SIDIS MC Simulations

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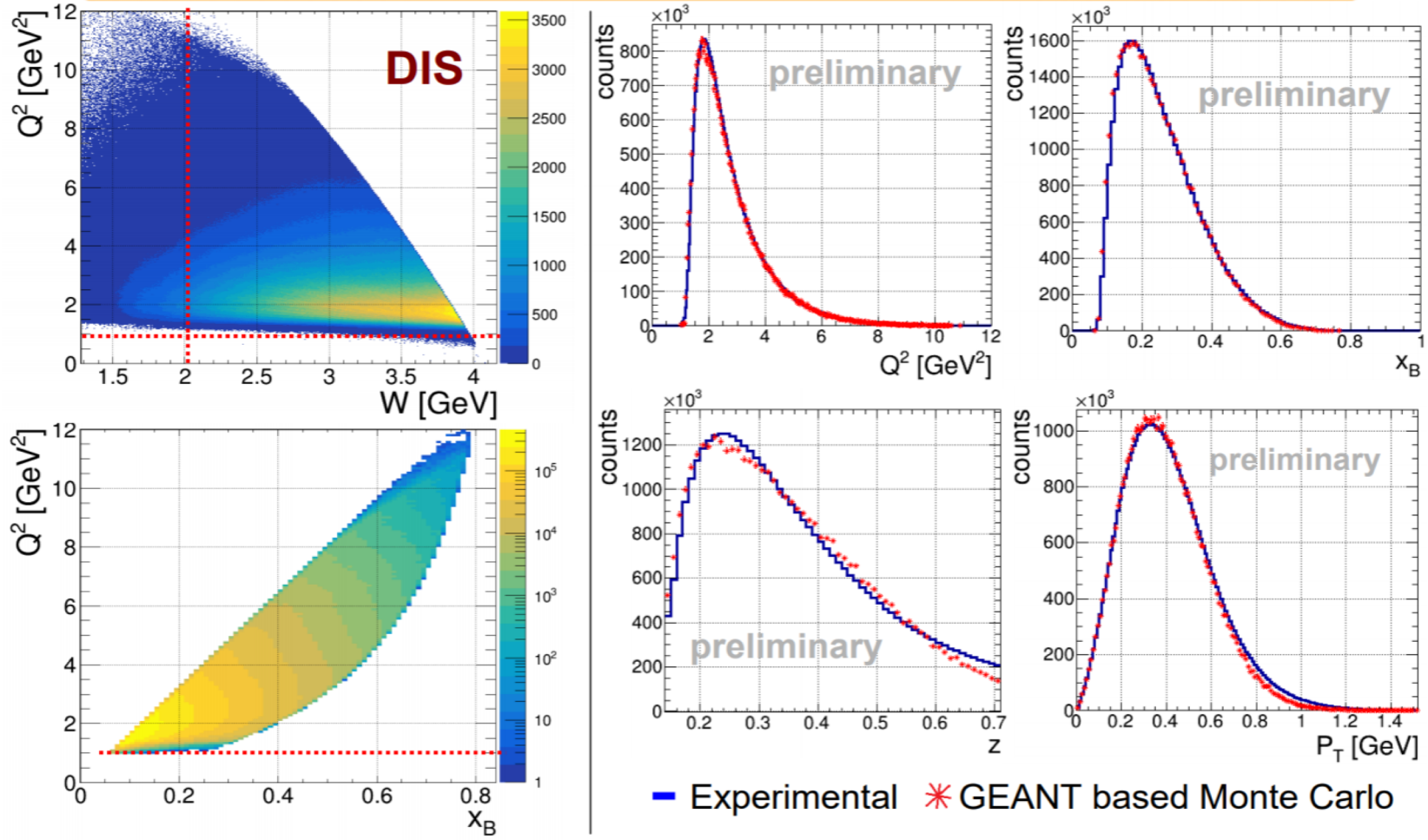
TMD Studies: from JLab to EIC
Jlab, May 7, 2020

- MC simulations
  - Full events (LEPTO/PYTHIA/….)
  - Dedicated processes (ep→e'πX, ep→e'ππX,….)
- MC vs data
- The role of vector mesons
- MC studies
  - Phase space
  - Contributions in SIDIS
  - Fitting the P_T-distributions
- MC vs Theory and validation of extractions
- Conclusions

SIDIS ehX: CLAS12 data vs MC

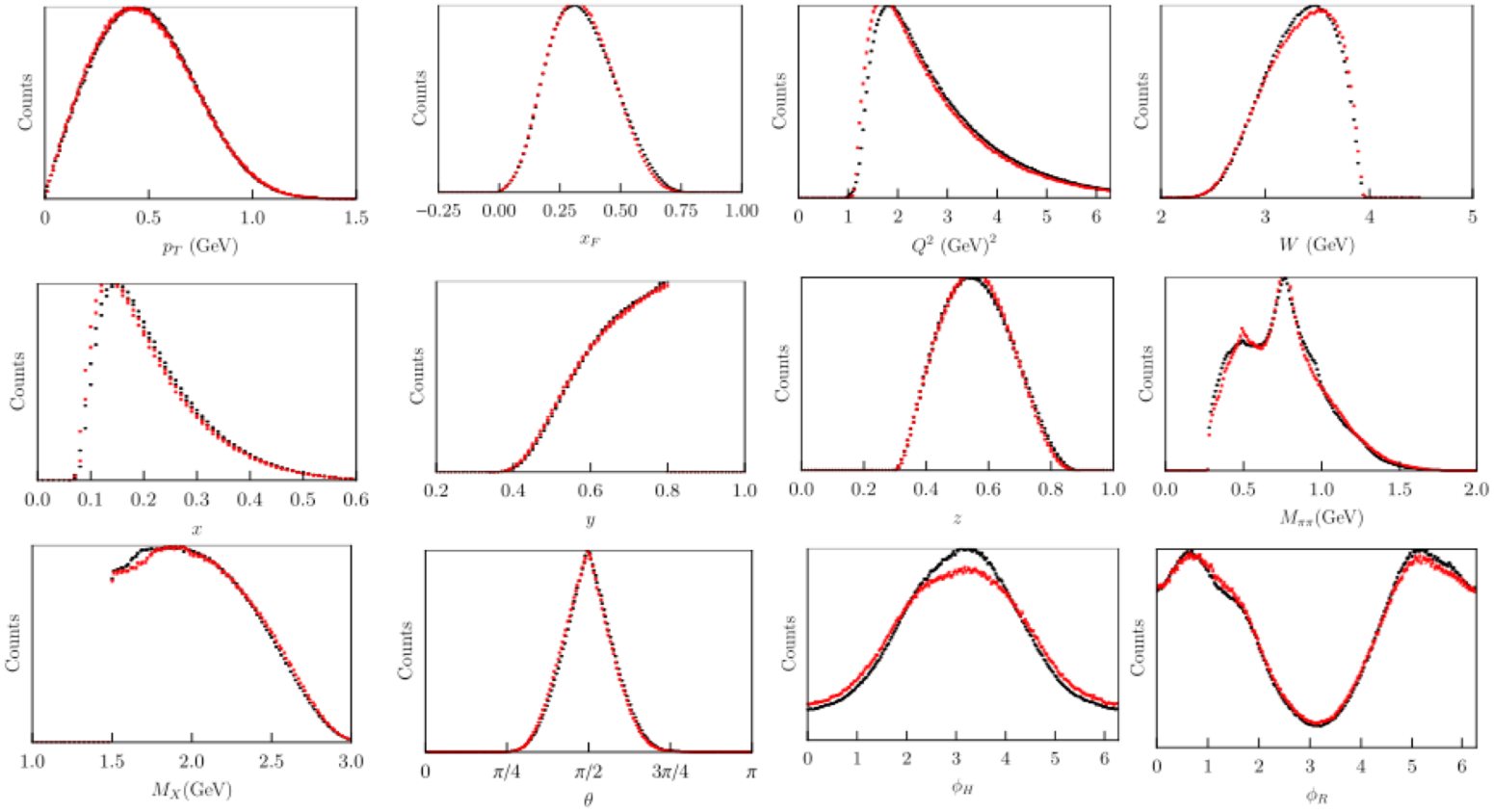
CLAS12 single hadron note: in review for publication

Kinematic coverage for π^+ (similar for π^- and π^0)



SIDIS ehhX: CLAS12 data vs MC

CLAS12 dihadron production ep→ehhX (T.Hayward)

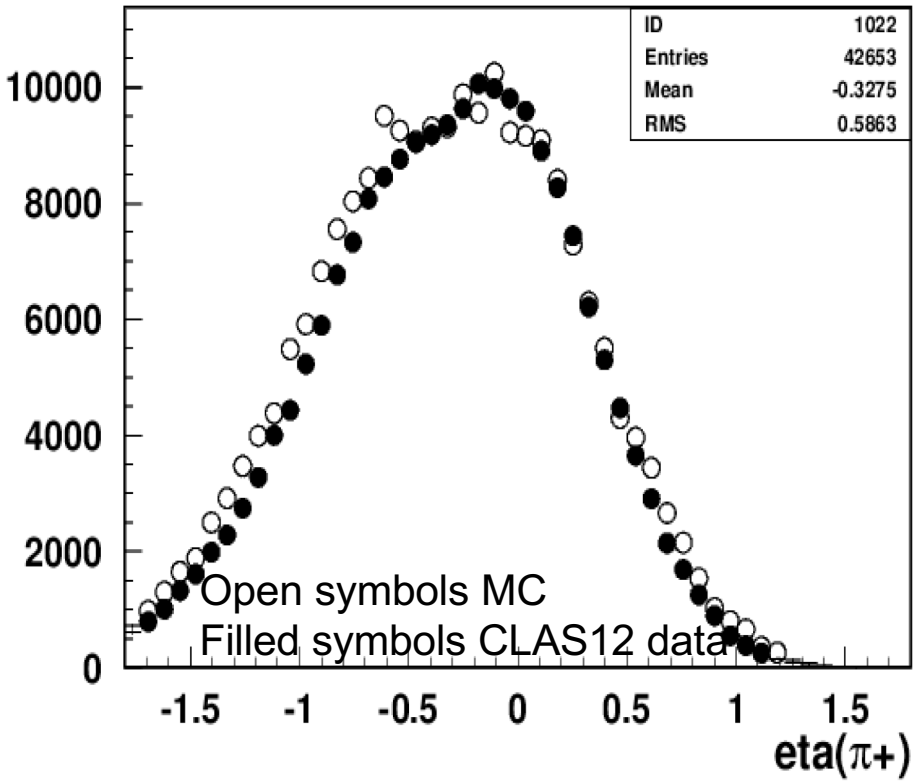


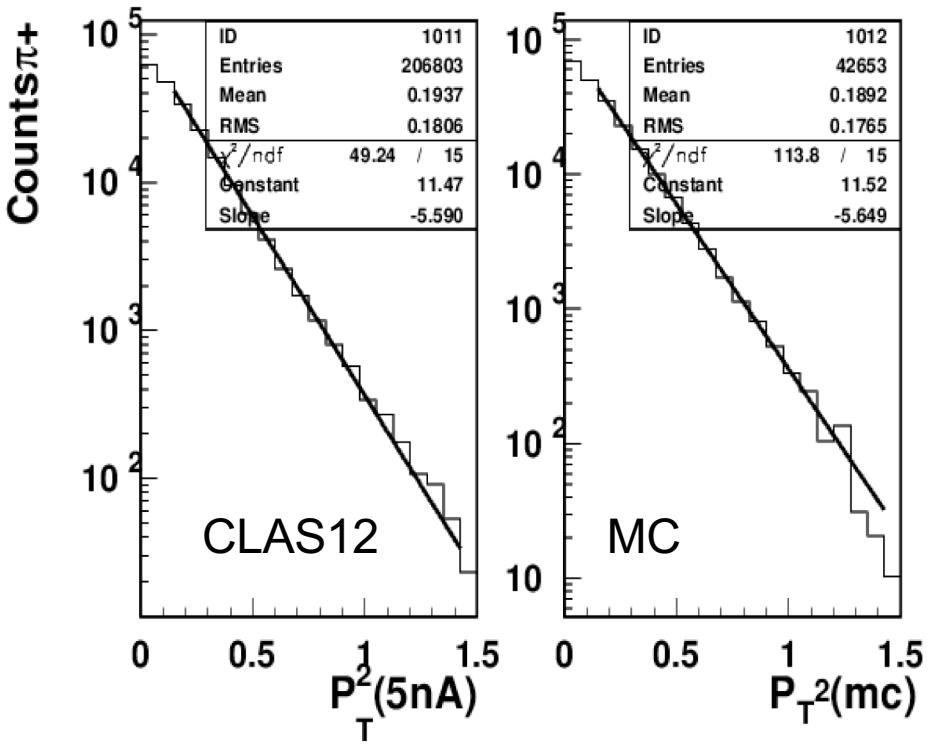
CLAS12 MC, based on the PEPSI(LEPTO) simulation with most parameters ”default” is in a good agreement with CLAS12 measurements for all relevant distributions

CLAS12 Studies: pions

Using PEPSI (LUND) generator rapidity in Breit frame

Boglione et al
https://arxiv.org/pdf/1904.12882.pdf





Distributions of pions vs rapidity in good agreement with LUND-MC (LEPTO) in most of the kinematics

CLAS12 Studies: protons

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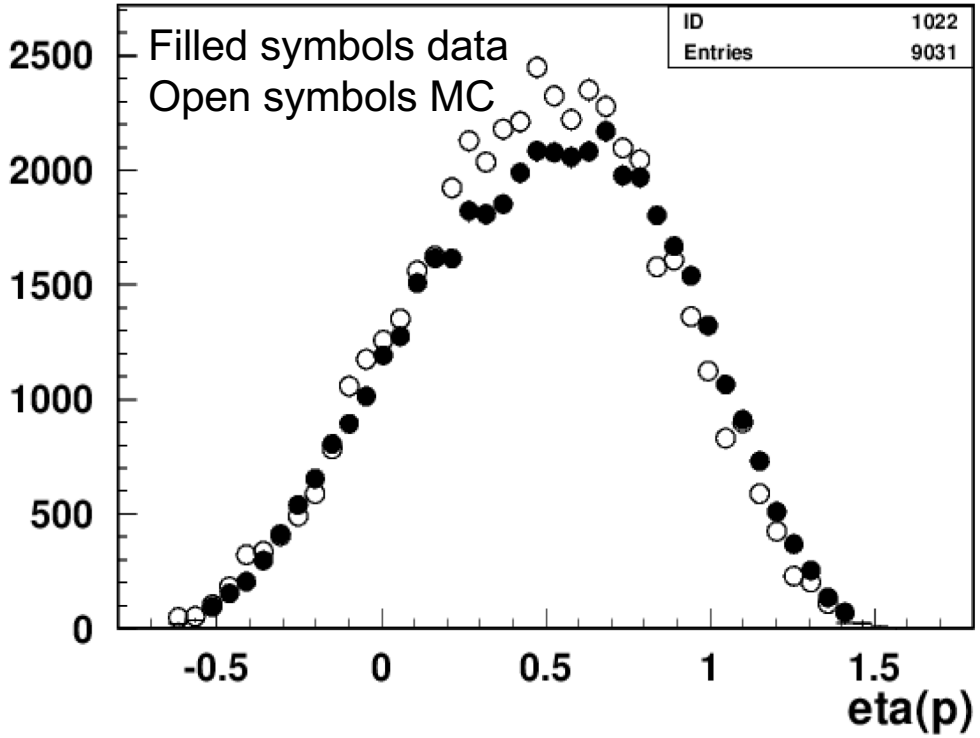
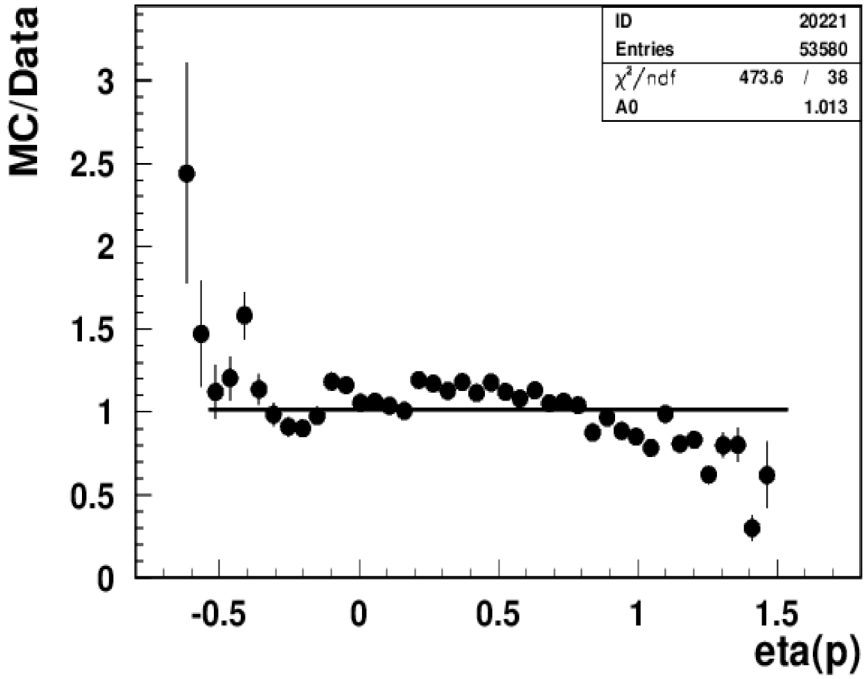
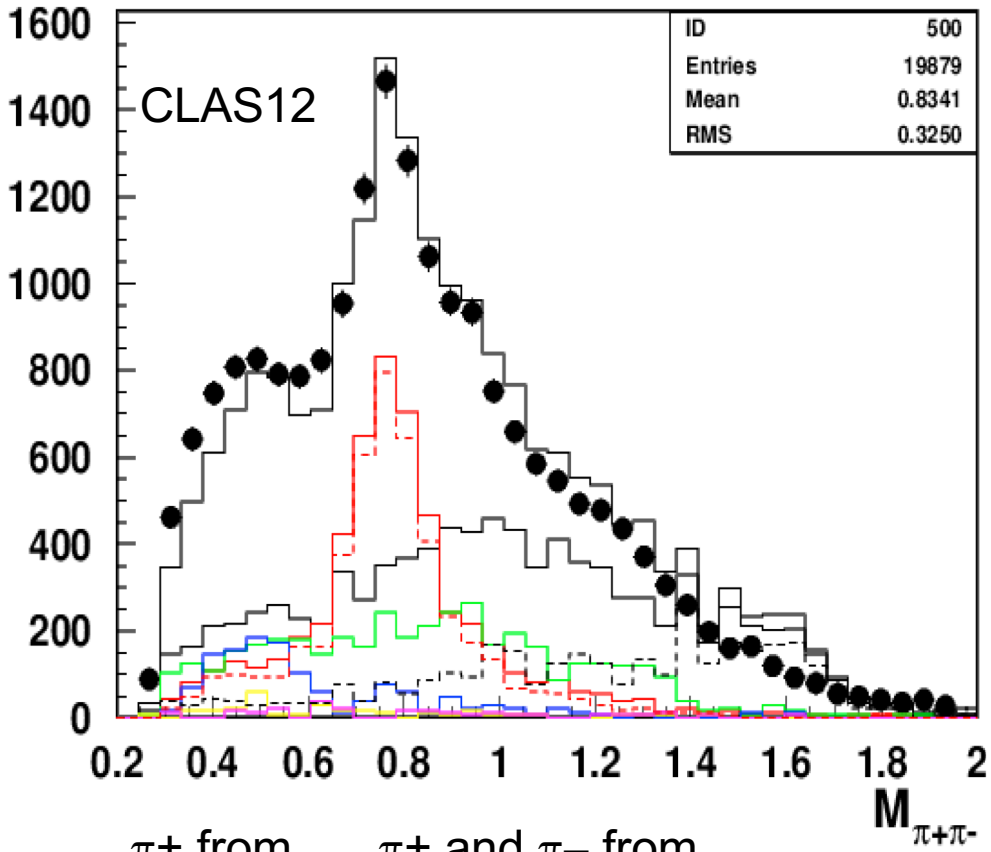
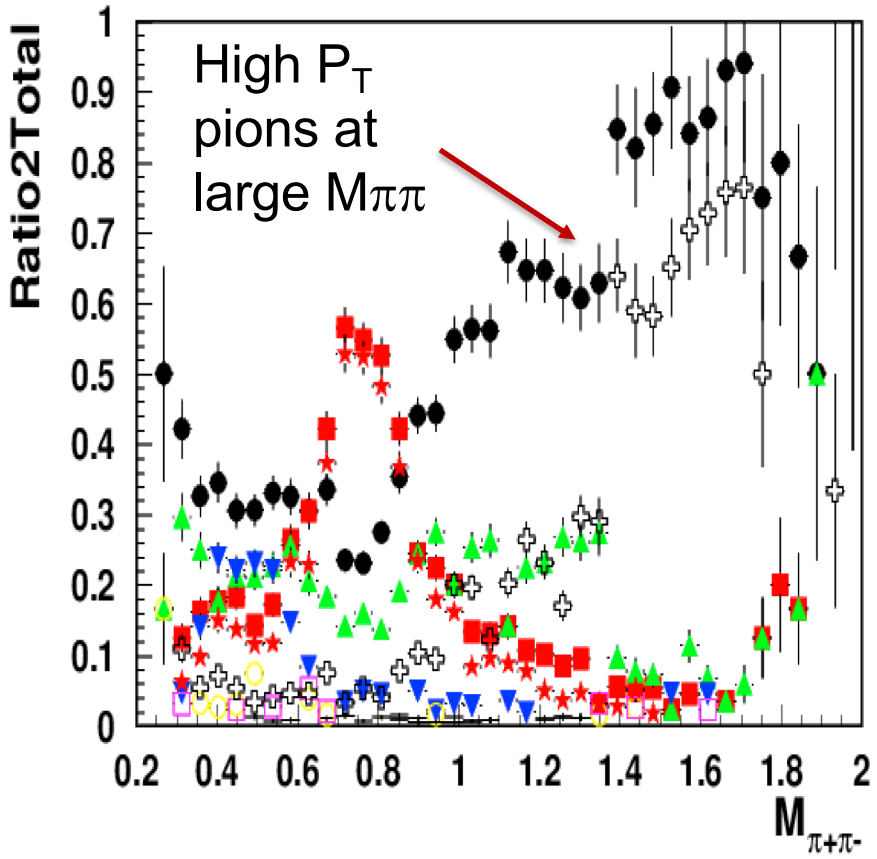




Distributions of protons vs rapidity in good agreement with LUND-MC (LEPTO) in most of the kinematics

Sources of inclusive pions: CLAS12 vs MC



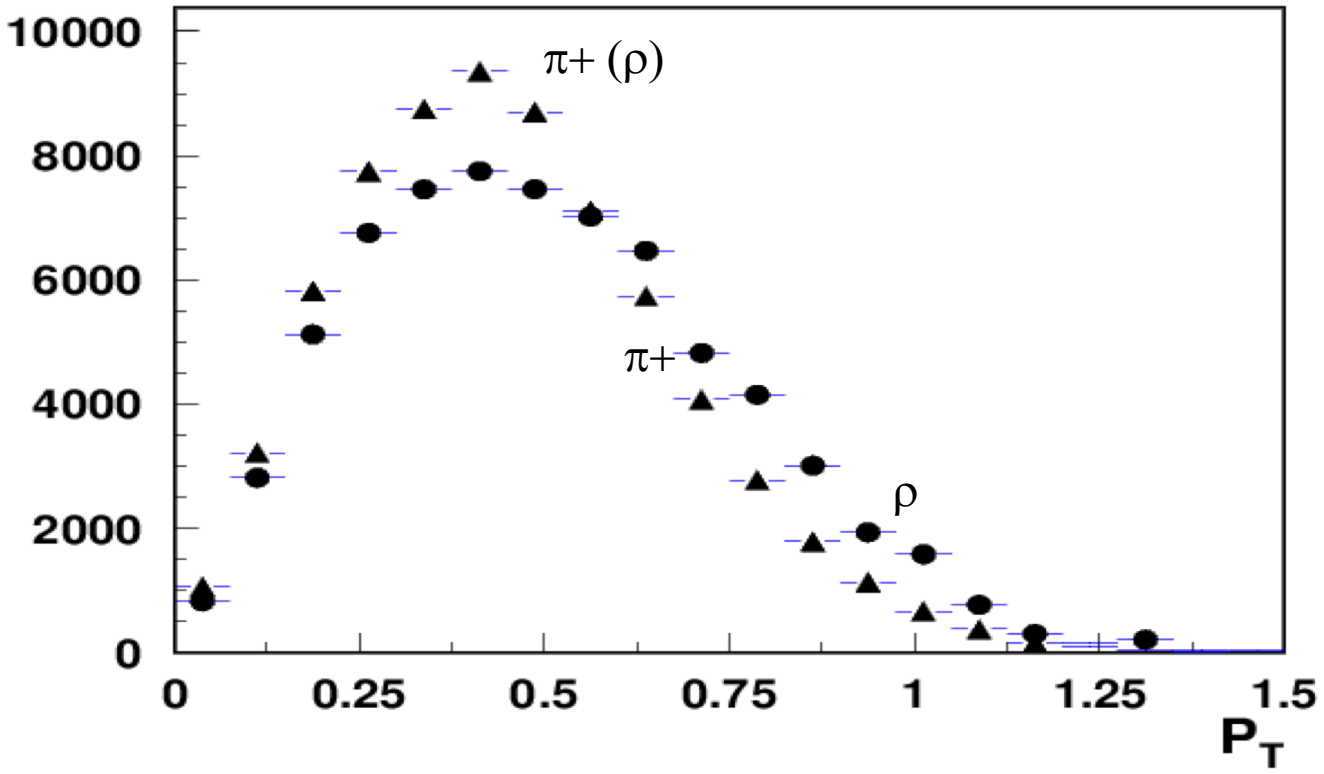


$\pi+$ from	$\pi+$ and $\pi-$ from
$\rho 0$	----
string	----
$\rho+$	
ω	

Dominant fraction of inclusive pions come from VM decays

Very important to have multidimensional TMD Fragmentation Functions!

P_T-widths

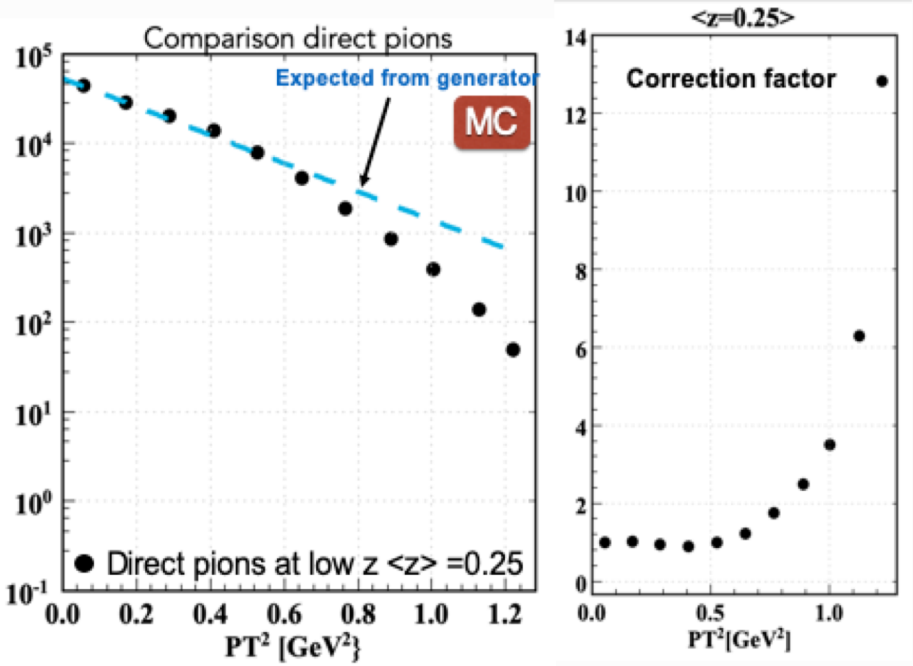


For the same <z> rho (pi+pi-) is wider than pi+

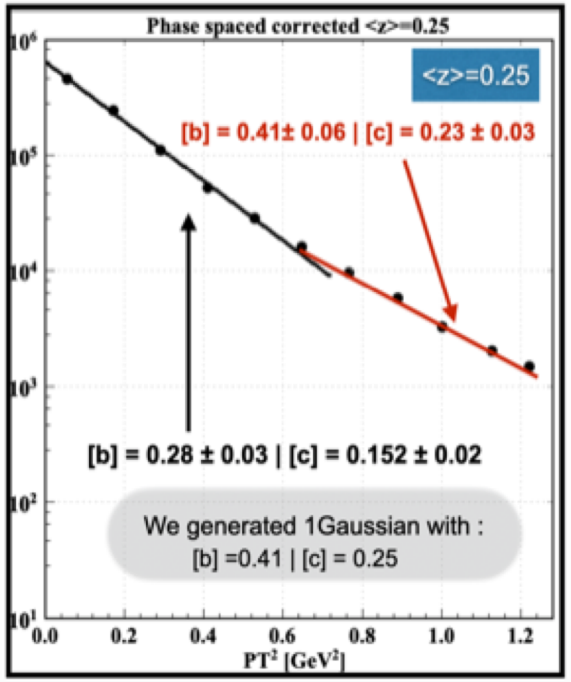
CLAS12 Multiplicities: the role of high P_T

G. Angelini (GW)

LUND MC at 12 GeV



Applied to all pion samp



- Corrections due to phase space (energy needed to produce a hadron with a given z,P_T at given x,Q^2) are detector and model independent
- Corrections due to fraction of fragmentation VMs and diffractive VMs are model dependent, but can be extracted from MC (work in progress)

At low z, only the high P_T shows the generated Gaussian transverse momentum distribution.

JETSET

Test: It is not trivial to achieve agreement with data, when using in the single-pion MC with widths of k_T-distributions of pions extracted from the same data

So why the LUND-MCs are so successful in description of hard scattering processes, and SIDIS in the first place?

- The hadronization into different hadrons, in particular Vector Mesons is accounted (full kinematics)
- The correlations between target and current fragments included (mainly lower z)
- …….

TMD extractions, parameterizations, grids

Important note from theorists: parametrizations should be used in the kinematics they are applicable. Validations mostly done for given Fragmentation Functions, by variations of experimental data within errors(TMD extraction talks).

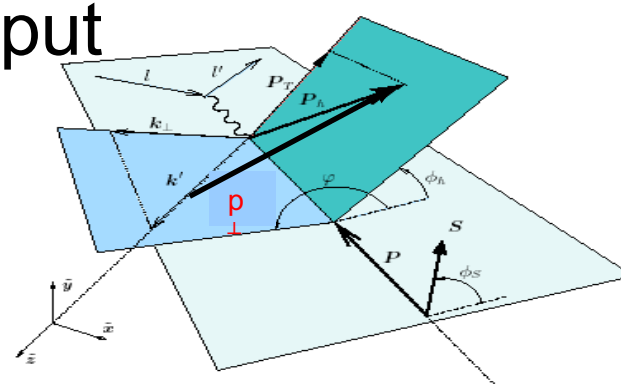
How to validate the TMD parameterization in 3D (discussion session):

- Compare kinematic dependences with new data (ex. P_T,Q^2-dependences)
- Compare kinematical dependences with direct calculations and lattice
- Compare kinematical dependences with other extractions
- Compare kinematical dependences with QCD inspired model predictions
- Common sense & intuition about non-perturbative kinematics

Use MC validation: generate pions with probabilities from extracted SFs for a given experiment, including the RC and compare multiplicities and SSAs with a given experiment (accounting phase space limitations & correlations between variables)

$$F^h_{XY}(x,z,P_T,Q^2) \propto \sum H^q \times f^q(x,k_T,..) \otimes D^{q\to h}(z,p_T,..) + Y(Q^2,P_T) + \mathcal{O}\big(M/Q\big)$$

MC Generator to simulate SIDIS output



SIDIS MC in 7D (10D)

$$F^h_{XY}(x,z,P_T,Q^2) \propto \sum H^q \times f^q(x,k_T,..) \otimes D^{q\to h}(z,p_T,..) + Y(Q^2,P_T) + \mathcal{O}(M/Q)$$

$$\frac{d\sigma^{eN\to e'hX}_{\lambda\Lambda}}{dx dQ^2 dz dP^2_{hT} d\phi_h d\phi_l d\phi_s} = \sum_{l=1}^{L} SF_l$$

Theory

Provide a set of SF_l

For a given model/theory based on underlying non-perturbative input and assumptions calculate SF_l

$$F_l(x_1, x_2, x_3, ...x_N, P_1, P_2, ...P_M)$$

step-1 $x_i, Q^2_i z_i P^{i2}_{hT} \phi^i_h \phi^i_l \phi^i_s$

step-2 (for a given E_{beam},λ,Λ) P^{el}_i, P^h_i

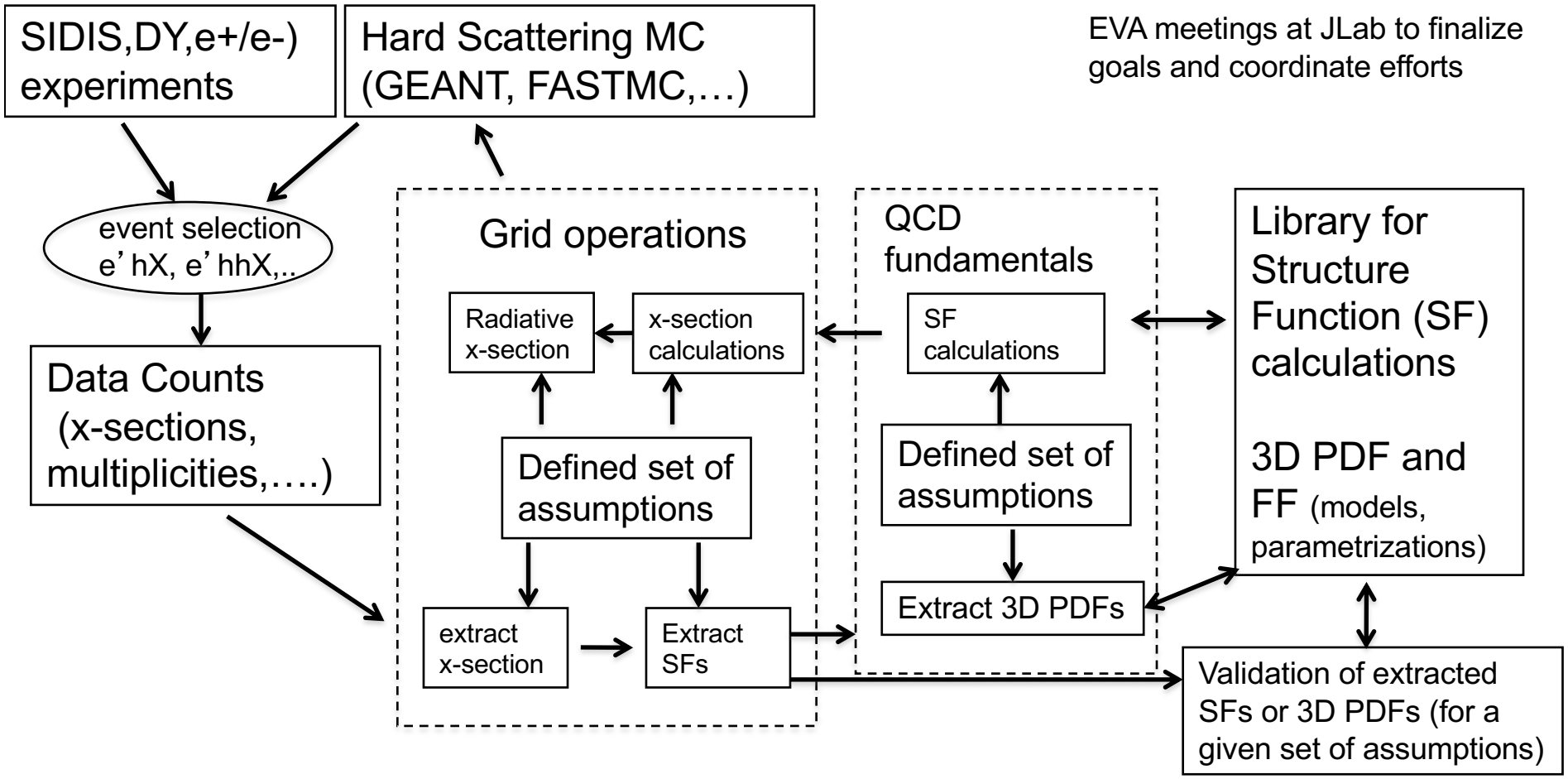
step-3 (detected for a given Detector configuration)

$x_j, Q^2_j z_j P^2_{hT,j} \phi^j_h \phi^j_l \phi^j_s$

$$F_l(x_1, x_2, x_3, ...x_N, P^*_1, P^*_2, ...P^*_M)$$

Need criteria to compare the input and output parameter spaces (validate)

3D PDF Extraction and VAlidation (EVA) framework



Development of a reliable techniques for the extraction of 3D PDFs and fragmentation functions from the multidimensional experimental observables with controlled systematics requires close collaboration of experiment, theory and computing

3D PDF Extraction and VAlidation (EVA) framework

The list of different experimental and theoretical items includes things like:

1) Effects from limited kinematic acceptance, both due to limited beam energies, and due to limited acceptances of detectors
2) Contributions from Vector Mesons
3) Contributions from target fragmentation
4) Self consistency of radiative corrections and possible effects of other azimuthal moments
5) Sensitivity to used parameterizations, showing up even for 1D analysis, and promising to be much bigger for 3D
6) Systematics in extraction due to binning of data on extraction of P_T and Q^2-dependence of SIDIS observables and possibly underlying TMDs
7) Effects from ignored HT contributions
8) Modification of TMDs in medium

……..

All these items may be more or less critical for extraction of TMDs, but only detailed simulations can help to identify their relevance.

Support slides