Lessons from the early LHC data for MC tuning

P. Skands (CERN)

Multiple Partonic Interactions at LHC, November 2011, Hamburg

A Factorized View

1. Where is the energy going?

Note: only linearized Sphericity is IR safe

Sum(pT) densities, event shapes, mini-jet rates, ctrl&fwd energy flow, energy correlations… ≈ sensitive to pQCD + pMPI

2. How many tracks is it divided onto?

N_{tracks}, dN_{tracks}/dp_T, Associated track densities, track correlations…

≈ sensitive to hadronization + soft MPI

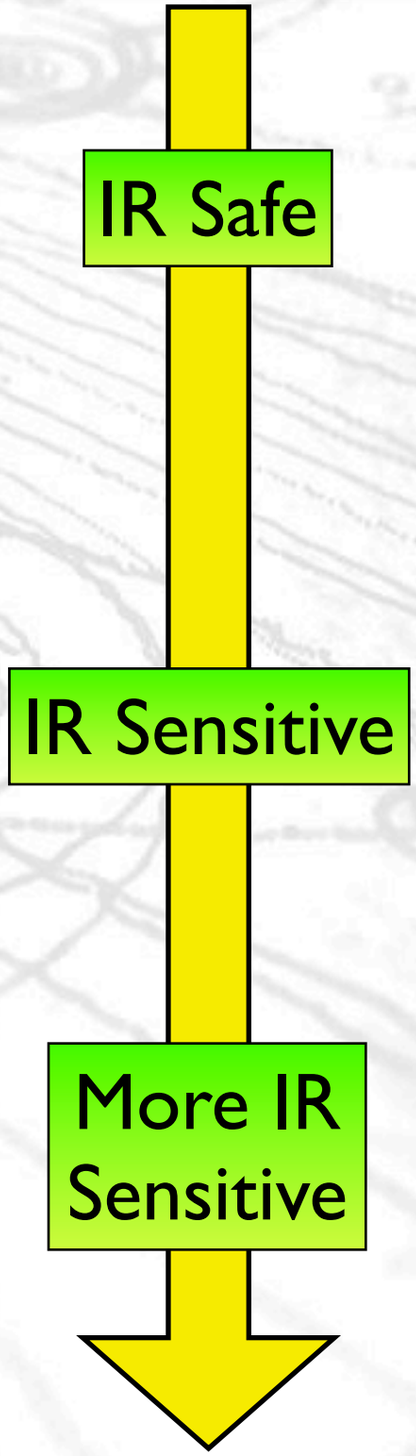
3. Are there gaps in it?

Created by diffraction (and color reconnections?). Destroyed by UE.

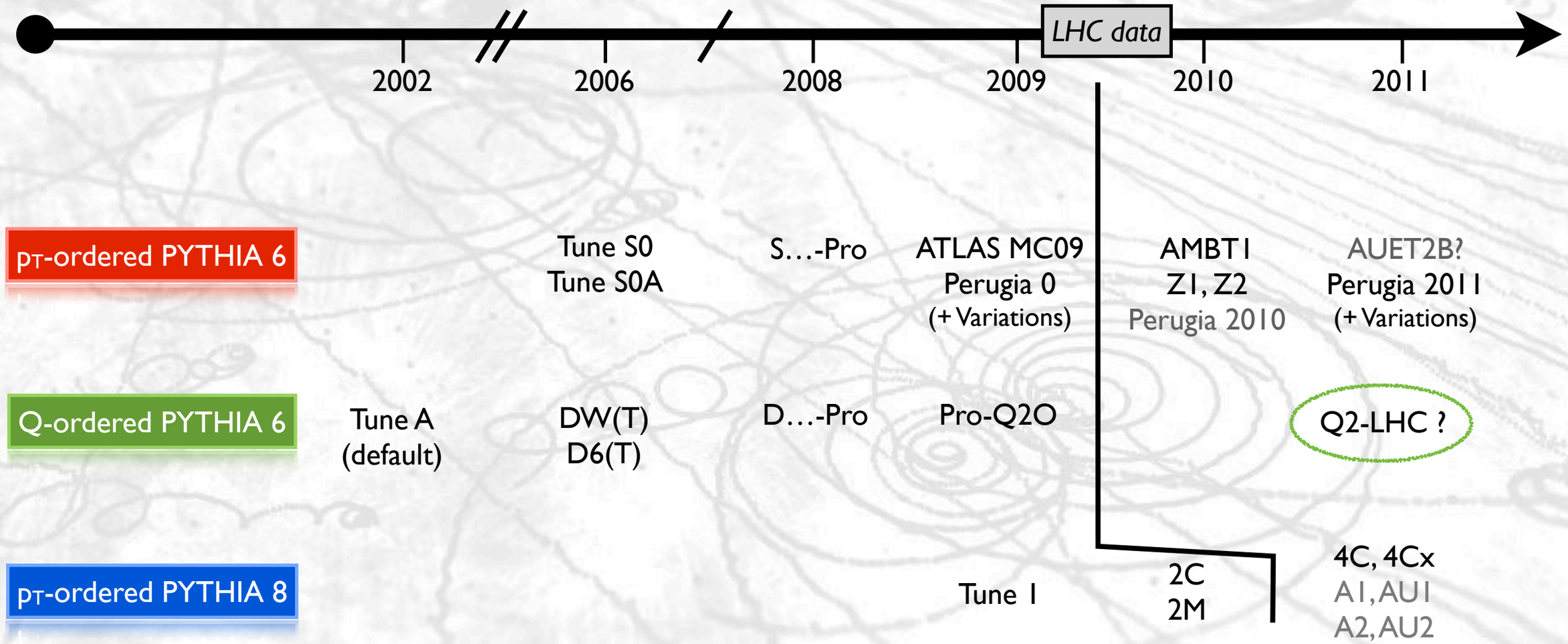
4. What kind of tracks?

Strangeness per track, baryons per track, baryon asymmetry, …
hadron-hadron correlations ≈ sensitive to details of hadronization

+ collective effects (+Quarkonium sensitive to color reconnections?)



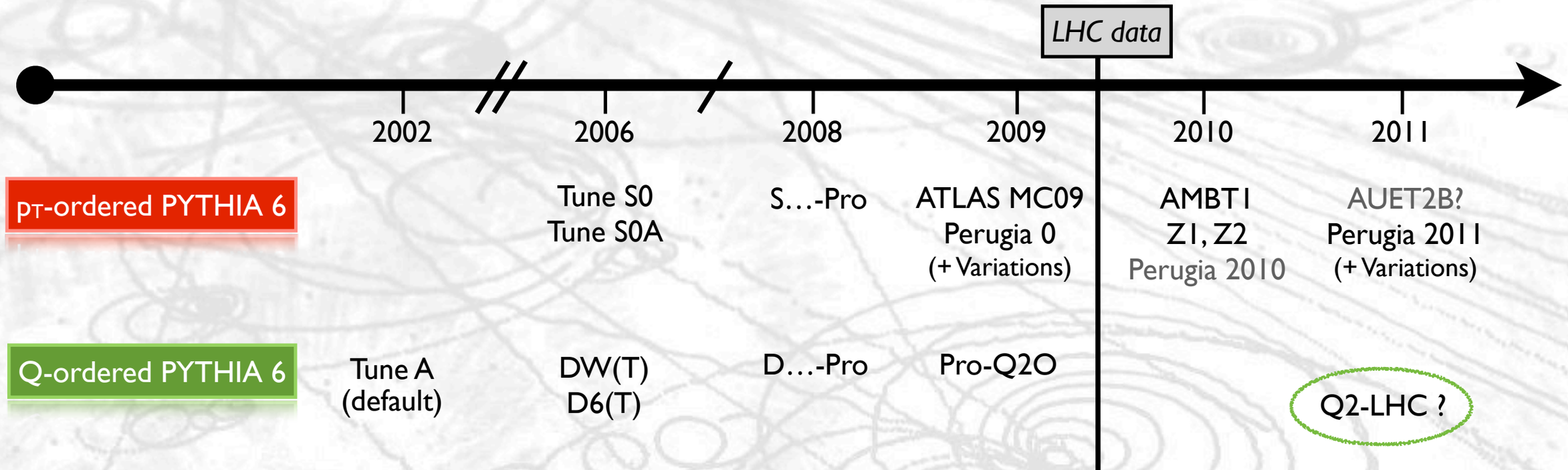
PYTHIA Models



Note: tunes differ significantly in which data sets they include

- LEP fragmentation parameters
- Level of Underlying Event & Minimum-bias Tails
- Soft part of Drell-Yan p_T spectrum

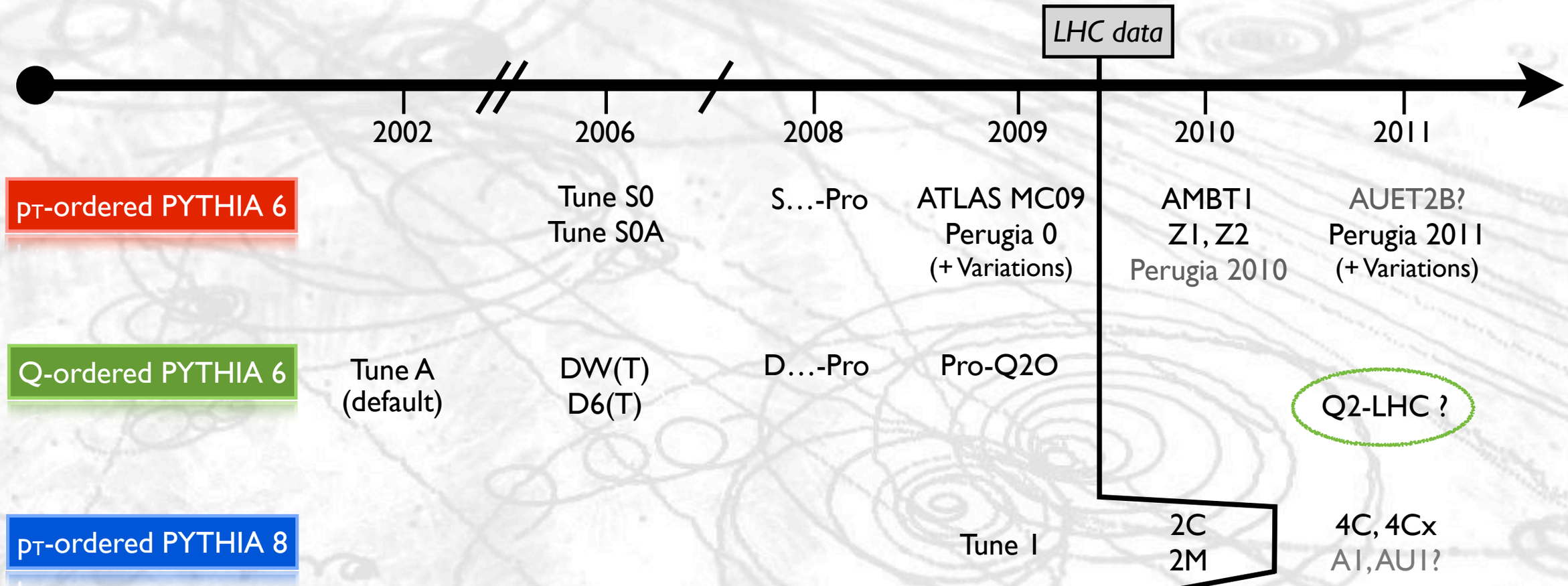
PYTHIA Models



Main Data Sets included in each Tune (no guarantee that all subsets ok)

	A	DW, D6, ...	S0, S0A	MC09(c)	Pro-..., Perugia 0, Tune 1, 2C, 2M	AMBT1	Perugia 2010	Perugia 2011	Z1, Z2	4C, 4Cx	AUET2B, A2, AU2
LEP					✔		✔	✔		✔	✔
TeV MB			✔	✔	✔		✔	✔			?
TeV UE	✔	✔		✔	✔		✔	✔			✔?
TeV DY		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
LHC MB						✔	✔	✔		✔	?
LHC UE								✔	✔		✔

PYTHIA Models



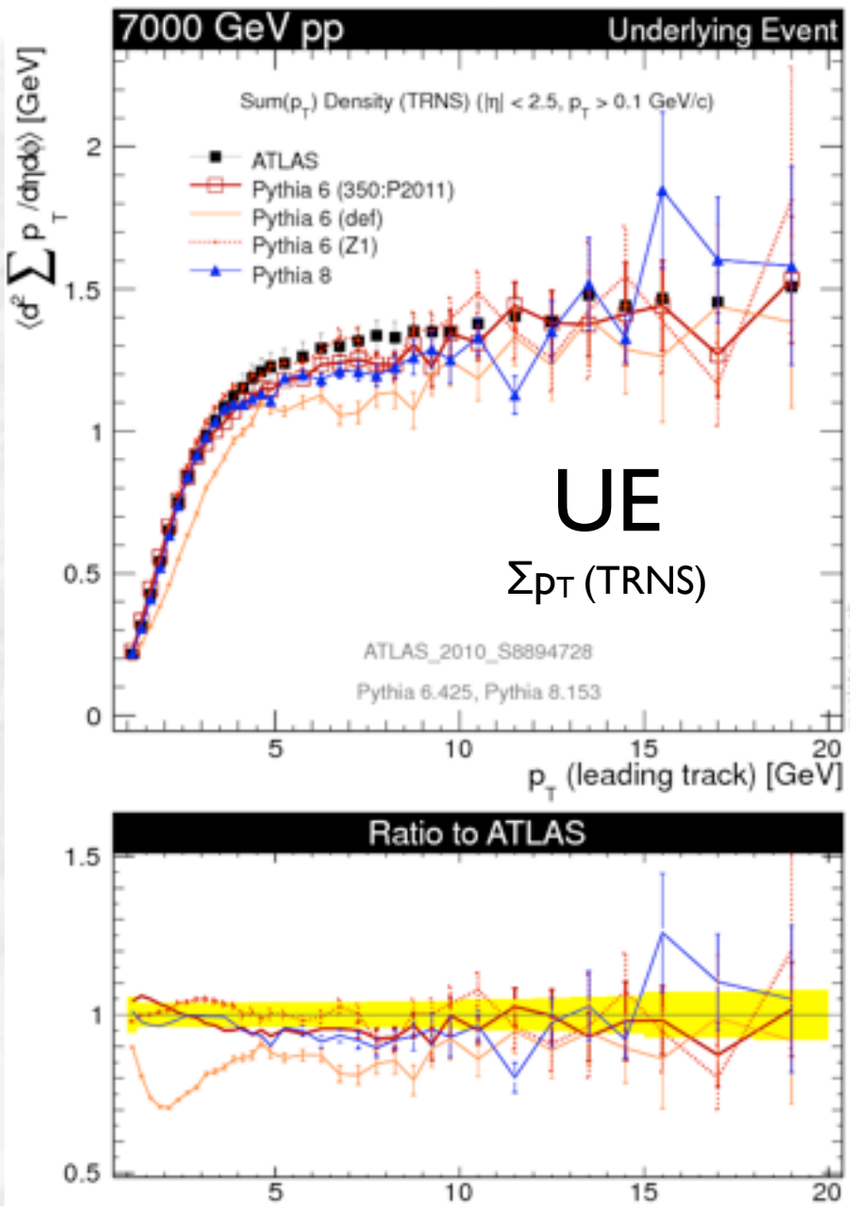
Main Data Sets included in each Tune (no guarantee that all subsets ok)

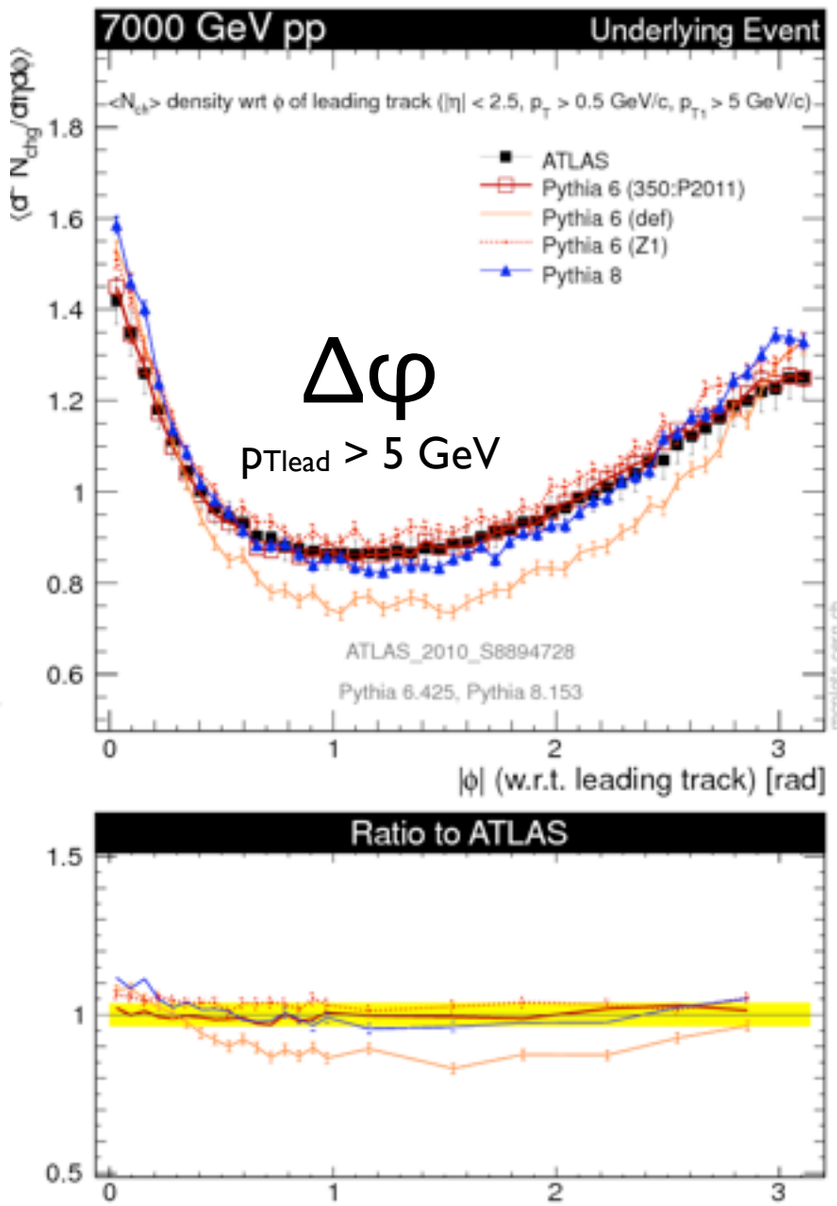
	A (default)	DW, D6, ...	S0, S0A	MC09(c)	Pro-..., Perugia 0, Tune 1, 2C, 2M	AMBT1	Perugia 2010	Perugia 2011	Z1, Z2	4C, 4Cx	AUET2B, A2, AU2
LEP					✔		✔	✔		✔	✔
TeV MB			✔	✔	✔		✔	✔		(✔)	?
TeV UE	✔	✔		✔	✔		✔	✔		(✔)	✔?
TeV DY		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
LHC MB						✔	✔	✔		✔	?
LHC UE								✔	✔		✔

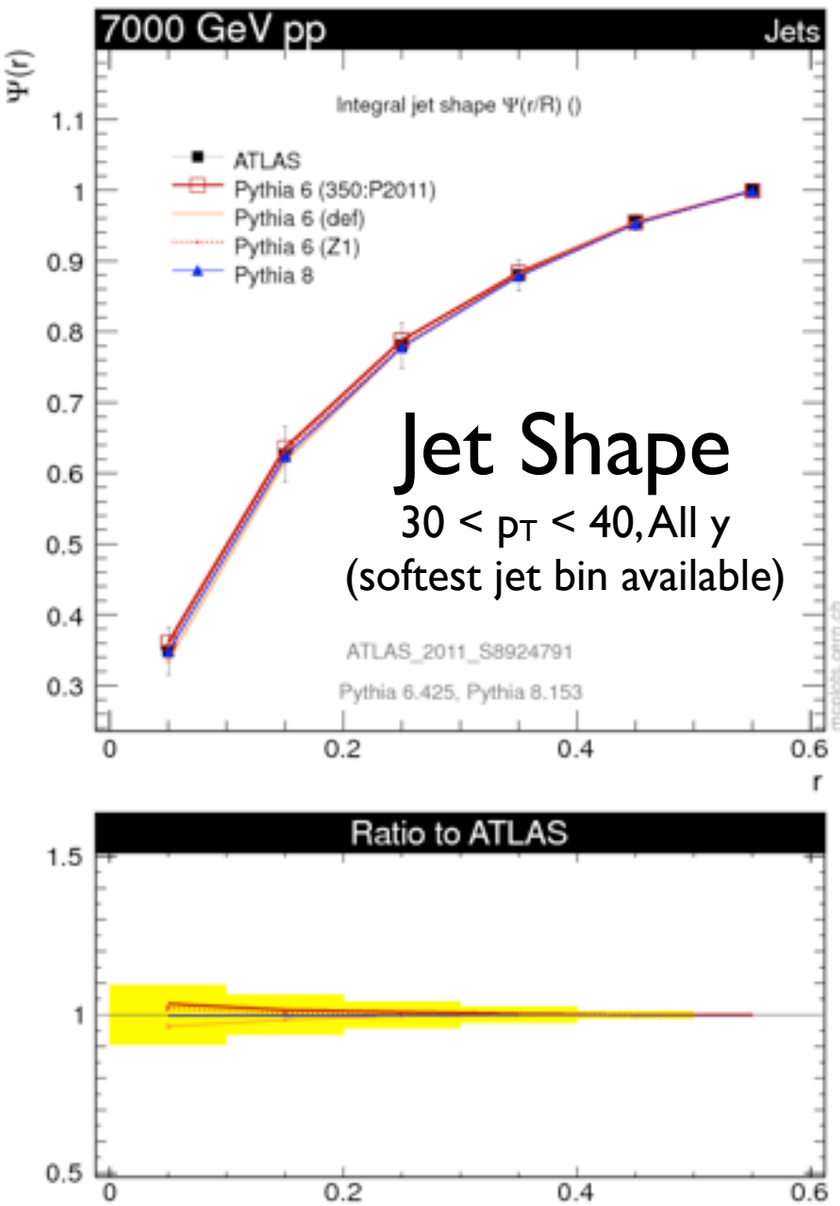
What Works*

*) if you use an up-to-date tune. Here comparing to PY6 default (~ Tune A) to show changes.

Underlying Event & Jet Shapes







PS: yes, we **should** update the PYTHIA 6 defaults ...

What Works*

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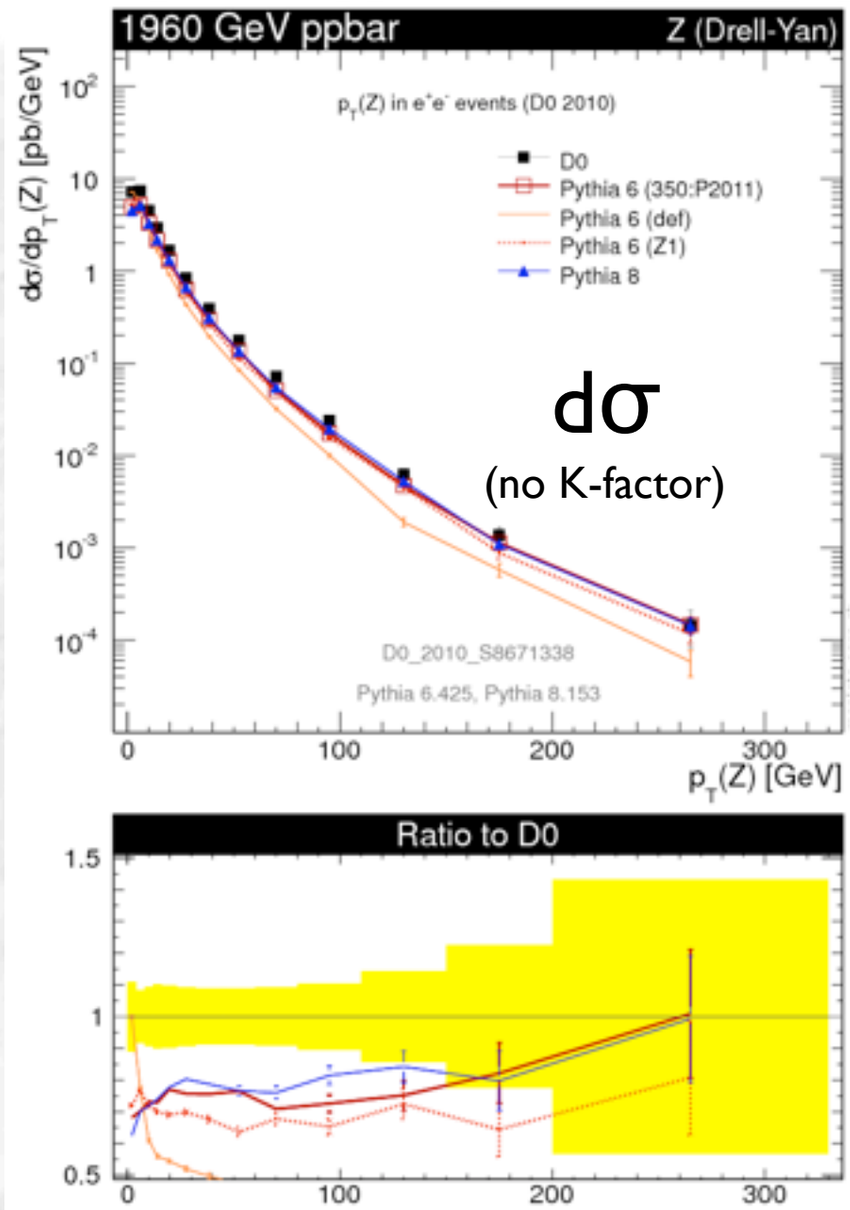
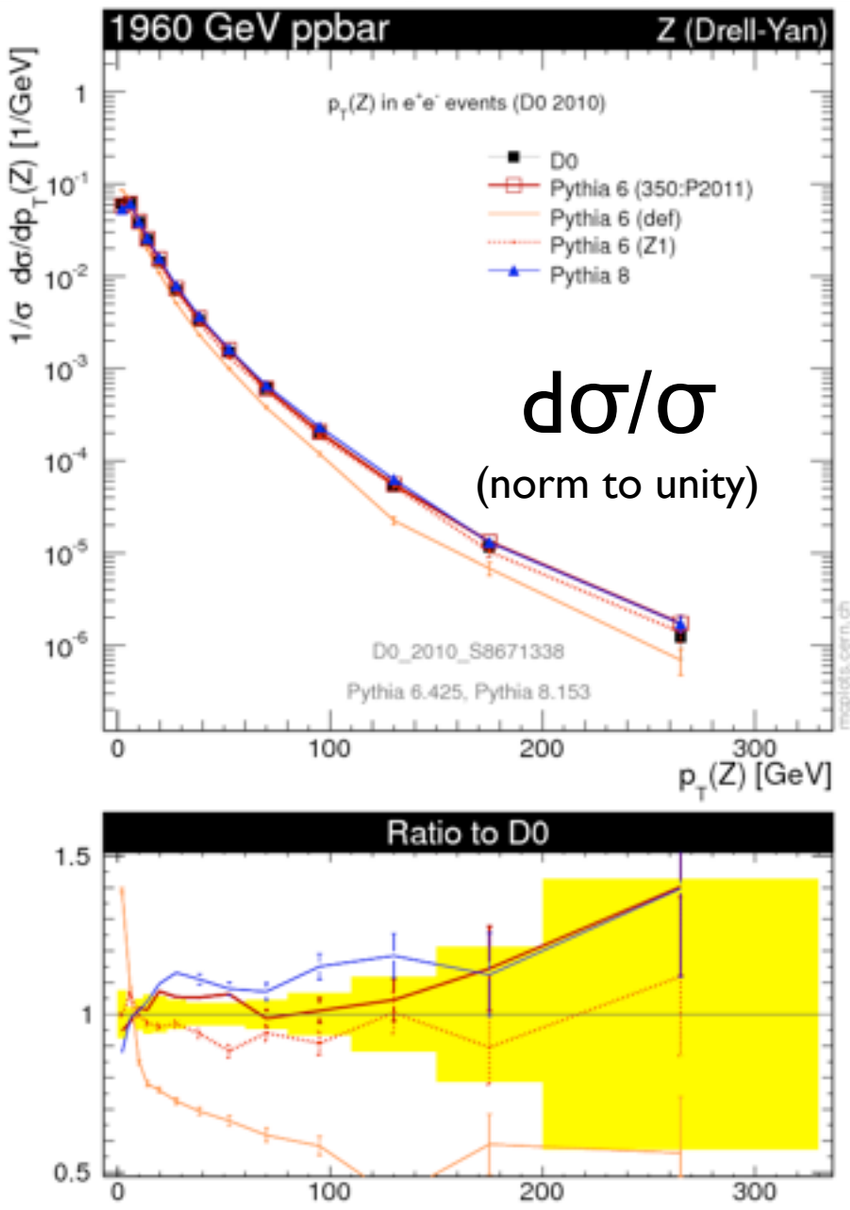
Drell-Yan pT (Normalized to Unity)

Apologies: we don't have DY measurements from LHC on the mcplots site yet



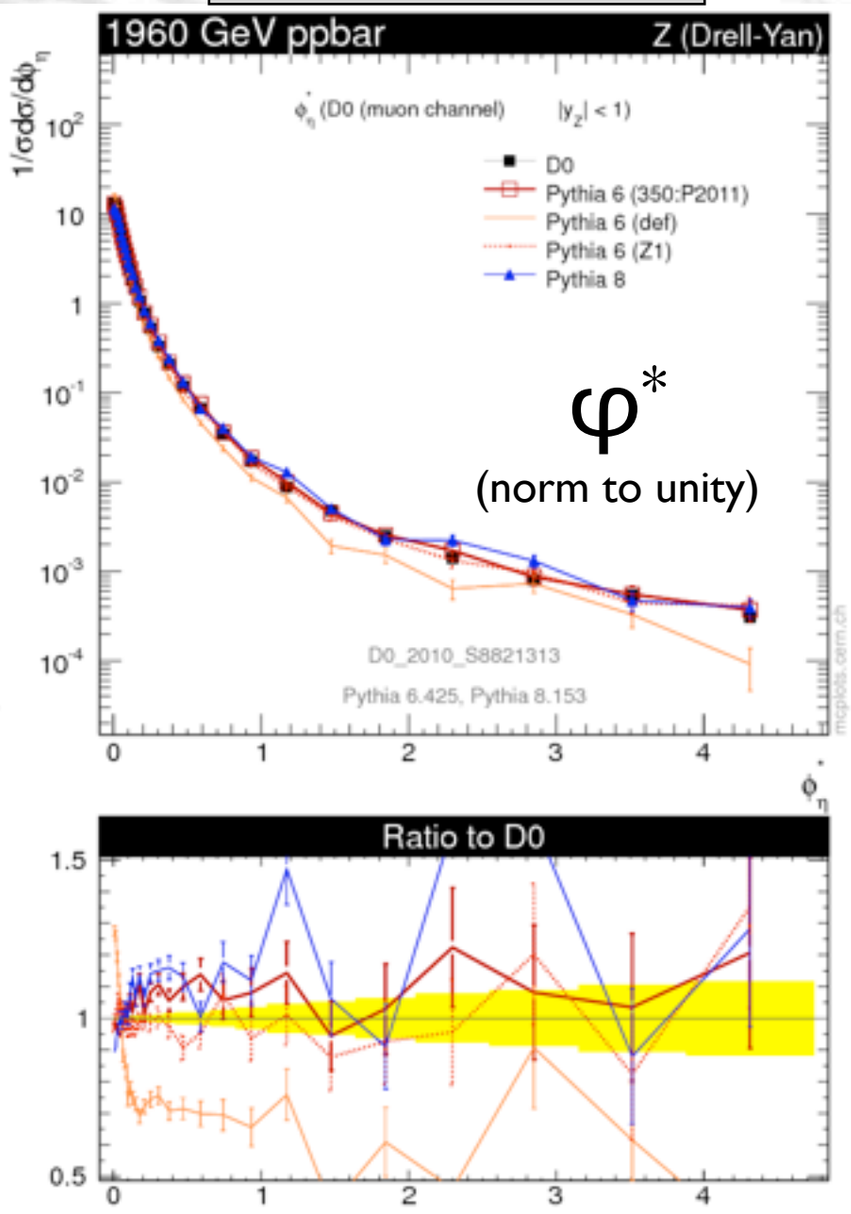
dσ

(no K-factor)



dσ/σ

(norm to unity)



φ*

(norm to unity)

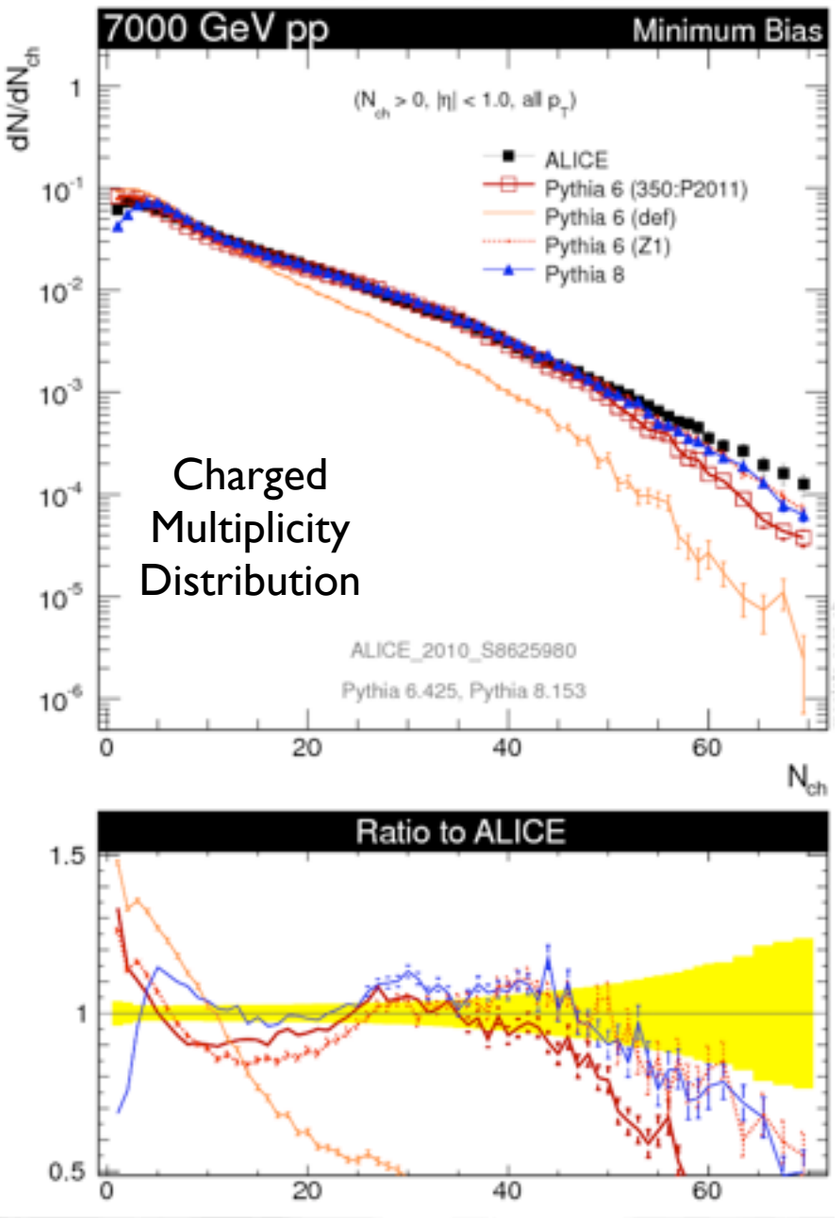
PS: yes, we **should** update the PYTHIA 6 defaults ...

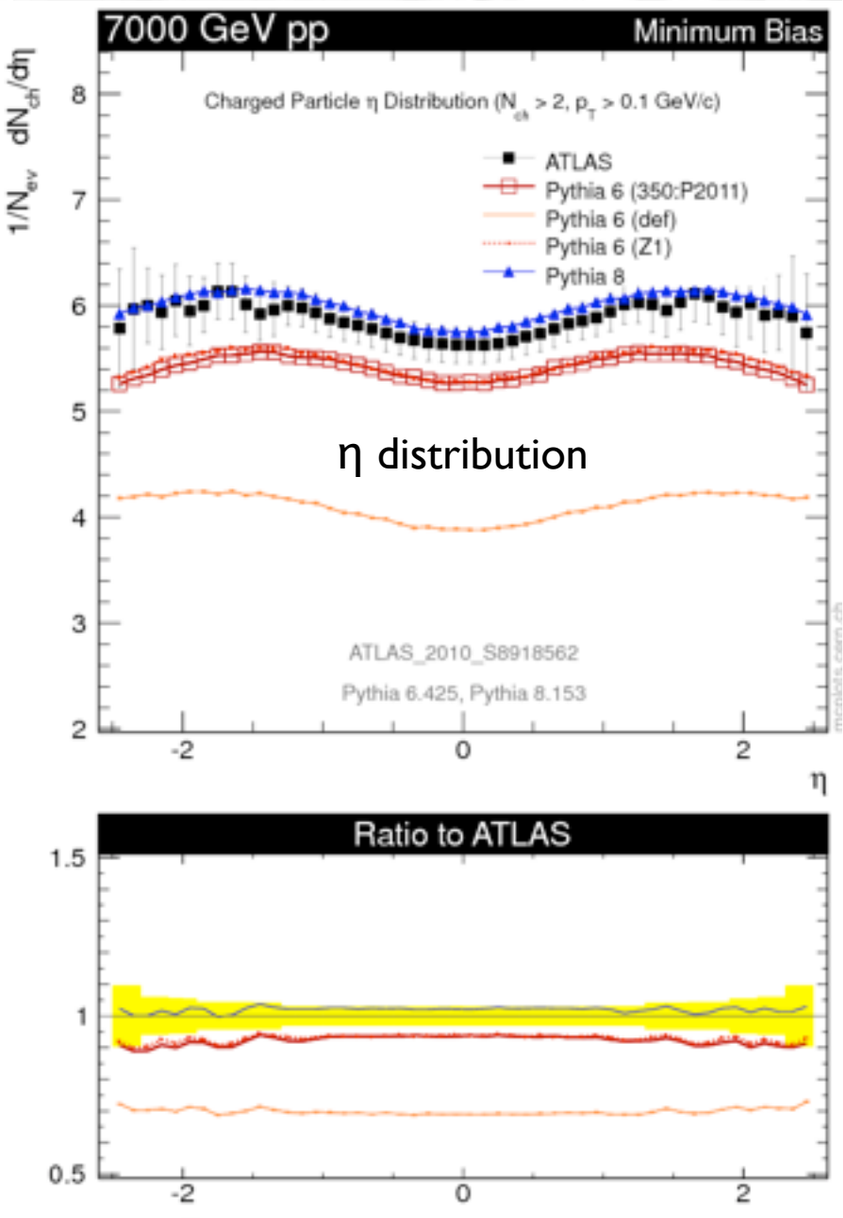
What Kind of Works*

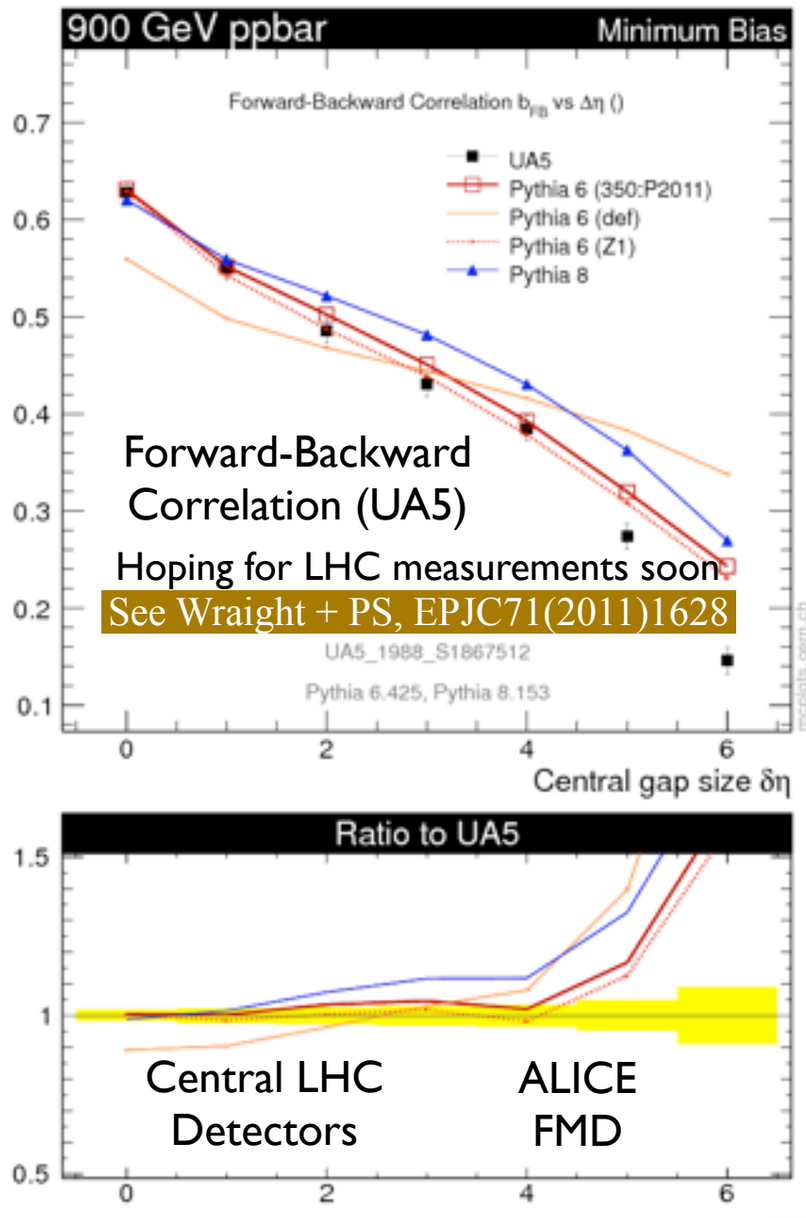
*) if you use an up-to-date tune. Here comparing to PY6 default (~ Tune A) to show changes.

Minimum-Bias Multiplicities

(here showing as inclusive as possible)







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What Doesn't Work

p_T Spectra (in particular mass dependence)

Strange and baryon production

Structure of very soft events

Very high-multiplicity events (CMS ridge)

(No time to address here, plus no good model yet)

Diffraction and forward energy

(will return to diffraction on Friday)

Organized Tuning

Can we be more general than this-tune-does-this, that-tune-does-that?

Yes Schulz & PS, **Eur.Phys.J. C71 (2011) 1644**

The new automated tuning tools can be used to generate unbiased optimizations for different observable regions

Same parameters → consistent model (not just "best tune")

Critical for this task (take home message):

Need "comparable" observable sets for each region

Example: test ENERGY SCALING of MB: use different collider energies as "regions"
(Other complementary data sets could be used to test other model aspects)

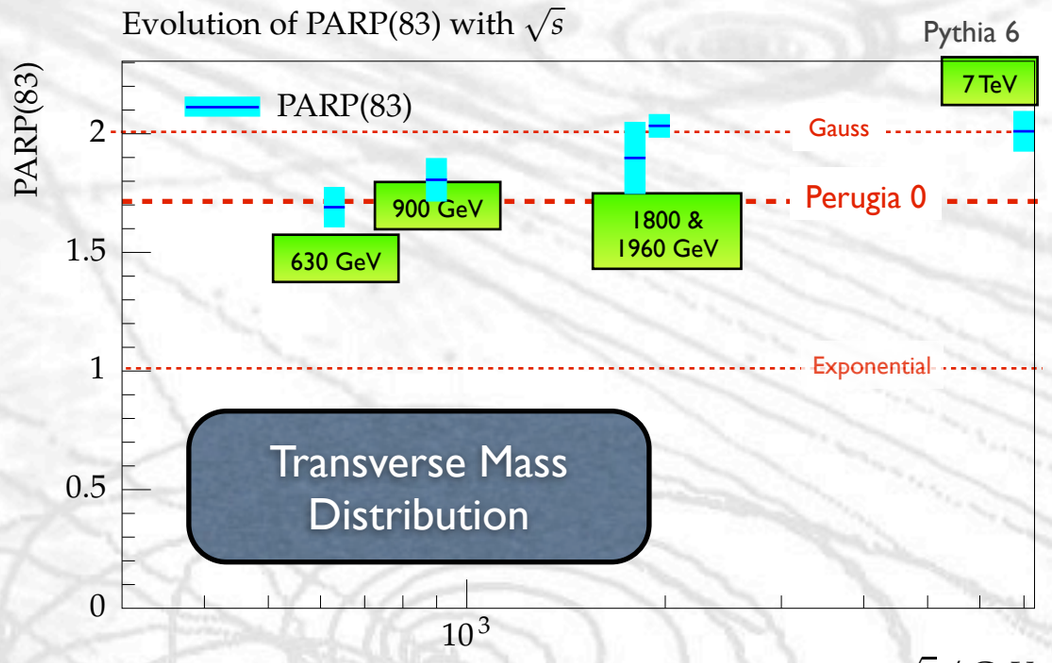
Tuning vs Testing Models

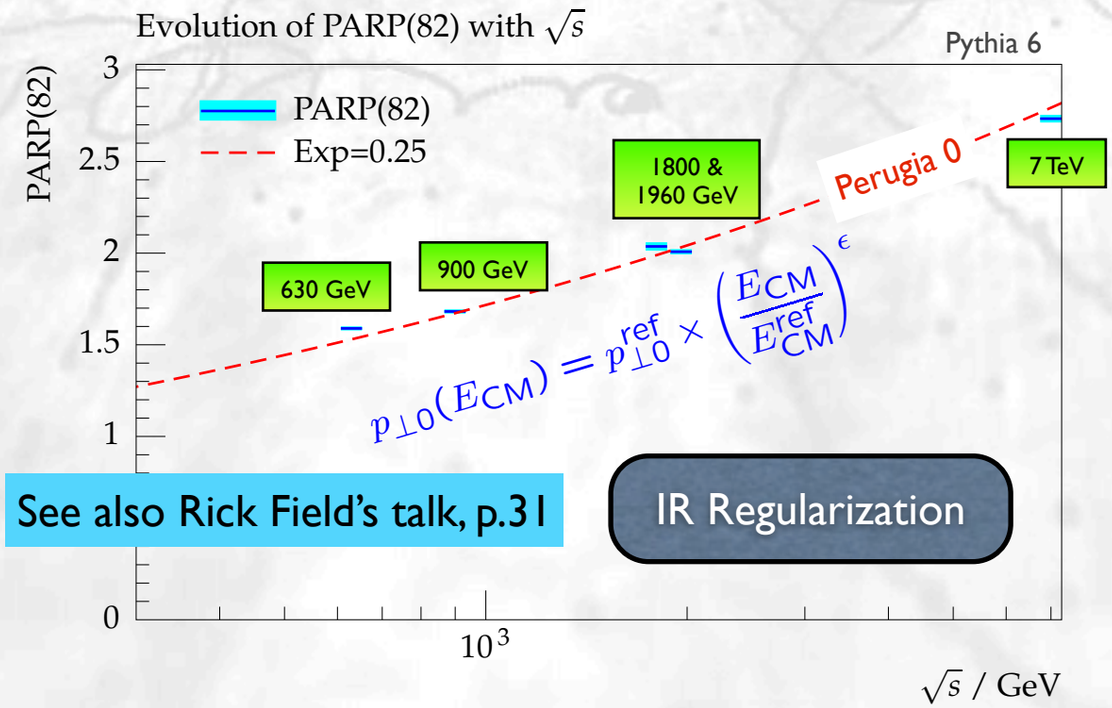
TEST models

Tune parameters in several complementary regions

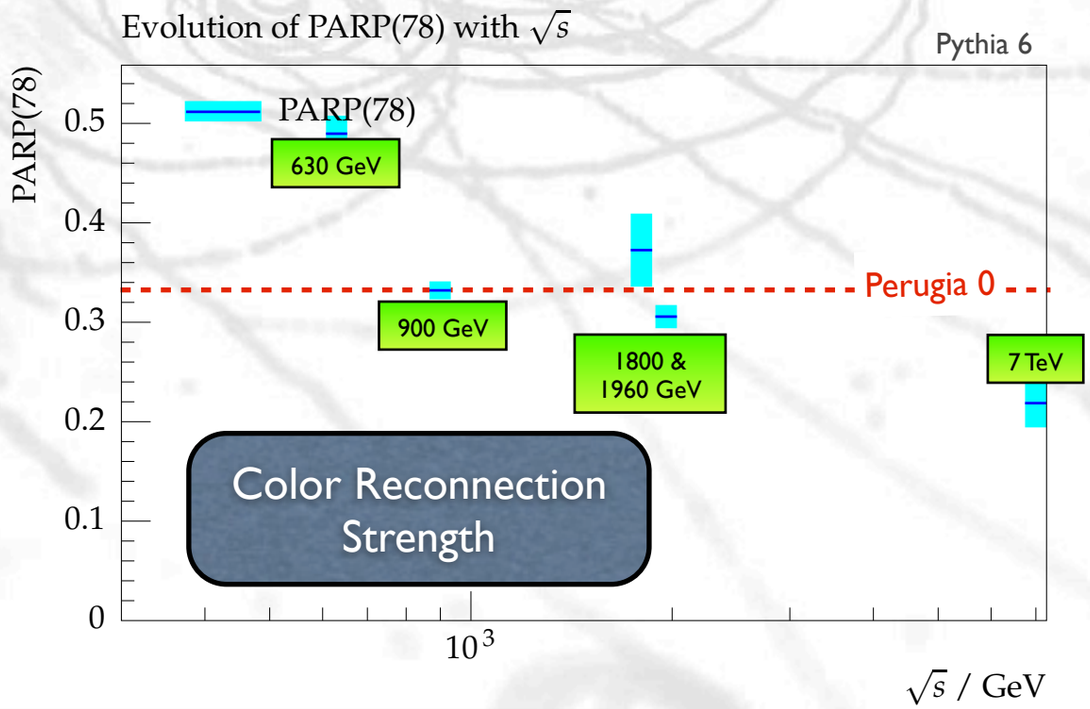
Consistent model → same parameters

Model breakdown → non-universal parameters





See also Rick Field's talk, p.31



"Energy Scaling of MB Tunes", H. Schulz + PS, **Eur.Phys.J. C71 (2011) 1644**

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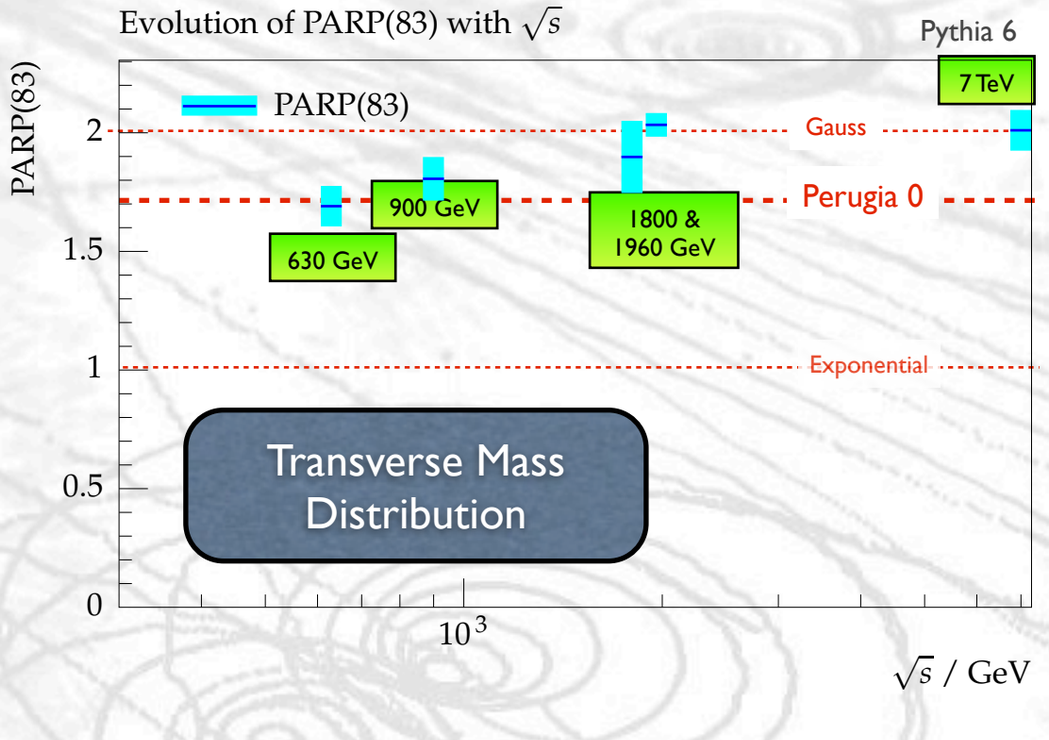

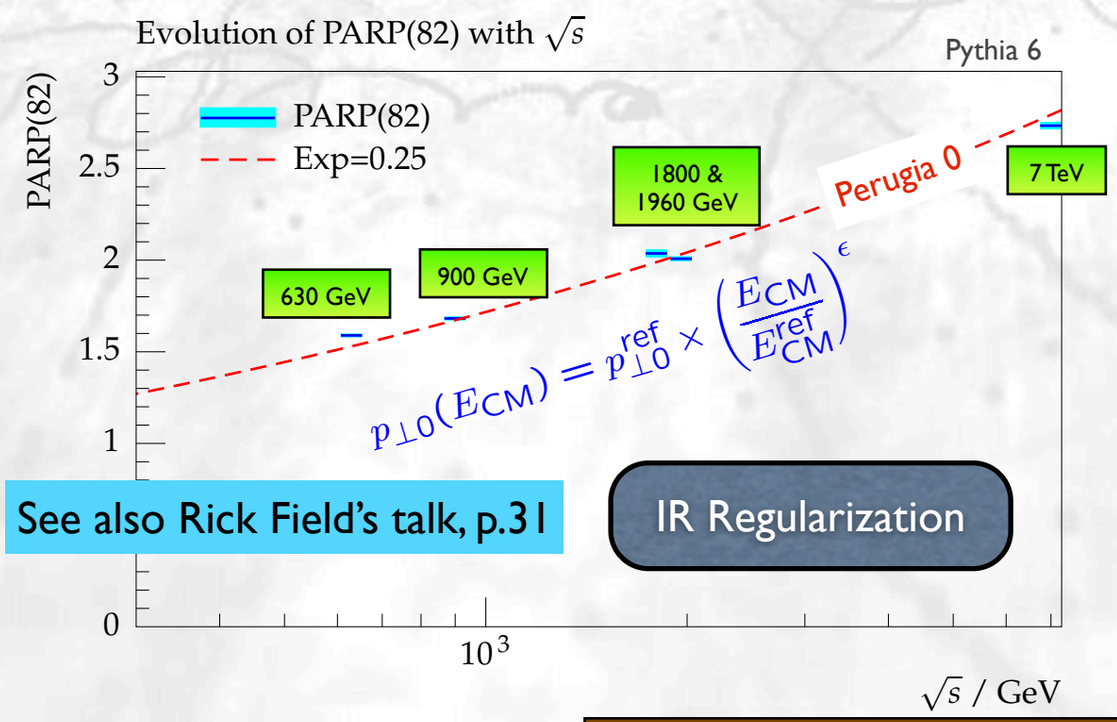

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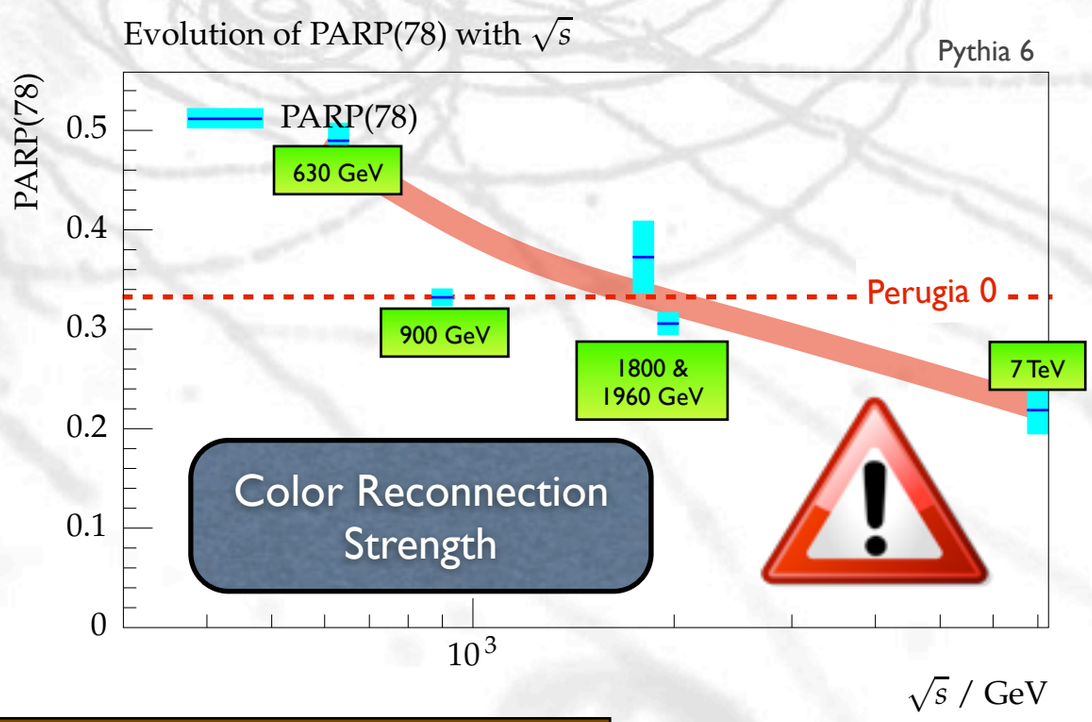

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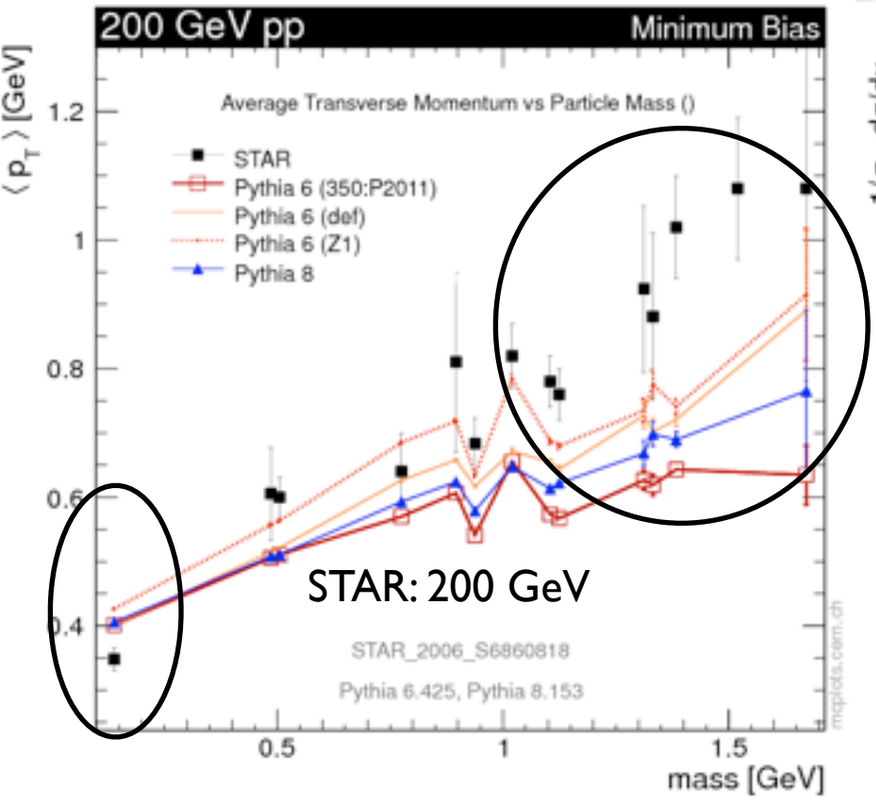
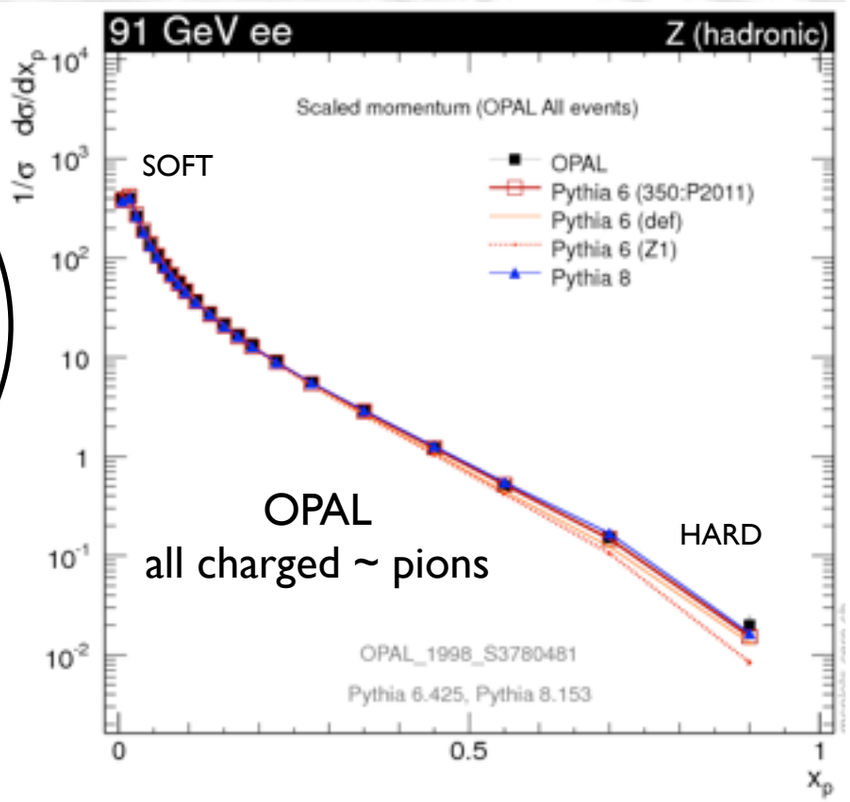
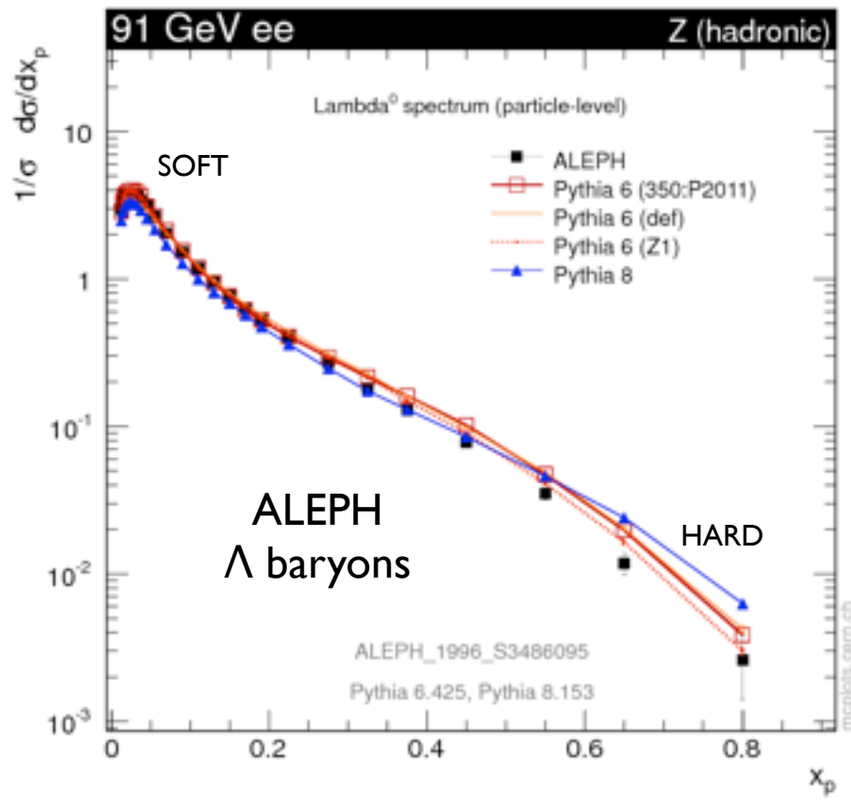
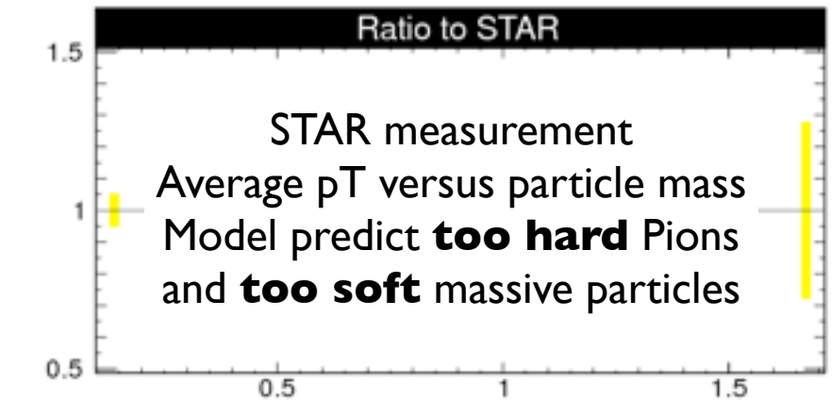
pT Spectra / Mass Dependence

Must be compared with LEP

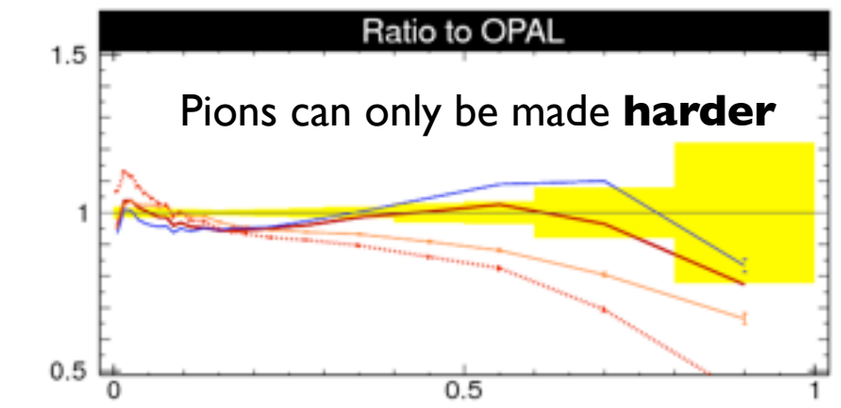




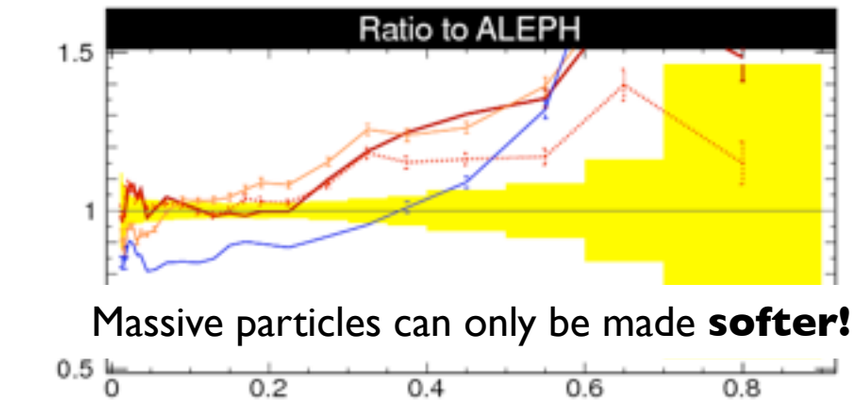




STAR measurement
Average pT versus particle mass
Model predict **too hard** Pions
and **too soft** massive particles



Pions can only be made **harder**

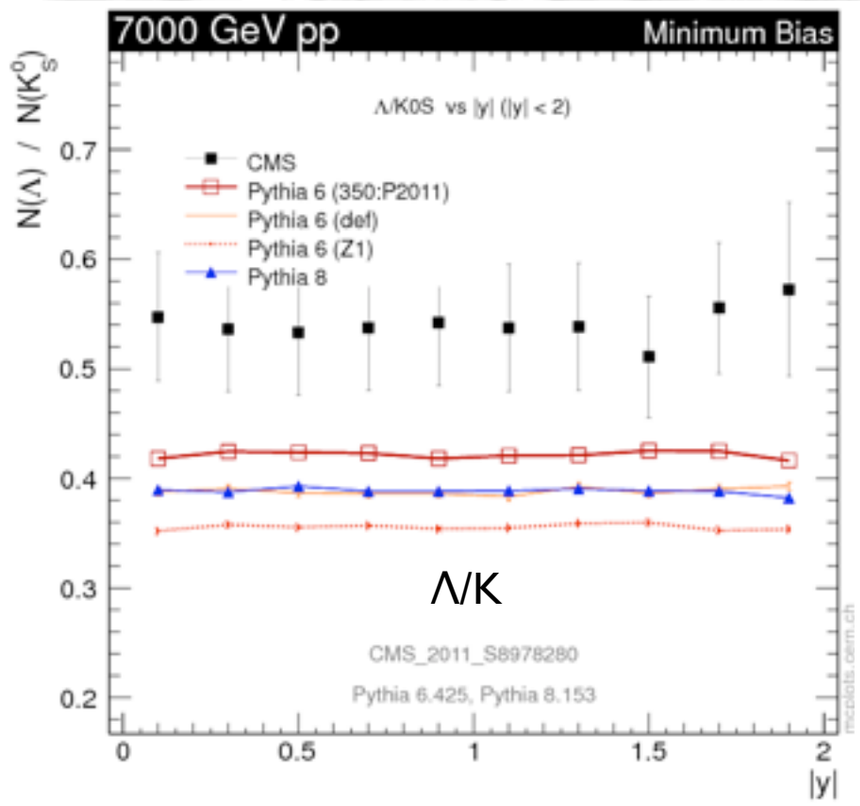


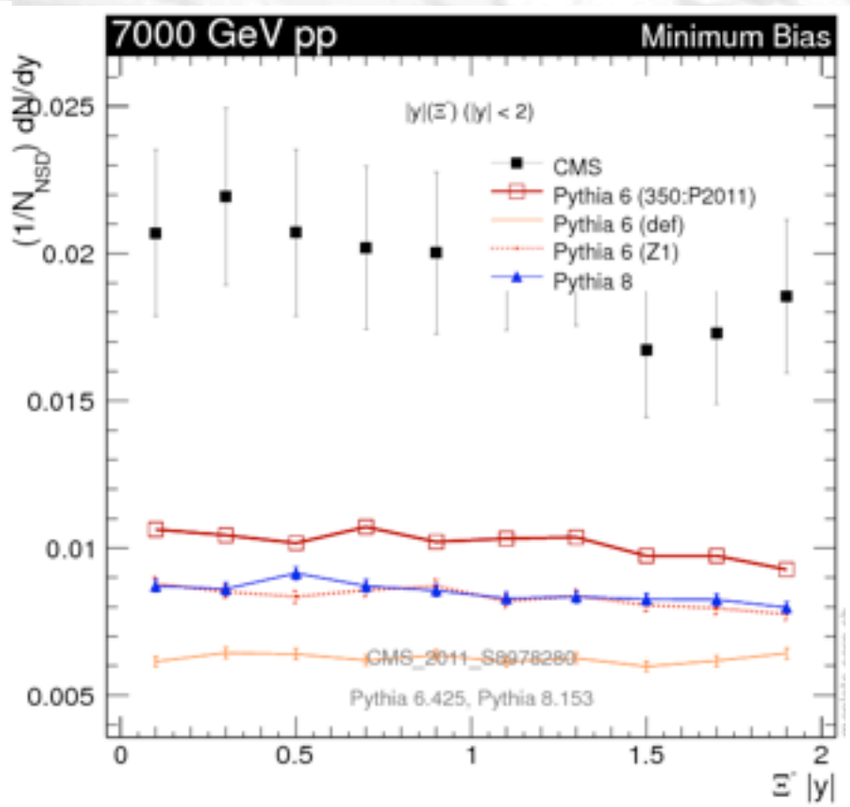
Massive particles can only be made **softer!**

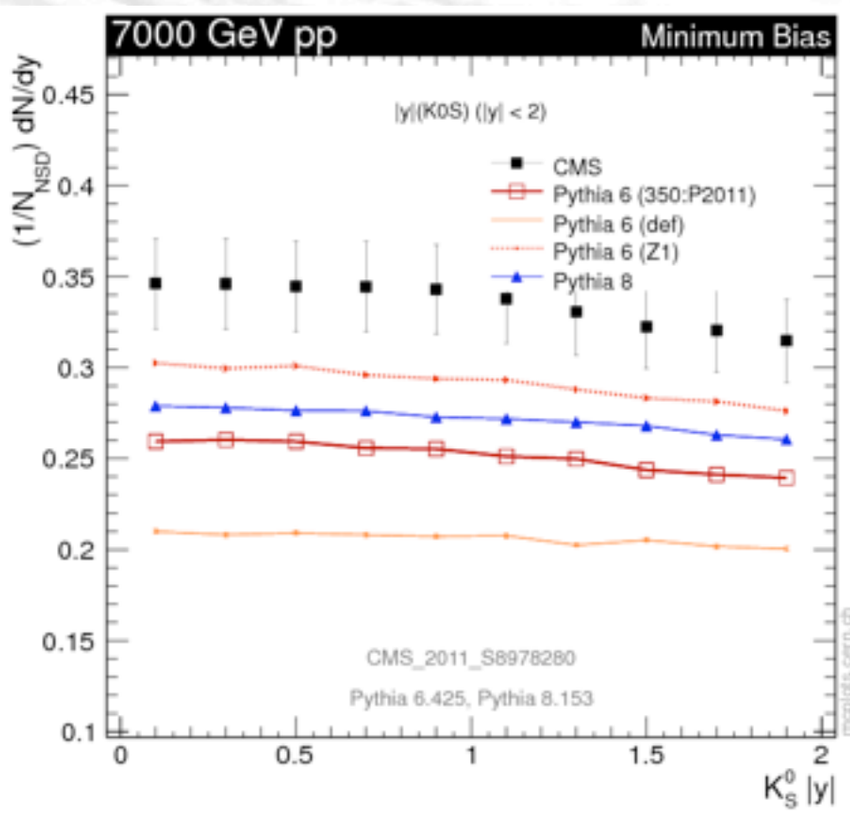
So: tuning problem? or physics problem? Will return on Friday

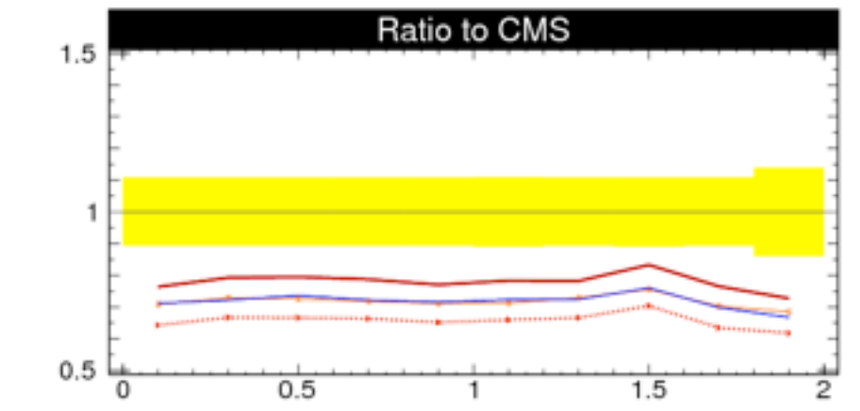
Strangeness and Baryons

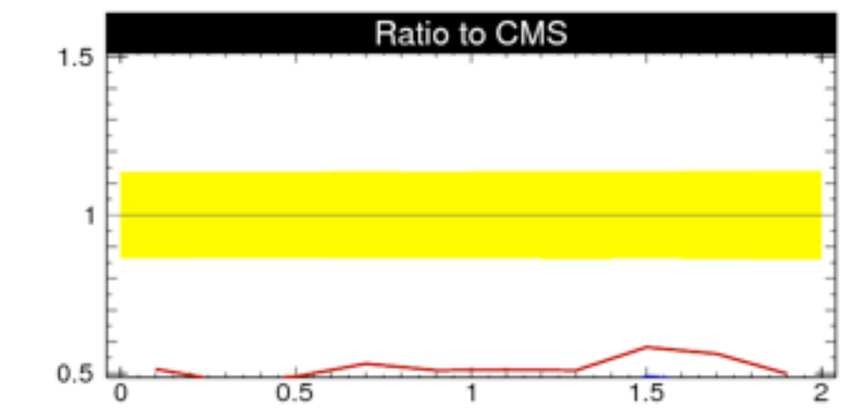
Tried to learn from early data, but still not there …

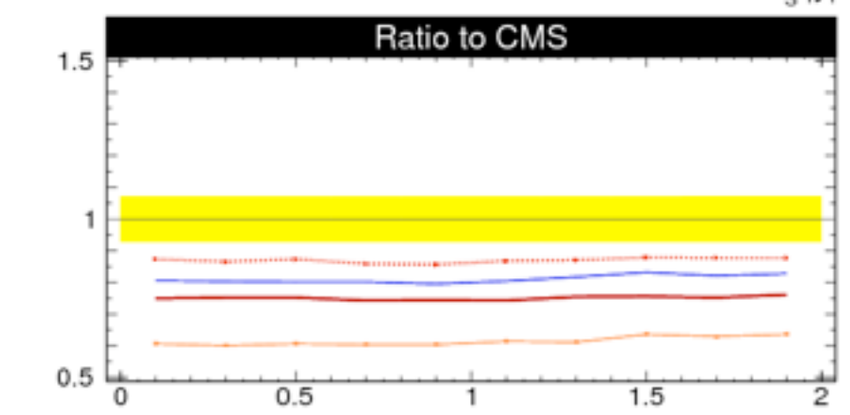








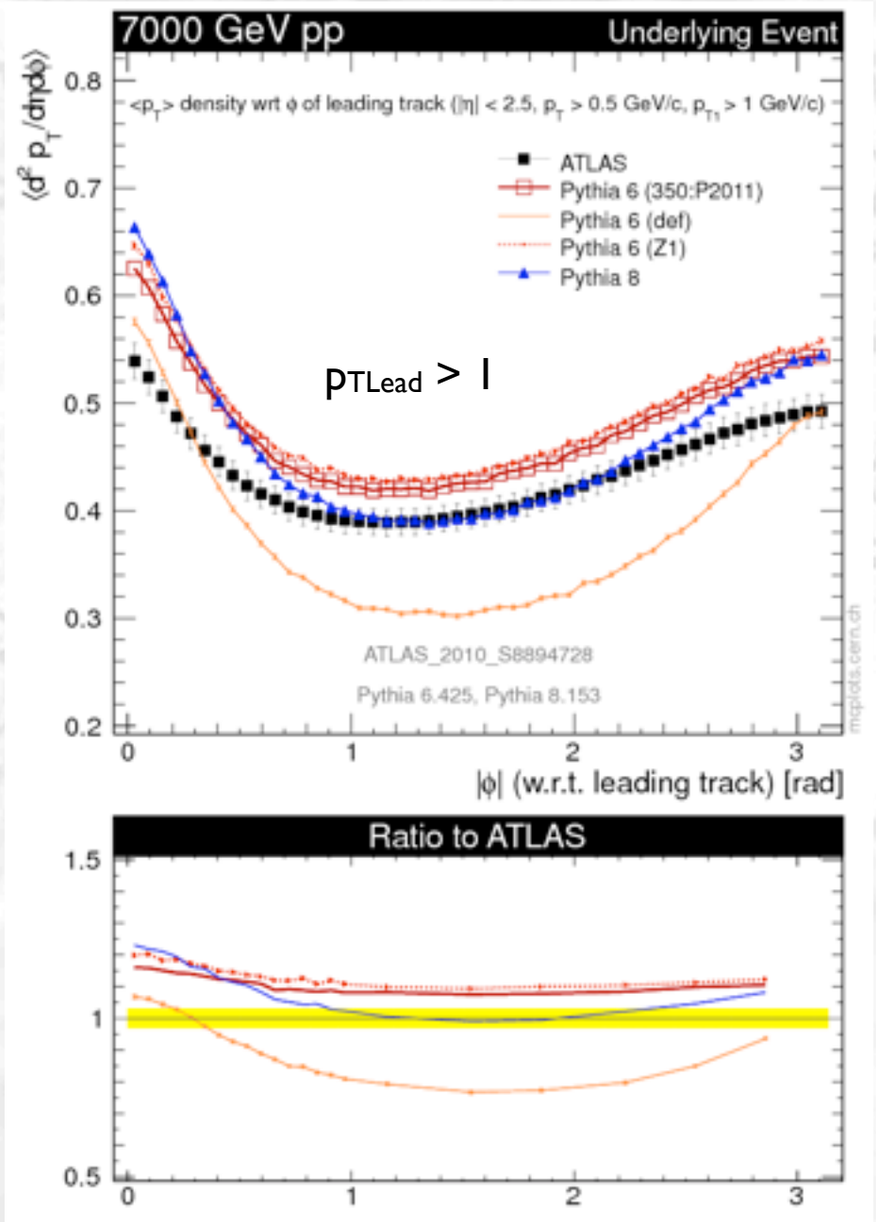




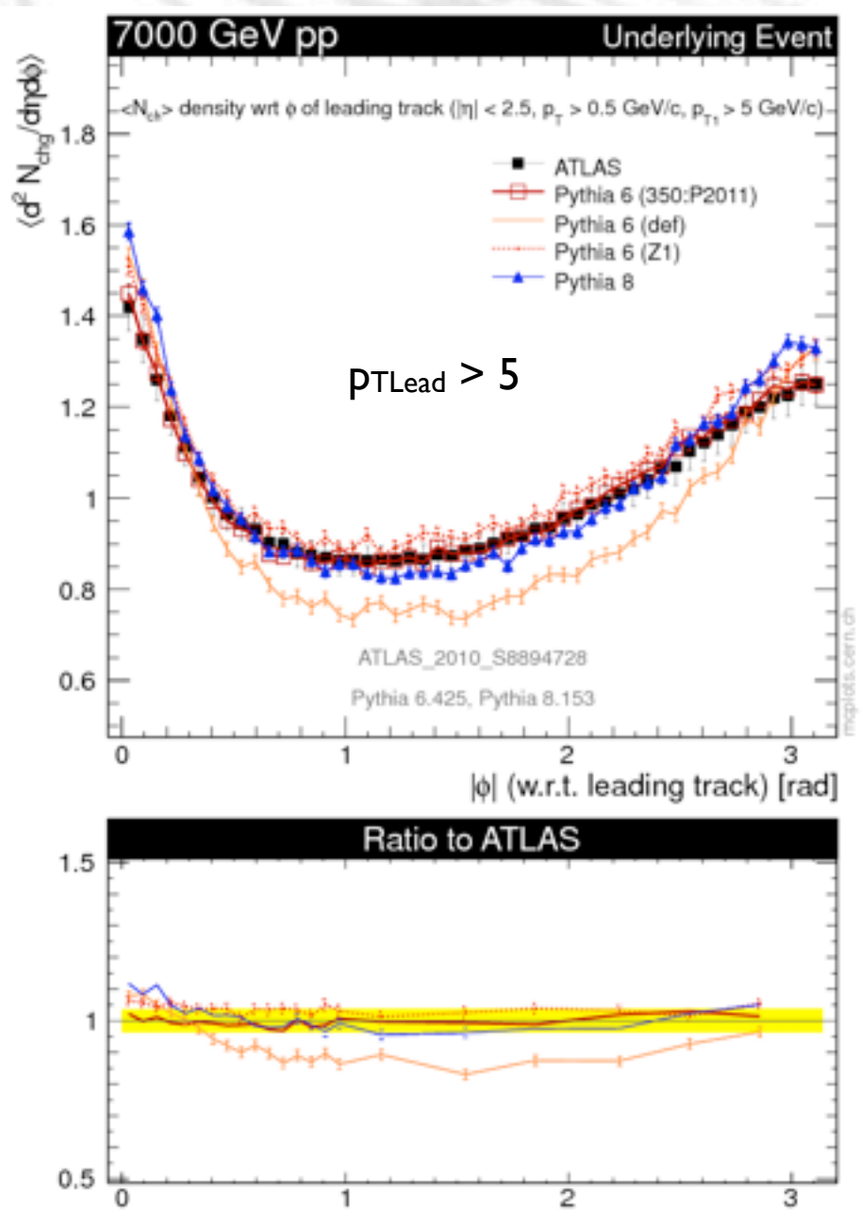
Again, quite difficult to adjust flavor parameters while remaining within LEP bounds …

Very Soft Structure

Minimum-Bias too lumpy?



Underlying Event ok?



Summary

How did the models fare?

Lots could be said…

Bottom line:

Not too bad on averages

See also talks by Rick Field and others

E.g., UE level underpredicted by ~ 10-20% relative to Tevatron tunes (I won my bet!)

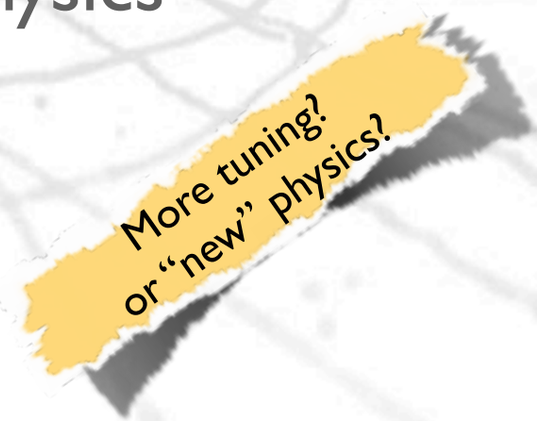
Significant discrepancies on more exclusive physics

Strangeness, Baryons, and Baryon Transport ⟷ LEP

p_T spectra

High-multiplicity tail (+ridge!) → needs more study!

Forward measurements and Diffraction



No single model/tune does it all **… (game still open)**

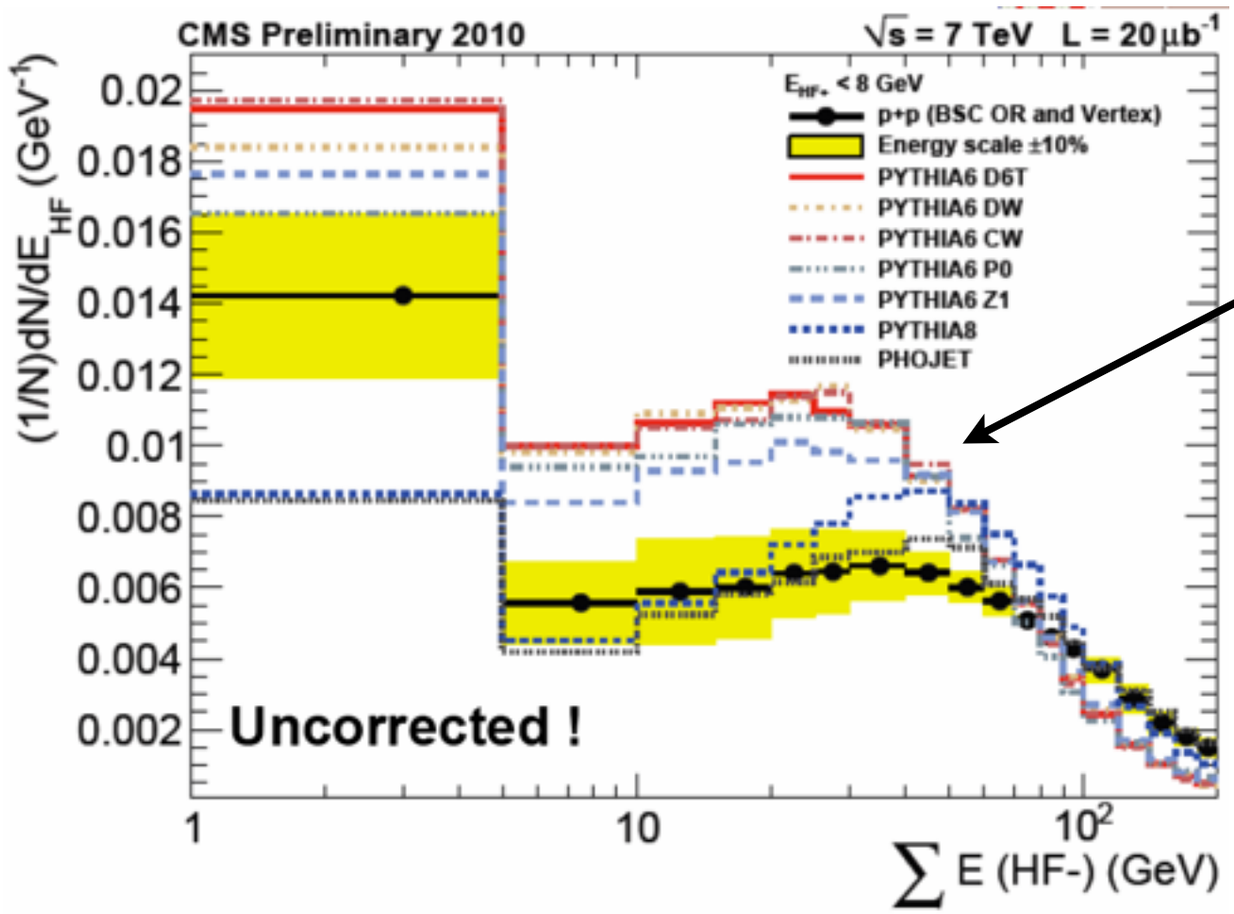
Diffraction

Framework needs testing and tuning

E.g., interplay between non-diffractive and diffractive components

+ LEP tuning used directly for diffractive modeling

Hadronization preceded by shower at LEP, but not in diffraction → dedicated diffraction tuning of fragmentation pars?



Study this bump

+ Room for new models,
e.g., KMR (SHERPA)
Others?