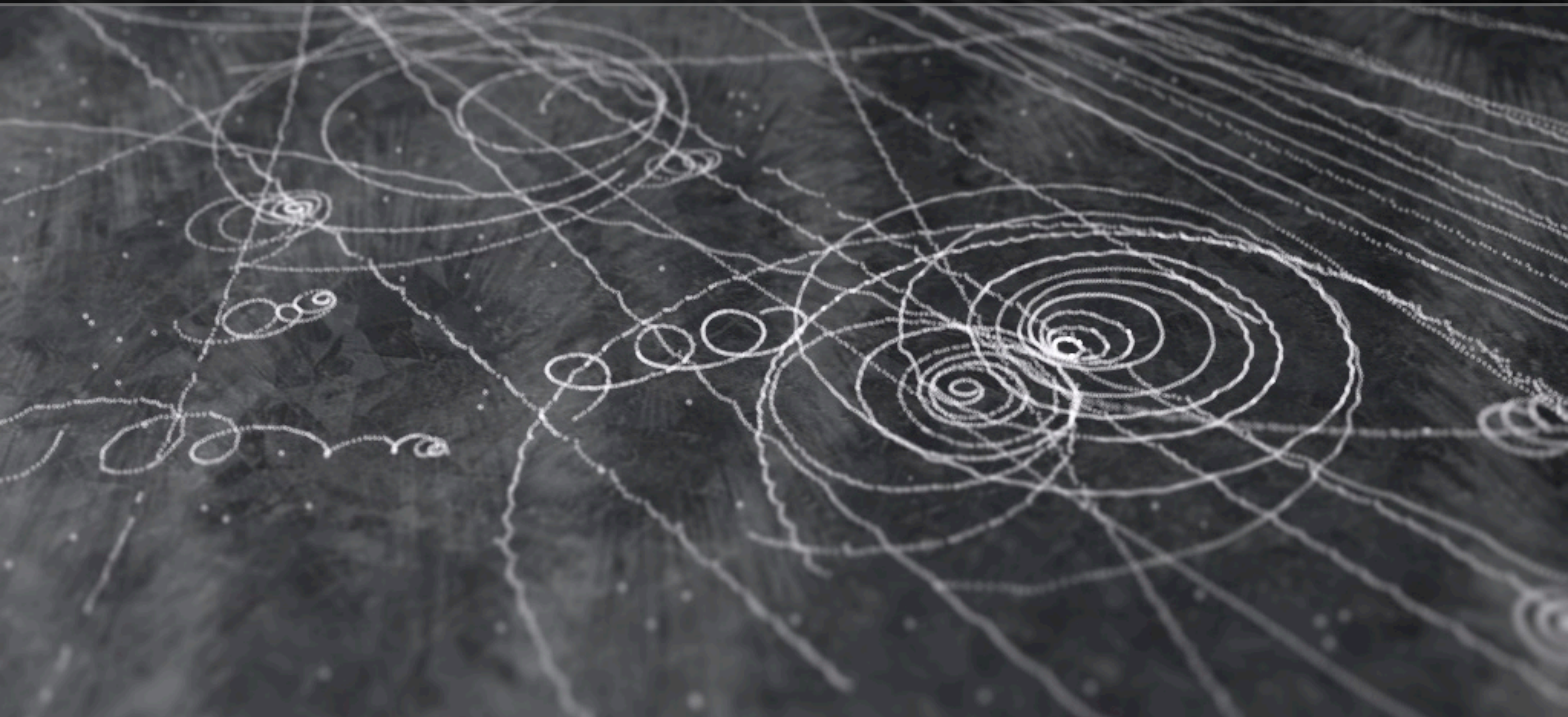
Lessons from the early LHC data for MC tuning

P. Skands (CERN)



Multiple Partonic Interactions at LHC, November 2011, Hamburg

A Factorized View

1. Where is the energy going?

Note: only <u>linearized</u> 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

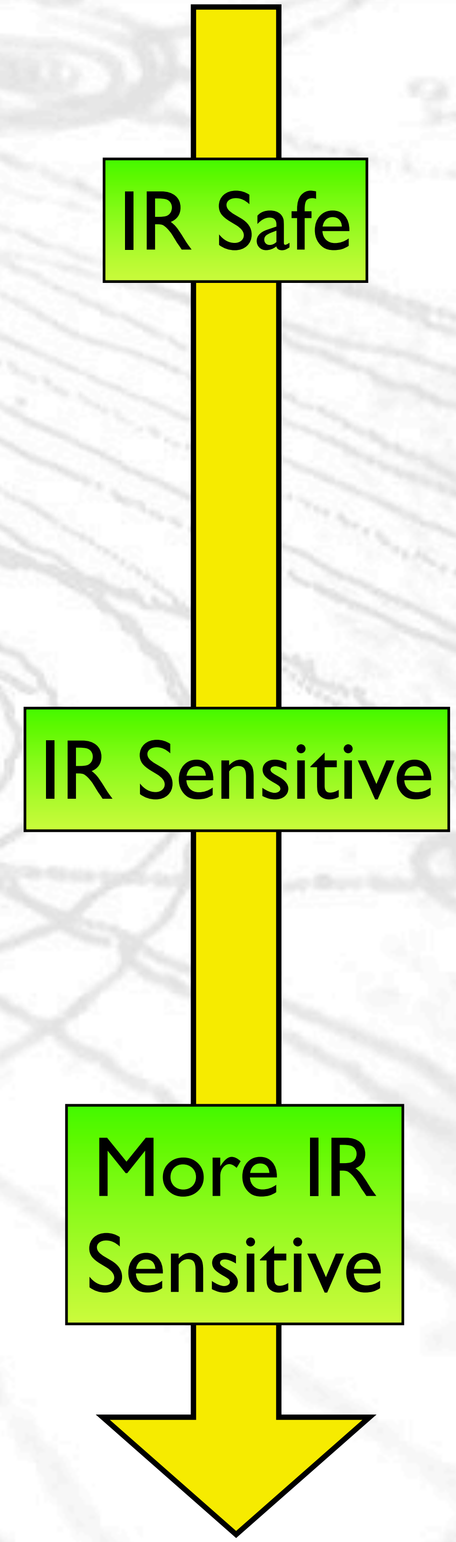
3. Are there gaps in it?

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

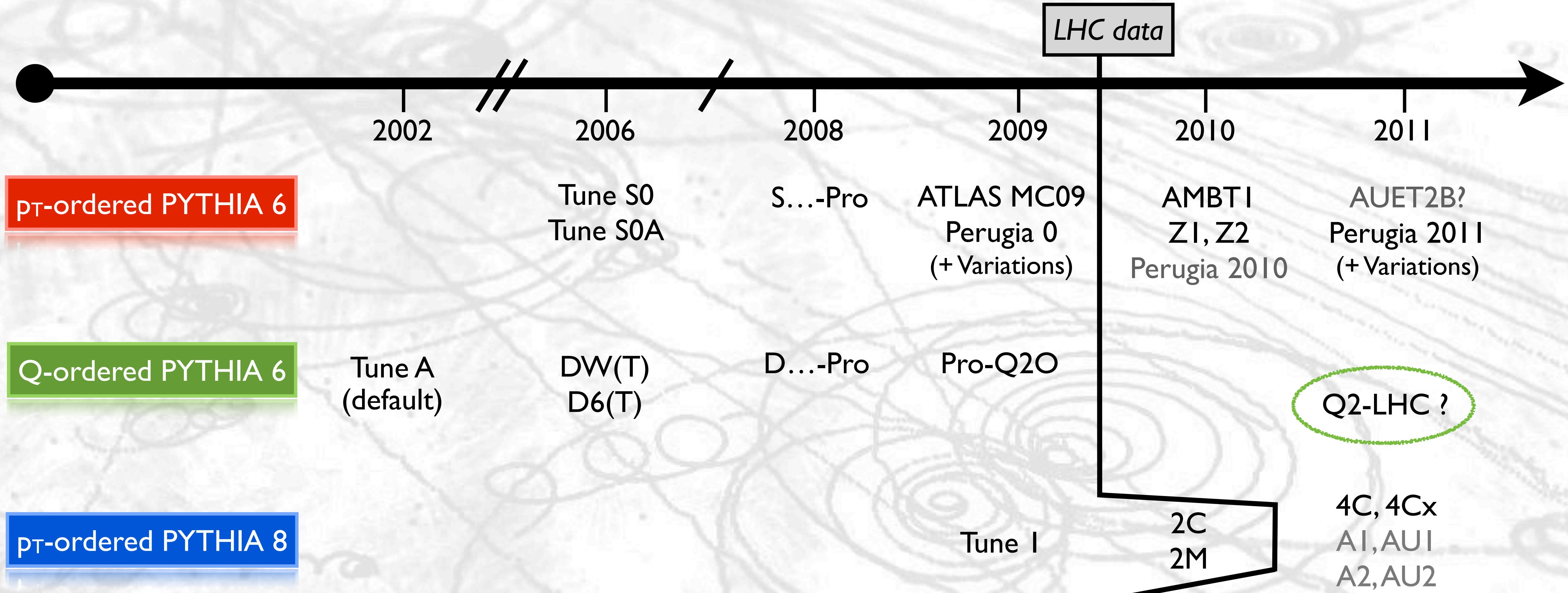
LHC data (between 2009 and 2010)

	2002	2006	2008	2009	2010	2011
p_T-ordered PYTHIA 6		Tune S0 Tune S0A	S…-Pro	ATLAS MC09 Perugia 0 (+Variations)	AMBT1 Z1, Z2 Perugia 2010	AUET2B? Perugia 2011 (+Variations)
Q-ordered PYTHIA 6	Tune A (default)	DW(T) D6(T)	D…-Pro	Pro-Q2O		Q2-LHC ?
p_T-ordered PYTHIA 8				Tune 1	2C 2M	4C, 4Cx A1, AU1 A2, AU2

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

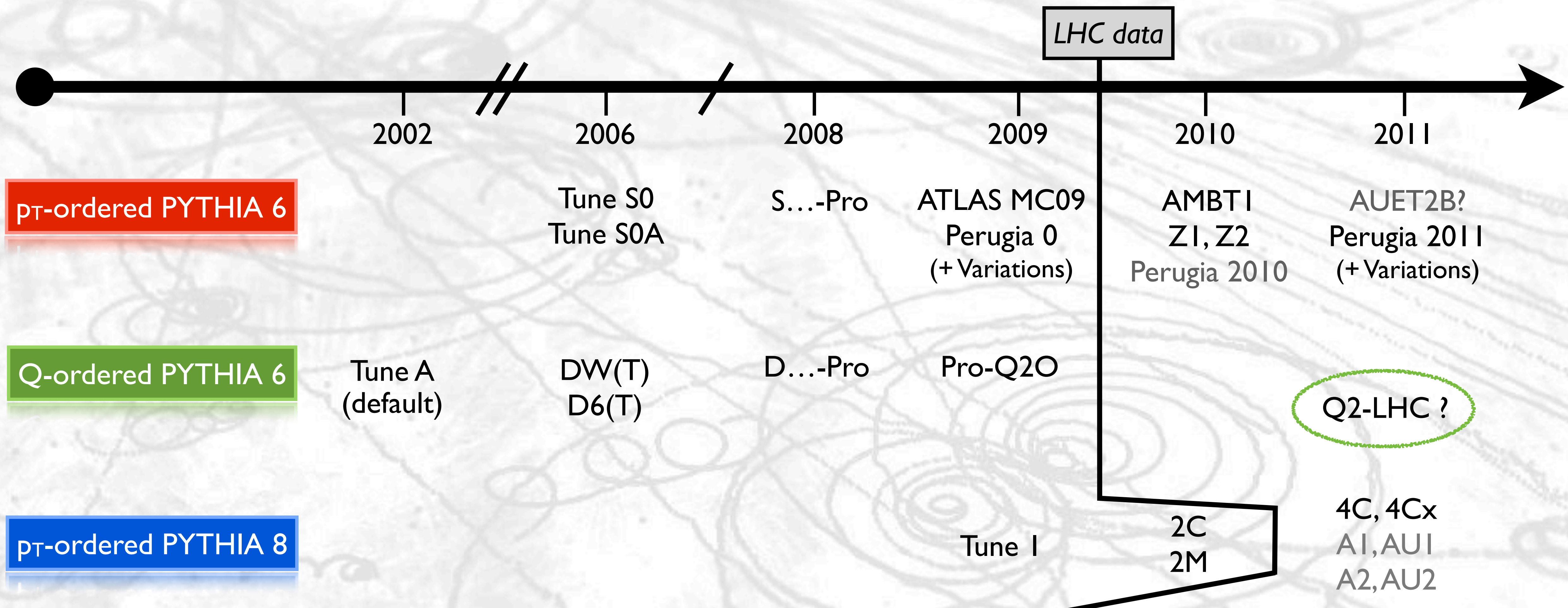
PYTHIA Models



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



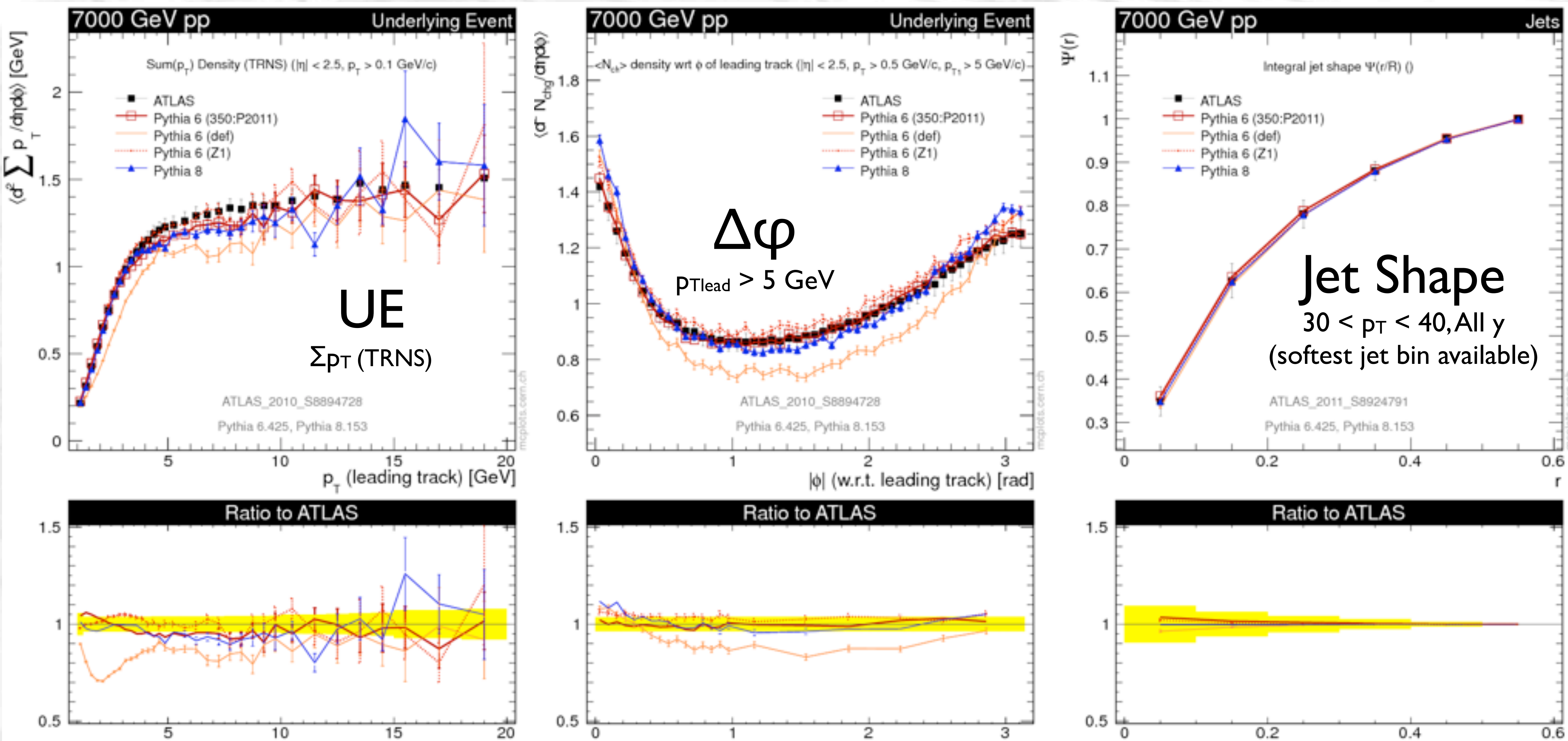
Main Data Sets included in each Tune (no guarantee that all subsets ok)

	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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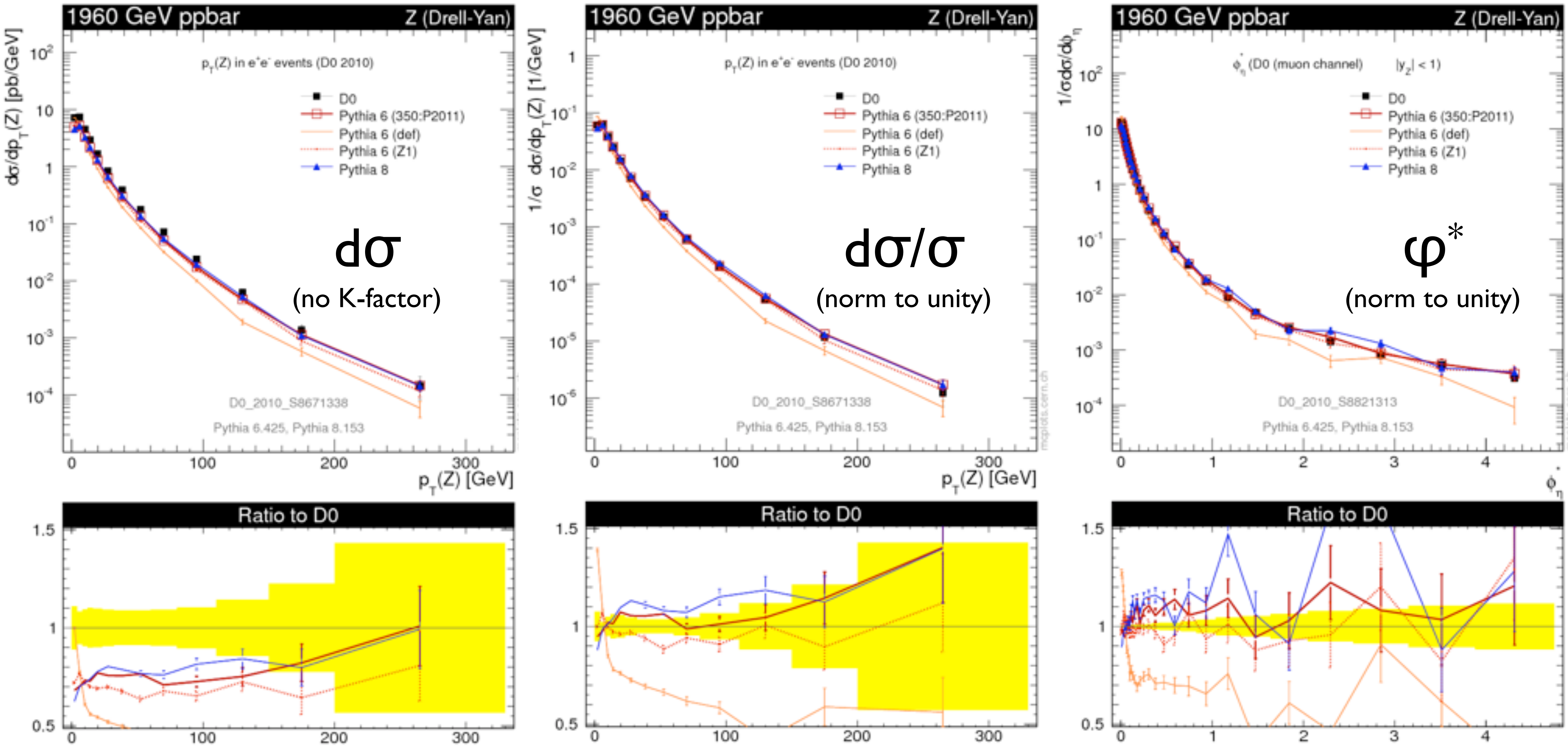
Drell-Yan p_T (Normalized to Unity)

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



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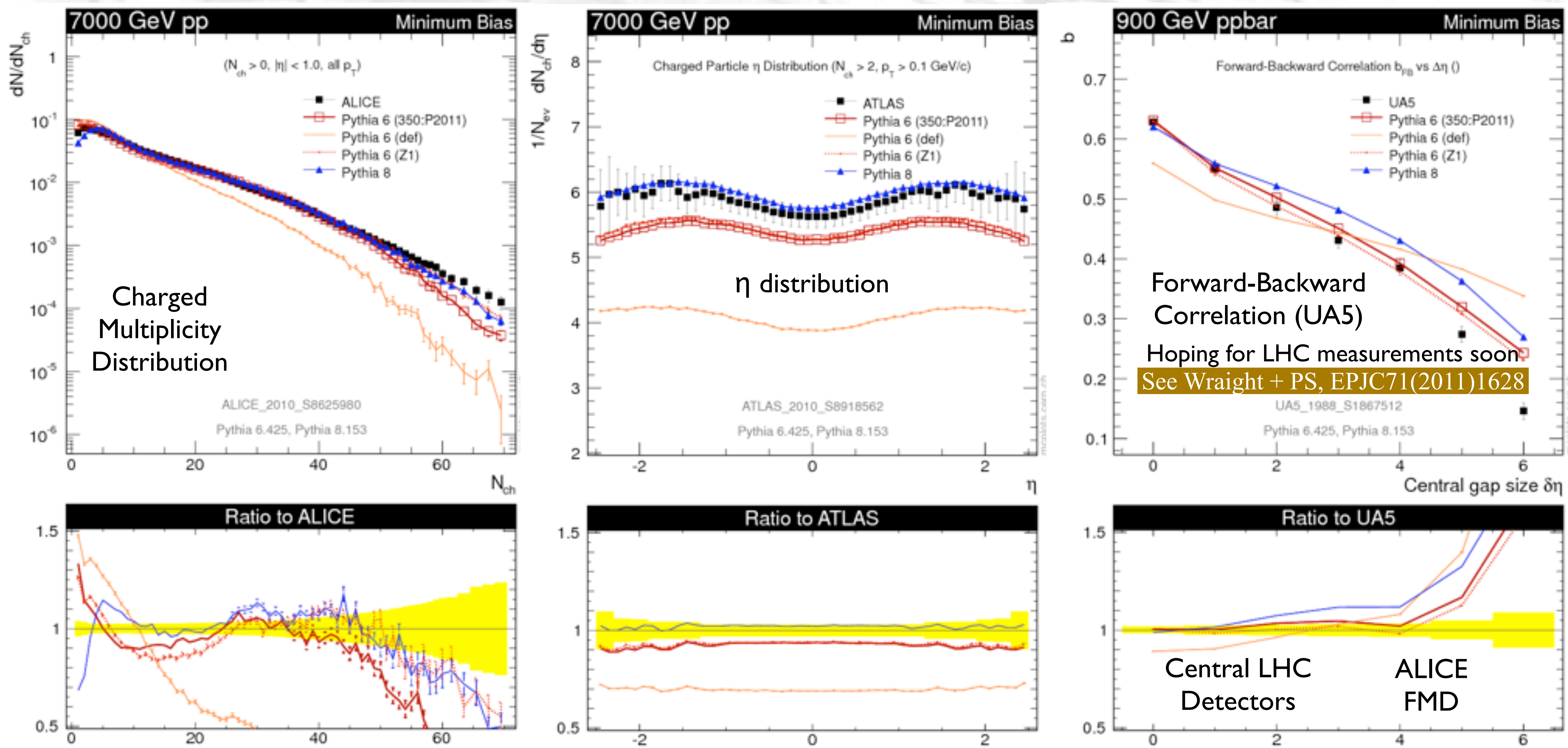
What Kind of Works*

*) 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)



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

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):

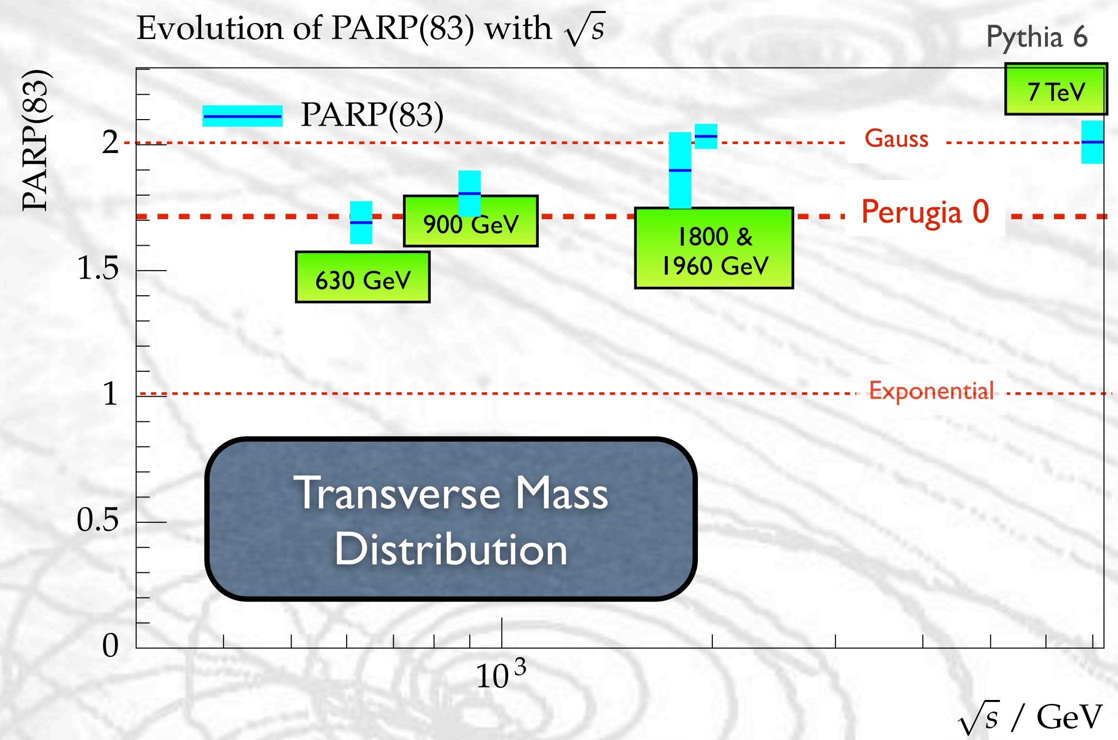
Need "comparable" observable sets for each region

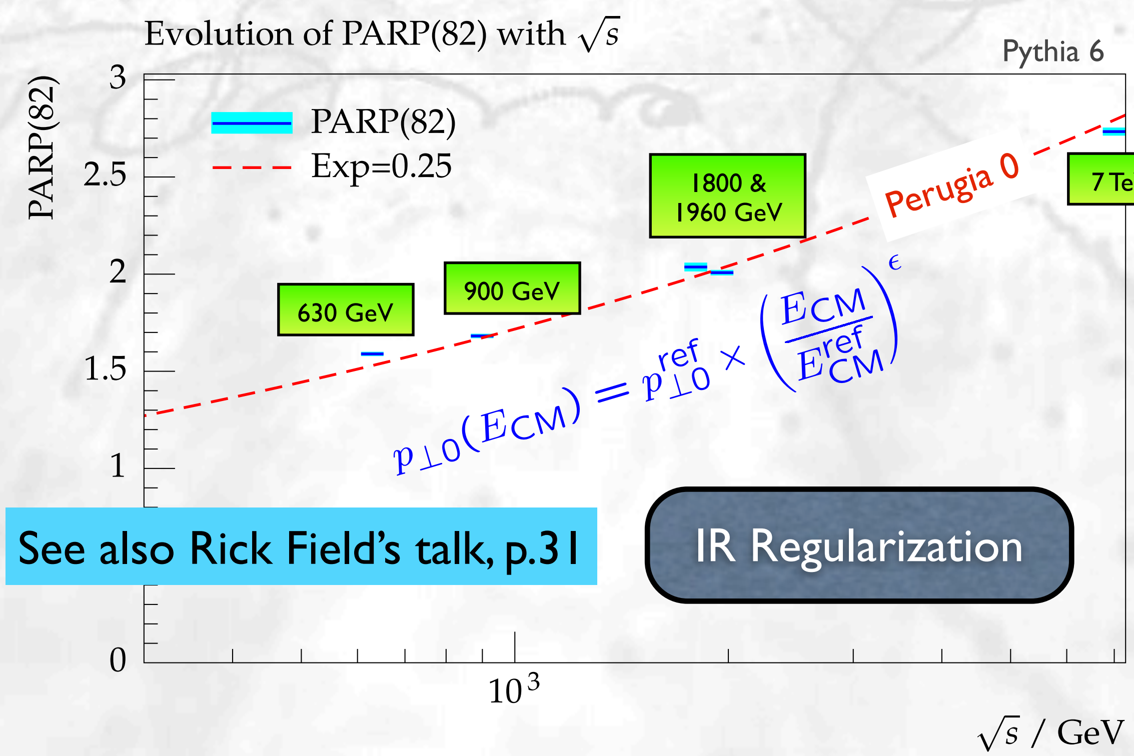
Example: test ENERGY SCALING of MB: use different collider energies as "regions"
(Other complementary data sets could be used to test other model aspects)

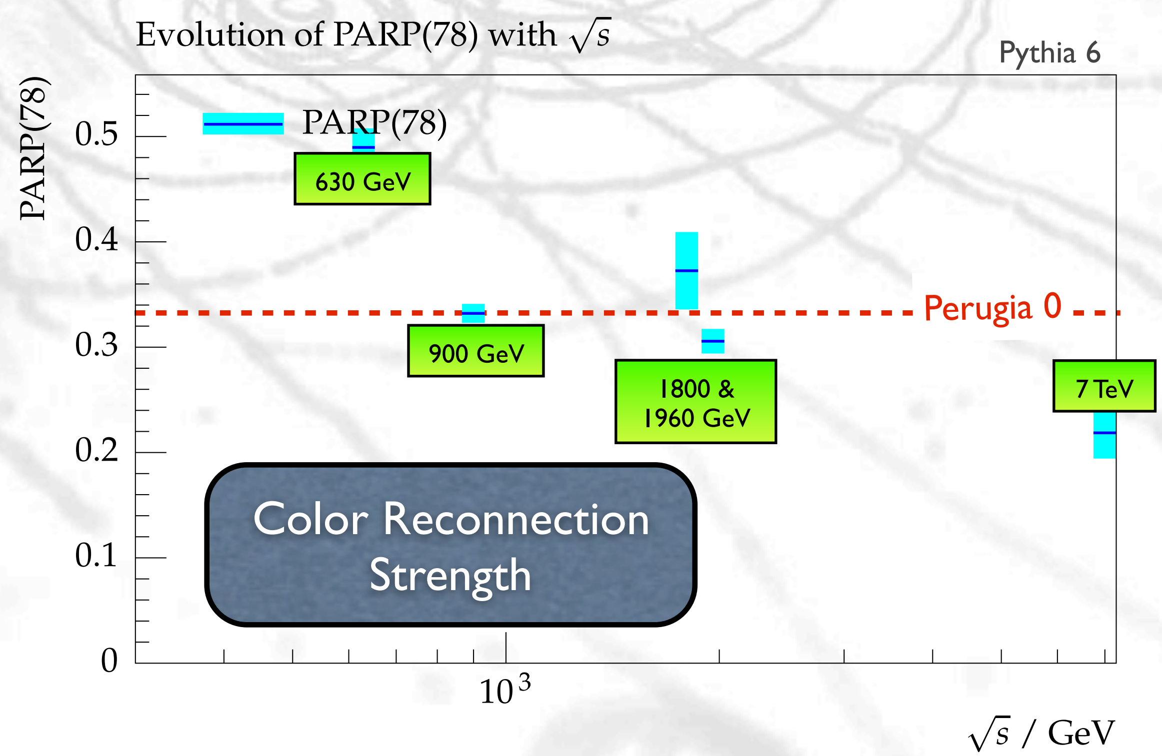
Tuning vs Testing Models

TEST models

- Tune parameters in several complementary regions
- Consistent model → same parameters
- Model breakdown → non-universal parameters







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

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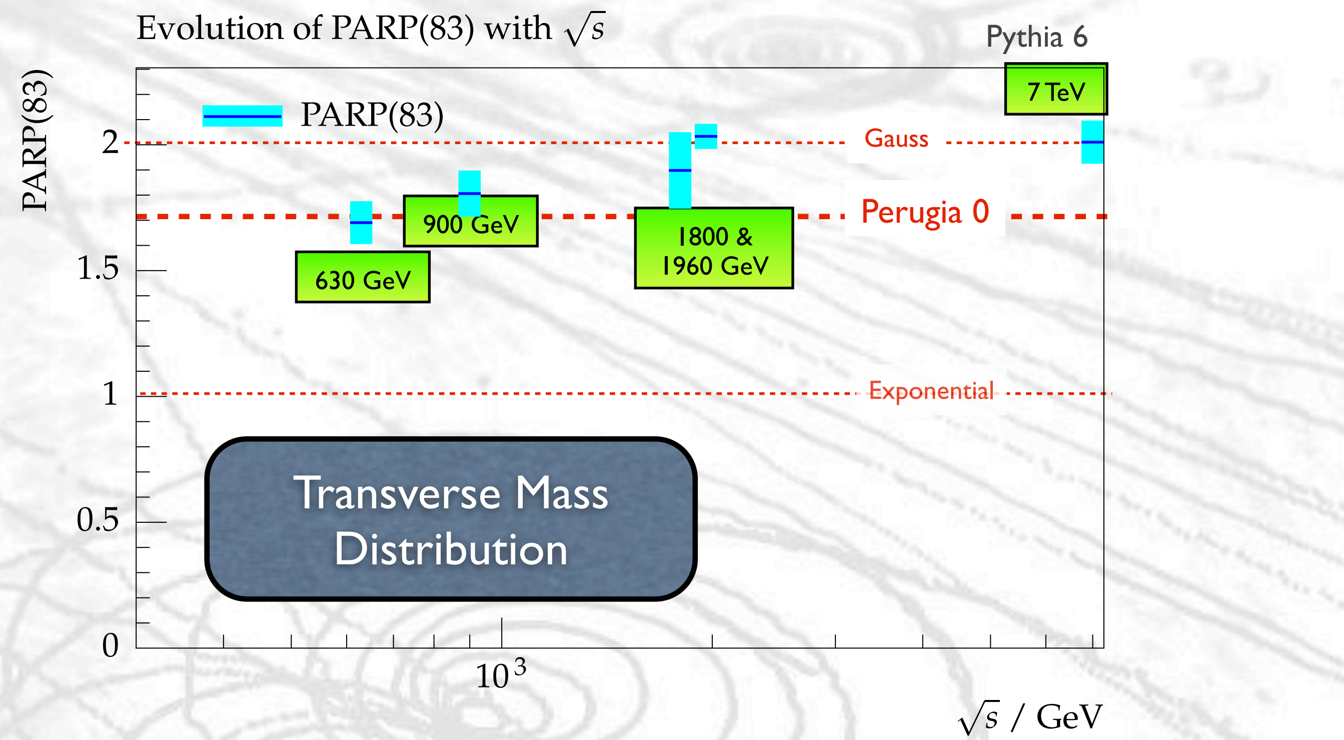
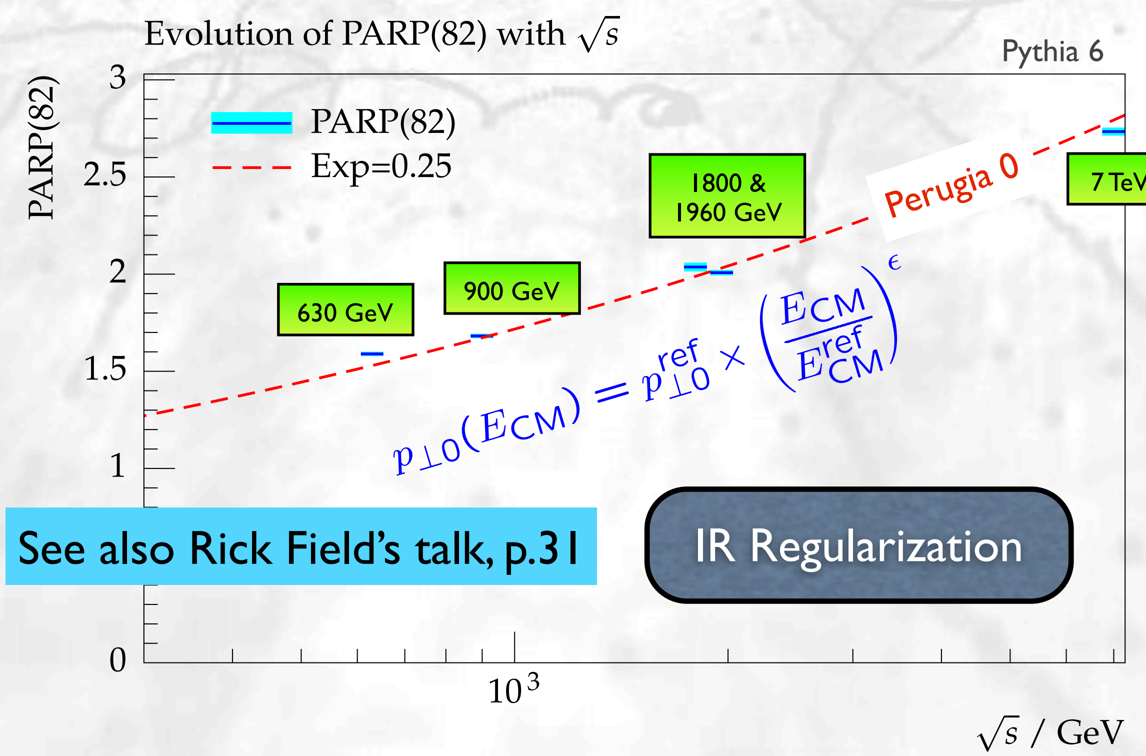
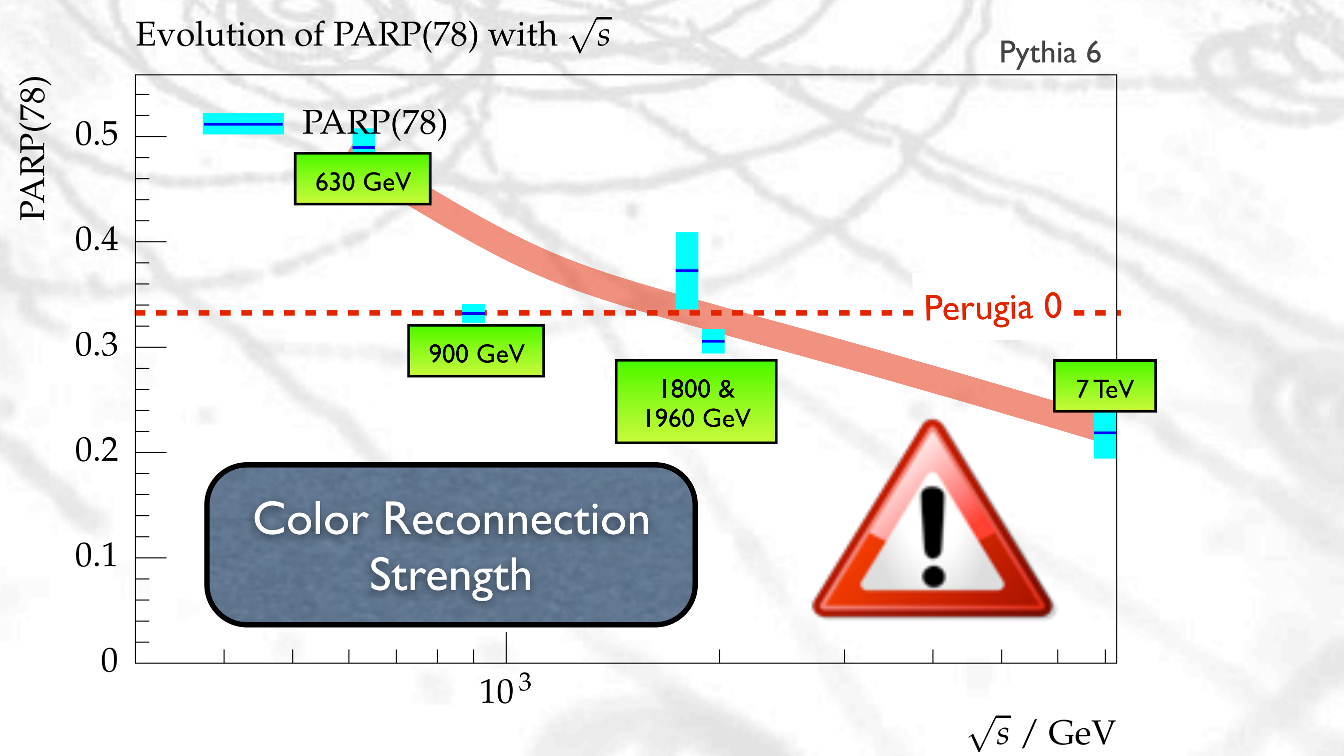




See also Rick Field's talk, p.31



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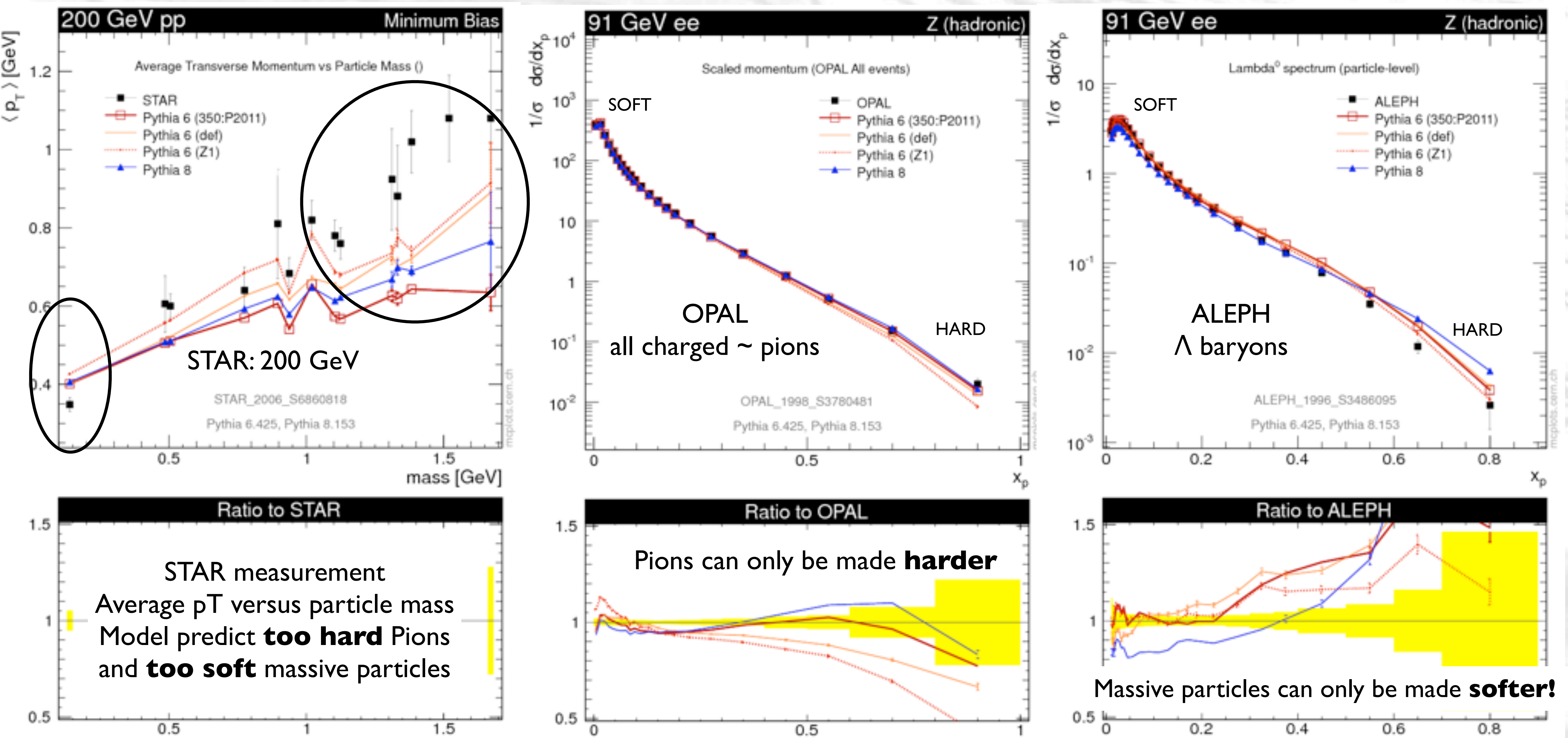
pT Spectra / Mass Dependence

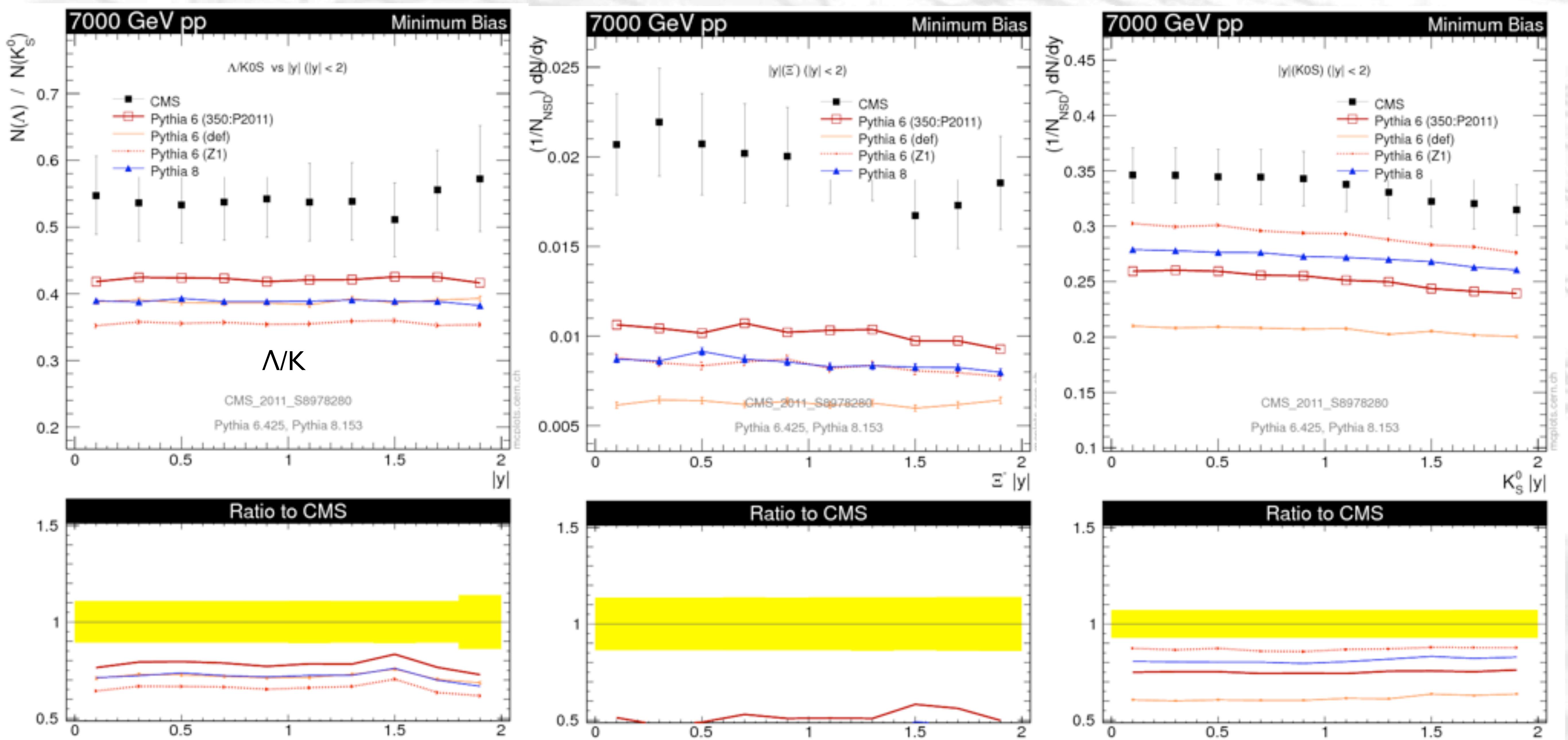
Must be compared with LEP



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

Strangeness and Baryons

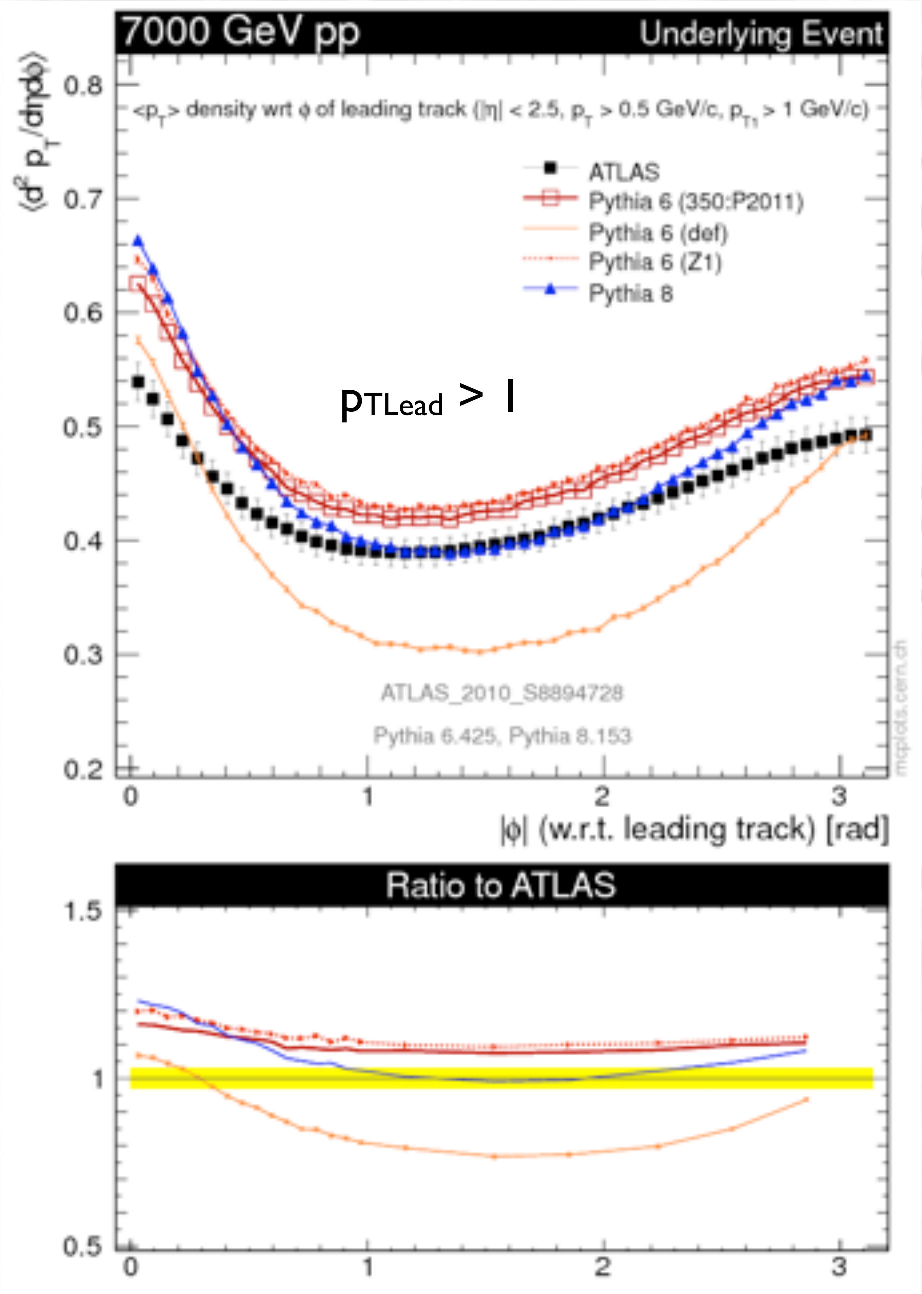
Tried to learn from early data, but still not there …



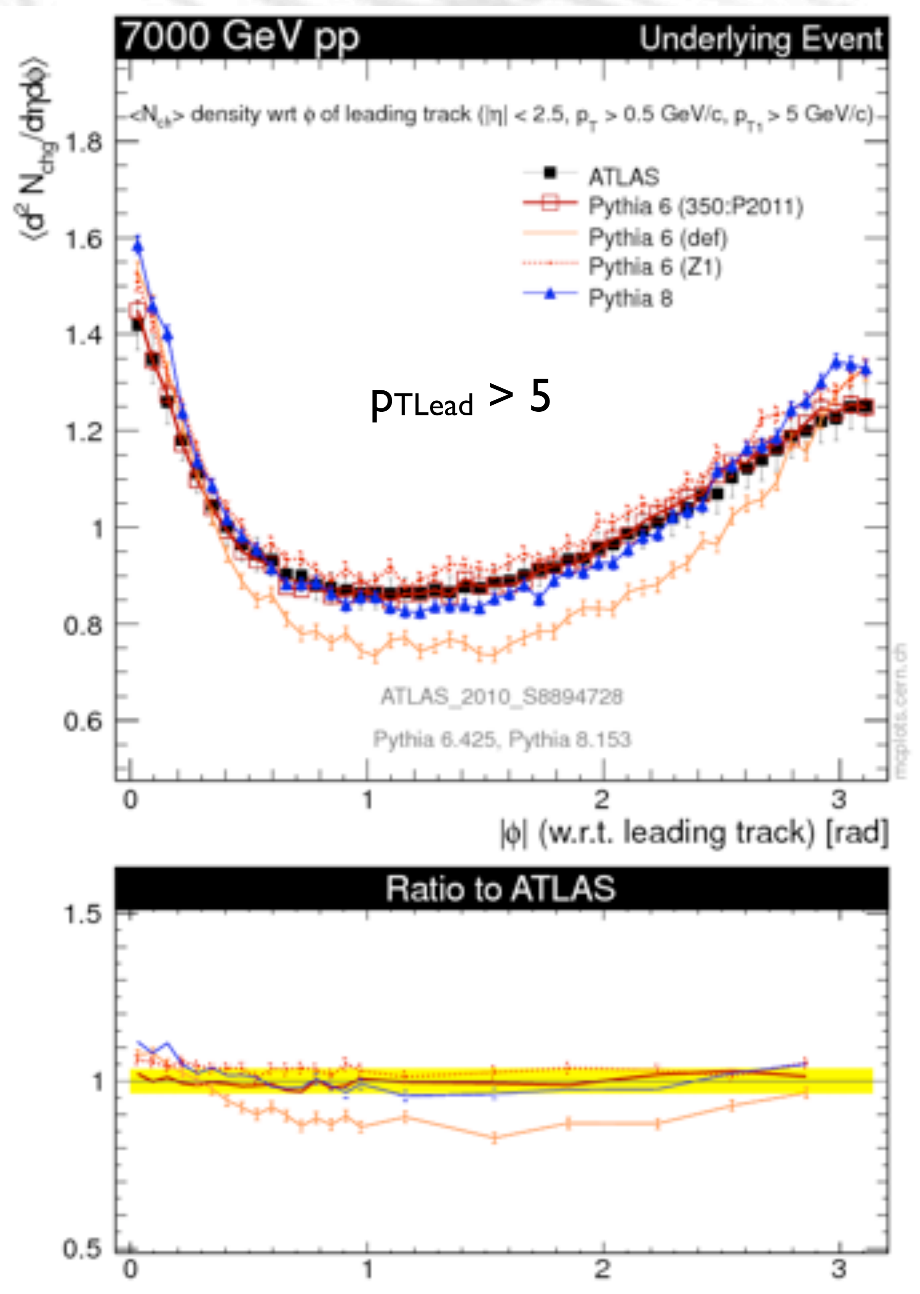
Again, quite difficult to adjust flavor parameters while remaining within LEP bounds …

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

More tuning? or "new" physics?

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

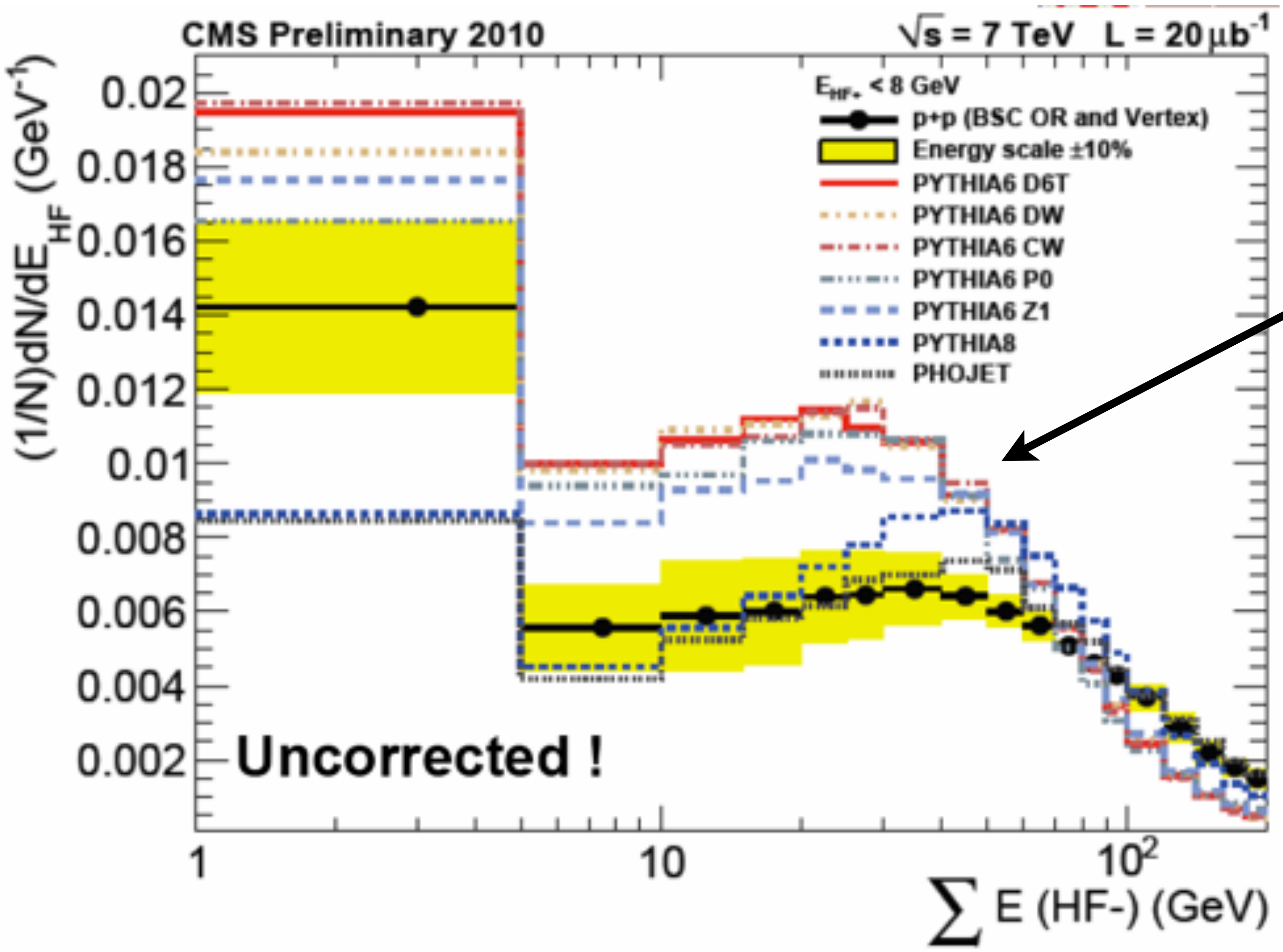
Diffraction

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?