Impressions from UE&MC working group

- discussion on what is Min Bias
  - experimental aspects ... trigger
  - how to treat diffraction
- Model builders view ...
- what can be learned from forward region
- program for fitting and tuning....

Impressions from UE&MC working group

Minimum Bias and Underlying Event Working Group

chaired by *Michelangelo Mangano (CERN)*

from Monday 01 March 2010 at 08:00 to Tuesday 02 March 2010 at 18:00 (Europe/Zurich)
at CERN (TH Theory Conference Room)

Description *BOOKED a meeting in EVO.*

Title: Minimum Bias and Underlying Event Working Group

Description: Minimum Bias and Underlying Event Working Group

Community: Universe

Meeting Access Information: - Meeting URL-

evo.caltech.edu/evoGate/koala.jnlp

Phone Bridge ID: 1670901

Support michelangelo.mangano@cern.ch

Go to day

Monday 01 March 2010

09:30 - 13:00 Minimum Bias, LHC experimental results
Convener: Michelangelo Mangano (CERN)

- 09:30 **Welcome coffee** 30' (TH common room)
  Served in the TH common room, on the floor under the TH Auditorium, in front of the TH secretariat
- 10:00 **Introduction** 20'
  Setting the goals for the meeting
  Speakers: Michelangelo Mangano (CERN)
  Material: Slides
- 10:20 **ALICE** 40'
  Speakers: Jan Fiete Grosse-Oetringhaus (CERN)
  Material: Slides
- 11:00 **ATLAS** 40'
  Speakers: Emily Nurse, William H. Bell (*Universite de Geneve*)
  Material: Slides
- 11:40 **CMS** 40'
  Speakers: Edward Allen Wenger (*Massachusetts Inst. of Technology (MIT)*)
  Material: Slides
- 12:20 **LHCb** 40'
  Speakers: Michael Schmelling
  Material: Slides

13:00 - 14:00 lunch break

14:00 - 16:30 Modeling of MB and diffraction

- 14:00 **Min-Bias Models - The modeling of SD, DD, and ND** 45'
  Speakers: Peter Skands (CERN)
  Material: Slides
- 14:45 **Discriminating power of forward calorimetric observables for MB&UE modeling** 20'
  Speakers: Hannes Jung
  Material: Slides
- 15:05 **Discussion** 55'
  - First assessment of the inputs from the available LHC data
  - Overview of additional observables providing inputs for the understanding of MB data: correlations (pT versus Nchg, etc), forward observables, input from TOTEM, etc.
  Material: Slides
  - Remarks from ATLAS 15'
    Speakers: Emily Nurse
- 16:00 **coffee break** 30'

16:30 - 18:30 Modeling of MB and diffraction: Impact of MC modeling on the extraction of luminosity from MB triggers

- 16:30 **MC studies** 30'
  Speakers: Beate Heinemann (*LBNL and UC Berkeley*)
  Material: Paper

Tuesday 02 March 2010

09:00 - 10:30 Underlying event issues

- 09:00 **Current status of our understanding of the UE and its relationship to MB** 40'
  Speakers: Richard D. Field
  Material: Slides
- 09:40 **On the characterisation of the underlying event** 20'
  Speakers: Sebastian Sapeta
  Material: Slides
- 10:00 **Discussion** 30'

10:30 - 11:00 coffee break

11:00 - 13:00 Tuning issues

- 11:00 **Introduction** 15'
  Speakers: Michelangelo Mangano (CERN)
  Material: Slides
- 11:15 **Remarks from ATLAS** 15'
  Speakers: Judith Katzy (*DESY, HAMBURG*)
  Material: Slides
- 11:30 **Remarks from CMS** 20'
  Speakers: paolo bartalini
  Material: Slides
- 11:50 **Remarks from LHCb** 20'
  Speakers: Raluca Muresan
  Material: Slides

13:00 - 14:00 Lunch break

14:00 - 16:30 Executive session
Meeting of the WG conveners
Location: 40-R-B10

MB&UE WG

Primary areas of interest and goals

- Determination of general properties of the structure of final states in MB events and in the UE of hard collisions
- Definition of common observables, to be used for comparison across the experiments
- Discussion of MC event-generator tools, definition of common benchmarks
- Global tuning of MC parameters

WG composition

ALICE	Jan Fiete Grosse-Oetringhaus
ATLAS	Kevin Einsweiler/Stefan Tapprogge
CMS	Rick Field
LHCb	Raluca Muresan/Michael Schmelling
TOTEM	Ken Österberg/Valentina Avati
LPCC	Michelangelo Mangano

plus experts from the experiments and TH, as consultants

LPCC

Format/Goals of this meeting

- Open sessions on Monday full day and Tuesday morning
  - Mon-AM: Overview of 2009 results
  - Mon-PM:
    - Review of theory models
    - Discussion of **proposals** for common observables and distributions
    - Impact of MC modeling on luminosity determination: discussion of **proposals** for common tools for the relative rate determination
  - Tue-AM:
    - Review of UE modeling, and proposals for common observables
    - Tuning: discussion of **possible strategies** for a joint global tuning of MC parameters related to MB

- Executive session (WG members and consultants) on Tuesday afternoon:
  - prepare the **recommendations** from this meeting
  - define the **targets** for the next meeting

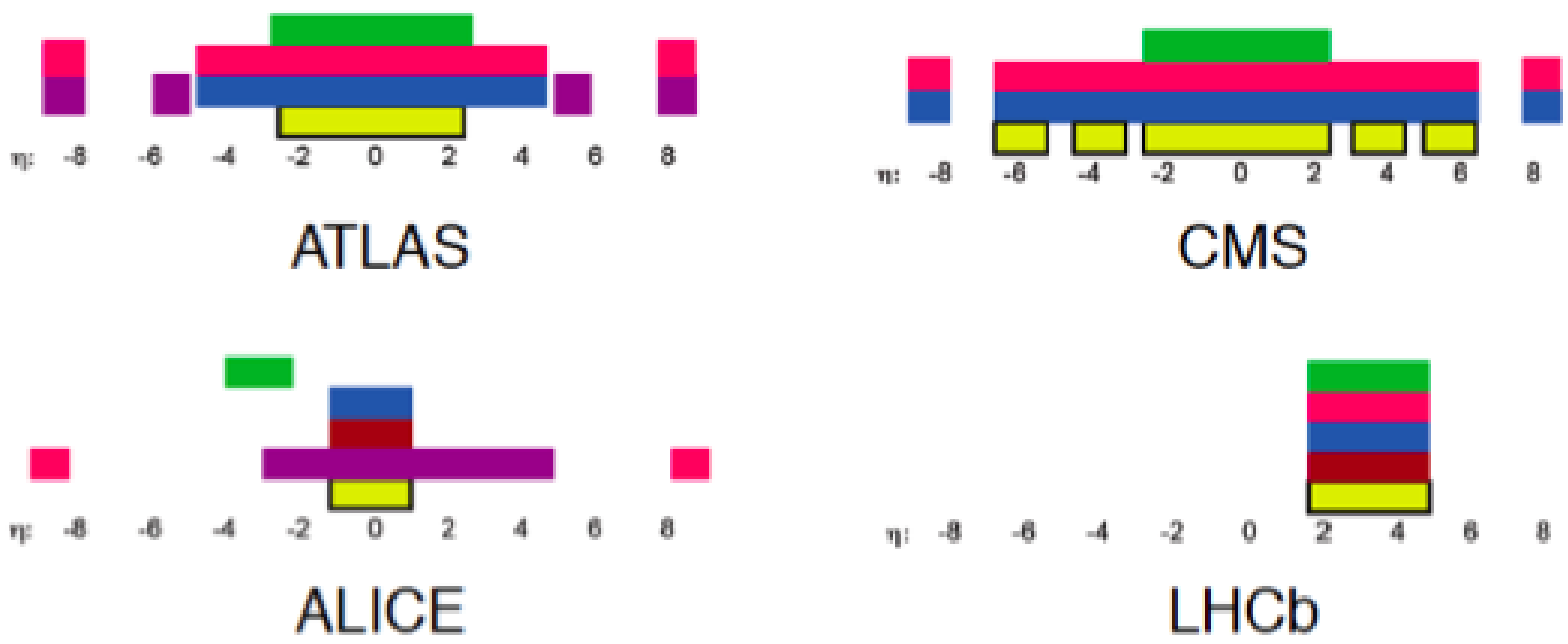
What is minimum bias ?

How to trigger ?

How to define on hadron level ?

Angular Coverage

➜ *range in η covered by the LHC experiments*



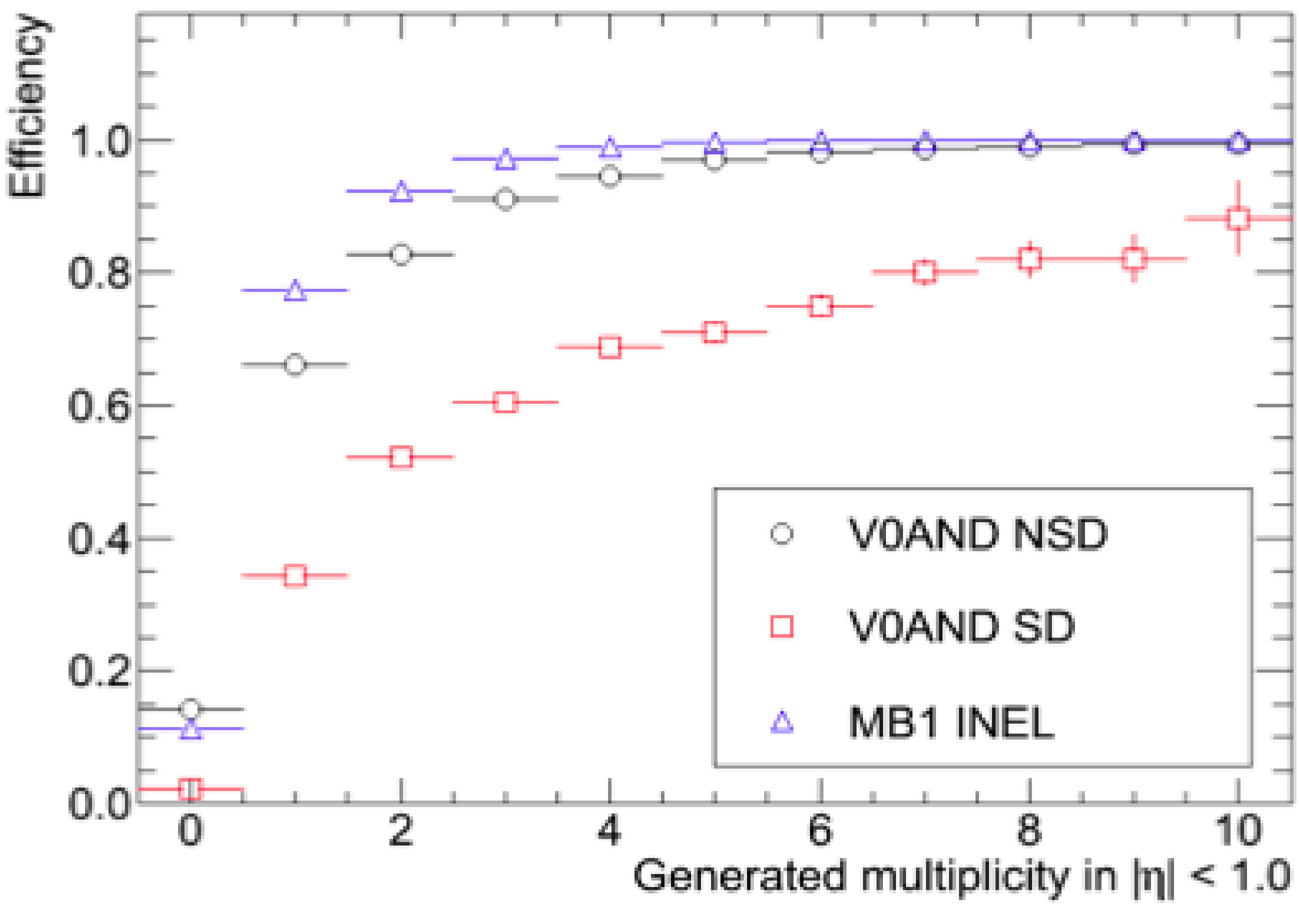
tracking, ECAL, HCAL, counters lumi, muon, hadron PID

- specifics of LHCb
  - ➜ tracking, particle-ID and calorimetry in full acceptance
  - ➜ particle identification for hadrons (also ALICE)
  - ➜ no dedicated lumi counters
  - ➜ no acceptance in very forward region

Trigger for MB Physics

- ALICE measures MB properties for all inelastic (INEL) and non single-diffractive (NSD) events
  - "MB1" trigger for INEL: central pixel hit (SPD) or forward scintillator (V0)
    - One particle in 8 η units
    - (Trigger-)sensitive to 96-98% of the inelastic x-section
  - "V0AND" trigger for NSD: both forward scintillators
- Possible ND trigger V0AND + several hits centrally
  - 90% ND and 20% SD/DD

900 GeV		ND	SD	DD
Pythia	MB1	100	77	92
	V0AND	98	29	49
Phojet	MB1	100	86	98
	V0AND	98	34	66

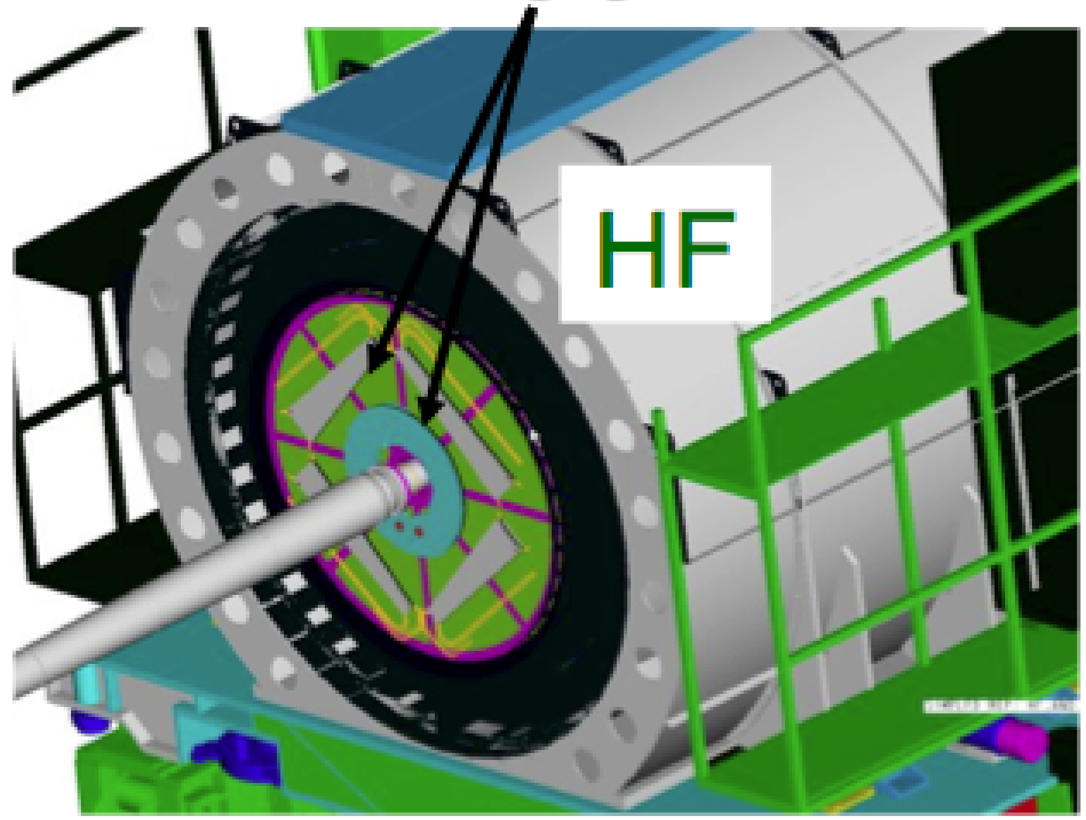


TRIGGER FOR DATA-TAKING

- Data collected Dec. 12th, 14th
- ≈10 Hz collision rate (no pileup)

Trigger:

- Single hit in Beam-Scintillator Counters (BSC)
- In time with both beams crossing interaction point: Beam Pickups (BPTX)



BSC: $3.23 < |\eta| < 4.65$

HF: $2.9 < |\eta| < 5.2$

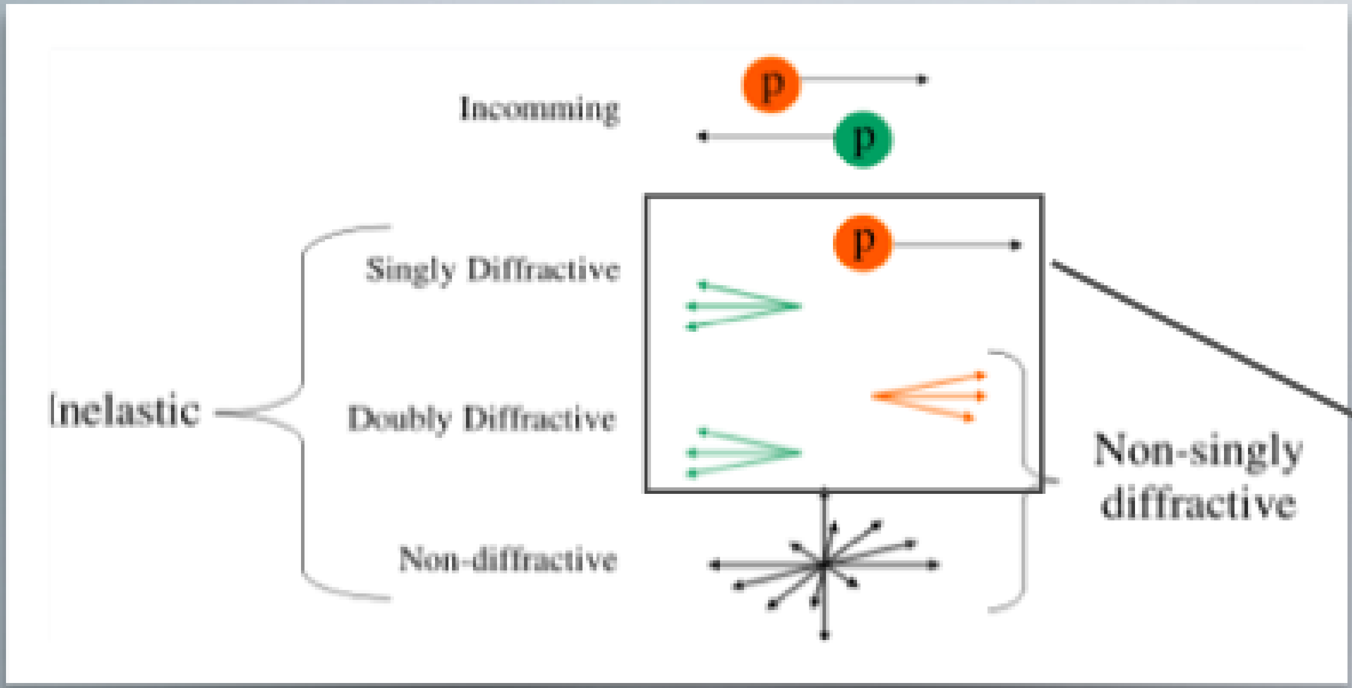
Diffractive Treatment Single Diffraction

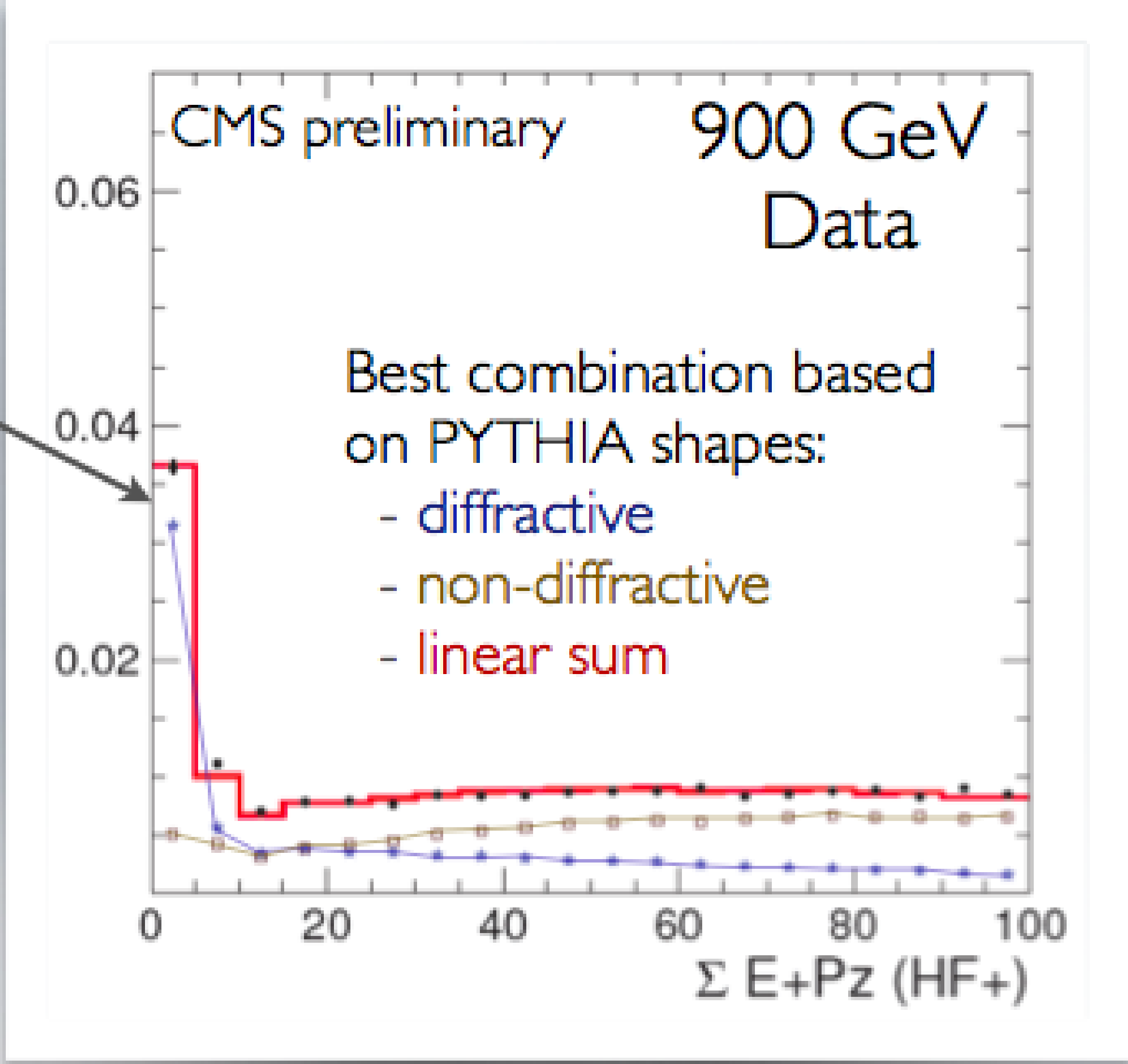
- Use MC generator for corrections per process type (SD, DD, ND)
- Combine using measured weights
- Replay measurement conditions
  - $M^2/s < 0.05$ for UA5 measurement
  - Weight SD such that replayed fraction matches measurement
  - Experiments have corrected for non-SD contribution in their measurements

SD, 900 GeV	Pythia	Phojet
MC fraction	22.3%	19.1%
Replay	18.9%	15.2%
Measurement	(15.3 ± 2.3)%	

*UA5: Z. Phys. C33, 175, (1986) derived from ratio of SD/NSD

DIFFRACTIVE COMPONENT





HF calorimeter energy distribution in data used to constrain SD+DD fraction using PYTHIA (PHOJET) event shapes.

<u>Selection Efficiency:</u>

NSD: ~86%
SD: ~19%
DD: ~34%

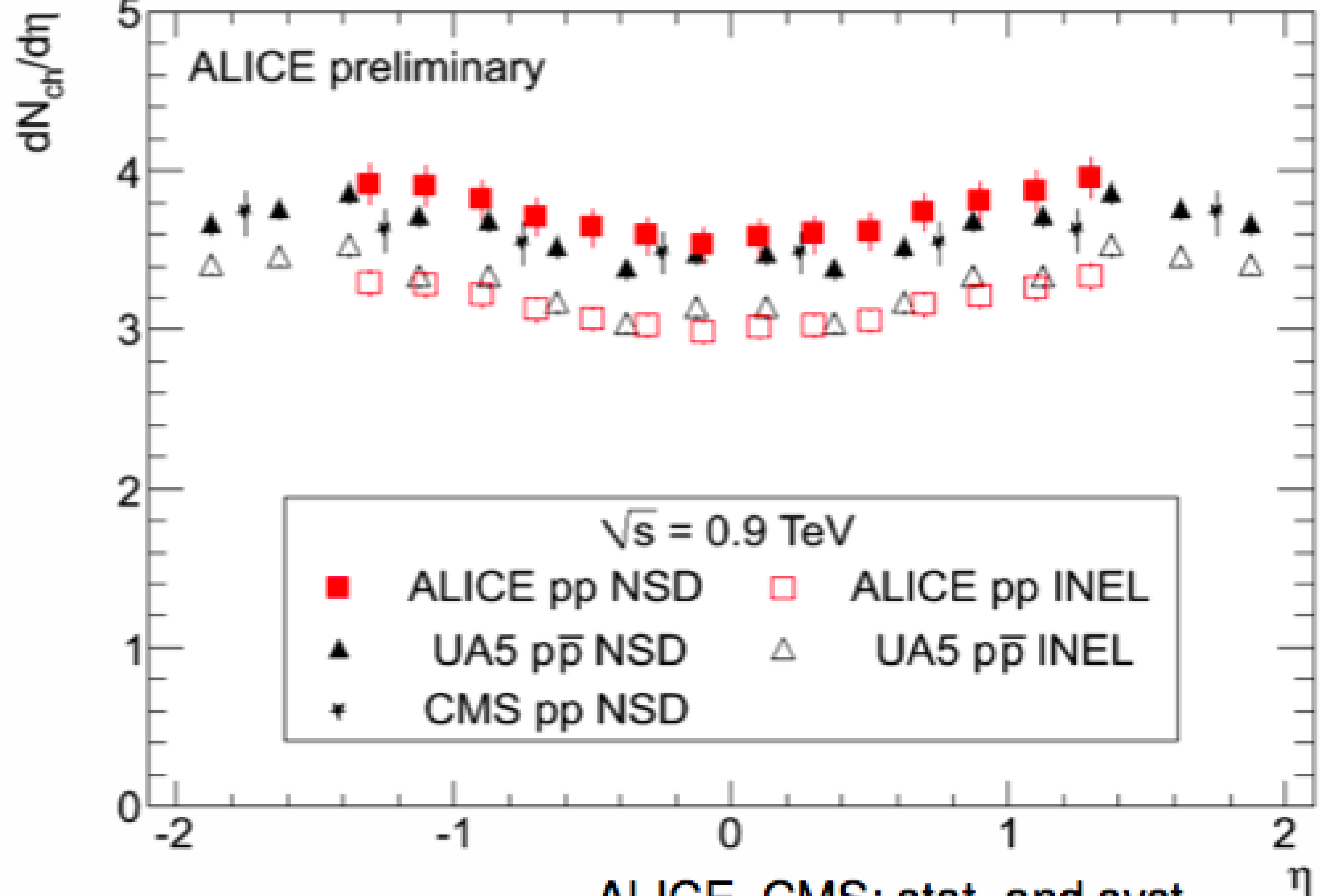
13

Towards a Hadron-Level Definition for SD

- ALICE plans to use a hadron-level definition for SD (for the correction to NSD)
  - Study difference between MC flags and hadron-level definition
- Use the UA5 definition
  - $M^2/s < 0.05$
- First observations
  - The SD bin gets other contributions
    - Small contribution from DD, ND
    - Central diffraction flows to 90% into SD (Phojet)

$dN_{ch}/d\eta$

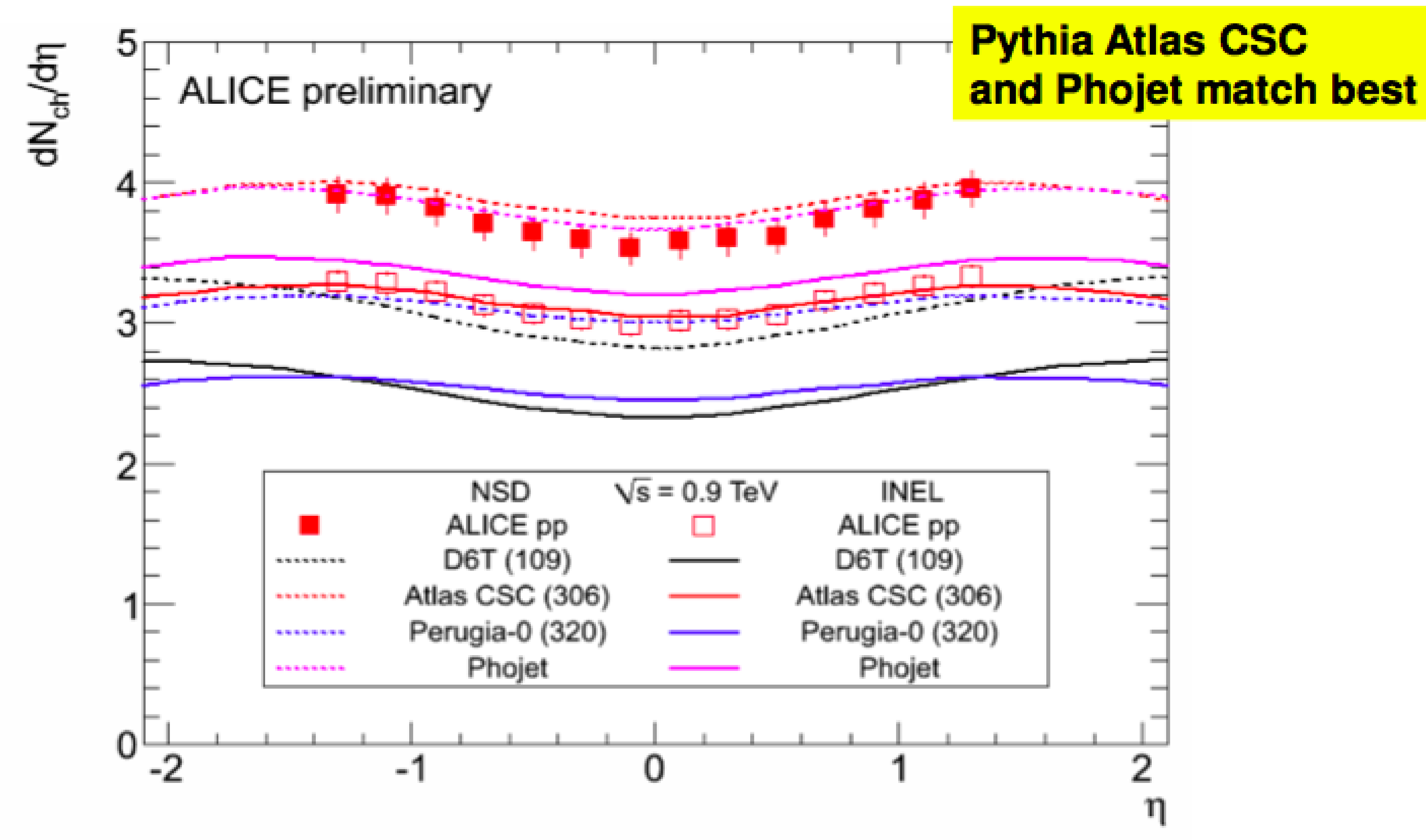
- 900 GeV
- High-statistics measurement (90k events)
- Different triggers for NSD and INEL



ALICE, CMS: stat. and syst. uncertainty added in squares

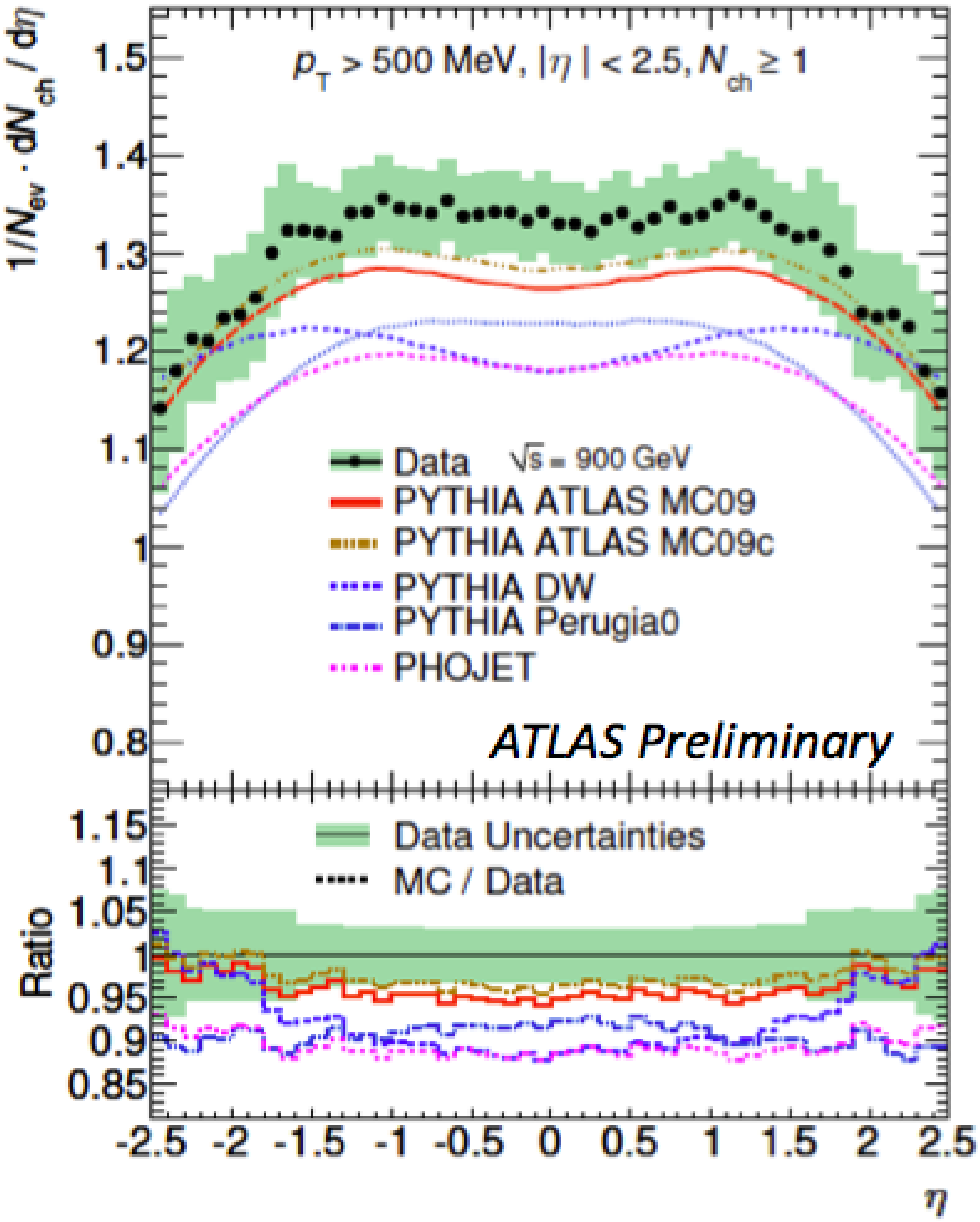
	INEL	NSD
ALICE preliminary	**3.02 ± 0.01 ± 0.07**	**3.58 ± 0.01 ± 0.11**
ALICE published	**3.10 ± 0.13 ± 0.22**	**3.51 ± 0.15 ± 0.25**
UA5 Z. Phys. C33 1 (1986)	**3.09 ± 0.05 ± ?**	**3.43 ± 0.05 ± ?**
CMS JHEP 02 (2010) 041		**3.48 ± 0.02 ± 0.13**

Comparison to MC

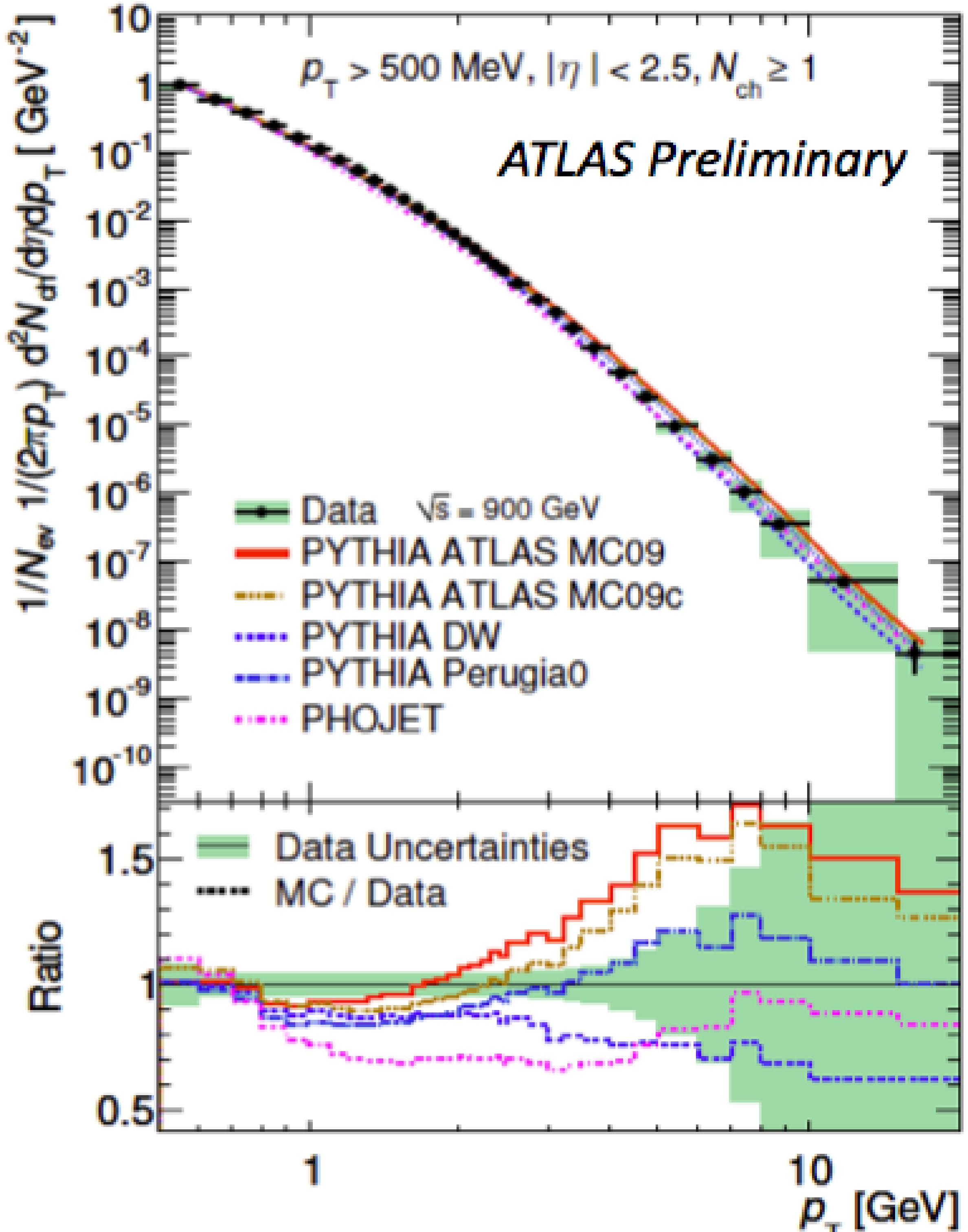


D6T/Atlas: Pythia 6.4.14 - Perugia-0: Pythia 6.4.21 - Phojet 1.12 with Pythia 6.2.14

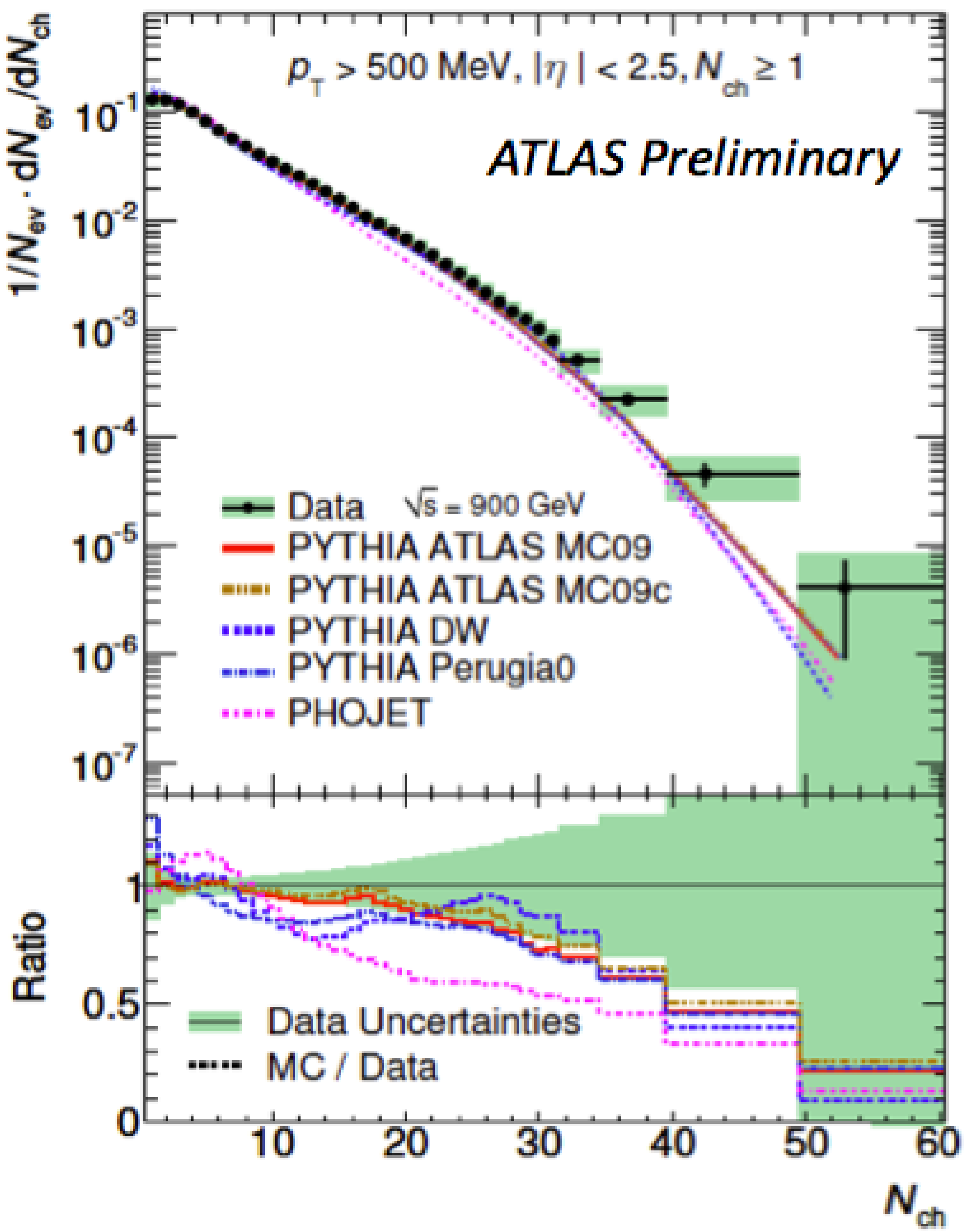
$dN_{ch}/d\eta$



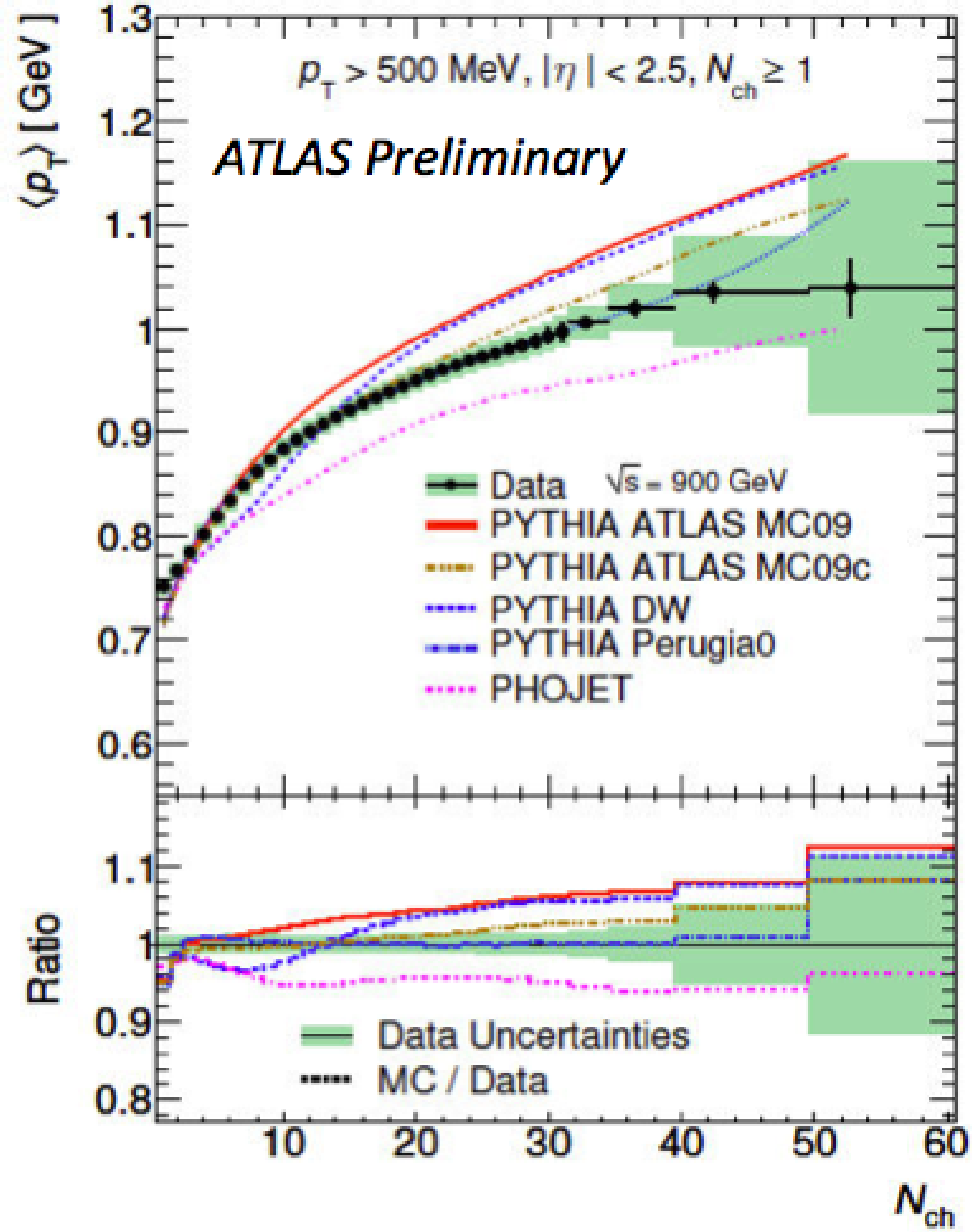
$1/p_T\, dN_{ch}/dp_T$



dN_{ev}/dN_{ch}



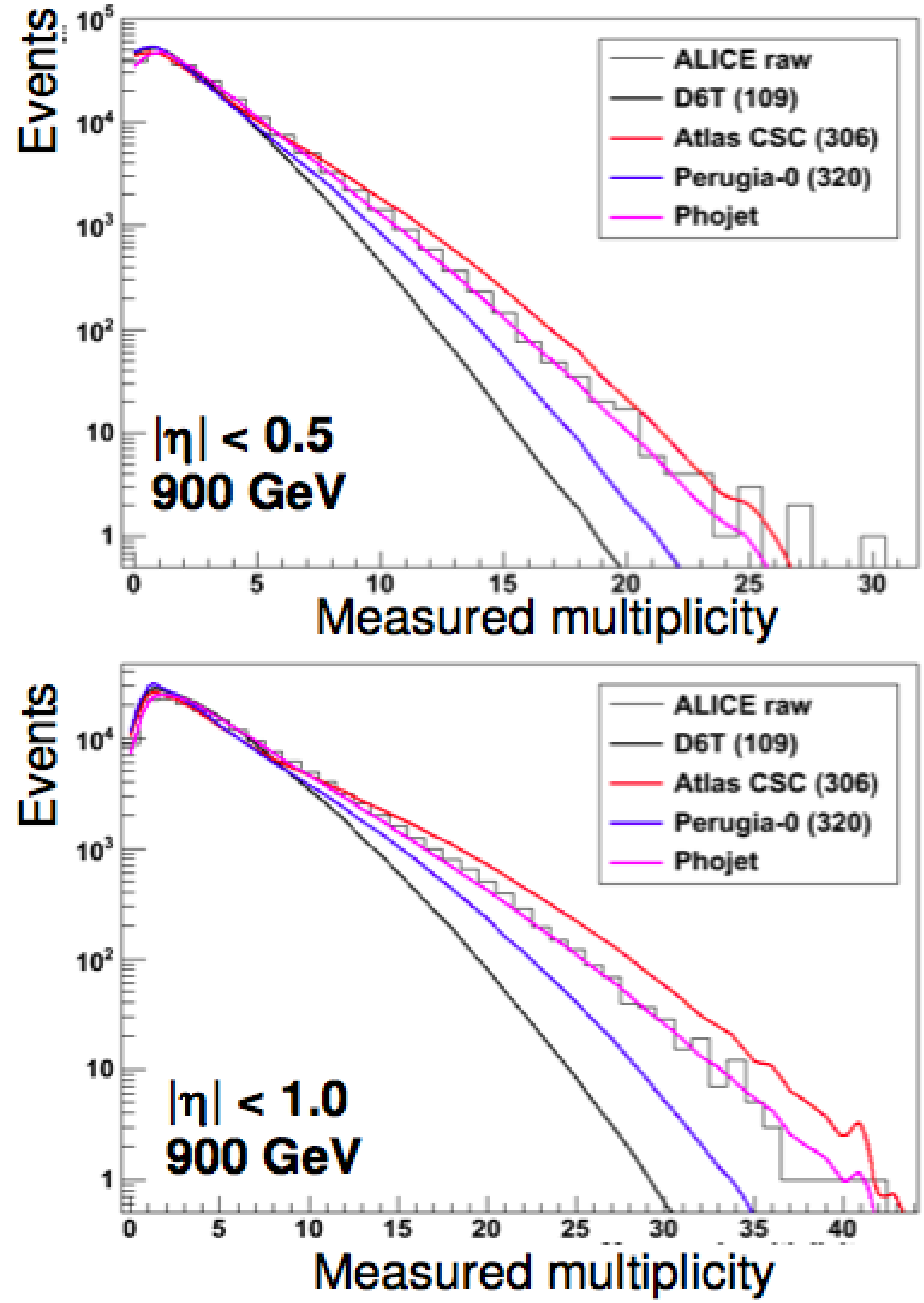
$<p_T>$ vs N_{ch}



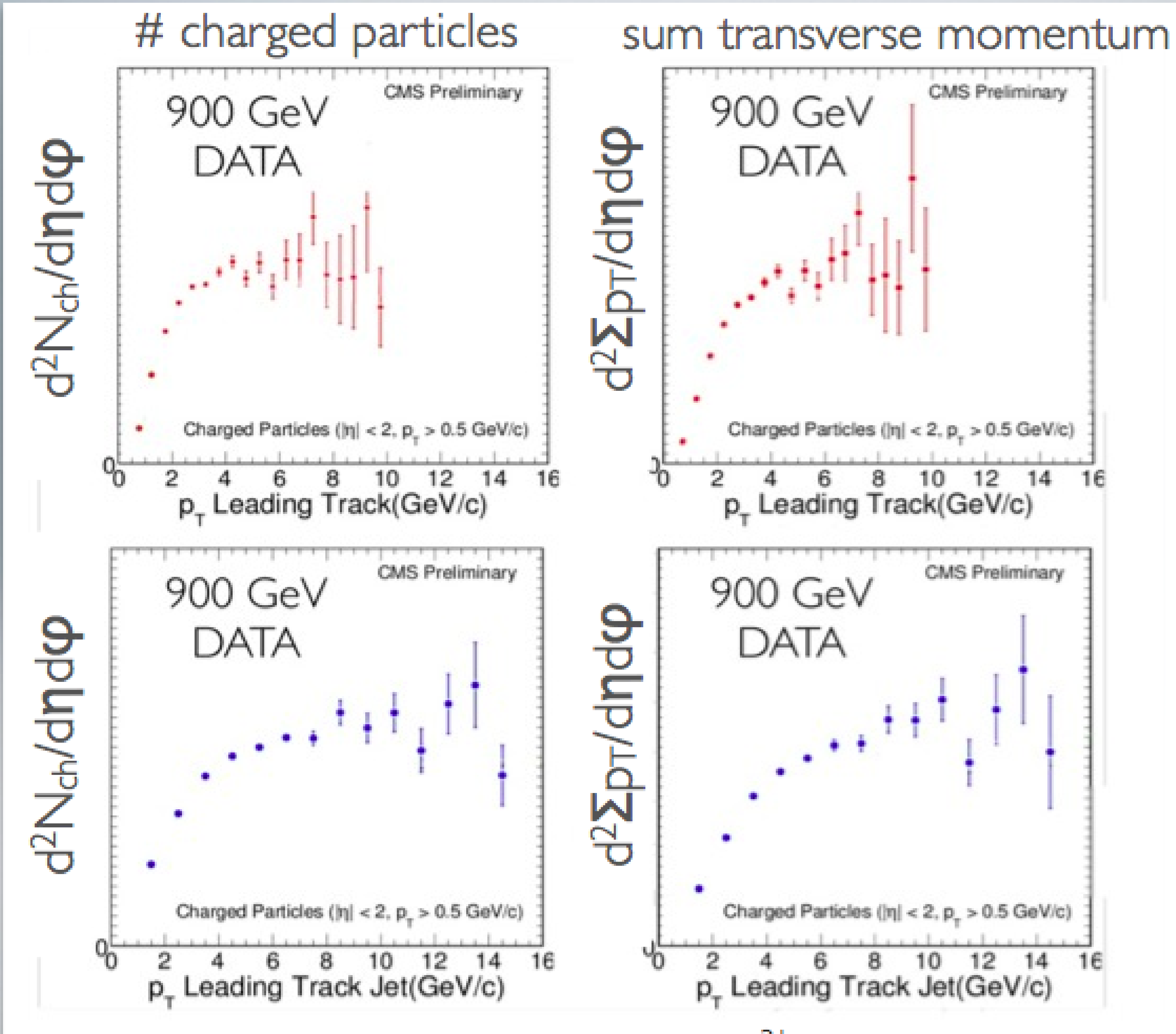
Multiplicity Distributions

- 900 GeV
- Work in progress
- RAW spectra
- MCs propagated through detector response

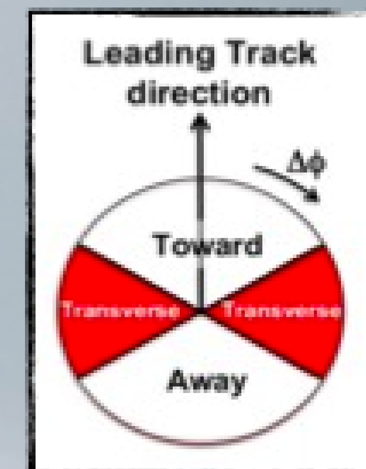
Phojet remarkably close to data



UNDERLYING EVENT



Leading track



Leading jet from tracks

most similar to DW tune

Min-Bias Models
The Modeling of ND, SD, DD

Peter Skands (CERN PH-TH)

UE/MB Meeting, CERN, March 1, 2010

Charged Multiplicity

- One of the most fundamental quantities to measure
  - But fundamental does not imply easy
  - **Experimental Complications: Corrections** for Trigger Bias, Diffraction, Zero Bin, Long-Lived particles, Extrapolations from raw measurement to: hadron-level (with acceptance cuts) and/or to: hadron-level (full phase space), ...

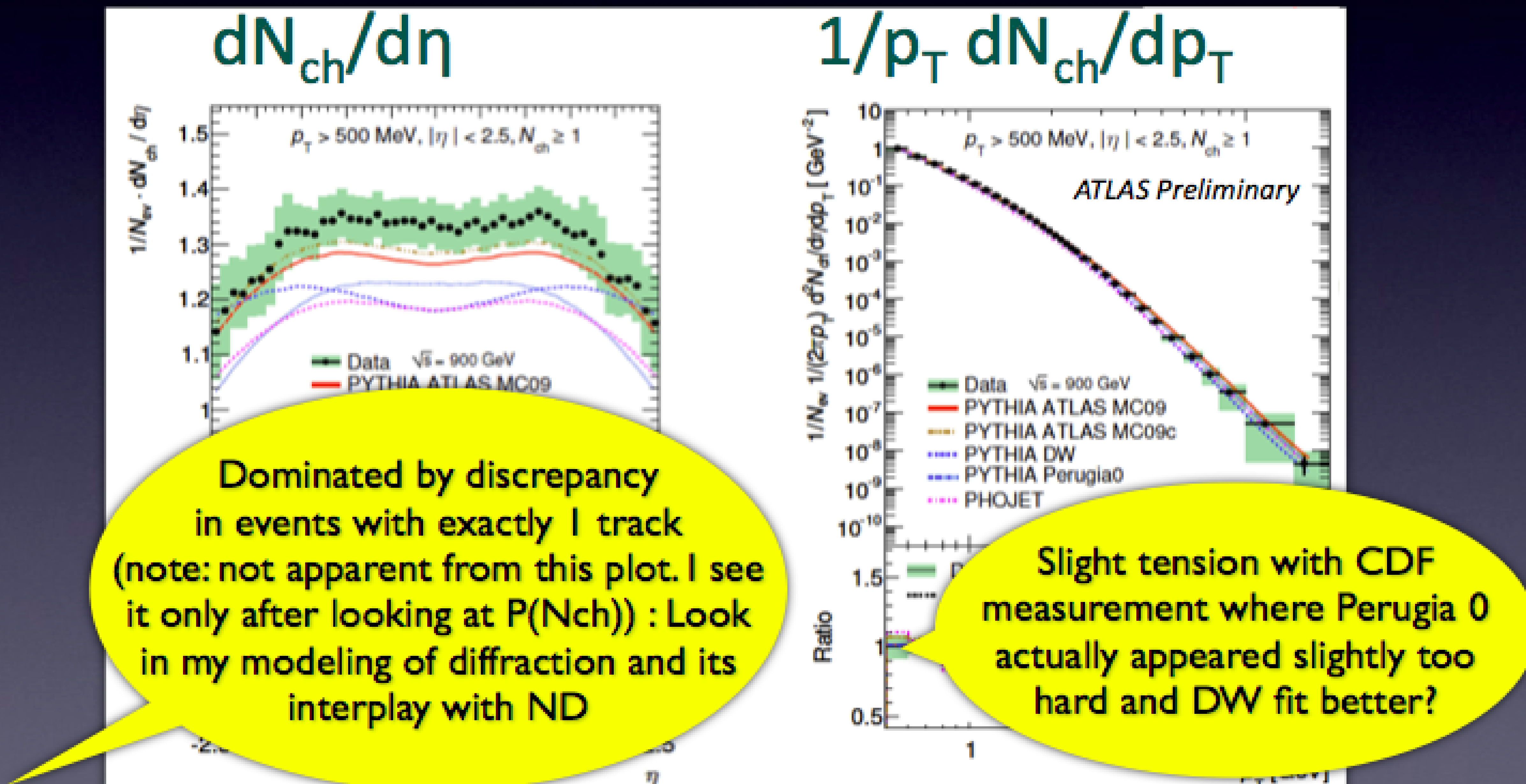
Charged Multiplicity

- One of the most fundamental quantities to measure
  - **Theoretical Complications:**
    - N_{ch} is very **IR sensitive** ...A model that fits N_{ch} but fails on p_T is getting the overall energy flow wrong > agreement on N_{ch} alone may be deceptive

- Need to test several distributions, in several phase space regions, to get complete picture
    - Who breaks down and where : can see patterns and ask why
    - *(Note: a 10% agreement with an IR sensitive number is usually pretty good...)*

The Overall Picture

- How does a model builder look at this?



Measured Results

- **How to Compare to Older Measurements?**
  - Bubble chambers etc extrapolated to full phase space
  - More model-dependent at Tevatron and LHC experiments

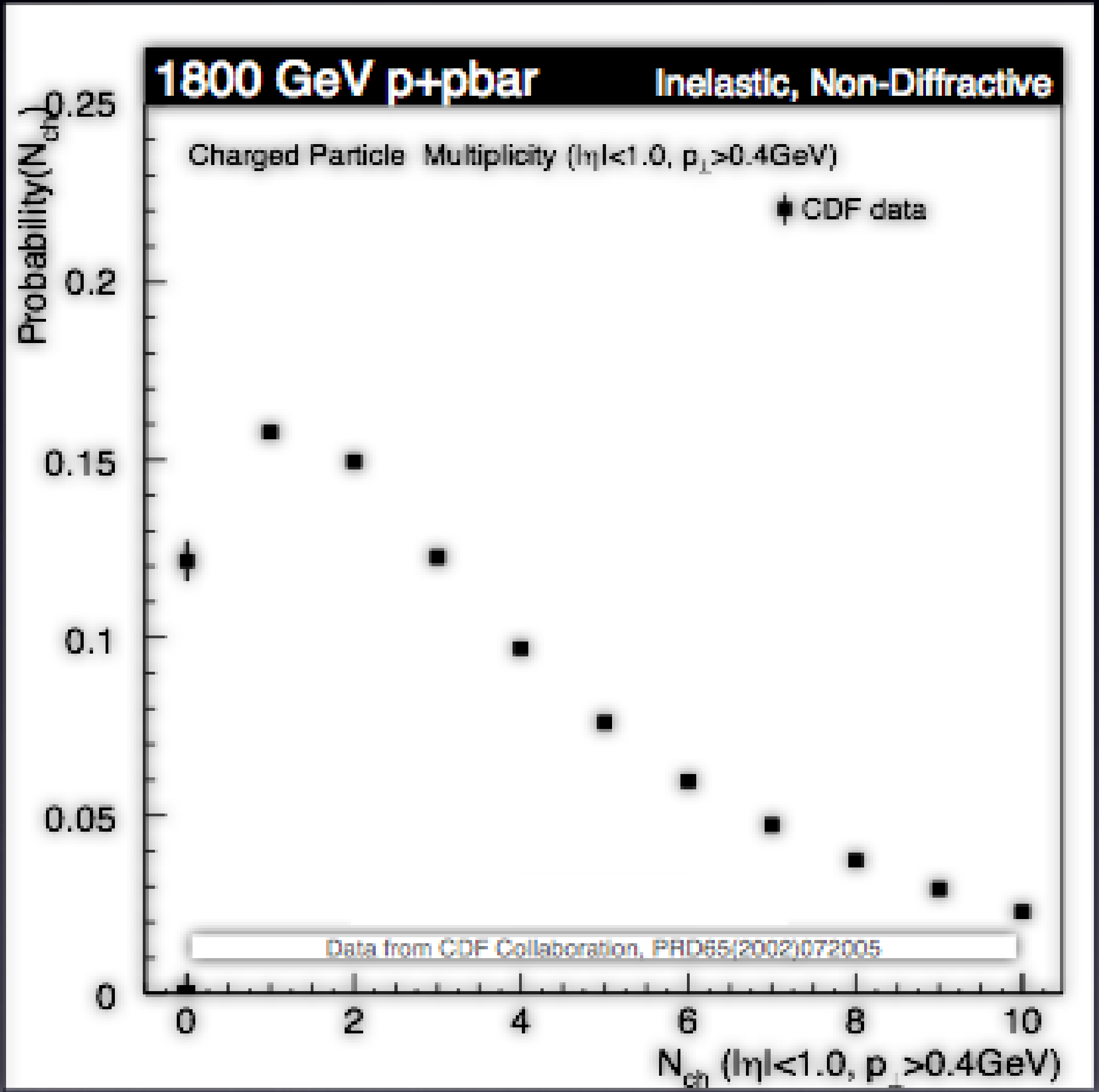
- **How to Compare to Theory?**
  - Inelastic > 'NSD' > Inelastic Non-Diffractive, ... ?
    - For all: Define event set in terms of hadron-level cuts (model-*inspired*, *yes*, but not model-*dependent*)
  - Model constraints not helped by filling up unmeasured region with some model/fit (especially if it is some other guy's model) - Keep main measured result as close to raw acceptance as possible. Extrapolate *only* to do comparisons (inflates uncertainties)

Low Multiplicities: Correcting for Diffraction

- Diffractive processes
  - Large part of total cross section ↗ cf. Beate's talk
  - Populate the low-multiplicity bins: lower $\langle N_{ch} \rangle$
  - Characteristic rapidity spectrum with large rapidity gaps: affect dN_{ch}/deta
  - Impossible to interpret min-bias spectra without knowing precisely how diffraction was treated

Low Multiplicities: Correcting for Diffraction

- CDF Run-I Data
  - Corrected to pT>0.4 GeV instead of full PS: less model dependence
  - First few bins corrected for diffraction (also affects average Nch and dN/deta)



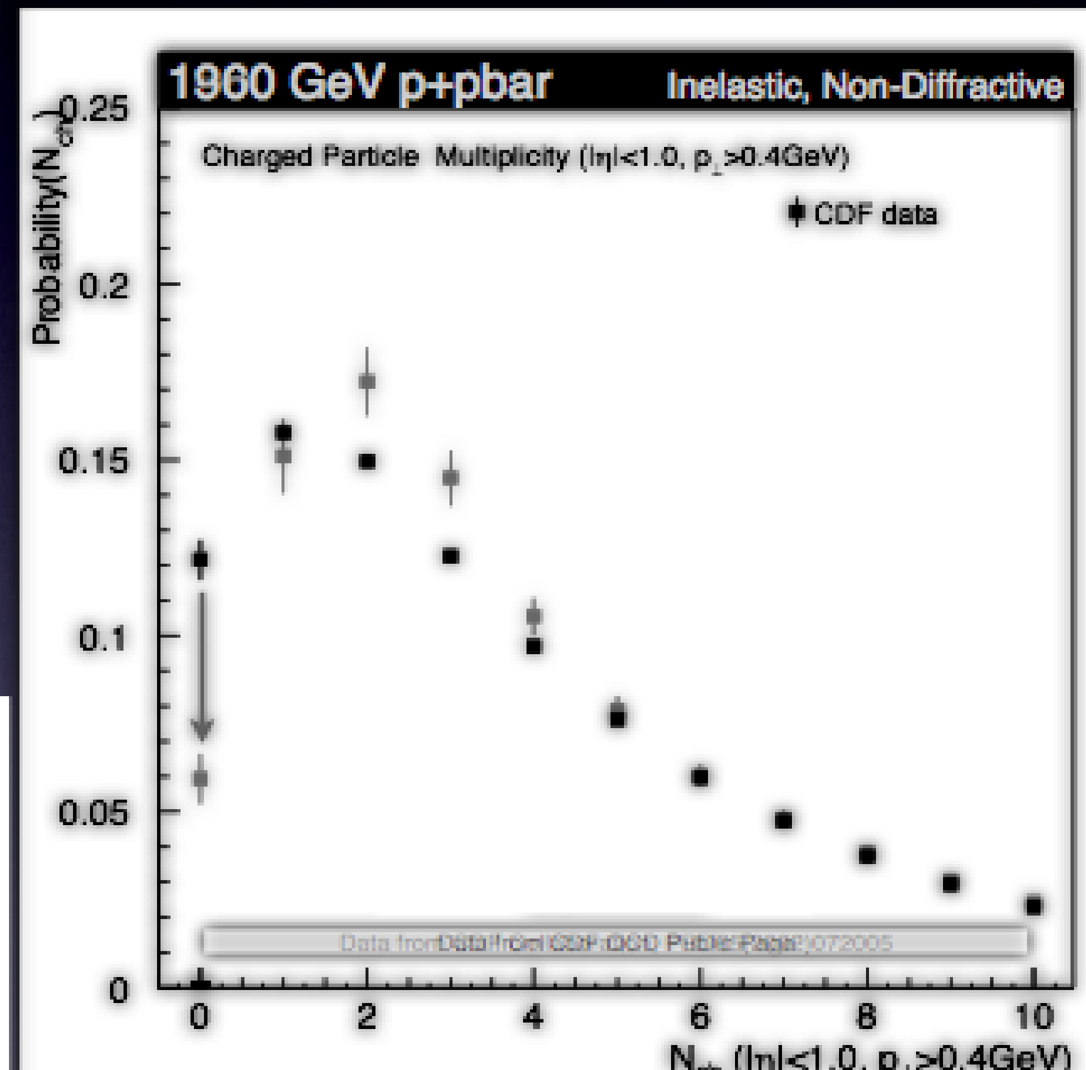
The Zero Bin

- The most problematic is the **zero bin:** *the event was triggered, but no fiducial tracks*
  - *E.g, was it a diffractive event with no tracks, or an inelastic non-diffractive event, with no tracks? Or ... ?*

Predictions for Mean Densities of Charged Tracks

	$\frac{\langle N_{ch}\rangle \|_{N_{ch}\geq 0}}{\Delta\eta\Delta\phi}$	$\frac{\langle N_{ch}\rangle \|_{N_{ch}\geq 1}}{\Delta\eta\Delta\phi}$	$\frac{\langle N_{ch}\rangle \|_{N_{ch}\geq 2}}{\Delta\eta\Delta\phi}$	$\frac{\langle N_{ch}\rangle \|_{N_{ch}\geq 3}}{\Delta\eta\Delta\phi}$
LHC 10 TeV	0.40 ± 0.05	0.41 ± 0.05	0.43 ± 0.05	0.46 ± 0.06
LHC 14 TeV	0.44 ± 0.05	0.45 ± 0.06	0.47 ± 0.06	0.51 ± 0.06

PS, Perugia Proceedings, arXiv:0905.3418 [hep-ph]



Redefine the event sample to include at least one fiducial track?

→ATLAS

Ways Out

A) Trust the theorists. Correct to specific set of fundamental processes → NSD, INEL, ...

"Traditional" strategy.
Employed by most previous experiments.

Also used in the first two LHC papers
ALICE Collaboration, Eur. Phys. J. C65 (2010) 111
CMS Collaboration, JHEP 02 (2010) 041

However, it lacks a clear definition at the particle level

Ways Out

A) Trust the theorists. Correct to specific set of fundamental processes → NSD, INEL, ...

I	particle/jet	P(I,1)	P(I,2)	P(I,3)	P(I,4)	P(I,5)
1	p+	0.38955	-0.09031	-444.18188	444.18305	0.93827
2	p+	0.55491	-0.32947	118.14484	118.15033	0.93827
3	pi+	-0.10520	0.04623	21.97324	21.97398	0.13957
4	pi-	-0.36420	0.20220	79.60000	79.60121	0.13957
5	pi+	0.18465	-0.31136	44.33333	44.33503	0.13957
6	pi-	-0.65347	0.35445	10.76828	10.79481	0.13957
7	pi+	-0.31719	-0.18864	4.89293	4.90881	0.13957
8	pi-	0.18684	-0.24438	0.75472	0.82687	0.13957
9	pi+	0.01778	0.47298	1.28424	1.37578	0.13957
10	pi-	0.28540	-0.36795	2.98245	3.02181	0.13957
11	K+	0.01880	0.15742	2.95334	2.99849	0.49360
12	pi-	0.07232	0.23225	6.16625	6.17263	0.13957
13	pi+	-0.37412	0.04117	0.68340	0.79257	0.13957
14	pi-	0.12547	0.33701	2.03239	2.06867	0.13957
15	pi+	0.03865	0.05823	0.98258	0.99490	0.13957
16	pi-	0.16134	0.03535	4.09086	4.09657	0.13957
17	pi-	-0.06906	0.08845	1.96279	1.97095	0.13957
18	pi+	0.11852	-0.32616	3.70555	3.72438	0.13957
sum(p). mass:		0.27097	0.16745	-136.87069	751.99084	739.42987

eta gap
= 13.6 units

Ways Out

A) Trust the theorists. Correct to specific set of fundamental processes → NSD, INEL, ...

I	particle/jet	P(I,1)	P(I,2)	P(I,3)	P(I,4)	P(I,5)
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6	pi-	-0.65347	0.35445	10.76828	10.79481	0.13957
7	pi+	[illegible]	[illegible]	[illegible]	[illegible]	0.13957
8	pi-	[illegible]	[illegible]	[illegible]	[illegible]	0.13957
9	pi+	[illegible]	[illegible]	[illegible]	[illegible]	0.13957
10	pi-	0.28540	-0.36795	2.98245	3.02181	0.13957
11	K+	0.01880	0.15742	2.95334	2.99849	0.49360
12	pi-	0.07232	0.23225	6.16625	6.17263	0.13957
13	pi+	-0.37412	0.04117	0.68340	0.79257	0.13957
14	pi-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	pi+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	pi-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	pi-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	pi+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
sum(p). ma[illegible]						

eta gap = 13.6 units

MC "Truth" : Double Diffractive

Minimal Conclusion: gap definition not foolproof if we see charged only

I	particle/jet	P(I,1)	P(I,2)	P(I,3)	P(I,4)	P(I,5)
1	p+	0.18101	-0.23124	427.60408	427.60521	0.93827
2	p+	-0.06244	-0.10079	-231.29111	231.29304	0.93827

Moral: What some theorist/model defines as SD, DD, etc, *is not itself a physical observable!*

Tails of one are *indistinguishable* from the other (even with a perfect detector with full PID)

If no physical measurement can tell the difference, it does not make sense to correct back to

25	K L0	-0.45356	0.56332	4.42730	4.51350	0.49767

And this is even assuming we had the perfect model on which everyone agrees ...

33	pi+	0.29351	-0.13195	0.09074	0.36231	0.13957
sum momentum		0.00000	0.00000	0.00000	900.00000	900.00000

Ways Out

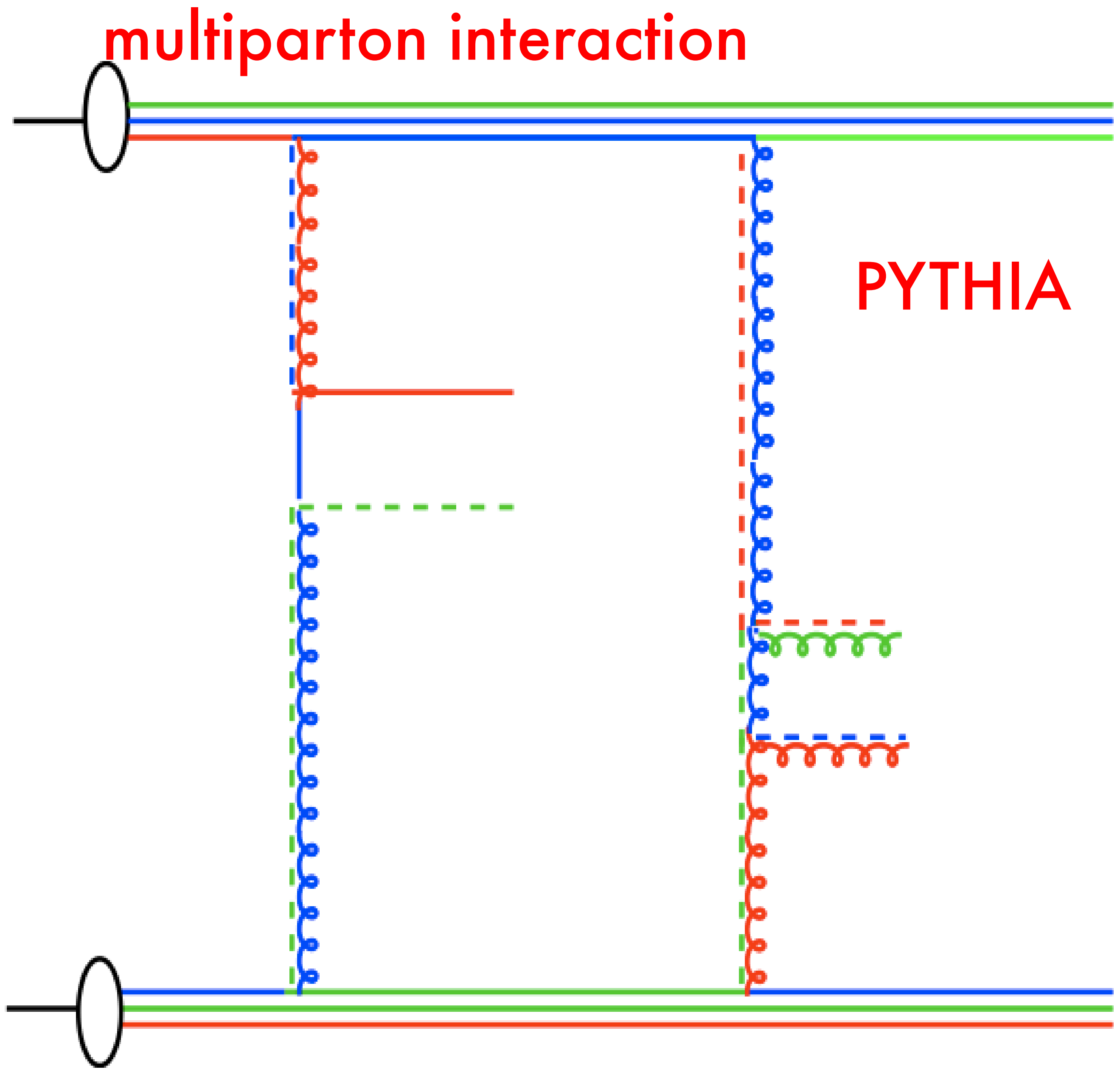
A) Trust the theorists. Correct to specific set of fundamental processes → NSD, INEL, ...

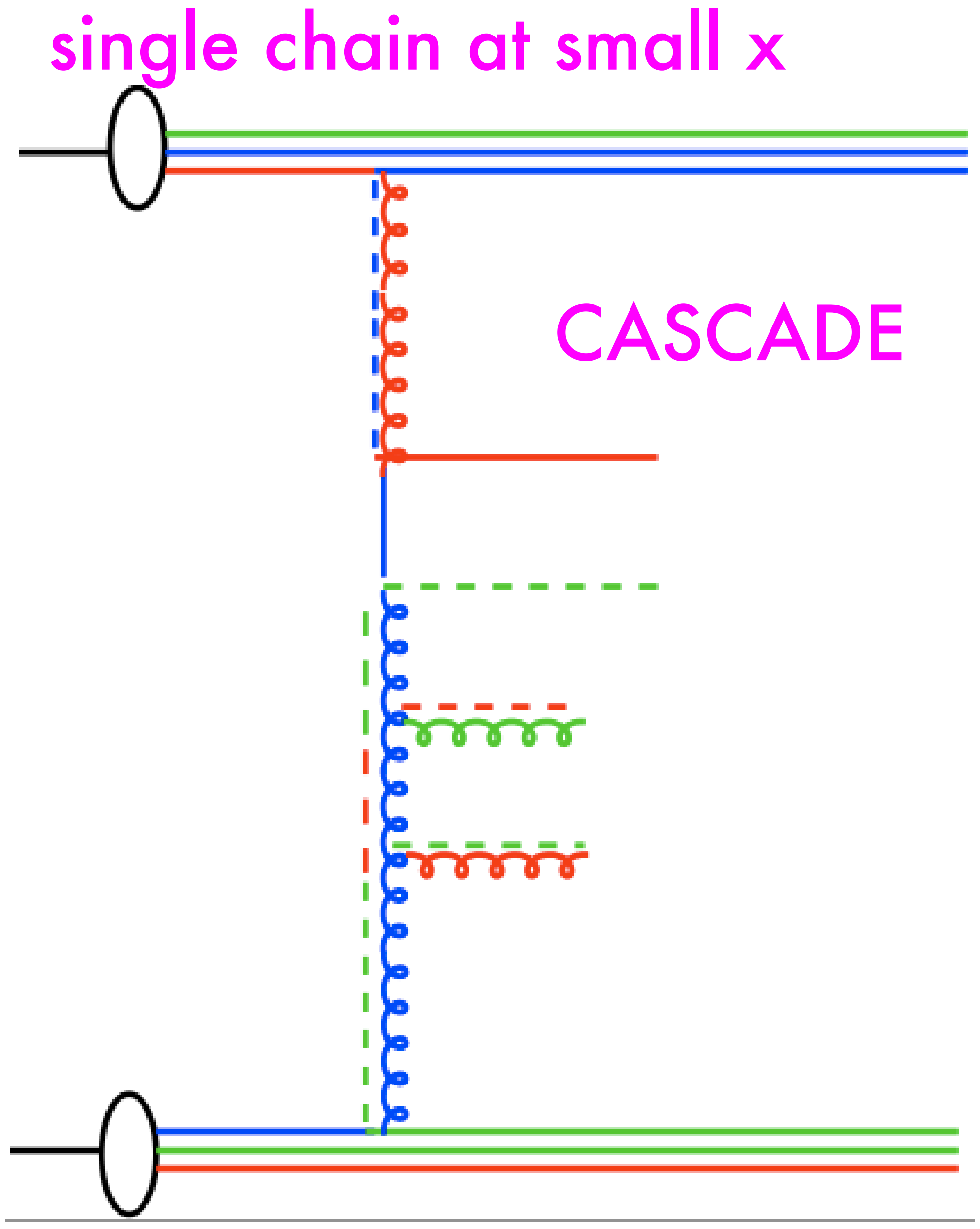
B) Report a measurement with a given set of hadron-level cuts → MB

Employed in the third LHC paper
ATLAS Collaboration, preliminary
(see talk this morning)

Can we tell MPI from parton radiation ?

- parton radiation in forward region:

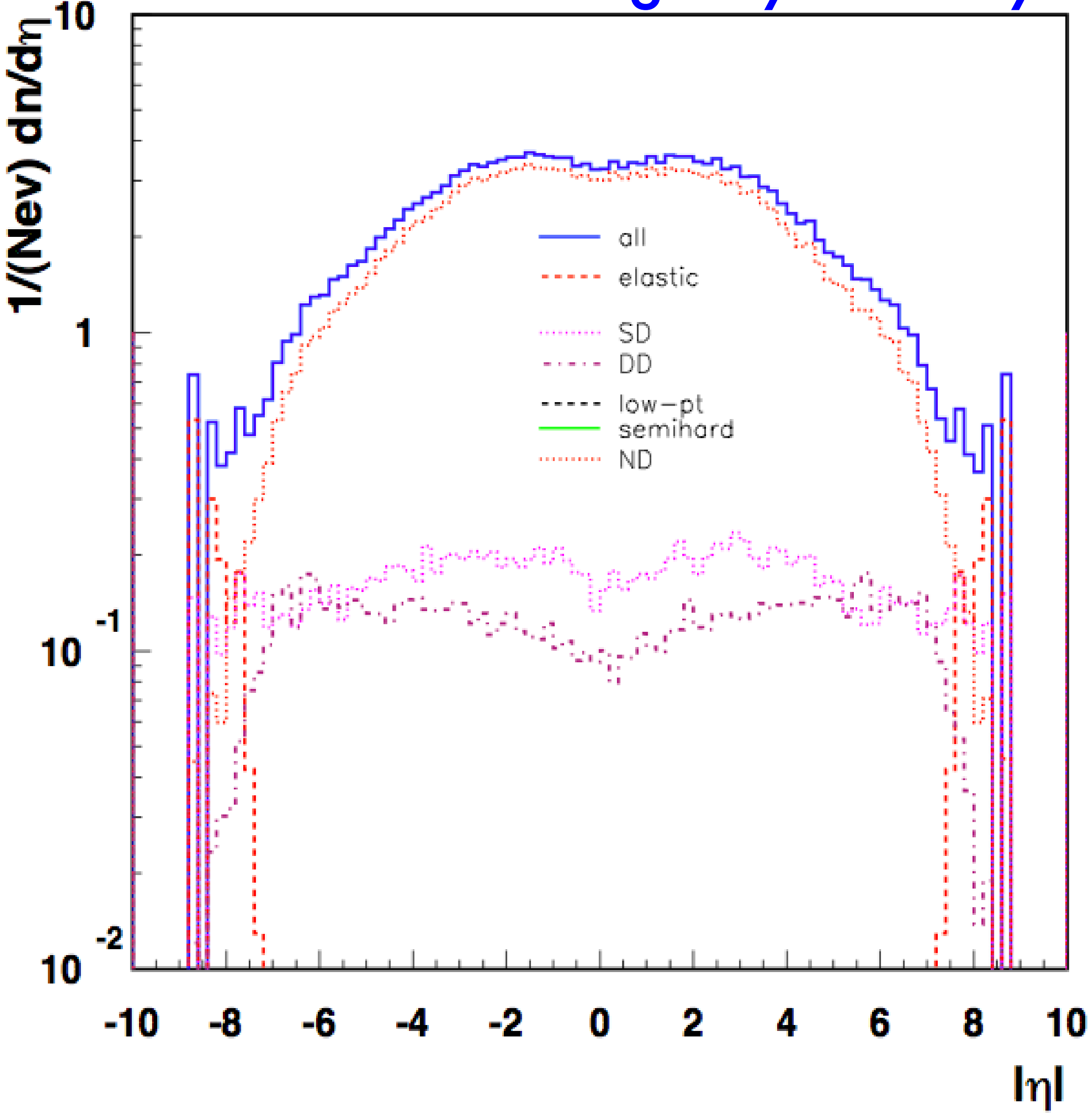




- which of the two is correct or are they both describing the same ... ???

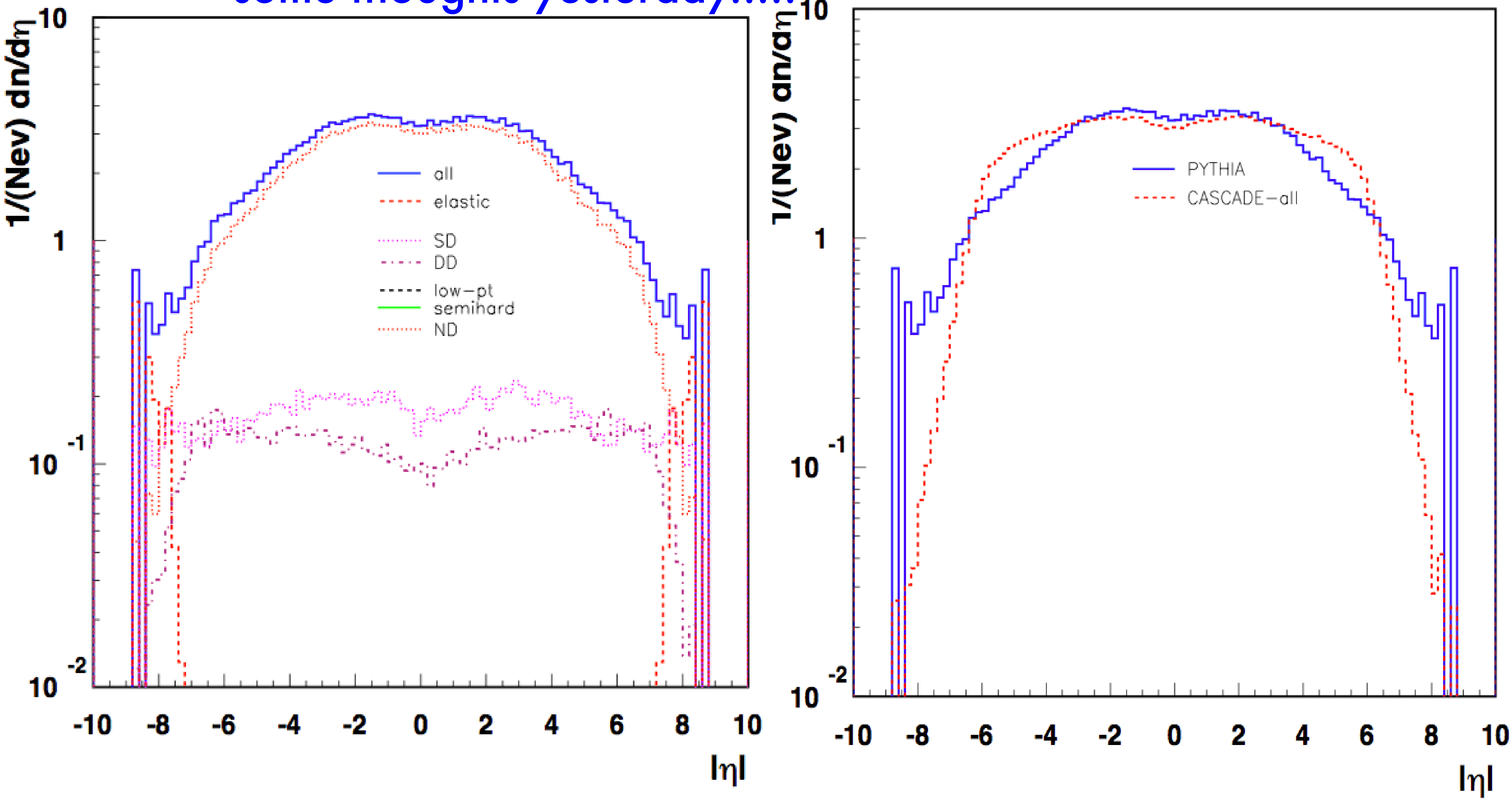
charged particle multiplicity

- some thoughts yesterday.....



charged particle multiplicity

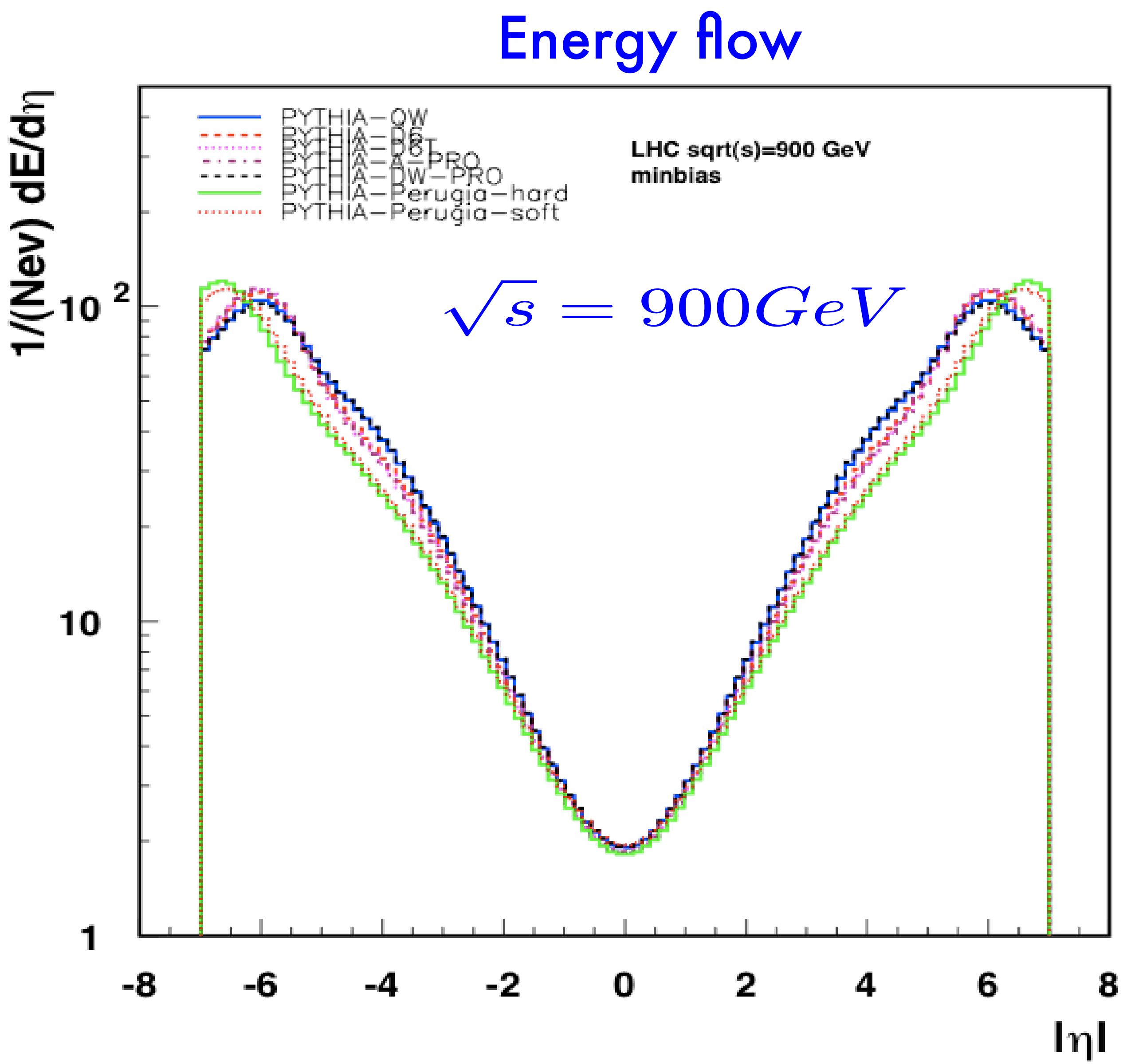
- some thoughts yesterday.....

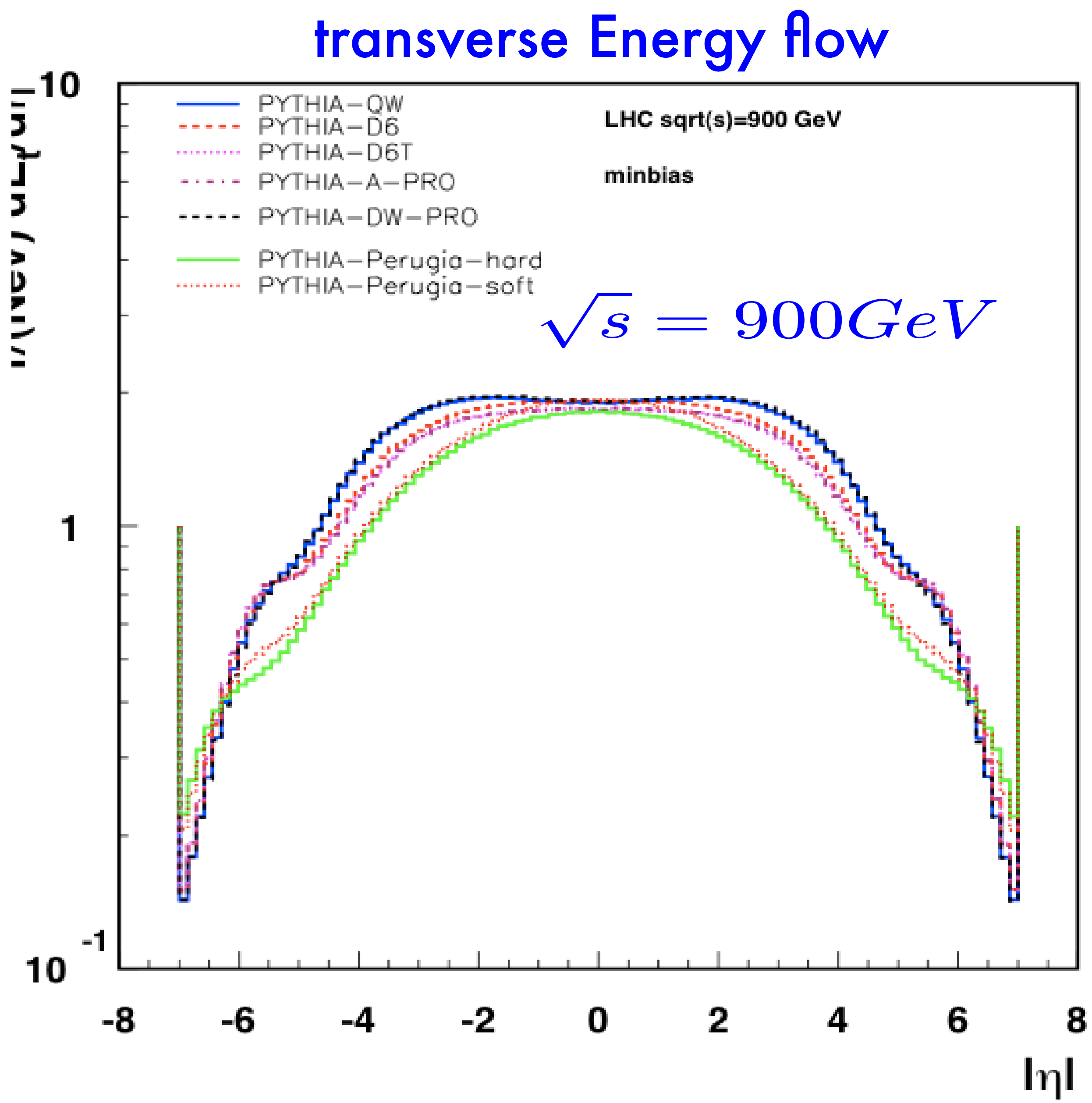


- CASCADE without tuning.....
- hmmm.... in $|\eta|<2$ CASCADE does as well as PYTHIA

What happens in the forward region ?

Energy flow at 900 GeV

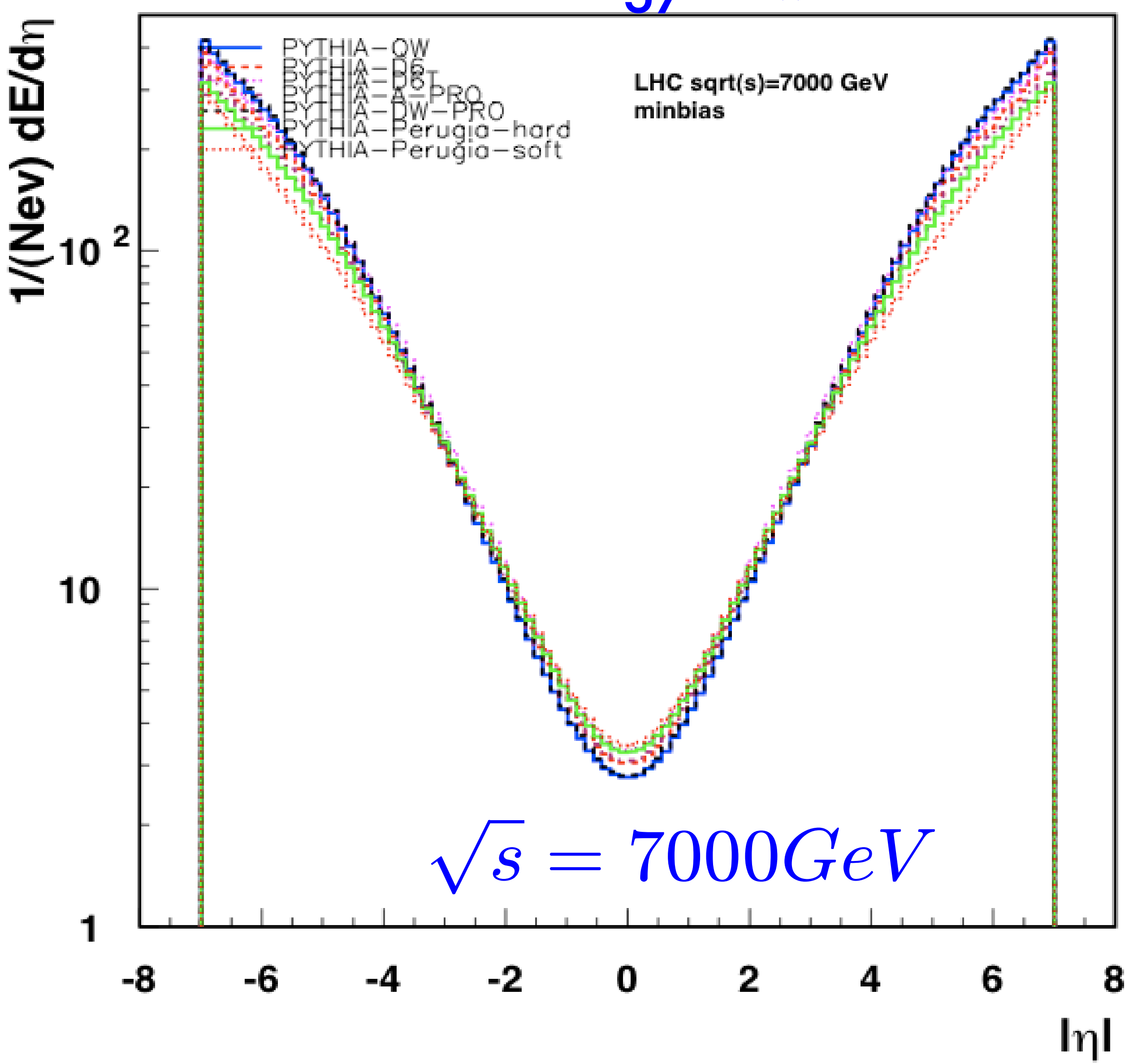




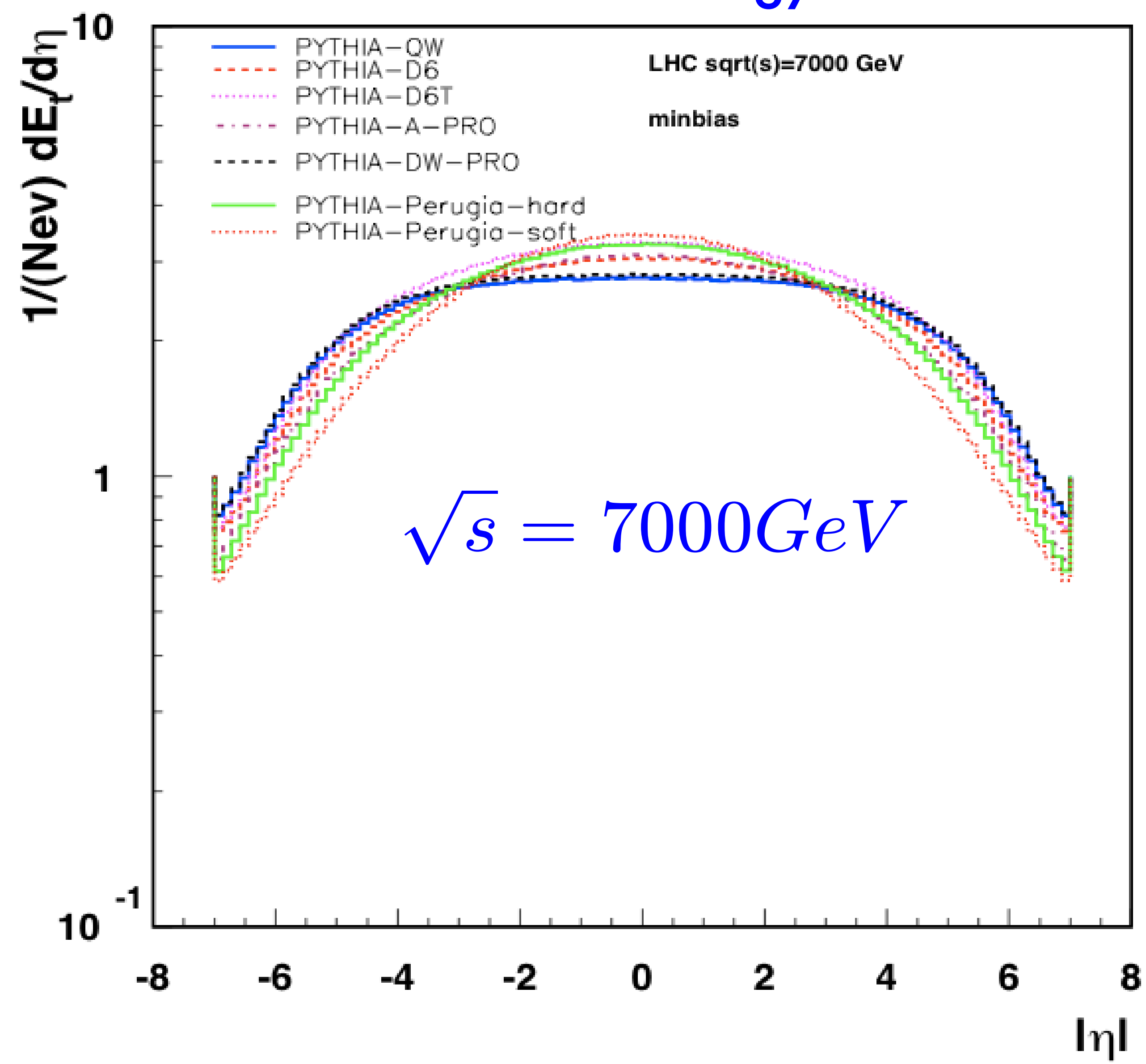
- energy flow in central region at low $\sqrt{s}$ does not change much with tunes
- Significant effects visible in forward/backward region $|\eta| > 2$
- use this for tuning of parameters ....

energy flow at 7000 GeV

Energy flow

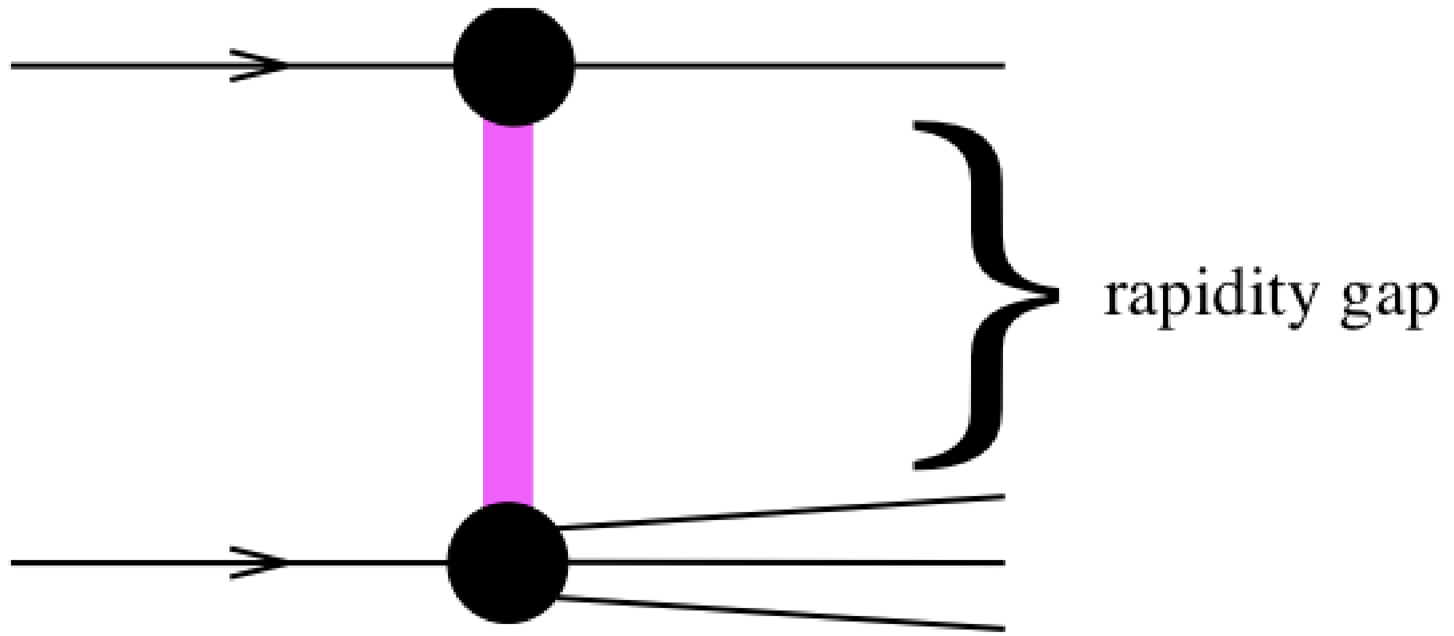


transverse Energy flow



- Energy flow in central region at large $\sqrt{s}$ depends on tunes
- Still large effects visible in forward/backward region $|\eta| > 2$
- "All" tunes give different results $\rightarrow$ use it for tuning

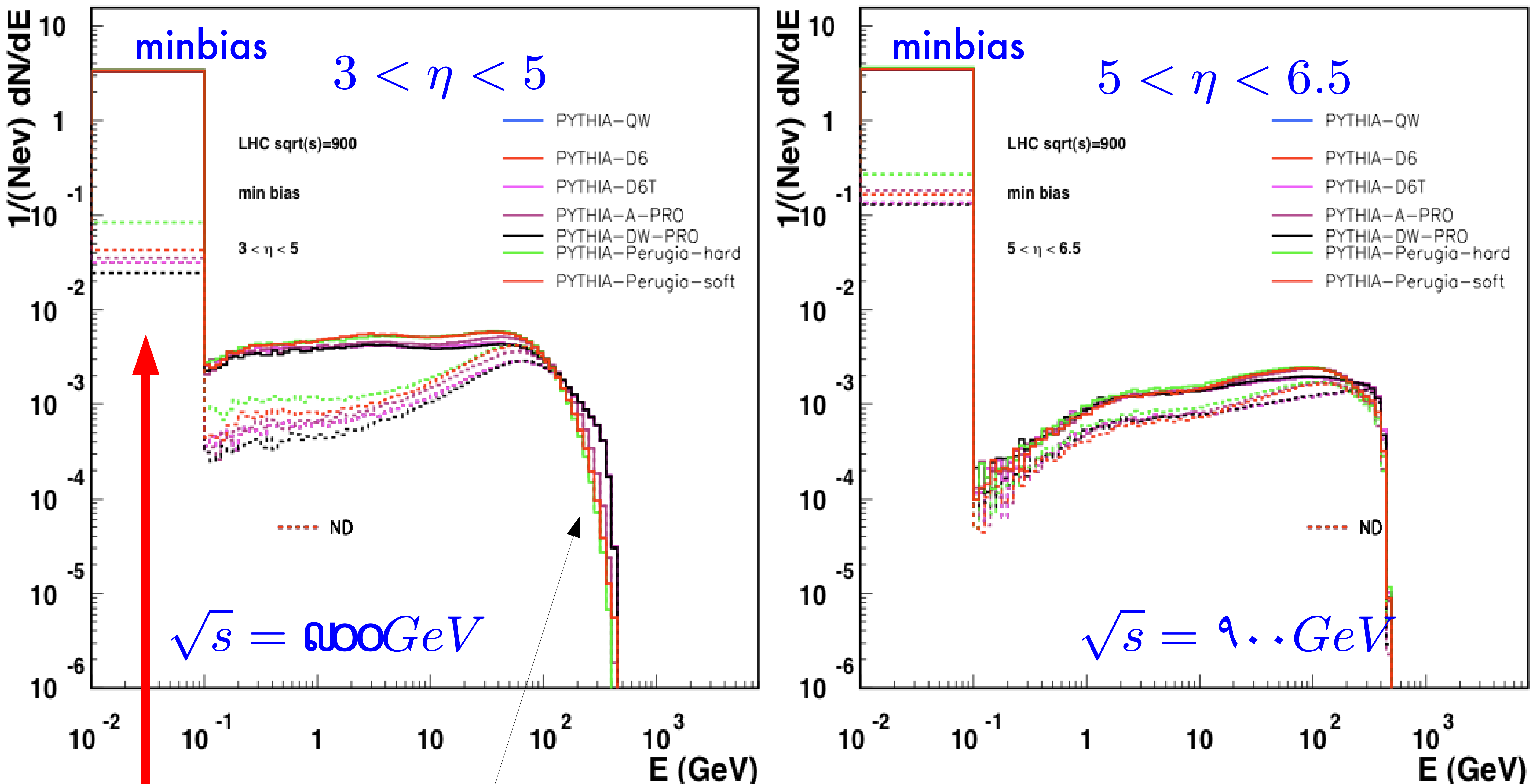
Looking for diffraction



diffraction:

- identified by rapidity gap
- little energy deposit in forward regions
- make use of forward colorimetric coverage

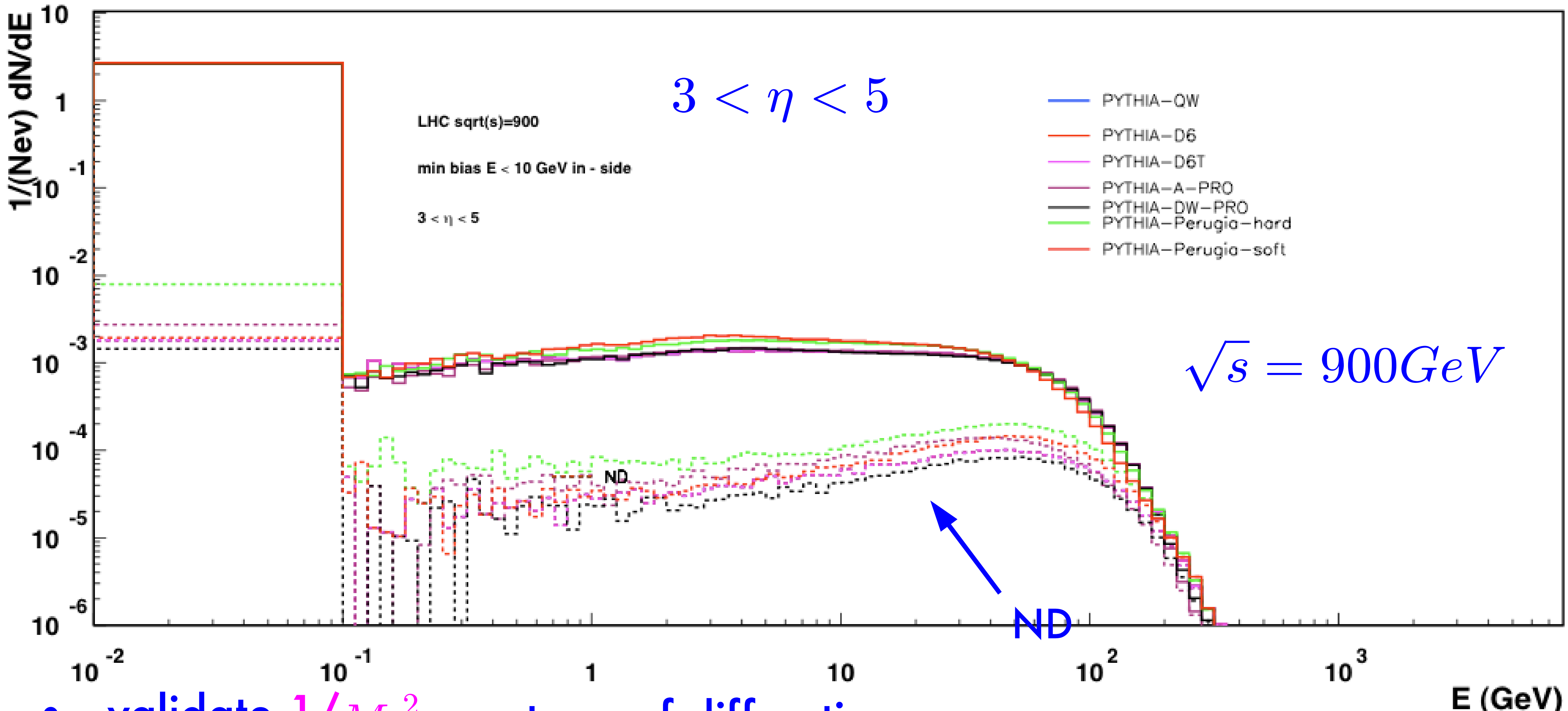
Looking for diffraction ...



- Diffraction: rapidity gaps → no energy deposition in forward calos
- Amount of non-diffractive contribution changes with different tunes ....
- .... but also high energy region depends on tunes...

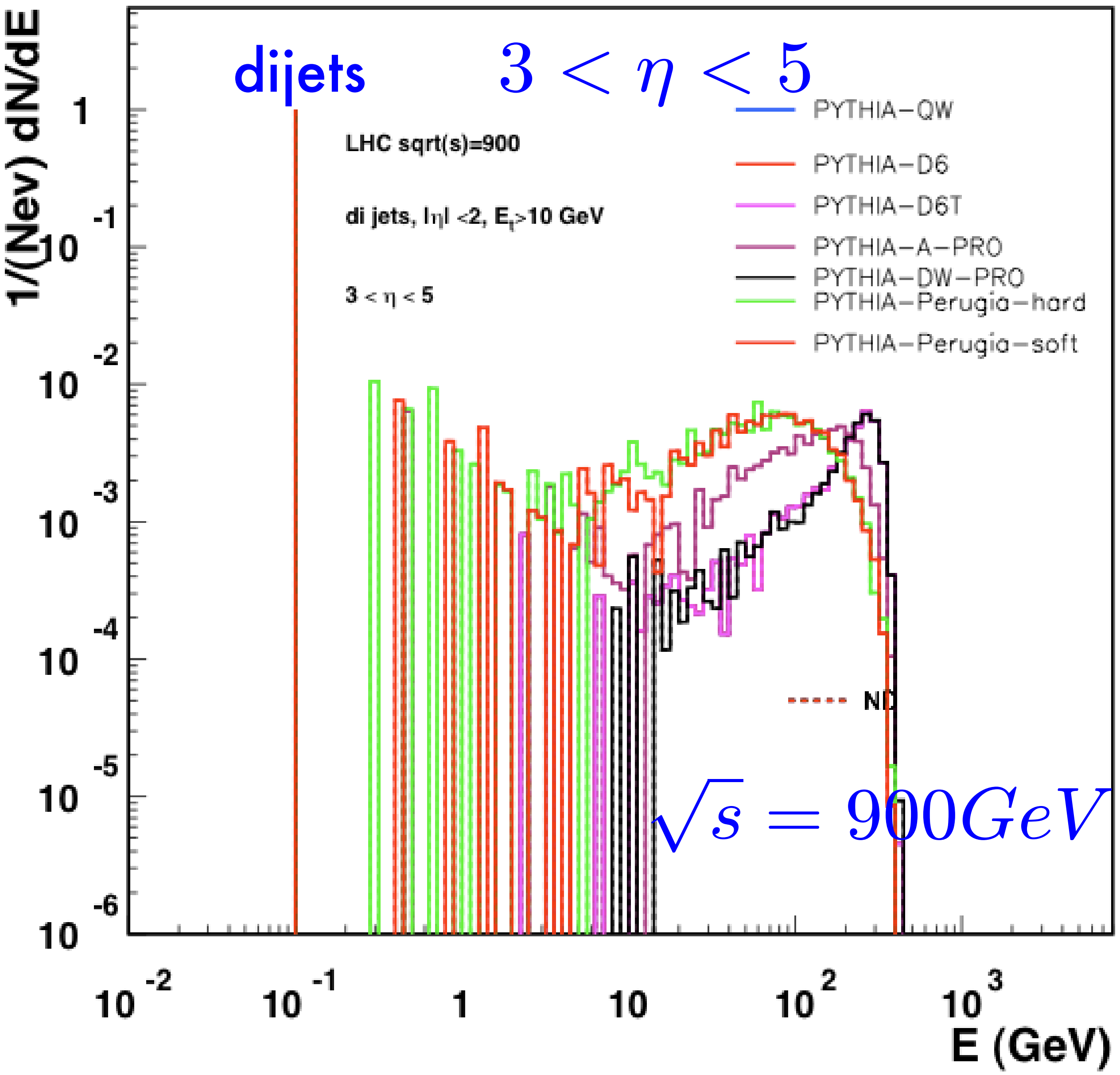
Selecting diffraction

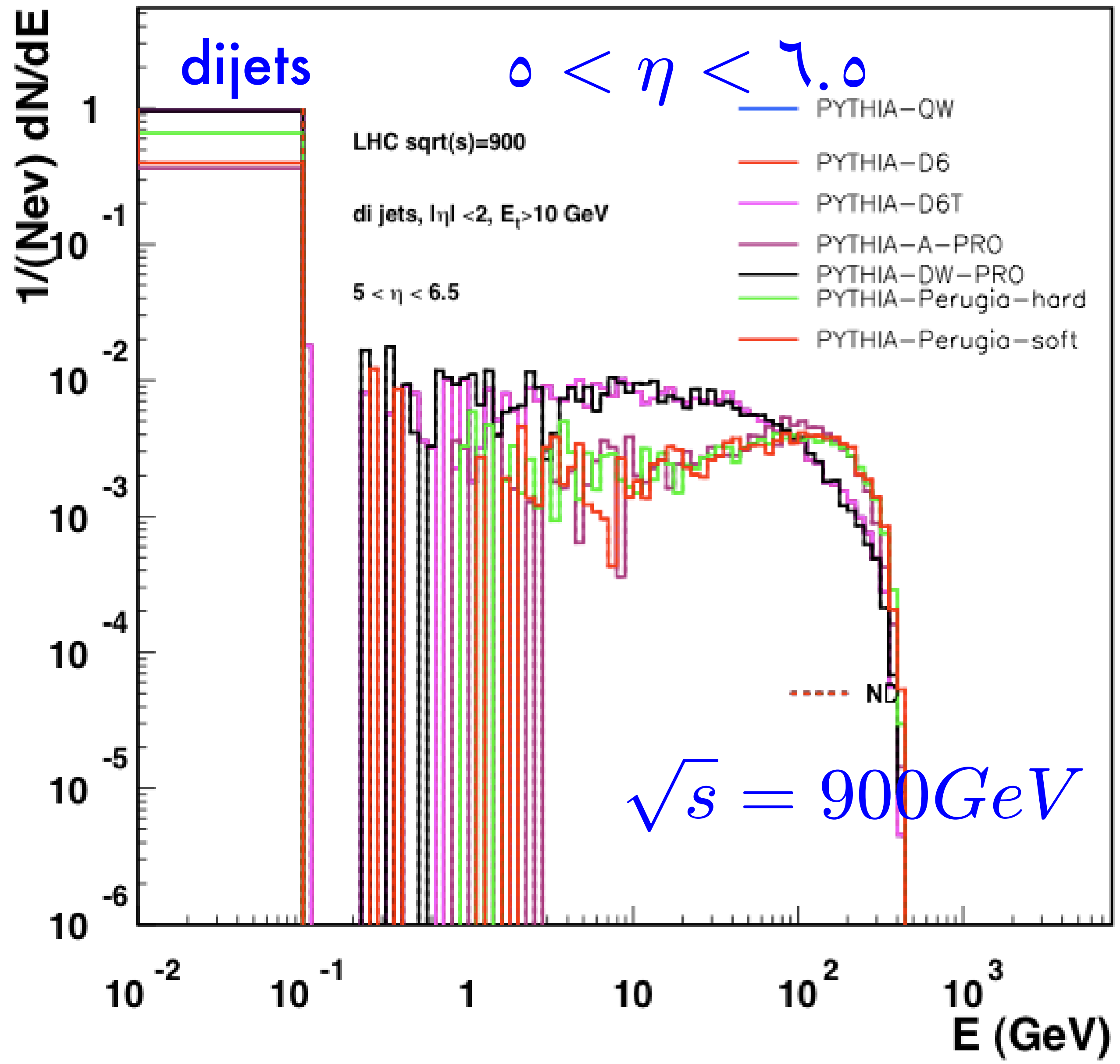
- select diffraction with E< 10 GeV in $-5 < \eta < -3$



- validate $1/M_x^2$ spectrum of diffraction
- estimate contribution from diffraction and non – diffraction
- NOTE: spectrum in PHOJET is different ...

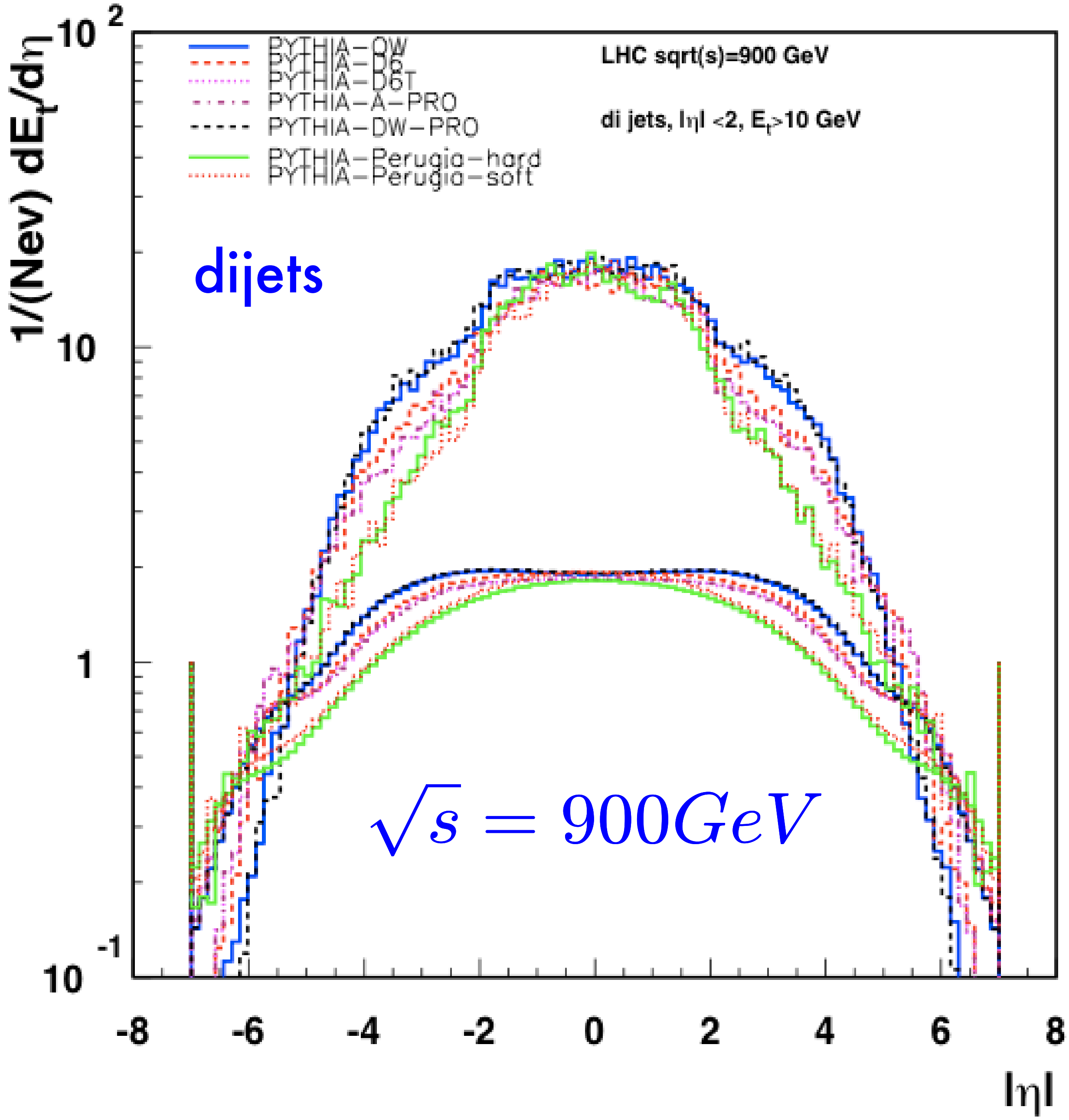
Using a hard scale

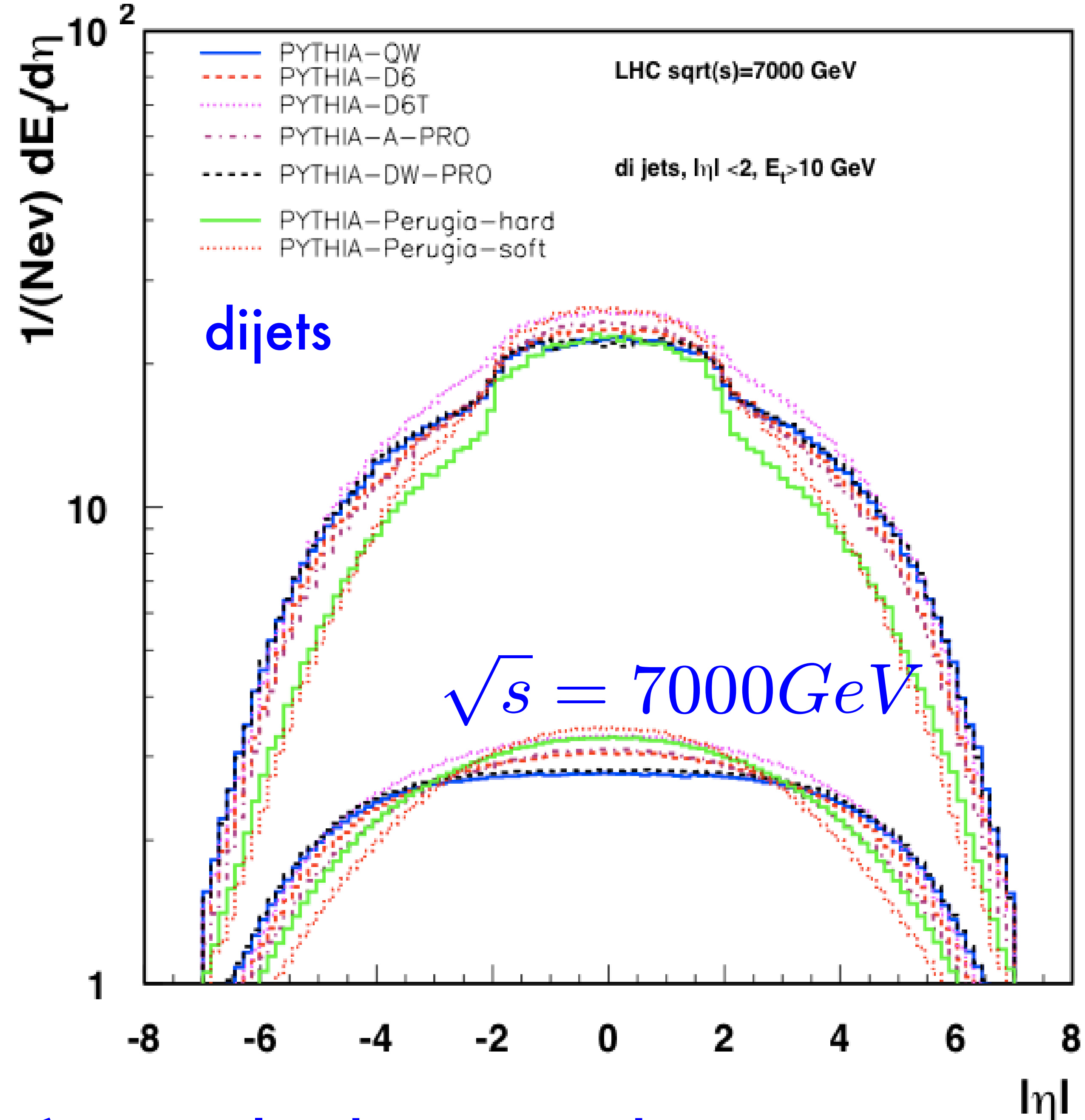




- use dijets with E_t > 10 GeV, $|\eta|$ < 2, only ND contributions are simulated
  - hard diffractive contribution is not simulated in MC !!!!!
  - tail of energy distribution is different... especially in large eta range
- sensitivity to parton radiation: initial state radiation and MPI

Using a hard scale



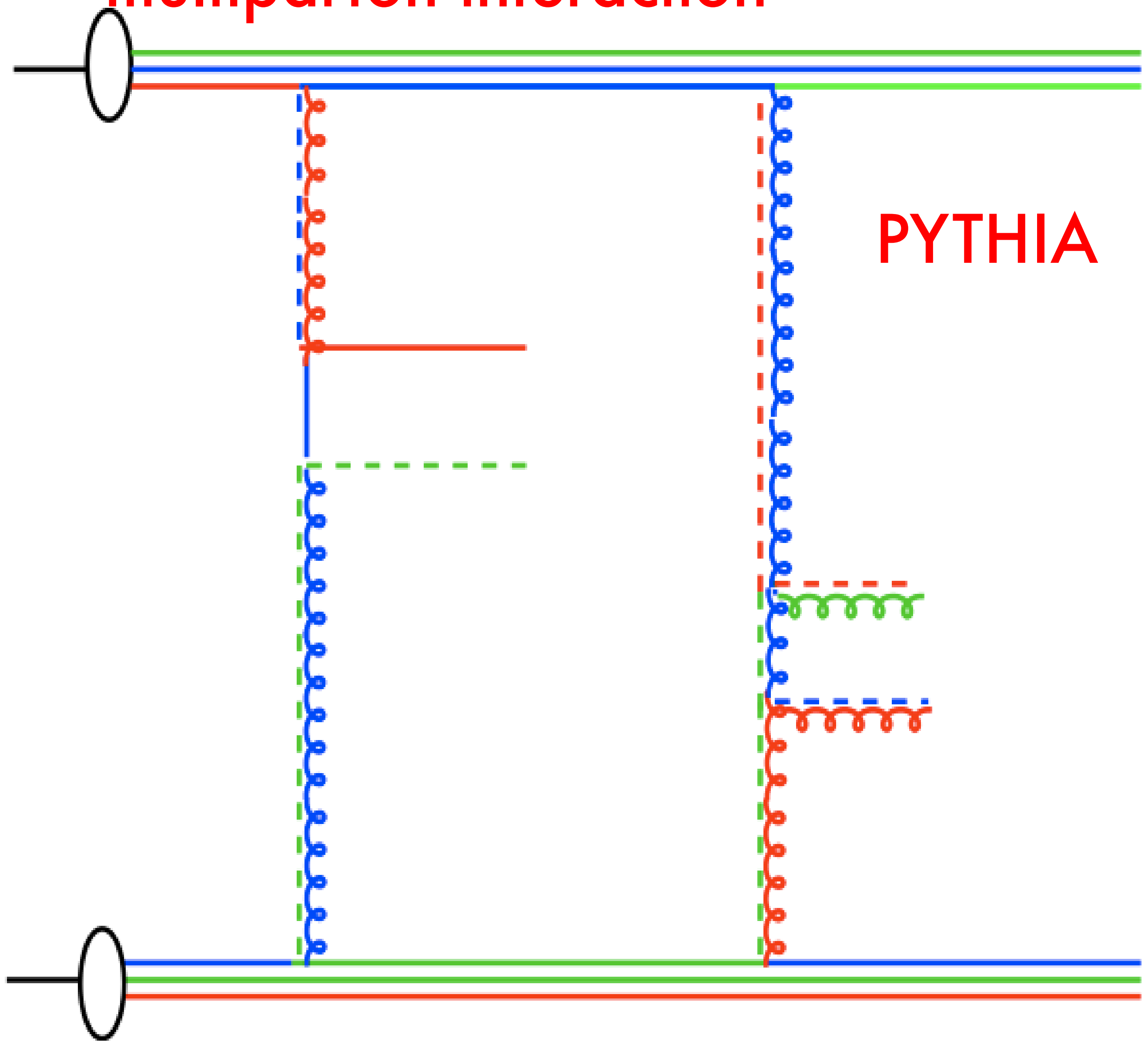


- Et flow in central region ($|\eta|$ < 2) is similar between the tunes
- differences (~ factor 2) show up in forward regions
- important especially low energies $\sqrt{s} = 900\ GeV$?!?!?!

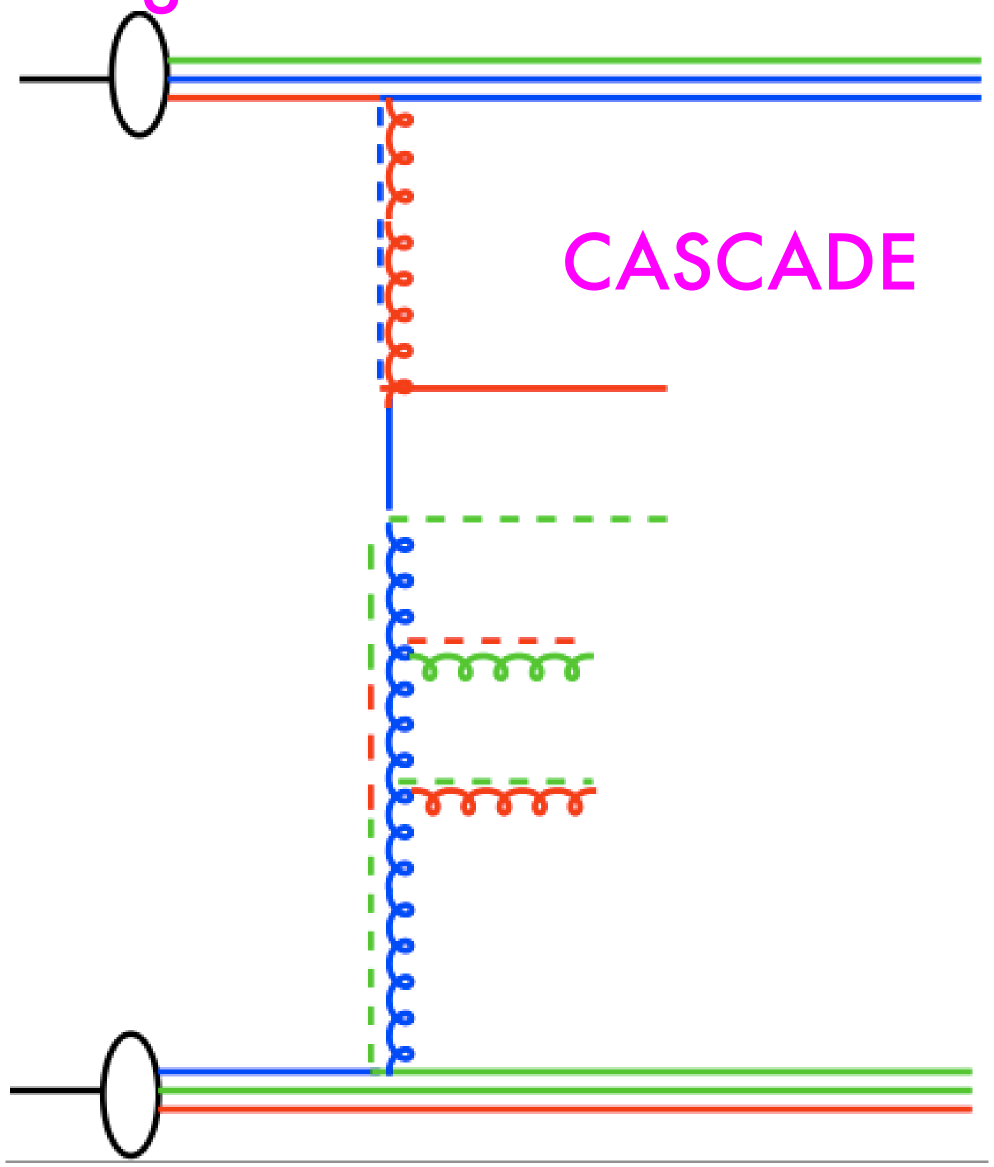
How well do we know parton radiation in forward region ?

- parton radiation in forward region:

multiparton interaction

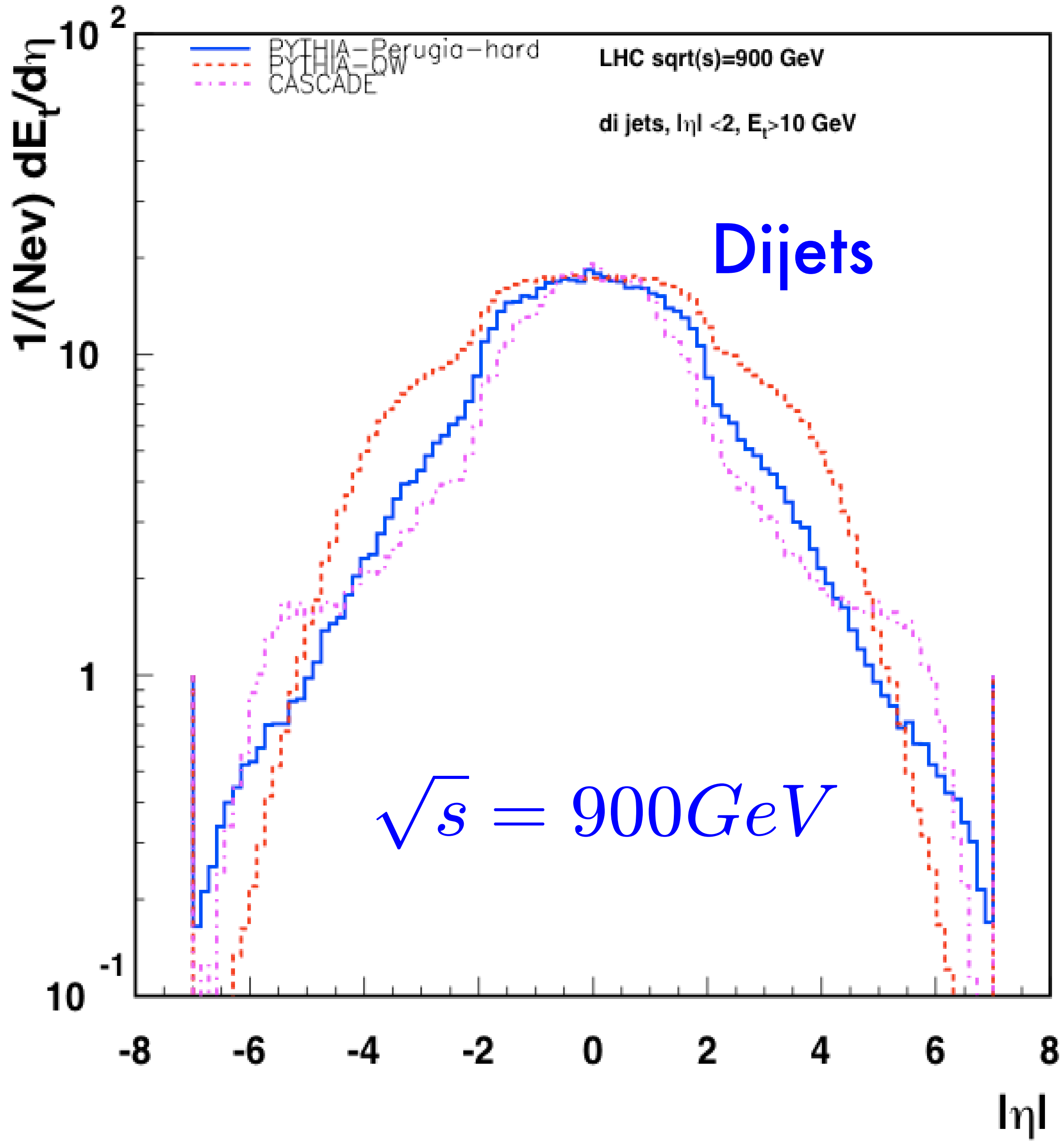


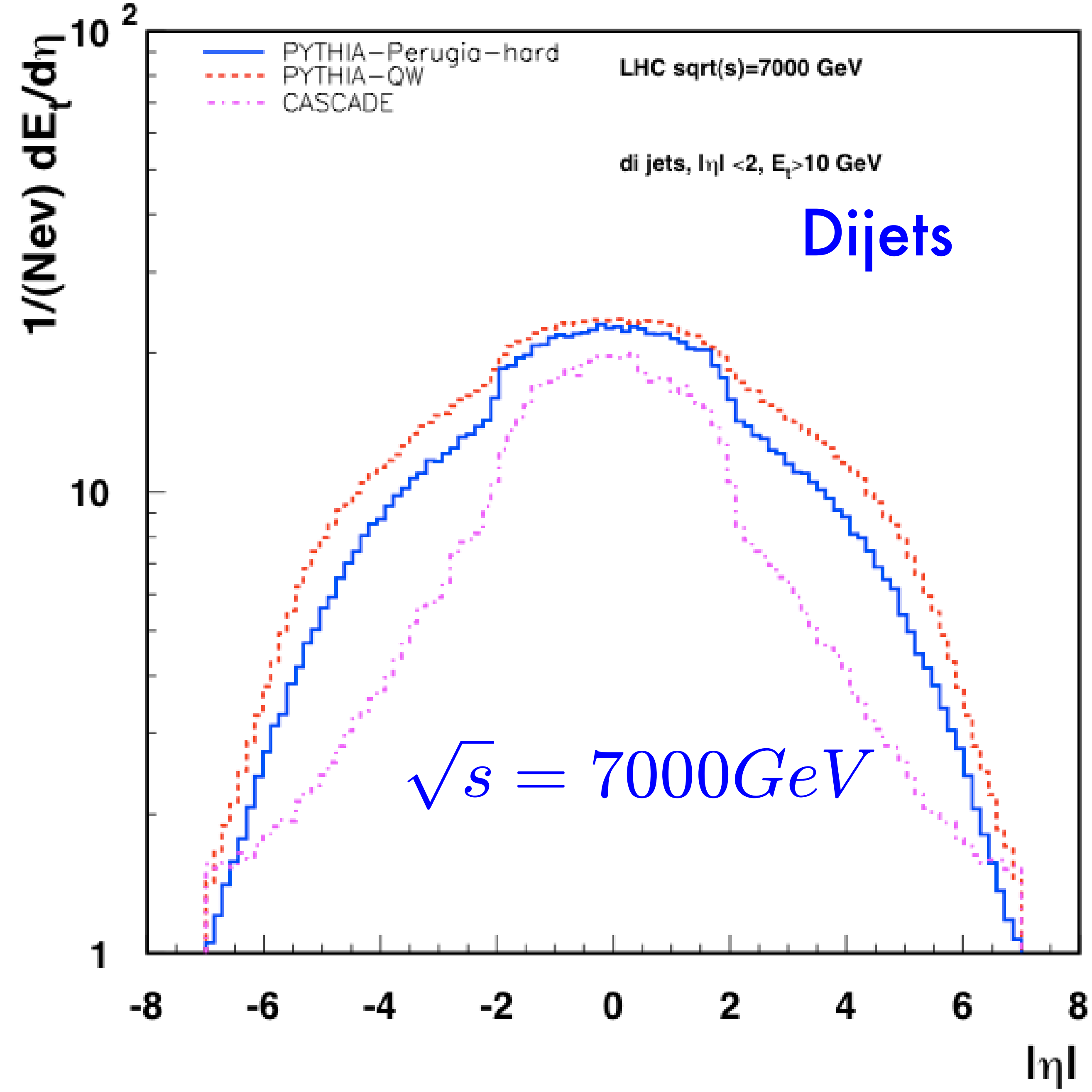
single chain at small x



- which of the two is correct or are they both describing the same ... ???

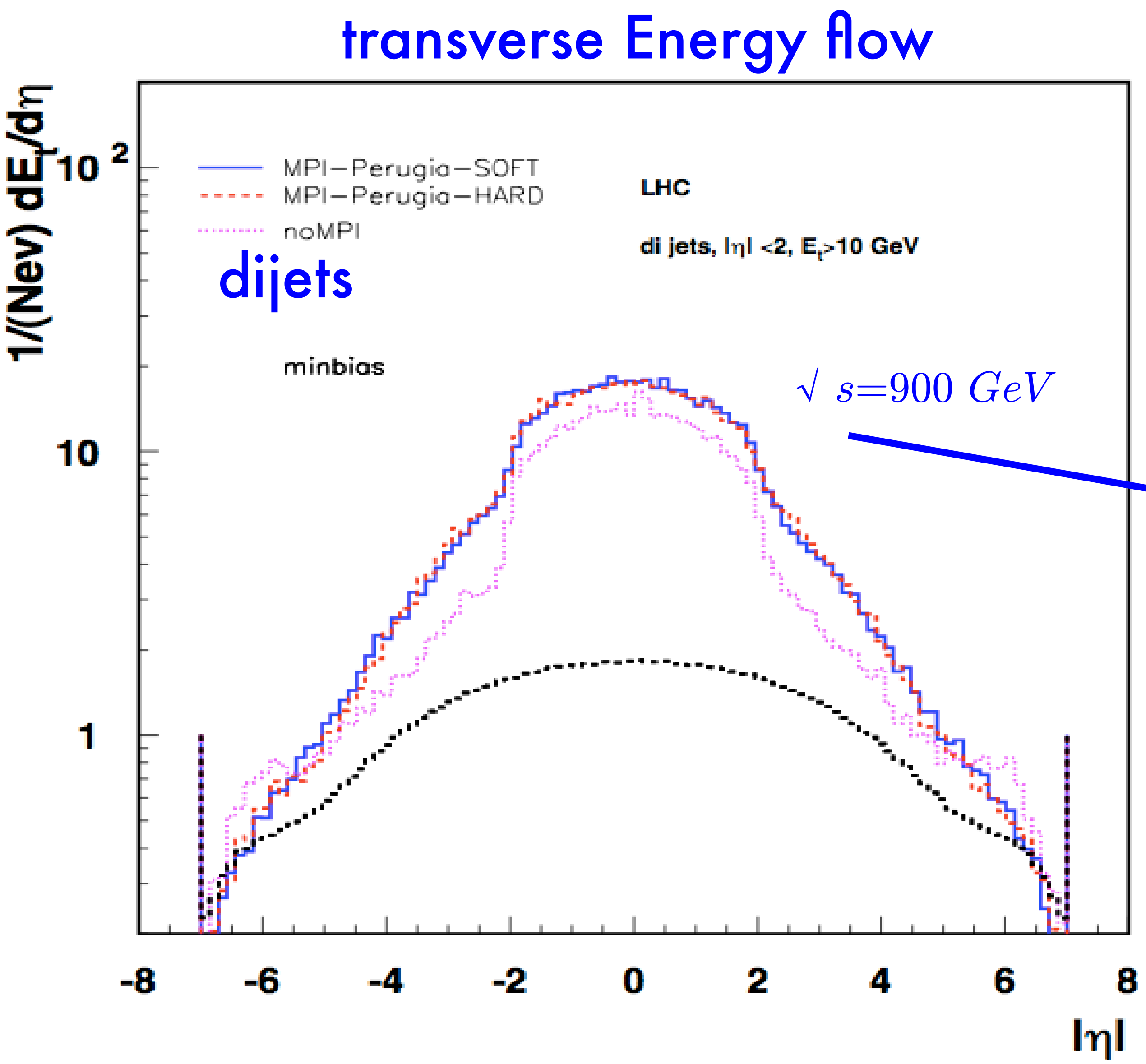
How well do we know parton radiation in forward region ?

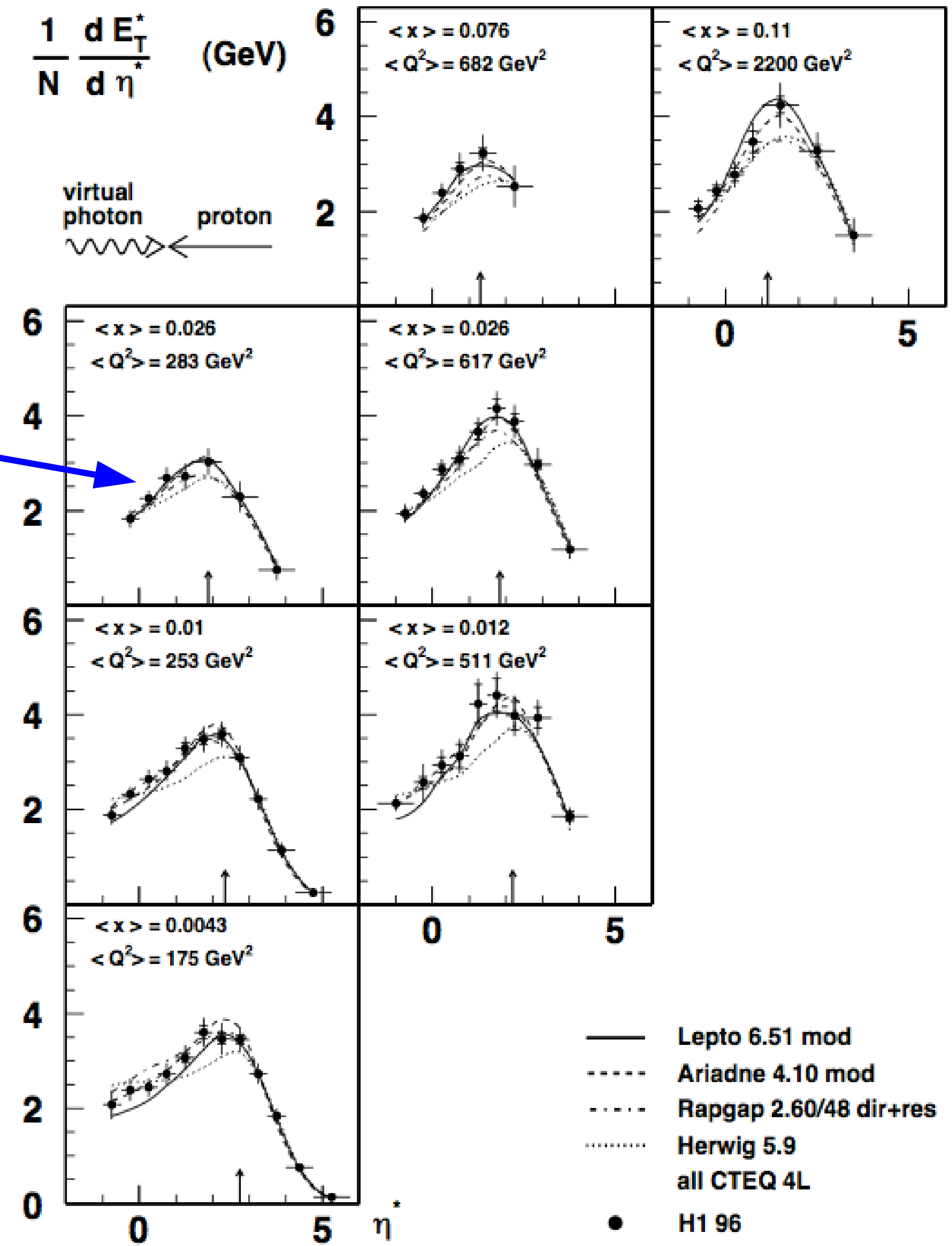




- Can additional radiation in forward region coming from different parton showering (not ordered in kt) ?
- How is the $\sqrt{s}$ dependence of transverse energy flow ?

trans. energy flow at 900 GeV - HERA





- Trans energy in central region does not change much with $\sqrt{s}$
- Significant difference with $\sqrt{s}$ seen in region of $|\eta| > 2$

Program for working group

LPC

Define tuning goals for this WG

- Unlikely that we'll ever have an event generator that, with a single global tuning, can describe with comparable accuracy all aspects of all LHC final states
- This implies that, depending on the specific application (e.g. measurement of mtop, of mW, of CP violation in B decays, etc), each experiment will likely need to develop specific, analysis- and experiment-dependent tunes, to optimize the data vs MC agreement
- Furthermore, in order to become available sooner, many tunings will be done on detector-level observables, after detector simulation of the MC events

- In spite of this, there is a premium in
  - approaching the above possible experiment-specific differences in a coherent way
  - performing global tunings of generic final-state properties, to be used as defaults for "generic" analysis, and as reference benchmarks for more specific tunings, or comparisons across experiments
- The WG should
  - focus on this class of tunings
  - contribute to set standards (tools, protocols, ...) and a discussion forum on physics issues for the more specific tunings that will eventually become necessary
- In particular, focus on MB/UE properties, incorporating (possibly at different stages) elements like:
  - inclusive charged-track/ET quantities (a la Field/Perugia)
  - SD/DD/ND separation
  - multiparticle correlations, identified particle spectra, etc
  - ....

Possible approaches

1. MC developers do their own tuning
   - which input datasets? how to account for (un)correlated systematics from different exps?
2. Tuners do their own tuning
   - same as above, plus
   - if no good tune for given parameters, need input of MC developer to modify modeling
3. Experiments do their own individual tuning
   - same as above, plus
   - what if Pythia tune from ATLAS and CMS differ? What are the Pythia authors supposed to adopt as default tune for the next version?
4. **All key players play together**

LPCC

A possible direction

My personal elaboration of discussions with P. Bartalini (CMS), J. Butterworth (ATLAS/Rivet), A. Buckley (ATLAS/Professor), H. Jung (CMS/Profit), J. Katzy (ATLAS), W. Pokorski (Genser), P. Skands (Pythia)

- Agree to support a global reference tuning for the MB/UE parameters, from a joint effort of the experiments and of interested MC developers
- Start by agreeing on common tuning tools:
  - Rivet is accepted as a de-facto standard in the area of its functionality. Agree?
  - Fitting has two tools, Professor and Profit. The respective proponents agree that they should both be pushed, to ensure cross-checks and better control of systematics, validation of systematic uncertainties, etc (see e.g. the parallel with the several independent PDF or CKM fitters). Agree? Anything else?
  - Hand-driven tunings can be part of the game as well, they could be useful for independent validation etc, but the final results should be reproducible with openly available tools. Agree?
- The "experts" define the distributions to be used for the tunings
- Genser & LPCC can support/host the efforts required to make the tools available to all experiments and MC developers, and support the overall infrastructure necessary for the global tuning task.
  - The authors of the tuning packages and generators, the Genser and LPCC management, and the MC coordinators and tuners of the exp's identify technical needs and resources.
  - The LPCC can provide whatever resource is necessary, host the "tuning team", etc.

Conclusion

- Was a very lively and interesting meeting
- ca 50 people attended, mainly form experiment
- good and interesting discussion
- agreement to have monthly EVO meeting and 4/year personal meetings

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- TERASCALE (as agreed on meeting):
  - Profit was agreed to be one out of two programs for fitting
  - HERA data should be included in tuning

Extra Slides

Selecting diffraction

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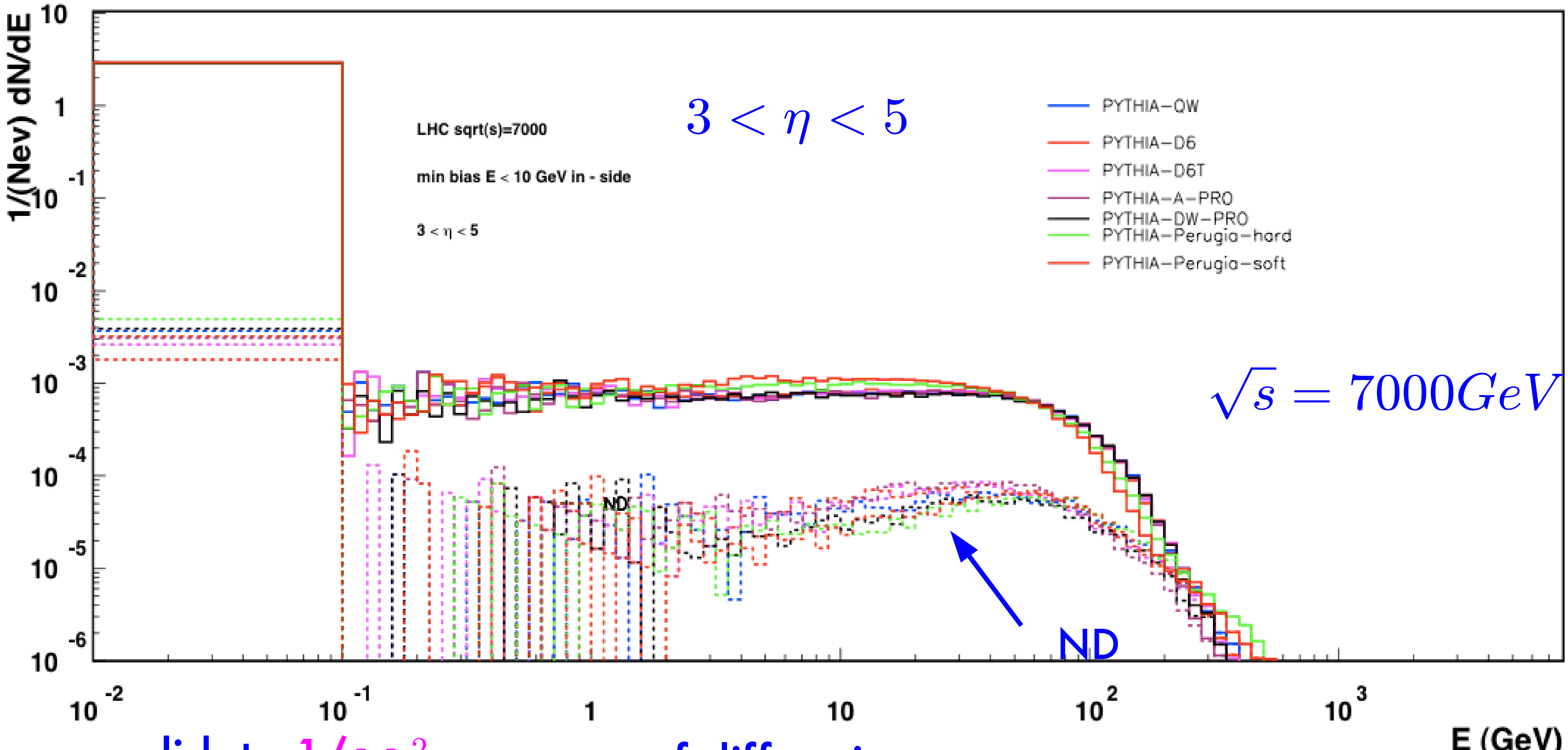

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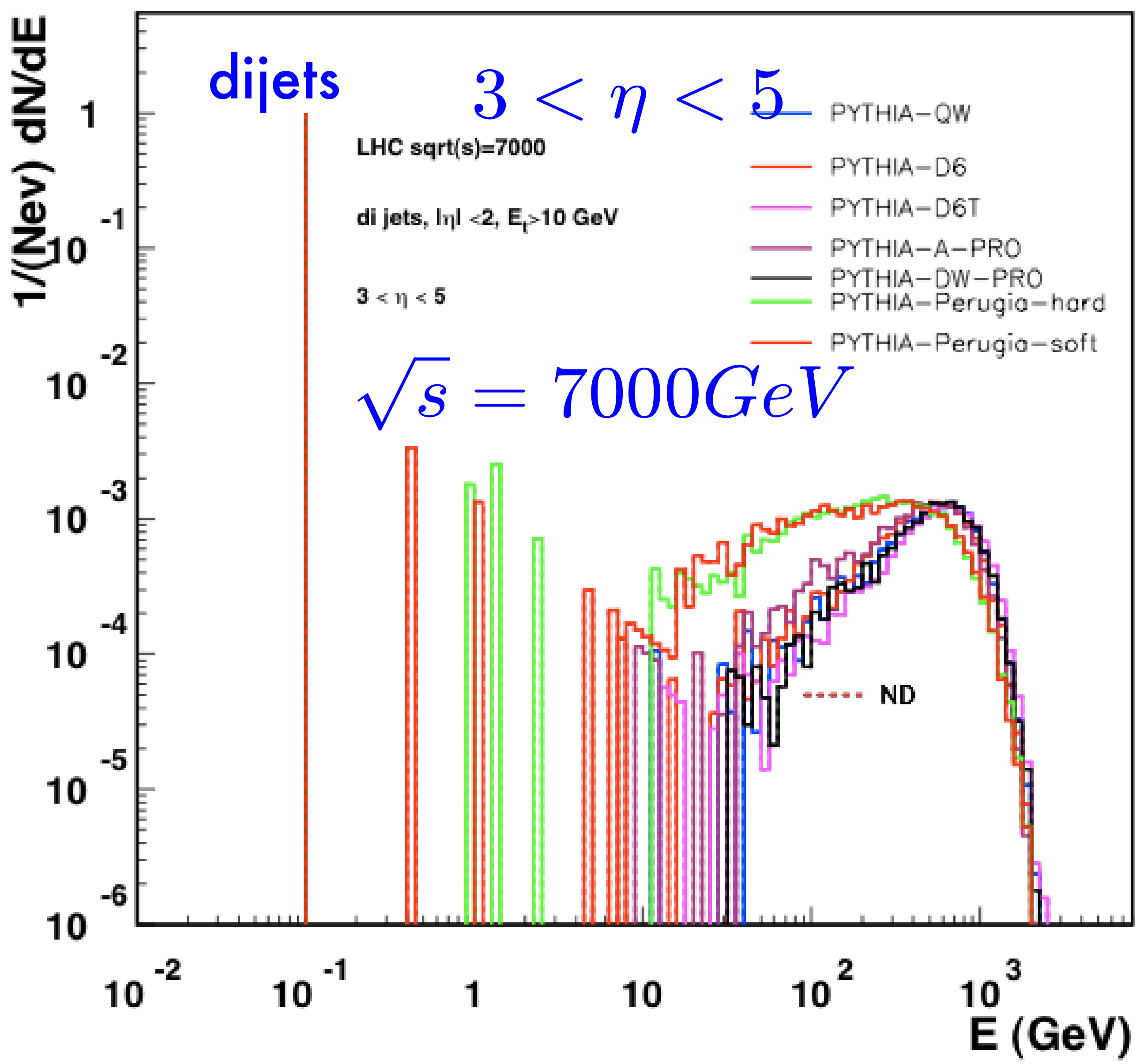

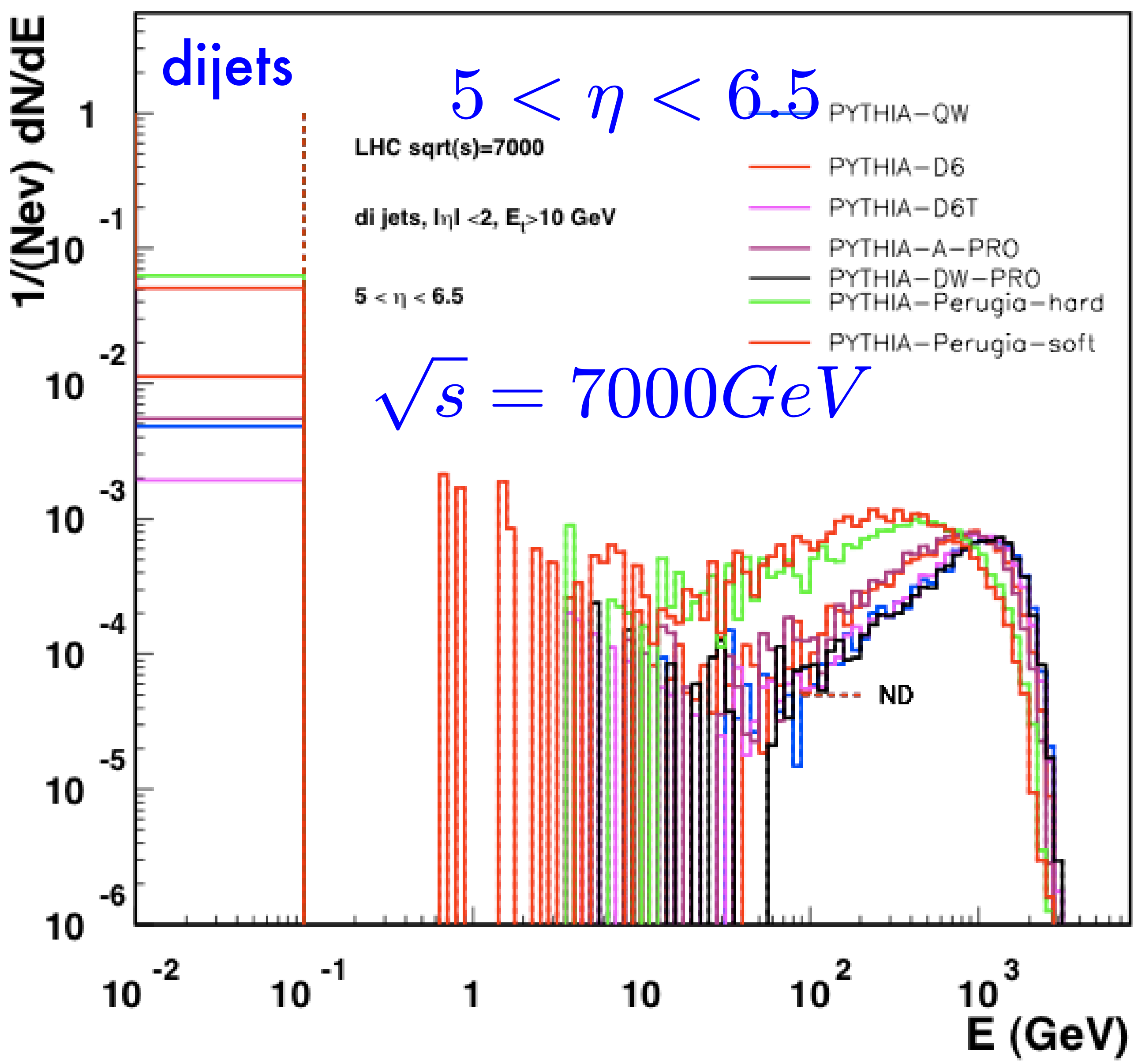

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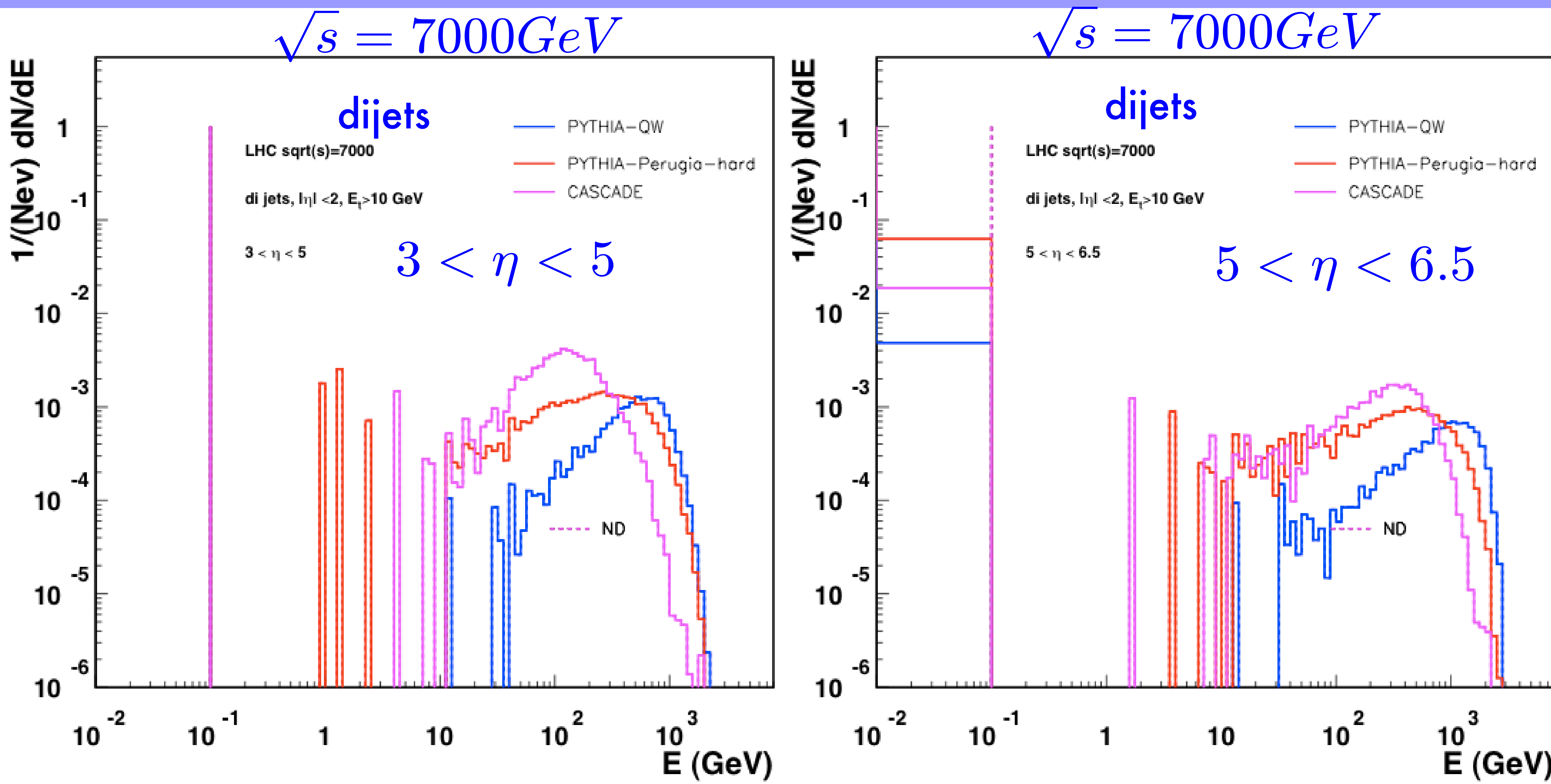
Parton radiation in forward region



from non-diffractive processes ?

- very forward region depends on parton showering etc ...