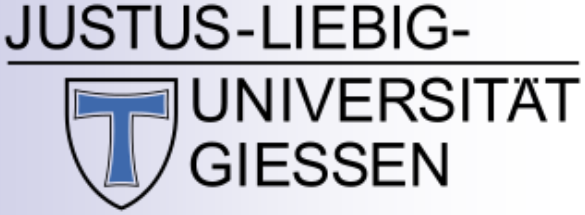
DIS2022: XXIX International Workshop on Deep-Inelastic Scattering and Related Subjects

May 02 - 06, 2022

Hard exclusive $\pi^- \Delta^{++}$ electro-production off the proton with CLAS12

A first potential access to p-Δ transition GPDs



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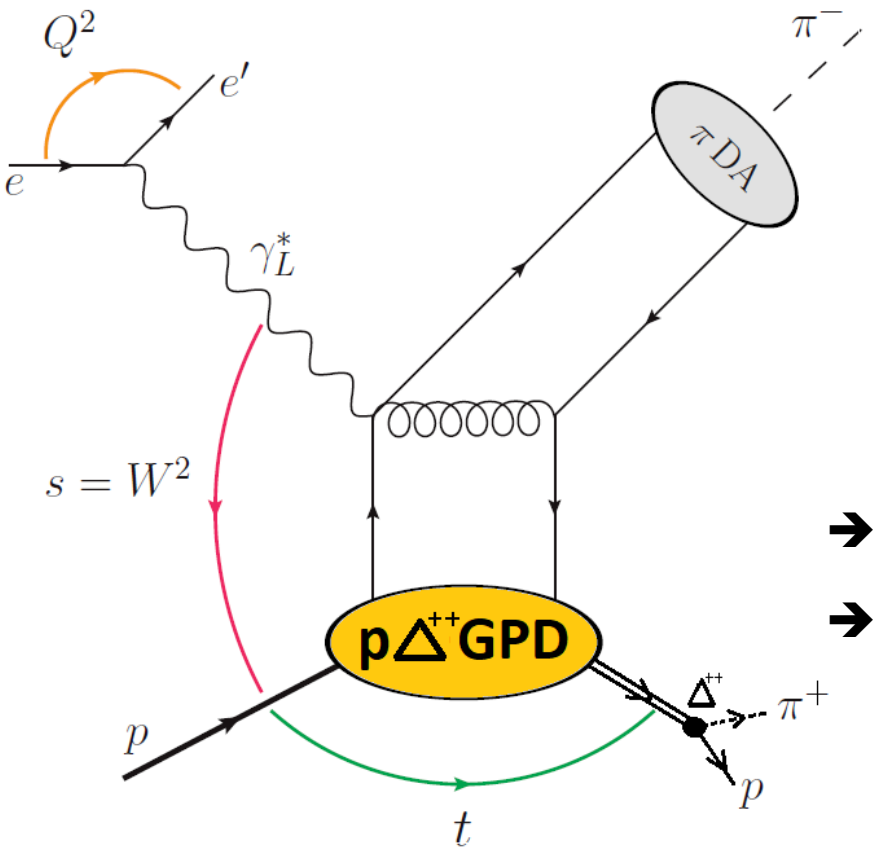
05/04/2022

Motivation

$$ep \rightarrow e\Delta^{++}\pi^{-} \rightarrow ep\pi^{+}\pi^{-}$$



Factorisation expected for:

$-t / Q^2 \ll 1$ and $Q^2 > M_\Delta^2$

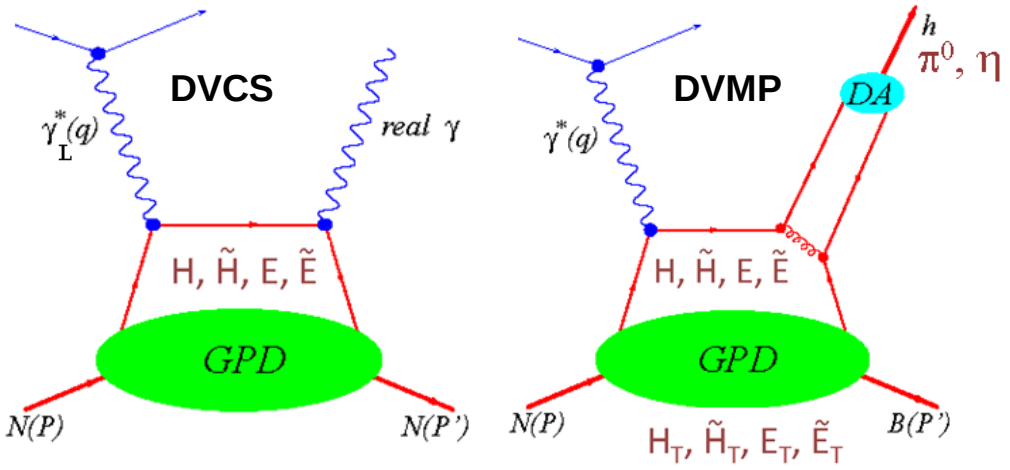
x_B fixed

➔ Provides access to p-Δ transition GPDs

➔ 3D structure of the Δ resonance and of the excitation process

➔ $\pi^{\pm}$ is expected to be especially sensitive to the tensor charge of the resonance

Motivation

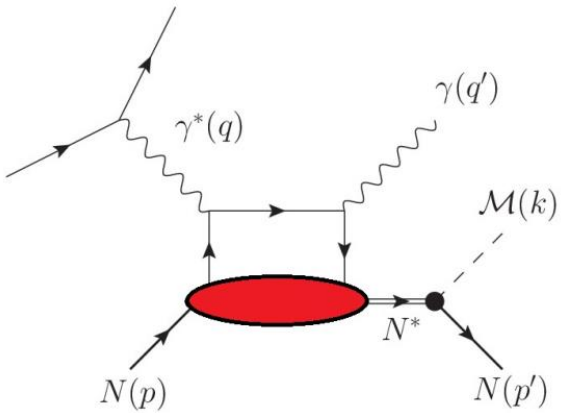


classical GPDs:

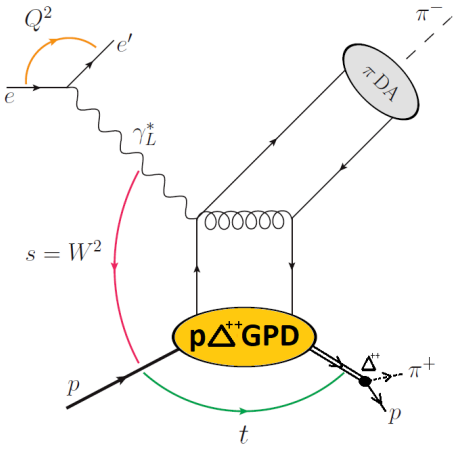
nucleon \ quark pol.	N/q	U	L	T
	U	H		$\bar{E}_T$
	L		$\widetilde{H}$	$\widetilde{E}_T$
	T	E	$\widetilde{E}$	$H_T, \widetilde{H}_T$

4 chiral even GPDs

4 chiral odd GPDs



non-diag. DVCS



non-diag. DVMP

- **8 helicity non-flip trans. GPDs (twist 2)**

→ 3 are dominating in the large N_C limit

→ Connection to proton-proton GPDs via symmetry considerations

➔ Description of leading twist efects / longitudinal photons → σ_L

→ First theoretical works available

- **8 helicity flip trans. GPDs**

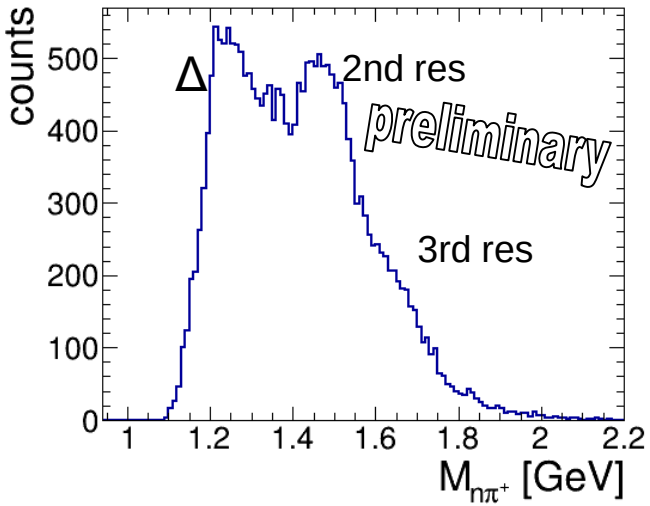
→ Needed for twist-3 sector (non-diag DVMP)

→ Theory in progress (no publ. so far)

Why is $\pi^- \Delta^{++}$ special?

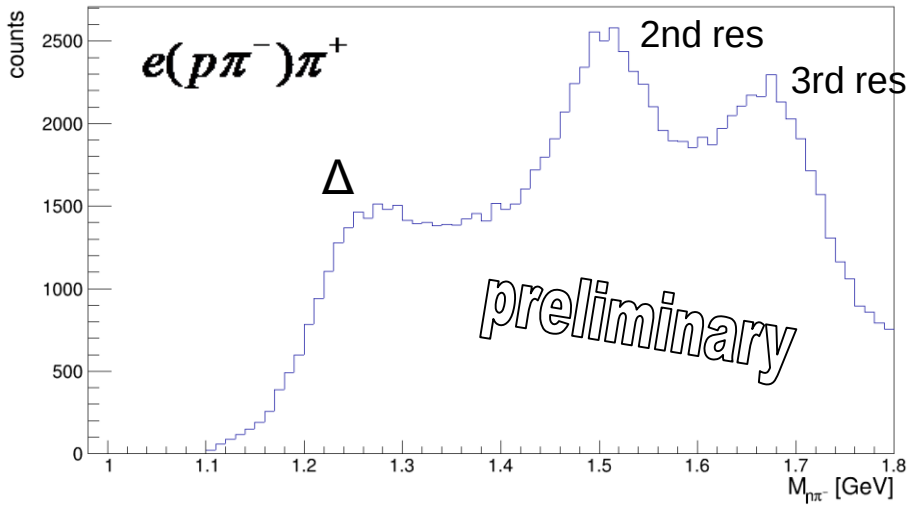
non-diagonal DVCS

$$\gamma^* p \rightarrow N^* \gamma \rightarrow p \; meson \; \gamma$$



other non-diagonal DVMP channels

$$ep \rightarrow e\Delta^0\pi^+ \rightarrow e(p\pi^-)\pi^+$$



$$ep \rightarrow e\Delta^{++}\pi^- \rightarrow \underbrace{ep\pi^+}\pi^-$$

I_z = +3/2

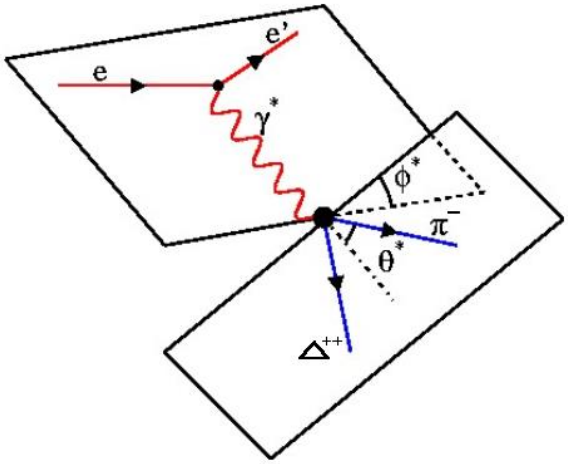
➔ The $p\pi^+$ final state can **only** be populated by **Δ-resonances**

➔ Large gap between Δ(1232) and higher resonances

Hard Exclusive π^- Electroproduction and BSA

Cross section (longitudinally pol. beam and unpol. target):

$$2\pi\frac{d^2\sigma}{dtd\phi} = \frac{d\sigma_T}{dt} + \epsilon\frac{d\sigma_L}{dt} + \epsilon\cdot cos(2\phi)\frac{d\sigma_{TT}}{dt} + \sqrt{2\epsilon(1+\epsilon)}\cdot cos(\phi)\frac{d\sigma_{LT}}{dt} + h\cdot\sqrt{2\epsilon(1-\epsilon)}\cdot sin(\phi)\frac{d\sigma_{LT'}}{dt}$$

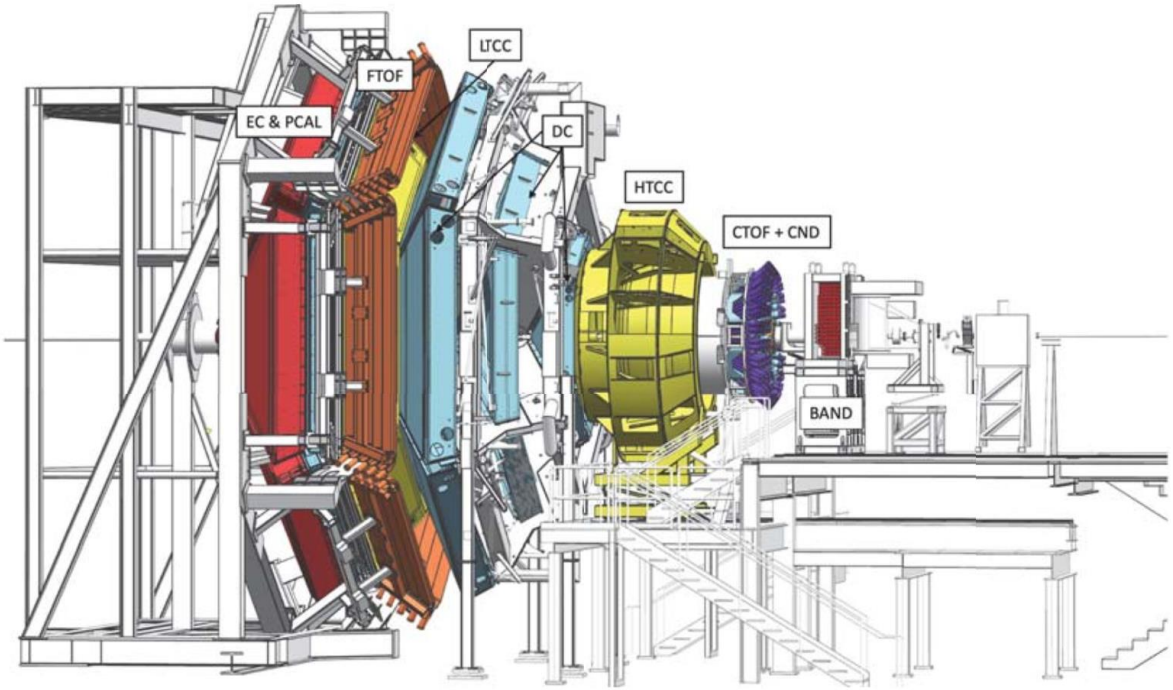


$$\sigma = \sigma_0(1 + A_{UU}^{\cos(2\phi)}\cos(2\phi) + A_{UU}^{\cos(\phi)}\cos(\phi) + hA_{LU}^{\sin(\phi)}\sin(\phi))$$

$$BSA(t,\phi,x_B,Q^2) = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = \frac{A_{LU}^{\sin\phi}\sin\phi}{1 + A_{UU}^{\cos\phi}\cos\phi + A_{UU}^{\cos 2\phi}\cos 2\phi}$$

$$A_{LU}^{\sin\phi} = \frac{\sqrt{2\epsilon(1-\epsilon)}\,\sigma_{LT'}}{\sigma_T + \epsilon\sigma_L}$$

CLAS12 Experimental Setup in Hall B at JLAB



V. Burkert et al., Nucl. Instrum. Meth.A 959 (2020) 163419

➔ Data recorded with CLAS12 during fall 2018 and spring 2019

➔ 10.6 / 10.2 GeV e^- beam ➔ ~87 % average polarization ➔ liquid H_2 target

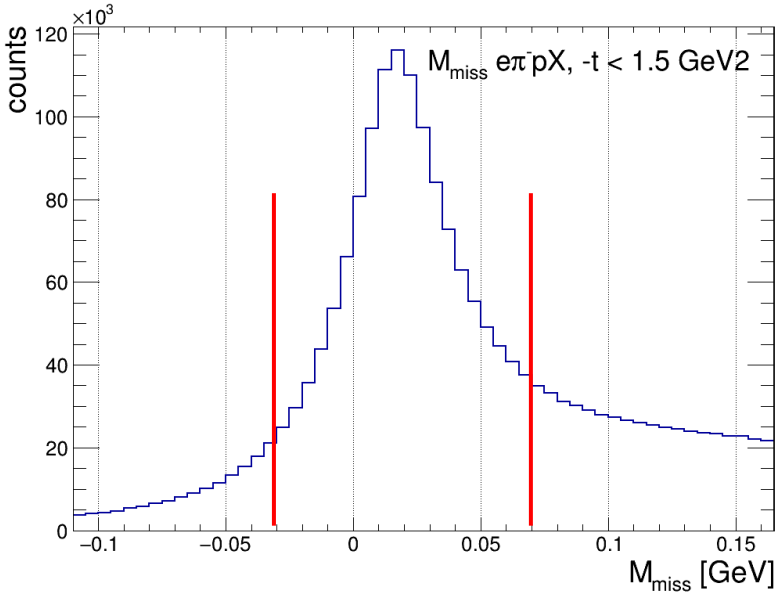
➔ Analysed data ~ 35 % of the approved RG-A beam time

Event Selection and Kinematic Cuts

$$ep \rightarrow e\Delta^{++}\pi^{-} \rightarrow ep\pi^{-}X$$

$$X = \pi^{+}$$

➔ 2 σ cut around the missing π^{+}

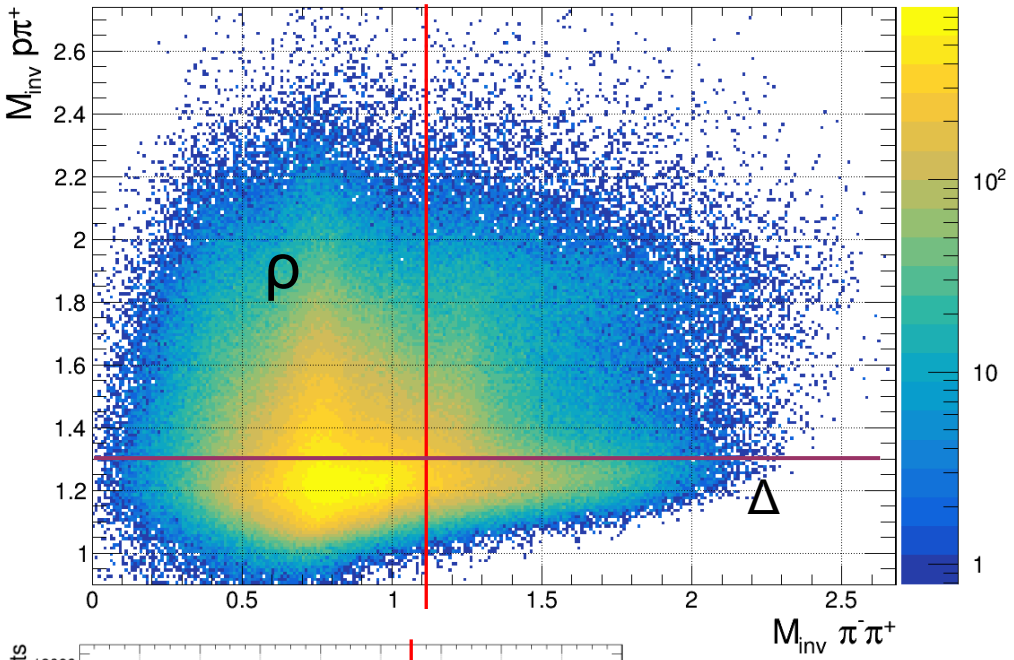


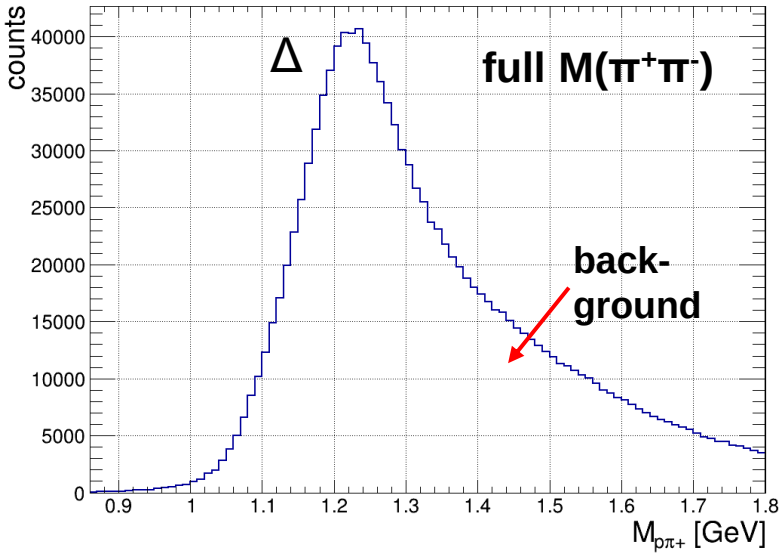
Kinematic cuts:

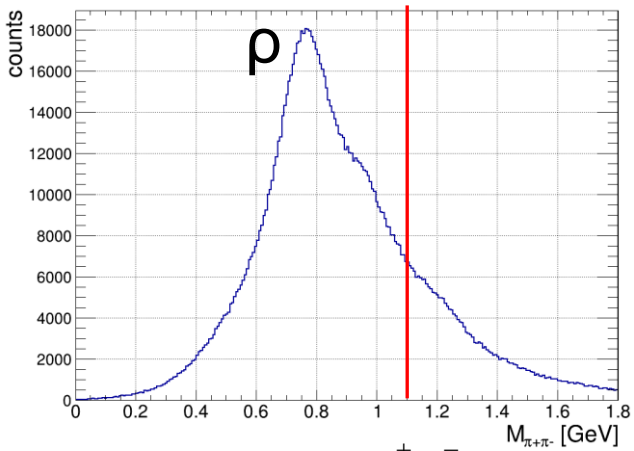
$Q^2 > 1.5$ GeV² W > 2 GeV y < 0.75

-t < 1.5 GeV² (only the forward region)

Event Selection and Background Rejection





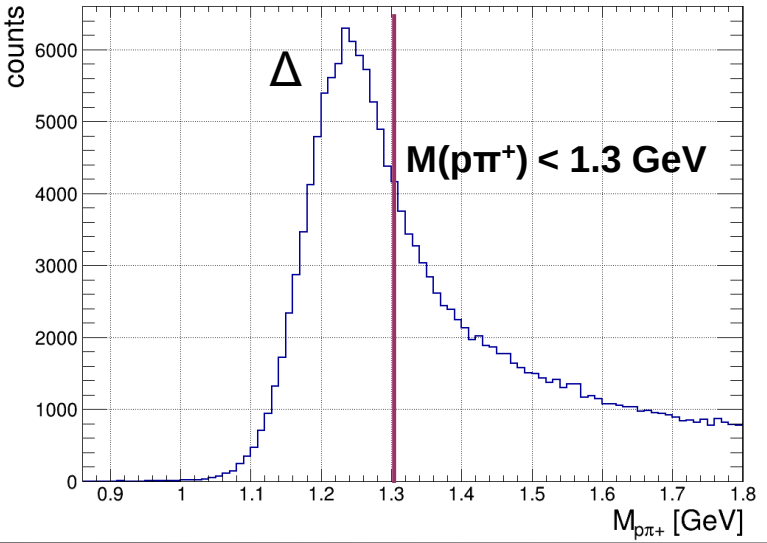


$ep \rightarrow ep\rho \rightarrow ep\pi^+\pi^-$

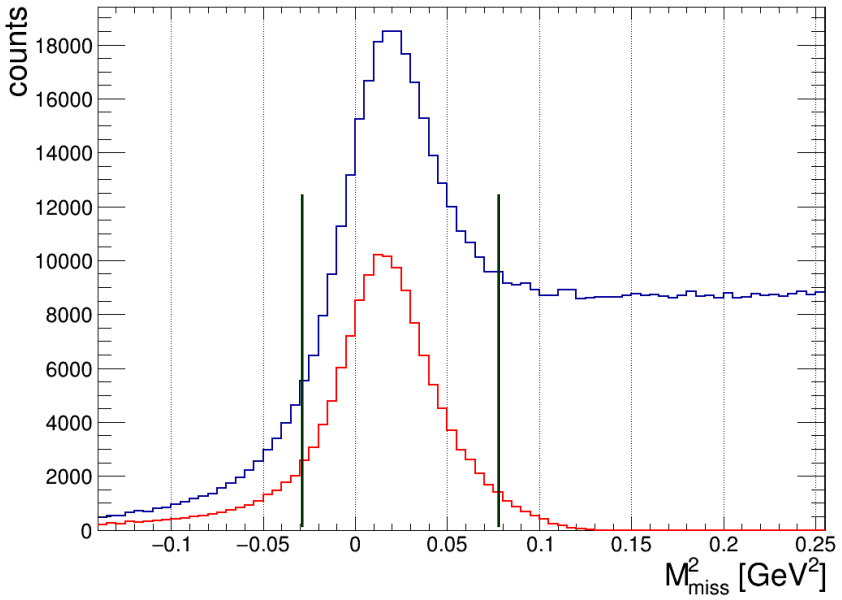
M(π⁺π⁻) > 1.1 GeV

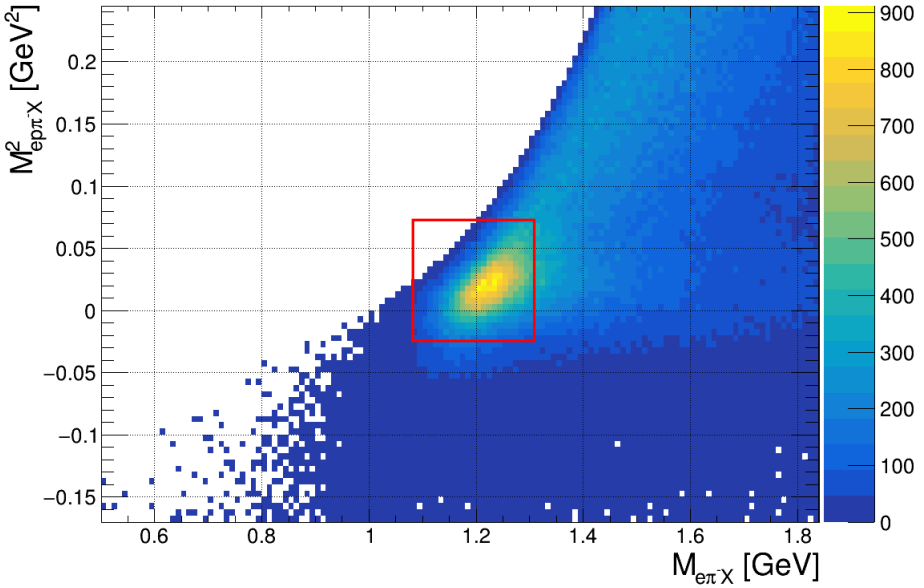
ρ contamination

< 0.8 %



Event Selection and Background Rejection





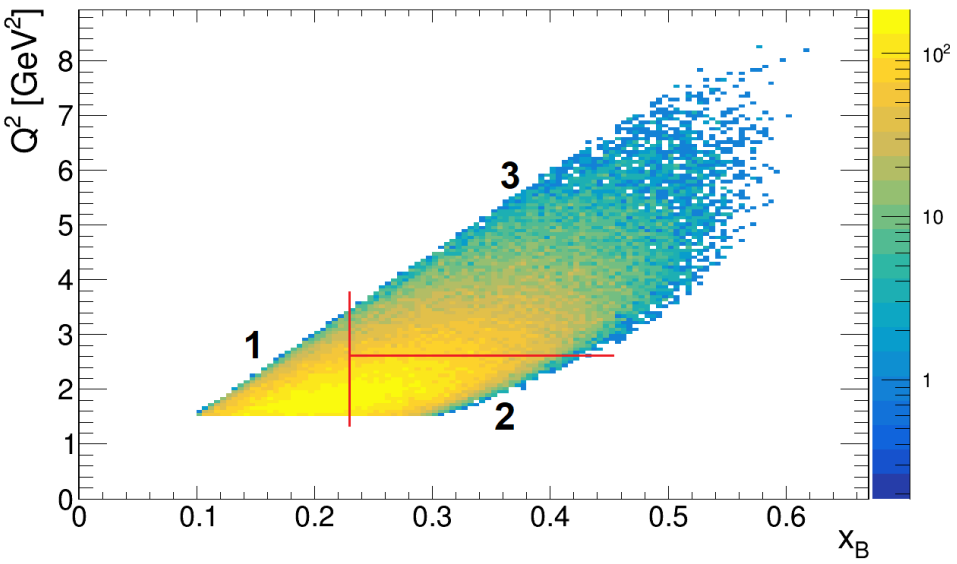
Missing π^+ after $M(\pi^+\pi^-) > 1.1$ GeV

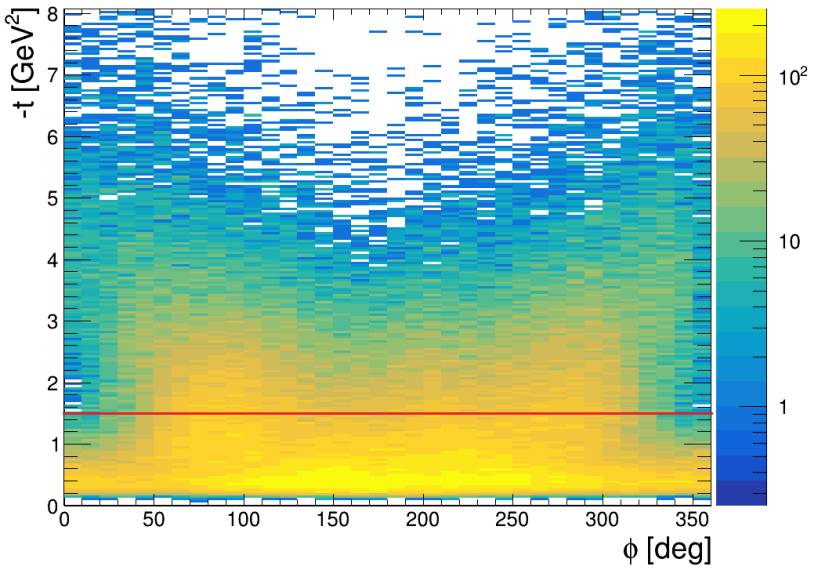
Missing π^+ after $M(\pi^+\pi^-) > 1.1$ GeV and $M(p\pi^+) < 1.3$ GeV

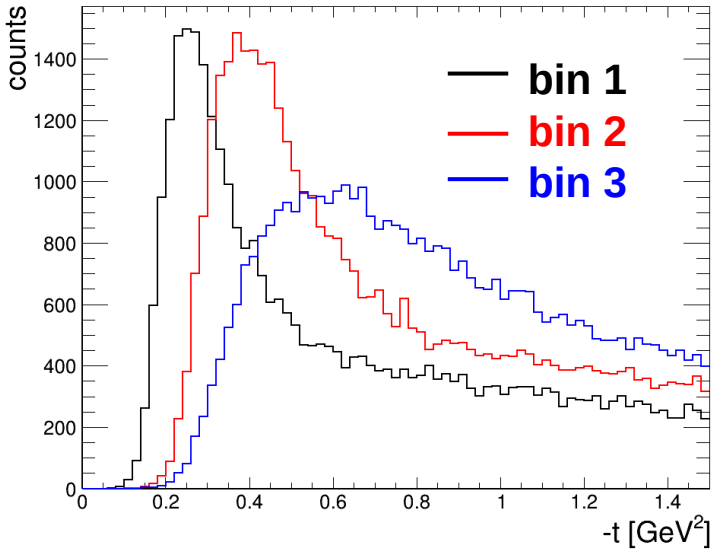
➔ **Selecting the Δ events, allows only one π^- in addition**

➔ **Sample is cleaned up automatically**

Kinematic Coverage







Monte Carlo Simulations

2 MC samples have been used:

a) Semi-inclusive DIS MC

→ Does not contain the $\pi^-\Delta^{++}$ production in „forward“ kinematics

→ Contains nonres. background as well as ρ production and other potential BG channels

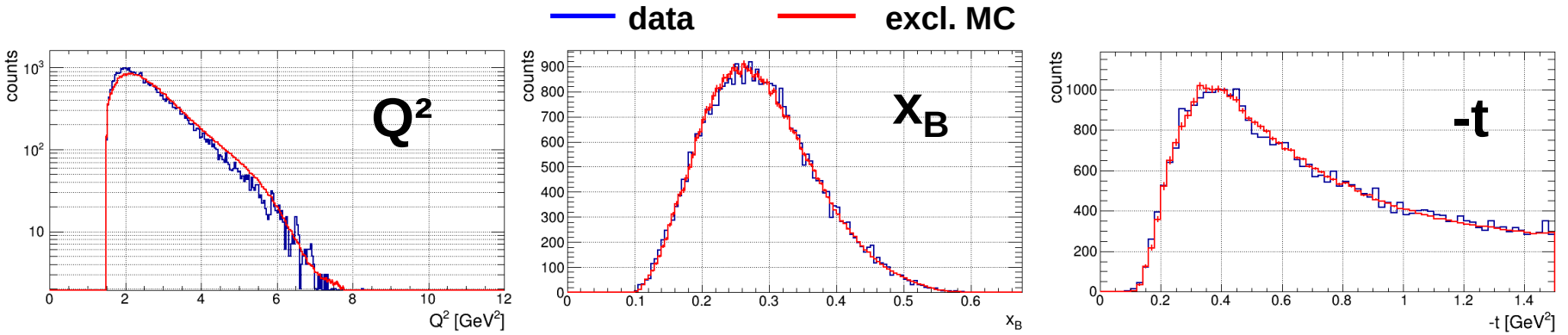
➔ Used to estimate background shape and contaminations

b) Exclusive $\pi^-\Delta^{++}$ MC

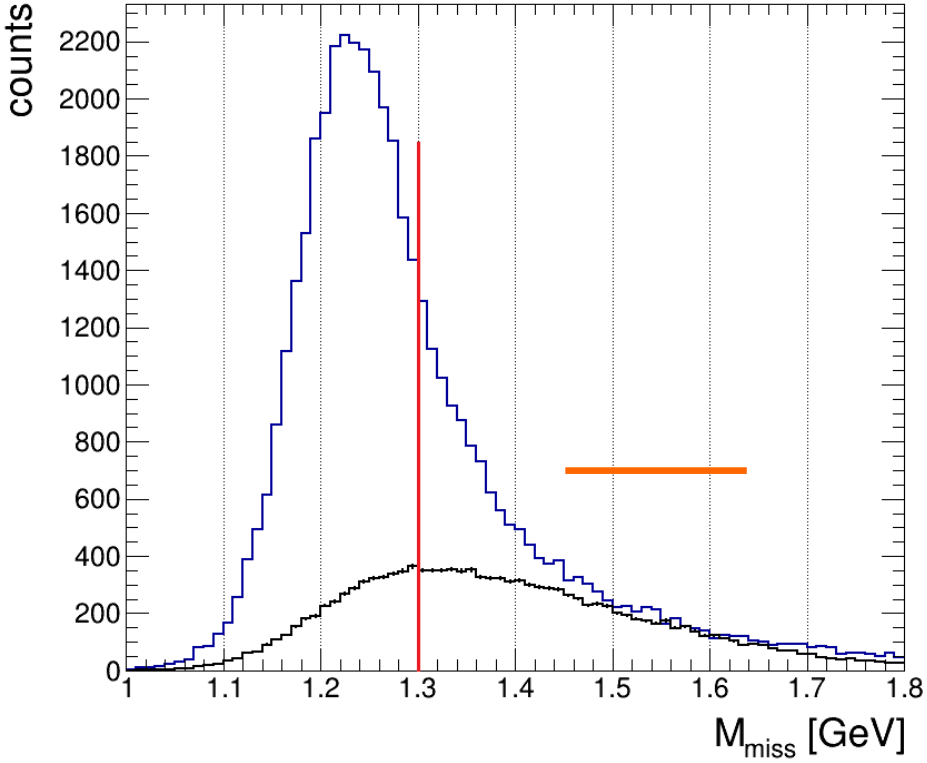
→ Phase space simulation with a weigth added to match experimental data

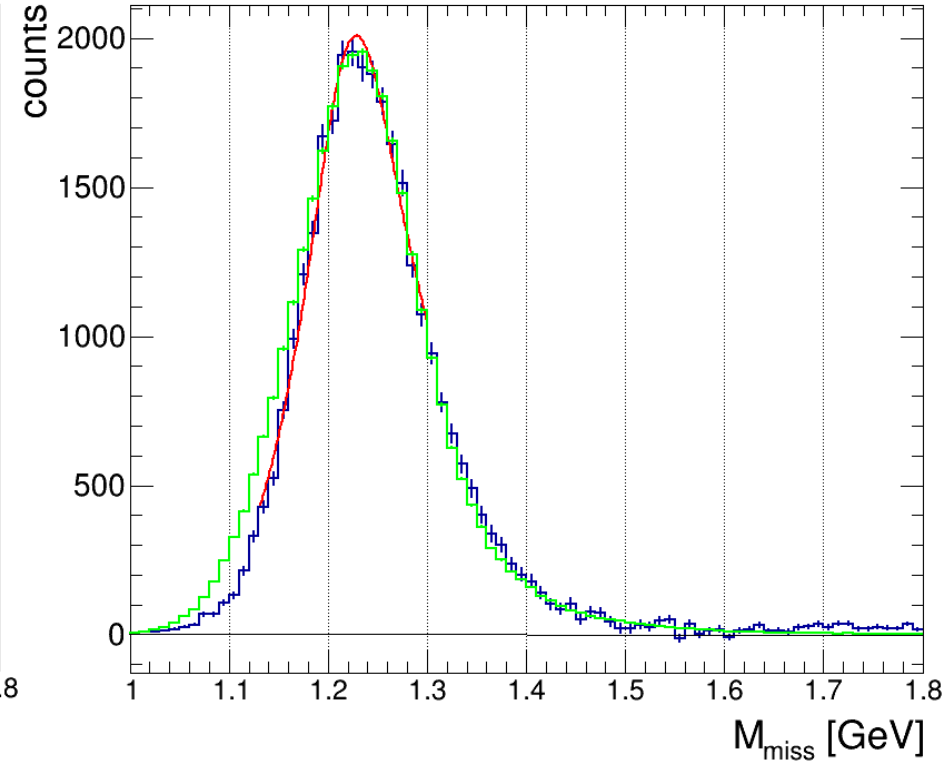
→ Δ peak with PDG mass and FWHM

➔ Both MCs are processed through the full simulation and reconstruction chain



Event Selection and Background Estimate





experimental data

SIDIS MC (same cuts)

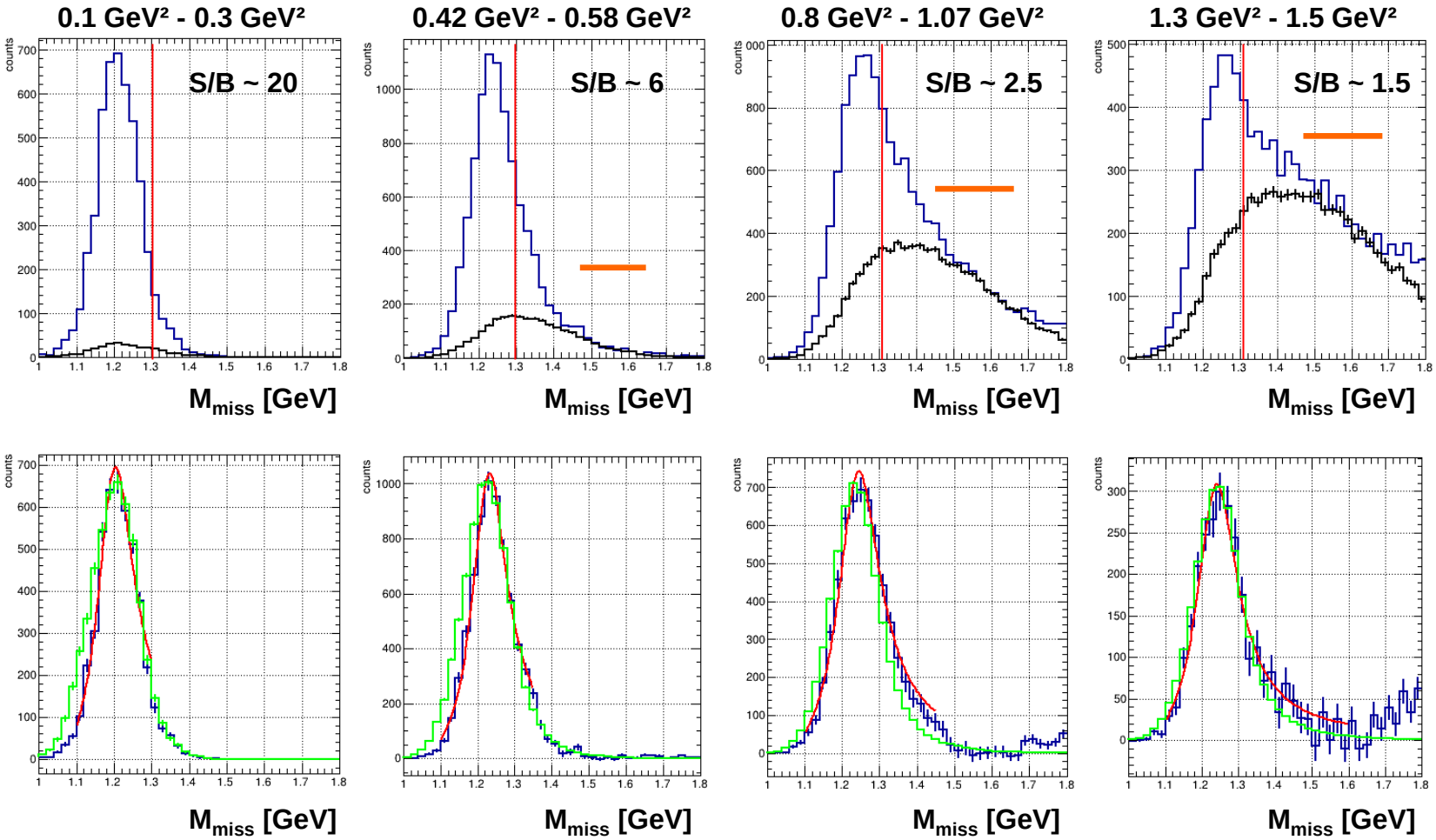
data after SIDIS MC subtraction

fit of a Sill function (BW with thr. effects)

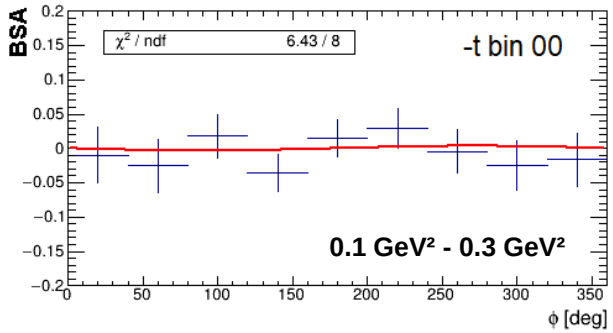
exclusive MC (for comparison)

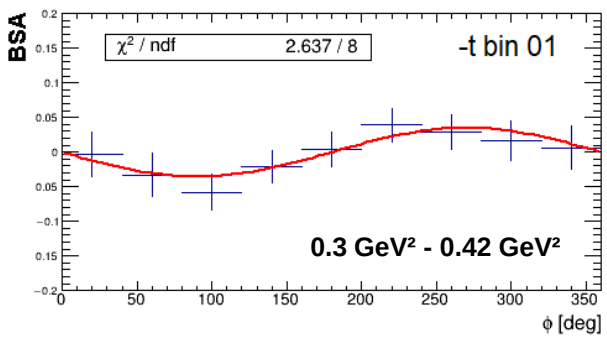
Background: 98 – 99 % non-resonant events

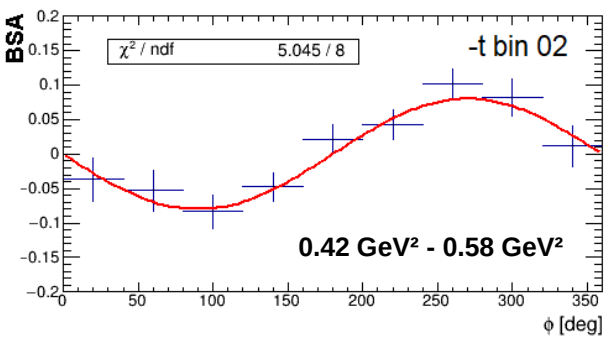
Event Selection and Background Estimate

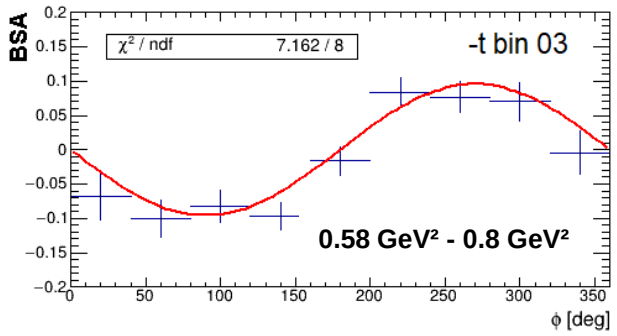


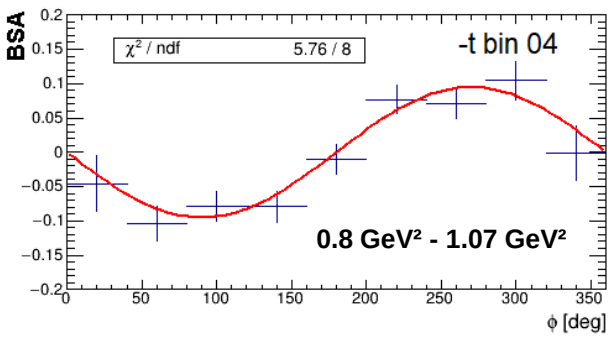
Resulting Beam Spin Asymmtries (Q^2-x_B integrated)

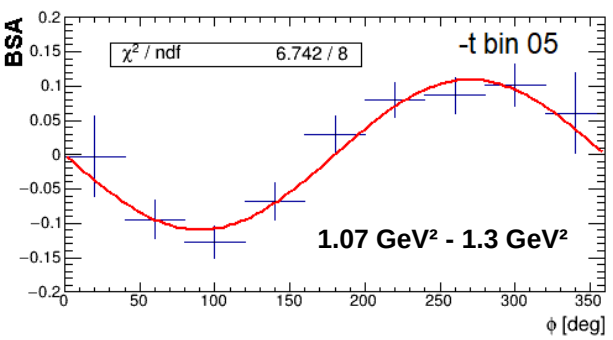


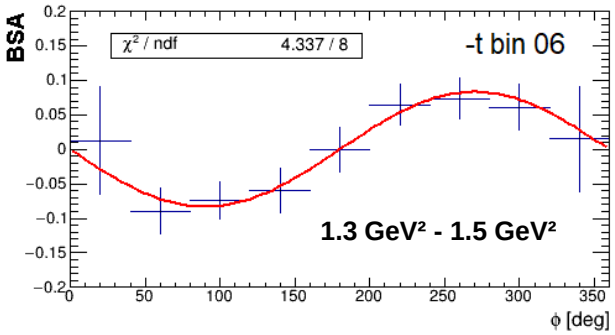










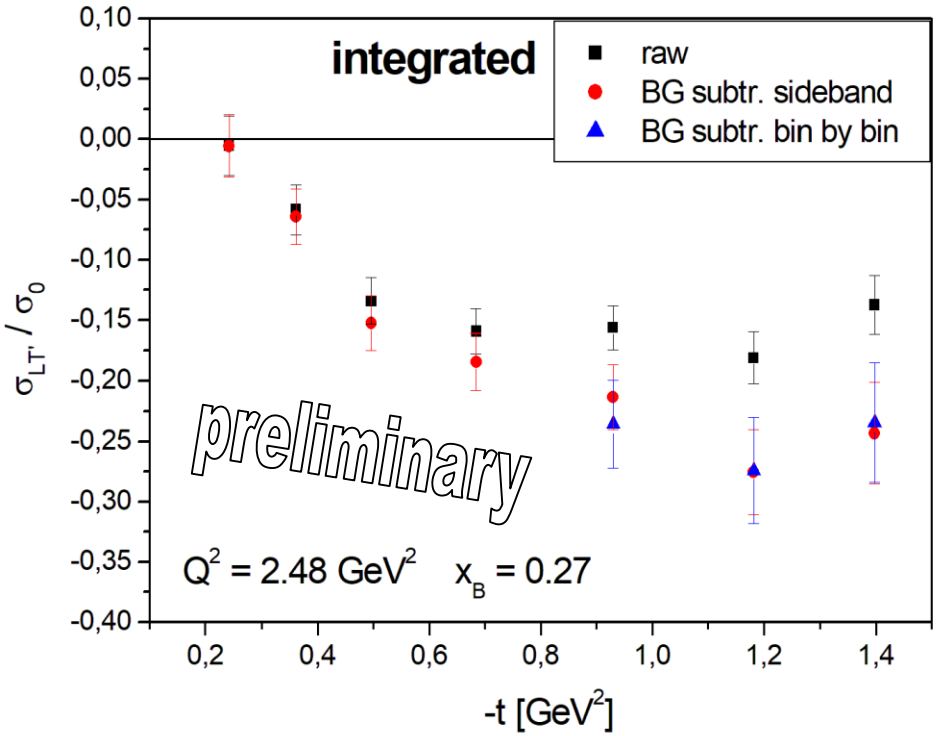


preliminary

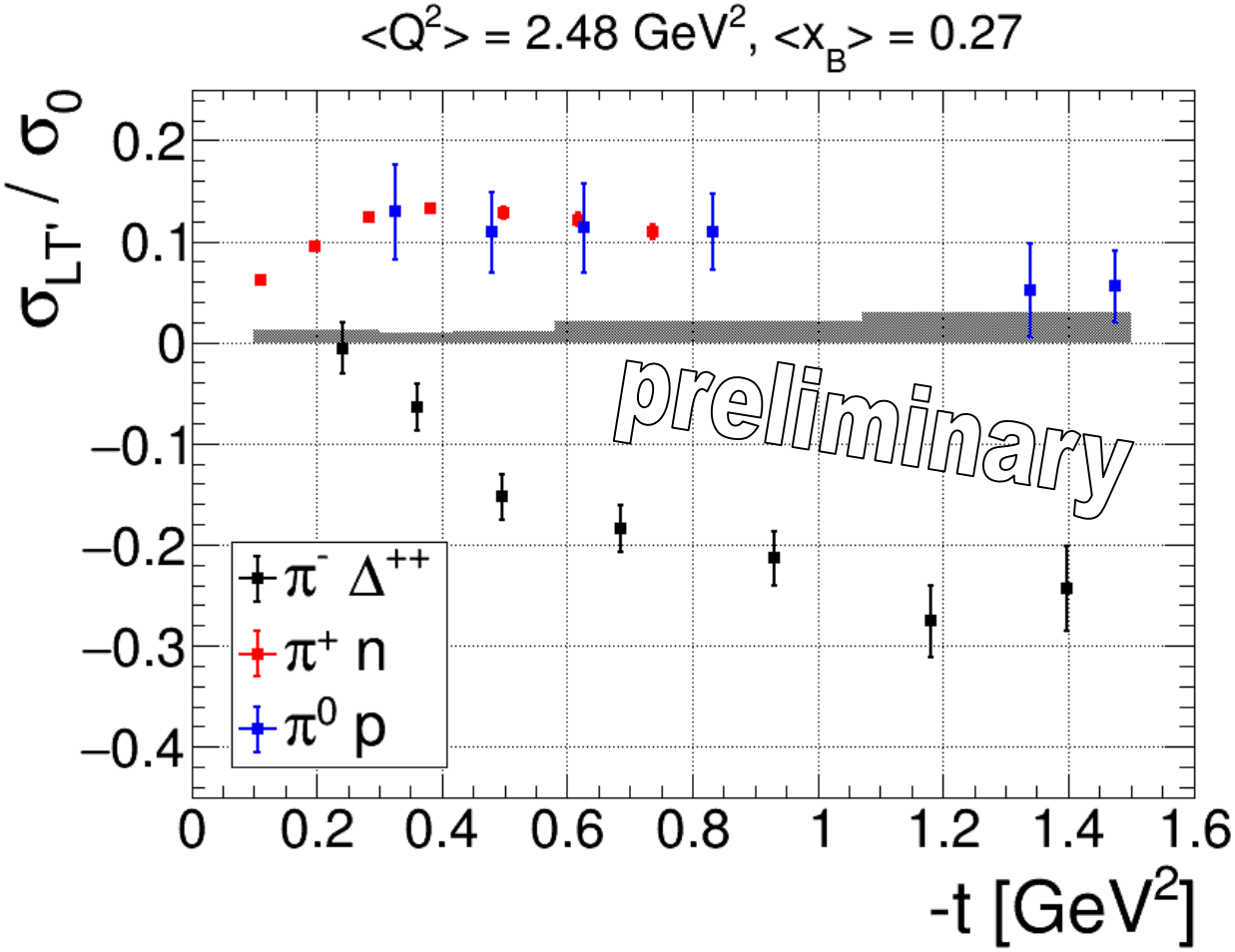
Background Subtraction

- Based on the obtained S/B ratio and based on the asymmetry of the sideband, the contribution of the non-resonant background has been subtracted.
- As a crosscheck, a bin-by-bin background subtraction has been performed with a fit of the signal and background function in each phi bin and for each helicity state.

➔ A good agreement of the two methods has been found.

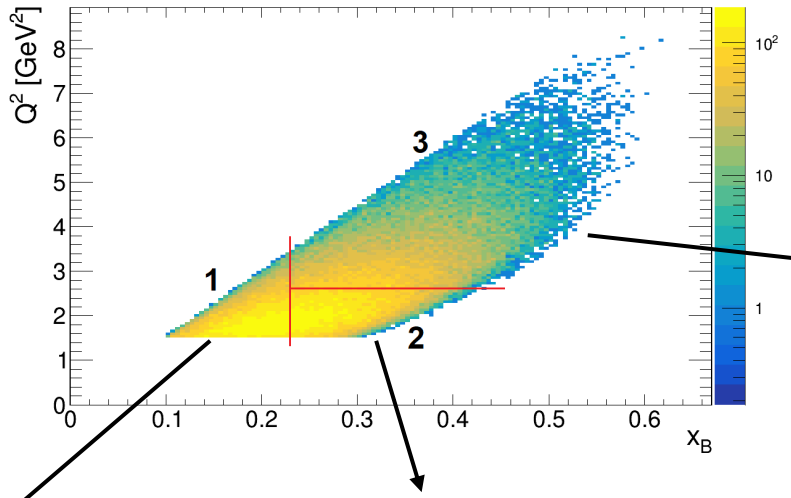


Q^2 - x_B Integrated Result

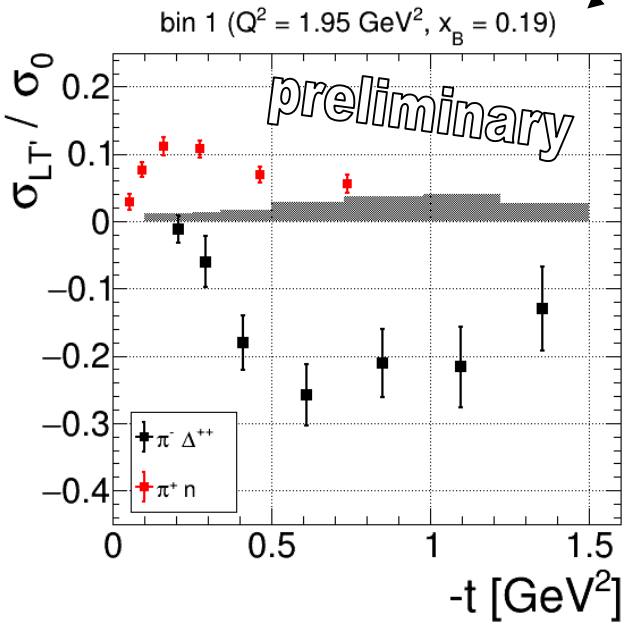


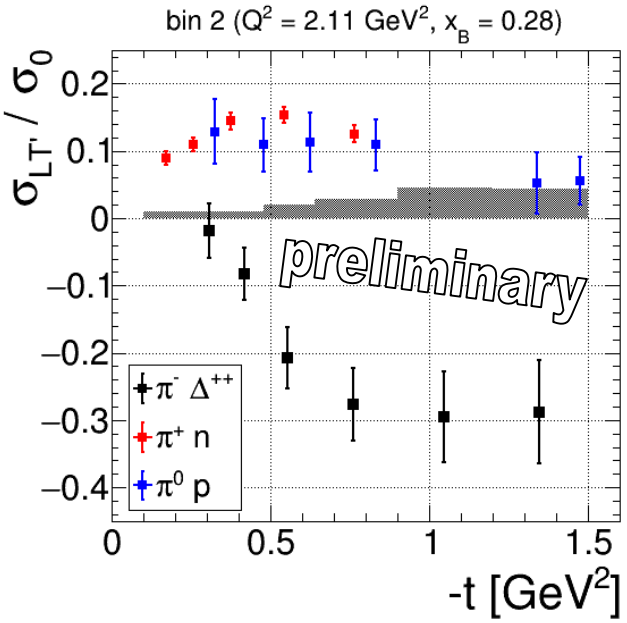
Different sources of systematic uncertainty have been studied:
beam polarisation, background subtraction, fiducial volume, extraction method, acceptance, bin migration, radiative effects

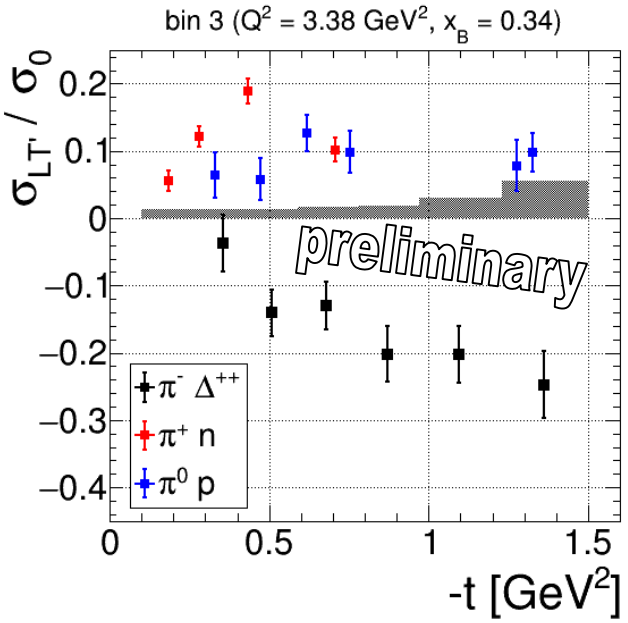
Multidimensional Results



preliminary







Conclusion and Outlook

- Hard exclusive $\pi^{-}\Delta^{++}$ production can be well measured with CLAS12
- The obtained BSA is clearly negative and ~ 2 times larger than for the hard exclusive π^{+} production.
- The extracted BSA is a potential first „clean“ observable sensitive to p-Δ transition GPDs
- Theory predictions are so far only available for twist-2 transition GPDs

➔ Extension of the framework to the twist-3 sector needed