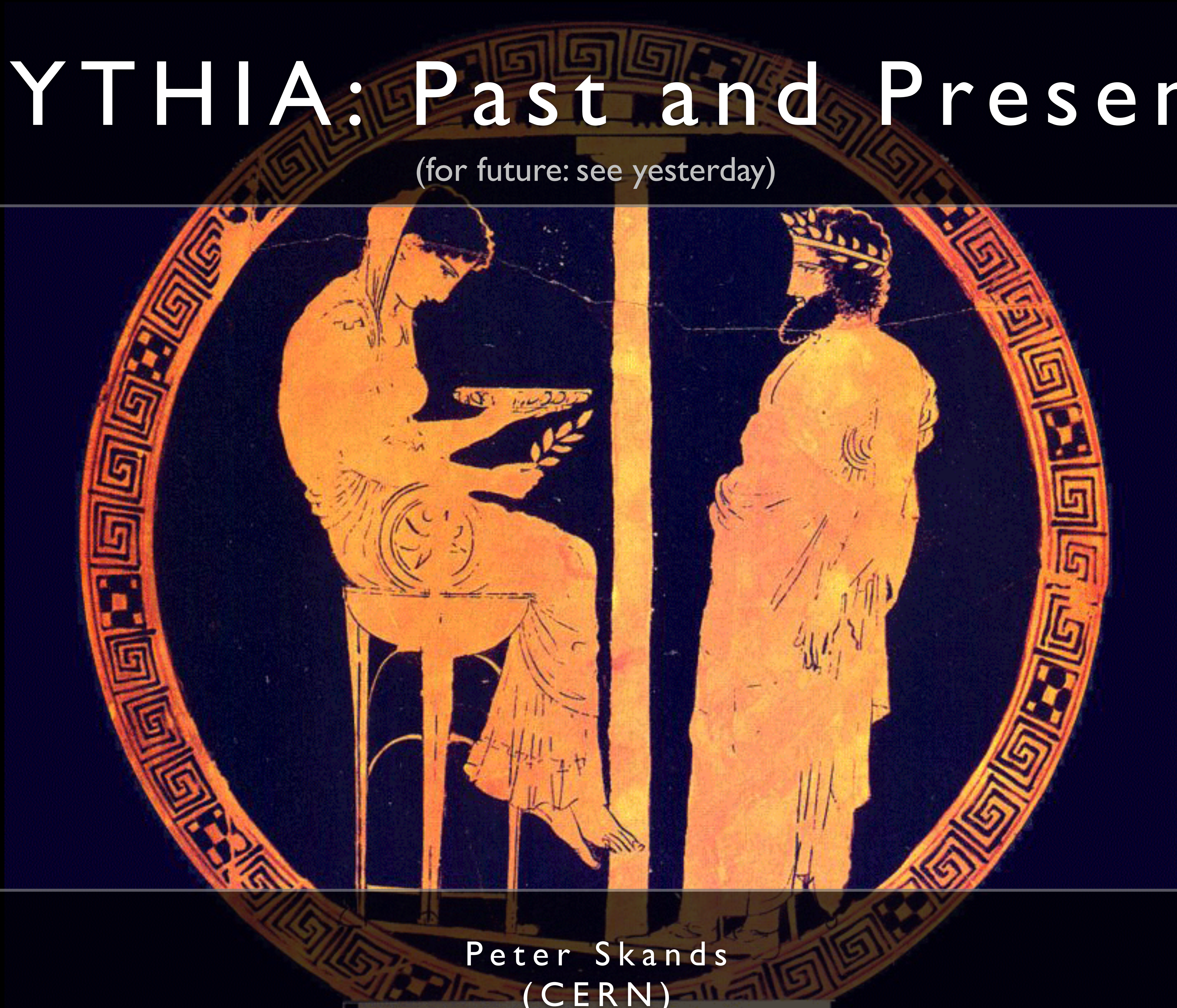
Stockholm, Apr 25 2012

PYTHIA: Past and Present

(for future: see yesterday)



Peter Skands
(CERN)

PYTHIA 8

Ambition

Cleaner code

More user-friendly

Easy **interfacing**

Physics Improvements

Current Status

Ready and tuned for Min-Bias & UE (+ *diffraction improved over Pythia 6)*

Improved shower model + interfaces to POWHEG and CKKW-L

Better interfaces to (B)SM generators via LHEF and semi-internal processes

Team Members

- Stefan Ask
- Richard Corke
- Stephen Mrenna
- Stefan Prestel
- Torbjorn Sjostrand
- Peter Skands

Contributors

- Bertrand Bellenot
- Lisa Carloni
- Tomas Kasemets
- Mikhail Kirsanov
- Ben Lloyd
- Marc Montull
- Sparsh Navin
- MSTW, CTEQ, H1: PDFs
- DELPHI, LHCb: D/B BRs
- + several bug reports & fixes

Key differences between PYTHIA 8 and PYTHIA 6

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New features, not found in 6.4

- Up-to-date decay data and PDFs
- Underlying Event
  - *Interleaved MI + ISR + FSR*
  - *Richer mix of underlying-event processes (γ, J/ψ, DY, . . .)*
  - *Possibility for two selected hard interactions in same event*
  - *Alow parton rescattering*
  - *Possibility to use one PDF set for hard process and another for rest*
- Hard scattering in diffractive systems
- New SM and BSM processes

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- Independent fragmentation
- Mass-ordered showers

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- ep, γp and $\gamma\gamma$ beams
- Some matrix elements, in particular Technicolor, partly SUSY

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SUSY with NMFV and/or CPV *(not fully validated)*
Large Extra Dimensions, Unparticles
Hidden Valley scenario with hidden radiation

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Physics (1/3)

Perturbative Resonance Decays

- Angular correlations often included (on a process-by-process basis - no generic formalism)
- User implementations *(semi-internal resonance)*

Physics (1/3)

Hard Physics

Standard Model

almost all $2\to 1$

almost all $2\to 2$

A few $2\to 3$

BSM: a bit of everything *(see documentation)*

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almost all 2→ 2

A few 2→3

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External Input

Les Houches Accord and LHEF *(e.g., from MadGraph, CompHEP, AlpGen,…)*

User implementations *(semi-internal process)*

Inheriting from PYTHIA's 2→2 base class, then modify to suit you

(+ automated in MadGraph 5)

Perturbative Resonance Decays

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- User implementations *(semi-internal resonance)*

Physics (2/3)

[T. Kasemets, arXiv:1002.4376]

Physics (2/3)

Parton Distributions

- Internal *(faster than LHAPDF)*
  - *The standard CTEQ and MSTW LO sets, plus a few NLO ones*
  - *New generation: MSTW LO*, LO**, CTEQ CT09MC*
- Interface to LHAPDF **[T. Kasemets, arXiv:1002.4376]**
- Can use separate PDFs for hard scattering and UE *(to 'stay tuned')*

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- Includes QCD and QED
- Dipole-style recoils *(partly new)*
- Improved high-$p_\perp$ behavior **[R. Corke]**

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Matrix-Element Matching

- Automatic first-order matching for most gluon-emission processes in resonance decays, e.g.,:
  - $Z \to qq \to qqg$,
  - $t \to bW \to bWg$,
  - $H \to bb \to bbg$,
  - …
- Automatic first-order matching for internal $2 \to 1$ color-singlet processes, e.g.:
  - $pp \to Z/W/Z'/W'$+jet
  - $pp \to H$+jet
  - *More to come …*
- Interface to AlpGen, MadGraph, … via Les Houches Accords

Interfaces to External MEs (MLM)

B. Cooper et al., arXiv:1109.5295 [hep-ph]

If using one code for MEs and another for showering

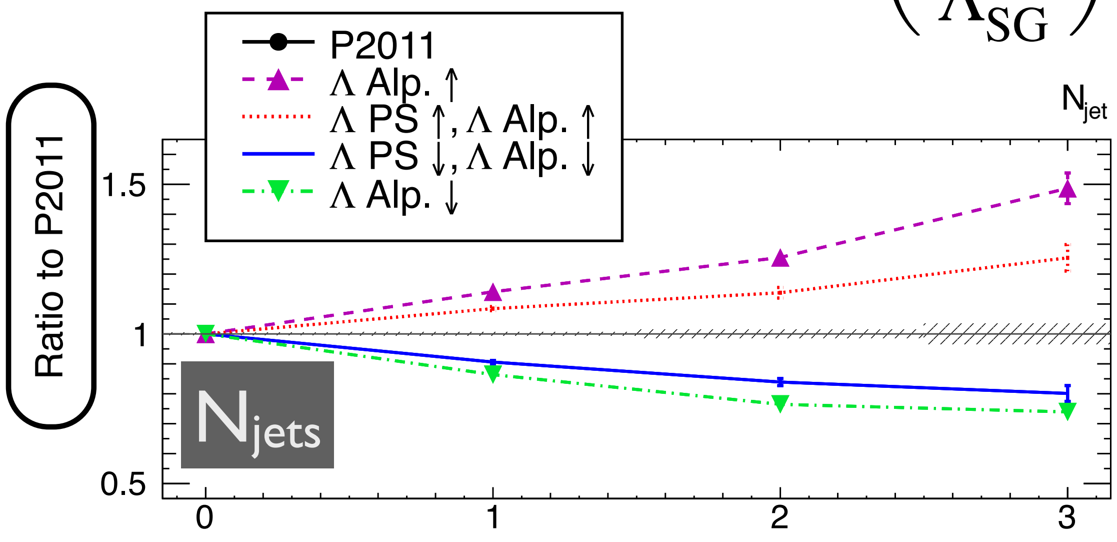
Tree-level corrections use α_s from Matrix-element Generator

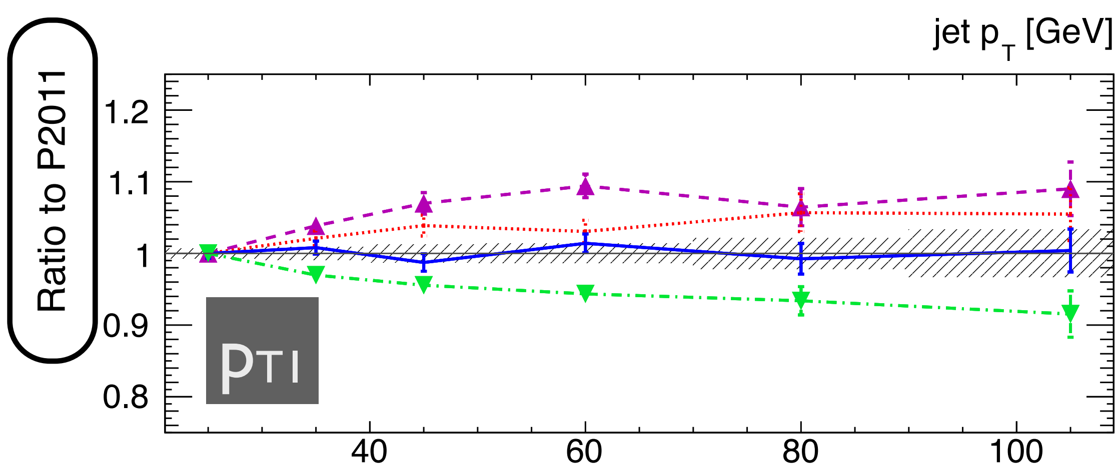
Virtual corrections use α_s from Shower Generator (Sudakov)

Mismatch if the two do not use same Λ_{QCD} or $\alpha_s(m_Z)$

$$\alpha_s^2\, b_0 \ln\left(\frac{\Lambda_{\rm MG}^2}{\Lambda_{\rm SG}^2}\right) \frac{dQ^2}{Q^2} \sum_i P_i(z)\, |M_F|^2 \,.$$

note: running **order** also has a (subleading) effect





AlpGen: can set xlclu = Λ_{QCD} since v.2.14 (default remains to inherit from PDF)

Pythia 6: set common PARP(61)=PARP(72)=PARP(81) = Λ_{QCD} in Perugia 2011 tunes

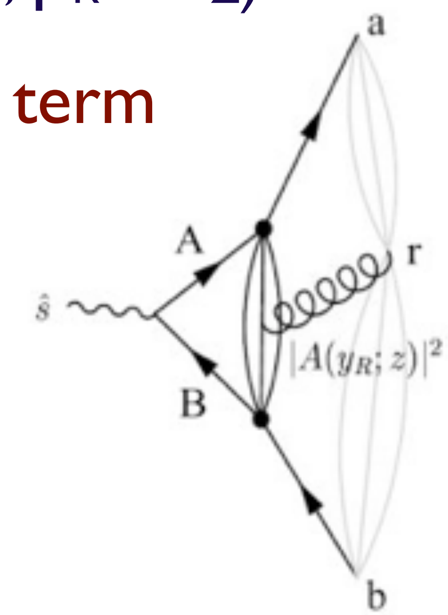
Pythia 8: use TimeShower:alphaSvalue and SpaceShower:alphaSvalue

Scales: pT and CMW

Compute $e^+e^- \to 3$ jets, for arbitrary choice of μ_R (e.g., $\mu_R = m_Z$)

One-loop correction $2\text{Re}[M^0 M^{1*}]$ includes a universal $O(\alpha_s^2)$ term from integrating quark loops over all of phase space

$$n_f \;\; A_3^0 \left(\ln \left(\frac{s_{23}}{\mu_R^2} \right) + \ln \left(\frac{s_{13}}{\mu_R^2} \right) \right) \qquad + \text{ gluon loops}$$



Proportional to the β function (b_0).

Can be absorbed by using $\mu_R^4 = s_{13}\, s_{23} = p_T^2\, s$. (~ "BLM")

In an ordered shower, quark (and gluon) loops restricted by strong-ordering condition → modified to

$\mu_R = p_T$ (but depends on ordering variable?)

Additional logs induced by gluon loops can be absorbed by replacing Λ^{MS} by $\Lambda^{MC} \sim 1.5\ \Lambda^{MS}$ (with mild dependence on number of flavors)

Catani, Marchesini, Webber, NPB349 (1991) 635

There are obviously still order 2 uncertainties on μ_R, but this is the background for the central choice made in showers

Physics (3/3)

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Underlying-Event and Min-Bias

- Multiple parton–parton interactions
  - *Multi-parton PDFs constructed from (flavor and momentum) sum rules*
  - *Combined (interleaved) evolution MI + ISR + FSR downwards in $p_{\perp}$ (partly new)*
  - *Optional rescattering* ***[R. Corke]***
- Beam remnants colour-connected to interacting systems
  - *String junctions → variable amount of baryon transport*
- Defaults tuned to LHC (tune 4C)
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Hadronization

- String fragmentation
  - *Lund symmetric fragmentation function for (u,d,s) + Bowler modification for heavy quarks (c,b)*
- Hadron and Particle decays
  - *Usually isotropic, or:*
  - *User decays (DecayHandler)*
  - *Link to external packages*
    - EVTGEN for B decays
    - TAUOLA for τ decays
- Bose-Einstein effects
  - *Two-particle model (off by default)*

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Output

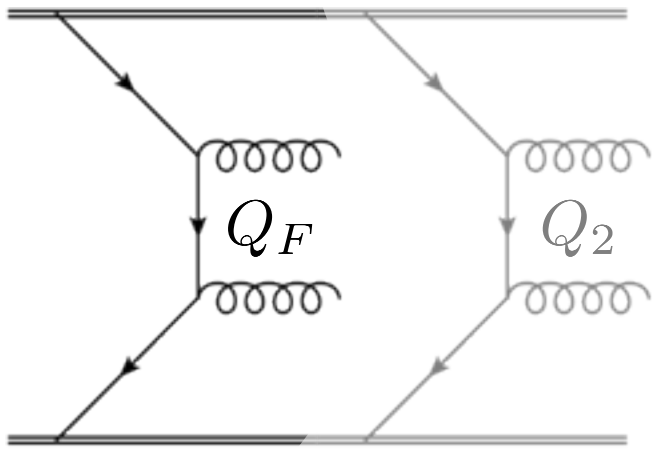
- Interface to HEPMC included

Multiple Interactions and Hadronization

Factorization: Subdivide Calculation

Multiple Parton Interactions go beyond existing theorems → perturbative short-distance physics in Underlying Event

→ Generalize factorization to MPI



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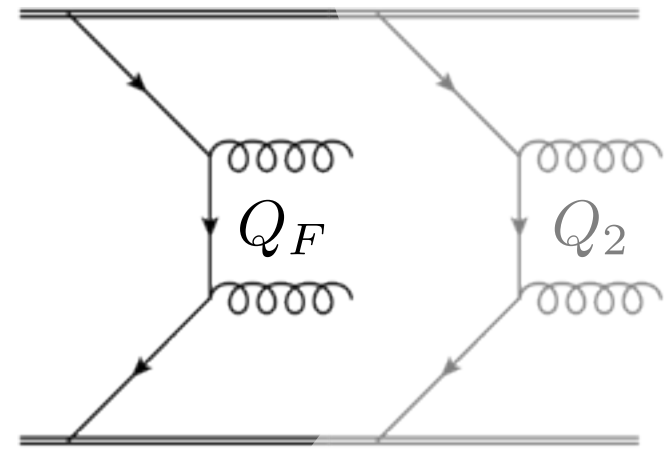


Infrared* Safety Corrections $\propto \frac{Q_{\mathrm{IR}}^2}{Q_{\mathrm{UV}}^2}$

*Soft and Collinear

… in minimum-bias, we typically do not have a hard scale ($Q_{UV} \sim Q_{IR}$), wherefore *all* observables depend significantly on IR physics …

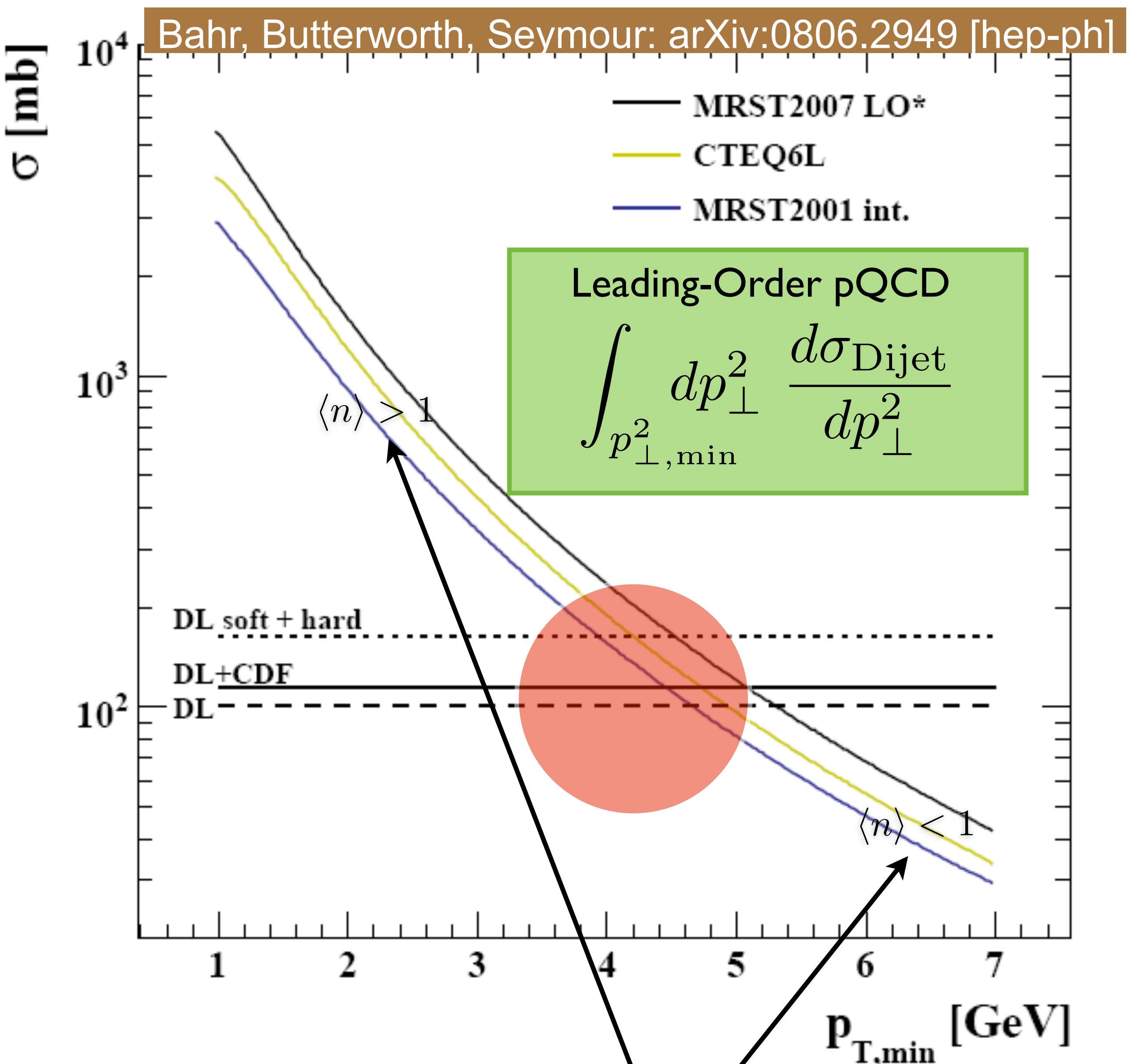
Combining IR safe + IR sensitive observables → stereo vision:

IR safe → overall energy flow/correlations

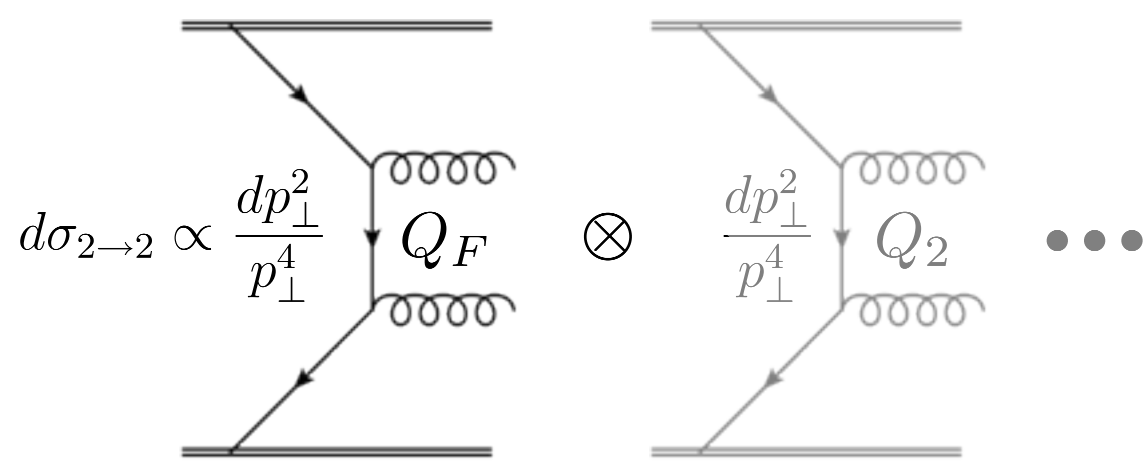
IR sensitive → spectra and correlations of individual particles/tracks.

Multiple Interactions

= Allow several parton-parton interactions per hadron-hadron collision. Requires extended factorization ansatz.



Earliest MC model ("old" PYTHIA 6 model)
Sjöstrand, van Zijl PRD36 (1987) 2019



Lesson from bremsstrahlung in pQCD: divergences → fixed-order breaks down
Perturbation theory still ok, with resummation (unitarity)

→ Resum dijets?
Yes → MPI!

$$\sigma_{2\to2}(p_{\perp\min}) = \langle n\rangle(p_{\perp\min})\ \sigma_{\rm tot}$$

Parton-Parton Cross Section — Hadron-Hadron Cross Section

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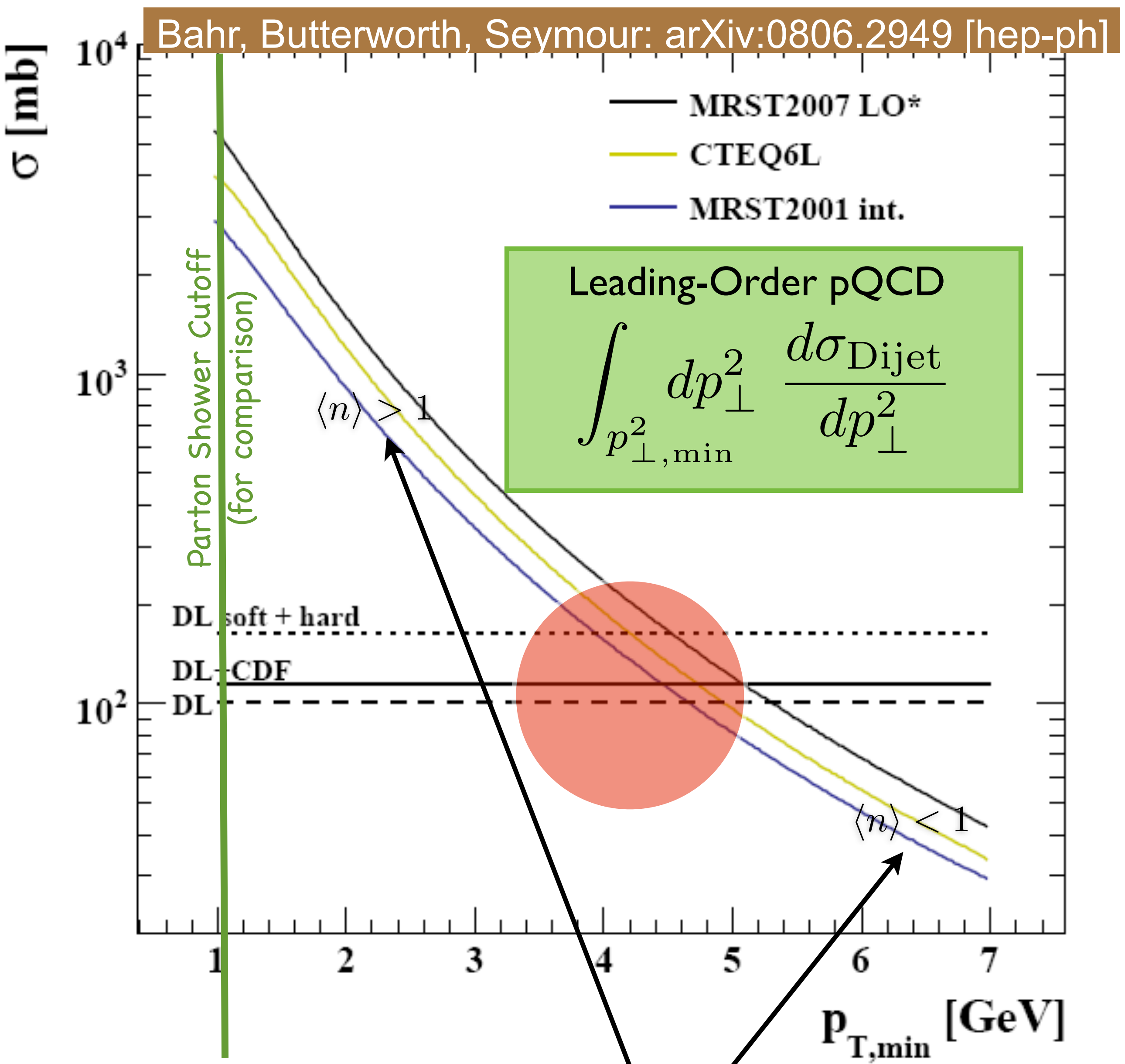

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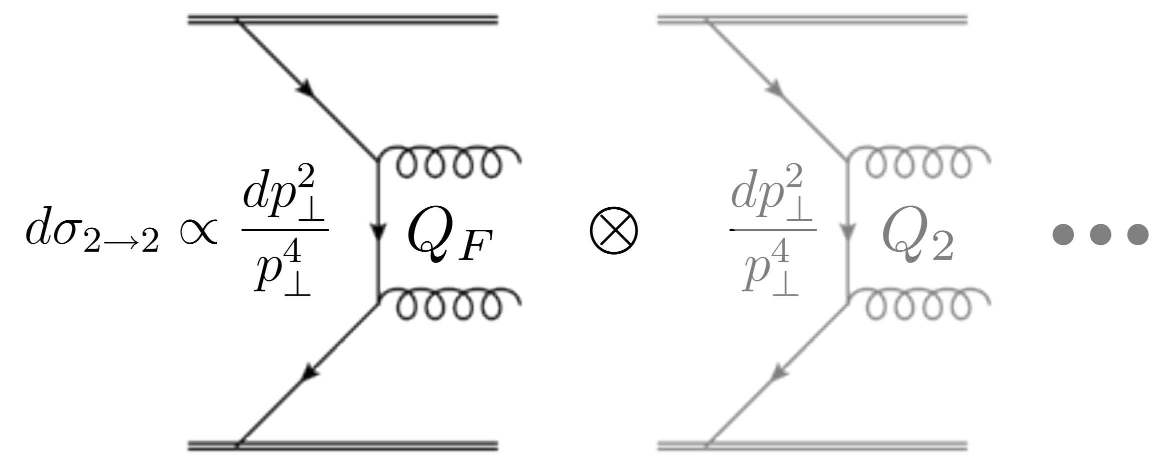

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1: A Simple Model

The minimal model incorporating single-parton factorization, perturbative unitarity, and energy-and-momentum conservation

$$\sigma_{2\to 2}(p_{\perp\min}) = \langle n \rangle (p_{\perp\min})\ \sigma_{\rm tot}$$

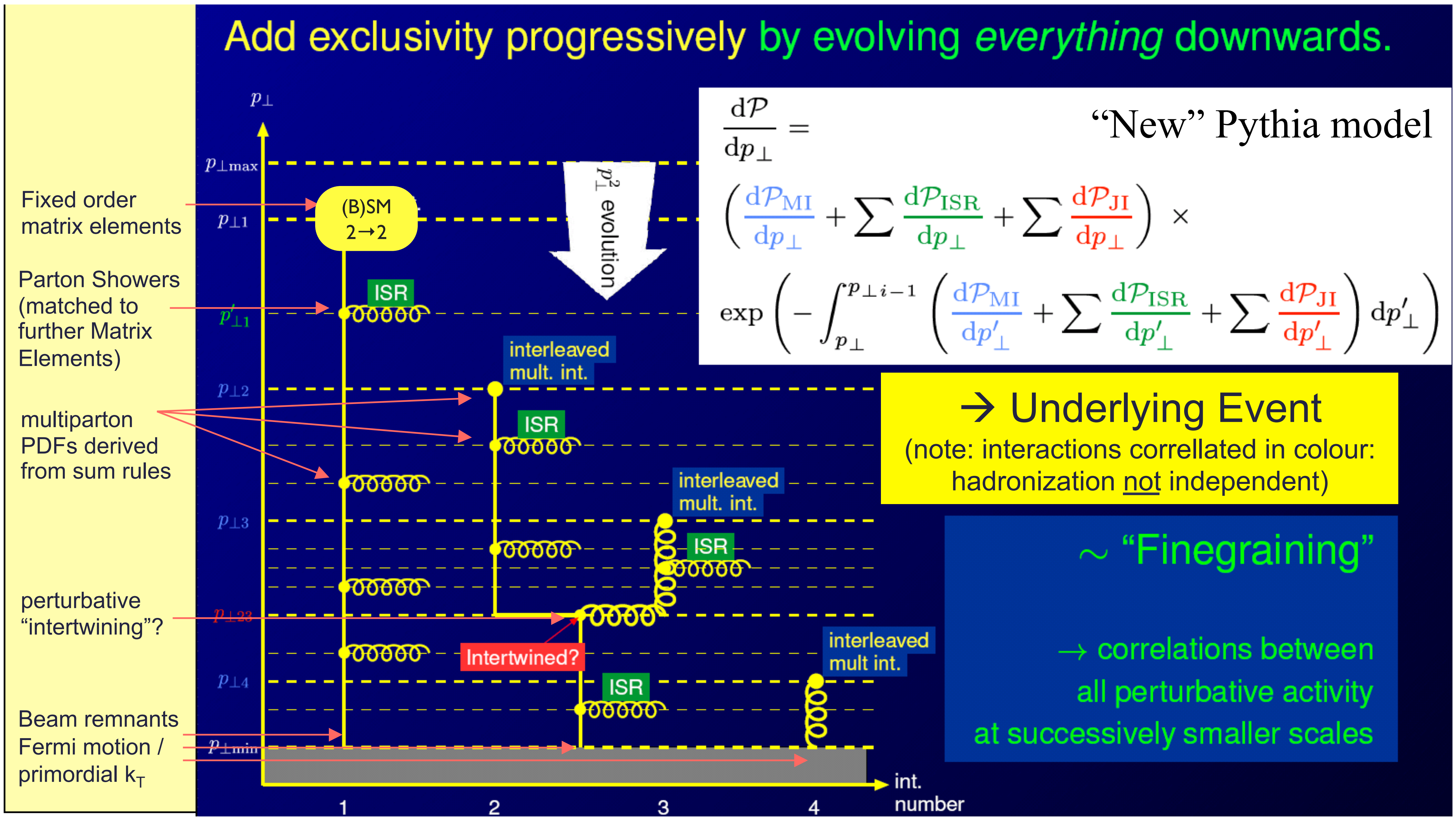
Parton-Parton Cross Section — Hadron-Hadron Cross Section

1. Choose $p_{T\min}$ cutoff
   = main tuning parameter
2. Interpret $<n>(p_{T\min})$ as mean of Poisson distribution
   Equivalent to assuming all parton-parton interactions equivalent and independent ~ each take an instantaneous "snapshot" of the proton
3. Generate n parton-parton interactions (pQCD 2→2)
   Veto if total beam momentum exceeded → overall (E,p) cons
4. Add impact-parameter dependence → $<n> = <n>(b)$
   Assume factorization of transverse and longitudinal d.o.f., → PDFs : $f(x,b) = f(x)g(b)$ ← Ordinary CTEQ, MSTW, NNPDF, …
   b distribution ∝ EM form factor → **JIMMY model** Butterworth, Forshaw, Seymour Z.Phys. C72 (1996) 637
   Constant of proportionality = second main tuning parameter
5. Add separate class of "soft" (zero-p_T) interactions representing interactions with $p_T < p_{T\min}$ and require $\sigma_{\rm soft} + \sigma_{\rm hard} = \sigma_{\rm tot}$
   → **Herwig++ model** Bähr et al, arXiv:0905.4671

2: Interleaved Evolution

Equivalent to 1 at lowest order, but can include correlated evolution + generalizes "perturbative resolution" to higher twist

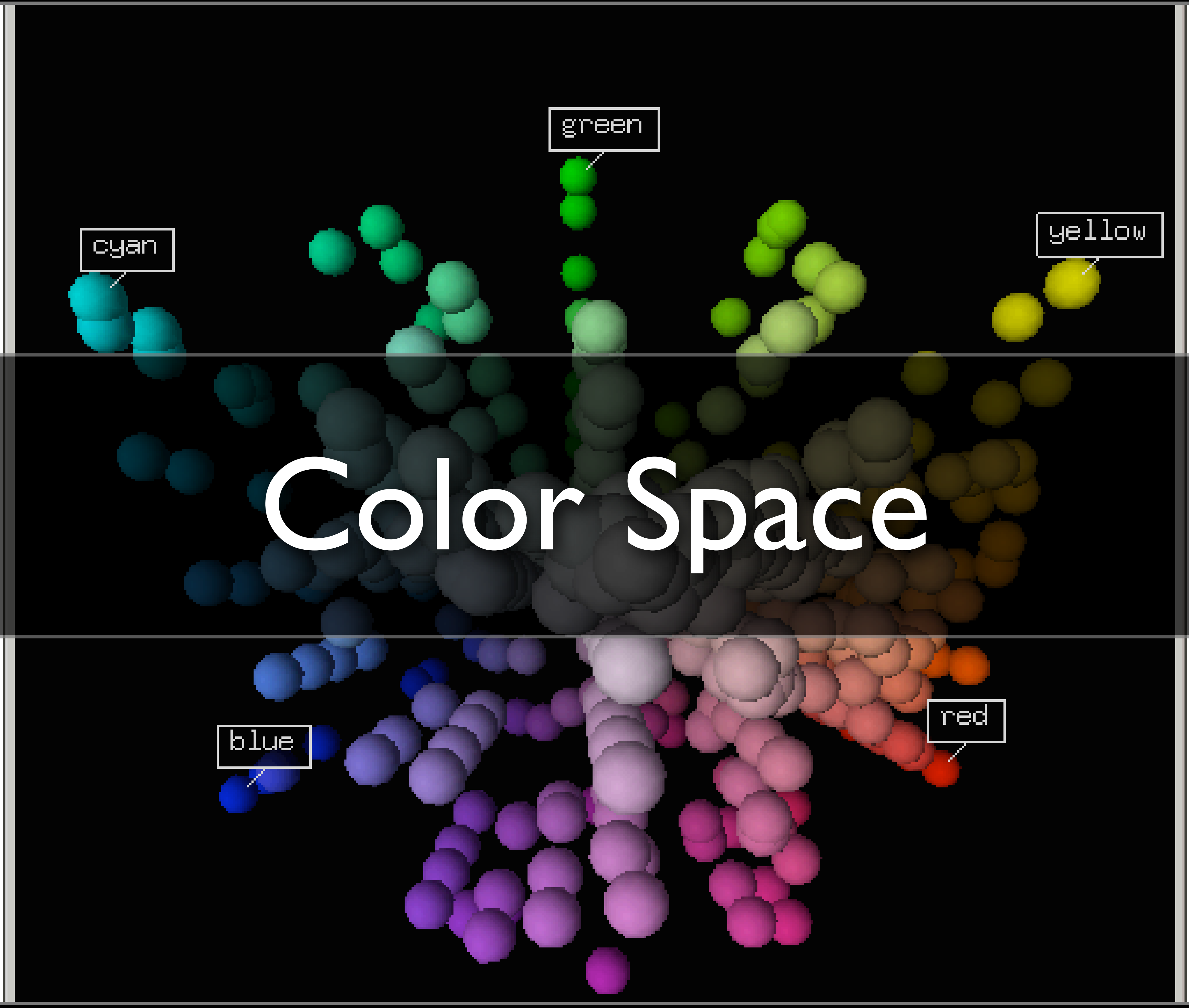
Sjöstrand, P.S., JHEP 0403 (2004) 053; EPJ C39 (2005) 129



+ (x,b) correlations Corke, Sjöstrand JHEP 1105 (2011) 009

+ KMR model (see talk by K. Zapp)

Color Space



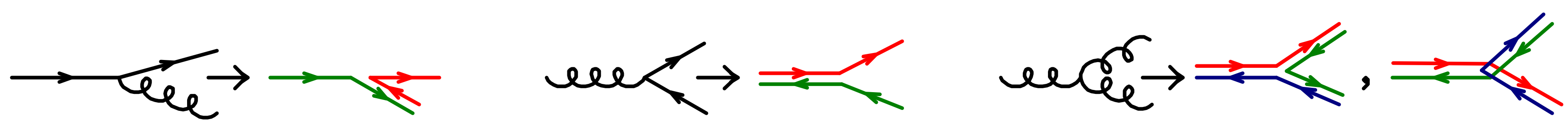
Color Flow in MC Models

"Planar Limit"

*) except as reflected by the implementation of QCD coherence effects in the Monte Carlos via angular or dipole ordering

Equivalent to $N_C \to \infty$: no color interference*

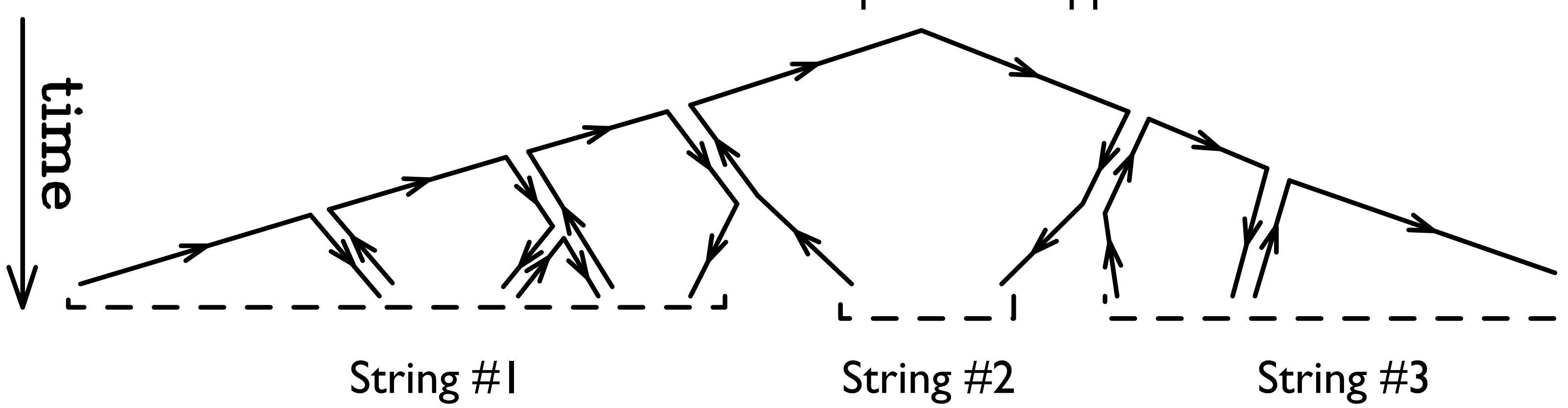
Rules for color flow:



For an entire cascade:

Illustrations from: P.Nason & P.S., PDG Review on *MC Event Generators*, 2012

Example: $Z^0 \to q\bar{q}$



Coherence of pQCD cascades → not much "overlap" between strings

→ planar approx pretty good

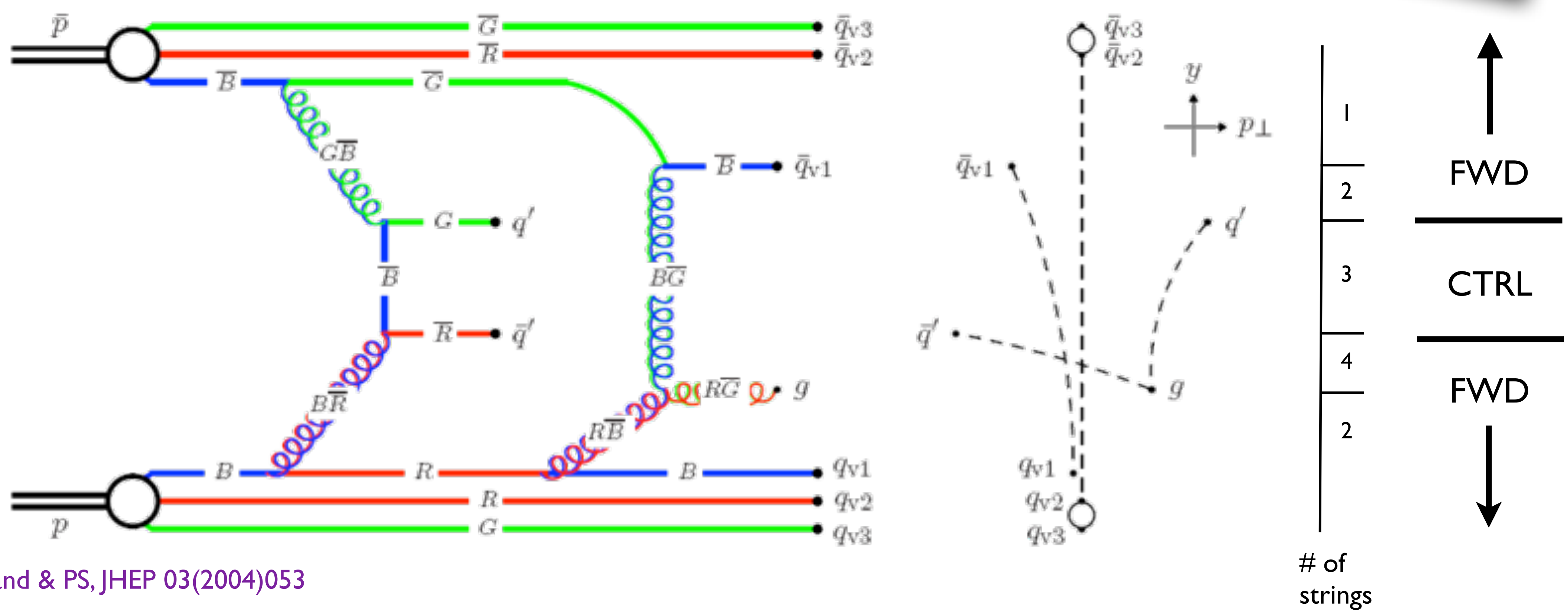
LEP measurements in WW confirm this (at least to order 10% ~ $1/N_c^2$)

Color Connections

Each MPI (or cut Pomeron) exchanges color between the beams

- ► The colour flow determines the hadronizing string topology
  - Each MPI, even when soft, is a color spark
  - Final distributions <u>crucially</u> depend on color space

Different models make different ansätze



Sjöstrand & PS, JHEP 03(2004)053

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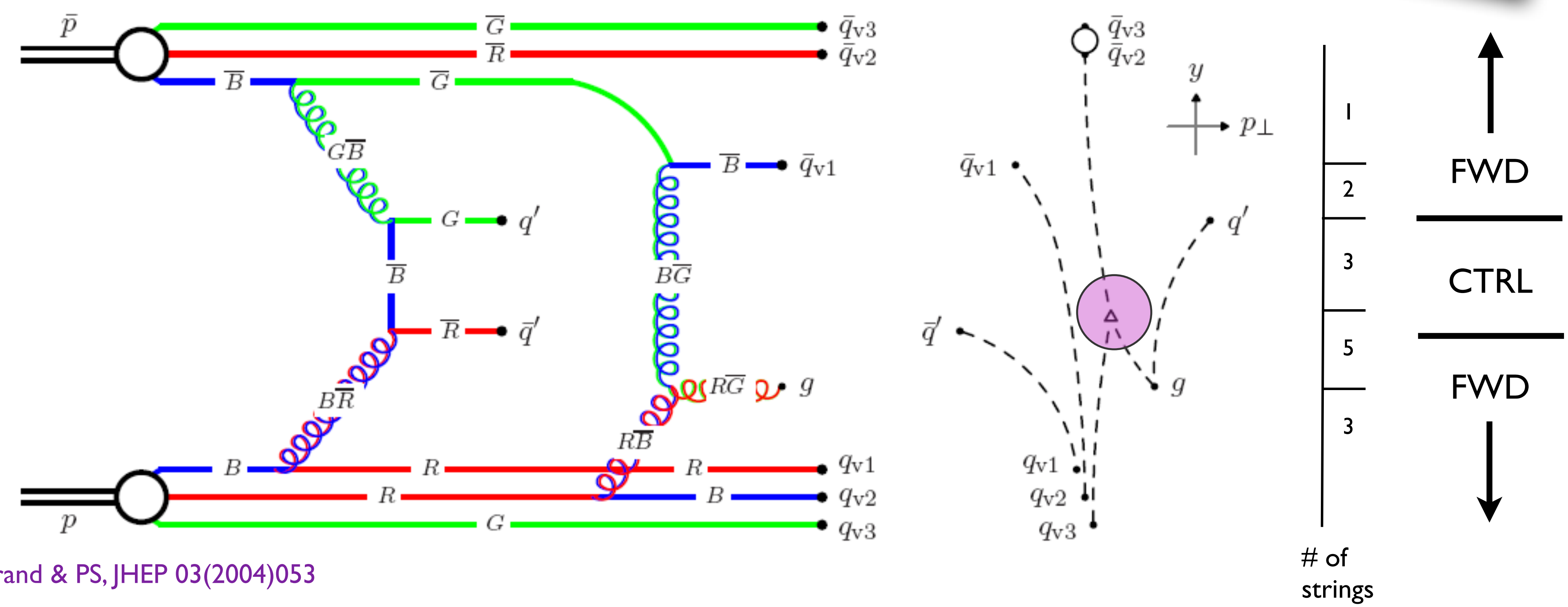

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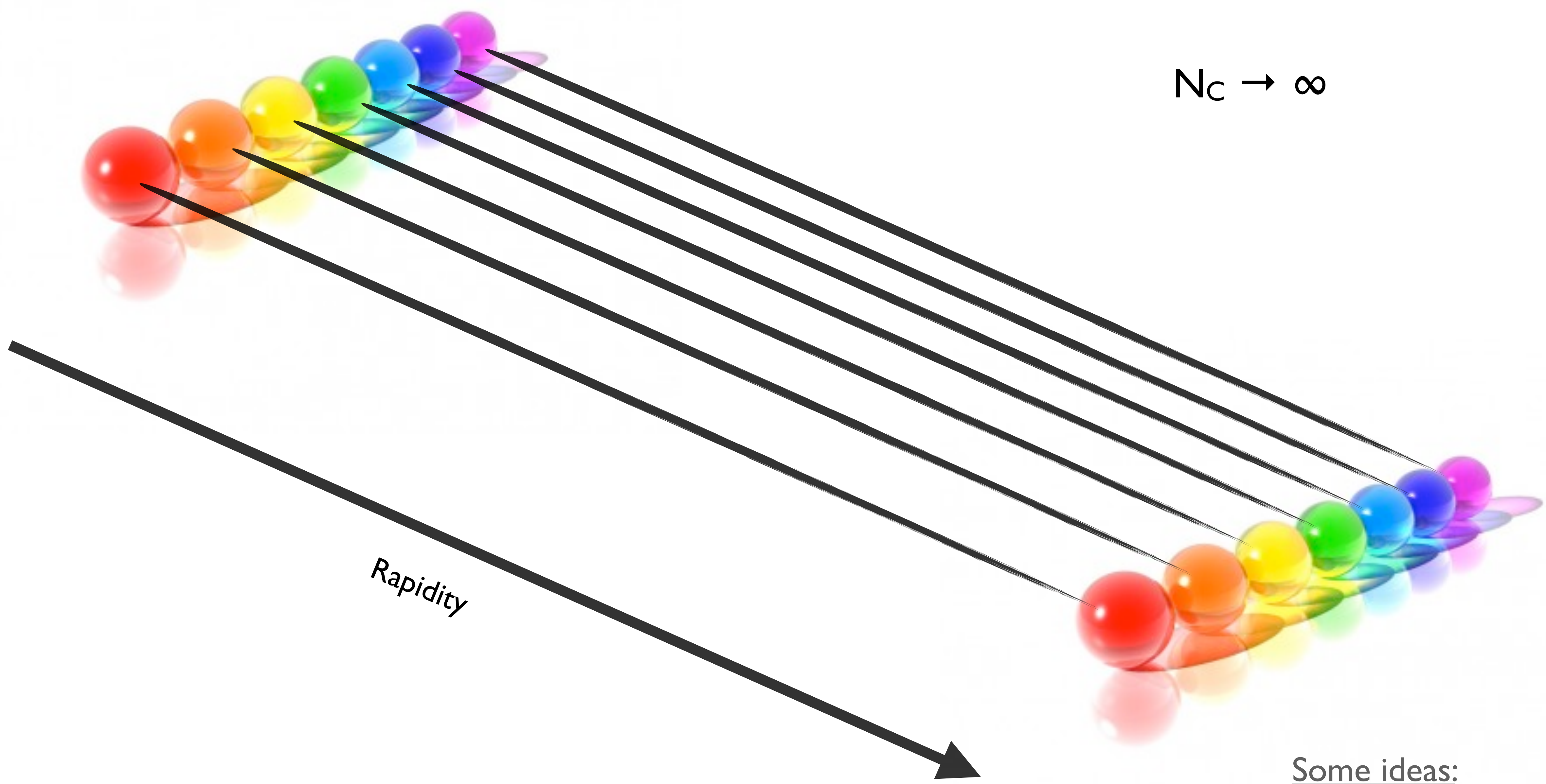
Color Connections

Better theory models needed



$N_C \rightarrow \infty$

Multiplicity $\propto N_{MPI}$

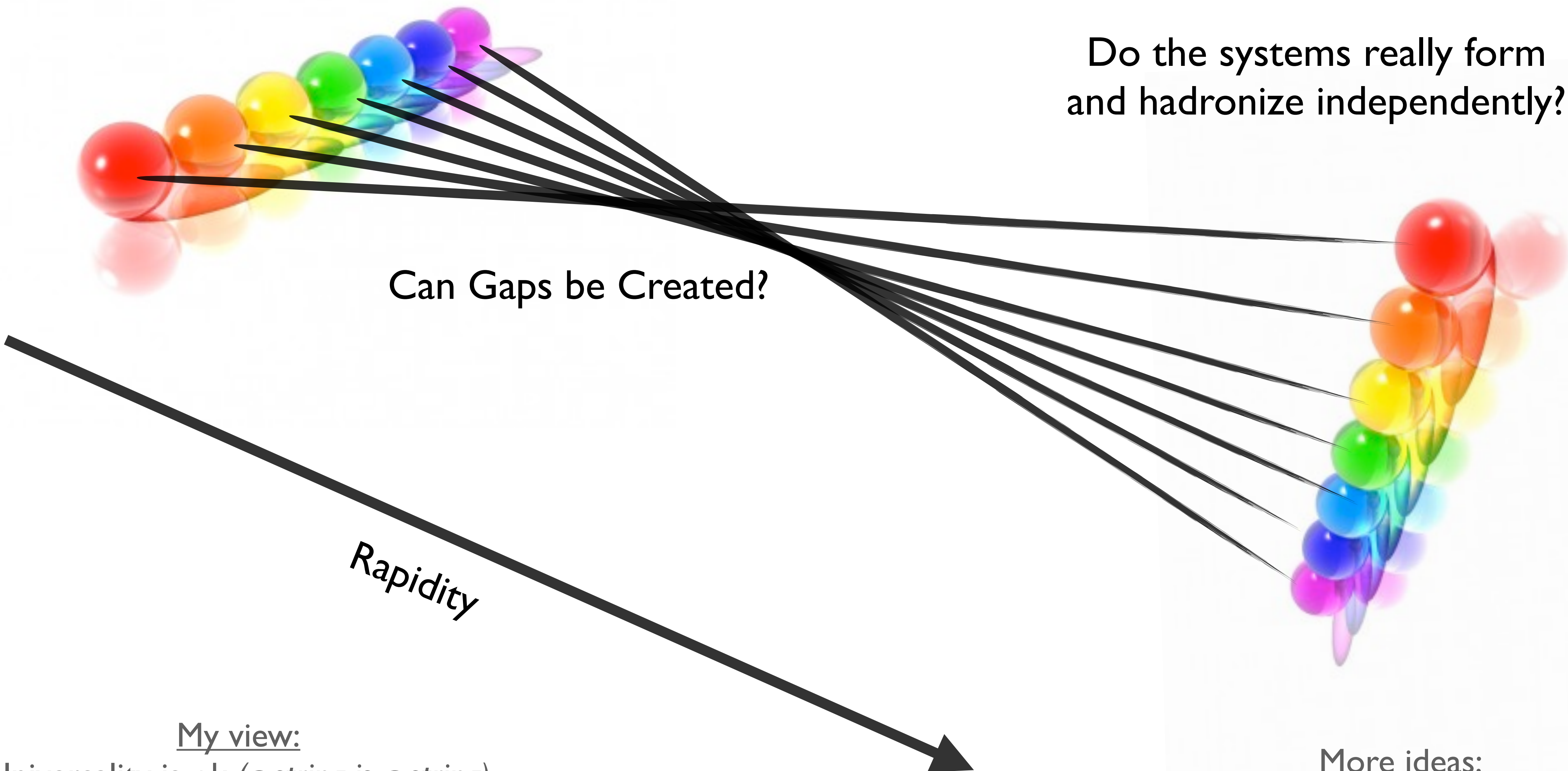
Some ideas:
Hydro? (EPOS)
E-dependent string parameters? (DPMJET)
"Color Ropes"?

Color Reconnections?

E.g.,
…
Generalized Area Law (Rathsman: Phys. Lett. B452 (1999) 364)
Color Annealing (P.S., Wicke: Eur. Phys. J. C52 (2007) 133)
…

Better theory models needed

Do the systems really form
and hadronize independently?



My view:
Universality is ok *(a string is a string)*
Problem is $3 \neq \infty$
Use String Area Law to govern
collapse of color wavefunction

Multiplicity $\overset{<}{\not\propto}$ N_{MPI}

More ideas:
Coherent string formation?
Color reconnections?
String dynamics?

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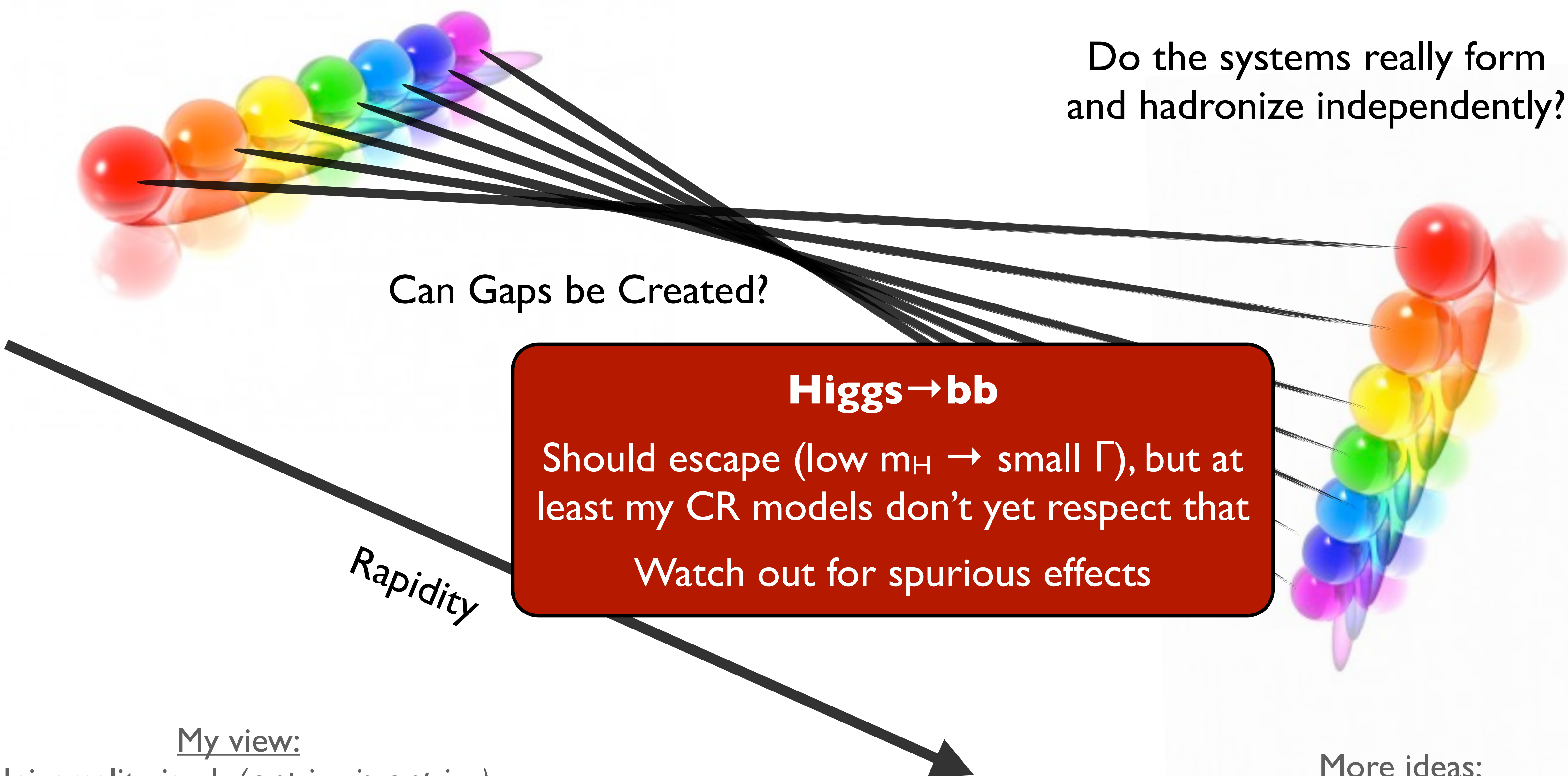

Higgs→bb

Should escape (low m_H → small Γ), but at least my CR models don't yet respect that

Watch out for spurious effects

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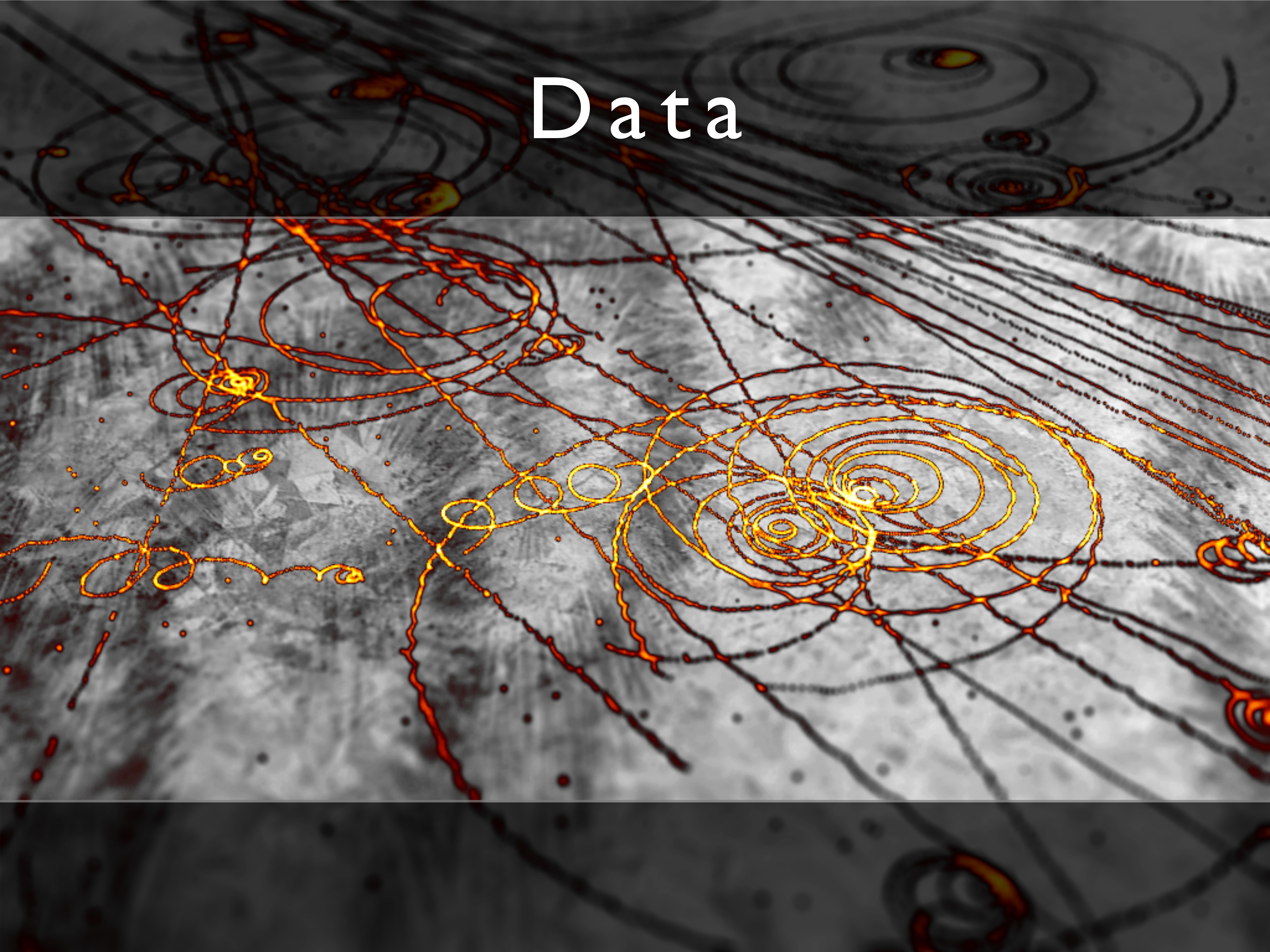
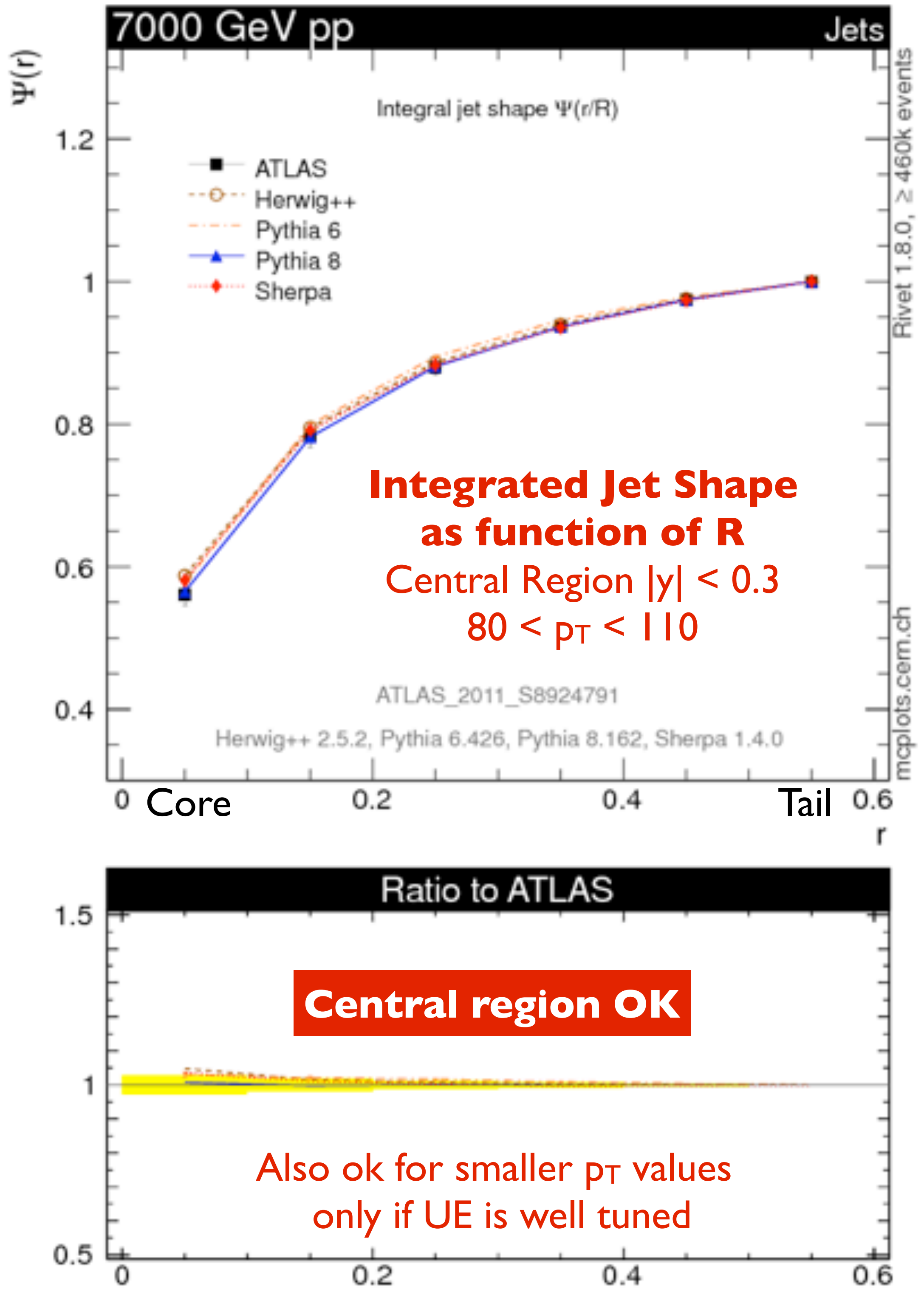
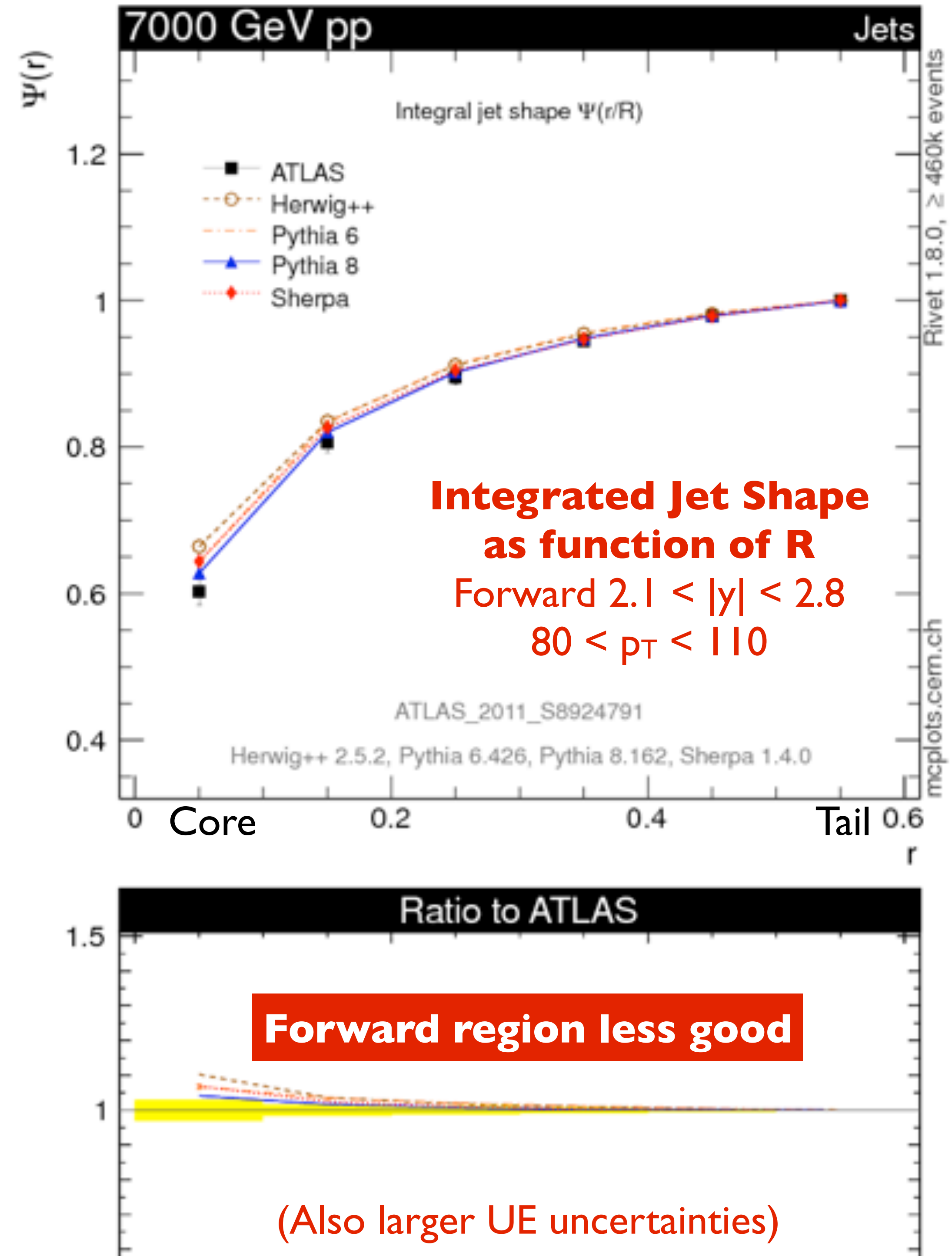
Data



FSR: Jet Shapes





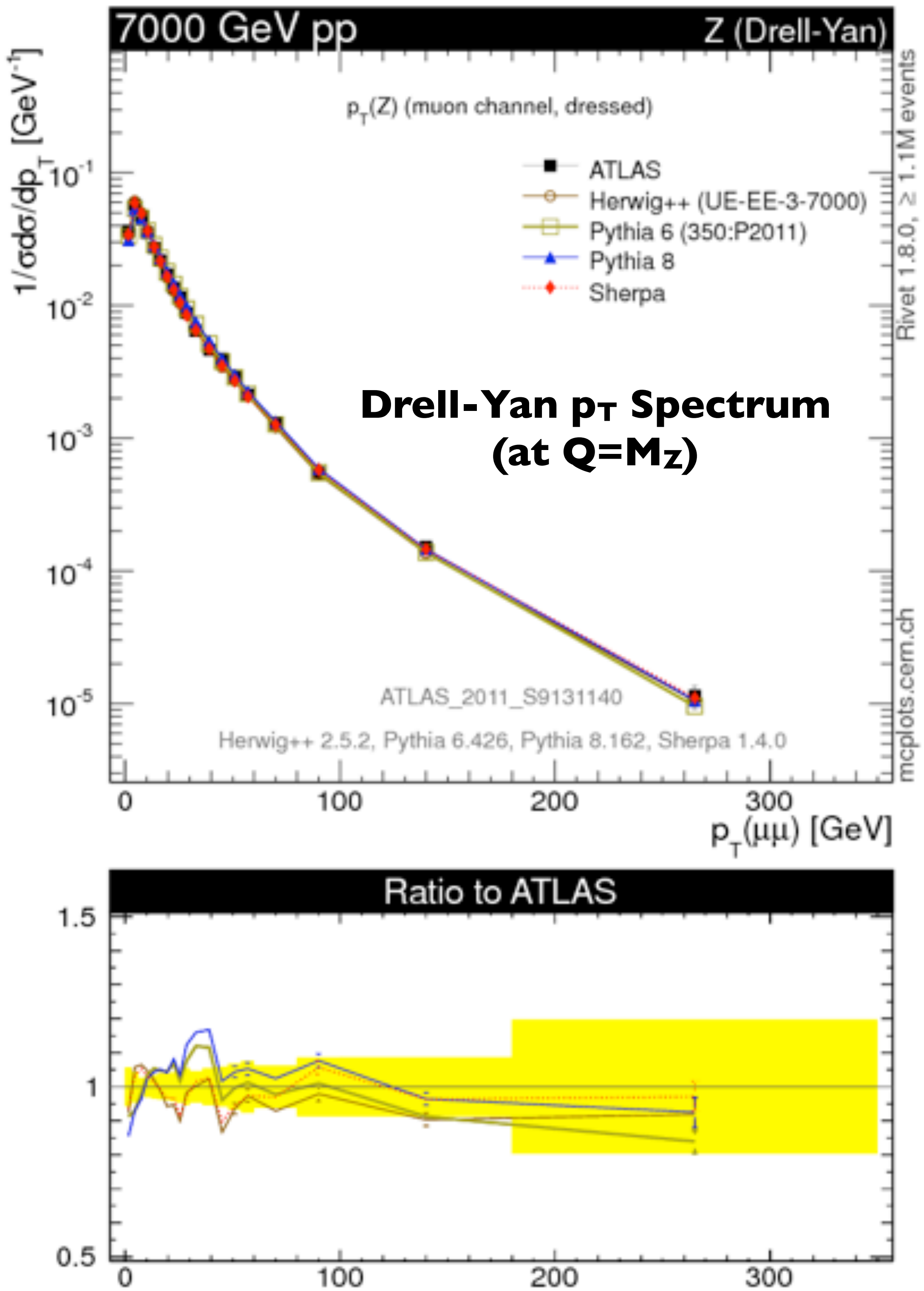
Issue for WBF?

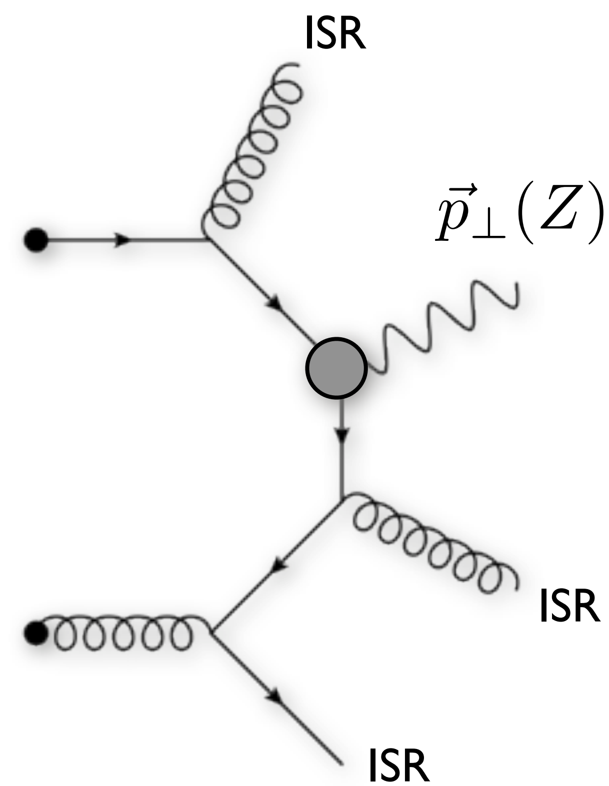
Plots from mcplots.cern.ch

ISR*: Drell-Yan p_T

ATLAS: arXiv:1107.2381
CMS: arXiv:1110.4973

*From Quarks, at $Q=M_Z$





$$\vec{p}_\perp(Z) \sim \sum_{j\in jets} \vec{p}_\perp(j)$$

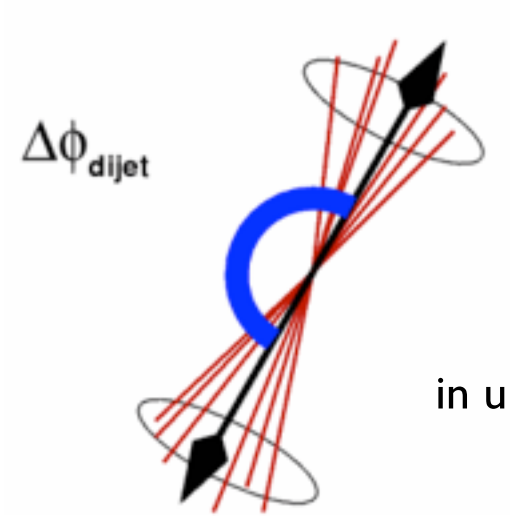
Particularly sensitive to

1. α_s renormalization scale choice
2. Recoil strategy (color dipoles vs global vs …)
3. FSR off ISR (ISR jet broadening)

Non-trivial result that modern GPMC shower models all reproduce it ~ correctly

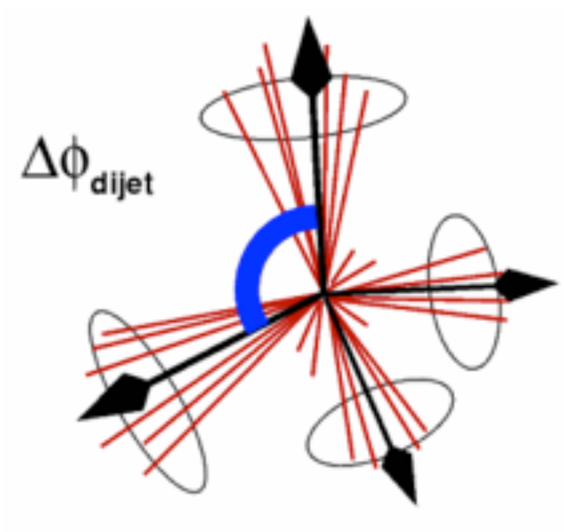
Note: old PYTHIA 6 model (Tune A) did not give correct distribution, except with extreme μ_R choice (DW, D6, Pro-Q2O)

ISR: Dijet Decorrelation



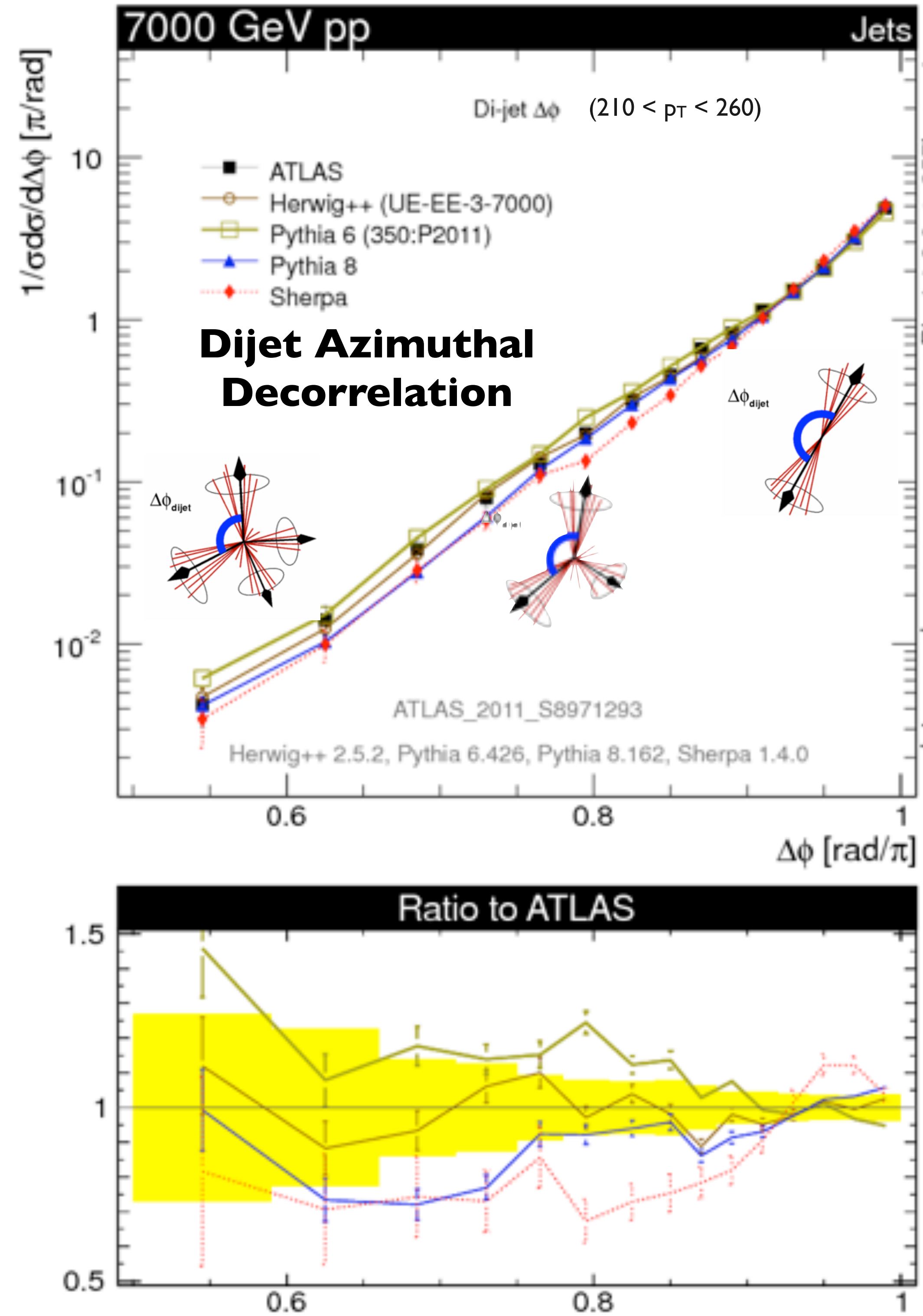
~ 1

in units of 180 degrees



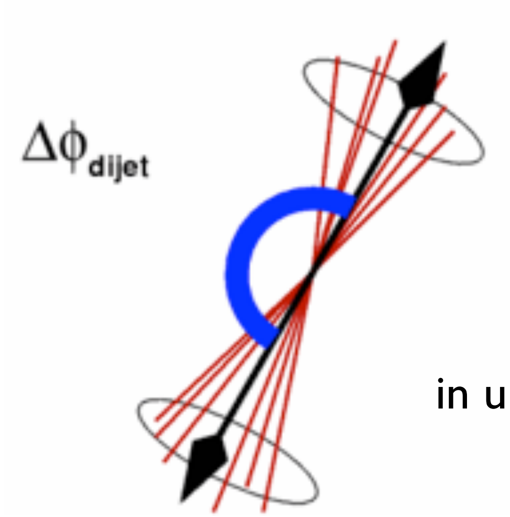
~ ½

ATLAS Phys.Rev.Lett. 106 (2011) 172002



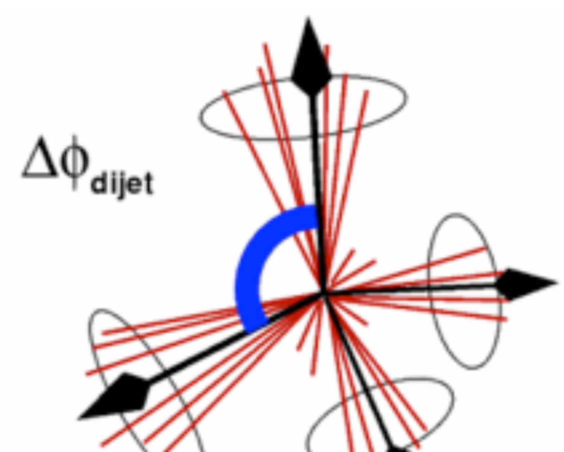
Plots from mcplots.cern.ch

ISR: Dijet Decorrelation



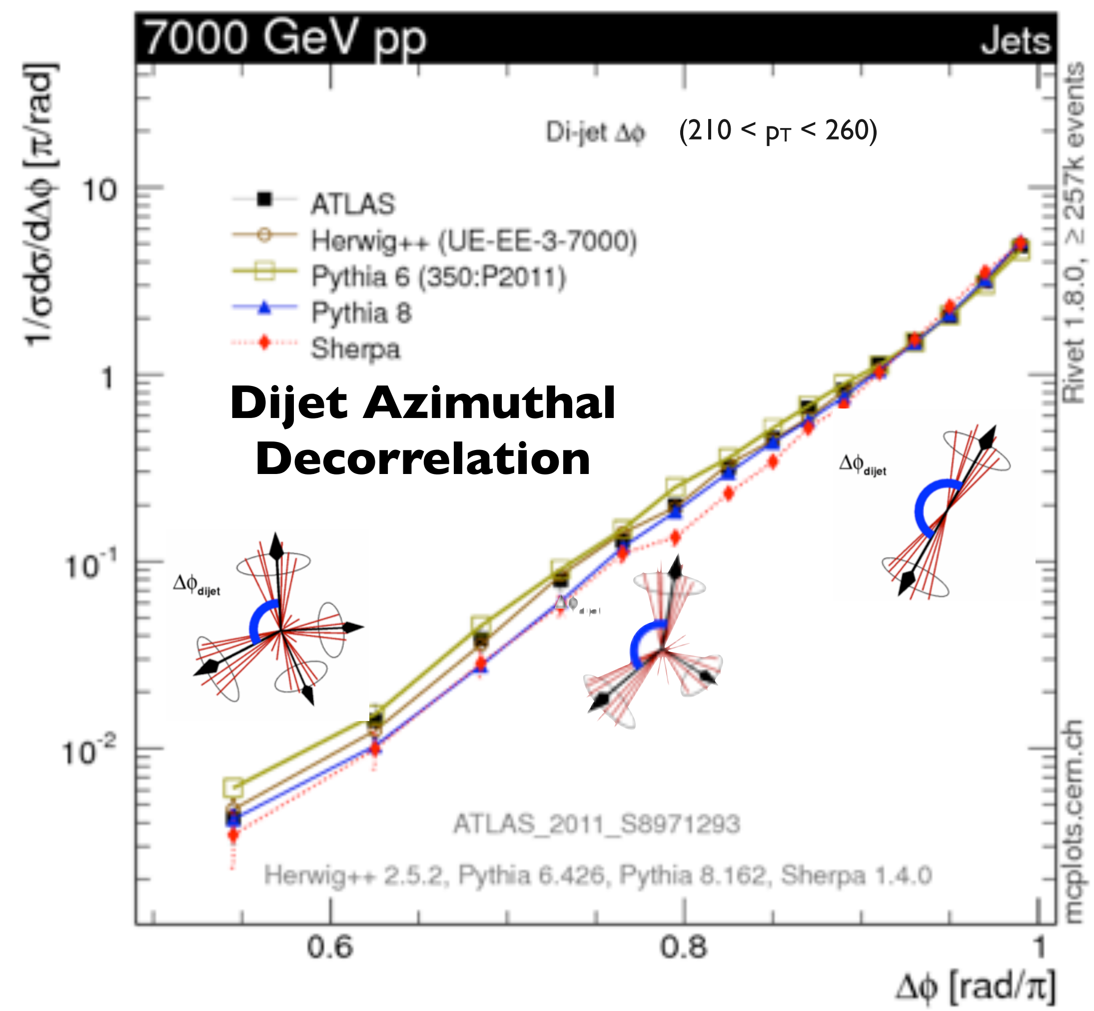
~ 1

in units of 180 degrees



~ ½

ATLAS Phys.Rev.Lett. 106 (2011) 172002



IR Safe Summary (ISR/FSR):

LO + showers *generally* in good *O(20%)* agreement with LHC *(modulo bad tunes, pathological cases)*

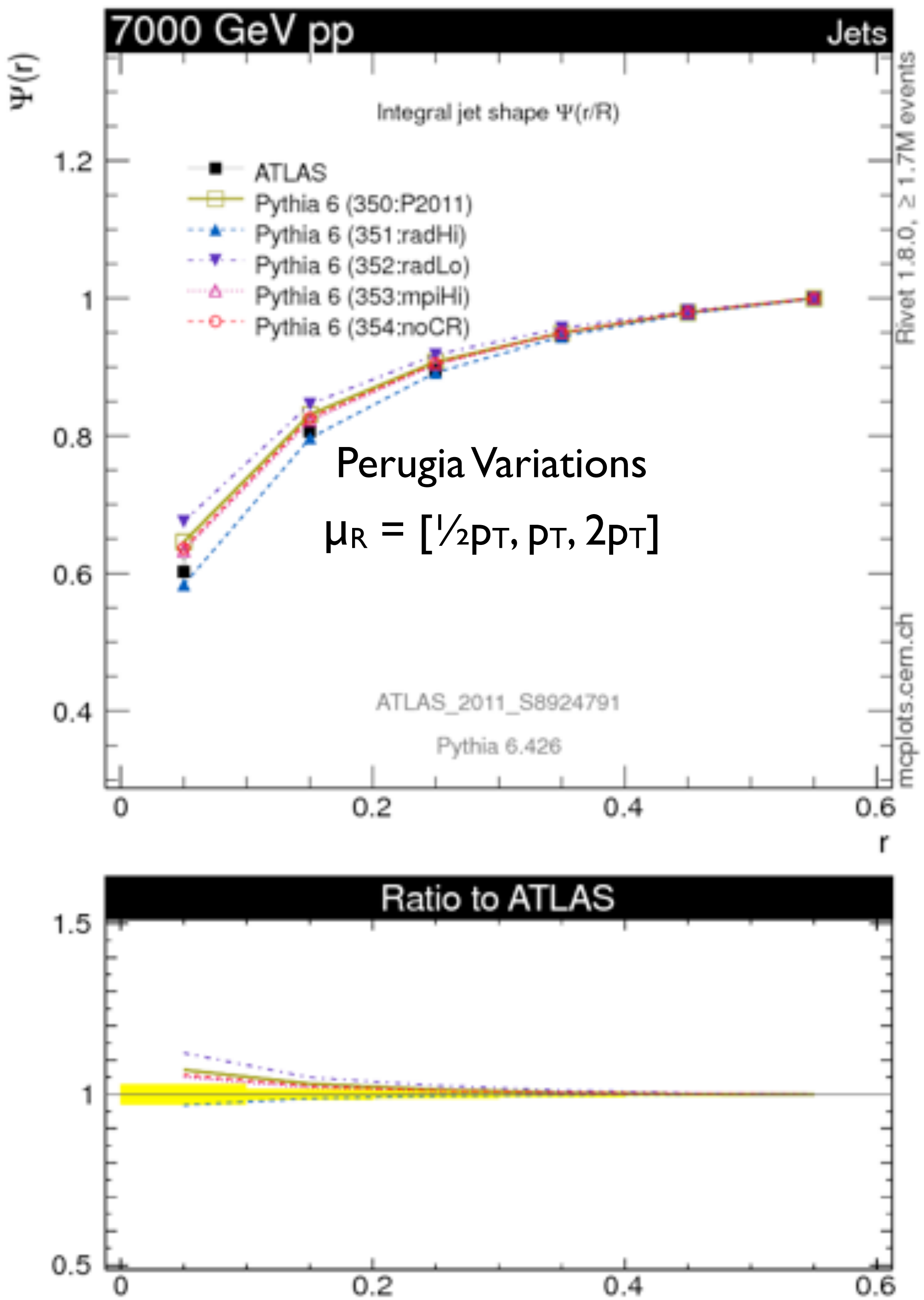
Room for improvement: Quantification of *uncertainties* is still more art than science.

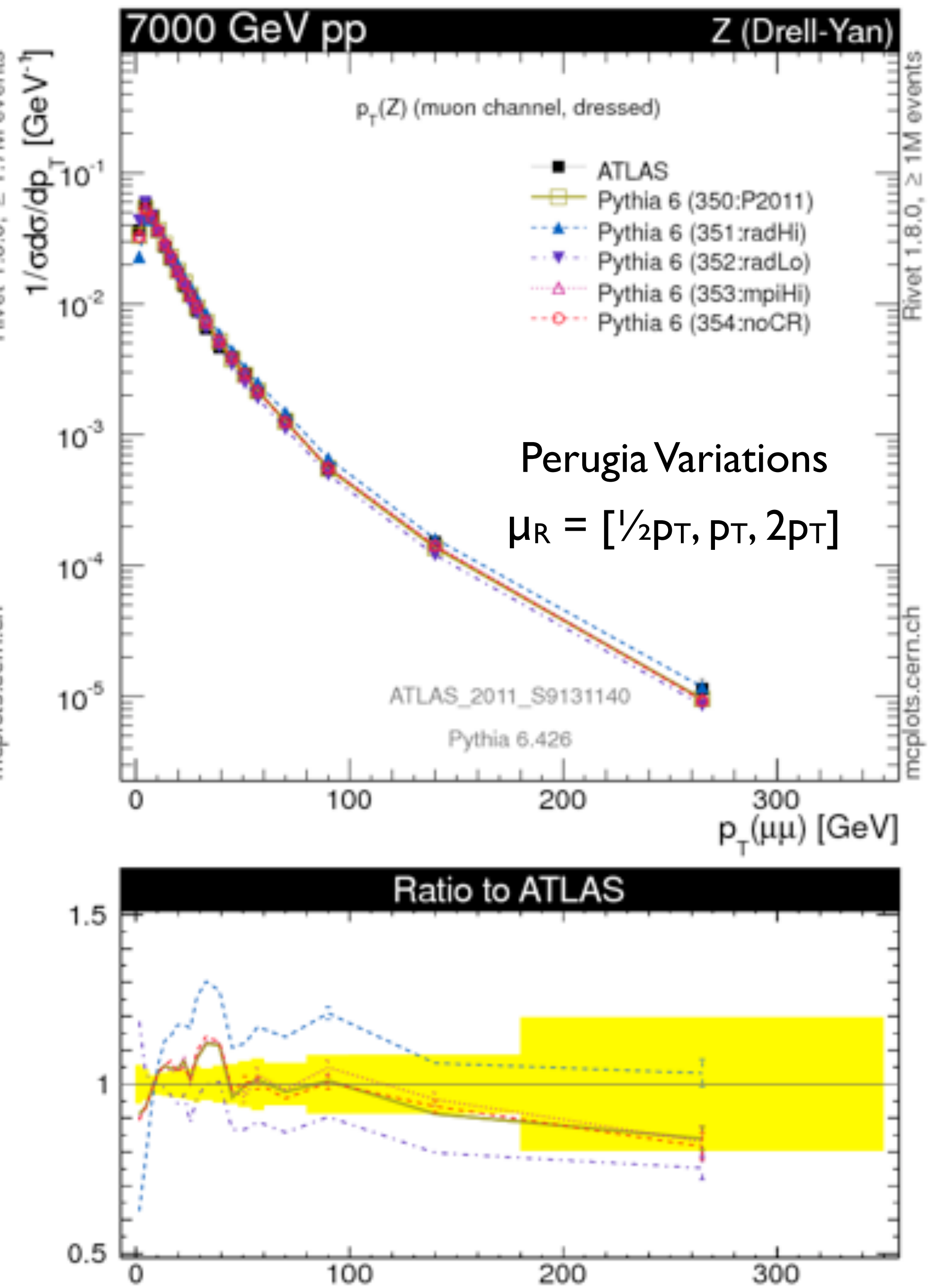
Cutting Edge: multi-jet matching at NLO and systematic NLL showering

Bottom Line: perturbation theory is solvable. Expect progress.

Uncertainties

Buckley et al. (Professor) *"Systematic Event Generator Tuning for LHC"*, EPJC65 (2010) 331
P.S. *"Tuning MC Event Generators: The Perugia Tunes"*, PRD82 (2010) 074018
Schulz, P.S. *"Energy Scaling of Minimum-Bias Tunes"*, EPJC71 (2011) 1644
Giele, Kosower, P.S. *"Higher-Order Corrections to Timelike Jets"*, PRD84 (2011) 054003





Variation of μ_R here done for ISR + FSR together (theoretically consistent, but may not be most conservative?)

+ Similar variations for PDFs (CTEQ vs MSTW) Amount of MPI, Color reconnections, Energy scaling

+ Variations of Fragmentation parameters (IR sensitive) on the way

Pythia 6: The Perugia Variations

PS - PRD82 (2010) 074018

Central Tune + 9 variations

Note: no variation of hadronization parameters! (sorry, ten was already a lot)

Perugia 2011 Tune Set

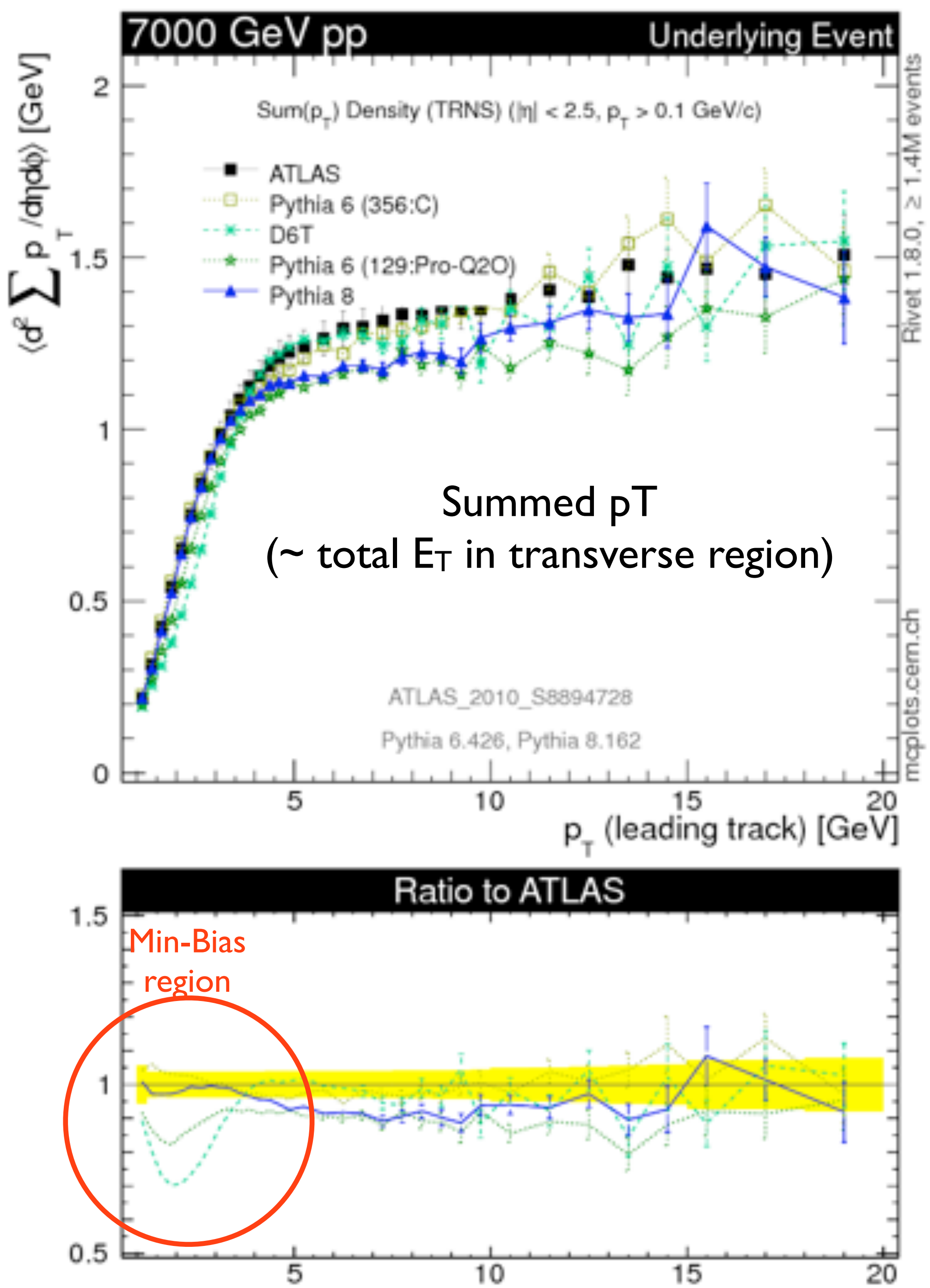
(350)	Perugia 2011	Central Perugia 2011 tune (CTEQ5L)	
(351)	Perugia 2011 radHi	Variation using $\alpha_s(\frac{1}{2}p_\perp)$ for ISR and FSR	Harder radiation
(352)	Perugia 2011 radLo	Variation using $\alpha_s(2p_\perp)$ for ISR and FSR	Softer radiation
(353)	Perugia 2011 mpiHi	Variation using $\Lambda_{\rm QCD} = 0.26\,{\rm GeV}$ also for MPI	UE more "jetty"
(354)	Perugia 2011 noCR	Variation without color reconnections	Softer hadrons
(355)	Perugia 2011 M	Variation using MRST LO** PDFs	UE more "jetty"
(356)	Perugia 2011 C	Variation using CTEQ 6L1 PDFs	Recommended
(357)	Perugia 2011 T16	Variation using `PARP(90)=0.16` scaling away from 7 TeV	
(358)	Perugia 2011 T32	Variation using `PARP(90)=0.32` scaling away from 7 TeV	
(359)	Perugia 2011 Tevatron	Variation optimized for Tevatron	~ low at LHC

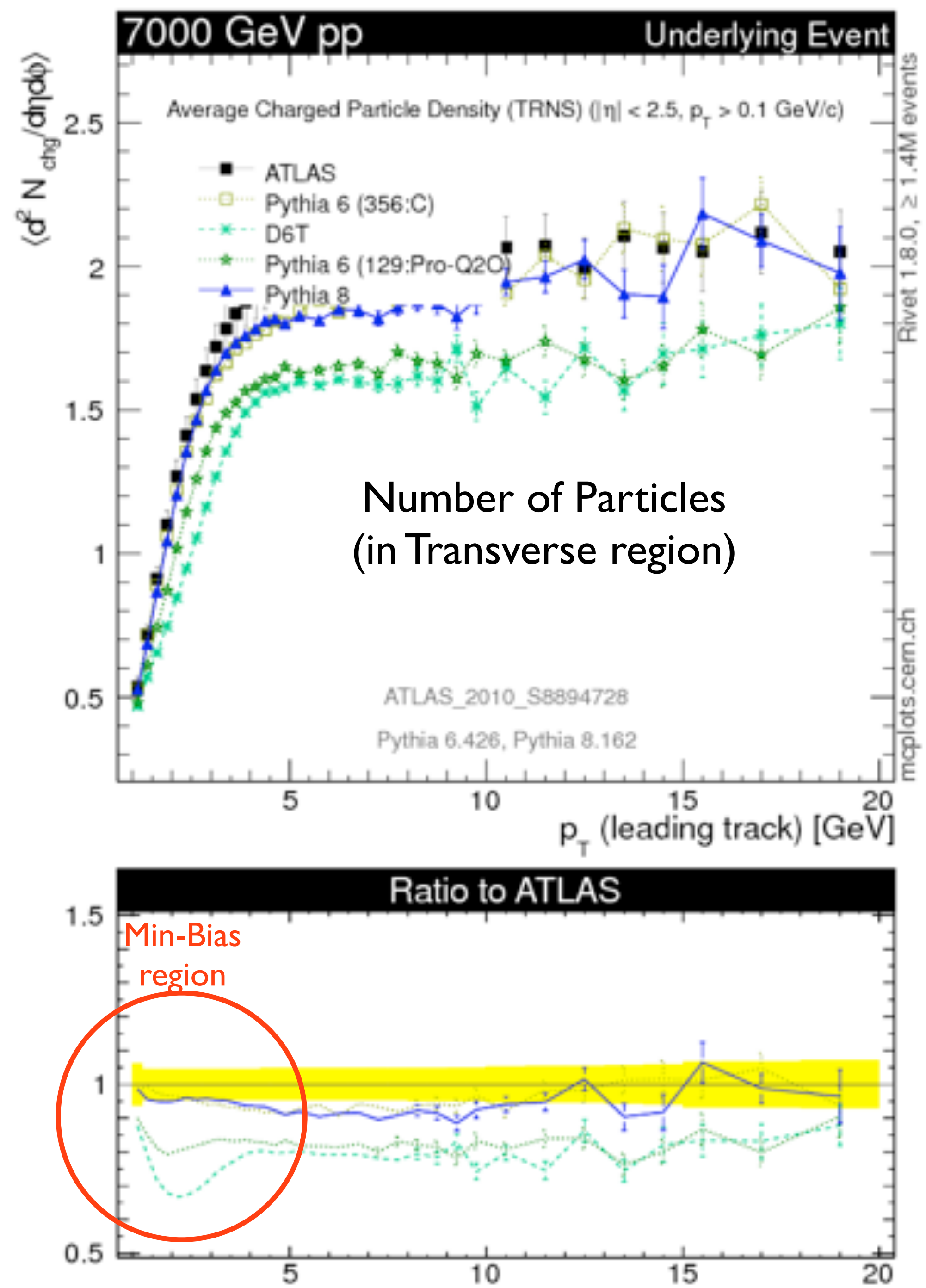
Can be obtained in standalone Pythia from 6.4.25+

MSTP(5) = 350	MSTP(5) = 351	MSTP(5) = 352	MSTP(5) = …
Perugia 2011	Perugia 2011 radHi	Perugia 2011 radLo	…

Underlying Event

Note: the UE is more active than Min-Bias, which is more active than Pile-Up



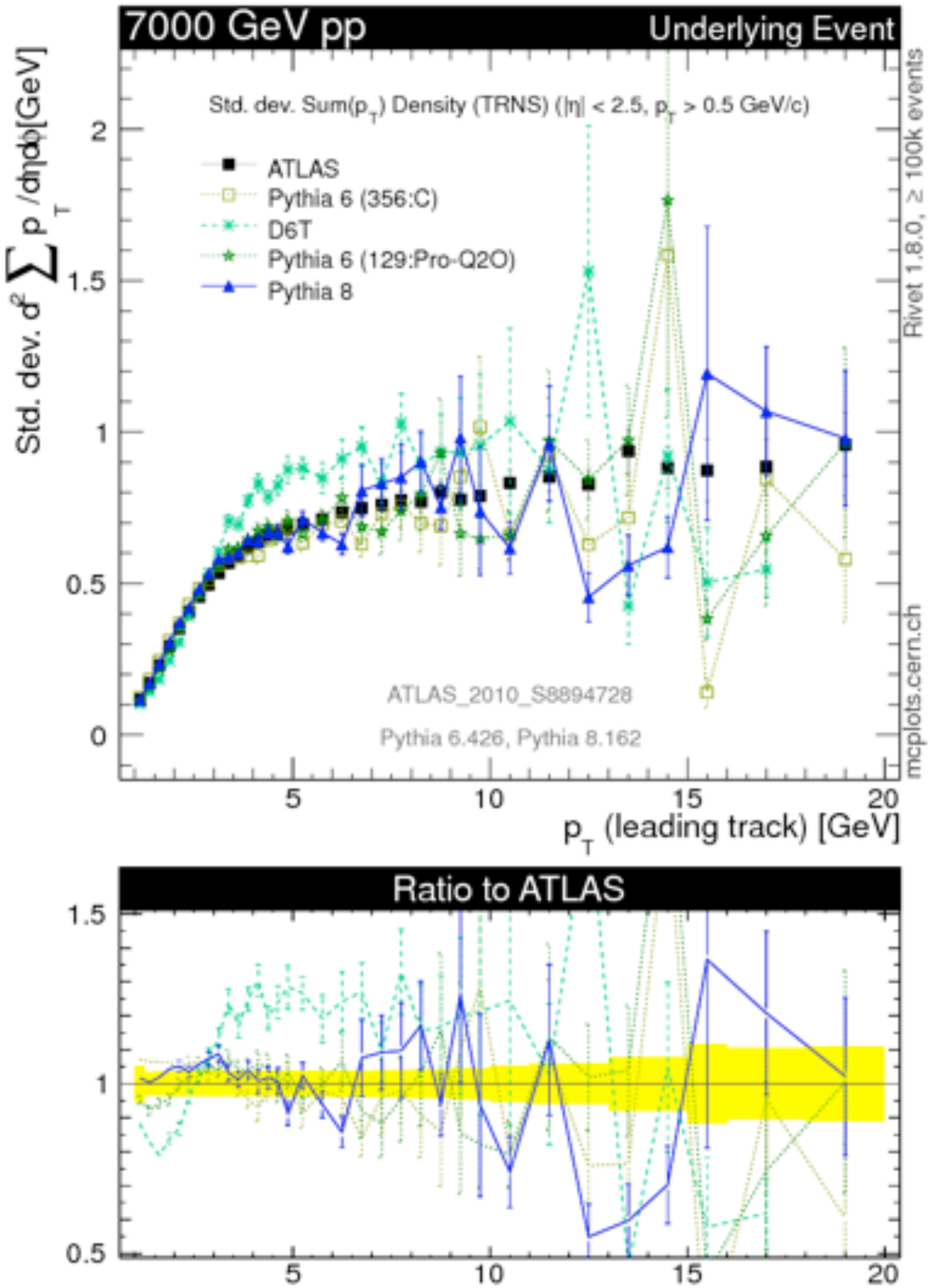


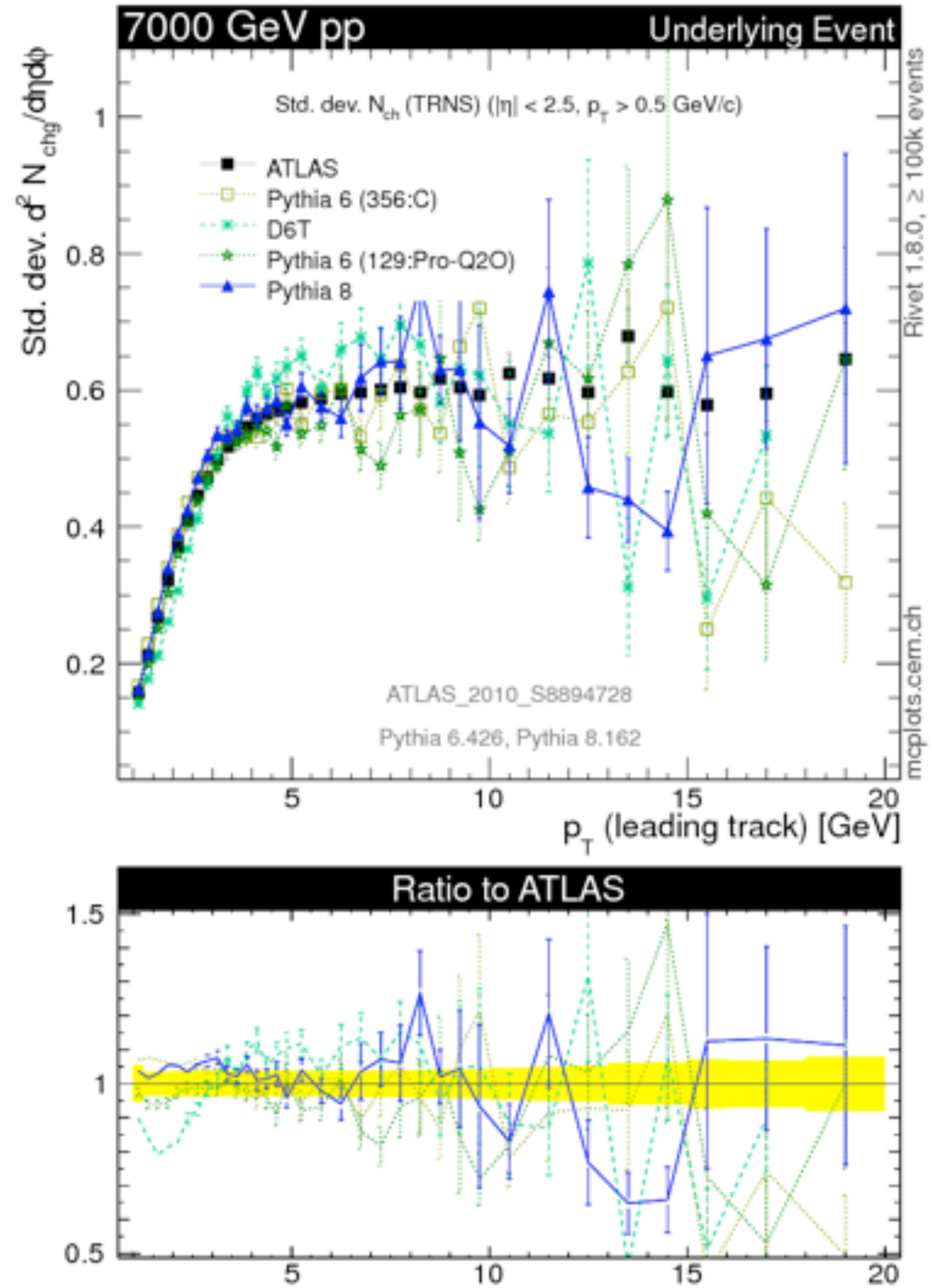
PYTHIA 8 a bit
too low?

Q2-ordered tunes
(D6T and Pro-Q20)
have the right energy,
but it's distributed on
too few particles
→ momentum spectra
too hard

Underlying Event: RMS

Measures the event-by-event FLUCTUATIONS of the Underlying Event



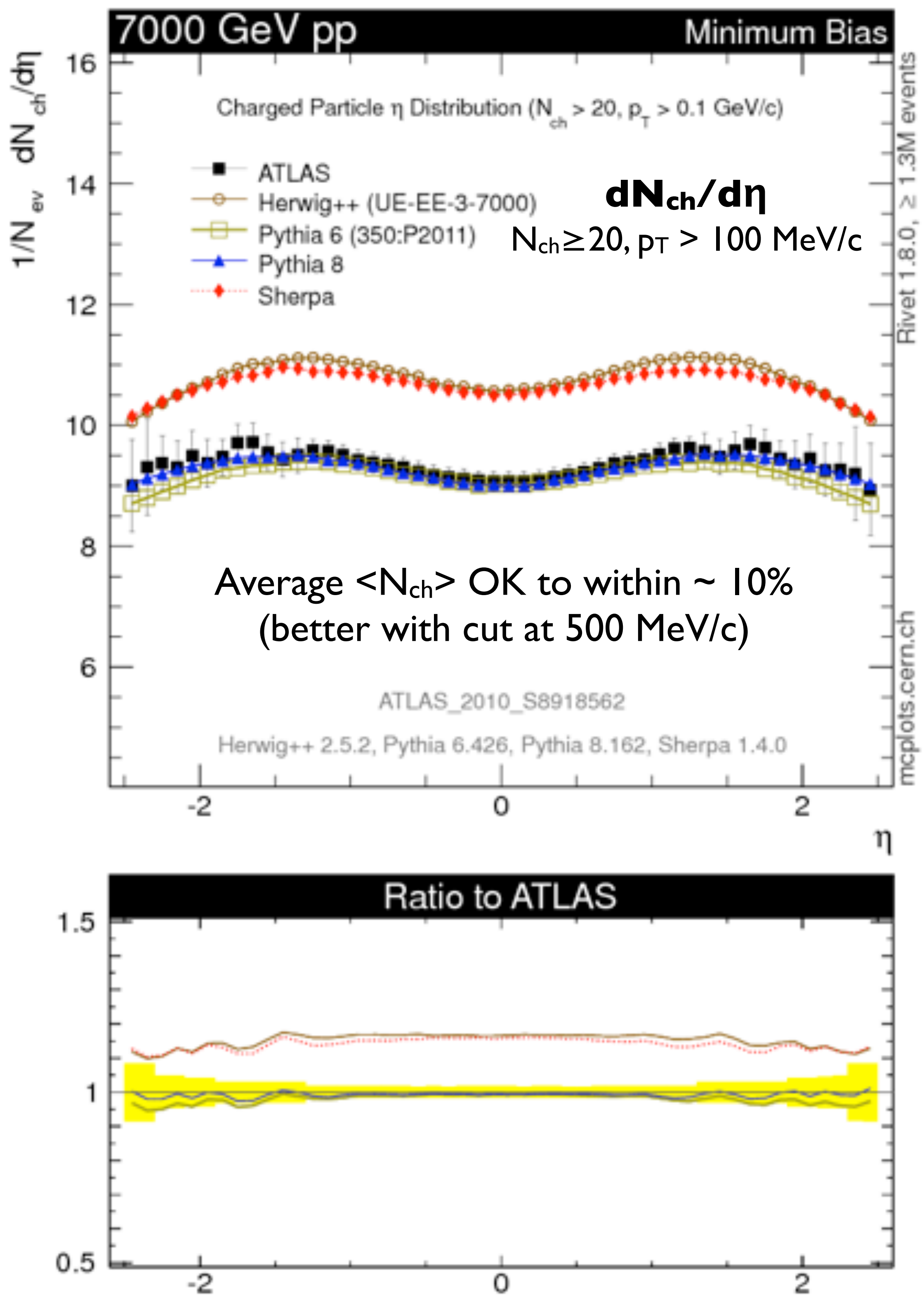


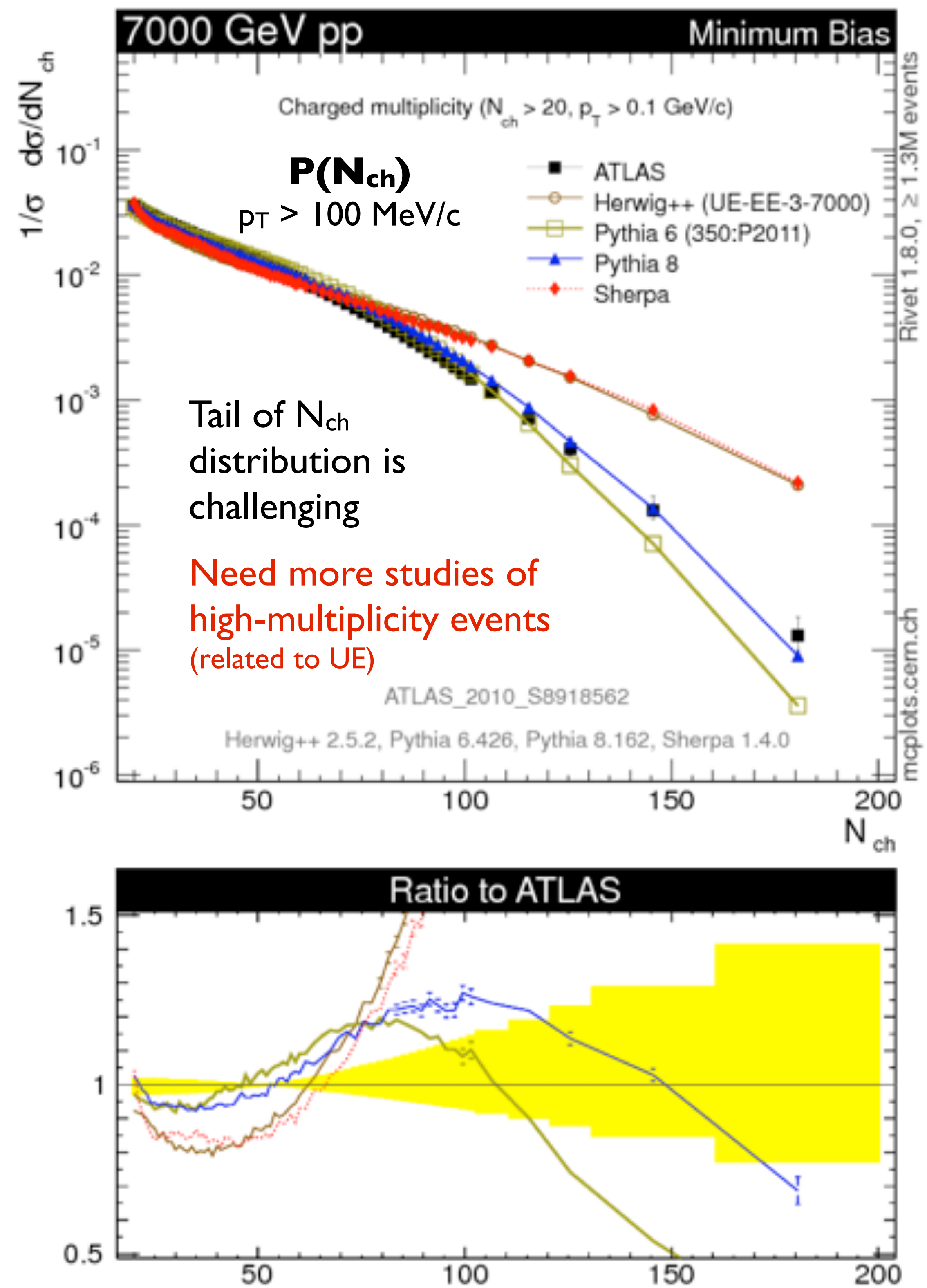
Never previously measured. Not used for tuning.

All in all Amazing agreement

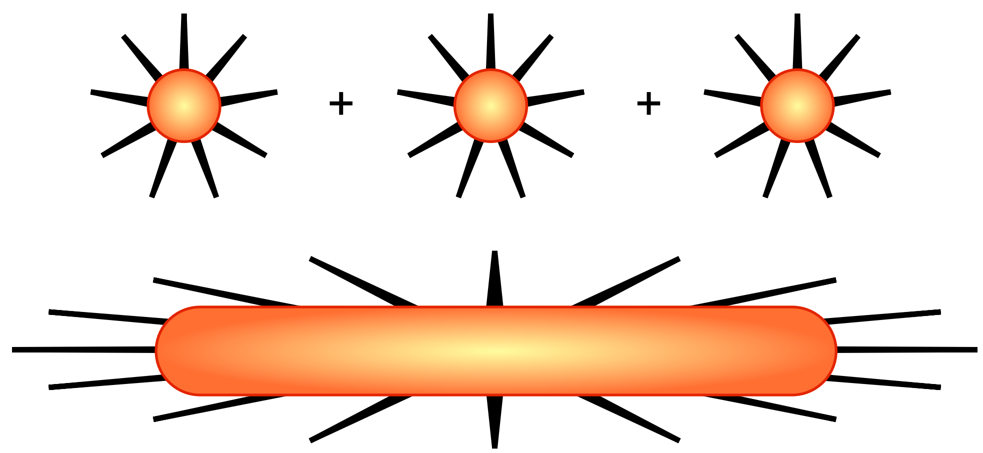
D6T has too large RMS

Min-Bias: Inclusive Particles



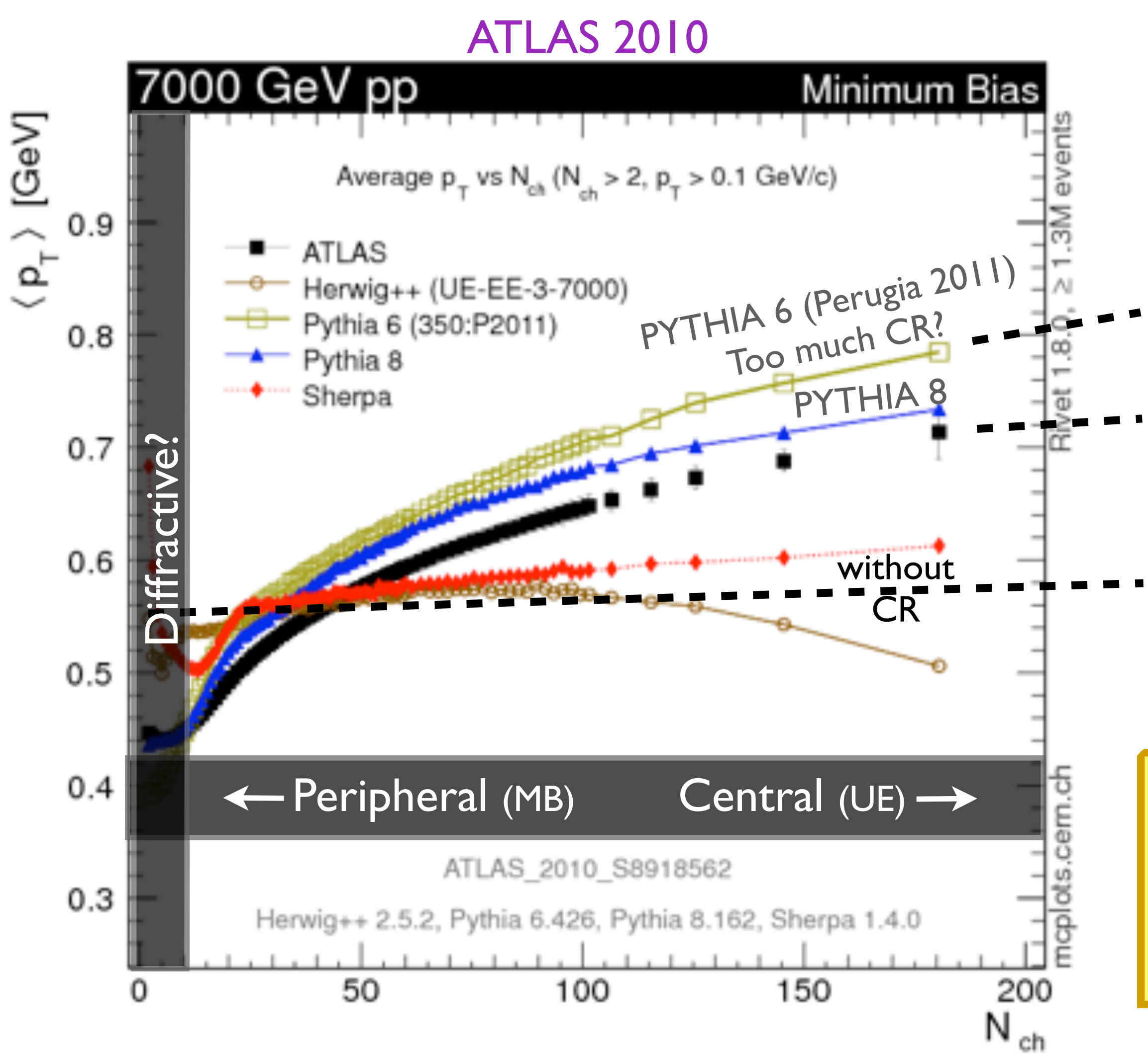


Min-Bias: $\langle p_T \rangle$ vs N_{ch}



Independent Particle Production:
→ **averages stay the same**

Color Correlations / Jets / Collective effects:
→ **average rises**



Extrapolation to high multiplicity ~ UE

Average particles slightly too hard
→ Too much energy, or energy distributed on too few particles

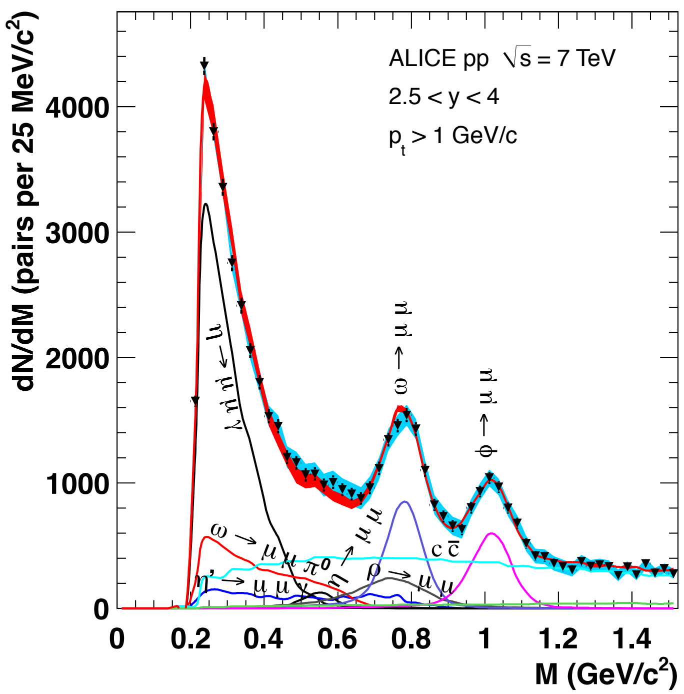
~ OK?

Average particles slightly too soft
→ Too little energy, or energy distributed on too many particles

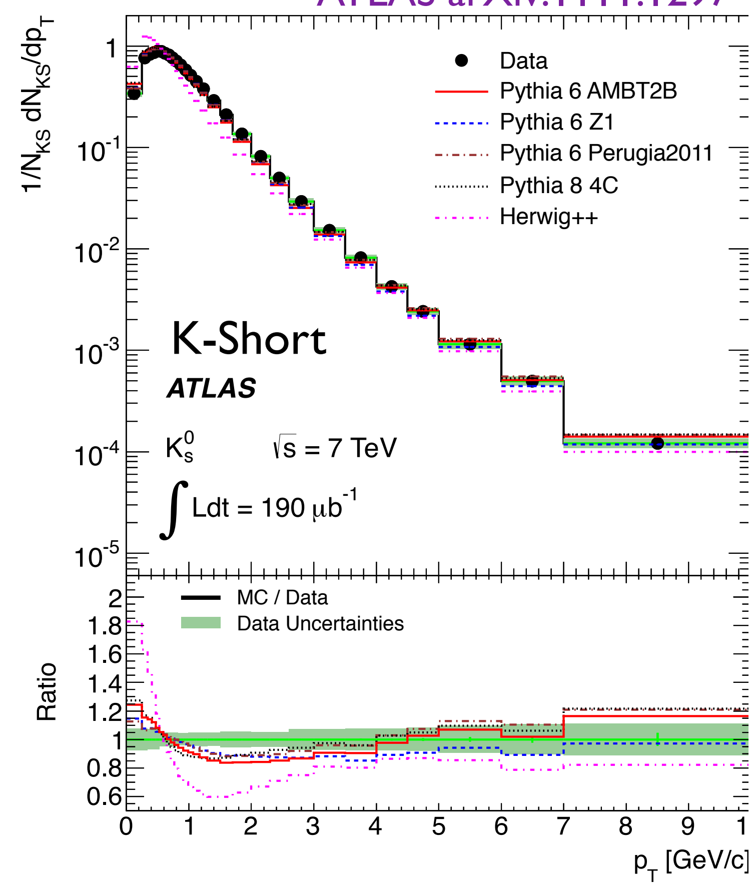
Evolution of other distributions with N_{ch} also interesting: e.g., $\langle p_T \rangle(N_{ch})$ for identified particles, strangeness & baryon ratios, 2P correlations, …

Identified Particles

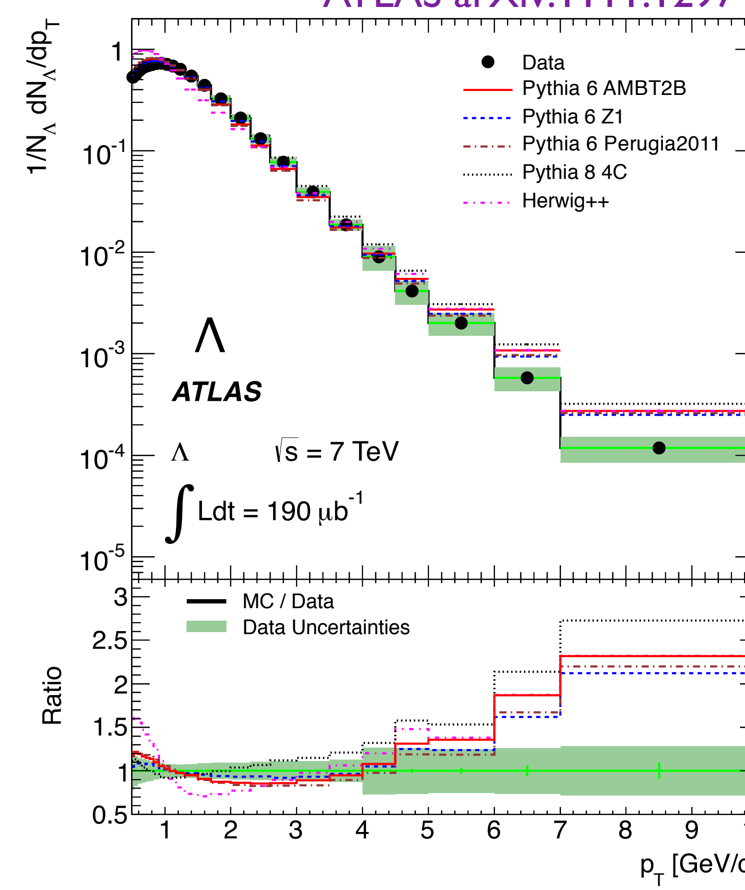
ALICE arXiv:1112.2222



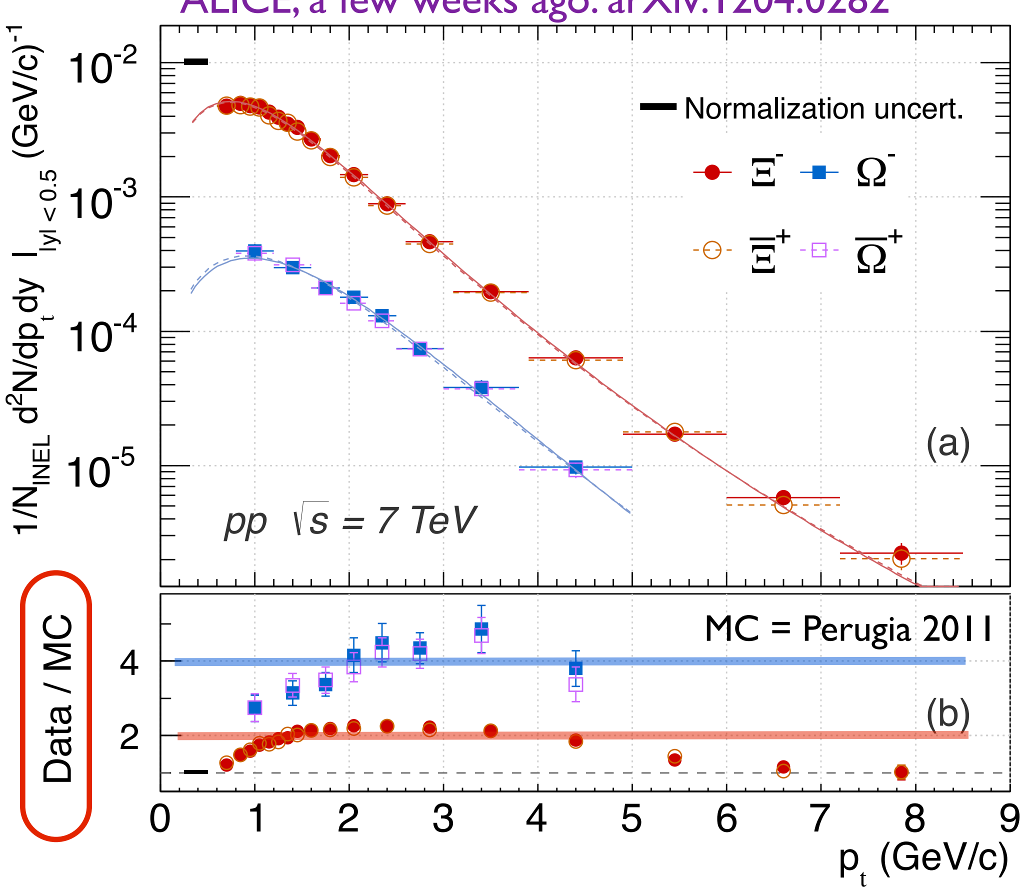
ATLAS arXiv:1111.1297



ATLAS arXiv:1111.1297



ALICE, a few weeks ago: arXiv:1204.0282

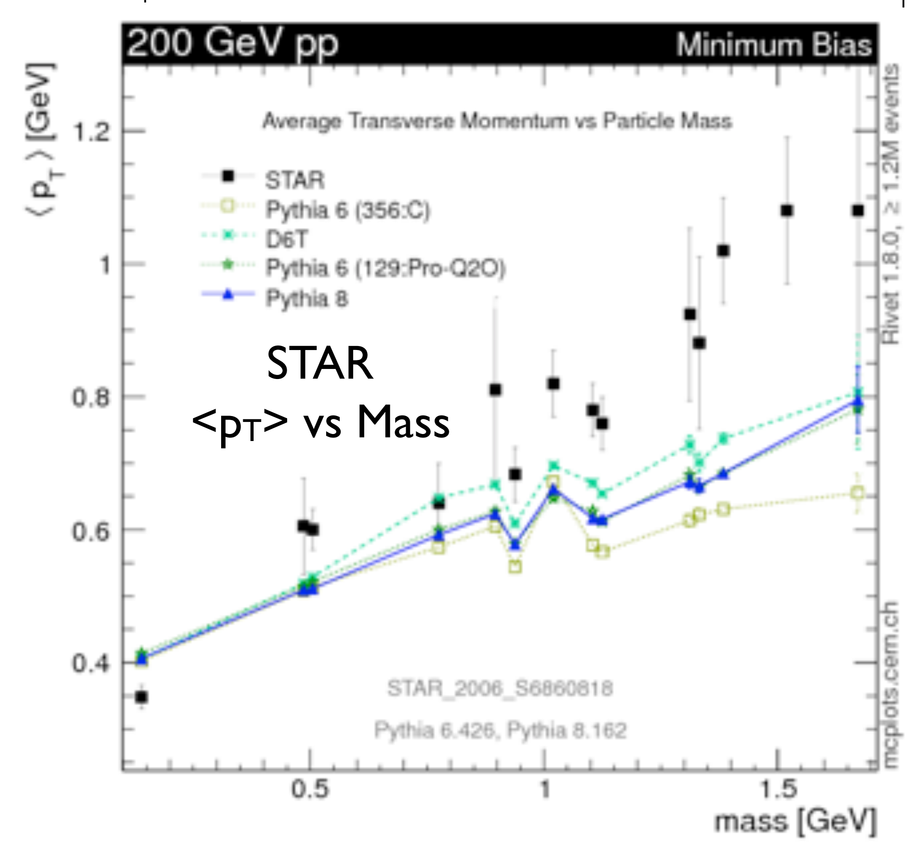


Wrong Mass Dependence?

(even *after* we tried to adjust LEP yields)

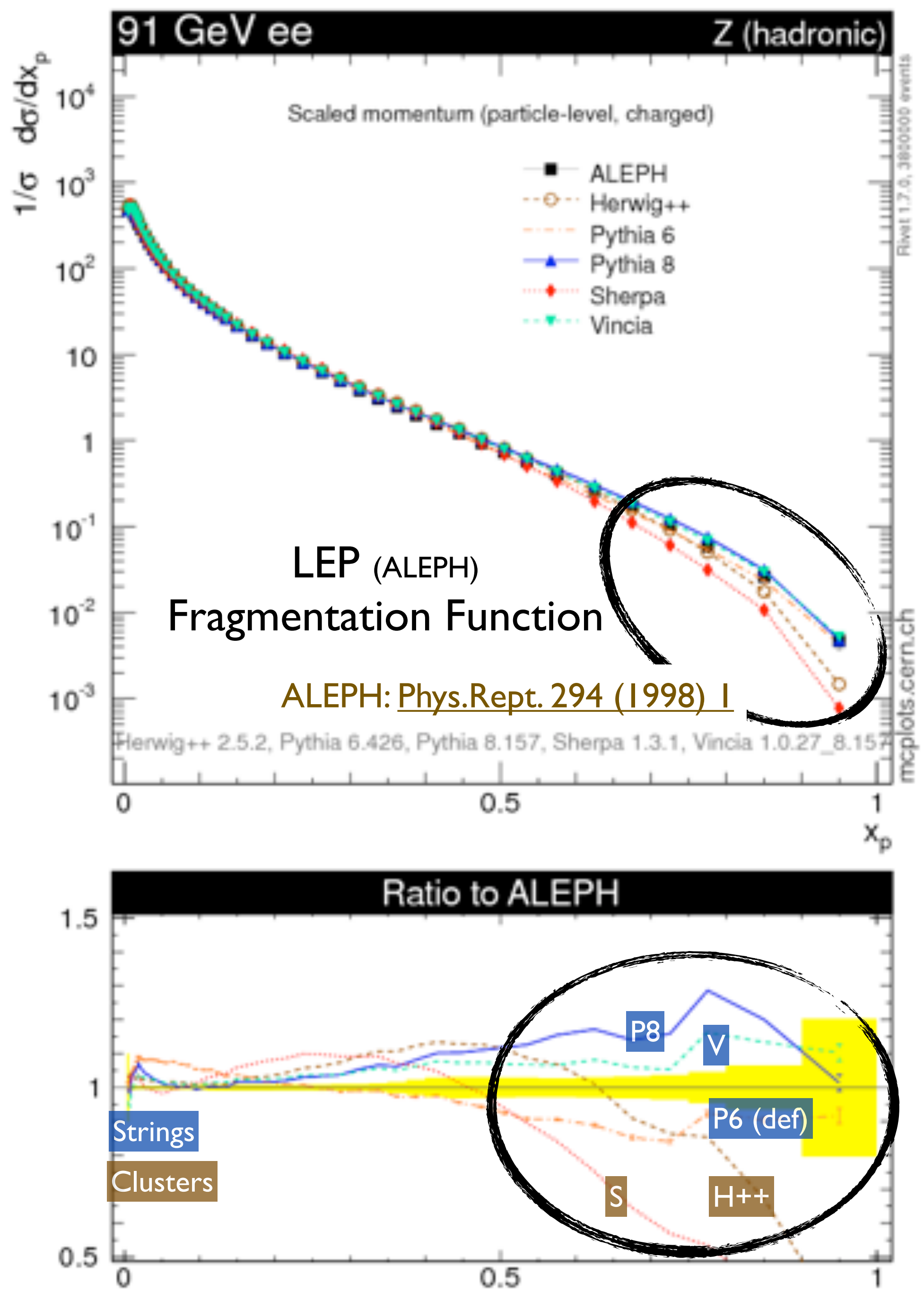
Especially at intermediate $p_T \sim 1$-4 GeV

Question: how to reconcile ee and pp data?



Extreme Fragmentation

How often does an entire jet fragment into **a single/isolated particle?** (can produce dangerous fakes)
Controlled by the behavior of the fragmentation function at z→1. Deep Sudakov region, very tough to model.
Intrinsically suppressed in cluster models. But even good string tunes probably not very reliable.



Plots from mcplots.cern.ch

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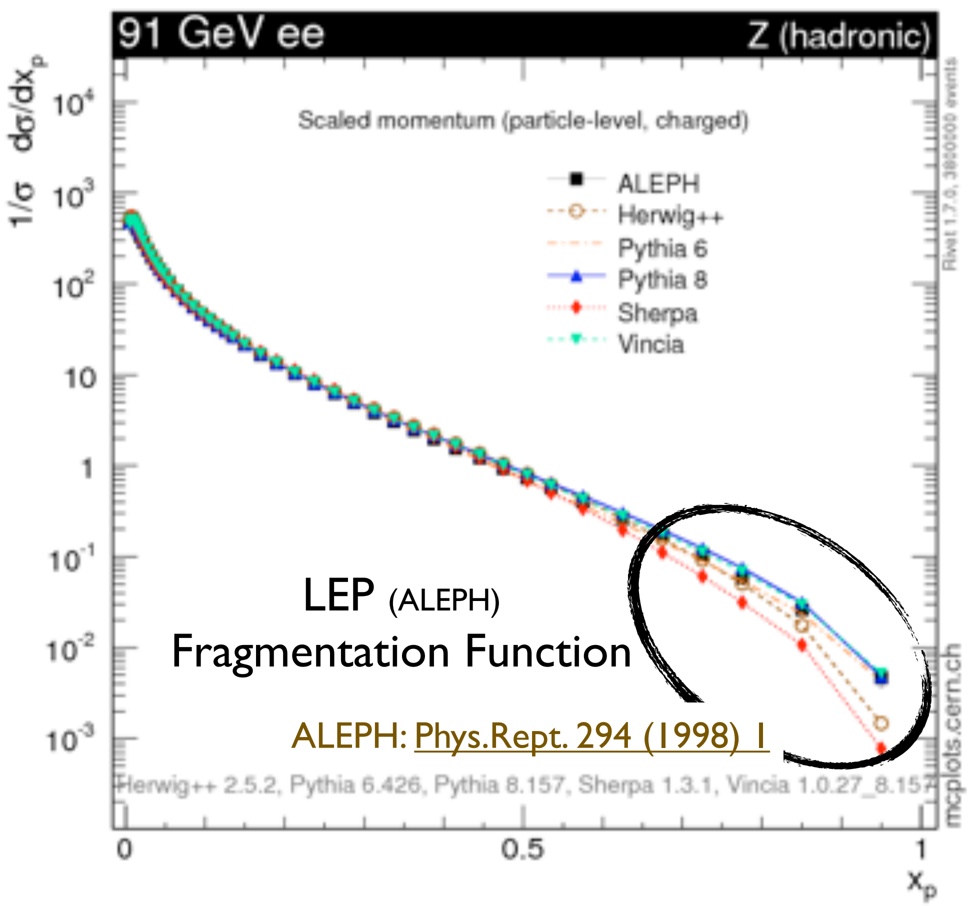

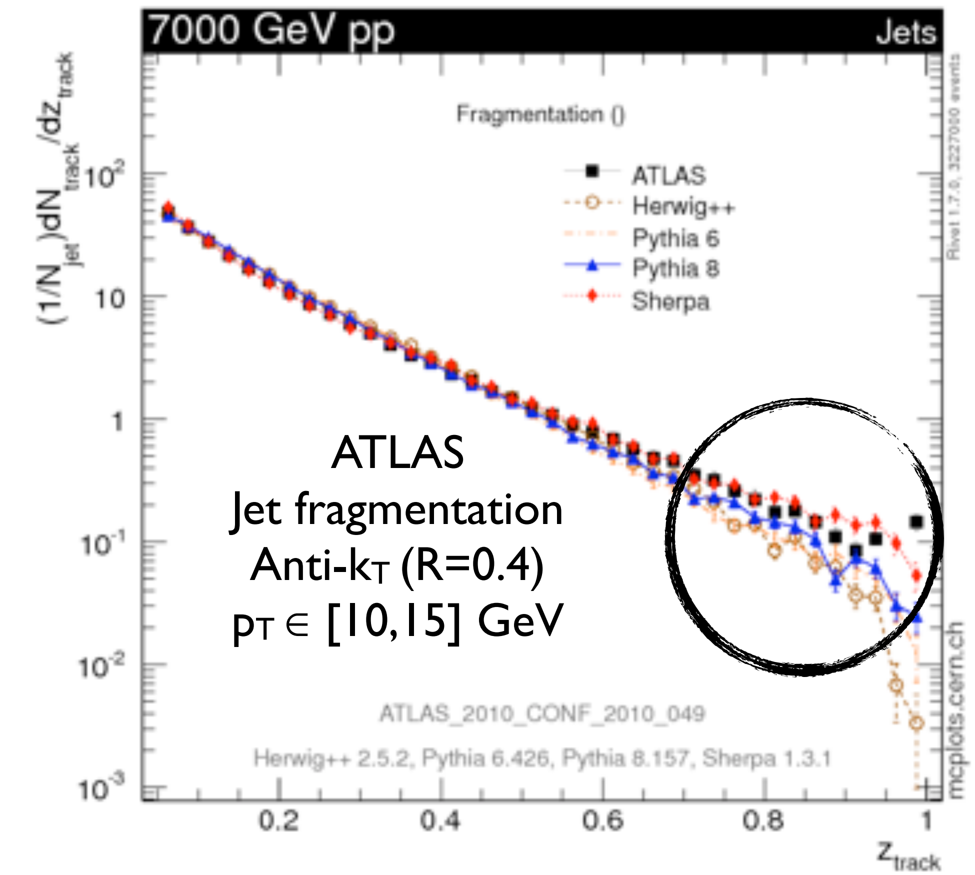

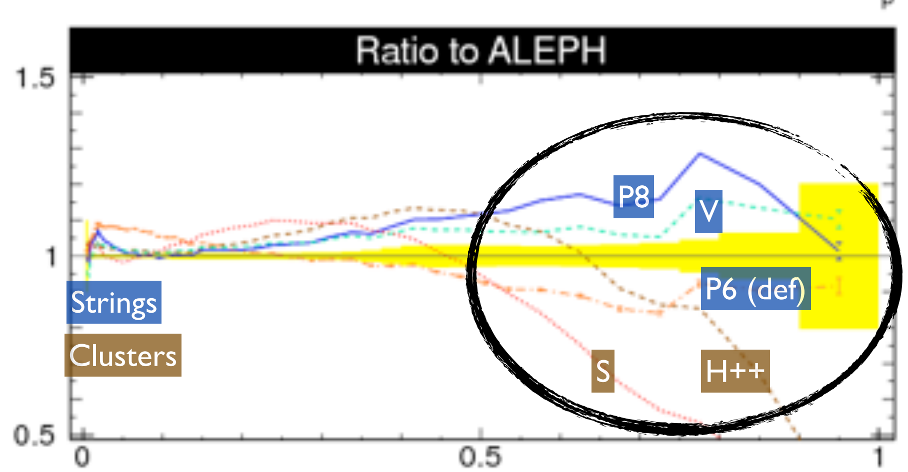

Pattern changes in pp jets

(though here only *inside* jets, and jets only at 10-15 GeV)

Needs to be studied in more detail if MC models to be used in $z \to 1$ region

Plots from mcplots.cern.ch

Pile-Up

= additional zero-bias interactions (contain more diffraction than ordinary min-bias)

Processes with *no hard scale*:

Larger uncertainties → Good UE does *not* guarantee good pile-up.

Error of 50% on a soft component → not bad.

Multiply it by 60 Pile-Up interactions → bad!

Calibration & filtering

Good at recovering jet calibration (with loss of resolution),

But missing energy and isolation sensitive to modeling.

H→WW H→γγ? (E.g., γγ studies by ATLAS, CMS, CDF, D0)

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Models

MC models so far: problems describing both MB & UE simultaneously

→ Consider using dedicated MB/diffraction model for pile-up

(UE/MB tension may be resolved in 2012 (eg. studies by R. Field), but for now must live with it)

Experimentalists advised to use unbiased data for PU (when possible)

Diffraction in PYTHIA 6

Diffractive Cross Section Formulæ:

$$\frac{d\sigma_{sd(AX)}(s)}{dt\,dM^2} = \frac{g_{3\mathbb{P}}}{16\pi}\,\beta_{A\mathbb{P}}^2\,\beta_{B\mathbb{P}}\,\frac{1}{M^2}\,\exp(B_{sd(AX)}t)\,F_{sd}\,,$$

$$\frac{d\sigma_{dd}(s)}{dt\,dM_1^2\,dM_2^2} = \frac{g_{3\mathbb{P}}^2}{16\pi}\,\beta_{A\mathbb{P}}\,\beta_{B\mathbb{P}}\,\frac{1}{M_1^2}\,\frac{1}{M_2^2}\,\exp(B_{dd}t)\,F_{dd}\,.$$

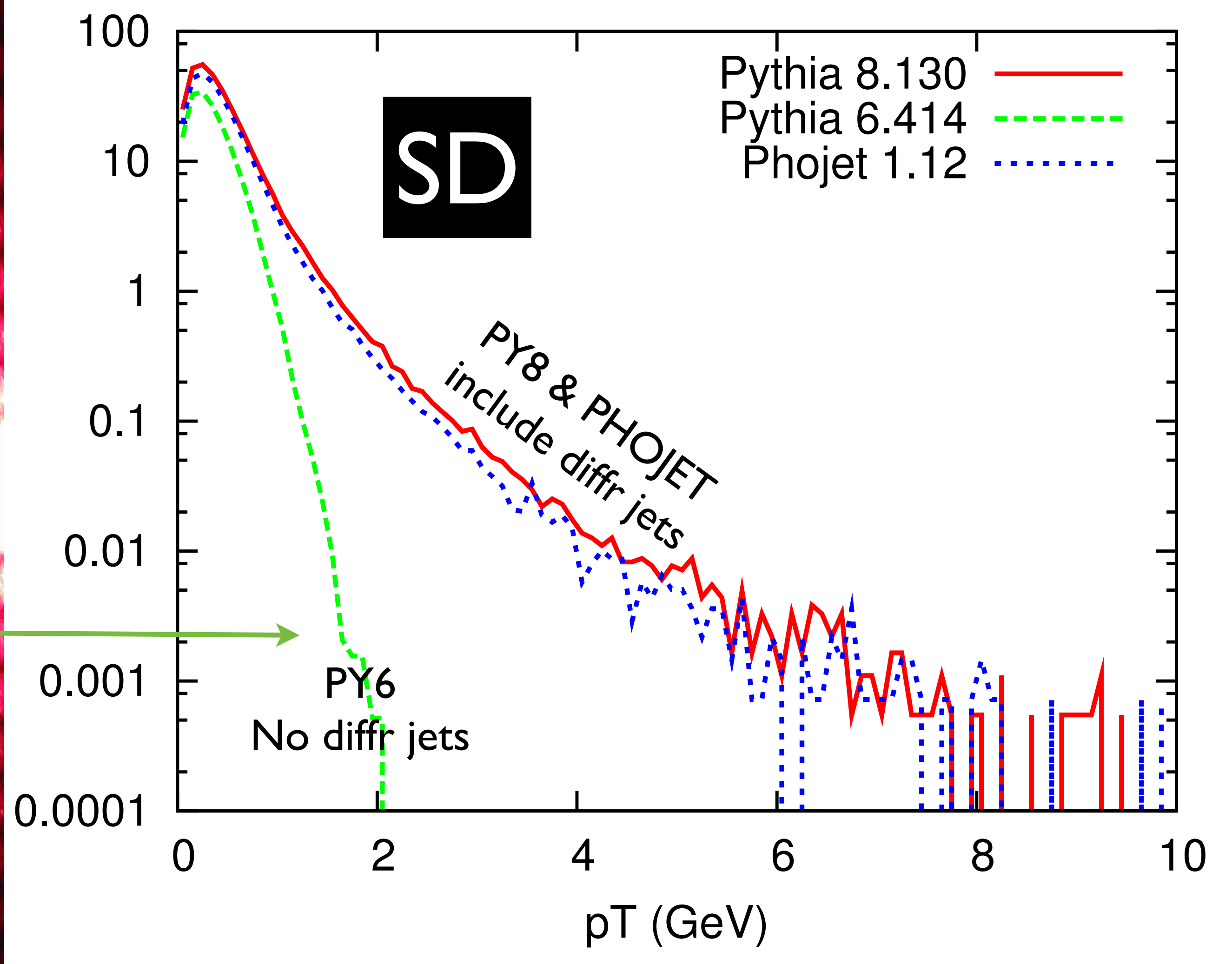
Spectra:

$2\,m_{pi} < M_D < 1$ GeV: 2-body decay

$M_D > 1$ GeV : string fragmentation

Partonic Substructure in Pomeron:

Only in POMPYT addon (P. Bruni, A. Edin, G. Ingelman) ▶ high-p_T "jetty" diffraction absent



Very soft spectra without POMPYT

Status: Supported, but not actively developed

Diffraction in PYTHIA 8

Navin, arXiv:1005.3894

Diffractive Cross Section Formulæ:

$$\frac{d\sigma_{sd(AX)}(s)}{dt\, dM^2} = \frac{g_{3\mathbb{P}}}{16\pi}\, \beta_{A\mathbb{P}}^2\, \beta_{B\mathbb{P}}\, \frac{1}{M^2}\, \exp(B_{sd(AX)}t)\, F_{sd} \,,$$

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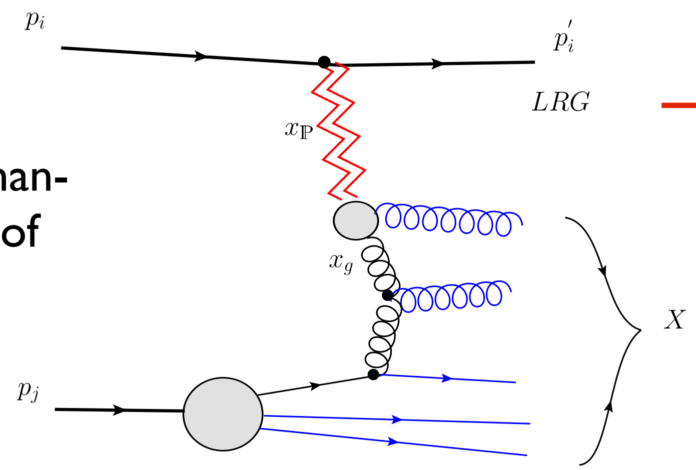
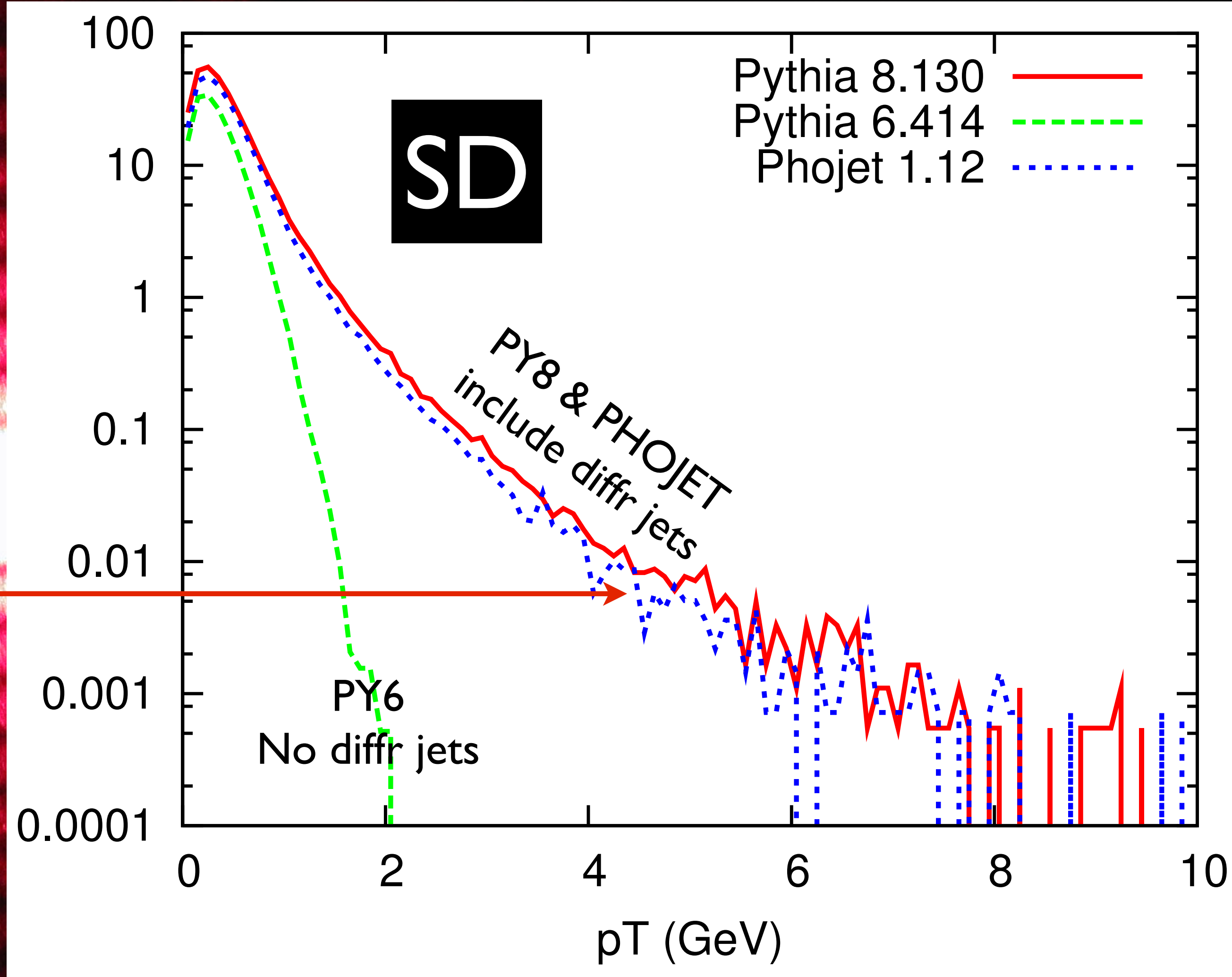
Partonic Substructure in Pomeron:

Follows the Ingelman-Schlein approach of Pompyt





PYTHIA 8

- $M_X \leq 10\,\text{GeV}$: original longitudinal string description used
- $M_X > 10\,\text{GeV}$: new perturbative description used (incl full MPI+showers for $\mathbb{P}$p system)

Choice between 5 Pomeron PDFs. Free parameter $\sigma_{\mathbb{P}p}$ needed to fix $\langle n_{\text{interactions}}\rangle = \sigma_{\text{jet}}/\sigma_{\mathbb{P}p}$.

Framework needs testing and tuning, e.g. of $\sigma_{\mathbb{P}p}$.

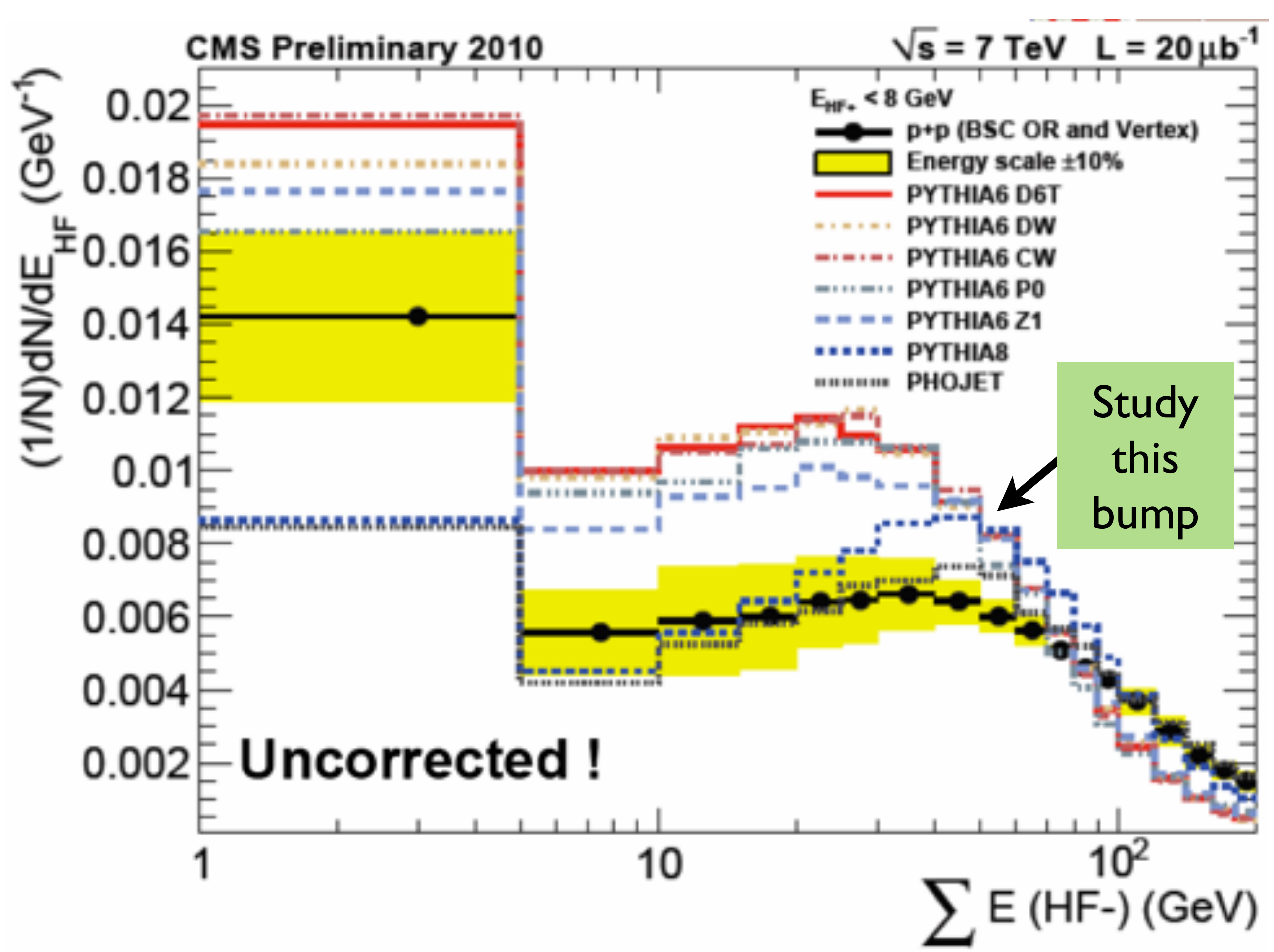
Diffraction

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?



+ Little experience with new PYTHIA 8 MPI component in high-mass diffractive events

→ This component especially needs testing and tuning

E.g., look at n_{ch} and p_T spectra in high-mass (>10GeV) diffraction

(Not important for UE as such, but **can be important if using PYTHIA to simulate pile-up!)**

$\sigma_{\mathbb{P}p}$ determines level of UE in high-mass diffraction through <n_{MPI}> $= \sigma_{jet}/\sigma_{\mathbb{P}p}$. (Larger $\sigma_{\mathbb{P}p}$ → smaller UE)

Summary

<u>Recommended for PYTHIA 6:</u>
Global: "Perugia 2011" (MSTP(5)=350)
+ Perugia Variations
+ LHC MB: "AMBT1" (MSTP(5)=340)
+ LHC UE "Z1" (MSTP(5)=341)

Summary

PYTHIA6 is winding down

- Supported but not developed
- Still main option for current run (sigh)
- *But not after long shutdown 2013!*

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PYTHIA8 is the natural successor

Already several improvements over PYTHIA6 on soft physics

(including modern range of PDFs (CTEQ6, LO*, etc) in standalone version)

Though still a few things not yet carried over (such as *ep*, some SUSY, etc)

If you want new features (e.g., x-dependent proton size, rescattering, ψ', hard diffraction, interfaces to CKKW-L, POWHEG, MadGraph-5, VINCIA, …) then be prepared to use PYTHIA 8

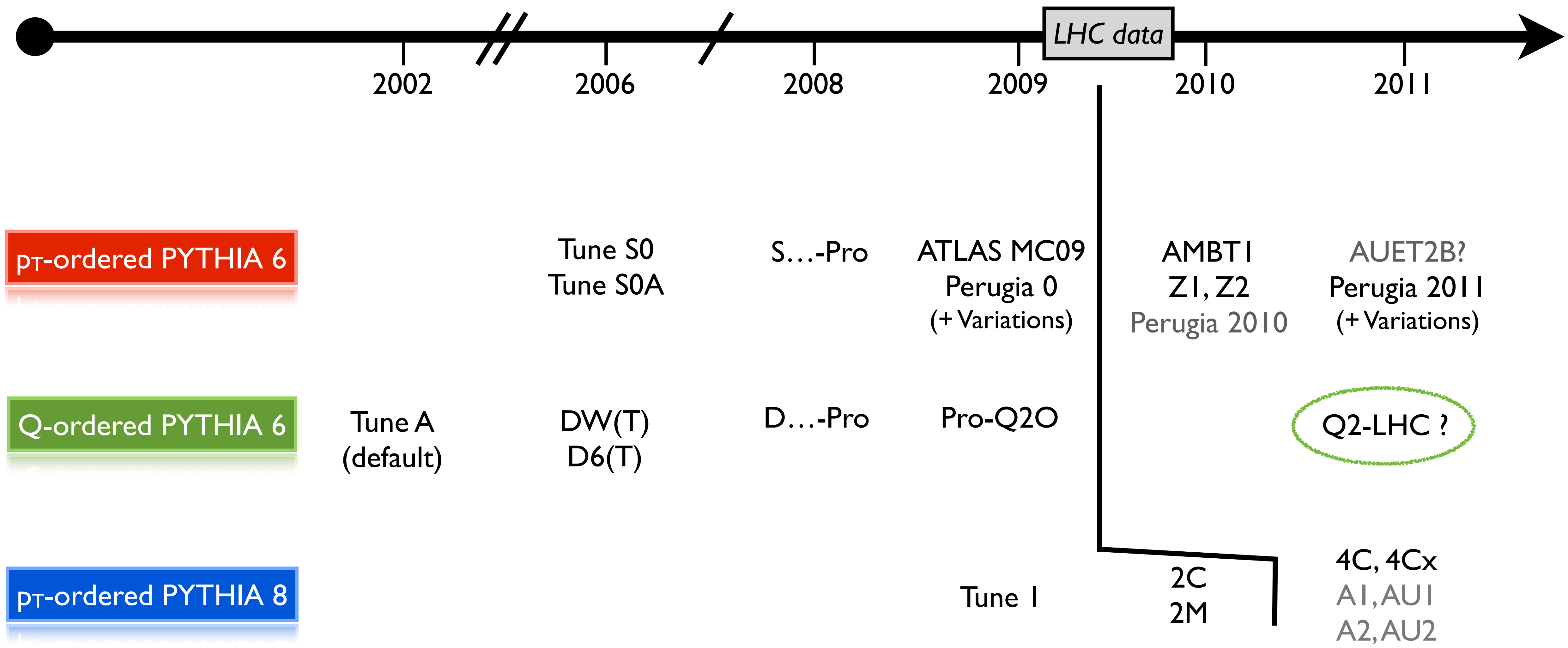
Provide Feedback, both what works and what does not

Do your own tunes to data and tell outcome

Recommended for PYTHIA 8:
"Tune 4C" (Tune:pp = 5)

Backup Slides

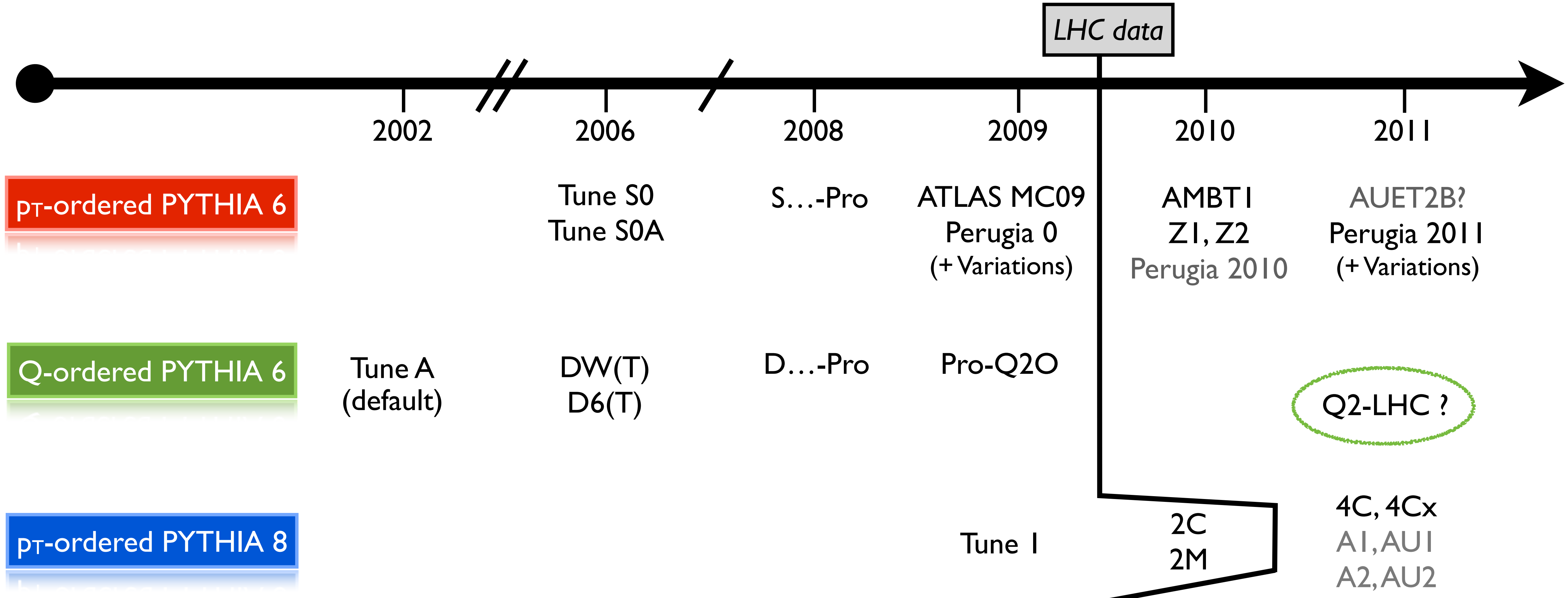
PYTHIA Models



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								✔	✔		✔

Interfaces to External MEs (POWHEG/SCALUP)

Slide from T. Sjöstrand, TH-LPCC workshop, August 2011, CERN

Standard Les Houches interface (LHA, LHEF) specifies startup scale `SCALUP` for showers, so "trivial" to interface any external program, including POWHEG.
Problem: for ISR

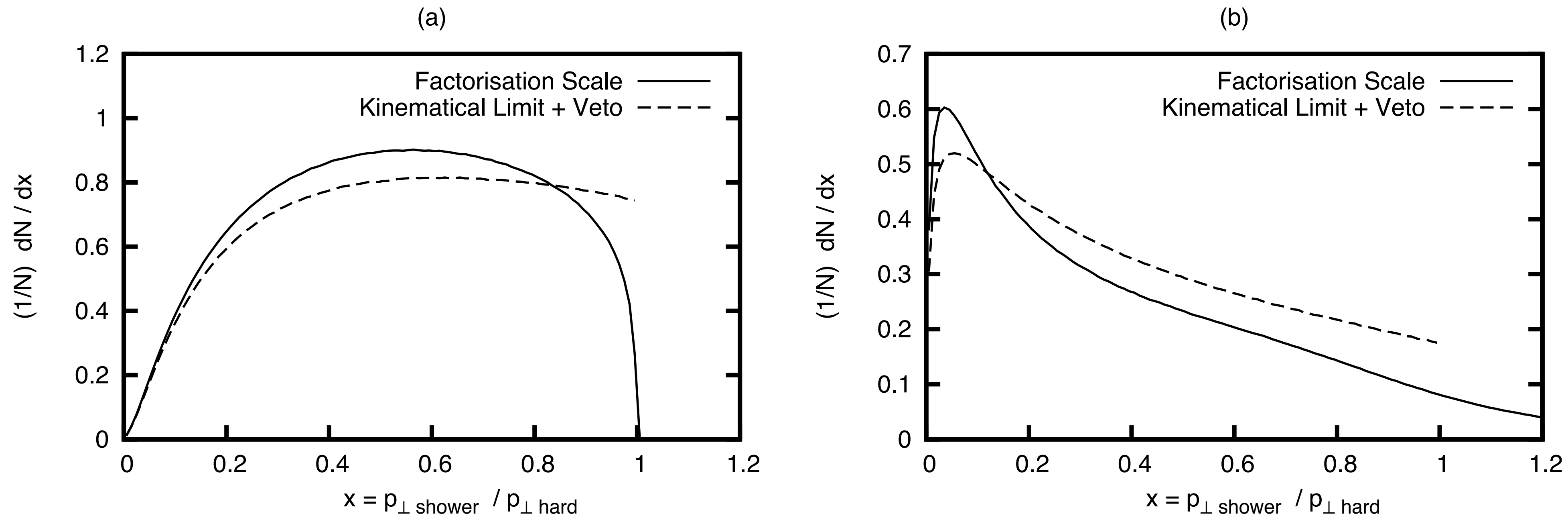
$$p_\perp^2 = \mathrm{p}_{\perp\mathrm{evol}}^2 - \frac{\mathrm{p}_{\perp\mathrm{evol}}^4}{p_{\perp\mathrm{evol,max}}^2}$$

$\int d\Phi_r \frac{R(v,r)}{B(v)} \theta(k_\mathrm{T}(v,r) - p_\mathrm{T})$

not needed if shower ordered in p_T?

i.e. $p_\perp$ decreases for $\theta^* > 90^\circ$ but $\mathrm{p}_{\perp\mathrm{evol}}$ monotonously increasing.

Solution: run "power" shower but kill emissions above the hardest one, by POWHEG's definition.



Available for ISR-dominated, coming for QCD jets with FSR issues.

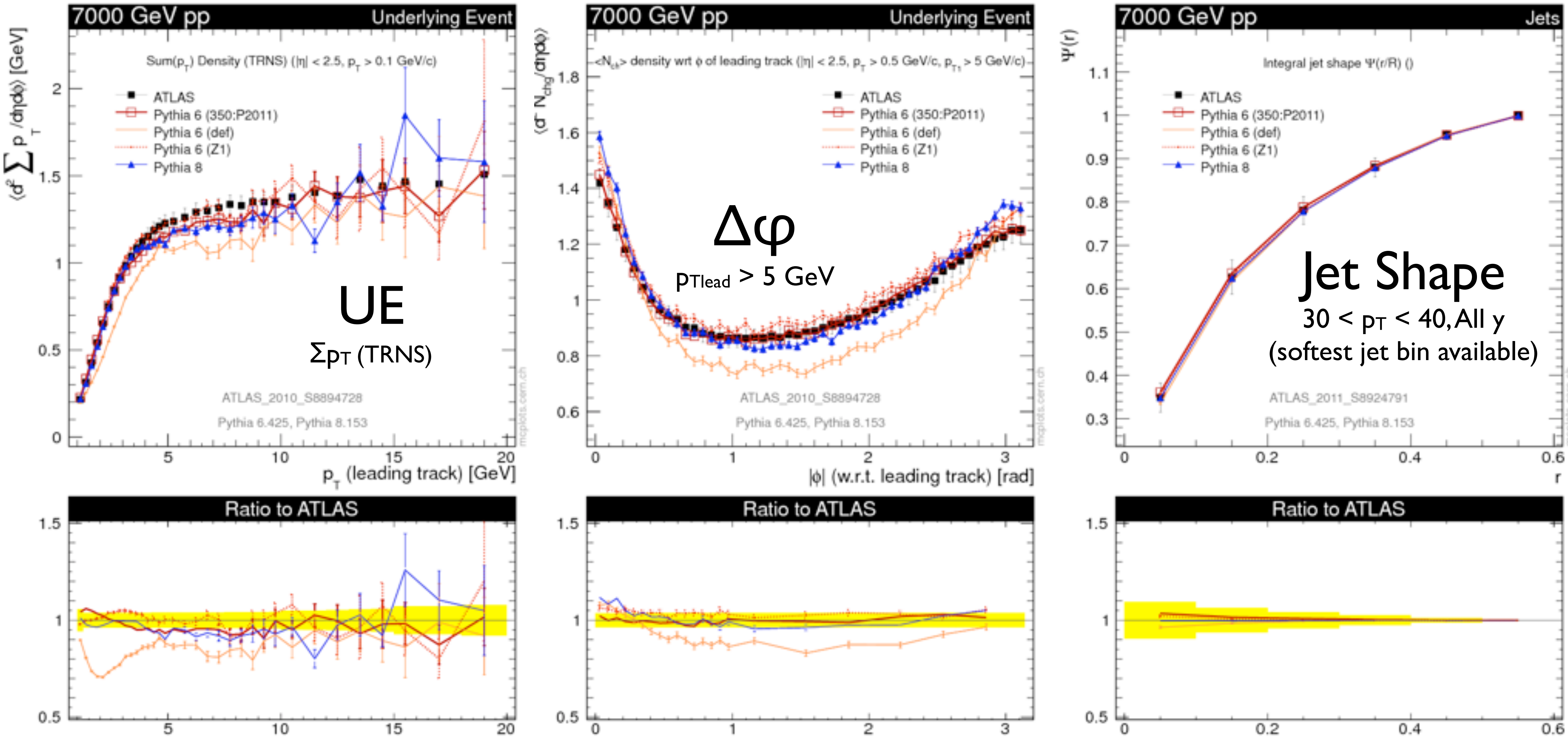
in PYTHIA 8

Note: Other things that may differ in comparisons: PDFs (NLO vs LO), Scale Choices

What Works*

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

Underlying Event & Jet Shapes



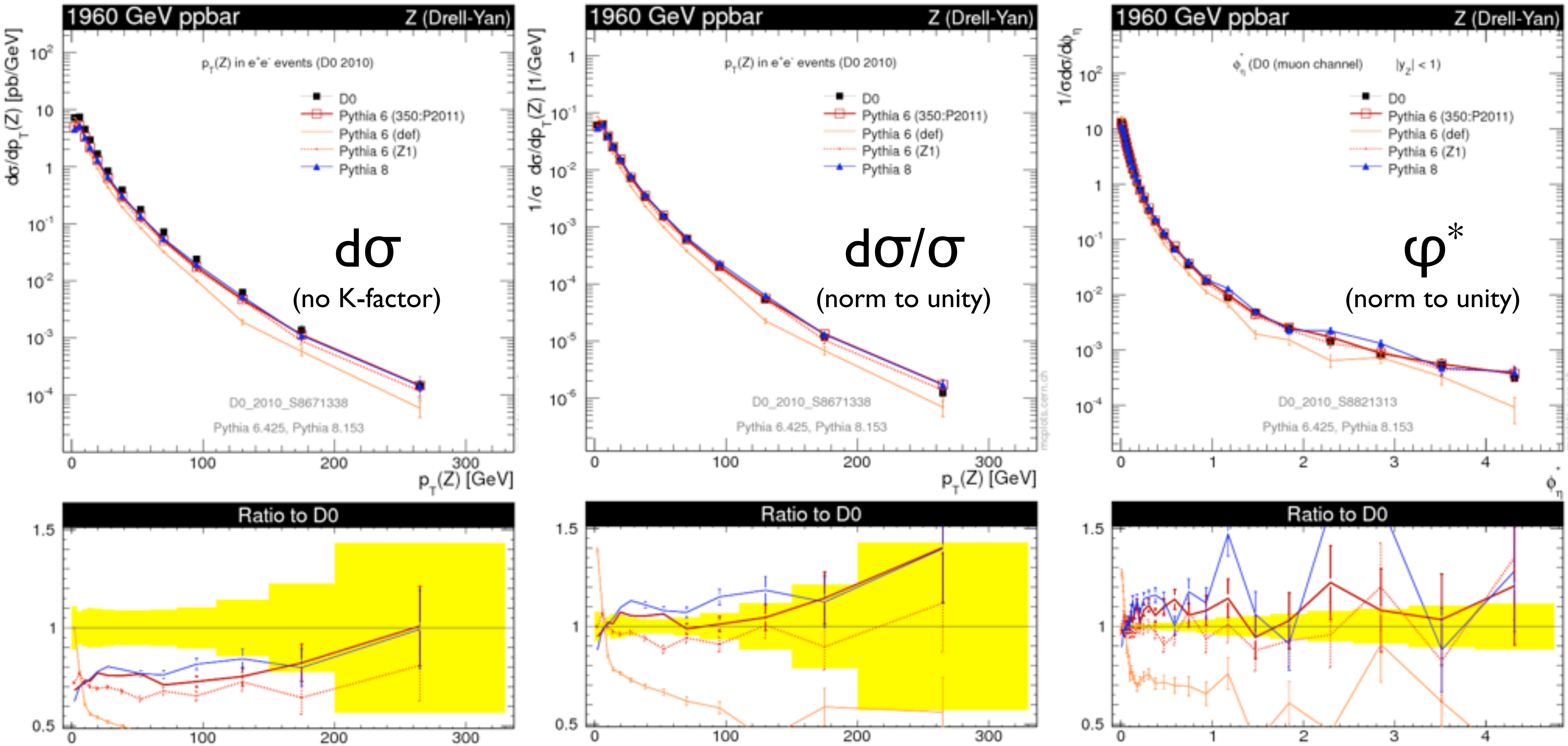
PS: yes, we **should** update the PYTHIA 6 defaults ...

What Works*

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

Drell-Yan pT (Normalized to Unity)

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



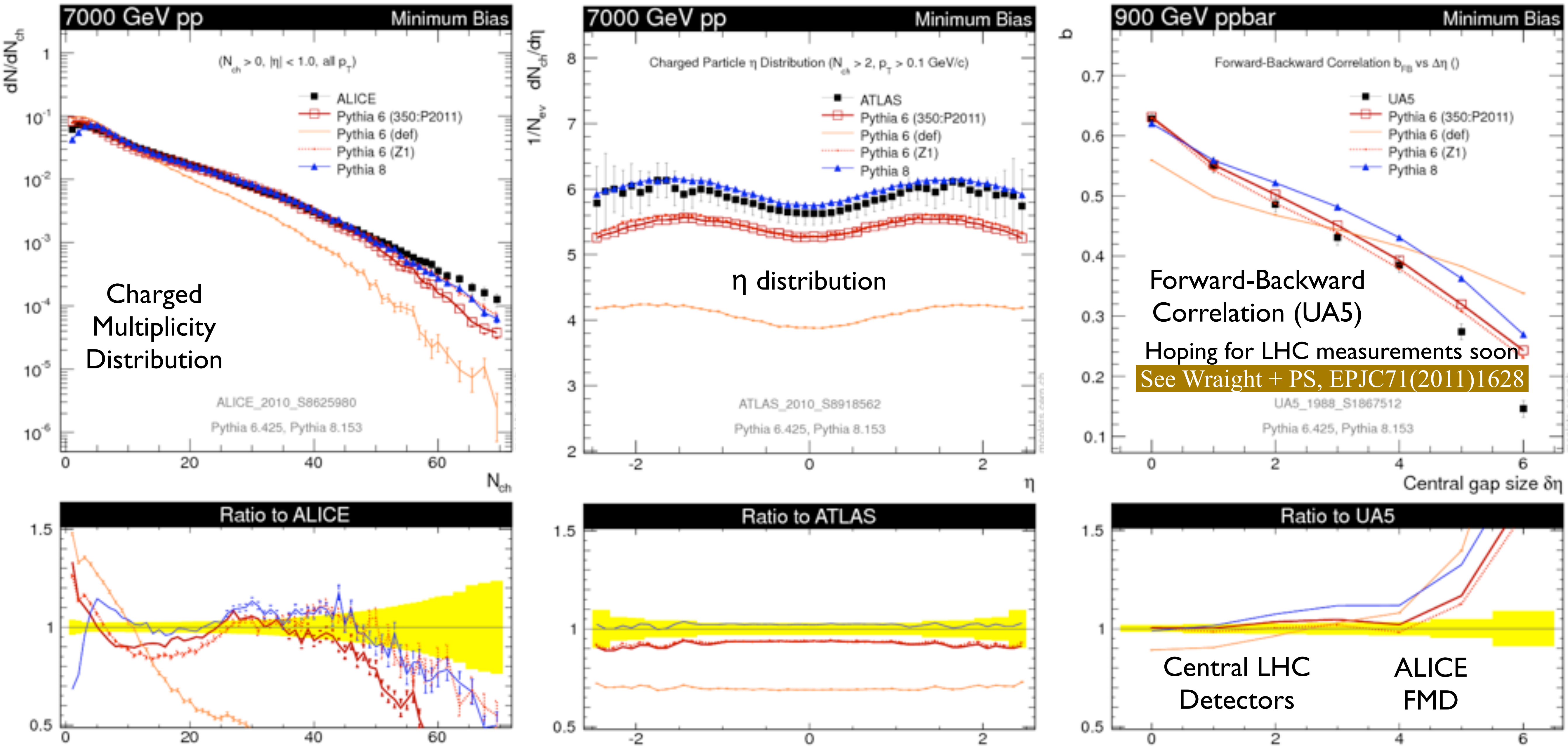
PS: yes, we **should** update the PYTHIA 6 defaults ...

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

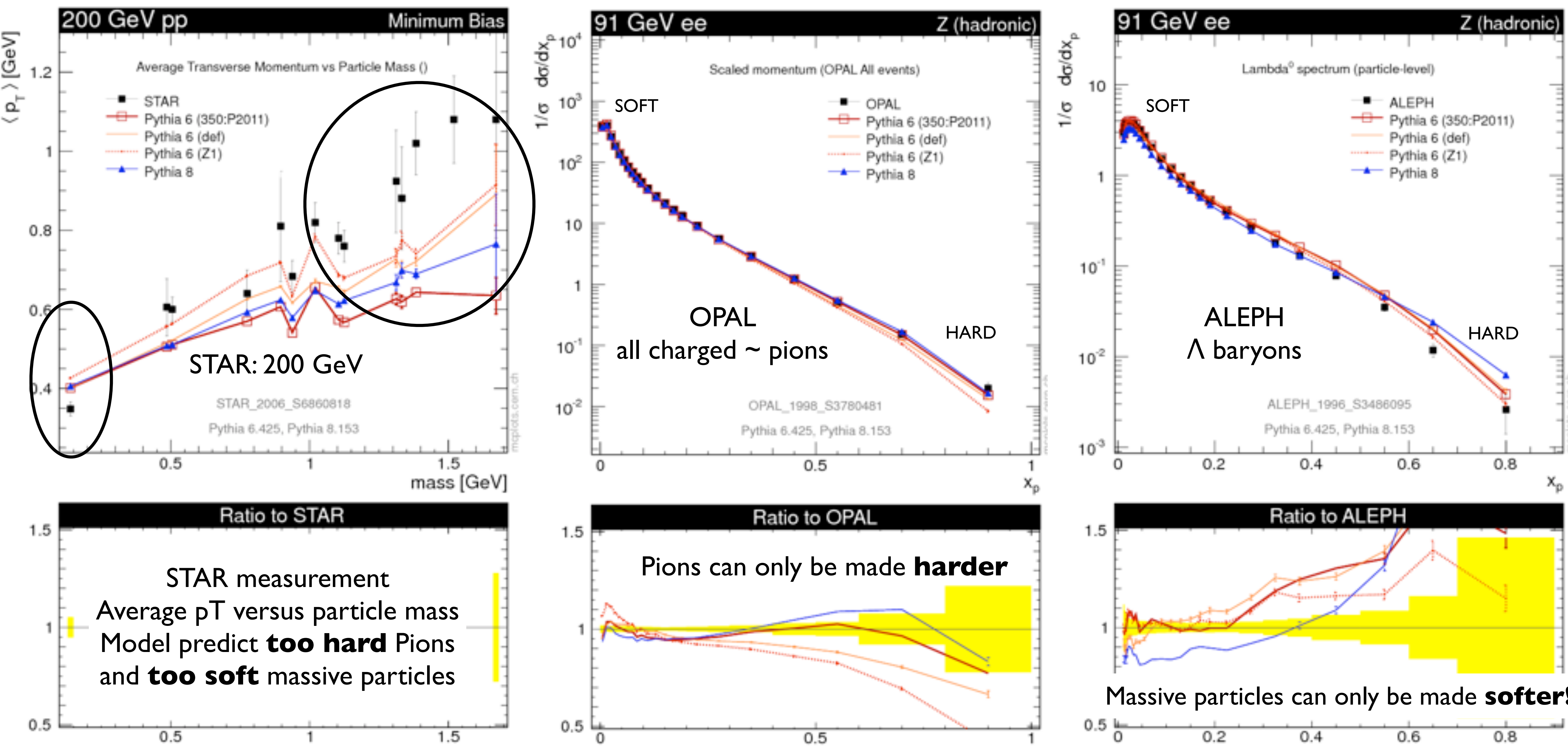
(here showing as inclusive as possible)



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

pT Spectra / Mass Dependence

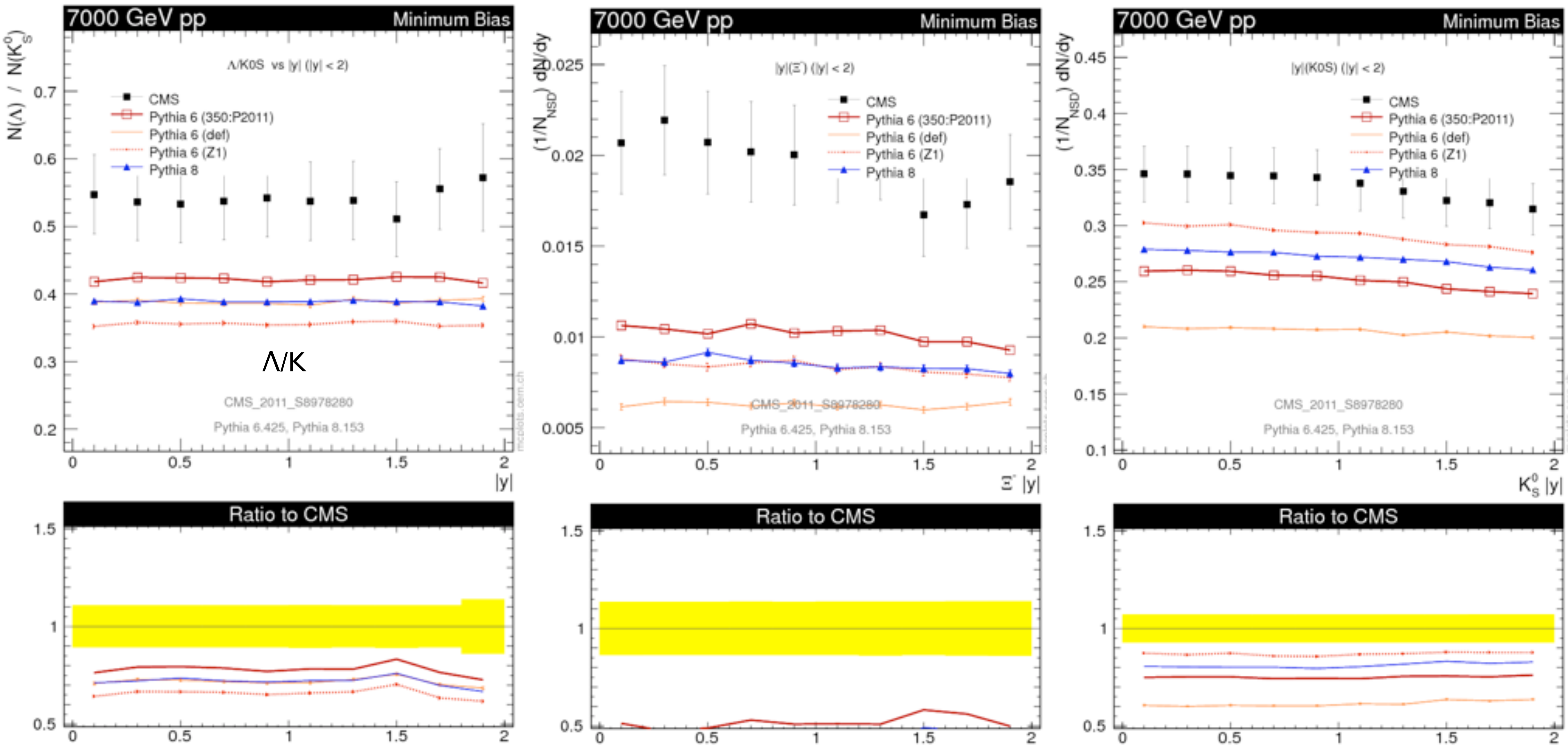
Must be compared with LEP



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

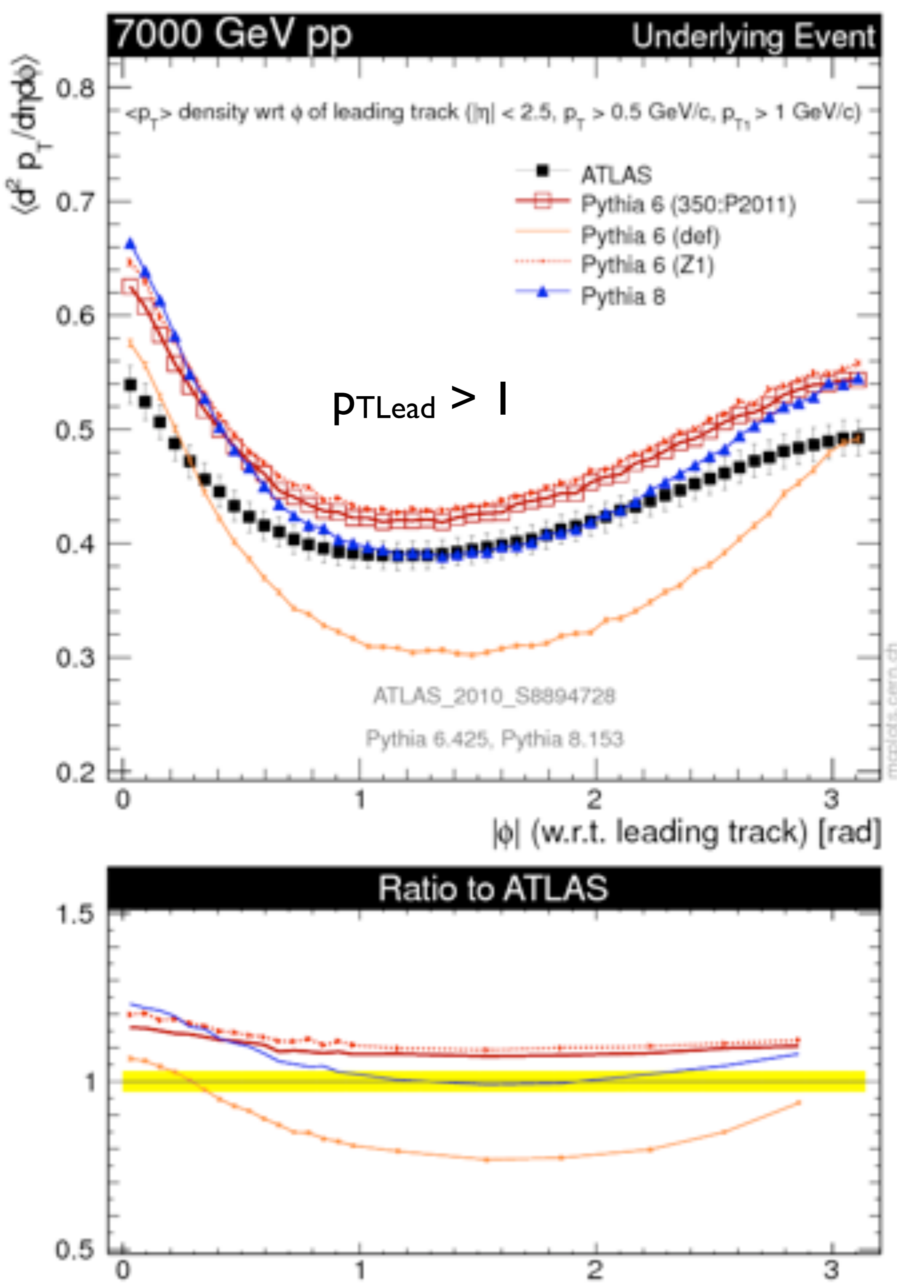
Strangeness and Baryons

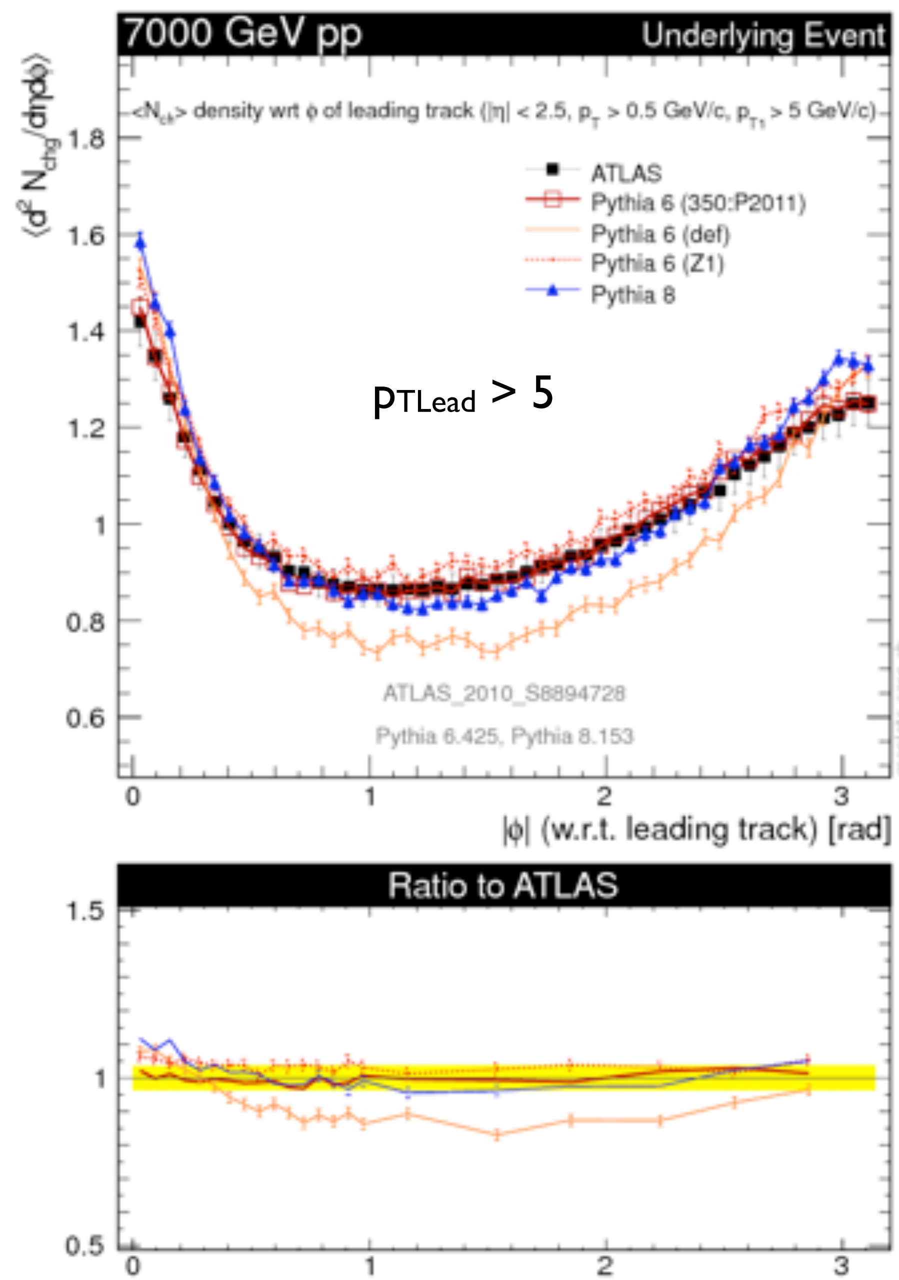
Tried to learn from early data, but still not there …



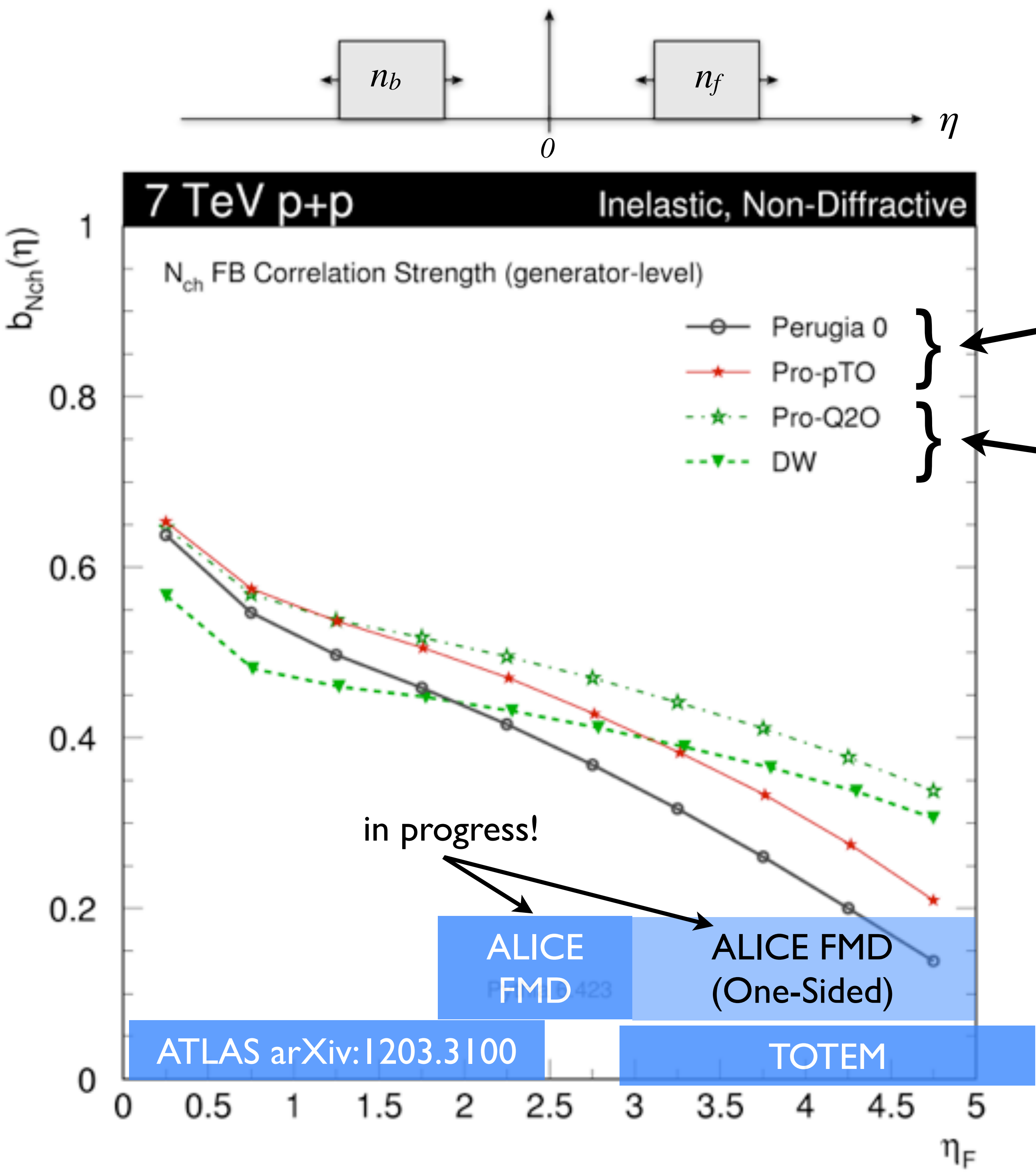
Again, quite difficult to adjust flavor parameters while remaining within LEP bounds …

Very Soft Structure





Forward-Backward Correlation



$$b = \frac{\sigma(n_b, n_f)}{\sigma(n_b)\sigma(n_f)} = \frac{\langle n_b n_f \rangle - \langle n_f \rangle^2}{\langle n_f^2 \rangle - \langle n_f \rangle^2}$$

Few MPI (each gives more multiplicity)
→ **Low** long-distance Correlations

Lots of MPI (each gives little multiplicity)
→ **High** long-distance Correlations

Note: must use **multiplicity distribution** as cross-check

Diffraction → uncorrelated fluctuations
→ expect to see higher correlation in diff-suppressed samples than in diff-enhanced ones
(e.g., by placing cuts on number of central tracks?)

Additional plots in P.S., arXiv:0803.0678 ;
Wraight & P.S.: EPJ C71 (2011) 1628 ;
ATLAS arXiv: 1203.3100 [hep-ex]

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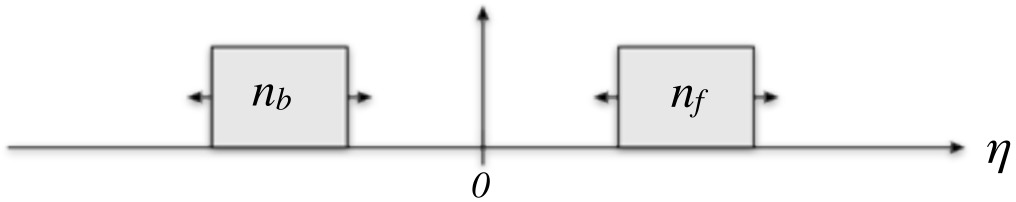

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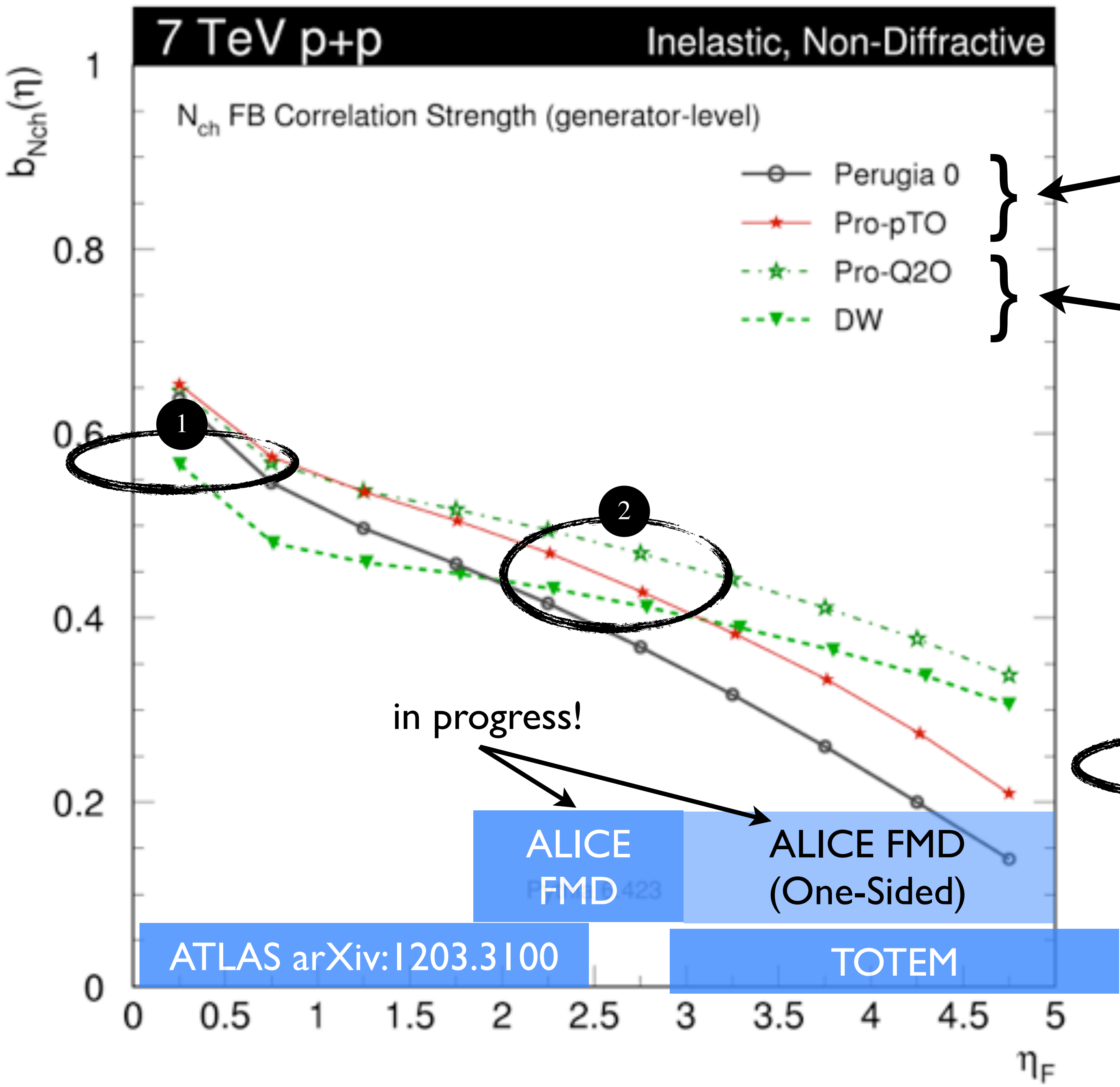

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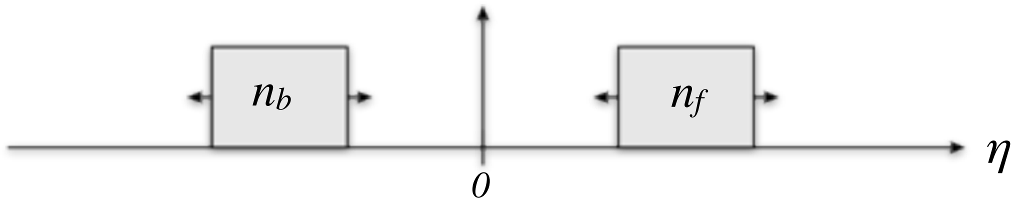

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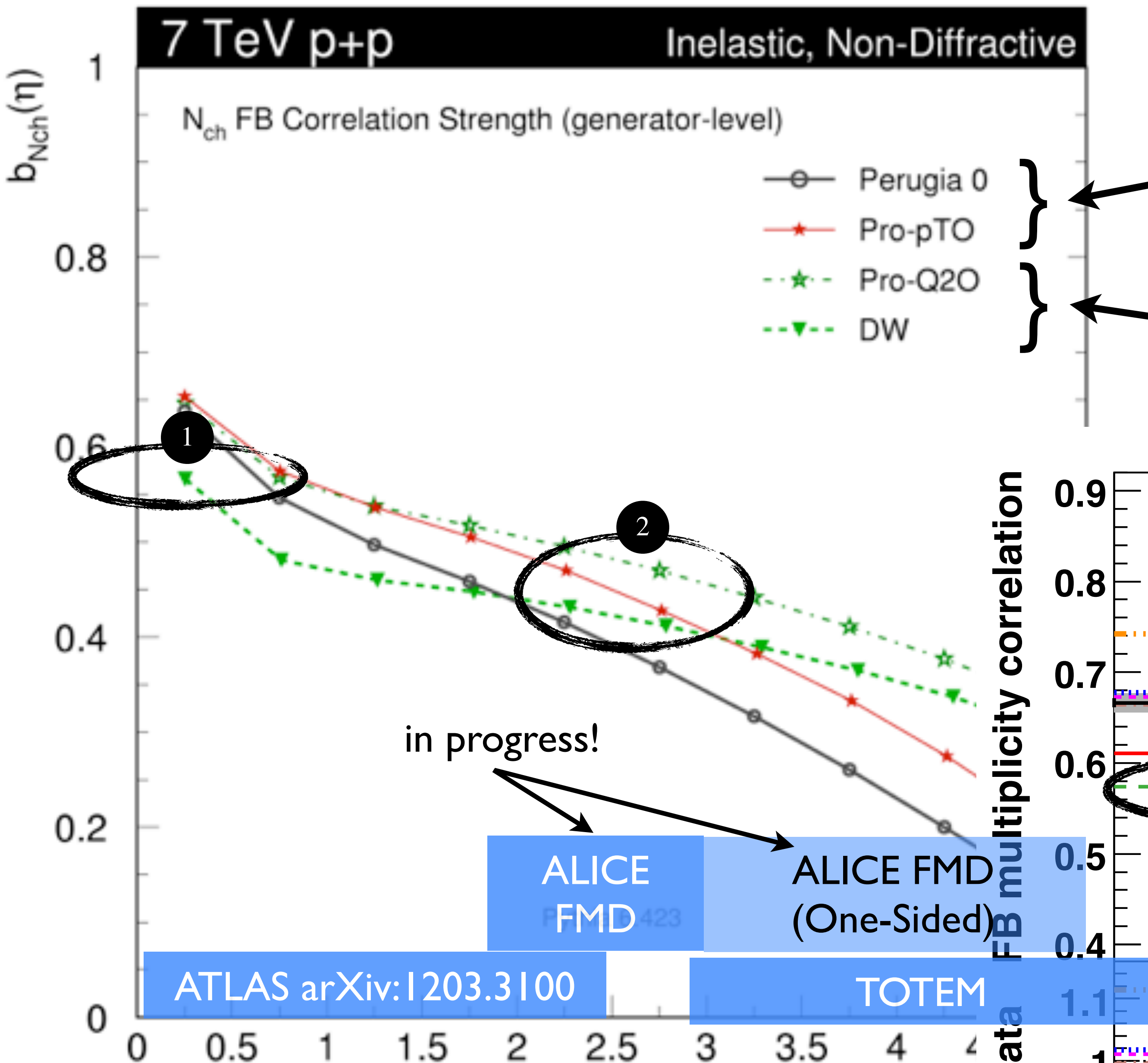

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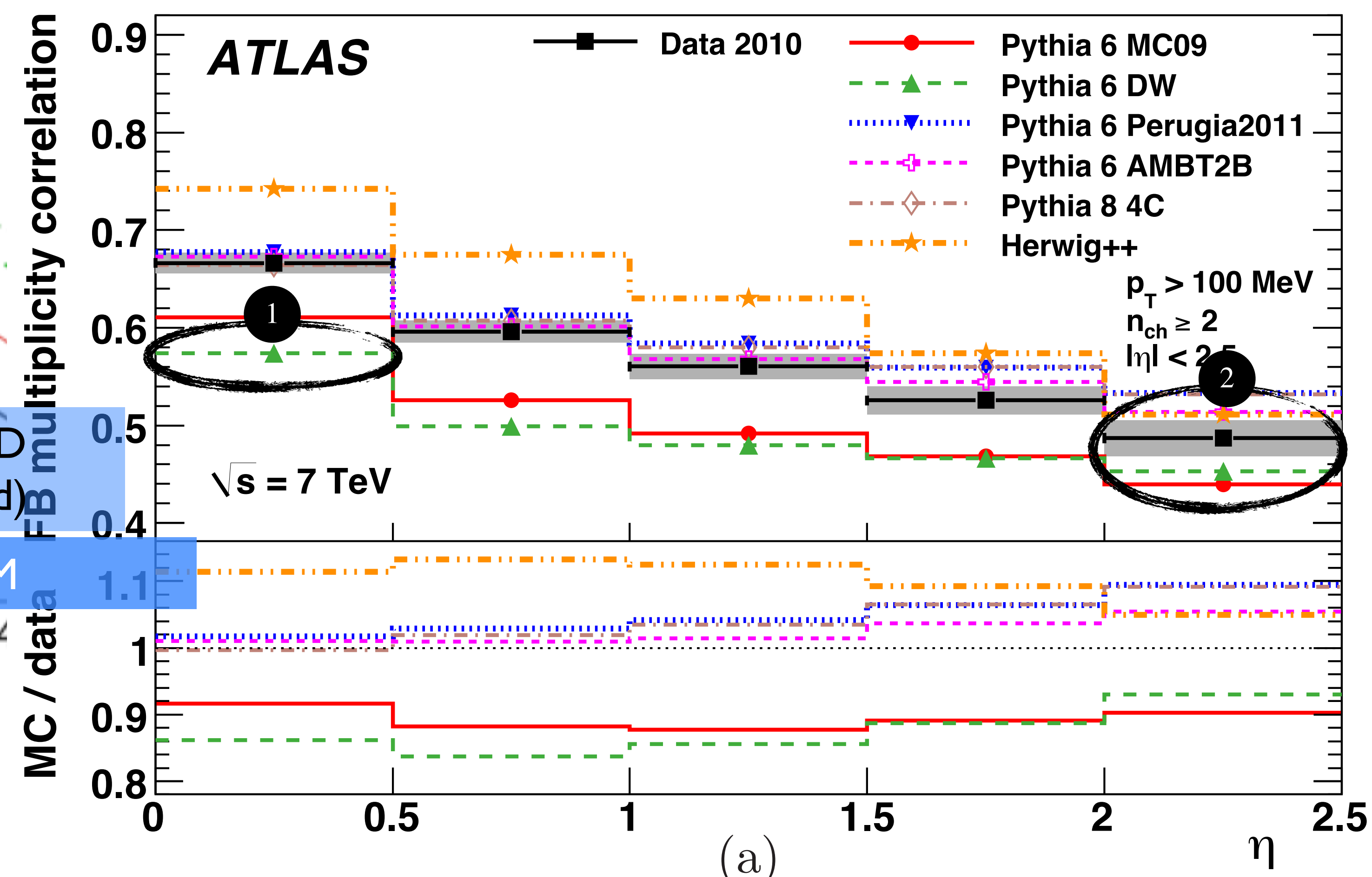

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