Measurement of azimuthal decorrelation angle between the leading jet and the scattered lepton in deep inelastic scattering at HERA

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on behalf of the ZEUS collaboration
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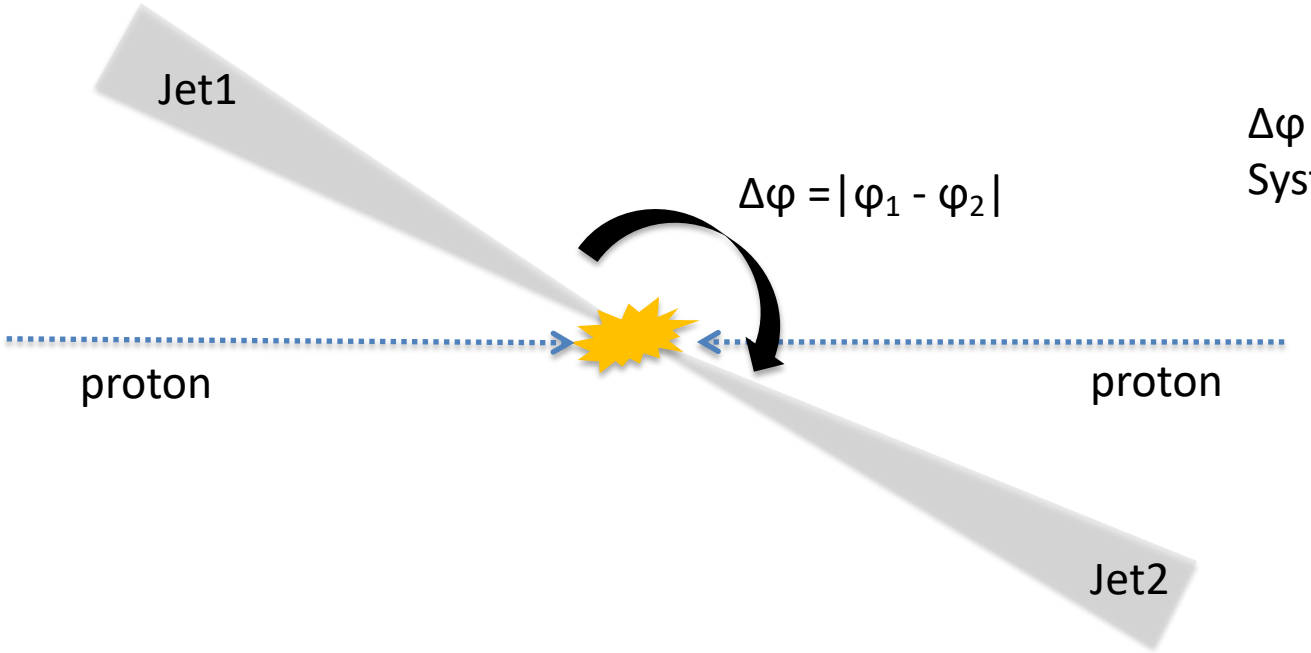
Measurements in proton collisions

Azimuthal angular decorrelation angle ($\Delta\varphi$) was studied for dijet events in proton collisions [1-3].

- Study parton radiation effects.
- Test pQCD and MC generators.
- High order perturbative effects.
- Search for new physics.



$\Delta\varphi = \pi \rightarrow p_{T1} = p_{T2}$
System = balance

LO pQCD calculations, $\Delta\varphi = \pi$ gives a delta function.

[1] D0, Phys. Rev. Lett. 94, 221801 (2005).
[2] CMS, Phys. Rev. Lett. 106, 122003 (2011).
[3] ATLAS, Phys. Rev. Lett. 106, 172002 (2011).

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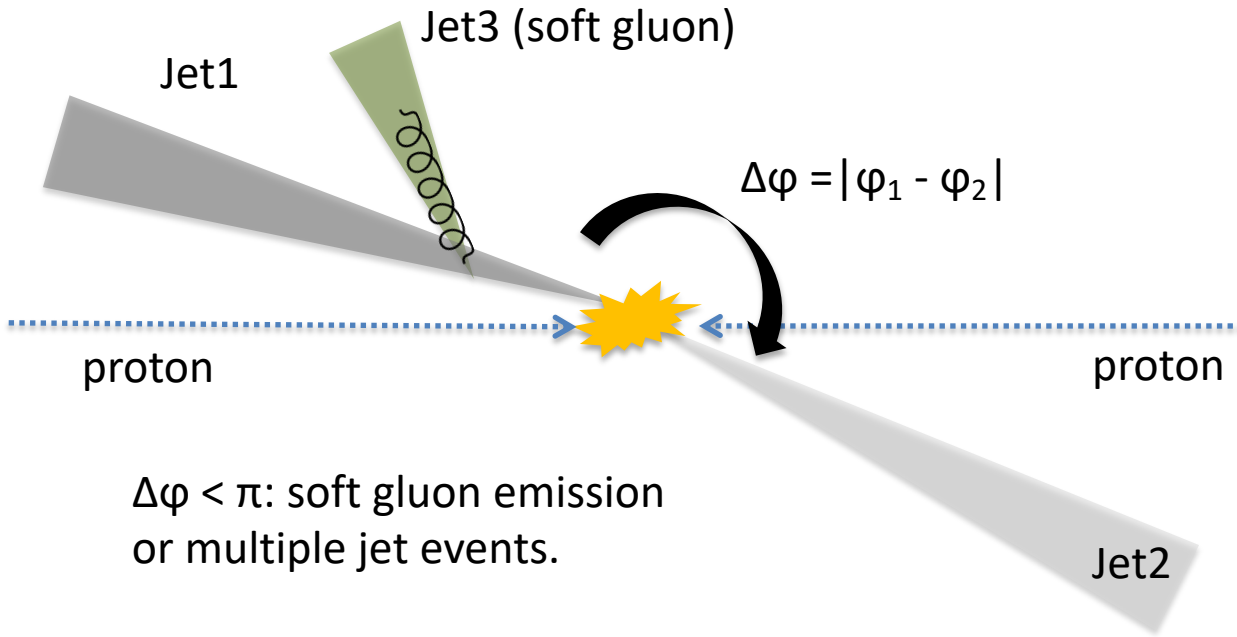
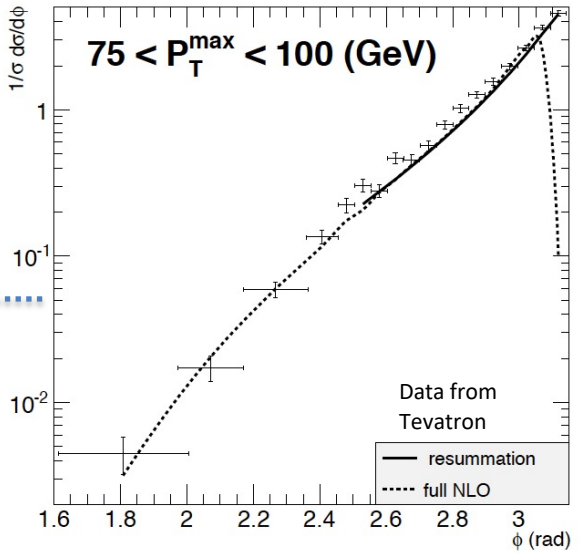


$\Delta\varphi < \pi$: soft gluon emission or multiple jet events.



Singularity persist at $\Delta\varphi = \pi$ with one or more gluon radiation.

Theoretical work [4] (including gluon radiation) describes the data very well.

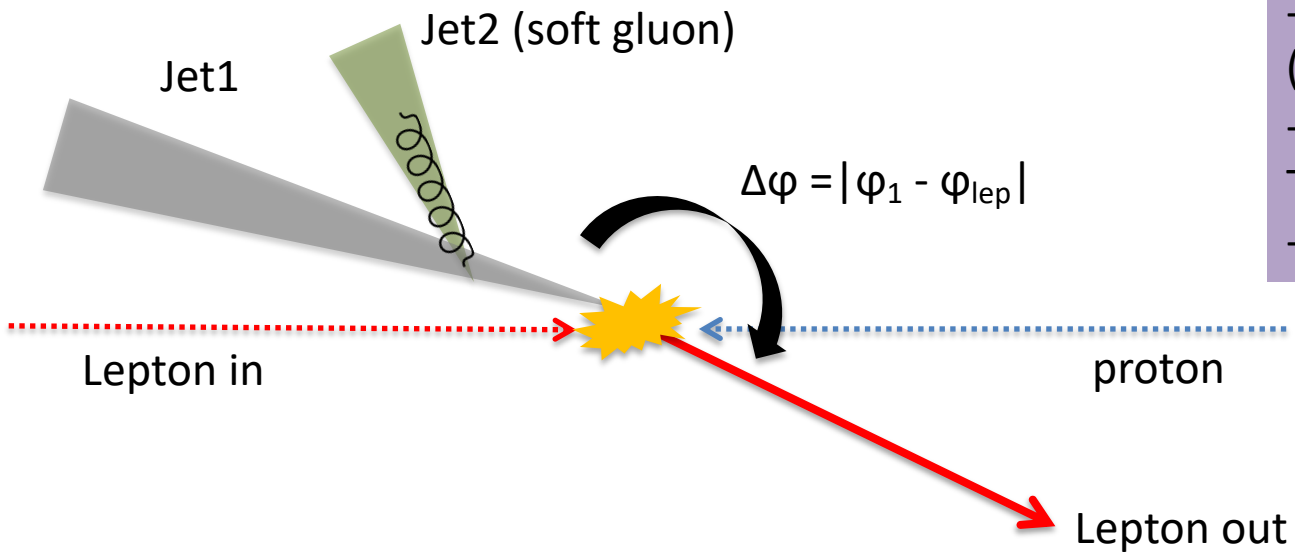
[4] Phys. Rev. D 92, 094007 (2015).

Motivation

Azimuthal angular decorrelation angle ($\Delta\varphi$) was studied in dijet events in p+p collisions [1-3].

Never done for lepton - jet

- Study parton radiation effects.
- Test pQCD and MC generators.
- High order perturbative effects.
- Search for new physics.



-Access **small Bjorken-x** (HERA kinematic region).
-Study **Q^2 dependence** on TMD evolution.
-**Non-perturbative** effects.

Test theoretical framework [4, 5] for lepton-jet decorrelation angle.

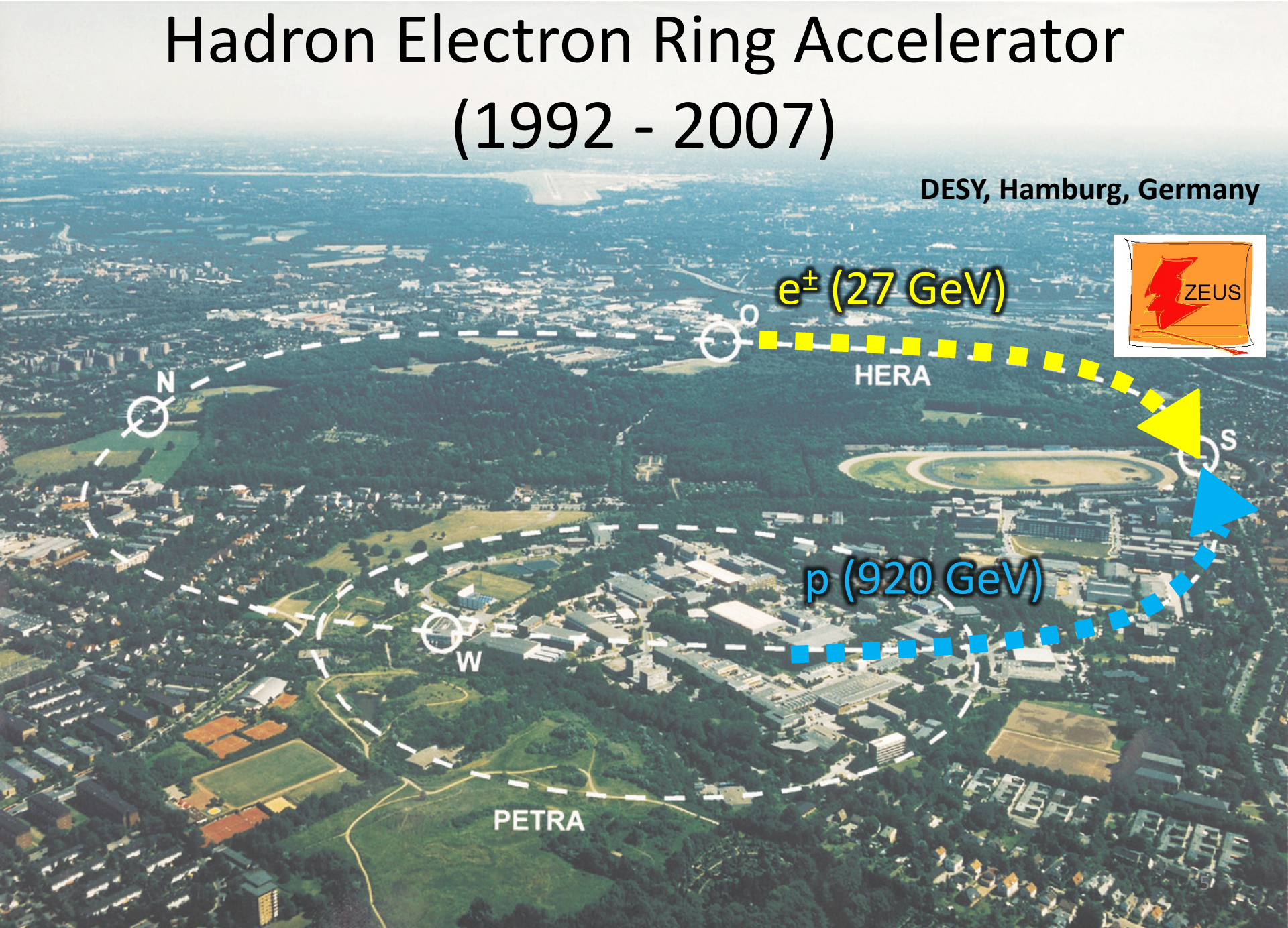
Lepton-proton collisions provide a theoretically simpler environment to test the calculations [6].

[5] Phys. Rev. Lett. 304 125, 082001 (2020)

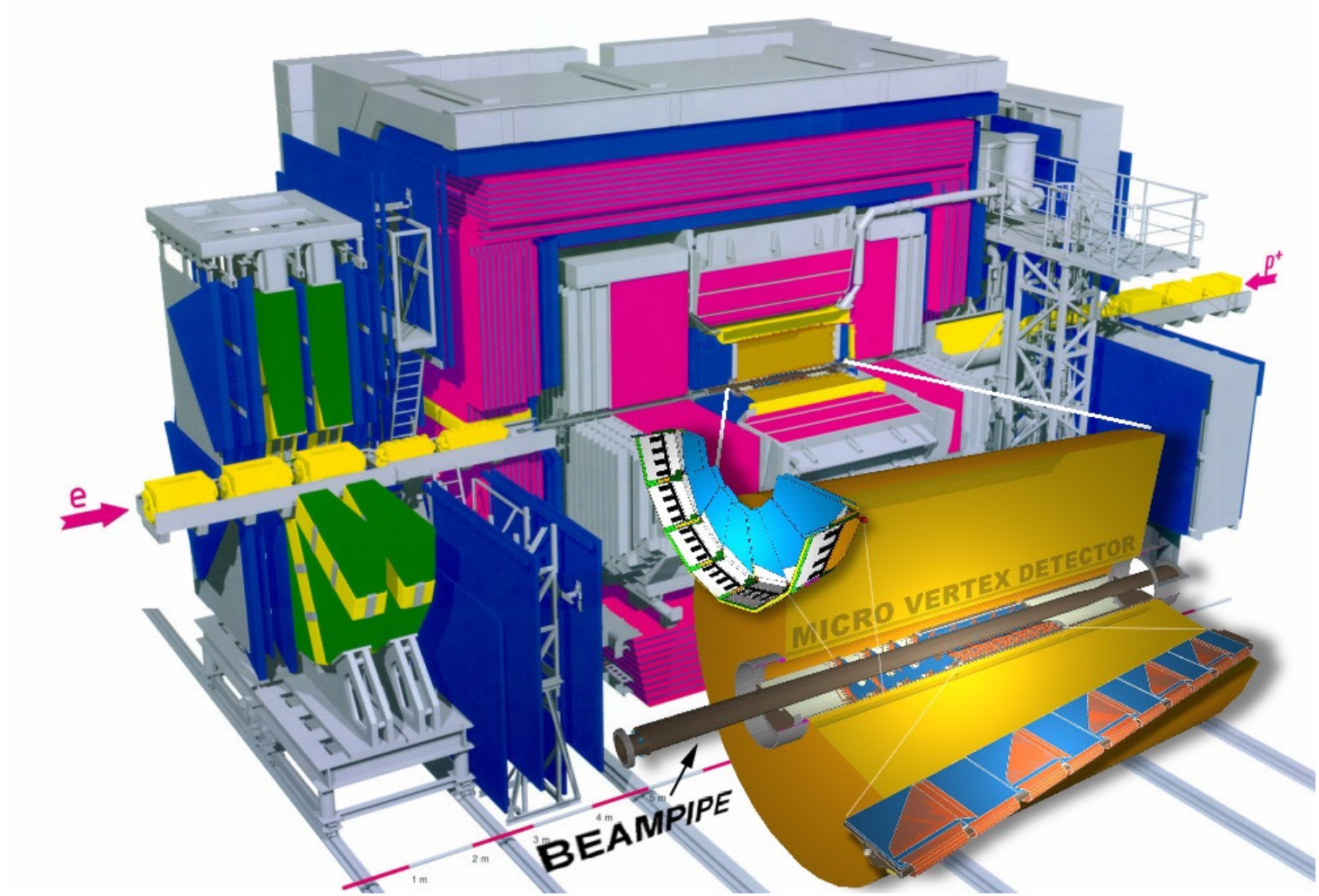
[6] Phys. Rev. Lett. 122, 192003 (2019).

Hadron Electron Ring Accelerator (1992 - 2007)

DESY, Hamburg, Germany



ZEUS Experiment

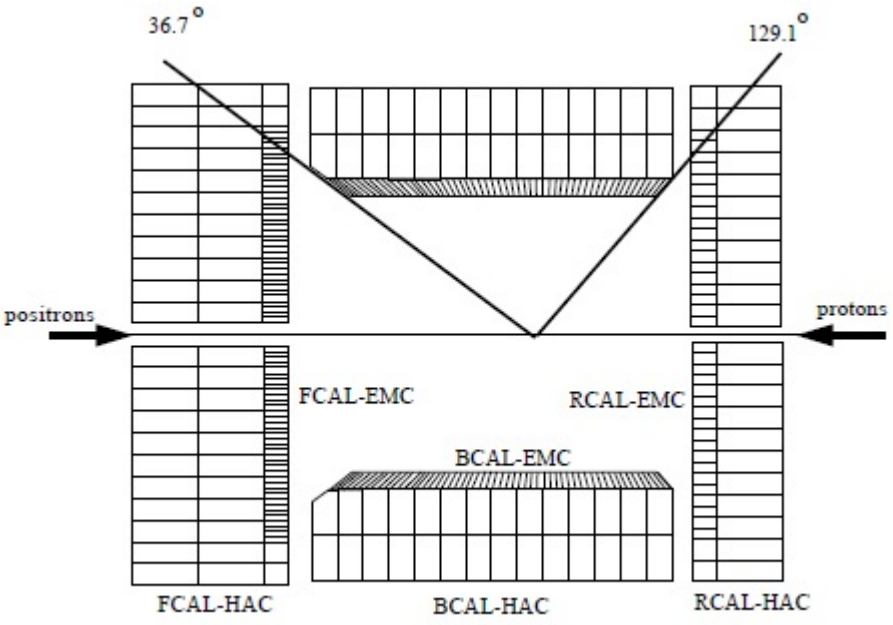


- One of the two largest multi-purpose collider experiments at HERA.
- The detector component, optimized to measure jets, was a high-resolution Uranium Calorimeter that surround a thin superconducting solenoid (1.43T) and the tracking detectors (CTD and MVD).

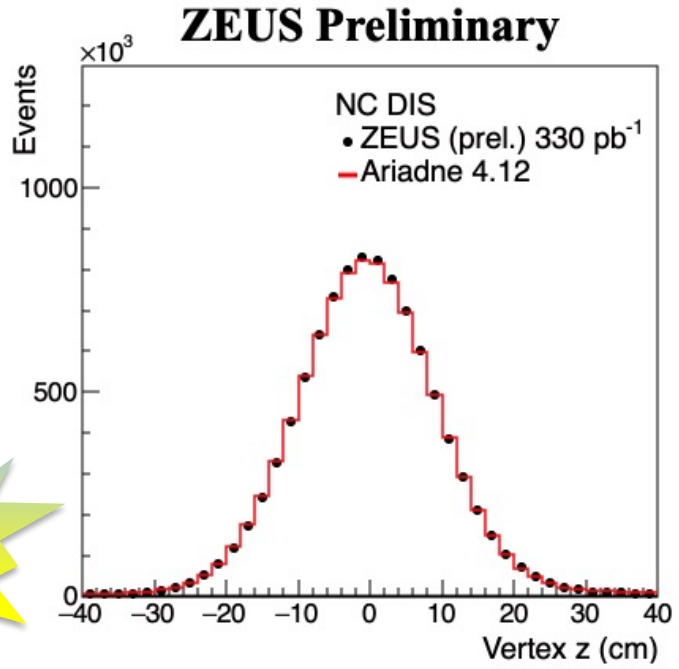
Event selection and control plots

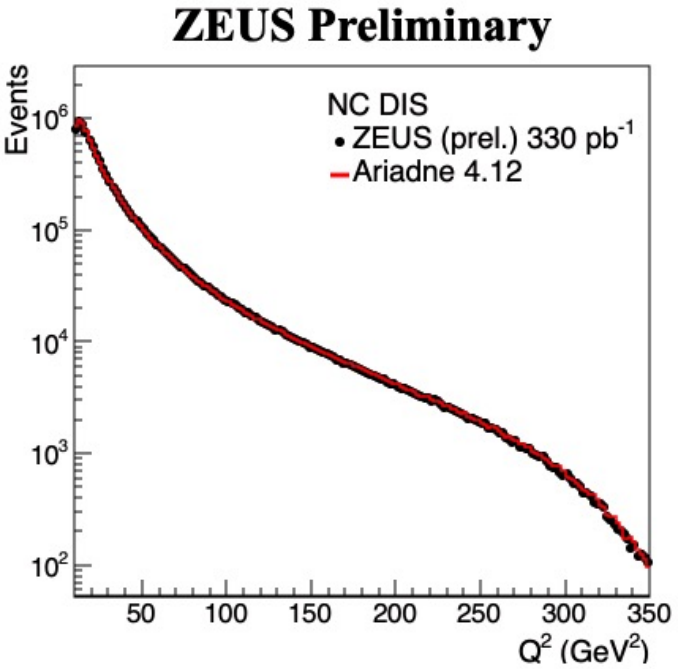
- Data from the HERA II period with √s = 318 GeV and integrated luminosity of ~330 pb^{-1}.
- Jets are reconstructed using the k_T [7] algorithm in the laboratory frame.
- Measurements were obtained for the kinematic region shown in the table below (like previous γ–jet measurements at ZEUS).
- No significant differences in the results when separating electron and positrons.

$10\ GeV^2 < Q^2 < 350\ GeV^2$
$E_{lepton} > 10\ GeV$
$140^o < \theta_{lepton} < 180^o$
$E_T^{jet} > 2.5\ GeV$
$\lvert\eta_{jet}\rvert < 1$

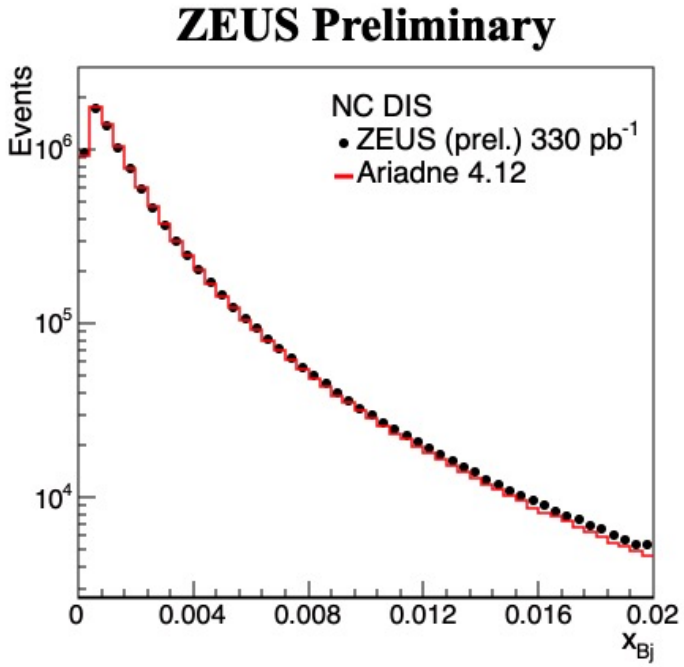


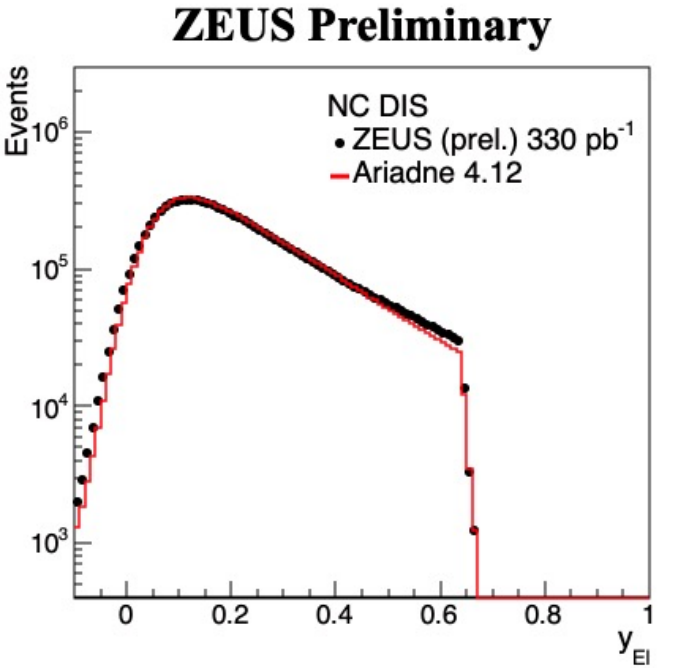
[7] Phys. Lett. B 691 (2010) 127-137)





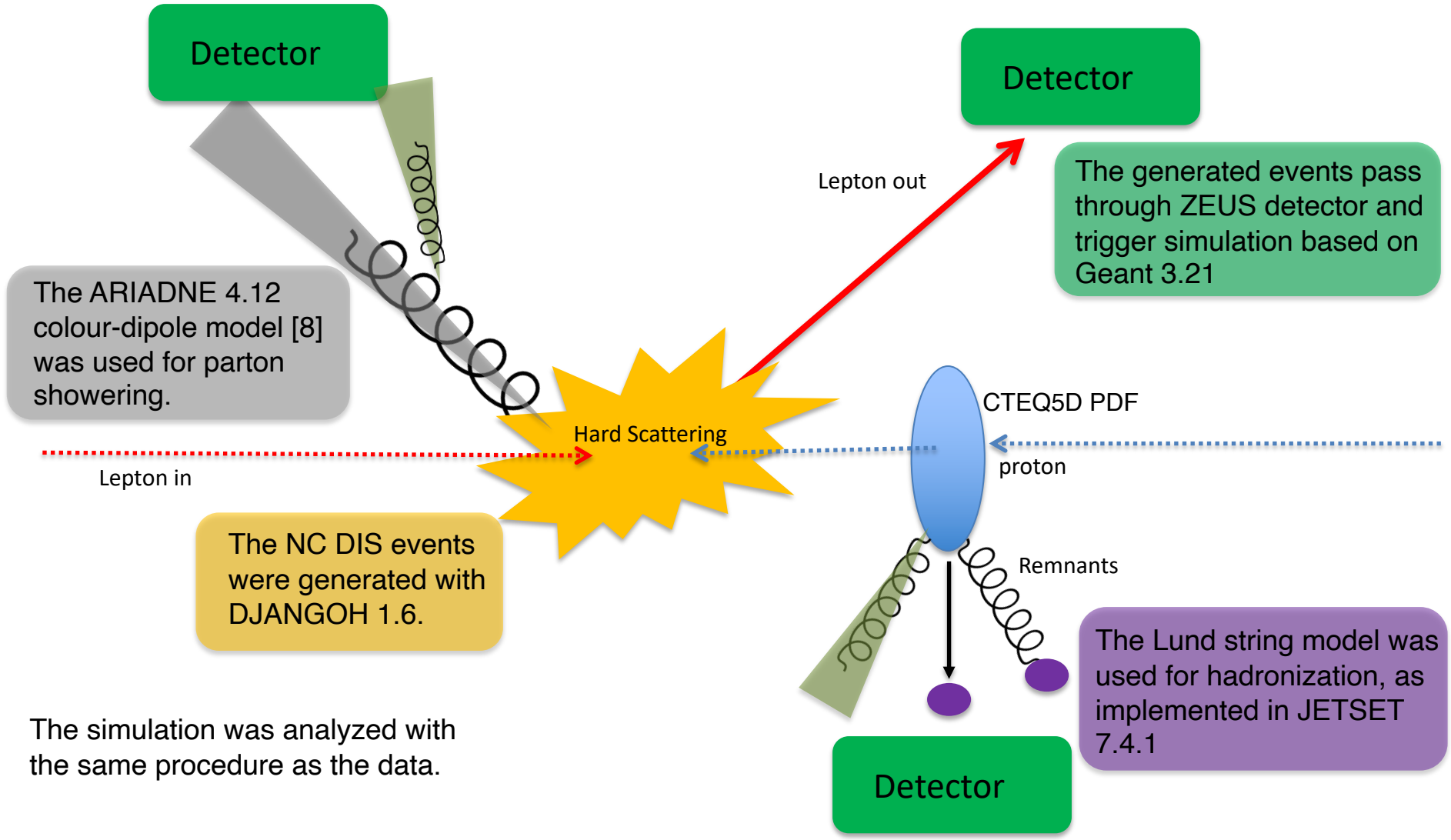
Good agreement data & MC





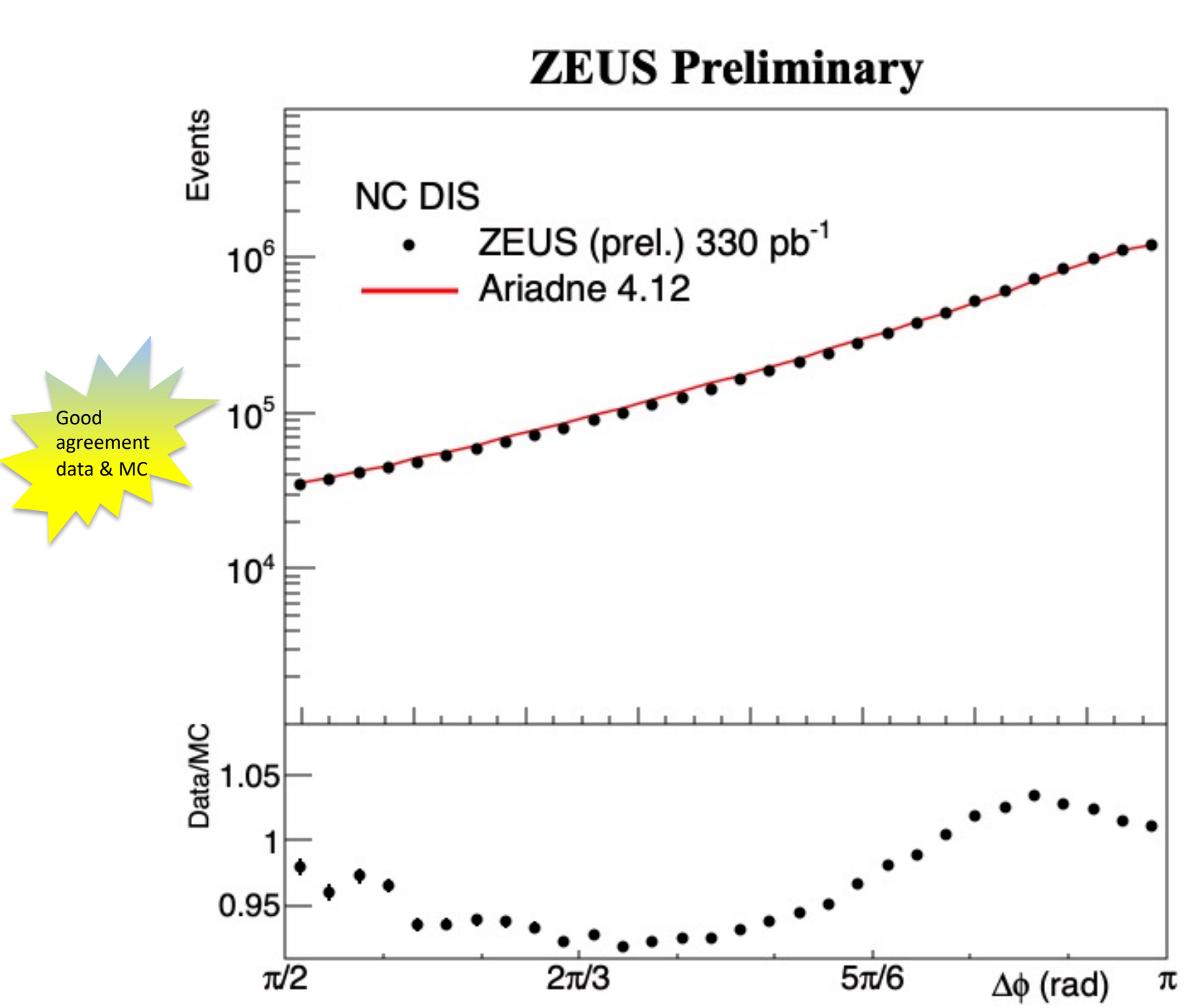
*Simplified representation

Simulation



The simulation was analyzed with the same procedure as the data.

[8] ARIADNE, Comp. Phys. Comm. 71,15 (1992).



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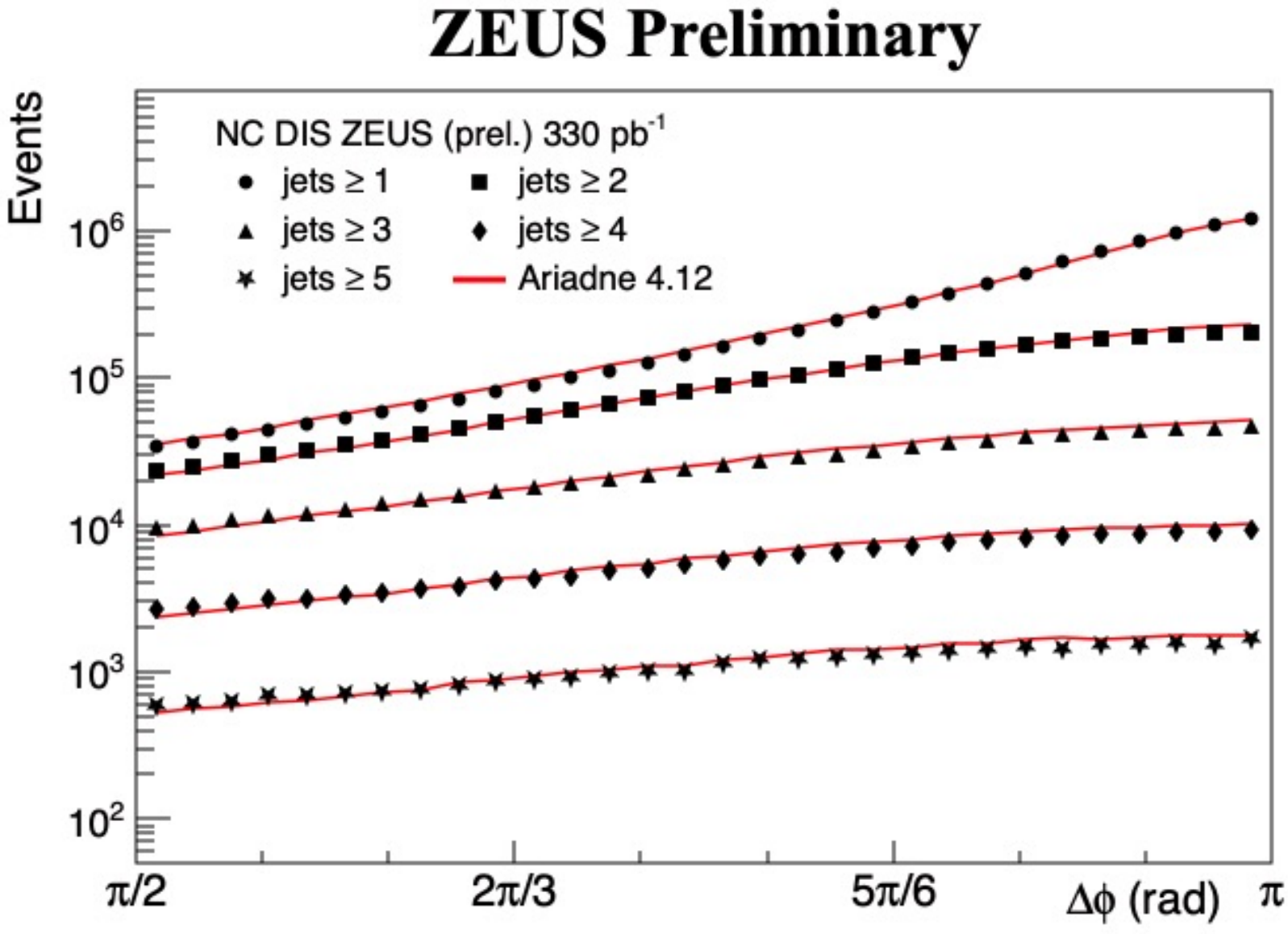
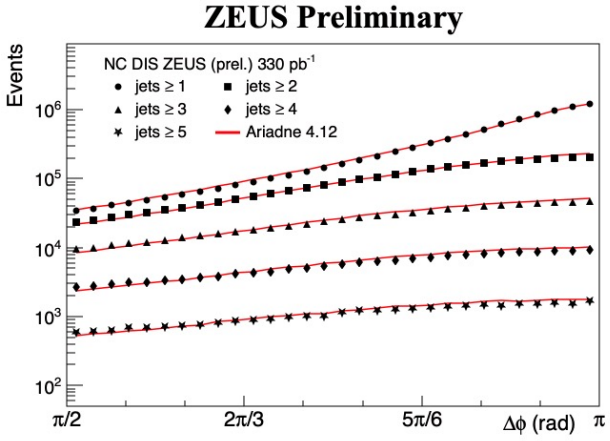
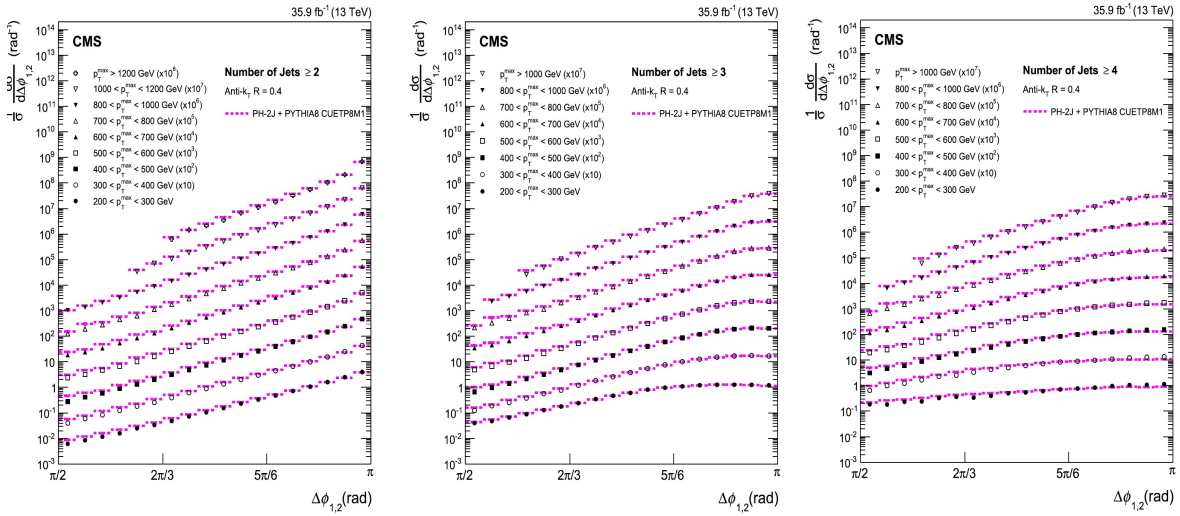


Good agreement between data and MC, but degrades at large multiplicity events

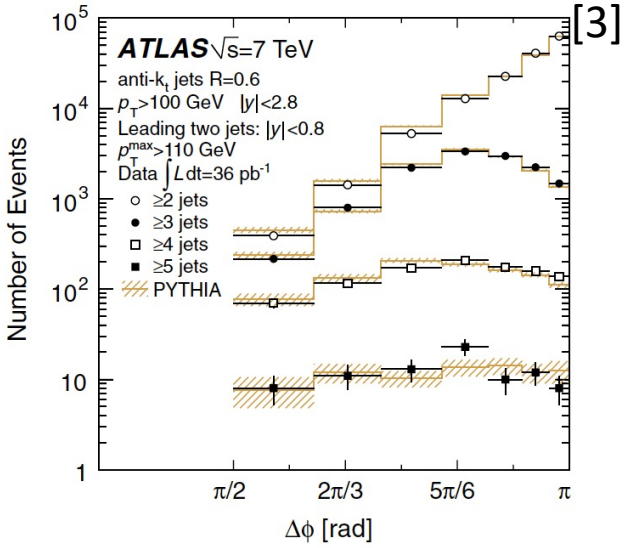
Multi-jet events

[9]





[3]



- Decorrelation measurements in different jet multiplicities per event, exhibit the same behavior as reported in [3] and [9].
- High jet multiplicity events should be dominated by soft gluon radiation.
- The agreement with the MC model degrades.
- Similar conclusions were reported in proton collisions by the CMS collaboration [9], stating the need from improvements of theoretical models.

[9] CMS, Eur. Phys. J. C 78:566 (2018).

Unfolding and Systematics

- Unfolding in 1-D will be performed with the **TUnfold** package [10].
- Differential cross section measurements will be presented, at different **p_T, Q^2 and jet multiplicity regions**.
- The following sources of systematic uncertainty were considered for normalized cross sections measurements, according to previous ZEUS analyses and similar from other experiments measurements in proton collisions:
  - The **energy of the scattered lepton** was varied by its known scale uncertainty of 2%.
  - The **jet energy scale** was varied 4% for values of $E^{jet}_T < 10$ GeV and 2.5% for $E^{jet}_T > 10$ GeV.
  - The uncertainty due to the **selection cuts** was estimated by varying the values of the cuts within the resolution of each variable.
  - The **differences** in the measurements obtained by using **ARIADNE and Lepto-MEPS** to correct the data for detector effects and bin migration.
  - The **decorrelation angle** was varied to account for its **resolution** effect into the measurements.
- TUnfold calculate systematics by propagating variations of bin migration matrix.

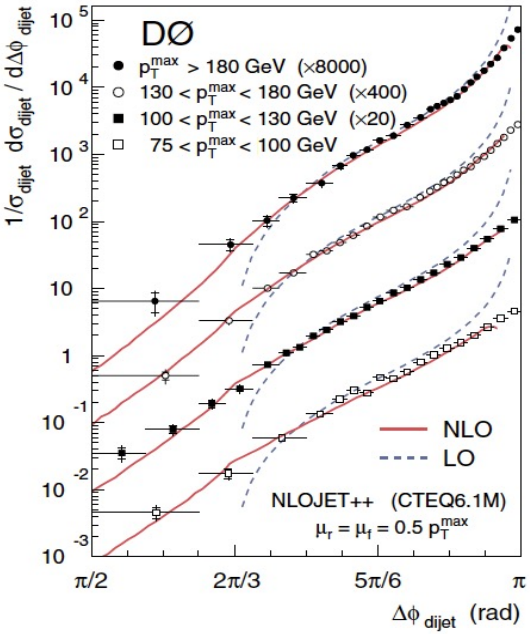
[10] TUnfold, JINST 7, T10003 (2012).

Summary

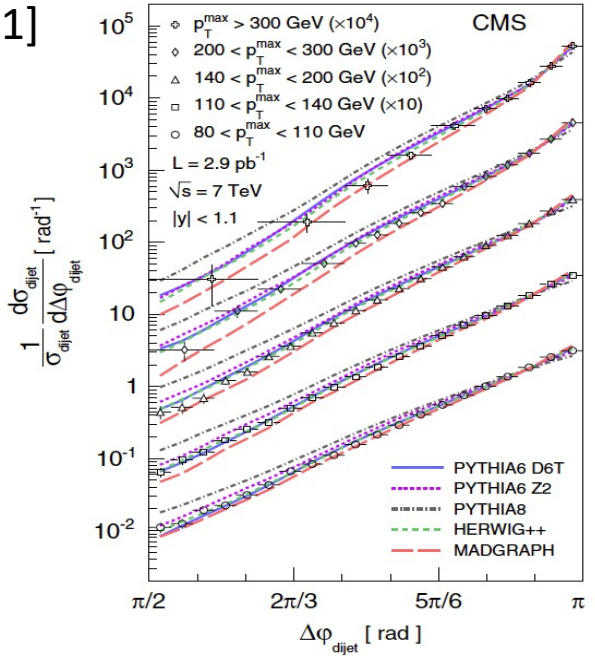
- Perform decorrelation measurements of lepton and leading jet in DIS, similar to previous ZEUS γ–jet results and other experiments in proton collisions.
- The MC predictions from ARIADNE [8] describe the main features of the data well. However, some discrepancies are observable.
- Dedicated predictions for ep collisions from [5] are in progress.
- Differential cross section measurements will be presented, at different p_T, Q^2 and jet multiplicity bins.
- These measurements represent a prelude (p_T range, systematics, etc) of future measurement at a new electron ion collider (EIC), particularly for measurements using polarized beams.

Backup

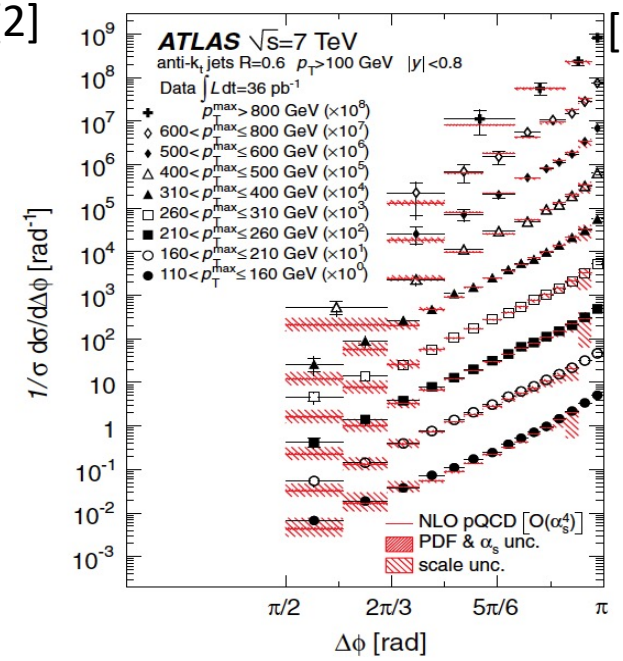
Initial results from proton collisions



[1]



[2]



[3]

Similar conclusions for Tevatron (ppbar at 1.96GeV), ATLAS and CMS (pp):
- NLO describes the data better than LO calculations (except at $\Delta\varphi \sim \pi$).
- MC generators describe the data fairly good however discrepancies at $\Delta\varphi \sim \pi/2$ where soft gluon radiation dominated.
- Suggest these results to tune MC generators at the time.