(Highly) Tentative Conclusions based on the Early LHC Data

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The Power of Prediction

- **We are at** a *unique* time in the LHC era
- Predictions, without foreknowledge, can be tested with **totally NEW data**
- This is right here and now, once and only
- Attempt to learn as much as possible from these "blind" tests, which *cannot be repeated*

The Basic Four

900 GeV ATLAS (N≥1) ALICE (N≥1,NSD) **2.36 TeV** ALICE (N≥1,NSD) **7 TeV** ALICE (N≥1)	$P(N)$	$dN/d\eta$	**900 GeV** ALICE (INEL, NSD) CMS (NSD) ATLAS (N≥1) **2.36 TeV** CMS (NSD) ALICE (INEL, NSD) **7 TeV** CMS (NSD)
900 GeV CMS (NSD) ATLAS (N≥1) **2.36 TeV** CMS (NSD) **7 TeV** CMS (NSD)	$dN/dp_\perp$	$\langle p_\perp \rangle(N)$	**900 GeV** ATLAS (N≥1) **2.36 TeV** - **7 TeV** -

(NSD): physical MB trigger + SD correction w/o physical SD definition

C. Zampolli: different model for each of these! *"Not satisfactory"*

Models should be "universal". Inability to get universal tune → more physics?

dN/dη

- **Really** $d\langle N\rangle/d\eta \Rightarrow$ most sensitive to **first few bins** of $P(N)$

dN/dη

- **Really** d⟨N⟩/dη ⇒ most sensitive to **first few bins** of P(N)
  - ⟨N⟩ **cannot** be interpreted without
    - *EITHER:* **a soft/zero trigger + good model of diffraction**
    - *OR:* **a hard trigger that suppresses diffraction**
    - Cannot be interpreted at all without physical trigger (~~NSD!~~)
- **It is the least useful** of the basic four
  - Mixes low-mult (diffractive/peripheral) and high-mult (non-diffractive/hard-core) physics over its entire range
- **Danger:** It is entirely possible to fit this variable while still mismodeling *both* diffraction *and* UE (the two wrongs → right effect)

$dN/dp_\perp$

- **Each track = one entry** ⇒ low-mult events relatively less important
  - Still mixes low-mult (diffractive/peripheral) and high-mult (non-diffractive/hard-core) physics over its entire range
  - → Compare $p_\perp$ spectrum under different trigger conditions
- Mainly sensitive to (string) **fragmentation** processes. Some sensitivity to semi-hard **(mini-)jet** production
  - **Soft models** → too soft spectrum?
  - When tuning to $\langle p_\perp \rangle(N)$, important to check **tail of** $dN/dp_\perp$

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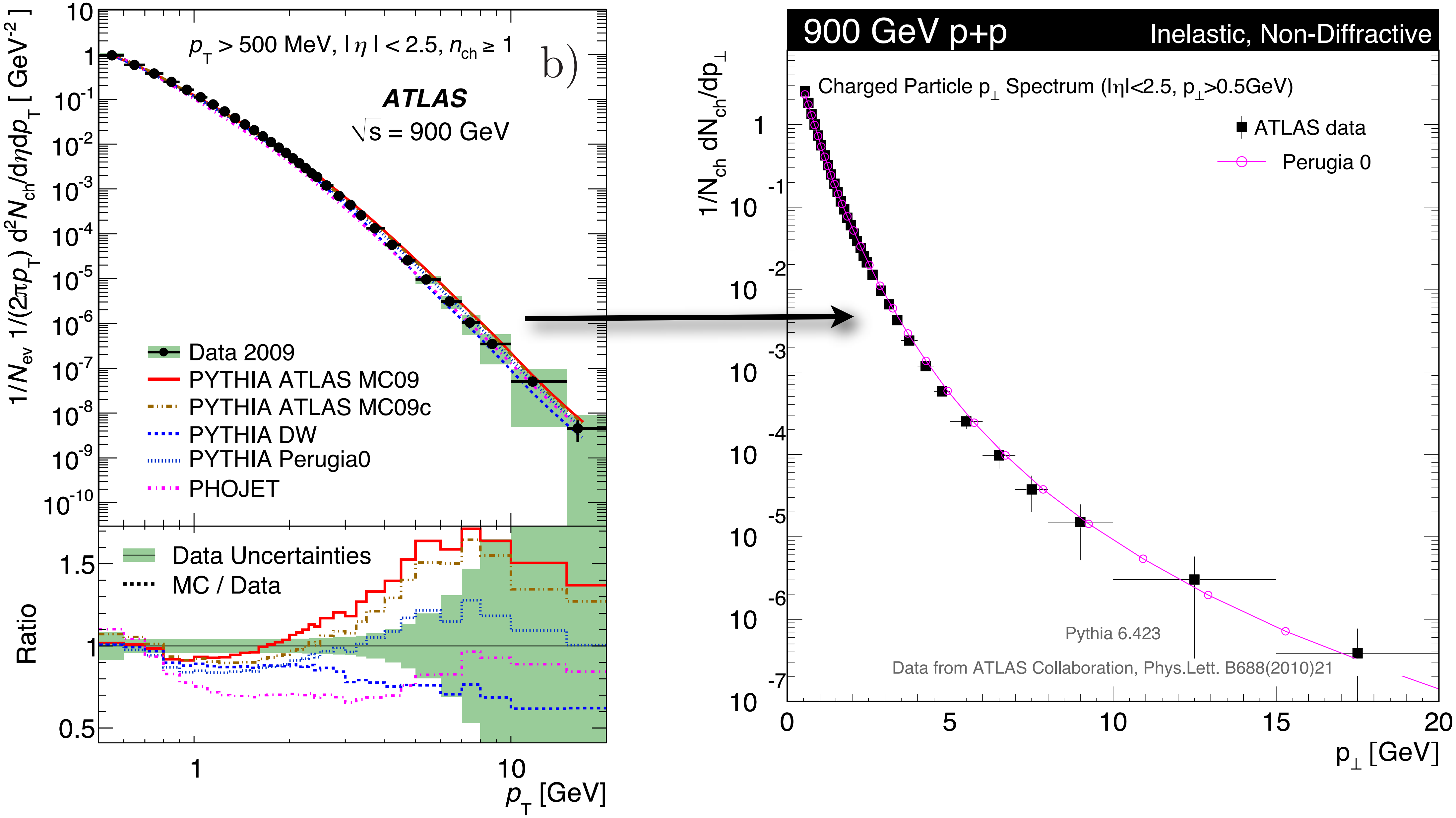
- → **To maximize fragmentation sensitivity:** convert to $x_\perp$ spectrum? ($\sim$ UE-corrected $p_\perp/E_{\perp jet}$)

dN/dp$_\perp$

- **Fast turnaround.** Data propagates quickly into HepDATA!
- + set of standard MC curves in paper gives us a reproducible counter-check and benchmark for future comparisons. EXCELLENT!



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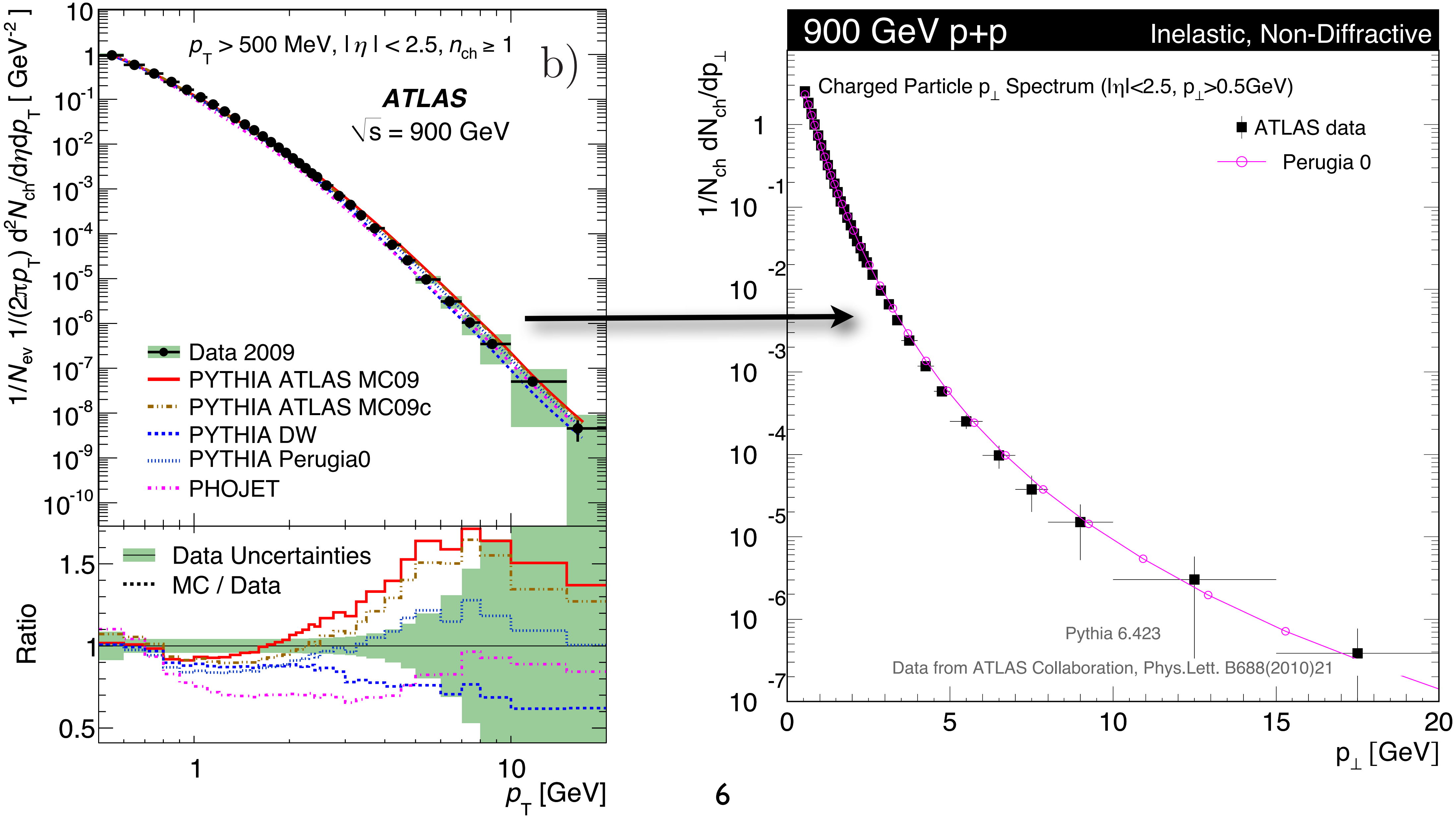
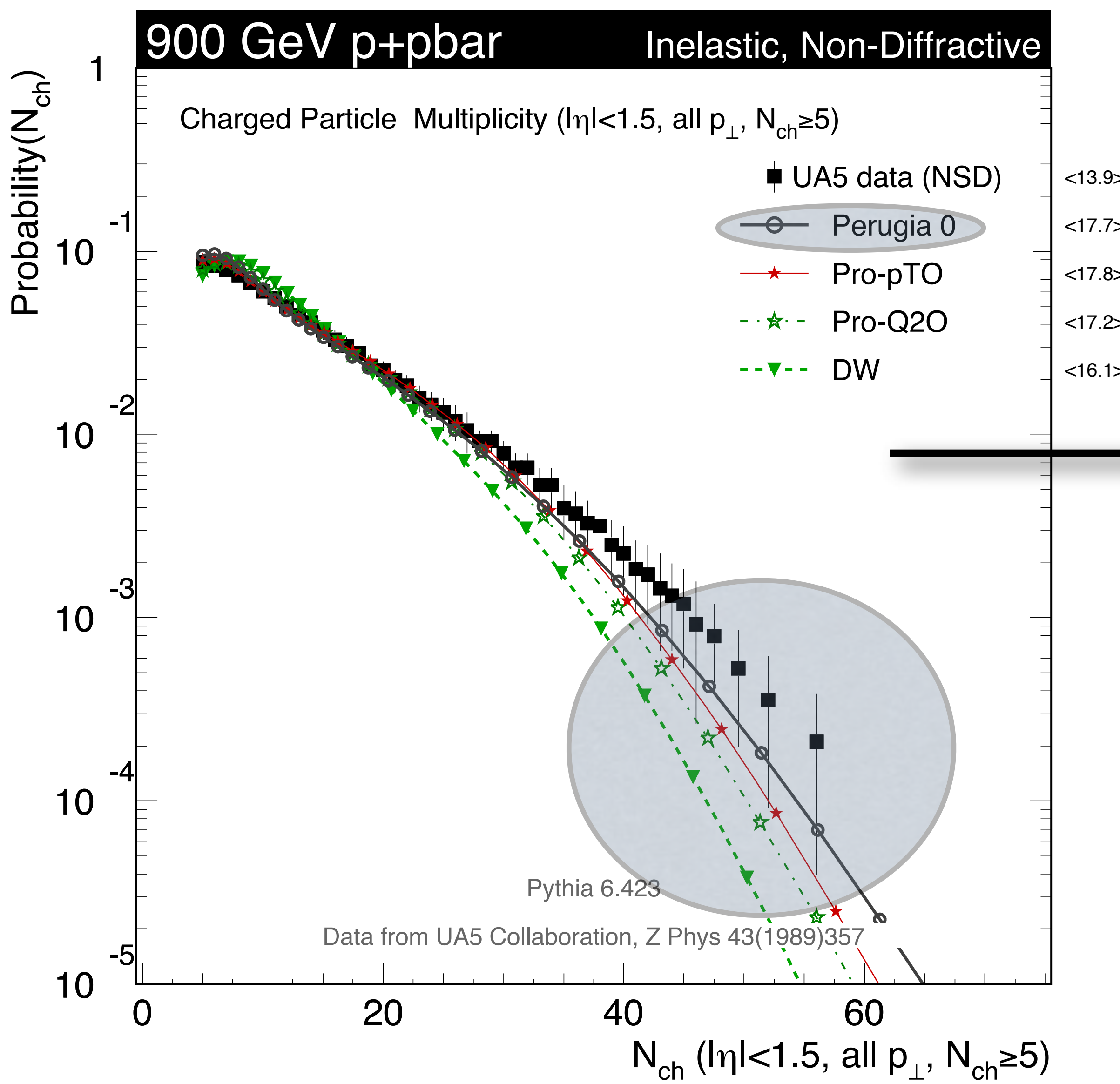


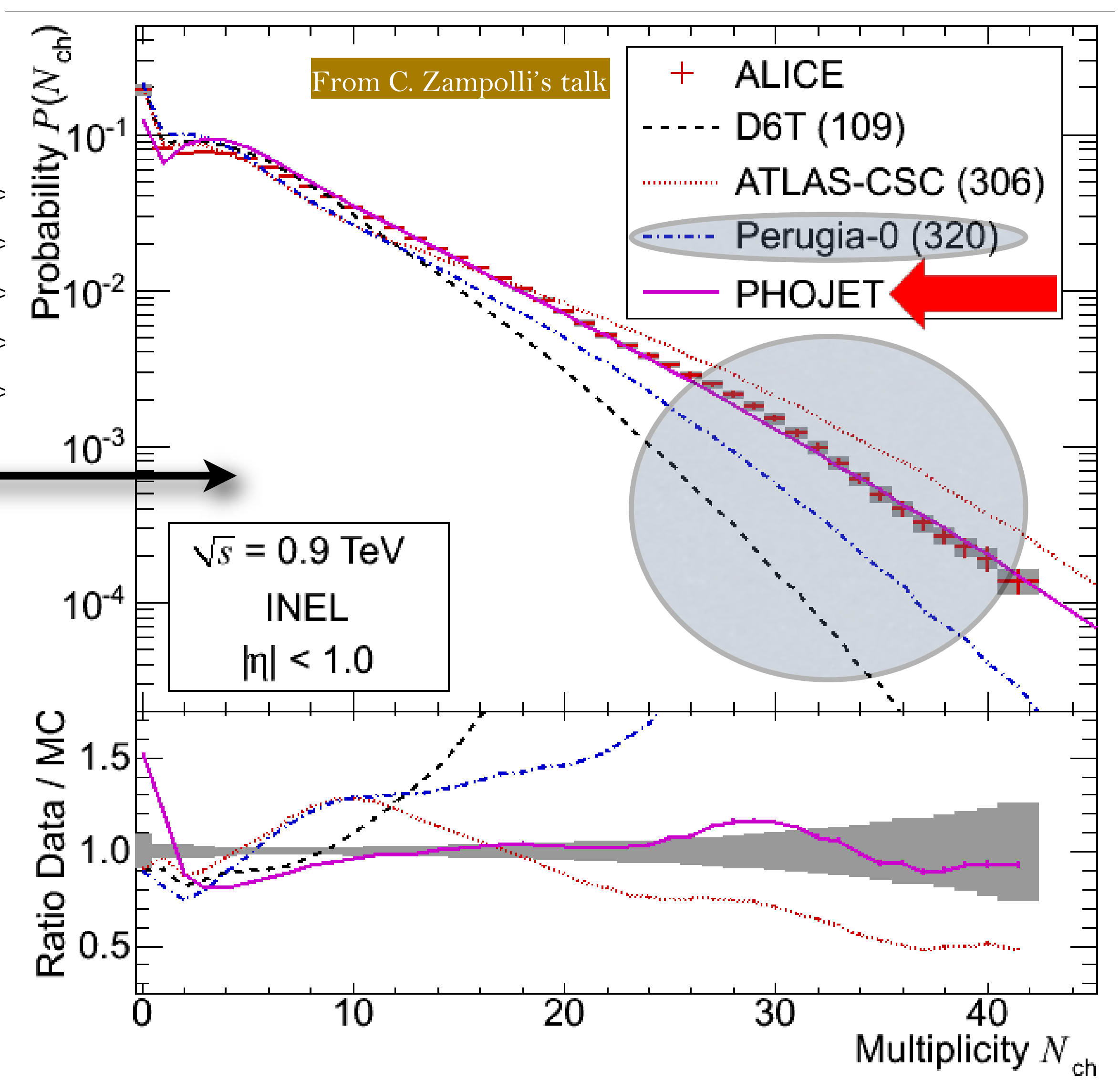
P(N)

- **One entry for each N:** low-mult events clearly distinguishable from high-mult
  - **Low peak** sensitive to diffraction, dominated by peripheral (LEP-like) collisions (?), no collective effects?
  - **Falloff of high-N tail** sensitive to UE, dominated by hard, central collisions. Departures from LEP fragmentation? Collective effects?
  - **Intermediate region (shape)** sensitive to proton mass distribution

P(N)

- **Extrapolations from Tevatron** have ~ too low tail already at 900 GeV (cf UA5) - gets worse when we go → 2.36 → 7 TeV





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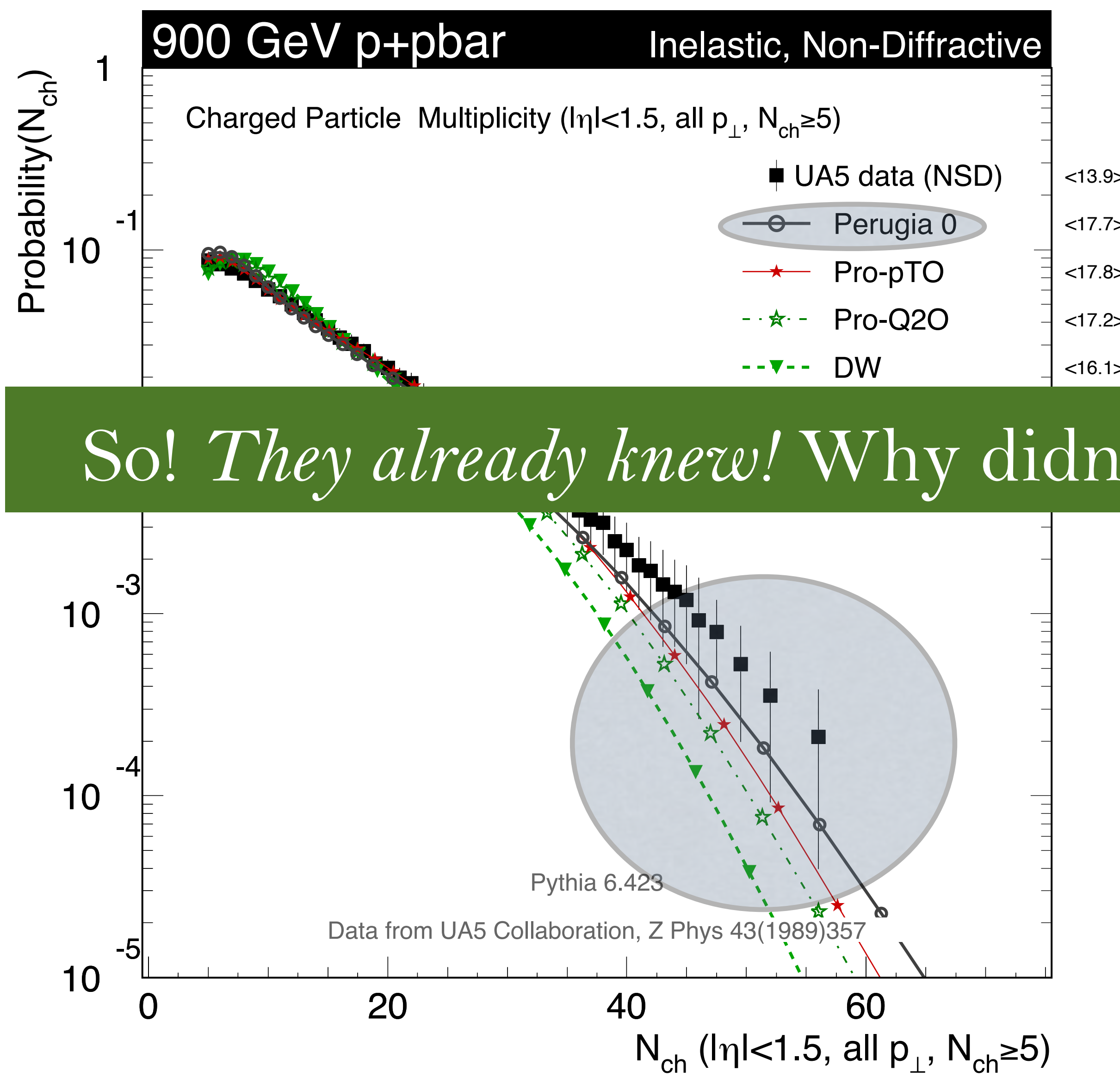
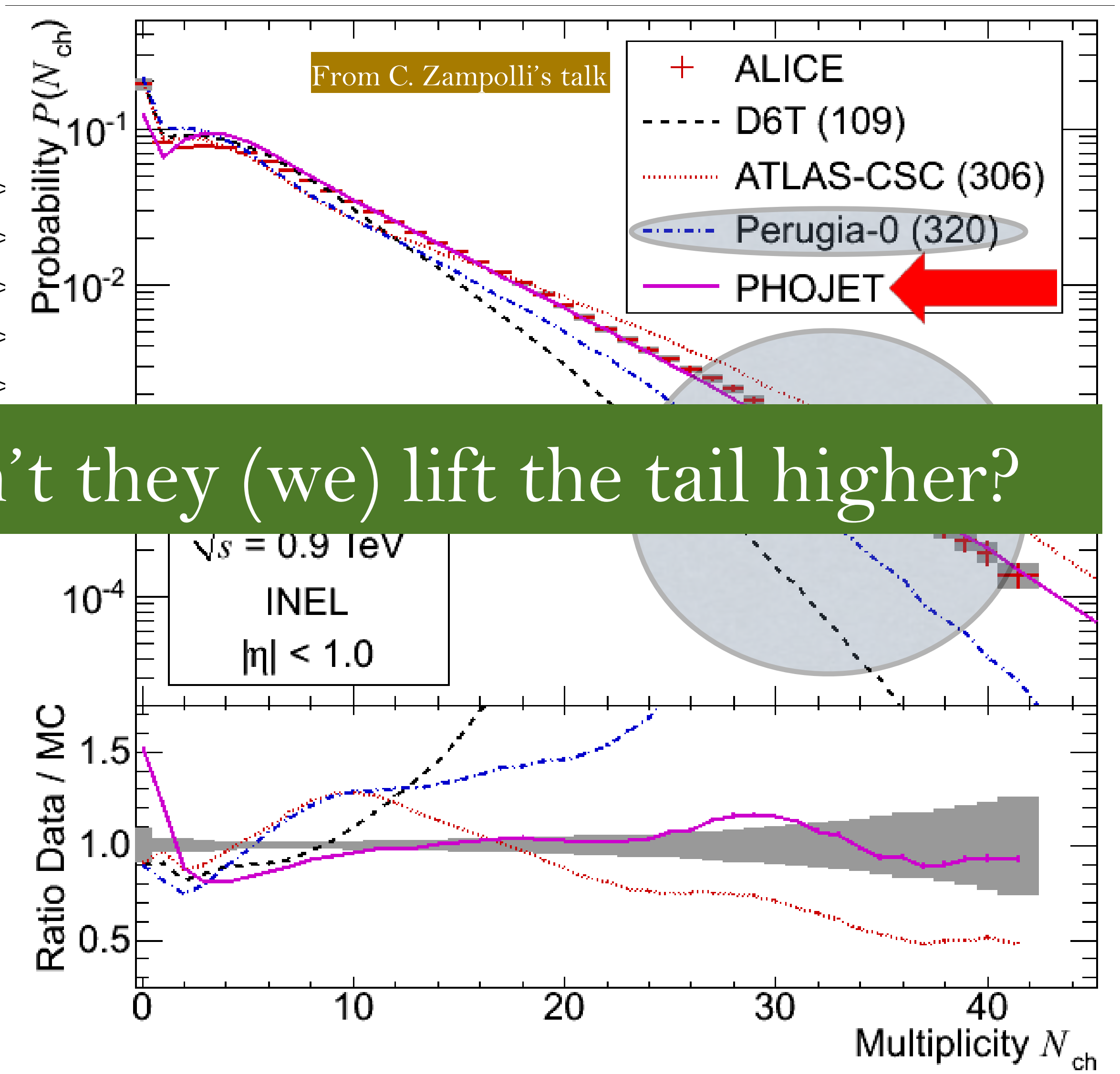
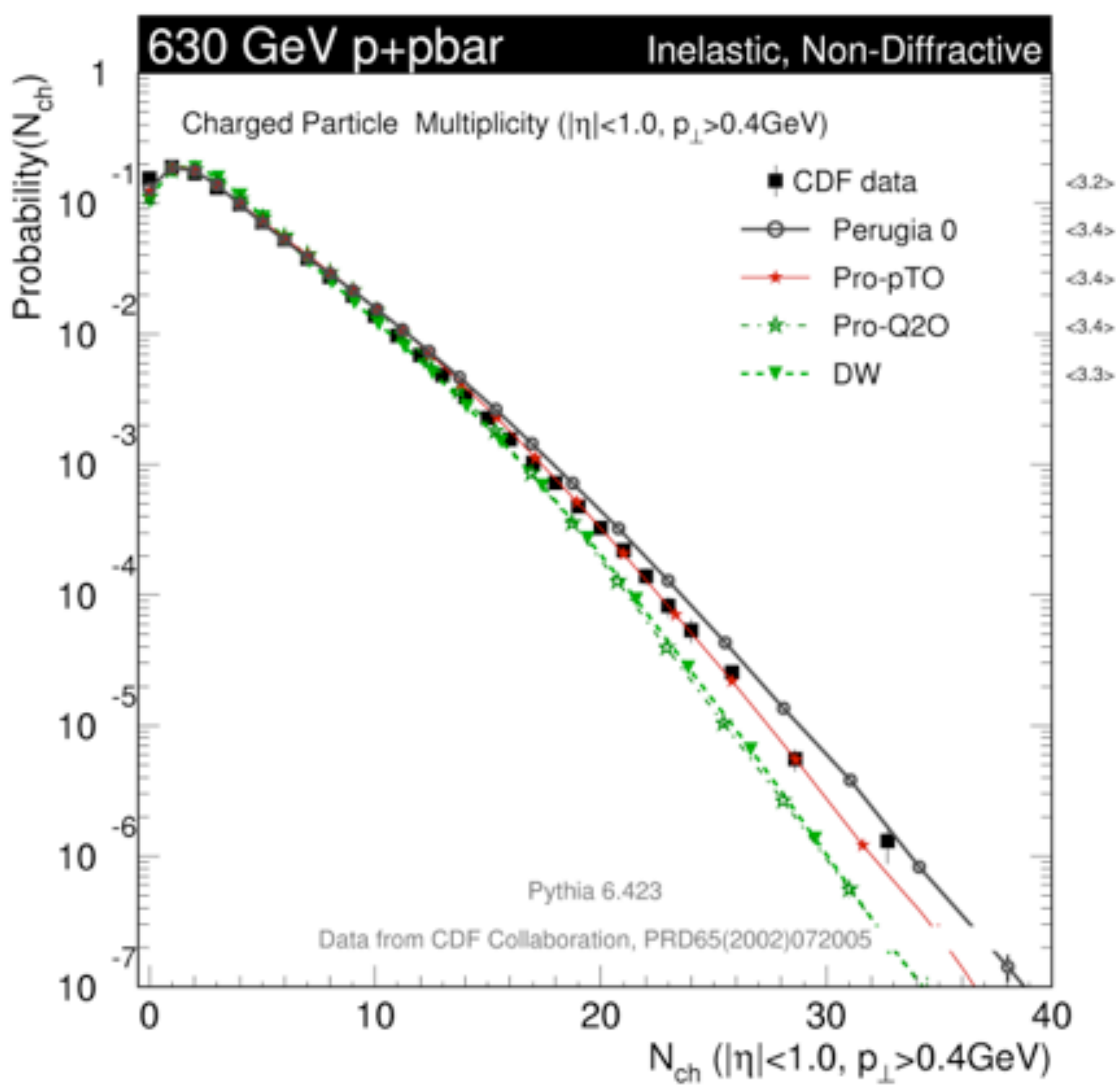


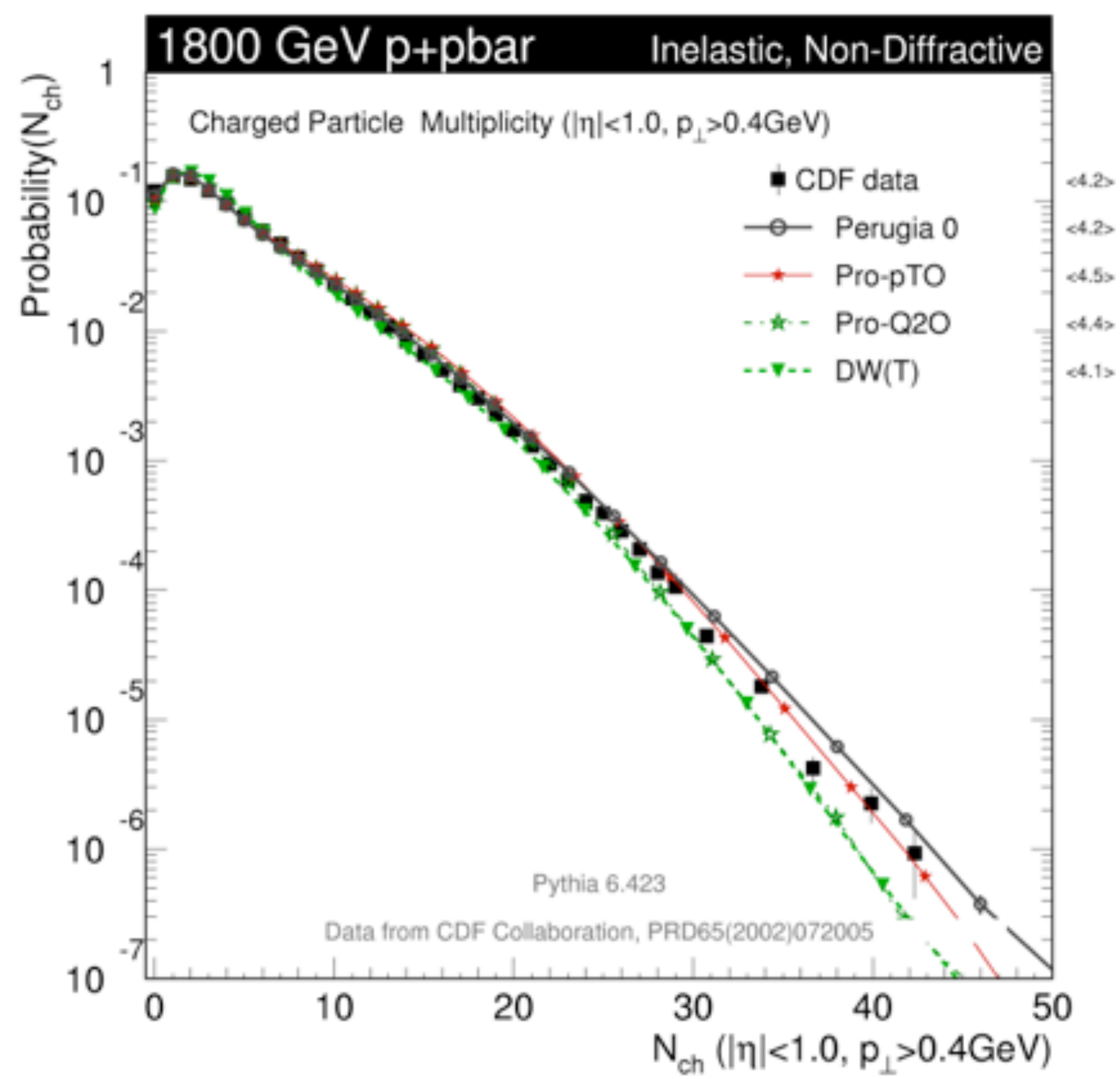


So! *They already knew!* Why didn't they (we) lift the tail higher?

P(N)

Tevatron tail tension. E.g., Perugia 0 already slightly high at both Tevatron energies - *(more LHC data at ~ 2-3 TeV would be useful)*



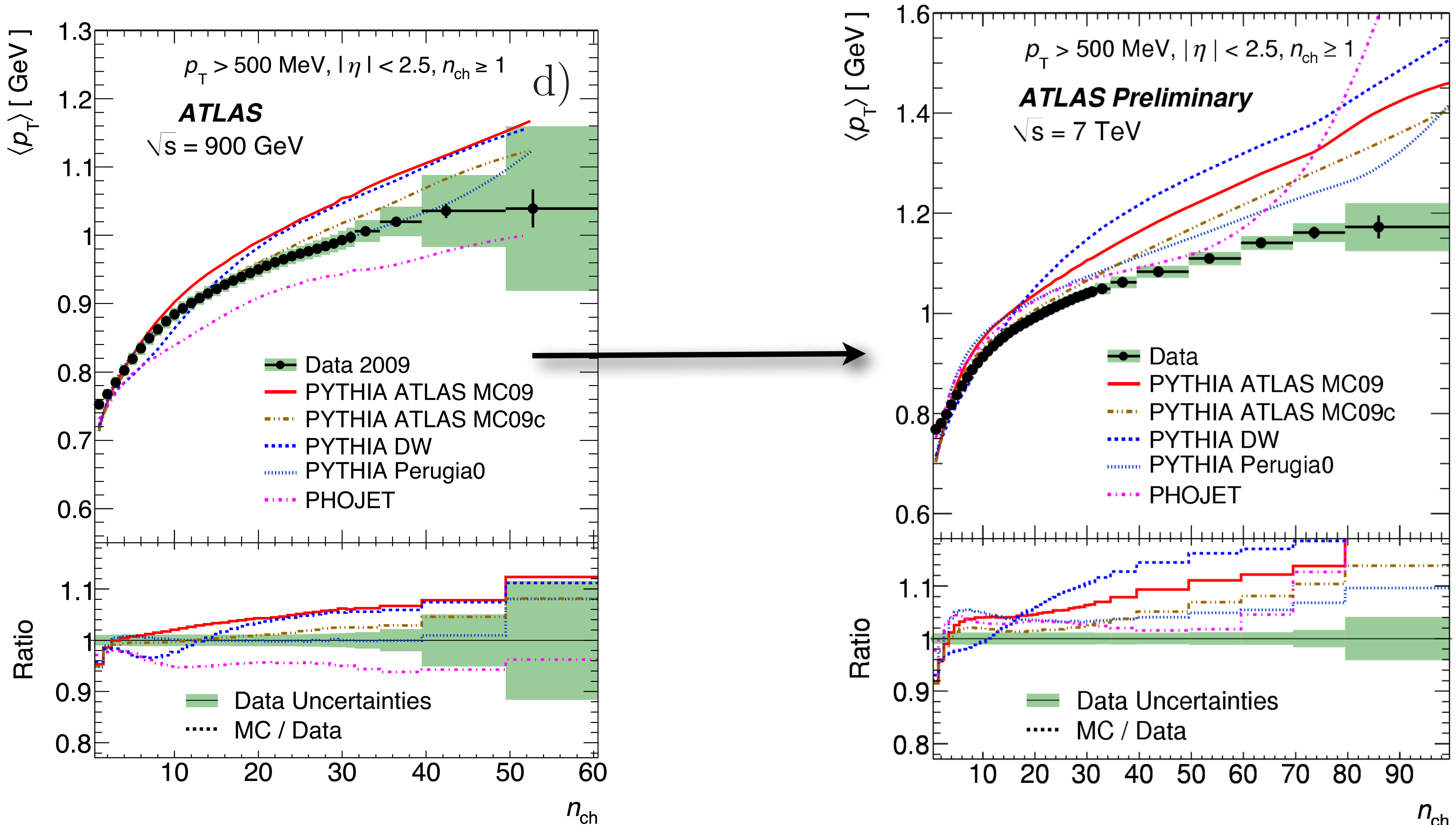


$\langle p_\perp \rangle (N)$

- **One entry for each N:** low-mult events clearly distinguishable from high-mult
  - **Low N** sensitive to diffraction, dominated by peripheral (LEP-like) collisions (?), no collective effects?
  - **High N** sensitive to UE, dominated by hard, central collisions. Departures from LEP fragmentation? Collective effects?
  - **Intermediate region (shape)** sensitive to proton mass distribution
- Appears to be a sensitive probe of infrared dynamics. Higher moments also sensitive?

⟨p⊥⟩(N)

- **Non-trivial energy dependence.**
- A (partial) tradeoff with ⟨N⟩ appears possible. Sufficient?



Conclusions

- **Question marks** concerning energy scaling
  - **Apparent tensions with Tevatron:** not certain that "trivial" retunings sufficient to span all energies?
- **What is** the cause?
  - **Energy-dependent energy dependence?**
    - Different scaling law?
    - Different scaling for diffraction vs non-diffractive?
    - Energy- vs x- dependence?
    - Other energy- or x-dependent phenomena? (e.g., mass distributions? collective effects? … ?)

Concrete Steps

- **A complete data set** **(~10^7 events)** at an **intermediate energy** of 2-3 TeV would add highly valuable information (+ aid confrontation with Tevatron constraints)
- **Tuning: map out** actual E_{CM}-dependence. E.g., separate tunings at each E_{CM} using complete data sets **[LPCC/MCnet project: H. Schulz]**
  - **Bring in data from Tevatron, RHIC (!), Hera(!), SPS, ISR, …**
- Continue to probe 900 GeV and 7 TeV with increased number of **observables and trigger conditions**
  - E.g., zero bias → INEL → diffractive and ND-enhanced triggers, with N≥1,2,3,...→ high-N / high-$p_\perp$ → UE, …. , study scaling of each sample
  - Correlations, identified-particle fragmentation functions

Extra Stuff

Event Samples

- **The problem with "NSD"** (if defined only by using specific MC flags)
  - **For any future** model that does not explicitly label SD, DD, ND (e.g., the one outlined in Hannes' talk), I would have to apply the following weighting function to all my generated INEL events:

    $\{p\}$ = set of all four-momenta (and particle species) in event

    $$\mathrm{weight}(\{p\}) = 1 - [\mathrm{d}\sigma_{\mathrm{SD}}(\{p\})/\mathrm{d}\sigma_{\mathrm{INEL}}(\{p\})]_{\mathrm{PY6.4.22}}$$

    which is a function of MSTP(1:200), PARP(1:200),…
  - **This is** a lot more *complicated* than a few hadron-level cuts
    - **I would in fact** have to do this for **ANY** model that generates (SD,DD,ND) spectra different from those of the chosen MC, i.e., any other PYTHIA tune, HERWIG, PHOJET, SHERPA, …
    - **I don't think**, e.g., the SHERPA authors would understand the reason why they have to apply this weighting function instead of just a set of hadron level cuts (but please feel free to check directly with Frank …)