Measurement of Hadron Production in DIS

on behalf of the H1 Collaboration

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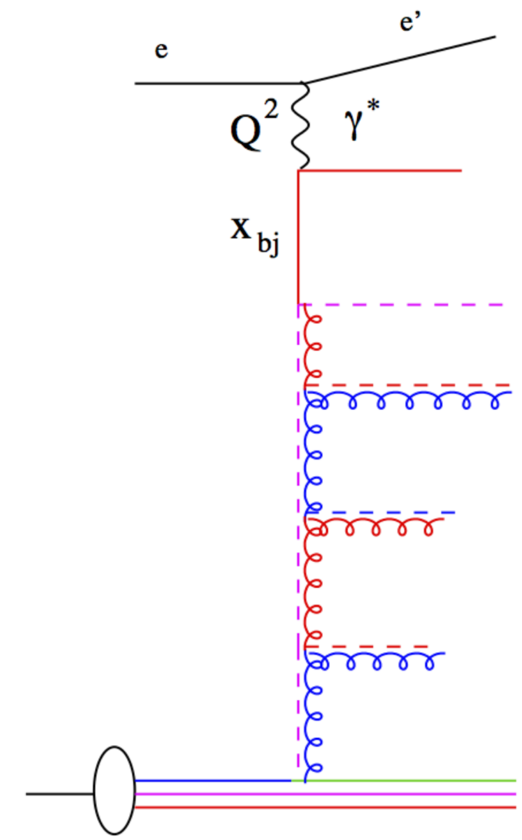
- inclusive charged particle spectra in DIS
- strange particle spectra in DIS
- comparison to pp

Introduction

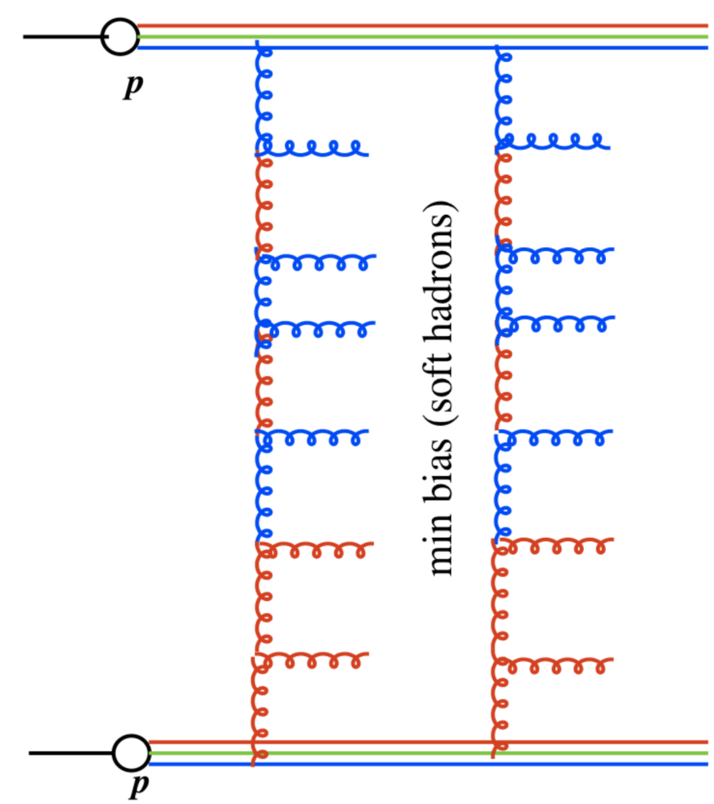
- measurement of hadron production in DIS constrain
  - at small p_t:

    hadronization parameters, also for strange particles
  - at large p_t:

    parton evolution



- measurement of hadron production in pp constrain
  - hadronization
  - but also multiparton interaction and UE parameters

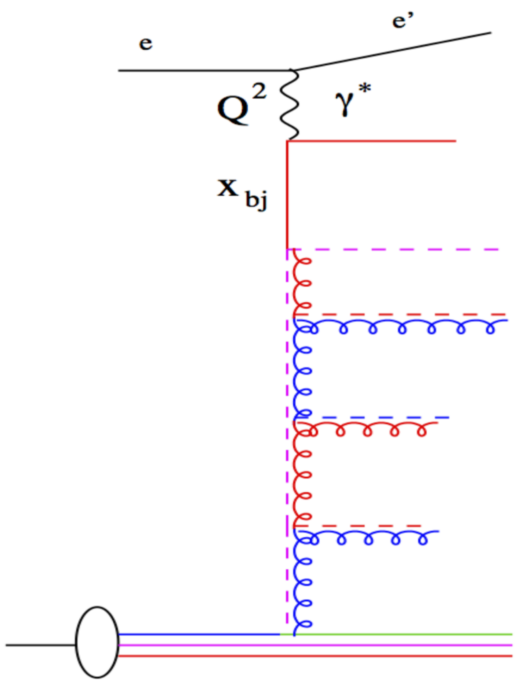


Charged particle spectra in DIS

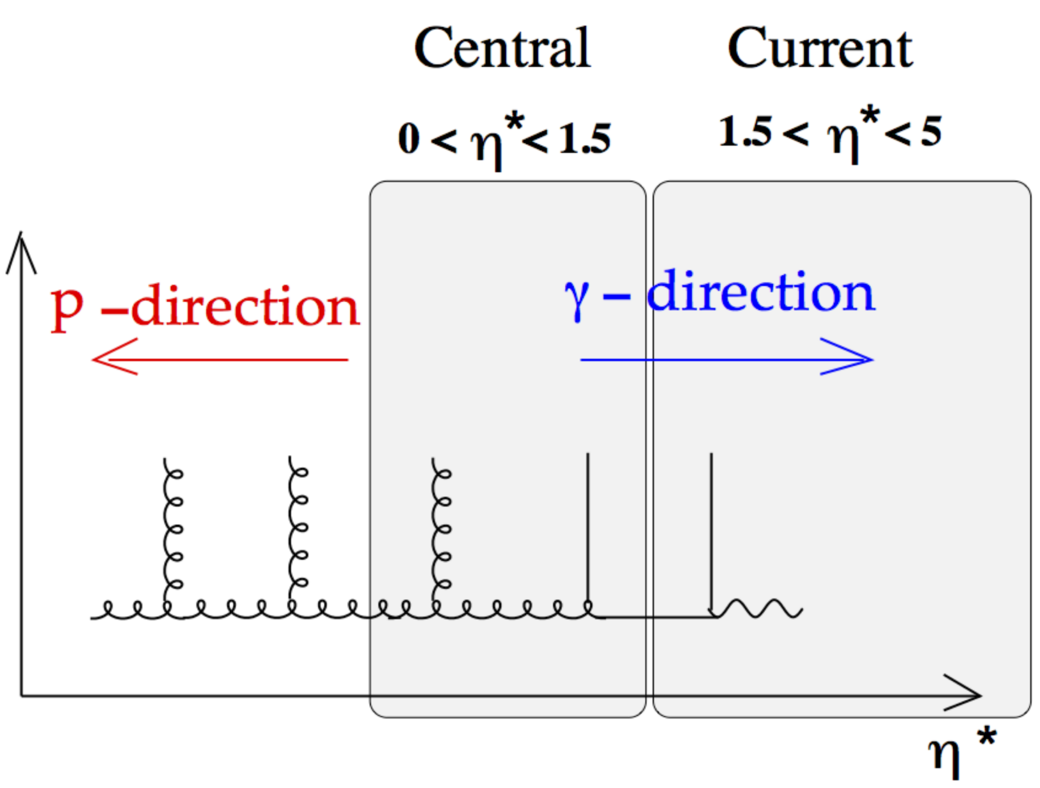
- kinematic range: $ep \to e'X$

  $e : 26.7\ \mathrm{GeV};\ p : 920\ \mathrm{GeV};\ \sqrt{s} = 319\ \mathrm{GeV}$

$$\begin{array}{rcl} 5 < & Q^2 & < 100\ \mathrm{GeV} \\ 0.05 < & y & < 0.6 \\ 0.0001 < & x_{bj} & < 0.01 \end{array}$$



- tracks -2 < η < 2.5, p_t > 0.150 (0.5) GeV in lab-frame
- measurement in hadronic center-of-mass frame:
  - η^* and $p_t{}^*$
    - ➔ η^* < 0: target (p-remnant) hemisphere
    - ➔ η^* > 0: γ - hemisphere
      - central: 0 < η^* < 1.5
      - current: 1.5 < η^* < 5



Charged particle spectra in DIS

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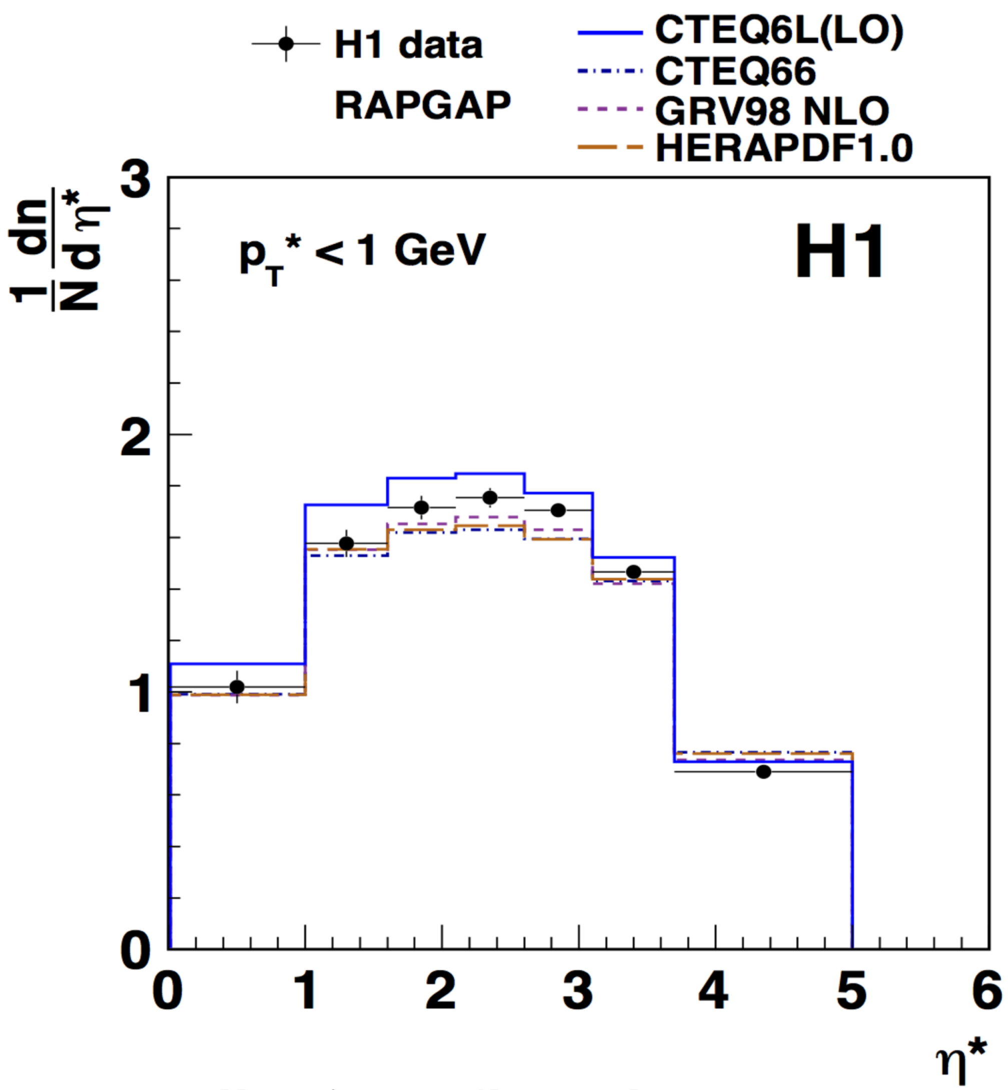

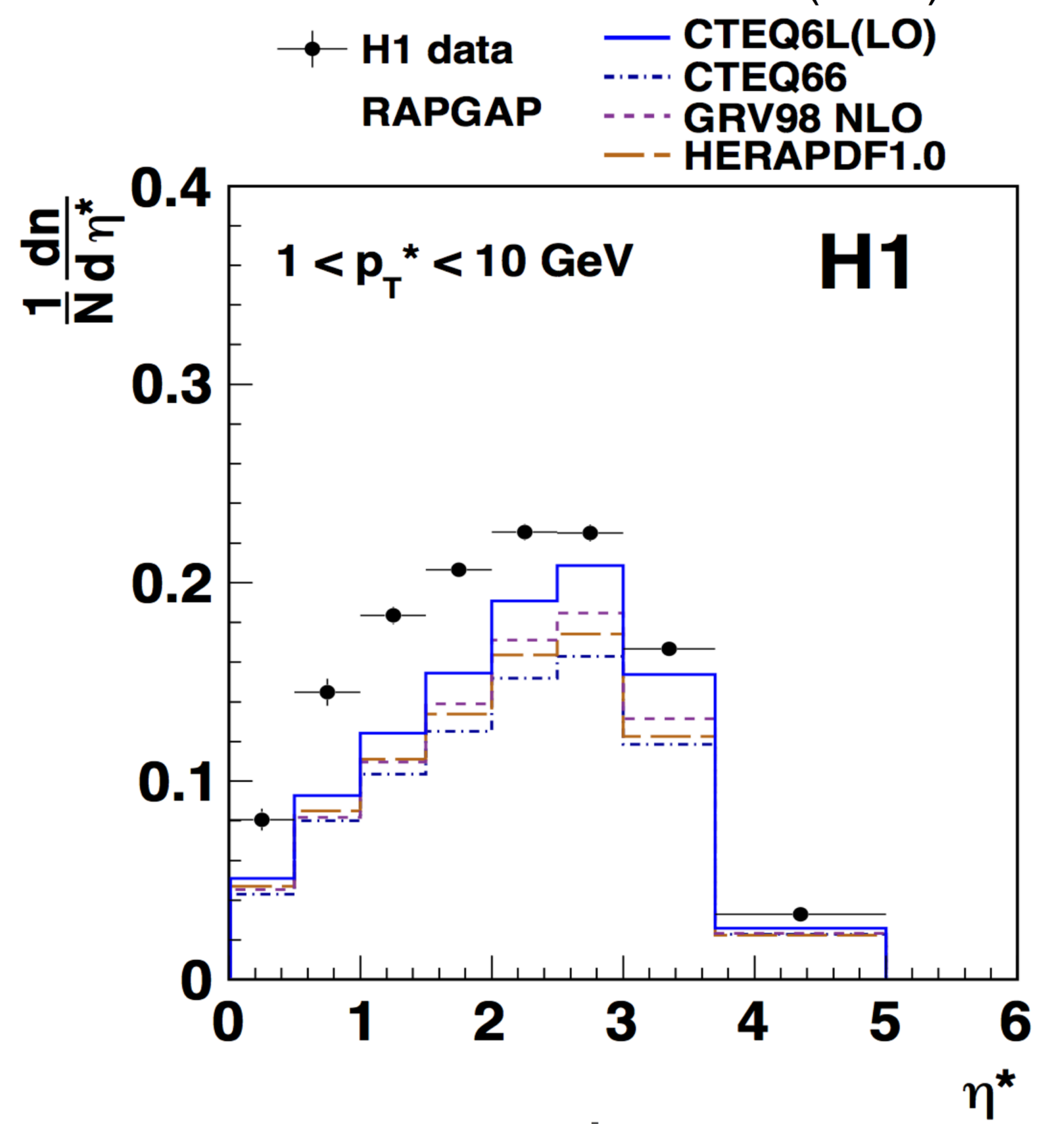

- at small p_t^* : ~ flat plateau
  - ➔ hadronization → described by MC
- at large p_t^* : rising towards photon (hard scale)
  - ➔ parton shower cascade → not described by MC

➔ small dependence on parton densities

- systematics:
  - ➔ dominant is model uncertainty for correction : 0.2 % – 5.5 %
  - ➔ total systematic: < 2.5 % for most bins

Charged particle spectra in DIS

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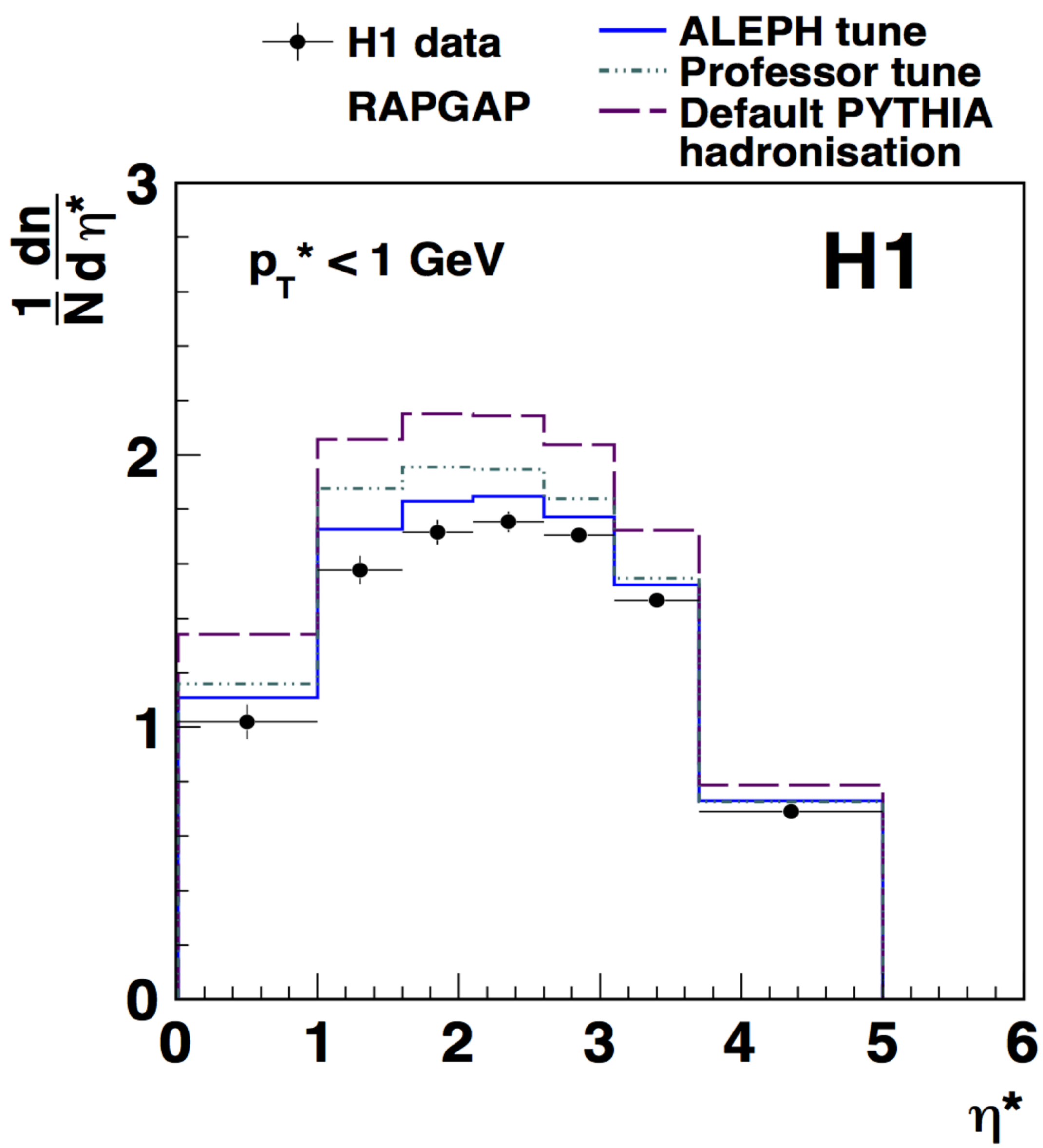

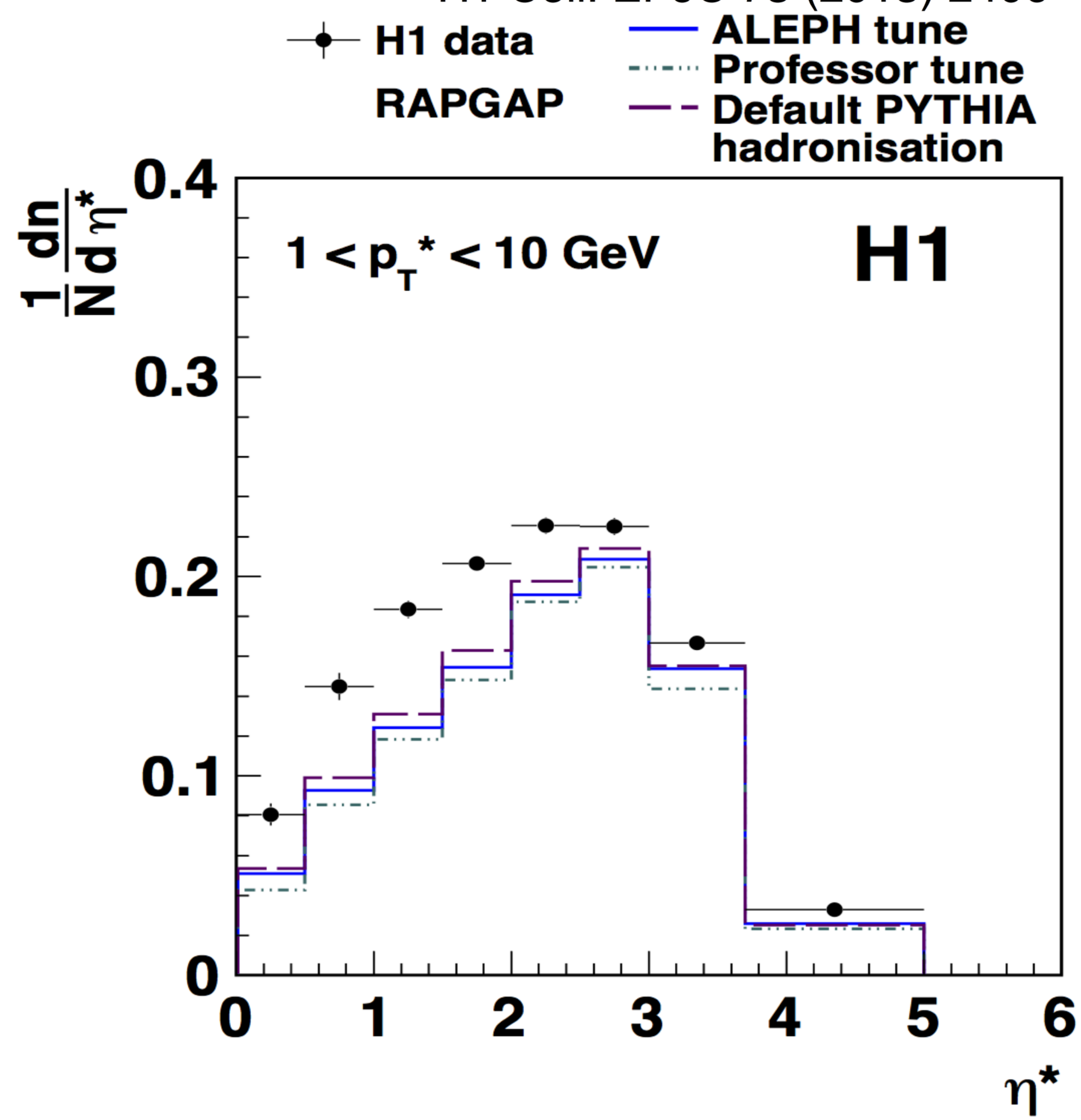

- dependence on hadronization parameters
  - at small p_t^*:
    hadronization is important: sensitivity to tune
  - at large p_t^*:
    hadronization plays little role

Charged particle spectra in DIS

- dependence on parton shower model:
  - RAPGAP: virtuality ordered collinear PS (a la PYTHIA/LEPTO)
  - DJANGOH: PS from Color Dipole Model (ARIADNE)
  - HERWIG++: angular ordered collinear PS
  - CASCADE: angular ordered small-x improved CCFM PS

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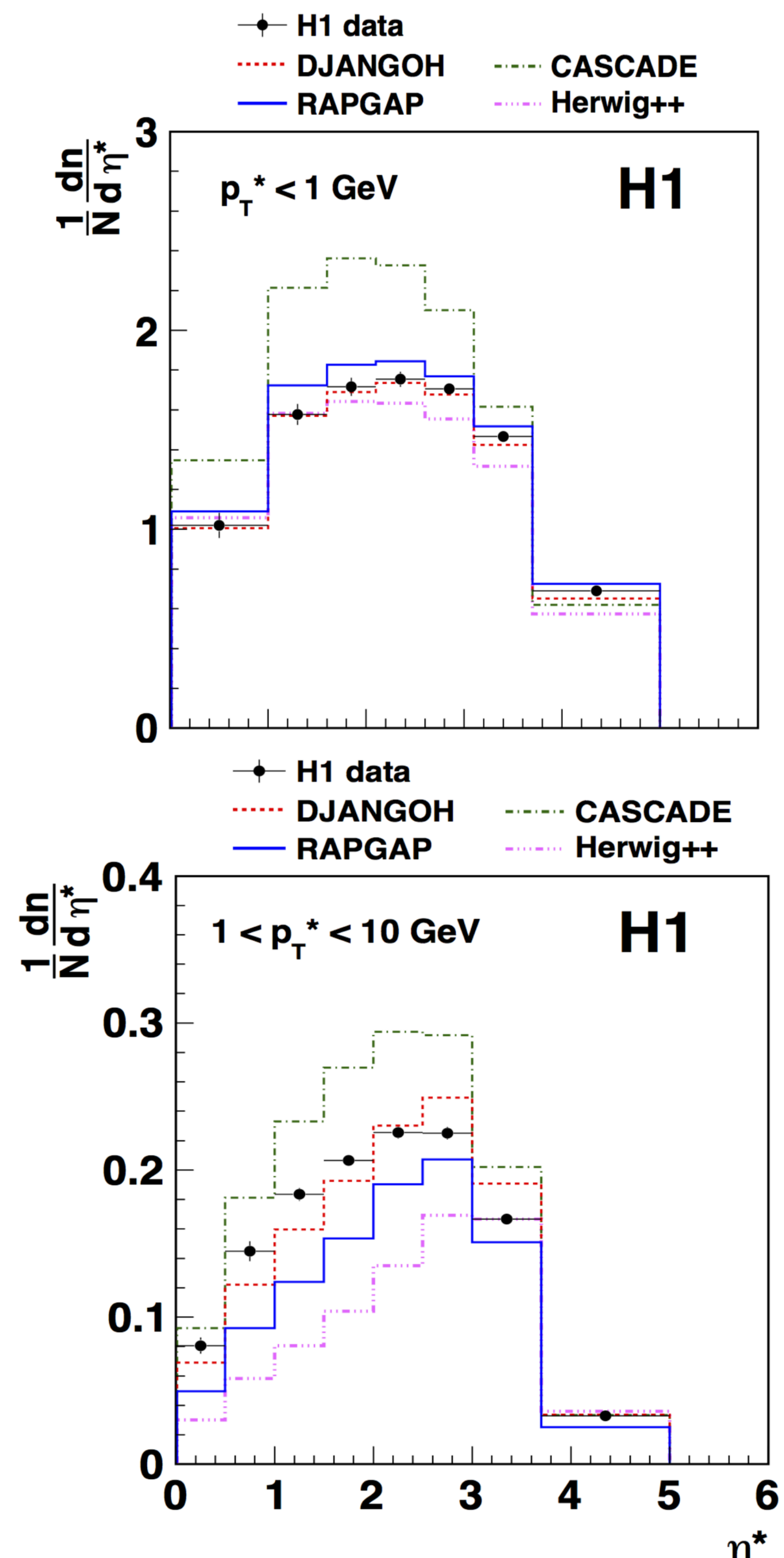

➔ for p_t^* < 1 GeV

➔ small sensitivity on PS (except CASCADE) → sensitive to hadronization

➔ for p_t^* > 1 GeV

➔ collinear parton shower (RAPGAP & HERWIG++) below data

➔ Color Dipole Model best

➔ small x improved CCFM shower to high

charged particle spectra in bins of Q^2 and x

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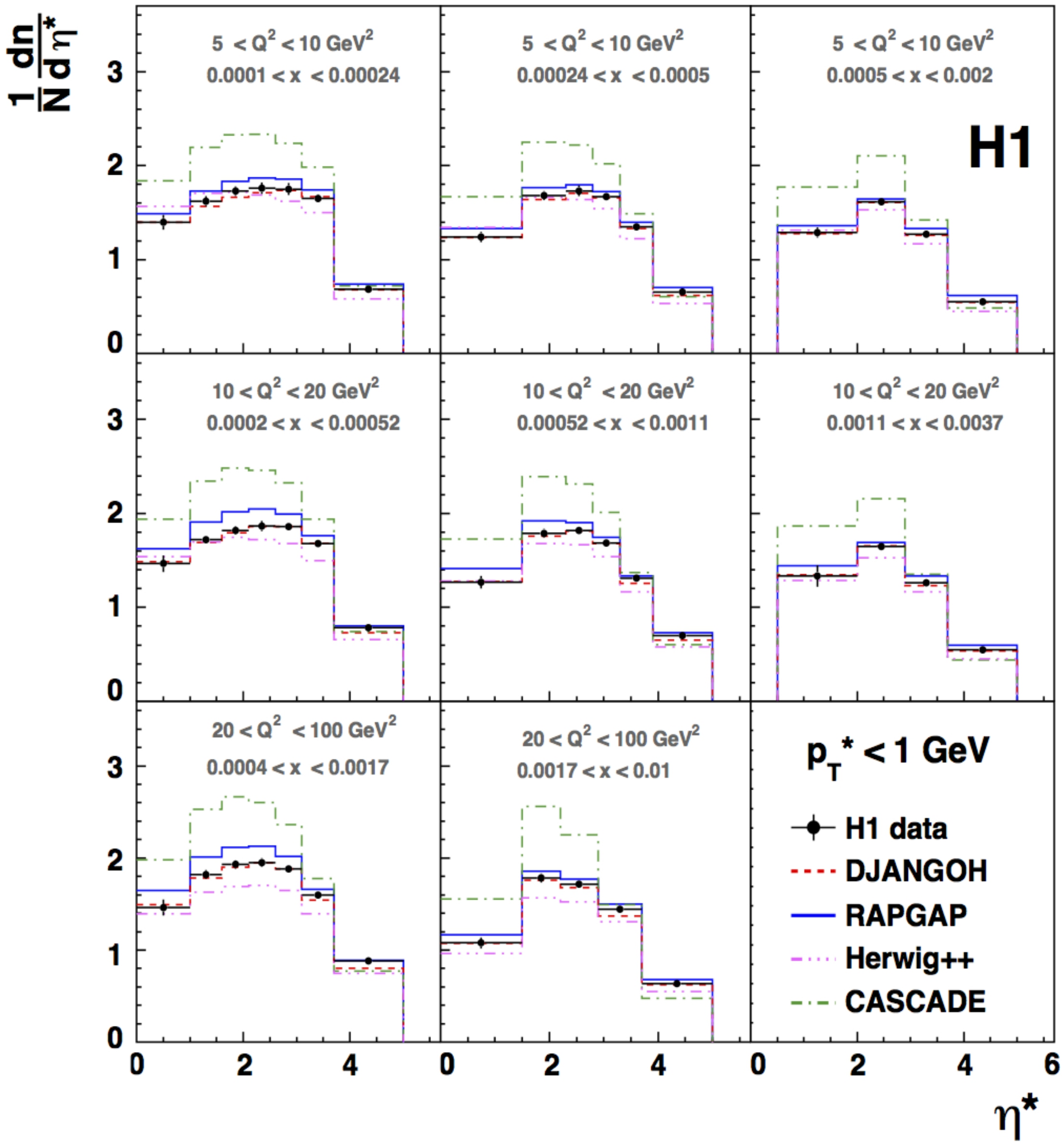

- at small $p^*_t < 1$ GeV
  - plateau at ~ 1.6 – 2.0 particles independent of Q^2
  - plateau size shrinks with increasing Q^2
  - "all" models describe measurements (except CASCADE)

charged particle spectra in bins of Q^2 and x

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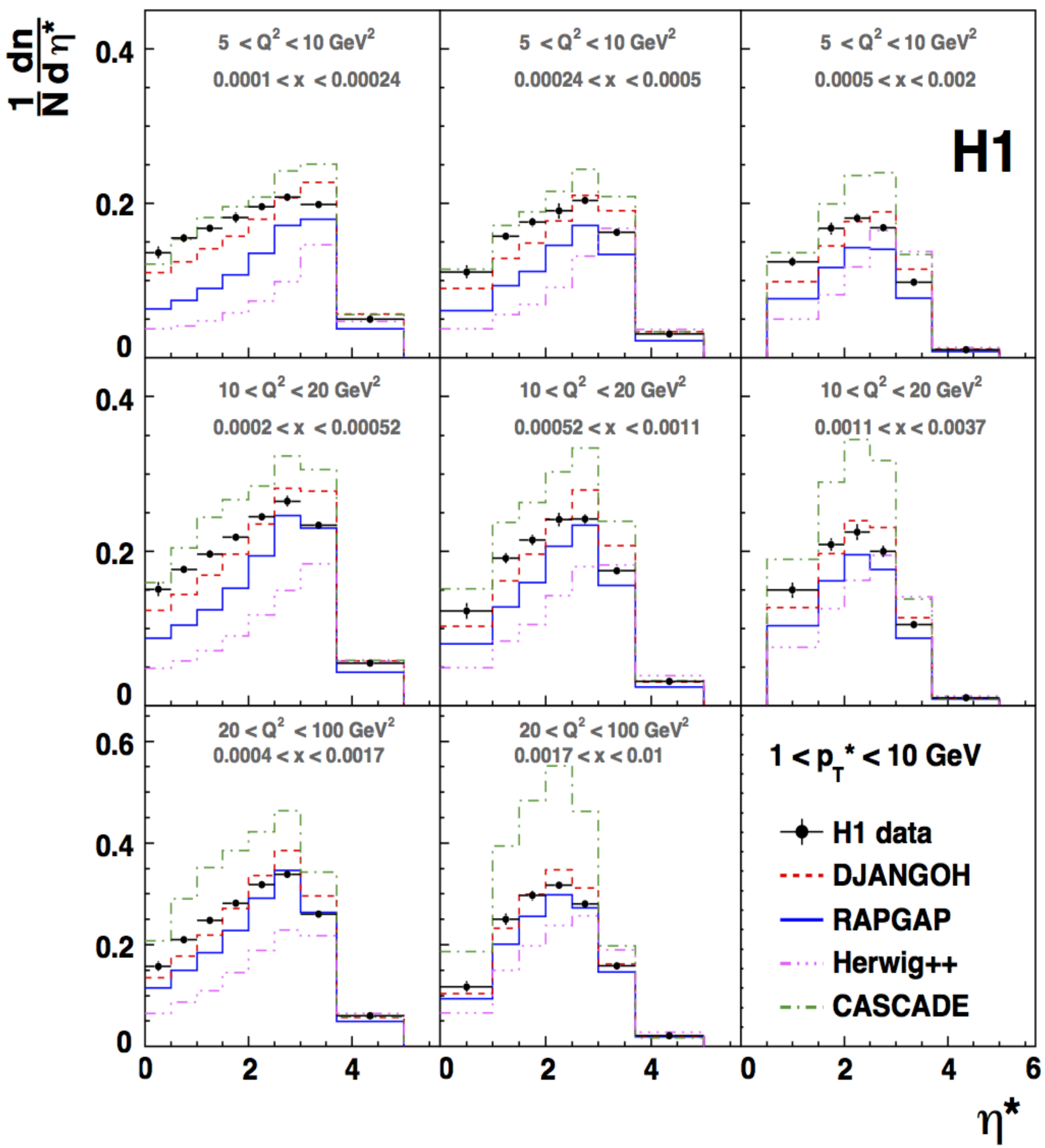

- at large $p^*{}_t$ > 1 GeV
  - models with collinear parton shower fail at small x and small Q^2 , while become better/good at large Q^2
  - small x improved CCFM parton shower is good at small x and small Q^2, while fails at larger Q^2
  - Color Dipole Model is reasonable over full range

charged particle spectra as fct of $p^*{}_t$ in bins of Q^2 and x

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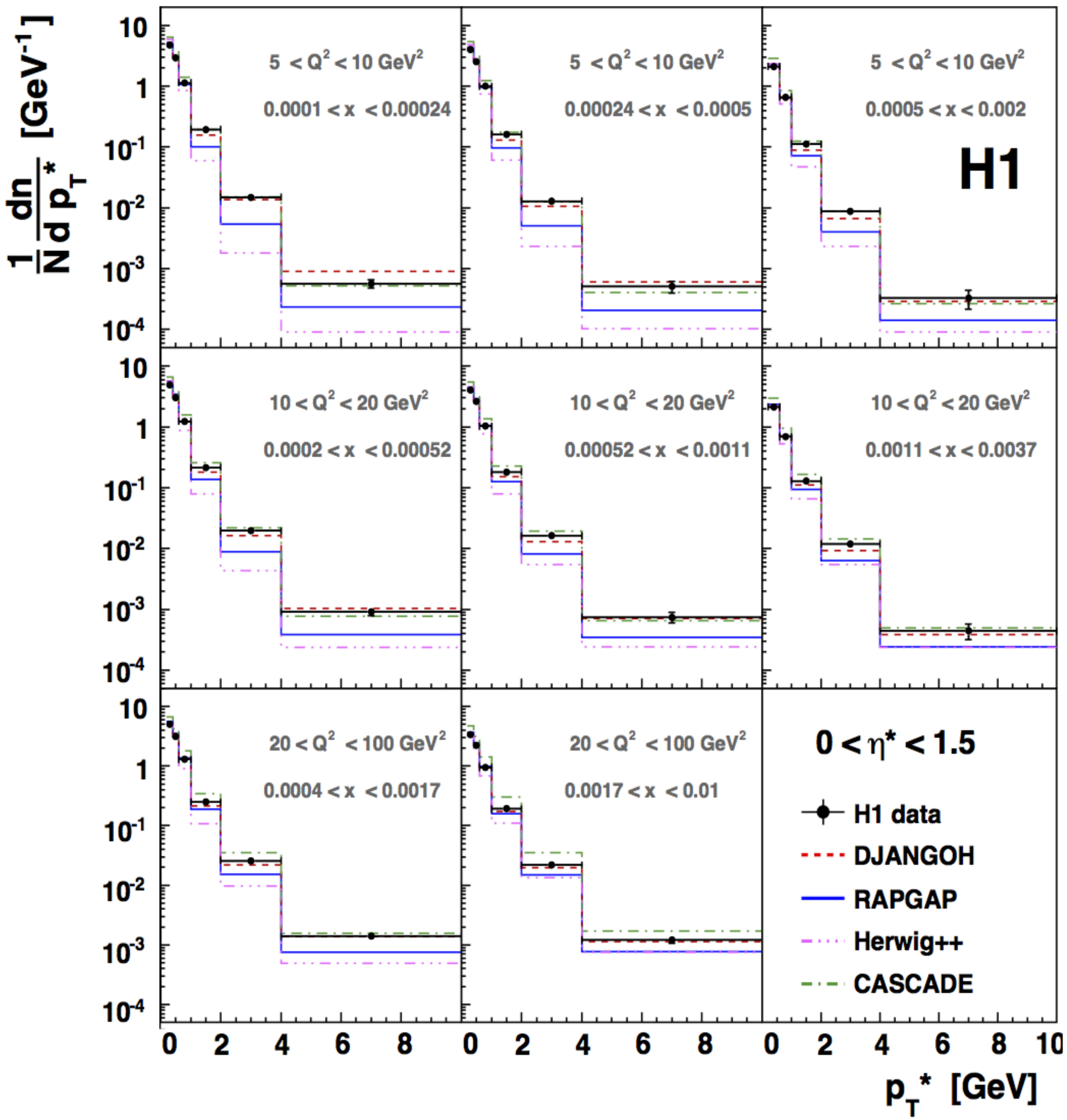

- spectra fall over 4-5 orders of magnitude at small x
- particle spectra as fct of $p^*{}_t$ give constraints on hardness of partons in parton shower
  - collinear shower models generate too soft spectra compared to measurement
  - small x improved (CCFM) shower generates hard spectrum → closer to measurement at large $p^*{}_t$
  - Color Dipole shower is best

charged particle spectra in 2 regions of η^*

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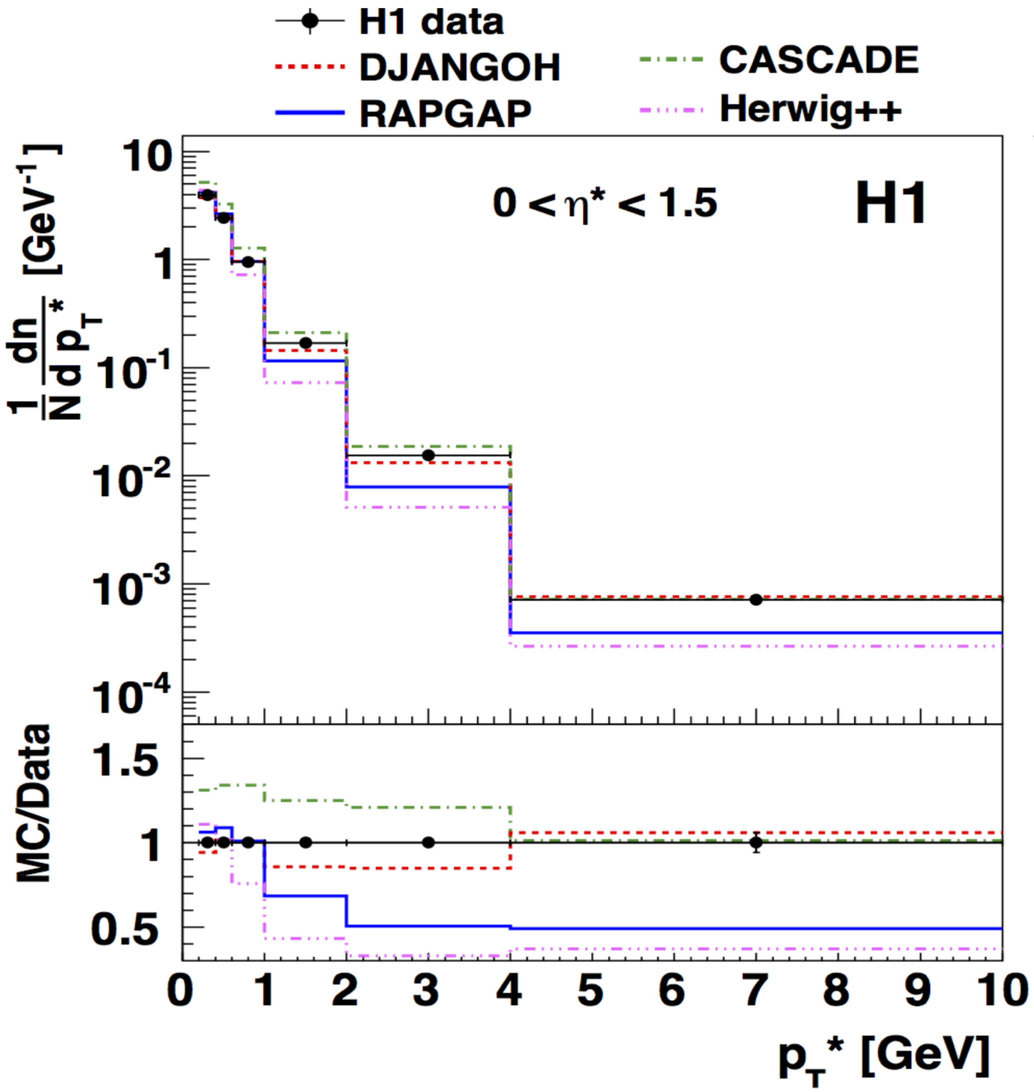
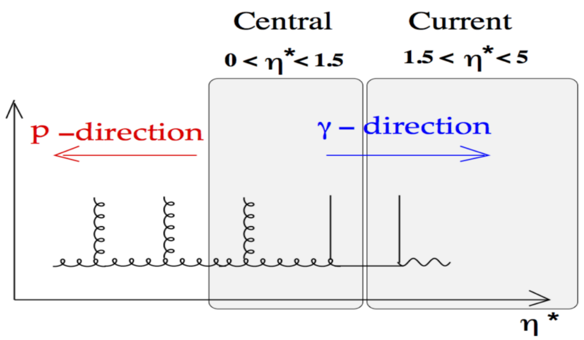
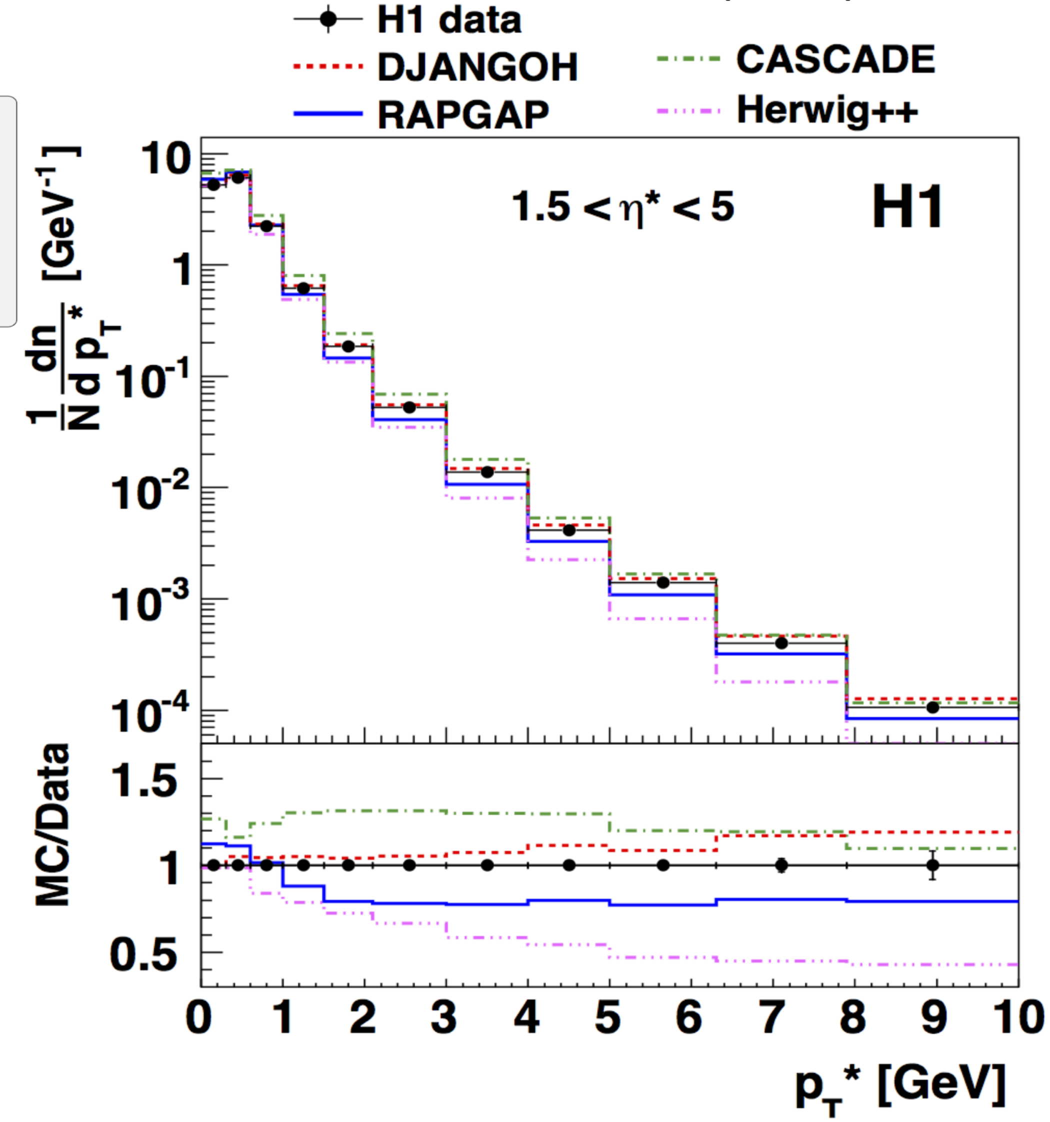




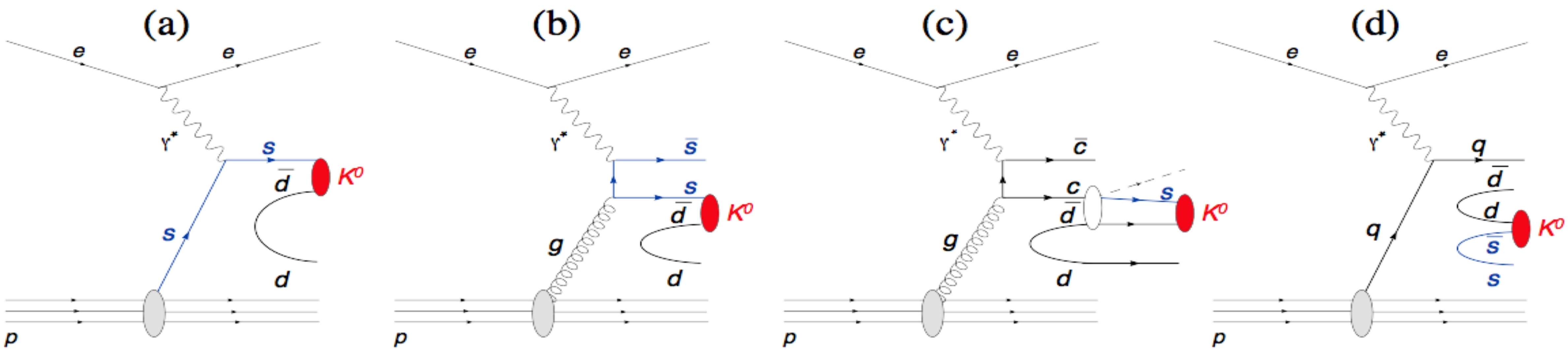


- $0 < \eta^* < 1.5$:
  - region sensitive to higher order radiation (parton shower)
  - ➔ data not described by collinear parton shower models
- $1.5 < \eta^* < 5$
  - region sensitive to hard scattering
  - ➔ at large $p^*_t \rightarrow$ data significantly larger than collinear shower predictions

$K^0{}_s$ production in DIS

H1prelim-13-033

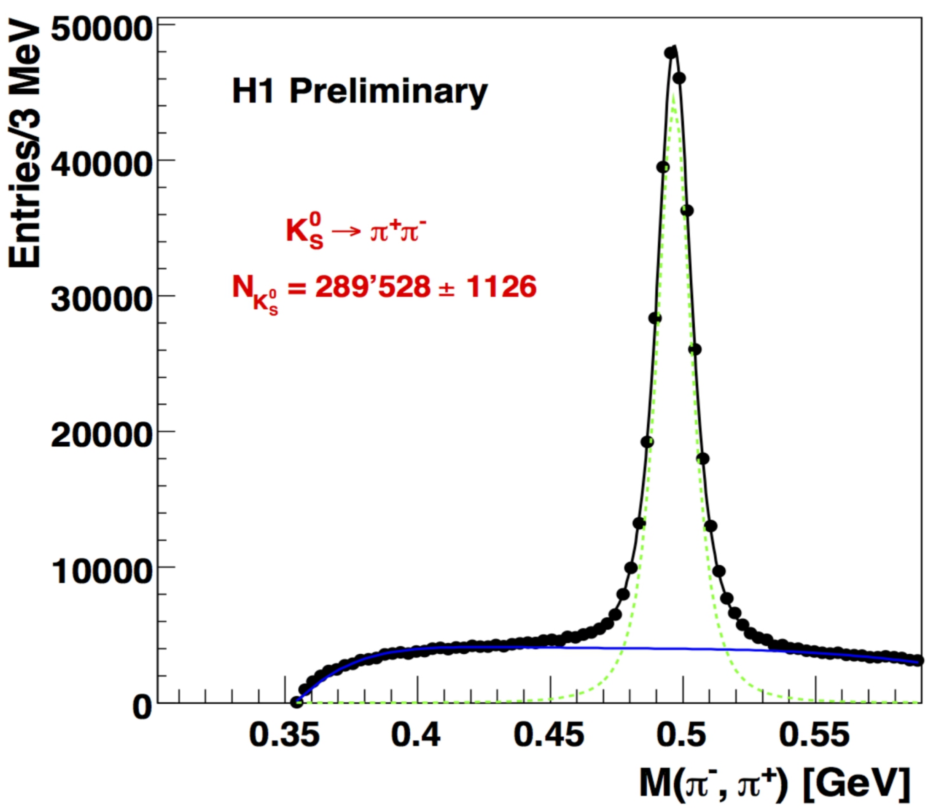
- mechanisms for strange particle production in DIS:



- dominant production mechanism is hadronization at small p_t !
  - role of quark mass in hadronization process !
- phase space: $ep \to e' K^0_s X$ at $\sqrt{s})$ = 319 GeV

$$7 < \quad Q^2 \quad < 100 \text{ GeV}$$
$$0.1 < \quad y \quad < 0.6$$
$$0.5 < \quad p_t \quad < 3.5$$
$$-1.3 < \quad \eta \quad < 1.3$$

➔ measure: $K^0_s \to \pi^+\pi^-$



$K^0{}_s$ cross sections

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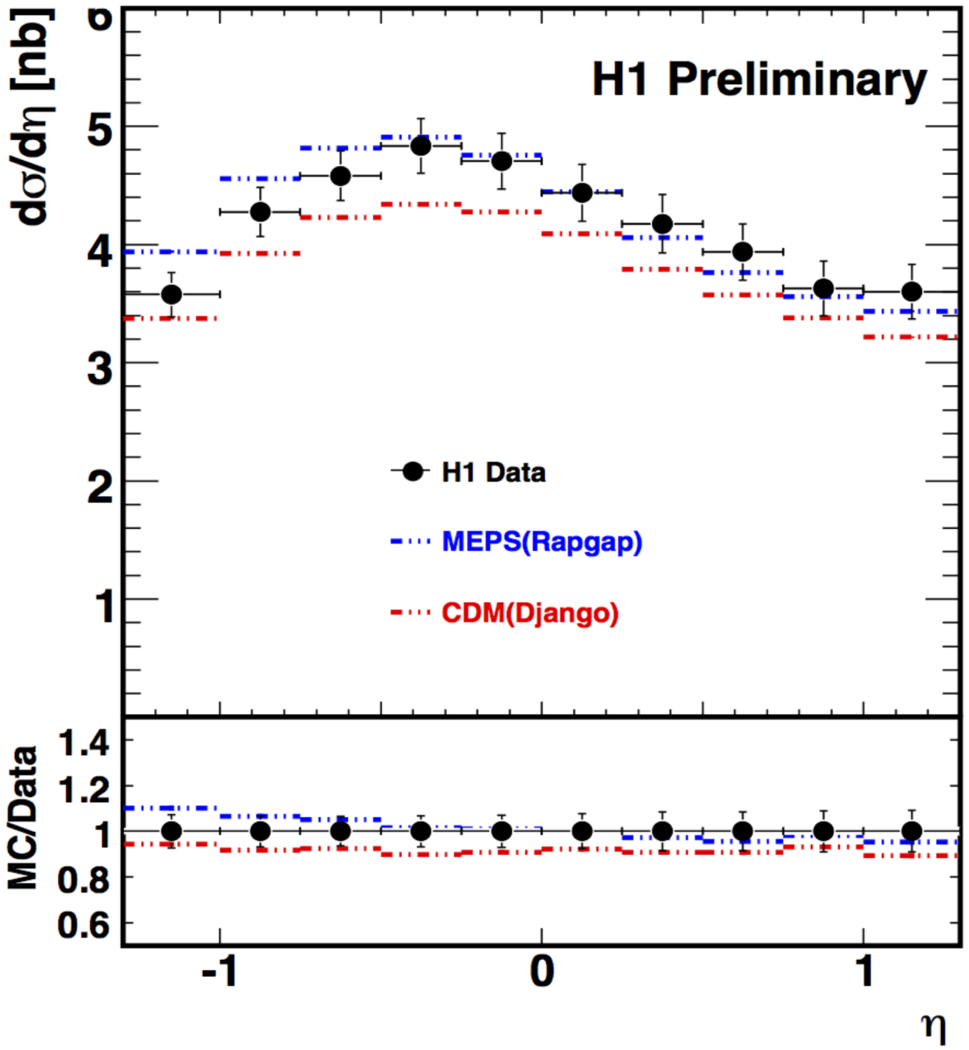

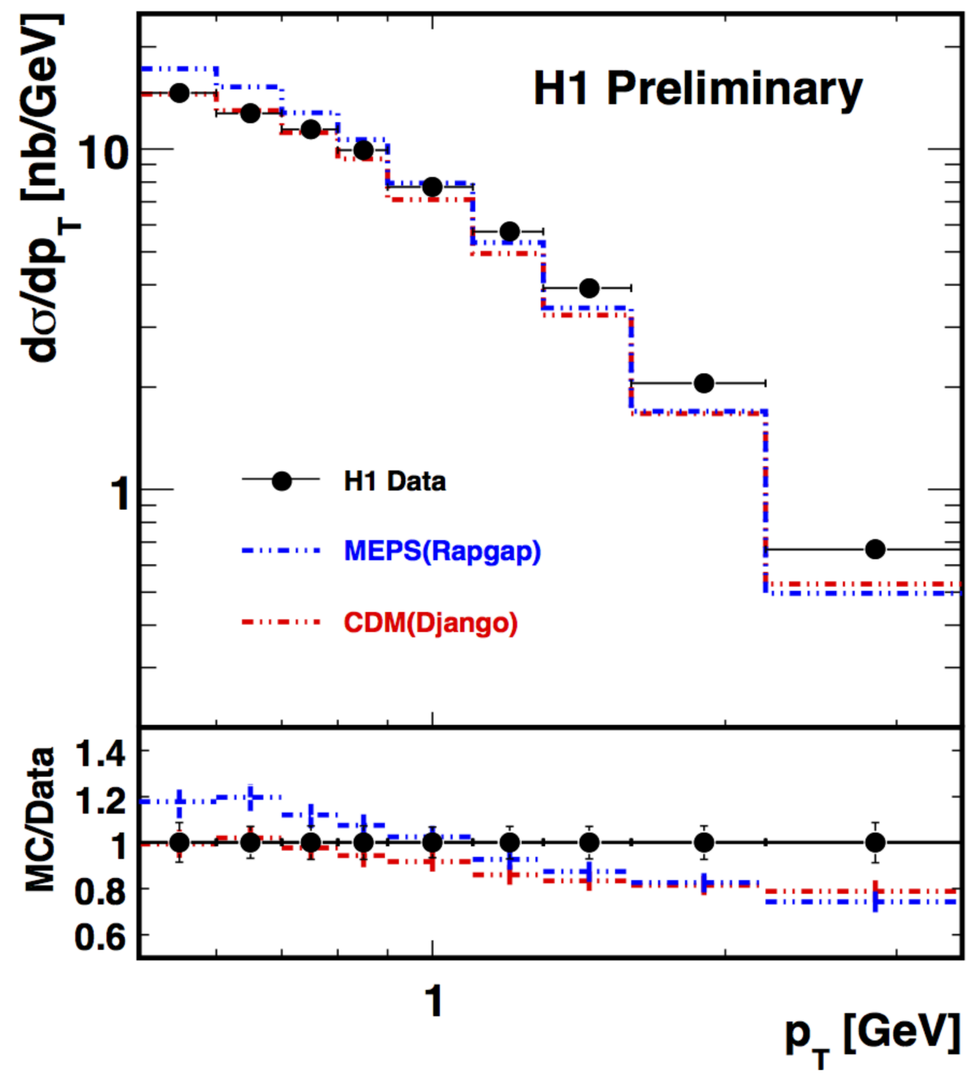

- $K^0{}_s$ cross section as function of (Q^2 and) η_K reasonably well described in shape
- small normalization difference with $\lambda_s = 0.286$ (LEP–ALEPH tune) strangeness suppression factor

- $K^0{}_s$ cross section as function of p_t is not well described by simulation: independent of λ_s

$K^0{}_s$ to inclusive charged particle ratio

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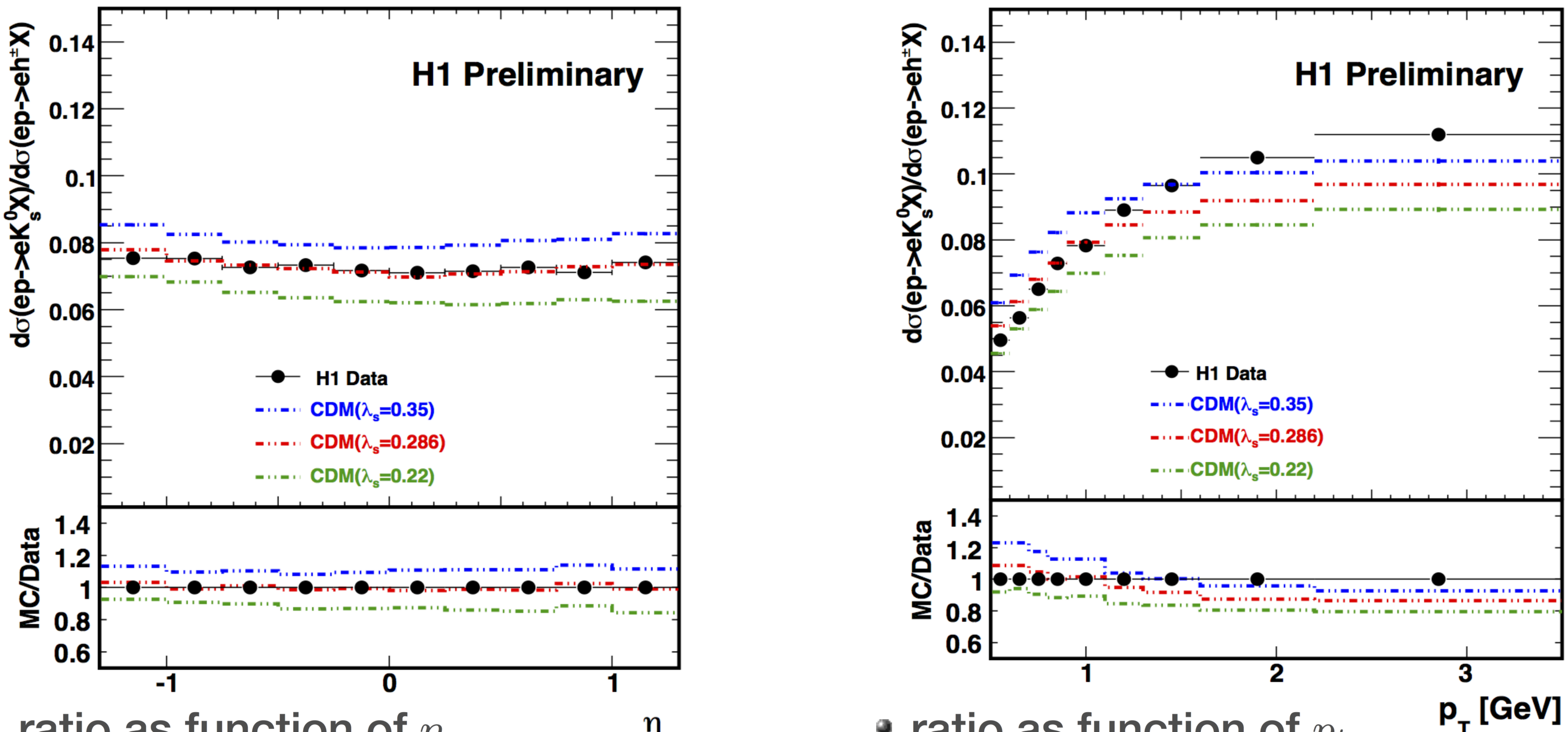
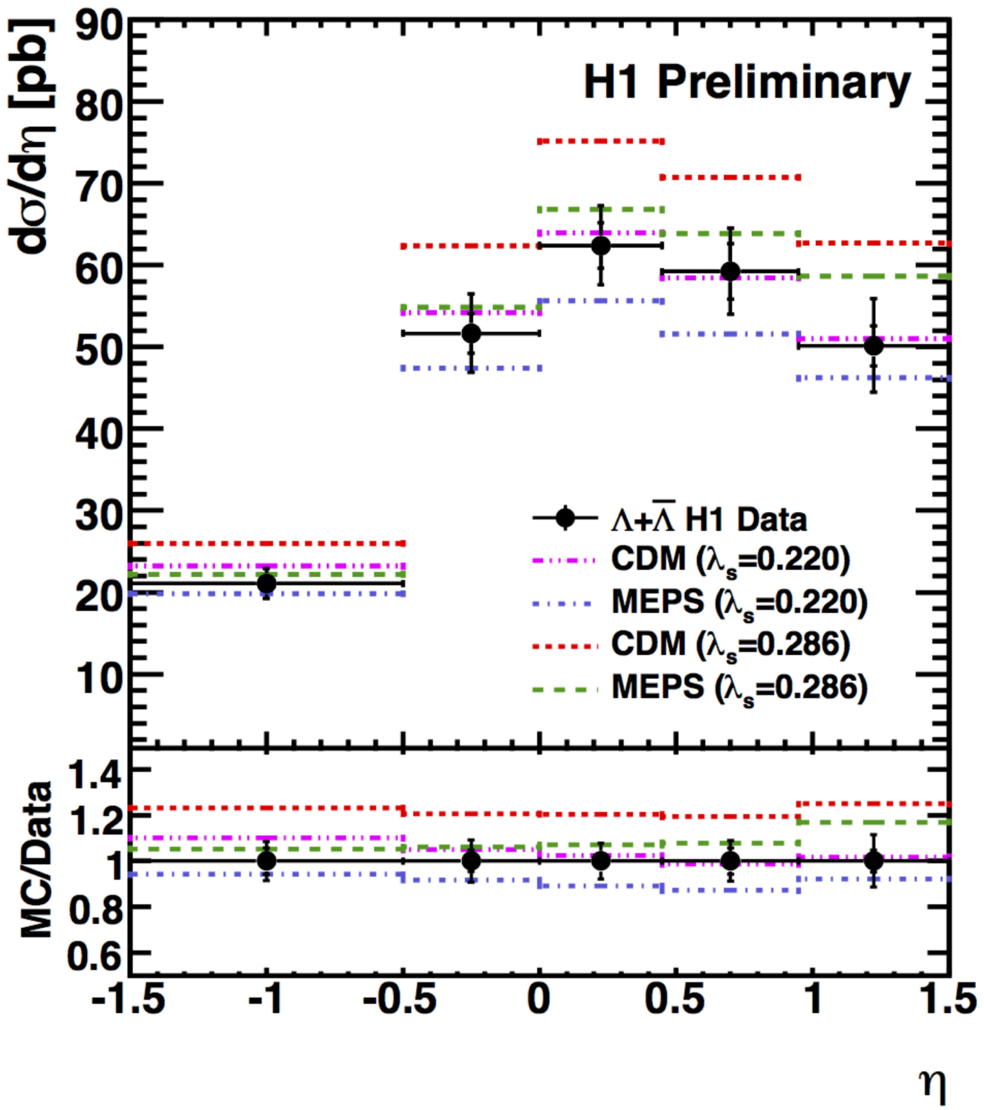


- ratio as function of η
  - reasonably well described in shape
  - **well described in rate for λ_s = 0.286**
- ratio as function of p_t
  - **NOT** well described in shape independent of λ_s
- **ratio of $K^0{}_s$ production to π production increases sensitivity to strangeness suppression, since some model uncertainties cancel**

Λ baryon production in DIS at large Q^2

- phase space:

$$145 < Q^2 < 20000 \text{ GeV}$$
$$0.2 < y < 0.6$$
$$p_t > 0.3 \text{ GeV}$$
$$-1.5 < \eta < 1.5$$



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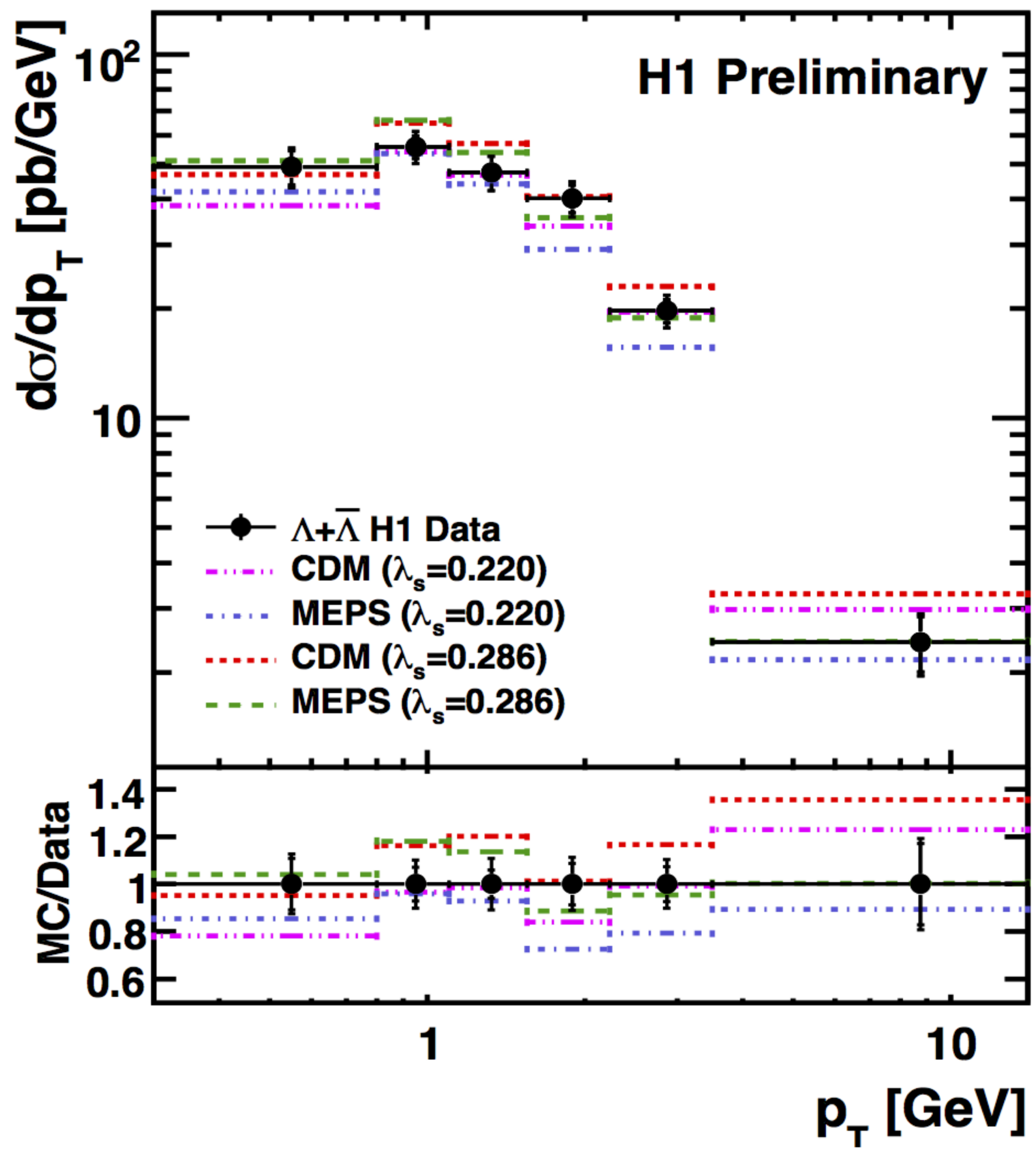

➔ reasonable description of data with models

➔ some dependence on λ_s

Λ to DIS ratio

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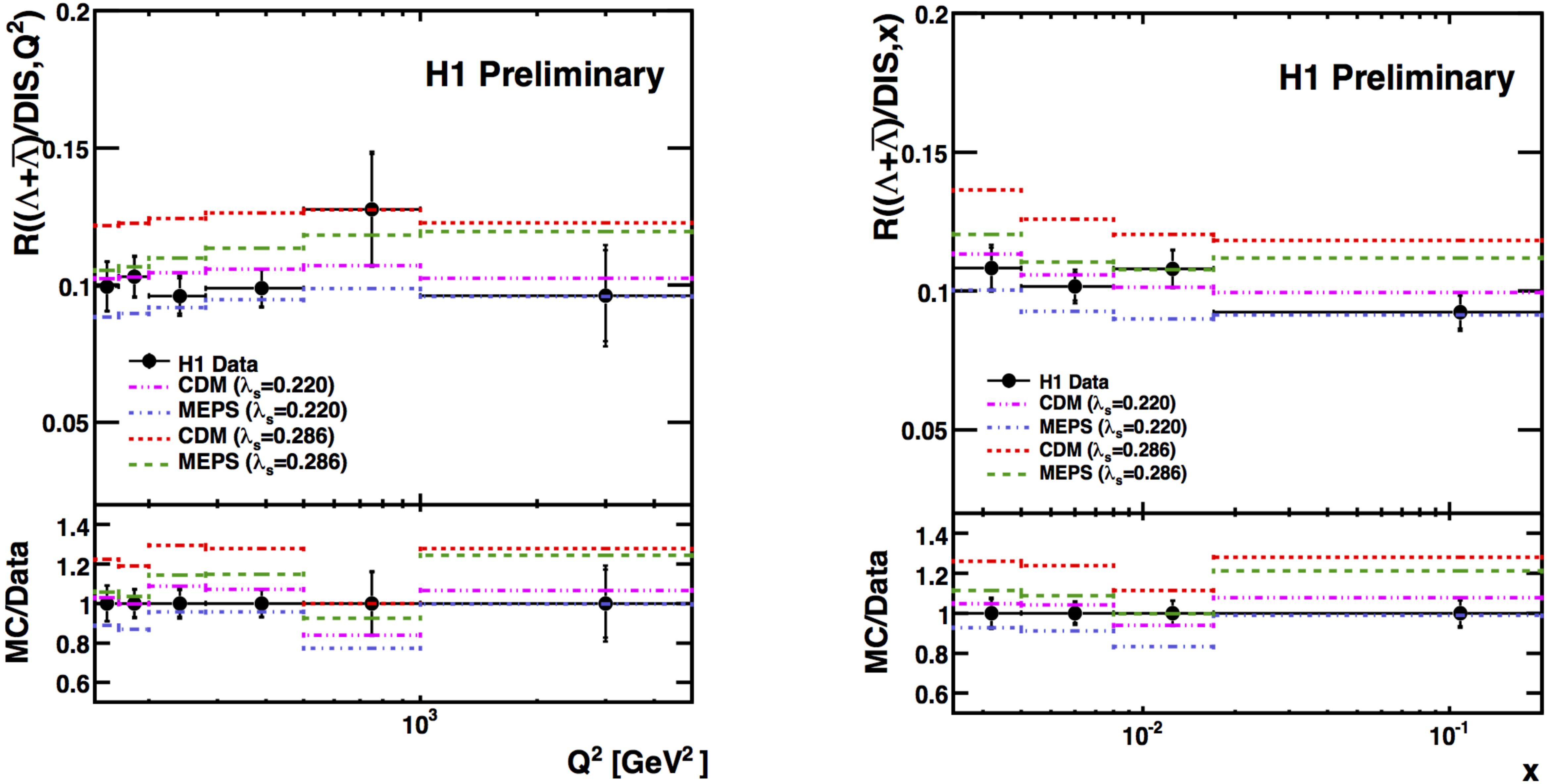

- Λ_s production shows similar Q^2 and x dependence as inclusive DIS
  - ➔ shape reasonably well reproduced by models
  - ➔ rate is sensitive to λ_s

➔ different λ_s $(=0.220)$ as compared to small Q^2 and $K^0{}_s$ $(\lambda_s=0.286)$ preferred

strange/charged particle ratio in UE in pp

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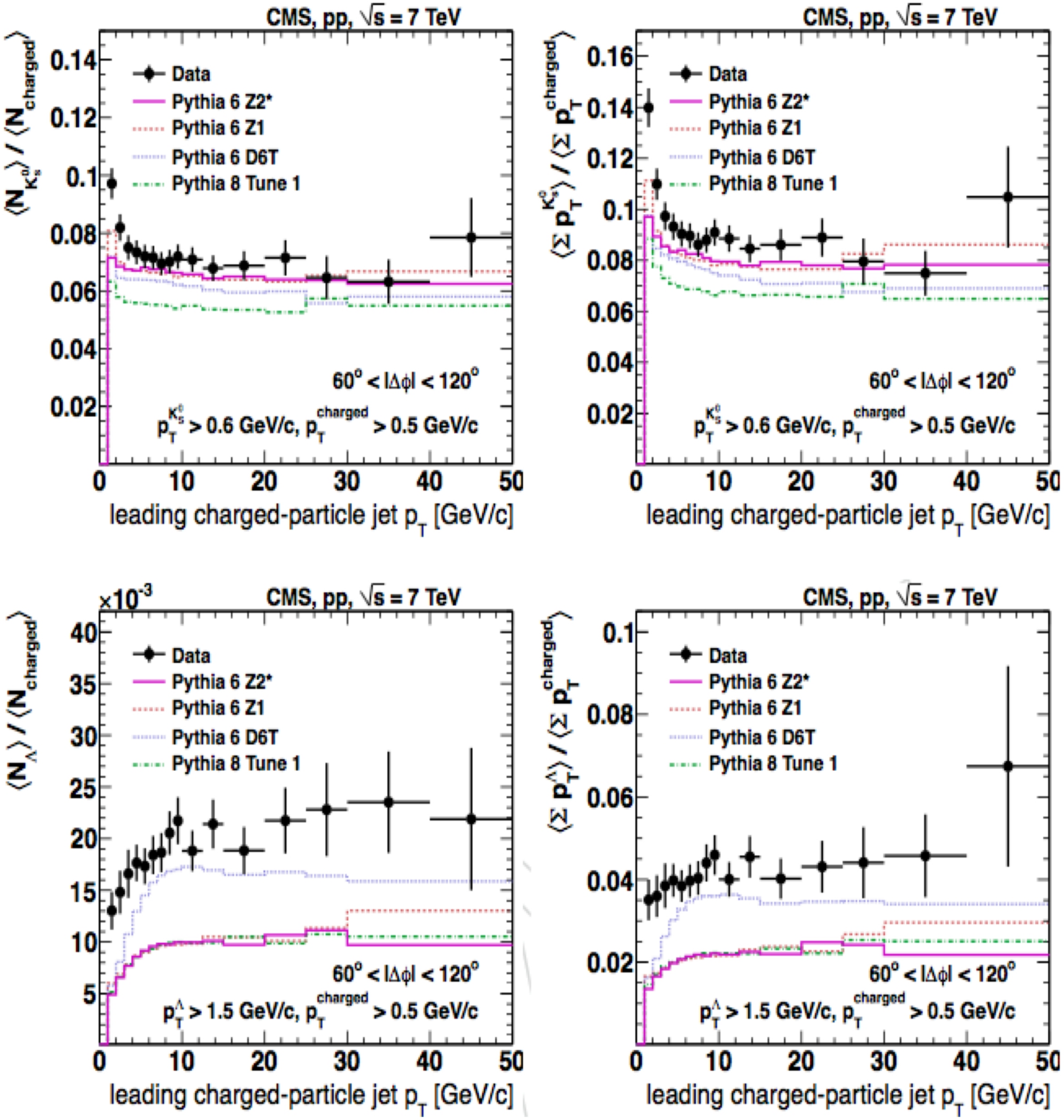
- $dn/d\eta$ for inclusive particle production is described by special min-bias tune
  - ➔ models are of by 30 % in $K^0{}_s$ and 50 % in Λ production
  - ➔ more than in DIS !
- measurement of strangeness production in transverse region to jets in pp:
  - small deficit in $K^0{}_s$ but significant deficit in Λ production → tune !
  - ➔ transverse region is sensitive to multiparton interactions but also to parton shower



Conclusion

- charged particle spectra in DIS give important information of
  - hadronization at small p_t
    - ➔ inclusive spectra at small p_t are reasonably well described with hadronization parameters obtained from LEP
  - higher order contributions (parton shower) at larger p_t
    - ➔ collinear parton shower models fail to describe "large" p_t tail
    - ➔ small x improved parton shower comes closer to data at small x
- strange particle production in DIS:
  - spectra of $K0_s$ are reasonably well described using strangeness suppression λ_s factor from LEP
  - spectra for Λ prefers smaller λ_s than for $K0_s$
  -

➔ DIS spectra provide a crucial test for hadronization and parton shower models: → no contribution from multiparton interactions !

- note: inclusive particle spectra and strangeness production in pp involve more components....