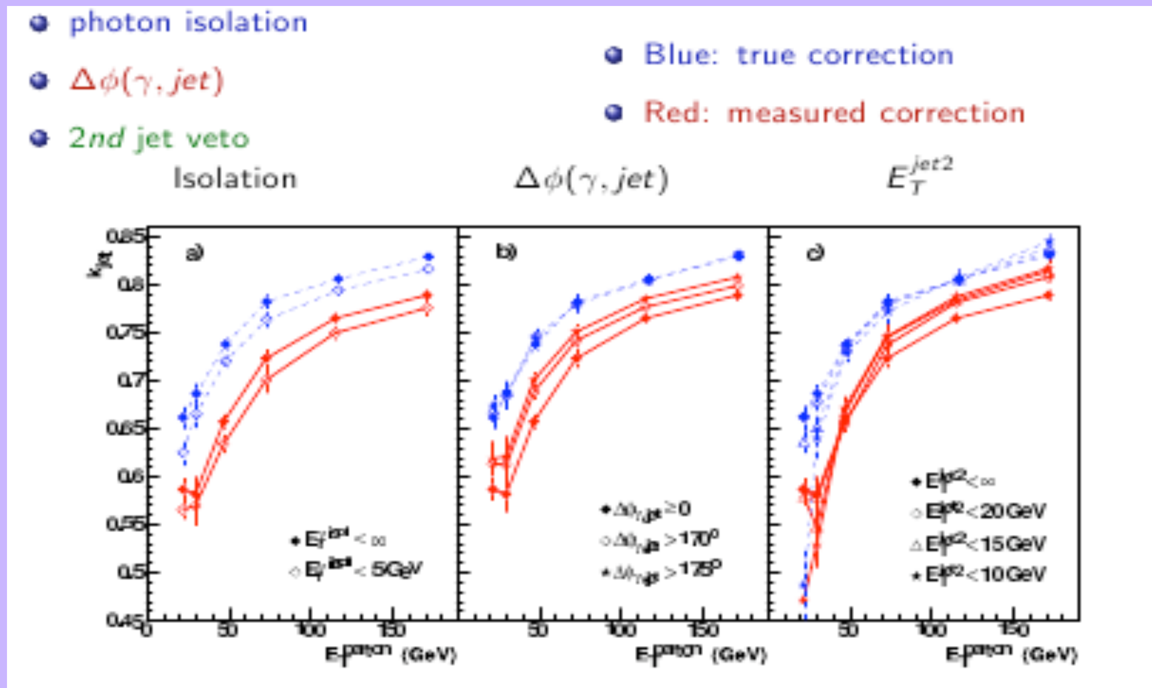
100 pb-1 -> deeper discrimination, enhanced considering ratio distribution

Back up - Jets

Jet Energy Scale at CMS

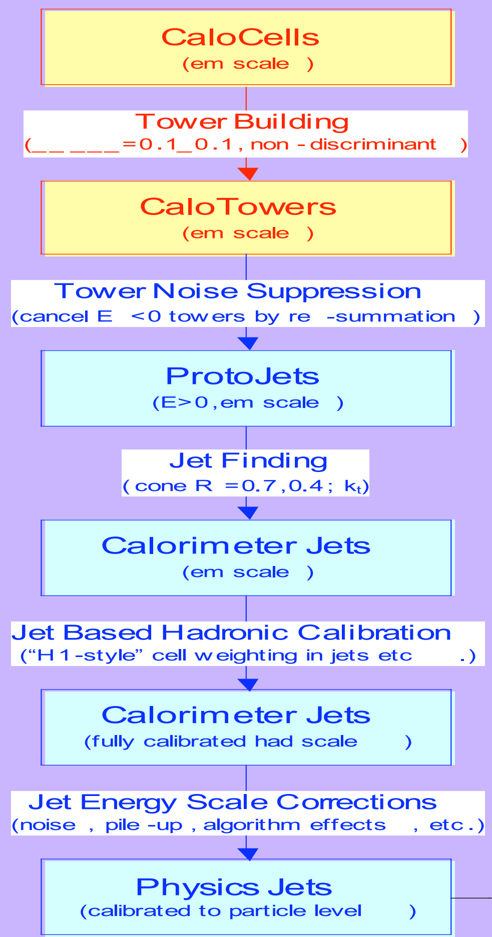
- Investigating several approaches to compute the absolute P_T corrections:
  - Derivation from the data through γ+jets or missing E_T projection method: careful study of the introduced bias
  - Bias studied also as a function of the jet type





Jet energy scale in ATLAS

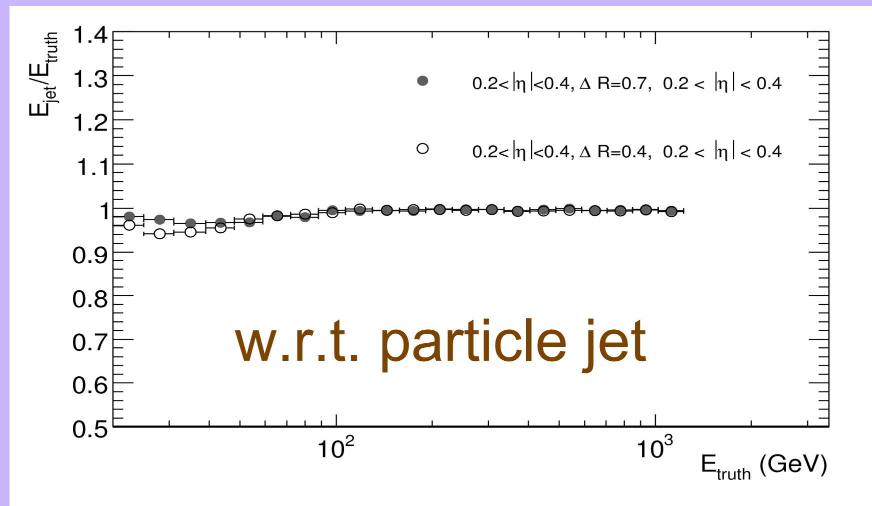
- The real strategy will come with the data.
- The current strategy:



$$E^{jet}_{rec} = \sum_{i=cells} w_i\left(\frac{E_i}{V_i}\right) E_i$$

$$w_i\left(\frac{E_i}{V_i}\right) = \sum_{j=0}^{3} a_j \log\frac{E_i}{V_i}$$

Fully MC based corrections: the importance of the test beam



Current strategy: a summary

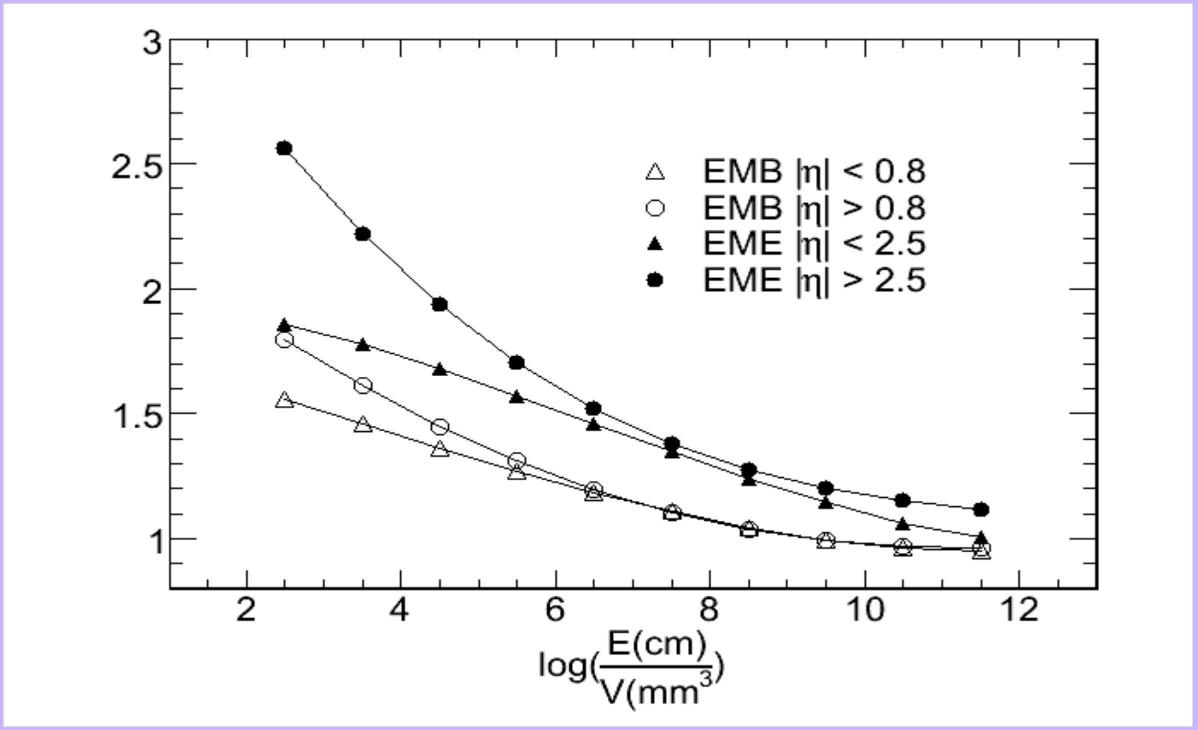
- Topological clustering as a noise suppression tool
- The main step is the correction at particle jet:
  - The corrections will tent to improve the jet resolution. The corrections will be heavily MC based.
- Real data (in situ) will be used for:
  - Check the uniformity of the jet scale with the di-jet balance
  - Check the MC predictions in “easy” events (γ+jet, Z+jet)
  - Check the scale of high P_T jets with bootstrap techniques
- UE subtraction: MC based after tuning
- Pile-up: topological clustering is supposed to account for that:
  - Anyhow, strategies for subtraction based on the number of vertices are in place

H1 jet corrections

- The total energy is computed as follows:
- The weights depend on the cell energy density (and pseudorapidity, through a rough binning)

$$E_{rec}^{jet} = \sum_{i=cells} w_i\left(\frac{E_i}{V_i}\right) E_i$$

$$w_i\left(\frac{E_i}{V_i}\right) = \sum_{j=0}^{3} a_j \log\frac{E_i}{V_i}$$



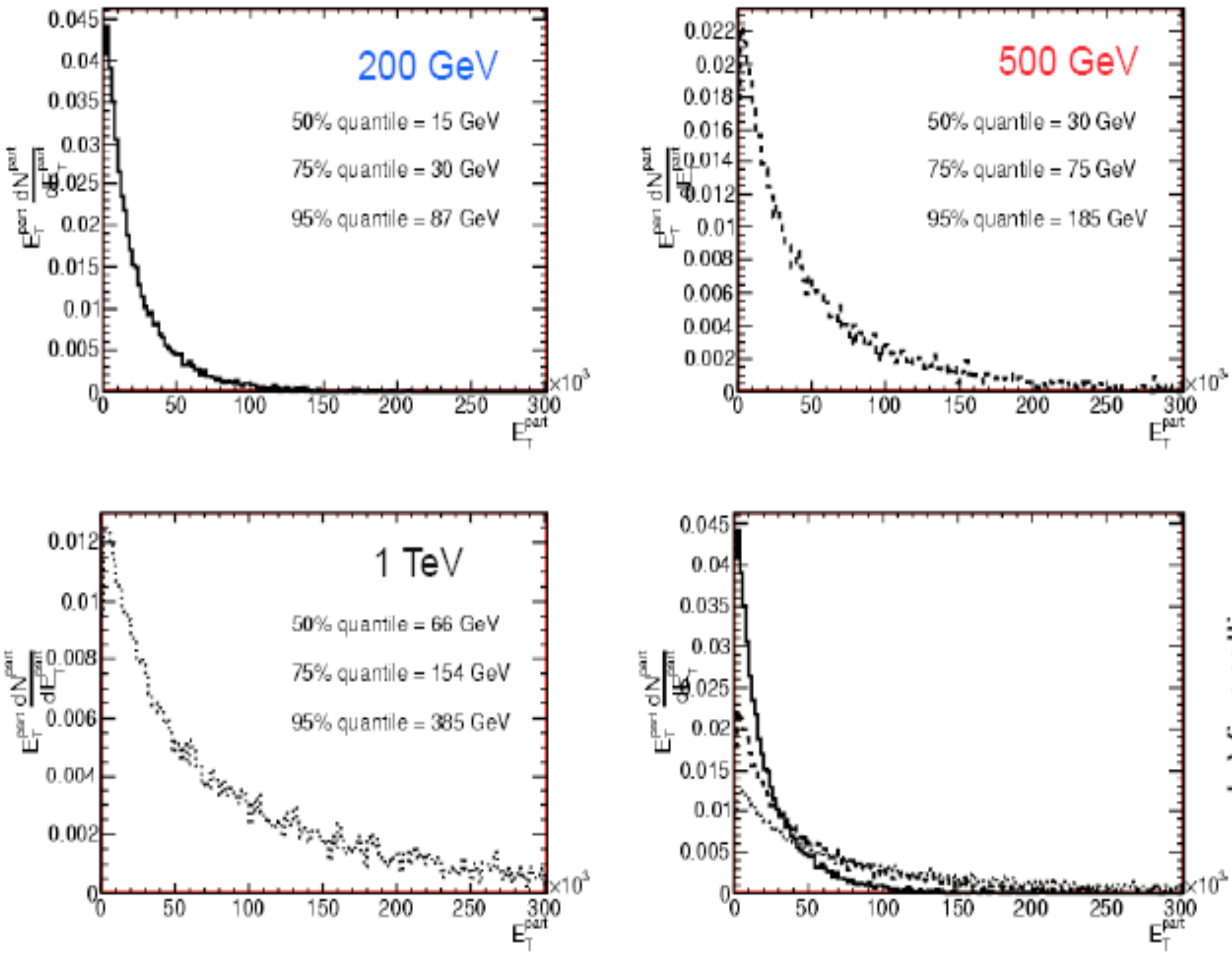
The weights enhance the response of low energy density cells (Had energy).

High density is associated with EM deposits: the weights go to 1

H1 jet corrections

- The weights w_i are the same for all the reco algos, all inputs.
  - They are the same still hard coded for EtMiss reconstruction
- Crack and Gap regions not taken into account in the weight computing. For each reco algo and input clusters, a scale factor is computed:
  - Intended to correct for non-linearities caused by the gap and the crack
  - It corrects also for residual reconstruction algorithm dependent effects

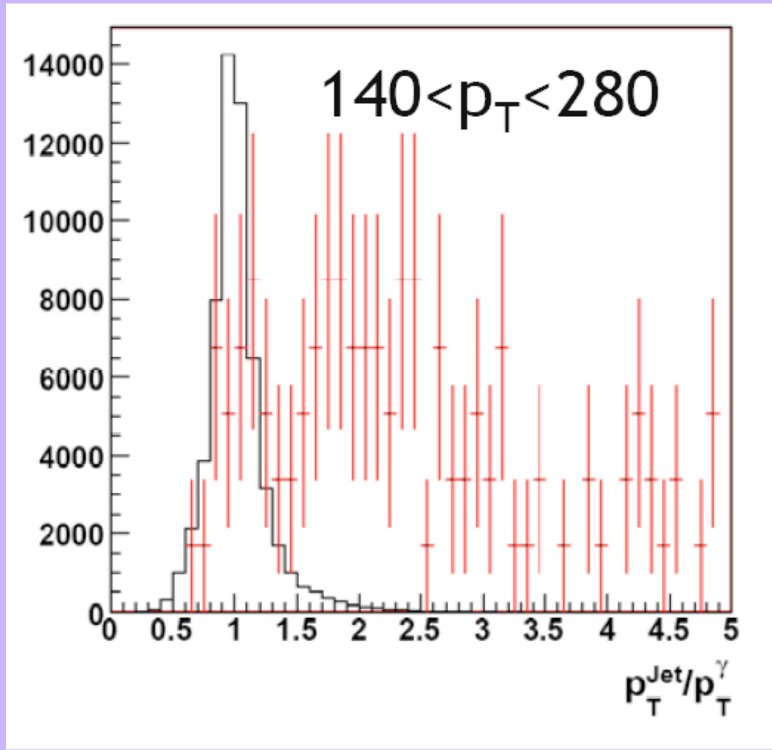
Jet Constituents

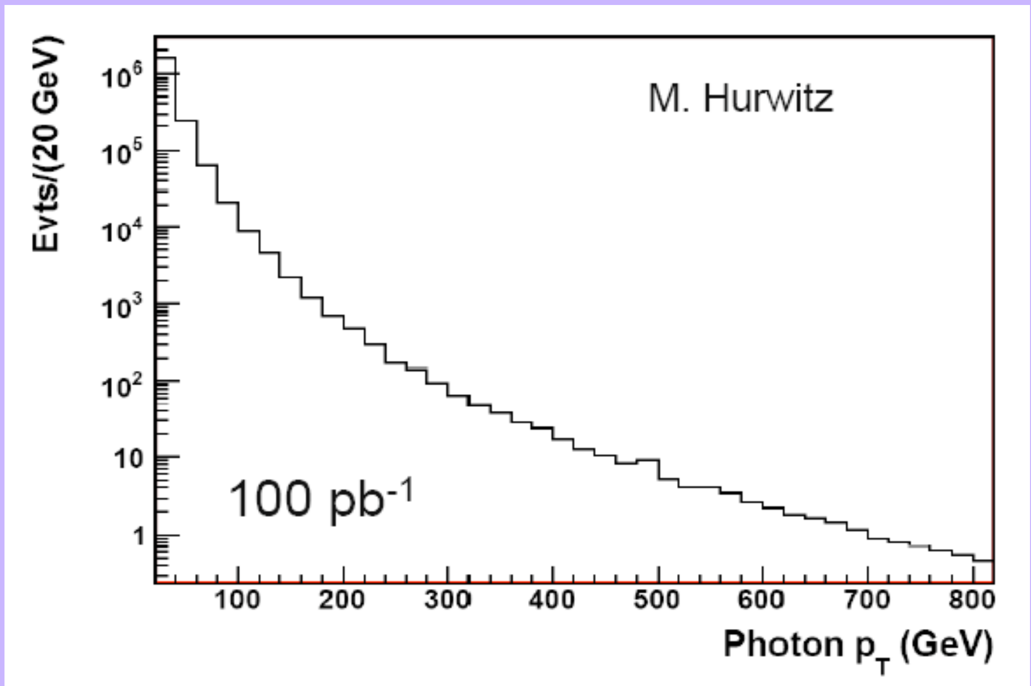


I. Viverelli

Inclusive Jet Cross Section (4)

- Check the energy scale with γ+jet
- The balance looks good, but:
  - Large background from DiJet
  - The balance does not work for photon-like jets (in red in the picture)

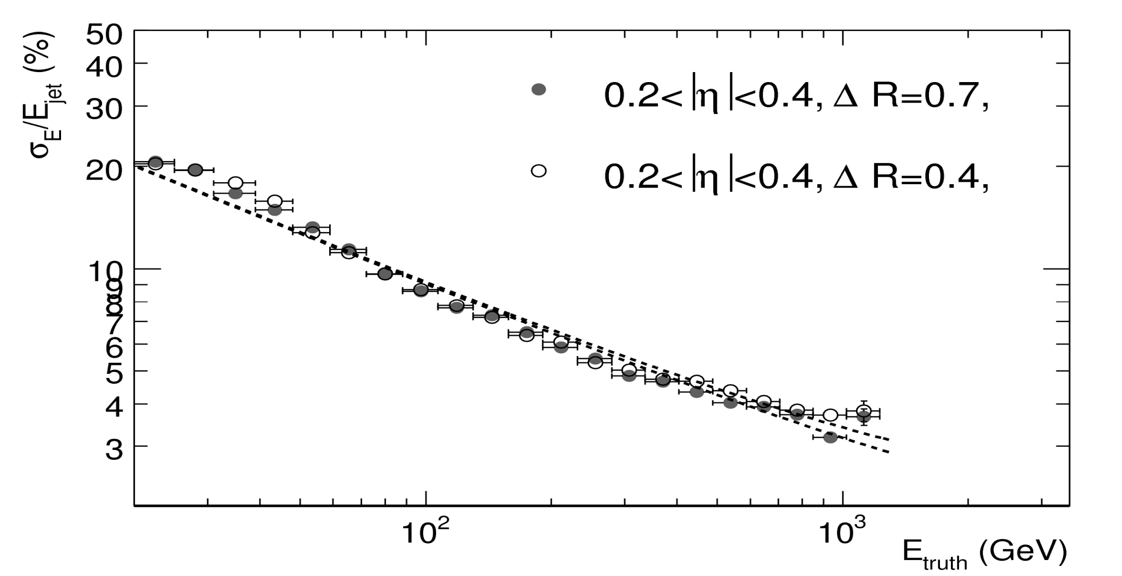


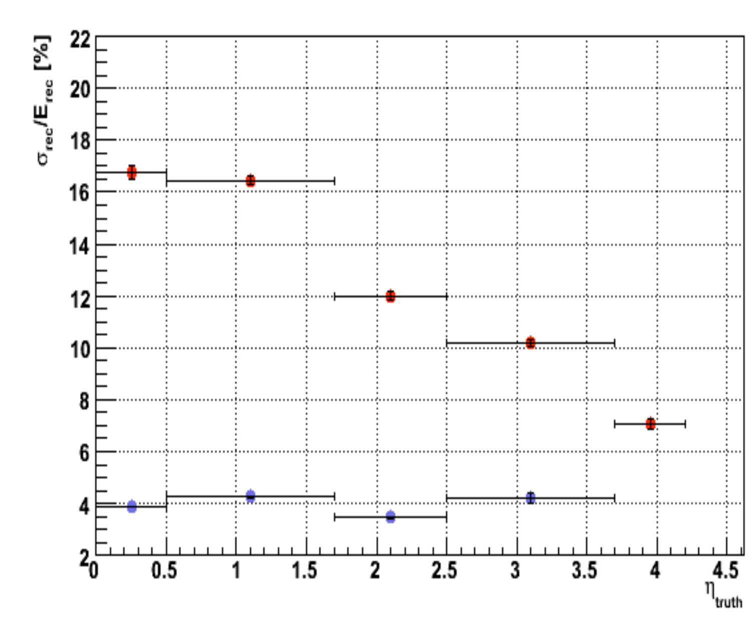


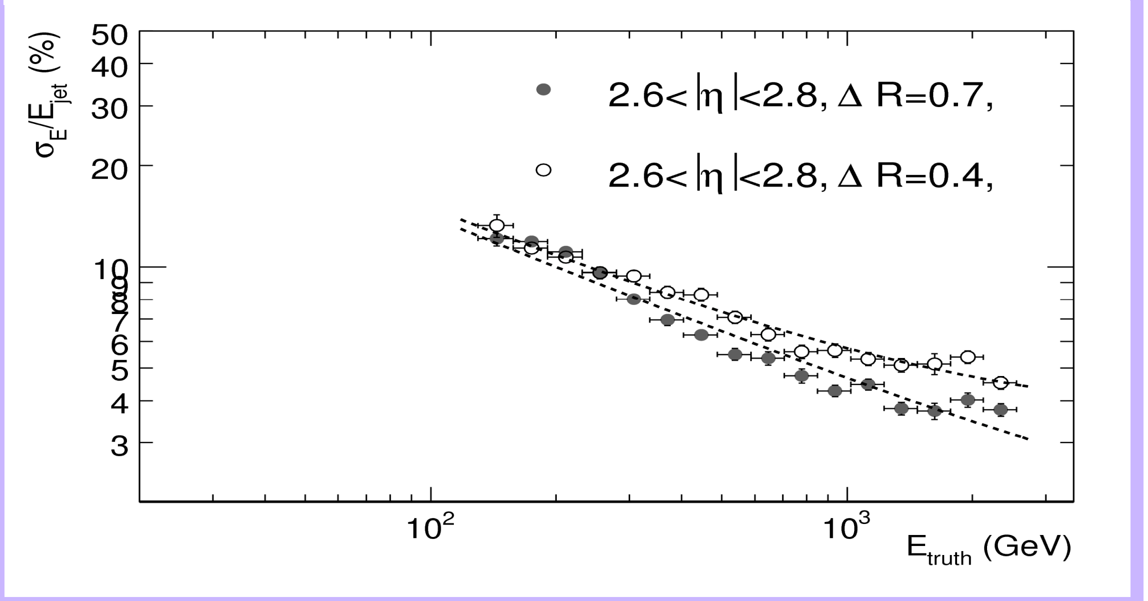
- 100 pb^{-1}: γ+jet can probe up to few hundreds GeV:
  - We need a way to get up to the TeV scale

Jet Resolution (ATLAS)

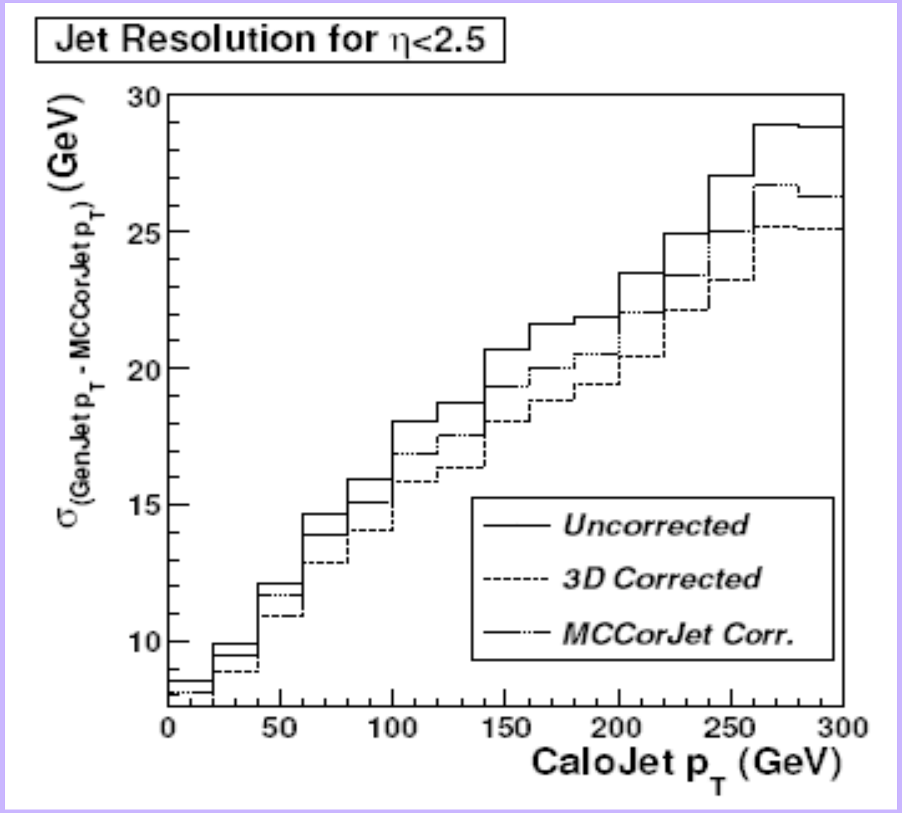
- Resolution:
  - Central region:~12% at 50 GeV, ~8% at 100GeV

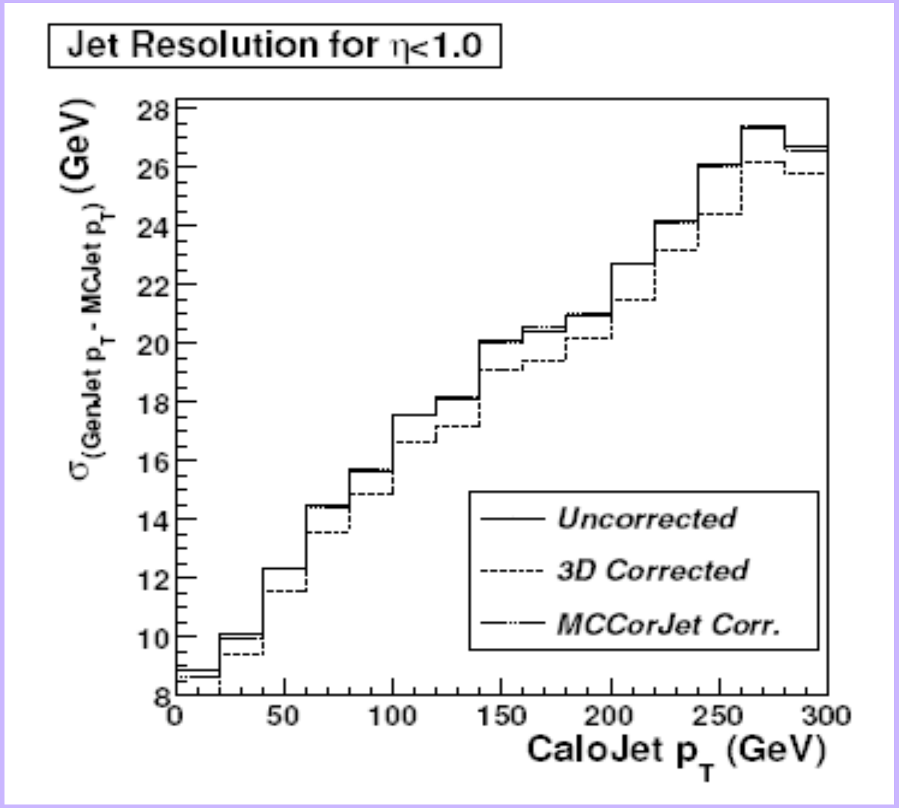






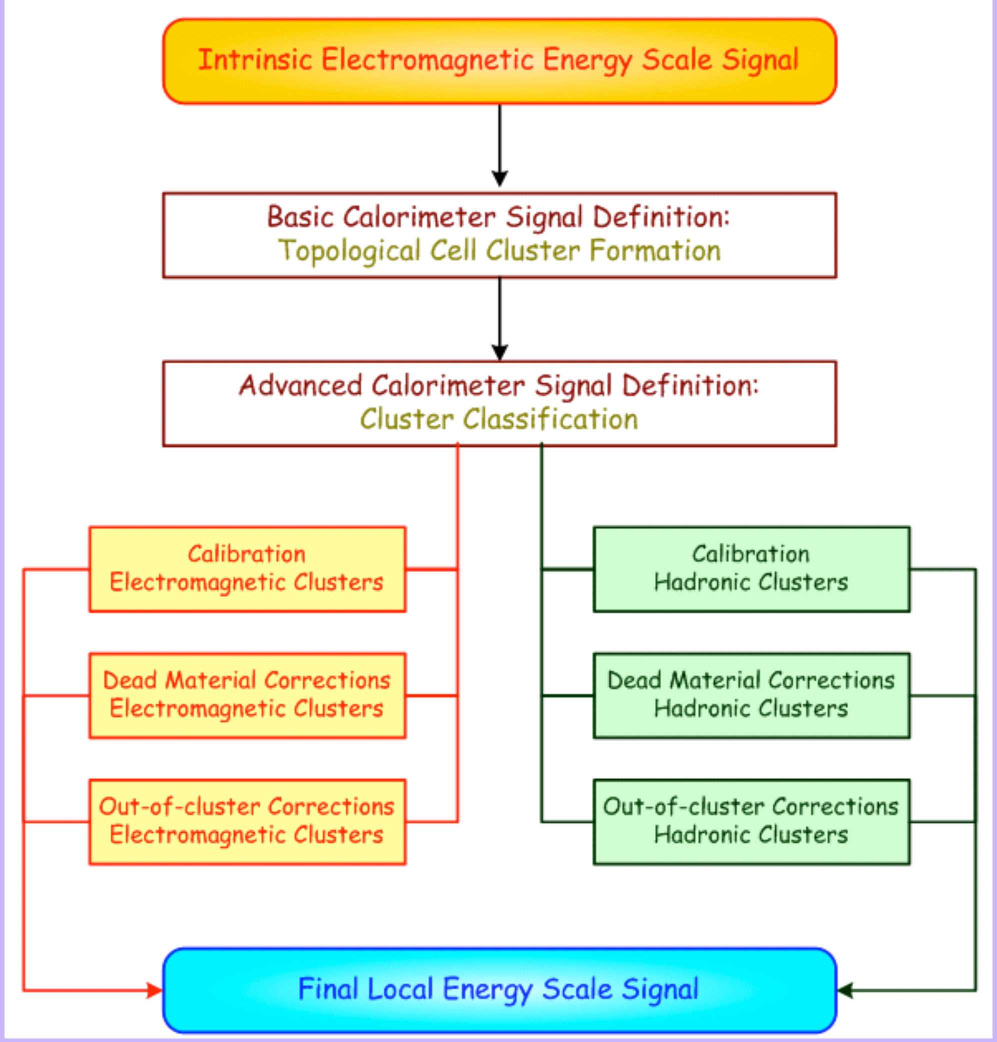
Jet Resolution (CMS)





ATLAS: toward a Local Hadron Calibration

- The local hadron calibration tries to exploit the high ATLAS calorimeter granularity
- Classification of the clusters based on cell energy density and shape variables
- Corrections applied based on the classification



Back up - MBUE

Parameter (PYTHIA v.6412+)	A	ATLAS	DW	DWT	S0
UE model MSTP(81)	1	1	1	1	21
UE infrared regularisation scale PARP(82)	2.0	1.8	1.9	1.9409	1.85
UE scaling power with $\sqrt{s}$ PARP(90)	0.25	0.16	0.25	0.16	0.16
UE hadron transverse mass distribution MSTP(82)	4	4	4	4	5
UE parameter 1 PARP(83)	0.5	0.5	0.5	0.5	1.6
UE parameter 2 PARP(84)	0.4	0.5	0.4	0.4	n/a
UE total gg fraction PARP(86)	0.95	0.66	1.0	1.0	n/a
ISR infrared cutoff PARP(62)	1.0	1.0	1.25	1.25	(= PARP(82))
ISR renormalisation scale prefactor PARP(64)	1.0	1.0	0.2	0.2	1.0
ISR Q^2_{max} factor PARP(67)	4.0	1.0	2.5	2.5	n/a
ISR infrared regularisation scheme MSTP(70)	n/a	n/a	n/a	n/a	2
ISR FSR off ISR scheme MSTP(72)	n/a	n/a	n/a	n/a	0
FSR model MSTJ(41)	2	2	2	2	$(p_T - ordered)$
FSR Λ_{QCD} PARJ(81)	0.29	0.29	0.29	0.29	0.14
BR colour scheme MSTP(89)	n/a	n/a	n/a	n/a	1
BR composite x enhancement factor PARP(79)	n/a	n/a	n/a	n/a	2
BR primordial k_T width $<\|k_T\|>$ PARP(91)	1.0	1.0	2.1	2.1	n/a
BR primordial k_T UV cutoff PARP(93)	5.0	5.0	15.0	15.0	5.0
CR model MSTP(95)	n/a	n/a	n/a	n/a	6
CR strength ξ_R PARP(78)	n/a	n/a	n/a	n/a	0.2
CR gg fraction (old model) PARP(85)	0.9	0.33	1.0	1.0	n/a

Table 3.1: PYTHIA parameters, divided into main categories: UE (underlying event), ISR (initial state radiation), FSR (final state radiation), BR (beam remnants), and CR (colour reconnections). The UE reference energy for all models is PARP(89)=1800GeV, and all dimensionful parameters are given in units of GeV.

MB Triggers - ATLAS - efficiencies and bias

Shown below for each coincidence logic:

- Required counter threshold to suppress accidental rate to 1Hz
- Corresponding trigger efficiency for each type of event

Coincidence Logic	Counter Threshold [pC]	Trigger Efficiency			
		900 GeV		14 TeV	
		Non-Diff	Single/ Double Diff.	Non-Diff	Single/ Double Diff.
1+1	10.75	98%	35%	99%	42%
2+2	7.75	97%	27%	98%	36%
3+3	6.25	94%	20%	97%	30%
4+4	5.25	90%	15%	95%	24%
5+5	4.50	85%	10%	92%	19%
6+6	4.00	79%	7%	89%	14%

Data sets and triggers

Reminder:
Spring07 GEN samples have
Pythia 6.227 with DWT.

Samples	N_RECO	σ [pb]
MB	1500000	5,52E+010
QCD 20-30	97000	6,32E+008
QCD 30-50	100000	1,63E+008
QCD 50-80	120000	2,16E+007
QCD 80-120	40000	3,08E+006
QCD 120-170	28000	4,94E+005
QCD 170-230	30000	1.01E+005
QCD 230-300	54000	2,45E+004

Triggers “used”:

MB: Bandwidth 1 Hz

Jet20: Bandwidth 2.5 Hz

Jet60: Bandwidth 2.8 Hz

Jet120: Bandwidth 2.4 Hz

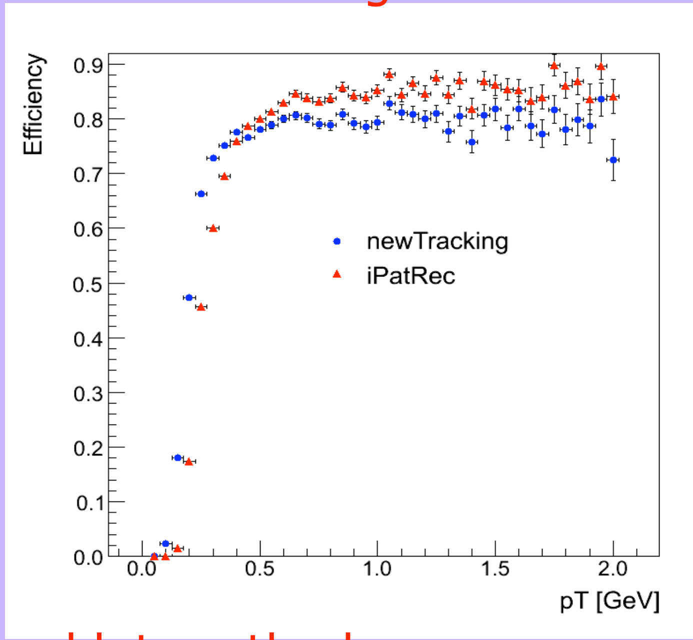
Often MC event weight >> 1
[for 100pb^{-1} Feasibility studies]

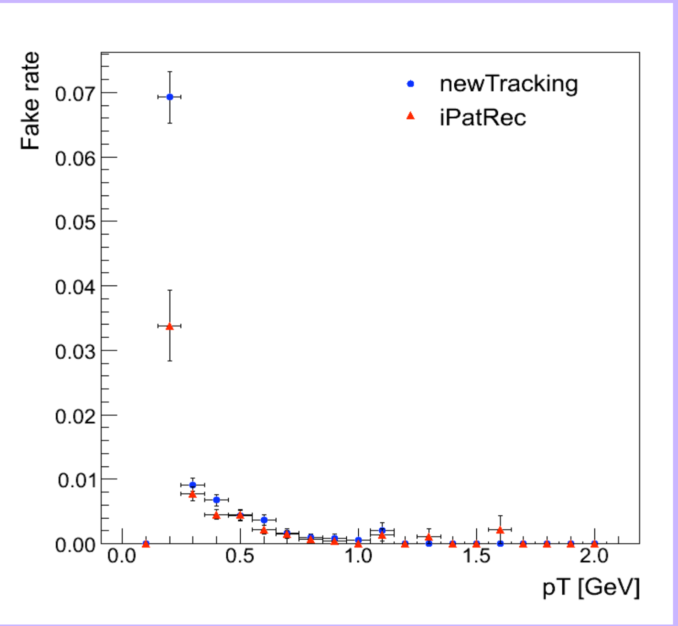
MB Trigger definition:
10+10 cells with E>1GeV in HF
[CMS AN 2007_017]

3 luminosity points considered:
1, 10 and 100 pb^{-1}

ATLAS - central UE activity - Tools definition

Standard tracking extended to low PT

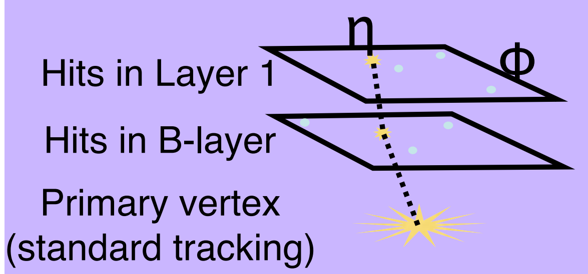


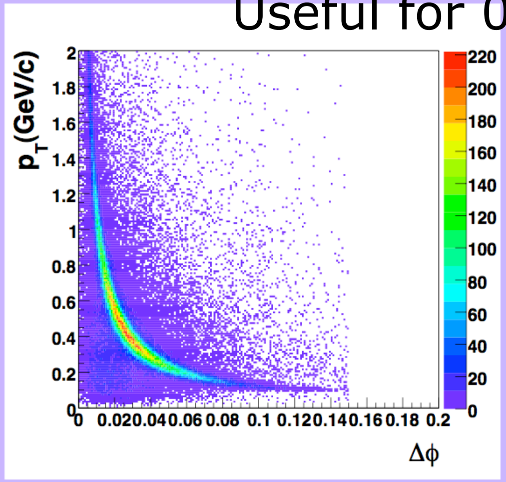


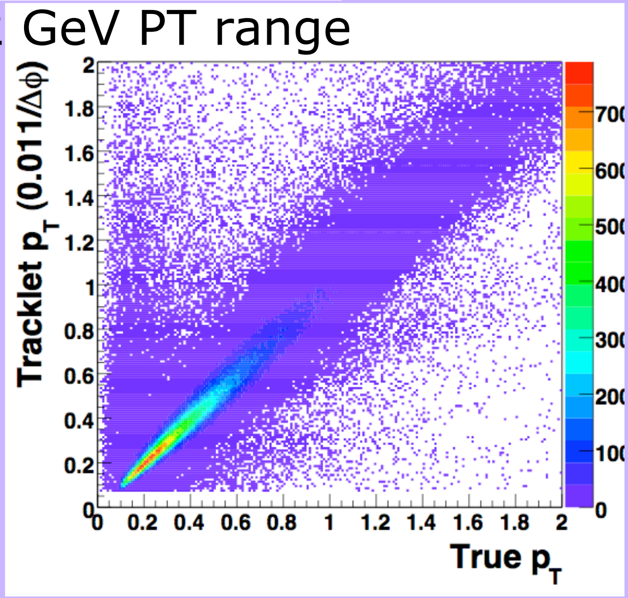
Useful for 0-2 GeV PT range

Tracklet method

Exploring methods with sensitivity at lower pT with even fewer pixel-hits



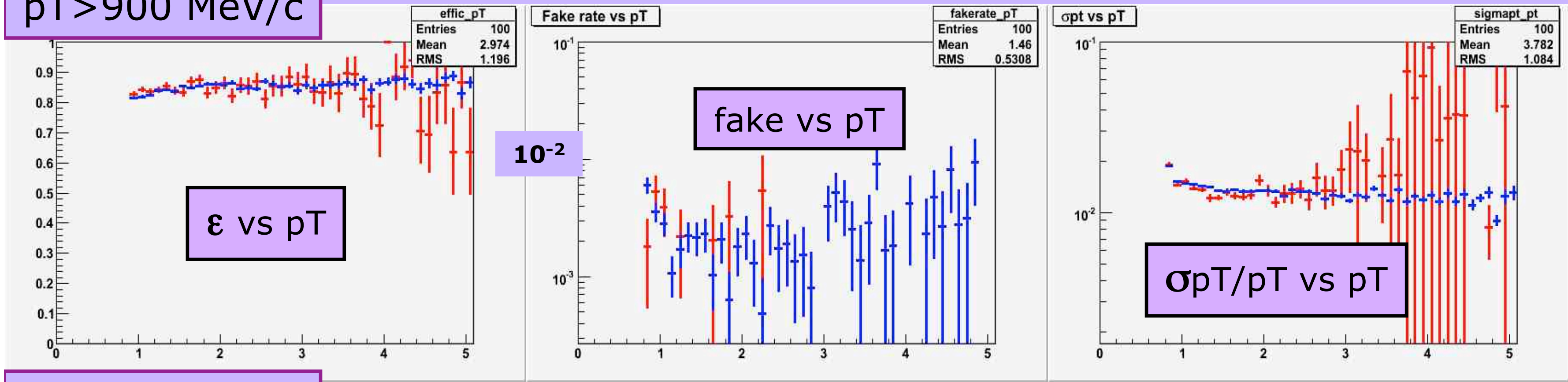




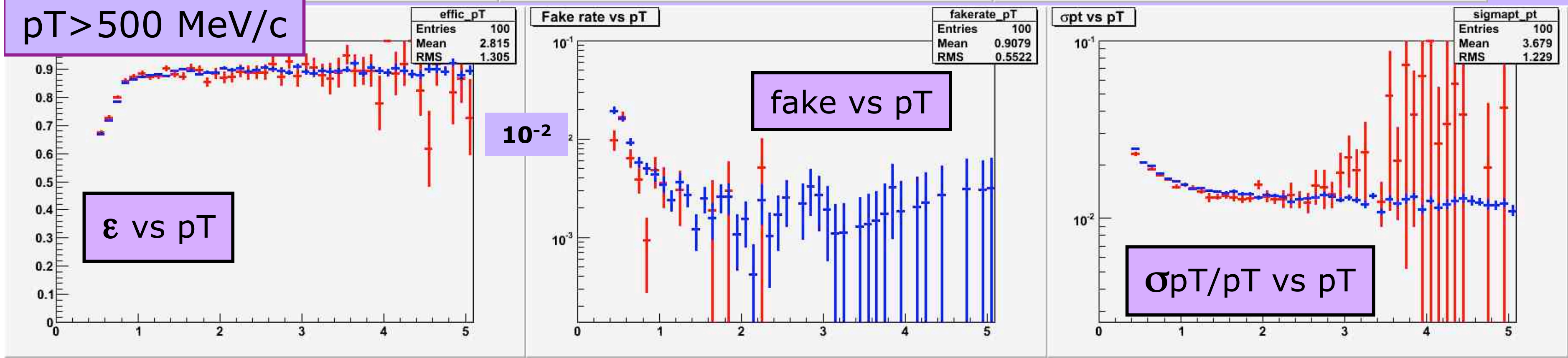
Tracking performances on **MB** and **QCD**

Association criteria based on 50% of shared hits

pT>900 MeV/c



pT>500 MeV/c



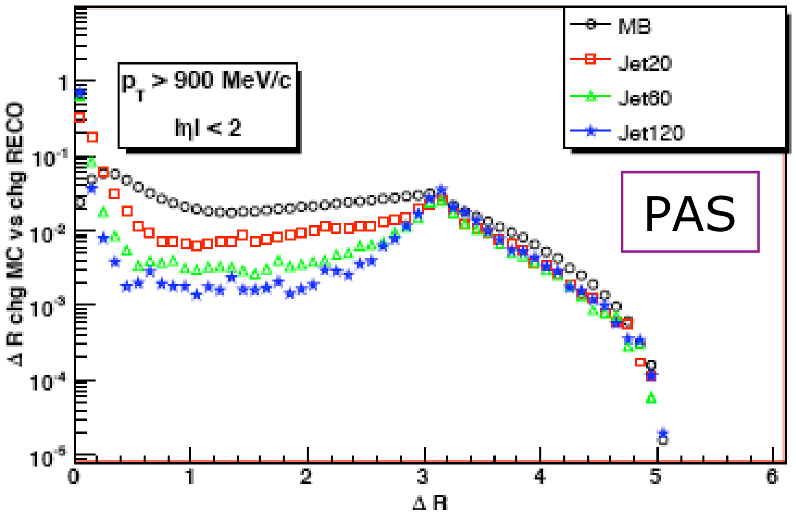
Tracking conf:

min P_T >=0.5
χ^2/ndof <= 5
d0 <= 3.5
z0 <= 30
5<=Hit<=7 & Lost = 0
Hit>=8 & Lost = 1

+ 900 MeV is the standard CMSSW tracking
+ seeding and tracking from 500 MeV is possible with sufficient high efficiency (from 70% to 90%) and under control fakes (~2% from 500 MeV)
+ Tracking from 500 MeV is used to enhance discriminative power of the observables in the transverse region (see previous)

Used Tools

ΔR reco/calo



PT ratio reco/calo

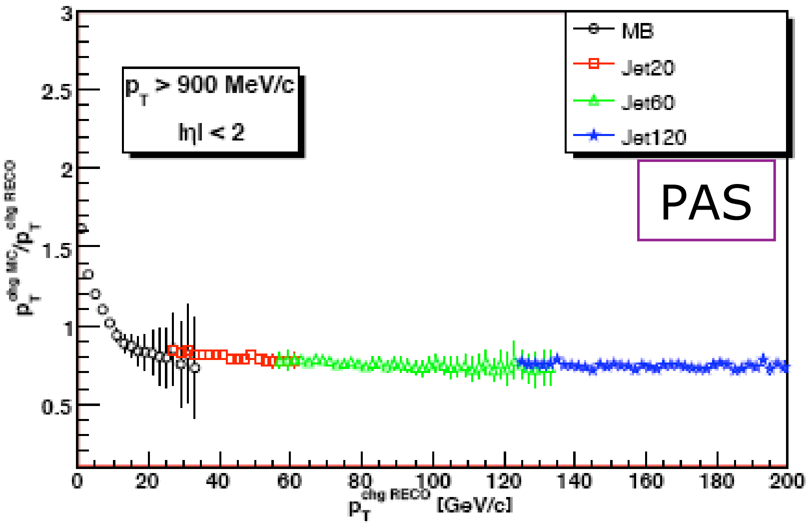


Figure 1: Charged Jet performances. *Left:* $\Delta R\ (= \sqrt{\Delta\phi + \Delta\eta})$ between the charged and the calorimetric leading jets. *Right:* charged jet response function $(P_T^{charged}/P_T^{calorimetric})$.

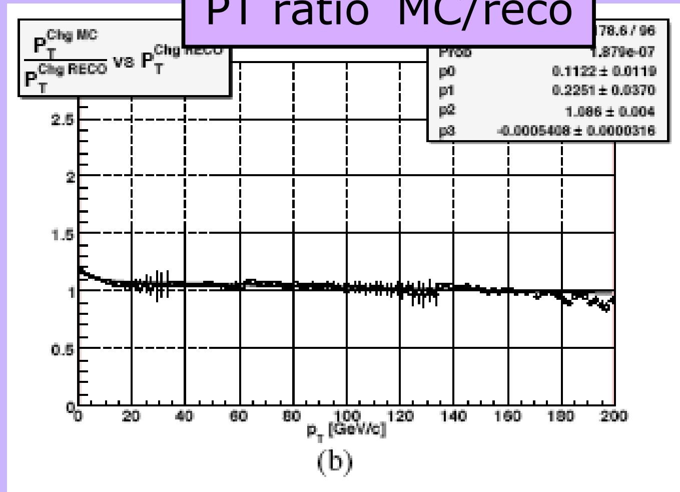
Charged jet instead of calorimetric:

+ access to low PT region

+ intrinsically free from pile up

+ better control of systematic effects at startup

PT ratio MC/reco



(b)

Absolute energy calibration of the leading charged jet reported with the fit adopted in the correction procedure

Feasibility@LHC - the **toward** and **transverse** region - 10 pb-1

dN/dηdϕ vs PT_chg

d(PT_{sum})/dηdϕ vs PT_chg

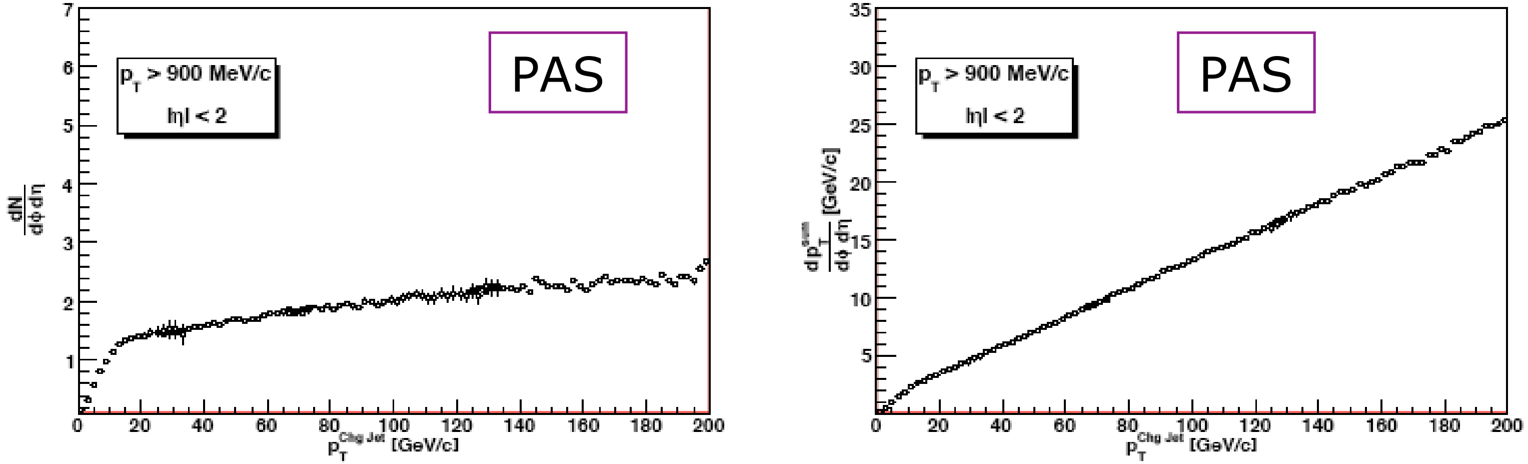


Figure 3: Toward region. Uncorrected distribution. Density of charged particles dN/dηdϕ (*left*) and average charged $\sum p_t$ density (*right*) versus the transverse momentum of the leading charged particle jet.

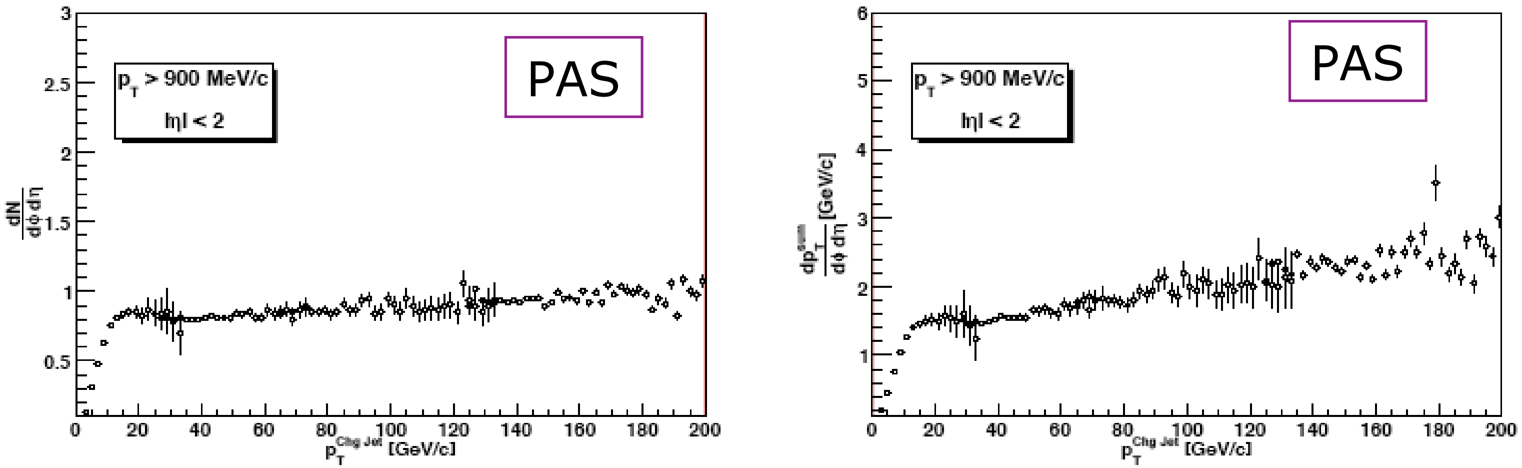
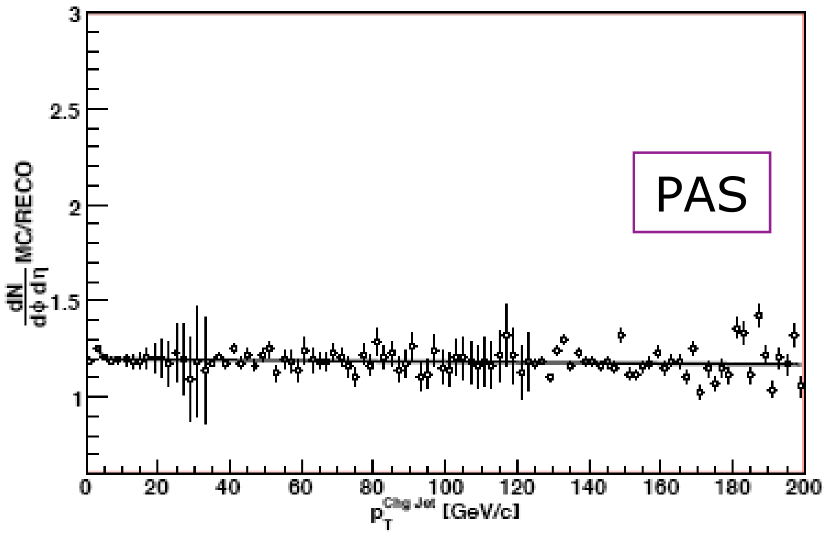


Figure 4: Same as figure 3 but in the transverse region.

Feasibility@LHC - correction functions - 10 pb-1

dN/dηdϕ (MC/RECO) vs PT_chg



d(PT_{sum})/dηdϕ (MC/RECO) vs PT_chg

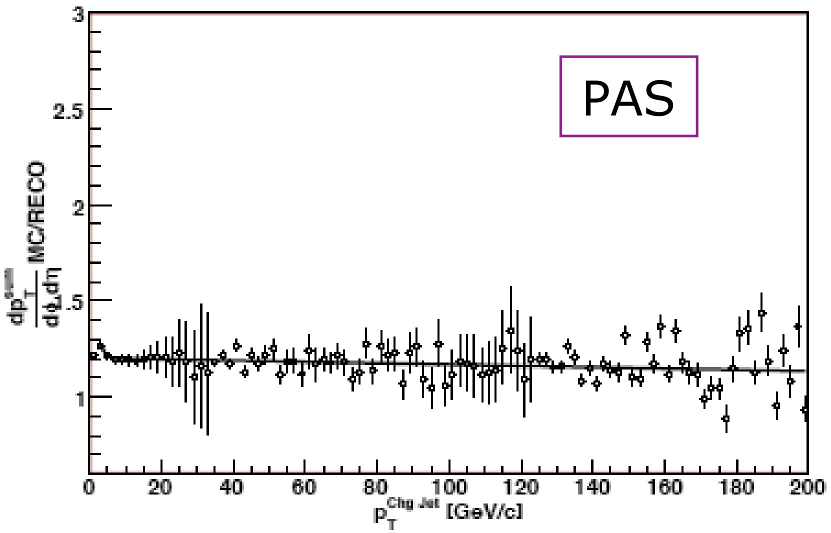


Figure 5: Ratio between generator level DWT expectations and reconstructed data for dN/dηdϕ (*left*) and average charged $\sum p_t$ density (*right*). The corrections as a function of the charged jet transverse momentum are then obtained from the fit.

Correction/calibration procedure a la CDF [PRD 65 (2003) 092002]:

+ Use the PT_chg calibration function vs PT_chg (RECO)

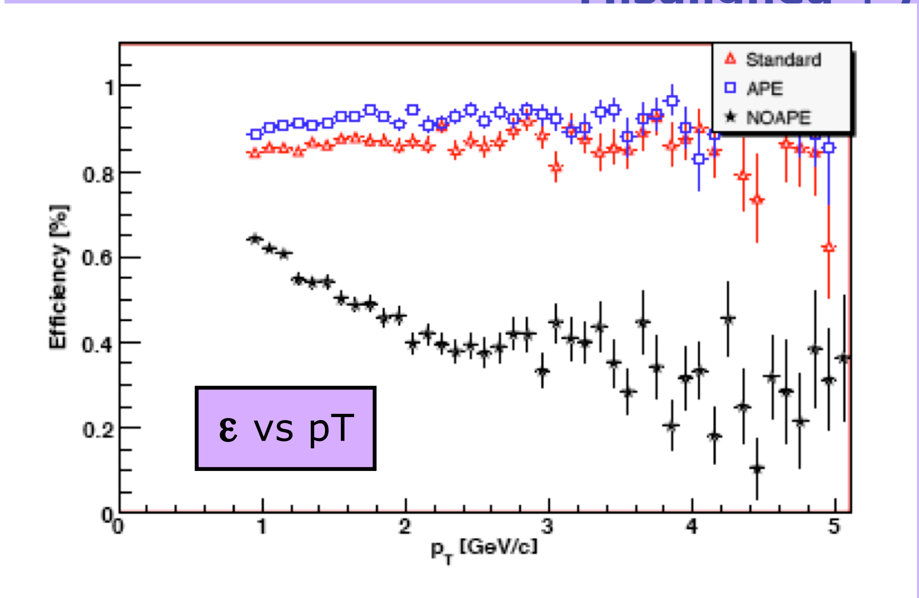
+ Response function vs PT_jet (MC) applied on a event by event basis

[At CDF it provides the same performances of the particle level correction]

Feasibility@LHC - startup scenario - 1 pb-1

Tracking at startup

Ideal aligned detector
Misaligned
Misaligned + APE



Survey + LAS

- Pixel Barrel
  - dX = dY = 225 μm
  - dZ = 337 μm
  - α = β = γ = 10 μrad
- TIB Layers
  - dX = dY = dZ = 750 μm
  - α = β = γ = 488 μrad
- TIB Rods
  - du = dv = dw = 450 μm
  - α = β = γ = 293 μrad
- TOB Rods
  - du = dv = dw = 100 μm
  - α = β = γ = 40 μrad

APE = Alignment Position Error

Performances on MB sample

+ Efficiency and fake performances are recovered using APE
(additional error to the hit taking into account alignment precision)

+ transverse momentum resolution partially recovered

+ Higher efficiency with APE is due to the MS effect recovered by a larger search window

Feasibility@LHC - startup scenario - 1 pb-1

dN/dηdϕ vs PT_chg

d(PT_{sum})/dηdϕ ratio vs PT_chg

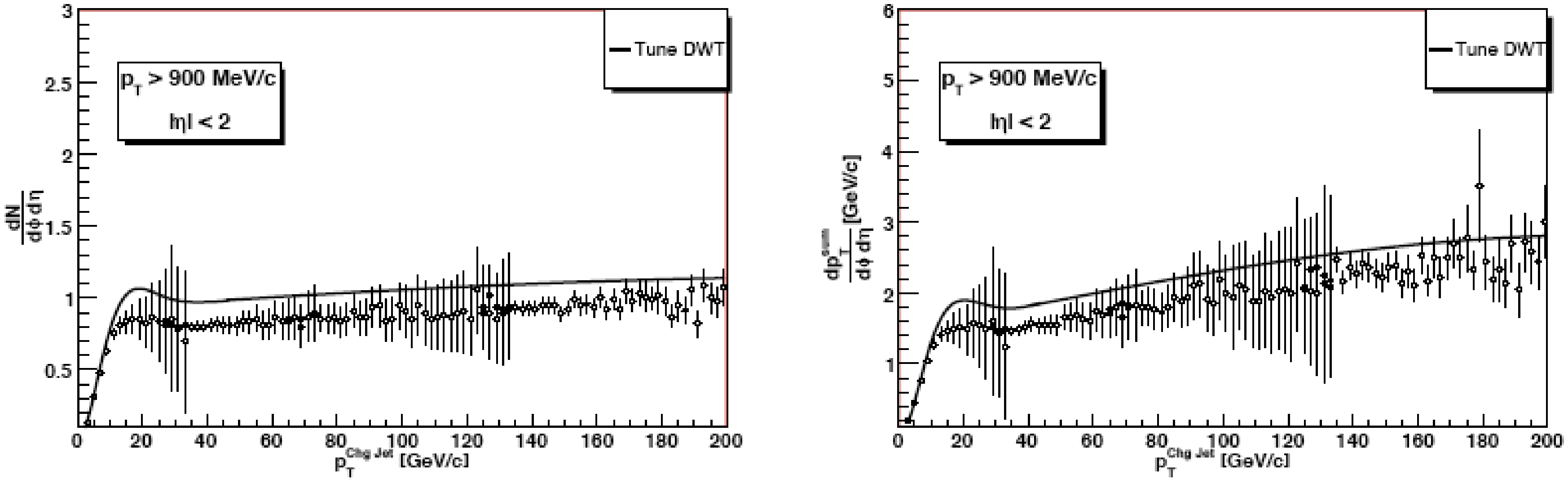


Figure 11: Transverse region. Uncorrected distribution at startup using APE. Density of charged particles dN/dηdϕ (*left*) and the average charged dpt/dηdϕ density (*right*) versus the transverse momentum of the leading charged jet.

Uncorrected data.

Recovering the tracking at startup assure the possibility to build UE observables from first days of datataking and start building correction functions

Feasibility@LHC - systematics

Systematics from adopted triggers and detector related inefficiency (bad channels, dishomogeneities…) are not considered, second order effect

- $\sigma_\epsilon = \sigma_{fake} = 1\%\ (2\%)$
- $\sigma_{Pt} = 2\%\ (4\%)$

considered uncertainties from tracking after 100 pb^{-1}
(x2) -> "safety" factor

$$\sigma_{dN} = \sigma_\epsilon$$

$$\sigma^2_{dPT} = dN^2 * \sigma^2_{Pt} + dPT^2 * \sigma^2_\epsilon$$

$$\sigma^2_{dN_{corr}} = dN^2 * (\sigma^2_\epsilon + \sigma^2_{fake}) + (1 - \epsilon + fake)^2 * \sigma^2_{dN}$$

$$\sigma^2_{dPT_{corr}} = dN^2_{corr} * \sigma^2_{Pt} + dPT^2_{corr} * (\sigma_{dN_{corr}}/dN_{corr})^2$$

Eg: fxing a point: PT_chg = 100 GeV/c, 100 pb^{-1}

$$dN/d\eta d\phi = 1.07 \pm 0.02\ (\text{statistical}) \pm 0.02\ (\text{systematic})$$

$$PT_{sum} = 2.25 \pm 0.06\ (\text{statistical}) \pm 0.07\ (\text{systematic})$$

pT>900 MeV/c

$$dN/d\eta d\phi = 1.75 \pm 0.03\ (\text{statistical}) \pm 0.03\ (\text{systematic})$$

$$PT_{sum} = 2.85 \pm 0.08\ (\text{statistical}) \pm 0.12\ (\text{systematic})$$

pT>500 MeV/c