Pion&Kaon SIDIS with CLAS12

Harut Avakian

DeepPWG meeting , JLab, June 15, 2017

- SIDIS studies with CLAS12
- The role of hadronic PID
- Full chain SIDIS simulation clasDIS->gemc->coatjava
- LTCC performance
- Conclusions

Hall B – Run Groups

Hall B

Proposal	Physics	Contact	Rating	Days	Group	New equipment	Energy	Run Group	Target
E12-06-108	Hard exclusive electro-production of π^0, η	Stoler	B	80	139	RICH (1 sector) Forward tagger	11	**A** F. Sabatié	liquid H_2
E12-06-108A	Exclusive N*->KY Studies with CLAS12	Carman		(60)					
E12-06-108B	Transition Form Factor of the η' Meson with CLAS12	Kunkel		(80)					
E12-06-112	Proton's quark dynamics in SIDIS pion production	Avakian	A	60					
E12-06-112A	Semi-inclusive Λ productiuon in target fragmentation region	Mirazita		(60)					
E12-06-112B	Colinear nucleon structure at twist-3	Pisano		(60)					
E12-06-119(a)	Deeply Virtual Compton Scattering	Sabatie	A	80					
E12-09-003	Excitation of nucleon resonances at high Q^2	Gothe	B+	40					
E12-11-005	Hadron spectroscopy with forward tagger	Battaglieri	A-	119					
E12-11-005A	Photoproduction of the very strangest baryon	Guo		(120)					
E12-12-001	Timelike Compton Scatt. & J/ψ production in e+e-	Nadel-Turonski	A-	120					
E12-12-007	Exclusive φ meson electroproduction with CLAS12	Stoler, Weiss	B+	60					
E12-07-104	Neutron magnetic form factor	Gilfoyle	A-	30	90	Neutron detector RICH (1 sector) Forward tagger	11	**B** K. Hafidi	liquid D_2 target
E12-09-007(a)	Study of partonic distributions in SIDIS kaon production	Hafidi	A-	30					
E12-09-008	Boer-Mulders asymmetry in K SIDIS w/ H and D targets	Contalbrigo	A-	56					
E12-09-008A	Hadron production in target fragmentation region	Mirazita		(60)					
E12-09-008B	Colinear nucleon structuer at twist-3	Pisano		(60)					
E12-11-003	DVCS on neutron target	Niccolai	A	90					
E12-11-003A	In medium structure functions, SRC, and the EMC effect	Hen		(90)					
Beam time partial sum				**765 (1355)**	**229**				

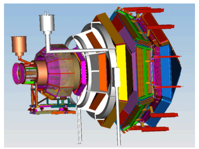
Experiment ending with A or B are run group experiments approved by the CLAS collaboration. They are running parallel to the experiments with same experiment number. Experiments ending with (a) and (b) take data with both run groups.

PAC Days
Boldface = days designated High Impact
Parentheses = days not counting toward High Impact total

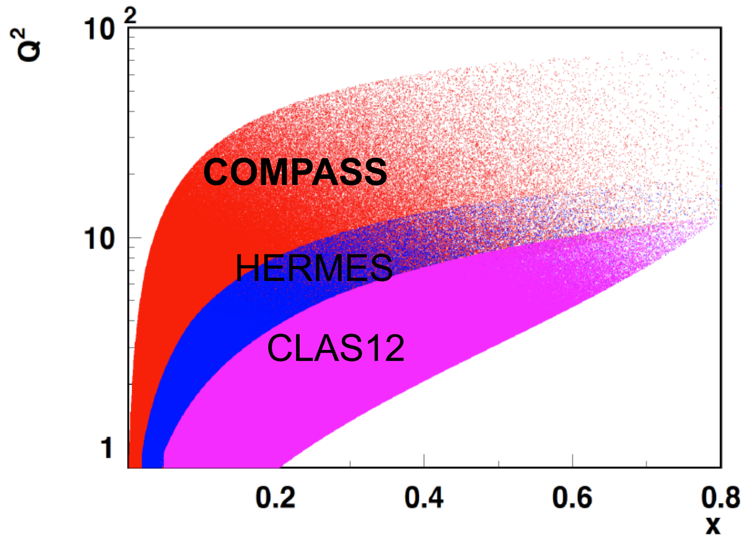
PAC41 "High Impact" Selection

Row Color
Yellow = High Impact
Green = backup expt

Exp#	Exp name	Hall	Run Group/ Days	PAC Days	PAC grade	Comments
			TOPIC 3 : PDFs			
E12-06-113	**BONuS** : The Structure of the Free Neutron at Large x-Bjorken	**B**	F/40	(40) approved **★21** ↓	A	Requires BONuS Radial TPC upgrade **★42 days High Impact for the experiment that runs first; experiments are equally important & both are essential**
E12-10-103	**MARATHON** : Measurement of the F2n/F2p, d/u Ratios and A=3 EMC Effect in DIS off the Tritium and Helium Mirror Nuclei	**A**	Tritium target group/61	↑ **★21** (42) approved	A	
E12-06-110	**A1n HallC–3He** : Meas of Neutron Spin Asymmetry A1n in the Valence Quark Region Using an 11 GeV Beam and a Polarized 3He Target in Hall C	**C**		**36**	A	Requires high luminosity 3He
			TOPIC 4T : TMDs			
C12-11-111	**TMD CLAS–HDIce** : SIDIS on Transverse polarized target	**B**	G/110	**110** concurrent	A	Requires transversely polarized HDIce with electron beam
C12-12-009	**Dihadron CLAS-HDIce** : Measurement of transversity with dihadron production in SIDIS with transversely polarized target	**B**	G/110	(**110**) concurrent	A	Requires transversely polarized HDIce with electron beam C1 Proposal
E12-06-112	**TMD CLAS-H(Unpol)** : Probing the Proton's Quark Dynamics in Semi-Inclusive Pion Production at 12 GeV	**B**	A/139	(60) approved **★10**	A	Hall B commissioning + 10 days **★plus (50) commissioning days**
			TOPIC 4G : GPDs			
E12-06-114	**DVCS HallA–H(UU,LU)** : Measurements of Electron-Helicity Dependent Cross Sections of DVCS with CEBAF at 12 GeV	**A**	Early: DVCS & GMp/62	(100) approved **★70**	A	Hall A commissioning
C12-12-010	**DVCS CLAS–HDIce** : DVCS at 11 GeV with transversely polarized target using the CLAS12 Detector	**B**	G/110	(**110**) concurrent	A	Requires transversely polarized HDIce with electron beam C1 Proposal
E12-11-003	**DVCS CLAS–D(UU,LU)** : DVCS on the Neutron with CLAS12 at 11 GeV	B	B/90	(90) approved	A	Requires D target; central neutron detector ready in 2016 **★Backup GPD-E meas if HDIce delayed**

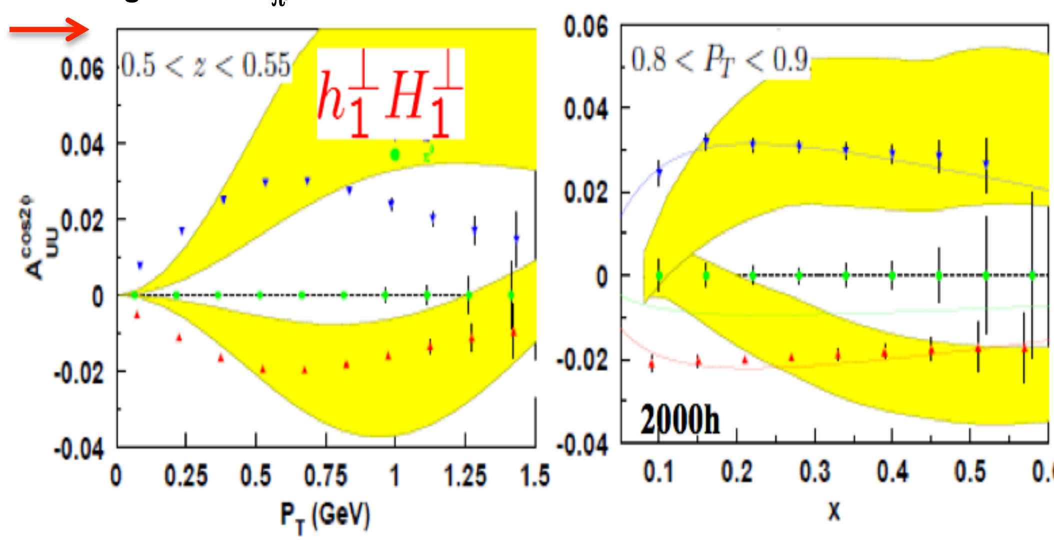


Evolution and k_T-dependence of TMDs

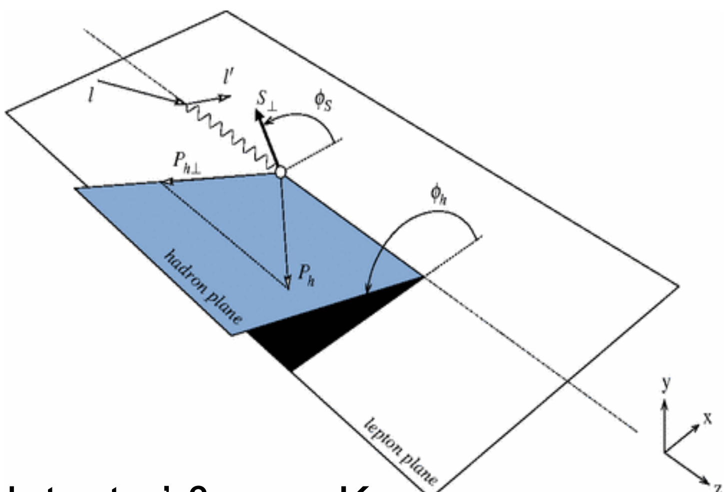


CLAS12 kinematical coverage

highest energies $z=E_\pi/\nu$



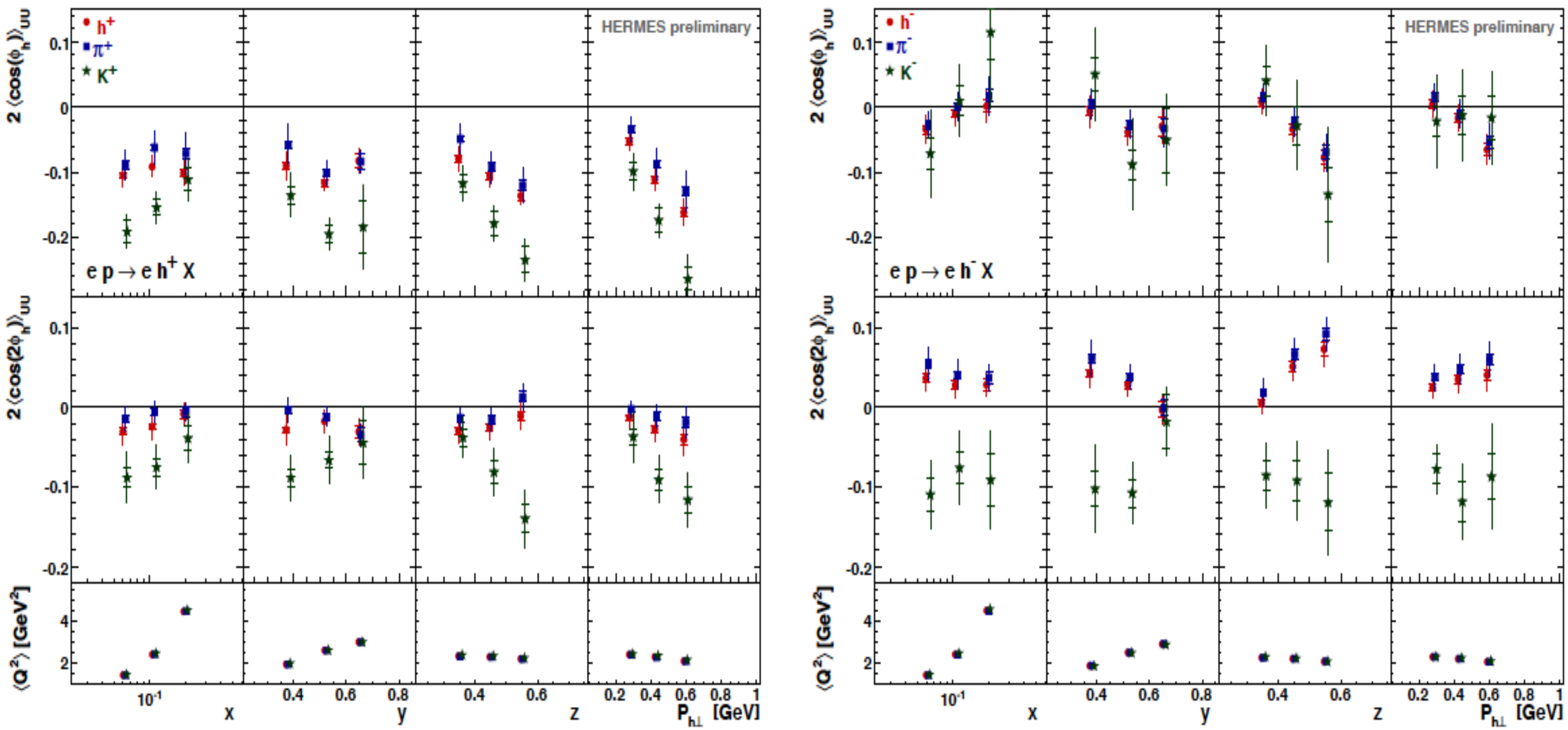
Accessing spin-orbit correlations in measurements of Boer-Mulders function $h_1^\perp(x, k_T)$



detect e' & π or K

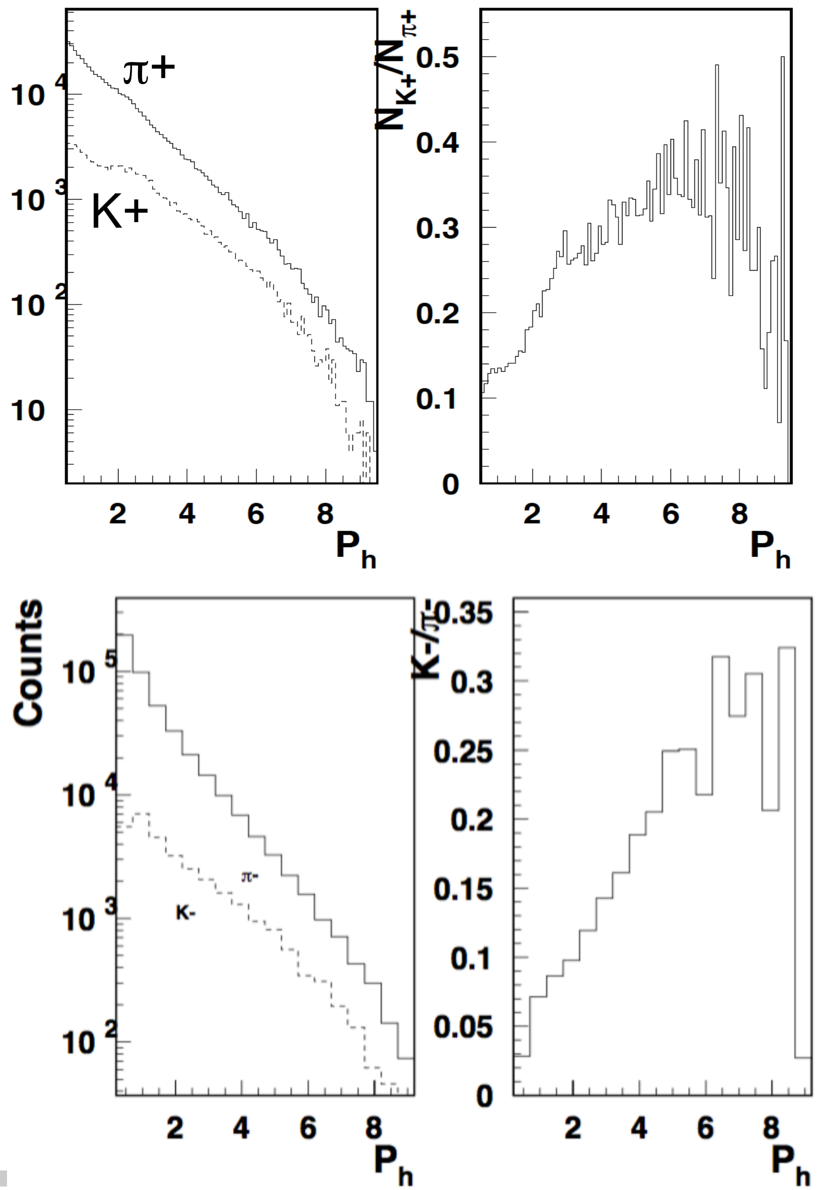
- Large acceptance of CLAS12 allows studies of P_T and Q^2-dependence of SSAs in a wide kinematic range in single and dihadron SIDIS
- Comparison of JLab12 data with HERMES, COMPASS will pin down transverse momentum dependence and the non-trivial Q^2 evolution of TMD PDFs in general, and Boer-Mulders (Sivers) functions in particular.

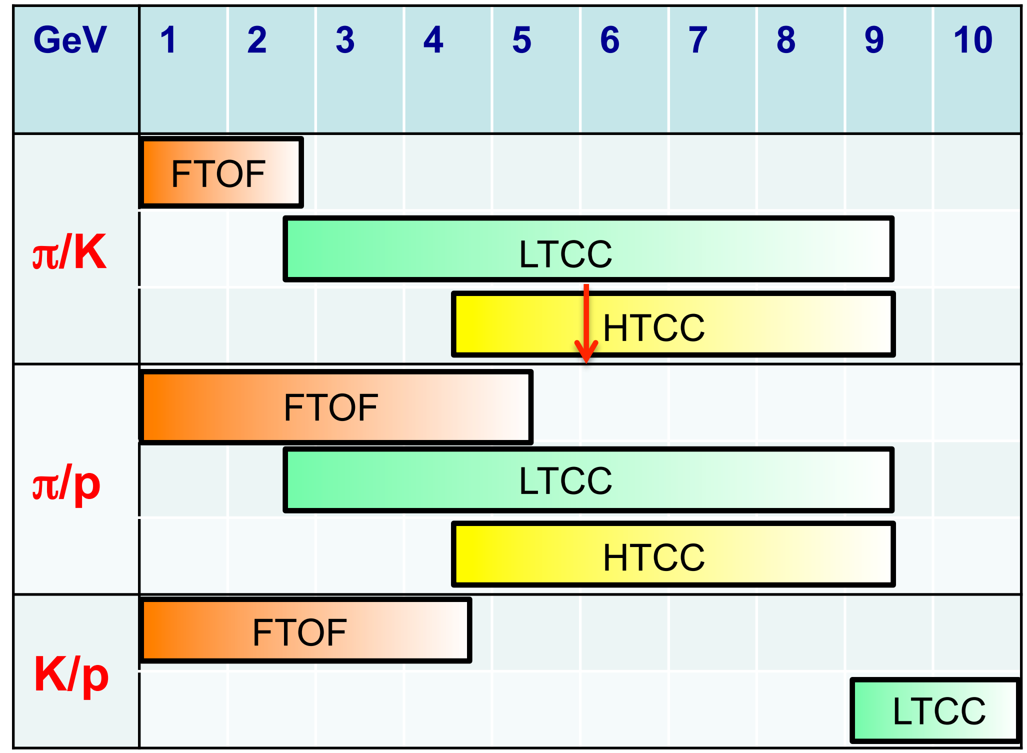
Kaons and pions



Kaon spin orbit correlations may be very different from pions
- bigger effects
- different signs (separation crucial!)

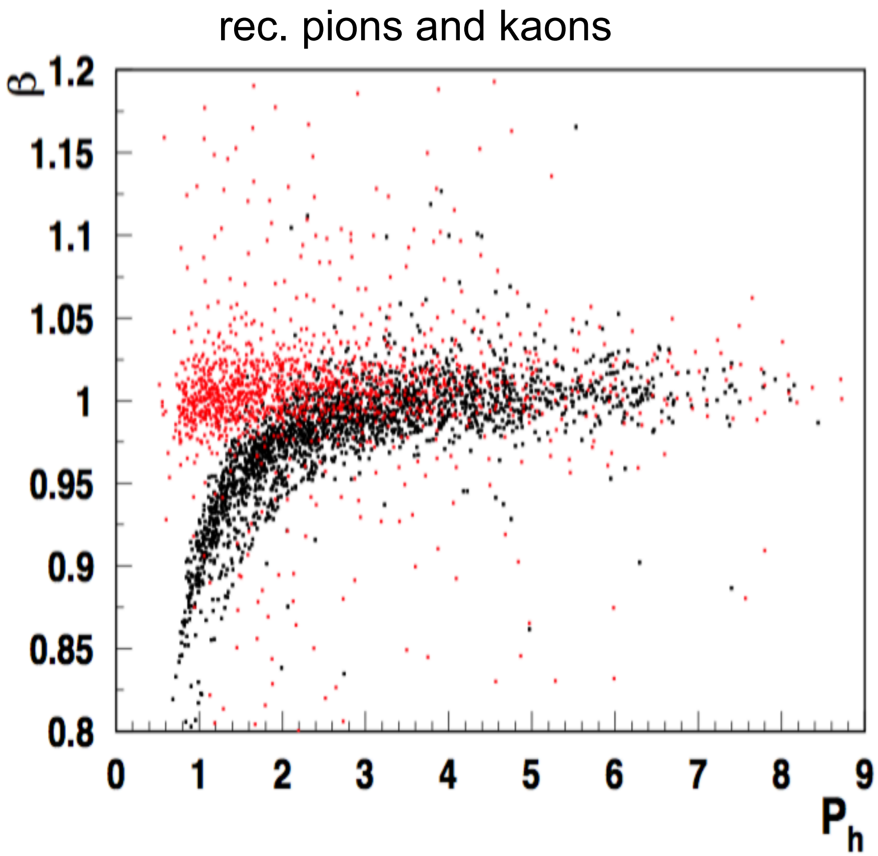
Pion/kaon expected rates

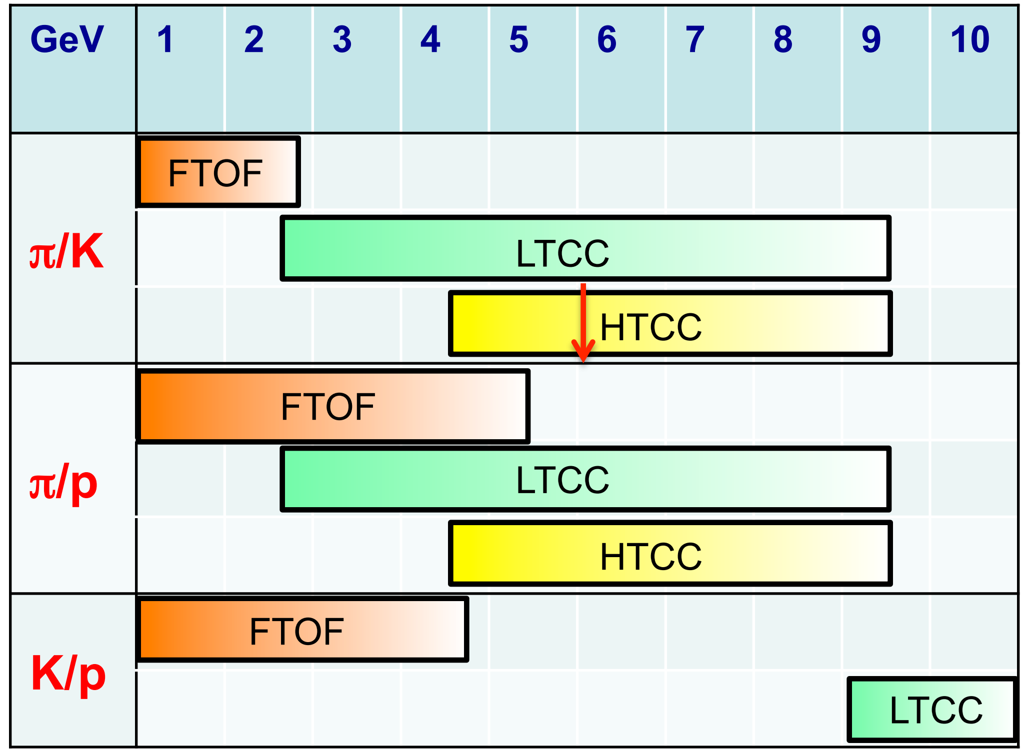




Significant fraction of
Kaons at high energies

PID possibilities with TOF



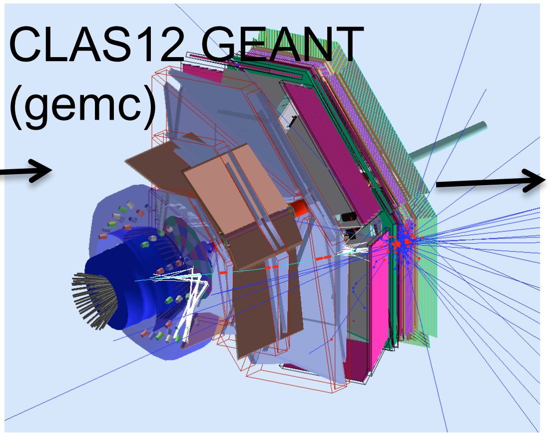


TOF should be combined with LTCC and HTCC for final PID
Will need well calibrated detector to do the probabilistic PID

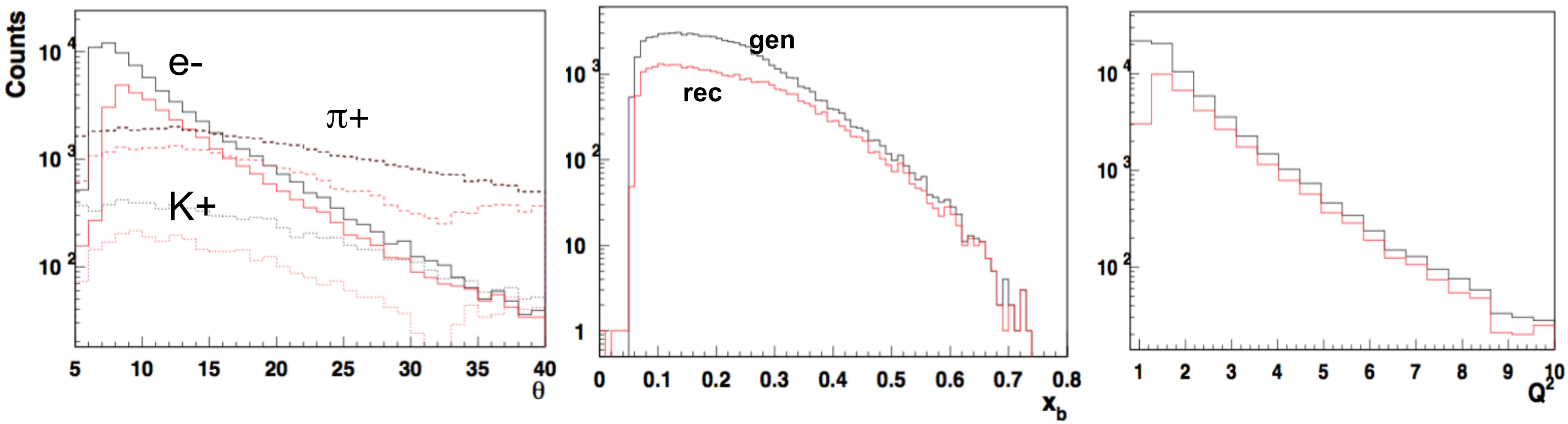
CLAS12 reconstruction chain

- GEMC 4a.1.0
- COATJAVA 4a.6.0

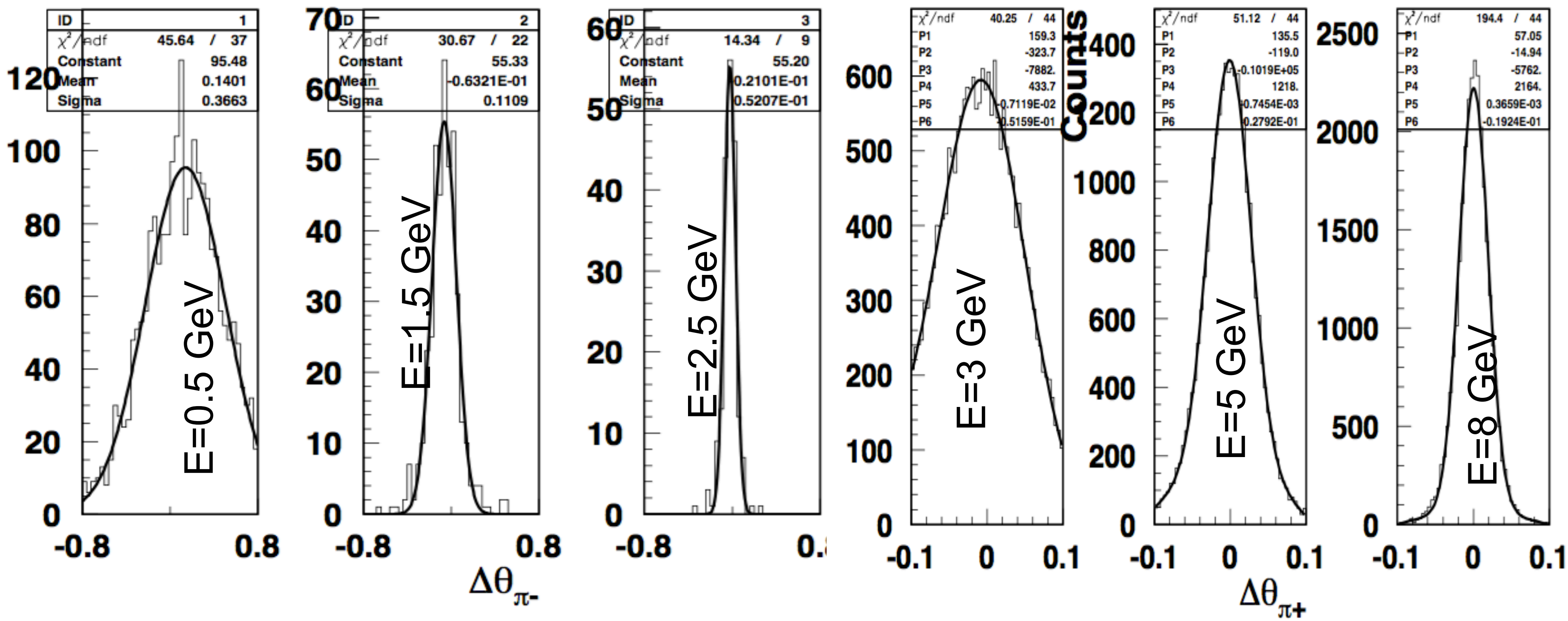
Generators:
Single uncorrelated particles (e-,γ, π+)
SIDIS events ep→e'hX
DVCS/DVMP (ep→ e'pγ, e'p π^0)



CLAS12 Rec
(coatjava)



Reconstruction of pions

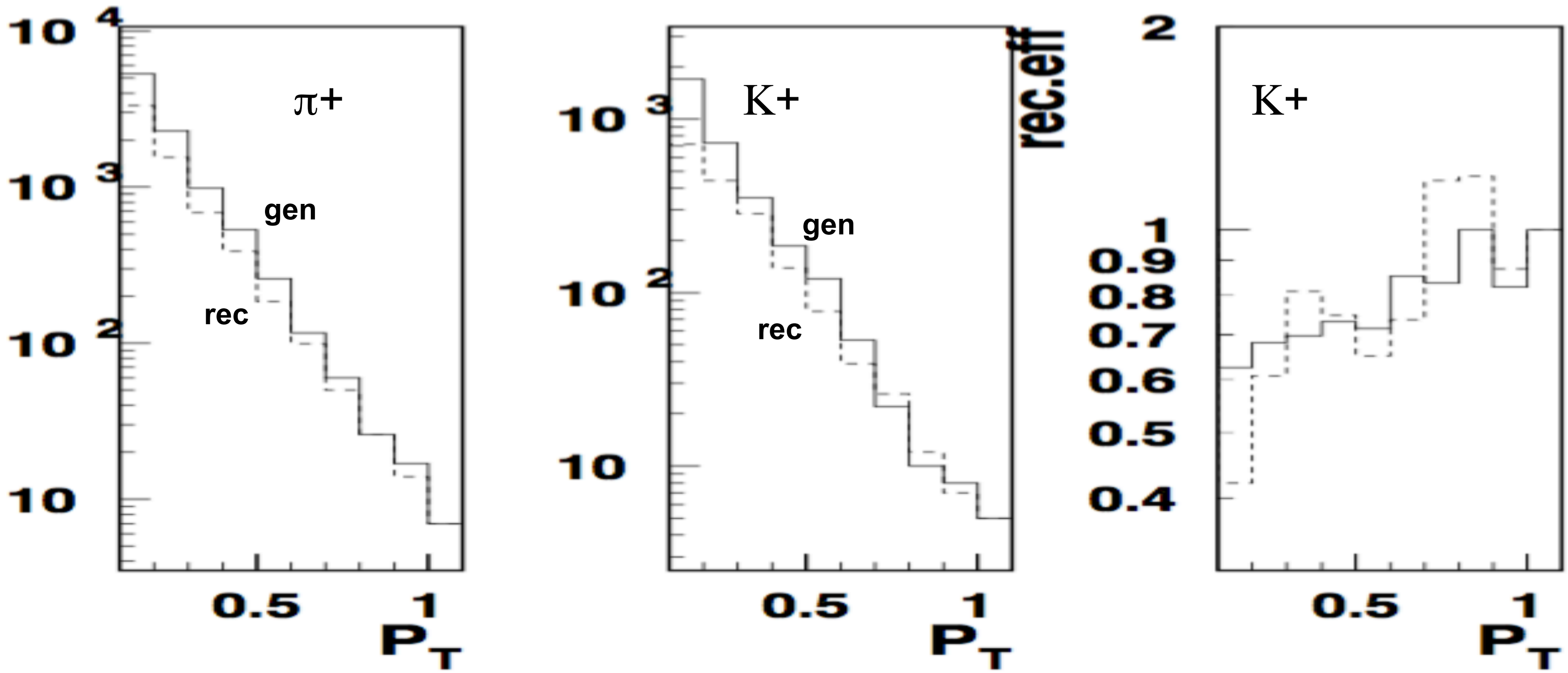


Angles of pions are well reconstructed (minor shifts <0.5 GeV)

CLAS12 reconstruction chain

- GEMC 4a.1.0
- COATJAVA 4a.6.0

Generators:
SIDIS events ep→e'hX

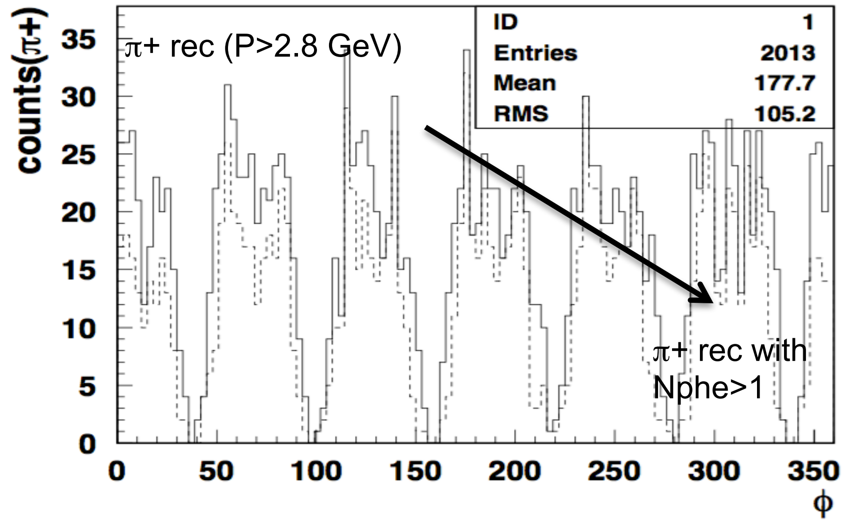


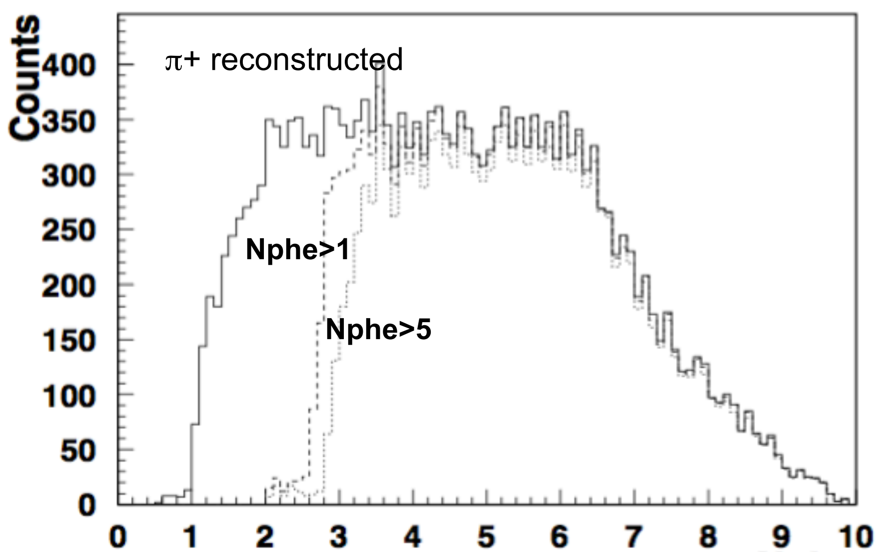
At high P_T fraction of Kaons increases

CLAS12: LTCC response

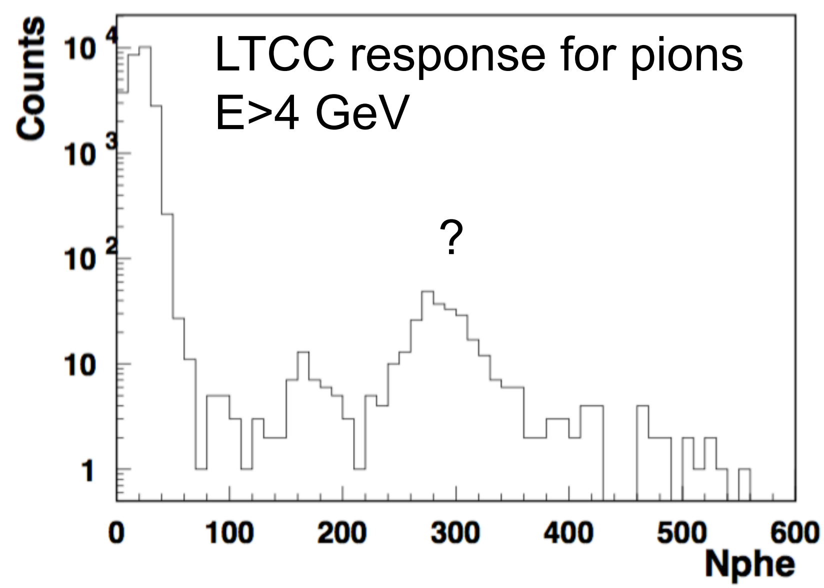
Generators:
Single uncorrelated particles (e-,γ, π+)
SIDIS events ep→e'hX

- GEMC 4a.1.0
- COATJAVA 4a.6.0

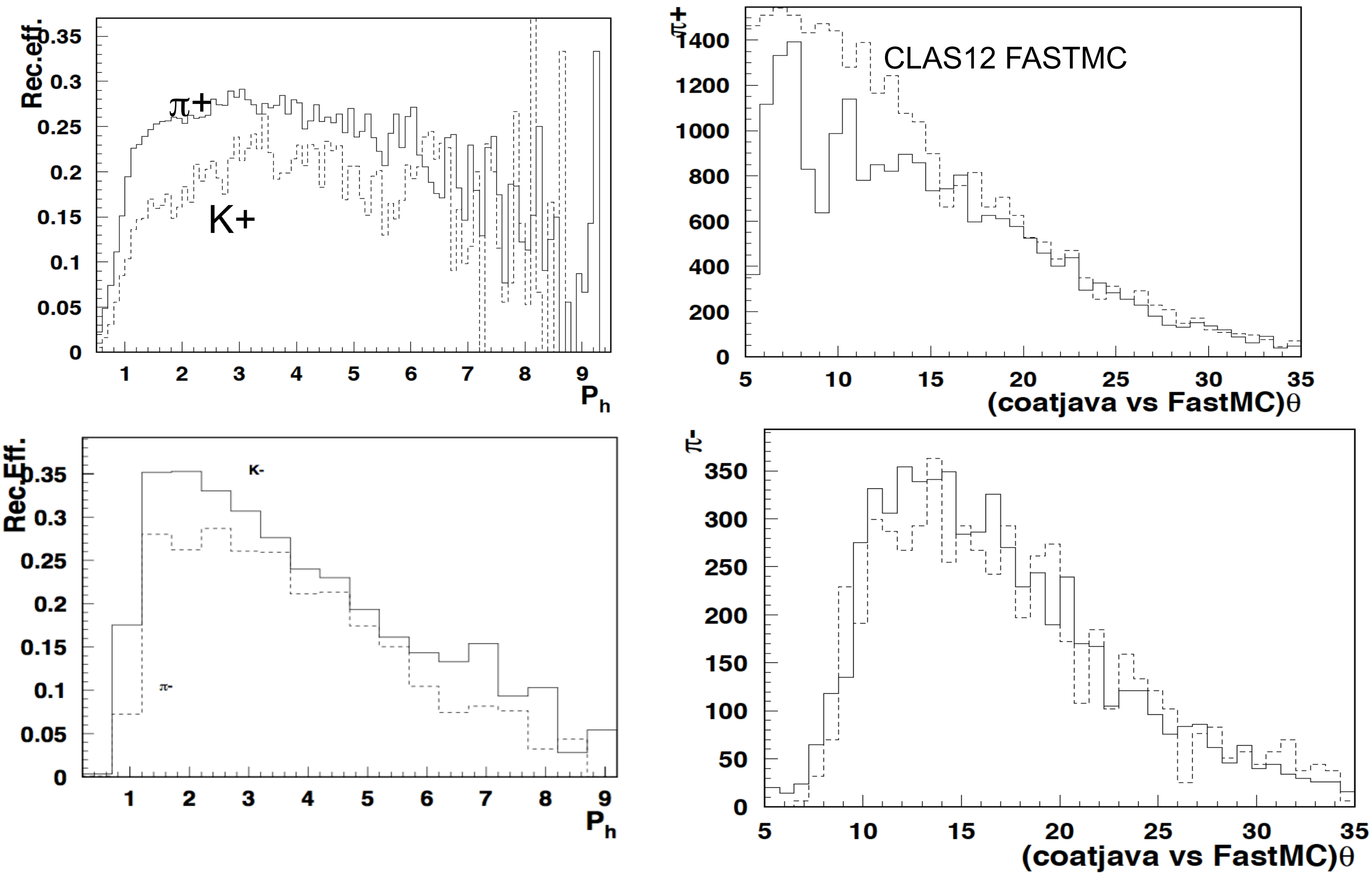




Even with lower Nphe the range ~3GeV may be covered



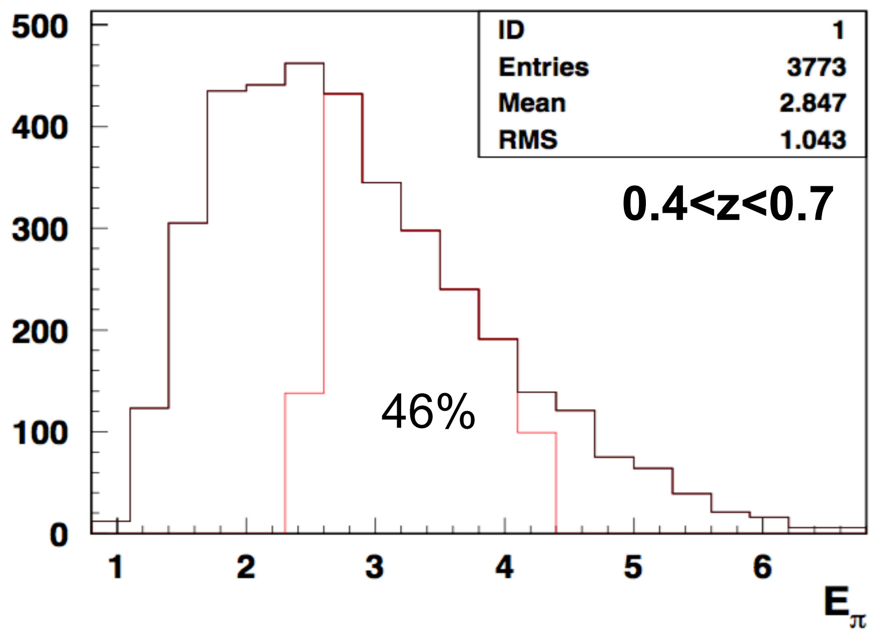
p/K acceptances from reconstruction

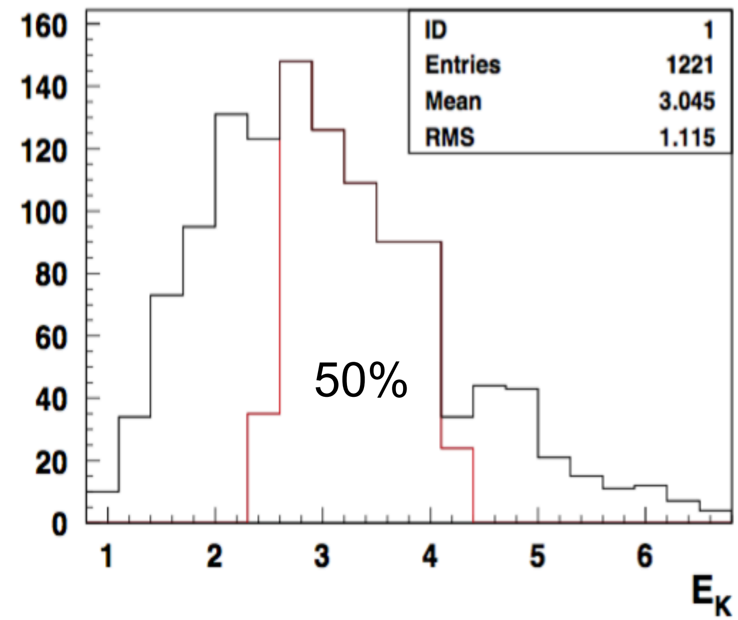


Acceptances compatible with old FASTMC used for projections for CLAS12 proposals

Pion distributions and contamination

ERR: Develop a plan to ensure there is sufficient C4F10 available for operation in Fall 2017, or demonstrate how the planned physics goals may be achieved with out it.





For 0.3<z<0.7 fraction decreases to 40%

40-50 % of pions and kaons are in the range of 2.5<P<4.2 GeV not covered by other detectors

The fraction of K+/π+~0.25 and K-/π- ~0.15 in the range of 2.5<P<4.2 GeV

<u>Need detailed studies of Kaons to understand the effect of ~10% contamination</u>

SUMMARY

Pion/Kaon identification critical for precision SIDIS studies!

For SIDIS with pions (highest priority):
- no major problems with acceptance with LTCC
- several LTCC sectors functional
- in relevant kinematics contamination could reach ~10% (K+) and ~5%(K-)
- need more input from KPP on LTCC performance
- need more studies with realistic LTCC/TOF studies +LTCC with CO_2
- look for alternative gas
- study detailed systematics due to partial PID

Pion/Kaon PID for commissioning run:
LTCC: one sector with C_4F_{10}
consider (make available) CO_2/… running for 1-2 sectors (need DA)
HTCC: P>4.5 GeV
TOF: P<2.5 GeV

Support slides…

Gases for LTCC CO_2/……..

Table II. Gases for Cerenkov counters and their characteristics

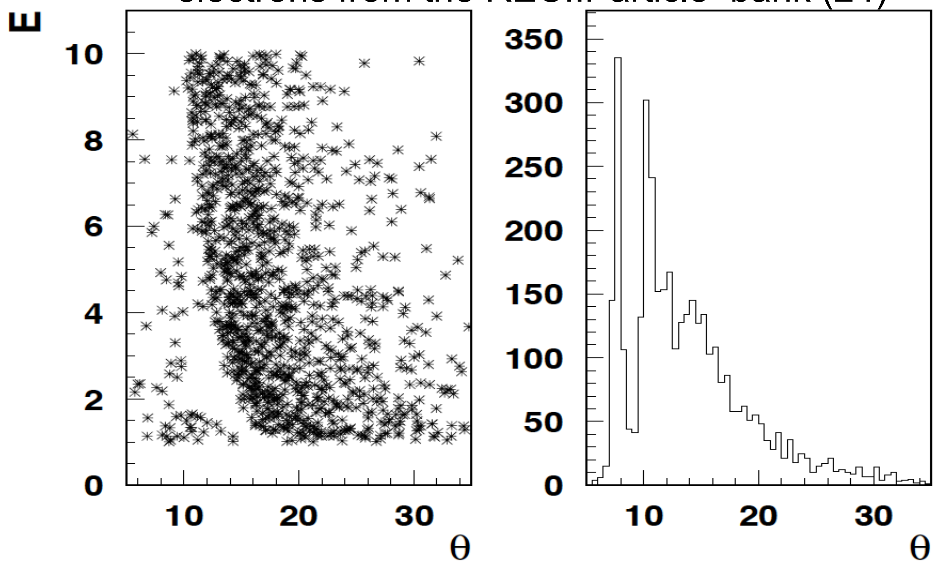
Gas	Chemical formula	T_{cr}, °C	P_{cr}, kg/cm²	$(n_D-1)\cdot 10^4$ (760 mm Hg, 0° C)	$(n-1)/\rho$, cm³/g	$\frac{A}{Z}\frac{n-1}{\rho}$, cm³/g	$(n_D-1)\cdot 10^2$ (20° C, 50 atm)	Literature
Hydrogen	H_2	—240	13.2	1.39	1.55	1.55	0.628	44, p. 52
Oxygen	O_2	—118	51.7	2.72	0.143	0.286	1.26	41, " 54
Air				2.926	0.226		1.35	40, " 37
Nitrogen	N_2	—147	34.6	2.97	0.239	0.478	1.39	44, " 50
Nitric oxide	NO_2	—93	66.1	3.03	0.226	0.452	1.50	48, " 217—218
Carbon monoxide	CO	—140	35.6	3.34	0.269	0.538	1.54	49, " 33
Ammonia	NH_3	132	115	3.77	0.488	0.832	0.328 *), 8.46 kg/cm²	44, " 39
Methane	CH_4	—82.1	47.3	4.41	0.614	0.983	2.29	50
Carbon dioxide	CO_2	31.0	75.3	4.50	0.228	0.456	3.08	49, p. 40
Freon-14	CF_4	—45.5	38.1	4.61	0.117	0.246	2.40	49, " 70
Nitrous oxide	N_2O	36.5	74.1	5.15	0.260	0.520	4.11 *), 49.4 atm	48, " 217—218
Acetylene	C_2H_2	35.7	63.7	6.10	0.521	0.965	4.80 *), 43.3 "	44, " 32
Hydrogen sulfide	H_2S	100	91.8	6.19	0.402	0.760	1.36 *), 18.4 kg/cm²	45, " 37
Sulfur dioxide	SO_2	158	80.4	6.60	0.225	0.450	0.221 *), 3.37 "	44, " 62
Ethylene	C_2H_4	9.2	51.6	6.96	0.551	0.964	6.03	44, " 59
Ethane	C_2H_6	32.3	49.8	7.06	0.521	0.866	4.56 *), 38.5 "	51, " 62
Freon-13	$CClF_3$	28.8	39.4	7.82**)	0.156	0.326	4.00 *), 32.4 "	51, " 55
Sulfur hexafluoride	SF_6			7.85	0.120	0.251		49, " 68
Propane	C_3H_8	96.8	43.4	10.05	0.503	0.850	0.897 *), 8.50 "	51, " 61
Freon-12	CCl_2F_2	112	40.9	11.27*)	0.204	0.422	0.646 *), 5.79 "	51, " 49
Freon C-318	C_4F_8	115	27.6	12.85**)	0.144	0.300		13
Chloroform	$CHCl_3$	263	55.8	14.55	0.276	0.563		13
FC-75	C_8OF_{16}	221	16.3	27.4**)	0.148	0.308		

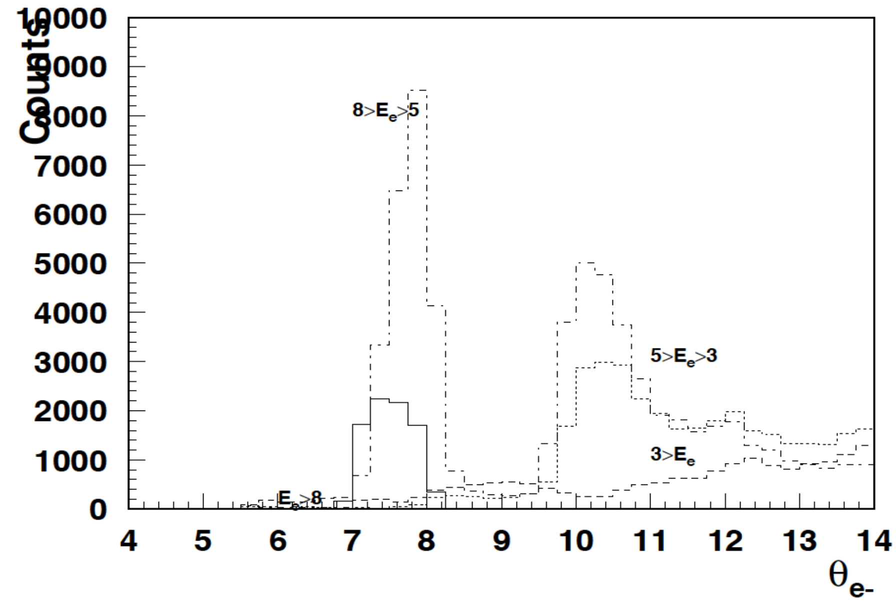
*At the saturated vapor pressure indicated alongside.

**Obtained by calculation based on molecular refraction[11,13].

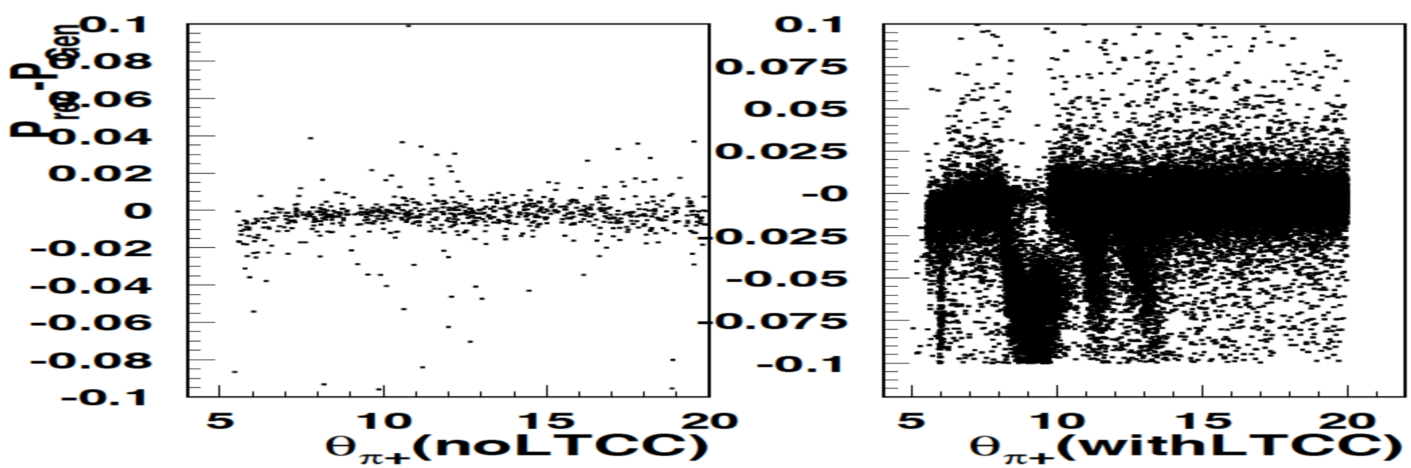
LTCC in 4a.0.2.

electrons from the REC::Particle bank (24)



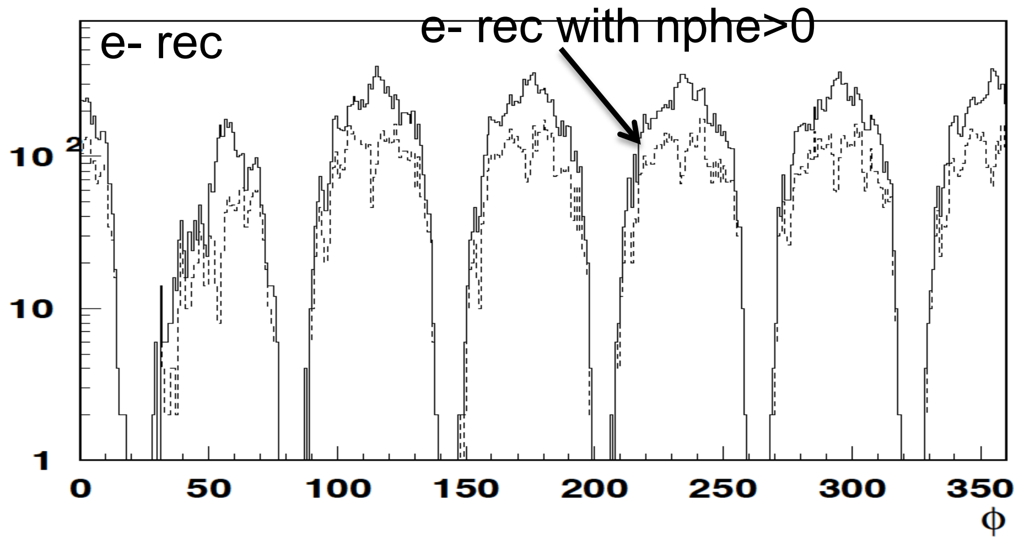


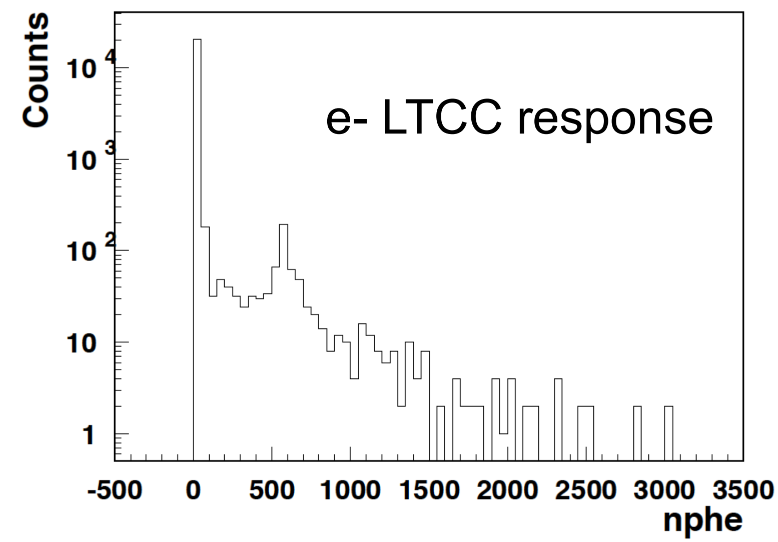
Hole at 8-10 degree was not there when running without LTCC

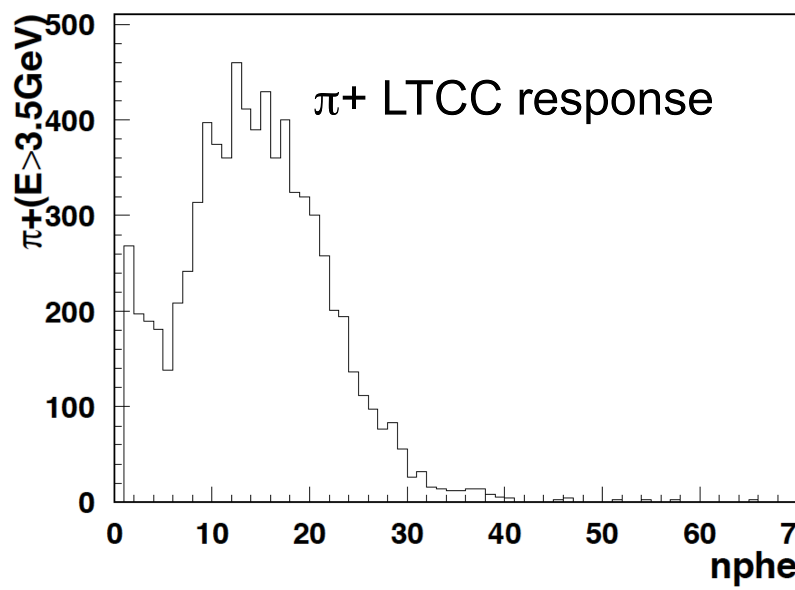


in Devel version LTCC fixed

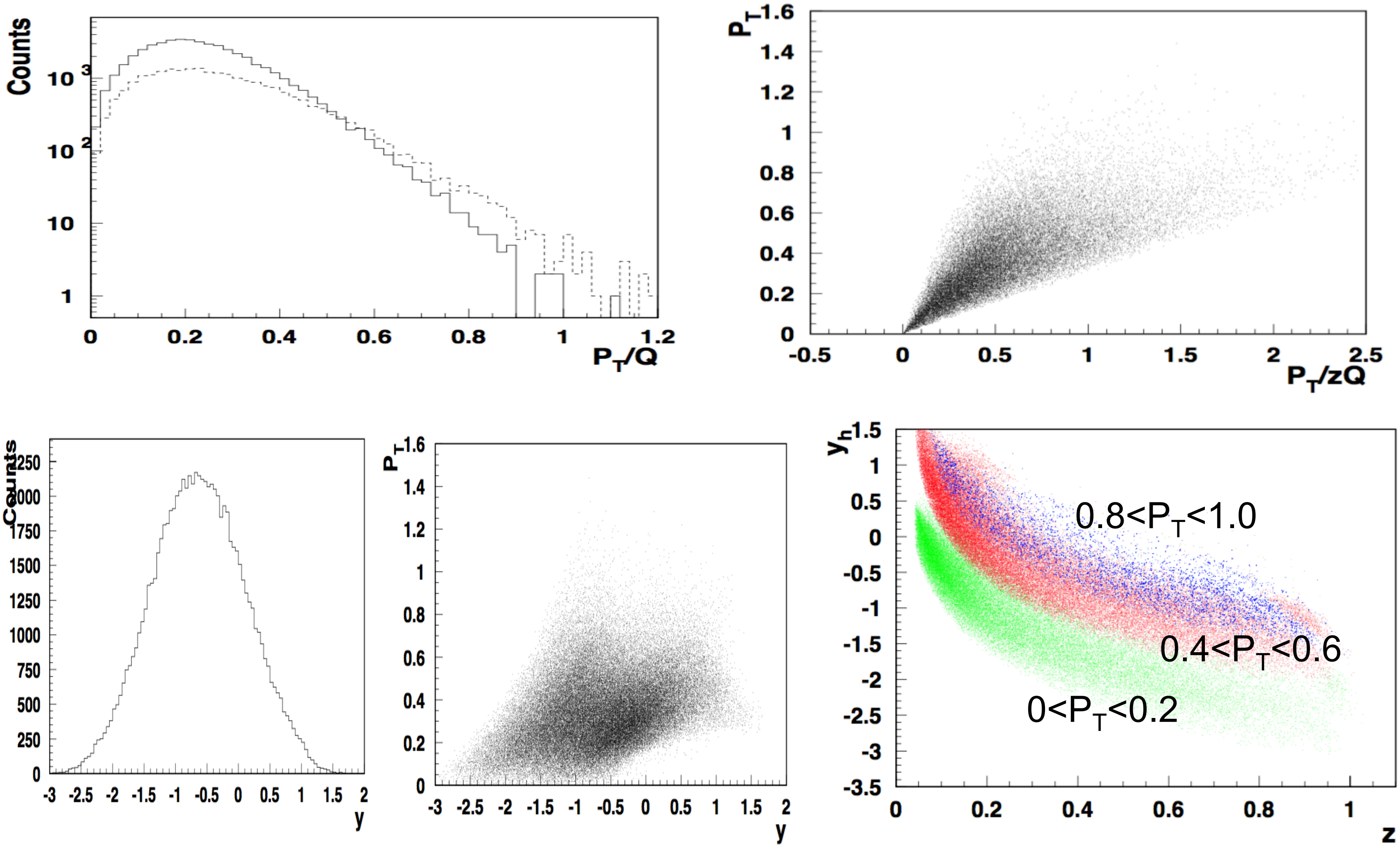
LTCC response from reconstruction







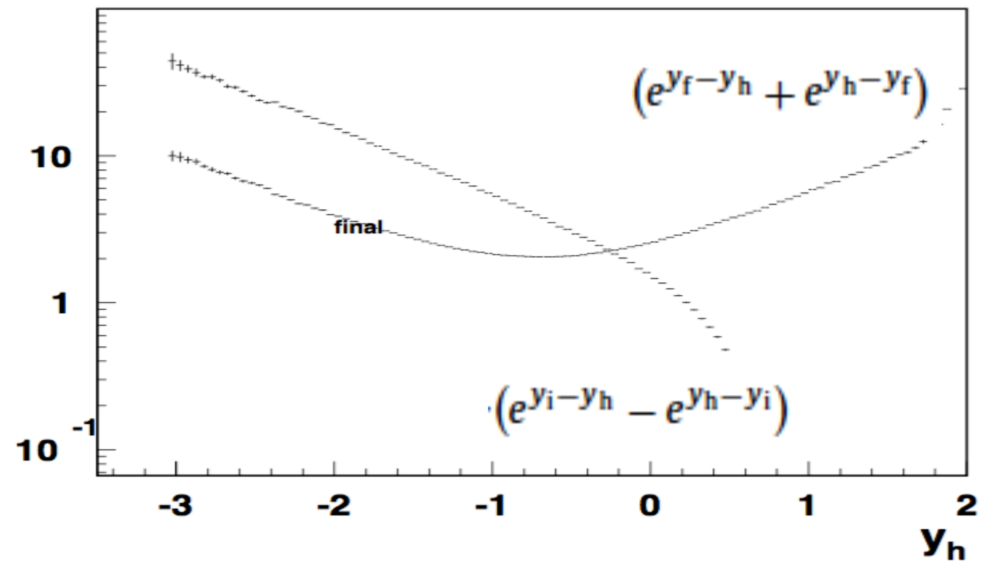
CLAS12-MC: kinematic distributions



$$P_h \cdot k_f = \frac{1}{2} M_{hT} M_{fT} \left(e^{y_f - y_h} + e^{y_h - y_f} \right)$$

and

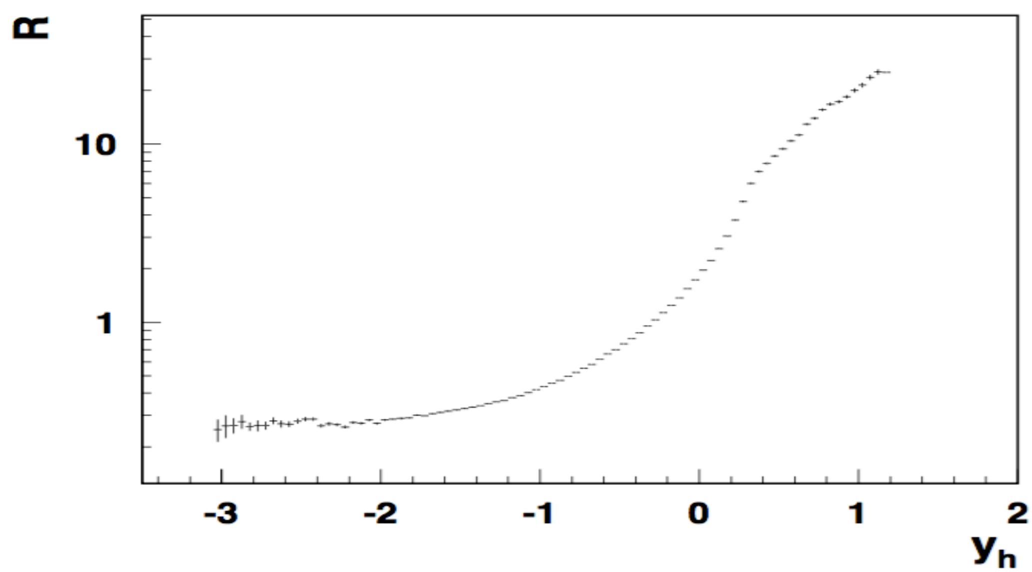
$$P_h \cdot k_i = \frac{1}{2} M_{hT} M_{iT} \left(e^{y_i - y_h} - e^{y_h - y_i} \right).$$



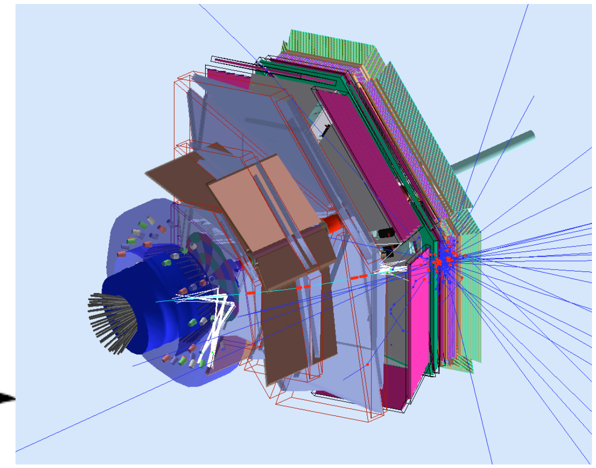
$$R(y_h, z_h, x_{bj}, Q) \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i},$$

for which we identify

$$R(y_h, z_h, x_{bj}, Q) \ll 1: \text{ collinear to outgoing quark},$$
$$R(y_h, z_h, x_{bj}, Q)^{-1} \ll 1: \text{ collinear to incoming quark}.$$



Studies of SIDIS using gemc 4a.0.2. (with LTCC)



clasDIS → gemc → coatjava → hipo-dst

FORTRAN code to access CLAS12 data in *hipo* format and more

G. Gavalian, S. Stepanyan

groovy scripts

hipo→ntuples→root