Sherpa: status & overview
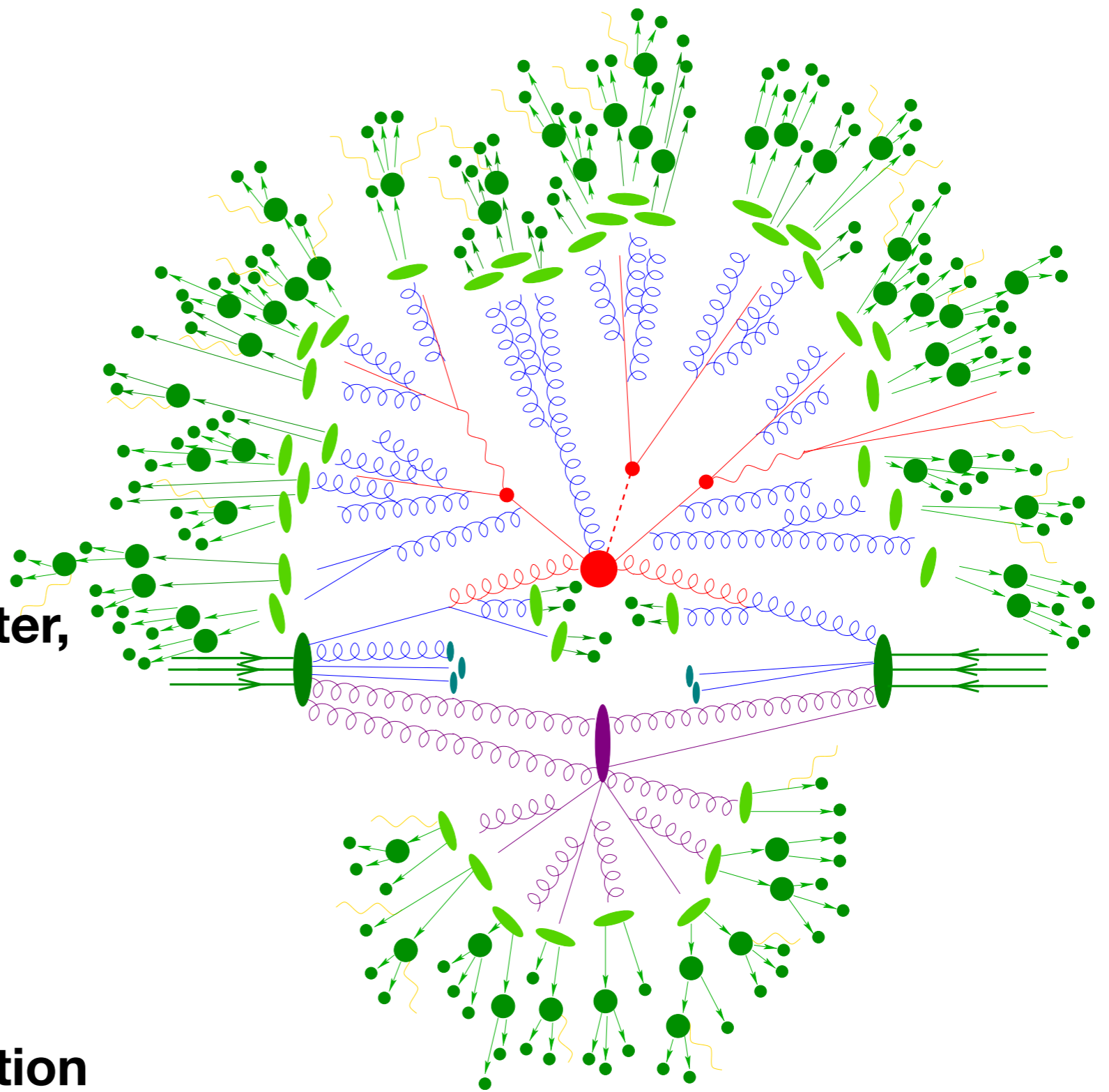
MPI@LHC 2023, Manchester, 20/11/2023

**Peter Meinzinger, IPPP,
Durham University,
on behalf of the collaboration**

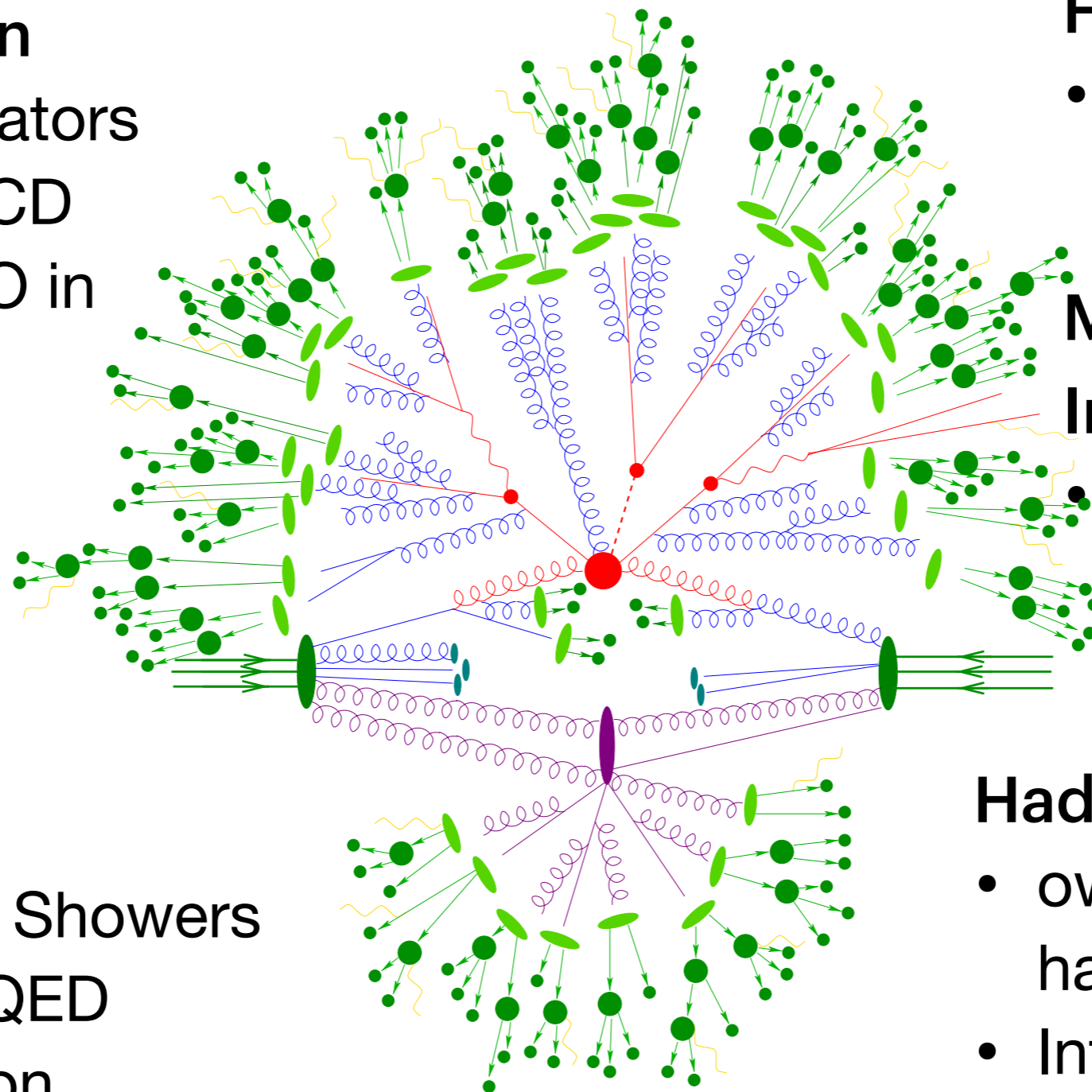# **Outline**

Sherpa 3.0 in preparation

General Purpose MC Event Generator

Hard Interaction
- two ME generators
- LO, NLO in QCD and EW, NNLO in QCD
- Matching and Merging

Radiative corrections
- two Parton Showers
- YFS-style QED resummation
- EW Sudakovs

Hadron Decays
- Including YFS QED corrections

Multiple Interactions
- Sjöstrand-van Zijl model

Hadronisation
- own cluster hadronisation model
- Interface to Pythia's string hadronisation

Sherpa 3.0 in preparation

Recent progress in 2022/23

Physics extensions:

- NLL-accurate parton shower ALARIC   [2208.06057], [2307.00728]

- Polarized vector boson cross-sections   [2310.14803]

- New cluster hadronisation with colour reconnections   [2203.11385]

- Photo-production at MC@NLO accuracy   [2310.18674]

Performance studies:

- HDF5 file I/O   [2309.13154]

- Nested Sampling   [2205.02030]

- Factorisation-aware NN   [2301.13562]

- Pilot runs and faster PDF evaluation   [2209.00843]

- Portable code for GPUs
  [2311.06198], [2302.10449], [2106.06507]

Amisic

Status of MPI modelling in Sherpa

- Rewrite for version 3 based on [Sjöstrand, van Zijl; *Phys.Rev.D* 36 (1987) 2019], using Regge-pole theory

- Parametrisation of [Schuler, Sjöstrand; *Z.Phys.C* 73 (1997) 677-688] and [Schuler, Sjöstrand; *Phys.Rev.D* 49 (1994) 2257-2267]

- Considering p, ρ, ϕ and J/ψ for the calculation of the total cross-section — allows for one consistent framework for both proton and photon interactions

Amisic

Status of MPI modelling in Sherpa

- Idea: for given hard process and impact parameter, calculate

$$\sigma_{\text{int}} = \int_{p_{\perp\text{min}}^2}^{p_\perp} \frac{\mathrm{d}\sigma}{\mathrm{d}p_\perp} \mathrm{d}p_\perp$$

$$\left\langle n_{\text{MPI}} \right\rangle = \frac{\sigma_{\text{int}}}{\sigma_{\text{non}-\text{diffr}}}$$

- Generate additional $2 \rightarrow 2$ scatterings by Poissonian statistics

- Tune regulator $p_{\perp 0}$, minimum scale $p_{\perp\text{min}}$, scaling factor, reference scales, etc.

- Photon MPI is modelled as superposition of the mesons

Further changes to soft physics

Minimum Bias and Beam Remnants

New MPI modelling allows natural extension to Minimum Bias

- Initial $p_\perp$ needs to be diced, then follow same procedure

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Beam Remnants modelling has been re-written

- different primordial-$k_\perp$ parameters for struck quarks vs spectator quarks

- Reduce emissions in beam jets by only creating minimally necessary colours and flavours

Tuning procedure

using Apprentice

1. Create set of Monte-Carlo generator runs

2. Simultaneously tune all parameters

3. Create bin-wise polynomical surrogates for MC response for different sets of generator runs

4. Reduce parameter ranges and iterate

5. After final tune, use equivalent replicas to estimate uncertainty
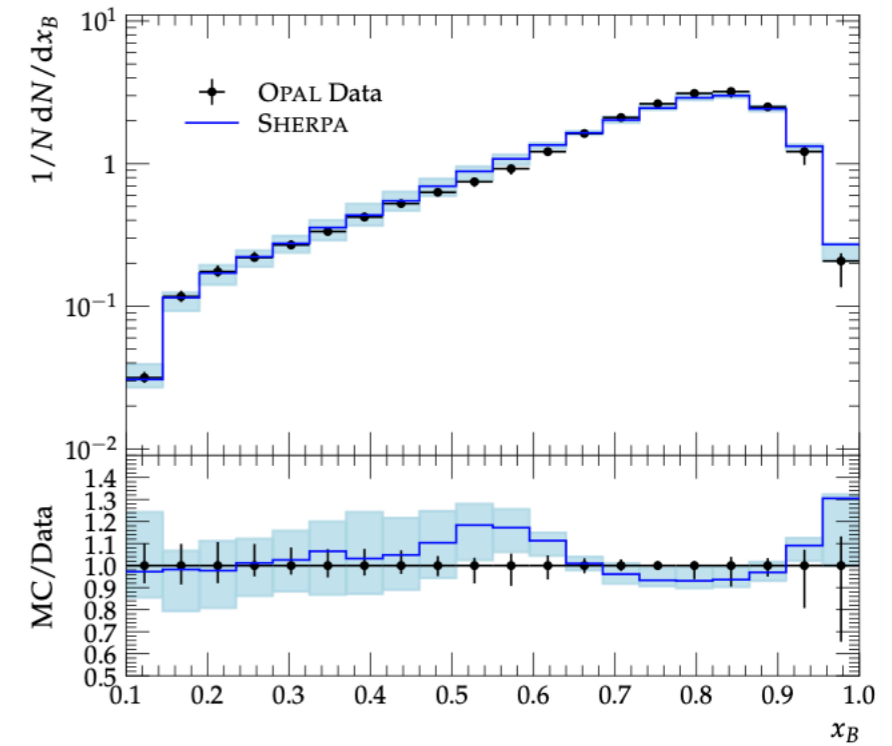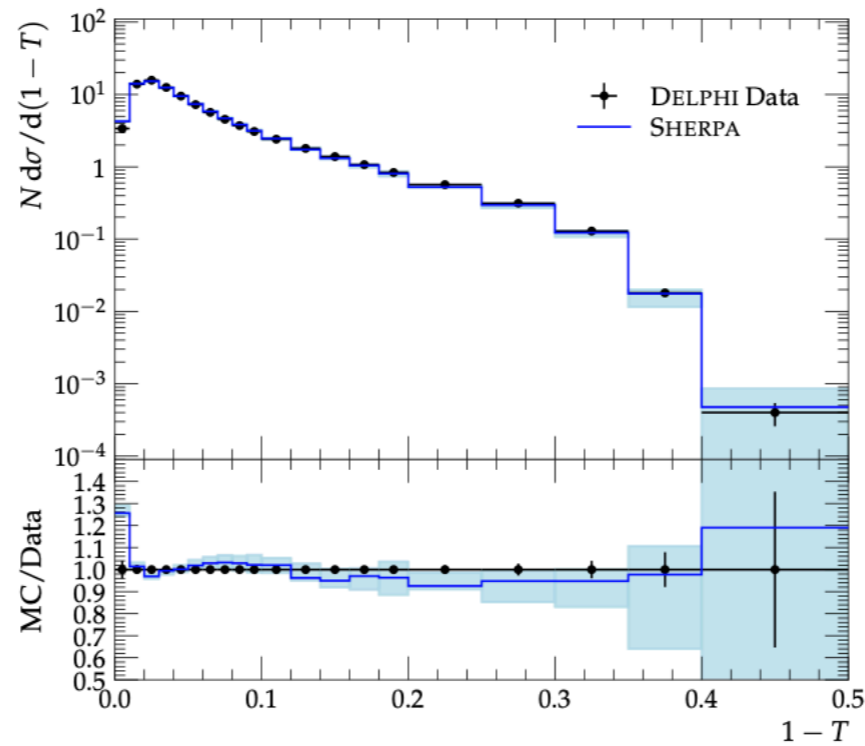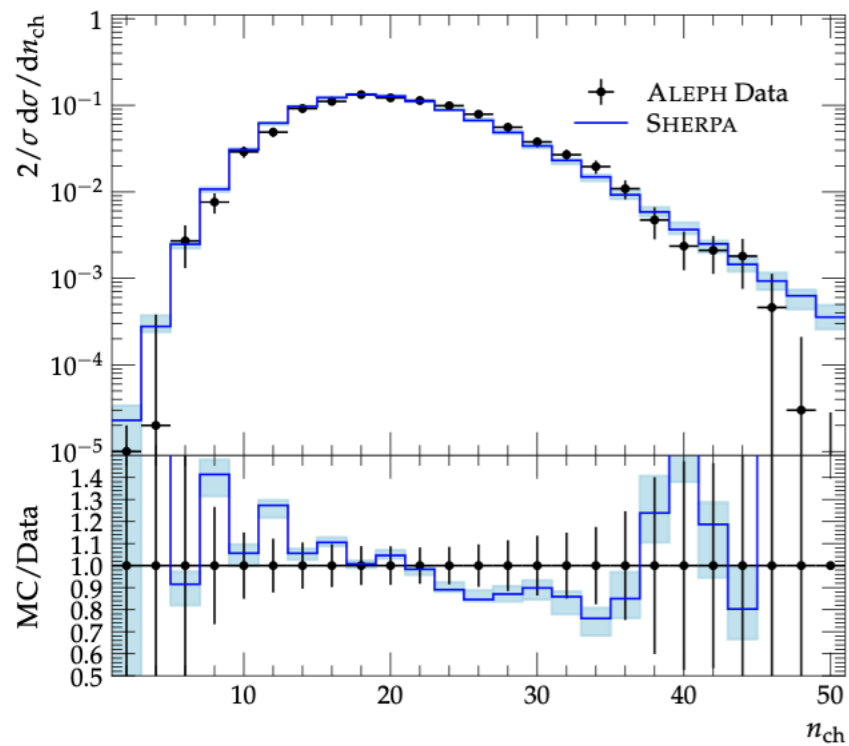
> Hadronisation is tuned
>
> Underlying Event, MinBias and Primordial-$k_\perp$ tuning
>
> are work-in-progress

Tuning on LEP data

Fragmentation effects

Modelling only as good as the tuning

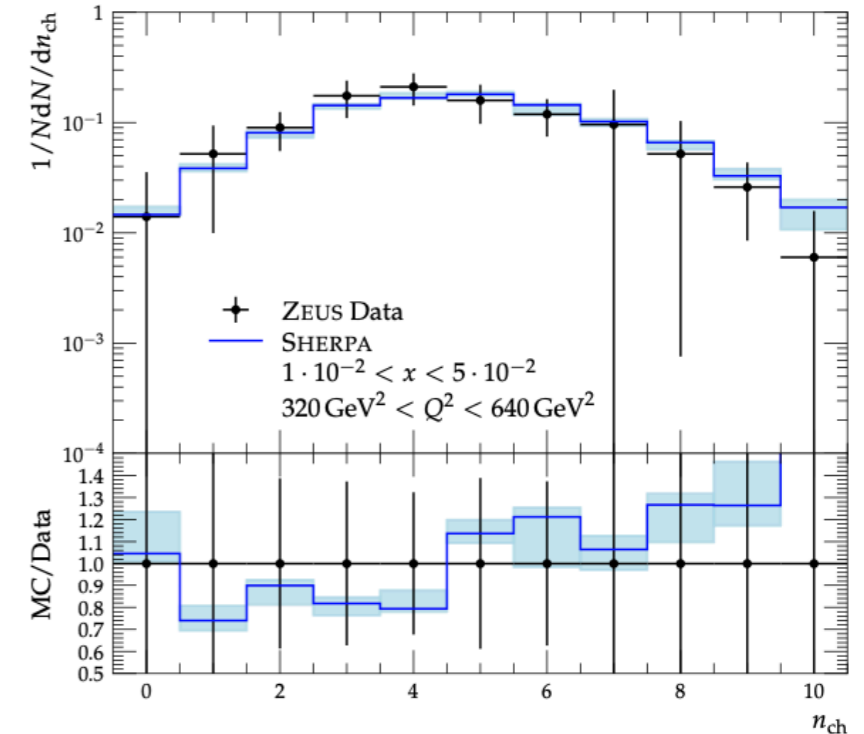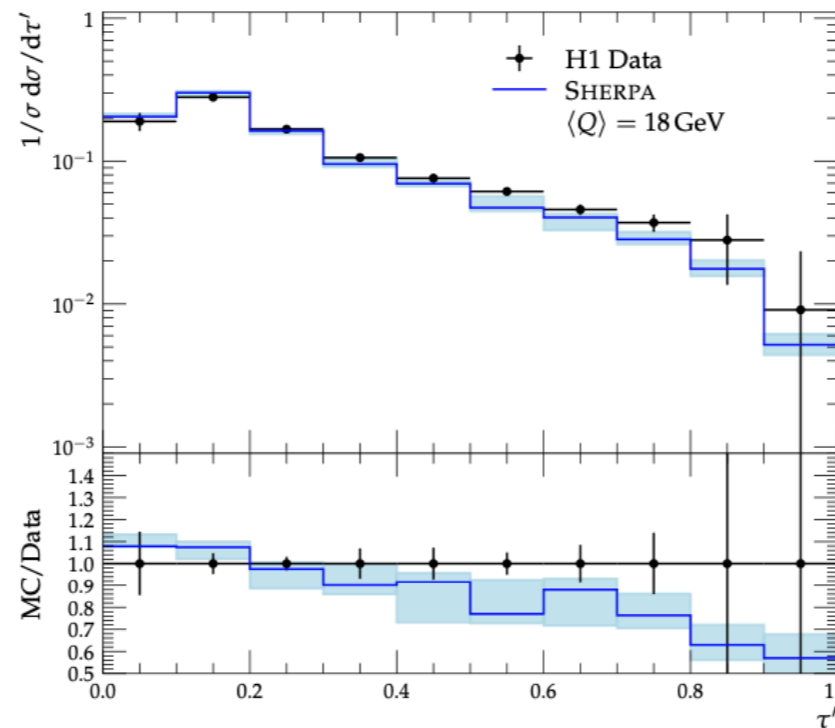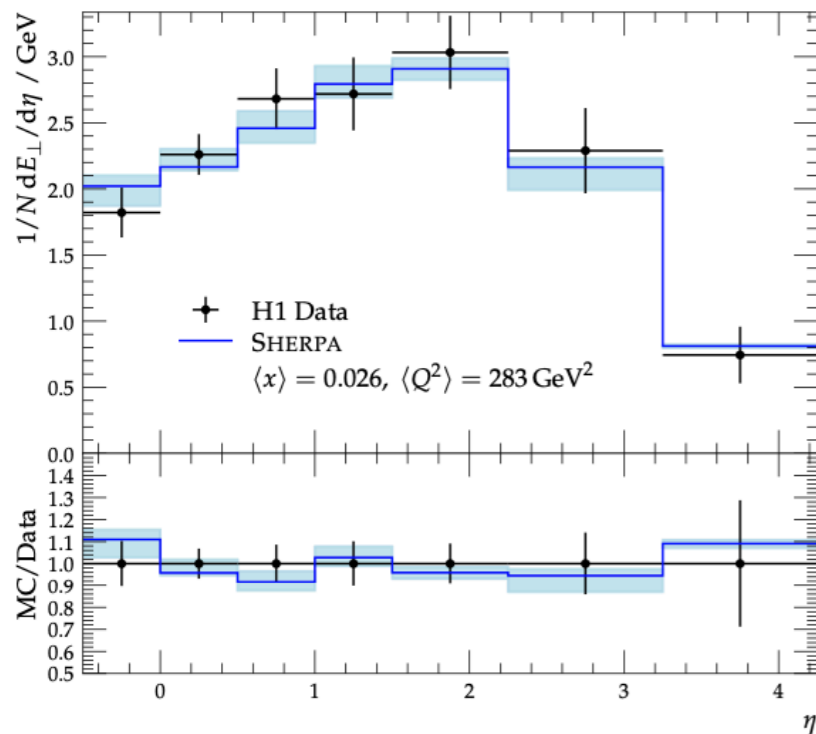

Replica tunes with
Apprentice

Non-perturbative tuning
uncertainties indicated by
the blue band

[2306.03682]

Tuning on HERA data

Fragmentation effects

Modelling only as good as the tuning

Replica tunes with
Apprentice

Non-perturbative tuning
uncertainties indicated by
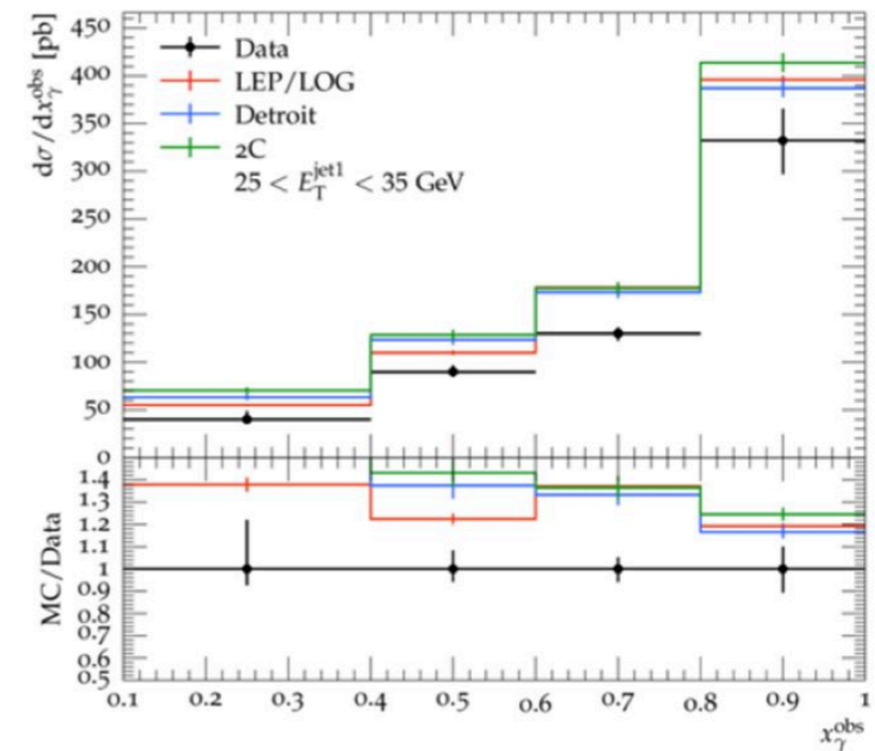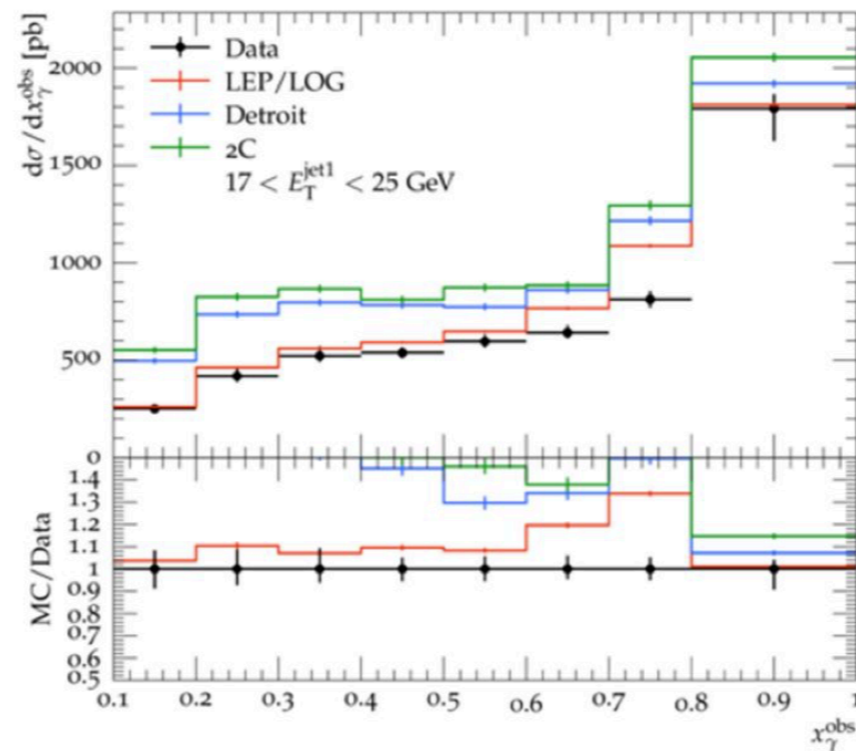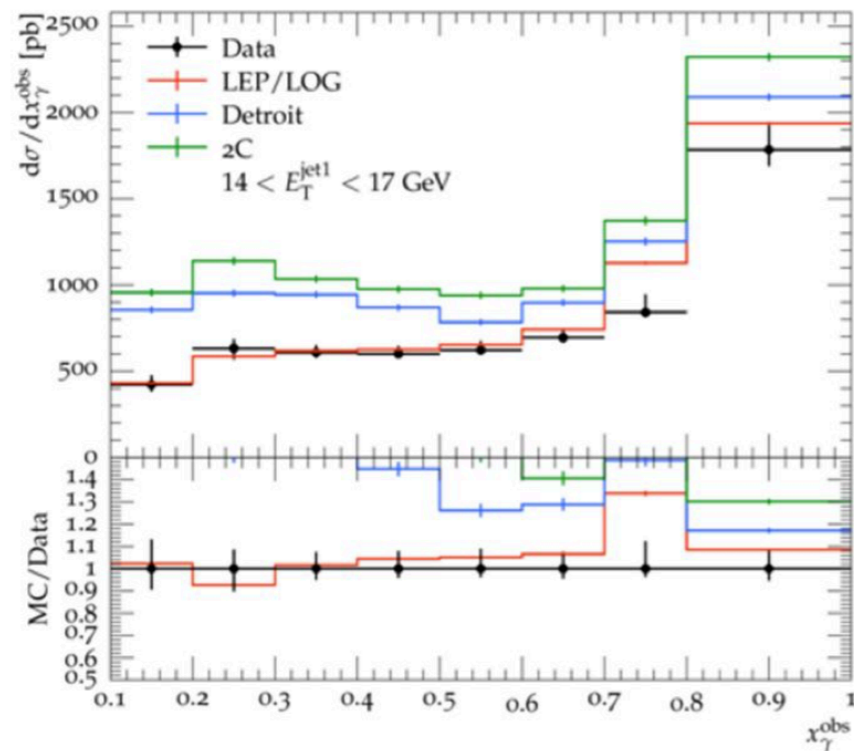the blue band

[2306.17736]

Outlook

Overlap to the EIC

Is one coherent tune possible?

- First study done by J.J. Castella and J. Butterworth with Pythia for HERA, LEP, CDF and LHC, c.f. talk at 25th MCnet meeting 2023
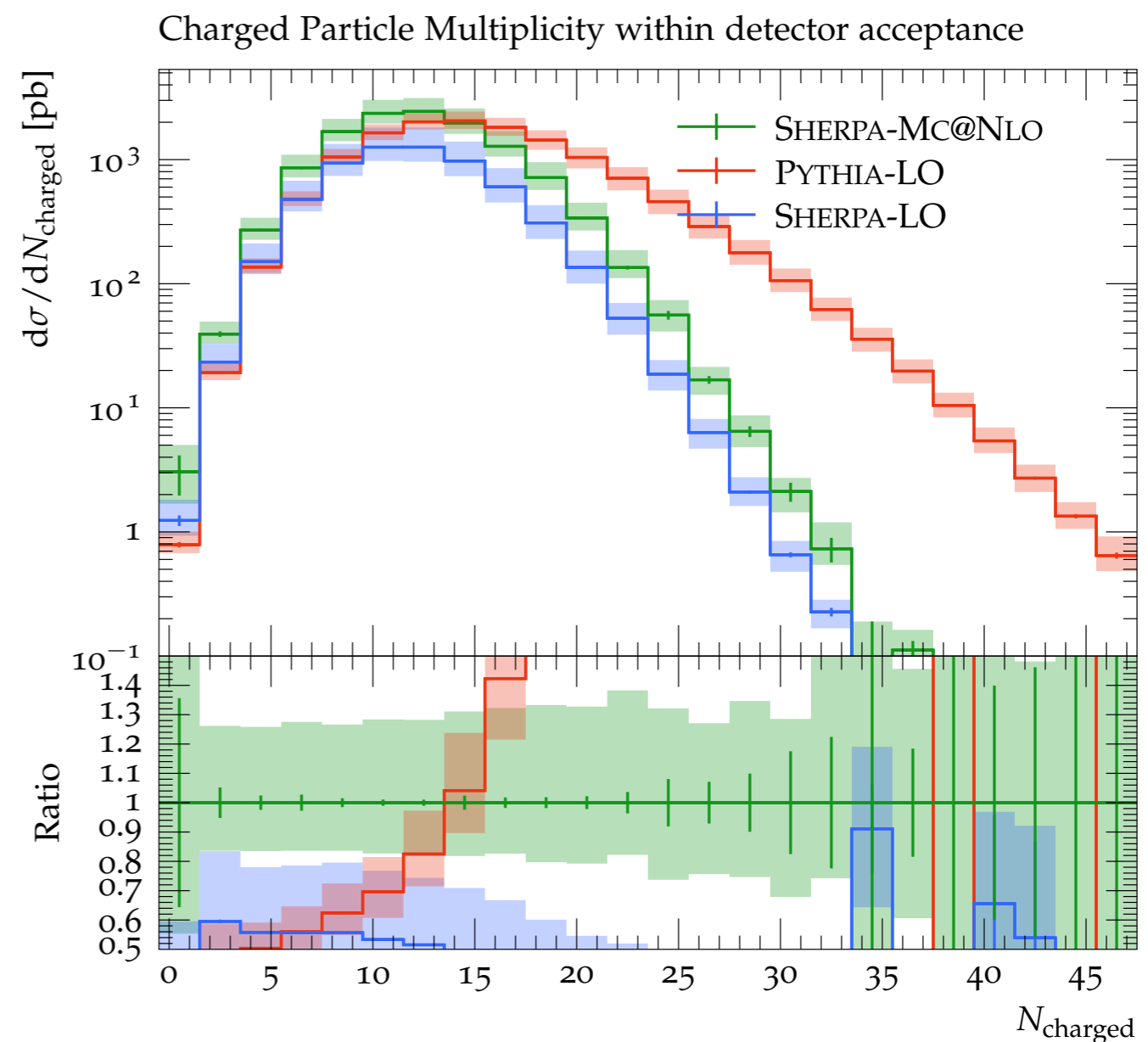

Comparison to ZEUS data (taken from J.J. Castella's slides)

Overlap to the EIC

Is one coherent tune possible?

- MPIs have no big impact on the cross-section, but visible in certain observables

- both Pythia and Sherpa not yet tuned to data for photo-production

Can we get a consistent fit of photon and proton MPI parameters?

Charged Particle Multiplicity within detector acceptance

SHERPA-MC@NLO
PYTHIA-LO
SHERPA-LO

$\mathrm{d}\sigma/\mathrm{d}N_{\mathrm{charged}}$ [pb]

Ratio

N_{charged}

Diffractive jet production

○ "Soft" diffractive jet production through extension of Amisic modelling

- Estimate the elastic cross-section in Regge theory

- Generate events with one or both proton diffracted

○ "Hard" diffractive jet production through implementation of Pomeron flux

- Follow [*Eur.Phys.J.C* 78 (2018) 4, 309] for Pomeron flux parametrisation

Summary

- Major re-writes of soft-physics modules for new Sherpa 3.0

- Tuning for the release is in progress

- Improved description of DIS

- MPIs in photon—proton collisions — interesting overlap of LHC with HERA and EIC

- Diffractive jet production planned