Analysis and Detector Meeting of the BM@N Experiment

“Lambda hyperons in carbon run”

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Goal and tasks of the job

Goal of the job:

To measure $\Lambda^0 \rightarrow p + \pi^-$ yields and inverse slopes in pT spectra.

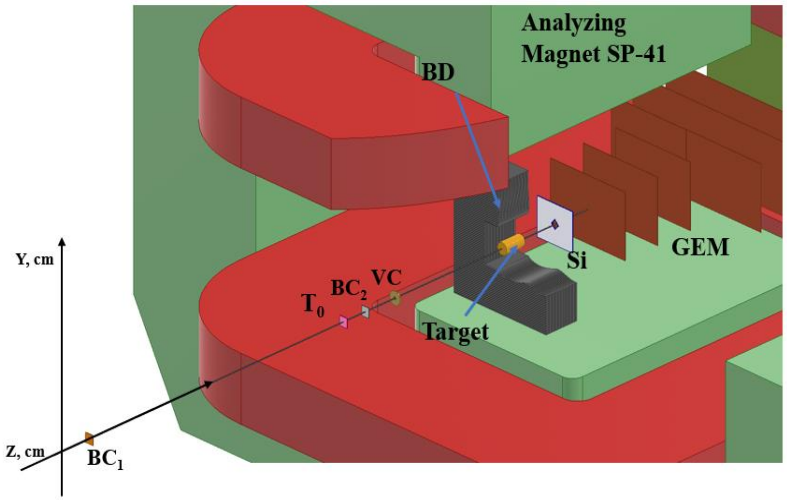
The results will be published.

Steps:

- To get the efficiency of signal reconstruction in the MC.
- To plot the mass distribution $\Lambda^0 \rightarrow p + \pi^-$ with efficiency ω_i over the kinematic range (p_T y).
- To Define kinematic areas with low reconstruction efficiency ω_i .
- Perform measurement of areas of low efficiency using the GQSM model.
- To estimate the number of extracted signals by the fitting method.
- To obtain the cross sections and yields in C+A (4, 4.5AGeV) reactions.
- To obtain inverse slopes in pT spectra in C+A (4, 4.5AGeV) reactions.

Analysis scheme C+A→X (run-6)

Setup scheme (spring 2017)



Kinematic measuring range:

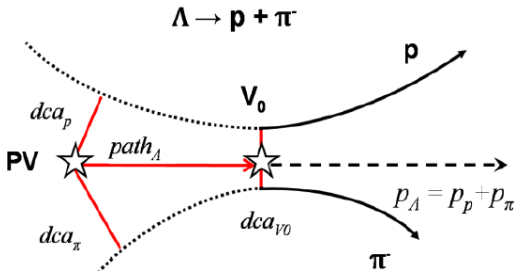
$0.1 < p_T < 1.05\ GeV/c$

4 AGeV: $1.2 < y_{lab} < 2.1$, **4.5 AGeV**: $1.25 < y_{lab} < 2.15$

Λ decay reconstruction in Central tracker(Si+GEM) in C+A interaction
C + A → X , A : C, Al, Cu, Sn, Pb

Gas Electron Multiplier (GEM) system:
To measure momenta of a charged particle and reconstruct the interaction point

Selection of events with Λ hyperon



Event topology:
PV – primary vertex
V0 – vertex of hyperon decay
dca – distance of the closest approach
path – decay length

Criteria for the selection of Λ-hyperons :

- ✓ **Each track has at least 4 of the 6 hits in (GEM);**
- ✓ **p_{pos} < 3.9(4.4) GeV/c for a beam energy of 4 (4.5) AGeV;**
- ✓ **p_{neg} > 0.3 GeV/c;**
- ✓ **dca < 1 cm;**
- ✓ **Distance between the decay vertex V_0 and the primary vertex: path > 2.0 - 2.5 cm (target dependent).**

*K. A. Alishina, Yu. Yu. Stepanenko, A.Y Khukhaeva" Gem residuals corrections in monte-carlo simulation for the run 6 at the BM@N experiment", PEPAN letters – volume 19,part 5, 2022

Procedure in MC modelling(QGSM)

1. Divide the kinematic measuring range by y, p_T into (8x8) cells in the MC simulation;

Kinematic measuring range:

$0.1 < p_T < 1.05\ GeV/c$

4 AGeV: $1.2 < y_{lab} < 2.1$

4.5 AGeV: $1.25 < y_{lab} < 2.15$

h18	h28	h38	h48	h58	h68	h78	h88
h17	h27	h37	h47	h57	h67	h77	h87
h16	h26	h36	h46	h56	h66	h76	h86
h15	h25	h35	h45	h55	h65	h75	h85
h14	h24	h34	h44	h54	h64	h74	h84
h13	h23	h33	h34	h53	h63	h73	h83
h12	h22	h32	h42	h52	h62	h72	h82
h11	h21	h31	h41	h51	h61	h71	h81

$$\boldsymbol{C + A \rightarrow X, 4.0(4.5) AGeV}$$

2. To get the number of events generated by the MC;
3. Fit with function (*) the 8x8 matrix cells of the MC for the reconstructed events with Λ.

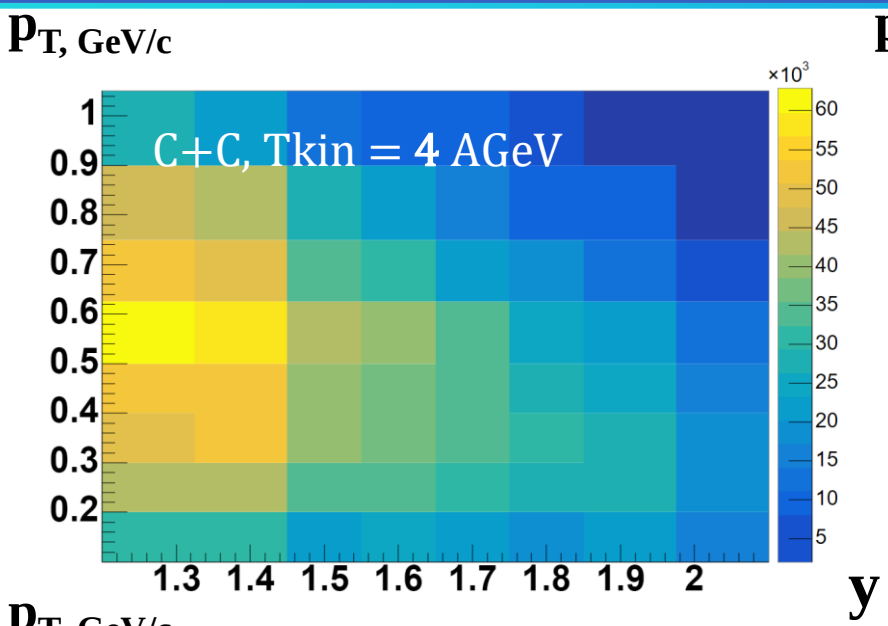
Function for background estimation:

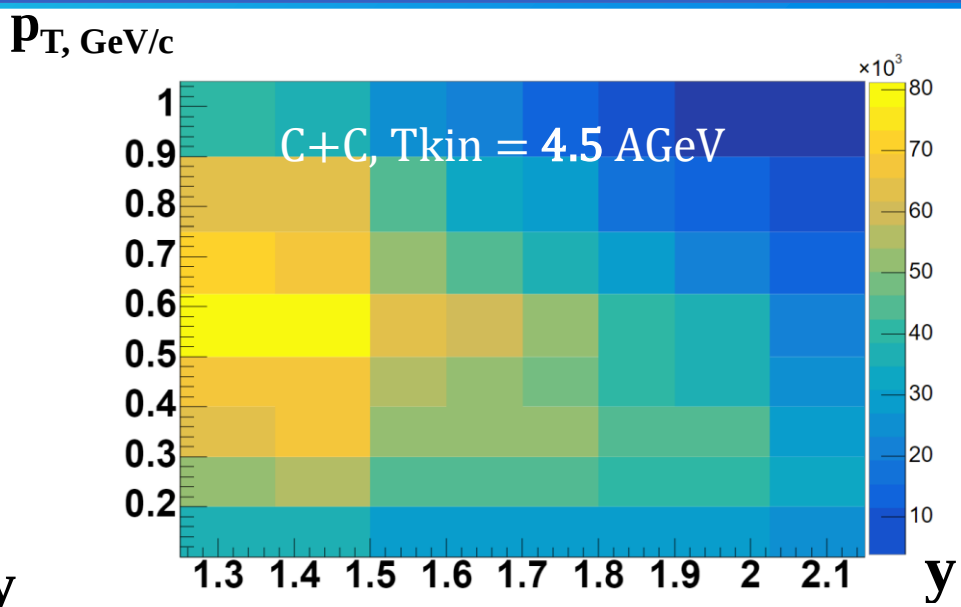
$$f_{bg} = N \cdot (x - M_0)^A \cdot e^{-B \cdot (x - M_0)} \qquad (*)$$

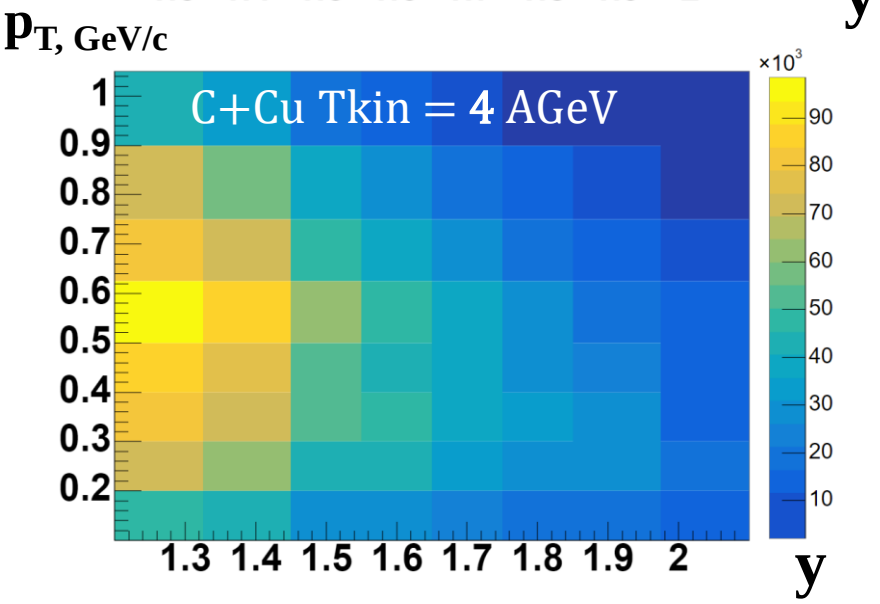
Where N, A, B are free parameters of the fitting function, $M_0 = 1.078$ ГэВ/c^2, x is the mass value.

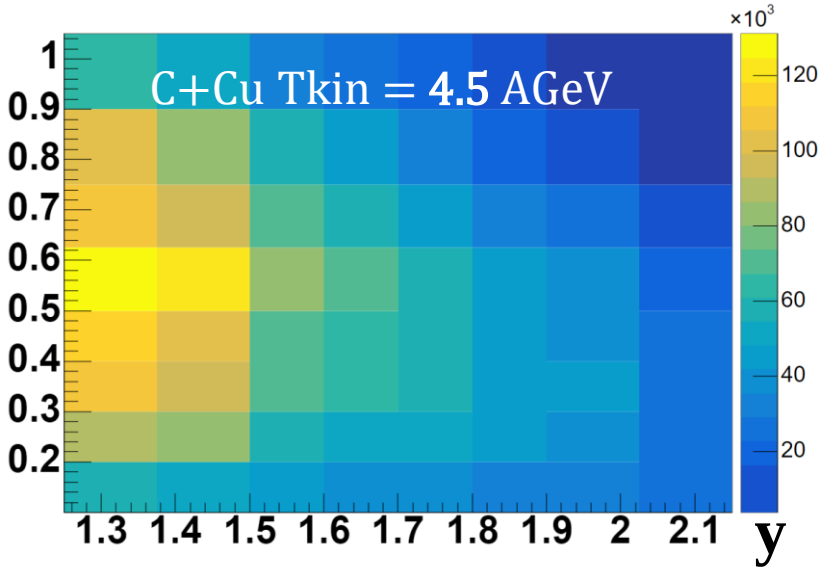
4. To get the weight of each cell: $\omega_i = MC_{rec\_i}/MC_{gen\_i}$, where MC_{rec_i} is the number of extracted MC signal (step 3), MC_{gen_i} is the number of events generated by the MC;

QGSM generated Λ's for P_T

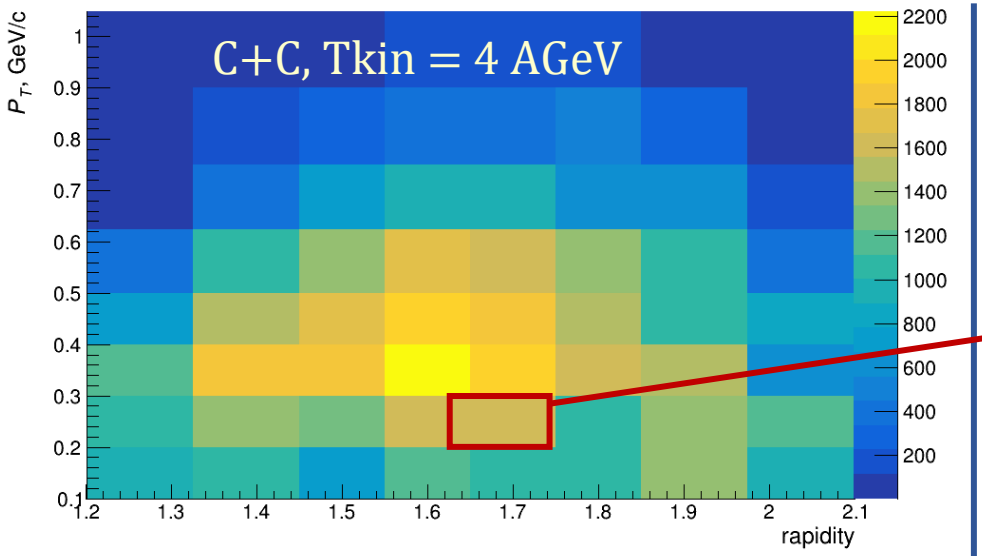


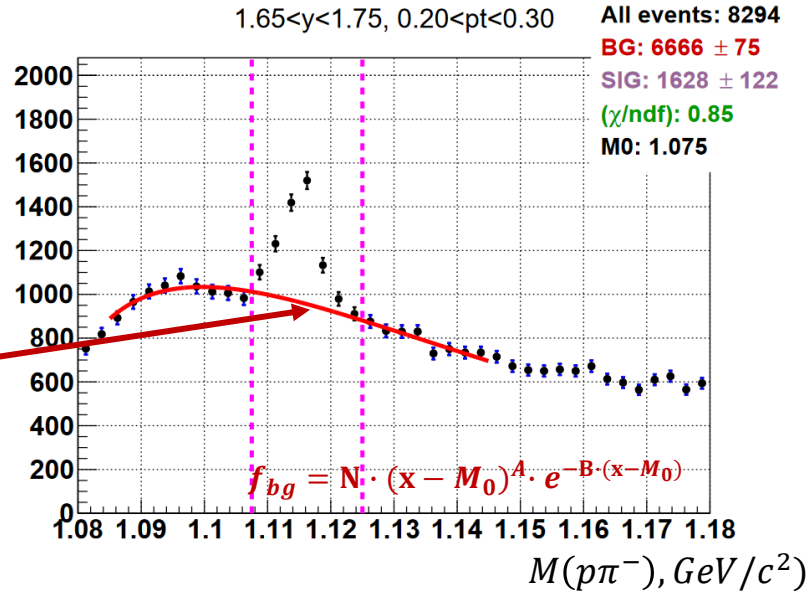


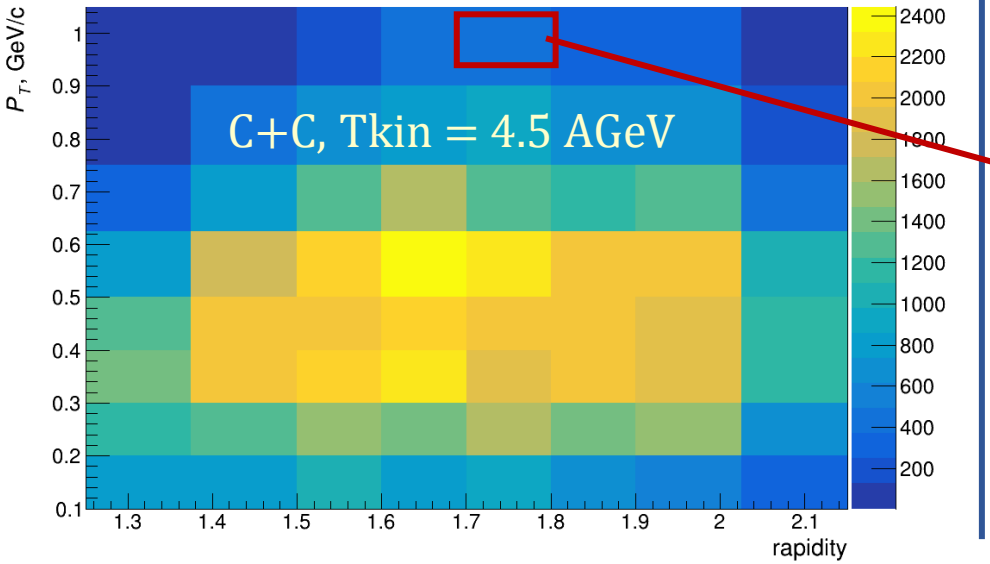




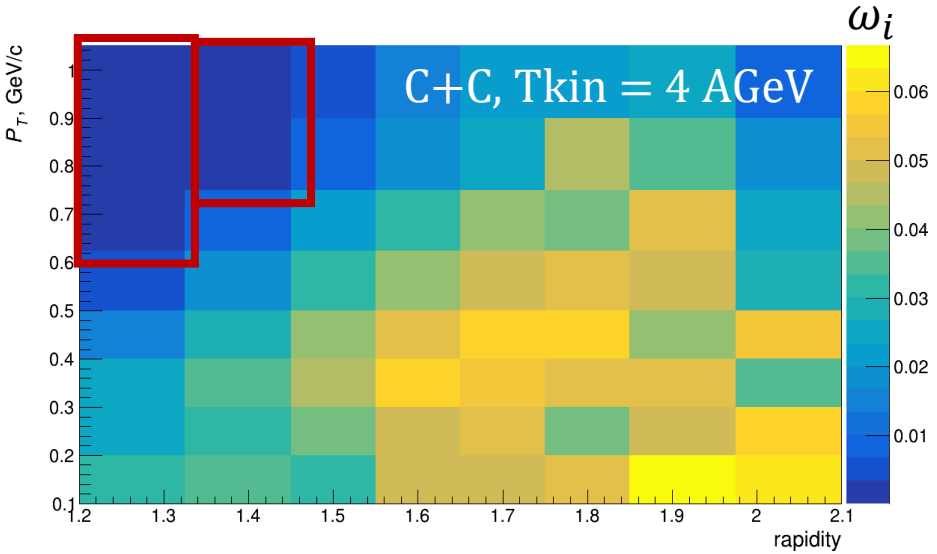
Distribution of the reconstructed signal in the MC

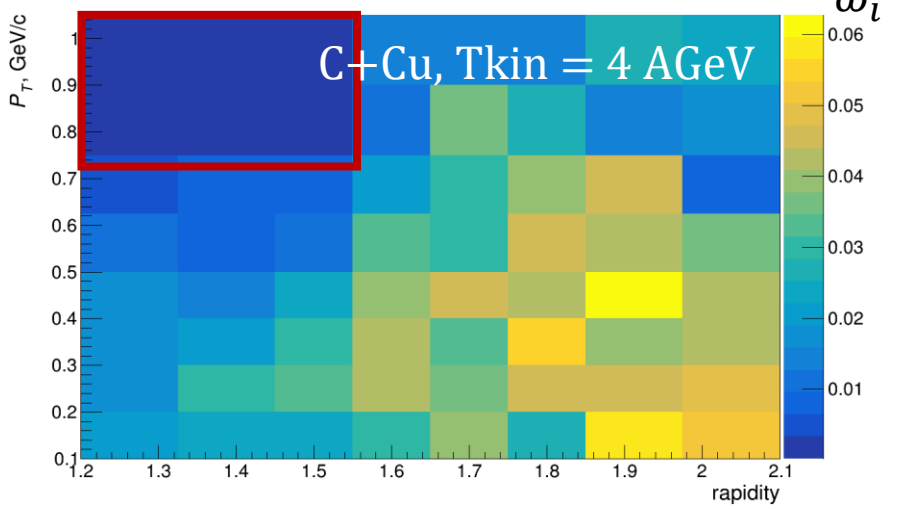


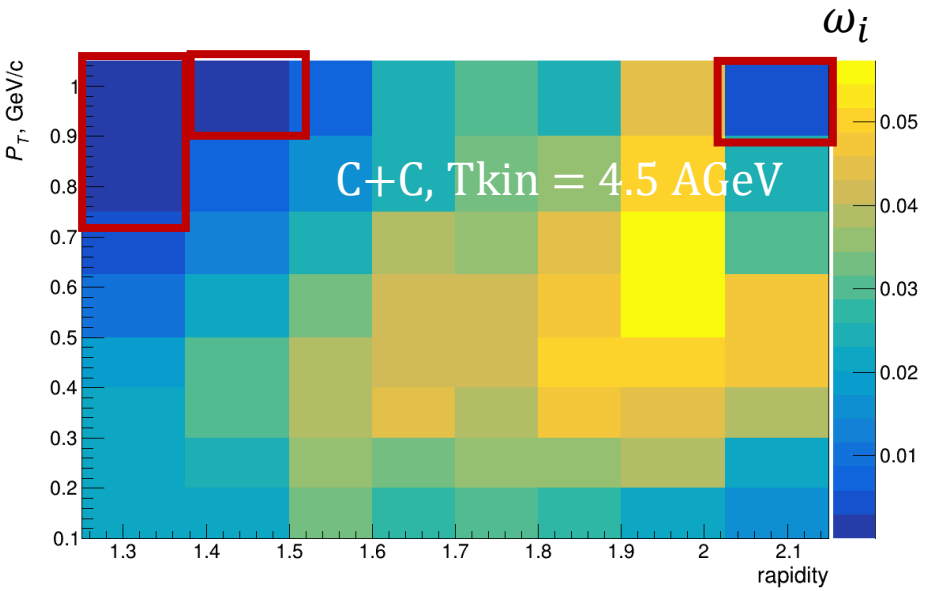


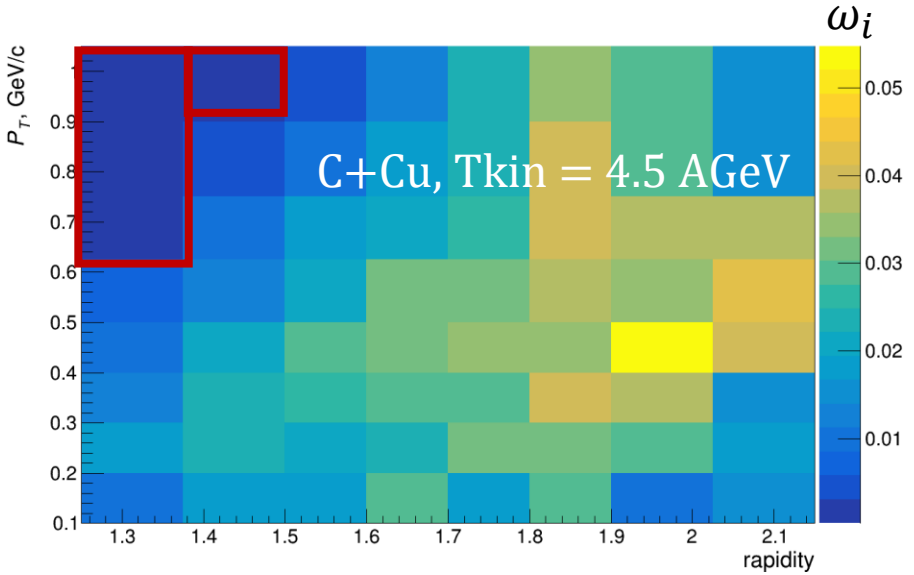


Reconstruction efficiency Λ's for $P_T(y)$









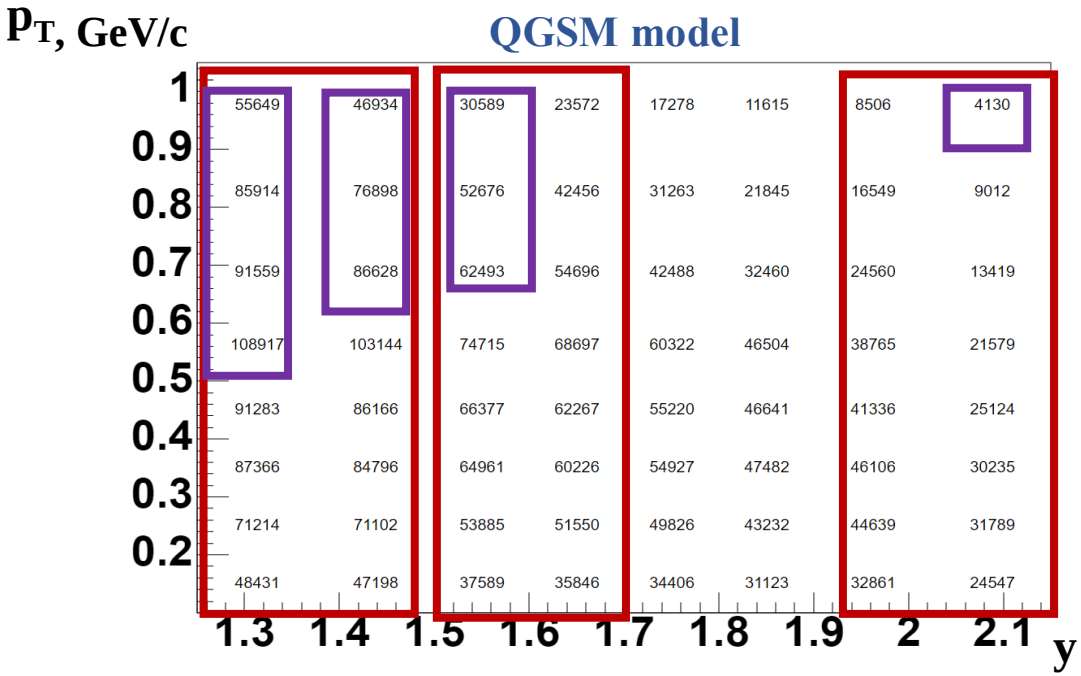
Cells with below $\omega_i \leq 0.01$ - are suppressed.

Extrapolation procedure from simulated data

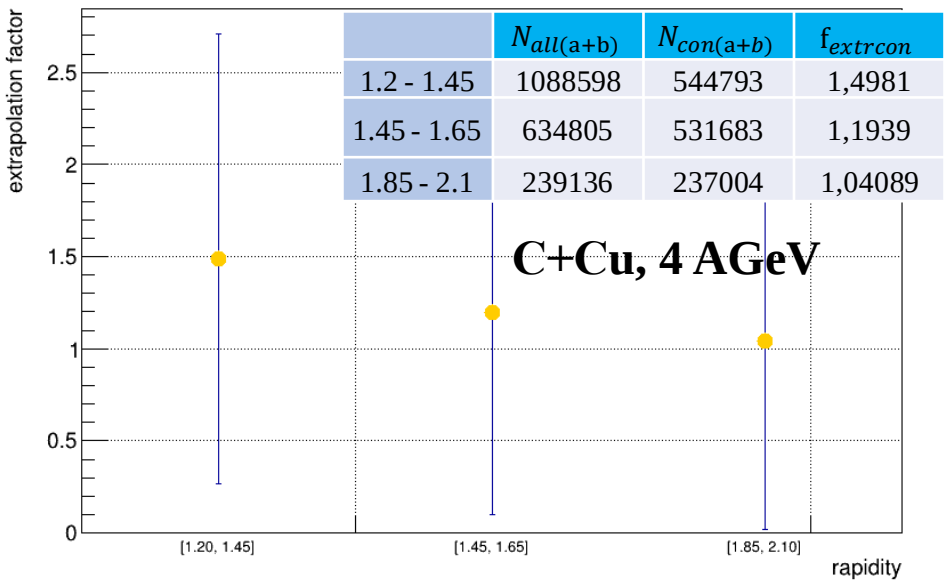
- Let's highlight the areas where cells have been discarded from consideration (**Purple rectangles**);
- Sum all the cells in two neighboring columns by the rapidity y;
- Sum the cells in which the efficiency $\omega_i \geq 0.01$;
- To obtain extrapolation factors by the formula : $f_{extr} = {}^{N_{all(a+b)}}/_{N_{con(a+b)}}$;

$N_{all(a+b)}$ – sum of all generated events in paired columns(a,b) by y; $N_{con(a+b)}$ – sum of all considered in paired columns (a,b) by y;

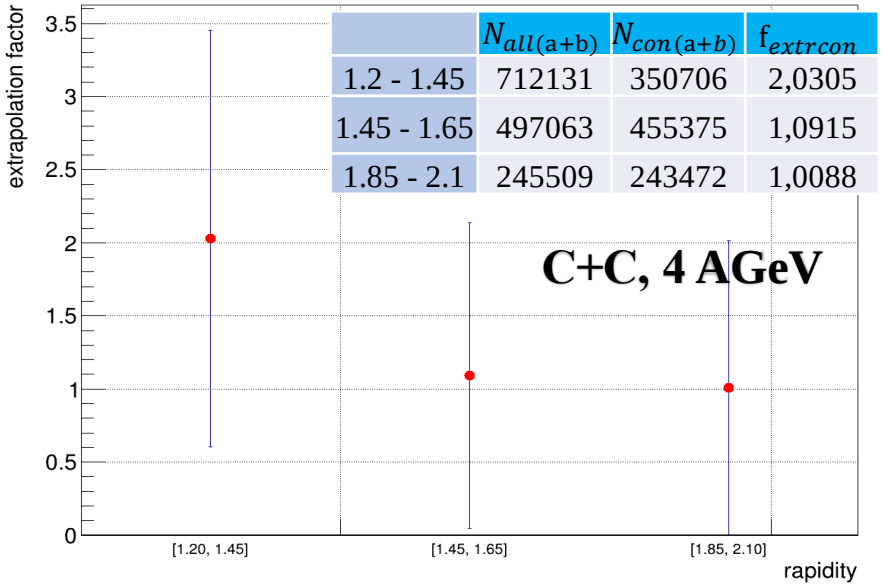
- Mass spectra $M_{inv}(\Lambda \to p\pi^-)$ is multiplied by the extrapolation factor $f_{extrcon}$;(DATA)



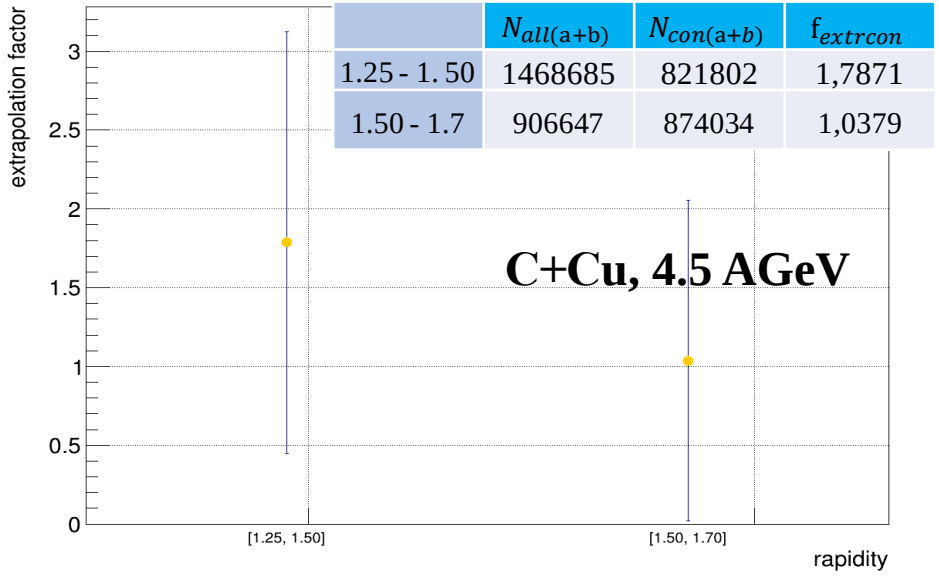
Extrapolation factor f_{extr}



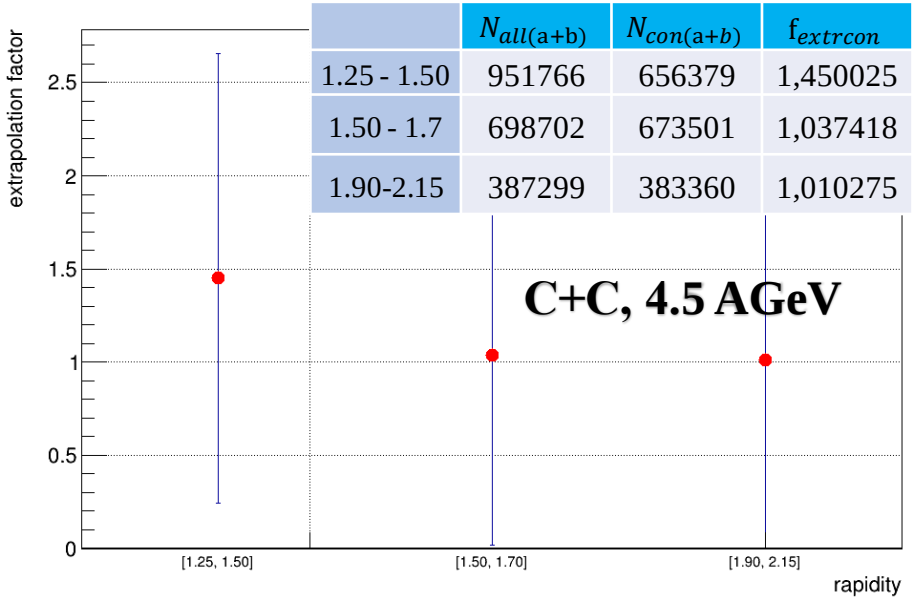
	N_{all}(a+b)	N_{con}(a+b)	$f_{extrcon}$
1.2 - 1.45	1088598	544793	1,4981
1.45 - 1.65	634805	531683	1,1939
1.85 - 2.1	239136	237004	1,04089



	N_{all}(a+b)	N_{con}(a+b)	$f_{extrcon}$
1.2 - 1.45	712131	350706	2,0305
1.45 - 1.65	497063	455375	1,0915
1.85 - 2.1	245509	243472	1,0088

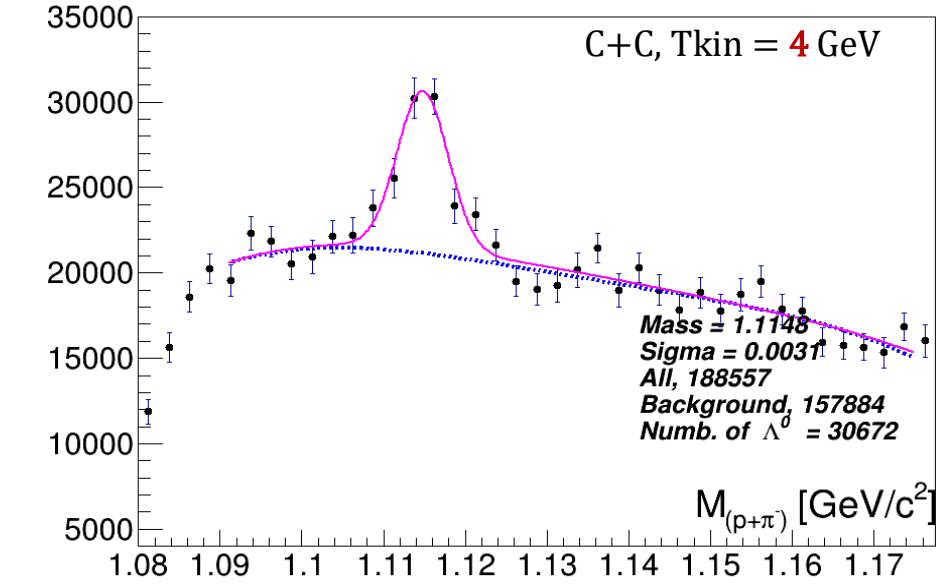


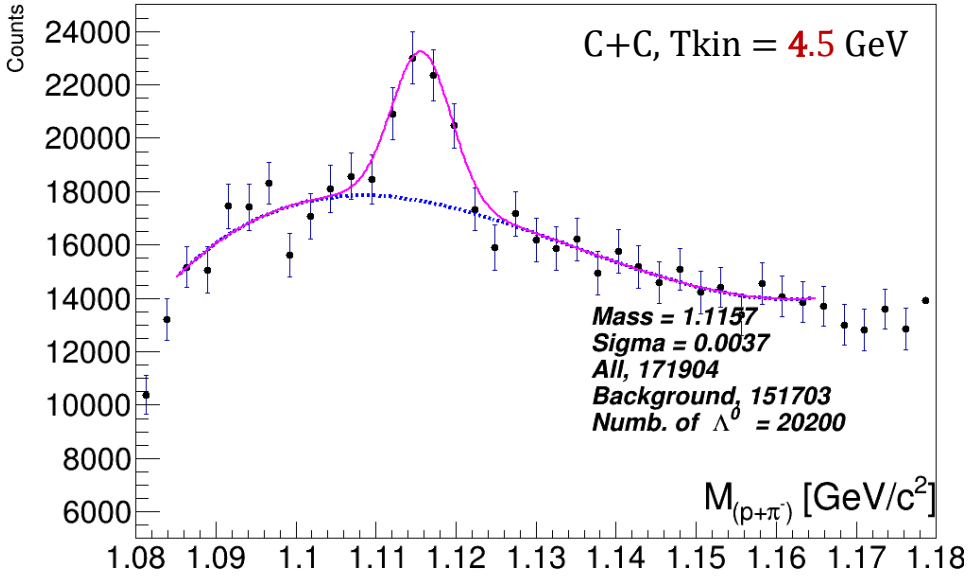
	N_{all}(a+b)	N_{con}(a+b)	$f_{extrcon}$
1.25 - 1. 50	1468685	821802	1,7871
1.50 - 1.7	906647	874034	1,0379



	N_{all}(a+b)	N_{con}(a+b)	$f_{extrcon}$
1.25 - 1.50	951766	656379	1,450025
1.50 - 1.7	698702	673501	1,037418
1.90-2.15	387299	383360	1,010275

One-dimensional mass distribution of the $\Lambda^0 \rightarrow p\pi^-$(DATA)





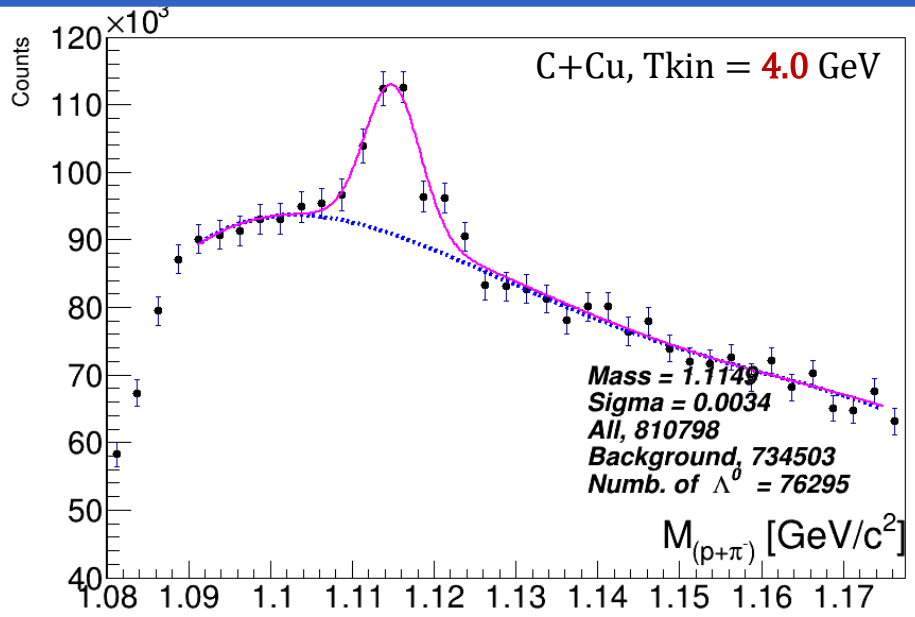
Procedure in DATA C+A → X

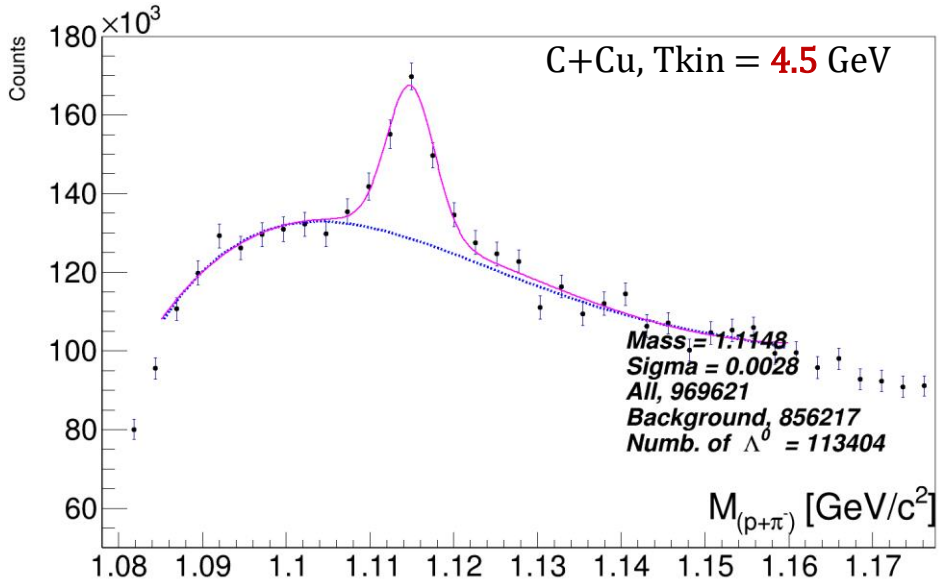
1) Split (y, p_T) area in small cells for MC/DATA (8x8);
2) To each event assigned the weight ω_i;
3) Sum the cells by $\sum_{ij} y_{ij}$ and by $\sum_{ij} pT_{ij}$

Reaction C+C	signal $N^{\Lambda}_{rec}(p_T/y)$
4.0 AGeV	30672
4.5 AGeV	20200

- Λ signal width ~ 2.0 - 4 MeV;
- **Signal** = hist – Background(bg) **in 1107.5-1125** MeV/c²;
- **Background** → $F(M_{p\pi^-})_{bg} = p_0 + p_1 M_{p\pi^-} + p_2 M_{p\pi^-}{}^2 + p_3 M_{p\pi^-}{}^3 + p_4 M_{p\pi^-}{}^4$ → 4th polynomial(**Blue dashed**);
- $err(stat) = \sqrt{\sum w_i^2}$;

One-dimensional mass distribution of the $\Lambda^0 \rightarrow p\pi^-$(DATA)





Procedure in DATA C+A → X

1) Split (y, p_T) area in small cells for MC/DATA (8x8);
2) To each event assigned the weight ω_i;
3) Sum the cells by $\sum_{ij} y_{ij}$ and by $\sum_{ij} pT_{ij}$

Reaction C+Cu	signal $N^{\Lambda}_{rec}(p_T/y)$
4.0 AGeV	76295
4.5 AGeV	113404

- Λ signal width ~ 2.0 - 4 MeV;
- **Signal** = hist – Background(bg) **in 1107.5-1125** MeV/c²
- **Background** → $F(M_{p\pi^-})_{bg} = p_0 + p_1 M_{p\pi^-} + p_2 M_{p\pi^-}{}^2 + p_3 M_{p\pi^-}{}^3 + p_4 M_{p\pi^-}{}^4$ → 4th polynomial(**Blue dashed**);
- $err(stat) = \sqrt{\sum w_i^2}$;

Cross sections and yields of the $\Lambda \rightarrow p\pi^-$

The inclusive cross section σ_Λ and Y_Λ of Λ hyperon in C+A interactions are calculated in bins of y (pT) according to the formulae:

$$\sigma_\Lambda(y) = \sum y[N^\Lambda_{rec}(y,p_T)/\varepsilon_{rec}(y,p_T)\cdot\varepsilon_{trig}\cdot\varepsilon_{pileup}\cdot L] \quad (**)$$

$$\sigma_\Lambda(p_T) = \sum p_T[N^\Lambda_{rec}(y,p_T)/\varepsilon_{rec}(y,p_T)\cdot\varepsilon_{trig}\cdot\varepsilon_{pileup}\cdot L] \quad (**)$$

$$Y_\Lambda(y) = \sigma_\Lambda(y)/\sigma_{inel} \quad (***)$$

$$Y_\Lambda(p_T) = \sigma_\Lambda(p_T)/\sigma_{inel} \quad (***)$$

where L is the luminosity, N^Λ_{rec} is the number of recontacted Λ-hyperons, ε_{rec} is the combined efficiency of the Λ - hyperon reconstruction, ε_{trig} is the trigger efficiency, ε_{pileup} is the suppression factors of reconstructed events, σ_{inel} - is the cross section for minimum bias inelastic C+A interactions(model).

Table. Trigger efficiency

4 AGeV	C	Al	Cu	Pb
ε_{trig}(BD≥2)	0.80±0.02			
ε_{trig}(BD≥3)		0.87±0.02	0.92±0.02	0.95±0.02

4.5 AGeV	C	Al	Cu	Pb
ε_{trig}(BD≥2)	0.80±0.02			
ε_{trig}(BD≥3)		0.83±0.02	0.91±0.02	0.94±0.02

Table. ε_{pileup} suppression factors.

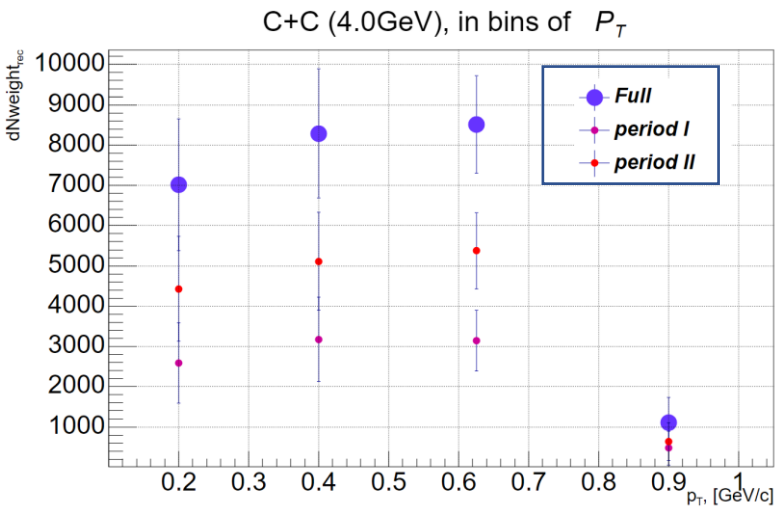
Selection	4AGeV	4.5AGeV
T0==1	+	+
BC2==1	+	+
Veto ==0	+	+
C	0,674	0,529
Al	0,740	0,618
Cu	0,779	0,621
Pb	0,784	0,686

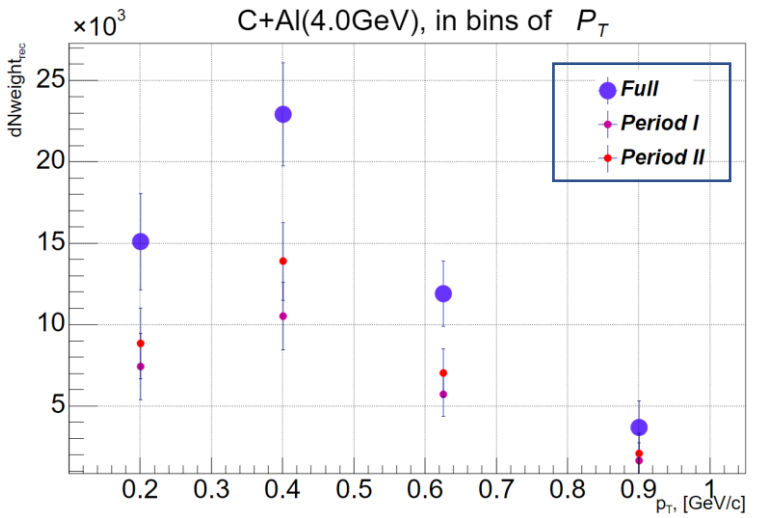
Yields of the $\Lambda \rightarrow p\pi^-$

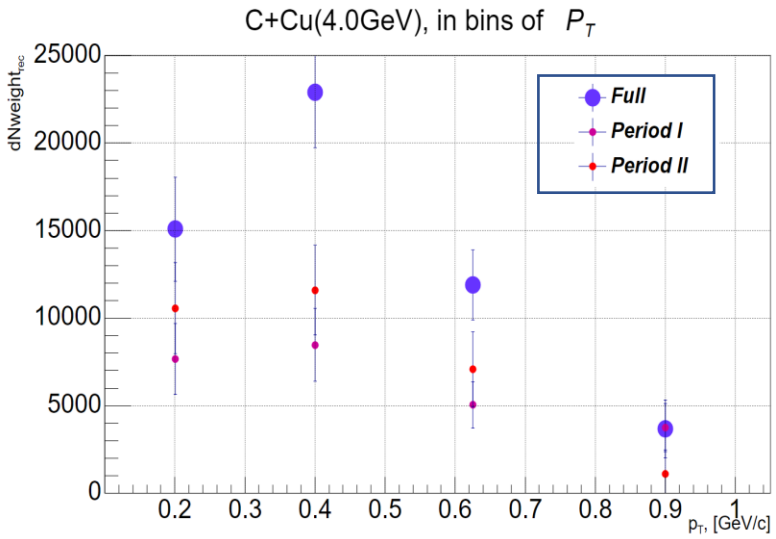
Preliminary

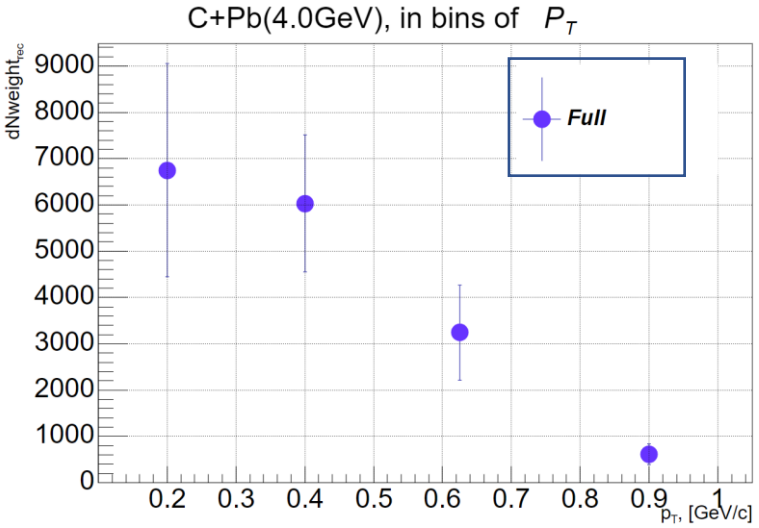
Results of the yields obtained by the 8*8 method.			
Target	**Full (yields ± stat ± sys_mean)**	**I period (yields ± stat ±sys_mean_Iper)**	**II period (yields ± stat ±sys_mean_IIper)**
		Yields total, 4.0 GeV	
C + C	**0,0112±0,0027± 0,00163**	0,0112±0,0039 ±0,0008	0,0107±0,0033 ±0,0009
C + Al	**0,0261±0,0068± 0,00171**	0,0277±0,0075±0,0048	0,0294±0,0114±0,0079
C + Cu	**0,0302±0,0063±0,00309**	0,0345±0,0093±0,0019	0,0273±0,0092±0,0066
C + Pb	**0,039±0,0153±0,00215**	0,039±0,0153±0,00215	-
		Yields total, 4.5 GeV	
C + C	**0,0125±0,0038± 0,0024**	0,0124±0,0060±0,0015	0,0117±0,0047±0,0014
C + Al	**0,0226±0,0055±0,0072**	0,0221±0.0083±0,0071	0,0228±0,0070±0,0083
C + Cu	**0,0369±0,0074±0,0059**	0,0346±0,0110±0,0046	0,0354±0,0093±0,0032
C + Pb	**0,0362±0,0109±0,0047**	0,0387±0,013±0,00101	0,0389±0,0185±0,0057

Signal distribution in bins of P_T (C+A, 4.0AGeV)



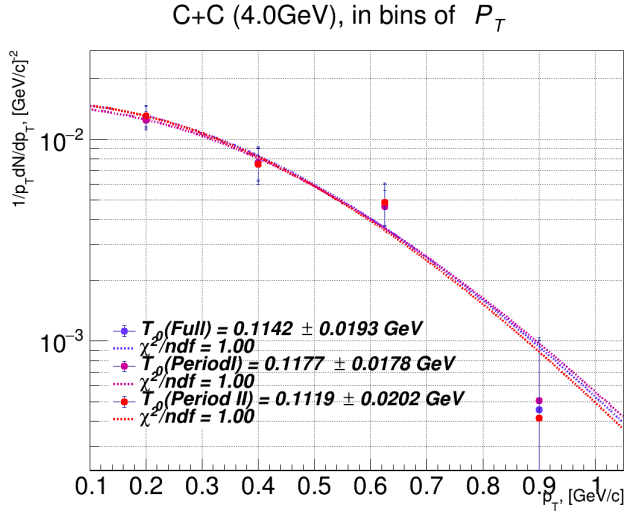


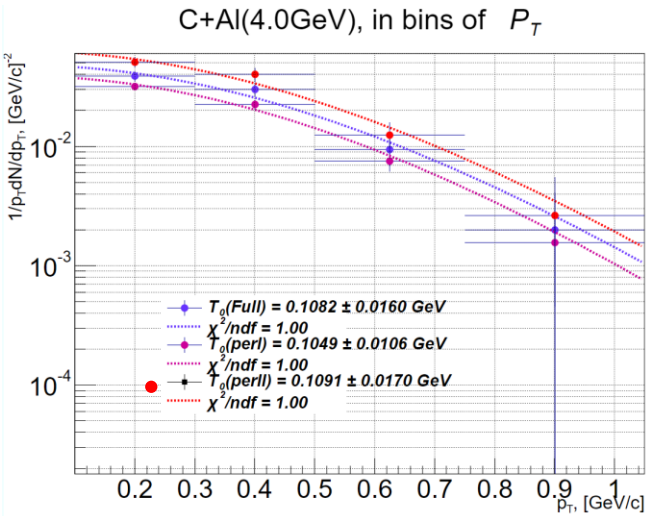


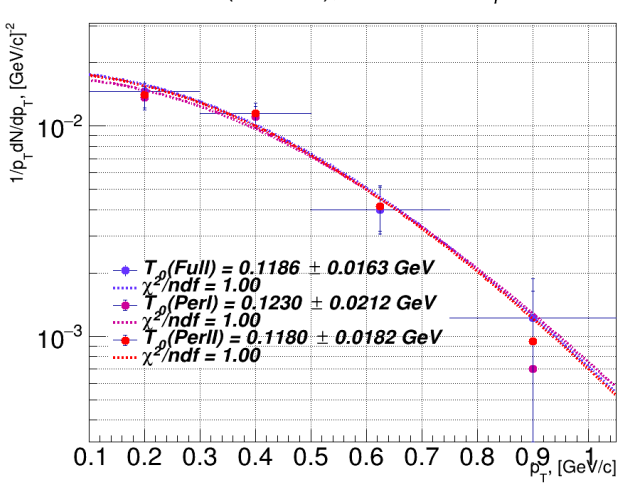


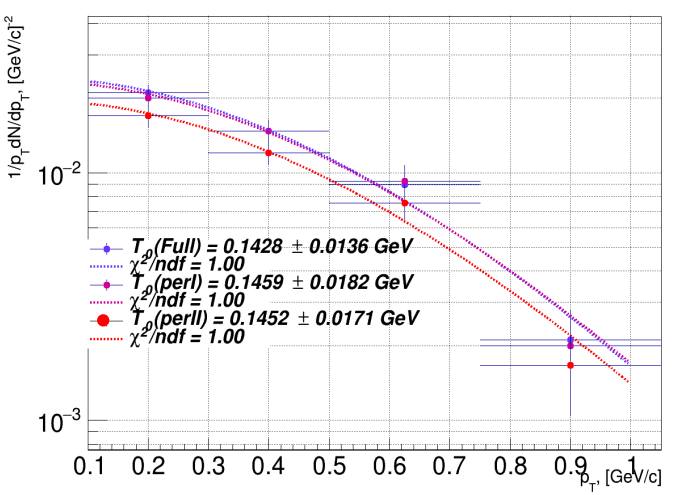
Signals were evaluated for each period. The same of the signals should coincidence with the signal evaluated for the full data sample.

Determination of slopes from momentum spectra





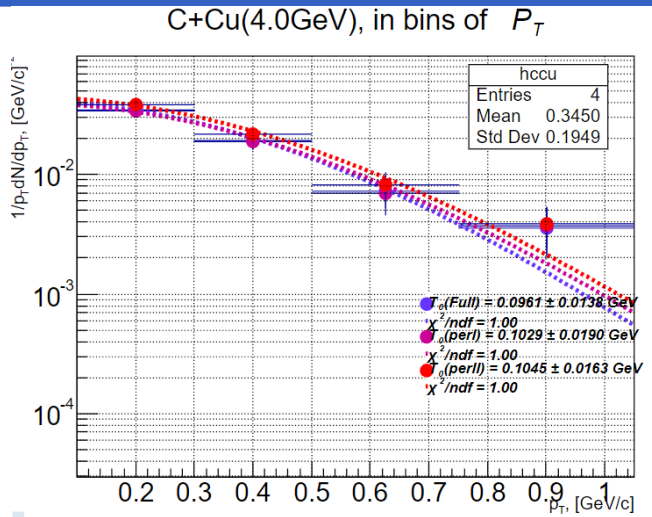




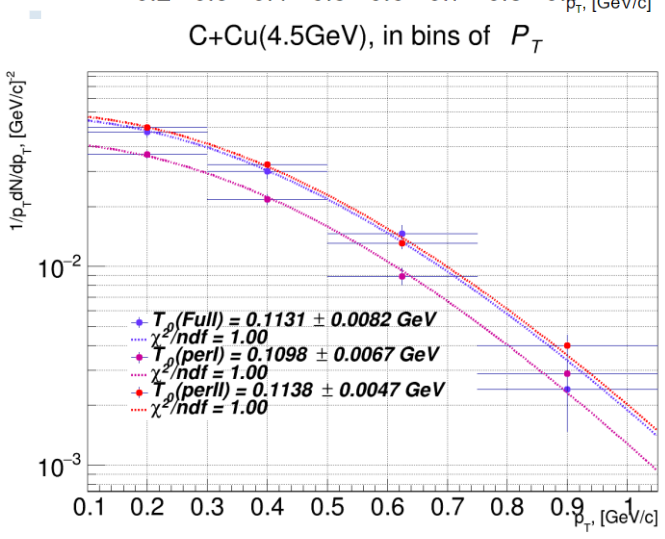
The measured spectra of the Λ yields in p_T are parameterized by the form: $1/p_T\, d^2N/dp_T dy = N \cdot \exp(-(m_T - m_\Lambda))/T))$,

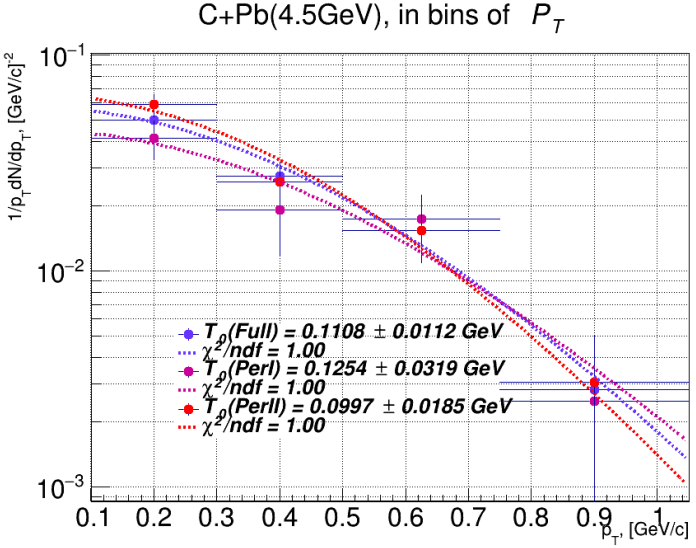
where $m_T = \sqrt{m_\Lambda^2 + p_T^2}$ is the transverse mass, the normalization N and the inverse slope parameter **T** are free parameters of the fit;

Determination of slopes from momentum spectra



C+Pb(4.0 AGeV)
– no statistic





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where $m_T = \sqrt{m_\Lambda^2 + p_T^2}$ is the transverse mass, the normalization N and the inverse slope parameter **T** are free parameters of the fit;

RESULTS

Preliminary

4.0 AGeV	T_0, MeV, C+C	T_0, MeV, C+Al	T_0 MeV, C+Cu	T_0 MeV, C+Pb
DCM-QGSM model	125.9	120.2	133.2	130.2
UrQMD model	107.3	128.0	132.8	135.5
PHSD model	86.6	100.0	105.4	98.2
Exp Data, Full	114.1±19.3	108.2±16	96.1±13.8	-
Exp Data, period I	117.6±17.8	104.6±10.6	102.9±19.0	
Exp Data, period II	111.9 ±20.2	109.1±17	104.5±16.3	

4.5 AGeV	T_0, MeV, C+C	T_0, MeV, C+Al	T_0, MeV, C+Cu	T_0, MeV, C+Pb
DCM-QGSM model	132	133	135	142
UrQMD model	122	128	130	134
PHSD model	101	106	109	108
Exp Data, Full	118.6±16.3	142.8±13.6	113.1±8.2	110.8±11.2
Exp Data, period I	123±21.2	145.9±18.2	109.8±6.7	125±31.9
Exp Data, period II	118±18.2	145.2±17.1	113.8±4.7	99.7±18.5

The systematic uncertainty will be estimated for slopes. The expected value of systematic uncertainty will be 40-50%.

Summary and plans

Done:

- ✓ The Λ^0 reconstruction efficiency was determined in each of the 64 cells for C+A reaction separately in MC.
- ✓ Cells with $\omega_i < 0.01$ were identified and excluded from the analysis.
- ✓ An extrapolation procedure was developed and applied to measure regions with $\omega_i < 0.01$.
- ✓ Mass distributions Λ^0 were obtained with weight ω_i for each cell out of 64 in the MC and physical data.
- ✓ **Preliminary results on the computation of yields and cross sections were obtained for C+A, (4, 4.5 AGeV).**
- ✓ **The slopes from the transverse pulse spectra were obtained for C+A (4, 4.5 AGeV)**

Plans:

Obtain final results taking into account systematic error.
Complete the analysis note. Prepare paper draft.

Приехали…

Thank you for your attention!

Back up

Yields of the $\Lambda \rightarrow p\pi^-$

III измерение – получено методом разбиений 8*8;

$err_{sysI\_meas} = abs[Y\_Imeas - Y\_IIImeas]/Y\_Imeas$- систематика относительно результатов, полученных эмбендингом – I измерение (4*4);

$err_{sysII\_meas} = abs[Y\_IImeas - Y\_IIImeas]/Y\_IImeas$- систематика относительно результатов, полученных альтернативным методом анализа– II измерение (4*4);

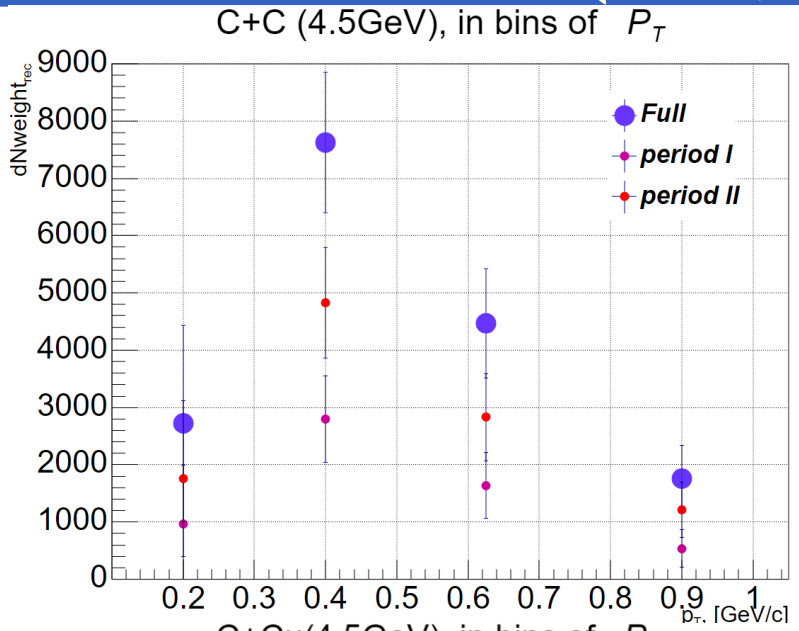
$err_{sysIV\_meas} = abs[Y\_IVmeas - Y\_IIImeas]/Y\_IVmeas$- систематика относительно результатов методом (4*4) с взвешенными гистограммами;

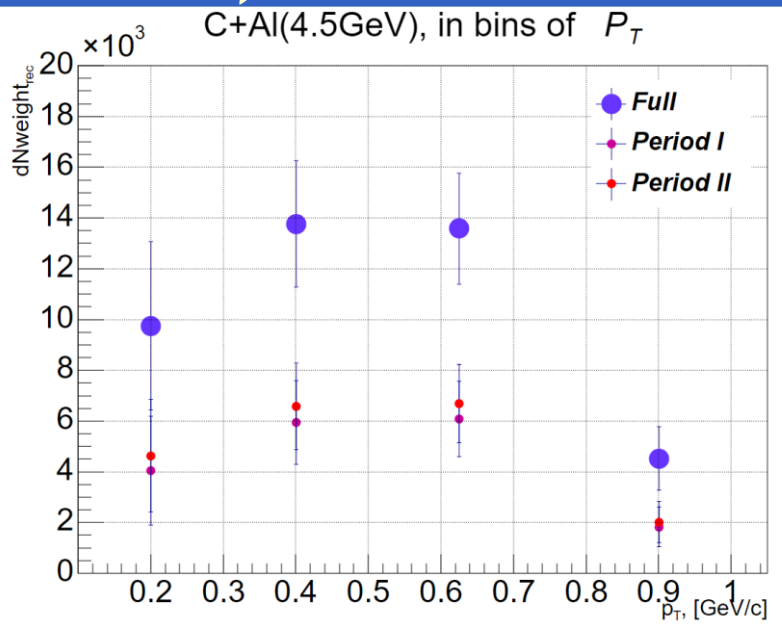
$sys\_mean = err_{sysI\_meas} + err_{sysII\_meas} + err_{sysIV\_meas}/3$ – среднее значение ошибки I и II, IV измерений.

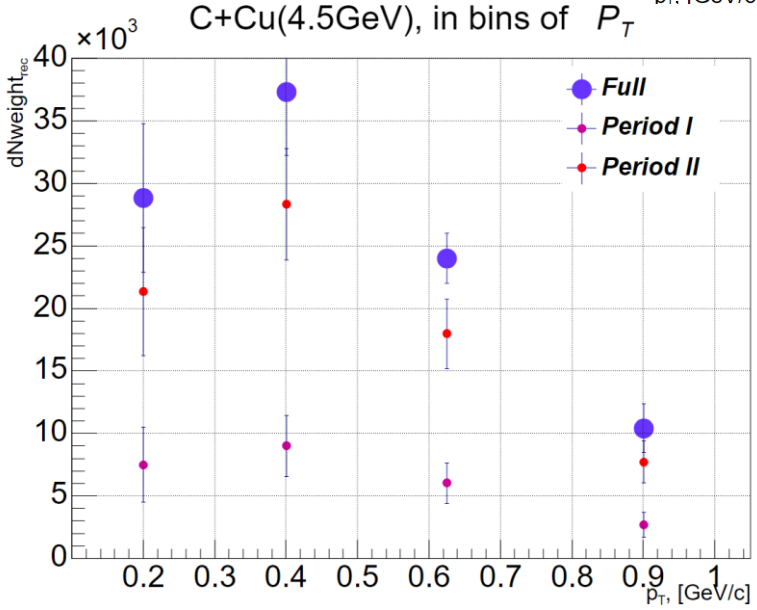
$sys\_mean\_Iper = err_{sysII\_meas} + err_{sysIV_{meas}}(4 * 4)/2$ – среднее значение ошибки II, IV измерений для периода 1.

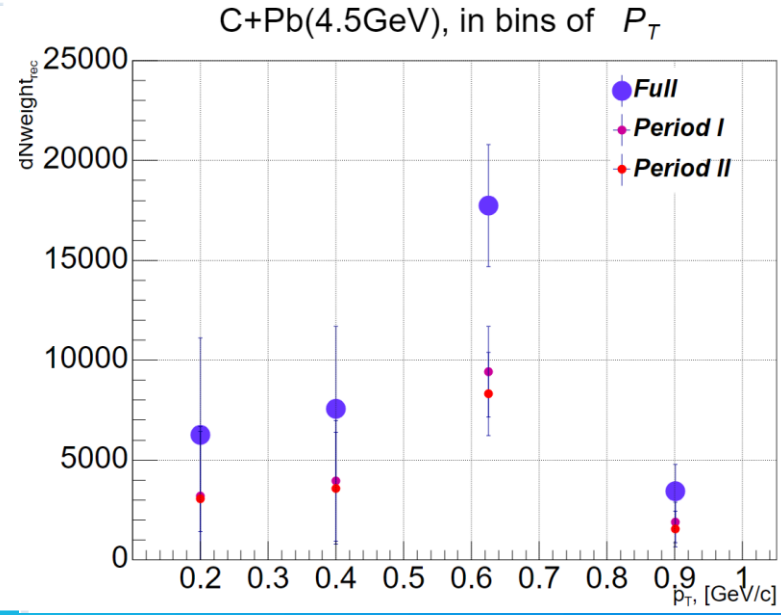
$sys\_mean\_IIper = err_{sysII\_meas} + err_{sysIV_{meas}}(4 * 4)/2$ - – среднее значение ошибки II, IV измерений для периода 2.

Signal distribution in bins of P_T (C+A, 4.5AGeV)

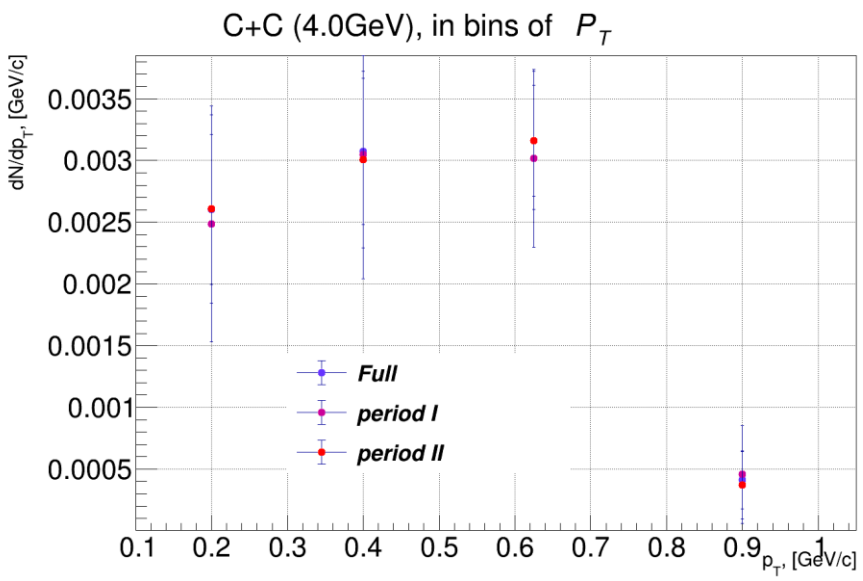


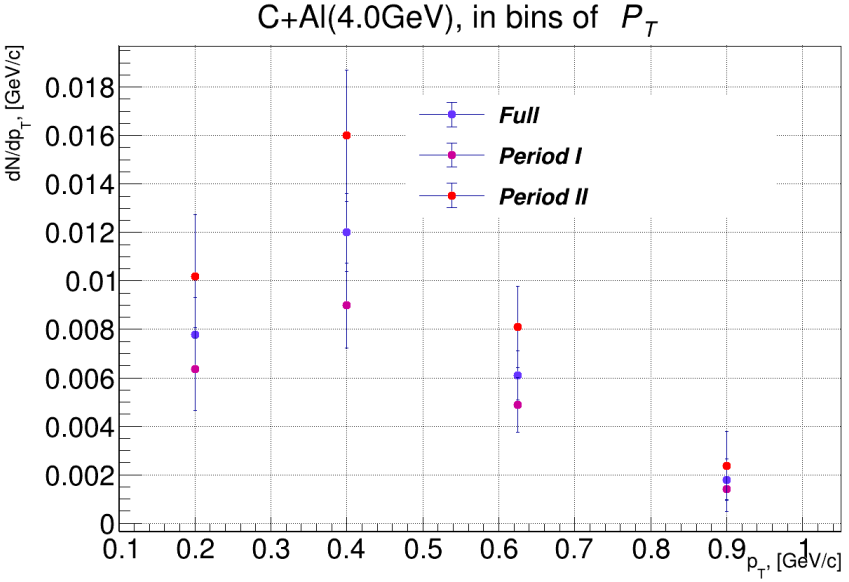


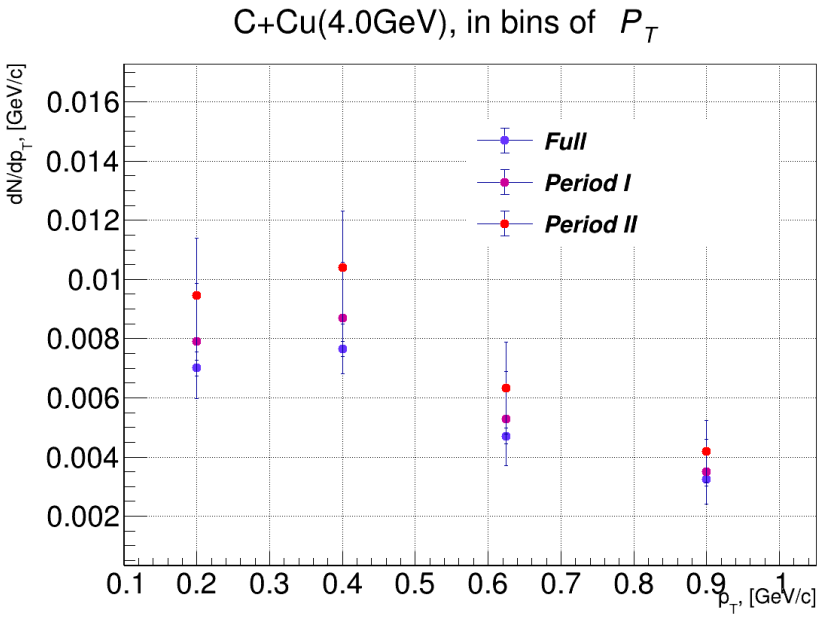


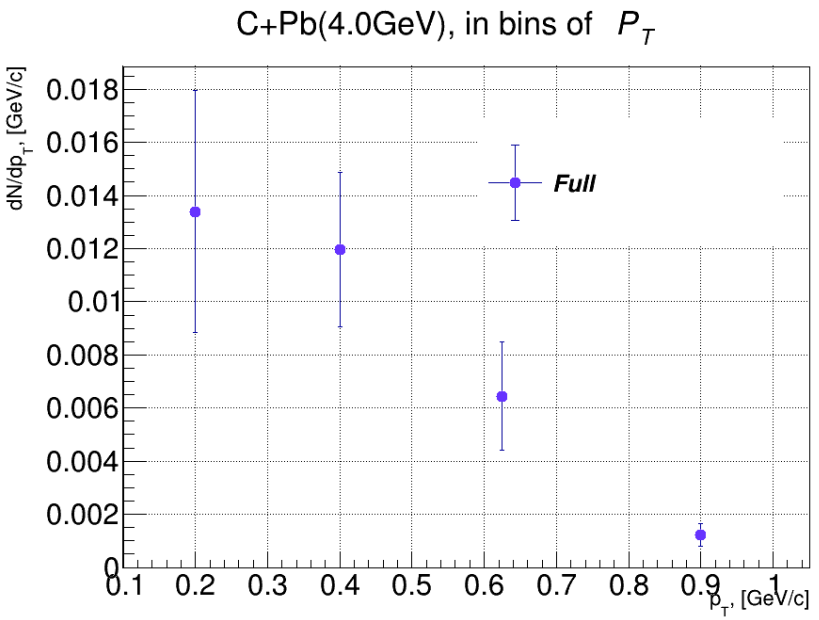


Differential yields in bins of P_T (C+A, 4AGeV)

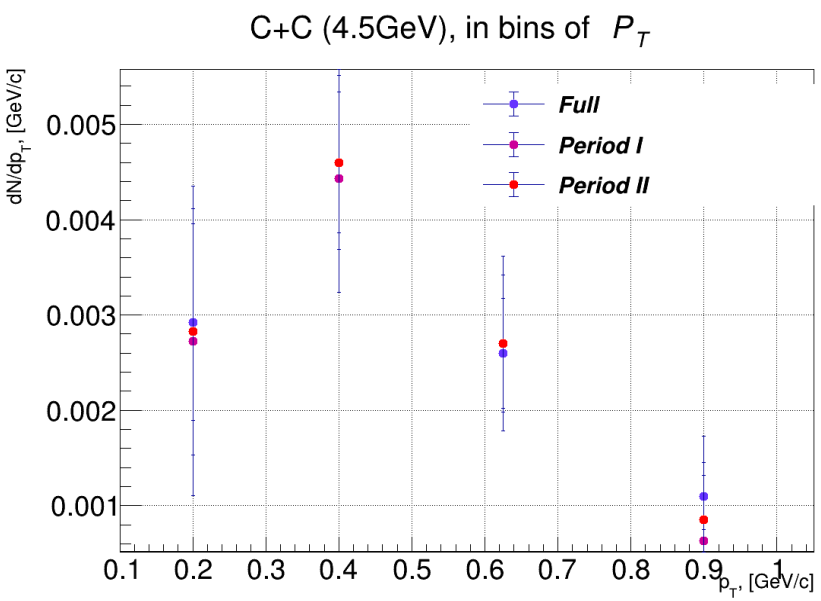


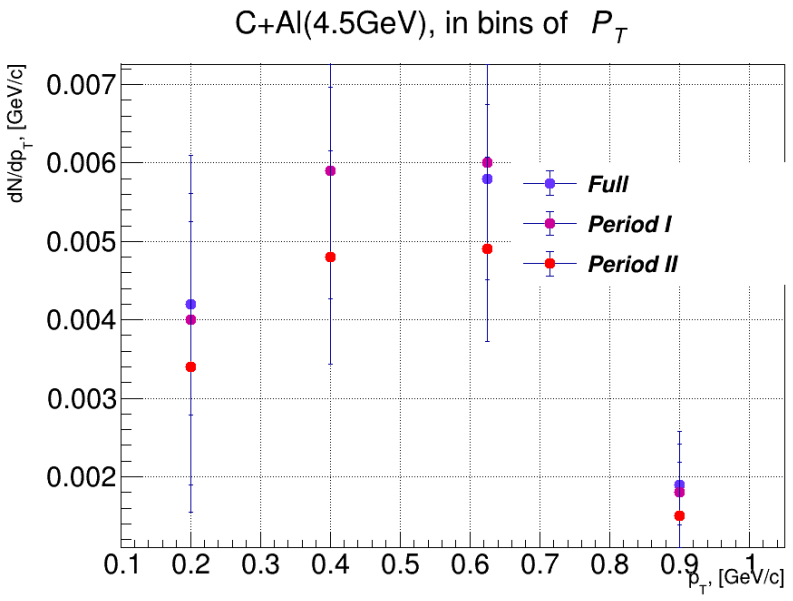


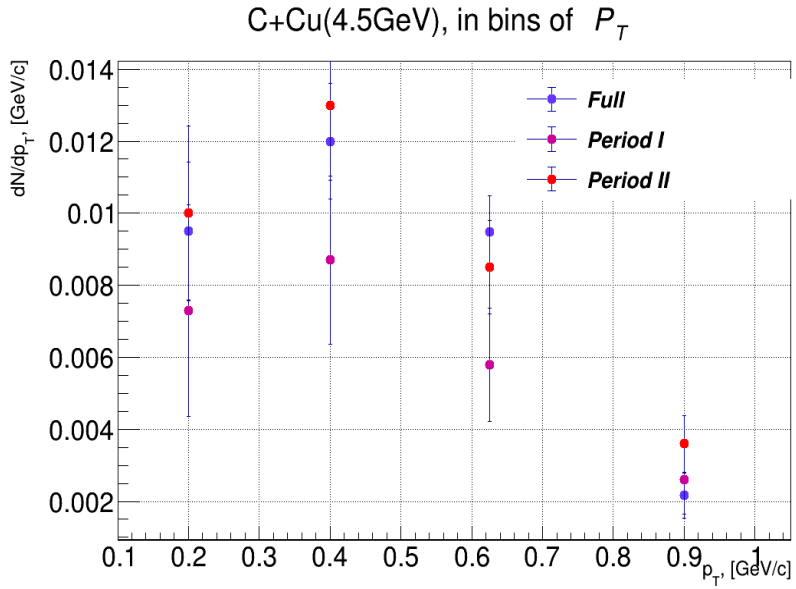


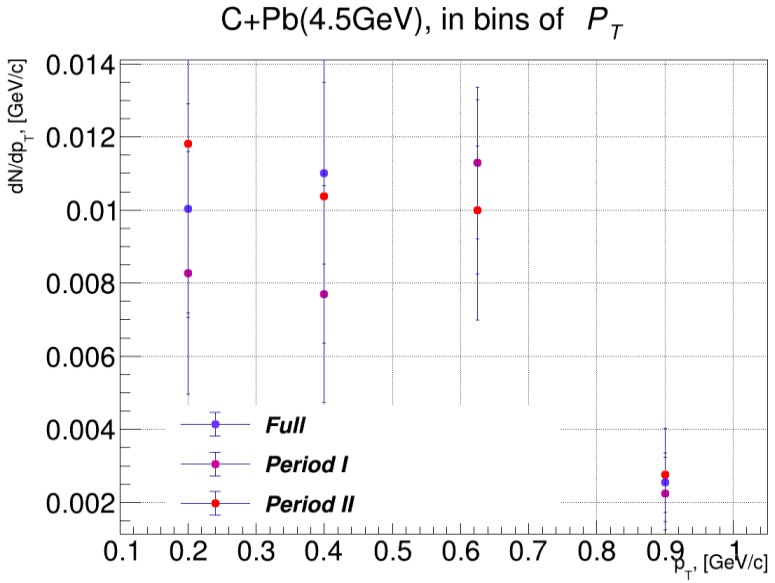


Differential yields in bins of P_T (C+A, 4.5AGeV)

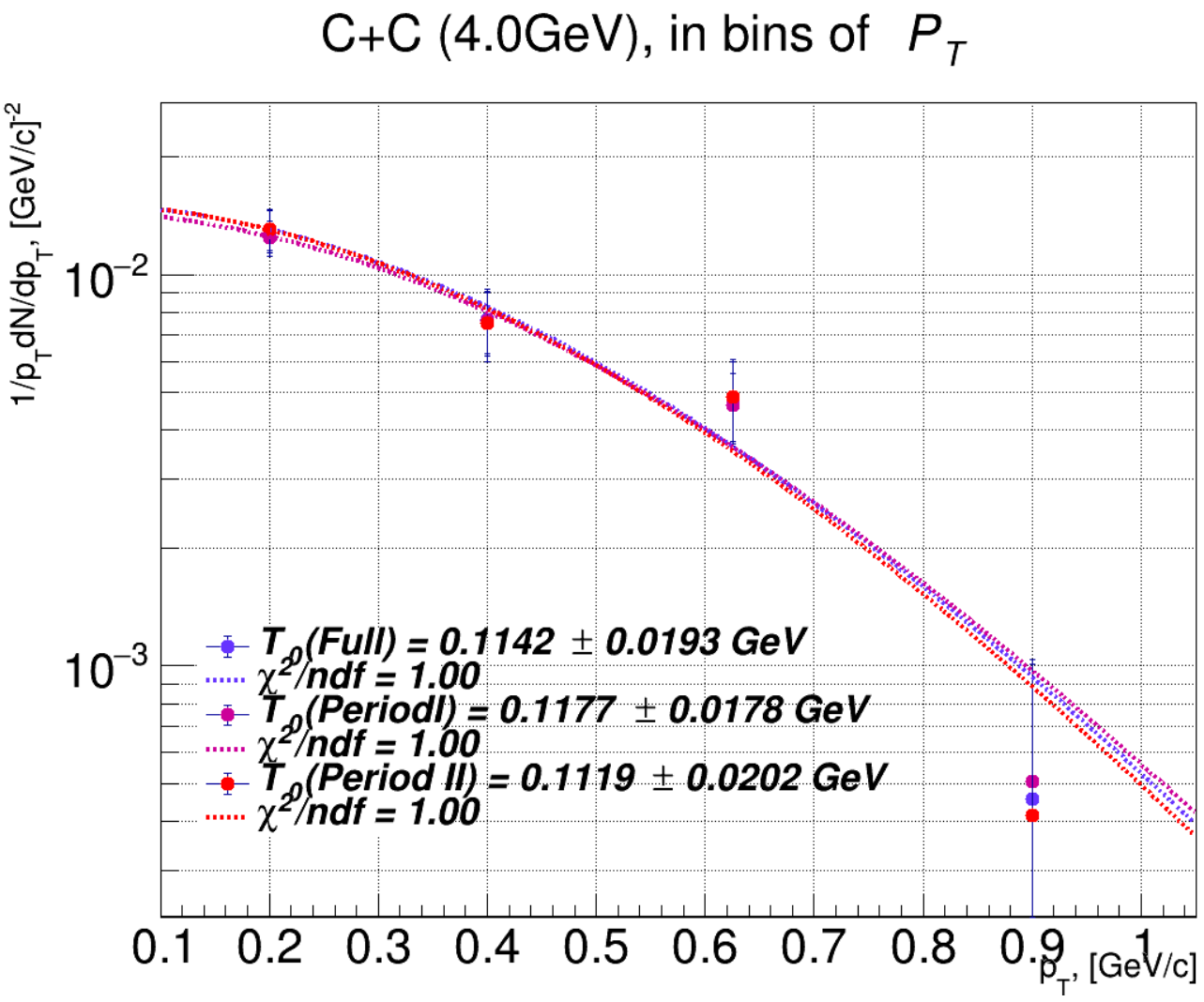




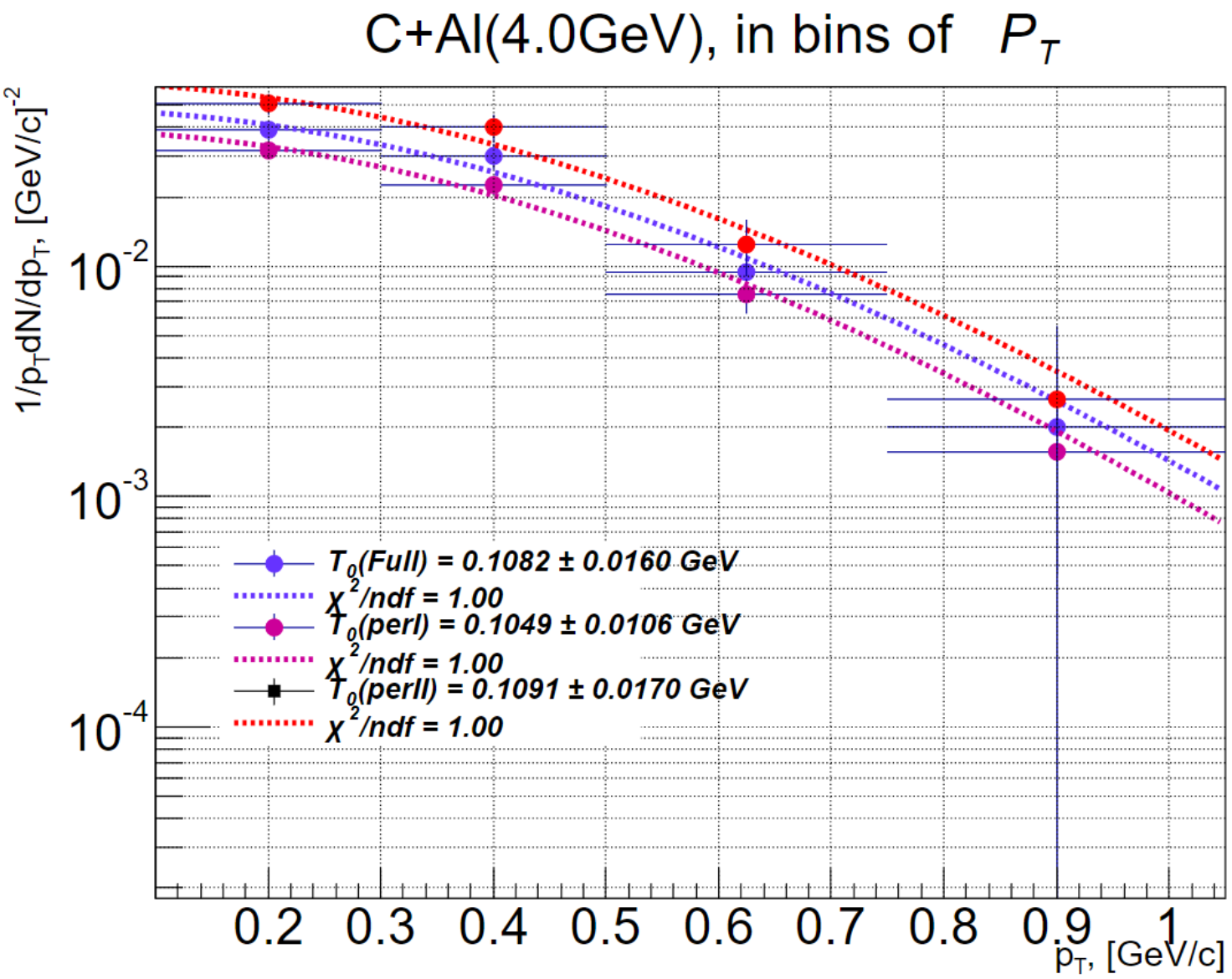




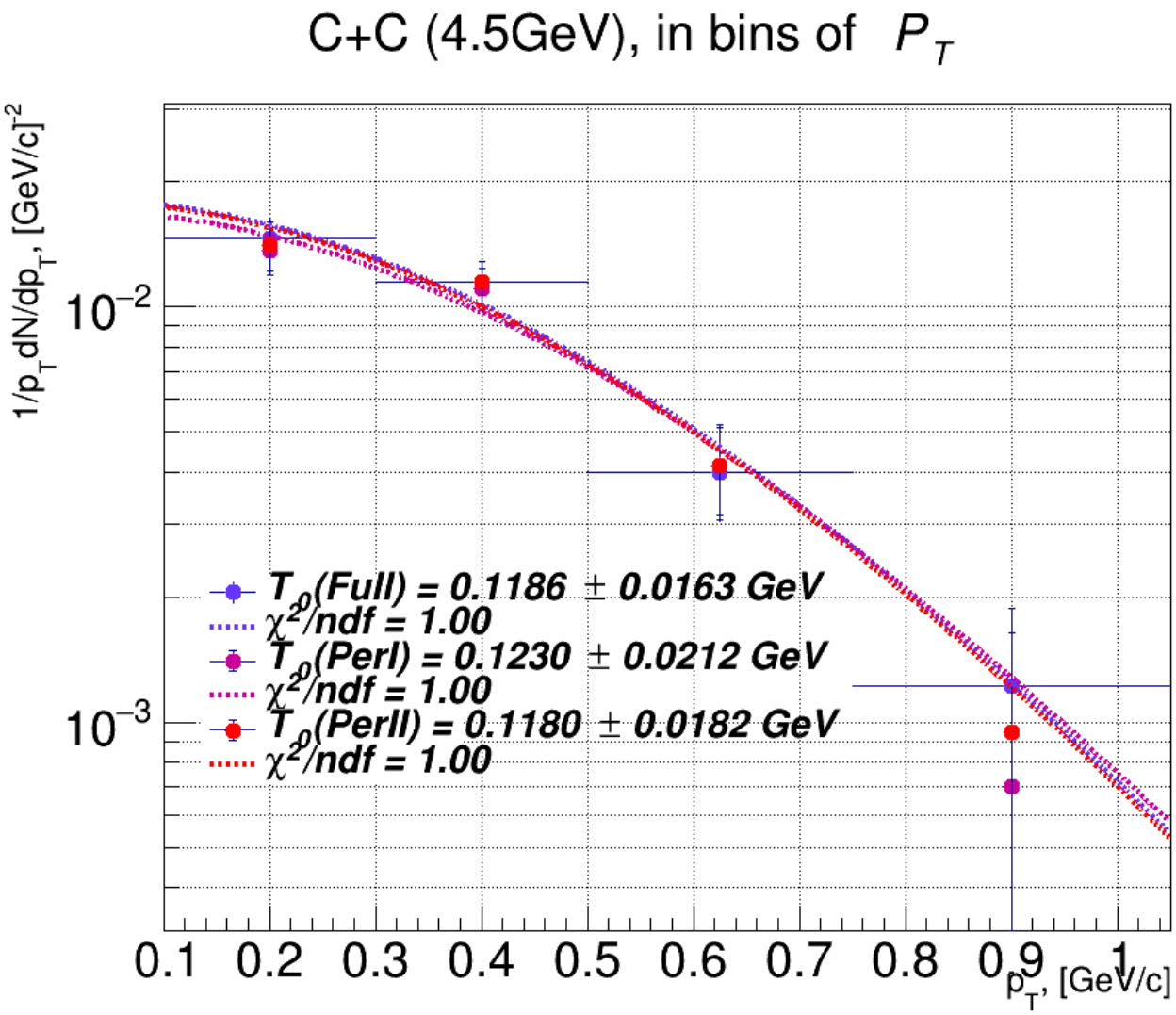
Determination of slopes from momentum spectra



Determination of slopes from momentum spectra

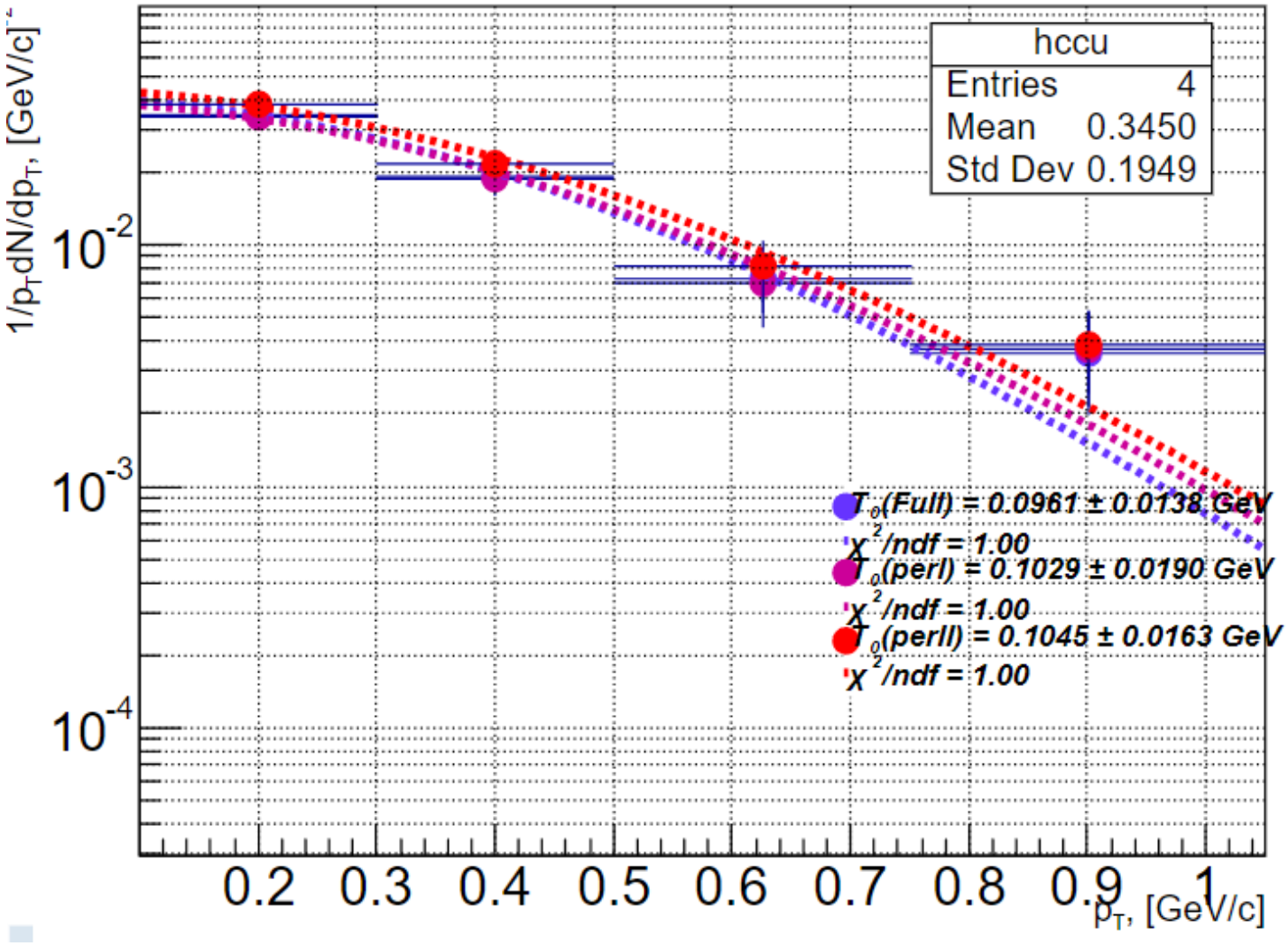


Determination of slopes from momentum spectra

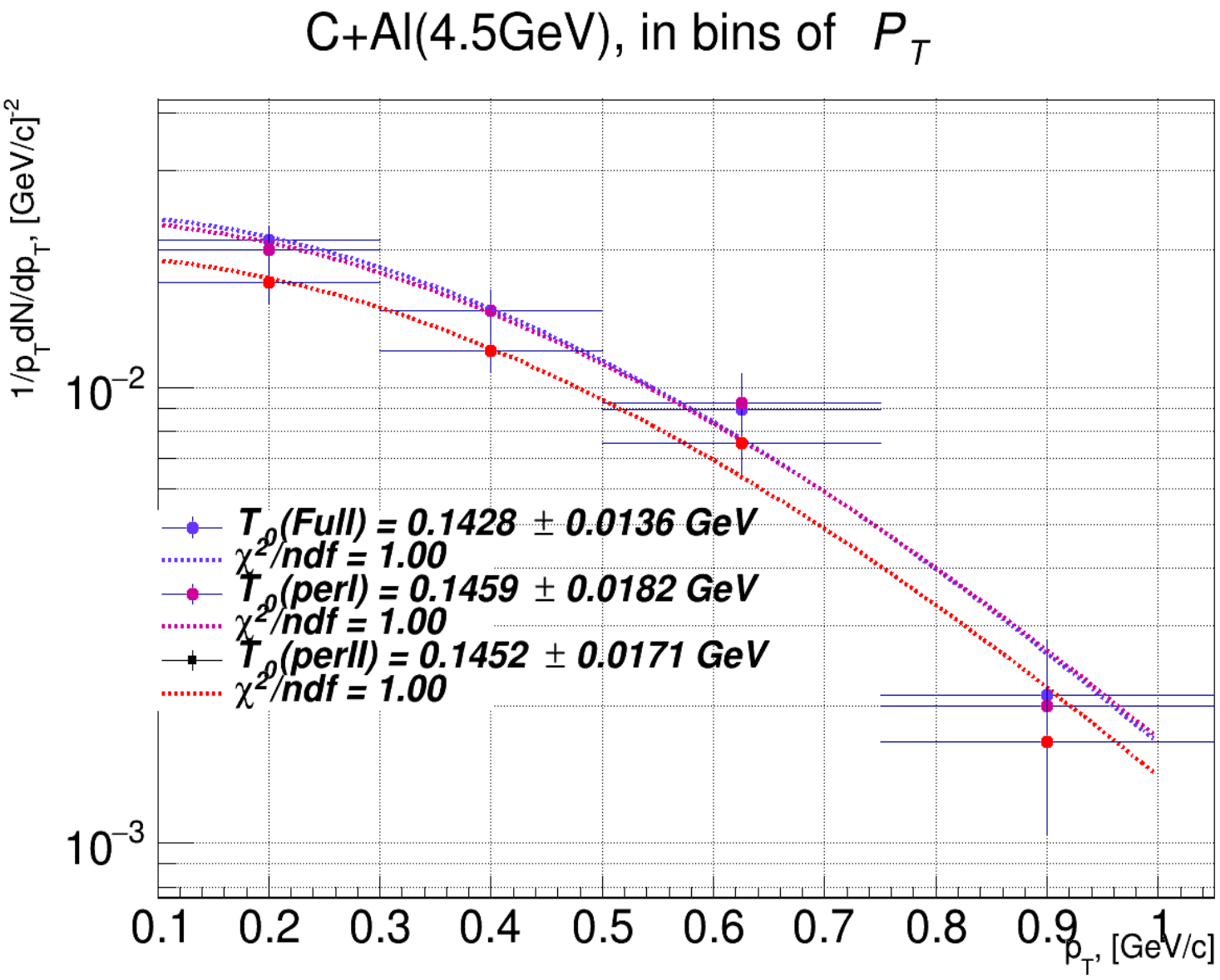


Determination of slopes from momentum spectra

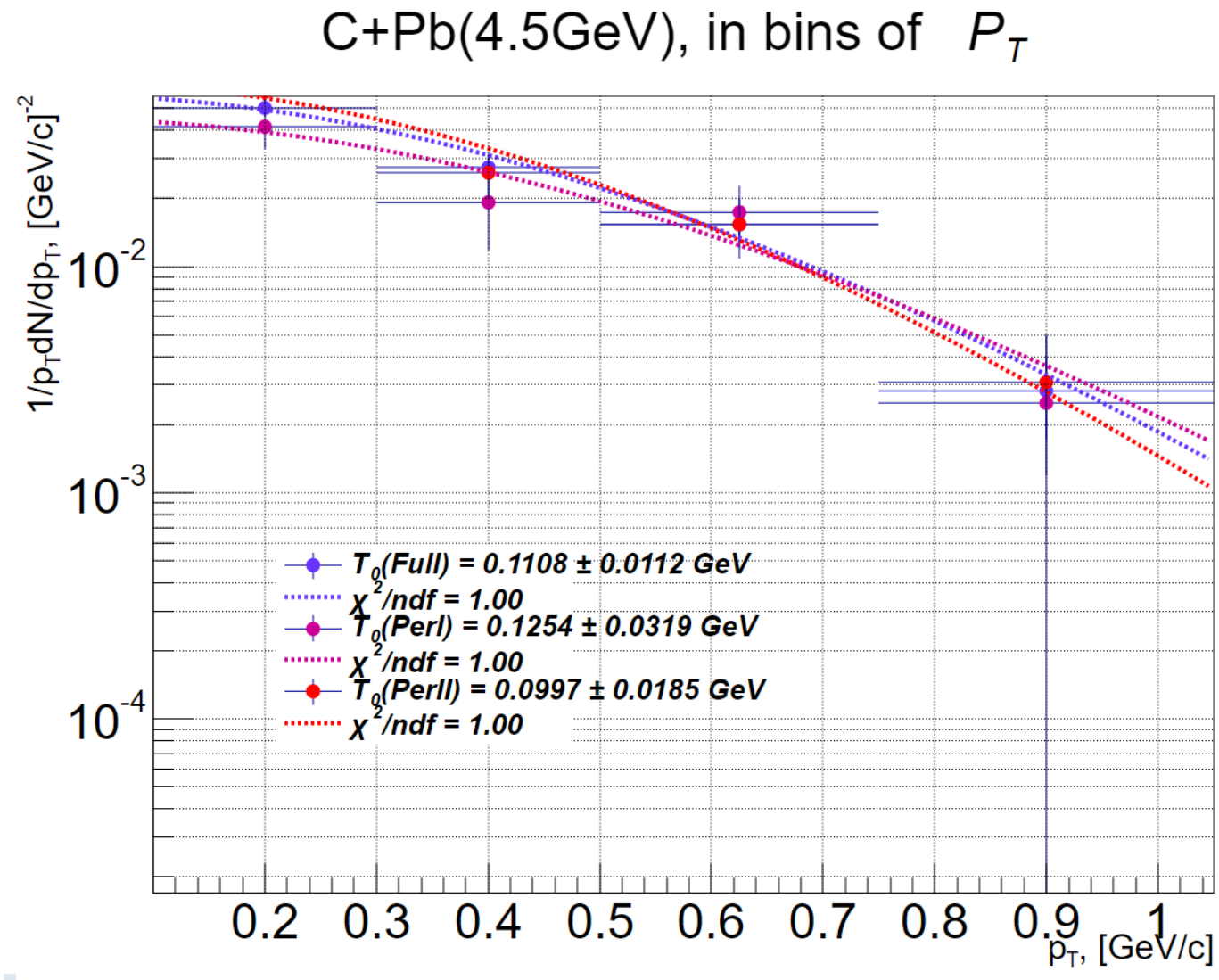
C+Cu(4.0GeV), in bins of P_T



Determination of slopes from momentum spectra

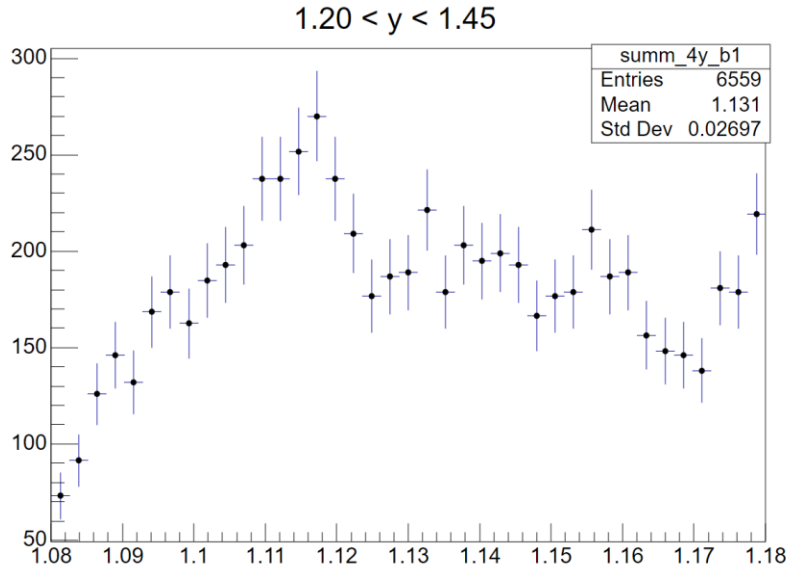


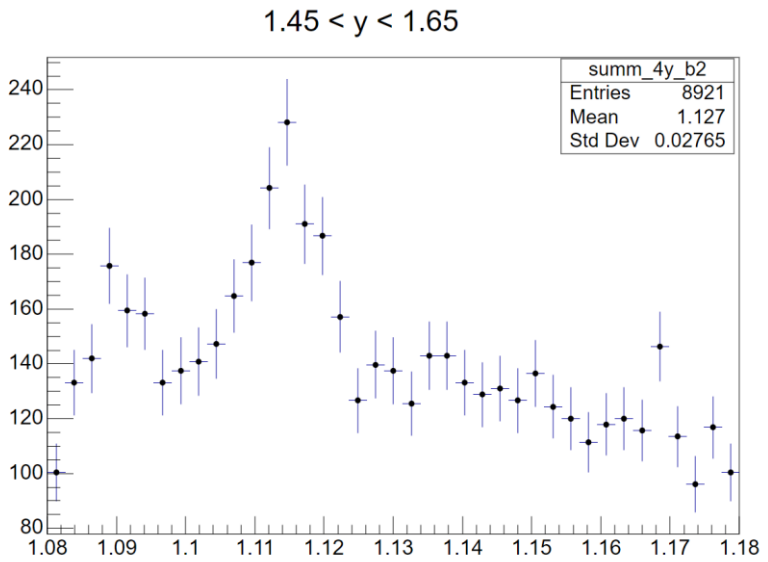
Determination of slopes from momentum spectra

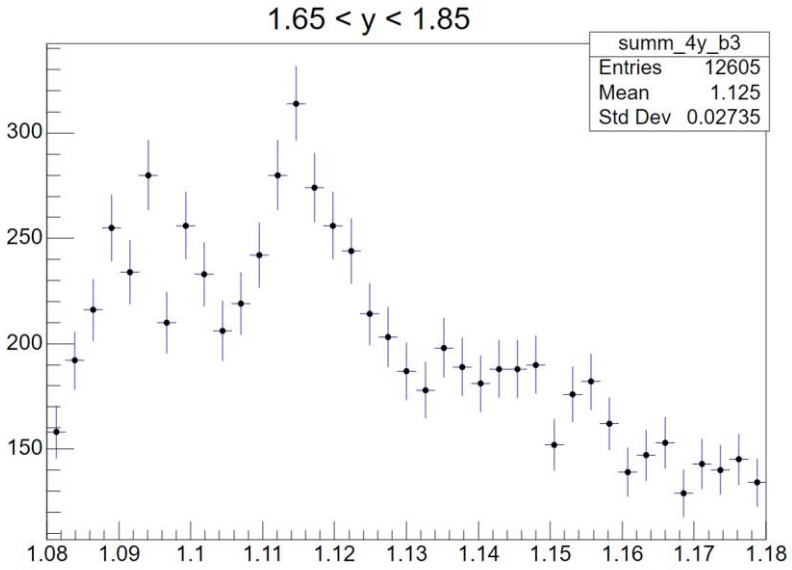


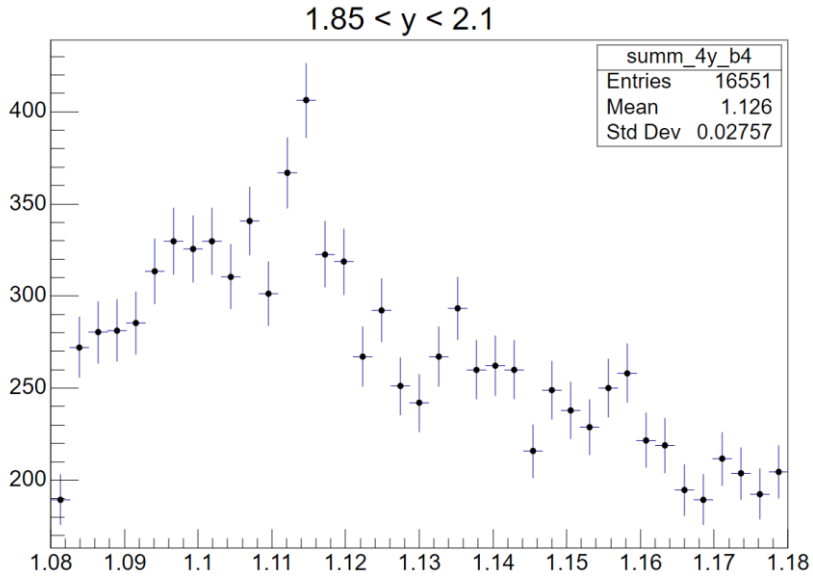
One-dimensional mass distribution of the $\Lambda^0 \rightarrow p\pi^-$ (DATA), without weight

C+C,4 AGeV



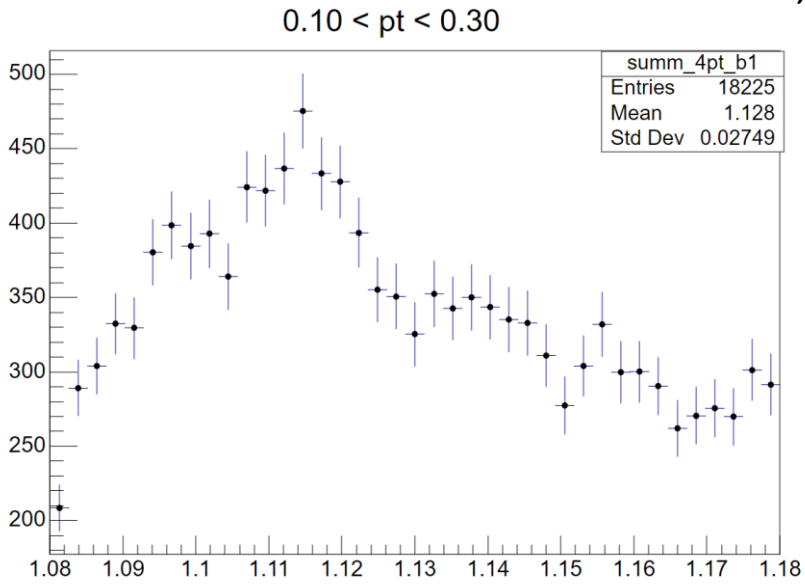


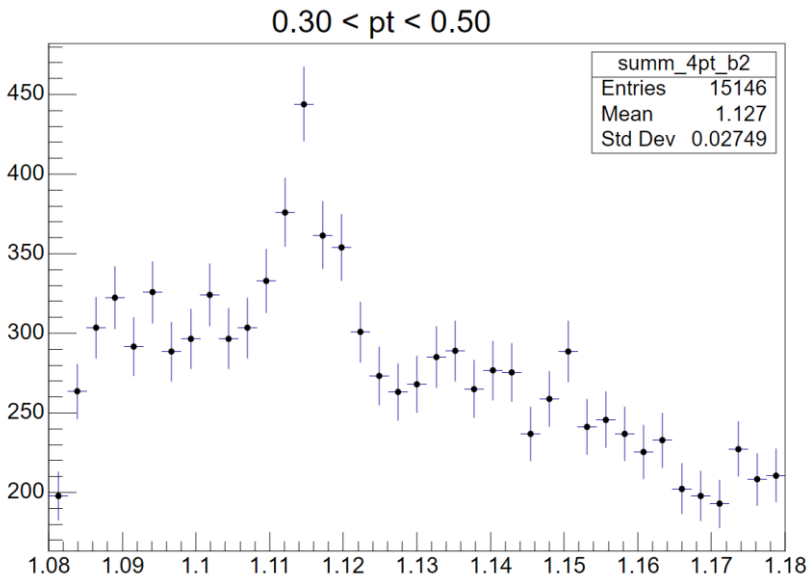


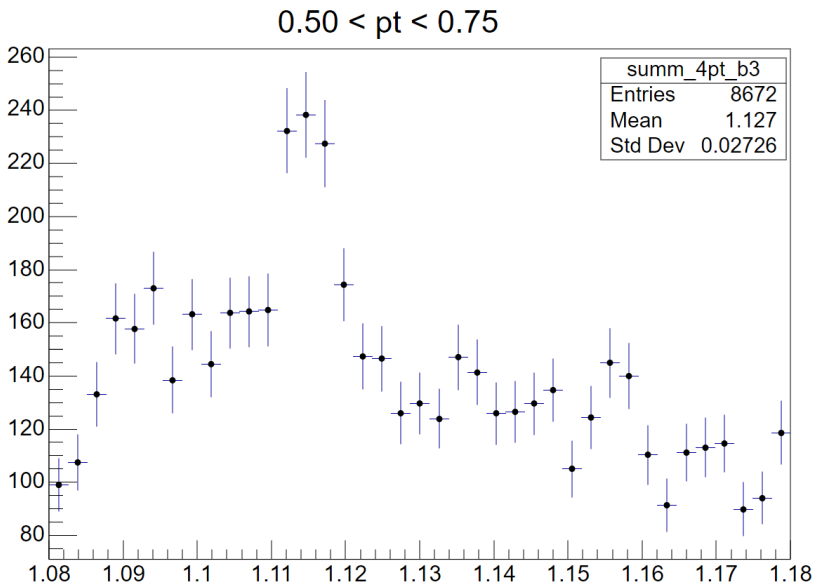


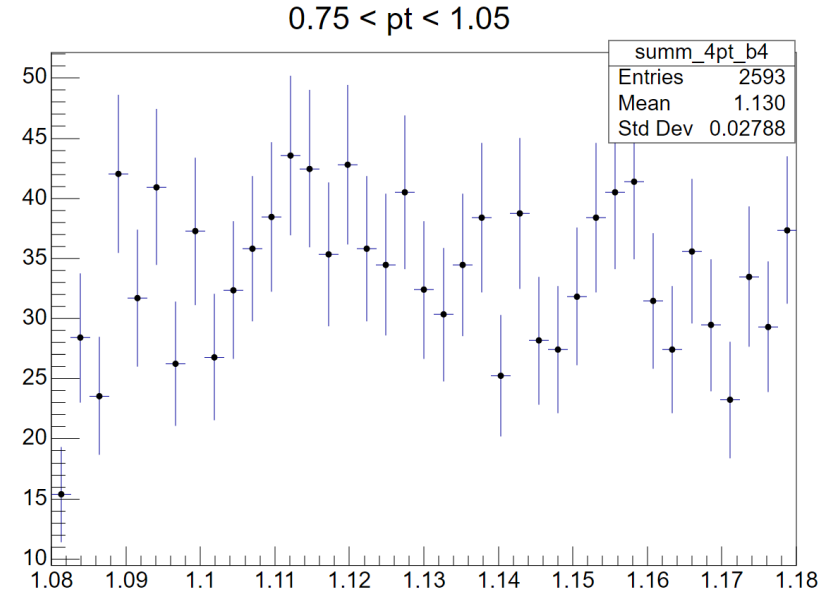
One-dimensional mass distribution of the $\Lambda^0 \rightarrow p\pi^-$ (DATA), without weight

C+C,4 AGeV



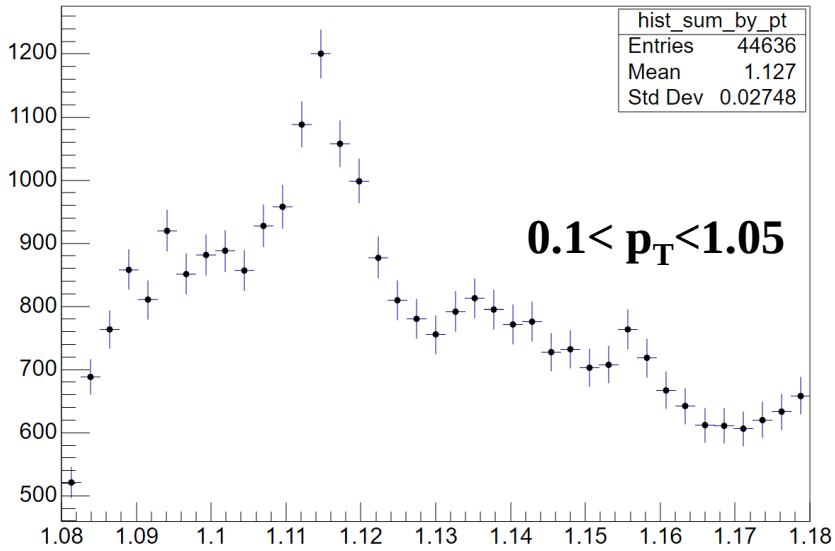




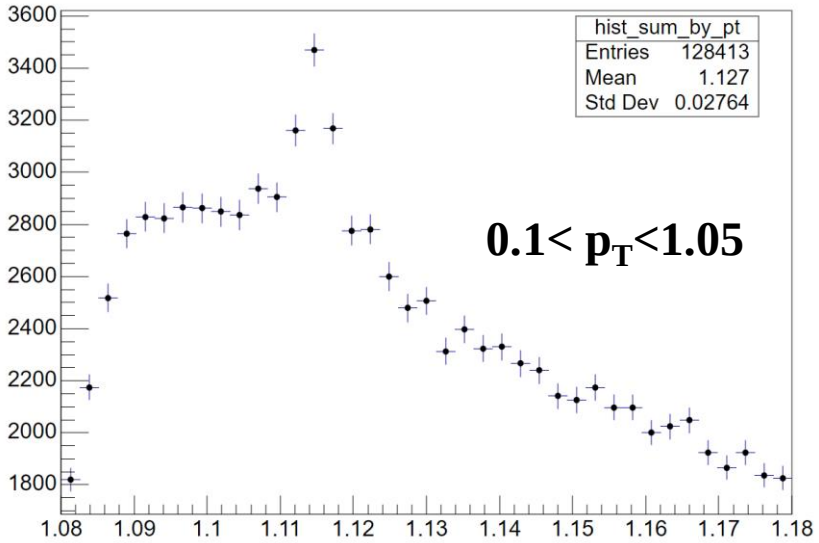


One-dimensional mass distribution of the $\Lambda^0 \rightarrow p\pi^-$ (DATA), without weight

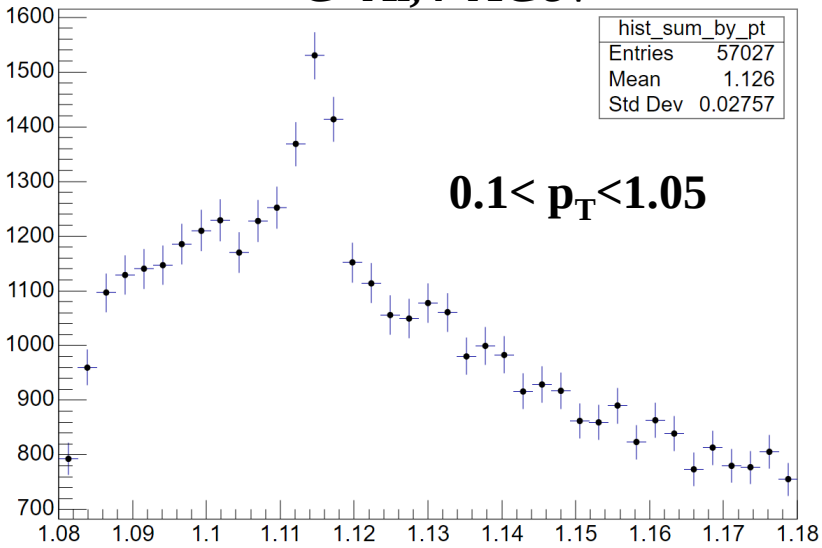
C+C,4 AGeV



C+Cu,4 AGeV



C+Al,4 AGeV



C+Pb, 4 AGeV