Exclusive Reactions Working Group Update

Raphaël Dupré (Paris-Saclay) - Salvatore Fazio (BNL) - Tuomas Lappi (Jyväskylä) - Barbara Pasquini (Pavia) - Daria Sokhan (Glasgow)

Physics conveners meeting - 6th May 2020

WG activities

Over 100 members currently signed up to the Google group:
eicug-yr-physics-exclusive@eicug.org

Weekly meetings
Fridays, nominally @ 10.30am, usually attended by 20-30 people

Past meetings with progress updates: https://indico.bnl.gov/category/291/

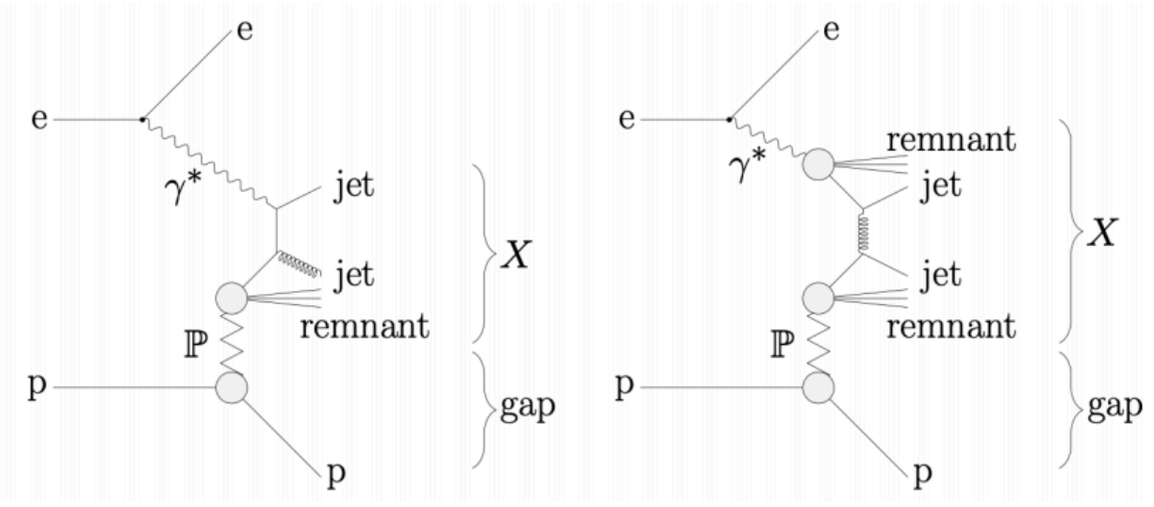
Ideas / topics jotted down in a shared (among the whole WG) Overleaf document:
https://www.overleaf.com/9542372781hhvvjvtbwgtw

Requested short summaries (in the Overleaf) of studies near completion, by the Pavia meeting.

Diffractive dijet photoproduction in ep

Zhengqiao Zhang (BNL)

27th March, 24th April



- Diffractive ep integrated in Pythia8.

$$\gamma^* + p \rightarrow \text{jet}_1 + \text{jet}_2 + p$$

- From HERA, expect DIS: Diffractive events 90:10
- Efficiency and purity of tagged diffractive events depends on ability to determine rapidity gap: to get both > 90% need rapidity coverage -2 to 4 (study with RAPGAP model).
- At 18 x 275 GeV:

  Detect proton in B0 and Roman Pots.

  Jets in Central Detector:

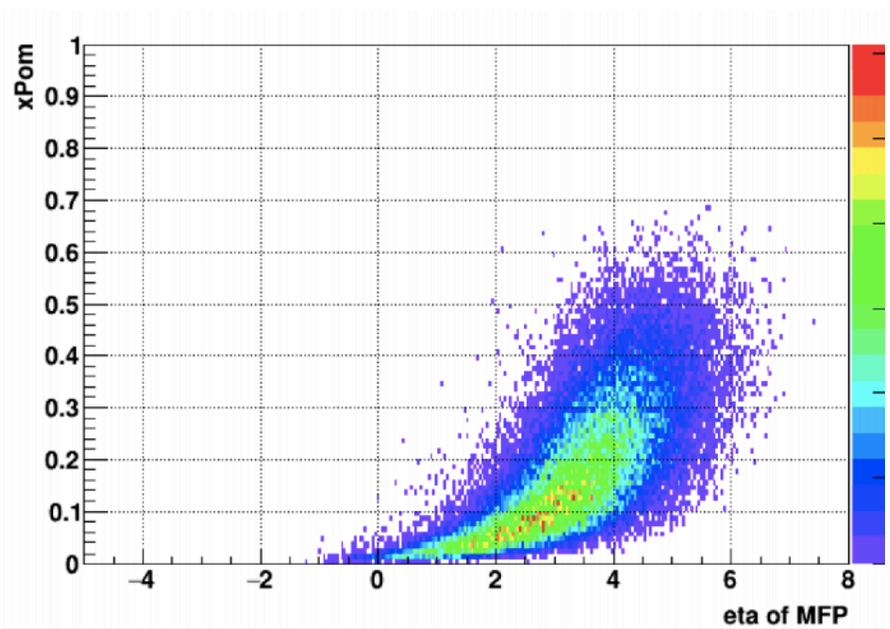
  Mean jet p_T 4.5 - 8 GeV/c

  Pseudorapidity from -4.5 to 4.5

  Electron scattering angle up to ~ 80 mrad.

After $x_{Pom} < 0.2$ cut (majority of diffractive events)

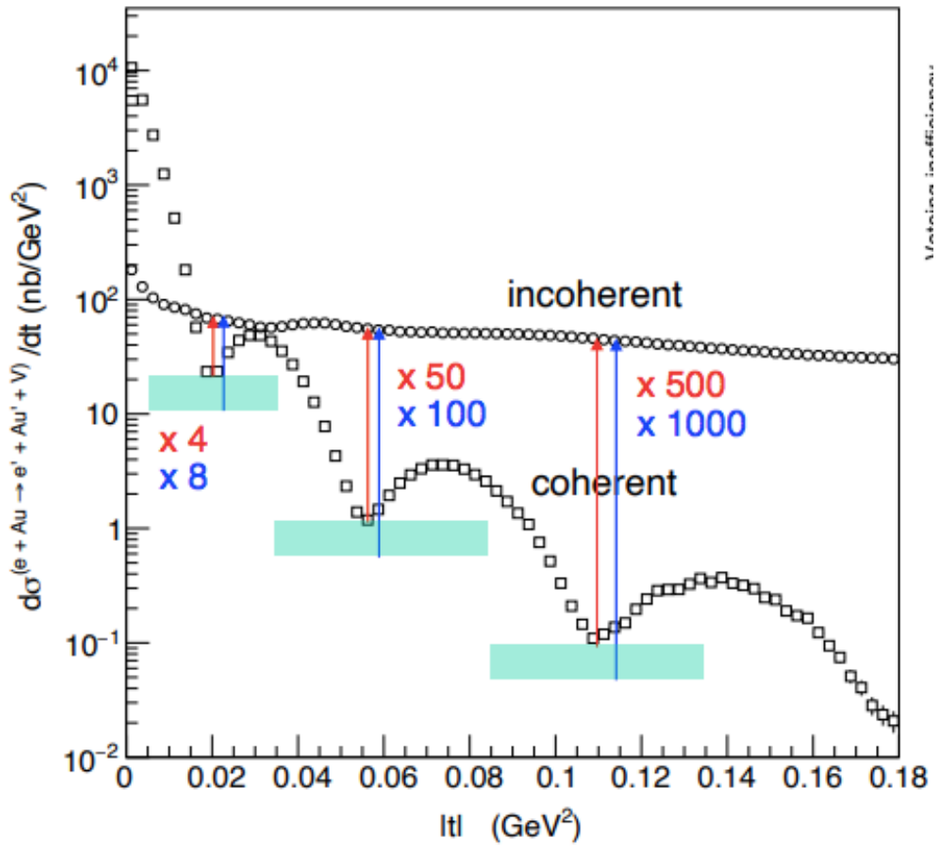
Protons	Scattering angle (mrad)	Momentum (GeV/c)	Momentum (GeV/c)
5 x 41 GeV	3 - 20	22 - 32	32
10 x 100 GeV	0.5 - 7	60 - 95	80 - 95
18 x 275 GeV	0.5 - 2.5	190 - 270	220 - 270



Coherent and incoherent contributions to e+A

Thomas Ullrich (BNL), 17th April

- J/Psi production study.
- Incoherent events need to be tagged with 1:500 - 1:1000 purity to extract (gluon) source distribution in Au (Pb).
- Third minimum essential for resolving b<0.5fm range. Factor of 1000 no distortion, 500 shows distortion but doesn't wash out minimum.
- Study of vetoing inefficiency done using BEAGLE with 10x40 ePb, need it at 18x110 (tagging group).



VMP in e+A

Thomas Ullrich (BNL), *28th Feb, 27th March, 3rd April*,

- Tracking study for J/Psi, phi, rho. To extract source distribution for all three mesons needs a smaller MS term (0.5%) in forward region to capture e' as well as VM decay for photo-production. Constraints already in the requirements table.

$$\text{MS term: } \left.\frac{\sigma_{p_T}}{p_T}\right|_{\text{MS}} = \frac{0.05}{L\,B\,\beta}\sqrt{1.43\frac{L}{X_0}}\left[1+0.038\,\log\frac{L}{X_0}\right]$$

- Photoproduction for phi (into KK) is a challenge: need to track down to p_T~ 100 MeV. Decay into two leptons is impossible to detect – branching ratio too small.

Reconstruction of VM: electrons vs muons

Yulia Furletova (JLab) *13th March*

- Reconstruction through invariant mass: need for PID and momentum resolution below a few %.
- Electrons: need hadron suppression by 10^4 due to the huge backgrounds & additional tools for *e* ID.
- Muons: in principle a cleaner sample, ID via passage through absorbers but needs good separation from showers produced by hadrons in the absorber.
- For *t* reconstruction need far-forward proton detection.

Update on exclusive VMP decay particles kinematics

Sylvester Joosten (ANL) 17th April,

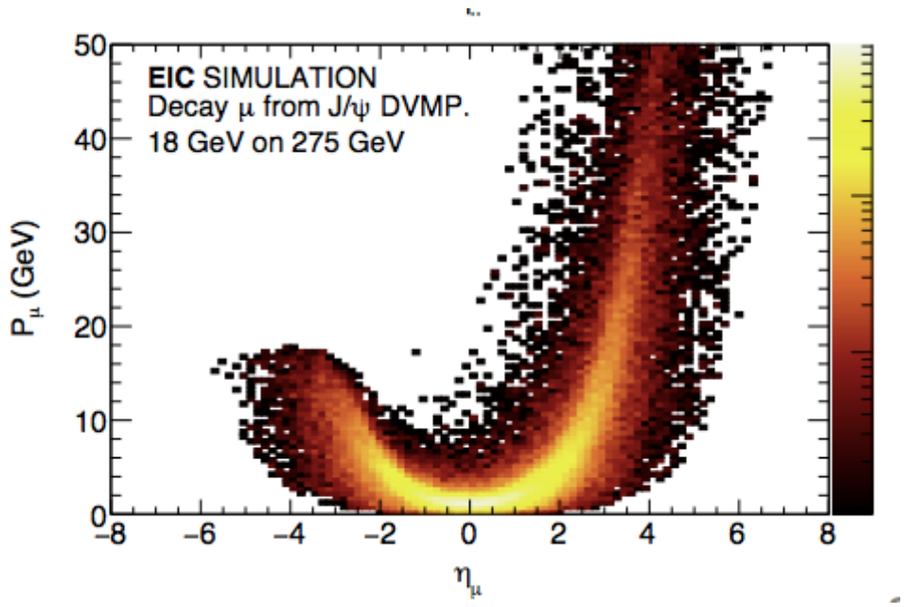
- **Protons**

	Scattering angle (mrad)	Momentum (GeV/c)
5 x 41 GeV	0 to > 20	25 - 41
5 x 100 GeV	0 - 15	55 - 100
10 x 100 GeV	0 - 15	55 - 100
18 x 275 GeV	0 - 5	150 - 275

- **Decay leptons:** -4 < eta < 4

Backward mom max given by electron beam energy.

Momentum (GeV/c)
< 15 forward
< 35 forward
< 35 forward
< 50 forward

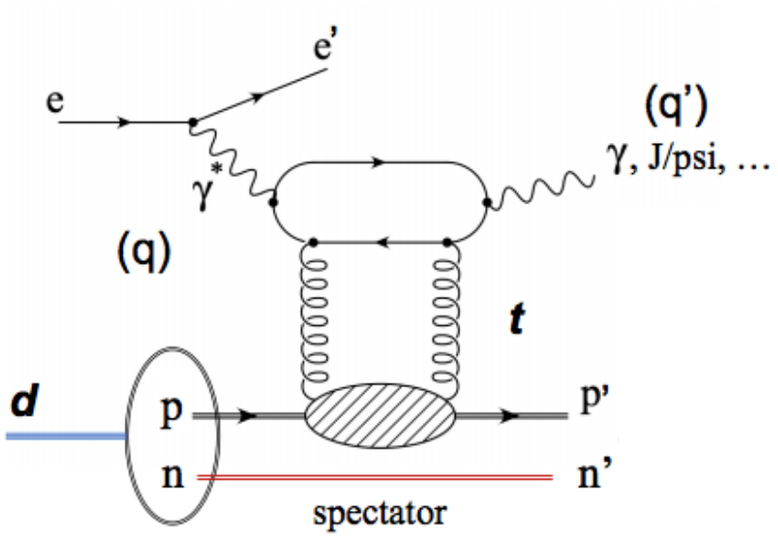


- **Electrons:** full momentum range up to beam one, pseudofrapitity range -8 to 0.

J/Ψ production on the deuteron with double-tagging

Kong Tu and Alexander Jentsch (BNL), *28th Feb, 13th March*

* BeAGLE generator: J/Ψ production in e+d with deuteron break-up. Can be modified for DVCS.



* Some observables are very sensitive to energy/momentum resolution, others to acceptance (K. Tu).

* Full simulation studied in EicROOT with GEANT4 (A. Jentsch).

* Comparison of proton and neutron tagging for different detector acceptances and resolutions:

- Neutron detector

Neutron Det.	Default	V1	V2
Acceptance	5 mrad	6 mrad	7 mrad
Energy reso.	$\frac{50\%}{\sqrt{E}} + 5\%$	$\frac{30\%}{\sqrt{E}} + 5\%$	$\frac{100\%}{\sqrt{E}} + 5\%$

- Proton detector
  - Acceptance: (0,5) + (7-22) mrad (default)

Proton Det.	Default	V1	V2
Momentum reso.	$\frac{dp_T}{p_T} = 3\%$	$\frac{dp_T}{p_T} = 5\%$	$\frac{dp_T}{p_T} = 10\%$

- Energy configurations:
  - 18 x 135 GeV (default)
  - 10 x 50 GeV
  - 5 x 20 GeV

Hard exclusive Pi0:

Maxime Defurne (CEA Saclay), F.-X. Girod (UConn), Salvatore Fazio (BNL)

13th March, Temple, 3rd April, 24th April

- Detection of both decay photons constrained by **energy threshold** (assume ~ 300 MeV min) in calorimeter and **angular resolution between clusters**.

Suppression of pi0 as background to DVCS at high energies (18 x 275 GeV)

- Most pi0 removed by DVCS min photon energy cut of 1 GeV
- Most pi0 photons are in the hadron endcap: can be removed by DVCS veto on forward photons.
- Rear endcap at 250 cm from IP and granularity of 25.2 cell size will give angular resolution of 0.03 mrad, sufficient to suppress almost all backward pi0.
- Ability to suppress pi0 as DVCS background depends on relative cross-sections.

Pi0 kinematics: reconstructing pi0s

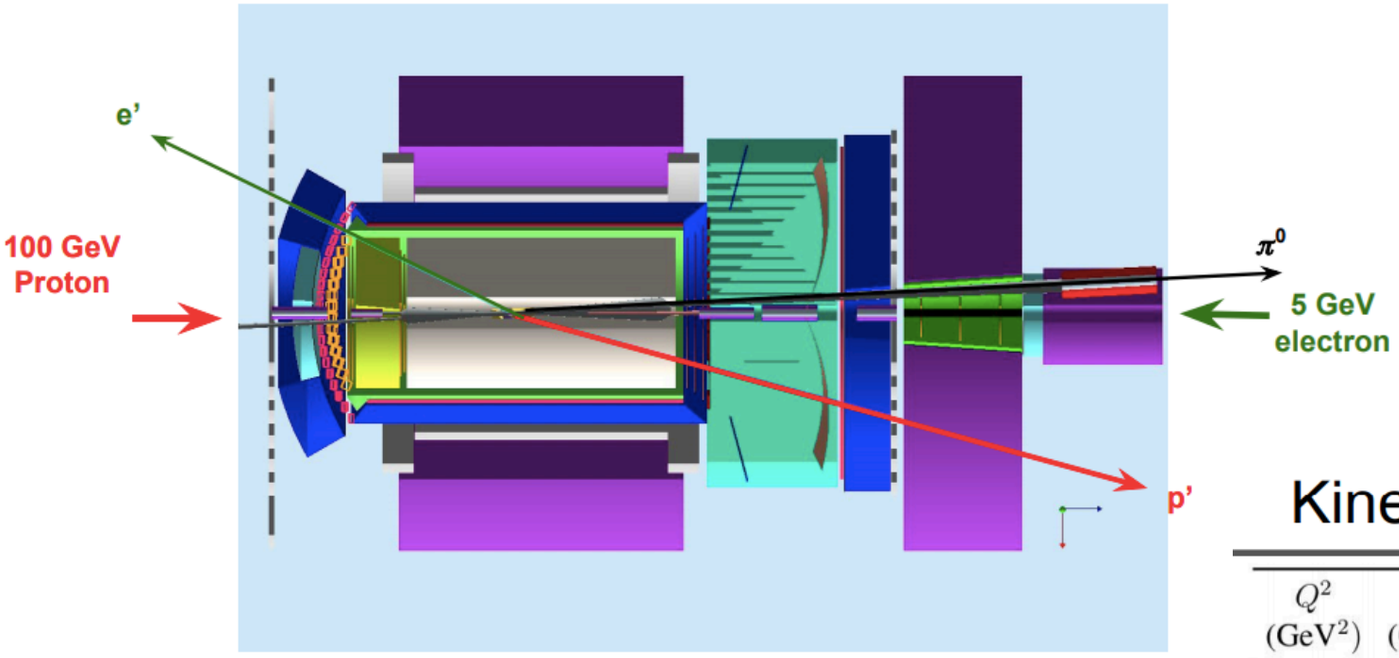
- Predominantly in hadron endcap, rapidity: 1.8 - 3.6.
- t_min limit: max pi0 momentum for each x_B, Q^2 bin: affects angular res.
- High t (0.5, 1 GeV): energy decreases, must be detectable.
- For 10x100 GeV and 18x275 GeV at t_{min}, high Q^2, high x_B edge has pi0 momentum > 80 GeV/c. Clusters start to merge. Low stats in this region.
- Calorimeter threshold affects the lower Q^2 region, more so for low CM energies and for higher t: threshold will determine truncation in t: parts of low Q^2, high x missing.
- Next steps: fold in proton and electron acceptance and full range of kinematics.

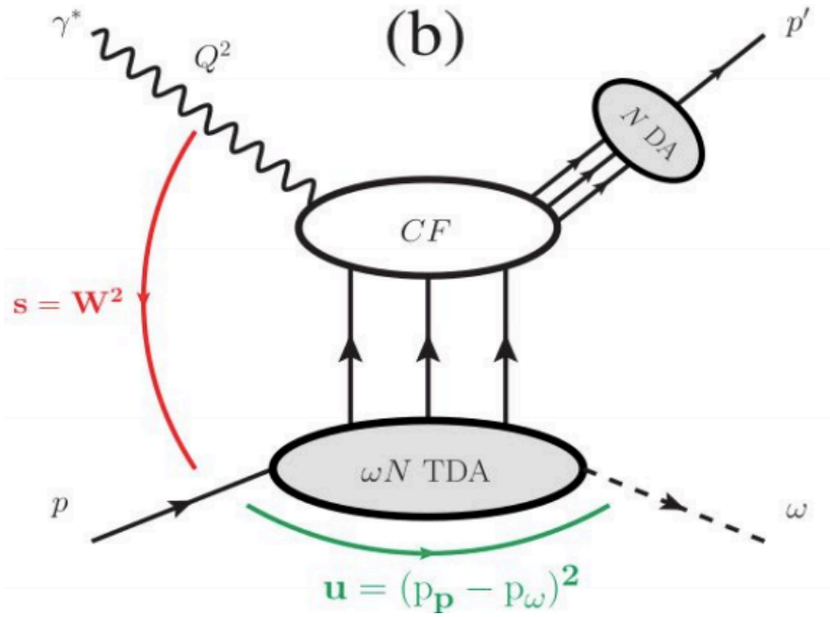
- Hard exclusive Pi0 production (GK model) added to PARTONS – outputs are being integrated into the MILOU generator (Kemal Tezgin, UConn).

U-channel pi0 production

Li (Bill) Wenliang (BNL), *17th April*

- Backward angle production of pi0 from proton: TDAs.
- Generator created.
- Cross-section ~ 0.1 of the forward-angle X-sec.





- Pi0 mom: 20-50 GeV. Pi0 angle from above 50 to below 35mrad. Photon opening angle 0.4-0.8 deg.
- Started compiling kinematics table.

Kinematics Table

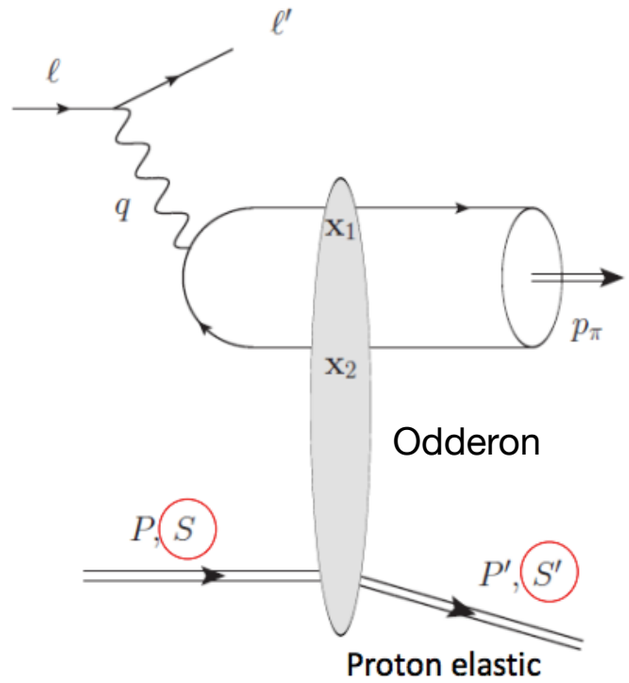
Q^2 (GeV^2)	W (GeV)	x_B	$\theta_{e'}$ (deg)	$P_{e'}$ (GeV)	$\theta_{p'}$ (deg)	$P_{p'}$ (GeV)	θ_{π^0} (deg)	P_{π^0} (GeV)	$-t$ (GeV^2)	$-u$	
6.0	3.19										
12.0	3.19										50 mrad
18.0	3.19		134	5.91	-2.53	66.3	2.86	32.74	26.98	-0.55	
24.0	3.19										
30.0	3.19										
36.0	3.19										

Q^2 (GeV^2)	W (GeV)	x_B	$\theta_{e'}$ (deg)	$P_{e'}$ (GeV)	$\theta_{p'}$ (deg)	$P_{p'}$ (GeV)	θ_{π^0} (deg)	P_{π^0} (GeV)	$-t$ (GeV^2)	$-u$	
6.0	3.19										
12.0	3.19										35 mrad
18.0	3.19		134	5.91	-3.02	55.63	2	43.45	25.92	0.5	
24.0	3.19										
30.0	3.19										
36.0	3.19										

Odderon/gluon Sivers searches at EIC

Yoshitaka Hatta (BNL), *1st May*

- Searched-for at HERA unsuccessful, possible observation at LHC (TOTEM).
- Requires high CMS energy and W, both low and high t (for spin-dependent and -independent odderon).
- Protons far forward, electrons and pions far backward.
- No cross-sections available yet, kinematics appear within the requirements from other channels.



GPD studies with PARTONS

Hervé Moutarde (CEA Saclay), Paweł Sznajder and the rest of the PARTONS team, *24th April*

Deliverables within the YR timeline

- Cross sections for **exclusive π^0 production**.
- **TCS observables**.
- Impact of EIC on the extraction of the **first Gegenbauer coefficient** of the D-term from global CFF fits.
- Integration in the **MILOU MC generator** of tables of CFFs output from PARTONS.
- **GPD evolution** computed with **APFEL**.

- Model-based and Neural Network-based global fits, multi-channel analysis at LO and NLO.
- D-term extraction very model-dependent: data from EIC required.

Krešimir Kumerički (Zagreb) *24th April*

- Flavour separation via Neural Networks: H

Physics with positron beams at EIC

Eric Voutier, *27th March*

- Physics case made, meeting held with accelerator experts to discuss possibility of polarised positron beams as an upgrade. No show-stoppers.

Benchmark channels - table from Temple

Process	Detector challenge	Key plot	Physics goal	Studies by
J/Ψ (+ other VM's) in *eA*	fwd instrumentation (veto incoh. bkgd. in *eA*) hermeticity (rapidity gap) p_T-resolution for decay $e^{\pm}, \mu^{\pm}$ *	$d\sigma/dt$	saturation & shadowing nGPDs	T. Ullrich
diffractive dijets (diff. structure functions)	jet p_T resolution (need to connect with jet, SIDIS subgroups)	$d\sigma/d\phi$ (angle btw recoil momentum and jet axis) for different t, jet p_T's	elliptic gluon Wigner distribution	Z. Zhang

Contact names have been replaced (alphabetically) by those who have carried out studies and shown updates in our meetings.

Process	Detector challenge	Key plot	Physics goal	Studies by
DVCS (ep) including polarization + positrons?	tracker, EMCAL coverage (e/γ separation, resonance bkg.) EMCAL granularity (γ vs π^0 bkg.) fwd h acceptance (for extended t-range) full 2π hermeticity (spin asymmetries)	$d\sigma/dt$ A_{UT} π^0 decay-γ: $\Delta(\theta)$	proton GPDs D-term Ji sum rule	M. Defurne, F.-X. Girod, S. Fazio

Process	Detector challenge	Key plot	Physics goal	Studies by
Coherent DVCS on D, ^{3}He, ^{4}He	$\|t\|$ acceptance in fwd spectrometer	$d\sigma/dt$	nuclear GPDs	R. Dupré, S. Fucini, S. Scopetta
DVCS on neutron: Double tagging on D	ZDC acceptance (n tagging) ZDC, VTX resolution (t reconstruction) spectator proton (RPs acceptance)	$d\sigma/dt$ for n DVCS (kinematics from tagging n and p)	neutron GPD GPD flavor separation	A. Jentsch, Z. (Kong) Tu

Process	Detector challenge	Key plot	Physics goal	Studies by
TCS (and J/Ψ) in *ep*	$e^{\pm}$ *p*-resolution fwd (*h*-going) coverage for decay leptons (near-threshold)	$d\sigma/dt$ for TCS and J/Ψ	GPDs, proton mass/trace anomaly (near thresh-old)	M. Boer, Y. Furletova, S. Joosten, J. Wagner (PARTONS)
exclusive ϕ and ρ in *ep* (and *eA*)	PID for hadronic decay channels: kaons...	$d\sigma/dt$	GPDs, gluon saturation	
exclusive π^0 and π^+	PID, EMCAL resolu-tion and granularity for π^0 decay	$d\sigma/dt$	GPDs (chiral-odd and chiral-even)	M. Defurne, F.-X. Girod, K. Tezgin (PARTONS), L. (Bill) Wenliang